Collective flow and correlation measurements with HADES in Au+Au collisions at 1.23 AGeV

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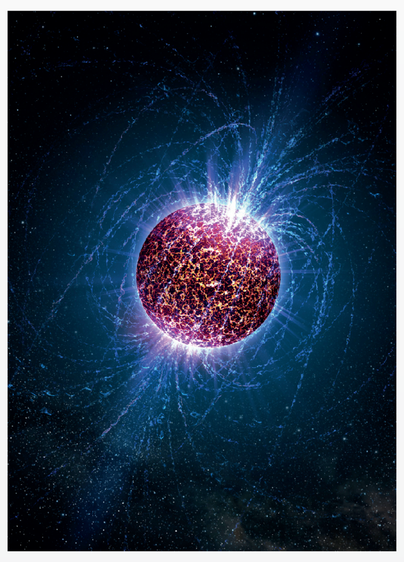
Motivation

Heavy-ion collisions allow to investigate the properties of strongly interacting matter under extreme conditions such as the high densities present in dense stellar objects like neutron stars and in the process of their merger.

Therefore, measurements are indispensable to determine the properties of dense matter such as its equation-of-state (EOS). For this purpose the measurement of collective flow effects in heavy-ion collisions has turned out to be decisive.

Neutron Star

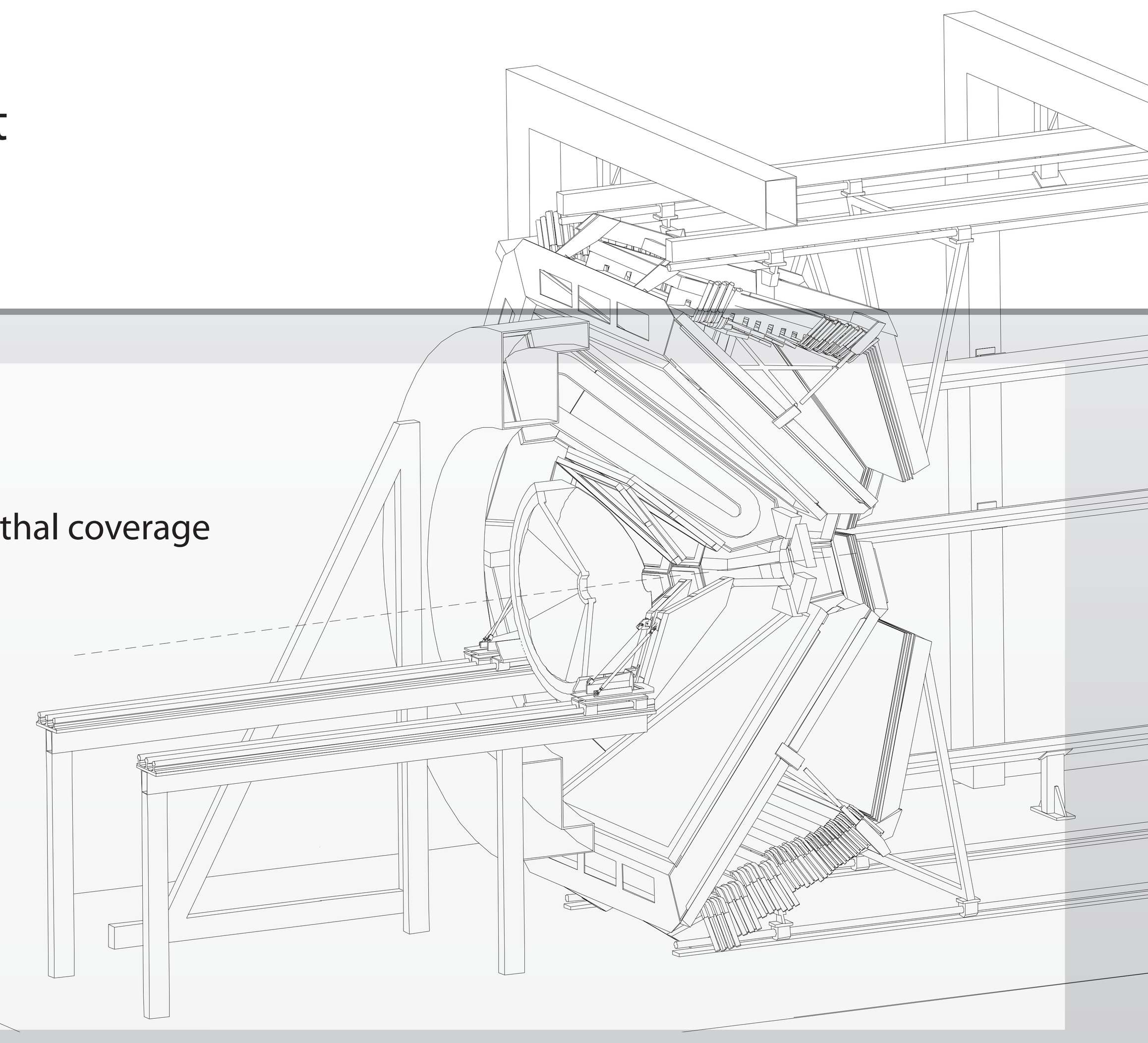


Casey Reed,Penn State University

Neutron Star Merger

NASA/Swift/Dana Berry, SkyWorks Digital, Inc.

HADES - Detector



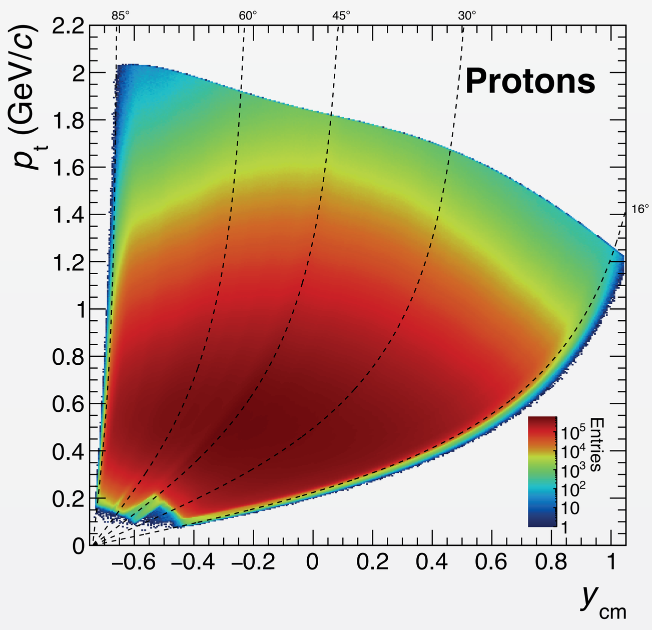
- Large acceptance with symmetric azimuthal coverage
- Polar angle coverage: 18˚ - 85˚
- Low-mass mini-drift chambers (MDC)
- Superconducting toroidal magnet
- CVD Diamond START detector
- Ring Imaging Cherenkov detector
- Time-of-flight walls (TOF and RPC)
- Small angle spectator hodoscope (Forward wall)

Multi-differential Flow Analysis

HADES provides a large acceptance combined with a high mass-resolution and excellent particle-identification capability.

The high statistics collected in Au+Au beamtime at 1.23 AGeV makes it possible to investigate all flow coefficients in a multi-differential analysis over a large region of phase space (as a function of transverse momentum p_t and rapidity) and for several intervals of reaction centrality.

This provides the possibility to characterize the particle production in heavy-ion collisions as a full 3D-picture in momentum space and puts strong constraints on the determination of the properties of dense matter, such as its viscosity and equation-of-state (EOS).



Method

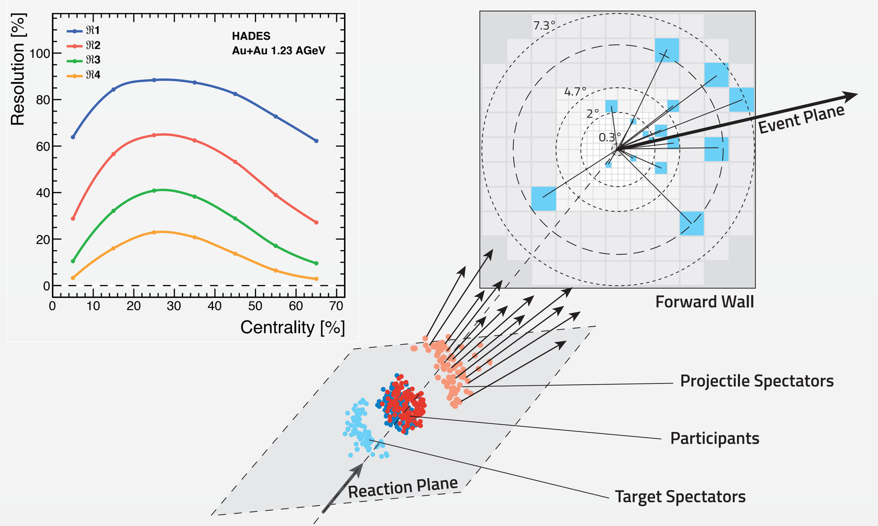
The flow coefficients vn are defined in relation to event plane angle

$$v_n^{obs} = \langle \cos[n(\varphi - \psi_{EP})] \rangle$$

and corrected for the corresponding event plane resolution

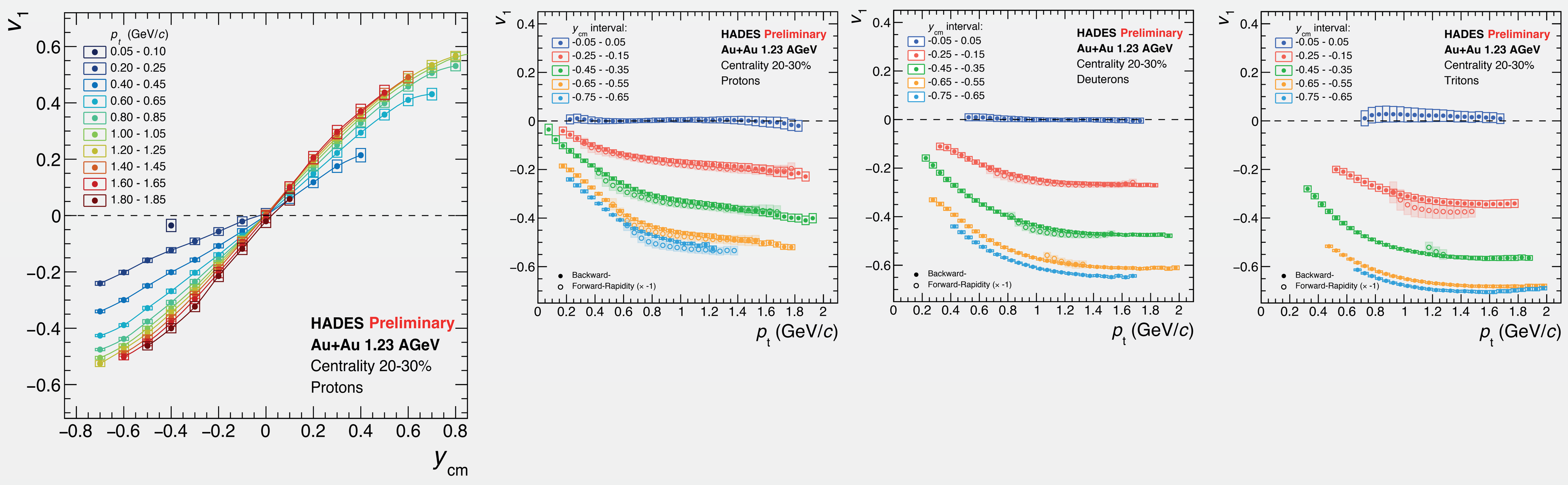
$$v_n = v_n^{obs} / \Re_n$$

and the reconstruction inefficiencies due to modulation in track densities



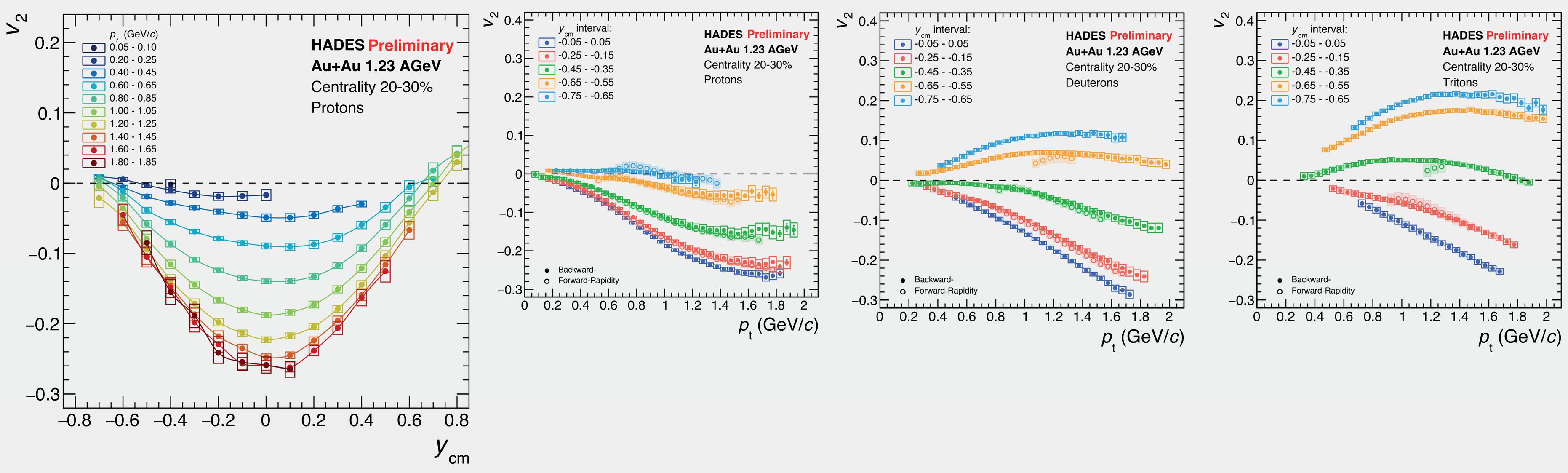
Directed Flow

v_1



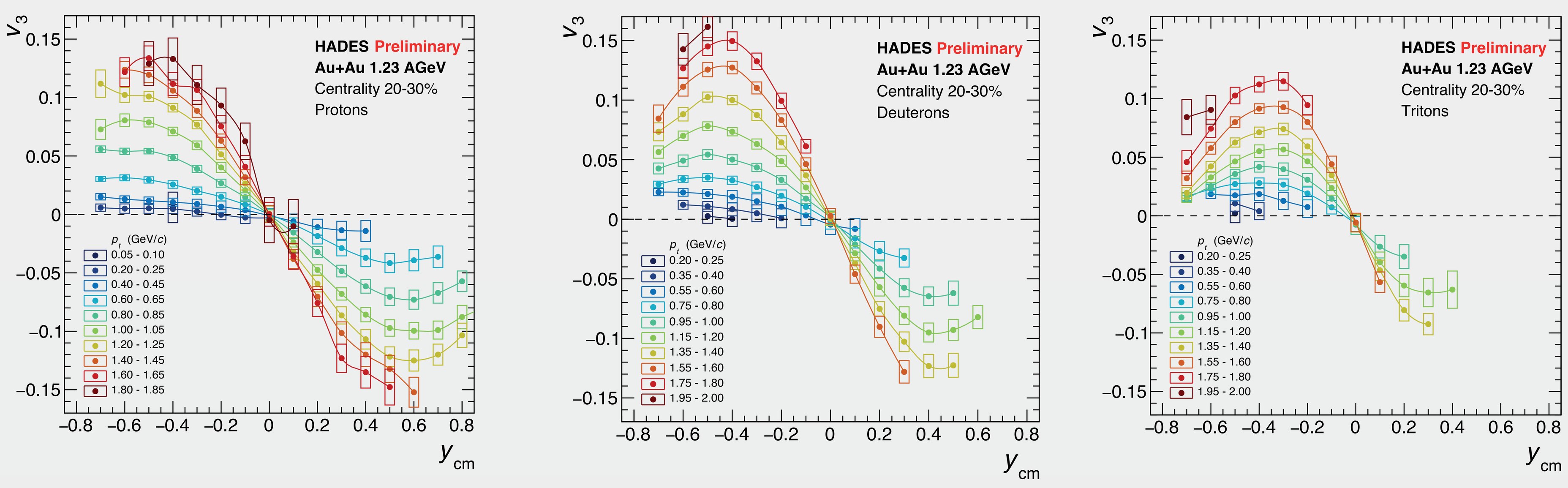
Elliptic Flow

v_2



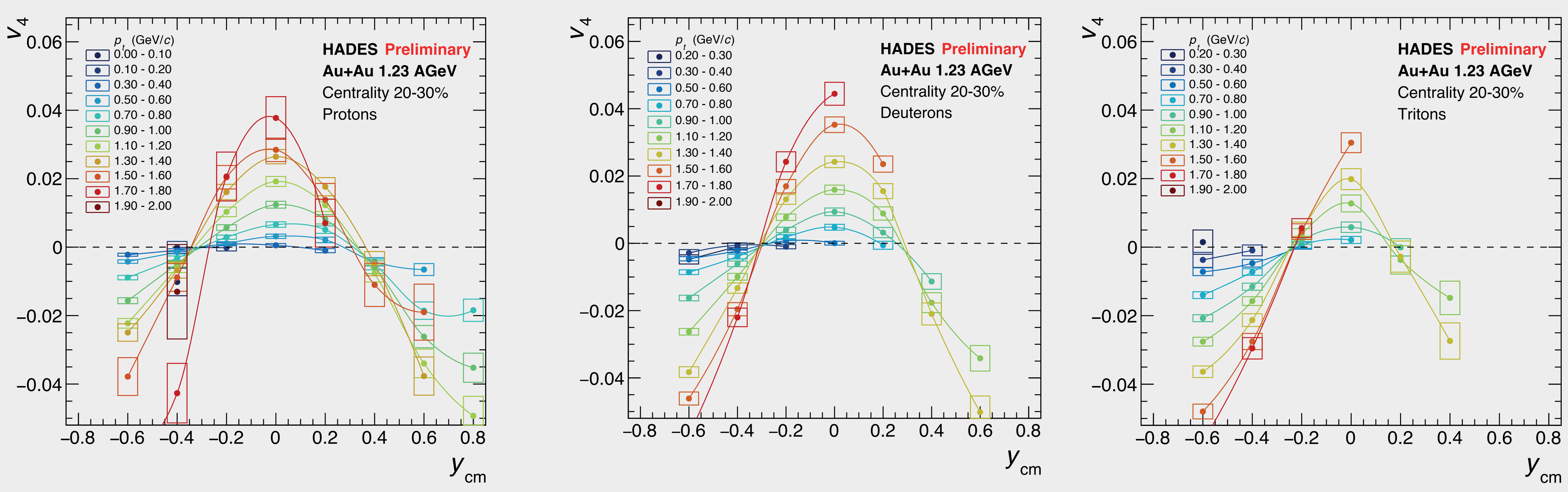
Triangular Flow

v_3



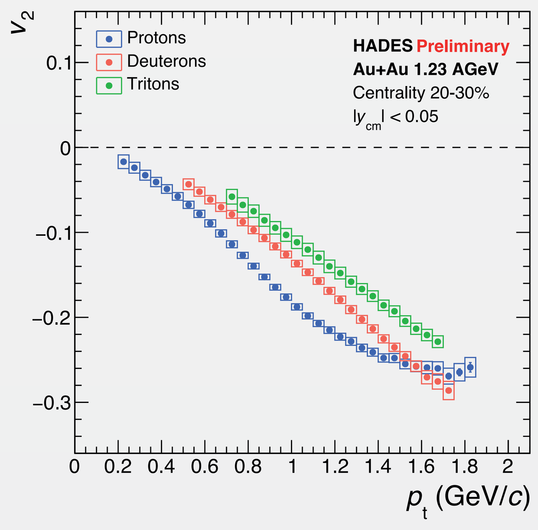
Quadrangular Flow

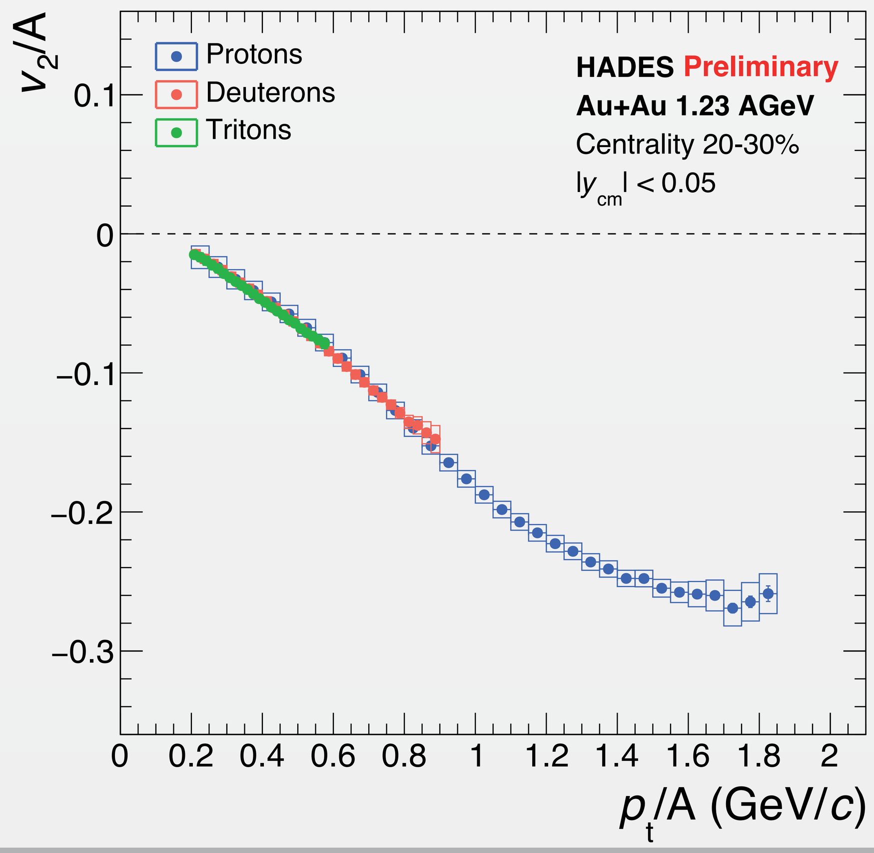
v_4



Nuclear Mass Scaling

Scaling of v_2 and p_t with nuclear mass A at mid-rapidity shows a universal curve as expected from a naive nucleon-coalescence scenario.

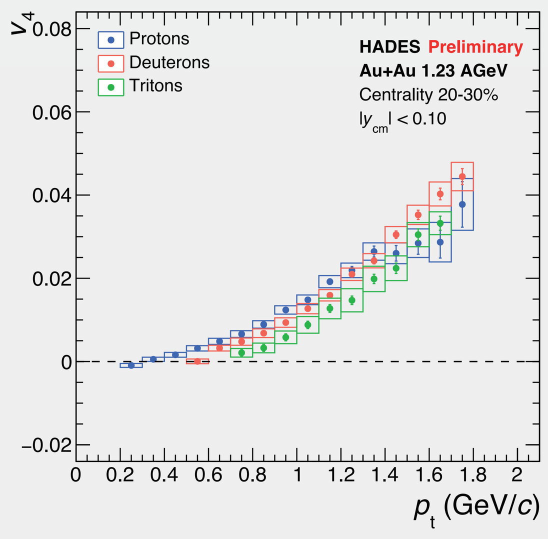


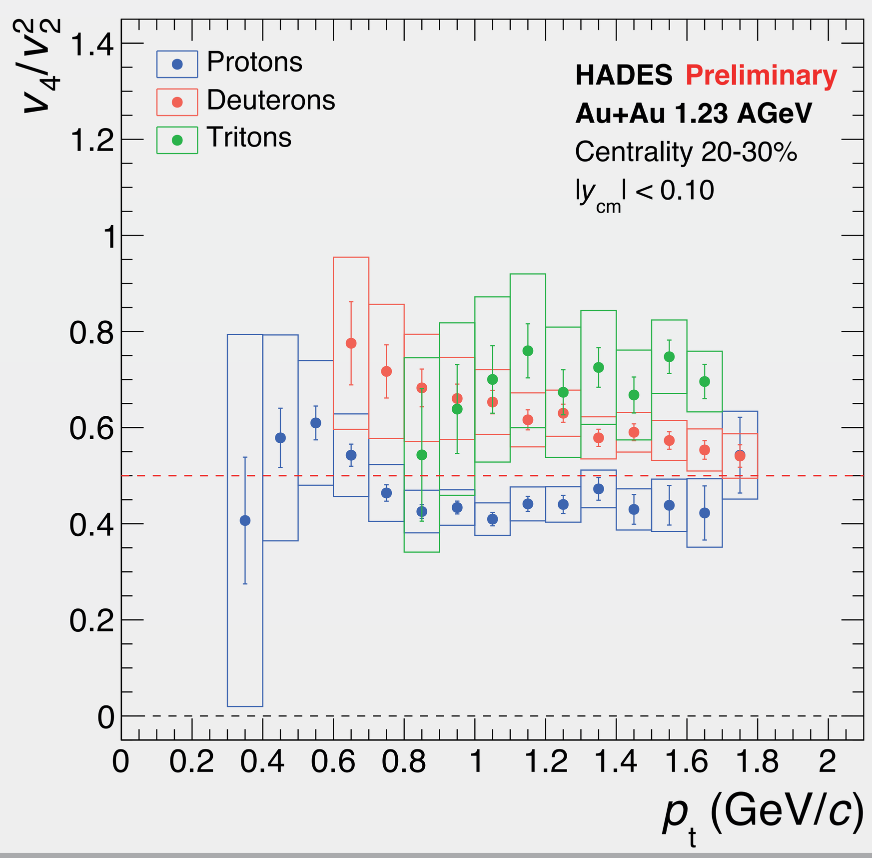


„Ideal-fluid Scaling"

Ideal fluid dynamics predicts the limit on the contribution to v_4 from v_2 at large p_t by $v_4 = 0.5(v_2)^2$

N. Borghini and J.-Y. Ollitrault Phys.Lett. B642 (2006) 227-231





Model comparison

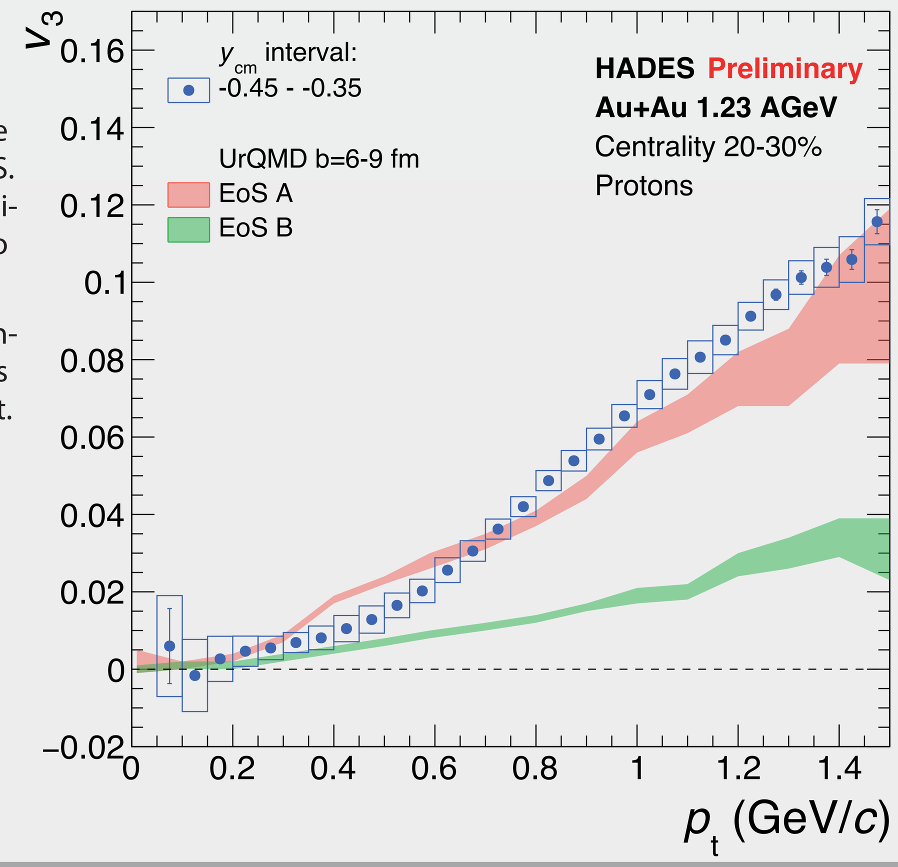
The comparison with predictions using the UrQMD model based on two different EOS. These are implemented via a baryon density dependent Skyrme-potential using two different sets of parameters.

Effects of momentum and isospin dependent potentials are not included in this model calculation, which can be important.

P. Hillmann et al., J.Phys. G45 (2018) no.8, 085101

$$V_{Sk} = \alpha \cdot \left(\frac{\rho_{int}}{\rho_0}\right) + \beta \cdot \left(\frac{\rho_{int}}{\rho_0}\right)^{\gamma}$$

Parameters	EoS A	EoS B
α [MeV]	-124	-356
β [MeV]	71	303
γ	2.00	1.17



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