Experiments with Antiprotons
Summary of the Working Group's Activities

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Our group[1] did not consider only experiments that are feasible with the present Antiproton Source at Fermilab. We also examined the possibilities that are opened by the increased antiproton production rate when the Main Injector becomes operational, as well as experiments that may involve new machines, or modifications to the existing or proposed accelerators. We viewed our discussions as a preparation for a more serious consideration, to take place in the Workshop on Physics at Fermilab in the 1990's to be held at Breckenridge, Colorado in August.

Most of the physics issues are discussed in G. Smith's contribution to this conference[2]; as a result I will focus my remarks on the more technical issues that were raised:

Charmonium Production in $p\bar{p}$ Collisions and Related Topics

There was consensus that this rich field of physics can be adequately studied in the Accumulator with the E760 apparatus[3] and its internal hydrogen gas jet target. Extensions to the E760 program, e.g. the search for states that decay to $\phi\phi$ (glueball search), or for bound states of hadrons[4] (cryptoexotics), have already been considered. The limitation will be the lowest momentum that antiprotons can be decelerated to in the Antiproton Accumulator. It is expected that this lowest momentum will be less than 2 GeV/c, thus the available mass range starts from a value less than 2.4 GeV/c^2 and extends to 4.3 GeV/c^2.

Charmed Baryon Production

The exclusive production of charmed baryon-antibaryon pairs in proton-antiproton collisions was proposed as a clean way to study these elusive states. There are two alternative ways to do this : either by installing in the Main Injector an extraction channel for antiprotons with energies in the range of 10 to 25 GeV (note that such an extraction line has to point 'backwards' in relation to a proton extraction line) or by installing an internal gas jet target in the Main Injector.

In the former case, one could extract antiprotons at the same time that the fixed target program, that uses protons from the Main Injector, is running. This implies an interleaved version of running, with a portion of the protons of the Main Injector being used for antiproton production, as well as periodic exclusive use of the Main Injector for antiproton acceleration and extraction. Such a scenario would mean a reduction of approximately 50% in the intensity of the protons available from the Main Injector for fixed target running.

In the latter case, one should at least make allowances for :

i. *Good vacuum.* With the proper practices a vacuum of the order of 5×10^{-9} Torr or better can achieved. This assumes a clean and pre-baked vacuum chamber but not one that can be baked in situ.

ii. *A modest stochastic cooling system:* a betatron cooling system will counteract the transverse emitance blowup caused by Coulomb scattering in the gas jet.

iii. *Long straight sections - interaction region.* A charmed baryon experiment has a size similar to experiments at the Brookhaven AGS, i.e. 15 meters long. If one wants to consider the possibility of studying bottomonium production[5] then the apparatus will be some 30 meters long ('Serpukhov' size). The currently envisioned long straight sections (26 meters long) do not seem adequate for such a use.

If one takes into account the fact that the use of the Main Injector as a storage ring with an internal gas target implies the exclusive use of that machine for the duration of such an experiment, one sees that this choice is problematical. Nevertheless the lessons of the Main Ring tunnel and of the Accumulator, i.e. that both machines had to accommodate interaction regions that were not part of their original design, point to the prudence of allowing for such interaction areas ahead of time.

CP Violation in Hyperon-Antihyperon Pair Production and Low Energy Antiproton Physics

Both of these rather different areas share a common characteristic, that is they need a new low energy antiproton machine to be carried out. In particular the CP Violation experiment involves the detection of $\Lambda\bar{\Lambda}$ through the decay $\Lambda \rightarrow p\,\pi$. This decay sequence is identified by reconstructing the decay vertex. A small beam pipe (diameter of the order of a centimeter) would be ideal.

Even though, no one from our group was an atomic physicist, we recognized that experiments with extremely low energy antiprotons (e.g. gravitational properties of antiprotons, precision atomic spectroscopy with antihydrogen) may be very interesting. A design effort for an RFQ deceleration system, to bring antiprotons down to an energy of a few KeV, was initiated [6].

Polarized Antiprotons

The Spin Splitter Collaboration has been studying the possibility of polarizing the antiprotons circulating in a storage ring[7]. The question of whether a polarizing apparatus could be incorporated in an antiproton storage ring at Fermilab was addressed by Y. Onel and S. Hsueh [8]. A detailed study to incorporate such a scheme in the Accumulator is under way.

Conclusions

Antiproton physics has an inter-disciplinary flavor that goes beyond the realm of the usual high energy physics regime. It was the feeling within our working group that if sufficiently interesting experiments can be proposed, then a new opportunity will exist at Fermilab. We look forward to Breckenridge, where we hope that the discussions will lead to detailed and concrete proposals for experiments.

References

1 P. Ferreti-Dalpiaz (INFN Ferrara), D. Hertzog (U of Illinois, Champaign), E. Menichetti (INFN Torino), A. Nathan (U of Illinois, Champaign), D. Peaslee (U of Maryland), P. Rapidis (Fermilab), J. Rosen (Northwestern U), and G. Smith (Penn. State U). S. Hsueh (Fermilab), F. Mills (Fermilab), and Y. Onel (Iowa State U) also participated in part of the discussions.

2 G. Smith, *Antiproton Physics up to 120 GeV*, this conference.

3 Fermilab Proposal No. 760, *A Proposal to Investigate the Formation of Charmonium States Using the Antiproton Accumulator Ring*, Fermilab-Ferrara-Genova-Irvine-Northwestern-Penn State-Torino Collaboration, approved December 1985.

4 J. Rosen, *Heavy Hadronic Molecules*, AIP Conf. Proc. No. 185, ed. S.U. Chung, p. 611.

5 We expect that $\sigma(p\bar{p} \rightarrow \Upsilon) / \sigma(p\bar{p} \rightarrow \psi) \cong (m_\psi / m_\Upsilon)^8 \cong 10^{-4}$. Since E760 with a luminosity of 10^{32} $cm^{-2}s^{-1}$ expects a few 10^4 events, it seems unlikely that a bottomonium experiment will succeed. In any case, the required beam momentum is 68 GeV/c; the design for the Main Injector allows for a maximum momentum of 75 GeV/c for continuous operation.

6 P. Zhou and F. Mills, *RFQ for Decelerating Anti-Proton Beams*, Fermilab, unpublished, to be presented in the Workshop on Physics at Fermilab in the 1990's at Breckenridge, Colorado, 1989.

7 H. Kreiser, Y. Onel, et al., *Polarized Antiprotons with the Spin Splitter*, in Proceedings of the European Particle Accelerator Conference, Rome, June 7-11, 1988, ed. by S. Tazzari, Vol. 2, p. 848, World Scientific, Singapore 1989.

8 S. Y. Hsueh, *A Second Solenoid*, Fermilab, unpublished, October 1988.

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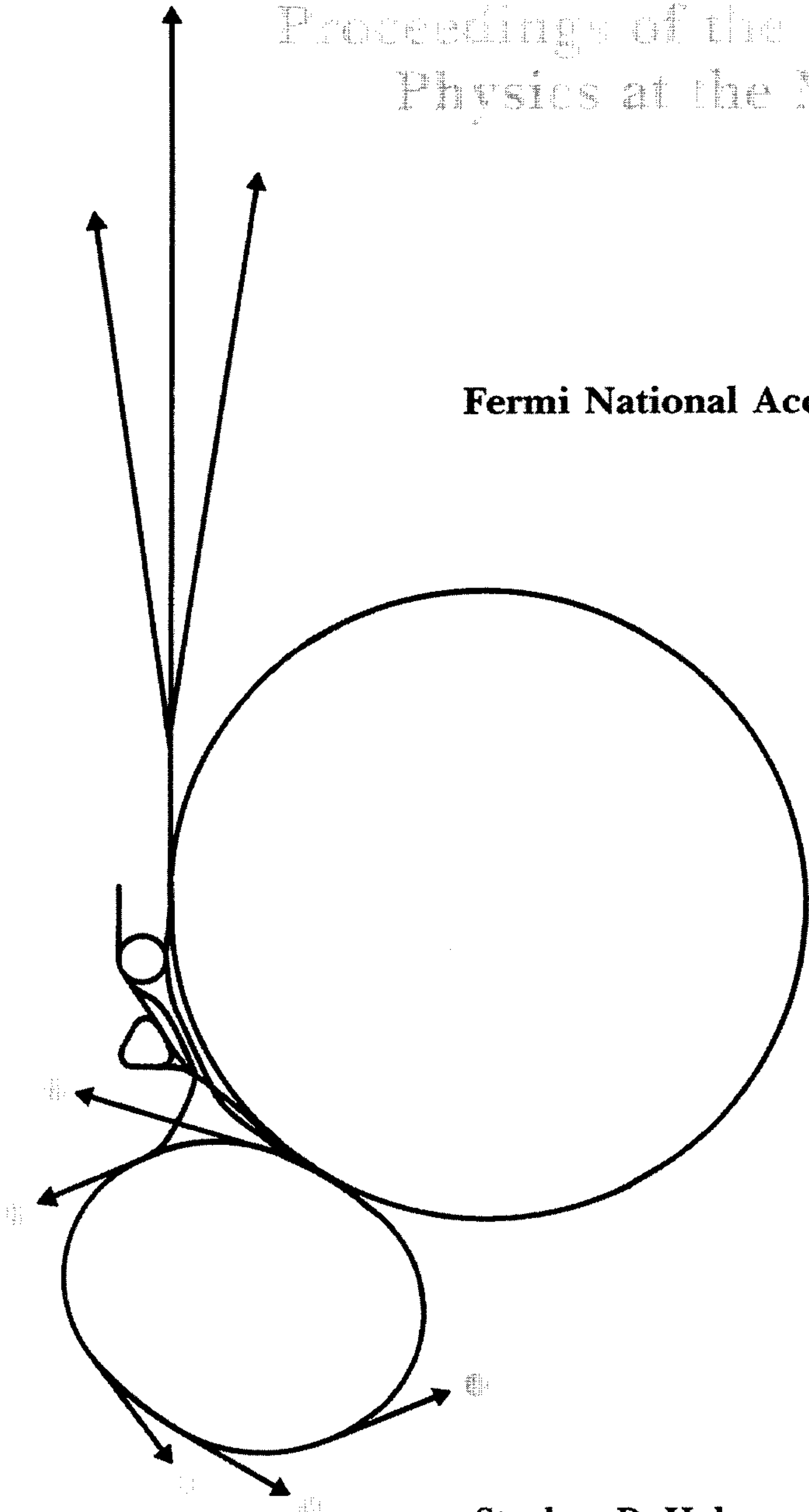

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