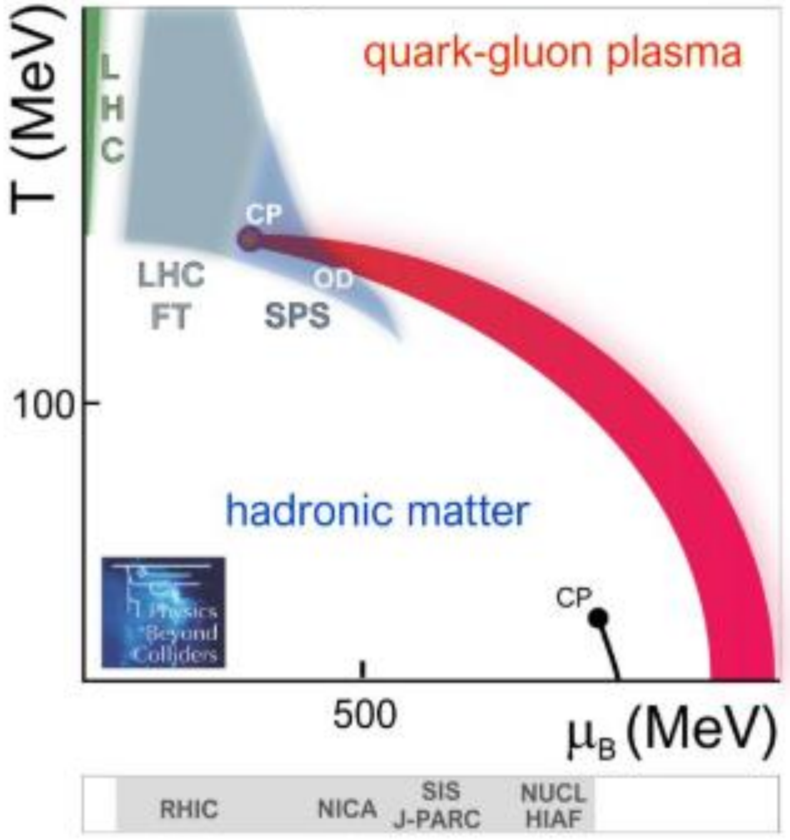
Plans for the analysis of multiplicity fluctuations in the MPD experiment

Valeria Zelina Ortiz Reyna, Maciej Rybczyński

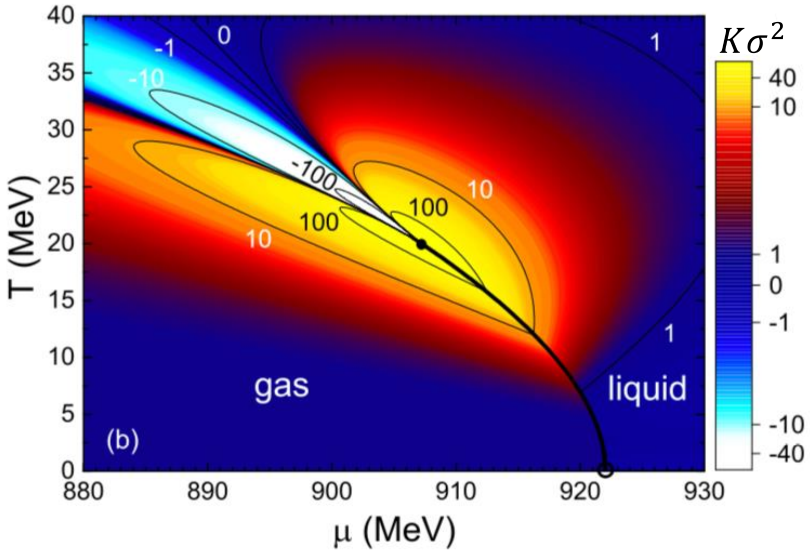
Jan Kochanowski University, Kielce, Poland

Motivation

Multiplicity (and net-charge) fluctuations measured using higher order moments of charged particles multiplicity distributions are tools to search for critical point of strongly interacting matter (CP). System size and energy scan gives an ideal opportunity to search for CP at NICA energies.



[arXiv:1901.04482v1]



Theoretical calculation of phase transition with values of intensive kurtosis for nuclear matter described with van der Waals equations.
[Vovchenko et al. Acta Phys.Polon. Supp. 10, 75]

CP→ increase of the correlation length ($\xi \to \infty$)
$\langle N^2 \rangle \sim \xi^2; \langle N^4 \rangle \sim \xi^7$

[Stephanov, J.Phys.G 38, 124147]

Higher order moments of multiplicity distribution

Definition:

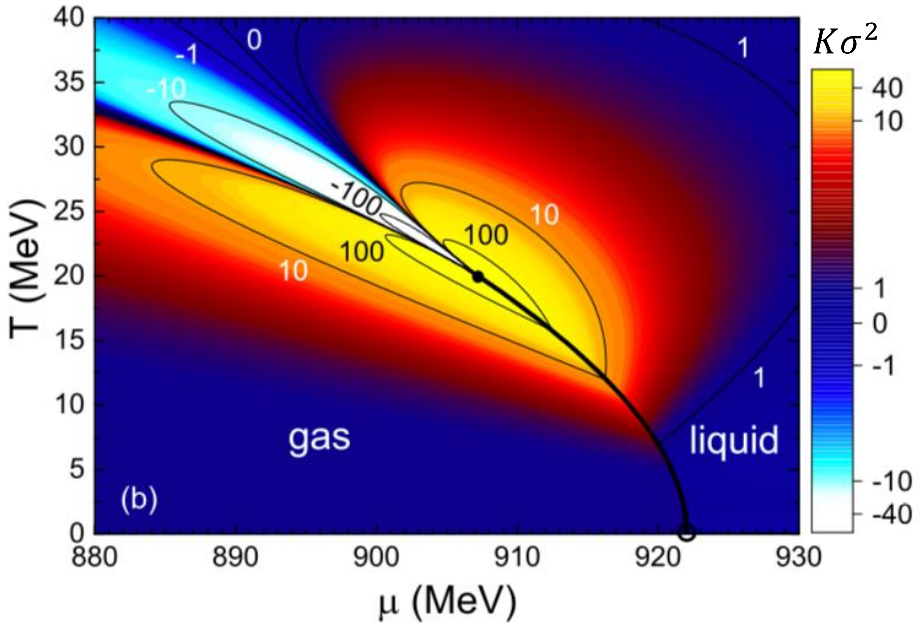
$$\kappa_1 = \langle N \rangle$$
$$\kappa_2 = \langle (\delta N)^2 \rangle = \sigma^2$$
$$\kappa_3 = \langle (\delta N)^3 \rangle = S\sigma^3$$
$$\kappa_4 = \langle (\delta N)^4 \rangle - 3\langle (\delta N)^2 \rangle^2 = K\sigma^4$$

where:

N – multiplicity;

$$\delta N = \langle N - \langle N \rangle \rangle$$

σ – standard deviation;
S – skewness;
K – kurtosis



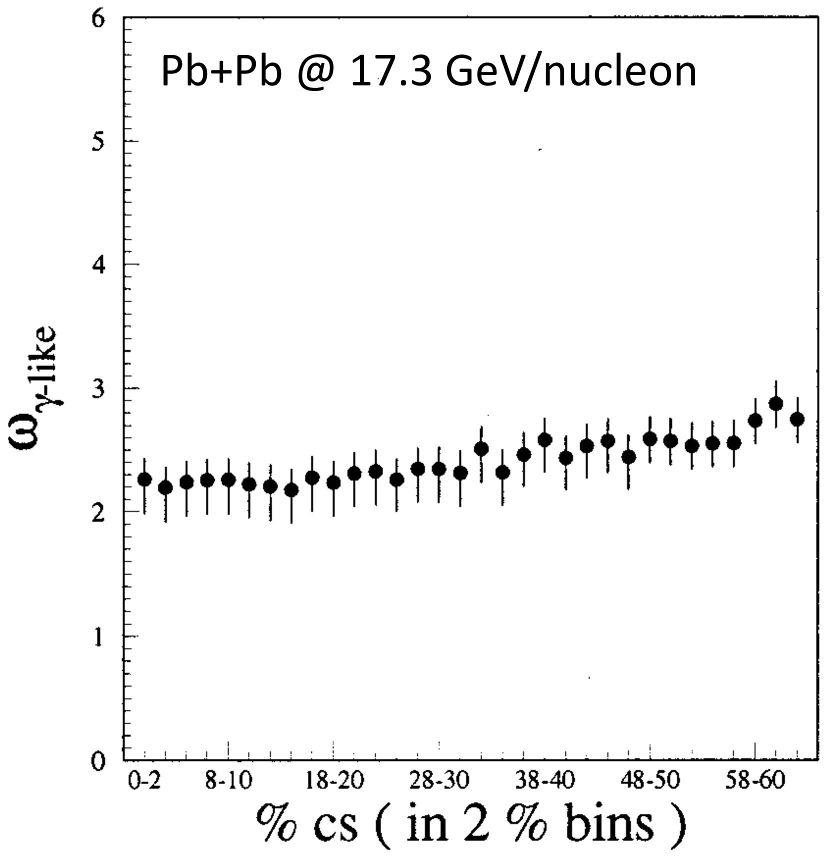
Nucleon system with van der Waals EOS in GCE formulation in the vicinity of the Critical Point [Vovchenko, Gorenstein, Stoecker, PRL 118, 182301; Vovchenko, et al., JPA 48, 305001]

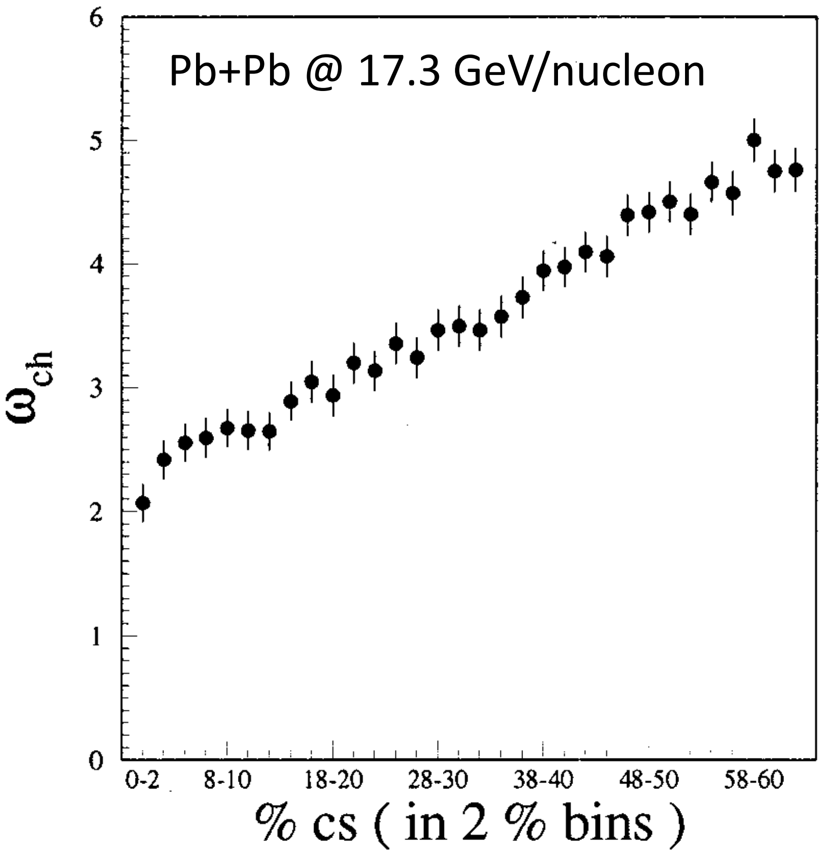
Cumulant ratios do not depend on the system volume

$$\omega = \frac{\kappa_2}{\kappa_1} \qquad S\sigma = \frac{\kappa_3}{\kappa_2} \qquad K\sigma^2 = \frac{\kappa_4}{\kappa_2}$$

Higher order moments: **scaled variance**, intensive skewness and intensive kurtosis of conserved quantities distributions are sensitive to the correlation length divergence

Multiplicity fluctuations results, so far: WA98@SPS

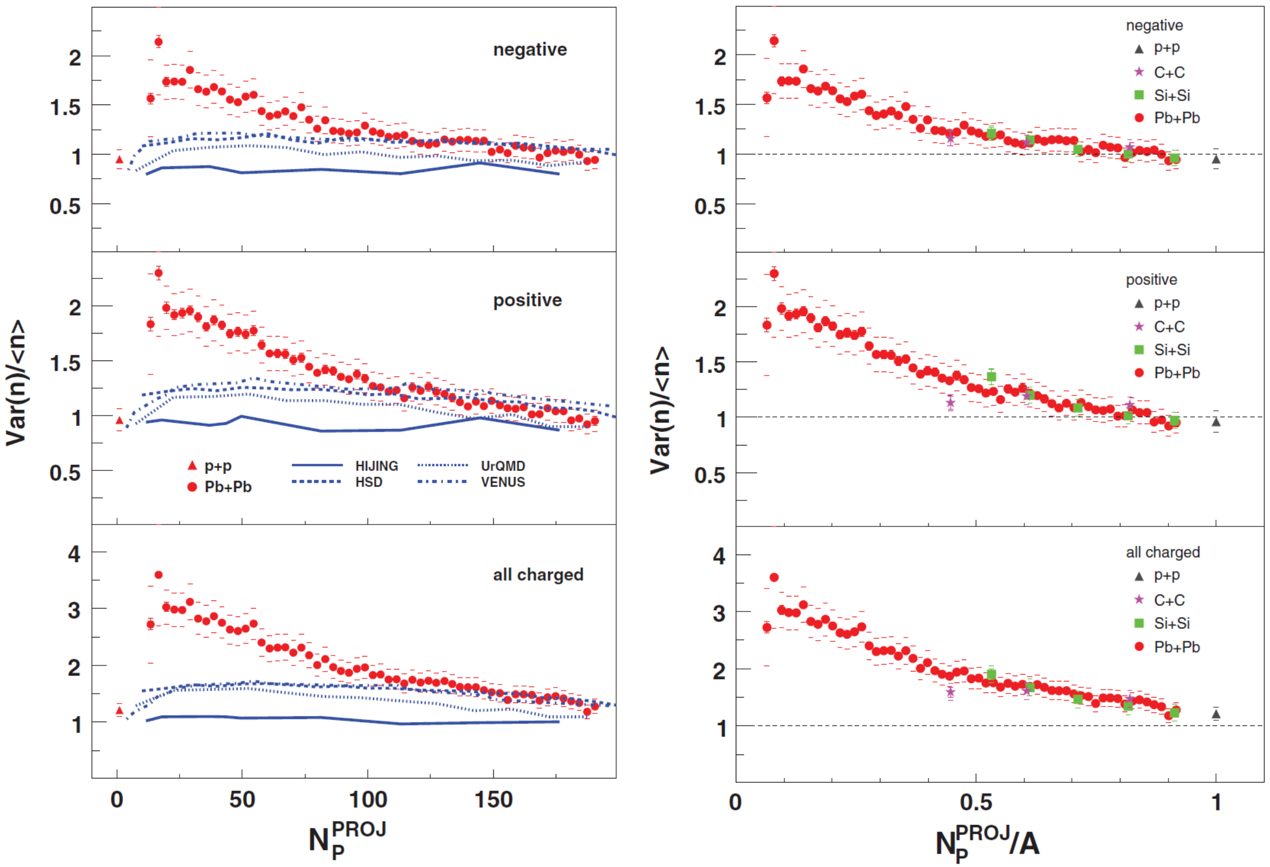


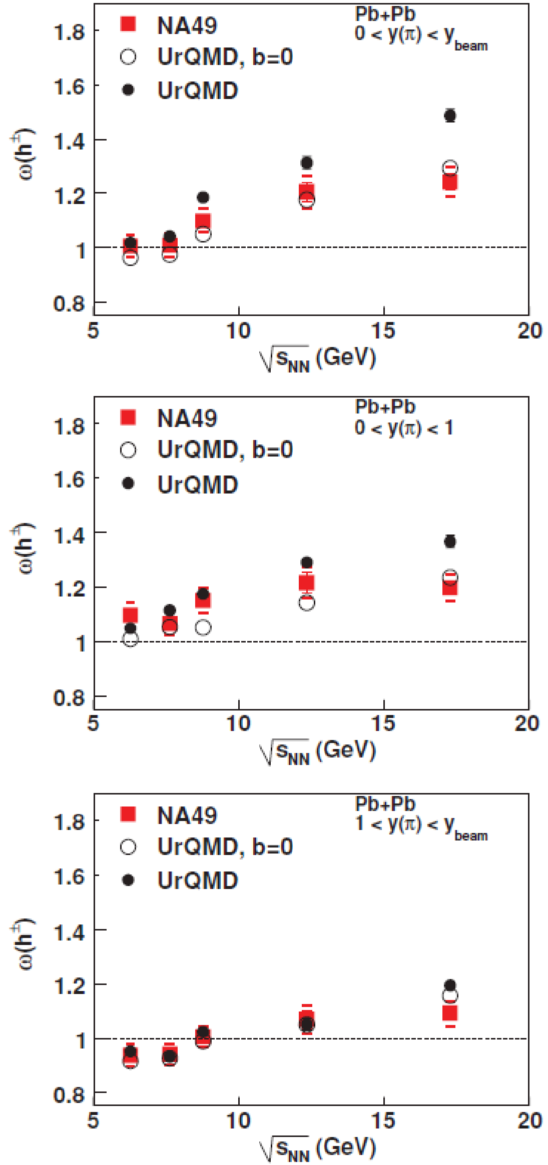


Fixed-target WA98 experiment measured both charged and neutral particles multiplicity fluctuations in the same experimental conditions
[M. M. Aggarwal et al., Phys. Rev. C **65**, 054912]

Multiplicity fluctuations results, so far: NA49@SPS

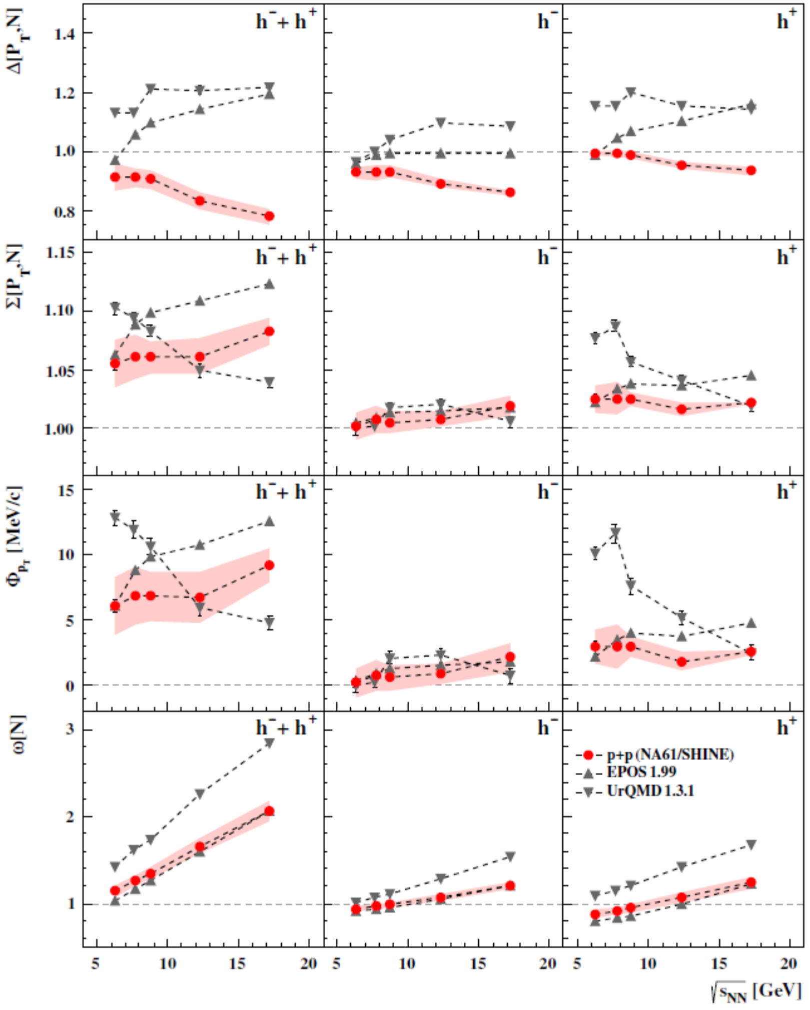
$\sqrt{s_{NN}} = 17.3$ GeV

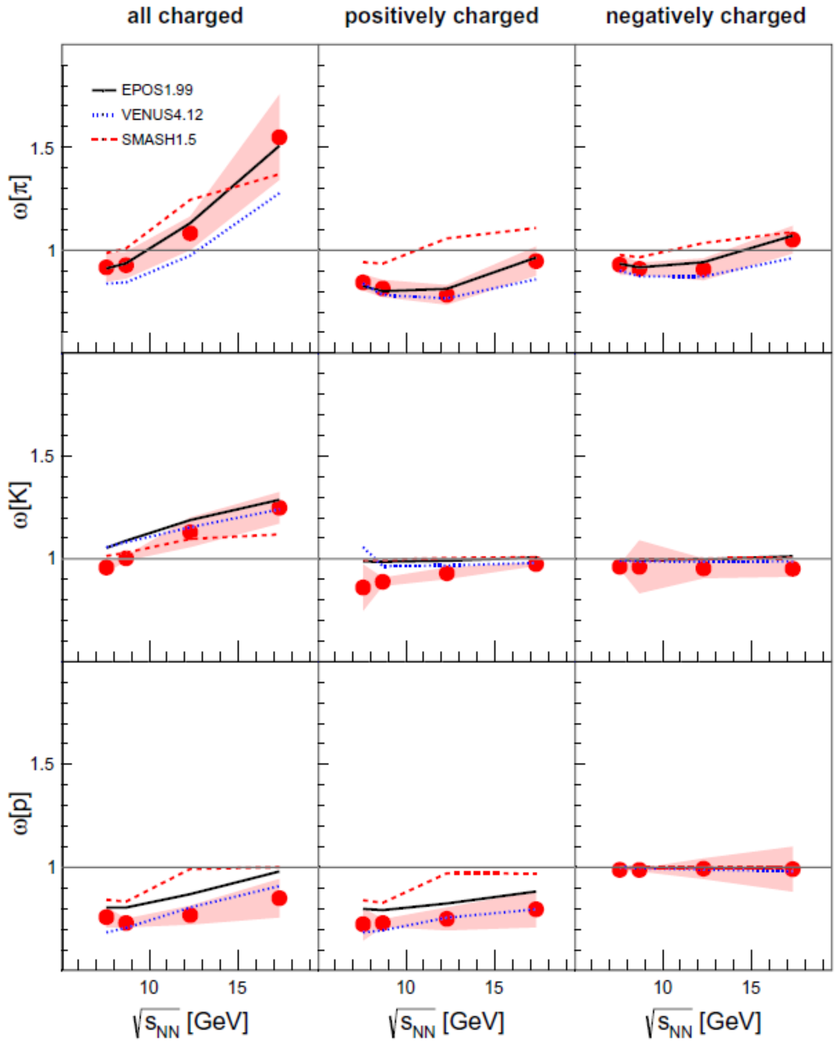




Fixed-target NA49 experiment measured centrality and system-size dependence [C. Alt et al., Phys. Rev. C **75**, 064904] as well as energy dependence [C. Alt et al., Phys. Rev. C **78**, 034914] of multiplicity fluctuations

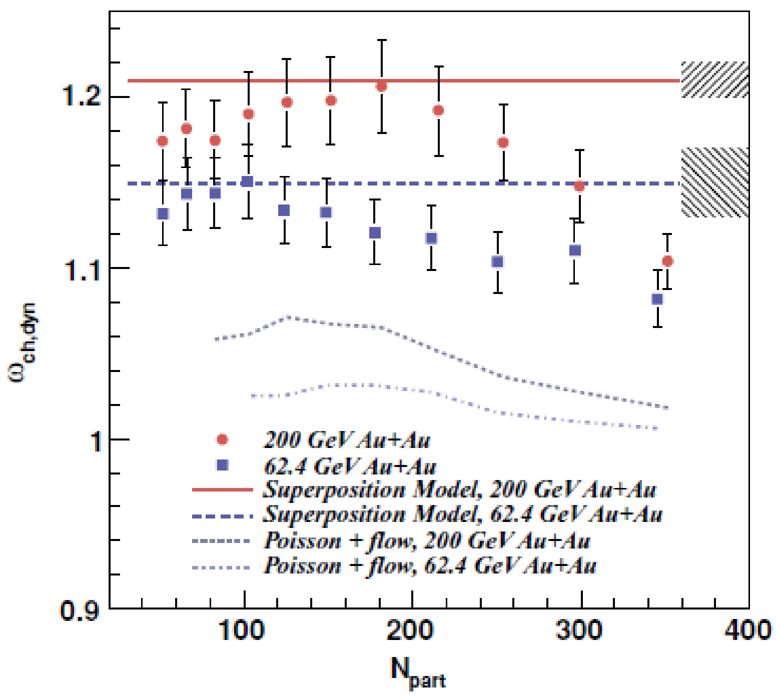
Multiplicity fluctuations results, so far: NA61/SHINE@SPS

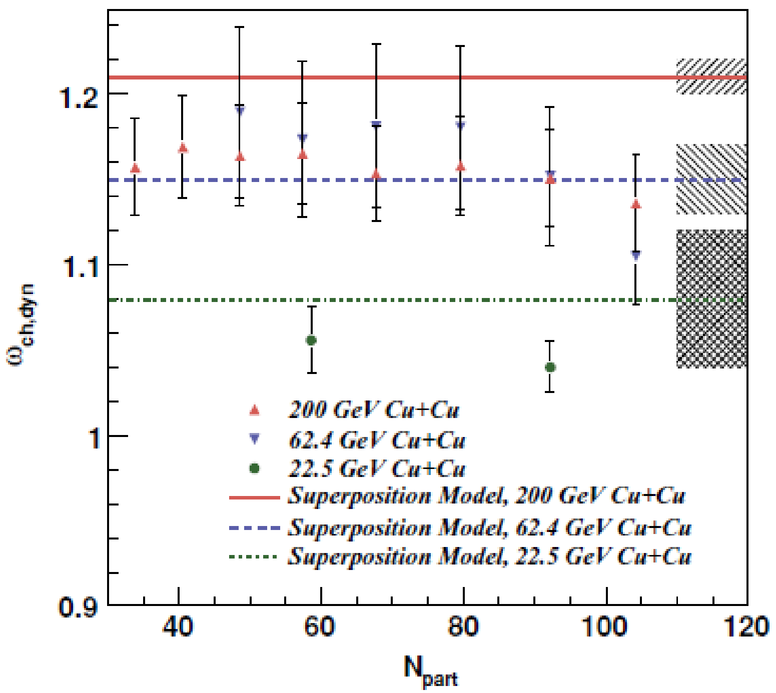




Fixed-target NA61/SHINE experiment used different measures of multiplicity fluctuations of charged hadrons [A. Aduszkiewicz et al., Eur. Phys. J. C **76**, 635] as well as identified particles [A. Acharya et al., Eur. Phys. J. C **81**, 384]

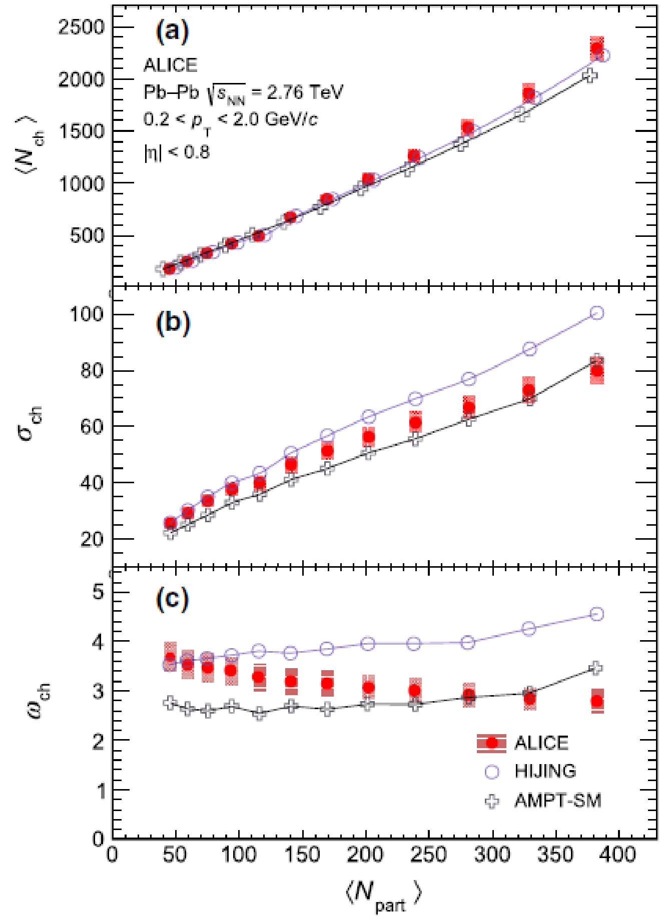
Multiplicity fluctuations results, so far: PHENIX@RHIC

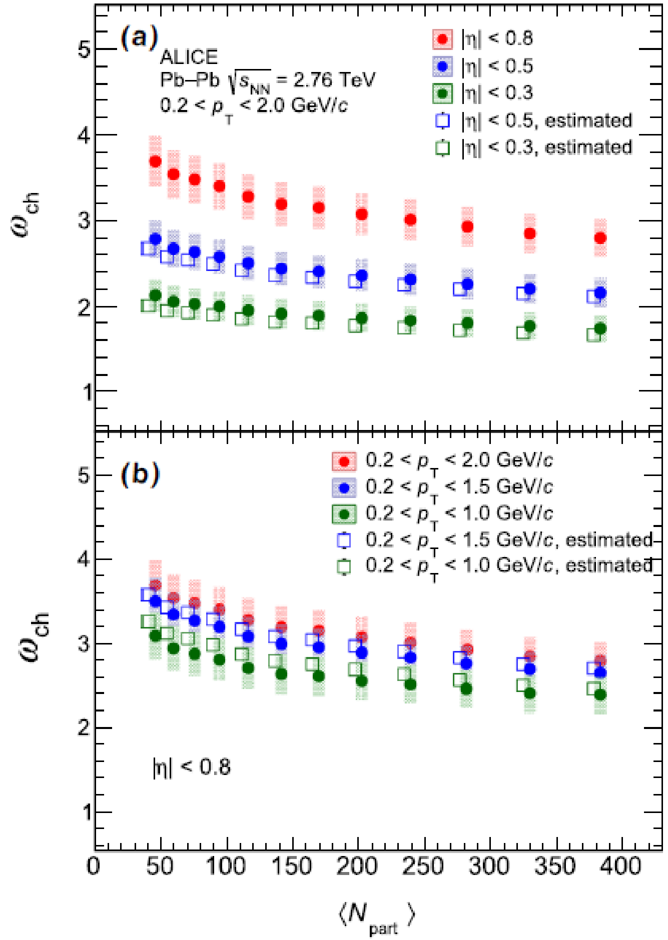




Multiplicity fluctuations from collider experiment [A. Adare et al. Phys. Rev. C **78**, 044902]
– quite small acceptance ~ 1% of charged particles

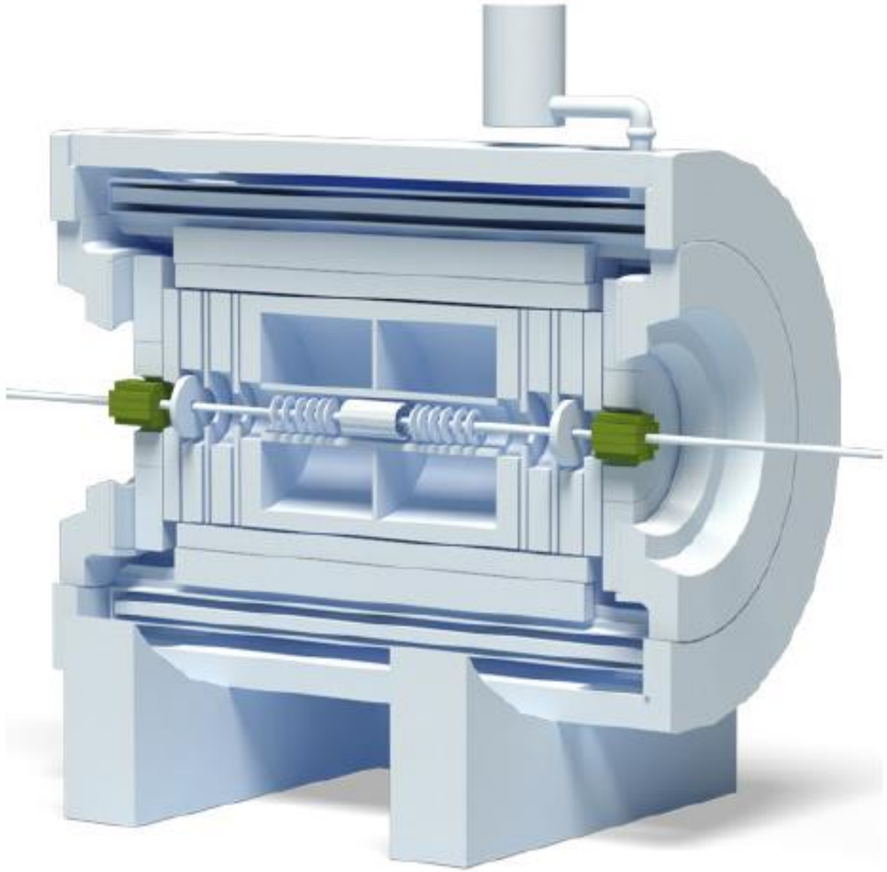
Multiplicity fluctuations results, so far: ALICE@LHC



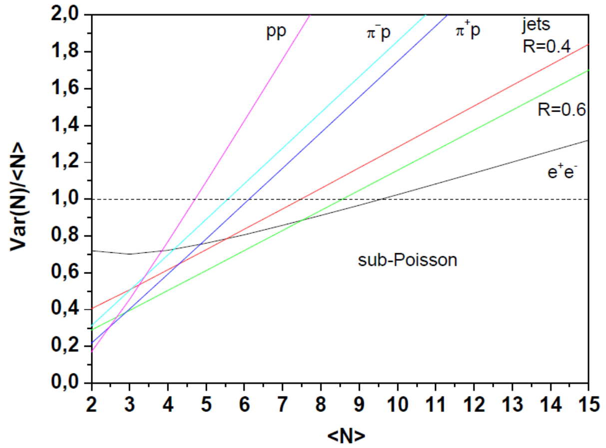


Recent results on multiplicity fluctuations obtained at, so far, highest energy: 2.76 TeV/nucleon [S. Acharya et al. Eur. Phys. J. C 81, 1012]

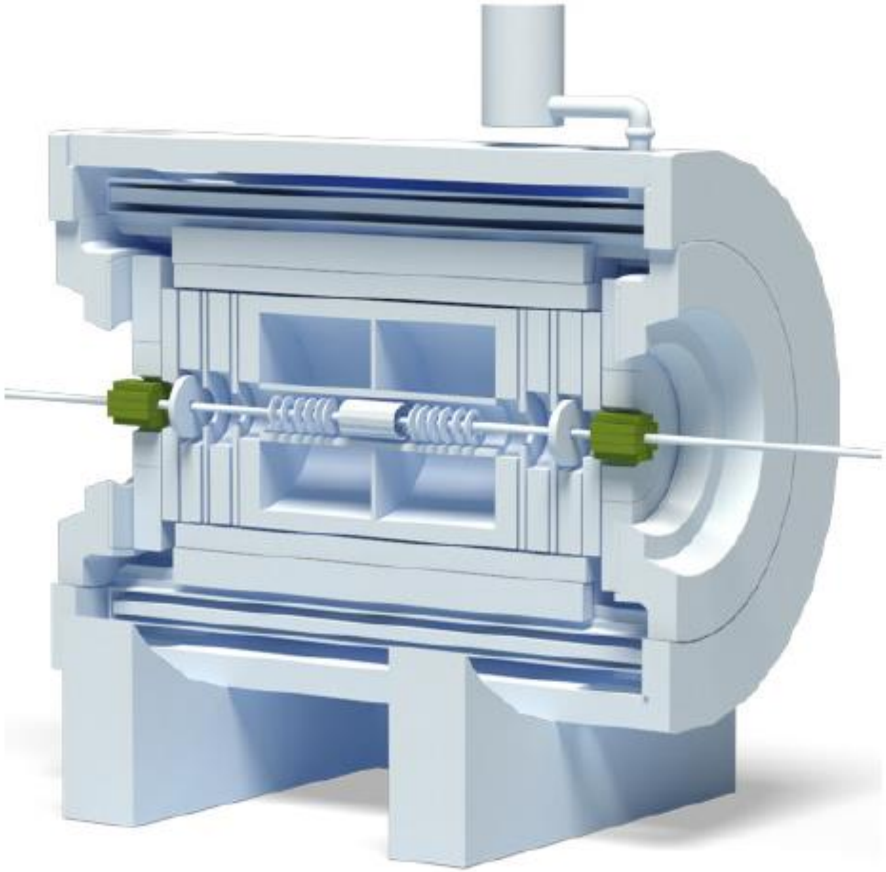
MPD experiment provides excellent opportunities for the measurement of multiplicity fluctuations



- ✓ Very good track resolution in the Time Projection Chamber
- ✓ Precise selection of collision centrality based on the measurement of number of colliding nucleons from both projectile and target beam (unique!)
- ✓ Not yet fully explored energy range of colliding ions ($4\ \mathrm{GeV} < \sqrt{s_{NN}} < 11\ \mathrm{GeV}$) → transition from sub-Poissonian to super-Poissonian multiplicity distributions



Measurement of multiplicity fluctuations – prerequisites and special needs



- ✓ Centrality selection (crucial!)

  Centrality dependence of multiplicity fluctuations in heavy-ion collisions have to be determined in the well defined narrow centrality bins of forward energy measured by FHCal to minimize volume fluctuations.

- ✓ 3D acceptance map (very important!)

  Phase-space (transverse momentum – rapidity – azimuthal angle) acceptance very important for comparison of the measured multiplicity fluctuations with various model predictions.

The ultimate goal would be the preparation of fully corrected multiplicity distributions – a source of full information on multiparticle production processes.

Team

- ✓ Multiplicity fluctuations at NICA energies is a subject of PhD thesis of Valeria Zelina Ortiz Reyna – a member of MPD collaboration from Jan Kochanowski University

- ✓ Two senior scientists from Jan Kochanowski University

- ✓ In case of needs for multiplicity fluctuations man power additional PhD students possible

Backup slides

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$$\omega = \frac{\kappa_2}{\kappa_1}$$

Scaled variance - the most commonly used intensive fluctuation measure independent of the number of sources or the system volume, but still depend on the volume fluctuations

$$\omega_A \equiv \frac{\langle A^2 \rangle - \langle A \rangle^2}{\langle A \rangle} = \frac{\langle a^2 \rangle - \langle a \rangle^2}{\langle a \rangle} + \langle a \rangle \frac{\langle N_S^2 \rangle - \langle N_S \rangle^2}{\langle N_S \rangle}$$

scaled variance of the quantity A for each source

scaled variance of the number of sources