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PROPOSAL TO STUDY ANNIHILATION AND NON-ANNIHILATION PROCESSES IN $\bar{p}$ d COLLISIONS IN THE 15-FOOT BUBBLE CHAMBER

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INTRODUCTION

The study of the interaction of anti-protons with nucleons offers a unique opportunity to observe processes not accessible to nucleon-nucleon or meson-nucleon interactions. With the development of the enrichment tecniques in the neutrino beam line, this traditionally fertile area of study becomes feasible in the fifteen-foot bubble chamber. Some of the basic problems that could be addressed include the relation of the annihilation process to the "screeching halt" pp processes. At energies where the quark picture is meaningful, are annihilation processes governed primarily by single $\bar{q}q$ annihilation, double or even triple? Further, one may ask if $\bar{p}$ N processes can be related to the e^+e^- results of recent years. Some of these questions will be spelled out in more detail in the section on specific physics objectives.

The fifteen-foot bubble chamber is well suited for studying hadron reactions at high energy. Furthermore, there are several considerations following from the large $\bar{p}$ d cross section and the size of the chamber that make it particularly well suited to $\bar{p}$ d physics. These special features will be presented in the next section.

The fifteen-foot chamber as a tool for hadron physics was discussed at the Sonoma workshop, October 1976, organized in part by the experimenters of this proposal. Part of the conference covered resolution and detection efficiency. Three meter tracks of 100 GeV/c are measurable to $\Delta p/p \simeq 1\%$ according to results presented by Prof. Kitagaki. With a 100 GeV/c $\bar{p}$ beam, secondary tracks would of course have a reduced path length, but they would also be of lower momentum. The general conclusion is that outgoing tracks can be measured quite successfully without gaps in the distributions with respect to longitudinal variables such as x or y. Due to its size, the fifteen-foot chamber is also useful as a detector of γ particles. The $\gamma\gamma$ effective mass shows a sharp π^o signal. While it is generally agreed that neutral decays of strange particles are well detected in the 15', it is not widely realized that it is an excellent detector of neutrons or anti-nuetrons coming from an interaction and interacting in the deuterium (See the discussion in the Physics Objectives section). Taken altogether, the fifteen-foot chamber is seen as a good, unbiased 4π detector of the products of interactions and this is precisely what is needed to differentiate annihilation from non-annihilation processes.

We therefore propose to have 150,000 pictures of $\bar{p}$ into the fifteen-foot chamber filled with deuterium.

SPECIAL EXPERIMENTAL CONSIDERATIONS

(a) To study neutral particle production with minimal ambiguity, one would like to have one and only one interaction in a frame. Given n tracks in the bubble chamber, the probability of one and only one interaction is $np\ (1-p)^{n-1}$, where p is the probability that a track interacts in the fiducial volume. This number is maximized if we set the number of beam tracks per picture to be

$$n = -\frac{1}{\log(1-p)} \ .$$

The value of p is $p = 1 - e^{-N\sigma\ell}$, where N is the number of targets per cm^3, ($N \simeq 4 \times 10^{22}$ in D_2 bubble chamber), σ is the total cross section ($\sigma \simeq$ 80 mb for $\bar{p}$ d interactions), and ℓ is the fiducial length ($\ell \simeq 3$ meters in the 15' chamber). Thus, the most desirable number of beam tracks per picture for a $\bar{p}$ d experiment in the 15' deuterium chamber is one, since $n = \frac{1}{N\sigma\ell} \simeq 1.0$.

(b) With an enrichment scheme in Enclosure 100, a $\bar{p}$ yield of 30% is achieved at energies up to 100 GeV for Expt. 311. Since the enrichment is made before the 30" and 15' beam lines are split, this 30% $\bar{p}$ beam is readily available in the 15' hadron line, with no further beam test requirements.

In the 15' hadron line, the π/p discriminating Č counter is in place. Since we want only one beam track, we do not necessarily need the tagging PWC and the last quadrupole magnet that fans out the beam, both of which are not available at the present time. We do need the beam kicker, which is operational now.

(c) We would fire the kicker and take a picture when the first particle in the beam spill is a $\bar{p}$. We would like to request 150,000 of such pictures.

If our run is mixed with another π^- run at the same energy, we will simply record the frame number of the $\bar{p}$ pictures. Although it is not a necessity, this would most conveniently be done using the film image of the data box as well as a magnetic tape. Our program then would be to scan and measure all $\bar{p}$ frames on 1/2 the film, exchange film with the π^- experimenters, then do the second half.

PHYSICS OBJECTIVES

(a) Comparison between $\bar{p}p$ and $\bar{p}n$ interactions. Pure $\bar{p}n$ interactions are the odd-prong events plus the even-prong events with spectator proton of momentum less than 280 MeV.[1] In Expt. E311, Oh, et al.[2] find $(\sigma_{\bar{p}p} - \sigma_{pp}) \sim 3.5$ mb and attribute the difference to baryon annihilation. However, there are several increasingly respectable quark models which would attribute this difference to $q\bar{q}$ annihilation. If this is in fact the case, there is a predictable difference between baryon annihilation $\bar{p}n$ vis-a-vis $\bar{p}p$ and a given quark model describing the same process. It is then of considerable interest to compare $\bar{p}n$ and $\bar{p}p$.

In quark models, the $\bar{p}$ beam is ideally suited for the study of $q\bar{q}$ annihilation since it possesses three valence antiquarks. The excess of particles produced in antinucleon-nucleon interactions over nucleon-nucleon interactions is the valence interactions. By simple quark counting[3], some definite results can be predicted for this excess. For example, the ratio of excess pions produced at $x = 0$ is 4:4:1 for $\pi^-:\pi^0:\pi^+$ in $\bar{p}n$ interaction. This same ratio is expected to be 2:5:2 in $p\bar{p}$ interaction.

At energies below 100 GeV, charged pions near $x = 0$ have laboratory momentum around 2.5 GeV for $p_T = 0.3$ GeV and around 7 GeV for $p_T = 1$ GeV. These momenta can be very accurately measured in the 15'. Furthermore, since the pions produced in valence interactions may have different p_T dependence, it is particularly important to measure wide angle pions above 7 GeV. This is much better done in the 15' bubble chamber rather than in, for example, the 30" hybrid system.

The detection efficiency of γ's in the 15' is around 15%. The 2% efficiency of detecting π^o is not to be entirely discounted. A π^o signal is clearly seen in the $m(\gamma\gamma)$ plot (Fig. 1) in the preliminary data in our 400 pp experiment.[4] In the moderately high statistics experiment we are proposing, enough π^o data can be obtained to compare with the yield of charged pions near $x = 0$.

The fifteen-foot chamber can be used to give a positive signal on non-annihilation events. It is sufficiently large that surviving baryons from a <u>non</u>-annihilation interaction have a reasonable probability for detection on a statistical basis. E.G., n or $\bar{n}$ neutrals have about 40% probability for re-interaction before escape. K_S^o re-interaction drops quite fast ($\beta\gamma c\tau \simeq 20$ cm at CM velocities) - Λ, $\bar{\Lambda}$ of course indicate survival of baryons. Notice that for optimum utilization of this technique, one needs one and only one track per picture - as proposed.

Other features of considerable interest such as the anomalously large π^o-π^- correlation will also be compared in $\bar{p}p$ and $\bar{p}n$ interactions.

(b) <u>Detection of short-lived particles that decay into neutral strange particles</u>. If the quark-antiquark annihilation cross section is as large as suggested in part (a), then the probability for producing new particles will be enhanced in $\bar{p}p$ interactions. The detection efficiency for such particles should be good since the 15' chamber is an excellent detector for neutral strange particles and detects γ's relatively well, allowing measurement of all hadronic decay products.

The sensitivity of the proposed experiment is 1.2 events per microbarn.

DATA PROCESSING

We are presently processing some 30,000 pictures of pp interactions at 400 GeV/c taken in the fifteen-foot chamber a year ago (Exp. 341). That experiment was approved as a feasibility test for the study of hadron interactions in the fifteen-foot chamber. We developed a microprocessor controlled Scan-Image-Plane-Digitizing-system at UCD[5] and a semi-automatic measuring system, CICERO,[6] at LBL. The measurement and analysis is still in progress, but we have achieved an important bench mark for the feasibility test - we can see an excellent π^o signal as shown.

In production, our IPD scan rate is 15-20 frames/hour/table. To scan a 150,000 picture exposure will take $4\frac{1}{2}$ FTE year. Three FTE-scanners are what we are planning to devote to this experiment. In other words, the IPD scan will take $1\frac{1}{2}$ year. Our measuring rate for the complex topologies of the 400 GeV/c pp interactions is about 5,000 events per FTE-year. The rate should be somewhat greater for events produced at energies where we expect to run. We should measure at $\sim$ 4 events/hour/machine, and allowing 3 FTE measurers, we will measure some 50,000 events in the two years we expect to devote to analysis.

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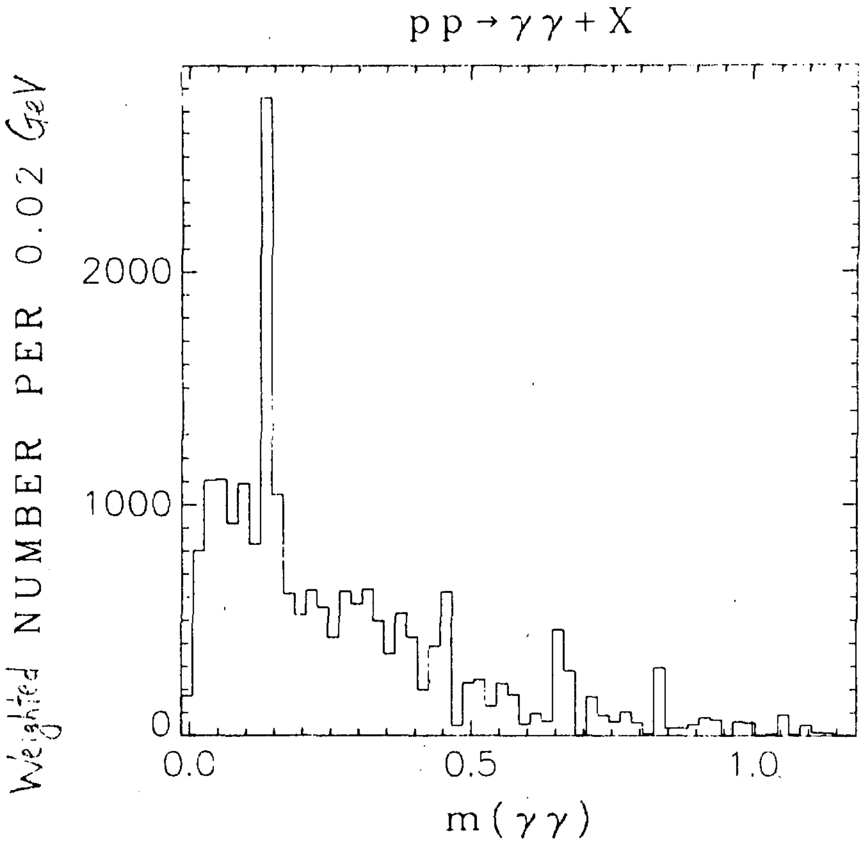

Fig. 1