Measurement of the charged-particle jet production in pp collisions with ALICE

Rencontres QGP France 2022

Yongzhen HOU

CCNU (Wuhan) & IPHC (Strasbourg)

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Multiplicity dependence jet production in pp 13 TeV

Go to Slide 5

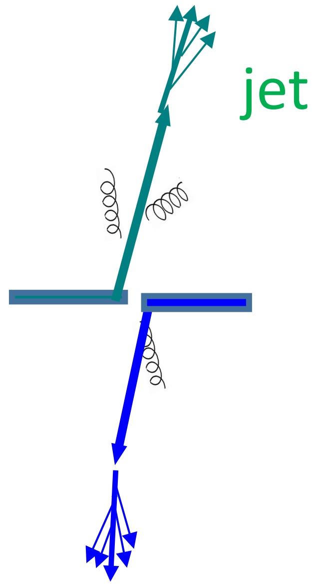
Go to slide 15

h+jet measurements in pp 5 TeV

yongzhen.hou@cern.ch

Motivation: why jets

- Jet is defined as collimated spray of particles originating from initial hard scattered partons.
- Jet cross section measurement in pp collisions can be precisely calculated by pQCD.



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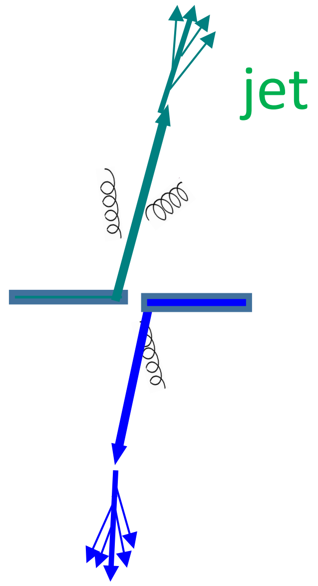

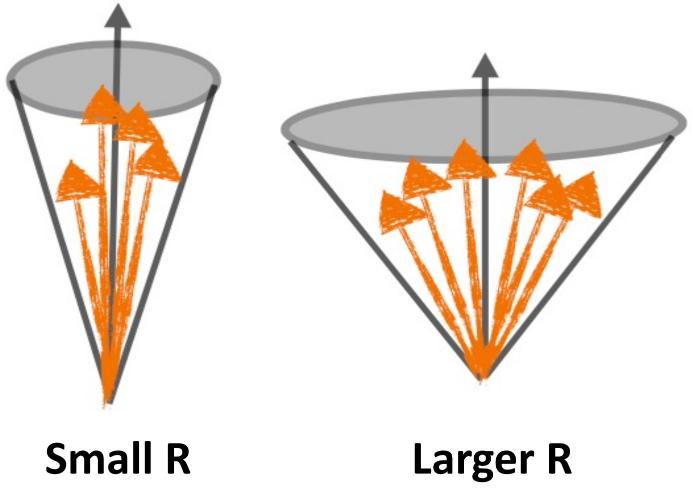

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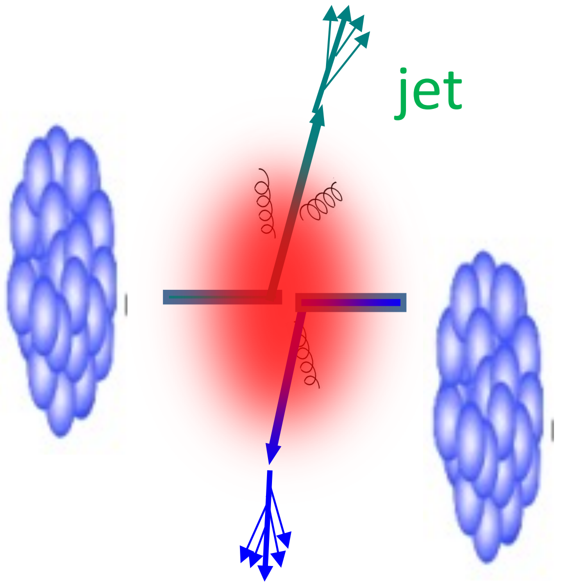
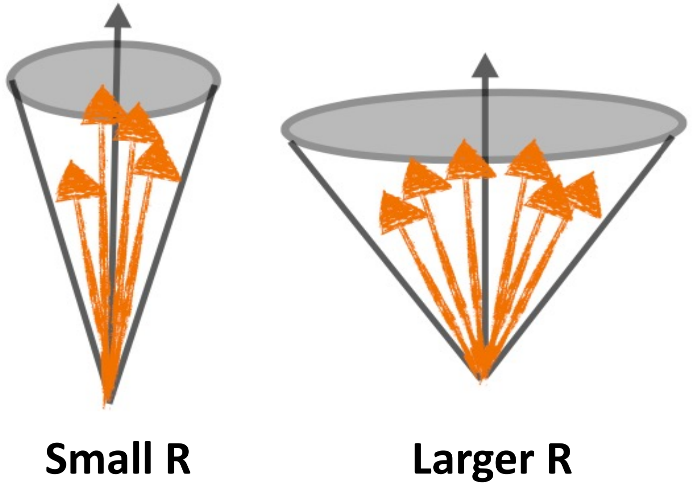
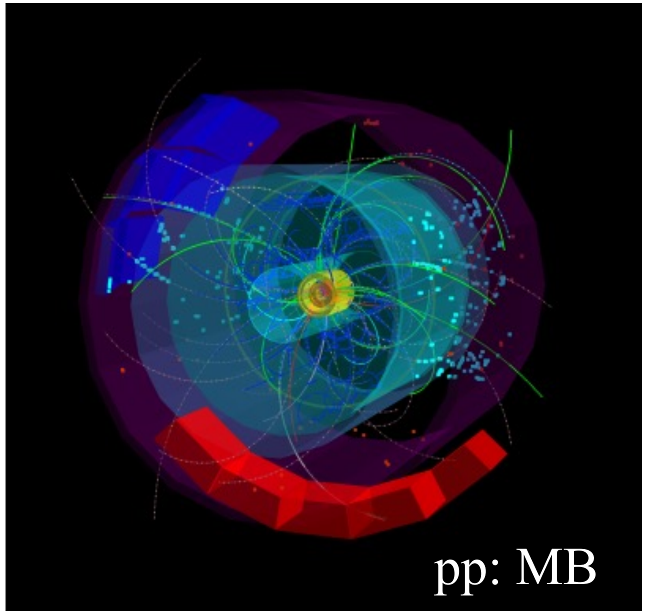
- Jet cross section measurement in pp collisions can be precisely calculated by pQCD.
- Investigate the splitting function of parton: close to original collimation information.
- Study jet quenching effect in nucleus-nucleus collision.

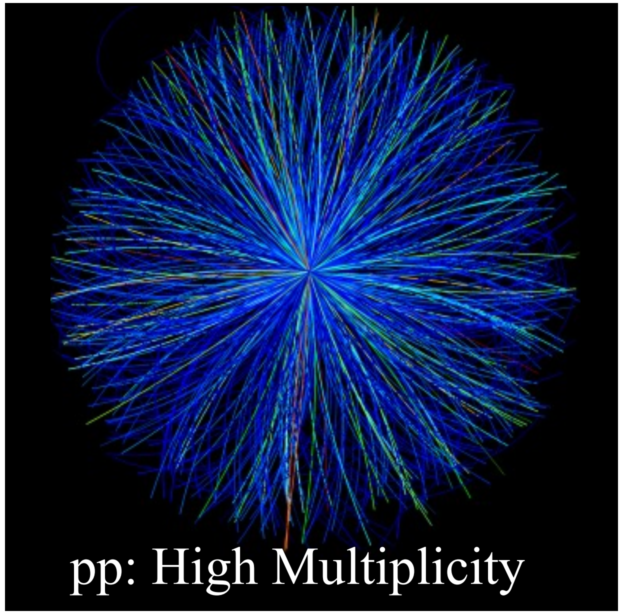
$$R_{AA} = \frac{dN^{AA}_{jets}/dp_T d\eta}{< T_{AA} > d\sigma^{pp}_{jets}/dp_T d\eta}$$

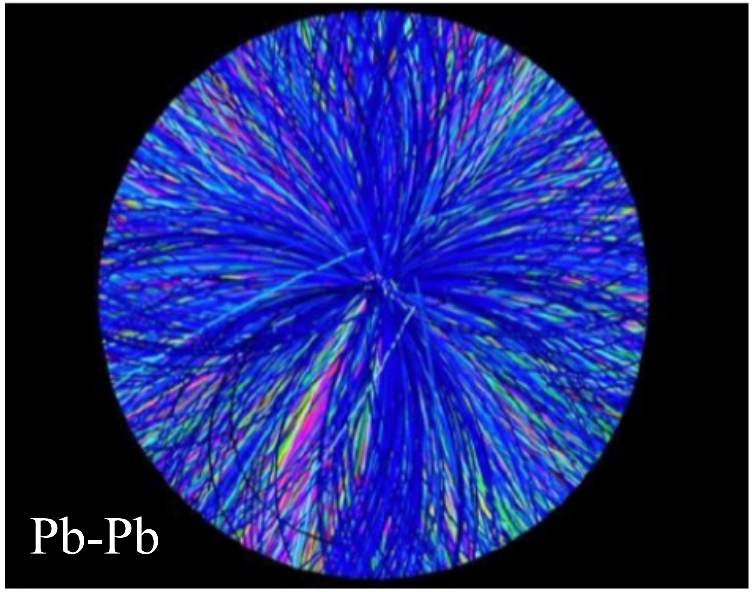




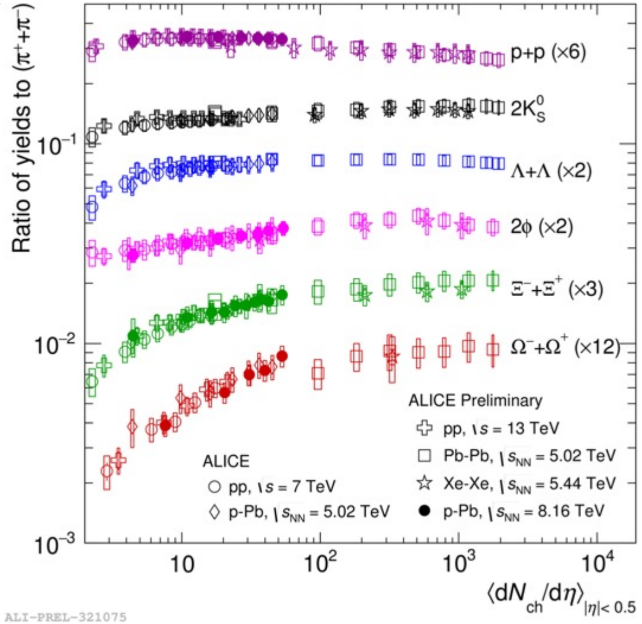
Motivation: why study high multiplicity jets



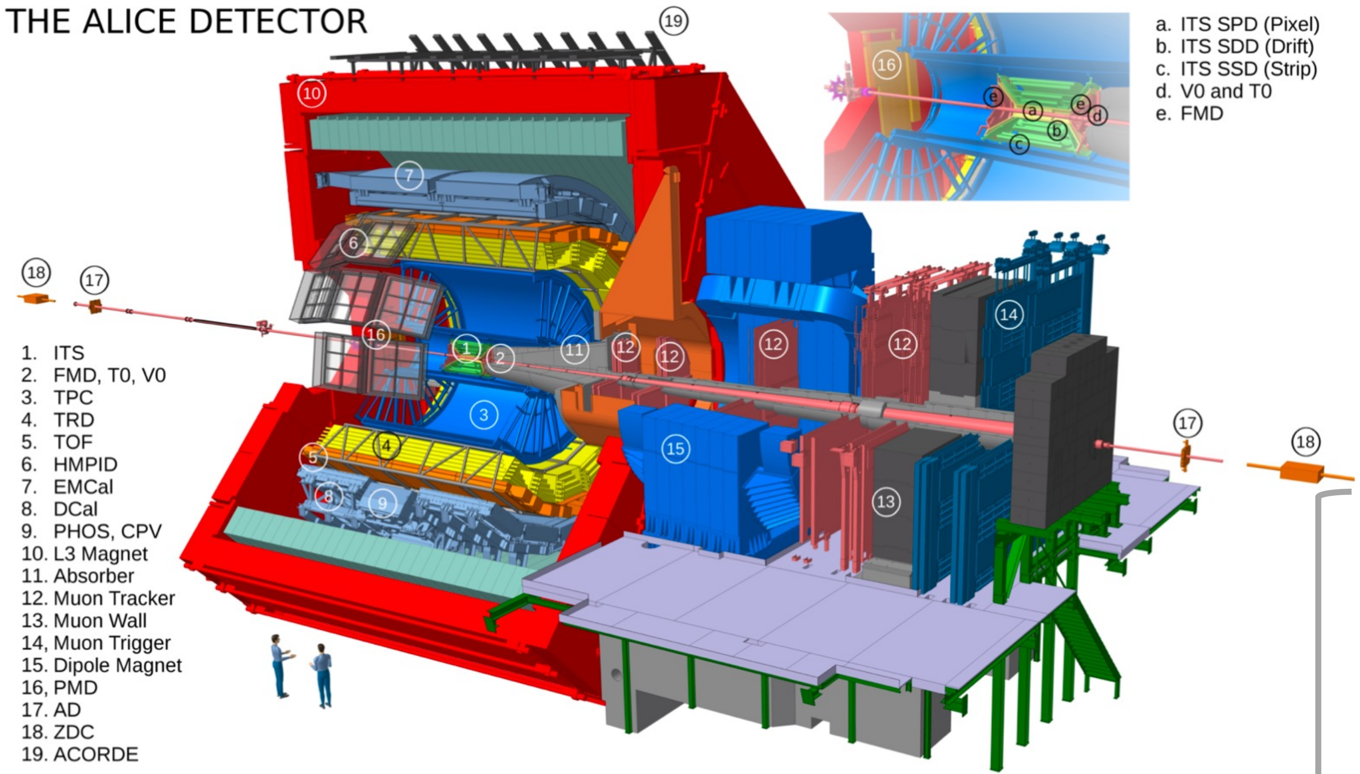




- High multiplicity pp events have similar behavior for particle productions as in pA/AA collisions
  - →What happens for jet production in high multiplicity environment: quenching? enhancement?



Jet measurements in ALICE



- **V0** (V0C + V0A)
  - $-3.7 < \eta < -1.7, 2.8 < \eta < 5.1$
  - Event multiplicity, centrality determination
  - Event trigger
- **ITS** (Inner Tracking System)
  - $|\eta| < 0.9,\ 0 < \varphi < 2\pi$
  - Primary vertex reconstruction
  - Event trigger
- **TPC** (Time Projection Chamber)
  - $|\eta| < 0.9,\ 0 < \varphi < 2\pi$
  - Charged particle tracking
  - Particle identification

Charged Tracks

$p_{\mathrm{T}}^{\mathrm{track}} > 0.15\ \mathrm{GeV}/c$

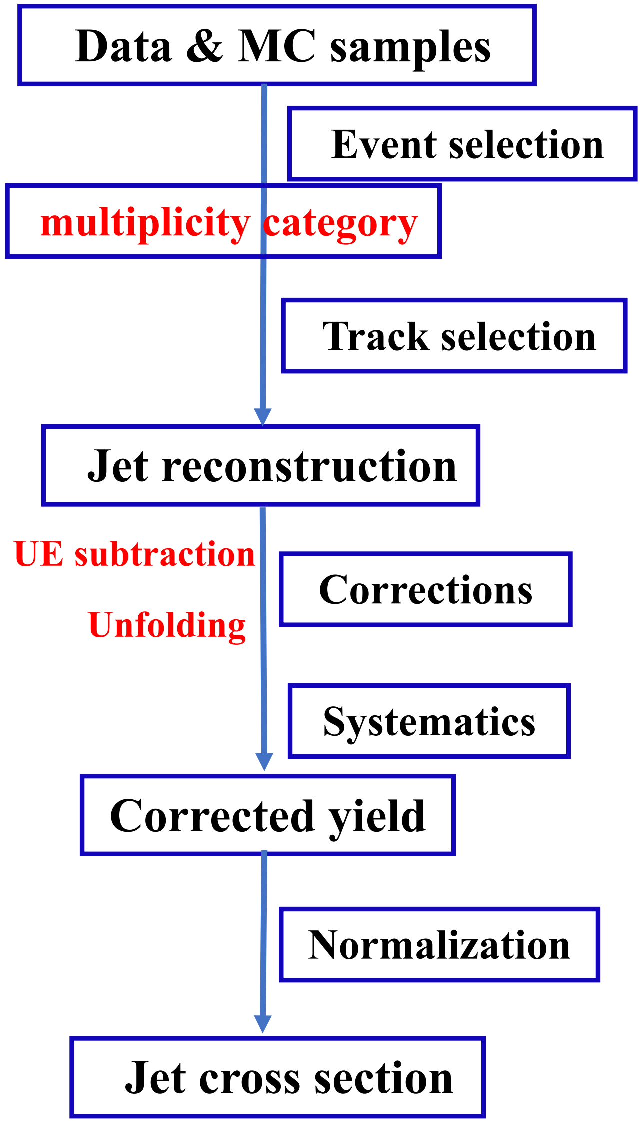
anti-k_{T} algorithm

Charged-particle jets

Analysis method

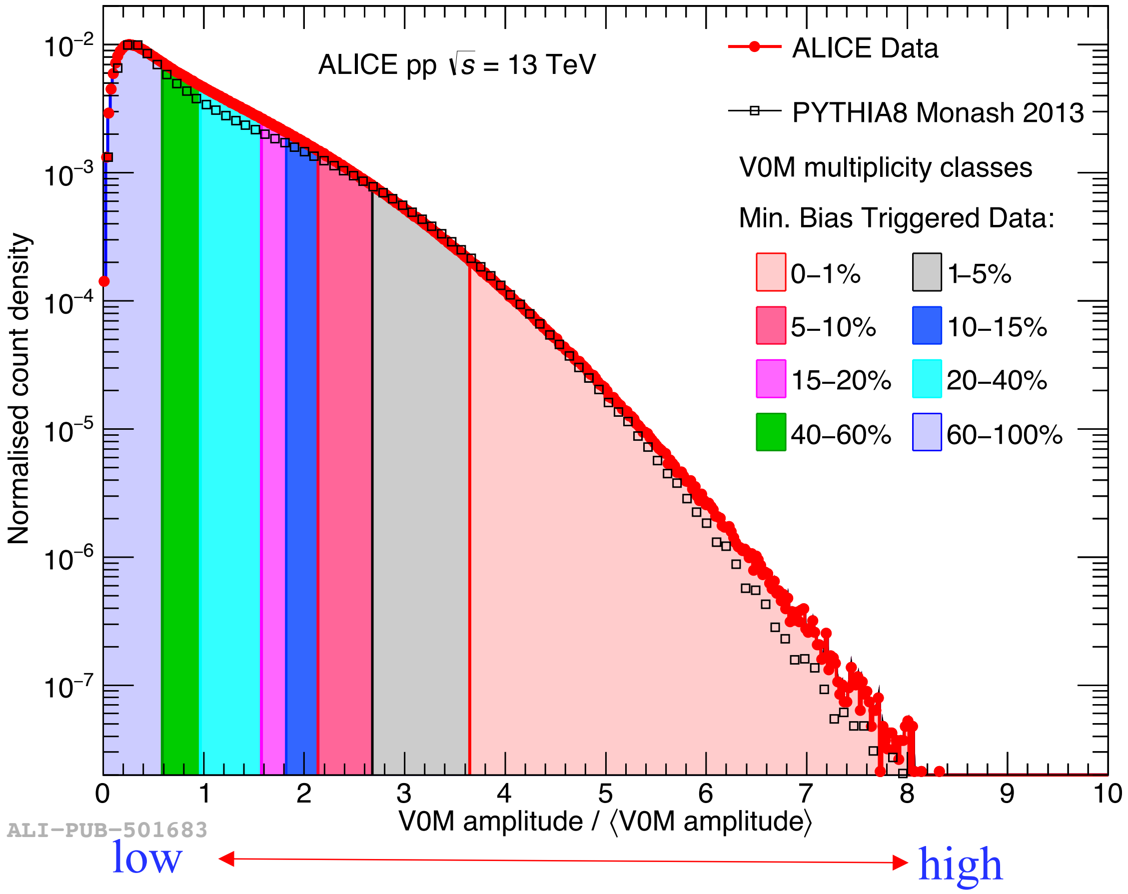
- Event selection: $|V_z| < 10\ cm$ + standard Physical Sel.
- Event activity categorization: V0M
- Jet reconstruction
  - Hybrid tracks, $p_T > 0.15$ GeV/c, $|\eta_{\text{track}}| < 0.9$
  - Charged jets, anti-k_T, R = 0.2 – 0.7, $p_{T,jet} > 1.0\ \text{GeV}/c$
  - Bkg estimation: k_T algorithm
    - $\rho = median\left\{\frac{p_{\text{T,jet}}^{k_T}}{A_{\text{jet}}}\right\} * C\ (C = \frac{A_{covered}}{A_{tot}})$
    - $p_{T,jet}^{corr} = p_{T,jet} - \rho . A_{jet}$, $\delta p_T = \sum_{RC}^{i} p_{T,i}^{track} - \rho . A$
- Unfolding correction (RooUnfold package: arXiv:1105.1160)
- Cross section normalization ($\sigma_{MB} = N_{evt} / \mathcal{L}_{int}$):

$$\frac{d^2\sigma^{\text{ch,jet}}}{dp_{\text{T}}d\eta}\left(p_{\text{T}}^{\text{ch,jet}}\right) = \frac{1}{\mathcal{L}_{int}}\frac{N_{\text{jets}}}{\Delta p_{\text{T}}\Delta\eta}(p_{\text{T}}^{\text{ch,jet}})$$



Multiplicity percentile estimation

- Select different multiplicity events using forward detector (V0) to minimize auto correlations between event activity estimation and jet measurements
- Using V0M amplitude to categorize event activities



V0M Mult (%)	$dN_{ch}/d\eta$
0-100	6.93+0.09
0-1	26.01+0.34
1-5	19.99+0.24
5-10	16.18+0.20
10-15	13.78+0.18
15-20	12.01+0.16
20-40	9.18+0.10
40-60	5.78+0.06
60-100	2.94+0.03

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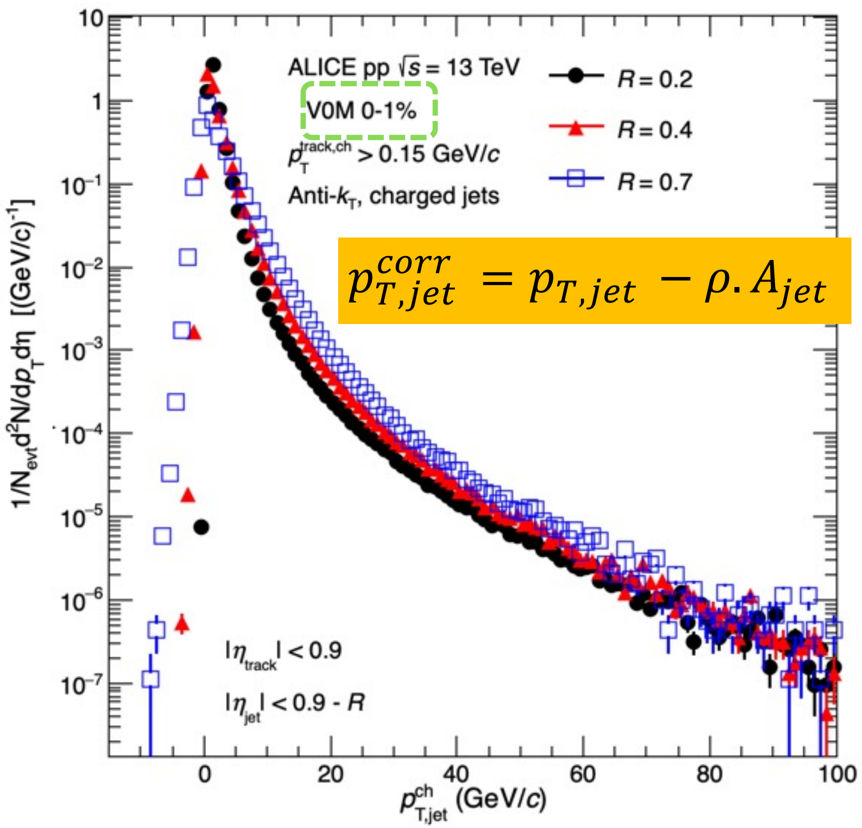
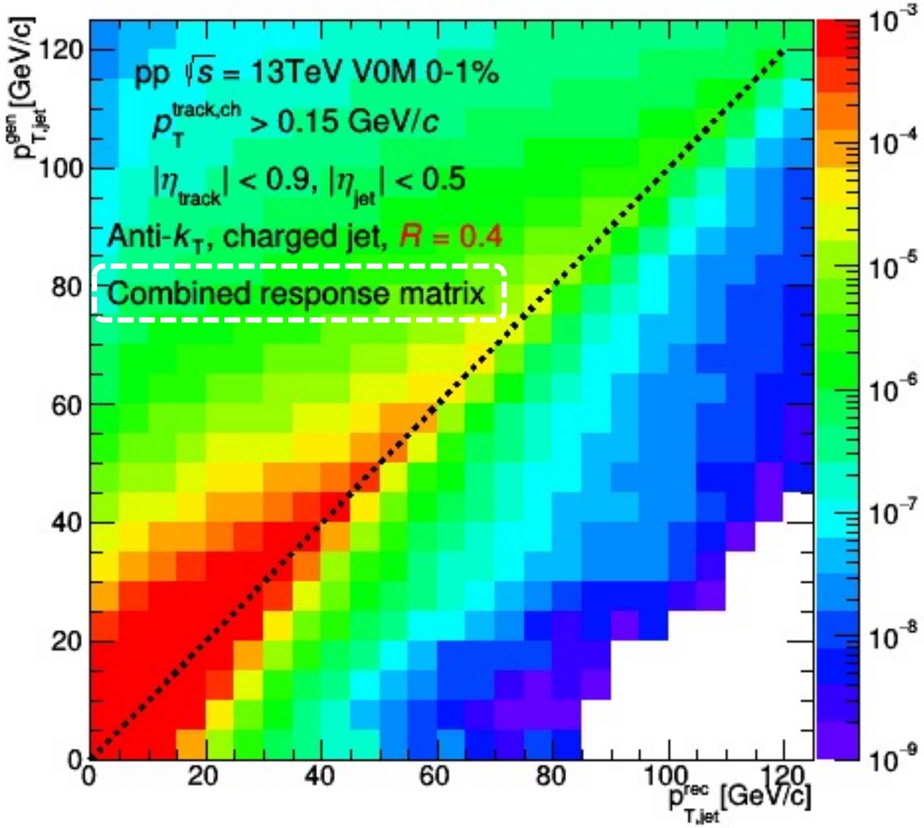
yongzhen.hou@cern.ch

Raw spectra and unfolding correction for detector effects





RM   Meas. spectra

$$\hat{A}x = b$$

$$\hat{A} = USV^T,$$

$$x = V^{-1}U^T b$$

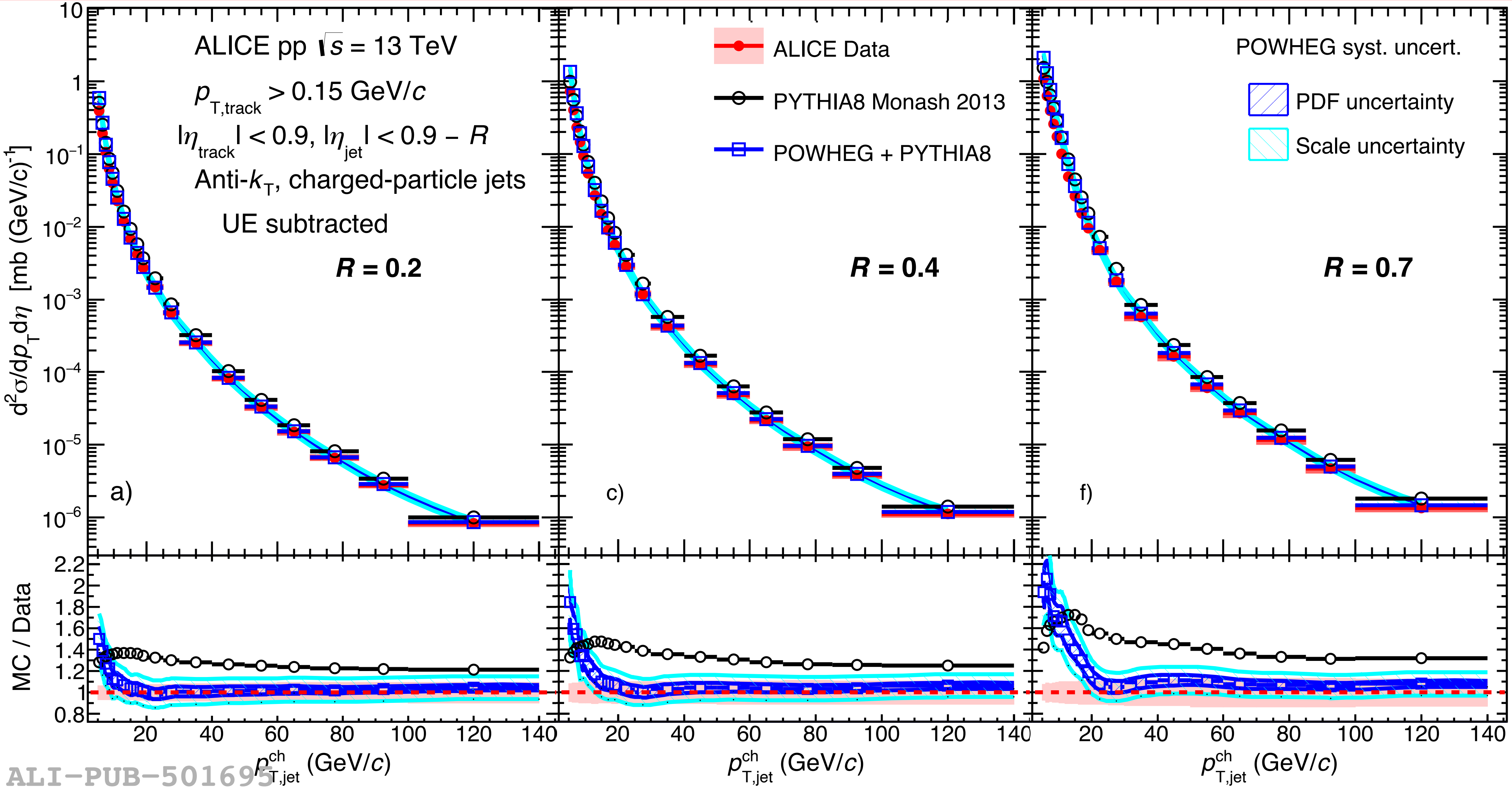
"True" spectra

arXiv:1105.1160

- Raw jet p_T distributions in 0-1% interval after UE subtraction
- Detector response matrix (RM) is obtained with MC simulation for jet energy scale and resolution correction
- Using the response matrix to perform unfolding and obtain the corrected jet yield

Inclusive jet cross section

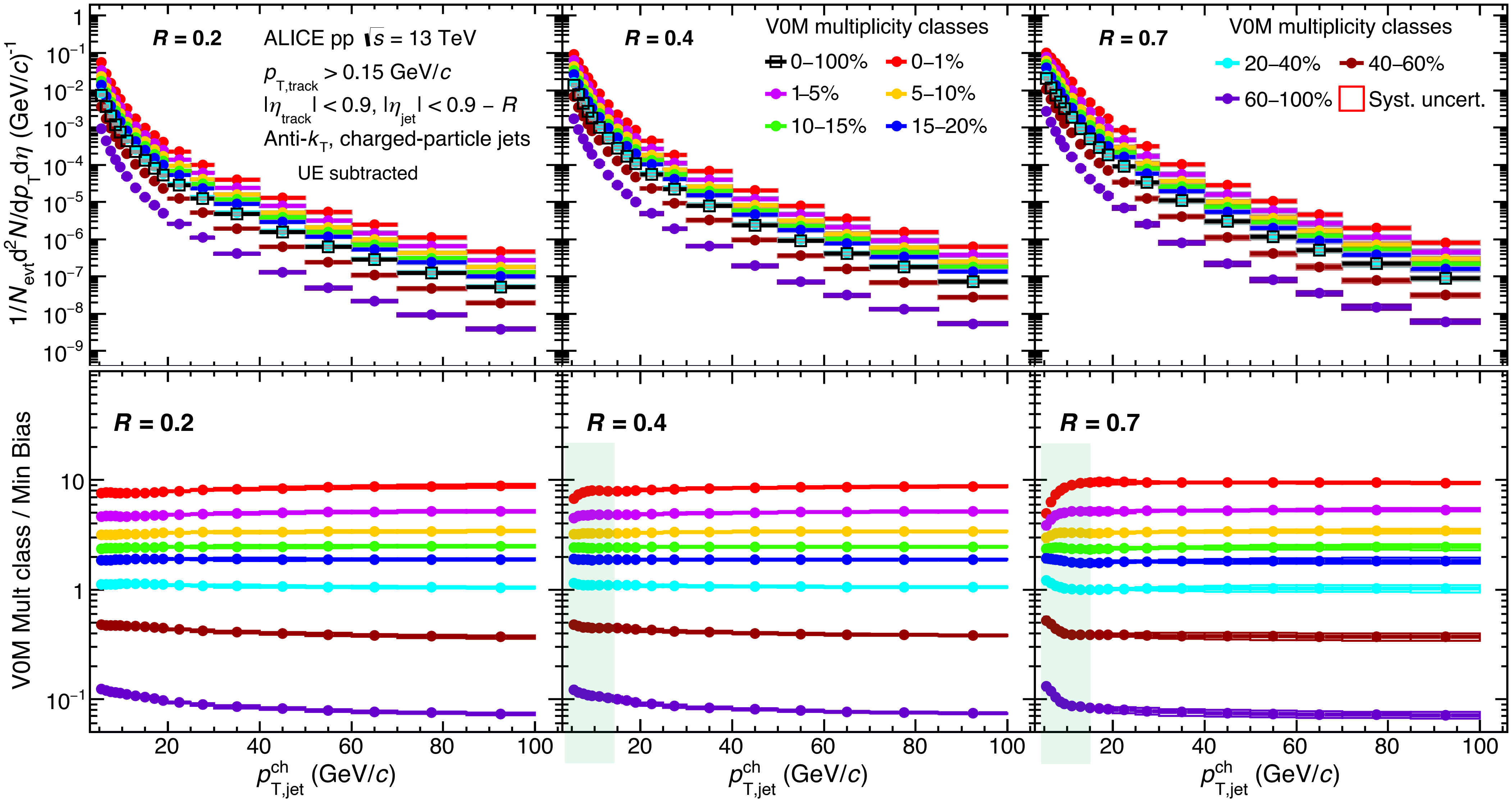
arXiv:2202.01548



- Cross sections are compared with different MC calculations with UE subtraction

Multiplicity-dependent jet production and ratio

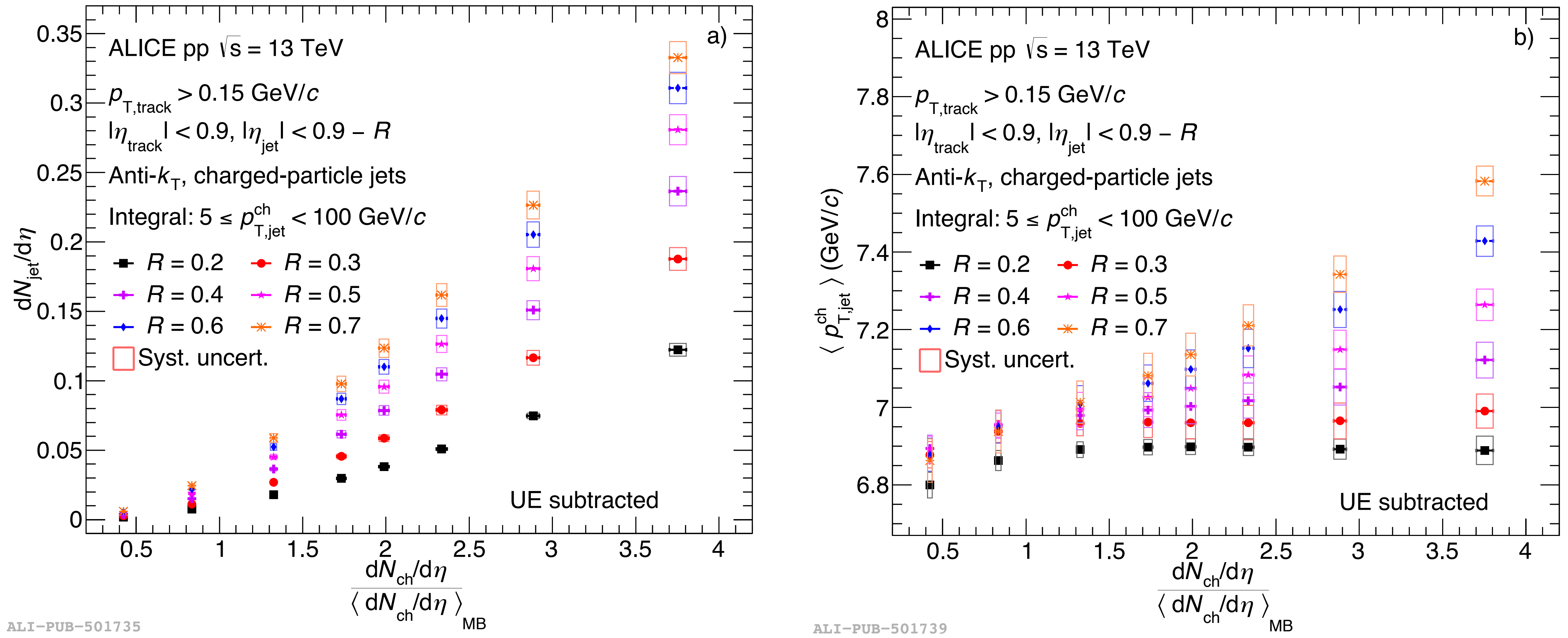
arXiv:2202.01548



- Jet production yield and spectra ratios from multiplicity classes to MB events for R = 0.2– 0.7

Integrated jet production and average p_T

arXiv:2202.01548

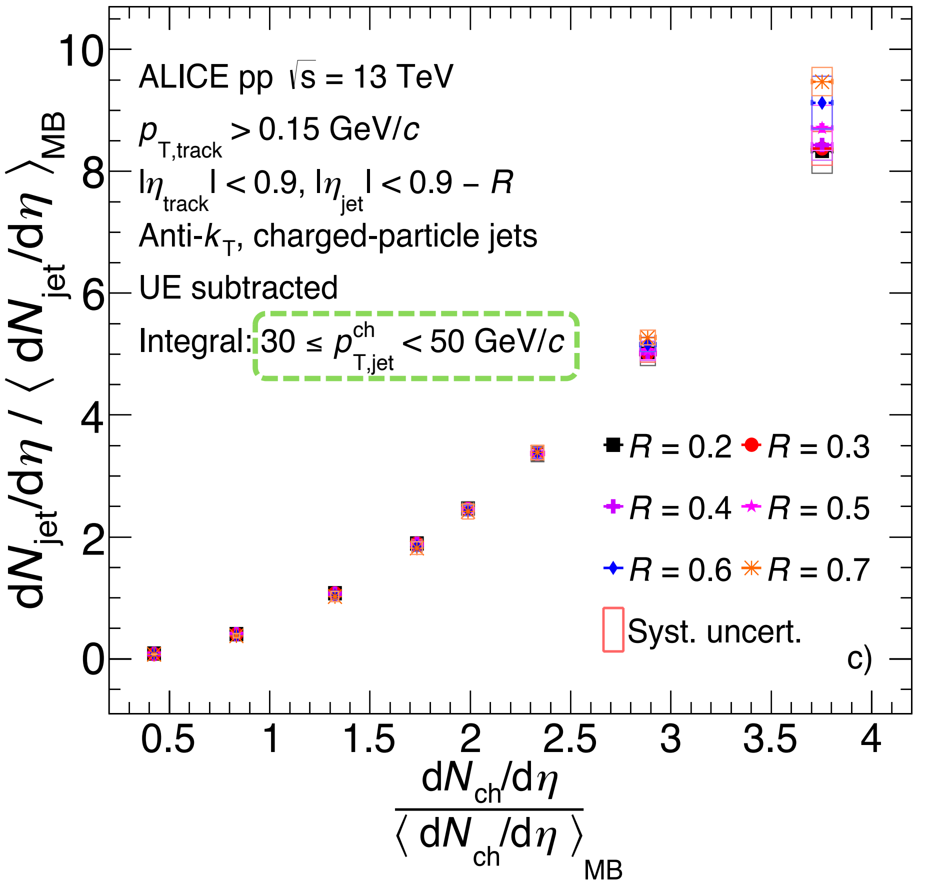


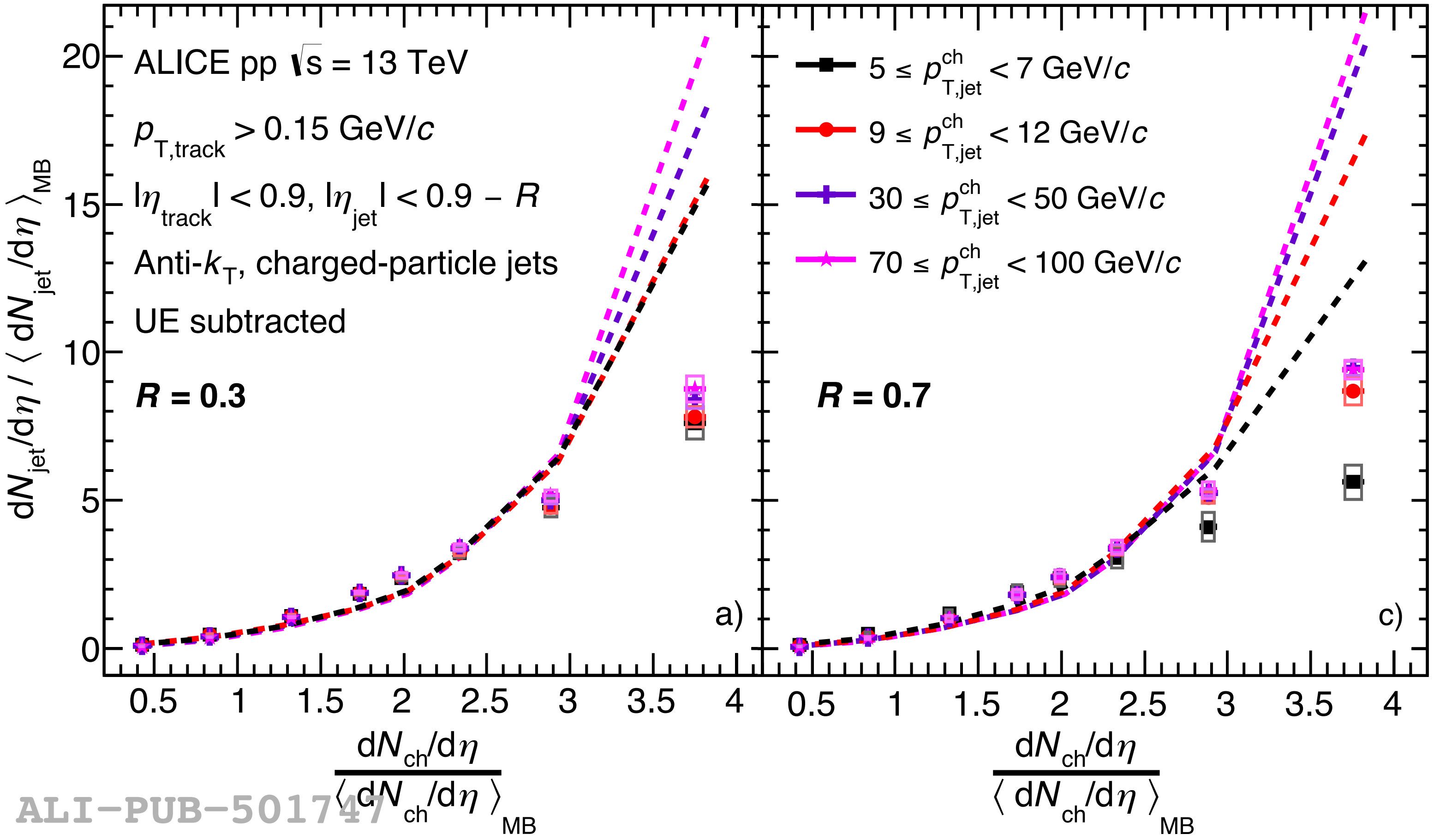
- Integrated jet production yield and the average p_T as a function of charged-particle multiplicity density for different radii in given jet p_T range ($5 < p_T < 100$ GeV/c)
  - Both jet yields and the average p_T are increasing with multiplicity

yongzhen.hou@cern.ch

Integrated jet production ratio

arXiv:2202.01548

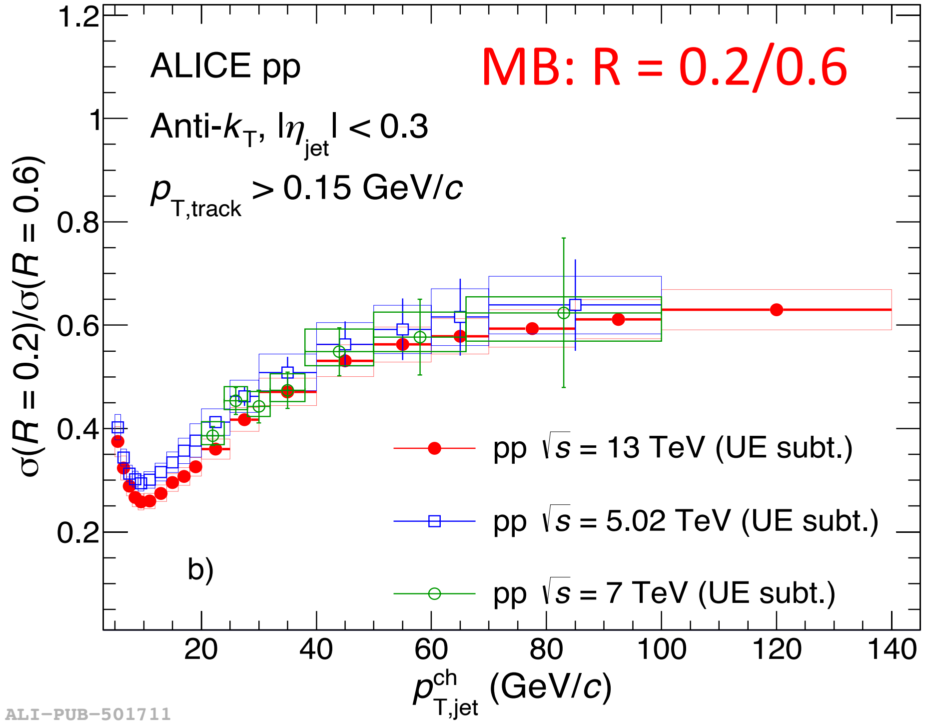


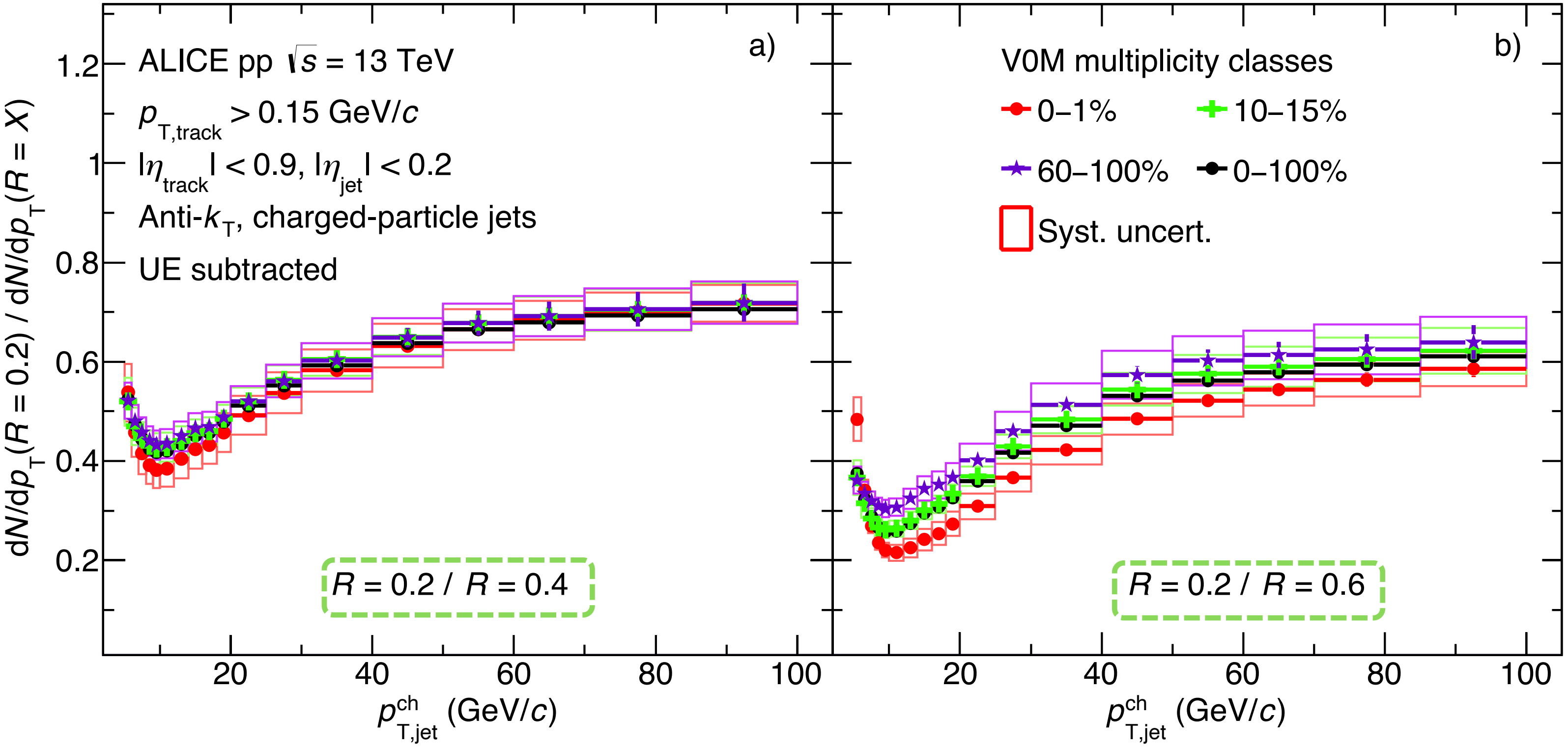


- Integrated jet production ratio (V0M / MB) for different jet radii and jet p_T bins
  - No strong jet R and p_T dependence on the jet production ratio
- PYTHIA8 simulation could describe the overall increasing trend as seen in data, though overshoot at HM

Jet spectra ratio with different R

arXiv:2202.01548





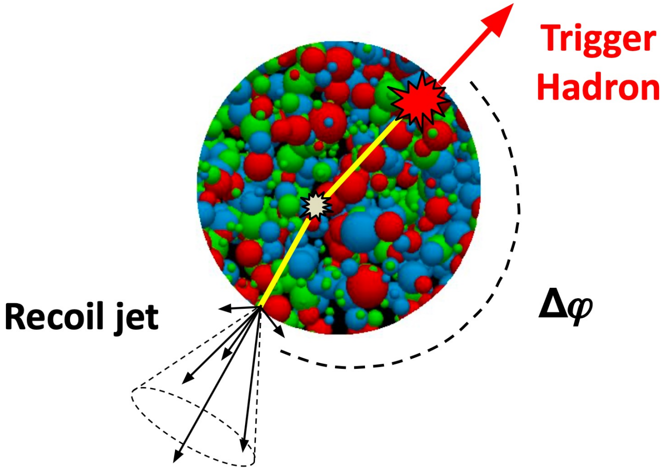
- Jet cross section ratio are increasing with jet p_T
- No significant collision energy or collision systems dependence when compared to earlier measurements
- No strong multiplicity dependence for smaller radii within uncertainty
- Hint of multiplicity ordered jet ratio for larger radii (0.2/0.6, 0.2/0.7)

Motivation: why study hadron-jets

- Trigger track close to surface, but no bias on recoil jets
- Provide a good handle of combinatorial background by varying trigger track intervals

  → **access low p_{T}, large R jets**

- Azimuthal distribution of recoil jets provides additional insight into QGP properties
- Hadron-jet acoplanarity broadening: vacuum (Sudakov) radiation
- Multiple soft scattering in the QGP may further broaden $\Delta\varphi$ distribution
  - ❑ Gives direct access to transport coefficient [Phys. Lett. B 773 (2017) 672]



$$\Delta_{\mathrm{recoil}}(p_{\mathrm{T}},\Delta\varphi) = \frac{1}{N_{\mathrm{trig}}}\frac{d^2N_{jet}}{dp^{\mathrm{ch}}_{\mathrm{T,jet}}d\Delta\varphi}\bigg|_{p_{\mathrm{T,trig}}\in\mathrm{TT}_{\mathrm{Sig}}} - c_{\mathrm{ref}}\cdot\frac{1}{N_{\mathrm{trig}}}\frac{d^2N_{jet}}{dp^{\mathrm{ch}}_{\mathrm{T,jet}}d\Delta\varphi}\bigg|_{p_{\mathrm{T,trig}}\in\mathrm{TT}_{\mathrm{Ref}}}$$

Semi-inclusive hadron-jet measurements in pp @ 5.02 TeV

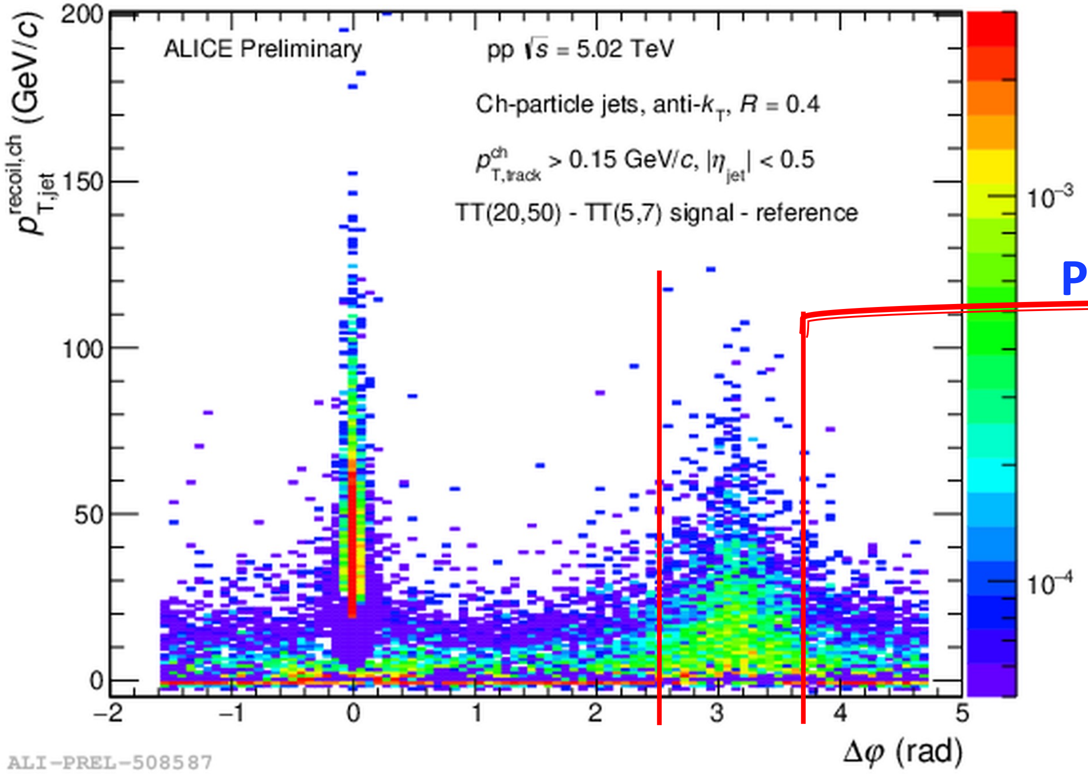
- Measure trigger-normalised yield of recoil jets from a high-p_T trigger

$$\Delta_{\mathrm{recoil}}(p_{\mathrm{T}}, \Delta\varphi) = \frac{1}{N_{\mathrm{trig}}} \frac{d^2 N_{\mathrm{jet}}}{dp_{\mathrm{T,jet}}^{\mathrm{ch}} d\Delta\varphi}\Bigg|_{p_{\mathrm{T,trig}} \in \mathrm{TT_{Sig}}} - c_{\mathrm{ref}} \cdot \frac{1}{N_{\mathrm{trig}}} \frac{d^2 N_{\mathrm{jet}}}{dp_{\mathrm{T,jet}}^{\mathrm{ch}} d\Delta\varphi}\Bigg|_{p_{\mathrm{T,trig}} \in \mathrm{TT_{Ref}}}$$

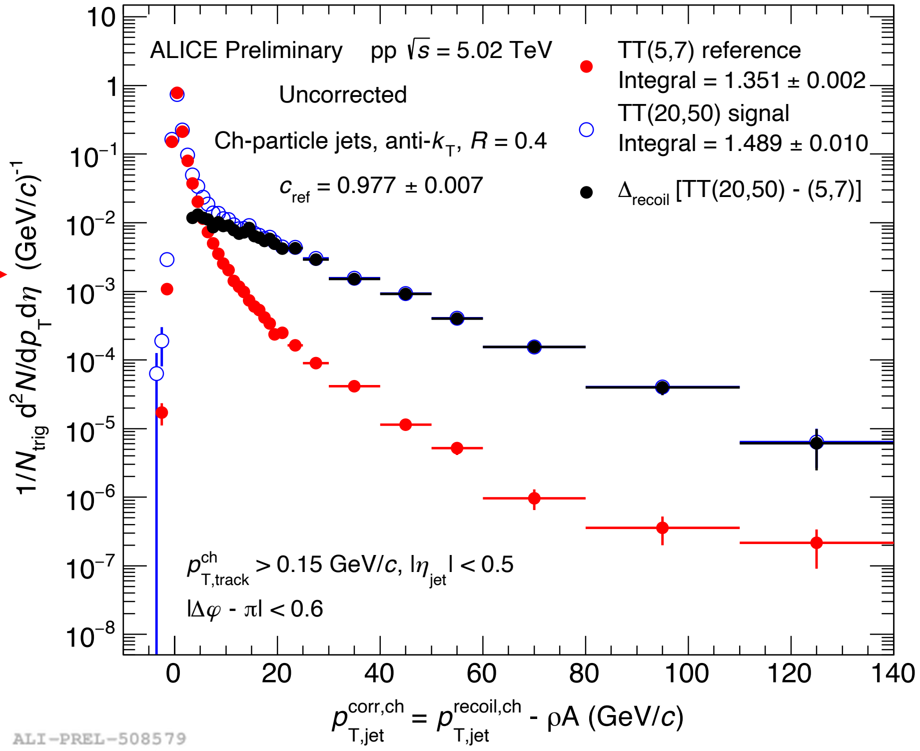
Trigger track (TT) p_T intervals:

$\mathrm{TT_{sig}}$: $20 < p_{\mathrm{T,trig}} < 50$ GeV/c

$\mathrm{TT_{ref}}$: $5 < p_{\mathrm{T,trig}} < 7$ GeV/c



Projection to Y axis



Semi-inclusive hadron-jet measurements in pp @ 5.02 TeV

- Measure trigger-normalised yield of recoil jets from a high-p_T trigger

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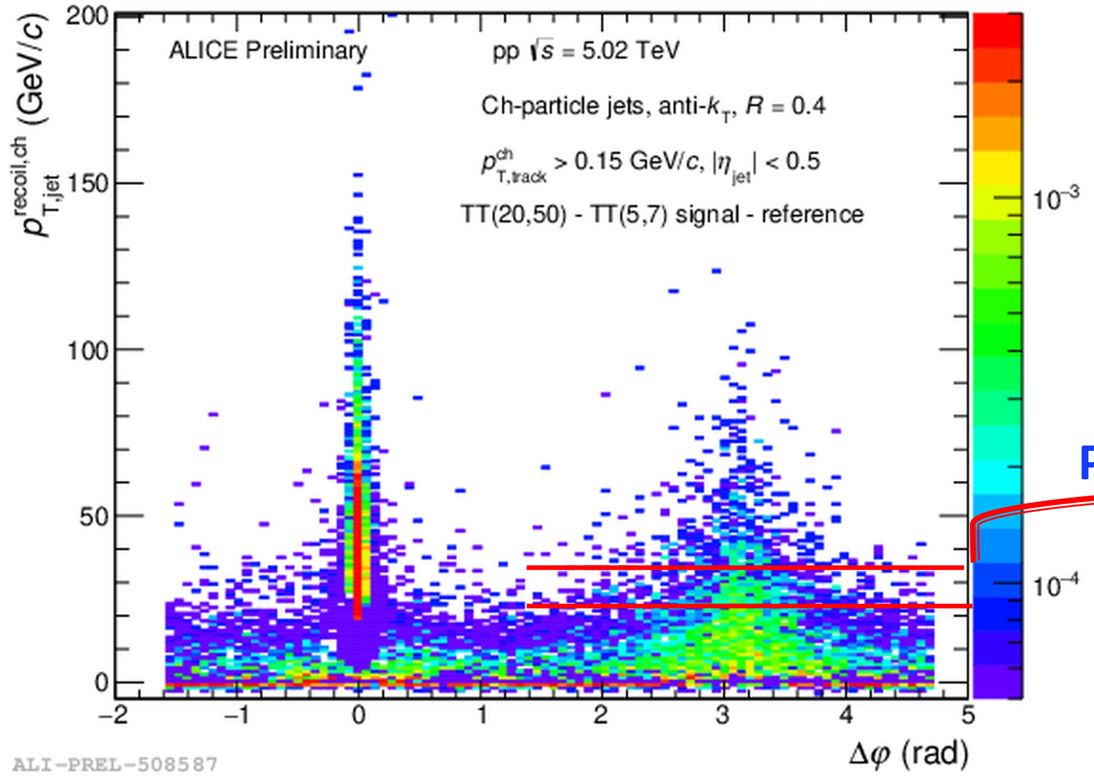
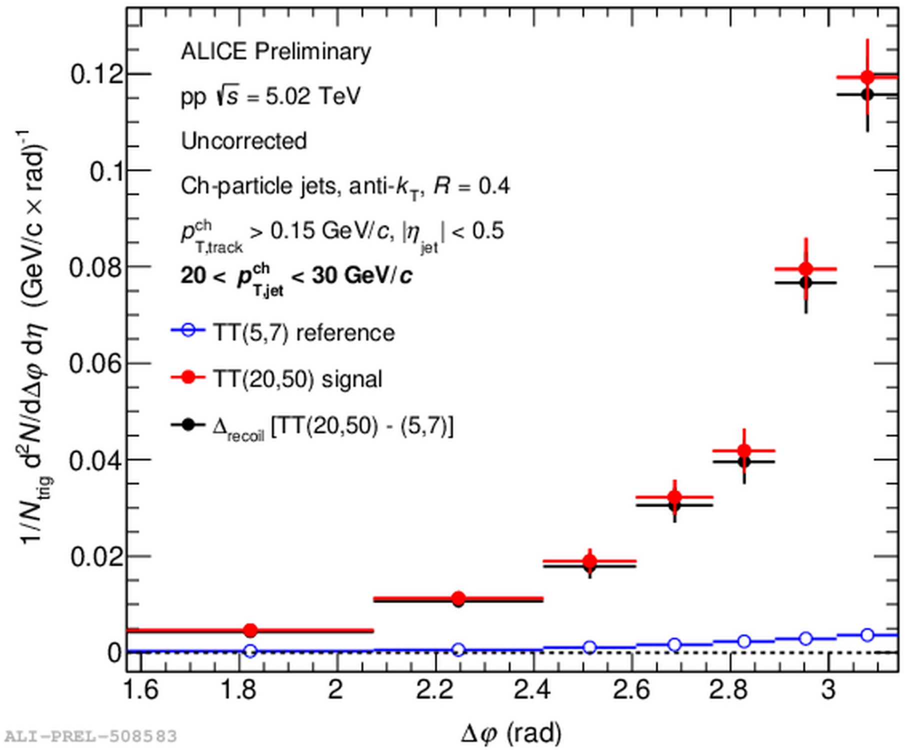


Projection to X axis



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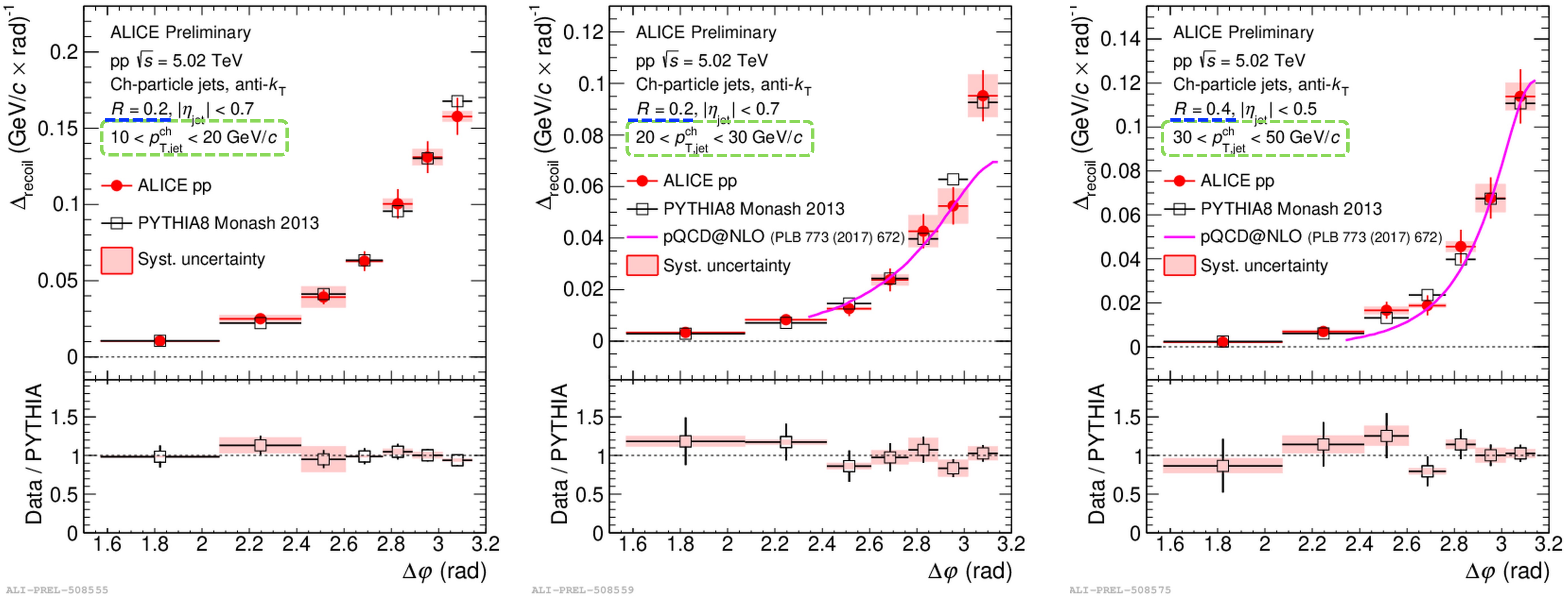
Hadron-jet Δ_{recoil} $(\Delta\varphi)$ distributions



- **First measurement of the fully-corrected** hadron+jet $\Delta\varphi$ distribution in pp collisions at $\sqrt{s} = 5.02$ TeV
  - **Good agreement of $\Delta\varphi$ distributions** between data and different predictions (PYTHIA8 and pQCD prediction[1])

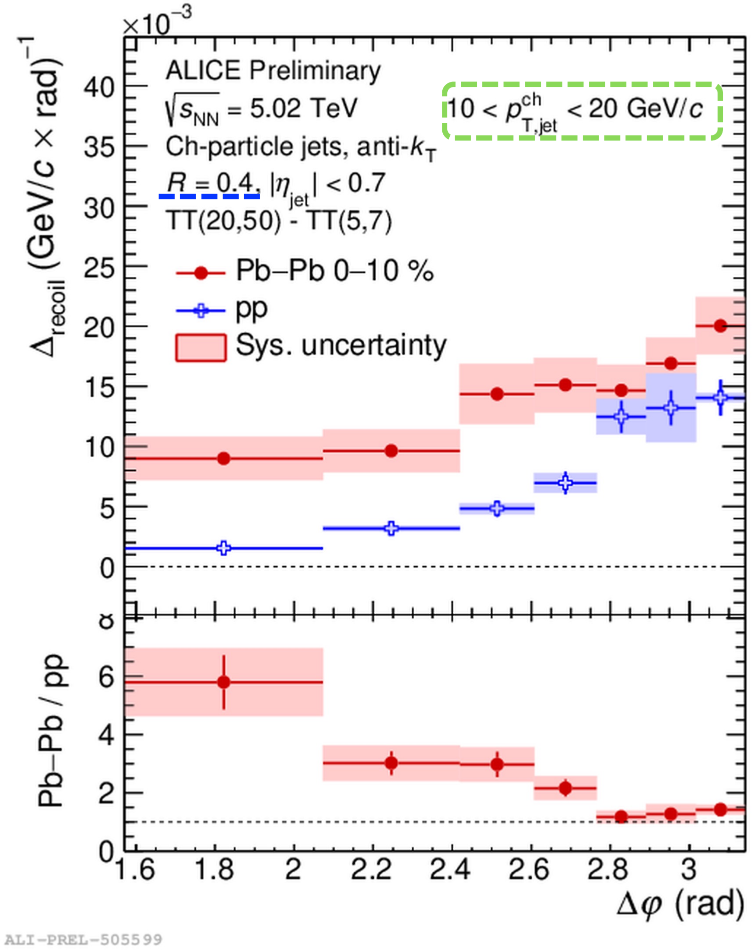
[Phys. Lett. B 773 (2017) 672][1]

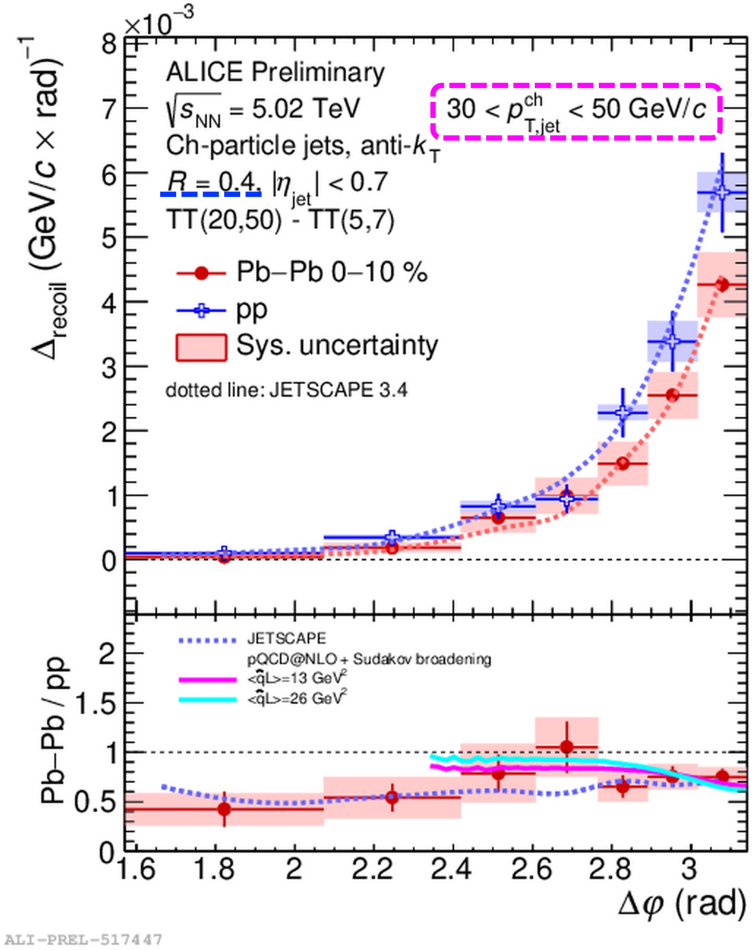
I_{AA} distributions in most central Pb-Pb collisions to pp

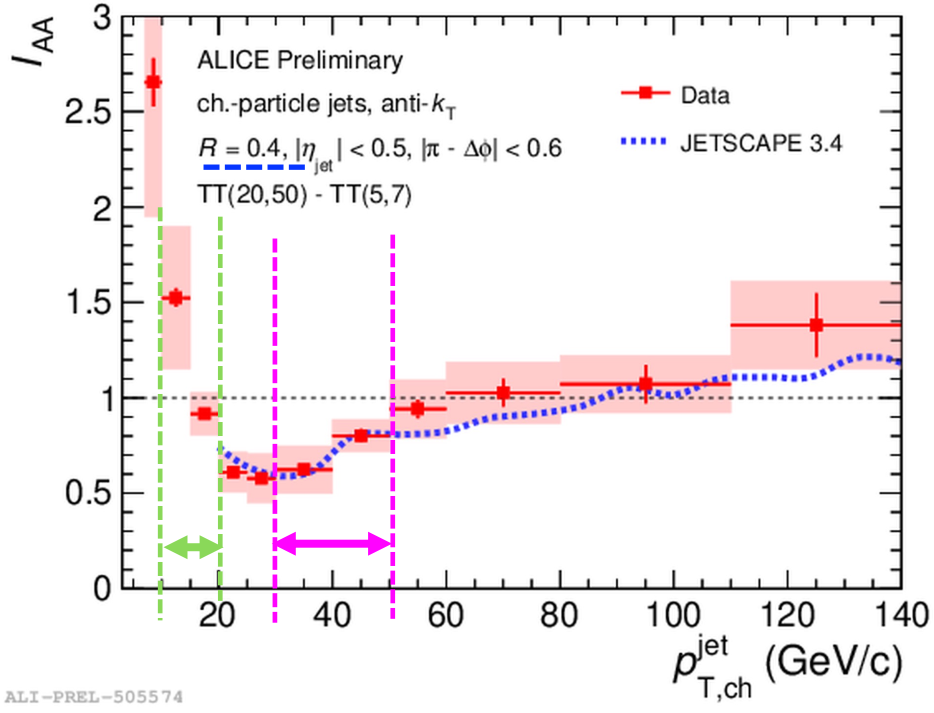
- **Broadening at low p_T for R = 0.4 jets**
- Recoil jet yield **suppressed at higher p_T**
- **Reasonable description** by JETSCAPE[2], and calculation including medium-induced p_T broadening[1] in $\Delta\varphi$, p_T

$$I_{AA} = \Delta^{Pb-Pb}_{recoil} / \Delta^{pp}_{recoil}$$

[Phys. Lett. B 773 (2017) 672][1]
[J. H. Putschke, arXiv:1903.07706][2]

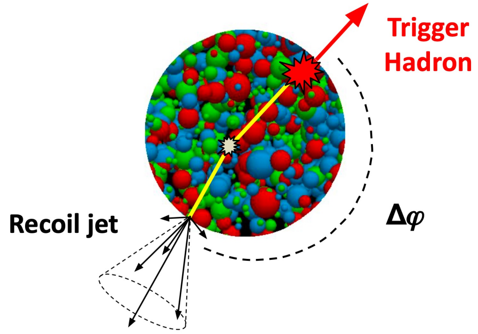






Summary and conclusion

- Multiplicity dependent jet production in pp collisions at 13 TeV has been measured in ALICE
  - Paper link: arXiv:2202.01548
  - Inclusive jet cross section using different resolution parameters (R = 0.2 - 0.7)
  - Multiplicity dependent jet production in different V0M multiplicity percentile
  - Integrated jet production yield and average p_{T} as function of multiplicity
  - Integrated jet production ratio with respect to MB one
  - Jet production ratio using 0.2 divided other jet resolution parameters



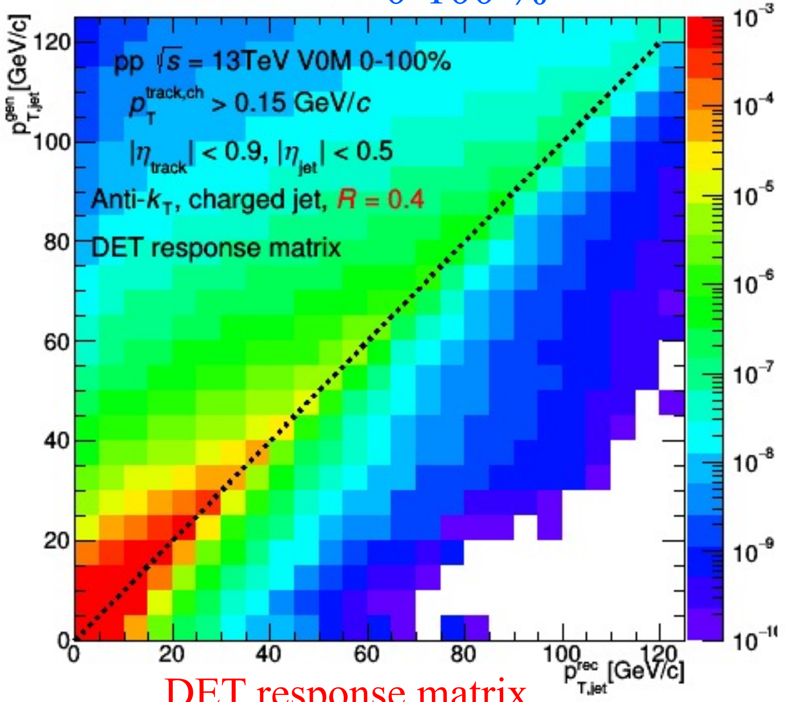
- Semi-inclusive recoil jet measurements via hadron-jet correlations
  - **fully-corrected** hadron+jet $\Delta\varphi$ distribution, quantitatively reproduced by PYTHIA
  - **broadening** and **suppression** of back-to-back hadron-jet correlation in most Pb-Pb collisions

yongzhen.hou@cern.ch

Thanks for your attention!

Response matrix combination

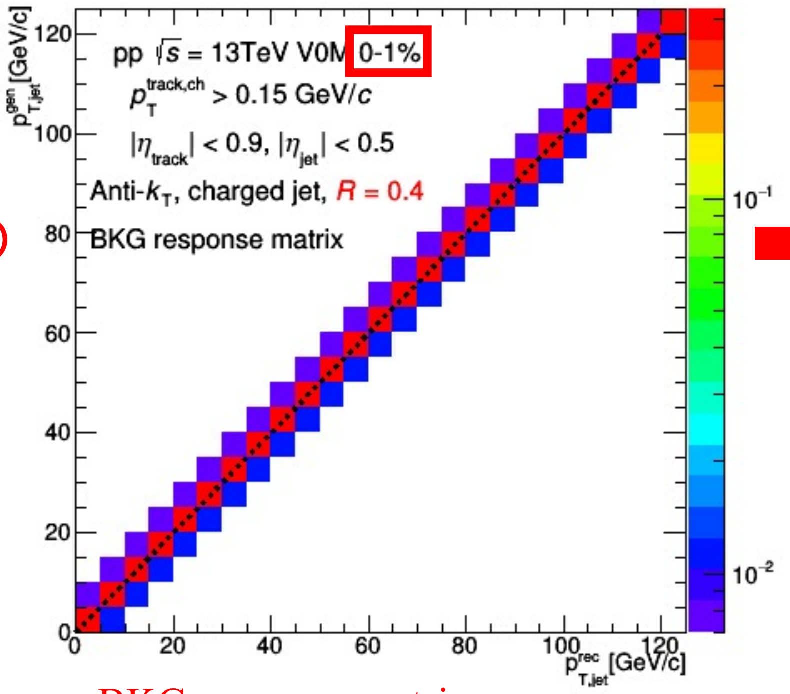
0-100 %



DET response matrix

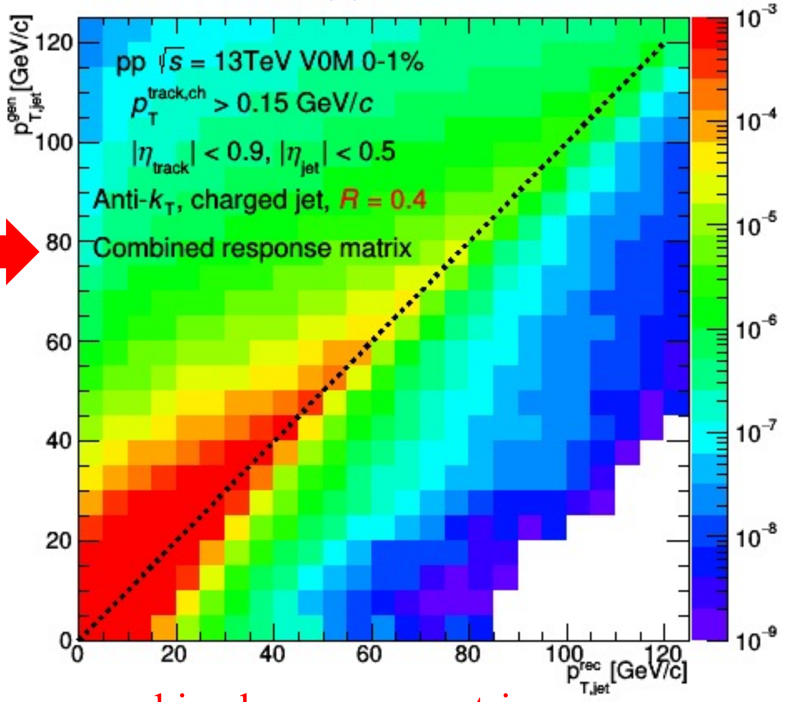
⊗

0-1%



BKG response matrix

0-1%



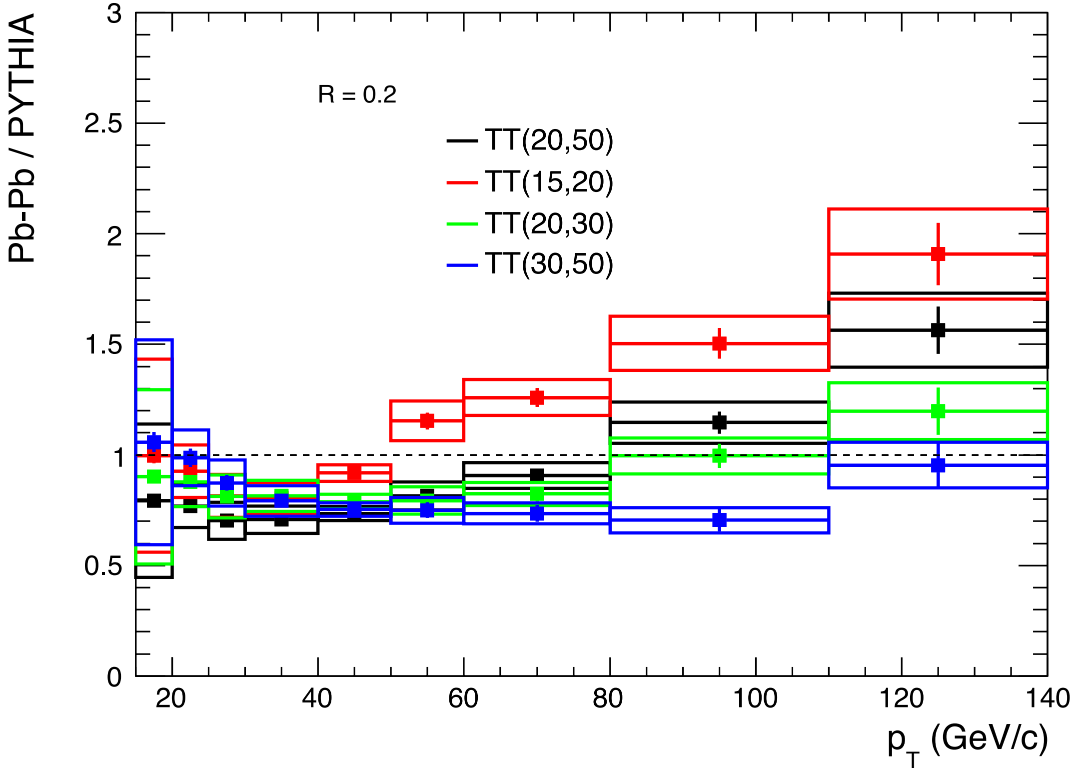
combined response matrix

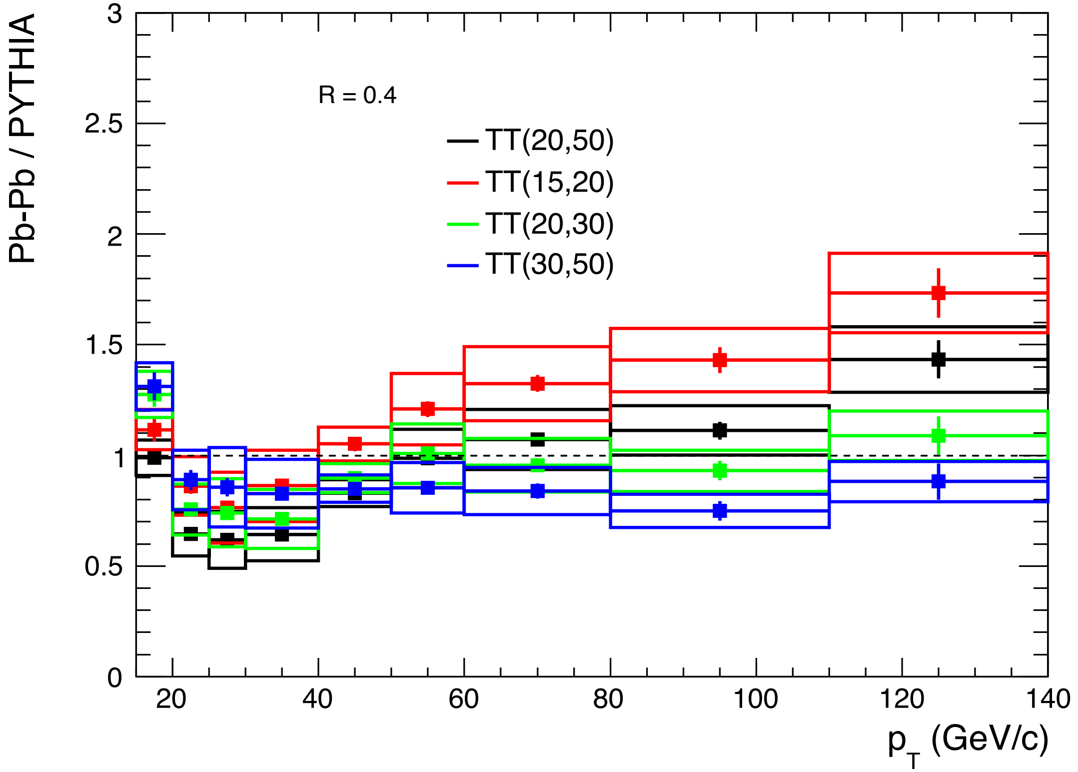
- Detector response matrix is obtained with MC simulation for jet energy scale and resolution correction
- Using δp_T distribution for background response matrix, and obtain the combined response matrix by $RM_{full} = RM_{bkg} \times RM_{det}$
- Using the response matrix to perform unfolding and obtain the corrected jet yield

Systematic uncertainty estimation

Uncertainty resources	how to estimate
track efficiency	varing tracking efficiency by -3%
unfolding	different generators, iterations, different methods(Svd/Bayes)
secondary particles	varying the DCA threshold of track selection (jet p_{T} ±0.5%)
track p_{T} resolution	varying tracking resolution by ±20%
Bkg subtraction	using different method to estimate δp_T
normalization	taking from luminosity paper (MB results)
multiplicity estimation	RM build from MC in multiplicity bins
total	**add in quadrature**

TT ratios





- IAA has a slightly TT-dependence
- This technique becomes a very interesting way to study the **interplay between hadron and jet suppression**