New results on fluctuations in NA61/SHINE experiment

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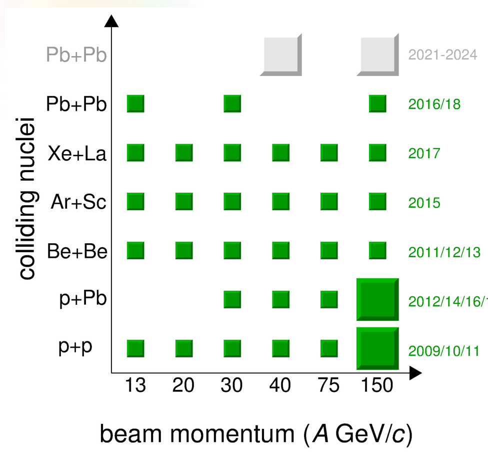
Motivation

Presented results are an important part of NA61/SHINE ion programme,which is devoted to study phase transition and search for the critical point of strongly interacting matter. A critical point, if present, is an end point of the first order phase transition line (hadronic matter $\longleftrightarrow$ quark-gluon plasma) that has the properties of a second order phase transition. At the critical point the correlation length diverges, what causes an increase of the fluctuations signal. Different models [1][2] point to different possible locations of the critical point. NA61/SHINE performs the system size - energy scan to sample very interesting region of phase space diagram. In this contribution, fluctuation analysis methods used by NA61/SHINE, recent fluctuation results and its comparison with model predictions will be discussed.



System size - energy scan scheme

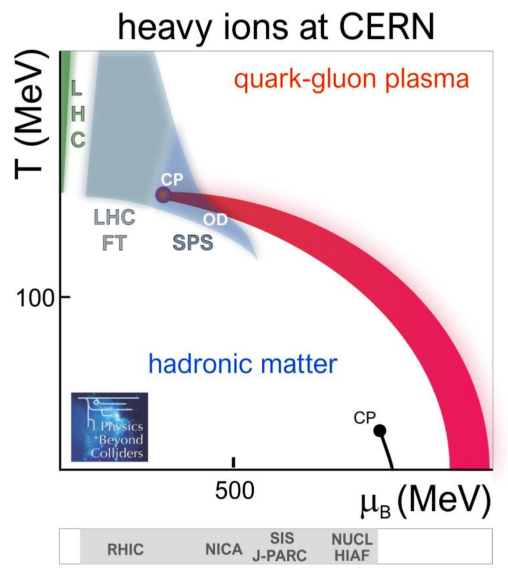
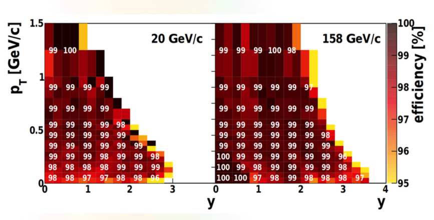


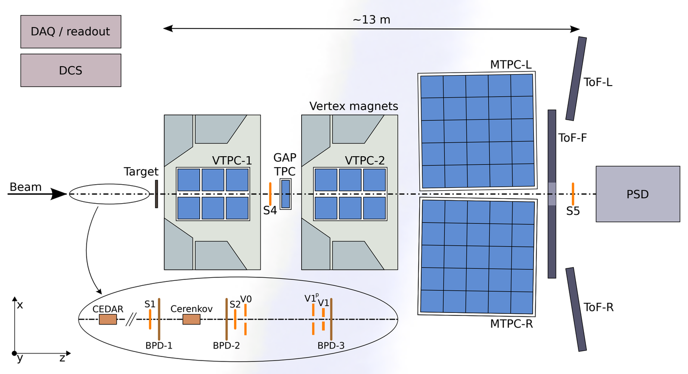
Diagram of strongly interacting matter

NA61/SHINE

NA61/SHINE is a fixed -target experiment placed in CERN, Switzerland. It uses the beam delivered by SPS accelerator. The setup contains large acceptance hadron spectrometer (TPC) with high tracking efficiency (>90%). Centrality selection in nucleus-nucleus is possible thanks to Projectile Spectator Detector (PSD). The experimental set-up and acceptance range are shown in the pictures below.



Acceptance of NA61/SHINE detector with tracking efficiency



NA61/SHINE detector [3]

Conclusions

- no indication of critical point in the multiplicity fluctuations analysis
- rapidity dependence of higher order moments of p+p at 158A GeV/c can be described by EPOS1.99 model
- no indication for a power-law increase is observed in the intermittency analysis of Ar+Sc at 150A GeV/c and Pb+Pb at 30A GeV/c

References

[1] Christian S Fischer, Jan Luecker, and Christian A Welzbacher. *Physical Review D*, 90(3):034022, 2014.

[2] Nikos G Antoniou and AS Kapoyannis. *Physics Letters B*, 563(3-4):165–172, 2003.

[3] N Abgrall et al. NA61/SHINE facility at the CERN SPS: beams and detector system. *Journal of Instrumentation*, 9(06):P06005, 2014.

[4] V Vovchenko, DV Anchishkin, MI Gorenstein, and RV Poberezhnyuk. *Physical Review C*, 92(5):054901, 2015.

Multiplicity and net charge fluctuations

Multiplicity (net-charge) fluctuations are defined by moments of a given multiplicity (net-charge) distribution higher than the first moment. One of obstacles in fluctuation measurements in heavy ion collisions is the inability to fix the size of the colliding system so the number of participants varies from event to event. To solve this problem we use quantities independent from the system size such as intensive quantities (IQ). They are obtained by dividing two extensive (dependent on the system size) quantities, e.g. cumulants of the distribution.

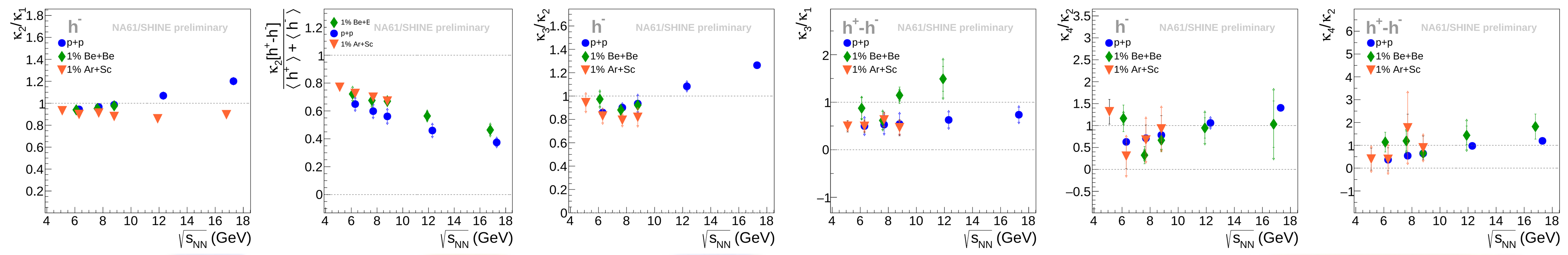
For multiplicity: $\omega[N] = \frac{k_2}{k_1}$, $S\sigma[N] = \frac{k_3}{k_2}$, $K\sigma^2[N] = \frac{k_4}{k_2}$,

For net-charge: $\omega[N] = \frac{k_2[h^+ - h^-]}{\langle h^+\rangle + \langle h^-\rangle}$, $S\sigma[N] = \frac{k_3}{k_1}$, $K\sigma^2[N] = \frac{k_4}{k_2}$,

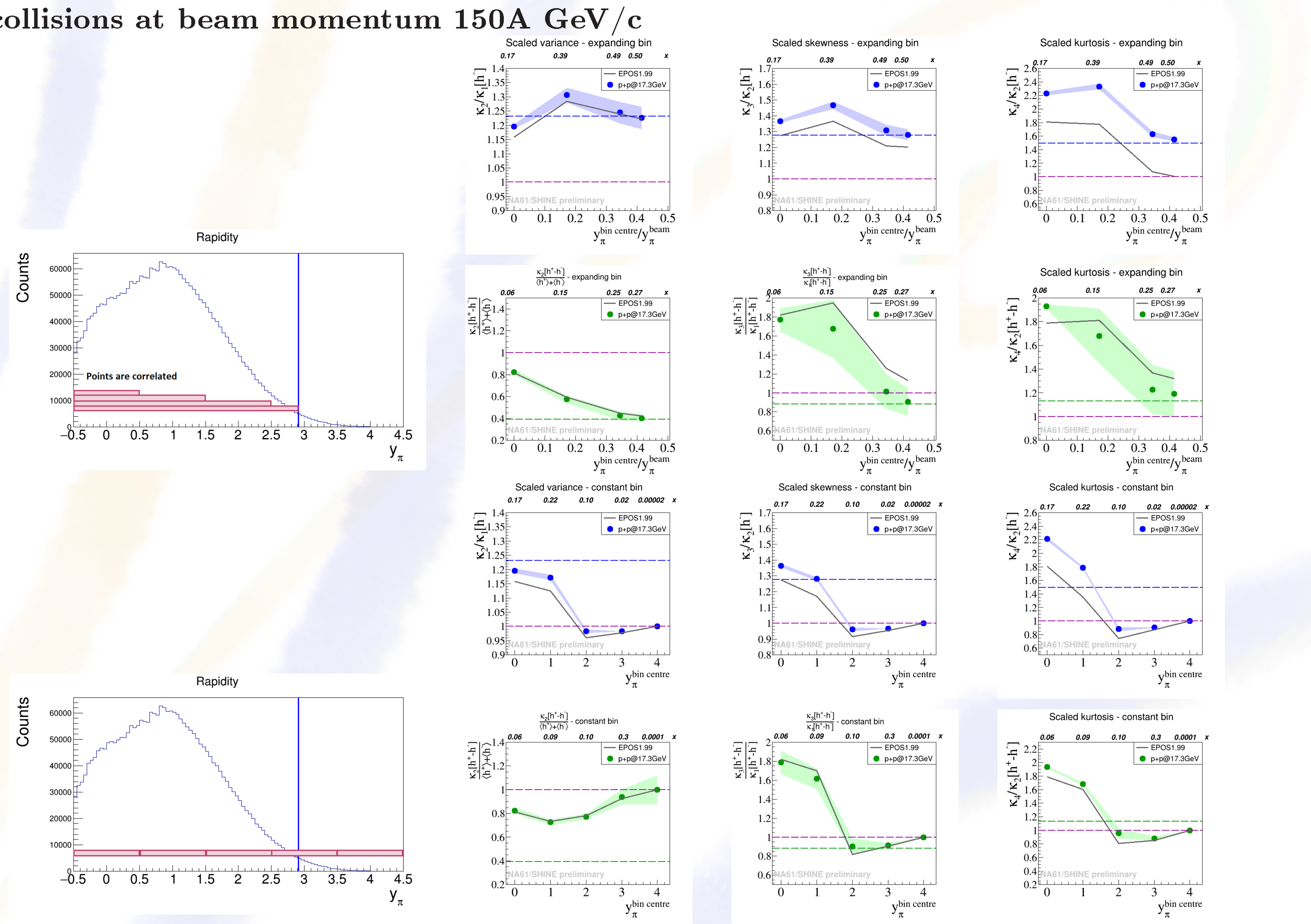
k_n - the n-th cumulant of the distribution

For the symmetric nuclear matter within Van der Waals equation of state, intensive quantities change values rapidly in the neighbourhood of the critical point, depending on the location on the phase diagram. [4] In the absence of critical point, for independent particle production $IQ = 1$ is expected. For the case of no fluctuations $IQ = 0$.

- **new results of h^- and net-charge energy dependence of $\omega[N]$, $S\sigma[N]$ and $K\sigma^2[N]$ for diffent systems**



- **new results of h^- and net-charge rapidity dependence of $\omega[N]$, $S\sigma[N]$ and $K\sigma^2[N]$ in p+p collisions at beam momentum 150A GeV/c**



Intermittency

In the critical point the system becomes scale invariant, what leads to the correlation length divergence what causes enhanced net-proton density fluctuations. Intermittency analysis examines how scaled second factorial moment $F_2(M)$ of proton momenta scales with a number of bins M at mid rapidity. In the critical system scaled factorial momnts shows a power law dependence on M.

$$F_2(M) = \frac{\left\langle \frac{1}{M}\sum_{i=1}^{M} n_i(n_i - 1)\right\rangle}{\left\langle \frac{1}{M}\sum_{i=1}^{M} ni\right\rangle} \sim (M)^{\phi_2}$$

M - the number of cells in p_T phase space
n_i - the number of particles in i_{th} cell
ϕ_2 = 5/6 for 2nd factorial moment in critical system

Instead of using p_x - p_y phase space, one can use cumulative quantities. They remove the dependence of F_2 on the shape of the single-particle distribution and transform any distribution into uniform one (0, 1).

$$Q_x = \frac{\int_{min}^{x} \rho(x)dx}{\int_{min}^{max} \rho(x)dx} \qquad Q_y(x) = \frac{\int_{y_{min}}^{y} P(x,y)dy}{P(x)}$$

Results from proton intermittency analysis with second scaled factorial moment and cumulative variables in inelastic Ar+Sc collisions at centrality 0-20% at 150A GeV/c beam momentum and Pb+Pb collisions at centrality 0-10% at 30A GeV/c beam momentum are presented.