Study of differential jet fragmentation in pp collisions at ALICE

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Physics Motivation

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Jet fragmentation transverse momentum distributions in pp and p-Pb collisions at $\sqrt{s}$, $\sqrt{s_{\mathrm{NN}}} = 5.02$ TeV

ALICE

The ALICE collaboration

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Abstract: Jet fragmentation transverse momentum (j_{T}) distributions are measured in proton-proton (pp) and proton-lead (p-Pb) collisions at $\sqrt{s_{\mathrm{NN}}} = 5.02$ TeV with the ALICE experiment at the LHC. Jets are reconstructed with the ALICE tracking detectors and electromagnetic calorimeter using the anti-k_{T} algorithm with resolution parameter $R = 0.4$ in the pseudorapidity range $|\eta| < 0.25$. The j_{T} values are calculated for charged particles inside a fixed cone with a radius $R = 0.4$ around the reconstructed jet axis. The measured j_{T} distributions are compared with a variety of parton-shower models. Herwig and Pythia 8 based models describe the data well for the higher j_{T} region, while they underestimate the lower j_{T} region. The j_{T} distributions are further characterised by fitting them with a function composed of an inverse gamma function for higher j_{T} values (called the "wide component"), related to the perturbative component of the fragmentation process, and with a Gaussian for lower j_{T} values (called the "narrow component"), predominantly connected to the hadronisation process. The width of the Gaussian has only a weak dependence on jet transverse momentum, while that of the inverse gamma function increases with increasing jet transverse momentum. For the narrow component, the measured trends are successfully described by all models except for Herwig. For the wide component, Herwig and PYTHIA 8 based models slightly underestimate the data for the higher jet transverse momentum region. These measurements set constraints on models of jet fragmentation and hadronisation.

Keywords: Heavy Ion Experiments

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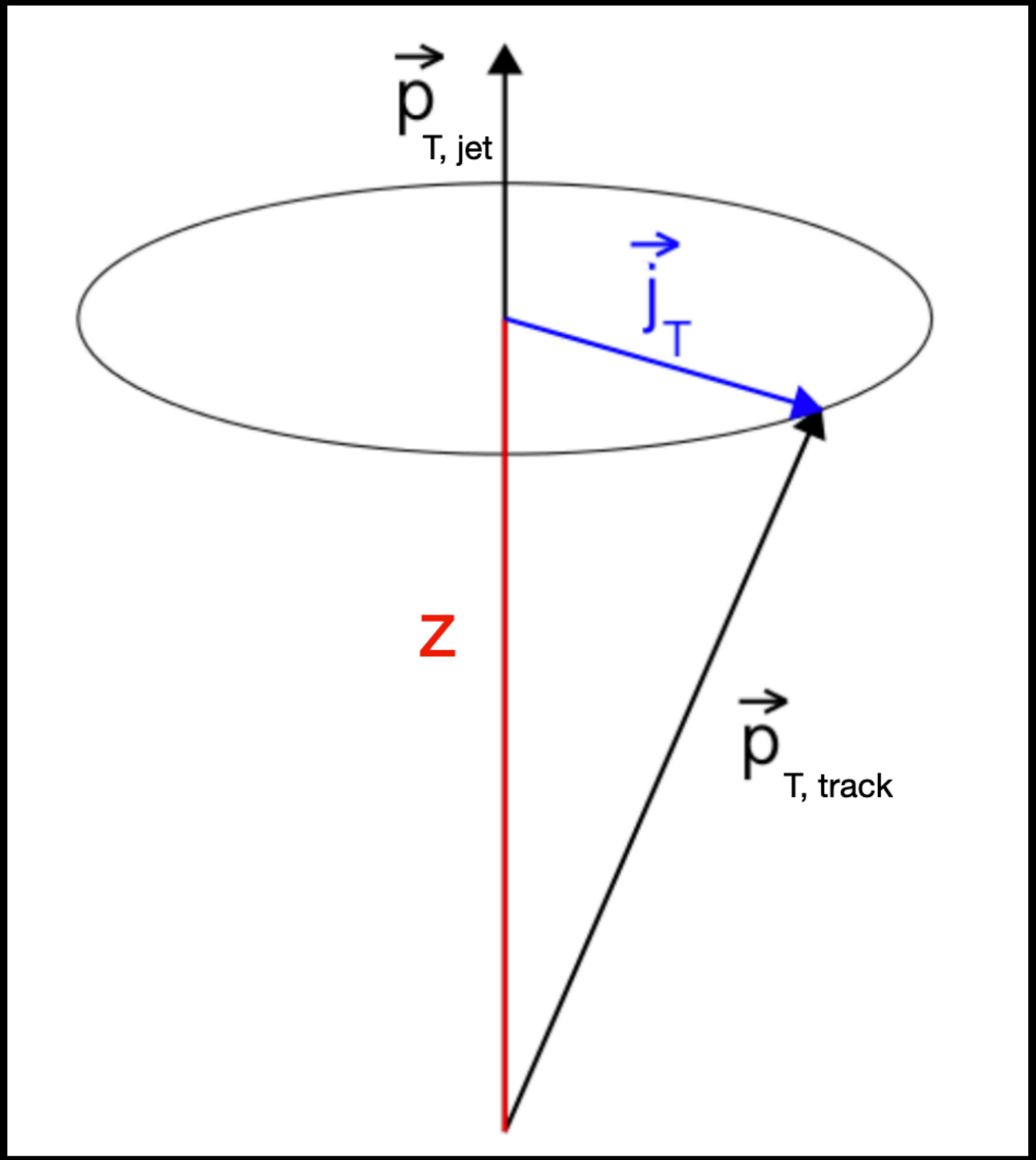
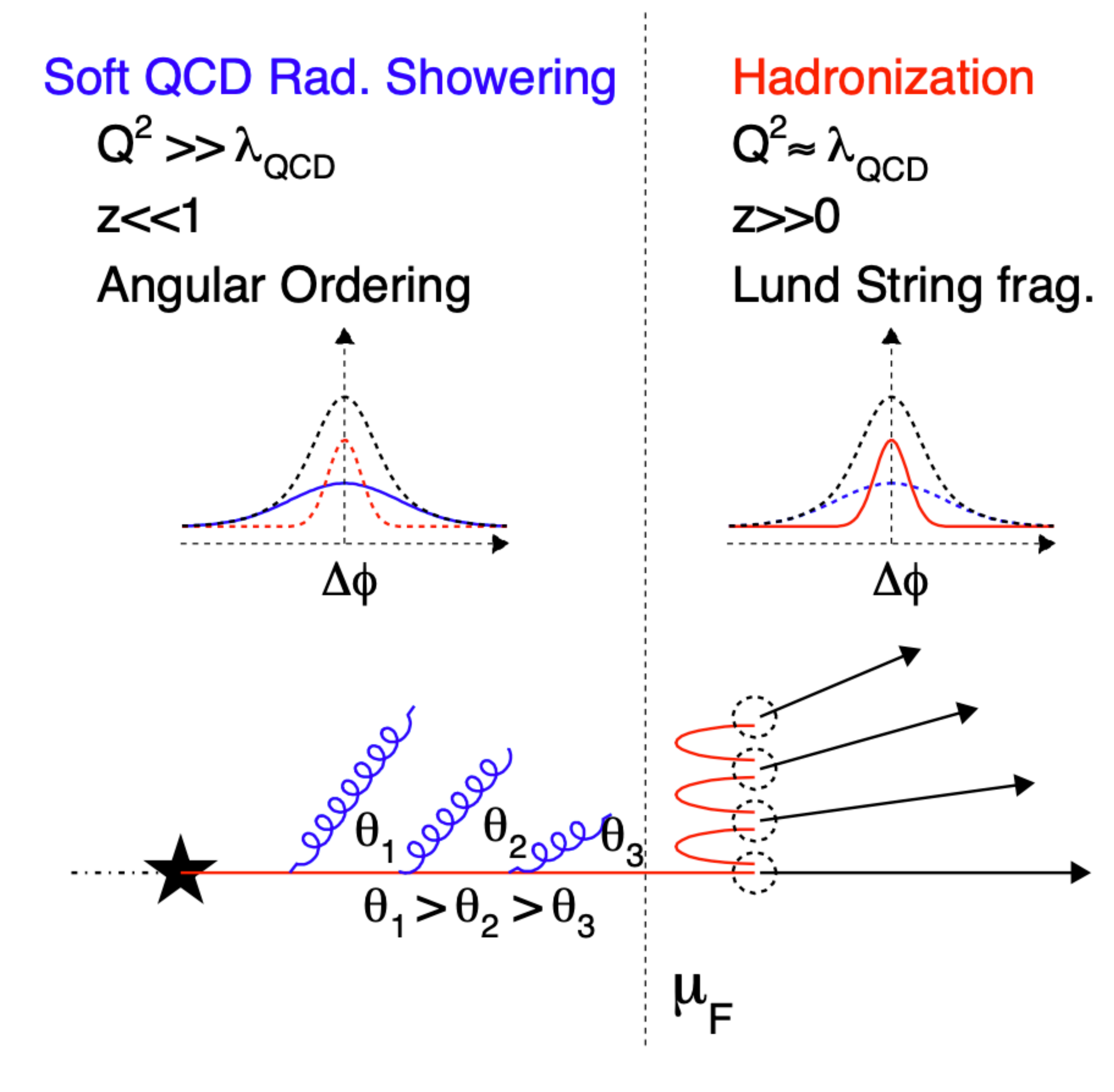
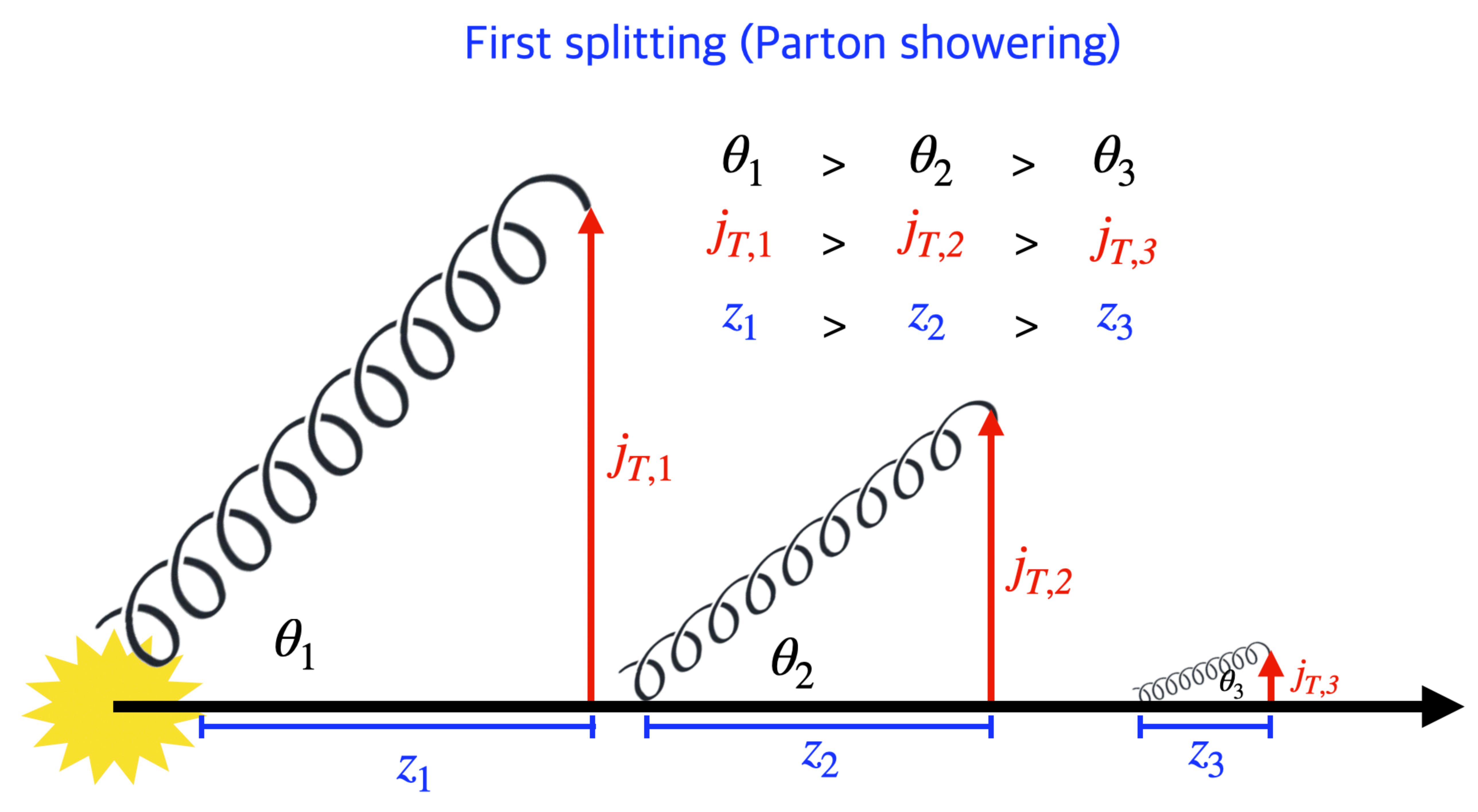
- Follow-up study of published result on j_T distribution in pp, p$-$Pb collision in inclusive z bin
- This study extends the analysis in multiple z bins

- $j_T = \dfrac{|\vec{p}_{jet} \times \vec{p}_{track}|}{|\vec{p}_{jet}|}$
- $z = \dfrac{\vec{p}_{jet} \cdot \vec{p}_{track}}{p^2_{jet}}$



Physics Motivation

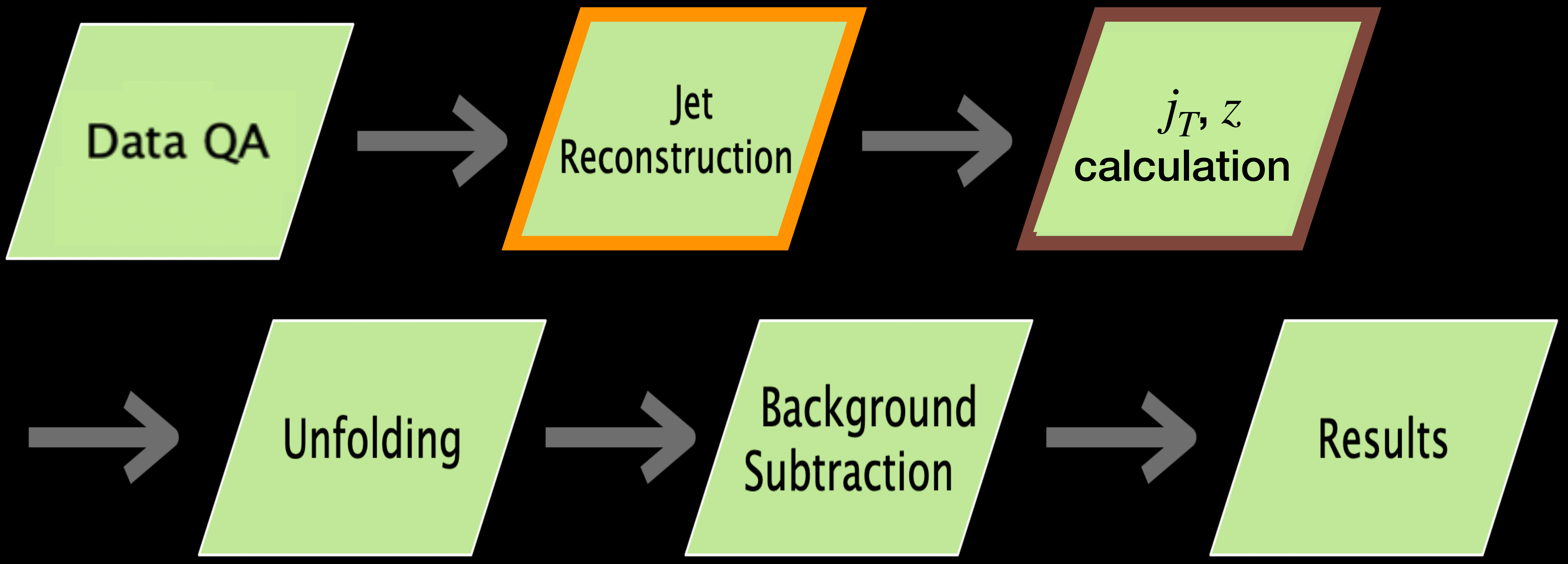




- Angular ordering in parton showering :
  - Small angle radiation at lower virtuality
  - Naive expectation of enhancement of high j_T, z at early stage
  - Naive expectation of enhancement of low j_T, z at late stage

ALICE Detector & Data analysis

- 2017 LHC pp collisions at $\sqrt{s}$ = 5.02 TeV

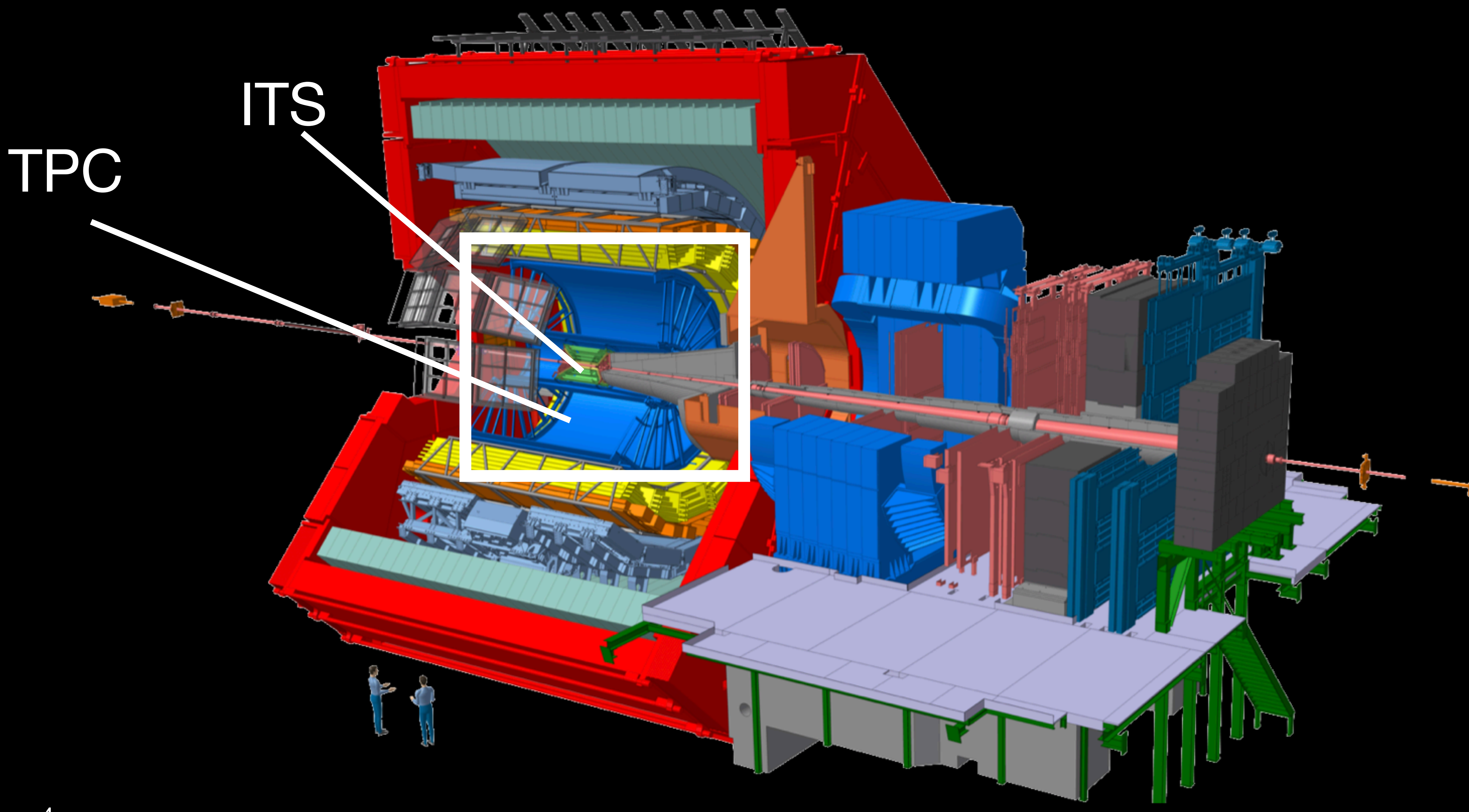


Jet reconstruction

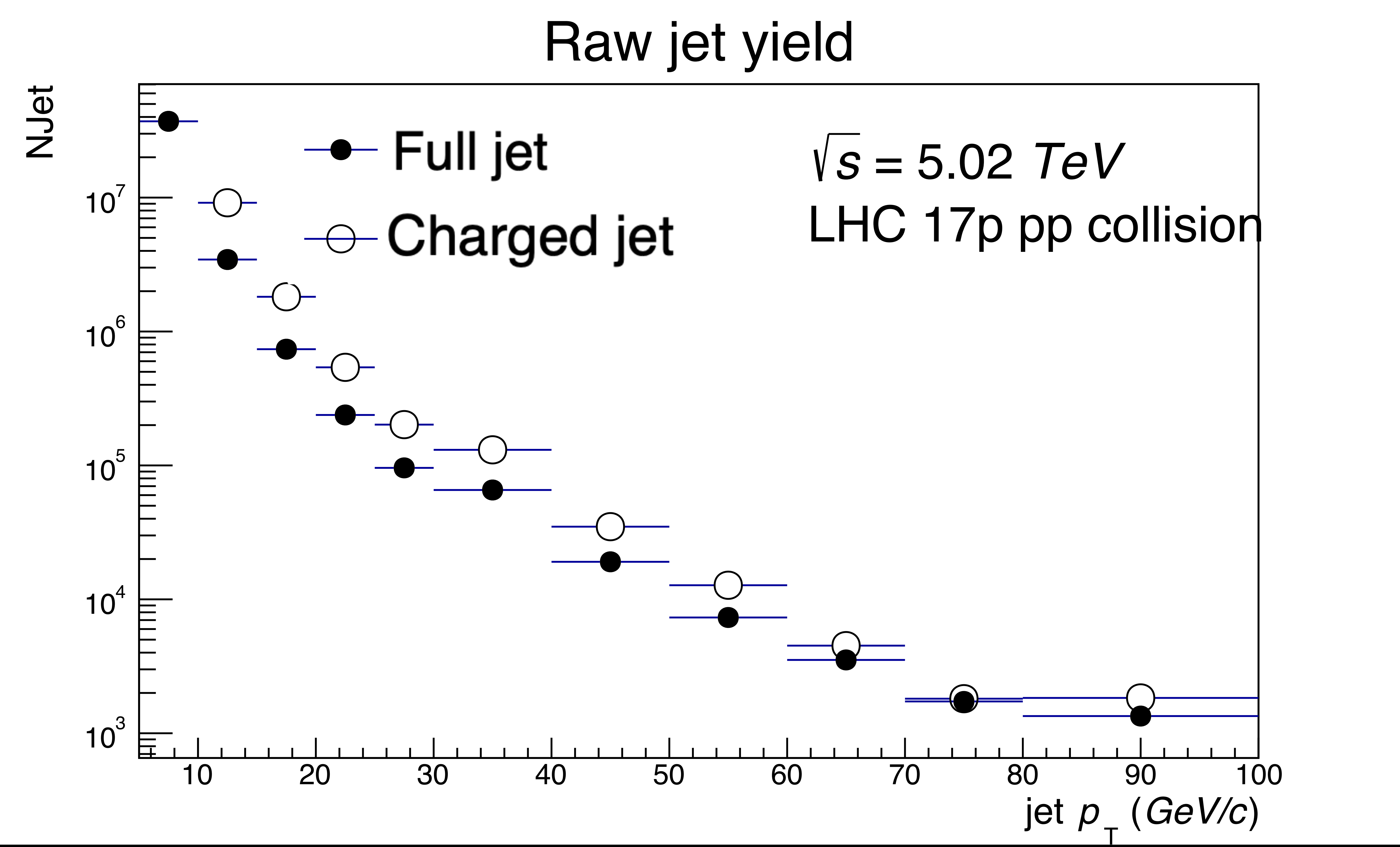
- Charged jet in $|\eta|$<0.5 with reconstructed tracks in ITS/TPC (p_T>0.15 GeV/c and $|\eta|$<0.9, 0 < ϕ < 2π)
- Anti-k_T algorithm with R=0.4

j_T, z measurement

- j_T and z are measured with charged jets and constituents reconstructed in ALICE ITS/TPC (|η| < 0.9, 0 < ϕ < 2π)
- Minimum p_T cut = 0.15 GeV/c for charged particles



Advantage of using charged jet



- Much more charged jets than full jets due to the limited acceptance of ALICE EMCal
- Acceptance of
  Tracking detector ($|\eta| < 0.9$, $0 < \phi < 2\pi$),
  EMCal ($|\eta| < 0.7$, $\Delta\phi = 110°$)
- More differential study can be done in various z bin

Analysis procedure

Unfolding

- 3D unfolding method is necessary for j_T in various z bins

2-D response matrix

$$(j_T^{obs},\ p_{T,\,jet}^{obs},\ j_T^{true},\ p_{T,\,jet}^{true})$$

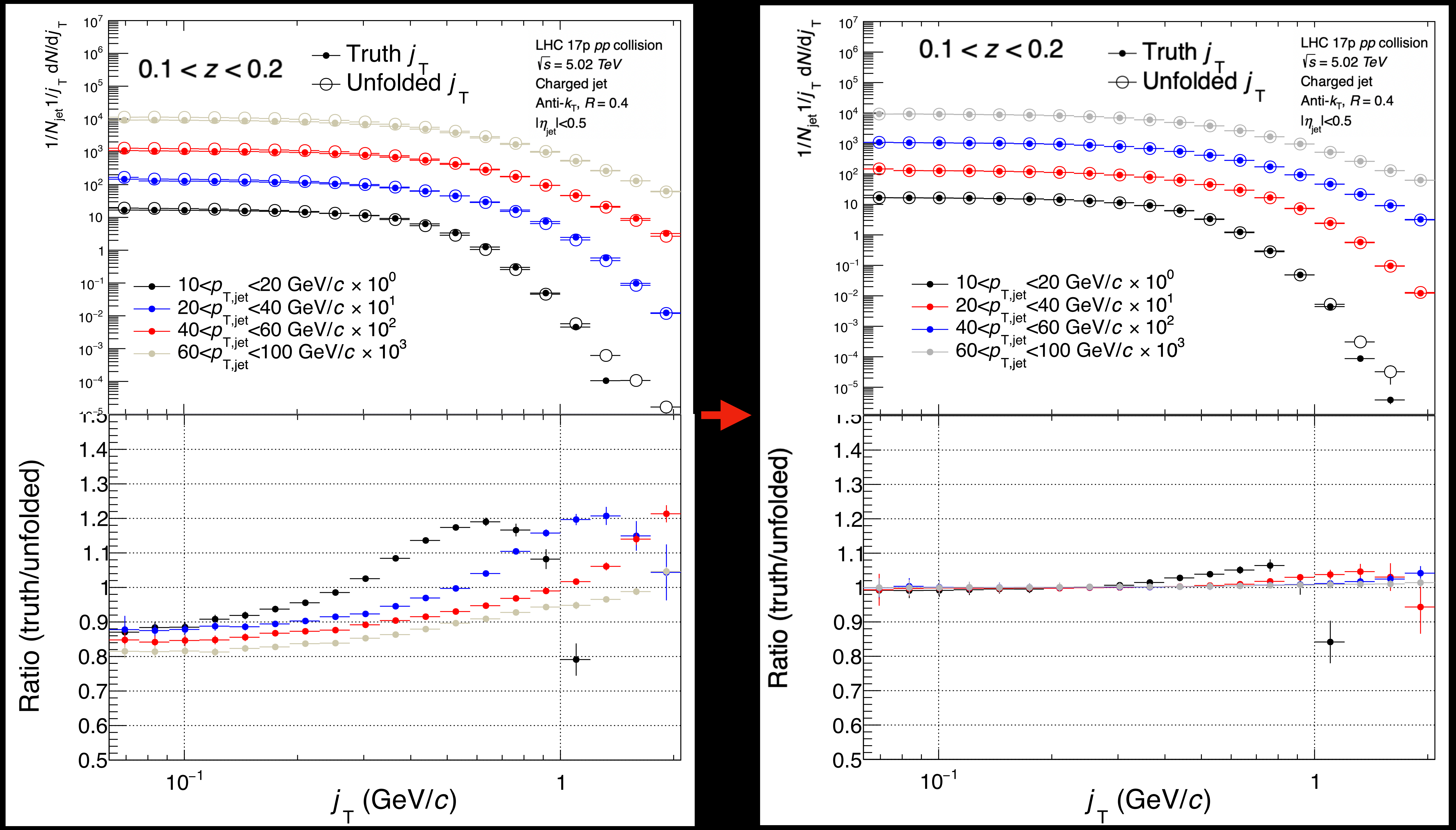
↓

3-D response matrix

$$(j_T^{obs},\ p_{T,\,jet}^{obs},\ z^{obs},\ j_T^{true},\ p_{T,\,jet}^{true},\ z^{true})$$

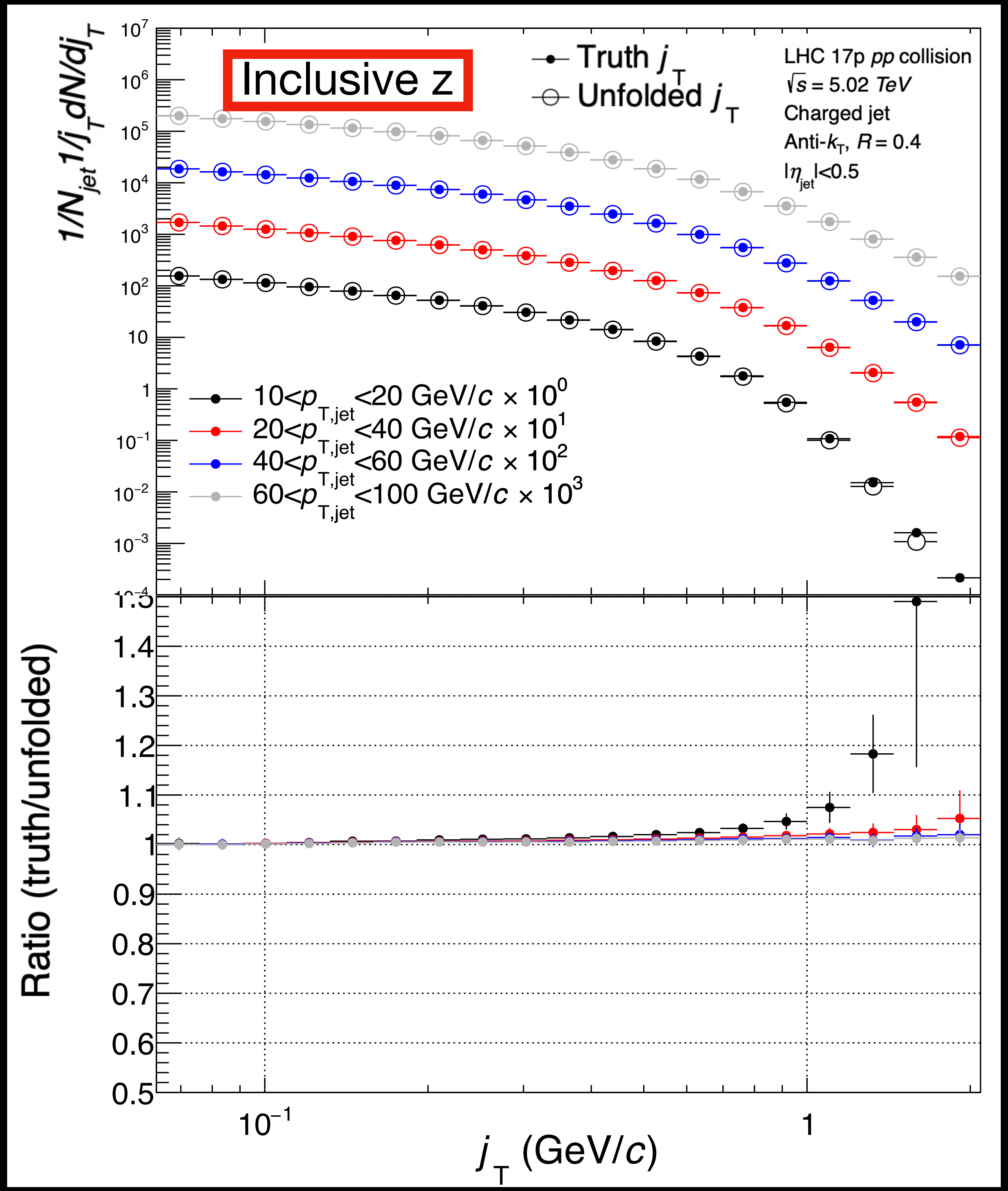
2-D unfolding

3-D unfolding



Analysis procedure

Unfolding closure test



Analysis procedure

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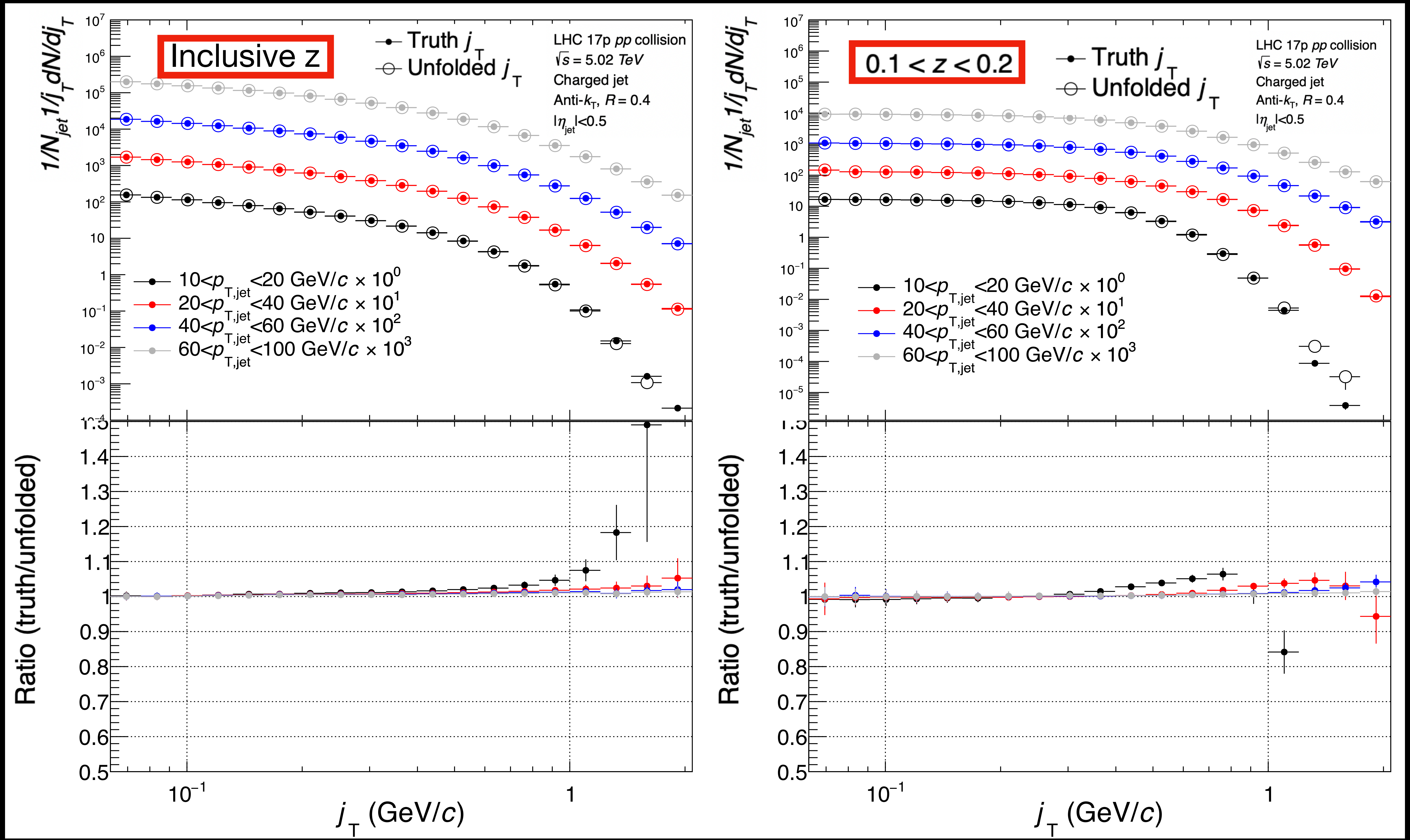
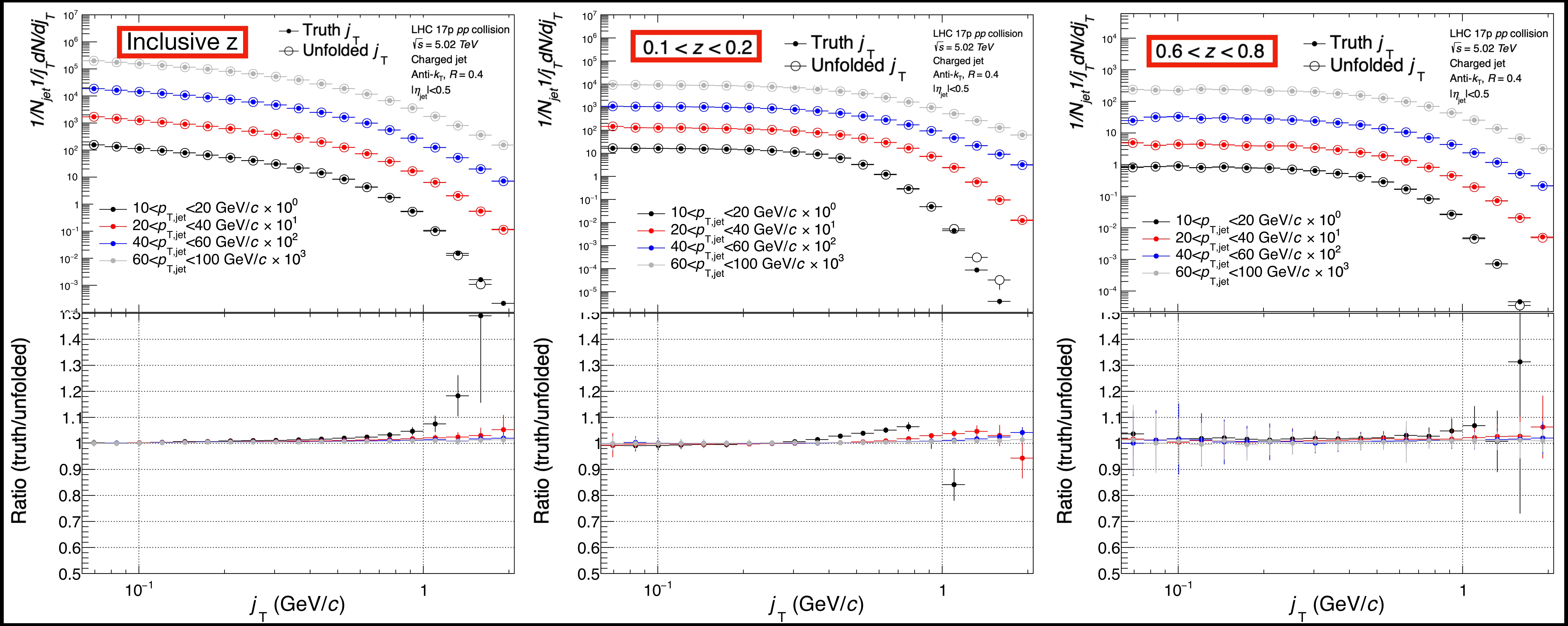


Analysis procedure

Unfolding closure test

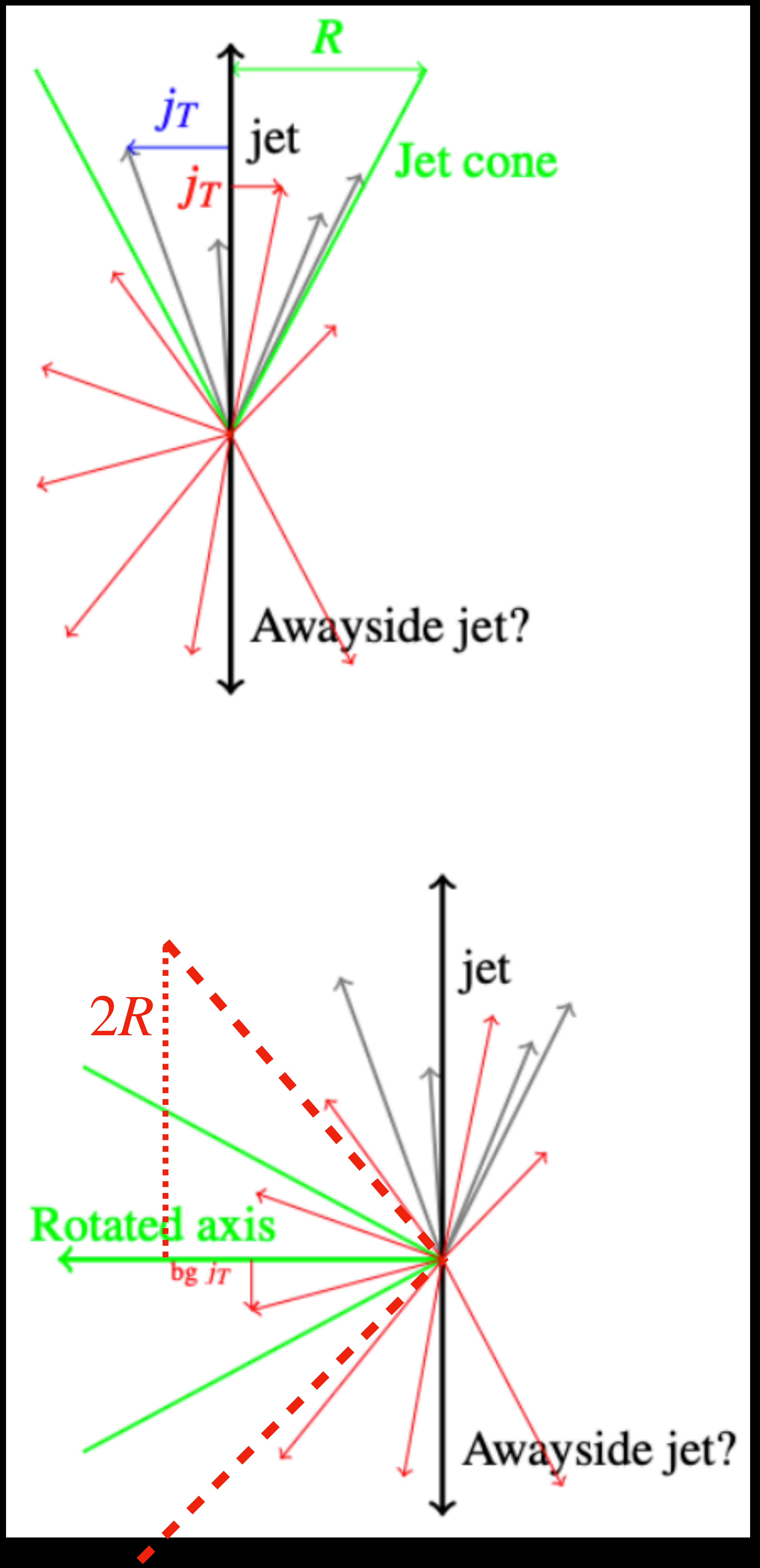


- Good j_T closure test results in different jet p_T and z bins

Analysis procedure

Background subtraction

- Perpendicular cone (Default)
  - Rotate the jet axis by 90˚ in positive ϕ direction
  - In case having no jets around the rotated axis(Delta R<0.8), calculate j_T, z around the axis for background



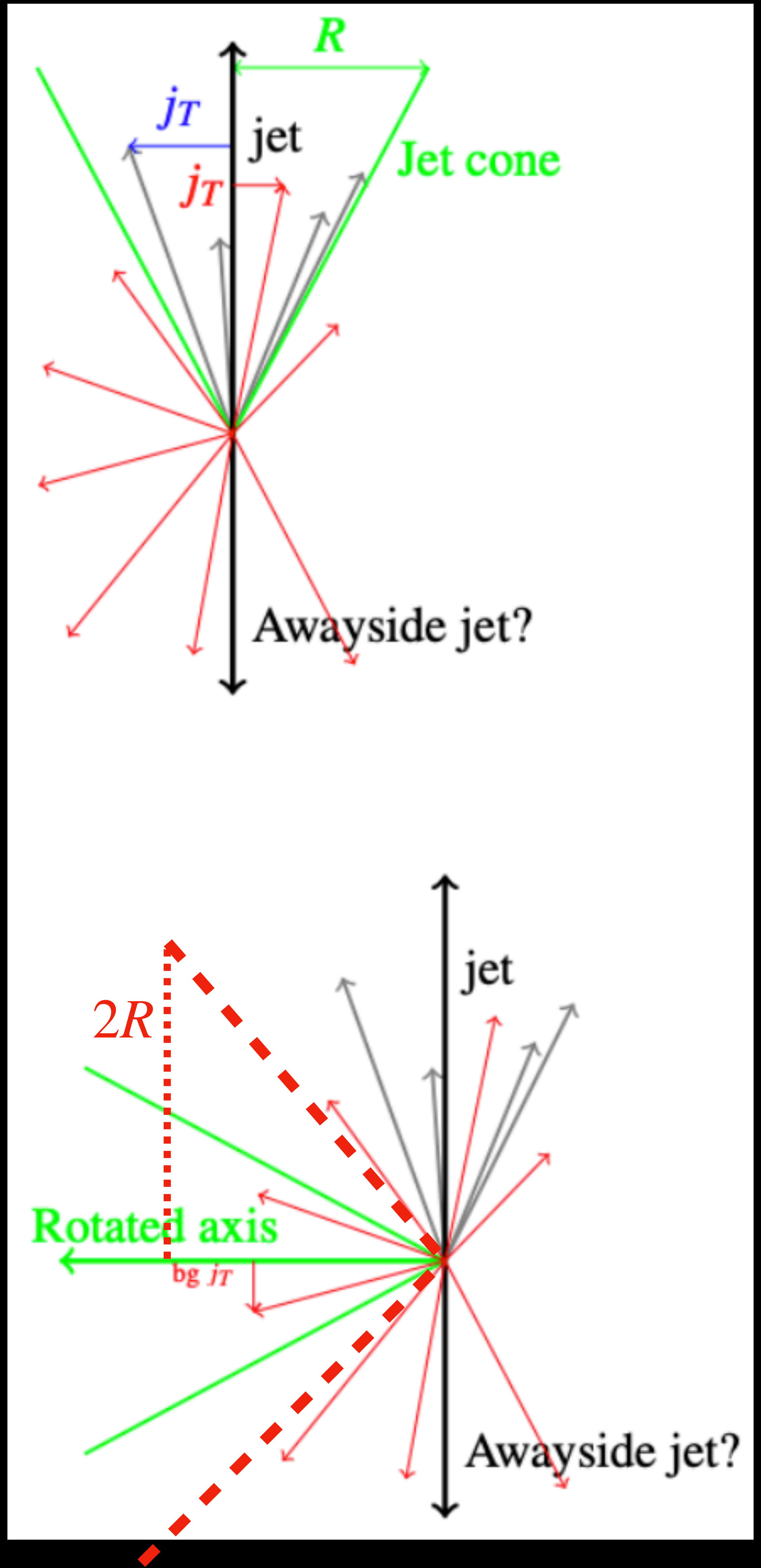
Analysis procedure

Background subtraction

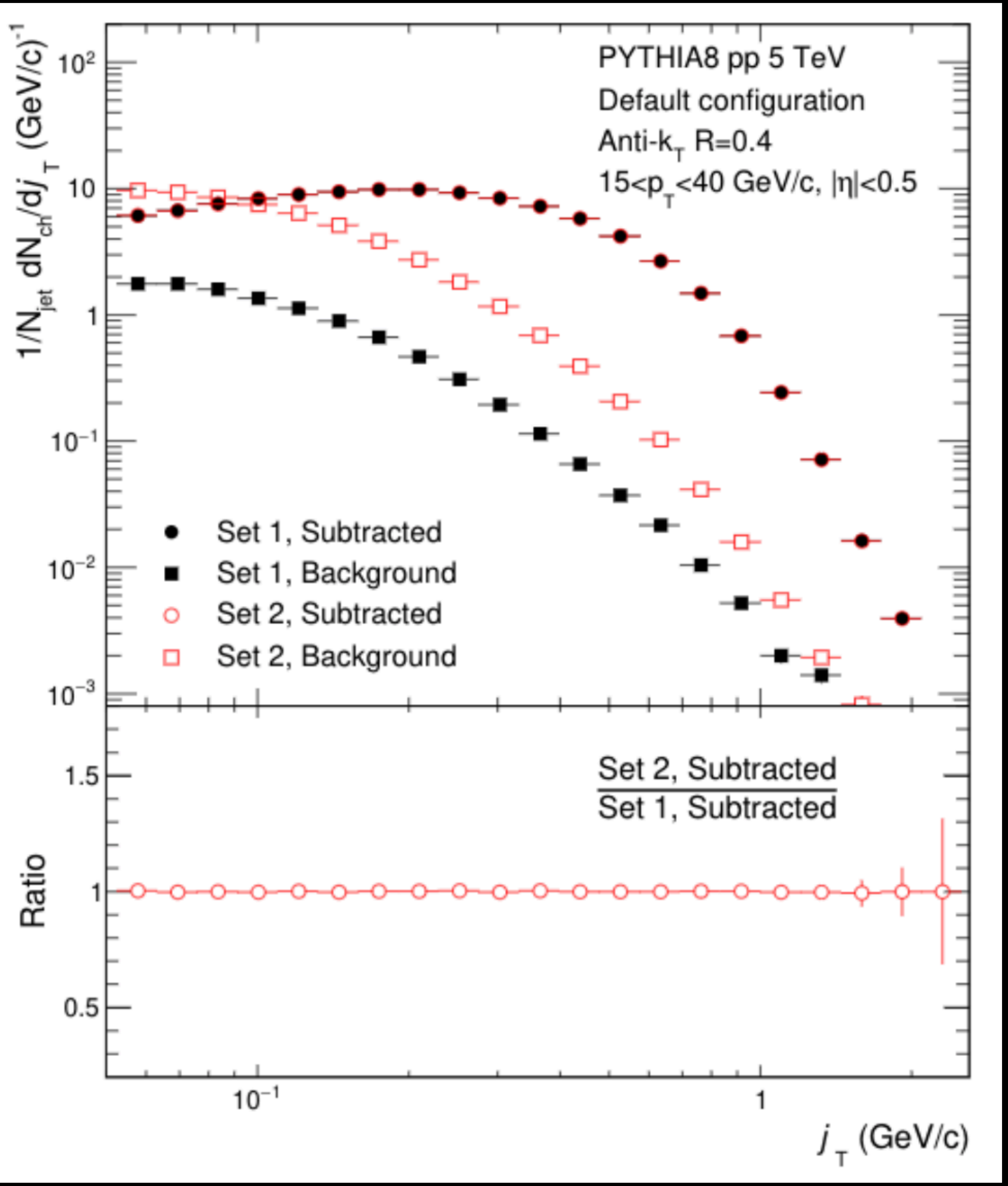
- Perpendicular cone (Default)
  - Rotate the jet axis by 90˚ in positive ϕ direction
  - In case having no jets around the rotated axis(Delta R<0.8), calculate j_T, z around the axis for background

- Random background method (Systematic check)
  - Collect all tracks outside the jet cone
  - Randomly assign new η & ϕ to all tracks using uniform distribution, $|\eta|<1.0$, p_T values are kept the same
  - Create a random jet cone from uniform η & ϕ distribution, $|\eta|<0.5$
  - Calculate j_T, z of the random tracks with respect to the random cone axis

j_T model study
Background subtraction

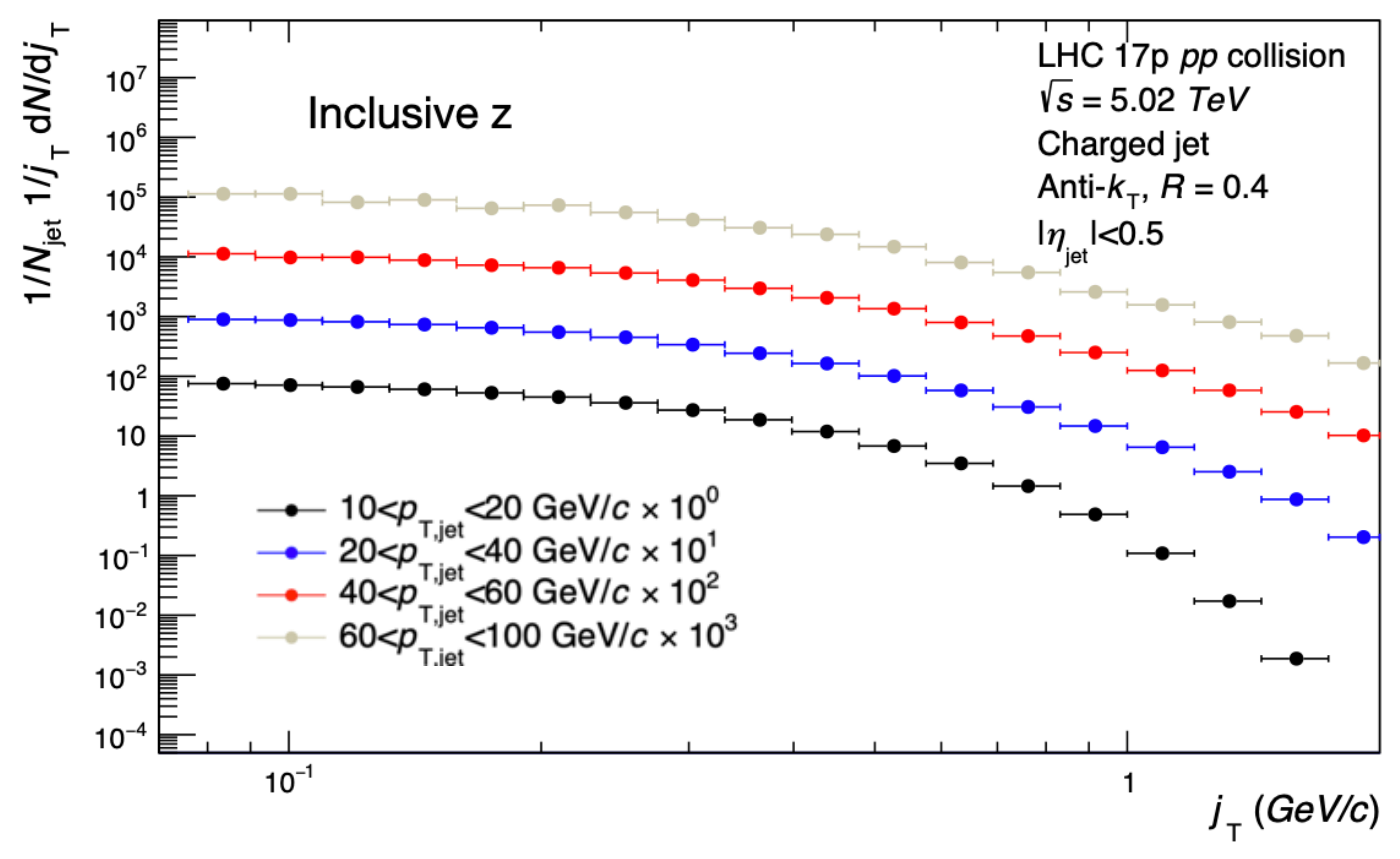


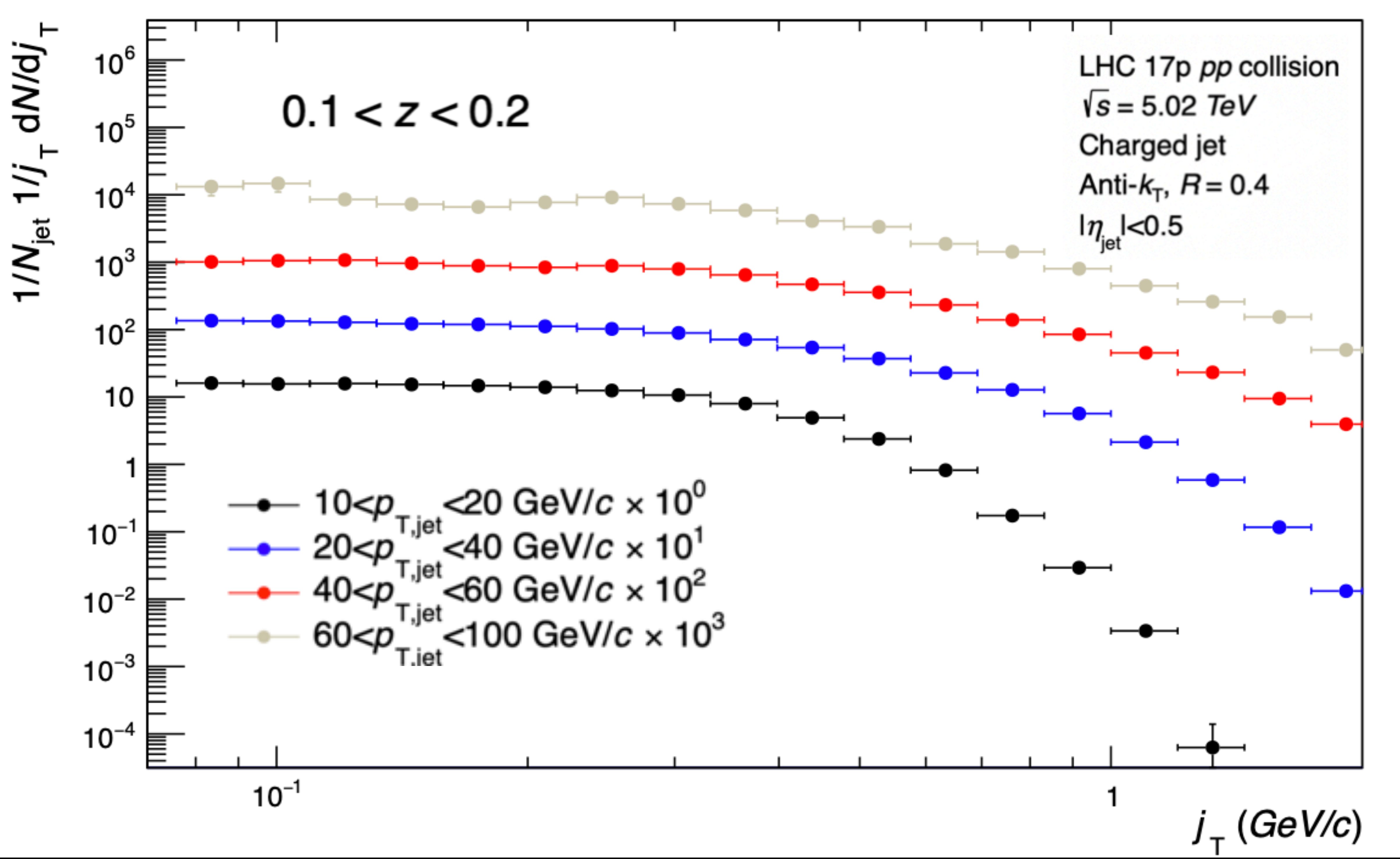
- Applied perpendicular cone method to subtract underlying event
- And verified that the method works well
- Set 1 - PYTHIA8 pp events without MPI
- Set 2 - A combination of first set and MB pp events



Analysis Result

j_T distribution

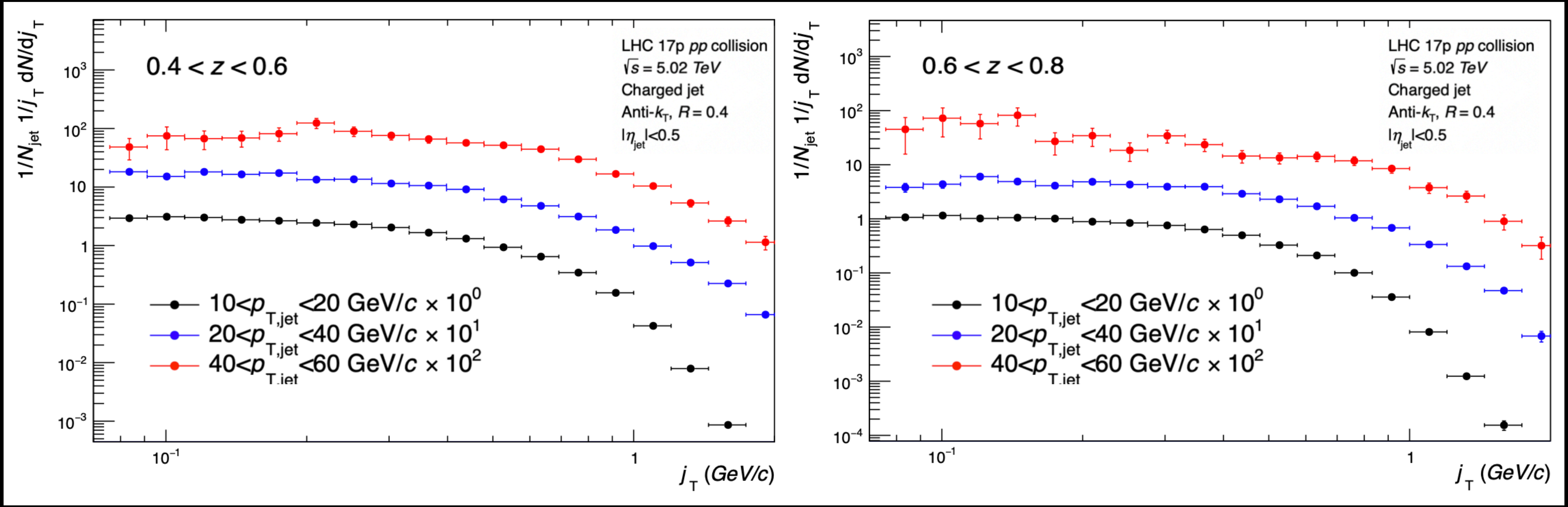




- Initial look on charged jet j_T distribution with 5.02 TeV pp data

Analysis Result

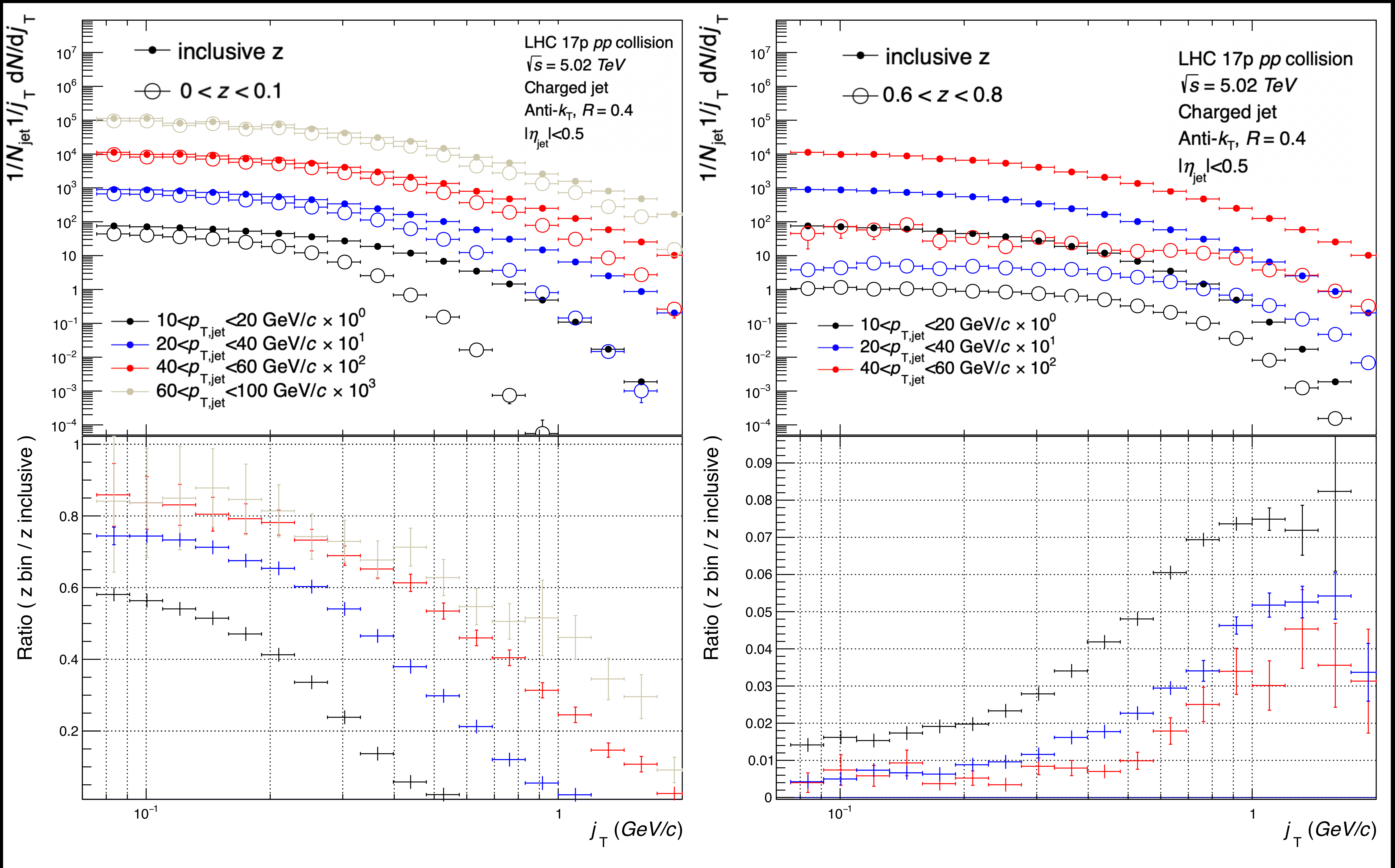
j_T distribution



- Initial look on charged jet j_T distribution with 5.02 TeV pp data
- Differential study can be done with charged jet j_T

Analysis Result

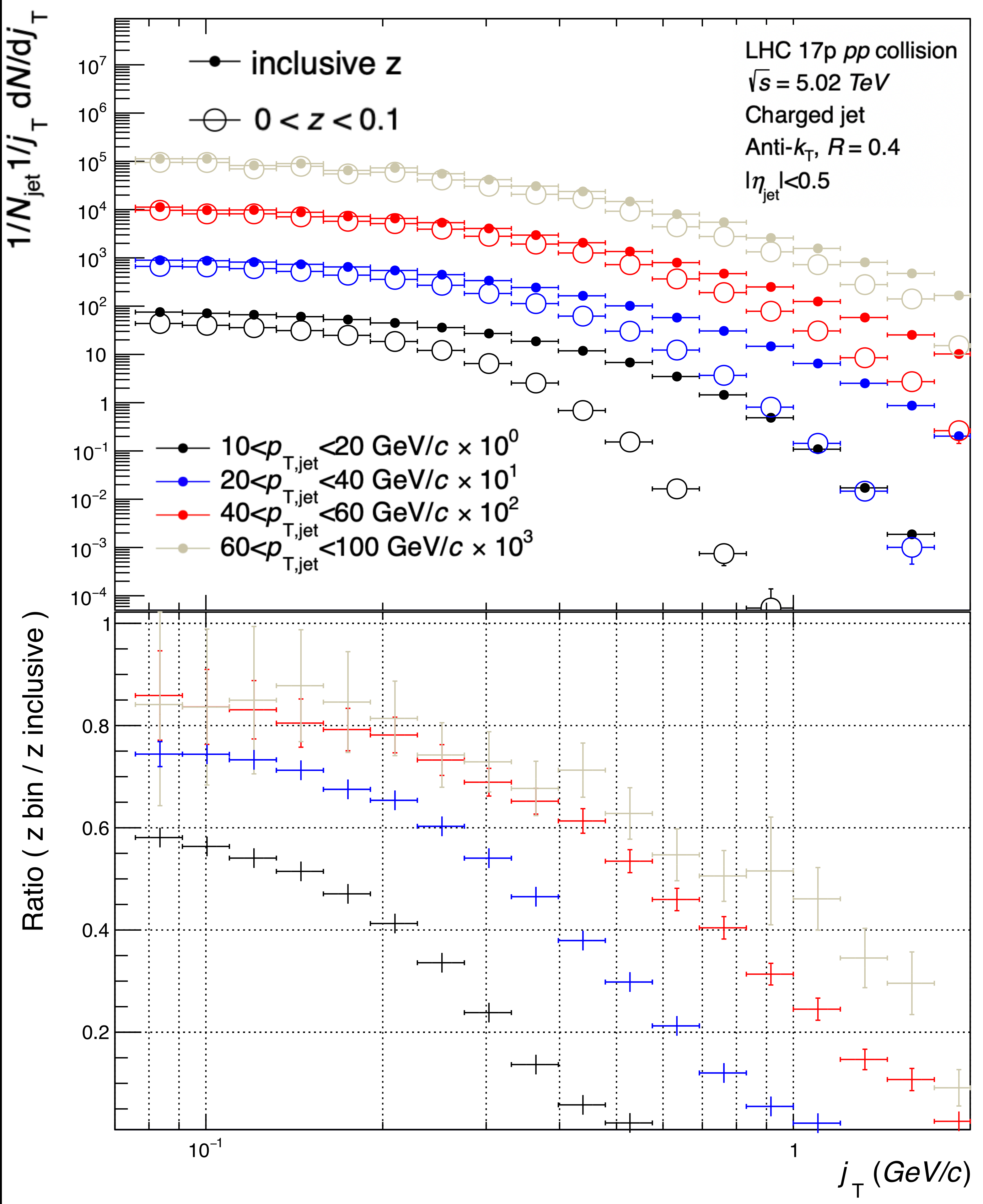
Angular ordering

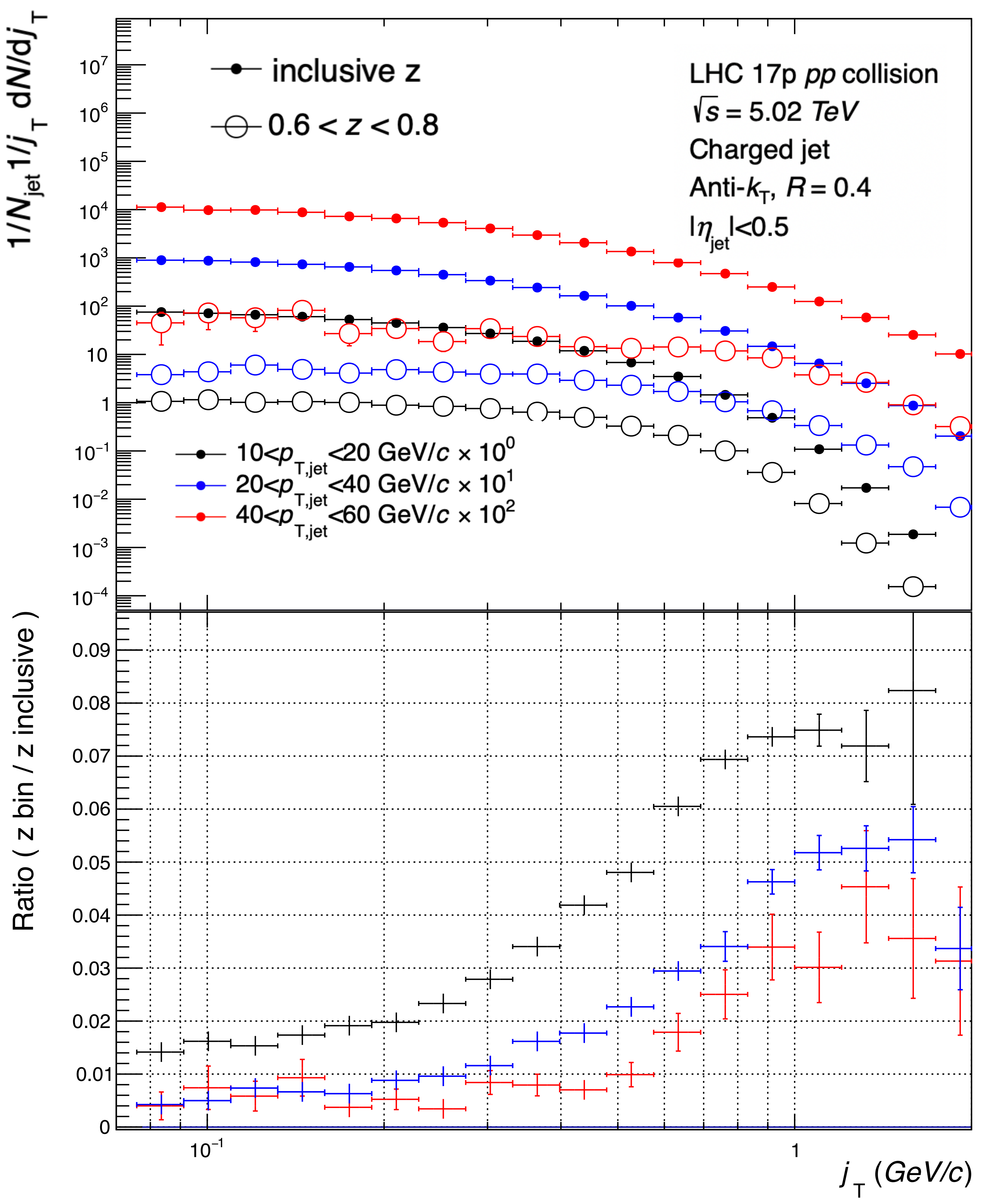


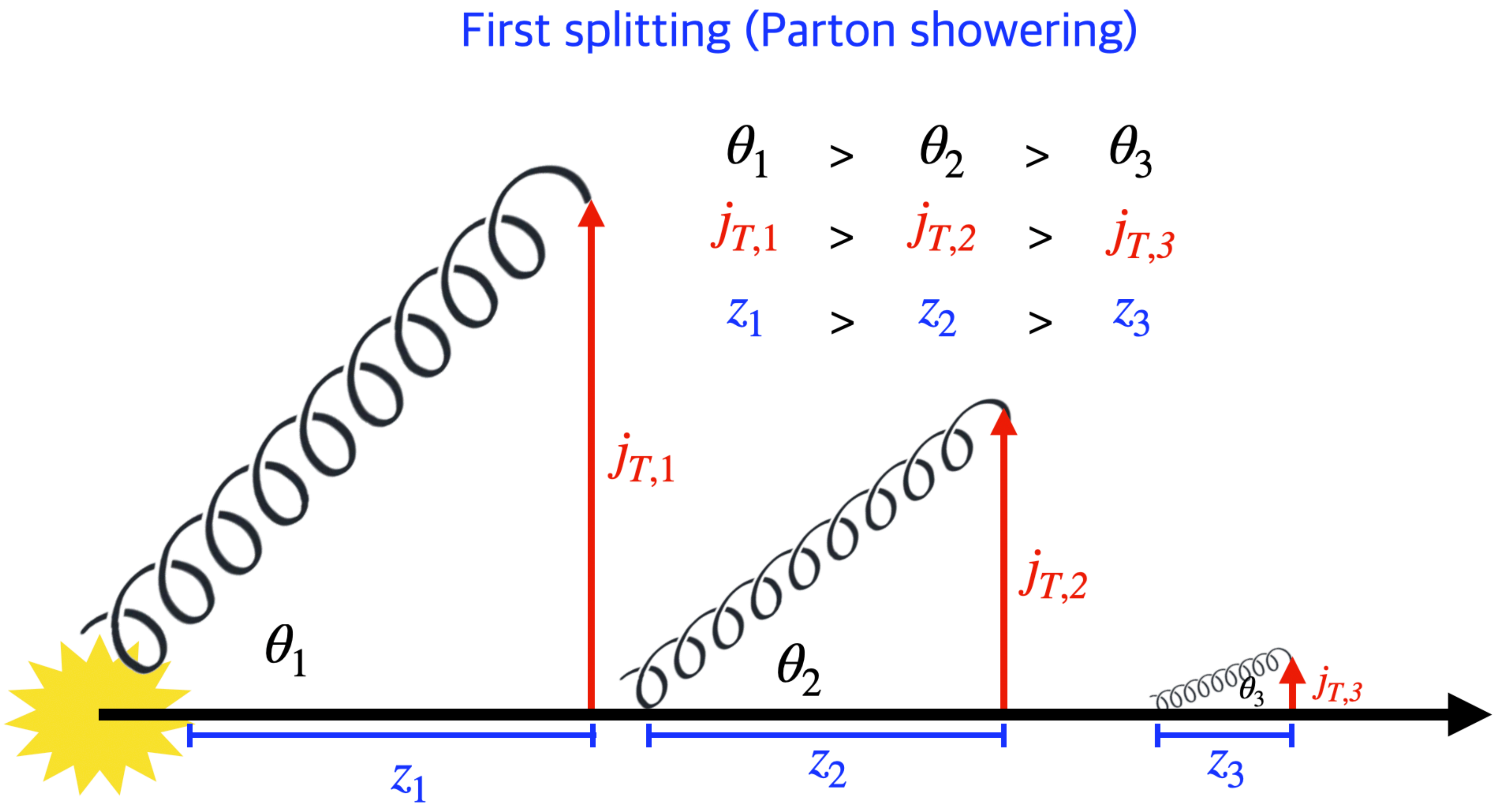
- Ratios of low, high z bin with respect to inclusive z

Analysis Result

Angular ordering

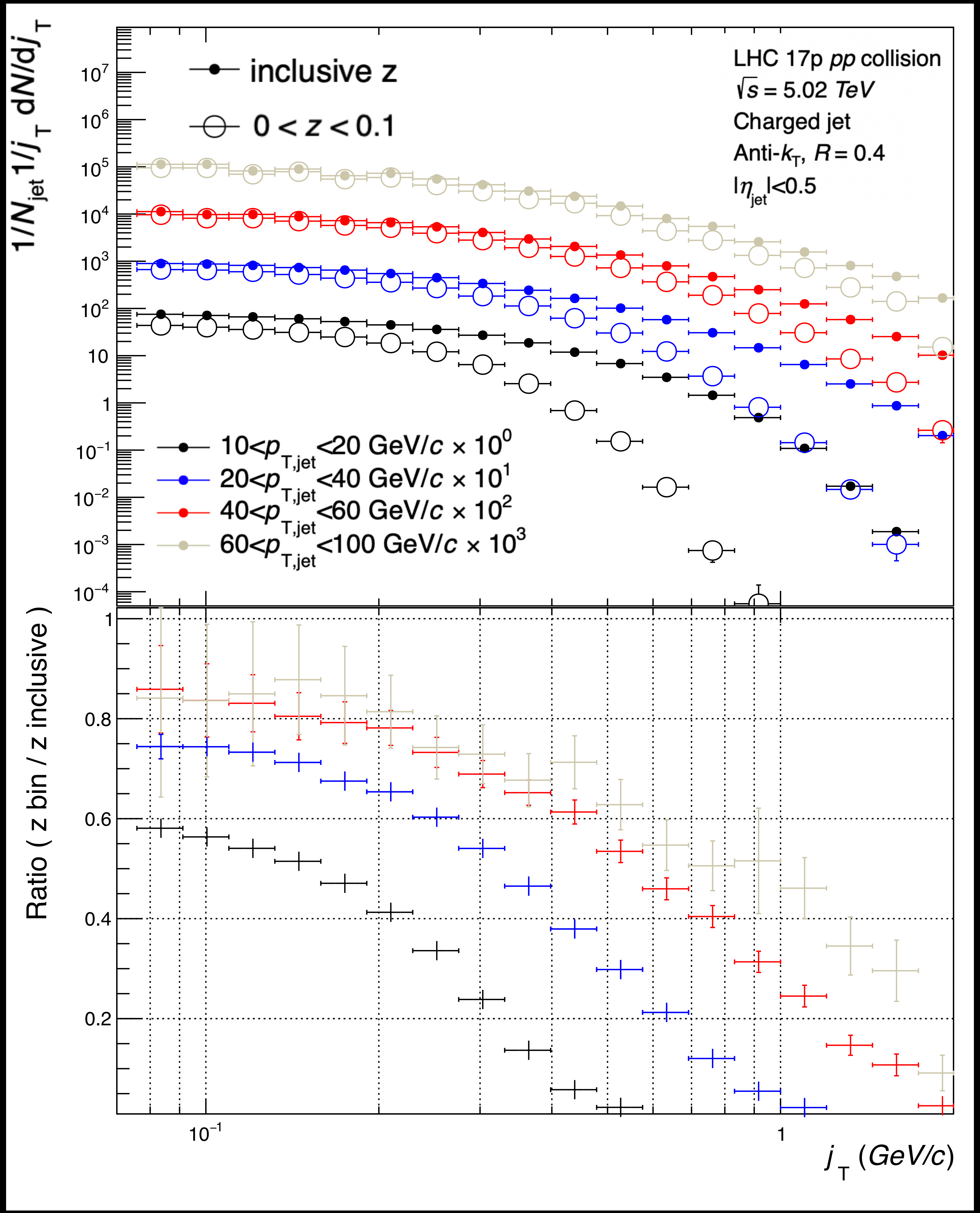






- In low z bin, low j_T components are dominant
- In high z bin, high j_T components are dominant
- Consistent with the angular ordering

Summary & Plan



- The analysis of z-dependent j_T is on-going
- Analysis has been done with charged jets and the 3D unfolding method
- Ratio plots of low, high z bin with respect to inclusive z are consistent with angular ordering
- Systematic study and model comparison will be followed
- Model study for checking jet fragmentation modification in small system is ongoing
- Aim to present poster at QM 2022

Thank you

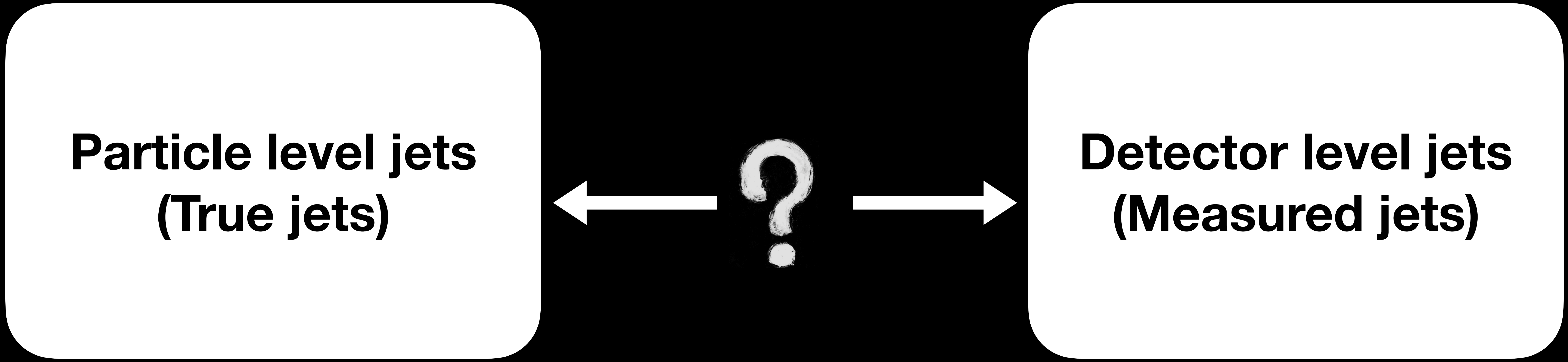
Thank you!

Back-up

Back-up

Unfolding

- Measured jet spectrum smeared by background energy density fluctuation
- By detector effect
- By the jet finding efficiency



Back-up

Unfolding

- The technique which de-convolutes the measured jet spectrum to obtain the true jet spectrum is called unfolding.

- Mathematically

$$M(p_T^{rec}) = \int G(p_T^{rec}, p_T^{gen})\ T(p_T^{gen})\ \epsilon(p_T^{gen})\ dp_T^{gen}$$

Measured jet spectrum — Functional description of smearing — True jet spectrum — Jet finding efficiency

- Discretize and write in matrix form

$$M_m = G_{m,t} \cdot T'_t \qquad (T_t = T'_t \cdot \frac{1}{\epsilon_t})$$

Back-up

Unfolding

- The technique which de-convolutes the measured jet spectrum to obtain the true jet spectrum is called unfolding.

- Mathematically

M … $en) \; \epsilon(p_T^{gen}) \; dp_T^{gen}$

Mea … sp … et … m … Jet finding efficiency

Particle level jets (True jets)

Detector level jets (Measured jets)

- Di … trix form

M_m … $_t$

$G_{m,t}$ is known as Response Matrix!
(Or combined response matrix)

Back-up

Unfolding

- The technique which de-convolutes the measured jet spectrum to obtain the true jet spectrum is called unfolding.
- Mathematically

M … en) $\epsilon(p_T^{gen})\ dp_T^{gen}$

Mea… sp… …t …m Jet finding efficiency

- Di… …trix form

M_n … e_t

Particle level jets
(True jets)

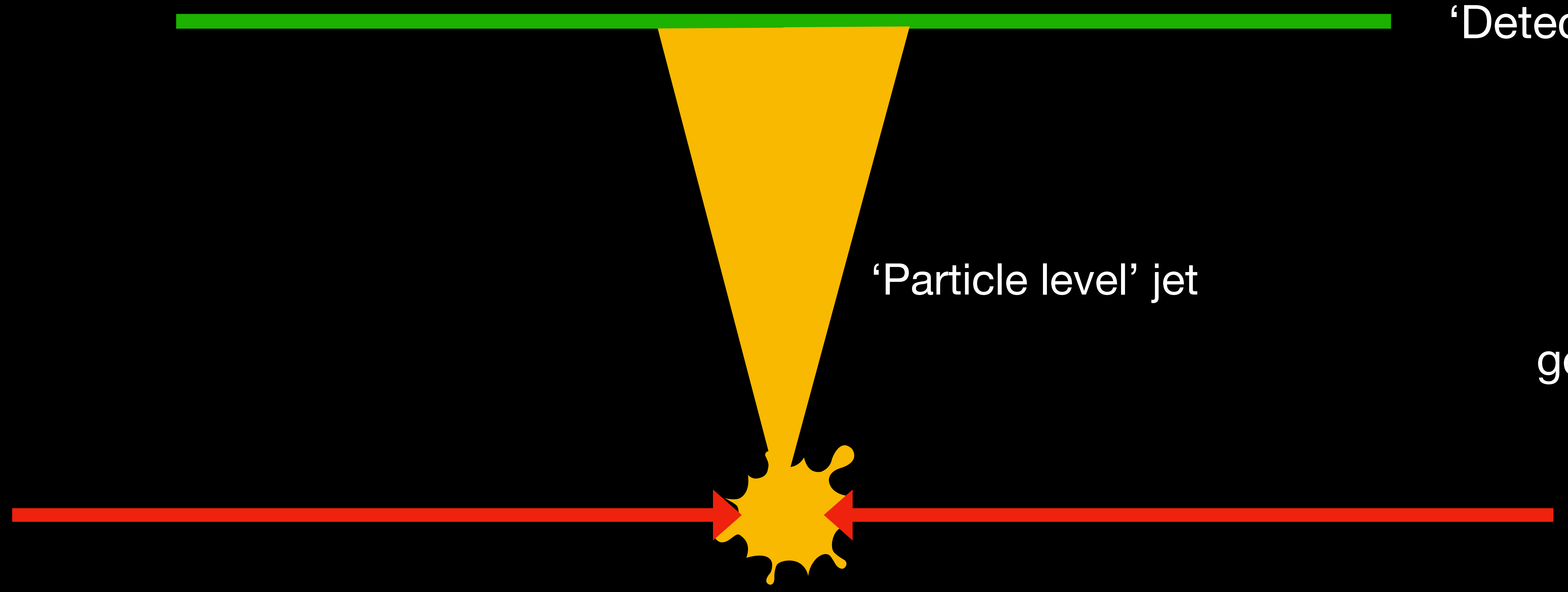
$\longleftarrow G_{m,t} \longrightarrow$

Detector level jets
(Measured jets)

$G_{m,t}$ is known as Response Matrix!
(Or combined response matrix)

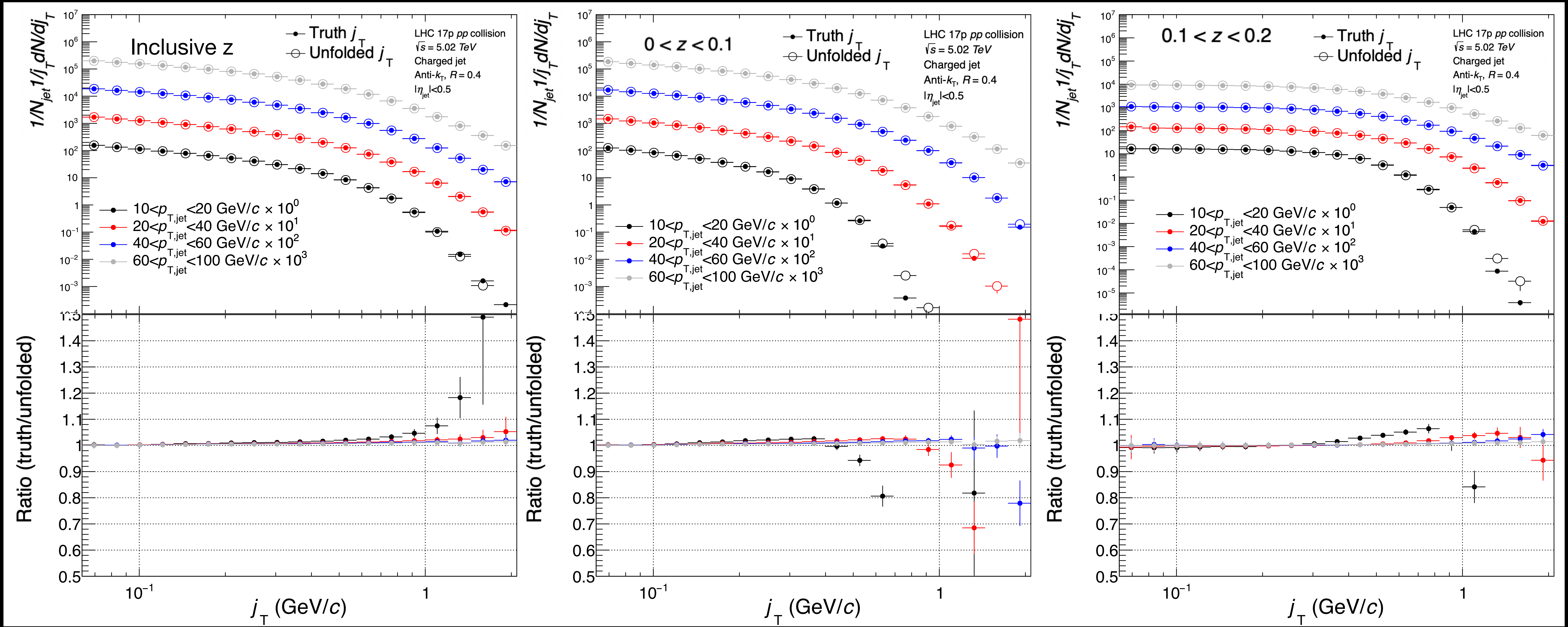
Back-up

Unfolding



Back-up

3-D closure test



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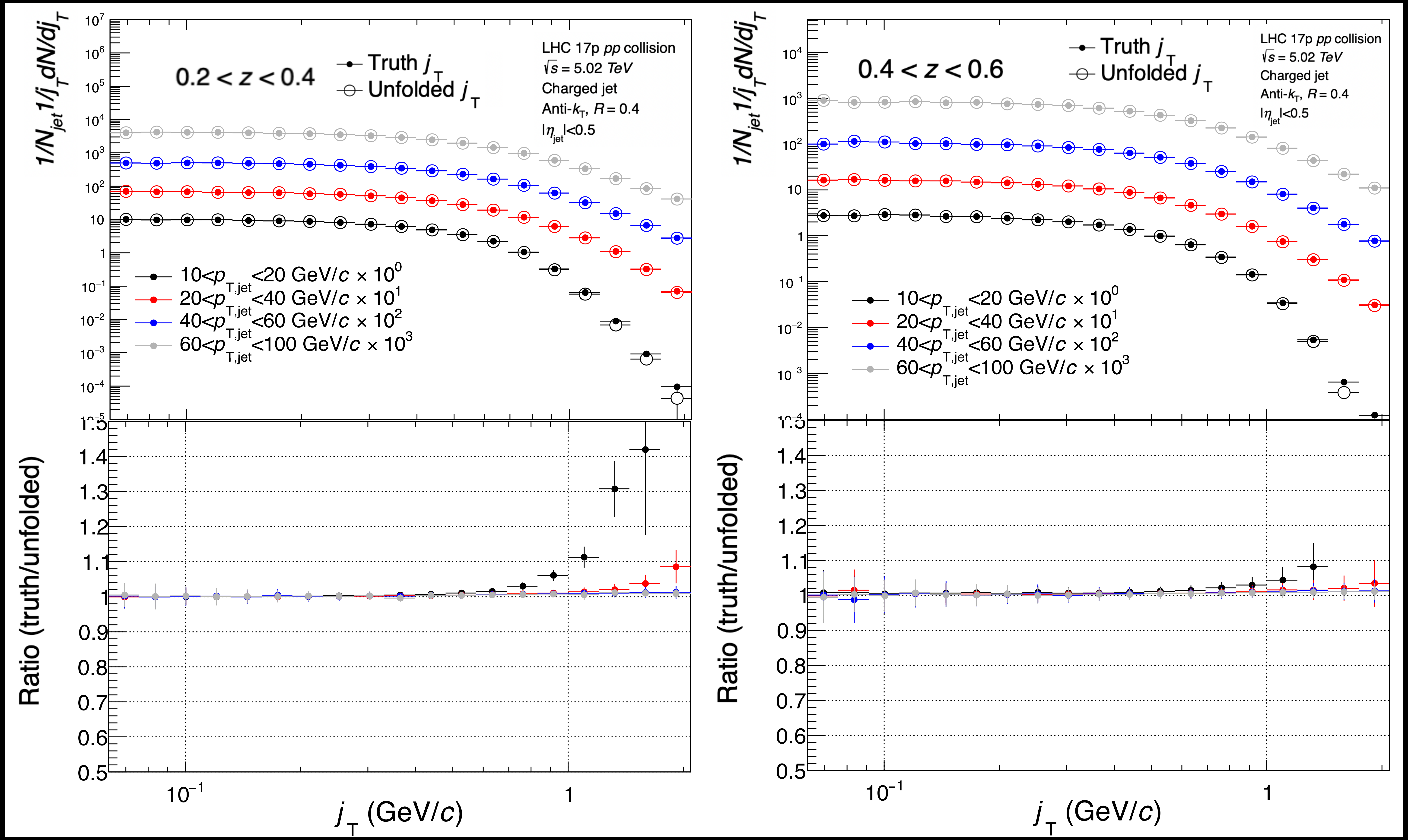

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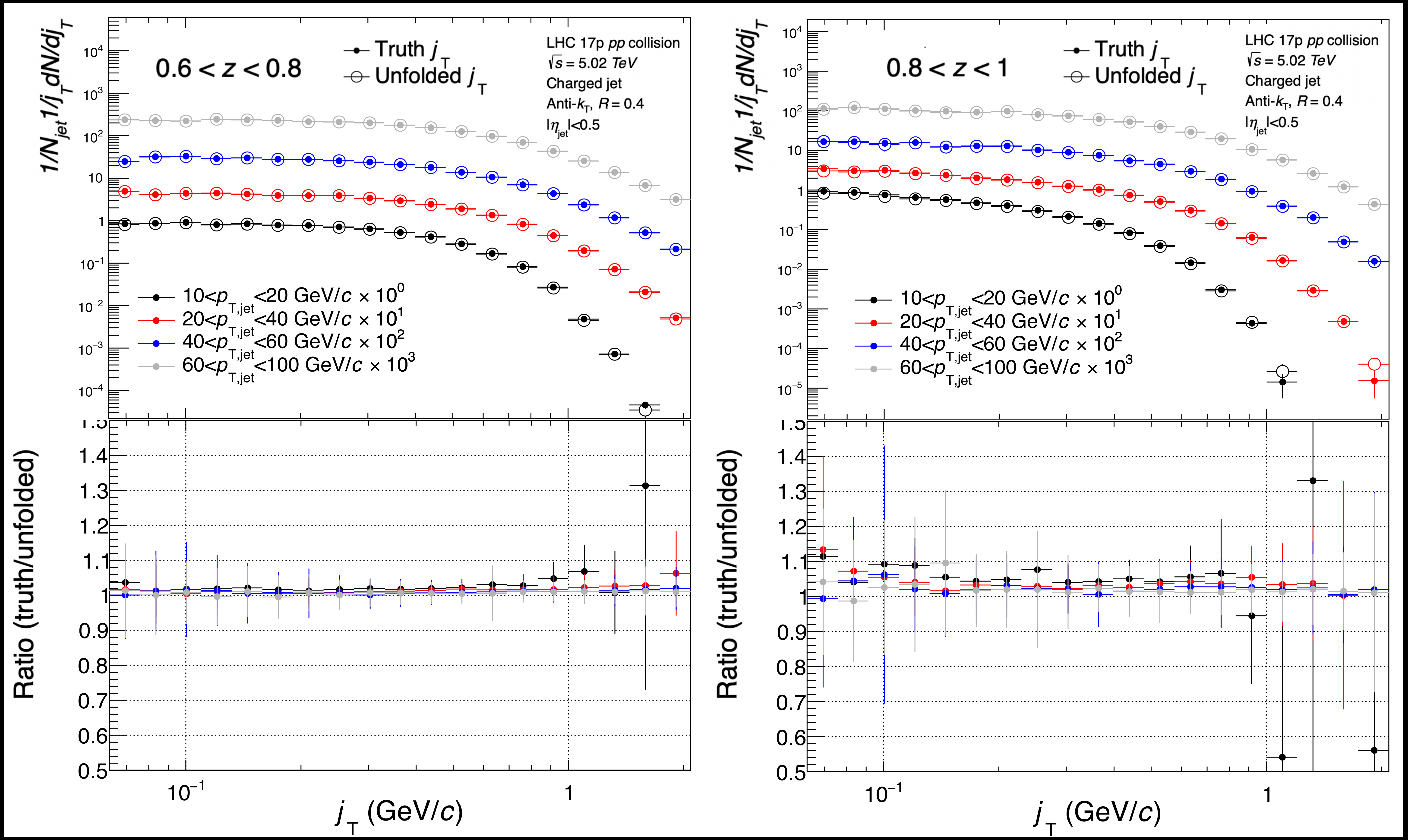
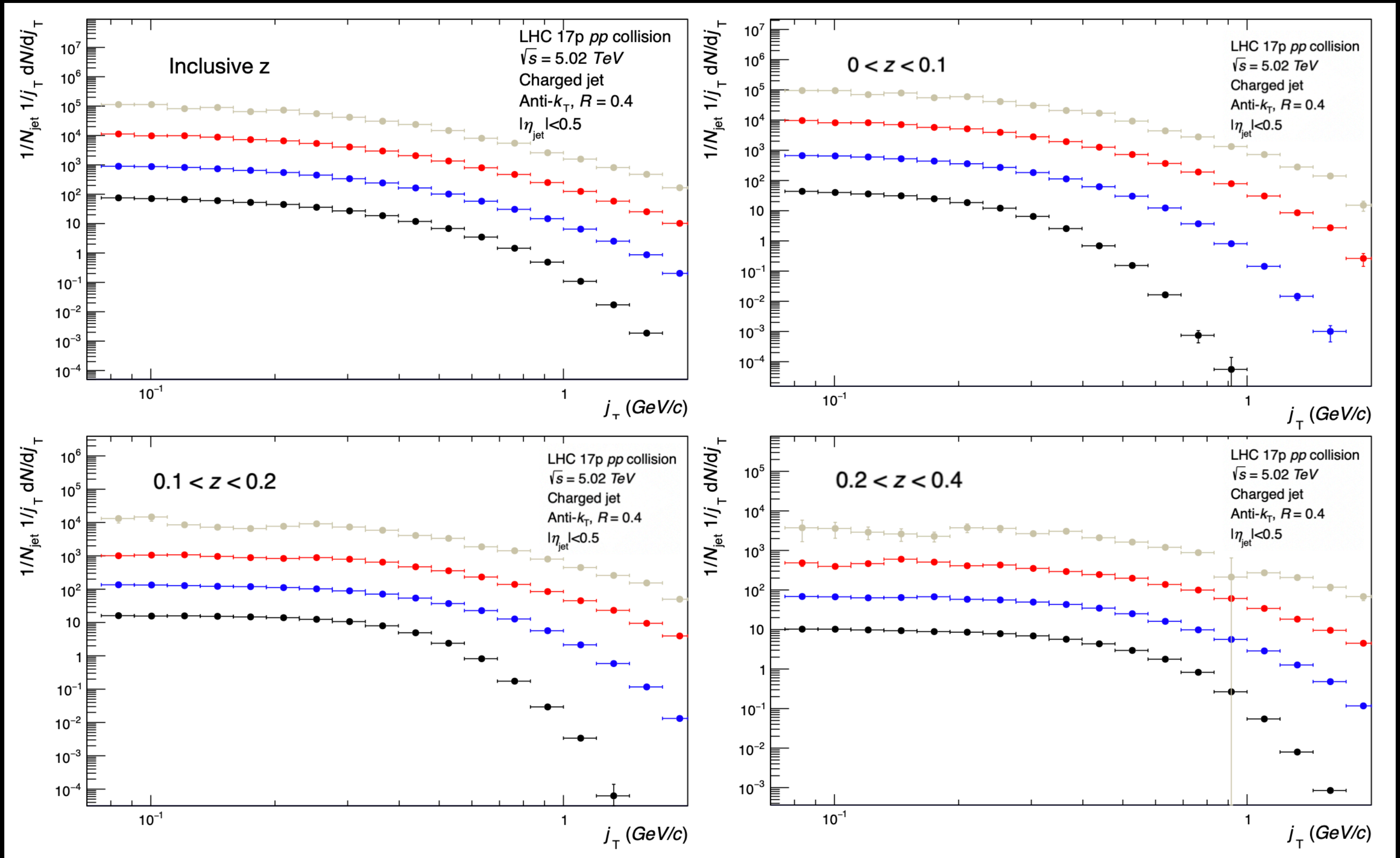
3-D closure test



Back-up

j_T distribution



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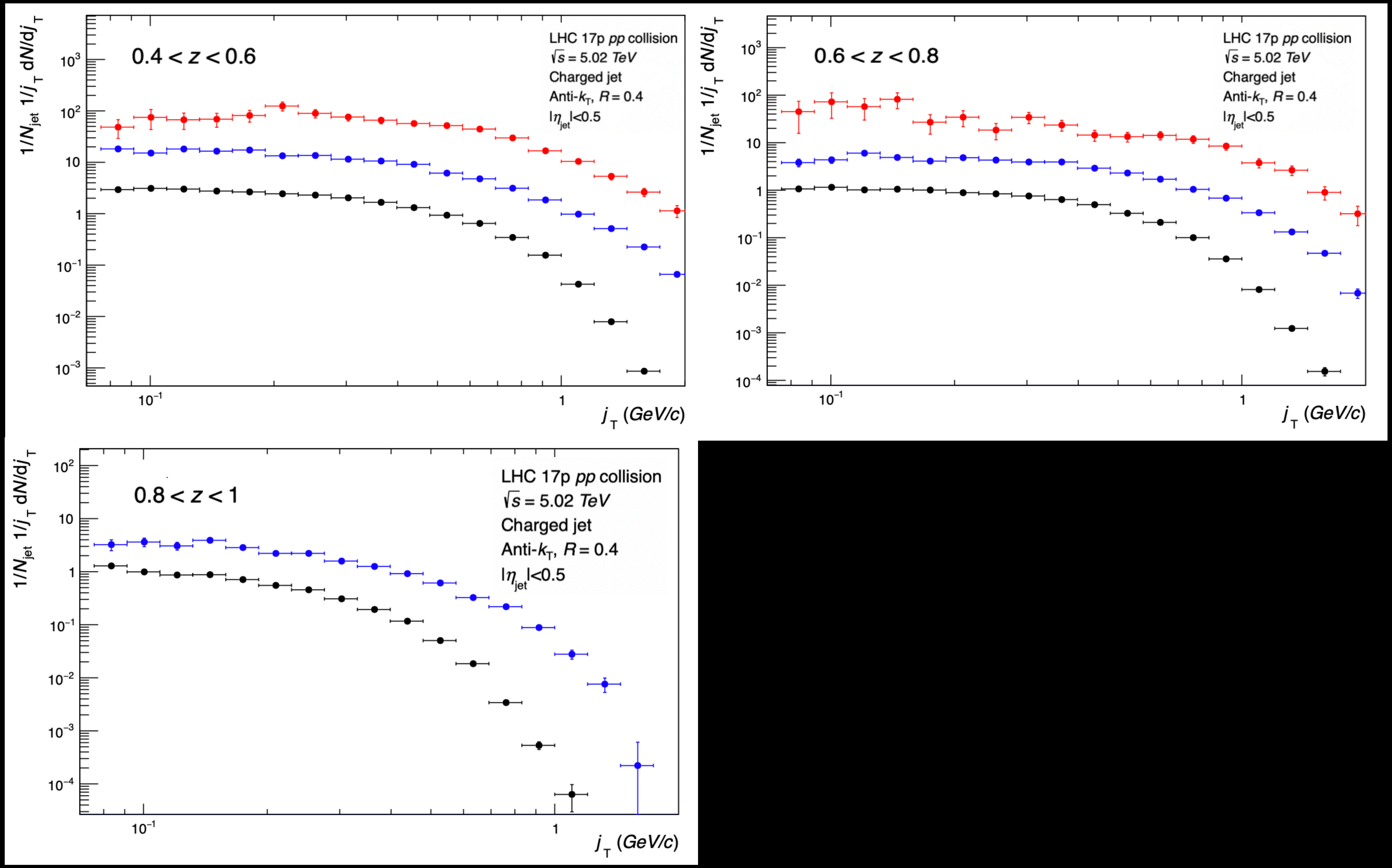
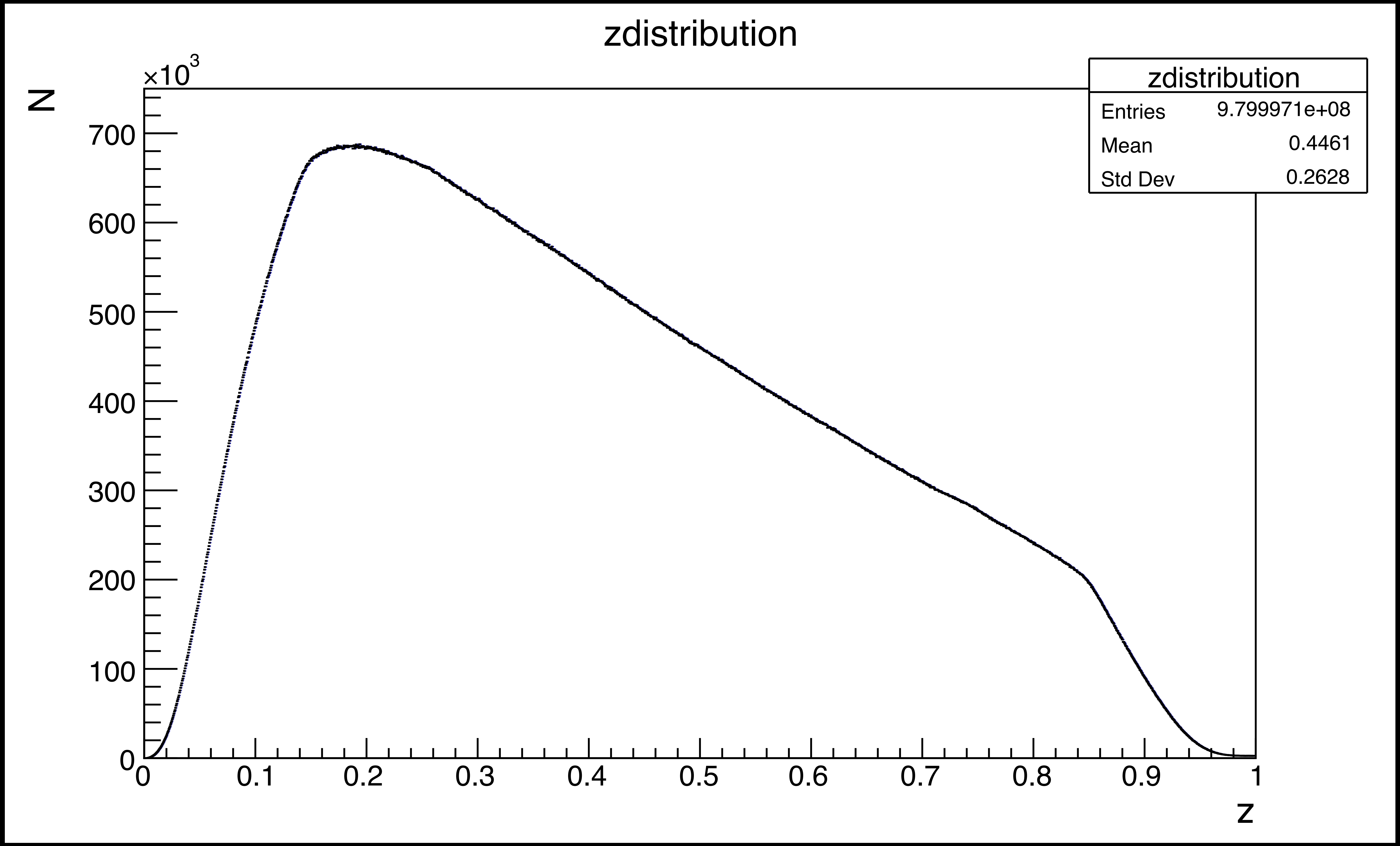
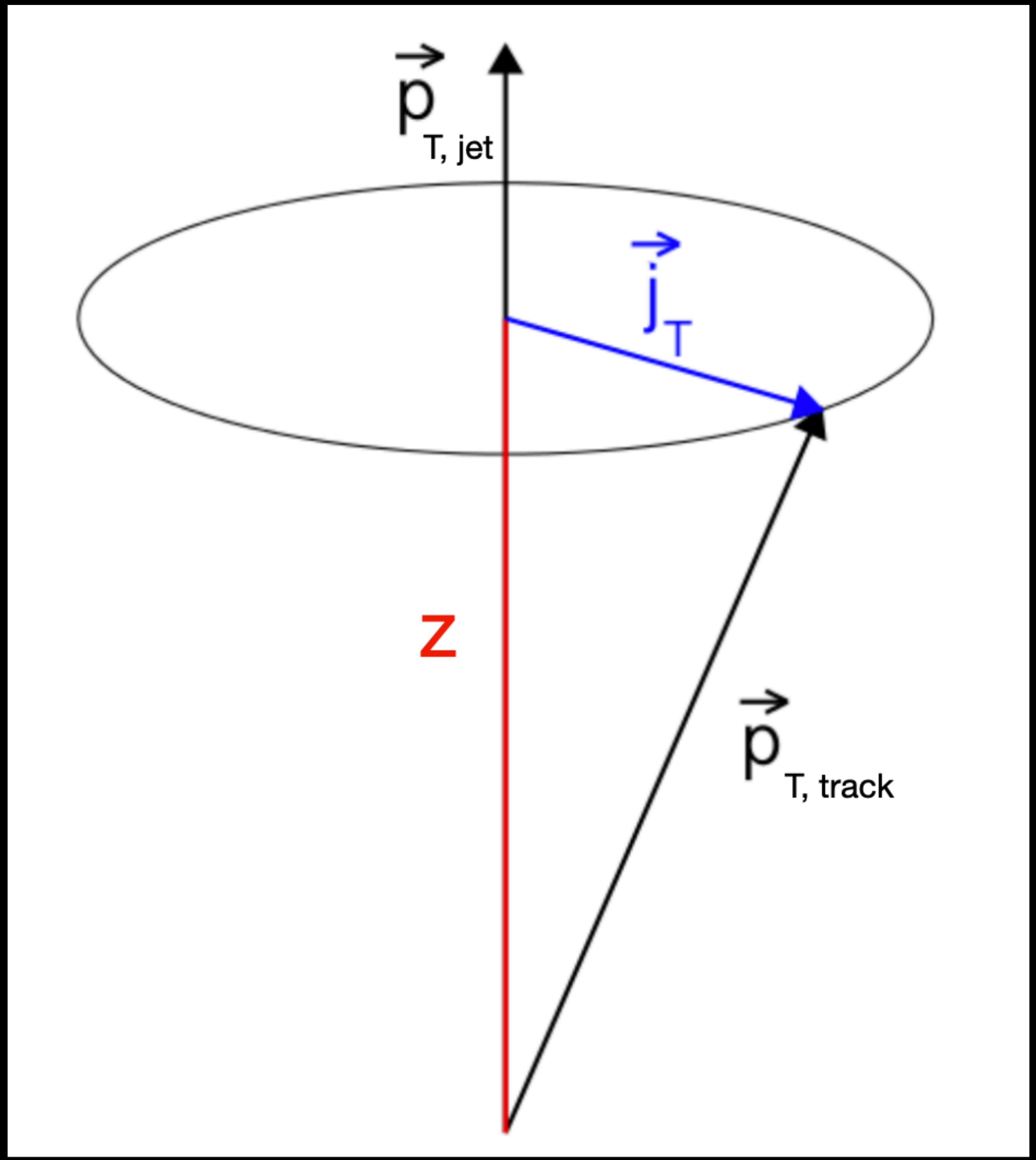
j_T distribution



Back-up

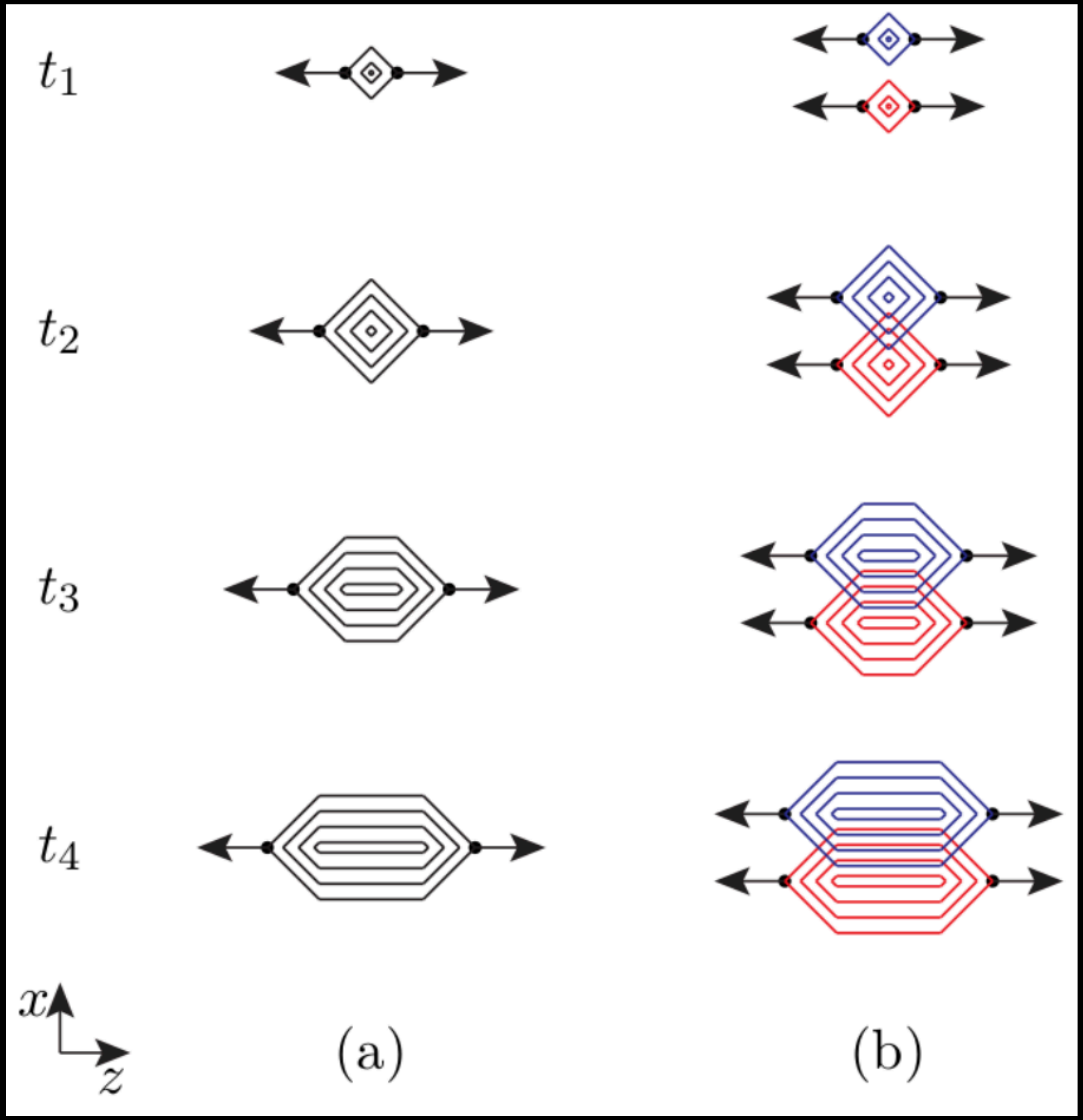
z distribution





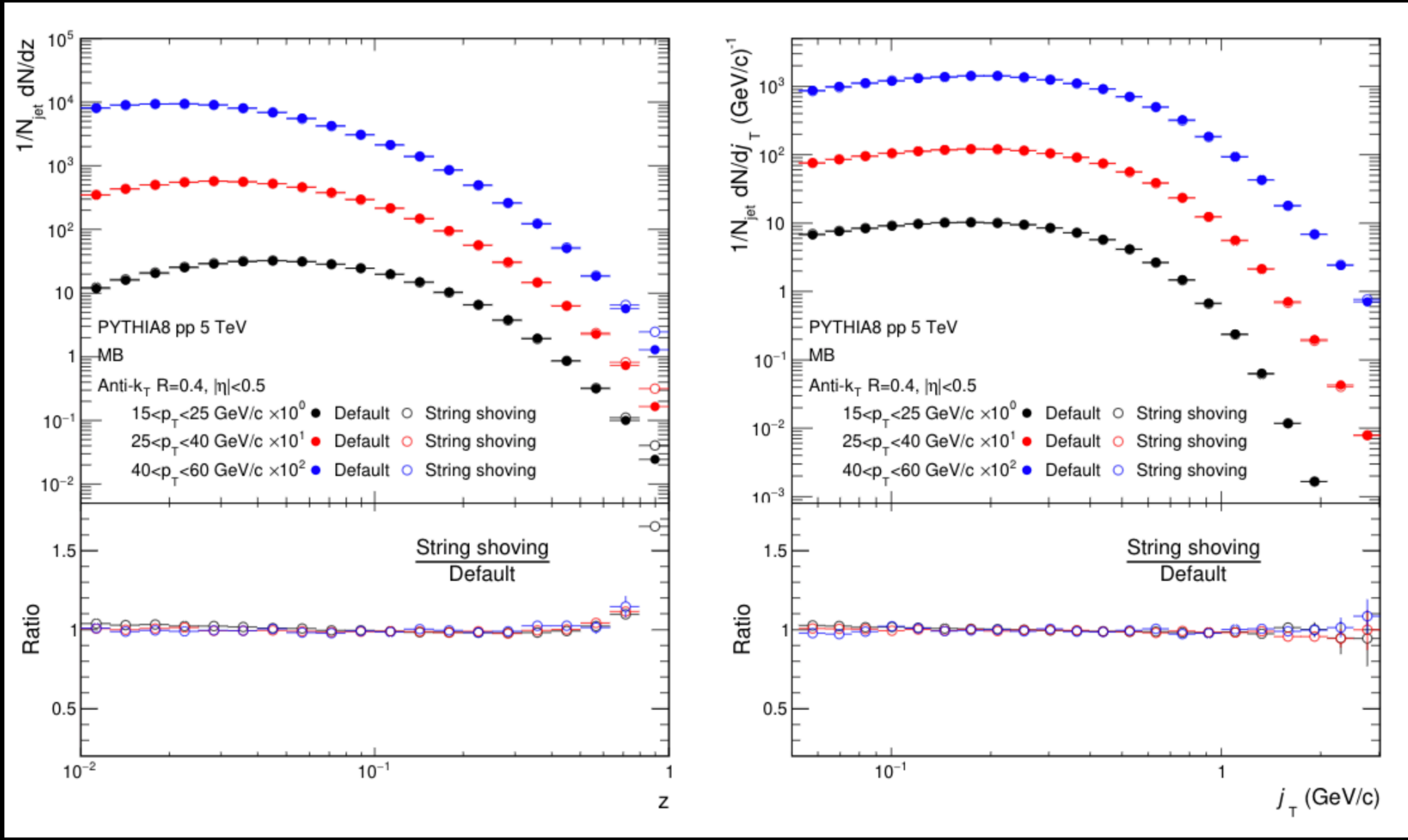
String shoving model

- To describe the long-range correlation of produced particles in high multiplicity pp collisions, a model called “string shoving” was proposed
- A repulsive force between flux tubes causes expansions of flux tubes both longitudinally and transversely



j_T model study

Initial look on z, j_T MB



j_T model study

Initial look on z, j_T HM