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Session A2: High Energy Inclusive Reactions

GAMMA-RAY MULTIPLICITY AND GAMMA-CHARGED PARTICLE CORRELATIONS IN 200 GeV/c pp INTERACTIONS*,**

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ABSTRACT

We have studied the reactions pp → gamma-rays plus anything (charged) at 200 GeV/c in the NAL 30-inch bubble chamber-wide gap spark chamber hybrid system. From a sample of 1234 inelastic bubble chamber events we have identified 2819 gamma-ray showers in the downstream spark chamber detector. Based on the shower data and charged tracks observed in the bubble chamber, we have determined the Mueller correlation parameters f_2^{oo} and f_2^{-o}. The relationship of these data to simple fragmentation and fluid model predictions is discussed.

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Recent experiments at the CERN, ISR, NAL and Serpukhov have revealed the existence of strong correlations between pions produced at high energies. *Dao and Whitmore have discussed these effects in a review article.*[1] Among those effects considered are: (1) $<n_{\pi^\circ}>$ may be *parameterized in the form* $\alpha n_- + \beta$, *where* n_- *is the* number of negative pions and $\alpha \approx 0.6$ at NAL energies and higher energies; and (2) values of the Mueller correlation parameter

$$f_2 = \begin{cases} <n(n-1)> - <n>^2 \text{ for } n_1 = n_2 = n \\ <n_1 n_2> - <n_1> <n_2> \text{ for } n_1 \neq n_2 \end{cases} \qquad (1)$$

are relatively large, positive and ordered according to $f_2^{cc} > f_2^{+-} > f_2^{-0} > f_2^{--}$. One implication of the second observation is that neutrally charged pairs of pions are more strongly correlated than singly or doubly charged pairs. *Dao and Whitmore have studied the* f_2 *parameter in terms of a* simple fragmentation model[2] and a critical fluid model[3]. Their anal*ysis shows that the presently available data agree fairly well with the* critical fluid model in its predicted energy dependence $\{(\ln s)^{3/2}\}$, whereas the fragmentation model gives a stronger energy dependence $(s^{1/2})$ than allowed by the data. Furthermore, f_2^{00} is predicted to be equal to f_2^{+-} for the fragmentation model and f_2^{-0} for the critical fluid model At 200 GeV/c, the measured values of f_2^{+-} and f_2^{-0} are 3.64 ± 0.09 and 1.84 ± 0.61 respectively[4]. A measurement at 69 GeV/c in the Serpukhov hydrogen bubble chamber Mirabelle gave $f_2^{00} = -2.0 \pm 1.0$, substantially below the predictions of either model at that energy[5]. Hence, a measurement of f_2^{00} (and a more precise measurement of f_2^{-0}) at NAL energies would clearly lend themselves to a better understanding of the mechanisms responsible for multiparticle production at high energies:

Measurements of multi-gamma-ray production are generally very difficult due to the requirements of reasonably large solid angle and high single gamma-ray detection efficiency. Hydrogen bubble chambers offer 4π solid angle; but suffer from poor detection efficiency, ranging from ~1.3% per gamma-ray for the bare NAL 30-inch chamber to ~6% for the largest chamber, such as Mirabelle. In the present experiment the single gamma-ray detection efficiency is ~24%, averaged over all of phase space. It should be noted, however, that a measurement of $\langle n_{\pi^\circ} \rangle$ in hydrogen bubble chambers is quite feasible since it is only necessary in this case that at the most one gamma-ray be detected and that detection efficiency be well known.

We have recently completed an analysis of 10,800 bubble chamber photographs taken as part of a 100,000 photograph exposure of the NAL 30-inch bubble chamber-wide gap spark chamber hybrid system to 200 GeV/c protons. The essential features of the hybrid system have been described elsewhere[6]. Gamma-rays which are produced at a laboratory angle of approximately ±4° relative to the incident beam direction are detected in the downstream spark chamber system by inserting 1.27 cm of lead (2.27 radiation lengths) between the last two spark chambers. The lead plate has dimensions 86 cm x 101 cm and is located at a distance of 6.84 m from the center of the bubble chamber. The spark chambers were triggered using the beam deflection-dE/dx systems in OR coincidence[6]. We estimate that the triggering efficiency for all inelastic events is 95%. The small loss is incurred primarily in the inelastic, low momentum transfer two-prong events.

A complete description of gamma-ray detection in the downstream spark chambers has been presented elsewhere[6]. The spark chamber phot--graphs were scanned, rescanned and checked by physicists. A total of

2819 gamma-ray showers were recorded. The overall combined scanning efficiency was in excess of 98%. The corresponding bubble chamber photographs were scanned in the usual fashion, resulting in 1234 events.

In order to eliminate spark chamber events resulting from the interaction of beam particles in materials downstream of the bubble chamber (primarily the bubble chamber windows), we have required that the beam track of each bubble chamber event be spatially coincident (to ±2 mm) with the trajectory recorded by an upstream proportional wire chamber beam tagging system and that the spark chamber trigger be in time coincidence with the beam. Since the beam of 6-8 particles was spread out over ~200 μsec, this eliminated essentially all beam background events.

Prompt background, produced by the interactions of produced gamma-rays or hadrons in materials between the hydrogen and the lead radiator, has been considered. Particular attention has been given to the possible existence of low energy ($\lesssim$200 MeV) gamma-rays produced by bremsstrahlung of primary gamma-rays in these materials. Because of the multiplicative nature of this process, such events could have serious effects on a measurement of a correlation parameter, such as f_2^{00}. Because of the high spatial resolution and multi-track efficiency of the spark chambers, it has been possible to selectively study individual gamma-ray showers according to their electron number. In an average sense this is equivalent to an approximate gamma-ray energy selection. Experimental evidence for low energy gamma-ray background is apparent, based on the observation that the ratio of one electron showers to two electron showers is larger than expected from directly produced gamma-rays. Monte Carlo studies reveal that, to a very good approximation, such low energy background would be confined to showers with three or fewer electrons. In the subsequent analysis, we have used only showers with four or more electrons.

In Figure 1 we show the geometrical acceptance (E_1) of the downstream detector (shaded area) expressed in terms of the gamma-ray C.M. rapidity variable. The overall distribution represents an approximation to the expected gamma-ray rapidity distribution where we have explicitly substituted measured π^- tracks for π°'s, with the subsequent decay $\pi^\circ \rightarrow \gamma\gamma$. The geometrical efficiency is estimated by these means to be 37.5%. Including an 80% transmission (E_2) of gamma-rays through materials between the event vertex and lead radiator and an 80% conversion probability (E_3) in the lead plate, the overall estimated efficiency of the detector per gamma-ray is $E_1E_2E_3 \sim 24\%$. The measured gamma-ray rapidity distribution is in good agreement with the geometrical distribution of Figure 1, suitably modified to account for the aforementioned transmission and conversion efficiencies. In Figure 2 we show the distribution of events, normalized to the cross section data of previous experiments[7], plotted as a function of the number of gamma-rays per event, $N(\gamma)$. The four or more electron cut discussed previously has been included in Figure 2.

In order to calculate f_2^{oo} and f_2^{-o} from the (N_γ) data, we assume that, for a given π° multiplicity, the center of mass momentum spectrum of produced π°'s is the same as that of π^-'s of the same multiplicity. Then we calculate the Monte Carlo probability $P_{N_\gamma}(j)$ to detect N_γ showers from various π° multiplicity (j) channels. Since the $\sigma(N_\gamma)$ data are a superposition of these probability functions, we minimize the chi-squared frunction

$$\chi^2 = \sum_{N} \left(\frac{\sigma(N_\gamma) - \sum_j a_j P_{N_\gamma}(j)}{\Delta\sigma(N_\gamma)} \right)^2 \qquad (2)$$

to find the a_j coefficients, which give the weight or cross section for the jth multiplicity. It is then a straight forward matter to calculate $\langle N_\gamma \rangle$ and $\langle N_\gamma (N_\gamma - 1) \rangle$ using the a_j's, and finally these quantities are related to the desired quantities by

$$\langle n_{\pi^o} \rangle = 0.5 \langle N_\gamma \rangle \tag{3}$$

and

$$f_2^{oo} = \frac{1}{4} f_2^{\gamma\gamma} - \frac{1}{4} \langle N_\gamma \rangle . \tag{4}$$

This method, when applied to a Monte Carlo generated N_γ distribution from π^- data, is seen to reproduce the expected values of "$\langle n_o \rangle$" and "f_2^{oo}" under these conditions, namely "$\langle n_o \rangle$" = 2.84 ± 0.04[7] and "f_2^{oo}" = 0.80 ± 0.09[7].

We find from the $\sigma(N_\gamma)$ data of Figure 2 the following values of $\langle n_{\pi^o} \rangle$ and f_2^{oo}:

$$\langle n_{\pi^o} \rangle = 3.4 \pm 0.1; \quad f_2^{oo} = -0.5 \pm 0.6 \tag{5}$$

Our measurement of $\langle n_{\pi^o} \rangle$ is in good agreement with the previously published value of 3.17 ± 0.32[8]. Our measurement of f_2^{oo} is clearly not in agreement with the previously measured value[4] of $f_2^{+-} = 3.64 \pm 0.09$ and is approximately 1.5 standard deviations larger than the published value of $f_2^{oo} = -2.0 \pm 1.0$ at 69 GeV/c from the Soviet-French collaboration[5]. Of course, this difference, if significant, could be accounted for in terms of a possible energy dependence of the correlation moment.

In a similar fashion, the quantity f_2^{-o} has been calculated from our data. The results are:

$$f_2^{-o} = 0.9 \pm 0.7. \tag{6}$$

Although the errors are large, our measurement of f_2^{-o} ($f_2^{+o} = f_2^{-o}$ as required in proton-proton collisions) is consistent with the previously measured value[4] of $f_2^{-o} = 1.84 \pm 0.61$.

FIGURE CAPTIONS

Figure 1 - A simulated center of mass rapidity distribution for gamma-rays produced in 200 GeV/c pp collisions. The shaded area corresponds to gamma-rays which fall within the geometrical acceptance of the lead radiator-spark chamber detector.

Figure 2 - The normalized distribution of gamma-rays, N_{γ}, observed in this experiment after removing showers with three or fewer electrons.

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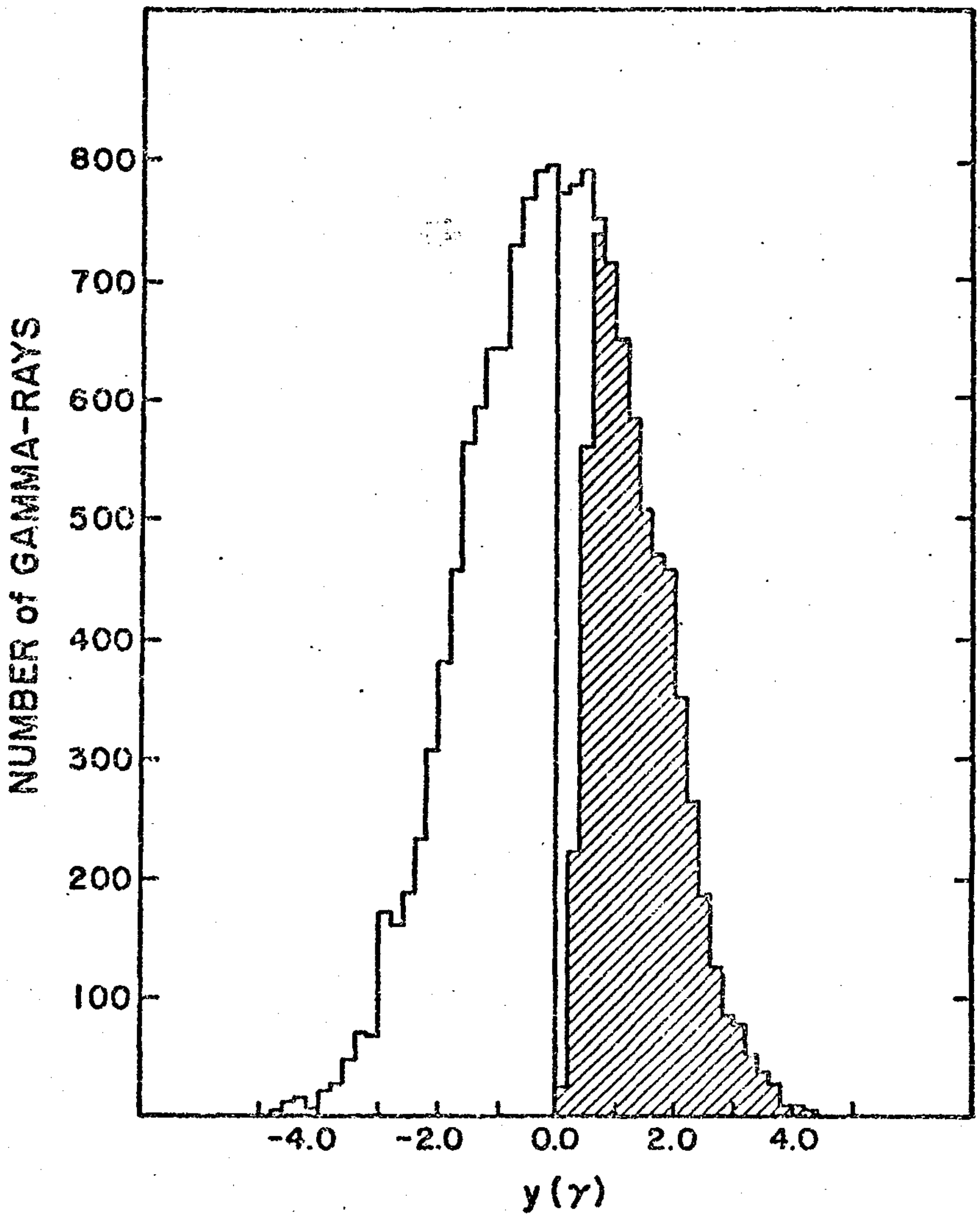
800
700
600
500
400
300
200
100
NUMBER of GAMMA-RAYS
-4.0
-2.0
0.0
2.0
4.0
y(γ)

FIGURE 1

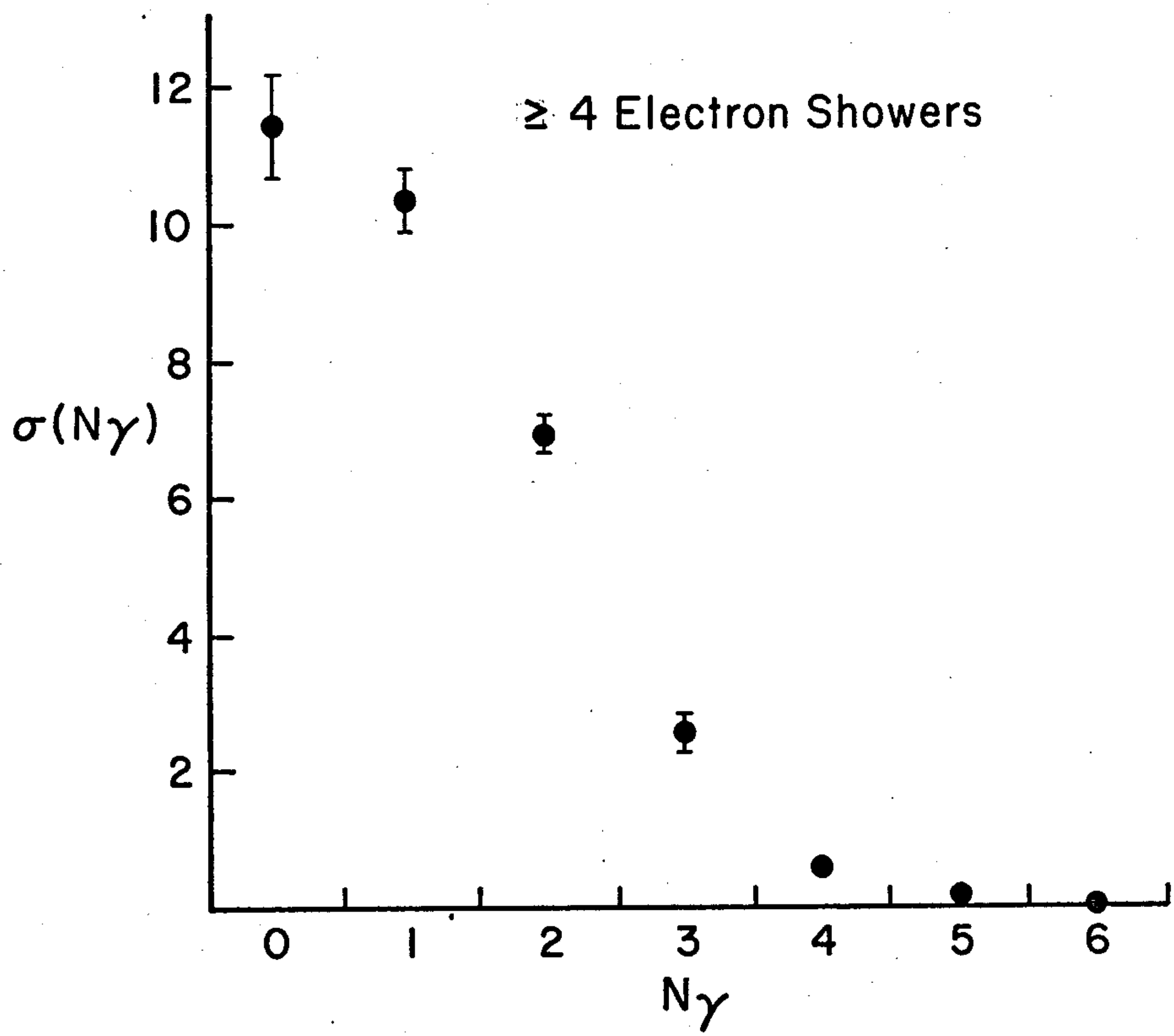

Figure 2