COLLIMATED GROUPS OF PARTICLES AS POSSIBLE MANIFESTATION OF HEAVY MESON PRODUCTION

Yu.A.Smorodin
P.N.Lebedev Physical Institute,
Academy of Sciences USSR, Moscow

ABSTRACT

The interpretation of miniclusters containing hadrons as well as γ-quanta by the cascade decays of heavy mesons, in the first turn, of charmed D^*-mesons is discussed.

1. Introduction.

Narrow groups of particles (NGP) - miniclusters - innovated by the Japan-Brazil collaboration /1/ have been intensively investigated in recent years with big scale X-ray film chambers.

We omit here for brevity the papers on chirons, where NGP have been considered as a new sort of produced particles, and confine ourselves to those examining the characteristic features of miniclusters themselves.

Investigated in the paper /2/ among the hadrons in chamber hadron blocks have been NGH. The paper /3/ considers NGG among the γ-e particles in G-block that failed to be accounted for without assuming availability of hadrons in the groups. The paper /4/ is concerned with distances from hadron to nearest cascades in family, indicating that hadrons fall into the narrow groups together with γ-e particles.

The conventional interpretation of NGG is electron-photon cascade being some cascade units of atmosphere above the chamber. Local nuclear interactions in the chamber target /5/ seem to be a trivial source of NGH. However NGP registered in the G- and H-blocks containing both hadrons and γ-e particles apparently cannot be interpreted by the known interaction processes that stimulate search for the new phenomena.

The purpose of the present paper is to show that the nontrivial NGP seem to be interpreted by the generation and subsequent decay of heavy mesons, in the first turn, by the charmed D^*-mesons now sufficiently well known /6/.

This possibility caused serious difficulties earlier due to the fact that the theoretical estimation on the charm production even at superhigh energies was small. Having suddenly revealed a high yield of D^*- mesons (up to 20%) in the jet particles, due to hard scattering of gluons, the experiment carried out with the SPS collider made it clear that earlier estimates disregarding some essential features (glueballs?) of the charm production are much lower. It is possible to treat nontrivial NGP as the manifestation of heavy mesons generation; high cross section of their production has been indicated in cosmic rays earlier /8,9/.

NGP could appear due to the strong interactions in the last tens meters of the atmosphere above a chamber. However the layer thickness less than 1/100 nuclear path is too small to explain the NGP flux, and the overhead floor is too low ($\sim$ 1 m) to account for the dimensions of NGP by the interactions in the floor substance.

2. Main characteristic features revealed by experiments.

Let us summarize the main characteristic peculiarities of NGP as they are established in the mutually consistent experiments.

1) The nature of NGP particles. As noted above, nontrivial NGP comprise γ-e particles and hadrons.

The penetrating ability of miniclusters due to hadrons has been pointed to in all the papers on chirons, from /1/. The most convincing and essential for estimates of NGP flux are the results of /3,4/.

In /3/, 30 γ-families each including more than two hadrons, necessary to sew accurately together cascades in the G- and H-blocks, have been selected among 54 γ-families with $\sum E_\gamma > 100$ TeV. Out of 1700 cascades in the G-block 156 were chosen (at threshold 2 TeV) and 130 (at threshold 4 TeV) penetrating into the H-block. One third of them had the spot optical density in the H-block exceeding that in the G-block. The simulations show that these very 3% of all γ-e particles are the penetrating nontrivial NGG. Seven of 30 such events in the G-block manifest a clearly revealed structure. Four events with 2-4 particles each in both blocks are presented in /3/ as a typical example of NGP.

In /4/ for 15 γ-families with $\sum E_\gamma > 100$ TeV, containing at least one hadron, distances R_{min} from a hadron to the nearest family cascade have been determined. The distribution over R_{min} (Fig.2) shows that 1/3 of the hadrons has a narrow, within 1 mm, accompaniment, i.e. belongs to an NGP.

2) Intensity of NGP flux. According to the data of /3,4/ the NGP flux can be estimated as 3% of the γ-e multiplicity of the γ-families and as 1/3 of the hadron number, with respect to the rate of γ-families with $\sum E_\gamma > 100$ TeV being 0.35 m^{-2} $year^{-1}$ (Pamir's data /10/). Using the data of /10/ on the mean family multiplicities one can obtain the general estimate consistent with the both results, i.e. there is on average about 1 NGP in a family with $\sum E_\gamma > 100$ TeV. This value seems to be strongly fluctuate.

3) Multiplicity of hadrons and γ-e particles in NGP. Experiment fails to give detailed information on the multiplicity of hadrons and γ-e particles and their correlation in NGP. Fig.1 shows the data available: the multiplicity of γ-e particles and hadrons in all NGH and NGG /2/, only 1/3 of them being nontrivial, and the total multiplicity of miniclusters observed in the two-layer chamber /1/. The distribution sharply falls so that the contribution of n = 5 decreases to several per cent.

For NGG $\langle n \rangle = 2.2$, for NGH $\langle n \rangle = 2.0$, and the total registered multiplicity in miniclusters with $n \geq 2$ seems to be about 4 ± 2. Note that these data can be treated as preliminary ones since the identification of hadrons and estimation of their registration efficiency for the decay cascades are very complicated.

4) Distribution over distances R. The summary of data on distances between the particles in NGP is shown in Fig.2, i.e. the distributions for NGH /2/ and those over R_{min} /4/. The former is distorted by the selection of events with $R < 0.5$ mm, the latter maximizes at 0.2 mm and extends to ~ 1 mm, where turns to usual distribution for family particles.

5) ER distribution. Fig.3 represents data /1/ on $\langle ER \rangle$ of miniclusters penetrating into lower chamber. The mean value is $\langle\langle ER \rangle\rangle = 2.0 \pm 2.2$ TeV m. The estimate of ER for NGH /2/ is close to that. The experiments don't show any differences in ER values for hadrons and γ-e particles,

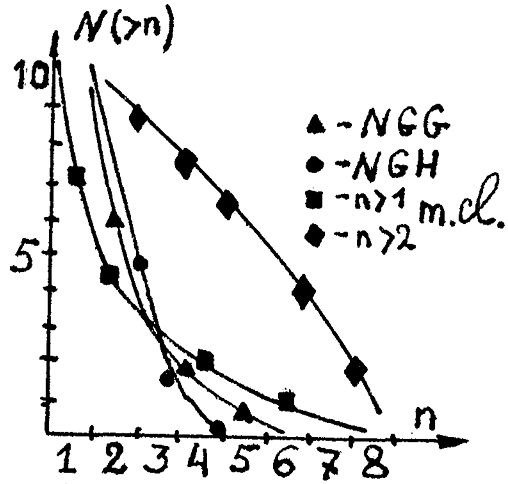

Fig.1. Data on n-distribution.

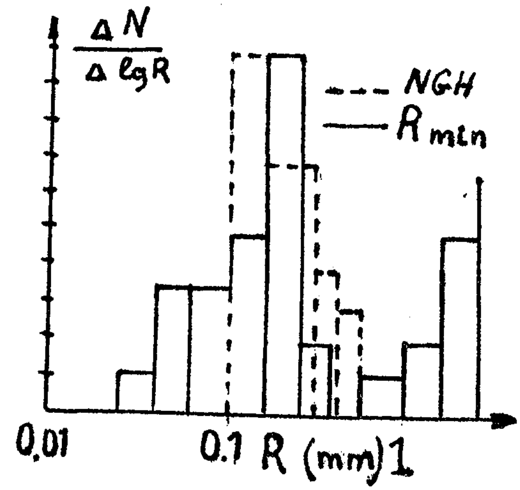

Fig.2. Data on R-distribution.

and seem to estimate the P_t value about 10 MeV/c.

It should be noted that small sizes of miniclusters are emphasized by the selection rules. The family target diagrams in /1/ show that in a number of events a minicluster is surrounded by particles with R $\sim$ 10 mm. The partial separation of the narrow peak in Fig.2 shows that this is really the case.

We think it premature to discuss the large cross section of strong interaction of miniclusters reported in /1/ since narrow beams of particles are observed. In /2/ the authors noted a weak absorption of NGH in chamber target, which is also natural for the beams.

3. Charmed and heavy mesons.

The experiment /7/ reveals the production of charmed mesons in excited D^*-state, which decay momentarily into D and π-mesons and quanta. Assuming the production of D^{+-} and D^0-mesons to be symmetric one can obtain from /8/ the main signatures of the decays and their probabilities:

1) 2h - 32% 2) h+2γ - 42%

3) h+γ - 28% .

These modes occur with small decay momenta, providing particle transversal momenta $\lesssim$ 10 MeV/c.

The subsequent decays of D-mesons occur at ct value about 0.03 cm leading to paths $\sim$10 m at particle energies of tens TeV. The lepton modes with signatures including e^{+-} and μ^{+-} are about 20%.

Among a bulk of hadron decays producing K and π-mesons one can single out the following signatures with possibilities:

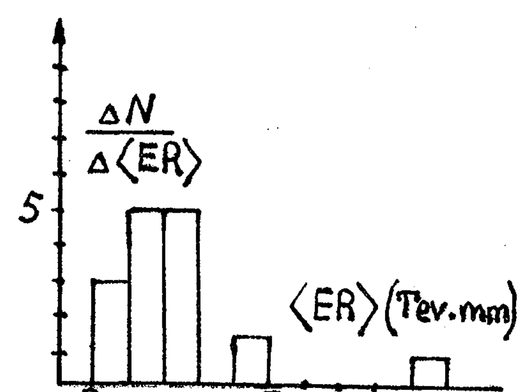

Fig.3. Data on ER-distribution.

1) 5h - 6% 2) 4h - 10% 3) 3h - 11% 4) 2h - 3%
5) 3h+2γ - 2% 6) 2h+2γ - 11% 7) 2h+4γ - 1% 8) h+nγ - 4%

The total decay momenta of these modes are hundreds MeV/c, but at a great number of particles after decay their transverse momenta are usually equal to tens MeV/c. For energies per particle 10 TeV NGP with $R < 1$ mm should be observed at paths ~ 100 m, the observation efficiency being estimated as 1/5 - 1/2.

Considering the meson systematics one can infer difference between the energies of the excited, $^3S_1$, and ground, $^1S_0$, states of mesons with quark mass increase. Thus, we should expect that the heavy mesons would generate NGP if value of their cross-section production is essential.

4. Discussion and results.

1) In the present half-qualitative analysis of the experimental data on NGP characteristics, i.e. multiplicity data, spatial-R and momentum-P distributions of NGP are consistent with the interpretation of NGP as cascade decays of charmed mesons.

2) Experimental estimations of the rate of NGP registration, namely about 1 observed NGP per γ -family with $\sum E_\gamma > 100$ TeV (nuclear-electron cascade initiated by primary proton at energies $\gtrsim 3 \cdot 10^{15}$ eV in the atmosphere) at observation efficiency 1/2 - 1/5, don't contradict the extrapolation of the latest SPS data on the superhigh energies and the data by K.Niu /8/ in cosmic rays.

3) Verification of the results seems to be possible when selecting and processing systematically by scanning X-ray films of hadron chambers with NGP. To compare experimental data with theory it is necessary to simulate decay cascades including the real efficiency of the particle registration.

4) The search for decays of heavy mesons which do not lead to NGP production, electron decays, etc. is also necessary.

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