SMALL ANGLE CHARGE EXCHANGE EXPERIMENTS

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ABSTRACT

An optical spark-chamber experiment is discussed to study $\pi^- p$, $K^- p$, and $\bar{p}p$ charge exchange reactions. The angular range $-t < 3\ (\mathrm{GeV}/c)^2$ is covered at 50 and 100 GeV/c. Expected rates are estimated from existing data around 10 GeV/c. About 150 hours of machine time are needed for testing and data taking.

A modest experimental program is proposed to study the reactions

$$\pi^- p \rightarrow \pi^o n \tag{1}$$

$$\pi^- p \rightarrow \eta^o n \tag{2}$$

$$K^- p \rightarrow \bar{K}^o n \tag{3}$$

$$\bar{p}p \rightarrow \bar{n}n \tag{4}$$

in the range $-t < 3\ (\mathrm{GeV}/c)^2$ at 50 and 100 GeV/c. This program requires no unusually large magnets or on-line computers and may be executed by a modest-size user group.

The general layout is shown on Fig. 1. An unseparated negative beam is incident on a 3-ft hydrogen target. Appropriate Cerenkov counters in the beam reliably tag the K^- and $\bar{p}$ components. The beam is focused on the detector 60 m downstream of the target. We assume 0.3 mrad divergence in both horizontal and vertical plane and a 3-mm image size. The momentum bite is of no importance. The target then has to have a diameter of about 5 cm. A flux of 2×10^6 ppp is assumed.

The crude outline of the detector design described here is patterned after that of some past experiments (Refs. 1-3). In reality one would probably use a more up-to-date design and define the desired reactions more carefully. Such changes will not materially alter the event rate or the overall requirements however.

The critical part of the detector is an anti-coincidence shield around the target. This shield is a lead-scintillator sandwich that detects charged particles and γ rays with high efficiency but is reasonably transparent to neutrons. For reactions (1) and (2) no lead is used in the angular range covered by the downstream spark chamber.

To avoid jamming the spark chamber, it seems convenient to put a sweeping magnet downstream of the target. A 20-kG field 3 meters long is adequate to sweep a 100-GeV/c beam away from the spark chamber. The aperture must allow the neutral particles free passage. The minimum size is 15×15 cm for a momentum transfer range $-t < 3\ (\mathrm{GeV}/c)^2$ at 100 GeV/c.

The spark chamber must detect the two γ rays from π^0 and η^0 decay [reactions (1) and (2)], a nuclear star from $\bar{n}$ or K_L^0 interactions [reactions (3) and (4)]. A $2\mathrm{m} \times 2\mathrm{m}$ optical chamber could be used with steel or lead-brass sandwich plates.

For reactions (1) and (2) the γ-ray conversion points could be measured to 1 mm accuracy. For the minimum γ ray opening angle $\tan \theta/2 = m/p$, or θ is about 2.8 mrad for π^0 decay at 100 GeV/c. This angle is then determined with an accuracy of ~1% (a comparable error is due to the finite length of the target). The shape of the opening angle spectrum can be used to estimate random background. If only 50% of the events with near-minimum opening angles are accepted, the bisector of this angle can be used for π^0 (η) direction. The <u>resolution</u> in t is limited by the target size. If we assume a 3-ft target the resolution is $\delta t \sim 0.1\ (\mathrm{GeV}/c)^2$ at the largest momentum transfer and $\delta t < 0.02\ (\mathrm{GeV}/c)^2$ for $-t < 0.6\ (\mathrm{GeV}/c)^2$.

For the highly unconstrained system proposed here a few comments concerning <u>background</u> are in order.

1. The trigger--one particle in, nothing out--has worked[1-6] in the energy range around 10 GeV/c. The contamination from events where the anti-shield failed has been small in all cases. There is no reason to expect this method to fail at higher energies.

2. The background can be studied by artificially reducing the efficiency of the anti-shield.

3. The addition of neutron counters to detect the recoil can reduce the background--but will cut the data rate.

To get some idea concerning the rates to expect at 100 GeV/c, we assume that the energy dependence of the cross sections established in the 10-GeV region holds up in the higher energy domain. Table I summarizes the cross-section estimates and the event rates expected at 100 GeV/c assuming 2×10^6 particles/pulse and a $\pi^-/K^-/\bar{p}$ ratio of $1/1.5 \times 10^{-2}/3 \times 10^{-3}$.

Table I. Cross-Section Estimates.

Reaction	σ_T (10 GeV/c)	Energy Dependence	Ref.	σ_T (100 GeV/c)	Events/pulse (100 GeV/c)
$\pi^- p \to \pi^o n$	48 μb	$1/p_{inc}$	1	5 μb	30
$\pi^o p \to \eta n$, $\eta \to 2\gamma$	10 μb	$\left(1/p_{inc}\right)^{1.4}$	5	0.3 μb	2
$K^- p \to \overline{K}^o n$	70 μb	$1/p_{inc}$ (?)	2	7 μb (?)	0.7
$\overline{p}p \to \overline{n}n$	250 μb	$\left(1/p_{inc}\right)^{1.4}$	7	8 μb	0.15

A data-taking period of 24 hours at 900 pulses/hour leads to 3000 events of the least copious reaction ($\overline{p}p \to \overline{n}n$). To keep the number of pictures relatively low, it may be convenient to remove low momentum transfer $\pi^- p$ charge exchange events after a while (adding another lead-scintillator sandwich in anticoincidence covering the center of the detector will accomplish this).

With tuning, debugging, bias checking, a total of about 150 hours of machine time seems reasonable to carry out the experiment at two momenta. It should be noted, however, that this estimate leaves the geometry unaltered between momenta. Therefore the momentum transfer region explored at 50 GeV/c will be $-t < 0.75\ (\mathrm{GeV/c})^2$. It may be worthwhile taking the extra time necessary to move the detector closer and shortening the target. (The aperture of the sweeping magnet would have to be larger for this modified geometry.)

POSSIBLE EMBELLISHMENTS

A. Improvements

1. The resolution in momentum transfer is primarily limited by the target size. Significant improvement can be obtained using a technique developed by Manelli et al. in Pisa. They use the target as a Cerenkov radiator, and by recording the observed pulse height they can estimate the interaction point to good accuracy.

2. To improve K^o detection the method used by Bertolucci et al.[3] can be incorporated. They detect the direction of the π^+ and π^- from $K^o_s \to 2\pi$ decay using thin plate spark chambers. One would use K^o_s decays beyond the sweeping magnet only (~50% survive at 100 GeV/c).

B. Extensions[8]

With some modification in the region around the target some other reactions can also be investigated.

For instance, if one were to focus the beam on the target, it should be possible to reduce the diameter of the target and anti-shield around it to about 2 cm. A reasonable fraction of Λ^{o}'s produced at low momentum transfer will escape and decay outside the shield. If these are detected with additional spark chambers, the following reactions could be studied:

$$\pi^{-} p \rightarrow \Lambda K^{o}$$

$$K^{-} p \rightarrow \Lambda \pi^{o}$$

$$K^{-} p \rightarrow \Lambda \phi$$
$$\hookrightarrow K_{s}^{o} K_{L}^{o} \ .$$

It seems likely that the reactions

$$K^{-} p \rightarrow n \overline{K}^{o} \text{ (backward charge exchange)}$$

$$K^{-} p \rightarrow n \overline{n} \Lambda$$

$$\overline{p} p \rightarrow \overline{K}^{o} K^{o}$$

$$\overline{p} p \rightarrow \Lambda \overline{\Lambda}$$

$$\overline{p} p \rightarrow n \overline{n} \text{ (backward charge exchange),}$$

all have sufficiently low cross sections that the corresponding rates would be too low to be useful, even low enough not to provide a serious background.

REFERENCES

[1] A. V. Stirling et al., Phys. Rev. Letters 14, 763 (1965).

[2] P. Astbury et al., Phys. Letters 22, 537 (1966).

[3] E. Bertolucci et al., Proceedings of CERN High Energy Collisions Conference, 1968, CERN 68-7 Vol. II, p. 190.

[4] P. Sonderegger et al., Phys. Letters 20, 75 (1966).

[5] O. Guisan et al., Phys. Letters 18, 200 (1965).

[6] I. Manelli et al., Phys. Rev. 168, 1515 (1968).

[7] P. Astbury et al., Phys. Letters 23, 160 (1966).

[8] These ideas are motivated by the work of the Pisa-Orsay groups (Ref. 3). They manage to use a 2.9-cm diameter anti-counter around their hydrogen target.

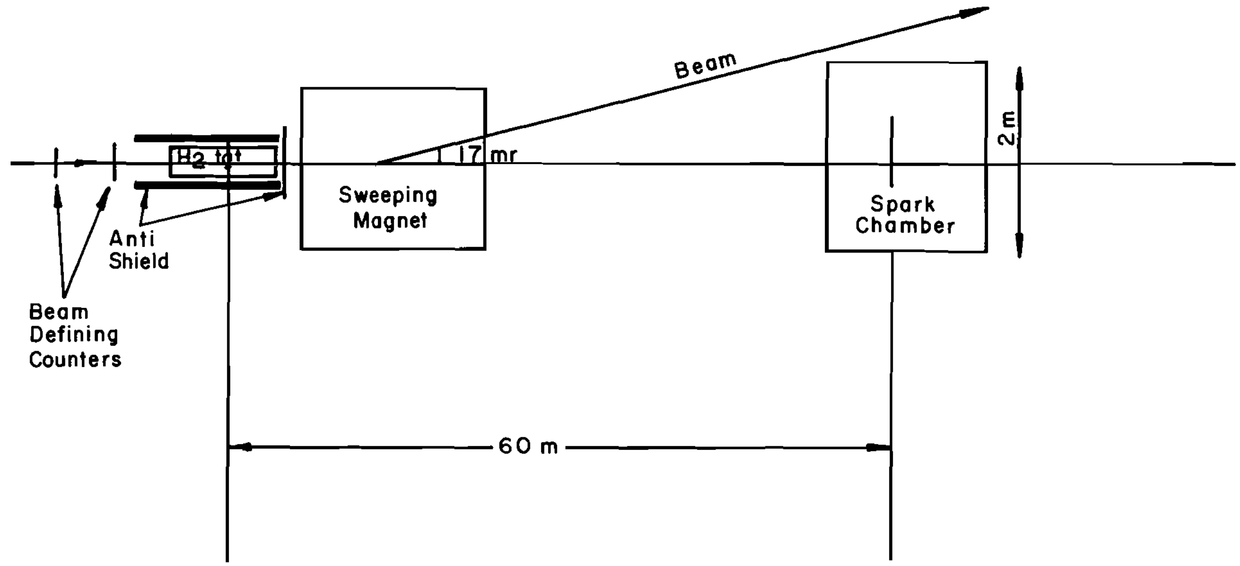

Fig. 1. Layout of experimental apparatus.