Preliminary figures request

${}^{3}_{\Lambda}H$ production in Run2020 FXT Au+Au 5.2 GeV

Yulou Yan(USTC)

Apr ,2024

Contact information

- PA name:

Yulou Yan yulou@mail.ustc.edu.cn

- Supervisor email address:

Yifei Zhang: ephy@ustc.edu.cn

Physics Motivation

- Hypernuclei production in heavy ion collisions

  ⇨ Y-N interaction
  ⇨ EOS of compact stars

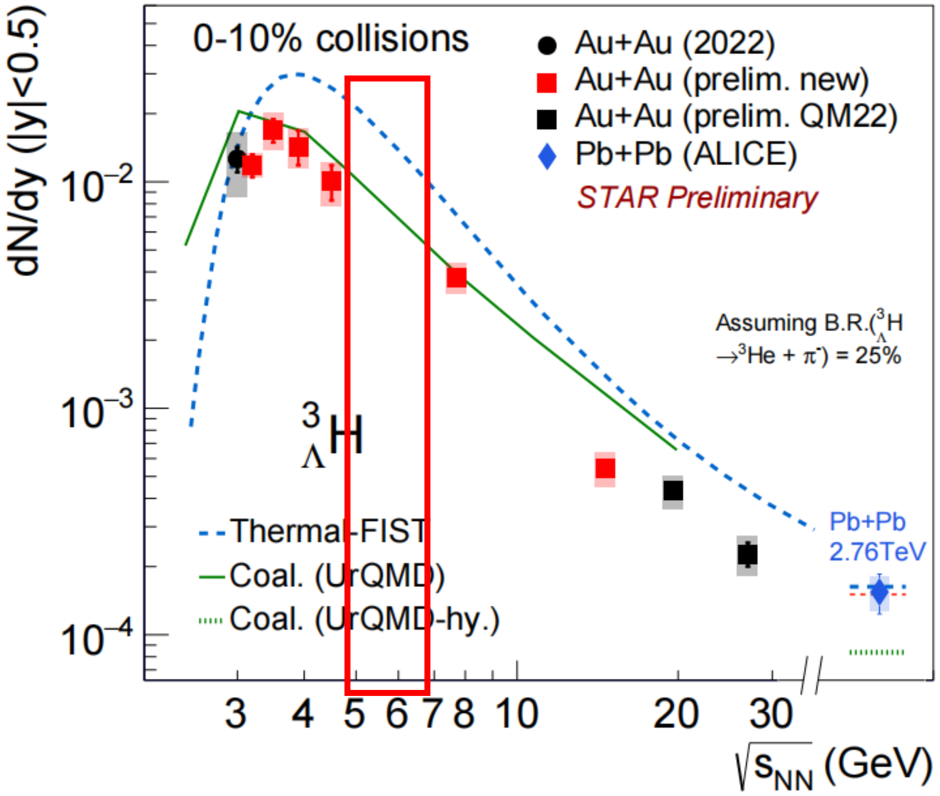
- Production mechanism

  ⇨ Thermal model

  ⇨ Coalescence model

- Observables:

⇨ Energy dependence of hypernuclei yields at mid-rapidity
⇨ Rapidity dependence of hypernuclei yields



•First time systematically measuring the energy dependence of hypernuclei production

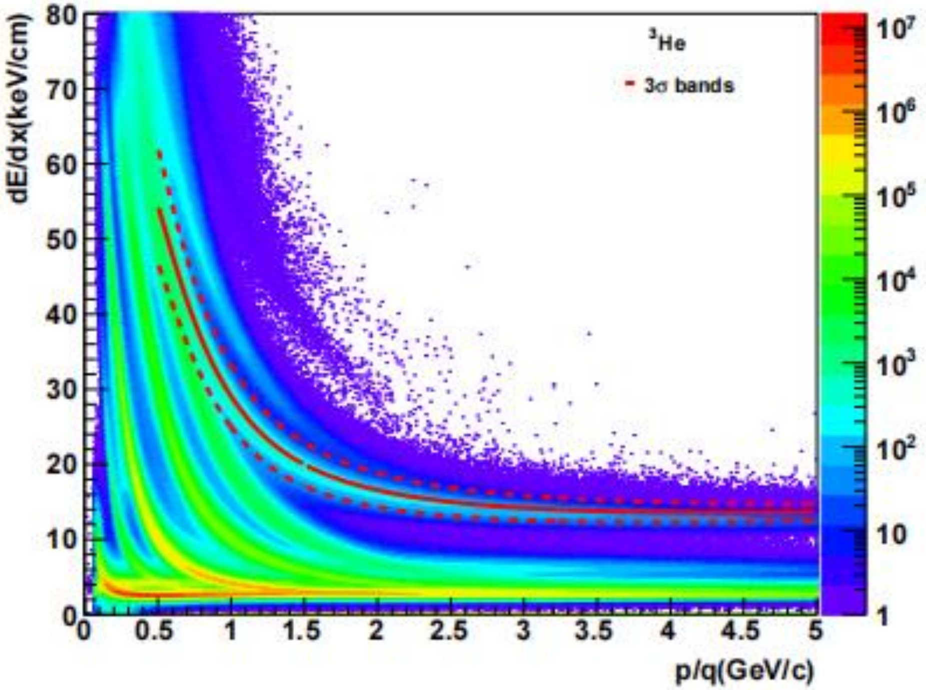
Dataset and event selections

	information
Dataset	Data: production_13p5GeV_fixedTarget_2020 Star Library:P21id
Trigger	750000
Badrun	21034002,21034007 https://drupal.star.bnl.gov/STAR/pwg/common/bes-ii-run-qa/FXT-datasets
Rapidity convention	y = -1*($y_{lab} - y_{\text{beam}}$), y_{beam} = -1.68 at FXT 5.2 GeV
Vertex cuts	198 < Vz < 202 cm $\sqrt{(Vx+0.3)*(Vx+0.3)+(Vy+2)*(Vy+2)} < 2$
Centrality definition& pileup rejection	https://drupal.star.bnl.gov/STAR/system/files/2023_0718_AuAu5p2Cent.pdf
Number of events	~ 89M good events(0-80% centrality)
Embedding request id	0223001
Track Cuts	pion p_T >0.1 GeV/c He3 p >0.4 GeV/c nHitsFit>15 nHitsDedx>5 nHitsFit/nHitsMax ≥ 0.52

1) PID based on TPC dE/dx $^{3}_{\Lambda}H -> ^{3}_{2}He + \pi^{-}$

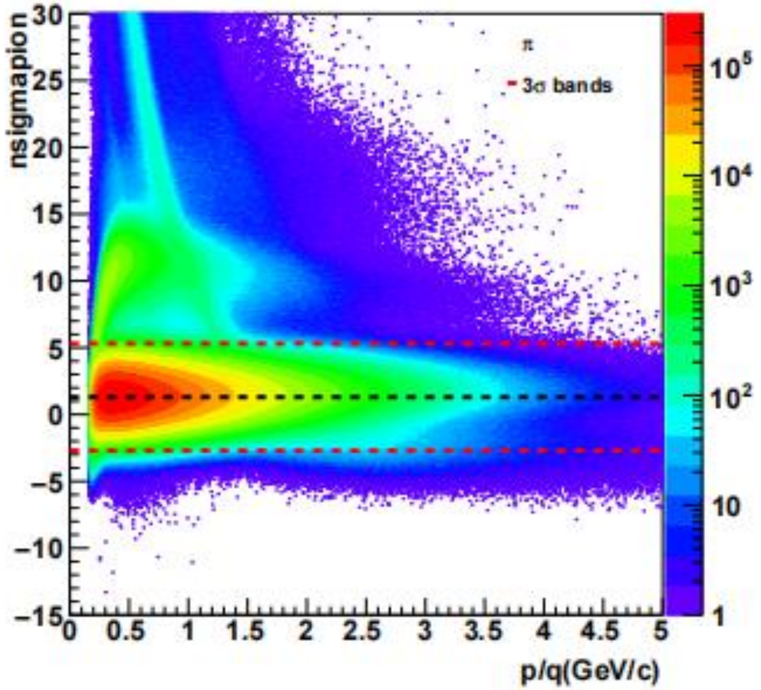
- He3

⇨ p/|q|>0.4GeV/c: ±3σ dE/dx band



- Pion:

⇨|dEdXPULL_pion($n\sigma_{\pi}$) -mean |<3 σ



dEdXPULL= $\frac{1}{(\frac{dE}{dx})_{error}} ln \frac{< dE/dx >}{(dE/dx)_{bichsel}}$

gTrack->dEdxPull([Particle_Mass], fdEdXMode, 1))

2) Reconstruct ${}^{3}_{\Lambda}H$ candidates

$${}^{3}_{\Lambda}H -> {}^{3}_{2}He + \pi^{-}$$

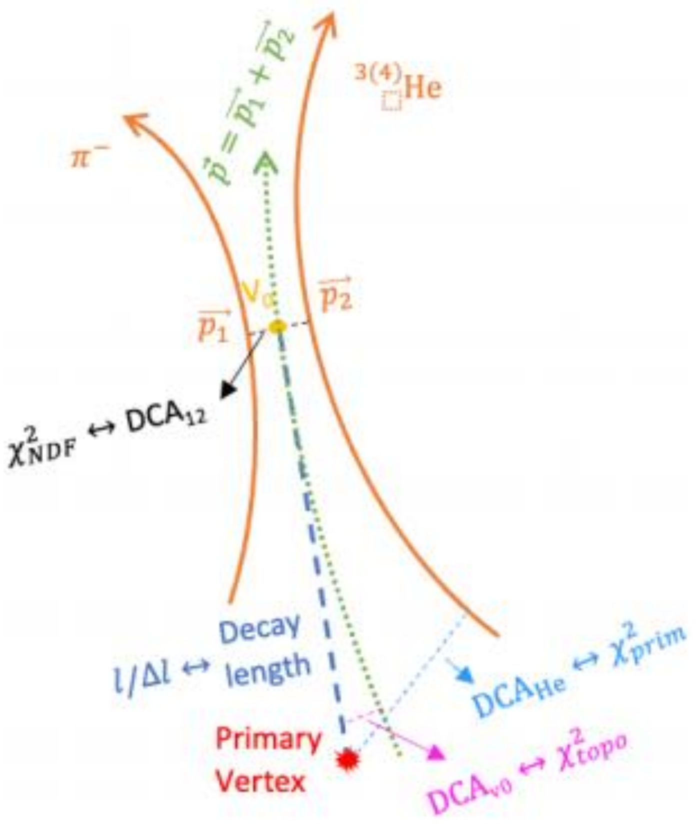
- Reconstructed by KFParticle package

- Background reconstruction

⇨Rotate He3 10°-350° randomly, 20 times statistics

- Topological cuts

0-10%	10-40%
l >1	l>1
ldl>6	ldl >1,
chi2topo<10	chi2topo<10
chi2ndf<2.2	chi2ndf<4
chi2primary_pi>5	chi2prim_pi>11
chi2prim_he>0	chi2prim_he>0

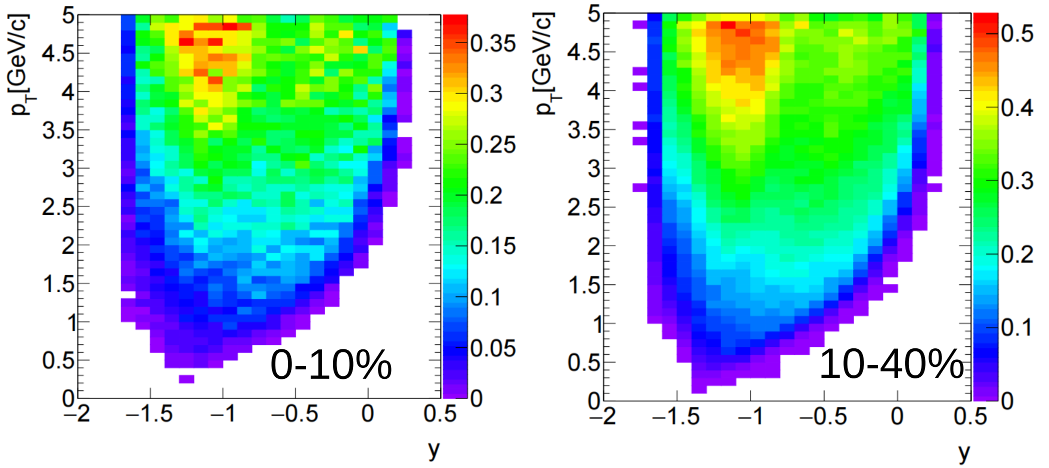


3) Efficiency correction

• We need to confirm that the topological variables in our data are well described by the embedding simulations
To make a fair comparison, we need to weight the embedding simulations
- H3L p_T distribution is weighted with a boltzmann function
- H3L rapidity distribution is weighted with a quadratic function
- H3L lifetime are also weighted according to global average value

• Reconstructing the embedded H3L signals via the same procedure as data
• Corrected p_T spectra:

$$\frac{1}{2\pi p_T}\frac{d^2N}{dp_T dy} \propto = \frac{N^{Raw}/(\epsilon^{reco} \times \epsilon^{PID})}{2\pi p_T \Delta p_T \Delta y}$$



4) dN/dy

(a) dN/dy
- Sum of yields in measured p_T region + unmeasured p_T region from function extrapolation
- Stat error: measured region * Fraction,
  Fraction = Integral(p_T>0)/Integral(measured p_T range) from fitting function

Systematic uncertainty sources

- Vary nHitsFit: nHitsFit>15, 17, 13
- Vary global average lifetime: H3L= 228.3±12.5 [ps]
- Vary raw count extraction
- Vary extrapolation function
- Vary the topological cuts

- If {default,var1}

⇨sys.err = |default-var1|
- If {default,var1,var2}

⇨sys.err = (max-min)*0.5
- Total sys.err added quadratically

- Vary raw count extraction

⇨ Vary the Gaussian+Linear fitting range

[2.97,3.02] , [2.97,3.01] , [2.96,3.02]

- Vary the topological cuts

0-10%	10-40%
l >0,1, 3	l>0,1, 3
chi2topo<8,10,12	chi2topo<8,10,12
chi2ndf<1.5,2.2, 3.5	chi2ndf<3,4,5
chi2primary_pi>3,5,7	chi2prim_pi>8,11,15

- Vary extrapolation function

⇨ function styles:

$C \cdot m_T exp(-\frac{m_T}{T})$ boltzmann(default)

$C \cdot exp(-\frac{m_T}{T})$ m_T exp

$C \cdot exp(-\frac{{p_T}^2}{\mu})$ p_T Gaus

$C \cdot exp(-\frac{p_T^{3/2}}{\mu})$ $p_T^{3/2}$ exp

$\int_0^R r dr m_T I_0(\frac{p_T sinh\rho(r)}{T_{kin}}) * K_1(\frac{m_T cosh\rho(r)}{T_{kin}})$ blast wave

⇨ function parameters: Bootstrap

Red denotes cuts variations in systematic uncertainty study

Summary of uncertainties

dN/dy

	dndy(cen:0-10%;-1.3~-0.8)
Tracking efficiency	10.02%
H3L Lifetime	6.50%
Topological cuts	12.09%
Raw count extraction	10.20%
Extrapolation	30.22%
	dndy(cen:0-10%;-0.8~-0.3)
Tracking efficiency	11.95%
H3L Lifetime	5.39%
Topological cuts	14.93%
Raw count extraction	3.36%
Extrapolation	27.34%

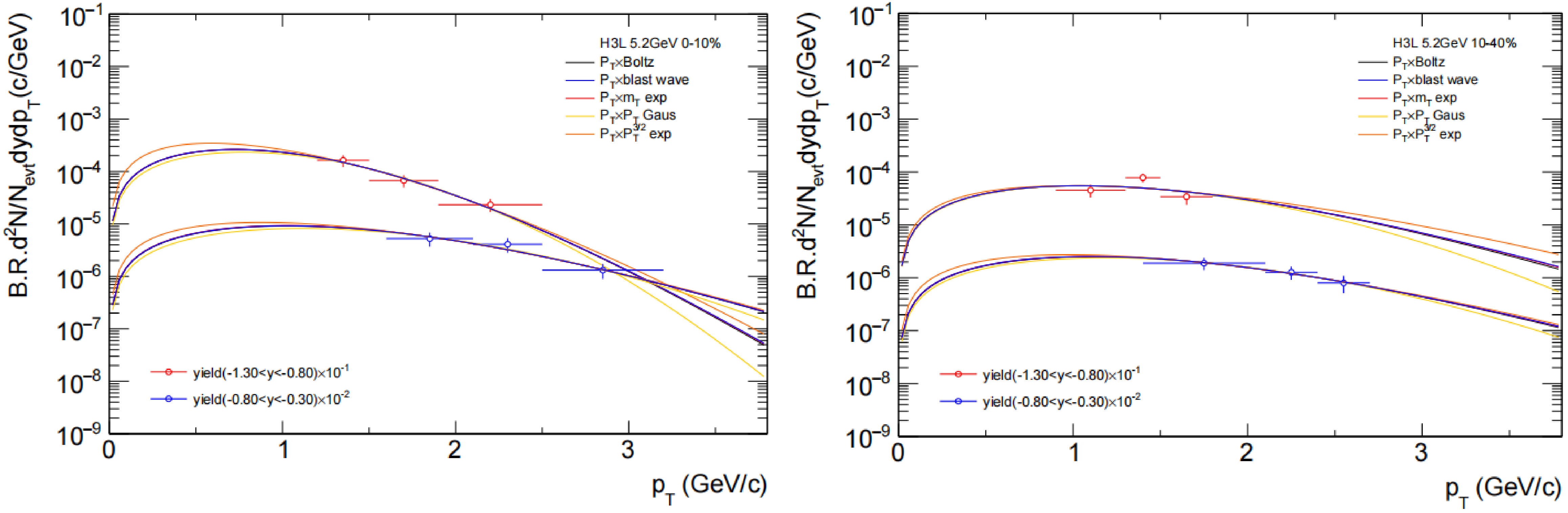
dN/dy

	dndy(cen:10-40%;-1.3~-0.8)
Tracking efficiency	10.01%
H3L Lifetime	3.43%
Topological cuts	9.00%
Raw count extraction	1.77%
Extrapolation	14.08%
	dndy(cen:10-40%;-0.8~-0.3)
Tracking efficiency	10.48%
H3L Lifetime	3.93%
Topological cuts	7.35%
Raw count extraction	4.82%
Extrapolation	17.83%

Preliminary figures request

Figure 1- p_T spectra in FXT Au+Au 5.2GeV

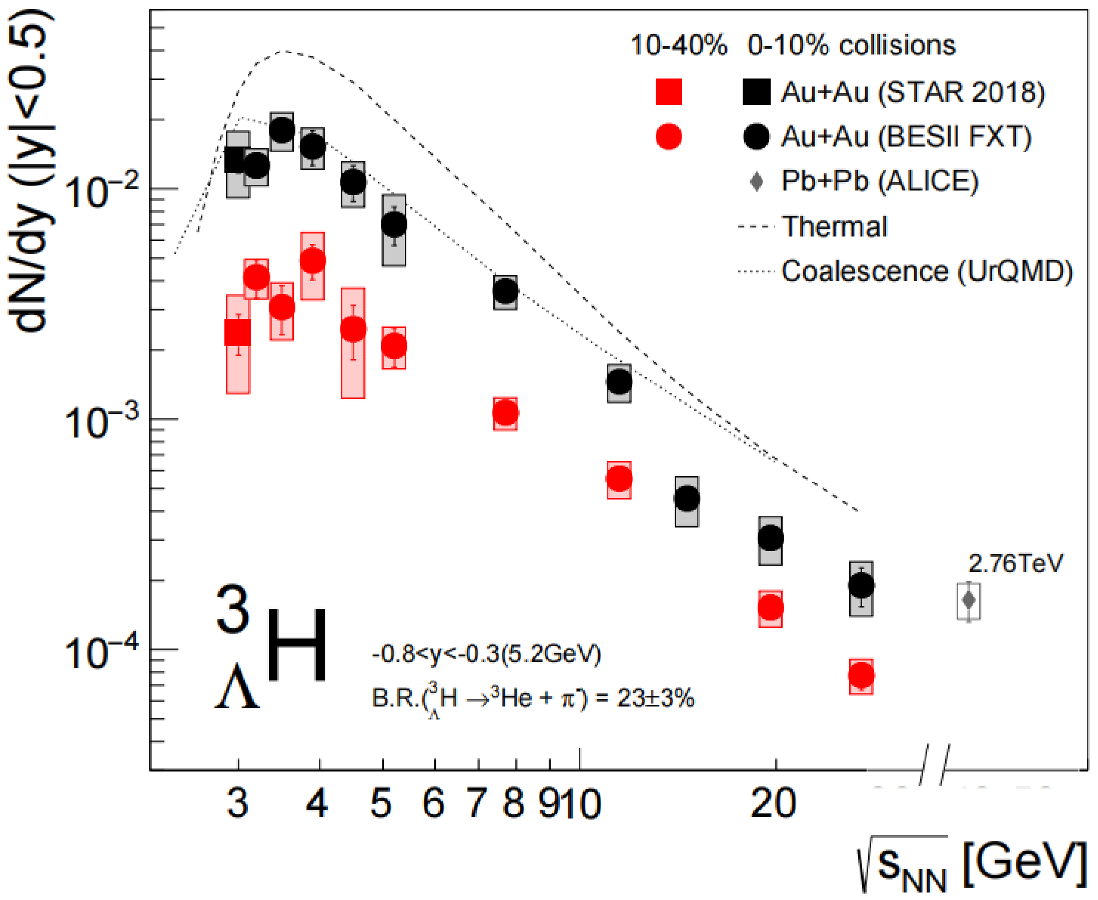
Preliminary



• p_T spectra in 0-10% and 10-40%,respectively.

Figure 2-Energy dependence of H3L production

Preliminary

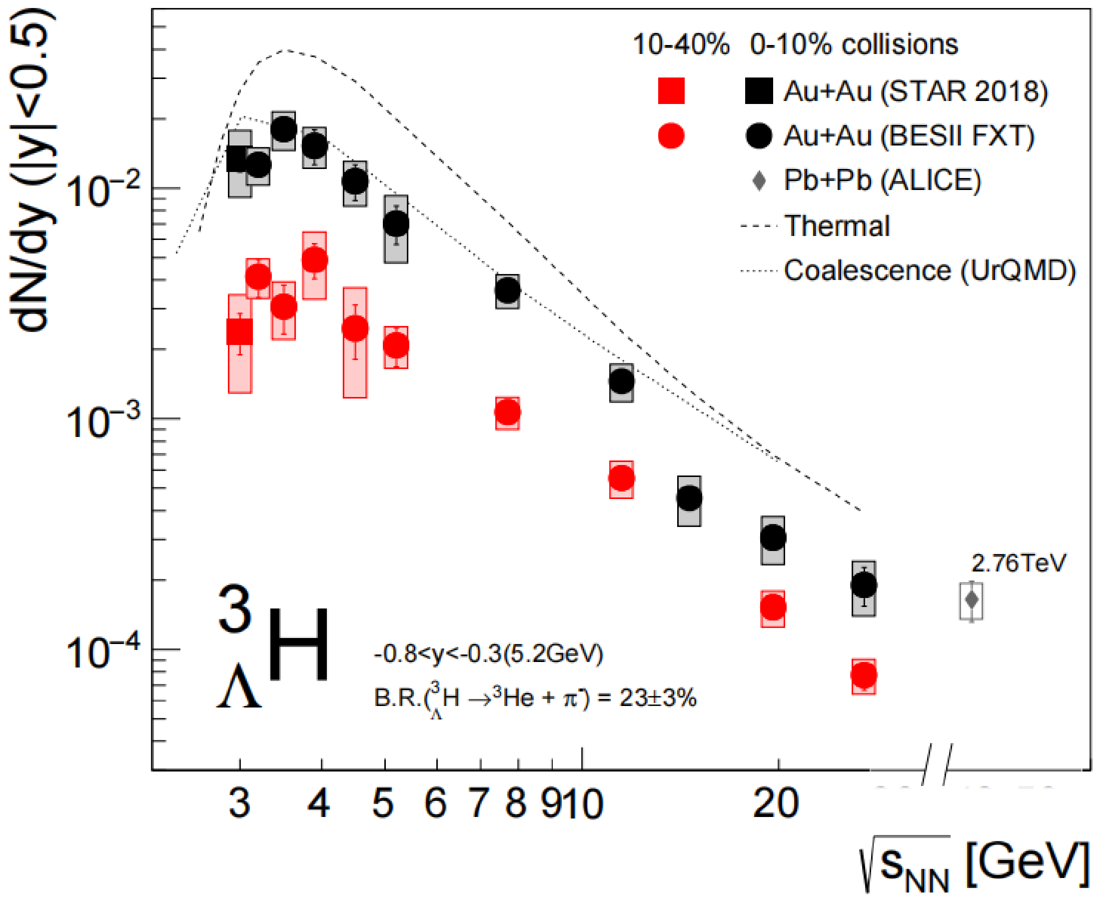


- The dN/dy vs energy

⇨Assuming B.R. =23%

https://drupal.star.bnl.gov/STAR/system/files/H3L_branchingratio.pdf

Preliminary



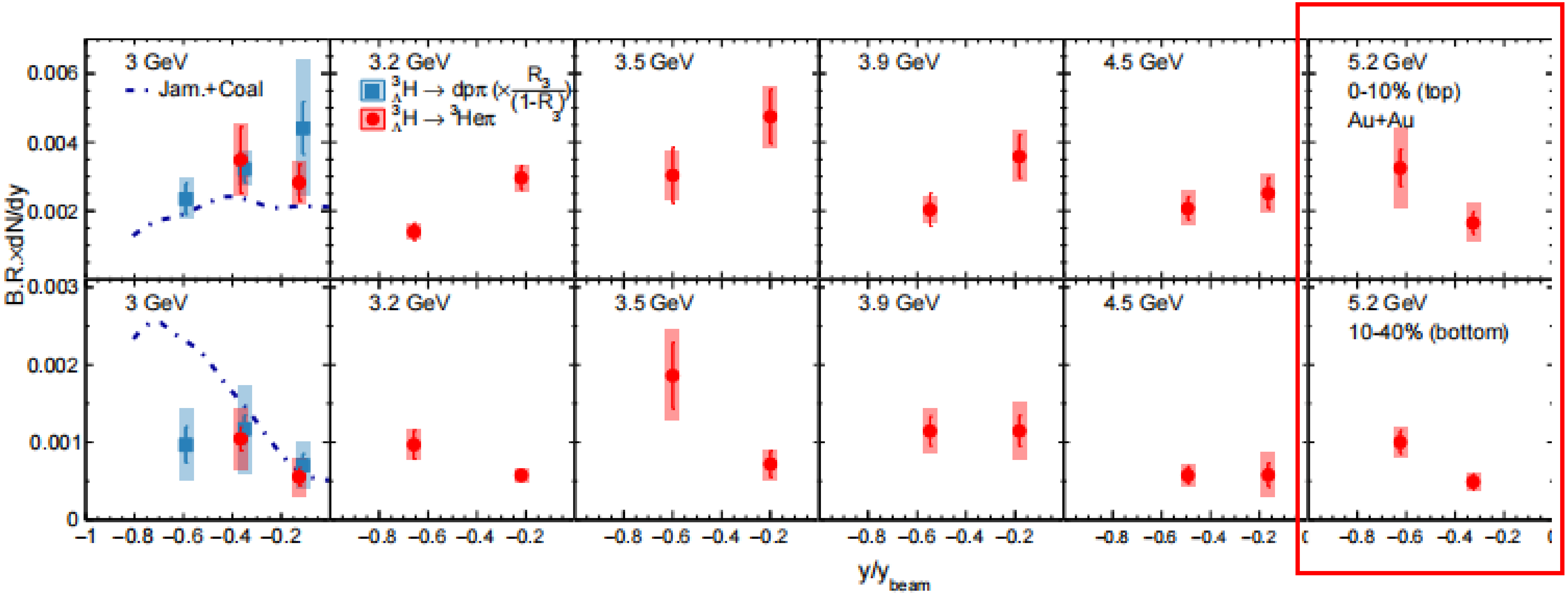
- The dN/dy vs energy

⇨Assuming B.R. =23%

https://drupal.star.bnl.gov/STAR/system/files/H3L_branchingratio.pdf

Figure 3-dN/dy vs y/ybeam in Au+Au 3-5.2GeV

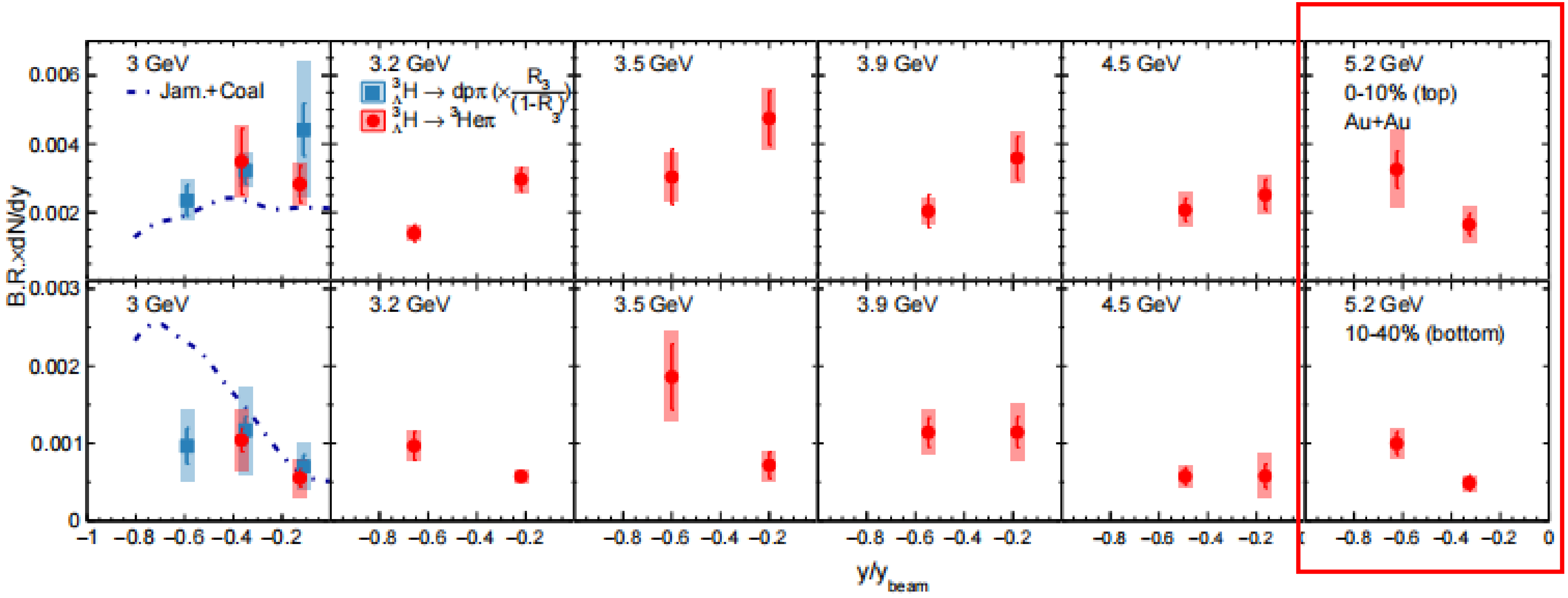
Preliminary



- Rapidity dependence of H3L yields at 5.2 GeV comparing to those of other energies in 0-10% and 10-40%.

Figure 3 (with barlow test version)

Preliminary



- Rapidity dependence of H3L yields at 5.2 GeV comparing to those of other energies in 0-10% and 10-40%.

Preliminary

(back up in case of future usage)

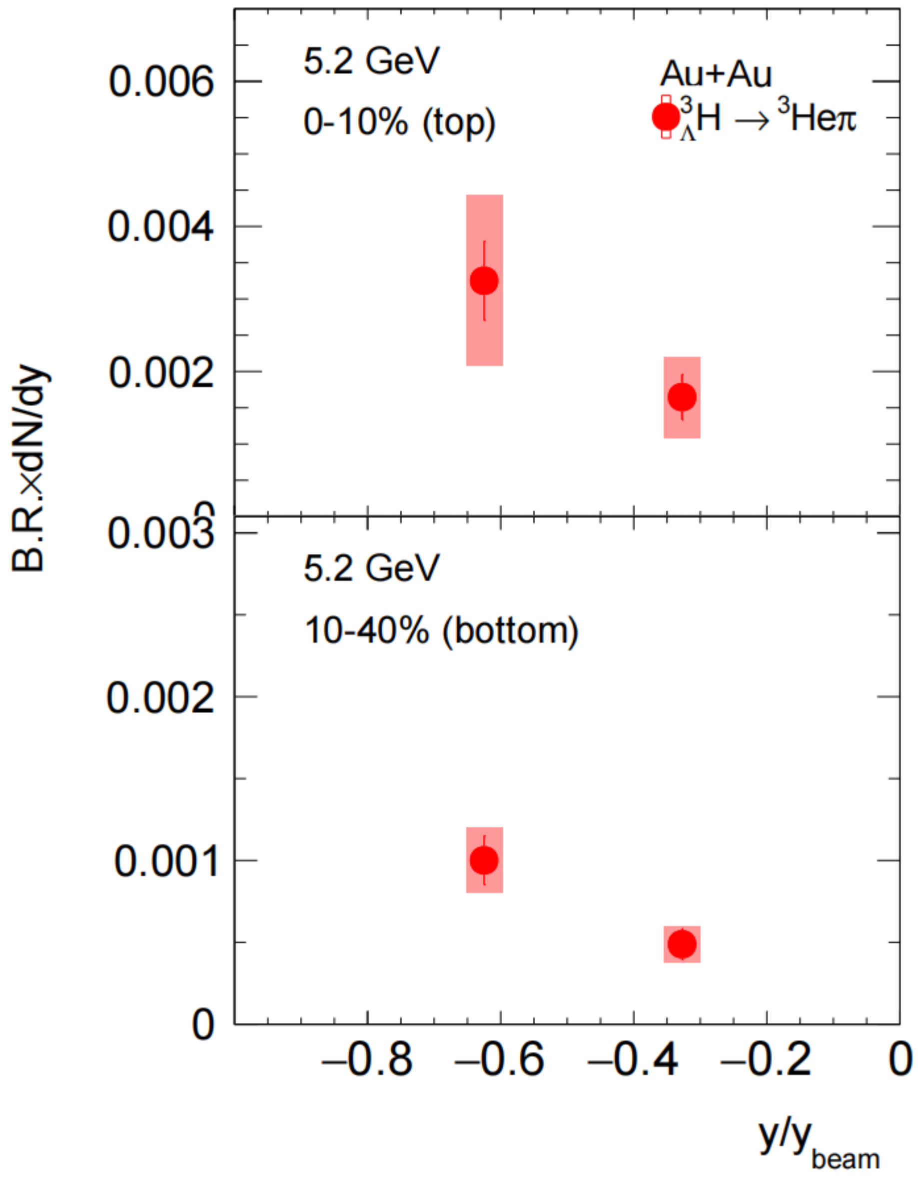
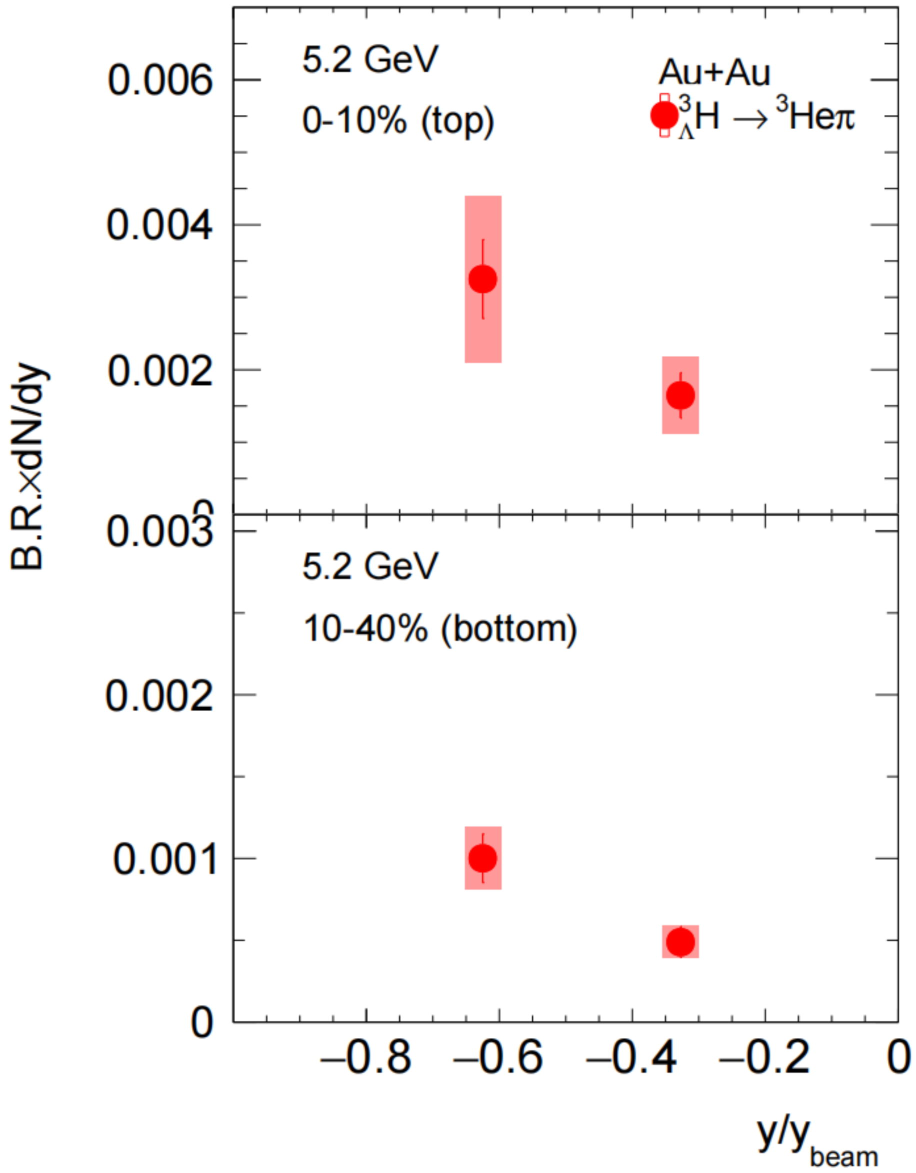


Figure 4 (with barlow test version)

Preliminary

(back up in case of future usage)



Back up

Back up (Barlow test)

The Barlow test method [2] is used to reduce the introduction of statistical fluctuations into the estimation of systematic uncertainties. The difference of the ${}^{3}_{\Lambda}\mathrm{H}$ yields between the maximum (Y_{Max}) and minimum (Y_{Min}) of the re-calculated ${}^{3}_{\Lambda}\mathrm{H}$ yields is

$$\Delta = \mid Y_{\mathrm{Max}} - Y_{\mathrm{Min}} \mid \tag{7}$$

Since Y_{Max} and Y_{Min} are calculated using the same dataset and have a strong correlation, the statistical uncertainty of Δ in Eq. 7 is :

$$\sigma_{\Delta} = \sqrt{\mid \sigma^{2}_{\mathrm{Max}} - \sigma^{2}_{\mathrm{Min}} \mid} \tag{8}$$

Where σ_{Max} and σ_{Min} are the statistical uncertainties with the the maximum (Y_{Max}) and minimum (Y_{Min}) of the re-calculated ${}^{3}_{\Lambda}\mathrm{H}$ yields, respectively. If the difference between the variation Y_{Max} and the default result Y_{Min} is bigger than the statistical uncertainty:

$$\Delta = \mid Y_{\mathrm{Max}} - Y_{\mathrm{Min}} \mid > \sigma_{\Delta}, \tag{9}$$

then the systematic uncertainty from the same source is calculated by:

$$\Delta_{i}^{sys} = 0.5 * \sqrt{(Y_{\mathrm{Max}} - Y_{\mathrm{Min}})^{2} - \mid \sigma^{2}_{\mathrm{Max}} - \sigma^{2}_{\mathrm{Min}} \mid} \tag{10}$$

If the difference between the variation Y_{Max} and the default result Y_{Min} is even smaller than the statistical uncertainty:

$$\Delta = \mid Y_{\mathrm{Max}} - Y_{\mathrm{Min}} \mid < \sigma_{\Delta}, \tag{11}$$

then this difference Δ is regarded as coming from the statistical fluctuation. This variation would not be included in the systematic uncertainties,which means the systematic uncertainty from this source is 0.

Summary of uncertainties (Barlow test)

dN/dy

	dndy(cen:0-10%;-1.3~-0.8)
Tracking efficiency	10.00%
H3L Lifetime	4.77%
Topological cuts	10.78%
Raw count extraction	9.59%
Extrapolation	30.22%
	dndy(cen:0-10%;-0.8~-0.3)
Tracking efficiency	11.47%
H3L Lifetime	3.37%
Topological cuts	12.22%
Raw count extraction	0.00%
Extrapolation	27.34%

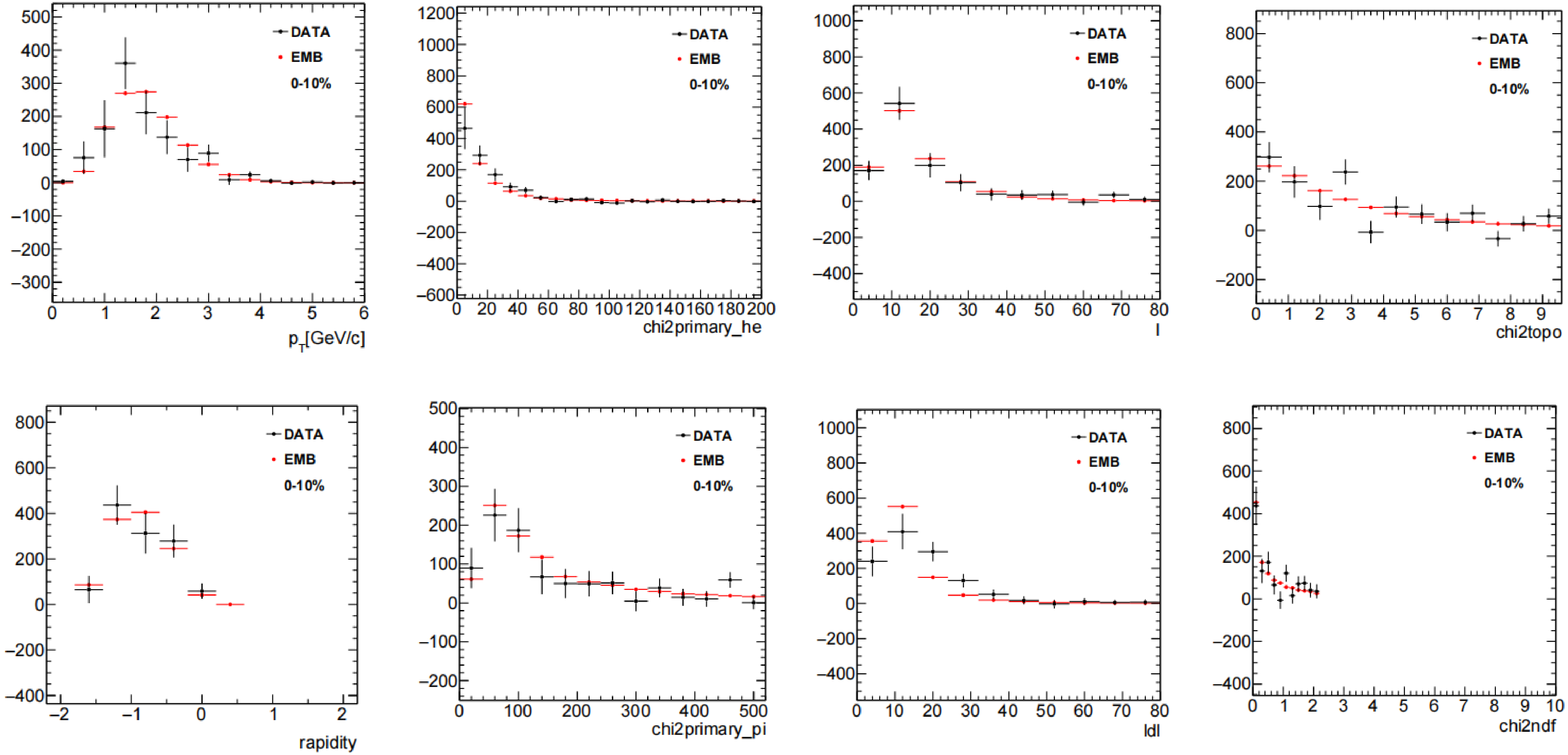
dN/dy

	dndy(cen:10-40%;-1.3~-0.8)
Tracking efficiency	10.00%
H3L Lifetime	2.11%
Topological cuts	8.31%
Raw count extraction	0.00%
Extrapolation	14.08%
	dndy(cen:10-40%;-0.8~-0.3)
Tracking efficiency	10.00%
H3L Lifetime	0.00%
Topological cuts	0.00%
Raw count extraction	0.00%
Extrapolation	17.83%

Analysis procedure

- 3.2 GeV(2019) H3L embedding: https://drupal.star.bnl.gov/STAR/starsimrequests/2022/Jul/30/hypernuclei-FXT-AuAu-32-GeV

Using integrated p_T and rapidity range; after weighting of p_T distribution

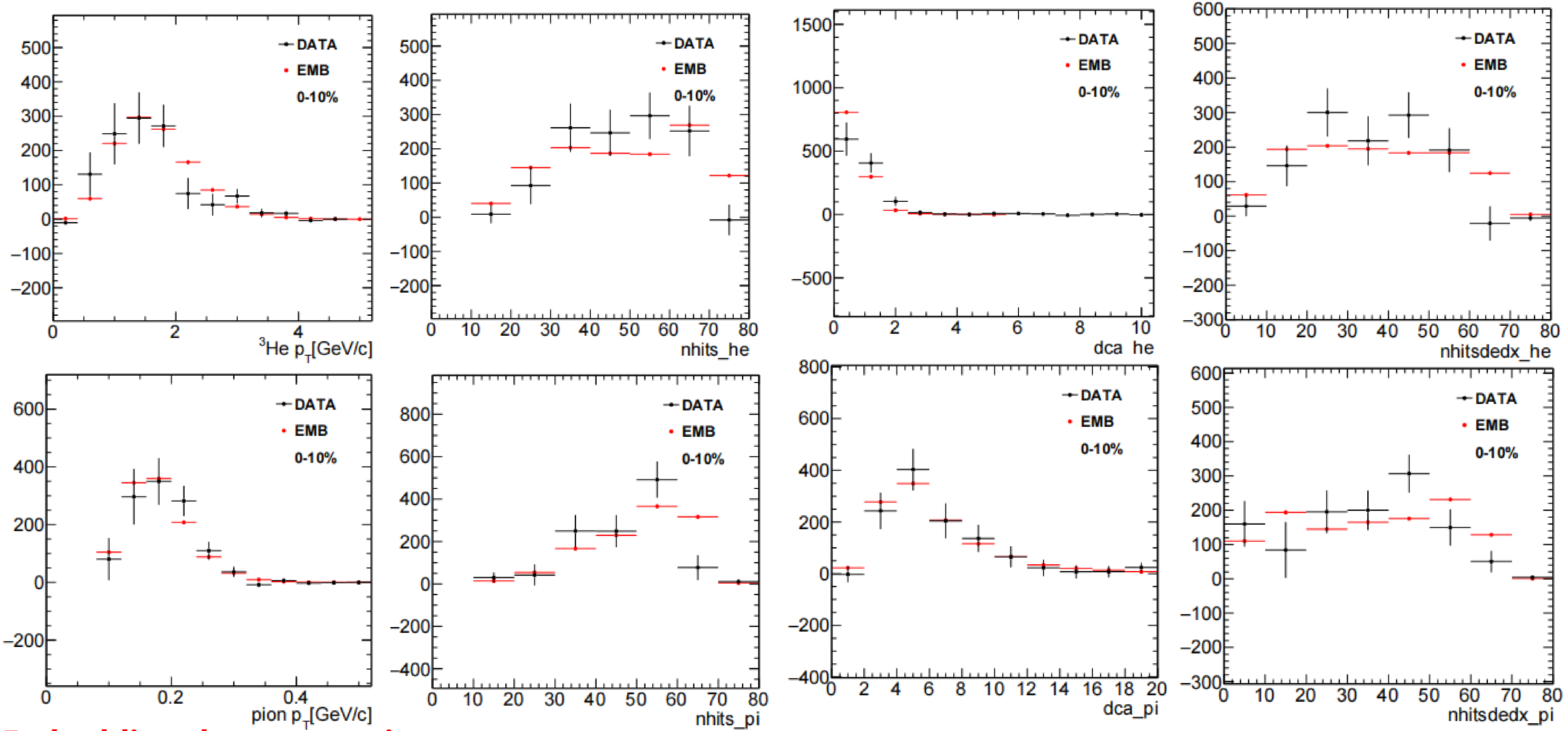


Embedding data comparison

Analysis procedure

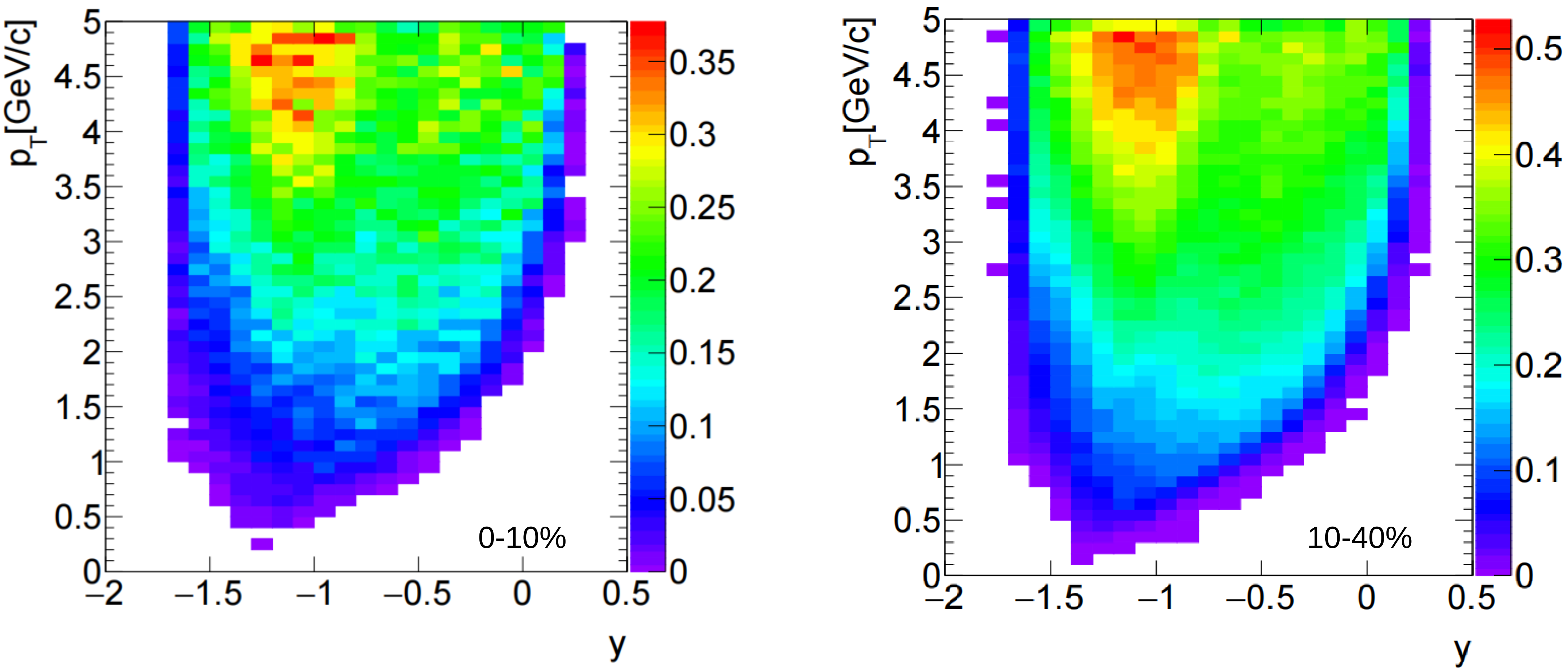
- 3.2 GeV(2019) H3L embedding: https://drupal.star.bnl.gov/STAR/starsimrequests/2022/Jul/30/hypernuclei-FXT-AuAu-32-GeV

Using integrated p_T and rapidity range; after weighting of p_T distribution



Embedding data comparison

Analysis procedure



- MC particles' p_T distribution is weighted with an boltzmann function
- MC particles' y distribution is weighted with a quadratic function
- Lifetime is weighted to H3L world average lifetime 228.3ps

Reconstuction efficiency

Analysis procedure

$$\frac{1}{2\pi p_T}\frac{d^2N}{dp_T dy} \propto = \frac{N^{Raw}/(\epsilon^{reco} \times \epsilon^{PID})}{2\pi p_T \Delta p_T \Delta y}$$

$C \cdot m_T exp(-\frac{m_T}{T})$ boltzmann(default)

$C \cdot exp(-\frac{m_T}{T})$ m_T exp

$C \cdot exp(-\frac{{p_T}^2}{\mu})$ p_T Gaus

$C \cdot exp(-\frac{p_T^{3/2}}{\mu})$ $p_T^{3/2}$ exp

$\int_0^R rdrm_T I_0(\frac{p_T sinh\rho(r)}{T_{kin}}) * K_1(\frac{m_T cosh\rho(r)}{T_{kin}})$ blast wave

- When fitting, option "I" is added.(fit range:0-4GeV/c)
- dN/dy

⇨Sum of yields in measured p_T region + unmeasured region p_T from function extrapolation.

⇨ Stat error: measured region * Fraction,
 Fraction = Integral(p_T>0)/Integral(measured p_T range) from fitting function.

H3L spectra in 0-10% and 10-40%

Back up (Reconstuction efficiency)