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LOW MASS πN ENHANCEMENT IN INELASTIC αp INTERACTION

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Abstract: Evidence for an enhancement in the isospin $I=\frac{1}{2}\,\pi$N system at $M=1130\,\text{MeV}/c^2$ ($\Gamma=80\,\text{MeV}/c^2$) has been found in the reaction $\alpha p\rightarrow\alpha x$ at an incident α-momentum of 4.00 and 5.08 GeV/c. A strong t-dependence of the cross section and a mass-slope correlation are seen as the main features of the data.

NUCLEAR REACTIONS ^{1}H (α, α), $E=1.74$, 2.57 GeV; measured $\sigma(\theta)$.

In recent years experimental high-energy nuclear physics has been developed intensively. The outcome of the experimental results in this field has been that the demarcation line between the two, up to now severely distinct theoretical branches, that of elementary particle physics and nuclear physics, is becoming less and less defined. In describing particle-nucleus collisions at high energy the concepts of elementary particle physics are combining with the tools of nuclear physics. In this frame hadron-nucleus collisions are investigated. In fact it is an almost unique tool, for example, to select states with specific quantum numbers. Pure isospin states and diffractive features of inclusive production have been investigated at very high energies following this approach [1]).

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Moreover, new experimental evidence 2) and theoretical predictions 3) of the existence of baryonic exotic states induce careful measurements to look for small effects.

Our study of the process

$$\alpha p \rightarrow \alpha x,$$

which selects a pure isospin state $I = \frac{1}{2}$ for the x-system, performed at medium energy, in the region of low produced masses, fits in all these domains.

An α-beam of 3×10^{10} α/pulse extracted from the synchrotron "Saturne" was focused as a 1 cm high by 2 cm wide spot on a liquid hydrogen target 5.9 cm thick. The position and shape of the incident beam were controlled by three wire chambers, and monitored by two counter telescopes: one looking at a thin target upstream from the hydrogen target, the other directly at this target. Their relative stability was within ± 1%. These monitors were calibrated by irradiation of graphite discs, using the $^{12}C(\alpha, x)^{11}C$ reaction; the cross section of this process has been measured in the same energy range 4). The use of an α-beam makes the scattered α's leave the target at high energy, so that their unambiguous identification ensures the coherence of the reaction. The outgoing α-particles were analyzed by a double focusing spectrometer, dispersing at the intermediate image and achromatic at the final image. The whole spectrometer was in vacuum. A set of five contiguous scintillation counters (1 mm thick) at the intermediate image, which selected five momentum bins with 1% FWHM resolution, and three successive scintillation counters (4 mm thick), at the

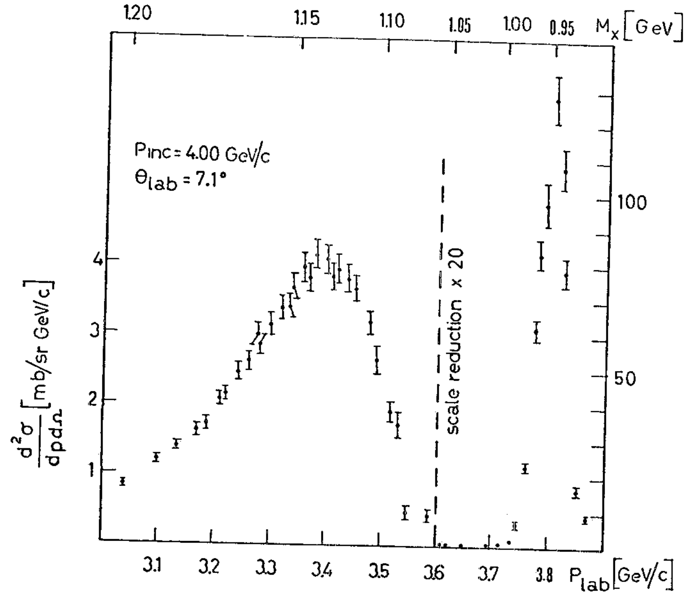

Fig. 1. Typical laboratory momentum spectrum of α-particles observed from αp collisions. The upper scale indicates the missing mass. The angular resolution is ±0.3°.

final image 14 m distant, provided the identification of the particles, both by the time-of-flight method and by pulse height analysis in plastic scintillators. Further details of the apparatus have been published elsewhere [5]).

We have performed measurements at incident beam momentum of 4.00 GeV/c for fixed $\theta_{\rm lab}$ values of 4.1°, 5.1°, 5.6°, 6.1°, 7.1°, 8.1° and at an incident beam momentum of 5.08 GeV/c for $\theta_{\rm lab}$ 4.6°, 5.6°, 6.6°, 7.1°. Data were corrected for empty target background, nuclear absorption and spectrometer efficiency. A typical experimental spectrum is shown in fig. 1. The peak centered at 3.81 GeV/c corresponds to elastic αp scattering. The second structure, centered at ~3.4 GeV/c, shows the signal of the coherent one-pion production. The bulk of our experimental data in the inelastic region are presented in figs. 2 and 3. The threshold enhancement, when the inelastic channel opens, is peaked around an invariant mass of

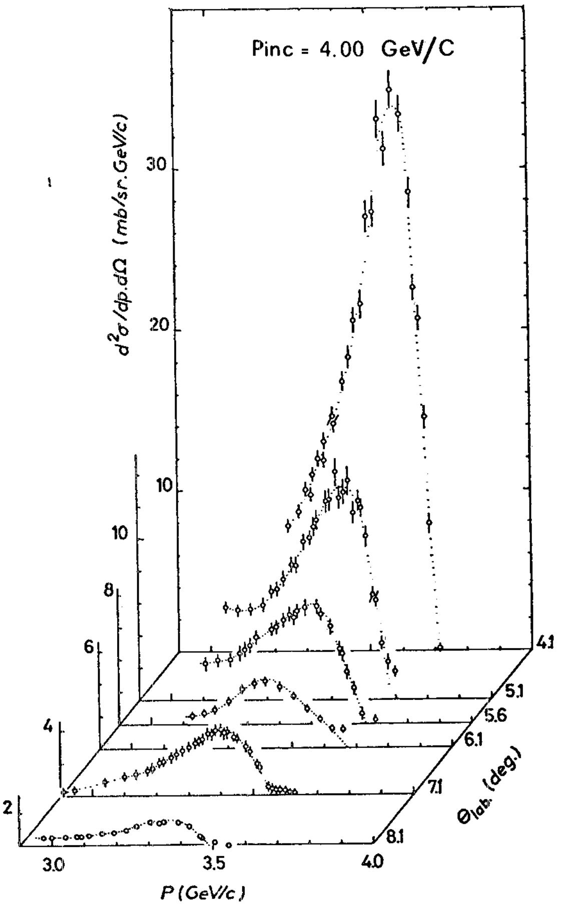

Fig. 2. Momentum spectra of α-particles observed at various angles, with a 4.00 GeV/c incident momentum beam. The dotted lines on each spectrum are drawn to guide eye. Quoted errors are statistical only. A systematic error ±5% due to normalization uncertainties must be added.

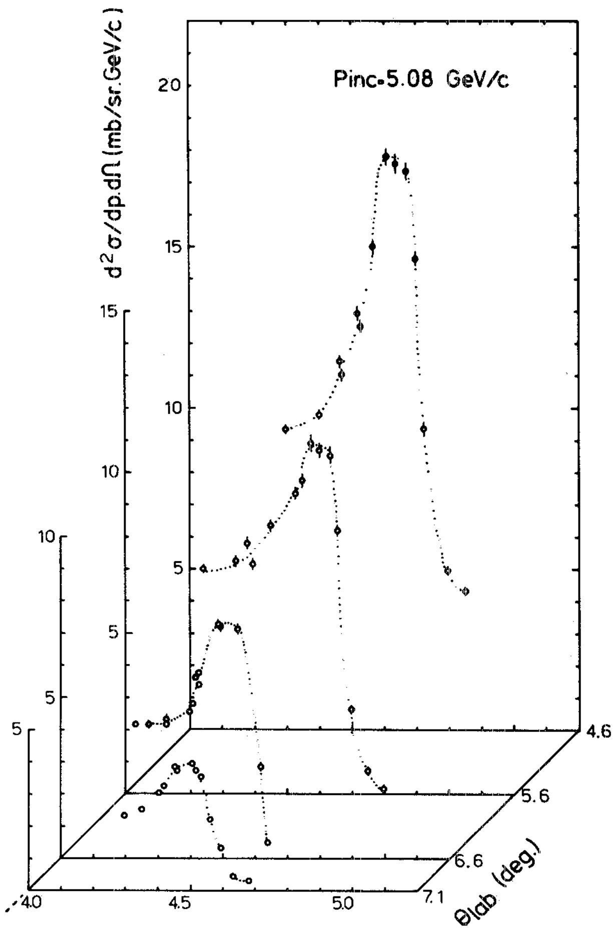

Fig. 3. Momentum spectra of α-particles observed at various angles, with a 5.08 GeV/c incident momentum beam. The dotted lines on each spectrum are drawn to guide eye. Quoted errors are statistical only. A systematic error ±5% due to normalization uncertainties must be added.

1130 MeV/c^2 and is 80 MeV/c^2 wide, independently of the angles. The differential cross section $d^2\sigma/dt\, dM^2$ versus t at fixed values for the mass of the πN system is shown in fig. 4. No apparent energy dependence, at fixed mass, emerges from data at 4.00 and 5.08 GeV/c. The cross section for fixed mass values, at small $|t|$ can be represented by an exponential function of the kind $d^2\sigma/dt\, dM^2 \approx \exp(bt)$. The slope parameter varies linearly between 19 and 9 $(\text{GeV}/c)^{-2}$, when the squared mass ranges from 1.21 to 1.44 GeV^2. At larger $|t|$ a flatter distribution breaks this slope. This last feature is more evident for low masses and becomes less pronounced when one moves away from the peak value. These trends bring to mind the typical behaviour of the inclusive diffractive experiments performed at higher energies [6].

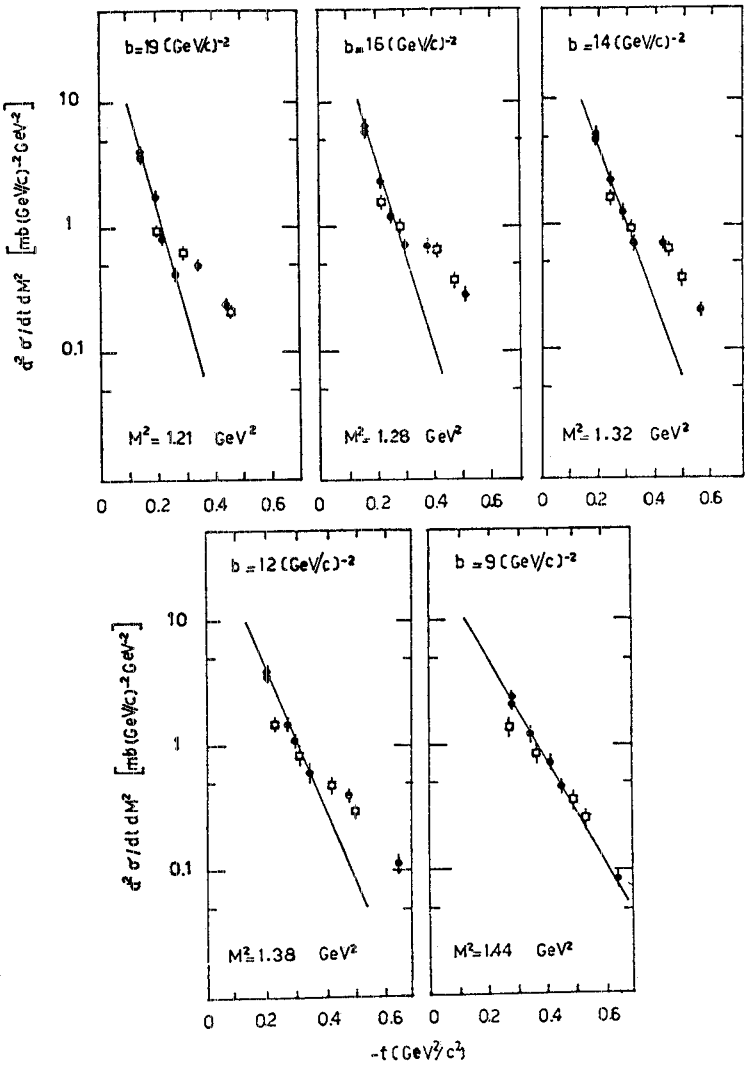

Fig. 4. $d^2\sigma/dtdM^2$ versus t for fixed values of M^2. The mass resolution varies for each mass according to the momentum resolution of ±0.5%. Values range from ±1% to ±1.5%, with decreasing masses. Data at 4.00 GeV/c (circles) and at 5.08 GeV/c (squares) are plotted together. Only data at 4.00 GeV/c have been used in fitting exponential slopes.

In conclusion the patterns of the reaction studied in this experiment are the following:

(i) The production of low πN masses is favoured, appearing as a pronounced bump at $M = 1130$ MeV/c^2 with $\Gamma = 80$ MeV/c^2.

(ii) The cross section is strongly peaked forward and decreases rapidly with $|t|$.

(iii) The shape of the enhancement and the value of the cross section are seemingly independent of energy.

(iv) A strong mass-slope correlation is evident.

A similar enhancement ($M_x = 1150\,\mathrm{MeV}/c^2$, $\Gamma = 120\,\mathrm{MeV}/c^2$) in the process $\mathrm{dp} \rightarrow \mathrm{dX}$, which also selects $I_x = \frac{1}{2}$, has already been observed by us in an earlier experiment [7]).

Possible diagrams to explain the observed features of these processes are shown in fig. 5. They represent the much talked about diffractive dissociation [6]). At the moderate energy and small four-momentum transfer of these experiments the Deck-like mechanism [8]) through the exchange of a pion should dominate. In fact in the dp interaction the enhancement has been explained [9]) as an effect of a Δ-excitation inside the deuteron by one-pion exchange. In this way a $\mathrm{d}\pi$ enhancement is produced close to the $\mathrm{N}\Delta$ mass; it reflects as a bump in the $\mathrm{N}\pi$ system and the absolute value of the cross section is very well predicted.

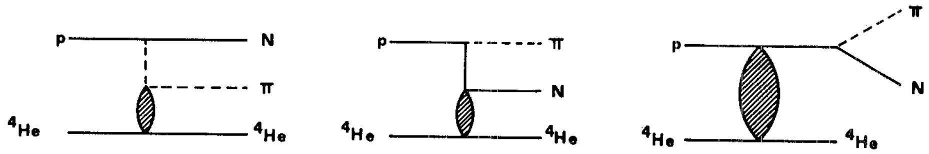

Fig. 5. Graphs contributing to diffraction dissociation.

A straightforward application [10]) of the same mechanism to αp data using a gaussian form factor [11]) is unlikely, since it provides roughly half the experimental cross section.

Other destructive mechanisms, relevant in heavier nuclei interactions, or multiple scattering effects of the ingoing and outgoing particles, not taken into account in the above mentioned estimation, are requested to explain such a discrepancy.

Experimental investigation of coherent production of heavier nuclei could provide further indications about Deck-like nuclear effects and their energy behaviour. It is also of interest to extend these measurements to higher effective mass to cover the region of the known excited states of the nucleon.

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