THE RESPONSE OF A SCINTILLATION COUNTER BELOW AN EMULSION CHAMBER TO HEAVY NUCLEUS INTERACTIONS IN THE CHAMBER

THE JACEE+ COLLABORATION

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ABSTRACT

In 1982 a hybrid electronic counter-emulsion chamber experiment was flown on a balloon to study heavy nucleus interactions in the 20 to $\gtrsim$100 GeV/AMU energy range. A gas Cerenkov counter, two solid Cerenkov counters, and a proportional counter hodoscope gave the primary energy, the primary charge and the trajectory of the particles, respectively. Using the trajectory information cosmic ray nuclei of $Z \geq 10$ were found reliably and efficiently, and interaction characteristics of the Fe group nuclei were measured in the chamber. A plastic scintillator below the emulsion chamber responded to showers resulting from interactions in the chamber and to non-interacting nuclei. Data on the response of the counter have been compared with simulations of hadronic-electromagnetic cascades to derive the average neutral energy fraction released by the heavy interactions, and to predict the performance of this kind of counter at higher energies. For the interacting events of highest produced particle multiplicity comparison between various simulations and the shower counter signal have been made.

1. The Instrument. The hybrid electronic counter-emulsion chamber instrument has been described[1] and some results of the interactions studies are presented at this conference[2,3]. Information on the measurements of primary charge and energy with the electronic counters is also presented[4]. For the purpose of this paper the counters above the emulsion chamber give a sample of heavy nuclei, carbon and above, energy of 22 GeV/AMU and above with charge known within Z±1 and energy differentially to 65 GeV/AMU and integrally above 65 GeV/AMU. The data available in this energy range contain 2,408 total particles. The

relevant emulsion chamber features are: Dimensions 50 cm x 50 cm x 21.5 cm ; 65 gm/cm^2 thick; 7.0 total radiation lengths; 1.4 interaction lengths thick for oxygen and 2.5 for Fe.

The burst scintillator was a 0.635 cm thick sheet of Ne 102 plastic, 57 cm x 57 cm, enclosed in a diffusion box viewed by two sets of two 7.62 cm photomultiplier tubes. One set of two tubes covered the pulse height range to 200 equivalent minimum ionizing particles (MIP). The other set (using dynode pulses) covered the range to 6000 equivalent MIP. The usable range of overlap included the fraction ($\simeq$20%) of C to Si nuclei which passed through the emulsion chamber and allowed in-flight calibration. Figure 1 shows the pulse height spectrum caused by oxygen nuclei with the prominant non-interacting peak. The use of only two photomultipliers resulted in nonuniformity (±15%) which was mapped with muons and checked with in-flight calibration for use in corrections. Because of the lateral spread of the showers in this energy range this correction has some residual error.

2. Simulations. A simulation program was developed to predict the shower signal in equivalent minimum ionizing particles [(Z fragments)^2 + protons + charged pions + (electrons > 1 MeV)]. The simulation program is modular with options allowed for processes such as fragmentation, pion generation, and electromagnetic cascade. Most shower counter simulations used a wounded nucleon model (WNM) with the average number of wounded nucleons equal to 0.3, an average inelasticity of 0.5, number of pions from $\langle N \rangle = 2.3E^{1/4}$, pion energies from the CKP model, and pion angles from a distribution with average $P_T = 300$ MeV/C. The electromagnetic cascade was a linear shower development function at the correct angle based on Rossi-Greisen but adjusted to later experimental results[5].

3. Results. Figure 2 shows the data from the burst counter for individual events with Z = 24 to 28. Also shown are results of simulations at 20 GeV/AMU and 60 GeV/AMU. These simulations were done by choosing, according to interaction length, a random location in the chamber at an incident angle of 30°. The results of repeated event simulations match well in average values the data from Z = 6 through 26 over the narrow energy range available to this experiment. Table I shows the results of simulations up to 200 GeV/AMU and data from this experiment. The results agreed with the average value of heavy nucleus energy going into electromagnetic cascades (0.12 for Fe), which has been used for energy estimation in passive emulsion chamber experiments at higher energies.

TABLE I

Pulse height and standard deviation for burst counter and simulations. Burst signal is in range 21 to 25 and ≥55 GeV/AMU. Simulations are average of 40 events.

E(GeV/n)	20	60	200
O Burst	252 ± 190	604 ± 468	
O SIM	231 ± 132	640 ± 455	1554 ± 1200

Fe Burst	951 ± 333	2082 ± 856	
Fe SIM	851 ± 239	2130 ± 934	5861 ± 2716

It is noted from Figure 2 that the events of highest produced particle multiplicity (as determined from the emulsions, see paper HE1.4-3 this conference) do not give exceptional burst counter signatures. Some simulations of these events have been attempted, using as a starting point the first interaction characteristics from the emulsions. One method of simulation started with the primary angle, interaction position, and number of wounded nucleons. The remainder of this simulation was the same as the WNM simulation described above. Another used the produced particle angular distribution list (reduced by a number of leading particles equal to the primary charge); and assumed a pion transverse momentum distribution of average $P_{t\pi^0}$ = 340 MeV/c and conservation of isotopic spin. These simulation results for the five highest multiplicity events generally exceeded the burst counter pulse height by one to four standard deviations. An analysis of individual event simulation results to varying parameters in the models is in progress. For peripheral interactions. such simulations are more obscured by subsequent fragment interactions which are not usually measured in the chamber.

4. Discussion. The behavior of the burst counter described above and the results of the simulations using the WNM compare well in average values and variance in the energy range of this experiment. Several effects, including the loss of shower particles from the sides of the scintillator, effect of shower lateral spread on uniformity corrections, and knock-on electrons cascading in the calorimeter have been estimated but not modeled in detail.

References

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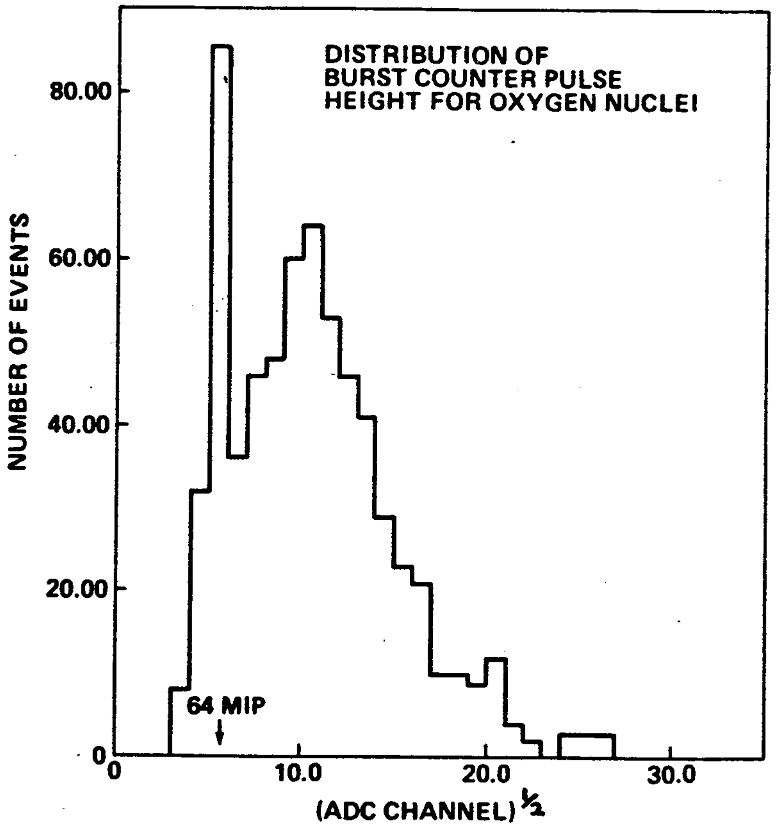

FIGURE 1

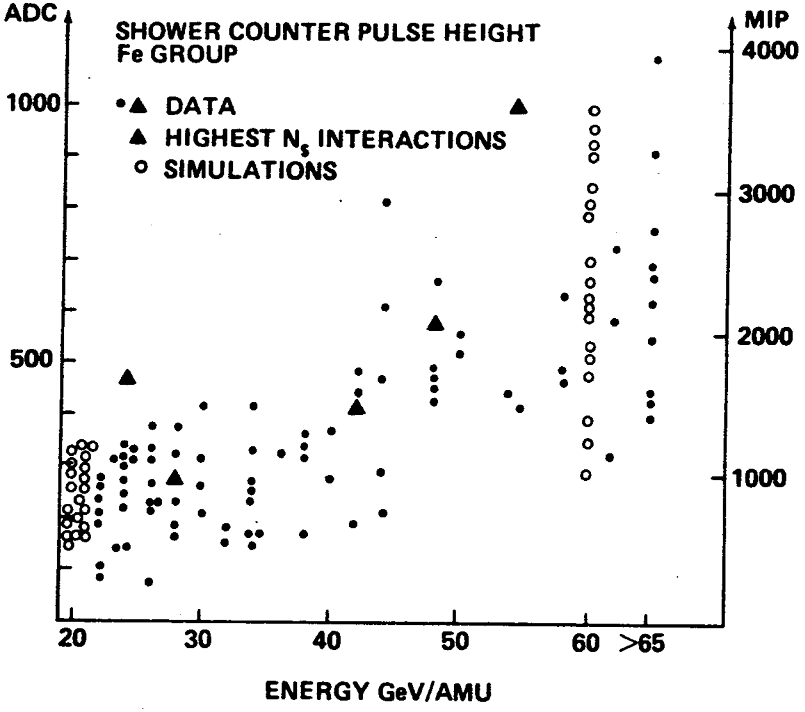

FIGURE 2