PROPOSAL FOR THE RENEWAL OF CONTRACT DE FG05-88ER40437 FOR THE PERIOD FROM APRIL 1, 1995 - MARCH 31, 1998
First year of the three year period, April 1, 1995 - March 31,1996

ABSTRACT DOE/ER/40437--72-Pt.1

Data analysis is in progress for recent experiments performed by the NA44 collaboration with the first running of 160 A GeV ^{208}Pb -induced reactions at the CERN SPS. Identified singles spectra were taken for pions, kaons, protons, deuterons, antiprotons and antideuterons. Two-pion interferometry measurements were made for semi-central-triggered ^{208}Pb + Pb collisions. An upgraded multi-particle spectrometer allows high statistics data sets of identified particles to be collected near mid-rapidity. A second series of experiments will be performed in the fall of 1995 with more emphasis on identical kaon interferometry and on the measurement of rare particle spectra and correlations. Modest instrumentation upgrades by TAMU are designed to increase the trigger function for better impact parameter selection and improved collection efficiency of valid events. An effort to achieve the highest degree of projectile-target stopping is outlined and it is argued that an excitation function on the SPS is needed to better understand reaction mechanisms.

Analysis of experimental results is in the final stages at LBL in the EOS collaboration for two-pion interferometry in the 1.2 A GeV Au+Au reaction, taken with full event characterization.

DISCLAIMER

PROPOSAL FOR THE RENEWAL OF DE-FG05-88ER40437 FOR THE PERIOD OF APRIL 1,1995 - MARCH 31, 1997, THE FIRST YEAR OF THE THREE YEAR CONTRACT APRIL 1, 1995 - MARCH 31,1998

Pion and Kaon Correlations In High Energy Heavy-Ion Collisions

Kevin L. Wolf
Cyclotron Institute
Texas A&M University
College Station, TX 77843

SUMMARY OF PROPOSED TECHNICAL SCOPE

Emphasis is placed on the trigger functions of experiments in the NA44 collaboration in preparation for further running of lead beams at the CERN SPS. A successful upgrade of the time-of-flight trigger electronics has established the feasibility and need for similar upgrades on other hodoscopes. A new impact parameter selection trigger counter has been designed and built and will be installed. Data analysis will continue on single particle spectra collected for 160 A GeV lead and 450 GeV proton collisions. It is planned to expand data analysis efforts into identical kaon interferometry. New experiments at decreased bombarding energies are proposed in the final year of this grant.

Analysis of data from the EOS time projection chamber will be completed with regard to two pion interferometry at Bevalac energies. The interpretation of this work is expected to be completed within the first six months of this grant.

Pion and Kaon Correlations In High Energy Heavy-Ion Collisions

TABLE OF CONTENTS

INTRODUCTION

A broad general goal in the study of relativistic heavy-ion collisions is to determine the properties of hot, dense strongly interacting matter. Working upward in energy from the Bevalac and SIS regime, the ultimate goal as usually stated is the identification of the quark-gluon plasma and the study of its properties. But one must approach the problem of the QGP cautiously, even when RHIC and the LHC are in operation. It is of extreme importance to map out the properties of lower energy interactions and characterize the various stages of heavy-ion reactions from the initial overlap of target and projectile, through interesting high density stages (or phase changes) and hadronization to the final dilute system at freeze-out. Probes and methods for each stage must be developed and modeled, and each increased energy regime should build upon the ones lower.

The long term interests in the present program coincide with the general category of equation of state studies through measurement of thermodynamic variables, in the five or six broad areas as defined by Muller[1] and others. The areas of identical particle interferometry, strange-particle production and antinucleon production must be added, for study of the reaction dynamics and as possible indicators of a QGP.

The NA44 collaboration has built up a second generation experiment at the CERN SPS, based on a focussing spectrometer that allows high quality identified single and multi-particle distributions to be measured around mid-rapidity. The design philosophy follows the idea of focussing on a small solid angle and reasonable momentum range in order to make highly accurate particle identification and momentum measurement with good resolution, instead of attempting to measure global emission of extremely high multiplicity events. The spectrometer features a high rate capability with particle identification available at the trigger level, which allows high statistics data sets to be collected even for rarely produced particles, and for lower probability two-particle correlations. Identical particle interferometry is an area of the highest priority in these experiments, since information can be obtained on the spatial extent of the emitting source along with the promise of measuring more exotic features of the reacting system. A comparision of apparent source sizes for different emitted particles (e.g. pions and kaons) can provide snapshots of the reaction at different freezeout times. Information about possible mechanisms operating in the energy dissipation can be discerned from the correlation of apparent size vs momentum of the pion or kaon pairs used, as outlined by Pratt, et al[2] for hydroflow expansion and by Sorge, et al[3] for string and rope breaking. Information about the lifetime of the emitting system can be determined from a comparision of R_{t-out} to R_{t-side} as outlined by Bertsch[4]. Thus a method of looking for a time delay due to a phase change is available, in principal, as a tool sensitive to a high baryon density quark-gluon plasma formation. Short QGP and hadronization times (1 fm/c) would make the time delay unmeasurable, but if a QGP exists, entropy generation over a short time would most probably result in a large source size. The measurement of strange particle and antibaryon yields provides another promising indicator of QGP formation, and are covered in the NA44 experiment through the singles measurements.

A plan is outlined to focus the TAMU effort on experiments at the CERN SPS and analysis of the data for experiments with ^{208}Pb ions, which were used for a successful first round of experiments at the end of calendar year 1994. A second set of more detailed experiments is scheduled for the end of calendar year 1995. A further upgrade of the trigger counters and electronics for experiment NA44 is planned, as an extension of upgrades already completed in 1994. A plan is developing to seek decreased beam energies to fill in the gap between the SPS and AGS results for running in latter part of this contract period. There is a large amount of uncertainty about SPS operation in 1996 and 1997. While the LHC is approved by the CERN Council, this facility in the far future could act either way for heavy-ion beam time in 1996 and 1997. While it could be argued that a heavy-ion program is necessary for the full LHC future research, money conservation may be emphasized as was the case for the construction of LEP from internal funds.

The analysis effort at LBL is drawing to a close with the two pion correlation analysis being one of the most difficult projects of the EOS TPC collaboration. The primary goal has been and remains the production of interferometry results correlated with the matter flow in the 1.2 A GeV Au+Au reaction. The experiment moves to BNL as E895 with approved running (tentative financially in the DOE budget) in the latter part of 1995. The physics interest of the EOS members of the TAMU group is certainly present since the excitation function experiment was proposed from the very earliest suggestion of heavy-ion running at the CERN PS, with the PI a member of that original group. While the pion analysis work of A.D. Chacon from TAMU will be extremely important for the TPC in the energy regime of the AGS compared to the Be .lac, no future involvem. : is possible unless increased manpower and funding can be identified at TAMU within the time restrictions of the current AGS schedule. Commitments on experiments at CERN were set well before the idea for extension of the EOS collaboration was conceived for BNL.

I.EXPERIMENT NA44 AT THE CERN SPS

A. Instrumentation

The spectrometer shown in Fig.1 was designed for two-particle interferometry measurements and, secondly to provide identified single particle spectra over a momentum range of 1-8 GeV/c around mid - rapidity for SPS beams. Coverage is in the region corresponding to high cross section and not for extreme high energy tails of spectra. The design philosophy emphasized complete identification within a small acceptance instead of attempting to handle the burden of the high multiplicities present for full events in heavy-ion reactions at these energies. Upgrades of the spectrometer have been performed for experiments with lead beams. A set of entrance slits have been installed to reduce the acceptance, if needed; however more efficient multi-particle data collection drives the experiment to larger acceptance. Ultimately the rates are limited by computer deadtime, but improved trigger efficiency will allow lower cross section processes to be studied. The effort at TAMU emphasizes the collection of valid events of the desired type. The trigger efficiency was quite low in S+Pb experiments for rarely produced particles (e.g. antiprotons and antideuterons) and in the important area of K^+K^+ correlations. As a figure of merit, in the previous running of 200 A GeV ^{32}S + Pb cental collsions, only 4% of the kaon-triggered events were used for KK-correlations after final tracking, identification and acceptance cuts. Thus there is a large factor available for improvement at the trigger level, which represents a considerable potential boost in valid event rate.

A fast in-beam Cherenkov counter generates the start signal and arrays of plastic scintillator slats form the stop signals in the high resolution (50-100ps) time of flight mass identification in the spectrometer. These arrays were constructed by the Japan-based groups in the collaboration several years ago and are the basis of this time-of-flight spectrometer. The hodoscopes are expected to be somewhat marginal in slat number for the event multiplicities, and could be upgraded with a scheme developed at TAMU. At the present time it is considered to be too expensive ($200k), but remains an option if needed in the future. Improved wire chambers and improved tracking in the lead-beam experiment has helped the situation somewhat, especially for multiple pion identification. Simulations have been run, but from the experience gained from past experiments, it is apparent that a large fraction of the multi-track events are governed by noise contributions and background interactions.

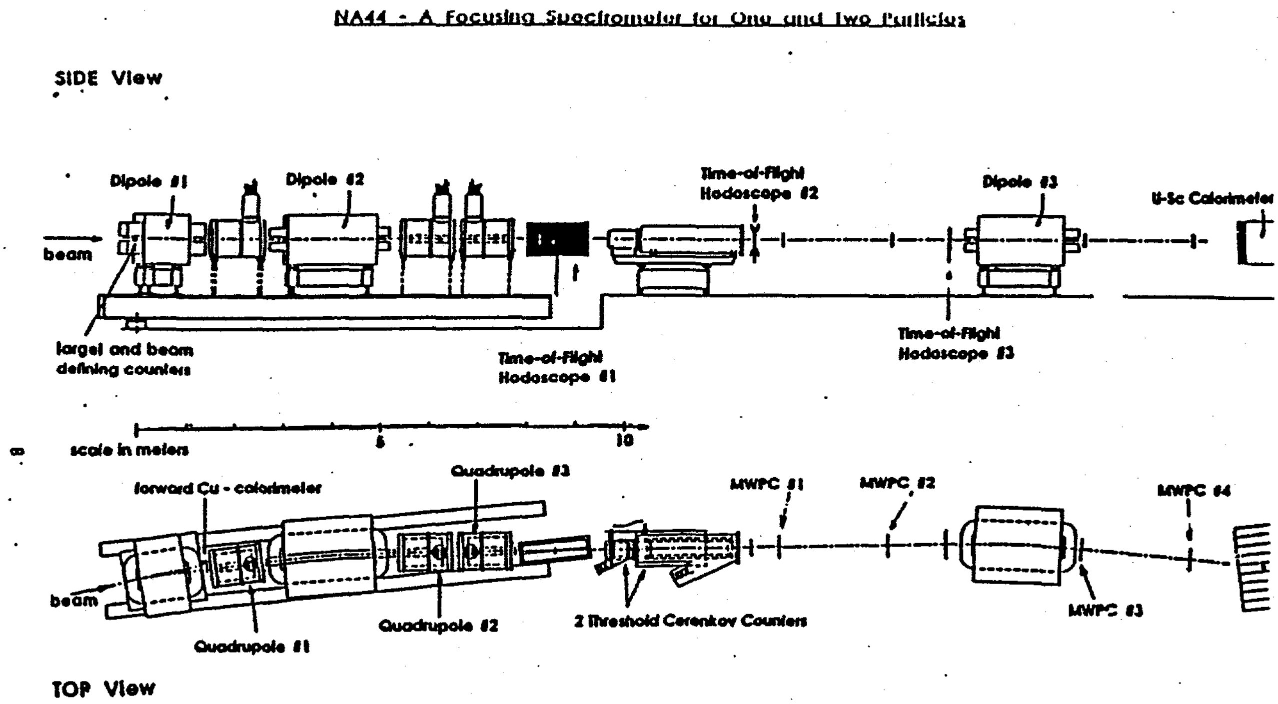

Figure 1 The layout of a focussing spectrometer built by the NA44 collaboration. Three superconducting quadrupoles and three dipoles are used. For lead beam running in 1994, the time-of-flight hodoscope H1 was replaced by a high spatial resolution wire chamber. High resolution wire chambers were completed recently at the H2 and H3 locations. Fast coincidence electronics were developed for the H3 hodoscope (50 plastic scintillator slats) to minimize pmt noise and noise pickup contributions. A threshold ionization Cherenkov counter (TIC) has been built and installed for lead beam experiments after H3. Another hodoscope (H-4) will be installed in front of the uranium calorimeters for the 1995 heavy-ion experiments.

A coincidence among the "ORs" from one end of each of the three sets of slats (H1,H2,H3) has been required in the trigger for sulfur beam experiments in the past. Low thresholds in the leading edge discriminators are necessary for good TOF resolution, along with accompanying noise and pickup which generates false triggers. To solve the significant filling of tapes with false noise events, an end-to-end coincidence for each hodoscope slat can be required with additional electronics. We have added a 50-fold dual coincidence to the final hodoscope in the flight path (H3 in Fig. 1) to reduce the noise contribution.

The coincidence efficiencies for the completed 160 A GeV Pb+Pb experiment were improved to about the 10% level for antiproton collection, and were approximately the same for KK-pair tests compared to previous measurements with the S+Pb reaction. Upgrades in the trigger efficiency were largely offset by increased particle multiplicities (real and neutron background) and the loss of the first TOF hodoscope (H-1) in the spectrometer from the trigger coincidence in favor of a high spatial resolution pad chamber to aid in the off-line tracking. The principal upgrade was in forming end-to-end conicidences in the TOF slats in H3 to eliminate noise firing of single discriminators, as described earlier. The installation of 50 channels of fast cincidences was expected to enhance the fraction of valid two-hit events on tape by a factor of three for the KK trigger and a similar factor for the antiproton trigger. The difficult part of the upgrade involved performing the task fast enough to meet the trigger, which was accomplished with signals arriving 5-10 ns faster than previous singles signals. The coincidence electronics has a short 3 ns throughput time and has ganged linear sums to speed up the signal. This solution used fast linear gates, is considered optimum, and as shown in Table I, the upgrade is needed on the 60 slat hodoscope designated H-2 and is probably needed on a 50 slat hodoscope, H-4, currently being built by Neils Bohr Institute. In addition, better double beam rejection, and a coincidence requirement from the pad chamber (location of H-1) is expected to boost the real rate fraction to the limit needed for full beam intensity running for KK-pairs and antiproton singles. Table II shows the upgrades for the experiment and the institutional responsibility.

TABLE I NA44 TRIGGER EFFICIENCY 160 A GeV Pb+Pb Run 3153

Fraction of events that remain when two hits are required in software

TRIGGER ELEMENT	FRACTION	
H-1 loc. Pad chmbr - two hits	0.27	
H-2 two or more hits	0.41	
H-3 two or more hits	upgrade complete	(0.33 in hardware)
H-4 under construction	????	
longer double beam reject	0.73	
reconstruct two tracks	0.022	(with no pions in trigger)
final two TOF KK tracks	0.015	(at 20% deadtime)

TABLE II UPGRADES OF SPECTROMETER FOR 1994,95 EXPERIMENTS

- improved trigger TOF electronics - TAMU
- T_0 ctr and mounting -TAMU
- two kaon trigger aerogel - LANL (TAMU, Creighton)
- TIC- Bich ctr - CERN (Hiroshima, Nantes)
- wire chambers - OSU, CERN
- tracking software - LANL,Hiroshima (NBI, U. Vienna)
- target region - (TAMU)
- computer upgrade - Creighton, CERN
- slits - LANL (Columbia, OSU, TAMU)
- silicon multiplicity - BNL, LANL
- H-4 Hodoscope - NBI

The only method for making impact parameter selection in the present experiment at the trigger level is, with the exception of self-bias in the spectrometer, through a plastic scintillator that covers 1.5 units of pseudorapidity starting at mid-rapidity. The assumption is that mostly mips will pass through the detector, and thus the pulse height will be proportional to multiplicity. A comparision with the off-line analysis of the silicon multiplicity array shows this assumption to be approximately correct. A new left-right split readout counter has been designed and built at TAMU and is expected to give additional information on beam diagnostics and allow more flexibility in the trigger. Evidence exists from sulfur beam data for additional problems in the design of the target region and the mounting of the T_0 detector that can bias results when the spectrometer angle is changed. Although installation of this new split counter was scheduled for the

1994 running perioa and the counter was compl~~ed, fast 1" diameter phototubes could not be delivered in time for installation. Instead the old counter was refurbished with new phototubes and operated satisfactorily. High loading of the PMTs is a constant problem with large signals in lead-beam experiments and high rates in proton beam running, and requires special tubes and modified bases. The new counter will be installed for proton experiments in May, 1995 and a solution has been devised for dynamic range and delta electron loading for lead beam running. Final multiplicity selection is performed off line with hit and ADC information from a silicon pad array, if enough events were collected at the trigger level.

The highest priority in the experiment in the future is in the collection of high statistics two-kaon data sets (K+K+ and some K-K-) for comparision with pion correlations, and as a cleaner signal that is less prone to resonance decay than pions. The increased kaon multiplicity of Pb+Pb central collisions relative to the S+Pb system can be used for the rapid collection of data sets. The high overall multiplicity can be handled with the upgraded tracking and particle identification, and a two-kaon trigger must be devised, in the presence of associated pions. TAMU has participated with LANL in the testing of an aerogel-based spot focussing counter. The readout function was designed and built by LANL with a Fresnel lens system that projected Cherenkov rings onto a high efficiency PMT supplied by TAMU. Successful tests were conducted on a prototype at the SPS in 1993, and the device was tested at the TAMU beam line at the PS in the summer of 1994. A brief running of the device in 1994 for lead beams proved less efficient for kaon pairs than simulated. If found to be the cause, the lens system will be replaced by an 8" diameter phototube. A second type of kaon-enrichment at the trigger level was developed by M. Murray of TAMU by differencing the pion hits in the TIC counter from the hits seen in the upgraded H-3 hodoscope. This system provided a factor of two enrichment in kaon pairs and with further noise reduction in the hodoscope coincidences, is expected to provide a factor of four enrichment that can be used in series with the two-kaon aerogel counter. The off-line particle identification is currently under development at CERN, based on a gas medium blob imaging threshold Cherenkov (TIC) counter. The TIC counter worked well in lead-beam experiments and the data are currently being checked and analyzed.

B. Physics Interests of the TAMU Group

Two new graduate students from TAMU were involved in experiments at the CERN PS and SPS during the summmer of 1994 and will take part in experiments in the summer and fall of 1995. Two major directions are open in the future, first the single particle inclusive measurements, mainly for rare particles , and secondly the KK correlation analyses. Both areas are understaffed with students, and it is in those two directions, that we are expected to proceed. Installation of an improved impact parameter trigger counter will be completed in May of 1995 and electronics upgrades will be completed as money becomes available for the modules. The full group will participate in the summer's installation and proton running, including a third new graduate student and two postdoctorals.

The specific interests and plans for TAMU are listed:

1) The concentration of our effort in trigger upgrades in NA44 lends directly to the physics interests in KK correlations and in rare particle production. It is argued that it is necessary to collect data with the largest solid angle possible for the spectrometer and at the highest beam rate approved by health-physics. Impact parameter restriction at the trigger level must be made as tightly as possible and still maintain full computer collection rate. The principal reason for the lead beam upgrade at the SPS was to allow much larger reacting systems to be formed compared to that possible with the sulfur beam. The impact parameter must be restricted to central collisions for a signifantly larger system to be formed with Pb + Pb. Secondly, one must restrict the participant nucleon geometry for the HBT work to avoid a wide dispersion in the initial participant source, i.e. to measure the size of a single source instead of an ensemble with widely different sizes. The dispersion in the source size with such a heavy system is much more important than in the S+Pb experiments because of the wide variation of transverse source size possible (1-7 fm), which it is assumed would be reflected in the final source sizes measured at freezeout. Final trimming of the impact parameter can be made offline with the silicon multiplicity counter, but the requirement for statistical accuracy dictates a quite limited amount of offline definition.

2) A "positive" kaon-pair trigger must replace the "negative" type of enrichment used in the past. The lower two lines of Table I shows the effect of a pion anticoincidence Cherenkov counter (done offline as a test) as was used for sulfur beam experiments. In the lead beam

experiments there nearly always is at least one pion in the acceptance, which rejects the event. A further reason for a "positive" two-kaon trigger is in a common class of events where two or more pions are in the event along with two kaons. Thus it is possible to do pi-pi correlations in the same events as KK correlations. This type of experiment should remove any doubt about different particles indicating different time scales and source sizes if the same parameters are determined as in the normal HBT events.

3) The SPS energy regime has been considered one of incomplete stopping of target - projectile participant nucleons, but with quite central collisions of lead ions complete stopping and extremely high baryon density may be possible. Stopping may occur either on average or in a fluctuation of special events. As discussed previously, a restrictive central collision trigger is necessary for practical use of the Pb-Pb system size. If sufficient event rates can be obtained with a highly central trigger, it may be advantageous to use a uranium target to produce increased stopping as demonstrated for S+W and S+U for E_t and multiplicity [5]. For sulfur beams an effective A=400 target was obtained from the prolate deformed uranium nucleus for near head-on collisions along the principal axis. The effect is the same for the saturated density core of a lead nucleus on uranium, and could provide approximately 15% more participant nucleons. The breaking of the target-projectile symmetry is of little consquence in these experiments since we are not attempting to measure dN/dy over a large range of rapidity.

4) A three dimensional HBT determination of a well defined set of central collisions for 160 A GeV Pb-induced reactions on a Pb or U target may represent the best conditions for observation of a time delay or an unusually large source from a high baryon density QGP. The nature of the HBT measurements, in averaging over a large number of events, is itself not sensitive to special types of events, for instance formed more rarely than the average from statistical fluctuations. However, unusual properties of selected events can be determined with the silicon multiplicity array that covers a large rapidity interval near mid-rapidity. Off-line analysis of pi-pi or KK correlations gated by unusually high dN/dY near mid rapidity from the silicon pads may result in a subset of events with an increased lifetime or large source dimensions. Similarly, events with large rapidity fluctuations may signal a phase transition. Detailed Monte Carlo simulations must be run to eliminate trigger bias effects.

5) The area of identified singles spectra will be pursued to higher and lower p_t for all charged particles, with emphasis on antiprotrons

and antideuterons. The variation of pi,p,K (-) spectral shapes with particle type can, in principal, provide information on whether or not hydroflow or other models are relevant at SPS energies. The dN/dY for antiprotons and the ratios of p-bar/p and d-bar/d are of interest in the study of reaction geometry. The singles spectra are important if a high baryon density QGP is formed. The dN/dY values at mid-rapidity and the spectral shapes can show possible strangeness or anti-baryon enhancemeent. The strange-particles and antibaryons may be the primary indicators of the existence of a QGP if the characteristic times are quite short for the QGP and for hadronization.

6) The SPS energy can be reduced to values just above transition, 50-60 A GeV for lead, and a series of beam energies can be used up to 160 A GeV to run an excitation function. Valuable information on reaction mechanisms can be obtained through singles spectra and in the k_t dependence of HBT correlations. A link to the AGS energy range would be a valuable addition for understanding the mechanisms operating. A reduced energy may result in a higher baryon density if there is incomplete stopping for 160 A GeV Pb + Pb.

II. ANALYSIS OF EOS TIME PROJECTION CHAMBER DATA

The main goal of the TAMU group in the EOS collaboration has been to investigate pion emission patterns and pion interferometry relative to the full event structure in very heavy ion reactions. The measurement and the identification of all charged particles in an event as done in the EOS TPC allows a characterization of event class and the determination of the pion pair emission relative to the reaction plane. The ability to determine the space-time extent of the emitting source for pions emitted perpendicular to the reaction plane may provide a more realistic determination of the reaction zone size, shape and time delay, compared to results that have been obtained with pion-pair triggered or central triggered data. Current calculations claim that the pions observed perpendicular to the reaction plane result largely from rescattering from the matter flow instead of pion absorption, which if true, would again result in some reaction zone modification. However these calculations do not predict the measured relatively low absolute yields of pions, which has been attributed to pion absorption in the participant and spectator matter. The comparision of the two-pion correlation along with the pion flow that is anti-correlated with the nucleon flow is expected to provide a challenge to current theoretical calculations based on BUU or RQMD models.

A second goal i. the two-pion interferomet. work is to compare the source sizes and shapes as determined in a large acceptance device such as the TPC, with previous results obtained with a limited solid angle device. Previous results from our collaboration at LBL has shown an apparent oblate source shape relative to the beam axis for a number of systems [6] and it was demonstrated to be a property of central collisions for 1.3 A GeV ^{139}La + ^{139}La, when measured in a limited solid angle spectrometer[7]. The analysis is nearing completion for TPC data taken for the 1.2 A GeV Au+Au reaction for comparision. The analysis project has proven to be more difficult than anticipated due to the tendency of the tracking program, and perhaps the TPC itself, to split tracks and make two (or three) apparent close pions out of a single track. The analysis effort will be completed by May 1, 1995.

III. THE STAR EXPERIMENT AT RHIC

The TAMU group was one of the original members of the STAR collaboration and remains interested in the physics goals and the experiments at RHIC. However the experiment has changed character completely since the inception, mainly due to budget constraints. Originally the experiment was patterned after CDF at Fermi Lab with a fine-grained hadronic calorimeter surrounding a TPC, which would lead to rapid data analysis and a sure efficient way into energy flow determinations. The present experimental setup consists of a TPC and trigger electronics, with second generation upgrades planned, but no effective calorimetry for high multiplicity heavy-ion reactions. A.D. Chacon from TAMU has performed simulations to show that the TPC will be able to make HBT measurements under ideal circumstances for sources up to about 10 fm. But there has not been funding for our small group to devote to other aspects of the STAR experiment. It is hoped that the construction capacity of the Cyclotron Institute at TAMU can be applied to a suitable project for STAR at RHIC or ALICE at the LHC in the future as in-house project construction winds down, and if a project of mutual physics interest can be found.

REFERENCES

1. B. Mueller, Nucl. Phys A544 95c(1992).
2. S. Pratt, et al, Nucl. Phys. A566 103c(1994).
3. H. Sorge, Nucl. Phys.A566 633c(1994).
4. G. Bertsch, Nucl. Phys. A498 173c(1989).
5. J. Schukraft, Nucl. Phys. A498 79c(1989).
6. A.D. Chacon, et al, Phys. Rev. C43 2670(1991).
7. H. Bossey, et al, Phys. Rev. C47 1659(1993).

IV. SUMMARY OF PROPOSED RESEARCH

The study of relativistic heavy-ion reactions is concentrated on data collection and analysis within the NA44 collaboration at the CERN SPS. Pion and kaon interferometry, and the measurement of identified single particle spectra near mid-rapidity are the focus of the proposed research to characterize the space-time geometry of the system for Pb+Pb and Pb + U, and to determine the best mechanistic description of heavy-ion collisions at the SPS. Information will be obtained on several types of probes that are expected to be important at RHIC for observation of effects of the quark-gluon plasma. The HBT studies will pursue time delays and large sources, while identified singles spectra will be used for strangeness production and antibaryon enhancement. Technical developments are concentrated on providing improved trigger function for collection of events of the desired type.

The analysis of Bevalac results for 1.2 A GeV Au + Au will be completed for HBT measurements using pions within the full event structure as measured with the EOS time projection chamber. Interest continues in HBT measurements in the STAR collaboration for experiments at RHIC.

V. STAFF, VITAE, PUBLICATIONS

<u>Research Staff</u>

K.L. Wolf, PI, professor and member of the Cyclotron Institute
A.D. Chacon, Postdoctoral Research Associate
M. Murray, Postdoctoral Research Associate

Graduate Students:
H. Jabs (Physics)
M. Hamelin (Chemistry)
J. Newsome (Physics)

Technical Staff:
B. Sadwhani (Computer Systems Manager)
M. Hodapp (Detector Construction)
W. Smolter (Detector Construction)

V. Recent Publications: 1990 - 94 K.L. Wolf

Midrapidity Pion Ratios in 1.05 GeV/nucleon $^{40}Ca + ^{40}Ca$ Collisions, J.W. Harris, J. Miller, H.G. Pugh, P. Renteln, G. Roche, P.N. Kirk, G. Krebs, R. Brockmann and K.L. Wolf, Phys. Rev. C41 147(1990).

Electromagnetic Dissociation of ^{28}Si at E_{lab}/A= 14.6 GeV/A by Nucleon Emission, J. Barrette, P. Braun-Munzinger, W.E. Cleland, G. David, E. Duek, M. Fatyga, D. Fox, S.V. Green, J.R. Hall, R. Heifetz, T.K. Hemmick, N. Herrmann, R.W. Hogue, G. Ingold, K. Jayanada, D. Kraus, A. Legault, D. Lissauer, W.J. Llope, T. Ludlam, R.D. Majka, D. Mackowiecki, S.K. Mark, J.T. Mitchell, M. Muthuswamy, E. O'Brien, L.H. Olsen, V. Polychronakos, M. Rawool-Sullivan, F.S. Rontondo, J. Sandweiss, B. Shivakumar, J. Simon, U. Sonnarara, J. Stachel, J. Sunier, H. Takai, T.G. Throwe, H. VanHecke, L. Waters, W.J. Willis, K. Wolf, D. Wolfe and C. Woody, Phys. Rev.C41 1512(1990).

Energy Flow and Stopping in Relativistic Heavy-Ion Collisions at E_{lab}/A=14.6 GeV, J. Barrette, R. Bellwied, P. Braun-Munzinger, W.E. Cleland, G. David, E. Duek, M. Fatyga, D. Fox, A. Gavron, S.V. Green, J. Hall, R. Heifetz, T.K. Hemmick, M. Herman, N. Herrmann, R.W. Hogue, G. Ingold, K. Jayanada, D. Kraus, A. Legault, D. Lissauer, W.J. Llope, T. Ludlam, R.D. Majka, D. Mackowiecki, S.K. Mark, J.T. Mitchell, M. Muthuswamy, E. O'Brien, L.H. Olsen, V. Polychronakos, M. Rawool-Sullivan, F.S. Rontondo, J. Sandweiss, B. Shivakumar, J. Simon, U. Sonnarara, J. Stachel, J. Sunier, H. Takai, T.G. Throwe, H. VanHecke, L. Waters, W.J. Willis, K. Wolf, D. Wolfe and C.L. Woody, Phys. Rev.C41 1512(1990).

Energy Flow and Stopping in Relativistic Heavy-Ion Collisions at E_{lab}/A=14.6 GeV, J. Barrette, R. Bellwied, P. Braun-Munzinger, W.E. Cleland, G. David, E. Duek, M. Fatyga, D. Fox, A. Gavron, S.V. Green, J. Hall, R. Heifetz, T.K. Hemmick, M. Herman, N. Herrmann, R.W. Hogue, G. Ingold, K. Jayanada, D. Kraus, A. Legault, D. Lissauer, W.J. Llope, T. Ludlam, R.D. Majka, D. Mackowiecki, S.K. Mark, J.T. Mitchell, M. Muthuswamy, E. O'Brien, L.H. Olsen, V. Polychronakos, M. Rawool-Sullivan, F.S. Rontondo, J. Sandweiss, B. Shivakumar, J. Simon, U. Sonnarara, J.

Stachel, J. Sunie. H. Takai, T.G. Throwe, VanHecke, L. Waters, W.J. Willis, K. Wolf, D. Wolfe and C.L. Woody, Phys. Rev. Lett. 64 1219(1990).

Search for Strange Quark Matter in High-Energy Heavy-Ion Collisions, J. Barrette, R. Bellwied, P. Braun-Munzinger, W.E. Cleland, G. David, E. Duek, M. Fatyga, D. Fox, S.V. Green, J.R. Hall, R. Heifetz, T.K. Hemmick, N. Herrmann, R.W. Hogue, G. Ingold, K. Jayanada, D. Kraus, A. Legault, D. Lissauer, W.J. Llope, T. Ludlam, R.D. Majka, D. Mackowiecki, S.K. Mark, J.T. Mitchell, M. Muthuswamy, E. O'Brien, L. Olsen, V. Polychronakos, M. Rawool-Sullivan, F.S. Rontondo, J. Sandweiss, B. Shivakumar, J. Simon, A.J. Slaughter, U. Sonnarara, J. Stachel, J. Sullivan, J. Sunier, H. Takai, T. Throwe, H. Van Hecke, L. Waters, K.L. Wolf, D. Wolfe, and C. Woody, Phys. Lett. B252 530(1990).

Response of a Sampling Calorimeter to Low Energy Particles, M.W. Rawool-Sullivan, J. Shoemaker, J. Simon, J.P. Sullivan, K.L. Wolf, A. Archuleta, G. Barasch, P. Bennett, D. Bertini, J. Bossevain, K. Holtzscheiter, B. Jacak, W. Sondheim, J. Sunier, H. Van Hecke and B. Wolf, Nucl. Phys. A525 677c(1991).

Pion Correlations in Relativistic Heavy Ion Collisions for Three Symmetric Systems, A.D. Chacon, J.A. Bistirlich, R.R. Bossingham, H. Bossey, H.R. Bowman, C.W. Clawson, K.M. Crowe, T.J. Humanic, M. Justice, P. Kammel, J.M. Kurck, S. Ljungfelt, C.A. Meyer, C. Petijean, J.O. Rasmussen, M.A. Stoyer, O. Hashimoto, Wm. C. McHarris, J.P. Sullivan, K.L. Wolf and W.A. Zjac, Phys. Rev. C43 2670(1991).

Forward Baryon Emission and Charged Multiplicity in Si-N Collisions, J. Barrette, R. Bellwied, P. Braun-Munzinger, W.E. Cleland, G. David, M. Fatyga, D. Fox, S.V. Green, J.R. Hall, R. Heifetz, T. Hemmick, N. Herrmann, R. Hogue, G. Ingold, K. Jayanada, D. Kraus, D. Lissauer, W.J. Llope, T. Ludlam, R.D. Majka, D. Mackowiecki, S.K. Mark, J.T. Mitchell, M. Muthuswamy, E. O'Brien, L. Olsen, V. Polychronakos, C. Pruneau, M. Rawool-Sullivan, F.S. Rontondo, J. Sandweiss, B. Shivakumar, J. Simon, U. Sonnarara, J. Stachel, J. Sullivan, J. Sunier, H. Takai, T. Throwe, H. Van Hecke, L. Waters, K.L. Wolf, D. Wolfe, and C. Woody, Nucl. Phys. A525 91c(1991).

Results on the Production of Exotic Objects in Relativistic Nucleus-Nucleus Collisions, J. Barrette, R. Bellwied, P. Braun-Munzinger, W.E. Cleland, G. David, M. Fatyga, D. Fox, S.V. Green, J.R. Hall, R. Heifetz, T. Hemmick, N. Herrmann, R. Hogue, G. Ingold, K. Jayanada, D. Kraus, D. Lissauer, W.J. Llope, T. Ludlam, R.D. Majka, D. Mackowiecki, S.K. Mark, J.T. Mitchell, M. Muthuswamy, E. O'Brien, L. Olsen, V. Polychronakos, C. Pruneau, M. Rawool-Sullivan, F.S. Rontondo, J. Sandweiss, B. Shivakumar, J. Simon, U. Sonnarara, J. Stachel, J. Sullivan, J. Sunier, H. Takai, T. Throwe, H. Van Hecke, L. Waters, K.L. Wolf, D. Wolfe, and C. Woody, Nucl. Phys. A525 369c(1991).

The Design and Construction of a Lead/Scintillator Sampling Calorimeter with Fiber Optic Readout, J.Simon-Gillo, A. Farooq, M.W. Rawool-Sullivan, A. Ray, J. Shoemaker, J.P. Sullivan, K.L. Wolf, E.F. Barasch, J.G. Bossevain, D. Fox, A. Gavron, K. Holzscheiter, B.V. Jacak, T. Lopez, W. Sondheim, J.W. Sunier, H. Van Hecke and B. Wolf, NIM A525 677(1991).

Forward Baryons in Relativistic Nucleus-Nucleus Collisions, J Barrette, R. Bellwied, P. Braun-Munzinger, W.E. Cleland, G. David, J. Dee, M. Fatyga, D. Fox, S.V. Green, J. Hall, T.K. Hemmick, R. Heifetz, N. Herrmann, R.W. Hogue, G. Ingold, K. Jayanada, D. Kraus, B. Shiva Kumar, M. Lisa, D. Lissauer, W.J. Llope, T. Ludlam, R. Majka, D. Mackowiecki, S.K. Mark, J.T. Mitchell, M. Muthuswamy, E. O'Brien, V. Polychronakos, C. Puruneau, F. Rontondo, J. Sandweiss, J. Simon, U. Sonnarara, J, Stachel, H. Takai, T. Throwe, L. Waters, C. Winter, C. Woody, K. Wolf, D. Wolfe, and Y. Zhang, Phys. Rev. C45 819(1992).

Response of the Participant Calorimeter to 1.5-6.8 GeV/c Electrons and Hadrons, D.Fox, J. Simon-Gillo, M.W. Rawool-Sullivan, J.G. Boissevain, W.E. Cleland, A. Gavron, B.V. Jacak, D. Kraus, W. Sondheim, J.P. Sullivan, H. van Hecke, S. Watson, K.L. Wolf, and Z. Zhang, NIM A317 474(1992).

Electromagnetic Dissociation,of Relativistic ^{28}Si into $p+^{27}Al$, J. Barrette, R. Bellwied, P. Braun-Munzinger, W.E. Cleland, G. David, J. Dee, O. Dietzsch, E. Deuk, M. Fatyga, D. Fox, S.V. Green, J.R. Hall, T.K. Hemmick, N. Herrmann, R.W.

Hogue, B. Hong, K. Jayanada, D. Kraus, B. Shiva Kumar, R. Lacasse, D. Lissauer, W.J. Llope, T. Ludlam, R. Majka, D. Mackowiecki, S.K. Mark, S. McCorkle, J.T. Mitchell, M. Muthuswamy, E. O'Brien, V. Polychronakos, C. Puruneau, F.S. Rontondo, J. Sandweiss, J. Simon-Gillo, U. Sonnarara, J. Stachel, H. Takai, E.M. Takagui, T.G. Throwe, L. Waters, W.J. Willis, C. Winter, K. Wolf, D. Wolfe, C.L. Woody, N. Xu, Y. Zhang, Z. Zhang, and Z. Zou, Phys. Rev. C45 2427(1992).

Charged Particle Multiplicity in ^{28}Si + Al,Cu, and Pb Reactions at E_{lab}=14.6 GeV/nucleon, J. Barrette, R. Bellwied, P. Braun-Munzinger, W.E. Cleland, G. David, O. Dietzsch, E. Deuk, M. Fatyga, D. Fox, S.V. Green, J.R. Hall, R. Heifetz, T.K. Hemmick, M. Herman, N. Herrmann, R.W. Hogue, G. Ingold, K. Jayanada, D. Kraus, B. Shiva Kumar, R. Lacasse, D. Lissauer, W.J. Llope, T. Ludlam, R. Majka, D. Mackowiecki, S.K. Mark, S. McCorkle, J.T. Mitchell, M. Muthuswamy, E. O'Brien, L. Olsen, V. Polychronakos, C. Puruneau, M. Rawool-Sullivan, F.S. Rontondo, J. Sandweiss, J. Simon-Gillo, U. Sonnarara, J. Stachel, J.P. Sullivan, J. Sunier, H. Takai, E.M. Takagui, T. Throwe, H. van Hecke, L. Waters, K. Wolf, D. Wolfe, C.L. Woody, N. Xu, and Z. Zhang, Phys. Rev. C46 312(1992).

Recent Results from Experiment E814 at Brookhaven, J. Barrette, R. Bellwied, P. Braun-Munzinger, W.E. Cleland, T.M. Cromier, G. David, J. Dee, G.E. Diebold, O. Dietzsch, M. Fatyga, D. Fox, J.V. Germani, M. Ghalambor-Dezfuli, S. Gilbert, S.V. Green, J.R. Hall, T.K. Hemmick, N. Herrmann, B. Hong, G. Ingold, K. Jayanada, D. Kraus, B. Shiva Kumar, R. Lacasse, D. Lissauer, W.J. Llope, T. Ludlam, R. Majka, D. Mackowiecki, S.K. Mark, S. McCorkle, J.T. Mitchell, M. Muthuswamy, E. O'Brien, L. Olsen, V. Polychronakos, C. Puruneau, F.S. Rontondo, J. Sandweiss, N.C. deSilva, J. Simon-Gillo, U. Sonnarara, J. Stachel, H. Takai, E.M. Takagui, T. G. Throwe, C. Winter, G. Wang, L. Waters, K. Wolf, D. Wolfe, C.L. Woody, N. Xu, Y. Zhang, Z. Zhang, and C. Zou, Nucl. Phys. A544 137(1992).

Momentum Distributions of Light Mass Fragments in Si-Nucleus Collisions at 14.6GeV/Nucleon, J. Barrette, R. Bellwied, P. Braun-Munzinger, W.E. Cleland, T. Cromier, G. David, J. Dee, G.E. Diebold, O. Dietzsch, E. Duek, M. Fatyga, D. Fox, S.V. Green, J.R. Hall, T.K. Hemmick, N. Herrmann, B. Hong, G. Ingold, K. Jayanada, D. Kraus, B. Shiva Kumar, R.

Lacasse, D. Lissa .r, W.J. Llope, T. Ludla. R. Majka, D. Mackowiecki, S.K. Mark, S. McCorkle, J.T. Mitchell, M. Muthuswamy, E. O'Brien, V. Polychronakos, C. Puruneau, F.S. Rontondo, J. Sandweiss, N.C. da Silva, J. Simon-Gillo, J. Slaughter, U. Sonnarara, J. Stachel, H. Takai, E.M. Takagui, T. G. Throwe, C. Winter, L. Waters, K. Wolf, D. Wolfe, C.L. Woody, N. Xu, Y. Zhang, Z. Zhang, and C. Zou, Nucl. Phys. A544 423(1992).

Antiproton Production in ^{28}Si-Nucleus Interactions, J. Barrette, R. Bellwied, P. Braun-Munzinger, W.E. Cleland, T. Cromier, G. David, J. Dee, G.E. Diebold, O. Dietzsch, E. Duek, M. Fatyga, D. Fox, S.V. Green, J.R. Hall, T.K. Hemmick, N. Herrmann, B. Hong, G. Ingold, K. Jayanada, D. Kraus, B. Shiva Kumar, R. Lacasse, D. Lissauer, W.J. Llope, T. Ludlam, R. Majka, D. Mackowiecki, S.K. Mark, S. McCorkle, J.T. Mitchell, M. Muthuswamy, E. O'Brien, V. Polychronakos, C. Puruneau, F.S. Rontondo, J. Sandweiss, N.C. da Silva, J. Simon-Gillo, J. Slaughter, U. Sonnarara, J. Stachel, H. Takai, E.M. Takagui, T. G. Throwe, C. Winter, L. Waters, K. Wolf, D. Wolfe, C.L. Woody, N. Xu, Y. Zhang, Z. Zhang, and C. Zou, Nucl. Phys. A544 599(1992).

Response of the Participant Calorimeter to Low Energy Pions,Muons, and Positrons, J.P. Sullivan, M.W. Rawool-Sullivan, J.G. Boissevain, D. Fox, A. Gavron, K. Holzscheiter, B.V. Jacak, J. Simon-Gillo, W.E. Sondheim, H. van Hecke, B. Wolf and K. Wolf, NIM A324 441(1993).

Two-Pion Correlations and Multiplicity Effects in La on La Collisions, H. Bossy, J.A. Bistirlich, R.R. Bossingham, A.D. Chacon, K.M. Crowe, Y. Dardenne, M. Justice, J.O. Rasmussen, A.A. Shihab-Eldin, M.A. Stoyer, K.D. Wyatt, J.P. Sullivan, K.L. Wolf, Phys. Rev. C 47 1659(1993).

Antiproton Production in Relativistic Si-Nucleus Collisions, J. Barrette, R. Bellwied, P. Braun-Munzinger, W.E. Cleland, T. Cromier, G. Dadusc, G. David, J. Dee, G.E. Diebold, O. Dietzsch, E. Duek, M. Fatyga, D. Fox, S.V. Greene, J.V. Germani, J.R. Hall, T.K. Hemmick, N. Herrman, R.W. Hogue, B. Hong, K. Jayananda, D. Kraus, B.S. Kumar, R. Lacasse, D. Lissauer, W.J. Llope, T.W. Ludlam, R. Majka, D. Makowieki, S.K. Mark, J. T. Mitchell, M. Muthuswamy, E. O'Brien, C. Purneau, F.S. Rotondo, J. Sandweiss, N.C. da Silva, J. Simon-Gillo, J. Slaughter, U. Sonnadara, J. Stachel, H. Takai, E.M.

Takagui, T.G. Throwe, L. Waters, Ch. Winter, K. Wolf, D. Wolfe, C.L. Woody, N. Xu, Y. Zhang, and C. Zou, Phys. Rev. Lett. 70 1763 (1993).

Measurement of Transverse Energy Production with Si and Au Beams at Relativistic Energy: Towards Hot and Dense Hadronic Matter, J. Barrette, R. Bellwied, S. Bennett, P. Braun-Munzinger, W.E. Cleland, T. M. Cromier, G. David, J. Dee, G.E. Diebold, O. Dietzsch, J.E. Diebold, O. Dietzsch, D. Fox, S.V. Greene, J.V. Germani, S. Gilbert, J.R. Hall, T.K. Hemmick, N. Herrman, B. Hong, K. Jayananda, D. Kraus, B. Shiva Kumar, R. Lacasse, Q. Li, D. Lissauer, W.J. Llope, T.W. Ludlam, S. McCorkle, R. Majka, D. Makowieki, S.K. Mark, R. Matheus, J.T. Mitchell, M. Muthuswamy, E. O'Brien, S. Panitkin, C. Purneau, M.N. Rao, M. Rosati, F. Rotondo, N.C. daSilva, J. Simon-Gillo, U. Sonnadara, J. Stachel, J. Sullivan, H. Takai, E.M. Takagui, T.G. Throwe, C. Winter, G. Wang, K.L. Wolf, D. Wolfe, C.L. Woody, N. Xu, Y. Zhang, Z. Zhang, and C. Zou, Phys. Rev. 70 2996(1993).

Mass and Charge Distributions of Cl-Induced Heavy-Ion Reactions, A.A. Marchetti, A.C. Mignerey, H. Madani, A. Gokmen, W.L. Kehoe, B. Libby, K. Morley, H. Breuer, K. Wolf, F. Obenshain, Phys. Rev. C 48 266(1993).

Identified Particle Interferometry in Heavy-Ion Collisions:Results From the CERN NA44 Experiment, H. Beker, H. Boggild, J. Boissevain, M. Cherney, J. Dodd, S. Esumi, C.W. Fabjan, D.E. Fields, A. Franz, K.H. Hansen, B. Holzer, T. Humanic, B. Jacak, R. Jayanti, H. Kalechofsky, T. Kobayashi, R. Kvatadze, Y.Y. Lee, M. Leltchouk, B. Lorstad, N. Maeda, A. Medvedev, Y. Miake, A. Miyabayashi, M. Murray, S. Nagamiya, S. Nishimura, E. Noteboom, S.U. Pandey, F. Piuz, V. Polychronakos, M. Potekhin, G. Poulard, A. Sakaguchi, M. Sarabura, K. Shigaki, J. Simon-Gillo, H. Sletten, W. Sondheim, T. Sugitate, J.P. Sullivan, Y. Sumi, H. van Hecke, W.J. Willis, K. Wolf, Nucl. Phys. A 566 115c(1994).

Single Particle Spectra From NA44 H. Boggild, J. Boissevain, M. Cherney, J. Dodd, S. Esumi, C.W. Fabjan, D.E. Fields, A. Franz, K.H. Hansen, B. Holzer, T. Humanic, B. Jacak, R. Jayanti, H. Kalechofsky, T. Kobayashi, R. Kvatadze, Y.Y. Lee, M. Leltchouk, B. Lorstad, N. Maeda, A. Medvedev, Y. Miake, A. Miyabayashi, M. Murray, S. Nagamiya, S. Nishimura, E. Noteboom, S.U. Pandey, F. Piuz, V. Polychronakos, M.

Potekhin, G. Po..ard, A. Sakaguchi, M. Sarabura, K. Shigaki, J. Simon-Gillo, H. Sletten, W. Sondheim, T. Sugitate, J.P. Sullivan, Y. Sumi, H. van Hecke, W.J. Willis, K. Wolf, Nucl. Phys. A 566 515c(1994).

The STAR Experiment at the Relativistic heavy Ion Collider, the STAR Collaboration, Nucl. Phys. A 566 277(1994).

Kaon Interferometry in Heavy-Ion Collisions at the CERN SPS, H. Beker, H. Boggild, J. Boissevain, M. Cherney, J. Dodd, S. Esumi, C.W. Fabjan, D.E. Fields, A. Franz, K.H. Hansen, B. Holzer, T. Humanic, B. Jacak, R. Jayanti, H. Kalechofsky, T. Kobayashi, R. Kvatadze, Y.Y. Lee, M. Leltchouk, B. Lorstad, N. Maeda, A. Medvedev, Y. Miake, A. Miyabayashi, M. Murray, S. Nagamiya, S. Nishimura, E. Noteboom, S.U. Pandey, F. Piuz, V. Polychronakos, M. Potekhin, G. Poulard, A. Sakaguchi, M. Sarabura, K. Shigaki, J. Simon-Gillo, H. Sletten, W. Sondheim, T. Sugitate, J.P. Sullivan, Y. Sumi, H. van Hecke, W.J. Willis, K. Wolf, Z. Phys. C 64 209(1994).

Determination of Critical Exponents from the Multifragmentation of Gold Nuclei, M.L. Gilkes, S. Albergo, F. Bieser, F.P. Brady, Z. Caccia, D.A. Cebra, A.D. Chacon, J.L. Chance, Y. Choi, S. Costa, J.B. Elliot, J.A. Hauger, A.S. Hirsch, E.L. Hjort, A. Insolia, M. Justice, D. Keane, J.C. Kintner, V. Lindenstruth, M.A. Lisa, U. Lynen, H.S. Mathis, M. McMahan, C. McParland, W.F. Muller, D.L. Olson, M.D. Partlan, N.T. Porile, R. Potenza, G. Rai, J. Rasmussen, H.G. Ritter, J. Romanski, J.L. Romero, G.V. Russo, H. Sann, R. Scharenberg, A. Scott, Y. Shao, B.K. Srivastava, T.J.M. Symons, M. Tincknell, C. Tuve, S. Wang, P. Warren, H.H. Wiemanand K. Wolf Phys. Rev. Lett. 73 1590(1994).

Use of Aerogel for Imaging Cherenkov Counters, D.E. Fields, H. van Hecke, J. Boissevain,B.V. Jacak, W.E. Sondheim, J.P. Sullivan, W.J. Willis, K. Wolf, E. Noteboom, P.M. Peters and R, Burke , NIM A 349 431(1994).

BIOGRAPHICAL SKETCH - Kevin L. Wolf

Education

PhD (Chemistry)	University of Washington, Seattle	1969
B.S.(Science)	Purdue University	1964

Experience

Professor of Chemistry	Texas A&M University	1982-present
Staff Scientist	Argonne National Laboratory	1973-82
Postdoctoral Fellow	Argonne National Laboratory	1970-72

Visiting Scientist

Lawrence Berkeley Laboratory	1979-80
GSI, Darmstadt, W.Germany	1982
Lawrence Berkeley Laboratory	1985,86

Organizations

American Chemical Society
American Physical Society
Society of Sigma Xi

Invited Lectures(1969-present)

17 international conferences
37 national society meetings

Total Publications(1968-present): 75

PUBLICATIONS

Kevin L. Wolf

1. "Proton-Fission Fragment Angular Distributions in the $^{235}U(d,pf)$ and $^{239}Pu(d,pf)$ Reactions," K. L. Wolf, R. Vandenbosch, and W. D. Loveland, Bull. Amer. Phys. Soc., 12, 1124 (1967).

2. "Dependence of Fission-Fragment Angular Distributions on Target Deformation and Spin," R. Vandenbosch, K. L. Wolf, J. P. Unik, C. Stephen, and J. R. Huizenga, Phys. Rev. Lett., 19, 1138 (1967).

3. "Angular Correlations in the (d,pf) Reaction," K. L. Wolf, R. Vandenbosch, and W. D. Loveland, Phys. Rev., 170, 1059 (1968)

4. "Short-Lived Spontaneous Fission Isomers," K. L. Wolf, and R. Vandenbosch, Bull. Amer. Phys. Soc., 13 1407 (1968).

5. "Spontaneous Fission Isomers with Short Half-Lives," R. Vandenbosch and K. L. Wolf, Proceedings, Second Symposium on Physics and Chemistry of Fission, Vienna, Austria, 1969, p. 439.

6. "Spontaneous Fission Isomerism in Uranium Isotopes," K. L. Wolf, R. Vandenbosch, P. A. Russo, M. K. Mehta, and C. R. Rudy, Phys. Rev., C1, 2096 (1970).

7. "A Study of Fission Isomerism in Curium and Berkelium Isotopes," K. L. Wolf, and J. P. Unik, Bull. Amer. Phys. Soc., 16, 55 (1971).

8. "Spin Isomers of the Shape Isomer ^{237m}Pu," P. A. Russo, R. Vandenbosch, M. Mehta, J. R. Tesmer, and K. L. Wolf, Bull. Amer. Phys. Soc., 16, 55 (1971).

9. "Properties of Fissioning Isomers," K. L. Wolf, and J. P. Unik, Abstracts of Papers, 162nd Amer. Chem. Soc. National Meeting, Wash. D.C., 1971, NUCL-2.

10. "Spin Isomers of the Shape Isomer ^{237m}Pu," P. A. Russo, R. Vandenbosch, M. Mehta, J. R. Tesmer, and K. L. Wolf, Phys. Rev., C3, 1595 (1971).

11. "Fissioning Isomers of Americium, Curium and Berkelium Isotopes," K. L. Wolf, and J. P. Unik, Phys. Lett., 38B (6), 405-407 (1972).

12. "Production of Actinides and the Search for Super-Heavy Elements Using Secondary Reactions Induced by GeV Protons," J. P. Unik, E. P. Horwitz, K. L. Wolf, I. Ahmad, S. Fried, D. Cohen, P. R. Fields, C. A. A. Bloomquist, and D. J. Henderson Nucl. Phys., A191 (2), 233-244 (1972).

13. "The Fissioning Isomer ^{237m}Np," K. L. Wolf, and J. P. Unik, Bull. Amer. Phys. Soc., 18, 97 (1973).

14. "The Fissioning Isomer $^{237}Np^{m}$," K. L. Wolf, and J. P. Unik, Phys. Lett., 43B 25-26 (2973).

15. "Mechanisms of Reactions Between ^{84}Kr Ions and Heavy Nuclei," V. E. Viola, Jr., J. R. Huizenga, J. Birkelund, K. L. Wolf, and J. P. Unik, Nucl. Chem. Technol, 9, (1974).

16. "Study of Strongly Damped Collisions in the Reaction of 600-MeV ^{84}Kr on a ^{209}Bi Target," K. L. Wolf, J. P. Unik, J. R. Huizenga, J. Birkelund, H. Freiesleben, and V. E. Viola, Jr. Phys. Rev. Lett., 33 (18), 1105-1108 (1974).

17. "Strongly Damped Collisions in the ^{209} Bi + ^{84}Kr Reaction," J. R. Huizenga, J. Birkelund, H. Freiesleben, K. L. Wolf, J. P. Unik, and V. E. Viola, Jr. Bull. Amer. Phys. Soc. II, 19 (9), 1025-1026 (1974).

18. "Mass Transfer and Kinetic Energy Release for Strongly Damped Collisions in the ^{209} Bi + ^{84}Kr Reaction," K. L. Wolf, J. P. Unik, V. E. Viola, Jr., J. R. Huizenga, J. Birkelund, H. Freiesleben, and Bull. Amer. Phys. Soc. II, 19 (9), 1026 (1974).

19. "Production of Actinide Elements Using Secondary Reactions Induced by 19 GeV Electrons," K. L. Wolf, J. P. Unik, E. P. Horwitz, C. A. A. Bloomquist, J. Inorg. Nucl. Chem., 37, 21-24 (1975).

20. "Elastic Scattering of ^{40}Ar and ^{84}Kr on ^{209}Bi and ^{238}U at 7.2 and 8.5 MeV," J. R. Birkelund, J. R. Huizenga, H. Freiesleben, K. L. Wolf, Phys. Rev., C13 (1), 133-146 (1976).

21. "Study of the Reaction ^{209}Bi + ^{136} Xe," W. U. Schroder, J. R. Birkelund, J. R. Huizenga, K. L. Wolf, J. P. Unik, and V. E. Viola, Jr.,Phys. Rev. Lett., 36 (10), 514-517 (1976).

22. "Streuung und Reaktionen von Ar und Kr on Ho, Bi, und U," H. Freiesleben, J. R. Huizenga, J. R. Birkelund, K. L. Wolf, J. P. Unik, V. E. Viola, Jr., Abstract, Deutsche Physikalische Gesellschaft, Baden Bei Wien, (1976).

23. "The Interaction of Very Heavy Ions with Heavy Targets," K. L. Wolf, and C. T. Roche, Proceedings, Symposium on Macroscopic Features of Heavy-Ion Collisions, Argonne National Laboratory, Argonne National Laboratory Report, ANL/PHY-76-2, 295-340 (1976).

24. "Fragment Charge Distributions from the Reaction ^{209}Bi + ^{136}Xe at 1130 MeV," J. R. Birkelund, W. U. Schroder, J. R. Huizenga, K. L. Wolf, J. P. Unik, and V. E. Viola, Jr., Argonne National Laboratory Report, ANL/PHY-76-2, 451-455, (1976).

25. "Nuclear Orbiting and Charge Diffusion in ^{84}Kr- and ^{136}Xe-Induced Reactions," K. L. Wolf, C. T. Roche, R. L. Boudrie, J. R. Huizenga, J. R. Birkelund, W. U. Schroder, and V. E. Viola, Jr., Abstracts, European Conference on Nuclear Physics with Heavy Ions, Caen, France, (1976).

26. "Study of Charge and Angular Distributions of Fragments from the ^{209}Bi + ^{84}Kr and ^{209}Bi + ^{136}Xe Reactions," W. U. Schroder, J. R. Birkelund, J. R. Huizenga, K. L. Wolf, J. P. Unik, and V. E. Viola, Jr., Abstracts, European Conference on Nuclear Physics with Heavy Ions, Caen, France, (1976).

27. "Energy Dissipation and Nucleon Transfer in Heavy-Ion Reactions," J. R. Huizenga, J. R. Birkelund, W. U. Schroder, K. L. Wolf, and V. E. Viola, Jr., Abstracts, European Conference on Nuclear Physics with Heavy Ions, Caen, France, (1976).

28. "Energy Dissipation and Nucleon Transfer in Heavy-Ion Reactions," J. R. Huizenga, J. R. Birkelund, W. U. Schroder, K. L. Wolf, and V. E. Viola, Jr., Phys. Rev. Lett., 37 (14), 885-888 (1976).

29. "Upper Limits on Complete Fusion Cross Sections for ^{84}Kr and ^{136}Xe Interactions," K. L. Wolf, J. P. Unik, J. R. Huizenga, H. Freiesleben, Bull. Amer. Phys. Soc., 21, 606 (1976).

30. "Charge Distributions of Reaction Products from Xe and Kr Induced Reactions on ^{209}Bi," W. U. Schroder, J. R. Birkelund, H. Freiesleben, J. R. Huizenga, K. L. Wolf, J. P. Unik, and V. E. Viola, Jr., Bull. Amer. Phys. Soc., 21, 606 (1976).

31. "Interaction Times for Damped Heavy-Ion Collisions," W. U. Schroder, J. R. Birkelund, J. R. Huizenga, K. L. Wolf, and V. E. Viola, Jr., Phys, Rev., C16 (2), 623-628 (1977).

32. "Dissipation, Mass Exchange and the Microscopic Time Scale of Heavy-Ion Collisions," W. U. Schroder, J. R. Huizenga, J. R. Birkelund, K. L. Wolf, and V. E. Viola, Jr., Phys. Lett., 71B (2), 283-286 (1977).

33. "The Production of Trans-Plutonium Nuclides by Bombardment of ^{238}U with ^{40}Ar, ^{84}Kr and ^{136}Xe Ions," K. L. Wolf, J. P. Unik, E. P. Horwitz, C. A. A. Bloomquist, and W. Delphin, Bull. Amer. Phys. Soc., 22 (1), 67 (1977).

34. "The Dependence of Nuclear Orbiting and Charge Distributions on Bombarding Energy in the ^{144}Sm + ^{84}Kr Reaction," A. Mignerey, D. Raich, K. L. Wolf, R. Boudrie, C. Roche, J. Birkelund, W. U. Schroder, J. R. Huizenga, and V. E. Viola, Jr., Abstract, 174th American Chemical Society National Meeting, Chicago, Illinois, NUCL-80 (1977).

35. "Mechanisms of Very Heavy-Ion Collisions: The ^{209}Bi + ^{136}Xe Reaction at E_{LAB} = 1130 MeV," W. U. Schroder, J. R. Birkelund, J. R. Huizenga, K. L. Wolf, and V. E. Viola, Jr., Physics Reports, 5, 45 (1978).

36. "The Reaction ^{56}Fe + ^{56}Fe at 9.0 MeV/Nucleon," K. L. Wolf, D. G. Raich, A. C. Mignerey, D. Hilscher, J. R. Birkelund, W. Wilke, J. R. Huizenga, W. U. Schroder, V. E. Viola, Jr., H. Breuer, and B. Glagola, Bull. Am. Phys. Soc. , 23, 46 (1978).

37. "Pion Production in High Energy Heavy Ion Collisions," K. L. Wolf, A. Sandoval, N. Van Sen, J. Gosset, H. H. Gutbrod, J. C. Jourdain, C. H. King, G. King, Ch. Lukner, W. G. Meyer, A. M. Poskanzer, R. Stock, and G. D. Westfall, Bull. Am. Phys. Soc., 23, 739 (1978).

38. "Incomplete momentum Transfer in Peripheral Heavy-Ion Collisions at 20 MeV/Nucleon," P. Dyer, T. C. Awes, C. K. Gelbke, B. B. Back A. Mignerey, K. L. Wolf, H. Breuer, V. E. Viola, Jr., and W. G. Meyer, Phys. Rev. Lett., 42 (9), 560-563 (1979).

39. "Pion Production in the $^{40}Ar + ^{40}Ca$ Reaction at 1.05 GeV/Nucleon," K. L. Wolf, H. H. Gutbrod, W. G. Meyer, A. M. Poskanzer, A. Sandoval, R. Stock, J. Gosset, C. H. King, G. King, N. Van Sen, and G. D. Westfall, Phys. Rev. Lett., 42, (22), 1448-1451 (1979).

40. "Nucleon Exchange and A/Z Equilibration in Interactions of 8.3-MeV/amu ^{56}Fe Ions with ^{56}Fe, ^{165}Ho, and ^{209}Bi," H. Breuer, B. G. Glagola, V. E. Viola, Jr., K. L. Wolf, A. C. Mignerey, J. R. Birkelund, D. Hilscher, A. D. Hoover, J. R. Huizenga, W. U. Schroder, and W. W. Wilcke, Phys. Rev. Lett., 43, (3), 191-194 (1979).

41. "Neutron Emission in the Reaction $^{165}Ho + ^{56}Fe$ at E_{LAB} = 8.5 MeV/u," D. Hilscher, J. R. Birkelund, A. D. Hoover, W. U. Schroder, W. W. Wilcke, J. R. Huizenga, A. C. Miginerey, K. L. Wolf, Phys. Rev. , C20, (2), 576-591 (1979).

42. "Structure in the Energy Spectra of the Fragments Produced in Damped Heavy-ion Reactions," D. Hilscher, J. R. Birkelund, A. D. Hoover, W. U. Schroder, W. W. Wilcke, J. R. Huizenga, A. C. Mignerey, K. L. Wolf, H. F. Breuer, and V. E. Viola, Jr., Phys. Rev., C 20, 556-559 (1979).

43. "Excitation Energy Dependence of the Total Kinetic Energy Release in the $^{241}Pu(^{3}He,af)$ Reaction," B. B. Back, J. M. Lebowitz, and K. L. Wolf, Phys. Rev. , C 20 (5), 1819-1823 (1979).

44. "Light-Particle Spectra Observed in Central and Peripheral Collisions of $^{16}O + ^{238}U$ at 20 MeV/nucleon," T. C. Awes, C. K. Gelke, B. B. Back, A. C. Mignerey, K. L. Wolf, P. Dyer, H. Breuer, and V. E. Viola, Jr., Phys. Lett., 87B (1,2), 43-46 (1979).

45. "Spectra of p, d, and t from Relativistic Nuclear Collisions," A. Sandoval, H. H. Gutbrod, W. G. Meyer, R. Stock, C. Lukner, A. M. Poskanzer, J. Gosset J.-C. Jourdain, C. H. King, G. King, N. Van Sen, G. D. Westfall, and K. L. Wolf, Phys. Rev., C 21, (4), 1321 (1980).

46. "Emission Patterns in Central and Peripheral Relativistic Heavy-Ion Collisions," R. Stock, H. H. Gutbrod, W. G. Meyer, A. M. Poskanzer, A. Sandoval, J. Gosset, C. H. King, G. King, C. Lukner, N. Van Sen, G. D. Westfall, and K. L. Wolf, Phys. Rev. lett., 44 (19), 1243 (1980).

47. "Possible Production of Actinide Spontaneous Fission Activities in Damped Collisions of $^{209}Bi + ^{56}Fe$," V. E. Viola, Jr., A. C. Mignerey, H. Breuer, K. L. Wolf, B. G. Glagola, W. W. Wilcke, W. U. Schroder, J. R. Huizenga, Phys. Rev, C 22 (1), 122 (1980).

48. "Bombarding-Energy Dependence of the $^{209}Bi + ^{136}Xe$ Reaction," W. W. Wilcke, J. R. Birkelund, A. D. Hoover, J. R. Huizenga, W. U. Schroder, V. E. Viola, Jr., K. L. Wolf, and A. C. Mignerey, Phys. Rev., C 22 (1), 128-147 (1980).

49. "Dependence of Isobaric Charge Distributions on Energy Loss and Mass Asymmetry in Damped Collisions," A. C. Mignerey, V. E. Viola, Jr., H. Breuer, K. L. Wolf, B. G. Glagola, J. R. Birkelund, D. Hilscher, J. R. Huizenga, W. U. Schroder, W. W. Wilcke, Phys. Rev. Lett., 45 (7), 509 (1980).

50. "Energy Dependence of Milti-Pion Production in High-Energy Nucleus-Nucleus Collisons," A. Sandoval, R. Stock, H. E. Stelzer, R. E. Renfordt, J. W. Harris, J. P. Brannigan, J. V. Geaga, L. J. Rosenberg, L. S. Schroeder, and K. L. Wolf, Phys. Rev. Lett., 45, (11), 874 (1980).

51. "Target Deformation Effects at Large Angular Momenta in Heavy-Ion Fusion Reactions," B. B. Back, R. R. Betts, W. Henning, K. L. Wolf, A. C. Mignerey, and J. M. Lebowitz, Phys. Rev. Lett., 45 (15), 1230-32 (1980).

52. "Correlated Fission Fragments Emitted in the Reaction of ^{16}O on ^{238}U at 20 Mev/Nucleon," B. B. Back, K. L. Wolf, A. C. Mignerey, C. K. Gelbke, T. C. Awes, H. Breuer, V. E. Viola, Jr., and P. Dyer, Phys. Rev., C22, (5), 1927-44 (1980).

53. "Production of Neutron-Excess Nuclei in ^{56}Fe-Induced Reactions," H. Breuer, K. L. Wolf, B. G. Glagola, K. K. Kwiatowski, A. C. Mignerey, V. E. Viola, Jr., W. U. Schroder, J. R. Huizenga, D. Hilscher, and J. Birkelund, Phys. Rev., C22, (6), 2454-56 (1980).

54. "Selectivity in Two-Particle Exclusive Heavy-Ion Reactions," R. R. Betts, H.-G. Clerc, B. B. Back, I. Ahmad, K. L. Wolf, and B. G. Glagola, Phys. Rev. Lett., 46, (5) 313-16 (1981).

55. "Charged Particle Identification with Modules of the Plastic Ball," H. H. Gutbrod, M. R. Maier, H. G. Ritter, A. I. Warwick, F. Weik, and K. L. Wolf, IEEE Transactions on Nuclear Sciences NS-28, No. 1 (1981).

56. "Comparison of Non-Compound Neutron and Proton Emission in ^{16}O Induced Reactions on ^{238}U at 319 MeV," J. Kasagi, S. Saini, T. C. Awes, A. Galonsky, C. K. Gelbke, G. Poggi, D. K. Scott, K. L. Wolf, and R. L. Legrain, Phys. Lett., 104B, 434-38 (1981).

57. "Lambda Production Near Threshold in Central Nucleus-Nucleus Collisions," J. W. Harris, A. Sandoval, R. Stock, H. Stroebele, R. E. Renfordt, J. V. Geaga, H. G. Pugh, L. S. Schroeder, K. L. Wolf, and A. Dacal, Phys. Rev. Lett., 47, 229-32 (1981).

58. "Compression Effects in Relativistic Nucleus-Nucleus Collisions," R. Stock, R. Bock, R. Brockman, J. W. Harris, A. Sandoval, H. Stroebel, K. L. Wolf, H. G. Pugh, L. S. Schroeder, M. Maier, R. E. Renfordt, A. Dacal, and M. E. Ortiz, Phys. Rev. Lett., 49, 1236 (1982).

59. "Linear Momentum Transfer in Nonrelativistic Nucleus-Nucleus Collisions," V. E. Viola, Jr., B. B. Back, K. L. Wolf, T. C. Awes, C. K. Gelbke, and H. Breuer, Phys. Rev., C26, 178 (1982).

60. "Pion Production and Multiplicity Selection in Relativistic Heavy Ion Collisions," K. L. Wolf, H. H. Gutbrod, W. G. Meyer, A. M. Poskanzer, A. Sandoval, R. Stock, J. Gosset, J.-C. Joirdain, C. H. King, G. King, Ch. Lukner, N. Van Sen, and G. D. Westfall, Phys. Rev., C26, 2572 (1982).

61. $^{165}Ho + ^{56}Fe$ Reaction at E_{Lab} = 462 MeV," A. D. Hoover, J. R. Birkelund, D. Hilscher, W. U. Schroder, W. W. Wilcke, J. R. Huizenga, H. Breuer, A. C. Mignerey, V. E. Viola, Jr., and K. L. Wolf, Phys. Rev., C25, 256 (1982).

62. "Collisions: The Mechanisms of Heavy Ion Dissipative $^{209}Bi + ^{84}Kr$ Reaction at E_{Lab} = 712 MeV," J. R. Birkelund, H. Freiesleben, J. R. Huizenga, W. U. Schroder, W. W. Wilcke, K. L. Wolf, J. P. Unik, and V. E. Viola, Jr., Phys. Rev., C26, 1984 (1982).

63. "The Analysis of Simultaneous Mass and Charge Data From Damped Heavy Ion Reactions," H. Breuer, N. R. Yoder, A. C. Mignerey, V. E. Viola, K. Kwiatkowski, and K. L. Wolf, Nuclear Instruments and Methods, 204, 419 (1983).

64. "Charged-Particle Exclusive Analysis of Central Ar + KCl and Ar + Pb Reactions at 1.8 and 0.8 GeV/Nucleon," H. Strobele, R. Brockmann, J. W. Harris, F. Riess, A. Sandoval, R. Stock, K. L. Wolf, H. G. Pugh, L. S. Schroeder, R. E. Renfordt, K. Tittel, and M. Maier, Phys. Rev., C27, 1349 (1983).

65. "Streamer Chamber Experiments," A. Sandoval, R. Bock, R. Brockmann, A. Dacal, J. W. Harris, M. Maier, M. E. Ortiz, H. G. Pugh, W. Rauch, R. E. Renfordt, F. Riess, L. S. Schroeder, R. Stock, H. Strobele, and K. L. Wolf, Nucl. Phys., A400, 365 (1983).

66. "Compression Effects in Relativistic Nucleus-Nucleus Collisions," R. Stock, R. Bock, R. Brockmann, A. Dacal, J. W. Harris, M. Maier, M. E. Ortiz, H. G. Pugh, R. E. Renfordt, A. Sandoval, L. S. Schroeder, H. Strobele, and K. L. Wolf, Phys. Scripta, T5, 130 (1983).

67. "Charge and Mass Exchange in ^{56}Fe-induced Reactions at 9.3 MeV/Nucleon," H. Breuer, A. C. Mignerey, V. E. Viola, K. L. Wolf, J. R. Birkelund, D. Hilscher, J. R. Huizenga, W. U. Schroder, and W. W. Wilcke, Phys. Rev., C28, 1086-1103 (1983).

68. "Bombarding Energy Dependence of the $^{144}Sm + ^{84}Kr$ Reaction," A. C. Mignerey, K. L. Wolf, D. G. Raich, V. E. Viola, Jr., J. R. Birkelund, W. U. Schroder, and J. R. Huizenga, Phys. Rev., C29, 158-73 (1984).

69. "Pion and Proton 'Temperatures' in Relativistic Heavy-Ion Reactions," R. Brockmann, J. W. Harris, A. Sandoval, R. Stock, H. Strobele, G. Odyniec, H. G. Pugh, L. S. Schroeder, R. E. Renfordt, D. Schall, D. Bangert, W. Rauch, and K. L. Wolf, Phys. Rev. Lett., 53, 2012-15 (1984).

70. "Intermediate Mass Fragment Emission," K. L. Wolf, J. P. Sullivan, G. M. Berkowitz, H. L. Kent, K. M. Pierpoline, B. S. Potts, C. T. Spillett, and J. Shoemaker, Notas de Fisica, 8, 397-413 (1985).

71. "Pion Production as a Probe of the Nuclear Matter Equation of State," J. W. Harris, R. Bock, R. Brockmann, A. Sandoval, R. Stock, H. Strobele, R. E. Renfordt, W. Rauch, and K. L. Wolf, Phys. Lett., 153B, 377-81 (1985).

IV. JUSTIFICATION OF EQUIPMENT, FACILITIES, CURRENT SUPPORT

Justification of Equipment

No equipment funds could be fit into the calendar year 1995 budget. Funds for electronics are needed for upgrades in the NA44 trigger electronics, A computer upgrade will be needed in the third year of the grant for data analysis and calculations for the NA 44 experiment.

Facilities

Experiments outlined in the proposal will be performed at the CERN SPS accelerator with 450 GeV protons and 160 A GeV lead ions, and lower energies if approval can be obtained. Initial data analysis for first pass tapes is performed at CERN, Geneva before subsequent analyses and simulations are performed at TAMU. Current dedicated computer facilities at TAMU include a VAX 3100 workstation and two model 3000 DEC alpha machines. Three CAMAC-based data acquisition systems are available for instrument development and tests, one of which is located at CERN. Machine shop capabilities include a small shop for use in development, a large shop and machinists associated with cyclotron facilities, and a fully computerized shop located at the TAMU Riverside campus.

Current and Pending Support

Agency	Title	Duration	% Time	Direct Costs
DOE	Pion Correlations and Calorimeter Design	4/1/94 -3/31/95	70	142,417
Texas state	Cyclotron Research	1/1/95 -12/31/95	30	48,000