JOURNAL OF THE PHYSICAL SOCIETY OF JAPAN Vol. 17, SUPPLEMENT A-III, 1962
INTERNATIONAL CONFERENCE ON COSMIC RAYS AND THE EARTH STORM Part III

III-7-5. Statistical Analysis of High Energy Jet Phenomena

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§1. Introduction

In the high energy nucleon-nucleon collisions, several authors have proposed a model which predicts that the angular distribution of the emitted particles from high energy jets should show a characteristic shape, that is, the probability density function $f(X)=dN/dX$ should have two symmetrical maxima (where $X=\log[\gamma_c\cdot \mathrm{tg}\,\theta_L]$, γ_c: the Lorentz factor of the initial or target nucleon in the c.m.s., θ_L: the angle of the secondary particle with respect to the primary direction in the laboratory system). Nikol'skii and Mishakova[1] insist that the two-center shower production mechanism can be explained as the statistical fluctuations of the angular distribution of the form $\log F/(1-F)=X$. Gierula, Miesowicz and Zielinski[2] analysed experimental data using the variable X/σ (σ:the standard deviation of X) and the parameter D, and concluded that the two-center model serves as a useful hypothesis.

The analyses done so far examined whether there exists *one* type of probability density function that can explain the experiments well. We should like to say that there exist the various types of the events in jet phenomena, and we have to regard the probability density function as composed of *two* (or more) probability density functions.

§2. Method of analysis

For the present we restrict ourselves to the cases where $n_h\leq 2$, $15\leq n_s\leq 25$, (so $<n_s>\sim 20$) and $25\leq\gamma_c\leq 100$. From the condition $n_h\leq 2$, we expect that the events we treat are almost the one initiated by the nucleon-nucleon collisions.

We take the square root of the second moment $\sigma_{(2)}=\sqrt{\Sigma X^2/n_s}$ as the characteristic of the jets. The dependence of the distribution of $\sigma_{(2)}$ on γ_c exists (Fig. 1).*

Under these rather restrictive conditions, we assume that there exist two types of jets: one is the two-fire-ball-like one with definite Lorentz factor of the fire ball, γ_M, and another one. From the 18 experimental data[3-6] the F-plot shown in Fig. 2 is obtained. We regard this to have a gradient 1, so $f(X)=10^X\log 10/(1+10^X)^2$. Then this pro-

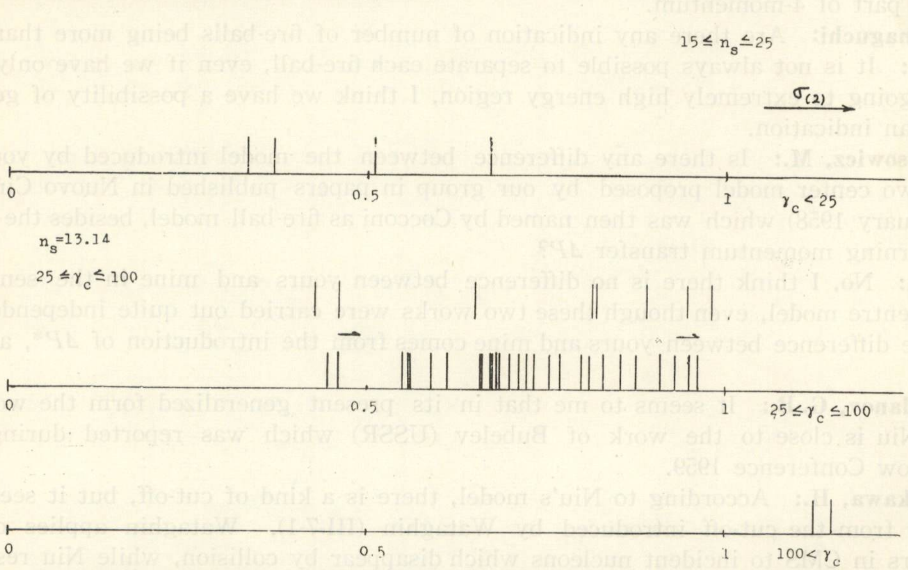

Fig. 1. The distribution of $\sigma_{(2)}$ of the experimental data with various range of n_s and γ_c.

* The data from 3) 4) 5) 6) 7) are used.

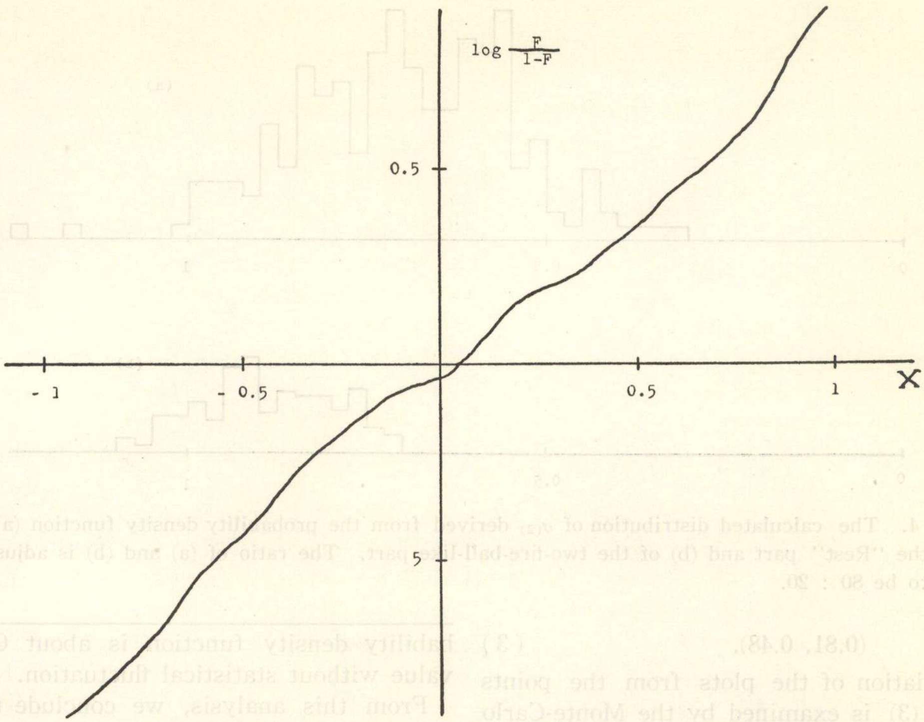

Fig. 2. The F-plot obtained from the 18 experimental data from 4) 5) 6) 7).

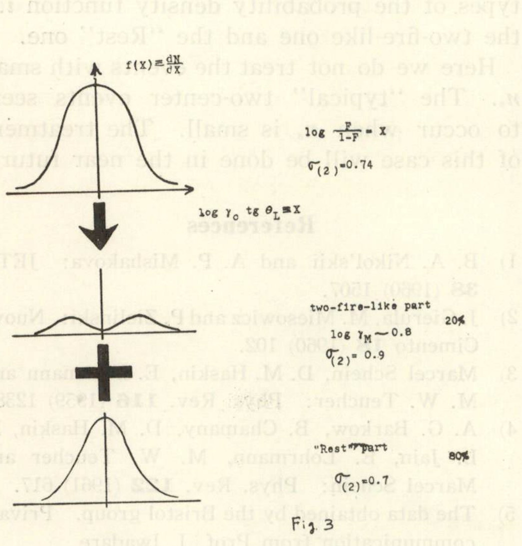

Fig. 3. The illustration of the division of the probability density $f(X)=10^X \cdot log\ 10/(1+10^X)^2$ into two parts, one: two-fire-ball-like part, and the other: the "Rest" part.

bability density function is divided into two parts, one: two-fire-ball-like part, $\sigma_{(2)}=0.9$ and the total probability of which is 20%, say, and the other, "Rest" part: $\sigma_{(2)}=0.7$ and total probability 80%* (Fig. 3).** Then $\gamma_M \sim 6.6$. This value of γ_M seems to be rather small for the "two-center" events. In fact the "typical" two-center events occur when n_s is small, so this smallness of γ_M is reasonable.

We adopt the other quantity $\sigma_{(4)}^4 - \sigma_{(2)}^4$ ($\sigma_{(4)}^4 = \Sigma X^4/n_s$: the fourth moment of X) as the characteristic of the events, and we plot $\sigma_{(2)}^2$ *vs* $\sigma_{(4)}^4 - \sigma_{(2)}^4$. If the event of $n_s=20$ is such that the gradient of its F-plot is 1, its plot without statistical fluctuation gives us the point

$$(\sigma_{(2)}^2,\ \sigma_{(4)}^4 - \sigma_{(2)}^4) = (0.55,\ 0.56). \tag{1}$$

On the other hand, the plots of the two-center events with various γ_M without statistical fluctuations are on the straight line

$$\sigma_{(4)}^4 - \sigma_{(2)}^4 = 0.55\,\sigma_{(2)}^2 + 0.035. \tag{2}$$

The point corresponding to the two-fire-ball-like part we adopt here is

* The gradient of the "Rest" part in the F-plot near $X=0$ is about 1.2.

** We adopted figures $\sigma_{(2)}=0.9$, 20%; $\sigma_{(2)}=0.7$, 80% tentatively consulting with the experimental data.

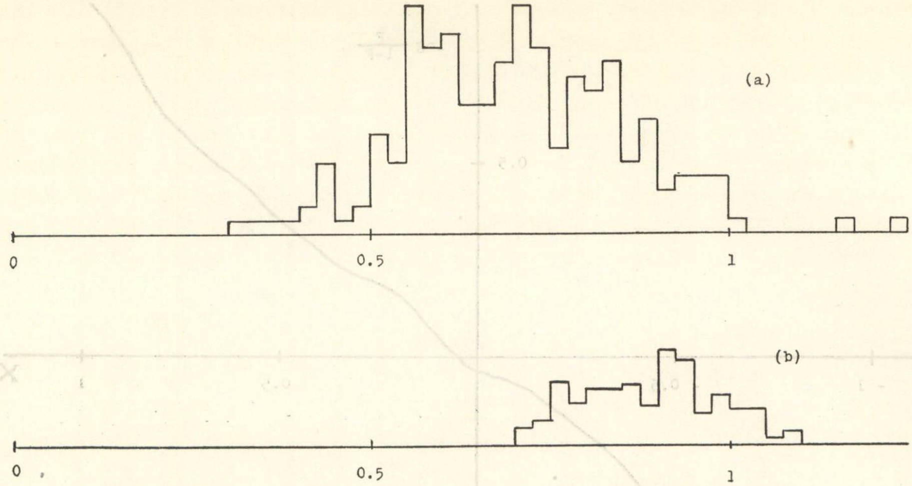

Fig. 4. The calculated distribution of $\sigma_{(2)}$ derived from the probability density function (a) of the "Rest" part and (b) of the two-fire-ball-like part. The ratio of (a) and (b) is adjusted to be 80 : 20.

$$(0.81,\ 0.48). \tag{3}$$

The deviation of the plots from the points (1) and (3) is examined by the Monte-Carlo method and the comparison with the experimental data is done.

§ 3. Results and Conclusions.

We calculated 100 events based on the two-fire-ball-like probability density function and 400 events the "Rest" probability density function. In both cases we take $n_s=20$. The distributions of $\sigma_{(2)}$ are shown in Fig. 4. The distributions of $\sigma_{(2)}^2$ *vs* $\sigma_{(4)}^4-\sigma_{(2)}^4$ are shown in Fig. 5 (a), (b). (In Fig. 5 (b), we show only the half of the events we calculated, *i.e.* 200 events). The two regions corresponding to the two probability density functions are overlapping a little each other. And we can say to which region each event belongs. The region corresponding to the probability density function of which gradient in F-plot is 1, cannot explain why the experimental plots scattered so widely. (Fig. 6)*

It may be noted that the mean value of $\sigma_{(2)}$ calculated from the two-fire-ball-like probability density function is about 0.9, the value without statistical fluctuation.

From this analysis, we conclude that, at least, the high energy jets with $n_h\leq 2$, $15\leq n_s\leq 25$, $25\leq\gamma_c\leq 100$ occur from the two types of the probability density function *i.e.* the two-fire-like one and the "Rest" one.

Here we do not treat the events with small n_s. The "typical" two-center events seem to occur when n_s is small. The treatment of this case will be done in the near future.

References

1) B. A. Nikol'skii and A. P. Mishakova: JETP **38** (1960) 1507.
2) J. Gierula, M. Miesowicz and P. Zielinski: Nuovo Cimento **18** (1960) 102.
3) Marcel Schein, D. M. Haskin, E. Lohrmann and M. W. Teucher: Phys. Rev. **116** (1959) 1238.
4) A. G. Barkow, B. Chamany, D. M. Haskin, P. L. Jain, E. Lohrmann, M. W. Teucher and Marcel Schein: Phys. Rev. **122** (1961) 617.
5) The data obtained by the Bristol group. Private communication from Prof. J. Iwadare.
6) Private communication to Prof. J. Nishimura from the Moscow group.
7) The data given in the reference 2).

Discussion

Zhdanov, G.B.: Is your procedure of analysis of angular distributions more sensitive to prove the 2-center mechanism of particle production than the procedure used by Dr. Gierula, Prof. Miesowicz and others?

* The data from 3) 4) 5) 6) are used.

Yoneyama, T.: I think their method and ours are different in aims. The method of Polish group can only say whether the angular distribution has double-(or any number of) maximum shape or not, and is not appropriate to the analysis of two-center events. According to their method, we cannot distinguish the events which have the same ratio of log γ_M to the second moment of each one of the two groups around its average. Our method, however, can determine whether a certain event is in its nature two-center type or another type taking into account the statistical fluctuation.

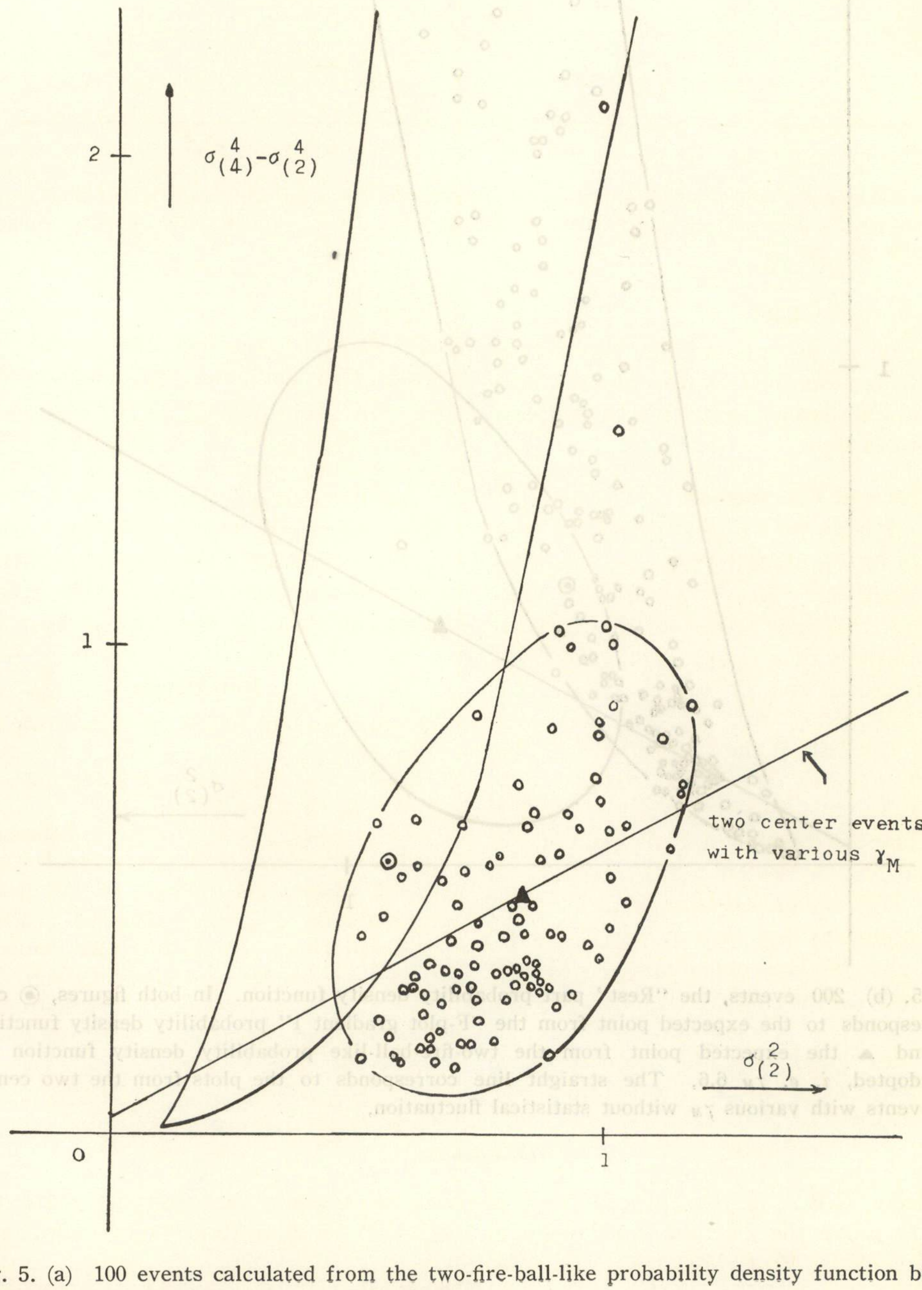

Fig. 5. (a) 100 events calculated from the two-fire-ball-like probability density function by the Monte-Carlo method.

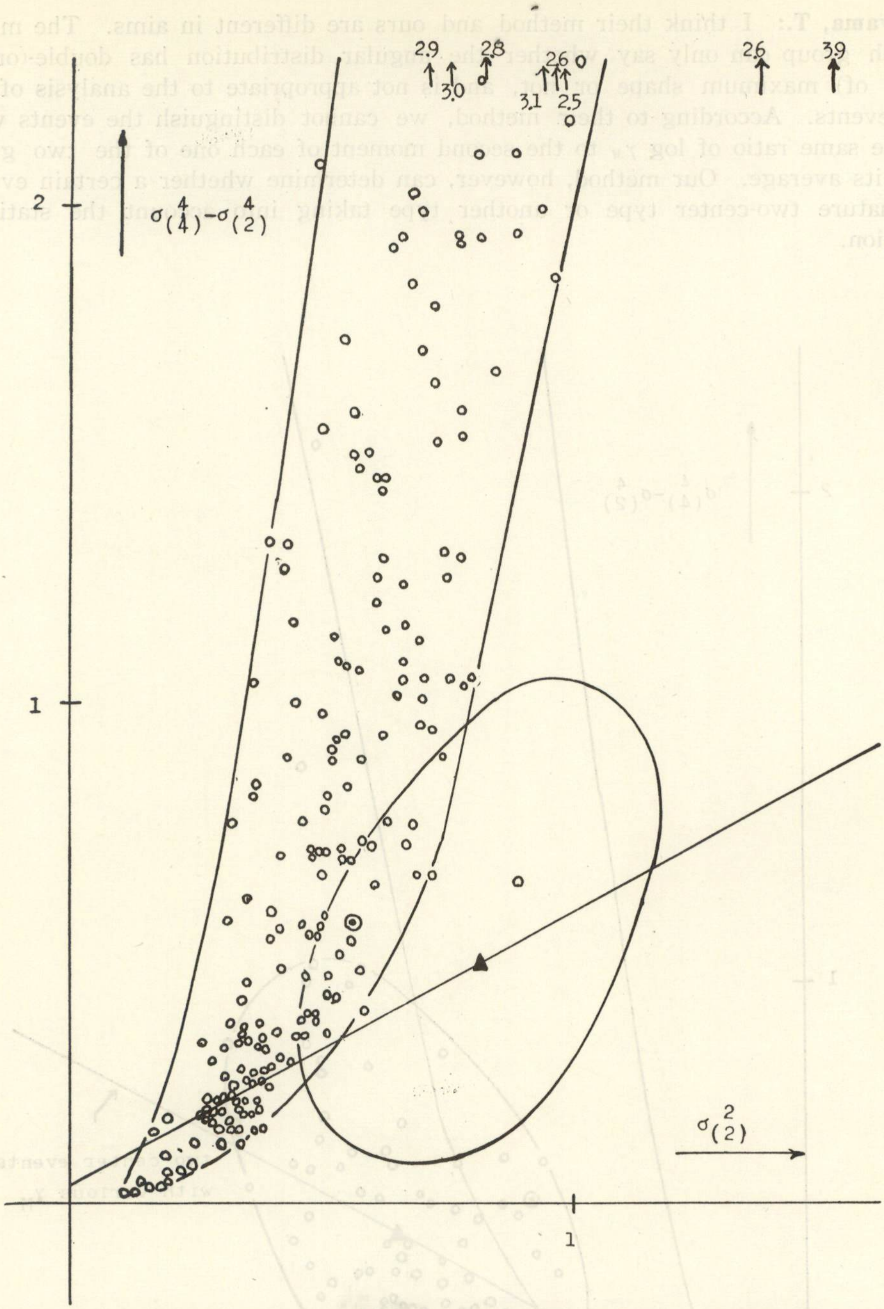

Fig. 5. (b) 200 events, the "Rest" part probability density function. In both figures, ⊙ corresponds to the expected point from the "F-plot gradient 1" probability density function, and ▲ the expected point from the two-fire-ball-like probability density function we adopted, *i. e.* γ_M 6.6. The straight line corresponds to the plots from the two center events with various γ_M without statistical fluctuation.

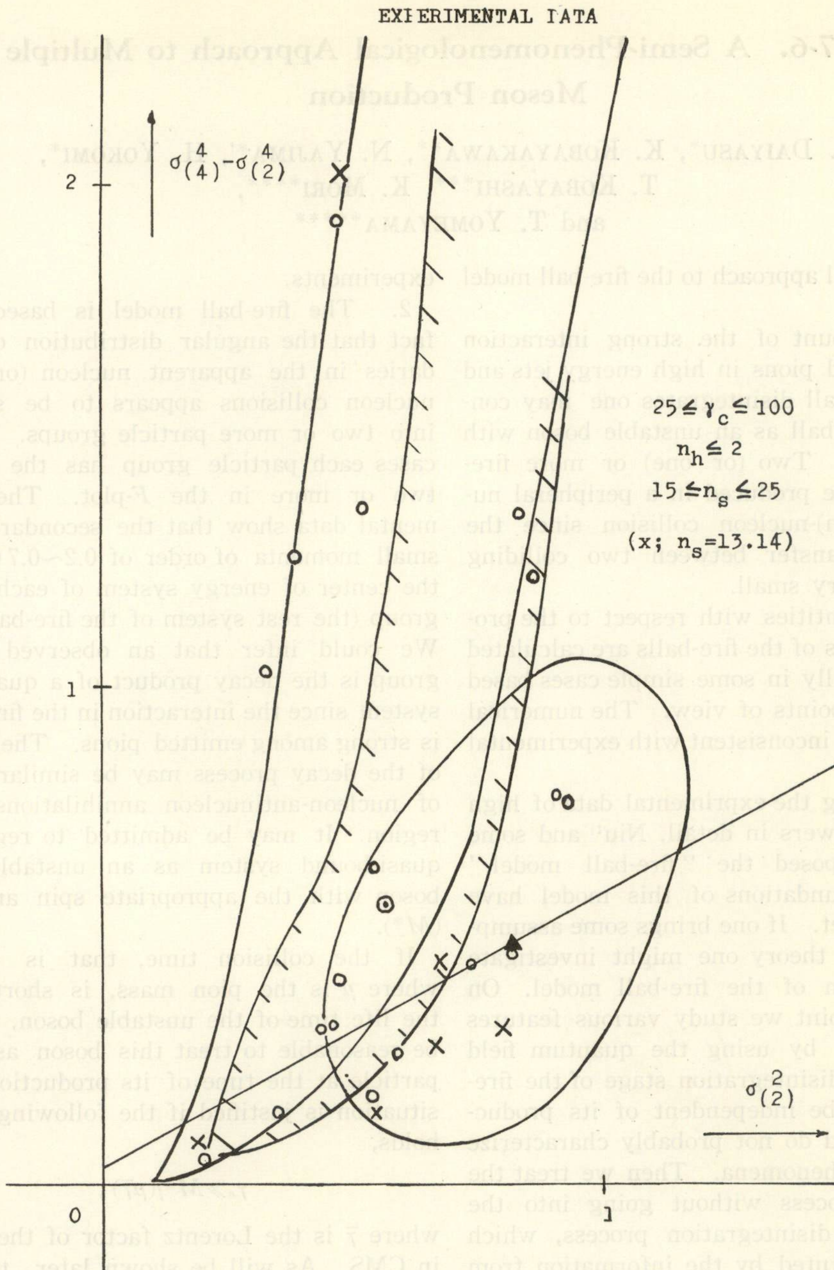

Fig. 6. The plots of the experimental data with $25 \leq \gamma_c \leq 100, n_h \leq 2, 15 \leq n_s \leq 25$. The shaded area covers the calculated plots from the "F-plot gradient 1" probability density function by the Monte-Carlo method.