Intermittency analysis of proton density as a probe for the critical point of strongly interacting matter in NA61/SHINE

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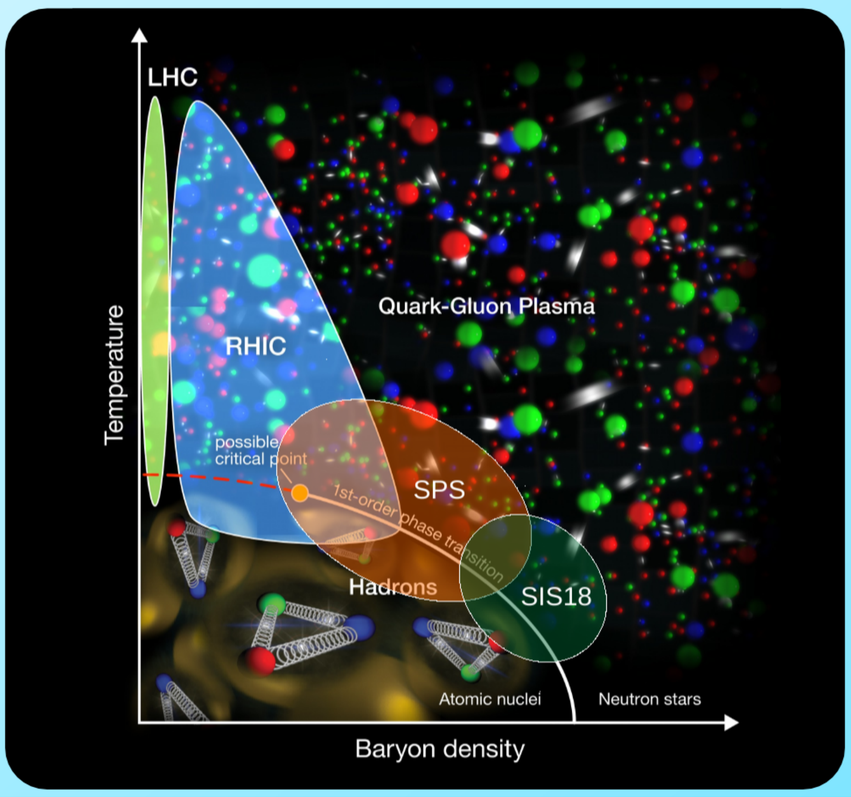

We look for **experimental signatures** of the **critical point of strongly interacting matter** in **NA61/SHINE medium-size system** (Be+Be, Ar+Sc, Xe+La) collisions at **150A GeV/c beam momentum**.

- We consider **local observables** related to the **order parameter** of the **chiral phase transition**, the **chiral condensate** $\sigma(\mathbf{x}) =< \bar{q}(\mathbf{x})q(\mathbf{x}) >$.
- At **finite baryon density**, the **critical fluctuations** of the chiral condensate are transferred to the **net-baryon density** [1]. For a critical system, we expect **net-proton density fluctuations** to obey **power-laws** with critical exponents determined by the **3D Ising universality class** [2-4].

- **Self-similar proton density fluctuations** correspond to **power-law scaling** of the proton **density-density correlation function** in **transverse momentum space**;
- **Intermittency analysis** examines how **Second Scaled Factorial Moments** (SSFM) $F_2(M)$ of proton momenta **scale** with the **number of 2D bins** M^2 at mid-rapidity:

$$F_2(M) = \left\langle \frac{1}{M^2}\sum_{i=1}^{M^2} n_i(n_i-1)\right\rangle \Bigg/ \left\langle \frac{1}{M^2}\sum_{i=1}^{M^2} n_i\right\rangle^2 ,$$

where $\langle \ldots \rangle$ denotes average over events.

- For **pure critical system**, we predict [4]:

$$F_2(M) \sim (M^2)^{\phi_{2,cr}} \quad , \quad \phi_{2,cr}^{(p)} = 5/6$$

- For a **noisy system**, **mixed event** moments must be **subtracted** from the data to reveal **critical component**:

$$\Delta F_2(M) = F_2^{(d)}(M) - F_2^{(m)}(M)$$

- **Intermittency analysis** requires **large statistics**, **adequate** (≥ 2) **proton mean multiplicity** in mid-rapidity and **reliable proton identification** (80-90% proton **purity**)

References

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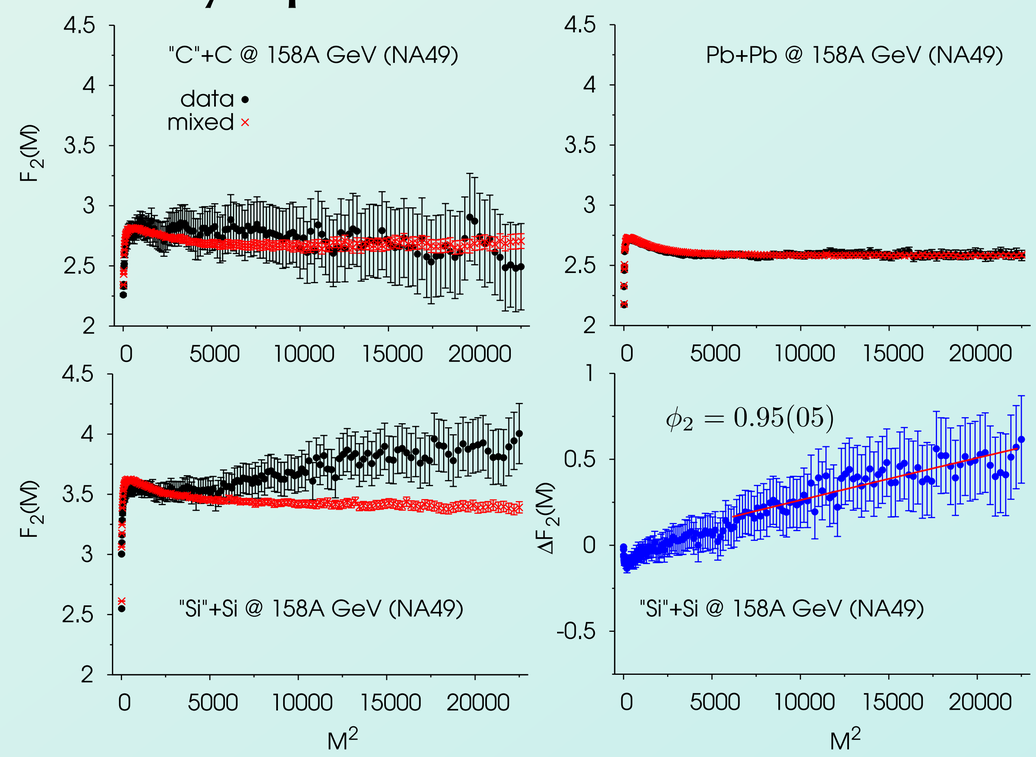
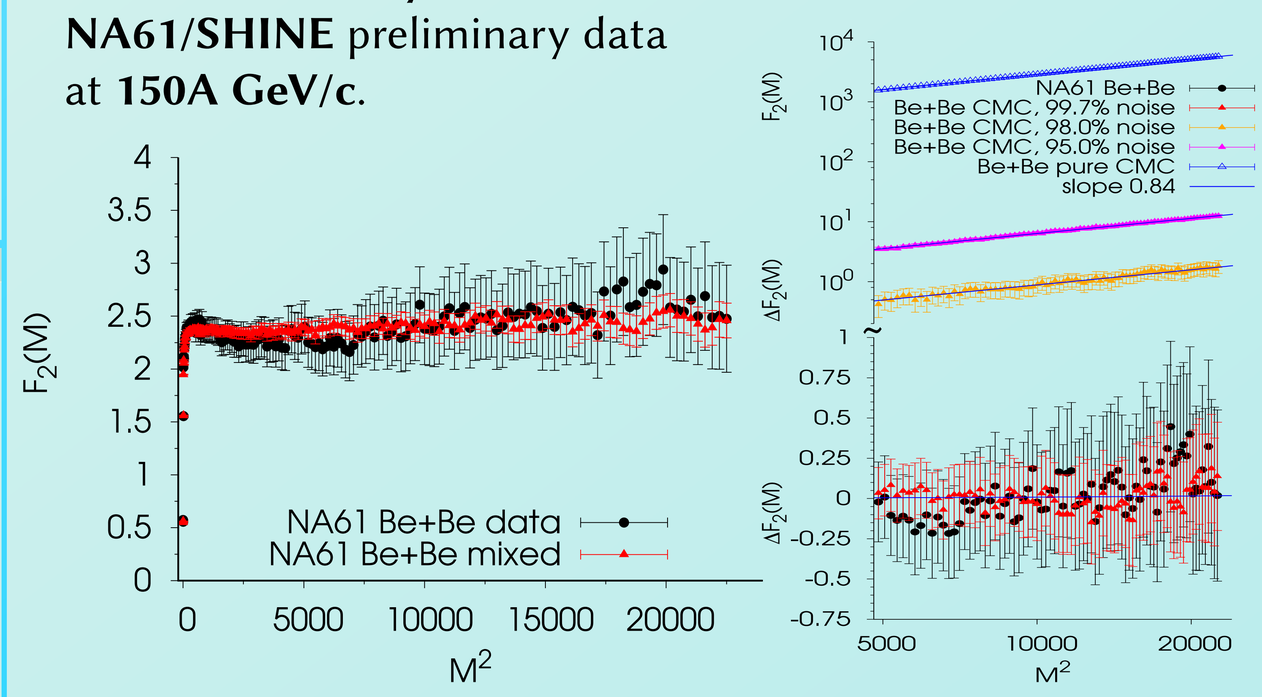
- **Previous analysis** [5] of **NA49 systems** revealed **significant power-law fluctuations** of proton density in **Si+Si** at **158A GeV/c**, with a power-law exponent **consistent** with the **theoretically expected critical value** within uncertainties.



- **No intermittent behaviour** is visible in **C+C & Pb+Pb systems** at the same energy.
- Results suggest a critical point in the vicinity of the **Si+Si** freeze-out state **($\mu_B \sim 250$ MeV)** [5].

- **No intermittency effect** is observed in **Be+Be NA61/SHINE** preliminary data at **150A GeV/c**.



- **Critical Monte Carlo (CMC)** [4] simulation of **background + critical protons** sets critical component **upper limit** at **~ 0.3%**.

Conclusions

Intermittency analysis of proton transverse momenta provides us with **a promising set of observables** for locating the **critical point** of strongly interacting matter.

Analysis of NA49 collisions at **158A GeV/c** detects **significant power law fluctuations** in the **Si+Si** system, although with large uncertainty in the determination of ϕ_2. **No intermittent behaviour** is visible in **C+C & Pb+Pb systems** at the same energy.

Possible connection of Si+Si **intermittent behaviour** to the **onset of fireball** [7] should be further investigated, as both are located **close** to the same **limiting system size**.

Analysis of NA61/SHINE medium-size systems is **ongoing**; **intermittency analysis** is expected to be **feasible** for at least the **Ar+Sc** system at **150A GeV/c**.

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