PROGRESS REPORT ON CONTRACT NO. AT-(40-1)-3509, October 1975

TITLE: Elementary Particle Physics at The Florida State University.

This report covers the eleven-month period from November 1, 1974, to September 30, 1975. During this period the experimental program has been heavily involved in the analysis of the 250 GeV π^-p experiment using the 15-foot bubble chamber at Fermilab. Preliminary results have already been obtained and presented. The continuing effort on the 15 GeV π^+d experiment at SLAC has begun to produce publications, including some interesting results on production of resonances at high momentum transfers and some experimental limits on production of charmed particles. The theoretical research has been concentrated in two areas: gravitation and strong interaction phenomenology.

I. Logistics

A. Personnel

During the spring of 1975 A.P. Colleraine left Florida State to go to San Diego where he is working on nuclear fusion research with General Atomics. Also during the spring R.E. Knop left the group. Efforts are currently being made to replace both of these persons. In August L. Thébaud left to take a teaching position at the Mont Alto campus of the Pennsylvania State University.

Numerous changes have occurred among the graduate students. In January of 1975 N.D. Pewitt finished his Ph.D. (see Enclosure B1) and accepted a position with the Center for Naval Analysis in Washington, D.C. In May, D.P. Wilkins completed his Ph.D. (see Enclosure B2) and entered active duty with the U.S. Army, initially at Ft. Gordon, GA, and then at Ft. Leavenworth, KS. In September D. Gluch accepted a teaching position at Florida A & M University in Tallahassee; although he is no longer on the ERDA contract he will continue to participate in research as he finishes his Ph.D. here. In June K. Sawyer joined the group, and in September A. Mathews also joined. K. Rauchwarger finished his M.S. (see Enclosure C1) and is pursuing doctoral work in another area of physics. C.D. Capps completed his Ph.D. in September (see Enclosure B3) and has accepted a postdoctoral position at the Max-Planck-Institut für Physik und Astrophysik, München.

B. Facilities

The most spectacular increase in experimental facilities came about when Schlumberger donated to us a used EMR 6050 computer. It is similar to the EMR 6050 that we already own; where they differ the new one is larger and better. The configuration of the new computer is: central processor (with time-of-day clock, programmed I/O and priority interrupts), 32K words of core storage, disc with 60 megabit capacity, card reader (1400 cards/min.), line printer, card punch, paper tape punch-reader, electrostatic printer-plotter, five tape drives and two controllers. The equipment is in place but not - except for the disc - hooked up because power connections and air-conditioning need to be added. The disc unit has been connected to the old EMR 6050 for use instead of the drum.

Modifications have been made to the image-plane scanning and measuring machines. The measuring arm for the last machine has been received, so that all four machines can measure when the arm is installed. One view of IPD #2 has been fitted with an adaptation of the Fermilab MOMM dual magnification system. This change allows the operator to choose either of two magnifications to look at a bubble chamber photograph. The values of magnification at present are 15x and 30x; these numbers can be changed easily if desired.

II. Experimental Research Program

A. 250 GeV/c π^-p Experiment with the 15-foot Bubble Chamber (S. Hagopian, J.E. Lannutti, J. Albright)

This experiment is being done in collaboration with Russ Huson's group at the Fermi National Accelerator Laboratory as the initial engineering run of the Fermilab 15-foot bubble chamber (Experiment #234). The exposure was made during October 1974 and 46K useful pictures were obtained with an average of 4 tracks per picture - a sensitivity level of about 1.2 events/μbarns - with about 0.64 events/picture.

The physics interests in this experiment are manifold, and include: search for charmed particles, study of the diffraction excitation of the beam π^-, search for particle production mechanisms via inclusive studies of neutral particles and π^0's, etc.

The first scan of the film has been completed and a second scan is in progress. This has been a thorough scan, prong count, beam count, and Vee search. Measurement of the strange particle event types has been in progress simultaneously with the scan. (These measurements are of special interest due to our charm search.) A partial list of various topologies on the film is as follows:

V's	∿1200	(∿½ measured)
4 prongs	∿3500	(∿⅓ predigitized)
6 prongs	∿4600	(measurements just begun)
Recoil proton events	∿6000	(measurements just begun)

The primary emphasis in measurements so far has been on finding and analysing events with neutral strange particle production. This effort can be viewed correctly only if one considers the large "background" of events consisting of γ-conversion electron pairs due to the large number of π^0's and a significant conversion probability due to chamber size.

Being the first experiment with the world's newest, largest chamber, there has been a great deal of pioneering work in establishing optical and magnetic field constants, trying scanning strategies, determining measuring errors, implementing computer data processing programs (HYDRA from CERN) on the PDP10 at Fermilab and our CDC 6400 at FSU, altering scanning-measuring tables, reorganizing and writing on-line computer programs for measuring tables, training scanners for large chamber film, setting up hardware and software on the Fermilab semi-automatic measurer (SAMM) to process FSU digitized data, etc.

Progress on and output from this experiment is most efficiently presented by listing talks and including copies of material discussed or published among the Enclosures of this report:

1. Invited talk at CERN in April by Huson.

2. Contributed talk at Washington APS in May by Kahn. (See Enclosure A1b).

3. Contributed talk at Washington APS in May by S. Hagopian. (See Enclosure A1a).

4. Invited talk at Fermilab on August 16 by Lannutti. (See transparencies as Enclosure A2).

5. Contributed paper on topological study presented at DPF meeting at Seattle on August 27 by S. Hagopian. (See Enclosure A3a).

6. Contributed paper on the charm search presented at DPF meeting at Seattle on August 27 by Harris. (See Enclosure A3b).

7. Contributed paper on strange particle production presented at DPF meeting at Seattle on August 27 by Kahn. (See Enclosure A3c).

8. Invited talk at B.C. Symposium at Fermilab on September 18 by Huson. (See Enclosure A4a).

9. Invited talk at B.C. Symposium at Fermilab on September 19 by Lannutti. (See transparencies as Enclosure A4b).

The highlights of the forementioned papers include the following:

1. Measuring rates and measuring accuracy for the 15-foot chamber are comparable with other bubble chambers and no unexplained difficulties have been found.

2. The smooth energy dependence of the topological cross sections and mean multiplicities continues up through 250 GeV/c π^-p points from this experiment. (The highest energy so far for this reaction.)

3. The inclusive K^0 and Λ^0 cross sections at this energy agree with extrapolations from lower energy experiments.

4. The number of K^0's and Λ^0's produced is approximately constant as a function of primary multiplicity. This is in contrast to π^0 production and has not been studied in previous experiments.

5. A threshold enhancement in $K\bar{K}$ and $K\Lambda$ production has been observed in this experiment along with a high-mass tail.

6. Occasional production of events with very high multiplicity of V's and γ's has been observed.

7. No evidence has been seen for charmed particle production--either as long-lived 4-prong "neutron stars," or as short-lived objects detectable in effective mass plots in the sample of data available so far--but the search is continuing.

Work on this experiment is proceeding on measurements. As can be seen by the measuring rates for this type of film, this work will continue throughout next year.

B. π^+d at 15 GeV/c (V. Hagopian, S. Hagopian, Albright, Lannutti)

About 900,000 photographs have been scanned and over 90% of these have been measured. The measurements during the past year were done in collaboration with the University of Tennessee and with Oak Ridge, using their Spiral Reader. The computational reduction was performed at Florida State University. It is expected that all data reduction should be completed before the end of this calendar year. Several papers have already been published in the prior reporting period - notably the measurement of the Δ(1236)-Δ(1236) component of the deuteron. During this period two Ph.D. dissertations (see Enclosure B) have been completed and one M.S. thesis (see Enclosure C) has been concluded.

A computer program was developed to use pulse-height information from the Spiral Reader to correctly identify the masses of particles with momentum less than 1.5 GeV/c. An M.S. thesis has been written on this topic (see Enclosure C). Also a program was developed using a Tektronix 4010 display unit connected to our CDC6500 computer to fix up events that failed the automatic measuring and pattern recognition process. This system resurrected about 60% of otherwise failed events. A paper on this subject has been submitted to Reviews of Scientific Equipment (see Enclosure F1).

The coherent reaction $\pi^+d \to \pi^+\pi^+\pi^-d$ was studied extensively. The increasing cross section as a function of beam momentum was established and explained in terms of minimum momentum-transfer cutoff. The A_1, A_3, ρ and d^* were studied and the

results reported in a paper published in Physics Review (see Enclosure E3). Since the publication of this paper, the forward scattering amplitude was compared with comparable data from hydrogen, and the amazing conclusion has been reached that the exchange mechanism for 3π production is not pure Pomeron exchange, as was always assumed; rather there is appreciable spin flip f^0 exchange. A paper on this subject is being written.

The strange particles produced a large quantity of excellent data. We have one of the largest inclusive samples of $K_S^0K_S^0$ data. A Ph.D. dissertation has been completed on this subject (see Enclosure B2). The $K_S^0K_S^0$ spectrum shows the (S^*,δ) resonance at 1047 MeV and possibly another one at 1190 MeV. The most surprising and interesting aspect of this work was that the momentum transfer distribution is larger, whereas data from π^-p had low momentum transfer distribution. One very interesting explanation is that planar duality diagrams forbid the production of $K_S^0K_S^0$ resonating as (S^*, δ) at low t from π^+ mesons but allow it from π^- beam mesons. This result was presented at the Divisional Meeting of Particle and Fields in Seattle, Washington, and will be published in the proceedings (see Enclosure F4). A paper on this $K_S^0K_S^0$ final state was also submitted to Physics Review Letters (see Enclosure F3).

A search for charmed mesons and baryons was conducted in these data both for long-lived (i.e. > 10^{-11} sec) and short-lived resonances. With the exception of one candidate, limits of 2 to 4 μb were placed for up to 2.5 to 3 GeV masses. The exception is a single large-mass ($\sim$1.95 GeV) V that has a very low probability of being background (less than 0.01 such events expected). This candidate alone is not claimed as the $D^0 \to K\pi$ because of our basic conservatism. A paper on this subject was submitted and our data reported during the Divisional Meeting in Seattle and also was submitted to Physics Review Letters (see Enclosure F2).

The rest of the data are currently being analysed, especially the 4, 6 and 8 prongs. Reactions such as $\pi^+d \to \pi^+\pi^+\pi^-\pi^0d$ (see Enclosure A1d) are being carefully studied to determine ω exchange and properties of the B resonance. The multibody final states (see Enclosure A1c) have a wealth of information on diffraction into 5 pion, $\rho\pi\pi$, $\rho\rho$ and other complex resonances. The analysis of this vast

quantity of data (over 75,000 events) is continuing.

C. K^-d from 470 to 850 MeV/c (Albright, Ezquerra, Madden)

During this report period we completed the measurement of all the events and also completed the process of counting beam tracks for determination of cross sections. The major interest centers on the two-prong + V topology with final states $\Lambda\pi^-p$, $\Sigma^0\pi^-p$ and $\Lambda\pi^-\pi^0p$. In the momentum range (670, 850) MeV/c the assignment of events to final states is complete, and analysis is proceeding. At the lower momenta the job of event assignment is somewhat easier, but was started later, and so it is still in progress. It appears that at the lower momenta (470 and 520) the events will be divided nearly equally among the three final states; this result will be mildly surprising, if it persists when all the events are assigned, because one might have expected fewer events for $\Lambda\pi^-\pi^0p$.

D. Multi-Particle Spectrometer at BNL (V. Hagopian, S. Hagopian)

During the past year we joined two new proposals for a total of three future MPS experiments. The original one was a $\pi^\pm d \rightarrow (m\pi)+d$ coherent production. The two new ones are (1) Ξ^* experiment (#673) with BNL and McGill University. This experiment uses as trigger a K^+ detector and a K^- beam. The reaction is $K^- + p \rightarrow K^+ + X$ where X has 2 units of strangeness. (2) Searches for exotic exchanges with BNL. (More will be discussed in our proposal for next year.) As specific progress on these experiments, one graduate student (K. Sawyer) spent all summer at BNL working with the MPS experiment #557. He also participated in the data taking of the same experiment. In addition several of us spent considerable time in BNL during the summer testing a K^+ detector which is on a semi-permanent loan from Rutherford laboratory. The testing of the K^+ detector involved installing it in the BNL test beam and taking data. This part of the test was performed by S. Hagopian and V. Hagopian during July and August 1975. The results of the test are that the equipment did not suffer major damage during transit and is capable of detecting K^+ up to 650 MeV/c. More details on these experiments with our share of the contribution are found in the 1976 Proposal.

E. Beam Design at Fermilab (J. Albright, J. Lannutti)

During the summers of 1973 and 1974 Lannutti worked with the Neutrino Department at Fermilab in the design, construction and tuning of the N3 and N5 beams. These are charged hadron beams leading to the 30-inch and 15-foot bubble chambers respectively. This work came to a kind of fruition with the running of the 250 GeV π^-p experiment in the 15-foot chamber in the fall of 1975.

During the summer of 1975 Albright went to Fermilab to work with these same beamlines. The emphasis was on planning the arrangements for specialized use of these beams for kaons. Details are in Enclosure G. In general, the work is divided into two parts: charged kaons and neutral kaons. For enriched beams of charged kaons there have been a variety of suggested methods, of which two appear to have merit; these are upstream double targeting using pulsed quadrupoles, and downstream double targeting. These two approaches appear to be complementary rather than competitive; they both require a lot of testing and equipment development before they can become routine. The neutral beam (for K^0_L, γ or neutron) appears to be closer to reality. The calculations have been completed for focussing a beam of π^- mesons 100m upstream from the 15-foot bubble chamber. From this focus a neutral beam is aimed directly at the chamber; it can be swept of charged particles and enriched for whichever of the three types of neutrals may be desired.

F. Software Development

1. Geometry and Kinematics (S. Hagopian) - The standard geometry program, TVGP, is not suitable for tracks in large bubble chambers with fish-eye optics and rapidly varying magnetic fields, so a special geometry and kinematics program, HYDRA, was obtained from CERN and implemented on the PDP10 computer at Fermilab, and on the CDC 6400 at FSU. Modifications were made for the 15-foot chamber magnetic field and optical constants.

2. On-Line Measuring (P. Hays) - A new program was written for use on our EMR computer to control measurement of events from 15-foot chamber film. Provision is made for measuring up to 25 tracks with up to 15 points per track. The measurer can record information,

such as special track codes for protons, vee's, gammas and kinks, and reject or restart the event through a button board, as well as digitize x,y points. Interfiducial distances are checked by the program and a remeasure message is sent if the measured value deviates too much from the accepted value. One or more measuring tables can be handled simultaneously.

III. Theoretical Research Program

A. Gravitation

Dirac's work has been mainly centered around the question of whether G varies. Many workers are examining the astronomical consequences of a variation of G. However they mostly use primitive methods to reduce their observations - methods which destroy the successes of the Einstein theory. A better method is being sought. A short paper on the subject has been published (see Enclosure E2). Another paper on this work was published in Vol. 9 of "Studies in the Natural Sciences," a journal of the Center for Theoretical Studies, University of Miami; copies of this paper are not yet available. It deals with G and with the related problem of the microwave background radiation.

A book, General Relativity, has been published (Enclosure D). A paper has been published on a method used in the book (see Enclosure E1). (Dirac)

The work entitled "Gravitational and Inertial Effects on Superconductive Shieldings" performed together with graduate student H.J. Perle of the University of Amsterdam has been completed. The paper should be submitted to the Journal Physica by now. The typing was done in Amsterdam and a copy is not yet available here. The termination of the work was considerably delayed by being lost in the mail between Amsterdam and Tallahassee. An abstract of the work is attached (see Enclosure F7).

The work on the theory of the Josephson effect of superconductors and superfluids in the gravitational field has been continued. The possibility of measuring Dirac's proposed variation of the gravitational constant by means of the static gravitational Josephson effect has been suggested

and investigated. The suggestion is not yet in the stage of planning a direct experiment.

The work on the causal Green's function of the electromagnetic field in DeSitter space in collaboration with H. David of the University of Brussels is near completion. The Green's function has been calculated explicitly, but the proof that it is the only causal Green's function obtainable by analytic continuation from the space with positive definite metric is not yet complete. (Halpern)

The experimental research performed by Van Flandern and Muller and by Shapiro and Reasenberg on the variation of the gravitational constant has been studied and compared. The theoretical interpretation of all these experimenters was found not in accord with Dirac's theory so that the experimental data can be used as a test of Dirac's theory only after considerable modification of the basic calculations. A decision on Dirac's theory will require a reconciliation of the results of the different observations. A workshop meeting has been prepared in Tallahassee to let representatives of the different groups meet and compare their methods and results as well as to make them acquainted with Dirac's theory. A different source of possible information on the variation of the gravitational constant, pulsars with a period varying almost as slowly as the time variation predicted by Dirac, is being investigated. (Dirac, Halpern)

The work on a field theory depending on a cosmological function gave rise to an investigation of an extension of the gauge group of electrodynamics for Dirac's equation of the spinning electron. The theory in its present form does not contain a cosmological function; rather the gauge group of similarity transformations of the Dirac spinors and the γ^- matrices. The Yang-Mills fields of this group contain the electromagnetic fields and the metric fields of gravitation on an equal footing. The field equations are fourth order equations which are straightforward generalizations of the equations of general relativity. The theory was presented at the Marcel Grossmann Meeting on gravitational physics which took place in July of this year in Trieste. (See Enclosure F6).

A paper on the subject has also been presented at the meeting in Bonn on Differential Geometry and Physics. This paper will be published in the

D. Analysis of Three-Pion Final States (Kimel, Gluch)

Work is currently being completed on an analysis of the three-pion final state using data from the FSU 15 GeV/c $\pi^+ d$ experiment. (See Enclosure E3). The theoretical basis for the analysis is a symmetrized Deck Model modified by subenergy unitarity. The approach used in order to include unitarity in the model is a modification of a technique developed by Goradia, Lasinski, Tabak and Smadja for isobar models.

At present, the computer program for calculating the model's predictions for the kinematic distributions is operational, and work has concentrated on increasing the efficiency of this program. In particular, considerable effort is being directed toward developing analytically integrable expressions for the unitarity correction terms. Also a program has been written to calculate the momenta of the three-pion system from the data with the intent of using the model to describe these. The preliminary results of the analysis successfully fit the gross features of the data, but they are incomplete. Conclusive results are anticipated within the near future.

E. Dynamics of the Pulsed UV Nitrogen Laser (Kimel)

As an example of intradepartmental cross-specialty research, we have recently done some theoretical work on the dynamics of a pulsed ultraviolet nitrogen laser as constructed by one of the solid state groups here. Using a simple phenomenological model, we calculate the threshold conditions, the power and width as a function of length and inversion density. The results are in excellent agreement with the data of this laboratory and elsewhere. (See Enclosure F5).

F. $\pi\pi$ Scattering and Exchange Mechanisms (Williams)

Our interest in this field has always been related to understanding the production mechanisms, and the extrapolation to the pion pole, to make it possible to extract detailed information on $\pi\pi$ scattering. One of the outstanding problems here is the apparent weakening of absorption in the production mechanism with increasing dipion mass. During the past year we have offered an explanation for this effect by combining a Born term form factor of increasing steepness with absorption of decreasing range to convert a simple (π

Springer Tracts of Modern Physics and contains much more detailed calculations and results. A publication for the Physical Review on the subject is in preparation. This paper will contain also the generalization of Dirac's theory of magnetic monopoles and an investigation of the possibility of including the weak interactions in the formalism. (Halpern)

A Masters thesis on the gravitational collapse of a large cloud containing non-interacting dust and randomly oriented electromagnetic radiation has just been concluded by R. Parsons. The subject was suggested and initiated by Halpern. The work was done by R. Parsons who found numerical solutions of the complicated equations. The results give insight into the rôle of electromagnetic radiation at the extreme stage of collapse just before the horizon is reached. (Halpern, Parsons, Dirac)

B. Non-Abelian Magnetic Charge and Lorentz Invariance (Thébaud)

We have investigated the theory of non-abelian magnetic charge, originally conceived as a possible model for colored quark dynamics, from two points of view. In the first of these, the work is based on the path-dependent techniques of Mandelstam. In the second approach a consistent Langrangian field-theory is constructed which possesses electromagnetic symmetry, reduces to the known gauge theories in appropriate limits, has a fundamental Maxwell field, has a simple four-momentum density, and admits a generalization of the Dirac charge quantization condition. However, both points of view lead to the conclusion that the theory ultimately is in contradiction with Lorentz convariance. (See Enclosures F11).

C. Meson Mixing in the Four-Quark Model (Thébaud, Kimel)

The masses and strong and electromagnetic decays of 0^- and 1^- mesons constructed of a quartet of quarks are related in a phenomenological scheme motivated by Bethe-Salpeter amplitudes, and used to test SU(4) breaking schemes. The small width of the ϕ_c, identified with the J particle, is consistent with the ρ and K^* widths, and leads to $m_0 = 760$ MeV, an obviously consistent result. The mass and width of the η_c' are predicted, as well as the 2γ partial widths for η, η', and η_c, the former two consistent with experiment. The results are currently being written up.

exchange) Born term into a Regge pole plus decreasing Regge cut as the mass of the produced dipion system increases. (See Enclosure F9). Although this is probably not a complete explanation of the effect, it points to problems of fundamental interest, such as (i) the need for a more precise statement of the role of diffraction dissociation in absorption, (ii) the need for a good connection between pion electroproduction, photoproduction and dipion production, i.e. extrapolations in external mass variables.

G. Analysis of Three-Body Final States (Williams, Capps, Madden)

Our formulation of the partial wave isobar model incorporating some unitarity constraints has been applied to 1271 events of $K^- + n \to \Sigma^+ + \pi^- + \pi^-$ for c.m. energies in the range 1620-1730 MeV to find Σ^* states decaying to $\Sigma\pi\pi$ through known $Y^*\pi$ intermediate states. This work has resulted in a dissertation for C.D. Capps (Enclosure B3). Essentially, we found some evidence for a $\Sigma^*(1690)$ resonance with $J^P = 3/2^+$, a possible radical excitation of the $\Sigma(1385)$. Some work is continuing on the $\Lambda\pi^-\pi^0$ final state with P. Madden (see Section IIc).

ENCLOSURES TO PROGRESS REPORT

for the period 1 November 1974 to 30 September 1975

A. Papers Presented at Meetings

1. Washington Meeting, April 1975; Bull. Am. Phys. Soc. Vol. 20, No. 4.

   a. "Preliminary Results from the 250 GeV/c π^- Engineering Run of the 15-foot Bubble Chamber", by S. Hagopian, Albright, Hays, Knop, Lannutti, Bogert, Hanft, Harris, Huson, Kahn, and Smart.

   b. "Production of Multiple Neutral Strange Particles in 250 GeV/c π^- Interactions", by Kahn, Bogert, Hanft, Harris, Huson, Smart, Albright, S. Hagopian, Hays, Knop and Lannutti.

   c. "Six and Eight-Prong Interactions by π^+d at 15 GeV/c", by Wind, S. Hagopian, V. Hagopian, Horne, Pewitt and Bensinger.

   d. "Study of the Reaction $\pi^+d \rightarrow \pi^+\pi^+\pi^-\pi^0 d$ at 15 GeV/c", by Richey, S. Hagopian, V. Hagopian, Horne, Pewitt, Wind and Bensinger.

2. "15-foot Experiences", talk presented by J.E. Lannutti at Fermilab on 16 August 1975.

3. Papers presented at the DPF meeting in Seattle, August 1975.

   a. "Topological Cross Sections and Multiplicity Momenta for π^-p Interactions at 250 GeV/c", by S. Hagopian, J.R. Albright, P. Hays, J. Lannutti, D. Bogert, R. Hanft, R. Harris, S. Kahn, F.R. Huson, C. Pascaud and W. Smart.

   b. "Search for Charm in 250 GeV/c π^-p Interactions", by R. Harris, D. Bogert, R. Hanft, S. Kahn, F.R. Huson, C. Pascaud, W. Smart, J.R. Albright, S. Hagopian, P. Hays, and J. Lannutti. FN-281

   c. "Neutral Strange Particle Production in π^-p Interactions at 250 GeV/c", by D. Bogert, R. Hanft, R. Harris, F.R. Huson, S. Kahn, C. Pascaud, W. Smart, J.R. Albright, S. Hagopian, P. Hays, and J. Lannutti.

4. Talks presented at the Fermilab Symposium on Hadrons

in Bubble Chambers, 18 and 19 September 1975.

a. "15-foot Chamber Characteristics," by F.R. Huson and J.E. Lannutti.

B. Ph.D. Theses

1. "Four Charged Particle Final States from the Reaction $\pi^+ d$ at 15 GeV/c," by N.D. Pewitt, FSU Publication HEP-75-1-03(1975).

2. "Strange Particle Final States from 15 GeV/c $\pi^+ d$ Interactions," by D.P. Wilkins, FSU Publication HEP-75-6-5(1975).

3. "A Study of the Reaction $K^- n \to \pi^- \pi^- \Sigma^+$ Using a Newly Developed Isobar Model with Unitarity," by C.D. Capps.

C. M.S. Theses

1. "Ionization Identification of Charged Particles in Bubble Chamber Experiments," by K.A. Rauchwarger, FSU Publication HEP-75-6-6(1975).

D. Book

General Relativity, by P.A.M. Dirac, Plenum Publishing Company (1975). Copies are not enclosed.

E. Papers Published

1. "An Action Principle for the Motion of Particles," by P.A.M. Dirac, Gen. Rel. Grav. 5, 741 (1974).

2. "Variation of G," by P.A.M. Dirac, Nature 254, 273 (1975).

3. "Reaction $\pi^+ d \to \pi^+ \pi^+ \pi^- d$ at 15 GeV/c," by C.P. Horne, S. Hagopian, V. Hagopian, J.E. Lannutti, N.D. Pewitt, D.P. Wilkins, B. Wind, and J.R. Bensinger, Phys. Rev. D 11, 996 (1975).

4. "Gravitational and Electromagnetic Radiation in Kerr-Maxwell Spaces," by R.W. Lind, J. Math. Phys. 16, 34 (1975).

5. "Stationary Kerr-Maxwell Spaces," by R.W. Lind, J. Math. Phys. 16, 39 (1975).

6. "Monte Carlo Generation of Two Body Resonant States," by R.E. Knop, J. Comp. Phys. 18, 115 (1975).

7. "An Experimental Model of Migmacell," by B. Maglich, M. Mazarakis, J. Galayda, B. Robinson, M. Lieberman, B. Weber, A.P. Colleraine, R. Gore, D. Santeller and C. Chieng, Nucl. Instr. and Meth. 120, 309 (1974).

8. "Search for Nuclear Resonances of Mass up to 8.5 GeV," by K. Abe, J. Alspector, R. Bomberowitz, K. J. Cohen, A.P. Colleraine, G. Cvijanovich, T. Delillo, W.C. Harrison, J. Mueller, J. Oostens, B. Robinson, and F. Sannes, Phys. Lett. 53B, 114 (1974).

F. Papers Submitted for Publication

1. "RESURX - A Computer Assisted Human Intervention System for High Energy Physics Data Reduction," by N.D. Pewitt, S. Hagopian, V. Hagopian, and B. Wind. Submitted to Rev. Sci. Instr.

2. "Search for Charmed Mesons and Baryons," by V. Hagopian, D.P. Wilkins, B. Wind, S. Hagopian, J.R. Albright, J.E. Lannutti, N.D. Pewitt, C.P. Horne and J.R. Bensinger. Submitted to Phys. Rev. Letters.

3. "Resonances in the $K_S K_S$ System," by D.P. Wilkins, J.R. Albright, S. Hagopian, V. Hagopian and J.E. Lannutti. Submitted to Phys. Rev. Letters.

4. "Duality and Low-Mass $K\bar{K}$ Resonances," by V. Hagopian, J.R. Albright, S. Hagopian, J.E. Lannutti, and D. P. Wilkins. Accepted for publication in Proceedings of the Seattle Meeting, APS Division of Particles and Fields.

5. "Dynamics of the Pulsed UV Nitrogen Laser," by P. Richter, J.D. Kimel and G.C. Moulton. Accepted for publication by Applied Optics.

6. "An Approach to a Unified Treatment of Electromagnetic and Gravitational Theory Emerging from the covariant Dirac Equation," by L. Halpern. Accepted for publication in proceedings of Marcel Grossmann Conference.

7. "Gravitational and Inertial Effects on Superconducting Shielding ," by L. Halpern and J.H. Perk. Submitted to Physica.

8. "Conclusions from the Extended Gauge Principle of Dirac's Equation," by L. Halpern. Accepted for publication in the proceedings of the Bonn Con-

ference on Differential Geometry and Physics, 1975. It will appear in Springer Tracts on Modern Physics. (Copies of this are not yet available).

9. "Absorption Weakening in Production of Higher Mass States," by P.K. Williams. Accepted for publication by Phys. Rev. D.

10. "Non-Abelian Magnetic Charge and Lorentz Invariance; I. Semi-Classical Model Building," by L. Thébaud. Submitted to Phys. Rev. D.

11. "Non-Abelian Magnetic Charge and Lorentz Invariance; II. A Quantum Field Theory Model," by L. Thébaud. Submitted to Phys. Rev. D.

G. Fermilab Technical Memo

"Methods for Transporting Kaons to Bubble Chambers at Fermilab," by J.R. Albright, TM-604 (1975).