

Multiplicity and net-charge fluctuations in ion+ion collisions at the SPS energies

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for the NA61/SHINE Collaboration



**Faculty
of Physics**

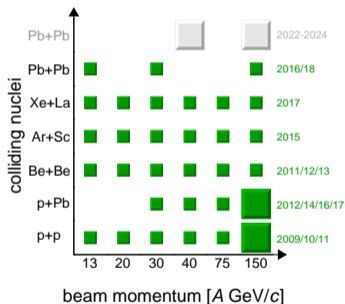
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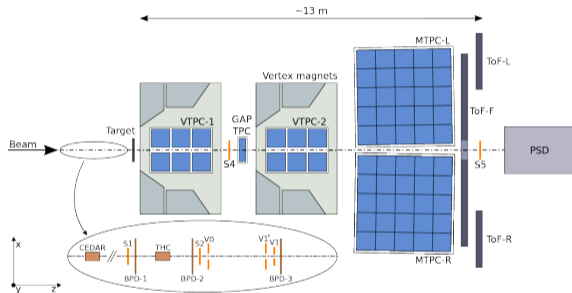
NA61/SHINE – fixed target experiment at SPS CERN

The ion programme aims to search for the critical point (**CP**) of strongly interacting matter and study the onset of deconfinement.

Energy and system size scan



<http://shine.web.cern.ch/>

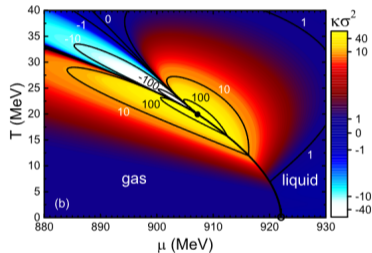
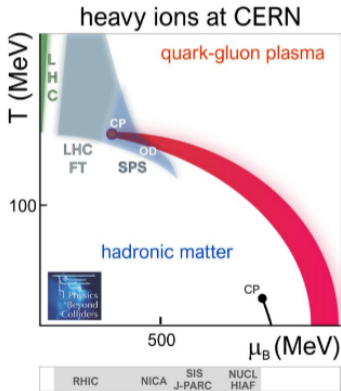


<http://shine.web.cern.ch/>

Large (up to 50%) acceptance and precise forward energy measurements makes NA61/SHINE a suitable experiment for fluctuations measurements. *Setup corresponds to analysed data.

Motivation

Multiplicity and net-charge fluctuations of higher order moments are tools to search for critical point of strongly interacting matter. 2D system size and energy scan gives an ideal opportunity to search for it at SPS energies.



Vovchenko et al. Acta Phys.Polon. Supp. 10,75

Theoretical calculation of phase transition with values of normalized kurtosis for nuclear matter described with van der Waals equations.

CP \rightarrow increase of the correlation length ($\xi \rightarrow \infty$)

$$\langle N^2 \rangle \sim \xi^2 \quad \langle N^4 \rangle \sim \xi^7$$

Stephanov, J.Phys.G 38,124147

arXiv:1901.04482v1 [hep-ex] 14 Jan 2019

Definitions of intensive quantities

	Multiplicity	Net-charge
Normalized kurtosis	$K\sigma^2 = \frac{\mu_4}{\mu_2} - 3\mu_2 = \frac{\kappa_4}{\kappa_2}$	$\frac{\kappa_4}{\kappa_2} [h^+ - h^-]$
Normalized skewness	$S\sigma = \frac{\mu_3}{\mu_2} = \frac{\kappa_3}{\kappa_2}$	$\frac{\kappa_3}{\kappa_1} [h^+ - h^-]$
Scaled variance	$\omega(N) = \frac{\mu_2}{\mu_1} = \frac{\kappa_2}{\kappa_1}$	$\frac{\kappa_2 [h^+ - h^-]}{\kappa_1 [h^+] + \kappa_1 [h^-]}$

μ_i and κ_i – central moment and cumulant of i-th order

Reference values:

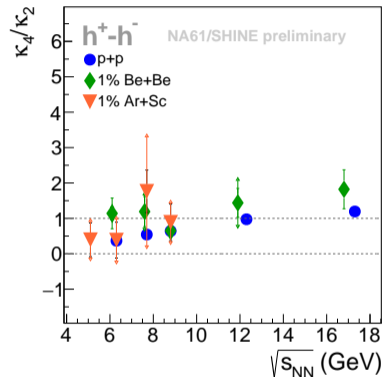
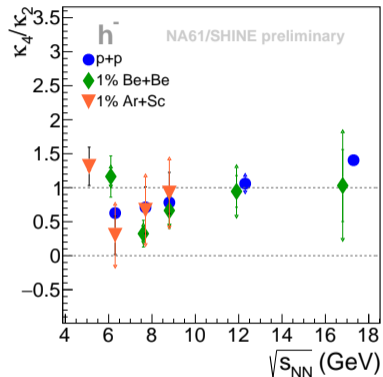
Multiplicity

- 0 without fluctuations
- 1 for Poisson distribution

Net-charge

- without fluctuations
- for Skellam distribution

System size and energy dependence



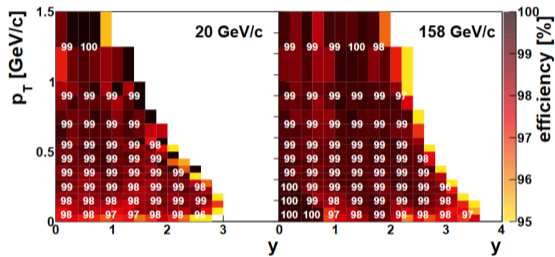
Statistical uncertainties – black bars.

Estimated systematic uncertainties – solid line of the same color as marker with arrows.

For A+A collisions only 1% of the most central ones.

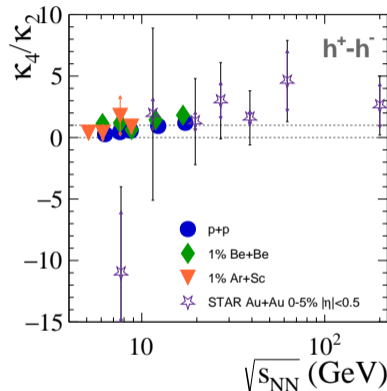
System size and energy dependence

Acceptance of NA61/SHINE:



arXiv:1401.4699v1 [physics.ins-det] 19 Jan 2014

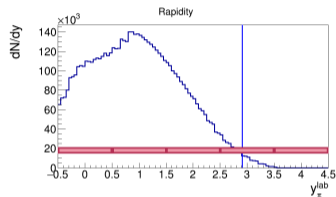
Acceptance of STAR: $|\eta| < 0.5$



Comparison with STAR: Phys. Rev. Lett. 113, 092301 (2014)

Rapidity dependence – constant bin

Constant bin – sensitivity for different measurements conditions.

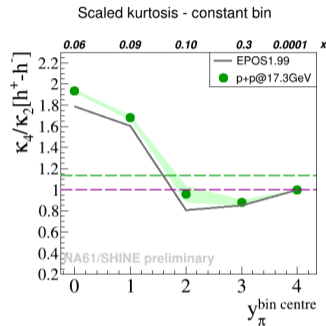
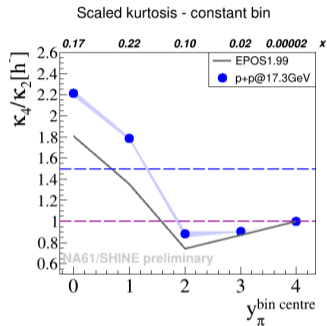


- EPOS1.99 qualitatively agrees with data
- the strongest signal for $y_\pi < 1.5$

Dashed green line – value in full analysis acceptance

Dashed blue line – value in full analysis acceptance

Dashed violet line – 1 (reference for Poisson distribution)



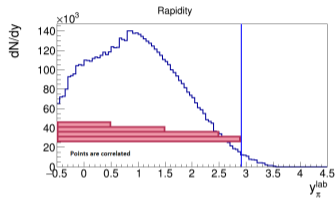
Top x axis – ratio of h^{accepted} to h^{total}

Statistical uncertainties – black bars (hidden behind markers).

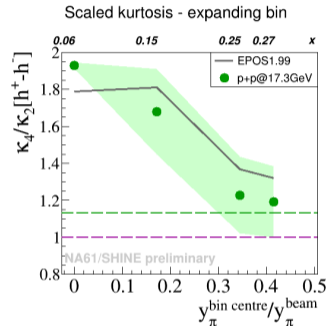
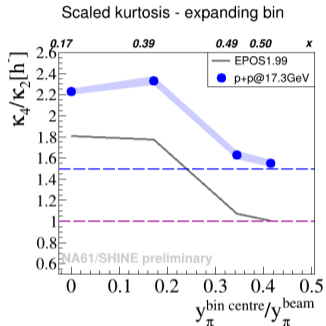
Estimated systematic uncertainties – colorband.

Rapidity dependence – expanding bin

Expanding bin - comparison of short- and long-range correlations.



- data present strong dependence on rapidity acceptance
- EPOS1.99 predicts similar dependence



Top x axis – ratio of $h^{accepted}$ to h^{total}

Statistical uncertainties – black bars (hidden behind markers).

Estimated systematic uncertainties – colorband.

Dashed green line – value in full analysis acceptance

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Dashed violet line – 1 (reference for Poisson distribution)

■ System size and energy dependence

- κ_4/κ_2 of multiplicity and net-charge fluctuations for p+p, Be+Be and Ar+Sc were measured in energy dependence
- comparison with STAR's results Au+Au interaction
- no indication of CP

■ Rapidity dependence in p+p interactions

- κ_4/κ_2 of multiplicity and net-charge fluctuations for p+p interactions at 158GeV/c were measured in rapidity dependence
- data present strong dependence on rapidity acceptance
- EPOS1.99 qualitatively describes the data

Thank you

Have a shiny day! ;)

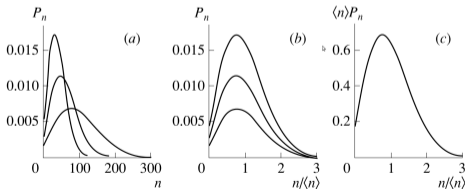
This work was supported by the Polish National Science Centre grant 2016/21/D/ST2/01983 and by WUT ID-UB.

Backup

Fluctuations – p+p interactions as a reference measure

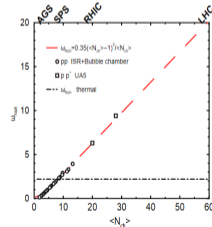
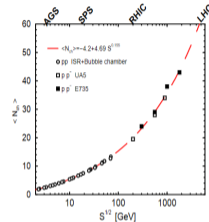
Known for decades property of multiplicity in full rapidity range in p+p interactions is the KNO-G scaling:

- (a) – multiplicity distributions measured at different energies $P(n)$
- (b) – represented as a function of ratio $n/\langle n \rangle$ have peak at the same place
- (c) – represented as a function of ratio $n/\langle n \rangle$ and multiplied by $\langle n \rangle$ are additionally normalised



A. I. Golokhvastov, Phys. Atom. Nucl. 64, 84, 2001

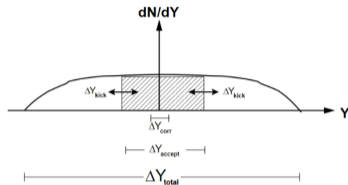
For full range:



arXiv:nucl-th/0003046v5 3 May 2001

Fluctuations – acceptance dependence

In modern experiments we usually do not measure everything.



arXiv:0810.2520v1 [nucl-th] 14 Oct 2008

ΔY_{total} – range of the total measured distribution

ΔY_{accept} – range of the accepted charged particles

ΔY_{corr} – charge correlation length

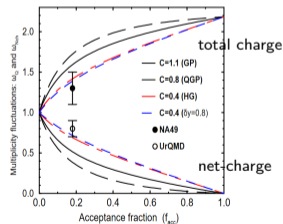
ΔY_{kick} – rapidity shift blurring acceptance boundaries

Extrem cases:

- full range – everything is detected, eg. there is no net-charge fluctuation
- infinitesimally small range – only single particles are measured

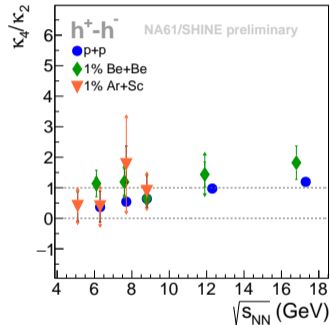
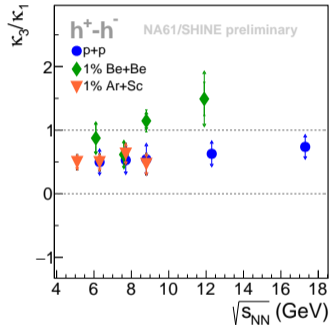
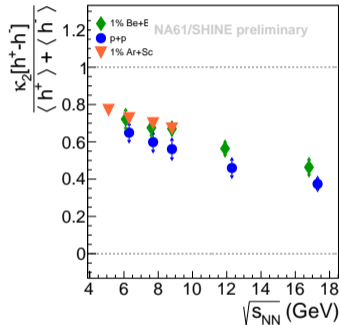
Searching for CP requires $\Delta Y_{corr} \ll \Delta Y_{accept} \ll \Delta Y_{total}$

arXiv:1512.05038v2 [nucl-th] 15 May 2016



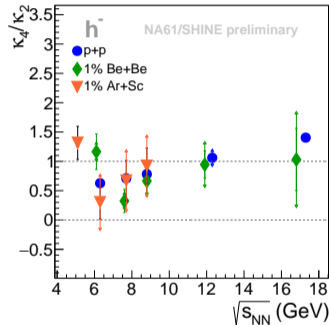
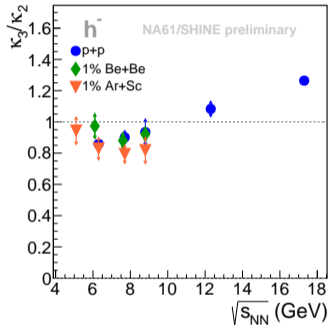
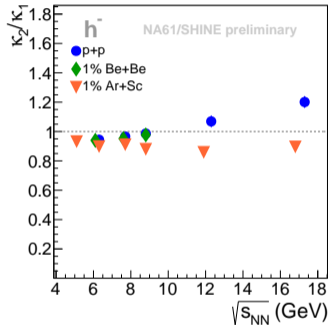
arXiv:nucl-th/0003046v5 3 May 2001

System size and energy dependence – net-charge



□ $p+p \approx Be+Be \approx Ar+Sc$ except for κ_3/κ_1

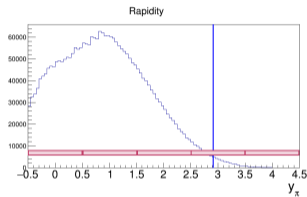
System size and energy dependence – negative charge



□ p+p $\not\approx$ Ar+Sc in case of κ_2/κ_1 but not for higher-order ratios

Rapidity dependence – negative charge

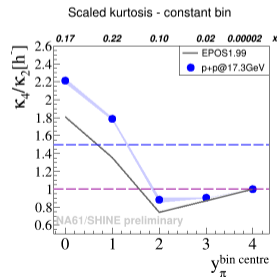
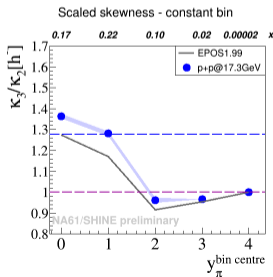
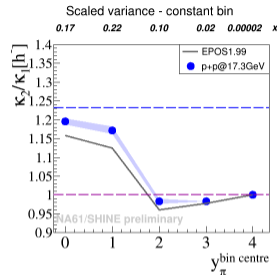
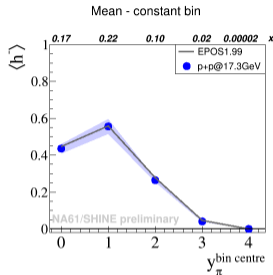
Constant bin – sensitivity for different measurements conditions.



- EPOS1.99 qualitatively agrees with data
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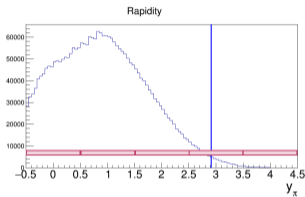
Dashed blue line – value in full analysis acceptance

Dashed violet line – 1 (reference for Poisson distribution)



Rapidity dependence – net-charge

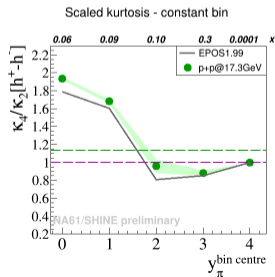
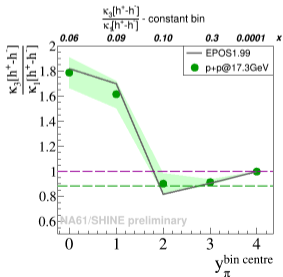
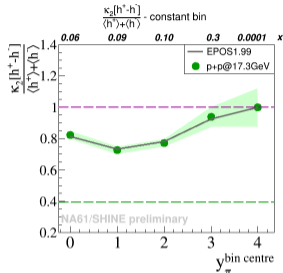
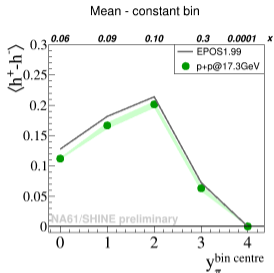
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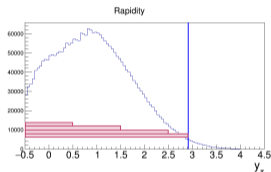
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Rapidity dependence – negative charge

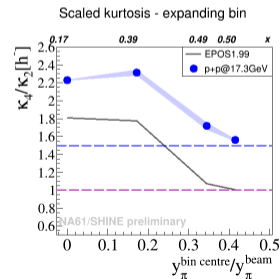
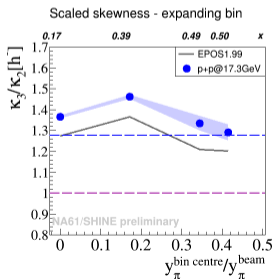
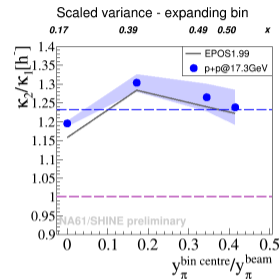
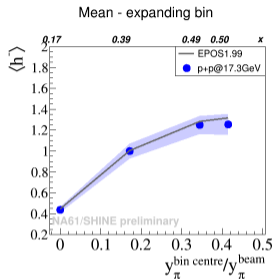
Expanding bin - comparison of short- and long-range correlations.



□ EPOS1.99 doesn't agree with data

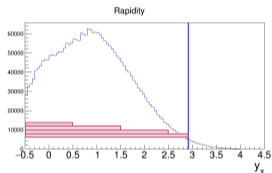
Dashed blue line – value in full analysis acceptance

Dashed violet line – 1 (reference for Poisson distribution)



Rapidity dependence – net-charge

Expanding bin - comparison of short- and long-range correlations.



□ EPOS1.99 is comparable with data

Dashed green line – value in full analysis acceptance

Dashed violet line – 1 (reference for Poisson distribution)

