Fermilab Library
0 1160 0019941 8

ALIGNMENT IN COSMIC RAY GAMMA-HADRON FAMILIES AND ITS POSSIBLE THEORETICAL INTERPRETATION

I. ROYZEN[*]
P. N. Lebedev Institute of Physics (FIAN)
Academy of Sciences of the USSR
Leninsky prospect 53, 117 924 Moscow, U. S. S. R.

and

Laboratoire de Physique Théorique et Hautes Energies[**]
Université de Paris XI, bâtiment 211, 91405 Orsay Cedex, France

hep-ph/9308218

LPTHE 92/57
November 1992

[*] On leave from P. N. Lebedev Physical Institute of Russian Akademy of Sciences

[**] Laboratoire associé au Centre National de la Recherche Scientifique

Few years ago the observation has been made [1] in cosmic ray experiments that the alignment of main energy fluxes along a straight line in target (transverse) plane exceeds significantly the background level. More precisely, at superhigh energies of initial particle ($E_0 \geqslant 10^{16}$ eV) the secondary particle superfamilies detected by deep lead X-ray emulsion chamber appeared to be situated almost almong a straight line in target plane (Fig. 1). The coplanar scattering of such a type was so surprising that an attempt has been undertaken to revise the results but instead they were confirmed with much better confidence level [2]. The analysis of the alignement effect for 74 γ-families and hadron-induced within chamber γ-families of energies $\Sigma E_\gamma = 100 \div 5000$ TeV (the hadron energies being restored, accounting that the energy of induced γ-family is about 1/3 of the hadron one) has been carried out. This analysis suggested that superfamily production happened predominantly low above the chamber (at the altitude $H \simeq 2$ km, since nuclear-electromagnetic cascade development would blur alignment, if several interactions contribute). It showed a coplanar scattering and scaling-like fragmentation spectrum of energy distinguished cores. The alignement parameter

$$-0.5 \leq \lambda = \frac{\sum\limits_{i \neq 0}^{m} \sum\limits_{j \neq k} \cos 2\,\Phi_{ijk}}{m(m-1)(m-2)} \leq 1$$

was used as the alignment criterion, where m stands for a number of centers of highest energy and ϕ_{ijk} is the angle between $\vec{k}i$ and $\vec{k}j$ vectors ; an event was recognized to have alignement, if $\lambda \geq 0{,}6$. Actually the events with $m = 4$ were chosen only, because statistical background is too high at $m = 3$, and rather poor statistics at $m = 5$ is available.

The experimental results are shown in Fig. 1-3 quoted from ref. [3] and in Fig. 4, 6 [4] where the abbreviations were used : E (energy distinguished core) ; XEC (X-ray emulsion chamber) ; MSF-model (mixed scaling fragmentation model [5]) ; E_γ is equal to EDC energy. Fourteen events with $\Sigma E_\gamma \geq 500$ TeV were observed where alignement was the most striking ($\lambda \geq 0.8$). Core transverse momentum p_T was estimated by rough relation $p_T H \simeq E_\gamma R$, R being a distance of spot from interaction axis. The ratio of mean value of relative core transverse momentum to its normal (in target plane) projection to the alignement line is $\langle p_T \rangle / \langle p_T^\perp \rangle \simeq 10$. No other peculiarities of the alignment events compared to "usual" cascades were noticed.

The purpose of present paper is to discuss the possible qualitative explanation of the above cosmic ray observations. Many properties of the alignement effect favour to consider it as a result of hard double inelastic diffraction (HDID) happened in the last hadron interaction just above ($H \approx 2$ km) XEC. Let us trace them step-by-step.

1. The threshold energy of the effect is about $\Sigma E_\gamma \simeq 100$ GeV, what is properly correlated with that of HDID [6].

2. The most important point is related to transverse momentum transfers. Making use of Fig. 1 and formula $p_T H = E_\gamma R$, it is easy to estimate that total transverse momentum of cores with $E_\gamma = 180$ TeV, 700 TeV and 279 TeV with respect to the core with $E_\gamma = 900$ TeV is about 3 GeV. In accordance with Fig. 4 this estimate should be typical for all alignment events observed. On the other hand, the exclusive peculiarity of HDID is that its differential cross-section remains nearly constant within a rather large p_T-domain, since it is proportional to three-Pomeron vertex squared $r^2(p_T^2)$, Fig. 5, which is, in turn, controlled by Pomeron

trajectory $\alpha_P(p_T^2)$ only. Namely, $r^2(p_T^2)$ is expected to be nearly constant within a domain $\langle\alpha'_P(p_T^2)\rangle\, p_T^2 < 1$. Since $\langle\alpha'_P(p_T^2)\rangle$ is less than $\alpha'_P(0) \simeq 0.2$ GeV^{-2}, this domain is compartible with transverse momenta typical for alignment events. (By the way, the experimental evidence has been obtained [7] long ago that $r(p_T^2) \simeq$ const $\simeq 0.8$ GeV^{-1} at least within the domain $p_T^2 \leqslant 2$ GeV^2).

3. The invariant mass of the whole 4EDC jet distribution, shown in Fig. 6, is compatible with inelastic diffraction picture too : typical mass values $\langle M^2\rangle \approx (60\,^{+120}_{-60})$ GeV^2, corresponding to this distribution, are suitable for inelastic diffraction because $\langle M^2\rangle/2\Sigma E_\gamma(\text{GeV}) \simeq 10^{-3}$.

The set of properties spoken of could be explained, if one assumes that the above alignment effect is originated by HDID and is nothing but a target plane projection of string ruptures between semihard scattered fast quark or diquark and incident hadron remnants, Fig. 7(a), (b). At very small ratios $M^2/2\Sigma E_\gamma(\text{GeV})$ this mechanism of quark decolourization seems to be much more favorable energetically, than any other one because it refers to a string of minimal energy. As to string parameters they seem to be quite reasonable too. In accordance with Fig. 4, the average value of relative core transverse momentum within a string is $\langle p_T\rangle \simeq 1$ GeV (if a hadron interaction altitude is $H \simeq 2$ km) and, therefore, average total transverse momentum normal to string orientation $\sqrt{2}\,\langle p_T^{\perp}\rangle \simeq \sqrt{2}\,.\,0.1\,\langle p_T\rangle \simeq 0.15$ GeV which is compartible (taking into account the accuracy of cosmic ray experiments) with the mean value of transverse momenta of secondaries in hadron interaction at cms energies of the order of values M involved. It is worthy to add that observed independence of $\langle p_T\rangle$ to alignement

effect can be easily understood by accounting of mixed string fragmentation mechanism of hadronization, shown in Fig. 7(c), which leads to the same value $<p_T>$ in the events with and without 4-core's alignment.

Of course, the suggested qualitative consideration is to be confirmed or refute by LHC and SSC accelerator experiments only.

Acknowledgments

Author is deeply thankful to Professor A. Capella, Professor A. Managadze and Professor J. Tran Than Van, for valuable discussions.

References

[1] Pamir collaboration, "On halo structure of big gamma-families", Izvestiya AN SSSR, ser. fiz., v. 49, n° 7, p. 1285-1287 (1985). (in Russian).
Pamir collaboration, "Analysis of structure of halo in families with energy ≥ 500 TeV", Proceedings 5th International Symposium on Very High Energy C. R. Interactions, Lodz, v. Contributed Papers, p. 9-14 (1988).

[2] T. P. Amineva, G. F. Fedorova et al., "Alignment of increased background region in gamma-hadron superfamilies", Proceedings 6th International Symposium on Very High Energy C. R. Interactions, Tarbes, 1990, v. Contributed Papers, p. 264-267 (1990).

[3] I.P. Ivanenko, V. K. Kopenkin, A. K. Managadze, I. V. Rakobolskaya, Pisma JETF v. 56, p. 192-196 (1992).

[4] A. K. Managadze, private communication.

[5] I. P. Ivanenko, A. K. Managadze, R. A. Muhamedshin, G. F. Fedorova, "Simulation of gamma-hadron superfamilies", preprint NIIJF MGU, n° 90-21/167, part I, n° 1, 44 p. (1990).

[6] A. Mironov, I. Royzen, Sov. Jad. Fiz., v. 47, 1125 ; v. 48, 194 (1988).

[7] A. Alberi, G. Goggi, Phys. Rep., v. 74, n°1 (1984).

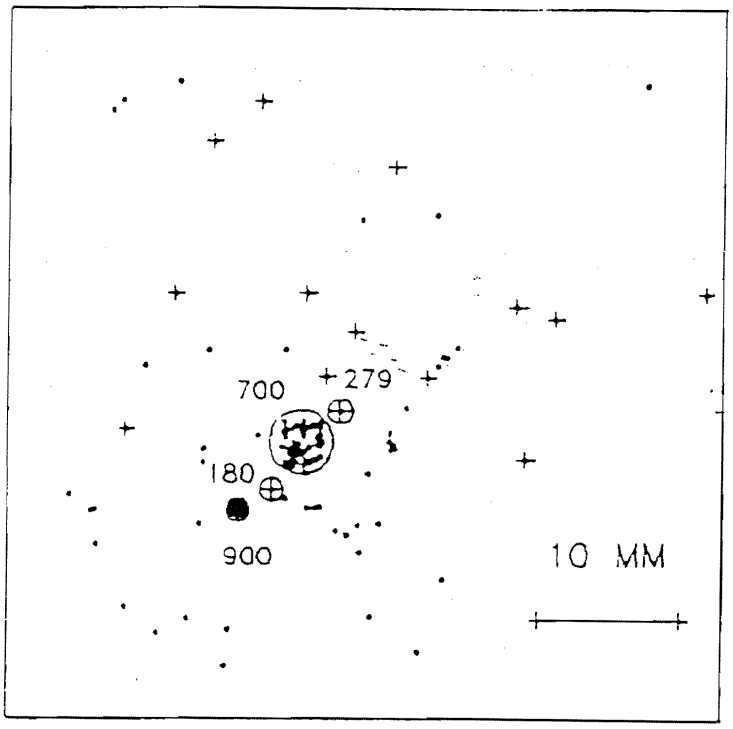


Fig. 1.

The example of target diagram with energy distinguished cores for the event with alignment (the family Pb-6). λ_4=0.95.

Figures stand for energy in TeV (already multiplied by 3 for hadrons).

EDC: ⊙ - electromagnetic halo; ⊗ - hadron halo; ⊕ - hadrons.

Family particles: • - gamma-quanta; + - hadrons.

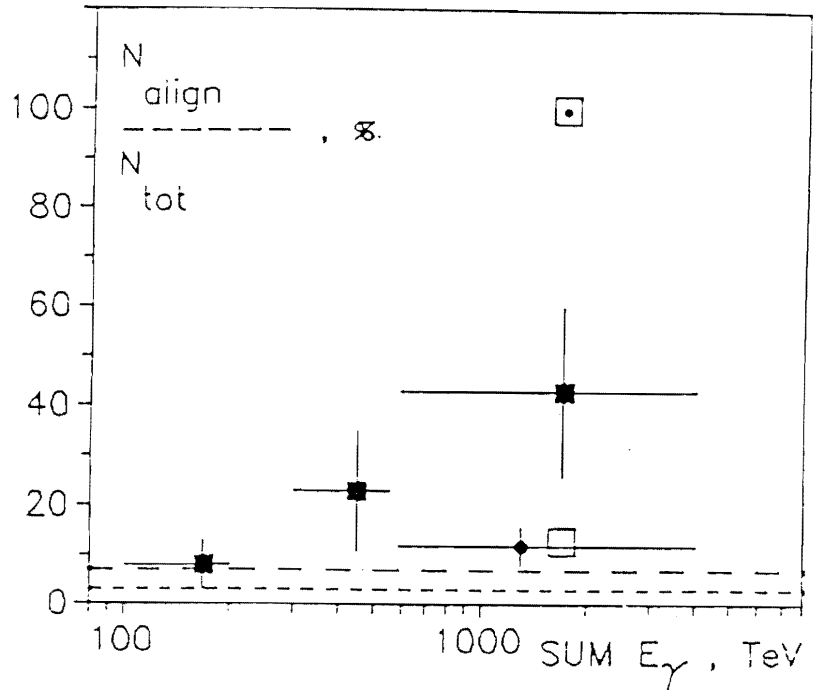


Fig. 2.

The dependence of fraction of events with alignment on the family energy (for selection criterion $\lambda_4 \geqslant 0.8$).

■ - experiment, deep lead XEC;

● - experiment, carbon XEC;

⊡ - 100% of events with alignment, incident upon chamber.

□ - estimation of the fraction of events with alignment according to simulation, taking the difference of detection conditions into account for lead and carbon XEC.

——— - the fraction of events with alignment among simulated families (MSF - model),

- - - - the fraction of events with alignment for 4 random incident points.

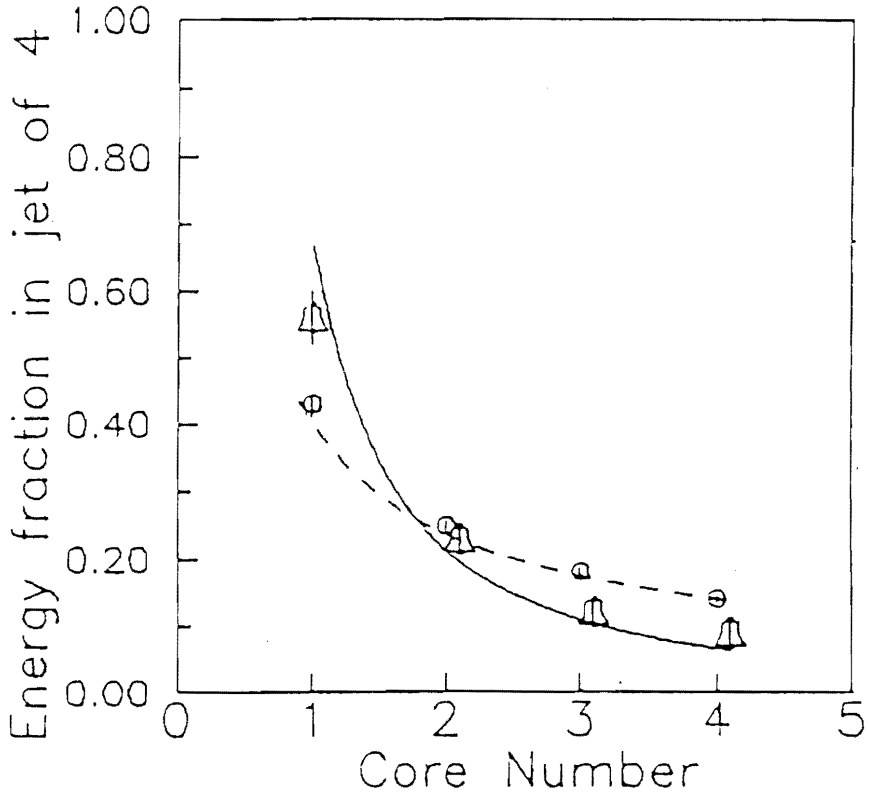


Fig. 3
Energy fraction distribution among
the most energetic 4 cores in a family.

ooooo Pb–experiment, Sum E_γ = 100–500 TeV
ΔΔΔΔΔ Pb–experiment, Sum E_γ > 500 TeV
——— MSF–model: just in interaction at E_o = 10 PeV
- - - - MSF–model: simulated families for any Sum E_γ

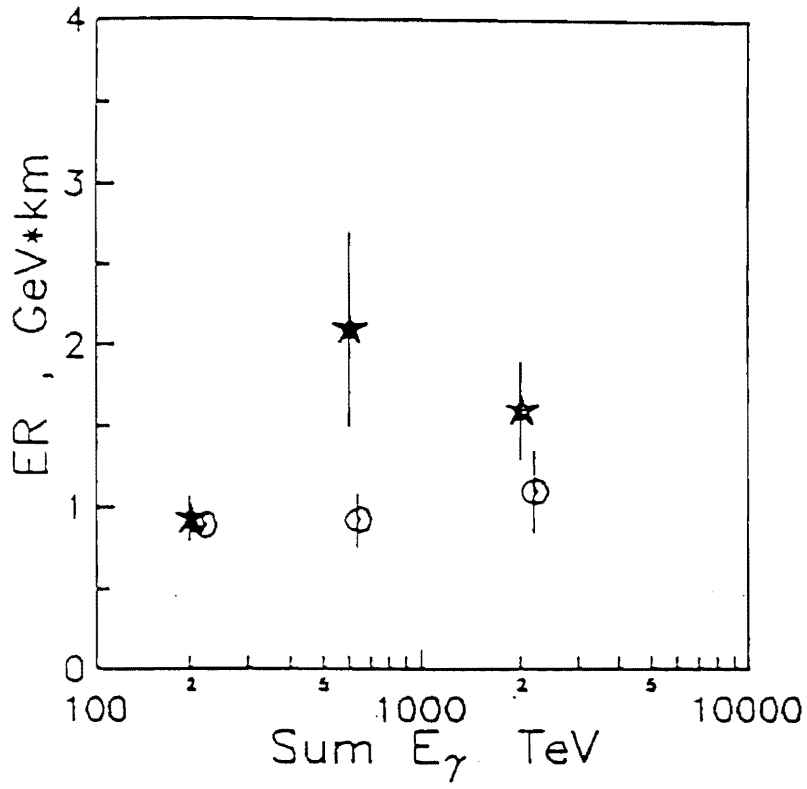


Fig. 4
The dependence of average ER within the jet of 4 EDC on the event energy.

★★★★★ Pb—chambers experiment
⊙⊙⊙⊙⊙ MSF—model

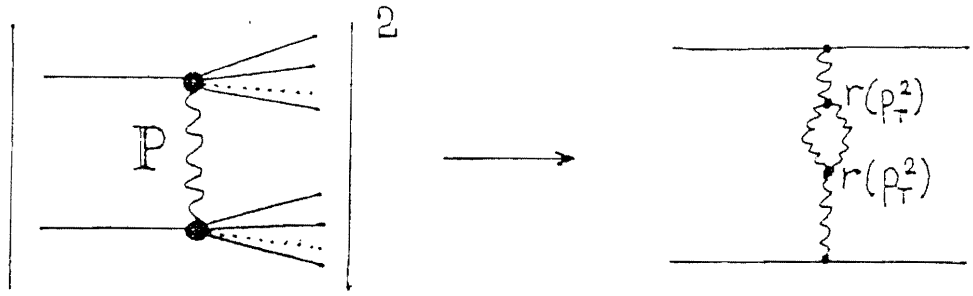
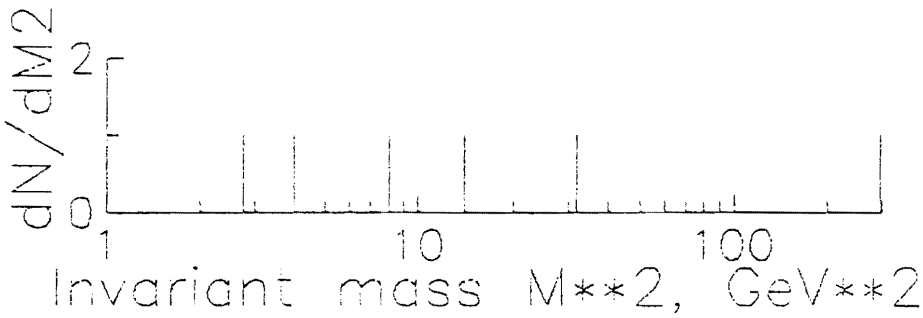


Fig. 5

Events with alignment



Events without alignment

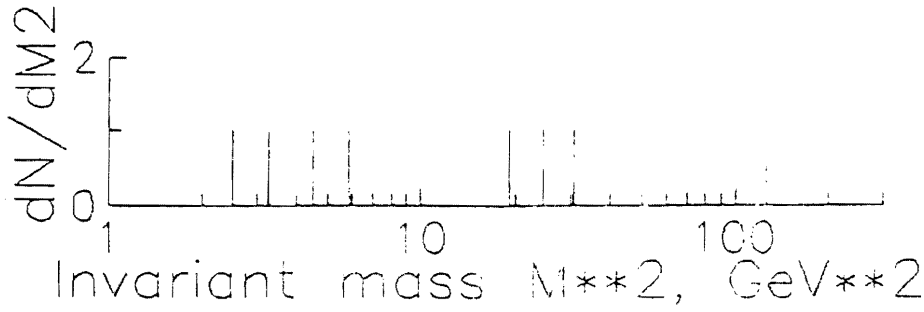


Fig 6

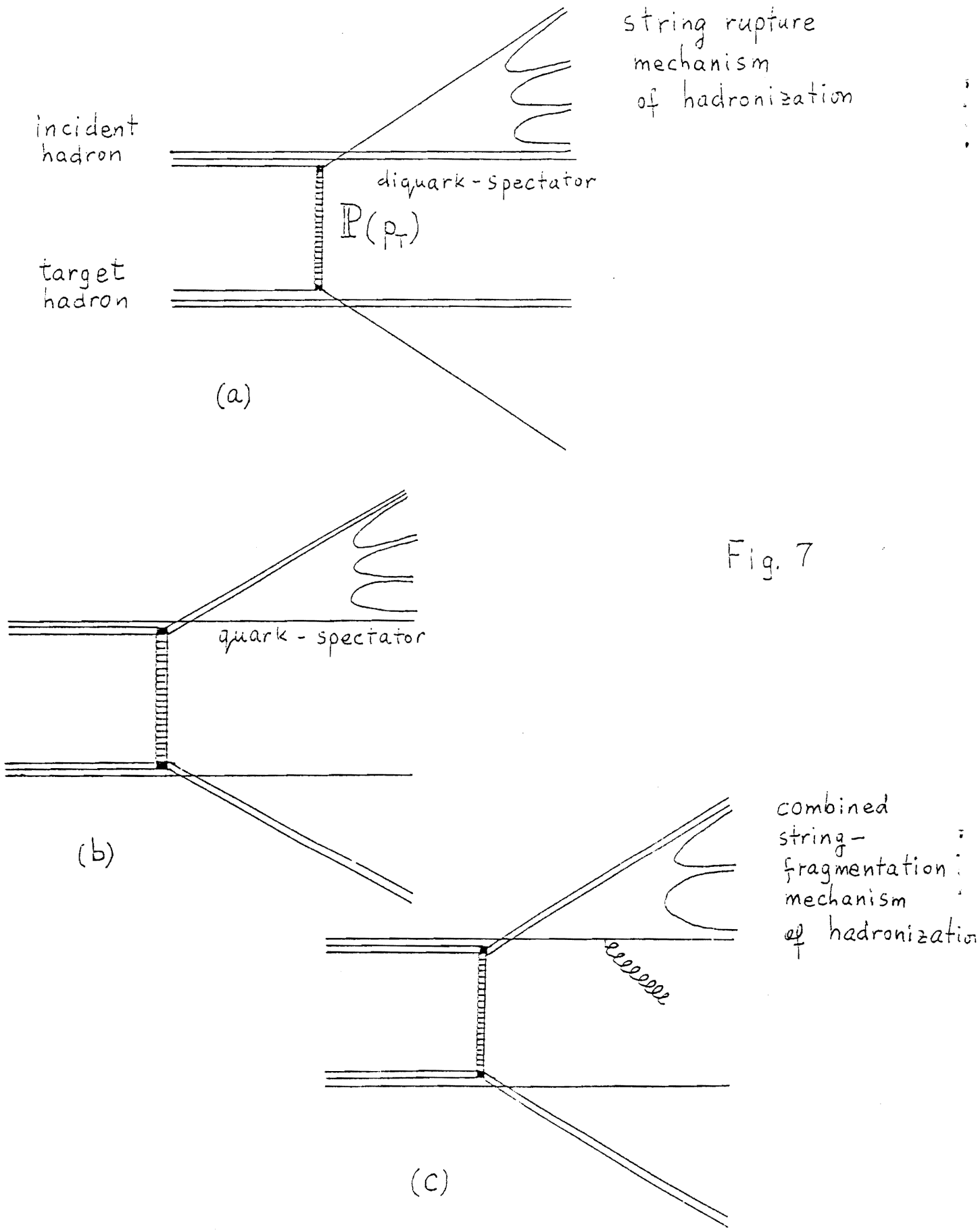

string rupture
mechanism
of hadronization
incident
hadron
diquark - spectator
$\mathbb{P}(p_T)$
target
hadron
(a)
quark - spectator
(b)
combined
string-
fragmentation
mechanism
of hadronization
(c)

Fig. 7