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ELASTIC SCATTERING AND SPIN PHYSICS

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Résumé - Nous étudions si les données expérimentales à hautes énergies existantes fournissent des informations sur la dépendance de spin des amplitudes de diffusion élastique nucléon-(anti)nucléon.

Abstract - We discuss whether existing high energy experimental data give some information on the spin dependence of the nucleon-(anti)nucleon elastic amplitudes.

It is usually assumed that spin effects are unimportant at high energy and low momentum transfer. In fact, almost all the analyses are made with this implicit assumption (for instance real part determination!), and it is normal to do that in the absence of any information. However, we are in the country of Descartes who tells us "ne pas prendre une chose pour vraie qu'elle ne soit évidemment telle".

Do we have any indication that spin effects are small? In principle yes, because proton-proton total cross-sections in colliders are measured by combining two of the three quantities:

1) the luminosity \( L \)

2) the extrapolated number of elastic events per second at \( t=0 \), i.e.,

\[ \frac{d\sigma}{dt}(E, t=0) \]

3) the total number of events per second which is

\[ \sigma_{\text{total}} \]

If spin effects are unimportant, (2) is proportional, by the optical theorem to

\[ (1 + \rho^2) L \sigma_{\text{total}}^2 \]

where \( \rho \) is the forward real part, which can be measured, or estimated from dispersion relations.

At the ISR, measurements of \( \sigma_T \) have been made by combining (1) and (2), (1) and (3), (2) and (3), and they are compatible with one another. At the SPPS collider the UA4 group has combined (2) and (3) and the UA1 group combines (1) and (2).

Again the results are compatible. Is this a proof that spin effects are not important? As we shall see, while the ISR measurements indicate that spin effects are small, the SPPS experiments allow a large spin dependence. This is because at
the ISR luminosity is accurately measured by the van der Meer method while, at the SPPS, luminosity is poorly known, the uncertainty being about 10%.

If we use the helicity basis and if particles are unpolarized, $\sigma_T$ is proportional to

$$A = \frac{f m}{2} \left[ <++|++> + <+-|+-> \right]$$

while $d\sigma/dt$ is proportional to

$$B = \left| <++|++> \right|^2 + \left| <+-|+-> \right|^2$$

noting that in the forward direction $<++|++> = 0$. The double flip amplitude $<++|-->$ is zero in Regge models.

So we have

$$2B > A^2.$$

The fact that all three methods of measurement of $\sigma_T$ at the ISR agree within 0.5 mb means that $|2B/A^2 - 1| < 2.5\%$.

Hence,

1) the double flip amplitude is less than 0.15 times the average no-flip amplitude

$$0.75 < \left| \frac{<+-|+->}{<++|++>} \right| < 1.23$$

ii) if $<+-|--> = 0$ and $<++|++> = <+-|+->$ we get

$$|\rho| < 0.15$$

Therefore, at the ISR we see indications that the forward direction spin effects are not large. On the other hand, at the SPPS the situation is not so primarily, because of the poorness of the luminosity measurements. The best we can hope is

$$\left| \frac{2B}{A^2} - 1 \right| < 10\%$$

corresponding, for instance, to

$$\frac{1}{2} < \left| \frac{<+-|+->}{<++|++>} \right| < 2.$$

It is therefore on the basis of the theoretical prejudice that we cannot see why spin effects could be large at 540 GeV c.m. and small at 60 GeV c.m., that we believe that we can disregard them at the SPPS collider. However, a measurement with polarized protons and antiprotons, which are needed anyway to distinguish the $V$-$A$ interaction of the $W$ from the $V$+$A$ interaction, would be extremely useful.

Concerning the ISR I would like to make another remark: the existence of a very marked dip on the differential cross-section is also an indication that amplitudes are close to being spin independent. If it was not the case, there would be no reason why their imaginary parts should all vanish approximately at the same value of $t$. 