COMITATO NAZIONALE PER L'ENERGIA NUCLEARE
Laboratori Nazionali di Frascati

LNF-73/17
9 Maggio 1973

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J. Banaigs[(x)], J. Berger[(x)], M. Cottereau[(+)], F.L. Fabbri, L. Goldzahl[(x)], L. Vu Hai[(x)], C. Le Brun[(+)] and P. Picozza: HIGH-ENERGY COHERENT INTERACTION OF DEUTERONS ON PROTONS. -

ABSTRACT. -

The reaction $dp \rightarrow d + (mm)$ 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.

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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:

(1) $$d + p \rightarrow d + (mm)$$

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

Only one experiment[(2)] has been performed on the coherent inelastic p-d interaction: it studied with a deuterium buble chamber the $pd \rightarrow pd + 2\pi$ process.

From the experimental point of view, 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 a momentum approaching its initial one.

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 $(GeV/c)^2$. 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 figure 1 is basically the same one that we have previously used in the study of d-d interactions[3]. The beam transport system focuses $(1.0 \div 1.5) 10^{11}$ deuterons/pulse on a liquid hydrogen target of 60 mm thickness. We have used three monitors: two counter telescopes M_o and M_1 and a secondary emission chamber, which have always been in agreement with each other within $\pm$ 1%. 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 $\pm$ 10%. The momentum of the incident deuterons is determined within $\pm$ 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 $\pm$ 0.3 degrees. The momentum calibration of the analysing spectrometer is achieved both by means of two body reactions and by the Cu-range method in our previous experiments[5]: the resulting momentum precision of the detected particles is $\pm$ 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

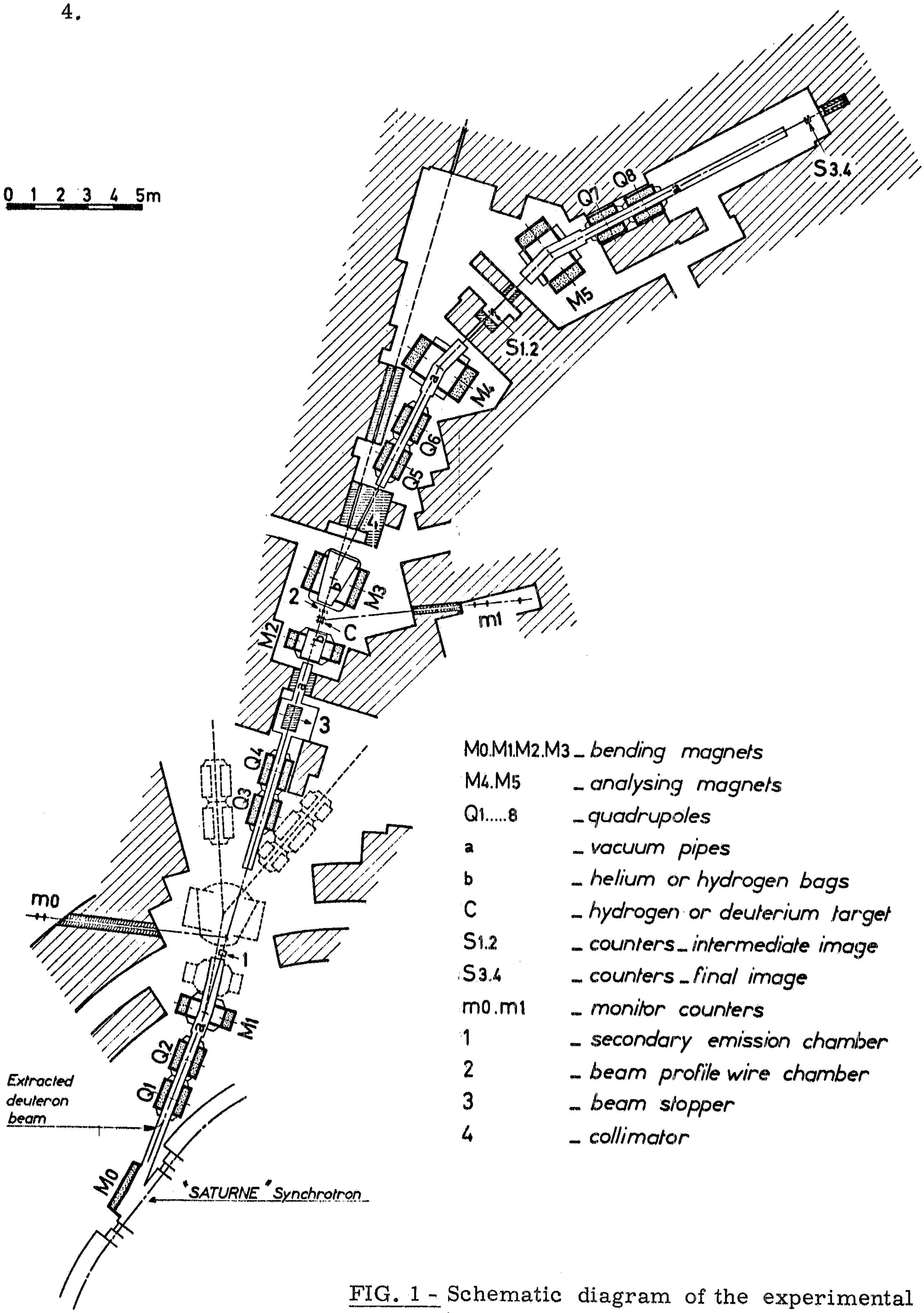


FIG. 1 - Schematic diagram of the experimental area and apparatus.

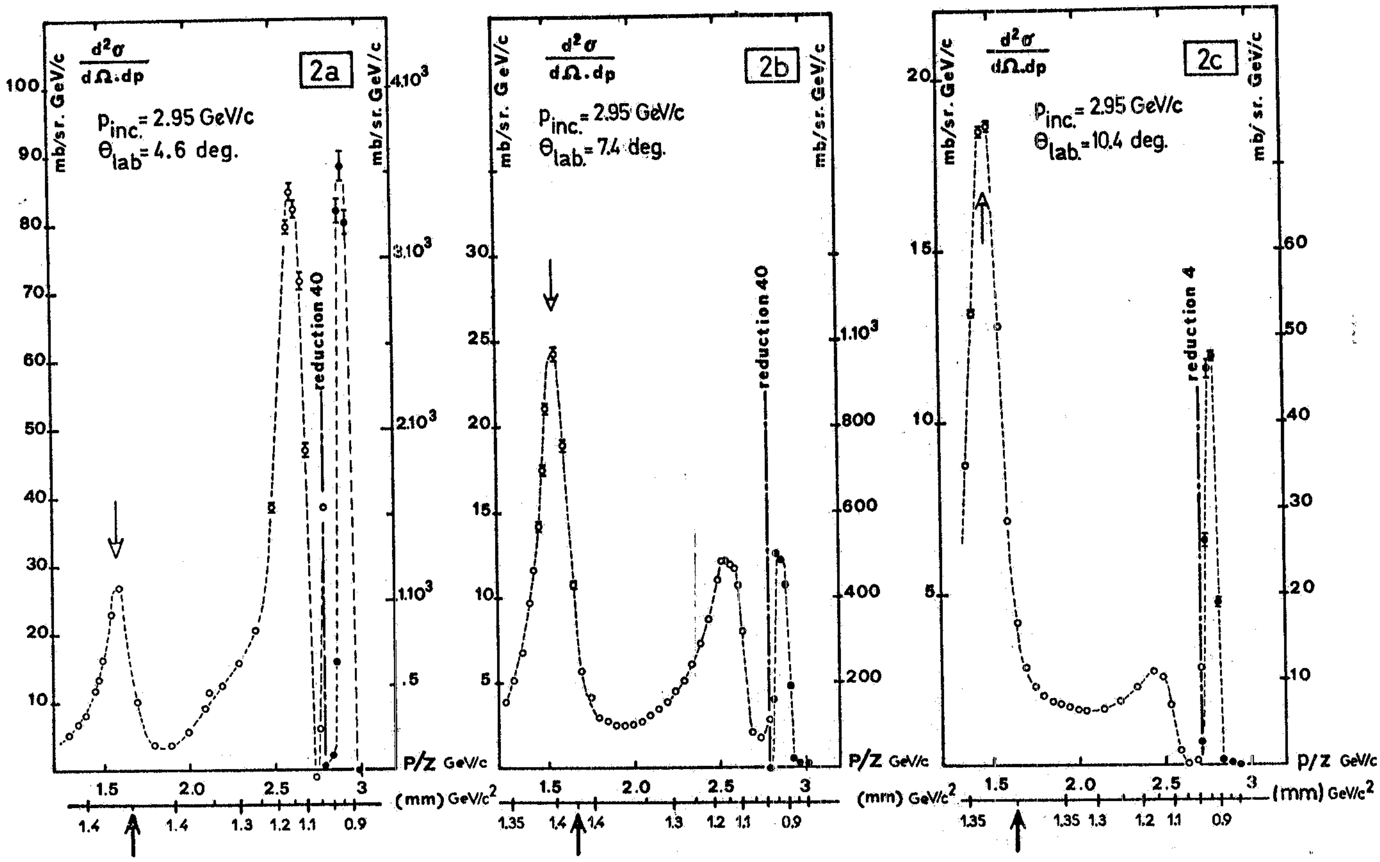
and by pulse height analysis in plastic scintillators. The solid angle of the apparatus is $5.3\,10^{-5}$ steradians. The spectrometer acceptance is calculated by a Monte Carlo program which takes into account the multiple scattering and the energy loss of deuterons, in their path from the production target to the final counters.

In figure 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 d-p 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 figure 3 versus the squared four-momentum transfer. The data can be fitted by an exponential function $f = Ae^{-\beta t}$ with $\beta = 21\,(GeV/c)^{-2}$.

The same spectra show also two peaks with an inelasticity ($\Delta p = P_{elastic} - P_{detected}$) of $\Delta p \simeq 300$ MeV/c and $\Delta p \simeq 1300$ 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 Δ (1236, $T = 3/2$) resonance.

The structure observed around the inelasticity $\Delta p \simeq 1300$ MeV/c in the spectra with $P_{inc} = 2.95$ MeV/c, corresponds to a missing mass between 1370 and 1450 MeV and has a width of $\simeq$ 20 MeV. Integration under the peak yelds 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



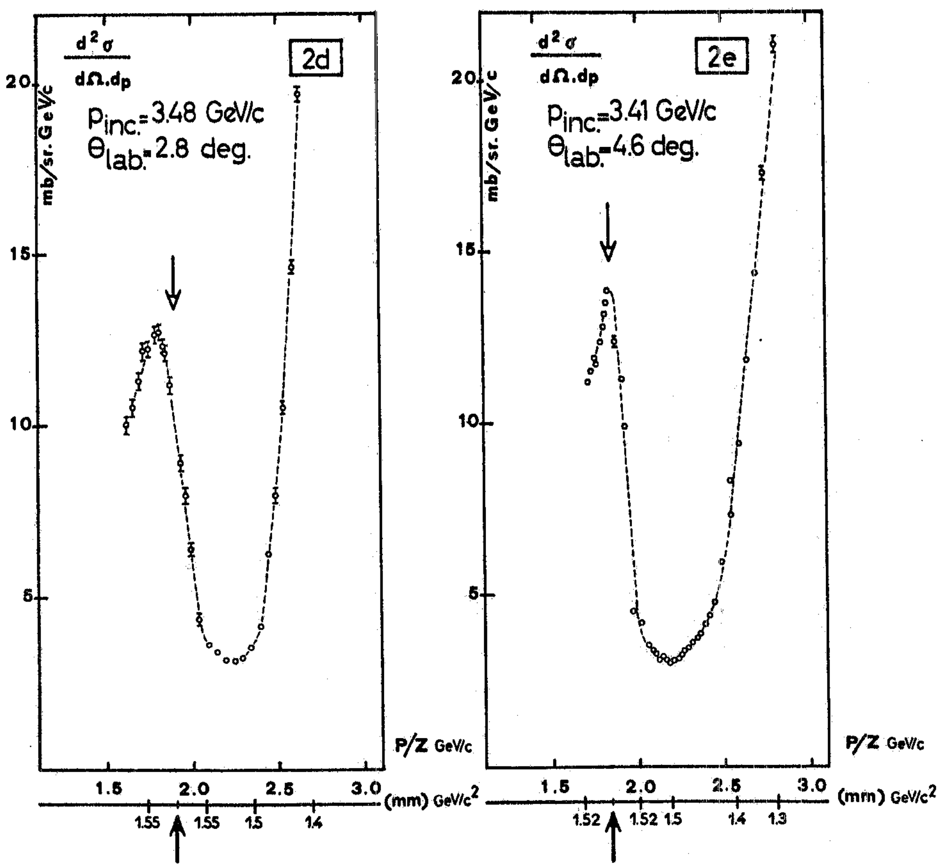


FIG. 2 - Laboratory momentum spectra of deuterons scattered from dp collision at various angles and for different momenta of incident deuterons. One scale shows the missing mass, (mm), for d+p → d+(mm); arrows indicate the maximum missing mass produced in this reaction. The lines are by hand fits. The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

mass region (N^* region) bumps have been observed in various production experiments[6] with a width varying between 100 and 200 MeV, 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:

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

Neglecting the effect of the Fermi motion this reaction can be related to the elementary process

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

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

Additional measurements carried out with 3.41 GeV/c (Fig. 2c) and 3.48 GeV/c (Fig. 2d) incident deuterons shows that, in the hypothesis of a baryon missing mass, the peak moves to 1555 MeV 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 $\Delta p \simeq 300$ 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, and this position does not change by varying the detection angle. This production can be due only to the coherent interaction. 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.

Figure 4 shows two graphs expected to contribute to the one pion coherent production at small squared four momentum transfer. The most important contribution is probably due to the graph(a) where the exchange of a pion is permitted. From this point of view it may be noticed that in the upper vertex of this graph an intermediate Δ, whose proton is reabsorbed, can occur.(7). In the other graph the pion production is due to the process $d + p \rightarrow p + (N + \pi)$ with the $(N\pi)$ system necessarily in the pure state $T = 1/2$.

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.

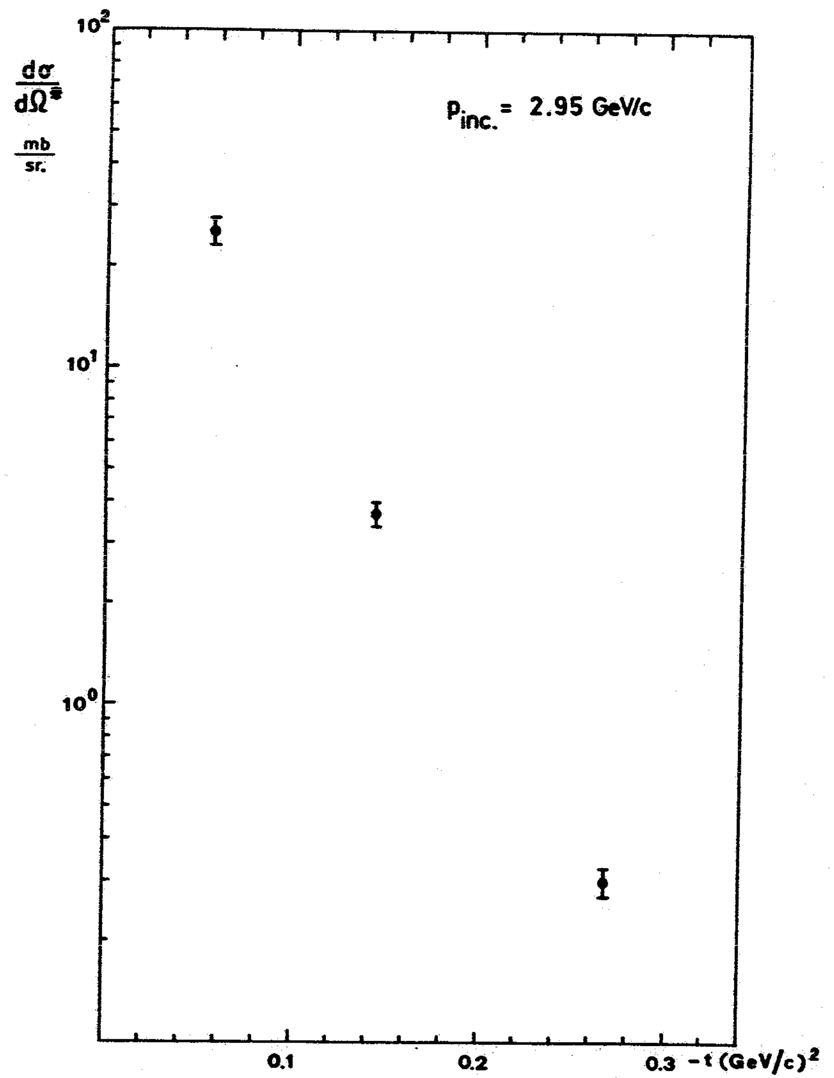


FIG. 3 - The dp elastic differential cross section at 2.95 GeV/c incident deuteron beam.

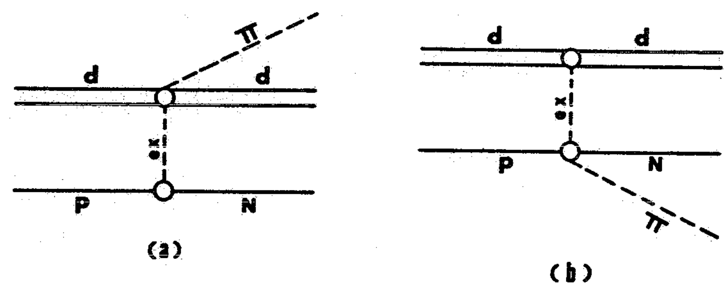


FIG. 4 - Two graphs expected to contribute to the coherent production at small t. In graph (a) the simplest particle exchange is π-exchange, in graph (b) is ω-exchange.

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