Production of light nuclei in Au+Au collisions at $\sqrt{s_{NN}}$ = 7.7 and 27 GeV at RHIC-STAR

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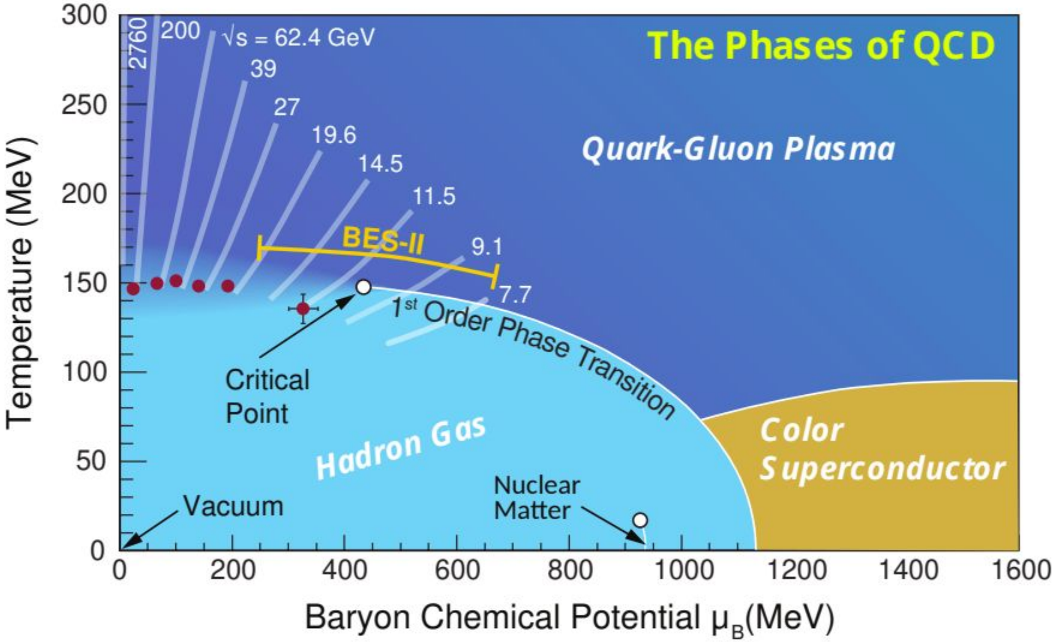
Previously presented:
https://indico.cern.ch/event/1329196/contributions/5665364/attachments/2756905/4803916/Updated_sibaram_ALICE_STAR_India_Colla_Nov_2023.pdf

Outline

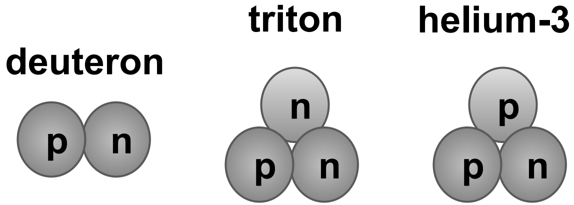
- Introduction
- The STAR experiment
- Analysis details
  - Data set, event, and track selection
  - Particle identification
  - Signal extraction
- Corrections
- Results
- Summary
- Outlook



Nucl. Phys. A **1017** 122343 (2022)

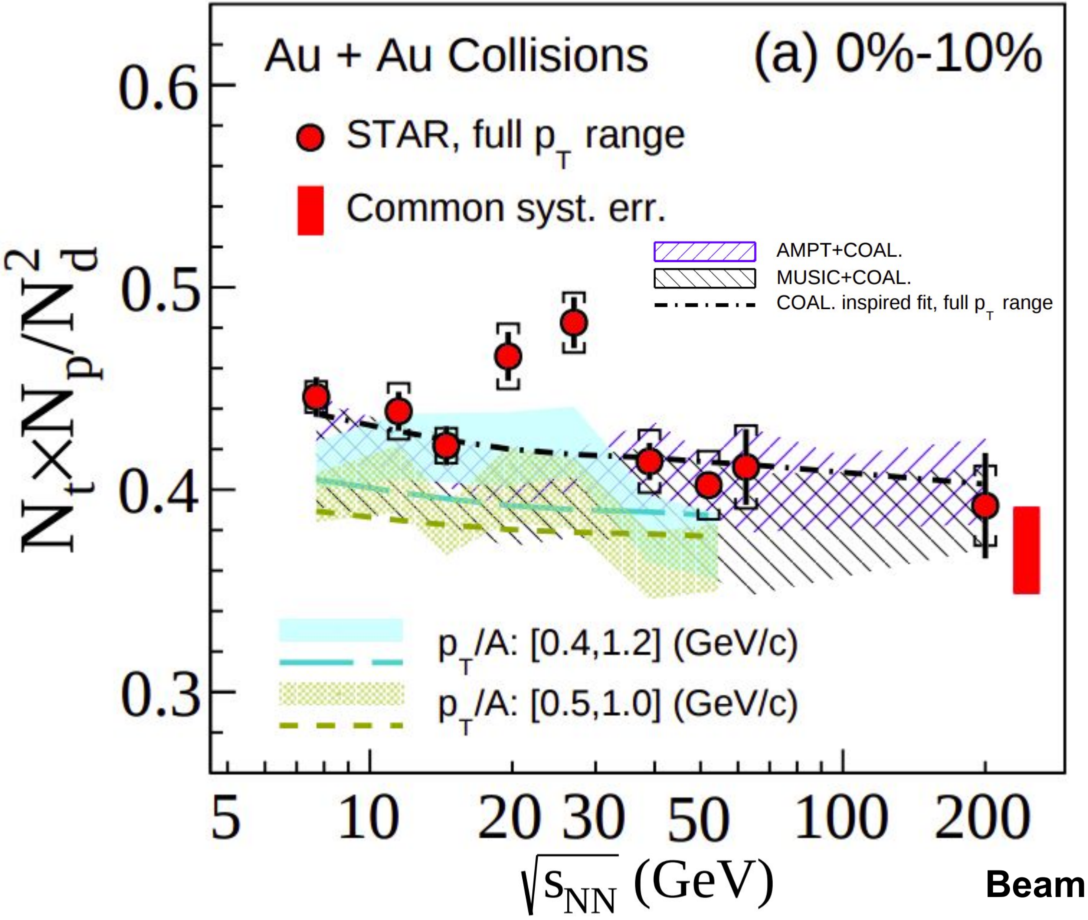
- Goal of heavy-ion collision experiment is to explore **QCD phase diagram**
- **QGP** to **Hadronic matter** -> continuous at low μ_B and 1st order at higher μ_B (by QCD)
- Search for **Critical Point (CP)** in phase diagram
- Choice of observable : **Compound light nuclei ratio** $\frac{N_t \times N_p}{N_d^2} \propto (1 + \Delta n)$

Phys. Lett. B **774** 103-107 (2017)
Eur. Phys. J. A **57** 11313 (2021)



Beam Energy Scan program (BES-I) collider mode :
7.7, 9.1, 11.5, 14.5, 19.6, 27, 39, 62.4, 200 GeV

Introduction



STAR, Phys. Rev. Lett. **130** 202301 (2023)

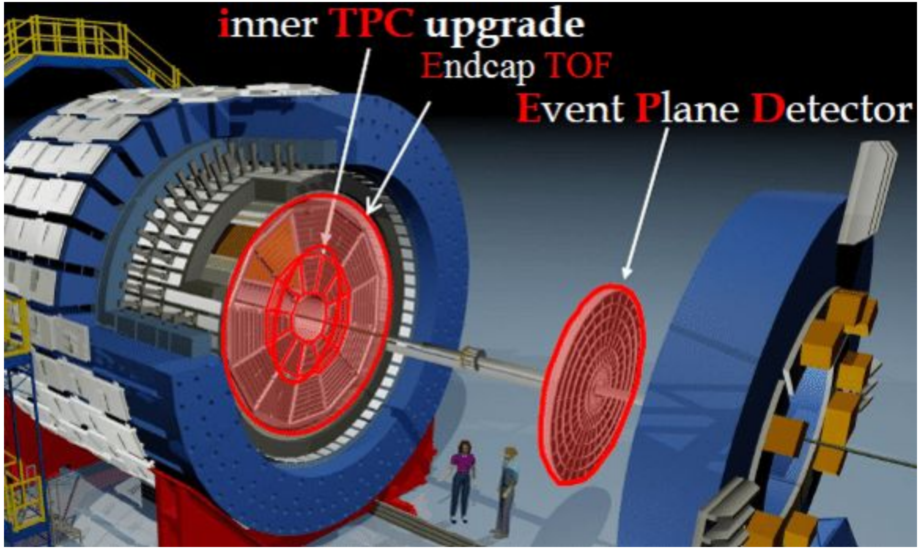
Deviation from baseline is 4.1 sigma

- Light nuclei yields and ratios could provide a probe to search for signature of critical phenomena

Beam Energy Scan program (BES-II) collider mode : 7.7, 9.2, 11.5, 14.6, 17.3, 19.6 GeV

The STAR experiment

- **Solenoidal Tracker at RHIC (STAR)** is one of the large detector systems at RHIC consisting of several sub-detectors
- **Time Projection Chamber (TPC)** and **Time of Flight (TOF)** are two sub-detectors used for particle identification at STAR



J. Phys. Conf. Ser. **742** 012022 (2016)

- The upgrade to **iTPC** provides better momentum resolution, better dE/dx resolution, and improved acceptance at high rapidity (**$|\eta| < 1.5$**)

$$\text{Pseudo-rapidity} : \eta = -\ln \tan \frac{\theta}{2}$$

Data set, Event, and track selection

Au+Au, $\sqrt{s_{NN}}$ = 7.7 GeV

Trigger setup:
production_7p7GeV_2021

Data file: picoDst

Stream: st_physics

Trigger selection: 810010,

810020, 810030, 810040

Production tag: P22ib

Number of Events ~ 52.5 M

Au+Au, $\sqrt{s_{NN}}$ = 27 GeV

Trigger setup:
27GeV_production_2018

Data file: picoDst

Stream: st_physics

Trigger selection:

610001, 610011, 610021, 610031,

610041

Production tag: P19ib

Number of Events ~ 267 M

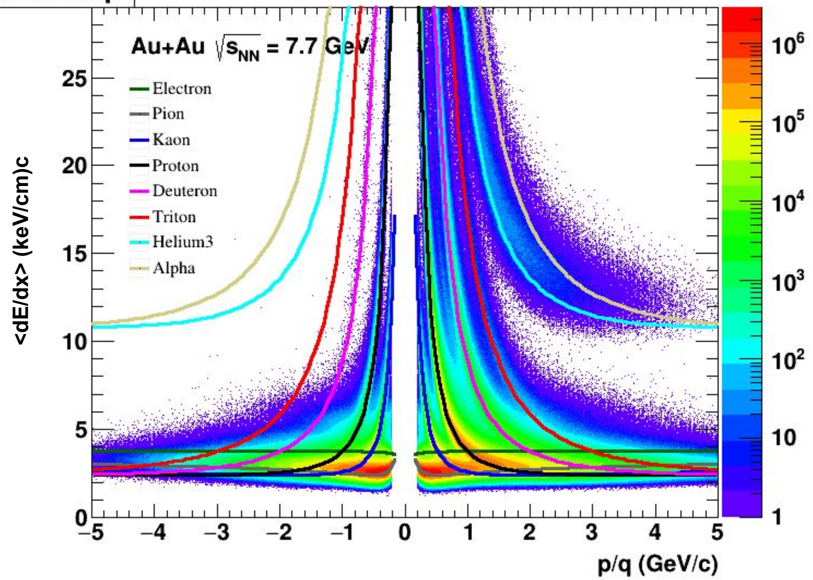
Event Selection:

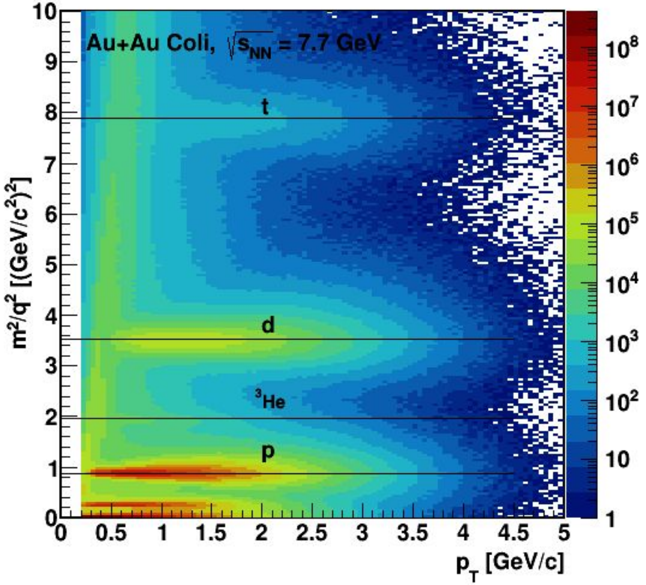
Cuts (27 GeV)	Value
$\lvert v_z \rvert$	≤ 70 (40) cm
v_r	≤ 2 cm

Track Selection:

Cuts (27 GeV)	Value
nHitsFit	≥ 25 (20)
nHitsdEdx	≥ 15 (10)
nHitsFit/nHitsPoss	≥ 0.52
DCA	< 1 cm
p_T (GeV/c)	≥ 0.2
$\lvert y \rvert$ (d)(t)(^{3}He)	< (0.3) (0.5) (0.5)

dEdx vs p





- **PID** using **dE/dx** information from **TPC** at low p_T

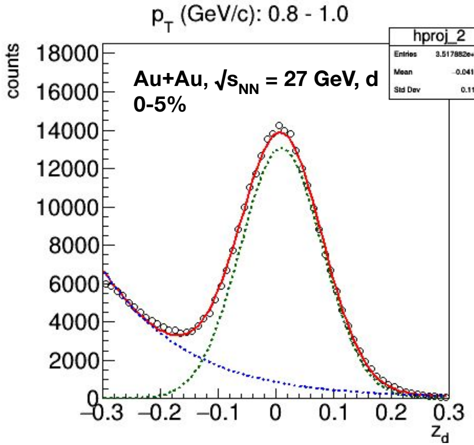
$$Z = ln\left(\frac{<dE/dx>}{<dE/dx>_{theory}}\right)$$

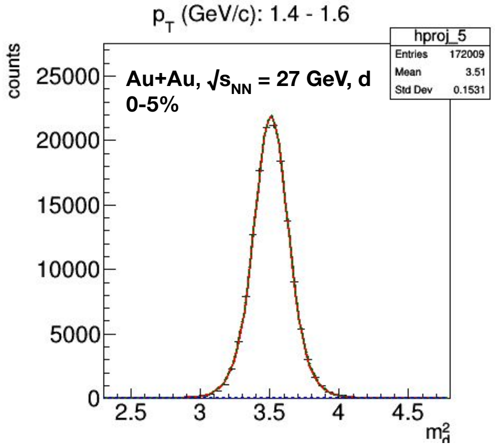
- **PID** using **m^2/q^2** information from **TOF** at intermediate p_T

$$\frac{m^2}{q^2} = p^2(1/\beta^2 - 1)$$

Nucl. Instrum. Meth. A **562** 154-197 (2006)

Signal extraction from TPC and TOF

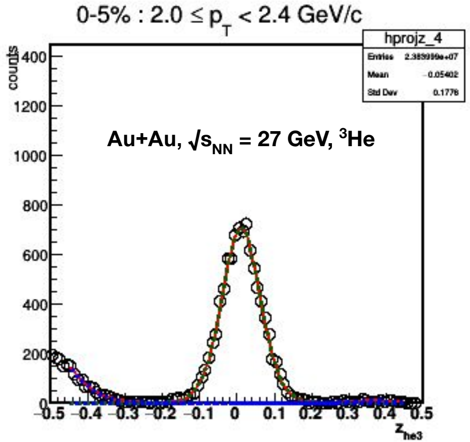




Total function

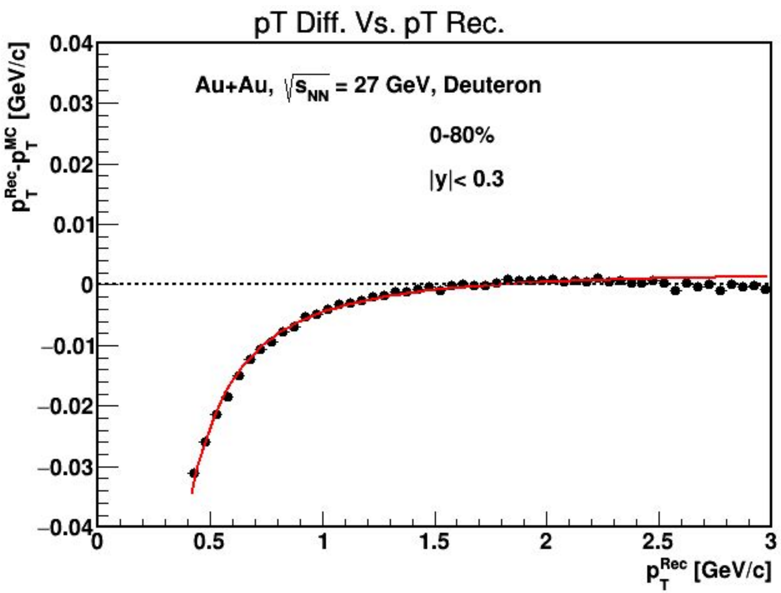
Background

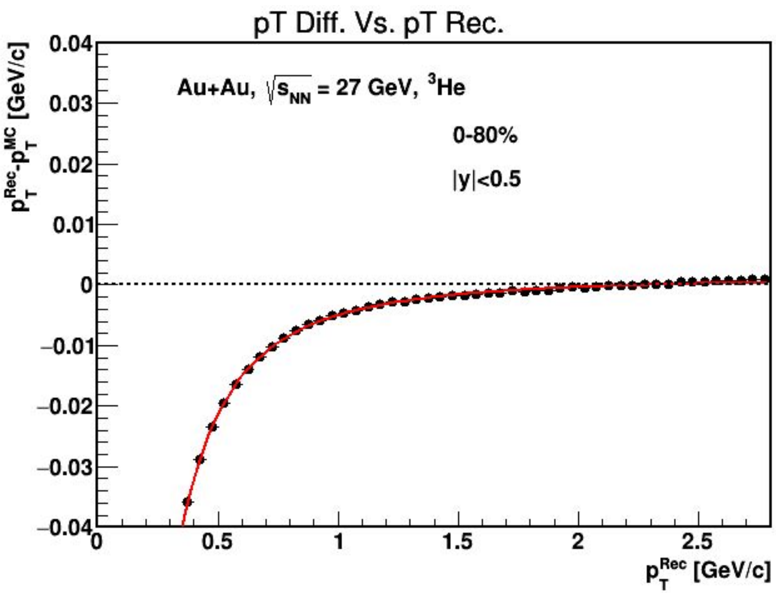
Signal



- ➔ At low p_T : Gaussian + exponential
- ➔ At intermediate p_T : student_t + exponential/gaussian

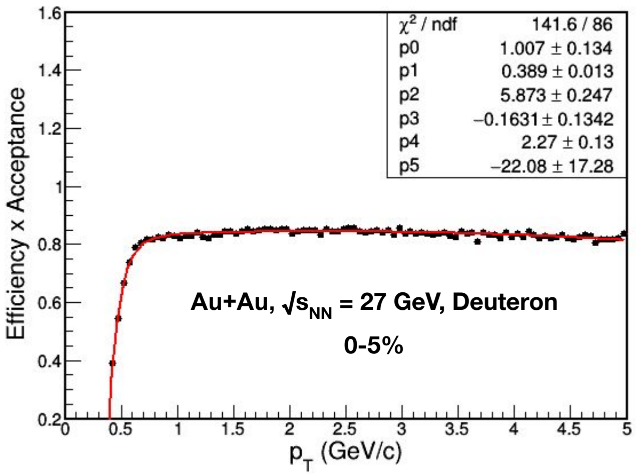
Energy loss correction

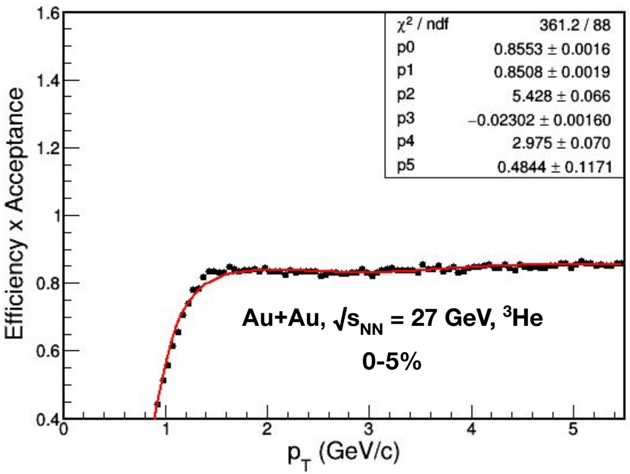




Fit function: $f(p_T) = a_1 + a_2\left(1 + \frac{a_3}{p_T^2}\right)^{a_4}$

TPC track efficiency and Absorption correction





Fit function:

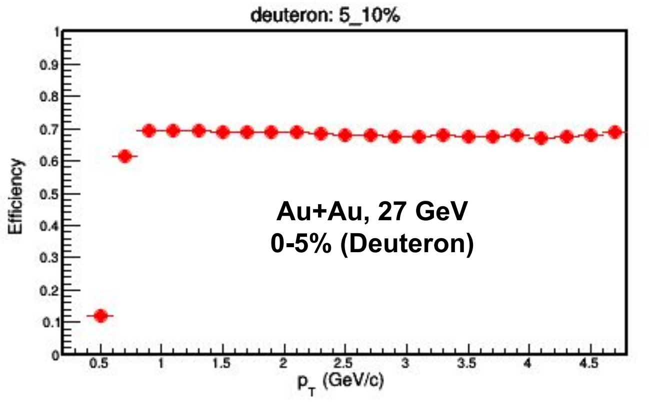
$$f(p_T) = a_1 exp(-(\frac{a_2}{p_T})^{a_3}) + a_4 exp(-\frac{(p_T - a_5)^2}{2a_6})$$

Absorption correction factor: $f(p_T) = p_0 + p_1p_T + p_2p_T^2 + p_3p_T^3 + p_4p_T^4 + p_5p_T^5 + p_6p_T^6 + p_7p_T^7 + p_8p_T^8$

Particle	p_0	p_1	p_2	p_3	p_4	p_5	p_6	p_7	p_8
Deuteron	1.17269	-0.342489	0.287993	-0.126426	0.0325183	-0.00508311	0.000475232	-2.44273e-05	5.30683e-07
^{3}He	1.24114	-0.325563	0.190857	-0.0591357	0.0108598	-0.00122826	8.46123e-05	-3.29416e-06	5.65162e-08

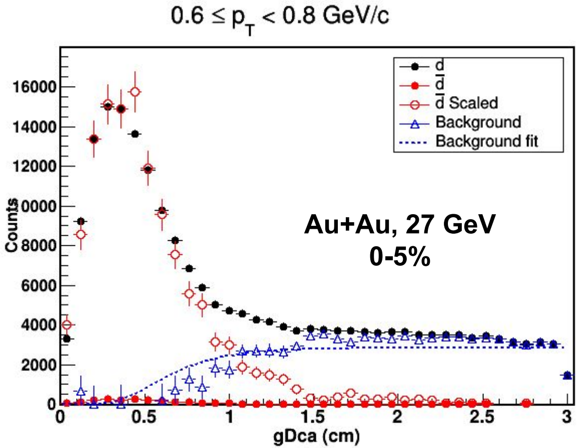
Reference: [Link1](), [Link2](), [Link3]()

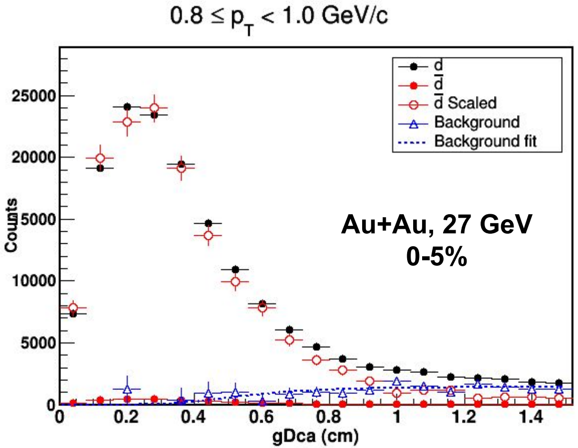
TOF matching efficiency and Background Corr.



➔ TOF matching efficiency is defined as

$$\epsilon_{TOF} = \frac{N_{TOF}}{N_{TPC}}$$



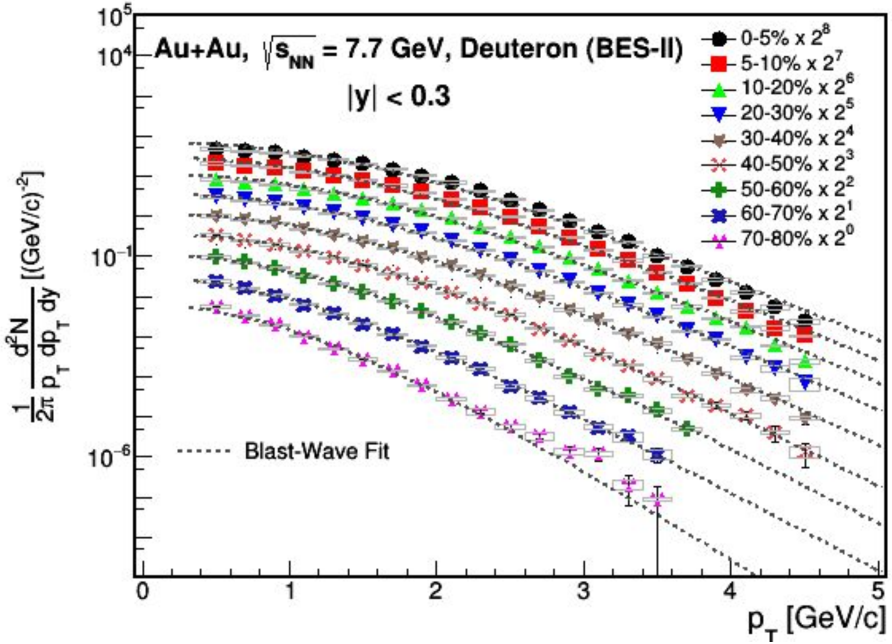


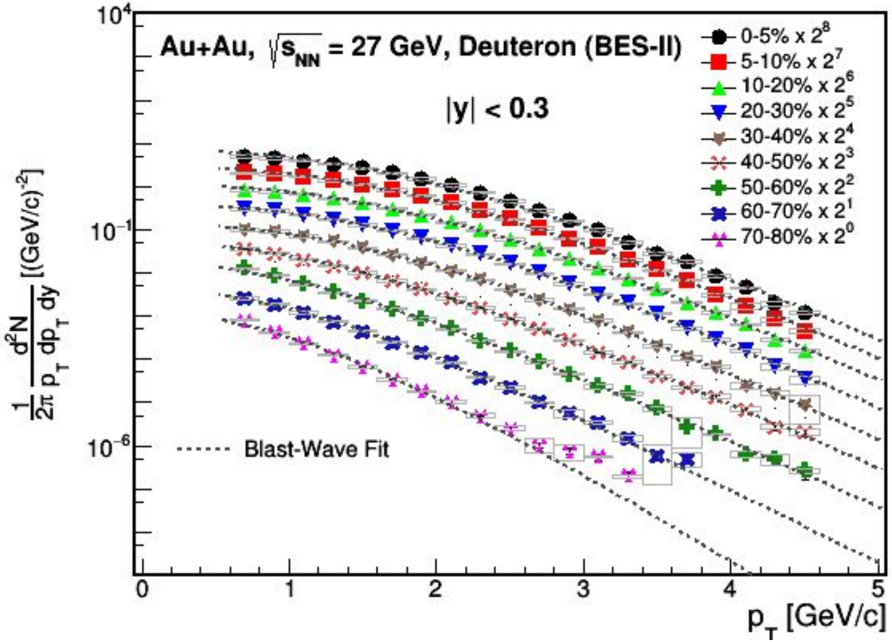
Fit function:

$$f(x) = a_1 \bar{d}\,(x) + d_{bkg}(x)$$

$$d_{bkg}(x) = a_2(1 - exp(\frac{x}{a_3}))^{a_4}$$

Corrected p_T spectra of deuteron





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

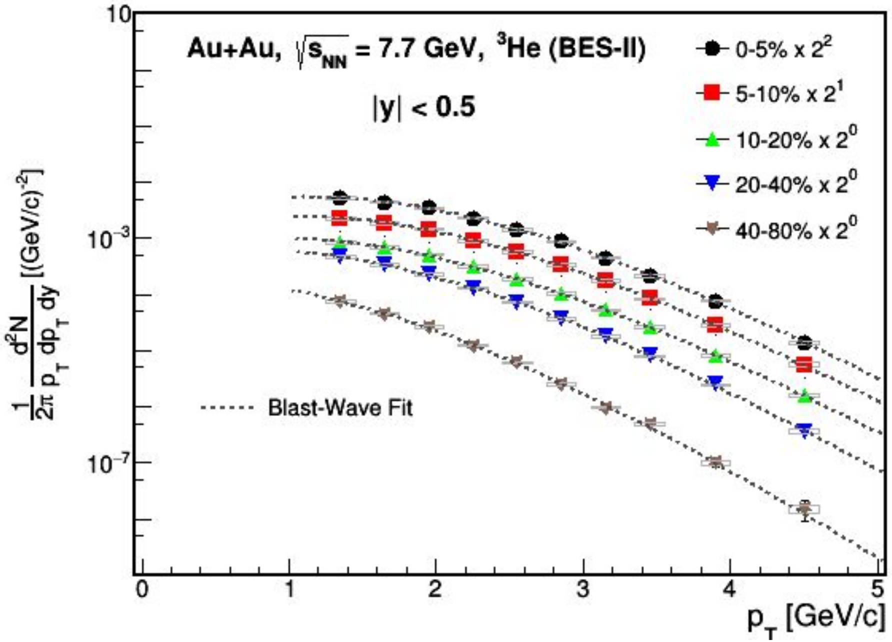
$$\rho = \tanh^{-1}\beta_r \;,\; \beta_r(r) = \beta_s\left(\frac{r}{R}\right)^n$$

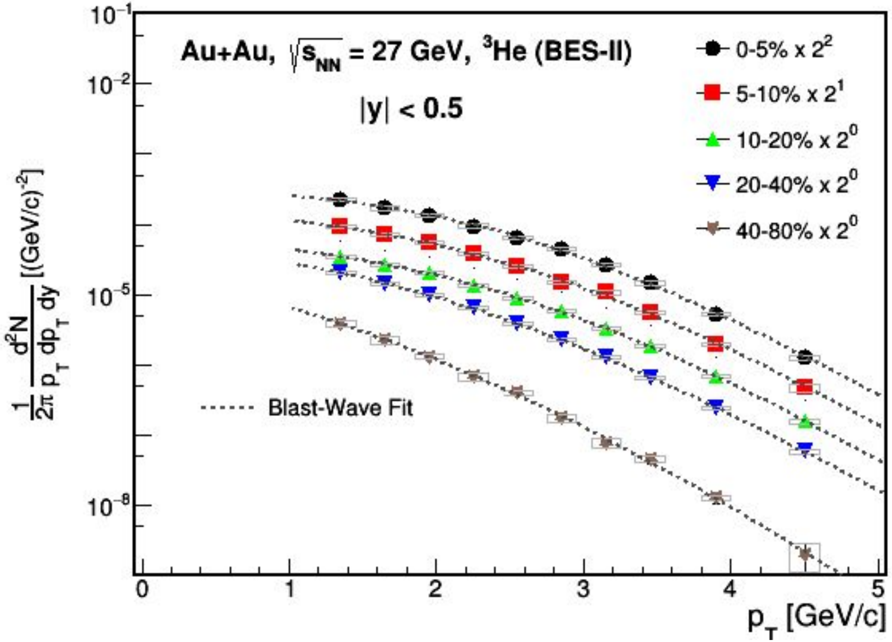
Phys. Rev. C **99**, 064905 (2019)

- ➢ Energy loss correction (✅)
- ➢ TPC efficiency and acceptance (✅)
- ➢ TOF efficiency (✅)
- ➢ Absorption correction (✅)
- ➢ Background correction (✅)

❑ A clear p_T and centrality dependence of light nuclei spectra is observed

Corrected p_T spectra of ^{3}He





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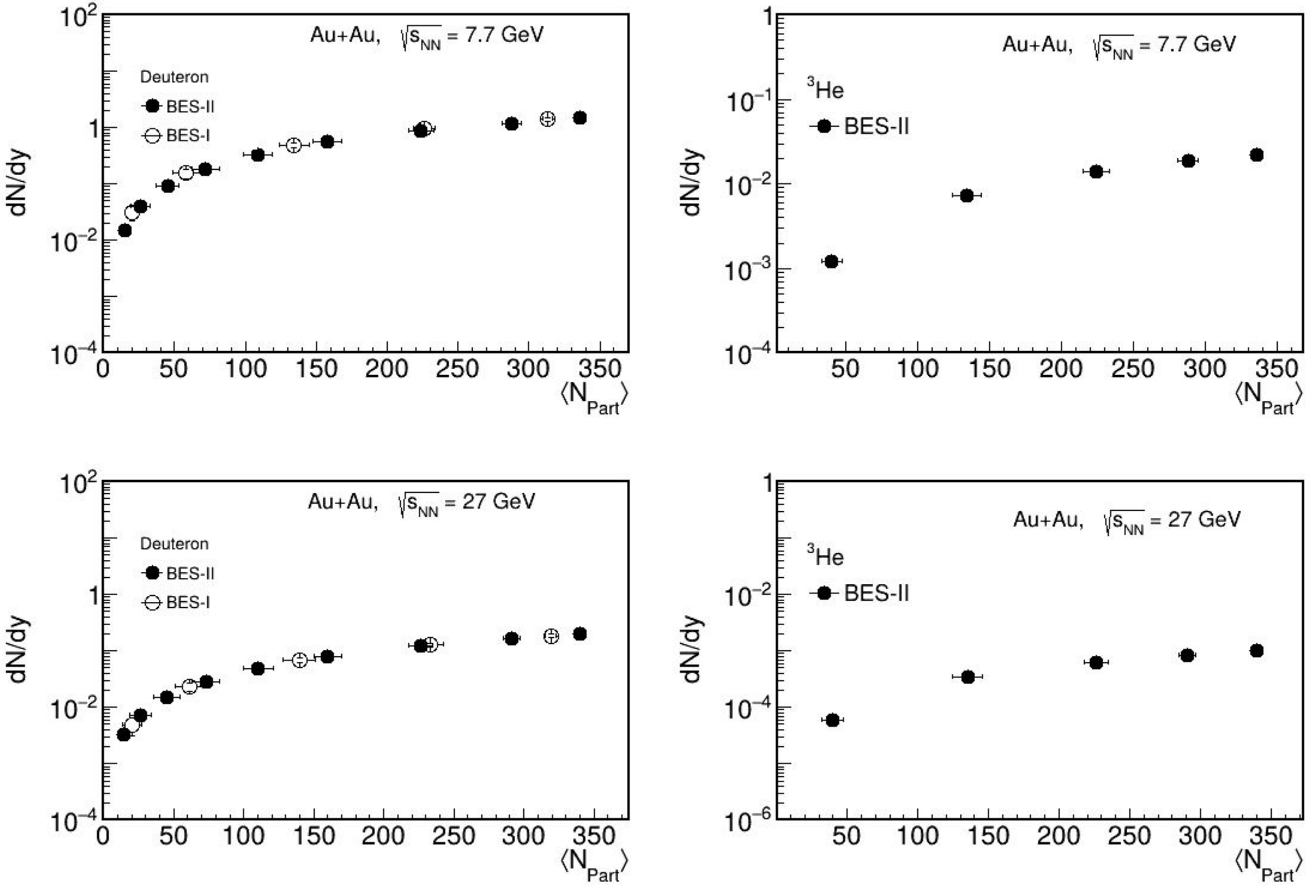
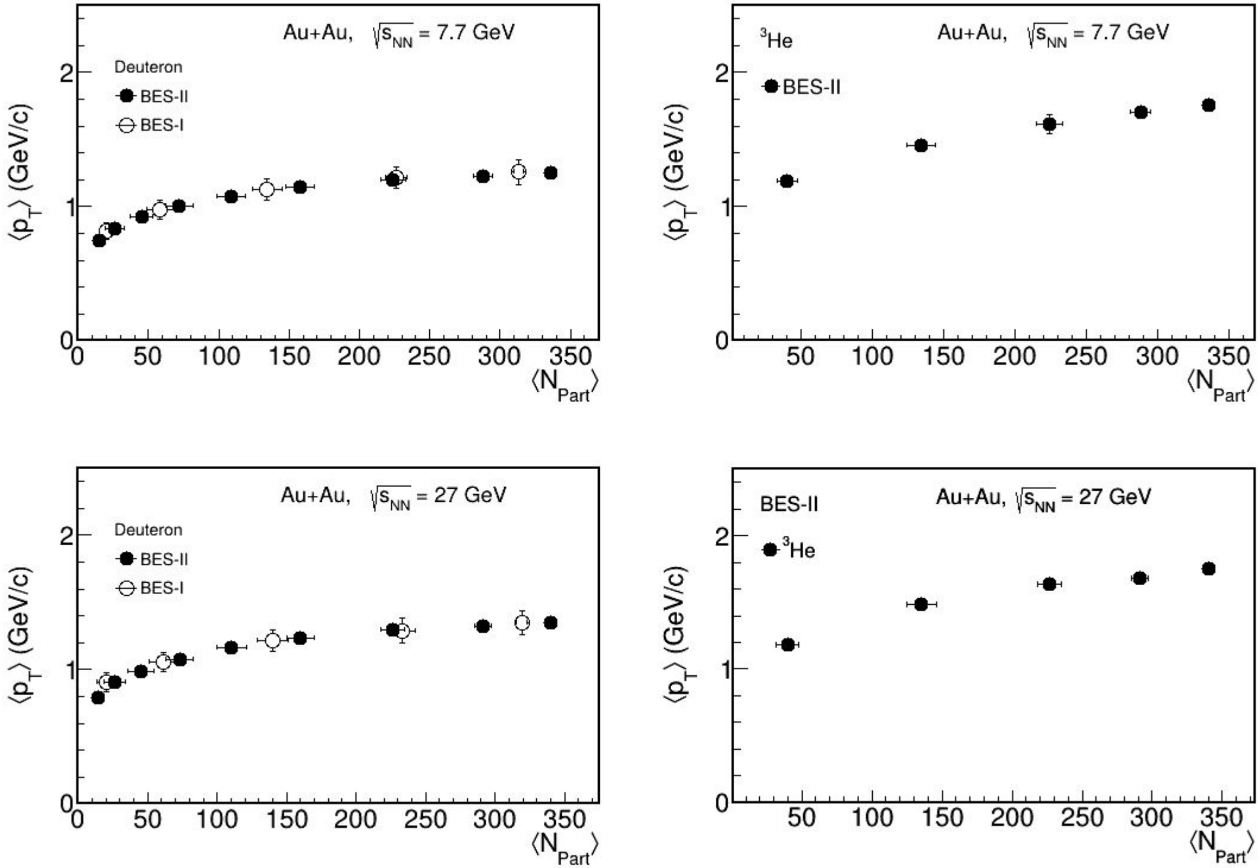
- ➢ Energy loss correction (✅)
- ➢ TPC efficiency and acceptance (✅)
- ➢ Absorption correction (✅)

❑ A clear p_T and centrality dependence of light nuclei spectra is observed

dN/dy



- Yield Increases with increasing centrality → effect of baryon stopping is stronger in central collisions



- <p_T> increases with increasing centrality → radial flow increases with centrality

- Corrected p_T spectra of deuteron is shown in Au+Au collisions at $\sqrt{s_{NN}}$ = 7.7 and 27 GeV
- 1st measurement of ^{3}He p_T spectra is presented in Au+Au collisions at $\sqrt{s_{NN}}$ = 7.7 and 27 GeV
- dN/dy and $\langle p_T \rangle$ is calculated for light nuclei in Au+Au collisions at $\sqrt{s_{NN}}$ = 7.7 and 27 GeV.

Outlook

- p_T spectra for proton in BES-II energies
- Estimate the compound light nuclei ratios
- Complete the analysis for other BES-II energies

Thank You All !

Backup

- ➔ At low p_T : $\frac{1}{\sqrt{2\pi\sigma^2}} e^{(x-\mu)^2/2\sigma^2} + ae^{bx}$
- ➔ At intermediate p_T : $\frac{\Gamma(\frac{\nu+1}{2})}{\Gamma(\frac{\nu}{2}\sqrt{\pi\nu\sigma^2})}[1 + \frac{1}{\nu}(\frac{x-\mu}{\sigma})^2]^{-\frac{\nu+1}{2}} + ae^{bx}$