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ELECTRON-POSITRON BREMSSTRAHLUNG AT ADONE. A NEW LIMIT FOR THE EXISTENCE OF A HEAVY ELECTRON.

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ELECTRON-POSITRON BREMSSTRAHLUNG AT ADONE. A NEW LIMIT FOR THE EXISTENCE OF A HEAVY ELECTRON.

SUMMARY. -

A new measurement of the cross section for the reaction $e^+e^- \to e^+e^-\gamma$ has been performed at the Adone storage ring, using also tagging counters for detecting secondary electrons. The results are in agreement with the QED predictions. New limits for the mass and coupling constant $(e^* e \gamma)$ of a heavy electron, e^*, have been established.

In this paper we report on the results of an experiment performed at the ADONE electron-positron storage ring, to study the reaction:

$$e^+e^- \to e^+e^-\gamma \ . \tag{1}$$

Two different kinematical region were studied, one characterized by having all three secondary particles emitted at wide angles and the other with one electron (or positron) emitted at a very forward angle. Previously reported results on the same reaction were obtained with a different experimental set-up(1).

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A schematic view of present experimental apparatus is reported in Fig. 1. It consists of a wide angle detector and two tagging

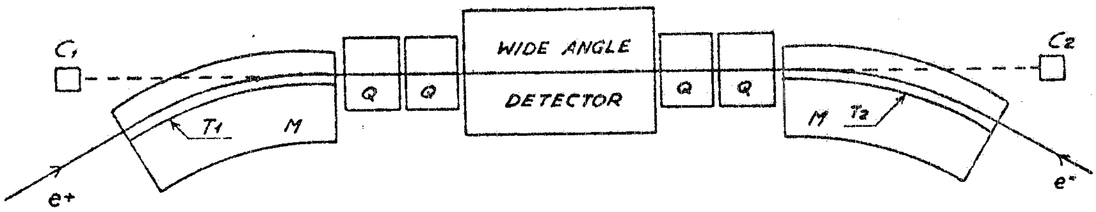

FIG. 1 - Top view of the experimental set-up. Q: Adonė quadrupole; M: bending magnet; T_1, T_2: tagging counters; C_1, C_2: Cerenkov counters.

counters T_1 and T_2. The wide angle detector$^{(2)}$ consists of two half-cylinders composed of optical spark chambers, lead and scintillation counters in a sandwich arrangement. The total solid angle cevered is $0.4 \times 4\pi$ sr for triggering and $0.66 \times 4\pi$ sr for tracking. The total thickness of each shower detector is 5.5 r.l.. Electron (photon) direction can be measured within $\sigma = \pm 2^\circ$ ($\pm 4^\circ$). The tagging counters$^{(3)}$ accept electrons or positrons emitted within $\sim$15 mrad with respect to the beam line and with a momentum range x = = 0.1-0.9 where x is given in units of the machine beam momentum. They are placed close to the vacuum chamber inside the Adone bending magnets adiacent to the apparatus which acts as a momentum analyser of secondary electron or positron. Each tagging counter is viewed by two photomultiplier tubes placed at the ends of the scintillator. The time measurement between those two photomultipliers can be used to reconstruct the impact position of the electron or positron on the scintillator and therefore to deduce its momentum.

Detection efficiency of the tagging counters has been measured as a function of x using the events from beam-gas bremsstrahlung in coincidence with the respective total absorption lead glass Cerenkov counters C_1 or C_2 (Fig. 1). For values of x larger than 0.8 the detection efficiency of the tagging counters is not known with precision, because in this energy region electrons impinge over the counter near the end of the counter and at grazing incidence. Actually the momentum of the tagged electron or positron was calculated using the measured angles of the particles detected in the wide angle detector and energy-momentum conservation, this value then was checked against the value obtained from the time of the flight measurement in the tagging counter. A trigger is generated if one charged particle is present in the upper (lower) part of the detector in coincidence with a photon in the lower (upper) part and an electron in the tagging counters, or if at least two cherged particles are in coincidence in the both part of the wide angle detector. Electrons and photons are easily recognized in the wide angle detector by observing their showers in the optical spark chambers.

Reaction (1) has been studied in the total c. m. energy range 1900-2900 MeV. These data were collected along with the systematic search for a narrow resonance(2, 4). Bhabha scattering detected in the wide-angle detector provides a check of the detection efficiency of this part of the apparatus. Small angle Bhabha scattering (3^o-6^o) in a different straight section of Adone provide a high rate monitor. Detection efficiency and monitoring system introduce a systematic error of $\sim \pm 10\%$ in the absolute QED prediction.

We divide the observed events from reaction (1) in two classes corresponding to two different kinematical regions:

a) The photon and the final electron (positron) are detected in the wide-angle detector while the final positron (electron) is detected by one of the tagging counter. We shall call these events virtual Compton scattering (VCS) if they satisfy the following selection criteria: the azimuthal nonalignement of the two wide-angle particles must be $\leq \pm 20^o$, and the kinematical reconstruction of each event must be compatible with the reaction (1).

b) All final particles are detected in the wide-angle detector. We shall call these events wide-angle bremsstrahlung (WAB) if they satisfy simultaneously the following criteria: the angle between any pair of final particle must be $\geq 12^{o}$, the acollinearity angle between the final electron and positron must be $\geq 12^{o}$, the complanarity angle(5) of the three particles must be $\leq 10^{o}$, kinematical reconstruction of each event must be compatible with reaction (1).

VCS events. - We have collected 143 possible events in a total integrated luminosity of 120 nb^{-1}. Of these events, only 127 satisfy the selection criteria. In Figs. 2a) and 2b) we show the momentum distribution of the tagged particles and the energy distribution of the wide-angle particles respectively.

The effective mass distribution of the wide-angle $(e^{\pm}, \gamma)$ system, evaluated through the $(e^{\pm}, \gamma)$ measured direction, is shown in Fig. 2c. Solid line in Fig. 2 are absolute QED predictions, the dashed part of the lines in Figs. 2a) and 2c) corresponds to the energy region where the detection efficiency of the tagging counters is not well known as explained above: The data corresponding to this energy region are not taken into account for λ^2 upper limit determination. Radiative corrections have not been take into account. The agreement is quite good.

WAB events. - We have collected 255 possible events in the same integrated luminosity as above. After the application of selection criteria, only 99 events were retained. Most of the rejected events have an acollinearity angle less than 12^{o}. The energy distribution of the final particles in these events are given in Fig. 2d), and in Fig. 2e) the effective mass distribution of the $(e^{\pm}, \gamma)$ system is shown. The solid lines are the absolute QED predictions(7). Radiative corrections have not been taken into account. The agreement is quite good.

In order to set a limit on the existence of a possible heavy electron (e^{*}), we have considered in addition to (1), the following reaction:

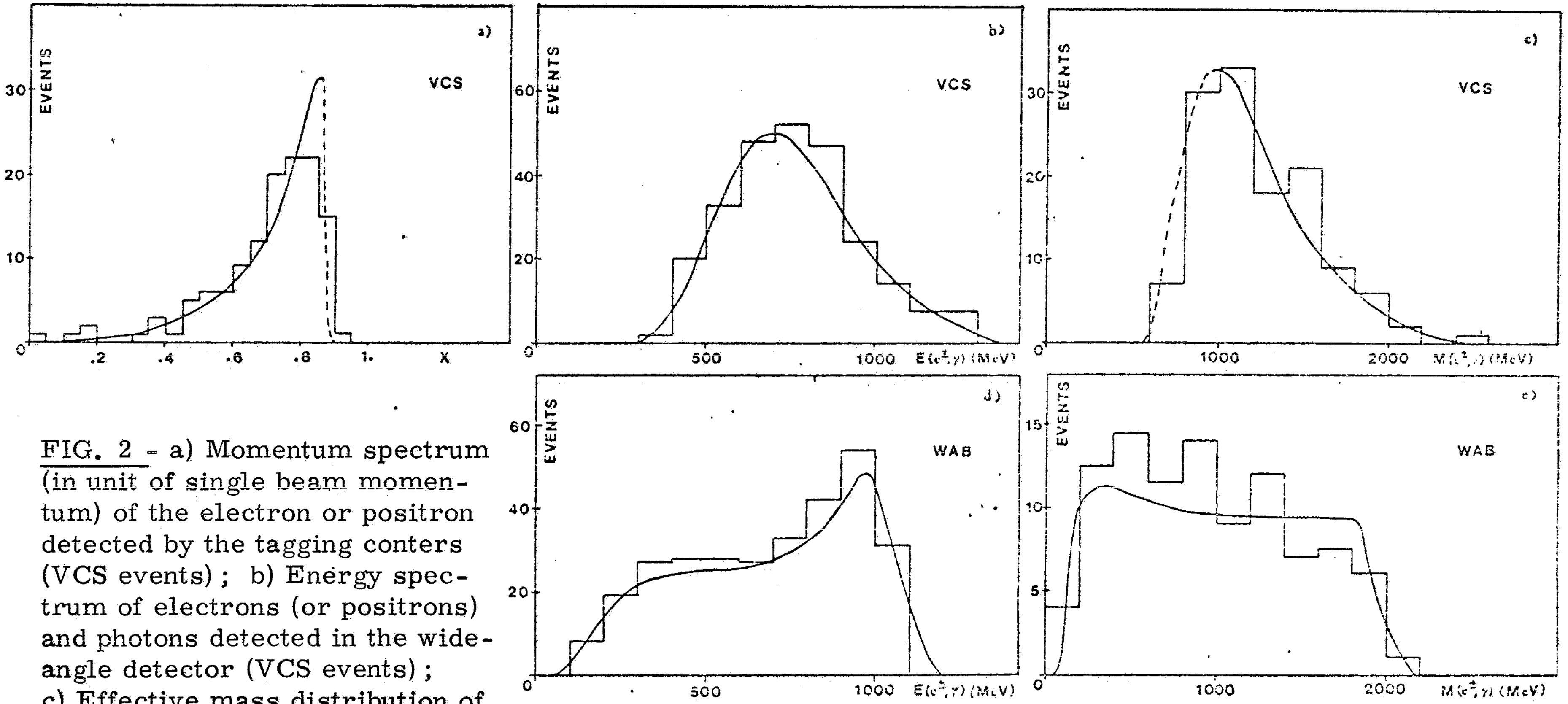

FIG. 2 - a) Momentum spectrum (in unit of single beam momentum) of the electron or positron detected by the tagging conters (VCS events) ; b) Energy spectrum of electrons (or positrons) and photons detected in the wide-angle detector (VCS events) ; c) Effective mass distribution of the wide angle (e$^{\pm}$, γ) system (VCS events). The solid lines are absolute QED predictions. In fig. a) and c) the dashed part indicates where the tagging efficiency is not well known. This uncertainty produces an indetermination of ± 15% on the whole distribution of fig. b).

d) Energy spectrum of electrons, positrons and photons emitted at wide angle (WAB events) ; e) Effective mass distribution of the (e$^{\pm}$, γ) system (WAB events). The solid lines are absolute QED predictions.

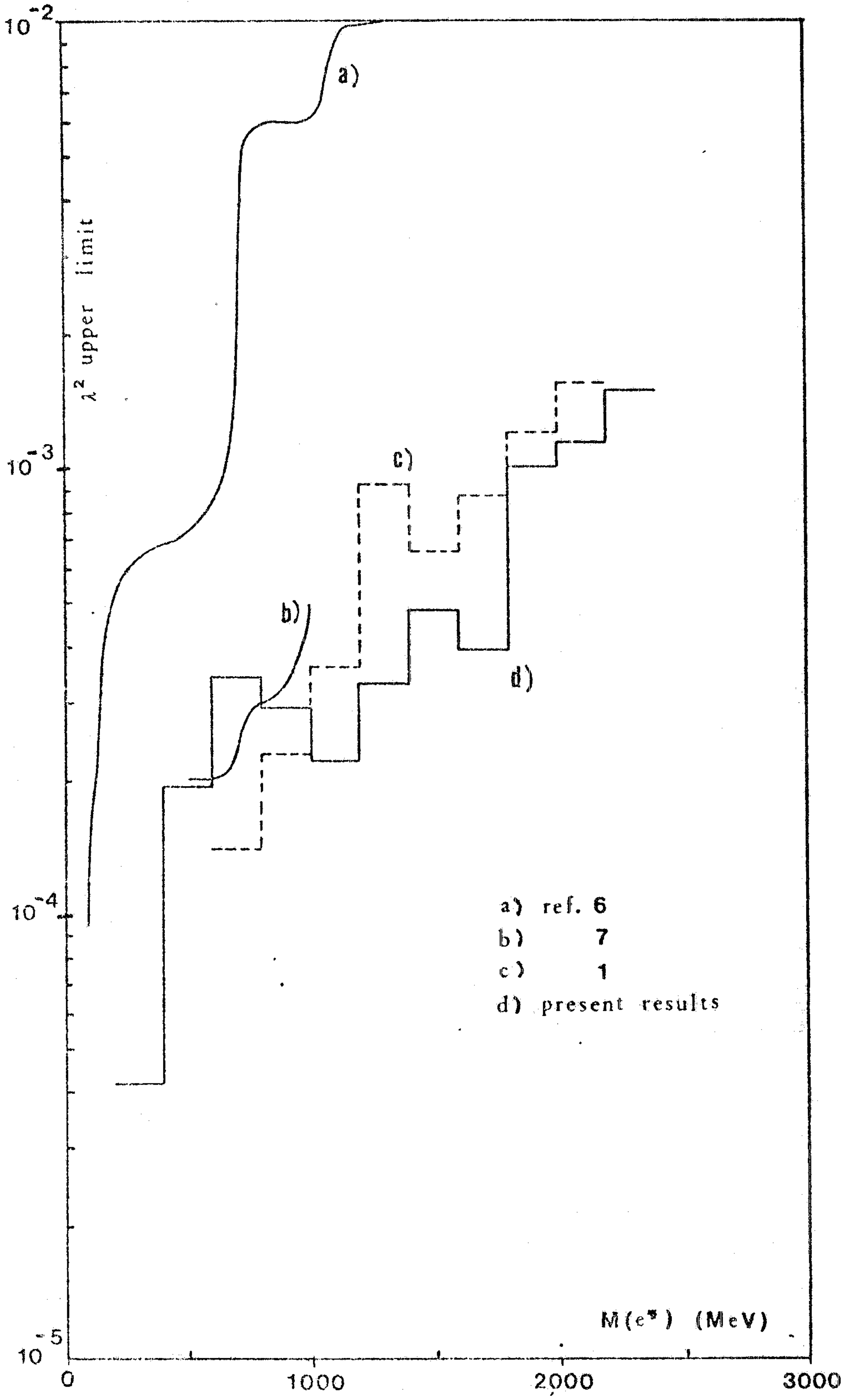

FIG. 3 - Upper limit (95% confidence level) on λ^2 versus the e^* mass.

$$e^+e^- \rightarrow e^{\pm} e^{*\mp} \qquad (2)$$
$$\hookrightarrow e^{\mp}\gamma \quad .$$

The production cross section of reaction (2) has been evaluated starting from the following interaction Hamiltonian(7):

$$H_r = (e\lambda/m^*)\, \bar{\psi}_{e^*} \sigma_{\mu\nu} \psi_e F^{\mu\nu} + \text{h.c.} \quad ,$$

where λ is the $(e^* e \gamma)$ coupling constsnt and m^* is the heavy electron mass. In order to set an upper limit (95% confidence level) on λ^2, we have estimated the expected yield from heavy-electron production and compared it with the data reported in Figs. 2c) and 2e). In Fig. 3 this upper limit together with previous results are shown.

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(3) - C. Bacci et al., Proceedings of the First EPS Conf. on Meson Resonance and Related Electromagnetic Phenomena, Bologna (1971), pag. 481 ; G. Barbiellini et al., ibid., pag. 505; Supplement au Journal de Physique 35, Fasc. 3, c-2 (1974).

(4) - C. Bacci et al., Phys. Letters 58B, 481 (1975).

(5) - If θ_1, θ_2, θ_3 are the angles between the final particles direction and a given plane. We call the complanarity angle of the three particles, the angle between each direction and the unique plane defined by $\theta_1 = \theta_2 = \theta_3$.

(6) - C. Carimalo, P. Kessler and J. Parisi, Nuclear Phys. B57, 582 (1973).

(7) - G. Parisi, private communication.

(8) - Due a trivial error, the results reported in Fig. 4 of ref. (1) are not correct. In Fig. 3 of the present paper we report the corrected values.

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