ISTITUTO NAZIONALE FISICA NUCLEARE

INFN/AE - 83/5
1 agosto 1983

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PROTON-PROTON ELASTIC SCATTERING BETWEEN 700 AND 2400 MeV WITH THE SATURNE POLARIZED PROTON BEAM

SERVIZIO RIPRODUZIONE DELLA
SEZIONE DI TRIESTE DELL'INFN

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WITH THE SATURNE POLARIZED PROTON BEAM(+)

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(+) Submitted to the Conference on Nuclear Structure and Particle Physics, University of Liverpool, 23-25 March 1983.

ABSTRACT

We have studied the elastic proton-proton scattering in the Coulomb-Nuclear interference region using the polarized proton beam available at Saturne II, Saclay. The experimental set-up consists of two telescopes of MWPCs, scintillator counters and a sensitive target made of thin slabs of plastic scintillator, orthogonal to the incoming beam.

The events due to the elastic scattering on the Hydrogen present in the target are identified correlating the forward scattering angle and the pulse amplitude in the scintillator where the interaction has taken place.

We collected data between 700 and 2400 MeV and present results on the reaction analysing power.

The measurement of hadron-hadron elastic scattering in the Coulomb-Nuclear interference region ($/t/\sim 0.005$ GeV^2) is a powerful method to obtain direct information on the nuclear amplitudes through their interference with the well-known electromagnetic ones. A typical example is given by the information available measuring the differential cross-section $d\sigma/dt$: for the pp elastic scattering, referring to the standard form of the scattering matrix given in the appendix, the measurement of the interference effects in $d\sigma/dt$ provides us with the knowledge of the ratio of Re $(a_N + b_N)$ and Im $(a_N + b_N)$ at small angles. Similarly, the interference effect in the polarization parameter P depends on two nuclear scattering amplitudes: a_N and e_N; these amplitudes can be obtained from the angular dependcnce of P at small scattering angle[1].

To measure P in elastic pp scattering at low t it is necessary to combine the specific requirements of a polarization measurement (use of a polarized beam or target or realization of a double scattering experiment) and the difficulties to constrain an exclusive reaction at small scattering angle (the recoil is slow and, in general, cannot escape from the target volume and the momentum of the forward scattered particle is very close to that of the projectile).

The existing measurements on P at energies $\gtrsim$ 800 MeV and small scattering angles are based on the following methods:

(i) detection of the forward scattered proton only and measurement of its momentum by a severe magnetic analysis in double scattering experiments (low rates)[2] or employing polarized beams[3,4]

(ii) detection of both the outgoing protons, using very thin targets, to allow the low recoling proton to escape from the target (low rates)[5].

However at energies > 800 MeV and $/t/ < 0.01$ GeV^2, there are no measurements of the P parameter (see fig. 1). The polarized proton beam of the Saturne II synchrotron (Saclay) with an energy up to 3000 MeV offers an unique facility to perform these measurements. We have therefore proposed[6] to study the polarization parameter of the pp elastic scattering in the Coulomb-Nuclear interference region between 800 and 3000 MeV at the Saturne II synchrotron with a simple apparatus (see fig.2) adequate to explore the whole available energy range.

The experimental method[7] is based on the measurement of the forward scattering angle with two telescopes of MWPCs and of the energy of the recoiling proton with a proton active target consisting of a telescope of 12 thin slabs of plastic NE-102 scintillator (Multiscintillator Target). The kinetic energy of the recoil, stopping in one of the scintillator slabs, is obtained from the pulse amplitude of the counter. The thickness of the scintillator counter is choosen to minimize the amount of energy released by the relativistic through-going protons while keeping a good efficiency in stopping the recoils.

The main interactions in the target are due to the elastic scattering on the Carbon nuclei present in the scintillator material, but these events can be rejected at the trigger level as the kinetic energy of a recoiling C nucleus is much lower than that of a proton recoil at the same momentum transfer. Other reactions on C nuclei produce a broad background that must be subtracted under the signal peak.

Skew tracks accompanied by fluctuations of the energy released by the relativistic through-going protons in the target are undistinguishable from pp elastic events for a simple counter trigger and would saturate the computer acquisition system (acquisition dead time: 2-3 msec/event). To reject these spurious triggers we have used, at the trigger level, a second level on-line filter evaluating, with a fast processor (ESOP (8)), the scattering angle θ from the track coordinates measured by the MWPCs and rejecting events when θ is smaller than a choosen threshold (decision dead time: < 100 μsec/event).

Table 1 shows the statistics of the data collected at various energies. The content of the fourth column indicates that the ratio between pp elastic events and the collected triggers is raised by a factor $\sim$10 when we employ tha fast second level decision filter.

The data reduction is in progress. Fig. 3 (a,b,c) shows preliminary results on the polarization parameter of the reaction $pp \to pp$ at three different energies of the incoming beam: 825, 1000, 1320 MeV. Data are compared with the prediction of the Saclay phase shift analysis[9] and the experimental results obtained by Pauletta et al.[4] at 800 MeV, the highest energy at which there are data on P in the Coulomb-Nuclear interference region.

AKNOWLEDGEMENTS

We wish to thank all the members of the Nucleon-Nucleon Collaboration for their encouragement and help.

The hospitality of the Laboratoire National Saturne and the assistance of the Saturne synchrotron staff is greately appreciated.

APPENDIX - pp elastic scattering matrix (10)

C. M. kinematical variables:

$\vec{k}_i$ - momentum of the incoming proton

$\vec{k}_f$ - momentum of the outgoing proton

$\vec{\sigma}_{1,2}$ - spin vector operators on the first and second nucleon wave function

coordinate system:

$$\vec{l} = (\vec{k}_f+\vec{k}_i)/|\vec{k}_f+\vec{k}_i|$$
$$\vec{m} = (\vec{k}_f-\vec{k}_i)/|\vec{k}_f-\vec{k}_i|$$
$$\vec{n} = (\vec{k}_f\times\vec{k}_i)/|\vec{k}_f\times\vec{k}_i|$$

scattering matrix:

$$\begin{aligned} M=(a+b) &+ (a-b)(\vec{\sigma}_1\cdot\vec{n})(\vec{\sigma}_2\cdot\vec{n})+ \\ &+ (c+d)(\vec{\sigma}_1\cdot\vec{m})(\vec{\sigma}_2\cdot\vec{m})+ \\ &+ (c-d)(\vec{\sigma}_1\cdot\vec{l})(\vec{\sigma}_2\cdot\vec{l})+ \\ &+ e(\vec{\sigma}_1+\vec{\sigma}_2)\cdot\vec{n} \end{aligned}$$

where each amplitude a,b,c,d,e is the sum of a nuclear term (subscript N in the text) and an electromagnetic one.

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beam kinetic energy (MeV)	running time (hours)	decision filter at trigger level	number of collected events	percentige of pp elastic events in the collected samples
765	20	YES	2.2×10^6	not yet analysed
825	32	NO	2.8×10^6	0.3
875	68	NO	5.3×10^6	not yet analysed
940	55	YES	4.3×10^6	not yet analysed
975	29	NO	1.0×10^6	not yet analysed
1000	72	YES	6.0×10^6	3.0
1320	50	YES	3.8×10^6	3.0
2400	45	YES	2.7×10^6	not yet analysed

TABLE 1. - Statistics of the collected data.

FIGURE CAPTIONS

Fig. 1 - Plot of the kinematical points at which the polarization parameter of the pp elastic scattering has been measured in the (beam kinetic energy, momentum transfer) plane ($/t/< 0.5$ GeV^2, $300<T<3000$ MeV).

Fig. 2 - The experimental set-up.

T1, T2,.... T12 - target scintillator counters

PC1, PC2, PC3 - first telescope of MWPCs

PC4, PC5, PC6 - second telescope of MWPCs

F1, F2, F3, F4 - beam defining counters

S, L, F7 - trigger counters.

Fig. 3 - Preliminary results on the polarization parameter of the pp elastic scattering (dots) compared with data at 800 MeV from ref. 4 (squares) and the prediction of the Saclay phase shift analysis (solid line) (9).

a) beam energy: 825 MeV; phase shift calculation at 850 MeV.

b) beam energy: 1000 MeV; phase shift calculation at 1000 MeV.

c) beam energy: 1320 MeV; phase shift calculation at 1320 MeV.

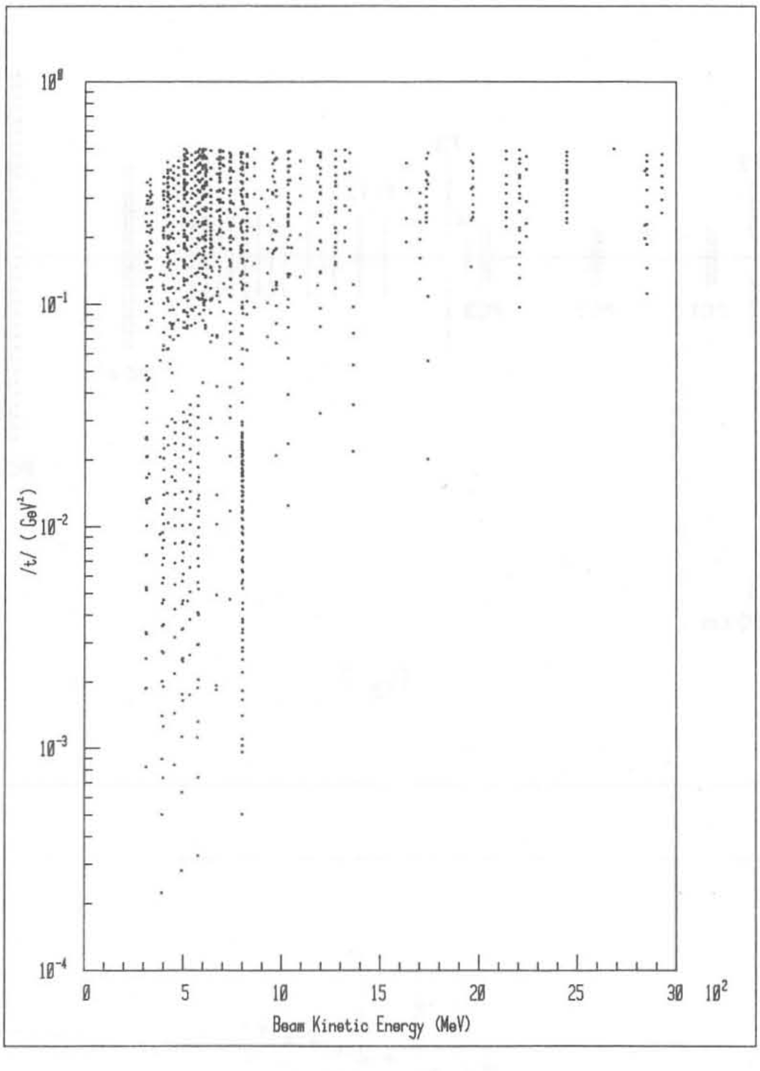
10^0
10^-1
10^-2
10^-3
10^-4
/t/ (GeV²)
0
5
10
15
20
25
30
10²
Beam Kinetic Energy (MeV)

Fig. 1

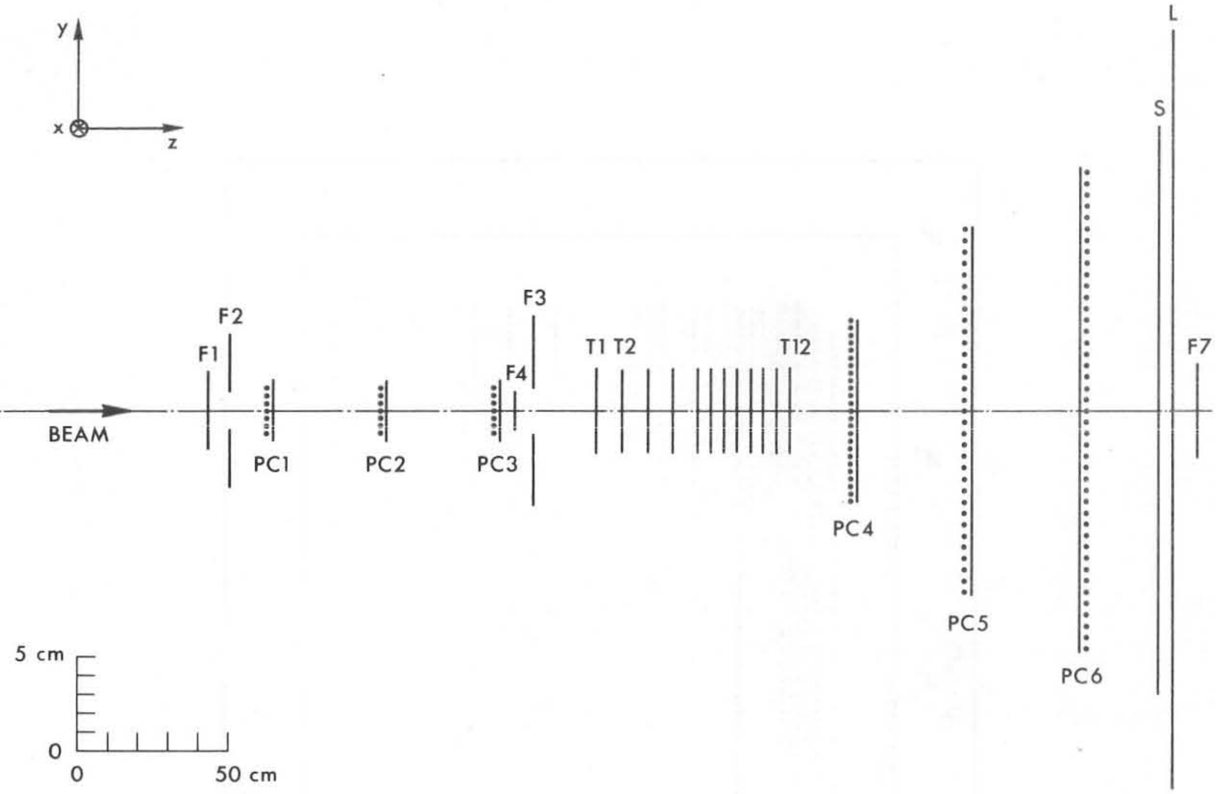
y
x
z
F1
F2
F3
F4
T1 T2
T12
F7
L
S
BEAM
PC1
PC2
PC3
PC4
PC5
PC6
5 cm
0
0
50 cm

Fig. 2

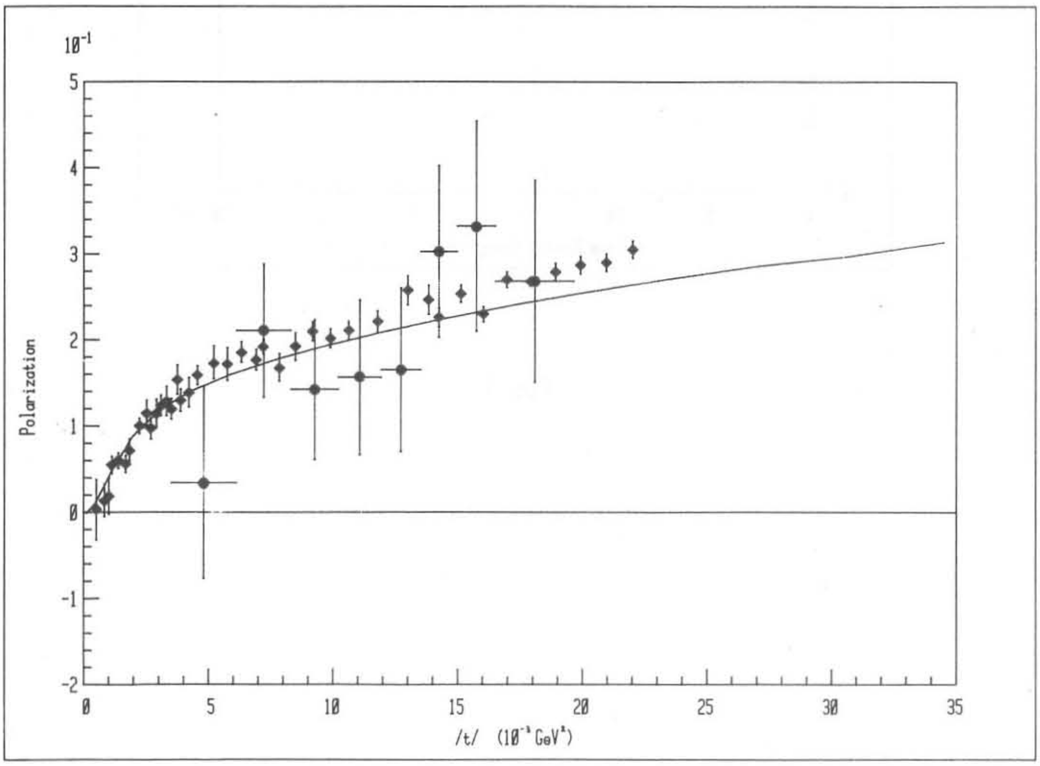
10^-1
Polarization
/t/ (10^-1 GeV^2)

Fig. 3.a

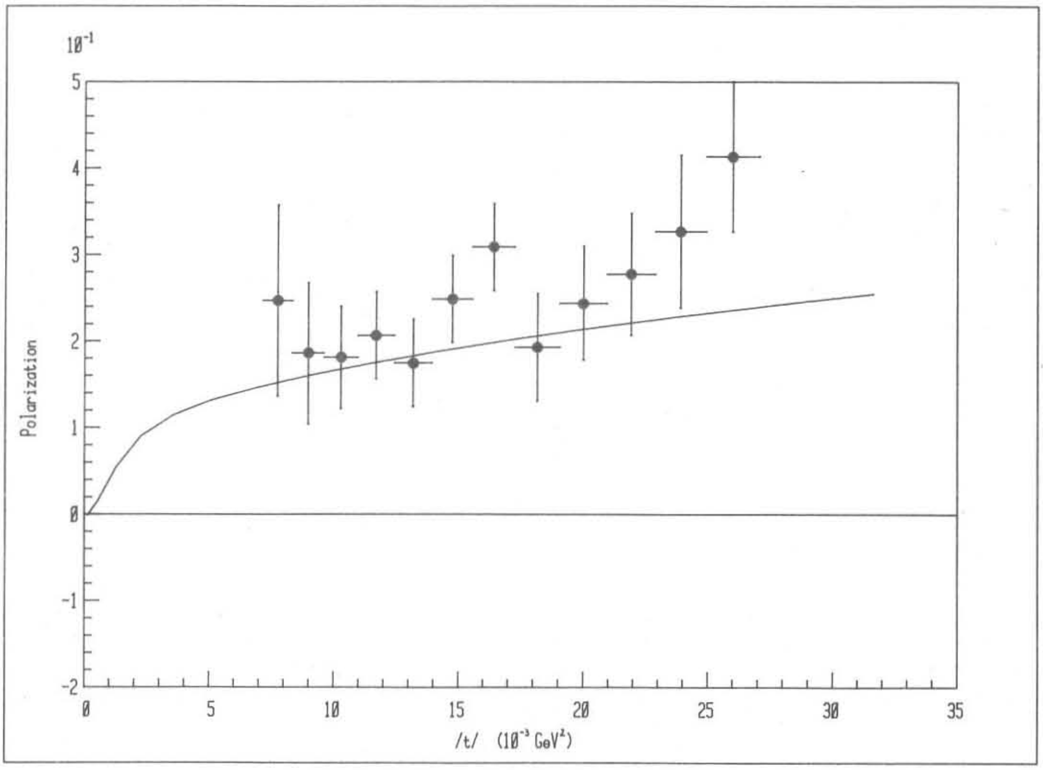
10^-1
5
4
3
2
1
0
-1
-2
Polarization
0
5
10
15
20
25
30
35
/t/ (10^-3 GeV^2)

Fig. 3.b

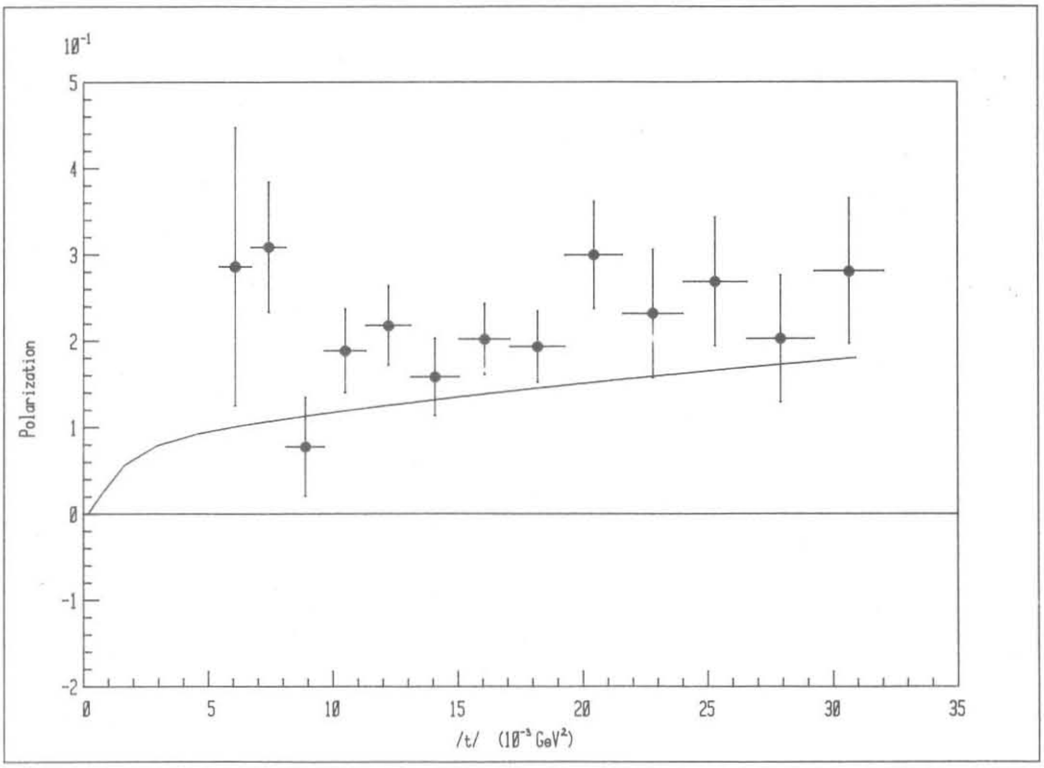
10^-1
5
4
3
2
1
0
-1
-2
Polarization
0
5
10
15
20
25
30
35
/t/ (10^-3 GeV^2)

Fig. 3.c