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ASYMPTOTIC THEOREMS AND $\pi^-p \rightarrow \pi^0n$ POLARIZATION

P. Gauron

*Division de Physique Théorique⁺, Institut de Physique Nucléaire,
91406 Orsay, France*

and

LPTPE, Université Pierre et Marie Curie, 75230 Paris Cedex 05, France

Résumé - Les résultats surprenants d'une mesure récente à Serpukhov de la polarisation $\pi^-p \rightarrow \pi^0n$ à 40 GeV/c confortent l'hypothèse que les amplitudes hadroniques peuvent croître aussi vite que permis par les principes généraux.

Abstract - The surprising results of the recent 40 GeV/c Serpukhov measurement of the polarization in $\pi^-p \rightarrow \pi^0n$ are shown to support the conjecture that hadronic amplitudes may grow as fast as they are permitted to by general principles.

The above title may seem a little bit strange. What have the asymptotic theorems to do with the polarization in $\pi^-p \rightarrow \pi^0n$?

This is precisely the subject of this talk, based on a work done in collaboration with E. Leader and B. Nicolescu /1/.

I - REMINDER ABOUT THE ASYMPTOTIC THEOREMS

a) Maximal behaviour of the total cross-sections σ_T

Experimentally, from the ISR /2/ and collider /3/ data, it seems now well established that the total cross-sections are increasing like \ln^2s between the ISR and collider energies. If such a behaviour is not a temporary one, that means that the growth of the total cross-sections is compatible with the maximal growth permitted by the well-known Froissart-Martin bound /4,5/.

$$\sigma_T \lesssim c \ln^2s \quad \text{as} \quad s \rightarrow \infty$$

Let us emphasize that this bound is a rigorous result, derived from general principles.

b) A Pomeranchuk-like theorem

This theorem states that

$$\text{if } \sigma_T \propto (\ln s)^\gamma, \quad \gamma > 0 \quad \text{as} \quad s \rightarrow \infty$$

$$\text{then } \frac{\sigma_T^A - \sigma_T^P}{\sigma_T^A + \sigma_T^P} \lesssim (\ln s)^{-\gamma/2}$$

where $\sigma_T^{A(P)}$ is the total cross-section for antiparticle (particle)-particle /16/. This theorem is also a rigorous result based on general principles.

Now we make the assumption that the difference of the total cross-sections $\sigma_T^A - \sigma_T^P$

⁺Laboratoire associé au C.N.R.S.

also grows as fast as permitted to by the asymptotic theorems.

Since from point a) $\gamma=2$, that means that

$$\sigma_T^A - \sigma_T^P \sim \ln s \quad \text{as } s \rightarrow \infty$$

Points a) and b) can be resumed by the following assumption, which was made by Lukaszuk and Nicolescu in 1973 /7/ (see also /8/) :

The strong forces are supposed to be as strong as they can be.

c) Theoretically, this implies the following expressions for the asymptotic parts of the even-and-odd under crossing amplitudes F^\pm :

$$F^+(s,0)_{AS} = i s C_+ \{ \ln(s/s_+) - i\pi/2 \}^2$$

$$F^-(s,0)_{AS} = s C_- \{ \ln(s/s_-) - i\pi/2 \}^2$$

This behaviour will be referred to respectively for F^+ as the Froissaron behaviour, which is experimentally supported, and for F^- as the maximal Odderon behaviour, which is only an assumption.

Because of the generality of the arguments involved, this behaviour should be universal and should be present in all hadronic reactions.

d) Phenomenological consequences

A first place to look is the pp and $\bar{p}p$ scattering where the presence of the Odderon is seen to induce effects at high but finite energies /9/. At $t=0$, it leads to :

- either a minimum in $\Delta\sigma = \sigma_T^{\bar{p}p} - \sigma_T^{pp}$ or a crossing between $\sigma_T^{\bar{p}p}$ and σ_T^{pp} , depending on the sign of the Odderon term.

- a crossing between ρ_{pp} and $\rho_{\bar{p}p}$ ($\rho = \text{Re } F/\text{Im } F$) or a noticeable difference between them, depending again on the sign of the Odderon.

In order to check these effects, we need to know both pp and $\bar{p}p$ at the same energy. But the ISR energies are too low for seeing the effects and pp is not measured at the collider energy. Then such a study remains inconclusive.

At $t \neq 0$, the interesting R420 experiment /10/ measured both the pp and $\bar{p}p$ differential cross-sections at $\sqrt{s} = 53$ GeV. On figure 1, we can see a clear difference between the two curves in the dip region of pp. If such a difference was confirmed, it would be a strong evidence for the existence of a non-negligible non-Regge term in the odd-under-crossing amplitude, a term like our maximal Odderon term. But this experiment is yet a preliminary one and we have to wait before drawing definite conclusions.

One can find another way of detecting the presence of the Odderon. Because the phase of the Odderon is very different from those of the conventional Regge terms, it could lead to strong interference effects. A good place to look is then the polarization in $\pi p \rightarrow \pi^0 n$ scattering at high energy, for which the amplitude is purely odd-under-crossing.

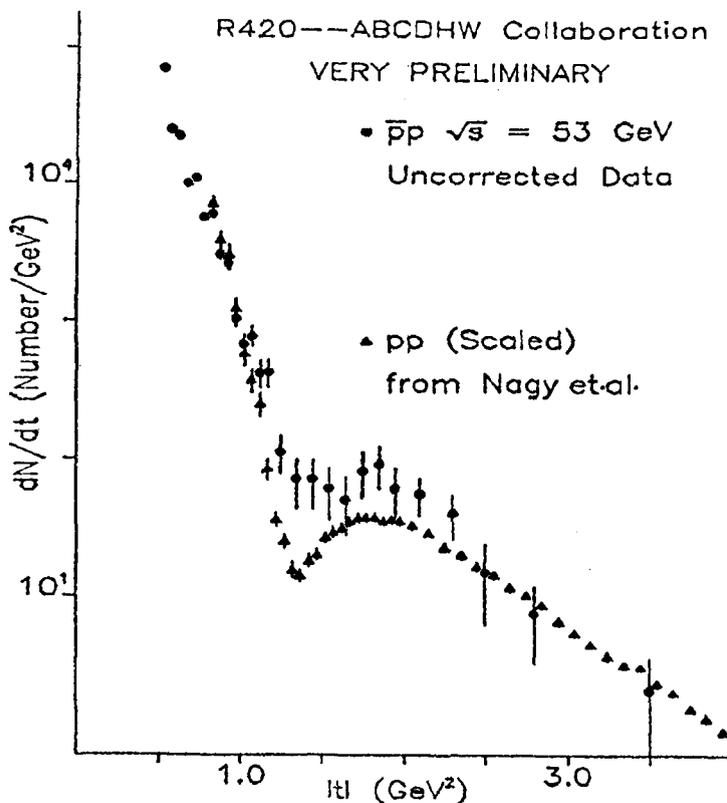


Fig. 1 - pp and $\bar{p}p$ measurement at $\sqrt{s} = 53$ GeV.

II - $\pi^- p \rightarrow \pi^0 n$ POLARIZATION

Until recently, the $\pi^- p \rightarrow \pi^0 n$ polarization was measured only at low energy ($5 \text{ GeV}/c \leq p_L \leq 11 \text{ GeV}/c$) /11,12/. At these energies, the polarization is everywhere positive in the range $0 < |t| \leq .5 \text{ (GeV)}^2$ (see Fig. 2). But a new Serpukhov experiment at $p_L = 40 \text{ GeV}/c$ /13/ seems to show an unexpected effect. A zero appears around $t = -.4 \text{ (GeV)}^2$, together with a minimum at $t \approx -.5 \text{ (GeV)}^2$ (see Fig. 2). Such a behaviour cannot be explained by any of the conventional models. Also certain possible incompatibilities between the data on $\Delta\sigma = \sigma_T^{\pi^- p} - \sigma_T^{\pi^+ p}$, $d\sigma/dt$ and $\rho = \text{Re } F(s, t=0)/\text{Im } F(s, t=0)$ on the one hand and the Regge models on the other hand seem to show the necessity of non-Regge terms.

The following analysis will show that these new data lend support to the Odderon-type behaviour.

a) Description of the model

In terms of the invariant amplitudes A' and B , we have

$$\Delta\sigma = \sigma_T^{\pi^- p} - \sigma_T^{\pi^+ p} = \frac{2}{p_L} \text{Im } A'(s, t=0)$$

$$\frac{d\sigma}{dt} = \frac{1}{8\pi p_L^2} \left\{ \left(1 - \frac{t}{4m^2}\right) |A'|^2 - \frac{t}{4m^2} \left(\frac{4m^2 p_L^2 + st}{4m^2 - t}\right) |B|^2 \right\}$$

$$P \frac{d\sigma}{dt} = \frac{\sin \theta}{8\pi \sqrt{s}} \operatorname{Im} (A'^* B)$$

A' and B are written as the sum of the contributions of the Regge poles ρ , ρ' and of the Odderon term

$$A' = A'_\rho + A'_{\rho'} + A'_O$$

$$B = B_\rho + B_{\rho'}$$

The contribution of the Odderon term in B was seen to have very weak effects /14/. In the interest of simplicity and in the absence of any evidence to the contrary, we will assume that the Odderon term does not contribute to B .

For the Reggeons $R = \rho, \rho'$ we have the standard expressions :

$$A'_R = \left[i + t g \frac{\pi}{2} \alpha_R(t) \right] a_R(t) [\alpha_R(t) + 1] s^{\alpha_R(t)} e^{\lambda_R t}$$

$$B_R = \left[i + t g \frac{\pi}{2} \alpha_R(t) \right] b_R(t) \alpha_R(t) [\alpha_R(t) + 1] s^{\alpha_R(t)-1} e^{\lambda_R t}$$

where $a_\rho(t) = a_\rho(1 + ct)$ $b_\rho(t) = b_\rho = \text{const.}$
 $a_{\rho'}(t) = a_{\rho'} = \text{const.}$

and

$\alpha_R(t)$ are linear Regge trajectories.

The Odderon term is :

$$A'_O = C_s \left[\ln^2(s/s_0) - i\pi \ln(s/s_0) \right] e^{\lambda_O t}$$

where the exponential is a good approximation for the t -dependence in the small t -range.

With these formulae, we performed a fit of about 300 data points for $\Delta\sigma$, $d\sigma/dt$ and the polarization P in the range $6 \text{ GeV}/c \leq p_L \leq 340 \text{ GeV}/c$. We obtained a good description of these data ($\chi^2 = 1.6/\text{point}$).

b) Results and predictions

The change of shape of the polarization between $5 \text{ GeV}/c$ and $40 \text{ GeV}/c$ is correctly described (see Fig. 2 and Fig. 3).

At low energy, the $\rho \otimes \rho'$ interference term dominates. The polarization is everywhere positive with the well known zero at $t = -.57$ which corresponds to the zero of the Regge ρ -trajectory.

At intermediate energies ($p_L \approx 40 \text{ GeV}/c$), the $\rho \otimes \rho'$ and $\rho \otimes$ Odderon term are of the same order of magnitude and cancel each other. The polarization is small and a moving zero appears in addition to the usual zero at $t = -.57$.

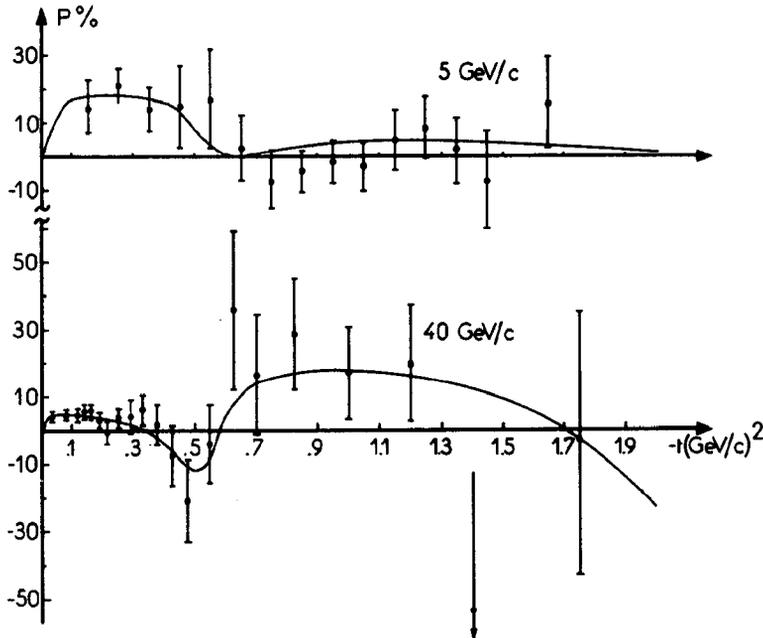


Fig. 2 - Polarization in $\pi^- p \rightarrow \pi^0 n$ at $p_L = 5 \text{ GeV/c}$ and 40 GeV/c . The curves correspond to the maximal Odderon asymptotic behaviour, as given in the text.

At Fermilab energies, the $\rho \otimes$ Odderon term becomes dominant. P is negative in the small- t region showing a pronounced dip at $t = -0.5$ with a minimum value of the order of -30% to -50% at $p_L = 100 \text{ GeV/c}$.

More data at moderate energies would be necessary in order to constrain further the Odderon parameters and therefore to give more precise predictions at Fermilab energies. However, at the present stage, the qualitative effect described above appears to be very stable.

III - CONCLUSION

First, we note that the asymptotic theorems, which are based on the general principles, can have effects at high but finite energy and can then be checked by experiments.

In this context, it seems highly desirable to measure the charge-exchange polarization $\pi^- p \rightarrow \pi^0 n$ for $p_L \gtrsim 100 \text{ GeV/c}$. Via the existence of the Odderon term, such an experiment could have important implications for the ISR and collider physics. Also the confirmation of the Odderon behaviour of the crossing-odd amplitude would allow to test the asymptotic theorems and is therefore of fundamental interest for any theory of strong interactions.

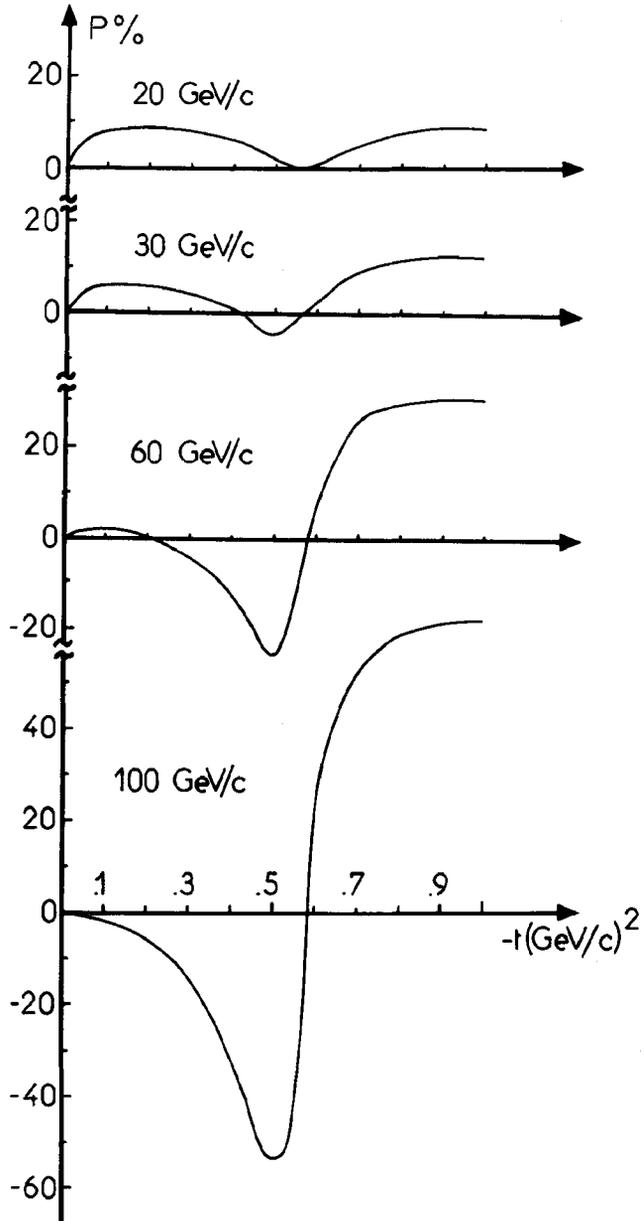


Fig. 3 - Theoretical predictions based on the maximal Odderon behaviour, showing the development and subsequent movement towards $t=0$ of a new zero in the polarization.

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