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FINAL REPORT

Contract and Grant: Continuation of Support for the Intercampus Institute for Research at Particle Accelerators

1977 to 1995

This is the final report to the DoE for the *Intercampus Institute for Research at Particle Accelerators*, or IIRPA, at least for the San Diego branch. Over the years that DoE supported IIRPA, we were told that yearly reports (and the final report) were not necessary because the previous year's summary in our annual request for funds constituted those reports. Therefore, it has taken some effort, and a corresponding long time, to put something together, after the fact. I apologize for the long delay.

The IIRPA was born as an idea that arose during discussions at the 1974 PEP summer study (SLAC/LBL), and began to be funded by DoE during the early stages of PEP detector design and construction. The intent was for the members of the Institute to be responsible for the *PEP-9 Facility*; all of the PEP experiments were supposed to be facilities, rather than just experimental setups for a particular group or research goal. IIRPA was approved as a Multicampus Research Unit (MRU) in 1977 by the University of California, and it was active on the UCD, UCSB and UCSD campuses for 10 years. The UCSB and UCSD branches continued to work together from 1987 to the termination date (1995) while the UCD branch went in a different direction. This report concentrates on the period of time when the Directorship of IIRPA was once again at the San Diego campus, 1989 to 1995.

The collection of yearly reports make up the appendices A through F, and Appendix G is the letter from me to the Office of the President which officially terminated IIRPA. The major publications, for which the members of IIRPA made significant contributions, are listed in Appendix H. It is a record to be proud of, and I thank those hard working IIRPA people who made it possible.

Following the termination of support by DoE, the Physics Department at UCSD would provide no advice or support for the tenure research appointment staff (two positions), but the staff of the IPAPS office, who had taken over administration of the contract, worked exceptionally hard to ease that transition. All of the IIRPA members are deeply appreciative of that effort.

Submitted: September 22, 1997

By: Wayne Vernon
Research Professor

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APPENDIX A

Intercampus Institute for Research at Particle Accelerators

– 1988 Yearly Report –

by Wayne Vernon, Director

1. Overview.

The Intercampus Institute for Research at Particle Accelerators (IIRPA) is devoted to helping UC experimental high energy researchers to work on large collaborations at central facilities such as the Stanford Linear Accelerator Center (SLAC). In previous years IIRPA has functioned as a coordinating body for the UC groups working on the two-photon aspects of the TPC/Two-Gamma experiment at PEP (an e^+e^- colliding beam facility); the DOE supported members of the institute at present are Alan Eisner, Mike Sullivan and Yao-Xun Wang. We will continue the PEP operation in the coming year with the initiation of the high luminosity running, and we will embark on a new mission as a coordinating center for calorimetry development at the Superconducting Super-Collider (SSC). The two-photon part of the collaboration will pursue new goals because of the expected large data set, and we also look forward to working on other new physics opportunities at PEP.

The upcoming era at PEP includes the commissioning of a new vertex detector inside the TPC wherein short lived objects such as B mesons and τ leptons may be identified by reconstructing their vertex locations. This combination of copious production of moving B mesons and improved detection capability will make the TPC/Two-Gamma experiment at PEP a most exciting place to be this coming year. So far this year we have operated the experiment for two months, November and December, and are expecting to start operations again this spring.

It seems very natural for the IIRPA to assume a new role as SSC detector development coordinator for those areas in which institute members are taking a leading role. The initial example of such an emerging area is to be found in the evolution of the "Spaghetti Calorimeter" where several groups may agree to have Hans Paar at UCSD coordinate the many activities related to this exciting development. We are asking that the DOE support a new, administrative position in the Institute to help Prof. Paar coordinate, monitor and assist in the distribution of funds and in the exchange of ideas for the Spaghetti Calorimeter effort. The Dean of Graduate Studies, the Dean of Natural Sciences and the Physics Department have contributed some special startup support toward this effort to increase the role played by UCSD in the development of SSC detectors.

There is another area where IIRPA ought to play a role: helping its members share communications resources and helping to solve common network problems. In the coming year we will have to increase our data analysis activities by moving some of the effort to the UC campus computers simply because there is insufficient VAX capacity to be had at SLAC and LBL. Several indirect subsidies at the campuses make it attractive to use their facilities provided that we have learned how to use video tape cartridges and that we have been able to maintain reliable network links so that central software and files are available. We asked DOE for support of a fraction of a person to maintain and improve the network connections between campuses and the centers at SLAC and LBL; these links also provide the connection to the ESNET backbone which will be increasingly important for SSC detector development work. The DOE response to this request was to not fund it, but to encourage us to keep trying because there will probably be some funds made available for such activities in another year or two.

2. Last Year's Activities.

The Institute researchers divided their time last year between the completion of several publications of interesting physics results and the preparation for the high luminosity running which is now starting. In Appendix A there is a listing of the work which has been published since the last IIRPA proposal to DOE. As can be easily seen from the length and quality of the publication list, the collaboration continues to be very productive. There are still a few major projects, such as the completion of the photon structure function analysis, which remain from the previous data-collecting runs, but most of the analysis goals of two years ago are completed.

At the end of the previous contract year (Dec.'87 and Jan.'88) IIRPA organized a meeting of potential collaborators to discuss SSC detector development. The meeting was jointly sponsored by IIRPA and the Physics Department and was held January 18, 1988 at UCSD and attended by people from four other UC campuses (UCD, UCI, UCR and UCSB), Los Alamos and Livermore; Gil Gilchriese from the SSC Central Design Group also attended. There was enough interest shown at the meeting to encourage us to make a proposal to the UC program entitled "INCOR" which is intended to help the Labs (LLNL and LANL) and researchers on UC campuses work on joint projects. We did not learn quickly enough what was needed to compete successfully in that round of proposals. In the meantime, we have found several interesting possibilities for SSC detector development collaborations at the national labs; we also found out that the President's Office of UC does not have the development of SSC detectors as that office's highest priority.

3. Future Activities.

Most of the effort of the IIRPA members must be directed toward the collection and analysis of data from the PEP running of the present and next contract year. The opportunity for doing very exciting physics must be pursued diligently, and we plan that several new students and young research people will be added to the collaboration in the next few months. In order to do the analysis in a timely fashion we will need more computing capability than is presently available in one spot; use of a total of 50 VAX-780 equivalent computers spread around the state will require better network links than we have at present. Our plan is that IIRPA take on the role of helping collaboration members improve and maintain their computer network links. It is also possible that IIRPA will participate in the acquisition of additional computer hardware for use at SLAC; this has already been done by using the discretionary DOE funds in IIRPA at SLAC to take over some charges which would have been paid by the NSF contract (from UCSD) so that the computer equipment may be purchased with NSF funds originating from UCSD.

As was mentioned in Section 2, we have begun to investigate how IIRPA might play a significant role in future SSC detector development activities. Our effort to find key people and resources in the national labs (LLL and LANL) will continue next year with special emphasis on radiation damage studies capabilities of the labs. In the meantime, the Spaghetti Calorimeter project is being funded at UCSD by DOE and NSF. It is our feeling that the coordination of the many tendrils of this development effort should be taken over by a full-time professional. We assume that the DOE wants to see this type of development pursued diligently but also with a minimum of redundant or wasted effort; this kind of job was the reason for the original funding of IIRPA. When several institutions are sharing resources and evolving development efforts, it is paramount that a single, responsible person be tracking all of the parts. We believe that the Institute can attract a strong person who can do the job, but who will also be able to move on to other physics objectives after the development phase is over. When this position is approved, recruiting for this "Executive Director" will begin and we expect to find a suitable person by the start of the second half of the contract year.

In the future, beyond next year, there are several other developments which will involve IIRPA. New buildings are going up on the UCSD campus and one of them is designed for large scale equipment construction; it has 9,000 sq. ft. of open, heavy load-bearing floor with a big overhead crane, associated shop areas and the expectation of state funds for major equipment items. This sort of investment by the campus in HEP will help to reverse the trend toward decreasing capability of local campuses to make a large apparatus.^[1] This new facility will be both a resource and a responsibility for IIRPA; we will be obligated to request some matching funds from federal agencies to purchase equipment if and when a major hardware

construction phase begins. A related development involves the more and more frequently expressed desire to create an accelerator physics program at UCSD, often for reasons associated with the need to have light sources such as free-electron-lasers more readily available on campus. There is a major role for IIRPA to play in this development: the coordination of surplus equipment acquisition and the locating of talented people at the labs (LBL, LLL, LANL and SLAC) who would give advice, do teaching and help with designs are natural functions for IIRPA.

Even longer term and more speculative projects for IIRPA still tend to be related to development work associated with the SSC. In addition to the Calorimeter project, we will investigate a few other directions. One obvious role for IIRPA is that of linking up with other Institutes, Centers and Labs in the UC system for purposes of sharing resources. The San Diego Supercomputer Center (SDSC) is one immediate candidate for cooperative projects such as the network coordination mentioned above. Another candidate is the Center for Magnetic Recording Research (CMRR) in which we hope to create a position where efforts to promote large scale data recording will be encouraged in directions which benefit HEP in the SSC era. During the next year we will explore the possibility of a joint effort by Center for Astronomy and Space Science (CASS) and IIRPA to promote the development of the next generation of digital data storage based on video tape, an effort which could be coordinated by CMRR if we all agree and can find enough resources.

References

1. *Report of the HEPAP Subpanel on Future Modes of Experimental Research in High Energy Physics, DOE/ER-0380, July 1988.*

APPENDIX B

YEAR-END REPORT FOR THE INTERCAMPUS INSTITUTE FOR RESEARCH AT PARTICLE ACCELERATORS

IIRPA - 1989

1. INTRODUCTION

The Institute has as its main function the core responsibilities for hardware, software and operations support of the experiment which began as PEP-9 at the Stanford Linear Accelerator Facility (SLAC). Having a separately funded organization has made it possible for multiple University of California campuses, presently UCSB and UCSD, to continue to participate in the PEP program during a time of great uncertainty. As the number of functioning facilities for high energy research in the United States continues to drop, the need for a place such as PEP with the TPC/Two-Gamma experiment becomes increasingly apparent if we are to continue to recruit graduate students for this worthwhile business. During this period while the SSC is evolving we see individual university groups beginning to fragment as they search for more and more possibilities with longer and longer time scales, and the support for an activity such as the TPC/Two-Gamma experiment is then eroded due to a lack of critical mass. The IIRPA has provided a major part of the stability at IR-2 and has helped keep the experiment alive. The continued existence of PEP and the TPC/Two-Gamma experiment will allow us to begin training several more graduate students at PEP during the coming year.

The Institute has devoted a considerable part of its resources this last year to work on the problems of designing and building a B Factory. At the present time the SLAC management is considering a proposal for turning PEP into a B Factory, and several parts of that document have been contributed by IIRPA people. There are on-going efforts related to machine design, vertex detectors, beam pipe technology and radiation masking/shielding which the Institute will continue to support, sometimes with University funding. If SLAC does not choose to support a B Factory development, then another site will very likely be promoted by the present advocates of this high luminosity facility. The Institute would then participate in that effort. The reason such a B Factory has so much widespread support is because of its high luminosity, which permits the study of rare processes in addition to the pursuit of CP violation, one of the most likely places to look for new physics beyond the Standard Model.

2. THE PREVIOUS YEAR'S ACTIVITIES

2.1 PEP and TPC/Two-Gamma Operations

There was a PEP run at the end of last year (Dec. '88) which resulted in collecting about 20 pb^{-1} of data with the new vertex detector and all other TPC/Two-Gamma components fully functional. Record luminosities of $6 \times 10^{31} \text{ cm}^{-2}\text{sec}^{-1}$ peak and single shift integrals of 1.1 pb^{-1} were achieved. Although PEP behaved flawlessly, there was no further running until recently (9 October 1989) because of SLC priority. Moreover, the "switching time" for changing from SLC to PEP injection and back to SLC was long enough to be considered disruptive of the SLC program. Now the Director has committed to running PEP with an allowed 20% negative impact on SLC. The controls for SLC operation have now improved to the point where the switch-over generally consumes less than $2\frac{1}{2}$ hours; work will continue to make the best case so far of 1 hour into a routine operation. There is now no reason to doubt that we can begin continuous running in November.

Analysis of data from previous runs is ongoing: there has been one new publication^[1] from the collaboration since last year's IIRPA proposal to DOE, and four additional papers have recently been submitted for publication. One of these, on the single-tagged $\gamma\gamma$ total cross section, was a joint project of Alan Eisner with Cary Zeitlin, a UCD graduate student who recently received his degree; it has been issued as an IIRPA preprint^[2]. In general, Institute members have played a major role in finding new physics channels to investigate and in pushing the the results to final publication. We are also investigating better ways to operate and update the analysis Monte Carlo programs; this summer the Institute supported Andy Smith, a UCSD graduate student, for a month so that he could start incorporating the new vertex detector into the GEANT Monte Carlo environment.

One of the traditional roles of IIRPA has been the upgrading and maintaining of the forward detectors. This has continued during the past year as the new phototubes and amplifiers on the NaI array were integrated into the data acquisition and radiation monitoring systems. Yao-Xun Wang has been responsible for the calibration software, and his summary of the current status of the energy resolution of the array is contained in Appendix A. Michael Sullivan has been in charge of the installation of the tubes on the crystal arrays, and of the hookup and testing of the associated amplifiers and light-pulser systems. Ransom Stephens, a UCSB graduate student, has also played a major role in these efforts; they were assisted this past summer by Yang Zhao, a UCSD graduate student supported by the Institute. Our former forward spectrometers have been reduced to one four-plane drift chamber, DC1, just in front of each NaI array. Sullivan remains responsible for the chambers themselves, while Wang has taken on the task of finding their calibration constants and revising the software to reflect this new configuration.

The NaI system will provide TPC/Two-Gamma (and PEP) with the most precise luminosity measurements. However, when lead shield doors in front of the NaI are closed (to protect the arrays from radiation during tuning and machine physics, as well as injection), a backup luminosity monitor embedded in the doors themselves takes over. Eisner has overall responsibility for luminosity monitoring. The shield door monitor, designed and built by him and Lee Knapp of UCSD in fiscal 1988, was fully operational within three hours of turn-on during the PEP run of Fall, 1988. Related efforts (carried out by Eisner) include coordinating luminosity measurements with the PEP operations group, keeping a data base of integrated luminosities, and assessing TPC/Two-Gamma data collection efficiency.

Trigger and timing electronics remains a major Institute responsibility. Eisner is solely responsible for the forward detector trigger and timing systems, and has been playing an increasing role with their much larger central detector counterparts (particularly as Mike Ronan of LBL, who is in charge of the latter, has been spending much of his time on SLC-PEP switching). The new high-luminosity trigger system based on Vertex Chamber information, designed jointly by Eisner, Ronan and an LBL engineer, is mostly installed and operating well; the last pieces (permitting full usage) will be tested at the start of our scheduled run in November, 1989. Eisner is responsible for assessing the way these new systems perform with colliding beams (Zhao assisted in these studies during the past summer) and for the ongoing project of developing new Monte Carlo trigger simulation software. Online data collection systems are the responsibility of Eisner and two LBL physicists, with Eisner focusing on planning, user-interfacing and documentation, and online diagnostic software. On the last of these he has worked closely with a UC Riverside graduate student, Mourad Daoudi.

Over the last few years, as the forward detector has decreased in size, the beam pipe has required quite a bit of attention due to the way in which it interacts with radiation masking and the forward detectors. Sullivan has played an ever larger role in caring for the beam pipe and other critical aspects of the experiment near the pipe such as the insertion region quadrupoles, skew quadrupoles, vertex detector installation and the moveable lead shielding of the NaI. A significant fraction of his time this last year was devoted to the removal and re-installation of the vertex chamber which had to be modified by installing water cooling lines. The heating problem which was uncovered during last year's December running is now under control, and the previous beam current limits can be increased to allow for considerably higher luminosity. Sullivan has carried out much of this work in his official role as one of two Directors of Operations for the TPC/Two-Gamma facility. As such, he has also organized the weekly hardware meetings, and participated in coordinating data-taking activities. (Eisner has also played a role in the latter, particularly in the definition of procedures.)

During the last year Sullivan has continued to study the radiation masking and shielding problems in PEP; as the beam currents increase and the machine tune is changed to adapt to a single interaction region, more sophisticated masking is needed. The report in Appendix B is an example of the type of effort which is needed in order to continually improve the luminosity at PEP while simultaneously trying to move the vertex detector closer to the interaction point. These studies and up-grades are also providing extremely valuable knowledge that can now be used in B-Factory design efforts.

Last year the Institute diverted some of its funds toward the purchase of computing equipment at IR-2. There was a strong feeling at the end of last year, during the brief data-taking run, that we ought to have a significant increase in computing capability in order to match the expected increase in data collection rate. Because of special University pricing of small Digital Equipment systems, it was possible to purchase a VAX 3200 for use at IR-2 with IIRPA funds at a cost which was considerably less than what would have been paid by SLAC. This machine can run Monte Carlo programs, for instance, three times faster than the old VAX 780 machines which we still use. The computer could also be used for data analysis if it had a disk drive and 8-mm tape deck; the cost of these additions will be shared between the Institute and SLAC in the coming year.

2.2 $\bar{B}B$ Related Efforts

Early activities in the B physics area began with summer workshops of the last three years, and the report from 1988 Snowmass which is included as Appendix C gives a good summary of the field at that time and is representative of the work done in that area by Eisner. The preparation of the report was finished at the end of the last contract year. Two parallel developments have taken place in the $\bar{B}B$ area during the year: the LBL/SLAC (with Frank Porter of CIT) efforts to design a prototype B-factory called "APIARY" and the Southern California $\bar{B}B$ Factory Consortium which was initiated by CIT and UCLA. The March 1989 meeting of that consortium was held at UCSD and sponsored jointly by the Physics Department and the IIRPA. A few pages from the meeting summary are included as Appendix D. Members of the Institute have participated in both efforts which have culminated recently in the creation of the two reports submitted to the SLAC director: **The Physics Program of a High-Luminosity Asymmetric B Factory at SLAC** and the machine report entitled **A Feasibility Study for a High-Luminosity Asymmetric B Factory Based on PEP**. While we do not know what direction SLAC will take in this area, we do know that the physics associated with the copious production of $\bar{B}B$ at the $\Upsilon(4S)$ resonance in an asymmetric collider will be one of the dominant features of the mid '90's particle physics landscape. If SLAC decides to modify the PEP ring and tunnel to make a B Factory, then it will be about three

years before the start of construction, and it seems natural that IIRPA should play a major role in the development and exploitation of that resource.

Contributions from IIRPA to the APIARY design effort have come mostly from Sullivan who has worked with Hobey DeStaebler of SLAC to devise the radiation masking scheme and inner wall absorber for a vertex detector which might be less than 2 cm from the beam crossing point. Contributions were made to the April Cal Tech **Workshop on High Luminosity Asymmetric Storage Rings for B Physics** and to the September Syracuse meeting on B factories. In addition, the report in Appendix E shows how the radiation masking designs were evolving at the time of a submission to the director's report, **A Feasibility Study for a High-Luminosity Asymmetric B Factory Based on PEP**.

The physics report which is being sent to the Experimental Policy Advisory Committee (EPAC), **The Physics Program of a High-Luminosity Asymmetric B Factory at SLAC**, contains a contribution from Eisner which is included here as Appendix F. This is a survey of one of the more reasonable schemes to search for the $b \rightarrow u$ transitions in B decay which ought to lead to a measurement of $|V_{ub}|$, the Kobayashi-Maskawa matrix element. Appendix G contains another part of the SLAC report, contributed by R. Erbacher and W. Vernon as an appendix, in which the roles of increased vertex resolution and smaller colliding beam crossing points are investigated. Robin Erbacher is an undergraduate who is supported part-time by IIRPA funds, initially this summer at SLAC and presently at UCSD.

REFERENCES:

- [1] H. Aihara, *et al.* (TPC/Two-Gamma Collaboration), "Charged-Hadron Inclusive Cross Sections and Fractions in e^+e^- Annihilation at $\sqrt{s} = 29$ GeV," Phys. Rev. Lett. **61**, 1263(1988).
- [2] H. Aihara, *et al.* (TPC/Two-Gamma Collaboration), "A Measurement of the Total Hadronic Cross Section in Tagged $\gamma\gamma$ Reactions," IIRPA report No. UC-IIRPA-89-02 (also SLAC-PUB-5101), September, 1989. Also submitted to Physical Review D.

APPENDIX C

IIRPA Annual Report – 1989

Summary and Statistics

The Intercampus Institute for Research at Particle Accelerators (IIRPA) continues to work exclusively on the TPC/Two-Gamma experiment and do planning for future uses of the PEP facility at the Stanford Linear Accelerator Center (SLAC). Details of that activity are contained in the attached year-end report. The requested summary statistics:

- Executive and Advisory: David Caldwell at UCSB is the Associate Director at Santa Barbara and Wayne Vernon is the Director. The advisory committee consists of Malcolm Derrick, Argonne Nat. Lab; Robert Eisberg, UCSB; John Gunion, UCD and Robert Swanson, UCSD.
- Present direct involvement with research: Prof. G. Masek, H. Paar, W. Vernon and D. Caldwell; Research Professors A. Eisner, M. Sullivan and Yao-xun Wang.
- Graduate Student involvement: four students have been supported (fractional time) during the last year, three more students (one each from UCD, UCSB and UCSD) have worked at SLAC with IIRPA researchers.
- Other campuses: IIRPA is a multi-campus structure, and the involvement is indicated in the above items and the attached report.
- There are three Research Professor series professional personnel in the Institute (full time) and a student lab assistant (part time).
- Last years publications are listed at the end of the attached report.
- Support for the Institute comes from the Department of Energy (\$235,000 last year), UCSD (\$35,000 last year) and UCSB (about \$5,000 last year).
- Expenditures are essentially all for direct research in the form of salaries for people working on the experiment or for future planning, mostly at SLAC. Administrative costs of about \$5,000 are paid at UCSB, through the Quantum Institute which provides the service.
- Space used by the Institute is minimal at the campuses; most research activity is carried on at SLAC.

Respectfully submitted, November 15, 1989,

Wayne Vernon, Director

APPENDIX D

I. Yearly Report – December 1991 through November 1992

A. Introduction.

The dominant Institute activity this last year has been the preparation of hardware and software for the LSND experiment at Los Alamos. As was described in our last year's (Four Year) proposal, the neutrino experiment at LAMPF, the proton linac, has become our major physics effort because it is going to start up this coming summer. We are building some of the hardware and working on significant parts of the Monte Carlo simulation of the physics processes in the liquid scintillation detector, starting with the cosmic-ray events which can lead to neutron production. This is elaborated in Section B.

We continue to be active in the B Factory planning at SLAC and, occasionally, at other places around the world. The main contribution to this effort has been in the area of interaction region design, at the asymmetric collision point where considerable complication sets in because of the high stored beam currents and the need to have detectors as close as possible to the collision. Recently we have begun serious studies of some detector problems, especially in areas where our previous experience is valuable, and also where the present LSND development efforts should play a role. See section C for more details about B Factory work.

The role of IIRPA as a student support center has been increased, in spite of the lack of allocated funds. Three undergraduates have been involved in the above programs, and a new graduate student has joined the group to pursue a thesis in neutrino scattering. We continue to work on the last of the Two-Photon analysis from the TPC/Two-Gamma experiment, and the Institute provides most of the training resources for Gary Greenbaum, a UCSD graduate student (NSF funded) at SLAC, who is doing a thesis on that data. Some resources have also been devoted to an exploratory study of Bjorken's Full Acceptance Detector (FAD) idea for the SSC; Greenbaum noticed the similarity between some of Bj's conjectures and some ideas for Two-Photon processes that Gary has been pursuing.

Other activities of the Institute this last year include the support of the 9th International Workshop on Photon-Photon Collisions at UCSD this spring (March 22-26, 1992), in which about a hundred researchers and students from the US and ten other countries met to review Two-Photon progress and investigate future directions. A lot of work was done by the two-photon research teams from both UCSB and UCSD; the Institute efforts included A. Eisner and W. Vernon serving on the local organizing committee for this conference. One area of interest centered on the question of whether $e\text{-}\gamma$ and $\gamma\text{-}\gamma$ colliders will be developed and what role they might play in future Two-Photon physics. Since the development of such colliders

would almost certainly make use of Free Electron Lasers (FEL), there has been a continuing effort at UCSD to investigate such devices and to involve students in that effort. In collaboration with Sally Ride, Director of the Cal Space Institute and a proponent of FEL's, we have found ways to support four graduate students in this area. Two of the students are supported by LANL, one in experiment and one in a theory group. A UCSB graduate student, Doug Borden, working at SLAC, is one of the strongest proponents of $\gamma\text{-}\gamma$ colliders; there is a working FEL at Santa Barbara; hence, there will be an effort next year to develop a more cohesive linking of these areas.

B. The Neutrino Experiment at LAMPF – LSND.

The physics motivations of the LSND experiment — particularly a search for neutrino oscillations in three different ways, and a measurement of the contribution (Δs) of strange quarks to the spin of the proton — were described in detail in the 1992 IIRPA proposal.

All of the IIRPA Scientists, A. Eisner, M. Sullivan and Y-X. Wang, have been working on Monte Carlo simulations of the LSND (Liquid Scintillator Neutrino Detector) and the way neutrinos, neutrons and cosmic rays will interact and be detected. Among the major activities of A. Eisner during the past year have been defining the overall structure of a GEANT-based simulation, and adding necessary ingredients for generating a realistic stream of events and for reproducing the expected response of the detector and its electronics. Important components include a proper modelling of the time and spectral distributions of both scintillation and Cerenkov light, tracking of the resulting (optical) photons, and modelling phototube response; and mechanisms for dealing with delayed events such as muon decays and the 2.2 MeV photons which flag neutrons following their capture by protons. Also essential are interfaces both to input (generator) events and to reconstruction programs which are under development. Much of this Monte Carlo code is in place, but much remains to be done.

Recently, Y-X. Wang has added a description of the material surrounding the scintillating tank, and, using a muon cosmic ray generator provided by M. Sullivan, has studied the sensitivity of the detector to this main source of background. In particular, because Michel electrons from decays of muons stopping in the scintillator can mimic $\bar{\nu}_\mu \rightarrow \bar{\nu}_e$ oscillations, an understanding of such events is essential to the success of the experiment. The tools developed are also necessary for studying backgrounds from neutrons produced by cosmic ray muons, from muon capture on carbon (which can result in a delayed nuclear decay) and from muon spallation.

At UCSD, we have enlisted the aid of a talented designer, M. Mojaver, to help build the “ Σ PMT” cards for the trigger in the experiment. A purchase order from LANL has enabled us to do this. An undergraduate, Kara Hayes, has begun work

on design verification, assembly and check-out of the cards. The artwork for the first prototype of the board is just being sent out; development of this four-layer "9U VME" circuit board, and its eventual checkout, should provide us with quite a few tools and skills for use in B Factory detector development. We have contracted to produce 20 of these big boards, which tally how many of the 128 photo-tubes in a VME crate have fired, but we may not have enough funds left in the LANL purchase order to complete the job.

Last summer the Institute hired Suzy Weaver, who had just graduated from UCSD, to work at LANL for a couple of months so that she could assist in the electronics design, prototype and evaluation for the LSND experiment. Since she did so well at that job, the LSND management was able to find some funds to appoint her to a one year "Graduate Research Associate" position. Electronics design and checkout has become a *critical path* for the experiment, and Suzy has made a significant impact on the size of the backlog. This temporary position is intended to be used for people just out of school so that they can be introduced to research and, hopefully, encouraged to continue on to graduate school.

Also this summer, a graduate student, Diane Evans, was invited to join the experiment, and she came to the lab in August for six weeks. She returned to UCSD to finish the requirements that remain before she can start thesis work, but she is interested in making neutrino scattering her thesis topic. This summer she began working with several of the LSND people, and is continuing to help develop some of the pieces of the "monoboard program" for the trigger, while at UCSD. She is also starting to learn how to run the LAHET and SUPERHET neutron transport codes in order to aid in the development of the Monte Carlo simulation for the experiment. Once again, the Institute may not have the funds to continue her full-time support next year; if she fails to find fellowship support, we may be in trouble.

C. Work on B Factories and Associated Detectors.

Most of IIRPA's contributions to the B Factory development have come from M. Sullivan and his continual efforts to improve the interaction region environment for these high current, asymmetric colliders. More and more people around the world have come to realize how important this type of careful design and evaluation will be for the future operation of the detector and the collider, working together. As Sullivan develops more insight into how to shield the detector from the junk near the beam, more groups invite him to talk and give advice. Since the Institute is too poor to support such efforts, we ask for "donations in kind" to help defray the loss of Sullivan's talent, needed for other IIRPA activities, when he works on very detailed design problems. This last year we have received funds from SLAC for this purpose; those funds have been used for travel and student support. Of

course, SLAC would prefer that we receive such support directly from DOE, and we are asking for such funds in this request.

The time for serious detector development work seems to have finally arrived, but the yearly support for it looks to be quite small and spread over a fairly large number of activities, as best we can tell. Institute efforts in this direction last year have been associated with a low level of planning and design for a possible central tracking device and with the evaluations of some calorimetry electronics options. Y-X. Wang has published the work which he and G. Godfrey did on the DME-base tube chambers [NIM **A320**(1992)238], work which is relevant to the possible use of such chambers for the intermediate tracker with Z readout, especially useful for triggering. A Stanford undergraduate, Francisco Villegas, was supported for a time during the summer at UCSD to do mechanical engineering work on the extremely thin and low density designs which would be essential for incorporating the tube chambers into the B Factory detector; he wishes to continue this work as part of his engineering degree program, if we can find some sort of support.

A. Eisner was an active participant in calorimeter design studies for a B Factory detector, pursued at SLAC in 1990-1991, and has recently begun to focus on the data acquisition electronics needed for that detector subsystem. Some options can be rejected with minimal investigation, but others will require more serious simulation, with the goal of prototyping the most promising contender(s). Of particular interest are time-stamped digitization schemes for use in a pipe-lined data acquisition architecture, with embedded microprocessors handling readout of data from individual crates, and integration with triggering at each level. This is the direction in which the SLAC B Factory data acquisition group is leaning. The simulation and prototyping effort would serve to evaluate not only the calorimeter electronics, but also some aspects of the data acquisition architecture. We expect that some of the effort which we are putting into the LSND development will be directly useful in the B Factory arena.

D. Other Activities.

Analysis of the TPC/Two-Gamma data has continued, with a major part of Y-X. Wang's time devoted to the completion of the paper, "Study of χ_{c2} Production in Photon-Photon Collisions" which has been submitted to Physics Letters. In addition, A. Eisner has spent considerable time with Gary Greenbaum, the UCSD Student, on finishing the forward detector and luminosity analysis for the last runs of the experiment, and on the measurement of the production of two body exclusive states ($\pi^+\pi^-$, K^+K^- , $\dots$) above the resonance region (relevant to testing QCD). This work should be completed during the next year. Finally, the IIRPA physicists continue to pay close attention to other remaining Two-Photon analysis projects, using their past experience to assist as needed.

Management of the DECStation 5000 computer, which was purchased a year ago, has taken a non-negligible amount of A. Eisner's time and effort because of the small level of Ultrix activity and support at SLAC. (Ultrix is DEC's Unix operating system.) The machine is very useful for Monte Carlo calculations and is a very powerful graphics workstation. It does work well as an X-window terminal to the LANL and SLAC machines, but it has taken a lot of effort to bring up the PHIGS standard graphics for local use. Another disc drive and a tape deck were added to the system, using UCSD campus funds. This provides the space for importing the standard CERN HEP software, which will allow us to locally run the LSND simulation and reconstruction programs. In addition, we expect the flexible graphics capabilities to be quite valuable for B Factory R&D work. While the first round of operating software upgrades and software importation will be completed soon, we expect system management to continue to require significant resources.

We invested some of the Institute's campus support in the subsidy for the International Photon-Photon Workshop this past spring, and in addition brought one more Russian physicist to this conference, for a total of three who were supported to attend. In addition, Kara Hayes, a UCSD undergraduate, was hired to assist in the conference organization, and seemed to enjoy the experience. The conference proceedings will appear soon, and their publication ended up costing the organizers (including IIRPA) an additional amount because the conference budget was slightly overrun.

APPENDIX E

Progress Report: The University of California Intercampus Institute for Research at Particle Accelerators (U.C. IIRPA)

November, 1992 – November, 1993

The Institute participates in many activities, in spite of its limited funding. We believe that this is possible because of the unique talent of its members and their ability to affiliate with a wide variety of experiments, development activities and multi-campus environments. Activities this last year were split between helping to bring up the neutrino oscillation experiment at Los Alamos, carrying on *B* Factory design and detector development work, finishing the analysis of the TPC/Two-Gamma experiment and a few other, longer term initiatives.

The LSND Experiment at LANL: Status and Hardware Efforts

The Liquid Scintillator Neutrino Detector (LSND) has been running since early August, and has been in a fairly stable data collection mode through September and up to the present. The LAMPF accelerator has performed flawlessly; neutrino production recently doubled because of an increase in beam current (to 800 microamps) and a reduction in the thickness of other targets which intercept beam protons before they reach the neutrino production target. Neutrino events are coming in at a rate of about 1 per hour, and cosmic ray backgrounds seem to be manageable and well understood.

Contributions by IIRPA to the experiment include support of students working on the experiment, help in some electronics fabrication and checkout, and work by the IIRPA physicists in both electronics checkout and Monte Carlo simulations. In addition, IIRPA funds were used to help support Diane Evans, a UCSD graduate student, for a year at the LSND experiment; she worked on many of the sub-systems such as the cable plant, laser calibration pulser, "Environmental Measurement System", and some neutron interaction simulations for the detector. Vernon spent 6 months of sabbatical time and the summer months at Los Alamos, and Sue Lueder, a UCSD undergraduate, did her *mentor research project* on some of the properties of the liquid scintillator test sphere at LANL.

Our hardware contributions to the experiment include the *Sum PMT Card*, which generates a running total, for each 100 ns interval, of the number of tubes with pulses corresponding to at least one-quarter of a single photo-electron. There is one of these cards in each of the 13 VME crates of the experiment, and the UCSD Physics Electronic Shop (PES), along with UCSD undergraduates, contributed to

the fabrication and checkout of the cards. Funding from LANL paid for about 2/3 of the cost, including two months of support for M. Mojaver, the designer. In collaboration with K. Johnston (and undergraduate students) from Louisiana Tech, we developed and installed the proton beam arrival-time monitor which maintains 100 picosecond timing accuracy for the neutrino creation process. That sub-system sends the timing information to selected QT digitizer cards (Q for Charge and T for time) which make up the 1400 channel system.

LSND Monte Carlo and Software Efforts

The IIRPA group holds the primary responsibility for the LSND Monte Carlo simulation. This is a Geant-based package, developed with two other collaborators in LSND. Over the past year we have made continued advances in the LSND detector simulation (particularly as more has been learned about the actual hardware performance); this is exemplified by improved modelling of the intensity and time distribution of light emission in the detector tank. We have in addition implemented several major new components:

- Simulation of the detailed behavior of the charge and time digitizers, as an event develops in 100 ns "timestamp" intervals.
- Simulation of scintillation, light transport, and phototube response for the active Veto Shield surrounding the LSND tank.
- Simulation of algorithms used in data acquisition to "compactify" raw data by extracting phototube hit time and charge-increment information.
- Storage (and output) of simulated data. along with Monte Carlo information, in a newly-devised LSND data structure, using CERN's Zebra memory-management system. We also provided some general code for defining and accessing the data structure.
- Production of raw data files, for use in testing data acquisition.

We are also responsible for Monte Carlo (and related) multi-version code management on the three platforms (VMS and Unix) at LAMPF; this code has been installed as well on IIRPA and UCSB workstations at SLAC. And we have participated in establishing recent CERN code and utilities on all the platforms.

Current Monte Carlo projects include an improved treatment of light absorption in the LSND tank (including fluorescence), a better representation of phototube response, and modelling of the recently-installed additional shielding against cosmic rays. Most important, since actual data are now available, we can begin to compare in detail the parameters of the Monte Carlo simulation with the actual behavior of the detector. This study will be used both to adjust the simulation and to look for any problems in data reduction. Finally, we expect to be collaborating with our UCSB colleagues in LSND on local (California-based) data analysis projects.

***B* Factory Status and Design Efforts**

The Institute activity on the planning for a *B* Factory at SLAC has been substantial during this past year. M. Sullivan has spent essentially all of his time refining and improving the design of the *B* Factory interaction region. Bringing two high current beams of different energy, that are stored in separate rings, into collision without swamping the detector with background or killing the detector with radiation has proven to be one of the more challenging aspects of a *B* Factory design. Sullivan has spent the last few years working with the design team at SLAC and concentrating on developing an interaction region for PEP-II, the SLAC, LBL, and LLNL *B* Factory proposal. He was asked to represent the SLAC project at the *B* Factory workshop in KEK, Japan last November, with a presentation entitled "The Interaction Region Design of the Asymmetric *B* Factory Based on PEP".

The task of producing a successful *B* Factory design has led naturally to the development of software tools and procedures for testing any interaction region design. Many of the problems associated with an interaction region design for a *B* Factory are also seen in designs of other very high luminosity "factories", in particular, ϕ factories. Consequently, Sullivan was invited to spend a month at Frascati investigating detector backgrounds from the two beams of the DAFNE ϕ factory design. He produced a preliminary estimate of detector backgrounds and laid the groundwork for further work by porting over and setting up some of the programs used to calculate detector backgrounds here at SLAC.

Last June, the DOE and the NSF sponsored a joint review of the SLAC and Cornell *B* Factory proposals. The conceptual design report for the SLAC machine proposal (put together by people from SLAC, LBL, LLNL, CalTech, and IIRPA) was updated for this review. Many sections of the 641 page report were rewritten to include the extensive work that had gone on since the release of the original report in Feb. 1991. The interaction region section was rewritten to include a more flexible and robust design by Sullivan. He also produced three additional *B* Factory notes about the flexibility of the improved design.

One important factor in controlling beam related backgrounds is the quality of the vacuum near the interaction region for the incoming beams. In the case of a *B* Factory, the mechanical and geometric complexity of the beam lines together with the fact that two separate beam lines are joined inside the detector make calculating the pressure profile a daunting task. Sullivan has developed a computer program that can model this complicated problem. The program is currently being used to design a pumping scenario that will achieve the required low vacuum for the PEP-II *B* Factory.

B Factory Detector Development Efforts

The U.C. IIRPA group has been an active participant in planning for a *B* Factory detector at SLAC, as well as for the collider facility itself. The detector was a part of the review process described earlier. Efforts during the first half of 1993 culminated with the production of a Detector Design Status Report, since issued as SLAC Report 419, with U.C. IIRPA as one of approximately six authoring institutions. While not all the major detector questions yet have clear answers, and all will be re-opened when a full collaboration forms, the Status Report selected a particular version as a "default" detector, in part to serve as a base for further work. This detector includes (proceeding radially outwards): a silicon strip Vertex Detector (with other options also discussed); a small-cell main Drift Chamber, with axial and stereo views; a Cerenkov particle identification system (the least settled item, but with a Fast Ring-Imaging Cherenkov Detector given the preferred place for now); a CsI Electromagnetic Calorimeter; a superconducting solenoid; and a flux return instrumented to aid in $\mu^\pm$ identification and K_L^0 detection. The Report also addresses data acquisition, triggering, and computing.

The IIRPA contributions to this Status Report reflected our involvement in the detector planning: one IIRPA physicist was among the three persons who wrote the Calorimeter chapter; and another described the option of including a tube chamber as an intermediate tracking device. We also provided some editorial assistance for other portions of the Report, and participated actively in discussions of more global issues such as overall detector geometry. (Geometry is closely tied to Calorimeter issues, both because of the high cost of CsI crystals, and because of the influence of intervening material on photon energy resolution. In addition, our group and other participants in the old PEP Two-Gamma experiment would like to ensure that the *B* Factory detector can be used for a solid program in two-photon physics, as one of its secondary goals.) We have also been participating in the Data Acquisition working group, particularly on matters related to the Calorimeter and a possible Tube Chamber.

An *Intermediate Tracker* has been proposed by IIRPA members and G. Godfrey of SLAC because it might provide a very clean, fast, charged particle trigger for the experiment. The use of DME gas in a Tube Chamber would allow us to determine that a track came from the origin, rather than from the walls of the machine – within a couple of microseconds. This is due to the superior signal-to-noise properties of the wire-chamber amplification process in DME which leads to high precision "double-ended readout" of the tubes. We have received some small funding from the *B* Factory to work on the prototype of a very low mass tube array and to demonstrate the electronic/algorithm solution for the trigger.

IIRPA efforts to date in the Calorimeter working group have focussed on crystal geometry and Monte Carlo (Geant-based) simulations. Much of this work is

reflected in the Status Report (SLAC-419). A separate detector Note by A. Eisner has also been issued this year, addressing the effect of intervening material (especially in the Particle ID system) on the Calorimeter, particularly considering the effects of the solenoidal field on the products of photon conversion.

The primary emphasis now in the Calorimeter group is on the building, and testing with beam, of a prototype array of about 50 crystals. Further Monte Carlo work will be needed both to aid in this design and to provide a target against which actual performance can be measured. Information from the test run can in turn be used to improve the simulation. Other Monte Carlo projects include a study of calorimeter-based triggering algorithms.

U.C. IIRPA has recently received *B* Factory R&D funds for investigations of Calorimeter Data Acquisition. Because of the high dynamic range required (a factor of about 2^{17}), current plans call for a multi-range ADC on each channel, using a front-end custom chip currently being engineered at SLAC. IIRPA physicists are involved in defining physics-motivated specifications for this chip, which includes both shaping and range-selection. Its output would be digitized at fixed sampling intervals by a commercial 8 to 10 bit ADC, the digitized values stored in a memory, and local intelligence used to extract signal properties. We intend to test this scheme and to evaluate potential components, in the context of a VME system with a separate microprocessor board. This work could evolve into readout electronics for the Calorimeter prototype test, if time schedules are appropriate. This project will be carried out in cooperation with SLAC physicists and engineers working on other aspects of *B* Factory data acquisition.

TPC/Two-Gamma Roundup

The IIRPA group has continued to devote a small fraction of its time to TPC/Two-Gamma. During the past year this has included some salvage efforts associated with the dismantling of that detector facility, which resided in the future *B* Factory interaction region. Some physics analysis is still going on, as well. This year saw the publication in Physics Letters of our paper "Study of χ_{c2} Production in Photon-Photon Collisions", which was largely written by IIRPA physicist Y- X. Wang. We also interacted extensively with the primary authors of two other papers, "Evidence for Spin-One Resonance Production in the Reaction $\gamma\gamma \rightarrow \pi^+\pi^-\pi^0\pi^0$ " (accepted for publication in Physical Review D), and "Measurement of the Kaon Content of Three-Prong Tau Decays" (submitted for publication).

There is still an active two-photon analysis group, made up of TPC/Two-Gamma collaborators resident at SLAC. Most of the work is being done by two students. Gary Greenbaum, of U.C. San Diego, has made good progress on a study of $\gamma\gamma \rightarrow \pi^+\pi^-$ at high p_T , extending both the statistics and angular range of our earlier publication on this subject. This process provides an important check of QCD hard scattering models. Because Gary is resident at SLAC, IIRPA physicists

provide most of his day-to-day guidance. We also provide a sounding board for a University of Massachusetts student, who is analyzing data on virtual photon structure functions, for which QCD makes rather firm predictions. We expect these projects, and hopefully some older loose ends, to be completed during the coming year.

Other Efforts and New Initiatives

There has been considerable effort directed toward a re-definition of the the Institute this last year. Prof. Caldwell has gathered the "Particle Astrophysicists" from the UC system, including LANL, LLL and LBL, to three meetings at the UC Office of the President. Five more UC campuses and the Labs are quite interested in joining the Institute, changing its name and adding the emphasis on new forms of particle physics which is so attractive to younger researchers and students at present. If the Office of the President supports this change in direction and scale, then about a hundred faculty and senior research people will be joining us, hopefully to the benefit of all.

There is a continuing, modest, effort in the direction of investigating, studying and proposing "gamma-gamma colliders" for inclusion in a future NLC, for instance. Steve Gierman, a UCSD graduate student, is at Los Alamos, working with the Advanced Free Electron Laser (AFEL) group, and another UCSD graduate student, Manal Teebi, is studying photocathodes for making high brightness electron beams (most of her support having come from a special LANL grant). These are the types of techniques which will be used in the production of the gamma beams which will be needed for such a collider. Quite a few people from around the world attended the sessions on the physics aspects of a gamma-gamma collider, at the Linear Collider Physics Workshop in Hawaii in April of this year; Vernon and V. Telnov chaired the sessions and Doug Borden (Prof. Caldwell's student) of UCSB gave the summary talk.

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APPENDIX G

IIRPA to INPAC Changeover

July 21, 1995

Walter E. Massey, Provost
Office of the Provost and Senior Vice President-Academic Affairs
University of California
Kaiser Building, 300 Lakeside Drive
Oakland, CA 94612-3550

Dear Walter:

I am writing this letter to inform you that my term as Director of the Inter-campus Institute for Research at Particle Accelerators (IIRPA) has come to an end. A new Institute to replace IIRPA has been formed: the Institute for Nuclear and Particle Astrophysics and Cosmology (INPAC). It has been approved by the Regents, and the interim executive board of INPAC met on June 7, 1995 at the Office of the President and unanimously approved the choice of David Caldwell (Research Professor, UCSB) for the initial Director of INPAC. I concur with this action.

I have been involved with IIRPA for more than 20 years, having started it in 1974, and I have followed the development of INPAC closely this last year. It is my opinion that the new, much larger, INPAC group has looked at many facets of the problems of Institute structure and the role of a new director, and they have agreed that the new direction, new name and installing David Caldwell as Director are the correct steps to take at this time. I also feel that a majority of the old IIRPA members agree with this change. I hope that INPAC flourishes, and fulfills the promise that it has shown this last year; I encourage the Office of the President to find ways to help support the new Institute.

Sincerely,

Wayne Vernon

Research Professor, Physics, UCSD

cc: C. Judson King, Vice Provost for Research
Carol McClain, Coordinator for Research
Richard Attiyeh, Vice Chancellor for Research, UCSD
David Caldwell, UCSB

APPENDIX H

Major Publications of IIRPA

1. M.P. Cain *et al.*, (32 authors), "Leptonic Structure Functions of the Photon." *Physics Letters B* **147**, 232 (1984) (5 pages).
2. A.M. Eisner, "Recent Results on Photon-Photon Interactions at PEP," in *Proc. of the International Symposium on High Energy e^+e^- Interactions, Vanderbilt*, AIP Conf. Proc. **121**, 61(1984) (22 pages).
3. D. Bintinger *et al.*, (32 authors), "Measurement of the Total Hadronic Cross Section in Virtual Photon-Photon Interactions." *Physical Review Letters* **54**, 763 (1985) (4 pages).
4. H. Aihara *et al.*, (114 authors), "Exclusive Production of $K^+K^-\pi^+\pi^-$ in Photon-Photon Collisions." *Physical Review Letters* **54**, 2564 (1985) (4 pages).
5. H. Aihara *et al.*, (120 authors, TPC/Two-Gamma Collaboration), "A Study of η Formation in Photon-Photon Collisions." *Physical Review D* **33**, 844 (1986) (4 pages).
6. H. Aihara *et al.*, (TPC/Two-Gamma Collaboration), "Charged D^* Meson Production in e^+e^- Annihilation at $\sqrt{s} = 29$ GeV." *Physical Review D* **34**, 1945 (1986) (5 pages).
7. H. Aihara *et al.*, (117 authors, TPC/Two-Gamma Collaboration), "A Limit on $\iota \rightarrow \gamma\gamma$ and the Interpretation of the Iota as a Glueball." *Physical Review Letters* **57**, 51 (1986) (4 pages).

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12. H. Aihara *et al.*, (TPC/Two-Gamma Collaboration), "Evidence for a Spin-One Particle Produced by Two Photons." *Physical Review Letters* **57**, 2500 (1986) (4 pages).

13. H. Aihara *et al.*, (TPC/Two-Gamma Collaboration), "Study of Baryon Correlations in e^+e^- Annihilation at 29 GeV." *Physical Review Letters* **57**, 3140 (1986) (4 pages).

14. H. Aihara *et al.*, (TPC/Two-Gamma Collaboration), "Search for High Mass Narrow Resonances in Virtual Photon-Photon Interactions." *Physical Review Letters* **57**, 3245 (1986) (4 pages).

15. H. Aihara *et al.*, (TPC/Two-Gamma Collaboration), "Observation of Scaling of the Photon Structure Function F_2^γ at low Q^2 ." *Physical Review Letters* **58**, 97 (1987) (4 pages).

16. H. Aihara *et al.*, (TPC/Two-Gamma Collaboration), "Measurement of τ Branching Ratios." *Physical Review D* **35**, 1553 (1987) (9 pages).
17. H. Aihara *et al.*, (TPC/Two-Gamma Collaboration), "Study of η' Formation in Photon-Photon Collisions." *Physical Review D* **35**, 2650 (1987) (5 pages).
18. H. Aihara *et al.*, (TPC/Two-Gamma Collaboration) "Comparison of $\pi^\pm$, $K^\pm$ and $p, \bar{p}$ Production in the Central Rapidity Region in Hadron-Hadron Collisions and in e^+e^- Annihilation." *Physics Letters B* **184**, 114 (1987) (5 pages).
19. A.M. Eisner, "Resonance Formation in Photon-Photon Collisions: Recent Results from the TPC/Two-Gamma Collaboration," in *Proc. of the XXIIIrd International Conference on High Energy Physics*, Berkeley, 1986, ed. S.C. Loken (World Scientific, 1987) 1211 (4 pages).
20. H. Aihara *et al.*, (108 authors, TPC/Two-Gamma Collaboration), "Measurement of the Photon Structure Function $F_2(x, Q^2)$ in the Region $0.2 < Q^2 < 7 \text{ GeV}^2$." *Zeitschrift für Physik C* **34**, 1 (1987) (13 pages).
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23. H. Aihara *et al.*, (TPC/Two-Gamma Collaboration), "Exclusive Production of Proton-Antiproton Pairs in Two-Photon Collisions at PEP." *Physical Review D* **36**, 3506 (1987) (4 pages).
24. A.M. Eisner, "Formation of Spin-0, 1 and 2 Mesons in $\gamma\gamma$ Collisions," in *Proc. of the International Euromphysics Conference on High Ener-*

gy Physics, Uppsala, 1987, ed. O. Botner (European Physical Society, 1987), 528 (4 pages).

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27. H. Aihara *et al.*, (TPC/Two-Gamma Collaboration), "Charged Hadron Inclusive Cross Sections and Fractions in e^+e^- Annihilation at $\sqrt{s} = 29$ GeV." *Physical Review Letters* **61**, 1263 (1988) (4 pages).
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31. H. Aihara *et al.*, (TPC/Two-Gamma Collaboration), "Exclusive production of $p\bar{p}\pi^+\pi^-$ in photon-photon collisions." *Physical Review D* **40**, 2772 (1989) (5 pages).

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33. H. Aihara *et al.*, (TPC/Two-Gamma Collaboration), "Measurement of the Total Hadronic Cross Section in Tagged $\gamma\gamma$ Reactions." *Physical Review D* **41**, 2667 (1990) (8 pages).
34. M. Alston-Garnjost *et al.*, (74 authors, TPC/Two-Gamma Collaboration), "Inclusive $D^{*\pm}$ Production in Photon-Photon Collisions." *Physics Letters B* **252**, 499 (1990) (6 pages).
35. H. Aihara *et al.*, "Test of Spin Dependence in Charm Quark Fragmentation to D^* ," *Physical Review D* **43**, 29(1991) (5 pages).
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38. D.A. Bauer *et al.*, "Measurements of the Kaon Content in Three-Prong τ Decays," *Physical Review D* **50**, R13 (1994) (5 pages).
39. M. Albert *et al.* (LSND Collaboration), "Measurement of the Reaction $^{12}\text{C}(\nu_\mu, \mu^-)X$ Near Threshold," *Physical Review C* **51**, 1065(1995) (5 pages).
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42. C. Athanassopoulos *et al.* (LSND Collaboration), "Evidence for neutrino oscillations from muon decay at rest," *Physical Review C* **54**, 2685(1996) (24 pages).

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