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Proposal to study $\bar{p}p$ annililations at 150 GeV/c using a Rapid Cycling Bubble Chamber and downstream Particle Identification

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ABSTRACT

We propose to study $\bar{p}p$ interactions at 150 GeV/c in a rapid cycling bubble chamber with downstream particle identification provided by ISIS. By suitable triggering particular emphasis will be placed on annihilation events which offer exciting prospects for the detection of the decays of charmed particle pairs. Additional counters will be used to veto non-annihilation events. We aim to obtain 10^5 annihilation events on about 700 Kpix in 30 days running time.

1. Introduction

We propose a study of $\bar{p}p$ interactions at the highest practical SPS energy, probably 150 GeV/c. Emphasis will be placed on a study of the annihilation channels with the highest possible statistics, including especially the identification of the resultant secondary particles. An exciting possibility in this experiment is the observation(perhaps via anomalies in strange particle production) of the production and decay of pairs of charmed hadrons [1]. The recent discovery [2] of narrow e^+e^- annihilation resonances and the possibility of their having charmed quark substructure has given a stimulus to this possibility, with $\bar{p}p$ annihilations being an obvious field for careful study. More generally $\bar{p}p$ annihilations provide a unique system for testing high energy reaction mechanisms [3],[4],[5].

The apparatus used to perform the experiment must be able to meet the following general requirements:

(i) Ability to deal with charged multiplicities(by extrapolation [4] $< n_{ch} > \sim 7$ for $\bar{p}p$ at 150 GeV/c.)

(ii) To identify π's K's and P's of either charge over a large range of laboratory momenta.

(iii)To identify K^o_s, Λ^o and Σ^- decays.

(iv) A reasonable event rate from milli-barn cross-sections.

We feel that these requirements make the proposed experiment a likely candidate for the 80cm rapid cycling bubble chamber (RCBC) and downstream applied to the backward hemisphere virtually dictate the use of a device having the spatial resolution ($\sim$ 50μm), isotropic detection and high multi-track efficiency of a bubble chamber. The requirement for forward particle identification can be satisfied by ISIS. Finally, cross-sections in the milli-barn range can readily be studied using RCBC's.

If the equipment becomes available as a facility at the SPS then the proposed experiment requires only a few weeks of running and installation time.

Because no other device combining all the above advantages is likely to be operating at SPS or FNAL before the proposed experiment becomes available we believe that this experiment can make a worth-while contribution to physics even though it is unlikely to be performed before 1979.

II Physics Interest in $\bar{p}p$ Annihilations

It has recently been emphasized [5] that the physics of non-annihilation and annihilation channels are quite different, and that one should design experiments, at as high an energy as possible, with as clear a separation of these channels as possible. The physics of annihilation channels is expected to be quite complicated, and will therefore require a detailed study with high statistics.

Characteristics of annihilation processes we intend to study are as follows:

1. Cross-section One expects, and observes roughly at low energies,

$$\sigma_{annih} \sim s^{-\frac{1}{2}} .$$

This behaviour is what one expects from simple Reggeology and ω-exchange and is in accord with the experimental observation at low energies:

These observations must clearly be tested at high energies, and techniques developed to identify experimentally the annihilation component.

2. Multiplicity distributions and Correlations At low energies the multiplicity distributions of annihilation processes are quite different from non- annihilation ones, indicating a difference in correlations between produced particles in the two cases. Present low energy annihilation data can be interpreted [5] as being consistent with an absence of clustering effects (unlike with pp scattering.)

With γ-detection we might also measure average numbers of π^o's as a function of prong number. Present results up to 15 GeV/c show annihilation events behaving differently from non-annihilation events.

3. Single particle distributions Since we resolve $\pi/K/P$ for most of the available x-range (to a few % from 5 to 100 GeV/c [6]), inclusive rapidity and p_T distributions can be obtained for these particles with < 5% error up to 150 GeV/c. Where Σ^-, Λ^o and K_s^o can be identified these can also be studied. Given that $\bar{p}p$ interactions separate into annihilation and non-annihilation components, it will be interesting to see if a form of scaling exists for annihilation alone normalized to the annihilation's cross-sections,ie. if

$$\frac{1}{\sigma_{annih}} f(x, \underline{p}_T, s) \rightarrow f(x, \underline{p}_T) .$$

Also the subtraction relation

$$\frac{d^3\sigma}{dp^3}(\bar{p}p) - \frac{d^3\sigma}{dp^3}(pp) = \left(\frac{d^3\sigma}{dp^3}\right)_{annih}$$

might be tested in detail.

It is important to see how $\langle p_T \rangle_{annih}$ varies with energy for different particles and multiplicities, and in particular if it achieves a higher value than the 'universal' 350 MeV.

The identification of secondary particles by ISIS is an essential part of this experiment.

4. Resonance production The accuracy obtainable on the affective masses of 2 and 3- body final states (see Figs 9 and 10 of ref [6]) is sufficient to permit a search for resonances decaying into 2 or more secondary charged particles. Because particle particle identification using the bubble chamber and ISIS is available such a survey can be performed using all events, and is not restricted to a handful of 4C fit channels. Thus we can expect to obtain good statistics on the inclusive production of $\rho, \omega, \Delta^{++}$, $Y^*(1385)$....

III Beam

A possible hadron beam line for use with the RCBC has been designed by Doble [7]. It would be about 500m long and have an acceptance of 4 μsr $\% \delta p/_p$. The production angle would be variable between 0 and 4 mr. with 10^{12} protons per second interacting in the target during the "flat top". Momentum analysis is carried out in the vertical plane but the optical design is such that vertical images downstream of the momentum "slit" are dispersion free.

Although at Fermilab the N5 beam line has an acceptance of only 0.3 μsr $\% \delta p/_p$ [8] the interaction rate in the target is much higher than envisaged at the SPS because of "fast" extraction being available. The net result,however, is that the possibilities for enriched beams should be very similar to those proposed for the 15 foot bubble chamber at Fermilab [9]. These possibilities are

About 40 $\bar{p}$'s per pulse might be expected at the RCBC with a beam purity of around 50%. The wanted and unwanted particles would be tagged using a "CEDAR' Cernekov Counter and proportioned wire chambers.

IV Trigger

We wish to employ the following triggers operating on the bubble chamber flash:

a) Beam trigger: derived from the Cerenkov beam tagging system

b) Interaction trigger: MWPC planes would be used to require beam interactions.

c) Annihilation trigger:

At present the best approach here seems to be the vetoing of clear non-annihilation events. Since ISIS cannot be used as part of the trigger logic we probably require a threshold Cerenkov counter beyond ISIS to veto $\bar{p}$'s above, say 100 GeV/c. This should climate (or at least identify) elastic and target fragmentation events. It also appears feasible to veto fast $\bar{n}$'s from non-annihilation events using a scintillator-converter sandwich to register $\bar{n}$ annihilations; we believe that it would not be unreasonably optimistic to expect 50% efficiency of such a trigger. We would thus hope to see a net 75% vetoing efficiency of non- annihilations.

Further work on the trigger system will be undertaken once the final configuration of the RCBC/ISIS system is known and when information from the FNAL $\bar{p}p$ exposure in the 30" chamber at 100 GeV/c becomes available [10]. This FNAL experiment includes an $\bar{n}$ converter/spark chamber detector from which helpful experience should be gained.

V The Exposure

the annihilation process and a fiducial length of 55 cms, the RCBC could accumulate 10^5 annihilation events in about 30 days running time with 3 $\bar{p}$ beam particles per cycle. Allowing for triggering inefficiencies and interactions outside the fiducial volume these events would require about 700 kpix.

VI The Analysis

At present both the Cambridge and Michigan State groups have a measuring capability of 200K conventional events per year.

These groups will participate in the first $\bar{p}p$ exposure of the 30" HBC at FNAL [10] and will use their experience gained in this exposure in the design of this experiment.

Although we would welcome collaborators, the Cambridge and Michigan State groups are prepared to guarantee that sufficient analysis capability will be available for the experiment.

Appendix

"Enriched beams for the RCBC in the CERN SPS north area"

With the exception of the multiple targetting schemes the methods of particle beam enrichment suggested by Neale [9] for use at Fermilab could be adapted for use by the proposed RCBC at the SPS in the north area. For details of the various schemes reference should be made to the Neale Report.

With 10^{12} protons interacting in the target the minimum acceptable flux at the end of the beam line is probably around 10^4 particles. Concerning beam purity it has been suggested that beams become useful when the wanted particles are $\gtrsim$ 10% of the total. In most cases it is possible to do much better than this.

The possibilities of p, $\bar{p}$, π^+,π^-, K^+ and K^- beams are discussed briefly in turn. A beam line such as the one proposed by Doble [7] is assumed (ie length $\sim$ 500 metres, $\delta\Omega.\delta p/_p \sim 4\mu sr$ % $\delta p/_p$). An incident proton momentum of 400 GeV/c is also assumed.

a) Proton Beams

Between 200 and 400 GeV/c the proton beam produced directly in the target should be adequate. Below 200 GeV/c the "halo" beams should consist mainly of protons (from Λ^o decay). The dipoles placed near the target will sweep away the charged secondaries.Collimators in the beam line enable specific parts of the target halo to be selected. It should be possible to produce positive beams down to PS energies with > 50% protons.

b) Antiproton Beams

The "halo" method should be used. Since the Doble beam line will have an undispersed image downstream of the momentum slit it will have similar properties to the N5 beam line at Fermilab. At 150 GeV/c the purity may be about 30% and the flux more than adequate. The flux and purity are likely to be inadequate before 200 GeV/c is reached.

Below 100 GeV/c a finite production angle (eg 4mr) must be used to minimise the background of π^- from Λ^0 decay. It should be possible to go down to 50 GeV/c and still have adequate beam purity.

c) Positive Pion Beams

A Beryllium filter at the momentum slit should enable considerable enrichment to take place at all momenta. Useable beams (ie >10%π^+ and adequate flux) should be available up to at least 300 GeV/c.

d) Negative Pion Beams

Adequate beams of negative pions can be produced directly in the target probably up to about 360 GeV/c.

e) Positive Kaon Beams

Since the Doble beam line has only half the length of the Fermilab N3 and N5 beam lines the situation for Kaons is more favourable at the SPS than at Fermilab. With the Beryllium Filter suggested for the positive pions adequate positive Kaon beams should certainly be available in the momentum range 100-200 below 50 GeV/c. The proton contamination increases rapidly with momentum and it will probably be purity rather than flux considerations that determine the upper momentum limit which could be somewhat in excess of 250 GeV/c.

Since the K^+/π^+ ratio increases but the K^+ flux decreases with production angle a suitable compromise between production angle and filter length has to be found at each momentum.

f) Negative Kaon Beams

Around 100 GeV/c the negative beams arriving at the RCBC would have only 2-3% of kaons. As currently envisaged the beam line layout precludes the use of multiple targetting techniques and in any case it is not clear that the fluxes would be adequate. Some improvement in the K^-/π^- ratio is obtainable by filtering but probably not sufficient to bring the purity up to 10%.

Summary

Based on criteria of a flux of wanted particles of $\gtrsim$ 5 per pulse of the RCBC and a purity $\gtrsim$ 10% then it is expected that the following particle beams could be available:

p	all momenta
$\bar{p}$	~ 50-150 GeV/c
π^+	$\lesssim$ 300 GeV/c
π^-	$\lesssim$ 360 GeV/c
K^+	~ 50-250 GeV/c
K^-	none

A 2-3 metre long Beryllium filter would probably be adequate for the π^+ and

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