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PROTON-TUNGSTEN NUCLEAR COLLISIONS AT 200 GEV*

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ABSTRACT

Nuclear track emulsions loaded with tungsten granules were exposed to 200 Gev protons at the National Accelerator Laboratory. Proton-tungsten nuclear interactions were located by area scanning and angular measurements were conducted on the shower particles. The average multiplicity $\langle n_s \rangle$, was found to be 16.8±1.5. The angular distribution was compared to that for proton-proton interactions and was found to be nearly the same for small angles, but considerably enhanced for large angles. Comparisons were made with intranuclear cascade models.

INTRODUCTION AND PROCEDURE

A study has been made of the collision of 200 Gev protons with tungsten (Wolfram) nuclei. Such collisions provide a severe test of theories relating to the development of intranuclear cascades and speculations on other forms of interactions in dense nuclear matter.

Nuclear track plates (Ilford G-5) were prepared with a dispersion of tungsten powder in the emulsion. The use of small granules made it possible to observe nearly all tracks produced in a given collision. For example, the collision shown in Fig. 1 took place near the middle of an irregular piece of tungsten, yet, all but the shortest recoil track can be seen readily.

After preparation, the plates were exposed to the 200 Gev proton beam at the National Accelerator Laboratory until an intensity of about 100,000 tracks per square centimeter had been obtained. The plates were scanned by both track following and area scanning methods. Each event was examined to be sure it took place in the tungsten by projecting the emitted tracks back to their origin. Emitted tracks from each collision were measured and grouped according to the usual criteria:

i) tracks of ionization less than 1.4 times minimum were called shower particles, n_s

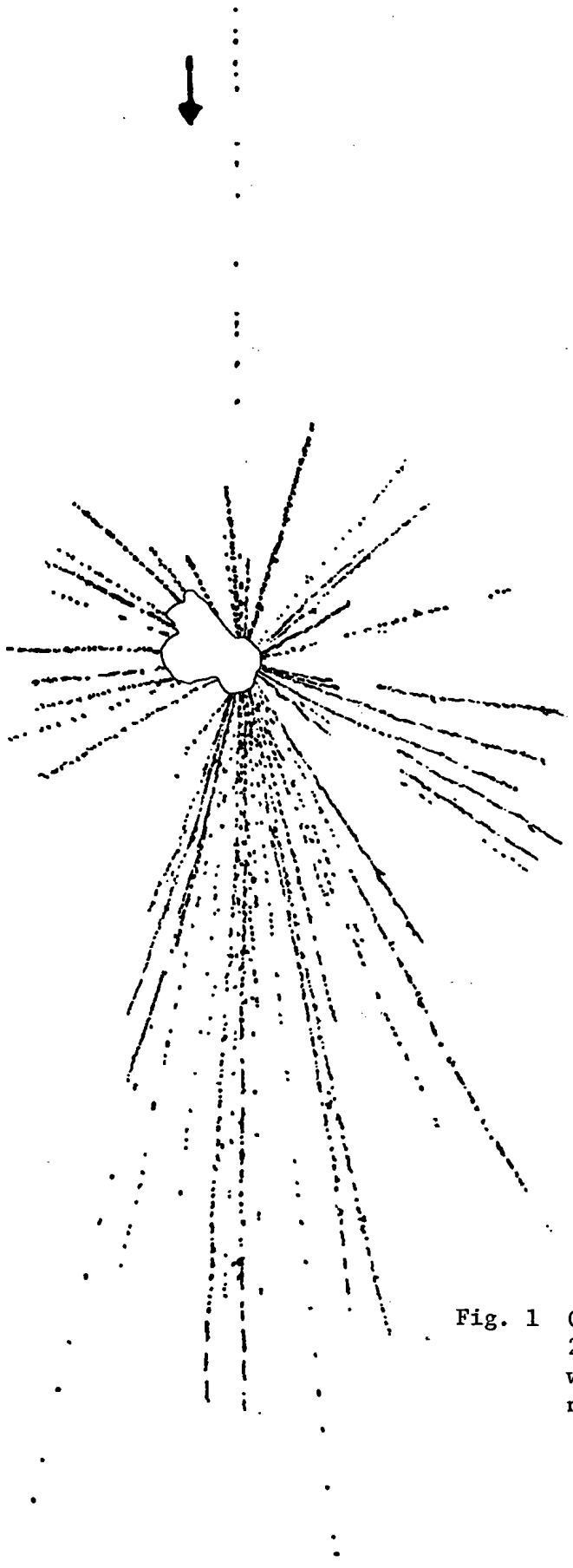

Fig. 1 Collision of 200 Gev proton with tungsten nucleus.

ii) tracks of ionization between 1.4 and 4.0 times minimum were called gray tracks, n_g

iii) tracks having an ionization greater than 4.0 times the minimum are referred to as black tracks, n_b

Spacial measurements were then made on each track which allowed the emission angles of each particle to be determined.

RESULTS

Perhaps the most important quantity relating to the nature of the intranuclear cascade is the multiplicity of charged particles. While the multiplicity is 7.65±.17 in p-p collisions at 200 Gev[1], it rises to 16.8±1.5 for proton-tungsten collisions at the same energy. These data along with the corresponding measurements for gray and black tracks are shown in Table I.

Table I Proton-tungsten collisions at 200 Gev. Comparison with theory and pure proton-proton collisions.

Observation	Multiplicity at 200 Gev	
	shower particles $\langle n_s \rangle$	gray and black tracks $\langle n_g + n_b \rangle$
p - tungsten collisions (this experiment)	16.8±1.5	34±1
Theory, Bali[2]	15.7	-
Theory, Trefil[3]	17	-
Theory, Artykov[4]	34	32
p - p collisions[1]	7.65±.17	-

The multiplicity calculations of Bali[2] shown in Table I are based on a Monte Carlo application of scaling[4] to the intranuclear cascade. The rather good agreement between calculation and experiment appears to support the concept of individual particle interactions in the dense nuclear matter. Fishbane, Newmeyer, and Trefil[3] have considered the intranuclear cascade up to tertiary collisions. On the basis of average behavior they would find an average shower multiplicity of about 17 for tungsten collisions. On the other hand, Artykov, Barashenkov, and Eliseev[4] have used a model which leads to a calculated multiplicity which is considerably larger than observed in the present experiment. Their model allows a group of intranuclear cascade particles to interact simultaneously with a single nucleon.

Another critical test of intranuclear cascade theories is concerned with the angular distribution of the emitted shower

particles. Analysis of the angular distribution is best made as a function of the rapidity. However, to a good approximation, the rapidity is closely proportional to the quantity $\mathrm{Log}_{10}^{\tan}\theta_L$, where θ_L is the emitted angle of the track in the laboratory frame of reference.

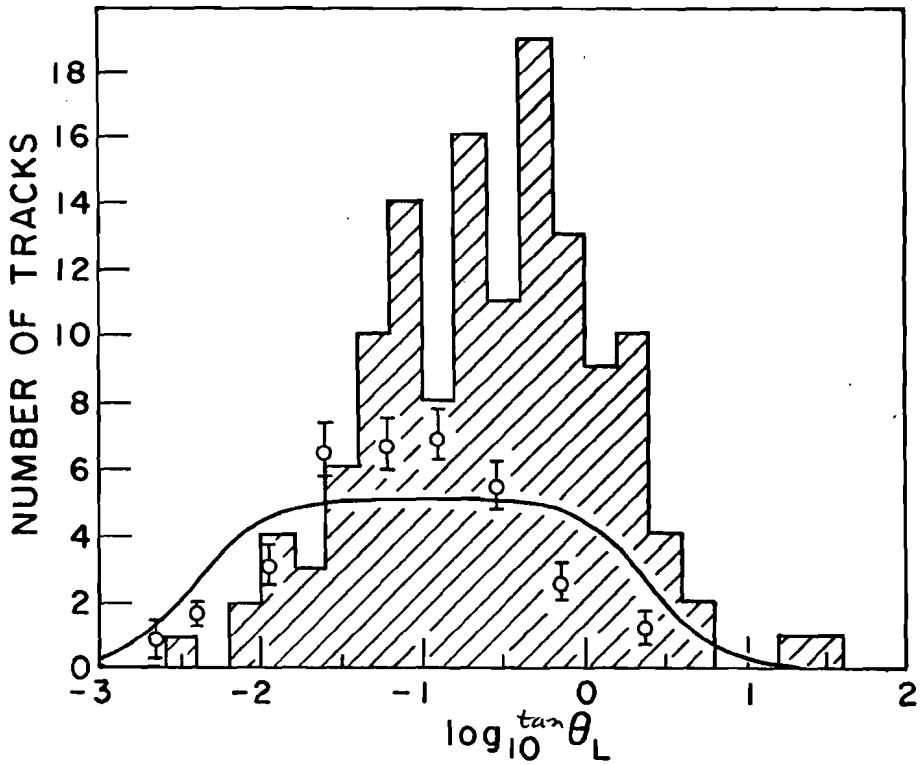

Fig. 2. Angular distribution of emitted particles produced by 200 Gev protons. The histogram is for collisions with tungsten nuclei and the points for p - p interactions. The solid curve is the expectation from scaling[5].

Fig. 2. presents the angular distribution of the tungsten events found in this experiment. The comparison data for pure p - p interactions[1] are shown by the points in the diagram along with the scaling theory predictions[5] given by the solid curve. Not only is the multiplicity much higher for tungsten events, but the shape of the angular distribution is quite different. It is evident that there is a surplus of secondary particles at the larger angles which has the effect of dramatically shifting the peak of the distribution toward lower rapidity. At small angles, the pure p - p and the p-tungsten angular distributions are nearly the same. This is in approximate agreement with the calculations of Fishbane, Newmeyer, and Trefil[3].

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