Intermittency of charged hadrons in NA61/SHINE

(poster presentation)

Tobiasz Czopowicz
for the **NA61/SHINE Collaboration**

Jan Kochanowski University
Warsaw University of Technology

Quark Matter 2022
Kraków
April 4–10, 2022

Critical point is a hypothetical end point of the first order phase transition line (QGP-HM) that has properties of second order phase transition.

2^{nd} order phase transition $\longrightarrow$ scale invariance $\longrightarrow$ power-law form of correlation function. These expectations

are for fluctuations and correlations in the configuration space which are expected to be projected to the momentum space via quantum statistics and/or collective flow. The main signal of the CP is anomaly in

fluctuations in a narrow domain of the phase diagram.

In the Grand Canonical Ensemble the correlation length diverges at the second order phase transition and the system becomes scale invariant. This phenomenon leads to enhanced multiplicity fluctuations with special properties, that can be revealed by **scaled factorial moments** $F_r(\delta)$ of order r:

$$F_r(\delta) = \frac{\left\langle \frac{1}{M} \sum_{i=1}^{M} n_i(n_i-1)\ldots(n_i-r+1) \right\rangle}{\left\langle \frac{1}{M} \sum_{i=1}^{M} n_i \right\rangle^r}$$

- δ - is the size of each of the M subdivision intervals of the momentum phase-space region Δ
- n_i - number of particles in i-th bin
- $\langle\ldots\rangle$ - averaging over events

When the system is a simple fractal and $F_r(\delta)$ follows a **power law** dependence:

$$F_r(\delta) = F_r(\Delta)\cdot(\Delta/\delta)^{\phi_r}.$$

Additionally, the exponent (intermittency index) ϕ_r obeys the relation:

$$\phi_r = (r-1)\cdot d_r,$$

where the anomalous fractal dimension d_r is independent of r.

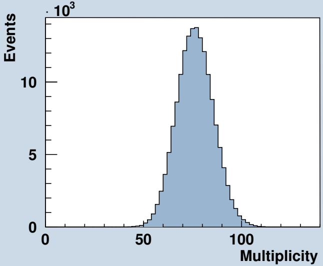
The goal of the analysis is to locate the **critical point** of the strongly interacting matter

— *by* —

measuring **Scaled Factorial Moments** of multiplicity distributions of a selection of **negative hadrons** from a selection of Pb+Pb at 30*A* GeV/*c* interactions using **statistically independent points** and **cumulative variables**.

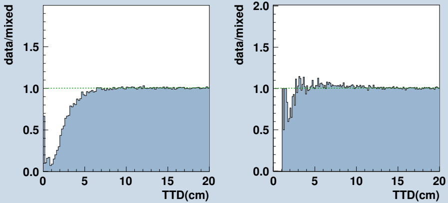
Negative hadrons

- negative hadrons are selected by removing electrons from all negative particles using a dE/dx graphical cut
- $p_x < 1.5$ GeV/*c*, $p_y < 1.5$ GeV/*c*
- $-0.50 < y_{\pi}^{CMS} < 0.50$



mTTD

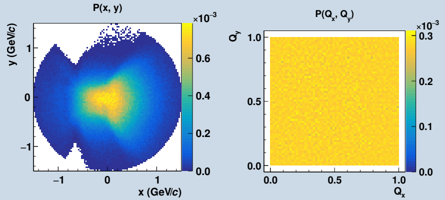
Using TPCs, it is not possible to reconstruct pairs of particles too close to each other in space Momentum-based Two-Track Distance cut was developed to describe the effect allowing for comparison with models



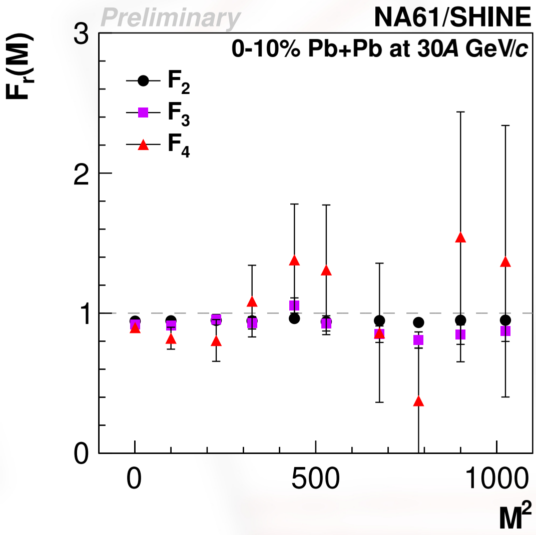
Cumulative transformation

instead of using $p_x - p_y$ distribution, one can use their cumulative equivalents, Q_x and Q_y.

Then, $F_r(M)$ would no longer depend on single-particle transverse momentum distribution



- preliminary results on $F_2(M)$, $F_3(M)$ and $F_4(M)$ for **negative hadrons** produced in 10% most central Pb+Pb collisions at 30*A* GeV/*c*at NA61/SHINE
- cumulative transformation of p_x and p_y used
- points are statistically independent – each point in the plot is calculated using a separate subset of the whole available data
- momentum-based Two-Track Distance cut used to remove split tracks
- $F_r(M) = \mathrm{const}(M)$
  no structures that could be related to the critical point are observed



Conclusions

- hadron intermittency analysis (scaled factorial moments of multiplicity distribution dependence on number of momentum bins) is a promising tool for locating the critical point of strongly interacting matter
- scaled factorial moments become independent of singe particle momentum distribution when cumulative transformation is used
- negative hadrons multiplicity allows to study scaled factorial moments up to the 4^{th} order
- so far, no prominent structures have been observed that could be related to the critical point

References

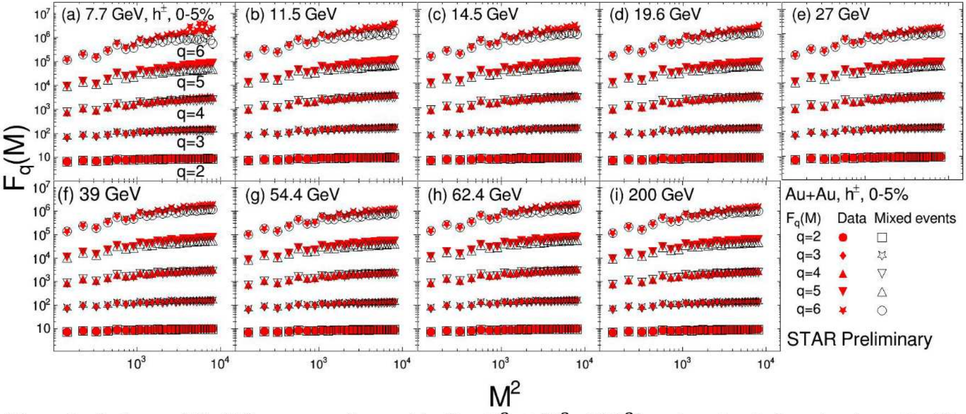
- Asakawa, Yazaki NPA 504 (1989) 668
- Barducci, Casalbuoni, De Curtis, Gatto, Pettini, PLB 231 (1989) 463
- Stephanov, PoS LAT2006 (2006) 024
- Wosiek, APPB 19 (1988) 863
- Satz, NPB 326 (1989) 613
- Bialas, Peschanski, NPB 273 (1986) 703
- Wosiek, APPB 19 (1988) 863
- Bialas, Hwa, PLB 253 (1991) 436
- Bialas, Peschanski, NPB 273 (1986) 703
- Antoniou, Diakonos, Kapoyannis, Kousouris, PRL 97 (2006) 032002
- Bialas, Gazdzicki, PLB 252 (1990) 483

Thank You!

Potential discrepancy with STAR

$F_q(M)$ (up to sixth order) for Charged particles in Au + Au Collisions

Charged particles



- The calculations of $F_q(M)$ were performed in the $M^2 \in [1^2,\ 100^2]$ and up to sixth order ($q = 2{\sim}6$). Statistical uncertainties are shown but smaller than maker size.
- $F_q^{data}(M)$ are larger than $F_q^{mix}(M)$ at large M^2 region.

$$\Delta F_q(M) = F_q^{data}(M) - F_q^{mix}(M)$$

2021/10/20 Intermittency-STAR **15**