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K^+, K^- and K^0_S total rates in pp collisions at 24 GeV/c

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The knowledge of charged-kaon production rates in pNi or at least pp collisions at the beam momentum of 24 GeV/c is essential for proper tuning of the Monte Carlo generators for the DIRAC experiment. In particular it is important for estimation of the finite-size corrections to the lifetime of $K^{\pm}\pi^{\mp}$-atoms.

The available phase space coverage of the existing data in the center of mass energy range around $\sqrt{s} = 6.8$ GeV is known to be incomplete and partially incompatible especially for charged kaons. The double differential cross sections for charged kaons in pp collisions at 24 GeV/c beam momentum have been measured by the CERN-Rome group, Allaby et al. [1, 2]. However, the precise data on the production of charged kaons in pp collisions at 158 GeV/c beam momentum recently obtained by the NA49 experiment at CERN [3] and a new evaluation of the energy dependence of kaon production in [3] has revealed that the resulting s-dependence for the K^+ production looks unphysical indicating an excess of the order of 60% in the K^+ yields of Allaby et al. For example, the Allaby et al. data at $p_T =$ 0.632 GeV/c, Feynman-x_F=0.2 (Fig. 66a in [3]) and x_F=0.2, p_T =0.55 GeV/c (Fig. 66b in [3]) are on the same level as the NA49 data for 24 GeV/c beam momentum and even *higher* for 19.2 GeV/c.

Meanwhile the Fritiof 6 - Monte Carlo generator for the DIRAC experiment was tuned to the measurements [4] of particle production in proton interactions with nuclei at 24 GeV/c. This experiment [4] was performed with the same spectrometer of the CERN-Rome group as the one in the experiment of Allaby et al., with the hydrogen target just replaced by a set of nuclear targets. Therefore if an excess in the K^+ yields of Allaby et al. is related to the performance of their spectrometer, the data of Eichten et al. [4] have to be also treated with a caution.

The K^+ and K^- total rates in pp collisions at 24 GeV/c were determined in the bubble chamber experiment [5]. For this a sample of events with inclusive production of two strange particles with opposite strangeness was analyzed. Only those channels in which a charged kaon was produced in association with a neutral kaon, a lambda or a charged sigma, i.e. the final states $K^+K^0_SX$, $K^0_SK^-X$, $K^+\Lambda X$, $K^+\Sigma^+X$ and $K^+\Sigma^-X$, were considered. Charged kaons were detected either by their pionic or muonic decay modes or, in the most cases, by a *statistical procedure*. The significant pion contamination (of about 40% for $p_{lab} > 1$ GeV/c) due to this separation procedure could indeed be not very important for invesigation of net strangeness and strangeness-transfer distributions which represented the main task of paper [5]. However the systematic errors on the total K^+ and K^- rates obtained in [5] and used in [3] can be quite large (as it is evident from Figs. 1 and 2 to be presented below).

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In this note, an attempt is made to estimate the K^+ and K^- total rates in pp interactions at 24 GeV/c. It is based on a study of energy evolution of the total yields of the charged and neutral kaons in [3] and reliable value of the measured total K^0_S rate in the bubble chamber pp experiment at 24 GeV/c [6].

Investigation of the energy dependence of the total charged kaon rates in [3] has been based on assumption that this dependence is closely related to the one for the neutral kaons:

$$\langle K^+\rangle + \langle K^-\rangle = \langle K^0\rangle + \langle \bar{K}^0\rangle = 2\langle K^0_S\rangle$$

or

$$R = 0.5(\langle K^+\rangle + \langle K^-\rangle)/\langle K^0_S\rangle = 1, \tag{1}$$

as might be expected from isospin symmetry. This relation is not fulfilled for ϕ with its branching fractions $Br(\phi \to K\bar{K}) = 0.491$ and $Br(\phi \to K^0_S K^0_L) = 0.341$ [7]. However the ϕ total production rate in pp collisions at 24 GeV/c is relatively small $\langle\phi\rangle = 0.0052 \pm 0.0011$ [8]. Therefore the influence of the ϕ production on (1) is negligible.

Indeed, the ratio R was determined in [3] to be 2.8 at $\sqrt{s}$ =3 GeV, 1.4 at $\sqrt{s}$ =3.5 GeV and 1.27 at $\sqrt{s}$=4 GeV. Thus it approaches unity rather quickly with increasing energy, so that it may be assumed, within a few percent error margin, that $R = 1$ at $\sqrt{s} > 5$ GeV.

In Fig. 1 taken from [3] (Fig. 130), the total yields $\langle K^+\rangle$, $\langle K^-\rangle$ and $\langle K^0_S\rangle$ are shown as a function of $\sqrt{s}$. The full line through the K^0_S data points is an eyeball fit which gives a consistent description of the data within point-by-point deviation of typically 10-20%. In a second step the ratios $\langle K^+\rangle/\langle K^0_S\rangle$ and $\langle K^-\rangle/\langle K^0_S\rangle$ were obtained in [3] from the available data. These ratios are presented in Fig. 2 also taken from [3] (Fig. 131). A smooth $\sqrt{s}$ dependence was imposed on these data points between the low energy range $\sqrt{s} < 4.8$ GeV and the higher energies $\sqrt{s} > 6.8$ GeV since the cross sections in the 4.8-6.8 GeV range were shown in [3] to deviate upwards. The $\langle K^+\rangle/\langle K^0_S\rangle$ and $\langle K^-\rangle/\langle K^0_S\rangle$ ratios thus obtained were then used to produce smooth lines in Fig. 1 through the K^+ and K^- data by multiplying with the K^0_S interpolation.

From the smooth lines in Fig. 2 one has at $\sqrt{s} = 6.8$ GeV

$$\langle K^+\rangle/\langle K^0_S\rangle = 1.51 \quad \text{and} \quad \langle K^-\rangle/\langle K^0_S\rangle = 0.43. \tag{2}$$

With the K^0_S total rate determined in the bubble chamber pp experiment at 24 GeV/c beam momentum [6]

$$\langle K^0_S\rangle = 0.0507 \pm .0020^2 \tag{3}$$

one then obtains:

$$\langle K^+\rangle = 0.0766 \quad \text{and} \quad \langle K^-\rangle = 0.0218 \tag{4}$$

with

$$\langle K^+\rangle/\langle K^-\rangle = 3.52. \tag{5}$$

[2] Different data points at $\sqrt{s} = 6.8$ GeV in Figs. 1 and 2 represent, in fact, the results of the same experiment. The data points with the lowest $\langle K^0_S\rangle$ in Fig. 1 and, respectively, the highest $\langle K^+\rangle/\langle K^0_S\rangle$ and $\langle K^-\rangle/\langle K^0_S\rangle$ in Fig. 2 have to be ignored since they are obtained from earlier result [9] of this experiment on the K^0_S rate. The final result was given in [5, 6].

The errors of the values (4) and (5) can be roughly estimated as equal to 10-20%. It is therefore quite assuring that the ratio of the $K^{*+}(892)$ and $K^{*-}(892)$ total rates in the same pp experiment at 24 GeV/c [6] is exactly the same as the K^+/K^- ratio:

$$\langle K^{*+}(892)\rangle/\langle K^{*-}(892)\rangle = 3.5 \pm 0.8, \tag{6}$$

as could be expected.

Significant difference between K^+ and K^- production arising from associate kaon plus hyperon versus kaon pair production persists even at SPS energies [3]. Therefore it is important to study evolution of the K^+/K^- ratio as a function of the kinematic variables and its s-dependence.

Besides, possible signature of new physics by the creation of a deconfined state of matter in heavy nuclear interactions, looked for since a long time, is supposed to rely completely on a comparison with elementary or proton-nuclei collisions. Therefore the detailed study of behaviour of the kaon production from low energy up to RICH and collider energies in pp and proton-nuclei collisions appears to be very important.

From this point of view it would be interesting to obtain the precise data on the K^+/K^-, $\bar{p}/p$ and $\bar{\Lambda}/\Lambda$ ratios and their dependence on Feynman-x_F and transverse momentum variables in pNi collisions at 24 GeV/c as it seems possible from the data already collected by the DIRAC experiment.

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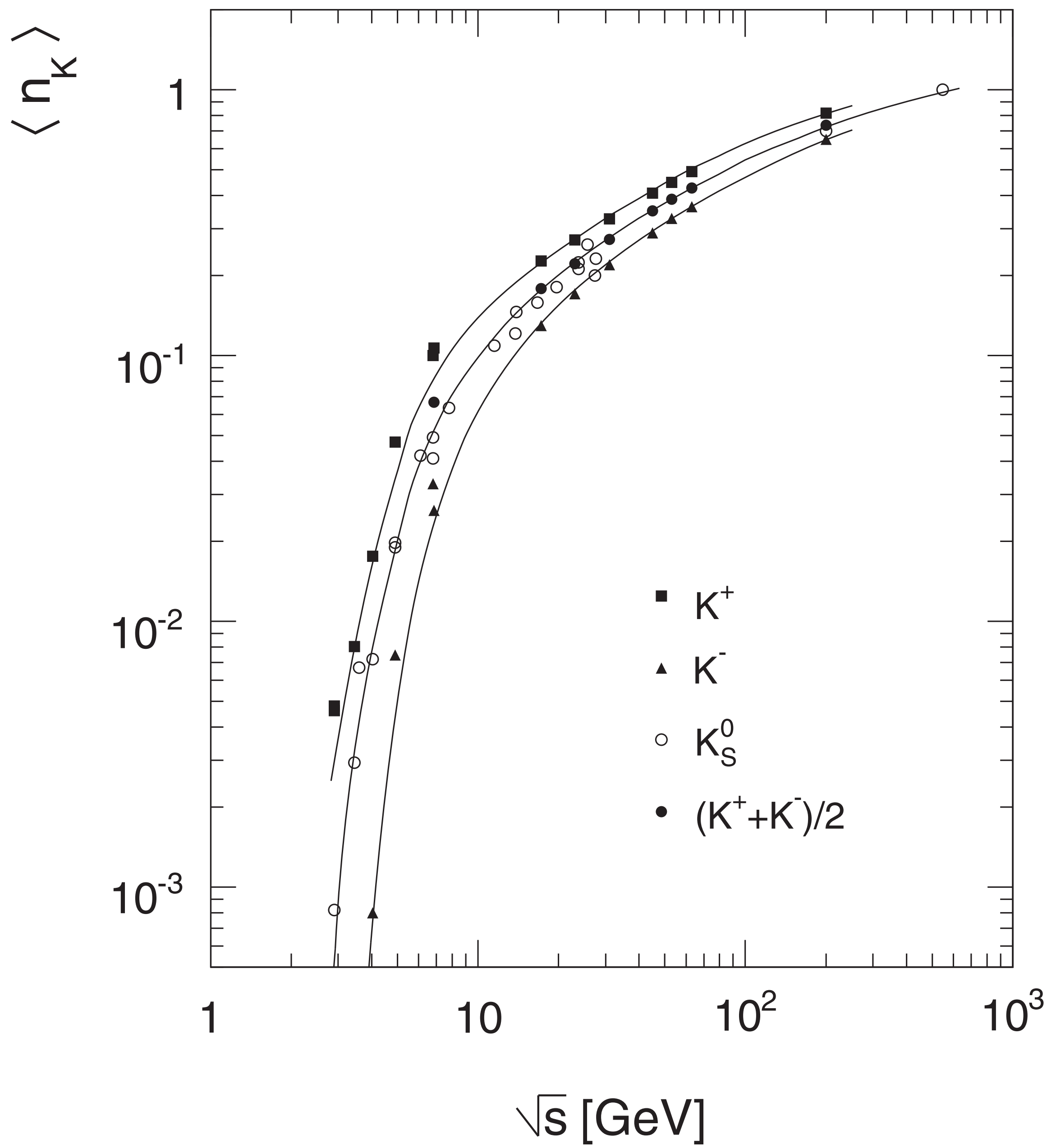

Figure 1: Fig. 130 taken from [3]: Total yeilds $\langle \mathrm{K}^+ \rangle$, $\langle \mathrm{K}^- \rangle$ and $\langle \mathrm{K}^0_S \rangle$ as a function of $\sqrt{s}$. The full line through the K^0_S results is eyeball fit, the lines through the K^+ and K^- data are derived from Fig. 2. The full circles in the K^0_S data correspond to $0.5(\langle \mathrm{K}^+ \rangle + \langle \mathrm{K}^- \rangle)$ established at corresponding $\sqrt{s}$ values

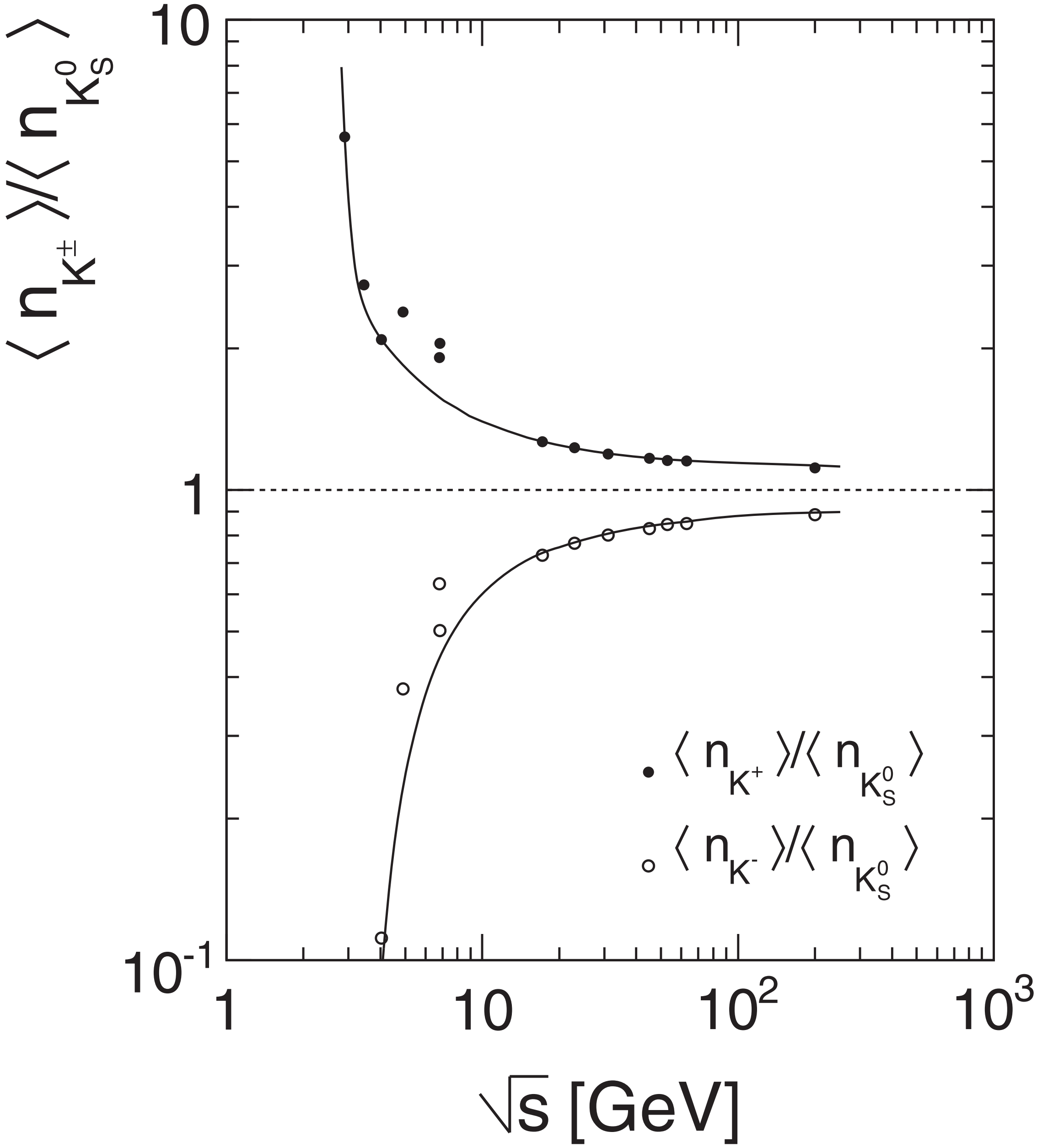

Figure 2: Fig. 131 from [3]: Ratios $\langle K^+ \rangle / \langle K^0_S \rangle$ and $\langle K^- \rangle / \langle K^0_S \rangle$ as a function of $\sqrt{s}$. The full lines are eyeball fits through the data at $\sqrt{s} < 4.9$ GeV and $\sqrt{s} > 6.8$ GeV