

EXCESSIVE PRODUCTION OF ELECTRON PAIRS
BY SOFT PHOTONS IN LOW MULTIPLICITY ION INTERACTIONS*

The JACEE Collaboration†

T. H. Burnett^h, S. Dake^b, M. Fuki^d, J. C. Gregory^g,
T. Hayashi^g, R. Holynskiⁱ, J. Iwai^h, W. V. Jones^e, A. Jurakⁱ,
J. J. Lord^h, O. Miyamura^c, T. Ogata^c, T. A. Parnell^f, T. Saito^a,
S. Strausz^h, T. Tabuki^a, Y. Takahashi^f, T. Tominaga^c, J. Watts^g,
B. Wilczynskaⁱ, R. J. Wilkes^h, W. Wolterⁱ, and B. Wosiekⁱ

^a Institute for Cosmic Ray Research, University of Tokyo;

^b Department of Physics, Kobe University;

^c Department of Applied Mathematics, Osaka University;

^d Okayama University of Science;

^e Department of Physics and Astronomy, Louisiana State University;

^f Space Science Laboratory, NASA Marshall Space Flight Center;

^g Department of Chemistry, University of Alabama, Huntsville;

^h Visual Techniques Laboratory, University of Washington;

ⁱ Institute for Nuclear Physics, Krakow.

Abstract

We report here on three multiply charged primary cosmic ray interactions with carbon nuclei, in which the number of materialized electron pairs within a distance of about 0.3 conversion length is larger than predicted from isospin considerations. These are the most energetic ($\Sigma E_{\nu} > 4$ TeV) of the low multiplicity (< 15 tracks) events observed in the JACEE-2 emulsion chamber.

1. Introduction.

The Japanese-American Cooperative Emulsion Experiment (JACEE) employs balloon-borne emulsion chambers to study the energy spectra, charge composition, and nuclear interactions of ultrahigh energy cosmic rays. Following exposure and processing, the emulsion plates are distributed to the participating laboratories for detailed scanning, tracing, and subsequent measurements using optical microscopes. Preliminary analysis is carried out on the data collected in the individual laboratories before it is combined with data from the other laboratories in the JACEE data bank. Comparisons among the datasets from the various laboratories are used to control the overall quality of the data.

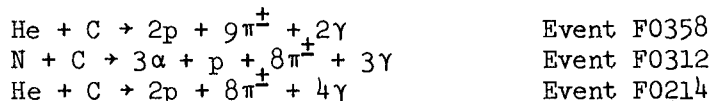
The data presented herein were collected in the plates of the JACEE-2 (second in the JACEE series of annual balloon flights) emulsion chamber. The unusual nature of the events was discovered during a study of the techniques used for determining the transverse momenta of high energy gamma rays emanating from a primary vertex in the target section of the emulsion chamber.

The JACEE-2 chamber consisted of a target section upstream of a thin calorimeter, which was used to measure the energies of cascades initiated by energetic gamma rays. The target was comprised of approximately 50 layers of double-sided emulsion plates (50 micron emulsion films on both sides of an 800 micron acrylic base plate) interleaved with 2 mm thick acrylic sheets. The calorimeter, which was a multilayer sandwich of lead sheets, x-ray films, and emulsion plates, had a vertical thickness of about 7 c.l.

Except for high multiplicity events, individual tracks of hadrons and leptons can be resolved near the vertex and then followed plate-to-plate to the calorimeter section. Consequently, cascades developing in the calorimeter can be correlated with tracks from the vertex.

2. Results.

The cones defined by the tracks of energetic charged particles from low multiplicity (< 15 tracks) interactions were scanned for possible evidence that cascading had begun in the target section of the emulsion chamber, i.e., upstream of the calorimeter. In this report we discuss the observations on the three most energetic ($\Sigma E_Y > 4$ TeV) events in the sample. Using standard nomenclature the three events are of the types:



where C represents the material of the acrylic target plates.

The detailed characteristics of the events are presented in Table 1. A total of 9 electron pairs were found near the interaction vertices. This is more than twice the number expected from photon conversions, assuming that the number of emitted photons in the volume scanned for pairs is equal to the number of charged pions emitted in that volume.

The pseudo-rapidity distributions of the produced hadrons in the forward cone are given in Fig. 1, which also shows the pseudo-rapidities of proton fragments, p, from the interactions and the photons, γ , producing the observed electron pairs. Proton fragments from the

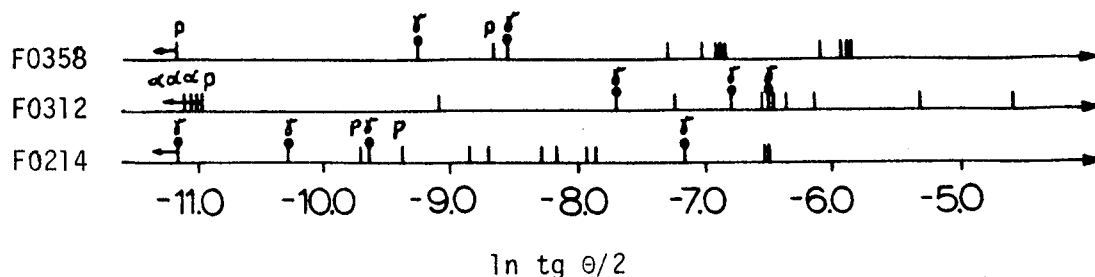


Fig. 1. Pseudo-rapidity distributions of produced particles, proton fragments, and gamma rays.

projectile were assumed to have the smallest emission angles among the charged particle tracks.

Figure 2 shows the dependence of the number of photons converted into electron pairs as a function of distance z from the interaction vertex. The solid line represents the number of materialized gamma rays, N_γ , producing electron pairs inside the scanned volume while the dashed line shows the number of pairs expected in that volume from isospin considerations.

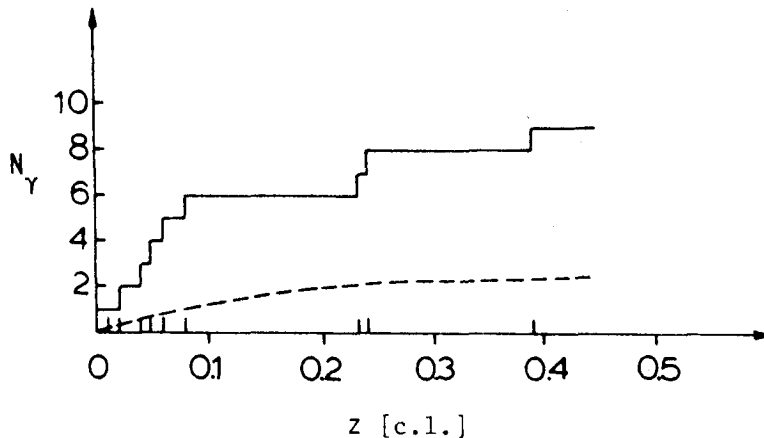


Fig. 2. Number of gamma rays producing electron pairs as a function of distance from the vertex.

3. Discussion.

The largest excess of pairs was observed in the most energetic event ($E \sim 60$ TeV), in which 4 photons materialized within a distance of 0.1 c.l. Three of the pairs were found in a very narrow cone of 0.0001 radians. The pairs evolved to 18 electrons in a distance of 0.4 c.l. and to 30 electrons in 0.5 c.l. A comparison with the results of cascade theory (Table 1, Col. 6) indicates that the materialization of one photon in the vicinity of the vertex is unlikely to produce the fast developing cascade. The observed pairs are most likely first generation and not fluctuations in the cascade development.

A characteristic feature of all the observed pairs is their narrow collimation, which suggests that they were emitted by the fragmenting projectile. Internal bremsstrahlung²⁾ from the deceleration of charged particles (or quarks) may explain the observed excess of pairs, since at projectile energies $E > 10^{12}$ eV the Doppler shift could raise the energy of soft photons above the ~ 0.5 GeV detection threshold. At the present stage, however, fluctuations in production of pairs can not be ruled out, and larger statistics are needed to give a quantitative description of these anomalous pairs.

Table 1. Characteristics of the interactions.

Event	E_0 (TeV)	Pair	z (c.l.)	n_e	n_e^+	n_e^*
F0358	24.0	1	0.04			
		2	0.23	4	2.1	
F0312	24.6	1	0.05			
		2	0.24	4	1.2	
F0214	60.0	1	0.01	2		
		2	0.02	4		
		3	0.06	6		
		4	0.08	8	1.1	
					
			0.36	17		
			0.55	30		6
			0.73	30		9

Table Captions

E_0 - primary energy estimated from the neutral component (ΣE_γ) and inelasticity coefficient $k = 0.5$.

z - distance to point of conversion (in conversion units).

n_e - number of electrons at given z .

n_e^+ - number of electrons predicted from the probability of pair conversion, based on isospin considerations.

n_e^* - number of cascade theory electrons with energies $w > 0.5$ GeV produced by an electron pair of energy $W_0 = 5 \text{ TeV}^1$). The cascade energy W_0 is estimated from the longitudinal development of the cascade downstream in the calorimeter.

References

* Research supported in part in the USA by DOE, NASA, and NSF and in part in Japan by JSPS and ICR.

† Mailing address for this paper: Institute for Nuclear Physics, ul. Kawioro 26A, 30-055, Krakow, Poland or Department of Physics and Astronomy, Louisiana State University, Baton Rouge, LA 70803, USA.

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