Inclusive and Direct Photons by Conversions and Dalitz Decays

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From "Charm in Phenix, July 1996, Santa Fe

1 Being too early may be worse than being too late

A recurring theme in some of the recent work on charm is typically[1] "*At RHIC eμ coincidence measurements could prove useful. Charm was first measured by this method at the CERN Intersecting Storage Rings (ISR)[2]...*" Interestingly, this statement ignores a real triumph of experimental physicists in the early 1970's even before the discovery of the J/Ψ, evidence of open charm was seen in hadron collisions[3]. The 'copious' yield of direct (i.e. not from Dalitz decays) single electrons and muons, at a level $e/\pi \sim 10^{-4}$ for $p_T \geq 1.3$, was eventually explained by Hinchliffe and Llewellyn-Smith[4] and Bourquin and Gaillard[5] as evidence of open-charm production. A glance at these papers from the early 1970's reveals much uncertainty about[5] "the conjectured charmed meson" whose discovery was published only in August 1976[6].

Part of the problem with the early direct lepton measurements and their interpretation as the result of semi-leptonic decays of charm was that there were several spurious results[7] from experiments that claimed to have measured direct leptons, but had not properly rejected or removed the background from the known sources of π^0 and η Dalitz decays. In fact, I said at the time that "all those who try to measure direct leptons become the world's experts on η Dalitz decay." (A proof of this is even in the literature[8].) A further confusion stemmed from the possibility that the ISR results[9], even with strong rejection of conversions, Dalitz and other low mass e^+e^- pairs, could possibly have been explained by a continuum, $d\sigma/dm \sim 1/m$, resulting from internal conversion of a direct photon signal[10] at the level of $\gamma/\pi^0 \simeq 5\%$ for $p_T \geq 1.3$ GeV/c. This wasn't the case[11], but the suggestion by Farrar and Frautschi[10], among others, initiated the study of direct photons in hadron collisions well before the advent of QCD and the "Inverse QCD Compton effect"[12].

References

[1] R. Vogt, *et al., Phys. Rev.* **D49** (1994) 3345. See also LBL-37981, hep-ph/9604369.

[2] A. Chilingarov, *et al., Phys. Lett.* **83B** (1979) 136, and references therein.

[3] *Proceedings of the XVII International Conference on High Energy Physics*, Ed: J. R. Smith, London, July 1974, The Science Research Council, Rutherford Laboratory, UK, section V, pp V-41–V-55.

[4] I. Hinchliffe and C. H. Llewellyn Smith, *Phys. Lett.* **61B** (1976) 472; *Nucl. Phys.* **B114** (1976) 45.

[5] M. Bourquin and J.-M. Gaillard, *Nucl. Phys.* **B114** (1976) 334.

[6] G. Goldhaber, *et al., Phys. Rev. Letters* **37** (1976) 255. A good measure of the confusion on this subject is that this letter was submitted for publication more than a year before its publication in the same issue of PRL in which a second charmed meson was reported, I. Peruzzi, *et al., ibid.* 569.

[7] See reference [5] for a good discussion.

[8] e.g., see M. R. Jane, *et al.,* Erratum, *Phys. Lett.* **73B** (1978) 503.

[9] F. W. Büsser, *et al., Nucl. Phys.* **B113** (1976) 189.

[10] G. R. Farrar and S. C. Frautschi, *Phys. Rev. Letters* **36** (1976) 1017. See also, C. O. Escobar, *Nucl. Phys.* **B89** (1975) 174; and E. L. Feinberg, *Nuovo Cimento* **34A** (1976) 391.

[11] J. H. Cobb, *et al., Phys. Lett.* **78B** (1978) 519.

[12] H. Fritzsch and P. Minkowski, *Phys. Lett.* **69B** (1977) 316.

On the Following Pages

A Closer Look at γ from measurements of e^+ e^-

(i) For photon conversions, the fully screened energy distribution [20] is

$$f(y) = \frac{9}{7}[y^2 + (1-y)^2 + \frac{2}{3}y(1-y)]$$

where y is the ratio of the energy of one member of the pair to the total pair energy. As this formula is not correct for very asymmetric pairs ... Multiple scattering was taken into account using the formulation of Bethe and Ashkin as given by Sternheimer [20], who emphasized the validity of this method for thin converters.

(ii) For Dalitz decays [21],

$$\frac{1}{\Gamma_{\gamma\gamma}}\frac{d\Gamma_{ee\gamma}}{dm} = \frac{4\alpha}{3\pi}\frac{1}{m}(1-x)^3\left(1-\frac{x_n}{x}\right)^{1/2}\left(1+\frac{x_n}{2x}\right) \quad ,$$

where m equals the mass of the e^+ e^- pair, M is the mass of the π^0 or η^0, m_e is the mass of an electron, $x = m^2/M^2$, x_n is the minimum value of x (when $m = 2m_e$), and the maximum value of x is 1.0. The total Dalitz conversion probability is

$$\delta = \frac{\Gamma_{ee\gamma}}{\Gamma_{\gamma\gamma}} = \frac{2\alpha}{3\pi}\left(\ln\frac{M^2}{m_e^2} - \frac{7}{2}\right) = \begin{array}{l} 1.19\% \text{ for } \pi^0 \\ 1.62\% \text{ fpr } \eta^0 \end{array} \quad .$$

Also, the decay angular distribution of the Dalitz pair in its rest frame is

$$\frac{3}{8}\frac{(1+\cos^2\theta + (x_n/x)\sin^2\theta)}{1 + x_n/2x} \quad ,$$

where θ is the polar angle of the Dalitz pair in its rest frame, with respect to the total momentum of the pair.

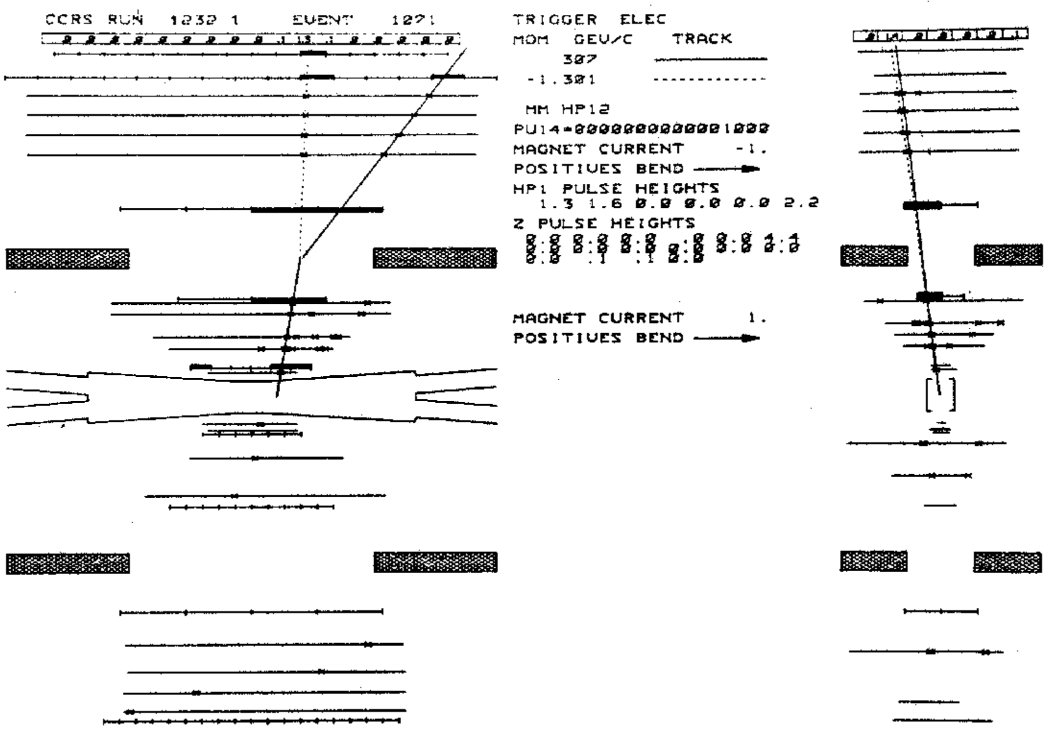


Fig. 2. Example of an identified e^+e^- pair event, which opens up in the magnet.

The Internal Conversion Method for Direct Photons

Works where the rate and background are high
from **MJT-XIV Moriond 1979**

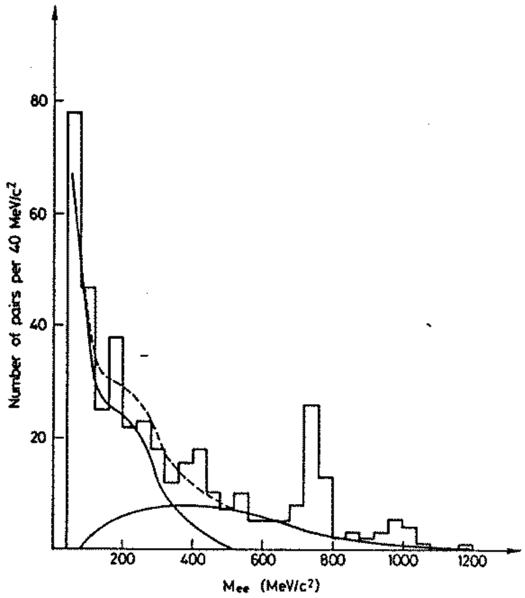


FIG. 38

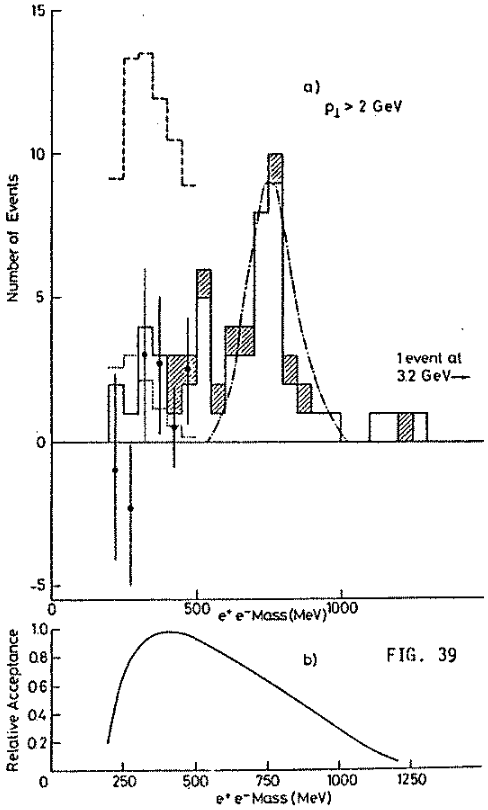
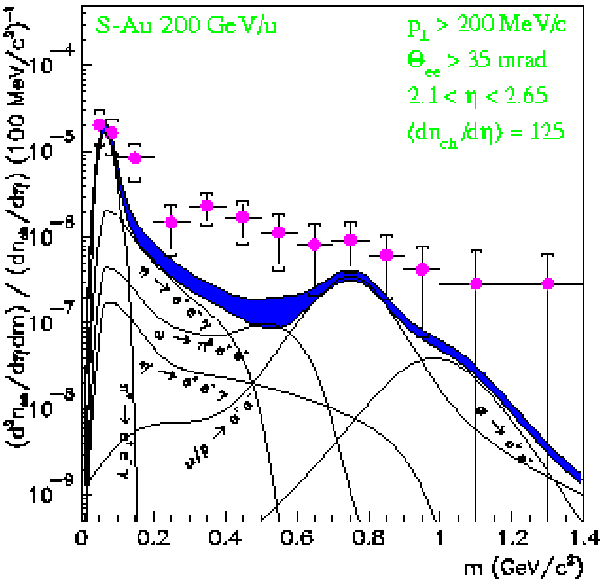
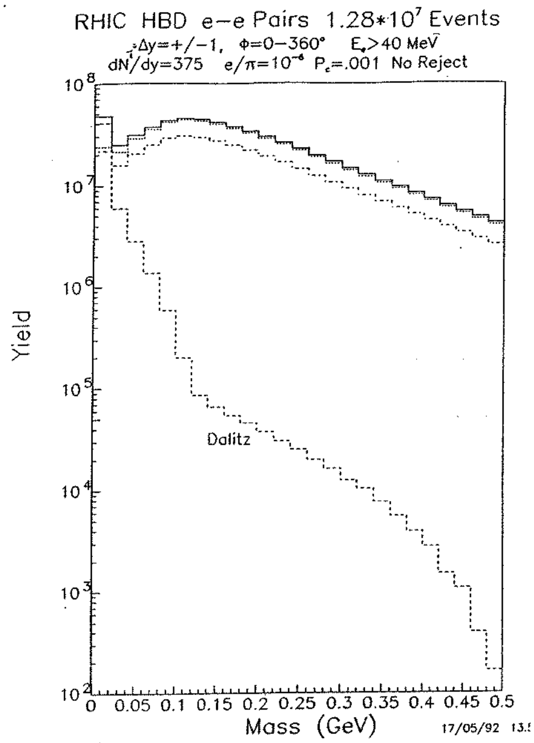


FIG. 39

On the left, (Fig. 38) is a 'same-side' low mass e$^+$ e$^-$ pair spectrum with $p_T \geq 1.6$ GeV/c from the Cern-Saclay-Zurich group. The dashed curve represents the sum of the two solid curves, which are various dalitz at low masses and a guess at Charm combinatorics at higher masses. However if this excess of pairs in the range 400$\leq M_{ee} \leq 600$ MeV/c^2 were due to the internal conversion of a directly produced photon, the limit would correspond to $\gamma/\pi^0 < 1.9\%$. Similarly, on the right (Fig 39) are the low mass pair data from J. H. Cobb, et al., PL 78B (1978) 519, for pairs with $2.0 \leq p_T \leq 3.0$ GeV/c. These data are not acceptance corrected, and the acceptance is shown. The peak from ρ^0, $\omega^0 \rightarrow$ e$^+$ e$^-$ is evident. The dotted line at low masses (a few events/bin) represents the contribution from all known Dalitz decays and the dashed line ($\sim$ 14 events/bin), which follows the acceptance, represents the internal conversion of direct photons at a rate $\gamma/\pi^0 = 0.10$. The authors concluded from this data that $\gamma/\pi^0 \leq (0.5 \pm 0.92)\%$ for $2.0 \leq p_T \leq 3.0$ GeV/c at the ISR.

Combinatoric pairs or Can PHENIX see π^0 Dalitz?





On the left is the now 'famous' CERES result on e^+ e^- from S+Au. The contributions of the various sources of Dalitz and direct decays are indicated. On the right is an old plot from Terry Awes showing that in PHENIX even the Dalitz pairs (dashed curve) get swamped by combinatorics. The PHENIX combinatorics in the mass region 0.2 to 0.5 GeV/c^2, where even the η dalitz doesn't contribute much, are huge and look very similar to the CERES effect—perhaps they didn't subtract the combinatorics perfectly. From Terry's plot, it appears difficult to find π^0 Dalitz in PHENIX—**WE HAVE TO REDO THIS ANALYSIS AND DO BETTER**, at least as well as—hopefully better than—CERES!