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QM 2023

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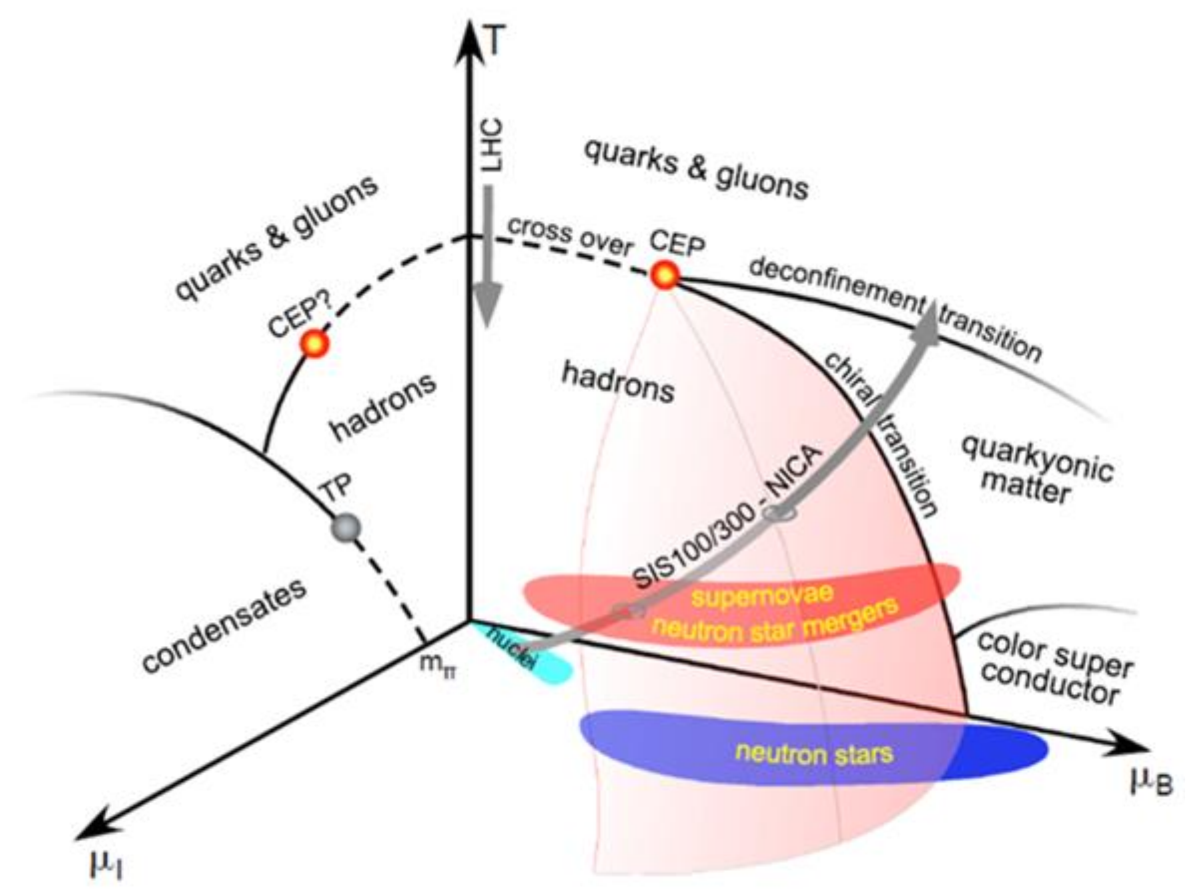
First feasibility study for Asymmetric Cumulants of flow amplitudes in CBM at FAIR

Phase diagram of QCD matter

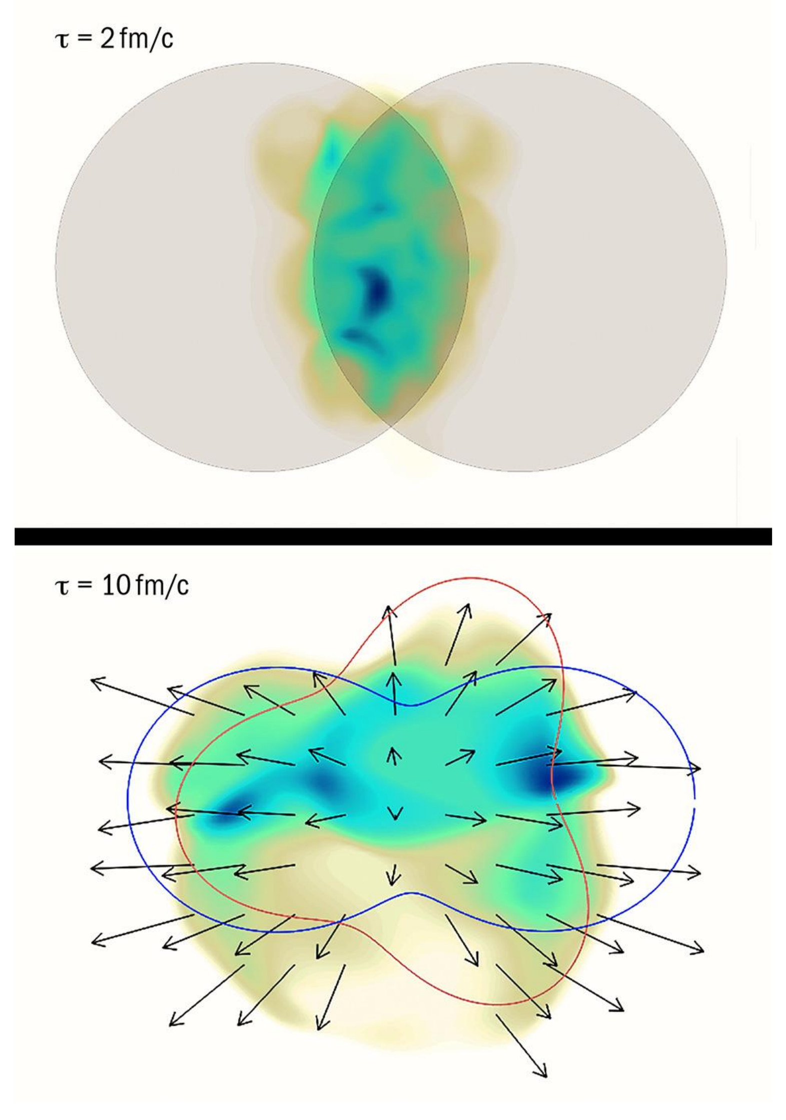
- ❑ CBM experiment at FAIR is optimized to explore properties of QCD matter at very high densities, by colliding heavy ions



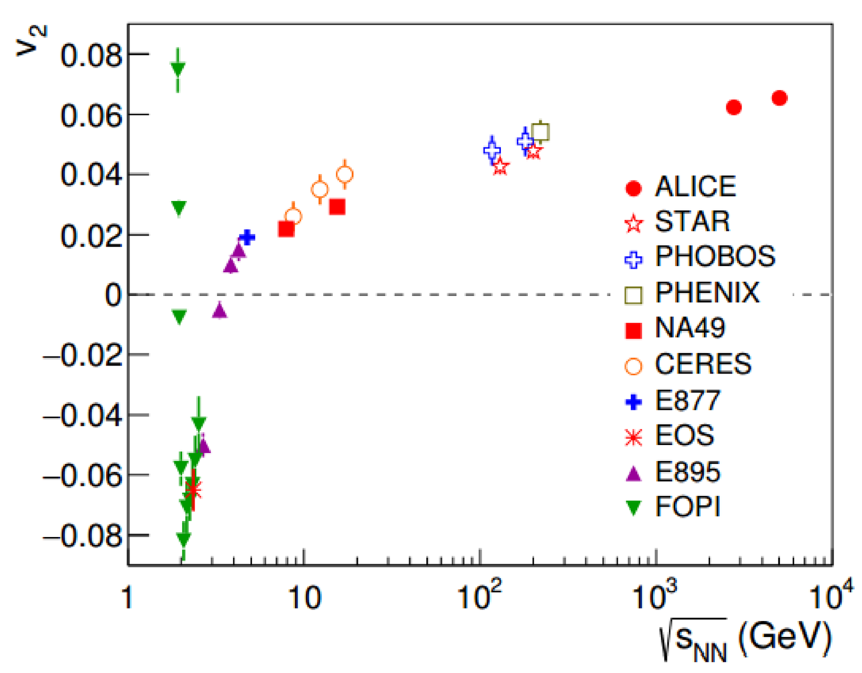
- ❑ Scientific objectives of CBM experiment:
  - What is the equation-of-state (EoS) of QCD matter in the regime of very high densities?
  - Does QCD phase diagram feature a critical point?
  - What is the nature of phase transition between ordinary and deconfined nuclear matter?
  - What are the fundamental degrees of freedom at high densities?

Collective anisotropic flow

- ❑ Results from ultrarelativistic heavy-ion collisions are consistent with the scenario in which the produced nuclear matter undergoes collective expansion, dominated by its hydrodynamic response to anisotropies in the initial-state geometry ⬄ **collective anisotropic flow**



CERN Courier, April 2021

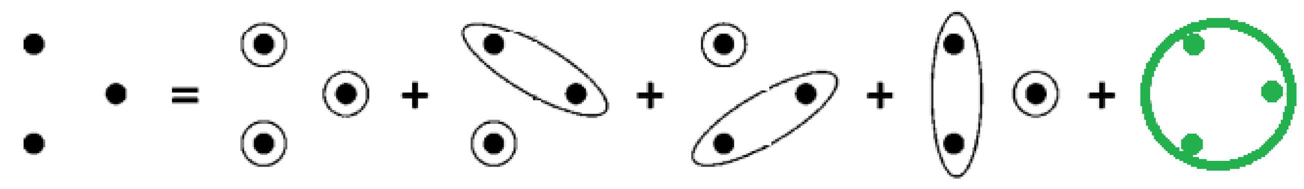


$$f(\varphi) = \frac{1}{2\pi}\left[1 + 2\sum_{n=1}^{\infty} v_n \cos[n(\varphi - \Psi_n)]\right]$$

- ❑ Fourier harmonics v_n quantify collective anisotropic flow, and are sensitive probe of EoS of nuclear matter, its transport properties (shear and bulk viscosities), etc.

Asymmetric Cumulants

- ❑ General mathematical formalism of multivariate cumulants can be applied to the stochastic event-by-event fluctuations of v_n harmonics



R. Kubo, J. Phys. Soc. Jpn. 17 (1962)

- ❑ Generalization is not trivial for correlations involving more than two v_n harmonics, and it was accomplished only recently

AB, M. Lesch, C. Mordasini, Seyed F. Taghavi, Phys.Rev.C 105 (2022) 2, 024912

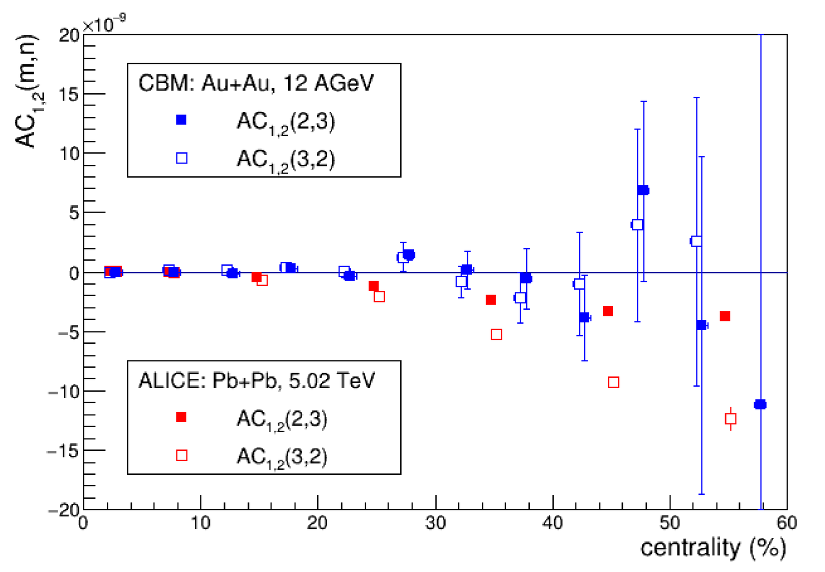
- ❑ New higher-order flow observables, which quantify correlations of different higher-order moments of v_n, and satisfy all fundamental properties of multivariate cumulants ⬄ **Asymmetric Cumulants (AC)**

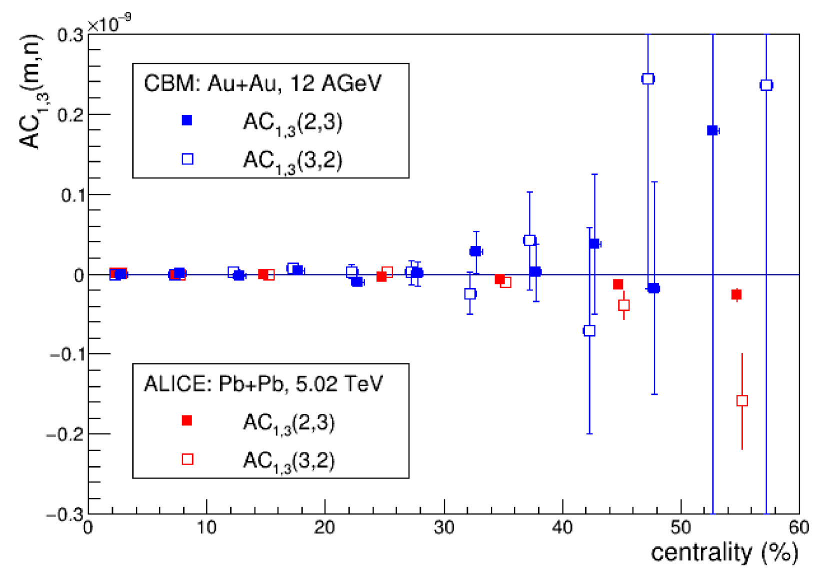
$$AC_{2,1}(m,n) = \langle v_m^4 v_n^2\rangle - \langle v_m^4\rangle\langle v_n^2\rangle - 2\langle v_m^2 v_n^2\rangle\langle v_m^2\rangle + 2\langle v_m^2\rangle^2\langle v_n^2\rangle,$$

$$AC_{3,1}(m,n) = \langle v_m^6 v_n^2\rangle - \langle v_m^6\rangle\langle v_n^2\rangle - 3\langle v_m^2 v_n^2\rangle\langle v_m^4\rangle - 3\langle v_m^4 v_n^2\rangle\langle v_m^2\rangle + 6\langle v_m^4\rangle\langle v_m^2\rangle\langle v_n^2\rangle + 6\langle v_m^2 v_n^2\rangle\langle v_m^2\rangle^2 - 6\langle v_m^2\rangle^3\langle v_n^2\rangle,$$

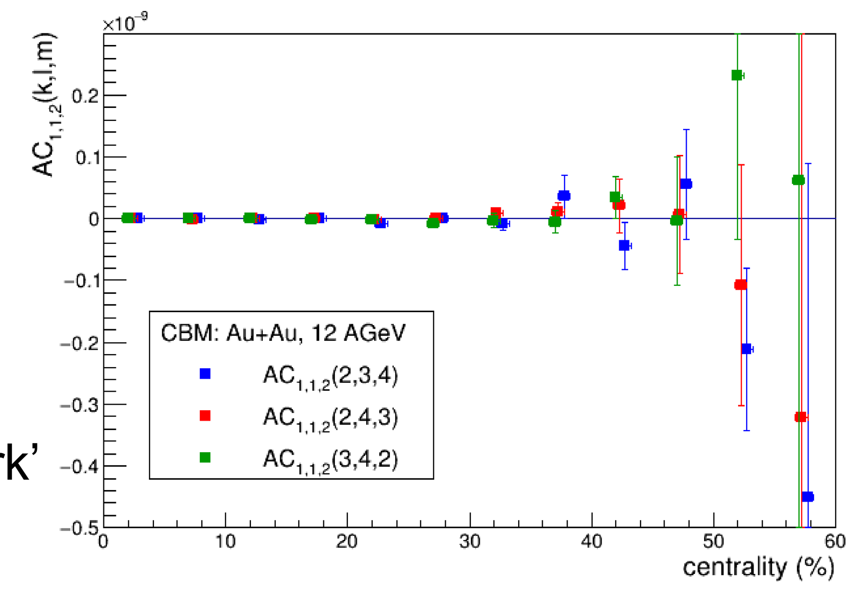
$$AC_{2,1,1}(k,l,m) = \langle v_k^4 v_l^2 v_m^2\rangle - \langle v_k^4 v_l^2\rangle\langle v_m^2\rangle - \langle v_k^4 v_m^2\rangle\langle v_l^2\rangle - \langle v_k^4\rangle\langle v_l^2 v_m^2\rangle + 2\langle v_k^4\rangle\langle v_l^2\rangle\langle v_m^2\rangle - 2\langle v_k^2 v_l^2\rangle\langle v_k^2 v_m^2\rangle - 2\langle v_k^2 v_l^2 v_m^2\rangle\langle v_k^2\rangle + 4\langle v_k^2 v_l^2\rangle\langle v_k^2\rangle\langle v_m^2\rangle + 4\langle v_k^2 v_m^2\rangle\langle v_k^2\rangle\langle v_l^2\rangle + 2\langle v_k^2\rangle^2\langle v_l^2 v_m^2\rangle - 6\langle v_k^2\rangle^2\langle v_l^2\rangle\langle v_m^2\rangle.$$

- ❑ By definition, AC extract new and independent information when compared to the previous lower-order flow observables
- ❑ In general, AC are not invariant under permutations of different v_n, therefore $AC_{1,2}$(2,3) and $AC_{1,2}$(3,2) are independent of each other
- ❑ First feasibility studies for AC observables in the CBM environment, using Monte Carlo simulations of Au+Au collisions at 12 AGeV:





- ❑ AC observables are measured with multiparticle correlations, which are challenging for:
  - small multiplicities
  - detectors with non-uniform azimuthal acceptance
- ❑ Support for 'Generic Framework' available in CBMRoot



Phys. Rev. C 89 (2014) no.6, 064904

- ❑ Measurements of AC will be feasible in the CBM environment!