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CONCLUSIONS FOR THE VIII^{e} MORIOND

ON THE POMERON

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Introduction:

We have enjoyed an interesting and stimulating week discussing the Pomeron and its properties. Our motivation for studying the Pomeron probably lies somewhere between two extremes --

(1) that the diffractive processes are not very fundamental in themselves, but that they cover up or conceal the remaining two-thirds of the cross section which is accounted for by a great variety of processes which exhibit a great deal of structure, and from which one is going to learn about the dynamics of two body strong interactions, and questions like possible internal structure of the nucleon; that is, one has to understand the one before being able to proceed to the other; or

(2) that diffraction is simply related to geometry, optics and absorption, and also represents the single largest cross section we deal with in particle physics; therefore, we should try to understand it before moving on to the more complex, smaller

cross section processes.

Wherever we derive our motivation, let's see what we have learned of the Pomeron.

Rising Total Cross Sections:

We have heard in some detail from Belletini about the ISR experiments on the p-p total cross section. The cross section is measured to rise about 4 mb through the ISR energy region, of (200-2000) GeV equivalent lab energy.

The experiments rely very heavily on the measurement of the luminosity of the circulating proton beams for the absolute normalisation and there has been much discussion of how reliable such measurements are. However, it seems that in recent months the stability of operation of the ISR has made the luminosity measurements much more reproducible. In addition, the agreement between the Cocconi group and the Belletini group results derived from very different techniques, is good confirmation of the effect. (Let me remind you that the Belletini group has a large--almost 4π-- scintillation counter hodoscope set up to measure multiplicity distributions in p-p scattering; they measure the total cross section by counting the secondaries and make a small correction for the losses due to particles which are emitted towards the beam holes or the cracks between the hodoscope counters: the Cocconi group make precision measurements of the forward elastic p-p scattering cross section with a counter hodoscope system and, using the optical theorem, relate this to the total cross section. They also justify this use of the optical theorem in determining the total cross section by measuring the real part of the p-p scattering amplitude at several energies and showing that it is small and a negligible effect for the total cross section.)

It is interesting that using the two experiments described above, one could measure the total p-p scattering cross section independent of questions of the luminosity, L. This arises since the Cocconi experiment is sensitive to $\frac{\sigma_T^2}{L}$(through the optical theorem), and the Belletini experiment measures $\frac{\sigma_T}{L}$, (through measurement of the secondary rate) -- thus the ratio of the two experiments measures the total cross section independent of L, $(\frac{\sigma_T^2}{L} \cdot \frac{L}{\sigma_T} \sim \sigma_T)$. Such an experiment, in which both sets of apparatus will measure σ_T in the same interaction region at the same time, is planned for this summer and should give good total cross section data quite independent of luminosity problems. Some data of this nature already exists, in which the two experiments were run in different interaction regions of the ISR; thus one has to make assumptions that the beam did not change shape between interaction regions. The results show a definite rise in σ_T of the same order as each experiment independently determined (i.e. $\sim$ 4 mb).

This discovery has caused a great deal of interest and raised many questions. The simple Pomeron, as a single pole, is surely dead now -- but no one seems too sad (in fact, Andre Martin seemed positively gleeful at the prospect in his review talk). We have a puzzle about whether the total cross section will continue to rise as the energy increases or will asymptotically approach a constant value from below. It will also be interesting to see whether the $\pi^{\pm}p$, $K^{-}p$ and γp cross sections will start to rise in the NAL energy region.

The elastic p-p scattering cross section has also been studied at ISR and has been shown to rise by the same amount as the total cross section, through the ISR energy range (i.e. ~ 10-12%). The ratio of elastic to total cross section is constant from ~ 60 GeV/c to 2000 GeV/c with a value of 0.175. A straightforward optical model calculation with a black disc would give this ratio as 0.5.

Differential Cross Sections and Shrinkage:

Another area of considerable interest during this week was the question of shrinkage in p-p scattering. We heard from the ISR experimenters (from Rubbia's group) and from Carrigan on the NAL U.S.-U.S.S.R. experiment. There is some controversy whether the small t region shrinks slowly much as the large t region but with a slope which is ~ 2 units steeper, or that there are two quite separate regions of shrinkage in p-p scattering -- the small t fast shrinking region and the large t slow shrinking region.

I presented the latter point of view in my introductory talk, where the p-p scattering data had been analyzed for all energies above 30 GeV/c and fit well with $\alpha' \sim .36\ \text{GeV}^{-2}$ for $t < 0.1\ \text{GeV}^2$, and with $\alpha' \sim .1 \pm .1\ \text{GeV}^{-2}$ for $.15 \leq t \leq .5\ \text{GeV}^2$. However, this fit requires that the Serpukov data be renormalized in absolute value by $\sim \Delta b = -.4\ \mathrm{GeV}^{-2}$, (within their quoted systematic errors). Carrigan presented preliminary results of the NAL experiment which showed that the small t region ($t \leq .15\ \mathrm{GeV}^2$), does shrink with an $\alpha' \sim .4\ \mathrm{GeV}^{-2}$ but that it saturates beyond 200 GeV -- that is, the p-p differential cross section for $t < .15\ \mathrm{GeV}^2$ shrinks with an $\alpha' \sim .4\ \mathrm{GeV}^{-2}$ up to 200 GeV, beyond which there is little change of slope as the energy increases. This is an interesting result but we will have to wait for confirmation as it is (a) preliminary, (b) the effect is at end of the NAL experiment's range of measurement, and (c) systematic shifts in b completely change the interpretation -- the ISR experiments, NAL, and Serpukov all have problems in setting the absolute scale and these shifts can change the picture from continued shrinkage to the saturation case. This is a very interesting question which will receive a great deal of attention in the next months, especially from the new NAL data.

It has also been interesting to see the large t structure emerging in the p-p elastic scattering experiments at the ISR. The accelerator energy data have long shown a break in the slope of the differential cross section around $t \sim 1.2\ \mathrm{GeV}^2$; as the energy increases this break becomes a deep hole and a secondary scattering peak appears. The structure is observed to be only weakly dependent on energy and is well fit by optical models. It appears that one can identify the structure as a secondary diffraction peak.

K^+p Interactions:

It has been exciting to see many new and interesting features emerging from p-p interactions at the ISR --

-- σ_T rising with energy

-- small t structure in $d\sigma/dt$

-- shrinkage of $d\sigma/dt$ -- does the shrinkage saturate as σ_T begine to rise?

-- emergence of secondary diffraction peak

-- energy dependence of real part of the scattering amplitude, especially in the region where σ_T rises.

All of these interesting effects are rather difficult to study since they appear near the end of the available energy at the ISR. However, the K^+p system is also exotic in the s-channel and is already displaying the feature of a rising total cross section for energies in the neighborhood of 30 GeV. Through the Serpukov and NAL energy ranges where one has good separated secondary beams of K^+ mesons, the K^+p system should provide an ideal laboratory to study the new dynamical effects giving rise to the above listed phenomena.

Factorization:

We learned that factorization in diffractive processes -- elastic, diffraction dissociation and leading particle inclusive reactions -- is surprisingly good, holding to $\sim$ 20 percent.

It would be interesting to have data on an even wider variety of processes, and more importantly, with rather better accuracy. At intermediate energies, we know that non-leading effects such as cuts, are quite important and at high energies the observations of rising cross sections have killed any idea of simple single pole dominance of the interactions -- thus, we expect breaking of factorization to occur, maybe even at the 10% level. It would be very interesting to have experiments of sufficient accuracy to observe this breaking, and perhaps even see some s-dependence to the breaking of factorization.

Inelastic Diffraction Processes:

We have seen further evidence during the week that the inelastic (diffraction dissociation) processes have properties very similar to the elastic scattering reactions -- except for their spin structure:

- the cross sections fall like a power law in momentum, $\sigma \propto p^{-n}$ where $n \sim 0.5$;
- particle and antiparticle cross sections are approximately equal;
- the differential cross section is sharply forward peaked, $d\sigma/dt \propto e^{at}$, and has a slope the same order (slightly steeper) as the related elastic slope;
- the particle and antiparticle differential cross sections exhibit a crossover;
- the cross sections factorize;

-- spin structure is not SCHC, nor TCHC.

We have not discussed the nature of these processes during this meeting. However, one of the interesting issues in the study of diffractive processes is whether these "diffraction dissociation states" are resonances or are kinematic in origin. I think that there is good evidence that a substantial contribution to these processes comes from kinematic enhancements, but there probably is some resonant production in addition. If this is indeed the situation it will be hard to sort it out experimentally since both contributions feed the same partial waves. One might hope to observe interference effects between the resonance and kinematic amplitudes (analogous to ω-ρ interference experiments), especially if the resonances are not too broad -- but these would be very difficult studies.

Spin Structure:

The spin structure in elastic scattering and vector meson photoproduction has been shown to be s-channel helicity conserving, in the main, but with a small (~ 15%) helicity flip amplitude. This helicity flip amplitude has natural parity, is isoscalar and displays almost no energy dependence, and is therefore associated with the Pomeron.

Coherent Multiparticle Production in Nuclei:

Yet another interesting feature of diffraction phenomena is the reporting of anomalous absorption of multiparticle states coherently produced in nucleii.

There have been several experiments in heavy liquid bubble chambers observing A_1 production by π's and Q production by K's. An optical model analysis of the data had implied that the A_1 and Q systems were absorbed in the nuclear matter with a cross section of order 20 mb. (i.e. not $3\sigma_\pi = 75$ mb, nor $\sigma_\pi + \sigma_\rho \approx 50$ mb, but $\sigma_A \sim \sigma_Q \sim \sigma_\pi$).

These results have been confirmed and greatly extended by an interesting spark chamber experiment at CERN. The coherent production of 3π and 5π final states by pions at 9, 12, and 15 GeV/c, and of $K\pi\pi$ final states by K^+ at 13 GeV/c have been studied with high statistics on a large number of nuclear targets. The absorption of the coherently produced multiparticle system was studied as a function of the size of the nucleus (i.e. how much nuclear matter it had to traverse) and the total cross sections deduced from an optical model analysis:they found

$$\sigma(3\pi) \sim (27 \pm 2) \text{ mb}$$

$$\sigma(5\pi) \sim (15 \pm 5) \text{ mb}$$

$$\sigma(K\pi\pi) \sim (22 \pm 3) \text{ mb}$$

New data on coherent production of $(N\pi\pi)$ final states at high energy and with many nuclear targets should be available shortly from a Rochester-Carnegie Mellon experiment at BNL. This is a very interesting phenomenon, which is really not understood by the theorists. Hopefully, more progress will be made in understanding this phenomena in the near future.

Very High Energy:

Finally, we come to questions of the high energy behaviour of diffractive processes. It is interesting to ask whether diffraction persists at high energies; does it continue to compete with the other mechanisms, or does it die away, or does it dominate?

It seems that neither of the last two possibilities is true. Diffraction is important at high energy, but it is not the whole story. It accounts for about one-third of the total cross sections. Further it seems to dominate the low multiplicities.

From data on $pp \to px$ near $x = 1$ at the ISR there are now good indications of the cross section scaling in s and $1/M^2$ -- both of which would indicate a substantial triple pomeron contribution to this process -- confirming diffraction dominance at this extreme edge of phase space.

Another interesting question concerns the multiplicity distribution -- if diffraction only contributes to the small multiplicities then as the energy increases the average multiplicity due to other processes (the so-called multiperipheral component) will increase and the overall multiplicity distribution should eventually show the two components separated by a valley. Model dependent analysis of NAL data indicate that such a separation may be expected at ISR energies.

Preliminary data from Belletini's ISR experiment does not show any sign of separation of the two components. This is not a definitive statement yet -- (a) the analysis of the experimental data is not yet complete, (b) it is not clear how converted electrons and positrons distribute themselves in multiplicity and whether the showers in the vacuum pipe could perhaps mask a valley between low multiplicity and high multiplicity events. We shall have to wait and see.

Final Comment:

One final question, which we should keep in mind when considering diffractive process --

we study diffraction in the following reactions:

-- elastic scattering

-- inelastic scattering - diffraction dissociation,

-- inelastic scattering - single particle inclusive,

Are all these processes really induced by the same t-channel mechanism?