EMULSION GRAIN DENSITY IN THE EXTREME RELATIVISTIC REGION

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Introduction

Several papers in the past few years have indicated that the ionization loss as measured by blob density in nuclear emulsion may not rise beyond its minimum value to a flat "plateau", but instead may rise and then decrease at very high velocities. Alekseyeva et al[1] have reported a drop of several percent in the blob denisty of electrons in the region between $\gamma \approx 200$ and $\gamma \approx 600$ ($\gamma = 1/\sqrt{1-\beta^2}$), while the data of B. Stiller[2] show a slight tendancy to "peak" at $\gamma \approx 750$. In this paper we report our measurements of the blob density of pion and electron tracks in the range $\gamma \approx 2$ to $\gamma \approx 4000$. We find no significant evidence for a departure from a flat plateau in the region $\gamma > 100$.

Experimental Procedures

Our data are gathered from 4 pellicles of 600μ Ilford K-5 emulsion. These are part of a stack exposed to 16 Bev negative pions at CERN in 1960, and developed at Berkeley a few days after exposure.

Electron tracks were located by area scanning a selected region of each pellicle for pairs produced by photons from π^0-meson decay. A total of 406 pairs was located, and from these most of our data are taken. Because the data gathered from electrons is not useful for values of γ much below $\gamma \approx 100$, secondary pions (and protons) produced by the primary interactions were used to extend our data to lower values of γ. Velocities were estimated from the values of $p\beta c$ obtained by multiple scattering measurements. For fast electrons, we have tried to minimize errors resulting from radiative energy loss by not scattering any single track for more than 1.5 cm, and for most we used only about 0.5 cm. Further, we discarded any electron track which showed evidence of a sudden change in $p\beta c$ along the scattered track length, either as a noticeable single scatter, or as indicated by our computer program. The scattering was performed on a Koristka R-4 microscope, and the calculations were carried out with a CDC 1604 computer. Our program for the computer divides each track into segments 10 cell-lengths long to facilitate the detection of changes in $p\beta c$ possibly caused by bremsstrahlung. To correct our readings for noise, we have used two methods on each track: (1) combinations of cell lengths of 2 and 3 times the basic cell length, and (2) subtraction of a constant noise appropriate for each observer, which was determined as a function of cell length by scattering measurements made on the primary 16 Bev pions. Tracks were generally discarded or rescattered if the two methods of noise removal did not yield results in statistical agreement. Most tracks were scattered at least twice, usually by different observers, and we found consistent results provided that the signal/noise ratio was held ≥ 1.5 for the primary cell length used. No track was used for which less than 20 cells could be measured.

We have used blob density as a measure of ionization. The greater information content of other track parameters(3) is offset for near minimum tracks by the ease and accuracy with which blob density data can be gathered (approximately 110 cm of electron track were blob-counted for this experiment).

The variation of blob density with depth in the emulsion was determined for each pellicle by blob-counting the tracks of primary pions. To do this, 12 pion tracks were found in each tenth of the pellicle thickness for each pellicle, and $\approx$ 400 blobs were counted for each track. Ten points of about 5000 blobs each were then plotted for each pellicle, and a smooth curve drawn through them was accepted as the variation of blob-density with depth for the pellicle.

The blob-density of electron and pion tracks was determined in each pellicle by the same scanner who determined the variation of blob-density with depth. For the electrons, care was taken that the blob density measurements extended over the same segment of track that was used for the scattering measurements. Thus, even if some undetected radiative energy loss occurred along the track, the ionization loss and value of γ would be averaged over the same range of $p\beta c$. The data from each electron and pion track were normalized by forming the ratio of blob density to that of primary pions at the same average depth in emulsion.

Results and Discussion

The normalized blob densities are shown in Fig. 1, in which the data from each pellicle are indicated by a different symbol. Each data point represents enough tracks to give a total of several thousand blobs, and thus an uncertainty in blob density of $< 2\%$. Each point is located at a value of γ corresponding to a weighted average for the tracks used. Inspection of Fig. 1 shows that the data from each pellicle are consistent with the assumption of a flat plateau starting at $\gamma \approx 100$.

Although the data seem to be in excellent agreement with the assumption above, there are possible sources of error which could conceal some departure from a flat plateau of ionization loss. Primary among these is the determination of γ from multiple scattering measurements. It is clear that if very large errors did exist, any structure of the curve would be lost. To check for systematic errors in our scattering data, the pellicles were taken to the Lawrence Radiation Laboratory at Berkeley and a random sample of tracks was scattered on the Koristka MS-2 belonging to the Barkas group. Consistent agreement within statistical errors was found, and we consider this the best evidence we have that our estimates of γ are not systematically in error. Another source of possible error rests in the variation of blob density with depth in the emulsions. Our data were insufficient to allow restricting all tracks to a small fraction of the emulsion thickness, and although care was taken in the normalization, one must recognize that the variation with depth is a severe handicap. Some encouragement comes, however, from the consistent results obtained from pellicles with rather different normalizing curves.

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References

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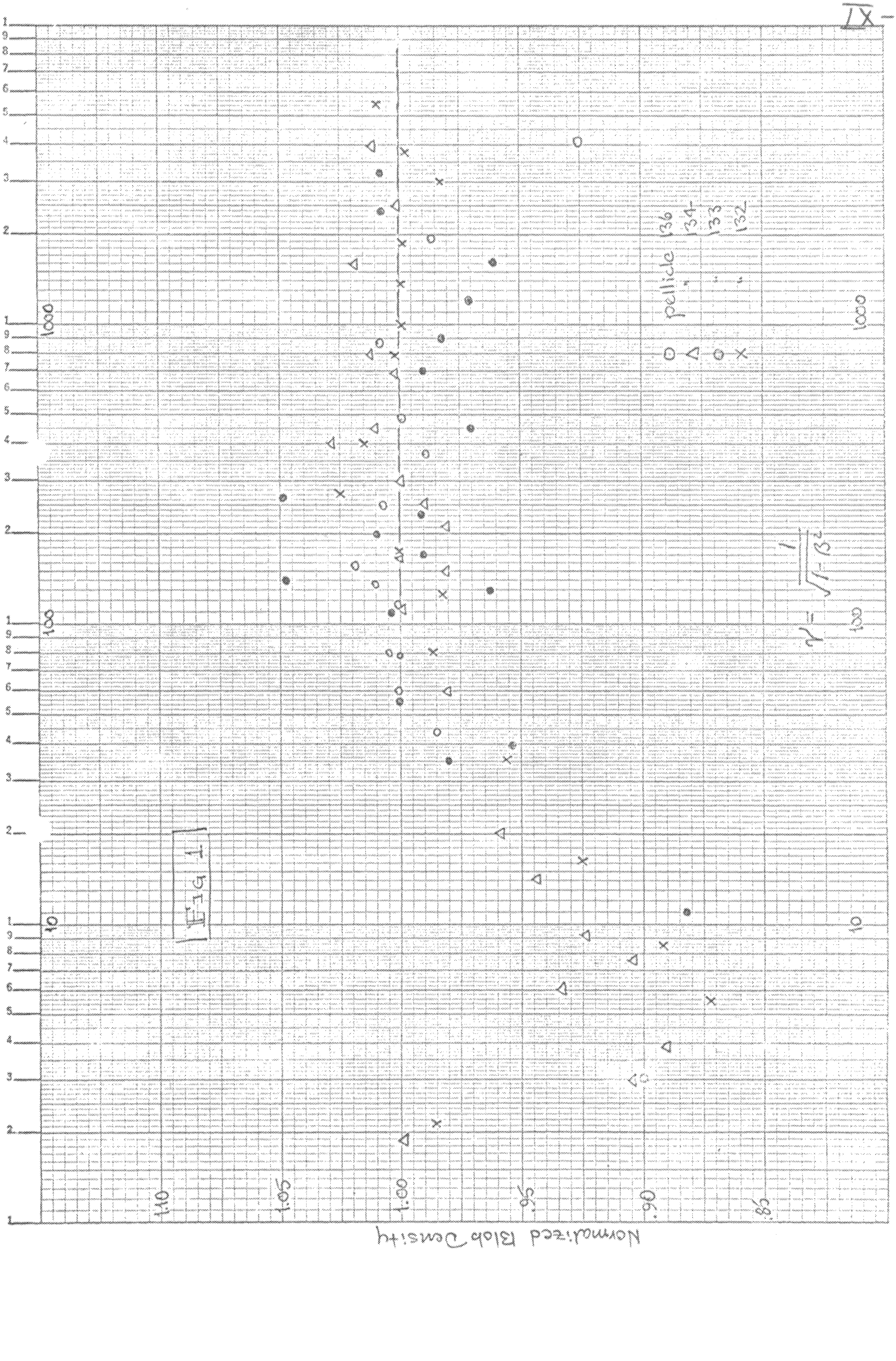

pellicle 136
134
133
132
1000
100
10
$\gamma = \frac{1}{\sqrt{1-\beta^2}}$
Fig 1
1.10
1.05
1.00
.95
.90
.85
Normalized Blob Density