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Experimental planning and support contribution for Annual Report FY-70

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EXPERIMENTAL PLANNING AND SUPPORT CONTRIBUTION FOR ANNUAL REPORT FY-70

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Experimental Planning and Support

Additions which will substantially increase the experimental program at Brookhaven's AGS were initiated last year. The development of the slow external proton beam and its extension into the new Experimental Hall have consumed the major construction effort. The design of a future bubble chamber complex in the North Area is in its final stage.

Experiments around the AGS are concentrated in three major areas, shown in Fig. 1. The largest of these is the East Experimental Area which fans out from a 60^{o} sector covering the F and G superperiods of the accelerator. It contains four charged secondary counter spark chamber beams and two bubble chamber beams in addition to the slow extracted primary proton beam. Nine counter experiments are set up simultaneously.

In the North Area is located the 80-in. bubble chamber. It is serviced by two separated charged-particle beams. These beams emanate from targets close to the I-10 straight section.

The third area, the Neutrino Area, is located in the Southwest Experimental Area which receives protons from the B-10 section. The 7-ft bubble chamber is located here.

Details of the experimental program and equipment are described in the following sections.

Experimental Facilities and Program

During the first half of this report period the AGS was shut down to allow major changes in the machine as the first phase of the Conversion Project. This shutdown made possible major changes in the configuration of beams for counter experiments in the East Area. At Target Station "A" of the slow external proton beam the shielding was increased and modified with view to operations at 10^{13} protons per second from the machine after the Conversion Project is completed. In the course of this modification of the shielding two new penetrations were provided in the massive beam backstop for the residual proton beam from Station "A". These penetrations make possible a greater variety of beams from the same target. The first new penetration, at 0^o to the direction of the incident proton beam on target, provides a well-collimated, intense beam of neutral particles simultaneously with operation of charged particle beams off the same target. The second penetration, at 2.5 in. above the proton beam axis, and at an angle of 5^o to the incident proton beam direction, allows the extraction of a diffracted proton beam of sufficiently low intensity to be useful for counter experiments. Operation of this port is compatible with extraction of a high energy negative particle beam in the 0^o secondary charged particle beam channel, Beam #10. A further modification of the beam configuration from Target Station "A" during this time to increase the utility of the station was to provide an alternate branch at the downstream end of Beam #10. This allows one experimenter to be setting up or modifying his apparatus while the beam is continuing to be utilized by a second experimenter in the alternate branch.

On the new neutral beam port two neutron experiments were set up, using the same intense neutron beam in a tandem arrangement. The first of these, Exp. #411, Michigan/Princeton, is studying the differential scattering cross section of neutrons from protons in a hydrogen target with higher precision than has been attained previously and over a wider range of 4-momentum transfer.

Experiment #486, a second Michigan/Princeton experiment is set up in tandem with Exp. #411. This experiment will study the total cross section for neutron scattering from various elements. The precision of such an experiment is a function of the available distance from the scattering target to the detector, a total absorption calorimeter in this case. The availability of the new East Experimental Building Addition with its long beam runs has been a factor in significantly increasing the level of precision in the study of these cross sections.

On the 0^{o} charged particle beam, Beam #10, the development and testing of the large array of magnets and wire chambers with their associated computer software for Exp. #370, BNL, continued through the whole period after the shutdown.

On the new long branch of Beam #10, a Northeastern University/State University of New York at Stony Brook collaboration, Exp. #463 was set up and began taking data on an experiment to search for massive bosons using a missing-mass spectometer technique.

Calculations and refinements of the beam optics and layout for the diffracted proton beam to Exp. #396 BNL also continued through the period.

From the internal target station at G-10 a full program of counter experiments continued and mode of sharing beam simultaneously between G-10 and the slow external proton beam was successfully employed. At Beam #6 (G-10 + 4.7^{o} on the outside of the AGS ring) a group from MIT, Brown and Padua Universities completed an experiment to measure the backward angular distributions for charge exchange and eta production in pi minus proton collisions. In a neutral branch of this beam a Princeton group performed an experiment to measure both the magnitude and phase of η_{oo}.

At Beam #5 (G-10 + 10^{o}, the mass-enriched counter beam) two experiments were completed. A Yale group, using a polarized proton target measured the asymmetry (left-right) in the elastic scattering of K^{+}, K^{-} mesons and antiprotons. A BNL group used the other branch to test CP violation by comparing the decays of K^{+} and K^{-} into the $\pi\pi\gamma$ mode.

On the neutral beam inside the AGS ring (Beam #7 at G-10 - 20^{o}) a group from Princeton and Cornell Universities performed an experiment to measure the phase of η_{+-} by studying K^{o} regeneration in liquid deuterium.

Alternate operation of the 30 and 31-in. bubble chambers, as instituted last year, was resumed after the AGS shutdown. A total of 1290 thousand pictures was taken in both of these chambers. Collaborators from the University of Michigan and BNL obtained 500 thousand pictures of K^{-} interactions in a H_2 - Ne mixture in the 31-in. chamber. In the late spring, a joint experiment by Syracuse, Maryland, Brandeis and Tufts Universities took 400 thousand pictures utilizing a beam of K^{-} mesons in liquid deuterium. The 30-in. chamber program began in April with a 200 thousand picture exposure for the University of Florida's investigation of $K^{-}N$ reactions in D_2. A BNL group then accomplished the first phase of a K^{+} experiment by taking 40 thousand pictures in D_2. In June, Harvard University physicists began their experiment on K^{-} - P interactions in liquid H_2. They are expected to complete about 150 thousand of these by the end of FY 1970 bringing the totals for this year to 390 thousand for the 30-in. chamber and 900 thousand for the 31-in. chamber.

Separated Beam #2 also supplied charged particle beams for two tests of experimental equipment. Negative pions were provided for tests of a track sensitive target, filled with H_2- Ne and immersed in a H_2- Ne mixture in the 30-in. bubble chamber. This work was carried out by members of the BNL Bubble Chamber Group. The other test was performed by Vanderbilt University and BNL personnel using K^- mesons to test the counters and spark chambers to be employed in a later measurement of the Σ^+ magnetic moment.

This year the 80-in. bubble chamber operated with Beam #4, the rf separated beam. During the spring a total of 550 thousand pictures was accumulated with the chamber filled with deuterium. Groups from the University of Tennessee, Purdue University, Weizmann Institute, Oak Ridge National Laboratory and Brookhaven National Laboratory received pictures with incident π^+,K^{π} and protons.

The feasibility of extending the useful momentum range for pions and antiprotons in the rf separated beam was successfully demonstrated. With a new mode of operation a π^+ beam up to 23 BeV/c can be delivered to the 80-in. bubble chamber. Antiproton beams near 15 BeV/c are also obtainable.

Experimental Equipment

During the year there were on the average 14 beams in operation or under construction in the East, West, North and Southwest Experimental Areas. Fig 2 shows the configuration of beams in the Target and East Experimental Area in the summer of 1970. Forty man-years of effort were expended on experimental beam construction by the experimental area operations group and the Laboratory's Plant Engineering and Planning Department. The construction of the slow external beam extension was culminated by the completion of the beam transport and shielding Target Station "C".

A summary of the inventory and usage of major experimental service items is given below.

Item	Inventory	% Usage
Magnets	239	85%
Power Supplies	205	93%
Beam Separators	12	83%
Shielding	90,000	92%
Experimental Power	54 MVA	70%
Experimental Cooling Water	4,050	93%

The power supply group has purchased eight additional 450 kW dc power supplies and six rack mounted 2.3 kW units. About 9 MVA of experimental power was made available in the New East Building Addition via 36 distribution boxes. An improved version of a power monitoring panel was built and installed in the experimental area control room to monitor the 54 MVA of experimental power.

With the basic construction complete on the East Experimental Building Addition, the building was outfitted to accept experiments. This work included the addition of control cables, timing signals systems, experimental information centers and the tying in of all signals with the experimental area control room.

During the long shutdown starting in May the 40 ton crane in the East Experimental Building was modified; its hoist speed was about doubled. Also during this period many modifications to magnet and power supplies were made, which should improve their performance and reliability.

These improvements were a) the radiation hardening of 50 magnets inside the ring enclosure b) replacing the rubber water supply hoses with phosphor bronze hose on 53 magnets c) installation of remote coil voltage readout plugs of 66 magnets inside the machine d) improvements to electronics controls on the power supplies. In addition two older Mark I bending magnets were converted to Mark II to reduce spare coil inventory and improve performance.

Another important category of work done during the long shutdown was preventive maintenance.

This was accomplished on 169 magnets and included flushing, hose replacement and flow switch cleaning. On power supplies 144 units had general cleaning, checks, tightening and regulation checks performed.

Seven 18D72 bending magnets, five N3Q36, two N8Q12 quadrupole magnets and two 10C20 septum magnets have been received and are being prepared for use in the experimental program. One 48D48 Mark II spectrometer magnet and one 96D40 spectrometer magnet have been designed and ordered. The large transporting device, capable of lifting, moving, and positioning approximately 120 tons will be used to position the 96D40 magnet. It was successfully used to position 48D48 and 30D72 bending magnets during the past year. The necessary vacuum boxes, collimators, mass slit, magnetic shielding for 48D48, 72D18, 18D72 bending magnets and pole pieces and shims are being designed and manufactured for secondary beams downstream of the slow external proton beam target.

The efforts of the Magnet Study Group have principally been devoted to the design and construction of cryogenically cooled magnets for accelerator and beam transport applications.

A 1-in. aperture magnet model has been pulsed in excess of 40 kG using high purity aluminum as a conductor. With a cycle typical of present accelerators, auxiliary losses are $\sim 15^{\circ}$K. In the presence of high magnetic fields the effective dc resistance is 1×10^{-9} Ω-cm.

Annealing treatments are being refined. Samples can now be produced at 4.2°K which has a resistance 20,000 times less than at room temperature.

The great thermal conductivity of the aluminum has promising features for thin current sheet septum magnets, as well as for general thermal stabilization. Currents in excess of 50,000 amps/cm^2 were passed through a ribbon 13½ inches long. This was surrounded by vacuum and cooled at its ends only through contact with a cryogent at 4.2°K and 15°K. Studies of high purity Al as a stabilizer for superconductors are also being made.

A facility for large scale cryogenic work has been assembled. A 2-in. aperture magnet, which is two feet long, is being assembled. Techniques for anodizing great lengths of very low resistance Al ribbon were developed successfully. Procedures for winding and forming large coils are being developed including compound bending of coil ends.

Before the end of FY 1970 a prototype will exist consisting of an 8-ft magnet and a dewar actually constructed with the problems of continuous assembly of such structures in mind. Both mechanical and magnetic stability will be studied. Methods are designed into the structure to cope with the effect on precision alignment of the contraction stresses upon cooling.

This prototype system will first be cooled by forced circulation of subcooled hydrogen. Later supercritical helium gas will be used. A circulating pump and heat exchanger system capable of cooling this prototype plus ultimately adjoining sections, is under construction.

The Magnet Study Group has also routinely maintained and provided precision-calibrated Hall probes for use by various experimental groups and precision calibration services for all beam transport magnets are provided.

The Beam Separator Group continued to operate 10 electrostatic separators in four beams in addition to the rf separated beam. During the long shutdown two new deflectors were installed in the rf beam. The older deflectors have accumulated approximately 11,000 hours of rf time and require refurbishing. Also during the shutdown the deflector vacuum systems changeover to an all metal-sealed system was completed. This brought about an improvement of the vacuum by more than a factor of 10.

A double pulsing mode is being added to the rf separators in the form of two 2-1/2 microsecond pulses separated by 100 milliseconds. The previous mode allowed one 5 microsecond pulse. An automatic cycling feature has been devised to allow the rf separators to run up to the present power level after an interlock trip out. This feature is intended to reduce the need for constant surveillance of the separator.

A new 2 meter (short) dc separator has been constructed complete with most of the improvements suggested by the separator testing and development program. This separator will be installed in the low energy separated beam designated Beam #11 from the "C" Target Station.

The same type of improved components will be installed in three separators during this next year. Work has started on a similar program for the two cylindrical separators.

An improved interlocking and current regulation system has been designed for the dc high voltage power supplies. Installation of this system on each of the separator power supplies is expected to be completed by late summer. The purpose of this system is to protect both the separator and the power supply from damage during all phases of separator operation. When the installation of these systems has been completed a reduction can be made in the number of shift operating personnel.

The Cryogenic Group support program has centered mainly around the designing, fabrication, and operation of liquid hydrogen and liquid deuterium targets. Seven hydrogen targets have been designed, constructed and operated. Most of the targets involve special design requirements tailored specifically for the intended experiment. These targets consist of a mylar flask surrounded by super-insulation and a vacuum container. Supporting equipment includes a liquid supply reservoir, liquid level detectors, vapor vent lines, vacuum electronics, electrical power control chassis and cryogenic transfer lines.

The year saw the successful employment of an automatic liquid hydrogen transfer system. The system allows a target watch to service more than one system during a watch period. The system consists of a pressurizing H_2 gas supply, a 175 liter liquid hydrogen supply dewar, a vacuum jacketed transfer line and cold valve, a LH_2 reservoir and target system, and a main electrical control chassis. This system also allows a reduction in the number of shift operating personnel.

The liquid Hydrogen Storage Facility distributed approximately 300,000 liters of liquid hydrogen. Both 1000 liter and 175 liter liquid hydrogen transport dewars have been maintained by the Cryogenic Group.

The Beam Instrumentation Group's major efforts have been to improve the instrumentation and operation of Beam #1 and Beam #2 and to provide for double pulsing of these beams. Preliminary design and preparation is now being done to further improve the quality of instrumentation and efficiency of operation in these beams, using a small special purpose digital computer.

The High Energy Electronic Equipment Pool (HEEP) has an inventory of some 3000 components, which they loan, maintain and repair, for use at the Laboratory. The counter experiments at AGS employed most of this equipment, with each peice being used in 2 or 3 experiments during the year. Equipment utilization was about 95%.

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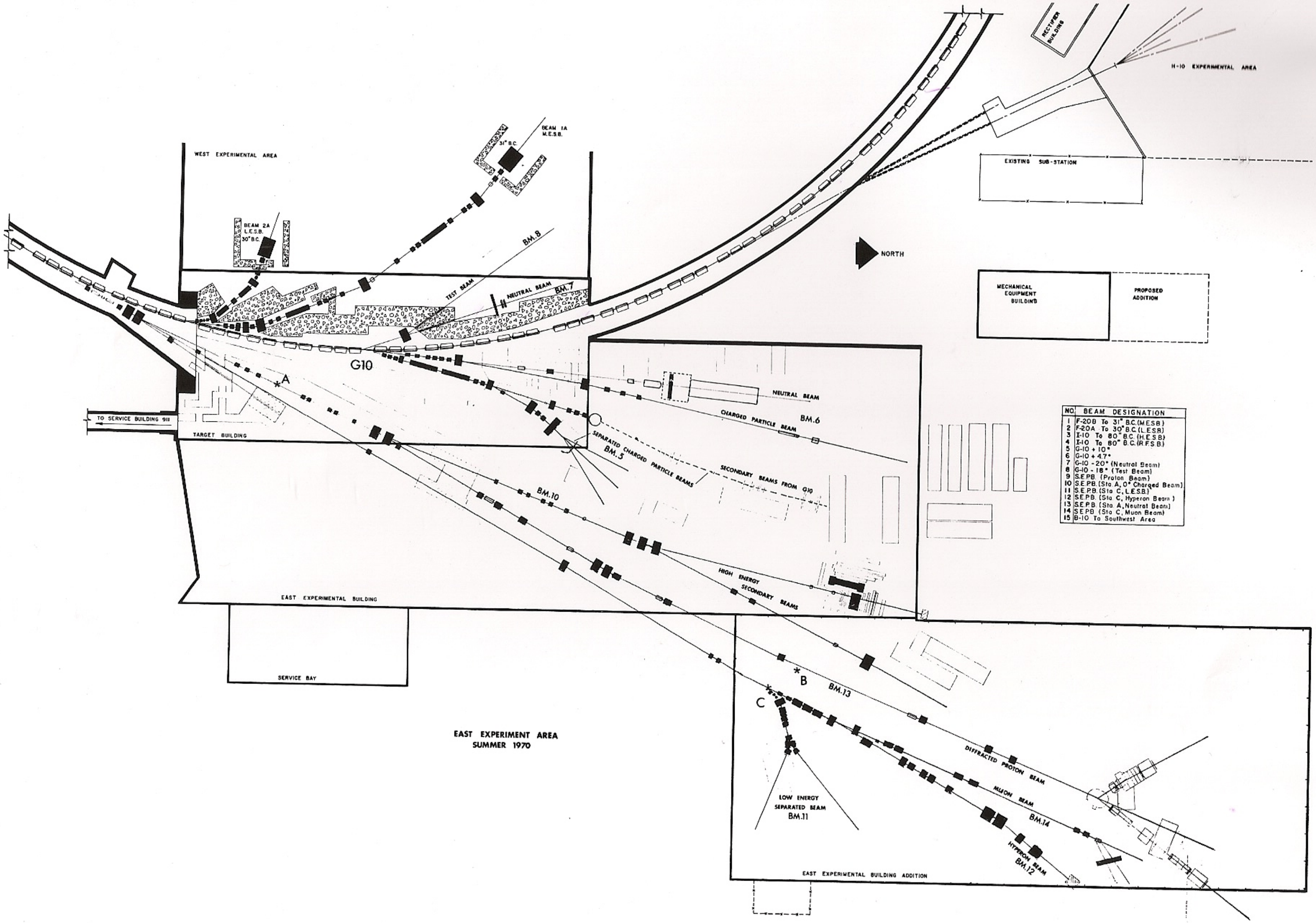

NO.	BEAM DESIGNATION
1	F-20B To 31" B.C. (M.E.S.B.)
2	F-20A To 30" B.C. (L.E.S.B.)
3	I-10 To 80" B.C. (H.E.S.B.)
4	I-10 To 80" B.C. (R.F.S.B.)
5	G-10 + 10°
6	G-10 + 4.7°
7	G-10 - 20° (Neutral Beam)
8	G-10 - 18° (Test Beam)
9	S.E.P.B. (Proton Beam)
10	S.E.P.B. (Sta. A, 0° Charged Beam)
11	S.E.P.B. (Sta. C, L.E.S.B.)
12	S.E.P.B. (Sta. C, Hyperon Beam)
13	S.E.P.B. (Sta. A, Neutral Beam)
14	S.E.P.B. (Sta. C, Muon Beam)
15	B-10 To Southwest Area

Fig. 1

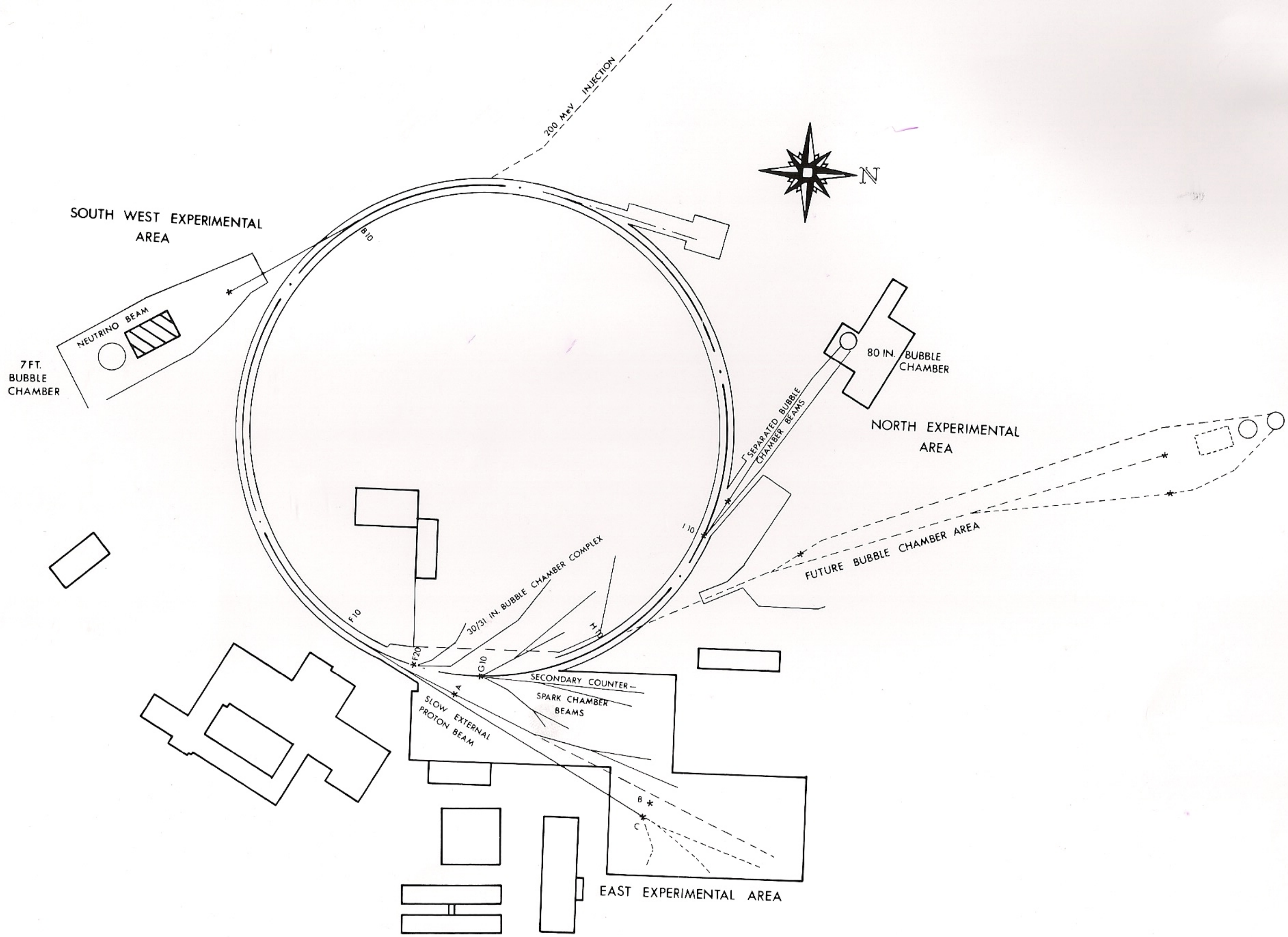
200 MeV INJECTION
N
SOUTH WEST EXPERIMENTAL AREA
NEUTRINO BEAM
7 FT. BUBBLE CHAMBER
B10
80 IN. BUBBLE CHAMBER
SEPARATED BUBBLE CHAMBER BEAMS
NORTH EXPERIMENTAL AREA
I 10
FUTURE BUBBLE CHAMBER AREA
F10
30/31 IN. BUBBLE CHAMBER COMPLEX
H
F20
G10
A
SECONDARY COUNTER–SPARK CHAMBER BEAMS
SLOW EXTERNAL PROTON BEAM
B
C
EAST EXPERIMENTAL AREA

Fig. 2