Light Nuclei v_1 and v_2 in Au+Au Collisions at $\sqrt{s_{NN}}$ = 3 GeV from STAR

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Outline

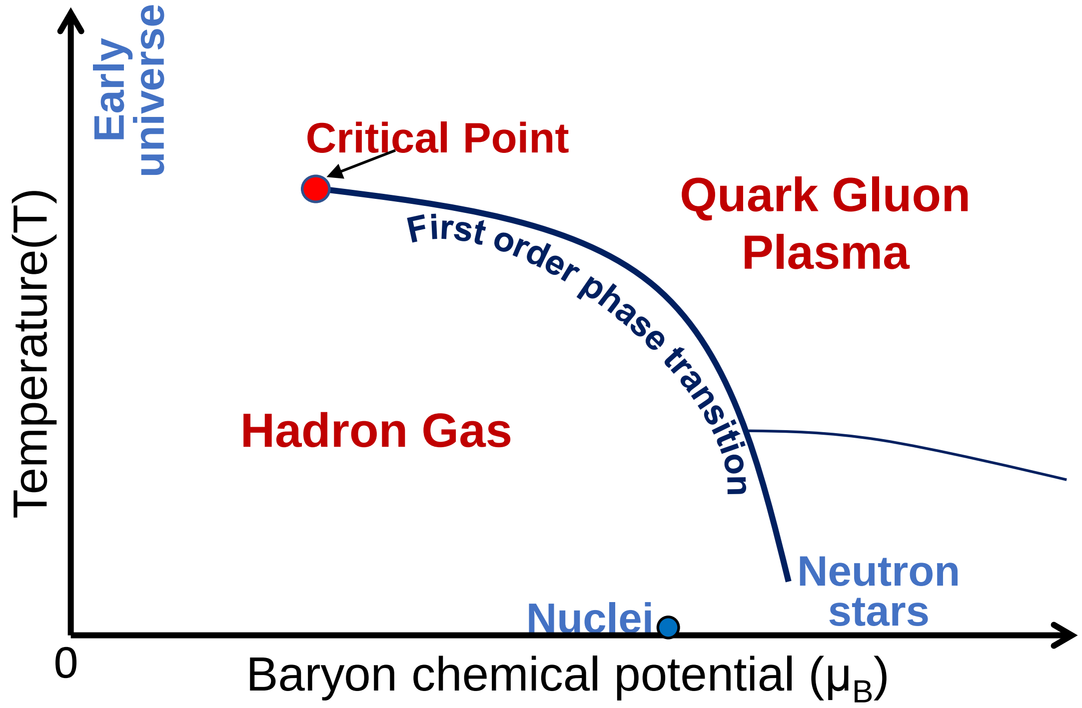
I. Introduction

II. STAR fixed-target experiment and light nuclei identification

III. Results and discussions

IV. Summary

I. QCD phase diagram



Correlations are essential feature of interacting many body system.

Light nuclei : nucleon-nucleon correlation

affecting the chemical composition, thermodynamical properties

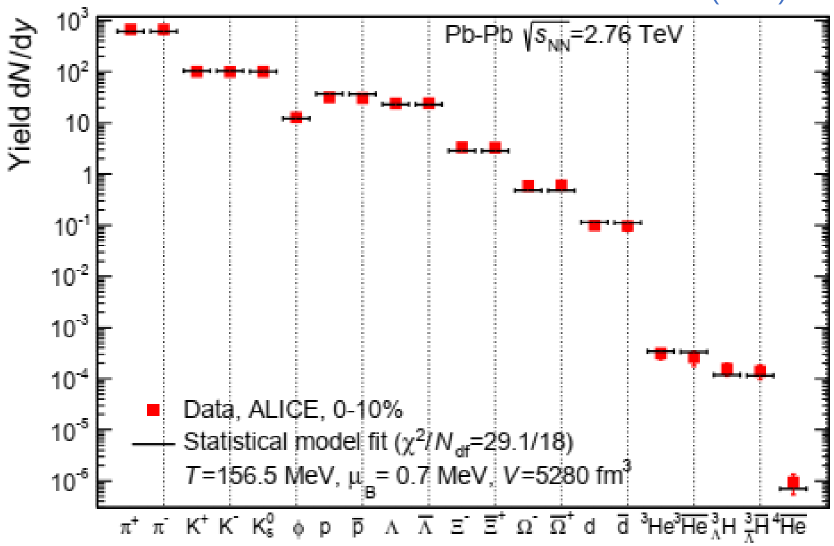
When and how are light nuclei formed in heavy-ion collisions?

I. Light nuclei in relativistic heavy-ion collisions

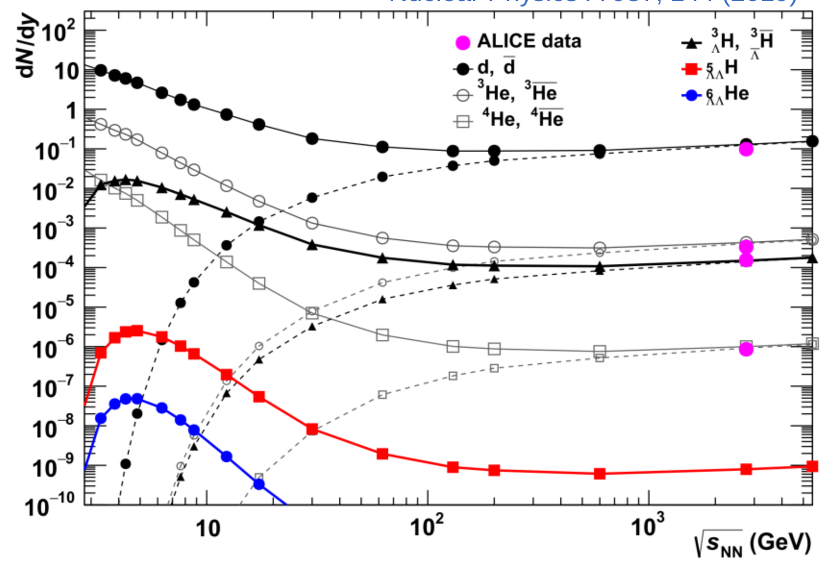
Thermal model

Formed early (before chemical freeze-out).

arXiv:1611.01347(2016)



Nuclear Physics A 987, 144 (2019)



Coalescence model

Formed later, combination of nucleons with close position and momentum.

$$E\frac{d^3N}{dp^3} = B_A\left(E_p\frac{d^3N_p}{dp_p^3}\right)^Z\left(E_n\frac{d^3N_n}{dp_n^3}\right)^N$$

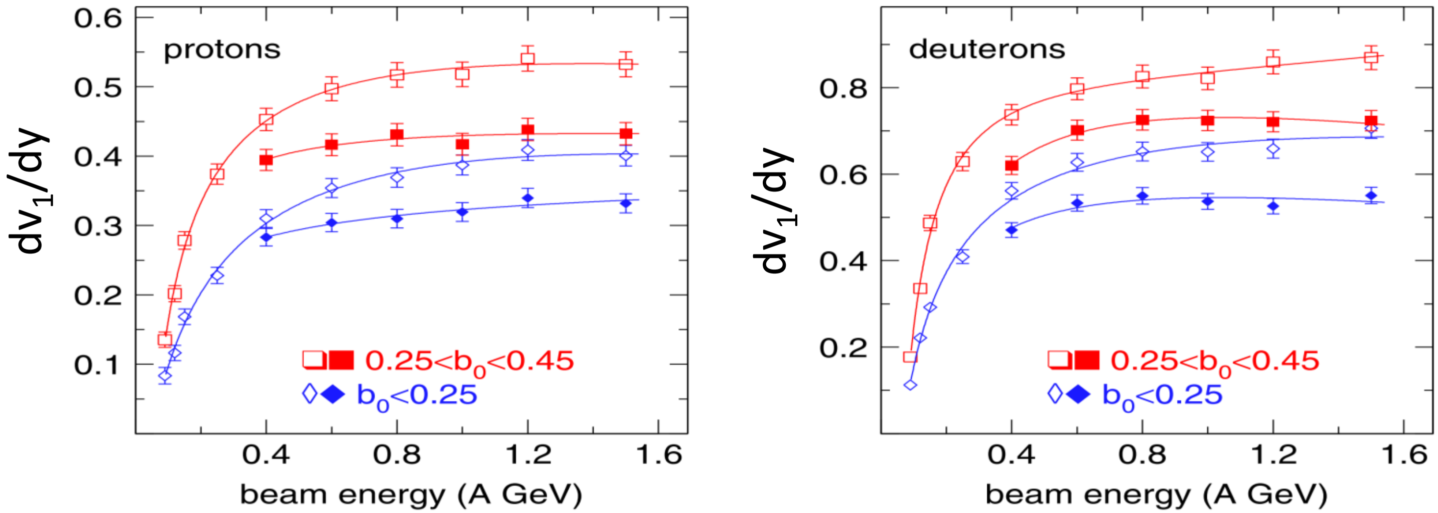
Atomic mass number scaling of collective flow v_n : $v_n^A(p_T, y) \approx A v_n^p\left(\frac{p_T}{A}, y\right)$

I. Deuteron v_1 slope at midrapidity

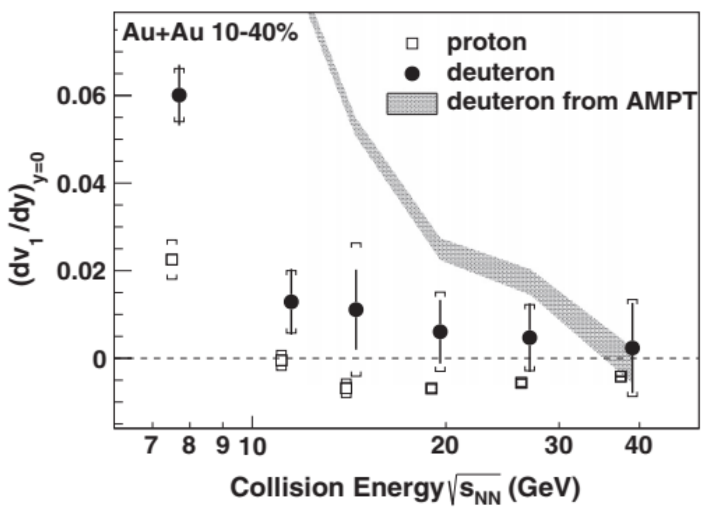
FOPI collaboration $\sqrt{s_{NN}}$ ~ 1.9-2.4 GeV

Au+Au

Nuclear Physics A 1, 876 (2012)



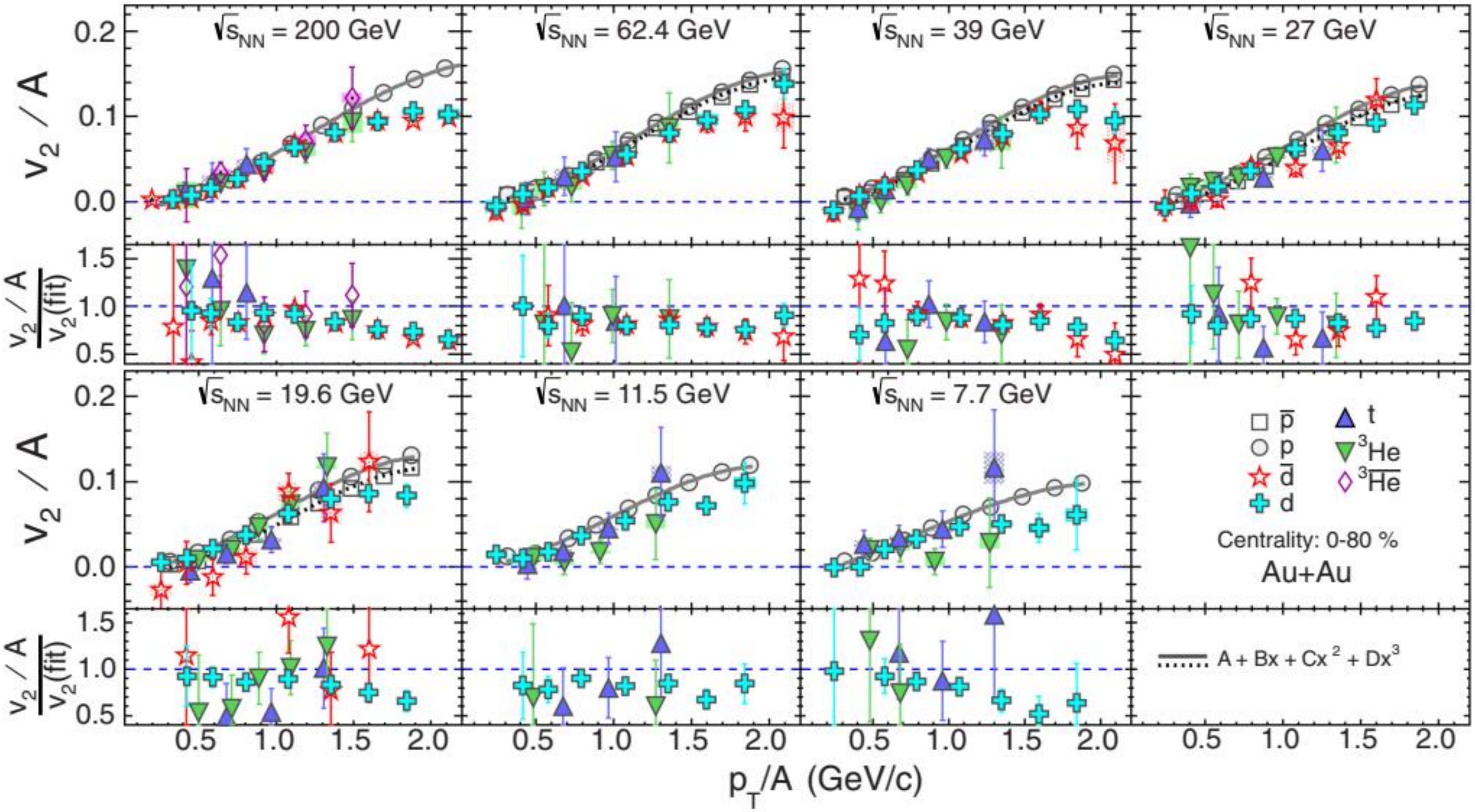
Phys. Rev. C 102, 044906 (2020)



- Deuteron dv_1/dy are always positive
- Do not follow the atomic-mass-number scaling at higher energies
- Implying change of dominant players

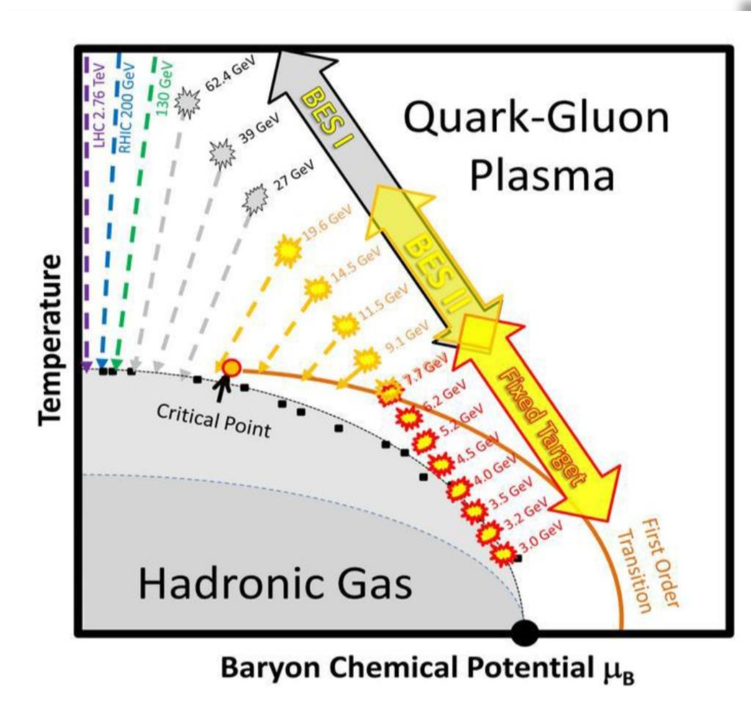
I. Light nucleus v_2 from STAR

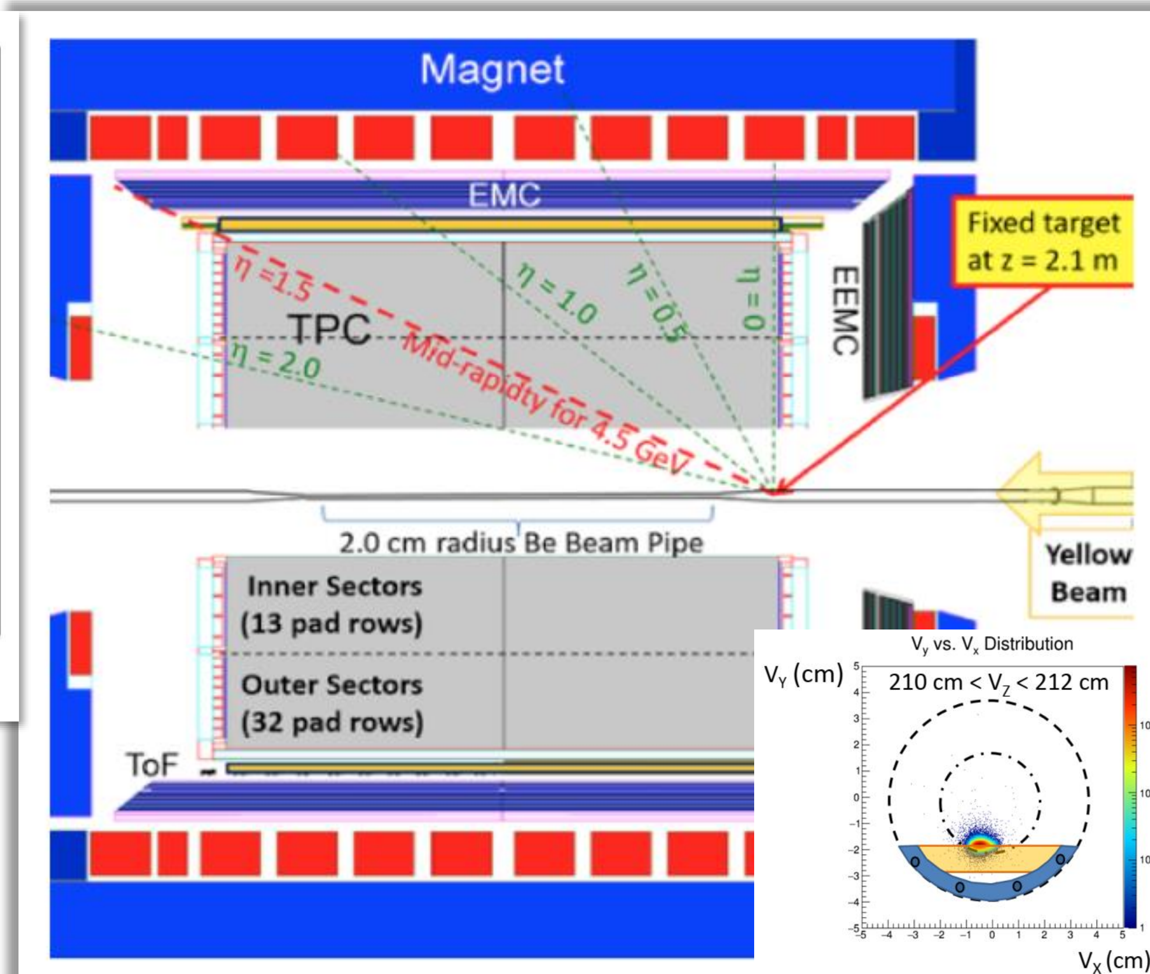
Phys. Rev. C 94, 034908 (2016)



Atomic-mass-number scaling of v_2 at low p_T, favored by coalescence production model.

II. Fixed target experiment at STAR

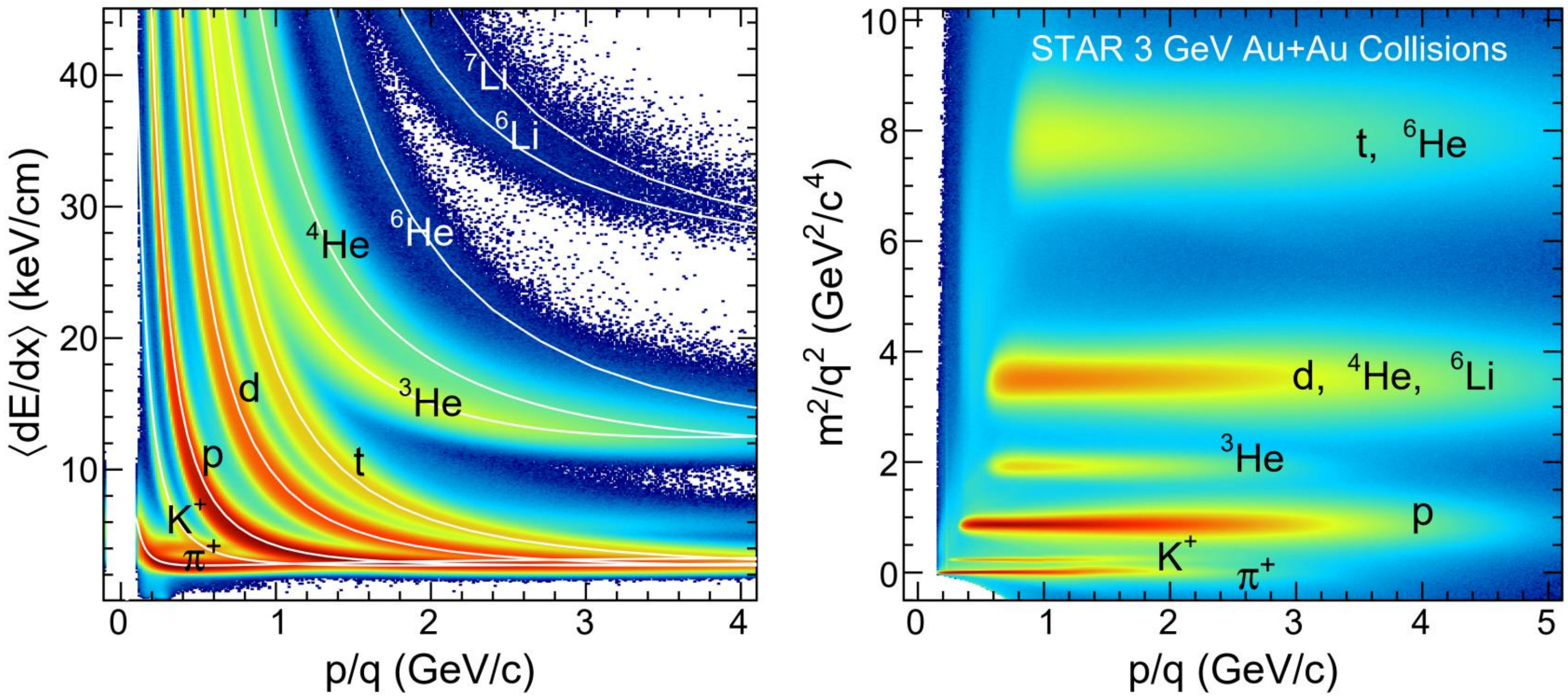




STAR's FXT extends the coverage of baryon chemical potential from 400 MeV to 720 MeV.

II. Data and light nuclei selection

Data recorded in 2018, ~250M events.

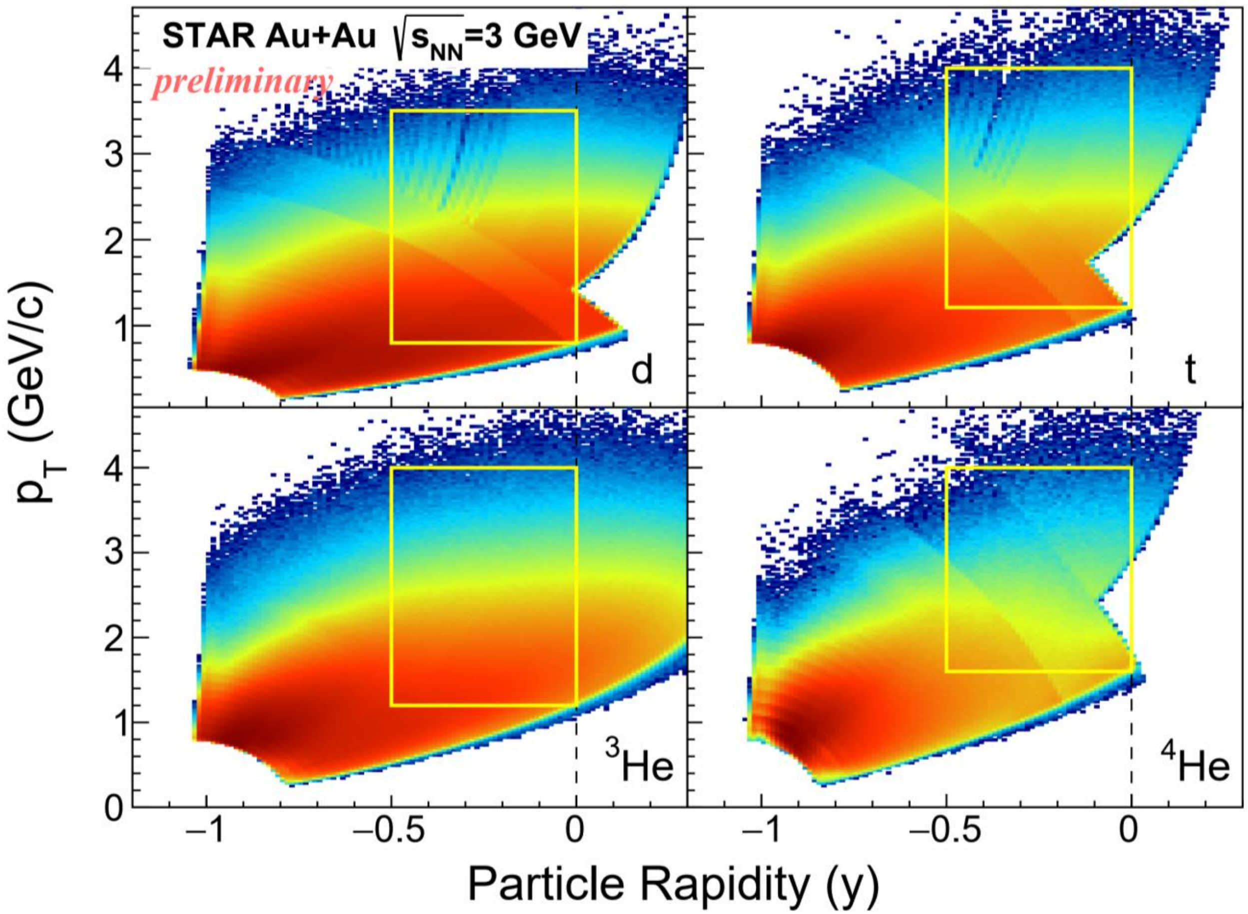


Light nuclei : d, t, ^{3}He, and ^{4}He

$$z = \ln\left(\frac{(dE/dx)_{measured}}{(dE/dx)_{expected}}\right)$$

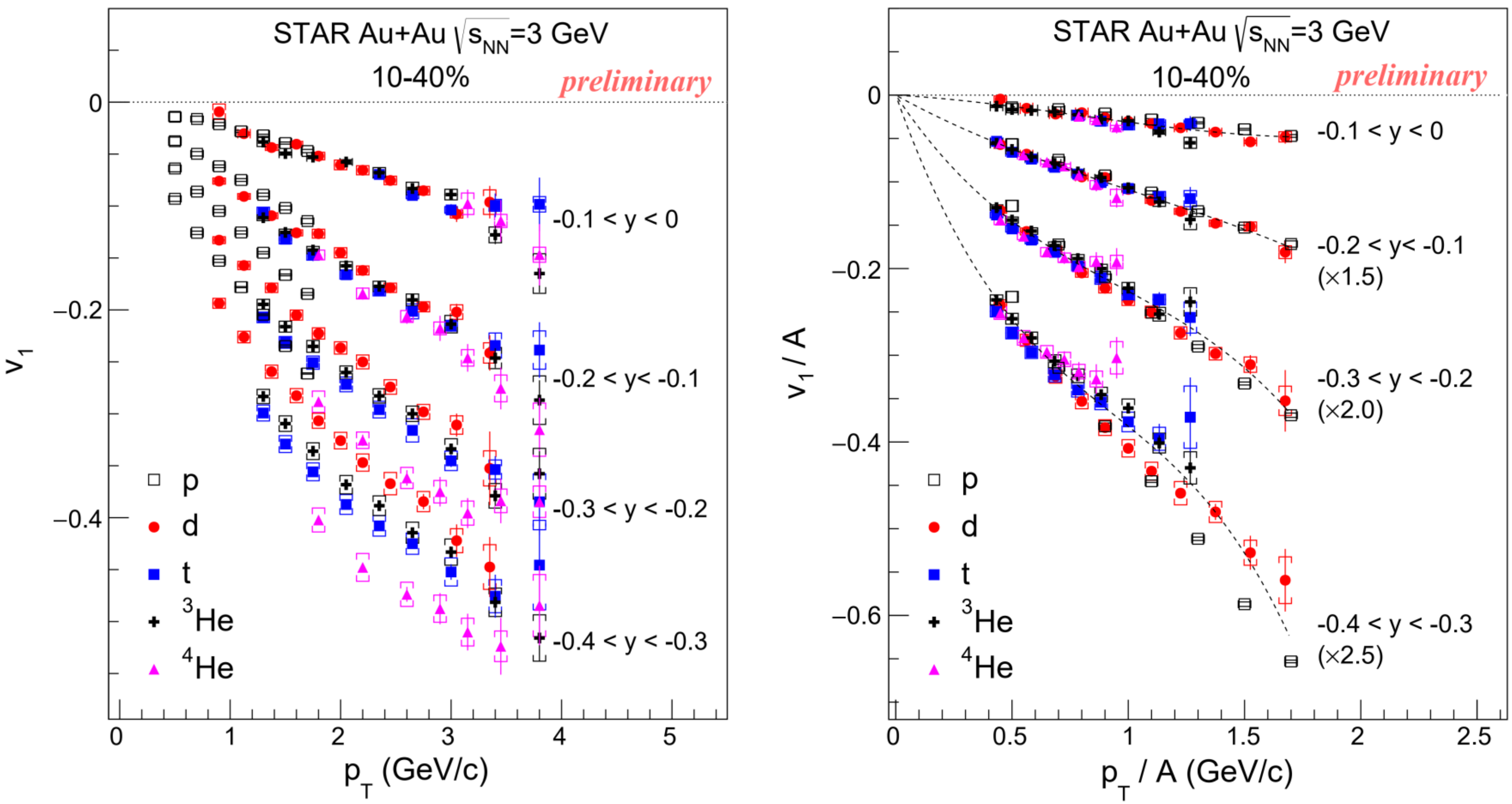
Momentum dependence PID, the TOF was used at high momentum.

II. Light nuclei acceptance



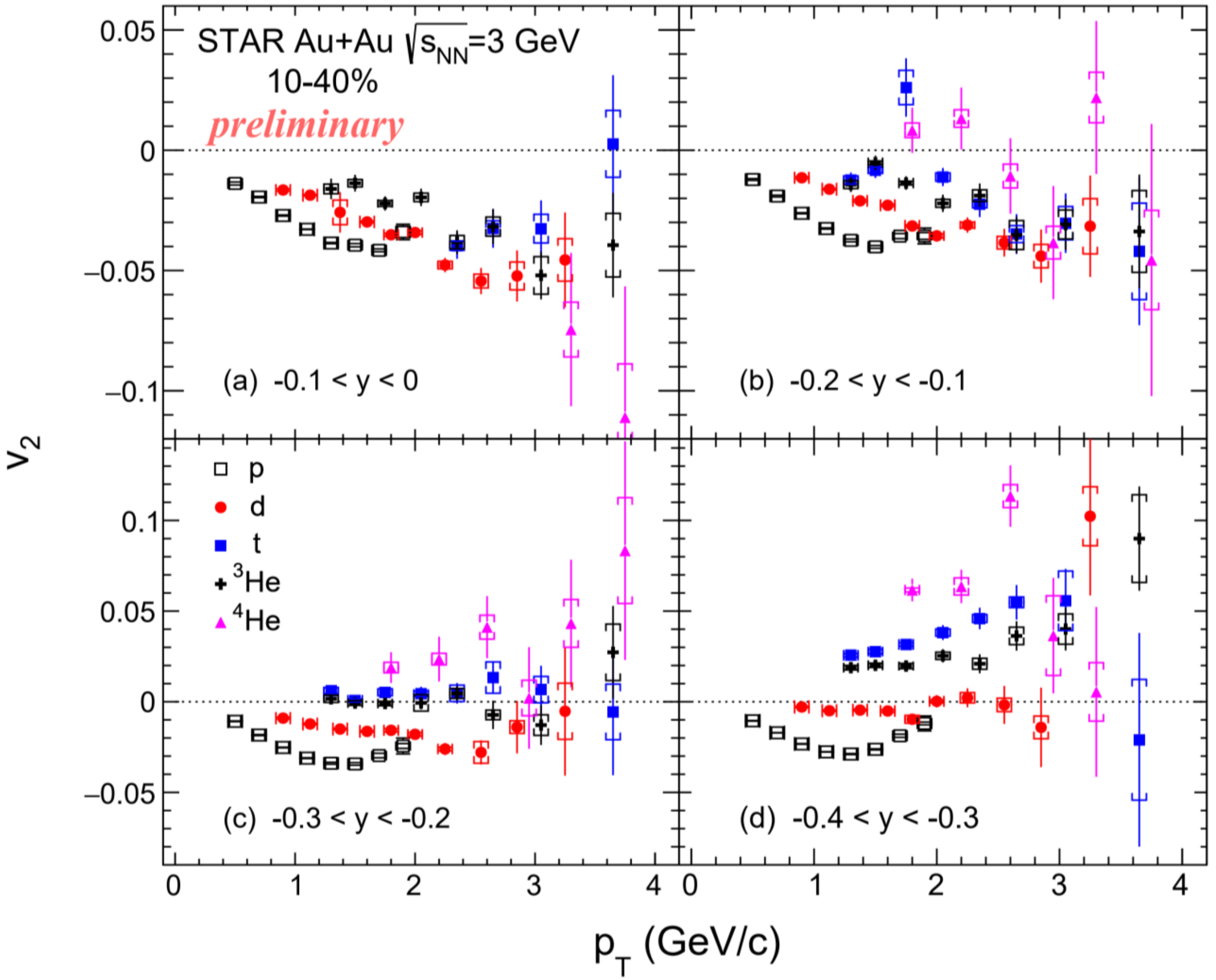
- p_T range (GeV/c) : d [0.8, 3.5], t [1.2, 4.0], ^{3}He [1.2, 4.0], ^{4}He [1.6, 4.0]
- Part of the tritons and ^{4}He within $-0.1<y<0$ can't be covered due to the TOF acceptance

III. p_T dependence of light nucleus v_1



Light nucleus $v_1(p_T)$ follow atomic-mass-number scaling at different rapidity bins.

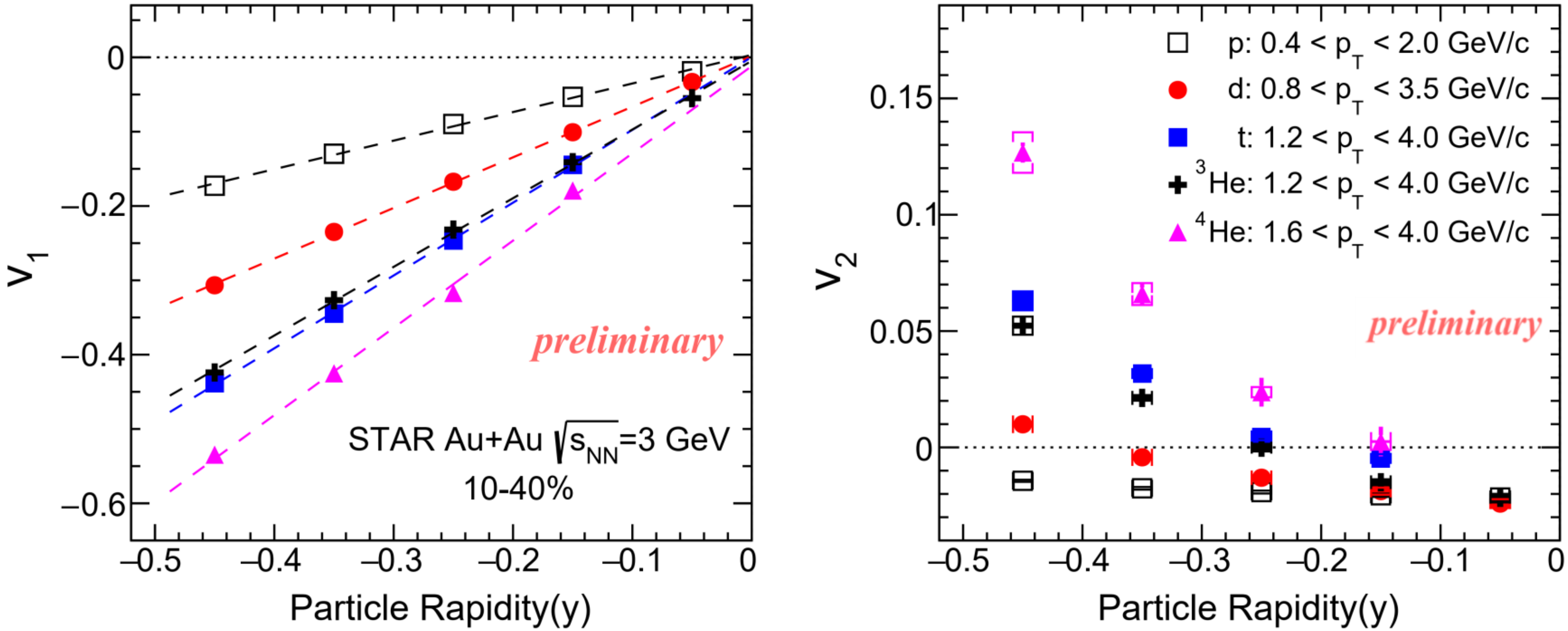
III. p_T dependence of light nucleus v_2



The p_T dependence of proton v_2 is not monotonic, do not following mass-number scaling.

III. Rapidity dependence of v_1 and v_2

Mass ordering of both v_1 and v_2.

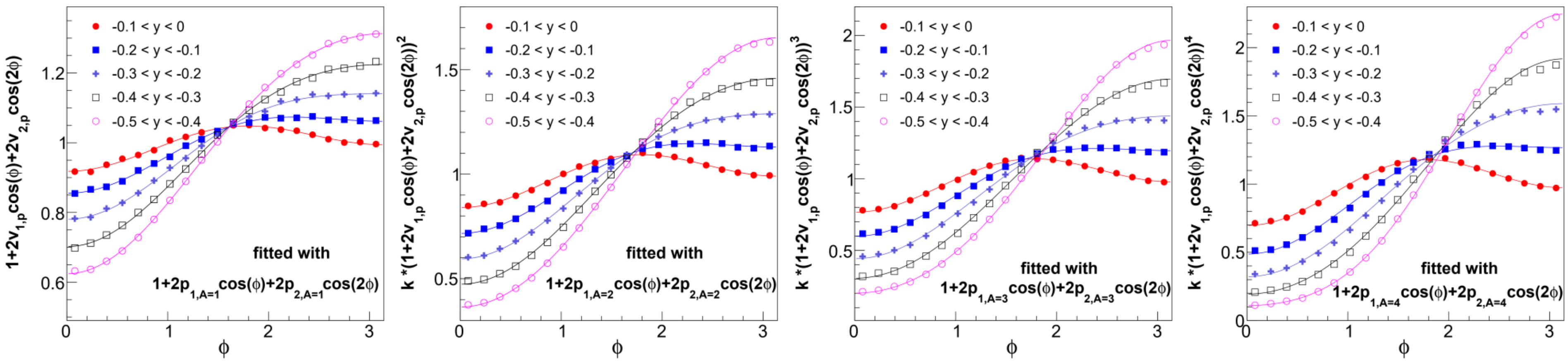


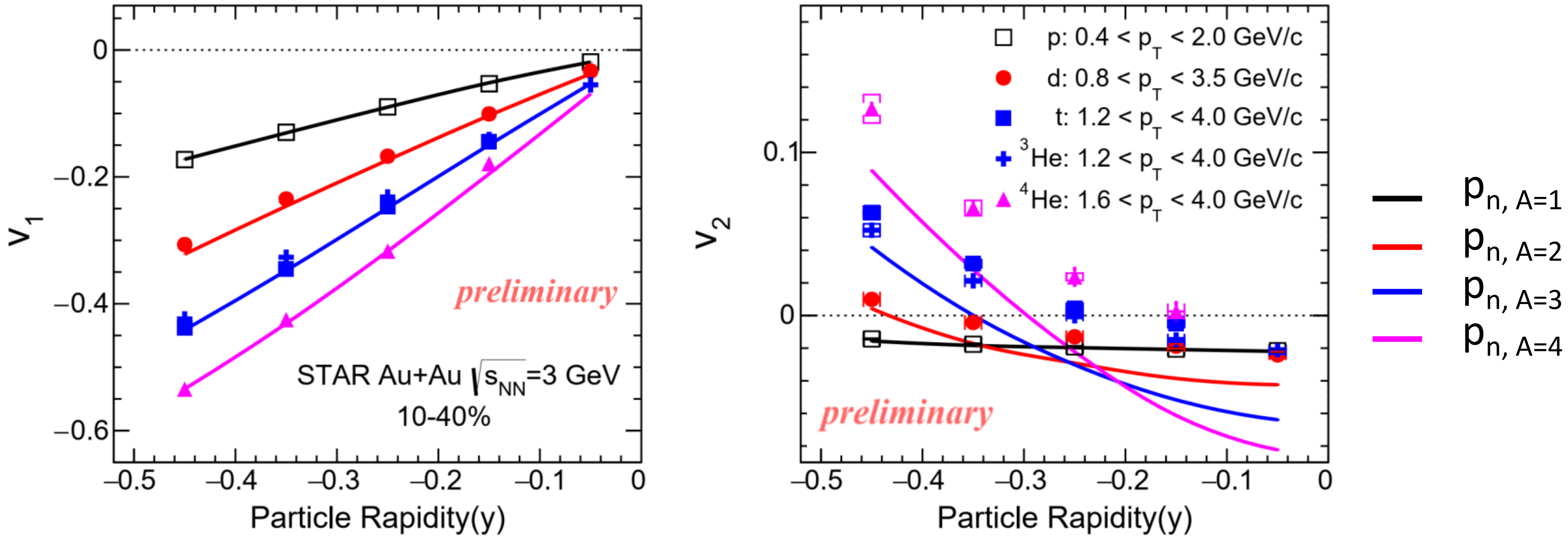
coalescence : can negative proton v_2 produce positive light nucleus v_2?

Proton : $$\frac{dN^p}{d\varphi} \sim 1 + 2v_1 \cos(\varphi - \psi_{RP}) + 2v_2 \cos(2(\varphi - \psi_{RP}))$$

Light nuclei (neutron $\frac{dN^n}{d\varphi} = \frac{dN^p}{d\varphi}$): $$\frac{dN^A}{d\varphi} \sim \left(\frac{dN^p}{d\varphi}\right)^A$$

III. Coalescence in momentum space



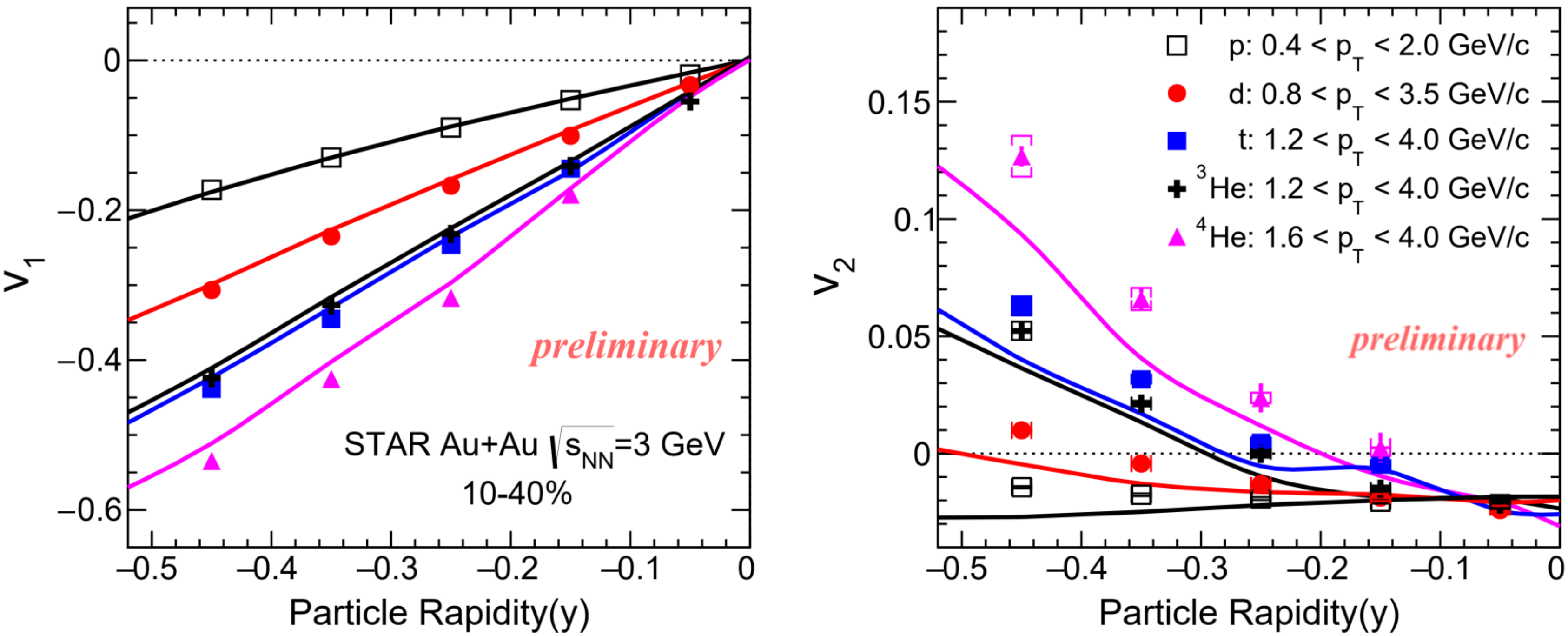


Negative proton v_2 can produce positive light nucleus v_2.

III. JAM+ nucleon coalescence

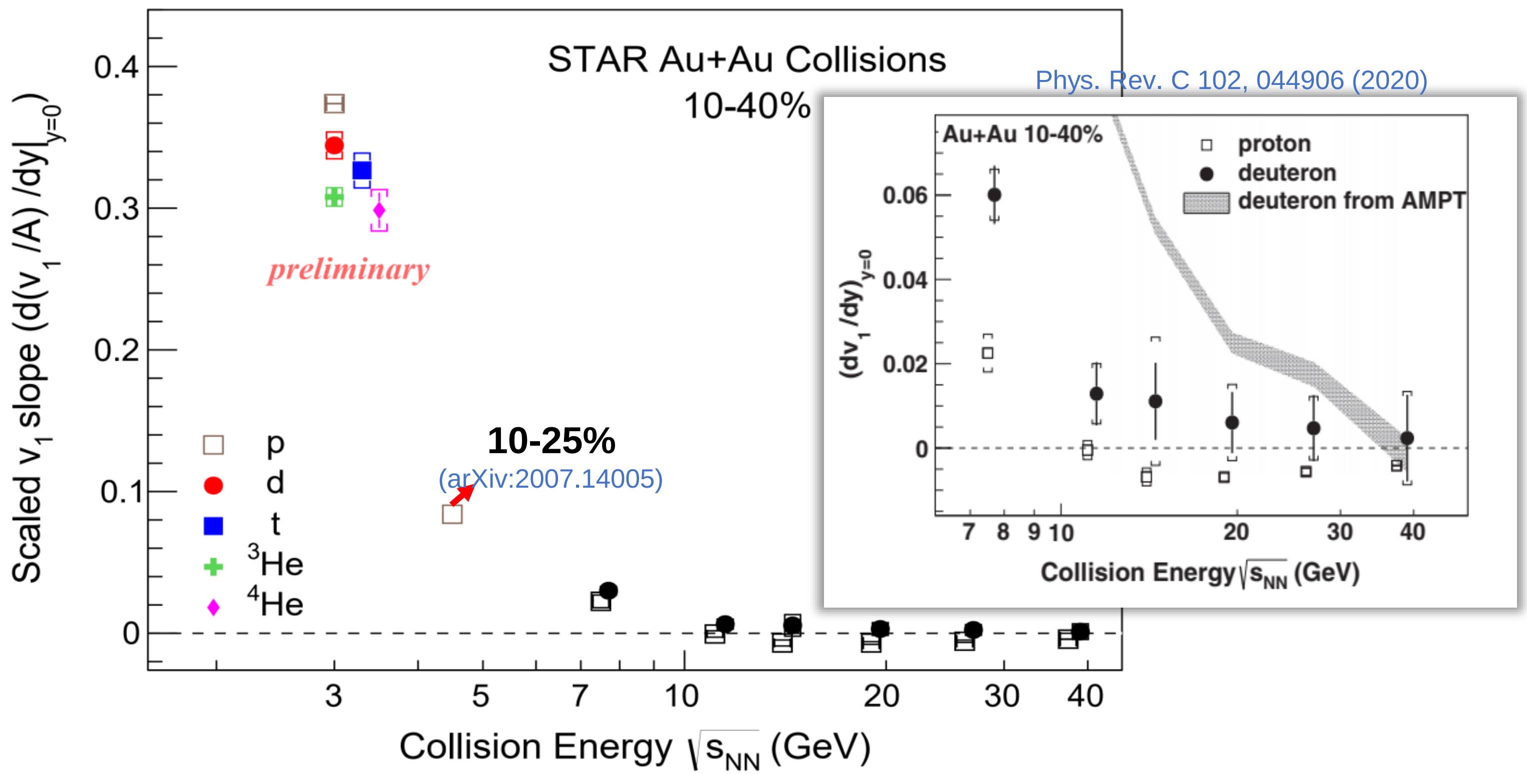
JAM : Jet AA Microscopic transport Model, **meanfield**

Coalescence of two nucleons:
relative coordinate and momentum distances Δr<4.0 fm, Δp<0.3 GeV/c



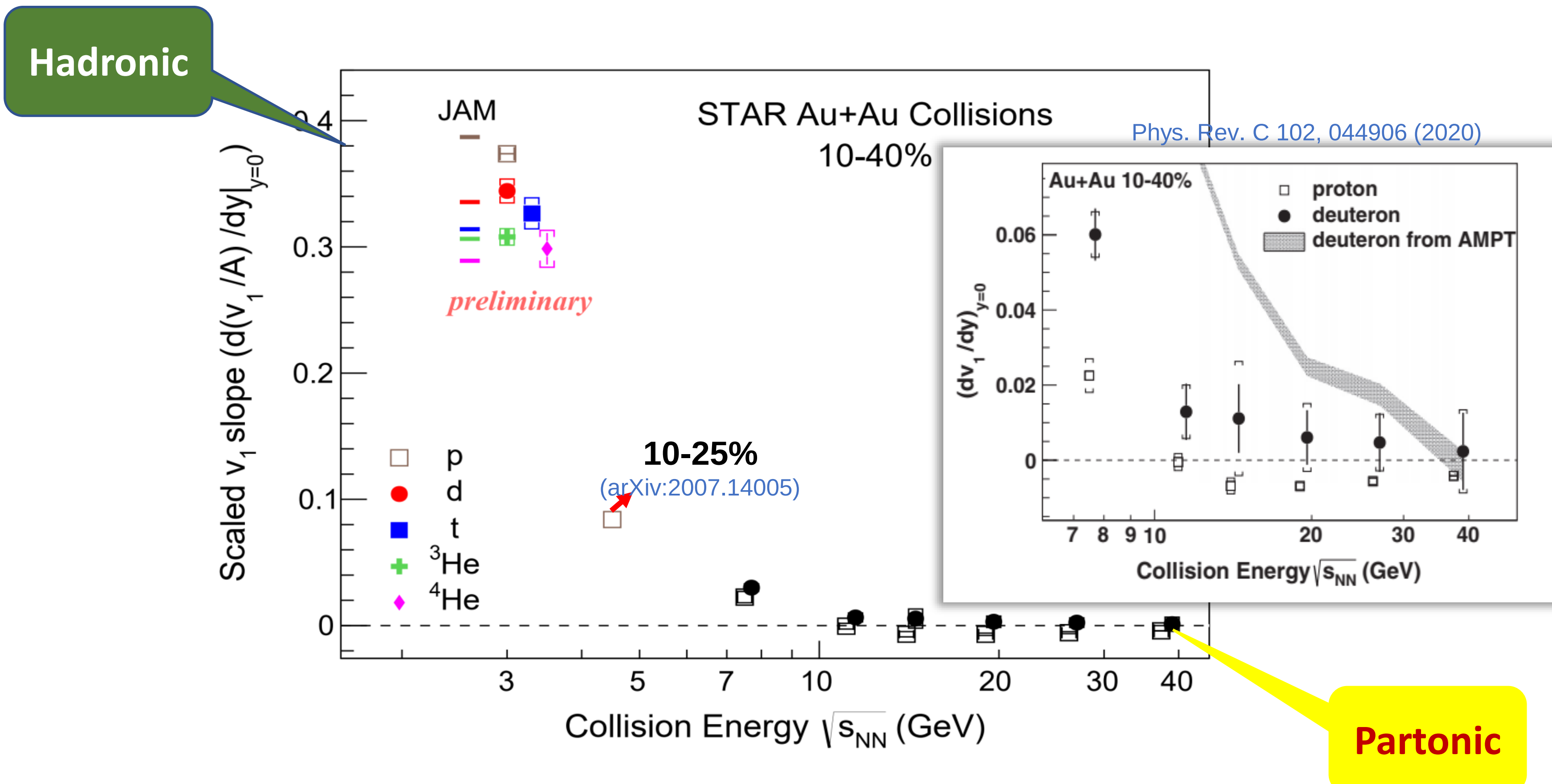
Can qualitatively describe the data.

III. Energy dependence of dv_1/dy



At $\sqrt{s_{NN}}$ = 3 GeV, the light nucleus v_1 slopes follow the atomic-mass- number scaling .

III. Energy dependence of dv_1/dy



- Hadronic model JAM reproduces light nuclei v_1 at 3 GeV
- Different scaling behavior at low and high collision energies → change of dominant interactions *See Shaowei's talk (March 15)*

Summary

- v_1 and v_2 measurements for *d, t, ^{3}He,* and *^{4}He* from Au+Au collisions at $\sqrt{s_{NN}}$= 3 GeV
  - At midrapidity, light nucleus $v_1(y)$ slope and $v_1(p_T)$ follow the atomic-mass-number scaling, as expected in coalescence scenario
  - v_2 values at midrapidity ($|y|<0.1$) are negative and not scaling
- Simple coalescence picture qualitatively describes the light nucleus v_1 and the sign change of $v_2(y)$, as a function of rapidity
- From high collision energy, $\sqrt{s_{NN}}$ > 15 GeV, to low energy, < 8GeV, atomic mass scaling for light-nuclei v_1 and v_2 is different, which may imply different dominant interactions :

  at high μ_B , hadronic interactions

  at low μ_B , partonic interactions

Back up

• Deuteron v_1 from beam energy scan

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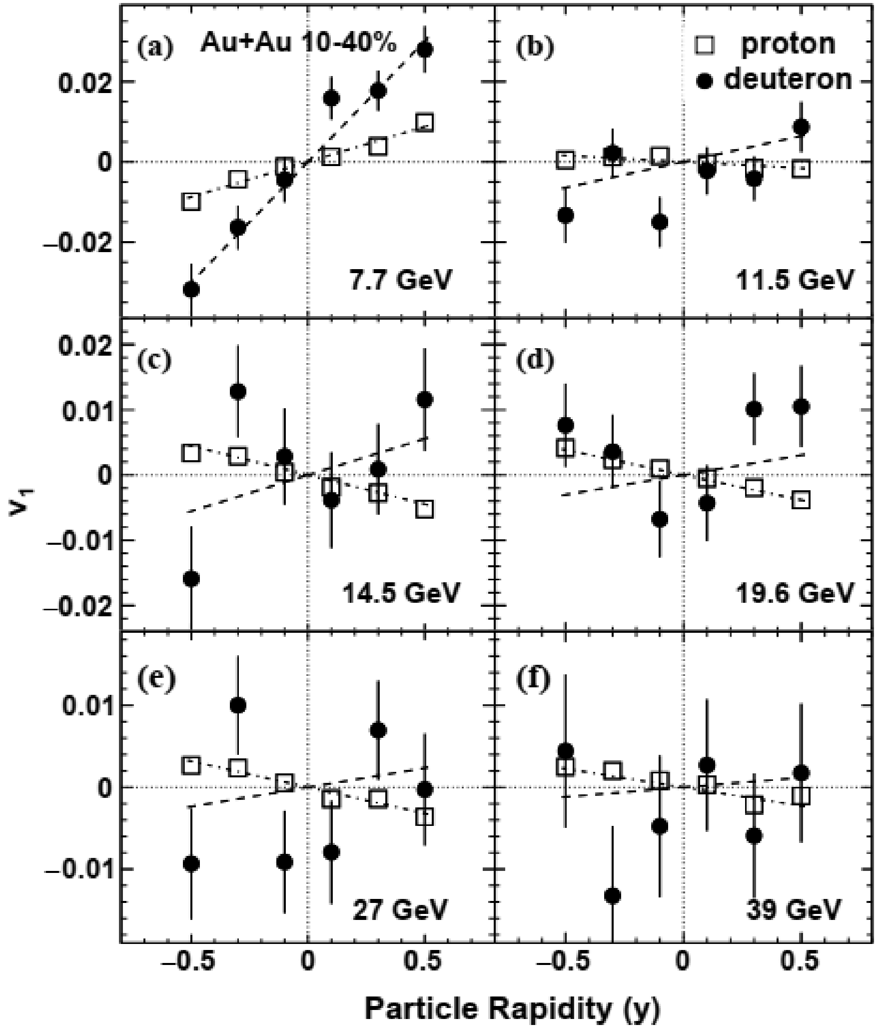

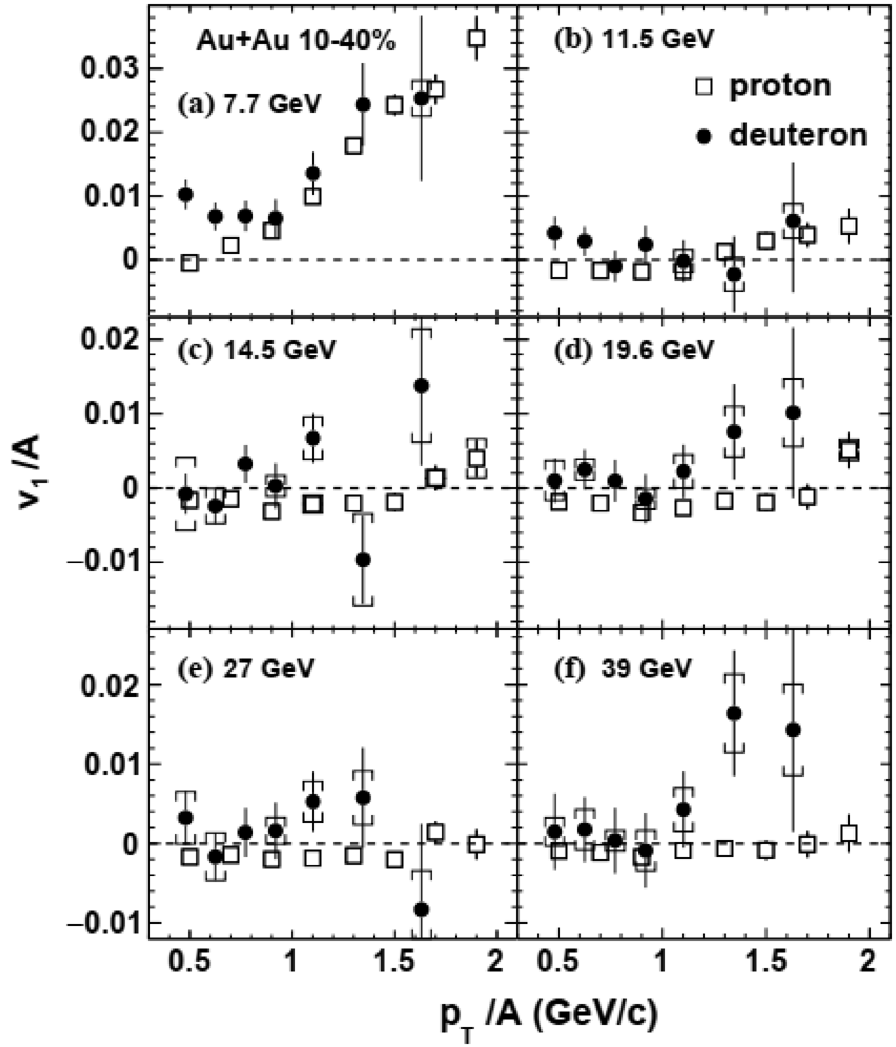

• Light nucleus v_2 from beam energy scan

Phys. Rev. C 94, 034908(2016)