Laboratori Nazionali di Frascati

LNF-73/58

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HIGH-ENERGY COHERENT INTERACTION OF DEUTERONS ON PROTONS

Phys. Letters 45B, 535 (1973).

HIGH-ENERGY COHERENT INTERACTION OF DEUTERONS ON PROTONS

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Received 18 June 1973

The reaction $dp \to d + (mm)$ has been performed with the aim of studying coherent interactions. The produced missing mass (mm) is in a pure isospin state $T = \frac{1}{2}$. We observe a significant inelastic coherent production at small transfer, decreasing with momentum transfer in a fashion similar to elastic scattering.

We present in this paper the results of an experiment on the coherent interactions of deuterons with hydrogen that has been performed with the extracted deuteron beam from the Saclay synchrotron "Saturne". The reaction studied is:

$$d + p \to d + (mm) \qquad (1)$$

A number of experimental and theoretical efforts [1] have been recently made in the study of coherent interactions between hadrons and nuclei.

This type of phenomena is in fact very interesting because it provides information on nuclear structure parameters, (e.g. nuclear radii and shape parameters), short range correlations, distribution of nucleons in target nuclei and scattering amplitudes of unstable states.

Moreover, coherent production selection rules isolate systems with particular quantum numbers. We notice that in the reaction we are studying (1) the missing mass (mm) is in a state with isospin $T = \frac{1}{2}$, so this process can be a way to investigate an N^* resonance.

Many experiments have been performed on pd elastic scattering, but only one [2] on the coherent inelastic pd interaction: it was studied with a deuterium bubble chamber the $pd \to pd + 2\pi$ process.

In counters experiment in fact, when a proton beam is used with a deuterium target, the elastic scattering can be detected without ambiguity, while the inelastic coherent process cannot generally be separated from the incoherent one at small four-momentum transfers, because deuterons cannot be easily detected. In our experiment the use of an incident deuteron beam resolves the problem, since the deuteron which interacts coherently with the proton target is scattered at low momentum transfer with momentum approaching its initial value.

We have measured the momentum spectra of the deuterons scattered by hydrogen at laboratory angles of 4.6-7.4 and 10.2 degrees, with a 2.95 GeV/c incident beam of deuterons. The spectra range from deuteron momenta of about 1300 MeV/c to that of the forward elastic peak, and the square of the four-momentum transfer ranges from 6×10^{-2} to $1 (\mathrm{GeV}/c)^2$. A few portions of the coherent inelastic region have also been explored for 3.48 and 3.41 GeV/c incident deuterons at laboratory angles of 2.8 and 4.6 degrees respectively.

The experimental apparatus shown on fig. 1 is basically the same that we have previously used in the study of d-d interactions [3]. The beam transport system focuses $(1.0 \div 1.5) \times 10^{11}$ deuterons/pulse on a liquid hydrogen target of 60 mm thickness. We have used three monitors: two counter telescopes M_0 and M_1 and a secondary emission chamber, which have always been in agreement with each other within ±1%.

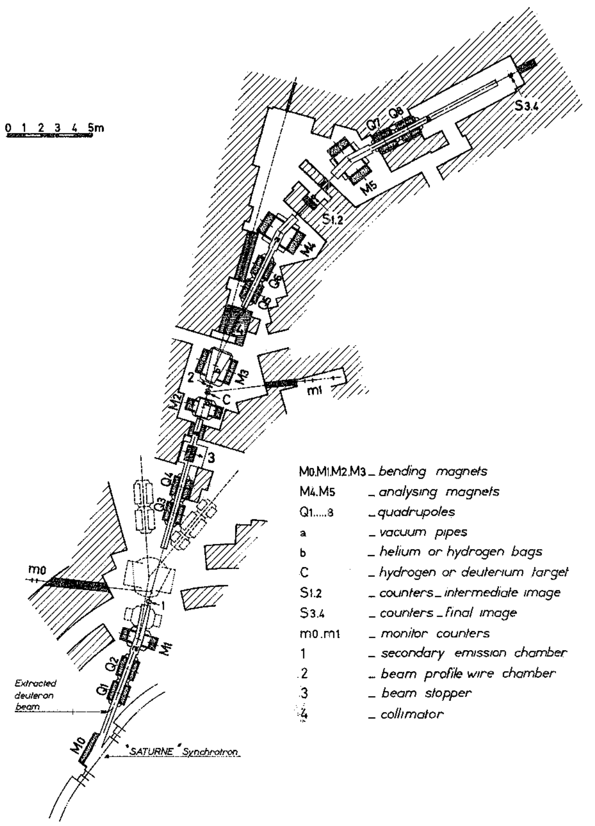

Fig. 1. Schematic diagram of the experimental area and apparatus.

The absolute monitoring is obtained by activation of a thin carbon target through the reaction $C^{12}(d, p2n)C^{11}$. The cross section of this reaction has been extrapolated from the value measured with 3.76 GeV/c incident deuterons [4] by assuming the same energy dependence as for the $C^{12}(p, pn)C^{11}$ cross section. With this method the absolute monitoring is within ±10%. The momentum of the incident deuterons is determined within ±0.5% by measuring the momentum spectrum of protons produced by the stripping of the incident deuterons in the target. The deuterons scattered from the liquid hydrogen target are analysed in momentum by a double focusing magnetic spectrometer. The absolute error for the laboratory angle of the detected deuteron is ±0.3 degrees. The momentum calibration of the analysing spectrometer is achieved both by means of two body reactions and by Cu-range method [5]: the resulting momentum precision of the detected particles is ±0.5%. In the present experiment the position of the elastic peaks is in agreement with the spectrometer calibration.

Two pairs of scintillation counters, S_1S_2 at the intermediate spectrometer's image and S_3S_4 at the final image (14 meters apart), allow the identification of particles both by the time of flight method and by pulse height analysis in plastic scintillators. The solid angle of the apparatus is 5.3×10^{-5} steradian. The spectrometer acceptance is calculated by a Monte Carlo program which takes into account the multiple scattering and the energy loss of deuterons, in their path from the production target to the final counters.

In fig. 2 we show the momentum spectra of deuterons scattered at various angles for different energies of the incident deuterons, with the corresponding missing mass scale. The data are corrected for empty target background, nuclear absorption and spectrometer efficiency.

On the three spectra for 2.95 GeV/c incident deuterons, the peaks at 2.91-2.84 and 2.77 GeV/c of scattered deuterons correspond to the dp elastic scattering. The width of the peaks is in agreement with the experimental resolution of our apparatus. The values of the elastic cross section, obtained by integrating under the peaks, are plotted in fig. 3 versus the squared four-momentum transfer. The data can be fitted by an exponential function $f = A \exp(-\beta t)$ with $\beta = 21(\mathrm{GeV}/c)^{-2}$.

The same spectra show also two peaks with an inelasticity ($\Delta p = P_{\mathrm{elastic}} - P_{\mathrm{detected}}$) of $\Delta p \approx 300$ MeV/c and $\Delta p \approx 1300$ MeV/c, respectively. The produced missing mass is necessarily in a pure $T = 1/2$ state, due to isospin conservation: this forbids the production of the $\Delta(1236, T = 3/2)$ resonance.

The structure observed around the inelasticity $\Delta p \approx 1300$ MeV/c in the spectra with $P_{\mathrm{inc}} = 2.95$ GeV/c, corresponds to a missing mass between 1370 and 1450 MeV/c^2 and has a width of ≈ 20 MeV/c^2. Integration under the peak yields a cross section which is $2 \div 3\%$ of the elastic one at 4.6 degrees, and this cross section does not decrease by increasing the momentum transfer. In this missing mass region (N^* region) bumps have been observed in various production experiments [6] with a width varying between 100 and 200 MeV/c^2, which is possibly connected to the P_{11} resonance. In our experiment, however, it is easier to explain the observed structure in the impulse approximation by the reaction:

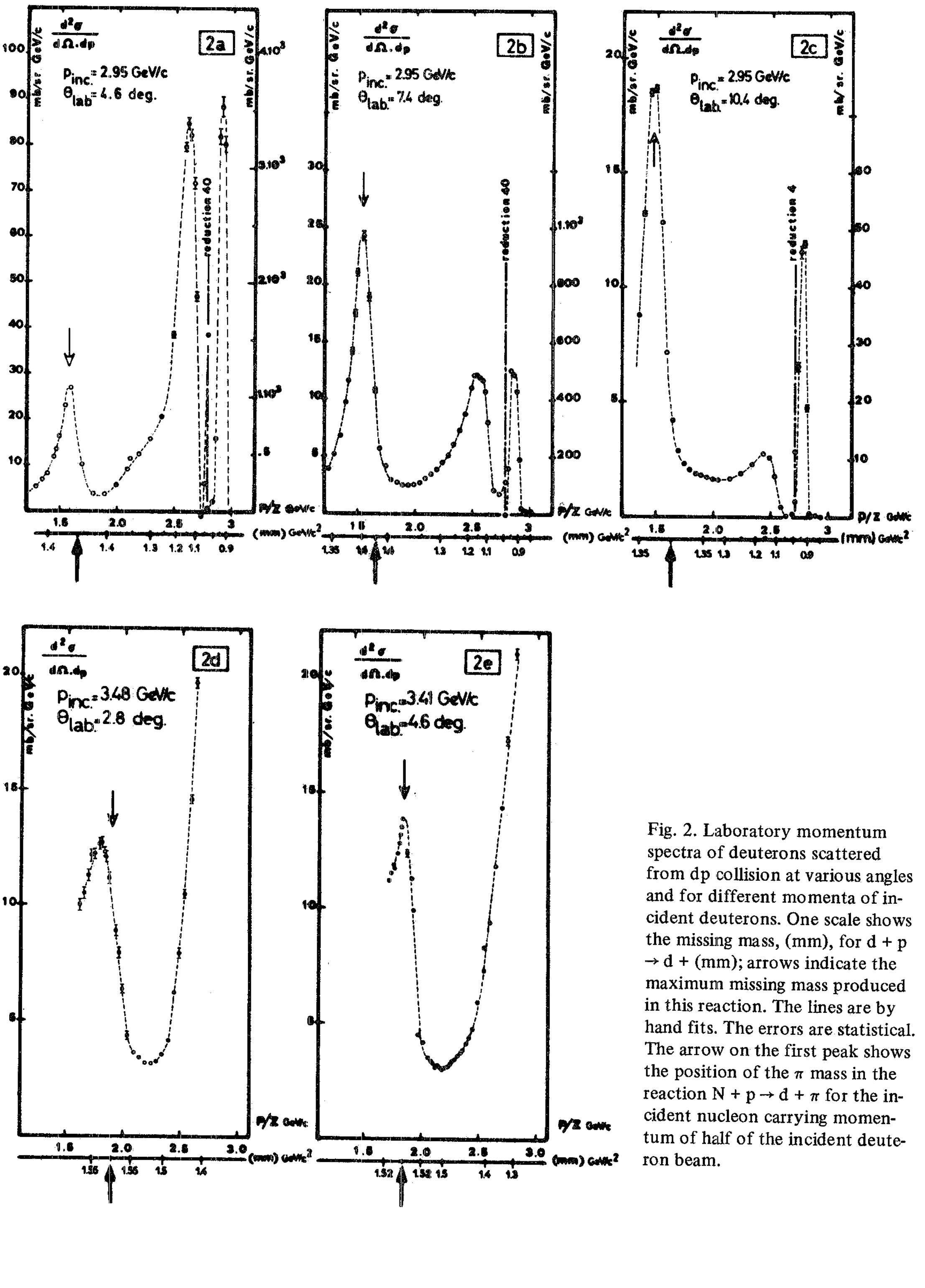

Fig. 2. Laboratory momentum spectra of deuterons scattered from dp collision at various angles and for different momenta of incident deuterons. One scale shows the missing mass, (mm), for d + p → d + (mm); arrows indicate the maximum missing mass produced in this reaction. The lines are by hand fits. The errors are statistical. The arrow on the first peak shows the position of the π mass in the reaction N + p → d + π for the incident nucleon carrying momentum of half of the incident deuteron beam.

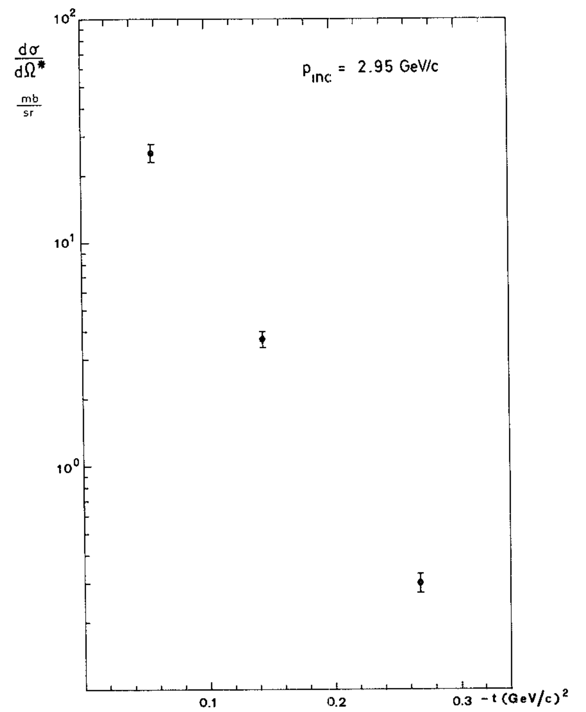

Fig. 3. The dp elastic differential cross section at 2.95 GeV/c incident deuteron beam.

$$(N_s + N) + p \rightarrow d + (mm) + N_s \qquad (2)$$

where N_s is the nucleon spectator. Neglecting the effect of the Fermi motion this reaction can be related to the elementary process

$$N + p \rightarrow d + (mm) \qquad (3)$$

with an incident nucleon carrying the half part of the incident deuteron momentum. With this assumption the momentum of the deuterons analysed in the region of the structure corresponds then to the missing mass of the pion.

Additional measurements carried out with 3.41 GeV/c (fig. 2e) and 3.48 GeV/c (fig. 2d) incident deuterons show that, in the hypothesis of a baryon missing mass, the peak moves to 1555 MeV/c^2, while it remains centered on the pion mass in the kinematics of the process (3). Moreover these measurements show no structure in the N^* region of missing mass.

We consider now the peaks at the inelasticity $\Delta p \approx 300$ MeV/c shown in the spectra with 2.95 GeV/c incident deuterons. The structure observed is centered at a missing mass of 1150 MeV/c^2, and this

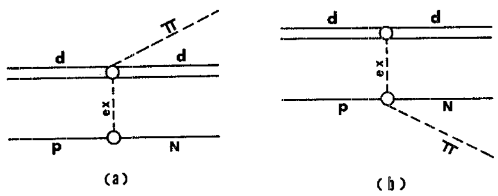

Fig. 4. Two graphs expected to contribute to the coherent production at small t.

position does not change by varying the detection angle. The differential cross section of this structure decreases in a manner similar to that of the elastic peak from 4.6 to 7.4 degrees. At 10.2 degrees this comparison is less clear, because the continuum contribution becomes more important.

Baryon resonances with a mass value around 1150 MeV/c^2 and in isospin state $T = 1/2$ have not been observed. Moreover, in this kinematical region, contributions from a process like (2) are not expected. By the other hand, the coherent one pion production in the reaction

$$d + p \rightarrow d + N + \pi \qquad (4)$$

at low momentum transfer, when the deuteron interacts as a whole with the proton target, can contribute, essentially through graphs such as those plotted in fig. 4. The most important contribution is probably due to the graph (a) where the exchange of a pion is permitted. Moreover, in the aim of the impulse approximation an intermediate Δ, whose proton is reabsorbed, can occur in the upper vertex of this graph. A detailed estimation of the graph (a) contribution is in progress.

Additional results, especially in coherent production regions of lower squared momentum transfer will be useful for a better comprehension of the involved mechanism.

We are much indebted to Dr. T. Risser for his participation in the first part of the experiment, to Dr. R. Baldini-Celio, Prof. L. Bertocchi and Prof. C. Wilkin for numerous fruitful discussions held on this subject-matter. We thank all the Saturne crews in Saclay for providing us with an excellent deuteron beam, and all the staff who helped us in setting up experimental apparatus.

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