Light Nuclei Production in Au+Au Collisions at Fixed Target $\sqrt{s_{NN}}$ = 3 GeV from STAR

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Outline

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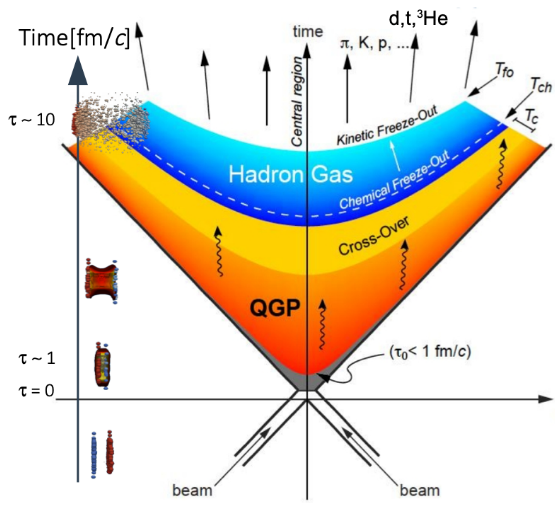
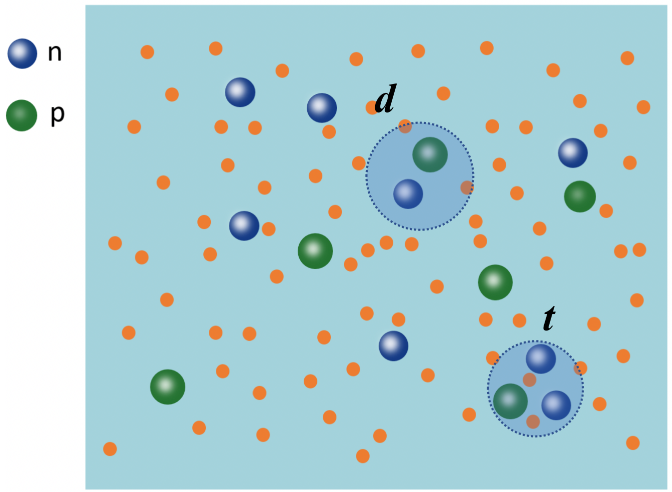
Introduction



➢ Heavy-ion Collisions

- **Chemical freeze-out:** Inelastic collisions ceases, chemical composition of particle yield get fixed
- **Kinetic freeze-out:** Elastic collisions ceases, momentum distributions of particles get fixed

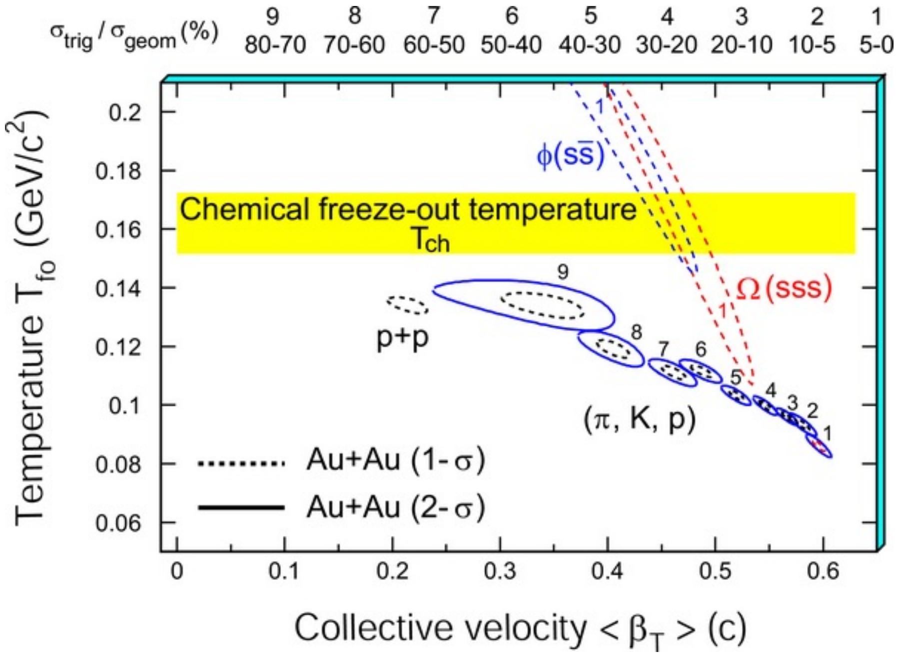


➢ Why Light Nuclei ?

- Light nuclei are formed in a restricted volume of phase space, they carry information about local baryon density fluctuations

Phys. Lett. B 774, 103 (2017)
Phys. Lett. B 781, 499 (2018)

Introduction

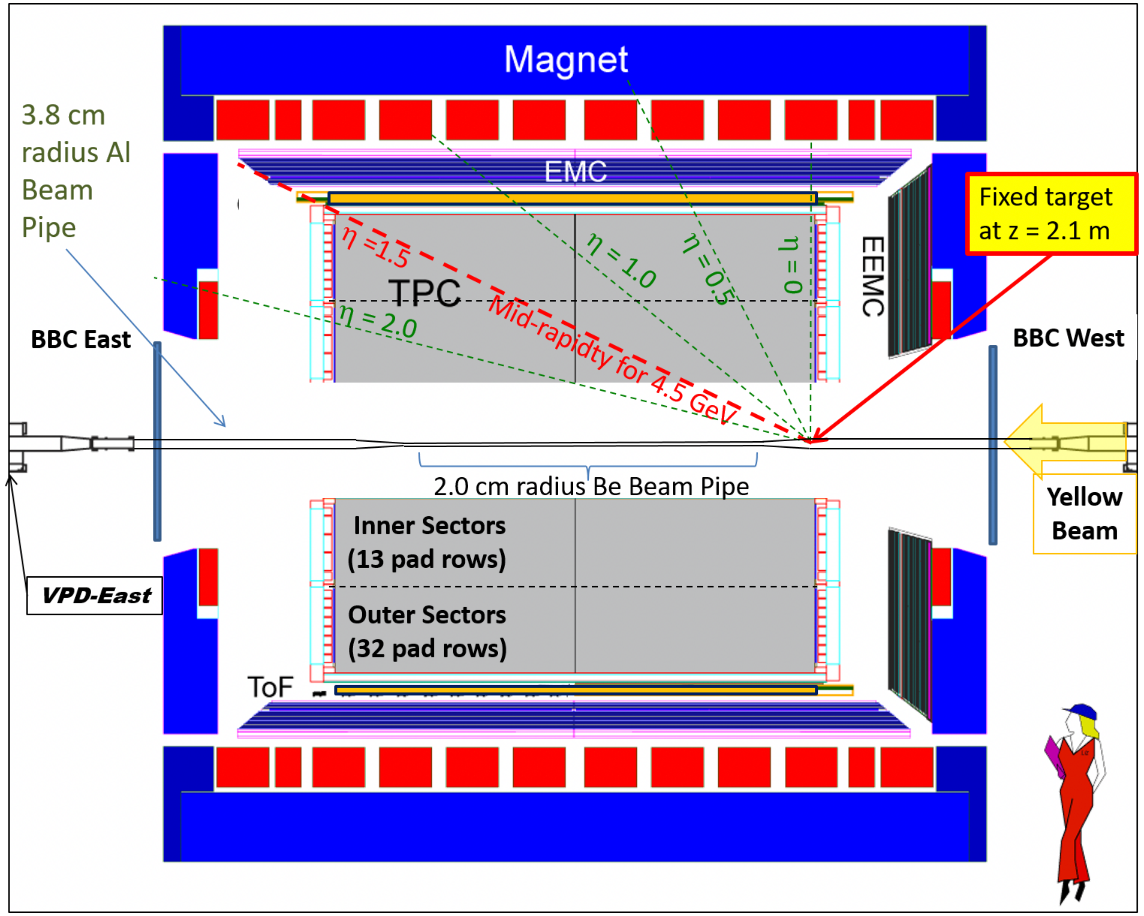


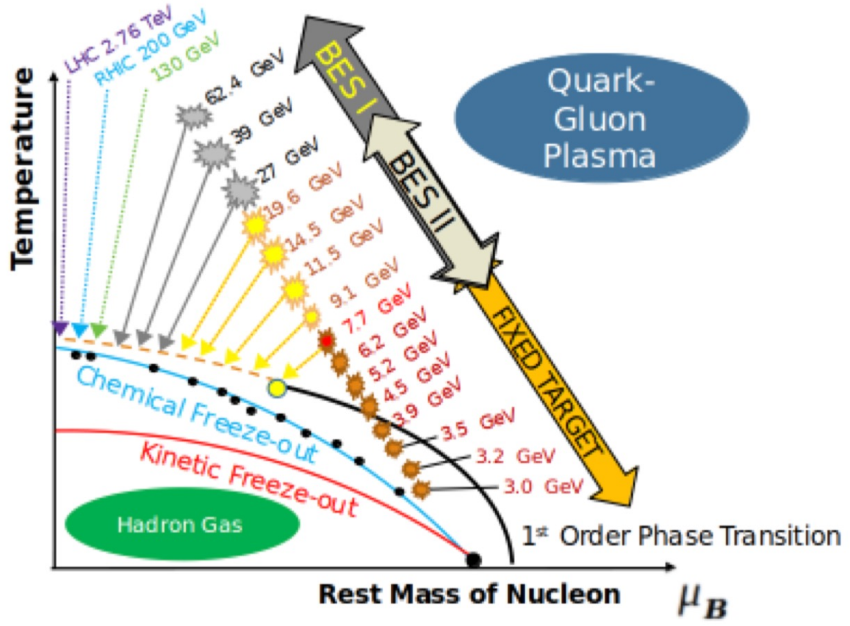
Nucl. Phys. A 757 102 (2005)

➢ Collective Motion

- The transverse momentum distributions of the different particles reflect the properties of the bulk of the matter at kinetic freezeout, after elastic collisions have ceased
- Information on an earlier stage can be deduced from the integrated yields of the different particles, which change only via inelastic collisions
- Collective motion leads to predictable behavior of the shape of the momentum spectra as a function of particle mass

STAR Fixed Target and Data Sets

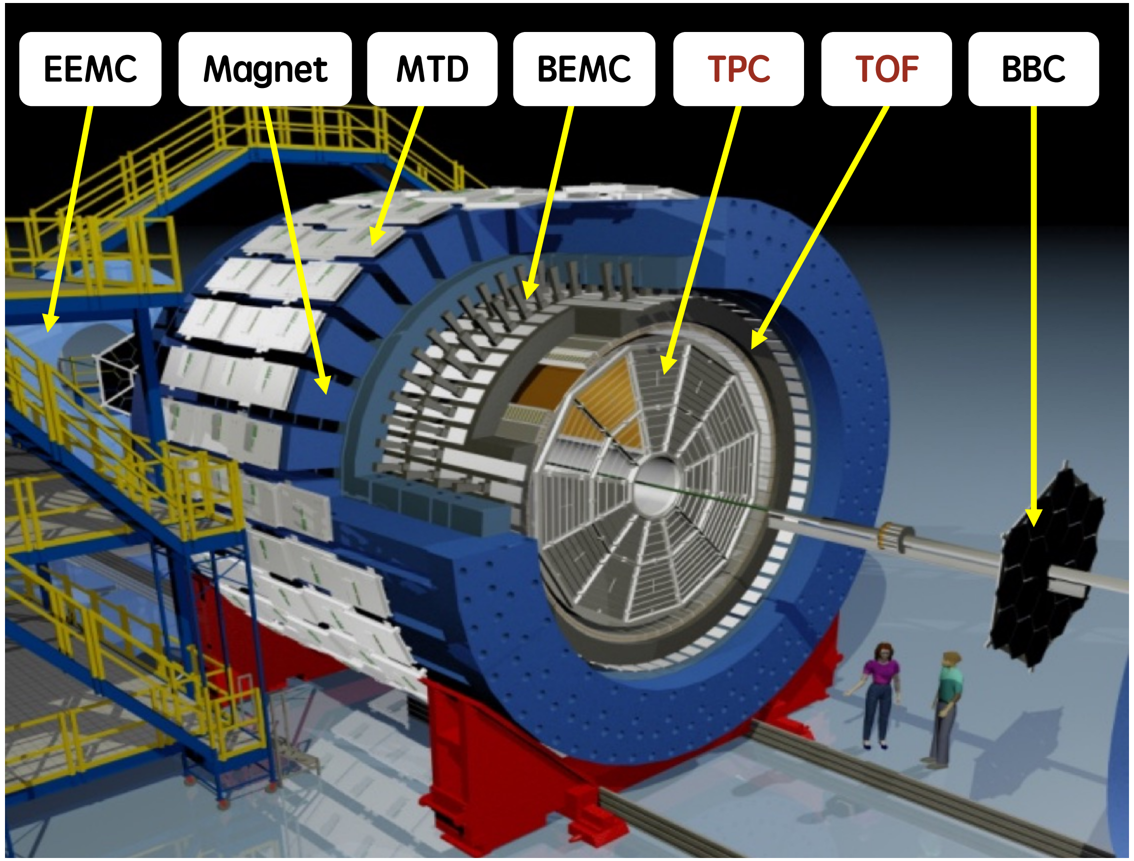


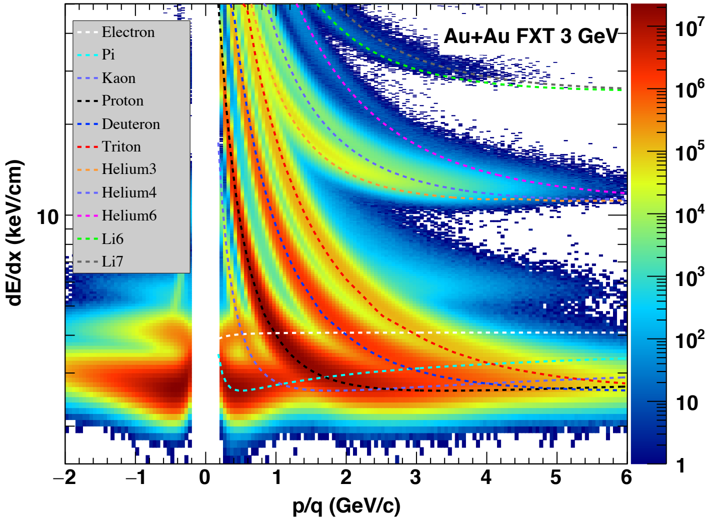


- Fixed Target (FXT) covers the collision energy $\sqrt{s_{NN}}$ = 3 - 13.7 GeV
- This study is based on the FXT $\sqrt{s_{NN}}$ = 3 GeV

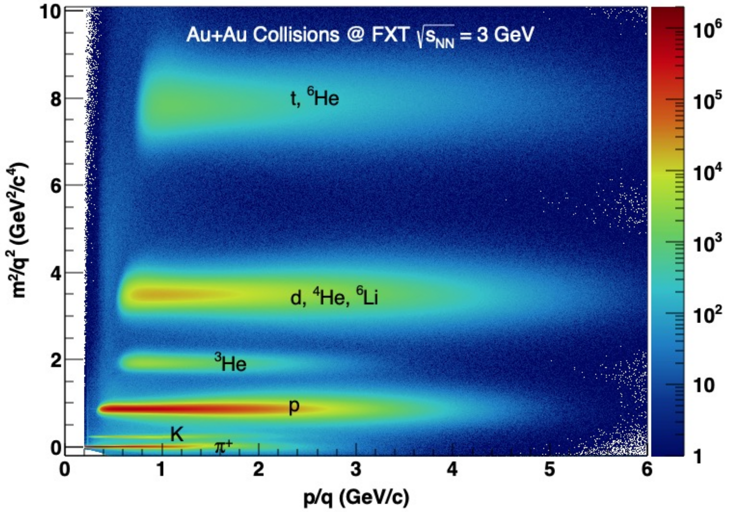
  Total events about 260M

Analysis Details --- STAR Detector & Particle Identification





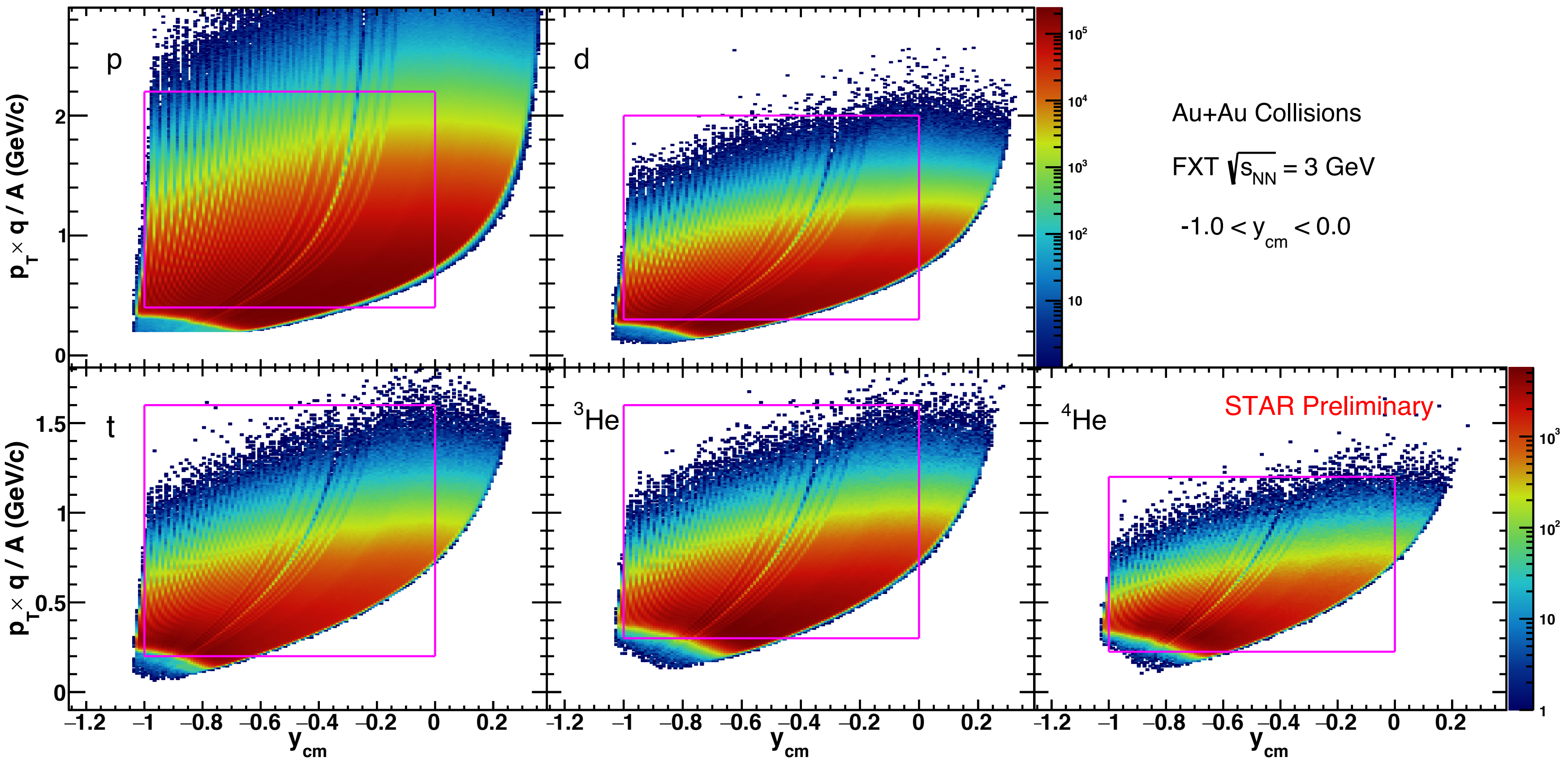
Low p_T: TPC



$$m^2 = p^2\left(\frac{c^2 t^2}{L^2} - 1\right)$$

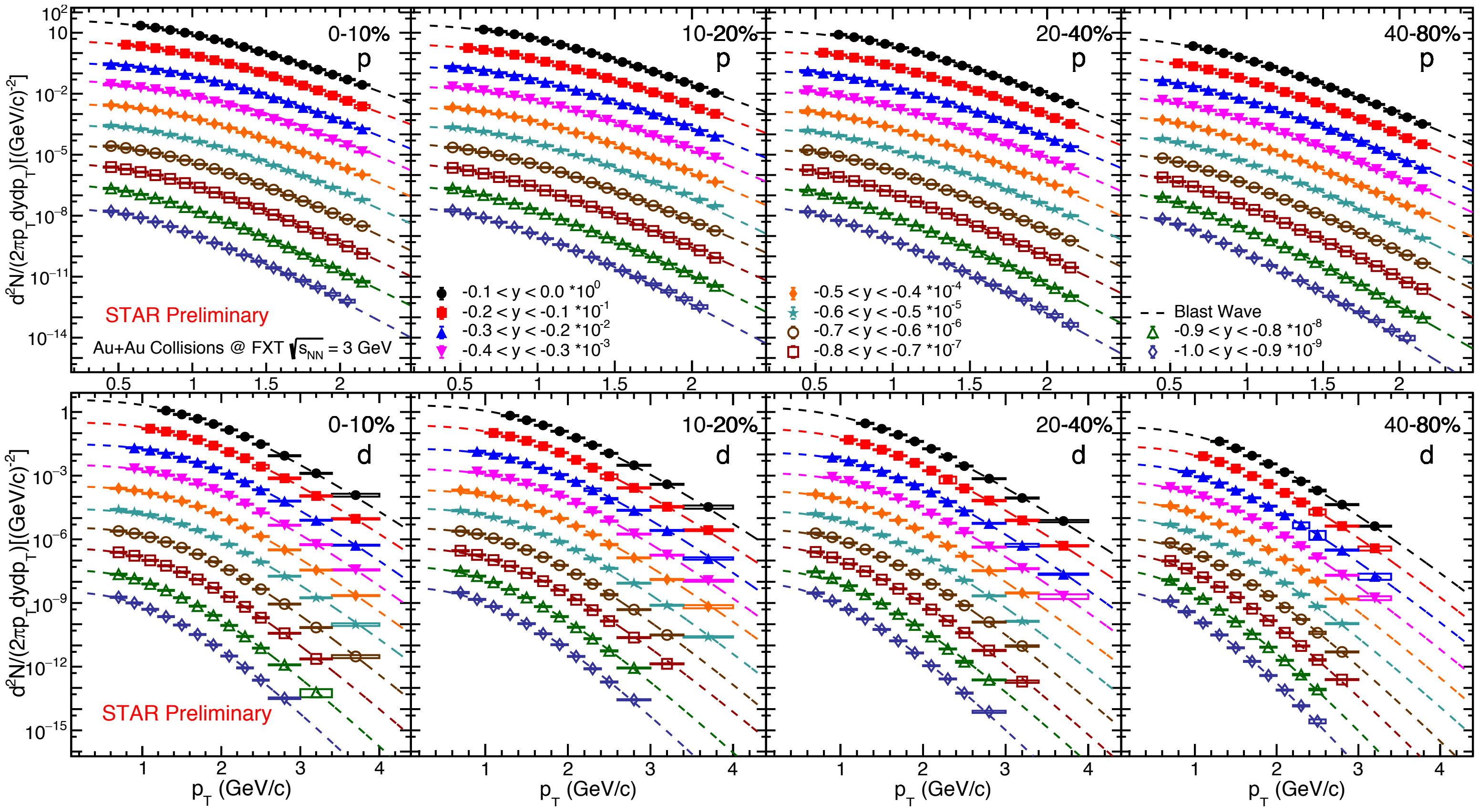
High p_T: TPC+TOF

Analysis Details --- Phase Space of Particles



- Mid-rapidity of FXT 3 GeV at y_{mid} = -1.045, $y_{cm} = -(y_{lab} - y_{mid})$
- The purple boxes in the figure indicate the p_T and rapidity ranges used in the analysis

Analysis Details --- Transverse Momentum Spectra



- p_T spectra of inclusive protons and deuterons at different rapidity windows are scaled by different factors

- Blast-Wave Function

$$\frac{1}{2\pi p_T}\frac{d^2N}{dp_T dy} \propto \int_0^R r dr m_T I_0\left(\frac{p_T \sinh\rho}{T}\right) K_1\left(\frac{m_T \cosh\rho}{T}\right)$$

$$\rho = \tanh^{-1}\beta_r, \quad \beta_r(r) = \beta\left(\frac{r}{R}\right)^n$$

T_{kin} : kinetic freeze-out temperature

$\langle \beta \rangle$: average radial flow velocity

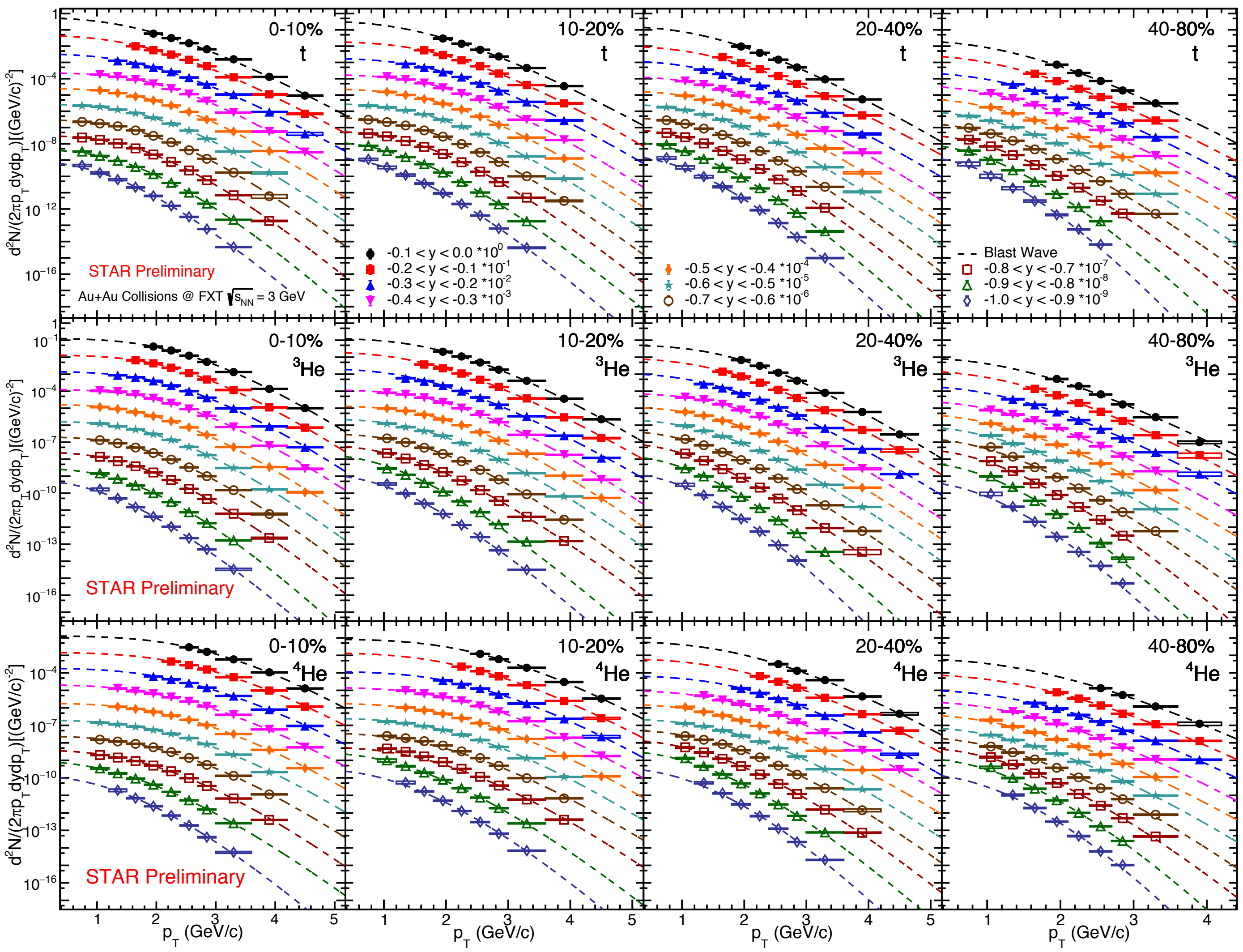
n : n=1

Analysis Details --- Transverse Momentum Spectra

Triton

^{3}He

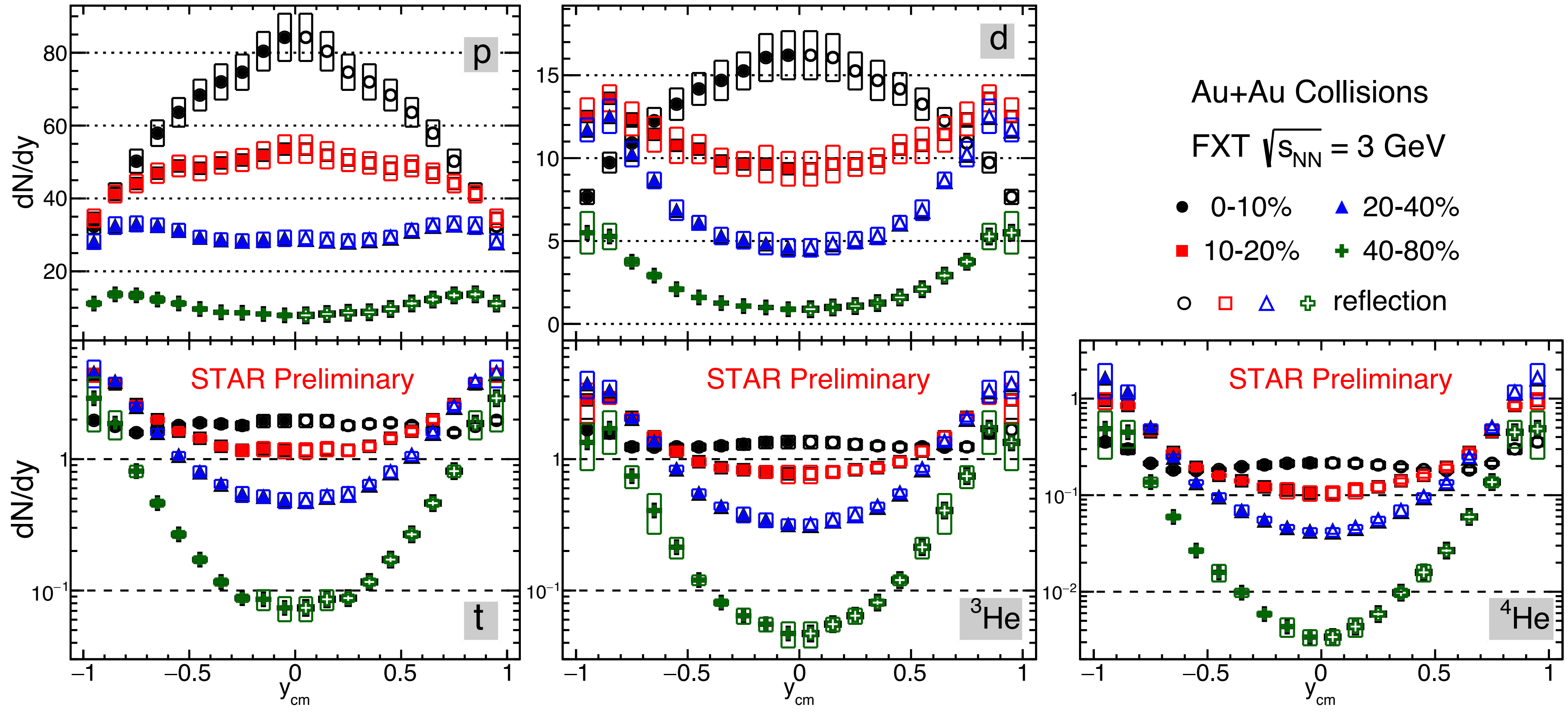
^{4}He



Mid-rapidity

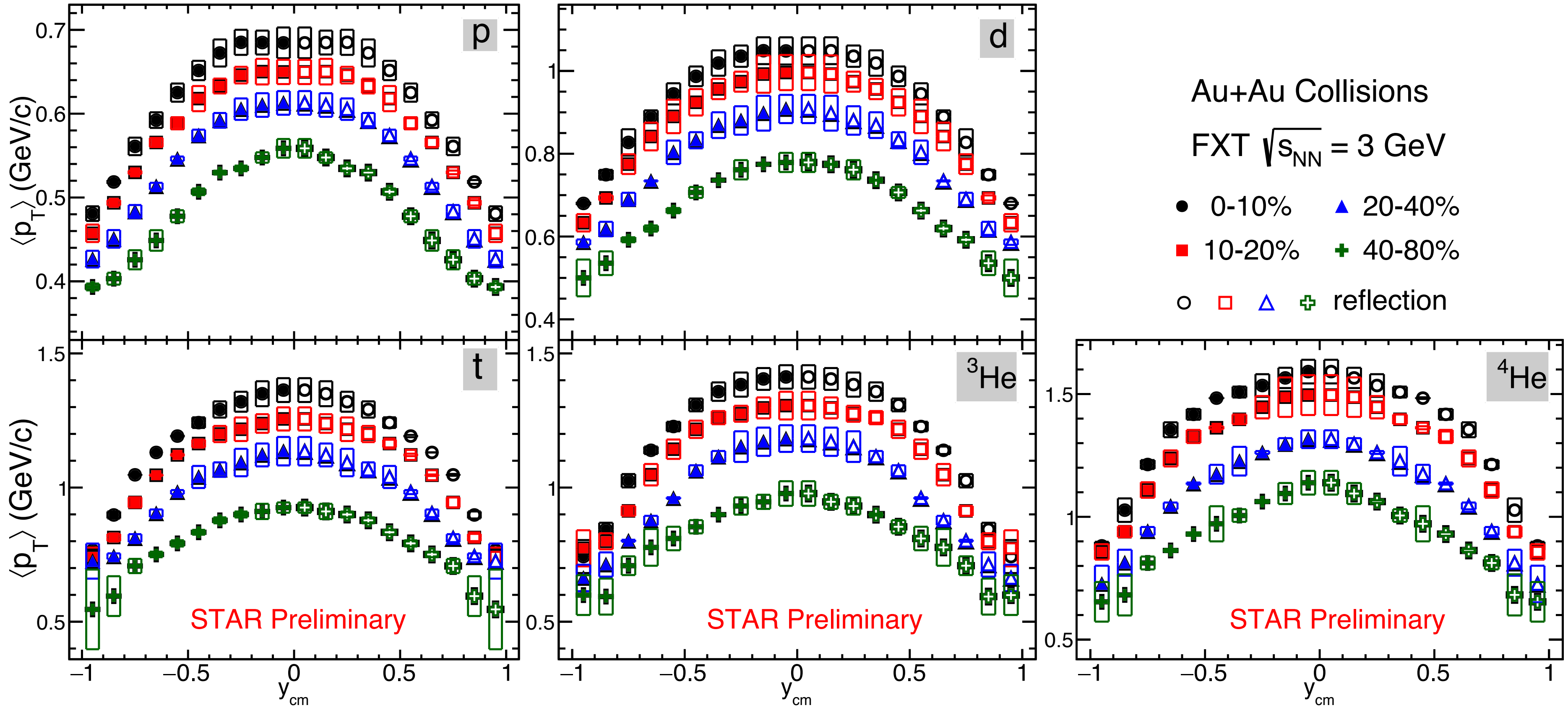
Backward Rapidity

Results --- dN/dy of Particles



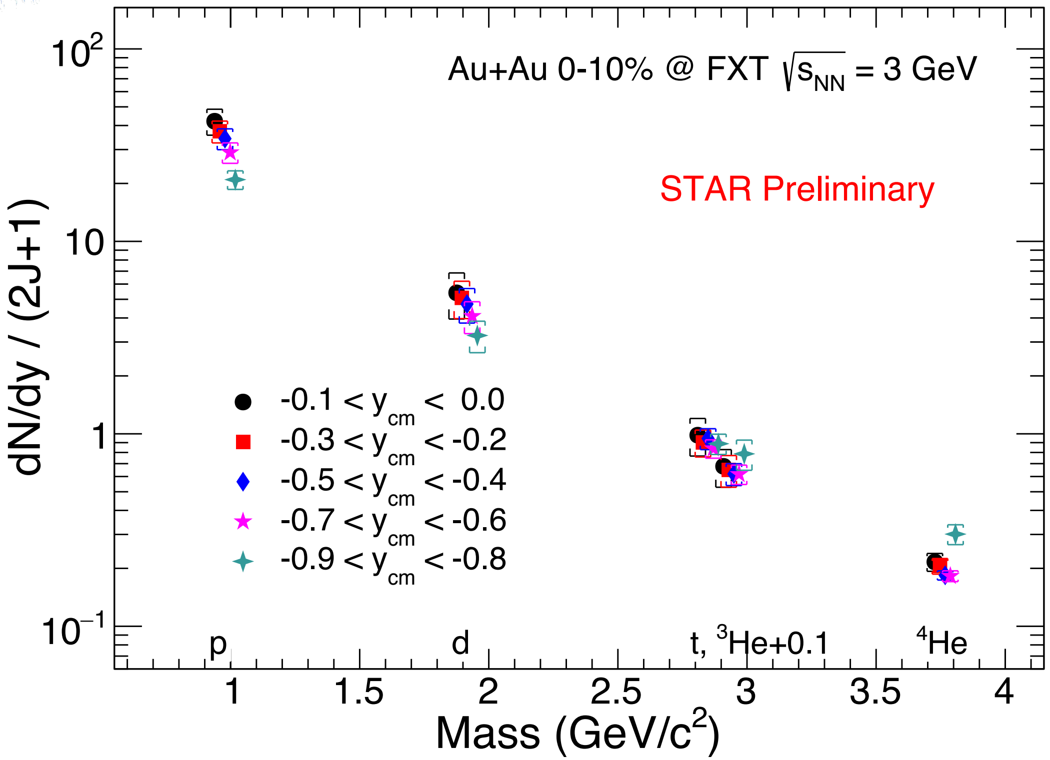
- $-1 < y_{cm} < 0$: obtained by p_T spectra; $0 < y_{cm} < 1$: reflection by measured range
- Systematic uncertainties are evaluated by various track cuts and different fit functions
- dN/dy of particles shows strong rapidity and centrality dependence

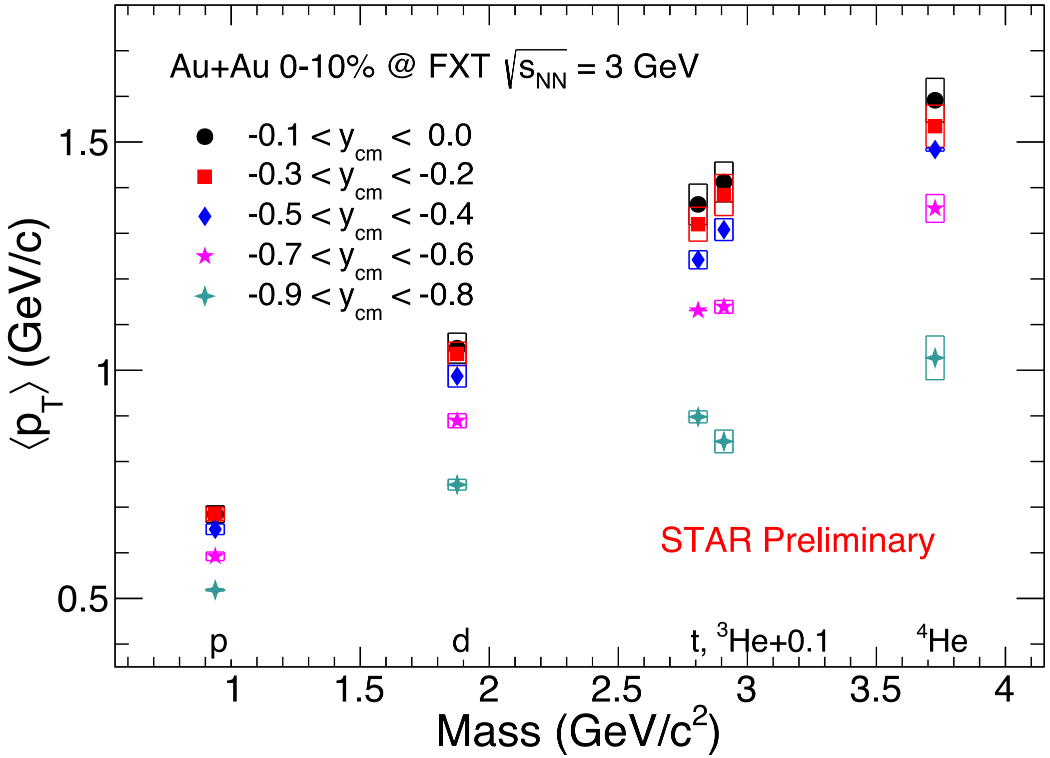
Results --- $\langle p_T \rangle$ of Particles



- $-1 < y_{cm} < 0$: obtained by p_T spectra; $0 < y_{cm} < 1$: reflection by measured range
- Systematic uncertainties of $\langle p_T \rangle$ are evaluated by different fit functions
- $\langle p_T \rangle$ of all particles decreases from mid-rapidity ($y_{cm} = 0$) to backward rapidity ($y_{cm} < 0$) in all centralities

Results --- dN/dy and $\langle p_T \rangle$ vs. Particle Mass





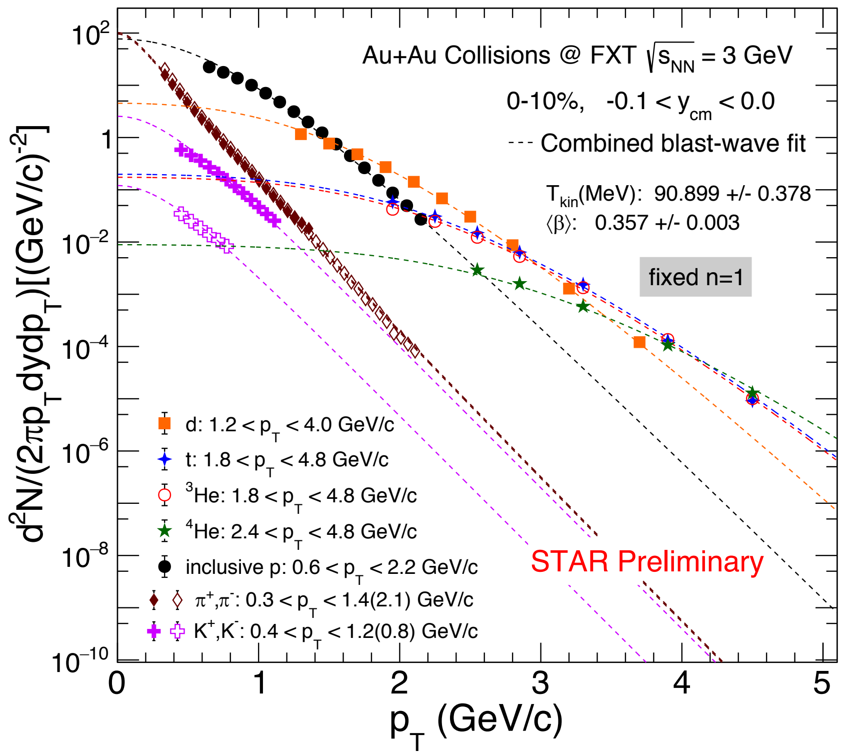
Mass of particles with a small shift at different rapidity ranges

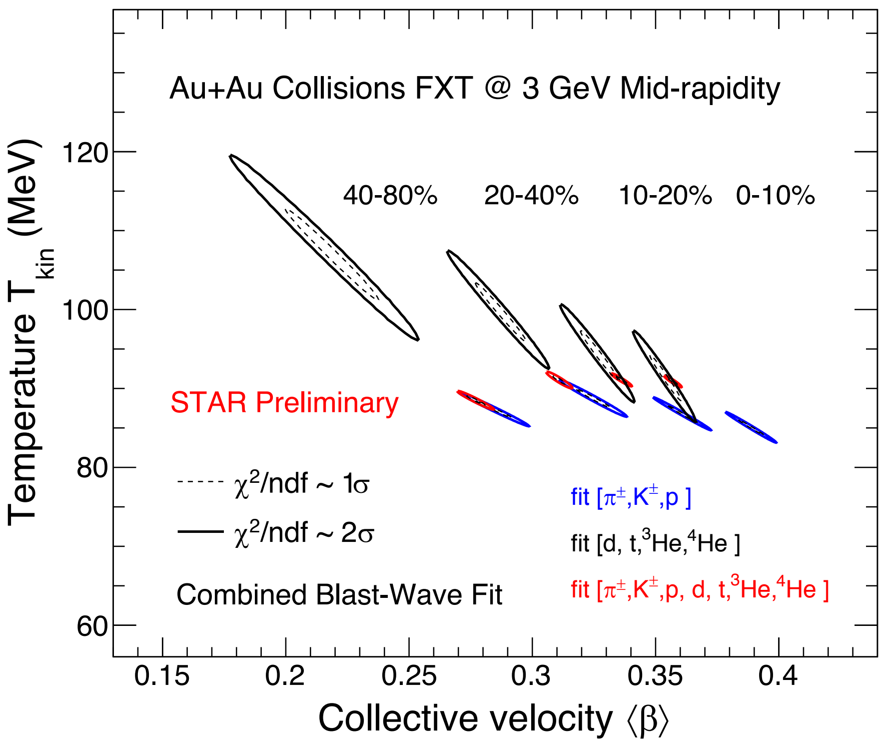
Nuclear Physics A 772 167–199 (2006)

Phys. Rev. Lett. 83, 5431 (1999)

- dN/dy decreases exponentially as a function of particle mass, 2J+1 is the spin degeneracy factor
- $\langle p_T \rangle$ increases linearly as a function of particle mass: collective motion of light nuclei !

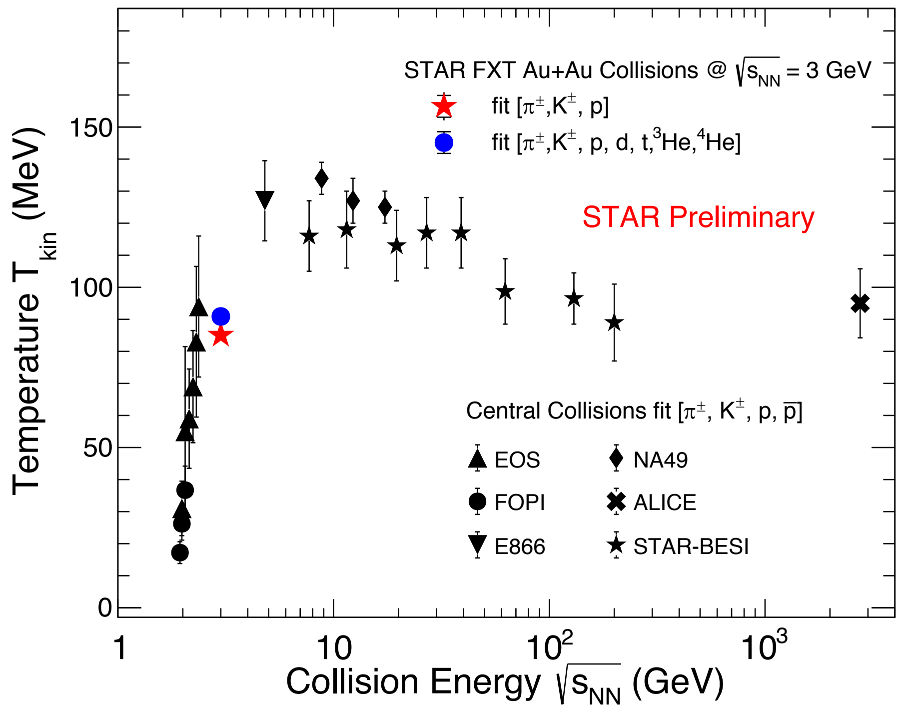
Results --- Combined Blast-Wave fit

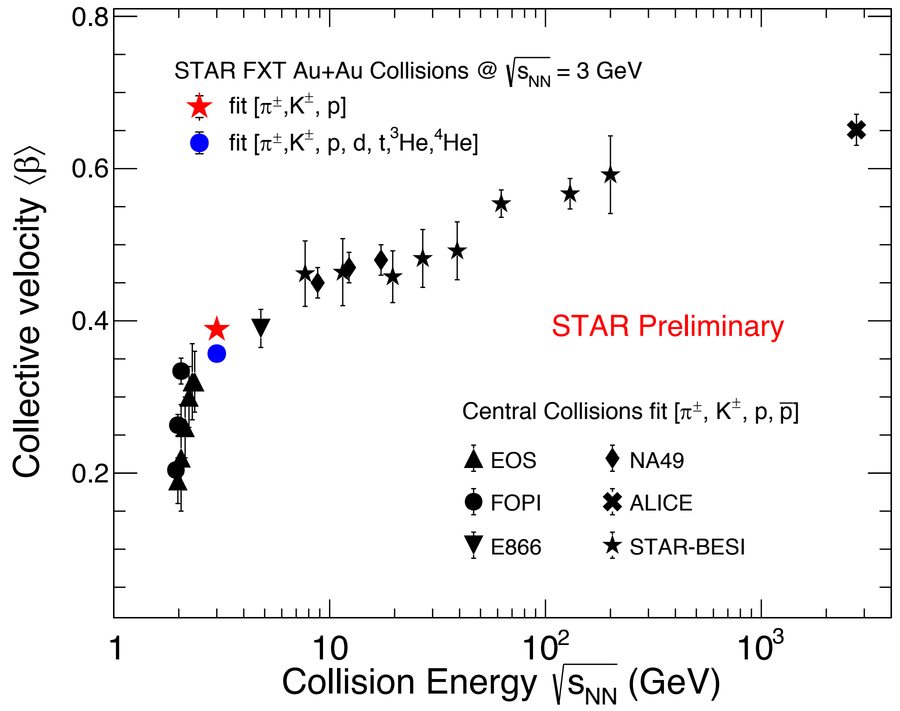




- We can get a common kinetic freeze-out temperature T_{kin} and average transverse radial flow velocity ⟨ β ⟩ through combined fit
- T_{kin} of light nuclei increases from central to peripheral collisions, while no obvious centrality dependence of pion, kaon and proton, ⟨ β ⟩ shows decrease trend from central to peripheral collisions
- The heavier particles correspond to higher values of T_{kin} and lower values of ⟨ β ⟩ with same system size, future investigations are needed to understand the driven physics

Results --- Energy dependence of T_{kin} and ⟨ β ⟩

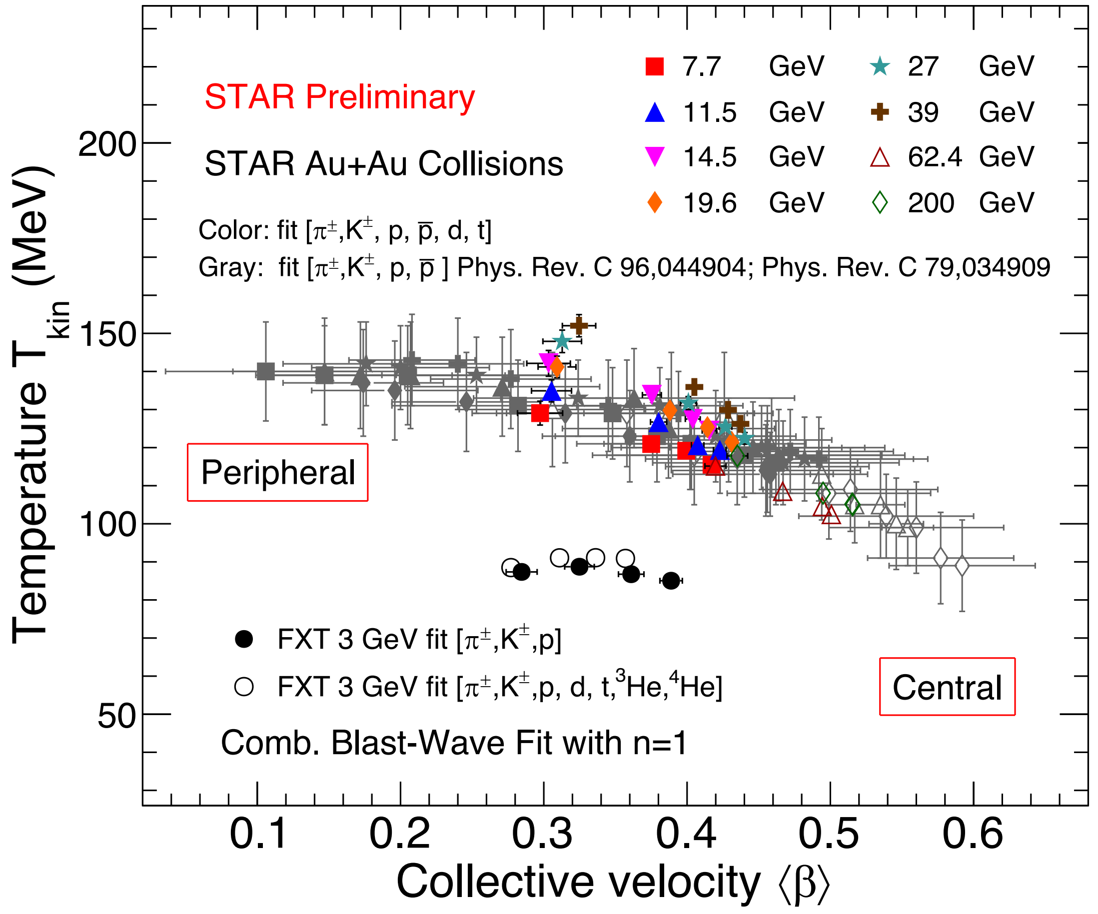




- T_{kin} and ⟨ β ⟩ at central collisions follow the energy dependence trend obtained by the world experiment

Phys. Rev. C 96, 044904(2017)
Phys. Rev. C 88, 044910 (2013)
Phys. Rev. C 79, 034909(2009)
Eur. Phys. J. C 2, 661 (1998)
Nucl. Phys. A612, 493 (1997)
Phys. Rev. Lett. 75, 2662 (1995)
arXiv:nucl-ex/9806002

Results --- Combined Blast-Wave fit



- Choose pion, kaon, inclusive proton, deuteron and triton for combined blast-wave fit at BES-I
- T_{kin} shows a stronger energy dependence from 7.7 to 39 GeV when light nuclei are considered into combined fit, especially in peripheral collisions
- FXT 3 GeV shows different trend compared to BES-I Au+Au collisions, indicate a different medium equation of state (EoS) at 3 GeV

Phys. Rev. C 96 (2017) 44904

Phys. Rev. C 79 (2009) 34909

Summary

- We report the first measurement of light nuclei (d, t, $^{3}\mathrm{He}$ and $^{4}\mathrm{He}$) production in Au + Au collisions at FXT $\sqrt{s_{NN}}$ = 3 GeV from STAR
- $\mathrm{p_T}$ spectra, dN/dy and $\langle \mathrm{p_T} \rangle$ of particles from mid-rapidity to backward rapidity have been presented
- The heavier particles correspond to higher values of $\mathrm{T_{kin}}$ and lower values of $\langle \beta \rangle$ with same system size, future investigations are needed to understand the driven physics
- FXT 3 GeV shows different $\mathrm{T_{kin}}$ vs. $\langle \beta \rangle$ trend compared to BES-I Au+Au collisions indicating a different medium equation of state (EoS) at 3 GeV

Thank you for your attention!