EXPERIMENTS IN THE MAIN RING

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ABSTRACT

Some comments are made about several proposals to do experiments using protons in the circulating beam. Several technical problems are reviewed, and it is emphasized that the best time to run such experiments is during the early operation of the accelerator.

A. Physics

The range of experiments which can be performed in the main ring is quite limited since only proton-initiated reactions can be studied. A further restriction is that only recoil particles at wide angles can be observed with ease. In spite of the limitations, the techniques which are appropriate for experiments in the ring make a particular range of physics accessible.

Since very thin targets must be used in order not to disturb the beam, very low-energy recoils can be observed, corresponding to very small momentum transfers. Low rate due to the thin target is compensated by multiple traversals of the beam. Thus, these experiments can compete with spectrometer-type experiments which propose to measure differential cross sections at very small $|t|$ by observing the fast-forward particle with very high resolution. It is much easier to discriminate against inelastic production by looking at the low-energy recoil.

A second advantage of these experiments is the ease of sampling many proton energies by taking data during the acceleration cycle. It is also possible to make use of the rf bunching of the beam to enable identification of particles by measuring their time-of-flight.

These experiments can be performed at a very early stage in the operation of the accelerator. The results obtained may be very valuable input to the further development of the experimental program at these energies. The relative simplicity of such experiments also is a strong argument in favor of including one or more in the initial stages of the experimental program.

B. Possible Difficulties

1. Target Considerations

Three kinds of targets have been suggested; each has its shortcomings:

a. Very thin CH_2 films--give a carbon background.

b. Low pressure H_2 gas target--requires a large-aperture detector.

c. Gas jet target--calibration and monitoring are very difficult.

All three targets will require considerable design work. Since they must fit into the main-ring vacuum pipe, there is a direct interaction with the accelerator.

The experience of the Russians with the H_2 gas-jet target at Serpukhov is encouraging, but they did not attempt to measure absolute cross sections. A method has been proposed to collect[1] the ionization produced by collisions of the protons with the gas molecules to provide at least a relative monitor of the jet density, but there is some doubt that the amount of ionization produced per proton is known accurately enough at very high energy to be an absolute monitor.

The jet target and the extended low-pressure target do not pose problems from significant beam loss. They will contain ~ 2×10^{-8} g/cm^2 which is a factor of ~ 60 below the level which would cause trouble. For the foil target with a 48-cm radiation length, the maximum thickness is ~ 100 Å and this may be impractically thin.

2. Restrictions on Equipment Size and Location

The tunnel width in straight sections allows an experiment ~ 2-1/2 m perpendicular to the beam. If an experiment is allowed to block the passage, it should be designed to be easily removable.

The apparatus must be located far from high-radiation areas such as the transfer hall and any limiting apertures which scrape the beam during acceleration. On the other hand, it should be located near an access to avoid long cable runs. Long straight section B appears to meet these requirements.

3. Radiation Problems

Radiation levels in the main-ring tunnel must be considered from two points of view. First, background radiation can give accidental counts, and second, radiation damage to the experiment must be considered.

When solid-state detectors are used, there are two factors which tend to reduce the first problem. Since these detectors have a small mass, minimum ionizing particles will lose only a small amount of energy relative to the stopping protons that these experiments detect. Also, their small size reduces the likelihood that particles will strike them.

Radiation damage to solid-state detectors has been studied in great detail. The only problem is to obtain reliable estimates of the particle fluxes which will strike the detectors. Even without additional knowledge, two observations can be made. The major initial effect of radiation damage is resolution broadening. In contrast with many nuclear-physics applications where closely-spaced energies must be resolved, the degradation of resolution will not be as serious a problem in the current application. Another encouraging point is the successful experience at Serpukhov with solid-state detectors in the ring.

An estimate of probable radiation levels has been obtained in two ways. Direct measurements have been made at the CERN-PS to allow extrapolation to ISR conditions.[2] A spark chamber was placed in a quiet area of the ring tunnel. The spark chambers were fired during the accelerator flattop both randomly and in coincidence with counters. The average number of particles was determined by counting the number of sparks. The result is $\sim 2.4 \times 10^2$ particles/(cm^2-sec) at ~ 1 m from the ring. Since it was concluded this flux is due primarily to beam-gas interactions, the result may be scaled to 10^{13} protons, 1×10^{-6} Torr, and 400 GeV (assuming particle multiplicity goes as $E^{1/4}$) to yield

$$N \approx 1.2 \times 10^4 \text{ particles/cm}^2\text{-sec.}$$

Another guess is based on an estimate by M. Awschalom that radiation levels away from any hot spots will be 2-3 rad/hr. Assuming this is due to minimum ionizing particles, this yields

$$N \approx 1.7 \times 10^4 \text{ particles/cm}^2\text{-sec.}$$

These estimates are applicable during flattop and do not consider any losses at injection, during acceleration, or due to any catastrophic disturbance of the beam orbit. If they are correct to an order of magnitude, background radiation in the ring will probably not be a problem for small detectors.

It is a good idea to plan to include some shielding around the apparatus to absorb low-energy neutrons which may be very plentiful. Such shielding should be thick enough to reduce rather than increase the charged particle fluxes at the apparatus.

4. Other Background

A source of target-associated background is from particles scattering off the vacuum-chamber walls. Since the solid-state detector arrays have little direction discrimination, there may be enough low-energy particles from the general spray being scattered into the detectors to cause a problem. The proposal to use a magnetic spectrometer would not have this problem.

5. Access

There is a general incompatibility between these experiments and machine operation in the sense that the apparatus is accessible only when the machine is not operating. This would pose a serious problem if the running schedule developed so that bugs in a circulating-beam experiment were being eliminated during a period of long constant running of the accelerator.

C. Conclusions

We conclude that even though the range of physics included in these proposals is somewhat limited, they do sample very important processes. They employ techniques which make them likely candidates to produce the first physics results at NAL energies.

1. Since the installation of the target and detector directly interacts with the main ring, it is desirable to choose a location and start the target engineering soon. It would be good to solve any problems with the target design, the geometry of the apparatus, or with maintaining the vacuum in the main ring well before the machine starts operation.

2. These experiments will probably have the least interaction with the machine schedule if they are run soon after the accelerator starts operating when frequent shutdowns are most likely.

3. It appears that solid-state detectors (or small scintillation counters) will operate successfully in the ring environment if they are located in as quiet an area as is anticipated.

REFERENCES

[1] R. A. Carrigan et al., A Proposal to Study Small Angle p-p Scattering at Very High Energies, National Accelerator Laboratory Proposal 36, 1970.

[2] V. Agoritsas, M. Bott-Bodenhausen, and B. D. Hyams, CERN Report NP/69-8, 1969, (unpublished).