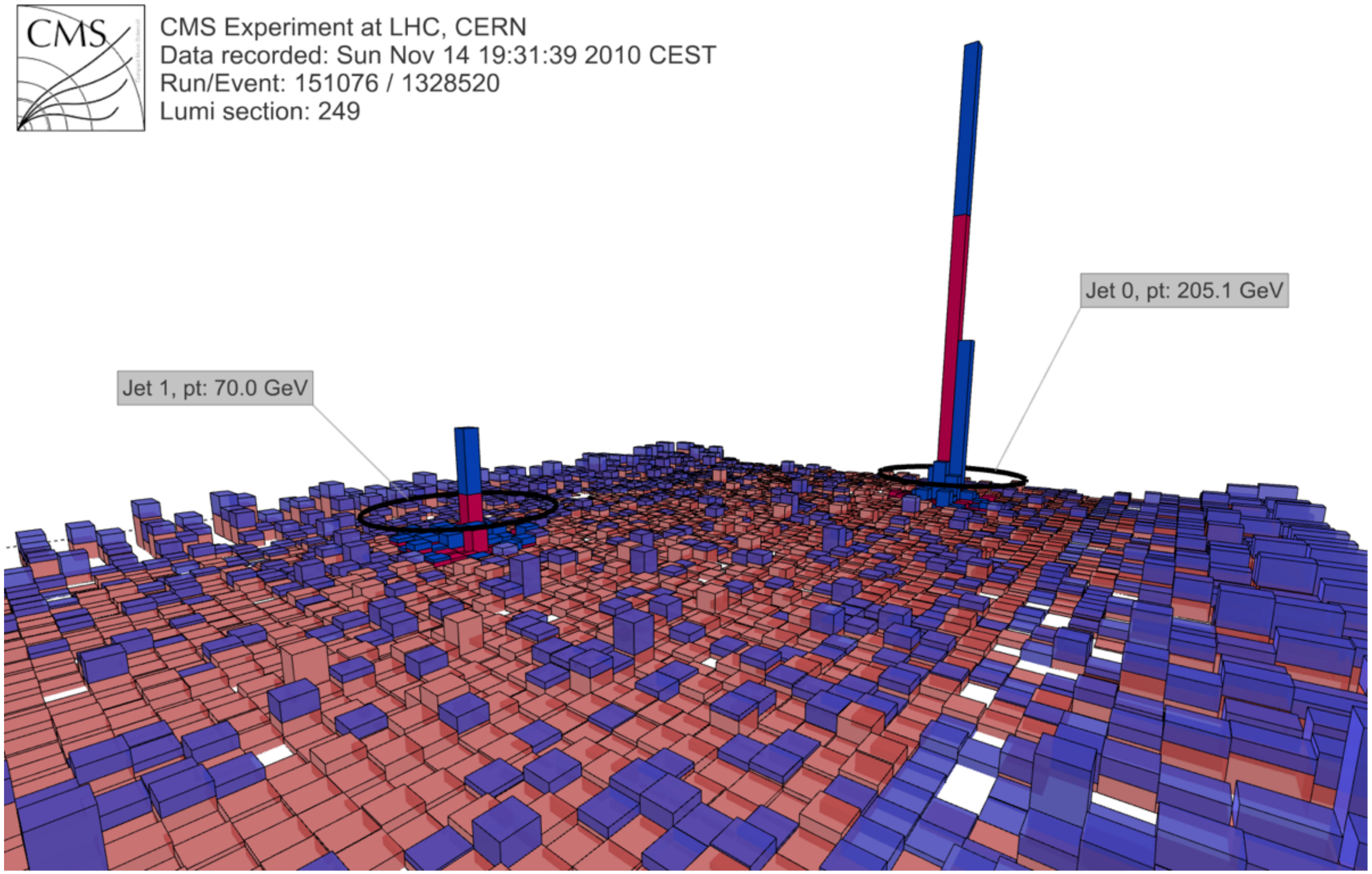
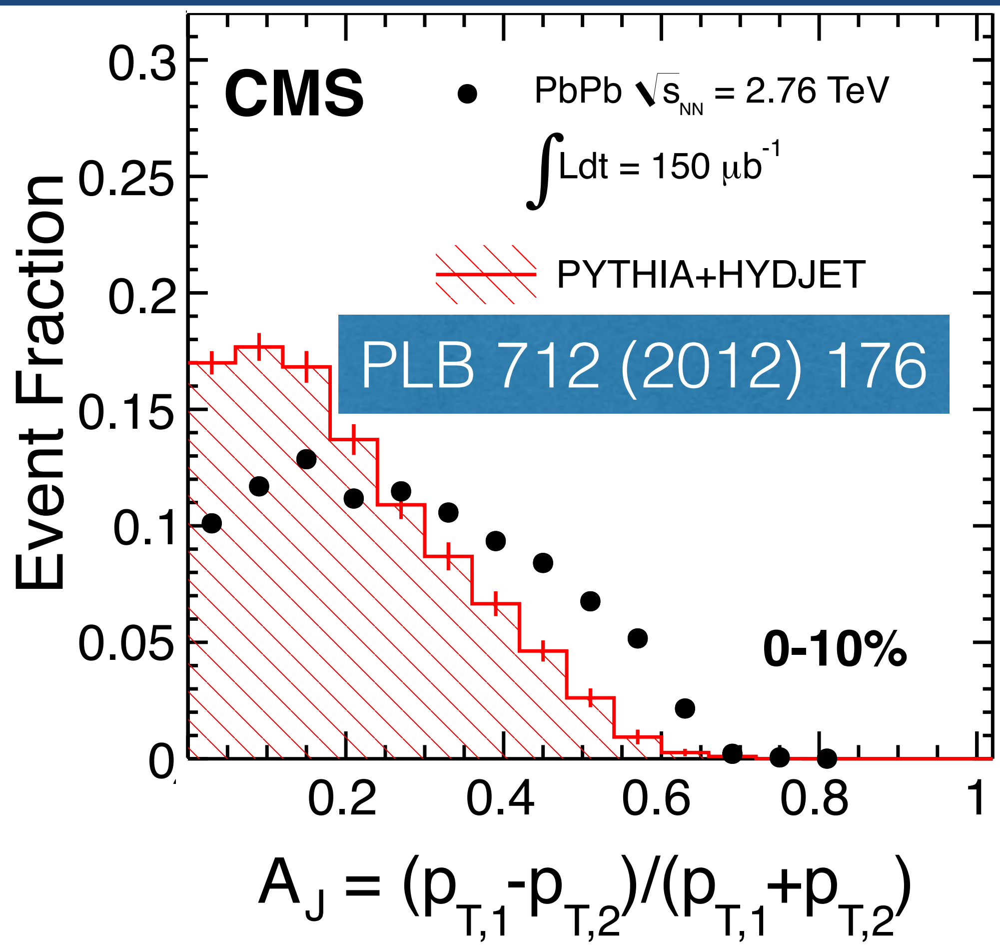


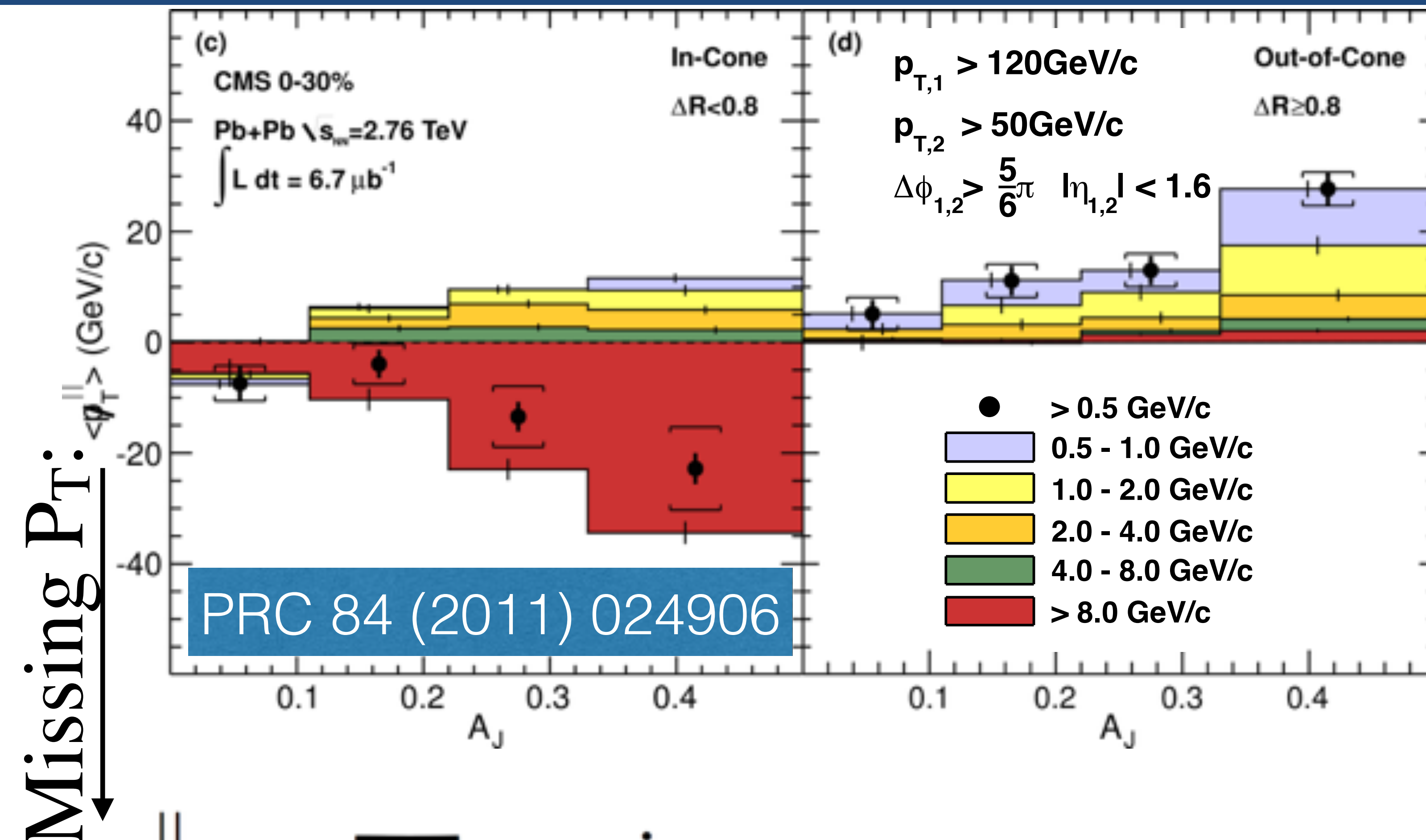
Angular distributions of the quenched energy flow from dijets with different radius parameters in CMS

Quark Matter 2015
Kobe, Japan
On behalf of the CMS experiment at the LHC

Christopher McGinn

Observation of Dijet Asymmetry in PbPb





$$\not{p}_{\mathrm{T}}^{\parallel} = \sum_{\mathrm{i}} -p_{\mathrm{T}}^{\mathrm{i}} \cos\left(\phi_{\mathrm{i}} - \phi_{\mathrm{Dijet}}\right)$$

- Modification observed of A_J in central PbPb
  - Where does the momentum go? (Far from the cone)
  - To study: characterize missing p_T incrementally in η-φ

Samples and Selection

- pp: 5.3 pb^{-1} at 2.76 TeV
- Single Jet 80 GeV Trigger
  - Fully efficient at 120 GeV

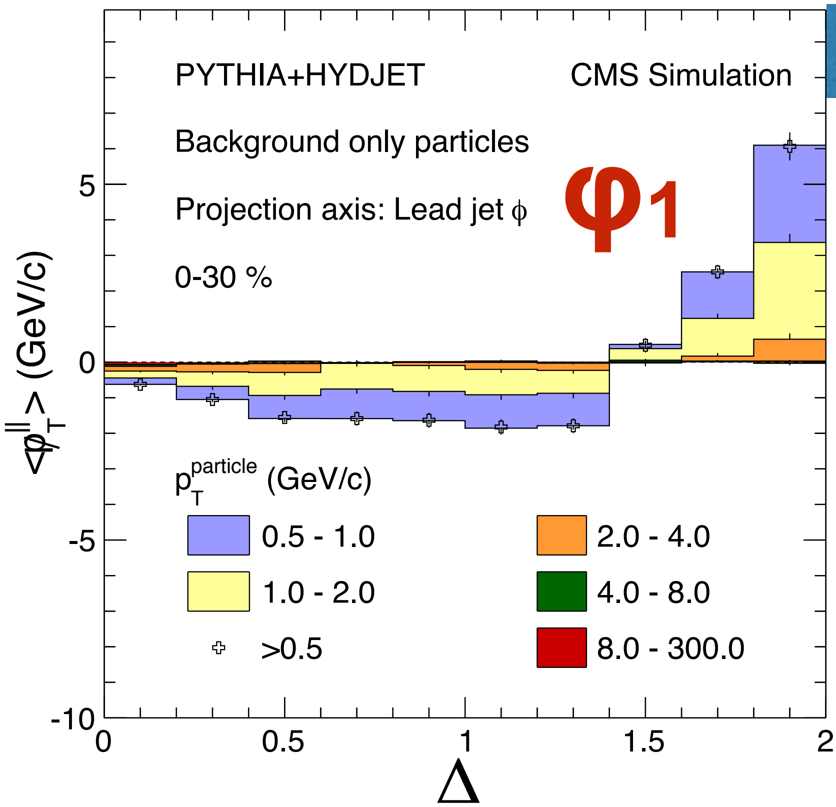
- PbPb: 166 μb^{-1} at 2.76 TeV
- Single Jet 80 GeV Trigger
  - Fully efficient at 120 GeV

- Dijet selection:
  - $p_{T,1} > 120$ GeV
  - $p_{T,2} > 50$ GeV
  - $|\eta_1|, |\eta_2| < 1.6$ (0.6)
  - $\Delta\varphi_{1,2} > 5\pi/6$
- Track Selection:
  - $p_T > 0.5$ GeV
  - $|\eta| < 2.4$

anti-k_t calorimeter jets (See backup slide 21)

Corrected for efficiency/fake rate
(See backup slides 20,22)

Analysis: The Dijet Axis



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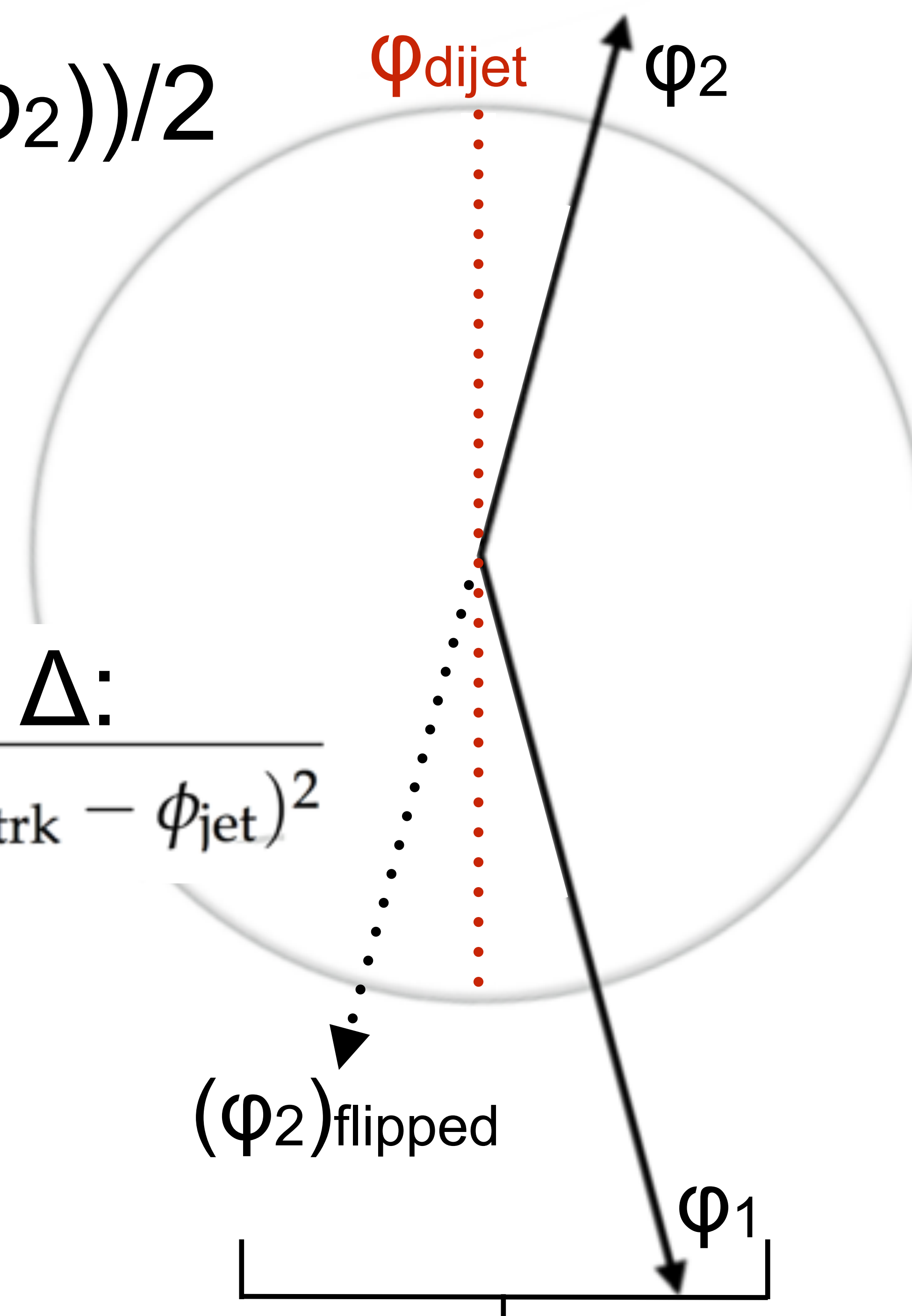
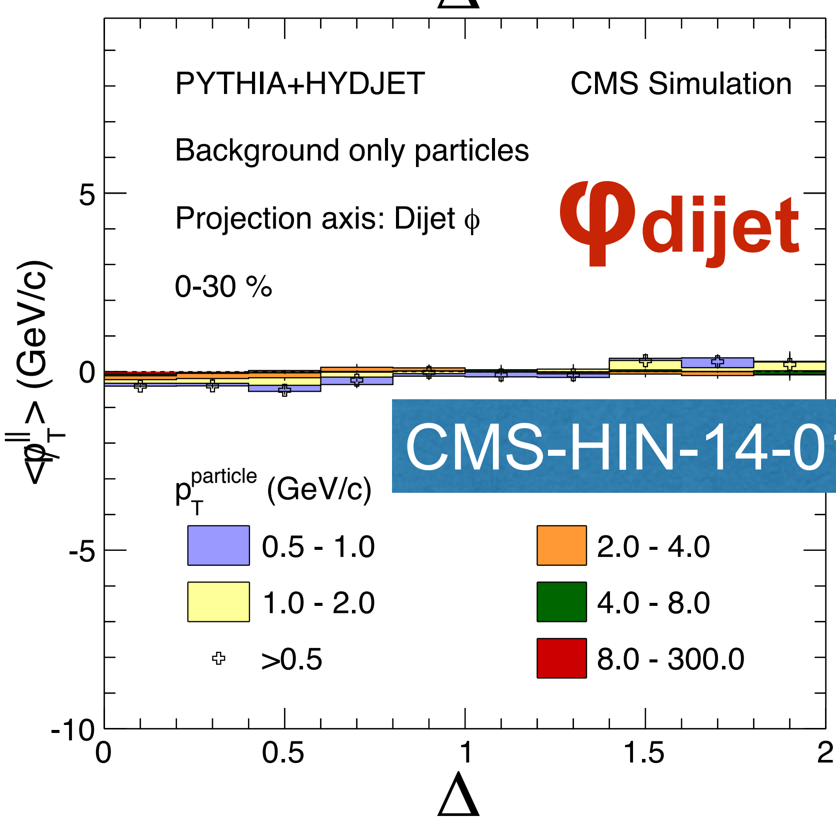
$$\varphi_{dijet} = (\varphi_1 + (\pi - \varphi_2))/2$$



φ_{dijet} -> Closure in Δ:

$$\Delta = \sqrt{(\eta_{trk} - \eta_{jet})^2 + (\phi_{trk} - \phi_{jet})^2}$$



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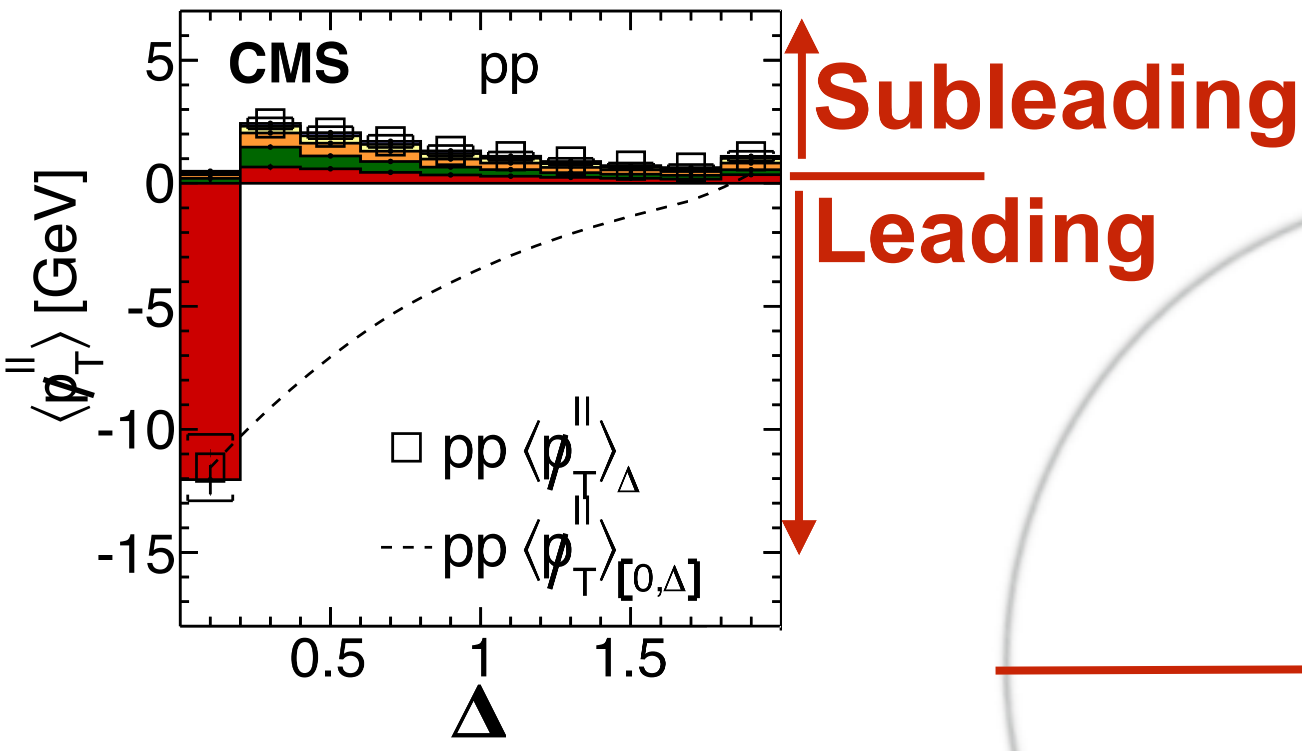
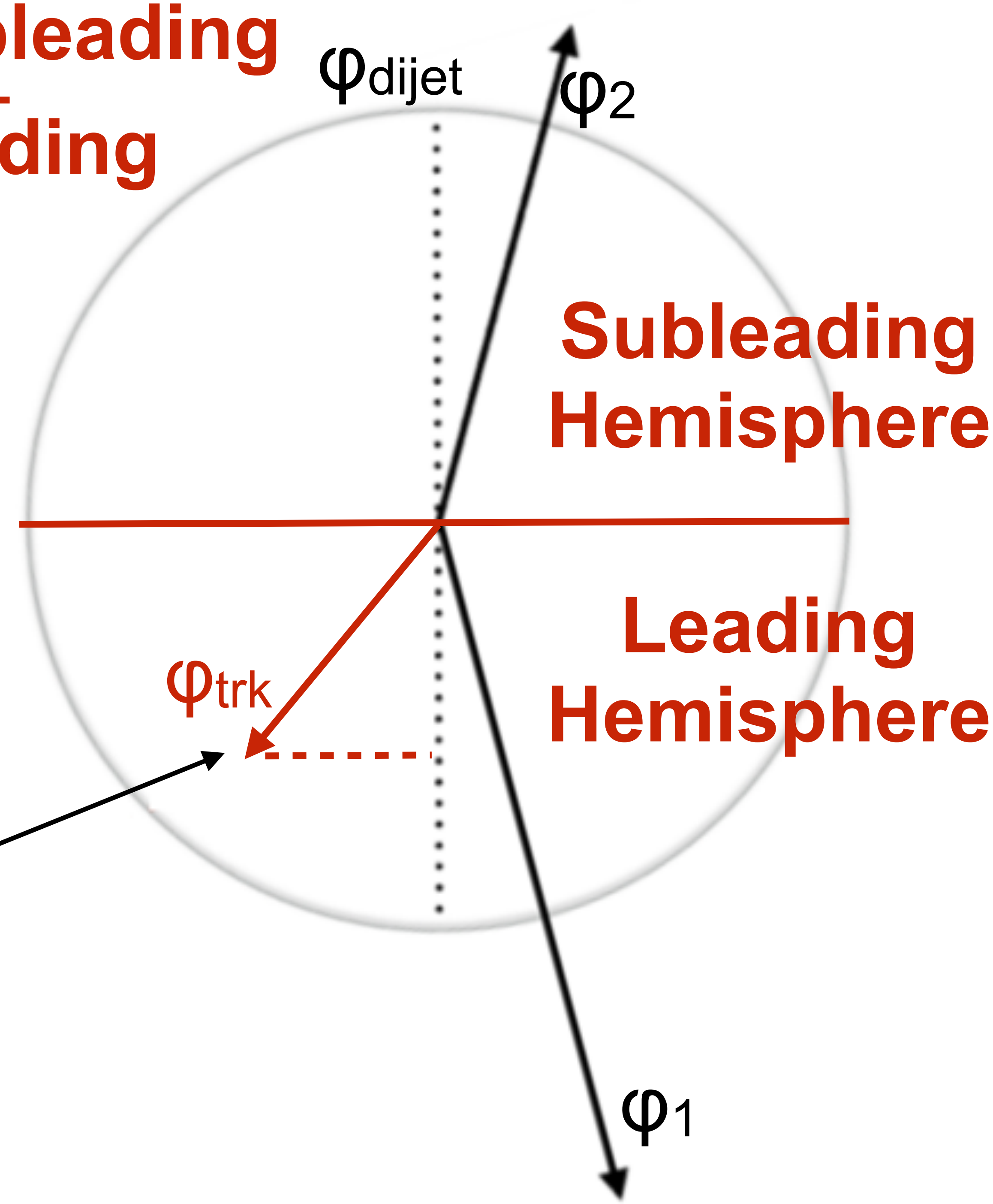
Flip subleading jet and bisect axes

Analysis: Binning Tracks by Δ

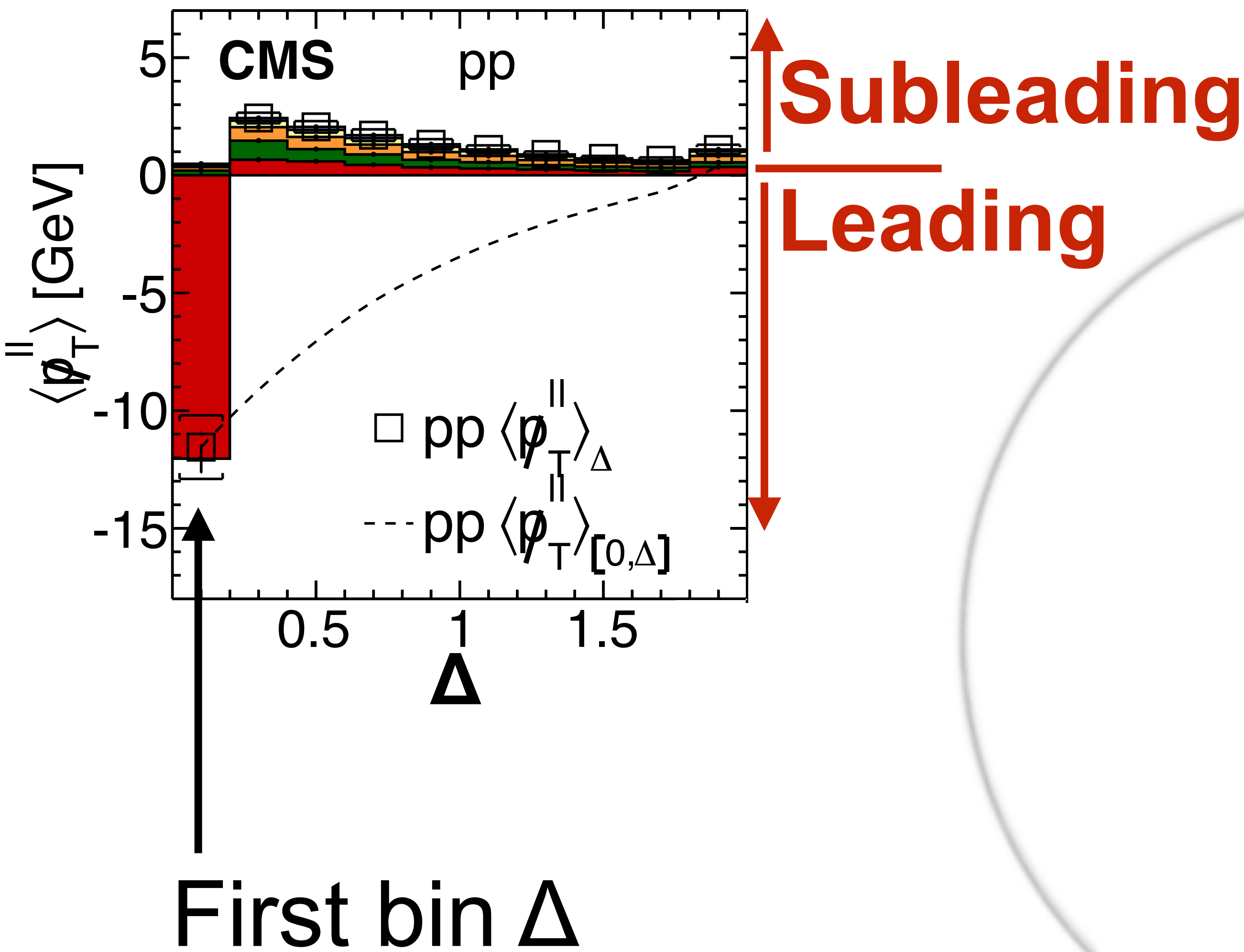


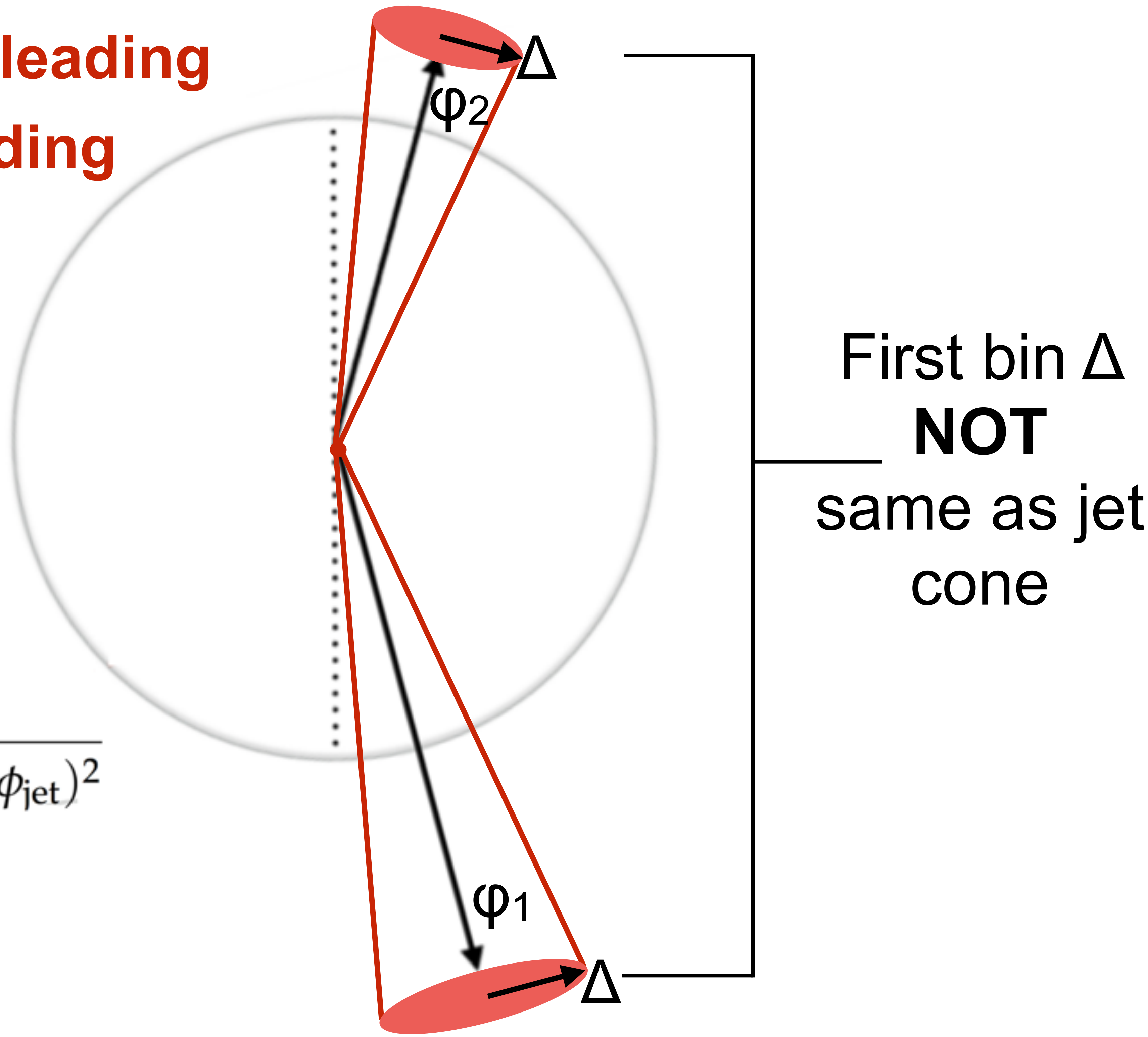


Track here contributes to Leading side

$$p_{\mathrm{T}}^{||} = -\mathrm{c}^{\mathrm{trk}} \times p_{\mathrm{T}}^{\mathrm{trk}} \times \cos\left(\phi_{\mathrm{trk}} - \phi_{\mathrm{dijet}}\right)$$

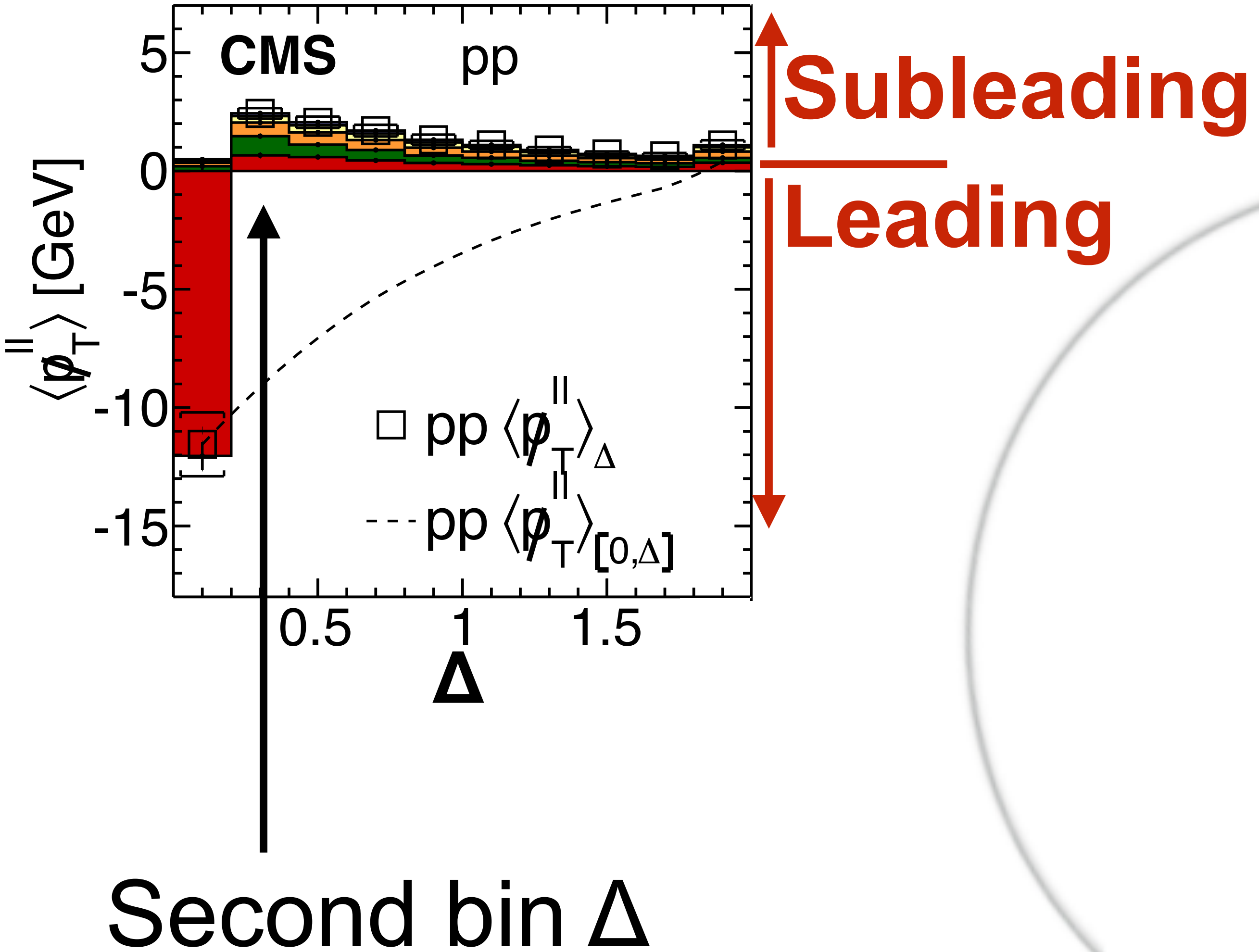
Analysis: Binning Tracks by Δ



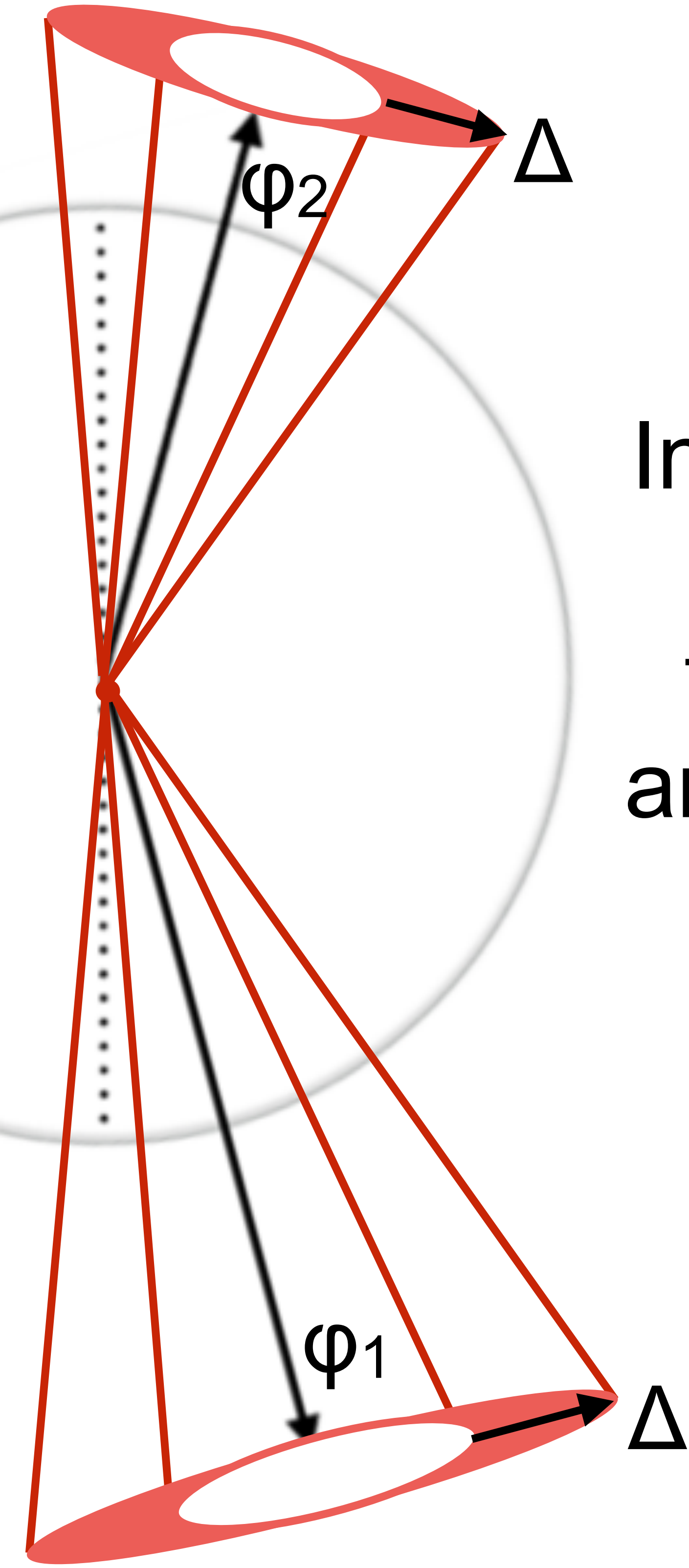


$$\Delta = \sqrt{(\eta_{\mathrm{trk}} - \eta_{\mathrm{jet}})^2 + (\phi_{\mathrm{trk}} - \phi_{\mathrm{jet}})^2}$$

Analysis: Binning Tracks by Δ

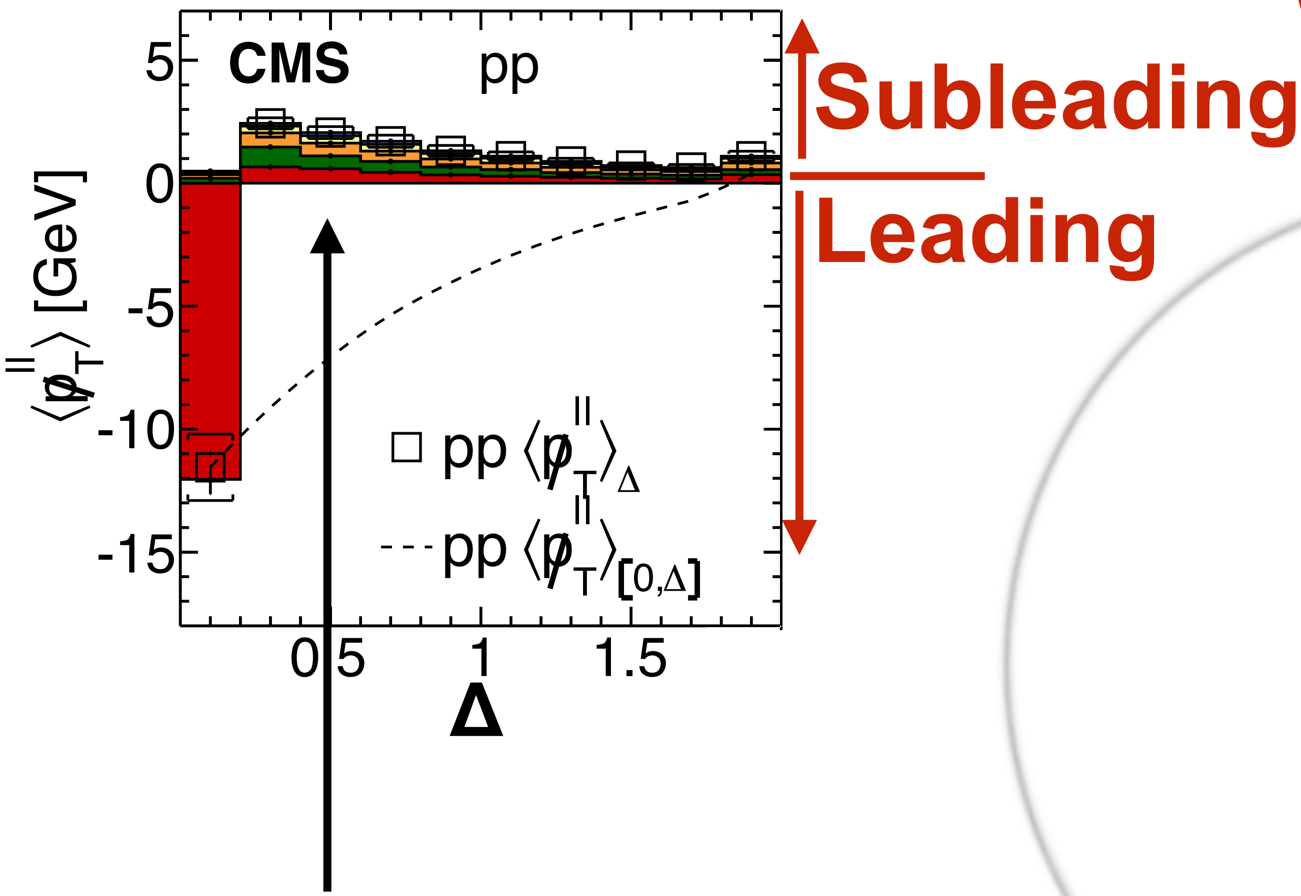


$$\Delta = \sqrt{(\eta_{\mathrm{trk}} - \eta_{\mathrm{jet}})^2 + (\phi_{\mathrm{trk}} - \phi_{\mathrm{jet}})^2}$$



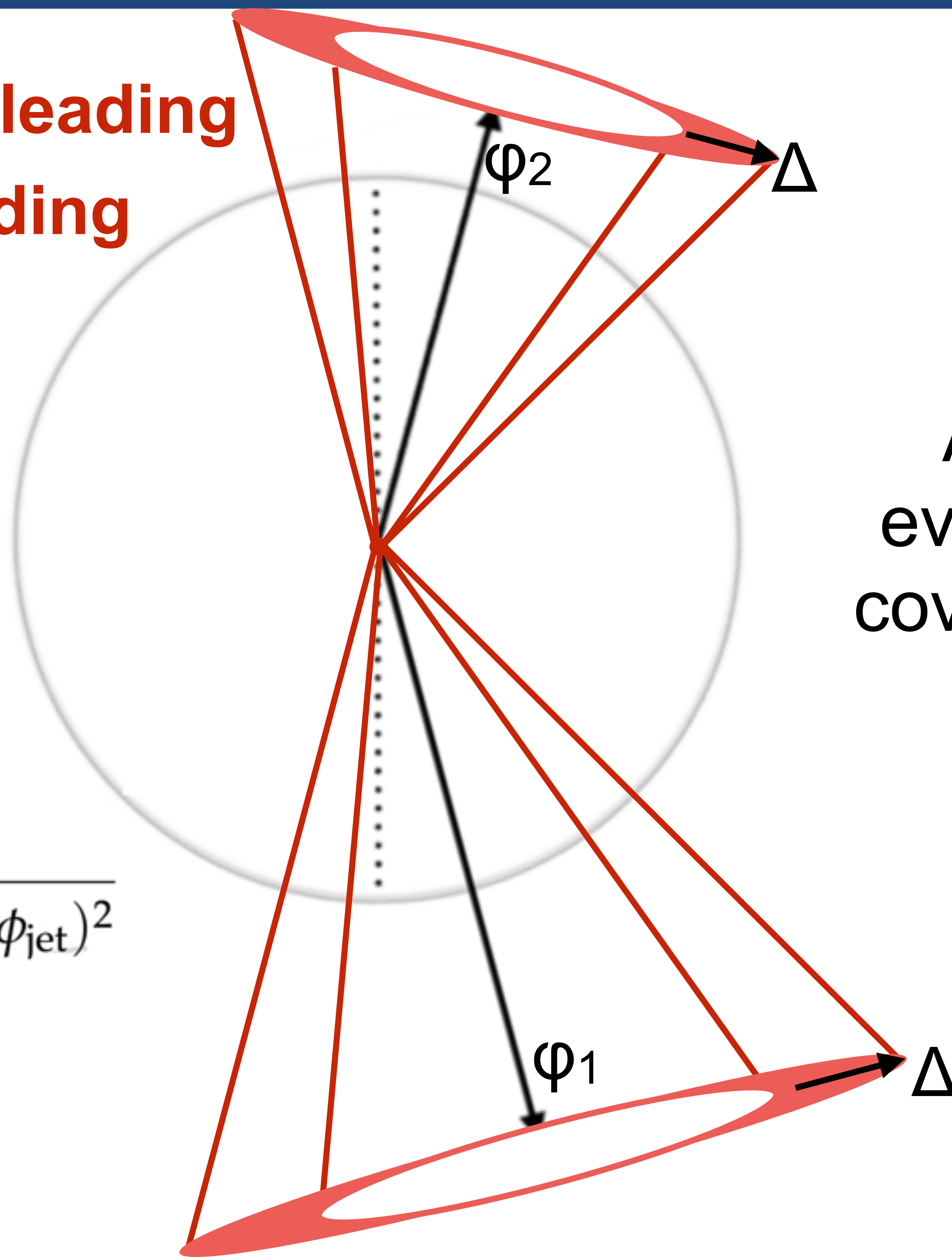
Increasing Δ -> Move away from leading and subleading jets

Analysis: Binning Tracks by Δ



Third bin Δ

$$\Delta = \sqrt{(\eta_{trk} - \eta_{jet})^2 + (\phi_{trk} - \phi_{jet})^2}$$



Annuli eventually cover entire event

Missing P_T vs. Δ with R = 0.3 (All A_J)

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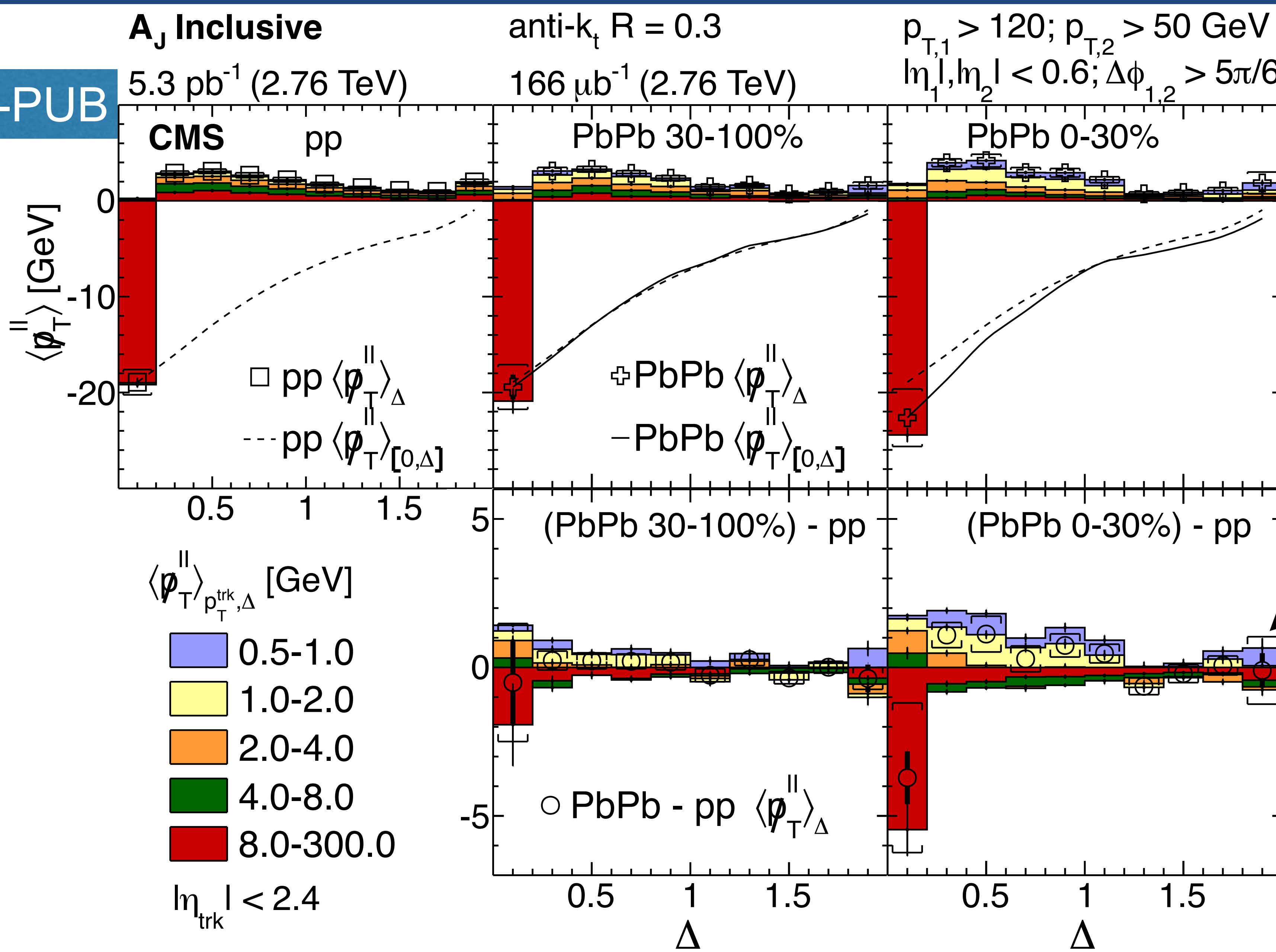
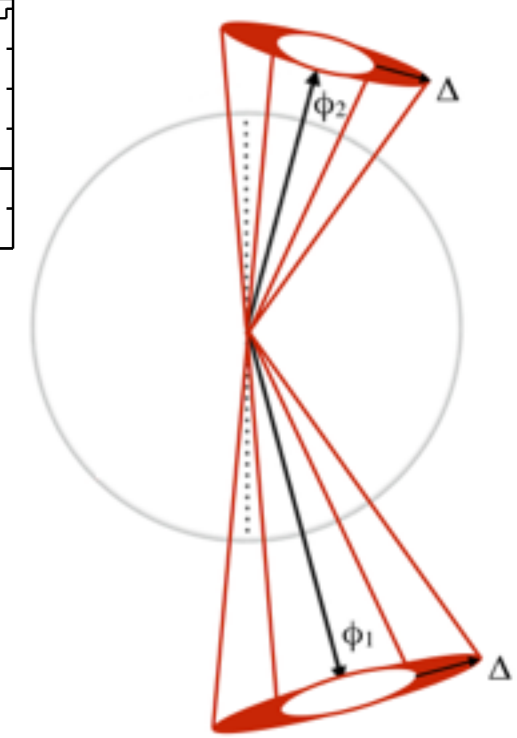


Subleading

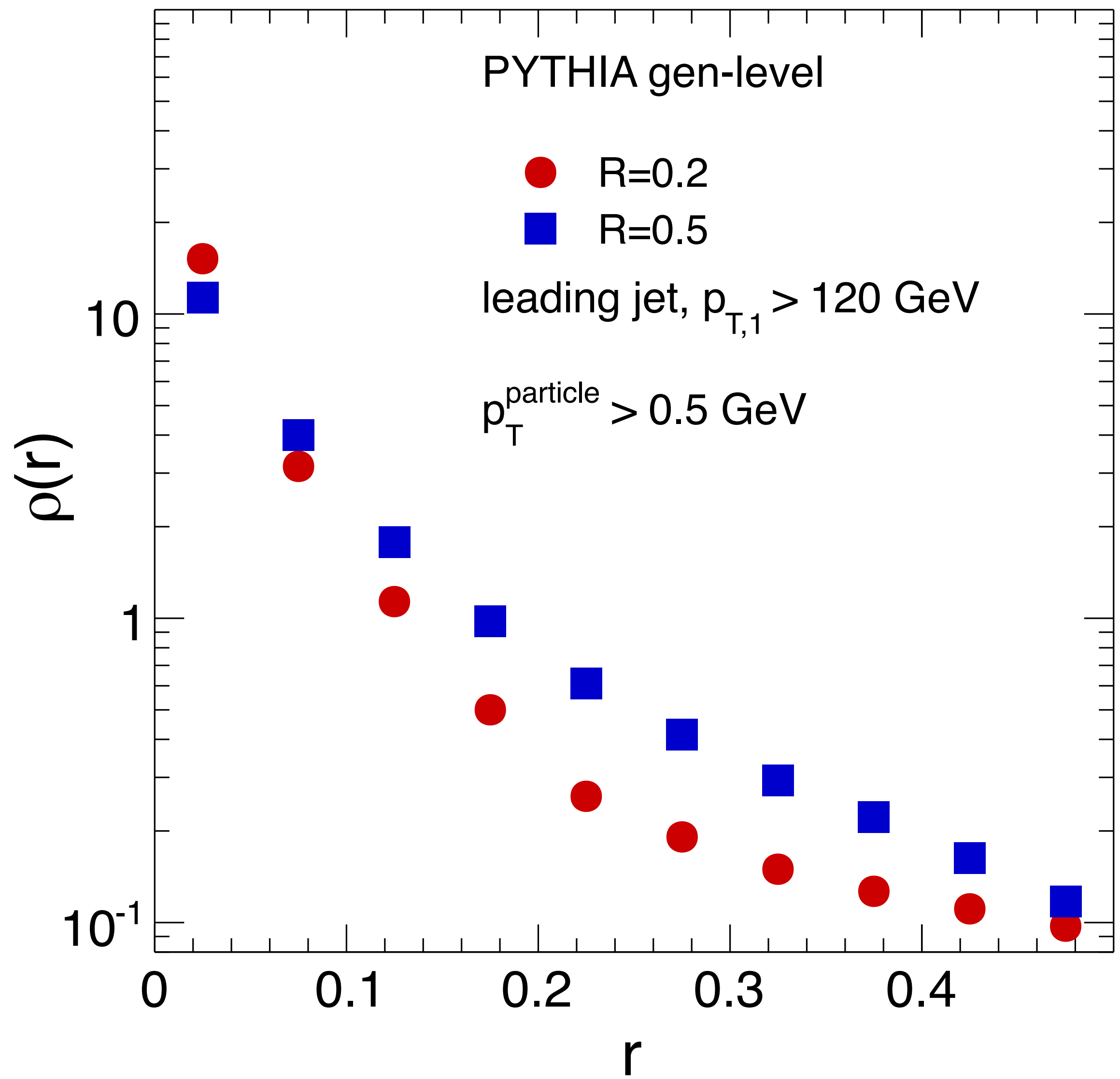
Leading

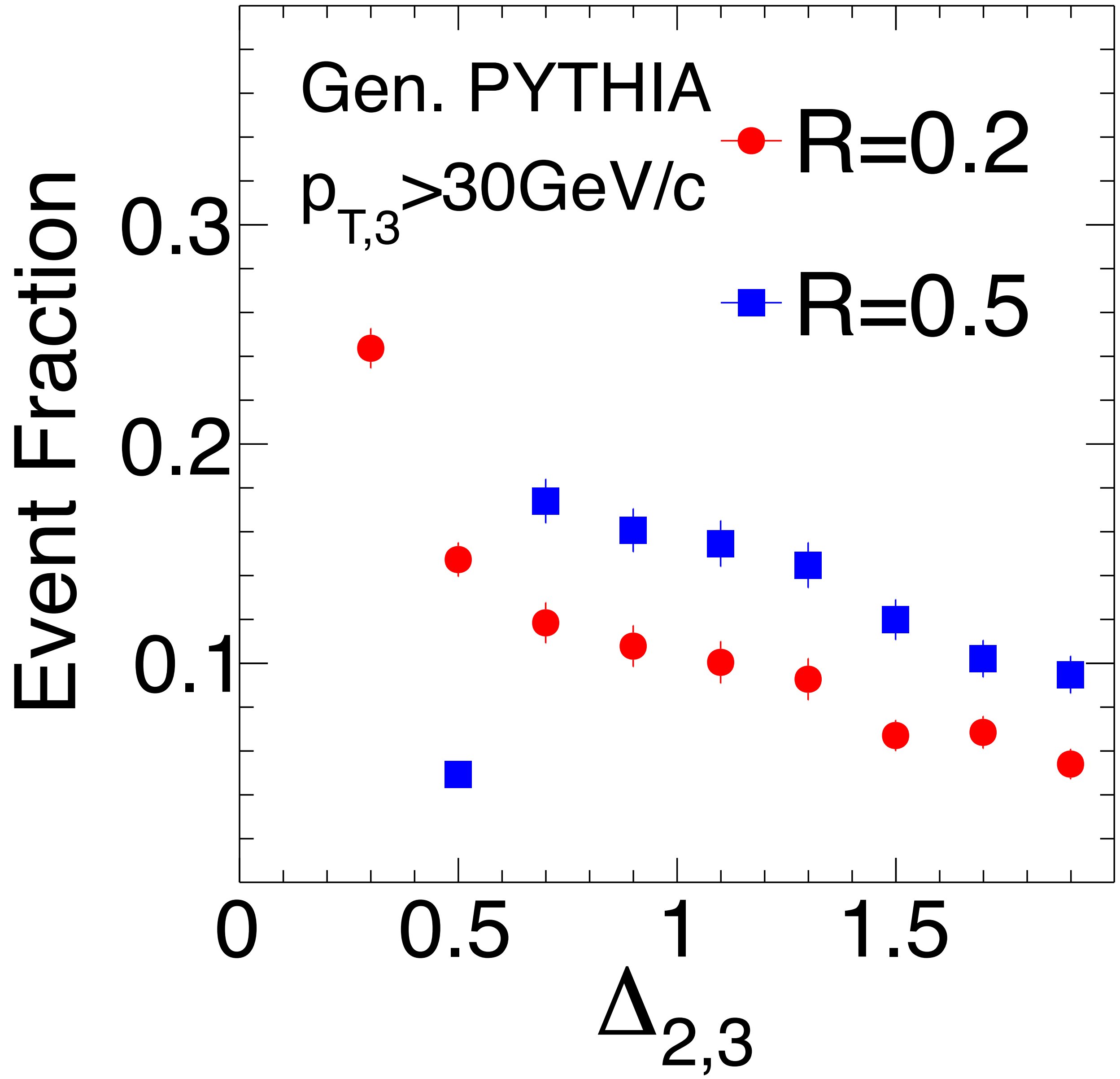
Last bin Δ is catch-all



- Asymmetry is balanced in central PbPb by low p_T particles through large angles
- Characterized finely in Δ increments of 0.2

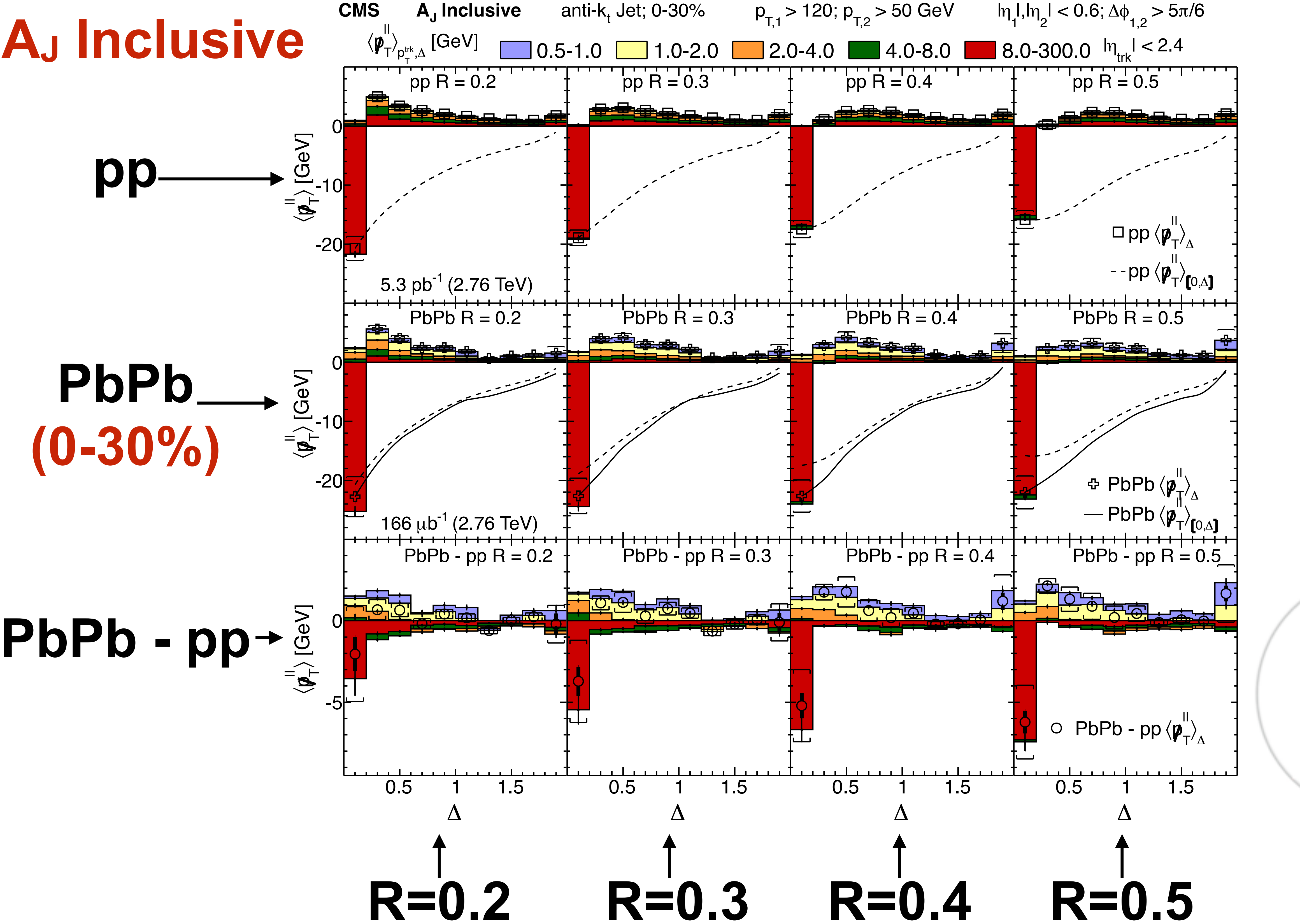
Missing P_T and Jet Radius

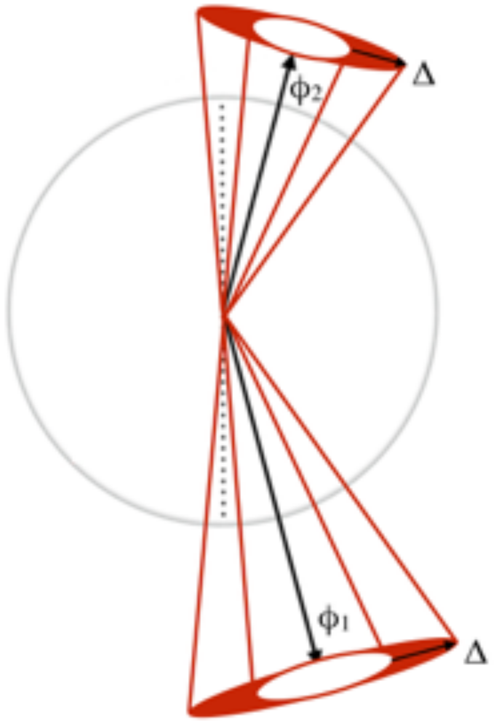




- Jet shape differences in Gen. PYTHIA for different R
- Shifting third jet position in Gen. PYTHIA relative to subleading jet

Multiple R Missing P_T vs. Δ





Zoom on pp and PbPb Distributions (I)

A_J Inclusive

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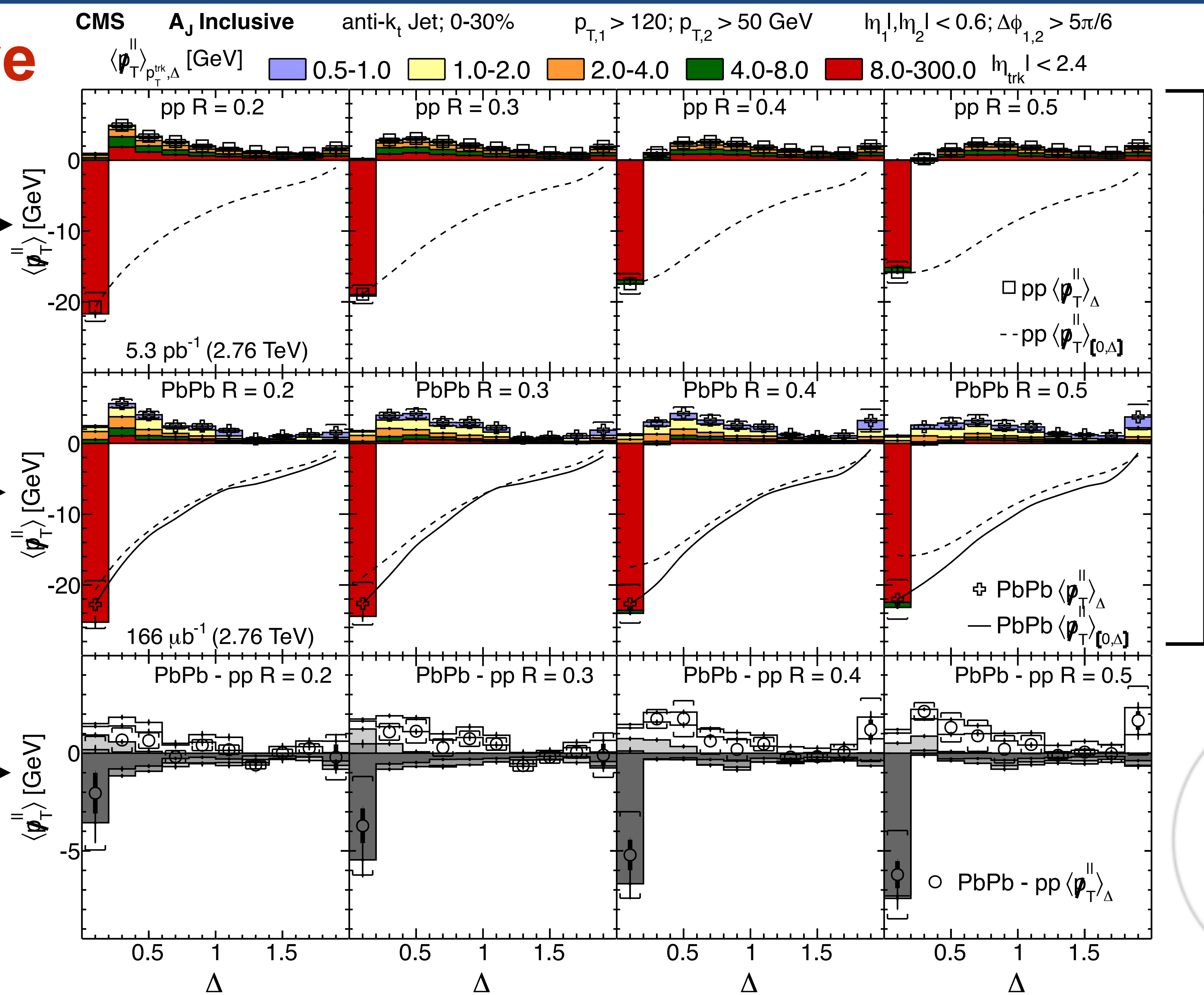
pp

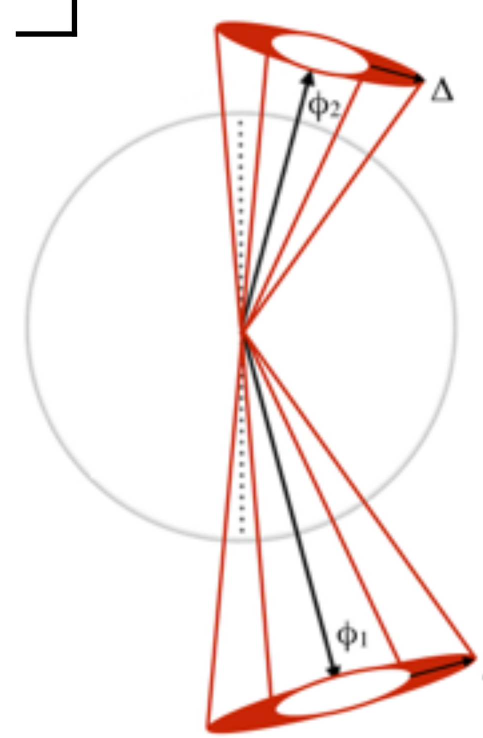
PbPb
(0-30%)

PbPb - pp



Zoom of Top Panels

R=0.2 **R=0.3** **R=0.4** **R=0.5**



Zoom on pp and PbPb Distributions (II)

A_J Inclusive

pp

PbPb
(0-30%)

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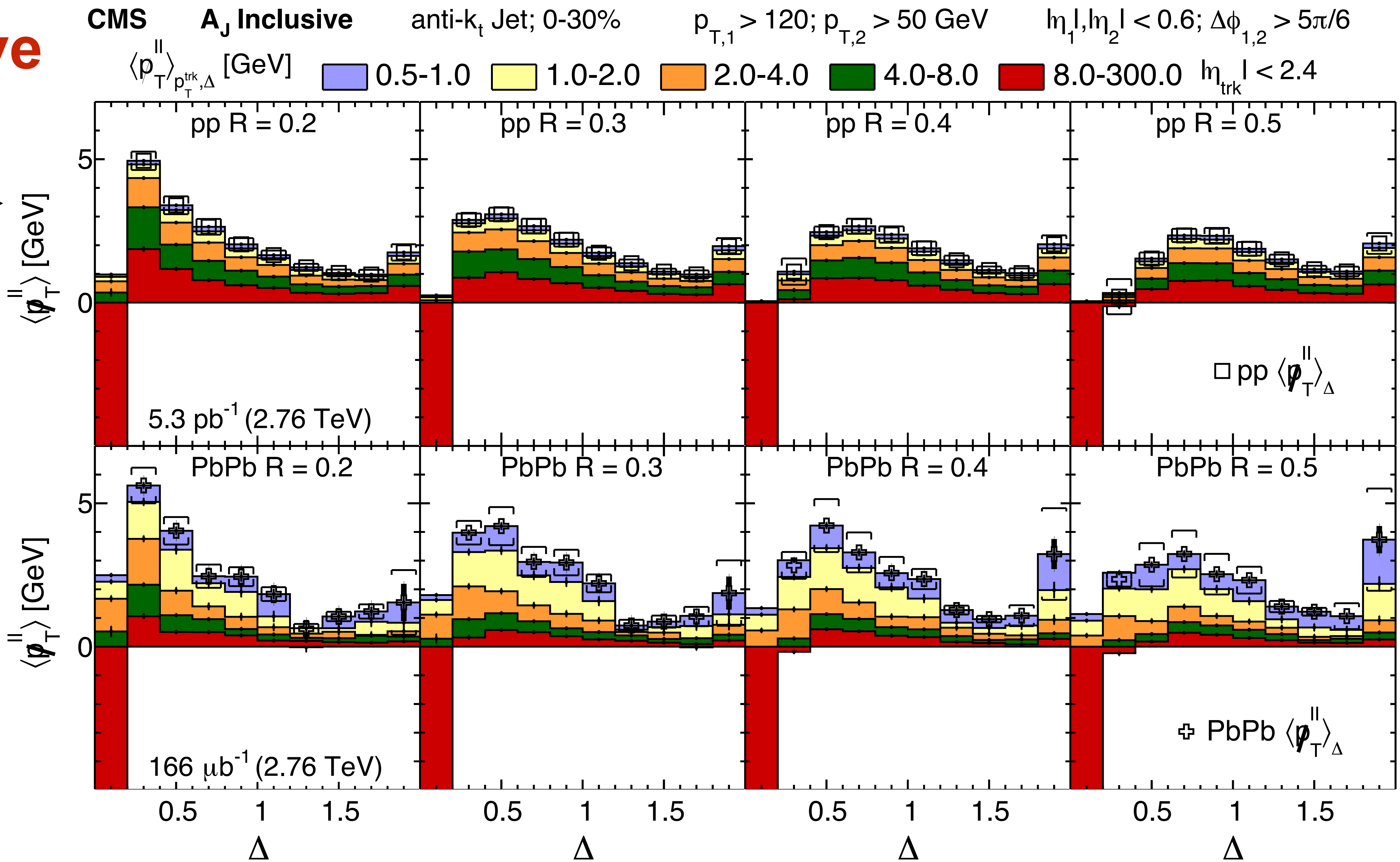

- Subleading side peak shifts outward in Δ from 0.2->0.5
  - Third jet possible position pushed out with R increase

pp and PbPb Cumulative Curves (I)

A_J Inclusive

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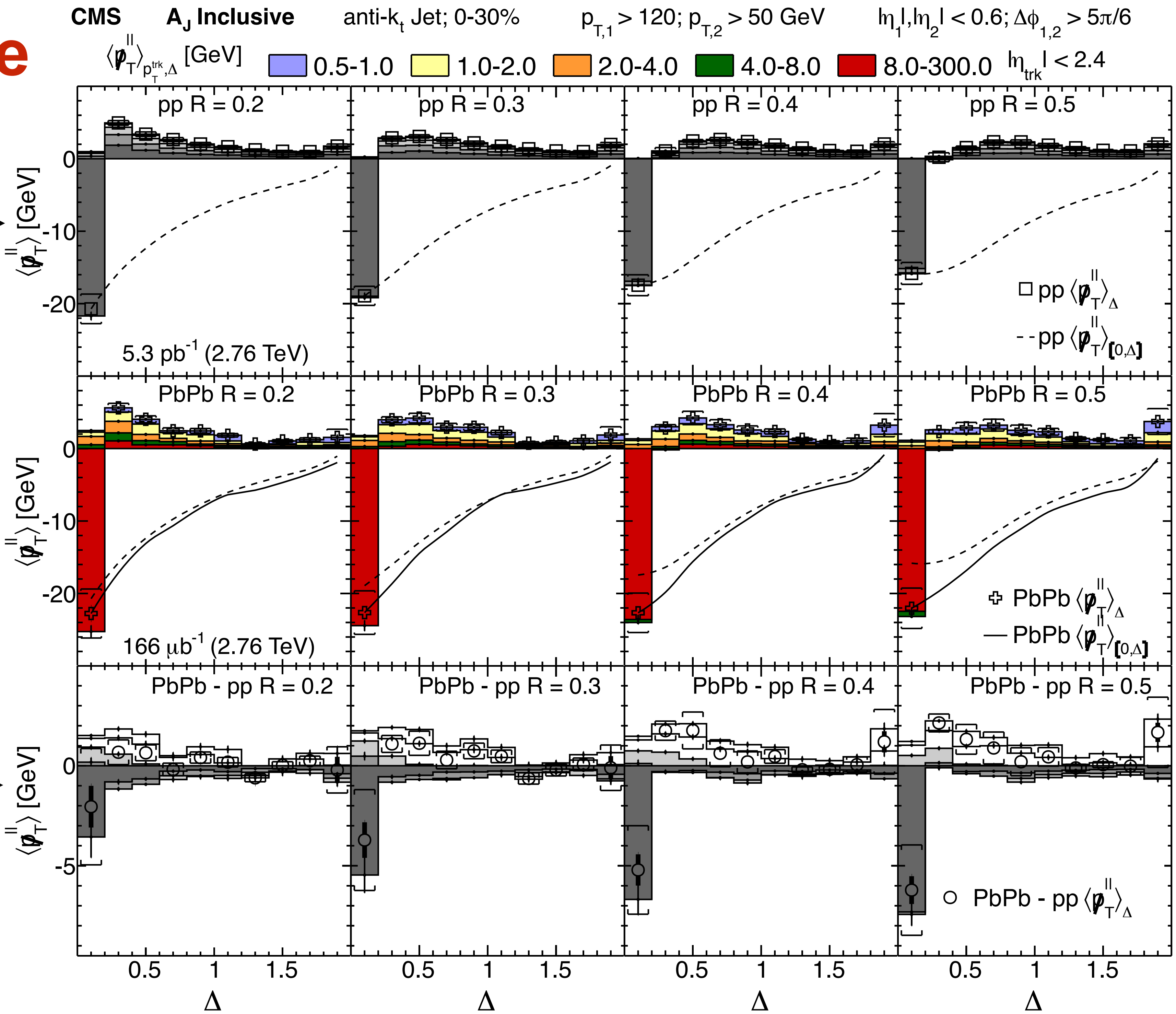
pp →

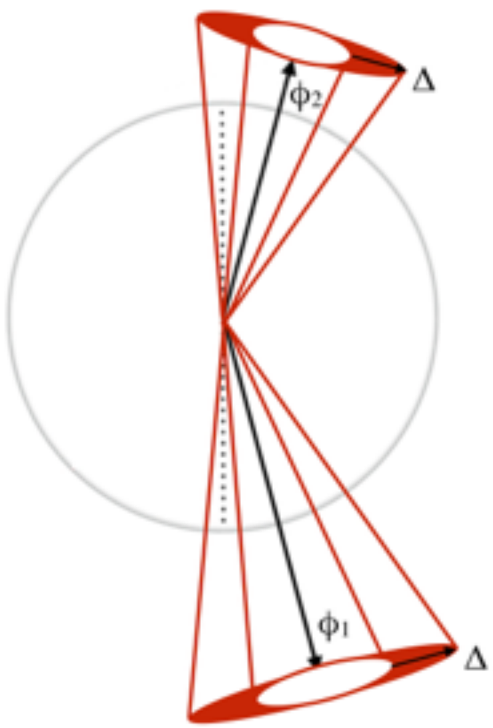
PbPb (0-30%) →

PbPb - pp →

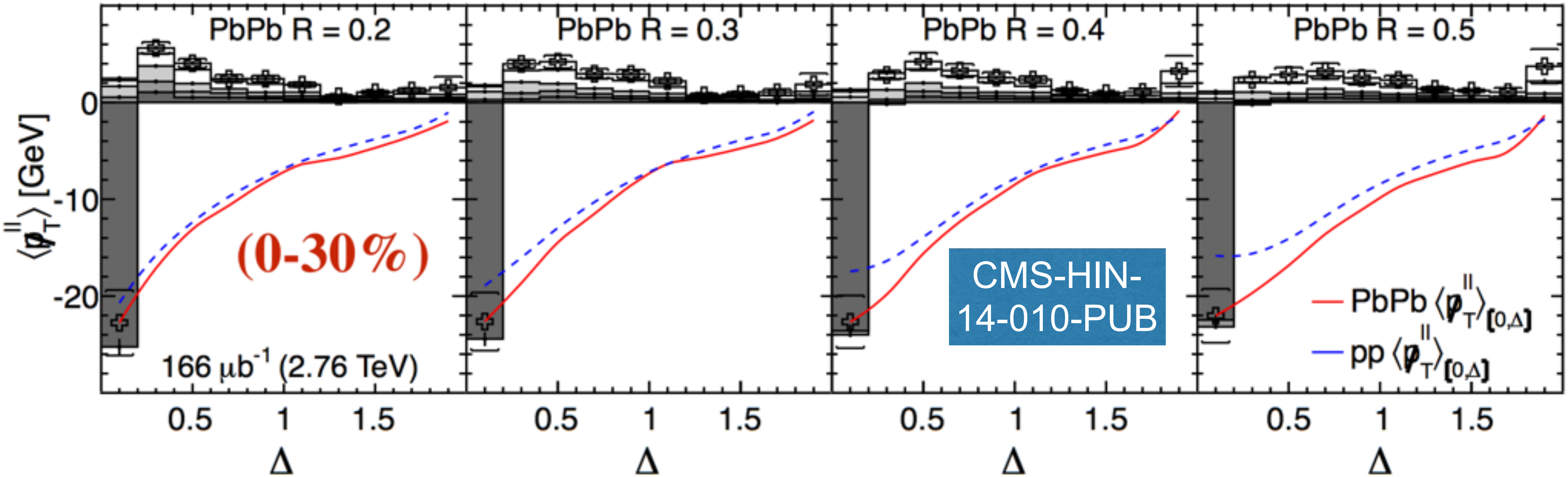


R=0.2 **R=0.3** **R=0.4** **R=0.5**

Compare Curves



pp and PbPb Cumulative Curves (II)



- Curve difference between PbPb and pp primarily in first bin Δ
- For all R, curves very similar between PbPb and pp with Δ > 0.2
  - Total missing p_T variation with R parameter in pp matched by PbPb
  - Constituent composition of missing p_T differs between systems

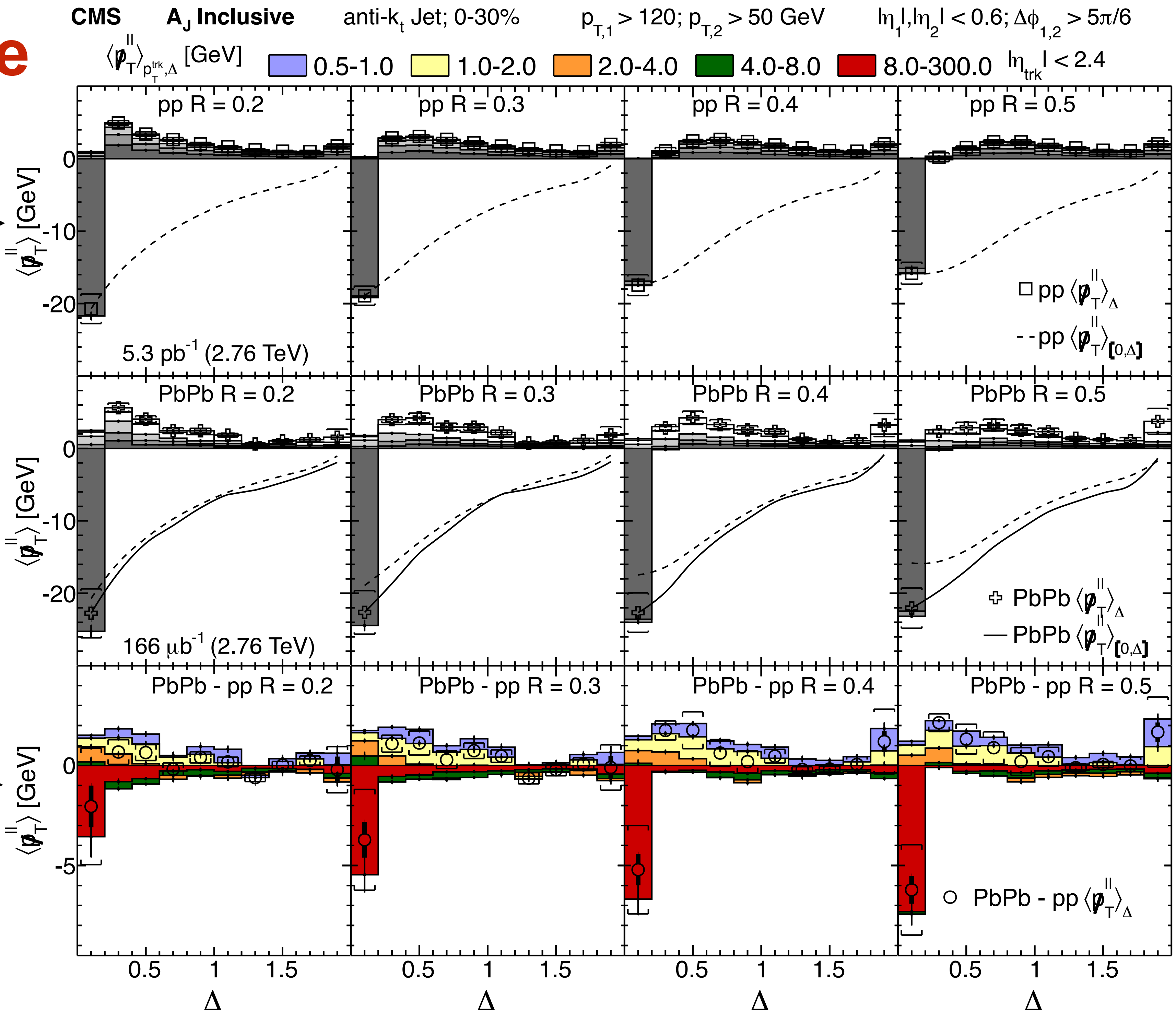
Difference of PbPb and pp (I)

A_J Inclusive

pp →

PbPb (0-30%) →

PbPb - pp →



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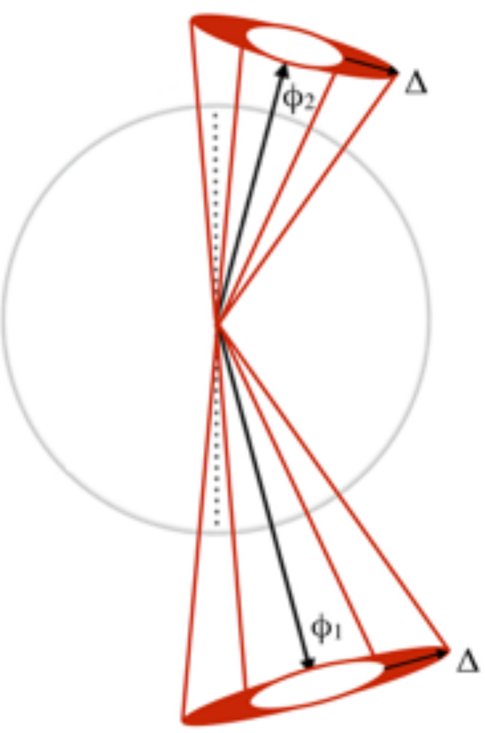
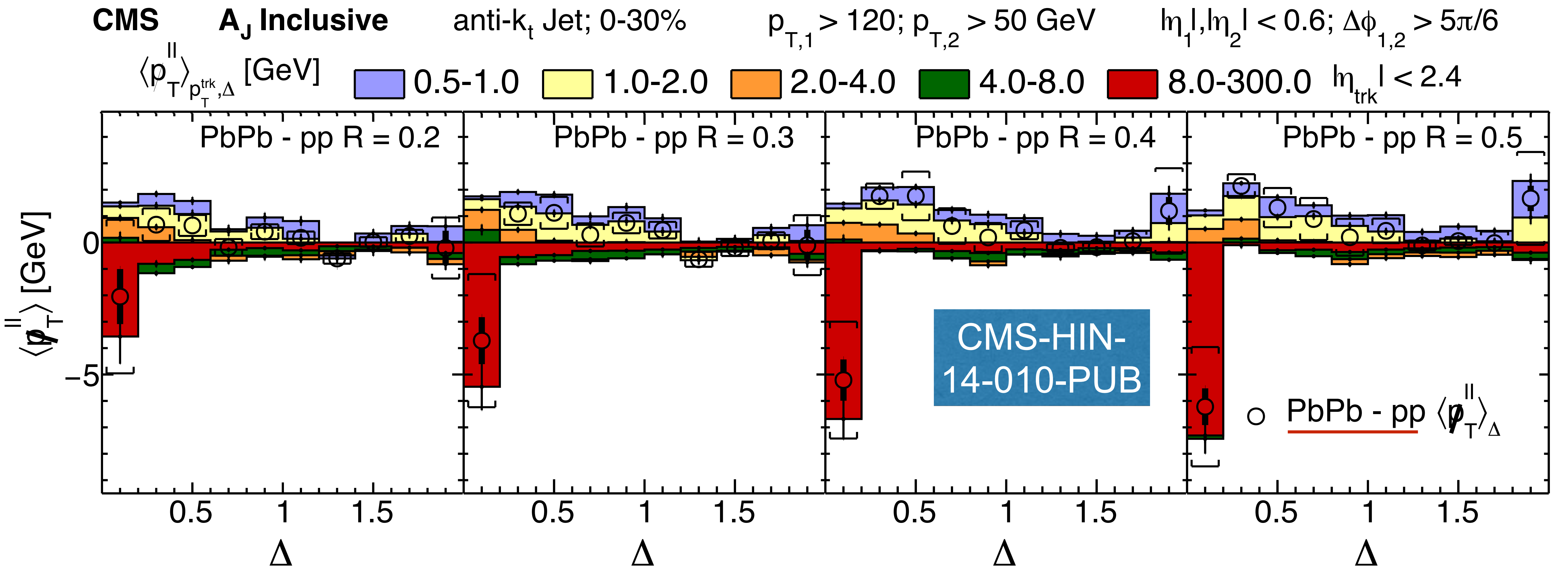


Zoom of Difference

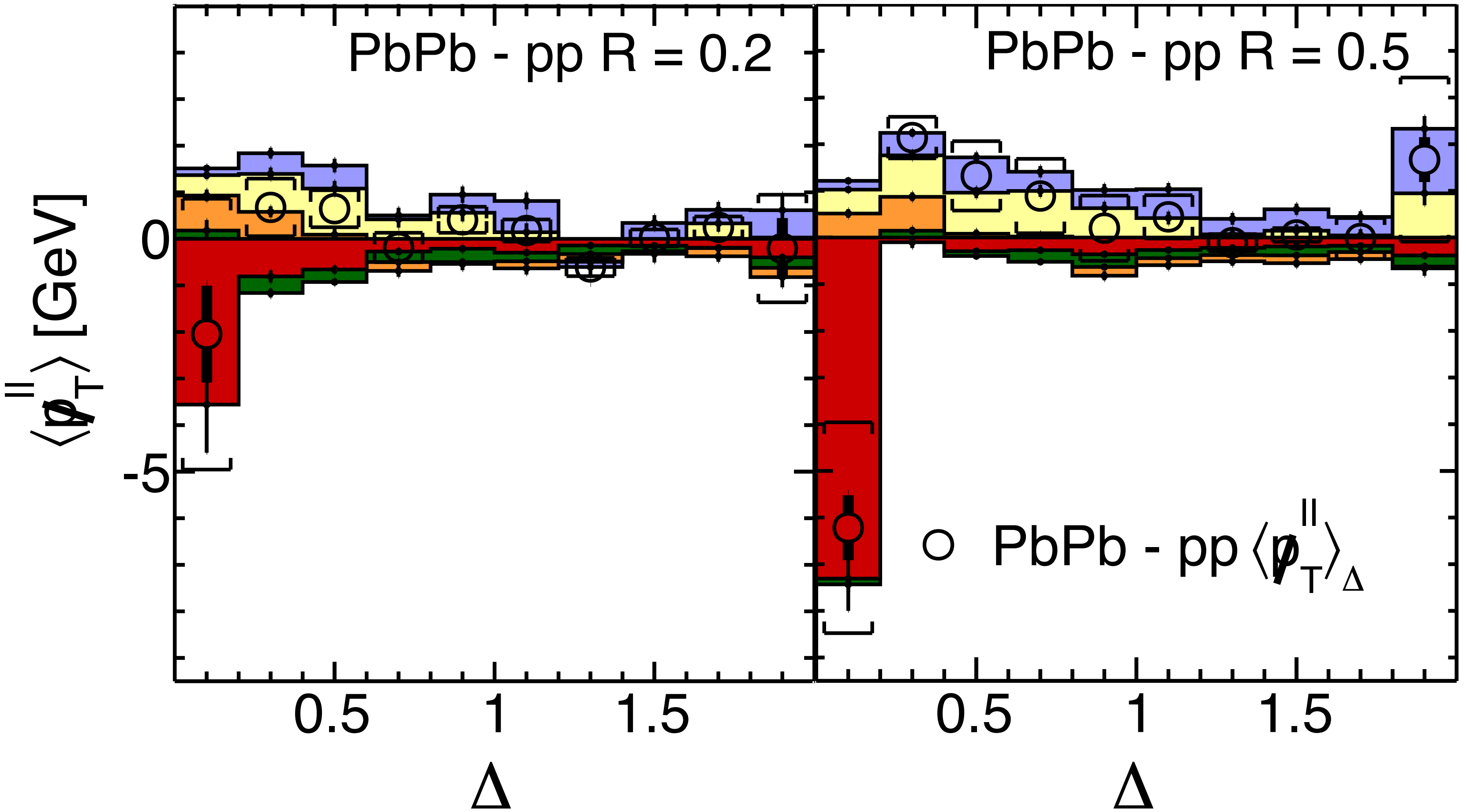
R=0.2 R=0.3 R=0.4 R=0.5

Difference of PbPb and pp (II)



- High p_T change in first bin Δ from R=0.2->0.5 within systematic
- Low p_T excess increases in both magnitude and angle with R=0.2->0.5
  - Final "catch-all" bin increase suggests longer tail

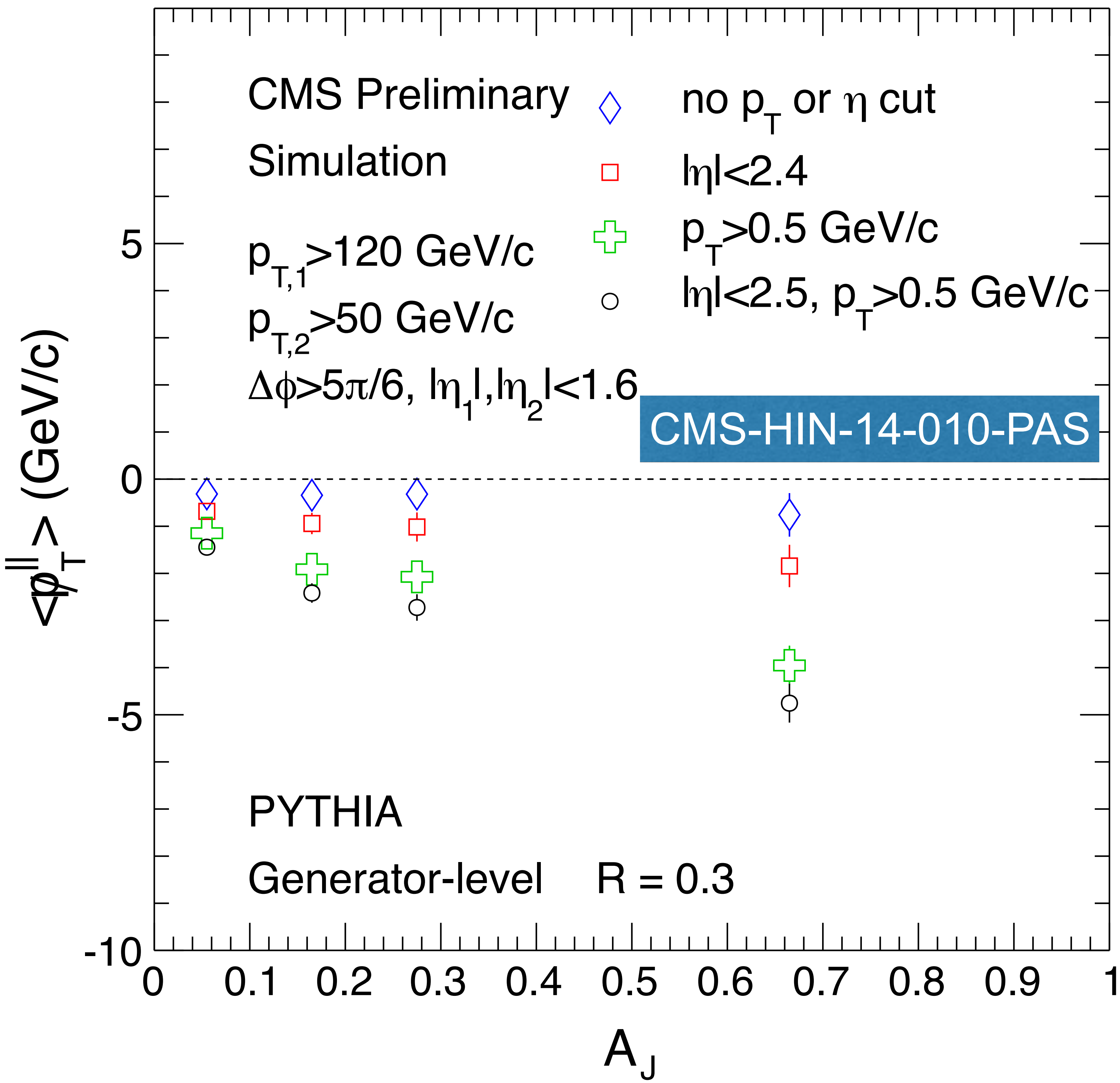
Summary and the Future



- Missing p_T finely characterized through large angles Δ
  - Different dijet configurations were sampled by R variation
- Cumulative curves similar to first order for all jet R
  - Modification primarily of constituents carrying momentum
- Increased statistics of Run2 -> precise mapping for models

Backup

Impact of Tracking Cuts on Missing P_T



Jet Reconstruction with HF/Voronoi Algorithm

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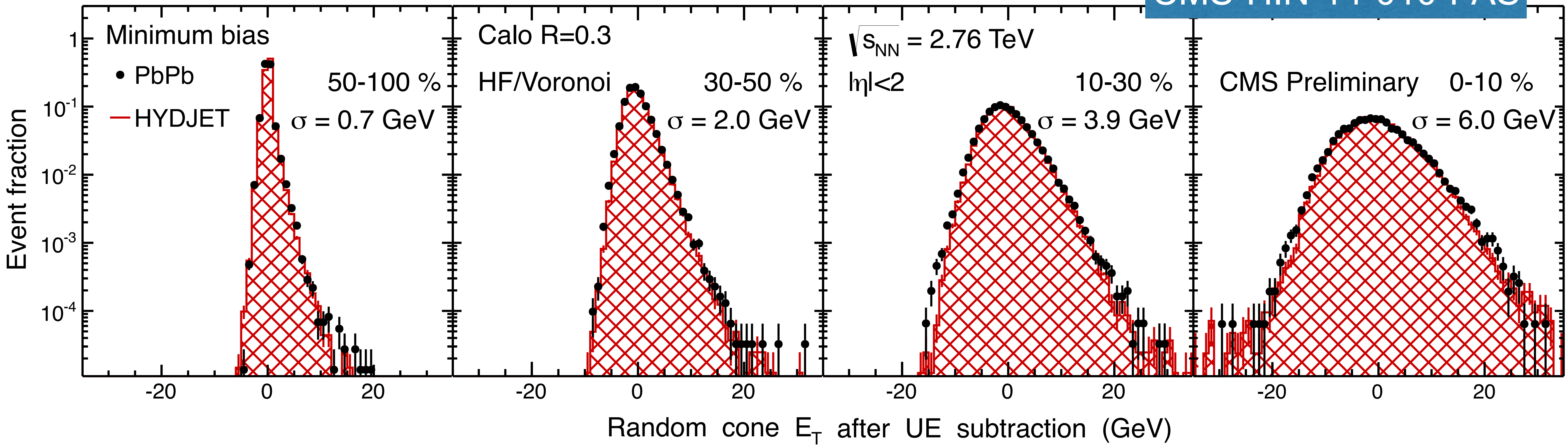

- UE at mid-η mapped by energy deposition at forward-η
- Equalization removes negative energy towers
  - Shifted from surrounding positive energy towers
- An energy correction based on fragmentation is applied to minimize bias from non-linear calorimeter response
  - Applied to pp and PbPb

Track Reconstruction and Correction

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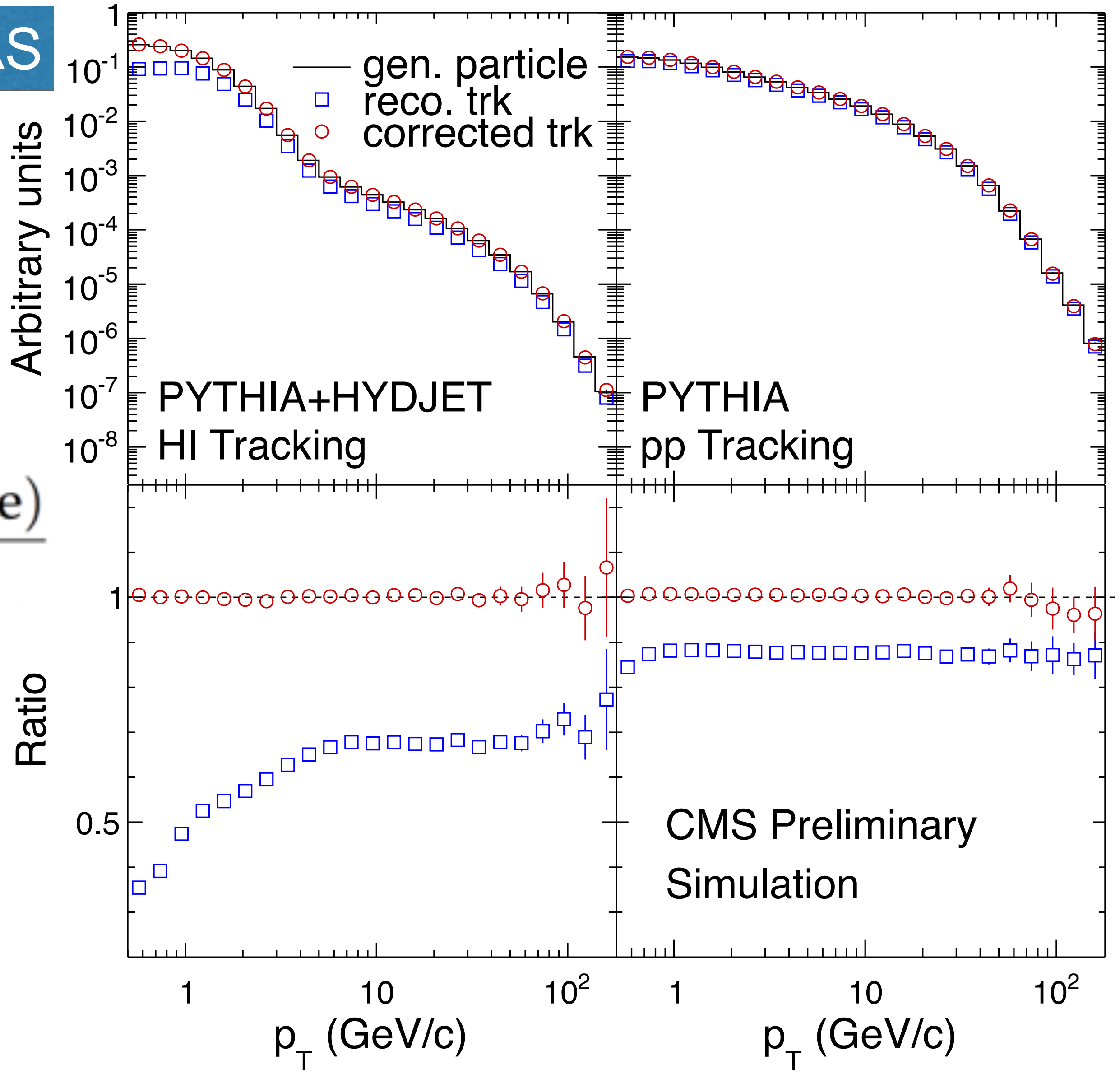
- Define tracking correction on track-by-track basis as:

$$c^{trk} = \frac{(1 - \text{misreconstruction}) \times (1 - \text{secondary-particle})}{(\text{efficiency}) \times (1 + \text{multiple-reconstruction})}$$

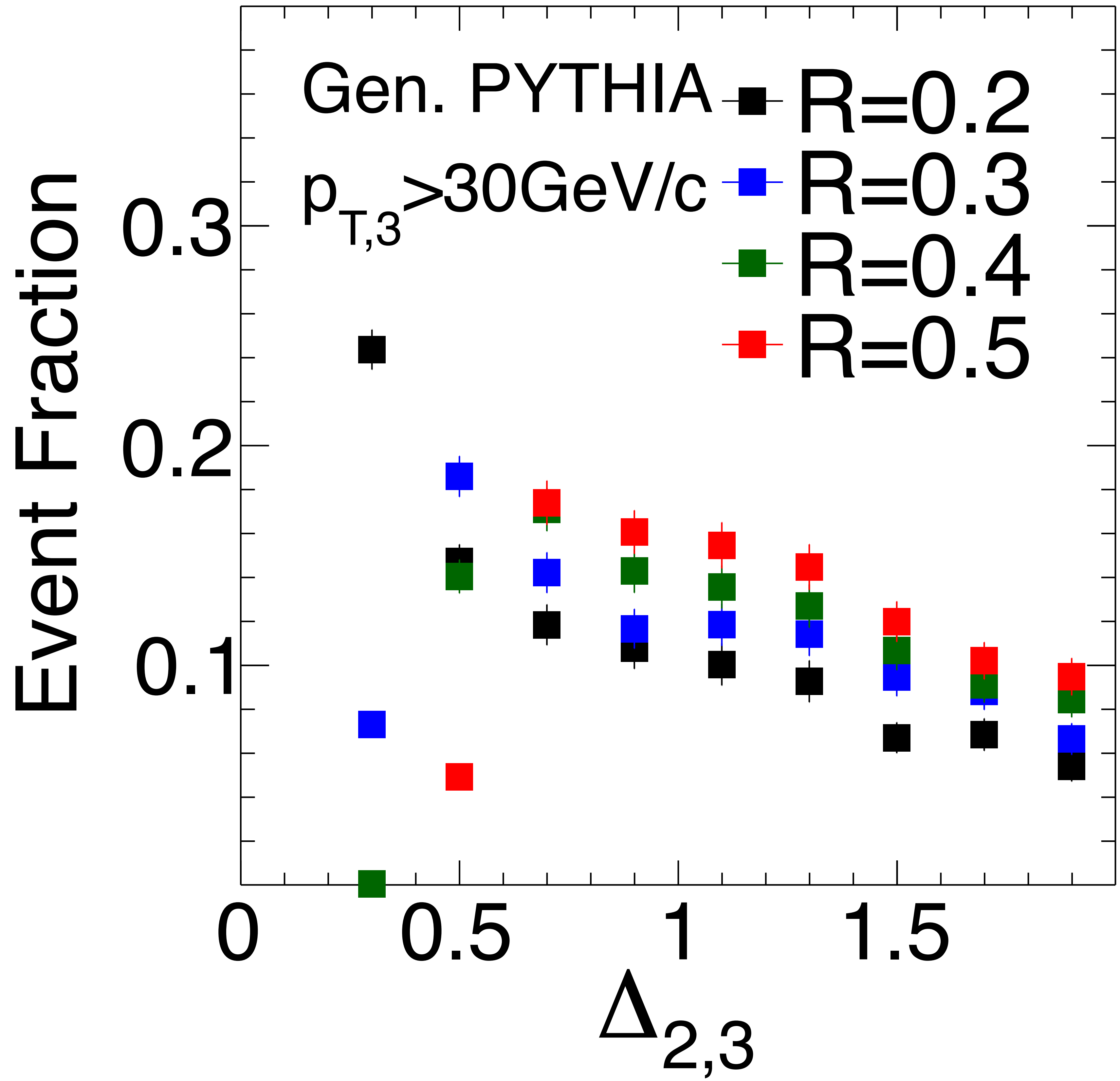


- Correct for efficiency/fake rate (+ secondary/multiple reco. in pp)
- Iterative tracking corrections in p_T, φ, η, centrality, and minimum jet distance

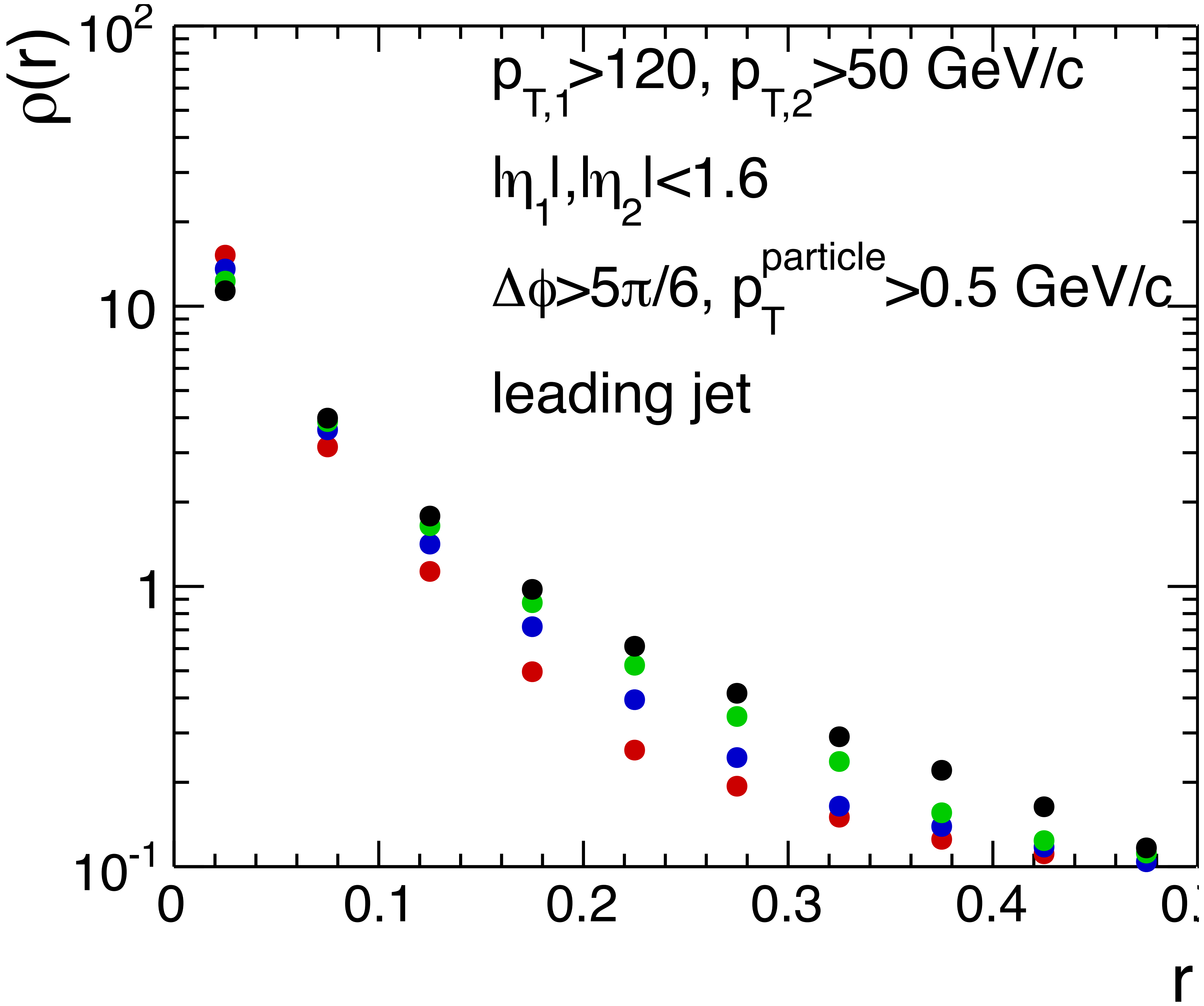
Summary of Systematics R = 0.2/0.4/0.5

	$R = 0.2$		$R = 0.4$		$R = 0.5$	
Δ	< 0.2	0.2–2.0	< 0.2	0.2–2.0	< 0.2	0.2–2.0
Jet reconstruction	1	0.1–0.4	1	0.1–0.5	1	0.1–0.7
Data/MC differences for JES	2	0.1–0.5	2	0.1–0.4	2	0.1–0.3
Fragmentation dependent JES	1	0.1–0.4	1	0.1–0.3	1	0.1–0.3
Track corrections	2	0.2–0.7	2	0.1–1.1	2	0.1–1.1
Data/MC differences for tracking	1	0.1–0.2	1	0.1	1	0.1
Total	3	0.2–0.9	3	0.3–1.1	3	0.2–1.1

3rd Jet Position in Gen. PYTHIA

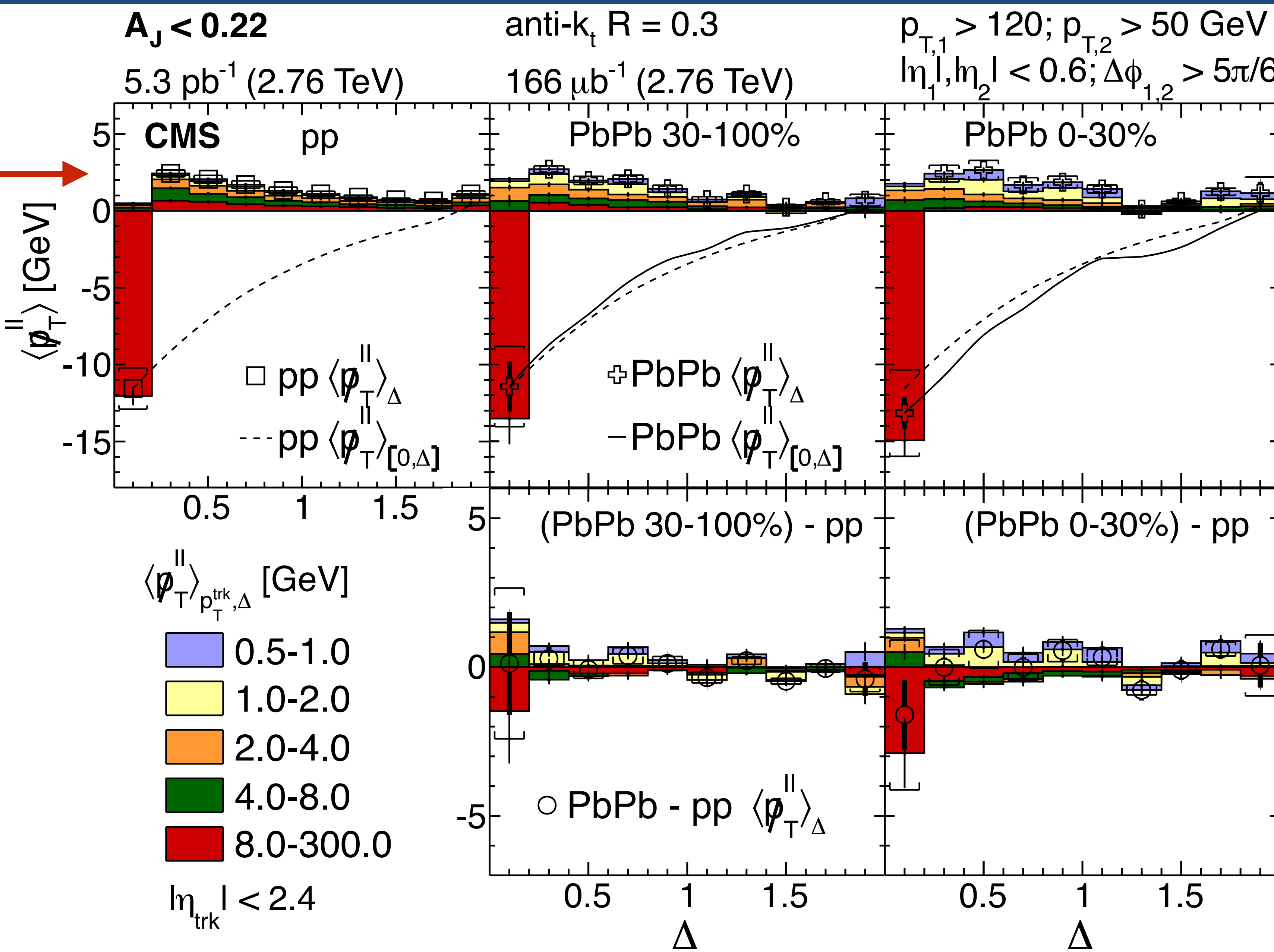


Gen. PYTHIA Jet Shapes



Missing P_T vs. Δ with R = 0.3 (A_J < 0.22)

Scale Change (Decrease)



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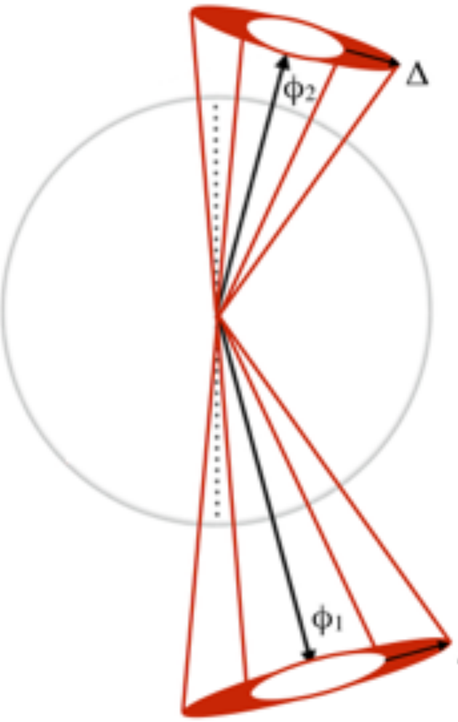
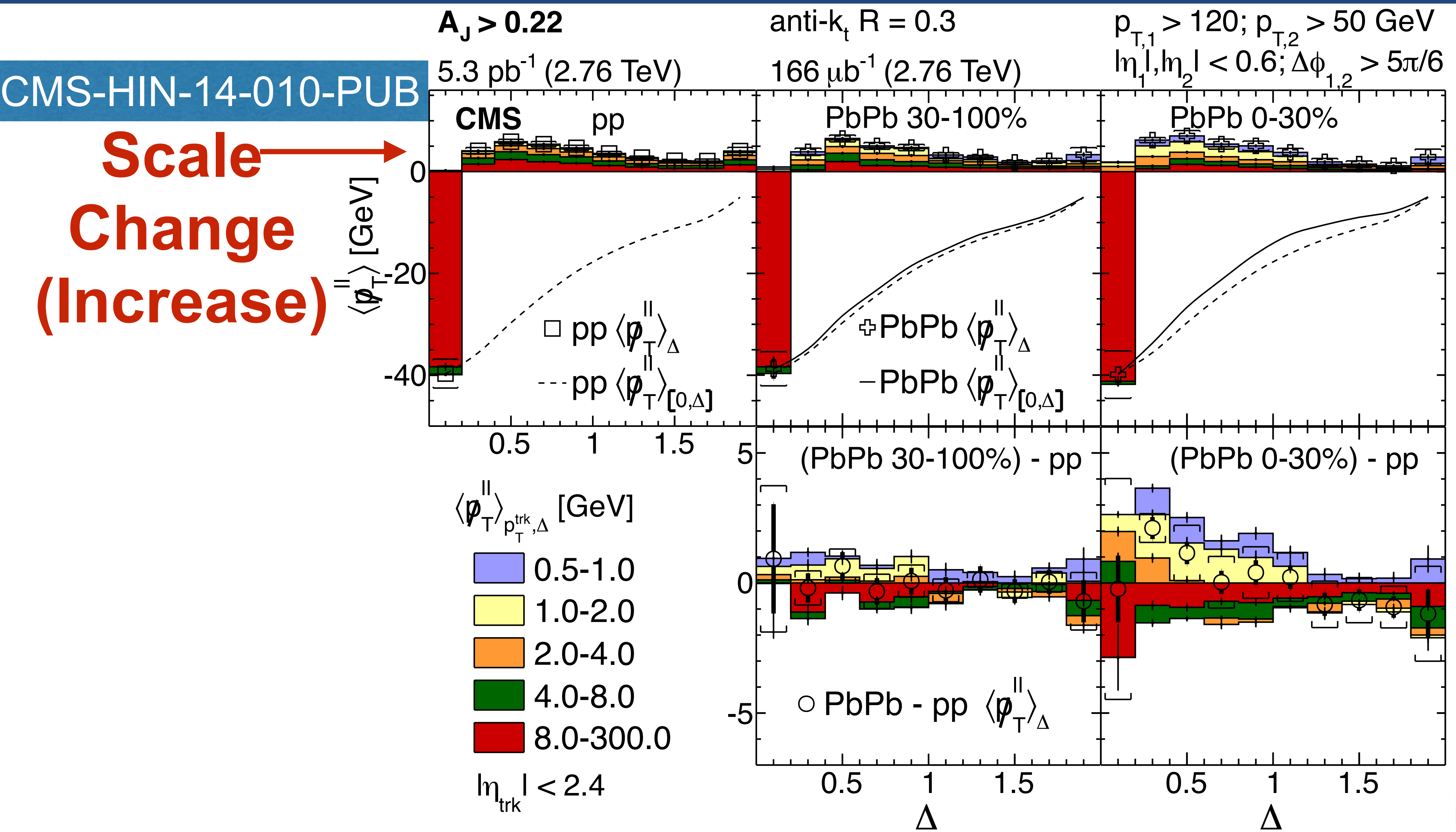
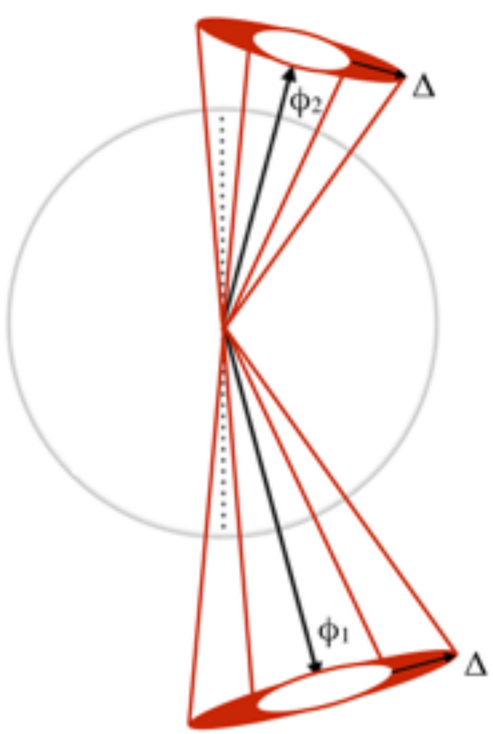


Missing P_T vs. Δ with R = 0.3 (A_J > 0.22)

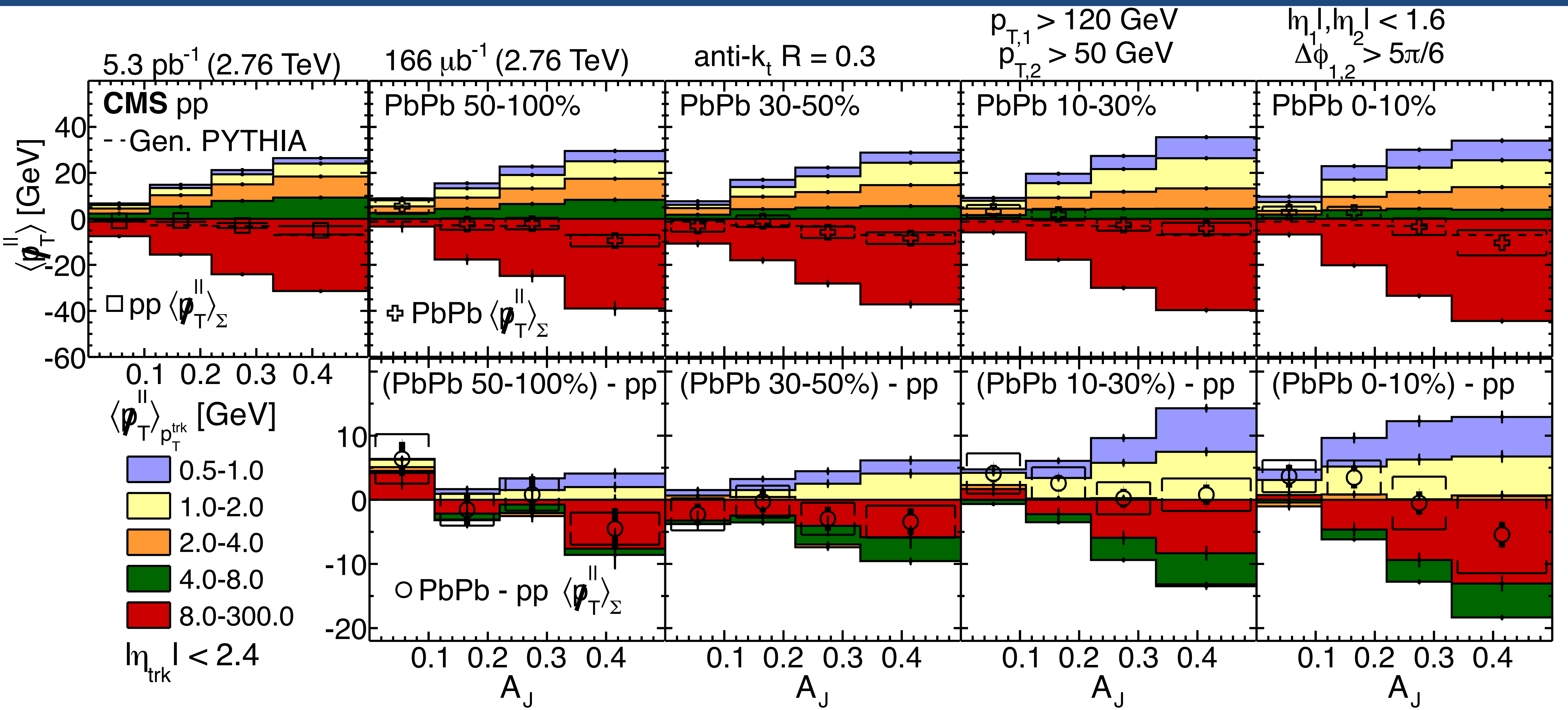
CMS-HIN-14-010-PUB





- Low p_T particles enhanced by cut on A_J > 0.22
- Cumulative curves track despite scale change

Missing P_T vs. A_J with R = 0.3



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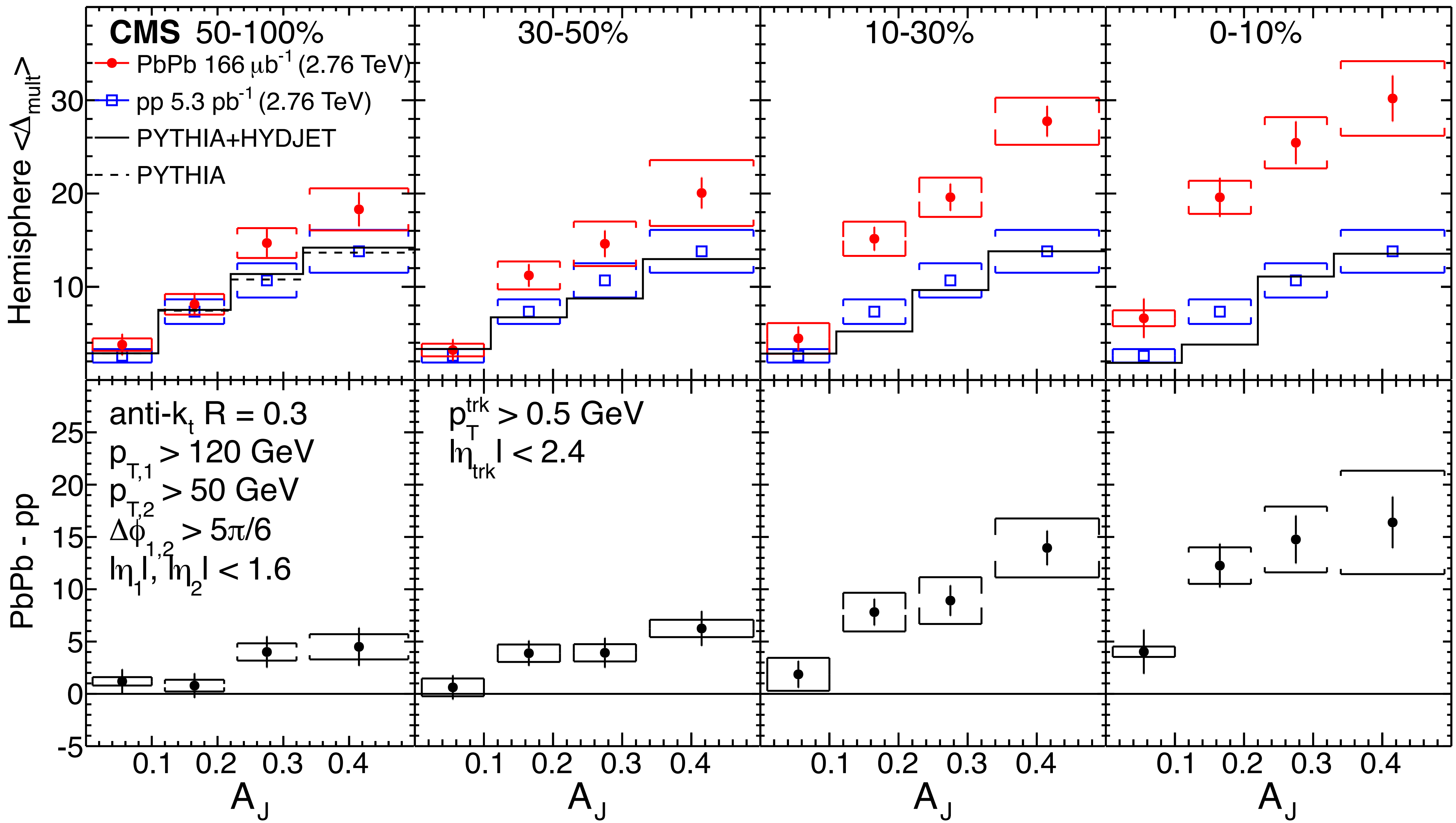
Hemisphere Multiplicity Difference



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- Multiplicity excess towards subleading side shows centrality and A_J dependence

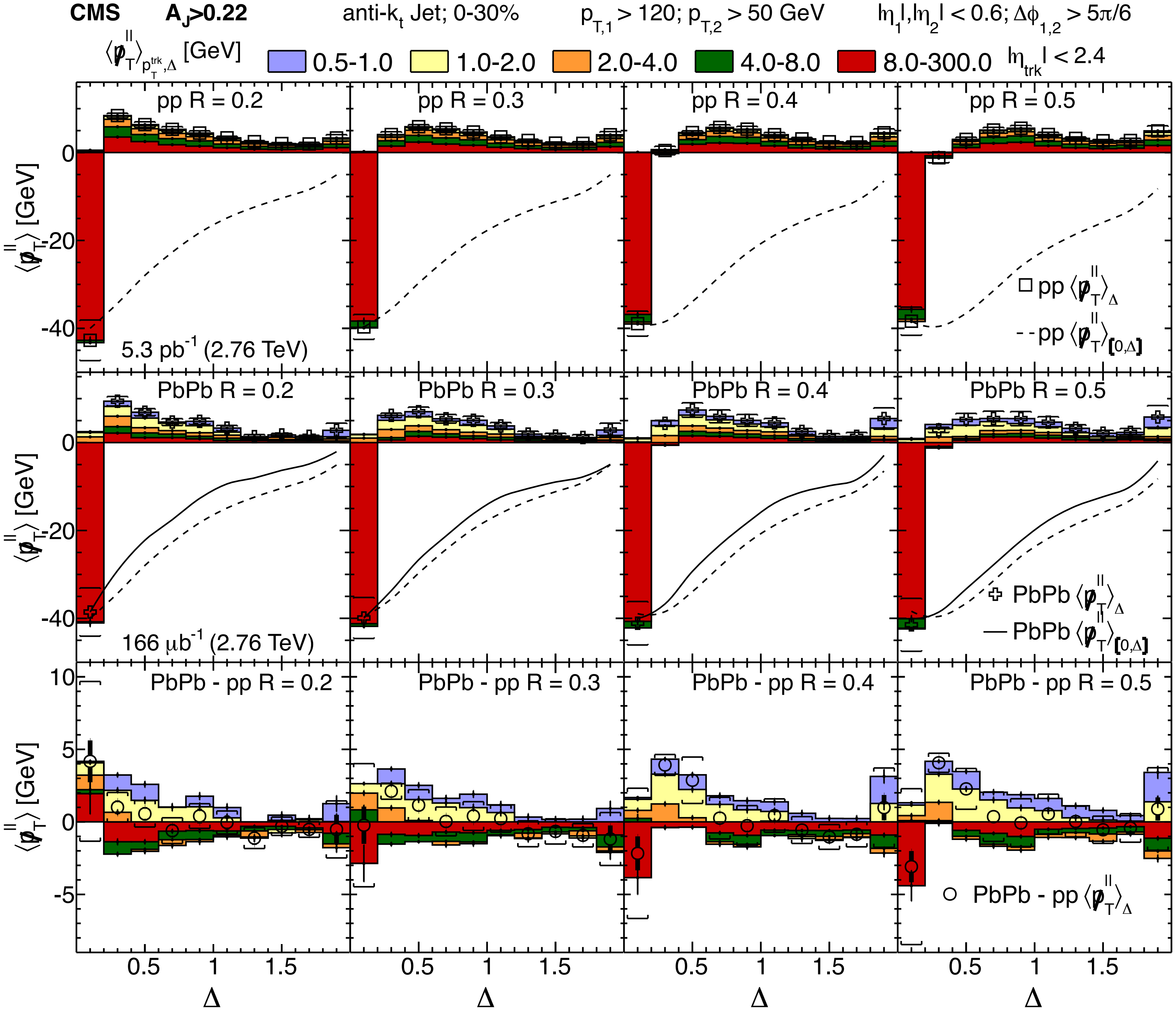
Multiple R Missing P_T vs. Δ (A_J > 0.22)

A_J > 0.22

pp →

PbPb **(0-30%)** →

PbPb - pp →



R=0.2 **R=0.3** **R=0.4** **R=0.5**

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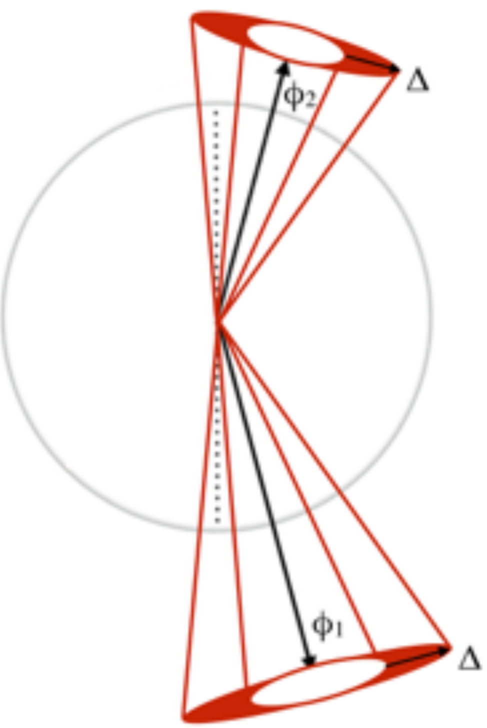


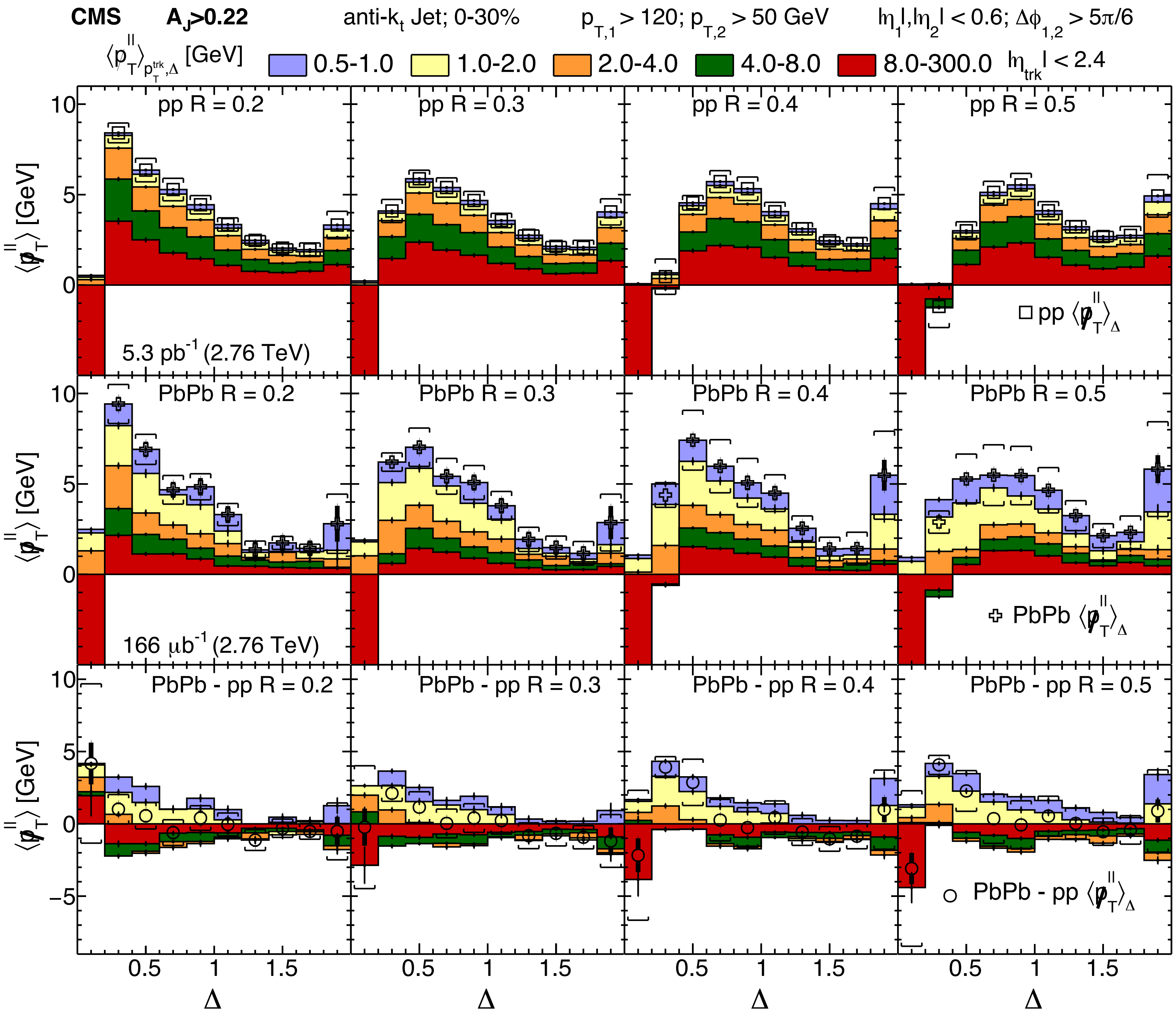
Multiple R Missing P_T vs. Δ (A_J > 0.22)

A_J > 0.22

pp

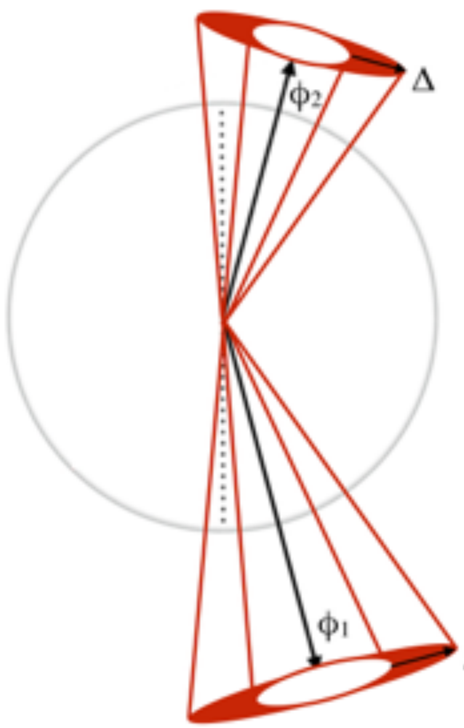
PbPb
(0-30%)

PbPb - pp



R=0.2 **R=0.3** **R=0.4** **R=0.5**

CMS-HIN-14-010-PUB

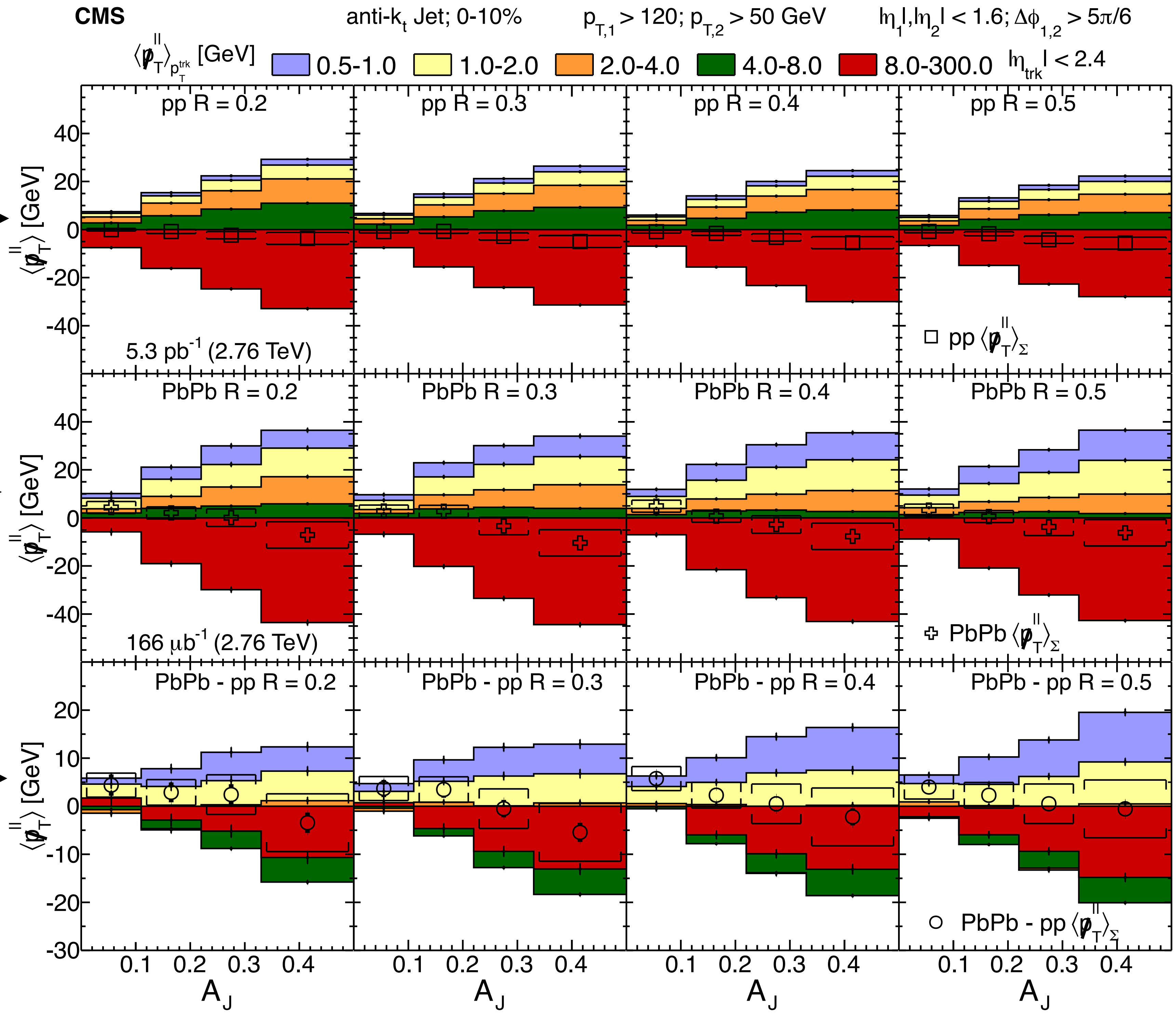


Multiple R Missing P_T vs. A_J

pp →

PbPb → (0-10%)

PbPb - pp →



R=0.2 R=0.3 R=0.4 R=0.5

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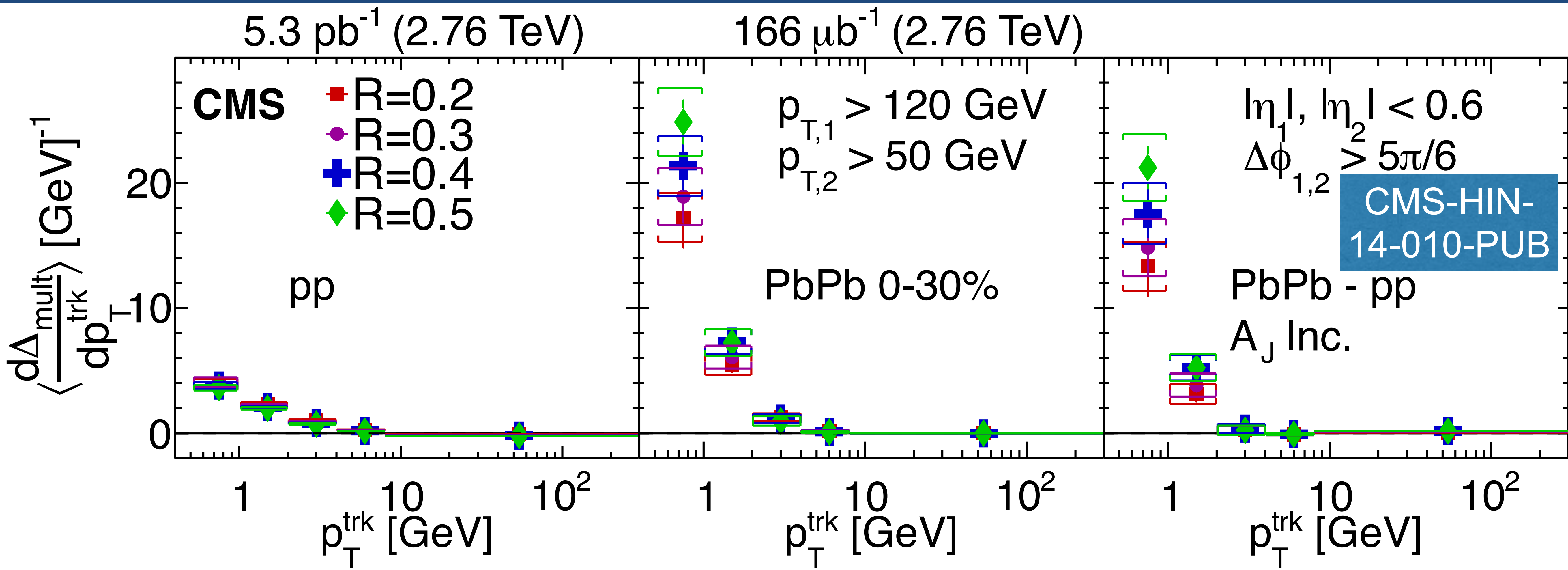
dN/dp_T for all R



$$\langle d\Delta_{mult}/dp_T \rangle = -c^{trk} \times \sout{p_T^{trk}} \times \cos\left(\phi_{trk} - \phi_{dijet}\right) \longrightarrow \text{(remove } p_T \text{ weight)}$$

- Potential R dependence in low p_T contribution (0.5-1.0 GeV)
- R = 0.2-> R = 0.5 difference slightly greater than summed statistical and systematic error