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1991 TECHNICAL PROGRESS REPORT OF THE UNIVERSITY OF SOUTH CAROLINA'S HIGH ENERGY PHYSICS GROUP

(Covers the period February 1990 through July 1991)

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1. Introduction

The high energy physics group at the University of South Carolina includes five teaching faculty members, one research faculty member, and five graduate students. The faculty are Professors F.T. Avignone, R.L. Childers, and C.W. Darden, Associate Professor C. Rosenfeld, Assistant Professor J.R. Wilson, and Research Assistant Professor A.T.M. Wang. Prof. Avignone works primarily in the area of low energy tests of fundamental interactions, with a present focus on double beta decay in germanium. The germanium research is not supported by this grant. Professors Childers, Darden, and Wilson devote most of their research effort to Fermilab experiment E-789, which is designed to observe charmless two-body decays of *b*-flavored mesons and baryons. Prof. Wilson also works on Fermilab experiment E-687 which studies charm physics in the wide-band photon beam. Professors Rosenfeld and Wang participate in the AMY Collaboration, which studies e^+e^- interactions using the TRISTAN collider at KEK. Prof. Rosenfeld and one student collaborate with personnel from KEK and INS, Tokyo, on an experiment to detect a 17 keV neutrino in the β-decay spectrum of ^{63}Ni. Members of the group also participate in several new initiatives which are described below.

A brief history of the group

The DOE has funded high energy physics at South Carolina since 1980. Professors Darden and Childers were the investigators on the DOE contract in its early years. Prof. Darden was an early member of the DASP II collaboration in 1977. The DASP detector was refurbished to capitalize on the enhanced DORIS e^+e^- collider for the study of the newly discovered Υ resonances. The group's participation in DASP II evolved naturally into membership in the ARGUS Collaboration which pursued the same line of physics with a greatly improved detector. The ARGUS Collaboration made several significant contributions to Υ and *b*-quark physics. The most celebrated of these was the evidence presented for B^o–$\bar{B}^o$ mixing. USC participation in ARGUS tapered off after 1987 and is not a part of the current program.

Prof. Rosenfeld joined the faculty at South Carolina in 1986 and brought with him membership in the AMY Collaboration. The AMY detector was then under construction in parallel with the TRISTAN collider, and it recorded its first data early in 1987. The AMY involvement became a prominent part of the South Carolina activities and remains so at the present time.

Professors Childers and Darden worked for a year with the AMY collaboration but then left to collaborate in Fermilab proposal P-789, an experiment to detect two-body non-charm decays of *b*-hadrons. The experiment was approved and data is now being taken.

Prof. J. Wilson joined the South Carolina faculty one year ago. He came to us from the University of Illinois where he was a key man in Fermilab experiment E-687. He continues his participation in E-687 and has joined E-789 as well as our SSC-related activities.

2. The AMY Program

2.1 Introduction

The AMY experiment was proposed to the TRISTAN management in 1983 and approved in January 1984. Like most detectors at e^+e^- colliders, AMY has a charged-particle tracking volume inside a solenoid magnet, an electromagnetic shower counter surrounding the tracking volume, and an iron absorber followed by counters and chambers for muon identification. Features that distinguish AMY from its competitors at TRISTAN are its relatively small overall size and cost, a high (3 T) magnetic field to compensate for the small size, placement of the shower counter inside the solenoid, especially thick iron for better muon identification, and good accessibility of the internal components. The design included a chamber to tag final-state electrons by the synchrotron x rays they radiate in the high field, but this chamber was not successful. AMY logged its first event early in 1987 shortly after observation of the first event in VENUS and before the TOPAZ detector was ready. The integrated luminosity through July 1991 was about 70 pb^{-1}.

The USC group has made very substantial contributions to the AMY hardware. Before coming to South Carolina C. Rosenfeld was deeply involved in design and construction of the muon drift chambers, the high voltage and preamplifier systems of the central tracker, and the trigger system. His involvement with the central tracker has persisted to the present, and the fundamental components of the trigger system became the basic contribution of the South Carolina group. The trigger system was funded in part under DOE's Outstanding Junior Investigator program.

The design that Rosenfeld conceived and implemented for the trigger proved to be very effective. It operates at a single "level," completing all "computations" in about 500 ns, much less than the 5 μs interval between bunch crossings. Most of the design effort was invested in deriving suitable signals from the central tracking chamber. This chamber is organized as six concentric superlayers. The first-stage hardware identifies radial track segments within a superlayer. It is an ensemble of 88 custom memory look-up modules (TSRC's) that couple tightly to the central tracker's FASTBUS TDC system. The following stage tallies the number of segments in each superlayer. These six tallies constitute the central tracker input to the trigger decision. This approach achieves an efficiency approaching 99% for beam-beam interactions and generates a trigger rate under 2 Hz as a result of beam-gas and beam-wall backgrounds. The greatest challenge to the trigger are low-multiplicity events, and the AMY system accepts even single charged particle events with good efficiency. A publication describing the trigger system is planned.

2.2 Trigger upgrade

In 1987 the USC group proposed a multifaceted upgrade of the trigger system. This upgrade became part of a package that included new pole-tip iron for the solenoid, new shower and charged particle instrumentation for the pole tips, and a vertex detector. At the time of the original trigger design the synthesis of radial tracks from track segments appeared exceedingly difficult given the schedule and resource constraints. We guessed correctly that full track finding was also unnecessary. For the upgrade, however, we designed a device to achieve radial track synthesis and justified it on the grounds that improvements in luminosity might bring higher backgrounds with which the trigger would have to cope. In addition to (1) global track finding, components of the trigger upgrade included (2) a system for more accurately counting the segments in a superlayer, (3) trigger hardware for the muon chambers which would facilitate a redundant dimuon trigger not dependent on the shower counter, (4) redefinition of a signal from the inner tracking chamber (a straw tube chamber inside the central tracker) used for cosmic ray suppression in order to improve the efficiency for dimuon events, (5) track trigger systems for the new endcap tracking chambers and vertex detector, and (6) new logic for shower counter energy triggers that would operate with reduced background. Three types of modules constitute the basic building blocks for all of these improvements. The upgrade called for 50 additional TSRC's, 30 high density ECL fan-in modules, and 50 CAMAC memory look-up modules. Fan-in and memory look-up units suitable for our purposes were not offered commercially. The custom design and fabrication of these modules was therefore an integral part of the project. The trigger upgrade was approved by the collaboration and was funded by DOE in 1989.

The design and fabrication did not progress as expeditiously as originally contemplated. It is, however, now approaching completion. All of the electronic modules have been fabricated and debugged. Some facets of the upgrade have been commissioned (numbers 2 and 4 above), and we expect to install the others during the next few months. The fan-in and memory look-up modules are units with rather general applicability (C. Rosenfeld *et al.*, submitted to the 1991 IEEE Nuclear Science Symposium), and we have expectations that when AMY has run its course, we will use these modules in future projects.

2.3 Personnel and current activities

The USC personnel in the AMY experiment, in addition to Rosenfeld, are Prof. A. Wang and graduate students S. Lusin, S. Wilson, and L. Zheng. Lusin has been in residence at KEK since 1987. As the only USC representative at the Laboratory full time from 1988 to 1990, he looked after the USC trigger hardware and kept it current with various changes in the detector. For his thesis he has been analyzing the $e^+e^-\to\mu^+\mu^-$ and $e^+e^-\to\tau^+\tau^-$ channels. In the TRISTAN energy range these final states exhibit asymmetry in the angular distribution as a consequence of γ–Z interference. He expects to receive his degree within a year. Wang and Wilson have expended much effort on the design and production of the modules for the trigger upgrade. Following completion of this task in March, Wang elected to remain in the US where she gives about 1/3 time to AMY and the rest to our SSC initiative and to P-803. S. Wilson has been in residence at KEK since mid-1990, takes AMY shifts, and assists with trigger maintenance. He was also pursuing an AMY analysis topic, but he decided in March to shift his effort to the 17 keV neutrino experiment and will prepare his thesis on that topic. L. Zheng has passed the PhD qualifying examination and is also now in residence at KEK. She assists with trigger maintenance and installation of the new components, and she is beginning to study the channel $e^+e^-\to c\bar{c}$. For calendar year 1991, USC has granted research leave to C. Rosenfeld to spend the year as a Visiting Foreign Scientist at KEK. Rosenfeld is working on the trigger upgrade, miscellaneous other AMY tasks, and the 17 keV neutrino experiment.

2.4 Future of the program

When the AMY experiment was originally proposed, the physics objectives were compelling and easy to state. In the energy range that TRISTAN would make accessible, discoveries of the top quark, Higgs particles, fourth-generation particles, and supersymmetric partners of leptons were all conceivable. We know now that such discoveries must await a higher energy accelerator, higher even than CERN's LEP collider. AMY must be counted a success, however, because it surveyed the new territory on a timely basis. The first four years of AMY operation have produced more than twenty publications in refereed journals.

What then, is AMY's future? First, collider operation will most likely continue until it interferes with some other project such as the proposed *B* factory. Three more years of operation is a conservative estimate. Second, one year ago the interaction regions were equipped with superconducting quadrupoles to improve the luminosity. No benefit has yet accrued from the new magnets. Much time was lost correcting installation errors and relearning how to operate the ring after the modifications. From August 1990 through July 1991 AMY logged just 8 pb^{-1} — only TRISTAN's first year was less productive. The accelerator group, however, remains optimistic. They assert that coupling of horizontal and vertical orbits is a limitation, and they are now installing new skew quadrupoles to overcome it. We therefore look forward to greatly improved performance from the accelerator. A large boost in luminosity is clearly necessary if the program is to remain viable.

Supposing that the luminosity is forthcoming, is there physics that we can do with it? Electroweak interference is an energy-dependent phenomenon. TRISTAN is the only facility which can undertake these measurements in its energy range. The LEP experiments do not compete in this arena. USC's two AMY students are both pursuing manifestations of electroweak interference. S. Lusin's analysis of the $\mu^+\mu^-$ and $\tau^+\tau^-$ final states is not yet complete, but we show his interim results in Figs. 1 and 2. These figures illustrate two points. First, the asymmetry is a pronounced effect in the lepton channels at this energy. Second, the errors are predominantly statistical. A large increment in our data sample would produce a correspondingly more stringent test of the standard model prediction. Although the discovery potential at TRISTAN has become small, it should not be totally discounted. For example a Z' could exist with a mass less than 200 GeV, such that cross sections at TRISTAN would deviate a little from the standard model values, whereas cross sections at the Z would be unaffected. A model like this, which even breaks lepton universality, is described by He *et al.*, PRD43, R22 (1991). In fact, it is apparent from Fig. 1 that our $\mu^+\mu^-$ cross section at 58 GeV, where it is well-measured, is anomalously low. If this effect persisted after 300 pb^{-1}, the implications would be very interesting.

The USC group proposes to remain engaged in AMY for the three-year duration of this grant. The level of our participation will decline significantly during the first year when Lusin and Wilson attain their degrees. We have a new student, M. Zheng (not to be confused with L. Zheng), for whom an AMY thesis is a possibility, but her options must be weighed carefully before commitments are made.

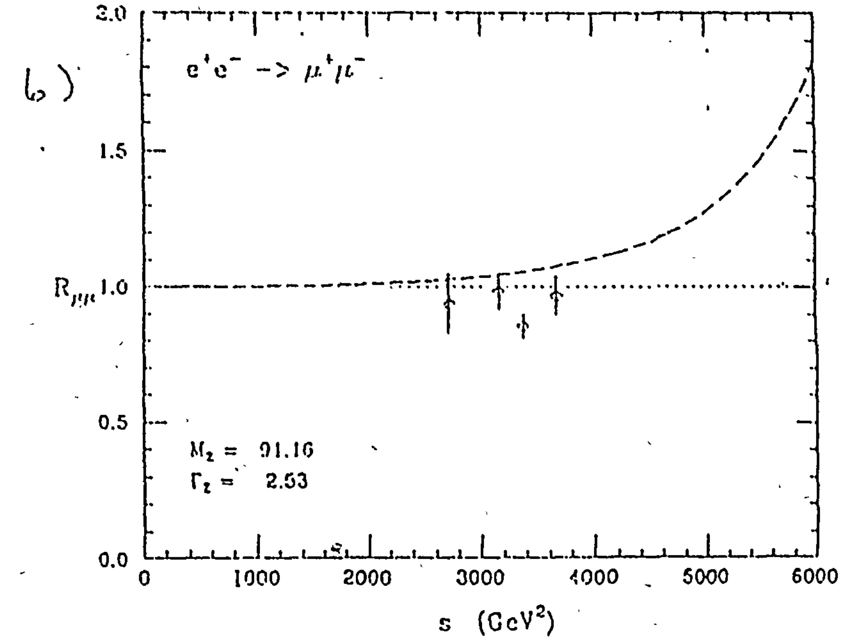
AMY DIMUON DATA   PRELIMINARY

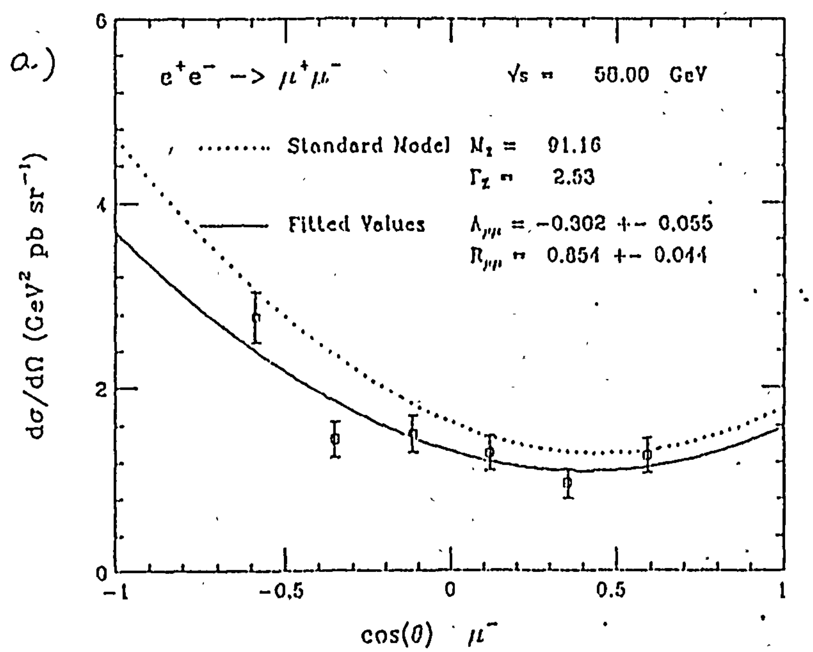
a) Differential cross-section for fall 1990 58 GeV period.

Int. lum = 27.16 pb**(-1)   GSW values: R mu-mu = 1.06
A mu-mu = -0.34

b) R mu-mu 52 - 61.4 GeV

c) A mu-mu 52 - 61.4 GeV





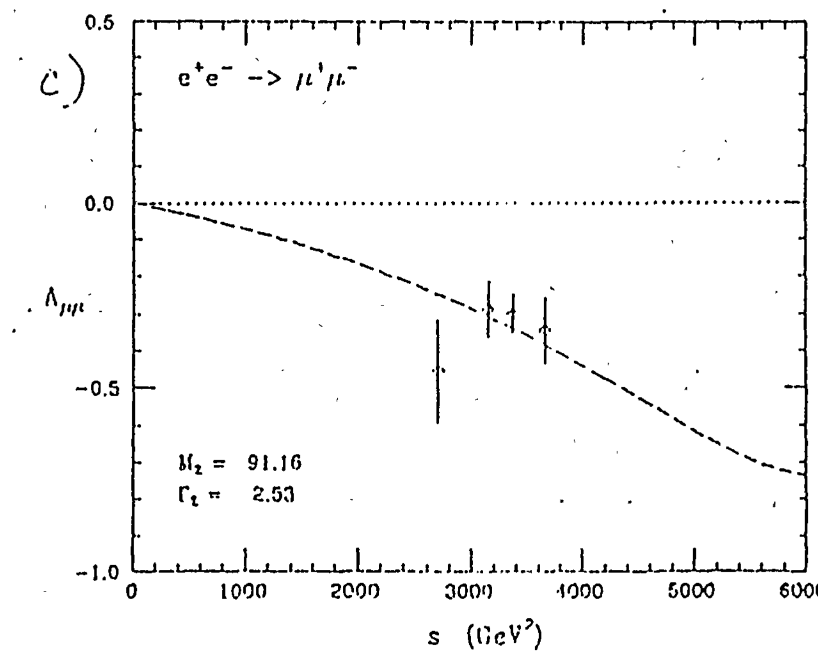


FIGURE 1. Dimuon Data

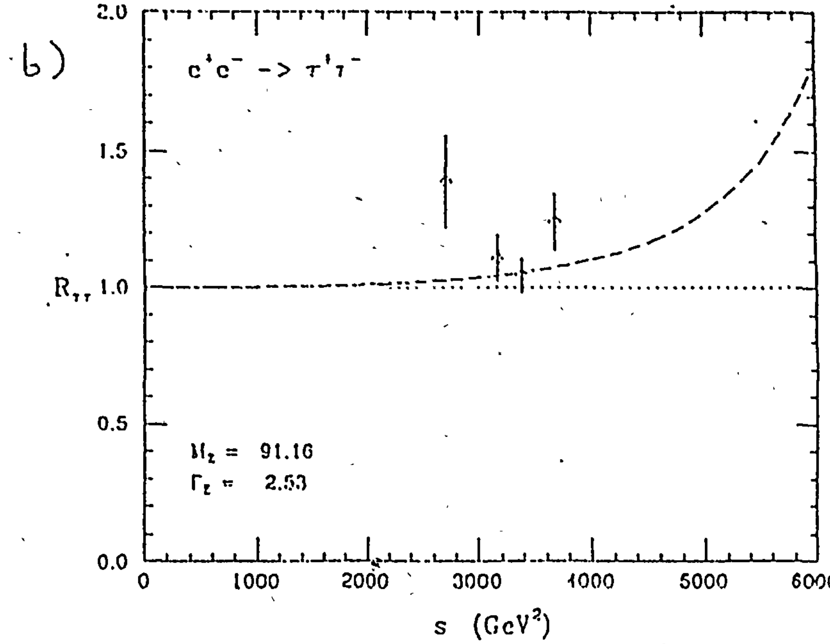
ANY TAU-PAIR DATA PRELIMINARY

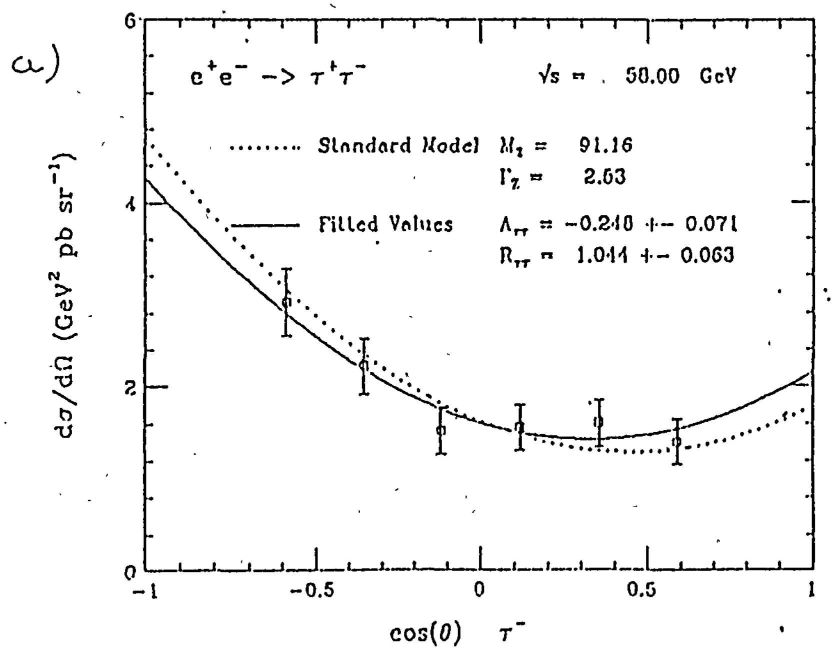
a) Differential cross-section for fall 1990 58 GeV period.

Int. lum = 27.16 pb**(-1) GSW values: R tau-tau = 1.06
A tau-tau = -0.34

b) R tau-tau 52 - 61.4 GeV

c) A tau-tau 52 - 61.4 GeV





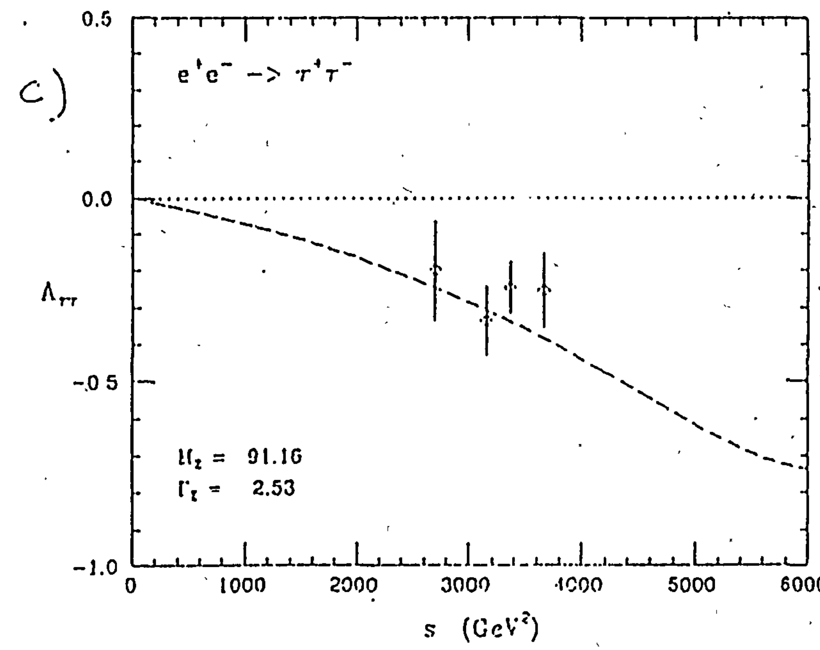


FIGURE 2. Tau-pair Data

3. Fermilab Experiment E-789

3.1 Introduction

Experiment E-789 at the Fermi National Accelerator Laboratory is a fixed-target high-flux experiment for detecting the decay of uncharged B mesons and baryons into exactly two charged particles, neither of which contains a *c* quark. Though such two-body decays have not yet been observed, some theorists predict a branching ratio for the decay of neutral B mesons into two charged pions to be approximately 1 in 10^5. This is a small branching ratio and there are many other sources of pions and kaons. The experiment would not be possible were it not for the high flux and for the fact that an appreciable fraction of the B mesons decay downstream of the target, while most of the background comes from the target itself.

The main goal of the experiment is to detect enough neutral B meson decays to get a measurement of the branching ratio to pion-pion, pion-kaon, and kaon-kaon or lamda-*b* decays to get the branching ratios to proton-pion, or proton-kaon. These rare decay modes (if they exist) skip over the *c* quark and could help determine the value of the Kobayashi-Maskawa matrix element for *b* to *u* quark transitions. If these decays can be detected, it may be possible to study CP-violations in the *b* quark system since these decays are predicted to have relatively large CP-violating contributions. Finally, neither the B_s nor the lambda-*b* have ever been detected, so their masses and lifetimes are unknown. It may be possible to determine these values.

The experiment is being carried out by physicists from Fermilab, Los Alamos National Laboratory, and the universities of California-Berkeley, Chicago, Northern Illinois, South Carolina, Abilene Christian University, and the Institute of Physics, Taiwan. Both the existing meson-east beamline and an improved version of the E-605/E-772 spectrometer are used. The spectrometer contains a ring-imaging Cherenkov detector, or RICH, as a means of distinguishing pions from kaons. The University of South Carolina was responsible for repairing and refurbishing the RICH counter, as well as implementing improvements to the readout, which will allow it to operate in a high-rate environment. The physical aspects of the detector were put in working condition first and the electronic components are just now coming into good order.

3.2 RICH gas system

Maintaining the physical aspects of the detector continues to occupy a great deal of time. The large volume (10^5 liters) of the radiator box, the complexity of the gas-handling system, and the need for reducing impurities to under 1 part in 10^6 all contribute to the need for continuous maintenance.

Inside the large radiator volume, interior mirrors direct the Cherenkov radiation to either one of two avalanche chambers. The avalanche chambers are so designed that they are most sensitive to Cherenkov radiation of approximately 140 nm wavelength. This makes for very efficient Cherenkov radiation detection, but puts a high demand on the radiator gas; it must be transparent in the hard-ultraviolet region. This affects both the selection of the gas and the purity at which it must be maintained. Water vapor and oxygen - both common contaminants - are not transparent in this spectral range.

At the outset, the radiator volume was filled with helium alone. It was possible to maintain a high degree of purity - and therefore high transmission in the UV - by using a liquid-nitrogen-cooled molecular sieve as part of the circulation system. However, because particle identification depends on the index of refraction of the gas, it is necessary to use a mixture of 10% argon and 90% helium to achieve kaon identification down to 25 GeV. Because the boiling point of liquid nitrogen is below that for argon, the molecular sieves have not been used to remove impurities from the helium-argon mixture. This precaution was taken because of the uncertainty of the effectiveness of the molecular sieve under these conditions, in spite of the fact that calculations indicate there should be no condensation or solidification of the free gas mixture.

For a mixture of helium and another noble gas, an effective method of purification has been the use of a getter furnace. In this device, manufactured by Centorr, impurities such as oxygen and water vapor are removed when the gas mixture is passed over hot titanium. With two such furnaces in parallel it was possible to maintain a transmission of 40%. That transmission is adequate, but marginal. The addition of a third Centorr furnace brought the transmission to 65%.

3.3 RICH data-acquisition system

A stable gas system allowed us to turn our efforts to the RICH data-acquisition system, or DAQ. This was one of the major bottlenecks and uncertainties of the entire experiment. The original system was based on a single fastbus crate full of LeCroy 1885 ADC's (2000 channels) read out by a single LeCroy 1821 Segment Manager/Interface. The long digitization time of the 1885's (780 microseconds) coupled with the slowness of single-word readout modes (block transfer does not work with the 1885) led to dead times of one millisecond per event due to the RICH system. This limited the number of events we were able to write to tape to 10,000 events per spill, with a live time of 50%, which was especially disconcerting since other members of the collaboration had put much effort into improving the DAQ to the point where 50,000 events could be written per spill.

It was too late to abandon fastbus so we chose instead to read out the RICH in four parallel streams. This involved four fastbus crates, four LeCroy 1821's, 40 ADC modules (10 in each crate) and four sets of interface electronics. After considerable effort this system is now running and is able to write data to tape. Analysis of these data have produced convincing evidence for rings of photons associated with tracks, so it appears that the detector is now functioning as we had hoped.

Our present plan is to run for one month at a low magnet current . This will give good acceptance for two-body hadronic D meson decays, while preserving some acceptance for dimuon J/ψ decays, which we will use to normalize our D sample for cross section purposes. The remainder of the run will be at a higher magnet current to optimize the acceptance of B meson decays.

4. Fermilab Experiment E-687

4.1 Introduction

Experiment E-687 is an open spectrometer experiment running at the wide-band photon laboratory at Fermi National Accelerator Laboratory. Originally formed in 1982 to study the decays of heavy quarks (charm and beauty baryons and mesons), the collaboration currently has members from INFN Bologna; University of California, Davis; University of Colorado; Fermilab; INFN Frascati; University of Illinois; INFN Milano; University of North Carolina at Asheville; Northern Kentucky University; Northwestern University; University of Notre Dame; INFN Pavia; Puerto Rico; and the University of South Carolina.

Photoproduction lends itself well to heavy quark investigations because the fraction of events that contain charm or beauty is enhanced by an order of magnitude relative to hadroproduction. This allows photoproduction experiments to run with much looser triggers and therefore have fewer systematic problems when making measurements of rare decay modes. The absence of a forward jet from the beam particle also reduces the number of tracks in the event and makes the reconstruction process much easier.

E-687 has accumulated a sample of about 10,000 reconstructed charm particle decays from the 1987-88 Fermilab fixed-target run. This makes it one of the largest charm samples in existence. E-687 has measured several rare decay modes with errors comparable to existing measurements, but in the area of semileptonic decays, where there has been some controversy, E-687 is unique in being able to observe both electronic and muonic decays.

Several improvements were made to the spectrometer and beam-tagging system before the second run that began in 1990. A silicon microstrip tracking system was added to measure the momentum of the incident electron before it passes through the radiator. This improved the recoil energy measurement by an order of magnitude thus allowing a more precise measurement of the photoproduction cross section as a function of energy than was possible during the 87-88 run. The electromagnetic calorimeter, which was destroyed by fire during the first run, was replaced, giving the spectrometer full coverage for decay modes involving π^0's and γ's.

The fixed-target run has resumed after a long shutdown (restarted July, 1991) and E-687 continues to accumulate data. The analysis of the 1990 data has begun and with 5% currently reconstructed, the data sample appears to contain about four times as many charmed particles as the 87-88 run. The 1991 portion of the run is estimated to contain another six times the yield of the 87-88 run. A sample of this size should permit the observation of doubly Cabibbo suppressed decays (DCSD) of D mesons. We also expect thousands of D_s and charmed baryon decays.

4.2 Personnel and current activities

J. R. Wilson is the USC faculty member associated with E-687 where he has been a member of the collaboration since 1986. His analysis expertise is in the area of charged particle tracking and neutral kaon analysis. Two noteworthy topics currently being investigated by E-687 are doubly Cabibbo suppressed decays (including D^0 - $\bar{D}^0$ mixing) and semileptonic form factors of the D^+. Wilson has looked for DCSD modes of the D^+ and has produced a limit that is a factor of two lower than the current world limit for the decay $D^+ \rightarrow K^+\pi^-\pi^+$, although this result is still preliminary. He also intends to use his knowledge of the K_s analysis to study semileptonic decays of the D^o. Both of these topics will benefit substantially from the large amount of data from the 90-91 run.

4.3 Future of the program

E-687 will conclude its data taking with the 1991 run. With the amount of computer time currently available, the main data processing will take about one year and results will start appearing soon after. While the 87-88 data sample was comparable in size to other existing charm samples, the 90-91 sample will be an order of magnitude larger. It is difficult to predict where the most interesting discoveries will be made, but good semileptonic measurements seem assured. It is also probable that we will observe B meson decays and produce the first measurement of the B photoproduction cross section.

5. Search for the 17 keV Neutrino

The first claim for the existence of a 17 keV neutrino was based on a measurement of the β-decay spectrum of tritium published by Simpson in 1985. Interest in the subject increased dramatically in December 1990 when two papers reporting the spectra of ^{35}S and ^{14}C confirmed the claim. This story has been chronicled in the pages of *CERN Courier* and *Physics Today* as well as in scholarly reports. Prof. T. Ohshima of KEK had recently participated in a measurement of the endpoint spectrum of tritium using an iron-free magnetic spectrometer at the Institute for Nuclear Science, Tokyo (INS). He understood the power of this instrument to investigate the 17 keV phenomenon, and he was acquainted with personnel both at INS and at KEK with the expertise to mount such an experiment. He formed a group and submitted a proposal for a high precision measurement of the β-decay spectrum of ^{63}Ni in a region 17 keV below the endpoint. A measurement of the ^{63}Ni spectrum using a similar spectrometer at Chalk River found no evidence for an extra neutrino. The Chalk River spectrometer was subsequently decommissioned. The INS experiment expects to improve on the Chalk River result by acquiring 20 times as much data and by paying close attention to the possible sources of systematic error.

Prof. Ohshima invited Rosenfeld and his student S. Wilson to join this experiment. The South Carolina participants contributed key ideas and components to the data acquisition system. Data taking began in July and will end in September. With respect to the quantity of data taken the experiment is meeting its objectives, and no debilitating problems with systematics have so far been uncovered. For determining the response function of the apparatus we use a ^{109}Cd source that emits electrons at a few discrete energies. In Fig. 3 we show the ^{109}Cd spectrum as we observe it in the spectrometer. The analysis effort is now building up steam. S. Wilson will be the only student to write a PhD thesis on this experiment. The project is having only minimal impact on USC's funding since both Rosenfeld and Wilson were in any case living in Japan and KEK purchased the small amount of equipment that was not already on hand. Strictly speaking the experiment is peripheral to this proposal because it will be nearing completion by the time the funding begins. It does, however, reflect the entrepreneural spirit of our group and our taste in physics.

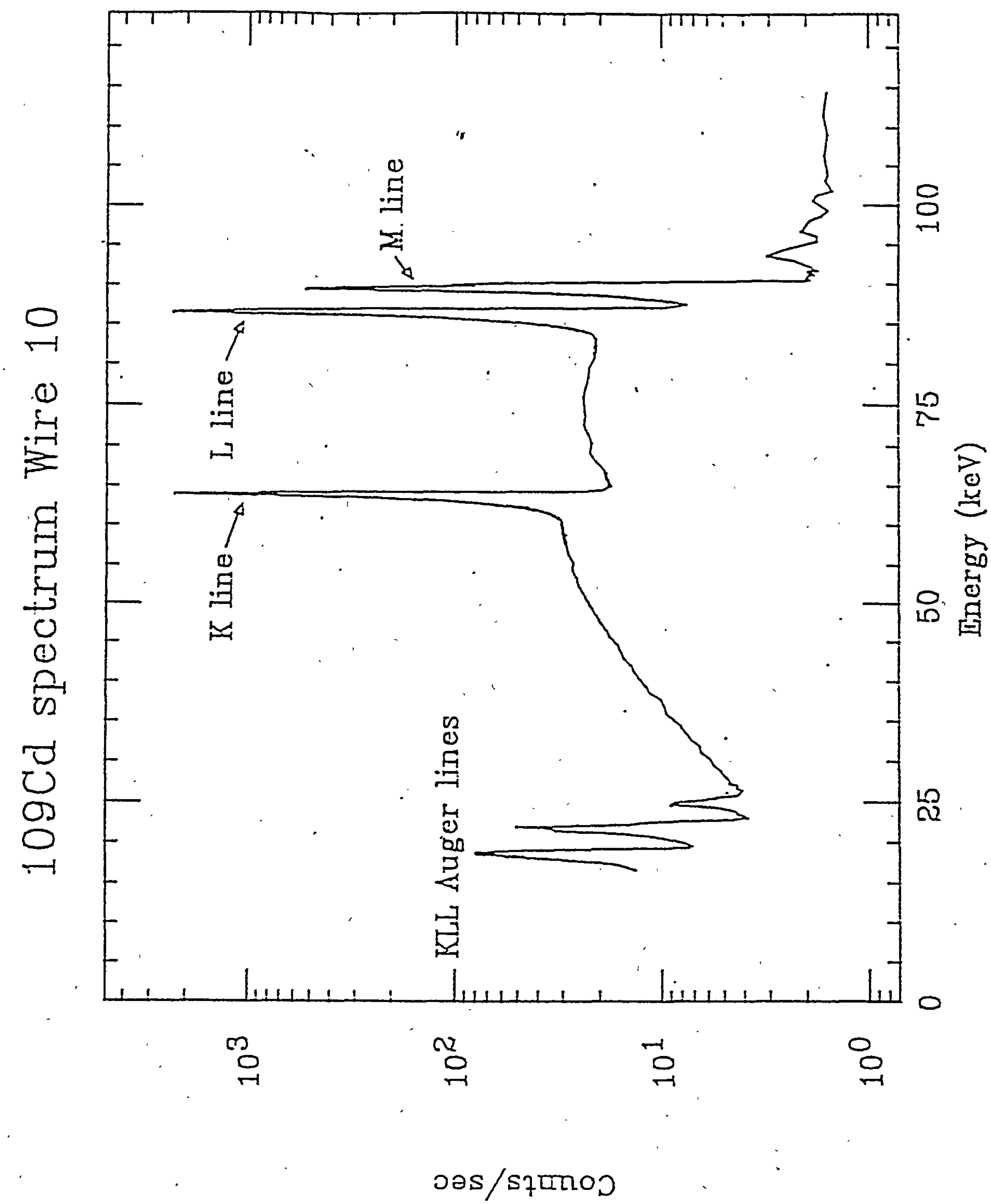


FIGURE. 3. The β–decay spectrum of a ^{109}Cd source as measured by one cell of a 30-cell detector in the Air Core Spectrometer of the Institute for Nuclear Science, Tokyo.

6. New Initiatives

6.1 Fermilab Proposal P-803

Profs. Avignone and Rosenfeld are charter members of Fermilab proposal P-803 (spokesman, N. Reay of Ohio State). This experiment will search for the oscillation of ν_μ to ν_τ with sensitivity better by a factor of 40 than previously achieved. The many searches which have been conducted for neutrino oscillations attest to the fundamental significance of this phenomenon. Were it to be observed, it would imply that neutrinos have mass and that generational mixing is a feature that the leptons share with the quarks. No experiments have confirmed a signal. Nearly all of the appearance experiments, however, have searched for transitions between electron and muon neutrinos and were insensitive to transitions involving the τ neutrino. The reason is not hard to find. An intense flux of τ neutrinos is impossible to generate with current techniques, and the identification of τ's created in a target is technically difficult. Disappearance experiments do not discriminate against ν_τ, but neither can they achieve the sensitivity needed if the transition rate is low. The fact that oscillations in the ν_e/ν_μ system have never been observed offers no basis for prejudice concerning the existence of oscillations with ν_τ.

Our interest in ν_μ/ν_τ oscillations is stimulated by questions from cosmology as well as particle physics. If the τ neutrino oscillates and therefore has mass, then it is a candidate for the cosmological dark matter. For a time the idea that a neutrino could play this role ("hot dark matter") was out of favor with modelers, but it seems now to be back in vogue. A neutrino that is to account for $\Omega = 1$ should have a mass in the vicinity of 10 to 60 eV. Direct measurements of the mass of ν_e have yielded interesting upper limits, but more importantly, in the Mikheyev-Smirnov-Wolfenstein (MSW) explanation of the solar neutrino problem both the e and μ neutrino masses are a small fraction of an eV. The solar neutrino problem itself shows no signs of abating. The deficit in Davis's experiment has persisted for many years, and the preliminary report from the SAGE experiment is confirmatory. So we must seriously consider MSW, and in that case the remaining neutrino candidate for the dark matter is ν_τ. At Singapore '90 D. Schramm offered his opinion that the τ neutrino was the most likely of the identifiable dark matter candidates. If the mass of ν_τ is at least 10 eV, P-803 achieves its optimum sensitivity in the mixing angle, reaching down to $\sin^2(2\alpha) = 10^{-4}$.

The new 120-GeV Main Injector for the Tevatron will be the source of the beam for this experiment. The extracted protons will interact in a thick target, and a double-horn system will focus the resulting pions and kaons into a decay pipe extending 300 to 500 m. The neutrinos exiting the pipe will pass through 100 m of earth and iron shielding on their way to the detector. This beam line is similar in concept to old designs, but the extraordinary intensity and repetition rate of the accelerator place heavy demands on the target, the horns, and the radiation containment. The high intensity, however, is essential to the sensitivity of P-803 and is the reason that the experiment is totally dependent on the new injector. This beam line is likely to be shared with an associated "long baseline" experiment that will further add to its complexity. The beam line cost is expected to be at least $20M, more than twice the cost of the experiment's detector.

In P-803 we will search for the explicit appearance of a τ. Since $c\tau_\tau = 0.1$ mm, the neutrino target must have roughly 10-micron spatial resolution. Therefore the neutrino target is nuclear emulsion, which is the only proven detector that provides sufficient resolution in a large mass at acceptable cost. In Fig. 4 we show a plan view of the proposed detector. The emulsion sits inside the superconducting coil formerly used with the 15-ft bubble chamber. The merits of this coil in this application are its large diameter and, perhaps, low power consumption, but no benefit accrues from its capability for high field. The optimum field in this experiment is only 0.5 T. Besides the emulsion, the coil encloses chambers for charged particle tracking, an electromagnetic calorimeter, and a "hadron calorimeter" that serves primarily for muon identification.

In P-803 the most serious backgrounds are charmed particle production and "white star kinks." White star kinks are instances in which a pion scatters on a nucleus in the emulsion, but the nucleus holds together or its breakup leaves no visible debris. Simulations yield the counterintuitive result that with suitable cuts the charmed particle background is much less than one event for the entire eight-month exposure. Recent measurements of white star kink frequency show that this background is also below the single event level. In Fig. 5 we indicate the sensitivity of P-803 with the familiar plot of the excluded region of ΔM^2 and $\sin^2(2\alpha)$ obtained in the case of no signal.

For track-following in the emulsion to proceed at a reasonable pace, the process must receive guidance from the tracking chambers. We believe this guidance must include a position measurement of a few tracks in each event with a precision of order 200 μm where the tracks exit the emulsion stack. Extrapolating trajectories from downstream drift chambers does not yield such high precision. The P-803 proposal envisions acquiring this measurement from scintillating fibers immediately adjacent to the emulsion. Fiber technology, however, has some severe problems. A fiber readout is expected to cost between $1.5M and $3.0M, and the combination of resolution and light output from today's fibers is at best marginal for our application. The collaboration is interested in alternative technologies, and South Carolina would like to pursue one or two new ideas. The prospects for success are not bright, but the possibility of a large payoff justifies a modest effort. Our budget for the second year includes $10K of equipment funds for this developmental work, which the University will match.

The Fermilab management has put P-803 in "deferred" status even though the science of this proposal has received generally high marks from the Fermilab program committee and other reviewers. The estimated cost including the beam line, however, is substantial and is not yet known with good accuracy. In the last six months the new Main Injector has itself barely survived a trip through the US legislative process. We are confident that if we are patient, the experiment will be approved in due course. A competitive experiment was proposed at CERN. We are not current with the status of the CERN proposal, but we would in any case not be deterred by the possibility that we might be scooped. Rather we interpret the competition as an indication that we are on the right track.

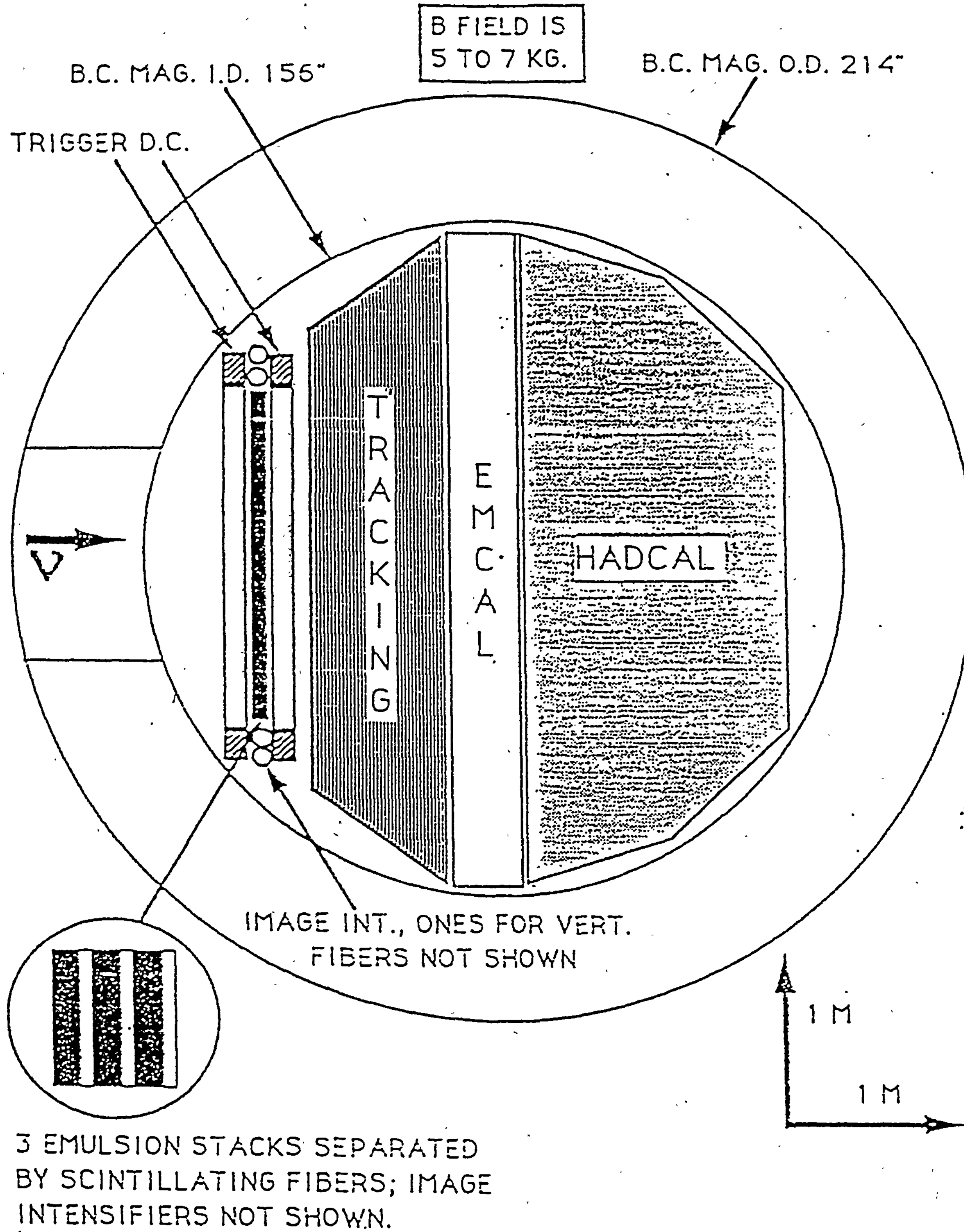


FIGURE 4 . Plan view of the experiment.

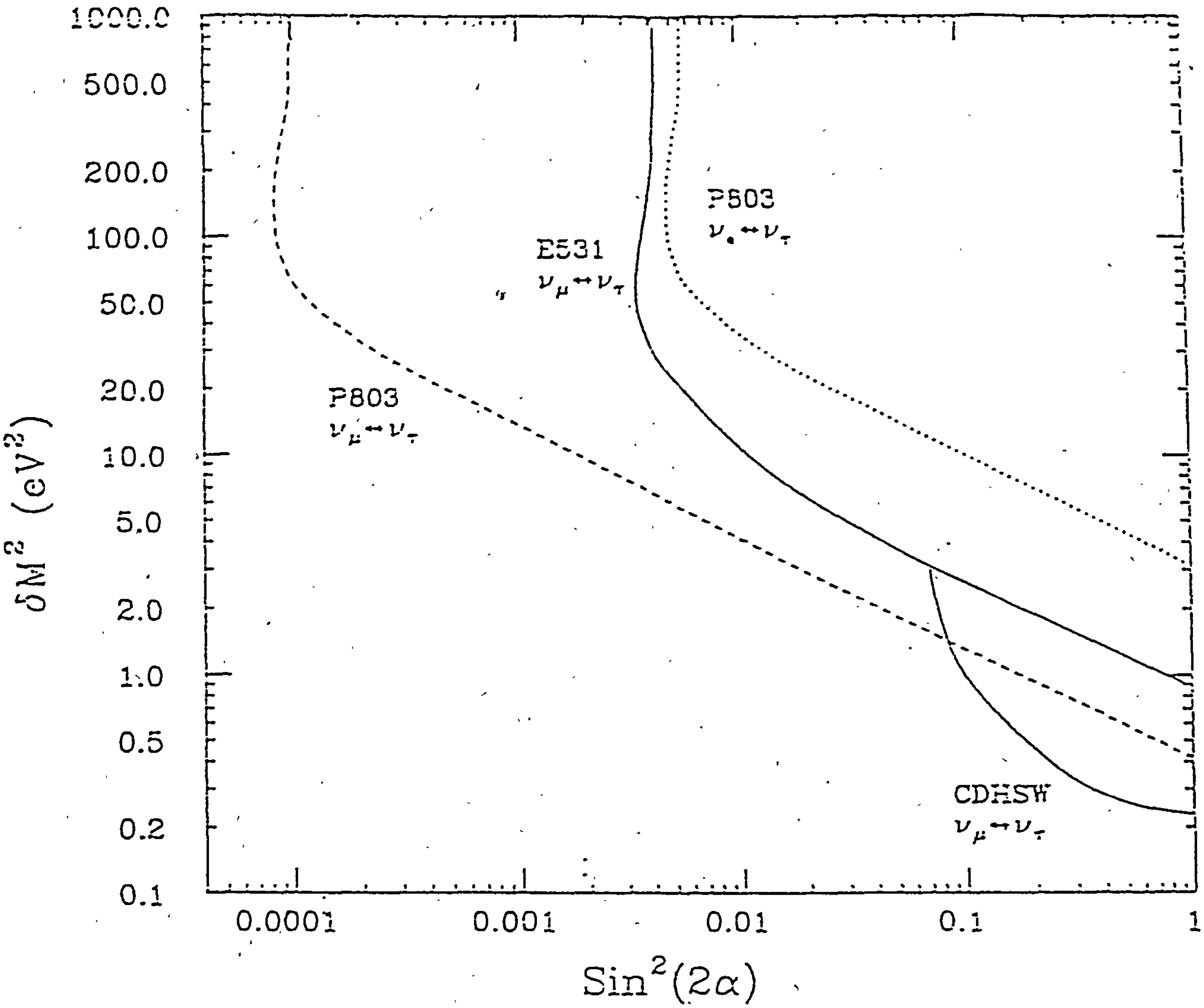


FIGURE 5. δM^2 versus $\sin^2(2\alpha)$ plane showing the previous limits for $\nu_\mu \leftrightarrow \nu_\tau$ oscillation (solid curves), and the improved limits on $\nu_\mu \leftrightarrow \nu_\tau$ (dashed) and $\nu_e \leftrightarrow \nu_\tau$ (dotted) which can be obtained from P803. The regions to the right of the appropriate curves are excluded at the 90% confidence level.

6.2 SSC-related activities

The primary theme of South Carolina's SSC activities is the development of an imaging preradiator. This device would constitute the first 1.5-3.0 radiation lengths of an electromagnetic calorimeter. It is finely segmented and heavily instrumented so as to determine precisely the point of initiation of showers within one radiation length in the radial direction and within 0.5 mm and 3.0 mm in the transverse coordinates. Significant material in front of it defeats its purpose, so it should be located within the magnetic volume just outside the tracking chambers. Ideally the main part of the calorimeter would follow immediately so that the coil would not degrade the energy resolution. The benefits of a preradiator, briefly stated, are as follows: 1) By discriminating against charged tracks for which shower development is delayed, even slightly, the $\pi^{\pm}$ contamination in the electron sample can be reduced by at least a factor of ten. 2) Contamination of the electron sample by accidental overlap of charged tracks with γs can be suppressed by detecting a small displacement between the charged track trajectory and the origin of the shower. 3) Up to about 100 GeV there is some power for discriminating single γs from π°'s by observing the origins of both showers in the π° case. 4) Tagging of *b*-quark jets by electrons is enhanced because electron showers are resolvable even when they are comparatively close to the jet axis. 5) The preradiator measurement of the origin of γ-induced showers in conjunction with the shower centroid location from the calorimeter determines the direction of the γ. The "pointing" of the γ may be essential for isolating the $H \rightarrow \gamma\gamma$ process. 6) The preradiator unambiguously associates a shower with a beam-crossing bucket. This feature may be valuable if the basic calorimeter design is weak in this respect.

The sampling medium that we prefer for the preradiator is scintillating fiber. The favorable attributes of fiber are its excellent spatial resolution and low cost. Its channel count is moderate, and inexpensive readout devices may be feasible. An unfavorable attribute is that fiber is "projective" rather than "pixellated." On this account interesting showers may sometimes be obscured (shadowed) by jets. A project to develop this kind of preradiator was initiated by groups at Rockefeller and Yale led by R. Rusack and P. Cushman. Profs. Rosenfeld, Wang, and Wilson have joined them in this effort.

South Carolina participation in the preradiator project has two foci. First, we are assisting with beam tests of preradiator prototypes at Fermilab. The testing operates under the rubric T-841 and is now in progress. Second, we are particularly interested in development of an inexpensive fiber readout device. A promising approach, proposed by R. Rusack, is to create a new type of phototube. In this device the photoelectrons are accelerated and arrive at the anode with energy of 10 keV. The anode is a "pixel detector" (PD) similar to the one under development by D. Nygren *et al.* at LBL. A phototube with a PD anode would accommodate hundreds of fibers at a comparatively low cost and would be radiation hard. In Nygren's design each channel on the detector chip is indium bump bonded to a clever readout circuit on a second chip. The incorporation of a PD in an imaging tube, however, presents some serious technical challenges. One of these is the processing of the detector surface so that 10-keV electrons will reach the active silicon. Another is designing a detector and readout that are well matched to scintillating fiber. A third is arranging for the indium bonding to survive the thermal processing involved in tube fabrication. Alternatively, it might be possible to integrate the detector and readout on a single substrate. To address some of these technical issues we have solicited proposals from Burle Industries (the successor to the photomultiplier division of RCA), Hamamatsu, and DEP. The resulting proposals are rather expensive compared with the presently available resources, and we are deliberating on how to proceed.

Our interest in a preradiator is conditional on finding a niche for it in one of the SSC detectors. The EMPACT Collaboration seemed friendly to the possibility of a preradiator, and Rosenfeld and Wilson became parties to the EMPACT First Expression of Interest and the EMPACT/TEXAS Letter of Intent. A preradiator does not fit so well in the SDC design because the EM calorimeter is outside the coil, and SDC has been cold to the idea. The phoenix that is now rising from the ashes of EMPACT/TEXAS and L* seems to be the most promising home for a preradiator. We attended the GEM organizational meeting and contributed some text to the GEM Letter of Intent. Since we were dilatory, however, about communicating our intentions to GEM management, our institution does not appear on the LOI masthead. Our Yale collaborator, P. Cushman, will also be a GEM participant.

Finally, Professors Avignone, Childers, and Darden are parties to the Super Fixed Target Beauty Facility First Expression of Interest. This facility would make use of an external 20 TeV proton beam from the SSC to generate high-momentum B mesons.

7. Publications Coauthored by Group Members, 1990 and 1991

7.1 ARGUS publications

Observation of Semileptonic Charmless B Meson Decays.
ARGUS Collaboration (H. Albrecht *et al.*).
Phys. Lett. B234, 409 (1990).

Study of Antideuteron Production in e^+e^- Annihilation at 10 GeV Centre-of-Mass Energy.
ARGUS Collaboration (H. Albrecht *et al.*).
Phys. Lett. B236, 102 (1990).

Search for Hadronic $b \to u$ Decays.
ARGUS Collaboration (H. Albrecht *et al.*).
Phys. Lett. B241, 278 (1990).

Observation of the Decay $D_s^+ \to \eta' \pi^+$.
ARGUS Collaboration (H. Albrecht *et al.*).
Phys. Lett. B245, 315 (1990).

Determination of the Michel Parameter in Tau Decay.
ARGUS Collaboration (H. Albrecht *et al.*).
Phys. Lett. B246, 278 (1990).

Measurement of Ξ_c Production in e^+e^- Annihilation at 10.5 GeV Center-of-Mass Energy.
ARGUS Collaboration (H. Albrecht *et al.*).
Phys. Lett. B247, 121 (1990).

Study of Inclusive Semileptonic B Meson Decays.
ARGUS Collaboration (H. Albrecht *et al.*).
Phys. Lett. B249, 359 (1990).

Determination of the Tau-Neutrino Helicity.
ARGUS Collaboration (H. Albrecht *et al.*).
Phys. Lett. B250, 164 (1990).

A Study of Cabibbo-Suppressed D^0 Decays.
ARGUS Collaboration (H. Albrecht *et al.*).
Z. Phys. 46C , 9 (1990).

Inclusive π^0 and η Meson Production in Electron Positron Interactions at $\sqrt{s}$=10 GeV.
ARGUS Collaboration (H. Albrecht *et al.*).
Z. Phys. 46C , 15 (1990).

Measurement of K^+K^- Production in $\gamma\gamma$ Collisions.
ARGUS Collaboration (H. Albrecht *et al.*).
Z. Phys. 48C , 183 (1990).

Exclusive Hadronic Decays of B Mesons.
ARGUS Collaboration (H. Albrecht *et al.*).
Z. Phys. 48C , 543 (1990).

Search for $b \to s$ gluon in B Meson Decays.
ARGUS Collaboration (H. Albrecht *et al.*).
Phys. Lett. B254, 288 (1991).

Reconstruction of Semileptonic $b \to u$ Decays.
ARGUS Collaboration (H. Albrecht *et al.*).
Phys. Lett. B255, 297 (1991).

Observation of the Decays $D_s^- \to \phi e^- \bar{\nu}$ and $D^- \to K^{*0} e^- \bar{\nu}$.
ARGUS Collaboration (H. Albrecht *et al.*).
Phys. Lett. B255, 634 (1991).

Observation of the Decay $\tau \rightarrow \rho\pi\pi\nu_{\tau}$.
ARGUS Collaboration (H. Albrecht *et al.*).
Phys. Lett. B260, 259 (1991).

Search for $b \rightarrow sX^{+}X^{-}$ in Exclusive Decays of *B* Mesons.
ARGUS Collaboration (H. Albrecht *et al.*).
Phys. Lett. B262, 148 (1991).

A Spin Parity Analysis of $\gamma\gamma \rightarrow \rho^{+}\rho^{-}$.
ARGUS Collaboration (H. Albrecht *et al.*).
Phys. Lett. B267, 535 (1991).

Observations of Λ_c^+ Semileptonic Decay.
ARGUS Collaboration (H. Albrecht *et al.*).
Phys. Lett. B269, 234 (1991).

Study of *pp* and $\Lambda\Lambda$ Production in e^+e^- Annihilation at 10 GeV Center of Mass Energy.
ARGUS Collaboration (H. Albrecht et al.).
Z. Phys. 49C , 349 (1991).

Observation of Spin-Parity 2^+ Dominance in the Reaction $\gamma\gamma \rightarrow \rho^{\circ}\rho^{\circ}$ Near Threshhold.
ARGUS Collaboration (H. Albrecht *et al.*).
Z. Phys. 50C , 1 (1991).

Inclusive Production of D°, D^{+}, and $D^{*}(2010)^{+}$ Mesons in *B* Decays and Nonresonant e^+e^- Annihilation at 10.6 GeV.
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Z. Phys. C52, 353 (1991).

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ARGUS Collaboration (H. Albrecht *et al.*).
DESY-91-056, Jun 1991.

7.2 AMY publications

A Search for SUSY Particles in e^+e^- Annihilations at $\sqrt{s}$=50-60.8 GeV.
Y. Sakai *et al.* (the AMY Collaboration).
Physics Letters.B234, 534 (1990).

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G.N. Kim *et al.* (the AMY Collaboration).
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Physics Letters B244, 573 (1990).

A Measurement of the Photon Structure Function F_2.
T. Sasaki *et al.* (the AMY Collaboration).
Physics Letters B252, 491 (1990).

Multihadron-event Properties in e^+e^- Annihilation at $\sqrt{s} = 52\text{–}57$ GeV.
Y.K. Li *et al.* (the AMY Collaboration).
Physical Review D41, 2675 (1990).

Charged-particle Multiplicities in e^+e^- Annihilations at $\sqrt{s} = 50\text{–}61.4$ GeV.
H.W. Zheng *et al.* (the AMY Collaboration).
Physical Review D42, 737 (1990).

Mass Limits of Charged Higgs Boson at Large tanβ from e^+e^- Annihilations at $\sqrt{s} = 50–60.8$ GeV.
J.R. Smith *et al.* (the AMY Collaboration).
Physical Review D42, 949 (1990).

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Physical Review D42, 1339 (1990).

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D. Stuart *et al.* (the AMY Collaboration).
Physical Review Letters 64, 983 (1990).

Search for Charged Heavy Leptons with Arbitrary Neutrino Masses in e^+e^- Annihilations at $\sqrt{s} = 50–60.8$ GeV.
G.N. Kim *et al.* (the AMY Collaboration).
International Journal of Modern Physics 6, 2583 (1991).

7.3 Fermilab E687 publications

Measurement of Λ_c^+ and D_s^+ Lifetimes.
P.L. Frabetti *et al.* (the E687 Collaboration).
Physics Letters B251, 639 (1990).

A Measurement of the D^0 and D^+ Lifetimes.
P.L. Frabetti *et al.* (the E687 Collaboration).
Physics Letters B263, 584 (1991).