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NEUTRAL KAON REGENERATION IN THE MOMENTUM REGION OF 14 - 50 GEV/C

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NEUTRAL KAON REGENERATION IN THE MOMENTUM REGION OF 14 - 50 GEV/C

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Регенерация нейтральных каонов в области импульсов
14 ÷ 50 Гэв/с

Приводятся результаты измерений амплитуды регенерации нейтральных каонов в области импульсов 14 - 50 Гэв/с. Результаты сравниваются с расчетами по модели Редже и дисперсионными соотношениями.

Препринт Объединенного института ядерных исследований.
Дубна, 1972

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Birulev V.K., Genchev V., Govorun N.N. et al.

Neutral Kaon Regeneration in the Momentum Region of 14-50 GeV/c

The measurement results are presented for the neutral kaon regeneration amplitude in the momentum region 14-50 GeV/c. The results are compared with the calculations over Regge model and dispersion relations.

Preprint. Joint Institute for Nuclear Research.
Dubna, 1972

Previously we have reported the first results of the neutral kaon transmission regeneration measurements on hydrogen in the momentum region of 14–42 GeV/c [1]. It is shown that the modulus of the regeneration amplitude decreases with increasing energy and the phase is consistent with the constant value $\varphi^{o}_{21} = (-118 \pm 13)^{o}$. For independent determination of the modulus and phase energy dependence, it is necessary to increase both statistical accuracy and decay zone length where K^{o}_{L} and K^{o}_{S} decay amplitudes interfere.

This report presents the results of new measurements for the decay zone enlarged from 6 to 9 m in length.

As before [1], two pion decays of kaons were selected out of all detected by a spectrometer [2] (fig. 1) with the help of 3 selection criteria :

1) decaying particles should not be leptons,

2) the invariant mass $m_{\pi\pi}$ of two decaying particles identified as pions must be in the kaon mass region,

3) the scattering angle θ between incident and reconstructed directions of the kaon flight must be close to zero. The limits of the selection criteria were placed on 3 standard deviations for the corresponding momentum : $\sigma_{m} = 2.06$ (MeV) + 0.058 x P (MeV/GeV/c) and $\sigma_{\theta^2} = 0.0172\ (\mathrm{mrad})^2 + 9.14 \times P^{-2}\ (\mathrm{mrad}^2)\times(\mathrm{GeV/c})^2)$.

The invariant mass and angular distributions of candidates into two pion events with the help of which the above resolutions were determined are shown in figs. 2 and 3. The total number of observed two pion events was about 5 000 and 800 in measurements with and without hydrogen, respectively.

All selected two pion events with a momentum from 14 to 50 GeV/c were divided into momentum bins of ± 2 GeV/c. Inside each momentum bin the events were divided into time bins. Time was measured in the rest frame of the kaon starting from $t = 0$ at the end of the hydrogen target. The obtained time distributions of two pion events were fitted by the known interference formula containing the modulus $|f^{o}_{21}(p)|$ and the phase $\varphi^{o}_{21}(p)$ of the regeneration amplitude :

$$\frac{d^2N_H}{dp\,dt}(p,t) = M_H \cdot S(p) \cdot \mathcal{E}(p,t) \cdot W_{2\pi} \cdot \Big\{ |\rho(p)|^2 \cdot \exp(-\Gamma_S \cdot t) + |\eta_{+-}|^2 \cdot \exp(-\Gamma_L \cdot t) + 2|\rho(p)| \cdot |\eta_{+-}| \cdot \exp\!\left(-\frac{\Gamma_L+\Gamma_S}{2} t\right) \cdot \cos(\delta t + \phi_\rho(p) - \phi_{+-}) \Big\}$$

where

$$|\rho(p)|^2 = \frac{\pi^2 \cdot N_\Omega^2 \cdot \Lambda_s^2 \cdot 2|f^{o}_{21}(p)|^2}{k^2} \cdot |\rho'(p)|^2$$

$$\phi_\rho(p) = \varphi^{o}_{21}(p) + \frac{\pi}{2} + \arg \rho'(p)$$

and

$$\rho'(p) = \frac{1 - \exp(i\delta - \frac{1}{2})\ell}{-(i\delta - \frac{1}{2})} .$$

All remaining notations are similar to those of the report /1/. Having performed the fit procedure, we used the spectrum S(p) of kaons reconstructed from detected $K^{o}_{\mu 3}$ decays. The efficiency of the spectrometer $\mathcal{E}(p,t)$ was calculated by the Monte-Carlo method including experimental errors and multiple scattering. The spectrum and efficiency calculation was checked by reproducing the mass and angular resolution of the spectrometer and by fitting the time distribution of $K^{o}_{L} \rightarrow \pi^+\pi^-$ events without hydrogen target :

$$\frac{dN_{vac}}{dt}(t) = \int M_{vac} \cdot S(p) \cdot \mathcal{E}(p,t) \cdot W_{2\pi} \cdot |\eta_{+-}|^2 dp.$$

For the value of $|\eta_{+-}| = 1.92 \times 10^{-3}$ we obtained the best fit with $\chi^2 = 50$ (74 d.f.) for M_{vac} determined from the observed number of $K^0_{\mu 3}$ decays (see fig. 4). For the measurement with hydrogen we performed 2 modifications of the fit procedure :

1) M_H, $|\rho(p)|$ and $\varphi^0_{21}(p)$ were considered as free parameters and

2) M_H, $|\rho(p)|$ were free parameters while $\varphi^0_{21}(p)$ = const was supposed to be common for all momentum bins.

In the first case we obtained the best fit for $\varphi^0_{21}(p)$ shown in fig. 5 with $\chi^2 = 46$ (86 d.f.). In the second case the best fit was obtained for the mean value of $\varphi^0_{21} = (-131 \pm 8)^\circ$ with $\chi^2 = 51$ (93 d.f.). In both the cases the minimum of χ^2 was obtained for the same value of M_H. The shape of the χ^2- curve is shown in the insert of fig. 5.

The fitted time distribution and the values of $2 \cdot |f_{21}(p)|/K$ calculated from the last fit are shown in fig. 6.

The conclusions drawn from the above results are the following :

1) The regeneration phase is energy independent in the region of 10-50 GeV and within experimental errors coincides with the value of -130° predicted by the complex angular momentum model (CAM) for ρ and ω poles with cuts /3/.

2) The modulus of the regeneration amplitude decreases with increasing energy by the law $2 \cdot |f_{21}(p)|/K = (0.79 \pm 0.3) \times P^{-0.53 \pm 0.13}$ mb$\times$(GeV/c) which is also very close to the CAM prediction for ρ and ω contribution to the scattering amplitude /3/.

3) Both the phase and the modulus of regeneration amplitude measurements exclude the Pomeranchuk theorem /4/ violation in kaon and antikaon scattering phenomena.

4) Our results are not in agreement with more sophistical CAM models such as complex Regge-poles, ρ-, ω-poles and dipoles and so on /5/.

5) The difference between the total cross-sections of the neutral kaon and the antikaon on protons $\Delta\sigma(p) = \sigma_{tot}(K^0p) - \sigma_{tot}(\bar{K}^0p)$, calculated from the measured $|f^0_{21}(p)|$ and φ^0_{21} using the optical theorem, decreases with increasing energy as

$$\Delta\sigma(p) = (7.3 \pm 3) \times p^{-0.53 \pm 0.13} \text{ (see fig. 7).}$$

Using the isospin invariance one can compare our results with the K^+ and K^- total cross-section measurements on neutrons for the same energy region /6/. As is seen from fig. 7, both the measurements are in good agreement.

6) In ref. /11/ Nguen Van Hieu has considered the asymptotic behaviour of the regeneration amplitude and has shown that if its imaginary part has a logarithmic energy behaviour at $S \to \infty$ a limiting ratio must be fulfilled :

$$(1) \qquad \lim_{s\to\infty} \left| \frac{\mathrm{Re}\, f^0_{21}(s,0)}{\mathrm{Im}\, f^0_{21}(s,0)} \right| \geqslant A_1 \cdot \ln s ,$$

where A_1 is a constant. If $f^0_{21}(S)$ takes the form, for example,

$$(2) \qquad f^0_{21}(S) \sim S^{\alpha} \cdot (\ln S)^{\beta} \qquad \text{where } \alpha < 1$$

then at $S \to \infty$ the ratio (1) tends to be constant.

Not assuming that the region of 10-50 GeV/c is an asymptotic one for the regeneration process we , however, tested the confidence of both the hypotheses and found out that our data on the regeneration phase satisfied better the asymptotic form (2) - $\chi^2 = 4$ at 8 degrees of freedom than (1) - $\chi^2 = 10$ at 8 degrees of freedom.

The compilation of all available data on the regeneration on hydrogen is listed in Table I.

In conclusion we would like to express our deep gratitude to Profs. A.M. Baldin and A.A. Logunov for their continuous support of this experiment. We are also thankful to our colleagues A. Maier, K.-F. Albrecht and H. Risek from the Institute of High Energy Physics (Zeuthen, DDR) for generating the events by the Monte-Carlo method.

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T A B L E I

Compilation of the Hydrogen Regeneration Data

P_K GeV/c	$2\|f^{o}_{21}\|$ /K,mb	φ^{o}_{21}, degree	$\Delta\sigma$,mb	$(d\sigma/dt)\frac{mb}{(GeV/c)^2}$	Refs
I,3-2.0	0.8I±0.25	-I32±I4		I.3I±0.40	Brody et al./7/
2,0-3.3	0.65±0.I5	-I29±I3		0.85±0.20	
6	0.4I±0.I2	-I23±I8		0.34±0.I0	
8	0.34±0.I3	-I52±I9		0.24±0.09	
3-I0	0.43±0.II	-I0I±42	5.4±I.4	$0.38^{+.220}_{-.I70}$	Buchanan et al. /9/
2-3.0	0.84±0.I6		$7.2^{+2}_{-I.4}$	I.42±0.27	Darriulat et al /8/
3-4	0.56±0.II		$4.7^{+I.2}_{-0.8}$	0.63±0.I2	
4-5	0.56±0.I4	-I32±I7	$4.7^{+I.2}_{-0.94}$	0.63±0.I6	
5-7	0.78±0.26		$6.7^{+2.5}_{-2.2}$	I.22±0.4I	
I4-I8	0.234±0.043	-I58±25	2,22±0.46	0.III±0.04I	Birulev et al. this report
I8-22	0.I47±0.0I5	-I34±I5	I.39±0.I4	0.044±0.009	
22-26	0.I49±0,0I2	-I24±I2	I.42±0.I2	0.045±0.007	
26-30	0.I23±0.0I0	-I44±I3	I.I7±0.09	0.03I±0.005	
30-34	0.I36±0.0I0	-I3I±I3	I.29±0.I0	0.037±0.006	
34-38	0.I20±0.0I0	-I25±I6	I.I4±0.08	0.029±0.005	
38-42	0.I09±0.0I2	-I42±29	I.03±0.09	0.024±0.005	
42-50	0.097±0.0I2	- 90±35	0.92±0.09	0.0I9±0.005	

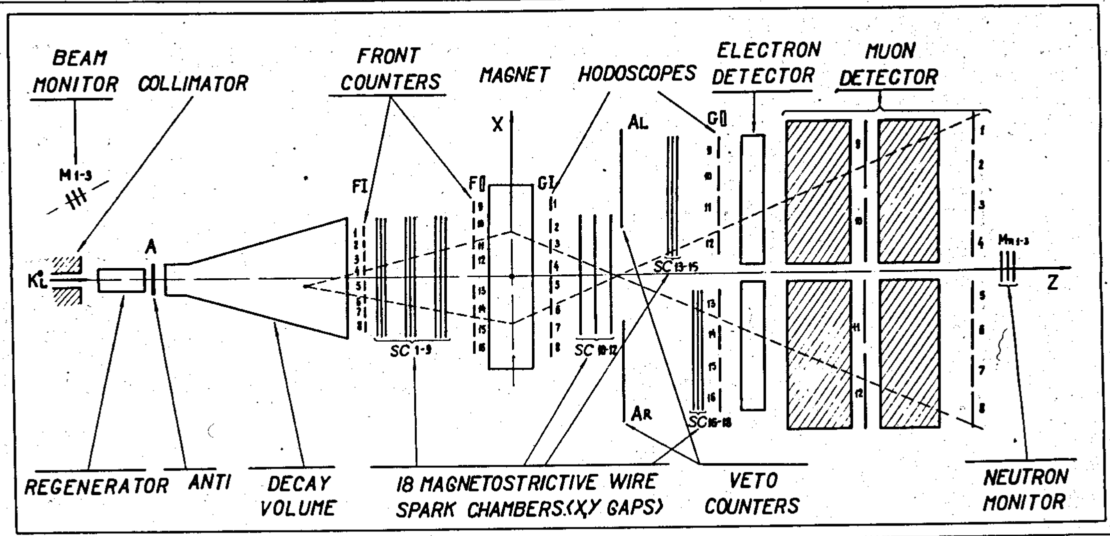

Fig.1. The layout of the on-line spectrometer.

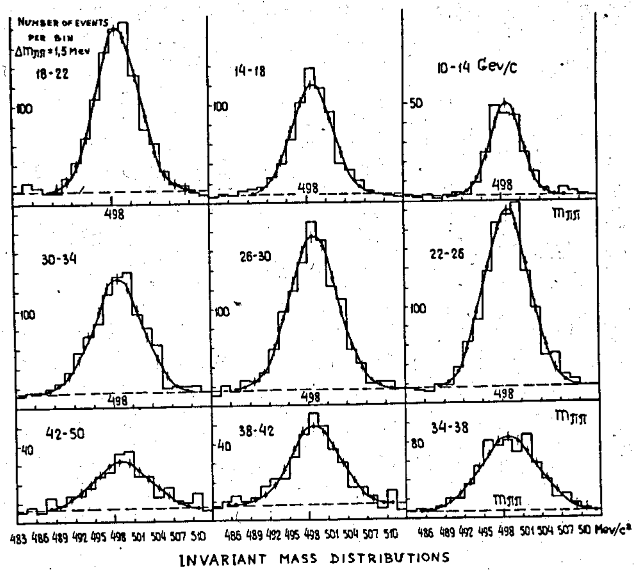

Fig.2. The invariant mass distribution of the events with $\theta^2 < 9\,\sigma_{\theta^2}(p)$. The solid and dashed lines are the result of approximation of experimental distributions by superposition of the Gaussian curve and constant background.

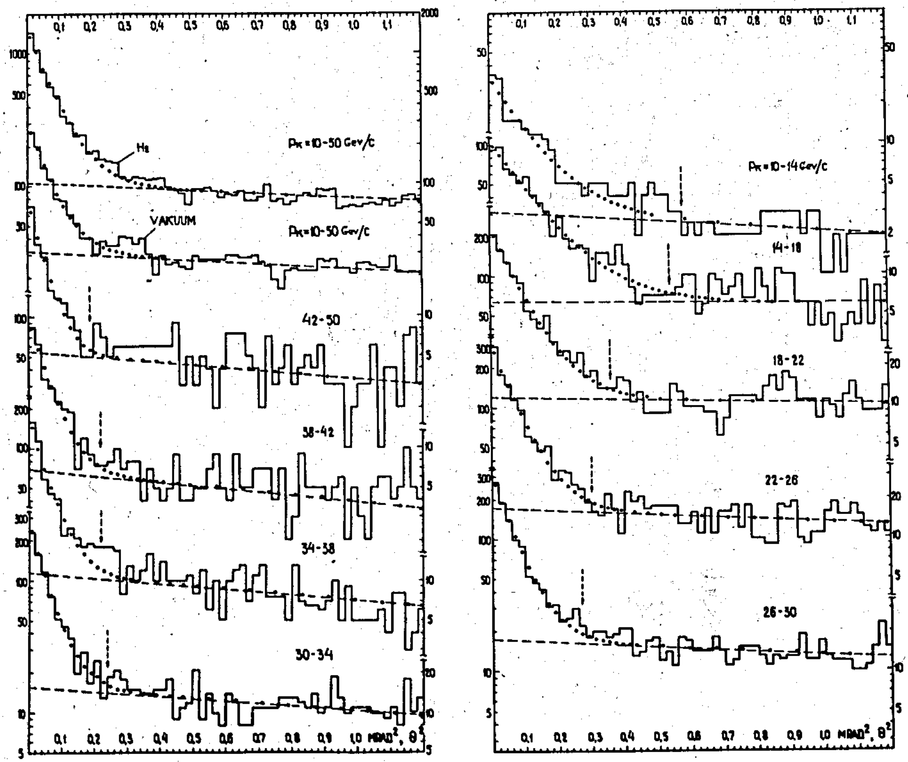

Fig.3. The angular distribution of the events with $498-3\cdot\sigma_m(p) < m_{\pi\pi} < 498 + 3\cdot\sigma_m(p)$. The dots are the result of approximation of experimental distributions by superposition of the Gaussian curve and straight line. The linear parts representing the background are shown by the dashed line.

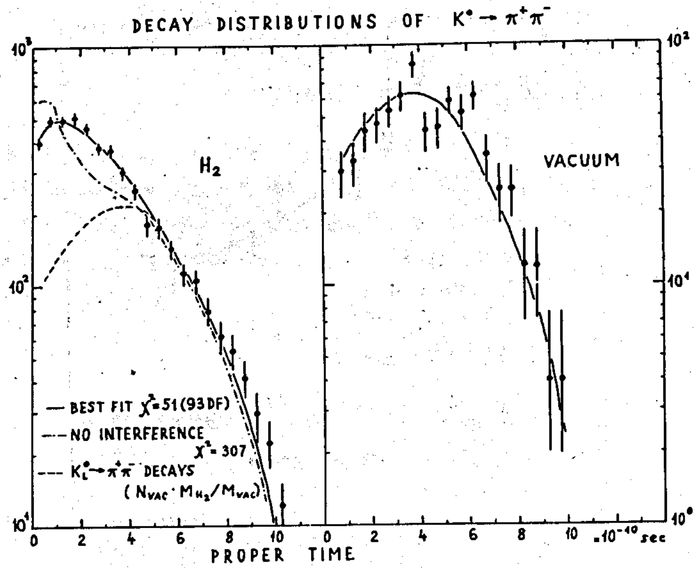

Fig.4. The time distribution of $K^0 \rightarrow \pi^+\pi^-$ events with and without hydrogen.

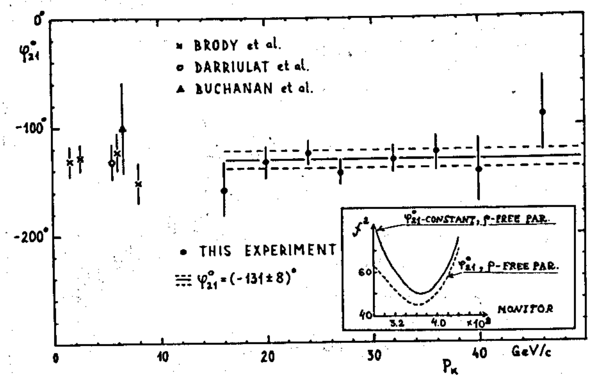

Fig.5. The phase of the regeneration amplitude as an energy function.

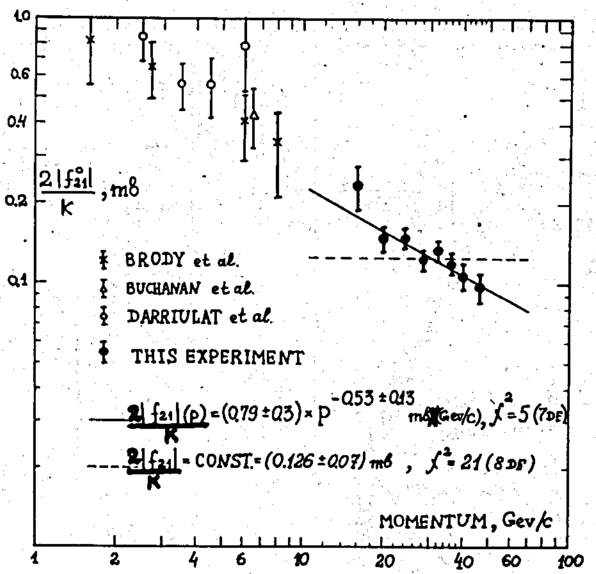

Fig.6. The modulus of the regeneration amplitude as an energy function.

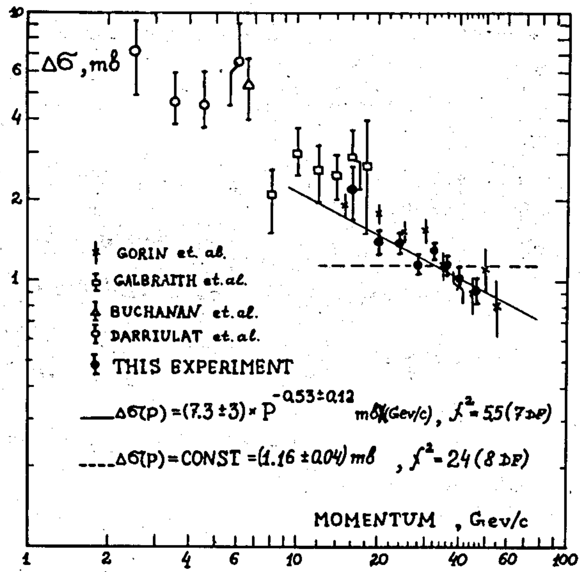

Fig.7. The kaon-antikaon total cross section difference as an energy function.