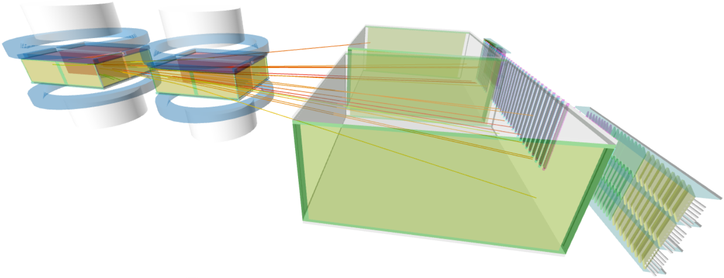

Pion spectra in Ar+Sc collisions in the NA61/SHINE Collaboration

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WFiA UWr,
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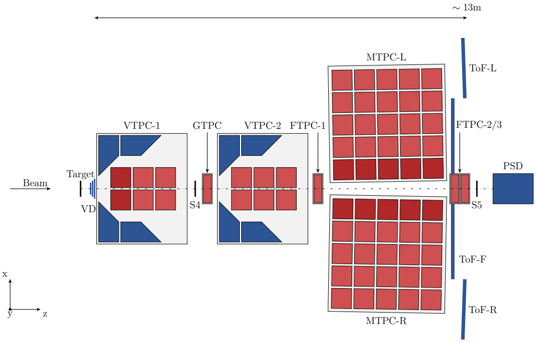
March 8, 2018

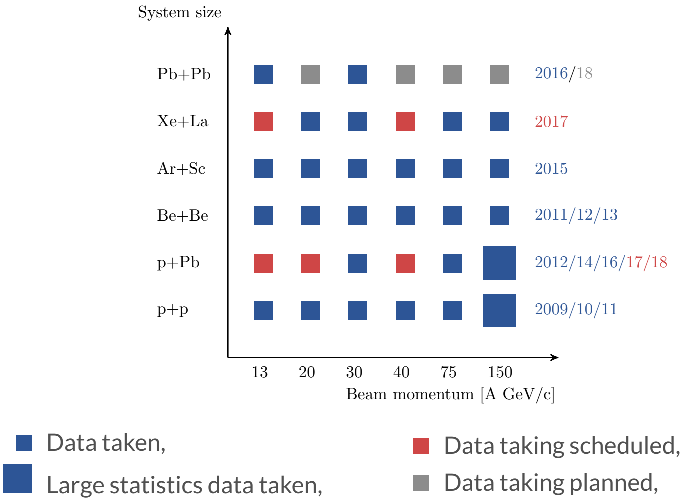
The NA61/SHINE detector



- **Fixed target** experiment,
- Located **at the SPS** accelerator,
- **Large acceptance** spectrometer – coverage of the full forward hemisphere, down to $p_{\mathrm{T}} = 0$,
- Selection of **events based on forward energy** (projectile spectators) measured in PSD.

Strong interactions programme at NA61/SHINE

The NA61/SHINE performs a 2D **scan over system size and collision energy** to study the phase diagram of strongly interacting matter in **temperature and baryon density**.



Strong interactions programme at NA61/SHINE

In this talk news on 4π π^- spectra and mean multiplicity in 5% most violent ^{40}Ar+^{45}Sc collisions at 13*A*, 19*A*, 30*A*, 40*A*, 75*A* and 150*A* GeV/c beam momentum will be presented.

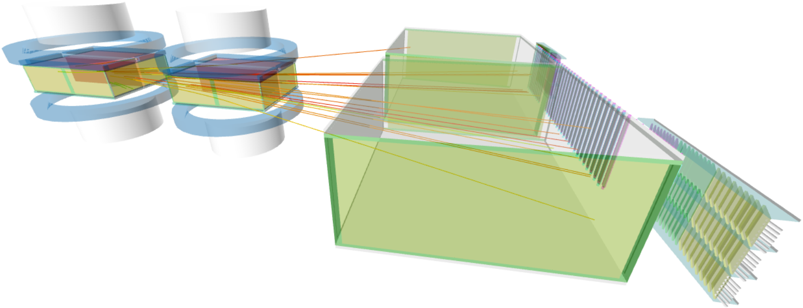
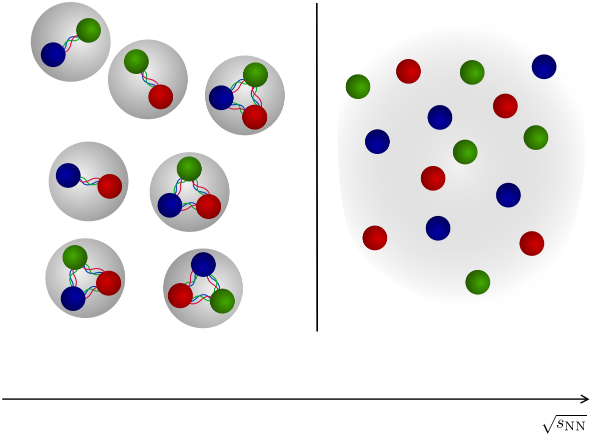
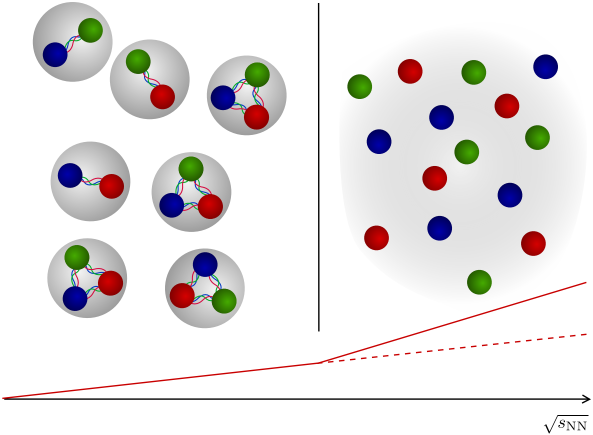


Figure: shine3d.web.cern.ch/shine3d/

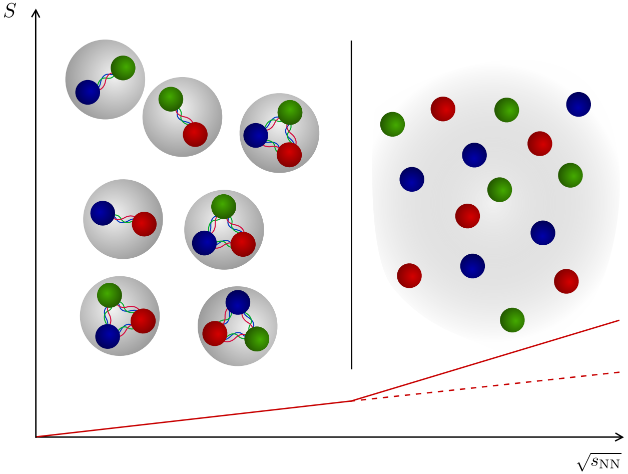
Why?



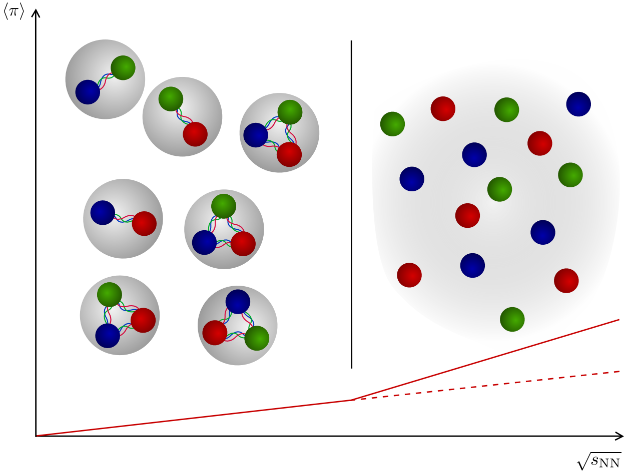
Why?



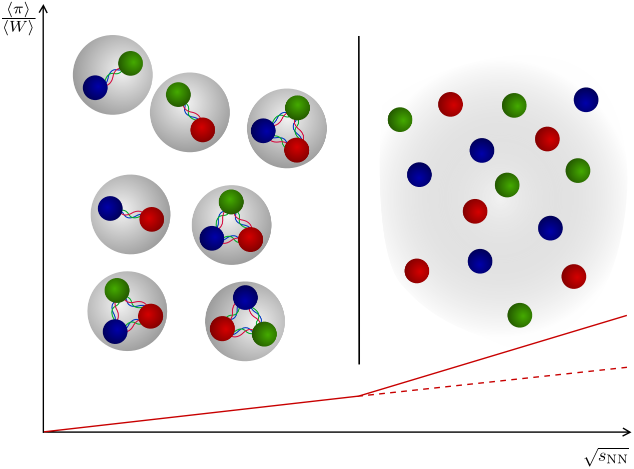
Why?



Why?

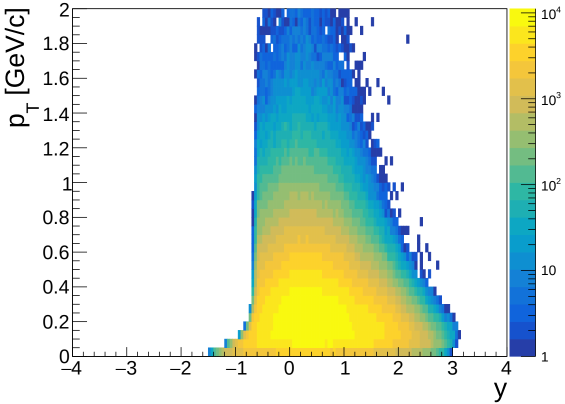


Why?



The h$^-$ method

Example for ^{40}Ar+^{45}Sc at 19A GeV/c



The h$^-$ method is used to extract π^- spectra in Ar+Sc interactions at different beam momenta. Results refer to pions produced by strong interaction processes and in electromagnetic decays of produced hadrons.

The h^{-} method

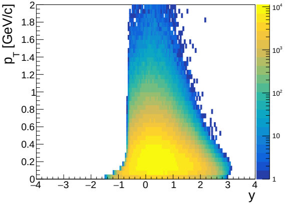
- The experimental data undergoes series of **quality cuts**.
- Spectra of negatively charged particles are detrmined using the selected events and tracks.
- The spectra are **corrected for acceptance, reconstruction efficiency and contamination of particles other than** primary π^- mesons by EPOS 1.99 Monte Carlo model[1].
- Mean π^- multiplicity in 4π is estimated by summing up the measured spectra and correcting it for missing acceptance by extrapolation.

[1] Liu et al. *PRC* 74.

The h$^-$ method

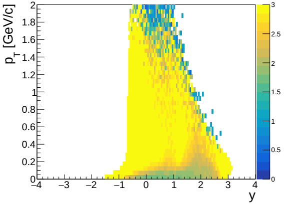
Example for ^{40}Ar+^{45}Sc at 19A GeV/c

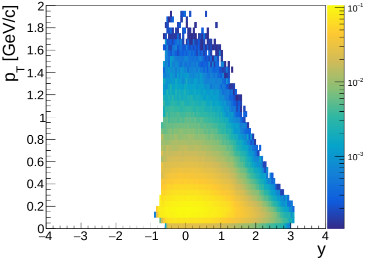
Raw data



$$\times \frac{1}{N_{\text{event}}} \times$$

MC corrections



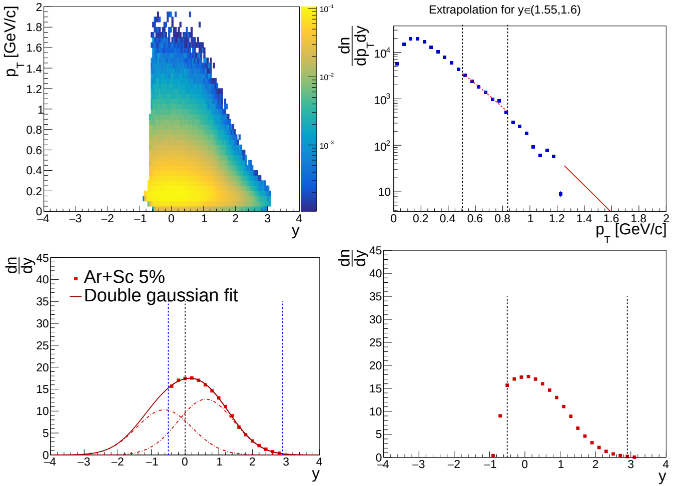


Corrected π^- spectrum

Extrapolation to 4π acceptance

Example for ^{40}Ar+^{45}Sc at 19*A* GeV/c

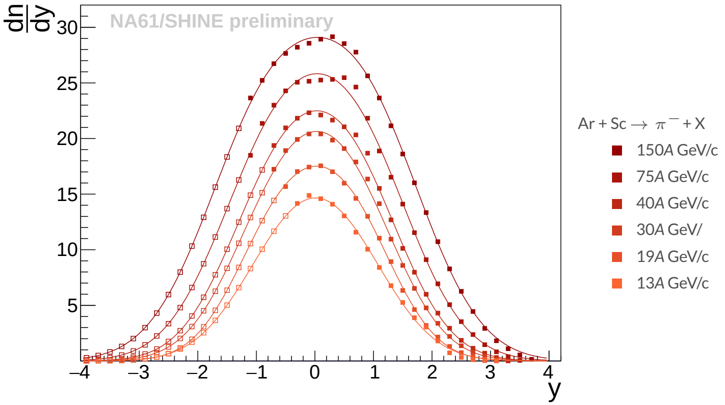
Extrapolation in p_T



Sum

Fitting Gaussians

Results: π^- rapidity spectra



- π^- spectra measured in large acceptance: p_T down to 0, in full forward hemisphere.
- Rapidity spectra are approximately gaussian, independently of the collision energy,
- Only statistical uncertainties plotted.

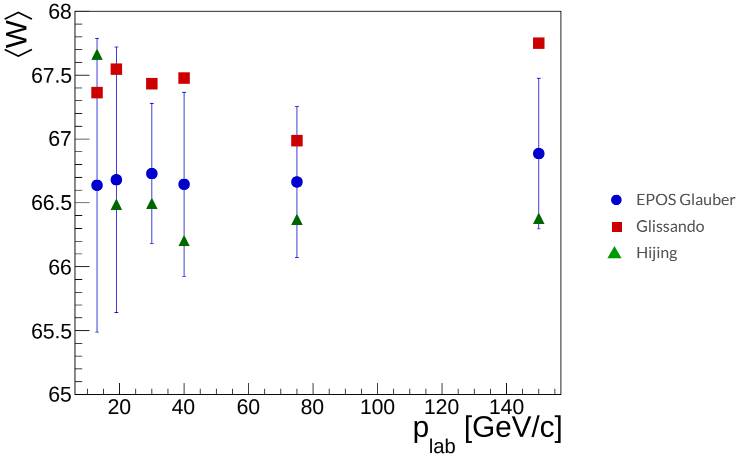
Mean number of wounded nucleons $\langle W \rangle$

- Mean number of wounded nucleons (nucleons interacting inelastically calculated within the Glauber model) $\langle W \rangle$ obtained using **EPOS 1.99**[2] Monte Carlo,
- Systematic and statistical uncertainties plotted. Systematic uncertainties are based on the uncertainty of p+p inelastic collision cross section and the difference between EPOS and Hijing values.
- $\langle W \rangle$ calculated from EPOS is $< 1\%$ smaller than that from Glissando[3],
- 5% most violent events chosen based on the number of projectile spectators. **Event selection based on the full simulation of the PSD response is under way**. Uncertainty coming from the selection is not shown here.

[2] Liu et al. *PRC* 74.

[3] Rybczyński et al. *Comp. Phys. Comm.* 185.6.

Mean number of wounded nucleons $\langle W \rangle$



Example of 5% most violent Ar+Sc collisions

Results: $\langle\pi^-\rangle$ and $\langle W\rangle$

Preliminary results for 4π, 5% event class $\langle\pi^-\rangle$ and $\langle W\rangle$ for Ar+Sc at different SPS momenta.

- Systematic uncertainty of $\langle\pi^-\rangle$ is estimated to be 5% based on previous NA61/SHINE analysis[4].

	p_{lab} [A GeV/c]	$\langle\pi^-\rangle$	$\langle W\rangle$
Ar+Sc	13	38.46 ± 1.92	66.63 ± 0.50
	19	48.03 ± 2.40	66.68 ± 1.02
	30	59.72 ± 2.98	66.72 ± 0.50
	40	66.28 ± 3.31	66.64 ± 0.57
	75	86.12 ± 4.30	66.66 ± 0.52
	150	108.92 ± 5.44	66.88 ± 0.50

[4] N. Abgrall et al. *EPJ C* 74.3, p. 1.

The "Kink" plot

The Fermi statistical model predicts linear increase of $\langle\pi\rangle/\langle W\rangle$ with the Fermi energy measure

$$F = \left[\frac{(\sqrt{s_{\mathrm{NN}}} - 2m_{\mathrm{N}})^3}{\sqrt{s_{\mathrm{NN}}}}\right]^{1/4}$$

An increase of the slope of $\langle\pi\rangle/\langle W\rangle$ – **KINK** – at the onset of deconfinement is predicted by the SMES[5] due to the larger number of effective degrees of freedom in comparison to HRG.

[5] Gazdzicki and Gorenstein. *APP* B30.

Estimation of $\langle\pi\rangle$ from $\langle\pi^-\rangle$

As for the NA61 Ar+Sc, Be+Be and p+p data we only have the $\langle\pi^-\rangle$ value, the multiplicities of $\langle\pi^+\rangle$ and $\langle\pi^0\rangle$ are as:

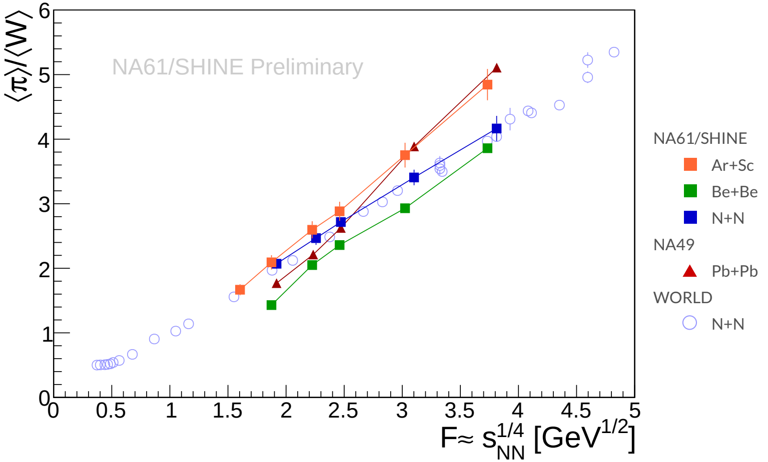
$$\langle\pi\rangle_{\text{N+N}} = 3\langle\pi^-\rangle_{\text{N+N}}$$

$$\langle\pi\rangle_{\text{Ar+Sc}} = 3\langle\pi^-\rangle_{\text{Ar+Sc}}$$

$$\langle\pi\rangle_{\text{Be+Be}} = 3\langle\pi^-\rangle_{\text{Be+Be}}$$

This approach is motivated by the fact that the **NA61/SHINE acceptance is the largest for** π^-.

The "Kink" plot



- At **high SPS energies Be+Be approximately follows p+p**, whereas **Ar+Sc follows Pb+Pb**.
- At **low SPS energies no simple systematic is observed**. The reason might be physical or due to systematic bias in $\langle W \rangle$ estimate. Full simulation of fragmentation process and PSD response is needed.

Summary

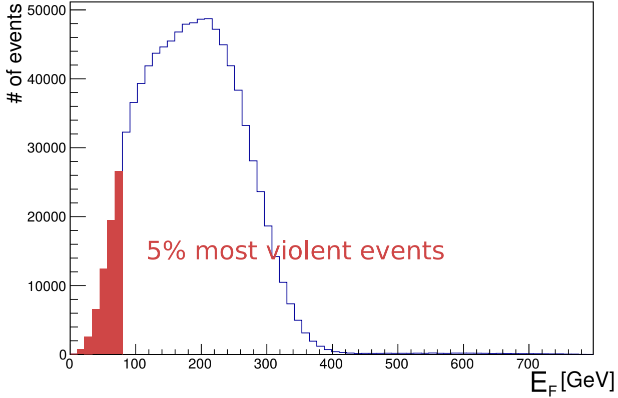
- Preliminary results on π^- multiplicites in 5% most violent collisions of Ar+Sc at $p_{\text{lab}} = 13A, 19A, 30A, 40A, 75A, 150A$ GeV/c are presented.
- At **high SPS energies Ar+Sc follows Pb+Pb**.
- At **low SPS energies no simple systematic is observed**.
- **Full simulation of fragmentation process and PSD response is urgently needed.**

Thank you for your attention.

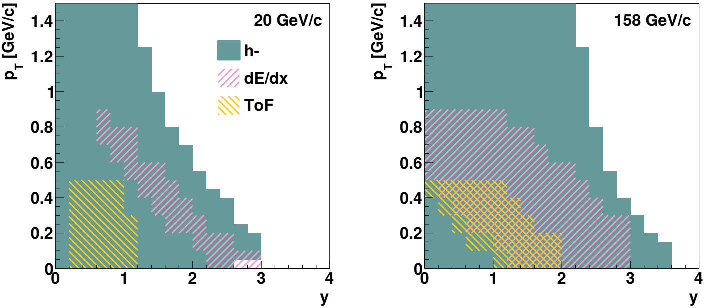
Event classes

Event (centrality) classes are **chosen using the forward energy**, E_F $\approx$ energy of projectile spectators. E_F is measured by the PSD zero-degree calorimeter. This is an important feature of NA61/SHINE.

Example for Ar+Sc at 13*A* GeV/c

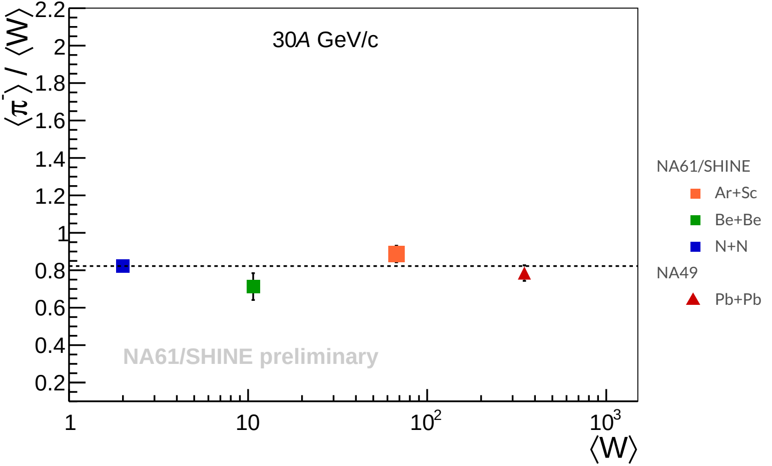


PID methods in NA61/SHINE



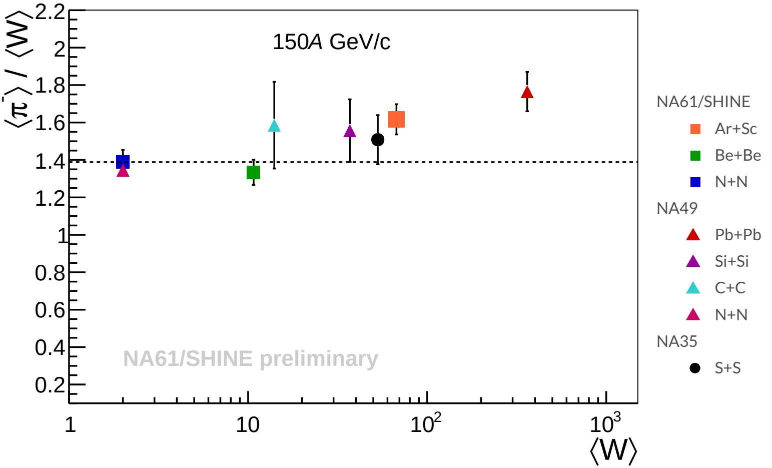
- *dE/dx* method estimates multiplicities of $\pi^{\pm}$, $K^{\pm}$, p and $\bar{p}$ using **energy loss measurements** in TPCs,
- *tof-dE/dx* method estimates multiplicities of $\pi^{\pm}$, $K^{\pm}$, p and $\bar{p}$ using **energy loss and particle time of flight measurements** in ToFs,
- h^{-} method estimates multiplicities of π^{-} based on the fact that **the majority of negatively charged hadrons produced in p+p and A+A collisions are π^{-}.**

Results: $\langle \pi^- \rangle / \langle W \rangle$ ratio



- **No increase with system size,**
- Systematic and statistical uncertainties plotted.

Results: $\langle \pi^- \rangle / \langle W \rangle$ ratio



- Data suggests monotonic increase with system size at 150*A* GeV/c. **Ar+Sc and Be+Be measurements in line**.
- Systematic and statistical uncertainties plotted.

Isospin correction

In order to compare results obtained for different systems, the **isospin correction** should be taken into account. To this end phenomenological formulas are used

$$\langle \pi^- \rangle_{\mathrm{N+N}} = \langle \pi^- \rangle_{\mathrm{p+p}} + \frac{1}{3}$$

$$\langle \pi^- \rangle^{\mathrm{I}}_{\mathrm{Au+Au}} = (\langle \pi^- \rangle_{\mathrm{Au+Au}} + \langle \pi^+ \rangle_{\mathrm{Au+Au}})/2$$

The correction is only applied to measurements where its effect is the strongest. This assumption is based on the compilation of the world data presented in[6] and the model presented therein.

Where needed, the data is corrected for slight differences in beam momentum.

[6] Golokhvastov. *Physics of Atomic Nuclei* 64.1, p. 84.