First results on spectra of identified hadrons in central Xe+La collisions from NA61/SHINE at CERN SPS

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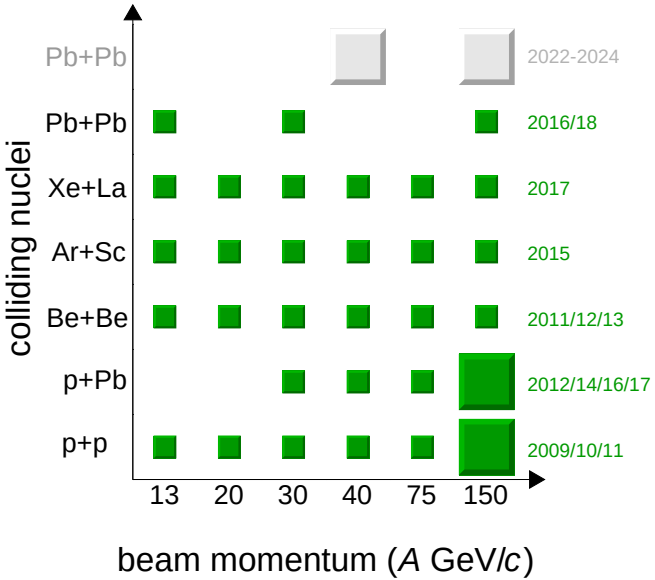
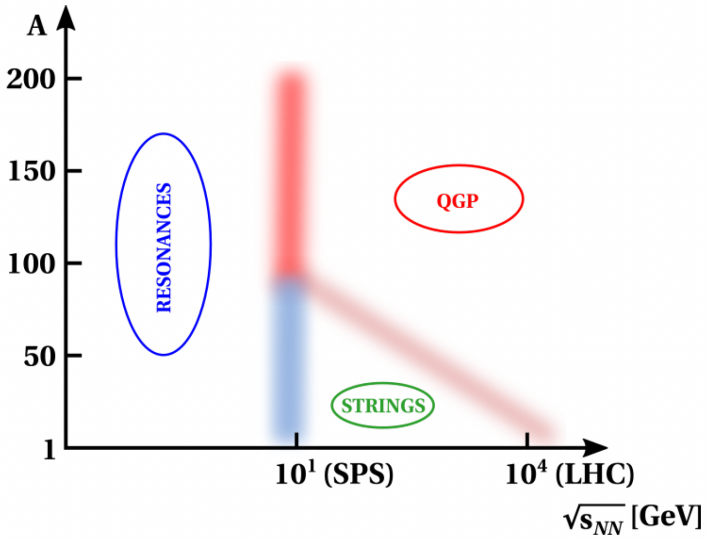
NA61/SHINE Collaboration, CERN

December 3, 2023

NA61/SHINE 2D scan

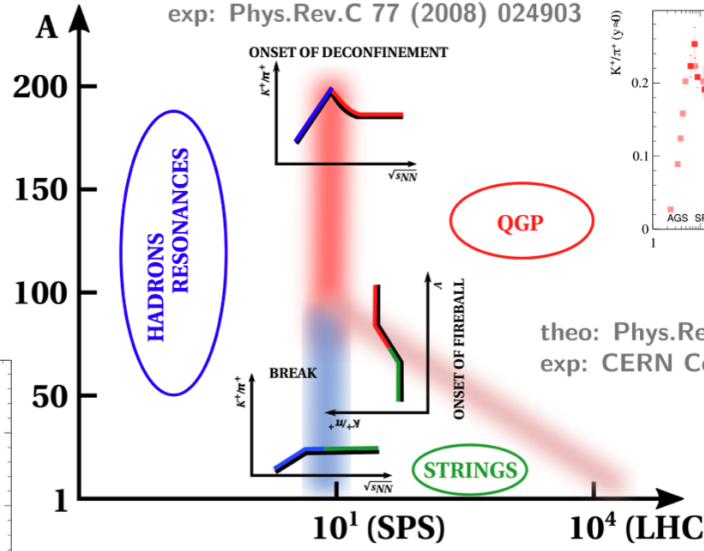


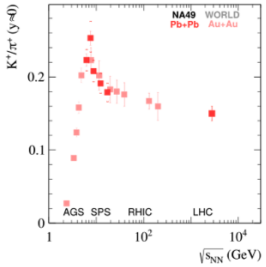


Two-dimensional scan in collision energy and mass of colliding nuclei.

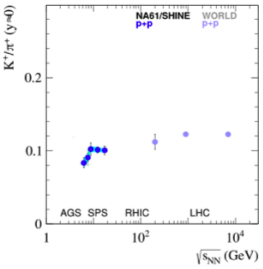
Diagram of high-energy nuclear collisions

theo: Acta Phys.Polon.B 46 (2015) 10, 1991
exp: Phys.Rev.C 77 (2008) 024903

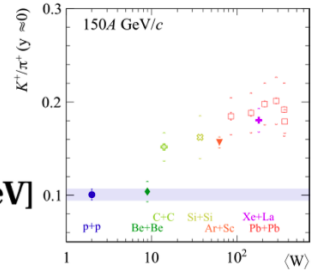




theo: Phys.Part.Nucl. 51 (2020) 3, 337-339
exp: Phys.Rev.C 102 (2020) 011901

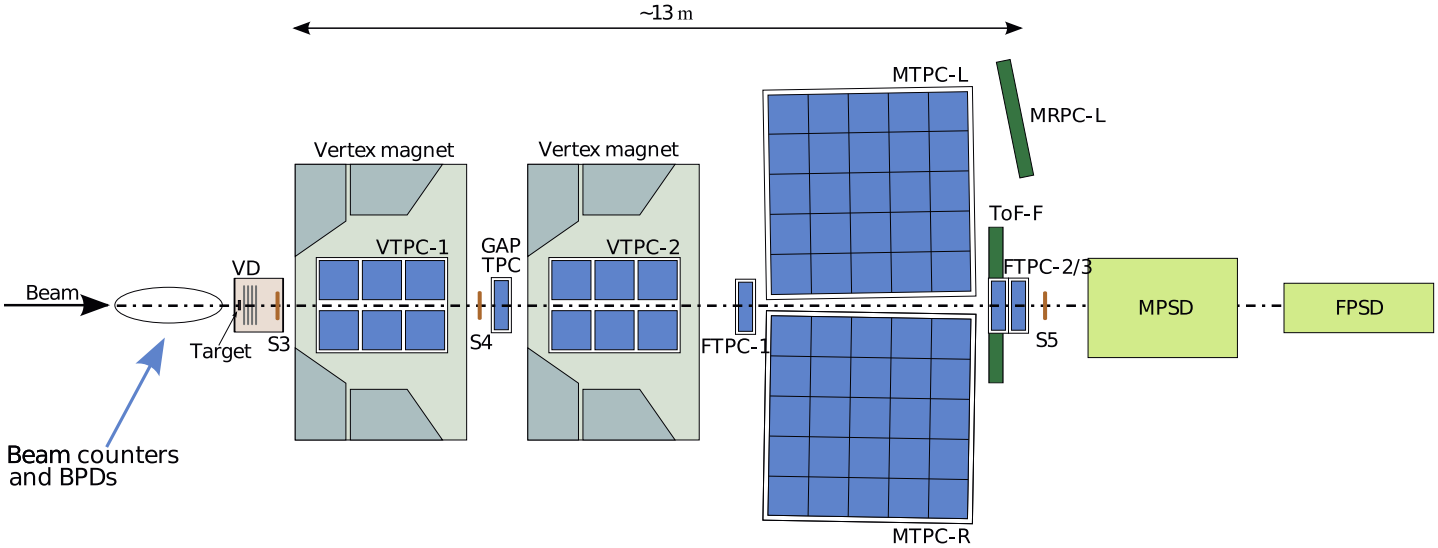


theo: Phys.Rev.D 90 (2014) 025031
exp: CERN Courier, Sep 23rd, 2019



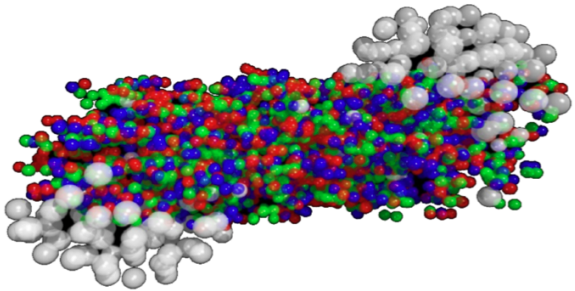
Universe 9 (2023) 2, 106

Layout of the NA61/SHINE experimental setup



Coverage of the full forward hemisphere, down to $p_T = 0$.

Centrality selection



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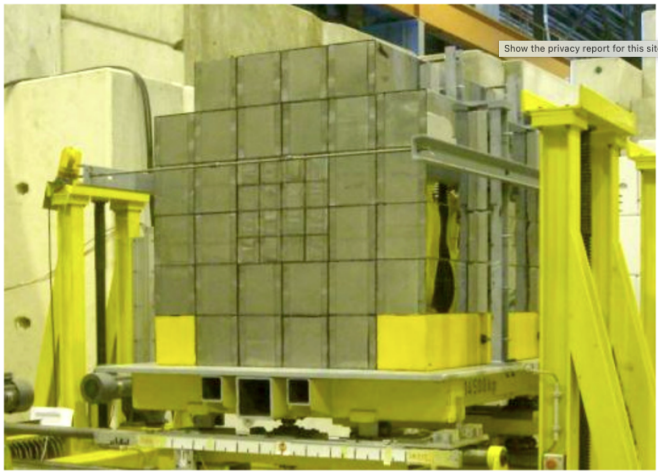
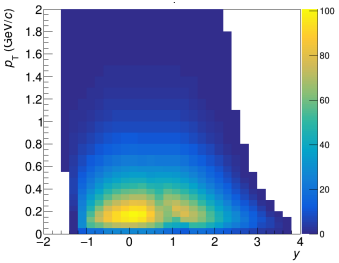


Centrality selection is based on the projectile spectator energy E_F measured by the Projectile Spectator Detector (PSD).
For Xe+La 20% of the most central events are selected as events with $E_F < 6.8$ TeV (total beam energy: 19.4 TeV).

h^- method for π^-

h^- – all negatively charged hadrons (≈90% $\pi^- + K^- + \bar{p} + ...$)

h^- raw spectrum



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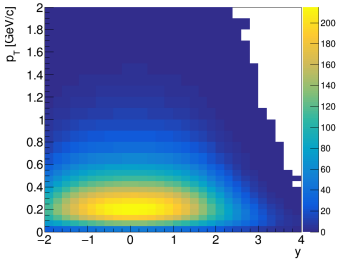
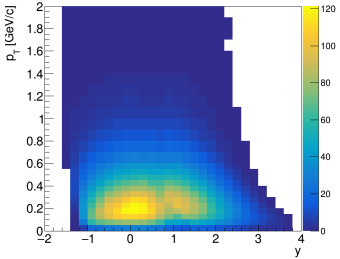
π^- MC generated



h^- MC selected



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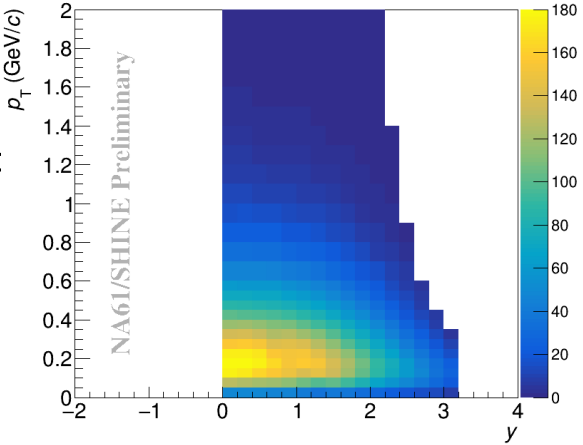
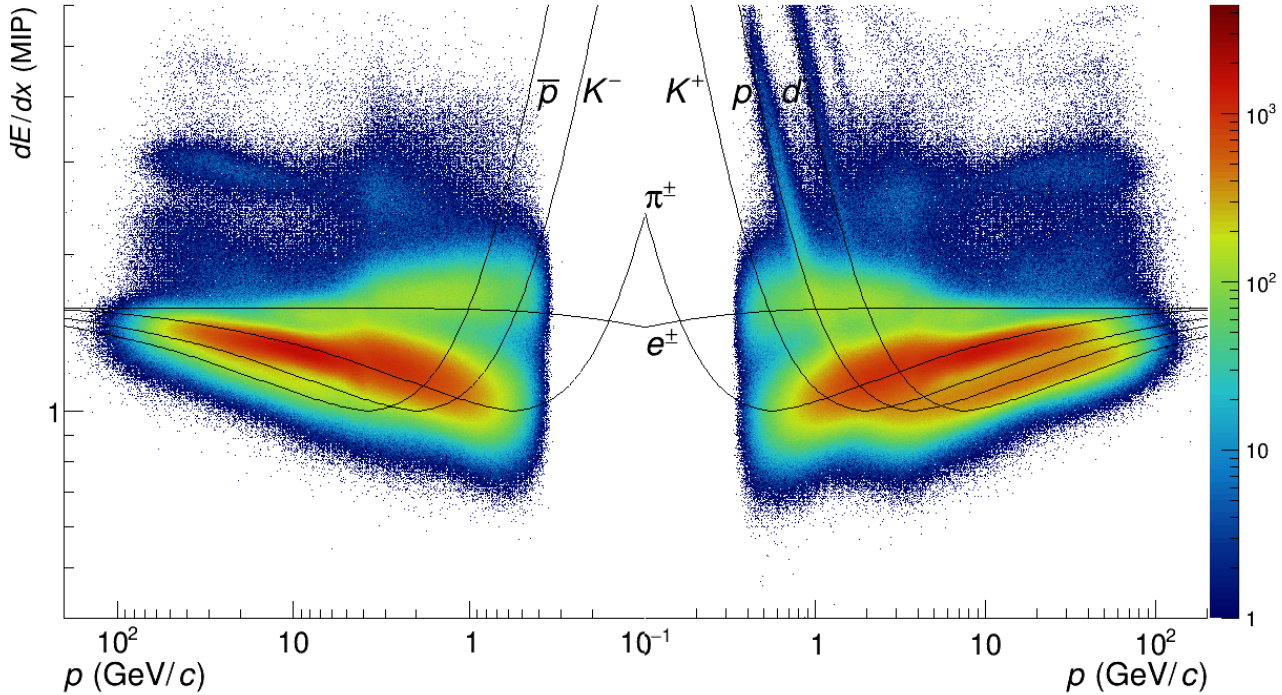
π^- corrected spectrum



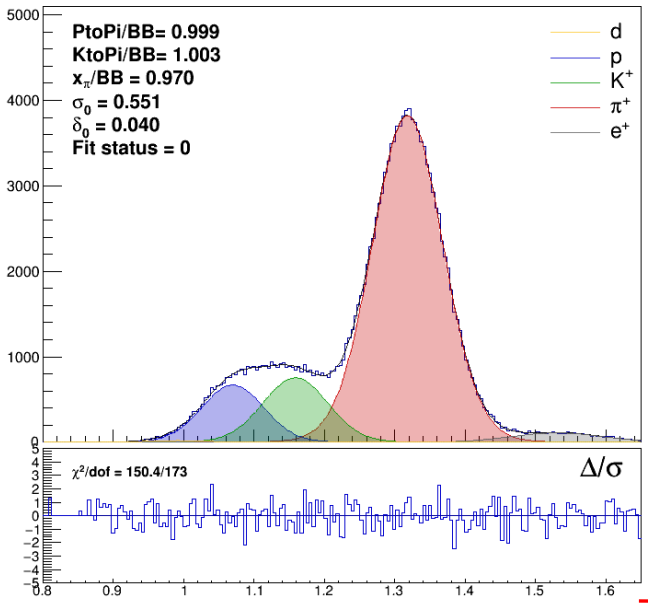
Raw h^- spectrum, MC generated π^- and selected h^- spectra, corrected spectrum of π^- using h^- method for Xe+La at 150A GeV/c.

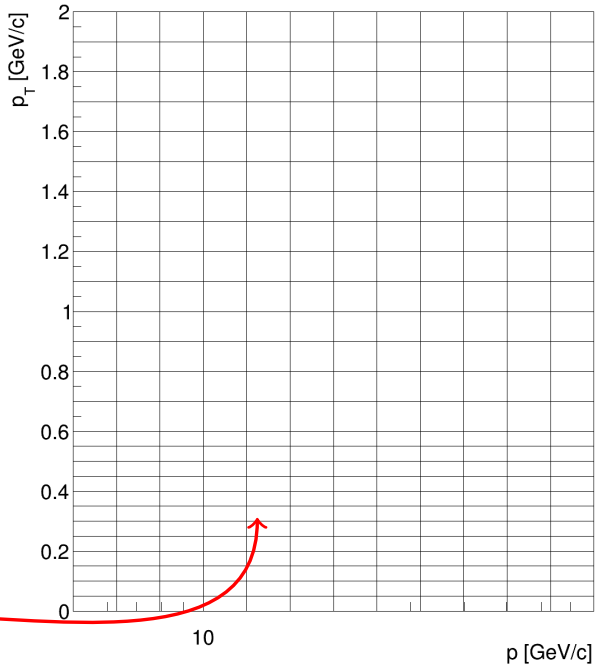
$\mathrm{d}E/\mathrm{d}x$ vs p after all cuts



Bethe: $\left\langle -\frac{\mathrm{d}E}{\mathrm{d}x} \right\rangle = \frac{A}{\beta^2} \left[\ln B\beta^2\gamma^2 - 2\beta^2 - \delta(\beta\gamma) \right], \ (0.1 \leq \beta\gamma \leq 1000)$

Fitting



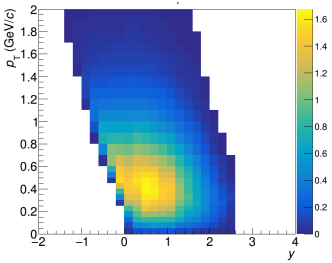


Fit with sum of asymmetric Gaussians for $p, \bar{p}, K^{\pm}, \pi^{\pm}, e^{\pm}, d$:

$$f(x) = \sum_{i=p,K,\pi,e,d} N_i \frac{1}{\sum_l n_l} \sum_l \frac{n_l}{\sqrt{2\pi}\sigma_{i,l}} \exp\left[-\frac{1}{2}\left(\frac{x - x'_i}{(1 \pm \delta)\sigma_{i,l}}\right)^2\right]$$

MC corrections for dE/dx method for K^-

K^- raw spectrum



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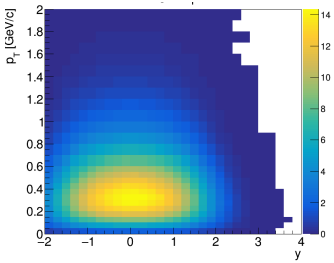
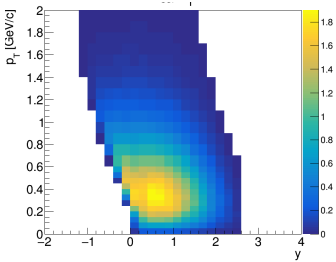
K^- MC generated

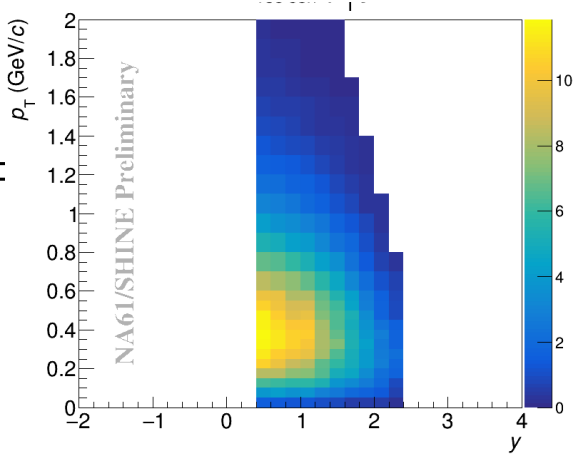


K^- MC selected



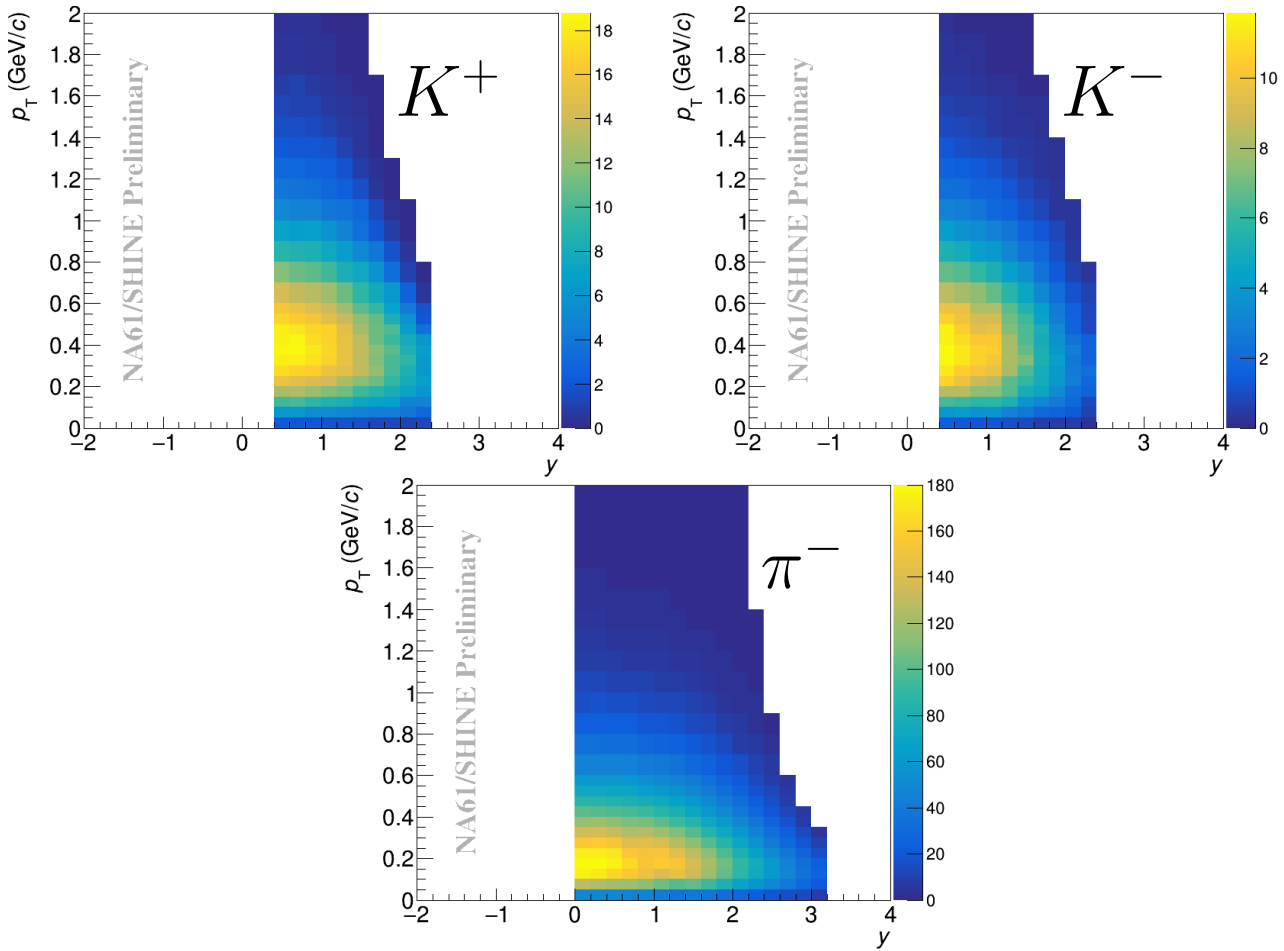
$=$

K^- corrected spectrum

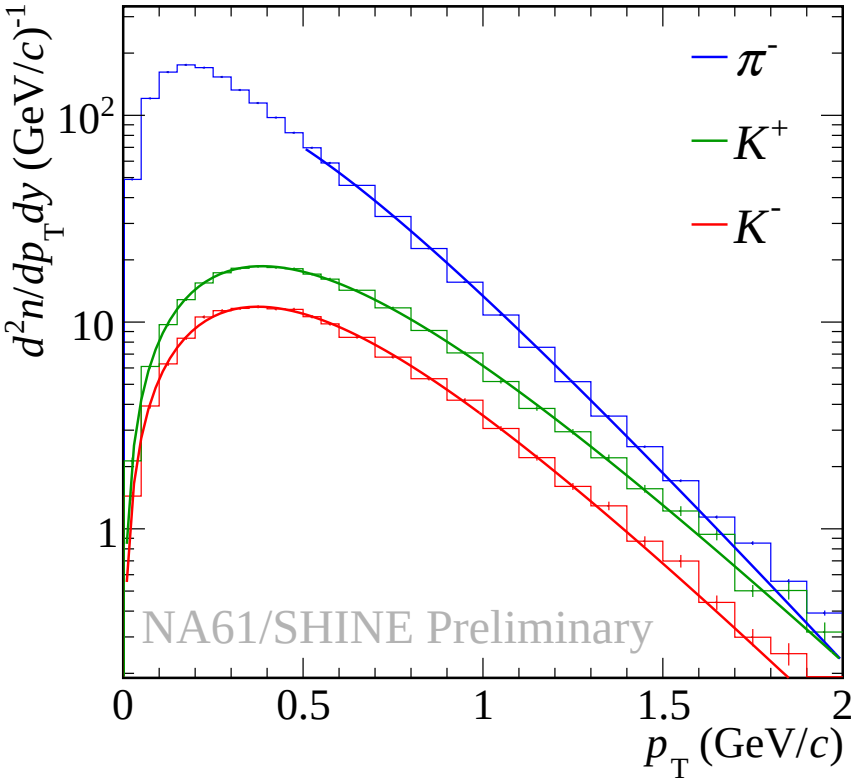


Raw K^- spectrum, MC generated and selected K^- spectra, corrected spectrum of K^- using dE/dx method for Xe+La at 150A GeV/c.

Corrected $\mathrm{d}^2n/\mathrm{d}y\mathrm{d}p_\mathrm{T}$ spectra of K^+, K^- and π^-

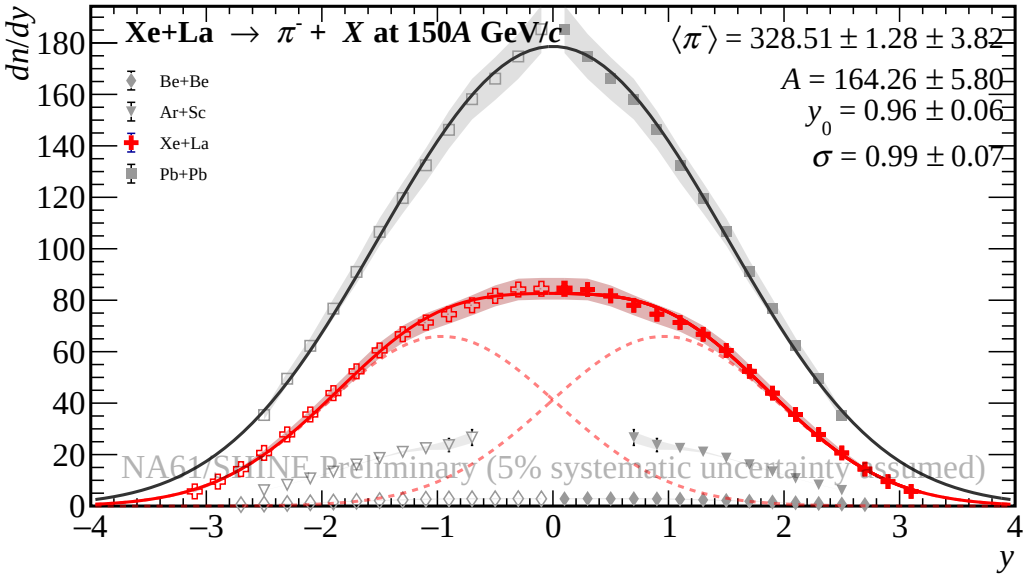


$K^{\pm}$ and π^{-} p_{T} spectra at $y = 0.4 - 0.6$



p_{T} spectra are presented for $y = 0.4 - 0.6$ – closest to midrapidity measured point for $K^{\pm}$.

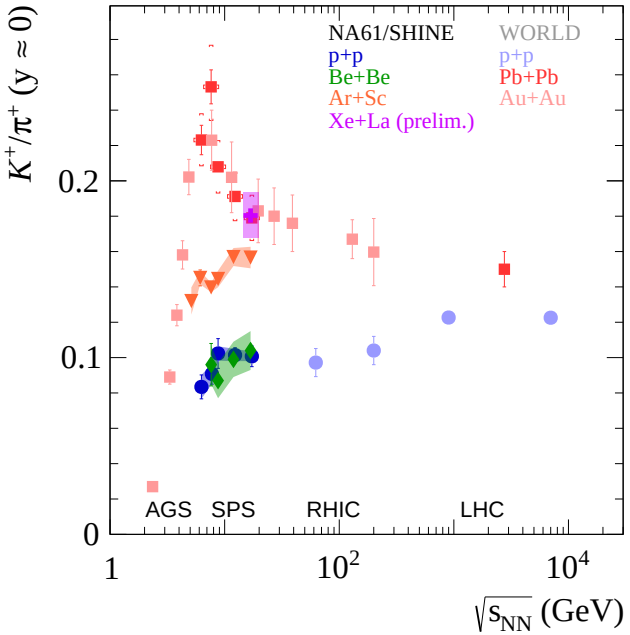
dn/dy spectrum of π^-

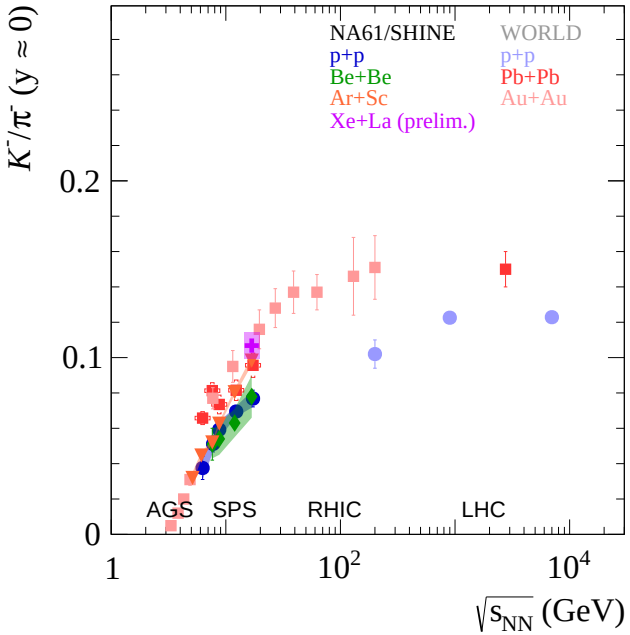


Assigned systematic uncertainty is 5% of the bin value.
For all spectra open points are reflected measured data points.
Fit with sum of two symmetric Gaussians:

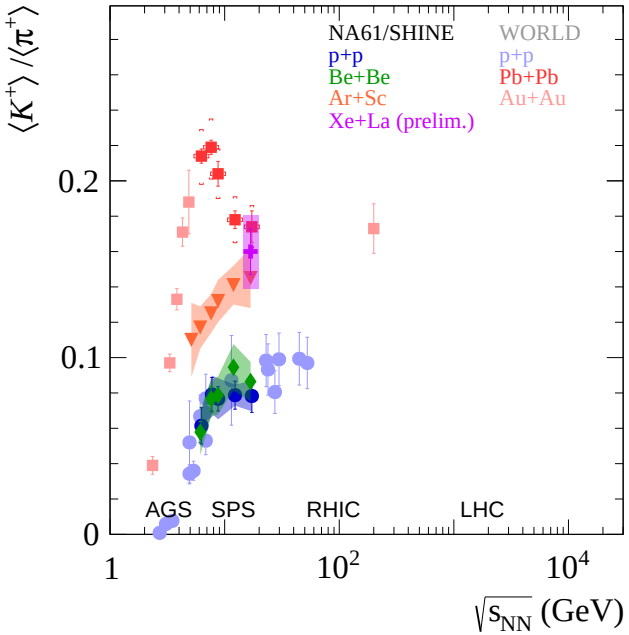
$$\frac{\mathrm{d}n}{\mathrm{d}y} = \frac{A}{\sigma\sqrt{2\pi}}\left(\exp\left[-\frac{(y-y_0)^2}{2\sigma^2}\right] + \exp\left[-\frac{(y+y_0)^2}{2\sigma^2}\right]\right).$$

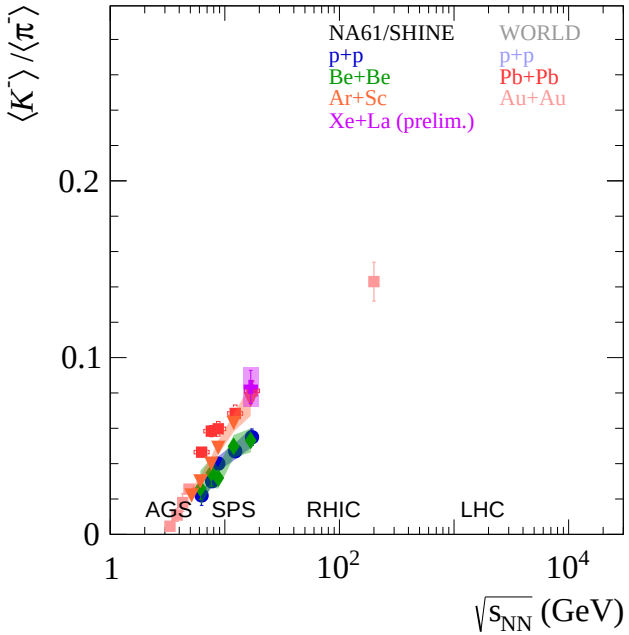
K^+/π^+ and K^-/π^- at $y \approx 0$



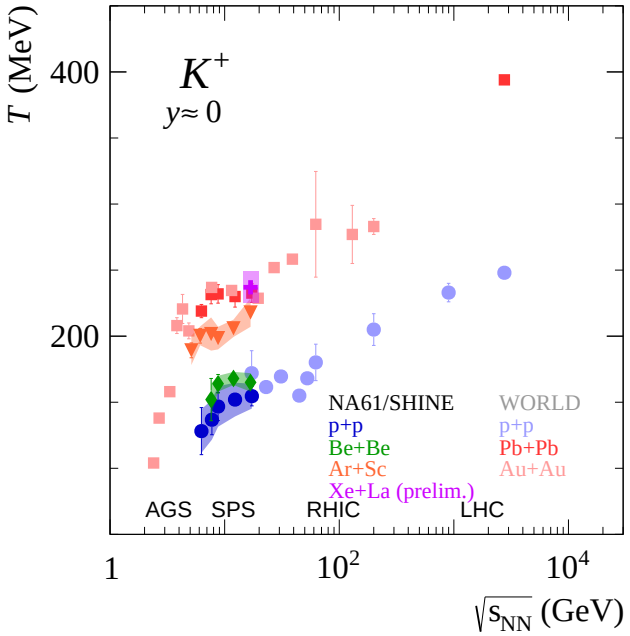


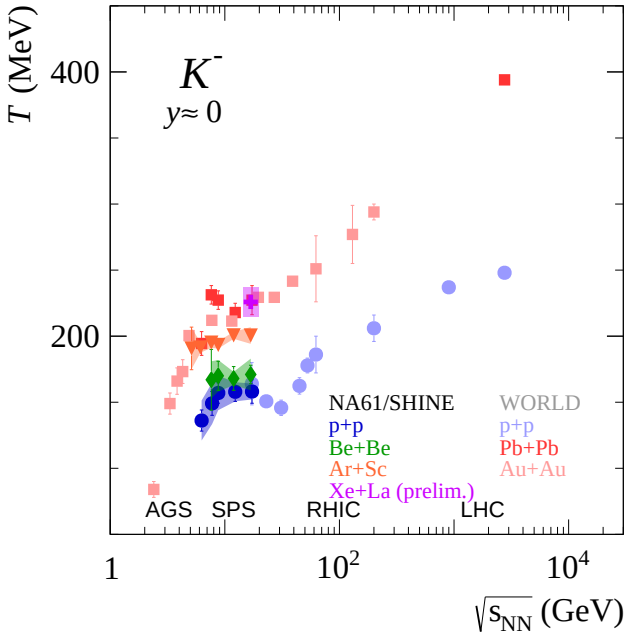
$\langle K^+ \rangle / \langle \pi^+ \rangle$ and $\langle K^- \rangle / \langle \pi^- \rangle$





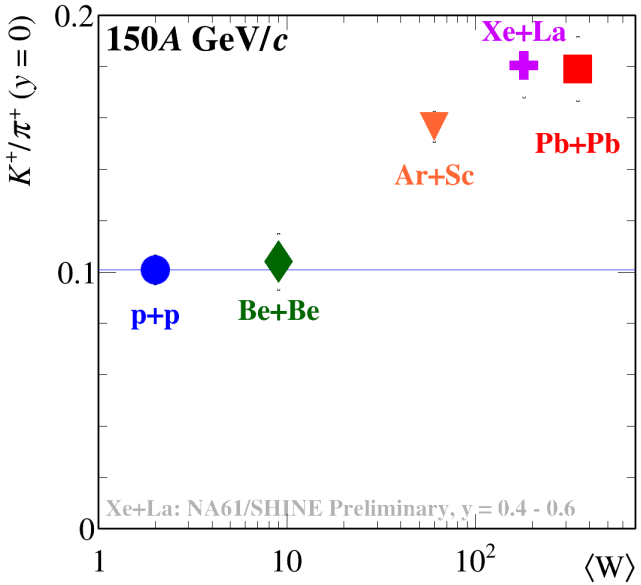
Inverse slope parameter T for K^+ and K^-

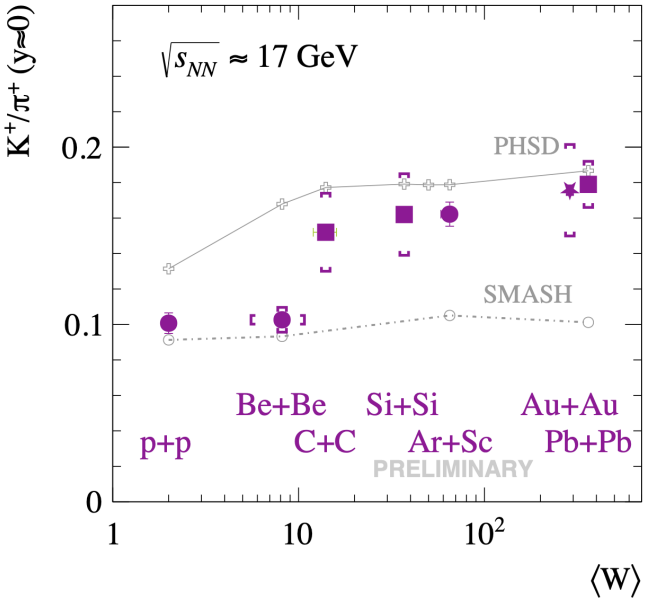




System size dependence of K^+/π^+ at $y \approx 0$

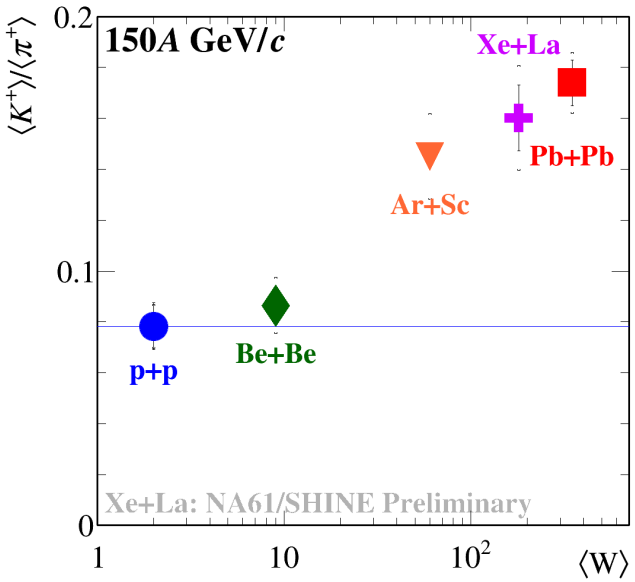
Comparison with models:

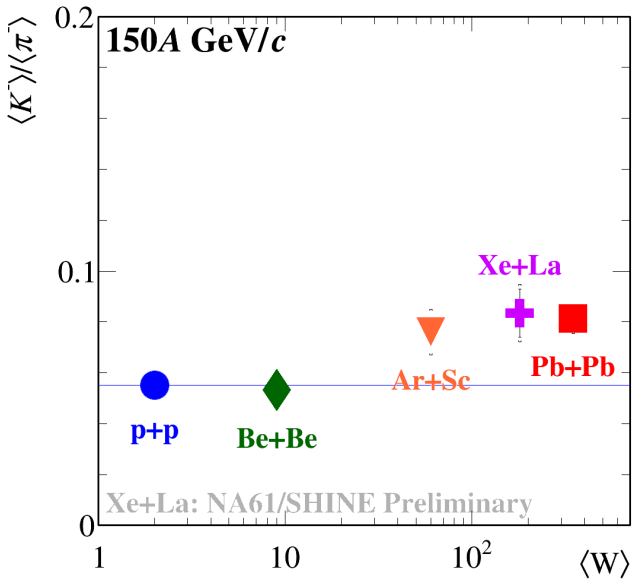




Statistical uncertainties are shown as bars and systematic with square braces.

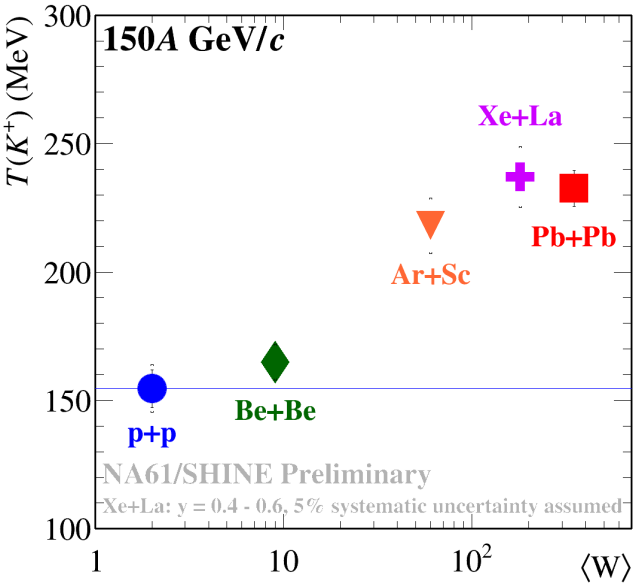
System size dependence of $\langle K^+ \rangle / \langle \pi^+ \rangle$ and $\langle K^- \rangle / \langle \pi^- \rangle$

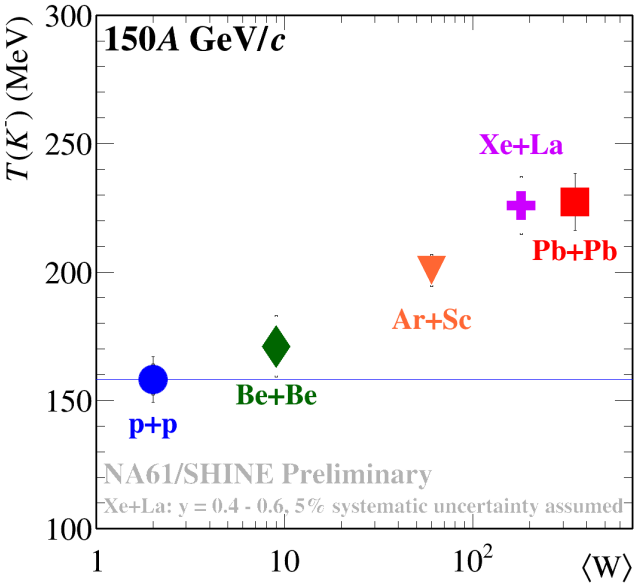




Statistical uncertainties are shown as bars and systematic with square braces.

System size dependence of T for K^+ and K^-





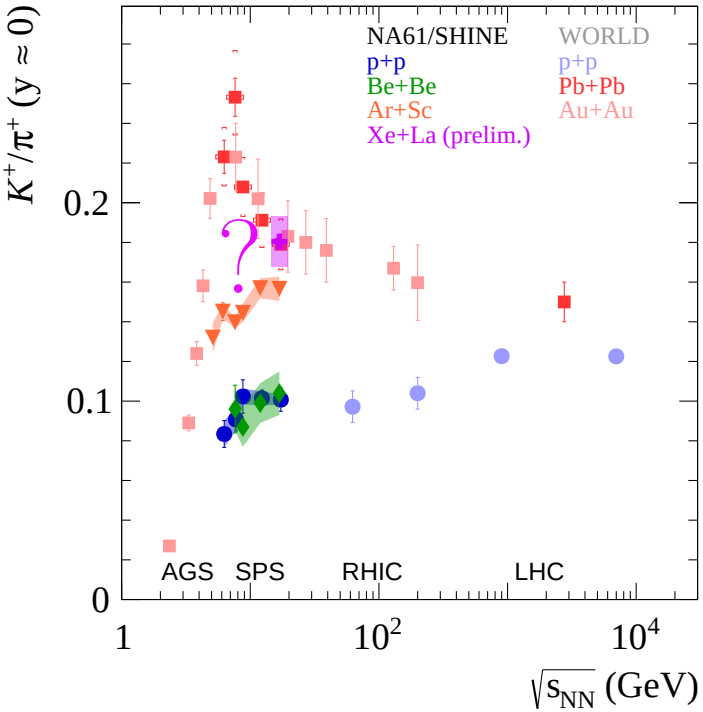
Statistical uncertainties are shown as bars and systematic with square braces.

Summary

- First results on spectra and total yields of π^-, K^+ and K^- produced in central Xe+La collisions at beam momentum $150A$ GeV/c are presented.
- K^+/π^+ and K^-/π^- ratios at $y \approx 0$ and $\langle K^+ \rangle / \langle \pi^+ \rangle$ and $\langle K^- \rangle / \langle \pi^- \rangle$ for Xe+La are close to the corresponding ratios for Pb+Pb.
- The inverse slope parameter of the p_{T} spectra of $K^{\pm}$ at midrapidity for Xe+La is close to Pb+Pb.

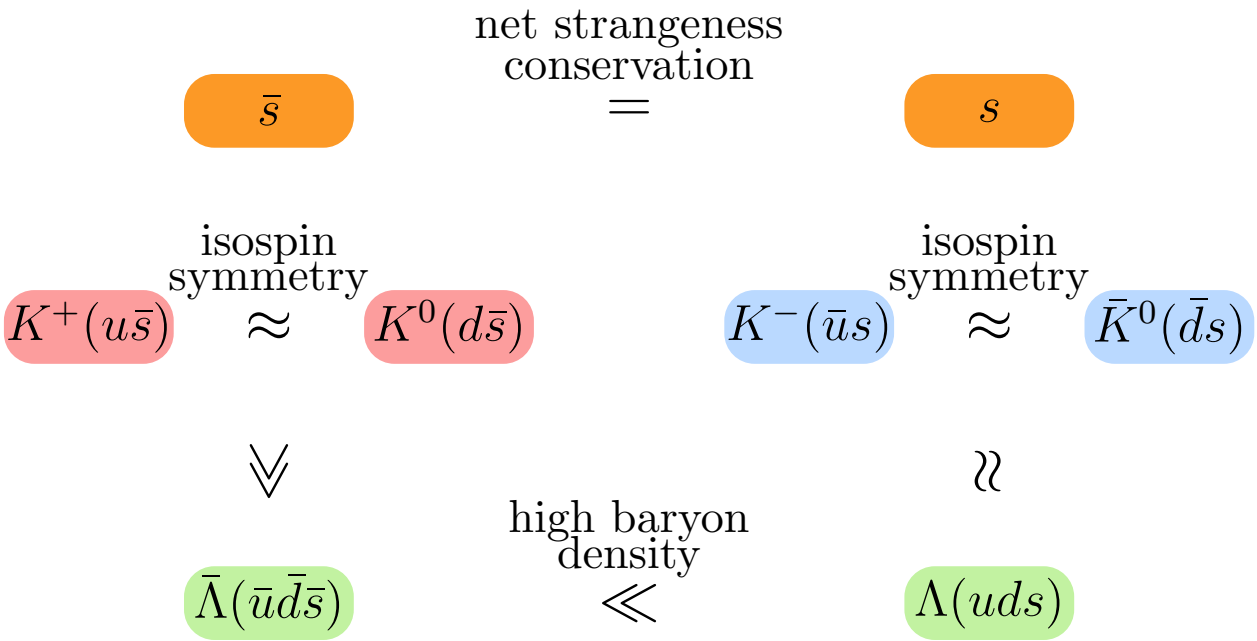
Outlook

- New results at lower SPS beam momenta ($13A-75A$ GeV/c) will be released soon and they will answer the question whether horn is visible in Xe+La.



Backup Slides

Distribution of strangeness between hadrons



– sensitive to strangeness content only

– sensitive to strangeness content and baryon density

How to measure strangeness

$$2\langle N_{s\bar{s}}\rangle = \langle \Lambda + \bar{\Lambda}\rangle + \langle K^+ + K^- + K^0 + \bar{K}^0\rangle + ...$$

$$2\langle N_{s\bar{s}}\rangle \approx \langle \Lambda\rangle + \langle K^+ + K^- + K^0 + \bar{K}^0\rangle,$$

$$\langle N_{s\bar{s}}\rangle \approx \langle \Lambda\rangle + \langle K^- + \bar{K}^0\rangle \approx \langle K^+ + K^0\rangle \approx 2\langle K^+\rangle.$$

How to measure entropy

Entropy $\sim \langle \pi \rangle$

$$\langle \pi \rangle = \langle \pi^+ + \pi^0 + \pi^-\rangle \approx 3\langle \pi^+\rangle$$

Experimental measure of strangeness to entropy ratio

$$\frac{\text{strangeness}}{\text{entropy}} \sim \frac{\langle N_{s\bar{s}}\rangle}{\langle \pi\rangle} \approx \frac{2\langle K^+\rangle}{3\langle \pi^+\rangle}$$