Jet measurements with LHC Run 3 data at ALICE

Sungkyunkwan University
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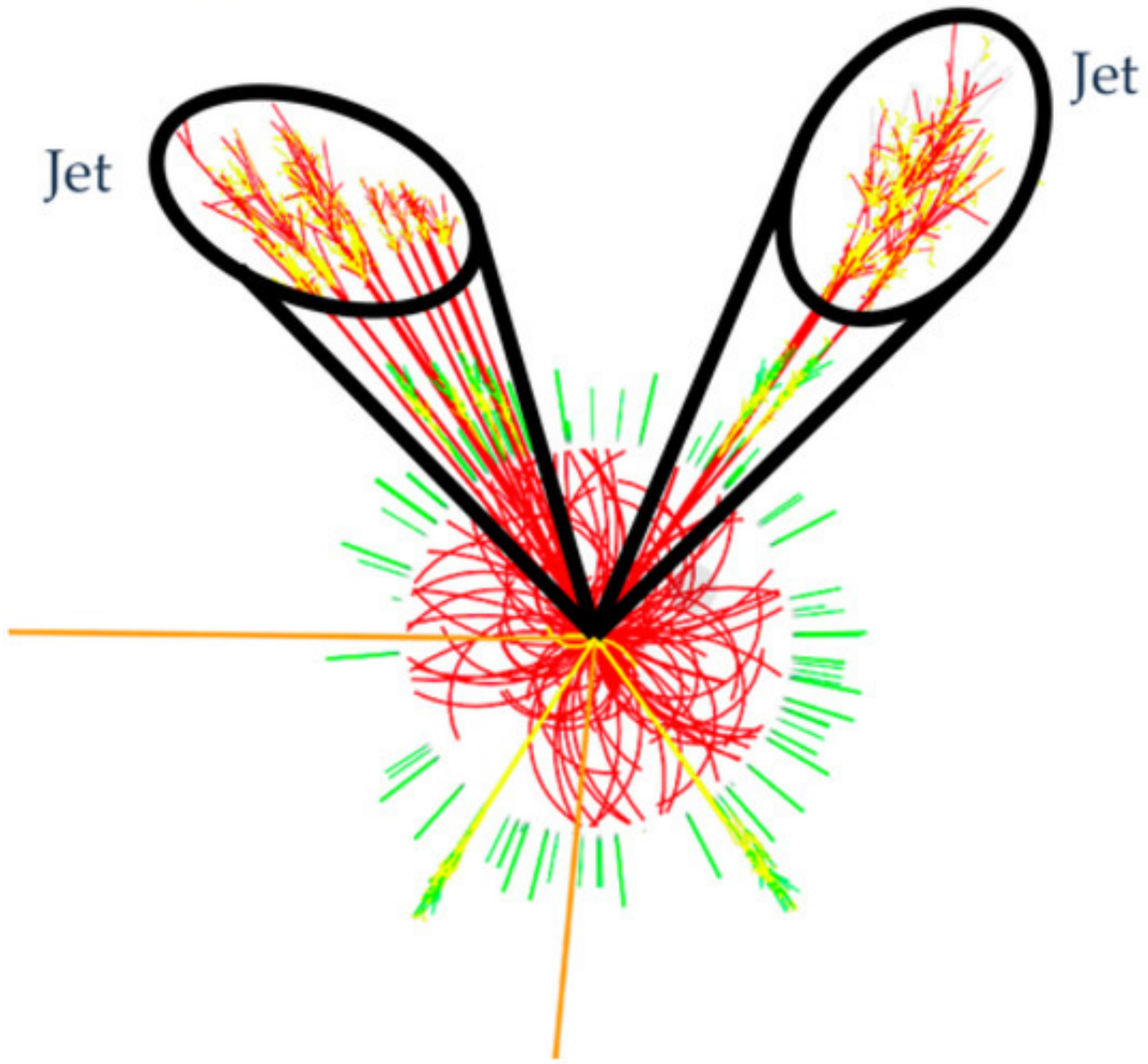
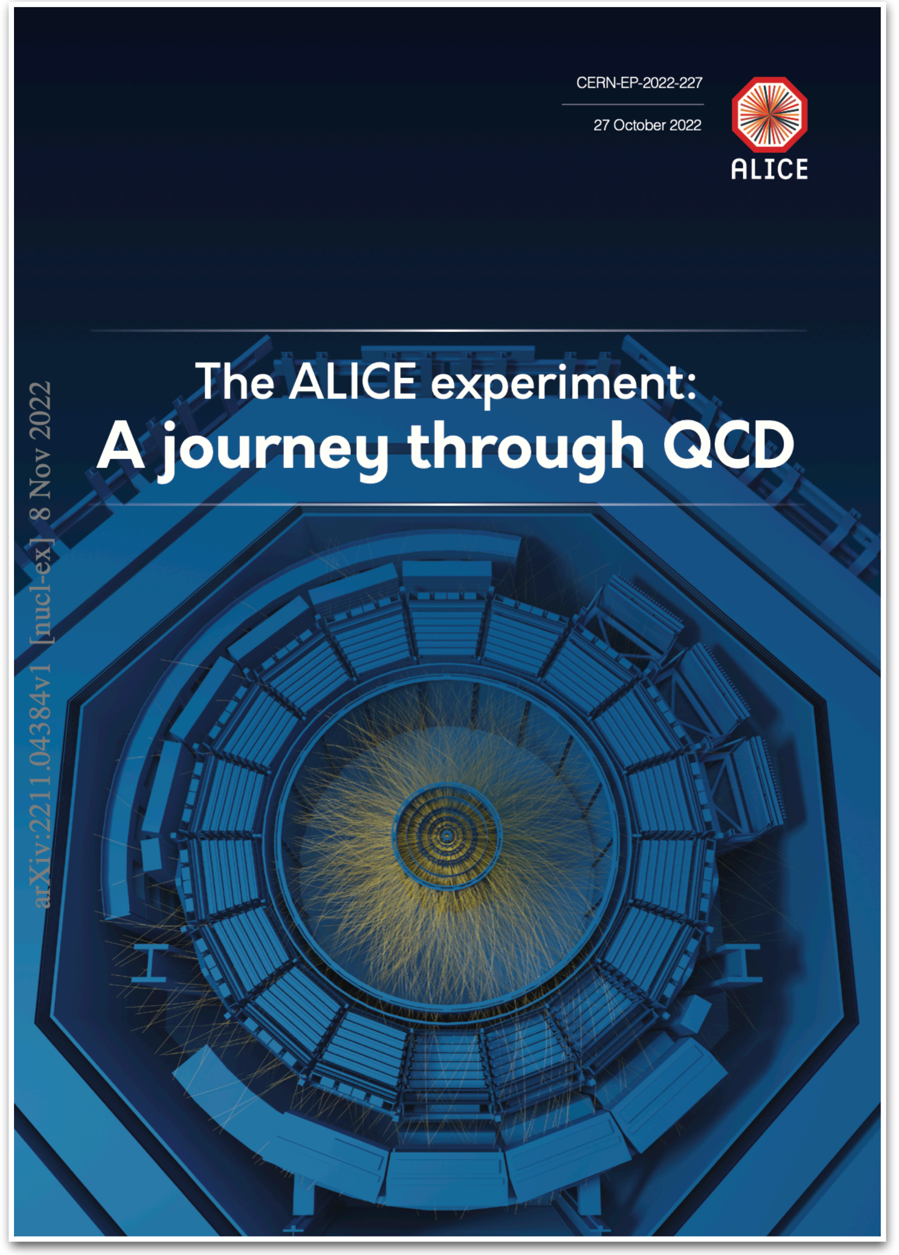
Introduction



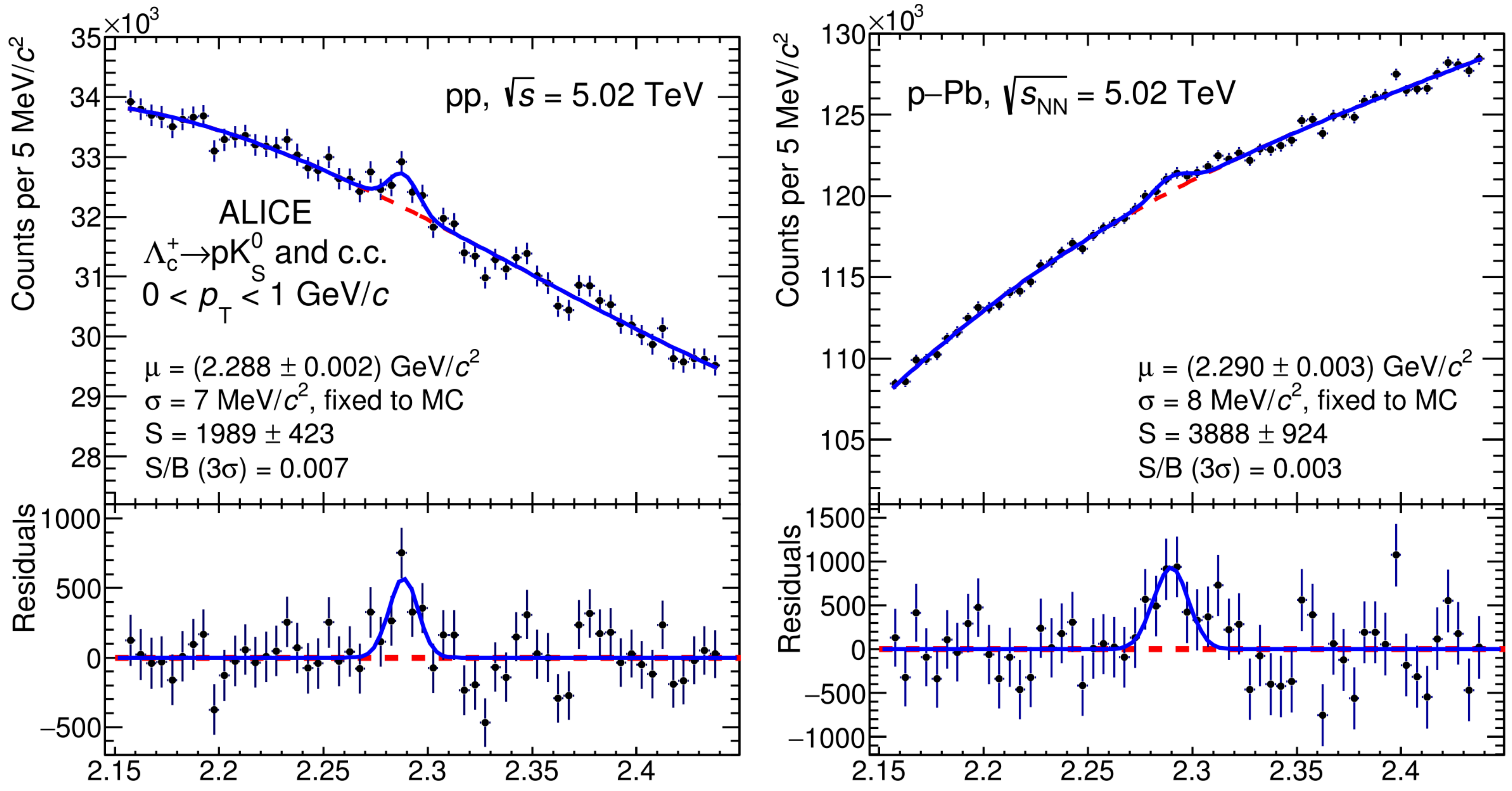
arXiv : 2211.04384



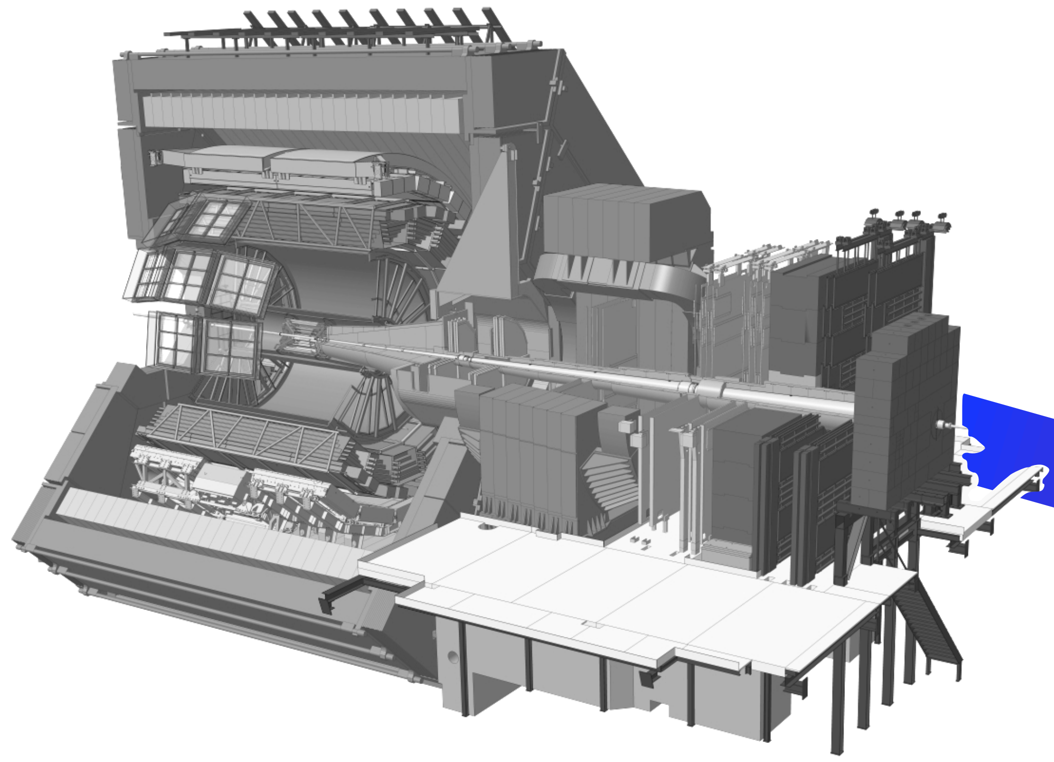
- Jets are collimated "spray" of hadrons originating from a high momentum quark or gluon produced in elementary particle collisions
  - **Theoretically expected by perturbative QCD**
- Jets are a powerful probe of QGP (Quark-gluon plasma) of matter created in heavy-ion collisions elementary particle collisions
  - **Jet modification interacted with medium**
- **Many successful campaigns in Run1 & Run2**
  - Many important measurements testing QCD in vacuum and probing "jet quenching" effects in medium
  - Many novel observables measured for the first time

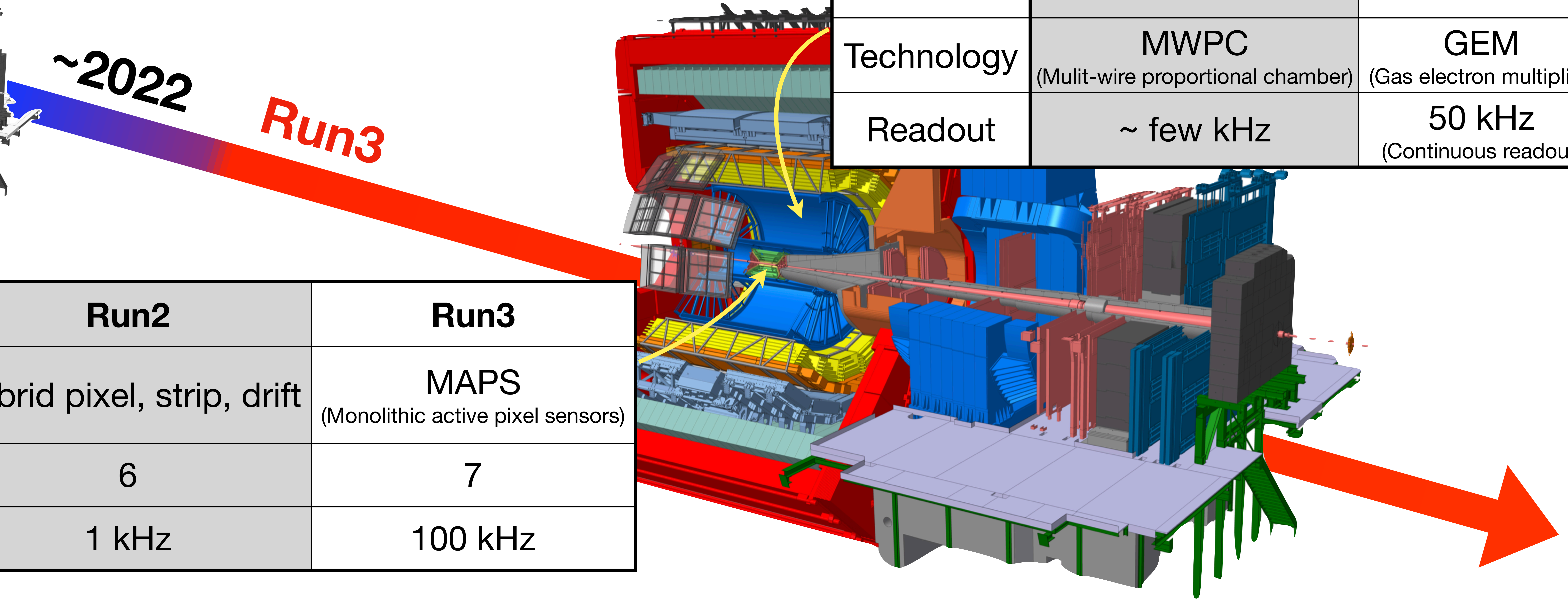
Bottlenecks in Run2 jet analyses

- All jet analyses : statistics
  - **Rare process of phase space inaccessible with Run 2 data**
  - **pp reference statistics often limiting factor when comparing pp and Pb—Pb**
- Heavy-flavour jet analyses : spatial resolution
  - **Statistical precision dependent on background subtraction**
  - **High-purity heavy-flavour jet candidate samples also crucial for high-precision measurements**



ALICE in Run3





TPC	Run2	Run3
Technology	MWPC (Mulit-wire proportional chamber)	GEM (Gas electron multiplier)
Readout	~ few kHz	50 kHz (Continuous readout)

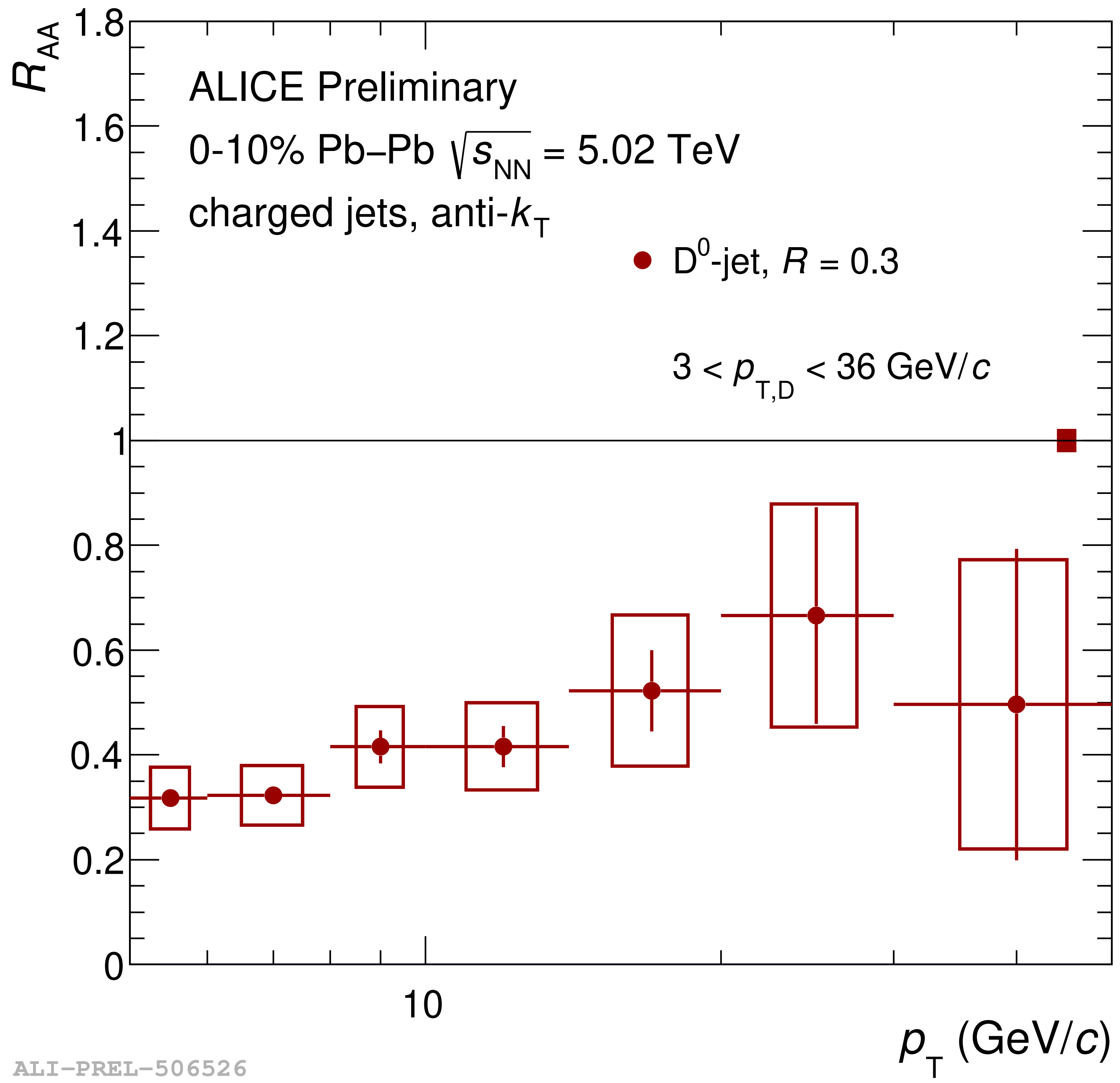
ITS	Run2	Run3
Technology	Hybrid pixel, strip, drift	MAPS (Monolithic active pixel sensors)
# of layers	6	7
Max rate (Pb—Pb)	1 kHz	100 kHz

- ALICE detector upgrade!
  - **Continuous readout : increasing rate capability about ~ 50 times**
  - **ITS impact parameter resolution : improving vertex precision about 3 ~ 6 times**
- New integrated system for data acquisition
  - **Allows for distributed and efficient processing of data**

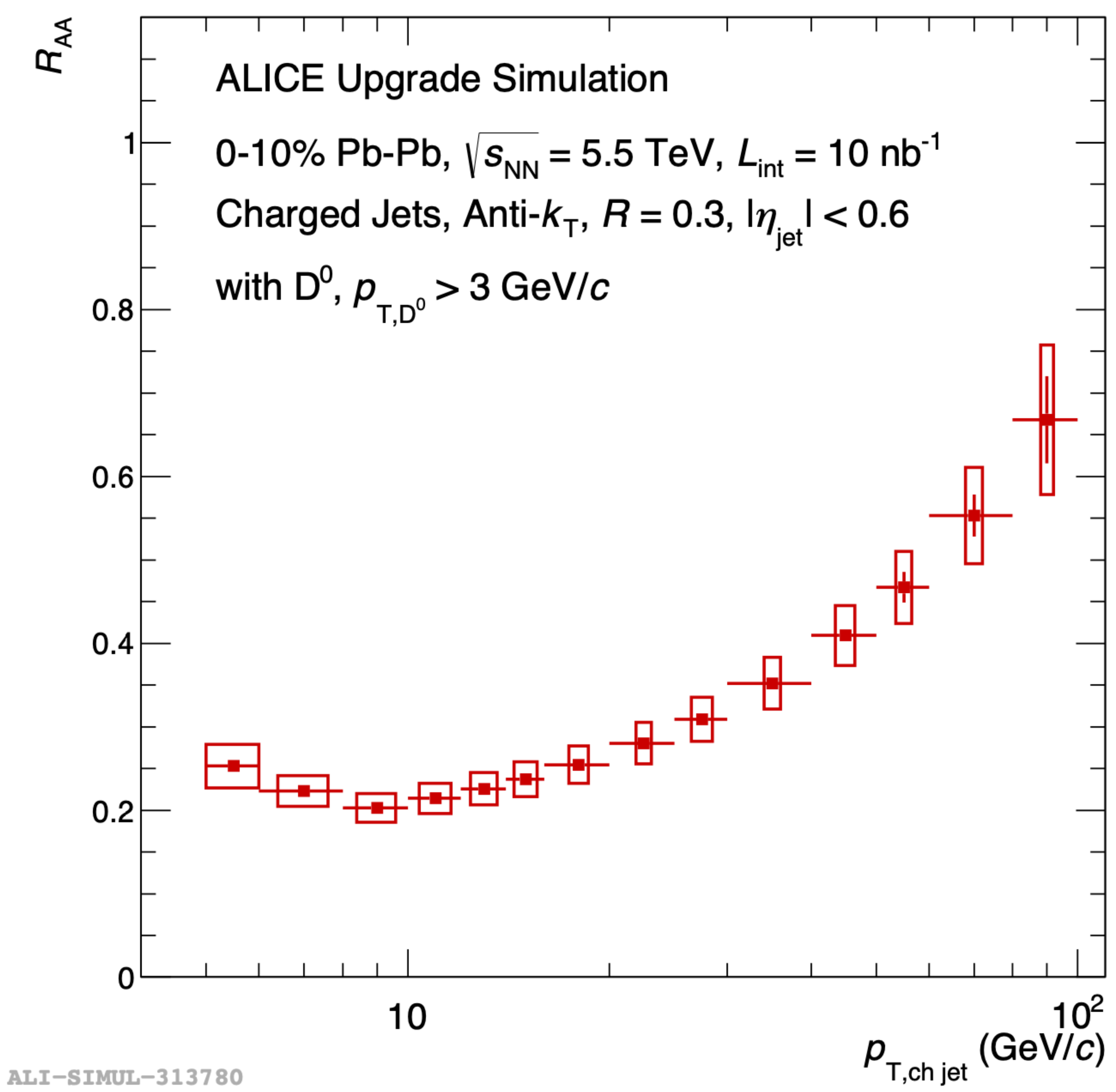
Opportunities for HF jet in Run3

D^0 **tagged jets**

Run 2



Run 3+4



- Opportunities for Run 3
  - **Heavy-flavour nuclear modification factor**
  - **Charmed baryon jet measurements**
  - **Heavy-flavour jet correlation measurements**

Jet framework in O2

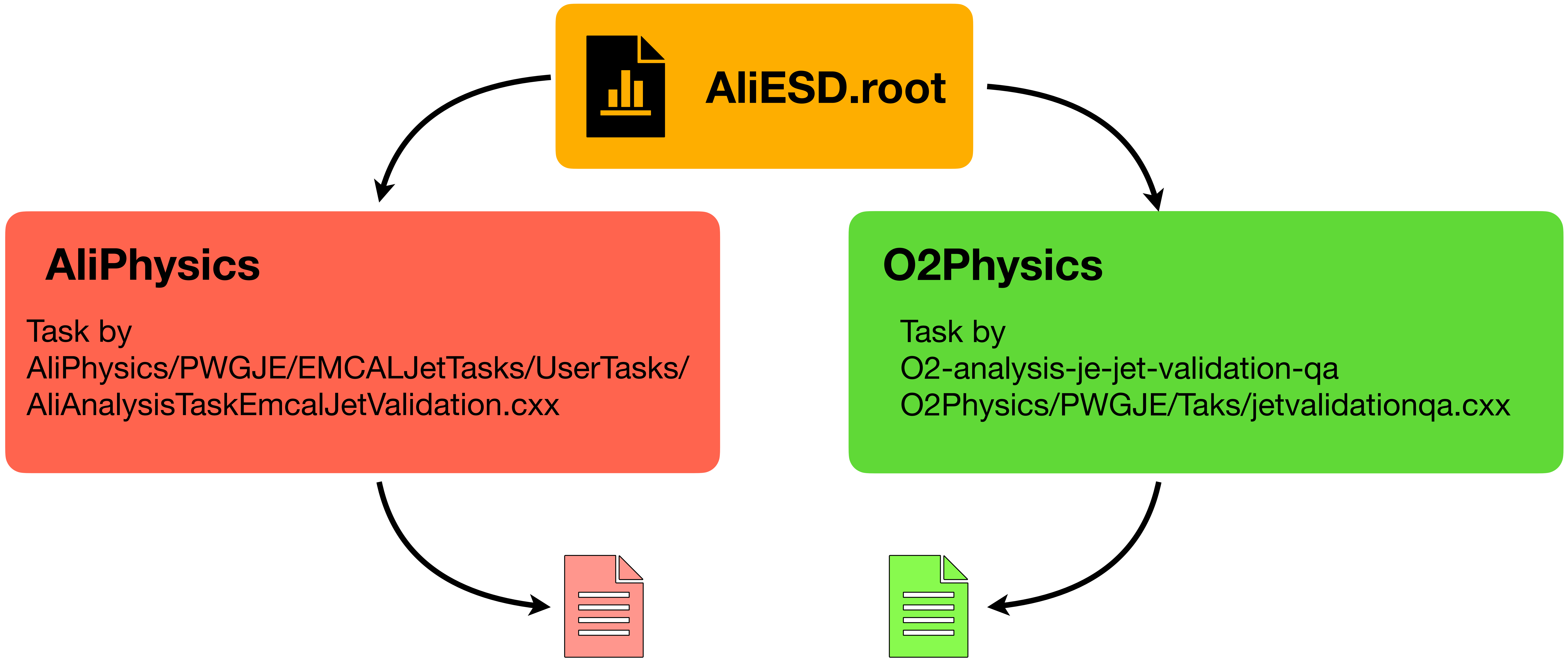
- Current framework includes …
  - **Jet finding implemented for charged, neutral and full jets**
  - **Jet finding for HF jets**
  - **Full QA framework for jets**
  - **Jet matching between truth and detector level**
  - **Weighted MC processing**
  - **Jet triggering capabilities**
  - **Jet substructure tasks for inclusive and HF jets**
  - **Tree output tasks for jets and substructure for inclusive and HF jets**
  - **Background subtraction**

- Working in progress …
  - **Need for an embedding framework becoming urgent in order to use MC for Pb—Pb collisions**

Run 3 validation framework

Run 3 validation framework

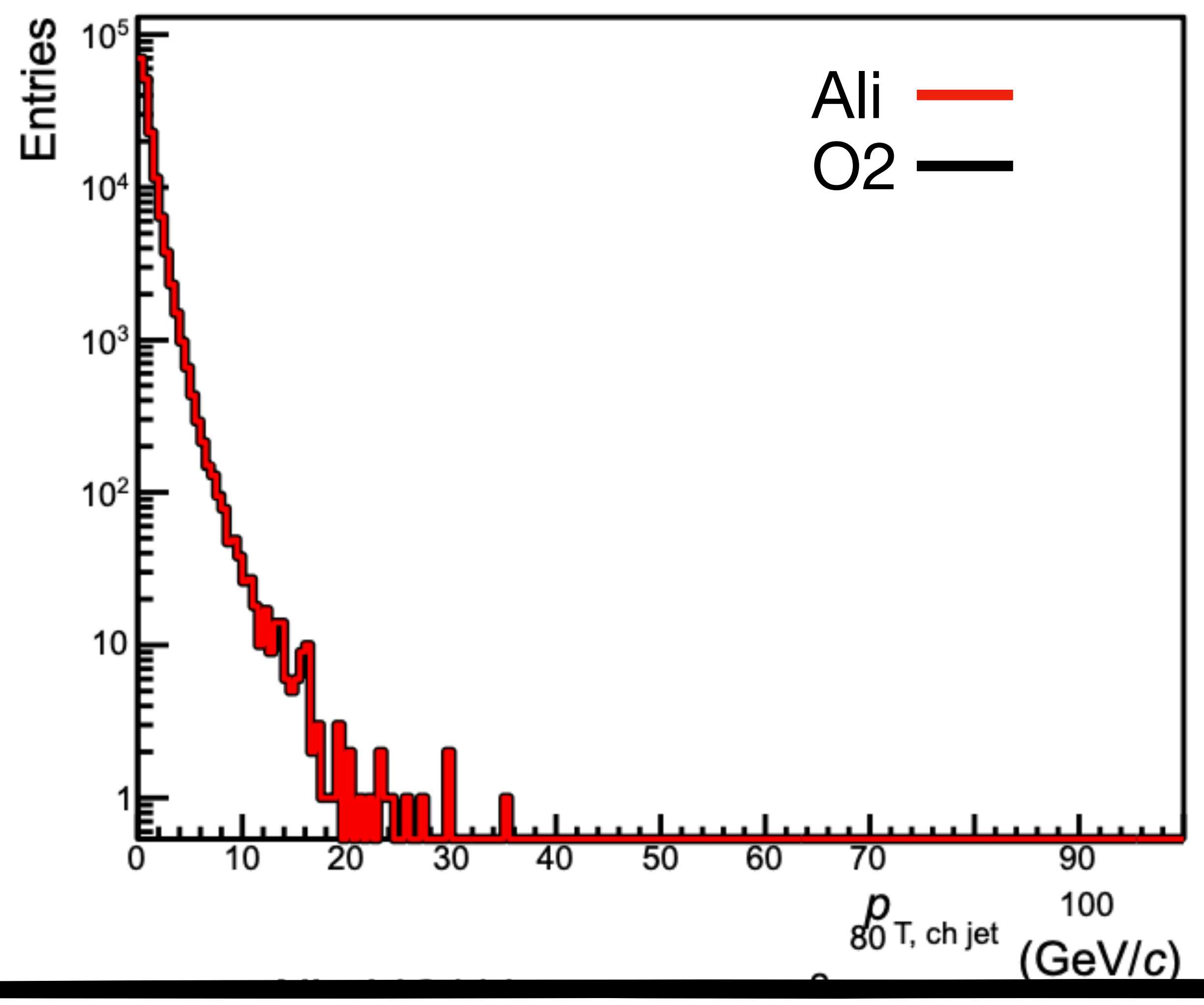
Scheme

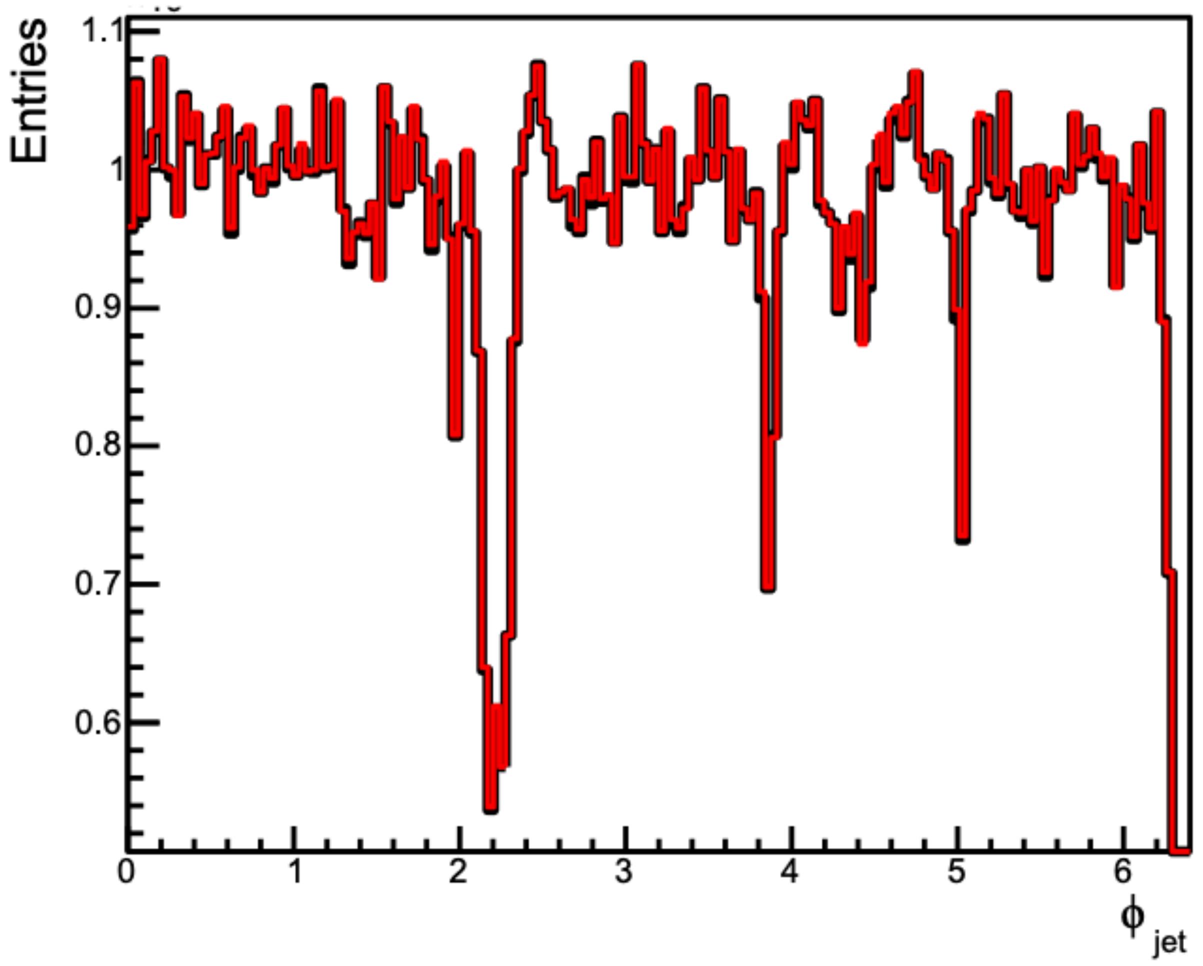


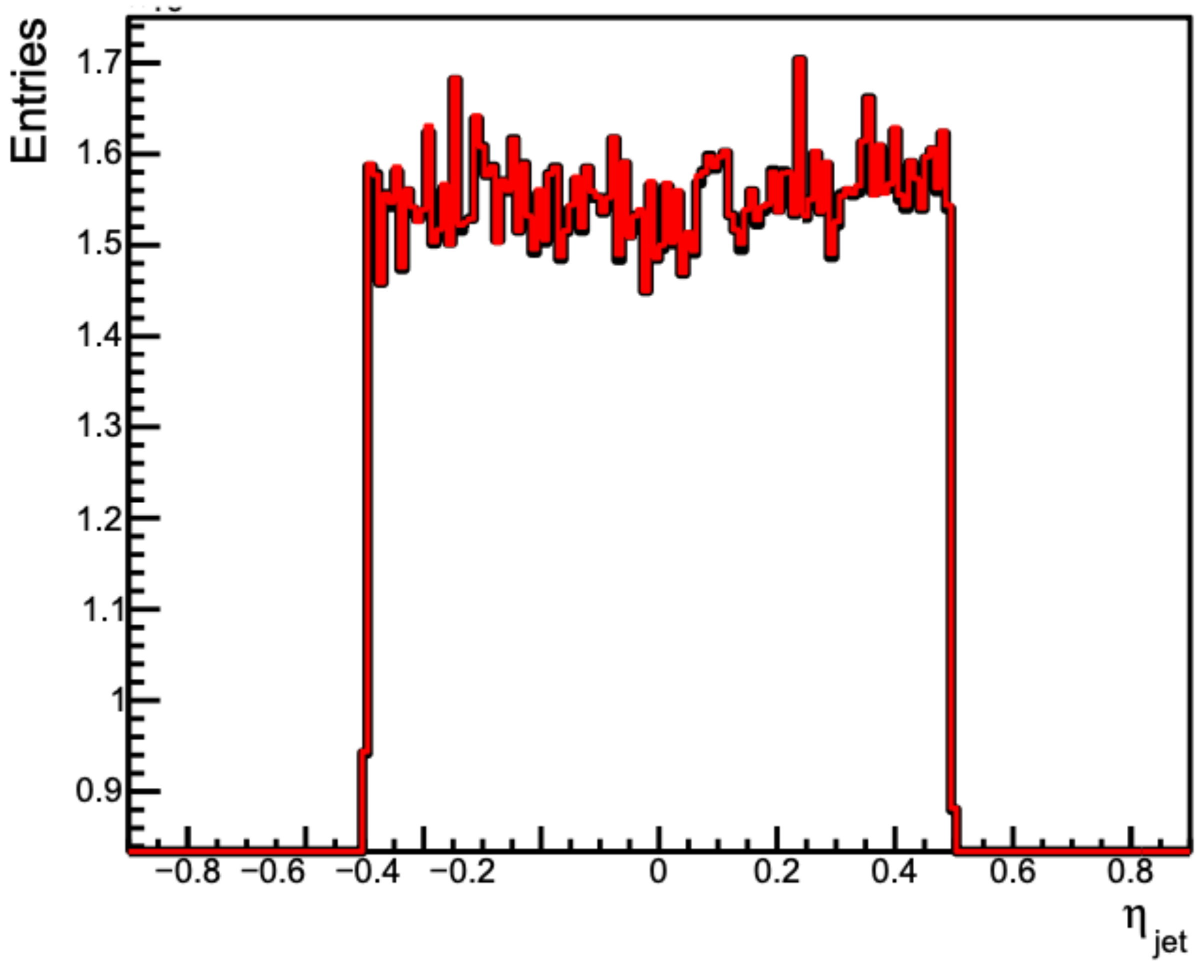
Compare with each AnalysisResult.root file

Run 3 validation framework

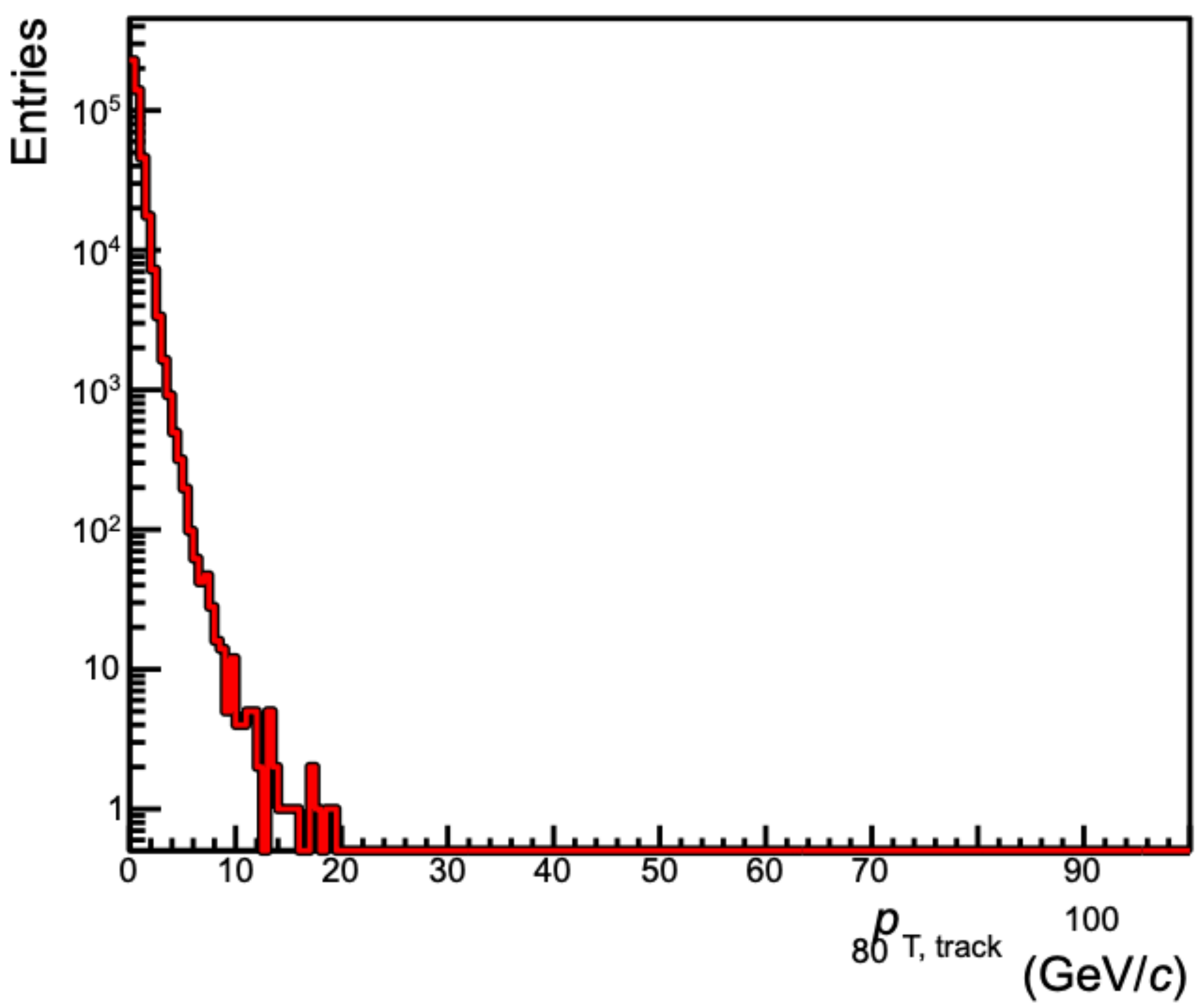
Jets

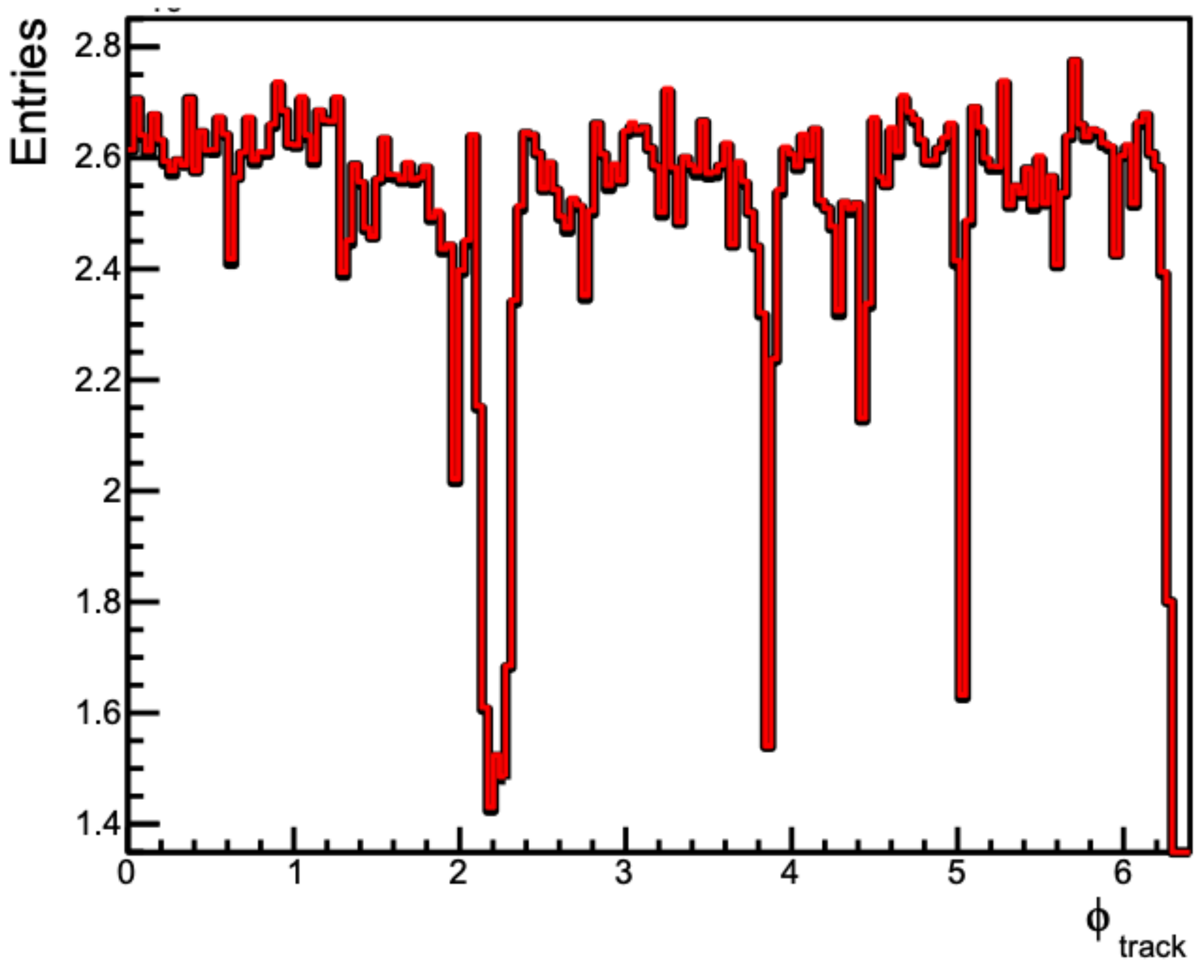


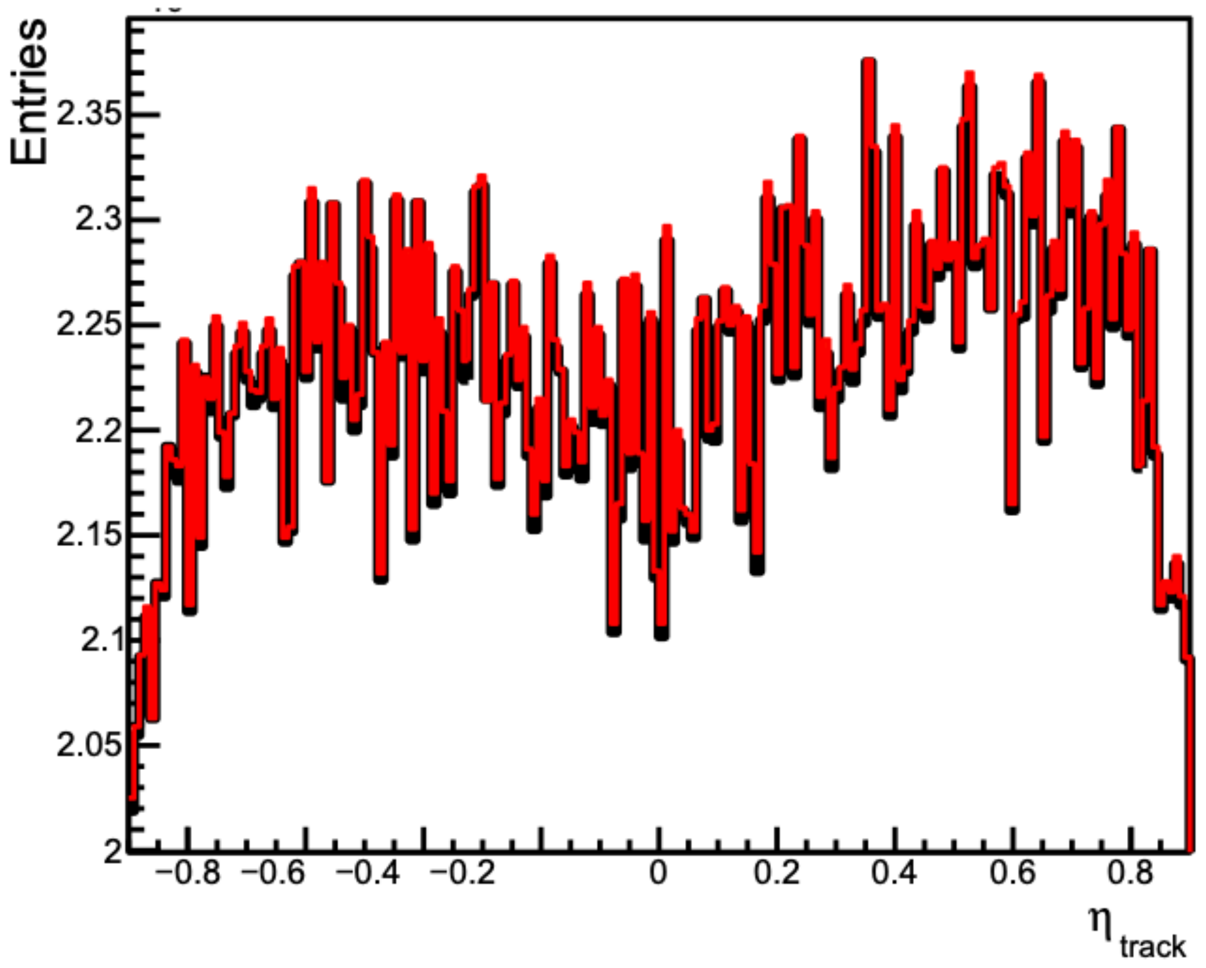




Tracks





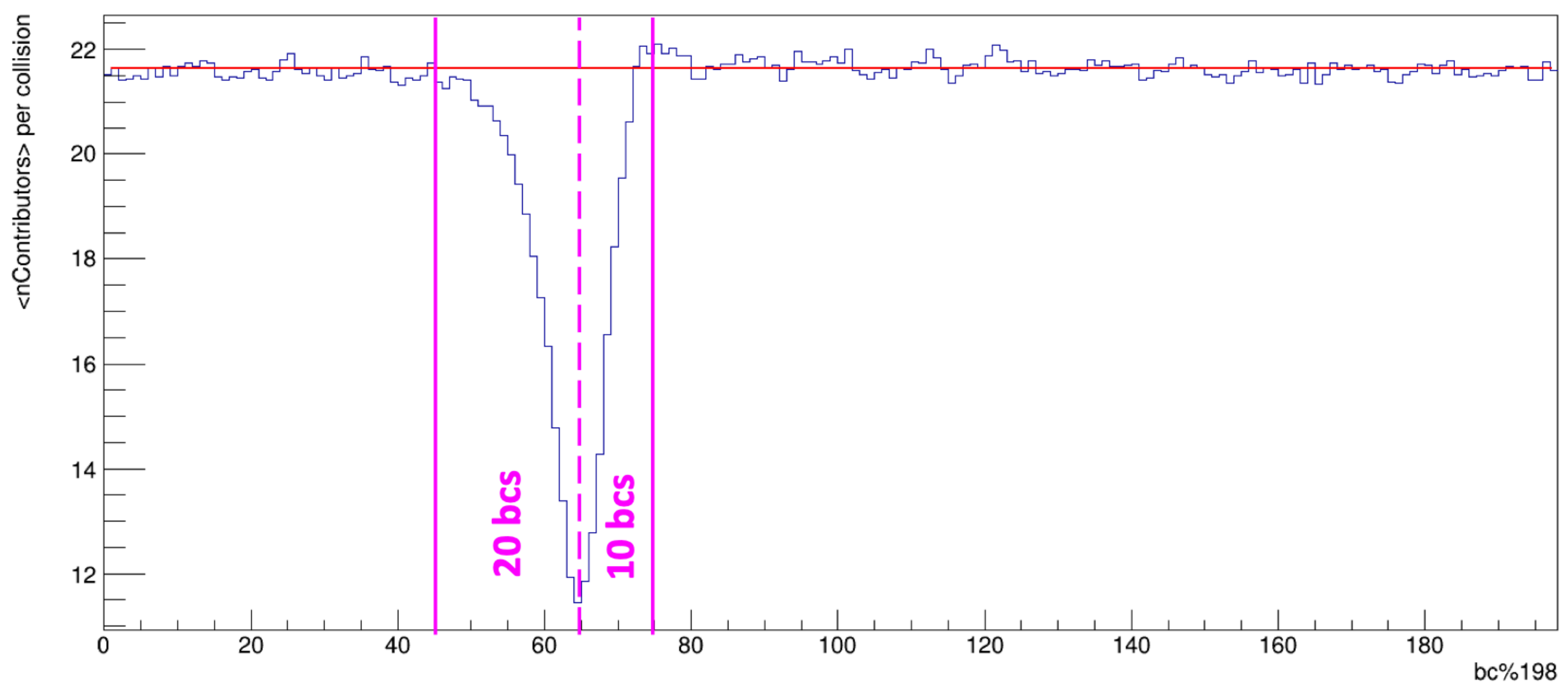


Charged-jet production in pp collisions

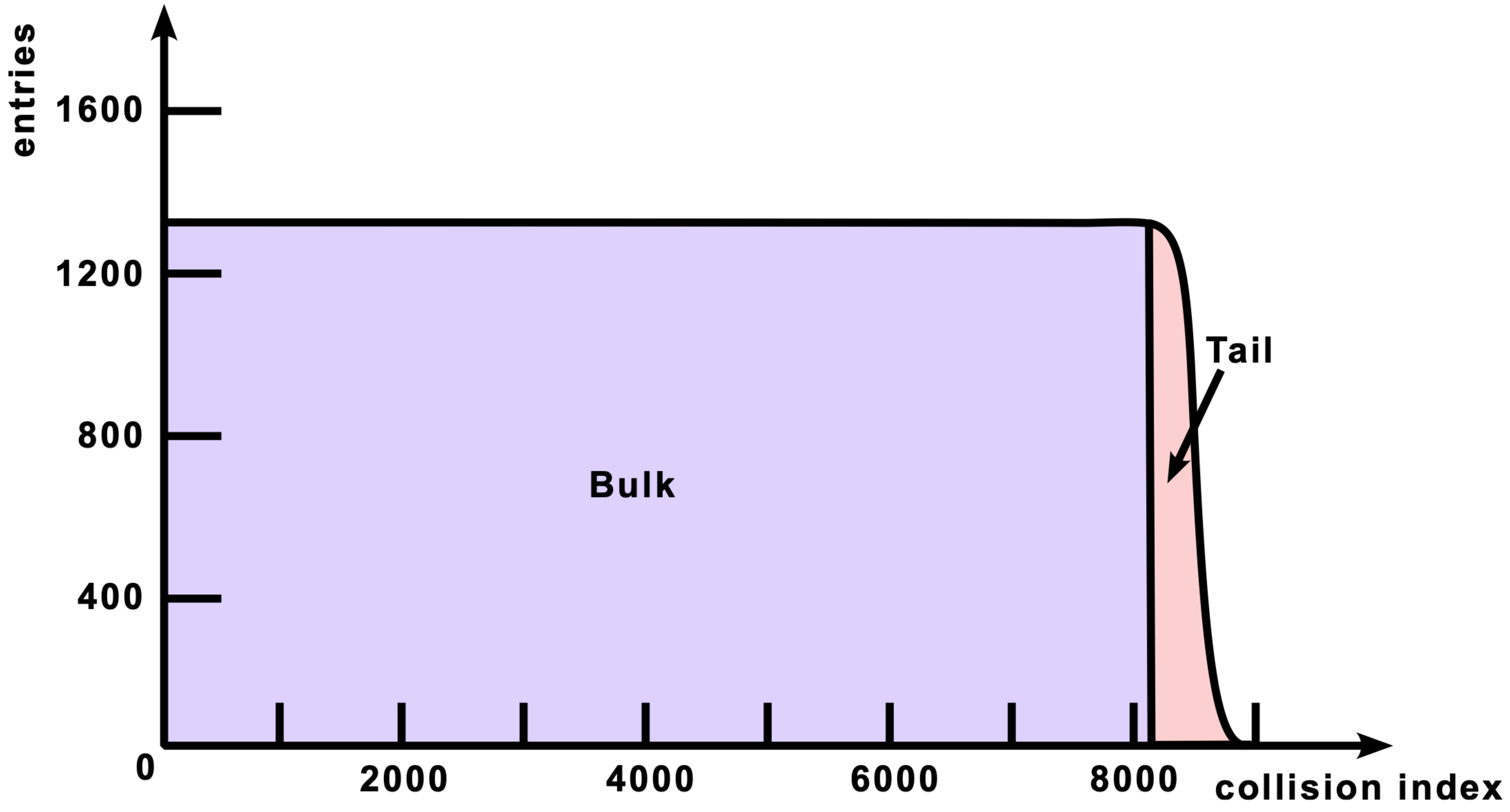
J. Bae

Selections

- Event Selections
  - ***Sel8* : minimum bias selection in ALICE Run 3**
    - Vertex triggering using FT0 detector (FT0C - FT0A)
    - Without ITS readout frame border
    - Without Time frame border



ITS readout frame border schematics



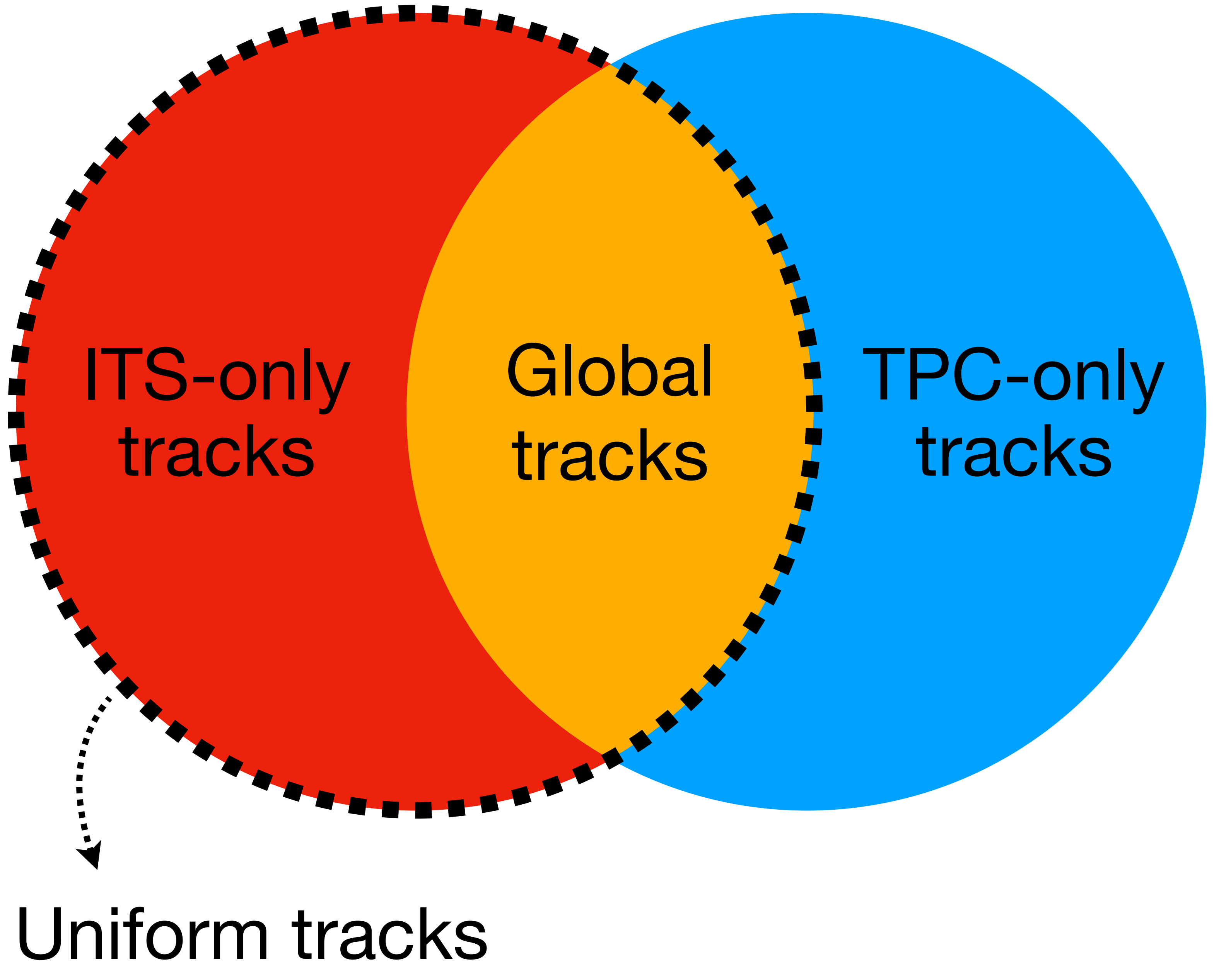
Time frame border schematics

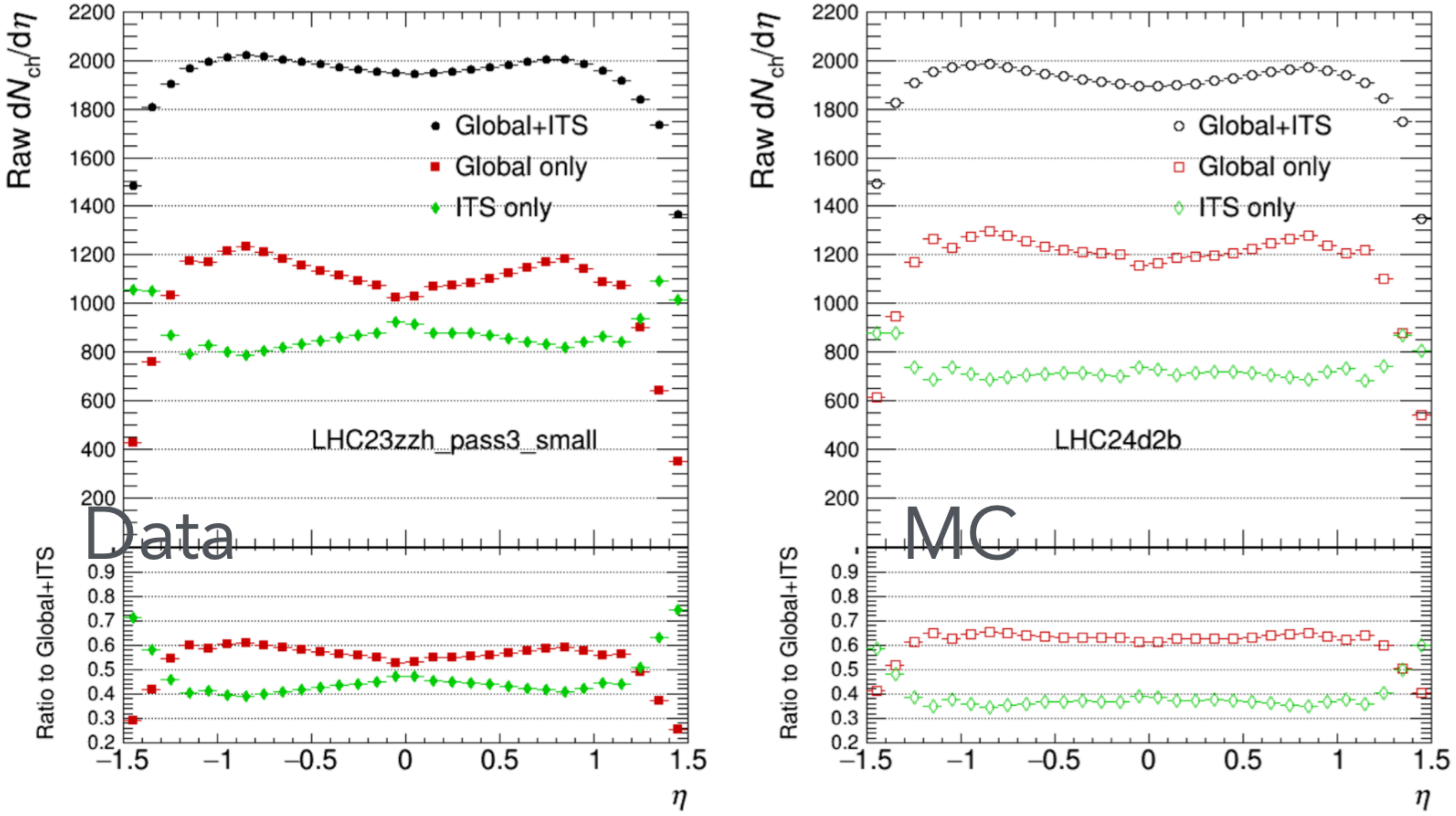
Selections

- Event Selections
  - ***Sel8*** **: minimum bias selection in ALICE Run 3**
    - Vertex triggering using FT0 detector (FT0C - FT0A)
    - Without ITS readout frame border
    - Without Time frame border
  - ***Sel8Full***
    - Reject collisions in case of pileup with another collision in the same bunch crossing
    - Consider small difference between z-vertex from PV and from FT0

Selections

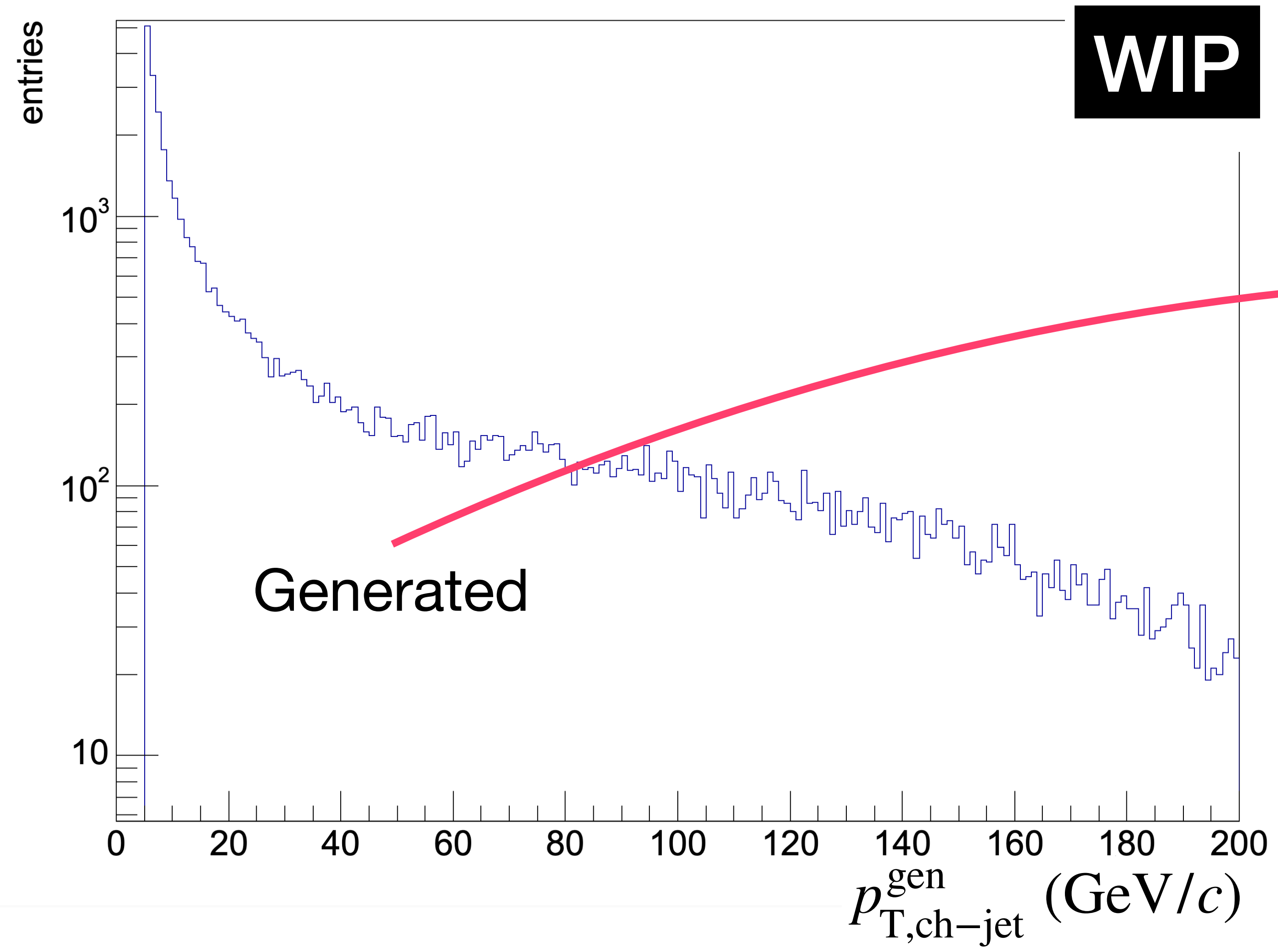
- Track Selections
  - **Global tracks : best quality tracks that are matched between ITS and TPC**
  - **TPC calibration is ongoing … : Define uniform tracks**

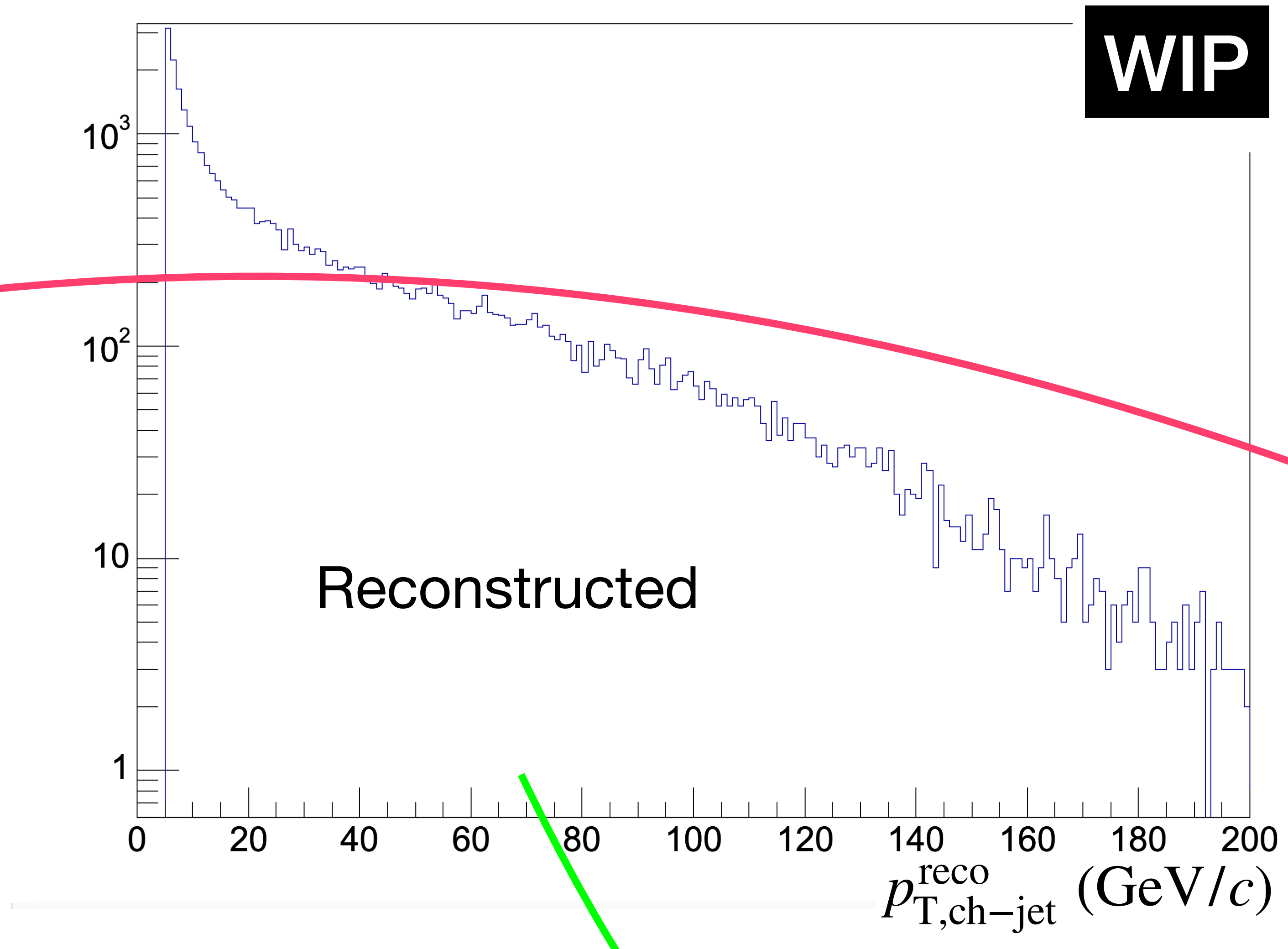


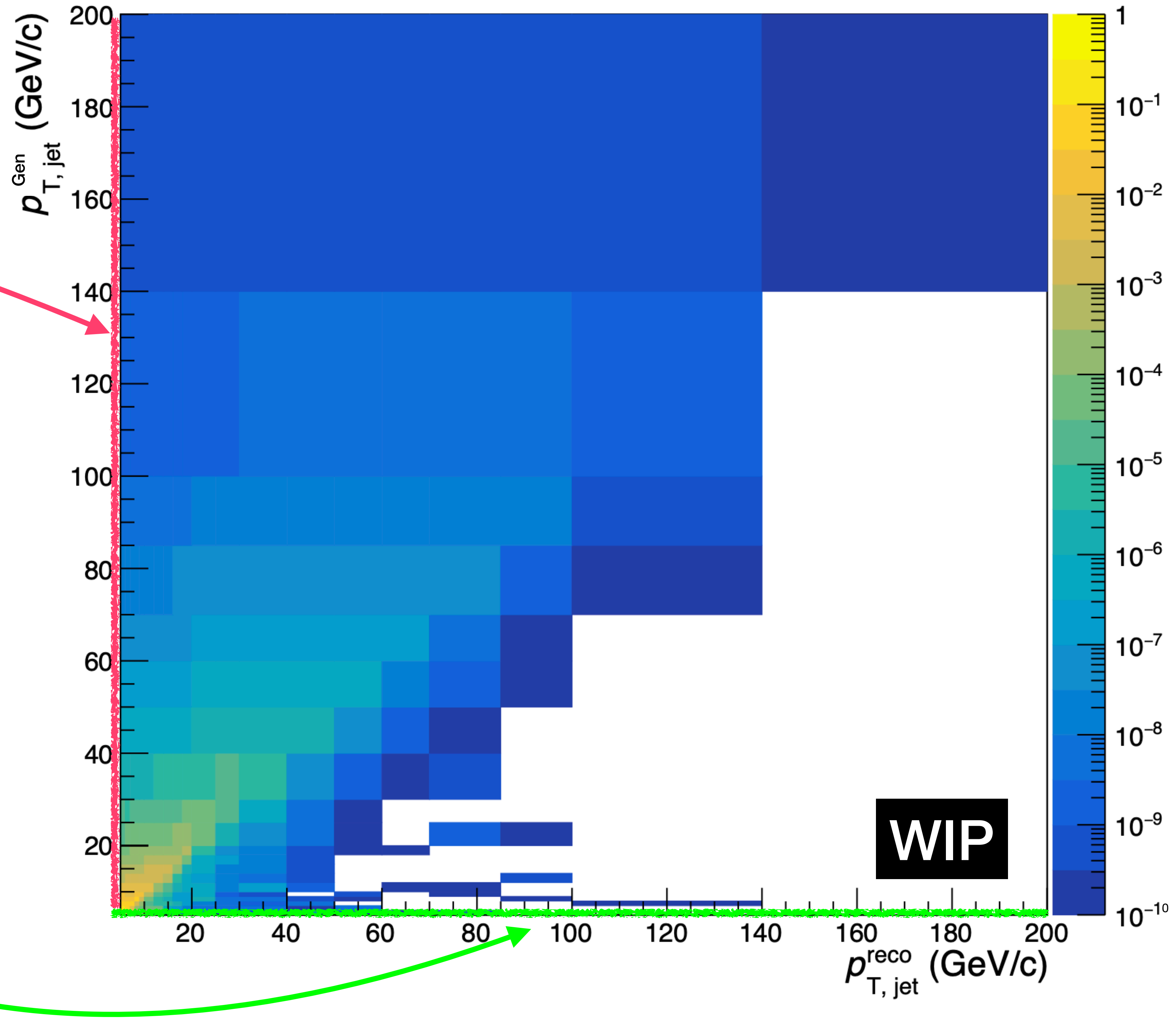


PWGMM analysis by Abhi Modak

Response Matrix for p_T Correction







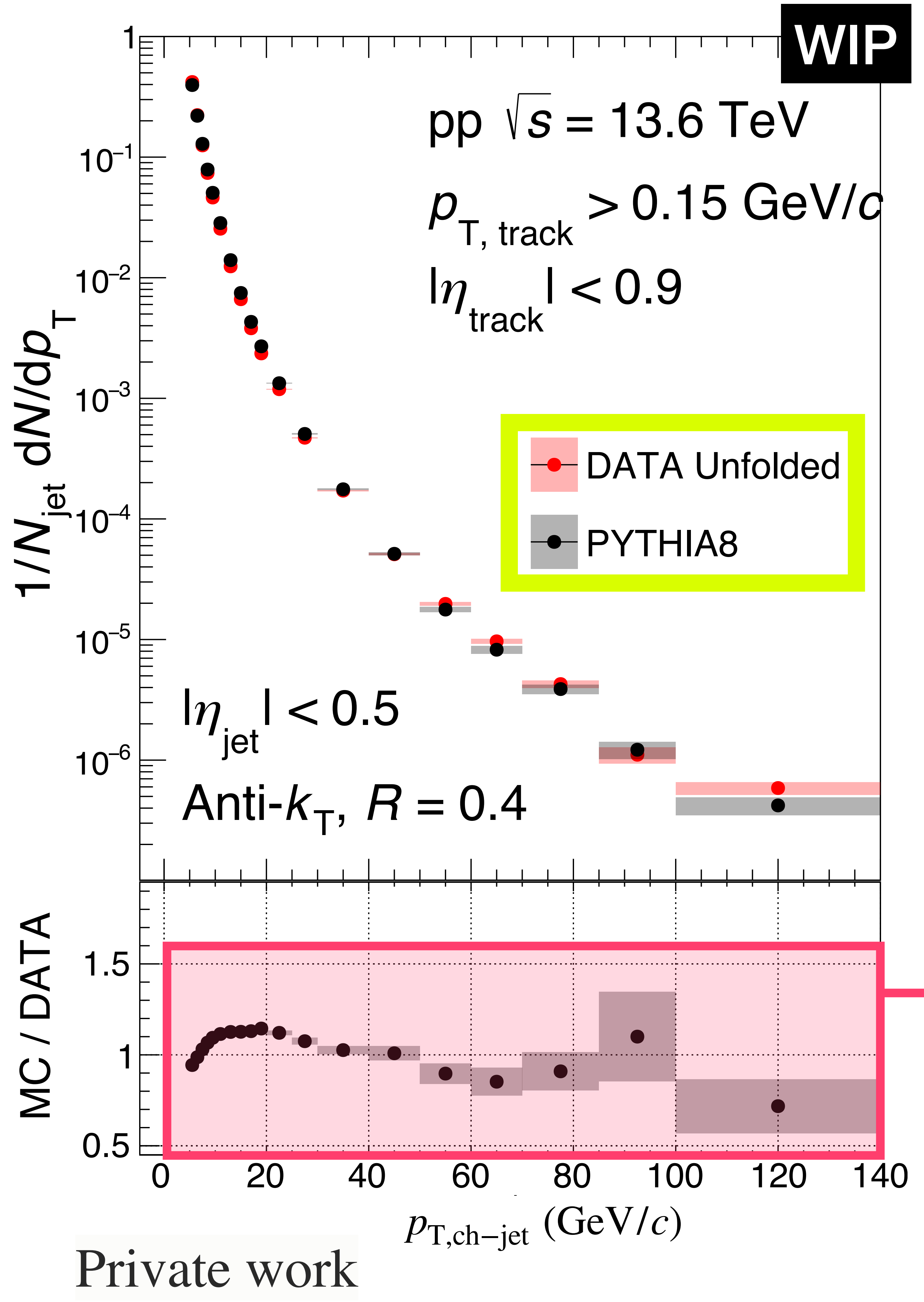
- Jet-jet enhanced MC

- **Clustered jets** are employed to construct a p_T **response matrix (RM) (X: reconstructed, Y: generated)**
  - A perfect reconstruction would show a diagonal matrix
  - has **missed** and **fake jets** (underflows), not only matched jets
  - p_T **corrected raw Data**: $p_{T,jet}^{corr} = M \times p_{T,jet}^{raw}$, called '**Unfolding**'
  - contains **multiple efficiencies**:
    - Collisions reconstruction, tracking, kinematic, and jet reconstruction

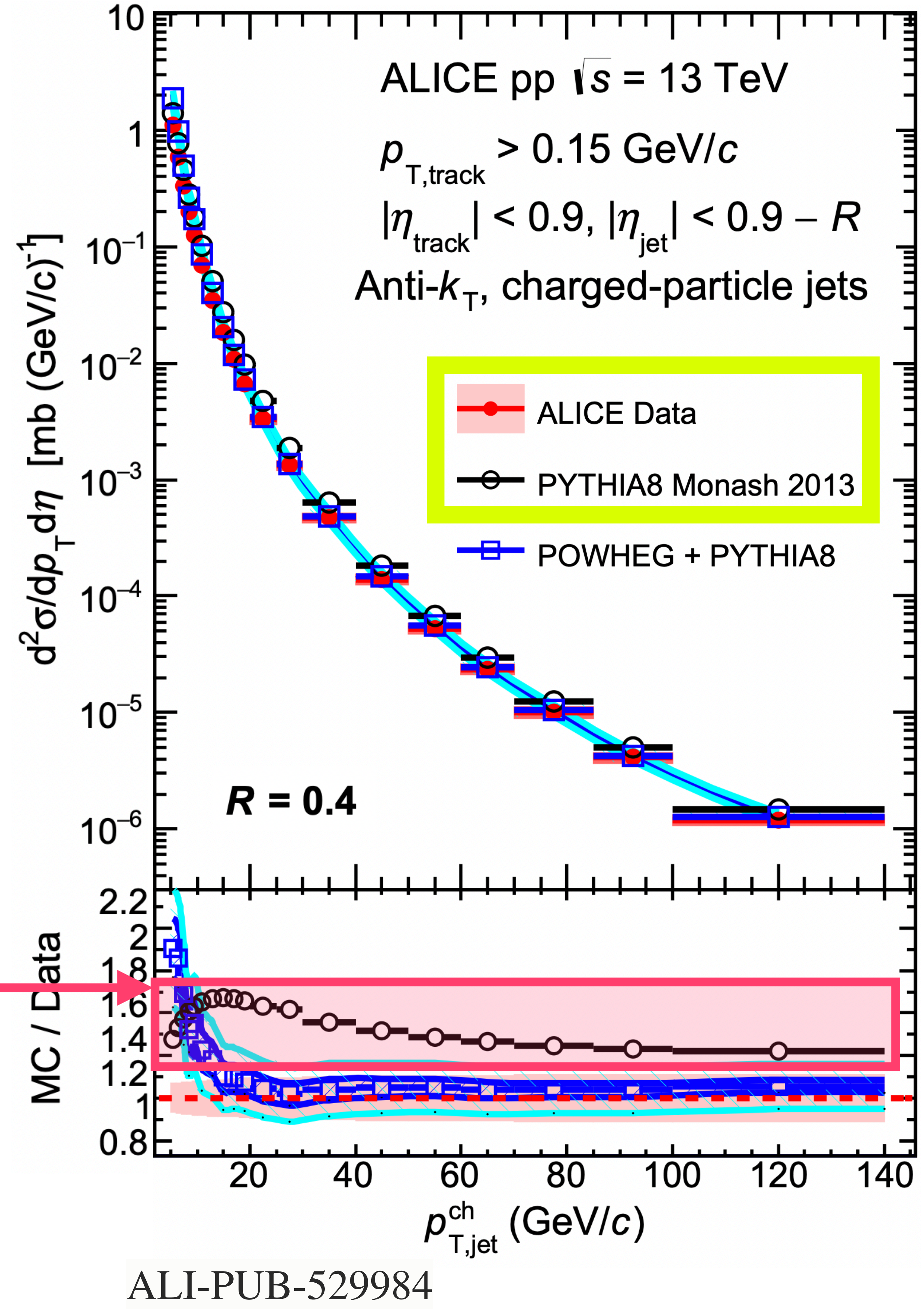
Charged-jet production in pp collisions

p_T Corrected (Unfolded) Raw Data

Run 3 (13.6 TeV)

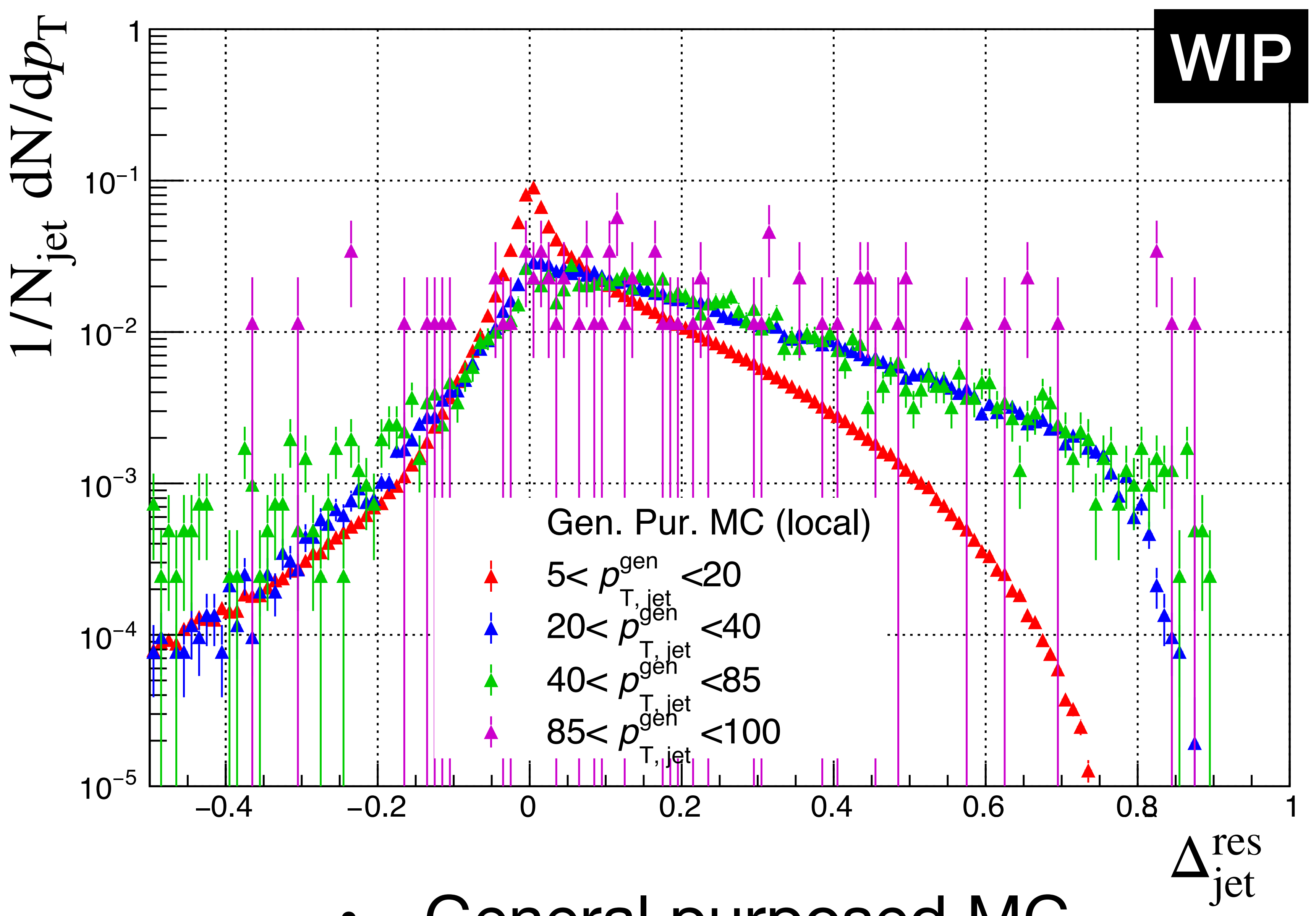


Run 2 (13 TeV)

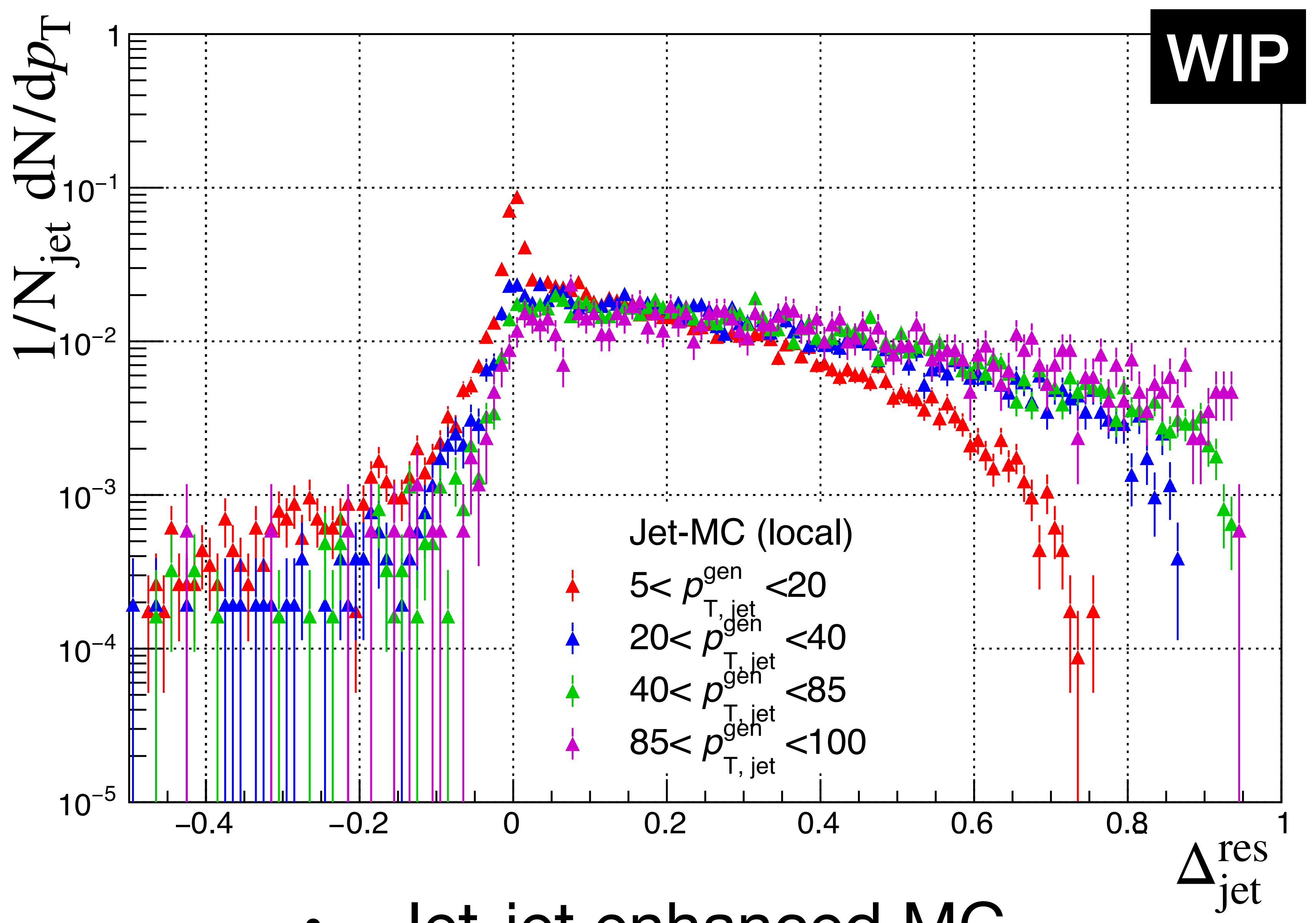


- First look at unfolded charged-particle jet distribution in ALICE Run 3 pp collisions at $\sqrt{s}$ = 13.6 TeV
  - **Probability distribution** in Run 3 vs **cross-section** in Run 2
- **PYTHIA8** to **Corrected DATA** ratios exhibit similar trend.
- While some efficiencies included in response matrix should be looked at.

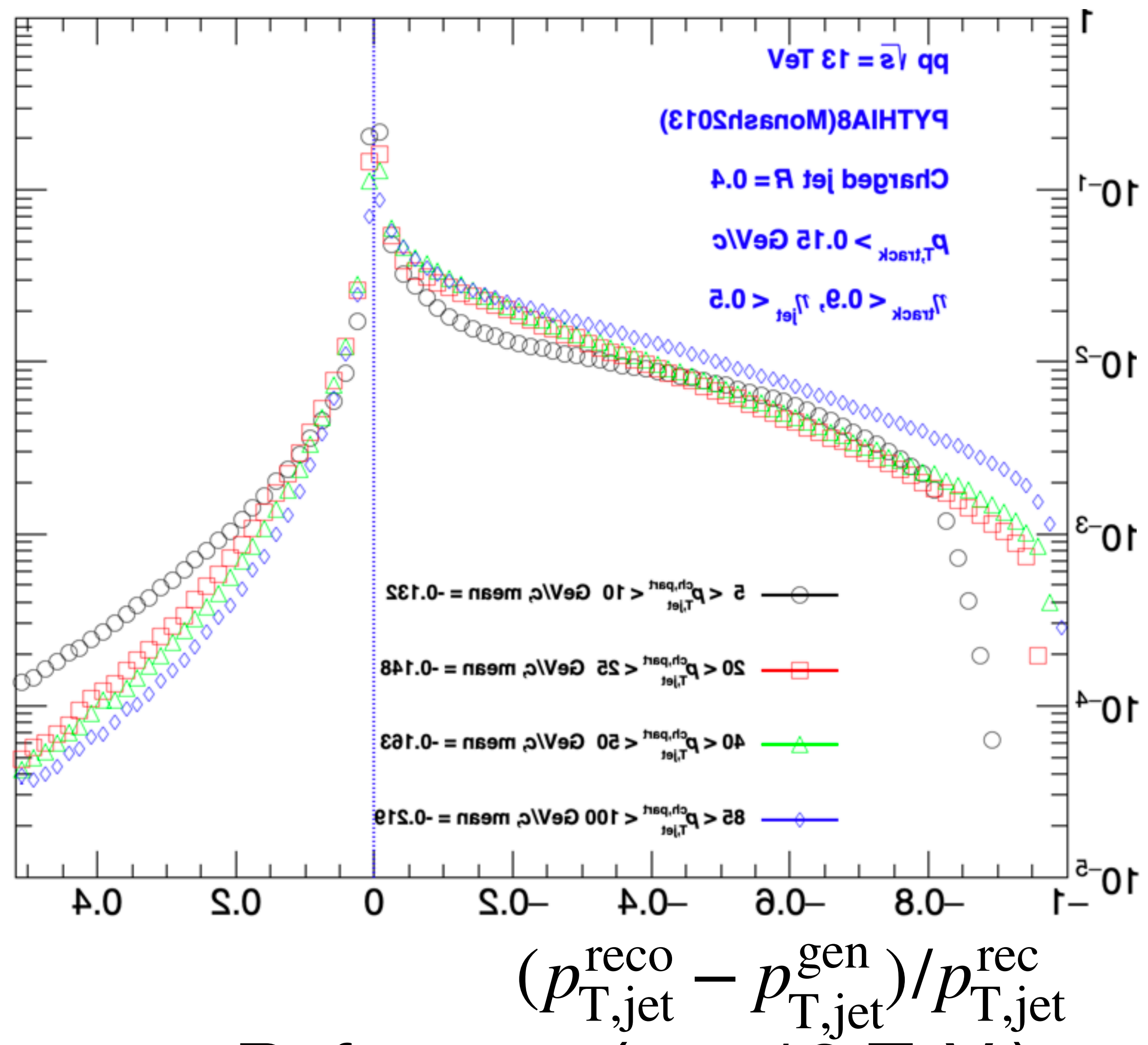
Issue 1: Low Jet p_{T} Resolution



- General purposed MC



- Jet-jet enhanced MC



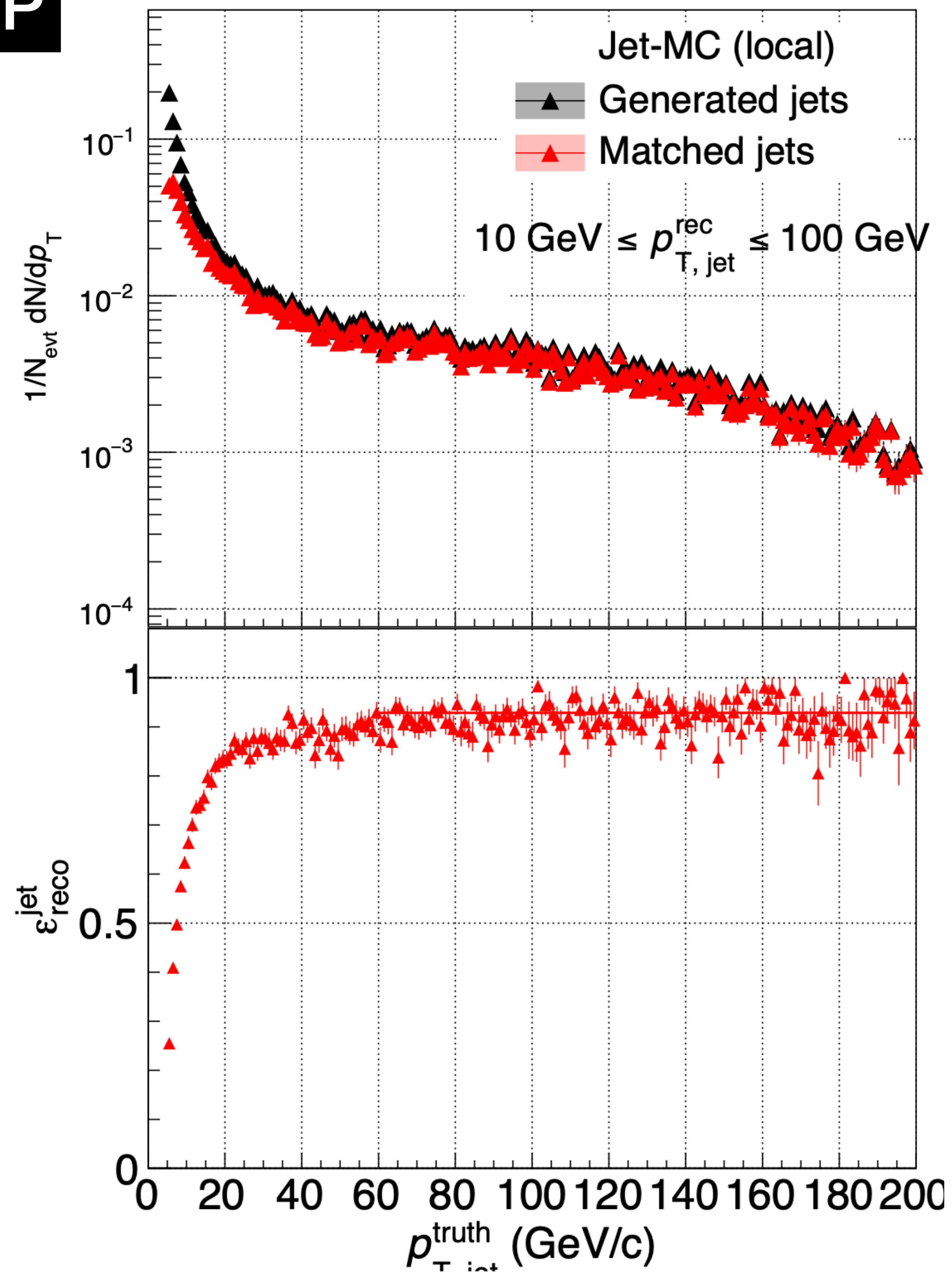
- Reference (pp, 13 TeV)

$$\Delta^{\mathrm{res}}_{\mathrm{jet}} = \frac{p^{\mathrm{Gen}}_{\mathrm{T,jet}} - p^{\mathrm{Reco}}_{\mathrm{T,jet}}}{p^{\mathrm{Gen}}_{\mathrm{T,jet}}}$$

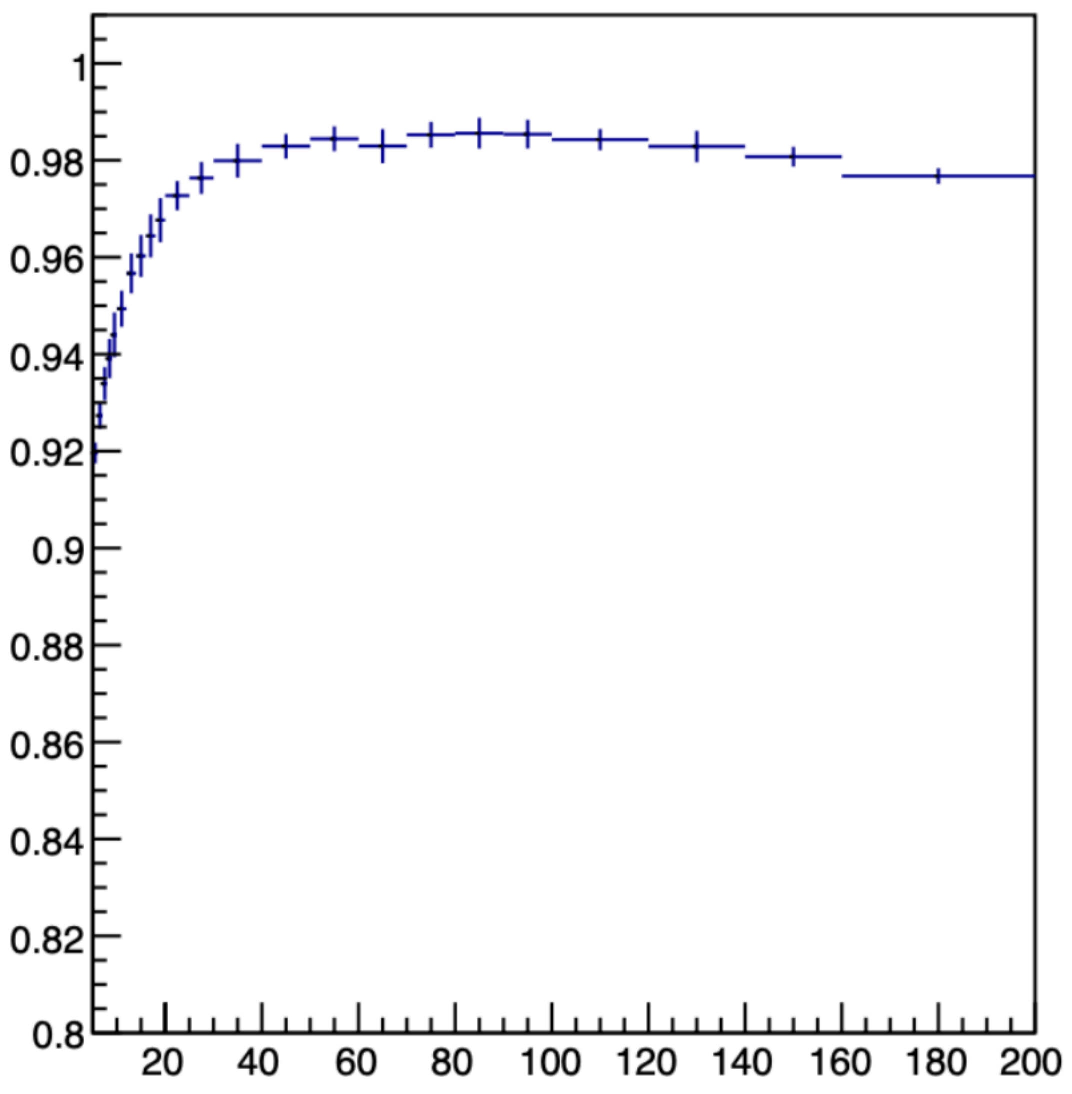
- Gen. purp. MC (left) hardly describes high $p_{\mathrm{T,jet}}$ classes
- Jet MC (middle) supplements, but resolution remains low due to unanchored status
- Shapes seems to have consistency with the previous (right) in low p_{T}.
- high p_{T} classes should be discussed with track p_{T} resolution and jet enhanced MC sample (WIP)

Issue 2: Low Jet Reconstruction Efficiency

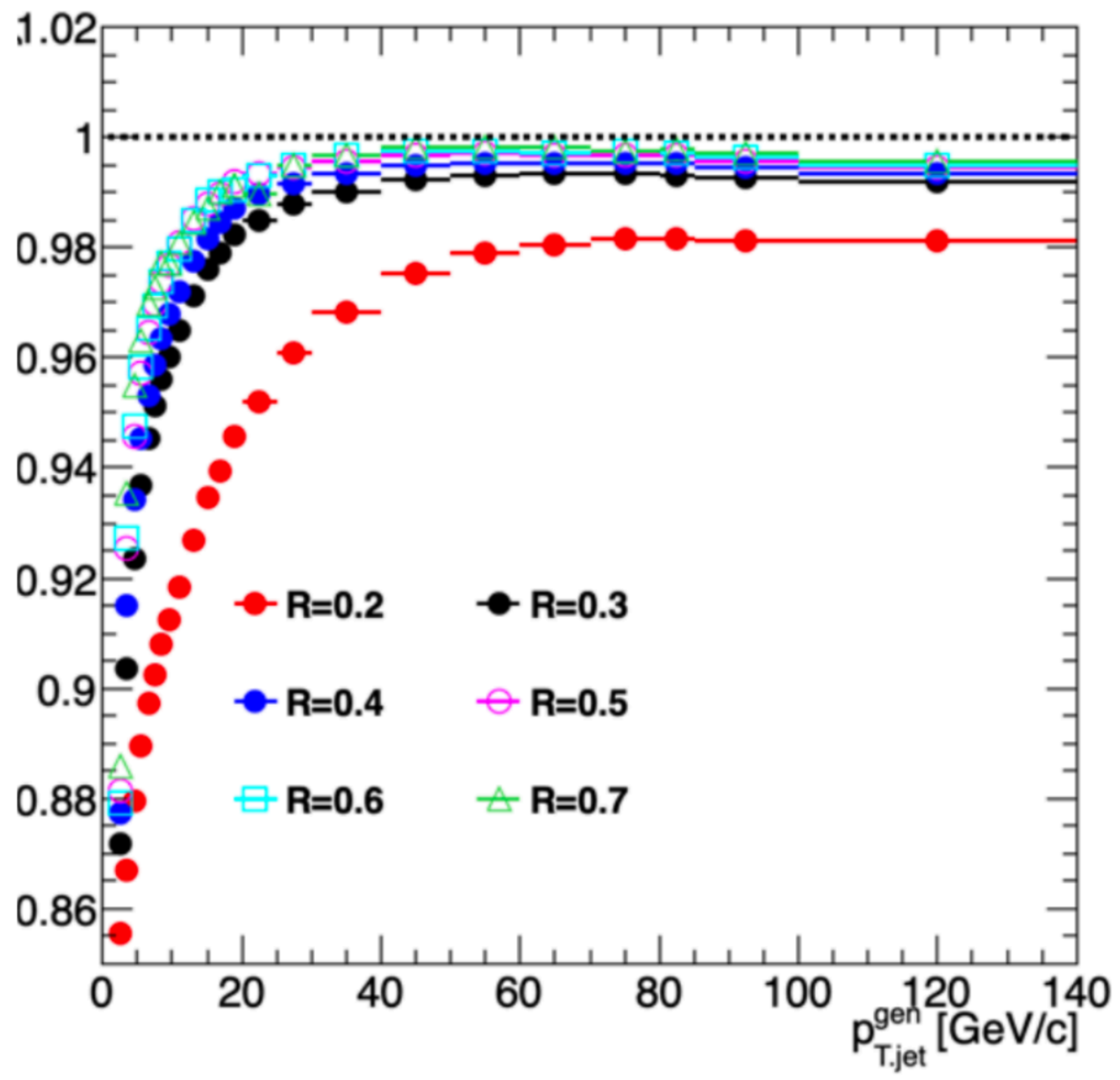
WIP



References



▶ Reference
(pp, ch-jet, 5.02 TeV, Hadi)



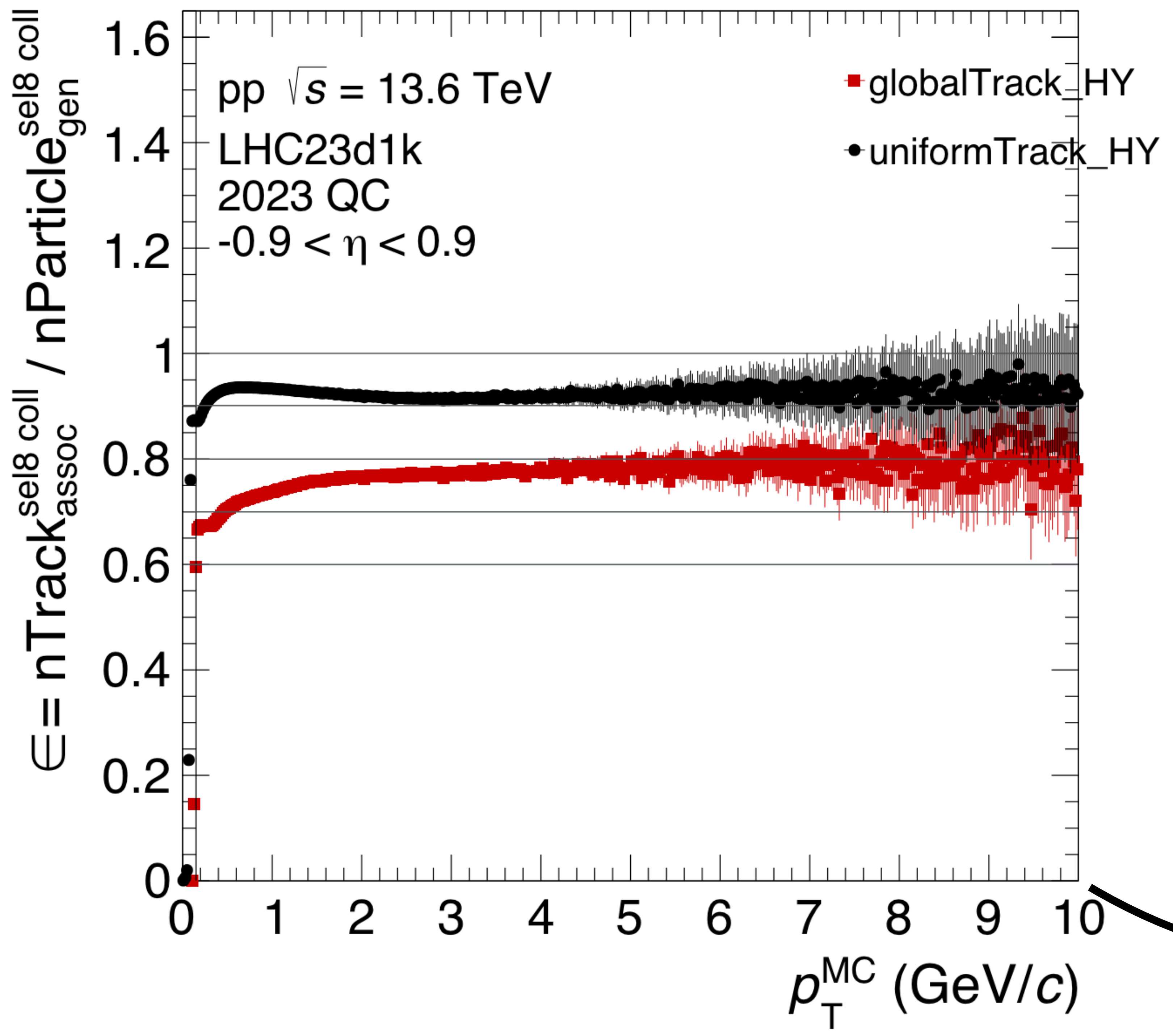
Run 2 pp@13 TeV ,Yongzhen

$$\varepsilon_{\rm reco}^{\rm jet}(p_{\rm T,jet}^{\rm gen}) = \frac{N_{\rm matched}(p_{\rm T,jet}^{\rm gen})}{N_{\rm generated}(p_{\rm T,jet}^{\rm gen})}$$

- **Run 3 data have more missed events than previous** due to the continuous readout : $\varepsilon_{\rm reco}^{\rm jet}$ ~ 93%
- While previosly Run 2 result shown 98 ~ 99%, still insufficient.

Track reconstruction efficiency check

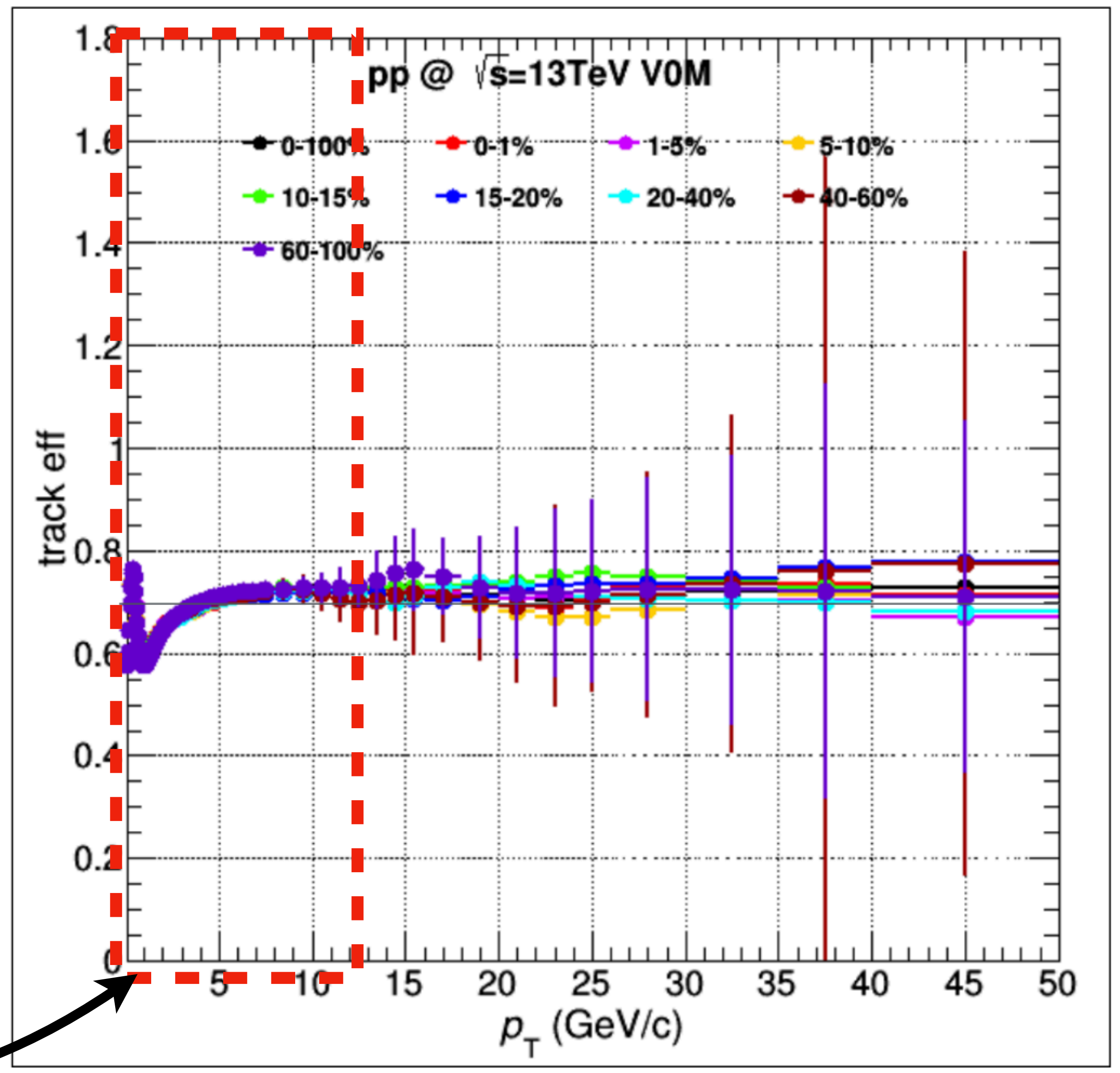
$$\varepsilon_{\rm trk}^{\rm sel8Full} = \frac{\text{Gen . MC primary ch} - \text{ptls}(p_{\rm T})\ \text{linked to trks}_{\rm sel8Full}}{\text{Gen . MC primary ch} - \text{ptls}(p_{\rm T})_{\rm sel8Full}}$$



vs "hybrid tracks" in Run 2 pp@13TeV

https://indico.cern.ch/event/981904/contributions/4136500/attachments/2157171/3638641/20201206_wuhanMeeting_yongzhen.pdf

- Hybrid tracks, $p_{\rm T} > 0.15$ GeV/c, $|\eta_{\rm track}| < 0.9$



By Yongzhen

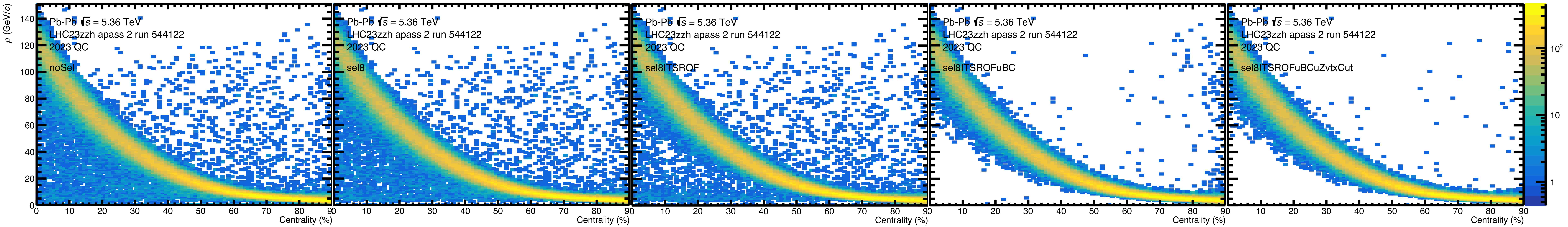
- Track reconstruction efficiency on uniform tracks is better than previous Run 2 result ~ 90% at low $p_{\rm T}$.
- Investigating other possible causes of the low jet reconstruction efficiency

Charged-jet production in Pb—Pb collisions

A. Landou , W. Feng

Event selection

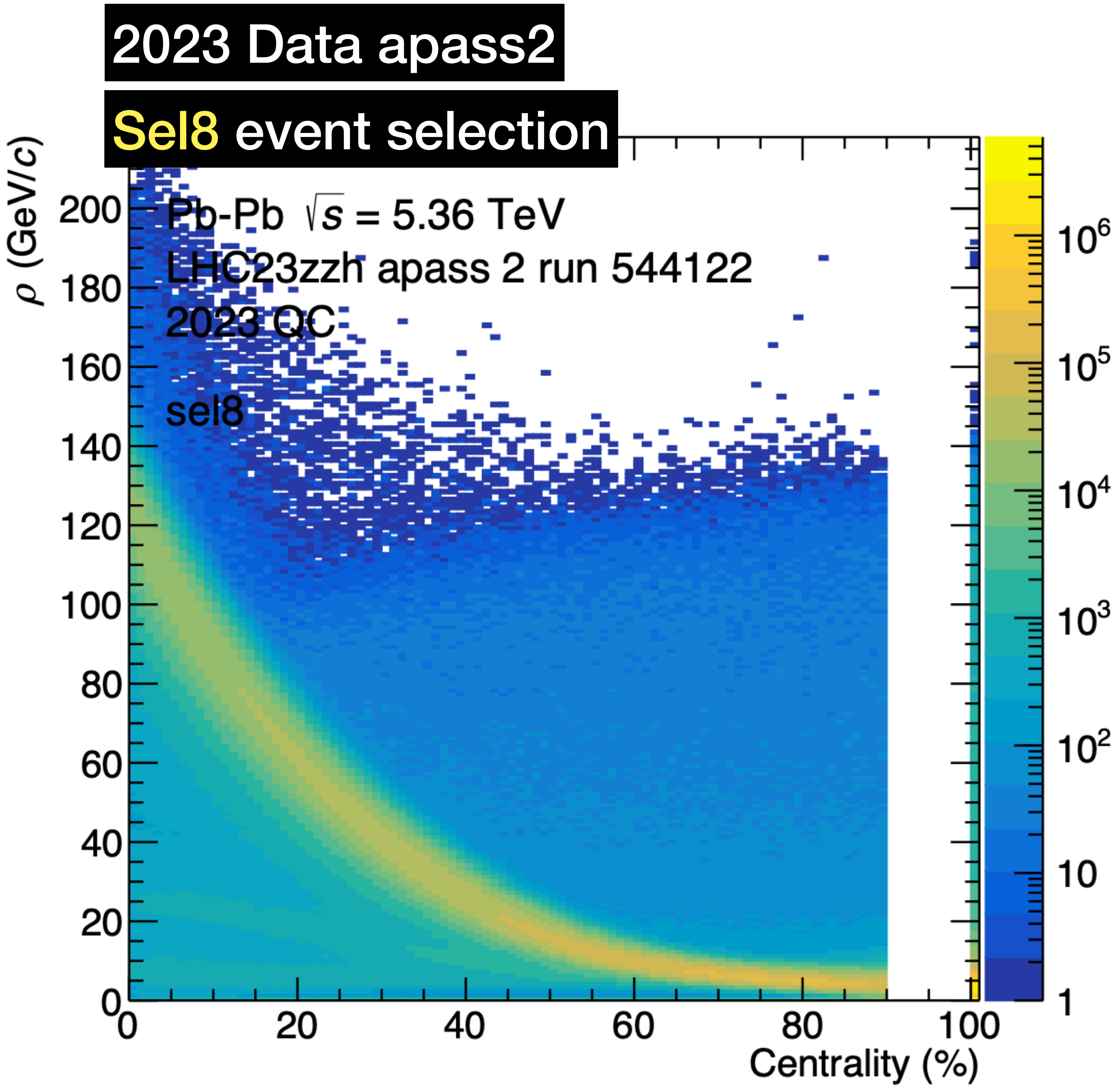
loose → tight

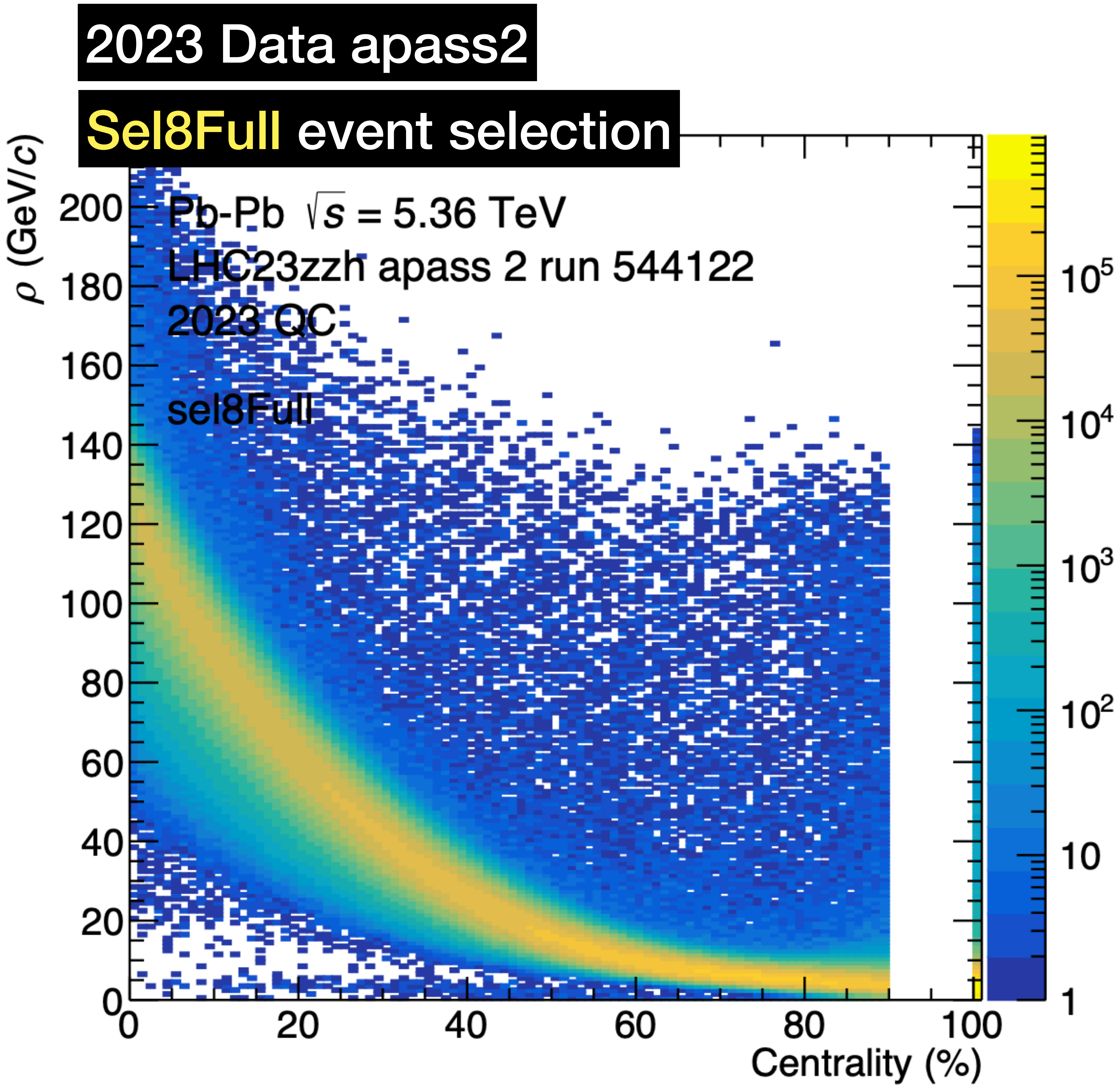


No selection | +Vertex triggering | +Without ITSRO frame & Time frame | +Without Bunch pileup | +Good vertex vs PV

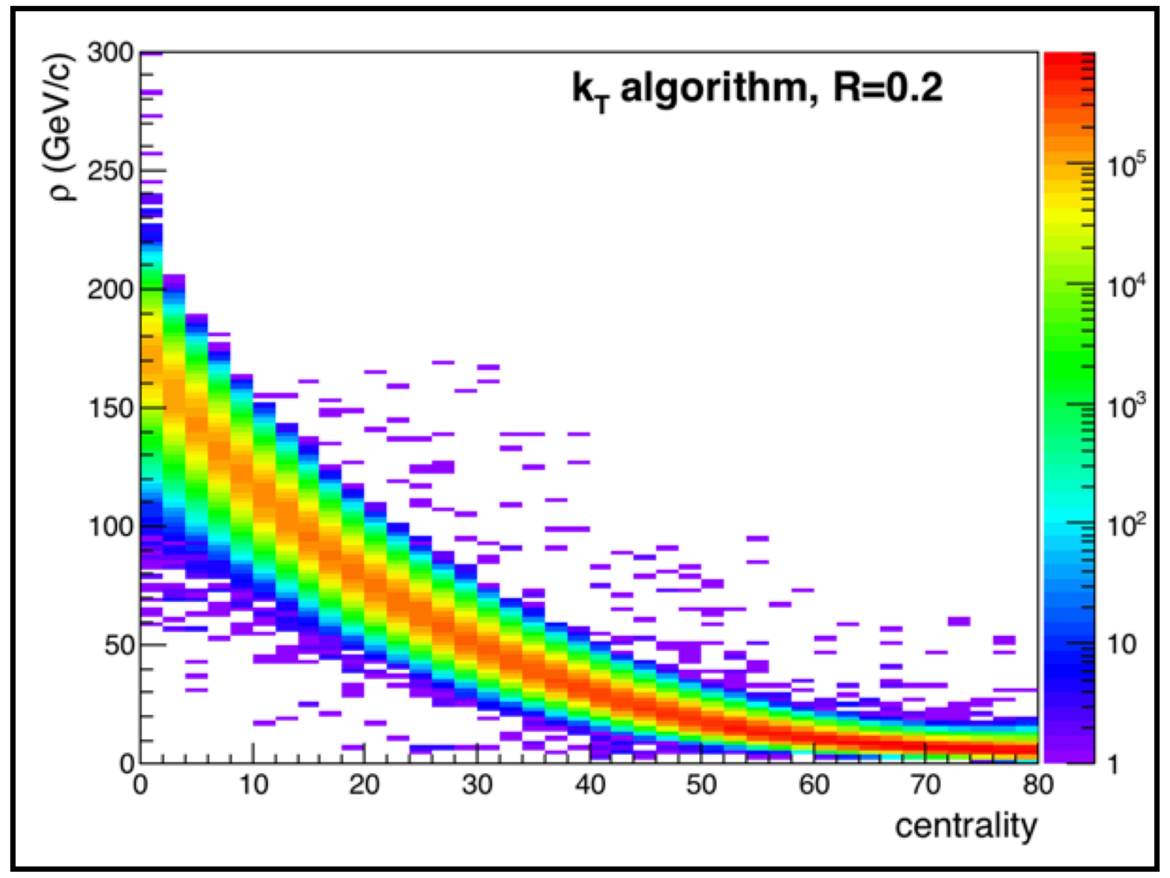
	No selection	+Vertex triggering	+Without ITSRO frame & Time frame (Minimum bias) MB event	+Without Bunch pileup	+Good vertex vs PV
All collisions	3955	3588	3588	3443	3336
%left	-	91%	87%	84%	74%
0~10%	284	281	269	263	263
%left	-	99%	95%	93%	93%
50~90%	1299	1273	1220	1172	1147
%left	-	98%	94%	90%	88%

Rho vs Centrality





Run2 results

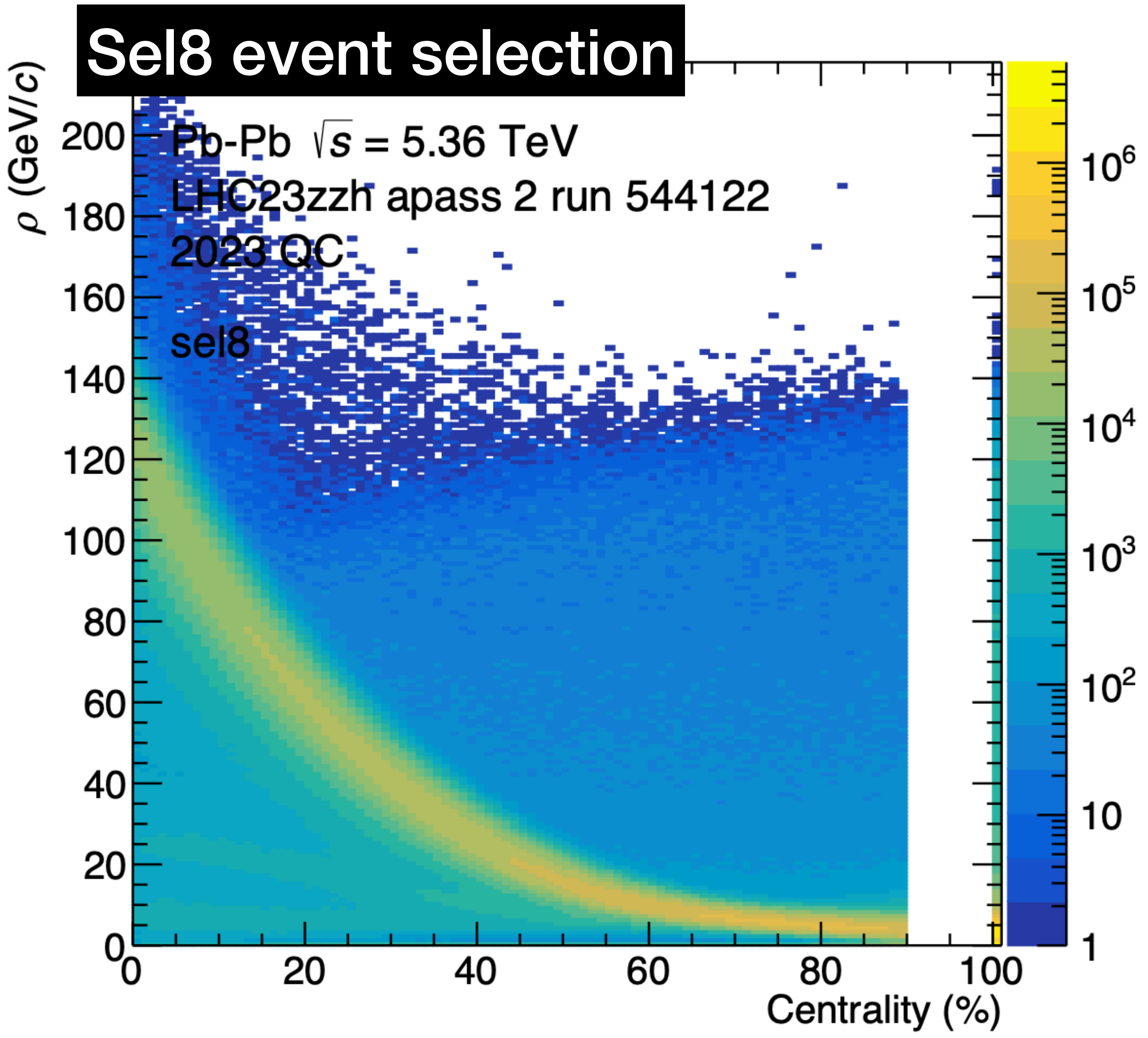


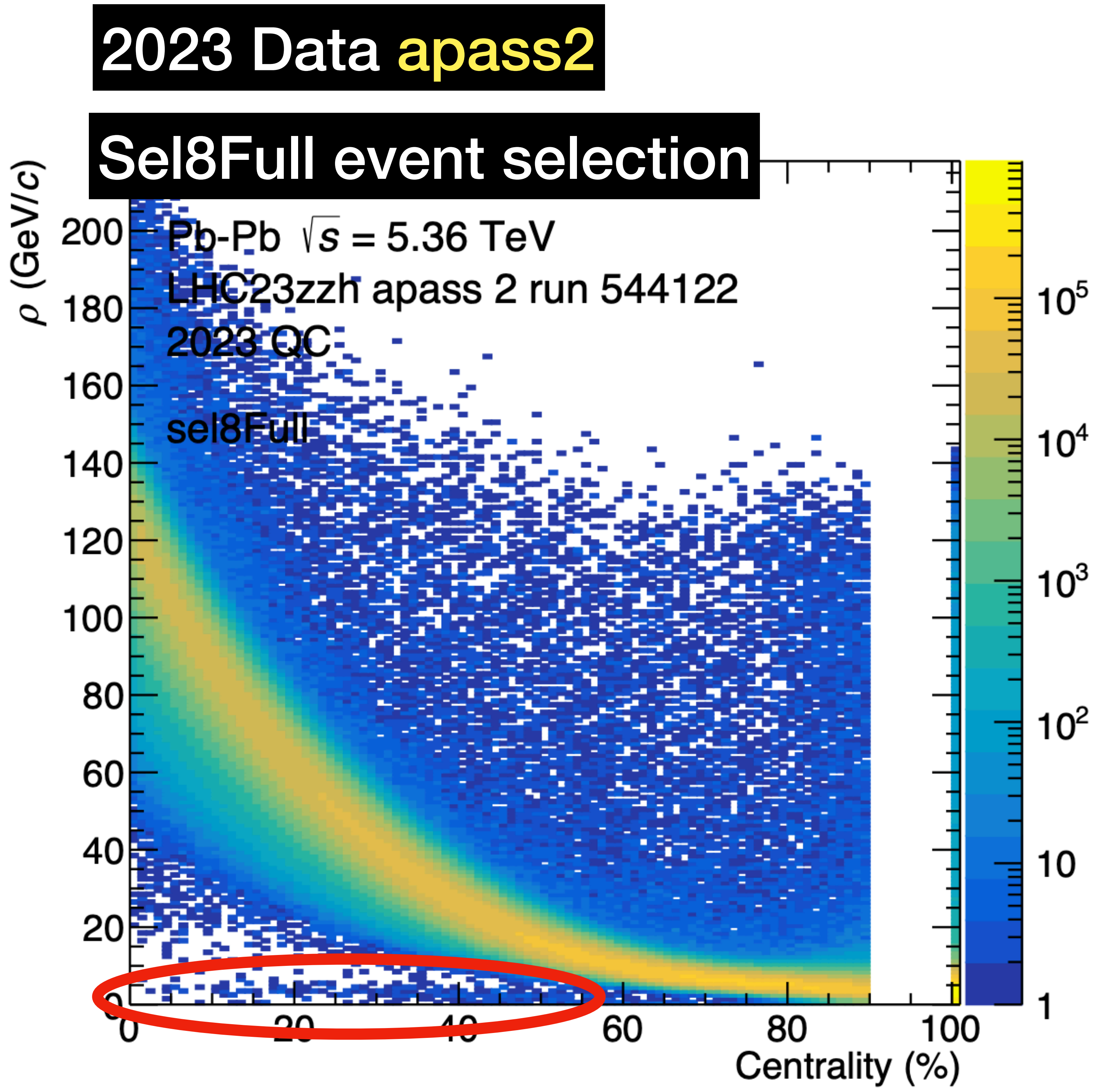
ANA-818

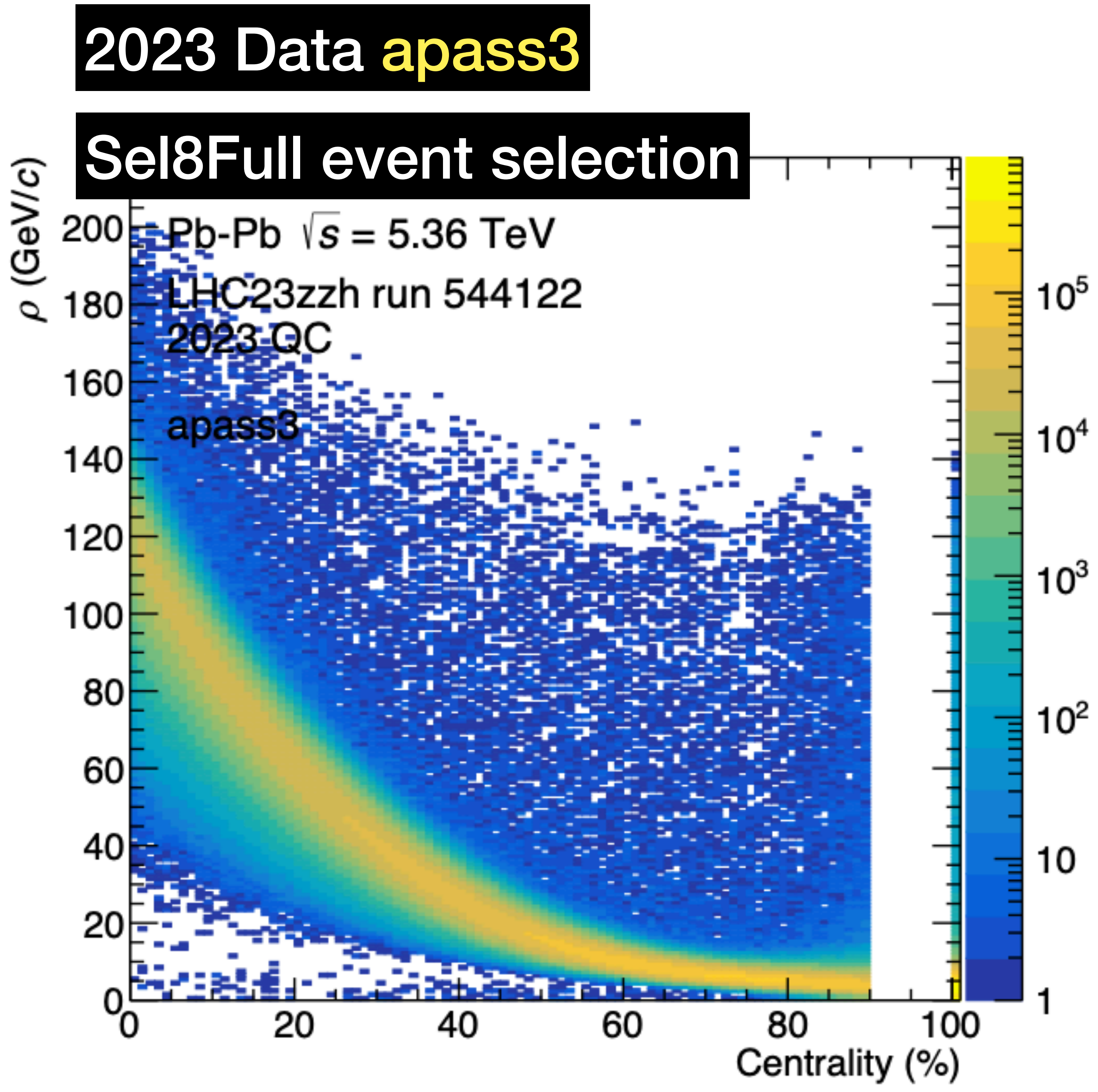
$$\rho = \mathrm{median}\left(\frac{p_{\mathrm{T}}^{\mathrm{jet}}}{A}\right)$$

- Rho distribution according to centrality becomes more distinct with tighter event selection.
- Similar distribution with Run2 result.

Rho vs Centrality





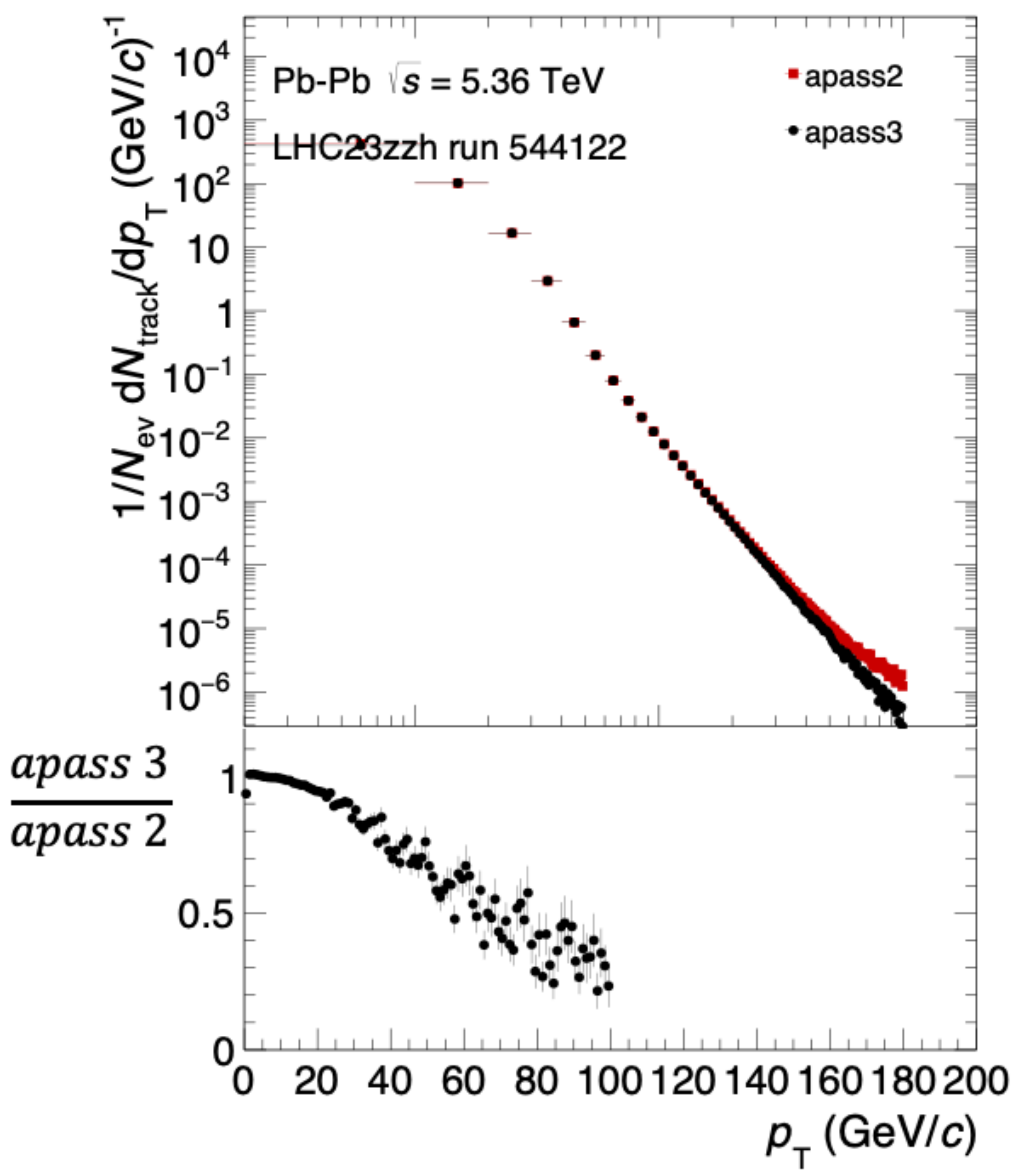


$$\rho = \mathrm{median}(\frac{p_{\mathrm{T}}^{\mathrm{jet}}}{A})$$

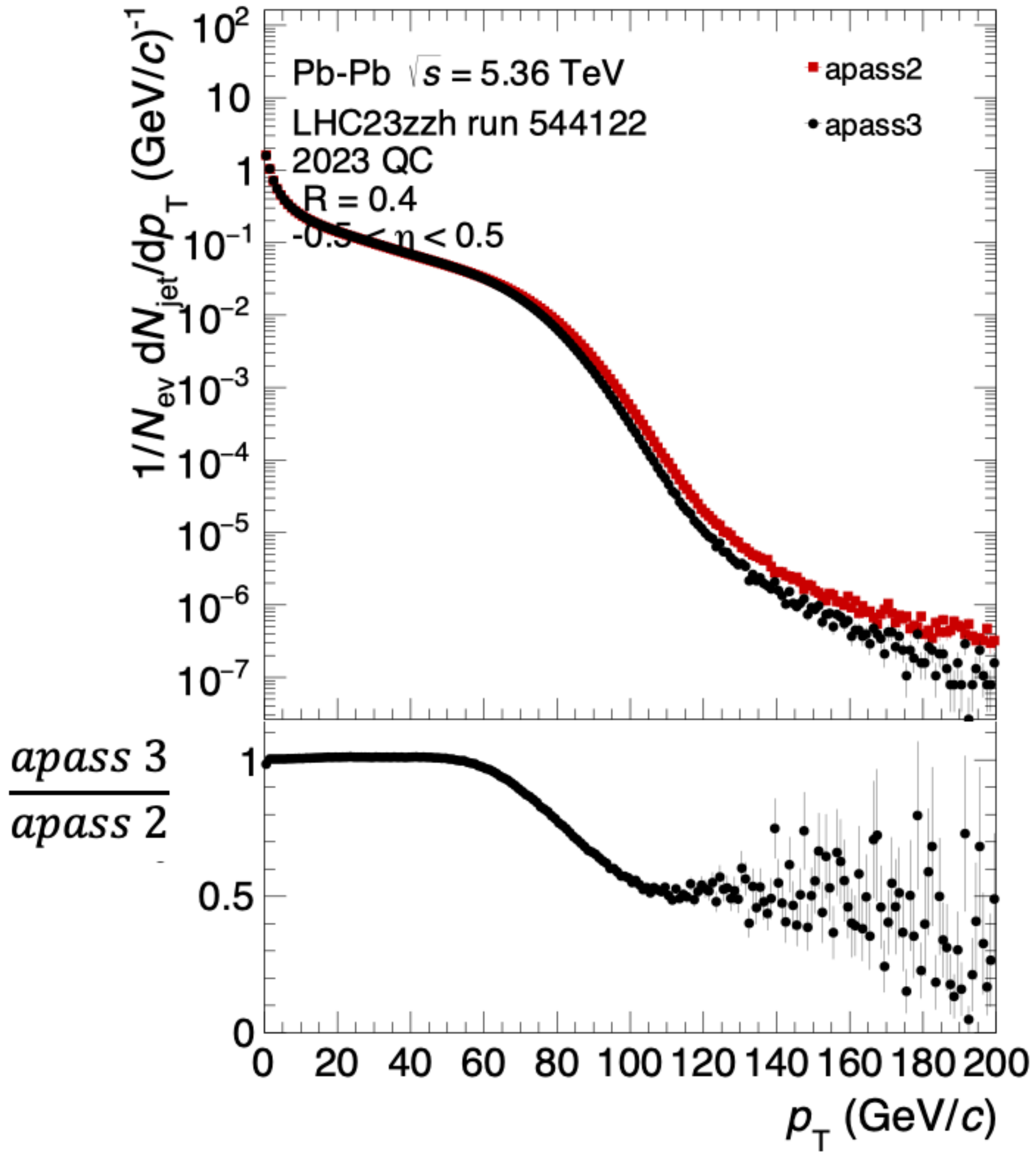
- Rho distribution according to centrality becomes more distinct with tighter event selection.
- Similar distribution with Run2 result.
- The abnormal distribution at $\rho = 0$ on apass2 data is disappeared in apass3

2023 Data apass2 vs apass3

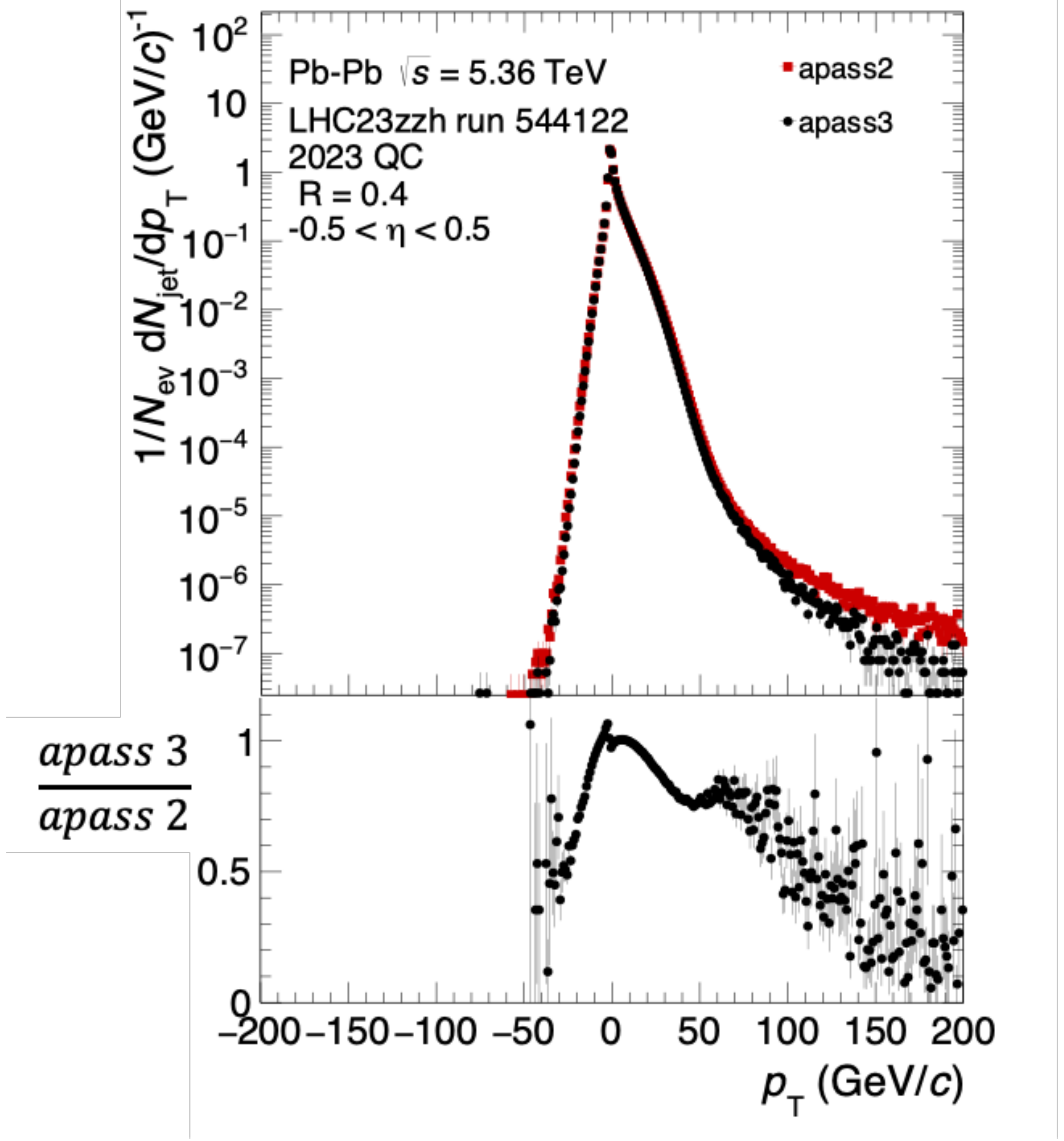
Track



Before bkg subtraction

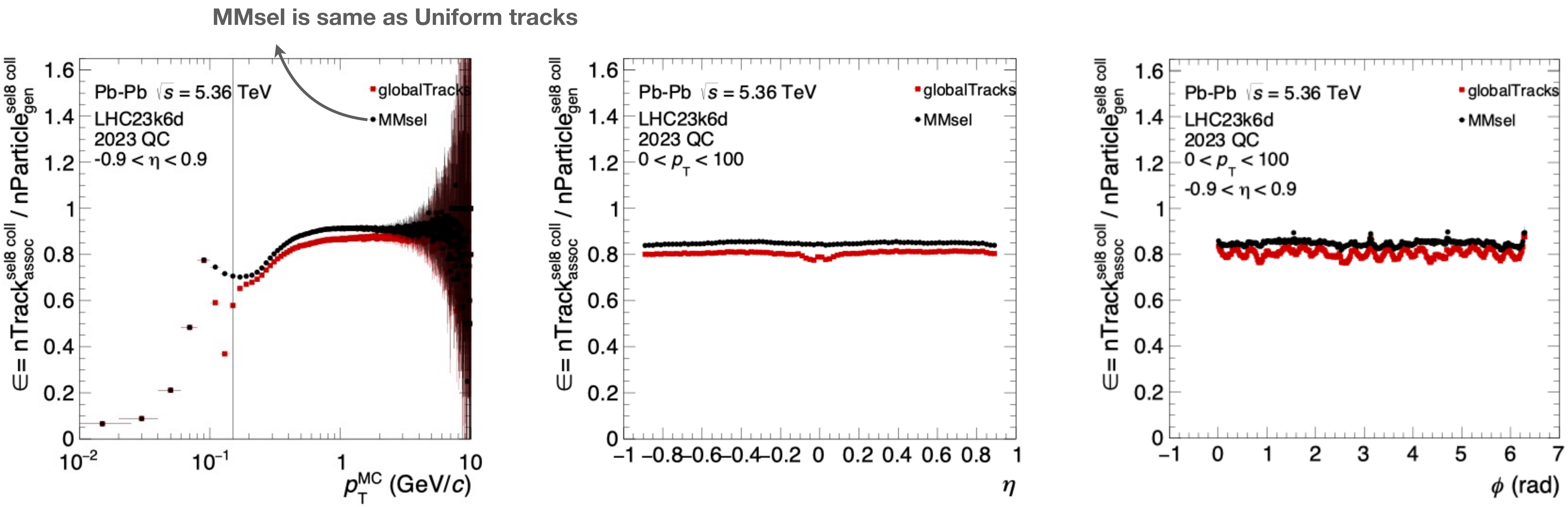


After bkg subtraction



- Background : Area-based method
- Without leading track cut

Track reconstruction efficiency check



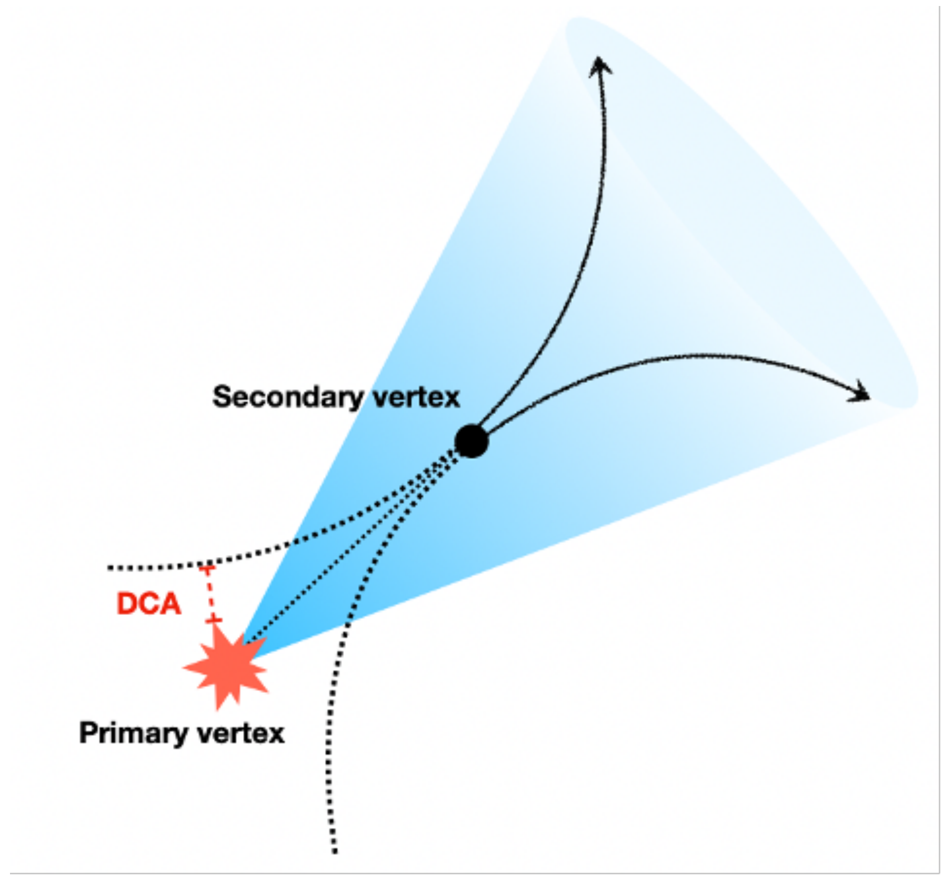
$$\varepsilon^{\mathrm{jet}}_{\mathrm{reco}}(p^{\mathrm{gen}}_{\mathrm{T,jet}}) = \frac{N_{\mathrm{matched}}(p^{\mathrm{gen}}_{\mathrm{T,jet}})}{N_{\mathrm{generated}}(p^{\mathrm{gen}}_{\mathrm{T,jet}})}$$

- Track reconstruction efficiency using uniform tracks is better than using global tracks
- Efficiencies as a function of centrality will be studied.

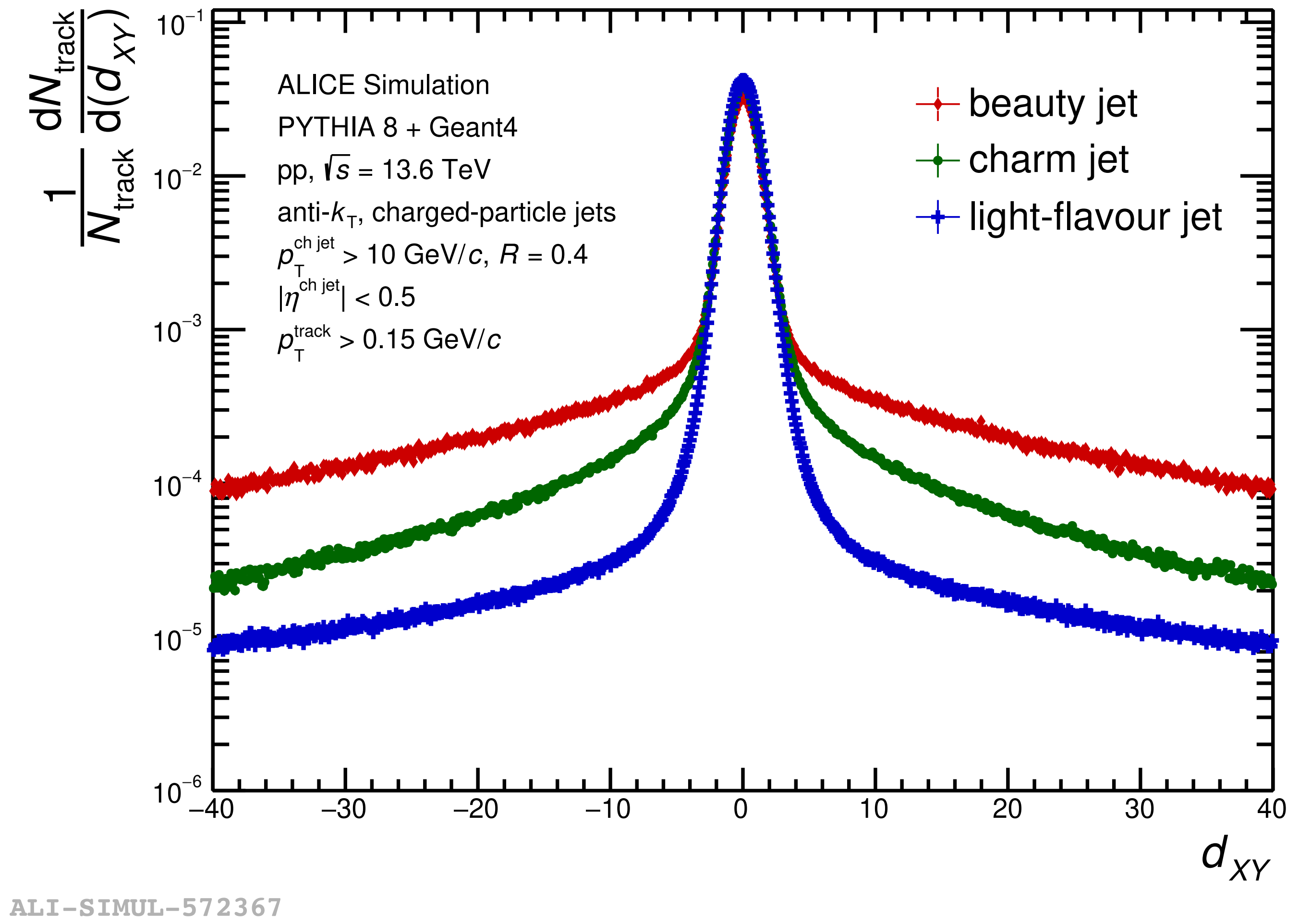
Heavy flavour charged-jet tagging in pp collisions

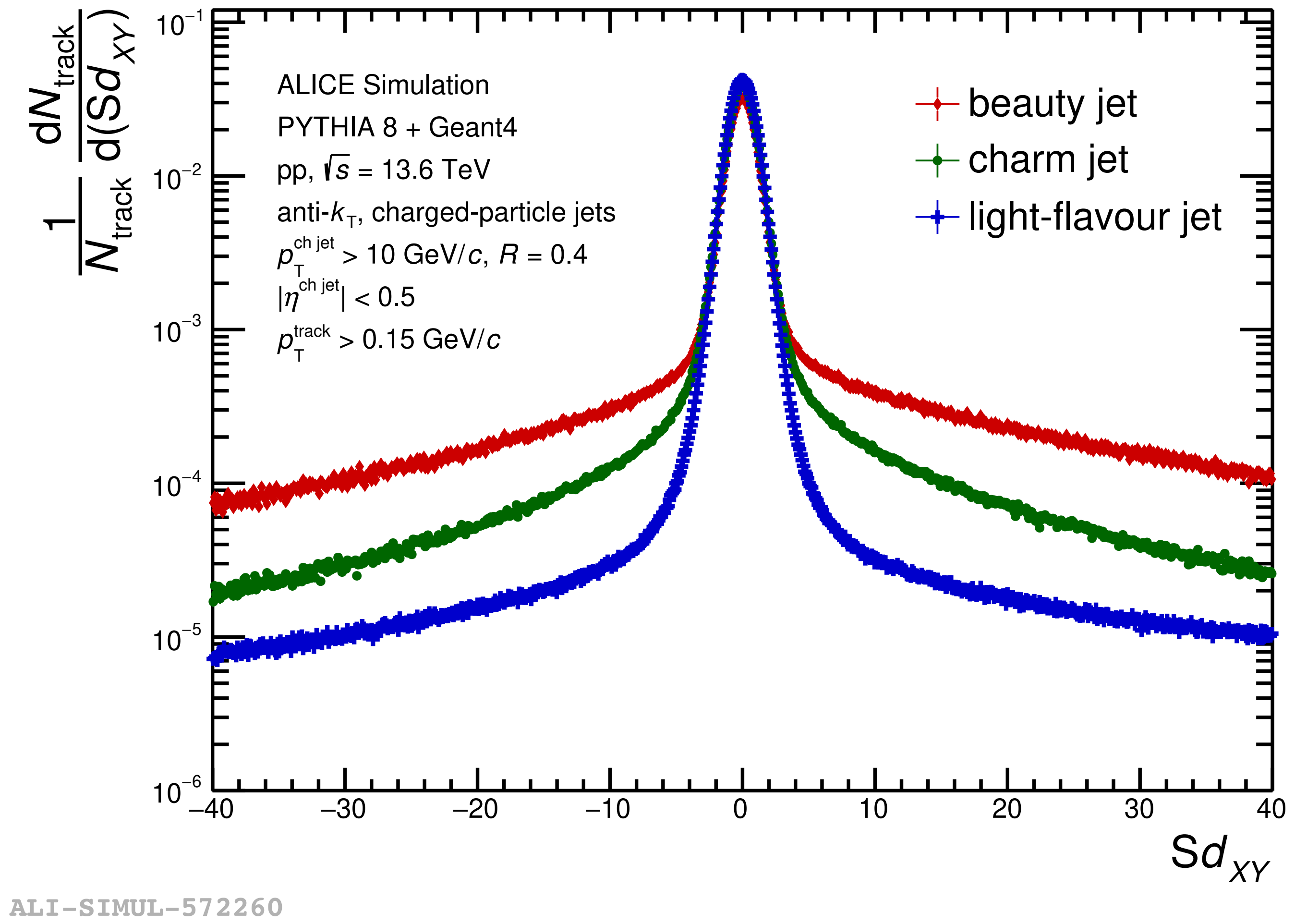
H. Lee , H. Park

Heavy-flavour tagging strategy



- Tracks from heavy quark jet likely have large **DCA (Distance of closest approach to primary vertex)** because of their log lifetime
- Select heavy flavour jet candidates using large DCA which is called as **impact parameter**





- Geometric sign :

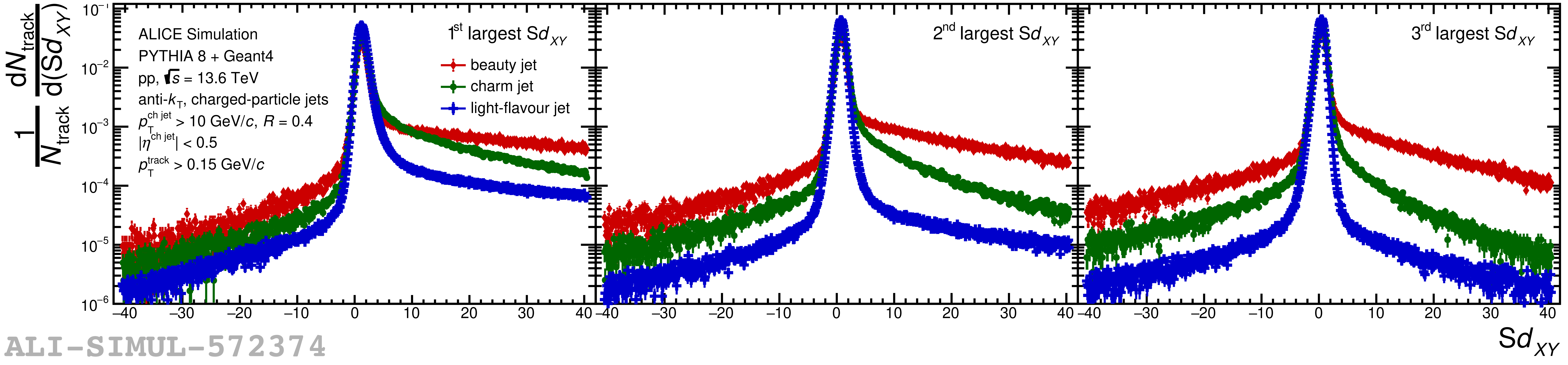
$$sign(\overrightarrow{\mathrm{DCA}_{xy}} \cdot \overrightarrow{\mathrm{Jet}_{P_\mathrm{T}}}) = \pm 1$$

- IP significance :

$$d_{xy} = \mathrm{DCA}_{xy}/\sigma_{xy}$$

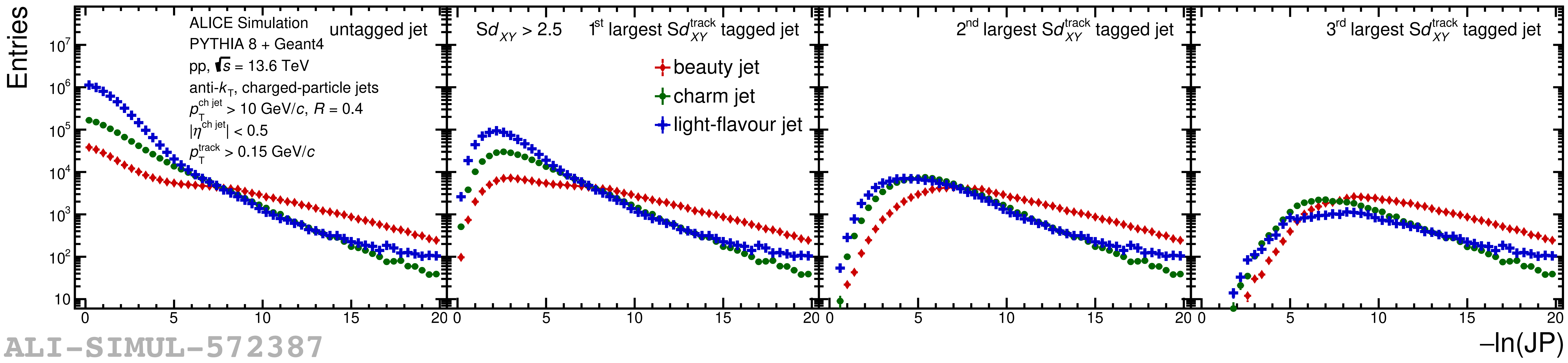
$$\mathrm{S}d_{xy} = \mathrm{Geometric\ sign} \times d_{xy}$$

Track counting method



- Selects the N tracks within the jet with the highest Sd_{xy}.
- Larger for heavy-flavour tracks than light-flavor tracks, showing more pronounced asymmetry in beauty and charm jets.
- The heavy-flavour jet by counting the tracks that exceed a set tagger working point threshold.

Jet Probability method



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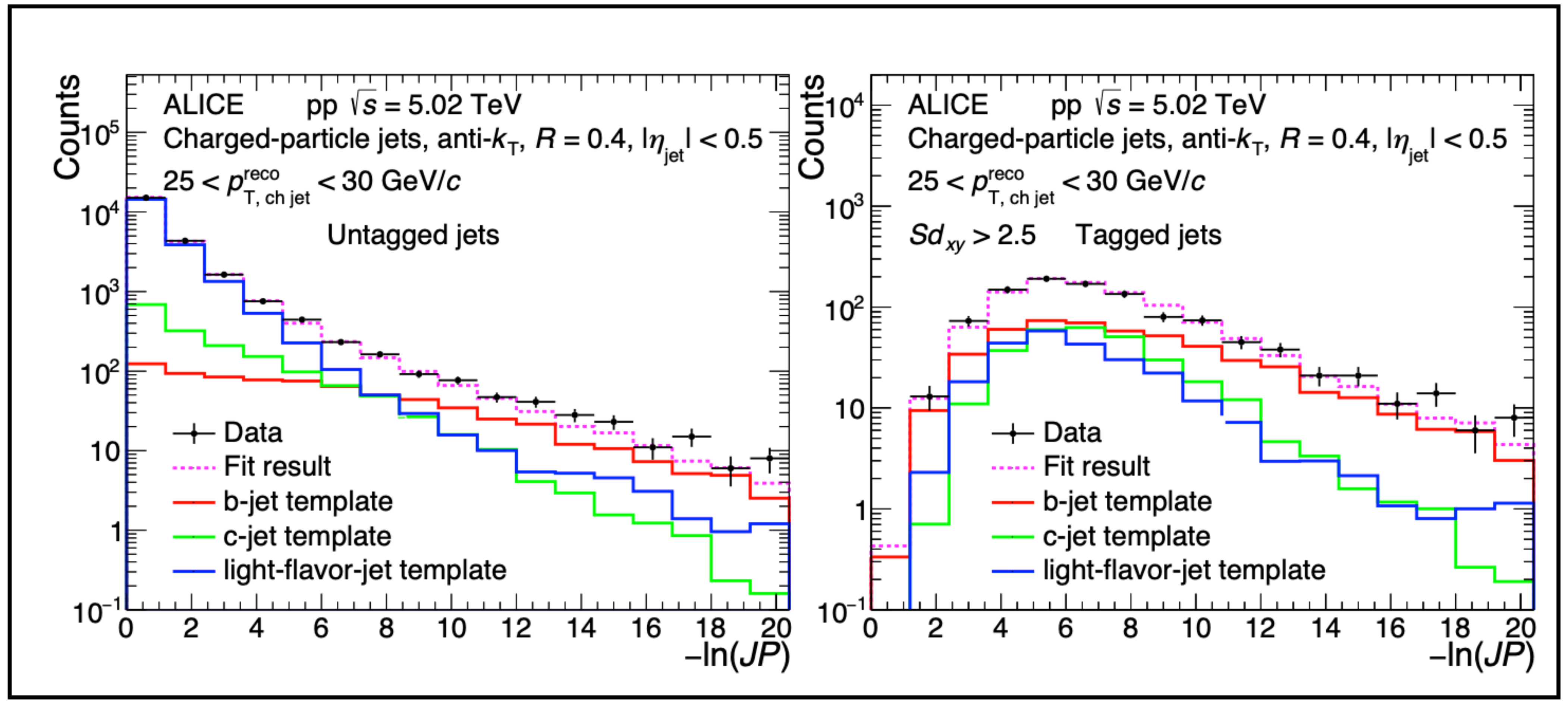
Track probability : $P_{\mathrm{trk}}(\mathrm{S}d_{xy}) = \dfrac{\int_{-40}^{-|\mathrm{S}d_{xy}|} R(x)\,dx}{\int_{-40}^{0} R(x)\,dx}$

Jet probability: $\mathrm{JP} = \Pi \times \sum_{k=0}^{N_{\mathrm{trk}}-1} \dfrac{(-\log\Pi)^k}{k!}, \Pi = \prod_{i=1}^{N_{\mathrm{trk}}} P_{\mathrm{trk}}(\mathrm{S}d_{xy})$

- The $-\log(\mathrm{JP})$ distribution provides a clear separation between jets with low and high probabilities of containing heavy-flavour hadron decays

Run2 results



arXiv:2110.06104

Summary

- Run3 on going analysis in Jet working group
  - Jet resolution & reconstruction efficiency in pp and Pb—Pb collisions
  - Implementing background subtraction method in Pb—Pb collisions
  - heavy-flavour tagging using classical method in pp collisions
  - …
- Various analyses of jets are being conducted in Run3!
  - Many measurements will be possible for the first time.
  - with less systematic uncertainty than Run2.
  - dynamical and fast evolving field.
- Various activities are underway, aiming for HP2024 & QM2025.

Thank you for listening!