EP&S 74-6

BNL-19275

BROOKHAVEN NATIONAL LABORATORY
Associated Universities, Inc.
Upton, New York

ACCELERATOR DEPARTMENT
Informal Report

REPORT TO THE HIGH ENERGY DISCUSSION GROUP DECEMBER 6, 1973

David Berley
July 12, 1974

ABSTRACT

A summary of the AGS experimental program and a review of some of the facilities being planned were discussed at the Dec. 6, 1973 meeting of the High Energy Discussion Group. Among these were (a) a status report of the MPS, (b) a review of the superconducting particle beam transport equipment, and (c) a new design for a low energy separated beam.

NOTICE
This report was prepared as an account of work sponsored by the United States Government. Neither the United States nor the United States Atomic Energy Commission, nor any of their employees, nor any of their contractors, subcontractors, or their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness or usefulness of any information, apparatus, product or process disclosed, or represents that its use would not infringe privately owned rights.

Report to the High Energy Discussion Group
December 6, 1973

Future Programs at the AGS

Since the AGS resumed operation on August 9, it has been operating moderately well. A fraction of the scheduled time at the AGS actually available for experimenters was between .7 and .8. The multiplicity of experiments; that is the number of experiments which operated simultaneously, averaged about 5 near the beginning of the running period and then declined to about 3 in recent weeks. Two reasons for this decline are: the experiments are complicated and difficult to operate, and there are an inadequate number of proposed approved experiments, especially at G10, waiting to run in order to program efficiently.

From the G10 target station we have two beams operating; Beam 5 and Beam 6. In the Separated Beam 5, the Yale/BNL Group has changed the particle from K^- to π^- and is now studying ρ production with the polarized target, measuring density matrix elements in the neutral dipion system. Following this experiment, but with an intervening interval of approximately one year, the BNL (Kycia) Group will measure the $K_S \rightarrow \gamma\gamma$ branching ratio. In Beam 6, the Rochester/BNL Group is adding lead glass to the Columbia kaon spectrometer and will study K_L radiative decays.

The A and D target stations will be completed this Spring, and two experiments are scheduled. At A, the MIT (Ting) Group will measure lepton, anti-lepton, and hadron, anti-hadron pair production in pp collisions. At D, the Stanford (Schwartz) Group will measure the $\pi\mu$ atomic Lamb Shift.

At the B target station, a group from the University of Pennsylvania is continuing the measurement of particle spectra. The part of the experiment concentrating on the target fragmentation region is nearly complete. They are setting up to study the kinematic region associated with projectile fragmentation. The other experiment operating at the B target station, is the $K_L \rightarrow \mu\mu$ search by a Princeton Group. The new additions at the B target station will be the MPS in one branch of the Medium Energy Separated Beam, and a group from Carleton and the National Research Council of Canada measuring K* productions in K^-p collisions. Kwan Lai has joined that effort, and for the next experiment the particle will be changed to pions. They will look for non-strange boson production.

In the beam B1, due to follow Experiment 637, are two experiments in the MASS spectrometer. In the neutral beam, Christenson and his group from NYU are preparing the measurement of η^{00}.

At the C target station, recent approvals have been in the muon beam where Melissinos and his collaborators from the University of Rochester are studying μ interactions on nuclei. This group will not be prepared to do their experiment before next Summer. A second approval at the C target station is an experiment proposed by Bob Tripp of Berkeley to study K^- p charge exchange below 1 GeV/c. The Princeton Group continues their measurement of the form factors in Σ beta decay. In the other branch of the Low Energy Separated Beam, two groups are attempting to measure the Σ^- magnetic moment by observing fine structure in the energy spectrum of Σ^- bound to heavy nuclei. Following the X-ray experiments, a group from Yale will measure K^-p scattering from polarized targets, the same target now in Beam 5 and used by Experiment 615.

There are some recent 80-in. Bubble Chamber approvals, some with the TST and particles of the highest energy available in Beam 4 incident. Other approvals augment the number of pictures previously taken without the TST to improve the statistics in K^-p and K^+p interactions. Altogether they represent a 1½ to 2 year program for the 80-in. Bubble Chamber.

The 7-ft. Bubble Chamber had 1.3 million neutrino pictures approved for groups from BNL and Wisconsin.

Other electronic neutrino experiments are Experiment 605 (Columbia), looking for inelastic neutrino interactions in which no muon emerges; and a second by a Harvard/Pennsylvania collaboration looking for elastic neutrino proton scatterings. The first of these is being set up behind the 7-ft. Bubble Chamber, the second has not yet commenced.

Considerable construction work is in progress in the experimental areas. Figure 1 illustrates the experimental area as it will appear by the Summer of 1974. The major emphasis is first, upon closing some of the cracks in the shielding to the neutrino area. Second, the A and D target stations are being installed. Thanks to the efforts of Al Maschke and Y.Y. Lee, we shall be able to operate A or D together with B and C; simultaneous operation of three target stations. Figure 2 shows the A and D target stations as they looked a few weeks ago. To the left you see the A target station with pedestals for the double arm spectrometer to be used in the Ting di-hadron or di-lepton experiment. One of those spectrometer arms is now installed for magnetic measurements. To the right is the location of the D target station with the beam stop in place. Third, the Medium Energy Separated Beam to the MPS and to the miss mass spectrometer is under construction. About six weeks ago, the area looked as it does in Figure 3. Most of the magnets are in place. At that time, one of the separator doublets was installed. This week, the second one is going in. The MPS magnet has been turned on to 9.6 kiloamps, and operates stably at about 9. The spark chambers have been tested to the magnet field, the magnetostrictive wires operate. The E cross B drift is somewhat less than expected.

The schedule for the MESB and the MPS is shown in Table III. The MESB will be complete for commissioning by about Feb. 1. At that time the experimental groups expecting to use the separated beam will get it working. In the near future, we shall have a workshop to plan for this period.

The magnetic field mapping for the MPS will start about Dec. 17 and continue for approximately 3 months. Sitoshi Ozaki tells me that thereafter until the shutdown on April 23 there will be systems testing. There will be 6 XUVX chambers and 6 YY modules. The purpose of the tests will be to try to reconstruct tracks. Following the shutdown the MPS will run, but there will be no physics output; although, of course, physical processes will be looked at. The physics program will begin seriously in late Summer, about Sept. of 1974. Sitoshi would like to see run alternately the four experiments which are approved, so that the people can find out what their problems will be.

There will be a High Energy Unseparated Beam to the MPS in mid '75. We had at one time discussed making this beam with superconducting magnets; however, we have decided not to go ahead with superconductivity in the Al beam. This was a difficult decision for many of us, especially in view of the emphasis which energy conservation will have in the next decade and the relevance of such a superconducting transport system to future high energy facilities. The decision reflects the financial condition of the

Laboratory. This year's budget had a much larger effect on our ability to carry forth the program than at least I had anticipated. As for superconductivity, had we started from scratch, superconductivity would probably have been less expensive, certainly no more expensive than the conventional magnet system. However, we started with a considerable inventory of conventional magnets.

Many of you are interested in our work on superconductivity, so I shall digress for a moment to describe some of the results with the 8^{o} magnet, a superconducting dipole pair used in the proton beam transport system to the neutrino target. Figure 4 is a picture of this dipole doublet before it was installed in the North Area. From the magnet dewars there are long helium transfer lines which now go through the shielding. The dewar which you see in Figure 4 is outside the shield, the magnets are inside the shield. A helium refrigerator is just behind the dewar and not visible in the picture. Figure 5 shows the magnet assembled in the tunnel, the transfer lines go off to the right in the picture. Gordon Danby, the principal in the construction of this magnet, and Joe Allinger, the project engineer, are shown. This magnet is the largest superconducting magnet system in the world. It will operate automatically, and that is unattended. It is now operated by members of the fllor watch. Experience with the magnet has been extremely encouraging. Of the 25 kJ per pulse in the AGS beam, approximately a half a kJ of beam has hit the magnets upon occasion without the magnets going normal. About 10% of that went into the superconductor, very encouraging for ISA. This system is a pilot plant for larger systems; the magnet is a recovery system refrigerator reserve of helium supply and all of the components which would go with a larger system. The magnet itself is accurate to the 10^{-4} level.

The step this group would like to make is to go to higher field magnets. The 20-in. long model of the 8^{o} magnet has been operated at 50kG. Danby is confident that precision magnets can be constructed. A large saving with superconductivity can be achieved with high field magnets.

There have been some ideas for new facilities. This Summer there was a conference at Brookhaven on hyper-nuclear physics. They are in need of higher intensity kaon beams in order to do precision nuclear physics experiments. Although the Low Energy Separated Beam at Brookhaven is the most intense kaon beam in the world, it occurred to me that it could be improved considerably. One thing which would have to be given up is the high momentum range which the present beam can now reach. If the maximum momentum of 1.1 GeV/c, which is presently achievable, would be reduced to say 800 MeV/c, a large increase in the solid angle and a large decrease in the length of the beam could be accomplished. I made a preliminary design using conventional techniques, but Bill Willis came forth with a better idea. He suggests using edge focusing to keep the overall length short. A sketch of his layout is shown in Figure 6. A production angle of 6° is taken in order not to sacrifice much flux, and to help get the beam away from the primary direction. The first magnet bends by 20° with vertical focusing at the exit edge of the magnet. Following this there is electrostatic deflection in the vertical plane followed by a large quadrupole doublet and a small vertical bending magnet in between the two focusing elements. Then there is a second stage of electrostatic deflection, and the beam enters a bending magnet to a vertically focusing edge. At the mass slit there is a double focus where the beam emerges at an angle of 46° to the proton beam. The exit face of the magnet acts as a field lens focusing in a horizontal plane.

Along the mass slit there is a large magnet with a deflection of about 60°. By edge focusing and gradients this magnet would produce a focus near its downstream edge. The magnet he suggests should be adjustable, in order to alter the characteristics according to the needs of the experiments. This last magnet, rather than the first stage of the beam, provides a fine momentum resolution.

One problem in building this beam, is the gap in the separator which will be about 1-ft. Since one wants to obtain fields of the order of 50 kilovolts per centimeter, and we are restricted to handling voltages of about 400 or 500 kilovolts, Bill suggests that there be three electrodes. One in the middle which would be at one polarity, and those, top and bottom, which would be at the opposite polarity. He has the beginnings of a design of such an electrode system, with the electric shields being made of very thin low Z material. The vertical deflection in the separators is compensated by magnetic deflection in between the two electrostatic elements; that is the purpose of the septum magnets between the two focusing elements.

A comparison of the present beam (C2/C4) with the one proposed by Bill Willis is shown in Figure 6. The solid angle of the present beam is 2.64 millisteradians; proposed, 20 millisteradians. The length of the present beam is 14.5 meters; proposed, 5.8 meters. The increase in antiproton flux is just proportional to the solid angle of kaon flux. There is an additional factor of 10 because of the reduction in decay lengths. So, the antiproton flux will be increased by about an order of magnitude, the kaon flux by 2 orders of magnitude. Things don't always work out as well as first estimated, but there is every indication to believe that there is a substantial improvement to be obtained.

Another facility we are deeply concerned about is the muon beam. If there are any ideas about what do do, or how to use the muon beam if it is converted to a high intensity pion beam, they are welcome.

The AGS runs well. Please submit proposals. The availability of beams is indicated on Table II . Beam 5 will soon be available after the Yale/BNL Group finishes their experiment. It will then be unscheduled for about 9 months, waiting for the $K^0 \to \gamma\gamma$ apparatus to be installed. Beam 6 will be available the third quarter of this year. Beam A1 to the MPS will be available in mid '75. B1, following the Argo experiment, will be available in the beginning of next year--about one year from now. The Medium Energy Separated Beam is scheduled to mid '75. Beam B5, the new short neutral beam, will be available in mid '74. The muon beam is open now for a short period. The Rochester experiment should be complete by sometime in mid '75. The Low Energy Separated Beam; both branches will be available during the first quarter of 1975, and the hyperon beam very shortly. In the neutrino area there is lots of room for experiments; we welcome them.

Distribution: B2

TABLE I

East Experimental Area

Beam	Exp.	Correspondent		
5	650	Zeller	$\pi^- p_{\phi} \rightarrow \pi^+\pi^- n$	400
G10	590	Kycia	$K_S \rightarrow \gamma\gamma$	900
6	651	Carithers	K_L radiative decays	1000
A	598	Ting	$PP \rightarrow \ell \bar{\ell} + \ldots$, $K \bar{K} + \ldots$	1000
D	614	Schwartz	$\pi - \mu$ atomic Lamb shift	1000
A1			No approvals	
B1	637	Weisberg	$\bar{\pi}, K, p$ P $\rightarrow$ $\bar{\pi}, K, p$ spectra proj. frag.	500
B1	550/551	MASS		300 + 300
B2		MPS		
	546	Hargrove	$K^- p \rightarrow K^+ p$	500
	633	Lai	A_4, P_5 search	550
B5	572	Jensen	$K_L^o \rightarrow \mu^+\mu^-$	559/7 00
	615	Christenson	η_{oo}	
C1	631	Melissinos	μ nucleus interactions	1000
C2	548	Smith	$\Sigma^{\pm} \rightarrow e^{\pm} \nu N$	325/1050
C	634	Tripp	$K^- p \rightarrow K^o N$	750
C4	574	Kane	X-rays	434/700
	559	Wu	X-rays	257/700
	524	Hughes	$K^- P_{\phi}$	550
		Engels	Y^*	

80-in. Bubble Chamber

π, p - (TST) $K^- p$, $K^- D$

1½ - 2 yr. program (will try to operate 80-in. simultaneously with East Area)

7-ft. Bubble Chamber

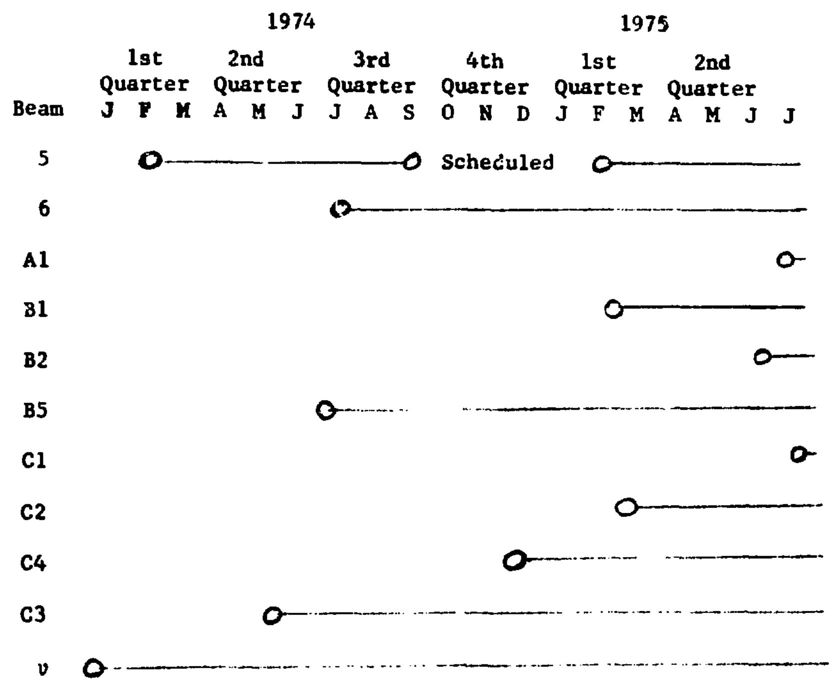
1.3 M ν pix.

Electronic ν experiments

Exp. #605 (Lee) $\nu A \rightarrow \nu \ldots$

Exp. #615 (Mann) $\nu p \rightarrow \nu p$

TABLE II



When AGS Beams Will Be Available

TABLE III

MPS SCHEDULE

1. Magnet turned on to ~ 5 KA
   Spark chamber tests in magnetic field

2. MESB - Complete Feb 1

3. Map magnetic field - Dec. 15 - March 15

4. Systems test before shutdown on April 21
   6XUVX and 6YY modules
   Reconstruct tracks

5. MPS run, no physics output until late Summer

6. Begin physics program $\sim$ Sept. 1974

7. A1 - High Energy Unseparated Beam - July 1975
   (not superconducting)
   (A and C) or (B and C)

TABLE IV

LESB

	Present	Proposed
$\Delta P/P$	$\pm$ 1%	
Ω	2.64 msr	20 msr
Length	14.5 m	5.8 m
K^- stop	$\sim$2000/sec.	

At 700 MeV/c

$$\frac{P}{M} CT = 5.2 \text{ m}$$

$$\Delta \ell = 8.7 \text{ m}$$

$$e^{\Delta \ell / \frac{P}{M} (r)} = 5.2$$

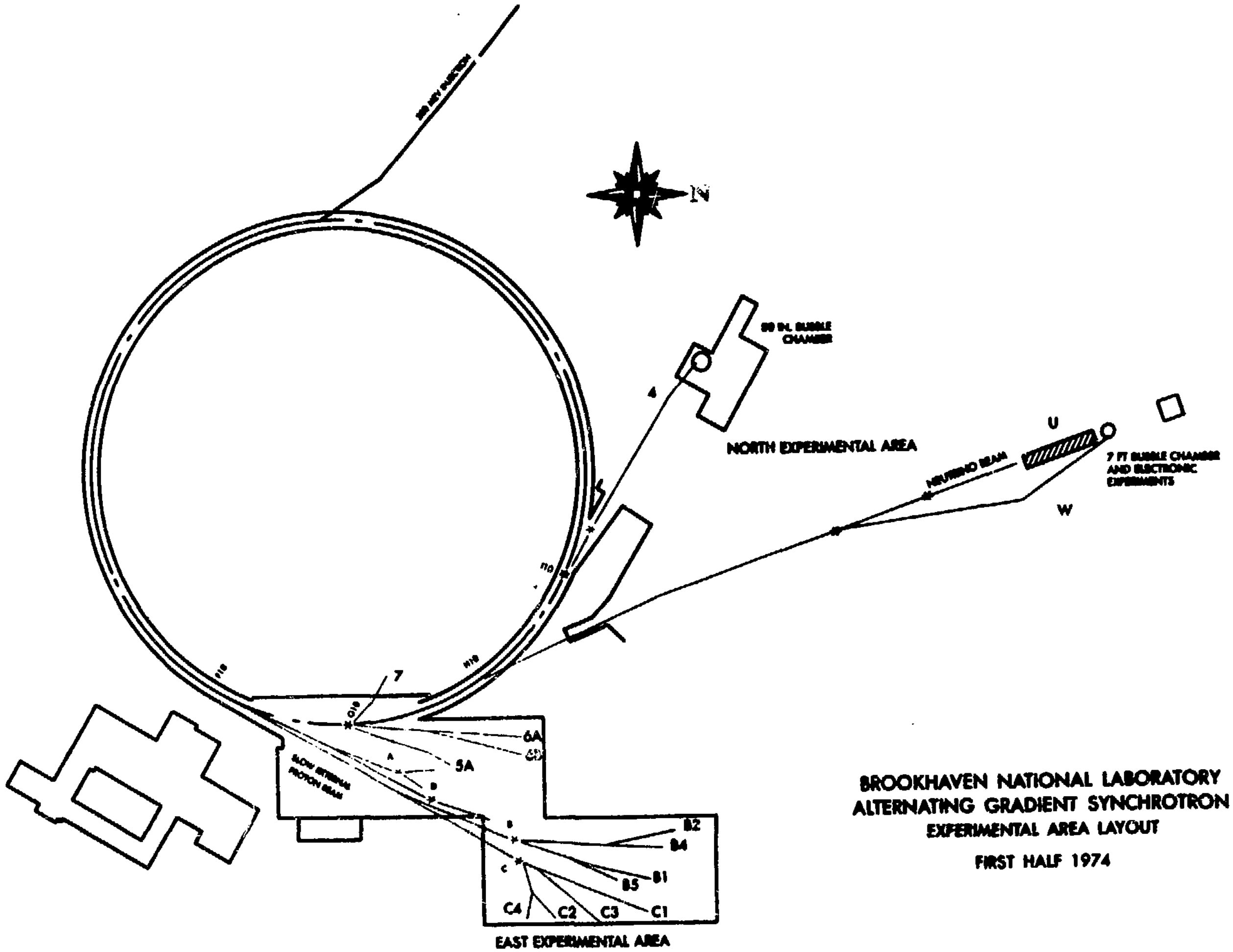

NORTH EXPERIMENTAL AREA
U
W
7
6A
5A
B2
B4
B1
B5
C4
C2
C3
C1
EAST EXPERIMENTAL AREA
BROOKHAVEN NATIONAL LABORATORY
ALTERNATING GRADIENT SYNCHROTRON
EXPERIMENTAL AREA LAYOUT
FIRST HALF 1974

FIGURE 1

FIGURE 2

FIGURE 3

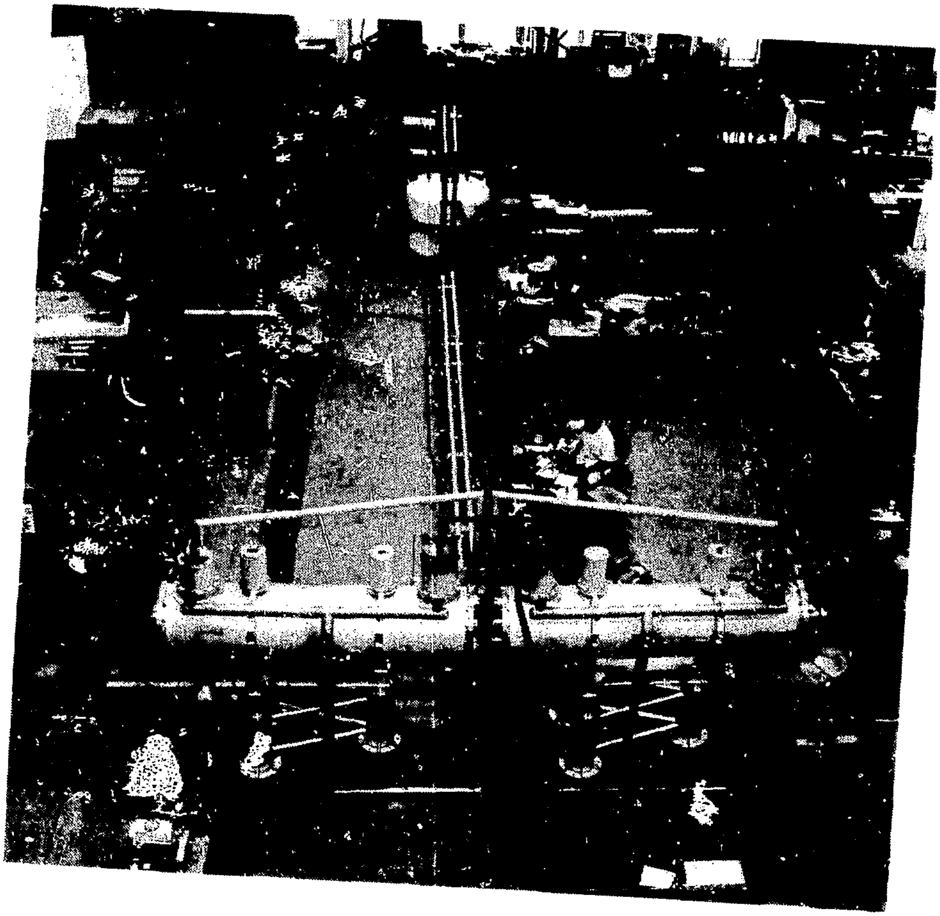


FIGURE 4

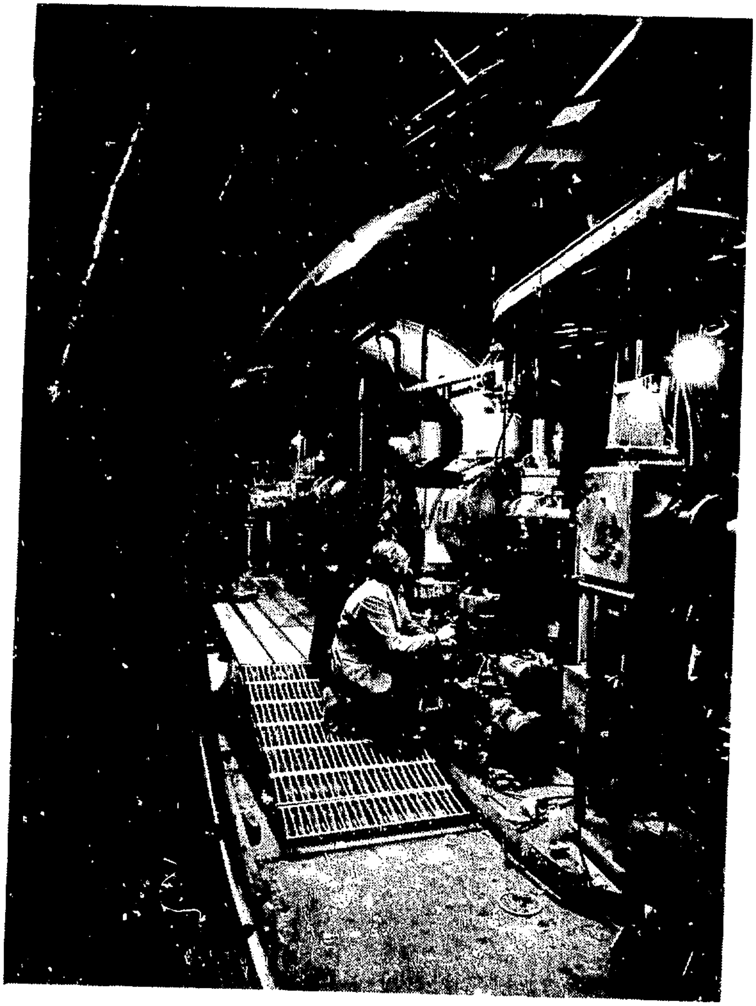
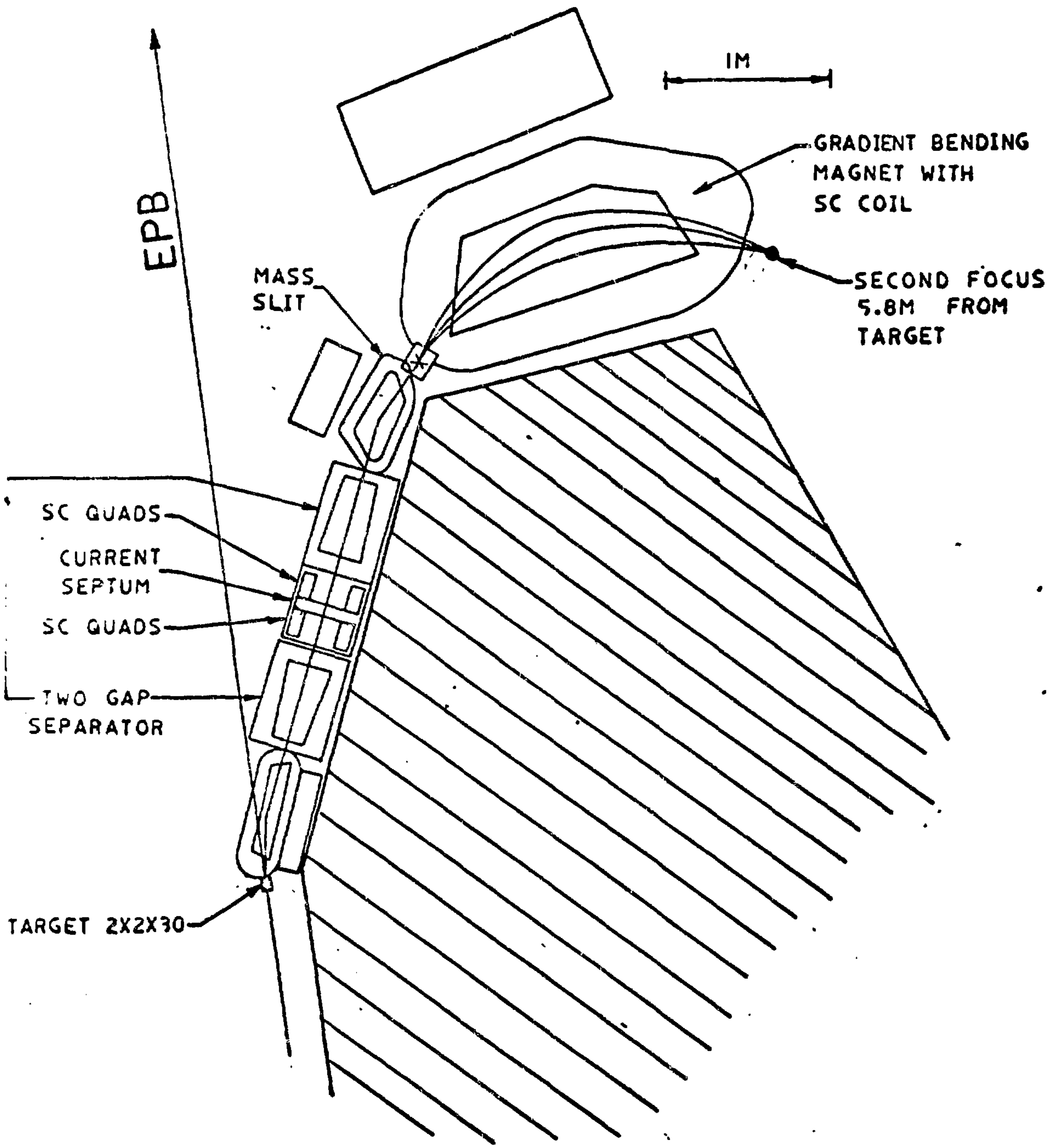


FIGURE [illegible]



EPB
IM
GRADIENT BENDING
MAGNET WITH
SC COIL
MASS
SLIT
SECOND FOCUS
5.8M FROM
TARGET
SC QUADS
CURRENT
SEPTUM
SC QUADS
TWO GAP
SEPARATOR
TARGET 2X2X30

FIGURE 6