ANNUAL PROGRESS REPORT

UCLA

EXPERIMENTAL AND THEORETICAL

HIGH ENERGY PHYSICS RESEARCH

SEPTEMBER 1, 1991

TO

SEPTEMBER 31, 1992

DOE GRANT NO: DE-FG03-91ER40662

TASK A	TASK E
TASK B	TASK H
TASK C	TASK K
TASK D	

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DOE Contract: DE-FG03-91ER40662, Task A

Title of Project: UCLA Hadronization Model, PEP4/9 e^+e^- Analysis, $\bar{P}$ Decay

Task Manager: Charles Buchanan

Activities in FY 1992, Major Results To-Date, Goals:

During the past year, Task A personnel participated significantly in four important areas (basically paralleling our proposal for FY92):

1) CP and CPT phenomenology at a ϕ factory.
2) Phenomenology of the hadronization process.
3) Analysis of strange and charmed baryon data from PEP4/9.
4) Simulation and equipment for a search for antiproton decay in the FNAL accumulator.

Important papers (potentially, seminal ones) have been produced in (1) and (2).

(1) The paper produced by Buchanan, Cousins, Dib, Peccei and Quackenbush appears to be emerging as a definitive "Bible" in the area of what can be measured in the CP and CPT sector with a high luminosity ϕ factory, showing that a ϕ factory (with its very complex two-kaon interfering system) is the only place where all the CP and CPT non-conserving amplitudes can be uniquely measured. Buchanan and Quackenbush (partially supported by Task A) were responsible for the detailed distribution and simulation studies which were the basis for the conclusions formed in the paper.

(2) Our study of the phenomenology of hadronization continues to progress. The UCLA ansatz was presented by SeBong Chun at Moriond in March, by Charles Buchanan at the Aachen QCD conference in June, and submitted (in what we feel may be a seminal paper in understanding hadronization) to Physics Letters B in September 1992. The basis of the ansatz fits nicely with conceptions of soft QCD: a narrow colortube between quark and antiquark; an area law behavior in space-time. With only five significant parameters, we describe virtually all measured rates, distributions, and correlations amongst the many flavored mesons and baryons produced in e^+e^- annihilations from $E_{cm} \simeq 10$ GeV to 91 GeV. The most striking result in 1992

is the very close agreement between our prediction and the shape of the B-hadron momentum spectrum measured at LEP at 91 GeV (which other models have not been able to predict). Our next studies include (a) whether the Blankenbecler-Brodsky crossing symmetry hypothesis that meson distributions vary as $(1-z)^2$, spin $\frac{1}{2}$ baryons as $(1-z)^3$, and spin $\frac{3}{2}$ baryons as $(1-z)^5$ is compatible with data; (b) the areas of P_T compensation and "popcorn" meson production between baryon and antibaryon where we have introduced ad hoc phenomenological parameters; (c) whether there are physical models which would predict the values of a $\simeq$ 1.9 and b $\simeq$ 1.15 GeV^{-2} used in our fragmentation function $f(z) \sim (\frac{1}{z})(1-z)^a \exp(-bm_H^2/z)$; and (d) extending our treatment to include closed strings (e.g., $b\bar{b}$ resonances) and hadrons containing orbital excitations.

(3) Two papers (to be submitted to Phys. Rev. Lett.) from James Oyang's thesis work at PEP4/9 on strange baryon production and correlations are in final draft form and being circulated within the PEP4/9 collaboration. Their most important result is that, whereas relativistic string models such as Lund and UCLA are compatible with all the data, a simple cluster model such as Webber's gives much too strong a short range baryon-antibaryon correlation and requires some sort of softening mechanism similar to the intermediate "popcorn" mesons possible between baryon and antibaryon in the string models. A paper on Λ_c production from Sahak Khacheryan's thesis is in the first stages of drafting. The Λ_c multiplicity at 29 GeV seems similar to or a little higher than that measured at 10 GeV (continuum).

(4) Our Task, in conjunction with Thomas Muller, has joined a small collaboration to probe the antiproton lifetime to $10^7 - 10^9$ years. The rationale is as follows: The most likely explanation of the baryon excess in the universal is a small asymmetry in the decay of a heavy particle in the early universe which preferentially decayed to quarks rather than antiquarks, followed by the annihilation of almost all the antibaryons. If so, preserving CPT in decays would imply that the antiproton lifetime is the same as the proton's, namely $\gtrsim 10^{33}$ years. However, the small population of antiprotons could also be explained by a symmetric early universe and a CPT violating antiproton lifetime of $\lesssim 10^8 - 10^9$ year. A lifetime between 10^9 and 10^{33} year would imply <u>both</u> an early universe decay asymmetry <u>and</u> a CPT violation in antiproton decay compared to proton decay, a very unlikely possibility. A collaboration called APEX (Steve Geer, FNAL Spokesman) has been formed to put rather simple tracking and calorimeter equipment around the antiproton accumulator beam pipe at FNAL at a total equipment cost of ~ \$200-250K. A test run in Spring 92 has already raised the limit on the antiproton lifetime from tens of hours to 2-3 $\times 10^3$ years. A run of 100-1000 hours in Fall 93 has been proposed and

would probe to $10^6 - 10^7$ years. This run would create no interference with Tevatron running and seems to be receiving favorable reactions in the FNAL leadership; the proposal will be formally considered by the FNAL-PAC in December 1992. If the Fall 93 run is successful, further improvements and running time in the next 2 years could push the limit to 10^9 years and close the window on this possibility. At UCLA we have begun simulation studies of signal and background and are preparing to build a spaghetti scintillating fiber tracking system.

Projection for FY 93. Our group will consist of:

Charles Buchanan	Faculty.
SeBong Chun	Research Physicist on hadronization.
Rick Berg	Graduate Student, finishing thesis on PEP4/9 vertex chamber data for strange baryons and correlations. (Last of our PEP4/9 analyses.)
Brent Corbin	3^{rd} year Graduate Student, recently joined our group, working both on hadronization and on the $\bar{P}$ experiment.
Sharon Wong	Secretary, 25%.

We will focus on: (A) continuing our hadronization studies (see (2) above) in collaboration with other international interested physicists, and (B) preparing equipment and simulation for the $\bar{P}$ run in Fall 93. Please recall that there was a supplement, agreed to by DOE and UCLA, to the FY92 Task A budget of $15K in order to allow Task A to carry out its projected activities (see above) for FY92. However, it was finally agreed to carry this supplement over into FY 93 and to recoup the deficit projected for FY92 in this way.

Charles D Buchanan

Charles D. Buchanan, Task Manager 10/5/92

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Progress Report

Task B

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DOE Grant No: DE-FG03-92ER40662

Title of Task: ICARUS, Astroparticle Physics and B Physics With Hadron Beams and Colliders

Task Manager: David B. Cline

Introduction

The current physics efforts in Task B are essentially two fold.

(I) ICARUS and Astroparticle Physics

(II) B Physics with Hadron Beams and Colliders

In this report we review the activity of 1992. There has been great progress in both areas as this report discusses. We illustrate this progress with the reproductions of several review reports produced in 1992 (see Appendix). With an eye to the future, we are also carrying out a very small effort in High Energy Collider Physics (i.e. LHC/SSC) and are starting a small study of the scientific goals of an Asymmetric ϕ Factory. The team involved in this activity is A. Boden, M. Cheng, D. Cline, W. Gabella, W. Hong, S. Lazic, Y. Liu, S. Otwinowski, S. Ramachandran, J. Rhoades, B. Ritzi, H. Wang, and M. Zhou.

B1) ICARUS and Other Astroparticle Projects at UCLA

The ICARUS/Astroparticle Activity is carried out by the team of M. Cheng, D. Cline, S. Lazic, Y. Liu, S. Otwinowski, H. Wang, M. Zhou. M. Cheng received his thesis on this project during this period.

a) Physics Goals of ICARUS

The technical development of the ICARUS detector will be discussed in Section B1b. In Appendix B1-A we list the general scientific goals of the ICARUS project. Some of the specific results of the ICARUS research and development programs are discussed in Appendix B1-B.

b) Technical Progress in the ICARUS Project

INTRODUCTION

The satisfactory results obtained on small scale tests [2, 3, 4] allowed us to begin in 1989 the construction of the 3 ton prototype [5].

The step from small to large volumes has been made possible by:

a) the argon purification performed in gas phase with industrial methods with special care for the cleaning of the materials that come in contact with the purified argon [4];
b) the use of a recirculation system that purifies continually the gas due to the heat leakage of the dewar and liquefies it back into the detector. This inhibits the diffusion inside the liquid of electronegative impurities produced by degassing of materials in the high temperature region of the detector;
c) the use of signal feed-throughs made on vetronite support with the technique of the printed circuit board and welding each pin on it.

The final assembling of the overall system, including the wire chambers, the argon purification, the recirculation system and the readout electronics began on Jan '91 and was accomplished on May '91.

Since June '91 the detector operation and the data taking is going on without interruption up to nowadays.

This report, summarizing the group activity from Jan '91 to June '92, will be constituted by four parts :

1_ A schematic chronological account of the test phases, with particular regard to the mechanical , purification system and cryogenics developments
2_ The electronic readout improvements and calibration
3_ The data acquisition and the graphic user interface
4_ The data analysis and the evaluation of detector performances

CRONOLOGICAL ACCOUNT

Jan - March 1991

First filling of the detector to verify:

1_ the reliability of the mechanics (wire chamber, feed-through's, electric contacts) under thermal stresses

2_ the LAr purity level reachable in large volumes for high gas flow through the purifier.

3_ the reliability, the efficiency of the recirculation system and the consumption of LAr.

The liquefaction process was performed in a few steps. (a) Cleaning of all the detector pieces in solvents and demineralized water. (b) Evacuation of the dewar down to 10^{-7} mbar and bake-out at 90° during 15 days. (c) Cooling down to LAr temperature using pure argon gas to thermalize uniformely the detector during 7 days. (d) Liquefaction into the dewar of commercial liquid argon passed through Oxisorb and molecular sieves at a speed of 8 l/hour.

The results concerning the LAr purity were satisfactory. The electron lifetime measured with the internal "laser purity monitor" was ≈ 2 ms in 300 liters of LAr liquefied at a speed of 8 l/hour. It was stable under the action of the recirculation system (running at a speed of 4 l/hour).

The purity of the gas phase on top of the liquid was also measured by condensing a small fraction of it in the external "laser purity monitor". The result of 100 μs, very different from the lifetime in the liquid phase, strongly supports the hypothesis that most of the impurity are produced by degassing of the warmer surfaces in contact with the gas phase and by small leaks of the ≈ 2000 feed-through's. The recirculation system acts effectively againts this process because it extracts, purifies and recondences the gas phase.

Instead we had some serious problems on the wire chamber. A tens of the wires (over ≈ 8000) loosen their tension during cooling down to LAr temperature due to bad clamping of the copper pins. This implied that, by applying the voltage on them, short circuits were found between wire planes due to electrostatic attraction. This in turn made impossible the continuation of the test.

The Lar was evacuated in 5 days and the detector was brought back to room temperure. The wire chamber was extracted and the faulted wires were cut away.

April - June 1991

The actual filling was started. It took 16 days to fill the dewar with 2000 l of purified LAr. Electron lifetime was continually monitored: it was about 1 ms at the beginning increasing steadily during liquefaction and reaching a stable value of ≈ 3 ms at the end due to the presence of the recirculation system.

A test done stopping the recirculation showed that the lifetime exponentially dropped down to less than 1 ms within 4 hours. Restoring of the purity was acheived in 12 hours by reactivating the recirculation.

No major defects were found on the wire chamber except a short-circuit on some screen wires of the induction plane. This had the only effect of limiting the electric field applicable to the drift region to 700 V/cm.

As a next step we started connecting the analog electronic chain (preamplifiers, HV, decoupling capacitors, test capacitors) onto the signal feed-through's at one end and the the digital boards at the other. It followed the characterization of the complete data acqisition chain for the 272 available channels (see next two sections).

At the end of June the first tracks (cosmic rays) were seen on the on-line display.

From July 1991 to now

Electron lifetime in the detector is continually checked with the internal "laser purity monitor": no significant change in the electron lifetime has ever been found, it fluctuates between 2.5 and 3 ms.

ELECTRONICS

The assembling of the electronic read-out took place from end of '90 to May '91 in parallel with the construction and installation of the wire chambers. During this period the following activities have been done:

1_ test and installation of preamplifiers, amplifiers and flash ADCs (John Oliver Boards);
2_ measurement of the test capacitances;
3_ connection of the wires to the read-out chain and to the HV supply;
4_ connection of the race track HV supply;
5_ writing of the on-line calibration program;
6_ set up of the trigger logic.

The chamber was operating at the beginnig of june '91. Due to some unconsistencies found analizing cosmic muons tracks the whole electronic system have been again checked during november and december '91.

Besides minor improvements concernig electrostatic shielding of the preamplifiers boxes and ground masses, we remeasured also the test capacitances of the 192 collection wires presently in use (1% error) and the cross talk between the wires. After the addition of a bigger decoupling capacitance (20nF for 1nF) on the virtual ground of the connecting kapton cables, the overall measured cross talk was 2% (the C.T. is defined as the ratio between the signal induced on a disconnected wire and the signals injected in all the remaining wires).

During these tests we found that most of the preamplifiers was instables showing occasional spikes and low frequency noise. This effect is due to two laser trimmed resistors on the integrated circuit. Because of that we are presently using a subset of the preamplifiers restricting the number of exploitable channels to 256 .

Now the noise on a collection wire is about 800 electrons (460 "parallel" noise and

2.34 el./pF).

The gain stability and linearity have been repeatedly checked through periodic calibration runs (normally one or two for each "physical" run). At the time being the day by day flactuations (2% on average) are mainly due to the noise and the limited sample (100 calibration pulses) used for the gain computation.

DATA ACQUISITION

Tha DAQ is based on new custom designed adc boards (manufacterer Caen), featuring up to 1.6 ms of waveform recording (sample rate from 50 ns to 400 ns) on a multibuffer architecture (zero deadtime on buffer switching).

To face the delay due to the new boards development we exploited initially the existing "John Oliver Boards" (JOB) and in the meantime we rewrote the software to handle both the old and the new cards.

A new graphic user interface, showing the tracks viewed both in induction and collection planes, has been also added to help the events scanning.

The first 2 Caen adc cards were delivered in July '91. A bunch of 18 cards filling a crate (for a total of 288 channels) was delivered in Oct '91. The full debug and test was achieved early this year: we are now taking data flawlessy since several months.

The ADC boards are controlled by a 68010 VME/VSB CPU, which performs event formatting and data reduction. Presently the complete event acquisition,including writing on the exabyte tape, runs at 1Hz for source events (70 kbyte) without data reduction.

The final setup (it will be installed as soon as the CAEN will accomplish the delivery) foresees 8 fulfilled crates (2048 channels), each of which controlled via VSB by a 68040 CPU. A VME master will coordinate the CPUs and collect the event chuncks to be stored on tape media.

Tests have been performed with a 68040 CPU showing an acquisition rate from the Caen cards to a VME memory up to 2 Mbytes/sec, being the limiting factor the transfer time from the Caen buffers. Given the parallel structure of the system, and taking into account the improved performances of the quicker CPUs and of the new tape devices, the final speed for reading an event as big as 4 Mbyte should not be much worse than 1Hz.

Most of the software development is now aimed to the signal processing needed both to optimize data reduction in terms of speed and efficiency, and to obtain signal/noise enhancement for the off-line analysis purposes. Besides the standard pulse fitting procedures (which have a big computational load), we are experiencing good results with non linear and hybrid linear-non linear filtering such as median filters for granular noise deletion and morphological filters to track baseline fluctations. Also, the bubble chamber like imaging of ICARUS events open a way to test standard procedures ported from the image processing world to perform tasks as resolution improvement, pattern recognition or 3-D reconstruction.

DETECTOR PERFORMANCES

A large amount of data have been collected with the 3 ton prototype using cosmic rays and 6 MeV monochromatic gamma rays to study the response of the detector in a wide range of energy from few MeV to several GeV.

From the analysis of through-going cosmic muons it has been already possible to extract several parameters characterizing the detector: electron lifetime, free electron yield, electron diffusion, energy resolution, space resolutions and particle identification capability.

As for the source events, the analysis is still preliminary and concerns for the time being only the self trigger capability and the energy resolution

Electron lifetime

The electron lifetime value given by the purity monitor has been checked by means of cosmic ray muons crossing vertically the drift volume. The trigger was made up by three scintillators placed two on top and one on the bottom of the dewar in coincidence with the signal on the wires planes. The events have been selected requiring that there was no evidence of large multiple scattering and delta rays ensuring thus that they were minimum ionazing particles. The distribution of the charge deposited along the tracks is measured for each drift time slice with a binning of 17 μs, the most probable value is extracted and plotted as a function of the drift time (fig. 1); an exponential fit to this plot gives directly the free electron yield and the electron lifetime. This measure has been repeatedly performed giving a stable value of lifetime of about 2.5 ms, in agreement with the data from the purity monitor.

Free electron yield

Varying the electric field applied in the drift region from 150 to 350 V/cm we measured a free electron yield of 2.05 and 2.35 el./100 eV respectively. These values are in slight disagreement with other published data, especially at 150 V/cm where we find a free electron yield ≈ 20 % higher than that reported in ref. [6]. We believe that this difference is due to the fact that we are using a real minimum ionizing particle while data in [6] refer to ≈ 400 keV electrons for which the end of range higher ionization increases the recombination in particular at low fields. A more extensive scan as a function of the electric field is under way for a careful measure of the electron-ion recombination at low fields.

Electron diffusion

The analysis of the signal risetime allows the determination of the longitudinal diffusion as a function of the drift time. The risetime (RT) is proportional to the spread (σ) of the signal due to diffusion and $\sigma^2 = 2Dt$ (where D is the longitudinal diffusion coefficient and t is the drift time), hence a linear fit of RT^2 versus drift time gives directly D. The data taken 350 V/cm (fig. 2) and at 250 V/cm give a value of $D = 6.0 \pm 0.2$ cm^2/s in agreement with the calculated value if one takes into account both the thermal brownian motion and the mutual coulombian repulsion of the electrons along the track [8].

Energy resolution

The energy resolution for minimum ionizing particles can be extracted from the width of the charge distribution over one wire which is due both to the intrinsic fluctuations and to the electronic noise (fig.3): the measured value of ≈ 900 electrons states the electronic noise dominates, limiting the energy resolution to ≈ 10 % for 380 KeV of deposited energy. In fig. 3 a second peak is also visible due to low energy delta rays that cannot be separated from the main track.

Spatial resolution

The spatial resolution along the drift direction has been measured from the distribution of the residuals to a linear fit of the tracks of high energy crossing muons. An r.m.s. resolution of 290 μm has been found roughly independent from the electric field (fig. 4) and the drift distance. In a dedicated test on a small scale with the preamplifiers immersed in LAr and a low input capacitance we got a signal to noise ratio of ≈ 20 and a spatial resolution of 58 μm [7].

From the results presented above turns out that a certain amount of technical work has to be done in order to improve the S/N ratio. This can be accomplished by connecting the preamplifiers directly to the wires inside the LAr thus reducing the input capacitance due to the cables and the intrinsic thermal noise.

Particle identification capability

At present we are working on the analysis on stopping muons to extract informations on the detector capability of separating particles by dE/dx vs range and on the recombination dependence on the dE/dx. The distribution of the released charge vs. the distance from the decay point for two different electric fields is shown in fig. 5 together with a MonteCarlo simulation which does not take into account the charge recombination. A preliminary result shows that the recombination is approximately independent from the dE/dx in disagreement with theoretical predictions like Birks law.

Source events analysis

At present time we are taking data of events from a 6.13 MeV monocromatic gamma ray source ($^{238}P_u$-^{13}C) in order to study the detector response to low energy electron tracks also in view of the possibility of using this kind of detector for the study of the solar neutrinos. We applied the maximum allowable electric field (700 V/cm) in order to minimize the effect of the electron lifetime on the energy resolution and to maximize the signal to noise ratio.

In this test it is crucial to exploit the self triggering capabilities of our device. Our recent mesurements demonstrate that we can trigger on isolated events with energy down to $\approx$1 MeV just using the integrated signal coming from the collection wires.

To evaluate the energy resolution we intend to extract the Compton edge and the pair production peak.

The source is placed outside the dewar, close to its lateral wall 1 meter below the top flange and it is collimated by means of lead blocks in such a way that the Compton and pairs electrons are produced as close as possible to the wire chamber.

The source emits 4 10^3 γ/s and 1.9 10^5 neutron/s over 4π. The presence of the neutrons, whose spectrum extends from thermal energies up to 8 MeV, increases the background of the measure. In fact, due to inelstic and capture reactions both on Ar and stainless steel, the neutrons produce γ rays with a wide energy spectrum.

A large amount of data has to be collected as the signal over background ratio is only 1/8 . Therefore we prepared an offline batch program which performs signal extraction and pattern recognitions of the electron tracks. The mean computer time for processing one trigger is about 3 second in our Sun station to be compared with 1 sec of acquisition time.

At the time being we are optimizing the trigger setup against neutron background and the offline analysis. The Compton edge and pairs peak are already visible, but further quantitative analisys is needed.

CONCLUSIONS

The experience with the 3 ton prototype, equipped with complex mechanical and electrical apparata immersed in the liquid and with hundreds of feed-throughs, has shown that the ultrapure liquid argon technique is reliable even if some technical improvements are necessaries:

a) Liquid phase purification to speed up the filling of very large volumes.
b) Development of low noise pre-amplifiers to increase the signal to noise ratio.
c) Design of very large wire chambers mechanically reliable during the cooling to LAr temperature.
d) Study of the best T = 0 system, especially optimized for solar neutrino search.

Next R&D program should be mainly based on the above items.

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FIGURE CAPTIONS

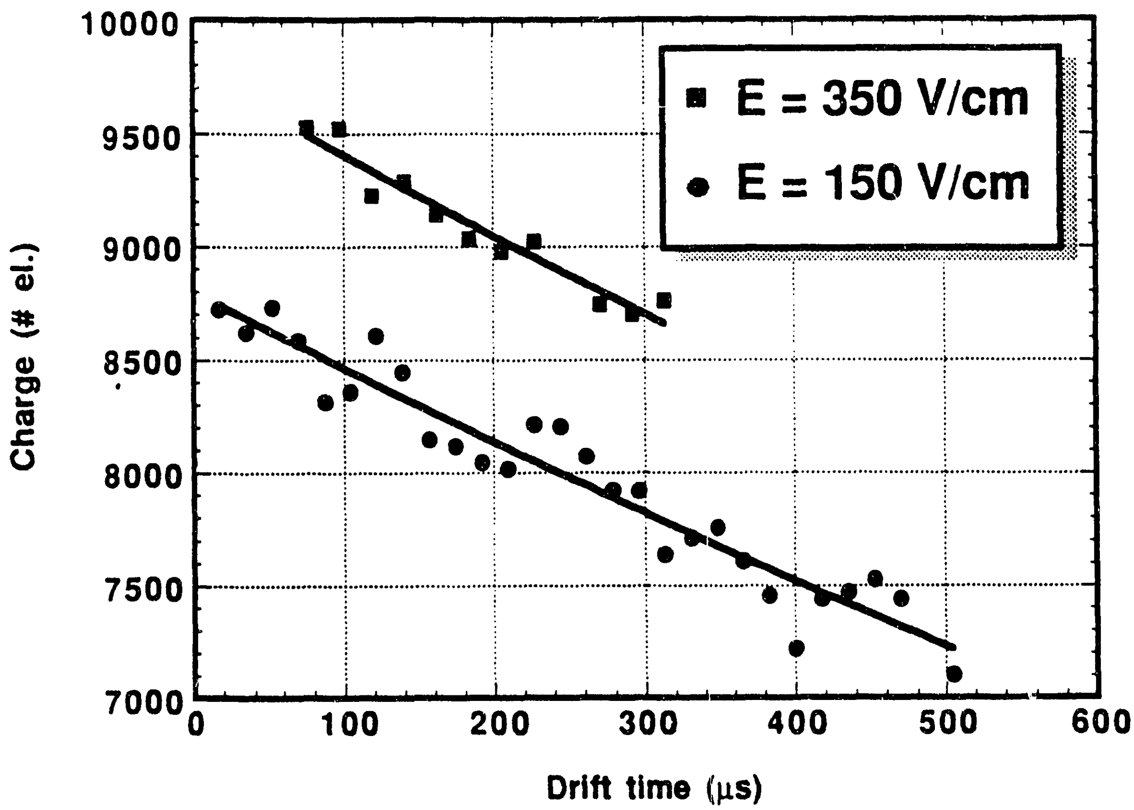
Fig. 1 Released charge vs the drift time T measured from high energy crossing muons at 350 and 150 V/cm. The exponential fit gives directly the lifetime. The extrapolation at T=0 gives the free electron yield.

Fig. 2 Squared rise time vs. the drift time at 350 V/cm. The linear fit of the data gives a diffusion coefficient D = 6.0 ± 0.2.

Fig. 3 Distribution of the collected charge by each wire for a minimum ionazing muon fitted with a double gaussian. The width of the distribution is dominated by the electronic noise (900 electrons). The second peak is produced by low energy delta rays superimposed to the main track.

Fig. 4 Distribution of the residual to a linear fit of the measured coordinates along the drift direction (r.m.s. = 290 μm). The non gaussian tails are due to peak displacements produced by low energy delta rays superimposed to the main track

Fig. 5 Collected charge vs distance from the stopping point for atmospheric muons decaying inside the detector (as in fig. 2) for two different electric fields. The upper curve is the result of a Montecarlo simulation that does not take into account the electron recombination. Lines are drawn to guide the eye.



E.F. (V/cm)	Lifetime (μs)	Free charge (# el.)
350	2584	9775
150	2540	8800

Fig. 1

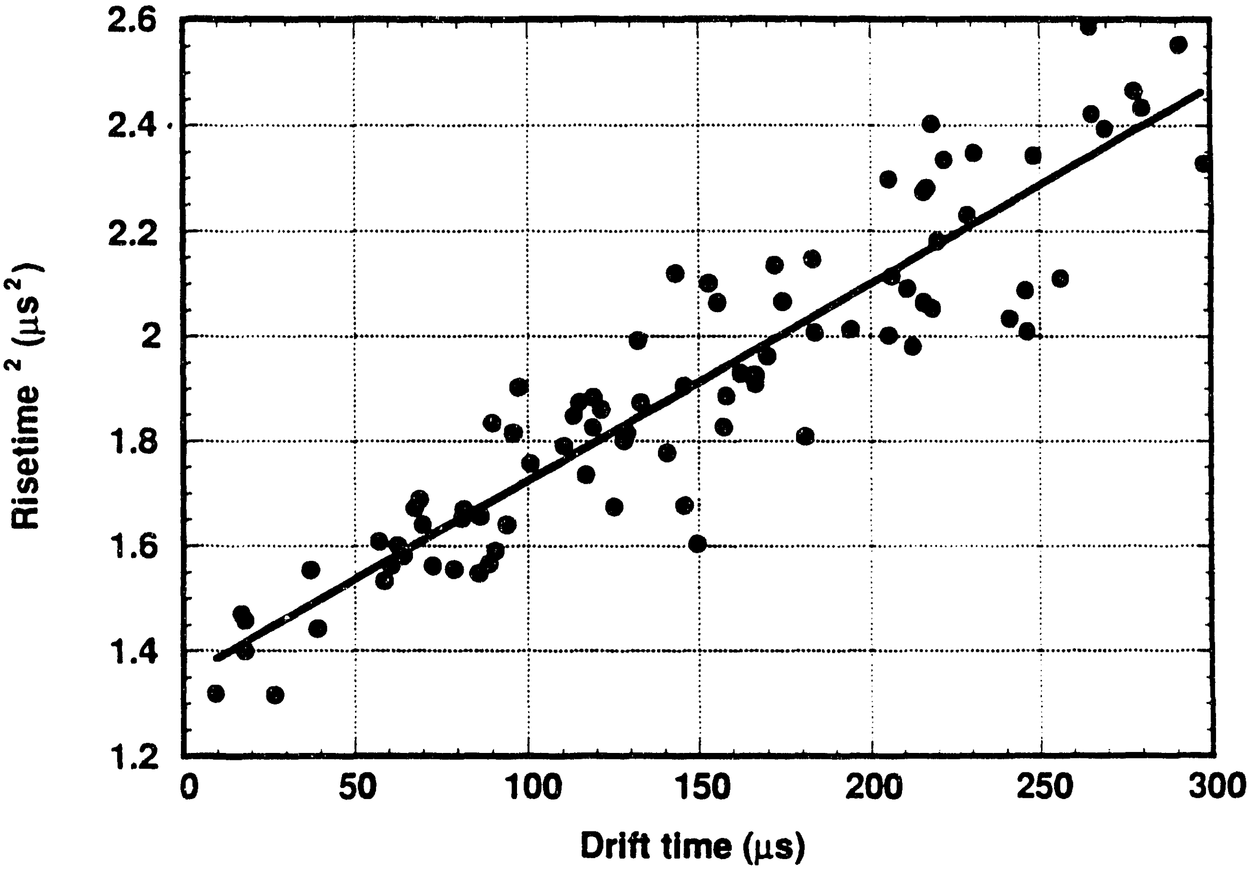
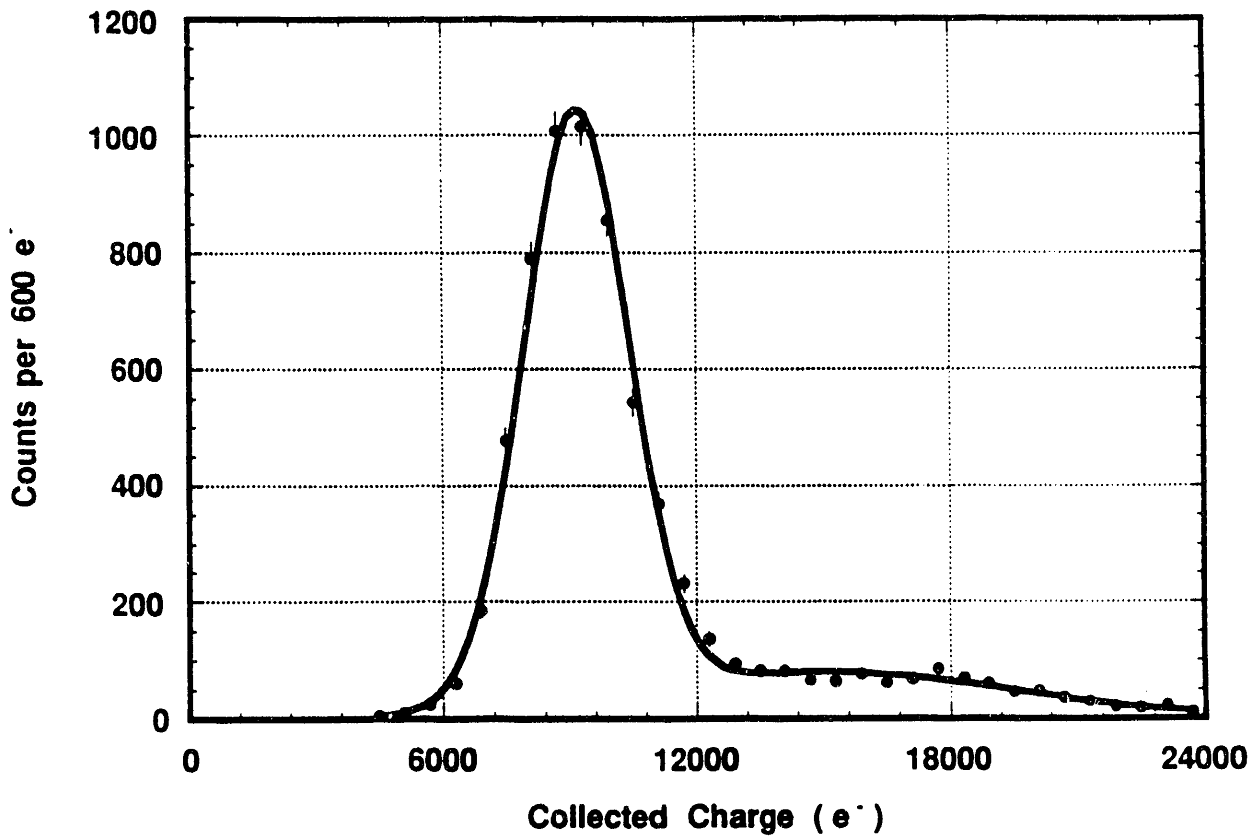

2.6
2.4
2.2
2
1.8
1.6
1.4
1.2
Risetime ^{2} (μs^2)
0
50
100
150
200
250
300
Drift time (μs)

Fig. 2



Counts per 600 e⁻
1200
1000
800
600
400
200
0
0
6000
12000
18000
24000
Collected Charge (e⁻)

Fig. 3

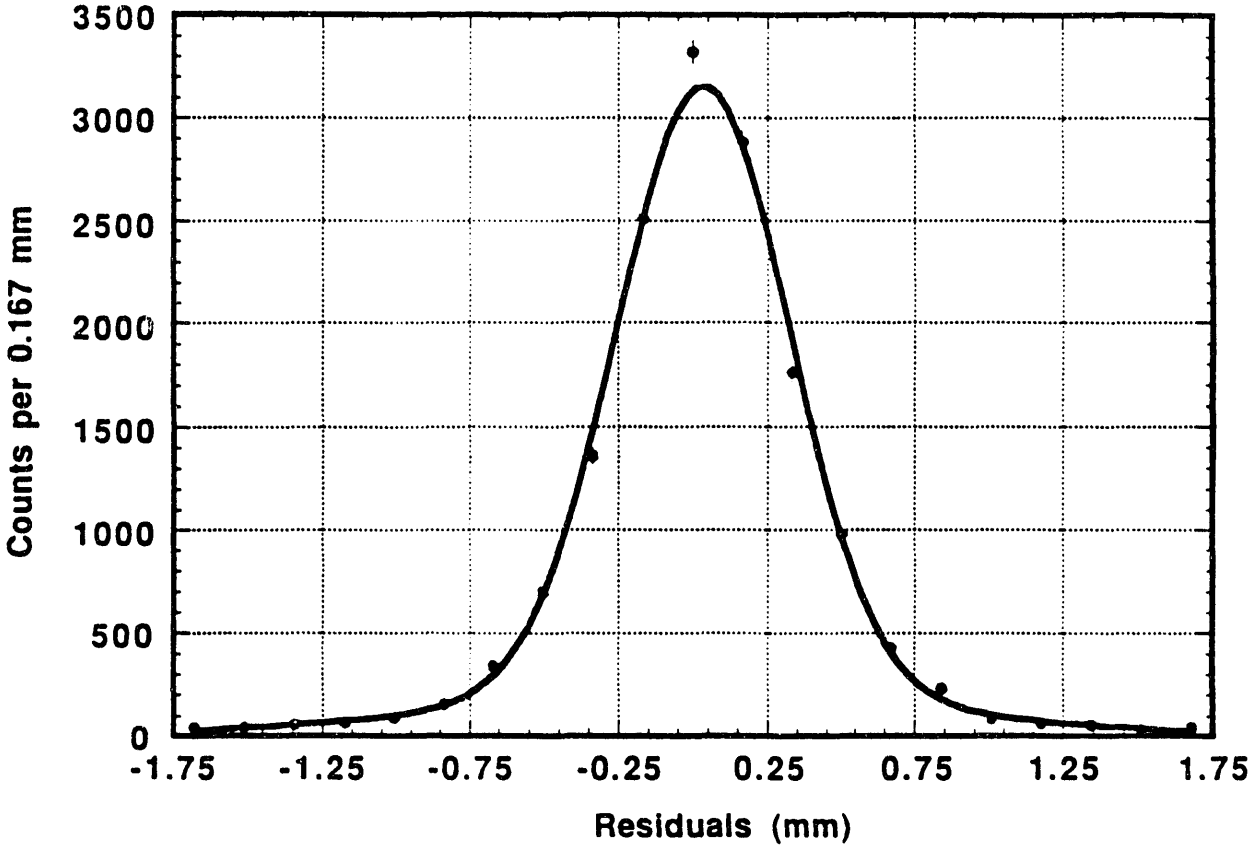
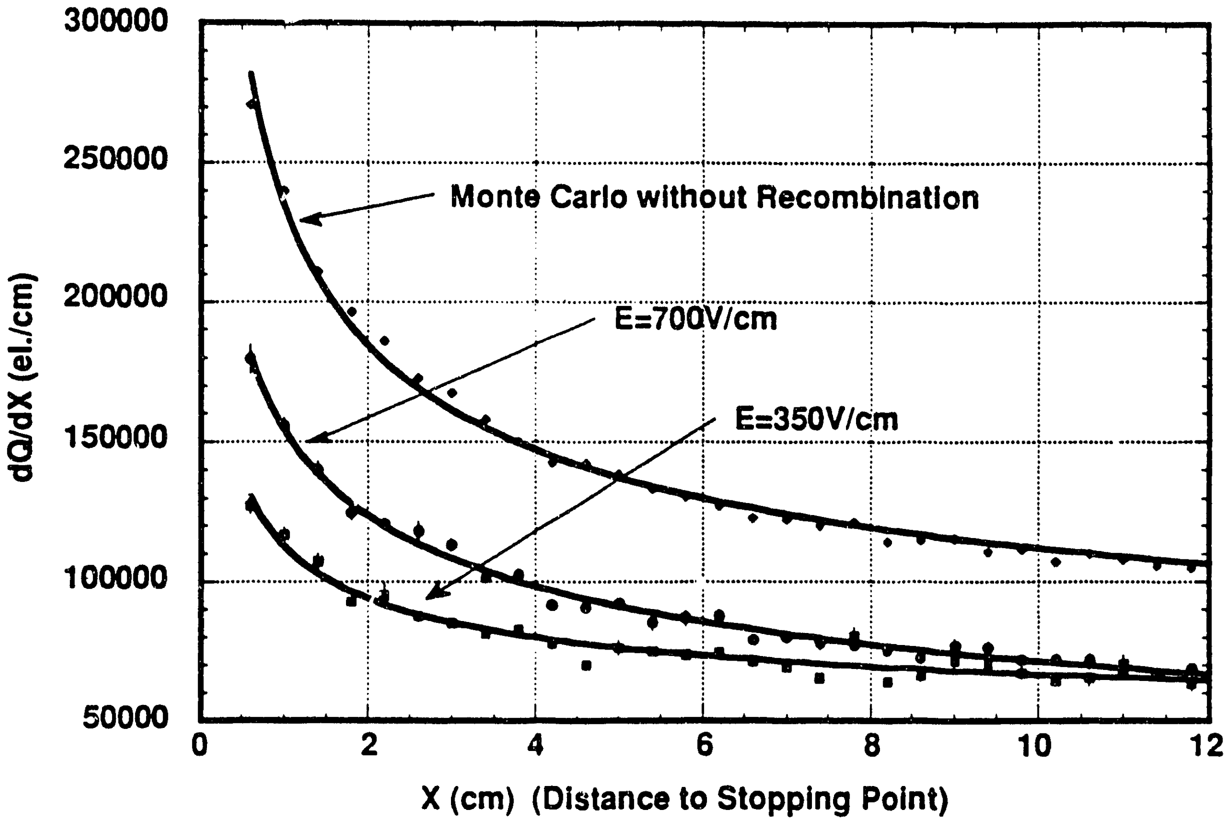

3500
3000
2500
2000
1500
1000
500
0
Counts per 0.167 mm
-1.75
-1.25
-0.75
-0.25
0.25
0.75
1.25
1.75
Residuals (mm)

Fig. 4



300000
250000
200000
150000
100000
50000
dQ/dX (el./cm)
Monte Carlo without Recombination
E=700V/cm
E=350V/cm
0
2
4
6
8
10
12
X (cm) (Distance to Stopping Point)

Fig. 5

c) <u>Long Baseline Neutrino Beam from CERN to the Gran Sasso and ICARUS</u>

During the past year a plan has been developed to propose to build a beam line off the SPS-LHC extraction proton beam line to extract an 80 GeV proton beam. This beam would then be used for a target for a neutrino beam that would be directed towards the Gran Sasso. Figures 6, 7, and 8 show some of the details. Using the ICARUS detection ($\sim$ 4000 tons) it would be possible to search for

$$\nu_\mu \to \nu_e,\ \nu_e + \mathrm{N} \to \mathrm{e} + \mathrm{x}$$
$$\nu_\mu \to \nu_\tau,\ \nu_\tau + \mathrm{N} \to \tau + \mathrm{x}$$

in a totally unexplored region. Figures 9, 10 shows the area of the δ^2m, $\sin^2 2\theta$ plot that could be covered by this search. The new tunnel to the LEP (LHC) region is expected to be completed in 1996 and this beam could be activated in 1997. We believe this is a very important program for ICARUS and for the search for neutrino mass.

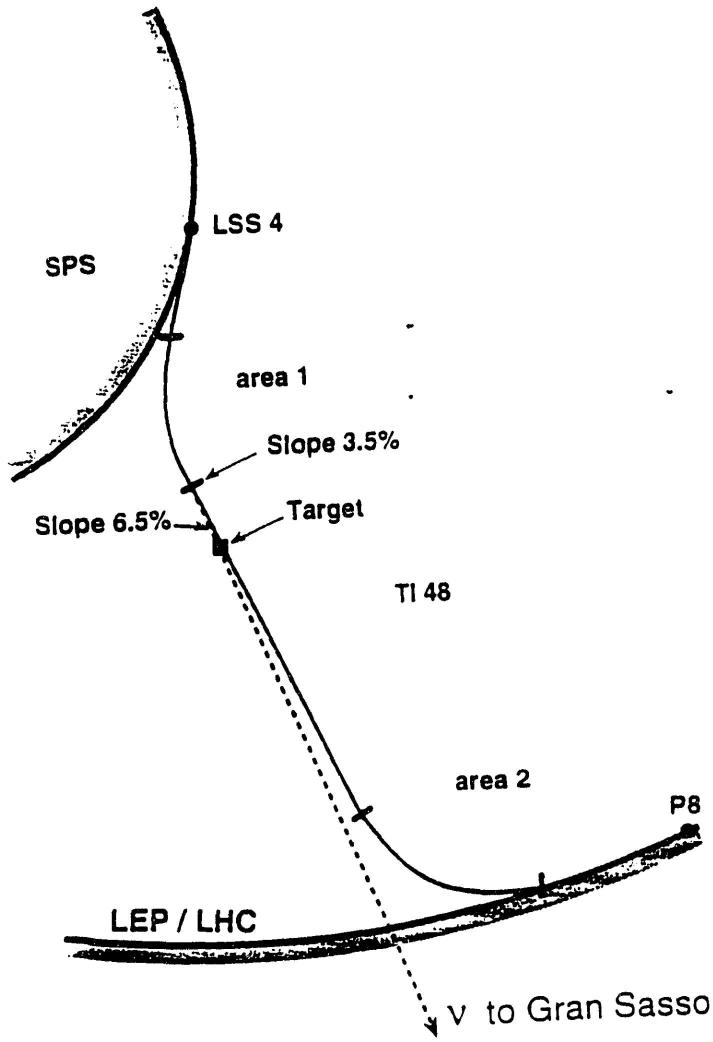


Fig. 6

CERN Neutrino Beam in the Direction of Gran Sasso

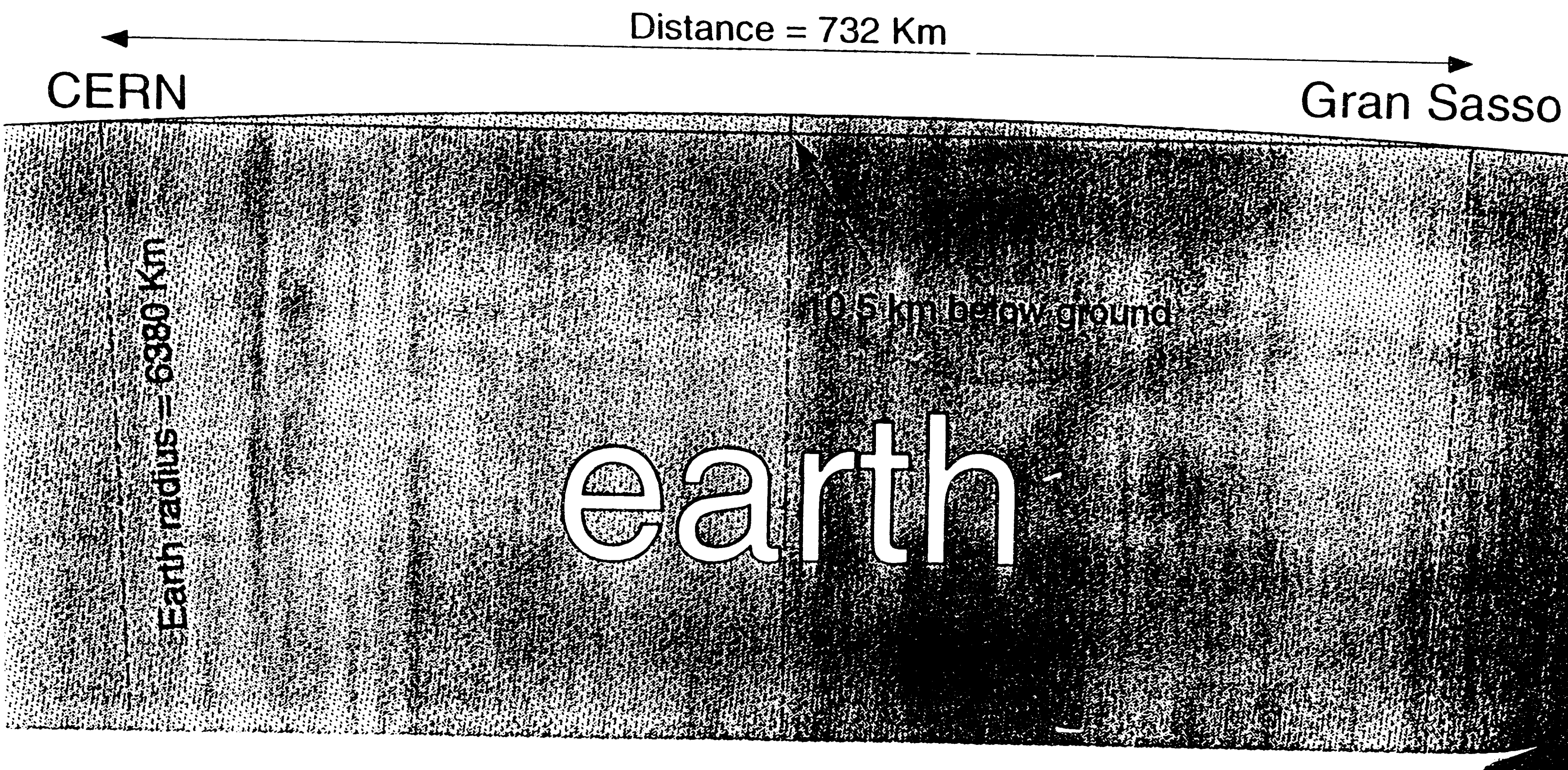
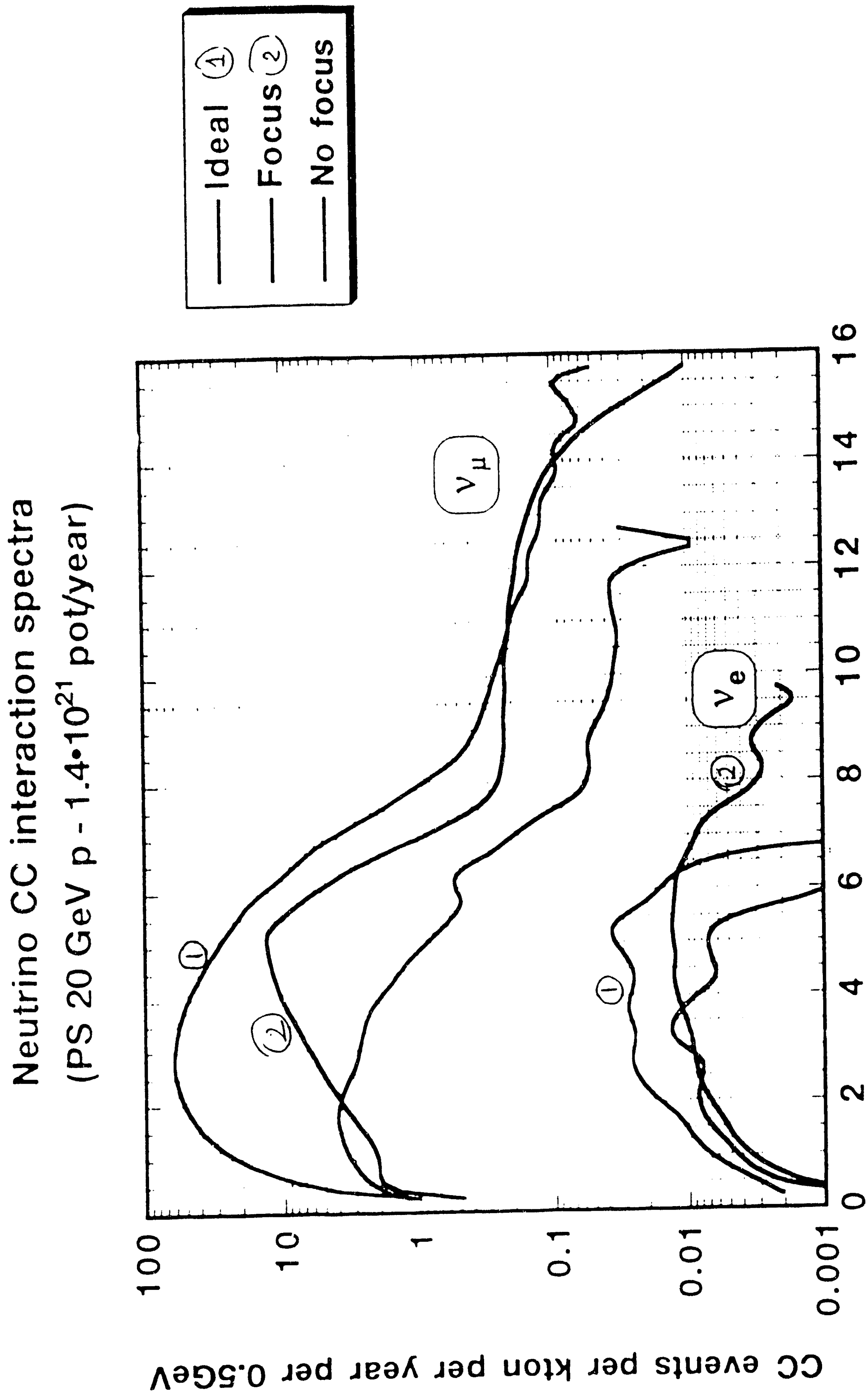


Fig. 7



Neutrino CC interaction spectra
(PS 20 GeV p - 1.4•10²¹ pot/year)
Ideal ①
Focus ②
No focus
ν_μ
ν_e
ν energy (GeV)
CC events per kton per year per 0.5GeV
100
10
1
0.1
0.01
0.001
0
2
4
6
8
10
12
14
16

Fig. 8

Exp. sensitivity

$$P_{\nu\mu\rightarrow\nu e}(E) = \sin^2(2\theta)\,\sin^2(\Delta m^2 L/2.5E)$$

if $L \ll E/\Delta m^2$ $\quad P_{\nu\mu\rightarrow\nu e}(E) = \sin^2(2\theta)\,(\Delta m^2 L/2.5E)^2$

$$\rightarrow \frac{dN_{ie}(E)}{dE} \Big/ \frac{dN_{i\mu}(E)}{dE}$$

after integration:

$$\frac{N_{ie}}{N_{i\mu}} = \sin^2(2\theta)\,(\Delta m^2 L/2.5)^2 \frac{\int_0^{E_{max}} (dN_{i\mu}/dE)\,E^{-2}\,dE}{\int_0^{E_{max}} (dN_{i\mu}/dE)\,dE}$$

$\rightarrow \langle E^{-2}\rangle$

hence:

$$\Delta m^2 \sin(2\theta) = 2.5\langle E^{-2}\rangle^{-1/2} L^{-1}\,(N_{ie}/N_{i\mu})^{-1/2}$$

Fig. 9

EXCLUSION PLOTS (90% C.L.)

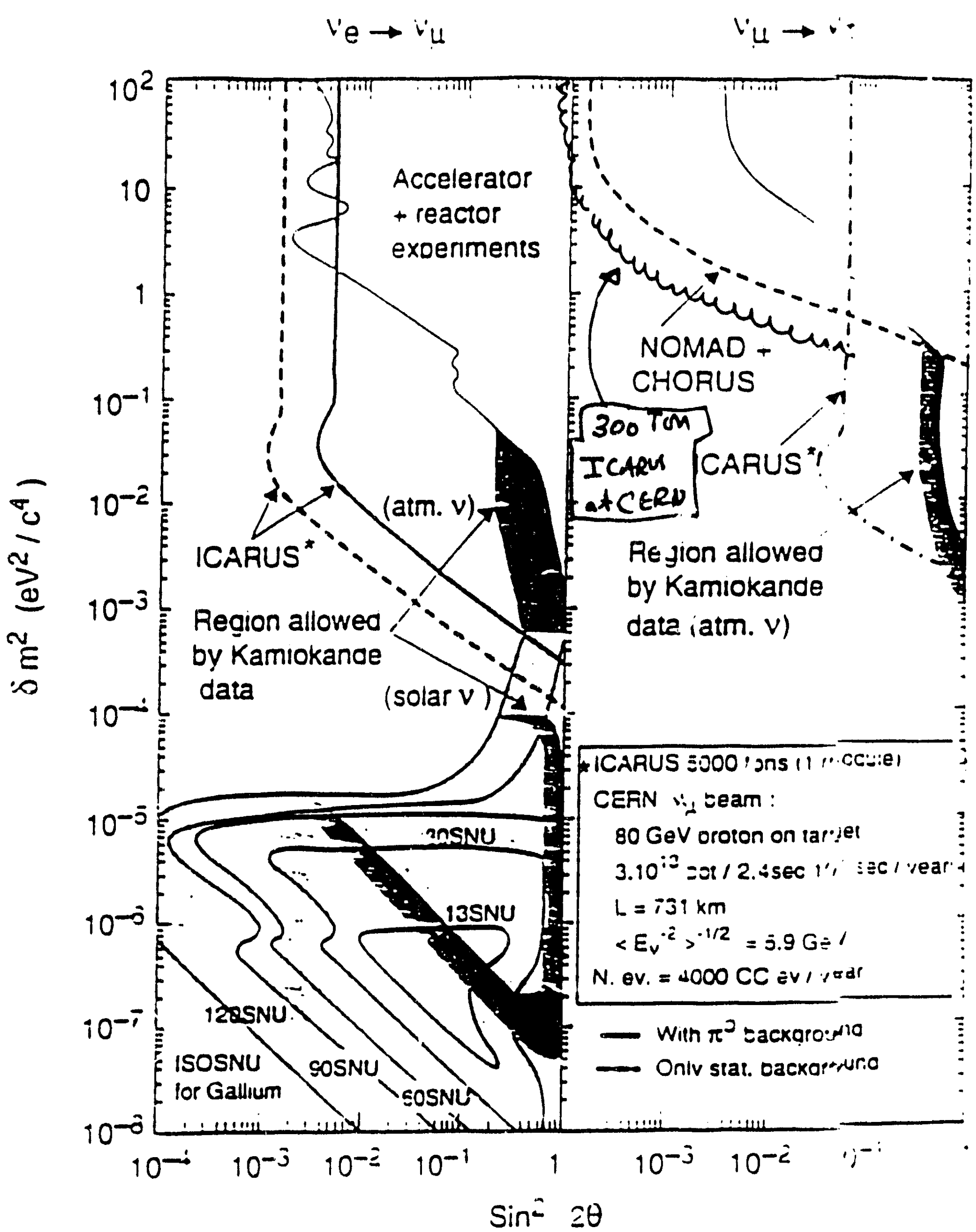


Fig. 10

d) Future ICARUS Program

ICARUS is a Liquid Argon three-dimensional TPC that uses electron drift to completely image particle physics events within the energy range of about 2 MeV to 10 GeV or higher. ICARUS was proposed in 1983 and has been developed at CERN and the Gran Sasso Laboratory over the past 6 years. The major goals of ICARUS are to study new physics beyond the Standard Model:

1) Mixing of Solar Neutrinos with a 1000 ton detector
2) Study of Proton Decay at a later stage with a 10,000 ton detector.

In respect of solar neutrinos and the technique allows the study of both the elastic scattering of ν_e ν_μ ν_τ, and the inverse β decay induced by ν_e. Thus the experiment directly tests the existence of solar oscillations, and is independent of the calculations of solar neutrino flux. It was shown how the flux of ν_μ and ν_τ neutrino that could arise from solar neutrino mixing, can be inferred from these two measurements for a large range of parameters that are allowed by current measurements.

The ultimate 10,000 ton ICARUS Detector will be used to uniquely search for $p \rightarrow K^+\bar{\nu}$ decays up to $\tau_p \sim 2 \times 10^{33}$ years. The SUSY-GUT minimal SU(5) theory predicts this decay mode to be the dominant one with a lifetime between 10^{32} - 10^{34} years, not contradicting the present 7×10^{31} years experimental limit on this decay mode. The theory also predicts that the SUSY particle mass scale may be in or beyond the TeV range, a prediction extremely important for the SSC experiments. Thus the ICARUS experiment and the search for the SUSY particles at the SSC represent the major tests for the SUSY-GUT theories.

A wide range of other particle physics experiments can be also carried with ICARUS particularly in the field of ν_τ detection.

The status and schedule of the ICARUS program is as follows:

1) A 3 ton detector with full imaging has been tested and is operated at CERN

2) A design of the 1000 ton detector to study Solar Neutrinos is underway. The completion of this detector is planned for 1995-1996, depending upon U.S. and Japanese support.

3) The study of background events (^{42}Ar) is in progress at the Gran Sasso Laboratory. So far no ^{42}Ar has been detected.

4) Monte Carlo simulation of the sensitivity of the 1000 ton ICARUS to the current MSW predicted neutrino fluxes shows very promising results.(M. Cheng, Thesis, UCLA, 1991).

5) A 100 ton detector made in an Expendable Modular Fashion is being designed to initially operate at CERN in the neutrino beam to study background for $p \rightarrow K^+\nu$ and to search for $\nu_\mu \rightarrow \nu_\tau$.

6) The ultimate 10,000 ton ICARUS detector will be designed later depending on the results achieved with the 1000 ton detector.

The ICARUS collaboration has an U.S. component (UCLA) that has played an important role from the initial concept to the present measurements. The UCLA team is very active in the Gran Sasso tests.

The future program is likely to have two components

(a) A 300 ton detector at CERN (further tests and neutrino oscillation)

(b) A 4000 ton detector at the Gran Sasso. (proton decay, $p \to K^+\bar{\nu}$, solar neutrinos and long base line neutrino beam for the $\nu_\mu \to \nu_e$ and $\nu_\mu \to \nu_\tau$ search) (see Figures 11, 12, 13)

INFN has approved $\sim$ 50 million dollars for ICARUS in the next 5 year plan. This will go a long ways towards achieving the goals of (a) and (b). On September 14, 1992, we learned the following from P. Picchi concerning the ICARUS program.

(i) INFN has set aside 30 MSF for a 300 ton detector to be constructed (1993 $\rightarrow$) and operated in a neutrino beam at CERN. The major goal to is to understand the construction techniques but it can also be used to search for

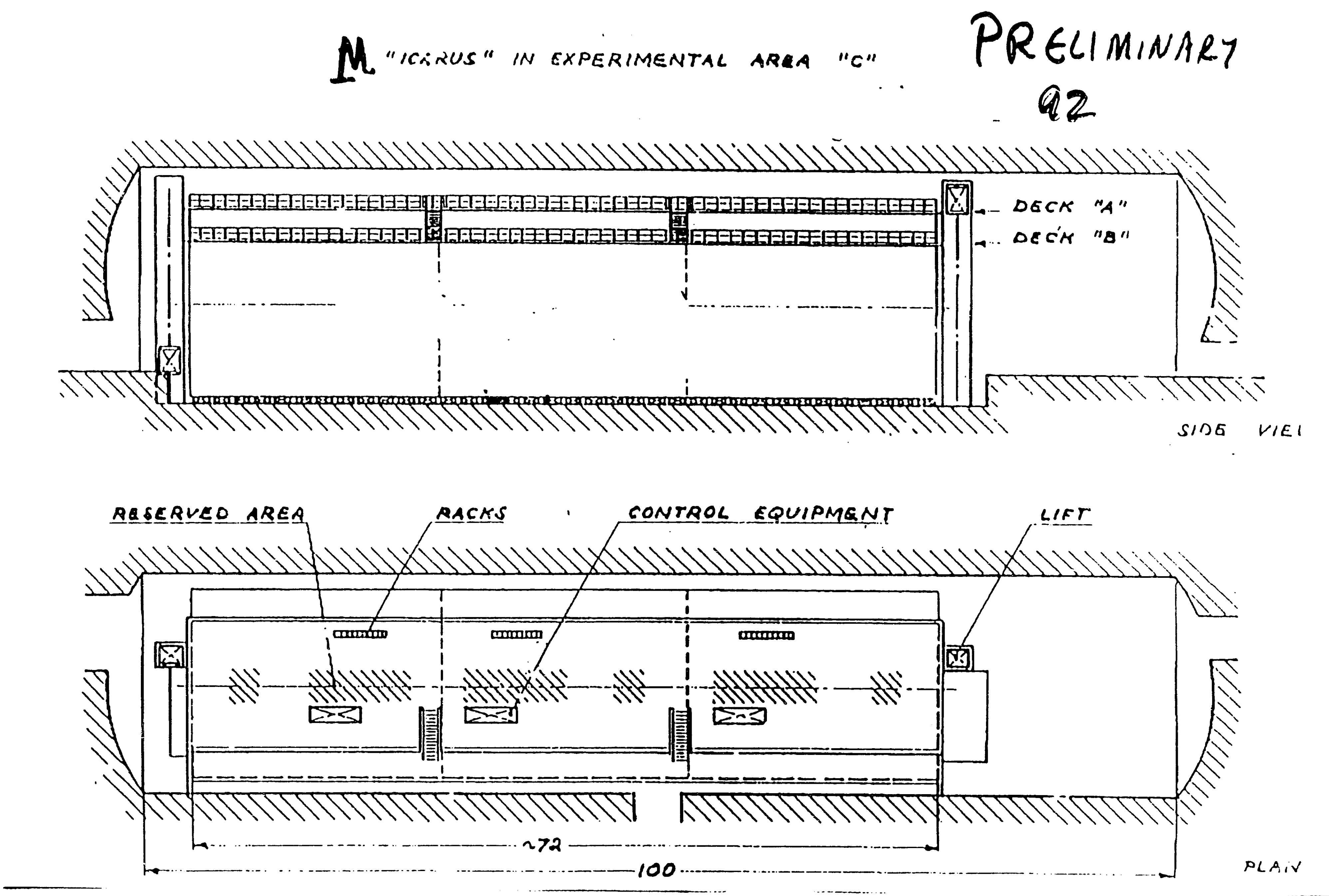
$\nu_\mu \to \nu_\tau$ to $\sin^2 2\theta \lesssim 10^{-4}$

in CERN neutrino beam. UCLA will be a participant to that experiment and UCLA will look out for the HV feed through problem (S. Lazic, Otwinowski).

(ii) 30 MSF has been approved to start the 5000 ton detector at the Gran Sasso

The Xe WIMP experiment will consist of Torino, Padova, Pavia, and UCLA. H. Wang will carry out his thesis on the work doing some construction in the Fall (92) at UCLA. A new ^{42}Ar experiment will be started. Y. Liu and S. Lazic will play a key role in this new measurement. M. Zhou will become a Frascati employee October 1, 1992. D. Cline, J. P. Revol and others will organize a small workshop on the long baseline neutrino beam experiment at CERN the last week of January 1993.

It is essential that the U.S. team keep the current activity in ICARUS! The scientific goals are of the utmost importance.



M "ICARUS" IN EXPERIMENTAL AREA "C"
PRELIMINARY
92
DECK "A"
DECK "B"
SIDE VIEW
RESERVED AREA
RACKS
CONTROL EQUIPMENT
LIFT
~72
100
PLAN

Fig. 11

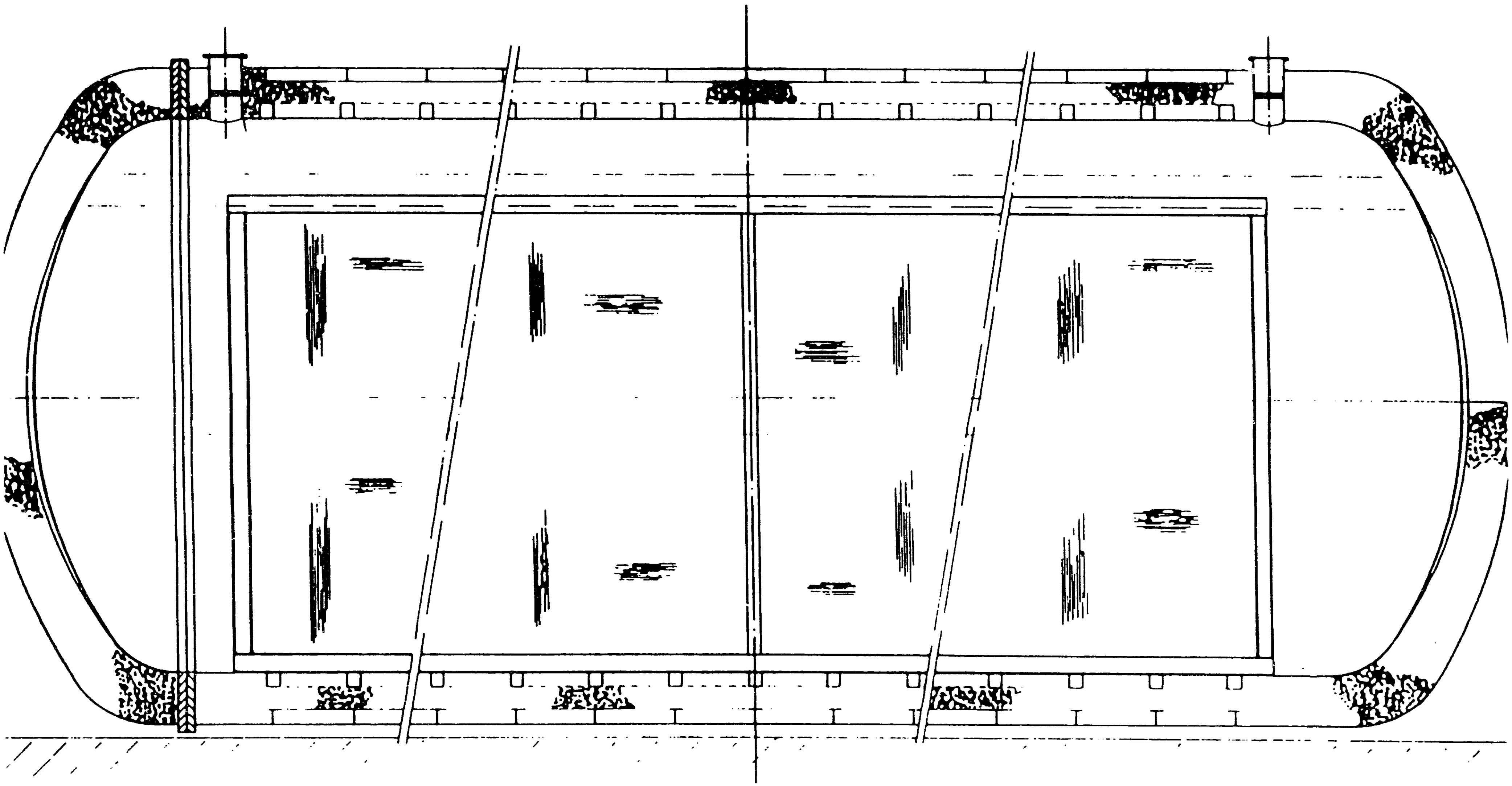


Fig. 12

LONGITUDINAL SECTION

TRANSVERSAL SECTION

WIRE CHAMBERS
CATHODS
RACE TRACKS

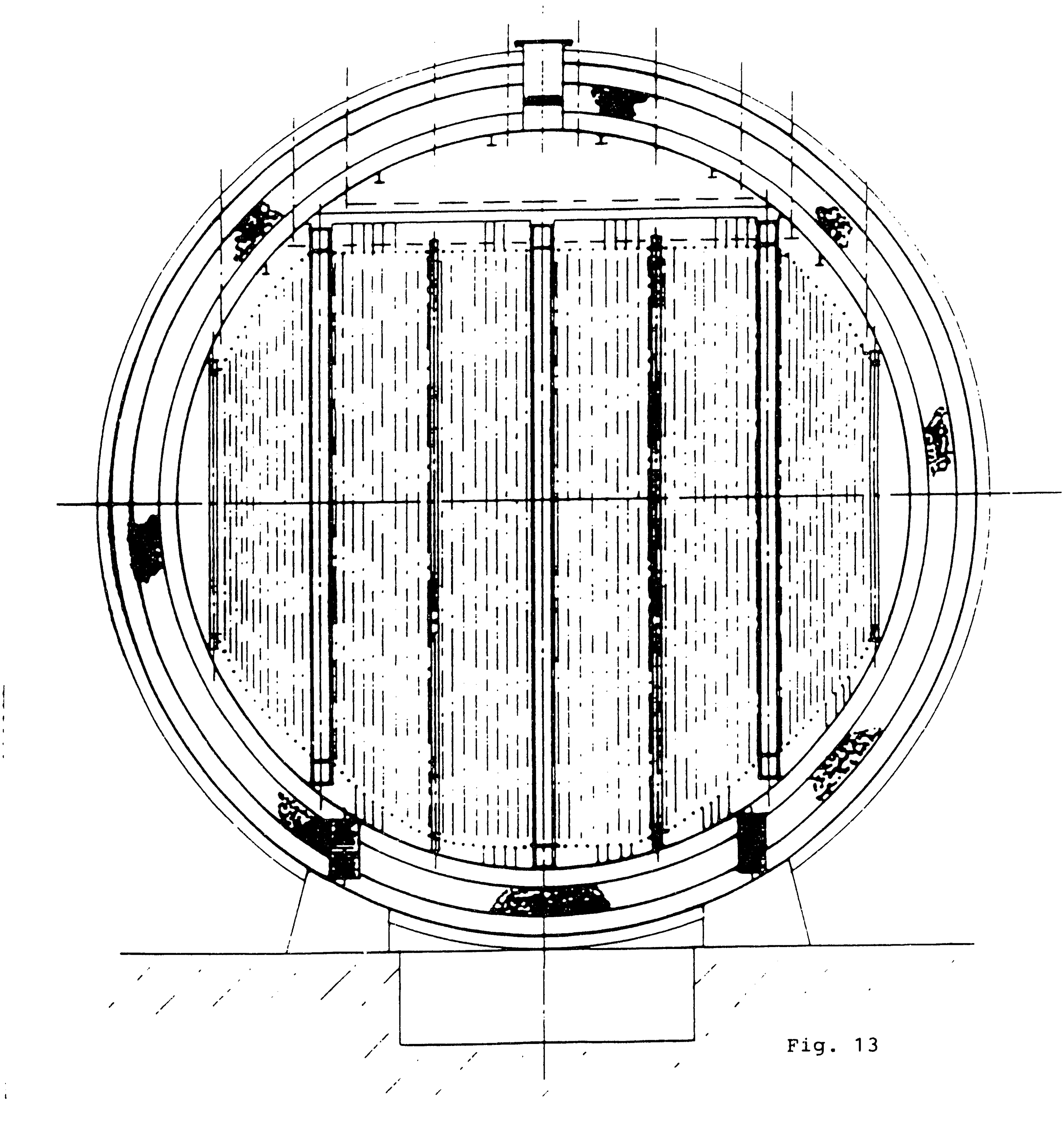


Fig. 13

e) WIMP Experiment with Xenon (See Apendix B1-C)

Introduction

One of the technical difficulties to use liquid as a detector medium is the purification. Especially for liquid xenon (LXe), which has many special characters: high density, high charge and scintillation yields, fast decay time of scintillation light, proportional scintillation, electron avalanche, etc. A more careful handling is required for purification due to its higher temperature compared with liquid argon. Since LXe time projection chambers for cosmic gamma rays or double beta decay experiments and homogeneous LXe calorimeters for future collider experiments were proposed, energetic investigations to increase the purity of LXe have been continued by many scientists. Remarkable results in those experiments were made by Aprile et al., who got 220 microsec lifetime for drifting electrons in LXe and Ichige, et.al., with more than 1 m attenuation length. They used a similar method in the purification system which consists of a chain of Oxisorb, molecular sieves and hot getters.

Recently, we tried to purify xenon gas only by an Oxisorb like the ICARUS prototype purifier by which 2 msec LAr electron lifetime was reached. In consequence of additional simple processes on xenon gas, a lifetime of drifting electrons in LXe was extraordinarily improved from several microsec to several msec.

The Monitor Chamber

The monitor chamber that we used is an improved version of the chamber published in a previous paper. Fig. 14 shows the chamber configuration and its related electronics. In the new chamber, the cathode plate is replaced by a closing box which is made by a stainless steel plate with a gridded window (10mm in diameter) and a cylindric semi-box with a gold-coated photocathode on the center. The inner surface of the plate and the semi-box are fully evaporated with Cr203 and a 100 volt potential is applied between these two parts to produce an electric field inside the box which has a gap of 10mm. Electron clouds, which are photoproduced by a 266nm UV laser pulse with 20 nsec width impinging on the photocathode, drifts towards the window plate and only those electrons within the window can pass through and continue to drift to the double gridded drift chamber which has the same configuration as the previous chamber.

As shown in the schematic of electrical connections, the window and photocathode are coupled together with the anode to a single charge sensitive pre-amplifier input. By this, we avoid an absolute calibration. When the electrons stay inside the box, the amplifier reads the same signal from the window plate and the photocathode but with the opposite polarity. During that time the drifting electrons cannot produce a signal on the amplifier. The incomplete cancellation is very small compared to the cathode pulse height, usually the difference is less than 0.2%.

There are two main advantages on account of this box. The first advantage is that the reflected UV light is absorbed by the inner surface of the box, so that extra electrons are not produced outside the box. The second is that the large electrical noise from the laser is shifted by about 10 microsec from the cathode signal which correspond to the drift time of the electrons inside the box. This reduces a lot of effort for electrical shielding and a more precise measurement of the cathode signal can be done easily.

Results

In our first test we purified xenon by the normal way without any processes mentioned above. The gas which was under pressure of 2 bars was simply passed through the Oxisorb from the room temperature storage 1 to the pre-cooled chamber at -100 degrees. In this case, the anode signal was not observed because of an insufficient purity of the liquid. By an analyses on the shape of the cathode signal, the lifetime of drifting electrons was about 4 microsec at an electric field of few 100 v/cm. This test was run twice and no difference was observed.

Fig. 15 is an example of a typical signal from the monitor chamber in the case of the purification with the full process at 400 v/cm. There is no significant difference between the cathode and the anode pulse heights and the ratio Qa/Qc is close to unity (> 0.99) under electric field variation from 15 to 400 V/cm. These results lead a lifetime of higher than 15 msec at 15 V/cm and more than 3msec at 400 V/cm. Although the process 1 and 2 were skipped from a second time purification, we could obtain the same result even for a different xenon gas.

As for the flush of Oxisorb, we have already found its importance for the purification of argon which was for the ICARUS test; the electron lifetime in LAr was improved form 100-200 microsec to more that 2 msec only by flushing the Oxisorb. To explain this phenomena we suspect mainly an effect of carbon dioxide which stays inside the Oxisorb cartridge with a higher concentration than the one in input argon. In a previous paper we showed that at least 25 ppb carbon dioxide can be absorbed on the walls of the chamber cell whose size is similar to the present chamber as well as that the rate constant for the electron attachment to carbon dioxide is high enough (1.6×10^{10} M^{-1} sec^{-1} at 800 V/cm). In case of LXe we can not expect the adsorption effect so much because of its higher temperature than LAr. From this point of view the additional processes 2 and 3 (not indicated) were performed.

Electron mobility was also measured by measuring the electron drift time for 50mm between the first and the second grids. The electron drift velocity v_d is determined at each electric field.

Conclusion

A very long lifetime for drifting electrons in liquid xenon were achieved by the purifier used only one Oxisorb and a simple distillation. The result which has a low concentration of electronegative impurity is equivalent to or better than the best result in the publication until now and such liquid xenon will be applicable for any kind of drift chamber. For further application, for example, calorimeters using scintillation, TPC which is determined time zero by scintillation signal and WIMPs detector proposed by us which has long drift space and is used proportional scintillation, etc.

Future WIMP Work

A beam test will be done in Italy. After this test, we will move to Mont-Blanc for the first WIMPs detector test.

There is also work to be done at UCLA. The WIMPs detector central wire planes will be wired here, which consist of one anode plane and two grid planes, all with the same diameter of 10 cm, the anode, which is the most difficult one is made of 3.5 micro-meter wires place at every 2 mm one the anode ring (for the safety of the experiment, we are going to make a copy of the anode with 4 micro-meter wires, in case of damage).

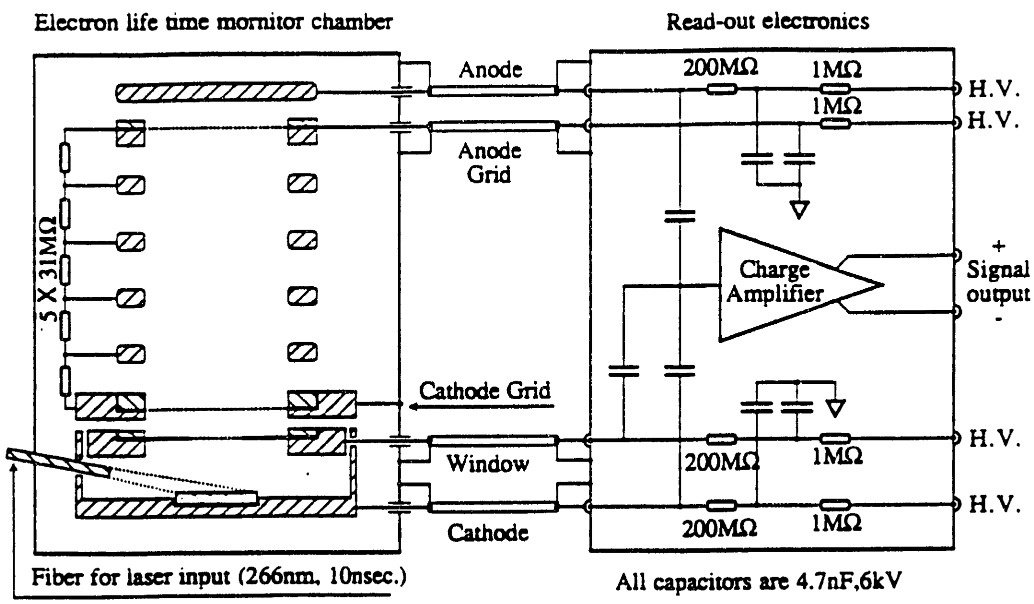
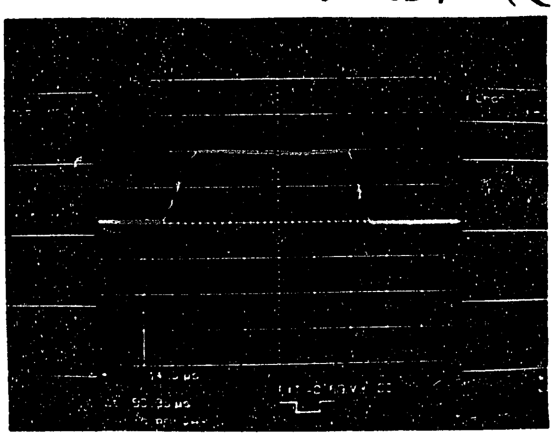


Fig. 14

Life time: $\tau = \tau_D / \ln(Q_C / Q_A)$



$(E = 50\ V/cm)$

$\tau_D = 50\ \mu sec \qquad Q_A / Q_C \geq 0.99$

$$\tau \geq 5\ msec$$

Fig. 15

f) The SNBO Project

A small effort has been expended towards the study of a Super Nova Detector at the WIPP Site (A DOE site). Progress in this project is described in the report of Appendix B1-D.

g) Update on the Status of the DOE Equipment Stored at CERN

S. Otwinowski is keeping a careful watch on the status of this equipment. The following memo gives a recent update.

9/15/92

To : D.Cline

From: S.Otwinowski

Subject: Status of the D.O.E. Equipment Stored at C.E.R.N.

The attached tables list the status of the D.O.E. equipment at C.E.R.N.

SOtw

S.Otwinowski 9/14/92

INVENTORY OF U.S. POSITION DETECTOR AT C.E.R.N.

Bldg	Nb of Boxes	Remark
156	26	in cabinet
156	16	in Super Gondola modules
899	15	in 8-packs
899	276	in wooden boxes
All	333	

S.Otwinowski 9/15/92

INVENTORY OF U.S. URANIUM PLATES AT C.E.R.N

- Uranium plates in wooden boxes:

Bldg	Plates Dimension [mm]	Nb of Plates	Weight [kg]	Remark
156	1600 x 200 x 2	943	11 138.1	39-46 plates per box
156	1400 x 196 x 2	939	9 651.7	39-54 plates per box
156	1140 x 235-272 x 2	4 641	48 693.1	39 plates per box
156	1140 x 205-251 x 2	351	3 427.8	39 plates per box
156	1140 x 166-250 x 2	351	3 115.0	39 plates per box
156	1200 x 197 x 2	156	1 336.8	39 plates per box
156	1000 x 197 x 2	312	2 263.0	39 plates per box
156	1103 x 277-315 x 5	1 056	30 947.0	24 plates per box
	All Plates	8 749	110 572.5	

- Uranium plates in wooden boxes:

  177 boxes not open - building 156

  7 boxes open - Building 156

- Uranium Plates inside the modules:

  23 Super Gondola Modules - building 156

  4 Forward Modules - building 156

S.Otwinowski 9/15/92

INVENTORY OF U.S. TEAM EQUIPMENT AT C.E.R.N.

	Equipment	Serial Nb	Place	Owners
1	Macintosh Plus + Drive		32-2C13	UCLA
2	CDU Chips, mounted, 60		20-R014	UCLA
3	ToolBox		20-R014	UCLA
4	Capactance Meter		20-R014	UCLA
5	Soldering Iron		20-R014	UCLA
6	Laser-Writer II NT	CABOB1MGOOOG	32-2C13	MIT/UCLA
7	Macintosh II + Micron Card + Crate			UCLA
8	MacVee Module			UCLA
9	CDU Time Sequencer Junior			UCLA
10	ImageWriter II			UCLA

B2) B Physics with Hadron Beams and Colliders

Since our work in UA1 initiating B physics at hadron colliders we have joined the effort on B physics at FNAL (E771) and are making plans for B physics studies at the SSC (SFT). Our goals are

(i) The Observation of CP Violation in the B System

(ii) The Search for Flavor Changing Weak Neutral Current B Decays at Tree Level

B physics with hadron interactions is extremely difficult and requires very advanced detectors. We review the progress of our efforts in the following sections. The team involved in this effort is A. Boden, D. Cline, W. Gabella, S. Ramachandran, and J. Rosenzweig.

a) The E771 experiment at Fermilab (See Appendix B2-B)

Introduction

The Fermilab Beauty Experiment E771 was tested in the first half of the last fixed target run at Fermilab during the spring and summer of 1990. Testing continued during the second half of this run, which started in the summer of 1991 and ended in January, 1992. Physics-quality data was taken during the last three weeks of the run.

E771 was expected to take data during the following run, which was originally scheduled for 1993. This run has now been postponed until 1994/1995. In a break with Fermilab tradition, the Director announced that he was defining all current fixed target experiments as completed, and he requested that experiments wishing for future beam time should submit a new proposal. E771 submitted this proposal in September, and has been allocated the number P867. This proposal will be considered at the December PAC meeting. P867 is the only fixed target beauty experiment to submit a new proposal; Kaplan has submitted a letter of intent for a new B physics experiment which may be based initially on E789.

During the three weeks of data taking during the last run, E771 accumulated approximately 110 million diumuon triggers and 60 million single muon triggers. Assuming a longer run, improved trigger efficiency and acceptance, higher beam intensity, improved reconstruction efficiency, and greater live time for the data acquisition system, P867 expects to accumulate one hundred times these numbers of triggers.

Progress on E771 Physics

Overview of Physics Goals

The primary physics motivation of Fermilab E771 is the observation of B meson and hadroproduction and decays. The collaboration anticipates measurements for the hadroproduction cross-section from the 1991 run, and the reconstruction of samples of several types of exclusive decay modes for B mesons. In addition, E771 is in a unique position to directly observe the lifetimes of several B mesons.

1991 E771 Run

E771 took beam from June 1991 through January 1992. The first few months were used for detector check-out, and we estimate that during the last 3 weeks the experiment took useful data. It is estimated that we have 110 million di-muon triggers and 60 million single-muon triggers on tape. Clearly such a large number of events represents a significant analysis task.

Single-Muon Analysis

A team from the University of Pennsylvania has assumed primary responsibility for the analysis of single muon triggers taken in the 1991 run.

Pt Trigger and Muon Trajectory Analysis

Analysis of the Penn Pt trigger suggest that it performed well in the 1991 run. The trigger aims at triggering for muons with Pt greater than 0.8 GeV. As the trigger board produces trajectory information as a part of the trigger logic, it naturally serves as the starting point for the reconstruction of the muon trajectory in the spectrometer. Penn estimates that 30% of the Pt trigger firings result in reconstructed muon trajectories in both sections of the E771 spectrometer. The remainder of the trigger signals are attributed to noisy and inefficient pad chambers and analysis cuts.

Single-Muon Silicon Analysis

Penn personnel have made seminal contributions to E771 silicon analysis. In particular, Penn has designed and implemented a sophisticated interactive graphics system for silicon analysis. This system provides invaluable visual feedback into the design and performance of reconstruction techniques. Independent work by the Penn group has verified many results from the silicon analysis, providing an important contribution to the analysis of system performance, alignment measurements, and vertex reconstruction techniques.

As in the case of the di-muon triggers below, the muon trajectory from the spectrometer is matched to a reconstructed silicon trajectory. This trajectory is compared to the reconstructed primary vertex (see below), and muons with significant impact parameter are retained for further study. A muon with both significant impact parameter and high transverse momentum are the desired signatures for B candidates.

Di-Muon Analysis

The code for spectrometer event reconstruction and J/Psi identification has been tuned-up over the last few months, and is now running smoothly and delivering J/Psi (see Figure 16). University of Virginia personnel have assumed the major responsibility for the delivery and tuning of this code.

Di-Muon Silicon Analysis

As stated in previous reports, UCLA personnel have in the past and continue to play a primary role in the analysis of silicon data for E771. In particular, UCLA personnel are responsible for the official silicon analysis architecture, and all of the major components.

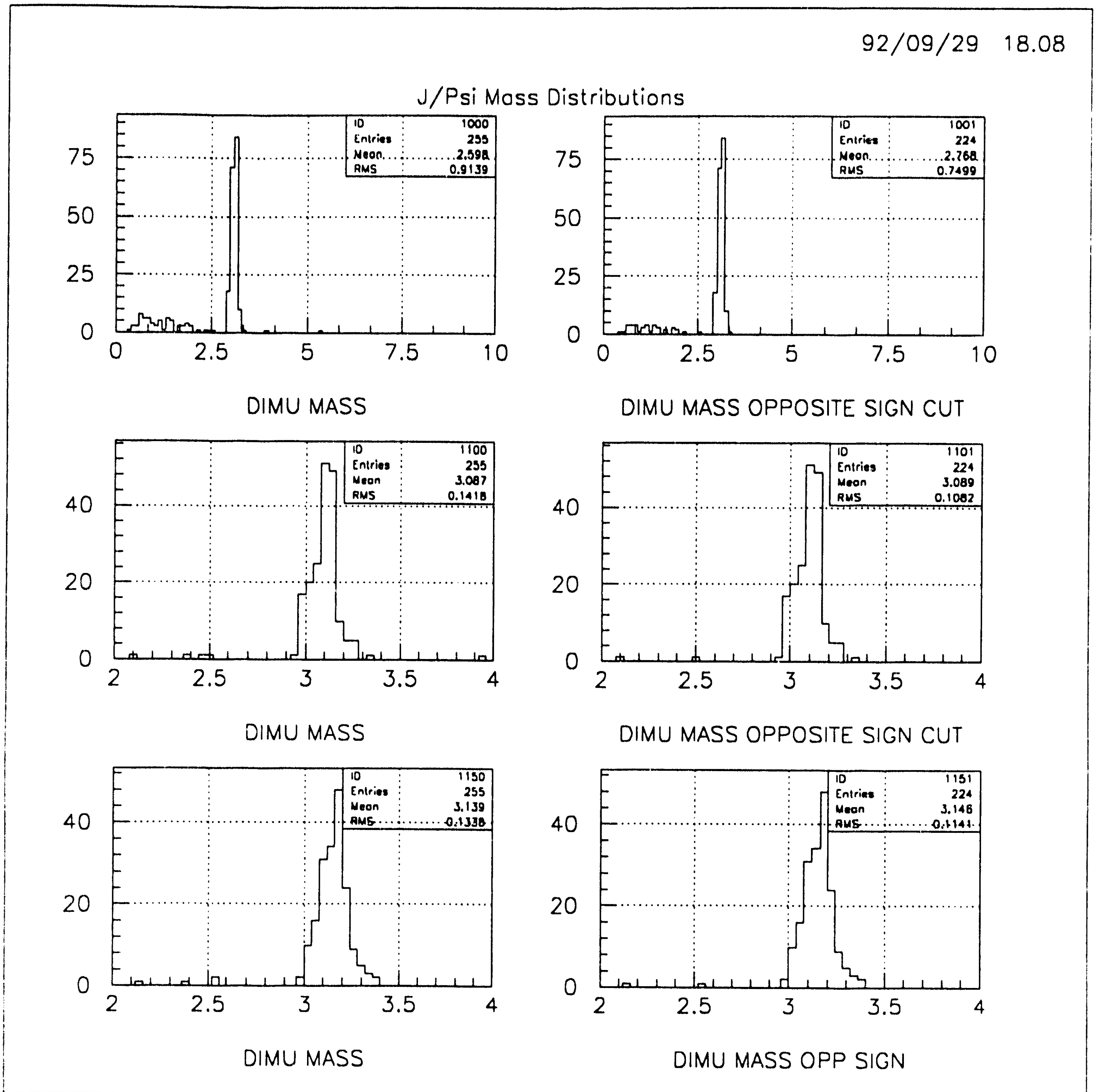

92/09/29 18.08
J/Psi Mass Distributions
ID 1000
Entries 255
Mean 2.598
RMS 0.9139
DIMU MASS
ID 1001
Entries 224
Mean 2.768
RMS 0.7499
DIMU MASS OPPOSITE SIGN CUT
ID 1100
Entries 255
Mean 3.087
RMS 0.1418
DIMU MASS
ID 1101
Entries 224
Mean 3.089
RMS 0.1082
DIMU MASS OPPOSITE SIGN CUT
ID 1150
Entries 255
Mean 3.139
RMS 0.1338
DIMU MASS
ID 1151
Entries 224
Mean 3.146
RMS 0.1141
DIMU MASS OPP SIGN

Fig. 16

Primary Vertex Reconstruction

The problem of correctly reconstructing the primary vertex position in the presence of considerable noise and clutter in the silicon system remains a significant issue. In the majority (75%) of the events, the silicon worked well enough to allow the identification of a subset of the tracks that meet a nominal set of confidence criteria. Reconstructed vertex position distributions match the physical target configuration (see Figure 17) and allow estimates of primary vertex resolution from data. Results are consistent with expectations from Monte Carlo studies, and are critical to the successful acceptance or rejection of B candidates. The remaining 25% of the events appear to cluttered to have high confidence in any reconstructed primary vertex.

Muon Trajectory Matching

It is a straightforward task to select the set of silicon trajectories that match spectrometer tracks. From the sets of silicon trajectories that match each of the muons, the set of tracks that best match the muons is selected by the following set of criteria:

1) trajectory match quality
2) presence/absence of stereo hits
3) mass (sensitive only to trajectory slope parameters)
4) Point of closest Approach (PCA) separation and/or position
5) Impact Parameter (presuming you have confidence in the primary vertex)

Comparison of Muon and Primary Vertex

Once the muon pair is identified in the silicon, it is a simple task to compare the PCA position to the reconstructed primary position, looking for a statistically significant difference as the signal for a B candidate. While there are hints of such signals, the existing J/Psi data set is still to small to allow any significant accumulation of B candidates.

Production Runs at Fermilab

The official experiment production runs are going to be run on the Fermilab unix farm facility. E771 personnel from Duke, Fermilab, and UCLA have ported the dimuon analysis code to the farm facility, and are currently running a large pre-production test job on a small number of farm nodes. Results from this job look favorable (see Figure 16). We are negotiating with FNAL to obtain a larger number of farm nodes on which we intend to start full production runs.

The Future of E771

The running conditions anticipated in the 1994 run are summarized in Table I. It is assumed that the Fermilab beam energy will remain at 800 GeV/c, though there has been discussion of running at 900 GeV/c. The running time is based on a 10 month run with 2.5 months required for tuning the detector and electronics.

i) Yields and Efficiencies in the 1994 Run

The objective of the 1994 run is to accumulate the maximum numbers of inclusive and exclusive B decays as detected by the presence of high p_t single muons or high mass muon pairs. Estimates of the numbers of events produced in several B decay modes are

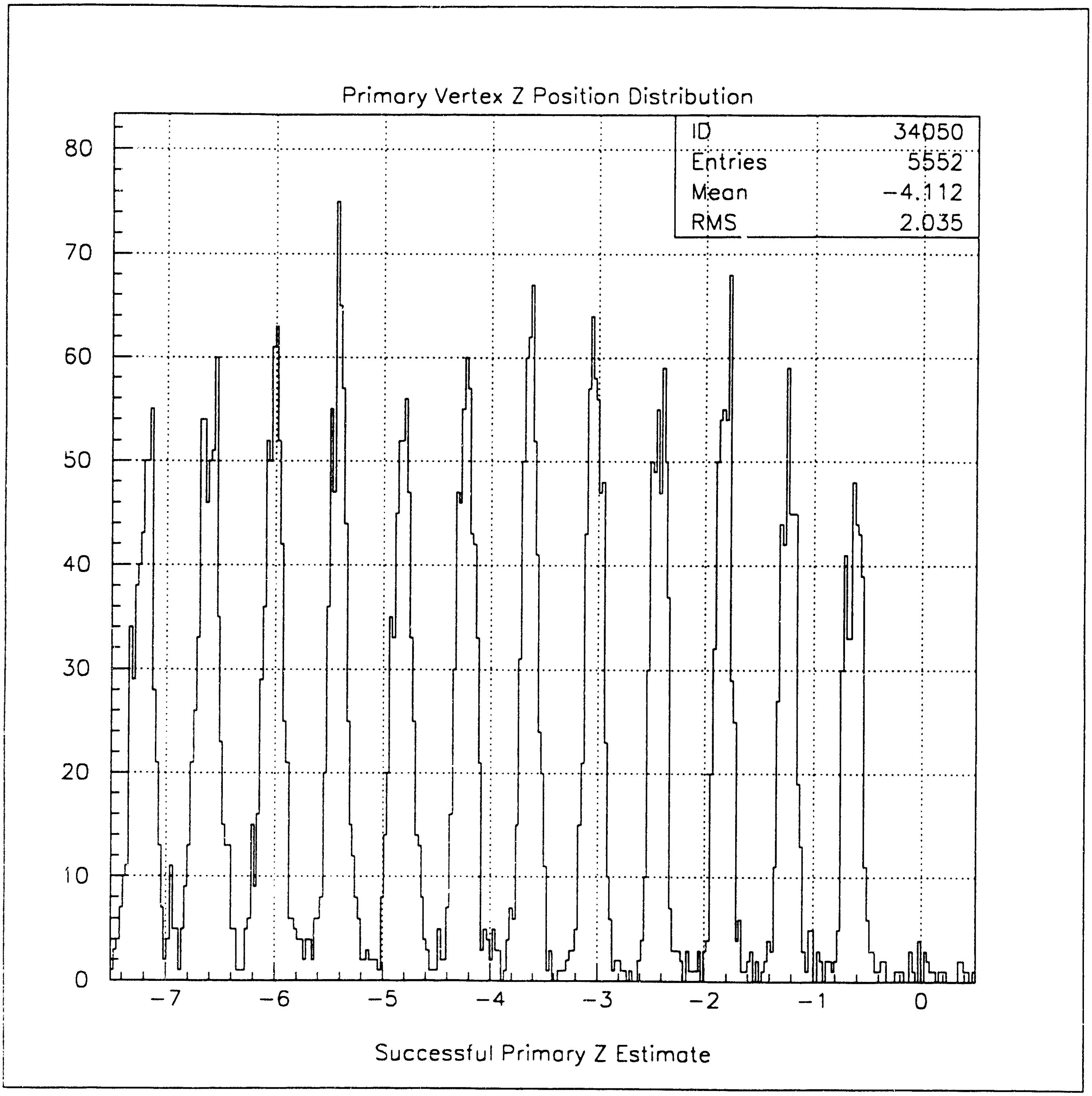

Primary Vertex Z Position Distribution
ID 34050
Entries 5552
Mean −4.112
RMS 2.035
80
70
60
50
40
30
20
10
0
−7
−6
−5
−4
−3
−2
−1
0
Successful Primary Z Estimate

Fig. 17

Table I
1991/1994 Run Conditions

	1991 Run	1994 Run
Proton Beam Momentum	800 GeV/c	800 GeV/c
Running Time	6.6×10^{5} seconds*	5.1×10^{6} seconds**
Spill Length	≈22 sec. every 57 sec.	≈22 sec. every 57 sec.
Target Material	2 mm Si foils (12)	2 mm Si foils (12)
Target Radiation Length	25.6%	25.6%
Target Interaction Length from σ_T(pSi)	4.10%	4.10%
Average Interactions/Second in Target	1.9×10^{6}	$\geq5\times10^{6}$
Beam/Second	4.6×10^{7}	$\geq1.2\times10^{8}$
Beam σ_x,σ_y	2.3 mm, 1.8 mm	4.0 mm, 4.0 mm
Total "Usable" Integrated Beam	3.0×10^{13}	$\geq6.1\times10^{14}$
Total Integrated Beam/cm^2 ($<\pm\sigma_{x,y}$)	$\approx3.3\times10^{14}$/cm^2***	$\geq8.2\times10^{14}$/cm^2
Total Integrated Interactions in Target	1.2×10^{12}	$\geq2.5\times10^{13}$

Table II
Summary of Overall 1994 Yields for Selected B Decays

Selected Decay Modes	Produced	Triggered• Recorded• Accepted	Totally Recnsted	Fraction of Mode Recovered
$J/\Psi \to \mu\mu$	4.8×10^{7}	2.7×10^{6}	2.2×10^{6}	4.6×10^{-2}
$B \to J/\Psi \to \mu\mu$	46,000	7,800	≈5200	1.1×10^{-1}
$B^0_d \to \Psi K^0_s \to \mu\mu\pi^+\pi^-$	730	≈35	≈20	2.7×10^{-2}
$B^0_d \to \Psi K^+\pi^- \to \mu\mu K^+\pi^-$	1660	≈140	≈45	2.7×10^{-2}
$B^0_d \to \Psi K^*(890) \to \mu\mu K^+\pi^-$	310	≈25	≈10	3.2×10^{-2}
$B^0_d \to \Psi' K^*(890) \to \Psi\pi^+\pi^- K^+\pi^-$ $\to \mu\mu\pi^+\pi^- K^+\pi^-$	760	≈65	≈7	1.0×10^{-2}
$B^0_s \to \Psi\phi \to \mu\mu K^+K^-$	570	≈50	≈25	4.4×10^{-2}
$B^{\pm}_u \to \Psi K^{\pm} \to \mu\mu K^{\pm}$	1,300	≈130	≈65	5.0×10^{-2}
$B^{\pm}_u \to \Psi K^{\pm}\pi^+\pi^- \to \mu\mu K^{\pm}\pi^+\pi^-$	1,800	≈80	≈25	1.4×10^{-2}
$B \to \mu$	7.2×10^{6}	9×10^{5}	8.2×10^{5}	1.1×10^{-1}
$BB \to \mu\mu$	3.7×10^{5}	6.3×10^{4}	5.2×10^{4}	1.4×10^{-1}
$B^0_d \to \pi^-\mu^+\nu$	2,800	≈220	≈145	5.2×10^{-2}
$B^{\pm}_u \to \rho^0\mu^{\pm}\nu \to \pi^+\pi^-\mu^{\pm}\nu$	11,200	≈560	≈300	2.7×10^{-2}
$B^0_s \to D^+_s\mu^-\nu \to \pi^+K^+K^-\mu^-\nu$	7,000	≈250	≈100	1.4×10^{-2}
$\bar{B}B \to \mu \bullet B^0_d \to D^-_d + X^+ \to$ all chrg$+X^+$	113,000	3,100	1,180	1.0×10^{-2}
$\bar{B}B \to \mu \bullet B^0_s \to D^-_s + X^+ \to$ all chrg$+X^+$	25,000	690	310	1.2×10^{-2}
$\bar{B}B \to \mu \bullet B^0_d \to D^-_d X^+ \to K^-\pi^+\pi^- + X^+$	51,500	1300	585	1.1×10^{-3}
$\bar{B}B \to \mu \bullet B^0_s \to D^-_s X^+ \to K^-K^+\pi^+ + X^+$	13,400	330	150	1.1×10^{-2}

given in the P867 Proposal (which is appended as Appendix B2-A), and the details of the numbers of events triggered on, logged to tape, accepted, and reconstructed are also included. These figures are summarized in Table II.

ii) Physics Goals in the 1994 Run

The increased yield of beauty events expected in the 1994 run will permit more beauty physics issues to be addressed. These issues include:

Determination of the cross section for beauty production.
Determination of the lifetimes of the B^{+-} and B^0 decays.
High precision measurements of various exclusive branching ratios.
Determination of the average mixing of neutral B's using the double semi-muonic decays of the B pairs.
Observation of B_S^o.
Measurement of the B baryon (in particular (λ_b).

Techniques for extraction of these quantities and calculation of backgrounds are give in the proposal.

iii) 1994 Experimental Set-up

The E771 Spectrometer configuration is shown in Figure 18. The configuration remains essentially the same for P867.

Then only new component is the proposed RICH counter to provide K, π identification. This would enhance the capabilities for achieving the B_S and λ_b physics goals, and improve background rejections.

Existing detector components will be modified as follows:

The silicon microvertex detector will be fully instrumented. During the 1991 run 10K channels were instrumented out of a total of 17.5K. Approximately 4K of these channels were instrumented with prototype electronics which needs to be upgraded. The additional channels will be used to complete the beam silicon system and to add planes to the silicon tracker.

A second level trigger will be added. This will use associative memories and will be completely independent of the first level triggers in that it will detect secondary vertices in the silicon vertex detector.

The RPC muon detection system will be upgraded by the addition of a fourth plane of RPC's and of a second layer of RPC in the central regions of the first two planes. Twelve panels of RPC will be rearranged. These modifications will improve the acceptance and efficiency of the 1A trigger.

Miscellaneous hardware upgrades include the modification of the pad chamber read-out system.

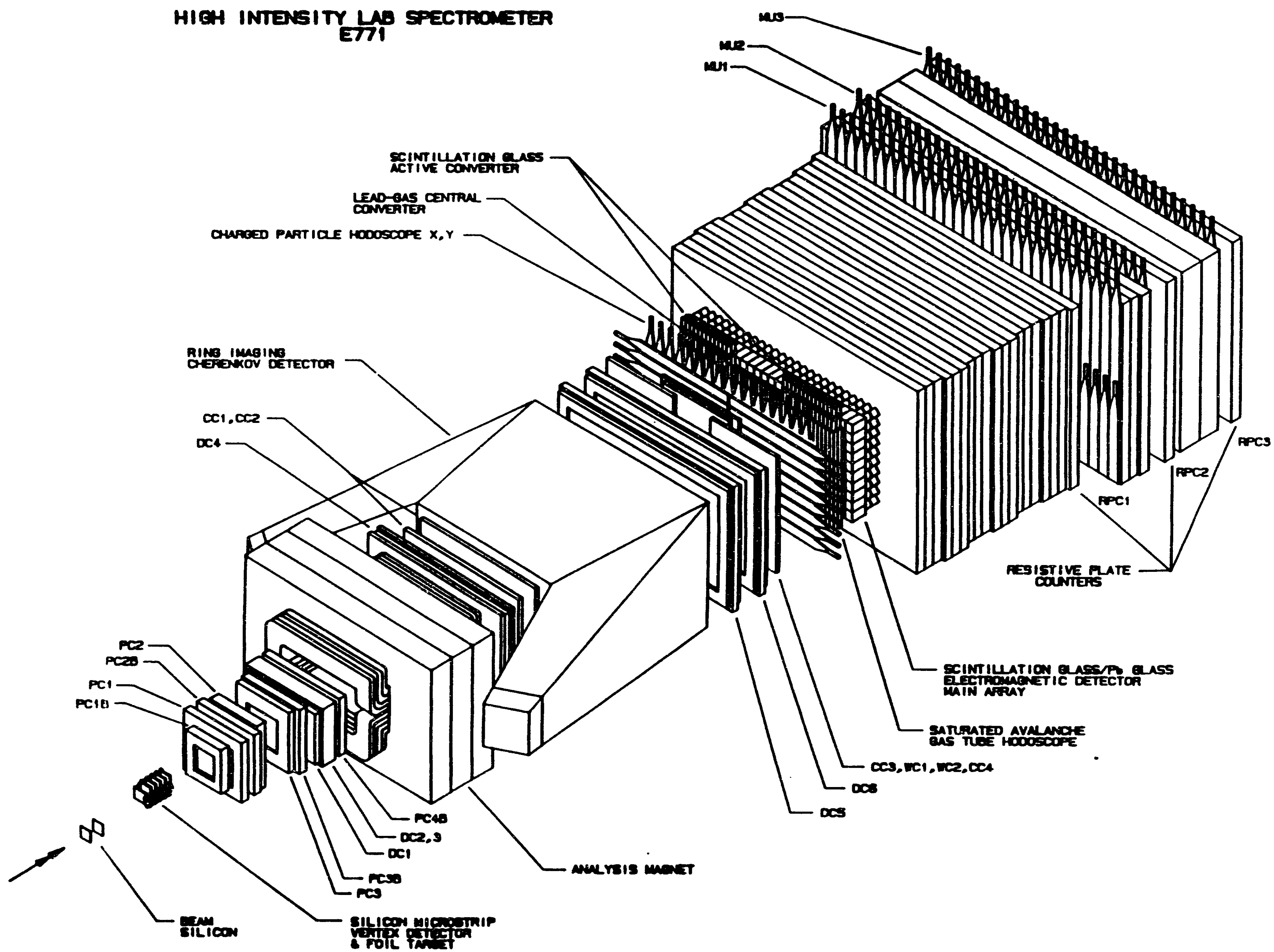

HIGH INTENSITY LAB SPECTROMETER
E771
MU3
MU2
MU1
SCINTILLATION GLASS
ACTIVE CONVERTER
LEAD-GAS CENTRAL
CONVERTER
CHARGED PARTICLE HODOSCOPE X,Y
RING IMAGING
CHERENKOV DETECTOR
CC1,CC2
DC4
RPC3
RPC2
RPC1
RESISTIVE PLATE
COUNTERS
SCINTILLATION GLASS/Pb GLASS
ELECTROMAGNETIC DETECTOR
MAIN ARRAY
SATURATED AVALANCHE
GAS TUBE HODOSCOPE
CC3,WC1,WC2,CC4
DC6
DC5
PC2
PC2B
PC1
PC1B
PC4B
DC2,3
DC1
PC3B
PC3
ANALYSIS MAGNET
BEAM
SILICON
SILICON MICROSTRIP
VERTEX DETECTOR
& FOIL TARGET

Fig. 18

Additional computer hardware is needed for monitoring and analyzing data.

iv) Summary

P867 aims to continue the study of beauty physics started in E771. With relatively modest upgrades to the existing detector we expect to accumulate significant data samples of various B decay modes.

UCLA has a major role in E771, particularly with respect to the computer systems, online and offline software, and silicon analysis. We expect to continue this contribution to P867.

c) Progress in SFT - Fermilab E 853

The UCLA group is a large contributor to the effort of the E853, bent crystal channeling experiment, at Fermilab. This is the development and testing of a novel extraction scheme from a storage ring. It has potential applications at the Superconducting Super Collider, as well as Fermilab itself. This study came out of the Super Fixed Target (SFT) B physics experiment proposed at the SSC by many groups including UCLA.

We finished the tracking and simulation studies of discrete modulation of the RF as a method to control the proton halo in the Tevatron. The paper "RF Voltage Modulation at Discrete Frequencies with Application to Crystal channeling Extraction", Fermilab-TM-1783 and UCLA-CAA0092-5/92, was submitted to Particle Accelerators. The paper examines the ideas of Jamie Rosenzweig (UCLA) and Steve Peggs (Fermilab) and is coauthored with them and with Richard Kick (Fermilab). It shows that discrete RF amplitude modulation is an attractive idea for enhancing the beam halo and controlling the proton flux on the bent crystal.

Detailed optics calculations were begun for the Tevatron and the extraction line used in E853. This involved "mapping" the magnet aperatures throught the extraction line. During Summer 1992, Sathyadev (Dev) Ramachandran (UCLA) worked at Fermilab modeling the flat crystal test using the Geant particle detector code. With C. Thornton Murphy (Fermilab) the spokesperson for E853, they made a first pass to estimate the inelastic scatter of beam halo protons from the flat crystal into a scintillator paddle 1 meter from the crystal. With Jean Rhoades (UCLA) and Gerry Jackson (Fermilab), a first version of a data acquisition code was written by Bill Gabella on the Fermilab ACNET system. Also, electronics for the instrumentation of the flat crystal test were implemented and checked.

d) <u>Studies of B Physics with the SDC Detector</u>

A <u>very</u> small simulation effort is under way to study the usefulness of the SDC detector for B physics. D. Cline and J. Rhoades are the principles in this effort.

Introduction

The SDC is a general purpose detector designed for the SSC. The physics goals of SDC include studies of electroweak symmetry breaking, properties of the top quark, and searches for new physics.

The tracking system is a major part of SDC, requiring good pattern recognition capability, high resolution vertex detection, and the ability to provide identification of high p_t tracks for a level 1 or level 2 trigger.

The proposed scintillating fiber detector, to be discussed further by Professor Atac, is part of the central tracking system. It provides excellent momentum, direction, and vertex resolutions, and also the level 1 trigger.

Simulation

Considerable effort has been put into Monte Carlo and simulation studies for SDC, but much work remains to be done, both in detector simulation and physics studies.

Detector simulations are based on the GEANT package. Detailed versions exist for detector components, and these can be linked together to simulate the whole detector or various subsystems of it. The geometry input to GEANT is shown for a quadrant of the full SDC detector in Figure 19 and for the scintillating fiber central tracking subsystem in Figure 20.

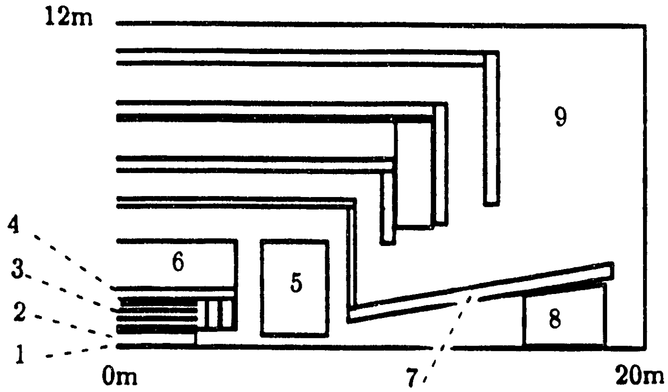
The two Monte Carlo packages ISAJET and PYTHIA have been used for event generation. Most studies have used minium bias events or Higgs decays.

Detailed studies of the scintillating fiber tracker have been done using the package SFT-SIM in conjunction with GEANT and PYTHIA, giving information about occupancy, pattern recognition, and reconstructed momenta for different experimental configurations.

B Physics

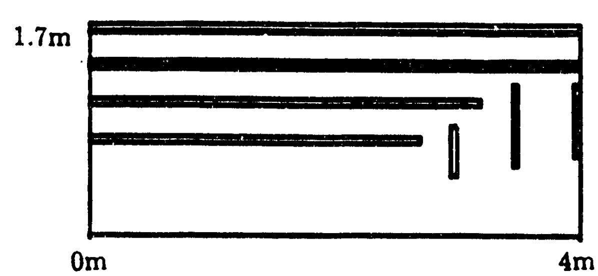
There has been little attempt to study beauty physics at SDC. Since UCLA has long been interested in this topic, a project is in progress to investigate the extent to which SDC can be used for B physics.

Topics being addressed include the performance of the triggers, the elimination of backgrounds, and the extent to which the scintillating fiber detector helps in tracking the decay particles. As a start, we are using the decay $B \rightarrow \psi K$. Results will be presented later.



Full SDC geometry including scintillating fiber central tracking and muon chamber subsystems. 1: BEAM PIPE, 2: MVTX, 3: CENTRAL, 4: COIL, 5: ENDPLUGCAL, 6: BARRELCAL, 7: ABSORBER, 8: FORWARDCAL, 9: MUON

Fig. 19



Central Tracker with superlayers and disks.

Fig. 20

B3) High Energy Collider Physics

Overview of the High Energy Collider Program

There are two high energy colliders being constructed, SSC and LHC. Both are subject to great uncertainty and the time schedule for both is uncertain. Our group has played a small but key role in the development of detectors for both machines.

(1) For LHC we have helped the conceptual design of the compact muon solenoid from the very start. Our interest in muons and the physics has helped motivate the CMS. We have helped organize a California based consortium to join (UCLA, UCR, UCD, UT Dallas). We are members of the RD5 muon study experiment at CERN (see below). We are now proposing scintillating fiber tracking for CMS using the Rockwell VLPCs.

(2) For SDC at the SSC we were among the first to join and to develop Scintillating Fiber Tracking and brought in the Rockwell International Corporation with the VLPC's (see Task H). We believe this is an extremely healthy example of Industry - University collaboration in the USA.

The Task B effort in either of these projects is very small but consistent with the unknown time scale of the SSC (1999-2003?) and LHC (1998-2000?) As the real schedule for these machines is clarified we will likely devote more effort. At present our work is more in the conceptual frame work.

The RD5 Program (See Appendix B3-A)

Introduction:

The RD5 experiment at CERN is measuring the properties of muons from hadron decays and of hadron punchthrough, i.e. angle, momentum and timing distributions of the outgoing particles will be measured for various absorber thicknesses, including the effect of strong magnetization of the absorber. In the next generation of high luminosity hadron colliders, the SSC and LHC, interesting events must be found in a background which is 11 orders of magnitude higher than the process under consideration. To have success in this very difficult experimental environment, one must have reliable punchthrough data, which is necessary for the construction of a muon trigger, allowing a fast and efficient cut on the transverse momentum of the muons produced. The RD5 detector includes beam defining chambers, a tracking calorimeter (TRACAL) inside a 3T superconducting magnet (M1) and muon chambers before, inside and after a 1.5T toroidal magnet (M2). The entire detector is a total of 32 interaction lengths [Fig 21]. In addition to the physics measurements mentioned above, RD5 provides an environment to test new detector technologies. A group, consisting of members of GEM collaboration, from the SSC has joined RD5 for this reason.

UCLA Role:

a) The pion beam used by RD5 contains a large contamination of muons. It is required that these superimposed muon events be subtracted offline during the data

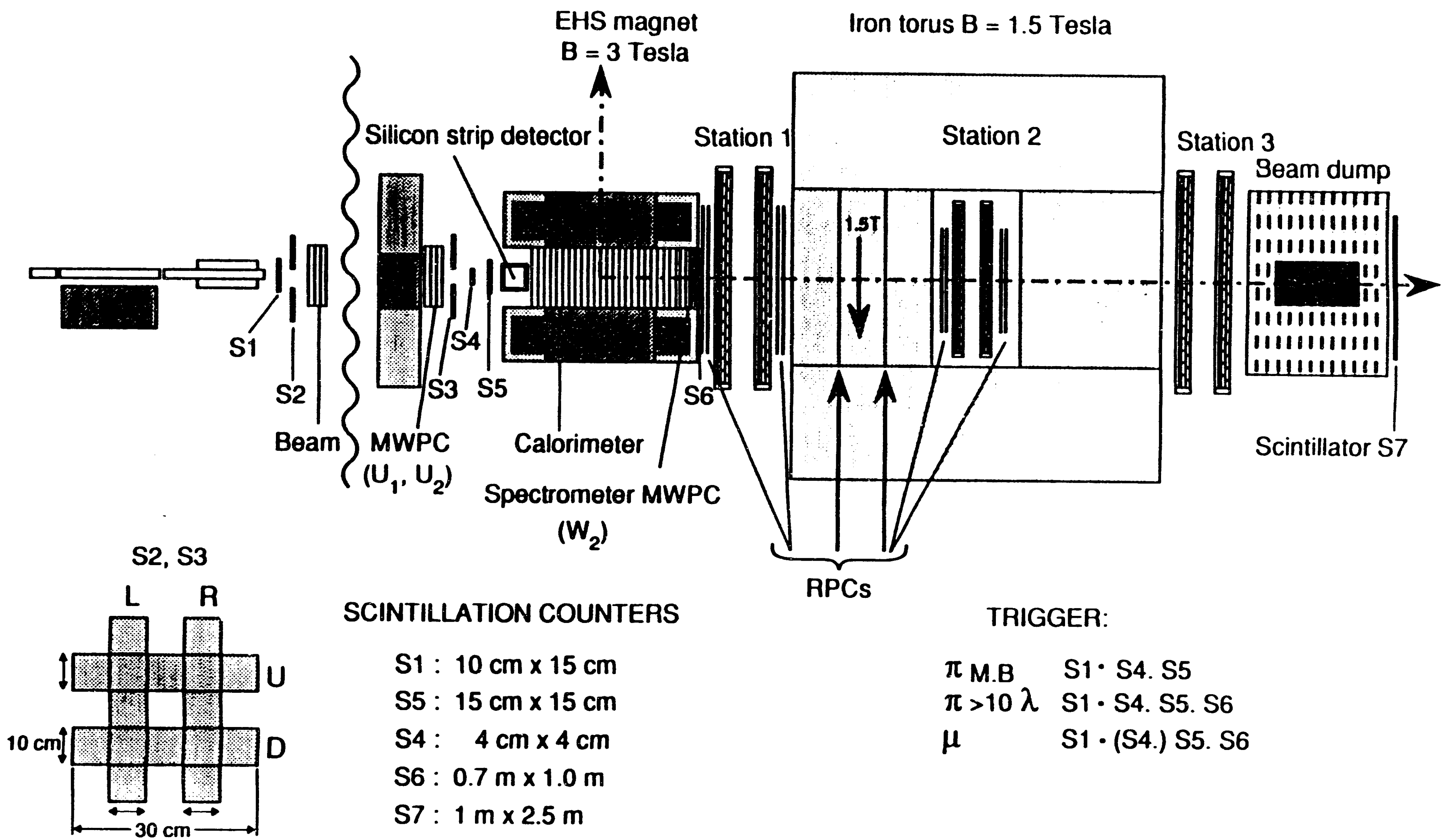

EHS magnet
B = 3 Tesla
Iron torus B = 1.5 Tesla
Silicon strip detector
Station 1
Station 2
Station 3
Beam dump
1.5T
S1
S2
Beam
MWPC
(U_1, U_2)
S3
S4
S5
Calorimeter
Spectrometer MWPC
(W_2)
S6
Scintillator S7
RPCs
S2, S3
L
R
U
D
10 cm
30 cm
SCINTILLATION COUNTERS
S1 : 10 cm x 15 cm
S5 : 15 cm x 15 cm
S4 : 4 cm x 4 cm
S6 : 0.7 m x 1.0 m
S7 : 1 m x 2.5 m
TRIGGER:
π M.B S1 · S4. S5
π >10 λ S1 · S4. S5. S6
μ S1 · (S4.) S5. S6

FIG. 21

analysis process; also, because the data acquisition system can only record a certain number of events per spill, these muon events exclude some interesting hadron punchthrough events, thus reducing the statistics associated with the punchthrough measurements. In order to solve this problem, a hardware trigger was built to look at the hits in TRACAL and decide whether the event was a muon track or a pion induced shower before the event is written on tape. During the 1991 runs the trigger condition used by the hardware trigger was not successful in excluding the moun background. A detailed study of the 1991 data was conducted to find a new trigger condition which excludes a substantial portion of the muon background but does not exclude any pions. Such a trigger condition was found and is being used during the 1992 runs.

b) The analysis of the 1991 punchthrough data has been completed [Fig 22]. The integral punchthrough probability as a function of meters of equivalent iron was calculated for 30, 40, 50, 75, 100, 200 and 300 GeV/c pion data. As part of the analysis, it was necessary to develop an algorithm to separate the superimposed muon events from the pion data sample. Upon the completion of this analysis, we are now assisting in the preparation of an RD5 paper for publication.

c) As a continuation of the analysis of the integral punchthrough probabilities, we have compared the RD5 results with a parameterization of previous punchthrough data [Fig 23]. We want to understand the discrepancies between our results and this parameterization to determine if a modification of the latter is justified.

d) In the next step of the analysis of the 1991 data, we wish to find the angular distribution of punchthrough particles with respect to the beam direction. This will be done by reconstructing the punchthrough particle's track from hits in the muon chambers. This analysis is beginning now.

RD5 in 1992:

The RD5 detector has undergone a major expansion since the 1991 runs [Fig 24]. An important change, from the point of view of the punchthrough measurements, is the installation of additional muon chambers at stations 2 and 3. These chambers will provide an additional verification of our punchthrough measurements and will improve our ability to reject background.

The beam halo has a sizable rate, and is uniformly distributed over the whole area of the muon chambers. These muons could fake pion punchthrough. Large anticounters were installed to veto beam halo events.

Starting during the second 1992 run period, the M1 magnet will be operated. An important goal of RD5 is to understand the effect of high magnetic fields on punchthrough probabilities and the properties of the punchthrough particles.

This year, we will also record events from a positive pion beam. We will also take data with lower incident momenta, extending down to 15 GeV/c.

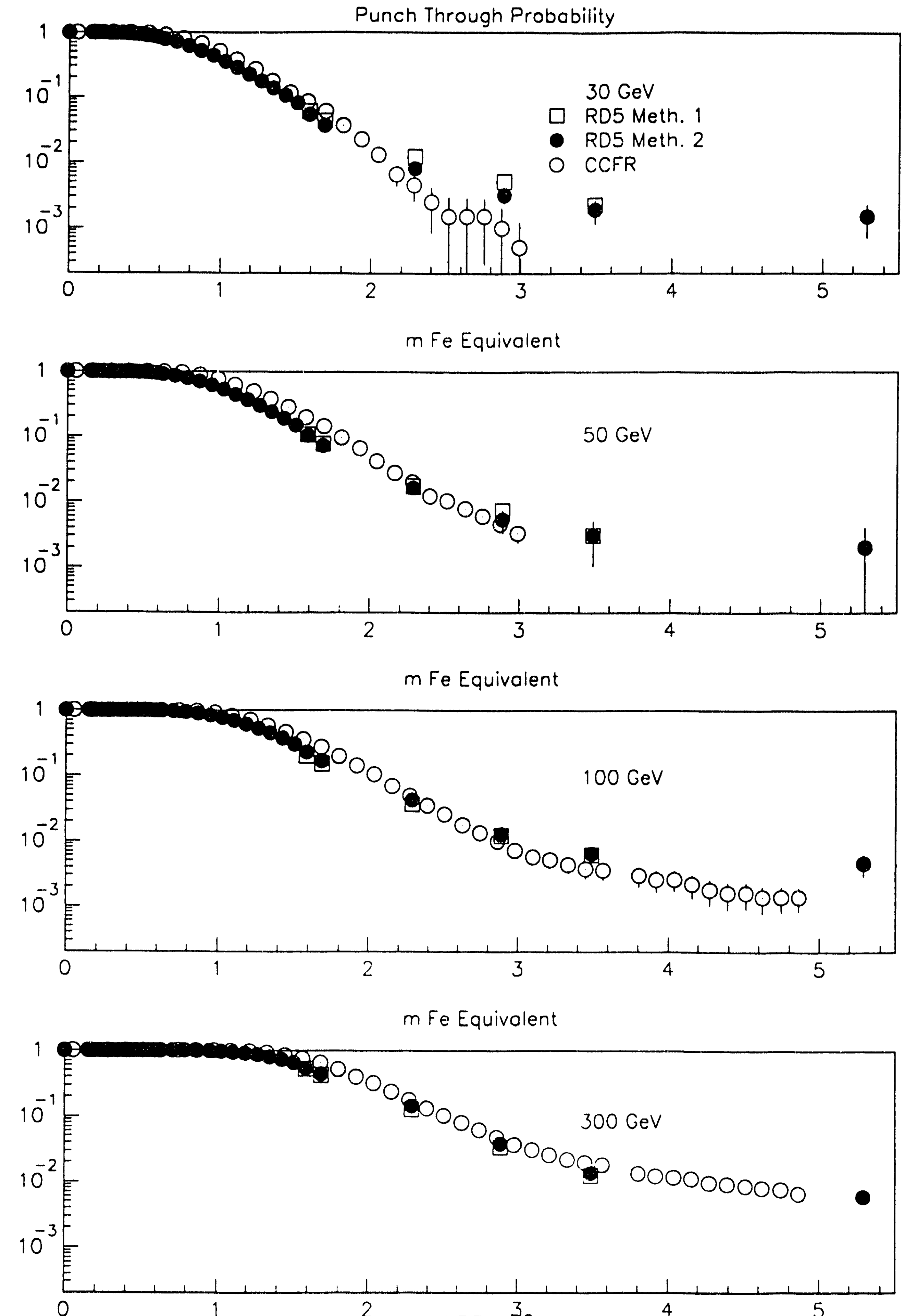
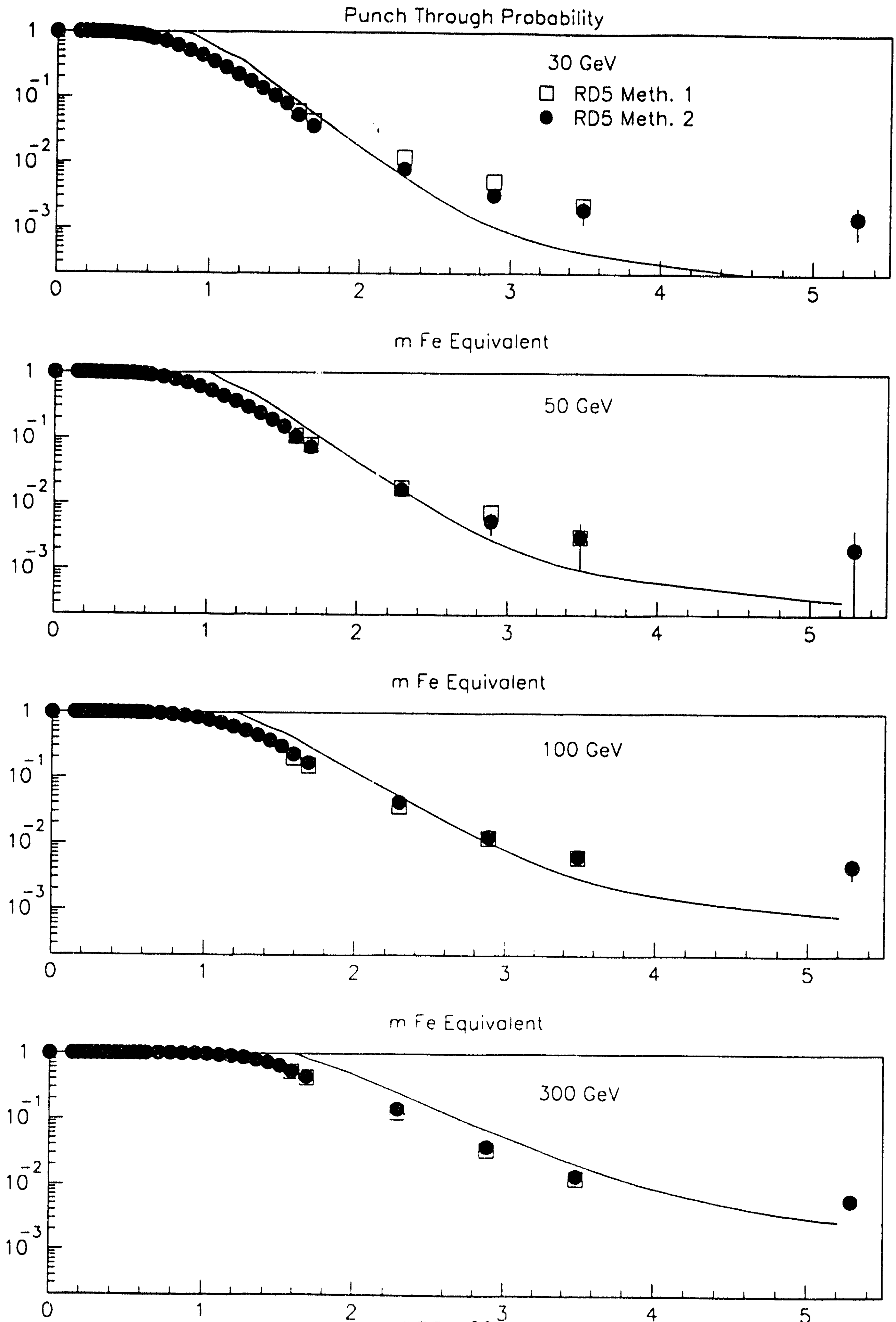

Punch Through Probability
30 GeV
RD5 Meth. 1
RD5 Meth. 2
CCFR
m Fe Equivalent
50 GeV
m Fe Equivalent
100 GeV
m Fe Equivalent
300 GeV

FIG. 22



Punch Through Probability
30 GeV
RD5 Meth. 1
RD5 Meth. 2
m Fe Equivalent
50 GeV
m Fe Equivalent
100 GeV
m Fe Equivalent
300 GeV

FIG. 23

RD-5 '92

Setup for the first run period

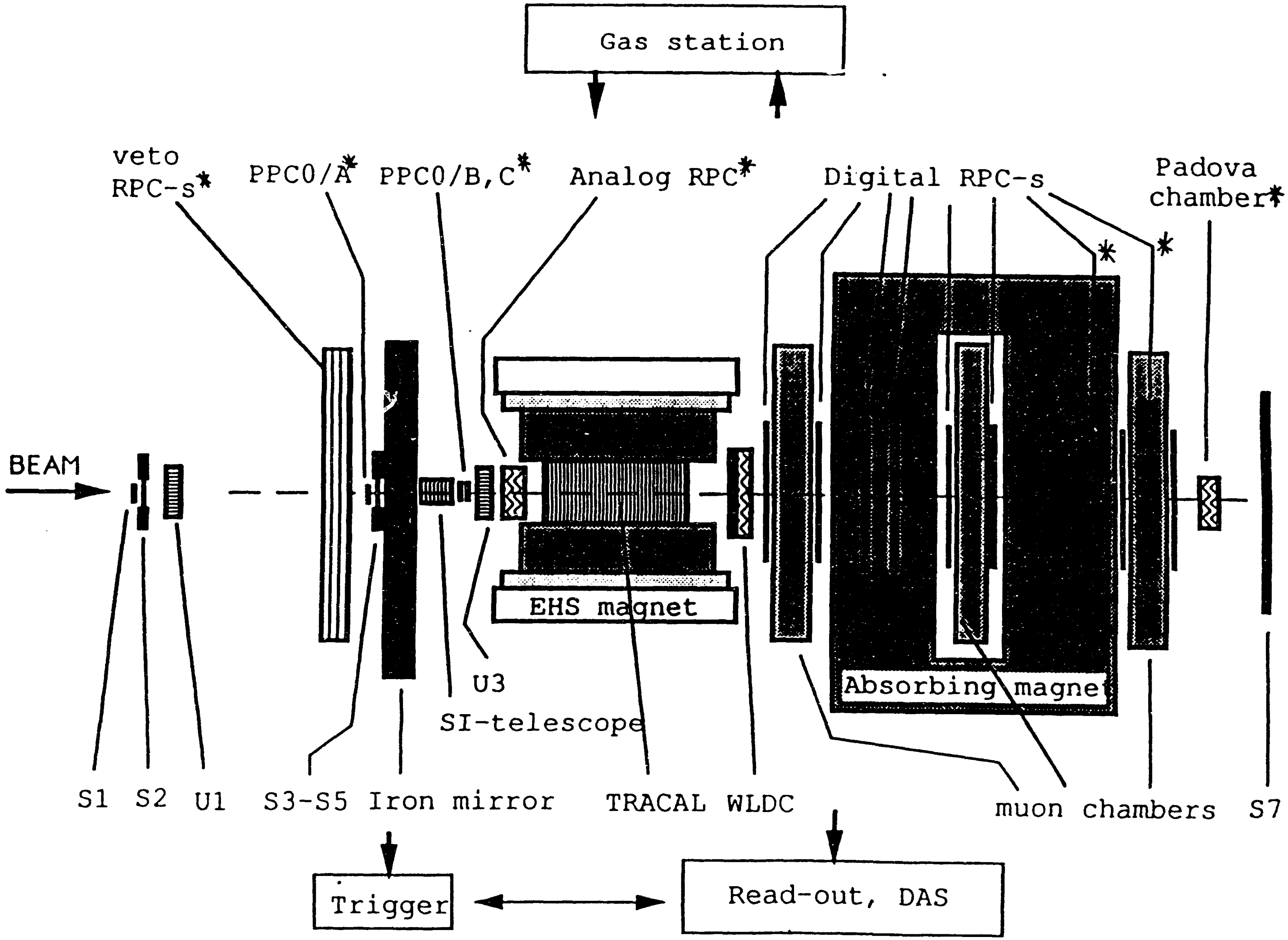


FIG. 24

* New in 92

Our highest priority work at this time, Fall, 1992, is completeing all the loose ends from the punchthrough analysis. We still have to complete the 200 GeV data, which was left for last because there was some difficulty reading the data tapes. We are solving this problem however, it is very important that we understand quantitatively the systematic errors associated with the subtraction of muons from the pion data. We have decided that the only way to determine this is to visually scan the events in question and count the number of times that muons are missidentified as pions. This will be a little time consuming, but we think that it is the safest way to proceed.

Next we will work on the angular distribution of punchthrough particles. Luckily we have some help from Chris Lydon from the GEM group. We will be working with him on this analysis.

RD5 Run Schedule:

1992

1) Starting July 30, for 14 days (completed)
2) September 24, for 18 days
3) October 26, for 14 days

1993

1) April, for 14 days
2) June, for 14 days
3) September, for 14 days

B4) The ϕ Factory Project

We initiated, with important DOE encouragement, the UCLA ϕ Factory project in 1989. A major building is being constructed on the UCLA Southwest Campus that would house this project. A Temple review was held and the scientific goals were endorsed. The remainder of the story is a typical example of the confusion and lack of imagination that presently surrounds our field. Frascati picked up our ideas on the physics and managed to get support (after all we do not represent a country or even California but Frascati represents Italy). The HEPAP subpanel showing very bad judgement opted to kill small motivated projects in favor of the big labs (SSC, FNAL, SLAC). We believe this attitude will ultimately hurt or kill HEP in the USA and the DOE but for now we have abandoned the symmetric ϕ Factory project and have started to study an Asymmetric ϕ Factory. While the odds are against us we will push ahead. Appendix B4-A and B4-B illustrate our current efforts. They are very small but represent what we believe to be a true spirit of scientific endeavor that is lacking in much of the HEP establishment in the USA!

Table III lists the types of Asymmetric ϕ Factories that might be constructed and the pros and cons!

LOCATION OF CAA SPACE FOR AN ASYMMETRIC PHI FACTORY
AND LIGHT SOURCE

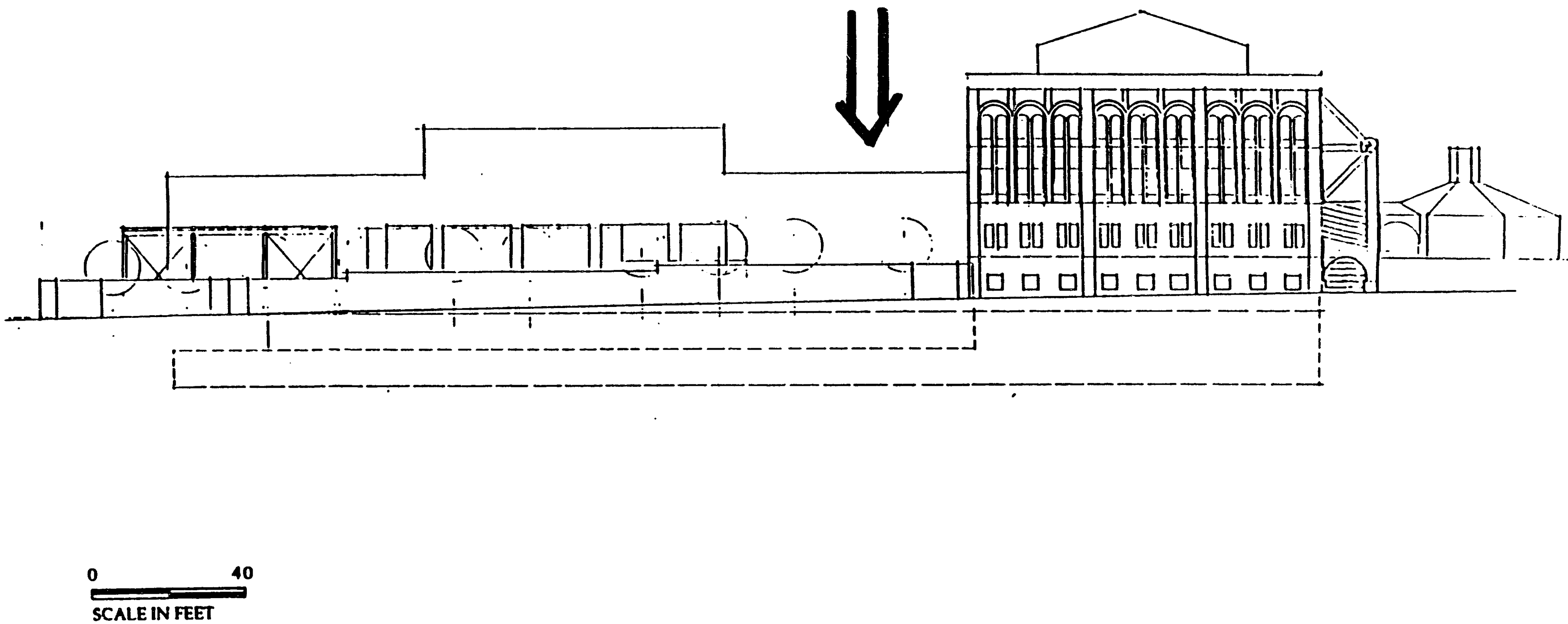


Fig. 25

UCLA
Science and Technology
Research Building EIR

Figure 8
East Elevation Study

TABLE III

Types of Asymmetric ϕ Factories

Type	Advantages	Disadvantages
1) Low Energy e^+ Storage Ring or Accumulator and High Energy e^- Linac	a) Rapid Damping Time of e^+ Reduce Instabilities b) Easy to Produce Low Energy e^+ Storage Ring	a) Need High Rep Rate e^- Linac b) High Energy Linac Expensive c) e^- May Not be Trapped in e^+ Bunch
2) Low energy e^- Linac and High energy e^+ Storage Ring	a) Low Energy Super Conducting Linac b) e^- Trapped in e^+ Bunch	a) Expensive e^+ Source b) Damping Time of e^+ Ring May Allow Build up of Instabilities
3) (e^-) Linac or (e^+) Linac	Requires Novel e^+ Source for e^+ Linac	
4) e^- Storage Ring on e^+ Storage Ring	More Difficult than a Symmetric e^+e^- Collider	

Progress Report

Task C

Institution:	University of California, Los Angeles Department of Physics, 405 Hilgard Ave. Los Angeles, CA. 90024
DOE Grant No:	DE-FG03-92ER40662
Title of Task:	Theoretical High Energy Physics
Co-Task Managers:	N. Byers, S. Ferrara, R. Peccei

During 1991/1992 academic year the theorists supported by the Department of Energy grant at UCLA investigated a large number of active research areas in theoretical particle physics and astrophysics. To illustrate the scope of these activities, brief reports of the work carried out by the faculty members (N. Byers, S. Ferrara, G. Gelmini, R. D. Peccei and H. Sonoda), post doctoral fellows (B. Hill and C. Dib) and graduate students (P. G. Baillie, T. Gould and B. Kastening) on the grant follows.

For the 1992/1993 academic year, the faculty component of the DOE supported theory group should be strengthened by the addition of Zvi Bern, who will be joining UCLA in September 1992. (Bern will submit a separate proposal to DOE for support and, if this proposal reviews well as we trust, he will then join Task C). This Fall C. Dib will leave UCLA, for the University of Oregon, and he will be replaced on the task by B. Gradwohl. Also both T. Gould and B. Kastening have graduated, going on as postdocs to Johns Hopkins and Utrecht, respectively. They will be replaced on the task by M. Bodner, a recent graduate student of Ferrara who has remained at UCLA for a further year, and F. Pettit who is working with R. D. Peccei.

As an appendix to this report we list the papers written by the members of the DOE supported theory group, which appeared as UCLA preprints in 1991/92.

Research Activities of N. Byers in 1991/92

My time up until the end of November 1991 was spent completing and writing up the research into and predictions of production cross sections for beautiful and charmed mesons in e^+e^- annihilations in threshold regions. This work was done in collaboration with Estia Eichten (Fermilab) and with the help of Dave Besson, Persis Drell and collaborators at Cornell (CESR) radiative and beam smearing corrections were applied so that our predictions could be directly compared with measured data. A long paper containing the detailed exposition of the theory (we found two simple ways to model the basic features of quantum chromodynamics in a realistic coupled channel treatment of the production cross sections that are consistent with presently available data) and a full account of our results was written. A final version of this long paper is being completed by E. Eichten at Fermilab. We present results for all the exclusive production cross sections as functions of energy throughout the threshold region. So far exclusive production cross sections for beautiful mesons have been measured only in the region of the $\Upsilon(5S)$ resonance and are incompletely measured near threshold for charmed mesons. We give results based on two different models for light quark pair production in the QCD field of the heavy quarks. Results for inclusive cross sections are rather similar for the two models; however, exclusive cross sections have marked differences. Hopefully, these exclusive production cross sections will be measured in the not-too- distant future at a B factory (beautiful mesons) and at BEPC (charmed mesons). Comparision of measured cross sections with our predictions may support one model over the other and yield further information about dynamical light quarks.

In winter 1991/92 I shifted my research interest to relativistic astrophysics, a field I had an interest in and did some work in many years ago. In order to take it up again, I needed to work hard to become familiar with recent developments in the field. Colleagues at Caltech, mainly Kip Thorne and John Preskill, have been very encouraging and helpful in this effort. Discussions with these colleagues and attendance at atrophysical seminars at Caltech have enabled me to identify a research area where I might usefully make some contribution. I am presently addressing the question of whether quantum fluctuations provide a mechanism for what Hawking [1] has called the chronology protection conjecture; namely that the laws of physics do not allow the appearance of closed timelike curves. Various authors [2] [3] [4] have shown that closed timelike curves (CTC's) occur in classical solutions to general relativity theory and cause a breakdown between past and future. Such solutions, were they to exist, may not be consistent with familiar notions of causality (and unitarity). Recently several authors have discussed this matter. [5] I am studying these and working on field theoretic calculations along lines suggested by Kim and Thorne. [6]

Research Activities of S. Ferrara in 1991/92

My scientific activity supported by the DOE Grant in the last twelve months, produced seven research papers (listed below) whose accomplishments were and will be presented at several International Conferences and Workshops (listed below).

The projects covered different topics on:

a) Geometry and quantum symmetries of superstring vacua, in particular the relation between duality symmetries and world-sheet instanton corrections.

b) Moduli loop corrections to gauge couplings and Θ terms in four dimensional superstrings and their influence in the unification of gauge couplings. In particular, a simple picture emerges where threshold effects due to stringy massive modes can be interpreted as generalized Wess-Zumino-terms for (target space) duality anomalies.

c) New "minimal" electromagnetic couplings and their influence on the gyromagnetic ratio of elementary particles of any spin.

d) Methods of algebraic geometry, in particular Picard-Fuchs equations, as tools to exactly solve perturbed (N = 2 supersymmetric) conformal field theories. These results allow one to exactly compute some low energy couplings, such as the Yukawa couplings and the normalization of kinetic terms in Calabi-Yau compactifications of superstrings.

These projects involved the following scientists from both U. S. institutions and Europe, some of whom visited UCLA as DOE consultants: R. D'Auria (DOE Consultant), A. Ceresole (Caltech), W. Lerche (CERN), J. Louis (CERN), C. Kounnas (DOE Consultant), J. P. Derendinger (Neuchatel) P. Fre′. (DOE Consultant), P. Soriani (SISSA), V. Telegdi (Caltech), M. Porrati (CERN), F. Zwirner (CERN).

Main conferences and Workshops attended in 1991 and DOE supported, in which the results of the above mentioned research projects were presented:

[1.] Workshop on "Mirror Symmetry" held at the Mathematical Research Institute in Berkeley (Ca.), May 1991.

[2.] Superstring Workshop 1991, held at the Institute for Theoretical Physics, Stony Brook (NY), May, 1991.

[3.] Int'l School of Subnuclear Physics, 29th Course "Physics at the Highest Energy and Luminosity", held in Erice (Italy), July 1991.

References

[1] S. W. Hawking, "The Chronology Protection Conjecture", Cambridge University (DAMTP) Preprint, July 1991.

[2] Kip S. Thorne, "Do the Laws of Physics Permit Closed Timelike Curves?", Annals of new York Academy of Sciences, 1992.

[3] Michael S. Morris, Kip S. Thorne, Ulvi Yurtsever, Phys. Rev. Lett. 61::1446 (1988).

[4] John Friedman, Michael S. Morris, Igor D. Novikov, Fernando Echecerria, Gunnar Klinkhammer, Kip S. Thorne, Ulvi Yurtsever, Phys. Rev. D42::1915 (1990).

[5] See, e.g., John L. Friedman, Nicolas J. Papastamatiou, Jonathan Z. Simon, "Failure of unitarity for interacting fields on sapetimes with closed timelike curves", U. of Wisconsin preprint 1992 and David Boulware, U. of Washington (Seattle) preprint 1992.

[6] Sung-Won Kim and Kip S. Thorne, Phys. Rev. D43::3929 (1991).

Main Conferences Attended and to be Attended in 1992 and DOE Supported:

[1.] 12th Capri Symposium "Thirty Years of Elementary Particle Physics", Capri, May 1992.

[2.] Int'l Workshop in Theoretical Physics (Erice, June 1992) "String Quantum Gravity and Physics at the Planck Scale".

[3.] Int'l School of Subnuclear Physics (Erice, July 1992) "From Superstrings to the Real Superworld".

[4.] Advanced Research NATO Workshop "Integrable Quantum Field Theory", (Como, September 92)

[5.] National Symposium on General Relativity, (Bardonecchia, September 92).

[6.] Rome Symposium on "Strings and Conformal Field Theories", (Accademia dei Lincei, Rome, September 92).

[7.] International Summer Institute in Particle Physics, Corfu, (September 92).

[8.] INFN Eloisatron Workshop "From Superstrings to Supergravity", (Erice, Dec. 92).

Research papers in this period (1991 - 1992).

[1.] "One loop corrections to string effective field theories: field-dependent gauge couplings and σ-model anomalies", J. P. Derendinger, S. Ferrara, C. Kounnas, F. Zwirner, Nucl. Phys. B372 (1992) 145

[2.] "All-loop gauge couplings from anomaly cancellations in string effective theories", J. P. Derendinger, S. Ferrara, C. Kounnas, F. Zwirner, Phys. Lett. B271 (1991) 307.

[3.] " Flat holomorphic connections and Picard-Fuchs identities from N=2 supergravity", S. Ferrara, J. Louis, Phys. Lett. B278 (1992) 240

[4.] "On the moduli space of the T_6/Z_3 orbifold and its modular group", S. Ferrara, P. Fre$'$, P. Soriani, Preprint CERN TH 6364/92, SISSA 5/92/EP, [To appear in Classical and Quantum Gravity]

[5.] "Picard-Fuchs equations and special geometry", A. Ceresole, R. D'Auria, S. Ferrara, W. Lerche, J. Louis, Preprint CERN-TH 6441/92, UCLA/92 TEP/8;

CALT-68-1776, PDLFIS-TH-08/92, submitted to Int'l Journal of Mod. Phys. A

[6.] "$g = 2$ as the natural value of the tree-level gyromagnetic ratio of elementary particles", S. Ferrara, M. Porrati; V. Telegdi, Preprint CERN TH.6432/92, UCLA/92/TEP/7, [submitted to Phys. Rev. D.]

[7.] "Supersymmetric sum rules on magnetic dipole moments of arbitrary-spin particles", S. Ferrara, M. Porrati, Preprint CERN TH.6493/92, UCLA/92/TEP/17, [submitted to Phys. Lett. B.]

[4] "Baryon Asymmetry from Planck Scale Physics", G. Gelmini and R. Holman, NSF-ITP-92-101 and UCLA/92/TEP/25

[5] "Dark Matter Particle Candidates", G. Gelmini, UCLA/92/TEP/6, to be published in the proceedings of the worshop "TAUP91"(Toledo, Spain, September 1991).

Invited Talks at International Conferences and Proceedings

[1.] "Dark matter particle candidates", presented in the "2nd. International Workshop on Theoretical Aspects of Underground Physics (TAUP91)", Toledo, Spain, September 1991;

[2.] "Dark matter candidates", in the "Trieste Conference on Recent Developments in the Phenomenology of Particle Physics", September 1991;

[3.] "Overview of models for and constraints on the 17 keV neutrino" presented in the workshop on " The Many Aspects of Neutrino Physics", Fermi National AcceleratorLaboratory, U.S.A., November 1991;

[4.] "Neutrino masses", presented in the "Annual Informal Particle Theory Meeting" , Rutherford -Appleton Laboratories, England, December 1991.

Research Activities of Graciela Gelmini in 1991/92

Together with my former student P. Gondolo (who finished his Ph.D. at UCLA last year) now in Uppsala, Sweden, and S. Sarkar, I analyzed the bounds on heavy unstable particles from their decay into neutrinos [1]. This is a careful analysis of bounds that were roughly estimated in ref. [2]. The recent revised version of [1] incorporates the suggestions of the referee to consider the effect of "hadronic blasts" (i.e. hadronic showers generated by a nucleus fragmented in the collision with a very high energy neutrino, within a Cherenkov light detector) in bounds from contained events .

The most recent break-through in our understanding of how the baryon number B of the universe might be generated comes from the existence of configurations in the standard model that give rise to unsupressed violations of $B + L$ (baryon plus lepton number) at high temperature. If L-violating interactions are in thermal equilibrium in the early universe, simultaneously with the $B + L$ violating ones, no B-asymmetry remains. The preservation of the necessary B-asymmetry yields, therefore, an upper bound of a few eV on Majorana masses for the light neutrinos. With T. Yanagida [3], I examined a way to avoid this bound, by having L-violation occur after the electroweak phase transition. With R. Holman [4], I examined instead the possibility that Planck-scale physics may violate explicitly global symmetries (in this particular case L-number) to produce the B-asymmetry of the universe, in combination with the above mentioned $B + L$ violating interactions.

Together with M. Gleiser, I am presently examining the importance of including explicitly the shrinking of subcritical bubbles formed in first order phase transitions in the master equation describing their development, an effect that had been neglected in previous treatments of the problem.

In the past year I have given a number of invited review talks on both neutrino physics and on dark matter, at international conferences. My talk at the TAUP 91 Workshop [5] summarizes the status of dark matter candidates.

References

[1] "Cosmic Neutrinos from Unstable Relic Particles"; G. Gelmini, P. Gondolo and S. Sarkar; UCLA/91/TEP/31, (revised June 1992).

[2] J. Ellis, G. Gelmini, J. Lopez, D. Nanopoulos and S. Sarkar, Nucl. Phys. B373 (1992) 399.

[3] "Eluding Neutrino Mass Constraints from Baryogenesis", G. Gelmini and T. Yanagida, UCLA/92/TEP/24

Research Activities of R. D. Peccei in 1991/92

A principal focus of my research in the past year was the physics which could emerge from a high luminosity Φ factory. In collaboration with both experimentalists and theorists on the DOE grant at UCLA, a rather comprehensive investigation was carried out [1] of the variety of CP and CPT tests which could be done at such a machine. One of the principal conclusions of this study was that, because at a Φ factory one can measure precisely K_s decays, one can hope to finally disentangle all CPT violating parameters in the $K^0 - \bar{K}^0$ complex from each other. This is a rather important point for, as I have shown in collaboration with C. Dib [2], present day tests of CPT actually only put bounds on differences of CPT violating parameters and not on the individual parameters themselves. An analysis of the potential of a high luminosity Φ factory for measuring CP violation in other modes of the K^0 complex, besides the 2π mode, is being presently completed with a student, F. Pettit [3]. Some of the results of the above work were presented at several international conferences and workshops (see below).

A second theme of continuing interest for me remained the physics of neutrinos. Following an in depth article on the theoretical constraints - both from particle physics and from astrophysics and cosmology - that the reported 17 KeV neutrino had to obey [4] [5], I have been investigating the implications of $B + L$ violating phenomena on the neutrino sector. One of the interesting results obtained, which I reported upon at the XXVI Conference of High Energy Physics [6], is that eV neutrino masses most likely necessitate having lepton number violated at around the 10^{10} GeV scale. It follows, in this case, that the observed B asymmetry in the Universe is entirely dependent on CP violating phases in the neutrino sector. The connection of these two phenomena is being explored further, particularly to see if one could ever test for the presence of these phases in neutrino oscillations.

A variety of other subjects have also been studied, ranging from precision electroweak tests [7] [8] and multi W production at very high energy [9] to more theoretical topics like mass generation in chiral theories [10]. Two sets of summer school lectures were also presented and written up, on $B + L$ violation at high energy [11] and on features of high energy lepton hadron scattering [12], and a third set of lectures, on new phenomena below the mega TeV scale [13], was just delivered. In addition, I gave a summary talk [14] at an international workshop and the rapporteur talk [15] on the standard model at the DPF meeting of the American Physical Society in Vancouver.

References

[1] C. Buchanan, R. Cousins, C. Dib. R. D. Peccei and J. Quackenbush, "Testing CP and CPT Violation in the Neutral Kaon System at a Phi Factory", Phys. Rev. D45 (1992) 4088.

[2] C. Dib and R., D. Peccei, "CPT Constraints in the Neutral Kaon System", Phys., Rev. to be published.

[3] R. D. Peccei and F. Pettit, "Testing Rare CP Violating Modes at a Phi Factory", paper in preparation.

[4] G. Gelmini, S. Nussinov and R. D. Peccei, "Perils of a 17 KeV Neutrino", Int. Journal Mod. Phys. A 7 (1992) 3141

[5] R. D. Peccei, "Constraints and Model Considerations for a 17 KeV Neutrino", to appear in the Proceedings of First School on Particle Physics and Cosmology, Baksan, Russia.

[6] R. D. Peccei, "Baryogenesis and Neutrino Masses", to appear in the Proceedings of the XXVI International Conference on High Energy Physics, Dallas, Texas, manuscript in preparation.

[7] R. D. Peccei and S. Peris "Effects of Heavy Physics on Electroweak Radiative Corrections and the Role of Goldstone Dynamics", Phys. Rev. D. 49 (1991) 809.

[8] R. D. Peccei, "Precision Tests of the Electroweak Theory", Proceedings of Beyond the Standard Model II, Norman, Oklahoma.

[9] D. Morris, R. D. Peccei and R. Rosenfeld, "Multiple W production at High Energy", paper in preparation.

[10] S. Khlebnikov and R. D. Peccei, "Novel Mass Generating Mechanism in Chiral Gauge Theories", paper in preparation.

[11] R. D. Peccei, "Do Weak Interactions Become Strong at High Energy", to appear in the Proceedings of the XXIX Erice Summer School, Erice, Italy.

[12] R. D. Peccei, "High Energy Lepton Hadron Scattering as a Probe of QCD", to appear in the Proceedings of the 1992 SLAC Summer School.

[13] R. D. Peccei, "New Phenomena below the Mega TeV scale", lectures at the XXX Erice Summer School, Erice, Italy, manuscript in preparation.

[14] R. D. Peccei "Summary of the First Latin American Workshop on the Fundamental Interactions", to appear in the Proceedings of the Workshop, Oaxtapec, Mexico

[15] R. D. Peccei "Status of the Standard Model in 1991", Proceedings of the DPF Workshop, Vancouver, B.C. Canada.

Invited Talks at International Conferences, Summer Schools and Workshops 1991/92

[1.] First Baksan School on Particle Physics and Cosmology, Baksan, Russia, May 1991.

[2.] XXIX Summer School on Subnuclear Physics, Erice, Italy, July 1991.

[3.] 1991 SLAC Summer Institute, Stanford, California, August 1991.

[4.] DPF Meeting of the American Physical Society, Vancouver, B.C., Canada, August 1991.

[5.] First International Workshop on the Phenomenology of Fundamental Interactions, Trieste, Italy, September 1991.

[6.] International Symposium on the 25th Anniversary of the Salam Glashow Weinberg Theory, Dakha, Bangladesh, April 1992.

[7.] Washington Meeting of the American Physical Society, Washington D.C., April 1992.

[8] 1992 Gordon Conference on Particle Physics, Andover, N.H., July 1992.

[9] XXX Summer School on Subnuclear Physics, Erice, Italy, July 1992.

[10] XXVI International Conference on High Energy Physics, Dallas, Texas, August 1992.

Research Activities of H. Sonoda in 1991/1992

During the last year, I continued to work on the implications of the renormalization group (RG) for short distance behavior of quantum field theories. My work has resulted in two papers.

In ref. [1], I have introduced a variational formula that realizes the derivative of correlation functions with respect to a parameter in terms of an operator insertion. Let g_E be the fine structure constant of QCD with massless quarks. Then one has that

$$-\partial_{g_E} \langle \mathcal{V}_i(0) \rangle = \lim_{\epsilon \to 0} \Bigg[\int_{r \geq \epsilon} d^4 r \ \langle (\mathcal{V}_E(r) - \langle \mathcal{V}_E \rangle) \, \mathcal{V}_i \, (0) \rangle_{g_E} \\ - \int_{1 \geq r \geq \epsilon} d^4 r \ (C_E)_{i,j}(r; g_E) \, \langle \mathcal{V}_j(0) \rangle_{g_E} + (c_E)_{i,j}(g_E) \, \langle \mathcal{V}_j(0) \rangle_{g_E} \Bigg],$$

where $\mathcal{V}_E$ is an operator conjugate to g_E, $C_E(r)$ is the part of an operator product coefficient as singular as $1/r^4$,

$$\mathcal{V}_E(r) \, \mathcal{V}_i \, (0) = (C_E)_{i,j}(r; g_E) \, \mathcal{V}_j \, (0) + o\left(\frac{1}{r^4}\right),$$

and c_E is a finite counterterm. By imposing the consistency of this formula with the RG, I determined the operator coefficient C_E in terms of the beta function, anomalous dimensions of $\mathcal{V}$'s, and finite counterterm. Especially for two operators $\mathcal{V}_i$ and $\mathcal{V}_j$ of the same scale dimension $x_i = x_j$, we find

$$C_E(1; g_E) = \frac{1}{2\pi^2} \frac{d\gamma_{i,j}(g_E)}{dg_E},$$

where $\gamma_{i,j}$ is the anomalous dimension. Namely, the RG determines not only the scaling property of the coefficient function, but also the form of the coefficient function itself.

In ref. [2], I applied the above variational formula to the coefficient functions in operator product expansions (OPE). The derivative of an OPE coefficient with respect to g_E is now realized by an integral over an infinitesimal range. By recursive use of the variational formula, one can calculate the OPE coefficients systematically in powers of g_E. I would like to apply this result for calculations of OPE coefficients in a theory obtained by deforming a two-dimensional conformal field theory by mass parameters.

References

[1.] H. Sonoda, "Composite Operators in QCD," UCLA/91/TEP/47(25 pages), accepted for publication in Nuclear Physics B.

2.] H. Sonoda, "Operator Coefficients of Composite Operators in the $(\phi^4)_4$ Theory," UCLA/92/TEP/15 (31 pages), submitted for publication in Nuclear Physics B.

Research Activities of Brian Hill in 1991/92

While a large number of interesting papers have been generated on the heavy quark effective theory and its application to lattice measurement of weak matrix elements, some fundamental issues remain inadequately addressed. Until they are addressed, there is little hope of applying the method to 1/m corrections of the B meson decay constant, which are surprisingly large if lattice results obtained without the use of the heavy quark effective theory are to be believed. If the 1/m corrections were to be confirmed, and if other tests of the heavy quark effective theory give satisfactory results, then estimates of the B meson decay constant using this technique could be taken more seriously. It is with this rather critical viewpoint that I was motivated to undertake the three related lines of research described below.

(1) The most important test of the heavy quark effective theory on the lattice is to compute and compare with experiment the value of the B-B* mass splitting. Building on a suggestion of Lepage and Thacker, the requisite analytical calculations for this lattice calculation were performed by Jonathan Flynn and myself [1]. Since then, preliminary results for this quantity have been reported by Maiani, Martinelli and Sachrajda. They are over a factor of two low, even after including the corrections that we computed. Their calculation is of a somewhat preliminary nature however. A major project for me, begun this spring, has been to perform the lattice calculation outlined in Ref. [1] in collaboration with Jonathan Flynn, and Aida El-Khadra. I expect that at least preliminary results from this project will be available before the lattice conference in September.

(2) An internal consistency check of the heavy quark effective theory is to recompute the B meson decay constant using alternate discretizations of the axial current. Any such operator that can be perturbatively renormalized can be employed to give a substantially independent lattice measurement of this quantity. Oscar Hernandez and I [2] proposed and renormalized a few such operators last fall. Aida El-Khadra, Jonathan Flynn and I are computing the B decay constant on the lattice using these operators and will complete this investigation before the lattice conference in September. With the first of the operators that Oscar Hernandez and I proposed using, we are seeing a reduction in the decay constant that is about two sigma (statistical) below the previously reported value. At this point, I expect our conclusions will be that the systematic errors in past calculations of the decay constant have been over-optimistically estimated, and that a likely value for the infinite mass limit of the heavy-light meson decay constant is below 200 MeV. I should mention, since it is not standard, that both this lattice calculation and the calculation described in (1) will have a correct treatment of correlated errors.

(3) In the first line of research described above, I mentioned that the B-B* mass splitting fails to agree with the experimentally known value. At the Heavy Quark Workshop at the Santa Barbara ITP, which I had the opportunity to attend in January, other participants were hopeful that the application of Symanzik's improvement program would patch the discrepancy up. If this were to be the case, it would become particularly interesting to measure the matrix element of the improved axial current operator. With this in mind, Oscar Hernandez and I studied the improvement of the heavy quark action and renormalized the improved axial current operator [3]. In fact, I am skeptical that improvement will have a significant impact on B-B* splitting or on the decay constant. In my mind, the spirit of the improvement program is to squeeze the accuracy of lattice calculations below the factors of two, which must have other origins.

Once these projects come to fruition, the issues which appear to bar us from computing subleading corrections using the heavy quark effective theory need to be tackled. (The reason the B-B* splitting, which is a 1/m correction can be computed at present, is that there is no contribution at zeroth order in 1/m). Perhaps the somewhat formal reparametrization invariances studied by Manohar, Luke and Falk are a beginning point for tackling these practical concerns.

References

[1] J. M. Flynn and B. R. Hill, Phys Lett B 264 (1991) 173.

[2] O. F. Hernandez and B. R. Hill, Phys Lett B 280 (1992) 91.

[3] O. F. Hernandez and B. R. Hill, UCLA/92/TEP/9, submitted to Phys Lett. B.

Research Activities of C. O. Dib in 1991/92

During the last year I continued investigating some of the interesting physics possibilities which could be studied with a high luminosity Φ factory. In collaboration with C. Buchanan, R. Cousins, R. D. Peccei and J. Quackenbush, I examined CP and CPT tests which could be carried out in such a machine. The results of our study [1] were rather encouraging, showing both the range and intrinsic potential of a Φ factory to elucidate these important issues. With an integrated luminosity of $10^{40} cm^{-2}$, one should be able to pin down statistically ϵ'/ϵ to a few parts in 10^4, thereby clarifyng the present discrepancy existing between the FNAL and CERN measurements. A by-product of this study was the brief report [2] on the present status of CPT violation in the neutral Kaon system, written with R. D. Peccei. Contrary to common lore, CPT violating phenomena are not really seriously constrained by present measurements. However, they could be so constrained by a high luminosity Φ factory, since such an accelerator would allow disentangling CPT violation in the neutral Kaon mass matrix from that occuring in the various decay amplitudes. A study of the present bounds on CPT violation in the Kaon system is presented in [2].

A study was also carried out of the sensitivity of the process $K^+ \to \pi^+\nu\bar{\nu}$ for determination of the Koboyashi Maskawa matrix element V_{td} [3]. The result of this investigation show that a measurement of the branching fraction of $K^+ \to \pi^+\nu\bar{\nu}$ to a 30% accuracy will provide a better measurement of V_{td} than can presenly be inferred, provided that an actual value of m_t is known. Even then, additional knowledge of V_{cb} and of m_c will be necessary for a really accurate determination of V_{td} through this measurement.

References

[1.] C. Buchanan, R. Cousins, C. Dib, R. D. Peccei and J. Quackenbush, "Testing CP and CPT Violation in the Neutral Kaon System at a Φ Factory", Phys. Rev. D45 (1992) 4088

[2.] C. Dib and R. D. Peccei, "CPT Constraints in the Neutral Kaon System", Phys., Rev. to be published.

[3.] C. O. Dib, "Bound on V_{td} from $K^{\pm} \to \pi^{\pm}\nu\bar{\nu}$ and B factories", UCLA/91/ TEP/45

Research Activities of P. G. Baillie in 1991/92

During the last year, I have investigated the possibility of measuring deviations from the Standard Model predictions for WWγ and WWZ couplings. In particular, such deviations would affect the flavour-changing neutral current transition $b \rightarrow s\mu^+\mu^-$, which could be observed at CDF in the next few years. Unfortunately, CDF cannot measure the inclusive rate $\Gamma(B \rightarrow X_s\mu^+\mu^-)$, i.e. $\Gamma(b \rightarrow s\mu^+\mu^-)$, so specific final states like $K\mu^+\mu^-$ and $K^*\mu^+\mu^-$ must be considered. However, one now requires models to estimate hadronic matrix elements, which increases the theoretical uncertainty: predictions depend on the model used. It seems that the rarer decay to a K (by a factor of about 3) is a better candidate to detect deviations from the Standard Model — this is being due to both having fewer form factors for the K, and also due to experimental cuts.

I have also assisted Carol Anway of CDF (a student of Thomas Müller) in writing a Monte Carlo program to simulate $B \rightarrow K^*\mu^+\mu^-$ using various hadronic models. A routine for $B \rightarrow K\mu^+\mu^-$ is currently under development.

Finally, I have started to look at the question of gauge invariance in extensions to the Standard Model effective Lagrangian, with reference to recent papers by De Rujula *et al* and by Burgess and London.

Research Activities of T. M. Gould in 1991/92

During the past year, I have been involved in a study of multi-instanton contributions to baryon and lepton number $(B + L)$ violating cross-sections in the electroweak theory. In lowest order semi-classical approximation, the one-instanton contribution to the total $(B + L)$ violating cross-section is growing exponentially with center-of-mass energy E:

$$\sigma \sim \exp\left(- \frac{16\pi^2}{g^2}\left[1 - a\left(\frac{E}{E_0}\right)^{4/3}\right]\right) , \tag{1}$$

where a is a number of order unity. The severe suppression due to the large action of the instanton, $16\,\pi^2/g^2 \simeq 360$, is apparently overcome at an energy scale, E_0, which is approximately the electroweak sphaleron energy, $E_0 \simeq 4\pi^2\, M_w/g^2 \simeq 10\ TeV$. The possibility of unsuppressed $B + L$ violating events at experimentally accessible energies is the prime motivation for studying the calculation of instanton-induced cross-sections. However, the interesting regime is beyond the valid region of this lowest-order semi-classical approximation, which is $E << E_0$, and in this regime, the cross-section approaches its unitarity bound.

Previous work on the subject had assumed that configurations of multiple instantons and anti-instantons will contribute at the unitarity bound of the total cross-section, and unitarize the cross-section in this regime. In a recent preprint, [1], I used an exact instanton-anti-instanton configuration, constructed with a non-perturbative variational procedure, to improve on the short distance interactions among dilute multi-instanton configurations. In agreement with previous authors, the multi-instanton contributions become important at energies where the one-instanton estimate is still greatly suppressed:

$$\sigma \sim \exp\left(- \frac{16\,\pi^2}{g^2}\ [0.65\,]\right) , \tag{2}$$

and where the dilute approximation is still roughly valid. Further calculations appear in my doctoral dissertation which support this conclusion. These results imply that the requirements of unitarity limit the exponential growth of the total cross-section to a region where the cross-section is still unobservably small.

Reference

[1] T. M. Gould, UCLA 91/TEP/39, Nucl. Phys. B., to be published

Research Activities of Boris Kastening in 1991/92

In summer '91, Xinmin Zhang and I finished a paper about sphalerons in an SU(2) model with one Higgs doublet and one scalar singlet. We showed that vacuum stability forces the sphaleron energy to remain in the range in which it is in the minimal standard model. Also we evaluated numerically sphaleron energies for part of the parameter space of the scalar potential. The results are published in [1].

After finishing that work, I was concerned with effective potentials. I succeeded in finding a method to use the renormalization group to improve the effective potential in massive ϕ^4 theory. I found analytic results up to two loops. The results are published in [2]. This spring I extended the results to the O(N) symmetric case. The corresponding paper [3] has now appeared as a UCLA preprint.

During this period I also finished two papers related to subjects I had worked on earlier. In one of them [4] I compute fermionic instanton zero modes in an SU(2) model with spontaneous symmetry breaking for the case of non-degenerate masses within a fermion SU(2) doublet. The other paper [5] restricts the parameters of the two-Higgs-doublet potential by requiring vacuum stability and the observed electroweak symmetry breaking pattern at tree level.

References

[1] B. Kastening and X. Zhang, Phys. Rev. D45 (1992) 3884.

[2] B. Kastening, Phys. Lett. B283 (1992) 287.

[3] B. Kastening, UCLA preprint UCLA/92/TEP/26.

[4] B. Kastening, UCLA preprint UCLA/92/TEP/21.

[5] B. Kastening, UCLA preprint UCLA/92/TEP/22.

Appendix: Papers Written by Members of the Theory Group Supported by DOE

Preprint	Title	Authors
UCLA/91/TEP/6	The Standard Model and Beyond Introduction and Overview of TASI 90	R. D. Peccei
UCLA/91/TEP/10	Sphalerons in the Two-Doublet Higgs Model	B. Kastening, R. D. Peccei X. Zhang
UCLA/91/TEP/13	Effects of Heavy Physics on Electroweak Radiative Corrections and the Role of Goldstone Dynamics	R. D. Peccei S. Peris
UCLA/91/TEP/15	The Perils of a 17 KeV Neutrino	G. Gelmini S. Nussinov R. D. Peccei
UCLA/91/TEP/17	Precision Tests of the Electroweak Theory	R. D. Peccei
UCLA/91/TEP/19	The Rule of Operator Mixing	H. Sonoda
UCLA/91/TEP/24	Summary of the First Latin American Workshop on Phenomenology of the Fundamental Interactions	R. D. Peccei
UCLA/TEP/91/29	Sphalerons in One Higgs-Doublet and One Scalar Field $SU(2)$ Model	B. Kastening X. Zhang
UCLA/91/TEP/31	Cosmic Neutrinos From Unstable Relic Particles	Paolo Gondolo Graciela Gelmini Subir Sarkar
UCLA/91/TEP/39	Exact Multi-Instanton Unitarization	Thomas M. Gould
UCLA/91/TEP/40	Status of the Standard Model in 1991	R. D. Peccei
UCLA/91/TEP/42	Constraints and Model Considerations For a 17 KeV Neutrino	R. D. Peccei

UCLA/91/TEP/44	Testing CP and CPT Violation in the Neutral Kaon System at Phi Factory	C. Buchanan R. Cousins C. Dib R. D. Peccei J. Quackenbush
UCLA/91/TEP/45	Bound on V_{td} from $K^{\pm} \to \pi^{\pm}\nu\bar{\nu}$ and B Factories	Claudio O. Dib
UCLA/91/TEP/47	Composite Operators in QCD	H. Sonoda
UCLA/91/TEP/48	CPT Constraints in the Neutral Kaon System	C. Dib R. Peccei
UCLA/91/TEP/51	Point Split Lattice Operators for B Decays	Oscar Hernandez Brian Hill
UCLA/91/TEP/53	Renormalization Group Improvement of The Effective Potential of Massive Phi Four Theory	Boris Kastening
UCLA/91/TEP/56	Do Weak Interactions Become Strong at High Energy?	R. D. Peccei
UCLA/92/TEP/5	High Energy Lepton Hadron Scattering as a Probe of QCD	R. D. Peccei
UCLA/92/TEP/6	Dark Matter Particles	G. Gelmini
UCLA/92/TEP/7	$g = 2$ as the Natural Value of the Geomagnetic Ratio of Elementary Particles	S. Ferrara M. Porrati V. Telegdi
UCLA/92 TEP/8	Picard-Fuchs Equations and Special Geometry	A. Ceresole R. D'Auria S. Ferrara W. Lerche J. Louis
UCLA/92/TEP/9	Improved Heavy Quark Effective Theory Currents	Oscar Hernandez Brian R. Hill
UCLA/92/TEP/15	Operator Coefficients for Composite Operators in the $(\phi^4)_4$ Theory	H. Sonoda

UCLA/92/TEP/17	Supersymmetric Sum Rules on Magnetic Dipole-Moments of Arbitrary-Spin Particles	Sergio Ferrara Massimo Porrati
UCLA/92/TEP/21	Fermionic Instanton Zero Modes in Models with Spontaneous Symmetry Breaking and Broken Custodial $SU(2)$ Symmetry	Boris Kastening
UCLA/92/TEP/22	Bounds from Stability and Symmetry Breaking on Parameters in the Two-Higgs-Doublet Potential	Boris Kastening
UCLA/92/TEP/24	Eluding Neutrino Mass Constraints from Baryogenesis	G. Gelmini T. Yanagida
UCLA/92/TEP/25	Baryon Asymmetry from Planck-Scale Physics	Graciela Gelmini Richard Holman
UCLA/92/TEP/26	Renormalization Group Improvement of the Effective Potential in Massive $0(N)$ Symmetric ϕ^4 theory	B. Kastening

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DOE Contract: DE-FG03-91ER40662, Task D

Title of Project: H Dibaryon Search at BNL
Kaon Experiments (E799/E832) at FermiLab

Co-Principal Investigators:
Katsushi Arisaka, Robert Cousins, and William Slater

Scientific, Professional Staff:
Professional Staff: Jonathan Kubic, Frank Chase, Sharon Wong
Post-doctoral Researchers: John Quackenbush, John Jennings
Graduate Students: Doug Roberts, Matthew Weaver
Undergraduate Students: Charles Ju, Robert Troy, David Morse, Daniel Chun, Xuan Tran, Vanessa Zouvelos

General:

We have been active in the following three areas:

1) H Dibaryon Search at BNL.
2) Search for $K_L^0 \to \pi^0\gamma\gamma$ and $\pi^0\nu\bar{\nu}$ at FNAL-E799.
3) Detector design and construction for FNAL-KTeV (E799-II/E832) project.

1) H Dibaryon Search at BNL.

During the past year, the Task D subgroup led by Cousins has planned and carried out a search for the H dibaryon at Brookhaven National Laboratory. The H is a six-quark state (*uuddss* quarks in a symmetrized state) hypothesized by Jaffe in 1974, and the subject of theoretical speculation and some experimental search ever since. Previous experiments to date are generally viewed as having insufficient sensitivity to discover the H if it exists.

In the summer of 1991, a small group led by Val Fitch (Princeton) proposed that the BNL E791 detector (built for rare kaon decay searches of which Cousins was co-leader) be used to search for the H. The idea was that the high-intensity neutral beam used for the kaon searches might contain a small but observable component of H particles, which are also neutral. A collaboration formed, with Cousins and Alan Schwartz (also of Princeton) as Co-spokesmen, and submitted a 70-page proposal to BNL in January, 1992. The experiment, designated E888, was approved by the BNL PAC the next month for running during the May/June/July proton beam run a few months later. After a very busy spring, we took the proposed data sets as planned.

E888 in fact consists of two separate searches for the H, each with a two-week run, which are complementary in that they cover different (but overlapping) ranges in H lifetime (and hence H mass).

The H search using the first detection method, referred to as the "H decay search", uses the E791 detector with very minor modifications to look for single $\Lambda \rightarrow p\pi^-$ decays emerging from the neutral beam decay volume. These Λ's could come from H decays such as $H \rightarrow \Lambda n$. This search is sensitive to H's produced in our target with lifetimes in the range $10^{-7} - 10^{-9}$ s (long enough for some to survive to our decay volume, and short enough to have a reasonable chance to decay in it).

In the H search using the second detection method, referred to as the "H dissociation search", we seek not H decays, but rather H interactions which produce two Λ's though diffractive dissociation:

$$H + A \rightarrow H^* + A \rightarrow \Lambda\,\Lambda + A.$$

Here A is a target nucleus in the dissociator, and H^* is an excited H whose mass is sufficiently high to decay strongly to $\Lambda\Lambda$. The dissociation search is sensitive to lifetime ranges from 10^{-8} s to infinity, since we require only that the H survive to the dissociator to be inserted at the downstream end of our decay volume. The sensitivity to arbitrarily long lifetimes (associated with deeply bound H's) while directly observing the H interaction products is an exciting prospect. For this dissociation search, we moved the existing E791 drift chambers into a different configuration, and made some major trigger and software modifications.

Combined, the decay and dissociation searches cover almost the complete range of expected H lifetimes if the H is too light to decay strongly to $\Lambda\Lambda$. (Extremely lightly bound H's may decay with a lifetime shorter than that of the lambda, and would probably escape detection by us.) It was difficult to estimate the running time required to set meaningful production cross section limits on the H or to discover it, since there is no established theory of H production. However, based on reasonable models, we expect that the data sets we took in 1992 will be adequate for discovering the H if it exists.

UCLA responsibilities during the run spanned a wide range of activities in addition to the leadership. We shared in the design, background studies, and trigger simulations; re-mapped portions of the magnetic field which changed from E791; took responsibility for modifying and maintaining the UCLA-built readout system; modified and maintained the online diagnostic software; and manned a large fraction of the shifts.

Because of the rapidity with which the experiment was proposed and carried out, the offline software is only now being developed. (We used preliminary versions during the run to check for the integrity of the data tapes.) It will be several months before enough events are reconstructed so that we can anticipate what the outcome of the search will be. Analysis is also complicated by the fact that BNL budget cuts have necessitated the demise of the IBM 3090 mainframe which was the home of our offline analysis. We are in the process of transferring the analysis to the 3090 at SLAC, where we have collaborators (Stanley Wojcicki's group).

2) Search for $K_L^0 \to \pi^0\gamma\gamma$ and $\pi^0\nu\bar{\nu}$ at FNAL-E799.

In the summer of 1991, we constructed the pre-shower detector consisted of 9,000 fibers and 32 newly developed position sensitive photomultipliers. The detector was installed during the E799 run in the Fall and physics data was taken successfully.

Analysis of these data is in progress on the UCLA Vaxstation cluster. The $\pi^0\gamma\gamma$ signal is not projected to be very large—of order 150 events. Doug Roberts is writing his thesis on this reaction. Response of the PSD is simulated in montecarlo in order to meld the PSD signal with that in the lead-glass calorimeter. To understand and measure the combined detector responses for a single shower is the key to extracting this signal.

Matt Weaver is pushing the limit on $\pi^0\nu\bar{\nu}$ to a new level with data from the E799 run. This analysis uses only π^0 decaying by the Dalitz mode, which in principle locates the decay vertex. The main backgrounds come from $K_L \to \pi^\pm e^\mp \gamma\nu$ in which the $\pi^\pm$ is misidentified as $e^\pm$ and from $\Lambda^0 \to n\pi^0$ which in principle can be completely removed because of the limited $P_\perp$. However, there is a large uncertainty in the Λ decay vertex coordinates, so that the longitudinal direction is not perfectly determined. However, because the main uncertainty in the vertex location is in the z-direction (along the beam) the x, y coordinates can be better localized. The limit to be achieved appears to be in the 10^{-5} decade, about a factor of 10 better than known currently.

The Analysis of both $\pi^0\gamma\gamma$ and $\pi^0\nu\bar{\nu}$ is expected to be completed in the next 6 months.

3) Detector design and construction for FNAL-KTeV project.

Design of the KTeV detector proceeds, with extensive simulation of the UCLA detector elements, and the beam geometry. By now, the photon veto counters have been optimized in location and aperture. The Back-Anti counter is specified in major dimensions, granularity and composition. Both the photon veto and Back-Anti counters will be constructed of scintillating tiles with embedded wave-shifting optical fiber readout. Use of blue fibers coupled with an air gap groove to the scintillator material has proved to be the best way to construct these detectors. Assembly is simple, machining is easy, and the vexatious problem of attaching light guides is eliminated. The fibers are insensitive to radiation, so only the scintillator tile part of the counters will detect particles. The material to be used is 2.5 mm thick, along with 1-mm fibers. This combination gives 8 photoelectrons for a minimum ionizing particle.

Other simulations that we have done include extensive modelling of the neutral beam and its collimators and also the muon identification filters that interact with the Back-Anti counter. Since the whole beam is dumped into the BA, and the average neutron (neutrons comprise about half the beam) has an energy of 160 GeV, the level of activity here is quite high. There are eight interaction lengths of steel in the BA, so most of this energy is absorbed here. As a result, most of the hadronic interactions are from secondaries, i.e., there is extensive hadron showering. As a result the number of neutrons, in particular, proliferates so that there is a significant backstreaming of low energy neutrons, a few hundred MeV on average, that makes its way upstream through the first meter of muon steel. Typically, these neutrons eventually are captured and release two photons with an energy that totals to the average binding energy of a neutron—about 8 Mev. These gammas often give Compton electrons, and when this happens in the HA counter, there can be an accidental indication of a hadronic interaction in the CsI; a signal that is taken as a veto in the gamma-trigger in the ϵ'/ϵ experiments. This must be eliminated as a source of systematic error before the design of the downstream detectors is finalized. Such studies, while somewhat laborious to carry out to the required accuracy, are possible with the CPU power at our disposal, and we are carrying them out.

Another hardware responsibility taken by us is the development of low-gain/highly-linear photomultipliers for the CsI calorimeter. The measurement of ϵ'/ϵ at 10^{-4} accuracy requires extreme linearity in photomultipliers. We have developed an automated system to measure the linearity at 0.1% accuracy. By using this system, we are collaborating with Hamamatsu Company in developing a new type of phototubes.

Katsushi Arisaka, Co-Principal Investigator — 10/5/92

Robert Cousins, Co-Principal Investigator

William Slater, Co-Principal Investigator

PROGRESS REPORT UCLA at CDF 1992
TASK E

Institution :	University of California, Los Angeles Physics Department, 405 Hilgard Ave. Los Angeles, CA 90024
DOE Grant No :	DE - FG03 - 92ER40662
Title of Project :	UCLA Participation in the Experiment CDF at Fermilab
Co-Task Managers :	Jay Hauser, Thomas Müller

Scientific, Professional Staff :

Professional Staff :	Frank Chase, Jim Kolonko, Anchi Kao
Post doctoral researchers :	Stephan Lammel, Mike Lindgren
Graduate students :	Carol Anway, Farhad Keyvan, Dirk Neuberger
Undergraduate students :	Simon Black, Armik Mirzayan, Tran Thuan

General :

The Collider Detector at Fermilab (CDF) is a general purpose detector designed to study proton - antiproton interactions at 1800 GeV center of mass energy. At present, the Tevatron Collider where CDF is situated, is unique in its physics potential with respect to searches for massive particles, in particular the top quark, supersymmetric particles, new gauge bosons, and for precision tests of the Standard Model.

Since summer 1990, UCLA has been a member of the collaboration having taken up the following responsibilities :

- Participation in the preparation of CDF for the ongoing and coming data taking runs, the operation of the detector, management of the experiment.
- Participation in the improvement of the forward ('Plug') calorimeters.
- Data analysis.

In order to be able to carry out these responsibilities which we regard as a necessary minimum contribution to the overall performance of CDF, and to pursue our physics interests, we assembled the group of postdoctoral researchers, graduate and undergraduate students, supplemented (part time) by professional staff, as listed above. While the core of the UCLA CDF effort is supported by the Department of Energy, we were able to use funds from Germany to additionally support Neuberger and Dr. Lammel*.

Activities during 1992

1. CDF Operations

After contributing to the commissioning of the calorimeter readout of CDF for the 1992 data taking run, the UCLA group has been fully involved in data-taking shifts. Two of our graduate students have taken additional responsibilities to run the data acquisition system of the detector during extended periods of time as CDF 'Aces'. These 'aces' carry the highest responsibility for the continuity of the CDF data taking.

Another key activity, initiated and pursued by Lammel, has been to utilize the larger IBM RISC processor computer farm at Fermilab (3000 VAX-780 equivalents) for CDF data reconstruction. Only through this measure can CDF data be processed with the same speed as they come in. This is the first time this large computer farm has been fully used; an accomplishment the competing collider group (D0) has not matched.

Finally, UCLA is active in managing the CDF collaboration : Prof. Hauser is co-chairing the exotic analysis group, Prof. Müller is coordinating the shower maximum detector activities of the plug upgrade, and both are involved in committee work ('godfathers') in the CDF experiment.

2. Data analysis

Our physics interest is precision studies of electroweak interactions on the one hand, and the direct search for physics beyond the Standard Model on the other.

One physics study , the measurement of the decay asymmetry of W bosons with the data from the 1988/89 run (Hauser), has been completed and published in Physics Review Letters (see appendix). The results allowed to test different structure functions in a regime of momentum transfer where up to now no direct measurements exist.

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* This support, however, is coming to an end early in 1993.

One of the ongoing analyses focuses on the search for flavour changing neutral current decays of b quarks, in particular in the modes $B \rightarrow \mu^+\mu^- K^*$ and $B \rightarrow \mu^+\mu^-$ ('penguin diagrams'), neither of which has so far been seen. Since the Standard Model predicts branching ratios of around 10^{-6}, we have a chance to measure a signal with the data from the present run. The study of these decays will give us information about the top quark mass (if not discovered) and the possible presence of an anomalous magnetic moment of the W or a fourth generation. Anway, in collaboration with a theory student (Grant Baillie) from UCLA, has created a full Monte Carlo program simulating b production and subsequent decays into all modes where two leptons are involved.

The other activity is the study of events with a W or a Z boson in association with a photon. A signal would present the first observation of the trilinear gauge coupling of electroweak bosons. Significant deviations from the predicted W and Z cross sections would indicate smaller structures in the vector boson sector. Our group has performed a study of quality variables allowing single photon signals to be separated from π^0 background (Neuberger). Lindgren and Müller are presently implementing a W/Z gamma event generator written by Baur into the CDF detector simulation software.

Finally, we are also active in the search for exotic phenomena in CDF with the emphasis on Super Symmetry. The CDF Exotics analysis group was created during the last year to concentrate on searches for SUSY, charged Higgs, leptoquarks, and other particle phenomena beyond the Standard Model. In the current data run, our group (Hauser, Keyvan and Lammel) has taken major responsibility for the CDF missing transverse energy trigger and software algorithm development for selecting SUSY data samples. We expect to find a signal of supersymmetry in the present run if the mass scale is below 200 GeV. Ultimately, mass scales of up to 300 GeV should be reachable with CDF.

3. CDF Upgrade

UCLA contributes to the CDF upgrade program by designing and building, in collaboration with the Rockefeller group, the Shower Maximum Detector (SMD) of the plug calorimeter. We finished analyzing data from the tests of a large prototype detector we built in 1991, which showed unprecedented position resolution for electromagnetic showers and two-shower resolving power, as described in a report soon to be published in Nuclear Instruments and Methods. Our experience, gained in the test beam and subsequent R/D efforts, resulted in an improved design of the SMD, which is now incorporated in a Conceptual Design Report of the CDF endplug upgrade. The new design of the SMD forsees about 8000 narrow strips of scintillator with wavelength shifting green fibers imbedded, read out by a new generation of multianode photomultipliers which are being developed by UCLA. The whole technology was planned to be applicable at the SSC, and it happened so that most of the concepts developed by the CDF plug upgrade group were copied for the SDC calorimeter.

Despite of the progress made with the conceptual design of the plug calorimeter, many R/D activities still are going on. Our group pursues the optimization of light yield of scintillator and of the performance of multichannel phototubes (MCPMT). Recent devices of MCPMT made by Hamamatsu and by Philips show much better behaviour than previous tubes. We have measured samples of various devices in our lab at UCLA, testing channel-to-channel gain, cross-talk, linearity, and gain variations within single pixels. Our undergraduate students have written a Monte Carlo ray-tracing program for optimizing light transmission from optical fibers to the MCPMT's, from which we realized that optical cross-talk is a major problem in all but the most recent MCPMT designs.

Appendix : List of Publications 1992

F. Abe et al. (CDF Collaboration): "Lower limit on the top-quark mass from events with two leptons in $p\bar{p}$ collisions at $\sqrt{s} = 1.8$ TeV", PRL 68 (1992), 447.

F. Abe et al. (CDF Collaboration): "Inclusive jet cross section in $\bar{p}p$ collisions at $\sqrt{s} = 1.8$ TeV", PRL 68 (1992), 1104.

F. Abe et al. (CDF Collaboration): "Topology of three-jet events in $\bar{p}p$ collisions at $\sqrt{s} = 1.8$ TeV", PRL 45 (1992), 1448.

F. Abe et al. (CDF Collaboration): "Search for new gauge bosons in $\bar{p}p$ collisions at $\sqrt{s} = 1.8$ TeV", PRL 68 (1992), 1463.

F. Abe et al. (CDF Collaboration): "Lepton asymmetry in w-boson decays from $\bar{p}p$ collisions at $\sqrt{s} = 1.8$ TeV", PRL 68 (1992), 1458.

F. Abe et al. (CDF Collaboration): "Properties of events with large total transverse energy produced in proton-antiproton collisions at $\sqrt{s} = 1.8$ TeV", PRL 45 (1992), 2249.

F. Abe et al. (CDF Collaboration): "Measurement of the isolated prompt photon cross section in $\bar{p}p$ collisions at $\sqrt{s} = 1.8$ TeV", PRL 68 (1992), 2734.

F. Abe et al. (CDF Collaboration): "Measurement of the ratio $B(W \rightarrow \tau\nu)$ /$B(W\ W \rightarrow e\nu)$ in $\bar{p}p$ collisions at $\sqrt{s} = 1.8$ TeV", PRL 68 (1992), 3398.

F. Abe et al. (CDF Collaboration): "Measurement of $B^0\bar{B}^0$ mixing at the Fermilab Tevatron collider" PRL 67 (1992), 3351.

F. Abe et al. (CDF Collaboration): "Limit on the top-quark mass from proton-antiproton collisions at $\sqrt{s} = 1.8$ TeV", PRL 45 (1992), 3921.

F. Abe et al. (CDF Collaboration): "Measurement of the production and muonic decay rate of W and Z bosons in $p\bar{p}$ collisions at $\sqrt{s} = 1.8$ TeV", PRL 69 (1992), 28.

J. Hauser, Mike Lindgren, Thomas Muller, Dirk Nerberger et al: "A scintillating fiber detector for electron and photon identification at high luminosity colliders", UCLA HEP92-003 (1992) to appear in Nuclear Instruments and Methods.

10/5/92

Group leaders J. Hauser Th. Müller Date

Progress Report

Task H

Institution	University of California Los Angeles Department of Physics, 405 Hilgard Ave. Los Angeles, CA 90024
DOE Grant No:	DE-FG03-92ER40662
Title of Task:	VLPC/Scintillating Fiber R & D
Task Manager:	Muzaffer Atac
Scientific Personnel:	D. Chrisman, J. Park, J. Rhoades, B Ritzi

A) Scintillating Fiber and Visible Light Photon Counter (VLPC)
Research and Development

Scintillating fiber tracking is being developed for the SSC laboratory as part of the detector subsystem research and development program. As part of this research, photons produced in polystyrene based scintillating fibers are detected by VLPCs. The VLPCs are silicon impurity band conduction solid state devices with quantum efficiencies near 85%. The application of this research may extend to future LHC detectors as well. Two important publications resulted from work in this task in 1992. These papers are appended for information purposes. The team supported by this task are: M. Atac, D. Chrisman, J. Park, J. Rhoades and B. Ritzi.

Recent development work includes the building of 32 VLPC channels mounted in one cassette which is cooled by helium vapor. In tests with cosmic rays, 830 μm diameter scintillating fibers were coupled to clear non-scintillating light guides, which were in turn coupled directly to VLPC's inside a helium cryostat with a 30 liter capacity. The VLPC's are cooled quite efficiently by the cold helium vapor and were maintained at their operating temperature for up to 9 days with little intervention. The fibers were stacked to form an array, with four layers and four fibers per layer, in order to observe cosmic ray tracks. In this test, an average of 6 photoelectrons, produced by minimum ionizing cosmic rays, were detected at the end of 4 meters of scintillating fiber plus 3 meters of clear fiber. Very clean tracks were observed with no cross talk between channels and tracking efficiencies about 98%. A beam test at BNL was also conducted, in which the scintillating fiber length is increased to 4.3 m and the number of readout channels is increased to 128. Preliminary results indicate that sufficient light is being transmitted down these long fibers and that this larger number of readout channels is operating as expected. The data is being analyzed.

Futhermore, successful tests have been conducted with smaller diameter fibers, and in addition to practical mechanical limitations, the diameter of the fiber is only limited by the light attenuation in the fiber.

In a manner similar to that described by C. D'Ambrosio et al., scintillating fibers can be mounted on thin cylindrical shells concentric with the beam pipe.

Some advantages of reading of scintillating fiber layers with VLPC's are: long fiber length due to high quantum efficiency of the VLPC's, short rise time, and high rate capability ($\sim 10^7$ photons per second). In addition, the scintillation light can be brought to the VLPC's via clear light guides. Therefore the VLPC's and associated front end electronics do not have to be situated inside the tracking volume, thus reducing the amount of heat and passive material before the calorimeter.

Detailed Monte Carlo simulation studies are now beginning to address the feasibility of this type of tracking scheme in the LHC environment. These details include understanding occupancy, track finding efficiencies and tracking resolution as a function of luminosity and fiber diameter.

The successful tests at UCLA and promising results of the BNL beam test, show that scintillating fibers read out by VLPC's may be a viable option for tracking in the next generation of collider detectors and should be considered an option for CMS which deserves further study.

B) Tracking with Scintillating Fibers and VLPCs in RD5:

The CMS collaboration has expressed an interest [Ref. 3] in scintillating fiber tracking, using the VLPC as a photon transducer. As a further proof of principle and an extension of the research conducted by the Fiber Tracking Group in the U.S., it has been suggested that we conduct a scintillating fiber test as part of RD5. The LHC has a very high design luminosity, one order of magnitude higher than the SSC, therefore, minimizing occupancy within the tracking volume is a greater challenge at the LHC. In order to meet this challenge we propose a test using .5 mm fibers. The scale of the test will to some extent be determined by the space available within the RD5 detector. Preliminary measurements indicate that we can employ at least two superlayers, separated by 15 cm, with a total of 128 readout channels. Because of the limited availability of test beams in the U.S., RD5 represents a unique opportunity to move into the next phase of development for scintillating fiber tracking with VLPC's, that being the integration of this tracking system into a dedicated large scale detector. Integration into RD5 and the utilization of its existing beam defining chambers, such as the silicon microstrip detector, will enable us to determine spatial resolution and tracking efficiency of scintillating fiber tracking to high precision. These measurements have not been done by any group. This is a great opportunity to carry out the tests at CERN using a high energy beam with the hardware and software in place while such beams are not available in the U.S. at least for the next 2-3 years.

C) Artificial Neural Network Trigger Processor for CMS:

As mentioned in the introduction to Task B, an efficient and fast first level muon trigger is an important part of a successful detector at the SSC and LHC. We are concerned with identifying very high p_t tracks, which have very small bending in the r, ϕ plane. To identify these very straight tracks, one must have a muon detector with high granularity, and consequently, a large number of channels. To make matters more difficult, stochastic energy loss processes become more important with increasing muon energy. These processes tend to confuse the measurement of the muon tracks and requires one to add additional measurement planes which further increase the number of readout channels. Trigger processors using look up tables may in practice, become prohibitively complex, while trigger processors using shift registers may be too slow. We propose to compare performance of conventional trigger processors with a trained feed forward neural network.

In a collider detector, such as CMS, once the geometry of the moun trigger detectors is defined, each muon is seen as a pattern of hits in muon stations. The pattern is just a four-tuple of strip numbers in the muon stations (n_1, n_2, n_3, n_4). To select muons with $p_t > p_t^{cut}$ one has to define a set of valid patterns taking into account fluctuations due to multiple scattering and energy loss. The trigger processor, in this case a neural network, should check whether the measured hit pattern belong to the predefined set. The neural network will be trained to recognize this predefined set by giving it the results from simulation. The software neural network, JETNET 2.0, in conjuction with the existing CMS detector simulation program, will be used to conduct the initial study.

D) Fermilab P865

UCLA is participating to upgrade E789 experiment at Fermilab for a search for rare B-meson decays. This is to focus attention on a few rare, low multiplicity decay modes with large expected CP-violating asymmetries. These include $B_d \rightarrow \pi^+\pi^-$, $B_d \rightarrow J/\psi K_s$, and $B_s \rightarrow \rho^\circ K_s$, two of which have yet to be observed. Available evidence suggest that these modes should have observable branching ratios of order 10^{-5}. The goal is to have 10^8 $b\bar{b}$ events in a large acceptance in the 1994/95 run. The experimental groups are working toward a proposal, P865, to carry out this long time sought research.

The experiment can only be successful if the background is reduced by a factor of 50 to 100. For this, an optical impact-parameter trigger has been proposed by Charpak, Giomataris, and Lederman[4)]. Success of such a trigger very much depends on the special crystal, a high quantum efficiency and high granularity photodetector. The Visible Light Photon Counters (VLPC's) offer the desired specifications of the photodetector. The optical trigger arrangement as a sketch is shown in Fig. 1. The UCLA group together with Lausanne University and CEN Saclay groups, are working toward producing the optical trigger devices. Some preliminary results obtained with LiF crystal and vacuum photomultipliers show that the optical trigger is working, in principal, for selective impact parameter interval of charged particle tracks producing cerenkov photons that make total internal reflection. The UCLA group is going to work on the photodetector connection using the Visible Light Photon Counters (VLPC's). A copy of the letter of intent is appended.

The UCLA group is going to put together a 192 channel VLPC system with optical fiber coupling and join for the tests at a CERN test beam. The crystal and the associated equipment will be provided by the University of Lausanne group.

References

1) F. Lacava, "Punchthrough in Hadronic Showers: A Parameterization of the Total Probability", ROM-NI 968 12/90
2) A. Bodek, "Punchthrough in Hadronic Shower Cascades, Muon Identification and Scaling Laws for Different Absorbers", UR-911
3) "CMS, The Compact Muon Solenoid Letter of Intent", CERN/LHCC 92-3
4) G. Charpak, et al., "Study of an Optical Trigger to be Used for Beauty Search in Fixed Target Mode at the LHC", CERN/DRDC/91-32 DRDC/30

OPTICAL TRIGGER ARRANGEMENT

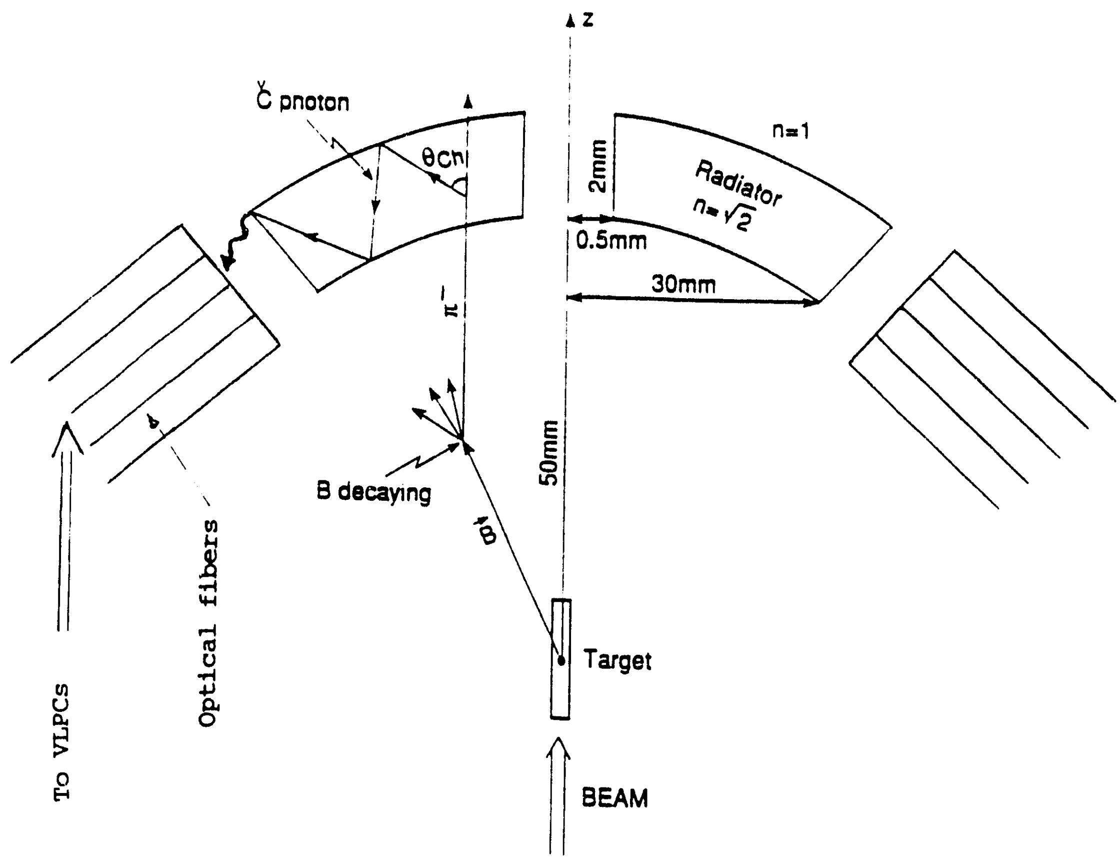

Figure 1

UCLA

Fermilab

Fermi National Accelerator Laboratory
P.O. Box 500 • Batavia, Illinois • 60510

2 September, 1992

John Peoples
Director
Fermilab

Dear John,

Here is our Letter of Intent to pursue a program of fixed-target beauty experimentation. We intend to construct, in stages, a new, high-rate, large-acceptance spectrometer including particle identification, sophisticated triggering capabilities, and high-bandwidth data acquisition. For the first (1994/95) run, the most attractive approach is to use the existing E605 apparatus (also used in E772 and E789) to provide triggering and particle identification over a portion of the aperture. This will provide sensitivity for dihadronic *B* decays 100 times greater than that of E789, and even larger improvement factors for other decay modes. We request at this time minimal support in carrying out simulations and design studies for a detailed Proposal to be written over the next several months.

Sincerely,

Dan

Daniel M. Kaplan
Associate Professor of Physics
Northern Illinois University
HEPnet: FNAL::KAPLAN
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P865

LETTER OF INTENT
for a
HIGH-SENSITIVITY STUDY
of
RARE LOW-MULTIPLICITY BEAUTY DECAYS

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September 1, 1992

ABSTRACT

We propose a comprehensive study of low-multiplicity B decays to fully-charged final states, to be carried out using a high-rate open-geometry spectrometer. This spectrometer will be assembled in stages over the next two fixed-target runs, building on systems already available from E789 and (possibly) other fixed-target experiments. It will differ from existing open-geometry spectrometers in the use of a small beam and target, with a small beam hole extending through the apparatus, to maximize rate capability while allowing efficient triggering based on decay-vertex topology and the presence of high-transverse-momenum secondaries. Our goal for the 1994/95 run is $\sim$ 100 events reconstructed per mode in $B^0 \to$dihadrons, $B^0 \to J/\psi K_s$, $B^\pm \to J/\psi K^\pm$, $B \to D\pi^\pm$, etc. Our long-term goal is observation of CP violation in B decay, which we may achieve by the end of the decade if we can develop further techniques for increasing the rate capability of the spectrometer.

I. Physics goals

Observation of CP violation in B-meson decay is one of the most sought-after goals of contemporary high energy physics. Recent work has focused attention on a few rare, low-multiplicity decay modes with large expected CP-violating asymmetries which, taken together, can test the Kobayashi-Maskawa model for CP violation by overconstraining the "unitarity triangle." These include the decays $B_d \to \pi^+\pi^-$, $B_d \to J/\psi K_s$, and $B_s \to \rho^0 K_s$, two of which have yet to be observed. Available evidence suggests that these modes should have observable branching ratios (to final states with no neutrals) of order 10^{-5}, thus observation of CP violation in these modes will require the production of at least 10^9 B mesons in an experiment configured to have large acceptance and good tagging capability. Our intended experiment will have substantial sensitivity to other low-multiplicity modes as well. Although CP sensitivity is our ultimate goal, for the 1994/95 run we propose as a step along the way $\sim 10^8$ $b\bar{b}$ events produced into a large acceptance. Below, we argue that this level of sensitivity is a reasonable extrapolation of what we have already achieved in E789.

II. Experimental approach

Sections III et seq. lay out our proposal for the first (1994/95) run. Here we consider how sensitivity at the *CP*-violation level might ultimately be obtained in a subsequent run.

Many experimental approaches to beauty *CP* violation have been discussed. These include asymmetric e^+e^- collider experiments, Tevatron, LHC, and SSC collider experiments, and HERA, LHC, and SSC internal and external fixed-target experiments. Most of them share two things in common: they require accelerator facilities which do not yet exist, and they are expensive. We thus ask: is there another way to approach this physics which might be cheaper or feasible with existing accelerators? Specifically, might a fixed-target experiment at the Tevatron be able to measure a sample of $\sim 10^9$ B mesons? This question cannot at present be answered with certainty. A crucial difficulty is the small size of the $b\bar{b}$ cross section at fixed-target energy – $\sim 10^{-6}$ of the total cross section – which implies an interaction rate in excess of 200 MHz. The radiation-damage properties of silicon microstrip detectors then impose severe constraints on detector placement. These are the Scylla and Charybdis with which a Tevatron fixed-target beauty experiment must contend.

These difficulties, while substantial, do not appear to us insurmountable. We consider a detector configuration with a central beam hole and a beam tightly focused on a small target. The size of the hole is determined by the rate and radiation-flux capabilities of the detectors. Such a configuration facilitates triggers based on decay-vertex reconstruction and minimizes backgrounds due to secondary interactions. Ultimately it should permit operation well above one interaction per RF bucket.

It is unrealistic to expect to achieve *CP*-level sensitivity in a single step, both because of the difficulty of assembling and commissioning a new state-of-the-art apparatus, and because of the small size of the signal and challenging level of performance required. Experience teaches that in high-rate experiments aiming to detect small signals, each new order-of-magnitude in sensitivity brings with it new problems, the nature of which is often difficult to anticipate in advance. (For example, E70/288/494, before discovering the b quark, took data in Proton Center for five years; this experience was crucial and provided ultimately a factor > 1000 in sensitivity.) We intend to describe a program of staged upgrades, proceeding in a natural way towards a *CP*-level experiment by the end of the decade.

Three ideas for achieving *CP*-level sensitivity have been considered. One of us[1] has sketched an experiment based on radiation-hard silicon pixel detectors which appears to have the necessary interaction-rate capability. Pixel detectors are under intensive development by several groups[2] in preparation for experiments at LHC and SSC, and it is possible that they will become available in rad-hard versions before the end of the decade.

The second idea[3] is to take advantage of the strong energy dependence of the beauty cross section, yet retain the relative ease of triggering and secondary-vertex reconstruction provided by fixed-target geometry, by arranging collisions between proton beams of widely differing energies. This might be achieved by modification of the Main Injector to allow collisions between its beam and that of the Tevatron; to preserve the desired small interaction region, the beams should be made to cross at a modest angle. Preliminary discussions with Main Injector accelerator physicists indicate that such a scheme may be feasible.[4]

A third possibility is that a spectrometer composed largely of silicon microstrip detectors might be operable beyond the generally accepted limit of irradiation, either through improvements in silicon-detector fabrication techniques or through explicit engineering of the mounting system for ease of chip replacement, so that damaged detectors might be replaced several times in the course of a run. (This approach is now being investigated by the ARGUS group for an internal-target B-decay CP-violation experiment at HERA.[5])

We recognize that any or all of these techniques may prove insufficient to reach CP sensitivity. However, even in that case one will have done some substantial B production and decay physics, made precise lifetime measurements, and developed techniques for triggering, vertex reconstruction, B tagging, and particle detection and identification at high rates which will be important for SSC and LHC beauty experiments.

III. Goal for the 1994/95 run

By 1994 it is possible that dihadronic decays of B^0 will have been seen by CLEO and likely that the B_s and Λ_b will have been firmly established by CDF and LEP, so the mere observation of these phenomena will no longer be a sufficient goal. Our goals for the first run are the measurement, at a useful level of statistical significance, of the ratios of various rare decays of these particles, as well as the exploration of the feasibility of various strategies for tagging the beauty quantum-number of the other B in the event. The former goal calls for the achievement of a significantly higher level of sensitivity than CLEO will by 1994-5; we take this to mean ~ 100 reconstructed decays per 10^{-5} branching ratio. This will yield a sufficient sample of fully and partially reconstructed B mesons and baryons to permit detailed study of cross sections, branching ratios, lifetimes, and tagging strategies.

Many B-tagging strategies seem potentially useful: tagging with high-p_t leptons or with moderate-p_t kaons; tagging with those particles but also imposing impact-parameter requirements at the primary vertex; tagging with partially-reconstructed decays; and tagging with fully-reconstructed decays. These strategies will provide various levels of purity and efficiency which can be approximately predicted by Monte-Carlo simulation. An experimental test is required before their utility can be assessed with confidence.

Before discussing the characteristics of the proposed spectrometer, we summarize what has been achieved so far. In the last run beauty sensitivity was achieved in open-geometry (E672, E771) and restricted-geometry experiments (E789) using various beam and spectrometer configurations (see Table III.1). The sensitivities achieved were limited by running time and radiation shielding. A factor ≈ 10 increase in sensitivity could be expected in each experiment from a full run. For 1994/95 we seek an additional order of magnitude: single-event sensitivity of $\approx 2 \times 10^{-7}$ per $B^0 \rightarrow$ dihadron mode, with corresponding sensitivities in other low-multiplicity modes (see also Table VI.1 below).

TABLE III.1 Fixed-target beauty results (estimated): 1990/91 run

	E672 (1990)[6]	E771[7]	E789
beam	530-GeV π^-	800-GeV p	800-GeV p
interaction rate achieved	0.6 MHz	2 MHz	65 MHz
running time (live beam-seconds)	5×10^5	4×10^5	1.2×10^6
interactions	2×10^{11}	8×10^{11}	3×10^{13}
$b\bar{b}$ produced	4×10^5	8×10^5	3×10^7
$B \to J/\psi$ acceptance $\times$ efficiency	6%	4%	0.15%
estimated $B \to J/\psi X$ observed*	≈ 30	≈ 40	≈ 100
BR per fully-reconstructed B	$\approx 4 \times 10^{-4}$†	$\approx 3 \times 10^{-4}$†	$\approx 2 \times 10^{-5}$‡

* Note that E789 detected both e^+e^- and $\mu^+\mu^-$ events while E672 and E771 detected only $\mu^+\mu^-$.

† In $B^\pm \to J/\psi K^\pm$ or $B^0 \to J/\psi K^*$.

‡ In each $B^0 \to$ dihadron mode.

IV. Characteristics of proposed spectrometer

We propose to configure a vertex spectrometer of silicon microstrip detectors to achieve larger solid-angle coverage than in E789 while maintaining E789's high rate capability. In E789 the first silicon detector was also the one located closest to the beam axis. It experienced the highest rates: 10^{-2} hits per interaction per 50-μm strip on the inner strip, which was located 0.3" from the beam. Since the pseudorapidity bite covered by a detector at a given distance from the beam axis is independent of its distance from the target, we conclude that a silicon detector located 0.3" from the beam axis at any distance from the target will see this same rate to a good approximation. Thus a substantially larger solid angle than E789's may be covered by a series of detectors, each 0.3" from the beam axis, spread over a suitable range of distances from the target, large-angle secondaries being detected close to the target and small-angle secondaries farther downstream.

We consider two such detector arms, one above and one below the beam, each composed of silicon-microstrip detectors (SMDs) measuring three views in stereo. The SMDs cover lab angles from 10 to 200 mrad, with a total channel count of about 20 to 40 thousand strips. (For comparison, the E789 vertex detector included 16,000 strips, of which about 10,000 were instrumented with electronics; this instrumentation is of course available and is assumed to be reused in the new experiment.) Following the two silicon-detector arms is a small dipole magnet of ≈ 300 MeV/c p_t kick, then an array of high-rate detectors to determine the momenta of charged particles. All detectors are assumed to have 1-RF-bucket resolution; for maximum rate capability the detectors downstream of the magnet might be gas microstrip chambers, scintillating-fiber hodoscopes,[8] $\approx$1-mm-pitch MWPCs operated with a fast gas and with drift-time measurement ("minidrift" chambers), straw tubes, or pad chambers similar to those being considered for the GEM tracker.

We are currently investigating the resolution needed and the optimum choice for these detectors. Since the silicon detectors accurately determine the track of each particle upstream of the magnet, measurement of a point in the bend view downstream of the magnet suffices for precise momentum determination. Additional measurements are provided to improve the precision of the momentum measurement and add redundancy to the pattern recognition. The acceptance of such a spectrometer for various low-multiplicity B decay modes has been estimated by Monte Carlo; the results are given in Table IV.1. Note that despite the beam hole, the acceptances are relatively large (e.g. $> 50\%$ for $B^0 \to \pi^+\pi^-$).

TABLE IV.1 Estimated beauty acceptance of 10 to 200 mr spectrometer*

$B^0 \to \pi^+\pi^-$	0.54
$B^0 \to J/\psi K_s \to l^+l^-\pi^+\pi^-$	0.15
$B^\pm \to J/\psi K^\pm \to l^+l^-K^\pm$	0.40
$B^\pm \to D\pi^\pm \to K\pi\pi$	0.40

* These estimates are preliminary; we will carry out additional Monte-Carlo simulation prior to presentation of a full Proposal.

Supplemented by suitable particle identification and an efficient beauty trigger, this spectrometer could constitute the nucleus of an experiment capable of exceeding our 1994/95 sensitivity goal by a factor > 5, since its acceptances are approximately 50 or more times larger than those achieved in E789 during the 1991 run. However, construction of the additional detectors and triggering systems required will be difficult to complete by 1994. Therefore, we describe in Section V.2 below our plan to utilize existing E789 equipment to trigger with somewhat reduced efficiency, giving effective acceptances of 10 to 15%.

V. Triggering

We describe in Section V.1 several strategies which appear promising for use in future runs. It is likely that not all will be feasible to implement by the 1994/95 run. In Section V.2 we propose a triggering strategy for the 1994/95 run which is consistent with the sensitivity goal described in Section III.

V.1 Trigger strategies for a high-sensitivity beauty experiment

We assume a data acquisition system similar in bandwidth to those of E690 and E791, hence the task of the trigger is to reduce the rate to $\lesssim 10\,\mathrm{kHz}$. (Note: this is an order-of-magnitude increase in bandwidth compared to the existing E789 data acquisition system.) Two promising ideas for triggering on the heavy-quark decay vertex are now under development by groups in Europe and at Fermilab: the optical impact-parameter trigger proposed by Charpak, Giomataris, and Lederman[9] and the Cherenkov multiplicity-jump trigger of Halling and Kwan.[10] Each appears capable of providing at least an order of magnitude in background suppression while maintaining high efficiency for beauty decays occurring downstream of the target. Both require the use of a thin ($\approx$ few mm) target. In addition, the optical impact-parameter trigger requires an interaction region of small diameter ($\approx$ few hundred μm) transverse to the beam axis, while the multiplicity-jump trigger is feasible with a plate target and transversely large beam. Development efforts are in progress, with first beam-test results already presented in seminars and conferences,[11] and we believe that with adequate support one or both of these devices will be ready in time for the 1994/95 run.

If the impact-parameter and multiplicity-jump triggers together can provide a rejection $\sim 10^3$, at 10^8 interactions/s the resulting rate ($\sim 100\,\mathrm{kHz}$) is low enough to trigger a pipelined processor of the E690/E789 variety, which must then provide an additional factor ~ 10 in rejection to bring the rate within the capability of the data-recording system. Such rejection can be achieved by looking for sets of tracks consistent with a vertex downstream of the target and with invariant mass in a suitable range near the B mass.

If the impact-parameter and multiplicity-jump triggers prove insufficient to satisfy the input bandwidth requirement of the pipelined processor, high-speed highly-parallel trigger systems may be employed to look for patterns in the silicon and chamber hits consistent with desired decay topologies (e.g. sufficiently many moderate-p_t tracks having non-zero impact parameters at the target); prototypes for such systems include the E605 fast trigger matrix and neural networks[12] under development by a number of groups. Calorimetric information may be used to select events with high E_t, providing rejection at the order-of-magnitude level.[13] Trigger strategies relying on high-p_t lepton detection have been used in other B experiments;[14] these have the drawback of low efficiency for nonleptonic modes.

V.2 Triggering in the 1994/95 run

We propose here a strategy which will permit the achievement of significant physics ($\approx 2 \times 10^{-7}$ single-event sensitivity) in the 1994/95 run. The proposed spectrometer is relatively small and can be mounted upstream of an existing fixed-target experiment, which can then provide triggering at somewhat reduced acceptance or luminosity. The most attractive option is to use the E605 spectrometer (Figure 1), which at a setting appropriate for beauty detection can operate at $\approx 10^8$ interactions/s. Located in Meson East, the E605 spectrometer (using small-cell drift chambers, scintillation hodoscopes, scintillation-sandwich calorimeters, a muon-detector array, and a ring-imaging Cherenkov counter) precisely momentum-analyzes and identifies charged particles deflected around the beam dump by the large "SM12" analyzing magnet. While it has small acceptance for multiparticle states, its beauty acceptance is relatively good if only a single particle is required to traverse it (in contrast to E789, in which two particles were required).

A high-p_t single-particle trigger based on roads in the hodoscopes in combination with an energy threshold in the calorimeter or hits in the muon detector counts at $\approx 10^{-2}$ per interaction. At 1 interaction/bucket, a factor 10 rejection from impact-parameter or multiplicity-jump triggers reduces this rate sufficiently for input to a pipelined processor, which can reduce the rate sufficiently for taping. We estimate that with some rearrangement of detectors, a one-particle trigger can be formed using the E605 spectrometer which is (for example) approximately 15% efficient for $B^0 \to \pi^+\pi^-$ decays, leading to the sensitivity estimates of Table VI.1. (This use of the E605 spectrometer does not preclude the use of some additional strategies described in Section V.1 should they become available; there is thus the possibility of substantially higher sensitivity if sufficient progress is made to permit triggering over the full solid angle.)

We have also considered combining elements of the E789 spectrometer with the E690 large-aperture spectrometer. This option has the advantage of requiring minimal construction of new equipment; the E789 SMD electronics, SMD mounting system, small-cell drift chambers, and muon detector could be installed around the existing E690 apparatus to make a hybrid experiment with substantial beauty sensitivity (as shown in Table VI.1). New detector chips with central beam holes would be installed in the existing E789 SMD fanout boards and configured so as to cover the aperture $5\,\text{mr} < |\theta_x| < 180\,\text{mr}$, $|\theta_y| < 180\,\text{mr}$. The E690 and E789 drift chambers would be suitably deadened near the beam to maximize their interaction-rate capability. We assume the use of an optical impact-parameter trigger to help in reducing the trigger rate to match the input bandwidth of the E690 pipelined processor. Assuming that the E690 spectrometer can operate at a 10-MHz interaction rate,[15] the larger trigger acceptance approximately makes up for what is lost in luminosity in comparison with the E605 option described above.

Some members of the E690 collaboration have expressed interest in the possibility of joining us for the 1994/95 run, however more work is needed to assess this option in detail. Compared to the first option proposed, the E690 option has substantially lower interaction-rate capability, and thus a more difficult upgrade path to the $\sim 10^{-8}$ sensitivity to be sought in the 1996/97 run. The existing N-East beam line would need to be substantially upgraded to permit a 10-MHz interaction rate with a few-percent target, or the E690 spectrometer would need to be moved to another beam line.

VI. Sensitivity estimates

Table VI.1 gives sensitivity estimates for the proposed experiment, triggered on one particle in the E605 spectrometer, compared to sensitivities achieved in E789. Using standard assumptions for B production and hadronization and branching ratios, in the 1991 run E789 achieved a sensitivity of $\lesssim 1$ event for $B^0 \to \pi^+\pi^-$. We assume in 1994/95 a factor 2.5 increase in running time, a factor 2 increase in average interaction rate, and a factor 20 increase in $B \to$ dihadron acceptance. The estimates below are based on 800-GeV operation of the Tevatron; operation at 900 GeV should provide 40% greater sensitivity due to the increase of the $b\bar{b}$ cross section with energy.[16] For comparison, estimates for the E690 option described above are also presented.

TABLE VI.1 Estimated sensitivity in representative modes*

	E789 (1991)	This proposal	E690 option
average interaction rate	25 MHz	50 MHz	10 MHz
running time (live beam-seconds)	1.2×10^6	3×10^6	3×10^6
interactions	3×10^{13}	1.5×10^{14}	3×10^{13}
$b\bar{b}$ produced	3×10^7	1.5×10^8	3×10^7
$B^0 \rightarrow \pi^+\pi^-$ (BR assumed 1×10^{-5})			
events produced	200	1000	200
acceptance	0.008	0.16	0.7
efficiency	0.2	0.2	0.2
events detected	0.4	40	30
$B^0 \rightarrow J/\psi K_s \rightarrow l^+l^-\pi^+\pi^-$ ($BR = 4 \times 10^{-5}$)			
events produced	1000	5000	1000
acceptance	10^{-4}	0.1	0.5
efficiency	0.2	0.2	0.1†
events detected	0	100	50
$B^\pm \rightarrow J/\psi K^\pm \rightarrow l^+l^-K^\pm$ ($BR = 9 \times 10^{-5}$)			
events produced	2000	11000	2000
acceptance	10^{-3}	0.1	0.6
efficiency	0.2	0.2	0.1†
events detected	0.6	200	120
$B^\pm \rightarrow D\pi^\pm \rightarrow K\pi\pi$ ($BR = 1.4 \times 10^{-4}$)			
events produced	3000	17000	3000
acceptance	10^{-3}	0.1	0.6
efficiency	0.02	0.2	0.2
events detected	0	300	360

* These estimates are preliminary; we will carry out additional Monte-Carlo simulation prior to presentation of a full Proposal.

† E690 assumed to reconstruct J/ψ in $\mu^+\mu^-$ mode only.

VII. Particle identification

Hadron identification is desirable in an experiment such as this, both to reduce the combinatoric background for decays containing charged kaons and to permit kaon tagging of the second B. Anderson *et al.*[17] have proposed a technique for Cherenkov-ring imaging which is well suited for this purpose: it is fast ($<$ 1 bucket timing) and has the granularity needed for high-multiplicity events. The photodetector consists of CsI-plated cathode pads coupled to a low-pressure MWPC. Small spherical mirrors focus the Cherenkov light on photodetectors located outside the aperture. A gaseous ethane radiator at 1 atm should provide π-K separation in the range $\approx$ 5 to 50 GeV.

Electrons can be identified using a TRD in combination with calorimetry. A TRD may also be helpful in identifying hadrons at high momentum. Muons can be identified using the standard technique of detectors interspersed with shielding.

Depending on manpower and resources available, the detectors just described may or may not be available for the 1994/95 run. In any case, the upstream spectrometer will be designed to have a resolution sufficient to allow kinematic separation of most low multiplicity decays.

VIII. Beam and target

The optical impact-parameter trigger requires a small interaction region. To achieve this we intend to focus a primary proton beam on a high-Z target (such as Fe or Au) approximately 300 μm in diameter $\times$ a few mm in thickness. In E789 we targeted $\approx$ 70% of the Meson-East beam on the thin edge of a Au target 250 μm high $\times$ 5 cm wide $\times$ 3 mm thick, at intensities up to 6×10^{10} protons per pulse. To achieve a comparable targeting fraction in 300 μm diameter will require moving the focussing elements in the beam line. The optimal way to implement this is under study. Depending on the target chosen and the limiting rates in the spectrometer, intensities up to about 10^{11} protons per pulse may be required. Since this is approximately two times greater than the beam intensity used in E789, some shielding improvement may be needed.

IX. Manpower

The proposed program represents a large undertaking and will require a strong collaboration. We have had discussions with many physicists (in addition to the co-authors of this Letter) who may be interested in joining us but are unable to make such a decision on the time scale required by the September 1 proposal deadline to which this Letter responds. We anticipate submitting a more detailed Proposal at a later date with a substantially strengthened collaboration.

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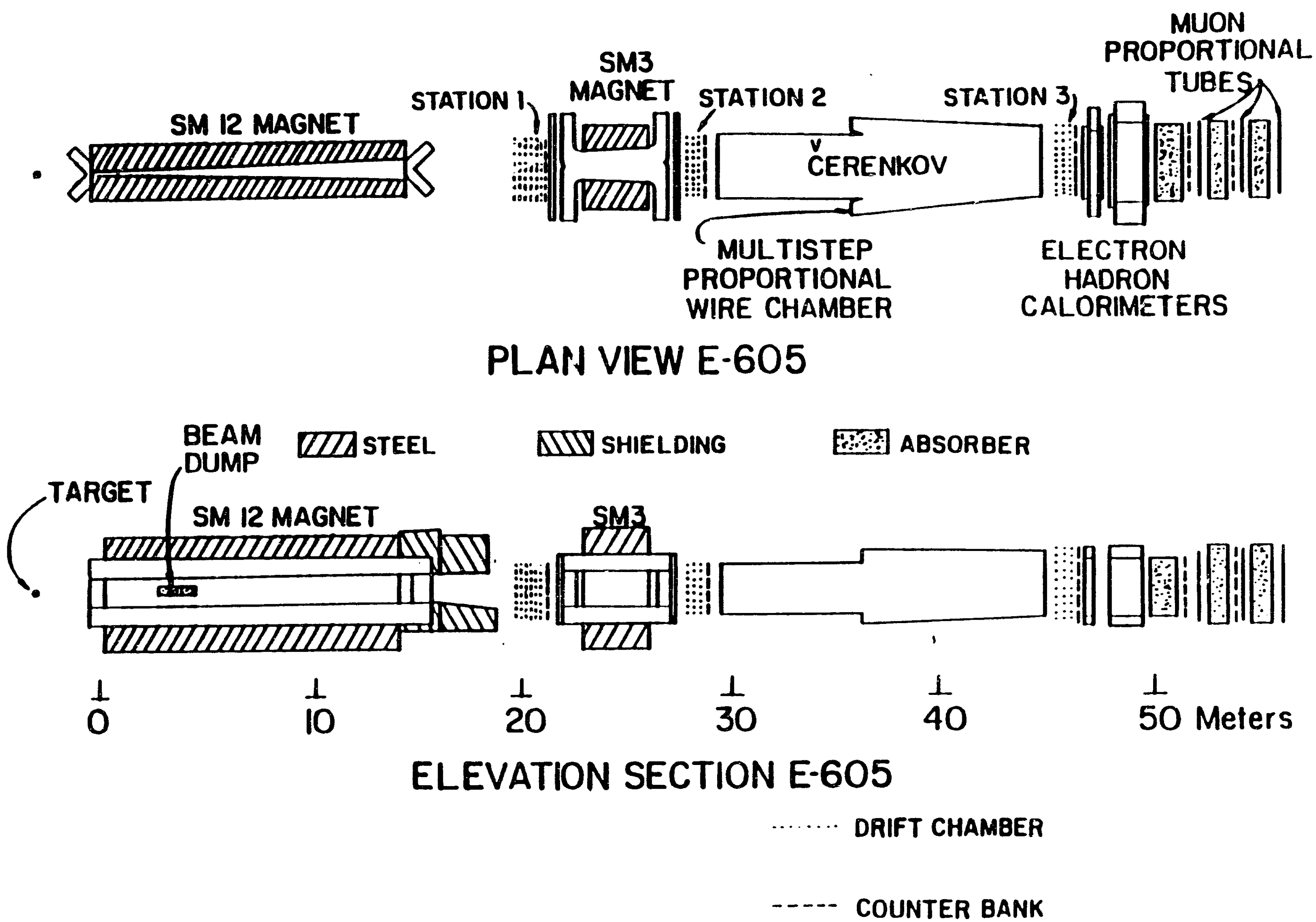
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TUBES
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WIRE CHAMBER
ELECTRON
HADRON
CALORIMETERS
PLAN VIEW E-605
BEAM
DUMP
STEEL
SHIELDING
ABSORBER
TARGET
SM 12 MAGNET
SM3
0
10
20
30
40
50 Meters
ELEVATION SECTION E-605
DRIFT CHAMBER
COUNTER BANK

Figure 1

PROGRESS REPORT

Task K

Institution: University of California Los Angeles
Department of Physics, 405 Hilgard Ave
Los Angeles, CA 90024

DOE Grant No: DE-FG03-92ER40662

Title of Task: Administrative Core

Task Manager: William Slater

Professional Staff: J. Kolonko, M. Laraneta

This task is responsibile for providing administrative and staff support services to the HEP group at large, for providing general support to the UCLA HEP common computing facility, and for helping organize and assist with conferences, symposiums and workshops hosted by the UCLA HEP group.

In late 1991, we purchased a VAXstation 4000/60 (12 MIPS) and shortly after that added four more identical workstations and a disk/tape subsystem. These workstations were then connected in a local area cluster so that to remote users they appear as a single computer. This is because the user files are stored in the disk system, and whichever node users log into accesses the same disk. This initial cluster worked smoothly enough that we decided to move the whole high energy computer user clientele to a further expanded cluster. The present cluster contains seven VAXstation 4000/60's and three VAXstation 3100/76's, earlier 7.6 MIPS machines purchased by the CDF task with university start-up funds. There are two disk subsystems with a total of 6 gbytes of storage, and a total of five Exabyte 8mm tape drives. In order to purchase the final two workstations and the second disk subsystem, we sold the VAX 6340 on the open market. We also equipped the boot and disk server nodes and the disk subsystems with an uninterruptable power supply. The cluster has proven to be remarkably stable and robust. Users have virtually continuous access except on the rare occasions that new software is to be installed or when major system parameters have to be tuned.

We have opted not to have maintenance agreements on the computing equipment. Disks are purchased with typically a five year warranty and the vendors will supply a replacement in advance of returning a failed unit. The aggregate CPU power is now 100 MIPS and it is our intention to upgrade (via a board swap) the Model 60 VAXstation to Model 90's which are three times as fast. Partial funding of this upgrade is planned to come from operating funds provided this task in 1993. The balance of funding is expected to come from the savings generated by cancelling external maintenance contracts in the other tasks. This means that funds that last year would have been spent on external maintenance agreements are now alloted to replacement parts in the form of additional computers that are installed in advance of the need for a replacement.

So far, this strategy has made a dramatic improvement in our computing resources. It is not without cost. UCLA has been our supporter by allowing us to tap into the services of the Physics Department computer personnel who also manage the Department VAX cluster and a SUN workstation LAN. Many of the problems are common enough that the same experienced people can handle both RISC and CISC operating systems. The university also provides support in having access to site-wide educational licenses for the various software systems needed for the cluster.

During 1992, the UCLA HEP group will have hosted four conferences and workshops. The 2nd International Conference on Gamma Ray and Neutrino Cosmology was held at UCLA, February 13-15, 1992. The proceedings of this meeting are in preparation with publishing done by World Scientific Publishing, Inc. This Fall, three workshops are scheduled. The first workshop will discuss a design for an asymmetric phi factory. This meeting will be held at UCLA, October 28, 1992. Immediately following this meeting on October 29-30, 1992, a second workshop will be held which will have both theorists and experimentalists discuss topics related to "low energy signals from the Planck scale". A third workshop is planned for December 10-12, 1992 in Napa, California to discuss mu plus, mu minus colliders: particle physics issues and design.

On February 3-5, 1993 and international symposium is scheduled entitled "30 Years of Neutral Currents from Weak Neutral Currents to the W and the Z and Beyond".

END

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