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PROPOSAL FOR A MEASUREMENT OF ELASTIC SCATTERING OF 400 MeV/c π^+ BY DEUTERIUM

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Recent experiments on elastic pion-nucleus scattering[1] have been extensively studied using different forms of multiple scattering expansion[2] but because of the complexity of the target many approximations have to be made. The clearest system where these theoretical models can be applied is the pion-deuteron case (the spin structure being much simpler than for nucleon deuteron). The deuteron wave function and the low energy two-nucleon interaction are reasonably well understood, and in the near future there will be available accurate (on-shell) pion-nucleon amplitudes in the medium energy range (70-300 MeV)[3]. At high energies the cross-section is quite well described by the Glauber theory, but there are serious doubts about applying this for medium energies. In a similar spirit, but without making some of the kinematic approximations, Carlson[4] has reproduced much of the available bubble chamber data. However, this data is generally of a very poor quality. It is the aim of this proposed experiment to provide good data which might prove a serious test of different theoretical approaches.

Good counter measurements exist at higher energies, ~ 1 GeV/c and above, as the difficulty of resolving elastic and inelastic scattering is avoided by detecting the recoiling deuteron which escapes from the target. In the case of low energy pions the recoil deuteron can escape only for large pion scattering angles ($\gtrsim 120°$ for 400 MeV/c), but it is possible to detect the recoil deuteron for quite small angle scattering if a scintillating target (deuterated cyclohexane C_6D_{12}) is used. The recoil deuteron is well defined in energy and in direction and these properties allow a distinction from the background of πC^{12} elastic scattering and πd and πC^{12} inelastic scattering giving proton recoils.

It is proposed to make a measurement of π^+d elastic scattering at 400 MeV/c over the angular range 20° to 180° taking some fifteen points with about 10^3 counts per point. The existing π^+ beam and spectrometer can be used for the measurement with only minor modifications.

Large angle scattering, $\theta \geq 120°$ (Fig. A)

As the recoil deuteron can escape from the target (see Table I), good πd elastic events can be identified unambiguously by coincidence between a pion scintillator and Cherenkov counter and a (thick) deuteron counter. If necessary a pulse height requirement can be applied to the sum of the pulses from target scintillator and deuteron counter.

For a C_6D_{12} target 3cm thick and a pion solid angle of 8 msr. (± 50 mr vertically and horizontally) the count rate should be ~ 1080 $(d\sigma/d\Omega)$m.b. per hour for 2×10^5 π/sec incident.

$45° \leq \theta \leq 120°$ (Fig. B)

In this angular region the deuteron recoils have ranges similar to the target thickness required, but not large enough to be easily detected external to the target. We propose to stop the recoil in the target and apply pulse height selection to the target signal in coincidence with the scattered pion. It is not at all clear that these requirements will adequately suppress the background from πd and πC^{12} inelastic, but momentum selection of the pions using the magnetic spectrometer should improve the situation by a large factor. The cross-sections for $C^{12}(\pi,\pi')$ given in Table I were estimated from the measurements[5)] of $O^{16}(\pi,\pi')$ for the case of a 2% momentum bite about the momentum of the pions elastically scattered by deuterium. Only a fraction of the C^{12} inelastic events will give a target pulse because of the 16 KeV binding energy of C^{12}; at pion-angles less than 35° none of these events will give pulses.

If the pion momentum selection does not give rise to a clean pulse height spectrum fron the scintillating target, then it will be necessary to collimate the target. This can be done by subdividing the liquid scintillator with glass slides with planes parallel to the recoiling deuterons. Much of the energy of the protons from the break up of C^{12} or deuterium can be dissipated in the glass.

The spectrometer has a solid angle of 4 msr. (± 25 mr horizontally × ± 50 mr vertically) which with a target 2 cm thick bisecting the scattering angle and $2 \times 10^5\ \pi^+$/sec should give a count rate of 360 sec $\theta/2$ $(d\sigma/d\Omega)$ m.b. per hour.

$20° \leq \theta \leq 45°$ (Fig. C)

At these angles less advantage can be gained from the differences in pion momenta from the various inelastic processes, and it is necessary to ask more of the collimation of the deuteron recoil in the target. A liquid scintillator target has been made with subdivision into 0.25 mm of liquid by 0.25 mm glass slides. It is hoped that this target will be effective for selecting πd elastic events down to 25°, and it may be usable at 20°. The thickness of C_6D_{12} is 15 mm which should give a count rate of 270 sec $\theta/2$ $(d\sigma/d\Omega)$ m.b. per hour.

We request about 15 data taking shifts for this measurement together with a similar number of parasitic shifts - 10% beam - with the beam elements powered but not the spectrometer. It should be possible to beam share at all times.

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3) A.A. Carter et al., Nucl. Phys., to be published.

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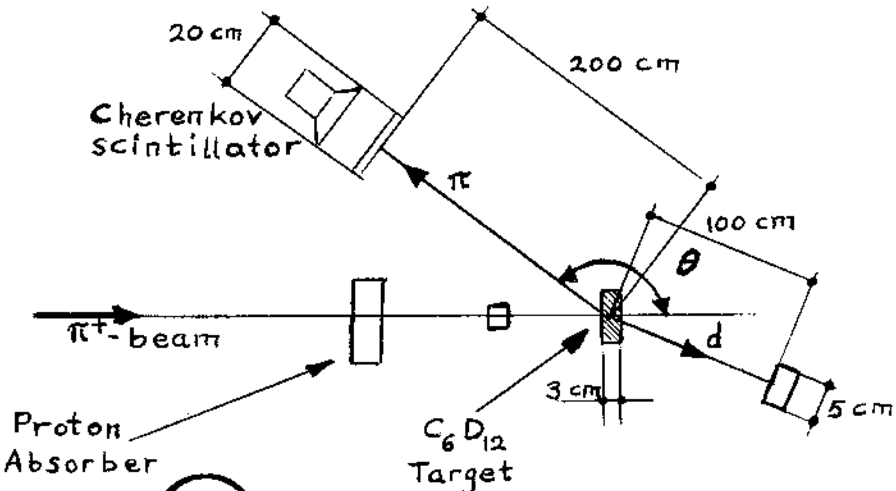
Table I

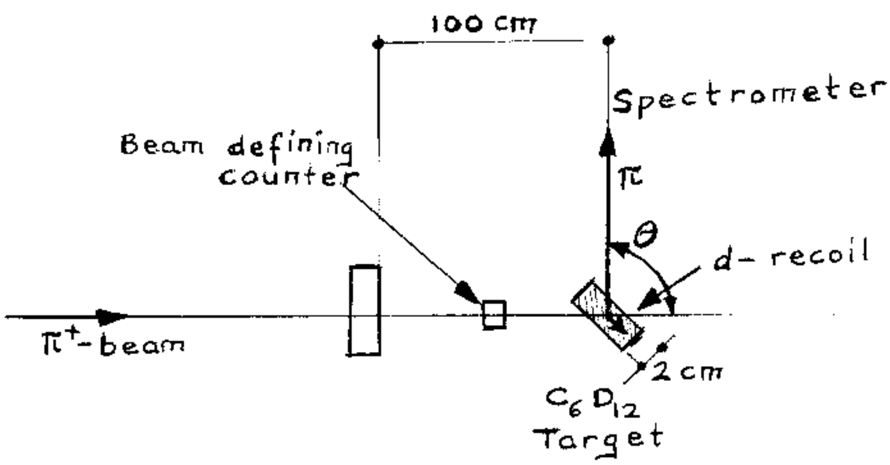
SCATTERING OF PIONS FROM C_6D_{12}

Scattering angle (degrees)	Moment transfer in cm (MeV/c)	d-recoil energy (MeV)	d-Range in C_6D_{12} (mm)	Counts per hour	$(d\sigma/d\Omega)\ \pi d$ Carlson [1] (mb/s.r.)	Cross-section $C^{12}(\pi,\pi')$ (mb/s.r.)
20	133	4.7	0.22	2460	9	< 40 *)
30	197	10.3	0.9	1400	5	6 *)
45	287	21.8	3.25	390	1	2.1
67.5	403	43.0	12.0	304	0.7	0.6
90	496	64.9	23.5	254	0.5	0.2
120	580	89.8	42	324	0.3	~ 0.1
150	629	104.5	56	216	0.2	-
180	644	109.6	62	216	0.2	-

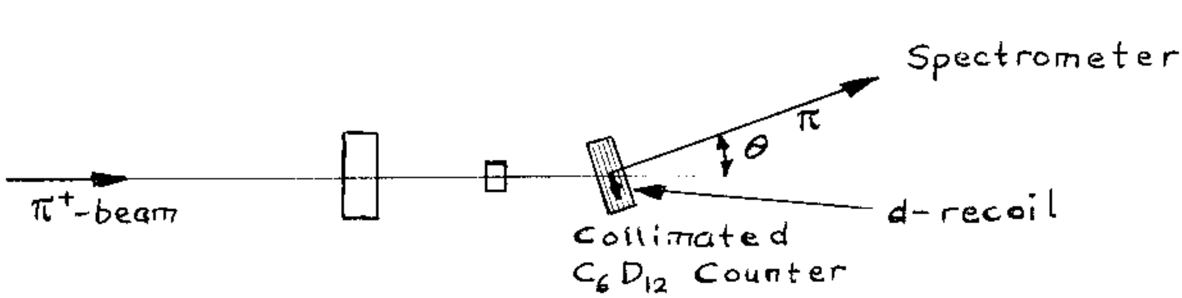
*) At these angles the energy loss (= d-recoil energy) of the scattered pions of interest is less than the binding energy of C^{12} so there can be no break-up of C^{12}.



(A) $\theta \gtrsim 120°$



(B) $45° \lesssim \theta \lesssim 120°$



(C) $20° \lesssim \theta \lesssim 45°$