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CONFIRMATION OF A SOFT PHOTON SIGNAL IN EXCESS OF Q.E.D. EXPECTATIONS IN $\pi^- p$ INTERACTIONS AT 280 GeV/c

A. Belogianni[1], W. Beusch[4], T.J. Brodbeck[7], D. Evans[3], B.R. French[4], A. Jacholkowski[4], J.B. Kinson[3], A. Kirk[3], V. Lenti[2], R.A. Loconsole[2], V. Manzari[2], I. Minashvili[6], V. Perepelitsa[5], N. Russakovich[6], P. Sonderegger[4], M. Spyropoulou-Stassinaki[1], G. Tchlatchidze[6], G. Vassiliadis[1], I. Vichou[1], O. Villalobos-Baillie[3]

1 Athens University, Nuclear Physics Department, Athens, Greece.
2 Dipartimento di Fisica dell'Università and Sezione INFN, Bari, Italy.
3 University of Birmingham, Physics Department, Birmingham, U.K.
4 CERN, European Organization for Nuclear Research, Geneva, Switzerland.
5 ITEP, Moscow, Russia.
6 JINR, Dubna, Russia.
7 School of Physics and Chemistry, University of Lancaster, Lancaster, U.K.

Abstract

Photons produced in $\pi^- p$ interactions at 280 GeV/c were detected by reconstructing the e^+e^- pairs produced via the materialisation of the photons in a 1 mm thick lead sheet placed in front of the MWPC's of the OMEGA spectrometer at CERN. A soft photon signal 7.8 ± 1.6 times the Q.E.D. inner bremsstrahlung prediction was observed confirming the results of a previous experiment.

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The first observation of a soft photon signal in excess of the Q.E.D. inner bremsstrahlung prediction was observed in a K^+p hydrogen bubble chamber experiment at 70 GeV/c[1]. Since then apparently conflicting results have been published, some experiments observe a signal of soft photons[2, 3] whilst others observe no excess signal[4]. It appears that these results can be reconciled if the signal exists only in the region $Y_{cms} > 0$. Experiment WA83[3] , which was made in order to confirm the original K^+p BEBC result, found a signal of one soft photon per six π^-p interactions at 280 GeV/c in the kinematic region $0.2 < E_\gamma < 1.$ GeV/c and $P_T < 10$ MeV/c . This is a factor 7.9 times the Q.E.D. inner bremsstrahlung prediction.

In experiment WA83 the soft photons were detected with a Pb-scintillating fiber calorimeter. The origin of the photons was assumed to be the main interaction vertex for the determination of their otherwise unmeasurable direction. The calculated probability of background soft photon production from various sources in the apparatus was found to be negligible inside the geometrical acceptance of the above calorimeter. However, we think that a direct measurement of the photon production point would give an experimental check of this type of background. The present experiment, using a different technique, was motivated by this idea.

The data for this experiment were collected using the set-up of the WA91 experiment in the CERN OMEGA spectrometer shown in figure 1. A 280 GeV/c π^- beam incident on a 60 cm long hydrogen target, was used to reproduce similar conditions to the WA83 exposure. The magnetic field (B = 1.1 T) direction was along the z (vertical) axis of the OMEGA coordinate system in which the beam is along the x-axis. All interaction triggers (minimum bias) were collected. A 50×50 cm^2 Pb sheet of 1 mm thickness was placed just before the B set of MWPC's at a distance of 73 cm downstream from the center of the hydrogen target.

The photons were detected via the materialisation in the Pb sheet into an electron-positron pair. The e^+e^- were reconstructed as V^0's from the digitisations produced in the MWPC's using a modified version of the standard TRIDENT[5] reconstruction program which enabled reconstruction of tracks originating in the Pb sheet with momenta down to 40 MeV/c. It was thus possible to determine the line of flight of the photon with an average error of 20 mrad by measuring its momentum. This error is mainly due to the multiple scattering of the electrons and positrons in the lead sheet in the energy range $0.2 < E_\gamma < 1$ GeV studied in this work. However, for the laboratory production angle of the soft photons θ_R (calculated in the x-y plane), we preferred the more precise direction given by the reconstructed interaction point in the hydrogen target and by the photon materialisation point in the lead sheet. Analogously, for the calculation of the photon polar angle θ and the associated variable P_T the geometrical coordinates have been used.

The requirements for accepting a positive and negative particle pair (V^0) as a photon candidate were:

a) that each track had at least 4 reconstructed space points;

b) that the mass of the V^0 found by the TRIDENT reconstruction program , assuming electron and positron masses for the negative and positive tracks respectively, was less than 70 MeV/c^2;

c) that the x coordinate of the photon apex, defined to be at the position where the two tracks have zero angle between them, was within ± 3 cm of the middle of the lead sheet, and

d) that the distance beween the two tracks in the x-y plane when the tracks had zero angle between them was less than 3 mm.

The above defined criteria (c) and (d) have been decided during the reconstruction and V^0 selection procedure by using the simulation described in the next paragraphs with the aim of keeping the rate of spurious γ's less than 7%.

Only those photons were taken where the spatial separation of their e^+e^- vertex from any charged track at the lead sheet was greater than 3 mm in the x-y plane This was necessary to avoid including soft photons which were produced in the Pb sheet by electrons or positrons originating upstream of the Pb sheet.

The efficiency for reconstructing such photons was determined by a method involving implanting simulated photons into the real data . The method generates photons , converts them in the lead sheet using the EGS4 code[6] , transports the resulting e^+e^- pairs through the MWPC's and simulates clusters in the MWPC's at the position where the e^+ and e^- cross the MWPC's. After digitizing these clusters were implanted on actual events and then passed through the TRIDENT reconstruction program. The validity of the efficiency correction can be assessed by comparing the efficiency corrected photon P_T spectrum , in a region of P_T where photons from hadronic decays dominate, with the predictions of the FRITIOF Monte Carlo program for hadronic interactions[7] as we will see below .

The P_T^2 spectrum of reconstructed photons emitted inside a cone of half angle of 215 mrad around the beam direction and with energy $0.2 < E_\gamma < 1$ GeV, uncorrected for efficiency is shown in figure 2. The shape expected from γ's of hadronic decays in the same kinematic region is shown by the dashed line. Since we know that the photon detection efficiency falls off with decreasing P_T^2 the presence of an increase in the observed uncorrected spectrum at small P_T^2 ($P_T < 10 MeV/c$ or $P_T^2 < 10^{-4}$ (GeV$/c)^2$) is evidence for a low P_T^2 signal not originating from hadronic decays.

Figure 3a shows the efficiency corrected P_T spectrum upon which is superimposed the predictions of the FRITIOF Monte Carlo. It was necessary to increase the FRITIOF MC background by 20% to fit the data above a P_T of 50 MeV$/c$. This can be attributed to the systematic errors of tunning the FRITIOF MC and/or calculating the γ detection efficiency. It can be seen that the data follow well the expected P_T distribution of photons coming from hadronic decay above a P_T of 50 MeV$/c$ where the contribution coming from Q.E.D. inner bremsstrahlung is small. For P_T <50 MeV$/c$ an excess exists which rises rapidly towards zero P_T . This excess is essentially concentrated in angles $\theta < 20$ mrad as can be seen by comparing figures 3a and 3b in the energy range $0.2 < E_{lab} < 1$ GeV referred in this paper.

The rate of photons to interactions in this kinematic region is 1/7.6 whereas the contribution from hadronic decays and Q.E.D inner bremsstrahlung are computed to be 1/68[7] and 1/62[7, 8] respectively. Subtracting from the data the hadronic decay contribution for the kinematic region $0.2 < E_\gamma < 1$ GeV and P_T<10 Mev$/c$ we find a ratio for the observed signal to the expected Q.E.D. inner bremsstrahlung of 7.8 ± 1.6, where the main contribution to the error comes from the uncertainty in the efficiency correction. This value may be compared to the value of 7.9 ± 1.4 found in the WA83 experiment for the same kinematic region.

In order to see if the low P_T photons observed in figure 3b originate from the interaction point we show, in figure 4, a correlation plot of θ_R against θ_P which is the production angle of the photons defined by the line of flight of the photon in the x-y plane as measured by the vector sum of the e^+ and e^- momenta. A 45^0 correlation is observed with a spread about this line of 20 mrad, which is what would be expected from the multiple scattering of the e^+e^- in the lead sheet. The fact that we observe a strong correlation is evidence that the photons originate from the point of interaction.

Thus, the angular precision offered by θ_R and θ_P angles can be exploited for the comparison of WA91 and WA83 experiments. Having observed the same signal in the very forward direction in both experiments, with the interaction and materialisation points entering into the angle measurement (WA91), we obtain already an evidence that the WA83 soft photons originate also from the target interactions. Otherwise, in WA91 where the material between target and photon detection is significantly less than in WA83, we should observe less signal.

In conclusion this experiment confirms the existence of a soft photon signal in the kinematic region 0.2 GeV $< E_\gamma <$ 1 GeV and $P_T <$ 10 MeV/c which is a factor 7.8 ± 1.6 above that expected from Q.E.D. inner bremsstrahlung.

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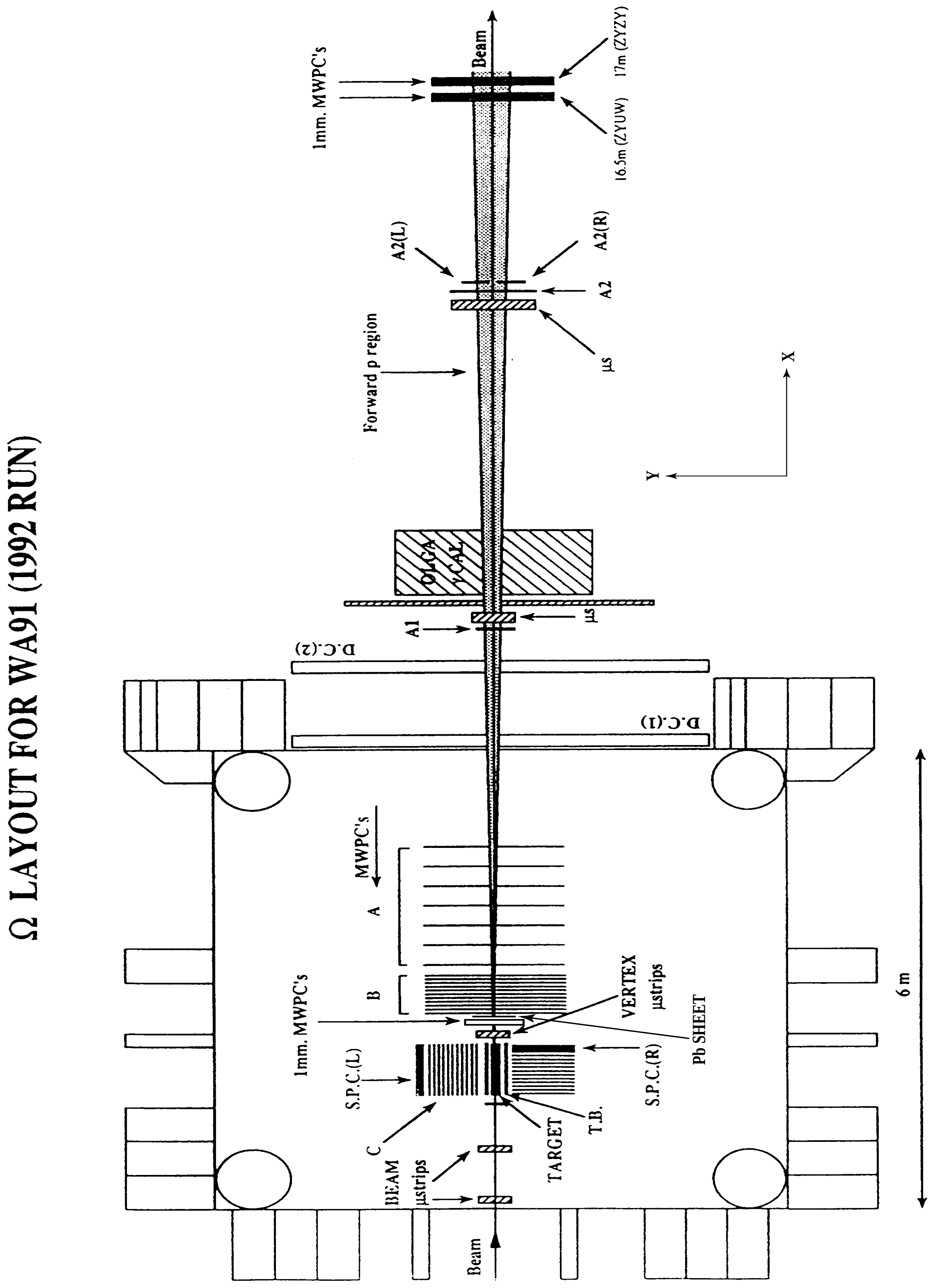

Figure 1: Layout of the OMEGA spectrometer for the experiment

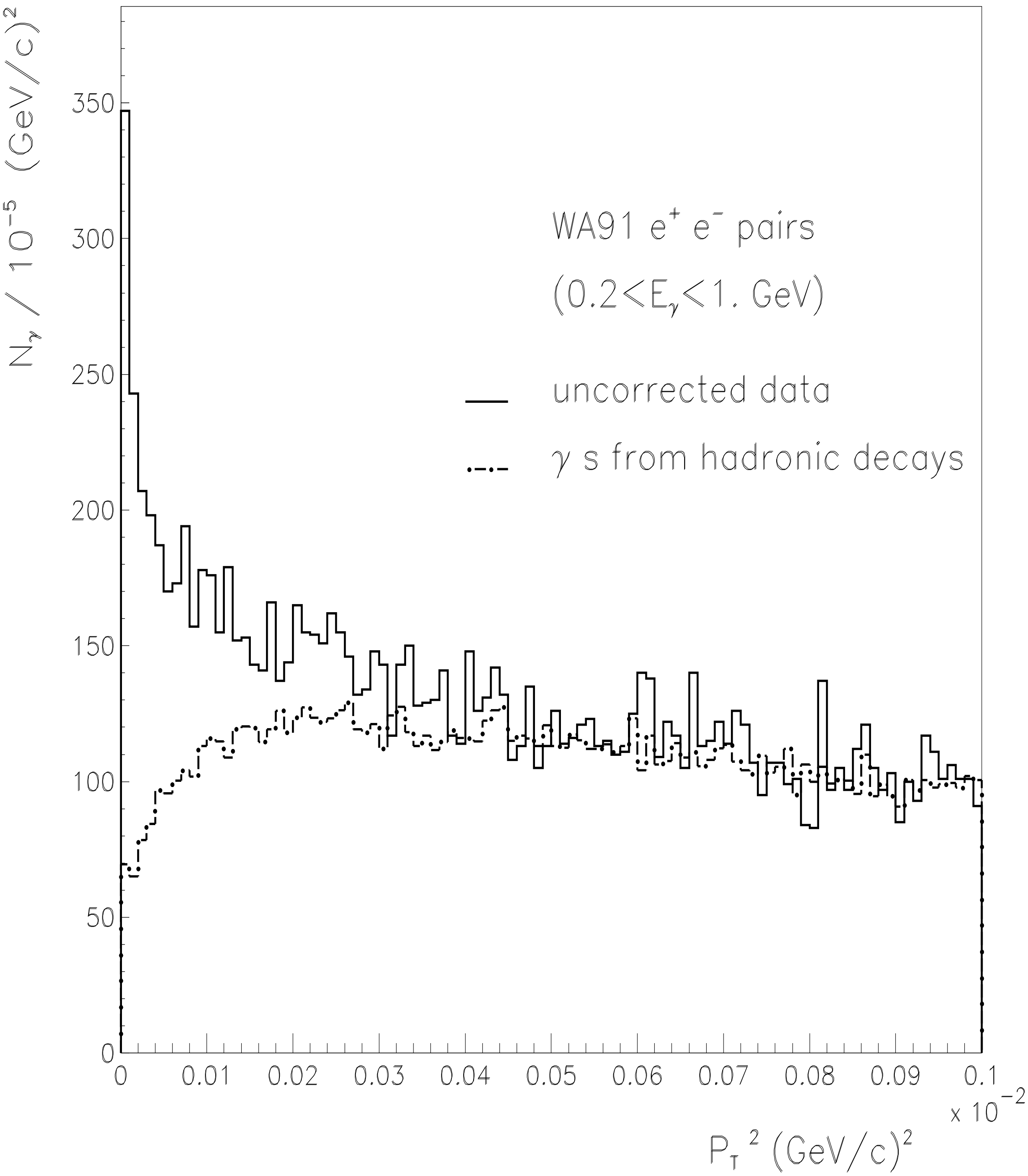

Figure 2: P_T^2 distribution for photons with energy $0.2 < E_\gamma < 1.0$ GeV uncorrected for detector efficiency.

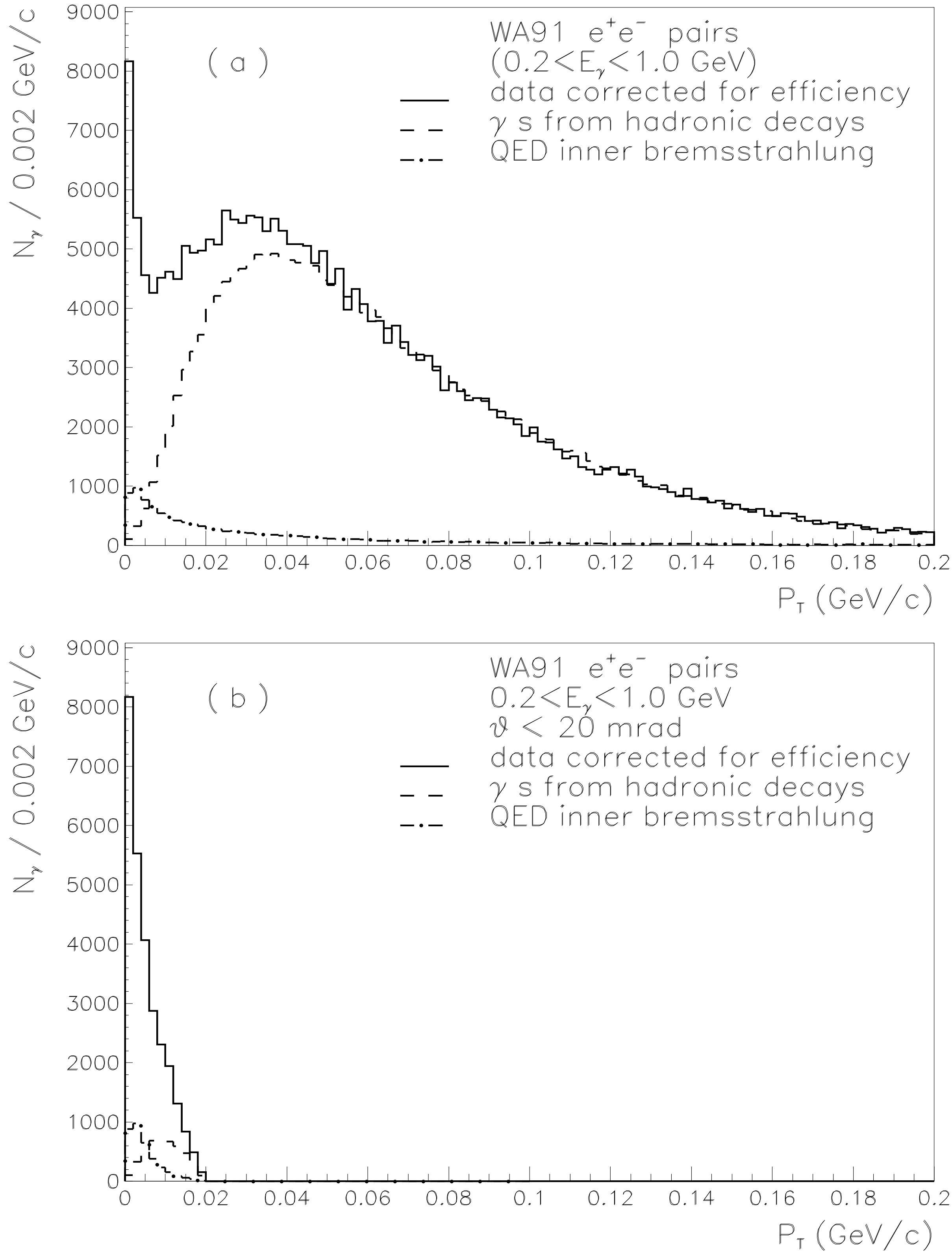

Figure 3: a) P_T distribution for photons with energy $0.2 < E_\gamma < 1.0 GeV$ corrected for detection efficiency. b) Same as fig. 3a but with additional restriction of $\theta < 20$ mrad.

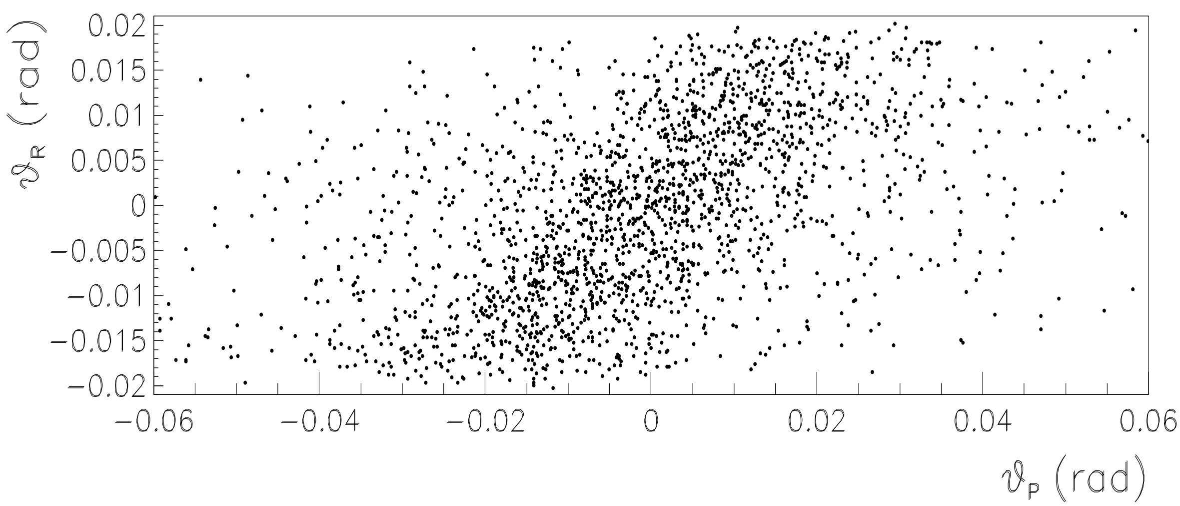

Figure 4: Correlation of θ_P versus θ_R as defined in the text.