Evidence for direct photons from quarks in electron-positron annihilation

TASSO Collaboration

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Abstract. Hadronic events from $e^+ e^-\text{-annihilations}$ with a high energy isolated photon have been investigated at C.M. energies between 14 GeV and 44 GeV. A forward-backward asymmetry $A_s$ of the positively charged jet with respect to the incident positron direction has been found: $A_s = -0.32 \pm 0.07$, providing evidence for photon bremsstrahlung from quarks. The forward-backward asymmetry of all hadronic events at C.M. energies between 30 GeV and 36 GeV has been measured. The value, corrected for the limited polar angle acceptance of the detector, is: $A = +0.021 \pm 0.005$.

1 Introduction

Direct photon emission from quarks is a powerful tool to explore various properties of the quarks and the hadronization mechanism [1–3]. If the photon is e.g. radiated at very short quark distances it is a signal from the time before fragmentation takes places.

Because of the electromagnetic coupling of direct photons to quarks, they can be used to probe the electric charge of the quarks. The most commonly used quark model assumes for the electric charges of the quarks $-1/3$ or $2/3$ independent of their colour, whereas the gluons are assumed to be neutral. Although this model is in agreement with all experimental results it is not the only way to build a consistent picture of the hadrons. There are competitive models, first proposed by Han and Nambu, which assume integer charged quarks, whose different colour states have different electric charges [4].

To exclude one of the models one needs a process with at least two photons coupling to the quarks, and at least one of these photons has to be real [5]. Quark bremsstrahlung in $e^+ e^-\text{-annihilations}$ fulfills these conditions. Models with integer charged quarks predict a cross section for this reaction which is higher by a factor of $\sim 1.75$ than the predictions from models assuming fractional charged quarks [5].

The detection of direct photon production is rather complicated, in particular since photons in $e^+ e^-\text{-annihilations}$ can be due to both radiation from the incoming leptons and to a lesser extent from the outgoing charged partons. If a photon is radiated from the initial state, the hadronic state is an eigenstate of the charge conjugation $C$ with $C = -1$, whereas photons emitted from quarks lead to a $C = +1$ state of the hadrons [3]. The interference of these two contributions to the direct photon signal leads to a negative asymmetry in the angular distribution of the positive quark relative to the positive incoming lepton [2]. This charge asymmetry provides therefore evidence for quark bremsstrahlung. A measurement of this charge asymmetry, performed with the TASSO detector at the PETRA storage ring, is reported here. The asymmetry is predicted to be maximum if the photon is radiated with a high transverse momentum relative to the jets as well as to the beam axis [3]. For the measurement of this asymmetry one must select hadronic events with a high energy isolated photon. The isolation of the photon from the jets is essential to reject photons from copiously produced $\pi^0$s, which appear in the jets.

2 The detector

A detailed description of the TASSO detector and its lead liquid argon barrel calorimeter can be found elsewhere [6–11]. Because the photon detection is central to this analysis a short description of the barrel lead liquid argon calorimeter is given below. The barrel calorimeter modules are located above and below the magnet coil. They cover 40% of solid angle extending from $42^\circ \leq \theta \leq 138^\circ$ in polar angle in two sections of azimuthal angle, namely $30^\circ \leq \phi \leq 150^\circ$ and $210^\circ \leq \phi \leq 330^\circ$. They consist of a system of towers and strips. The towers are composed of 2 mm thick lead plates of an area about $7 \times 7$ cm$^2$ (front towers) and about $14 \times 14$ cm$^2$ (back towers) stacked so as to point at the interaction region. Four front towers are followed by one back tower. The strips are about 2 cm wide and etched on copper clad epoxy circuit board. They run orthogonal to the beam axis ($z = \text{constant}$) and parallel to it ($\phi = \text{constant}$). The first active layer of the calorimeter is at a distance of 178 cm from the interaction point. The front towers contain 6.1 radiation lengths of material, the back towers 7.6 radiation lengths. There are 1.3 radiation lengths of material before the first active layer of the calorimeter. The towers provide a measurement of the total energy of electromagnetic showers with a resolution determined from electrons [9] with energy $1 < E < 5$ GeV

$$\sigma/E = (0.136/E^{1/2}) + 0.03 \quad (E \text{ in GeV}).$$

The electronic threshold of the towers corresponds to a energy deposit of about 18 MeV, which is much lower than the threshold used in the trigger. The strips provide a position resolution determined from electrons [9] with energy $1 < E < 5$ GeV

$$\sigma = (0.77/E + 0.53) \text{ cm} \quad (E \text{ in GeV}).$$

The calibration has been carried out with electrons from Bhabha scattering ($e^+ e^- \rightarrow e^+ e^-$) events. The detection efficiency for a single photon has been deter-