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DIRECT DETERMINATION OF THE KAON FORM FACTOR

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DIRECT DETERMINATION OF THE KAON FORM FACTOR

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Беретвас А. и др. **E1 - 12357**

Прямое измерение формфактора каона

Выполнено измерение электромагнитного формфактора K -мезона в области переданных импульсов от 0,036 до 0,116 /ГэВ/c/^{2}. Эксперимент проводился на пучке каонов с энергией 250 ГэВ в Фермилаб'е. Спектрометр состоял из жидководородной мишени, восьми станций пропорциональных камер, четырех модулей дрейфовых камер, изготовленных в ОИЯИ, двух магнитов, сцинтилляционных счетчиков, дифференциального черенковского счетчика и ливневого свинцово-стеклянного черенковского счетчика. По предварительным данным радиус каона $\langle r_k^2 \rangle^{1/2}$ = = 0,51±0,07 Фм.

Работа выполнена в Лаборатории высоких энергий ОИЯИ.

Сообщение Объединенного института ядерных исследований. Дубна 1979

Beretvas A. et al. **E1 - 12357**

Direct Determination of the Kaon Form Factor

The K^--meson electromagnetic form factor was determined for the momentum transfers from 0.036 to 0.166 $(\mathrm{GeV}/c)^2$. The experiment was carried out on a kaon beam of 250 GeV/c at Fermilab. The spectrometer consisted of a liquid hydrogen target, eight stations of proportional wire chambers, four modules of drift chambers constructed at JINR, two magnets, scintillation counters, a differential Cerenkov counter and a lead glass shower Cerenkov counter. According to the preliminary data, the kaon radius is $\langle r_k^2 \rangle = 0.26 \pm 0.07 F^2$.

The investigation has been performed at the Laboratory of High Energies, JINR.

Communication of the Joint Institute for Nuclear Research. Dubna 1979

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DIRECT DETERMINATION OF THE KAON FORM FACTOR

Determination of the kaon form factor in a space-like region has until now eluded experimental measurement. In electron-positron annihilation experiments the two-kaon final state is not dominated by simple resonance production and the extraction of the kaon form factor is not a straightforward matter, in contrast to the pion with its rho resonance dominance. For similar reasons electroproduction experiments cannot be usefully interpreted to produce the kaon form factor. Direct determination of a kaon charge by kaon scattering from electrons has not been possible before Fermilab energies became available because the unique kinematic characteristics of scattering with a relatively massive projectile require such energies to produce momentum transfers sensitive to the kaon form factor.

We have used a 250 GeV negative kaon beam at the Fermi National Accelerator Laboratory to measure the cross section for elastic scattering from atomic electrons of a 51 cm long liquid hydrogen target for momentum transfers from 0.026 to 0.116 $(\mathrm{GeV}/c)^2$. The electromagnetic form factor for these kaons is determined by

$$d\sigma/dq^2 = (d\sigma/dk^2)_{pt} \cdot |F_K(q^2)|^2 ,$$

where the point cross section is, apart from radiative corrections

$$(d\sigma/dq^2)_{pt} = (4\alpha^2 h^2 c^2/q^4)(1 - q^2/q^2_{max}).$$

The mean squared radius is determined by

$$\langle r_K^2 \rangle = -6 \, |dF_K(q^2)/dq^2|_{q^2=0} \, .$$

Elastic scatters were recorded by a high-resolution, single arm spectrometer which is illustrated in Figure 1. The incident beam kaon and the scattered kaon and electron were tracked by both proportional wire chamber (PWC) stations and drift chamber (DC) stations.

Both chamber types were used in track finding and event reconstruction to provide the high redundancy required for good efficiency. With PWC calibration an overall drift chamber resolution of approximately 100μm was achieved and made possible good discrimination against the copius interaction background. The momentum of the scattered kaon and of the electron were determined by two magnets with a total field integral of 70.35 kg-m followed by three PWC stations. This was followed by a 21 radiation length lead-glass shower counter system which was used in the trigger and in the final background determination.

An event trigger was determined by stringent beam requirements and a loose two-particle requirement. The beam logic was

$$\mathrm{BEAM} = C_D \cdot B_0 \cdot B_1 \cdot B_2 \cdot \overline{B_{2TWO}} \cdot \overline{\mathrm{AH}} \cdot \mathrm{KILL} \cdot \mathrm{SP} \cdot \overline{\mathrm{DP}} \cdot \mathrm{DCD},$$

C_D represents the differential Cerenkov counter signal requirement (100 feet of helium at ~13 PSI

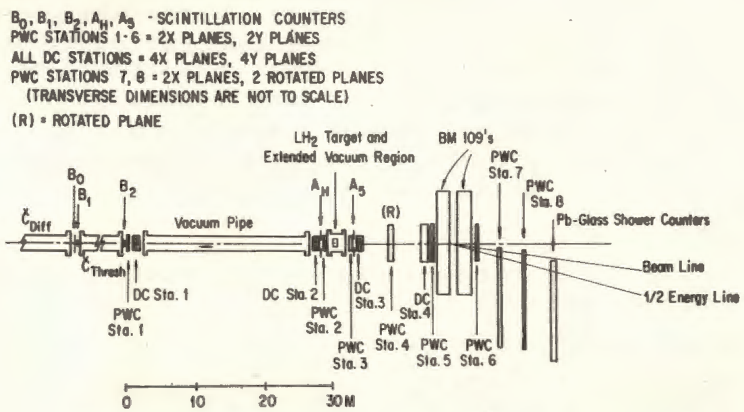

Fig. 1. High resolution, single arm spectrometer.

provided unambiguous identification of the 2 per cent kaons in the beam). B_0, B_1, B_2 and B_{2TWO} represent beam scintillation counter signals and a two-particle discrimination. A beam halo counter AH defined the lateral extent of the beam. KILL required that no other beam particle preceeded the event within 500 ns nor followed it within 460 ns. The beam PWC's provided a single particle requirement SP and discriminated against double particles DP. Similar requirements were formed by the beam drift chambers in the logic decision DCD. For a two second beam spill, the typical number of beam kaons was 30 000 (out of 1.5×10^6 beam particles). Of these about 10 000 satisfied the clean beam trigger requirement. The event trigger was

$$\mathrm{EVENT} = \mathrm{BEAM} \cdot \bar{A}_5 \cdot \mathrm{TP} \cdot \check{C},$$

where A_5 was a scintillation counter with a 4-inch hole which vetoed some of the strong interaction events (a small correction was required for the elastic kaon-electron scatters due to radiative photons and delta rays). TP required that there were at least two particles in PWC stations 5 or 6. Requirement $\check{C}$ was that some combination of the five lead-glass shower-counter sections produced a pulse consistent with an electron from an elastic kaon-electron scatter. The trigger rate was about 10^{-3} per incident kaon or ten per spill. Less than one per cent of these were elastic scatters. The geometric efficiency for detection of elastic events is determined largely by the shower counters and with safe cuts away from the counter edges this efficiency ranges from 84 to 100% for electrons from 36 to 116 GeV/c momentum. The upper momentum is near the kinematic limit of 128 GeV/c where the cross section vanishes.

Events were reconstructed by finding and fitting horizontal and vertical track projections and then matching these projections with rotated PWC's in stations 4, 7, or 8. Pairs of secondary tracks having a common target origin with a beam track taken to be candidates for elastic scattering. Monte Carlo calculations reproduced well the data and determined the efficiency for the event finding procedure to be 98.4%. An indication of the quality of track reconstruction is found in the plot in Figure 2 of longitudinal Z vertex positions for events subsequently fit as elastic scatters. The target position and length are well reproduced. The secondary peaks arise from elastic scattering from the vacuum window of the target and from stations 2 and 3 (Figure 1).

Events were tested for energy and momentum conservation in the elastic scattering process by means of a chi-square fit. In this fit it was assumed that an undetected photon was produced in the electron's direction either by radiation accompanying the elastic scatter or by electron bremsstrahlung in the target or spectrometer material. The resulting chi-square distribution is shown in Figure 3. It is clear from the small tail

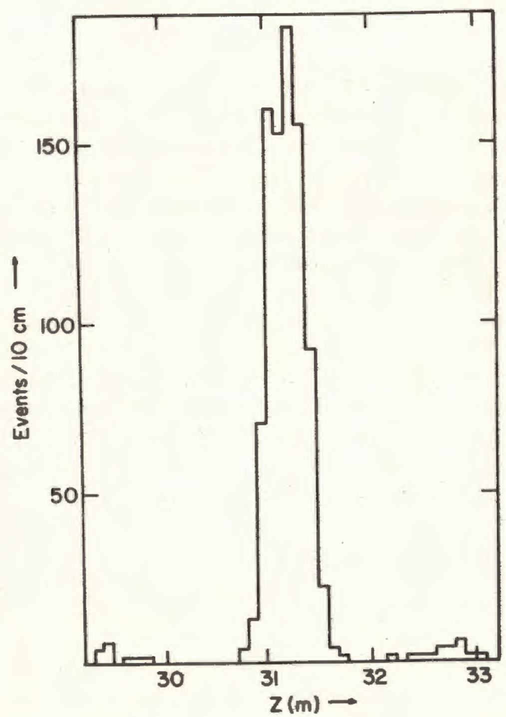

Fig. 2. Z vertex positions for events subsequently fit as elastic scatters.

in this distribution that background is very small. In fact, much of the tail can be accounted for by elastic scatters in which the kaon subsequently decays or undergoes nuclear scattering in the target or spectrometer. The fitted photon energy distribution is shown in Figure 4.

Events were selected to have Z vertex positions within 84 cm of target center, chi-square less than 30, and photon energy from -6 to +12 GeV. The z cut losses and losses due to the chi-square and photon energy cuts were determined by Monte Carlo calculations. A major correction was that of bremsstrahlung (typically 20%). Radiative corrections ranged from 4.4 to 10.6%.

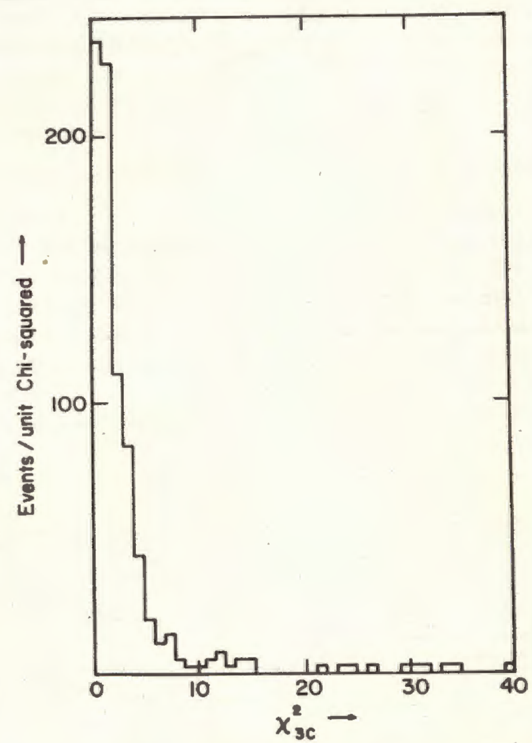

Fig. 3. Resulting chi-square distribution for fitted events.

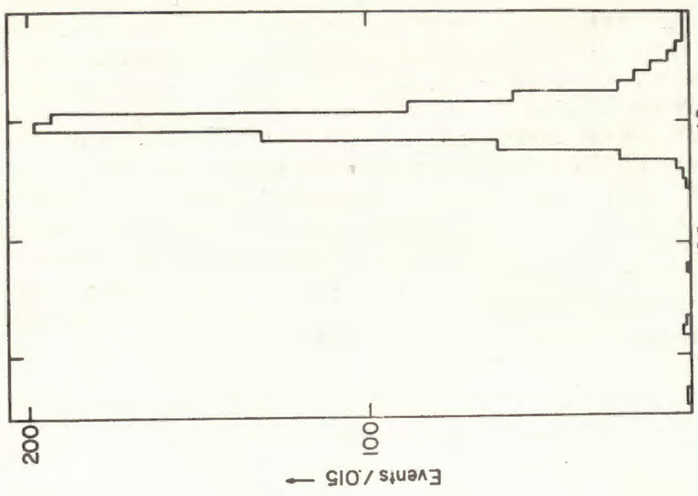

Fig. 5. Normalized pulse height distribution.

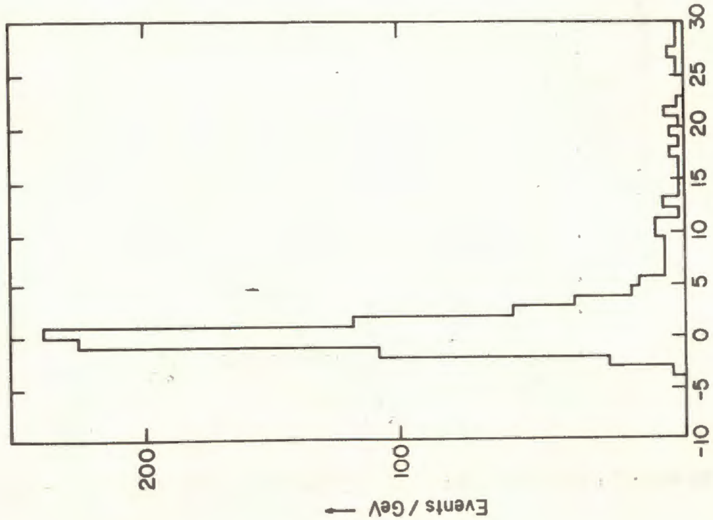

Fig. 4. Fitted photon energy distribution.

The pulse height distribution normalized by electron energy is shown in Figure 5. A hadronic background of less than 2% was estimated based upon the events below the electron peak. The tail at high pulse heights is caused by the kaon sharing the same shower counter blocks as the electron. Of the many additional corrections required, the principal ones affecting the beam flux are kaon beam attenuation (2.85%), beam momentum cut of +6 and -12 GeV (1.50%) and muons from kaon decay downstream of the differential Cerenkov counter (0.10%). Elastic scatter corrections include scattered kaon attenuation (4.25%) and decay (1.4 to 2.3%).

From the measured elastic scattering cross section and from the point cross section corrected to the measured electron energy, the form factor was determined as a function of the measured q^2. Our preliminary results are shown in Figure 6. A fit to the dipole form gives $\langle r_K^2 \rangle \simeq 0.26 \pm 0.07 F$ (or $\langle r_K^2 \rangle^{1/2} \simeq 0.51 \pm 0.07 F$). This may be compared to $\langle r_\pi^2 \rangle = 0.31 \pm 0.04 F^2$ (or $\langle r_\pi^2 \rangle^{1/2} = 0.56 \pm 0.04 F$) for the pion /1/. An accurate theoretical prediction has not been produced, but it is of interest to compare our result with the Chou-Yang model in which the kaon structure function is identified with the electromagnetic form factor. The model gives /2/ $\langle r_K^2 \rangle^{1/2} = 0.62 F$.

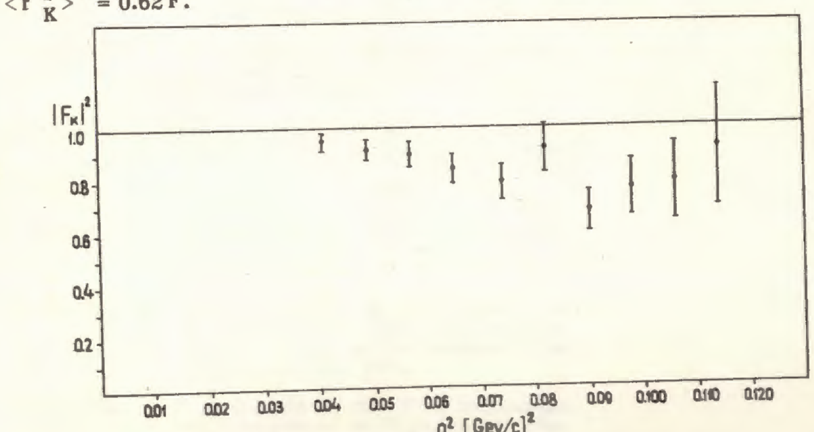

Fig. 6. Kaon form factor.

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