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Technical Program in FY 66

J. R. Sanford

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Accelerator Department
BROOKHAVEN NATIONAL LABORATORY
Associated Universities, Inc.
Upton, L.I., N.Y.

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TECHNICAL PROGRAM IN FY'66

Experimental Planning and Support Division

Introduction

The high energy physics research program at the AGS has utilized four experimental areas and seven target stations during the year. The secondary particle beams in these areas are planned, equipped, erected, and operated by Division personnel. During normal operations, three to four targets and five to six experiments often operate simultaneously. During the year, a total of nine counter and spark chamber experiments were completed, over 2 million pictures taken in the 30-inch hydrogen bubble chamber, and 1.2 million pictures in the 80-inch bubble chamber.

Experimental Facilities

The protons from the AGS are used every pulse for counter and bubble chamber experiments. Targets near AGS straight sections B10, F10 and G10 are used for counter and spark chamber experiments, while the 30-inch bubble chamber uses beams from F20, and the 80-inch bubble chamber is supplied by beams from I10. Each area was extensively used during the year.

The SW Experimental Area is served by a fast external proton beam from B10. It was used for only a brief period during the past year, but additional preparations and careful accelerator operations were needed for the final experiment. The experiment was another search for the intermediate boson carried out by Columbia University and Brookhaven physicists. The experiment consisted in looking for an anomalous source of high energy muons at large angles--such as might result from the decay of the intermedate boson. In this experiment the proton beam was transported all the way to a target just before the 82 ft thick iron plate shield wall. Counters located in holes within the shield measured the muon spectra.

The external proton beam was steered and focussed very carefully upon the target, so that it did not strike any parts of the beam transport system and produced pions which would decay to muons. The remote location of the SW areas, and the 8 ft change of elevation between the plane of the circulating proton and the final target helped to keep the background low. The counting rate at large angles was about one count/cm^2 per hour. They found no evidence for the existence of the intermediate boson, and set an upper limit on the production cross section of 2×10^{-34} cm^2.

Further around the AGS at F10 a high energy secondary particle beam has been erected and operated. The beam is used by a Brookhaven group for an experiment in which the real part of the nuclear scattering amplitude is determined from measurements of the differential elastic scattering cross section at very small angles. The beam uses two target locations, one at the upstream end of the F10 straight section when positively charged particles are desired, and the other at F9 when negatively charged particles are needed for the experiment.

The beam is momentum analyzed and focussed onto a 10 ft long liquid hydrogen target located 400 ft. from the target in the accelerator. A combination of vacuum tubes and He bags over the length of the beam minimizes the multiple scattering of the beam particles. When the beam is tuned for 20 BeV/c π^- mesons, there are 10^5 π^-mesons/pulse with a momentum resolution of ±0.29%. At 26 BeV/c there are 10^4 π^-/pulse.

After the hydrogen target the scattered particles are analyzed by hodoscope arrays before and after three 30D72 spectrometer magnets. The angle of scattering can be determined to 1 mr, and the absolute momentum of the elastically scattered particle to within 0.2%.

This beam, and the other counter beams and experiments as they are to be positioned in the summer of 1966 are illustrated in Fig. 1. This is a general layout drawing of the East and West Experimental Areas.

The secondary beams for G10 are the most numerous for the particle physics research using counter and spark chambers. During the year, four basic beams were used repeatedly. Two beams were relatively simple. One was a beam of neutral particles produced at 30^{o} to the circulating protons. This beam of K_2^o mesons was used by physicists from the University of Illinois to search for the 2γ decay of the K_2^o. They produced an enriched beam of K's by using a lead filter and a sweeping magnet before their beam collimators. At the distance the detector was located from the target, a flux of 35,000 K_2^o was measured for 5×10^{11} ppp on the target. The other beam is charged particle beam produced at 17^{o} and steered by two bending magnets into a test area. This test beam contains low energy particles and is frequently used by several groups at once for detector and equipment testing.

Two beams on the outside of the ring at G10 have been used extensively during the course of the year for counter and spark chamber experiments. An intermediate energy beam emerges from the G10 straight section at 4.7^{o} It has been used for pion and kaon beams from 6-18 GeV/c. At 12 GeV/c they measured 3×10^{5} pion/pulse. This beam was used by a group from the University of Pennsylvania for a measurement of the 180^{o} scattering of pion on protons, and by an experiment of Yale and Harvard on the decay of vector mesons into muon pairs. At present a pion/muon beam is being erected using the 4.7^{o}beam from G10. Pions in the beam will decay to muons, and muon proton scattering will be closely studied at high energies. This experiment is being undertaken by a research group from Columbia University and the University of Rochester.

The 10^{o} beam at G10 is a multipurpose separated beam used for 1-3.5 GeV/c particles. After the electrostatic beam separators the beam is split into two branches. The short branch is used for low energy K experiments. A Brookhaven group has done a $K^{\pm}$ total cross section experiment on hydrogen and deuterium from 1.5 to 2.5 GeV/c in that beam. The same group has been doing an extensive measurement of the polarization of Ξ^{-}'s produced by K^{-}-p interaction near 1.8 GeV/c in preparation for a measurement of the magnetic moment of the Ξ^{-}. When the beam is tuned for positive particles 2 GeV/c, there is a measured flux of K^{+} mesons of $10^{4}/10^{12}$ppp.

The longer branch was first used by the original designers of the separated beam facility for an experiment to measure the anti-proton-proton annihilation cross section into electron and pion pairs. After careful tuning of the beam, the California Institute of Technology and Brookhaven physicists measured an antiproton flux of 5×10^{4} at 2.5 GeV/c in this beam.

This experiment was followed by two K experiments using beams of K's. The first experiment by a group from the University of Rochester made a precise determination of $K^{\pm}$ lifetimes and searched for some violation of CPT invariance. At present a similar experiment is being done in the same bin by Princeton University.

In summary, the counter program used the research facility at F10 and G10, and along with the bubble chamber beams used most of the beam handling equipment available. A summary of equipment usage for the year showed that 85% of the magnets, 96% of the power supplies, and 87% of the inventory of shielding were utilized.

In addition to the counter beams, the AGS was used to provide beams for two operating bubble chambers. This was the first year of operation for the new low energy separated beam to the 30-in. bubble chamber. This beam is an improved version of the earlier beam for the same chamber. It can provide K mesons up to nearly 1 GeV/c. The new beam is composed of two stages of separation and uses the short electrostatic separators. The beam was carefully designed so that it could operate on every pulse using only a small fraction of the circulating proton intensity. When it is tuned for K^-'s at 750 MeV/c, there are 100 per 10^{11} ppp, and after degrading 10 stop in the chamber on the average. The chamber background from neutrons is about one proton recoil per 10^{11} ppp.

The beam was used with the chamber filled with liquid hydrogen for 260,500 pictures of K^--p interactions near 750 MeV/c for Duke University. 696,000 pictures of K^--p near 400 MeV/c for a group of physicists from Brookhaven, Yale University and the University of Massachusetts. The chamber was used in a stopping K^- beam while 586,000 pictures for Maryland and Princeton were taken.

The chamber was filled with deuterium during the past year, and 431,000 pictures of π^+-d interactions were taken for Columbia University at a pion momentum of 850 MeV/c. 103,000 pictures were taken for BNL and Carnegie Institute of Technology of K^+-d interactions near 625 MeV/c. In an exposure of K^--d interactions, 72,000 pictures were taken for a Brookhaven group. The chamber was also used for several test exposures.

In the North Area, the electrostatically separated Beam #3 has continued to serve physicists from many groups for research in the 80-in.

bubble chamber. A new radio-frequency separated beam, Beam #4, the first of its kind in the United States, was brought into operation and has greatly expanded the range of experiments possible in the 80-in. chamber. In order to accommodate both beams for use, Beam #3 was rebuilt to aim into a new location of the chamber, Beam #4 was aimed into the old chamber position, and the chamber was adapted to be able to move from one beam to the other.

Beam #4 employs a radiofrequency separator which has been under development in the Accelerator Department for several years. The principle of operation rests on an interference between two transverse oscillations imparted onto an essentially continuous beam at two points separated by a drift space. The phase of this interference for a given frequency depends on the time of flight along the drift space, different for particles of given momentum and different rest masses. For a fixed choice of frequency and drift length, this interference can be adjusted, at certain momenta, to be destructive for undesired particles, and, at the same time, to be constructive for desired ones. This results in a vanishing net deflection for undesired particles and an angular oscillation of considerable amplitude for desired ones. The separator is restricted to operate at certain momenta, where for the fixed frequency and drift length the time of flight difference between desired and undesired particles is sufficiently different from a multiple of one oscillation period, and where, in the case of rejection of two contaminants (e.g. protons and K mesons in a K^+ beam) the time of flight difference between the undesired species is sufficiently close to an integral multiple of one period, so that both can be rejected simultaneously.

The radio frequency separation technique opens up an energy region for research in bubble chambers where electrostatic separation ceases to be practical. In Beam #4, for instance, one can obtain K particles at momenta of 7.38, 9.0 and 12.8 BeV/c with high purity , whereas hitherto Beam #3 had an upper operating limit of about 5 BeV/c for K mesons. In addition Beam #4 is built to transport, without separation, π^- and protons at momenta up to 30 BeV/c. On the other hand, Beam #4 ceases to operate as a separated beam in the lower energy region of Beam #3.

The North Area thus has two mutually complementary tools available for physics research at high energies in the 80-in. bubble chamber. In the summer of 1965 a total of 600,000 pictures were taken in Beam #3.

About 235,000 of them were taken to complete runs started in earlier years. The remainder were new experiments including π^+-p exposures at 8.5 BeV/c and 7.75 BeV/c (60,000 and 34,000 pictures respectively), a K^--p experiment at 4.2 BeV/c (55,000 pictures), K^+-p runs at 5.5 BeV/c and 3.0 BeV/c (54,000 and 113,000 pictures) and 47,000 pictures of p-p interactions at 7 BeV/c incident momentum. Beam #4 was constructed in the fall of 1965, tested in December 1965 and it started operating in January 1966. Since then 600,000 pictures have been taken. These include π^--p exposures at 25 BeV/c and 16 BeV/c(102,000 and 62,000 pictures), a p-p experiment at 29 BeV/c (79,000 pictures), K^--p runs at 12.8 BeV/c, 9.04 BeV/c and 7.38 BeV/c. (107,000, 58,000 and 49,000 pictures respectively), and K^+- p exposures of 79,000 pictures at 12.8 BeV/c and 63,000 pictures at 7.38 BeV/c. A K^- exposure at 12.8 BeV/c momentum in deuterium was started.

Experimental Equipment

The experimental equipment used in particle beam handling systems consist of magnets and their power supplies, beam separators, shielding, etc. At the end of FY'66, 178 magnets, 141 power supplies, 12 electrostatic separators, and 75,000 tons of shielding were in the inventory or on order. In addition, 10 MVA of electrical power, and 4 large coolers for experimental water were acquired during the year.

During the past year additional conventional magnets were added to the pool of equipment. Four 18D36 bending magnets, 4-12S24 sextupole magnets, and 5-N8Q32 quadrupoles are of this type. Several unusual magnets were also designed. One of these was a 3-in. diameter quadrupole to be used for forming the external proton beam. With an input power of 65 kW it will produce a magnetic field gradient greater than 10 kG/in. Five 18Q32 quadrupoles were designed for application where quadrupoles of wide internal aperture are needed.

The magnet design and studies groups have developed a design for a more efficient quadrupole with a somewhat enlarged cross section. It is hoped that this type of magnet which has lower electrical power consumption can be used in areas where compact magnets are not essential. Magnet studies and measurements have been done on the new magnets, and on the large spectrometer magnets that are beginning to be used in high energy physics experiments.

Twenty-three new power supplies were purchased in the past year. These will all be used in general purpose beam applications. The power supply group has been studying improved regulators for the power supplies, and intend to improve on the ±0.1% magnetic field regulations, and on the general reliability of the supplies.

No new beam separators were designed or acquired during the past year. The twelve electrostatic separators all continued to give satisfactory service. The short separators in the new low energy beam to the 30-in. bubble chamber operated reliably with 500 kV across a 4-in. interelectrode gap, while the older separators did nearly as well. A development program on new electrode designs and tests is now underway.

The construction of the rf separator system was completed as described in last years report. The separator was installed in Beam #4 in the fall of 1965 and underwent deflection tests in December 1965. At an input power level of 10 megawatts the deflection were found to impart a maximum transverse momentum of 16.5 ± 1.2 MeV/c to the particles traveling in synchronism with the deflecting wave. This measurement agrees within experimental errors with cold measurements on the deflector and with theoretical computations (15.2 MeV/c transverse momentum expected at 10 megawatts). The separator sysem has operated successfully in the running period between January 1966 and June 1966, and only minor problems of reliability have been encountered. The setup and tuning adjustments of the separator in the operating beam is straightforward and the deflection amplitudes and their relative phase are sufficiently stable to require only minor adjustments in the course of a running week.

Cryogenic targets of liquid hydrogen, deuterium, and helium are used continually at the AGS and Cosmotron. Twelve targets were designed and constructed for the AGS and seven for the Cosmotron. Many of these targets have unusual design features that are needed for the specific experiments for which they have been constructed.

One such target system had two 6-in. diameter by 36-in. long inner vessels surrounded by a concentric cylinder wrapped with super-insulation inside a vacuum chamber. The target is connected to a 200 lite reserver in order to reduce the frequency of hydrogen fillings needed. This and a special pressure regulator for liquid density control and a temperature control bath for the pressure regulating control gas kept the density of the liquid in the target constant to one part in 10,000.

A large part of the high speed logic and scaling circuits used in the counter experiments at the AGS and Cosmotron are provided by the High Energy Electronics Equipment Pool (HEEP). During the past year HEEP has supplied forty experiments with a major portion of their electronic equipment. The inventory of such equipment is valued at several million dollars, and 90% is in use at all times.

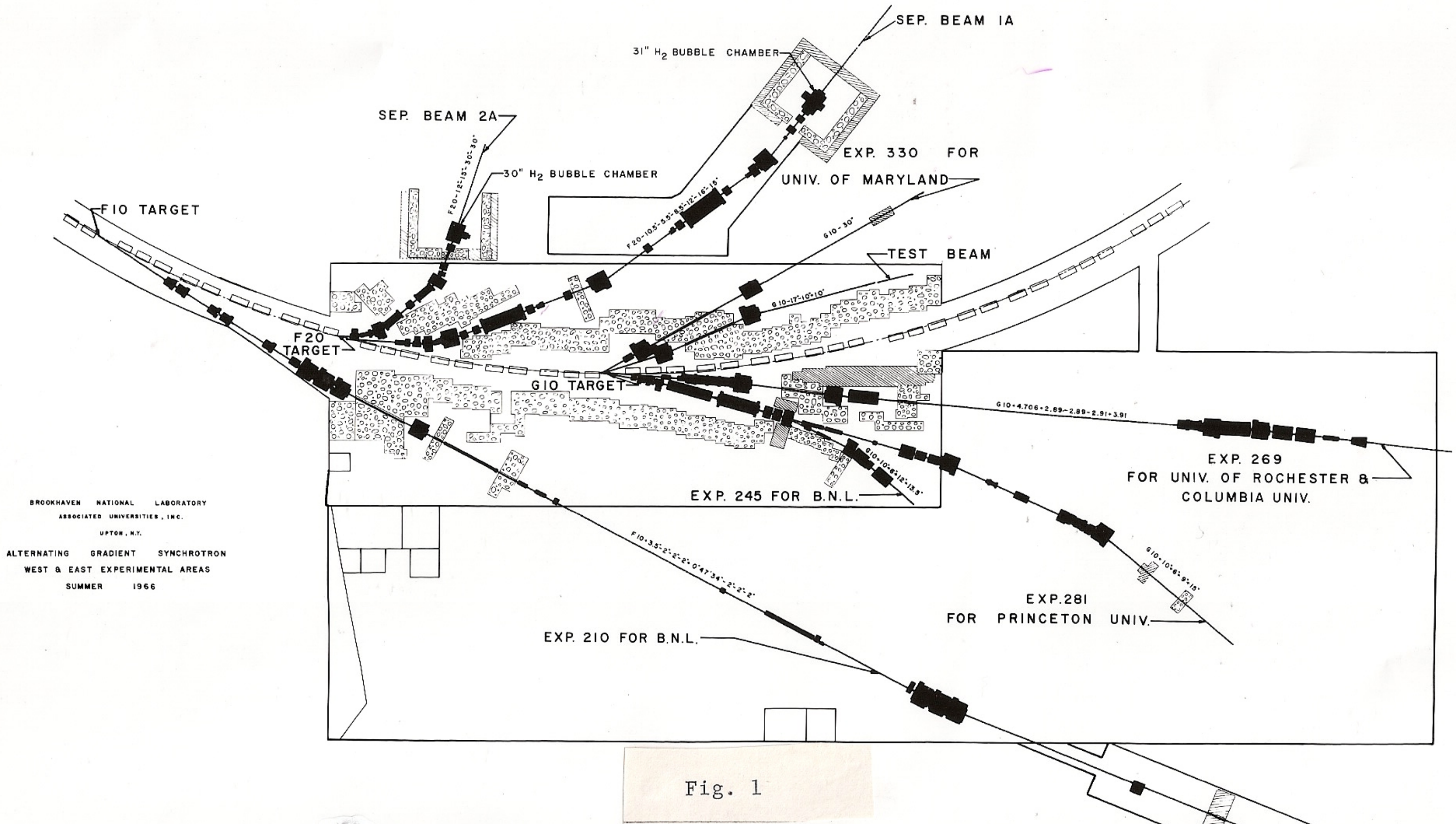

Fig. 1

This simplified drawing illustrates the secondary particle beams and experiments that were erected in the East and West Experimental Areas in the summer of 1966. Five counter and spark chamber experiments use particles from targets located at F10 and G10. The 30-in. bubble chamber is in a low energy separated beam for F20. The 31-in. bubble chamber also uses a target at F20, but only a portion of the beam illustrated here was completed.