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ABSTRACT -

Incident alphas on protons were used to measure the elastic cross section in the backward hemisphere at 3.20, 4.00 and 5.08 GeV/c. The level and shape of the angular distributions are strongly dependent on energy. A backward peak shows up at 4.00 GeV/c and becomes much steeper at 5.08 GeV/c.

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The high energy proton helium scattering has been the focus of interest as a test for the Glauber multiple scattering theory(1). Systematic measurements of the differential cross sections exist up to about 60° in the center of mass and for incoming protons of up to 1 GeV(2, 3). The theory explains the general pattern of the experimental data fairly well, even though more sophistication in the actual calculations is clearly needed.

The region above 60° in the CM has hardly been explored above 150 MeV. Experimental problems associated with the detection of the slow recoiling alpha or the separation of inelastic contribution have been the bottleneck holding up the traditional method of using a proton beam on a helium target. In spite of the experimental difficulties, the study of elastic scattering at large momentum transfer was felt to be of importance to accede to the higher order multiple scattering and to investigate the contribution of the u-channel close to 180°.

The use of an alpha particle beam available at the Saclay synchrotron Saturne allowed us to measure the alpha proton scattering very near to 180° for alpha momenta of 3.20, 4.00 and 5.08 GeV/c, corresponding to incident protons on alphas with kinetic energies of 300, 438 and 646 MeV respectively.

The process involved, with t-channel momentum transfers of several $(GeV/c)^2$, probes an interaction region of the order of 0.1 Fm.

The use of incident alphas and their subsequent detection after scattering off a hydrogen target insures that they will always have confortable energy left to get out. Besides, the very fact that the alphas are detected alleviates the task of the energy measuring spectrometer in discriminating against inelastic events. Also, an interesting feature of the kinematics is that the whole CM solid angle folds down in the laboratory system to a cone whose opening angle is given by $\mathrm{Arcsin}(m_p/m_\alpha) = 14.58°$. All this brought us to use a slightly modified version of an existing spectrometer(4).

A typical beam of $2\ 10^{10}$ alpha particles par cycle is focussed as a 1 cm high by 2 cm wide spot on a 5.9 cm long liquid hydrogen target. The scattered particles are analyzed by an achromatic double focussing spectrometer. A five counter hodoscope at the intermediate focus provides a 1% intrinsic resolution (FWHM). ^{4}He are identified by their energy loss in four counters and by a 14 meter time of flight.

Monitoring of the incident beam is provided through two counter telescopes: one is aimed at a thin target located upstream of the hydrogen target, the other looks at the interaction region. The stability of the two monitors is reliable at the 1% level. At each incident momentum, absolute flux calibration is obtained by irradiation of graphite discs. Use was made of the cross section for the reaction $^{12}C(\alpha, X)^{11}C$ measured(5) over the same alpha momentum range.

Figure 1 shows a typical elastic peak. Six different spectrometer settings allow considerable overlap between the five hodoscope elements. Corrections taking into account spectrometer acceptance, hodoscope counters efficiency and nuclear absorption have been made. Cross sections evaluated from the integration of such peaks then yield the numerical values listed in the Table I. They have also been plotted as a function of cos θ_{cm} in Figure 2.

The errors shown in the figures and in the table do not include the 10% uncertainty accountable to the acceptance determination and the incident flux measurement.

The leading feature of the data is the appearance of a backward peak in the differential cross section as the incoming beam momentum is raised from 3.20 to 5.08 GeV/c. At the same time, one notices a strong decrease in the overall level of the cross section.

An early theoretical approach on large angle alpha proton scattering considered a tribaryon exchange in the u-channel(6). This calculation did indeed predict a backward peak, but our experimental value for the slope at 5.08 GeV/c is larger by about a factor of two than the theoretical one. More recently, G. Igo(7) used a relativistic model of the same kind to fit the shape of experimental data on backward proton alpha scattering between T_p = 80 and 660 MeV (p_α = 1.57 to 5.14 GeV/c).

On the other hand, deuteron-proton backward scattering data had raised the question of possible contribution of isobars in the nucleus. Since that time, this question has been further investigated(8), and it would be interesting to consider to what extend isobaric components in ^{4}He could contribute to the behaviour observed in this experiment.

We are grateful to the crew of Saturne for the excellent alpha beam they provided us with. We wish to acknowledge the contribution of our technicians, P. Guilouet and G. Simoneau. We thank Drs. G. Igo, A. Morel and C. Wilkin for interesting discussions.

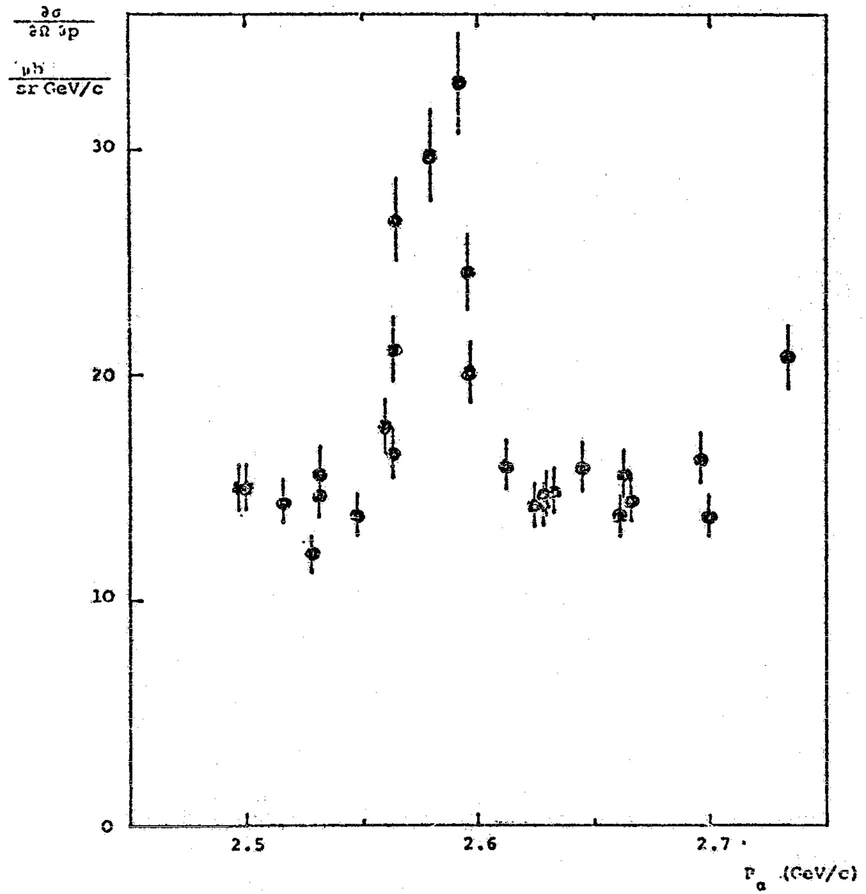

FIG. 1 - Typical backward elastic peak. Incident alphas of 5.08 GeV/c. Scattering angle in the laboratory is 7.34°. Six magnet settings were used

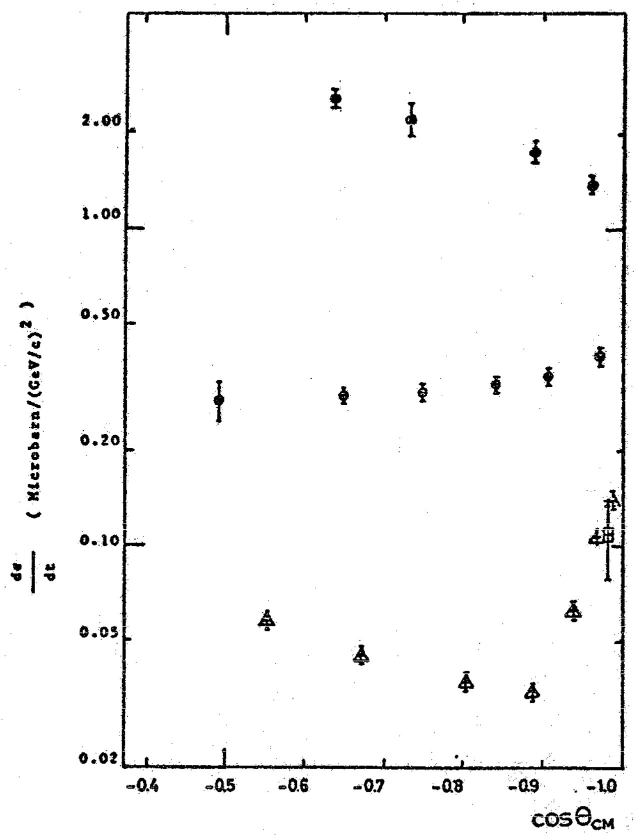

FIG. 2 - Differential cross section for the reaction $\alpha + p = \alpha + p$ in the center of mass system as a function of $\cos\theta_{cm}$.

● : p_α = 3.20 GeV/c equiv. to T_p = 300 MeV in p-α
o : p_α = 4.00 GeV/c equiv. to T_p = 438 Mev in p-α
Δ : p_α = 5.08 GeV/c equiv. to T_p = 646 MeV in p-α
⌶ : data from reference {9} at T_p = 665 MeV

TABLE I

Elastic Cross Sections for Alpha - Proton Scattering

Incident Momentum	$\theta_{cm} \pm \Delta\theta_{cm}$ §	Momentum Transfer - t	u	Cross section dσ / dt ± error
GeV/c	Degree	$(GeV/c)^2$	$(GeV/c)^2$	Microbarn/$(GeV/c)^2$
5.08	123.8 $^{-3.4}_{+2.9}$ (a)	2.657	5.607	0.213 ± .011
	132.4 ± 1.8 (a)	2.860	5.810	0.166 ± .008
	143.7 ± 1.1 (a)	3.085	6.035	0.137 ± .007
	152.8 ± 0.9 (a)	3.228	6.178	0.128 ± .006
	160.1 ± 0.7 (a)	3.314	6.264	0.231 ± .012
	165.6 ± 0.7 (a)	3.363	6.313	0.397 ± .020
	171.1 ± 0.6 (a)	3.396	6.346	0.515 ± .026
4.00	119.6 $^{-4.1}_{+3.9}$ (a)	1.681	6.195	1.61 ± .20
	130.6 ± 3.5 (b)	1.858	6.372	1.67 ± .07
	138.6 ± 2.6 (b)	1.970	6.484	1.71 ± .09
	147.4 ± 1.9 (b)	2.073	6.587	1.82 ± .09
	155.1 ± 1.6 (b)	2.146	6.600	1.93 ± .10
	166.3 ± 1.3 (b)	2.218	6.732	2.24 ± .11
3.20	129.7 $^{-2.6}_{+3.0}$ (a)	1.232	6.787	21.7 ± 1.0
	137.2 ± 1.3 (a)	1.303	6.858	18.7 ± 2.0
	152.8 ± 0.9 (a)	1.420	6.975	14.8 ± 1.0
	163.9 ± 0.7 (a)	1.473	7.028	11.7 ± 0.6

§ Angular acceptance of the two collimators used :

(a) $\Delta\theta_{lab} = 0.23°$ (b) $\Delta\theta_{lab} = 0.44°$

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