RECENT COSMIC-RAY RESULTS AT ULTRA-HIGH ENERGIES

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I will discuss two experiments. The first will be concerned with the fragmentation of heavy nuclei in the region between 1 and 15 Tev (1 Tev = 10^{12} ev). The second is a study of the nature of the secondaries produced in jets at energies greater than 1 Tev.

I. Fragmentation of Heavy Nuclei

The process of fragmentation of a primary heavy nucleus can occur as a result of repeated impacts with nuclei of the photographic emulsion such that singly or multiply-charged fragments are gradually "peeled" off. In a typical instance, if a heavy nucleus (Z,A) decomposes into a number of fragments (Z',A'), which eventually break up in turn into individually-charged particles of Z = 1, one might hope to obtain a beam of nucleons which carry the same energy per nucleon. (This assumes that the nuclear excitation in the center of mass is rather small.) It was thought that this process could be described as an evaporation in the rest frame of the colliding nucleus so that the fragments would emerge in the laboratory with a small spread in energy. This was the spirit in which we started studying the fragmentation of heavy nuclei, hoping to have a way of collecting statistics of interactions of particles which should have, a priori, nearly the same energy. Thus, we could overcome one of the main difficulties of the study of cosmic-ray jets, the determination of the primary energy, by combining the energy estimates of all these secondary particles.

By this approach, we started out to make an unbiased study of nucleon-nucleon collisions but ended up in studying rather the fragmentation of heavy nuclei. In fact, we are not really dealing with beams of mono-energetic nucleons because, as I will show, the so-called fragments may have lost energy in the fragmentation process. Thus, one should perhaps call these particles "surviving nucleons" rather than fragments which carry the same energy per nucleon.

This study of fragmentation processes is a joint effort of the University of Chicago, the University of Krakow, and Louisiana State University. Other collaborating laboratories may join in the analysis. The results, which I will present, are preliminary and reflect personal rather than collective views. The experiment was carried out in a stack of 80 liters of emulsion which was composed of 500 plates measuring 45 cm X 60 cm. Fig. 1 shows the flight curve for the emulsion stack. The flight was

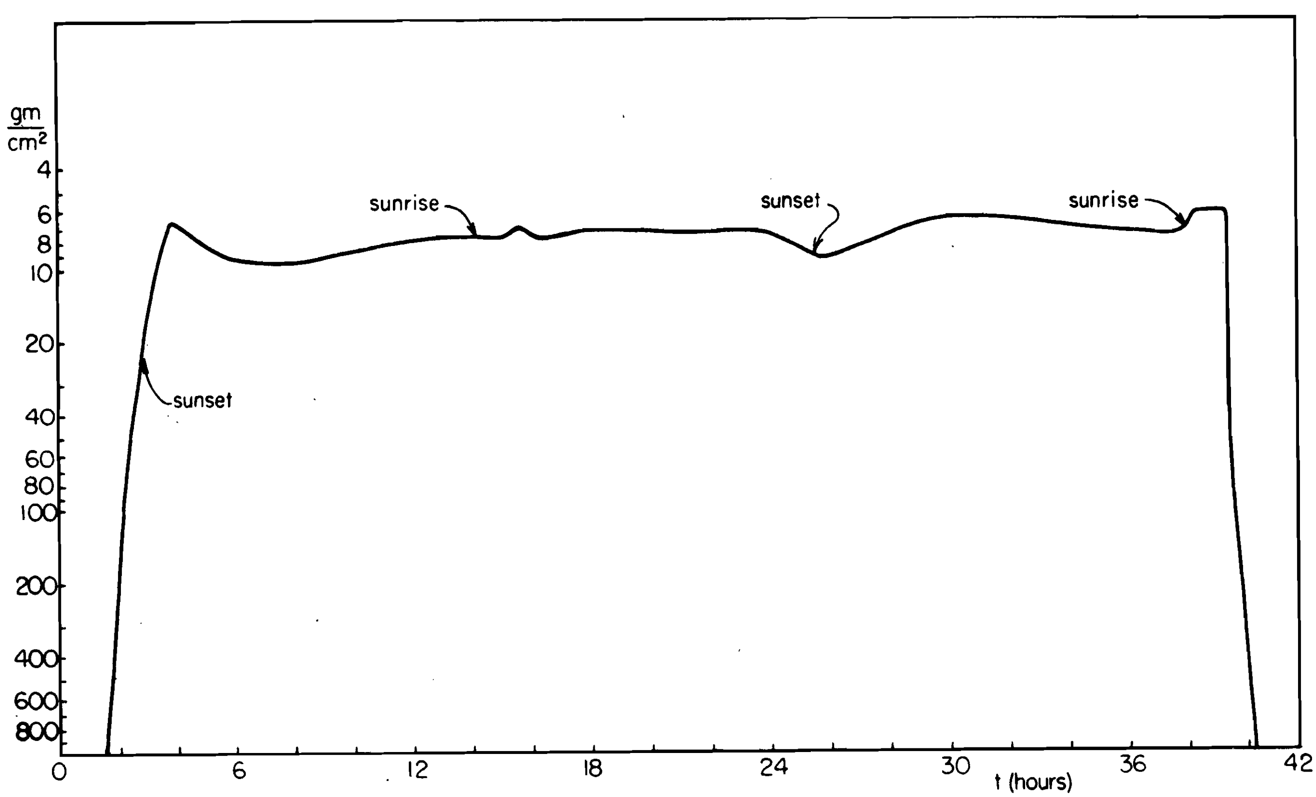


Fig. 1

unusual since the stack remained at about constant altitude (112,000 feet) corresponding to 5 or 6 grams per cm^2, for 36 hours.

The stack depth corresponded to two nuclear mean free paths. Usually, fragmentation of the primary heavy nuclei occurs in the upper part of the stack since the mean free path for fragmentation is relatively short; therefore, one can usually observe a very large fraction of secondary interactions produced by these fragments. One important characteristic is that we collected an unbiased sample of nuclear interactions by "track following" the individual fragments.

Fig. 2 shows a typical example of the kind of events we are studying. The angular distribution of the secondaries of these events are plotted with log (tan θ) as the coordinate. Under plausible assumptions, the average value of log (tan θ) = log $1/\gamma_c$. The first six log (tan θ) plots represent interactions in which a heavy fragment survived (a fragment of charge greater than two).

The original heavy nucleus ($Z = 15$ or 16) peeled off in steps in the first six collisions; each plot shows the angular distributions of the various particles created at each of these steps. Beyond the sixth interaction there are no longer any multiply-charged fragments and all that remains of the original heavy nucleus are protons (or deuterons, or tritons). Eight of the latter were subsequently observed to interact. One assumes that these nucleons, which are emitted at extremely small angles, are indeed the survivors of the fragmentation of the heavy nucleus; one may expect that their energies should be contained in a rather narrow range. Fig. 3 shows the particles created by interactions of the neutral fragments which were found in the "core" of the successive fragmentation of the heavy nucleus.

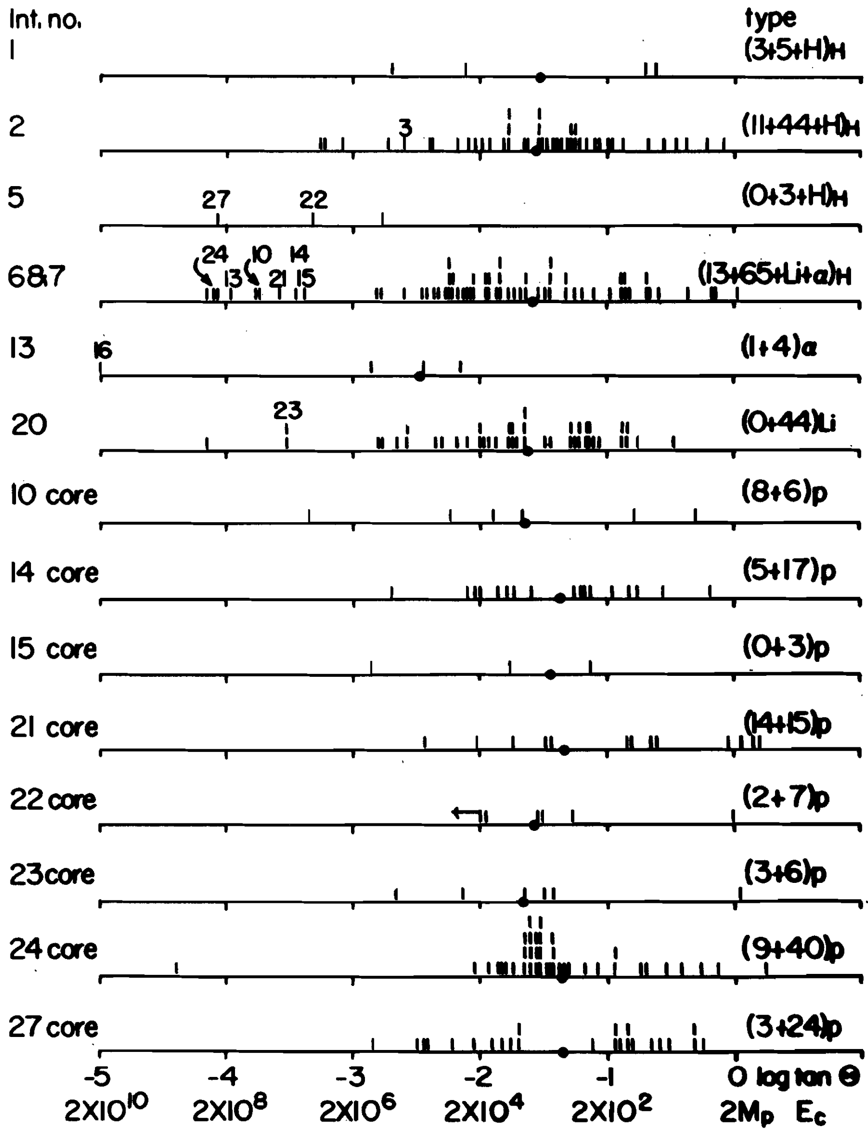

Int. no.
type
1
(3+5+H)H
2
3
(11+44+H)H
5
27
22
(0+3+H)H
6&7
24
10
14
13
21
15
(13+65+Li+a)H
13
16
(1+4)a
20
23
(0+44)Li
10 core
(8+6)p
14 core
(5+17)p
15 core
(0+3)p
21 core
(14+15)p
22 core
(2+7)p
23 core
(3+6)p
24 core
(9+40)p
27 core
(3+24)p
-5
-4
-3
-2
-1
0 log tan Θ
2X10^10
2X10^8
2X10^6
2X10^4
2X10^2
2Mp Ec

Fig. 2

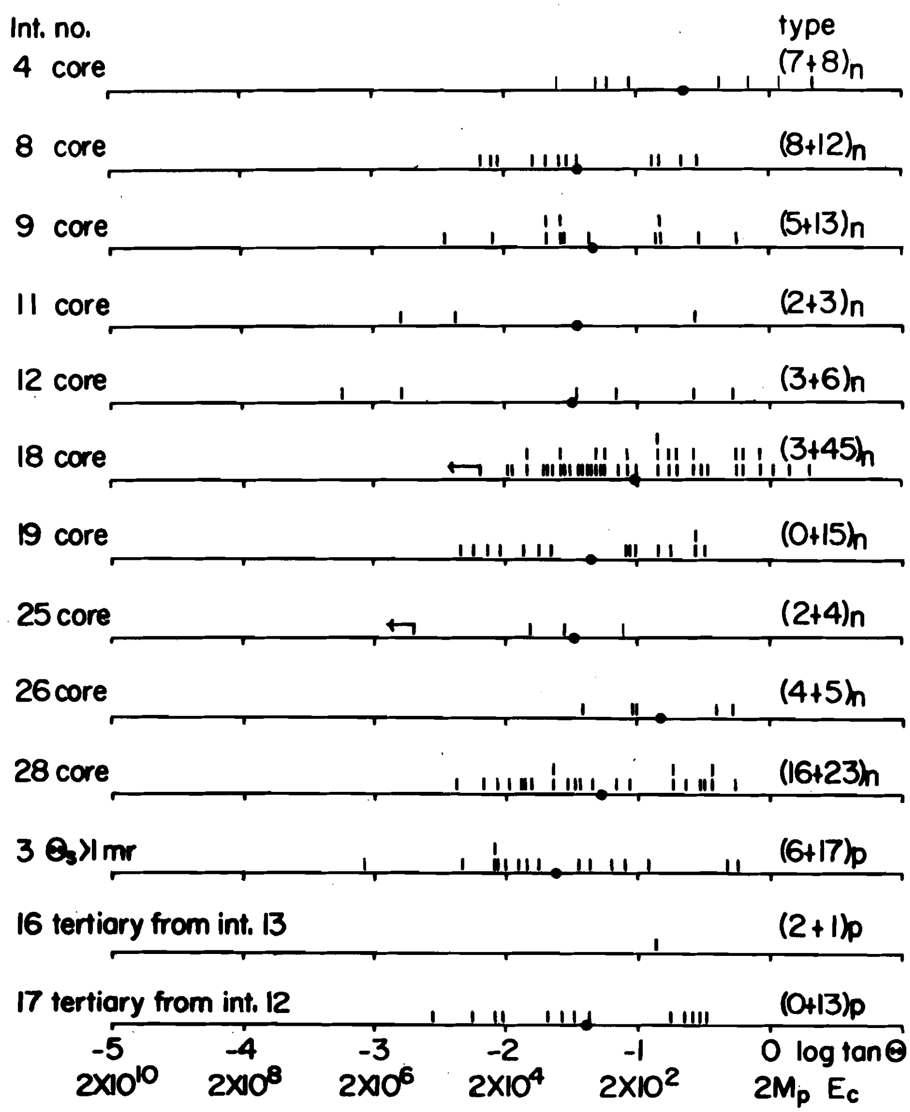

Int. no.
type
4 core
(7+8)n
8 core
(8+12)n
9 core
(5+13)n
11 core
(2+3)n
12 core
(3+6)n
18 core
(3+45)n
19 core
(0+15)n
25 core
(2+4)n
26 core
(4+5)n
28 core
(16+23)n
3 Θs>1 mr
(6+17)p
16 tertiary from int. 13
(2+1)p
17 tertiary from int. 12
(0+13)p
-5
-4
-3
-2
-1
0 log tan Θ
2X10^10
2X10^8
2X10^6
2X10^4
2X10^2
2Mp Ec

Fig. 3

One can argue that a good fraction of these interactions of neutral particles are due to neutrons which have peeled off the primary nucleus.

The energy of the primary heavy nucleus is determined by the composite angular distribution of all of the shower particles which have been produced by the interaction of the multiply-charged fragments. This is equivalent to averaging individual values of γ_c for each family of successive interactions to yield a single value γ_{comp}. The log (tan θ) distributions for different families of interactions are normalized by a shift along the x = log (tan θ) axis, of an amount given by log γ_{comp}. This yields a distribution of log (γ_{comp} tan θ), which is centered around the value zero. As shown in Fig. 4 the shaded area on the left corresponds to particles emitted at a very small angle. These particles are

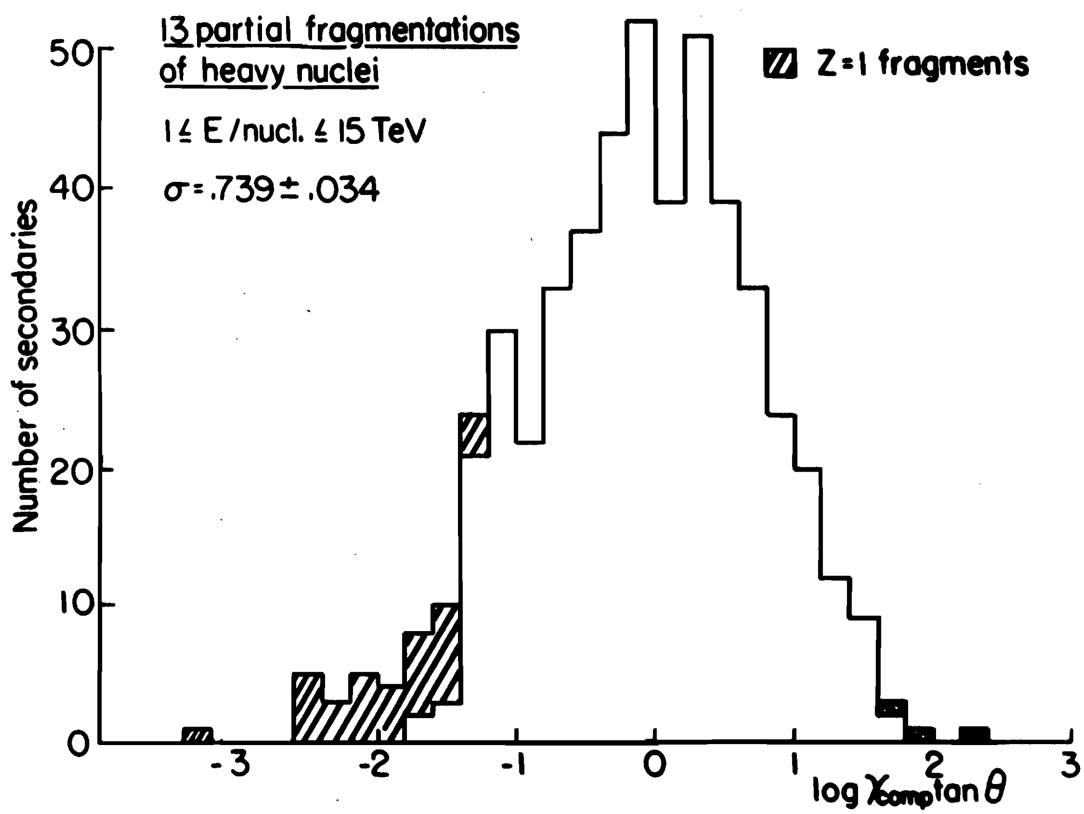


Fig. 4

the surviving nucleons or singly-charged fragments which have peeled off. Surviving nucleons are selected by the following criteria. At each interaction, Z changes by ΔZ so that there should be at least ΔZ singly-charged baryons released in such peeling off. We then select the smallest angle tracks, ΔZ in number, and call them surviving nucleons or fragments. If we disregard this small tail, then, the spread of the angular distribution is $\sigma = 0.74$ and the shape corresponds closely to a center-of-mass distribution $(\sin\theta)^{-1}d\theta$.

We have selected a sample of the interactions produced by singly-charged fragments, which we assume should have approximately the same energy, and made their composite angular distribution as shown in Fig. 5.

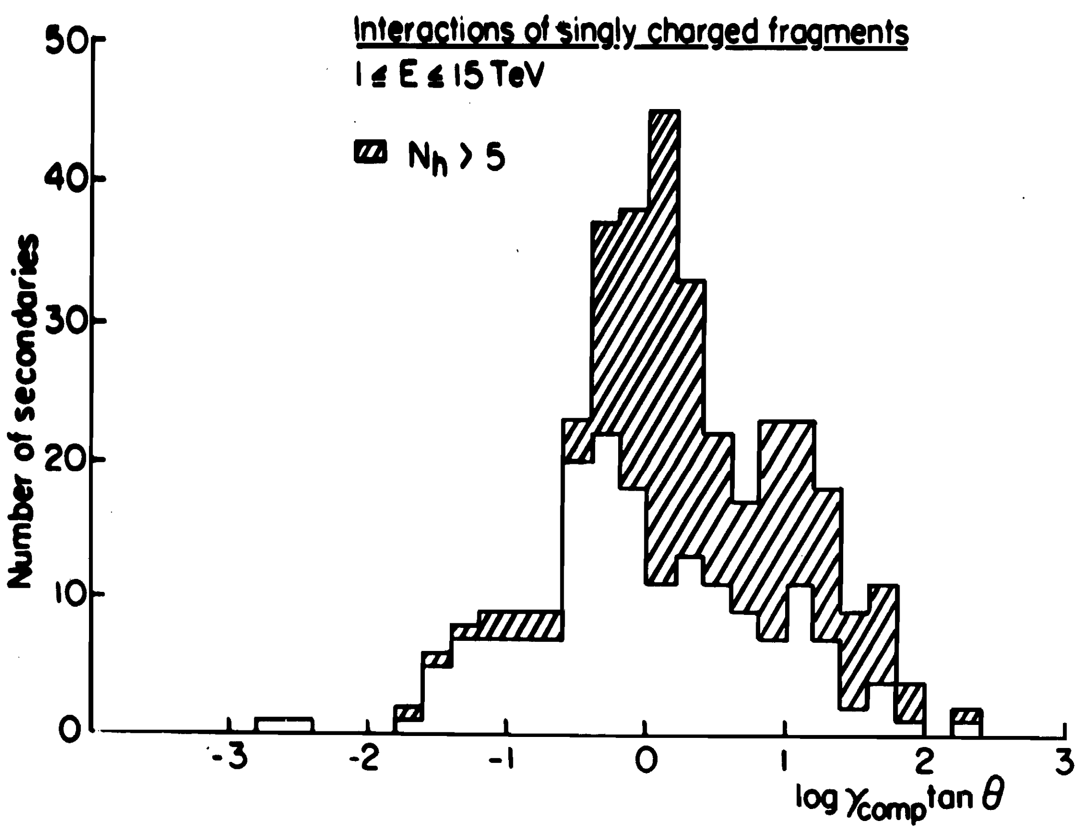


Fig. 5

(This distribution was normalized to log (γ_{comp} tan θ) coordinates in the same way as was the previous one.) We find that the angular distribution, for the secondaries, peaks around zero as expected when most of the fragments had the same energy per nucleon as the primary parent heavy nuclei. On the other hand, we see an unexpected unsymmetric tail, which can be understood in the following way. The shaded area corresponds to interactions of nucleons yielding evaporation tracks in number (N_h) greater than five. These represent interactions of nucleons mostly with silver or bromine nuclei where, as is well known, secondary effects such as nuclear cascading intervene. The result is a widening of the angular distribution and the appearance of an excess of secondaries emitted at large angles. The unshaded area represents "clean" collisions, for which $N_h < 5$, and not much more than one nucleon of the target has been involved. This distribution exhibits a reasonable symmetry in the peaking around zero, showing that these particles have indeed the estimated energy.

Fig. 6 shows an analogous distribution which is obtained for heavy nuclei which have completely broken up yielding no surviving $Z \geq 2$ fragments (i.e., a central collision of the primary heavy nucleus with a nucleus of the emulsion). There are several events in this distribution where the multiplicity may be of the order of 200 (i.e., 200 mesons created). The angular distribution is still very similar to the previous ones and has a shape which, again, in the coordinate shown, is close to $(\sin\theta)^{-1}d\theta$.

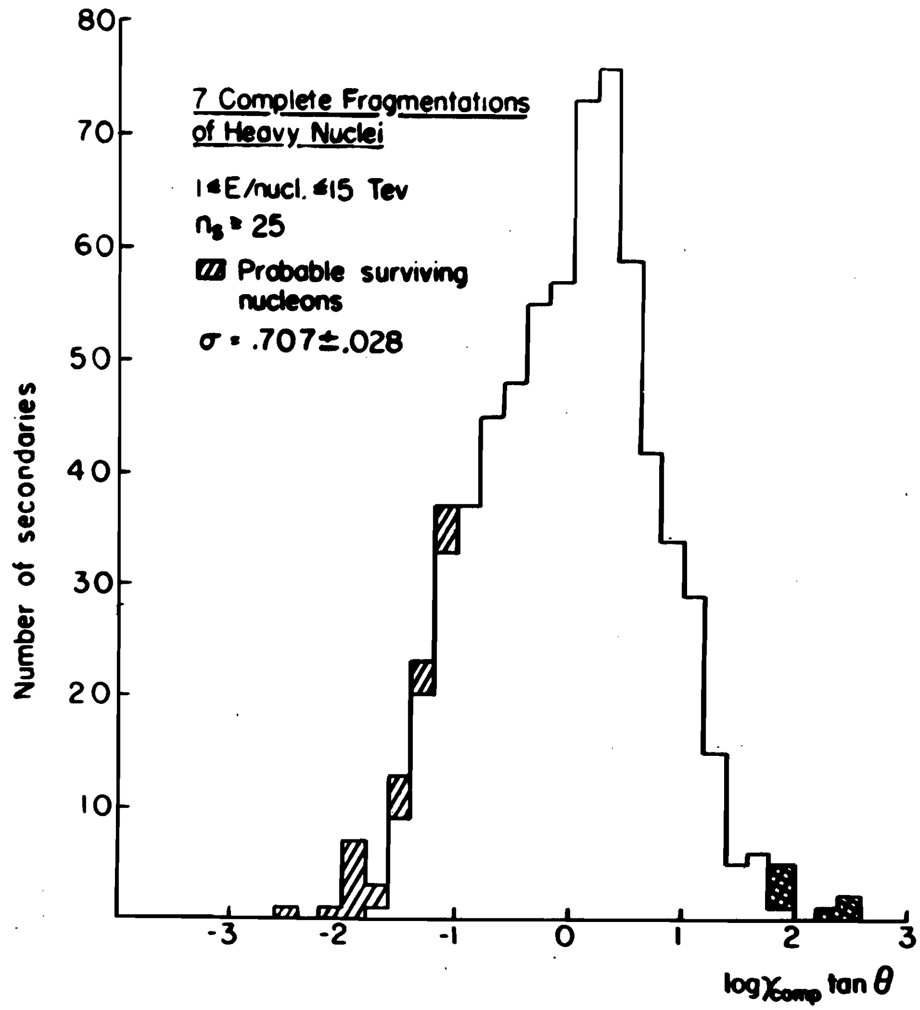


Fig. 6

The consistency in the energy estimates for the individual members of a family of interactions is shown in Fig. 7. Some difficulty arises here. The ordinate is log (γ_i/γ_{comp}) where γ_i is the γ of the individual collisions. This is a measure of the fluctuations of the estimated center-of-mass γ as compared to the mean and is expressed as a function of the multiplicity. The idea is that we are going to obtain a more realistic estimate of the primary energy when we have a large number of shower particles because we get a better average of the angular distribution.

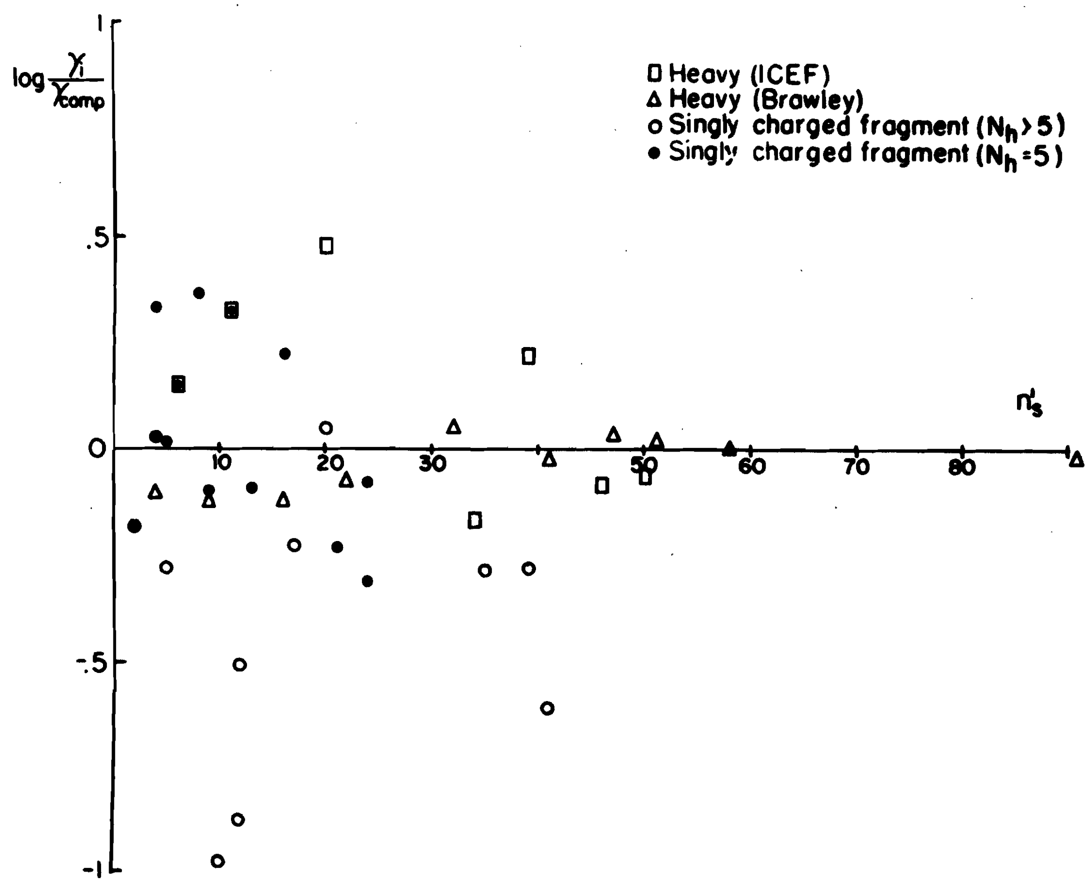


Fig. 7

The triangles refer to partial breakups of heavy nuclei and are fairly closely arranged around zero. The black dots represent the interaction of the surviving nucleons with low secondary multiplicity, i.e., approximately nucleon-nucleon collisions. There is here again symmetry with respect to zero. The white dots represent the events with large numbers of evaporation tracks in the secondary interaction. These energy estimates are very far off and this can be attributed to secondary cascading inside the target nucleus.

Fig. 8 illustrates the difficulty further. It shows the transverse momentum of the singly-charged fragments. If these were really fragmen-

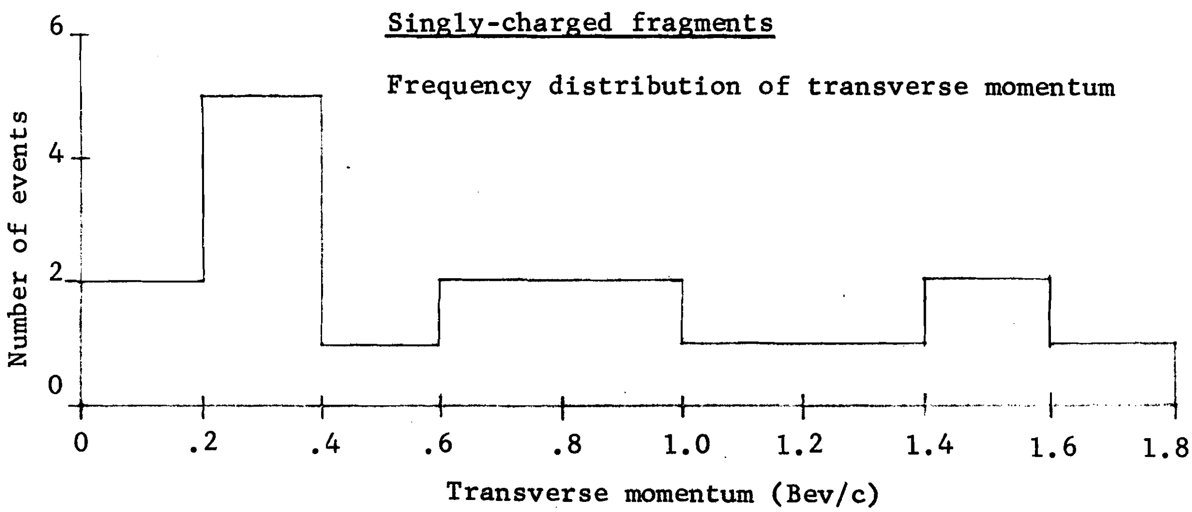

Singly-charged fragments
Frequency distribution of transverse momentum
Number of events
6
4
2
0
0
.2
.4
.6
.8
1.0
1.2
1.4
1.6
1.8
Transverse momentum (Bev/c)

Fig. 8

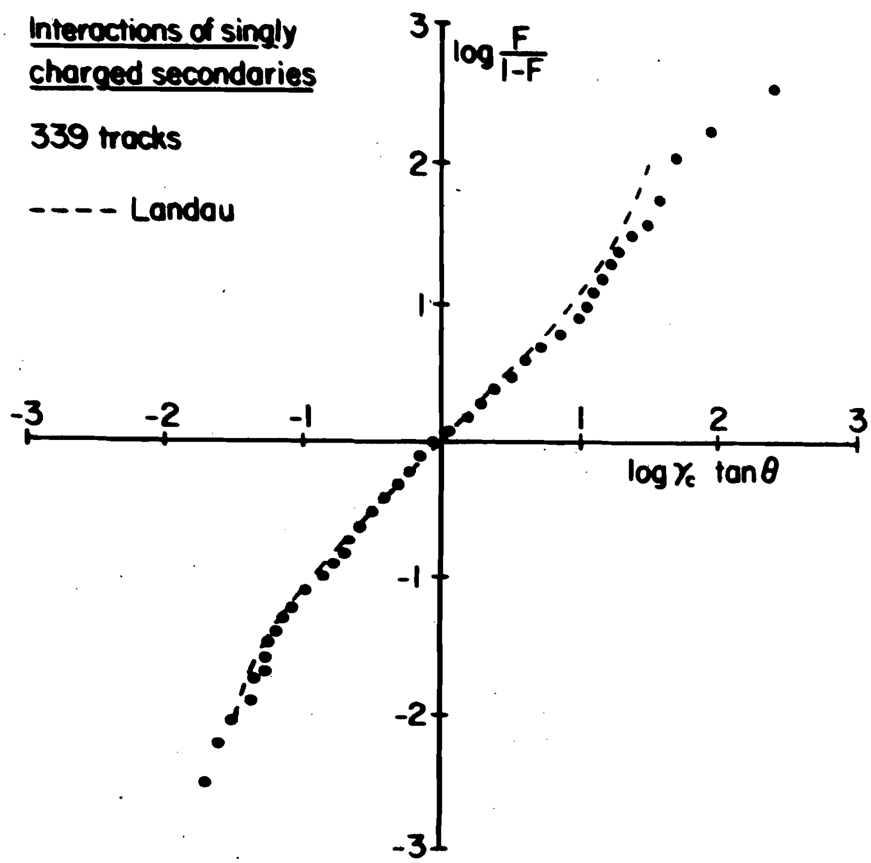
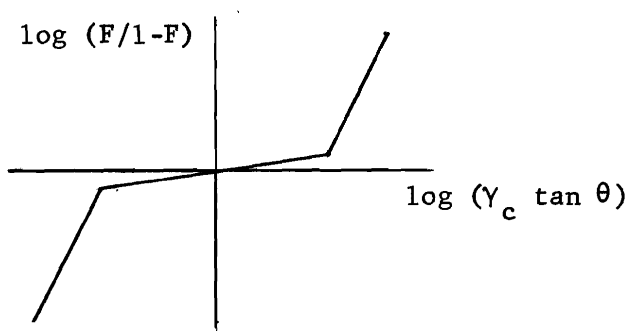

Interactions of singly charged secondaries
339 tracks
---- Landau
log F/(1-F)
3
2
1
-1
-2
-3
-3
-2
-1
1
2
3
log γc tan θ

Fig. 9

tation products from a process in which there was (by definition) a small momentum transfer in the center of mass of the collision, we should find these particles peaked about very small transverse momenta, instead of being distributed up to transverse momenta as high as ~ 2 Bev/c. This casts some doubt on the original approach. We do not have "fragments" but have surviving nucleons which have interacted, lost energy and as a result acquired a sizable transverse momentum.

One of the composite distributions previously illustrated is shown in Fig. 9 and is expressed in a Duller-Walker plot which has in ordinate log (F/1-F), where F is the fraction of tracks contained in a cone of angle θ and in abscissa log (γ_c tan θ). In this representation, an isotropic center-of-mass angular distribution yields a straight line of slope two. As the distribution becomes more and more asymmetric, one obtains a line of decreasing slope. For a $(\sin\theta)^{-1}$ distribution, the straight line has slope one. In the fireball representation two branches appear



as shown, where the individual branches have slope two. On the plot, the Landau distribution (dashed curve) of the one-dimensional hydrodynamical model seems to fit the data well. Near the origin, the distribution $(\sin\theta)^{-1}$ also fits the data, but not, of course, for large values of the abscissa.

The multiplicities in the selected sample of nucleon-induced events are given below. We cannot give nucleon-nucleon multiplicity; even clean collisions, namely, jets with no evaporation tracks, we know must contain a sizable fraction of interactions with complex nuclei. The only classification we can make is to split the sample, e.g., in three categories, $N_h \leq 1$, $N_h \leq 5$, and $N_h > 5$. The $N_h = 0,1$ jets are closest to nucleon-nucleon collisions.

Type of collision	$N_h = 0,1$	$N_h \leq 5$	$N_h > 5$
Average number of shower particles (n_s)	10.5	11.9	22
Number of events in sample	6	14	8

One can say that the value of the multiplicities is not very high. The reason that these multiplicities are somewhat lower than have been reported before may be that we have, by track following, identified a large number of very low multiplicity events which in the usual experiments escape detection. The average energy of the nucleons is about 5 Tev.

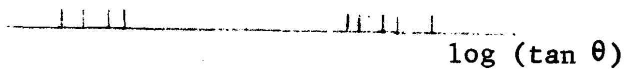
The spreads of the angular distributions for events shown in the figures were found to be:

$\sigma = 0.707 \pm 0.028$ for complete fragmentations

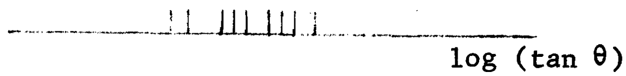
$\sigma = 0.739 \pm 0.034$ for partial fragmentations

$\sigma \approx 0.748 \pm 0.028$ for individual fragments (mostly nucleons)

A $(\sin \theta)^{-1} d\theta$ distribution has a spread, in our coordinates, of $\sigma = 0.67$. The spread in the distribution predicted by the Landau hydrodynamic model (one-dimensional theory) is also approximately 0.7 for the energy region $1 \rightarrow 10$ Tev although the three-dimensional theory, developed by Milehkin, would suggest larger σ-values. These results had been obtained before. Our composite angular distribution may mask the evidence for the production of "fireballs". In fact, if one looks for examples of fireballs, one can find a few among events with small N_h and N_s values. Among the log (tan θ) plots for about 20 individual jets, several have a structure of the type:



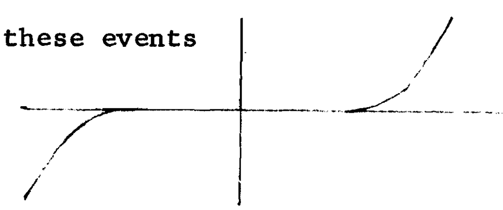
While there is a continuous transition to this structure from a more uniform structure:



in the sum of the distributions the gaps may, in fact, be filled. The distributions, however, show that the production of distinct fireballs is not the dominant mode and Landau distributions may be a satisfactory representation of the experimental results as a whole.

S.J. Lindenbaum (BNL): How do you explain the fireballs observed by other people?

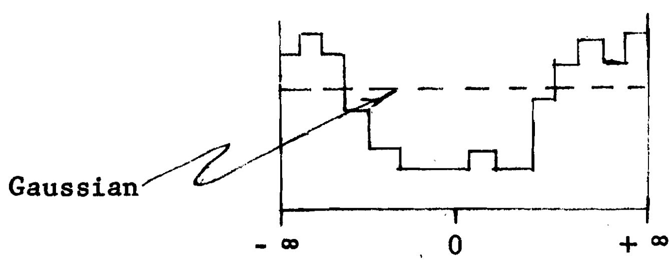
R. Levi Setti: One can certainly find individual events which exhibit the structure of fireballs and there is no doubt about the experimental evidence for these events. My objection in this connection refers mostly to the manner in which such events are selected. They do not represent an unbiased population. Furthermore, it is known that Duller-Walker plots for these events



are indistinguishable from those for distributions described by $\cos^m \overline{\theta}$ with very large m. Perhaps there is still too little evidence for criticizing the fireball model at this time. It is worth mentioning, however, that a common method of illustrating the existence of fireballs is by a distribution in the coordinate

$$x = \frac{\log(\gamma_c \tan\theta_i) - \overline{\log(\gamma_c \tan\theta)}}{\sigma}$$

where x is calculated for intervals corresponding to equal areas of a Gaussian distribution. With this change in coordinate, a Gaussian distribution becomes a straight line and distributions from events illustrating fireballs are shown in the sketch. The two-peak distribution

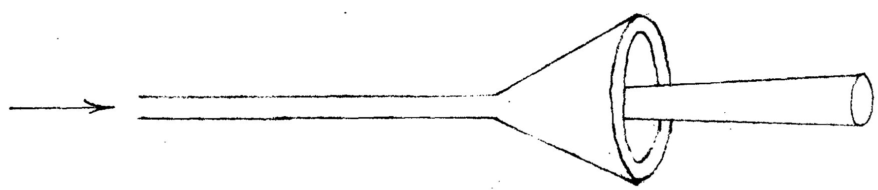


usually observed is certainly different from the straight line given by a gaussian distribution. However, a rectangular log (tan θ) or $\cos^m \theta$ distribution in the above representation also show two similar peaks. Thus this representation is rather insensitive to the actual shape of the original distribution.

Observed inelasticities are in agreement with previous results. They are low in this energy region. The fraction of the energy carried by charged secondaries has an average value $\langle K_{ch} \rangle \sim 0.16$.

II. The Nature of the Secondary Particles

Mr. C.O. Kim (University of Chicago) has undertaken the task of measuring scattering, ionization and tracing secondaries of jets found in another large emulsion stack (60 cm deep). In the laboratory system one observes particles emitted in two cones, one of small opening angle corresponding to forward emission in the center-of-mass system and a large angle cone corresponding to backward emission in the center-of-mass system. Tracks in the latter cone often emerge with energies $<$ 10 Bev



and are usually the only ones that can be directly identified by standard methods. Kim has limited his analysis to particles emitted within 1/4 of the backward solid angle. Fig. 10 illustrates a typical calibration of grain density as a function of residual range. Up to a range of about 12 cm, the calibration has been made with pions which have stopped in the emulsion and above this point with actual secondaries which did not stop. Since tracks in the emulsion are as long as 50 or 60 cm in some cases, one can observe the variation of ionization along the track and find the best fit to these curves. A few π and K mesons have been identified by this method and corresponding points marked on the figure. (Similar symbols on the figure indicate the measurements of different portions of track of the same particle.) This method gives a good resolution for $\beta \lesssim 0.95$.

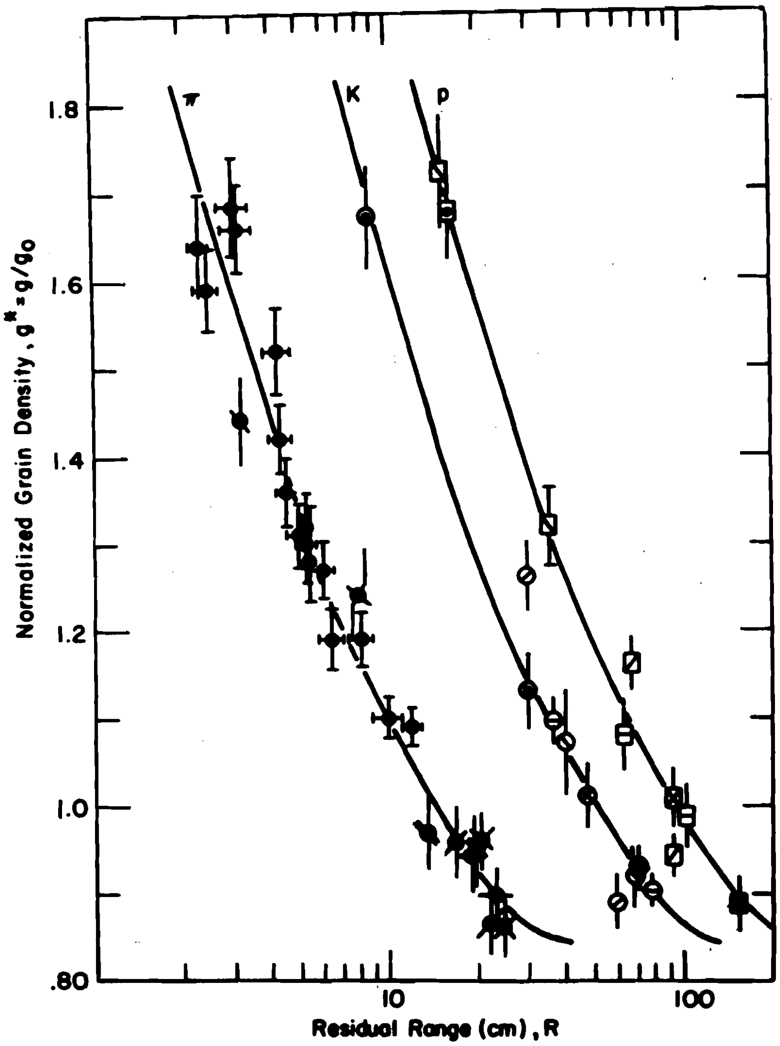


Fig. 10

On the other hand, Fig. 11 shows what happens for most of the statistics. The identification has been based on theoretical curves normalized to fit the data. These are curves which include corrections for the density effect following Sternheimer's calculation and are normalized to fit the data by a choice of parameters defined by the value of the minimum (observed experimentally) and by the value of the plateau. One can notice a substantial relativistic rise between the minimum and the plateau, by a

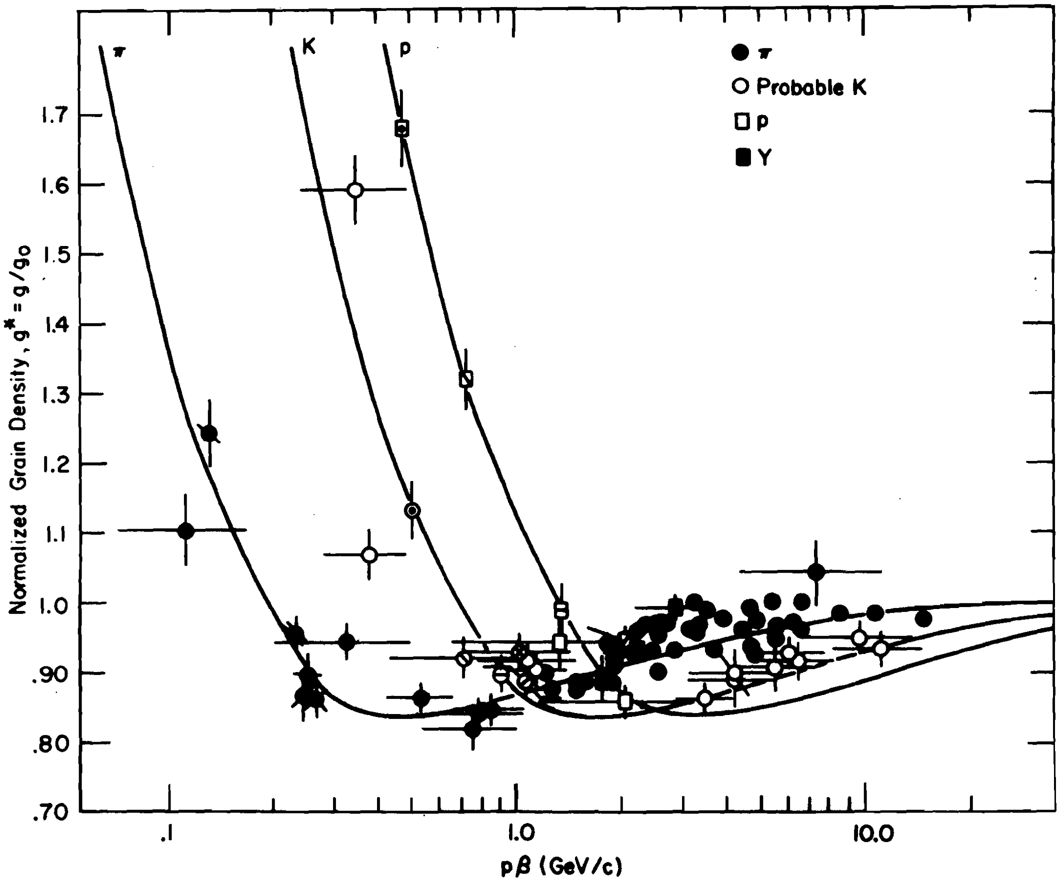


Fig. 11

factor of about 1.2. Since the plateau is reached asymptotically at very high γ values, it is important that the normalization of the curves be made using grain-density calibrations in the extremely relativistic region. This was accomplished by selecting electrons from very-high-energy electromagnetic showers which accompanied these jets, i.e., $\gamma \gtrapprox 1000$. It is difficult to identify particles in the region of confusion where the curves cross each other. In this region, however, as shown in Fig. 10, particles may be identified on the basis of the variation of ionization Δg^* a function of ΔR. Kim has assigned the black dots in

Fig. 11 to pions, and the white to K mesons. The separation is obviously not very clear and there may be some intermingling or contamination. Three of the particles, however, which have been assigned to K mesons, have shown themselves to be strange because, upon interaction, strange particles such as Σ's and hyperfragments were produced. If one accepts these identifications, many things fall into place. The number of particles which have been given assignments are as follows: π, 54; K, 17; p, 10; hyperons, 1. This gives a ratio $K/\pi = 0.31 \pm 0.09$.

If one takes the Landau theory which describes the final stage of de-excitation of the highly-heated volume and which is characterized by a critical temperature at which the meson emission occurs, then one finds a one-to-one correspondence between K/π ratio and the critical temperature, i.e.,

$$\frac{K}{\pi} = 0.31 \pm 0.09 \rightarrow kT_c = 1.20 {}^{+0.25}_{-0.37} m_\pi c^2 .$$

L.M. Lederman (Columbia): Are there not strong biases in interpreting tracks in this way?

R. Levi Setti: I am sure there are. On the other hand, this is the only piece of detailed information at the moment. The Bristol group had identified a total of ~ 25 secondaries by the same approach and their results are not in disagreement with our data. There is an over-all agreement for the K/π ratio. Independently, the fraction of heavy particles or x particles can be determined by other methods, such as from the over-all balance of the energy going into electromagnetic showers, i.e., π_o's, etc. and the assumption of charge independence. It is in this way inferred that ~ 25% of the produced particles are heavy particles. These results are in agreement with our independent estimate; they are, however, still rather preliminary. The bias, which cannot be avoided, consists in the preferential selection of large center-of-mass emission angles for the purpose of identification. Thus, the results do not represent the proper averaging over the entire CM solid angle.

Mr. Kim finds that the composition of particles changes as a function of center-of-mass angle.

$$\theta_{CM} > 175^{o}, \qquad K/\pi = 8/10$$
$$\theta_{CM} \leq 175^{o}, \qquad K/\pi = 9/44$$

i.e., the K mesons are preferentially emitted at very small angles. The average transverse momentum for these particles could be obtained

$$\langle p_t \rangle_\pi = 0.30 \text{ Bev/c}$$
$$\langle p_t \rangle_K = 0.32 \text{ Bev/c}$$
$$\langle p_t \rangle_p = 0.35 \text{ Bev/c}$$

If one divides the data into two groups corresponding to large and small angles then one finds for

$$\theta > 175^{o} \qquad \langle p_t \rangle_\pi = 0.22 \pm 0.07 \text{ Bev/c}, \quad \langle p_t \rangle_K = 0.17 \pm 0.06 \text{ Bev/c}$$

$$\theta \leq 175^{o} \qquad \langle p_t \rangle_\pi = 0.32 \pm .05 \text{ Bev/c}, \quad \langle p_t \rangle_K = 0.44 \pm 0.15 \text{ Bev/c}$$

If these results are confirmed, they are rather significant. It is well known that p_t appears to be almost constant as a function of energy and angle of emission in the center of mass. If this were completely true, the radiated energy would approach infinity at very small angles. However, these results indicate that at very small angles these values decrease as they should.

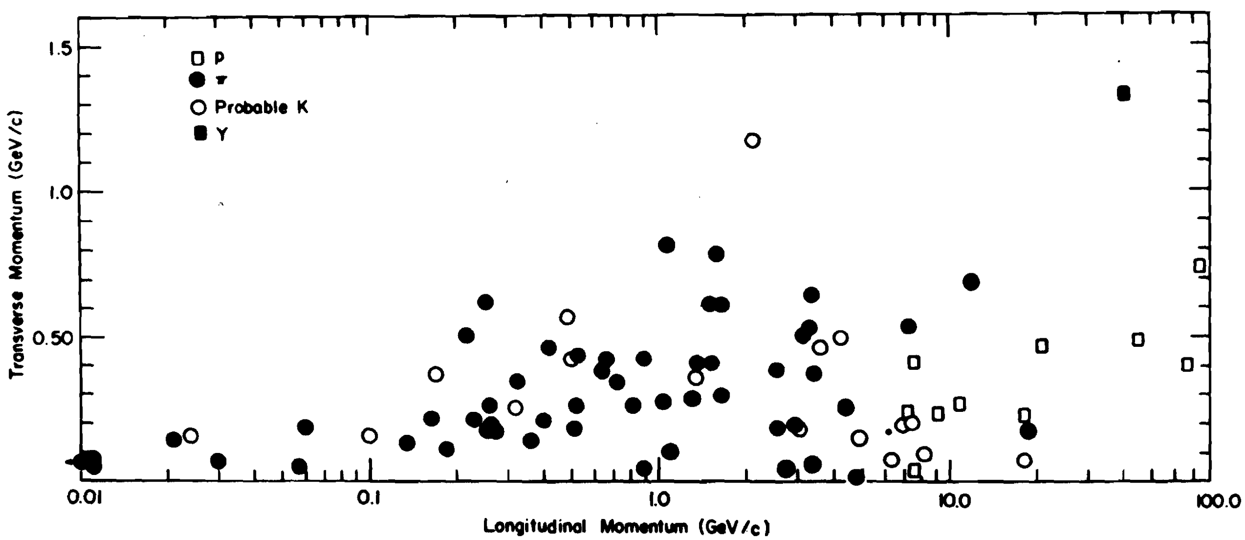


Fig. 12

Fig. 12 is a plot of longitudinal momentum versus transverse momentum. The protons are clustered at high longitudinal momenta as one would expect if these are surviving nucleons.

The variation of transverse momentum as a function of center-of-mass angle is shown in Fig. 13 and indicates that the p_t for pions and K's does decrease near 180° while all protons emerge at very small angle with larger p_t, again illustrating that these protons are surviving protons (persistent baryons).

Fig. 14 shows the transverse momentum distribution. The dotted curve corresponds to the predicted transverse momentum distribution of the one-dimensional Landau theory, modified by Milehkin. It is significant that

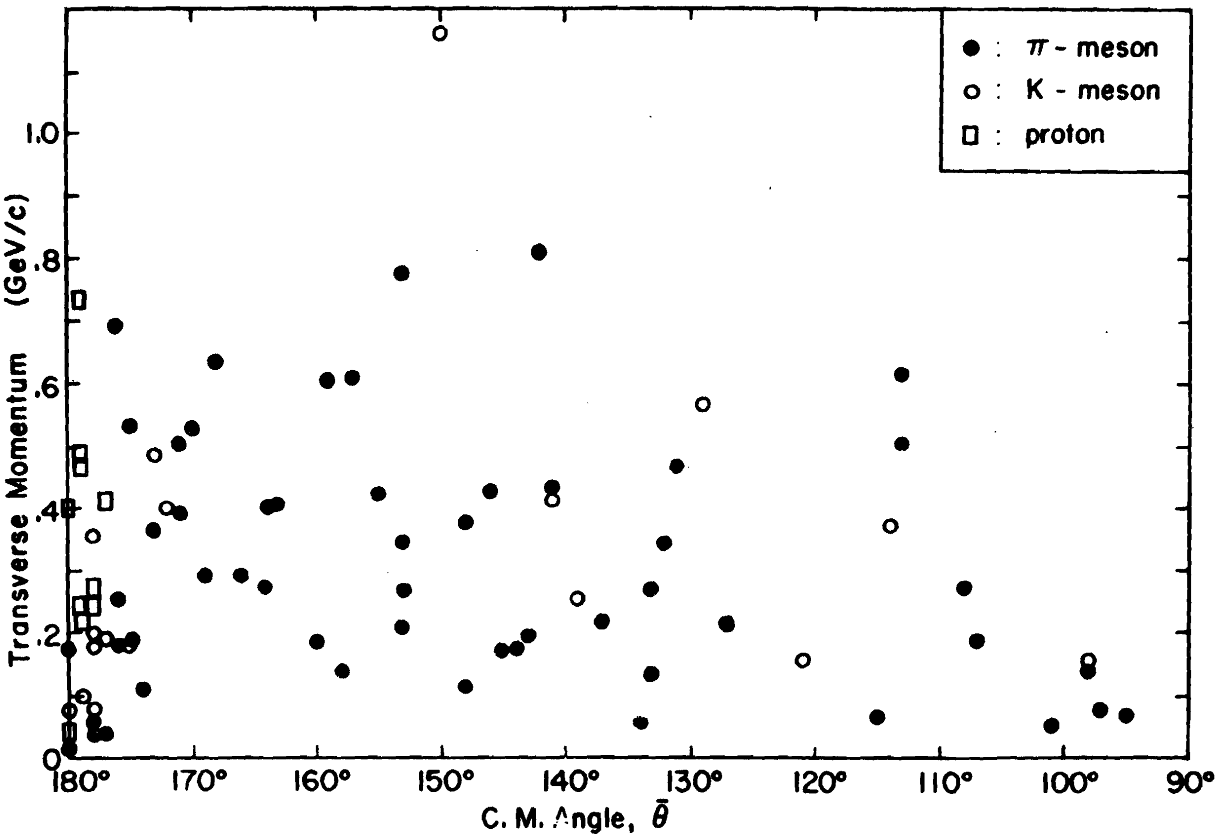

● : π - meson
○ : K - meson
□ : proton
Transverse Momentum (GeV/c)
1.0
.8
.6
.4
.2
0
180°
170°
160°
150°
140°
130°
120°
110°
100°
90°
C. M. Angle, $\bar{\theta}$

Fig. 13

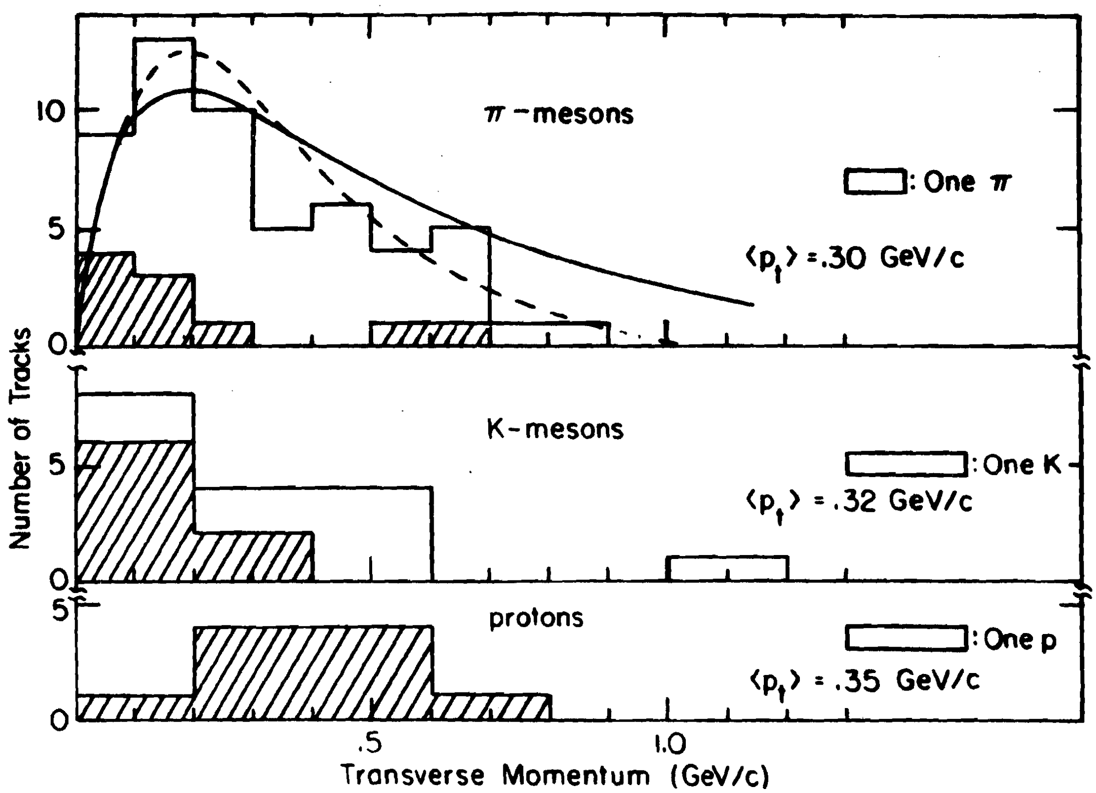

π -mesons
: One π
⟨p_t⟩ = .30 GeV/c
K-mesons
: One K
⟨p_t⟩ = .32 GeV/c
protons
: One p
⟨p_t⟩ = .35 GeV/c
Number of Tracks
10
5
0
.5
1.0
Transverse Momentum (GeV/c)

Fig. 14

this p_t distribution again is characterized by the same critical temperature $kT_c \approx m_\pi c^2$ as determined by the K/π ratio, and seems to fit the data rather well. This indicates that there is some internal consistency between the K/π ratio and the p_t distribution.

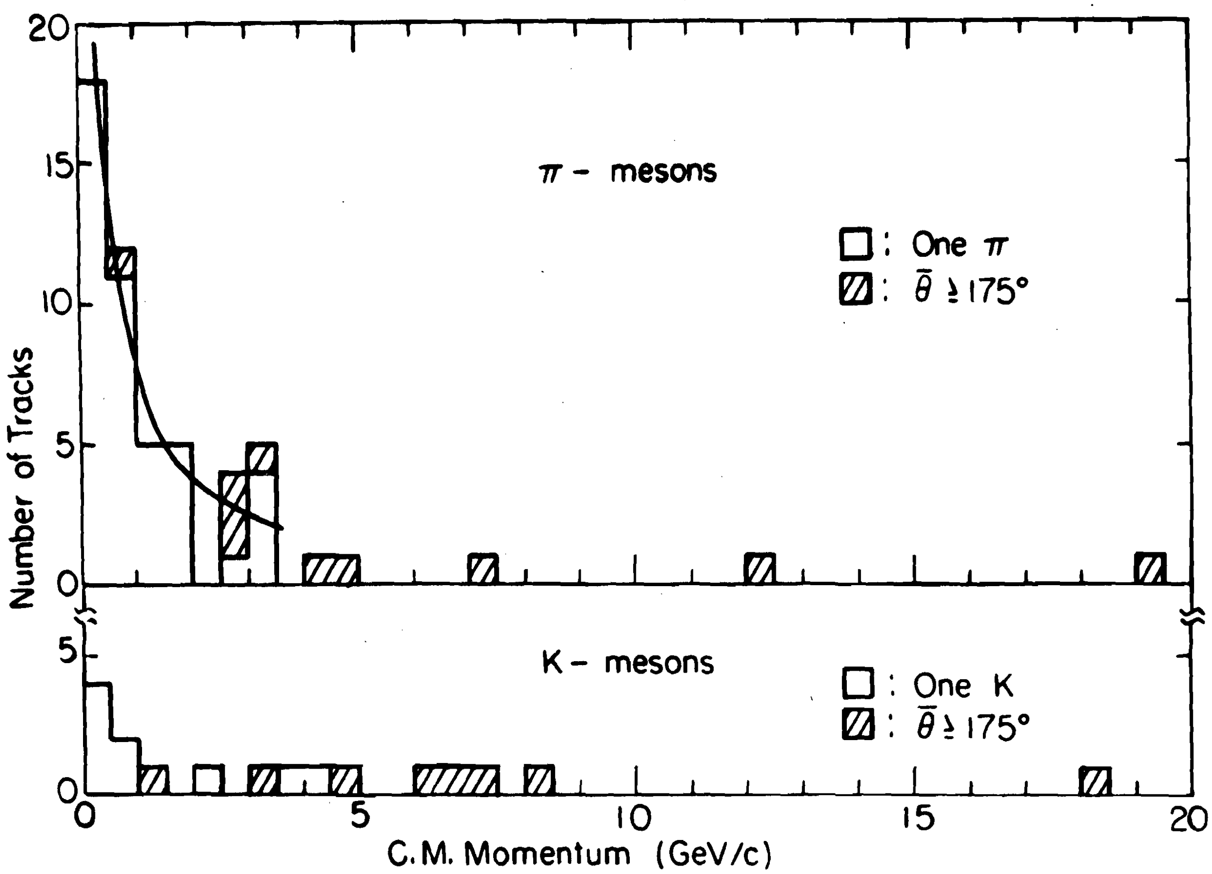


Fig. 15

Fig. 15 shows distributions of center-of-mass momentum for the K mesons and π mesons. The cross-hatched areas correspond to the extremely backward particles which are shown to carry the highest momenta. The curve shown is the "inverse momentum distribution" predicted by the Landau theory and seems to fit the data rather well, although the selection of measurable secondaries may have distorted the spectrum somewhat.

Discussion

G.B. Yodh (Maryland): I would like to know how the value of $K_{ch} = 0.16$ was determined?

R. Levi Setti: This value of K_{ch} is calculated in a rather unsatisfactory way because in this experiment we didn't have any individual measurements of energy of secondary particles in the shower so that we relied on the supposed constancy of the transverse momentum. Thus, we calculated K_{ch} from

$$E_{ch} = \sum \frac{\langle p_t \rangle}{\sin \theta_i} \quad ; \quad K_{ch} = \frac{E_{ch}}{E_{comp}}$$

where $\langle p_t \rangle = 0.35$ Bev/c.

R. Serber (Columbia): What does the Landau theory say about multiplicity?

R. Levi Setti: The variation with energy in the Landau theory is identical to that in the Fermi theory and is proportional to $E^{\frac{1}{4}}$. The experimental evidence is not in contradiction with this, but it cannot distinguish between a logarithmic increase and $E^{\frac{1}{4}}$.

E.H.S. Burhop (CERN): There is some evidence that the multiplicity approached a constant value at about 1000 Bev.

R. Levi Setti: This may be the case. I don't think it is substantiated well enough. We had this impression in the beginning ourselves, but it was based on such miserable statistics. On the other hand, an experiment similar to ours at the University of Chicago, by E. Lohrmann, M.W. Teucher and M. Schein a few years ago, gave, for the multiplicity corresponding to 250 Bev, a value of 9. At an energy 20 times higher, the multiplicity we find is not significantly larger.

M. Goldhaber (BNL): Shouldn't these theories be modified now that we are making θ's, ρ's, Ω's which then decrease the multiplicities?

R. Levi Setti: Yes, certainly this may have a lot to do with events in which you do observe a discrete structure. It certainly has the effect of emphasizing the apparent asymmetries. There have been several analyses made in the past to see if the center-of-mass emission was symmetric or asymmetric. It turned out that at low multiplicities a large number of cases showed some kind of asymmetric emission, namely, cases in which, for example, there were four or five particles emitted backward and perhaps one forward or vice versa. I believe that if you analyze the fluctuations statistically in terms of a binomial distribution made out of individual, independent particles, then you obtain a certain significant disagreement. However, if you introduce a correlation between these particles, then you can explain the asymmetries very easily.

M. Goldhaber: This also changes the comparison of the experiment with theory as far as the transverse momentum is concerned.

R. Levi Setti: It may not have such a strong effect if a resonant state is emitted. It will be the heavy particle which will be preferentially emitted at a very small angle.

M. Goldhaber: Like a K meson, roughly. If it has a transverse momentum comparable to the π, then you get at decay an extra spread.

R. Levi Setti: I wouldn't be sure that this process does not occur. However, from the fact that the transverse momentum for pions is so small at small angles, one may argue that these particles were really produced directly and not by intermediate states.

L.W. Jones (Michigan): Has there been any attempt to calculate the diffraction dissociation of heavy primaries by the mechanism of M.L. Good and W.D. Walker (coulomb dissociation)?

R. Levi Setti: I have the impression that coulomb dissociation would lead to a very clean fragmentation in the sense that you will certainly not transfer large momentum to the target nucleus. One should essentially see the heavy primary breaking up without showing any visible interaction. At these energies we have no example of this kind. Whenever the heavy nucleus undergoes fragmentation it is usually a very violent process accompanied by high multiplicities, even in the case of gradual peeling off.

G.B. Yodh: Have you followed tracks of jets with multiplicities greater than 5 and looked at their secondaries?

R. Levi Setti: This has been done by Mr. Kim for the tracks that he has identified. I had forgotten to mention that he based his identifications on the measurement of tracks which did not interact within 5 cm from the primary jet. In addition, he has found that about 80% of his secondaries produce a secondary interaction. He is, however, dealing with low energies, less than about 10 Bev, so that the secondary interaction is not very informative in general and scattering measurements give more reliable energy estimates.

M. Goldhaber: Do you have any evidence of states which live long enough to get away from the centers and which you might see break up later? You might see this for eta's at your energies.

R. Levi Setti: I am afraid we have nothing of that kind. It might be very difficult to distinguish this from a pair.

M. Goldhaber: It would not multiply later into a shower like an electron pair?

R. Levi Setti: In principle this is true. The point is that experimentally, after a few millimeters, you usually have many pairs which start multiplying into a giant cascade. To identify such things would involve following tracks of individual pairs, and this is really difficult.

M. Goldhaber: Getting back to the other point, maybe the primary production has a much more forward, backward distribution and some of the spread may be due to these resonance states which decay. If there are more states than you know at present, which is still likely, then maybe direct π and direct K production is a small part.

R. Levi Setti: We are at present attempting a statistical analysis of the spread in the center-of-mass angular distributions to detect possible correlations between the created particles.