Jet-Track Correlation Studies in PbPb and pp collisions at 5.02 TeV

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Motivation and Approach

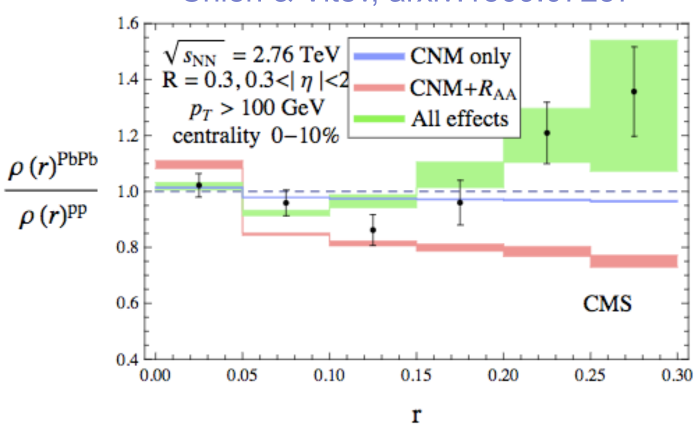
Motivation:

- Probe interactions between the QGP and high-p_T partons
- Look for parton energy loss and possible medium response
- 2.76 TeV measurements of p_T redistribution in the medium:
    - From small to large angles from the jet axis
    - Out-of-cone p_T carried by soft particles (p_T < 3 GeV)

Various theories can generally capture results, e.g:

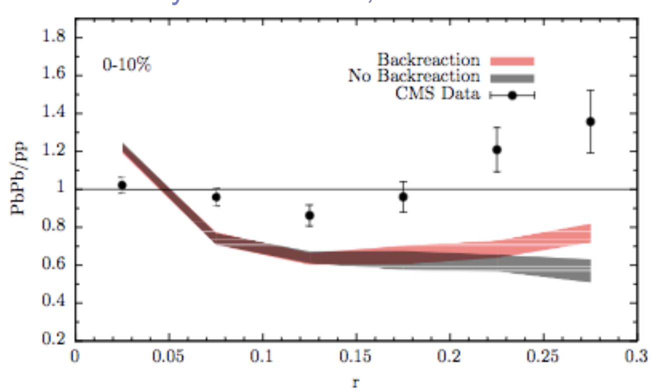
SCET$_G$ (Glauber gluon interactions in the QGP)

Chien & Vitev, arxiv:1509.07257



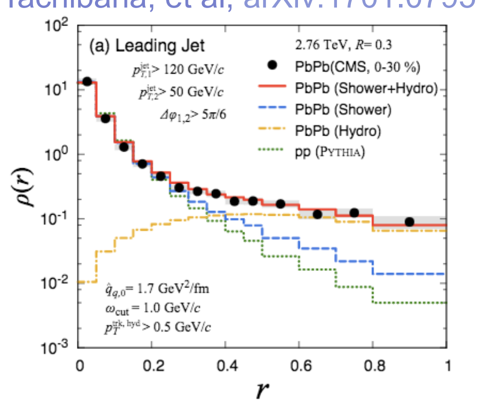
Hybrid model with backreaction ("plasma wake")

Casalderrey-Solana et al, arXiv:1609.05842



Shower+hydro medium response

Tachibana, et al, arXiv:1701.07951



Motivation and Approach

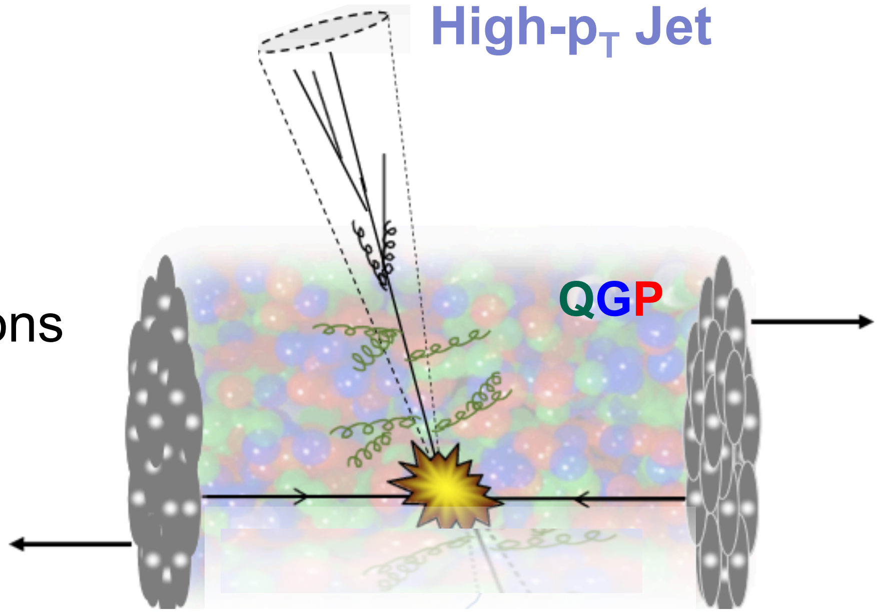
Motivation:

- Probe interactions between the QGP and high-p_T partons
- Look for parton energy loss and possible medium response
- Precisely measure modifications to large Δr from jet axis

→ Extend jet modification measurements to new $\sqrt{S_{NN}}$ = 5.02 TeV

Approach:

- Select high-p_T jets
- Construct charged particle correlations w.r.t. jet axis
- Weight correlations per-track by track p_T to construct p_T distributions and extract jet shapes



Event Selection and Datasets

Data Samples for results at 5.02 TeV:

- PbPb – 404 μb^{-1}
- pp – 27.4 pb^{-1}

Data Samples for results at 2.76 TeV:

- PbPb – 166 μb^{-1},
- pp – 5.3 pb^{-1}

Monte Carlo Samples:

- For corrections and systematic uncertainty determination
- **pp:** PYTHIA 6
- **PbPb:** PYTHIA 6 embedded in HYDJET tune Z2 (hydro+”minijets”), no simulated quenching

Jet and Track Reconstruction and Selection

Jets

Jet Reconstruction

- Anti-k_t calorimeter jets, R = 0.4
- **PbPb:** pile-up UE subtraction
- **pp:** no UE subtraction for jet energy determination

Inclusive Jet Selection

- p_T > 120 GeV
- $|\eta| < 1.6$
- May include multiple jets from one event

Tracks

Track Reconstruction:

- **PbPb:** heavy ion reconstruction, p_T > 0.4 GeV
- **pp:** pp reconstruction, p_T > 0.2 GeV
- Corrected for efficiency etc. as a function of η, φ, p_T, and centrality

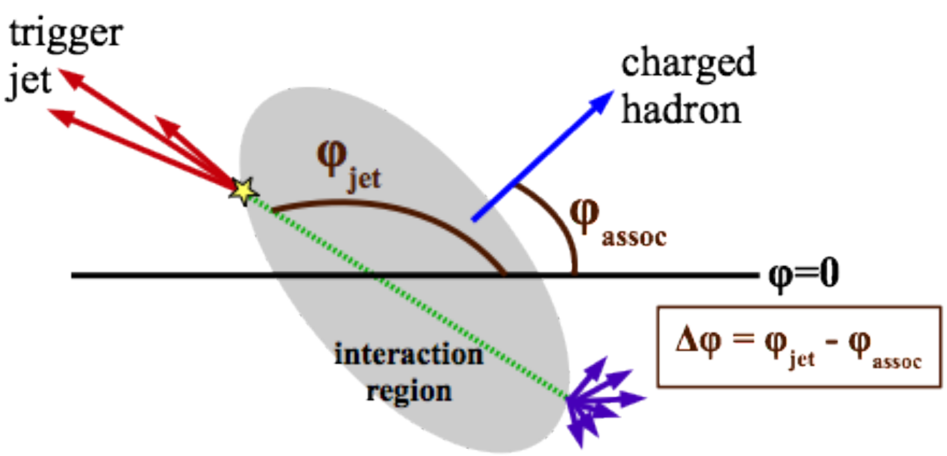
Track Selection:

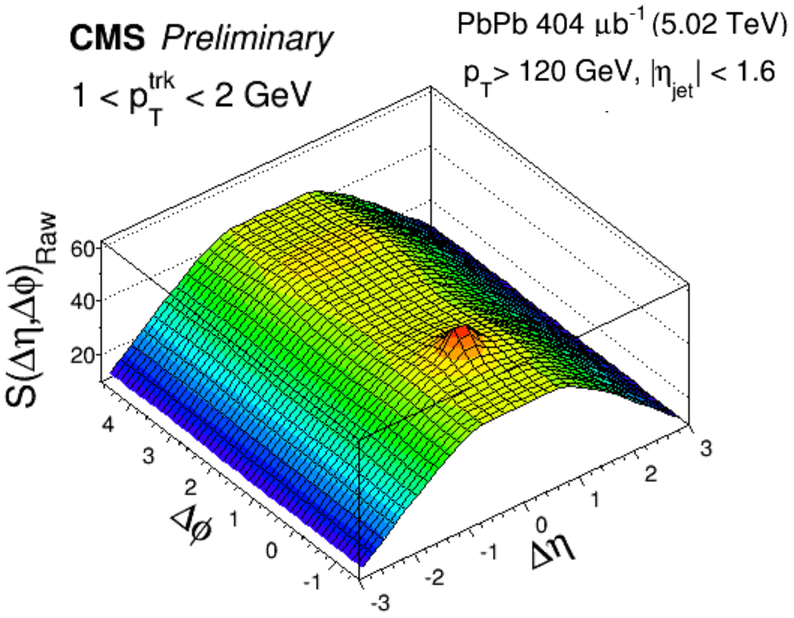
- $0.7 < p_T < 300$ GeV
- $|\eta| < 2.4$

Constructing Jet-Track Correlations

Analysis procedure in PbPb and pp:

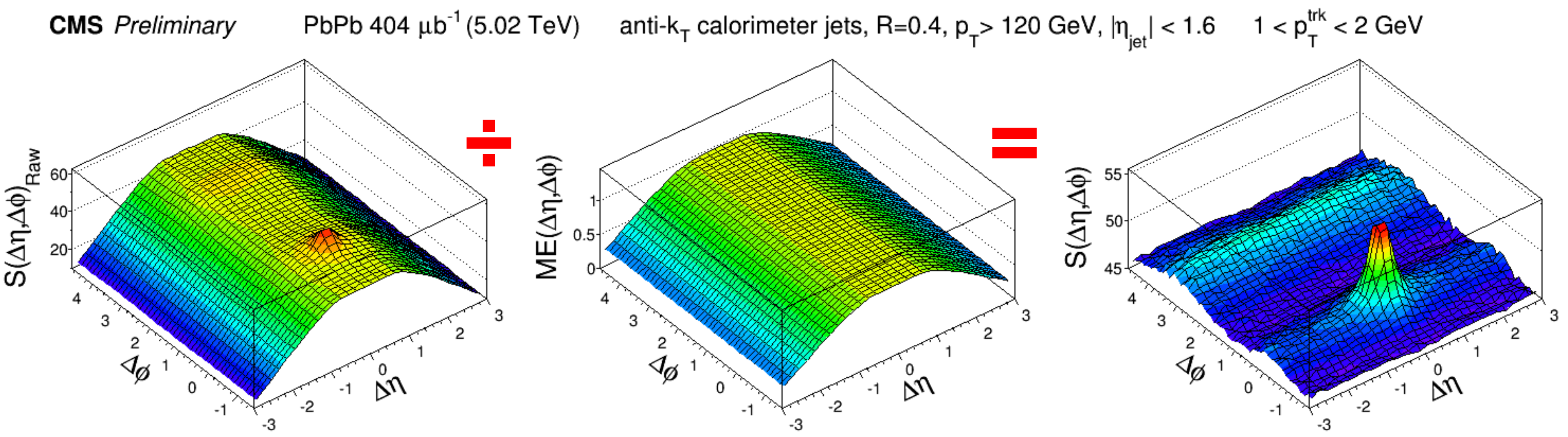
1. Construct 2D $\Delta\eta$—$\Delta\varphi$ charged particle correlations relative to jet axis
2. Pair acceptance geometric correction
3. Subtract long-range and uncorrelated background
4. Correct correlations for jet reconstruction-related biases





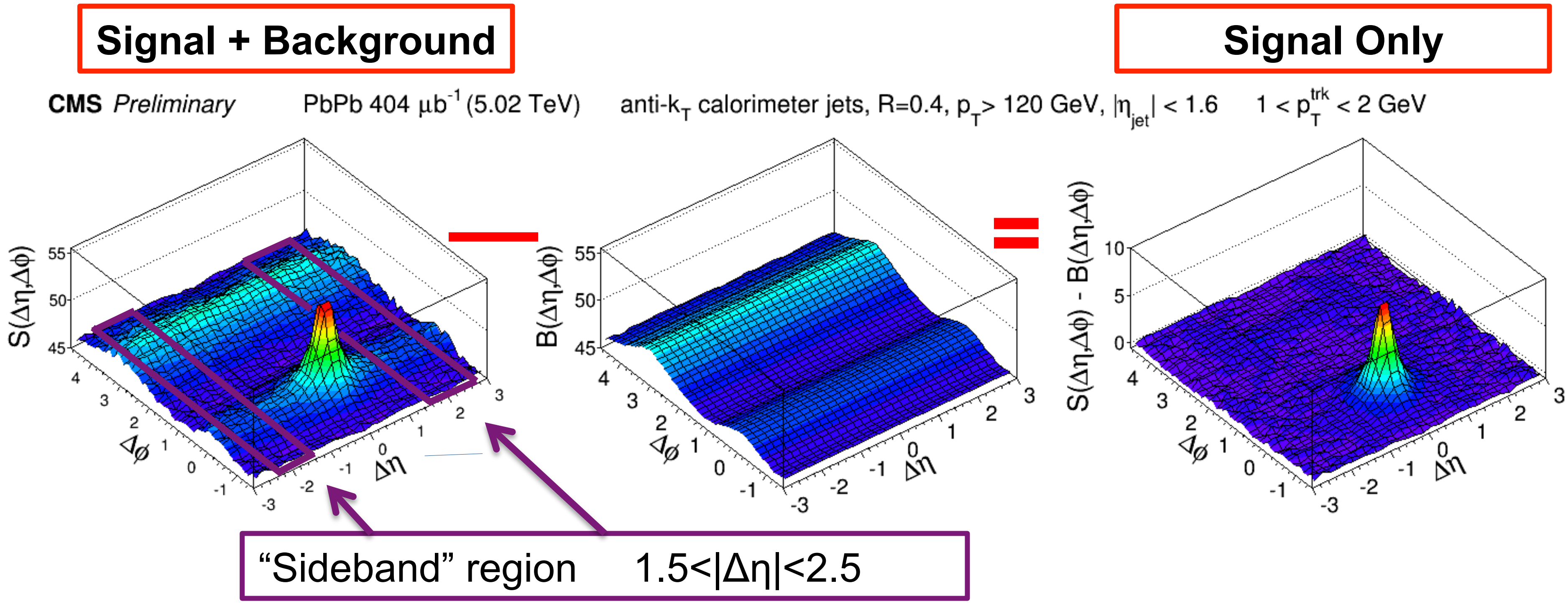
Pair-Acceptance Correction

- Finite jet and track acceptances result in trapezoidal geometry
- Correct for this pair acceptance effect with a mixed-event correction:
  - Jets from sample
  - Tracks from a minimum-bias event matched on centrality and v_z



Background Subtraction

- Project background (measured on 1.5<|Δη|<2.5) into Δφ
- Propagate this background distribution in 2D
- Subtract from background from signal to yield isolated jet peak

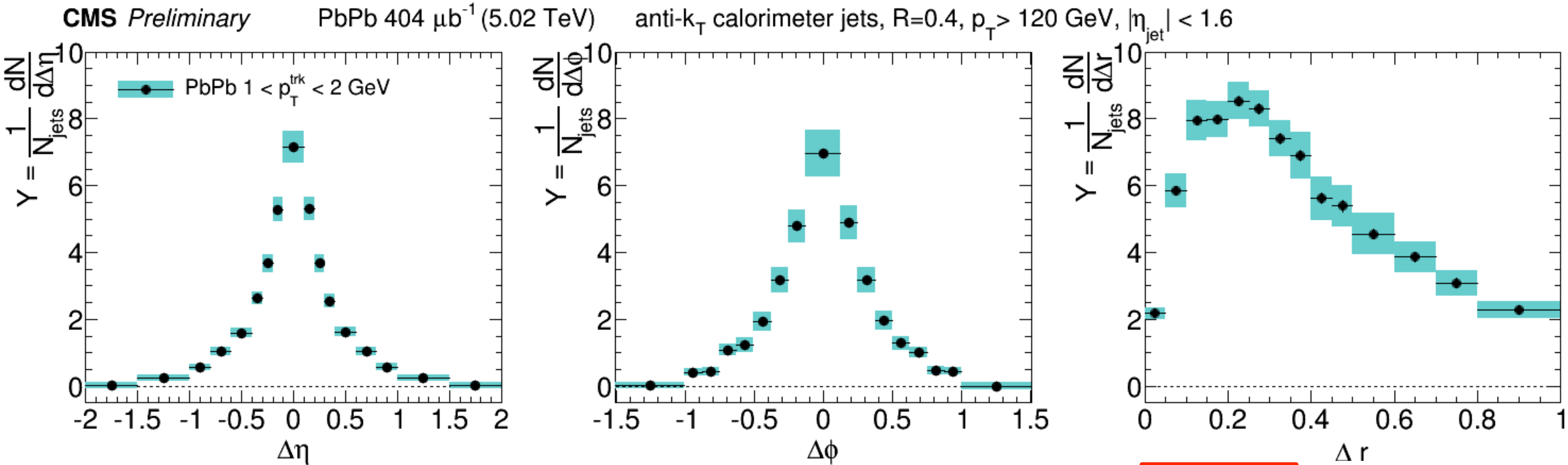


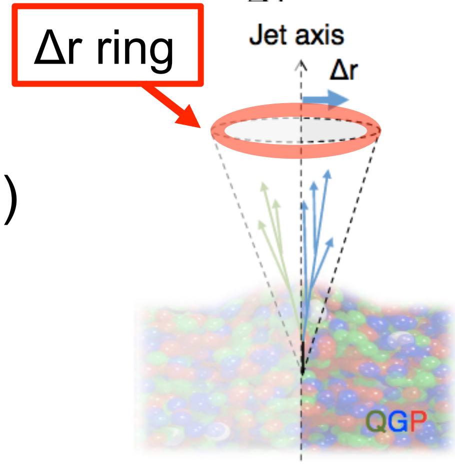
- Finally: apply two MC-based corrections for jet reconstruction biases

Observables and Results Presentation

Charged particle correlated yields:

Project into Δη **Project into Δφ** **Integrate in Δr rings**

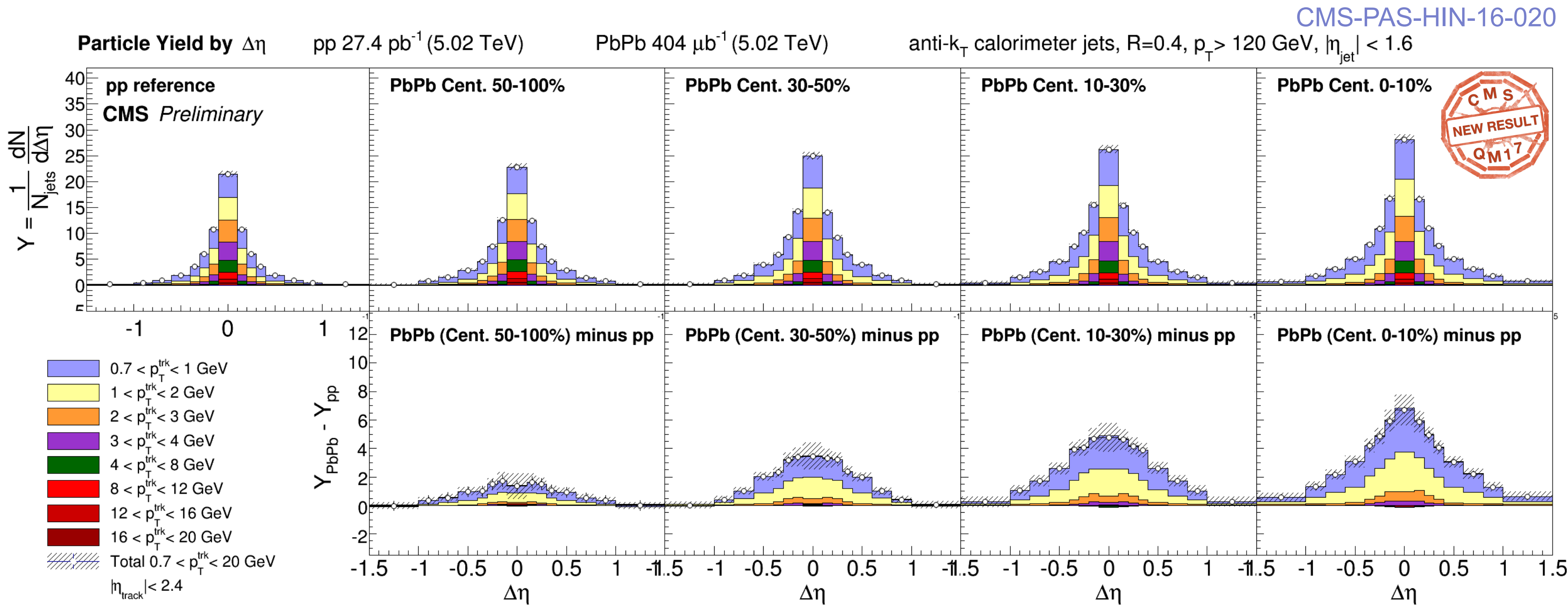




Jet shape ρ(Δr):

- Weight Δη-Δφ correlations per-track by track-p_T
- Integrate correlations in rings of $\Delta r = \sqrt{((\Delta\eta)^2+(\Delta\varphi)^2)}$
- Normalize to unity over range $|\Delta r| < 1$

Particle Yields by Δη



- Correlated charged particle yields as function of Δη
- Projected over |Δφ|<1.0
- Centrality and p_T-dependent excess of soft particles (p_T < 3 GeV) in PbPb
- No significant modifications in mid-p_T (4 – 8 GeV) range

Particle Yields by Δφ

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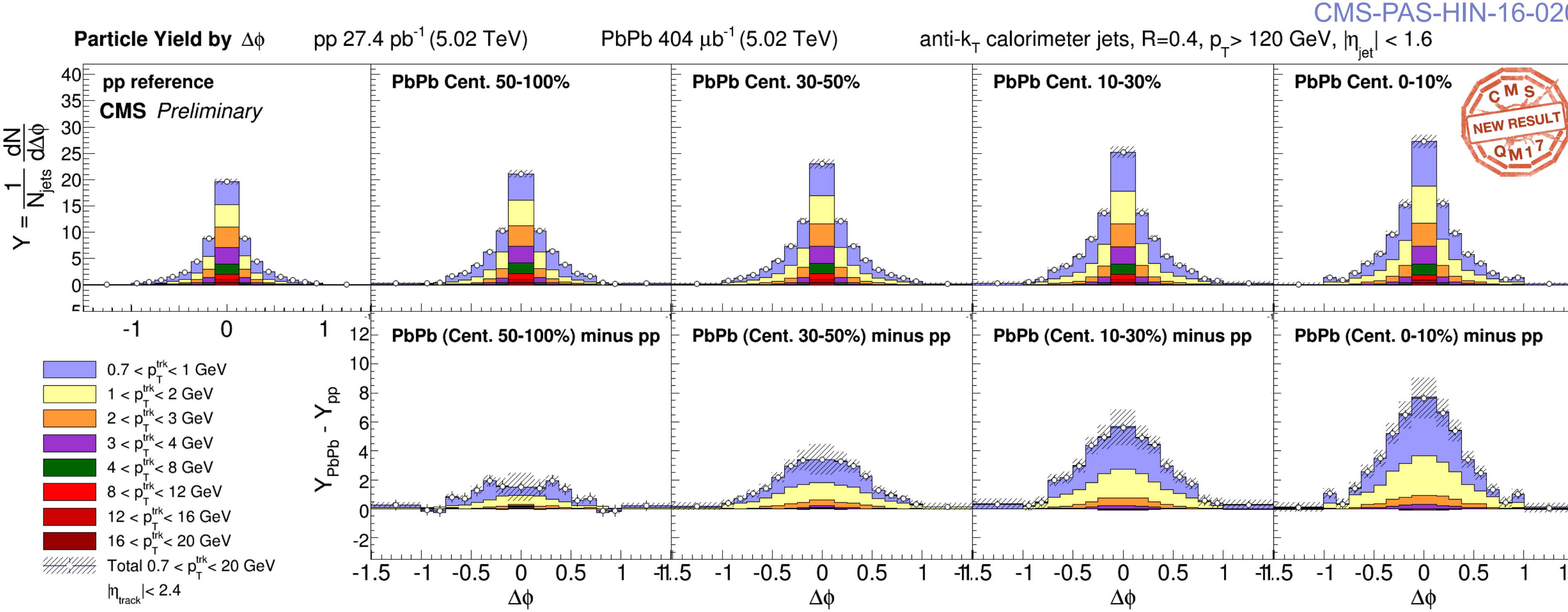

- Correlated charged particle yields as function of Δφ
- Projected over |Δη|<1.0
- Gaussian-like distribution of excess extends to large Δη and Δφ

Particle Yields by Δr

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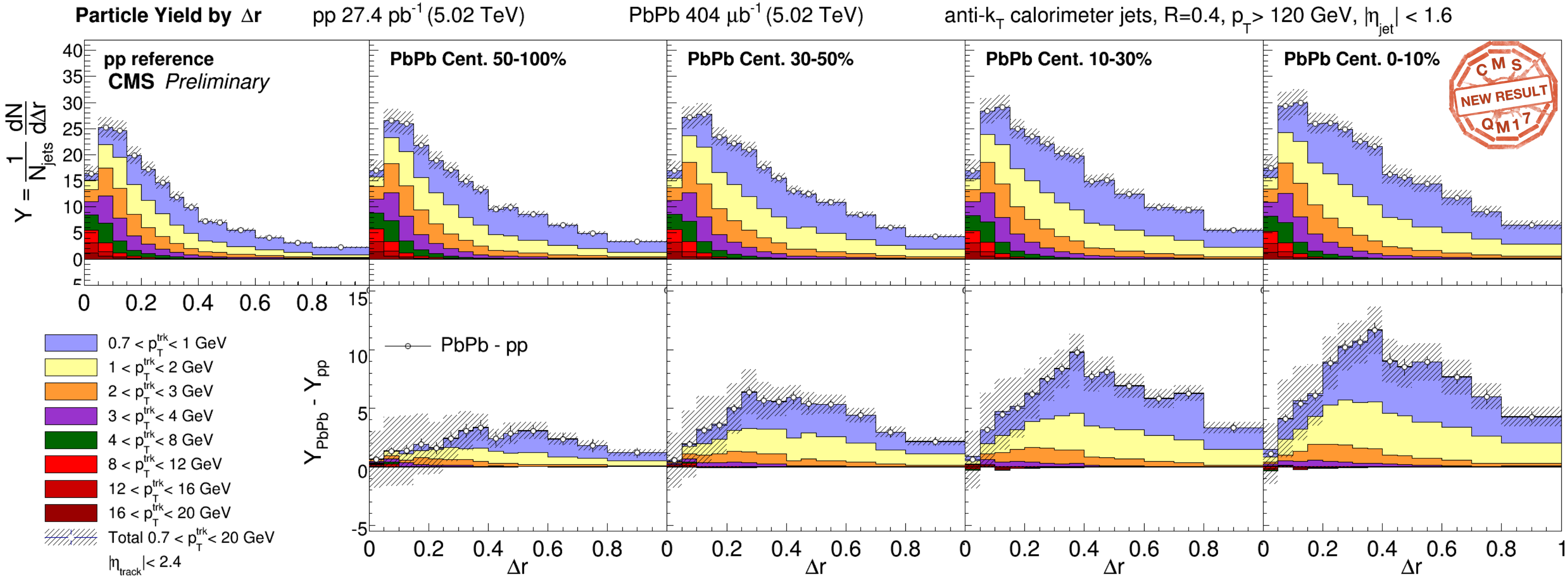

- 2D correlations integrated in radial rings (area of Δr bins grows with Δr)
- Soft charged particle excesses to at least Δr = 1 from the jet axis

- **Next:** integrate in Δr to obtain total correlated yield as function of p_T

Integrated Particle Yields (|Δr|<1)

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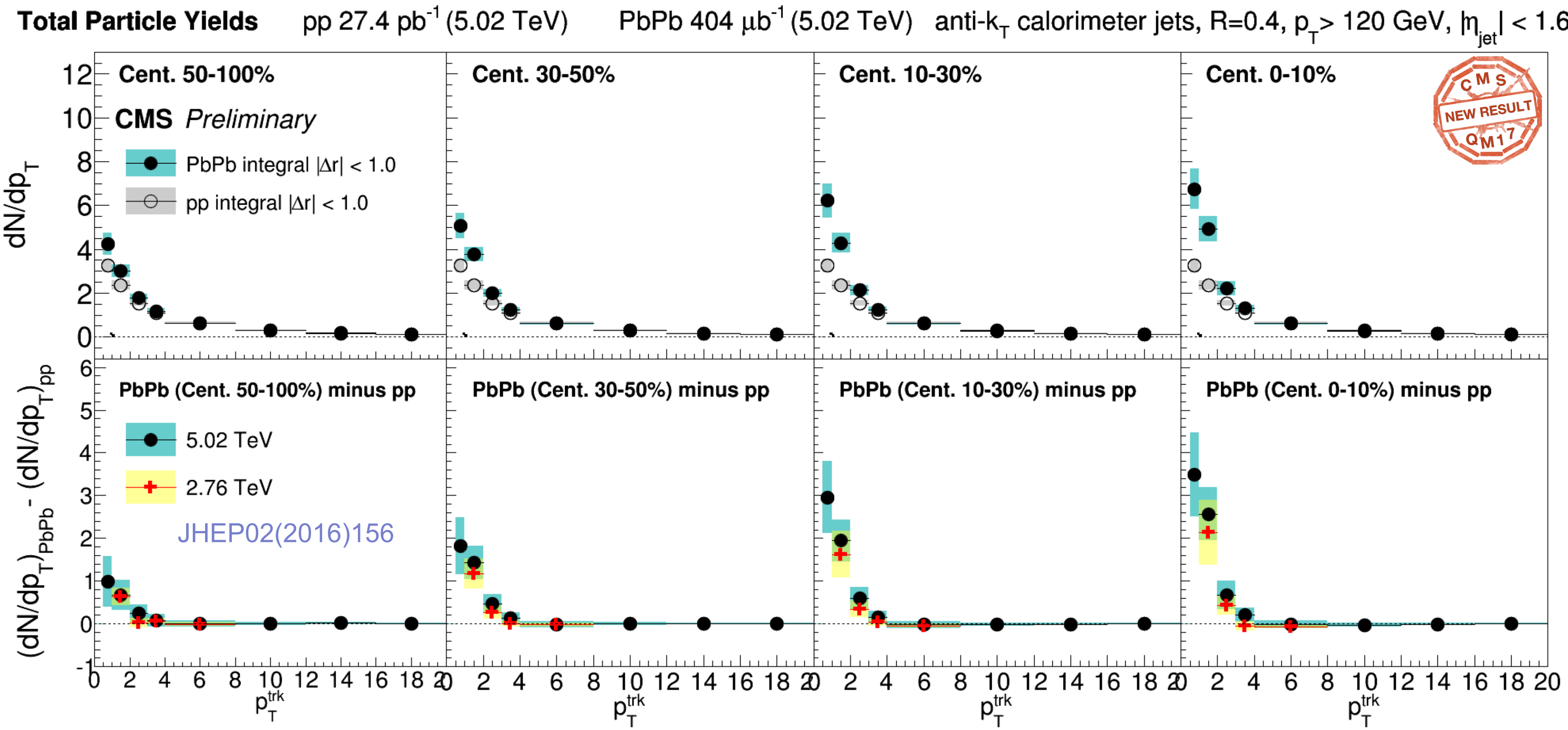
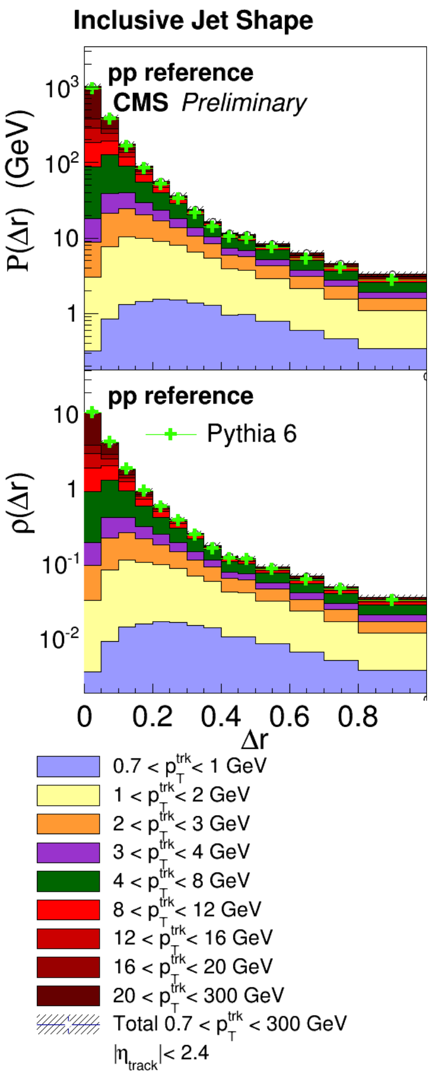


- Total correlated charged particle yield within |Δr|<1 as function of track-p_T
- Captures PbPb to pp jet fragmentation function modification

Radial p_T Profile and Jet Shape



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Transverse momentum profile P(Δr)

- Weight Δη-Δφ correlations per-track by track-p_T
- Integrate correlations in rings of $\Delta r = \sqrt{(\Delta\eta)^2+(\Delta\varphi)^2}$

$$P(\Delta r) = \frac{1}{\delta r}\frac{1}{N_{\text{jets}}}\Sigma_{\text{jets}}\Sigma_{\text{tracks}\in(r_a,r_b)}p_T^{\text{trk}}$$

Jet shape ρ(Δr)

- Normalize P(Δr) to unity over range Δr < 1
- Measures self-normalized p_T distribution of jet

$$\rho(\Delta r) = \frac{1}{\delta r}\frac{1}{N_{\text{jets}}}\Sigma_{\text{jets}}\frac{\Sigma_{\text{tracks}\in(r_a,r_b)}p_T^{\text{trk}}}{\Sigma_{\text{tracks}}p_T^{\text{trk}}}$$

Radial p_T Profile and Jet Shape

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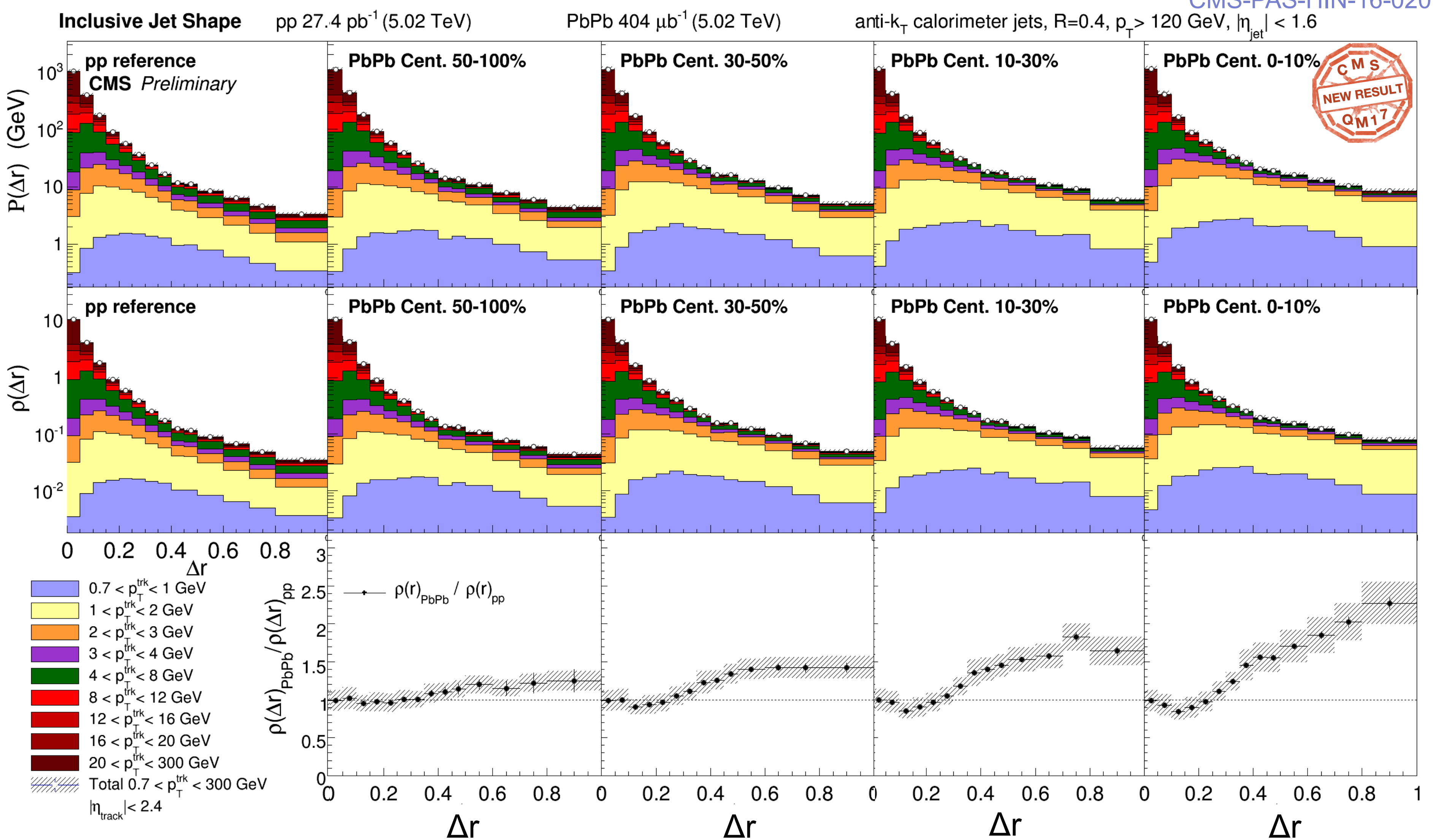
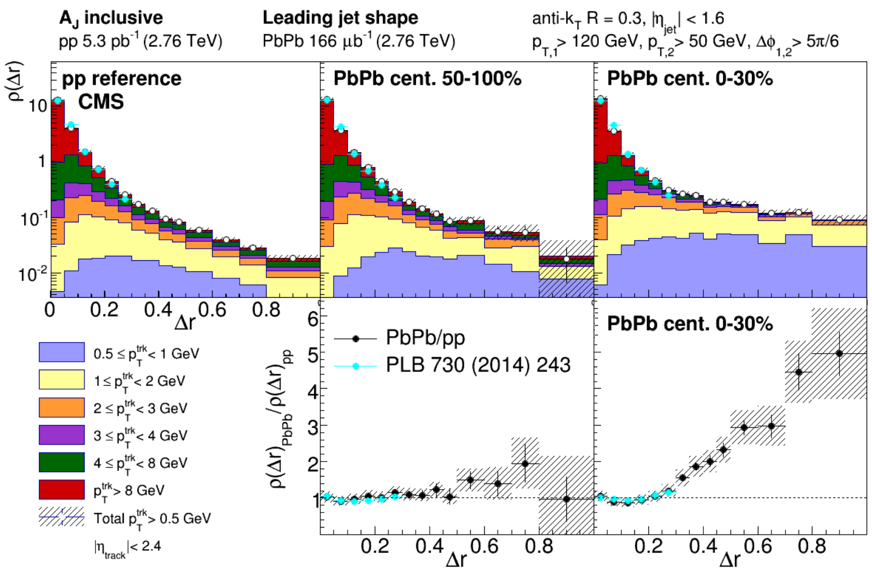


Radial p_T Profile and Jet Shape

2.76 TeV Leading Jets

10.1007/JHEP11(2016)055



- Anti-k_t calo jets, R = 0.3
- Leading jets, p_T > 120 GeV
- PLB: Inclusive jets, p_T > 120 GeV
- Normalized over Δr < 0.3
- 0-30% centrality bin

5.02 TeV Inclusive Jets

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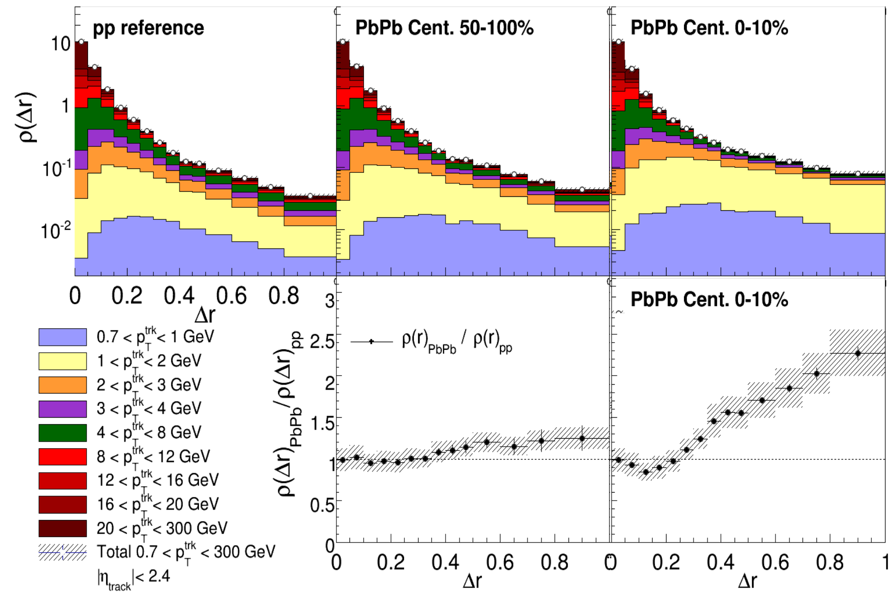

- Anti-k_t calo jets, R = 0.4
- Inclusive jets, p_T > 120 GeV
- Normalized over Δr < 1
- 0-10% centrality bin

PbPb to pp modifications are similar at 5.02 and 2.76 TeV: differences in pp reference jet shape account for differences in ratio $\rho(\Delta r)_{PbPb}/\rho(\Delta r)_{pp}$

Summary

- New study of charged particle distributions and jet shapes at 5.02 TeV
  - Quantified centrality and p_T-dependent excess of low-p_T particles
  - Redistribution of p_T to large angles from the jet axis
- Modifications similar at 5.02 TeV when compared to 2.76 TeV

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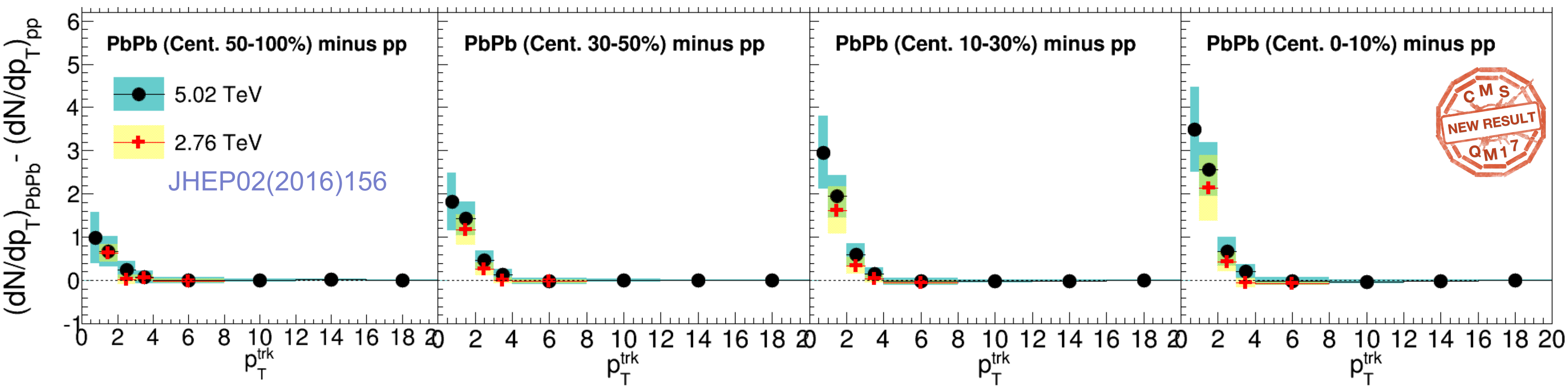
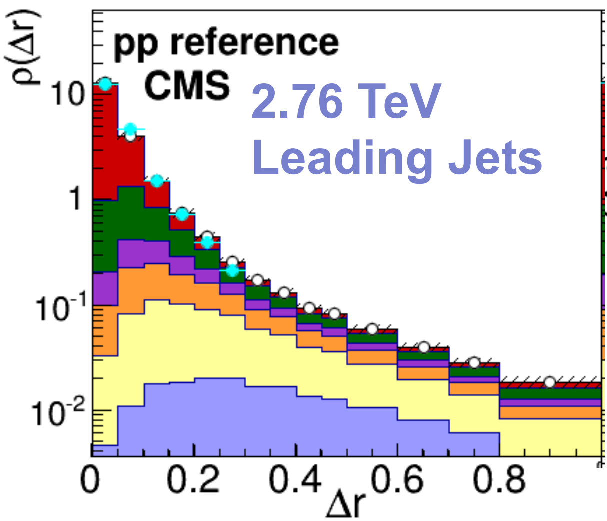
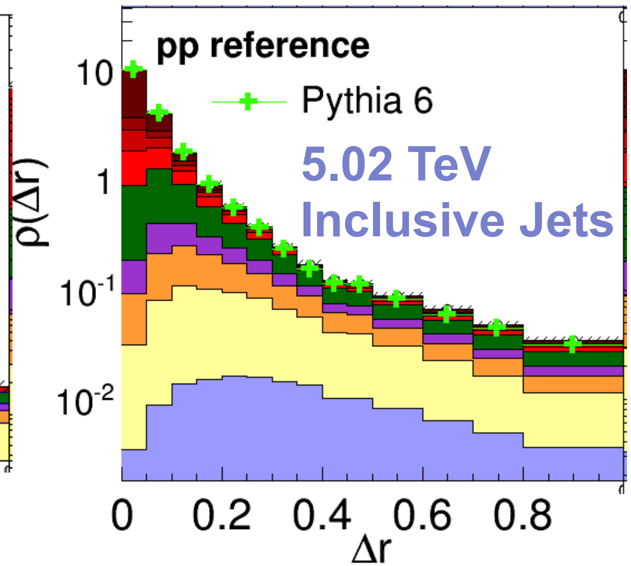
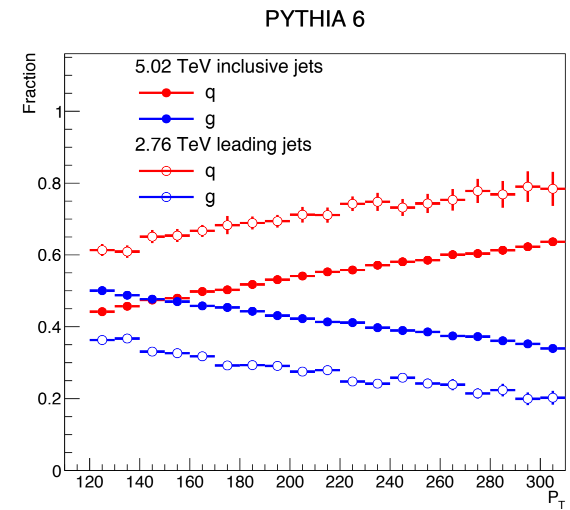


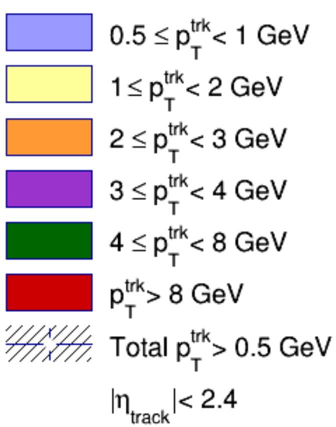
Backup

Collision Energy Comparison in pp









pp jet shapes are significantly broader and softer at 5.02 TeV

- 2.76 TeV Leading Jets: 64.0% Quark Jets, 33.4% Gluon Jets
- 5.02 TeV Inclusive Jets: 47.4 % Quark Jets, 47.6% Gluon Jets

In modification measurements:

- PbPb – pp differences are similar at 5.02 and 2.76 TeV
- Difference in jet shape ratio can be accounted for by differences in pp reference jet shape

Systematic Uncertainties

Source	0–10%	10–30%	30–50%	50–100%	ppRef
Background fluctuation bias	0–10%	0–5%	0–2%	0–1%	–
Background fluctuation bias residual	0–2%	0–3%	0–1%	0–1%	–
JFF bias	3–5%	3–4%	3–4%	3–4%	3%
Residual JES	4%	4%	4%	4%	4%
Tracking efficiency uncertainty	1%	1%	1%	1%	1%
Residual tracking efficiency	5%	5%	5%	5%	5%
Pair-acceptance corrections	1–5%	1–4%	1–4%	1–4%	1–2%
Background subtraction	1–9%	0–4%	0–4%	0–3%	0–3%
Total	7–16%	7–11%	7–9%	7–9%	7–8%

Background Fluctuation and JFF Bias Corrections