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ACCELERATOR DEPARTMENT
Informal Report

INTERSECTING STORAGE ACCELERATOR NOTES

What Not To Do With ISABELLE and Why

Michael N. Kreisler
University of Massachusetts

and

Y. Y. Lee
Brookhaven National Laboratory

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ABSTRACT

We examined the possibilities of μ P interactions and single beam whiplash to generate mono-energetic Neutron beams at ISABELLE. We reached the conclusion that it is impractical for both cases.

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During the summer study, we considered and finally rejected several experimental uses of ISABELLE. In the faint chance that a summary of our conclusions might be of interest and that our negative findings might save someone else a similar effort, we reluctantly present our results in this note.

QUESTION 1: Is a μ option feasible for ISABELLE?

At first glance, a μ option seems reasonably attractive. Due to time dilation, multiple turns are possible for the captured muons, thereby increasing the luminosity. (For 5 GeV/c μ 's in the 1 km ring, there would be 31 turns and at 15 GeV/c, 93 turns.)

An upper limit on the instantaneous captured μ beam is $\sim 10^6$ to 10^8 per A.G.S. pulse.¹ Although these fluxes may, in fact, be unobtainable, let us use 10^8 to investigate the practicality of this scheme. If we ignore such problems as losses due to decays during acceleration or losses during changes of phase space, the luminosity for μp interactions at 15 GeV/c μ 's against 200 GeV/c p's is

$$\mathcal{L}_{\mu p} \approx 10^{28} \times \text{Duty factor at 15 GeV/c.}$$

Assuming that the A.G.S. can pulse every second, the duty factor at 15 GeV/c including multiple turns is $\sim 3 \times 10^{-4}$. Since interesting cross sections are typically nanobarns, it is clear that the luminosity is several orders of magnitude too small. (Even ignoring the duty factor, a luminosity of 10^{28} with a 1 nb cross section, yields an event rate of only 10^{-5} /sec.)

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QUESTION 2; Does Whiplash occur with only one beam in ISABELLE? (or is the proton beam masochistic?)

During discussions of experiments in the Whiplash mode (see for example CRISP 72-42), we became interested in the possibility of such interactions occurring in a single beam. In particular, we considered the following questions:

- a) Could a high energy neutron beam from the reaction

be produced even if only one beam could be stored?

- b) Would neutrons from this reaction present a radiation problem near any low β region of ISABELLE?

- c) Do Single Beam Whiplash (SBW) processes dominate the beam loss rate at 200 GeV and thereby necessitate limitations on the machine parameters?

Since the threshold for neutron production by the N^* mechanism requires $p^* \sim .4 \text{ GeV}/c$, where p^* is the center of mass momentum for the pp system, SBW is important only in regions where the beam divergence is very large (very low β regions). Clearly if P_T^* is the threshold center of mass momentum, the minimum angle $\alpha_{\min}$ between two interacting protons at 200 GeV/c is just

$$\alpha_{\min} \approx 2 \frac{P_T^*}{P_{\text{Lab}}} = \frac{P_T^*}{100 \text{ GeV}/c} .$$

For the N^* process, α must be ≥ 4 mr.

Calculations of the luminosity for such processes can be done in many ways. The least painful is to use the work of Goldberg and Moneti (CRISP 72-42). If we have two beams crossing at an angle α , the luminosity is:

$$= \frac{N_1 N_2 C}{c^2 h} \tan \left(\frac{\alpha}{2} \right),$$

where N_1 and N_2 are the total number of circulating protons in each beam, C is the circumference of the ring, and h is the height of the beam. Since a large angle is required, only a small fraction of the beam can, in fact, participate in the SBW process. In the minimum β region (see p. 78, BNL 16716), the maximum half divergences are less than 1 mr.² Assuming a 1 mr half divergence, neglecting factors of two, and assuming that the distribution of transverse momentum (or divergences) is gaussian, we find that the effective number of particles in each beam should be reduced by ~ 20 . Therefore, the maximum, very optimistic, luminosity for SBW N^* production is:

$$\mathcal{L}_{SBW} \sim 10^{30} \times \tan (2 \text{ mr}) \times \frac{1}{400} \sim 5 \times 10^{24} \text{ cm}^{-2}.$$

Since the cross section of interest is ~ 1 to 10 mb, we expect a maximum event rate of 5×10^{-2} /sec, or ~ 180 /hour. Clearly, such low effective luminosities demonstrate the impossibility of a useful neutron beam and the lack of any radiation shielding worries with SBW.

Although SBW N^* production is not an important process, SBW pp elastic scattering is more serious. As shown in CRISP 72-42, elastic pp

scattering results in a magnification of the longitudinal momentum of the protons. If elastic scattering occurs such that the direction after the scatter in the center of mass is along the beam direction, the laboratory momenta of the protons are:

$$P_{LAB} \sim \gamma(\pm P^* + m) .$$

For $P^* = 0.4 \text{ GeV/c}$, the laboratory momentum would be changed by $\sim 80 \text{ GeV/c}$! Such protons would clearly be lost.

Assuming that a $\Delta p/p$ greater than .005 would cause the proton to be lost, we find that

$$\alpha_{min} \sim 50 \mu \text{ rads.}$$

Therefore, approximately all of the protons participate in this SBW process. The fraction of the elastic scattering cross section that results in at least a $\Delta p/p$ of .5% is proportional to α . The component of c.m. momentum along the beam must be greater than 5 MeV/c . Therefore,

$$p^* \cos \theta \geq .005,$$

where θ is the angle with respect to the proton beam direction. This can be written

$$\cos \theta \geq \frac{.005}{(100)(\alpha)} = \frac{50 \mu \text{ rads}}{\alpha} .$$

The luminosity can be found by taking the weighted average of $\tan \frac{\alpha}{2}$ times $(1 - \cos\theta)$, the fraction of c.m. angles allowed. The average is to be calculated over the actual profile of the beam. In the interaction region,

$\frac{\alpha_{\max}}{2} \approx 800 \mu \text{ rad.}$ This yields

$$\langle (\tan \frac{\alpha}{2}) \cdot (1 - \cos\theta) \rangle \sim 4 \times 10^{-4} .$$

The effective luminosity is $10^{30} \times 4 \times 10^{-4} = 4 \times 10^{26} \text{ cm}^{-2}$. Since the elastic cross section is $\sim 20 \text{ mb}$, we see that SBW will result in $\sim 20 \text{ mb}$, we see that SBW will result in $\sim 8 \text{ interactions/sec}$ that will cause the loss of 16 protons/sec. Clearly, such a loss rate will not dominate the beam loss mechanism.

References

- 1) T. Yamanouchi, private discussion.
- 2) Special region can be created with beam divergences as large as 10 mr. However, this factor of 10 increase would still not pose a serious problem.