A Search for the Production of Direct Leptons in Nucleon-Nucleus and Nucleus-Nucleus Collisions

Progress Report for the period
April 1, 1991 - December 1, 1993

Grant DE-FG05-88ER-40445

Submitted by

The Intermediate Energy Nuclear Physics Group
Department of Physics and Astronomy
Louisiana State University
and Agricultural and Mechanical College
Baton Rouge, LA 70803-4001

P. N. Kirk
Principal Investigator

December 15, 1993

Prepared for the Division of High Energy
and Nuclear Physics
United States Department of Energy

DISCLAIMER

This report was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency thereof, nor any of their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.

DEC 30 1993
OSTI

Se

Introduction

The purpose of this report is to describe activities performed by the Intermediate Energy Nuclear Physics Group (IENPG) at the Louisiana State University (LSU) under the terms of grant DE-FG05-88ER40445. The report will cover, for the most part, the period of time between April 1, 1991, and the present.

The principal focus of our activities is currently the muon subgroup of the PHENIX Collaboration. We are, however, in the process of concluding other activities, specifically our memberships in the Di-Lepton Spectrometer (DLS) Collaboration at LBL and the AMY Collaboration at KEK. These activities have been thoroughly discussed in previous progress reports and renewal proposals, and further discussion of these activities is possibly repetitious. However, this report has been prepared under the assumption that none of the referees with the exception of the grant monitor is familiar with the group or its previous work. Consequently we shall cite a few examples of our contributions to these collaborations when there seem to be valid reasons for so doing.

The renewal proposal that accompanies this progress report is, first and foremost, a request to support the continued activities of this group within the muon subgroup in the PHENIX Collaboration. We shall also ask the DOE to support us as we bring to a scientifically valid and responsible conclusion our long and valued affiliations with the DLS Collaboration and the AMY Collaboration. Finally, as we shall discuss in the renewal proposal, we have applied for membership in E866 at Fermilab, for which G. T. Garvey is spokesman. The E866 Collaboration is an order of magnitude smaller than PHENIX, and the experiment will be mounted and concluded on a far shorter time scale. The focus of the renewal proposal then is manifestly the muon subgroup of the PHENIX Collaboration, and the specific objective of this progress report is to address those questions that, in our opinion, seem most likely to arise in the minds of the referees as they consider our proposal within this context.

These questions are: (1) Does the record demonstrate that the IENPG has the capacity to make positive contributions to a large, international collaboration such as PHENIX ? (2) What specifically has the group contributed to PHENIX in the past ? (3) What are the strengths of the group ? (4) What are the weaknesses of the group, and what is the group leader doing to correct them ? (5) Are the goals of the group within the PHENIX

Collaboration well defined ? (6) Are they appropriate for a group of this size? (7) Is the budget in line both with reality and with the scope of the proposed activities ? We shall address questions (1) - (4) in this report and questions (5) - (7) in the accompanying renewal proposal.

Personnel

The IENPG currently comprises undergraduate John Heilman, graduate student Jiangchen Yu, senior postdoctoral associate Zhi-fu Wang, research associate Ying-chao Wang, and principal investigator P. N. Kirk. Mr. Hellman, a junior at LSU, is studying physics and computer science. Mr. Yu is a graduate student who will take his general examination during the week that begins on January 10, 1994. He is a bit tense these days, as might be expected, but we expect him to pass the examination and to begin full time research by the middle of January. Zhi-fu Wang is a senior post-doctoral research associate and colleague of many year's standing, and Ying-chao Wang is a technician who holds, interestingly enough, a baccalaureate degree in physics.

We regard the education of students as being an important part of our responsibilities to the DOE and to society as a whole. For this reason we take pride not only in the achievements of Mr. Hellman but in the record subsequently compiled by several of our students who are now in graduate school. The record will show that Mr. Robert Rylan, Mr. Alijeet Bains, and Mr. Mark Frey, all graduates of our group, have subsequently compiled noteworthy records at the University of Maryland, the University of Illinois, and Rice University, respectively. Although we claim no credit for the abundant natural abilities of these students, we played no small role in sustaining their general interest in physics.

Publications

During the calendar year 1993 five papers that were supported in part by grant DE-FG05-88ERO40445 appeared in print. They are:

1. Measurement of dielectron production in niobium-niobium collisions at 1.05 GeV/nucleon, S. Beedoe, et al., Phys. Rev. C, **47**, 2840 (1993)

2. Measurement of α_s from the moment of particle momenta within jets from $e^+ - e^-$ annihilation, K. B. Lee, et al., Phys. Lett. B, **313**, 469 (1993)
3. Search for anomalous $\gamma\gamma$ production at TRISTAN, K. L. Sterner, et al., Phys. Lett B, **303**, 385 (1993)
4. Mass dependence of pion production in heavy ion collisions near, but below, threshold, J. Miller, et al., Phys. Lett B, **314**, 7 (1993)
5. Relative dielectron yields in $p + p$ and $p + d$ interactions from $E_{beam} = 1.0 - 4.9$ Gev, W. K. Wilson, et al., Phys. Lett B, **316**, 245 (1993)

A copy of the principal investigator's publication list is included in Appendix "A" of the renewal proposal, but perhaps it might be useful for us to summarize briefly the rate of publications in the recent past. During the past three years, 1991 - 1993, nine publications that were supported in part by this grant have appeared in internationally recognized journals. During the preceding three years, 1988 - 1990, twenty-six publications that were supported in part by this grant have appeared in internationally recognized journals. The total for the preceding six years is then 35 publications, resulting in an average rate of approximately 6 publications per year.

Activities of the IENPG

In this section of our progress report we shall address the first two of the questions that were posed in the last paragraph of the Introduction; namely, (1) Does the record demonstrate that the IENPG has the capacity to make positive contributions to a large, international collaboration such as PHENIX ? and, (2) What specifically has the group contributed to PHENIX in the past ? Throughout this discussion we shall assume that the reader has a basic familiarity with PHENIX, although detailed knowledge is not necessary.

At the possible risk of oversimplification, one might subdivide the muon detector of PHENIX into two essential components, the instruments that identify a charged particle as being a muon, and the instruments that provide information pertaining to its location and trajectory. For simplicity we shall refer to the first set of instruments as the "muon identifier", or muon ID, for short, and the second set of instruments as the "muon tracker".

The active element of the muon ID will be, most likely, the so-called "limited streamer tubes" (LST), although we must emphasize that a definitive choice between competing technologies has not as yet been made. The LSTs under consideration are manufactured and sold commercially by a company in Houston, Texas, but the responsibility for testing and evaluating the LSTs was borne principally by Dr. Felix Obenshain of ORNL and his graduate student, Mr. Joe Kreke. The LSTs were assembled at ORNL, loaded onto a truck, and driven to BNL by Mr. Kreke and colleagues during late May. The LSTs had been previously scheduled for testing during the month of June, when the quark-matter conference and the meeting of the PHENIX Collaboration in Lund, Sweden, claimed the attention and physical presence of many members of the collaboration. Mr. Kreke was joined by Zhi-fu Wang and Ying-chao Wang of LSU in early June, and we are delighted to report that the two Wangs contributed in major ways to the successful testing of the LSTs.

On the following pages we display a series of photographs in which the two Wangs are shown at work on this project. In the first two photographs one sees Ying-chao Wang at the oscilloscope. In photograph 1 she is checking the performance of the counters in the M1 hodoscope, and in photograph 2 she is, flashlight in hand, searching for a light leak in the M2 hodoscope. Prior to the assembly of the apparatus at BNL the scintillators and photomultiplier (PM) tubes had been stored separately. Most of bases for the PM tubes required cleaning before use; many required repair; and all were attached to the corresponding light pipe by means of a silicon pad. The Wangs were responsible for the bulk of this work.

In photograph 3, Ms. Wang is exhibiting the individual members of the M4 hodoscope. At the time this photograph was taken Ms. Wang had just completed the assembly of the counters and was preparing them for testing. In photograph 4, Zhi-fu Wang is standing in front of the veto detectors, which had just been installed by the Wangs. This installation had been a bit troublesome in that the counters had required extensive repair and testing prior to installation.

In photograph 5, Ms. Wang is shown testing the gas system for the LSTs. The entire gas handling system was assembled and rendered operational by the Wangs. Photograph 6 was taken in the counting house, and it shows Dr. Wang wiring the fast electronics.

In photograph 7, Ms. Wang is shown busily engaged in everyone's favorite activity, cable pulling. Together the Wangs strung more than 700 cable.

Photograph 1

Photograph 2

Photograph 3

Photograph 4

Photograph 5

Photograph 6

Photograph 7

The Wangs spent the month of June at BNL. Their stay was prematurely terminated when they were, somewhat unceremoniously in our view, booted out of their rooms in order that the housing office might honor previous reservations. Fortunately, by that time the ranks of the experimenters had been replenished by persons returning from the quark-matter conference and the meeting of the collaboration in Lund, and data acquisition proceeded smoothly.

It is not necessary that the reader take the author's word in regard to the extent of the Wangs' contribution to this effort. For years, after the Wangs have completed every major assignment, I have requested an evaluation of their performance from the person most closely associated with them during the execution of the task, assuming, of course, that this person is someone other than me. This assignment was no exception. In July, I requested an evaluation of the Wangs' performance from Mr. Kreke, and I am enclosing with his permission the complete and unedited text of his response.

From: ORPH01::KREKE "Joseph G. Kreke " 22-JUL-1991 09:39:36.98
To: PHEPDS::KIRK
Cc: KREKE
Subj: evaluation of the Wangs

Dear Paul,

Sorry it has taken me so long to get back to you on this. I hope I haven't inconvenienced you too much with such a late response. As you know, it's a real burden when someone working for you is lazy or unenthusiastic and a real pleasure when that worker takes the initiative to get things done. Zhi-fu and Ying-Chao by far fall into the latter category. I asked them to help with many jobs and all of them were done with a great degree of skill and enthusiasm and always in a timely manner. The major jobs they worked on were the Veto counter, the gas system for the LSTs, M0, continuity checks of all MuID channels (and repair), and last but not least, cable-pulling. Their efforts on all these tasks were first-class and I would recommend their work to anyone. I look forward to working with them again.

As to their early departure, I'm not certain why. I think it had something to do with dormitory reservations running out. Toward the end of June all of the hardware was in place and the only items remaining were getting the DAQ up and getting the trigger electronics timed in. By that time Glenn Young and Xiaochun He had them under control and we had more than enough people to help with small last-minute jobs so I saw no reason to ask the Wangs to stay longer. When data taking started, we had at least three persons on each shift and with several people overlapping shifts we often had 5-6 there. I'm sure that if I had asked them to stay they would have but, again, we had plenty of helpers.

Thank-you for providing the Wangs to the project. They were a great team to work with.

Kind regards,

Joe Kreke

The Wangs were in Baton Rouge for less than two days before departing for their next assignment in Los Alamos. They were posted to Los Alamos from July 5 through November 20 in order to build a prototype for the drift chambers that are currently being considered for use as the active element in the muon tracker. While they were in Los Alamos they worked principally with the previous leader of the muon subgroup, Dr. Pat McGaughey, and the present leader of the muon subgroup, Dr. Wayne Kinnison.

Various members of the IENPG have been building drift chambers for years. For example, the front drift chambers that were used with such success throughout the entire lifetime of the Di-Lepton-Spectrometer were designed by the author; built by the Wangs' predecessors, Ms. Xu In-hua and Mr. Steve Christo; and maintained over all these years by present and past members of this group. For this reason the task was a familiar and pleasant one for the Wangs. If drift chambers of conventional design should, in fact, be selected by the collaboration as the technology of choice for the active elements of the muon tracker, the IENPG will be uniquely positioned to contribute to the construction and commissioning of the muon tracker.

The response of the drift chamber had been previously simulated by Dr. Pat McGaughey. Shortly after the Wangs' arrival at LANL, Dr. McGaughey delegated to them the responsibility for designing and constructing the prototype. The prototype comprised six sense planes that we denote in conventional notation by U, U', V, V', and Y, and Y'. The active area of each plane was 30 cm $\times$ 30 cm. The spacing between sense wires was 2.00 cm so that there were 15 sense wires per plane. The spacing between wires in the cathode was 5.00 mm, and the spacing between anode and cathode planes was 1.00 cm. Wires of different orientation were separated by aluminized mylar, so that the prototype might be regarded as an assembly of three smaller chambers, the U-U' chamber, the V-V' chamber, and the Y-Y' chamber. The entire prototype was contained within an aluminum box of dimensions 80 cm $\times$ 60 cm $\times$ 50 cm.

On the following pages we exhibit a series of photographs in which the Wangs are shown working on the prototype in various stages of its development. In photograph 8, Dr. Wang is shown at his desk designing the chamber. In photograph 9, Ms. Wang is shown in the electronics shop at LAMPF soldering some surface mount components onto one of the frames. Unfortunately the wires are too small to be visible, but they were soldered into place before

the components were added.

Photograph 10 was also taken in the electronics shop at LAMPF. Ms. Wang is shown gluing some connectors for ribbon cable onto the cover of the gas box. Photograph 11 was taken in the testing room of the P2 group at LANL and shows Ms. Wang cleaning one of the frames before inserting it into the gas box.

Photograph 12 shows Ms. Wang standing before the complete assembly. The input and output for gas are visible and located a few inches to the viewer's left of Ms. Wang's right hand. Patch panels for high voltage cable and ribbon cable may also be seen on the top cover. Photograph 13 shows the interior of the assembly. Actually, at the time this photograph was taken the prototype included only the U, U', Y, and Y' planes because the circuit boards that were required for the completion of the V and V' planes had not been delivered by the vendor.

In photograph 14, Dr. Wang is shown writing the software that will be required for calibrating the TDCs and testing the prototype. The photograph was taken in the testing room of the P2 group at LANL. Finally, in photograph 15, Ms. Wang is shown at the console in the counting house of the High Resolution Spectrometer (HRS) at LANL. The final test of the prototype will take place in facilities provided by the HRS, and the results of the test will determine whether we use drift chambers of conventional design or cathode strip chambers in the muon tracker.

Photograph 8

Photograph 9

Photograph 10

Photograph 11

Photograph 12

Photograph 13

Photograph 14

Photograph 15

Because of the high quality of their work, the Wangs attracted considerable attention at LANL, as they always do, and we include below the evaluation of their performance by Dr. Pat McGaughey of LANL. His evaluation is complete, unedited and included in this report with his permission. We call the reader's attention to the concluding sentence in the third paragraph of Dr. McGaughey's letter. The Wangs work with such speed that they were able, while simultaneously designing and assembling the drift chamber of conventional design, to contribute substantially to the development of the cathode strip chamber!

From: P2VAX::PLM 22-NOV-1993 17:17:14.45
To: PHEPDS::KIRK
CC:
Subj: Wang visit summary

Dear Paul,

Here is my summary report on the Wang's visit to Los Alamos:

Zhi-Fu and Ying-Chao Wang were stationed at Los Alamos National Laboratory for approximately five months in 1993, starting in early July and ending in late November. During this period we planned to have them design, construct and possibly test a drift chamber prototype detector for the PHENIX muon arm.

In less than one month the Wang's completed the mechanical drawings of the detector and a gas-tight enclosure. These were transmitted to the engineers who, working together with the Wang's, converted them into CAD designs, which were then sent out for construction. While waiting for these components to arrive, the Wang's assembled hardware and software for a couple of data acquisition systems to test chamber prototypes. They also provided a considerable amount of help in setting up a cathode strip readout detector at LAMPF.

After the mechanical components arrived, Zhi-Fu and Ying-Chao had them cleaned and began the assembly process. Working together with technicians at LAMPF, they oversaw the winding of the wire planes and construction of the ground foil planes. Next, they attached the various electrical components to the wire planes. Finally, the wire and ground planes were stacked and checked for electrical problems. At that time, the Wang's returned to LSU, leaving behind the assembled detector, which is ready for testing.

I consider the Wang's visit to have been very successful and essential for the completion of this project. They required only a small amount of oversight and worked well with a large number of people. Each time they were running short of work, they volunteered for more. It was unfortunate that they were unable to complete the testing of the prototype detector. But this was due to delays in obtaining the printed circuit boards which were beyond their control. We look forward to the Wang's return early next year, when we expect them to play an important role in the next phase of R+D for the PHENIX muon arm tracking system.

Thanks again for making it possible for them to come to Los Alamos.

Sincerely,

Patrick L. McGaughey

An examination of the record, then, shows that the IENPG has already contributed substantially to the activities of the muon subgroup of PHENIX despite the relatively brief interval of time in which we have focussed our efforts primarily on PHENIX. Actually, an examination of the record will show more than this; it will show that we have established an enviable record of achievement that antedates our membership in PHENIX by many years. As just one example of these achievements, we shall cite one of our contributions to the AMY Collaboration at KEK.

Although the AMY Collaboration is less than one-third the size of PHENIX, it was the largest collaboration with which we were ever affiliated prior to the time we joined PHENIX. Despite the small size of our group we made several major contributions to AMY, the most recent of which was impressive indeed.

As part of a major upgrade the AMY Collaboration decided to add so-called "front tracking chambers" (FTC) to the interior of the magnet. A postdoctoral research assistant at the University of Rochester accepted responsibility for the design and construction of the FTC, and, initially at least, we participated in the project primarily as loyal colleagues and workers. To the considerable misfortune of the AMY Collaboration, the postdoctoral research associate resigned his position to accept an assistant professorship, and we found ourselves suddenly and unexpectedly thrust into the spotlight. The construction of the FTC had been completed prior to the departure of the postdoctoral research associate, but the design and construction of the preamplifiers was not even underway. We accepted the responsibility for developing the preamplifiers under adverse conditions but managed to build them in record time. It was, in my opinion, the finest technical achievement of this group.

Only nine months remained until installation, a coincidence which provoked a number of obvious and tasteless jokes. In addition the preamplifiers were constrained to fit into the tiny annular volume that surrounded the outer circumference of each chamber. To compound our problems the same circuit board that was used to bus signals from the chamber was used to bus high voltage to the chamber, so that the resulting circuit boards were everywhere dense in components, traces, and circuitry for testing and calibrating the preamplifiers.

The constraints were tight; the time, short; and our tempers, frayed; yet in the following nine months we managed to design, to build, to test, and to ship approximately 1850 of the

preamplifiers, and they are still in use to this day. We reported our progress to the grant monitor in the progress report that we submitted in 1991, and we shall include a portion of that discussion below.

The text between this point and the row of asterisks below has been extracted verbatim from an earlier progress report and will therefore be familiar to the grant monitor.

Ongoing Activities of the IENPG

In this section of our progress report we shall describe the achievements of the group during the year that has elapsed since the submission of last year's progress report. In order to avoid repeating discussion that appeared in last year's report we shall refer the reader to specific sections of that report for details.

(a) development of a sensitive new preamplifier

Our participation in the AMY Collaboration was described in section (d) of last year's progress report which begins on page 27. The fast preamplifiers described therein were installed in the AMY apparatus in late April and early May, 1991. Despite a shortage of manpower at KEK that is approaching critical proportions, the amplifiers were gradually brought on line by a team of eager but untrained graduate students. We are happy to report that as of October 24, 1991, the preamps were being used successfully under actual experimental conditions during the current data-logging run.

This project is already successful, and it is regarded as such by our colleagues as we shall soon demonstrate. However, in the case of this specific project successful operation is not enough. Perfection is within easy reach; and at least one member of the group, Dr. Zhi-fu Wang, will return to KEK in January to address the remaining problems, which are minor but admittedly troublesome. Included below is the complete text of a message that we recently received from Dr. Robert Walker, who is currently in Japan. The message is unedited, but we have used boldface type for emphasis.

From: KEKVAX::RCW
"Robert C. Walker, AMY Group, KEK" 24-OCT-1991 13:47:15.57
To: PHEPDS::KIRK
CC: PHEPDS::WANG, URHEP::ALANSILL,RCW
Subj: Future post-doc work on the FTC.
Paul:

I've talked to the people here, and the idea of having Zhi-fu come to Japan again (if he doesn't object too strongly to the idea of having to apply for a visa again!) has been met with a very positive response. Specifically, he's talents would be most useful for:

1. Repairing some of the electronics that are not working.
2. There are some dead channels (the number ranges from 20-100/side, depending on the date and how "dead" is defined) that the people here have not been able to repair. The general feeling is that the "Wizard of LSU" could get these working in no time at all, and we could have the FTC in tip-top shape in January.

3. Alan has been floating the idea of fixing the ground loop problem between the calgate and preamp grounds on the preamp boards. I'm personally opposed to the idea, but I think it is something we all need to discuss and reach a decision.

As far as the present status of the FTC is concerned, I don't have anything new to report (we are getting beam now, by the way), except to say that things are generally in very good working order, and I hope to be able to report some greater concrete evidence of tracks before I leave. The only significant problems are 3 +HV lines that were damaged on Tsukuba side (1050-100 electronically dead channels/side (either dead because of preamp/postamp problems or calgate problems), and that the calibration system is not yet working, so we can't convert TAC counts to drift times yet. Online scanning of the FTC looks very promising, however.

A good time for Zhi-fu's trip would be sometime in January. I think it might be a good idea for either myself or Alan to come at the same time too, and we can finish up on the FTC hardware once and for all!

Bob

We would like to call the reader's attention to the phrase "Wizard of LSU" which appears in item #2 of Dr. Walker's list. The phrase refers, of course, to Dr. Zhi-fu Wang, and in my opinion it is singularly appropriate. I have no idea whether or not the DOE has ever wondered what it receives in return for Dr. Wang's salary, but if so I think this unsolicited endorsement of Dr. Wang should dispel all doubts. The "Wizard of LSU" as he is known at KEK, makes quite a name for himself wherever he goes.

The comment about "ground loops" that appears in item #3 of Dr. Walker's list refers to the existence of a small amount of noise that appeared when the amplifiers were assembled in mass and operated as a complete system. It was necessary to increase the threshold to the discriminator from 1.0 volts to 1.3 volts in order to suppress the noise. Dr. Walker believes the problem is too minor to worry about, and there is much to recommend this point of view. We set the thresholds to 1.0 volts during bench tests when a single board was operated in a benign environment and in isolation from other amplifiers. We would be astonished if this setting could be achieved under actual experimental conditions. Dr. Sill has a different point of view, though, and we must resolve our differences within the immediate future.

As mentioned in the paragraph that begins at the bottom of the preceding page, the system is in "very good working order", and is currently in use during an actual data logging run. Approximately 5% of the channels are either dead or functioning less than perfectly, however, and we see no reason to accept this degradation in the quality of the system. Our plans are to complete all work on the system in January, 1992.

Our affiliation with the DLS Collaboration at LBL is of even longer duration than our affiliation with AMY, and over the years we have contributed repeatedly and significantly to the success of the DLS. Because such a large portion of our energy and effort over the years has been devoted to the DLS, we shall cite in this report several examples of our contributions.

By the standards of PHENIX, or even AMY, the DLS Collaboration was, and is, tiny. We acknowledge that the ability to function successfully within the context of a small collaboration is no guarantee of successful functioning within the context of larger collaborations with their complex sociologies. Our purpose in citing contributions to the DLS is not to establish this point. To the contrary, we contend that our experience with the AMY Collaboration shows clearly that we have functioned successfully within a large collaboration and that we continue to do so. The purpose of these examples is to establish the existence of a track record that is both strong and long, and, in conjunction with the examples cited previously, to establish our fundamental technical competence.

Within the last year analysis of data logged on the DLS revealed an inefficiency in one of the Cherenkov counters. The inefficiency was attributed to a misalignment of mirrors, and the collaboration saw no alternative to opening the counter and checking the alignment. As some of the readers are doubtless aware, aligning mirrors is a thankless task. It requires patience, attention to detail, and skill in the manipulation of the lasers. The Wangs were dispatched to LBL to carry out the tests, and although this assignment required less than two weeks of time I requested an evaluation from Dr. James Carroll, of UCLA, upon their return. Dr. Carroll replied with characteristic cogency, and his complete and unedited response is included below with his permission.

From: LBL:"carroll" 19-APR-1993 15:59:08.84
To: ST%"kirk@phepds.span"
CC: CARROLL
Subj: RE: everything OK ?

Hi Paul

Everything went just as I have come to expect from ZhiFu - perfectly smooth. Please thank him/them for me, I didnt see them the morning they left. I assume he will tell you about the mysterious mirror-pair.

Jim

Perhaps it would be useful for us to comment on the curious phrase "him/them" that appears in Dr. Carroll's message. Although Zhi-fu Wang speaks English well, Ying-chao does not.

She can, on occasion, make herself understood, but her comprehension of rapidly spoken English is non-existent. She interacts with the English speaking world through Zhi-fu, and most of our colleagues have never conducted a single conversation with Ying-chao. For this reason it is no surprise that all the letters of evaluation contained in this report refer principally to Zhi-fu, but Ying-chao can and does perform admirably. She carries more than her fair share of the load, and we are anxious that her contributions to the group be recognized at this time.

We have already mentioned the design, construction, and maintenance of the front drift chambers in the DLS, and we shall cite these chambers as our final example of technical competence. There were two of these chambers, and they were among the most reliable and dependable instruments in the spectrometer despite their proximity to the target and their exposure to high fluxes of incident particles. The chambers worked reliably throughout the lifetime of the spectrometer, and it is appropriate, in our opinion, to ask why.

Instruments do not function reliably for years at a time for no reason. Such performance does not just happen. We contend that, in the long term, reliability is the product of design, and we have no hesitation in asserting that the front chambers in the DLS worked reliably for so long because the members of this group, both past and present, made it happen.

As one example of the steps that we took to ensure the proper functioning of our chambers we cite our experience with the LeCroy edge cards. As the readers may perhaps be aware the first edge cards produced by LeCroy were not troublefree. The nature of the problem that we encountered is described in considerable detail below. In response to the problem the author devised a simple procedure that produced startling results, and it was precisely because of procedures such as this that the front drift chambers functioned so well. We described the procedure to the DOE in our progress report for 1990, and we include a portion of that description below.

The text between this point and the row of asterisks was included in a previous progress report and will therefore be familiar to the grant monitor.

(b) testing and selection of PCOS amplifiers

Two paragraphs above we alluded to experience with the PCOS III amplifiers that are used

to process signals from the drift chambers in the DiLepton Spectrometer (DLS) at LBL. As the reader may perhaps have inferred, our experience with this system, initially at least, was not altogether satisfactory.

Although the PCOS III system is commonly used throughout this country and Europe, almost everyone who uses them has problems. First, it has been almost everyone's experience that if the low voltages are set to the recommended value, ± 5.00 volts, then the amplifiers will oscillate no matter how fine the power supplies may be and no matter how well filtered the input lines may be. Second, after connecting a group of amplifiers to the wires in one of the chambers, we found it difficult and frequently impossible to find a single value for the threshold voltage at which every amplifier in the group functioned properly. For example, at some nominal value for threshold voltage a portion of the amplifiers would work properly and efficiently, but other amplifiers would be inefficient. In order to bring the inefficient amplifiers into efficient operation we would lower the threshold voltage only to discover that the previously efficient amplifiers began to oscillate.

It is possible to solve this problem by maintaining a high threshold voltage and by increasing the high voltage supplied to the chamber accordingly. For many months this was the solution adopted by our collaboration. Unfortunately this solution has undesirable consequences, such as an increase in the multiplicity of hits and a decrease in the lifetime of the chamber itself.

The IENPG decided to devise a procedure for selecting amplifiers with similar characteristics. Our objective was to mount similar amplifiers on the same card and to use groups of similar cards on a chamber. This selection procedure was tedious but conceptually simple, and it was carried out at LSU by Mr. Mao.

The first step was to choose a value for the amplitude of the output pulse from a signal generator. This was done by arbitrarily selecting one amplifier as a standard for calibration. The low voltages applied to the standard amplifier were set to ± 5.00 volts, and the threshold voltage was set to 2.00 volts. The output of the signal generator, after appropriate attenuation and shaping, was connected to the input of the standard amplifier, and the amplitude of the pulse was slowly increased from zero. When the amplitude of the pulse reached some minimum value the standard amplifier began to fire, and at a slightly higher amplitude the

standard amplifier fired with an efficiency of 100%. We shall denote the smallest amplitude at which the standard amplifier was fully efficient by the symbol A_s . According to the literature supplied by Letroy, when the amplitude of the output pulse from the signal generator was fixed at A_s , the current being supplied to the standard amplifier was 4.0 ± 0.8 microamps. The amplitude of the output pulse from the signal generator was fixed at A_s for the entire duration of the selection procedure.

After the amplitude of the output pulse from the signal generator was fixed, all amplifiers, including the standard one, were subjected to the same sequence of steps. First, the magnitude of the positive low voltage was decreased from 5.00 volts to 4.75 volts. The reduction in voltage was necessary in order to decrease the noise to a tolerable level. Because the magnitude of the positive low voltage also controls the gain of the amplifier, the decrease in voltage caused the amplifier being tested to stop responding to the input current. We then slowly lowered the threshold voltage until the amplifier being tested was once again fully functioning. This value of threshold voltage, which we shall label V_h , was recorded. Then the threshold voltage was lowered again until finally, at some value which we label V_l , the amplifier being tested began to oscillate. The range of threshold voltages, V_t , that satisfied the inequality $V_l \leq V_t \leq V_h$ was the range in which the amplifier being tested responded to currents of 4 microamps with full efficiency but without oscillation.

In what must be regarded as an act of either heroism or masochism Mr. Mao tested all 760 amplifiers in the group connected to the front drift chambers and recorded V_h and V_l for all of them. Many amplifiers had no acceptable range of operation at all, by which we mean that V_l was larger than V_h . These amplifiers were retired from use. Some amplifiers had ranges of acceptable operation that hardly overlapped at all with others. Nonetheless, as a consequence of Mr. Mao's efforts, we were able to select a single value of V_t at which all the remaining amplifiers functioned properly.

This effort was spectacularly successful. Indeed, it will be a long time until we enjoy a comparable success. In May, 1990, we were able to demonstrate our success quantitatively during two weeks of running that were devoted exclusively to the study of the MWPC and the testing of the liquid hydrogen target.

On the pages that follow we exhibit seven graphs. Each of these graphs corresponds to one

of the seven planes of wires in the left front drift chamber. The ordinate on each graph is the probability for an accidental coincidence anywhere on the plane expressed in percent. The abscissa on each graph is the threshold voltage. We think the reader will agree that the results are striking, and perhaps we should discuss briefly the significance of these results.

In case some of the readers might be interested we shall include in this report one of the seven graphs mentioned above. The others are available on request.

In summary, then, we contend that we have already established a place for ourselves in the PHENIX Collaboration, and in response to the first of the questions that were posed in the Introduction we assert that not only are we capable of contributing to PHENIX, we already have. We also contend that an examination of the record provides abundant confirmation of our technical skills, our prior experience in large collaborations, and our knowledge of what must be done in order to ensure the long term reliability of the instruments for which we might be responsible.

The strength of the group is difficult to miss in my opinion. By any reasonable standard this group is very strong in terms of instrumentation. On the other hand there is one significant weakness that must surely also be evident, and that weakness is in some areas of computational physics.

Although every member of this group without exception is competent in the use of FORTRAN, experimental physics has evolved to the point where this level of competence is no longer adequate or even acceptable. A basic competence in skills and areas of knowledge that I might loosely call "file manipulation" and "computer architecture" has become as essential to the practice of the profession as the experimental skills that we already possess in abundance. It has been clear to the author for years that we must broaden the base of competence of this group. As the grant monitor will surely verify we have discussed this problem in every progress report and every renewal proposal that we have submitted for years, and we shall do so once again in 1993.

We have already taken on our own the first steps toward the goal of broadening the base of this group's competence. Indeed, the process of Grand UNIXification is well underway in

the IENPG. The author has developed, with some degree of difficulty to be sure, sufficient skill in the use of UNIX and the EMACS text editor that he rarely even logs on to the group's VAXstation any longer. We have announced to our colleagues our intention, and perhaps determination would be a better word, to participate in the development of off-line software for PHENIX. To this end we have purchased a SUN LX workstation, learned UNIX, and will soon turn our attention to GEANT and PISA, which is the simulation package for PHENIX. We have additional proposals in mind, but since they pertain to future, rather than to past, developments perhaps we should conclude this progress report and direct the reader's attention to the accompanying renewal proposal.

Figure 9

Reports

- DOE/ER/40445-1 Measurements of R and a Search for Heavy Quark Production in e^+e^- Annihilation at $\sqrt{s} = 50$ and 52 GeV, E. Sagawa, et al., Phys. Rev. Lett., **60**, 93. (1988).
- DOE/ER/40445-2 Search for Isolated Leptons in Low-Thrust e^+e^- Annihilation Events at $\sqrt{s} = 50$ and 62 GeV, S. Igarashi, et al., Phys. Rev. Lett., **60** 2359. (1988).
- DOE/ER/40445-3 Experimental Mass Limit for a Fourth-Generation Sequential Lepton from e^+e^- Annihilation at $\sqrt{s} = 56$ GeV, G. N. Kim, et al., Phys. Rev. Lett., **61** 911 (1988).
- DOE/ER/40445-4 First Observation of Dielectron Production in Proton-Nucleus Collisions below 10 GeV, G. Roche, et al., Phys. Rev. Lett., **61** 1069 (1988).
- DOE/ER/40445-5 Progress Report, December 1988.
- DOE/ER/40445-6 Measurements of cross sections and charge asymmetries for $e^+e^- \rightarrow \tau^+\tau^-$ and $e^+e^- \rightarrow \mu^+\mu^-$ for $\sqrt{s}$ from 52 to 57 GeV, A. Bacala, et al., Phys. Lett., **B281**, 112 (1989).
- DOE/ER/40445-7 Design of the BEVALAC Heavy Ion Spectrometer System and its performance in Studying ^{12}C Fragmentation, J. Engelage, et al., Nucl. Instru & Meth in Phys. Res., **277**, 431 (1989).
- DOE/ER/40445-8 Measurements of the e^+e^- Total Hadronic Cross Section and a Determination of M_Z and $\Lambda_{\overline{MS}}$, T. Mori, et al., Phys. Lett, **B218**, 499 (1989).
- DOE/ER/40445-9 Subthreshold Antiproton Production in $^{28}\text{Si} + ^{28}\text{Si}$ Collisions at 2.1 GeV/B/Nucleon, J. B. Carroll, et al., Phys. Rev. Lett., **62**, 1829 (1989).
- DOE/ER/40445-10 Threshold Behavior of Electro Pair Production in p-Be Collisions, C. Naudet, et al., Phys. Rev. Lett., **62**, 2652 (1989).
- DOE/ER/40445-11 Search for the Substructure of Leptons in High Energy QED

- Processes at TRISTAN, S. K. Kim, et al., Phys. Lett., **B223**, 476 (1989).
- DOE/ER/40445-12 Dielectron Production in Ca + Ca Collisions at 1.0 and 2.0 A GeV, G. Roche, et al., Phys. Lett. **B226**, 228 (1989).
- DOE/ER/40445-13 Experimental Evidence for the Non-Abelian Nature of QCD from a Study of Multijet Events Produced in e^+e^- Annihilations, I. H. Park, et al., Phys. Rev. Lett, **62**, 1713 (1989).
- DOE/ER/40445-14 Mass and Transverse Momentum dependence of the Dielectron Yield in p -Be Collisions at 4.9 GeV, A. Letessier-Selvon, et al, Phys. Rev. **C40**, 1513 (1989).
- DOE/ER/40445-15 Search for Unstable Heavy Neutral Lepton in e^+e^- Annihilations at $\sqrt{s}$ from 50 to 60.8 GeV., N. M. Shaw, et al., Phys. Rev. Lett., **63**, 1342 (1989).
- DOE/ER/40445-16 Comparison of Quark and Gluon Jets Produced in High Energy e^+e^- Annihilations, Y. K. Kim, Phys. Rev. Lett., **63** , 1772 (1989).
- DOE/ER/40445-17 Search for a Fourth-Generation Charge - 1/3 Quark, S. Eno, et al., Phys. Rev. Lett., **63** ,1910 (1989).
- DOE/ER/40445-18 Subthreshold Antiproton, K^- , K^+ and Energetic-Pion Production in Relativistic Nucleus-Nucleus Collisions, A. Shor, et al., Phys. Rev. Lett., **63**, 2192 (1989).
- DOE/ER/40445-19 Measurement of $e^+e^- \rightarrow b\bar{b}$ Forward-Backward Charge Asymmetry between $\sqrt{s} = 52$ and 57 GeV., H. Sagawa, et al., Phys. Rev. Lett., **63**, 2341 (1989).
- DOE/ER/40445-20 Midrapidity π^-/π^+ Ratios in 10.5 GeV/nucleon $^{40}\text{Ca} + ^{40}\text{Ca}$ Collisions, J. W. Harris, et al., Phys. Rev. C, **41**, 2675 (1990).
- DOE/ER/40445-21 The Di-Lepton Spectrometer, A. Yegneswaran, et al., Nucl. Instrum. & Meth. A, **290**, 61 (1990)
- DOE/ER/40445-22 Progress Report, December 1989

- DOE/ER/40445-23 Forward-Backward Charge Asymmetry in $e^+e^- \rightarrow$ Hadron Jets, D. Stuart, et al., Phys. Rev. Lett., **64**, 983 (1990).
- DOE/ER/40445-24 Multihadron-Event Properties in e^+e^- Annihilation at $\sqrt{s} = 52-57$ GeV, Y. K. Li, et al., Phys. Rev. D, **41**, 2675 (1990)
- DOE/ER/40445-25 A Search for Susy Particles in e^+e^- Annihilation at $\sqrt{s} = 50-60.8$ GeV, Y. Sakai, et al., Phys. Lett. B, **234**, 534 (1990).
- DOE/ER/40445-26 A Search for Lepto Quark and Colored Lepton Pair Production in e^+e^- Annihilations at Tristan, G. N. Kim, et al., Phys. Lett. B, **240**, 243 (1990).
- DOE/ER/40445-27 Observation of Anomalous Production of Muon Pairs in e^+e^- Annihilation into Four-Lepton Final States, Y. H. Ho, et al., Phys. Lett. B, **244**, 573 (1990).
- DOE/ER/40445-28 Mass Limits of Charged Higgs Boson at Large $\tan(\beta)$ from e^+e^- Annihilations at $\sqrt{s} = 50 - 60.8$ GeV, J. R. Smith, et al., Phys. Rev. D, **42**, 949 (1990).
- DOE/ER/40445-29 Measurements of R for e^+e^- Annihilation at the KEK collider TRISTAN, T. Kumita, et al., Phys. Rev. D, **42**, 1339 (1990).
- DOE/ER/40445-30 Progress Report, December 1990
- DOE/ER/40445-31 Measurement of Low Mass Dielectron in Niobium-Niobium Collisions at 1.05 AGeV, S. Beedoe, et al., submitted to Phys. Rev. C, 1991.
- DOE/ER/40445-32 Ratio of Dielectron Yields in p+d and p+p Collisions at 1.0 and 4.9 GeV Energies, H.Z. Huang, et al., submitted to Phys. Rev. Lett., 1991.
- DOE/ER/40445-33 Measurements at 0° of Negatively Charged Particles and Antinuclei Produced in 14.6 A GeV/c Si + A Collisions, M. Aoki, et al., submitted to Phys. Rev. Lett., 1991.
- DOE/ER/40445-34 Progress Report, December, 1991.
- DOE/ER/40445-35 Evidence for Hard Scattering of Hadronic Constituents of Photons in Photon-Photon Collisions at TRISTAN, R. Tanaka, et al., Phys. Lett. B, **277**, 215 (1992).

DOE/ER/40445-36	Mass Dependence of Pion Production in Heavy Ion Collisions Near, but Below, Threshold, J. Miller, et al., Phys. Lett. B, 314 , 7 (1993).
DOE/ER/40445-37	Relative Dielectron Yields in p+p and p+d Interactions for $E_{\text{beam}} = 1.0$ to 4.9 GeV, W.K. Wilson, et al., Phys. Lett. B, 316 , 245 (1993).
DOE/ER/40445-38	Progress Report, December, 1992.
DOE/ER/40445-39	Dielectron Yields in p+d and p+p Collisions at 4.9 GeV, H.Z. Huang, et al., Phys. Lett. B, 297 , 233-237 (1992).
DOE/ER/40445-40	Measurement of Dielectron Production in Niobium-Niobium Collisions at 1.05 GeV/nucleon, S. Beedoe, et al., Phys. Rev. C, 47 , 2840 (1993).
DOE/ER/40445-41	Search for Anomalous $\gamma\gamma$ Production at TRISTAN, K.L. Sterner, et al., Phys. Lett. B, 303 , 385 (1993).
DOE/ER/40445-42	Measurement of α_s , From the Moment of Particle Momenta Within Jets from $e^+ - e^-$ Annihilation, K.B. Lee, et al., Phys. Lett. B, 313 , 469 (1993).
DOE/ER/40445-43	Progress Report, December, 1993.

DATE

FILMED

1 / 26 / 94

END