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Annual

PROGRESS REPORT

DISCLAIMER

Progress Report

The Oregon experimental high energy physics group has been working, during the past year, on a number of projects, with principal emphasis on the preparation of the SLD experiment. In September Ray Frey joined as the second faculty member. We include in the following discussion of progress the work that Ray did while a postdoctoral researcher with the University of Michigan, since all of his efforts will be continued at Oregon.

1. SLD

The construction of SLD is nearing completion, after many years of effort from the participating institutions. While the Oregon group has only joined the effort since September of 1988 when Jim Brau moved to Oregon, work at Oregon is a continuation of his 5 previous years of effort to prepare the experiment.

The Oregon group works principally on the SLD luminosity monitor, Jim Brau being the responsible physicist for that subsystem. This subsystem is a small angle electromagnetic calorimeter, based on silicon detector sampling. A description of the system is contained in Ref. 1. This work is carried on in collaboration with the University of Tennessee, where the system engineer for the luminosity monitor is employed. The preparation of the original designs for this system has been divided between Tennessee and Oregon, with Tennessee receiving the first detectors, testing them and assembling them. Cary Zeitlin, of Oregon, is responsible, at SLAC, for the integration of this system into the SLD experiment. This includes the development of the electronics.

During this past year, the first luminosity monitor module was tested in the A2 beam at Brookhaven National Laboratory. The results of this test are being presented at the 1989 Nuclear Science Symposium in San Francisco, which has now been postponed to January, 1990. The detector was exposed to 2, 4, and 5.4 GeV electrons and the electromagnetic resolution was found to be consistent with the design goal of 3 percent at 50 GeV, as shown in Figure 1.

Cary Zeitlin has been working on the design and construction of the electronics for the readout of the luminosity monitor (LMSAT) and medium angle calorimeter (MASC). The readout system borrows substantially from that created for the SLD Liquid Argon Calorimeter (LAC). With the help of some of the LAC electronics experts, he produced electrical schematic diagrams and also detailed drawings specifying component placement for the "motherboards" which are at the heart of the readout system. One of the major difficulties associated with this design effort was the need to fit a substantial amount of circuitry and many connectors into a small space. Using the Macintosh-based program VersaCAD enabled him to create the placement drawings referred to above. These drawings were transferred over a computer link to the CAD system used in the SLAC layout shop. Combined with the electrical schematics, it was a straightforward job for the layout designer to produce the film used to fabricate the boards. The first boards were fabricated in April and May, and so far have performed well, with only a few minor flaws which are easily corrected in a single round of revisions.

The main purpose of the motherboards is to provide interconnection between the other circuit boards needed to read out our detector systems. These other boards include the preamp boards which directly receive the signals from the detectors; the controller board; the fiber optic/ECL converter board; the analog to digital converter board; and the instrumentation board. All but the preamp and instrumentation boards are taken directly from the LAC system. The preamp boards are a new design which he is currently testing, using the motherboards described above. The present focus of the preamp board testing is on a circuit designed to measure the leakage current of the detector diodes, which is a source of noise and must therefore be monitored.

The instrumentation board contains circuitry which will be used to monitor temperatures at the detector and on the preamp boards, and also to monitor the voltages being supplied to the electronics. These functions were present in the LAC version of the instrumentation board; to suit our specific needs, we have added circuitry to read out an extra set of detectors which will monitor radiation damage to the main detectors. The pathway for this data is entirely separate from the main SLD data stream, and will require the design of another board to interface with CAMAC. The instrumentation board was designed by Michael Fox, a SLAC engineer, and Cary; boards have been fabricated and are awaiting final loading of components before they can be tested. Michael and Cary will shortly undertake the design of the custom CAMAC interface mentioned above.

Cary has modified LAC software for electronics testing to suit our needs, attended meetings of the online software group to make our needs known to the experts, attended meetings of the commissioning group (which is the main forum for the discussion of schedules), and handled various system integration problems at SLAC such as cables and control lines.

This first luminosity monitor modules have been designed and constructed for the small beam pipe radius (16 millimeters), but the initial operation of the SLD will be with a larger radius beam pipe of 25 millimeters. This larger pipe requires a different calorimeter, as the silicon detectors are designed to fully cover the Bhabha electrons and positrons down to the smallest possible angles. The detectors for this "startup" luminosity monitor have been designed at Oregon and will be received early in 1990. They will be tested and mounted in Oregon.

In addition to the luminosity monitor effort, the Oregon group fabricated in the Oregon machine shop a large number of miscellaneous components for the SLD CRID (Cerenkov Ring Imaging Device). These were machined at Oregon and shipped directly to Tim Montagne of the Leith group at SLAC for mating with the other CRID components.

Also during the past year, several members of group worked with the new heavy leptons working group of SLD. Some of these results, regarding a search for heavy fourth generation down-like quarks, are summarized in Ref. 2.

2. SSC

The group has been active in a number of SSC related activities. One of these is the collaboration with the SICAPO group at CERN, to test silicon detectors in hadron calorimetry. This work is described later in section 3. Besides this, Jim Brau served as co-chairman of the silicon working group at the Tuscaloosa Workshop on Calorimetry at the SSC, and as editor of the subgroup report.[3]

The Oregon group has joined nine other institutions, including the existing high energy physics groups at the Universities of Arizona, Colorado, and Kansas, to propose to the Department of Energy, the Texas SSC Commission and the State of Colorado, the establishment of a laboratory in Boulder, Colorado, to support the construction of detectors for the SSC by this collaboration of institutions. If this laboratory is funded, the proposing universities will create 35 new faculty positions in high energy physics, including the creation of new programs at the six universities that do not presently have experimental high energy physics groups.

While the Oregon group has not yet committed to any of the proposed experiments at the SSC, it has been following closely the proposals and is evaluating how it can best contribute to the SSC physics program. With this goal in mind, the group has helped to prepare a subsystem proposal for an electromagnetic endcap calorimeter for the SSC, where the virtues of silicon calorimetry will be maximized and have a a maximal impact on the SSC experiments. Discussions with detector groups have indicated that there is an interest in this concept, providing the R&D proves successful.

Ray Frey has taken part in several meetings and workshops associated with SSC detector design. He attended the Tuscaloosa workshop on SSC calorimetry issues, where he presented a talk to the trigger and data acquisition group. He attended one other meeting of the trigger group held during the summer at LBL. He has attended a few meetings at LBL related to efforts to form an SSC collaboration around the concept of a large solenoidal detector.

3. SICAPO

The Oregon group has been active in the SICAPO Collaboration at CERN, where tests of the use of silicon detectors in hadron calorimeters are being conducted. The Oregon effort on this project has consisted of simulation studies with the Oak Ridge Monte Carlo CALOR, substantial contribution to the operation of the beam tests at CERN in the summer of 1989, and work with a U.S. company to develop silicon detectors for the SICAPO test calorimeter.

The Monte Carlo simulation work has included studies of compensation, leakage, and radiation damage suppression. Figure 2 shows the result of one such calculation in which the effect of adding layers of polyethylene to a silicon hadron calorimeter is studied. This possibility has been considered and studied by the SICAPO Collaboration. It is found in this study[4] that the neutron fluence in such a calorimeter can be reduced by an order of magnitude with the addition of about a centimeter of polyethylene for every $1/20\ \lambda$ cell of the calorimeter.

Throughout the SICAPO beam test on compensation and radiation damage in May-July, K. Furuno worked at CERN on the data collection and analysis.

As part of a generic SSC R&D project, the Oregon group has enlisted the support of the United Detector Technology (UDT) to develop the processing of high resistivity silicon detectors. Having worked on this project for just over one year, UDT has just delivered the first working detectors of the large area (28 cm^2) design of the SICAPO Collaboration. They have had many technical difficulties in achieving a successful procedure for manufacturing these large area diodes, but now appear to have found the way. However, even these devices do not yet quite meet the leakage current specifications requested for the project, namely 2 microamps per 28 cm^2 device.

4. Tau-charm Factory Proposal

The Oregon group has joined the collaboration which is proposing to build a τ-charm factory at SLAC. The τ-charm factory would explore the second generation quark family and the third generation lepton family with unprecedented sensitivity. The proposal relies on a high luminosity machine with a dedicated injector, and consequently nearly fulltime operation. The detector would be a substantial improvement over previous experiments to fully capitalize on the large data available.

The Oregon group has been working on the preparation of this proposal in three areas. A study of the sensitivity to doubly Cabibbo suppressed decays has been done by first year graduate student Mike Munroe. Ray Frey has studied various design issues for the electromagnetic calorimeter (CsI). Figure 3 is the energy deposited by 50 MeV photons in 12 radiation lengths of CsI according to the EGS monte carlo. The energy resolution is 5% and the efficiency is >99% at this energy. Jim Brau has been studying K_L^0 vetos in the hadron tagging system and $\pi - \mu$ separation in the combined electromagnetic calorimeter and hadron tagger with the Oak Ridge Monte Carlo CALOR. Figure 4 shows π and μ ranges in a stack consisting of alternating layers of iron and gas ionization detectors. One can see good $\pi - \mu$ separation down to low momentum. He has also studied with CALOR the neutron spallation problem for backgrounds to low energy photon detection. These studies are being prepared for the proposal which will be presented at SLAC in November, 1989.

5. Beamstrahlung

To make physics at the SLC a reality, many Mark II physicists have contributed to various aspects of the accelerator, itself. Ray Frey became involved with a group of four individuals building instrumentation to detect so-called "beamstrahlung". Beamstrahlung is hard electromagnetic radiation emitted by the particles of one bunch as they pass through the intense field of the other bunch as they cross at the interaction point (IP). It is the analog of ordinary synchrotron radiation, with the external field in this case created by the extreme charged particle density of an electron or positron bunch at the SLC IP. It was recognized during the early SLC design work that the fields at the IP, with intensities up to a MGauss, would make beamstrahlung observable. And, in fact, it was observed for the first time in late summer 1988.[5] The beamstrahlung detector consists essentially of a converter plate followed by a gas Cerenkov device. The beamstrahlung photons are converted to e^+e^- pairs, and those above threshold (about 20 MeV) are detected by an array of five photomultiplier tubes. The threshold is necessary because of the enormous flux of ordinary synchrotron photons with a critical energy of 2 MeV. The optics is arranged so that the photomultiplier tubes present a magnified image of the converter plate. The detector, its readout, and associated systems are described in detail in Ref. 6.

The beamstrahlung intensity is related to the parameters of the colliding beams in nearly the same way as is the luminosity. Since other physical processes used to measure luminosity, most notably Bhabha scattering in the Mark II detector, have relatively low rates, beamstrahlung was envisioned to be useful as a real-time tuning monitor for the SLC accelerator operators. Indeed, it is used as such. In addition to the beamstrahlung intensity, the aforementioned optics of the detector allow detection of beam angles at the IP. In particular, the slight deflection of one beam by the other at the IP is observable. The present work on beamstrahlung consists largely of a detailed study of the relationship between the measured beamstrahlung and the parameters of the beams at the IP. These parameters include the transverse bunch dimensions, the longitudinal bunch lengths, and the number of particles per bunch. If algorithms can be developed to infer these parameters from the observed signal, then the operators will have a powerful tuning tool. The outlook for this is quite optimistic, and a subset of such algorithms is already very useful.

6. Mark II Small Angle Monitors

It was the responsibility of Ray Frey to ready and commission the Small Angle Monitors (SAMs) while working for Michigan, and he plans to continue working on the SAM effort through the end of the Mark II lifetime at the SLC. The SAM detectors were designed to measure luminosity for Mark II by detecting small angle Bhabha scattering events. Traditionally in e^+e^- annihilation, Bhabha scattering at large angles has been used to measure luminosity, as it often has the smallest systematic error. However, at the SLC the e^+e^- final state derives largely from Z^0 decay, and, hence, cannot be used to determine Z^0-related cross sections. This underscores the importance of the SAMs, which have been used to normalize all Mark II physics results at the SLC, including the measurements of the Z^0 mass, width, and the number of light neutrino species.

Much effort in the past year has been devoted to ensuring that the SAM data and analysis procedures contribute the smallest possible errors for the measurement of the Z^0 resonance parameters. The systematic error for the Bhabha rate has been kept to $\lesssim 2\%$. The error on the measured number of neutrino species is proportional to this error.

7. Mark II Data Analysis

Since he began working with the Mark II collaboration, Ray Frey has been interested in the measurement of the Z^0 resonance parameters, namely the Z^0 mass, width, and cross section. His work on radiative corrections[7] has been directly applicable to these measurements. Likewise, the SAMs, as discussed above, are of primary importance in this effort. Since Mark II began collecting Z^0 data in Spring 1989, there have been two publications on this subject. The first[8] included the first $e^+e^- \rightarrow Z^0$ data, and represented the most accurate direct measurement of the Z^0 resonance parameters. The second[9] was an updated measurement with a larger event sample, and was the first measurement to place a limit on the number of massless neutrino species at less than four. This paper was submitted in near coincidence with similar results from the first LEP data. Ray gave a lecture on the early results at the 1989 TASI summer institute held at Boulder, Colorado.

In addition, Mark II has submitted for publication three other papers[10-12] based on the Z^0 data. There have also been three papers[13-15] from earlier PEP data which have appeared this year.

8. Foreign trips during April 1, 1989 - October 31, 1989

1. J.E. Brau, to CERN for the SICAPO Collaboration meeting, May 3-7, 1989.

2. K.Furuno, to CERN to work on the SICAPO beam test, May 31-July 27, 1989.

3. K.Furuno, to Barcelona to participate in the ECFA Study Week on Instrumentation for High Luminosity Hadron Collisions, September 13-21, 1989.

9. Personnel

The personnel working on this grant during the past year have been:

Jim Brau	Professor
Ray Frey	Assistant Professor
Koichiro Furuno	Podoctoral Research Associate
Cary Zeitlin	Postdoctoral Research Associate (stationed at SLAC)
Hyun Hwang	graduate student
Michael Munroe	graduate student
Hwanbae Park	graduate student
Kevin Pitts	graduate student
Sharon White	graduate student

10. Publications

(see Vitae)

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2. A. Weidemann and C. Zeitlin, "Searching for Fourth Generation Charge $-1/3$ Quarks with SLD", SLD Memo
3. Summary Report of the Silicon Calorimeter Working Group, J.E. Brau (editor), Workshop on Calorimetry for the Superconducting SuperCollider, Tuscaloosa, Alabama, March 1989
4. K.Furuno, J.E. Brau, and H.Hwang, "Neutron Flux Suppression with Polyethylene Moderators in Silicon Hadron Calorimeters", OREXP-89-0901 (1989)
5. G. Bonvicini, *et al.*, "First Observation of Beamstrahlung", Phys. Rev. Lett. **62** (1989) 2381
6. G. Bonvicini, *et al.*, "A Monitor for Gamma Radiation at Zero Degrees from the SLC Collision Point", Nucl. Inst. and Methods **A277** (1989) 297
7. J. Alexander, *et al.*, "Radiative Corrections to the Z^0 Resonance", Phys. Rev. **D37** (1988) 56

8. G. Abrams, *et al.*, "Initial Measurements of Z-Boson Resonance Parameters in e^+e^- Annihilation", Phys. Rev. Lett. **63** (1989) 724
9. G. Abrams, *et al.*, "Measurements of Z-Boson Resonance Parameters in e^+e^- Annihilation", submitted to Phys. Rev. Lett.
10. G. Abrams, *et al.*, "First Measurements Of Hadronic Decays of the Z Boson", submitted to Phys. Rev. Lett.
11. G. Abrams, *et al.*, "Measurement of Z Decays into Lepton Pairs", submitted to Phys. Rev. Lett.
12. G. Abrams, *et al.*, "Searches for New Quarks and Leptons Produced in Z-Boson Decay", submitted to Phys. Rev. Lett.
13. D.R. Wood, A. Petersen, *et al.*, "Determination of α_S from Energy-Energy Correlations in e^+e^- Annihilation at 29 GeV", Phys. Rev. **D37** (1988) 3091
14. S. Komamiya, C. Fordham, *et al.*, "Searches for Non-minimal Higgs Bosons from a Virtual Z Decaying into a Muon Pair at the SLAC Storage Ring PEP", Phys. Rev. **D40** (1989) 721
15. S. Bethke, *et al.*, "Studies of Jet Production Rates in e^+e^- Annihilation at $E_{cm} = 29$ GeV", Z. Phys. **C43** (1989) 325

FIGURE CAPTIONS

1) Energy distribution for electrons in the SLD LMSAT from test beam data.
2) Suppression of neutron radiation damage due to the addition of layers of polyethylene.
3) EGS monte carlo result showing the energy deposited from 50 MeV photons incident on a possible CsI electromagnetic calorimeter of a tau-charm detector.
4) CALOR monte carlo result of $\pi - \mu$ separation for a possible configuration of a tau-charm detector.

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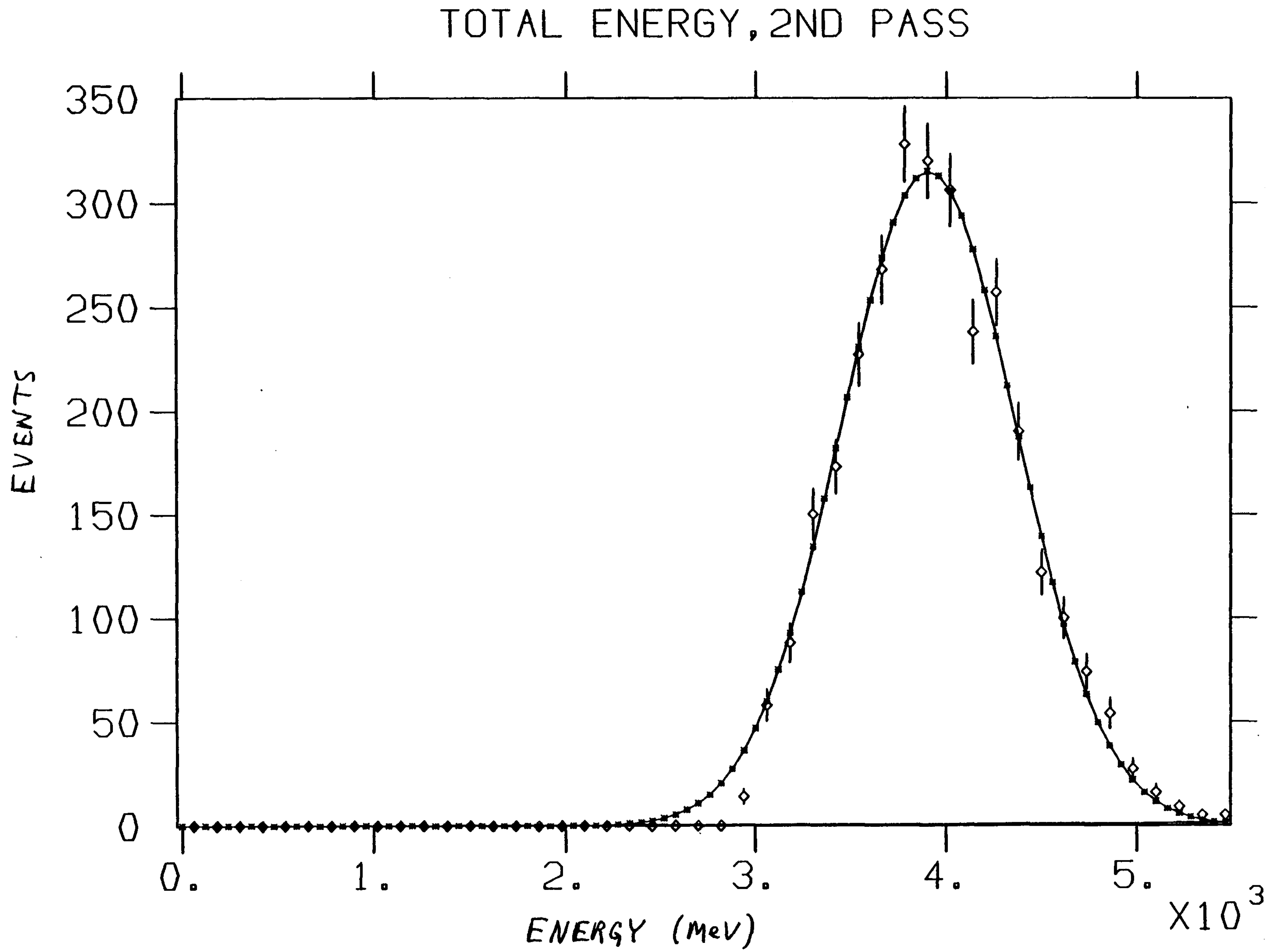

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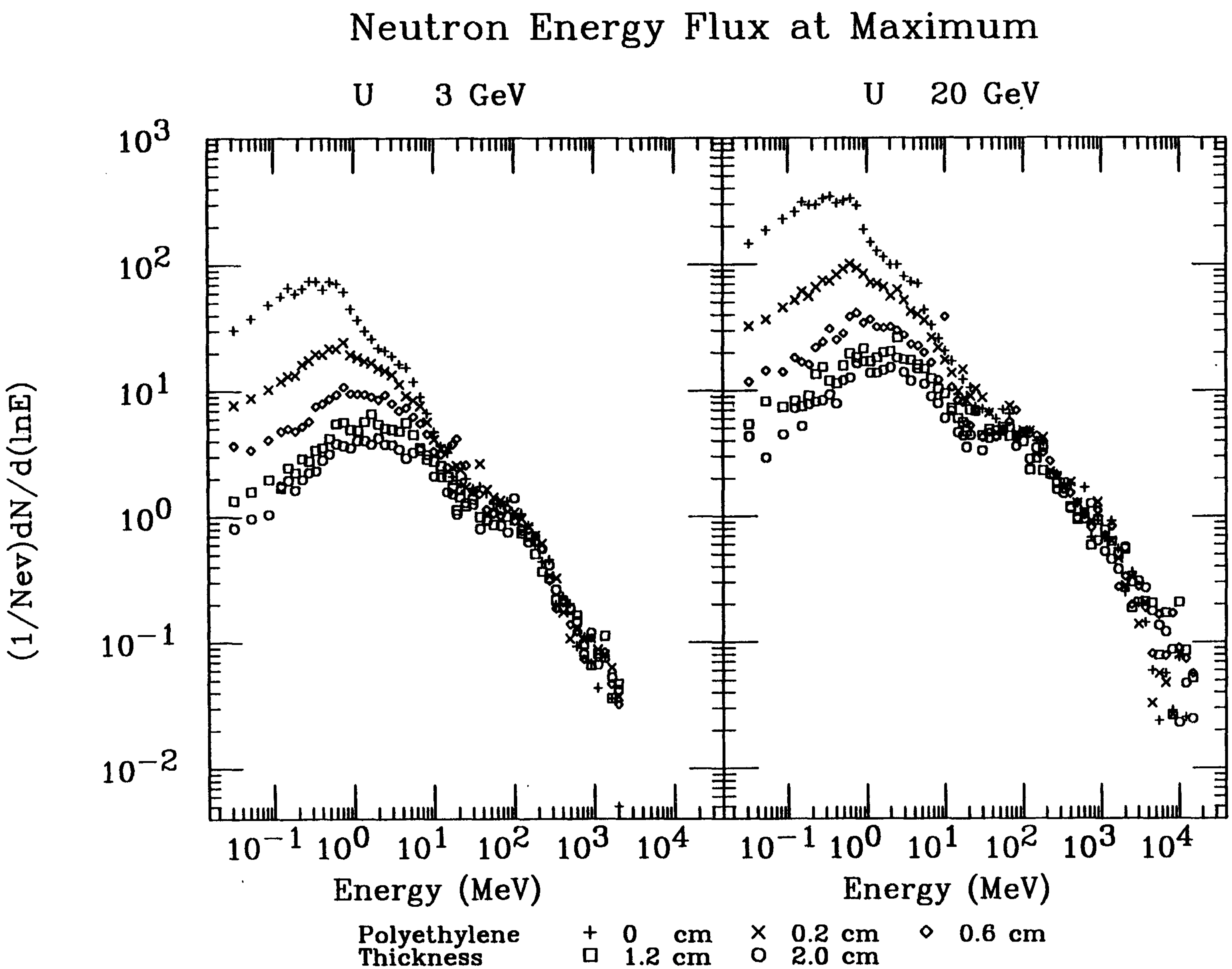
FIGURE 1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U 20 GeV
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10^3
10^2
10^1
10^0
10^{-1}
10^{-2}
10^{-1} 10^0 10^1 10^2 10^3 10^4
Energy (MeV)
Energy (MeV)
Polyethylene Thickness
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× 0.2 cm
◇ 0.6 cm
□ 1.2 cm
○ 2.0 cm

FIGURE 2

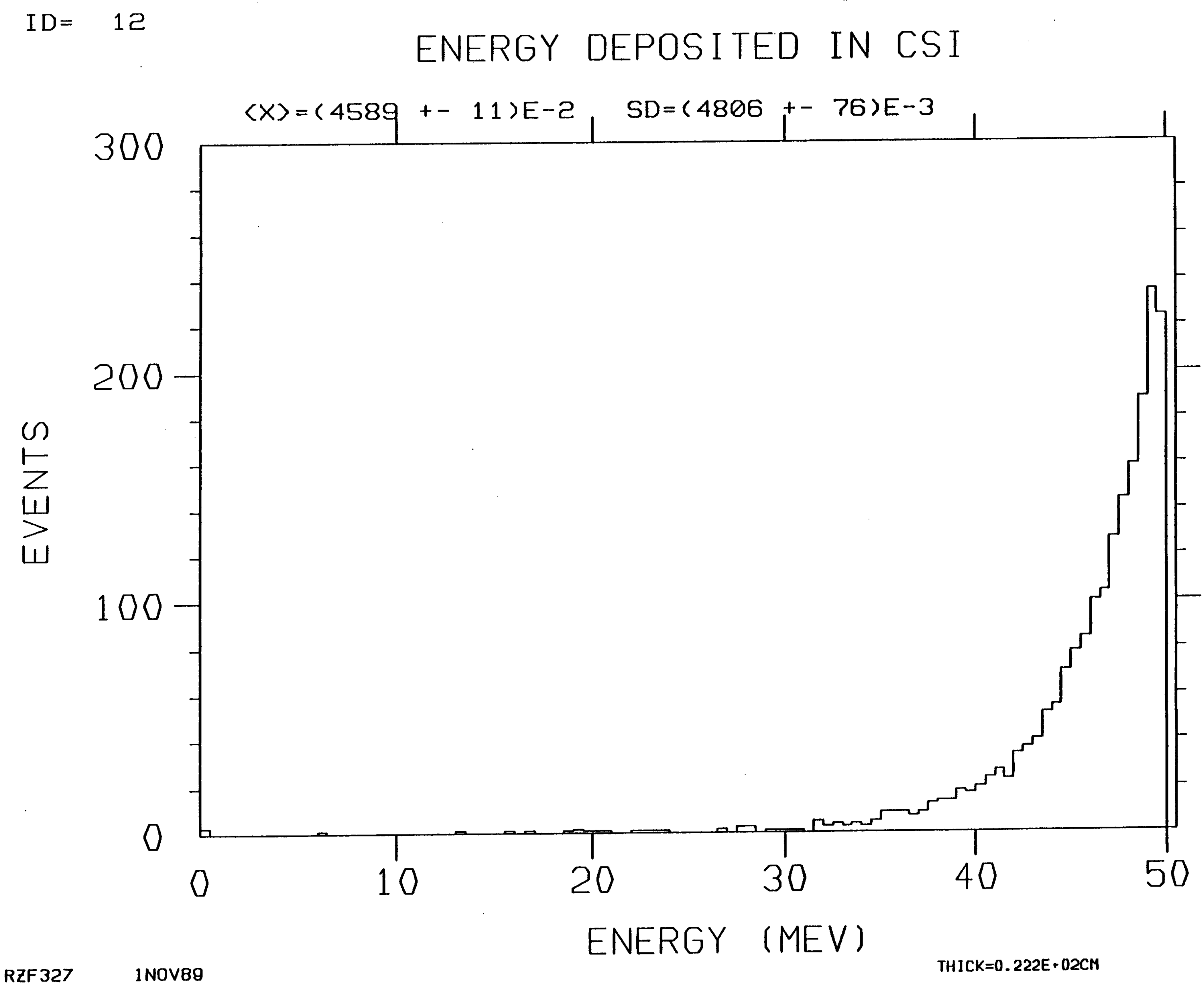

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FIGURE 3

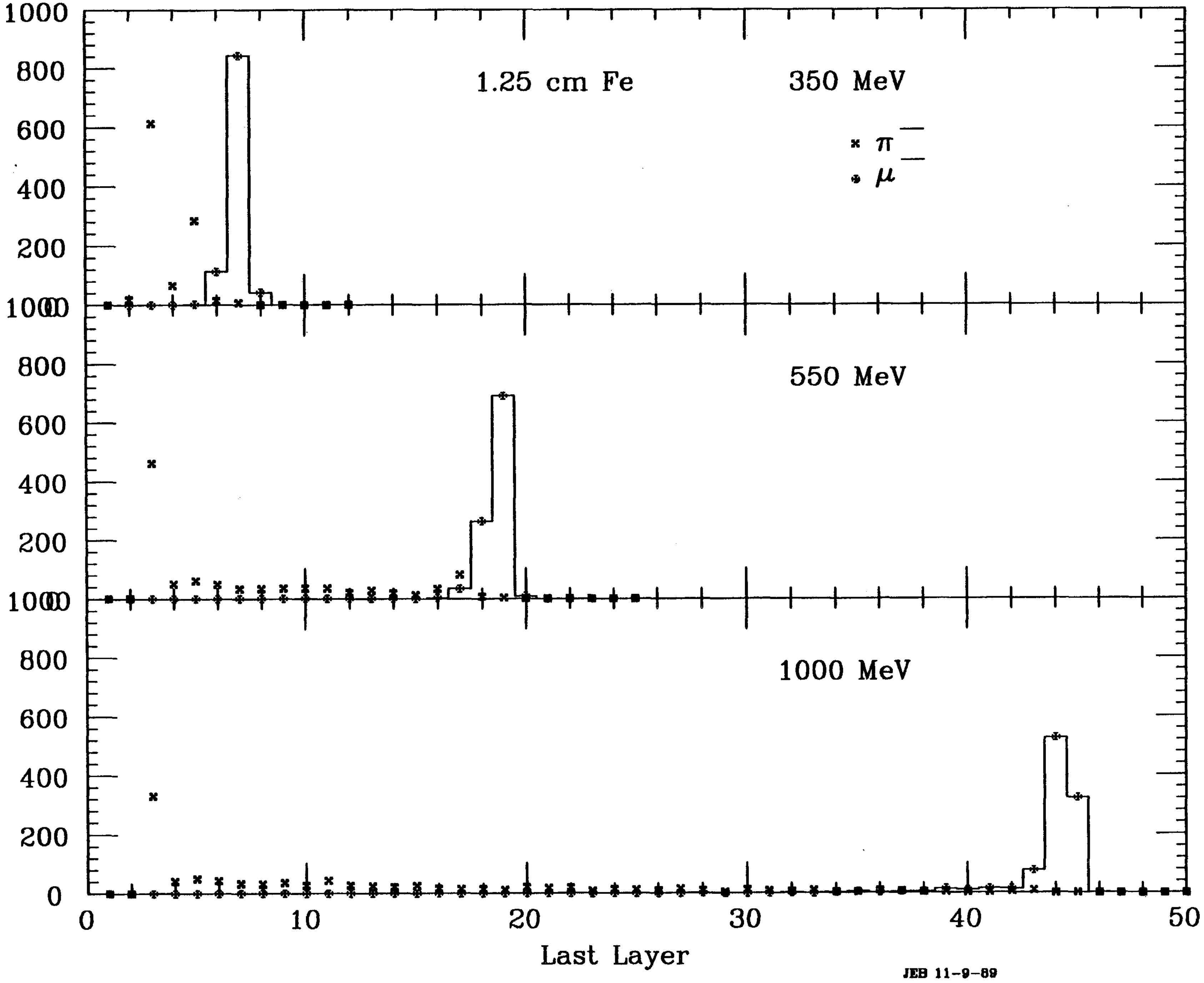

FIGURE 4