Studying the onset of deconfinement at NA61/SHINE

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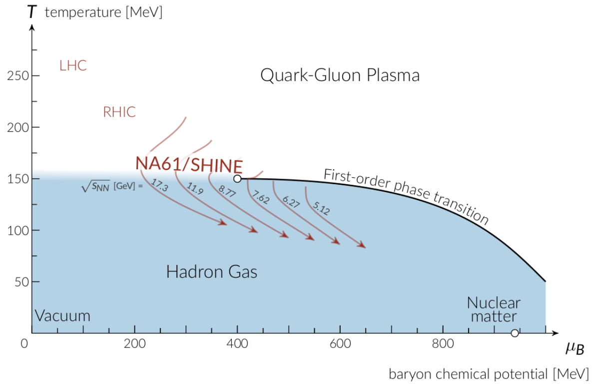
Outline

- Phase diagram of QCD
- Strangeness production in heavy ion collision
- Detector overview
- Spectra of charged hadrons
- System size dependence of K^+/π^+

Phase transition of strongly interacting matter



Under extreme conditions, confined hadronic matter undergoes a phase transition to a deconfined state of quarks and gluons.

Strangeness as a probe of deconfinement

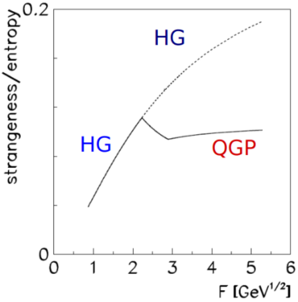
- Strangeness produced in the heavy ion collisions is used to study the deconfinement of matter.
- It is sensitive to the state of matter created in the fireball.

Confined Matter	Phase transition	Deconfined Matter
K mesons	$\rightarrow$	(anti-)strange quarks
$g_K = 4$	$T_c \approx 150$ MeV	$g_s = 12$
$2M \approx 2 \times 500$ MeV		$2m \approx 2 \times 100$ MeV

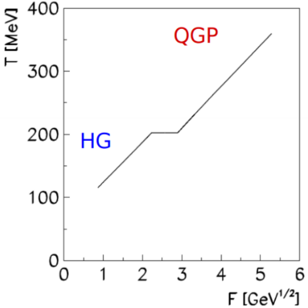
- Kaons are the lightest strangeness carrier in the confined phase with $M > T_c$.
- In the deconfined phase, (anti-)strange quarks are the strangeness carrier with $m < T_c$.

Strangeness in Statistical Model of Early Stage

As predicted in: Gazdzicki, Gorenstein; Acta Phys.Polon.B 30 (1999) 2705



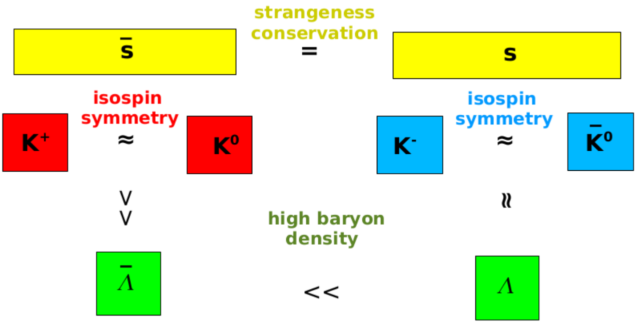
sharp peak (Horn) in strangeness to entropy ratio at phase transition in dependence of collision energy.



plateau (Step) in temperature of the system at phase transition in dependence of collision energy.

$$F \approx (s_{NN})^{1/4}$$

main strangeness carriers

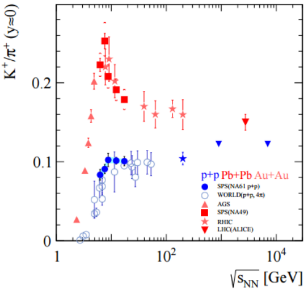


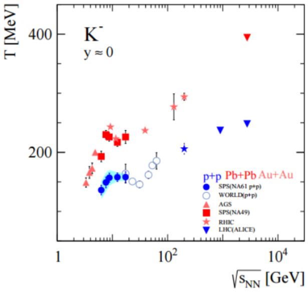
sensitive to strangeness content only

sensitive to strangeness content and baryon density

Gazdzicki, Gorenstein and Seyboth; Acta Phys. Polon., vol. B42, pp. 307–351, 2011

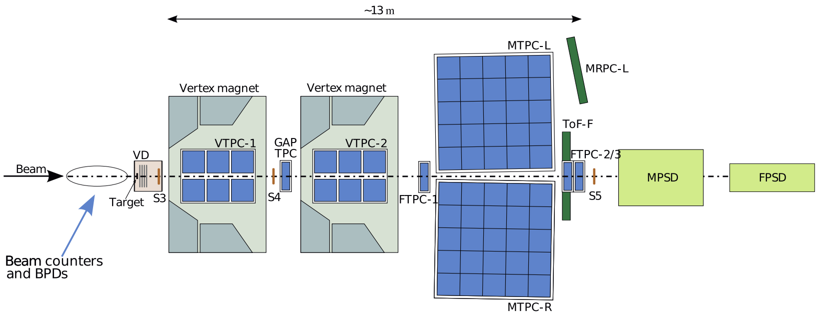
Step and Horn in collision energy dependence



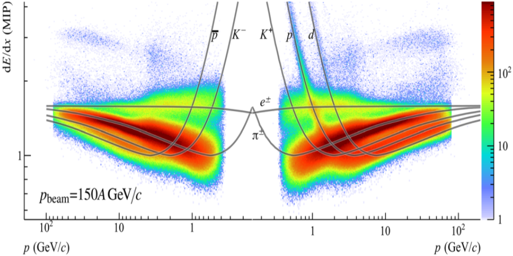


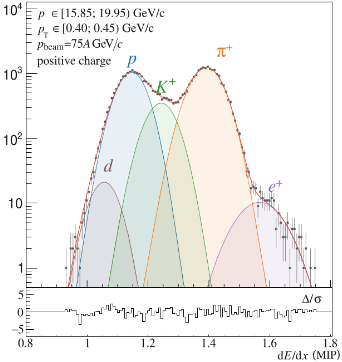
- A sharp peak in K^+/π^+ was observed in NA49 and STAR in Pb+Pb and Au+Au respectively. A plateau in inverse slope parameter of the transverse momentum spectra.
- One of the main motivation of NA61 is the study of system size dependence of K^+/π^+ and verify the NA49 and STAR results.

NA61/SHINE detector overview



- Beam counters and Beam Position Detectors (BPDs)
- 8 Time Projection Chambers (TPCs)
- Time-of-Flight detectors (ToF)
- Projectile Spectator Detectors (PSDs)
- Ion beams (Be, Ar, Xe, Pb) at 13A-150A GeV/c

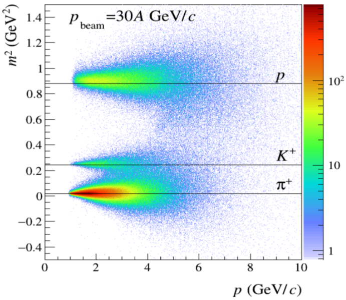


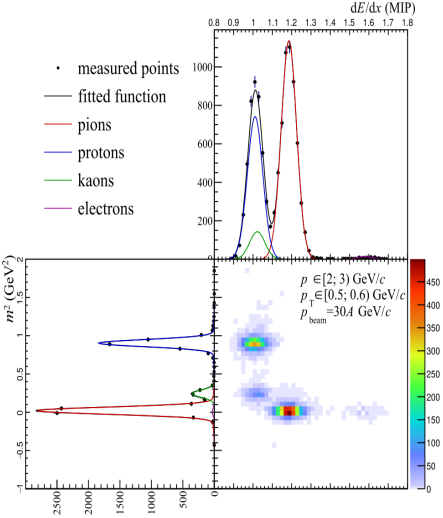


dE/dx analysis uses energy loss information of charged π, K, p in TPCs to identify particles. The curves calculated using the Bethe-Bloch function show the expected dependence of the mean dE/dx on momentum for the particle.

Identification of charged particles (*tof-dE/dx* method)

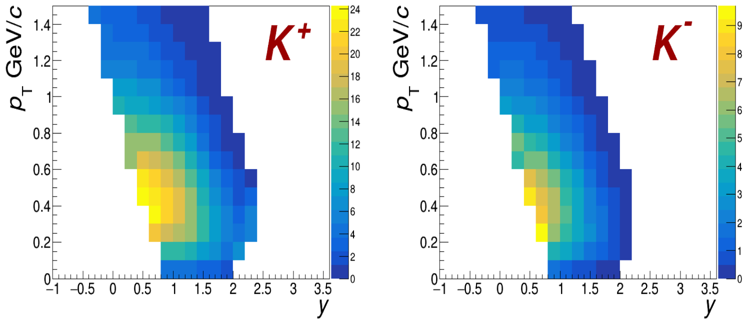
Estimates the number of low momenta (0.5-10 GeV/*c*) charged π, K, p in mid-rapidity region using an energy loss and a particle time of flight measurements.





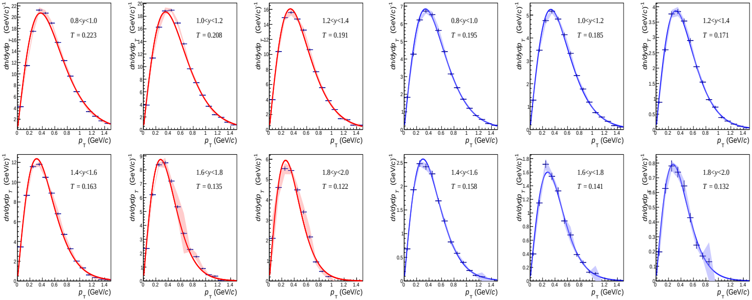
Preliminary results of K^+, K^- and π^- in Pb+Pb at 30A GeV/c

2D spectra of identified charged kaons (dE/dx)



The y vs p_T spectra of identified $K^{\pm}$ in Pb+Pb 30A GeV/c are corrected for detector geometrical acceptance and reconstruction efficiency as well as weak decays and secondary interactions using EPOS.

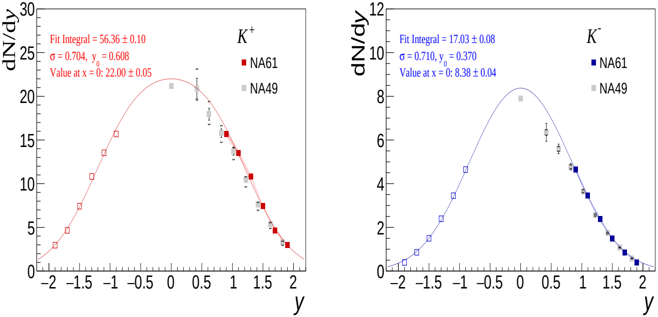
$d^2n/dydp_T$ distributions of charged kaons



$$\text{Fit function}: \ \frac{d^2n}{dydp_T} = A \cdot p_T \cdot exp\left[\frac{-(m_T - m_K)}{T}\right]$$

m_K, m_T are mass and transverse mass of kaon, respectively. $d^2n/dydp_T$ is integrated up to p_T 1.5 GeV/c and added with the integral of extrapolation of fit function in selected rapidity intervals to get the dn/dy.

Rapidity spectra of K^+ and K^-

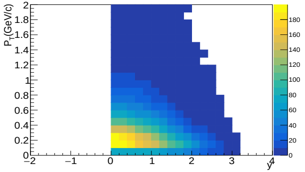


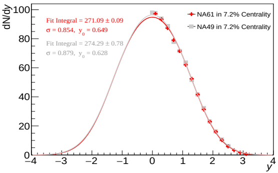
Double Gaussian fit function:

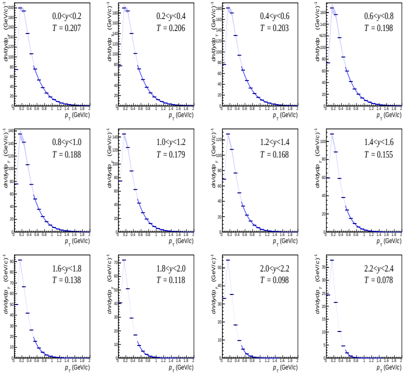
$$P(y) = \frac{A}{\sigma\sqrt{2\pi}}\left[exp\left(\frac{-(y-y_0)^2}{2\sigma^2}\right) + exp\left(\frac{-(y+y_0)^2}{2\sigma^2}\right)\right]$$

The fit parameters σ, y_0 are taken from NA49, Pb+Pb 30A GeV/c.
Mean kaon multiplicity is measured by extrapolation of the fitted.

π^- spectra from h^- analysis

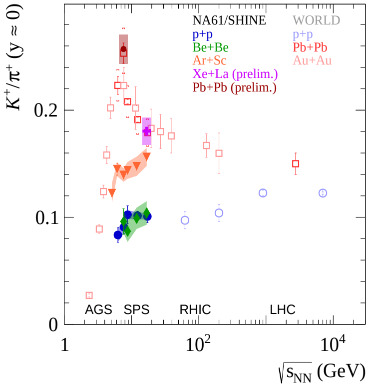


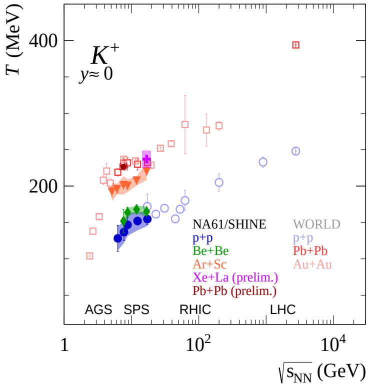




About 90% of all negatively charged produced hadrons are π^-. Particles like K^-, $\bar{p}$, ... can be reliably subtracted using the EPOS model.
The h^- analysis was done by Ali Bazgir.

Horn and step plots





The multiplicity and inverse slope parameter of K^+ at mid rapidity is obtained by extrapolation of fitting functions. The π^+ is obtained by π^+/π^- which was measured by NA49.

Summary

- New spectra on identified K^- and K^+, and π^- from $^-$ analysis in central Pb+Pb interactions ant 30A GeV/c are presented.
- Na61 results in Pb+Pb 30A GeV/c are in agreement with NA49 and STAR data.
- The K^+/π^+ in Pb+Pb 30A GeV/c measured in NA61/SHINE agrees with NA49 and STAR data.

Thank you for your attention

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Backup slides

Identity method for PID

- The peaks of *dE/dx* distribution for different tracks overlap and, therefore do not allow for unique identification.
- Each track has unique p, p_T and *dE/dx* which can be assigned to a probability of a track.

$$P_i^{p,p_T}(dE/dx) = \frac{\rho_i^{p,p_T}(dE/dx)}{\sum_i \rho_i^{p,p_T}(dE/dx)}$$

- $\rho_i^{p,p_T}(dE/dx)$ is the fitted *dE/dx* of the particle in a specific p, p_T bin.
- Multiplicities of identified particles at a given bin can be calculated,

$$n_i = \sum_i^m P_i \qquad i = \pi^\pm, K^\pm, p, \bar{p}, e^\pm, d$$