Stopping and Strangeness Production in Nuclear Collisions at CERN-SPS

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Results on baryon stopping at the CERN SPS, measured by the inclusive net proton rapidity distribution, are presented for centrality selected Pb+Pb collisions. A smooth evolution in the degree of stopping is observed when going from small to large systems. Neutral and charged kaon and Φ yields are presented for different centrality bins. Strangeness production is found to increase smoothly with centrality. Stopping and strangeness data are compared to central S+S collisions.

1. CENTRALITY SELECTION

The NA49 experiment is described in detail in [1]. Charged particles emitted from a collision are detected over a large fraction of phase space by tracking in four large volume time projection chambers (TPC's). Particle momentum and velocity are determined from tracking through a magnetic field and measuring the specific energy loss in the TPC gas (dE/dx). In the case of Pb+Pb collisions centrality samples are selected by a zero-degree calorimeter, which accepts charged and neutral particles emitted within 0.3^o of the beam [2,3]. Collisions are divided into six centrality bins using only the zero-degree energy.

In each centrality bin, a direct estimate of the number of interacting or participating nucleons ($\mathrm{N}_{\mathrm{part}}$) is made by estimating the net baryon number carried by produced particles [4]. Little extrapolation is required, since measurement of the charged particle spectra covers nearly all of phase space forward of the center of mass of the system. The net baryon number is carried by the net protons, net neutrons, and net hyperons. The number of net neutrons is assumed to be proportional to the number of net protons. The total number of net hyperons is estimated by balancing the net strangeness carried by the strange mesons, measured in the same experiment (for details see [4]). The estimated mean number of participating nucleons in each centrality bin is given in table 1.

2. STOPPING

Figure 1 shows the net proton rapidity distribution for the six Pb+Pb centrality samples. In going from peripheral to central collisions, the forward yield of net protons is strongly suppressed compared to that at mid-rapidity and the rapidity at which the largest yield is observed moves towards mid-rapidity, indicating a significant increase of stopping from peripheral to central collisions.

bin	frac. of cross sec.	$\langle N_{part} \rangle$	b(fm) (a)	b(fm) (b)
1	$0 - 0.05$	362 ± 12	2.2	2.2
2	$0.05 - 0.14$	304 ± 16	4.6	4.0
3	$0.14 - 0.23$	241 ± 16	6.5	5.6
4	$0.23 - 0.31$	188 ± 16	8.0	6.8
5	$0.31 - 0.48$	130 ± 14	9.5	8.3
6	$0.48 - 1.00$	72 ± 8	11.5	10.0

Table 1. Pb+Pb centrality bins from most central (1) to peripheral (6). Columns show the covered range in fraction of the total cross section, the mean number of participating nucleons, and the mean impact parameter for the corresponding range in cross section (a), and for which a Glauber calculation gives that number of wounded nucleons (b).

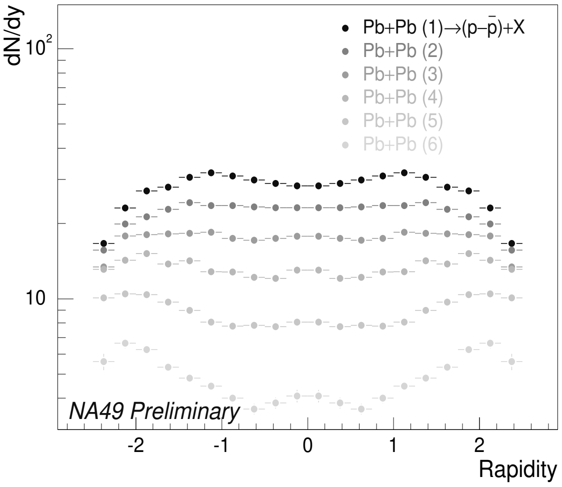

Figure 1. Rapidity distributions of net protons ($p - \overline{p}$). The panel shows results for peripheral (6) to central (1) Pb+Pb collisions.

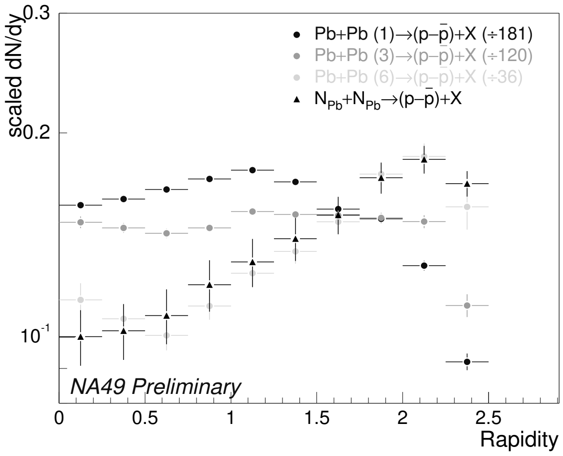

Figure 2. Rapidity distributions of net protons ($p - \overline{p}$) for various nuclear systems. The figure shows results for three of the Pb+Pb centrality bins, normalized by the estimate of the mean number of participating nucleons for that bin, along with the effective nucleon-nucleon reaction which is appropriate for comparison to Pb+Pb.

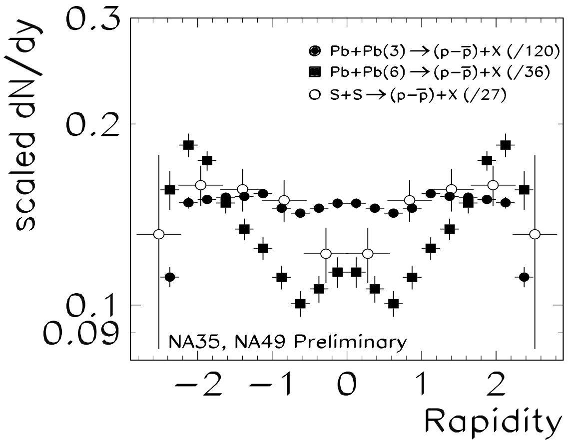

Figure 3. Rapidity distributions of net protons ($p - \overline{p}$) for various nuclear systems. The figure shows results for peripheral (centrality bin 6) and semi-central Pb+Pb collision (centrality bin 3), along with the results for central S+S collisions, both normalized by the estimate of the mean number of participating nucleons for that reaction.

In order to compare Pb+Pb to p+p, one must account for the enhanced yield in Pb+Pb of net protons which comes from stopping of neutrons. This is done by using data on p+p→n+X [5], making the simplifying assumption that nucleon stopping is similiar in p+p and p+n, and taking an isospin average to construct the effective nucleon-nucleon system ($N_{Pb} + N_{Pb}$) appropriate for comparison to Pb+Pb. Figure 2 shows three of the six Pb+Pb centrality bins, normalized by the estimated number of participating nucleons, compared to $N_{Pb} + N_{Pb}$.

Figure 3 shows two of the six Pb+Pb centrality bins compared to central S+S [6]; all spectra are normalized by the estimated number of participating nucleons. Although the Pb+Pb centrality bin 6 and central S+S collisions have approximately the same number of participating nucleons, the shape of the rapidity distributions are different. A central S+S collisions rather resembles a semi-central Pb+Pb reaction.

3. STRANGENESS PRODUCTION

In hadronic interactions roughly 70% of the produced strangeness is carried by kaons, therefore their yields are an approximate measure of the strangeness content of the reaction. Figures 4 and 5 show the rapidity distributions of charged and neutral kaons in central Pb+Pb collisions [7]. The charged kaon yields from two different identification methods are consistent and the distributions are well described by a Gaussian fit. The neutral kaon yield agrees with the mean of the charged kaons.

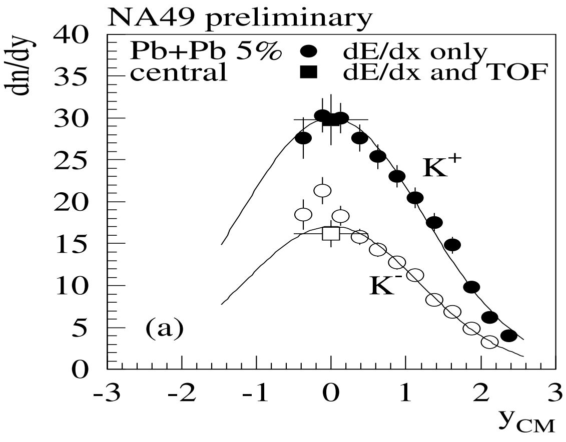

Figure 4. Rapidity distributions of charged kaons in central Pb+Pb collisions with Gaussian fits ($\sigma_{K^+} = 1.25, \sigma_{K^-} = 1.17$).

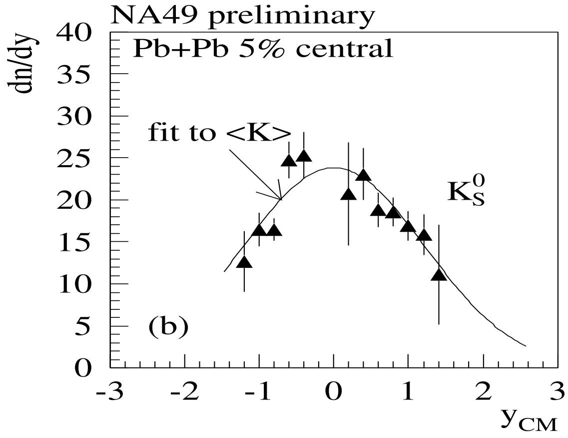

Figure 5. Rapidity distributions of neutral kaons in central Pb+Pb collisions with a Gaussian fit to the mean of K^+ and K^-.

In order to calculate the total integrated yields, the distributions are extrapolated to 4π. Figure 6 shows the total yield of various hadrons normalized to the number of participant nucleons for different centrality bins. A smooth increase for pions (20%) and kaons (factor 2.5 for K^+ and 1.5 for K^-) from p+p via peripheral to central Pb+Pb collisions is observed. Comparing with measurements of central S+S collisions [9,10] it is apparent that the mean number of participating nucleons is not the best measure for comparison of Pb+Pb and S+S. Again, a central S+S collision resembles a semi-central Pb+Pb reaction rather than a peripheral Pb+Pb collision with the same number of participating nucleons.

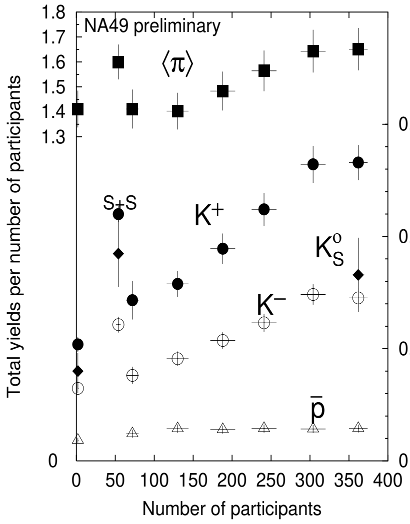

Figure 6. Dependence of the total yields per participant nucleon on the number of participants in p+p and Pb+Pb collisions in six centrality bins. Values for average charged pions, charged kaons, K^0_S and antiprotons are shown along with the results on S+S from NA35 [6]. The vertical scale on the left side belongs to pions, the right one to kaons and antiprotons.

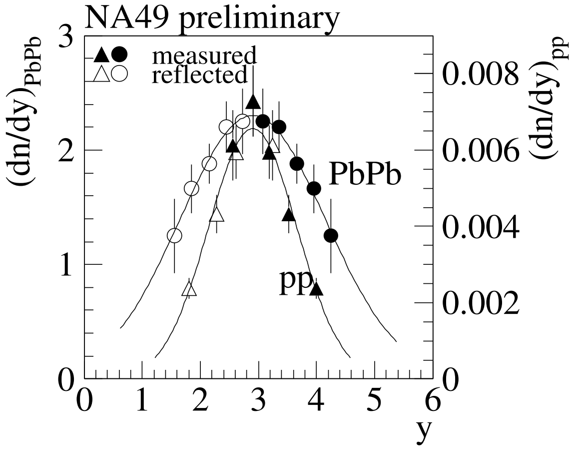

Figure 7. Rapidity distributions of the Φ-meson in central Pb+Pb and p+p collisions. The lines are Gaussian fits with $\sigma_{PbPb} = 1.25$ and $\sigma_{pp} = 0.76$.

Figure 7 shows the rapidity distribution of ϕ-mesons produced in central Pb+Pb collisions and in p+p. The distribution for Pb+Pb interactions is broader than in p+p; the $< \phi >/< \pi >$ ratio increases by a factor of 2.8 in going from minimum bias p+p to central Pb+Pb collisions.

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