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ϕ production in 158 GeV/u Pb + Pb collisions

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Abstract. Preliminary data on ϕ production in central Pb+Pb collisions at 158 GeV per nucleon are presented, measured by the NA49 experiment in the hadronic decay channel $\phi \to K^+K^-$. At mid-rapidity, the kaons were separated from pions and protons by combining dE/dx and time-of-flight information; in the forward rapidity range only dE/dx identification was used to obtain the rapidity distribution and a rapidity-integrated m_t-spectrum. The mid-rapidity yield obtained was $dN/dy = 1.85 \pm 0.3$ per event; the total ϕ multiplicity was estimated to be 5.0 ± 0.7 per event. Comparison with published pp data shows a slight, but not very significant strangeness enhancement.

1. Introduction

The ϕ meson, as a carrier of hidden strangeness, is of special interest in high-energy heavy-ion reactions in the context of strangeness production. It was suggested that an enhanced production could be a signature of the phase transition to the quark–gluon plasma [1]. Another aspect is that the ϕ mass, width and branching ratios could be influenced by the surrounding nuclear medium [2], and the hope is that this can be observed under special conditions, for example by selecting mid-rapidity ϕ's with small p_t.

Earlier measurements were made at AGS energies using Si + Au collisions [3]. Here we present preliminary data on ϕ production at CERN SPS energies obtained by the NA49 experiment.

2. The experiment

The experiment NA49 at the CERN SPS accelerator (figure 1) contains an arrangement of several large-volume tracking detectors (TPCs), which record a large fraction of the charged particles emitted in central Pb + Pb collisions at 158 GeV/nucleon. Additional time-of-flight (TOF) detectors provide particle identification in the momentum range between 4 and 12 GeV/c , which contains in particular the mid-rapidity kaons, protons and anti-protons.

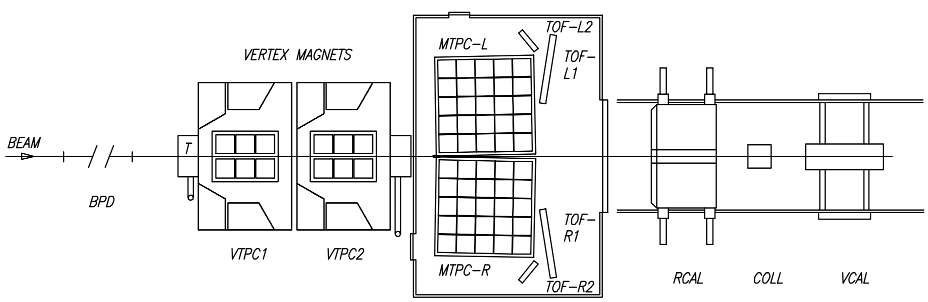


Figure 1. The NA49 experimental set-up.

The ϕ meson is observed through its hadronic decay channel $\phi \to K^+K^-$, which has a branching ratio of 49.1%. At mid-rapidity ($y = 2.9$), a relatively clean kaon identification (see figure 2) can be obtained by combining the dE/dx information (from MTPC-L/R) and the time of flight (from TOF-R1/L1). The time resolution of 60 ps allows a good separation of kaons from pions and protons for momenta up to 8 GeV/c.

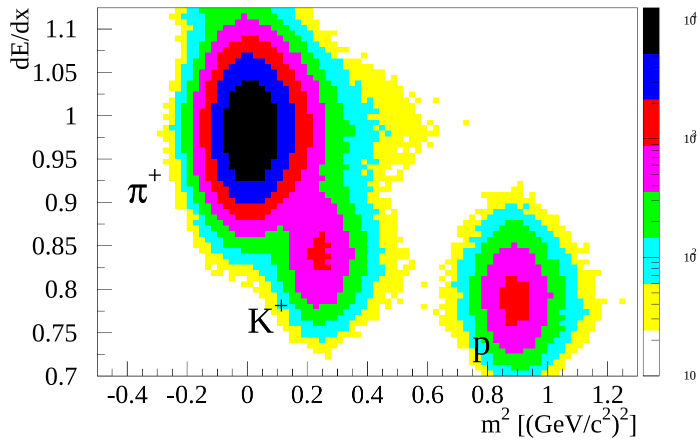


Figure 2. Particle identification by time of flight and dE/dx in the momentum range 4–6 GeV/c.

In the forward rapidity region ($y = 3 \ldots 4.5$), where TOF identification is not available, the dE/dx information is used to reduce the background pions in the K^+K^- invariant mass spectrum.

330 000 central Pb + Pb events from the 1995 CERN run period were used. There are four times more data on tape from the 1996 runs, which have not yet been processed.

3. The TOF analysis

Figure 3 shows the invariant mass spectrum of the charged kaons identified by the TOF detector system in the mid-rapidity region. The combinatorial background is reconstructed by the usual event mixing method and subtracted from the original spectrum.

A prominent ϕ resonance peak is observed at a mass of 1.019 GeV/c^2, which is in agreement with the Particle Data Group value [4]. The peak is broadened to a width of 9 GeV/c^2 due to the momentum resolution of the detector. The depletion on the left-hand side of the peak is a well understood consequence of the background subtraction method at limited acceptances [5].

A quantitative interpretation of the signal requires a simulation which takes into account the detector acceptance and efficiency. The method is described in detail in [5]. We assumed a Breit–Wigner resonance at 1.019 GeV/c^2 with a thermal p_t-distribution; the inverse slope parameter T was taken to be 290 MeV (see section 4). The simulated ϕ then decays into K^+K^-. The invariant mass spectrum of K^+K^- pairs is calculated as well as the combinatorial background. The background subtracted spectrum is fitted to the measured spectrum, with the ϕ-yield at mid-rapidity and the width Γ, which reflects the momentum resolution, as free fit parameters.

The full curve in figure 3 shows the result. The best fit is obtained for $\Gamma = 9$ MeV/c^2 and dN/dy = 1.7 ± 0.25 per event. Assuming a Gaussian rapidity distribution with $\sigma_y = 1.07$ (see section 4), this leads to a total yield of 4.5 ± 0.7 per event.

Due to the fact that the acceptance of the TOF system is concentrated at low p_t (figure 4),

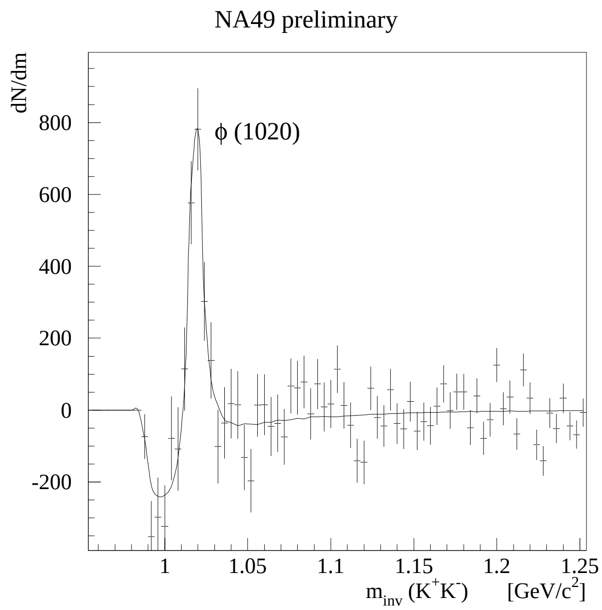


Figure 3. The K^+K^- invariant mass spectrum from TOF-identified kaons, background subtracted. The full curve shows the result of the simulation fitted to the data.

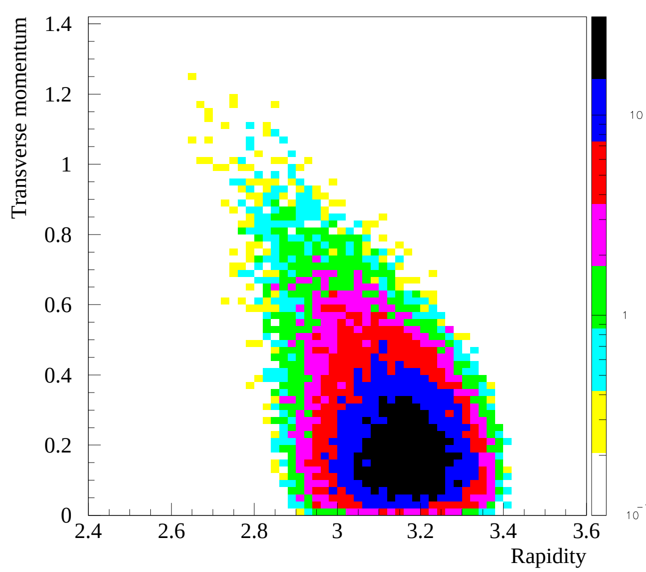


Figure 4. Distribution of TOF-accepted ϕ mesons in the rapidity p_t-plane (simulation).

the extracted ϕ yield depends on the assumed slope parameter for the p_t-distribution. This gives rise to some systematic uncertainty.

4. The dE/dx analysis

Using only the dE/dx measurement from the TPCs for kaon identification allows one to extend the analysis to the forward rapidity region ($y = 3 \ldots 4.5$). This method provides a sufficient reduction of the pion background. A clear ϕ peak can again be observed in the invariant mass distribution of the charged kaon candidates after subtraction of the combinatorial background from event mixing (figure 5). The position of the peak is the same as in the TOF data, but the width (6.5 MeV/c^2) is somewhat smaller. The depletion on the side of the peak is not visible because of the larger kinematical region covered by the TPCs. Thus, the yield was obtained by simply fitting a Gaussian to the peak.

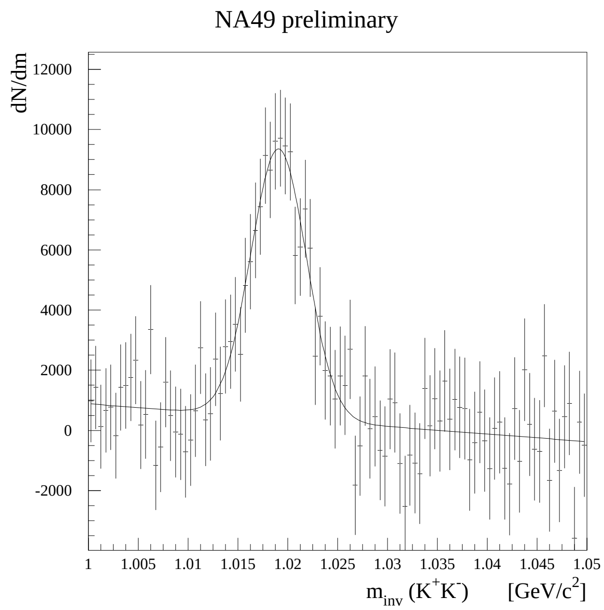
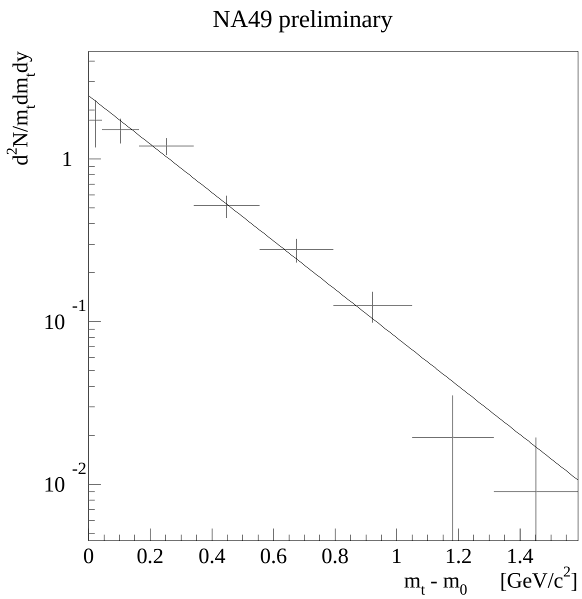


Figure 5. K^+K^- invariant mass spectrum from dE/dx-identified kaons, background subtracted. The full curve represents a Gaussian fit to the signal with $m_\phi = 1019.1 \pm 0.3$ MeV/c^2 and a full width half maximum of 6.5 MeV/c^2.

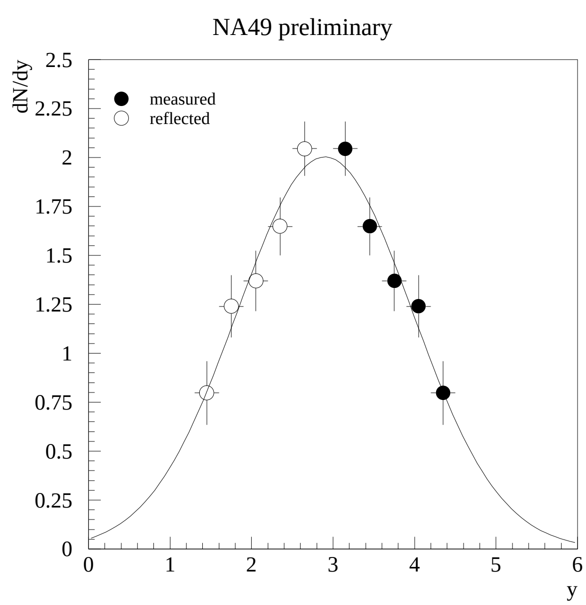
With the higher statistics due to the large acceptance of the TPCs, an m_t-spectrum can be obtained near mid-rapidity. As shown in figure 6(a), the spectrum can be described by an exponential law with an inverse slope parameter $T = 291 \pm 40$ MeV. Extracting the ϕ signal from the mass distributions in successive rapidity slices and applying an acceptance correction based on the experimentally determined inverse slope parameter then yields the rapidity distribution shown in figure 6(b). It can well be described by a Gaussian with a σ_y of 1.07, giving dN/d$y = 2.0 \pm 0.3$ at mid-rapidity and a total yield of 5.4 ± 0.7 per event.

5. Summary

The comparison between the TOF and the dE/dx results shows that there are still some uncertainties in the data. Taking the average of both results, we estimate the mid-rapidity ϕ yield to be dN/d$y = 1.85 \pm 0.3$ per event and the total multiplicity to be 5.0 ± 0.7 per event.



(a)



(b)

Figure 6. (a) m_t-spectrum for ϕ in the rapidity range $3.0 \leqslant y \leqslant 3.75$ from $\mathrm{d}E/\mathrm{d}x$-identified kaons. The full line is an exponential fit with inverse slope parameter $T = 291$ MeV. (b) The ϕ rapidity distribution from $\mathrm{d}E/\mathrm{d}x$-identified kaons. The full circles are measured, the open ones are reflected at mid-rapidity ($y = 2.9$). The full curve is a Gaussian fit with $\sigma_y = 1.07$.

Comparing this result with pp data, obtained by interpolating measurements in this energy region [6–10], one finds a ratio of 340 ± 100 between Pb + Pb and pp collisions.

A large part of the considerable error of this value is due to the uncertainty in the pp data. Hence, our preliminary NA49 ϕ data lie slightly above the proportionality line to the number of participating nucleons and below the enhancement observed for kaons [11, 12], but are consistent with both.

An error in the data analysis was discovered after the conference. The corrected values are quoted here. They differ slightly from those presented in the talk.

Acknowledgments

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References

[1] Shor A 1985 *Phys. Rev. Lett.* **54** 1122
[2] Hatsuda T and Shiomi H 1995 *Nucl. Phys.* A **590** 545c
[3] Wang Y *et al* 1994 *Nucl. Phys.* A **566** 379c
[4] 1996 *Phys. Rev.* D **54** 1
[5] Drijard D and Fischer H G 1984 *Nucl. Instrum. Methods* **225** 367
[6] Blobel V *et al* 1975 *Phys. Lett.* **59B** 88
[7] Anderson K J *et al* 1976 *Phys. Rev. Lett.* **37** 799
[8] Daum C *et al* 1981 *Nucl. Phys.* B **186** 205
[9] Drijard D *et al* 1981 *Z. Phys.* C **9** 293
[10] Aguilar-Benitez M *et al* 1991 *Z. Phys.* C **50** 405
[11] Alber T *et al* 1994 *Z. Phys.* C **64** 195
[12] Afanasiev S *et al* 1996 *Nucl. Phys.* A **610** 188c