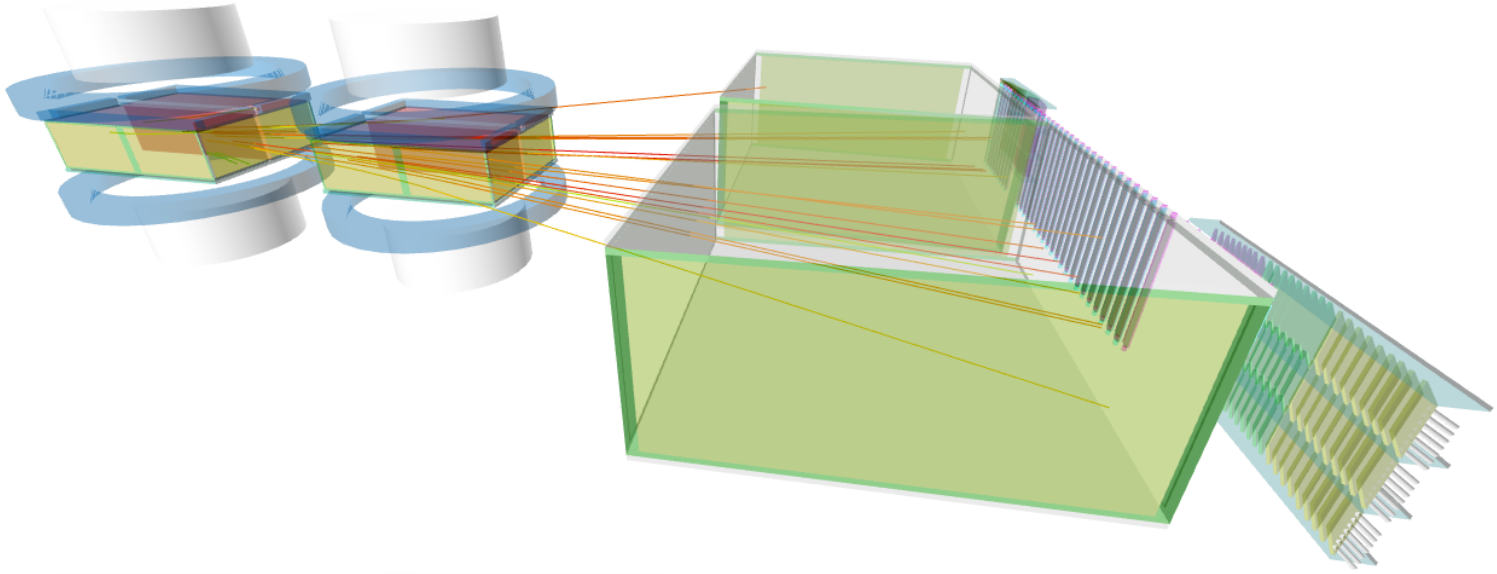

News on mean pion multiplicity from NA61/SHINE

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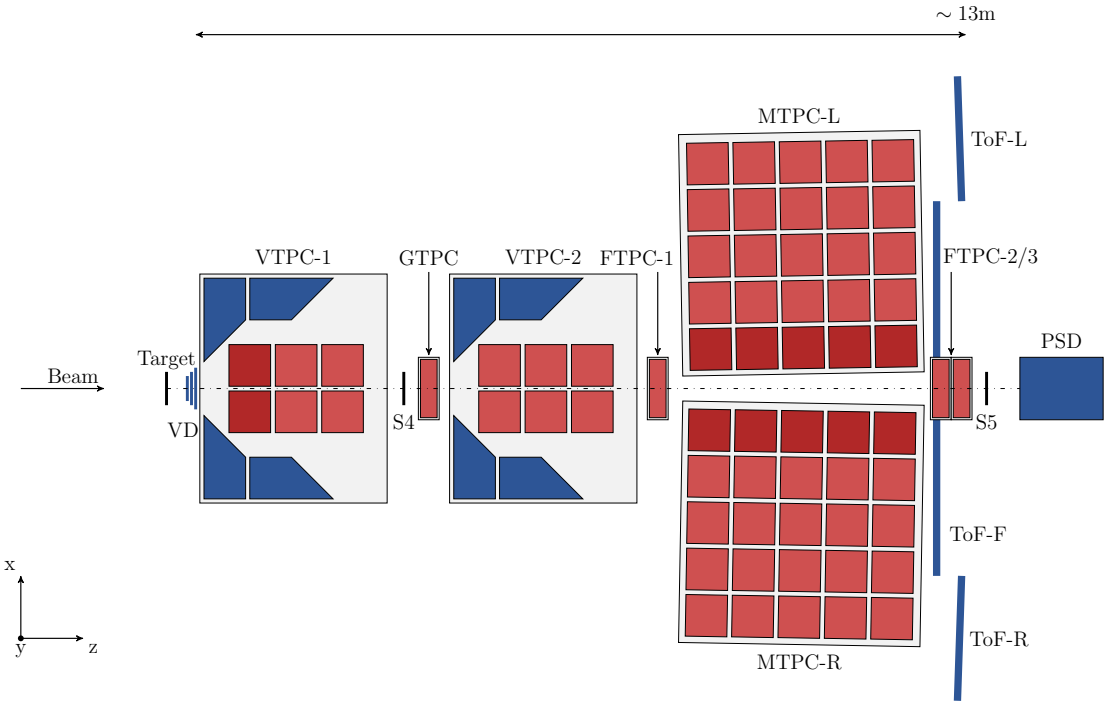
WFiA UWr,
for the NA61/SHINE collaboration

July 14, 2017

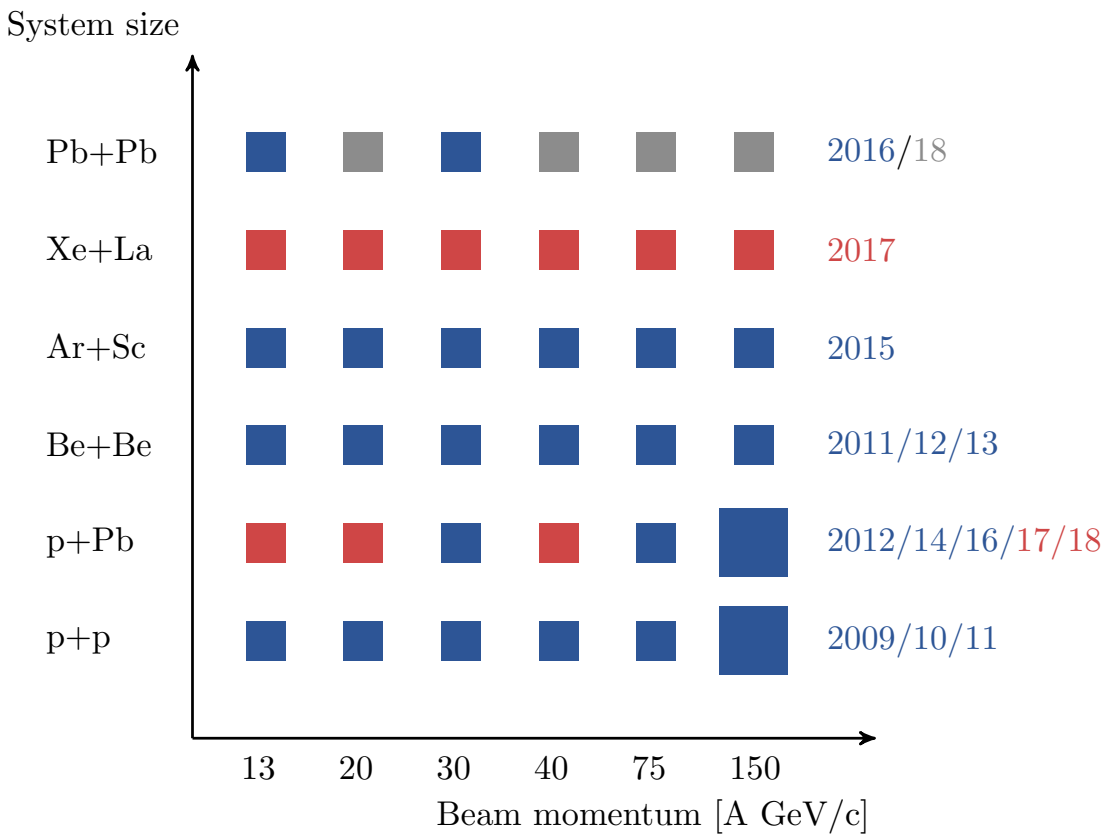
The NA61/SHINE detector



- **Fixed target** experiment,
- Located **at the SPS** accelerator,
- **Large acceptance** spectrometer – coverage of the full forward hemisphere, down to $p_T = 0$,
- 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**.



Data taken,

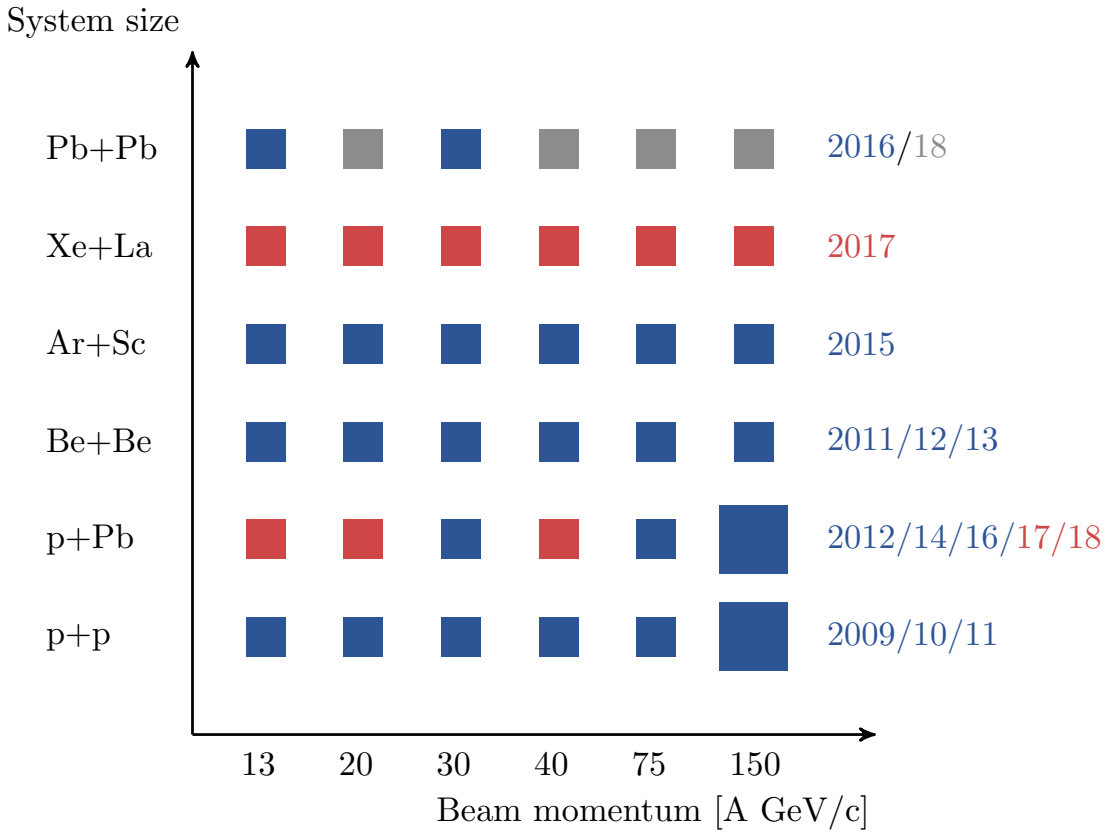
Large statistics data taken,

Data taking scheduled,

Data taking planned,

Strong interactions programme at NA61/SHINE

In this talk news on 4π mean π^- multiplicity in ^{7}Be+^{9}Be and ^{40}Ar+^{45}S collision in 5% most violent collisions will be presented.



Data taken,

Large statistics data taken,

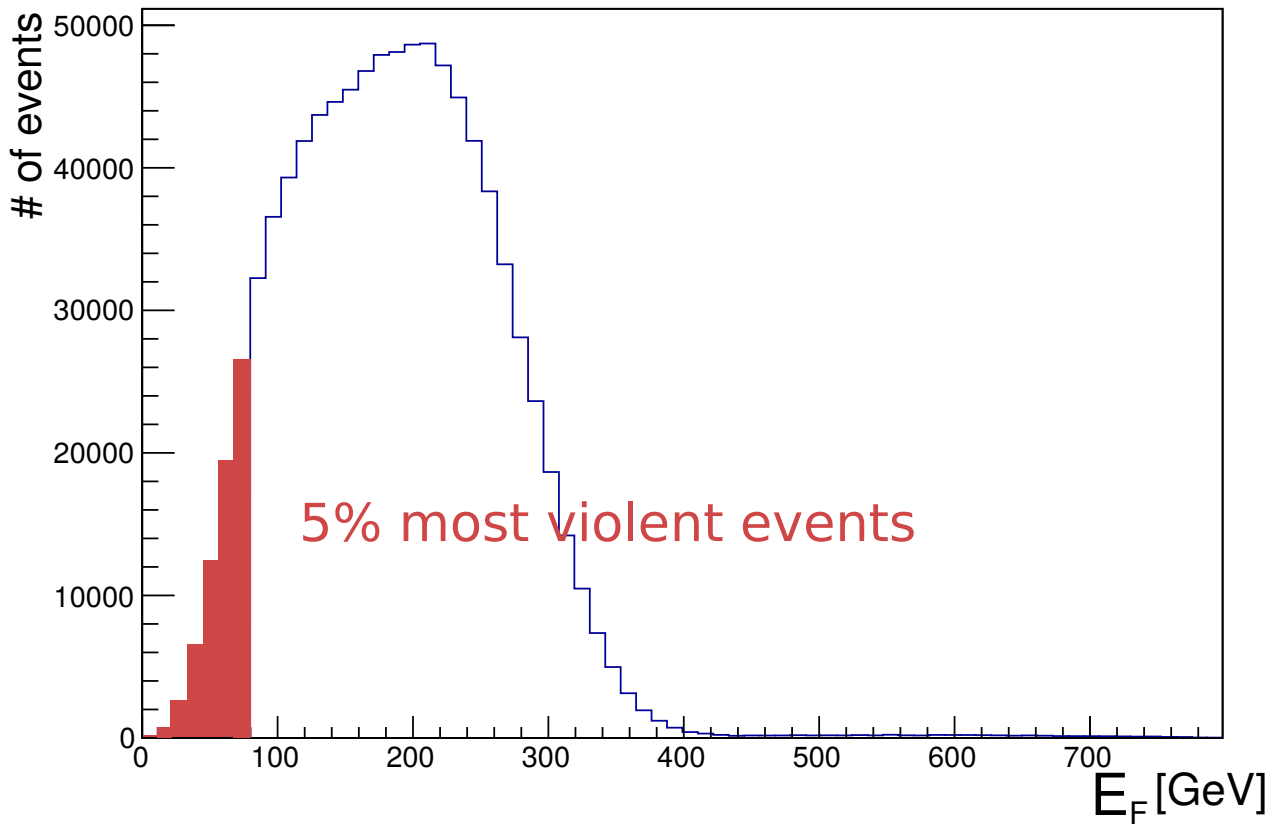
Data taking scheduled,

Data taking planned,

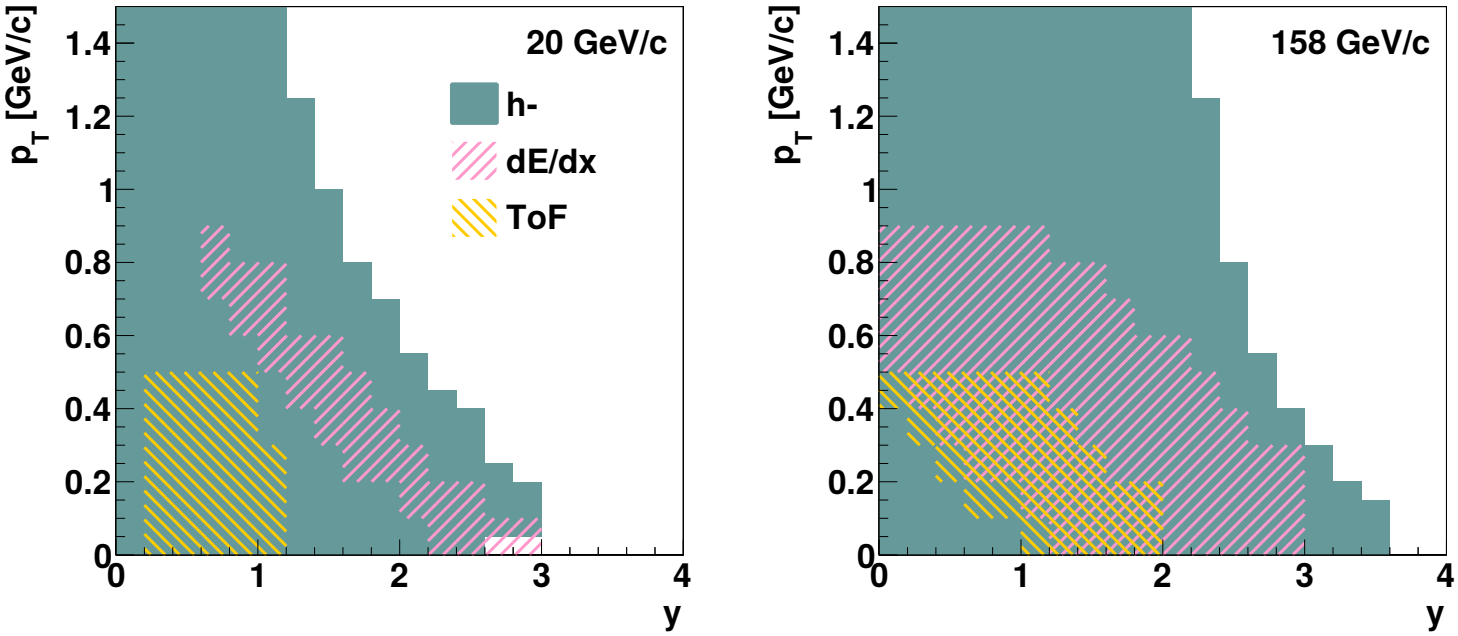
Event classes

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 a unique feature of the NA61/SHINE.

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

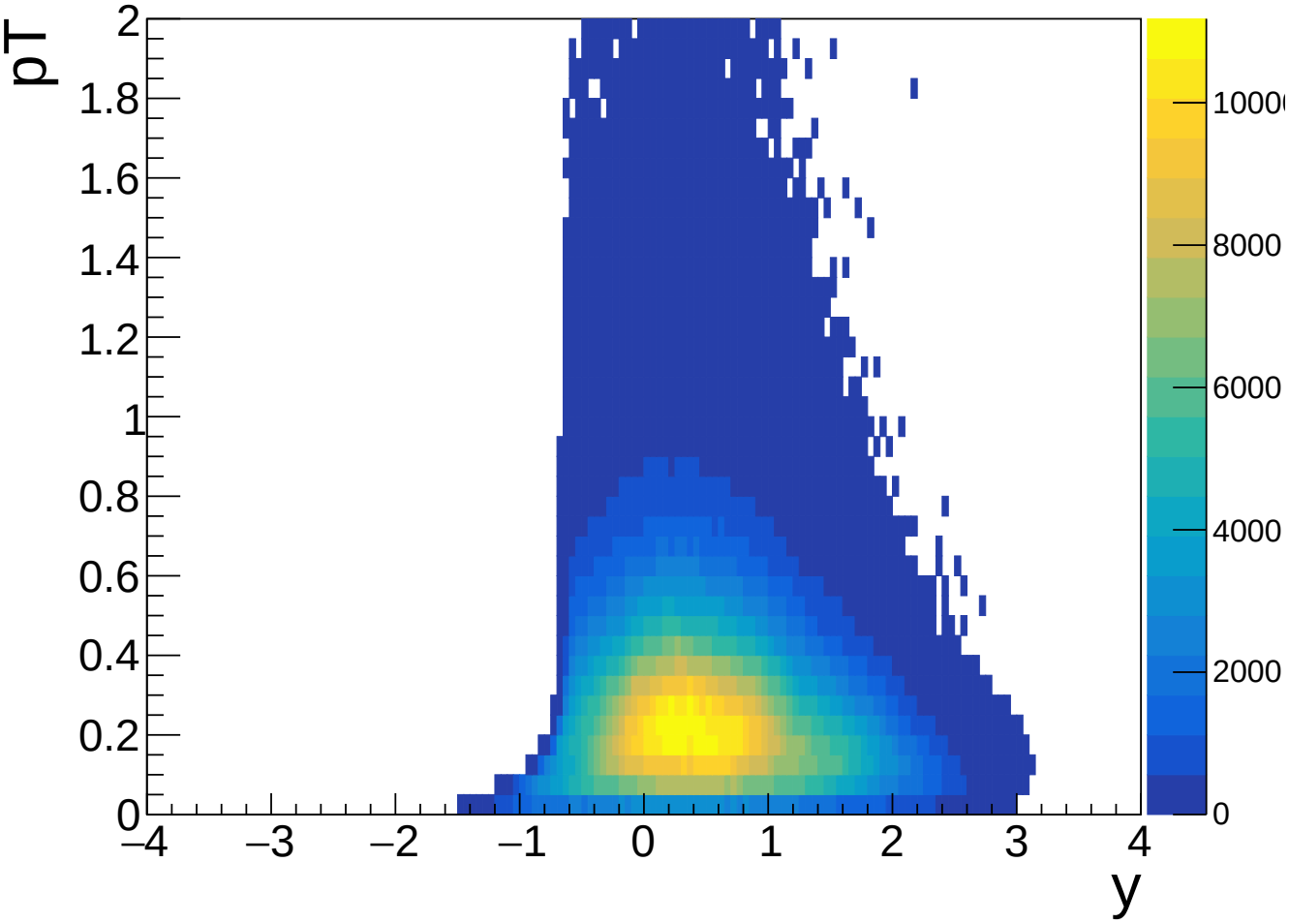


PID methods in NA61/SHINE



- 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^-.**

The h^- method



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

The h^- method

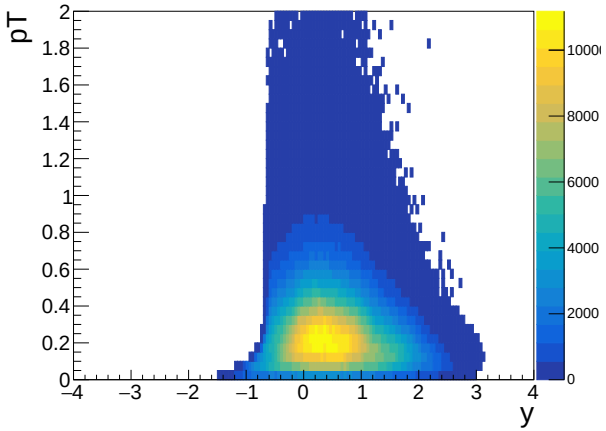
- The experimental data undergoes series of **quality cuts**.
- Spectra of negatively charged particles are detrmined using the selected events and tracks,
- The spectra are **corrected for acceptance, reconstruction efficiency and contamination of particles other than** primary π^- mesons by EPOS 1.99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

[1] Liu et al. *PRC* 74 (), p. 044902.

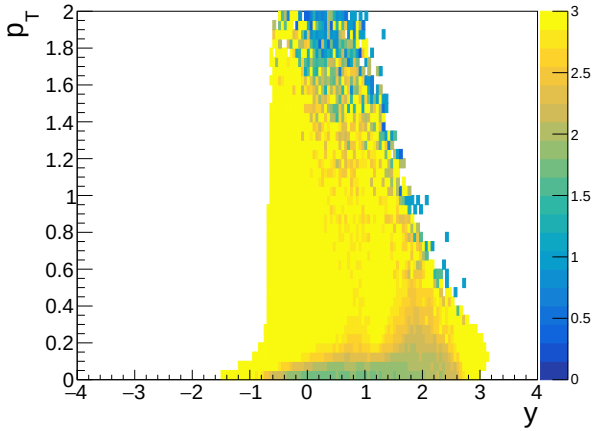
The h^- method

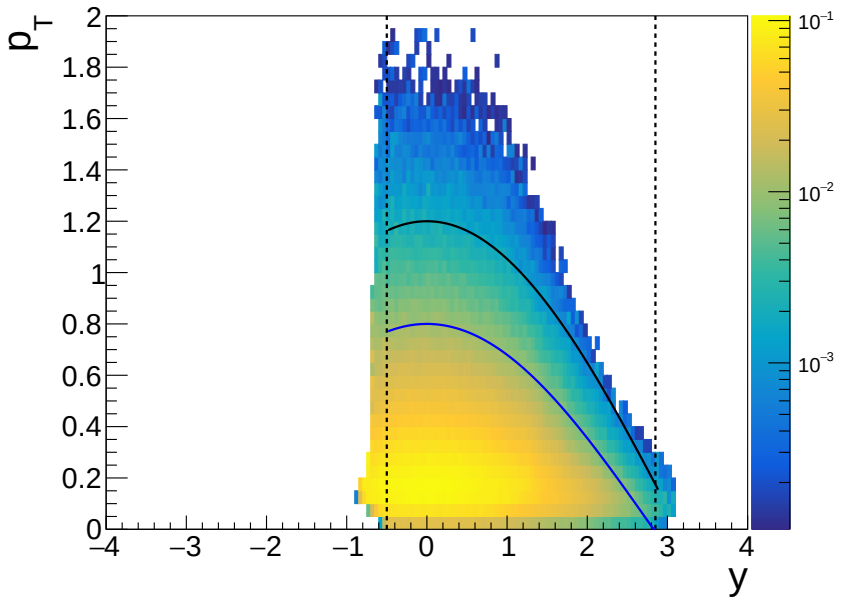
Example for $^{40}Ar+^{45}Sc$ at 19*A* GeV/c

Raw data



MC corrections



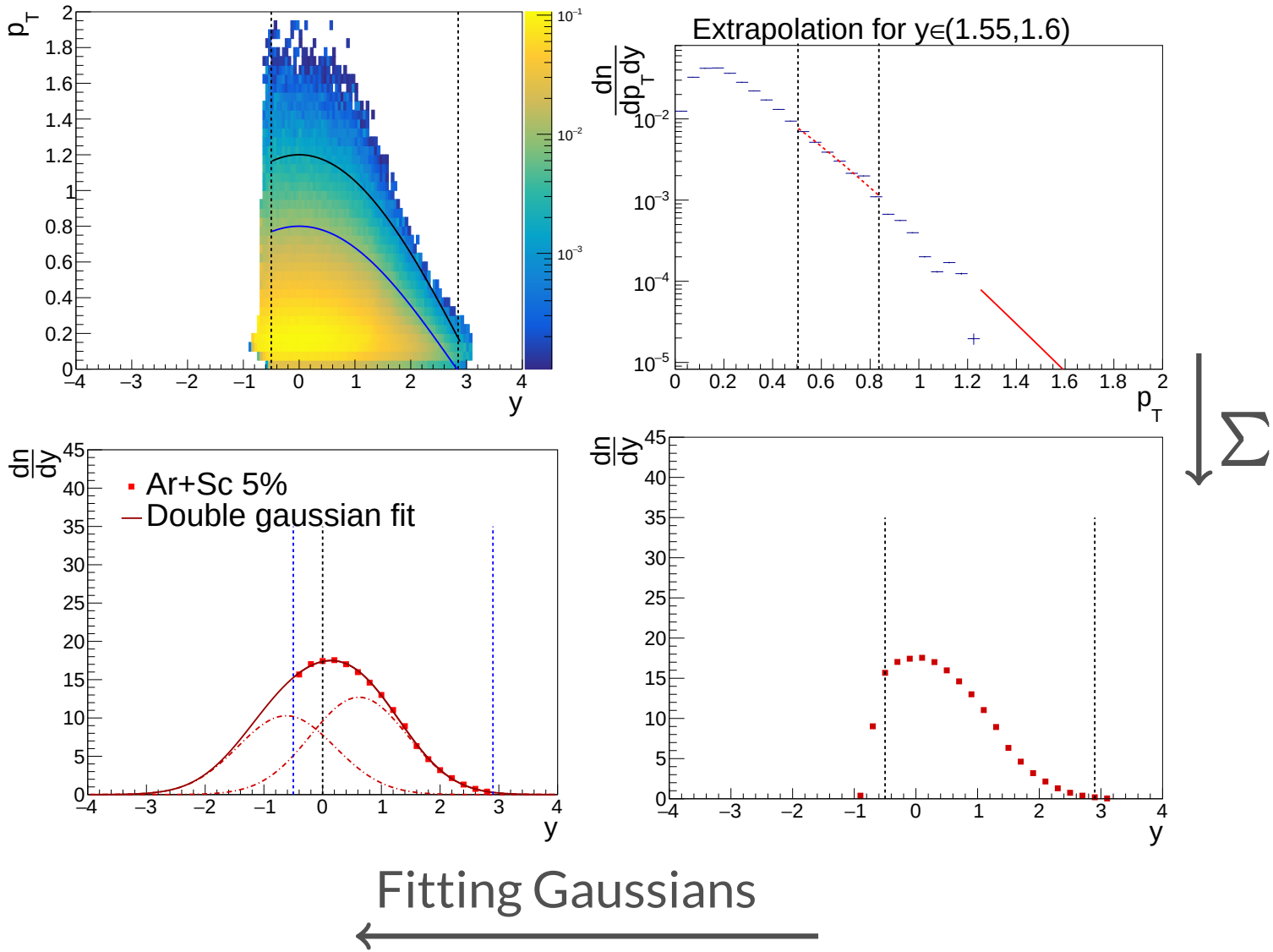


Corrected π^- spectrum

Extrapolation to 4π acceptance

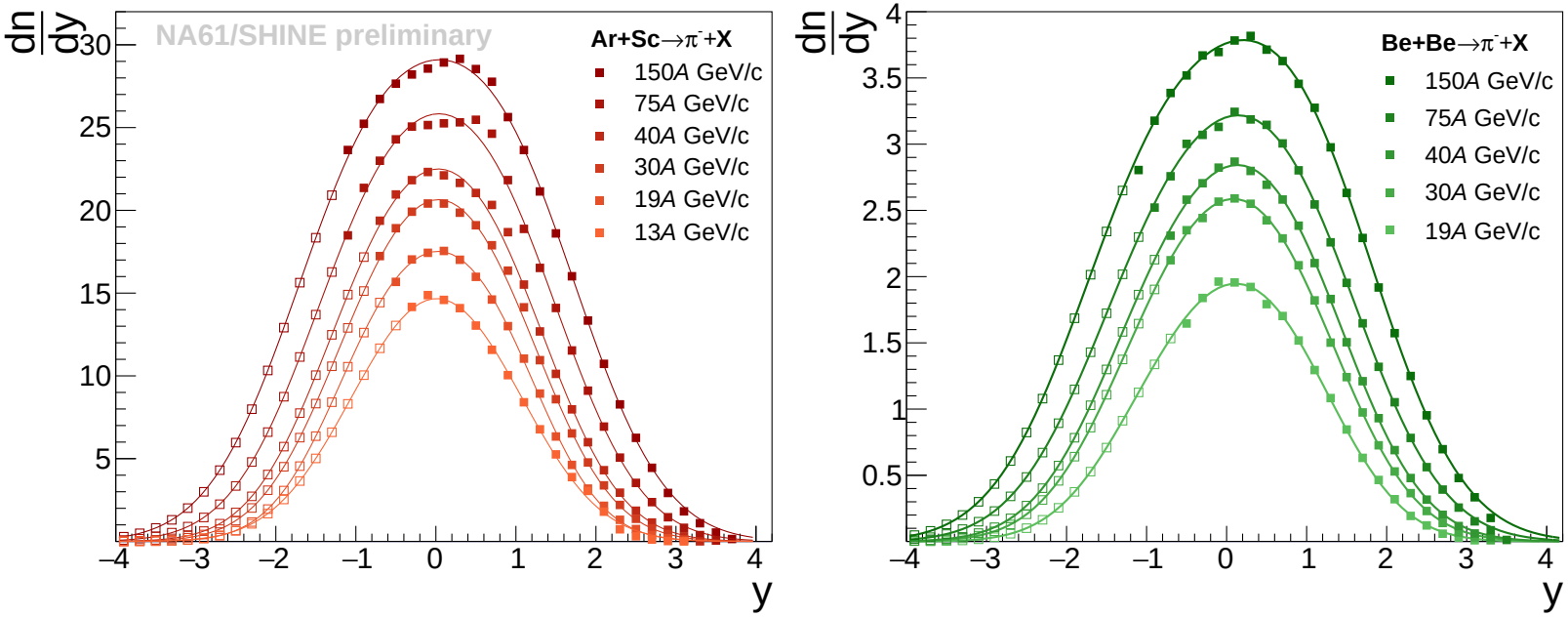
Example for $^{40}Ar+^{45}Sc$ at 19A GeV/c

Extrapolation in p_T



Fitting Gaussians

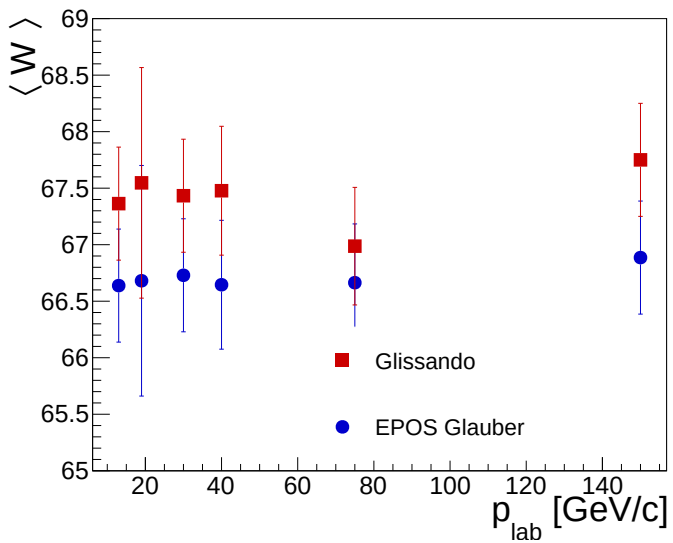
Results: π^- rapidity spectra



- 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.
- The EPOS $\langle W \rangle$ is by $< 1\%$ higher then the Glissando[3] calculation,
- 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**.



Example of 5% most violent Ar+Sc collisions

[2] Liu et al. *PRC* 74 (), p. 044902.

[3] Rybczyński et al. *Comp. Phys. Comm.* 185.6 (), p. 1759.

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 and Be+Be 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

	p_{lab} [A GeV/c]	$\langle \pi^- \rangle$	$\langle W \rangle$
Be+Be	20	5.32 ± 0.54	10.99 ± 1.02
	30	7.61 ± 0.76	10.86 ± 0.50
	40	8.75 ± 0.44	10.86 ± 0.57
	75	10.98 ± 0.55	10.83 ± 0.52
	158	14.32 ± 0.72	10.79 ± 0.50

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

Isospin correction

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

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

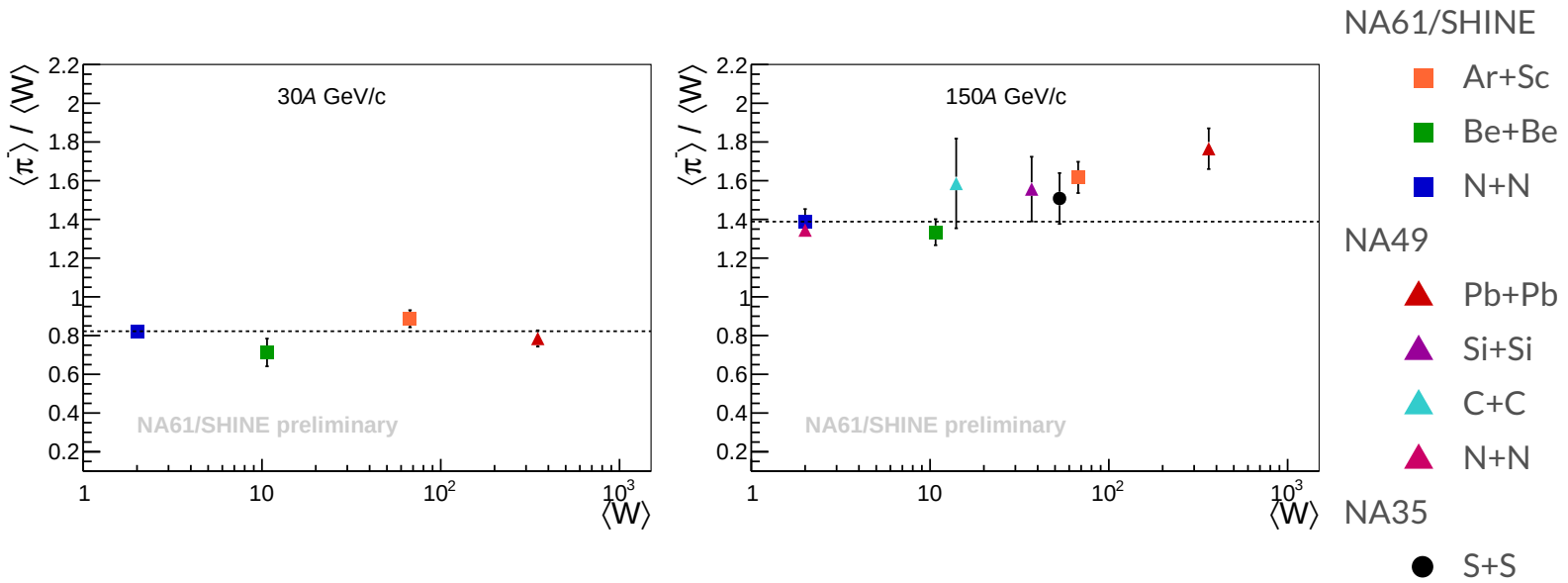
$$\langle \pi^- \rangle^{\text{I}}_{\text{Au+Au}} = (\langle \pi^- \rangle_{\text{Au+Au}} + \langle \pi^+ \rangle_{\text{Au+Au}})/2$$

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[5] and the model presented therein.

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

[5] Golokhvastov. *Physics of Atomic Nuclei* 64.1 (), p. 84.

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**.
- **No increase at 30*A* GeV/c**,
- Systematic and statistical uncertainties plotted.

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[6] due to the larger number of effective degrees of freedom in comparison to HRG.

[6] Gazdzicki and Gorenstein. *APP* B30 (), p. 2705.

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 approximated multiplying the previously corrected for isospin assymetry multiplicities by factor 3:

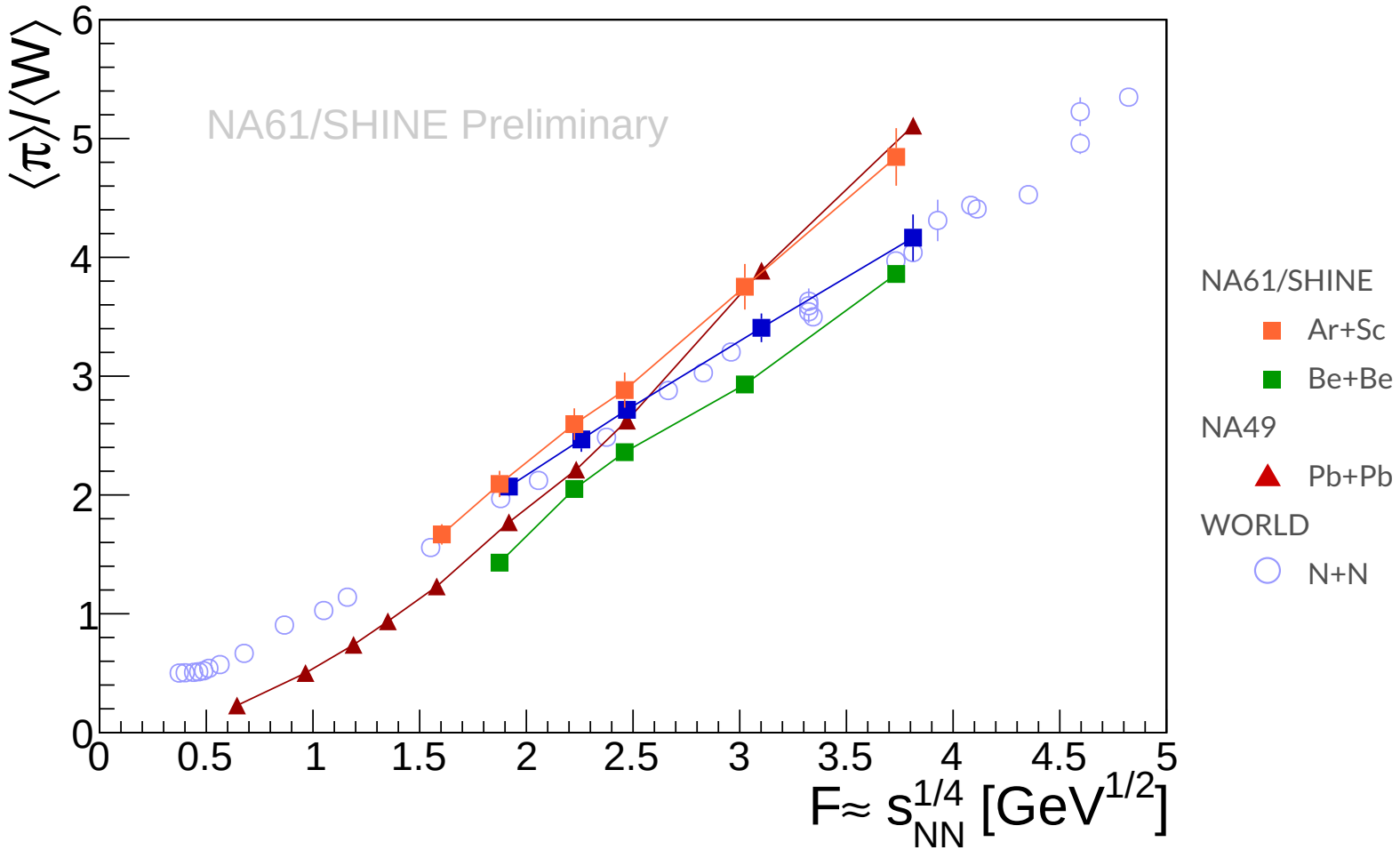
$$\langle \pi \rangle_{\text{p+p}} = 3 \langle \pi^- \rangle_{\text{p+p}}$$

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

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

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 $p_{\text{lab}} = 13A$, $19A$, $30A$, $40A$, $75A$, $150A$ and Be+Be at $p_{\text{lab}} = 20A$, $30A$, $40A$, $75A$, $158A$ GeV/c are presented.
- The $\langle \pi^- \rangle / \langle W \rangle$ system size dependence is compared with other systems.
- The $\langle \pi^- \rangle / \langle W \rangle$ energy dependence is compared with previous p+p and Pb+Pb measurements.
- At **high SPS energies Be+Be approximetely follows p+p**, whereas **Ar+Sc follows Pb+Pb**.
- At **low SPS energies no simple systematic is observed**.

Thank you for your attention.