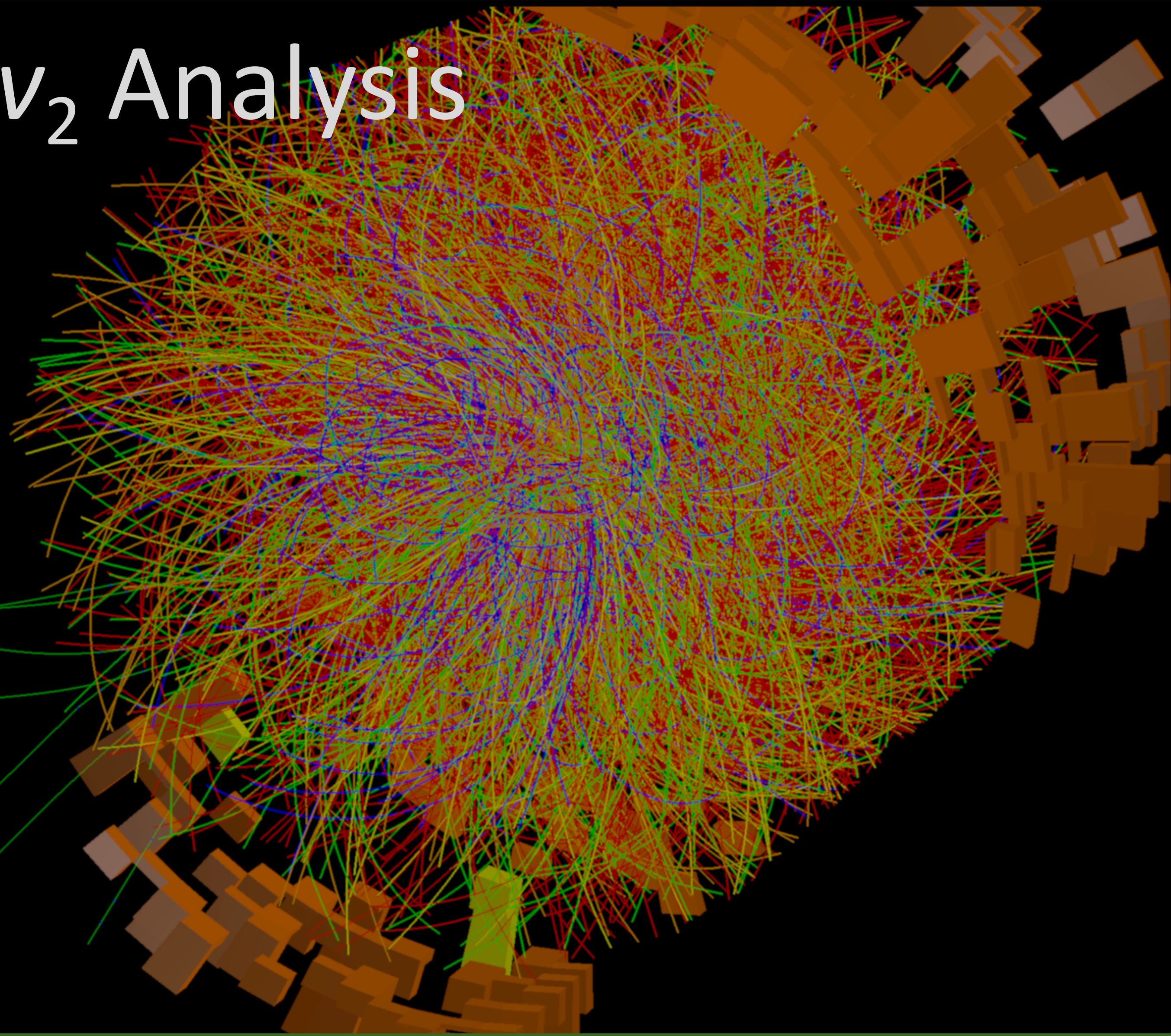
Inclucive Jet R_{AA} and v_2 Analysis

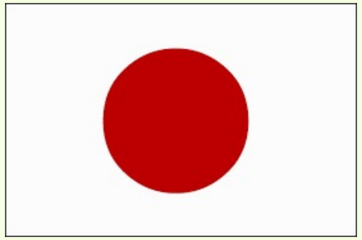


Univeristy Grenoble Alpes
University of Tsukuba
RIKEN (JRA)

Takuya Kumaoka

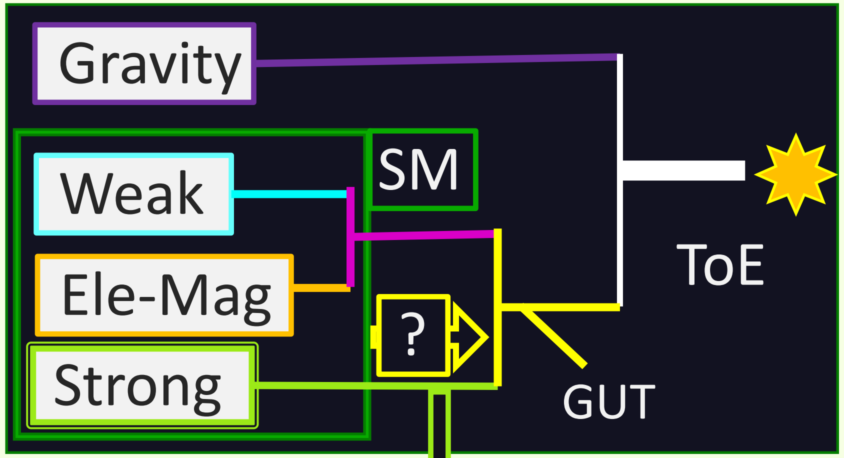
Brief my introduction

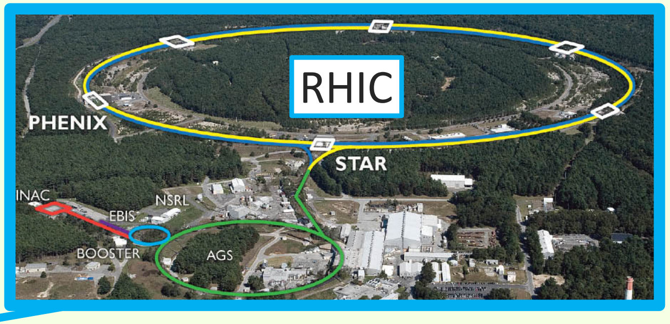
Name: Takuya Kumaoka （熊岡 卓哉)
Country: Japan
Doctoral student: 1.5 degree

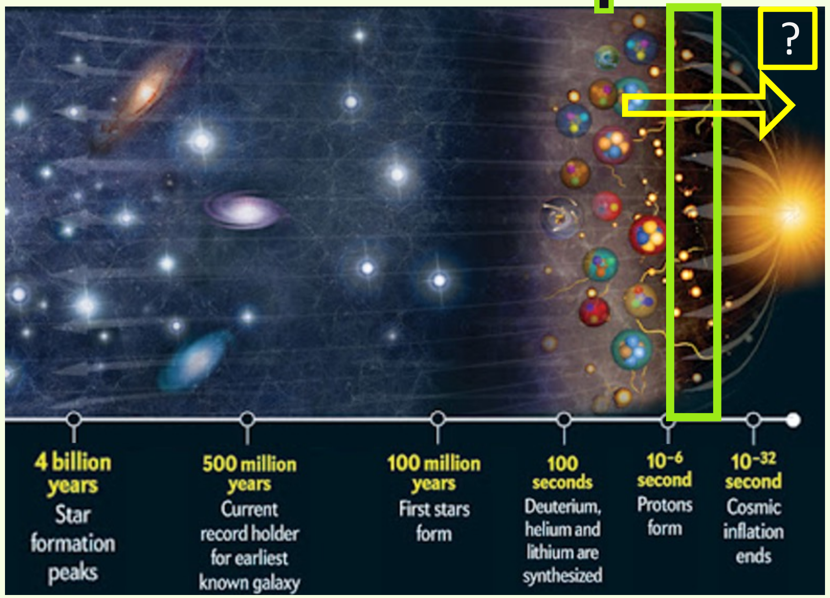


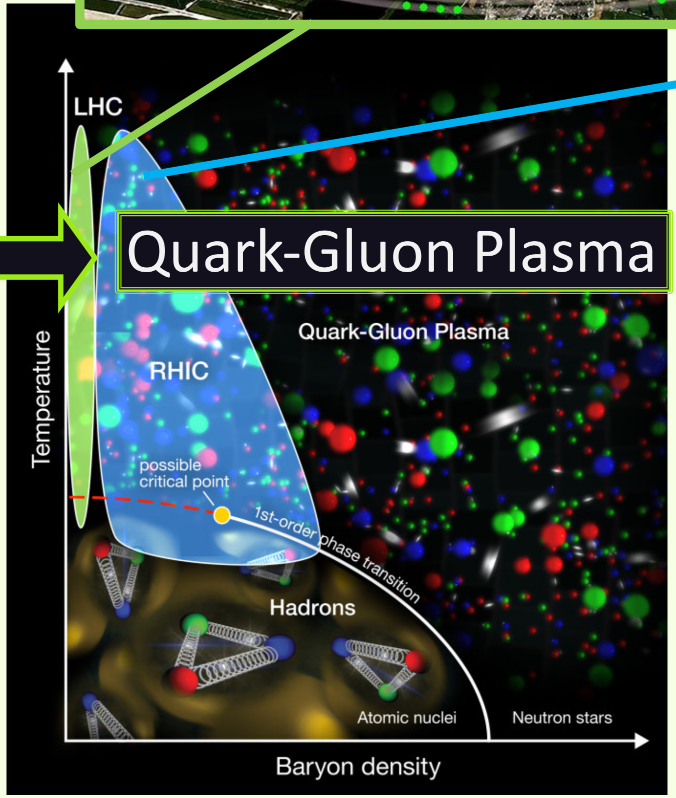
- Bachelor : Enginear of Chemistory
- Master: ILC-ILD (Future Japan linear collider) [test performance of the E-Cal (MPPC)]
  & LHC-ATLAS [muon software trigger for a new detector (NSW)]
- Doctor: LHC-ALICE [Jet analysis & FoCal R&D]
  - Incusive **full jet** neuclear modification factor (R_{AA})
  - Incusive **charged jet** neuclear modification factor (R_{AA}) and $\boldsymbol{v_2}$
  - Joined beam test (ELPH/SPS)
    -> FPGA study? / physics simulation

Study Modivation







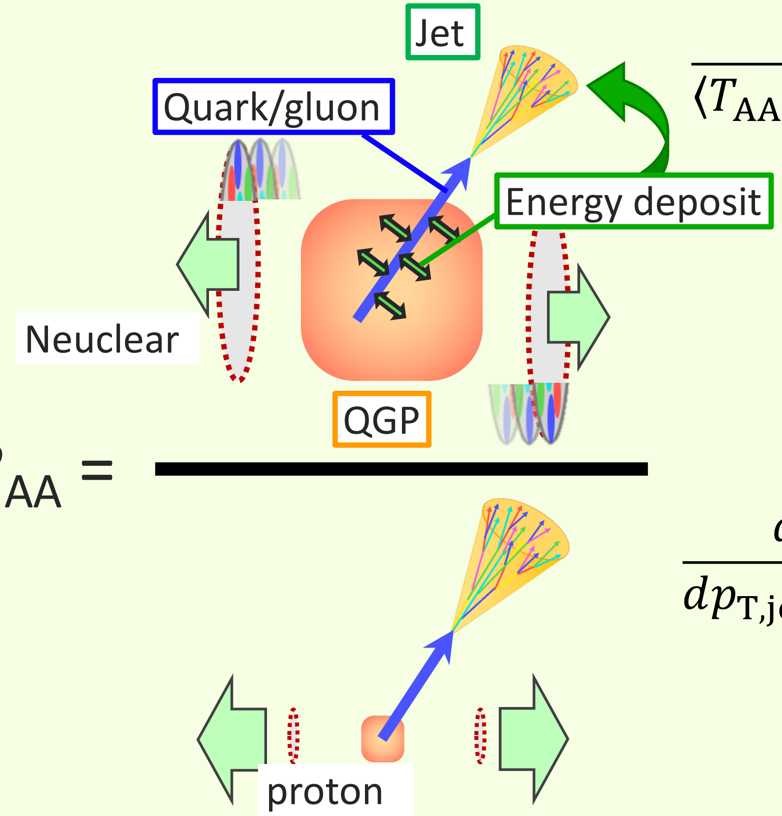


Quark-Gluon Plasma (QGP)
-> matter phase at high temperature and pressure

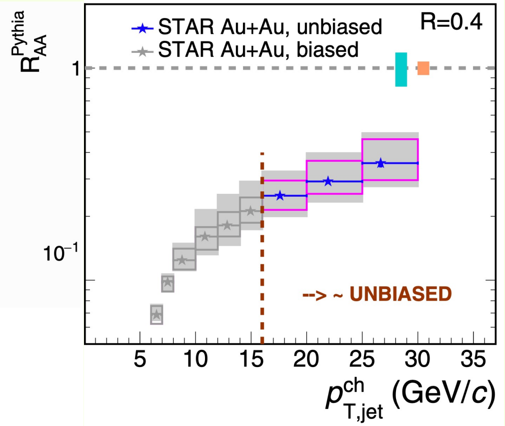
It was discovered by measurements of jet quenching effect / elliptic flow and etc…
→ Still, the features of QGP are not known.
(quenching mechanism, temperature, how it evolute and etc…)

Nuclear Modification Factor (R_{AA})

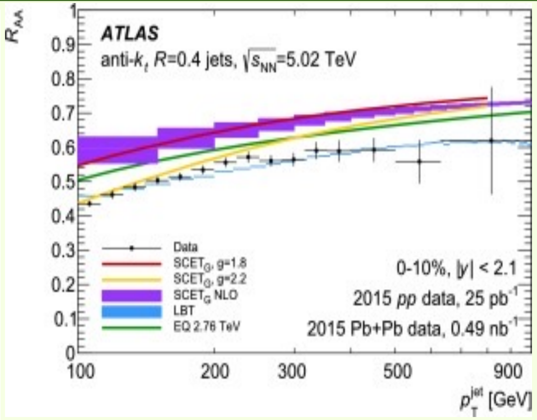
R_{AA} measurement is for making sure of QGP existence
→ Already discovered Jet suppression in many experiments.
→ **2018 statistics : Increase jet p_T reach and centrality dependence study**
→ Quantify $\hat{q}$ and dE/dx by compairing with models



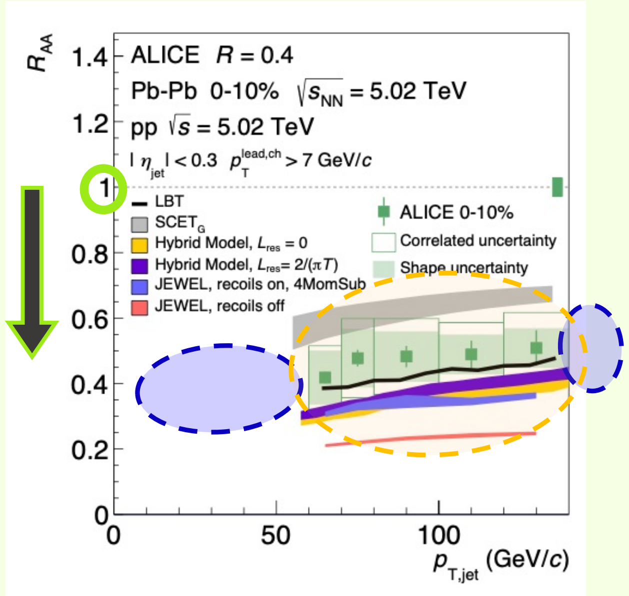
$$R_{AA} = \frac{\frac{1}{\langle T_{AA}\rangle N_{\text{event}}} \frac{d^2N}{dp_{\text{T,jet}}d\eta_{\text{T,jet}}}\Big|_{AA}}{\frac{d^2\sigma}{dp_{\text{T,jet}}d\eta_{\text{T,jet}}}\Big|_{pp}}$$



STAR Phys. Rev. C **102** (2020) 054913



ATLAS PLB 790 (2019) 108



ALICE Phys. Rev. C **101** (2018) 034911

ALICE, PHENIX/STAR, ATLAS/CMS experimnts
Jet suppression (R_{AA}<1).
Problem
- Not understand the difference between data and models
- **Limitted p_T range (60-140 GeV)**
- Only central collision data

This Analysis Purpose

Purpose

1. Measurement of R_{AA} in over previous study p_T region and comparison with theoretical models.
2. Measurements of R_{AA} at different centrality and different jet resolution parameters (R) and comparison with theoretical models.

Advantage

1. The data taken in 2018 has the number of statistics is about three times as large as that of the previous study.

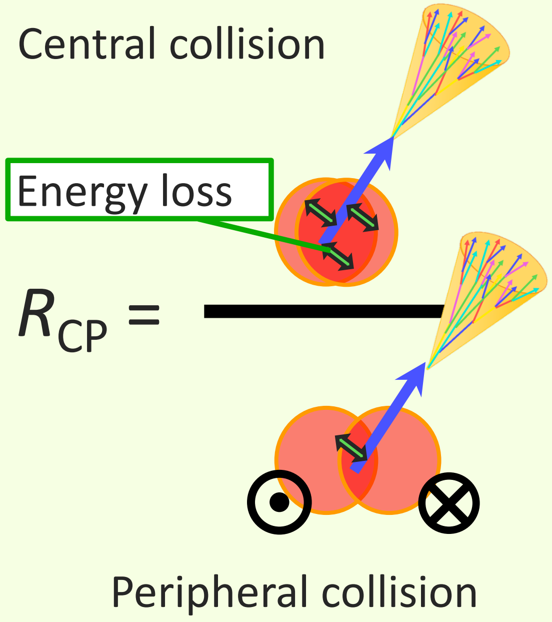
2. The data enable to study for various centrality.

・Enable to measure R_{AA} of peripheral collisions with small background.

→It is expected to **measure R_{AA} in low momentum regions.**

・ Enable to measure R_{CP}

→ It is expected **more precise measurement of jet suppression than R_{AA}**



Study Flow

1. Data selection: Jet QA (run priod LHC18q/r: Pb-Pb 5.02 TeV)

2. Measure the p_T density of the background: $\rho(p_T)$

3. Measure the raw jet for each jet parameters, respectively.
(**p_T distribution, R_{CP}, R dependency,** Jet Area, leading track p_T cut)

4. Jet QA for LHC20g4(PYTHIA8) anchored LHC18q/r

5. **Modify the jet distribution from detector effect (Embedding, Unfolding)** ⇐ stopped here

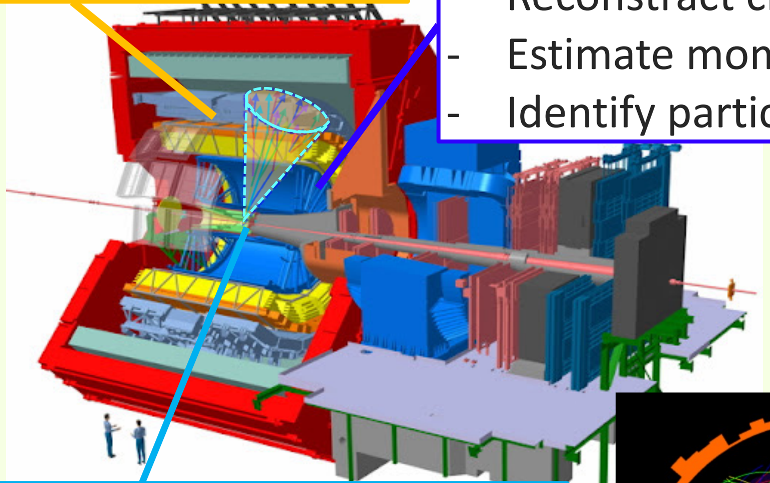
6. Estimate systematic uncertainty (Check the degree of jet fluctuation by changing jet parameters.)

Jet reconstruction

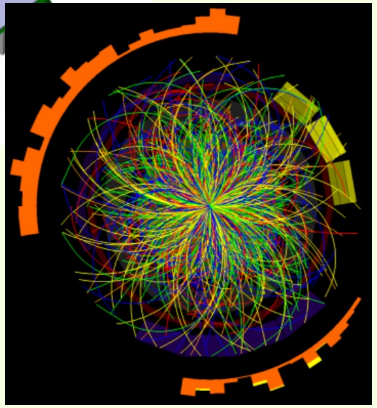
ALICE detectors for this study

EM-Calo ($|\eta| < 0.7$): Measure photons and gamma

TPC ($|\eta| < 0.9$):
- Reconstract charged track
- Estimate momentum
- Identify particles



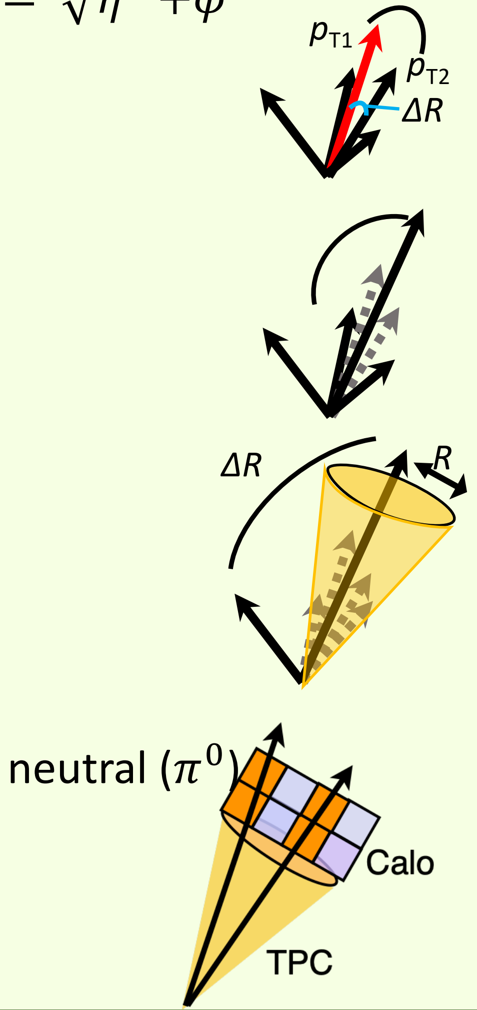
ITS: Measure the pass point of charged track and the number and measure the collision point



Reconstracted tracks

Jet reconstruction: Anti-k_T algorithm (Fast jet)

$R = \sqrt{\eta^2 + \phi^2}$



1. Combin charged tracks from largest p_T track

2. Repeat 1. process

3. Stop 2 process when the distance between reconstracting jet and track over R.

4. In full jet case (including neutral track), jets include EM-Cal information.

Measurement of background dencity

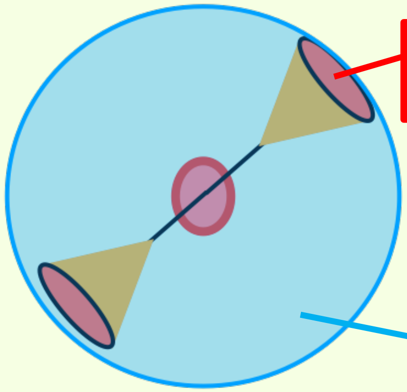
Need to subtract p_T of background from reconstracted jets p_T

$$p_{\mathrm{T,corr}}^{\mathrm{jet}} = p_{\mathrm{T}}^{\mathrm{jet}} - \rho A$$

Background p_T term

Anti-k_T jet p_T

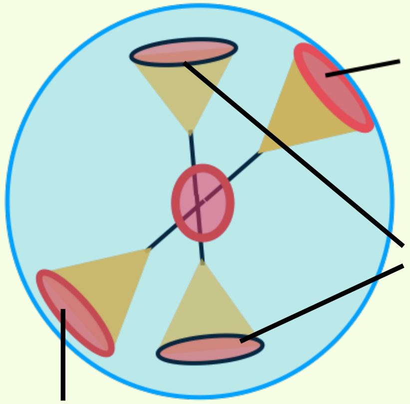
Measure jet p_T



Area of jet spread ($A = \pi R^2$)

Background p_T dencity: ρ

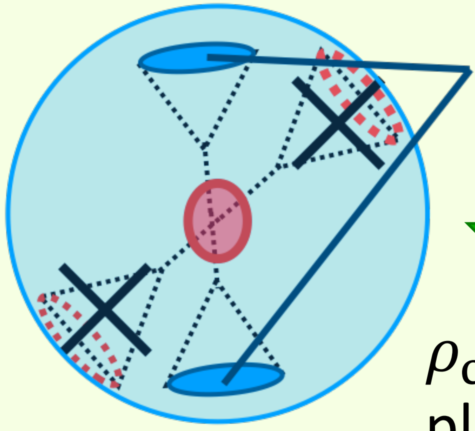
Measure process of the p_T density (ρ_{ch}) of only background charged tracks



Leading jet

Jets as background

Sub leading jet

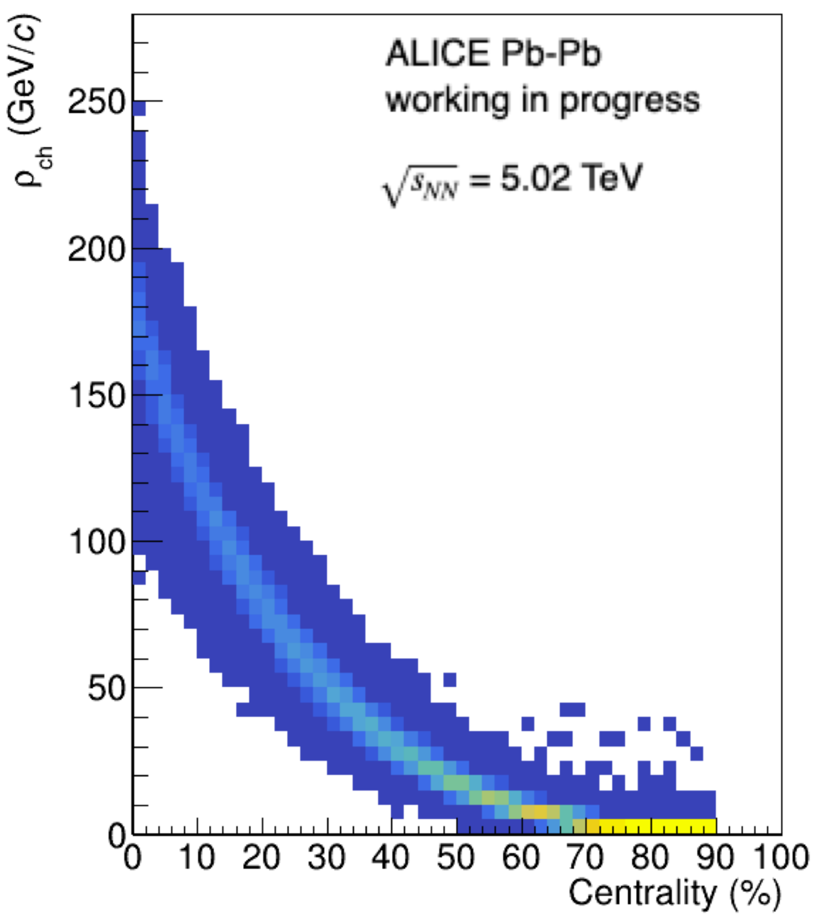


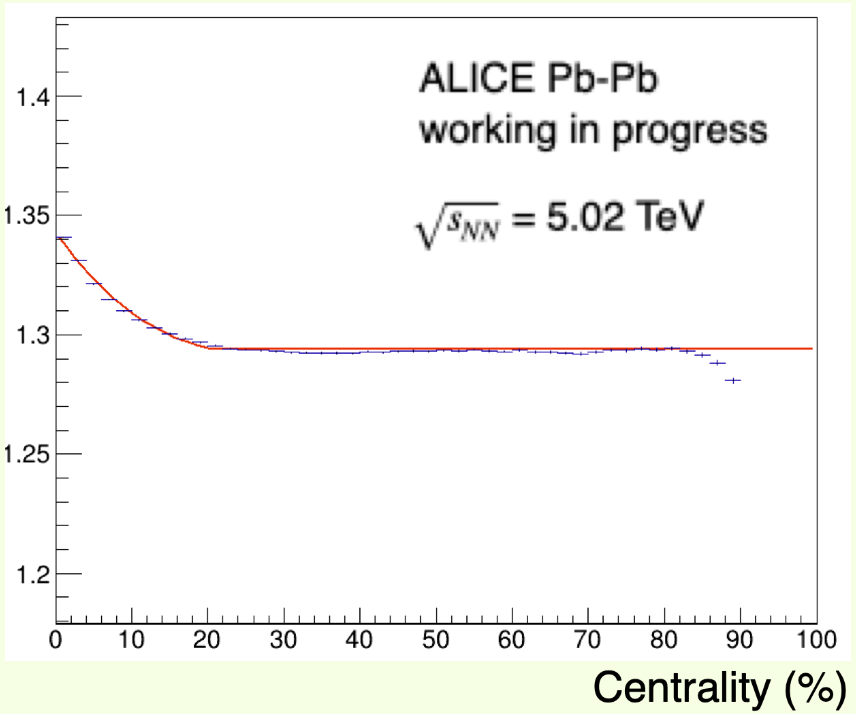
Measure p_T density

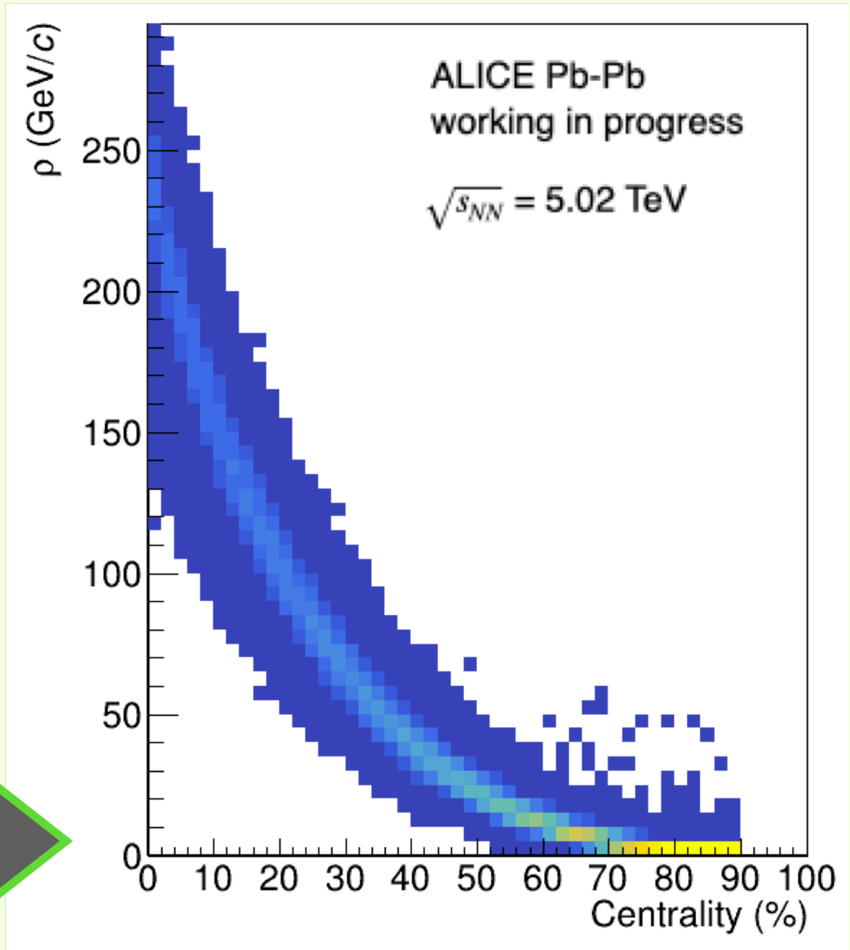
$$\rho_{\mathrm{ch}} = \mathrm{median}(p_{\mathrm{T},i}/A_i)$$

ρ_{ch} : regard backgroud spread platform

$$s(C) = \frac{(\sum p_{T,track}^{calo} + p_{T,cluster}^{calo})/A_{calo}}{\sum p_{T,track}^{TPC}/A_{TPC}}$$







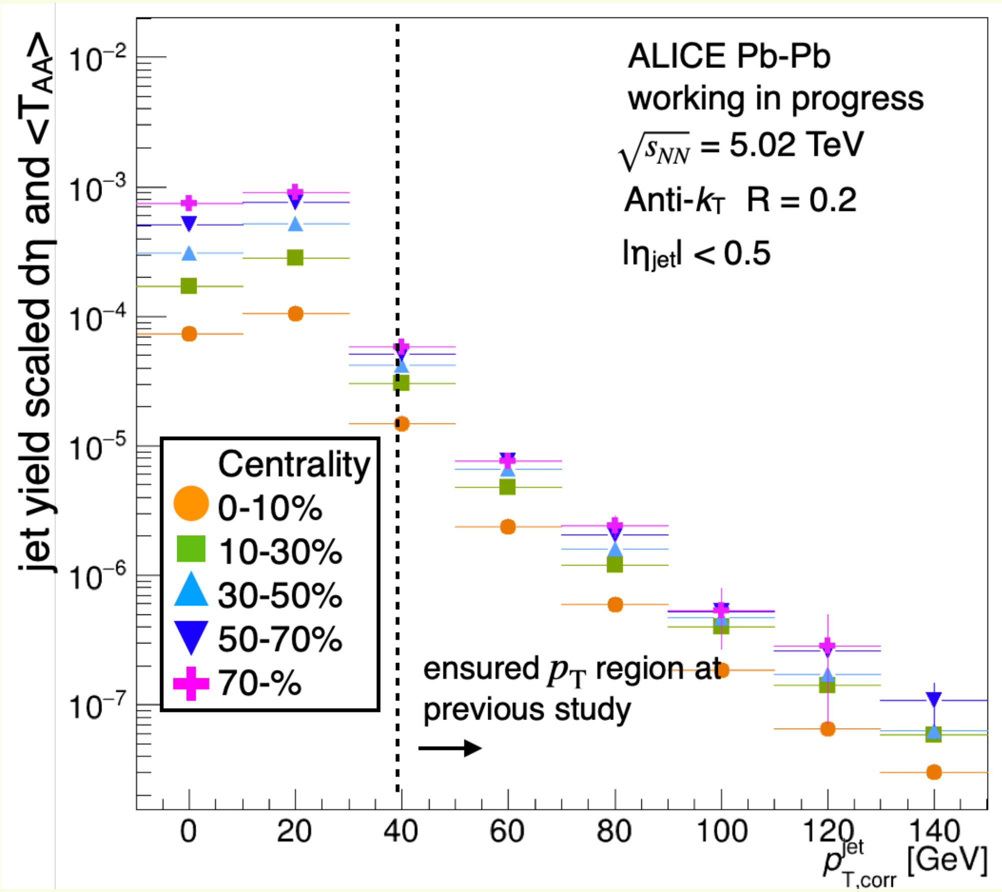
$$\rho(C) = s(C) \times \rho_{ch}(C)$$

C : Centrality

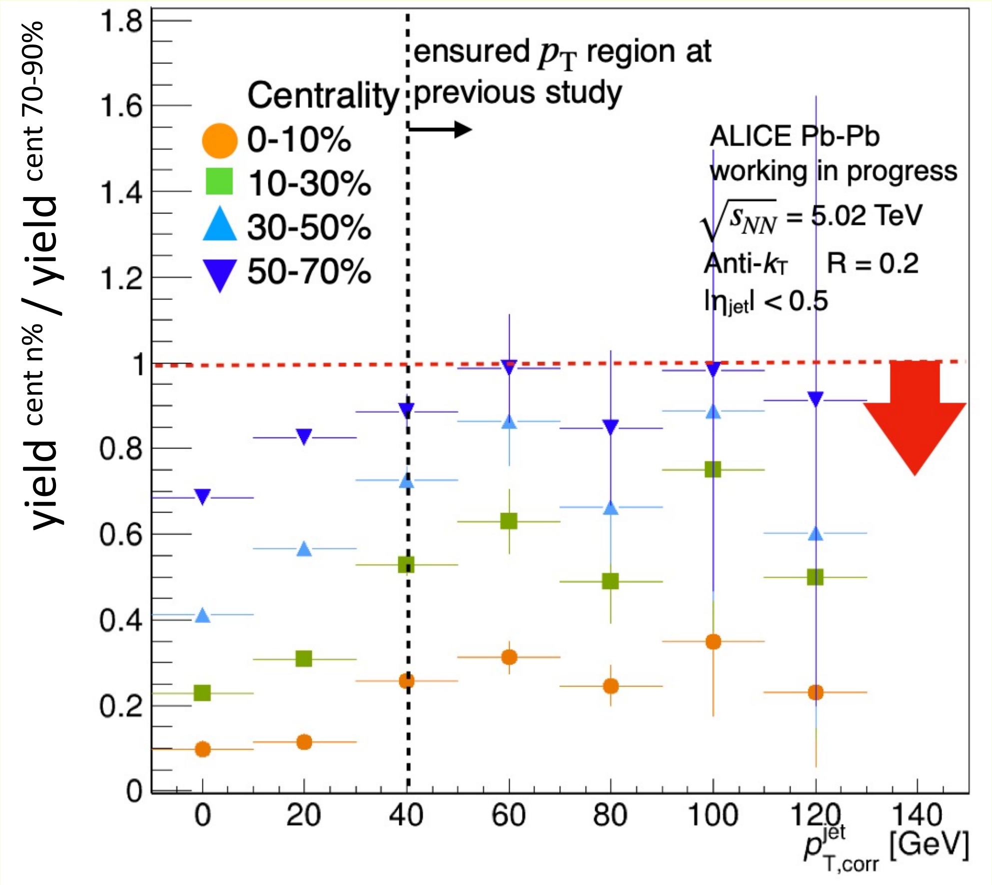
Raw Jet p_T distribution for each centrality

$p^{jet}_{T,corr} = p^{jet}_{T} - \rho A$

w/o unfolding and correction



various centrality jet distribution



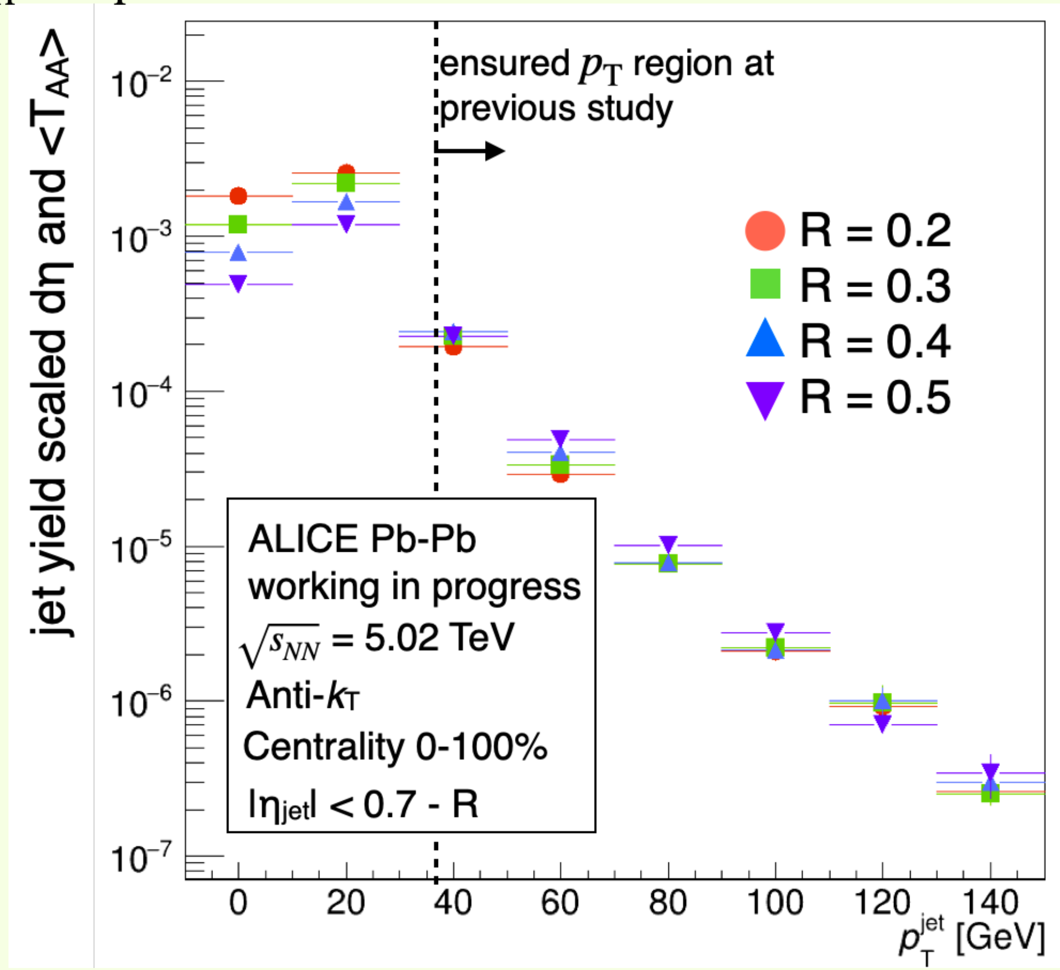
compare the peripheral distribution with various centrality one

These plots show the tendency of the distribution of the more central collision are more suppressed.

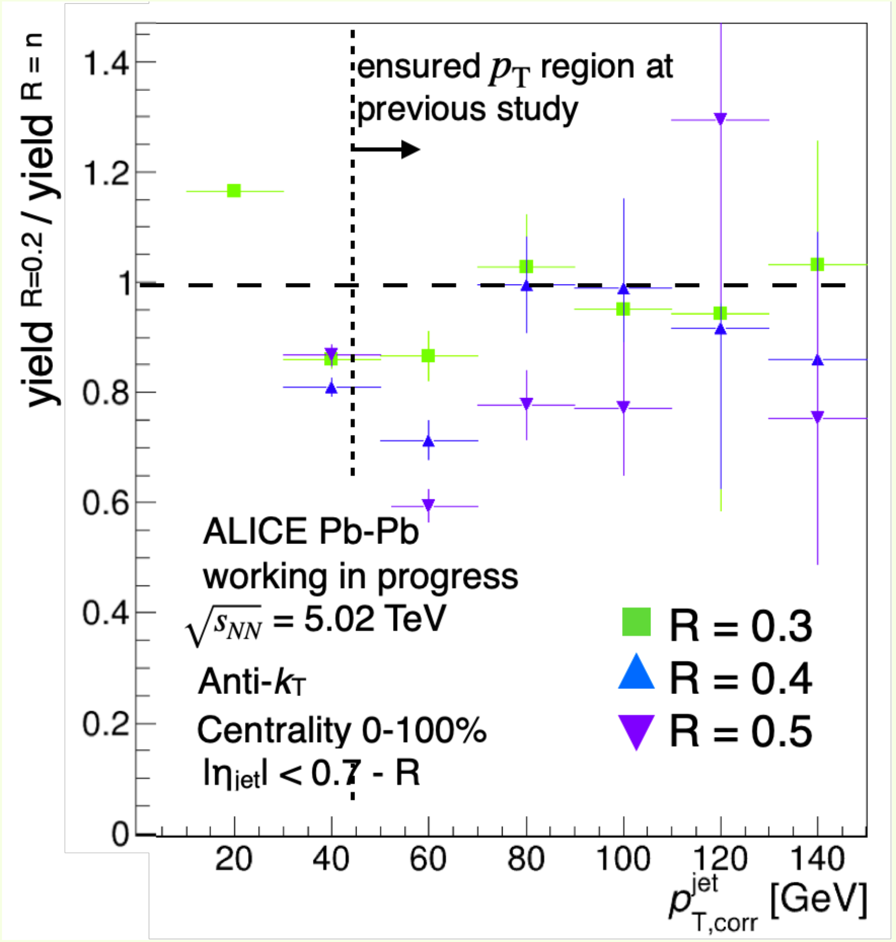
Raw Jet p_T distribution for each resolution parameter

$p_{T,corr}^{jet} = p_T^{jet} - \rho A$

w/o unfolding and correction



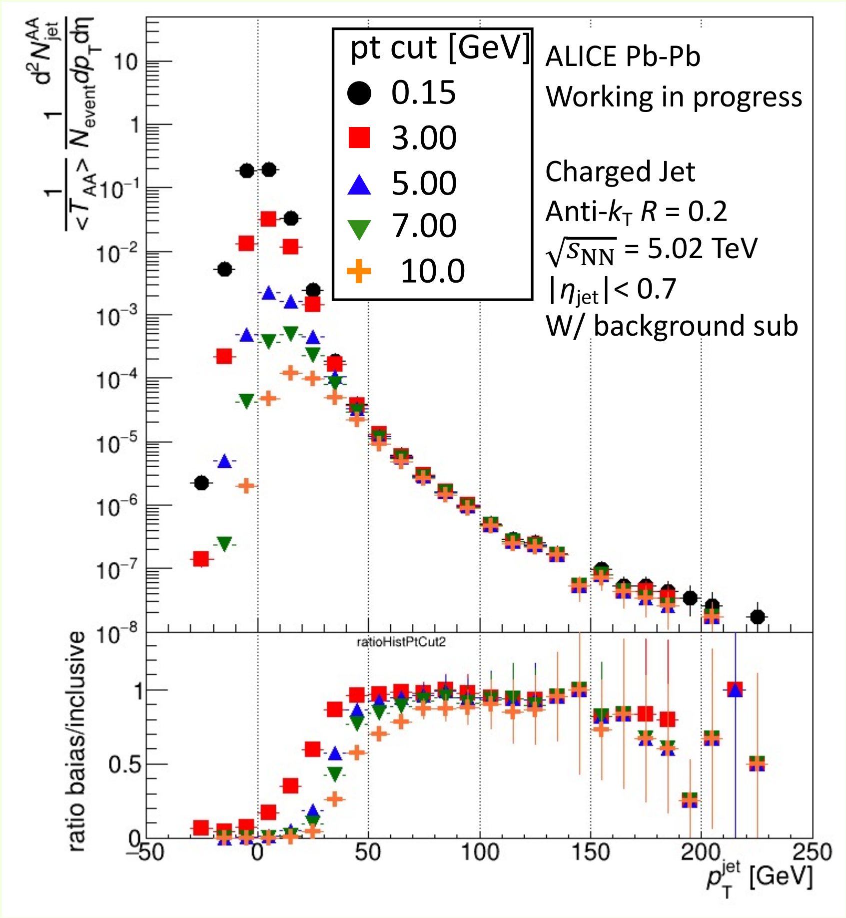
various R jet distribution

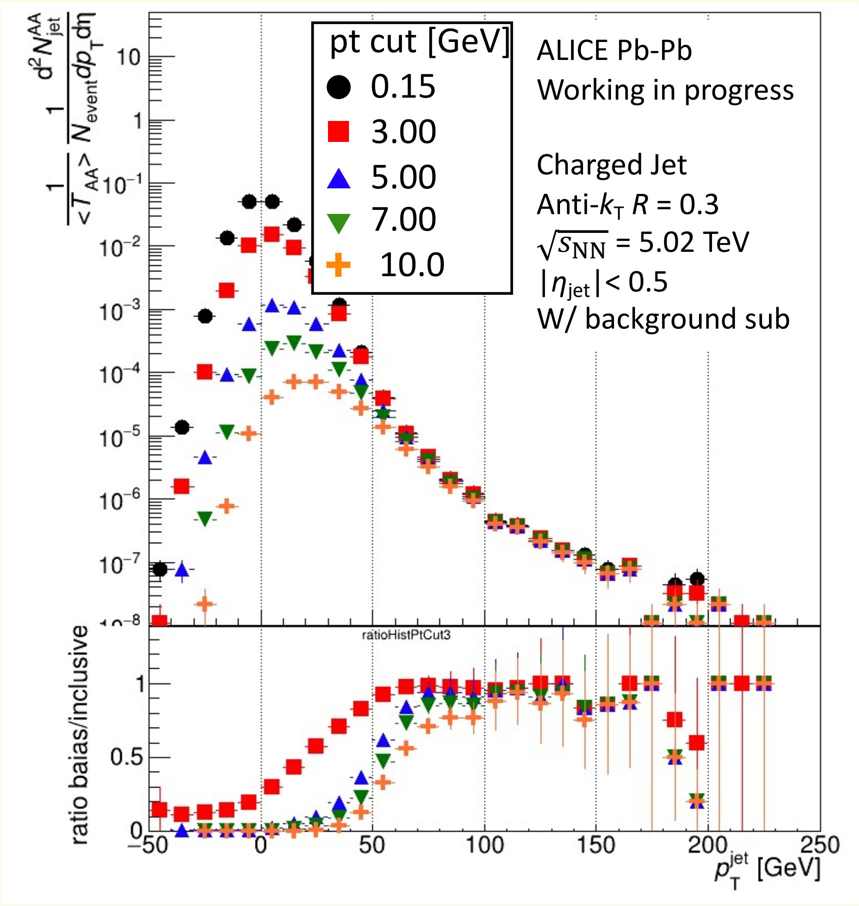


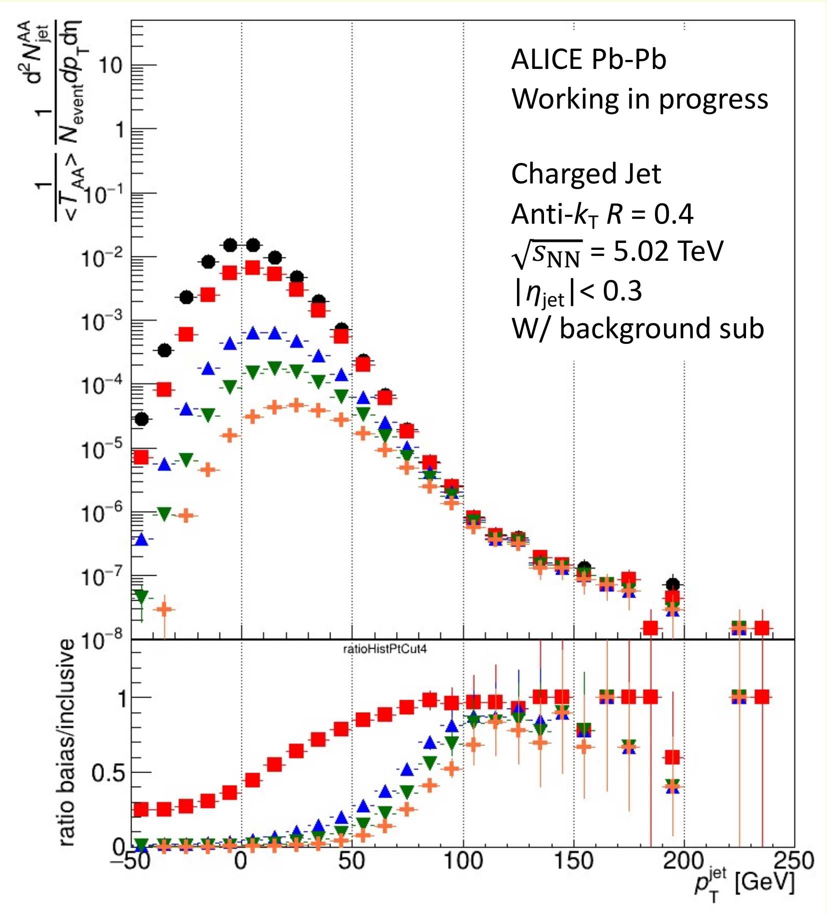
compare R=0.2 distribution with various R one

These plots show the tendency of the distribution having the larger R shifts to the higher .

Raw Jet p_T distribution for each leading track p_T cut





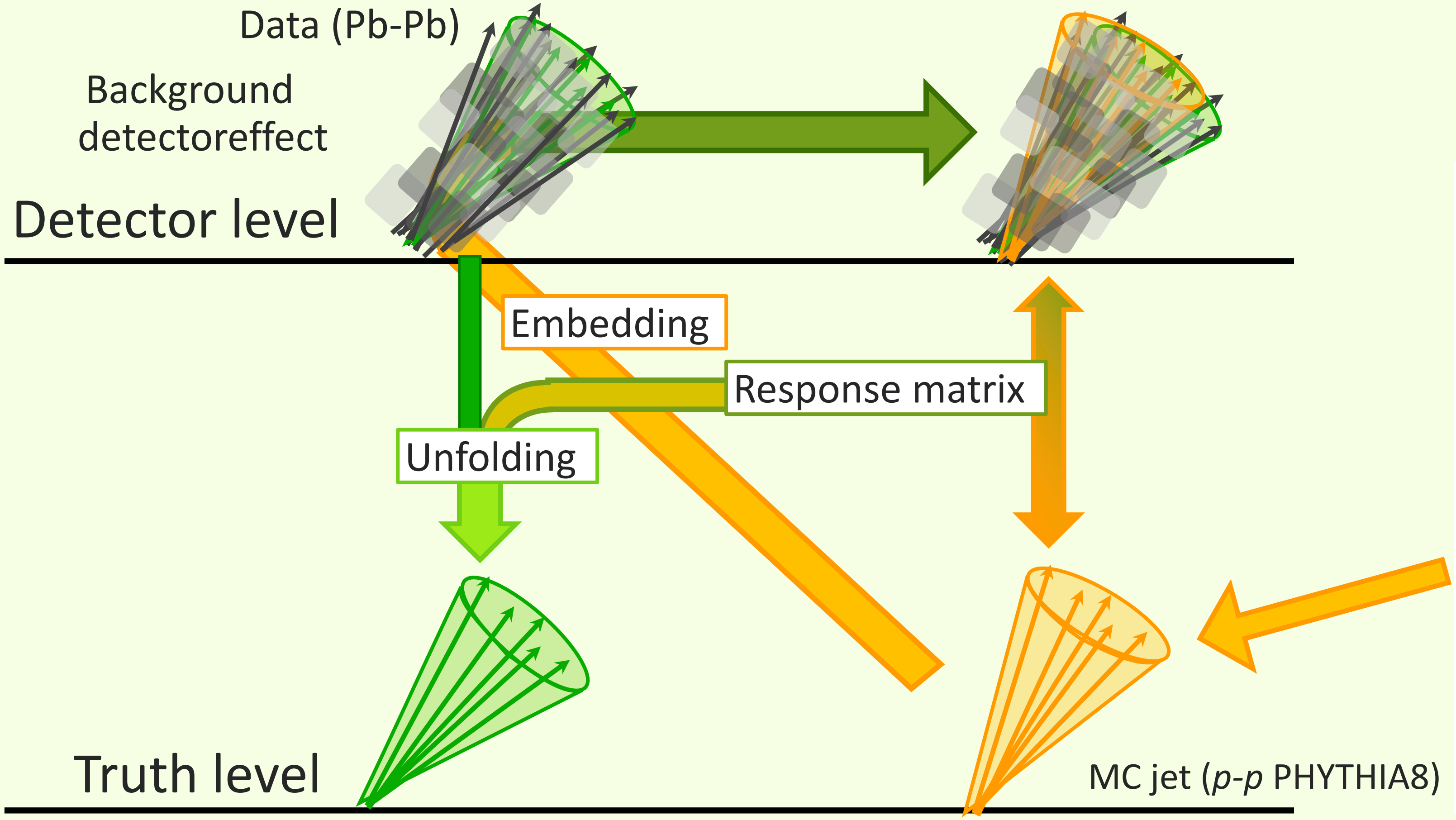


To reduce bias of the leading track pt cut, at least the pt cut require 5 GeV

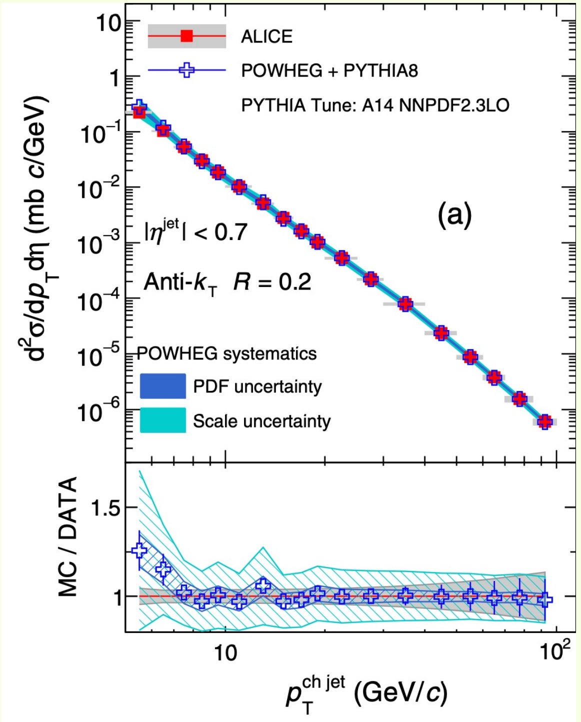
Embedding process

The measured jet p_T distribution is affected by the background events and the resolution / acceptance of the detector

→ Correcting p_T distribution distortions by simulation(**Unfolding**).



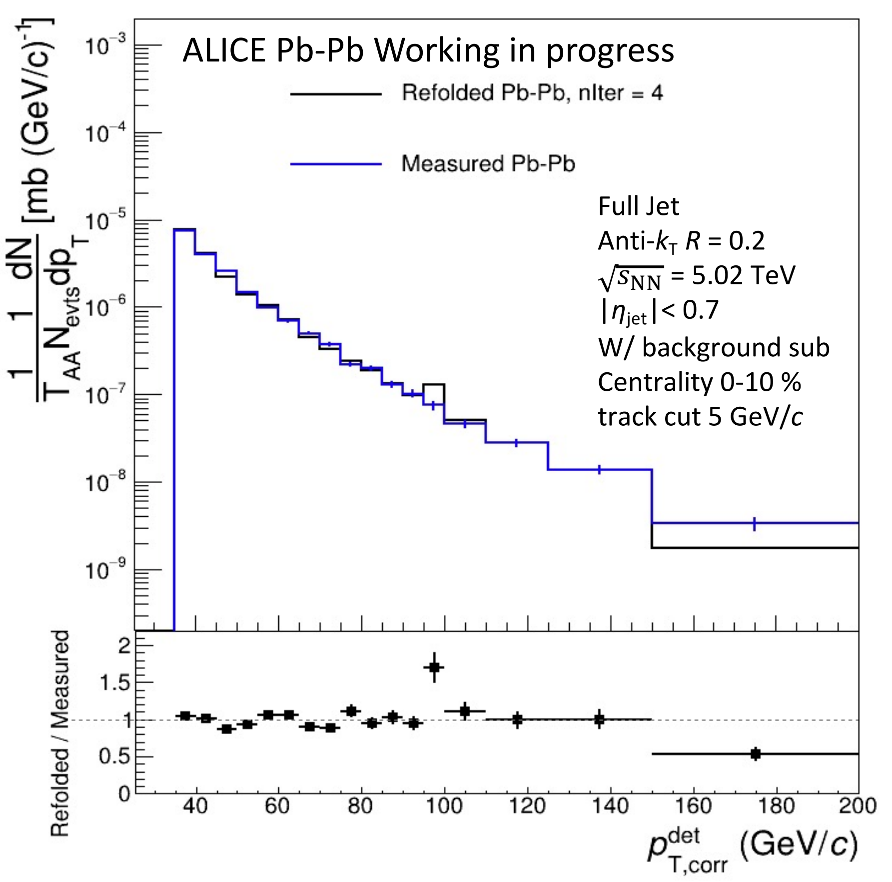
ALICE Collaboration
Phys. Rev. D **100**, 092004



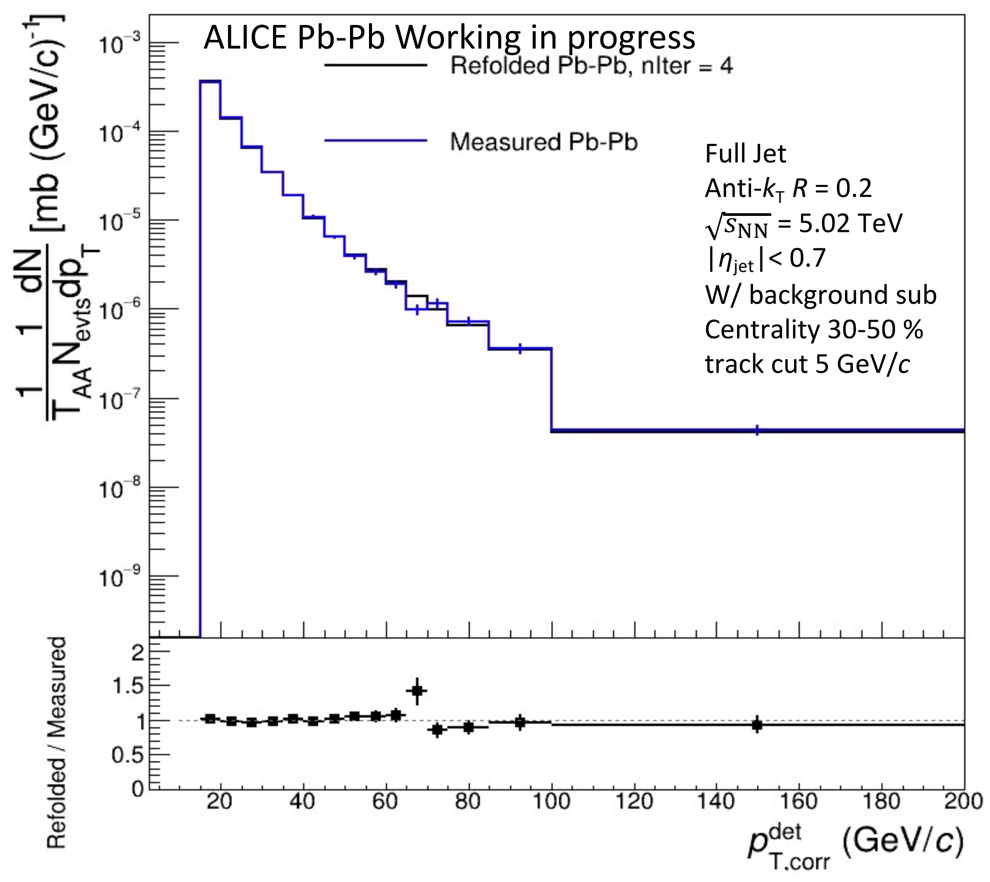
Refold test result

Refold: $\text{jet}^{\text{Mearsure}}_{\text{det}}$ → Unfold → $\text{jet}^{\text{Mearsure}}_{\text{gen}}$ → Fold → $\text{jet}^{\text{Mearsure}}_{\text{det}}$

Bayse 0-10 %



Bayse 30-50 %

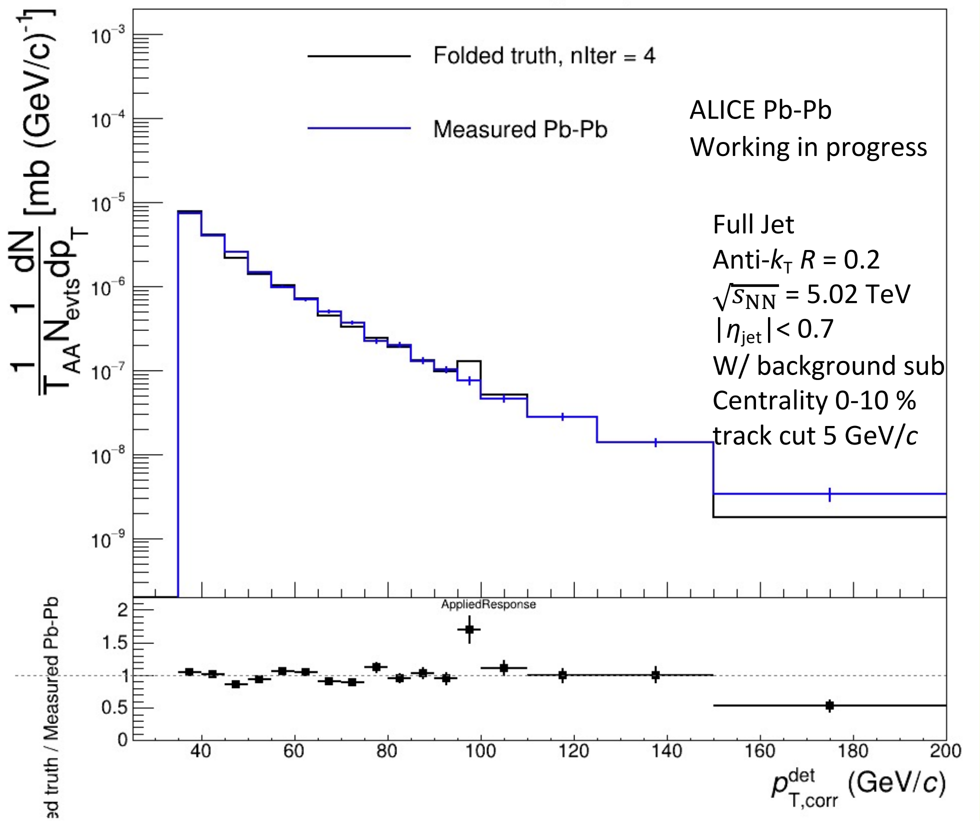


The peripheral result is stable than central one. It is reasonable

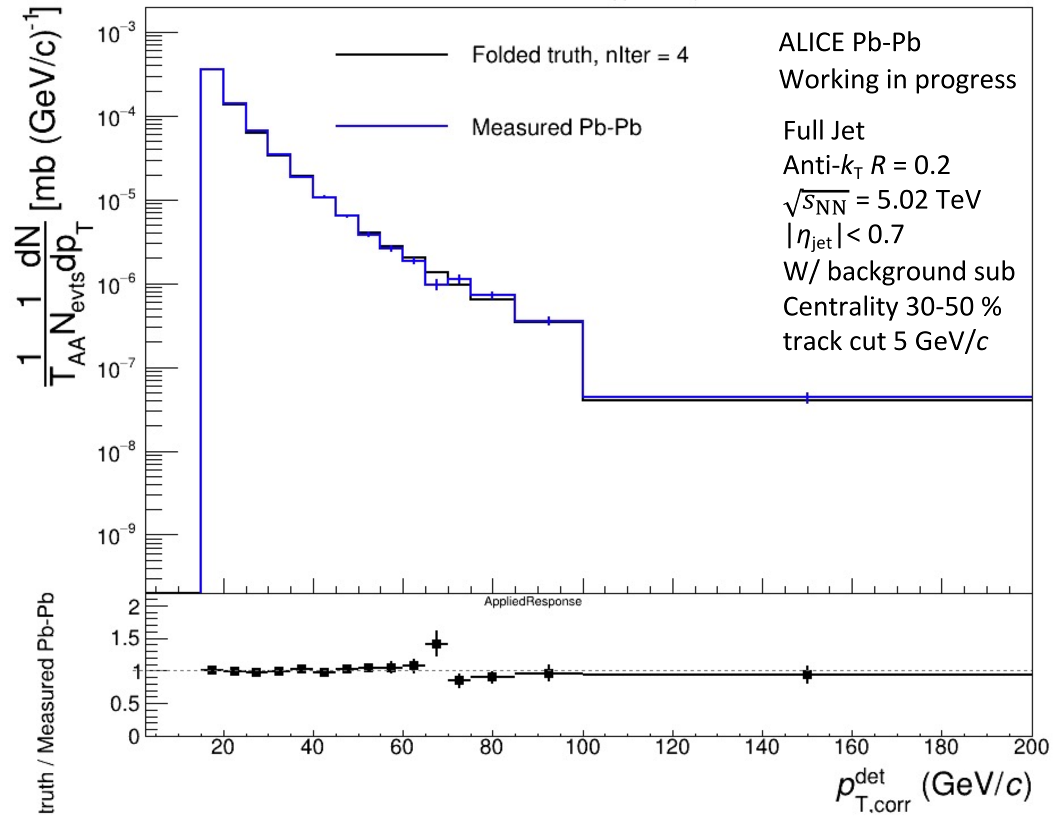
Closure test

Refold: jet^{MC}_{Gen} → Fold → jet^{MC}_{Det}

Bayse 0-10 %



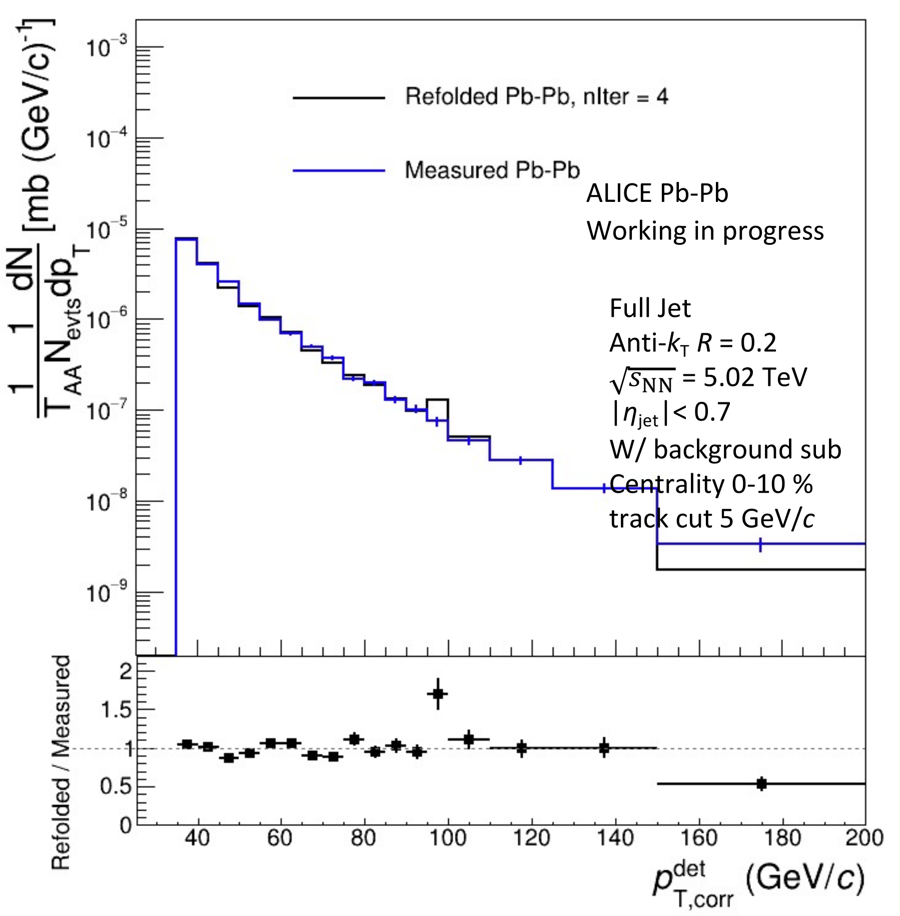
Bayse 30-50 %



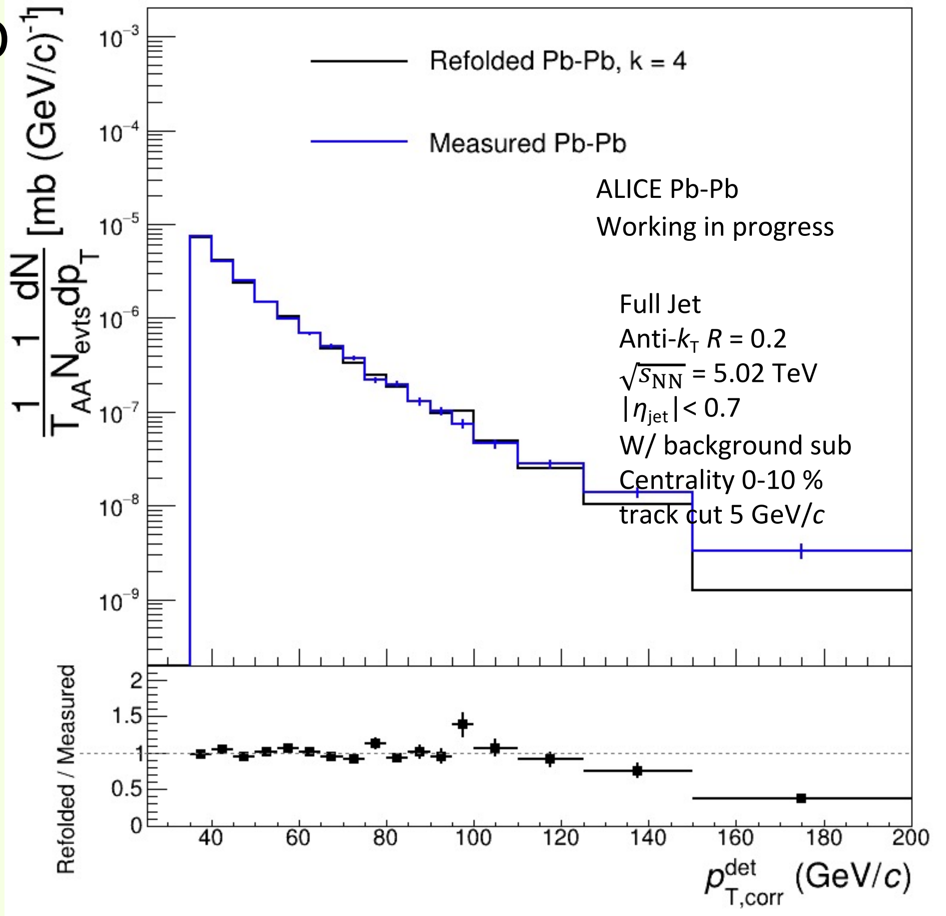
The peripheral result is stable than central one. It is reasonable

Comparison between two unfolding method

Bayse



SVD

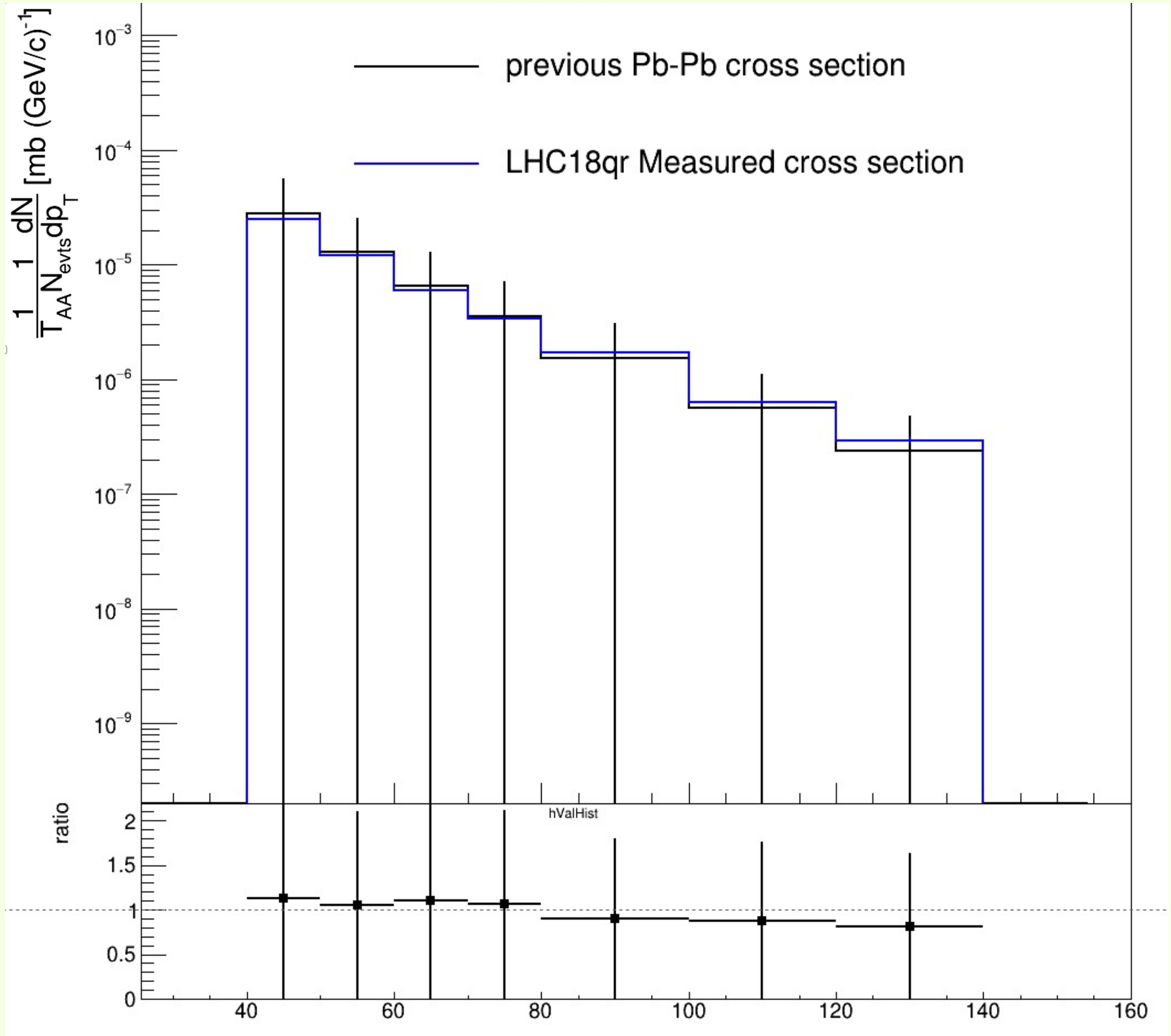


The results of the two kinds of the unfolding methods should be matched.

Mostly these results show the same results.

This difference become systematic uncertainty

Compare with previous study



The unfolded jet yeild is mostly matched the previous study jet yeild.

Change the analysis topic from full jet R_{AA} to charged jet R_{AA} and v_2

Full jet analysis

- I felt the only R_{AA} analysis cannot predict anything to physics.
- Full jet analysis takes much memory, so it is difficult to get permission of usage the train.

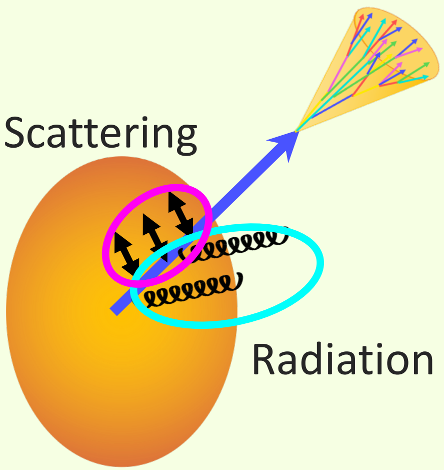
I am very interested in the gamma-jet analysis before long time.

-> But my doctoral term does not remain to do this difficult theme.

Charged jet analysis with Event plaen analysis

Add v2 measurement

Clarify the jet suppression mechanism



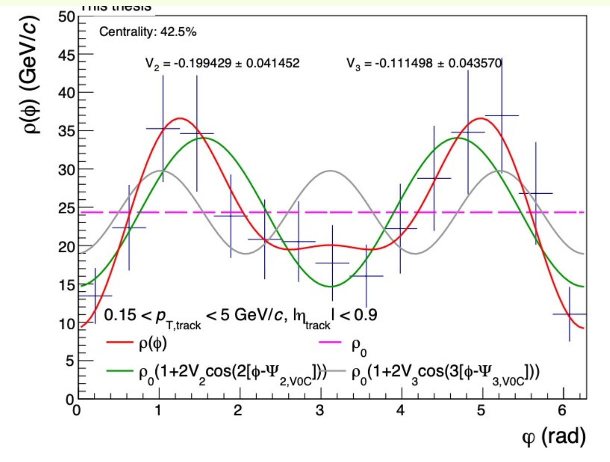
$$v_2^{\mathrm{jet}} = \frac{1}{\mathrm{Res}\left\{\psi_2^{meas}\right\}} \frac{\pi}{4} \frac{N_{in} - N_{out}}{N_{in} + N_{out}}$$

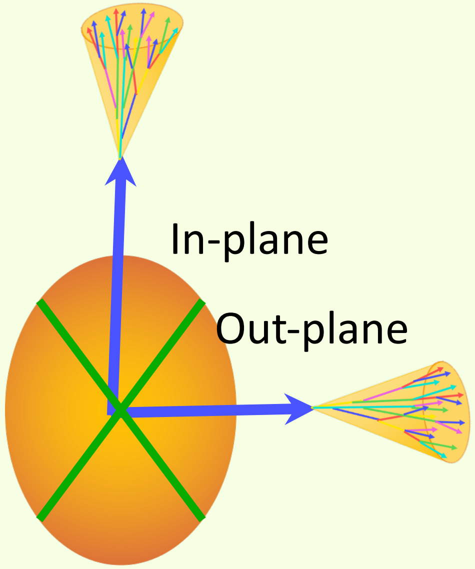
N_{in}, N_{out} : Jet yield at in-plane and at out-of-plane

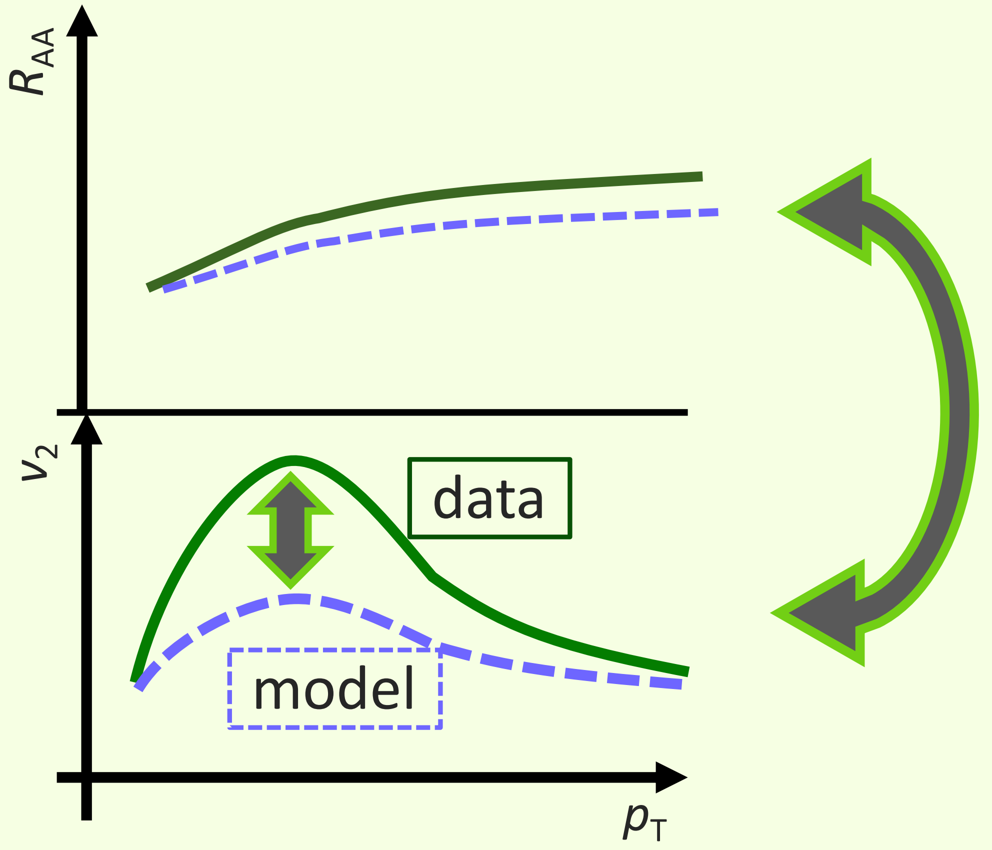
$\mathrm{Res}\left\{\psi_2^{meas}\right\}$: Event plane resolution

Radiation / Scattering dominant?

→ L^2 or L







Radiation / Scattering dominant?

→ L^2 or L

Current Progress

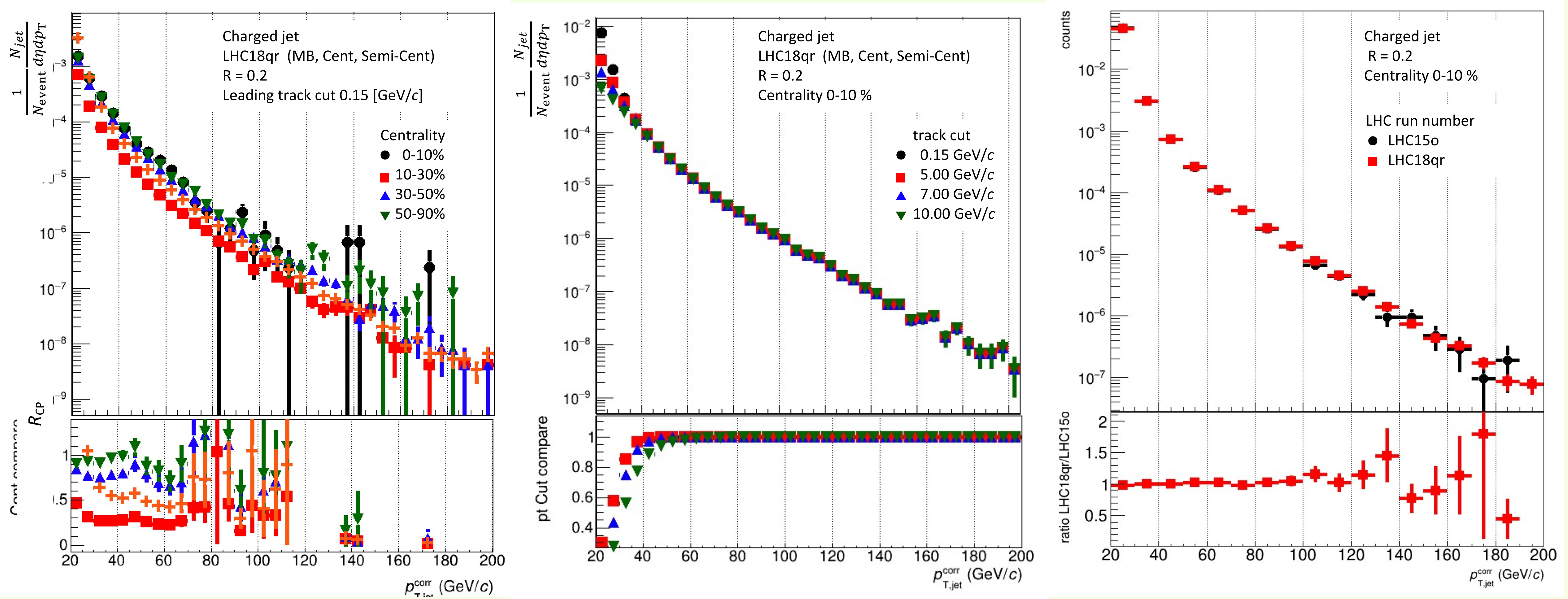
1. Create a new own task code.
 1-1. Git Merge (done)
 1-2. Train run (done)
 1-3. Run the code to read result file (done)

2. Event plane calibration code
 2-1. Test run of the code (done)
 2-2. Apply this code for train (on-going)
 2-3. Run train

3. Mearsure the Raw jet for each event plane
 3-1. Test run a simple code that gets event plane[w/o calibration] (done)
 3-2. Impliment more detail V2 calculation code (AliAnalysisTaskV2) (on-going)
 3-3. Run train code (after 2)

4. Embedding, Unfolding, Systematic Error

Raw Jet distribution



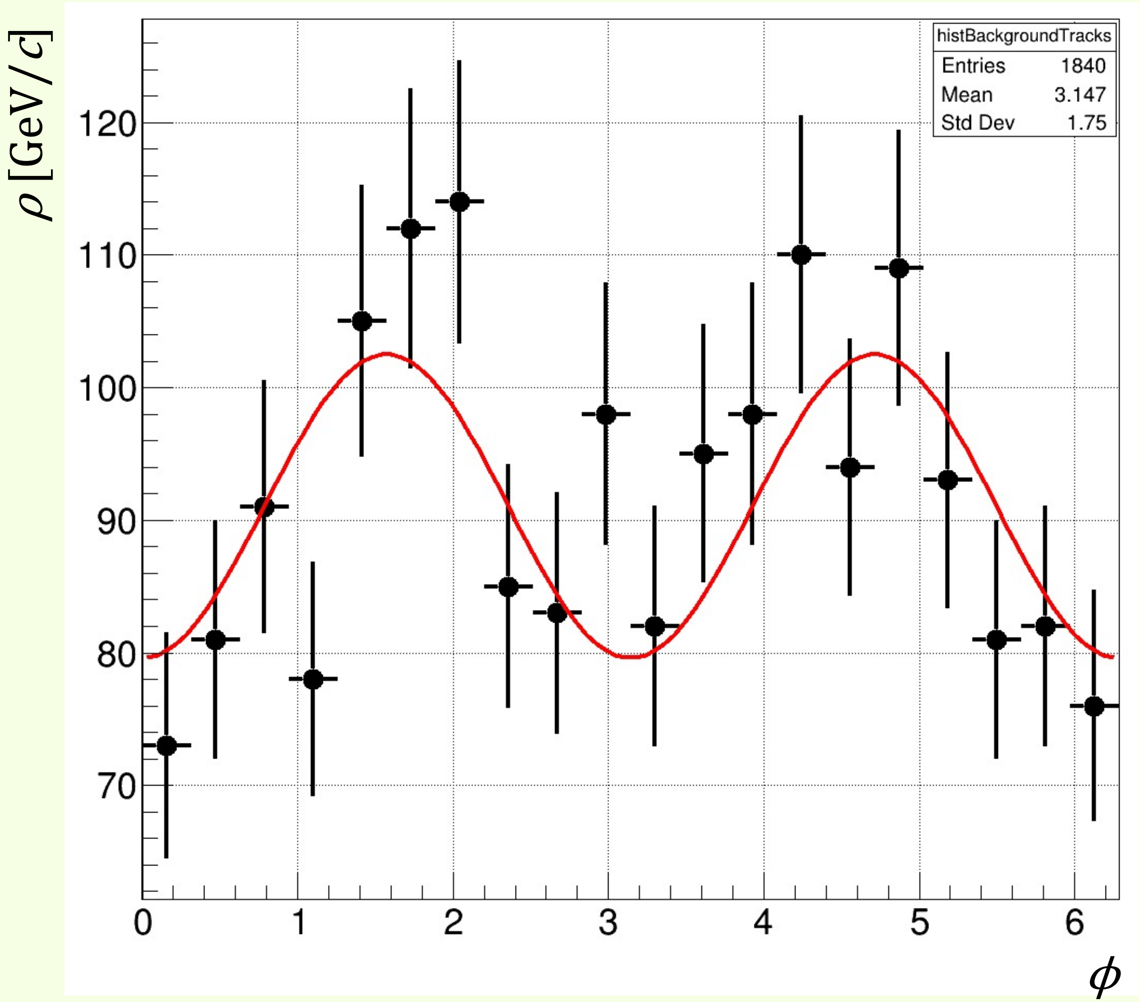
Cetrarity dependence

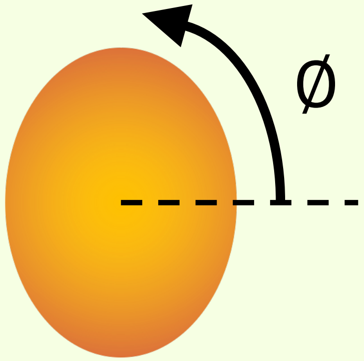
Leading track pt cut dependence

Difference between the run periods

Local Rho (background p_T density)

1 event



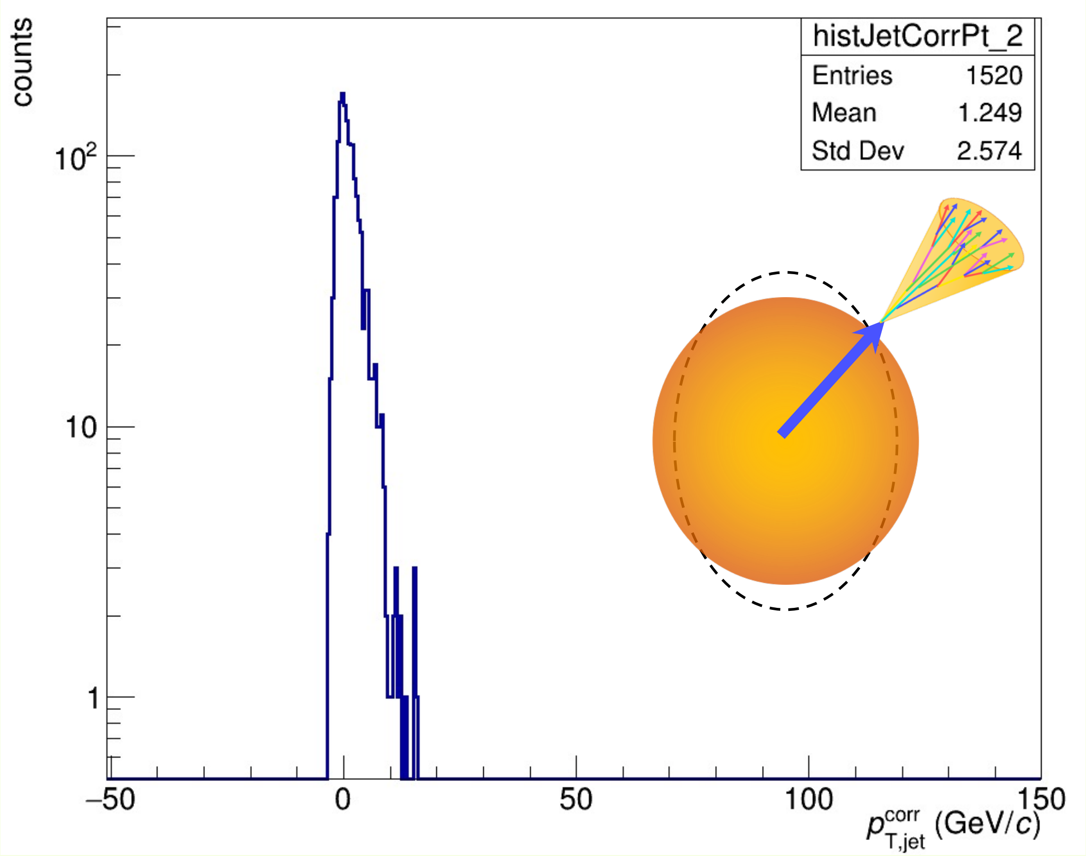


-> Need to calculate more detail event plane angle and correct phase.

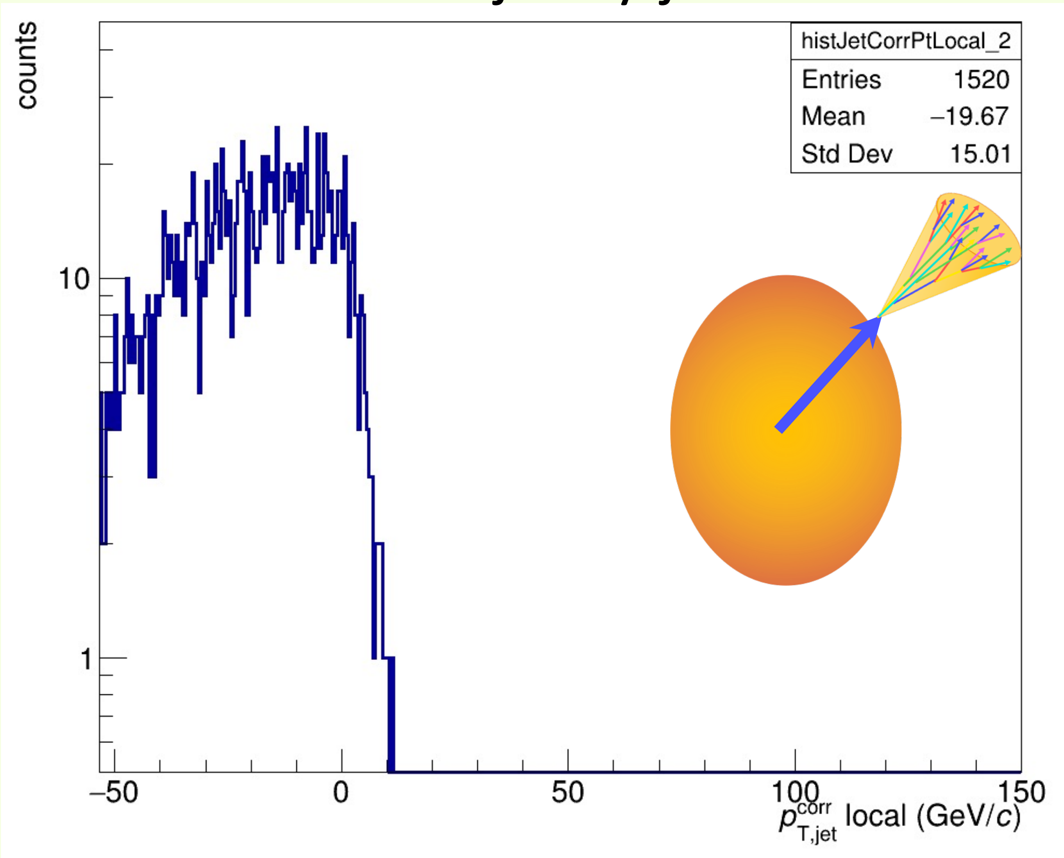
Compare backgroudn subtraction (average vs local)

300 Events

Average rho event-by-event



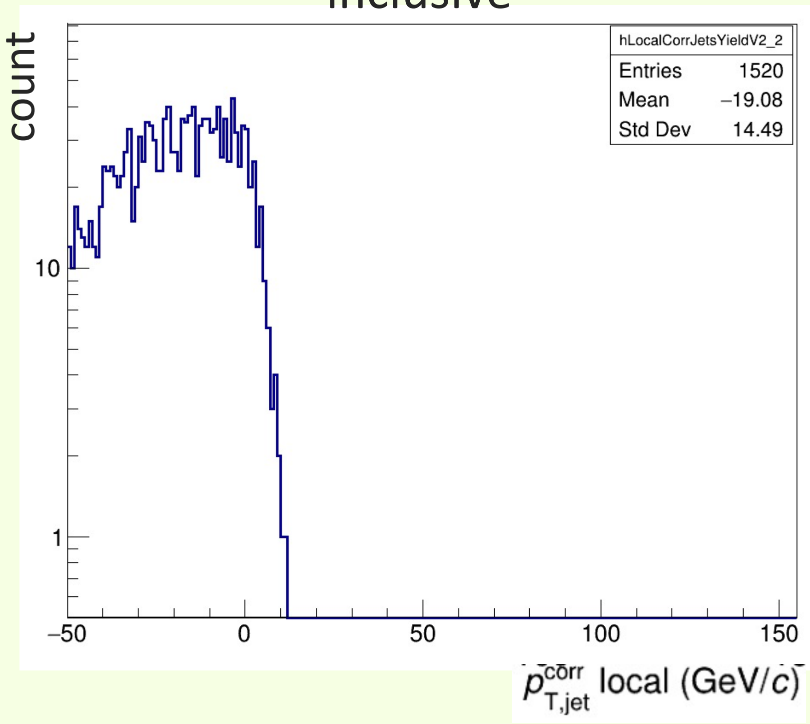
Local rho jet-by-jet



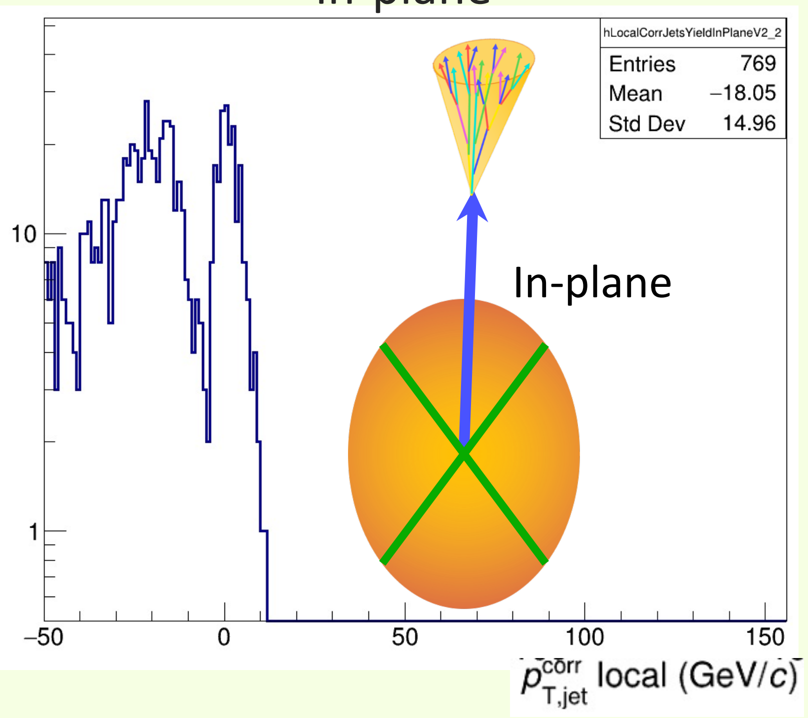
the local background measurement lower than average. But I still do not search the reason.

Compare differencies of the jet yields for dϕ

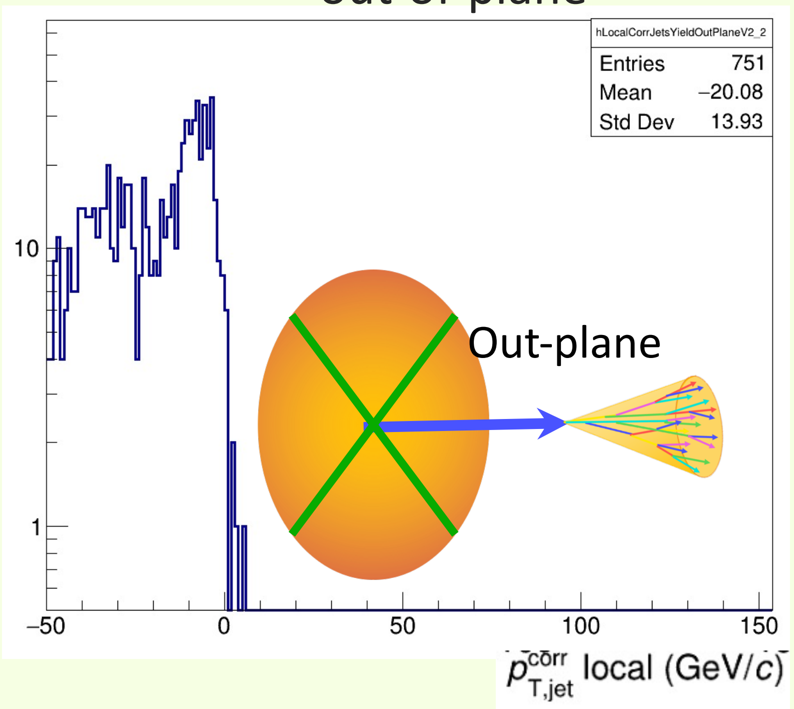
inclusive



in-plane



out-of-plane



- Need more accurate event plane measurement and calibration
- Need more statistic

Next plan

1. Create a new own base task code. (done)

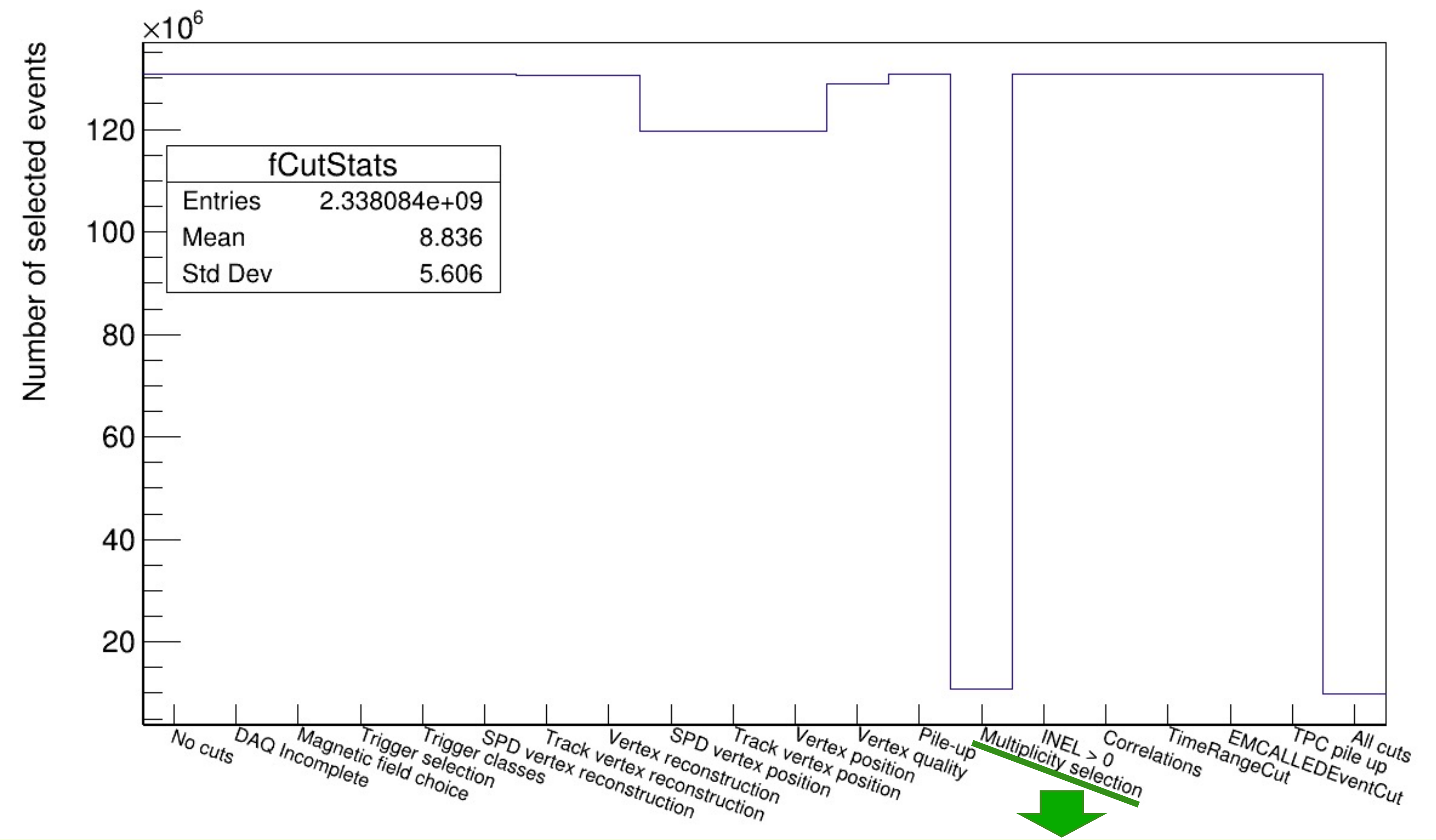
2. Event plane calibration code
   2-1. Test run of the code (done)
   2-2. Apply this code for train (on-going -> mid-Dec)
   2-3. Run train (the end of Dec)

3. Mearsure the Raw jet for each event plane
   3-1. Test run a simple code that gets event plane[w/o calibration] (done)
   3-2. Impliment more detail V2 calculation code (AliAnalysisTaskV2) (on-going -> mid-Dec)
   3-3. Run train code (Jan)

4. Embedding (Feb/Mar)
5. Unfolding (Ape)
6. Systematic Error (May)

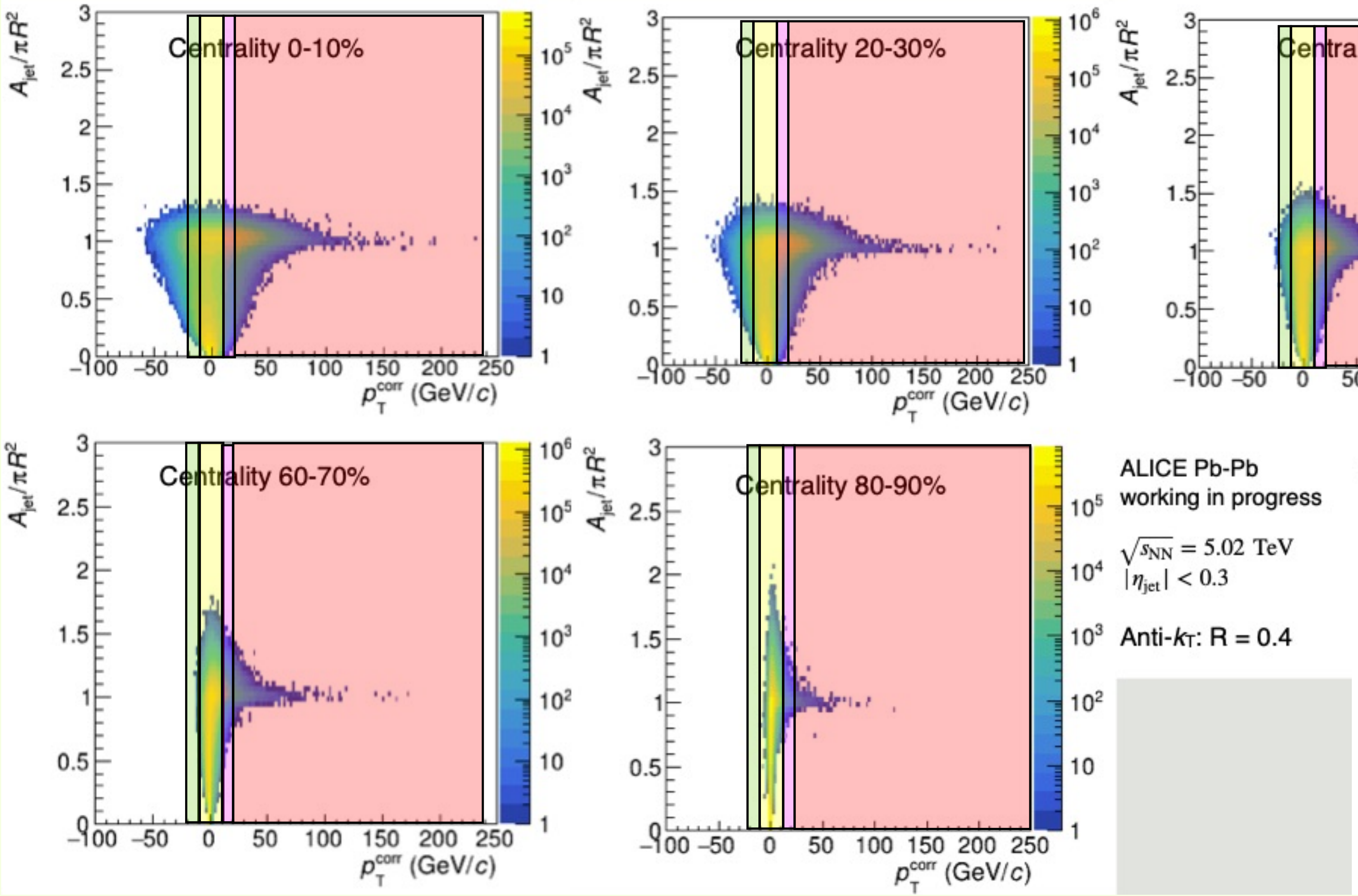
Backup Slides

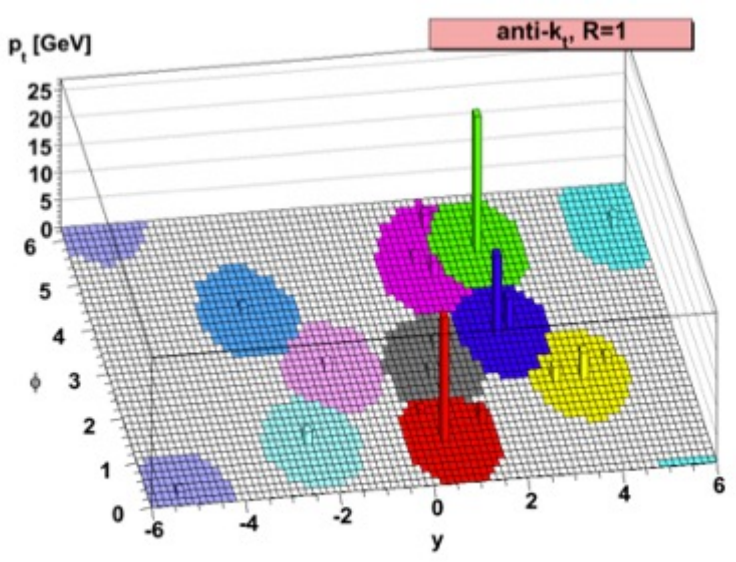
LHC20g4 cut status

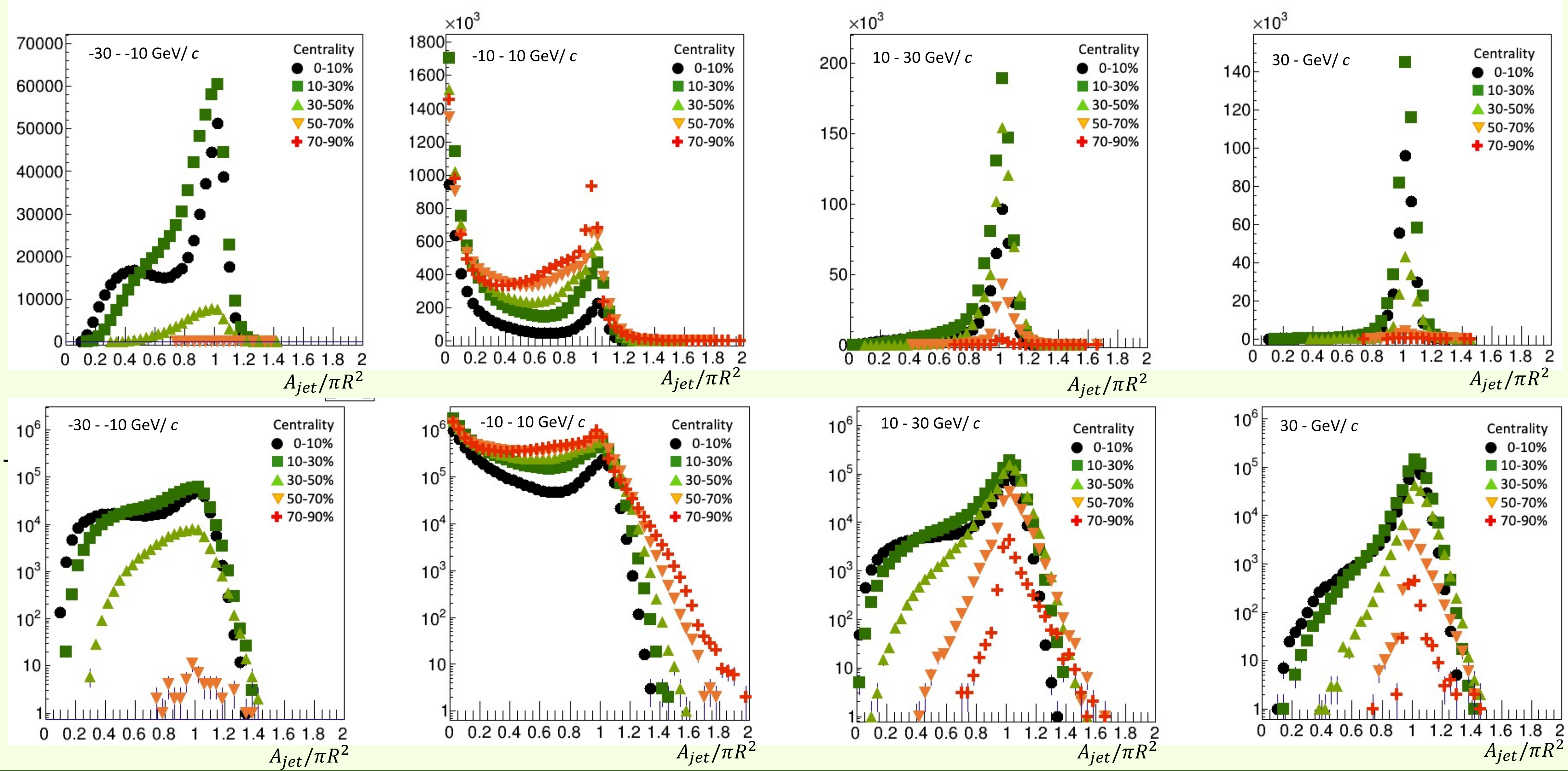


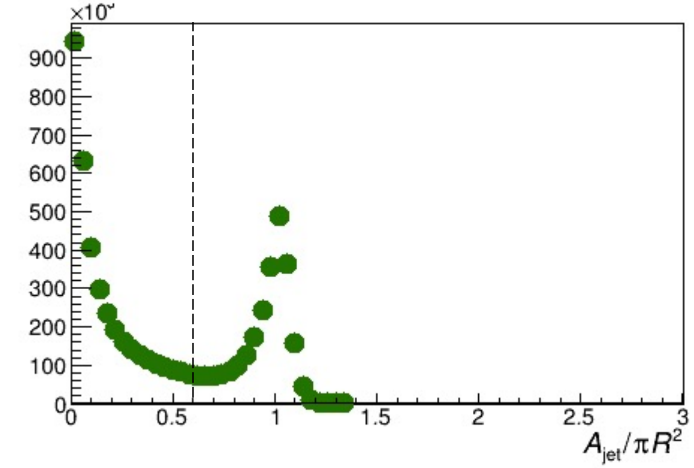
It is essential to estimate the reason why the multiplicity cut is so large

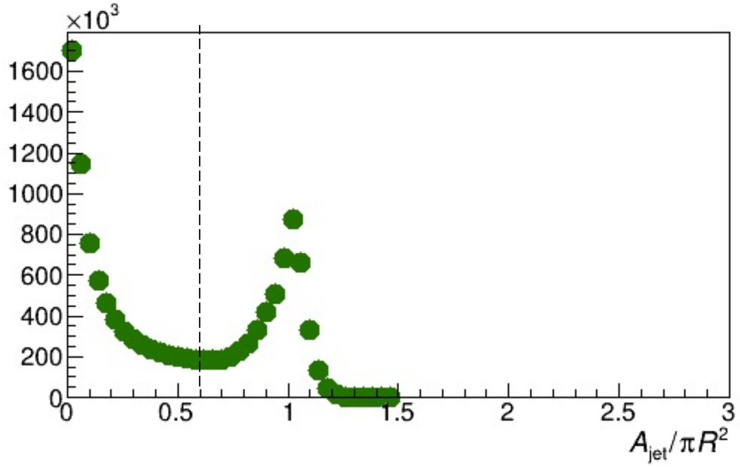
Previously meeting, I mistook plotting them (profile -> projection). Following plots seems good.

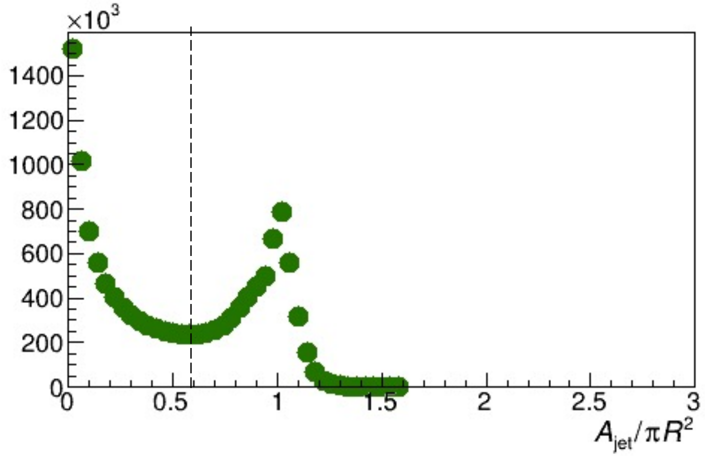


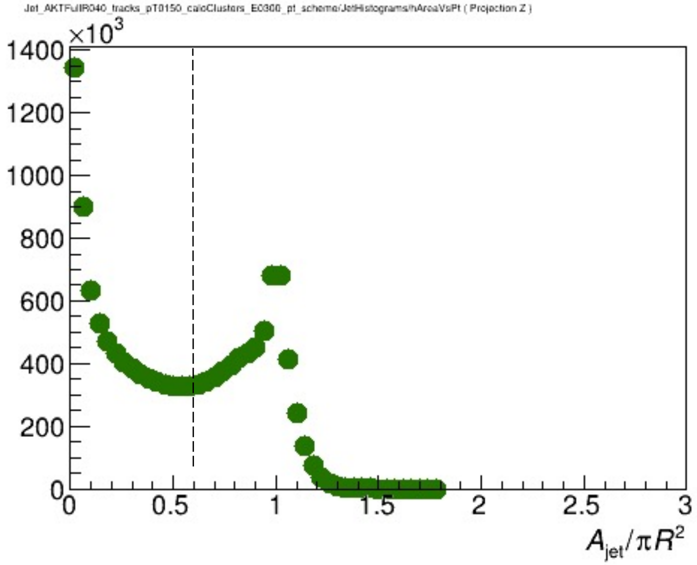


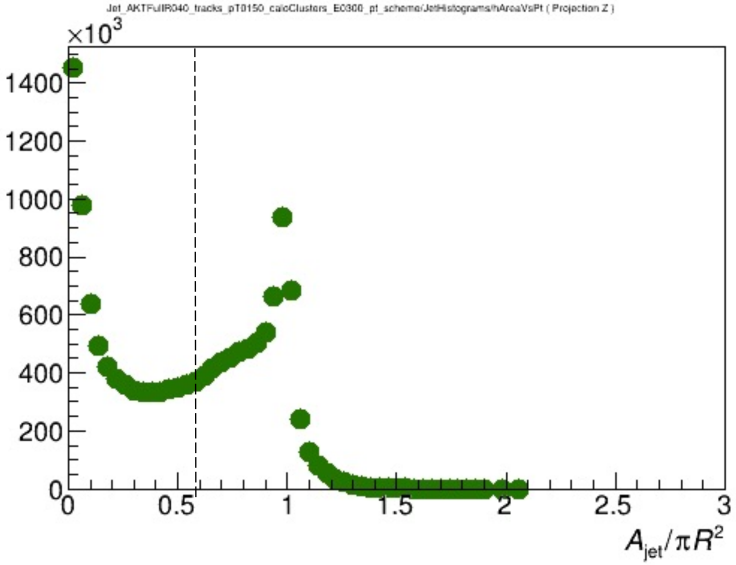

-30 - -10 GeV/ c
-10 - 10 GeV/ c
10 - 30 GeV/ c
30 - GeV/ c
Centrality
0-10%
10-30%
30-50%
50-70%
70-90%
$A_{jet}/\pi R^2$
×10^3







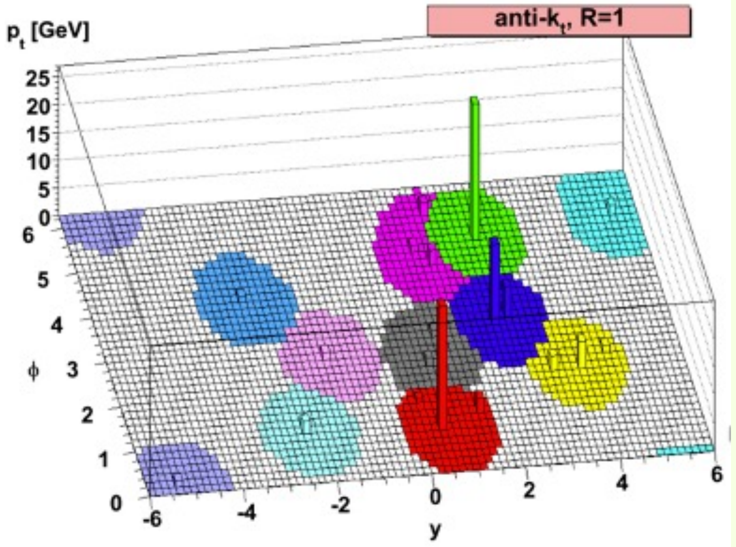


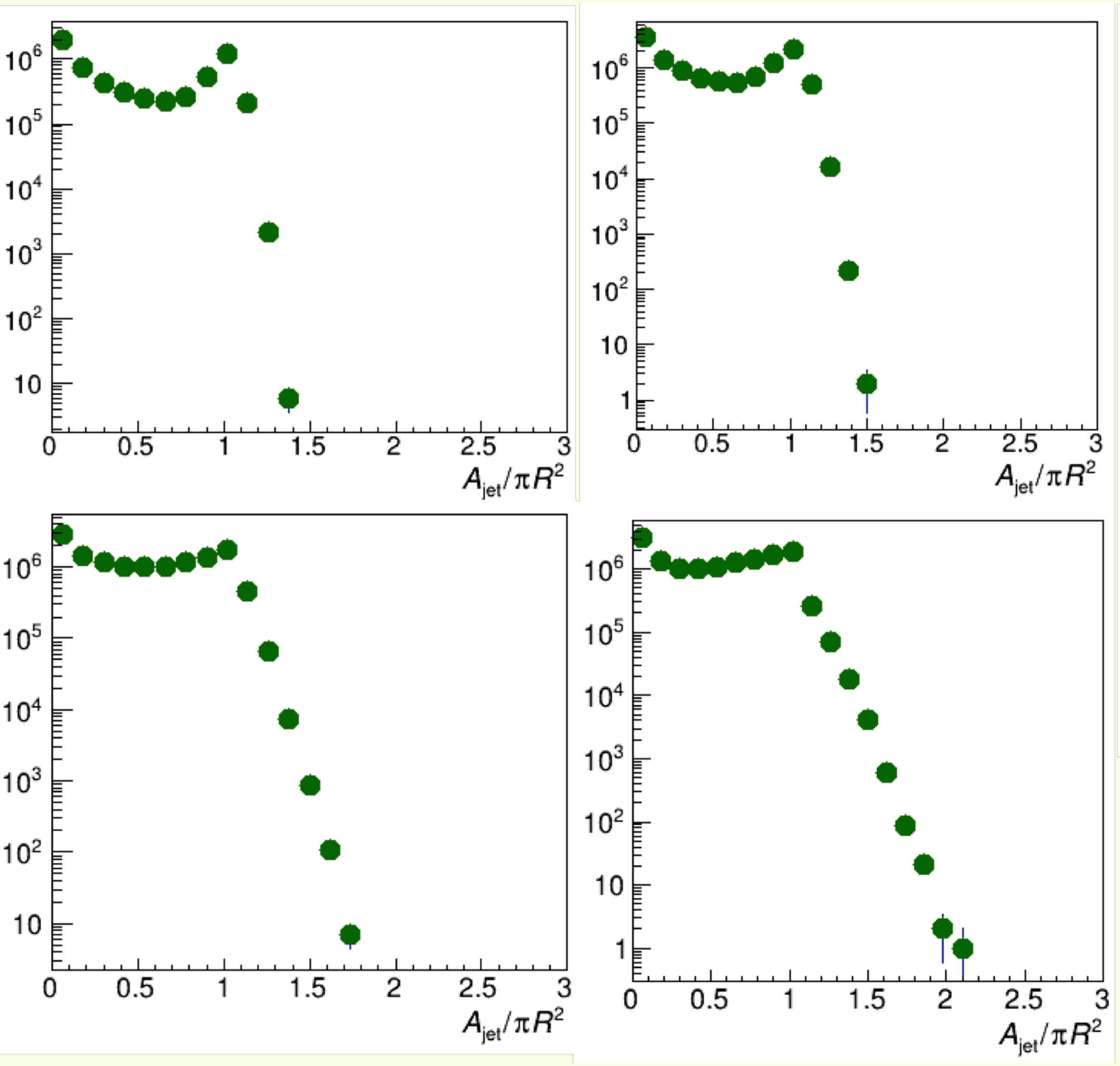


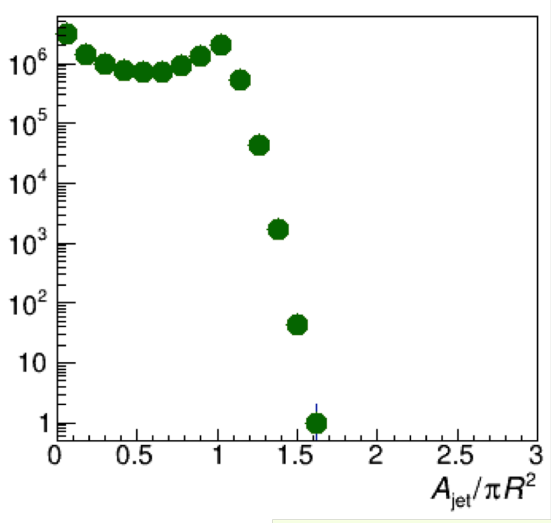
ALICE Pb-Pb
working in progress

$\sqrt{s_{NN}} = 5.02$ TeV
$|\eta_{jet}| < 0.3$

Anti-k_T: R = 0.4



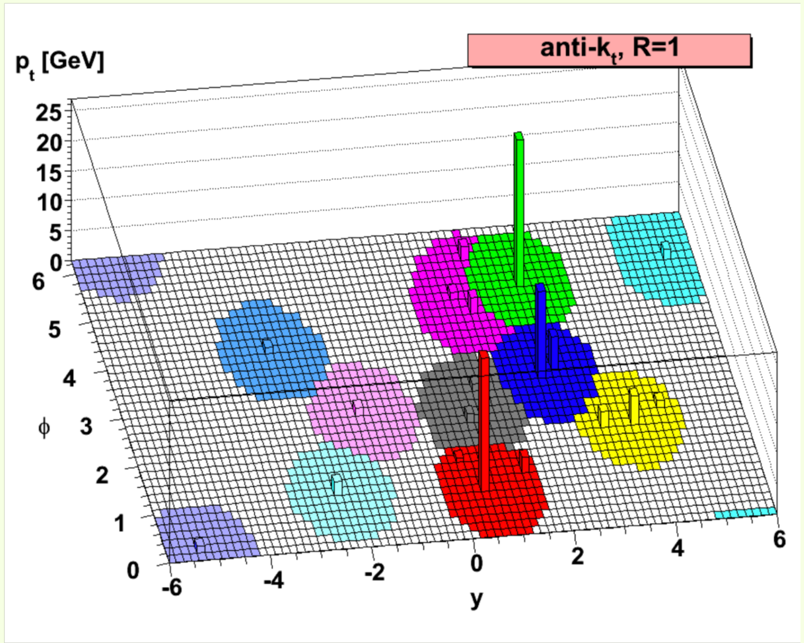




ALICE Pb-Pb
working in progress

$\sqrt{s_{NN}} = 5.02$ TeV
$|\eta_{jet}| < 0.3$

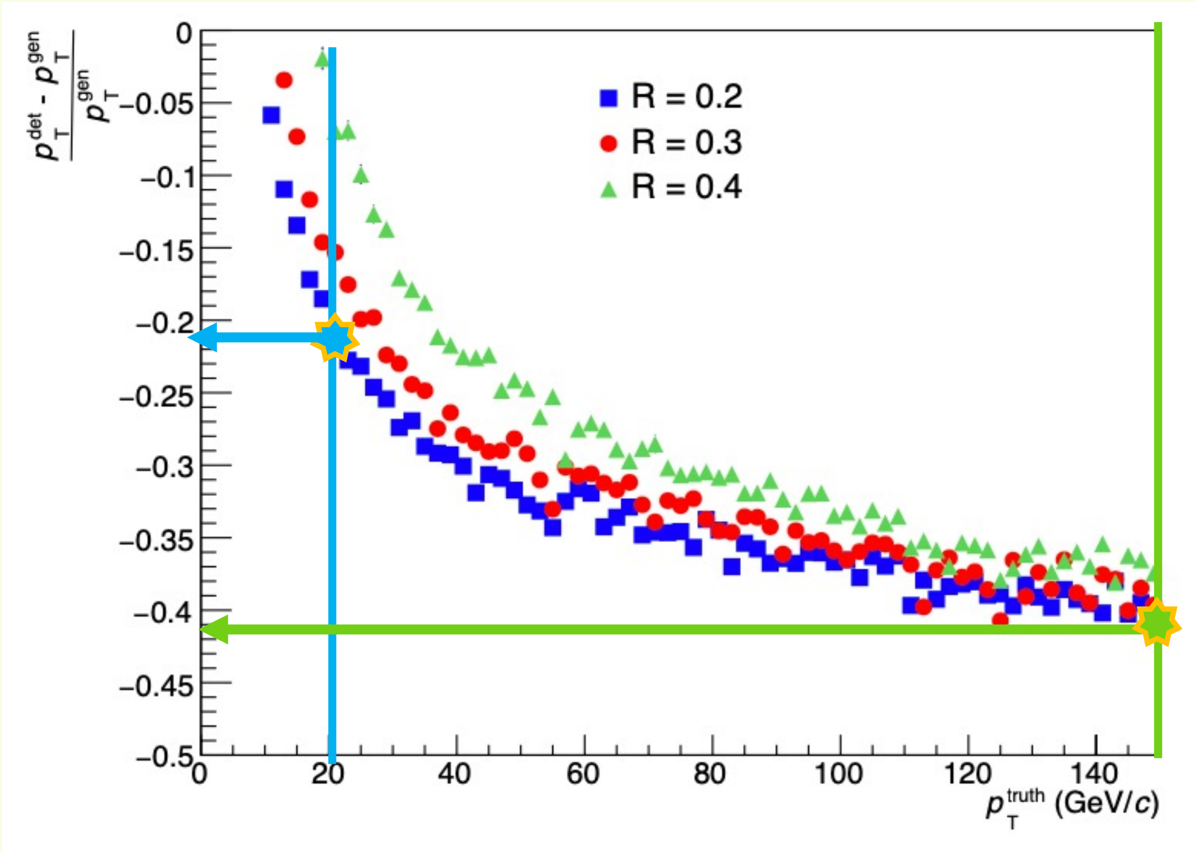
Anti-k_T: R = 0.4



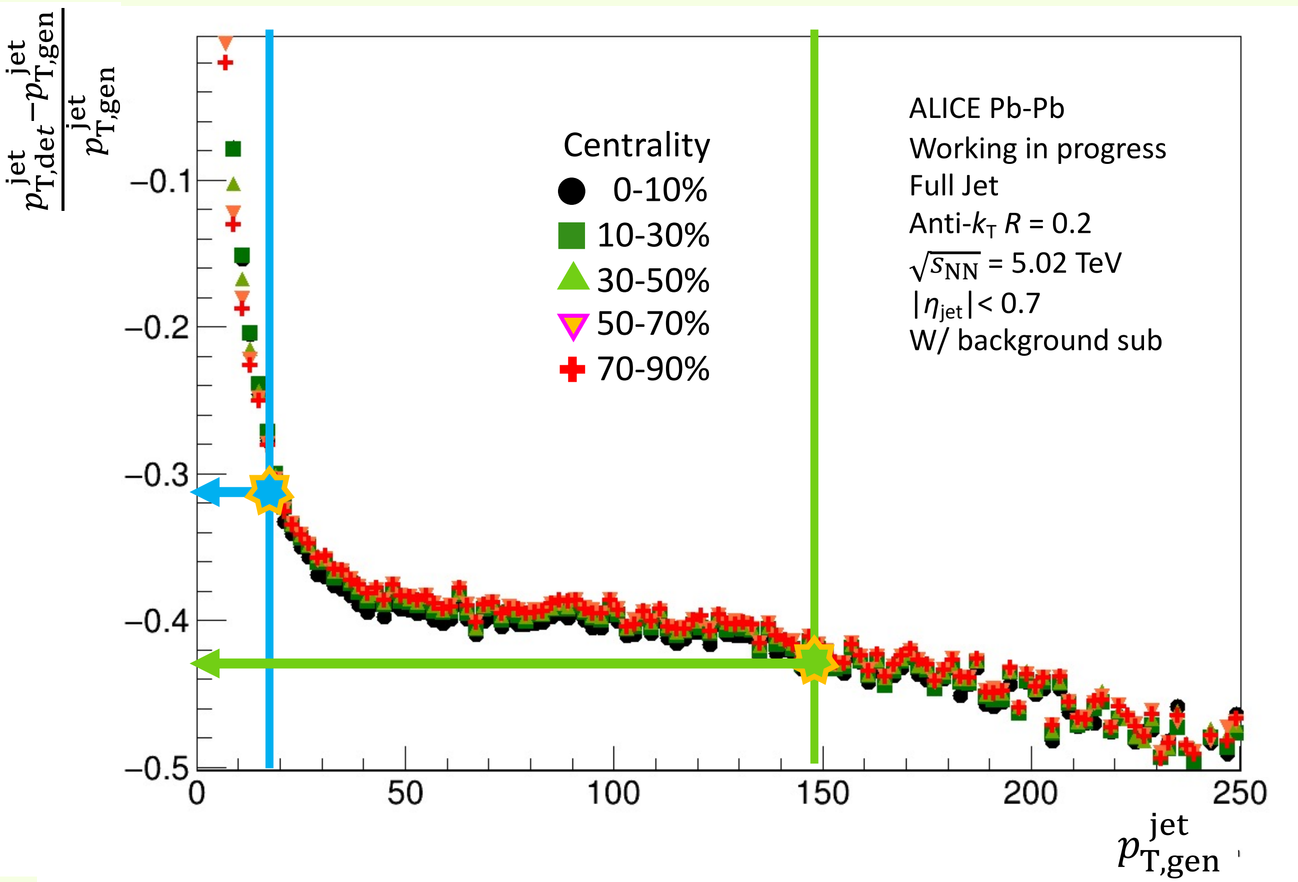
LHC15o Comparison

Jet Energy Scale(JES) shift

Preceding Study (2015)



This Study (LHC18r)



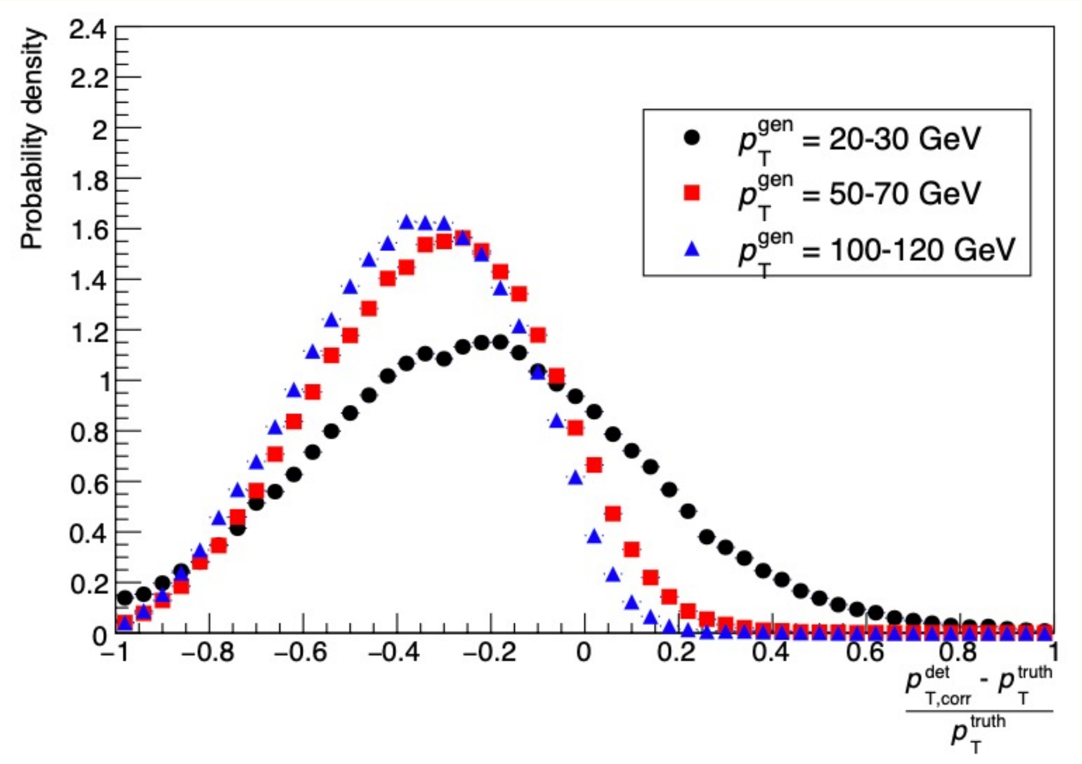
- The comparison result seems mostly the same.

On the other hand, the LHC18 result shows a sharply decreasing than the LHC15.

- The LHC18 results do not show the centrality dependence. (That seems strange)

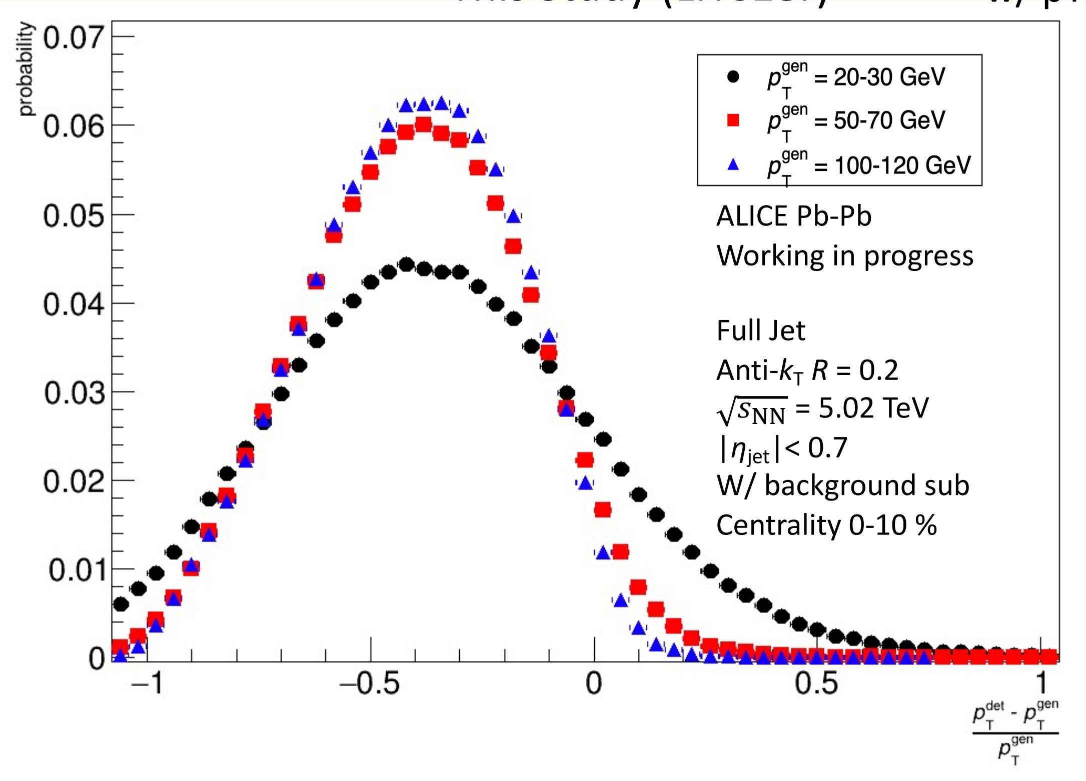
Jet Energy Scale(JES) shift

Preceding Study (2015)



This Study (LHC18r)

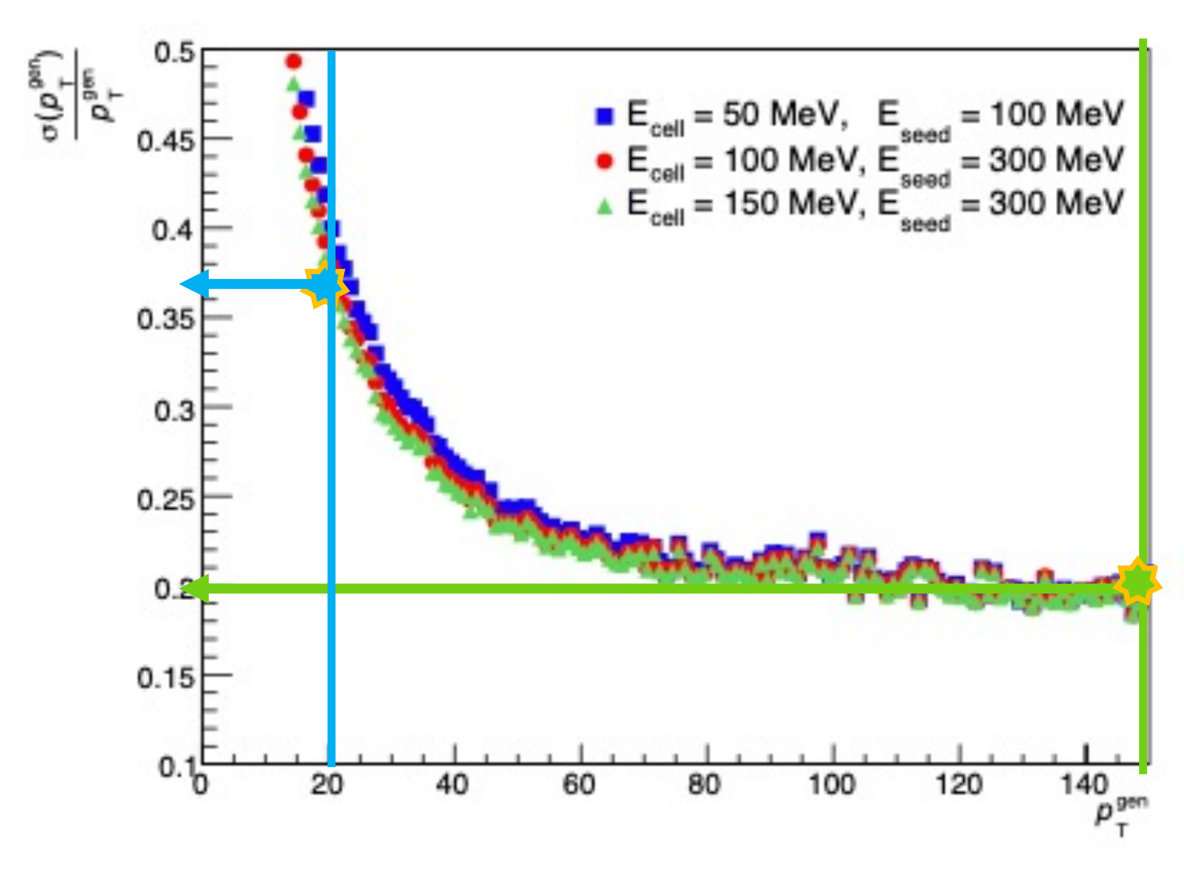
w/ pT scale



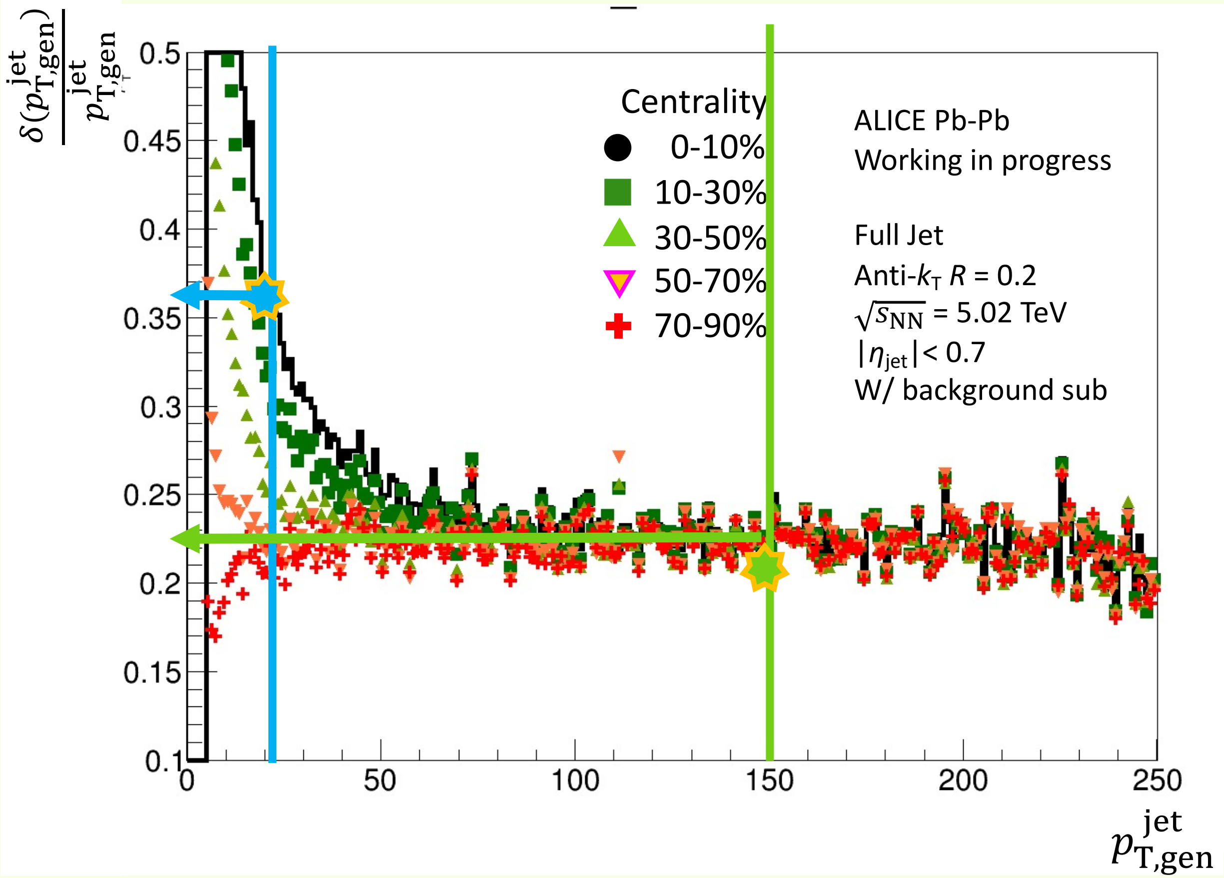
These plot’s shapes are similar.

Jet Energy Resolution (JER)

Preceding Study (2015)



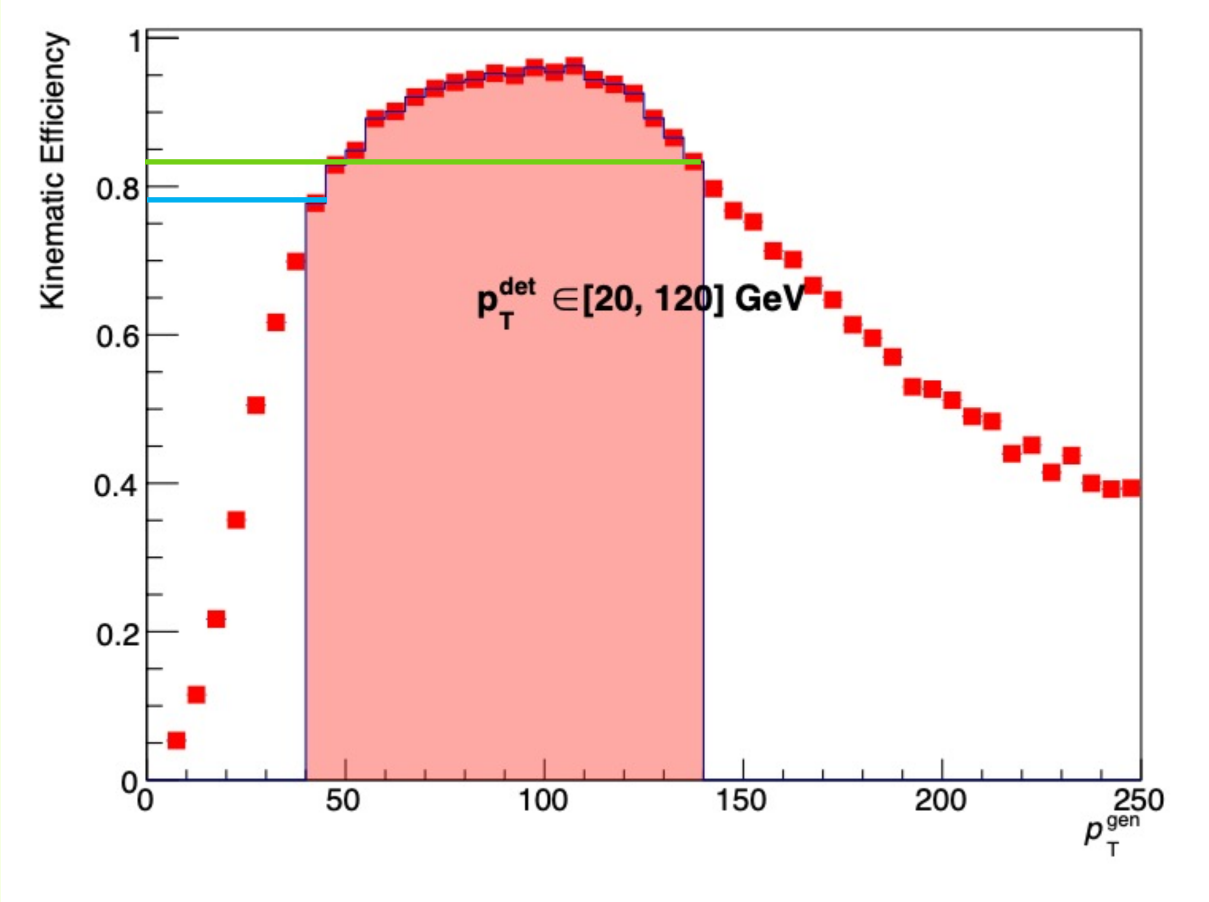
This Study (LHC18r)



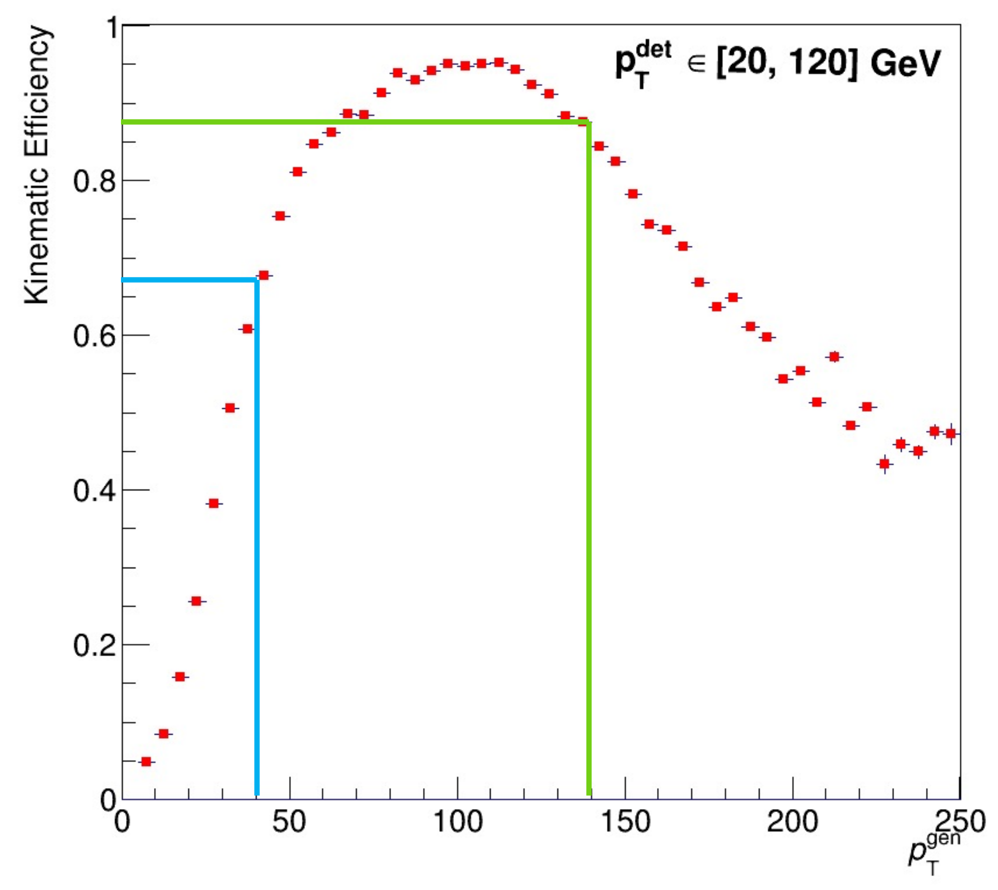
The JER plot of this study is far from the preceding study.
-> I still not understand the reason.

Kinematic efficiency

Preceding Study (2015)



This Study (LHC18r)

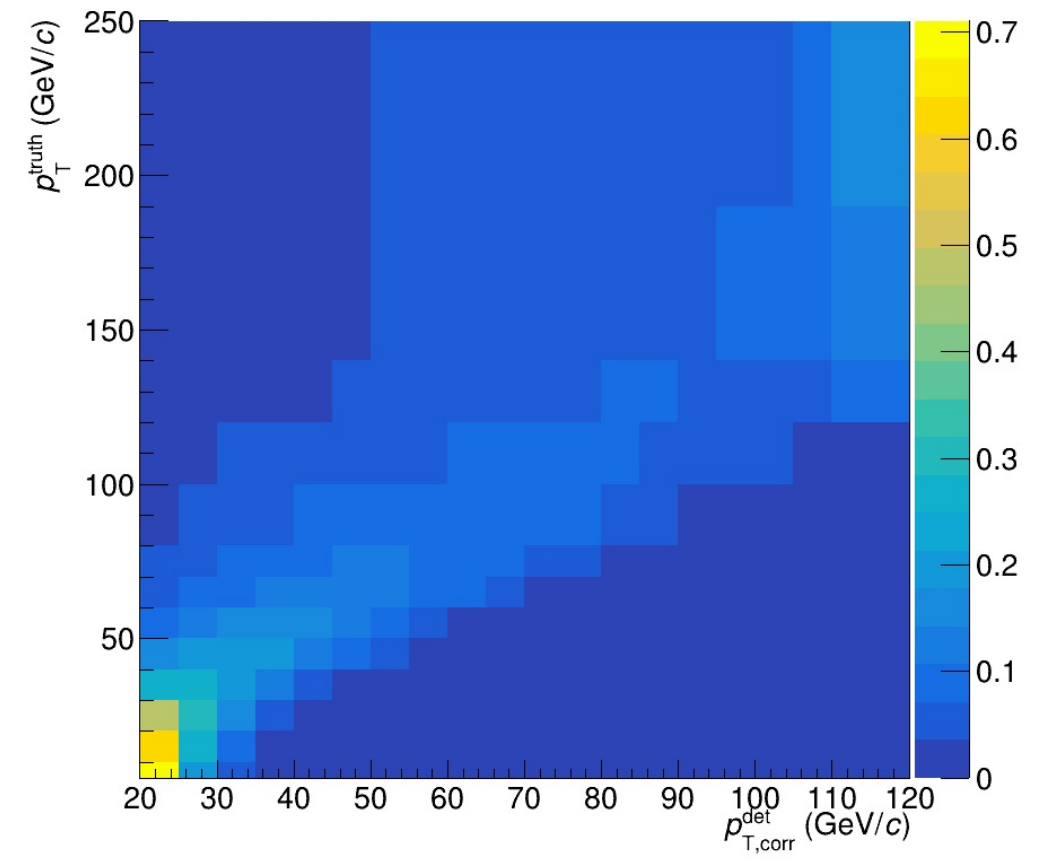


In high pT region, the efficiency seems resonable.

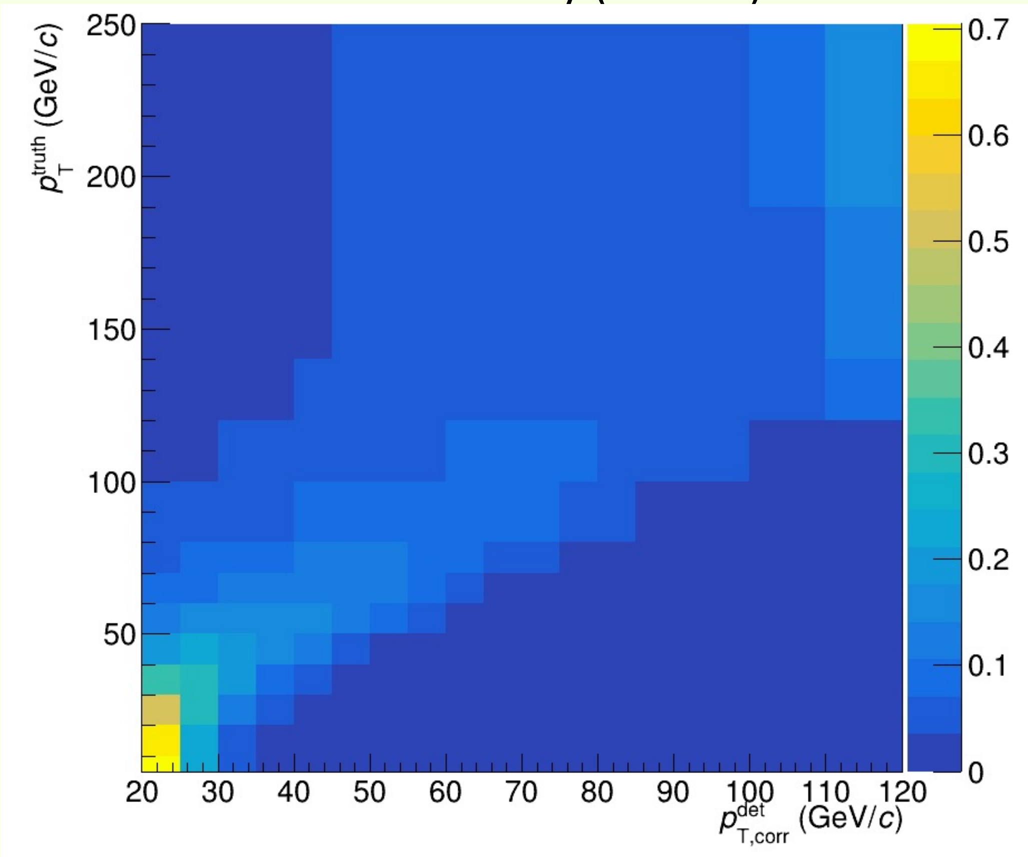
On the other hand, in low pT region, LHC18r result is lower than LHC15o results.

Response matrix

Preceding Study (2015)



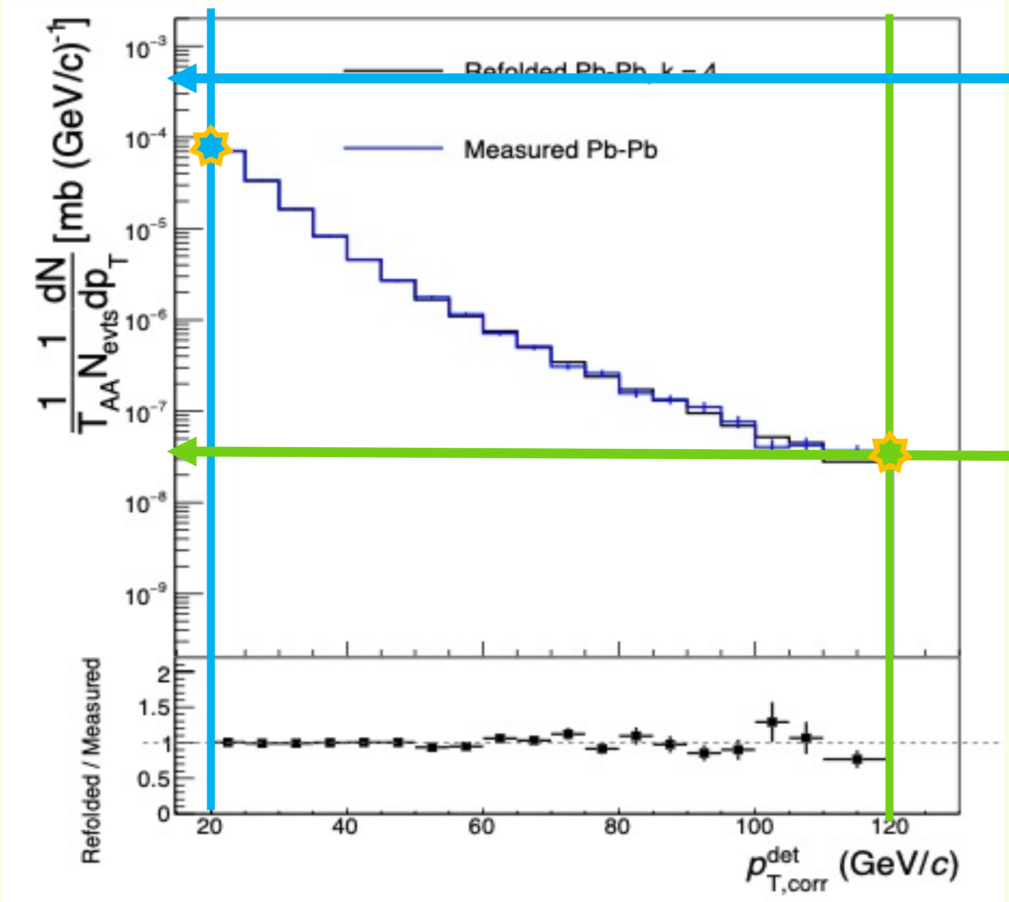
This Study (LHC18r)



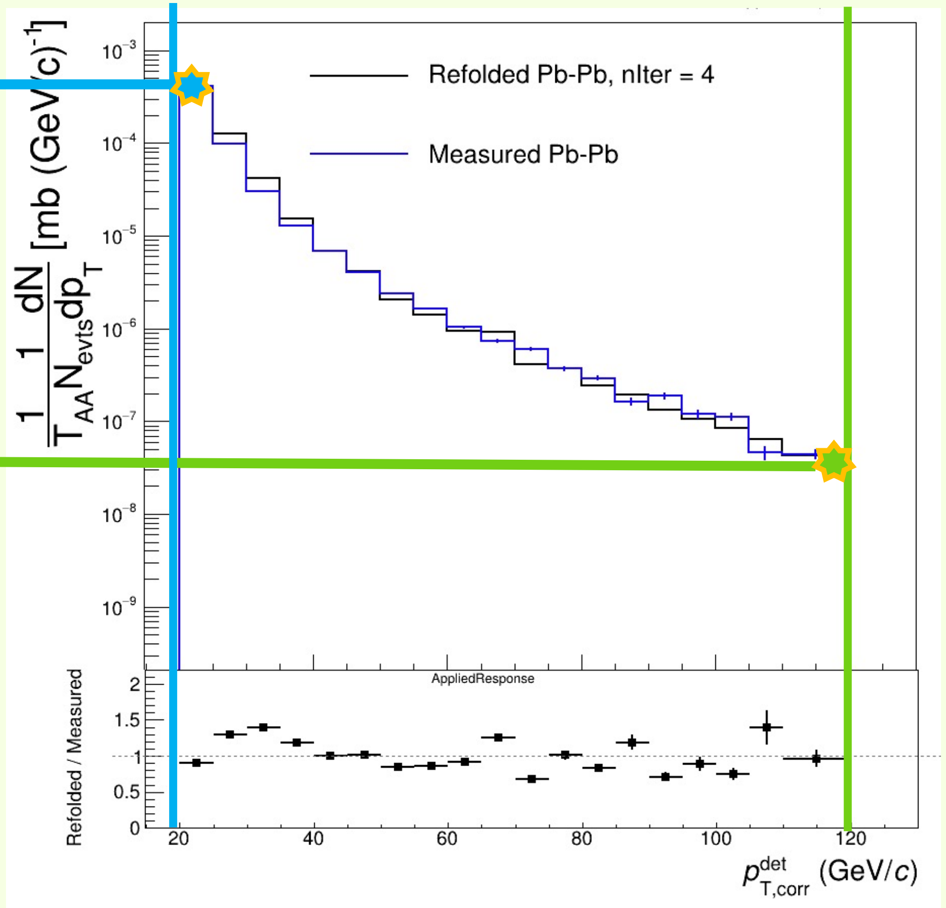
Mostly same reslut.

Refolding results

Preceding Study (2015)



Preceding Study (LHC18qr)



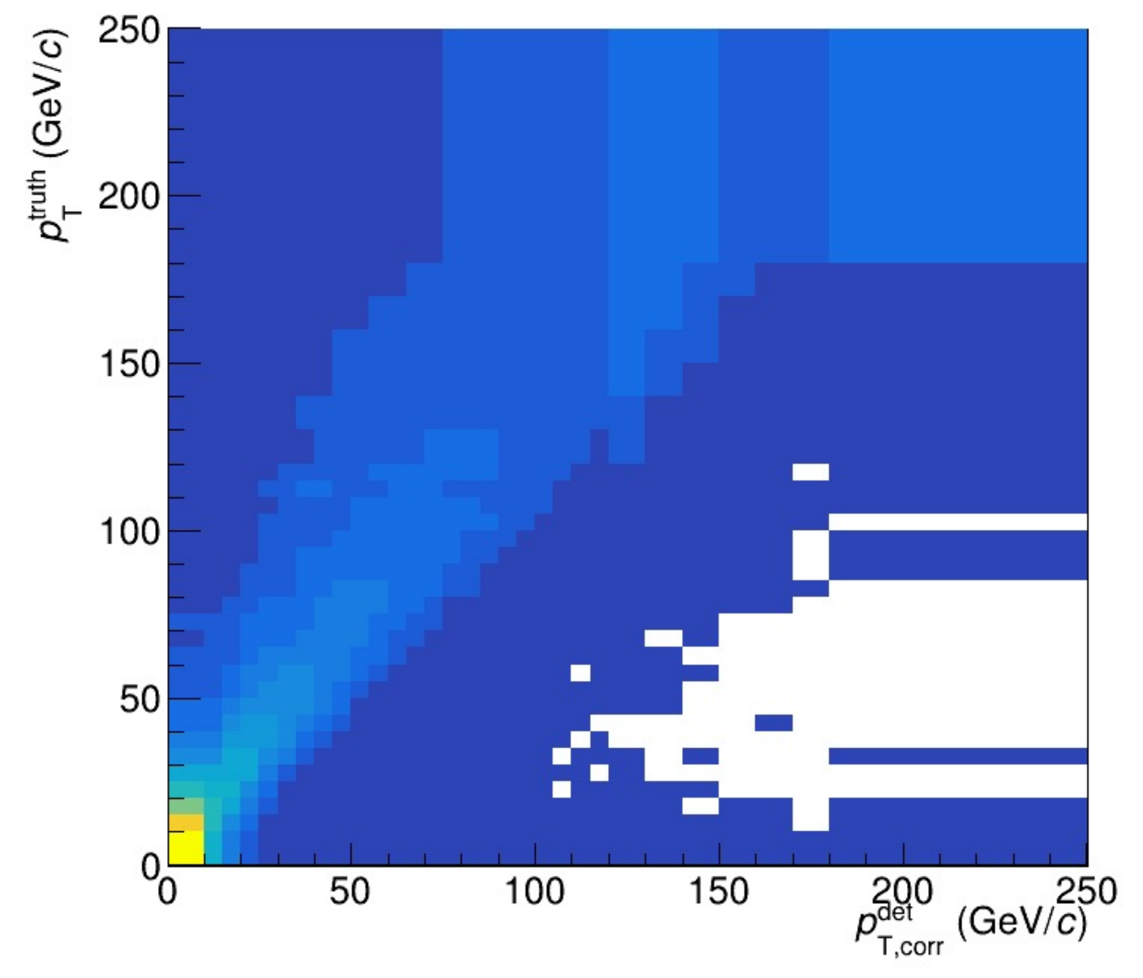
The measured resutls look slimilar.

However, the LHC18r refold results not stable.

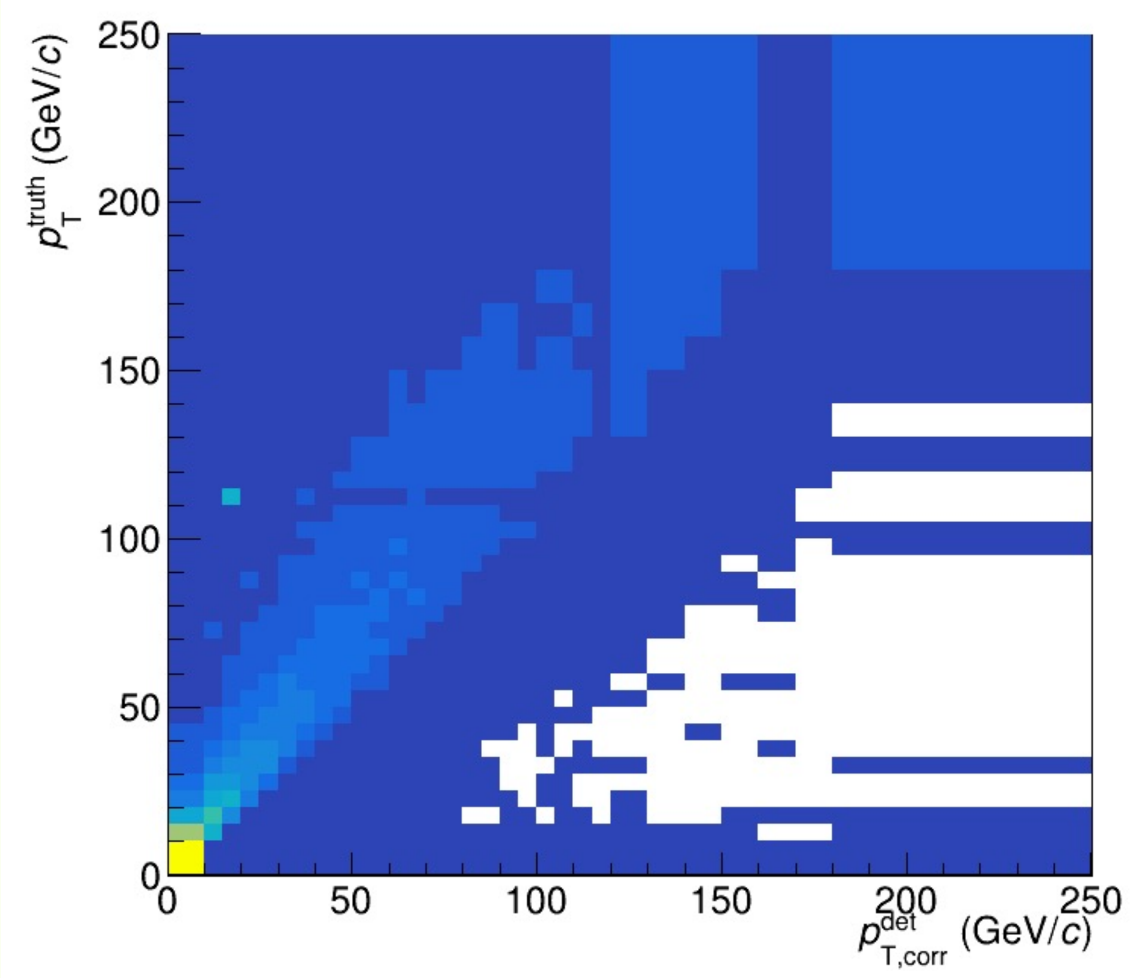
Different Centrality Comparison

Response Matrix (rebinned)

Centrality 0-10 %



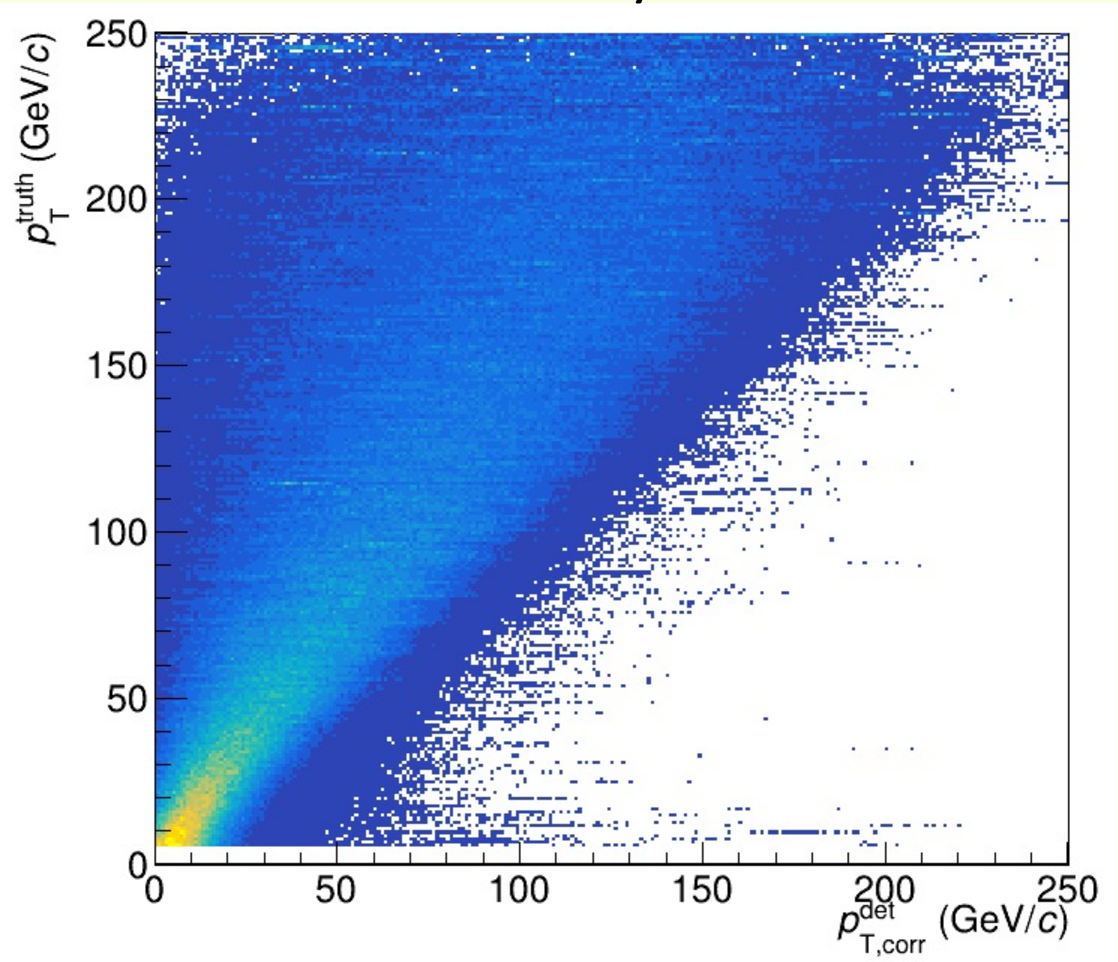
Centrality 70-90 %



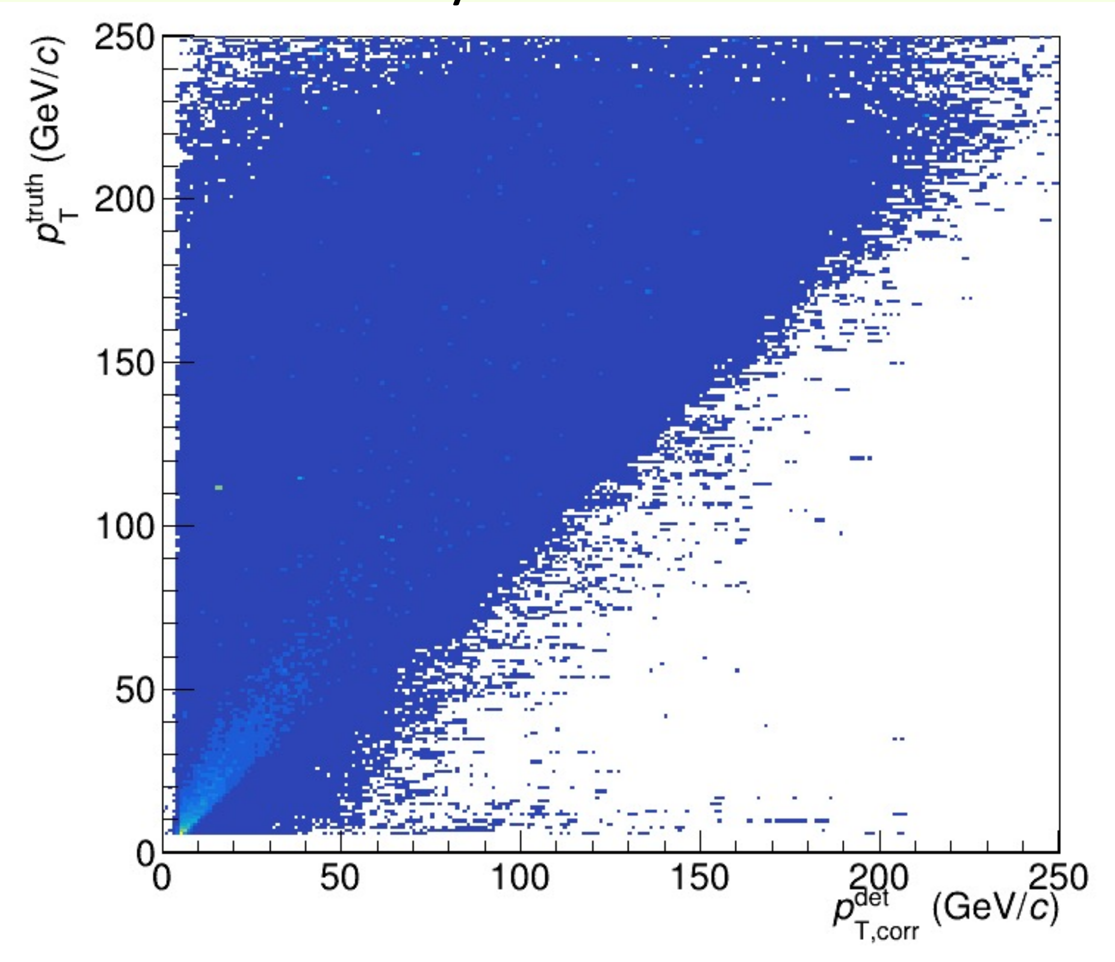
The peripheral RM is shaper than central RM

Response Matrix (fine binning)

Centrality 0-10 %

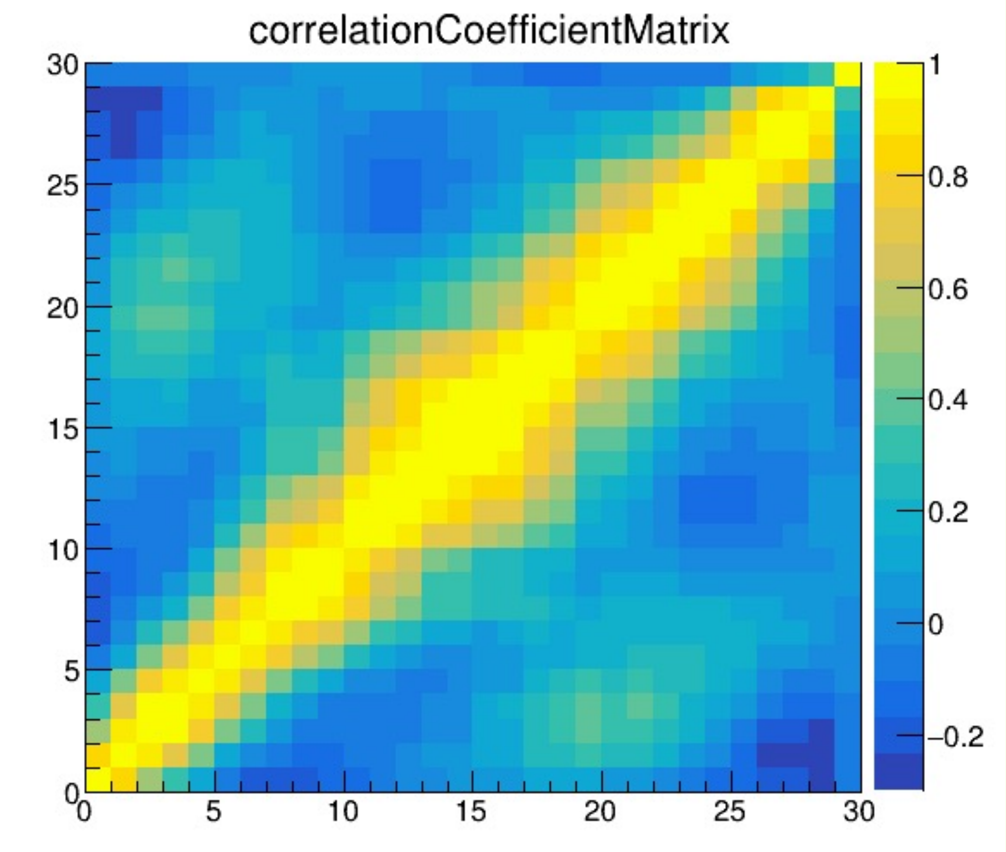


Centrality 70-90 %

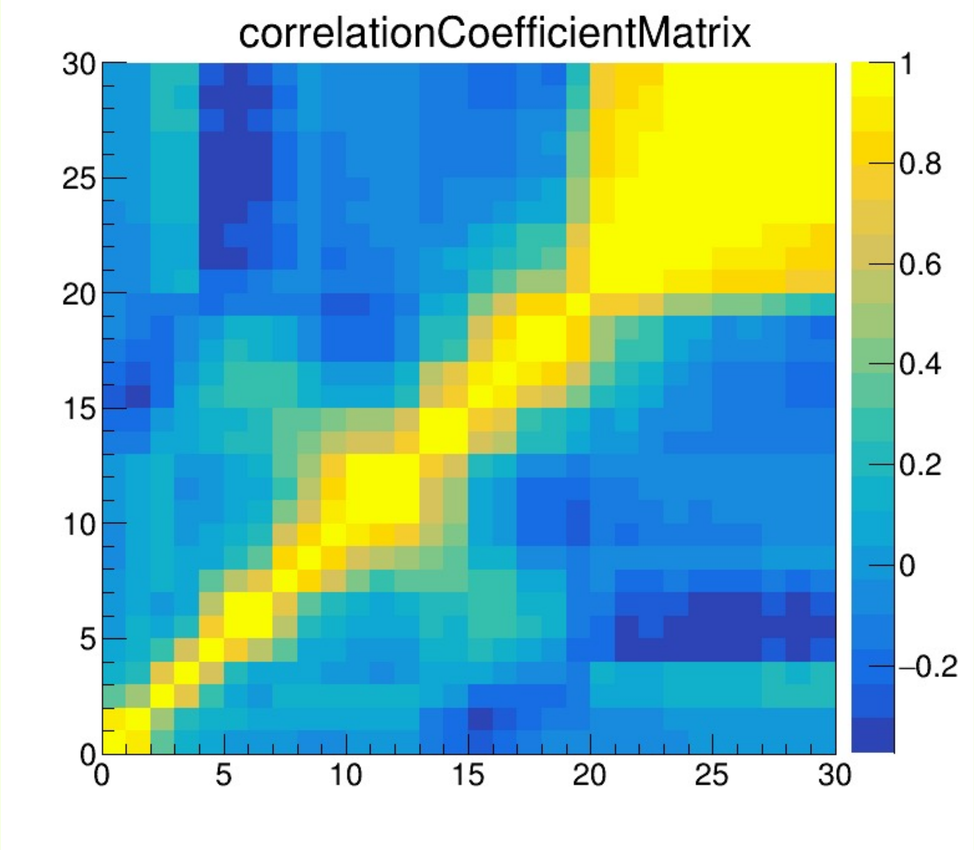


Coefficient Matrix

Centrality 0-10 %



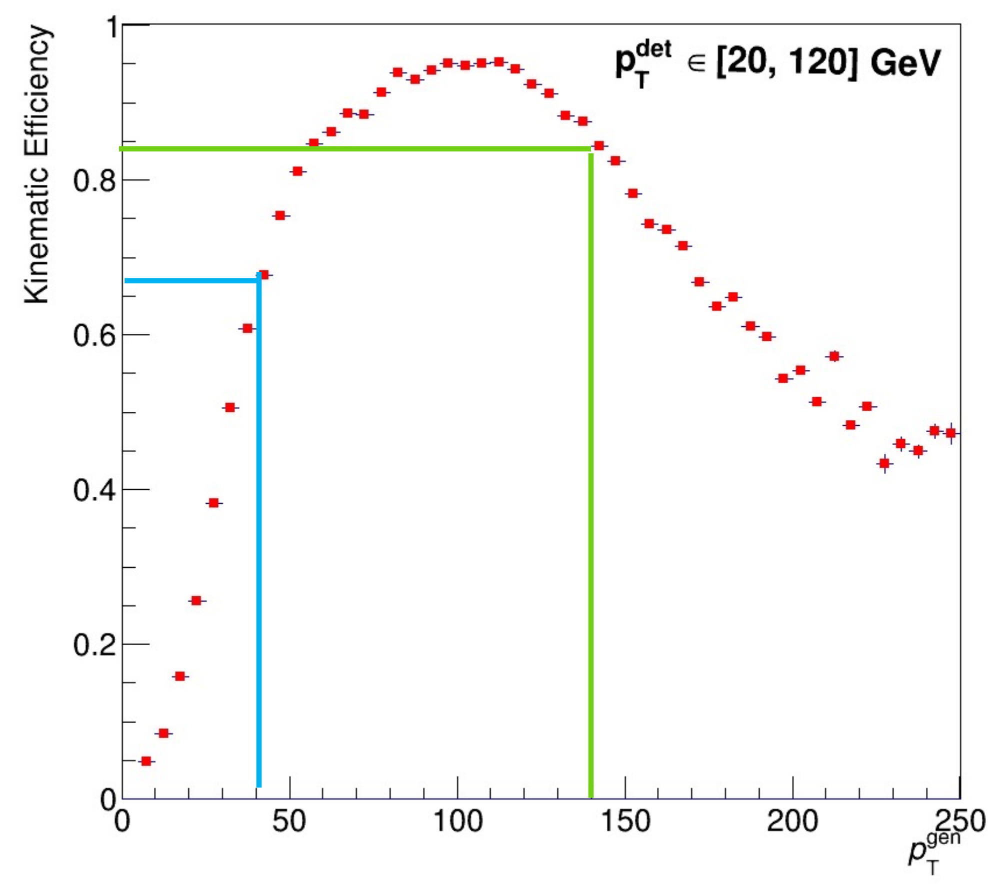
Centrality 70-90 %



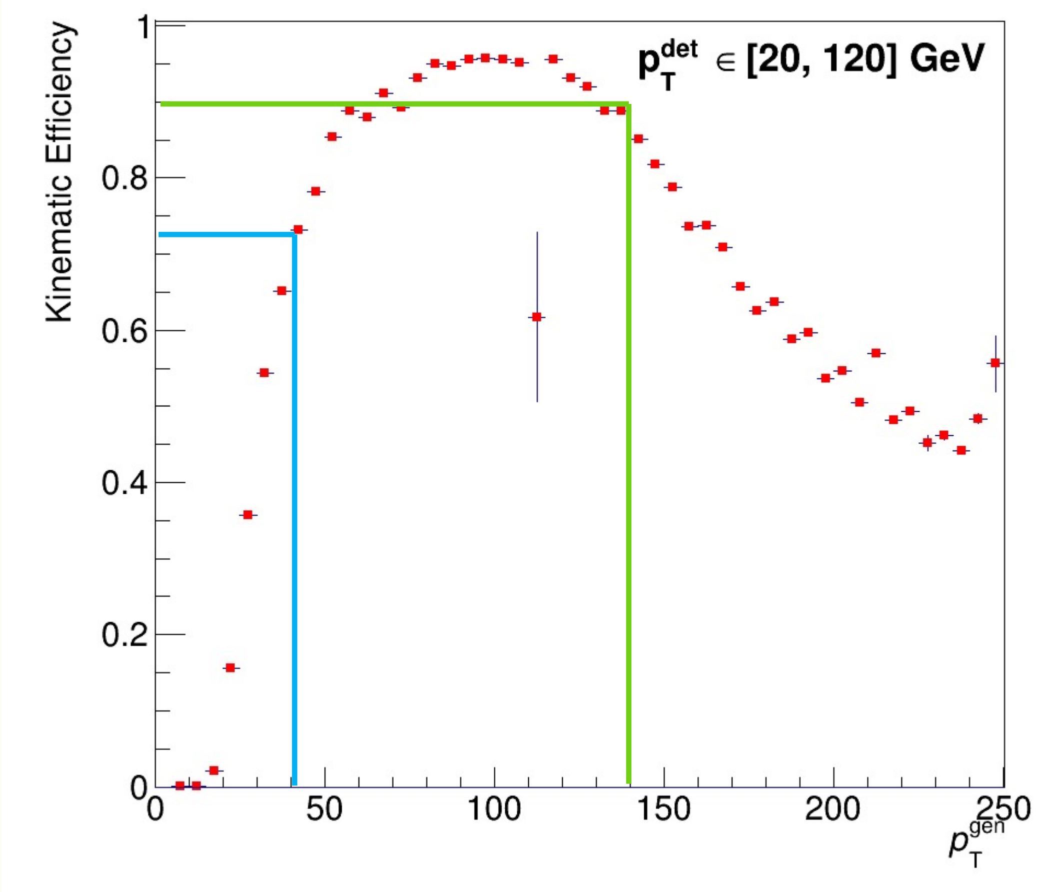
The peripheral RM is shaper than central RM

Kinematic efficiency

Centrality 0-10 %



Centrality 70-90 %

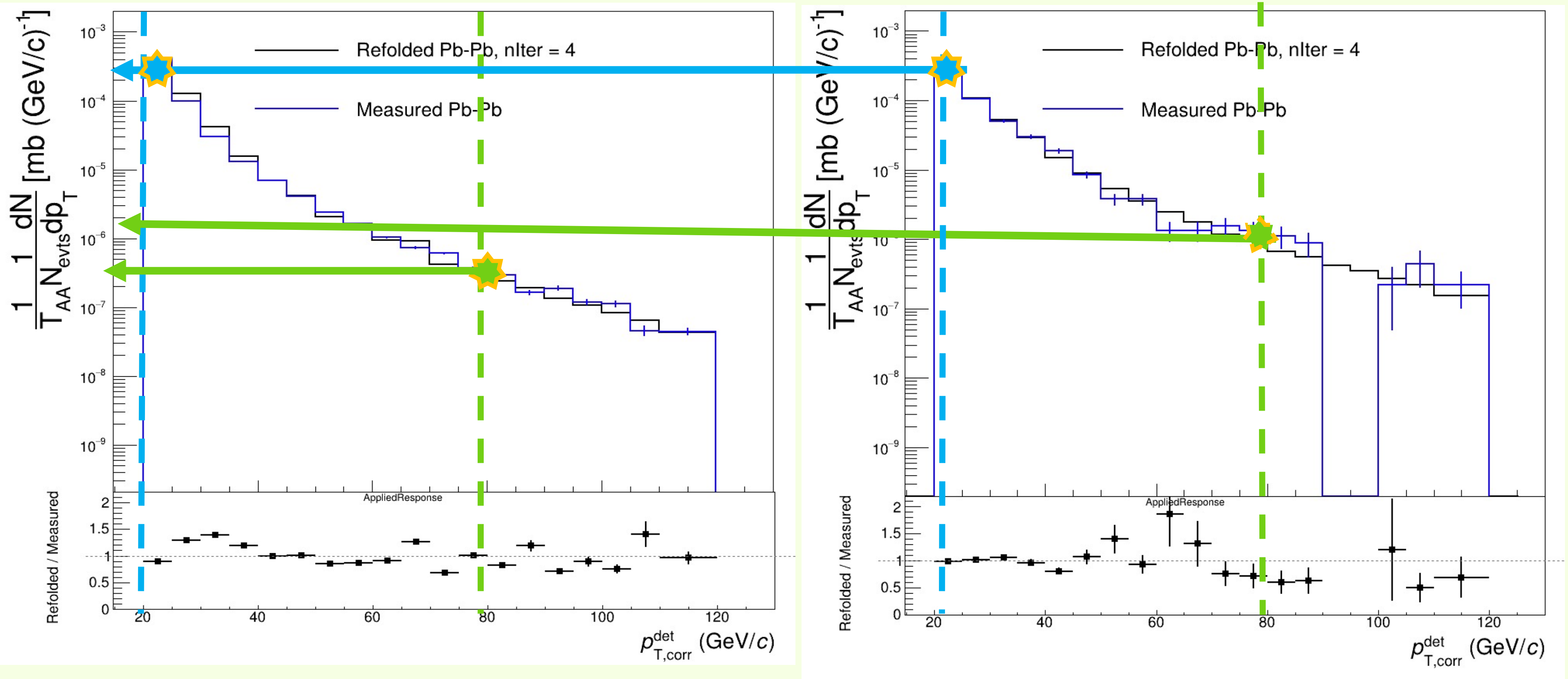


Peripehral kinematic efficiency is higher than the central one.

-> This result is reasonable

Unfolding results

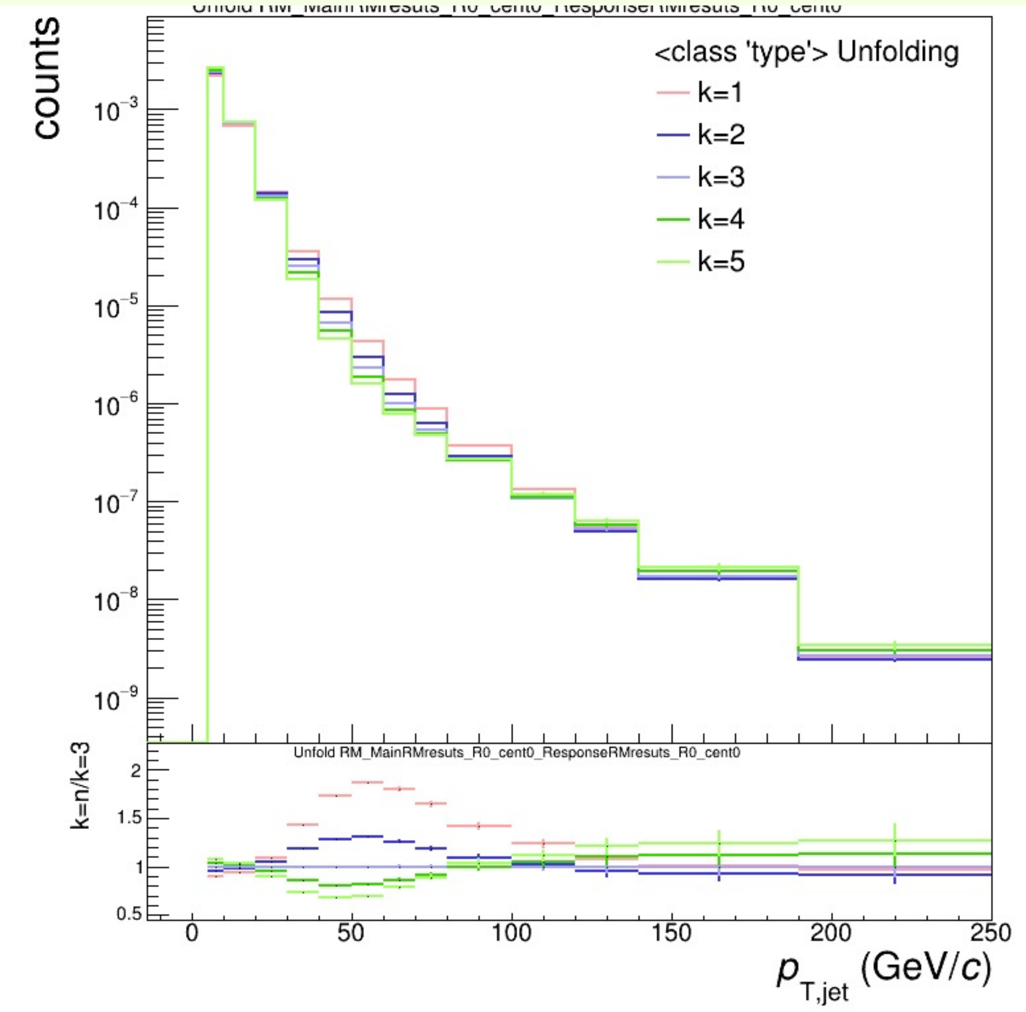
Centrality 0-10 %　　　　Centrality 70-90 %



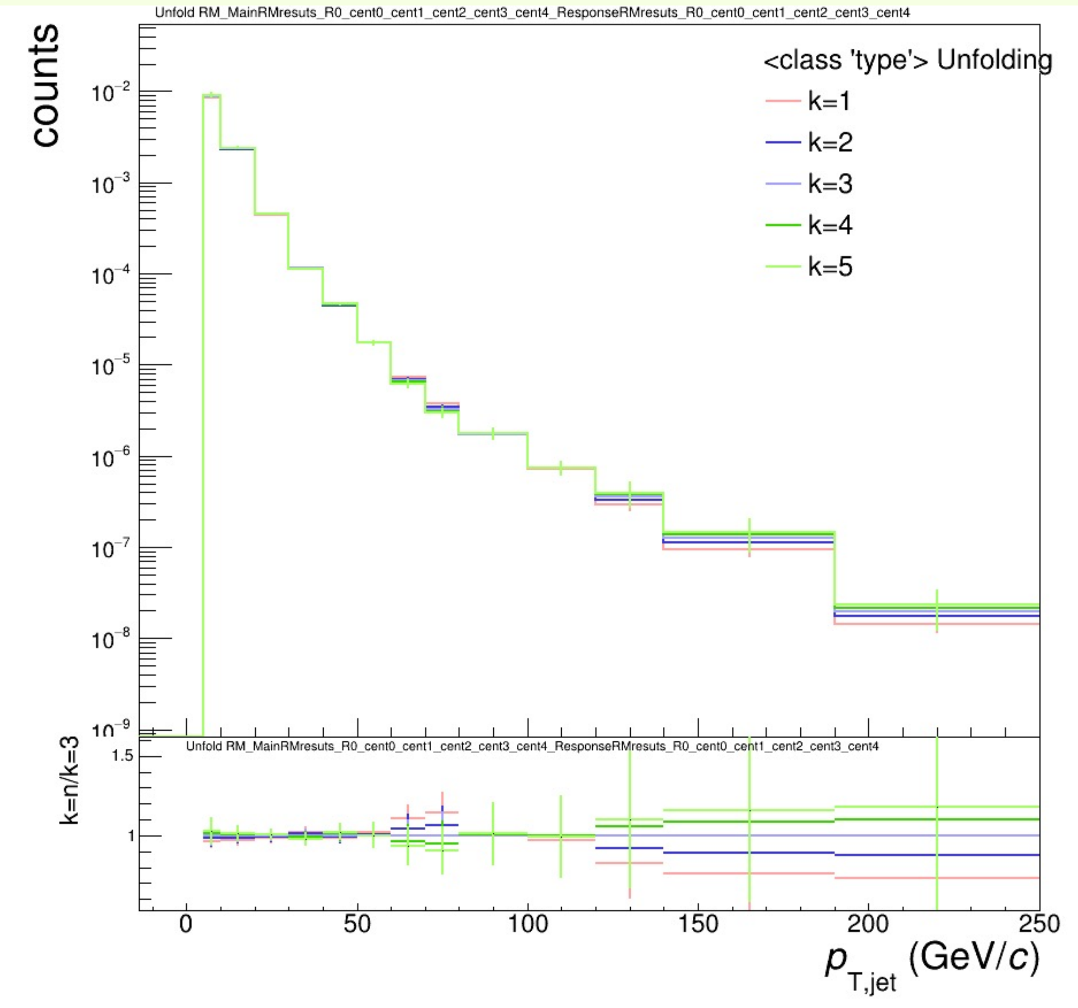
Not found a large difference between these plots.
But the peripheral result lack statistic in high pT region.

Stability of unfold with regularizaition parameter

Centrality 0-10 %

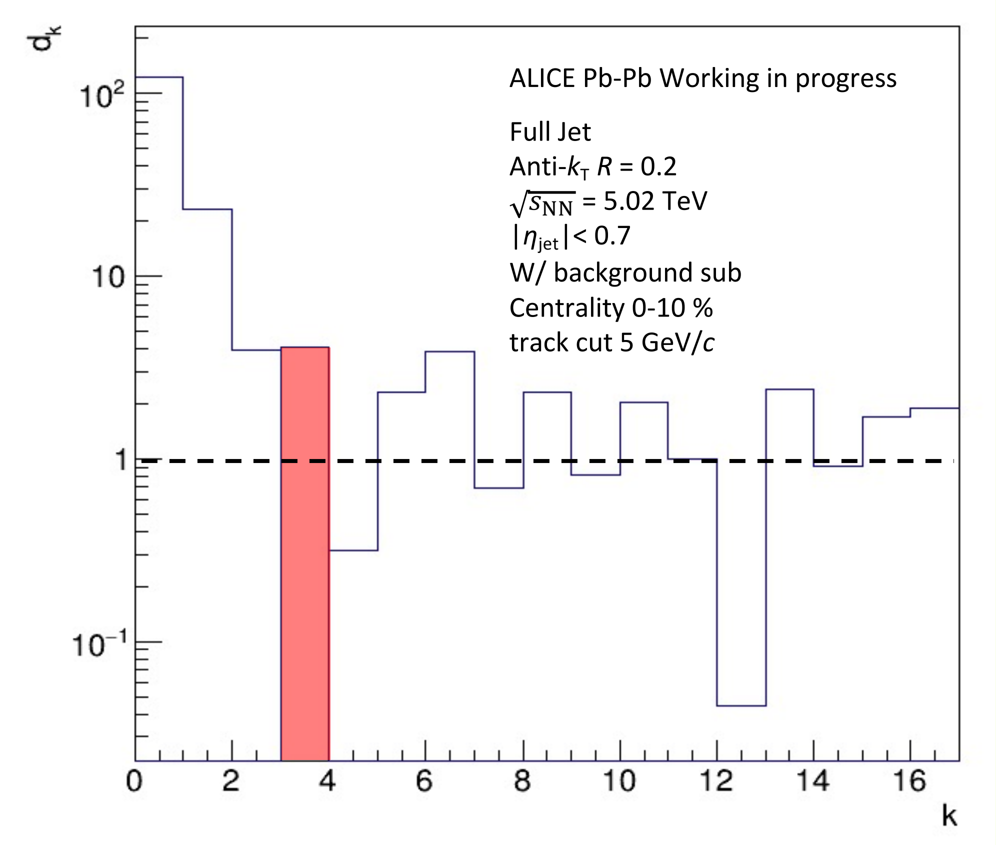


Centrality 70-90 %

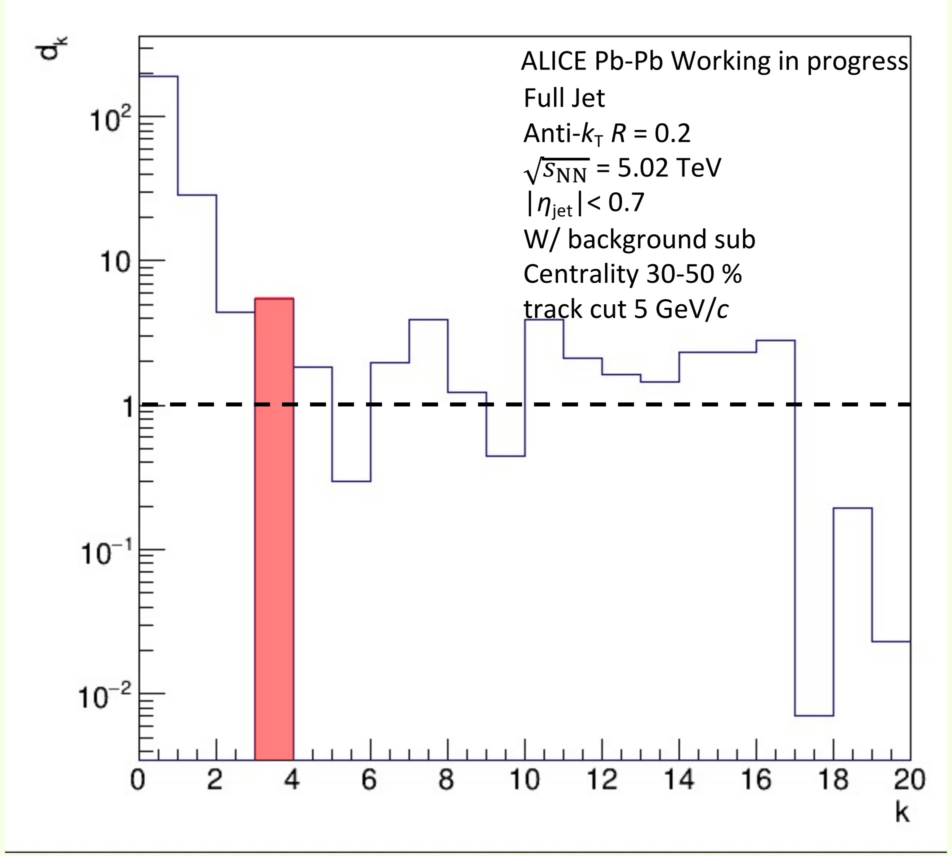


D-Vector of SVD unfolding

Cent 0-10 %



Cent 30-50 %



In SVD unfolding, we should select the regularization parameter k so that the d smaller than 1.
And it is prefere the k is small.
Both results satisfy these requirements.