Inclusive production of \( \pi^0 \)-mesons in \( \pi p, Kp \) and \( \gamma p \) collisions at energies around 100 GeV

Omega Photon Collaboration


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Received 2 May 1991; revised form 29 July 1991

Abstract. Measurements are reported of inclusive production of \( \pi^0 \)-mesons in the beam fragmentation region in \( \gamma p, \pi p \) and \( Kp \) collisions. Results include the ratio of \( \pi^0 \) production in \( Kp \) and \( \pi p \) collisions, showing reduced production from fragmentation of the \( K \)-meson, and the ratio of \( \pi^0 \) production in photon and hadron collisions which shows agreement with modified Vector Meson Dominance at low \( p_T \), and departures at higher \( p_T \) signalling the onset of direct photon reactions. The pattern of departure from Feynman scaling at high \( p_T \) points to a contribution of hard parton-parton collisions in both \( \gamma p \) and \( \pi p \) collisions.

1 Introduction

Inclusive production of \( \pi^0 \)-mesons, as a function of Feynman \( x_F = p_L/p_{MAX} \) and transverse momentum \( (p_T) \), induced by photon and hadron beams, has been measured over a range of incident energies. This work forms part of a programme [1, 2] to compare photoproduction reactions with corresponding reactions induced by incident hadrons, with the advantage that the reactions induced by both photons and hadrons are selected with closely similar triggers and detected in the same apparatus.

The present paper reports a comparison of a broad range of production of \( \pi^0 \)-mesons by photons and hadrons. At low \( p_T \) information is obtained about Vector Meson Dominance (VMD), while at higher \( p_T \) information is obtained about direct photon reactions, and about the contribution of hard parton-parton collisions. The major results are ratios of cross sections for different incident particles, different incident energies, different \( x_F \) and different \( p_T \), which are determined over a wide range of these variables with small statistical and systematic uncertainties.

An account of the general principles of the experiment is given in Sect. 2, and a more detailed account of the photon detector is given in Sect. 3. The analysis of the data is described in Sect. 4. Experimental results are presented in Sect. 5, and the conclusions are summarised in Sect. 6.

2 Experimental apparatus

The data were taken by the WA69 collaboration using the Omega Spectrometer at CERN. A description of the basic principles of this experiment has been given previously [1], so only a brief account is given here. A general layout of the experiment is shown in Fig. 1.

The beam line provided hadrons of either charge and of momenta 80 or 140 GeV/c. Two CEDAR Cherenkov counters were used in the beam to identify \( K \)-mesons and \( \pi \)-mesons, with the triggers scaled so that approximately a quarter of the collisions recorded were due to \( K \)-mesons. Photons, from an electron beam, were tagged in the energy range 60–170 GeV. Events were studied where the error on the photon energy, primarily due to multiple bremsstrahlung, was less than 1.5 GeV.
The incident particles impinged on a liquid hydrogen target of length 0.6 m. The trajectories of the resulting charged particles were detected in MWPCs inside, and drift chambers outside, the magnetic field. These detectors were followed by a Ring Image Cherenkov Counter (RICH) and a Transition Radiation Detector (TRAD), neither of which was used in the results described in the present paper, and a large photon detector which is described more fully in the next section.

An interaction trigger detected a large fraction of the total cross section. A closely similar trigger was used with photon and hadron beams so the results would be directly comparable. About $2 \times 10^7$ triggers were recorded with the photon beam, and a similar number for the hadron beam, distributed over the two momenta and the two charges.

### 3 Photon detector

The photon detector, shown in Fig. 2, was in two parts: an outer photon detector (GPD) and an inner detector (PLUG).

![Fig. 2. Photon detector, as seen from behind](image)

A full account of the GPD has been published [3]. The detector had four square quadrants, each of side 2.05 m, fitted around a central square aperture of side 0.42 m. Each quadrant was made of lead sheets interleaved with sampling layers of teflon tubes filled with liquid scintillator and had a total thickness of 24 radiation lengths. The tubes were arranged alternately in two orthogonal directions transverse to the incident beam direction. Groups of tubes were collected together on to light guides and photomultipliers. The pulse-height from each photomultiplier was digitised, as was a time of flight signal which was important for resolving hodoscope ambiguities.

A full account of the PLUG is being prepared for publication [4]. It consisted of converter blocks 25 radiation lengths thick, made from grooved lead sheets, with scintillating fibres embedded in the grooves. The fibres were approximately parallel to the incident beam direction, and, so that it would not be possible for a particle to traverse solely fibre and no lead, the sheets were formed to a wave of length 50 mm and amplitude 2 mm. The light was collected by a $13 \times 13$ array of light guides of size $32.3 \times 32.3$ mm$^2$ on to a corresponding number of photomultipliers. For the photon beam runs blocks were removed to allow the beam to pass through into the beam veto counter, while for the hadron beam runs data were recorded in the full array.

The gains of the GPD counters were calibrated with a radioactive source system, and their stability monitored regularly by a pulsed laser system. The calibration was tuned off-line to give the correct mass for the $\pi^n$-meson peak in $\gamma\gamma$ mass spectra. The calibration of the PLUG only used the $\pi^n$-meson mass: the gains of the 169 channels were adjusted by an iterative procedure at the start of a data-taking period.

In the WA69 configuration, with the RICH and TRAD detectors in front, the mean energy resolution of the GPD for $\gamma$-rays was

$$\sigma_E/E = \left(\frac{0.18}{E} + 0.072\right)^{1/2},$$

where $E$ is in GeV, and the position resolution was $\pm 2.5$ mm in each coordinate. The energy resolution of the PLUG was