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 investigation 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).
In this note, an attempt is made to estimate the \( \mathbb{K}^+ \) and \( \mathbb{K}^- \) 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 \( \mathbb{K}_S^0 \) 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:

\[
\langle \mathbb{K}^+ \rangle + \langle \mathbb{K}^- \rangle = \langle \mathbb{K}^0 \rangle + \langle \mathbb{K}^0 \rangle = 2 \langle \mathbb{K}_S^0 \rangle
\]

or

\[
R = 0.5(\langle \mathbb{K}^+ \rangle + \langle \mathbb{K}^- \rangle)/\langle \mathbb{K}_S^0 \rangle = 1,
\]

as might be expected from isospin symmetry. This relation is not fulfilled for \( \phi \) with its branching fractions \( Br(\phi \to \mathbb{K}\overline{\mathbb{K}}) = 0.491 \) and \( Br(\phi \to \mathbb{K}_S^0\overline{\mathbb{K}}_L^0) = 0.341 \) [7]. However the \( \phi \) 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 \( \phi \) 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 \( \langle \mathbb{K}^+ \rangle \), \( \langle \mathbb{K}^- \rangle \) and \( \langle \mathbb{K}_S^0 \rangle \) are shown as a function of \( \sqrt{s} \). The full line through the \( \mathbb{K}_S^0 \) 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 \( \langle \mathbb{K}^+ \rangle/\langle \mathbb{K}_S^0 \rangle \) and \( \langle \mathbb{K}^- \rangle/\langle \mathbb{K}_S^0 \rangle \) 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 \( \langle \mathbb{K}^+ \rangle/\langle \mathbb{K}_S^0 \rangle \) and \( \langle \mathbb{K}^- \rangle/\langle \mathbb{K}_S^0 \rangle \) ratios thus obtained were then used to produce smooth lines in Fig. 1 through the \( \mathbb{K}^+ \) and \( \mathbb{K}^- \) data by multiplying with the \( \mathbb{K}_S^0 \) interpolation.

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

\[
\langle \mathbb{K}^+ \rangle/\langle \mathbb{K}_S^0 \rangle = 1.51 \quad \text{and} \quad \langle \mathbb{K}^- \rangle/\langle \mathbb{K}_S^0 \rangle = 0.43.
\]

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

\[
\langle \mathbb{K}_S^0 \rangle = 0.0507 \pm 0.0020^2
\]

one then obtains:

\[
\langle \mathbb{K}^+ \rangle = 0.0766 \quad \text{and} \quad \langle \mathbb{K}^- \rangle = 0.0218
\]

With

\[
\langle \mathbb{K}^+ \rangle/\langle \mathbb{K}^- \rangle = 3.52.
\]

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 \( \langle \mathbb{K}_S^0 \rangle \) in Fig. 1 and, respectively, the highest \( \langle \mathbb{K}^+ \rangle/\langle \mathbb{K}_S^0 \rangle \) and \( \langle \mathbb{K}^- \rangle/\langle \mathbb{K}_S^0 \rangle \) in Fig. 2 have to be ignored since they are obtained from earlier result [9] of this experiment on the \( \mathbb{K}_S^0 \) 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:

$$\frac{\langle K^+(892) \rangle}{\langle K^-(892) \rangle} = 3.5 \pm 0.8,$$

(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 $\Lambda/\Lambda$ 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.

References

Figure 1: Fig. 130 taken from [3]: Total yields $\langle K^+ \rangle$, $\langle K^- \rangle$ and $\langle K^0_S \rangle$ 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 $0.5(\langle K^+ \rangle + \langle K^- \rangle)$ 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.