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Archives

POMERANCHUK HYPOTHESIS FOR INELASTIC REACTIONS

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ABSTRACT

We give arguments to support the belief that fragmentations of a target by a particle and its antiparticle occur with equal cross-sections in the high energy limit.

Recently, much interest - both theoretical ¹⁾⁻⁴⁾ and experimental ⁵⁾ - has been devoted to inelastic reactions. On the other hand, the Pomeranchuk theorem on the equality between total cross-sections in particle-particle and particle-antiparticle collisions at high energy is compatible with existing experimental data :

- i) direct experimental evidence is given by the Serpukhov experiments ⁶⁾ which are compatible with a common limit for K^+p and K^-p , π^+p and π^-p , and pp and $p\bar{p}$ cross-sections;
- ii) the experiments on elastic pp scattering at ISR give also some indirect support to the Pomeranchuk theorem, even though it is not possible to compare them with $p\bar{p}$. This support has a theoretical origin. The pp total cross-section seems to tend to a finite non-zero constant ⁷⁾, and the extrapolated differential cross-section, $d\sigma/dt$ at $t=0$, does not give clear indications of a logarithmic increase. This means that the forward amplitude would be bounded by s , which is a sufficient condition for the validity of the Pomeranchuk theorem ⁸⁾. Furthermore, there are indications that contrary to what happens at lower energies, the diffraction peak does not shrink any more ⁷⁾. This is suggesting a picture in which the maximum angular momentum would be of the order of $L_{\max} \simeq \sqrt{s}$.

Another fact is that some progress has been made on what could be called the "Pomeranchuk theorem for elastic cross-sections", which was originally proposed by Van Hove ^{8),9)}. This theorem states that at fixed momentum transfer

$$\frac{d\sigma}{dt}(\text{particle-particle}) / \frac{d\sigma}{dt}(\text{particle-antiparticle})$$

tends to unity. In another version, one could use $t(\log s)^\alpha = \text{const}$ instead of $t = \text{const}$. What we have shown ¹⁰⁾ is that this theorem holds if the phase of the scattering amplitude grows less fast than $\log s$. It was known that for reactions $A+B \rightarrow C+D$, $\bar{C}+B \rightarrow \bar{A}+D$ counter-examples could be built, with a phase growing like $\log s$ ¹¹⁾. However the second result we have also established ¹⁰⁾ is that for an elastic amplitude a sufficient condition for the phase to grow less fast than $\log s$ is that the ratio $(d\sigma/dt)(s,t)/(\sigma_{\text{total}}(s))^2$ decreases less fast than $1/\log s$ ^{*)}. Therefore, from the experimentally observed

*) Another sufficient condition to have a phase growing less fast than $\log s$ is $L_{\max}/\sqrt{s} \log s \rightarrow 0$, and $\sigma_{\text{total}} \rightarrow \text{const} \neq 0$. These two conditions ensure at the same time the validity of the Pomeranchuk theorem for total cross-sections.

disappearance of shrinking at ISR energies ⁷⁾, we are led to believe that the conditions for the validity of the "elastic" Pomanchuk theorem are fulfilled. Since, in addition, the differential cross-section is dropping rapidly with $|t|$, one can integrate and conclude

$$\sigma_{el}(\text{particle-particle}) / \sigma_{el}(\text{particle-antiparticle}) \rightarrow 1 .$$

The conclusion of all this is that $\sigma_{inelastic}(\text{particle-particle})$ and $\sigma_{inelastic}(\text{particle-antiparticle})$ should have a common non-zero limit at high energies. So far we have used a deductive approach combined with indications coming from experimental information on elastic collisions and total cross-sections. Now we ask the following question: is it reasonable to believe that the equality between the inelastic cross-sections will be the result of a compensation between the various dominant inelastic mechanisms? If one believes, following Yang ¹⁾, that high energy inelastic collisions are dominated by fragmentation either of the projectile or of the target, or both, without exchange of internal quantum numbers from one to the other, one can obviously establish a one-to-one correspondence between important inelastic final states in $A+B$ and $\bar{A}+B$ collisions at high energies. To

$$A+B \rightarrow (1+2+\dots+N) + (1'+2'+\dots+N')$$

where $(1+2+\dots+N)$ are fragments of A with finite momenta in the system with A at rest and $(1'+2'+\dots+N')$ are fragments of B with finite momenta in the B system (the lab. system), we associate

$$\bar{A}+B \rightarrow (\bar{1}+\bar{2}+\dots+\bar{N}) + (1'+2'+\dots+N')$$

[There are, of course, final states for which this one-to-one correspondence is not possible, like $p+\bar{p} \rightarrow n\pi$ which has no pp analogue, but these are supposed to be non-dominant.] Then it is very natural to postulate the equality of cross-sections for these processes. In the case where only the B particle fragments, for instance, we get

$$E_1 E_2 \dots E_N \frac{d\sigma(A+B \rightarrow A' + (1+2+\dots+N))}{d^3\vec{p}_1 d^3\vec{p}_2 \dots d^3\vec{p}_N} \delta((p_1+\dots+p_N - p_{A'} - p_B)^2 - M_A^2)$$

$$\cong E_1 E_2 \dots E_N \frac{d\sigma(\bar{A}+B \rightarrow \bar{A}' + (1+2+\dots+N))}{d^3\vec{p}_1 d^3\vec{p}_2 \dots d^3\vec{p}_N} \delta(\dots)$$

in the limit of infinite energy for $\vec{p}_1, \vec{p}_2, \dots, \vec{p}_N$ finite in the lab. (B) system.

An analogous asymptotic equation could be written in the case where both A and B produce fragments. Another motive to believe that such an equality should hold is that, again following Yang's ideas ¹⁾, the limited fragmentation of B is nothing but the generalization of the elastic events in which B has a finite recoil, i.e., the fixed t situation. For fixed t, if $d\sigma/dt$ is not going to zero or not going to zero too quickly, we have that $(d\sigma/dt)(\text{particle})/(d\sigma/dt)(\text{antiparticle})$ goes to one. Therefore we expect also to get an asymptotic equality between

$$\begin{aligned} A+B &\rightarrow A' + (1+2+\dots+N) \\ \bar{A}+B &\rightarrow \bar{A}' + (1+2+\dots+N) \end{aligned}$$

if these are dominant processes, and if $1,2,\dots,N$ have bounded momenta.

This latter argument has the advantage of leaving room for pionization, i.e., for appreciable contribution from processes in which longitudinal momenta of outgoing particles are small in the centre-of-mass. In that case, by subtracting from the total cross-section the elastic cross-section and the fragmentation cross-sections, one concludes again that the cross-section for "pionization" should become equal in particle-particle and particle-antiparticle collisions. However, now this is an over-all equality which cannot be reduced to an equality between differential cross-sections.

We should also indicate that the equality we propose for fragmentation events is of course very natural in a model in which a single simple Pomeron pole is exchanged between A and B. However, we expect it to have a much more general value than this particular model, which would lead to very rigid predictions such as factorization properties. In fact, the hope to establish such a result from first principles is not zero. To start with, one has to find a crossing property of the S matrix. This, according to our friends Bros, Epstein and Glaser ¹²⁾, does not seem to be impossible. Then one would still have to make an assumption analogous to the phase condition.

Anyway, we think that it is worth studying the question experimentally. One should not expect a very spectacular agreement, since total cross-sections for particle-particle and particle-antiparticle are still slightly different at presently available energies. To start with, one could look at three-body final states:

$$\begin{cases} \pi^- + P \rightarrow \pi^- \xrightarrow{\text{fast}} + (N + \pi^+) \xrightarrow{\text{slow}} \\ \pi^+ + P \rightarrow \pi^+ \xrightarrow{\text{fast}} + (N + \pi^+) \xrightarrow{\text{slow}} \\ K^+ + P \rightarrow K^+ + (N + \pi^+) \xrightarrow{\text{slow}} \\ K^- + P \rightarrow K^- + (N + \pi^+) \xrightarrow{\text{slow}} \end{cases}$$

One could also do this for inclusive experiments

$$\begin{cases} \pi^- + P \rightarrow \text{anything} + \text{slow } \pi^+ \\ \pi^+ + P \rightarrow \text{anything} + \text{slow } \pi^+ \end{cases}$$

By integration it is clear that these two cross-sections should be equal in the asymptotic limit.

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R E F E R E N C E S

- 1) T.T. Chou and C.N. Yang, Phys.Rev.Letters 25, 1072 (1970);
J. Benecke, T.T. Chou, C.N. Yang and E. Yen, Phys.Rev. 188, 2159 (1970).
- 2) R.P. Feynman, Phys.Rev.Letters 23, 1415 (1969).
- 3) L. Van Hove, Phys.Letters 28B, 429 (1969); Nuclear Phys. B9, 331 (1969).
- 4) Reviews on the subject are :
L. Van Hove, Physics Reports 1C, 348 (1971);
O. Czyzewski, CERN/D.PHII-Phys.71-8 (1971);
D. Horn, Physics Reports - to appear.
M. Jacob, Lectures at Erice and Les Houches (1971); CERN preprint TH.1340 (1971).
- 5) For a review, see :
G. Giacomelli, rapporteur's talk at the Amsterdam Conference on elementary particles, CERN preprint, September 1971;
see also :
Ref. 4), M. Jacob;
see, in particular :
J.V. Allaby et al., paper submitted to the Amsterdam Conference (1971);
L.G. Ratner et al., ANL-Bologna-Michigan collaboration, Phys.Rev.Letters 27, 68 (1971);
K. Winter et al., CERN-Hamburg collaboration, CERN preprint, October 1971 (submitted to Phys.Letters).
- 6) S.P. Denisov et al., Phys.Letters 36B, 415 (1971).
- 7) M. Holder et al., Phys.Letters 35B, 355 (1971); 36B, 400 (1971);
J.V. Allaby et al., Phys.Letters 36B, 504 (1971).
- 8) A. Martin, Nuovo Cimento 39, 704 (1965).
- 9) L. Van Hove, Phys.Letters 5, 252 (1963);
see also :
A.A. Logunov et al., Phys.Letters 7, 69 (1963).
- 10) H. Cornille and A. Martin - in preparation. A preliminary account of this work is contained in the lectures given by A. Martin at the 1971 Erice summer school, CERN preprint TH.1386 (1971).
- 11) A. Białas, J. Siciak and R. Wit, Acta Polonica 32, 651 (1971).
- 12) J. Bros, private communication;
see also :
R. Alvarez-Estrada, CERN preprint TH.1414 (1971).

A D D E N D U M

Important references are missing in this preprint. Related considerations with a somewhat different motivation have been made several years ago by Logunov and his collaborators, in particular in the following papers :

- A. Logunov, Nguyen Van Hieu and I.T. Todorov, Nuclear Phys. 67, 666 (1965);
Nguyen Van Hieu, R.V. Rerikh and A.A. Kelashvili, Nuclear Phys. 76, 551 (1968);
Nguyen Van Hieu, Proceedings of the CERN Topical Conference on high energy hadron collisions (1968).