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RESULTS FROM PLUTO AT PETRA

by

PLUTO Collaboration

(Paper presented by V. Blobel
at the International Conference on High Energy Physics
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RESULTS FROM PLUTO AT PETRA

PLUTO collaboration

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(Presented by V. Blobel)

ABSTRACT

Results obtained at the e^+e^- storage ring PETRA by the PLUTO collaboration at c.m. energies of 13, 17 and 27.4 GeV are presented. New limits on QED cut-off parameters are determined from Bhabha scattering; at 27.4 GeV the limits are $\Lambda_+ > 38$ GeV and $\Lambda_- > 60$ GeV. The measured values of the total hadronic cross section, and the study of the jet character of the hadronic events are well consistent with the expected production of b mesons (with $q_b = 1/3$), but do not require additional new quarks with charge 2/3. Hadronic events from two-photon exchange processes are observed with comparable rates as events from one-photon exchange. First results on the hadronic cross section in $\gamma\gamma$ collisions are given.

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1. INTRODCUTION

In this report results are presented obtained with the detector PLUTO at the e^+e^- storage ring PETRA. Since the start of physics runs in December '78 data were taken at c.m. energies E_{cm} = 13, 17 and 27.4 GeV. They allow a first look at hadronic final states from one-photon exchange[1] and two-photon exchange processes at previously unreached energies and allow sensitive tests on the validity of QED at large momentum transfers.

The detector PLUTO at PETRA has the following components: The inner detector consists of 13 cylindrical proportional chambers, operating in a magnetic field of 1.65 T. They provide a momentum resolution of $\sigma_p/p = 3\ \% \cdot p$ (p in GeV/c) at $p \geq 3$ GeV/c. Photon and electron energies are measured in a set of shower counters. The central detector is surrounded by two lead scintillator shower counters:

1) $90^o > \Theta > 52^o$ cylindrical shower counters of 8.6 r.l.
2) $55^o > \Theta > 15^o$ end cap shower counter, 1o.6 r.l..

In order to measure photons and electrons produced at small angles, the detector is equipped with two forward spectrometers, consisting of two shower counters:

3) $15^o > \Theta > 4^o$ lead scintillator shower counter (LAT), 14 r.l. with 4 planes of proportional tubes
4) $4^o > \Theta > 1.3^o$ lead glass shower counter (SAT), 12.5 r.l. with 4 planar proportional wire chambers.

For muon identification the flux return yoke is surrounded by an iron house, covered by planar drift chambers, to increase the total thickness of the hadron absorber to about 1 m iron equivalent.

The trigger, gated by the bunch crossing signal, is designed to be sensitive to QED events and to hadronic events from both one-photon exchange and two-photon exchange processes. The detector was triggered by one of the following conditions:

1) Two coplanar or ≥ 3 arbitrary tracks detected by the wire logic of the central detector;
2) more than 3 GeV energy deposited in the central shower counter;
3) more than 3 GeV in both forward spectrometers;
4) 2 x 0.5 GeV or 1 x 3 GeV energy in the forward spectrometers together with either

1 GeV shower energy or $\geq$ 1 track in the central detector.

2. BHABHA SCATTERING

The luminosity is determined by measuring the high rate of small angle Bhabha scattering $e^+e^- \to e^+e^-$, governed by small q^2, where QED is known to hold. The lead glass counters (SAT) of the forward spectrometer in the angular region $23 < \Theta < 70$ mrad are used for this purpose. This luminosity measurement has been checked with the Bhabha event rate in the LAT ($70 < \Theta <$ 260 mrad), and in the central detector shower counters. The rates agree generally within 5 % (LAT) and 6 % (central detector). The total integrated luminosities are 43 nb^{-1}, 88 nb^{-1} and 103 nb^{-1} at 13, 17 and 27.4 GeV., respectively.

Bhabha scatters in the central detector are identificed by the end cap and barrel shower counters, the charge signs by inner track chambers. The large angular region of $0.8 \geq \cos\Theta \geq -0.8$ allows a sensitive test on the validity of QED because of the very large q^2. Usually a possible break down of QED is described by a photon-propagator modification[2] in the lowest order Feynman diagrams. Introducing form factors F_T and F_S, depending on cut-off parameters Λ,

$$F_T = \left(1 \mp \frac{S}{\Lambda^2_{T\pm}} \right)^{-1} \qquad F_S = \left(1 \mp \frac{q^2}{\Lambda^2_{S\pm}}\right)^{-1}$$

the Bhabha cross section is modified to

$$\frac{d\sigma}{d\Omega} = \frac{\alpha^2}{2S} \left(\frac{q'^4 + S^2}{q^4} |F_S|^2 + \frac{2q'^4}{q^2 S} \mathrm{Re}\,(F_T F_S^*) + \frac{q'^4 + q^4}{S^2} |F_T|^2 \right) (1 + c\,(\Theta))$$

$$S = 4\,E_{beam}^{\ 2} \qquad q^2 = -\,s\,\sin\Theta/2 \qquad q'^2 = -\,s\,\cos^2\Theta/2$$

The parameters Λ_T and Λ_S refer to timelike and spacelike photons, respectively, the plus and minus signs to different ways to formulate a modified QED. $c\,(\Theta)$ is a radiative correction term[3].

The data at all energies agree well with the QED expectation ($1/\Lambda^2 = 0$). A QED violation would show up in a deviation at large scattering angles ($\cos\Theta < 0$). A fit assuming $\Lambda_S = \Lambda_T$ results at all energies in values of $1/\Lambda^2$ consistent with zero. Converting the fitted values into lower limits at the 95 % C.L. of the cut-off parameter Λ we obtain the following values:

$$E_{cm} = 17\text{ GeV} \qquad \Lambda_+ > 37\text{ GeV} \qquad \Lambda_- > 49\text{ GeV}$$
$$E_{cm} = 27.4\text{ GeV} \qquad \Lambda_+ > 38\text{ GeV} \qquad \Lambda_- > 60\text{ GeV}$$

3. THE TOTAL HADRONIC CROSS SECTION

To select hadronic events, all background events from beam halo particles, beam-gas reactions, QED reactions, cosmic rays and also two-photon exchange reactions have to be separated. The event selection is done by requiring $\geq$ 2 non collinear ($\Delta\phi < 150^0$) charged tracks, and applying a cut in the energy observed in the central detector (including neutral energy).The latter cut is particularly effective to discriminate beam gas events. Radiative scatters are removed by excluding any 2 or 3 prong events in which a track had an associated shower energy > 0.3 × E_{beam}. Contributions from τ-pair production are removed using the prong number and distribution of neutral energy of these events.

The acceptance factor ε of hadronic events is obtained from a Monte-Carlo study, using the Feynman and Field model[4)] (with u, d and s quarks) in a realistic simulation of the detector. The result is ε = 0.72 (average). For the determination of the total cross section additional corrections are necessary for radiation effects (- 10 %), and for the estimated contribution by two-photon exchange events derived from a Monte-Carlo study. The resulting values of $R = \sigma_{had}/\sigma_{\gamma\gamma}$ are given below:

E_{cm} = 13 GeV	R = 5.0 ± 0.5	(statistical
E_{cm} = 17 GeV	R = 4.3 ± 0.5	(statistical ±20% (system.))
E_{cm} = 27.4 GeV	R = 3.7 ± 0.8	(statistical

The systematic errors of 20% are mainly due to uncertainties in the luminosity determination and in the acceptance calculation.

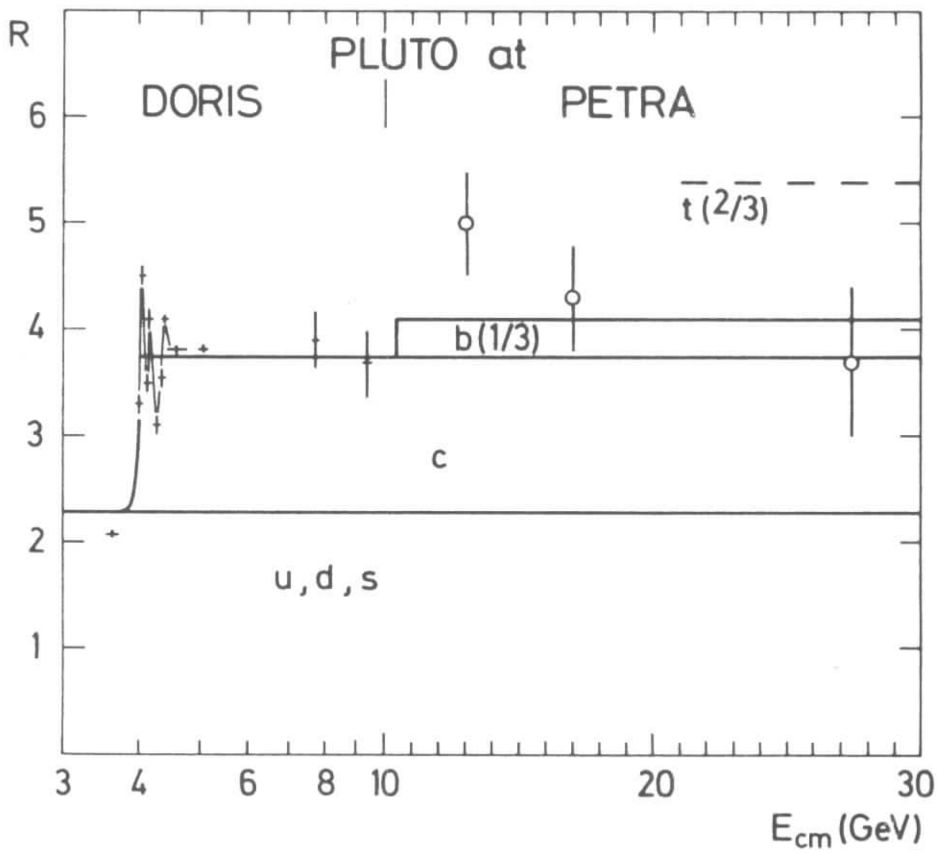


Fig. 1: Ratio R versus center of mass energy

The R values are shown in Fig. 1 together with values measured by PLUTO below 10 GeV[5]. The QCD expectation $R = 3 \Sigma Q_i^2 (1 + \alpha_s/\pi)$ is also shown. In the asymptotic regions the total cross sections are saturated by the contributions from the u, d, s and c quarks below 10 GeV, the higher energy data allow for a small increase due to a charge 1/3 quark (b). The 27.4 GeV data do not show evidence for an increase of R due to a potential new charge 2/3 quark (t).

4. JET ANALYSIS

For the investigation of the hadronic event topologies a minimum of 4 tracks was required in addition to the criteria given in Chapter 3. The jet character of the hadronic events[6] is measured by the quantity thrust, defined by

$$T = \max \frac{\Sigma_i |p_{Li}|}{\Sigma_i |p_i|}$$

where the p_{Li} are the longitudinal momenta w.r.t. an axis, which is chosen to maximize T. The range of T is between 1/2 for perfectly isotropic events and 1 for ideally jetlike events. If the transverse momenta of jet particles are assumed to be nearly constant with energy, the mean thrust should grow with increasing energy. Using the thrust axis as determined from all charged particles the ratio of $\langle p_L \rangle$ to $\langle p_T \rangle$ at E_{cm} = 27.4 GeV becomes as large as 3.1 ± 0.3.

Fig. 2a shows the observed mean values of $\langle 1 - T \rangle$ between 7.7 and 27.4 GeV, showing a clear decrease with increasing energy. The distributions of the observed thrust are shown in Fig. 2b-f for the different energies. Also shown are curves from a Monte-Carlo study based on the Feynman and Field model of quark parton jets, with full simulation of the detector and radiative corrections. The distributions generally follow the expected behaviour, using u, d and s quarks only. Also shown in Fig. 2a is the dependence of $\langle 1 - T \rangle$, if $b\bar{b}$ pair production and decay is included[7]. In the thrust distributions at higher energies the additional contributions for the c and b quarks are included. At 27.4 GeV in addition the expectation is shown, if a new heavy quark (2/3 charge) is added, assuming a threshold a few GeV below 27.4 GeV. No evidence is found for this additional contribution, which results in values of T around 0.7.

The observed mean transverse momenta w.r.t the thrust axis show a slight increase with energy between 13 and 27.4 GeV from 0.37 ± 0.01 to 0.43 ± 0.02 GeV. Part of this increase can be attributed to effects from the limited resolution and uncertainties in the determination of the jets axis. The effect of gluon emission in the quark pair production leads to a natural broadening of the energy flow in the final state, giving an increase of the mean transverse momentum. However, with present statistics no detailed analysis of these effects is possible.

5. TWO PHOTON EXCHANGE PROCESSES

Hadronic events from two-photon exchange processes[8] receive growing interest in the PETRA energy region. The basic diagram for this reaction is shown on top of the next page.

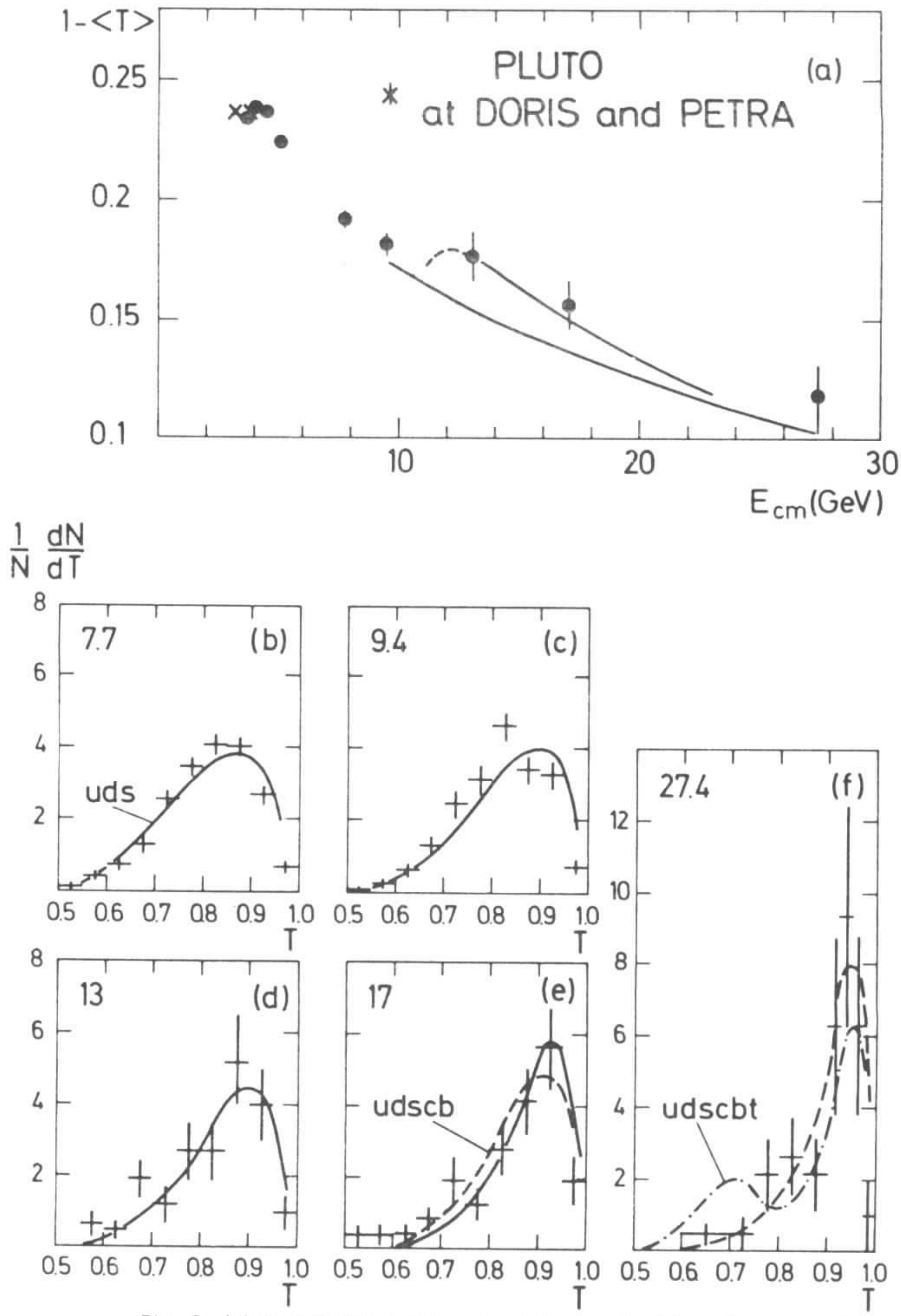
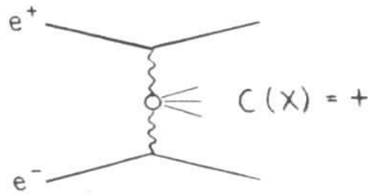


Fig. 2: (a) Mean observed values of <1-T> as a function of energy and (b) - (f) distributions of thrust for the different energies. The curves are explained in the text.



The genuine two-photon cross section $\sigma(\gamma\gamma \to$ hadrons) can be extracted from the measured cross section $\sigma(e^+e^- \to e^+e^- + X)$ using calculated flux factors of the incoming photons, usually in the 'equivalent photon approximation'. For a first analysis of our data taken at PETRA we have used events tagged in at least one of the forward spectrometers. The distribution of the vertices along the beam line, of the energy in the tagging counters and of the total energy and transverse momenta of the hadronic particles shows, that a 'single tag' is already a clean signature of 2γ events.

To reduce second order QED processes, we demand at least 3 particles in the central detector (3 tracks or 2 tracks + additional independent shower). Using tags in the SAT at 13 and 17 GeV (average $q^2 \approx 0.07$ and 0.11 GeV^2), the sample consists of 51 events with a background of 11 events. The data are compared to the Monte Carlo expectation assuming a constant $\gamma\gamma$ cross section with a limited p_T of 300 MeV/c, with flux factors calculated in the equivalent photon approximation, which should be applicable at least in the region of high W of our sample. From a comparison to the data we get the total cross section $\sigma(\gamma\gamma \to$ hadrons) as a function of the visible invariant mass W_{vis}, shown in Fig. 3, together

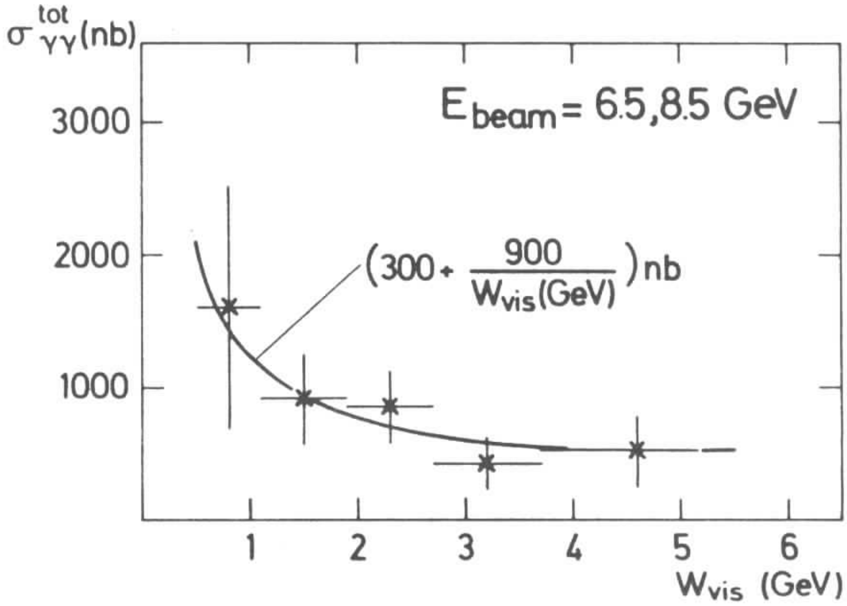


Fig. 3: First results on the total cross section $\sigma(\gamma\gamma \to$ hadrons) as a function of the visible invariant mass W_{vis}.

with a parametrization

$$\sigma(\gamma\gamma \to \text{hadrons}) = (300 + \frac{900}{W_{vis}(\text{GeV})})\ \text{nb}.$$

The constant term agrees in magnitude with the values expected for the diffractive part. The data taken at 27.4 GeV have an average q^2 as large as 0.4 GeV^2 even in the SAT; a preliminary analysis of these data indicates a q^2 dependence of hadronic production, which is being studied.

* * *

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