OPTIONS

Summary Report of Working Group*

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The work of the option group was concentrated on examining the $\bar{p}p$ and e-p options. We looked for weak points in the options as proposed and tried to think of ways to improve the presently conceived designs.

Insofar as we have been able to investigate them, we find the methods proposed for providing colliding $\bar{p}p$ and ep beams are basically sound and can be expected to perform at the levels given in the proposal.

Additionally, we tried to think of ways to produce the $\bar{p}p$ and ep colliding beams which might offer improved performance and/or lower cost. While we cannot report any revolutionary breakthroughs we have seen some promising directions for further investigation.

In particular, it is clear that some method of reducing the phase space of the beams, such as stochastic cooling, would pay big dividends in both $\bar{p}p$ and pp work and is worth considerable effort. In the case of the ep option longitudinal polarization of the electrons is attractive, but needs further work to become practical.

Finally, we have identified some areas where work needs to be done to clarify possible problems. In particular the background caused by Compton scattering of the synchrotron radiation that we would encounter in the e-p option needs study.

$\bar{p}p$ Option

$\bar{p}p$ physics possibilities and advantages have been reviewed by Halzen, Paschos, Trueman and Wang.[1] Briefly they find that $\bar{p}p$

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1. F. Halzen, E. Paschos, T. L. Trueman, L.L. Wang, "$\bar{p}p$ Option", these Proc.

physics at low $p_\perp$, e.g. total cross sections and Coulomb interference experiments can be done with $\bar{p}p$ at lower luminosity than with pp. In addition, at sufficiently high energy and Q^2, the fundamental process involving fermion-antifermion annihilation is of particular significance in its ability to make new massive particles.

A scheme for producing a beam of $\bar{p}$'s is presented in the Gray Book (BNL 18891). In this scheme the 200 GeV proton beam is brought on to a target and the emerging $\bar{p}$'s are introduced into the second ISA ring. By using a special high harmonic rf system in that ring the injection process can be repeated 10 or more times resulting in circulating $\bar{p}$ currents of about one mA. This scheme has been reviewed by various people. Fitch[2] has looked into the question of energy loss in the superconductor as a result of the decay of π's and K's injected along with the $\bar{p}$'s and the loss of $\bar{p}$'s due to inefficiencies in the capture process. He calculates that a negligibly small temperature rise will be experienced by the superconductor so that this phenomena is not of immediate concern. Hübner[3] has checked the production rate of these unwanted particles and made suggestions on amelioration of the problem should it become necessary. He also suggests chopping the 30 GeV $\bar{p}$ beam after the target to improve capture efficiency. This method could perhaps raise the luminosity somewhat and should be investigated further.

It is concluded that a luminosity of 10^{29} $cm^{-2}sec^{-1}$ or slightly more should be achieved. To bring the luminosity to this value, extra dipole magnets in which the p's and $\bar{p}$'s experience opposite fields will be required to reduce the crossing angle. This interaction region geometry is shown in Fig. 1.

If one could produce $\bar{p}$'s in sufficient quantity, $\bar{p}p$ collisions could be carried out in a single ring. This is an inspiring thought

2. V. Fitch, "Heating Effects of an Unseparated $\bar{p}$ Beam Injected into the ISA Ring", these Proc.

3. K. Hübner, "On the Contamination During Antiproton Injection Into ISABELLE", these Proc.

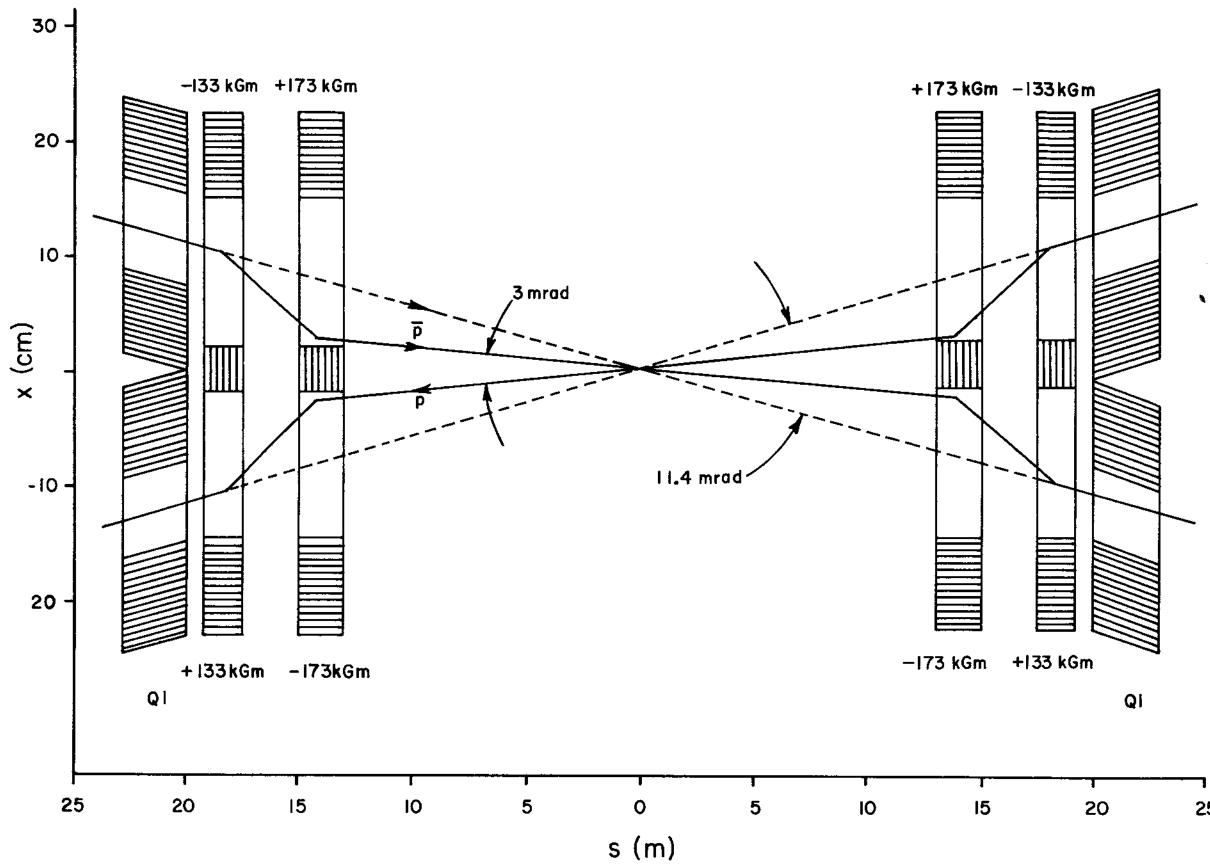

Fig. 1. Variable angle horizontal crossing geometry for $\bar{p}$-p collisions. Maximum crossing angle 11.4 mrad, minimum crossing angle 3 mrad.

since it allows one to dispense with one of the ISA rings and thus effect a substantial cost saving. Berley, Carroll and Mann[4] have pursued this concept vigorously and with great ingenuity.

Several possibilities including that of an intermediate accelerator ring were examined. The most promising possibility is one in which $\bar{p}$'s are made by 30 GeV protons from the AGS, injected into the ISA at 10 GeV and are held there in rather tight bunches. Successive injection bursts from the AGS are stacked in transverse phase space until the required number of $\bar{p}$'s have been accumulated. The $\bar{p}$'s are then accelerated to 30 GeV and counter-circulating protons are injected. Following this, the total beam is accelerated to the operating energy. If the AGS pulses once per second, enough $\bar{p}$'s for a luminosity of 10^{30} cm^{-2}sec^{-1} can be made in 10 hours. The technical problem that needs to be solved is how to inject all of these $\bar{p}$'s into the phase space volume accepted by the ISA. To do this some form of damping is necessary. One method that has been examined is the use of the stochastic cooling invented and under development at CERN. At the present state-of-the-art, the cooling times that can be achieved are too long to be practical.

It is clear that a practical cooling method would be of great benefit not only for $\bar{p}$'s but for p's too.

Areas that need detailed consideration are the targeting of the 200 GeV protons in the proposed $\bar{p}$p option and the conduction of the emergent p's to the beam dump.

e-p Option

As previously conceived, this option would provide for collisions between electrons and protons in each of the 2 lepton halls.[5] Sulak has looked briefly at the dimensions of these halls as compared with the dimensions of apparatus suggested in preliminary

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4. D. Berley, A. Carroll, A. Mann, "Single Ring $\bar{p}$-p Colliding Beams as an Interim ISABELLE", these Proc.

5. R. Chasman, "Status of ISABELLE at Time of Summer Study 1975", these Proc.

studies at the Fermilab 1973 Summer Study and the EPIC ep Study. The dimensions seem compatible, but further development of experiments will be necessary before final conclusions can be drawn.

The principal efforts of those working on the e-p option were to check the proposed scheme, suggest practical crossing geometries and the necessary matching optics, assess the practicality of using one of the p-rings for electrons, begin looking into various electromagnetic background problems and into the possibility of doing experiments with longitudinally polarized electrons.

Steffen, Maidment, and Cho[6,7] worked at suggestions by Steffen and Garren about crossing geometries. Several practical geometries were found. In layouts where a separate e-ring is disposed above or below the p-rings, it was pointed out by Garren that by alternating from top to bottom, the vertical dispersion problem can be solved very neatly, thus recommending this geometry strongly. The e-ring would then be on top in ½ of the machine and on the bottom in the other half. This could be alternated at each octant, if desired. For electron energies of 15 GeV, a luminosity of about $\frac{1}{2} \times 10^{32}$ or slightly more seems possible. At lower electron energies it may be possible to get somewhat higher luminosities.

Two practical methods for handling operational interferences between e-p and pp operations are seen. One possibility is to introduce the electron beam into one of the proton pipes at each crossing region. By doing this little or no geometrical interference arises but it will not be possible to use the e-ring while both p-rings are in use. A second possibility is to put bulges into the e-ring at the interaction regions allowing the electron ring to go around the apparatus in these places. This method prevents independent operation of the e-ring, but is expensive. A blend of the two may be the best compromise.

6. K. Steffen, J. Maidment and Y. Cho, "Review of e-p Collision Geometries", these Proc.

7. J. Maidment, "Comments on Injection into ISABELLE Electron Ring", these Proc.

The possibility of using one of the ISA rings for electrons was examined.[8] The conclusion was that there is no fundamental reason why it can't be done, but that at 15 GeV the extra shielding required to protect the cold region of the magnet from the 5.3 MW of synchrotron radiation would be prohibitively expensive. At 7.5 GeV the problem is quite manageable. In order to use one of the p-rings for e's,certain provisions, none of which appear to be terribly expensive, would need to be made in the original design:

First, a 2 mm wall Al tube, concentric with the present bore tube, would have to be added both to form a water jacket for the inner tube and to provide extra shielding; secondly, the pick-up electrodes and clearing electrodes and their enclosures will need to be designed for low interaction impedance at microwave frequencies; third, a careful study of field errors at very low excitation will need to be made and provision made for their correction. It should be noted that although the electron ring rf system will be rather modest at 7.5 GeV, its shunt impedance will be large enough that it will probably have to be removed from the ring each time a changeover from e to p ring is made, thus causing a delay in achieving a running vacuum for the p's.

It is beginning to be widely appreciated that in electron machines the synchrotron radiation that shines on the interaction region from the last magnet can cause important background effects, either by the penetration of the synchrotron x-rays directly through the wall of the vacuum enclosure and into the detection apparatus, or the scattering of these photons off the oncoming beam. It is even possible that π photoproduction events will occur if the last bend adjacent to the straight section is made as strong as the bend in the ring arcs since there would be a few photons in the MeV region shining on to the countermoving p-beam. It was recently

8. M. Tigner, "Storing and Accelerating Electrons in One of the p-Rings of ISABELLE", these Proc.

pointed out at SLAC by Patterson that one should use a soft bend adjacent to the straight sections to reduce the energy of the x-rays shining on to the interaction region. It is quite feasible to do this in the e-p option where one needs to bring the critical energy from 43 keV down to 8 keV or so (15 GeV electrons). Keeping the critical energy low will also prevent photoproduction for all practical purposes. The Compton scattering is another matter and requires further study. Not only is there radiation from the last bending magnet, but from the quadrupoles which focus the beam on to the interaction point. The total Compton scattering rates seem to be of the order of 0.1 to 1 per second with most of the photons going along the proton beam line. Computations of this and other electromagnetic scattering effects are being made by Bruck.[9]

We also looked briefly at polarization and its manipulation. At 15 GeV the polarization time is about 10 minutes and the polarization is 92% antiparallel to the guide field ($\bar{e}$'s). Considerable attention has been given to the subject of this polarization at the 1974 PEP Summer Study.[10] In addition, there have been studies at Rutherford Lab. which are referred in the PEP Summer Study report, and in the CERN LSR Storage Ring Study of an e-p option to be published shortly. The conclusion is that with methods invented so far the control of transverse polarization can be handled well while no really satisfactory method for obtaining longitudinal polarization in a useful experimental arrangement has yet been conceived.

In conclusion, the e-p option is attractive and feasible, but more study needs to be given to the control of the longitudinal polarization and to the effects of the synchrotron radiation.

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9. H. Bruck, "e-p Coulomb Interactions", these Proc.
10. Proceedings of the 1974 PEP Summer Study, PEP-137, (1974)