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ACCELERATOR DEPARTMENT
Informal Report

INTERSECTING STORAGE ACCELERATOR NOTES

Some Thoughts about Pion-Proton Interaction
Experiments at ISABELLE

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July 27, 1972

ABSTRACT

We investigated a possibility of doing pion-proton colliding beam experiments at ISABELLE. The rate is low and ~ 40 events/hour, however, we found that events to background ratio is very favorable.

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Introduction

Baltay¹⁾ proposed very interesting possibility of studying pion proton interactions at ISABELLE for the energy range very difficult to achieve by conventional accelerator experiment. In this note we are not going to discuss the importance of Physics but study the feasibility of such an experiment. The scheme, however, has some serious problems. First, unless one could find the way to target with gas target, it would be very hard to find any material which would survive in 15 amperes of particle current which deposits about 200 Joules of energy per 10^{-7} interaction length of material. Second, since we are targeting in very intense beam, the radiation around the area and consequently background event problem would be far more serious than conventional experiments. Third, as mentioned in the Baltay's paper¹⁾, there is difficulty to separate the particle.

Even if one could get the events rate as stated in the paper¹⁾, it is far less than the beam gas interaction of 300 event/sec/m by few order of magnitude. It is authors contention that unless one can beat the rate of beam gas interaction the experiment is not possible. In view of these problems we are going to alternate way of doing this much needed experiment. Fig. 1) shows the center of mass energy and equivalent laboratory momentum versus the pion momentum which collides with the 200 GeV proton in one ISABELLE ring. The graph shows, even with the meson energy of modest value, it can have equivalent laboratory momentum almost impossible to achieve with a convention accelerator.

Meson beam and interaction rate

We will discuss two alternative ways of producing "clean pion" beam. One of which is beam produced by AGS and the other is produced by the beam from ISABELLE.

i) A.G.S. option

Transport the A.G.S. beam through one of the injection channels the branch of which is extended close to interaction area. We target with conventional targeting and properly dump the "junks". Using Sanford and Wang²⁾ production curves we can assume reasonable rate of 2 pion/str/GeV/c/ interacting proton for energy range of few GeV/c to 20 GeV/c and about 1/10 of that for Kaons. For this energy range we can use conventional beam separators for separation of the beam. The following number seems reasonable without much of the difficulties.

Number of protons	2×10^{13}
Slide angle bite	1 m-str
Momentum bite	$\pm 5\%$ or ~ 1 GeV/c

Using these numbers we get

$$2 \times 2 \times 10^{13} \times 10^{-3} \times 1 = 4 \times 10^{10} \text{ pions / AGS pulse}$$

Let us now assume the cross section of πp to be 20 mb and calculate the rate of events. Assuming the pion beam has spot size of 2mm x 2mm, and

it is much larger than the circulating beam

$$\# \text{ event/pulse} = \frac{2 \times 4 \times 10^{10}}{.04 \text{ Cm}^2} \times \frac{6 \times 10^{14}}{2000 \text{ m}} \times 1 \text{ m} \times 20 \times 10^{-27} = 1.2 \times 10^{-2}$$

for 1m long interaction region,⁸⁾ or for two second repetition rate of AGS,

one event per 83 AGS pulse or every three minutes. In presence of beam gas interaction it seems very discouraging. However, since the A.G.S. pulse can be about 102 nanosecond long the total amount of the time the gate is open is

$$\frac{102 \times 10^{-9}}{1.2 \times 10^{-2}} = 8.5 \times 10^{-6} \text{ second/event}$$

and the beam gas interaction during the time is

$$300 \times 8.5 \times 10^{-6} \approx 2.5 \times 10^{-3}$$

the ratio of beam-gas to the beam-beam interaction is very favorable.

If we want to collect 10^4 events (1% statistical accuracy) we need 3×10^4 minutes or about 500 hours. One last thing must be mentioned is this experiment can parasite with either programs in ISABELLE and if we want to use only 1/2 of A.G.S. beam the running time required is 1000 hours.

11) ISA option

Instead of targeting inside the ring, we extract the proton from one of the rings (the machine needs an extraction system if one wants to pursue the option of $\bar{p}$) and target outside of the machine so that remaining beam and "junks" are properly dumped. The produced pions are returned to the machine to collide with the other ring. If one could have unequal beam energy for ISABELLE we could target with the optimum energy for given pion momentum. In order to avoid over heating of the target we may extract the proton one bunch at a time (2×10^{13} proton 102 nanosecond long bunch). Using the average of Hagedorn-Ranft³⁾ and Wang⁴⁾, pion production by 200 GeV proton is ~ 20 pion/GeV/c/str/interacting proton at 20 GeV/c pion momentum. Using the reasonable assumption of

solid angle 1m-str

momentum bite $\pm 5\%$ or 1 GeV/c

We get

$$20 \times 2 \times 10^{13} \times 10^{-3} \times 1 = 4 \times 10^{11} \text{ pion/bunch}$$

or given ISABELLE burst

$$30 \times 4 \times 10^{11} = 1.2 \times 10^{13} \text{ pions/burst}$$

The number of event per ISABELLE burst is using same criteria as the other option

$$\begin{aligned} \# \text{ event/burst} &= \frac{2 \times 1.2 \times 10^{13}}{.04} \times \frac{6 \times 10^{14}}{2000 \text{ m}} \times 1 \text{ m} \times 20 \times 10^{-27} \text{ cm}^2 \\ &= 3.6 \text{ event/burst} \end{aligned}$$

and get beam-gas to beam-beam ratio is

$$\frac{3.6}{300 \times 102 \times 10^{-9} \times 30} \approx 4 \times 10^3$$

However we have to think about duty cycle of ISABELLE. Suppose ISABELLE can cycle every 5 minutes then it is comparable with the other option within factor of two. Since the emittance of ISABELLE beam is smaller than AGS, we might get slightly better events rate than AGS option.

Conclusion

Although events rate is very low, the pion-proton interaction experiment at ISABELLE seems feasible. The total cross section measurement can be done by detecting every reaction as proposed by Carroll⁵⁾ and elastic scattering can be measured by the methods similar to the ones discussed by Foley and Ozaki⁶⁾ and by Orear⁷⁾.

References

1. C. Baltay CRISP 72-22 (1972).
2. J.S. Sanford and C.L. Wang BNL Accelerator Department internal report BNL 11479 JRS/CLW - 2 (1967).
3. R. Hagedorn and J. Ranft. Suppl. Nuovo Cimento 6, 169 (1968).
4. C.L. Wang BNL Accelerator Department internal report BNL 15893 EP & S 71-3.
5. A.S. Carroll CRISP 71-53.
6. K.J. Foley and S. Ozaki CRISP 71-22
7. J. Orear CRISP 71-16
8. If one states in terms of luminosity

$$\mathcal{L}_{\pi p} = \frac{2 \times 3 \times 10^8 \text{ m/sec}}{.04 \text{ cm}^2} \times \frac{4 \times 10^{10}}{30 \text{ m}} \times \frac{6 \times 10^{14}}{2000 \text{ m}} = 6 \times 10^{30} / \text{sec/m}$$

with duty factor of

$$\frac{100 \text{ ns}}{2} = 5 \times 10^8$$

and effectively

$$\mathcal{L}_{\pi p}^{\text{eff}} = 6 \times 10^{30} \times 5 \times 10^{-8} = 3 \times 10^{23} / \text{sec/m}$$

Figure Caption

Center of Laboratory energy and equivalent lab momentum versus meson momentum colliding with 200 GeV proton.