News on identified hadron production from NA61/SHINE

Syed Uzair Ahmed Shah
for NA61/SHINE Collaboration

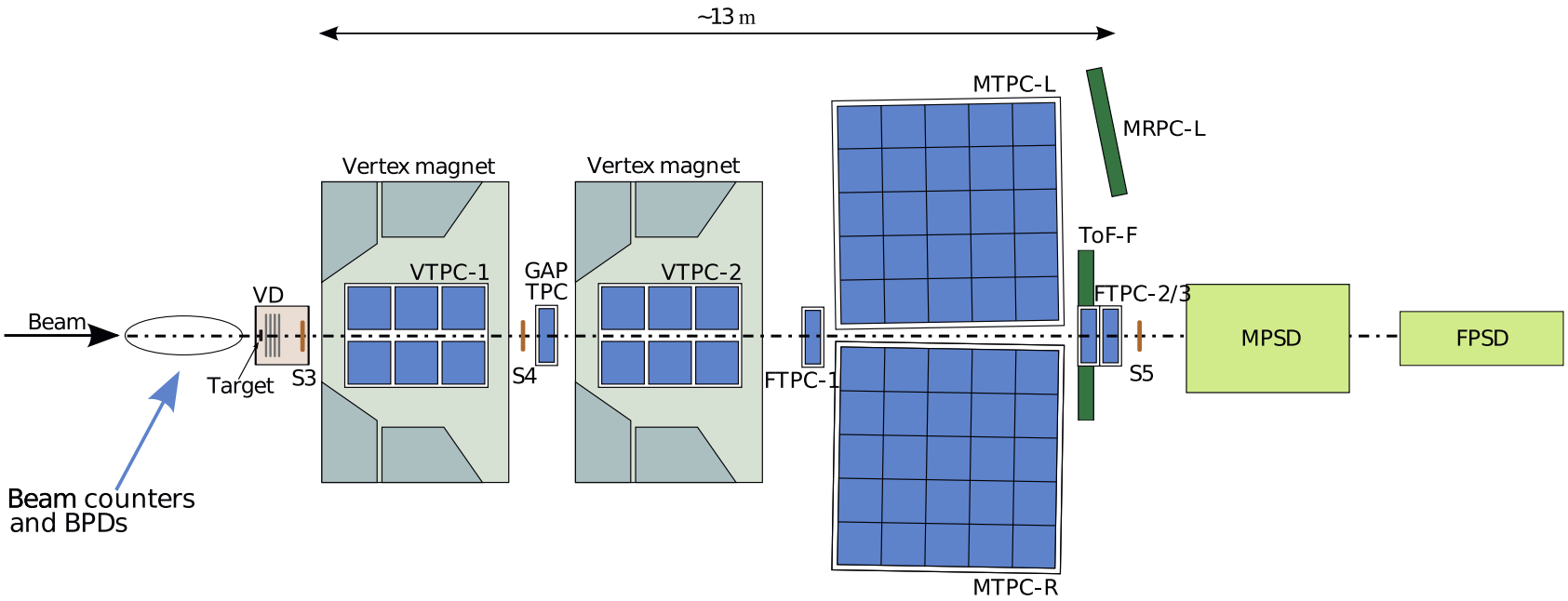
Jan Kochanowski University in Kielce, Poland

New Trends in High-Energy and Low-x Physics, Sep 5, 2024

Outline

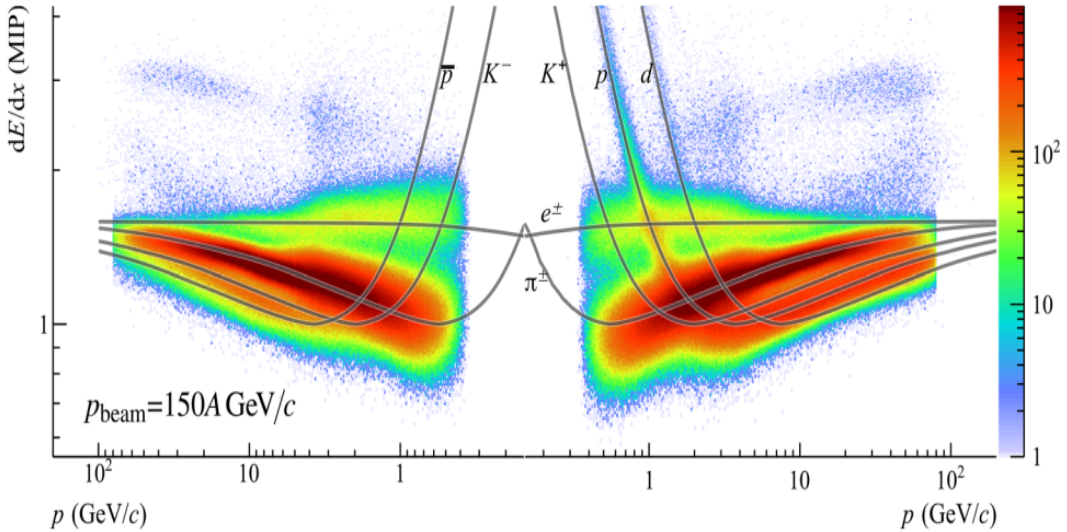
- Charged hadrons identification at NA61/SHINE
- K^0_S measurement
- Excess of charged over natural kaons
- $K^*(892)^0$ resonances measurement

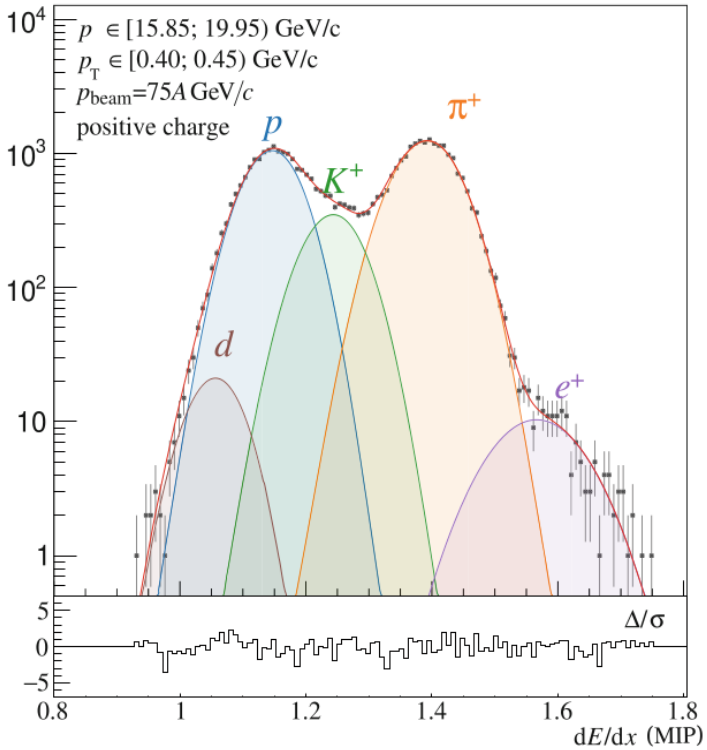
NA61/SHINE detector overview



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

Identification of charged particles (dE/dx method)

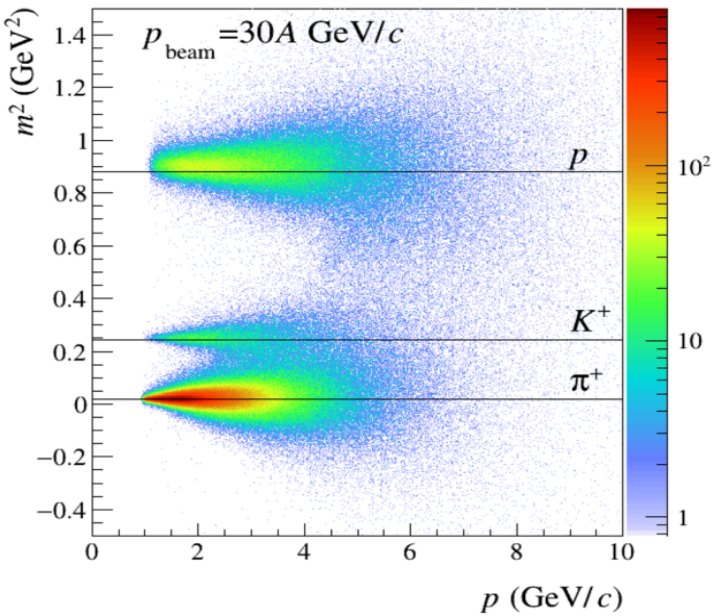


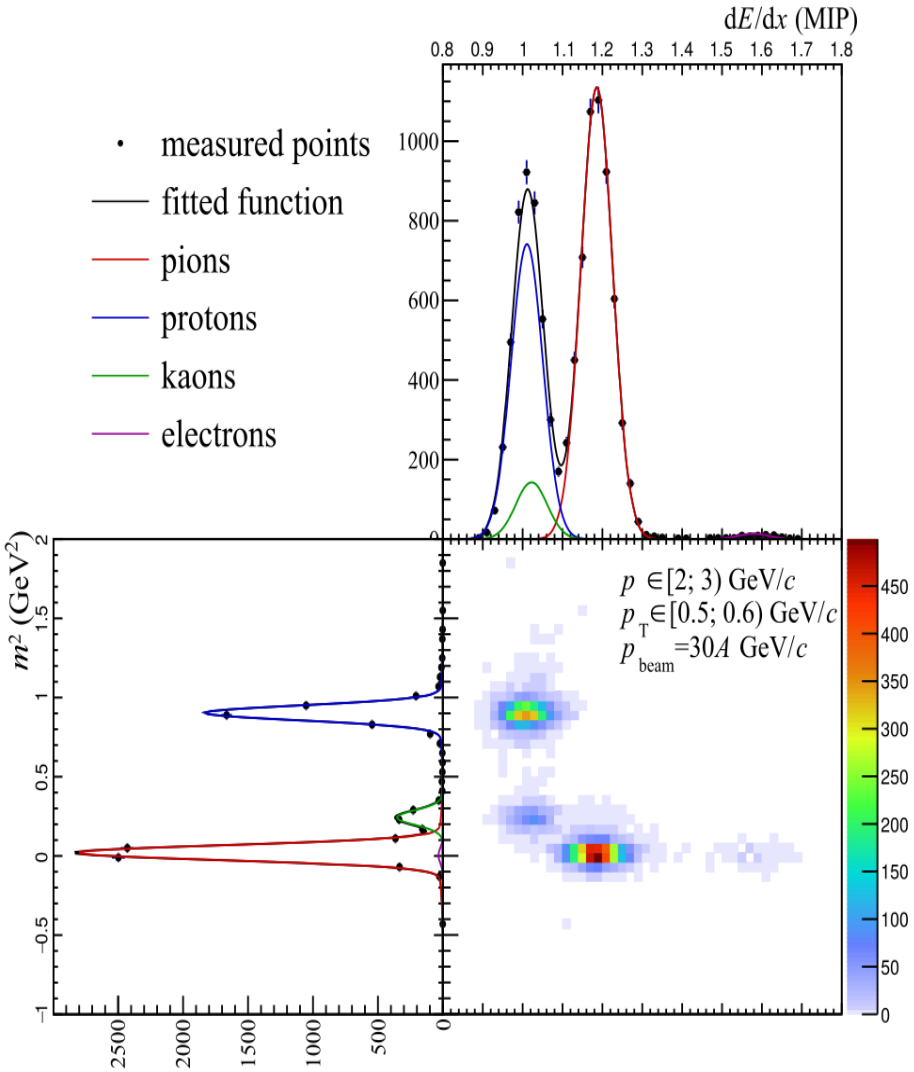


dE/dx analysis uses energy loss information of charged π, K, p in TPCs to identify particles. The curves calculated using the Bethe-Bloch function show the expected dependence of the mean dE/dx on momentum for the particle.

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.





Identity method for PID

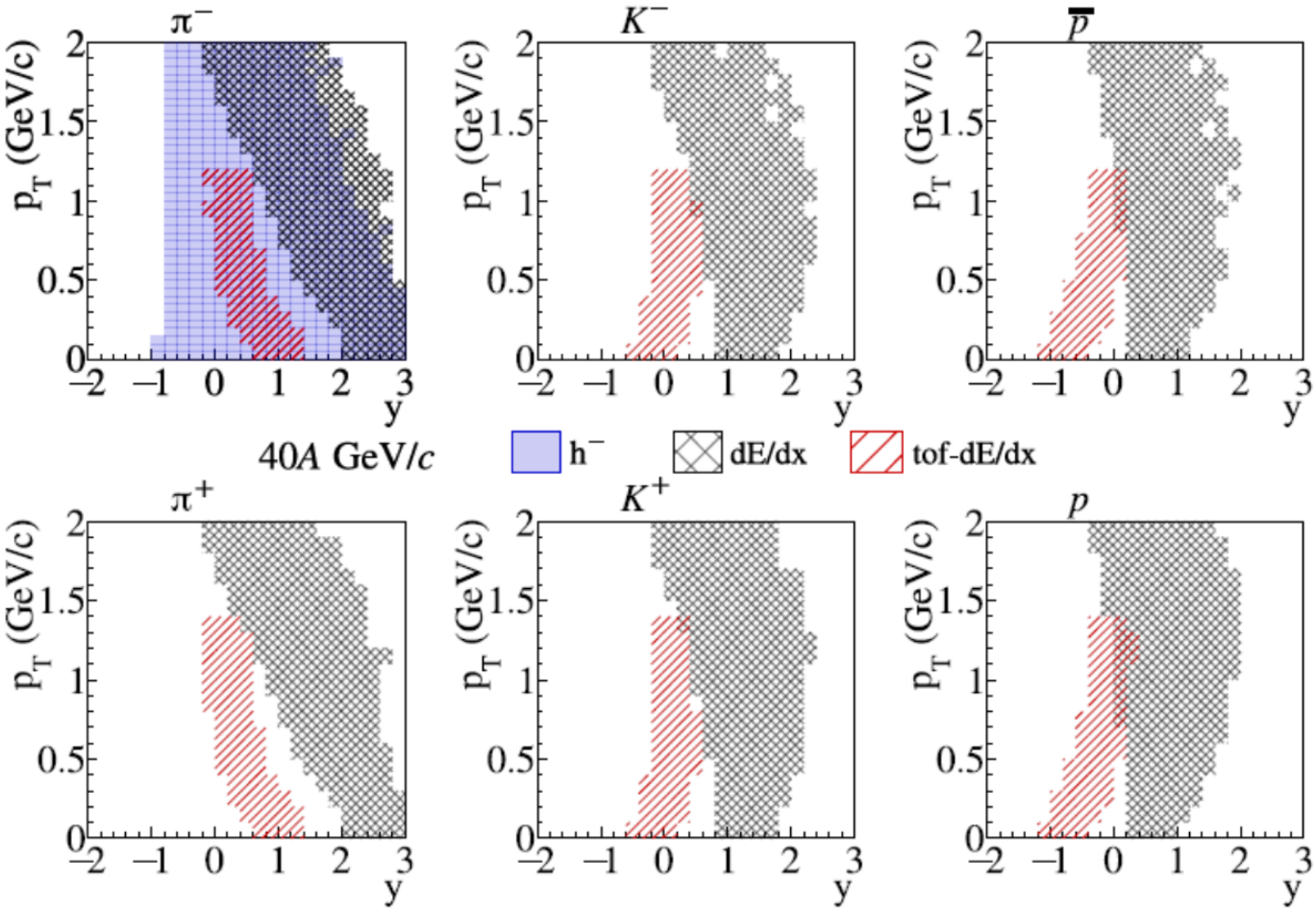
- The peaks of dE/dx distribution for different tracks overlap and, therefore do not allow for unique identification.
- Each track has unique p, p_T and dE/dx which can be assigned to a probability of a track.

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

- $\rho_i^{p,p_T}(dE/dx)$ 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,

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

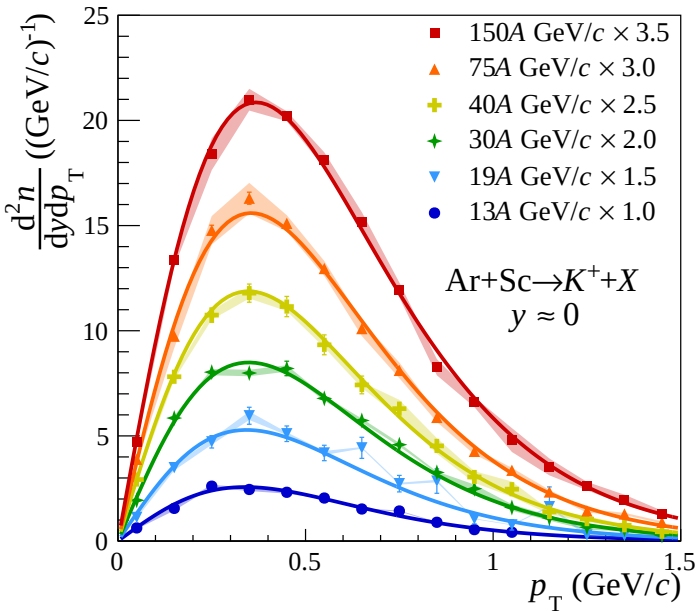
Acceptance of dE/dx and $top - dE/dx$ methods

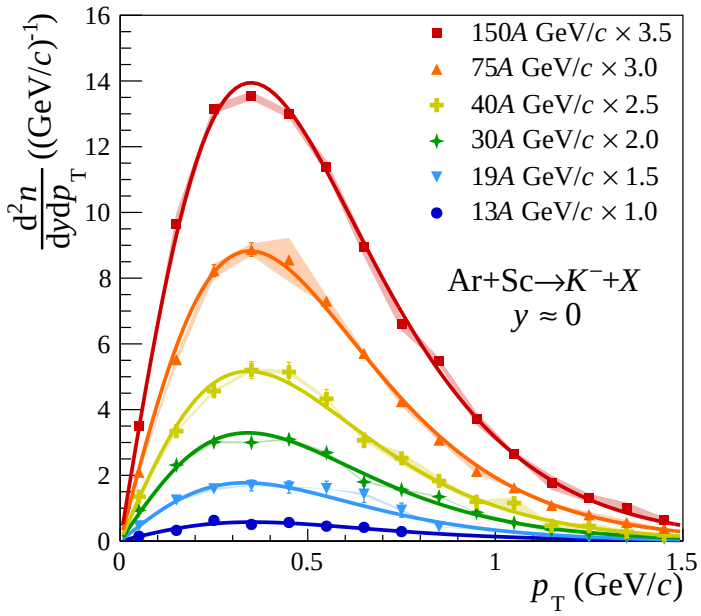


The final spectra of identified primary particles is corrected for detector geometrical acceptance and reconstruction efficiency as well as weak decays and secondary interactions.

Excess of charged over neutral kaons

Charged kaons production in Ar+Sc ($d^2n/dydp_T$)

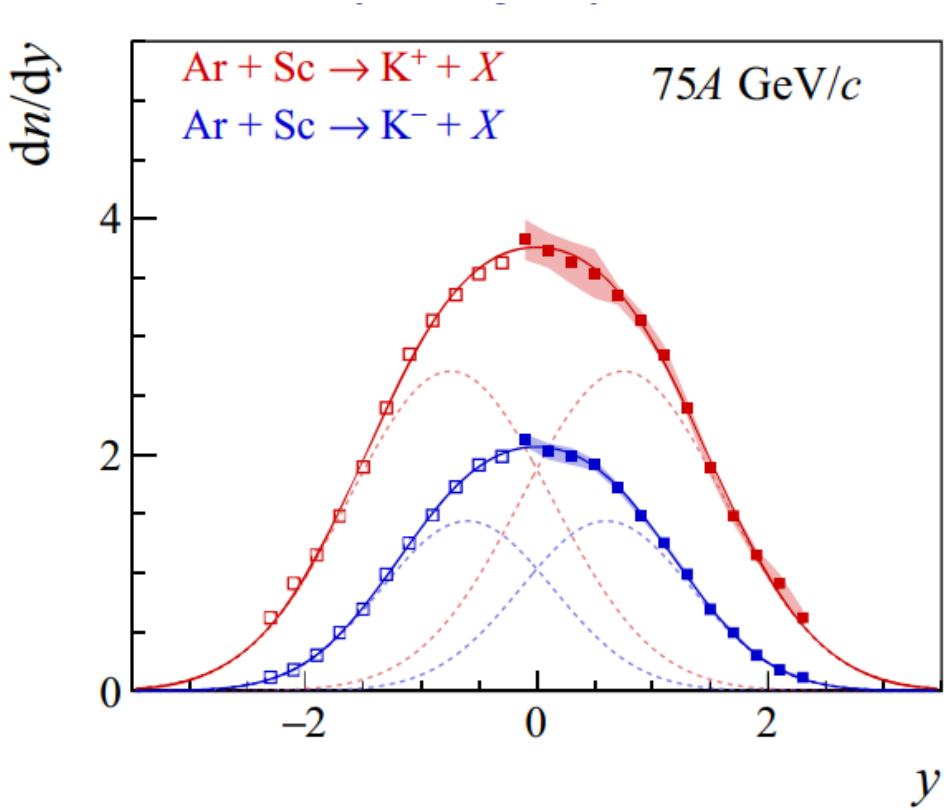




$d^2n/dydp_T$ spectra is fitted exponential function.

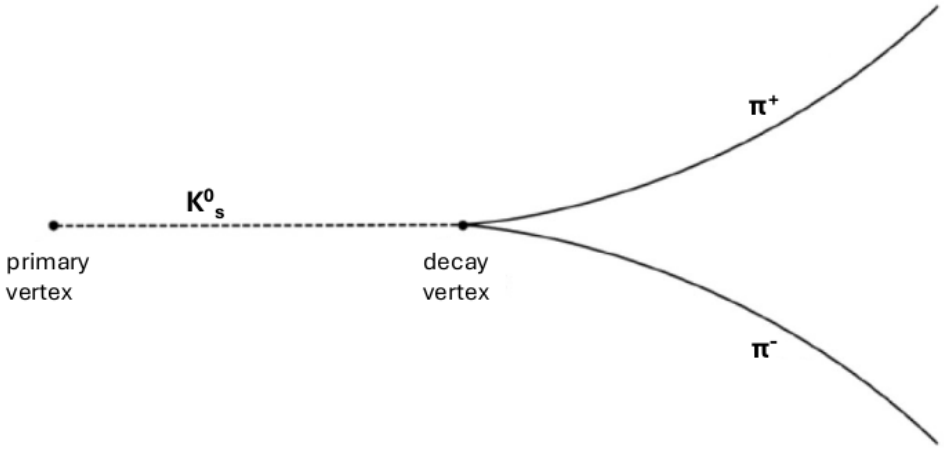
$$\frac{d^2n}{dydp_T} = A \times p_T \times exp\left[\frac{-(m_T - m_K)}{T}\right]$$

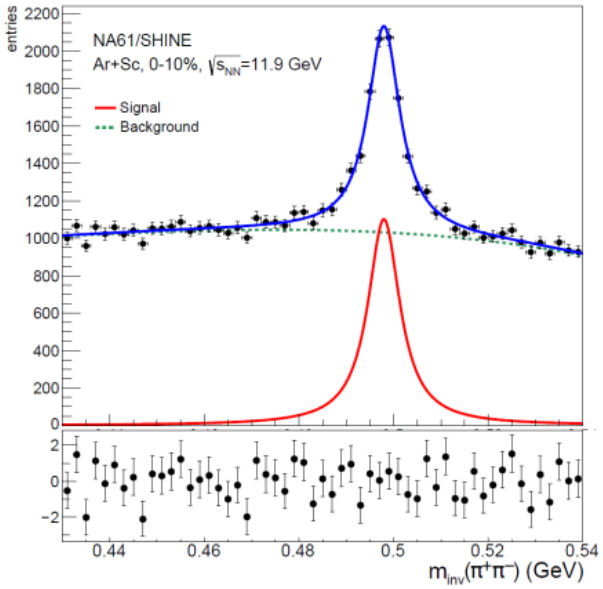
Charged kaons production in Ar+Sc at 75A GeV/c



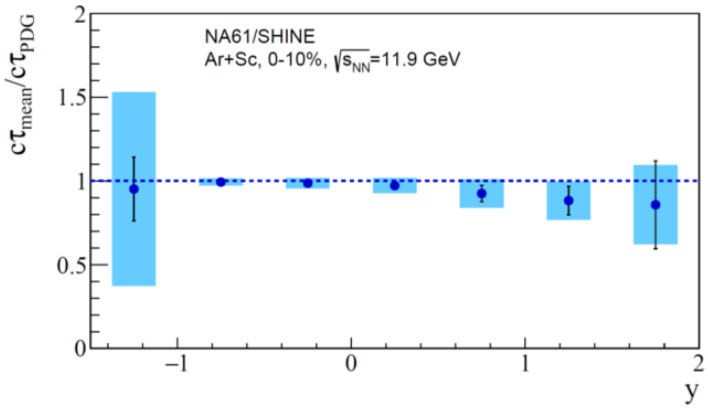
- Rapidity spectra were obtained by integrating the $d^2n/dydp_T$ spectra and extrapolation of fit.
- dn/dy were fitted with double-Gaussian and mean multiplicities were determined by integrating the fit

K^0_S production in Ar+Sc at 75A GeV/c





- Reconstruction based on decay topology
- K^0_S decay into $\pi^+\pi^-$ with BR$\approx$ 69.2%
- Breit-Wigner function used to describe signal and third-order Chebychev polynomial for background



Comparison of K^0_S with charged kaons in Ar+Sc

Ar, Sc nuclei are nearly isospin-symmetric (valence u ≈ d within 6%)
Expected,

$$K^+(u\bar{s}) \approx K^0(d\bar{s})$$

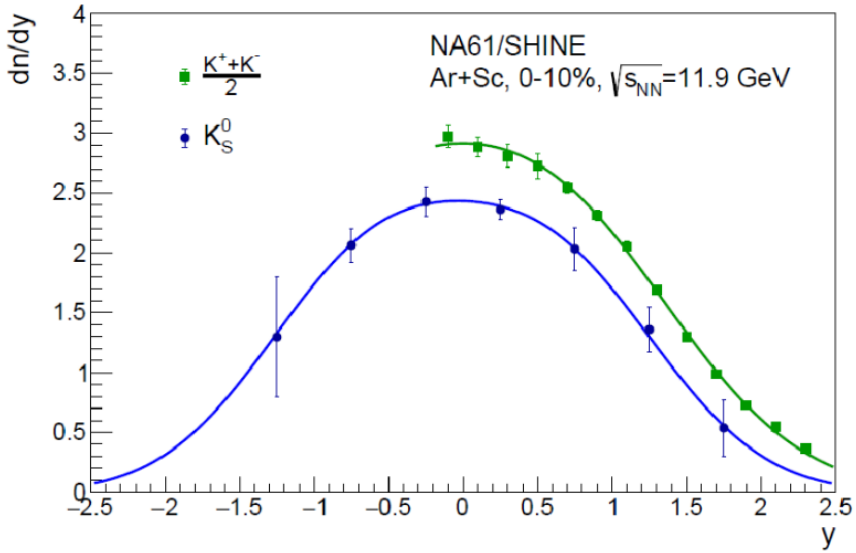
$$K^-(\bar{u}s) \approx \bar{K^0}(\bar{d}s)$$

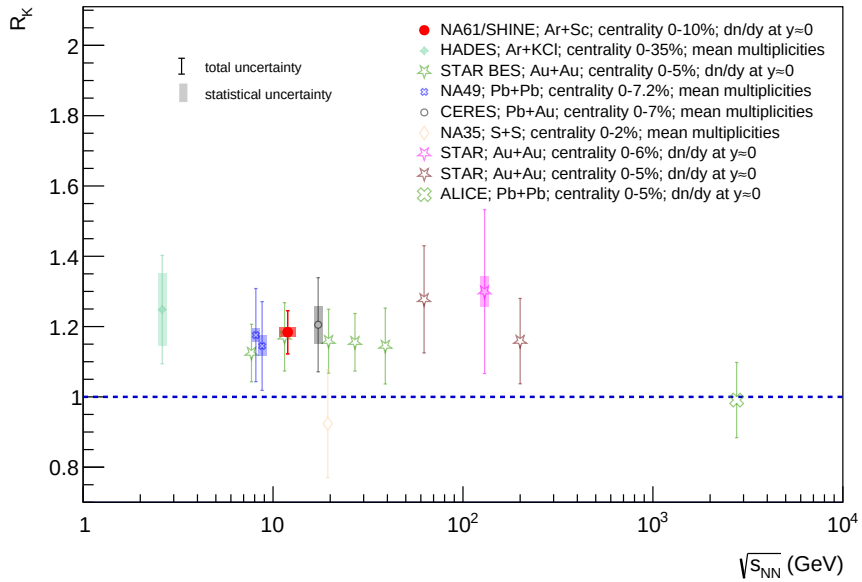
$$\frac{K^+ + K^-}{2} \approx \frac{K^0 + \bar{K^0}}{2} \approx K^0_S$$

Measured,

$$\frac{K^+ + K^-}{2} > K^0_S$$

Unexpected excess of charged K over neutral. R_K significantly higher than 1:
$R_K = 1.184 \pm 0.061$ (tot.)
World data show the excess of charged over neutral kaons.
arxiv.org/pdf/2312.06572





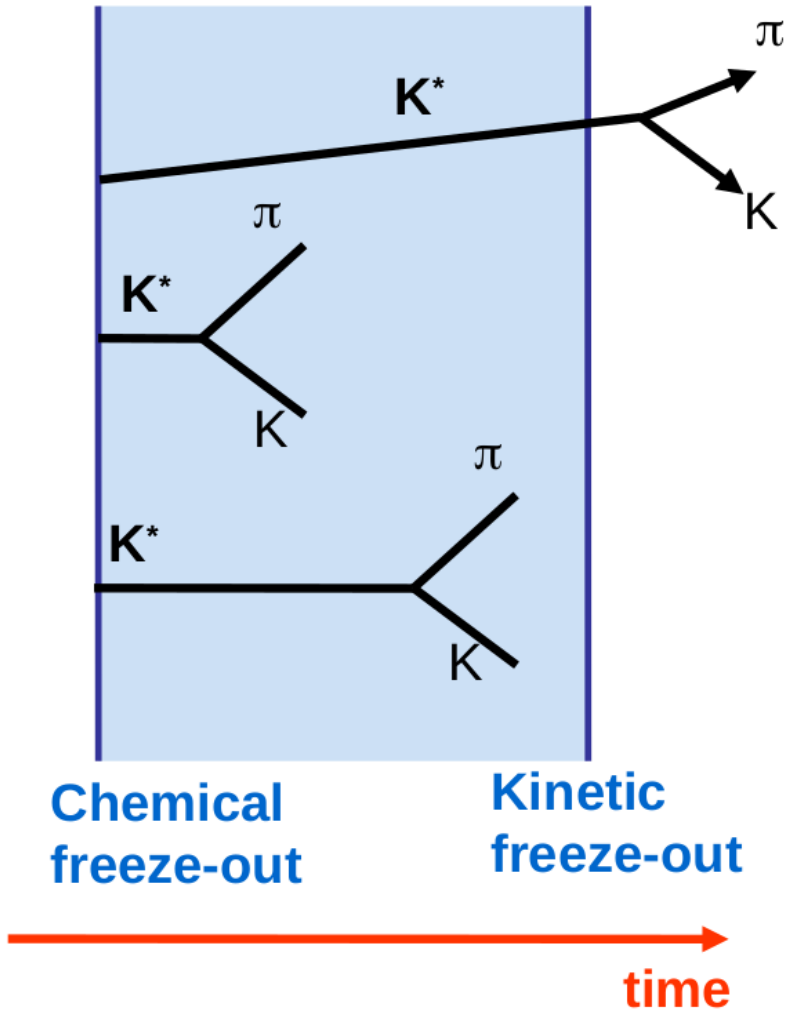
$K^*(892)^0$ resonances

$K^*(892)^0$

- K^* lifetime (≈ 4 fm/c) is comparable with the time between two freeze-outs.
- Some K^* resonances may decay inside the fireball.
- Suppression of K^* observed.
- Assuming no regeneration processes (Fig.) the time Δt between freeze-outs can be determined from :

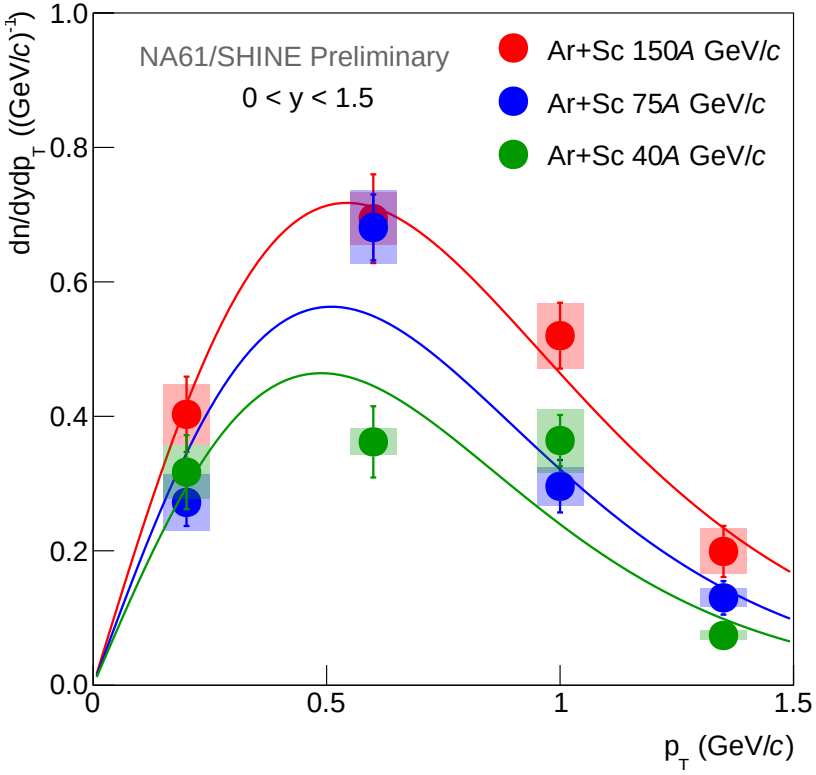
$$\frac{K^*}{K}(kinet) = \frac{K^*}{K}(chem).e^{\frac{\Delta t}{\tau}}$$

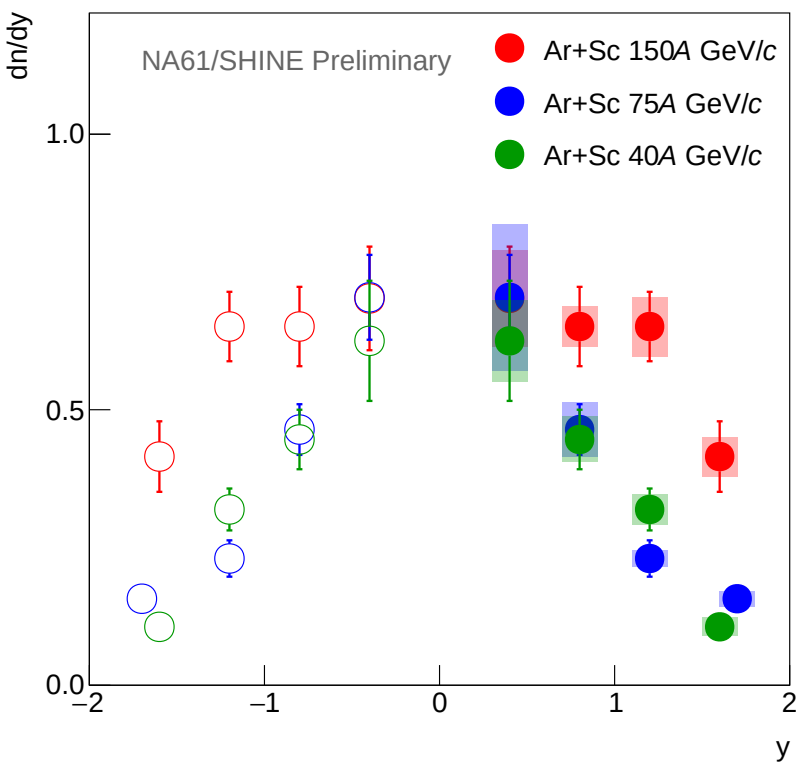
- $\frac{K^*}{K}(kinet)$ in $A + A$,
  $\frac{K^*}{K}(chem)$ in $p + p$.



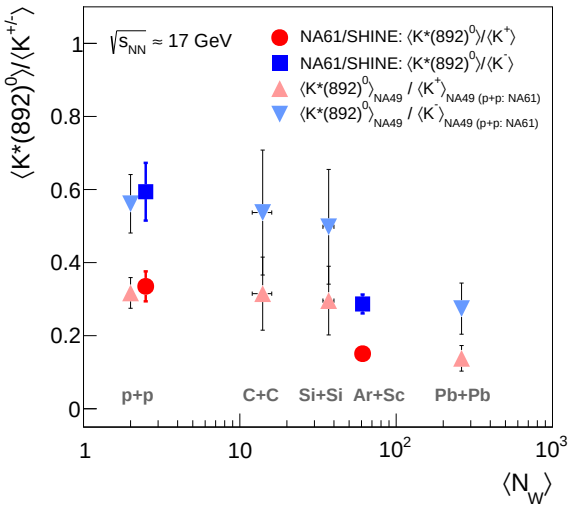
STAR Collaboration, J.Phys.G 35 (2008) 044029, AIP Conf.Proc. 631, 533, 2002

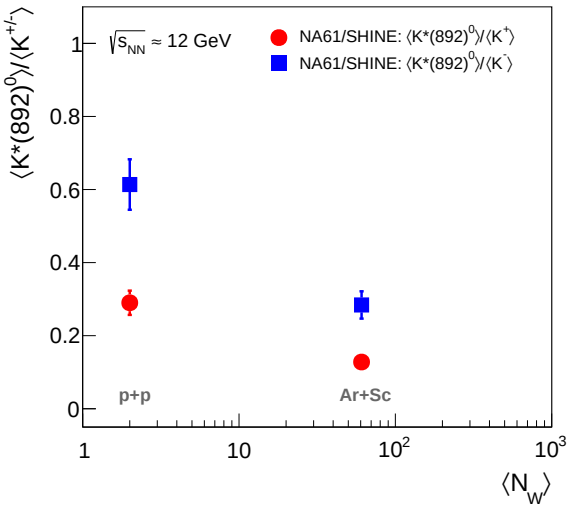
$K^*(892)^0$ spectra

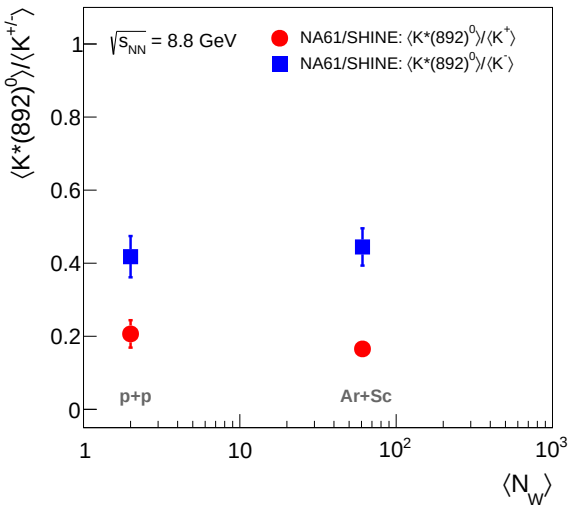




$\langle K^* \rangle / \langle K^{\pm} \rangle$ ratios



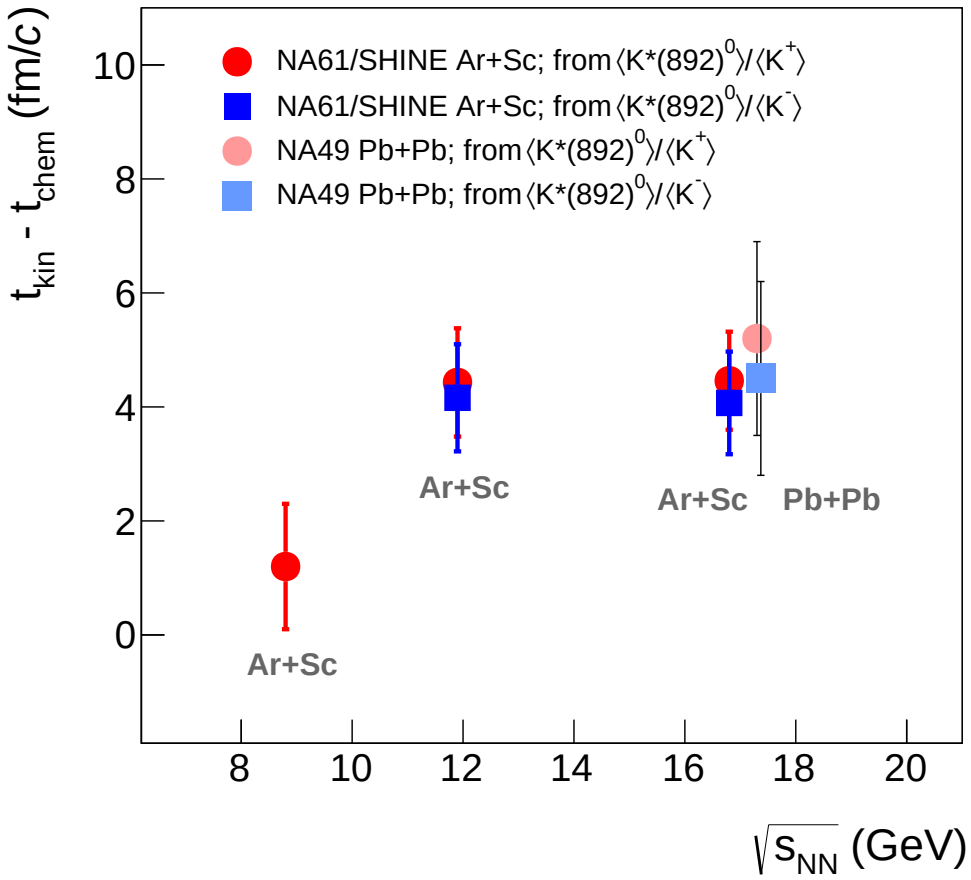




- Suppression of K^* in Ar+Sc at $\sqrt{s_{NN}} \approx 17$ GeV similar to Pb+Pb
- No suppression of K^* observed in Ar+Sc at $\sqrt{s_{NN}} = 8$ GeV

NA49: Phys.Rev.C 84, 064909, Phys.Rev.C 77, 024903, Phys.Rev.Lett. 94, 052301,
NA61 p+p: Eur.Phys.J.C 80, 460,
Ar+Sc: Eur.Phys.J.C 84, 416

Time between freeze-outs



Δt boosted by Lorentz factor $\gamma = \sqrt{1 + (\langle p_T \rangle / m_0 c)^2}$ (ALICE, Phys.Lett.B 802, 135225, 2020)

Summary

- Identification of charged hadrons at NA61/SHINE
- Excess of charged over neutral K meson production in Ar+Sc collisions at 75A GeV/c observed.
- First results on $K^*(892)^0$ production in 0-10% central Ar+Sc collisions at 40A, 75A, and 150A GeV/c are presented
- Estimated times between freeze-outs for Ar+Sc collisions at 150A and 75A GeV/c are similar.

Thank you for your attention

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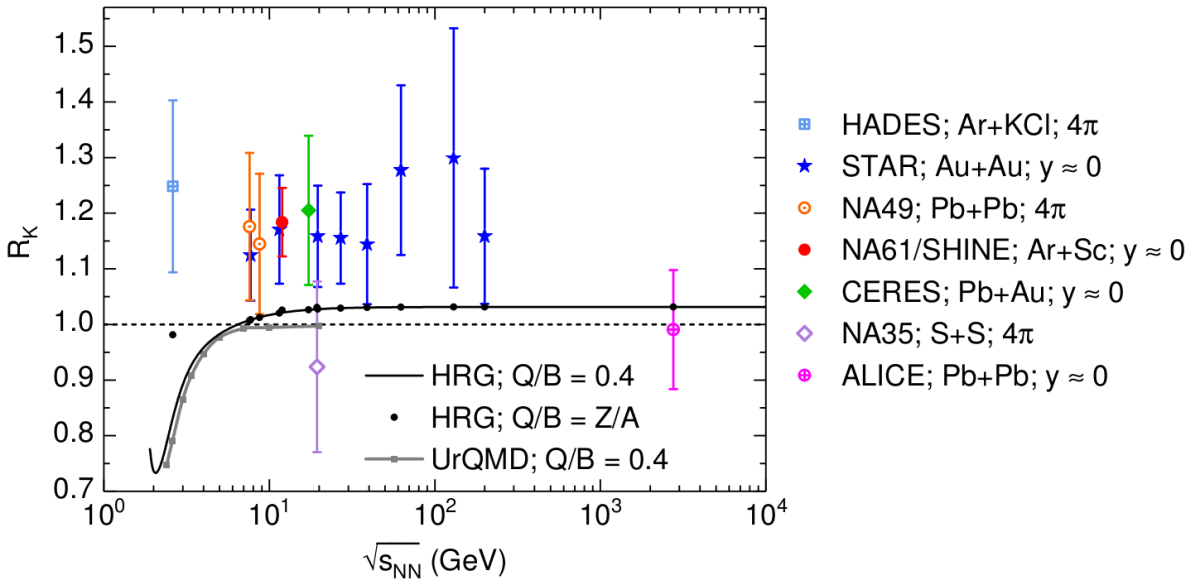
Backup slides

Model comparison of charge to neutral kaon ratio

Comparison with Hadron Resonance Gas (HRG) and UrQMD. Models predictions not equal to unity because known effects,



- small differences between the masses of charged and neutral kaons. $\phi(1020)$ decay slightly more in $K^+ + K^-$ than $K^0_S + K^0_L$ (included in HRG).
- electric charge to baryon number Q/B is taken into account, causing a very increase in the ratio for energy more than 10GeV