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## Inclusive $\rho^0$ , $K^{*0}$ (890) and $\bar{K}^{*0}$ (890) production in peripheral $K^+Al$ , $\pi^+Al$ and $\pi^+Au$ collisions at 250 GeV/c

EHS/NA22 Collaboration

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Average numbers of  $\rho^0$ ,  $K^{*0}$  (890) and  $\bar{K}^{*0}$  (890) produced in peripheral collisions (with the number of “grey” protons  $n_g \leq 2$ ) of  $K^+$  with Al and of  $\pi^+$  with Al and Au nuclei at 250 GeV/c are measured in the EHS(NA22) experiment at the CERN SPS. No evidence is found for suppression of vector meson production relative to  $K^+p$  and  $\pi^+p$  collisions at the same energy.

Inclusive vector meson production has been studied in hadron–proton interactions in many experiments over a wide energy range (see recent work (refs. [1–4] and references therein)). However, corresponding results are quite scarce in hadron–nucleus collisions at high energies and in full phase space.

Recently, vector meson production has been studied in hadron–nucleus collisions at 100 GeV/c in a Fermilab experiment [5], using the 30” hydrogen bubble chamber with thin metal foils mounted inside. The 5000 events recorded have been divided into “peripheral” collisions (defined by the number  $n_g$  of grey protons, i.e. protons with momentum  $200 \leq p \leq 1300$  MeV/c to be  $\leq 2$ ) on Ag, Au and Mg on one hand and “central” collisions (with  $n_g \geq 3$ ) on Ag and Au nuclei on the other. In both peripheral and central collisions the authors find relatively small  $\rho^0$  production:

$$\langle \rho^0 \rangle_{\text{per.}} = 0.22 \pm 0.06, \quad (1)$$

$$\langle \rho^0 \rangle_{\text{centr.}} = 0.26 \pm 0.07, \quad (2)$$

and even less  $K^{*\pm}$  (890) production (with an upper limit of  $\langle K^{*\pm} \rangle = 0.07$ ). They interpret this result as possible influence of a quark–gluon plasma formation, in analogy with suppression of  $J/\psi$  production in heavy ion collisions.

The purpose of this paper is to present a similar study of  $K^{*0}$  (890),  $\bar{K}^{*0}$  (890) and  $\rho^0$  production in  $\pi^+$  and  $K^+$  collisions at 250 GeV/c on Al and Au nuclei, as performed by the NA22 Collaboration in the European Hybrid Spectrometer (EHS) at the CERN SPS. Our results do not support the conclusions reached from the Fermilab experiment [5].

Full details on the experimental set-up of EHS and on the minimum bias interaction trigger are given in

refs. [6,7]. Due to the insertion of thin Al and Au foils inside the Rapid Cycling Bubble Chamber (RCBC), used as vertex detector, the study of interactions with hydrogen as well as with Al and Au nuclei became possible within a single experiment, subject to identical experimental biases. Results on vector meson production in  $K^+p$  and  $\pi^+p$  interactions at 250 GeV/c have already been published in refs. [1,3], and are used here for comparison.

The selection of the event and track sample is described in detail in refs. [8,9]. Events are accepted for analysis when the incident particle track is well measured and matches with hits in the upstream wire chambers, the reconstructed vertex position is within one of the foils, the outgoing tracks are satisfactorily measured and reconstructed, the loss of tracks due to measurement or reconstruction failure is at most one for charged particle multiplicities up to 10, and at most 20% for higher multiplicities. Quasi-elastic events or candidates for coherent interaction are excluded. The loss of events is corrected for by multiplicity dependent weights. Visual ionization information is used to identify protons up to 1.2 GeV/c and electrons up to 200 MeV/c. All unidentified tracks are assumed to be pions or kaons depending on the invariant mass distribution ( $\pi^+\pi^-$ ,  $K^+\pi^-$  or  $K^-\pi^+$ ) under consideration.

After these cuts a total of 7622 events passed the selection criteria. However, an ionization scan has been made on the smaller statistics of 5809 events: 2295 (2164)  $\pi^+Al$ , 1876 (1369)  $\pi^+Au$ , 902 (856)  $K^+Al$  and 736 (553)  $K^+Au$  events. The numbers in brackets correspond to events with the number of grey protons  $n_g \leq 2$ . Here we define them as protons identified from their ionization in RCBC, with velocity  $0.2 \leq \beta \leq 0.7$  (or equivalently  $0.19 \leq p \leq 0.92$  GeV/c).

The relative fraction of events with  $n_g \geq 3$  is small: only  $\approx 5.5\%$  for interactions on Al and  $\approx 26\%$  for interactions on Au. Moreover, the charged particle multiplicity increases with increasing  $n_g$  [9], so that the combinatorial background in the  $\pi^+\pi^-$  and  $K^\pm\pi^\mp$  invariant mass distributions is much larger for events with  $n_g \geq 3$ . Therefore, our statistics is insufficient to estimate reliably resonance production in central collisions (with  $n_g \geq 3$ )<sup>#1</sup>. For the same reason we also do not present results for the  $K^+Au$  sample, which has the smallest statistics, even for  $n_g \leq 2$ .

The inclusive cross section of  $K^{*0}(890)$ ,  $\bar{K}^{*0}(890)$

and  $\rho^0$  in  $K^+Al$ ,  $\pi^+Al$  and  $\pi^+Au$  interactions for events with  $n_g \leq 2$  is obtained from fits of the  $K^+\pi^-$ ,  $K^-\pi^+$  and  $\pi^+\pi^-$  invariant mass distributions by the expression

$$d\sigma/dM = BG(M) [1 + \beta BW(M)], \quad (3)$$

where  $BW(M)$  is a relativistic P-wave Breit-Wigner function, and  $BG(M)$  a background parametrized as

$$BG(M) = \alpha_1 (M - M_{th})^{\alpha_2} \exp(-\alpha_3 M - \alpha_4 M^2).$$

The  $\alpha_i$  and  $\beta$  are fit parameters; and  $M_{th}$  is the threshold mass.

All details of the fitting procedure including those of experimental resolution effects, use of particle identification, treatment of mutual reflections of  $\rho^0$ ,  $K^{*0}(890)$  and  $\bar{K}^{*0}(890)$ , etc., are identical to those described in our study of vector mesons in  $K^+p$  and  $\pi^+p$  interactions [1,3]. However, the fits were performed in the mass interval  $M_{min} \geq 0.48$  GeV/c<sup>2</sup> for the  $\pi^+\pi^-$  and  $M_{min} \geq 0.70$  GeV/c<sup>2</sup> for the  $K^\pm\pi^\mp$  invariant mass distributions.

For illustration, we show in fig. 1 the  $\pi^+\pi^-$  and  $K^+\pi^-$  invariant mass distributions in  $\pi^+Al$  interactions. The curves are best fits with expression (3) using the PDG resonance parameters [10] including experimental resolution. The inserts show the data in the resonance region after background subtraction. In spite of the large combinatorial background, clear  $\rho^0$  and  $K^{*0}(890)$  signals are present and well described by expression (3)<sup>#2</sup>.

Our fit results are summarized in table 1, where the average numbers of  $\rho^0$ ,  $K^{*0}(890)$  and  $\bar{K}^{*0}(890)$  in peripheral  $K^+Al$ ,  $\pi^+Al$  and  $\pi^+Au$  collisions are compared to those measured in  $K^+p$  and  $\pi^+p$  interactions [1,3] and to predictions of the two-string Lund model [11] (FRITIOF version 2 for elementary interactions and version 3 for collisions on nuclei). In the two FRITIOF versions we use the Lund scheme (JETSET 6.3) for string fragmentation with stan-

<sup>#1</sup> Since the same arguments can also be applied to the data sample with  $n_g \geq 3$  used in ref. [5], with comparable statistics, their result (2) for central collisions (surprisingly with the same error as for peripheral collisions (1)) should be treated with great caution.

<sup>#2</sup> Note that in ref. [5] the shape of the  $\rho^0$  signal above background had a two-bump structure, the  $\rho^0$  mass is below the PDG value and its width is about twice the accepted value.

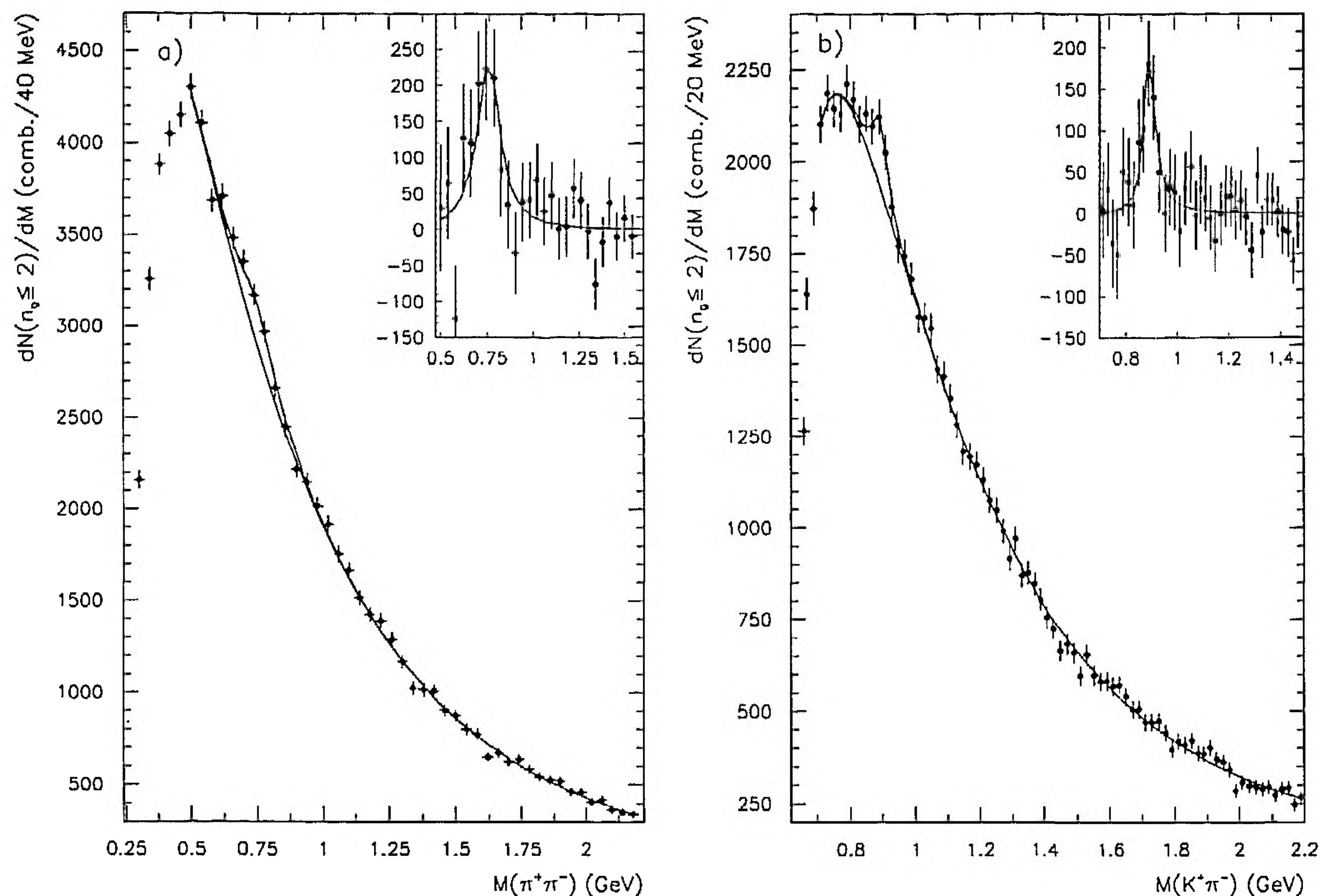


Fig. 1.  $\pi^+\pi^-$  (a) and  $K^+\pi^-$  (b) invariant mass distribution, corrected for reflections, in peripheral ( $n_g \leq 2$ )  $\pi^+$ Al interactions at 250 GeV/c.

standard parameters, except for a modified J-quark distribution [12] taken to be  $f(x_j) \sim x_j(1-x_j)^{10}$ . The latter was found necessary to describe the baryon  $x$ -spectra in this experiment [13]. In addition to pseudoscalar and vector mesons we include tensor mesons  $a_2(1370)$ ,  $f_2(1270)$ ,  $f'_2(1525)$  and  $K_2^*(1430)$  in the fragmentation scheme, in the ratios PS:V:T=50:35:15.

Table 1 shows that in peripheral meson-nucleus collisions the vector meson average multiplicities are the same within errors or even larger than in meson-proton interactions. In particular, for  $\rho^0$  production in  $\pi^+$ Al and  $\pi^+$ Au collisions (the samples with the largest statistics) we find

$$\begin{aligned} \langle \rho^0 \rangle_{\text{per.}}^{\pi^+\text{Al}} &= 0.45 \pm 0.13, \\ \langle \rho^0 \rangle_{\text{per.}}^{\pi^+\text{Au}} &= 0.43 \pm 0.21, \end{aligned} \quad (4)$$

to be compared with

$$\langle \rho^0 \rangle^{\pi^+\text{p}} = 0.46 \pm 0.02.$$

Our result (4) is twice larger than the value  $0.22 \pm 0.06$  measured in ref. [5]. Furthermore, our

values for  $\langle K^{*0}(890) \rangle$  and  $\langle \bar{K}^{*0}(890) \rangle$  are much larger than the upper limit of 0.07 for  $\langle K^{*\pm}(890) \rangle$  in ref. [5]<sup>#3</sup>.

Our observation that the average number of  $\rho_0$ 's per event in  $\pi^+$ A collisions is independent of the atomic mass number  $A$ , follows naturally from the fact that the restriction to  $n_g \leq 2$  selects interactions where the average number of projectile collisions is not very different from one. We find an analogous effect for  $\pi^-$ ,  $K_S^0$  and  $\Lambda^0$  production [14]. This feature of the data is not reproduced by the FRITIOF model, which predicts a considerably larger  $\rho^0$ -rate than measured in  $\pi^+$ A collisions.

The large experimental errors for the other reactions and known discrepancies for elementary collisions (see table 1) prevent us from drawing strong conclusions as to the reliability of FRITIOF in predicting  $K^{*0}$  and  $\bar{K}^{*0}$  production in meson-nucleus collisions.

<sup>#3</sup> The difference expected between our results and those of ref. [5] due to different beam momentum is  $\approx 20\%$  [3].

Table 1

Average multiplicities,  $\langle \text{Res} \rangle$ , of  $\rho^0$ ,  $K^{*0}(890)$  and  $\bar{K}^{*0}$  per collision (for events with  $n_b \leq 2$ ) in  $K^+Al$ ,  $\pi^+Al$  and  $\pi^+Au$  interactions at 250 GeV/c in comparison with the corresponding values in  $K^+p$  and  $\pi^+p$  interactions at 250 GeV/c [1,3] and with FRITIOF predictions.

Reaction	$\langle \text{Res} \rangle$	
	experiment	Fritiof
$K^+Al \rightarrow K^{*0}(890)X$	$0.34 \pm 0.16$	0.29
$K^+Al \rightarrow \bar{K}^{*0}(890)X$	$0.28 \pm 0.16$	0.09
$K^+Al \rightarrow \rho^0X$	$0.71 \pm 0.21$	0.60
$\pi^+Al \rightarrow K^{*0}(890)X$	$0.43 \pm 0.10$	0.13
$\pi^+Al \rightarrow \bar{K}^{*0}(890)X$	$0.17 \pm 0.10$	0.13
$\pi^+Al \rightarrow \rho^0X$	$0.45 \pm 0.13$	0.72
$\pi^+Au \rightarrow K^{*0}(890)X$	$0.34 \pm 0.16$	0.19
$\pi^+Au \rightarrow \bar{K}^{*0}(890)X$	$< 0.28$	0.17
$\pi^+Au \rightarrow \rho^0X$	$0.43 \pm 0.21$	0.96
$K^+p \rightarrow K^{*0}(890)X$	$0.29 \pm 0.03$	0.23
$K^+p \rightarrow \bar{K}^{*0}(890)X$	$0.14 \pm 0.03$	0.05
$K^+p \rightarrow \rho^0X$	$0.31 \pm 0.04$	0.40
$\pi^+p \rightarrow K^{*0}(890)X$	$0.13 \pm 0.01$	0.07
$\pi^+p \rightarrow \bar{K}^{*0}(890)X$	$0.15 \pm 0.01$	0.09
$\pi^+p \rightarrow \rho^0X$	$0.46 \pm 0.02$	0.48

In summary, in this analysis we find no evidence for suppression of vector meson production in peripheral hadron-nucleus collisions, relative to meson-proton interactions. This observation disagrees with the results of ref. [5].

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## References

- [1] NA22 Collab., N.M. Agababyan et al., Z. Phys. C 41 (1989) 539.
- [2] NA27 Collab., M. Aguilar-Benitez et al., Z. Phys. C 44 (1989) 531.
- [3] NA22 Collab., N.M. Agababyan et al., Z. Phys. C 46 (1990) 387.
- [4] NA27 Collab., M. Aguilar-Benitez et al., Z. Phys. C 50 (1991) 405.
- [5] E597 Collab., W.D. Walker et al., Phys. Lett. B 255 (1991) 155.
- [6] NA22 Collab., M. Adamus et al., Z. Phys. C 32 (1986) 475.
- [7] NA22 Collab., M. Adamus et al., Z. Phys. C 39 (1988) 311.
- [8] NA22 Collab., I.V. Ajinenko et al., Z. Phys. C 42 (1989) 377.
- [9] NA22 Collab., N.M. Agababyan et al., Z. Phys. C 50 (1991) 361.
- [10] Particle Data Group, M. Aguilar-Benitez et al., Review of particle properties, Phys. Lett. B 170 (1986) 1.
- [11] B. Andersson, G. Gustafson and B. Nilsson-Almqvist, Nucl. Phys. B 281 (1987) 289.
- [12] T. Sjöstrand, Comput. Phys. Commun. 27 (1982) 243.
- [13] NA22 Collab., I.V. Ajinenko et al., Z. Phys. C 44 (1989) 573.
- [14] F. Botterweck et al., Neutral strange particle production in  $K^+$  and  $\pi^+$  collisions with Al and Au nuclei at 250 GeV/c, IIHE-ULB-VUB preprint IIHE-92-01.