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MEASUREMENT OF THE $K_L + p \rightarrow K_S + p$ REGENERATION AMPLITUDE AT HIGH ENERGIES

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The measurement of the K^0 regeneration amplitude in the energy range 15—35 GeV using the Serpukhov proton synchrotron is reported.

1. Introduction

The K^0 regeneration experiment aimed at determining the difference of the complex K^0p and K^0p forward scattering amplitudes:

$$\Delta f = f - \bar{f}.$$

This can be done by measuring the $K_L p \rightarrow K_S p$ regeneration amplitude, ϱ, since they are related to each other by the following formula:

$$\varrho(p) = \frac{\pi N}{m}\, i\, \Delta f(p)\, \frac{1 - e^{\left(i\Delta m - \frac{\gamma_s}{2}\right)\frac{lm}{p}}}{\frac{\gamma_s}{2} - i\Delta m}\,.$$

Here N is the number of scattering centres per cm^3. Note that ϱ stands for the quantity known as transmission regeneration amplitude, which is characterized by the fact that all scattering centres act coherently. m and p are the mass and momentum of the incoming kaon, Δm is the K_L—K_S mass difference, γ_s is the total width (or inverse mean life $1/\tau_s$) of the K_S meson, finally, l is the length of the regenerator. We neglect the total width of the K_L, γ_L, in comparison with γ_s.

Experimentally one uses K_L beam, puts into it a regenerator (in our case a 3 m long liquid H_2 target), and counts the number of $\pi^+\pi^-$ decays of the transmission-regenerated K_S mesons downstream the regenerator. The number of this type of decays is given by the following formula:

$$N_{+-}(p,t) = S_L(p)\,\varepsilon(p,t)\cdot\gamma(K_S \rightarrow \pi^+\pi^-)\cdot\Big\{|\varrho|^2 e^{-\gamma_s t} + |\eta_{+-}|^2 + \\ + 2|\varrho|\,|\eta_{+-}|\, e^{-\frac{\gamma_s}{2}t}\cos(\Delta m t + \Phi_\varrho - \Phi_{+-})\Big\}, \tag{1}$$

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where $S_L(p)$ is the number of K_L mesons just behind the regenerator, $\varepsilon(p, t)$ is the detection efficiency, a function of p and the proper time t, elapsed in the K^0 restframe. The three terms in the bracket have the well-known meaning: close to the regenerator, say at $t \leq 2\,\tau_s$, we observe the regenerated K_S mesons, the intensity of which is rapidly falling off; very far, say at $t \geq 6\,\tau_S$, the $\pi^+\pi^-$ decays occur only because of the CP violation, the intensity of the decays is roughly constant and proportional to $|\eta_{+-}|^2$, often called Fitch level, which is the ratio of rates:

$$|\eta_{+-}|^2 = \frac{\gamma(K_L \to \pi^+\pi^-)}{\gamma(K_S \to \pi^+\pi^-)} \, .$$

In between one observes the interference of the $K_S \to \pi^+\pi^-$ and $K_L \to \pi^+\pi^-$ decay amplitudes, which offers the possibility to measure the phase difference $\Phi_\varrho - \Phi_{+-}$, Φ_ϱ and Φ_{+-} being the phase of ϱ and of η_{+-}, respectively. In conclusion, the time dependence of N_{+-} at fixed K_L momentum, p, gives information on the complex ϱ/η_{+-}, more explicitly on the two real numbers $|\varrho/\eta_{+-}|$ and $\Phi_\varrho - \Phi_{+-}$.

2. Experimental layout

The K_L beam was extracted by the usual technique from the Serpukhov 70 GeV proton synchrotron, putting an Al target into the internal proton beam. Charged particles were removed by a swipping magnet, and γ rays were absorbed by means of a lead filter. The remaining neutral component was collimated so that the average divergence of the beam at the entrance of the 3 m long liquid hydrogen regenerator was about 0.6 mrad.

Behind the regenerator an anticounter ensured that the outgoing particles were neutral. This counter was followed by a magnetic spectrometer [1], shown in Fig. 1. The first part of the spectrometer consisted of a 6 m long decay zone where the $\pi^+\pi^-$ decay took place. The spatial coordinates of the produced two charged tracks were measured before and behind a 2 m long magnet, 10 kG in strength, by wire spark chambers that enabled us to know both the decay position and the three-momentum of the neutral kaon. Crossing geometry, also indicated in the Figure, ensured by triggering counters, strongly disfavoured the registration of $K_L \to 3\,\pi$ decays, and considerably reduced the remaining background from the leptonic three-body decays as well. We had another facility to recognize muonic decay products by letting them traverse a 2 m thick iron wall and then registering them by counters.

The signals from the wire spark chambers and counters were recorded on-line on magnetic tapes, which, in turn were further analysed using off-line geometrical reconstruction [2] and SUMEX type programs.

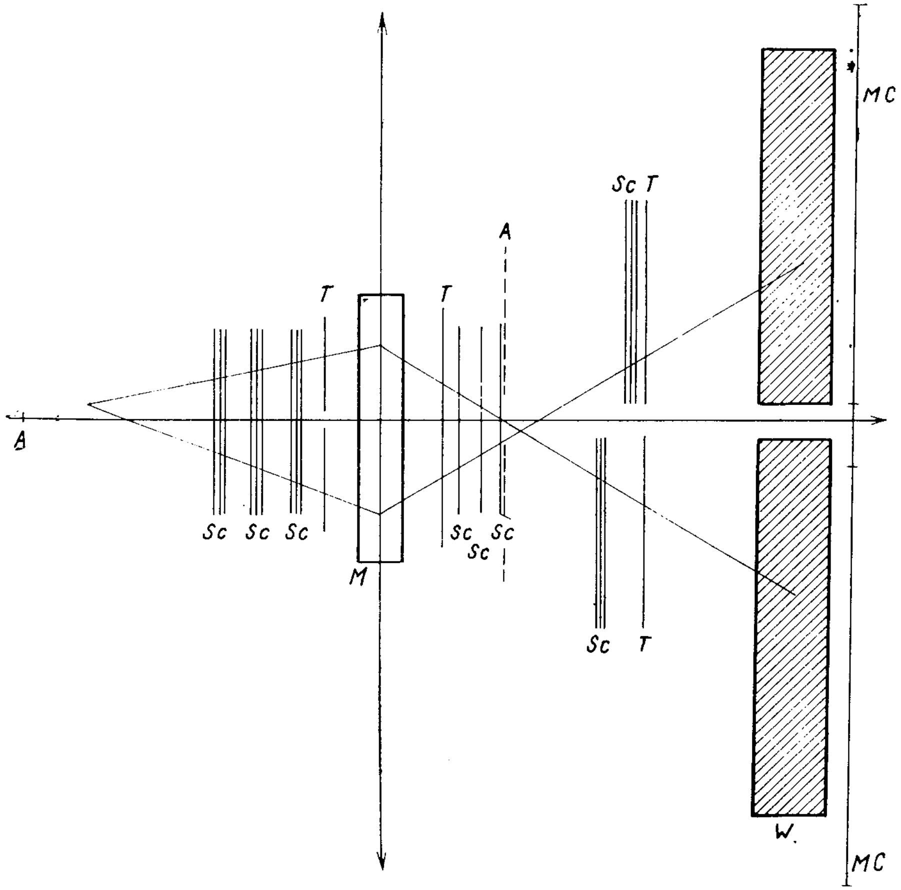

Fig. 1. The magnetic spectrometer. A — anticounters, T — triggering counters, SC — spark chambers, M — magnet, MC — muon counters, W — iron wall

3. Results

The presence of $K_L \rightarrow \pi^+\pi^-$ and regenerated $K_S \rightarrow \pi^+\pi^-$ decays could have been demonstrated by the effective mass distribution calculated for the reconstructed events assuming that both charged particles were pions. We have observed a narrow peak in this distribution around the K^0 mass with a half-width of $\pm$ 5 MeV in cases when θ^2, the square of the mean deviation of the K^0 meson from the average beam direction was less than 0.6 (mrad)^2 (Fig. 2). On the other hand, inspecting the θ^2 distribution we observed sharp peak in the forward direction (small θ^2) when the effective mass lied around the K^0 mass (Fig. 3).

In order to determine $N_{+-}(p, t)$ (cf. Eq. (1)) we chose therefore events from the mass interval 0.488–0.508 GeV, and for background subtraction we analysed the θ^2 distribution. The number of $\pi^+\pi^-$ decays, N_{+-}, was determined in each proper time interval by counting down the events having $\theta^2 \leq 0.6$ (mrad)^2 and situated beyond the background level, which latter was fixed using a linear extrapolation from the $\theta^2 > 0.6$ (mrad)^2 region.

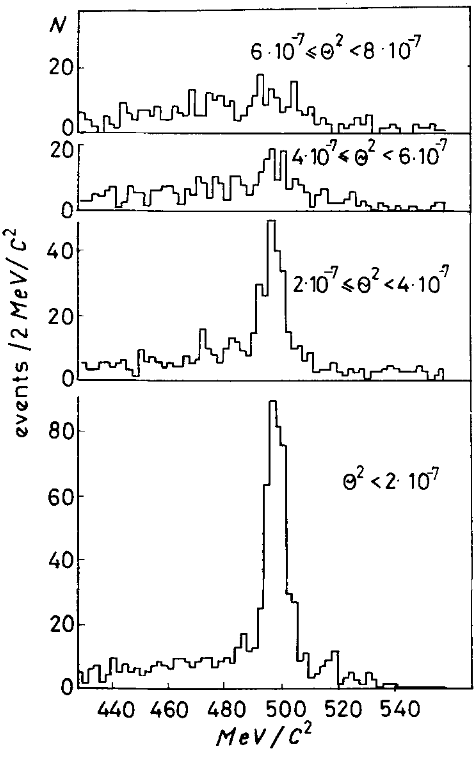

Fig. 2. The effective mass distribution of transmission-regenerated events. Gradually growing peak is observed around the K° mass when θ^2 decreases

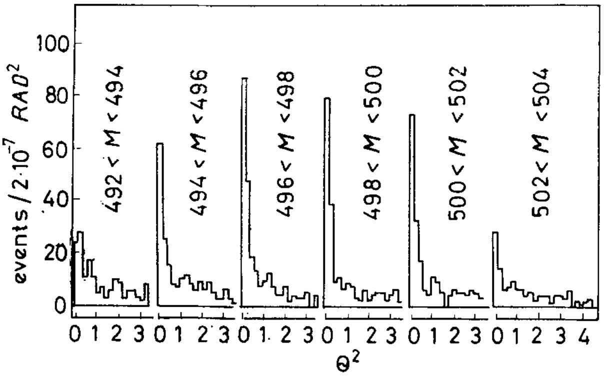

Fig. 3. The θ^2 distribution of events having an effective mass around the K° mass. The forward peak is significantly enhanced when M coincides with the kaon mass

Having calculated $\varepsilon(p, t)$ by Monte Carlo method, we had all to deduce ϱ/η_{+-}. Assuming η_{+-} to be the same as measured at lower energies, we arrived at the final result, presented also at the XVth International Conference in Kiev [3].

Fig. 4 shows $|\Delta f|$ normalised to the kaon momentum, p. The difference of the K^0p and $\bar{K}^0p$ total cross sections

$$\Delta\sigma = \sigma^{tot}_{K^0p} - \sigma^{tot}_{\bar{K}^0p} = \frac{Im\,\Delta f}{4\pi p}$$

is plotted in Fig. 5.

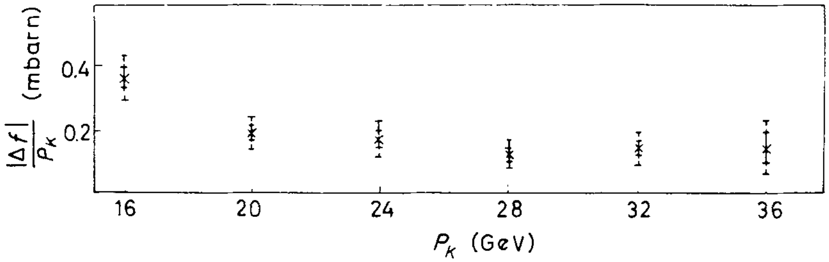

Fig. 4. The quantity $|\Delta f|/p$ as a function of p

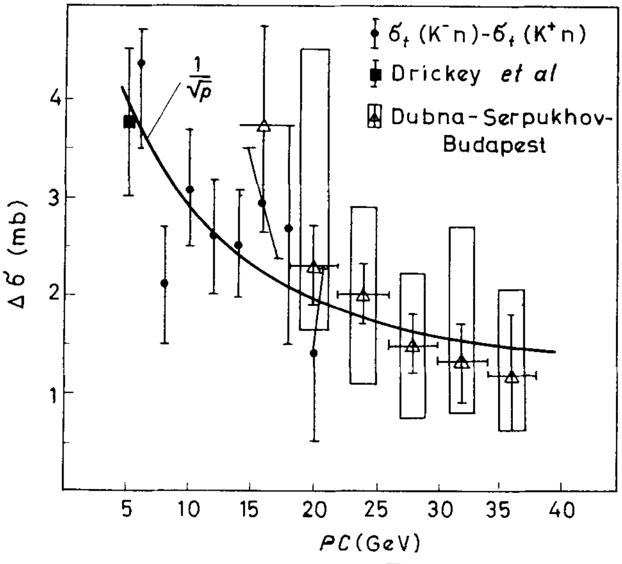

Fig. 5. The behavior of the difference of K^0p and $\bar{K}^0p$ total cross sections as a function of the kaon momentum, p

In both cases errors of two kinds are associated with the experimental points; the smaller ones indicate only statistical fluctuations, whereas the greater error bars take possible systematic errors into account as well.

Because of the rather large errors, no definite conclusion can yet be drawn. We have indication for the maintenance of the Pomeranchuk theorem, and there is some evidence against constant phase models.

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ИЗМЕРЕНИЕ АМПЛИТУДЫ РЕГЕНЕРАЦИИ $K_L + p \to K_S + p$ ПРИ ВЫСОКАХ ЭНЕРГИЯХ

Совместная работа Дубна—Серпухов—Будапешт

Резюме

Описано измерение амплитуды регенерации K^0 мезонов в интервале энергий 15—35 Гэв, проведенное на Серпуховском ускорителе.