Diffractive effects in spin flip pp amplitudes and predictions for RHIC

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Introduction

- First anticipation of diffractive effects in polarization data very old(EP, G. Soliani 1967; K. Hinotani, H. A Neal, EP & G. Walters 1979)
- Subsequent papers: S. V. Goloskokov *et al.* 1991, N. H. Buttimore *et al.* 1999,
- N. Achurin *et al.* 1999.

E. PREDAZZI, *et al.*
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Some Remarks on the Polarization Data for Pion-Nucleon Scattering (*).

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(ricevuto il 13 Marzo 1967)

Summary. — The recently measured data on the polarization of the recoil proton in $\pi^{\pm}p \to \pi^{\pm}p$ and $\pi^- p \to \pi^0 n$ are shown to imply that the ratio of the spin-flip amplitudes over $\sin\theta$ (« residual spin-flip amplitudes ») exhibits the same diffractive behaviour typical of elastic-scattering amplitudes at high energies and small angles. The resulting exponential forward peak is much narrower than that for the spin-nonflip amplitudes. It is also found that the assumption that the complete scattering amplitudes are purely imaginary leads to contradictions. In an absorptivelike framework, the contribution of the real to the imaginary part of the amplitudes can be estimated to be of the order of 10% in agreement with other experimental data.

1. – High-energy polarization data at small angles have been recently measured for a number of reactions [1-3] and the results indicate that indeed large polarization effects are still present in the high-energy domain as predicted

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(1) M. BORGHINI, G. COIGNET, L. DICK, L. DI LELLA, A. MICHALOWICZ, P. C. MACQ and J. C. OLIVER: *Phys. Lett.*, **21**, 114 (1966); M. BORGHINI, G. COIGNET, L. DICK, K. KURODA, L. DI LELLA, P. C. MACQ, A. MICHALOWICZ and J. C. OLIVER: *Phys. Lett.*, **24**, B 77 (1967).

(2) P. BONAMY, P. BORGEAUD, C. BRUNETON, P. FALK-VAIRANT, O. GUISAN, P. SONDEREGGER, C. CAVERZASIO, J. P. GUILLAUD, J. SCHNEIDER, M. YVERT, I. MANNELLI, F. SERGIAMPIETRI and L. VINCELLI: *Phys. Lett.*, **23**, 501 (1966).

(3) P. GRANNIS, J. ARENS, F. BETZ, O. CHAMBERLAIN, B. DIETERLE, C. SCHULTZ, G. SHAPIRO, H. STEINER, L. VAN ROSSUM and D. WELTON: *Phys. Rev.*, **148**, 1297 (1966); V. P. KANAVETS, I. I. LEVINTOV, B. V. MOROZOV and M. D. SHAFRANOV: *Sov. Phys. JETP*, **18**, 874 (1964).

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5. – The results of this paper can be summarized as follows. A detailed analysis of the recently measured polarization of the recoil nucleon in $\pi^{\pm}p \to \pi^{\pm}p$ and $\pi^{-}p \to \pi^{0}n$ leads to the conclusion that:

a) the residual spin-flip amplitudes exhibit a marked forward peak very similar to the one shown by the spin-nonflip amplitudes;

b) the slope of the forward peak of the residual spin-flip amplitudes is much larger than that of the corresponding spin-nonflip amplitudes;

c) the normalization of $|h^{R}_{\pm}(k, 0)|$ is on the contrary of the same order as that of $|g_{\pm}(k, 0)|$;

d) the growth with energy of $|h^{R}_{\pm}(k, 0)|$ is the same as that of $|g_{\pm}(k, 0)|$, *i.e.*, they grow roughly linearly with k;

e) the complete scattering amplitudes $f_j(k, \theta)\,(j = \frac{1}{2}, \frac{3}{2})$ are *not* purely imaginary, however the data are not inconsistent with the absorptive hypothesis that the $\pi^{\pm}p \to \pi^{\pm}p$ amplitudes are predominantly imaginary whereas $\pi^{-}p \to \pi^{0}n$ is essentially determined by the real parts of the amplitudes;

f) the contribution of the real part can be roughly estimated and it is found to be of the order of 10% with respect to the imaginary part in agreement with other data [8].

Note added in proof.

After this work was completed, Mr. T. LASINSKI of the Bubble Chamber Group of the University of Chicago has made a best-fit analysis of the experimental data for $(\pi^{-}p)$ $d\sigma/dt$ (as taken from the literature) and of $(\pi^{-}p)$ polarization data (as given in ref. [1]) with the parametrization proposed in the present paper. The result of this best fit completely supports the conclusions drawn in this paper, especially for the determination of the slope-parameters b_{-} and β_{-} whose average values turn out to be $b_{-} \simeq 3.8\ (\text{GeV/c})^{-2}$ and $\beta_{-} \simeq 8.4\ (\text{GeV/c})^{-2}$. The relative χ^2 are 26 at $p_L = 6$ GeV/c with 19 data points and 4 parameters; 23 at $p_L = 8$ GeV/c with 28 data points and 4 parameters; 29 at $p_L = 10$ GeV/c with 28 data points and 4 parameters; 16 at $p_L = 12$ GeV/c with 23 data points and 4 parameters. The b_{-} and β_{-} parameters appear to be practically energy-independent whereas the values of $|g_{-}(k, 0)|$ and $|h^{R}_{-}(k, 0)|$ vary slowly with energy. The authors would like to thank T. LASINSKI for communicating to them the results of his best fit.

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Behavior of the Spin-Flip Amplitude in High-Energy Proton-Proton and Pion-Proton Elastic Scatterings.

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(ricevuto il 23 Gennaio 1979)

Summary. — Data from recent experiments designed to study high-energy elastic πp and pp cross-sections and polarizations have been analyzed to extract information on the behaviour of the spin-flip amplitudes at small t. It is found that the reduced spin-flip amplitudes are, to a large degree, independent of the particular elastic interaction at small t, and have a magnitude comparable to the nonflip amplitudes as $t \to 0$.

In this paper we will illustrate that the general features of the small-$|t|$ spin-flip amplitude in high-energy pp and πp elastic scattering can be extracted from the differential cross-section and polarization data by using a model-independent procedure. The approach employed will be similar to that of Predazzi and Soliani in an earlier study of pion-nucleon scattering at lower energies ([1]).

In the past year high-statistics polarization data have become available at energies up to 300 GeV/c. These data, along with recent differential–cross-section results, permit for the first time a serious study to be made of the behavior of the spin-flip amplitude over a significant range in s for pp and πp

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([1]) E. Predazzi and G. Soliani: *Nuovo Cimento*, **51** A, 427 (1967).

Layout of the talk :

- 1. Preliminaries
- 2. Definition of the amplitudes
- 3. Fit to the existing pp polarization data
- 4. Predictions at RHIC and conclusions

1. Preliminaries

It was shown long ago (PS, 1967) that after removal of the kinematical zero, the Π p spin flip amplitude has all the properties typical of diffractive reactions (see PS).

This was confirmed later when pp polarization data (at somewhat higher energies) became available (see HNPW, 1979).

We will reanalyse these (pp) data in order:

- To check our previous conclusions and
- To predict what we expect at RHIC

2. Definition of the amplitudes

- We will confine our analysis to pp when the polarization is defined in terms of the five helicity amplitudes Φ_i by

- (1) $$P = 2\,\frac{\mathrm{Im}\left[(\phi_1 + \phi_2 + \phi_3 - \phi_4)\phi_5^*\right]}{\left[|\phi_1|^2 + |\phi_2|^2 + |\phi_3|^2 + |\phi_4|^2 + 4|\phi_5|^2\right]}$$

- where Φ_1,Φ_3 are spin non flip, Φ_2, Φ_4 double spin flip and Φ_5 single spin flip amplitudes. We neglect Φ_2 and Φ_4 and set

- $\Phi_1 = \Phi_3 = g(s,t)$
- (effective spin non flip amplitude) and
- $\Phi_5 = h(s,t)$
- (effective spin flip amplitude) so that the polarization (1) becomes
- (2) $2 \dfrac{\mathrm{Im}\left[g(s,t)\, h^*(s,t)\right]}{|g(s,t)|^2 + 2\,|h(s,t)|^2}$

We take the spin non flip amplitude from Giffon *et al.* (2000) where *all* proton-proton and proton-antiproton data have been fitted with a combination of Pomeron, Odderon and secondary reggeons with very good results. (see)

We take exactly the same form without any modification and with the same parameters.

- For the spin flip amplitude we take the empirical form

$$h(s,t) = (i\gamma_1 + \delta_1)\frac{\sqrt{-t}}{m_p}\tilde{s}^{\alpha_{sf}(t)} e^{\beta_1 t}\,\Theta(0.5-|t|) +$$

- (3)

$$+ (i\gamma_2 + \delta_2)\frac{\sqrt{-t}}{m_p}\tilde{s}^{\alpha_{sf}(t)} e^{\beta_2 t}\,\Theta(|t| - 0.5)$$

Where the kinematical zero has been removed with $(-t)^{1/2}$, $\hat{s}= s\ e^{-i\pi/2}$; the break in t is necessary to fit the data (but could be at almost any value $0.7>-t> 0.2$). The complex phase is an absolute necessity to fit the data but is quite expected from combining 2 and 3 gluon ladders (the latter has both C positive and negative and, therefore, can conceivably modify the simple, imaginary, Pomeron phase).

- The prospective spin flip Pomeron trajectory $\alpha^{sf(t)}$ is allowed to be *a priori* different from the spin non flip one and is taken of the usual linear form
- (4) $\alpha^{sf(t)} = \alpha_P(0) + \alpha'_P(0)\, t$

Fit to the existing pp polarization data

- pp polarization data exist at
- $s^{1/2}$ = 13.8, 16.8 19.4 and 23.8 GeV
- The data at 13.8, 16.8 and 23.8 are used as input (Figures 1) and 19.4 (Figure 2) as a control while figure 3 shows that the fit does not spoil the agreement with differential cross sections.
- The parameters are found in Table 1 and the
- χ^2/dof = 1.1

- An alternative fit to the same data is shown in Figures 5 and 6 when $(-t)^{1/2}$
- is replaced by $\sin\theta$. This corresponds to an amplitude with no diffraction (goes
- as $s^{-1/2}$) and the parameters are shown in Table 2. The fit is equally good (χ^2/dof = 1.1)

Predictions at RHIC and conclusions

- The conclusions are, in fact, dependent on the predictions at RHIC. These are, in fact radically different whether the kinematical zero has been removed by a factor $(-t)^{1/2}$ or $\sin\theta$ (Figures 4 and 7 respectively).
- In the first case (removal by a factor $(-t)^{1/2}$) the Polarization is sizeable, in the second (removal by a factor $\sin\theta$), the Polarization is insignificantly negligible.

ıde of the Pomeron contribution to *pp* Spin-flip.

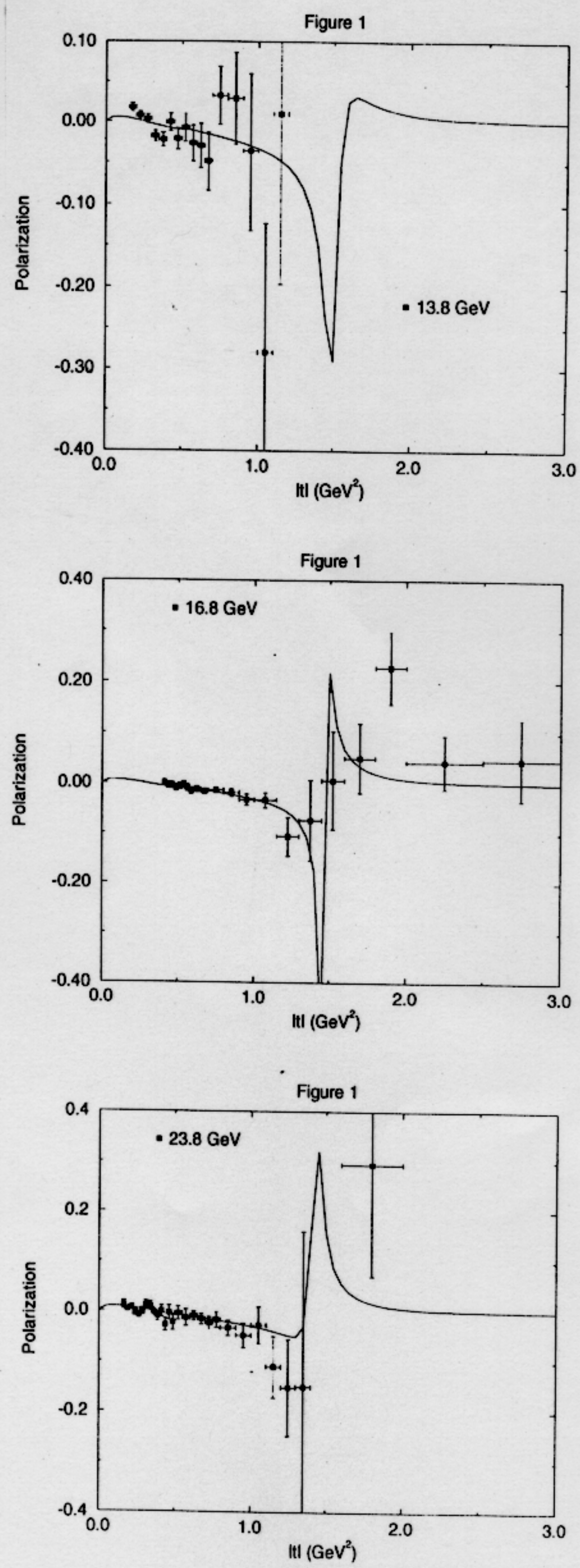

Fig. 1.

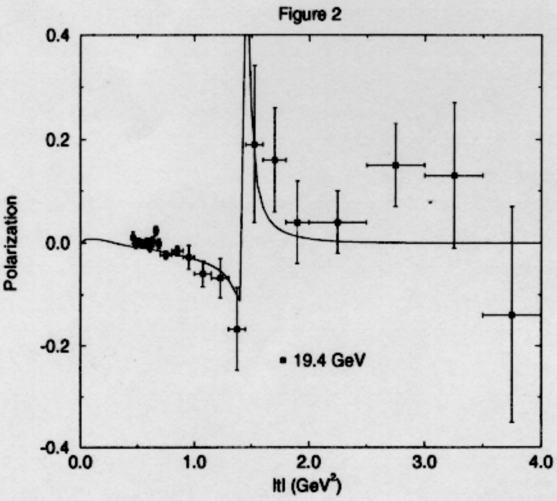

Fig. 2.

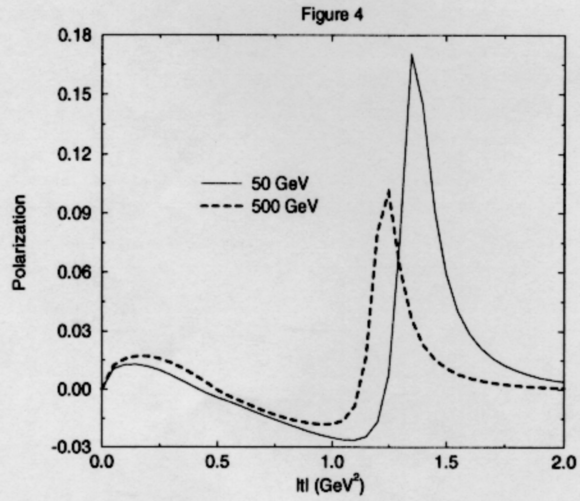

Fig. 4.

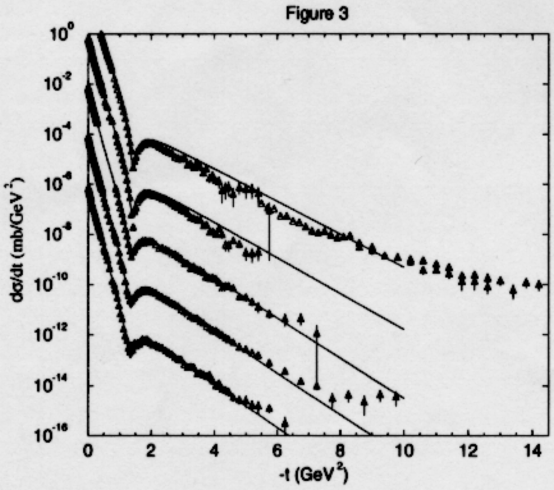

Fig. 3.

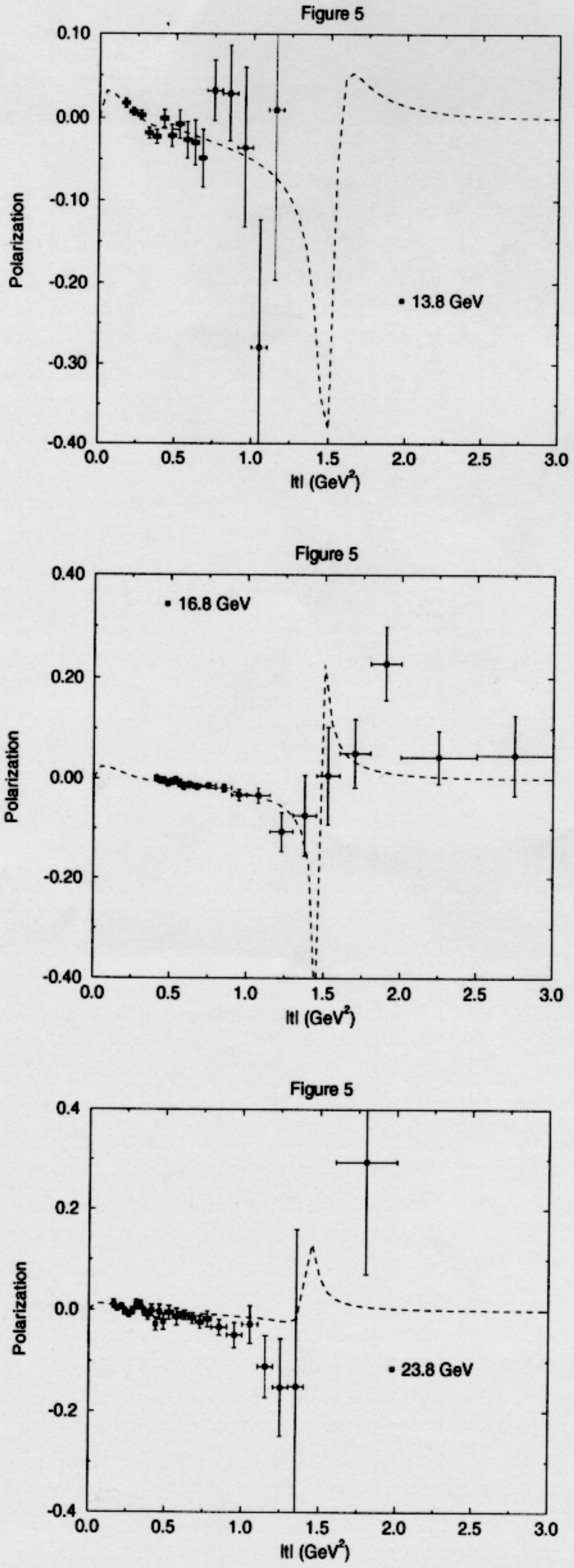

Fig. 5.

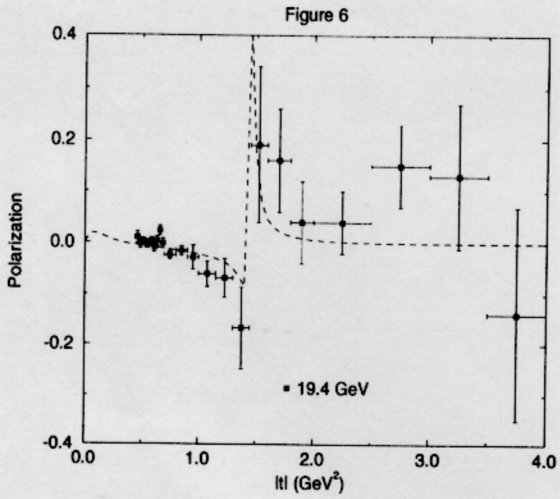

Fig. 6.

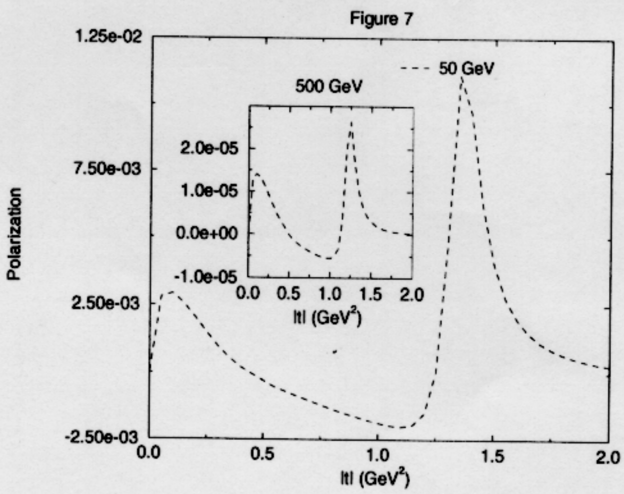

Fig. 7.

Table 1.

γ_1	1.35×10^{-1}	γ_2	2.55×10^{-2}
δ_1	2.64×10^{-1}	δ_2	5.38×10^{-2}
β_1 (GeV^{-2})	4.74	β_2 (GeV^{-2})	2.29
$\chi^2/d.f. = 1.1$			

Table 2.

$\alpha_P^{sf}(0) = -0.129$			
γ_1	-1031	γ_2	-46.8
δ_1	187	δ_2	3.67
β_1 (GeV^{-2})	7.84	β_2 (GeV^{-2})	2.29
$\chi^2/d.f. = 1.1$			

Table 3.

	Pomeron	Odderon
$\alpha_i(0)$	1.071	1.0
α'_i (GeV^{-2})	0.28	0.12
a_i	-0.066	0.100
b_i	14.56	28.10
d_i	0.07	-0.06
γ (GeV^{-2})	-	1.56
	***f*-Reggeon**	**ω-Reggeon**
$\alpha_i(0)$	0.72	0.46
α'_i (GeV^{-2})	0.50	0.50
a_i	-14.0	9.0
b_i (GeV^{-2})	1.64	0.38