PRELIMINARY RESULTS ON "GLANCING" COLLISIONS OF HIGH-ENERGY NEGATIVE PIONS

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(presented by A. J. Herz)

In this communication we report preliminary results on "glancing" collisions [1] of 6.1 and 18.1 GeV/c negative pions on charged and neutral targets in the large ($50 \times 60 \times 102$ cm^3) heavy-liquid bubble chamber of the Ecole Polytechnique [2]. The chamber contained a mixture of 87% propane and 13% Freon. In order to increase the detection efficiency for neutral pions (through materialization of at least one of the two photons) only events which lay within an acceptance volume near the entrance window were accepted for analysis. Interactions with strange-particle production were not considered.

INTERACTION ON PROTONS

Glancing collisions are expected to show low momentum transfer to the target; events were therefore selected according to the following criteria: (1) the number of secondary charged particles must be two or four, (2) one, and only one, of the secondaries must be an identified proton, (3) the momentum of the recoil proton must lie between 150 and 600 MeV/c (this ensures identification as well as low momentum transfer).

Our results are summarized in Figs. 1 and 2, where the transverse momentum of the outgoing pions is plotted against the longitudinal component of momentum $p^*_{\parallel \pi - p}$ in the pion-proton centre-of-mass system. Only inelastic events are considered, and there are separate plots for positive and negative secondaries and for the two primary momenta. The semicircles drawn on the graphs are the loci of points from elastic

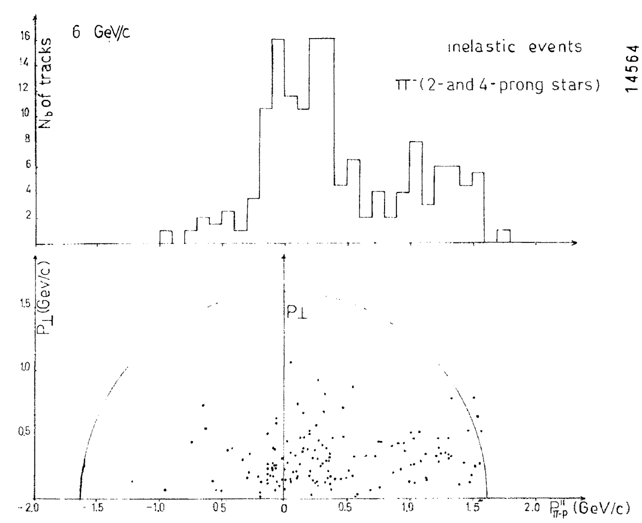

Fig. 1 a

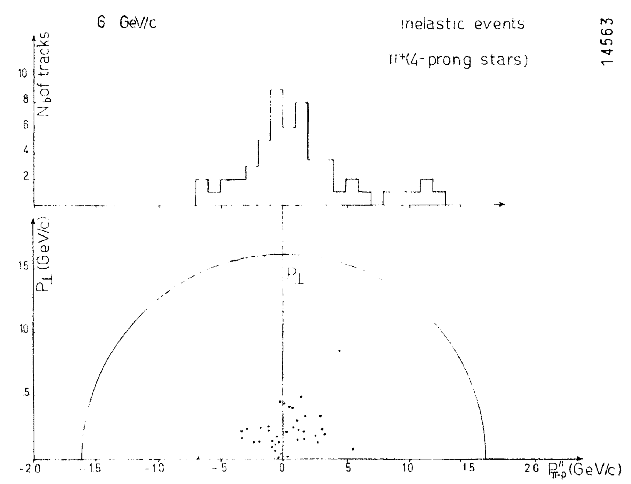

Fig. 1 b

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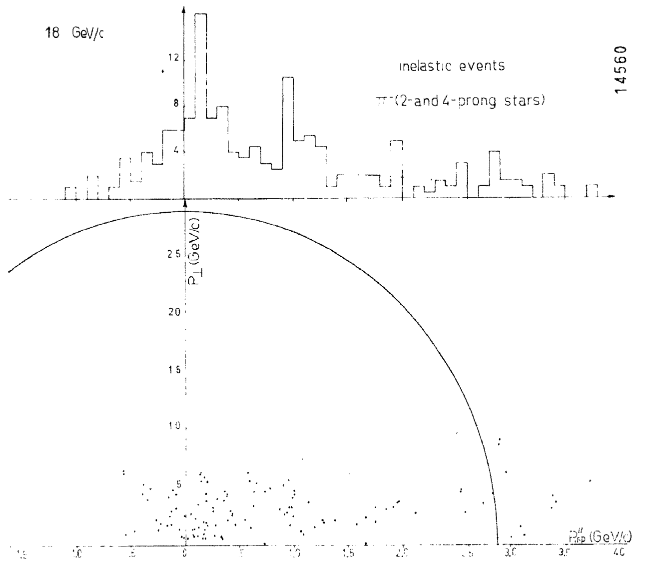

Fig. 2 a

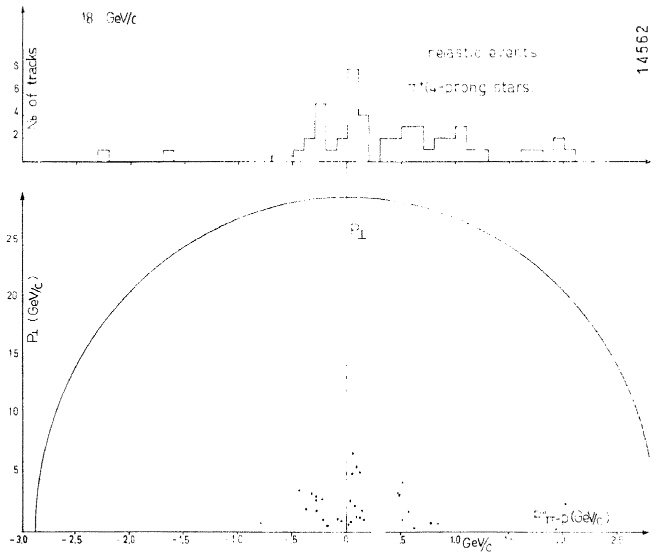

Fig. 2 b

interactions; their radius is the momentum of the primary in the pion-proton centre-of-mass system.

The forward collimation of the secondaries, associated with the backward collimation of the protons, is clearly visible. One also notes that the negative pions fall into two groups: one with lower momenta and features similar to those of the positive pions, the other a group of forward high-momentum particles with momenta close to the elastic value (we call this phenomenon quasi-elastic scattering). The occurrence of quasi-elastically-scattered negative secondaries, and the absence of positive ones, constitute evidence in favour of the suggestion by Drell and Hiida [3] that diffraction scattering of the incident pion off the virtual exchanged particle should occur.

NEUTRON-LIKE EVENTS AND DIFFRACTION DISSOCIATION

Neutron-like events with three charged prongs were selected and measured with the chief aim of investigating the possible occurrence of diffraction dissociation or Coulomb dissociation of beam particles [4]. Theoretical arguments suggest that of these two, diffraction is the more probable in this experiment where low-Z target nuclei predominate. We shall consider both processes under the general heading " diffraction ".

" Tridents ", i.e. neutron-like three-prong events can be the result of a collision of the primary pion with a nucleus acting coherently (diffraction dissociation); they can be collisions with a neutron in a nucleus in which the residual nucleus is left with little excitation, or one may be dealing with spurious events in which the other secondaries are neutral or too slow to be detected. To separate true coherent interactions from the background one may use the following criteria: (a) there must be energy and momentum balance between the primary and the three secondaries, (b) one invokes the uncertainty principle in the form $q_{\parallel} R > 1$, where $q_{\parallel}$ is the longitudinal momentum transfer to the target nucleus and $\hbar = c = 1$, which states that the interaction cannot be localized in a region whose dimension is less than $R \approx q_{\parallel}^{-1}$. Thus one finds for the case of interactions with carbon nuclei that the nucleus must have acted coherently if the momentum transfer to it was less than about 60 MeV/c.

130 tridents were measured at 18.1 GeV/c and 126 at 6.1 GeV/c. These events were taken to be neutron-like, although recoil protons with momenta below 130 MeV/c cannot be detected in this experiment, for both our data [5] and those of the CERN HBC group [6] suggest that very slow recoils are very rare in pion-proton collisions.

A very rough criterion, useful for the elimination of trident events which are definitely not due to diffraction dissociation is [7]

$$\frac{q_{\parallel\max}}{m_\pi} > \Sigma \sin \alpha_i$$

where $q_{\parallel\max}$ is the maximum permitted value (60 MeV/c for carbon) and the α_i are the angles between the

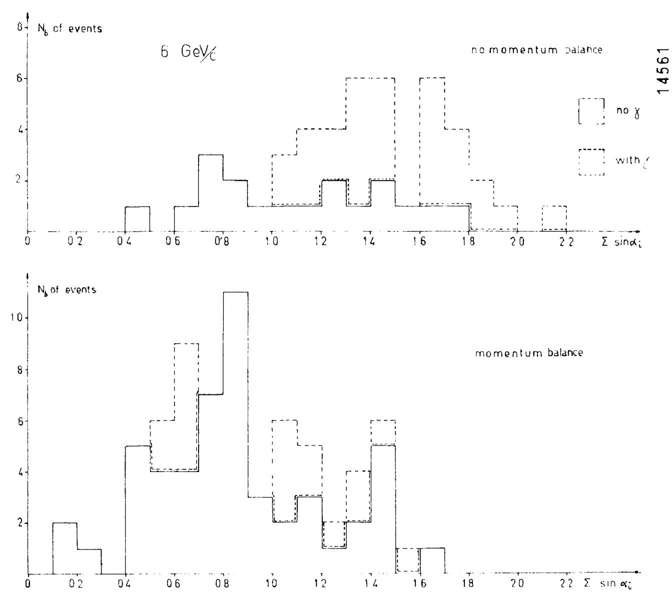

Fig. 3

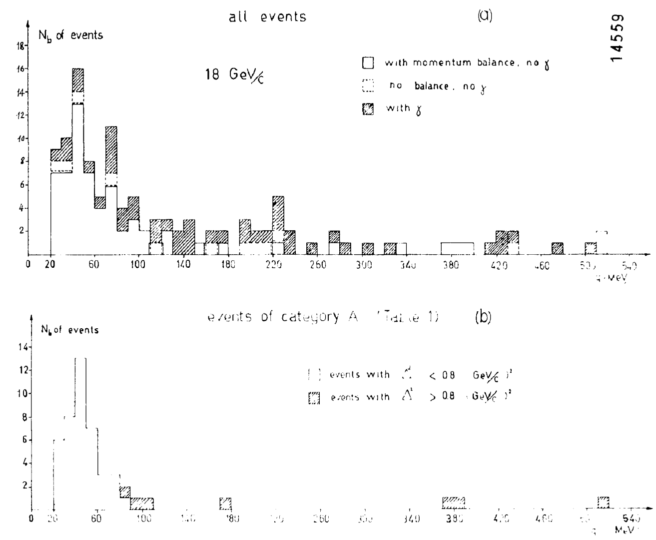

Fig. 4

secondaries and the beam direction. The distribution of $\Sigma \sin \alpha_1$ for the 6.1 GeV/c events is given in Fig. 3: for all but three of these events $\Sigma \sin \alpha_1$ exceeds the value of 0.44 appropriate for carbon targets. At 18.1 GeV/c on the other hand, 52% of the events fall within the limit. From this we conclude that diffraction dissociation does not occur, or is rare, at 6.1 GeV/c primary momentum, but may take place at 18.1 GeV/c. We therefore continue the consideration of the 18.1 GeV/c events.

It is very difficult to evaluate $q_{\parallel}$. We used a method due to Vegni [8] which gives $q_{\parallel}$ as function of M^*, the invariant mass of the three secondaries, and of α_M, the angle which the vector sum of the secondary momenta makes with the direction of the primary. It was assumed that the target is a carbon nucleus, an assumption which leads to error only when q is$_{\parallel}$ rather larger than 60 MeV/c, while simplifying the problem considerably.

The values of $q_{\parallel}$ thus obtained are plotted in Fig. 4 for various types of events (with and without momentum balance, with and without associated electron pairs). From Fig. 4a we note in particular that the events with momentum balance and without associated electron pairs are concentrated in the region of low $q_{\parallel}$, while the others are spread much more widely; 54% of all events with momentum balance and without pairs have $q_{\parallel}$ *below* 60 MeV/c. Taking all events at 18.1 GeV/c, irrespective of type, we find that about 30% of them meet the criteria for diffraction dissociation.

To try a different type of analysis one can attempt to classify the events as glancing collisions with a neutron. Of the tridents, the only ones which cannot be classified in this way are those in which all three secondaries are emitted forward in the pion-neutron

TABLE I

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18 GeV/c	N_b of events and %	Mean $\langle \Delta^2 \rangle$ (GeV/c)^2
A: Events with 3 charged secondaries emitted forward in C.M.S and no π^0 (with momentum balance and no γ)	41 + (7) [32.04% + 5.46%]	0.028
B: $\pi^+ \to \pi^-, \pi^-, \pi^+, \pi^0$; n	23 [17.9%]	
C: π^-, π^-, π^+; n	(1) [0.78%]	
D: π^-, π^+, π^-; n	6 + (5) [4.4% + 3.62%]	0.412
E: $\pi^-, \pi^0, \pi^-, \pi^+$; n	15 [11.7%]	
F: $\pi^0, \pi^0, \pi^-, \pi^+, \pi^-$; n	2 [1.56%]	
G: π^-, π^+, $m\pi^0$ m > 1 odd, $n\pi^0$ n > 0; n	9 [7.0%]	
H: π^-, $m\pi^0$ m > 0 even, $n\pi^0$ n > 0, π^+; n	4 [3.1%]	
I: π^-, π^+, $m\pi^0$ m > 0 even, $n\pi^0$ n > 0; n	11 [8.5%]	
L: π^-, $m\pi^0$ m > 1, $n\pi^0$ odd, π^-, π^+ n > 0; n	3 [2.2%]	
M: $n\pi^0$ n > 2 even, π^-, π^-, π^+; n	1 [0.8%]	

centre-of-mass system, and which have no associated electron pairs and show momentum balance. These events which cannot be due to one-pion exchange we call type A (see Table I). All the remaining events are classified as types B to M in Table I. This selection procedure leaves 38% of the tridents in class A, of which, as Fig. 4b shows, 70% have values of $q_{\parallel}$ below 60 MeV/c.

Further evidence for the existence of diffraction dissociation at 18.1 GeV/c comes from the distribution of the angle α_{M^*} plotted in Fig. 5. For type A events this distribution is in good agreement with the angular distribution for elastic scattering of pions calculated from the optical model, while the events from categories B to M in Table I give a very much wider distribution.

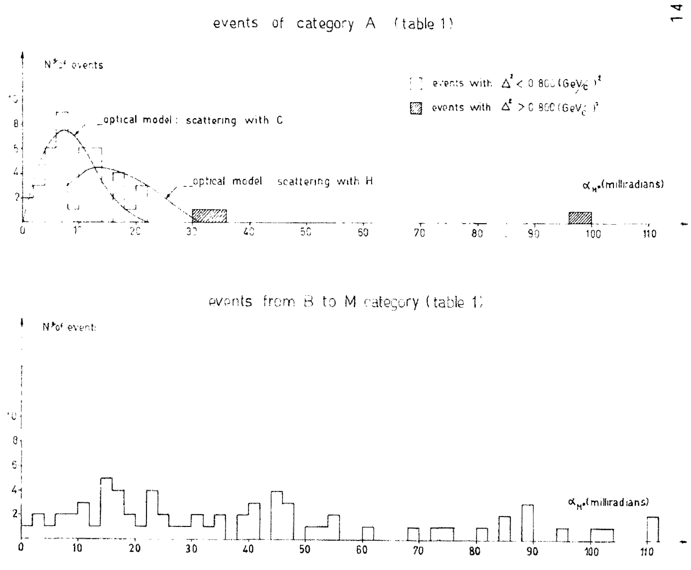

Fig. 5

LIST OF REFERENCES

1. S. D. Drell: Rev. Mod. Phys., *33*, 458 (1961); F. Salzman and G. Salzman: Phys. Rev., *125*, 1703 (1962).
2. M. Bloch, A. Lagarrigue, P. Rançon and A. Rousset: Rev. Sci. Inst., *32*, 1302 (1961).
3. S. D. Drell and K. Hiida: Phys. Rev. Letters, *7*, 199 (1961).
4. M. L. Good and W. D. Walker: Phys. Rev., *120*, 1855 and 1857 (1960).
5. G. Bellini *et al.*: Proc. Aix-en-Provence Conf. Elem. Particles, vol. 1, p. 449 (1961).
6. D. R. O. Morrison and Aurelia de Marco (private communication).
7. F. Baldassarre *et al.*: Proc. Aix-en-Provence Conf. Elem. Particles, vol. 1, p. 427 (1961).
8. G. Vegni (private communication).