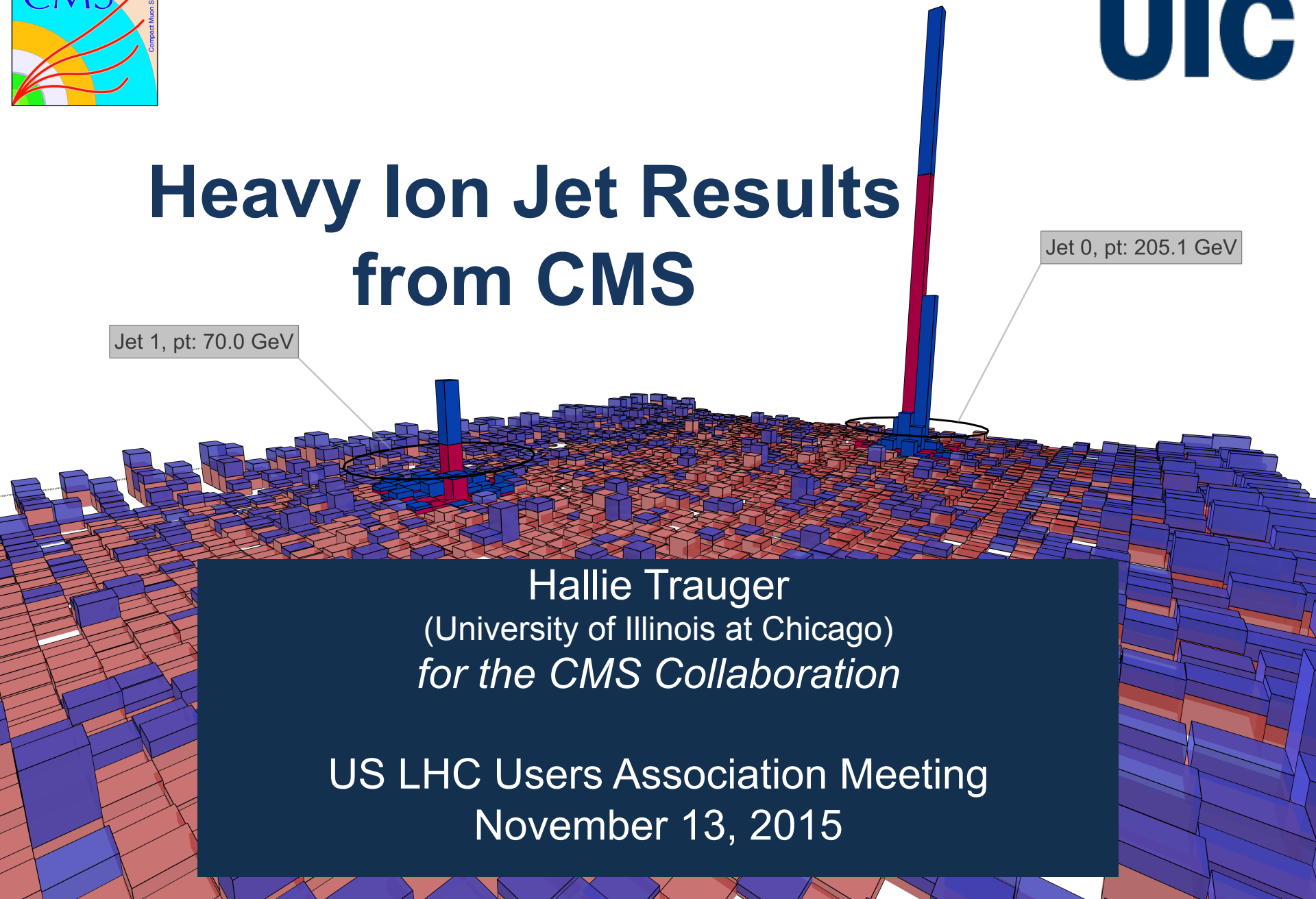
Heavy Ion Jet Results from CMS



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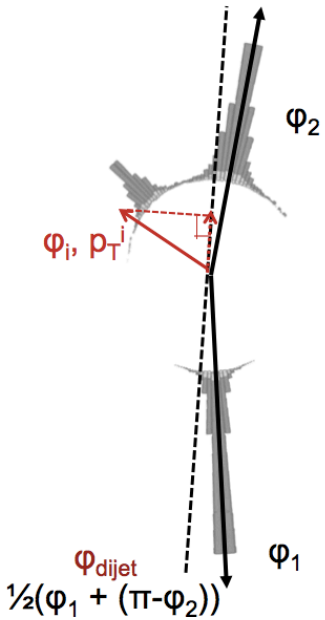
(University of Illinois at Chicago)
for the CMS Collaboration

US LHC Users Association Meeting
November 13, 2015

High-p_T Probes of the Quark Gluon Plasma



- PbPb collisions (and pp reference) at 2.76 TeV
- High-p_T partons are produced in initial hard scatterings
- Partons are used as probes passing through the QGP
- Select a sample of back-to-back dijets

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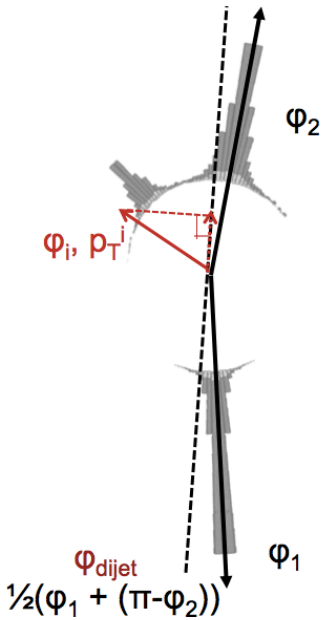

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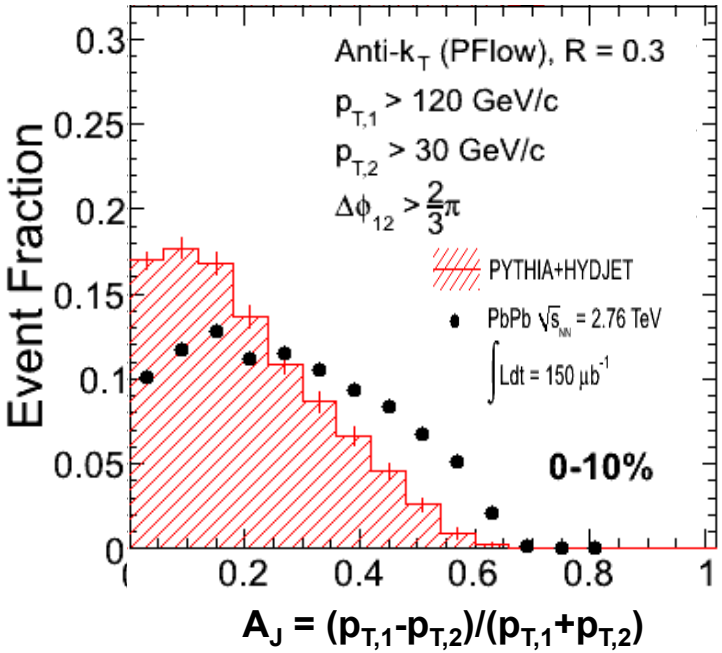
  $A_J = (p_{T,1}-p_{T,2})/(p_{T,1}+p_{T,2})$



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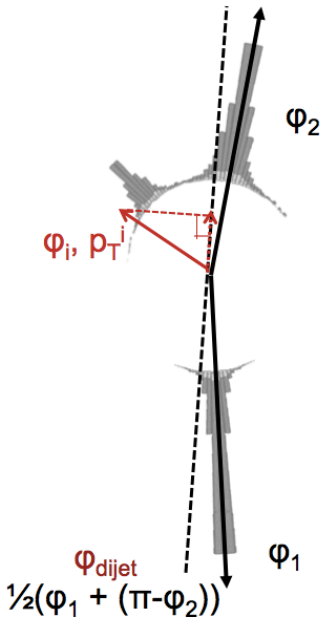

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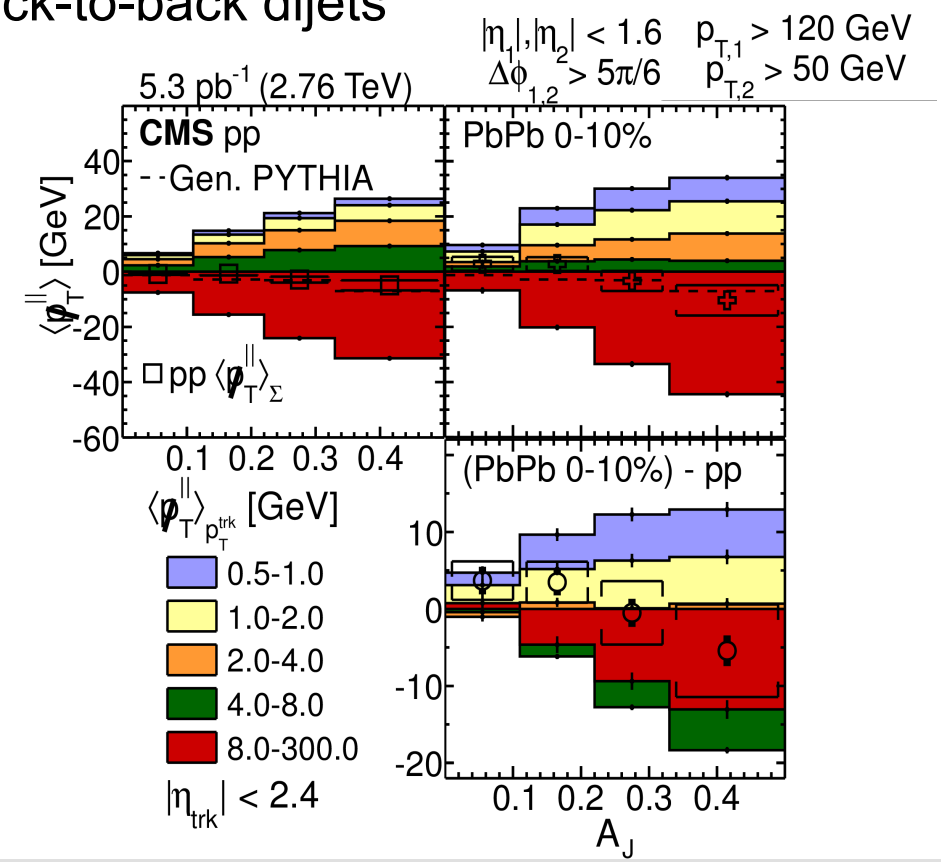

- Dijet asymmetry:
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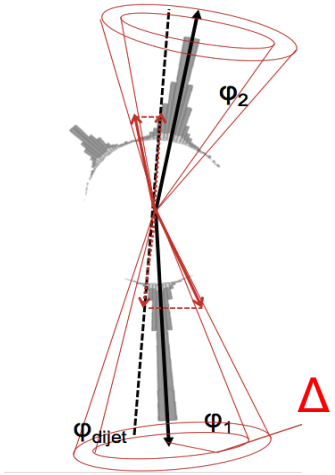
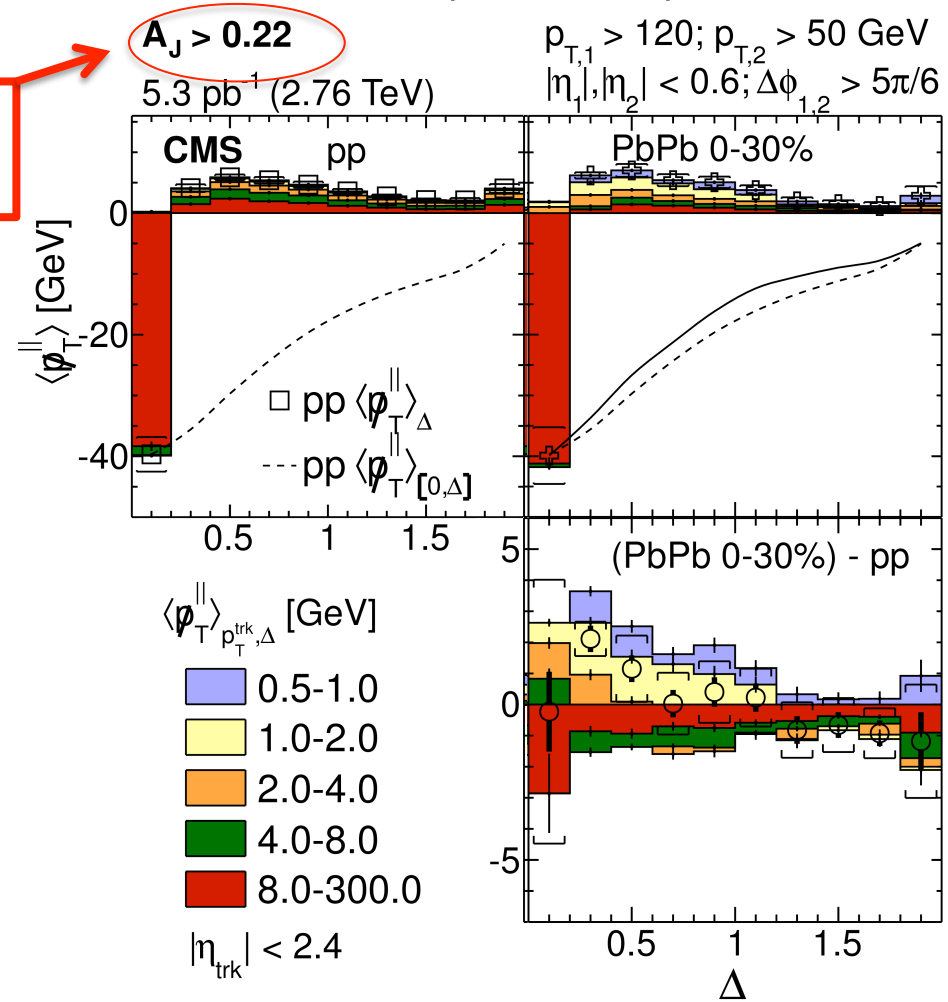
- Asymmetric dijets (large A_J) balancing distribution:
  - pp: more p_T>4 GeV
  - PbPb: mostly p_T<2 GeV

Angular Distribution of Missing-p_T



- Missing p_T vs. radius parameter $\Delta = \sqrt{(\Delta\eta^2+\Delta\varphi^2)}$

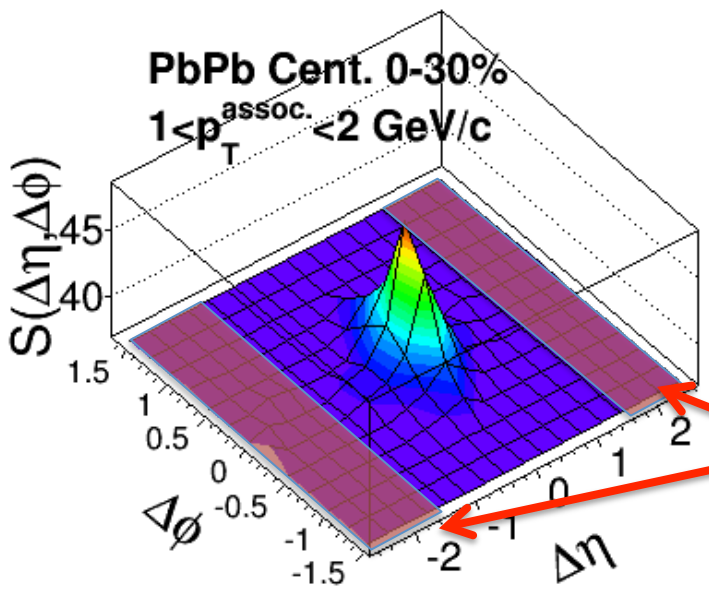
Focus on unbalanced dijets

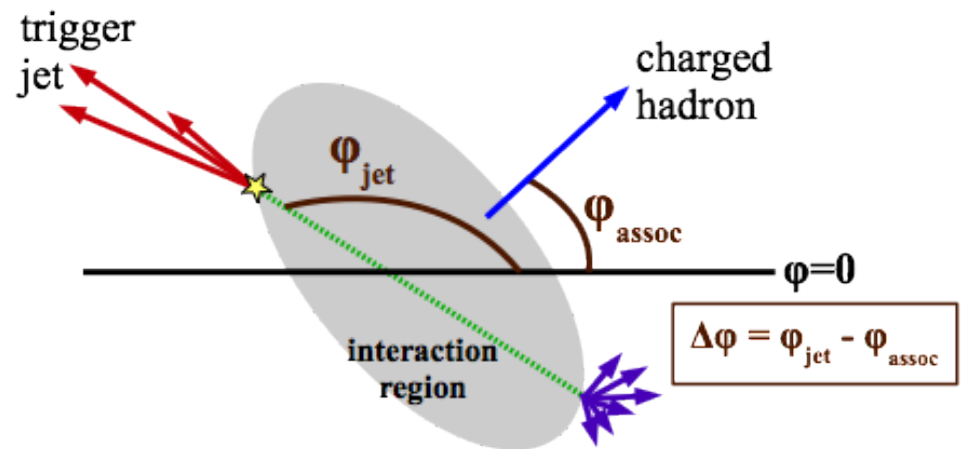


- **PbPb central:** soft excess to large Δ
- **pp and peripheral:** more particles with $p_T > 4$ GeV (also to large angles)

Dijet Correlated Yield Studies

- Construct 2D Δη-Δφ correlations to leading and subleading jet axes
- Subtract combinatorial and long-range correlated background (measured on 1.5<|Δη|<2.5 in "sideband" technique)
- Study each jet peak individually





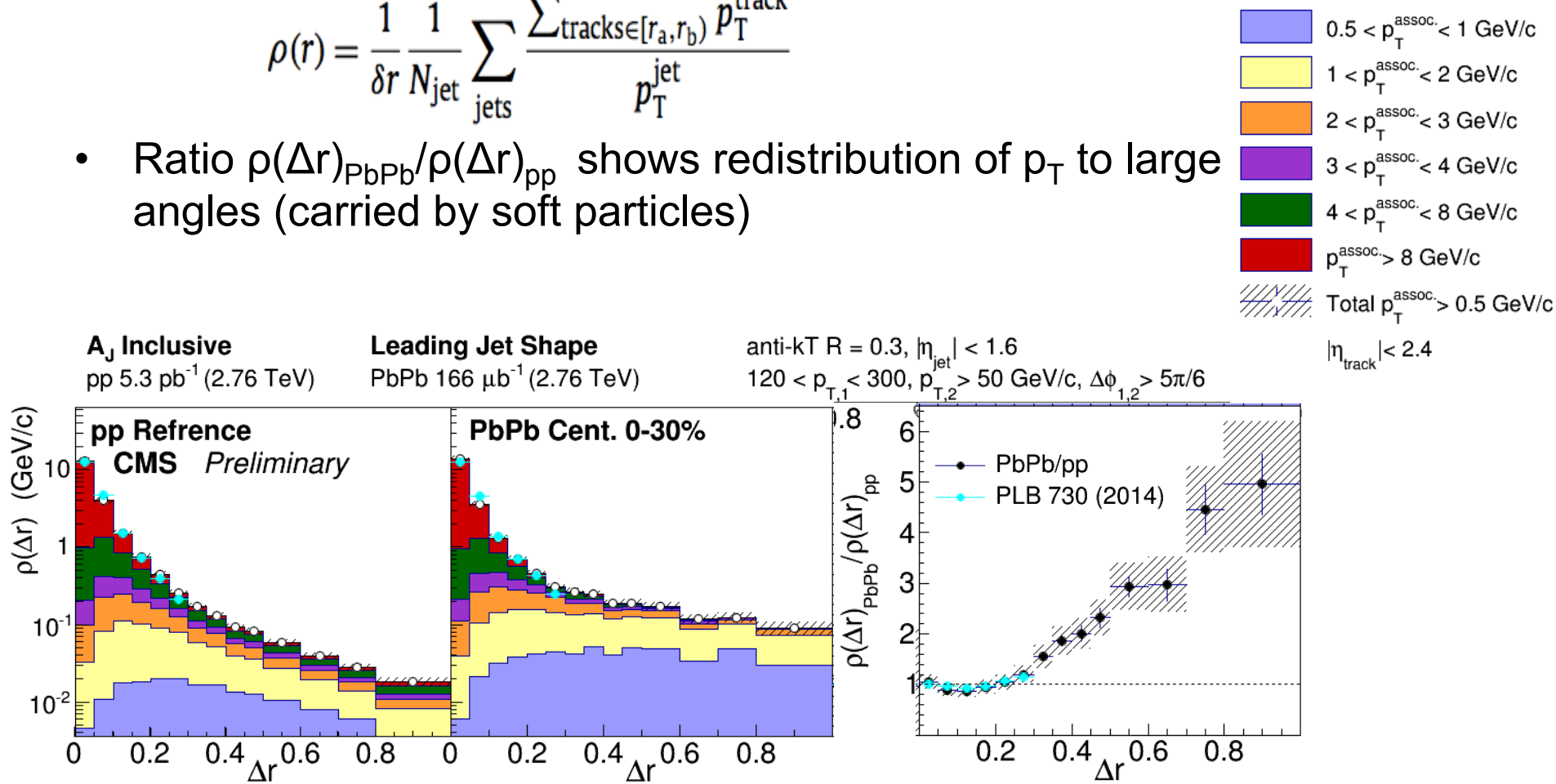
"Sideband" region
1.5<|Δη|<2.5

Jet Peak Modifications

- Measure jet shape from background-subtracted correlations:

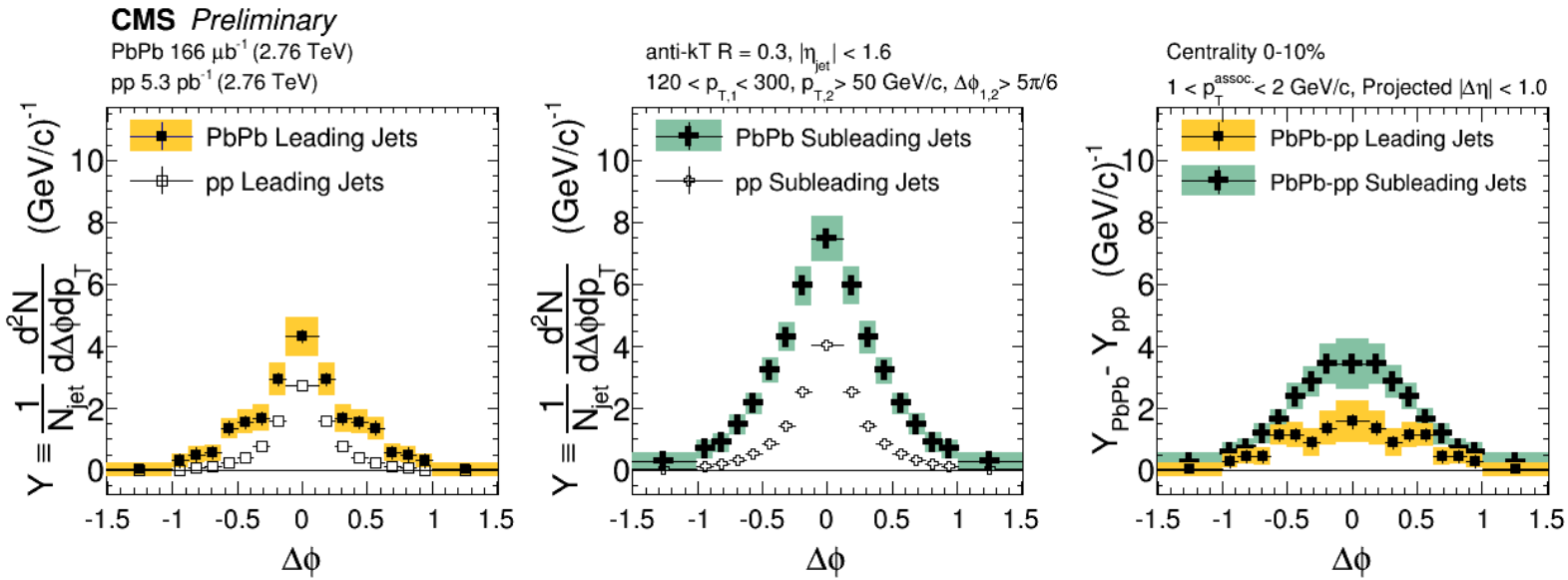
$$\rho(r) = \frac{1}{\delta r}\frac{1}{N_{\text{jet}}}\sum_{\text{jets}}\frac{\sum_{\text{tracks}\in[r_a,r_b)} p_T^{\text{track}}}{p_T^{\text{jet}}}$$

- Ratio $\rho(\Delta r)_{PbPb}/\rho(\Delta r)_{pp}$ shows redistribution of p_T to large angles (carried by soft particles)



Per-Jet Particle Yields

- Look at modifications to distributions of charged particles by p_T



- **Central PbPb:** enhancement of low-p_T ($1<p_T<2$ GeV) particles
- Enhancement present in leading, larger for subleading jets

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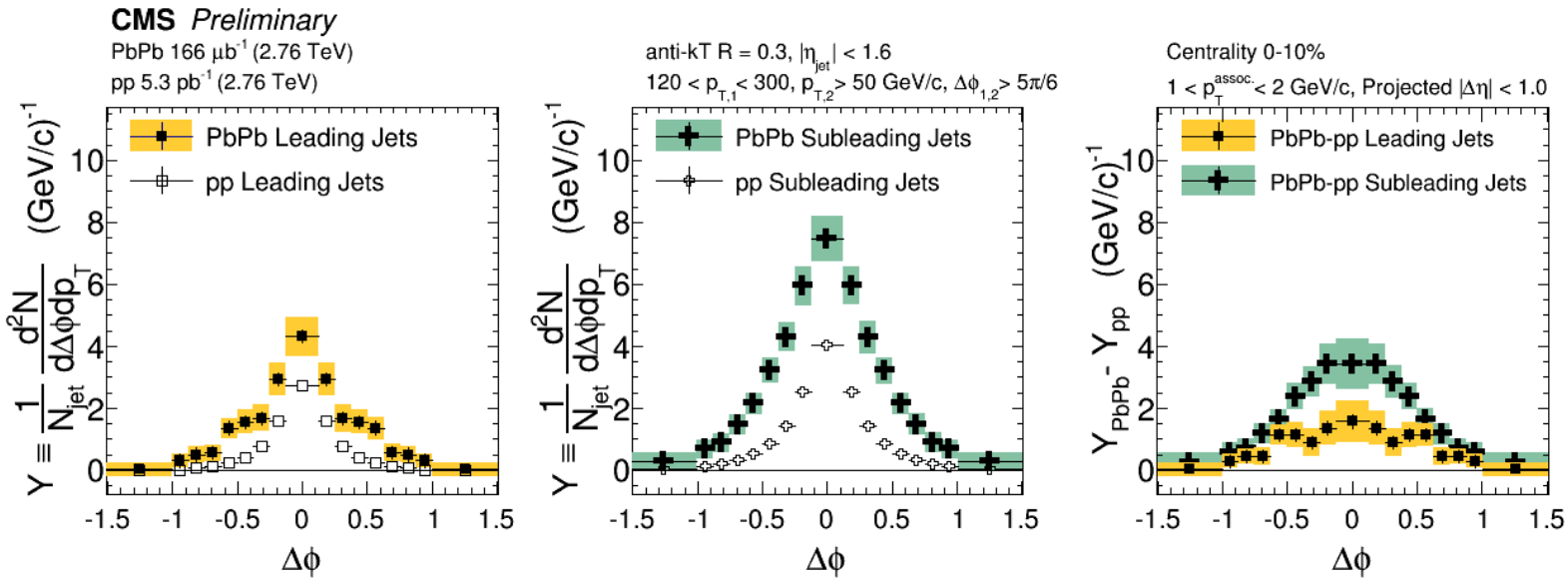
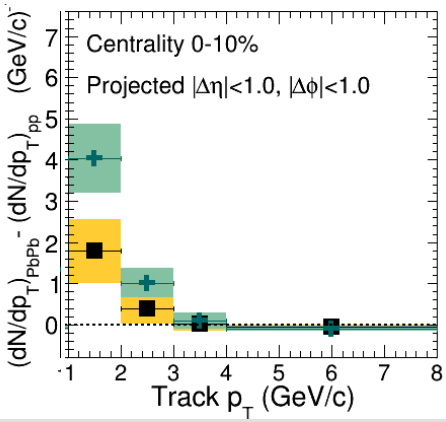


- **Central PbPb:** enhancement of low-p_T particles
- Present in leading, larger for subleading jets
- Integrate this excess: jet peak yield by track-p_T



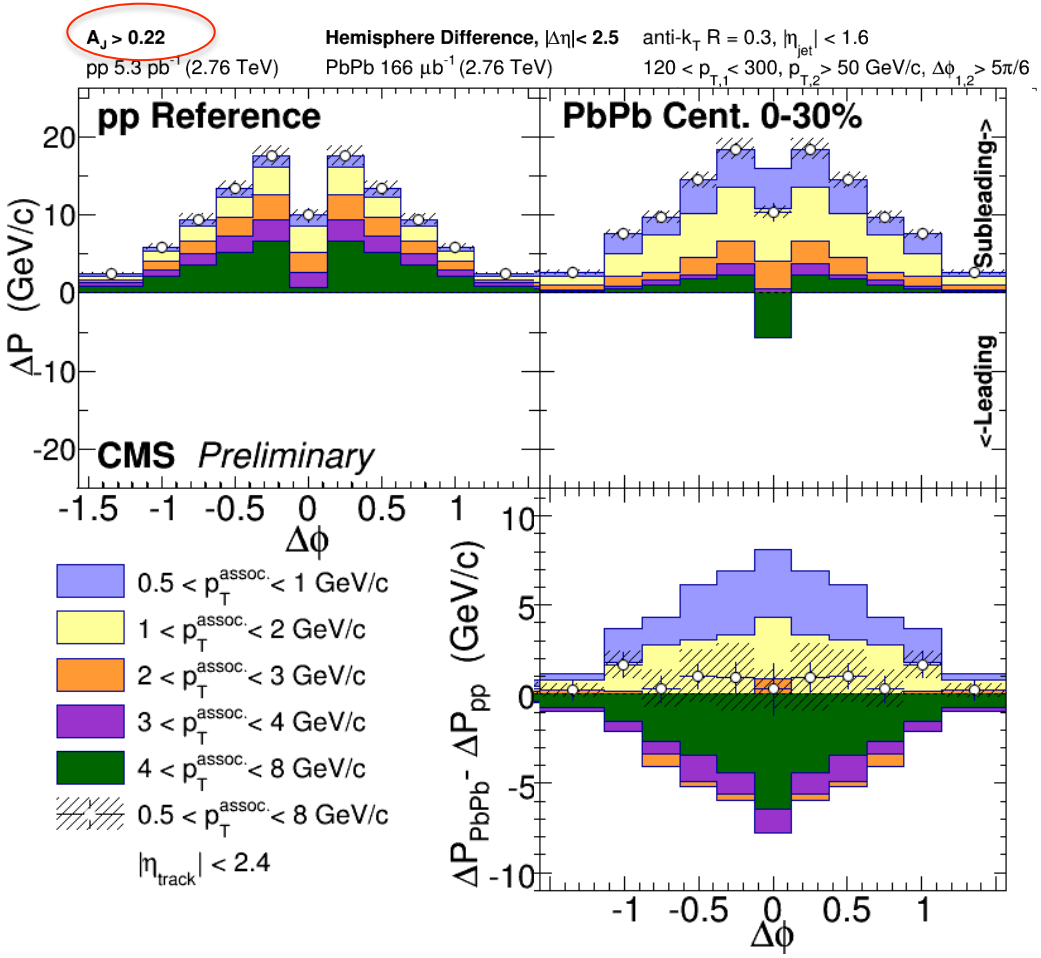
Decomposing Hemisphere p_T Balance

Hemisphere p_T balance by Δφ

- Low-p_T excess in PbPb central collisions enhanced
- Less high-p_T tracks relative to pp reference

Now decompose into…

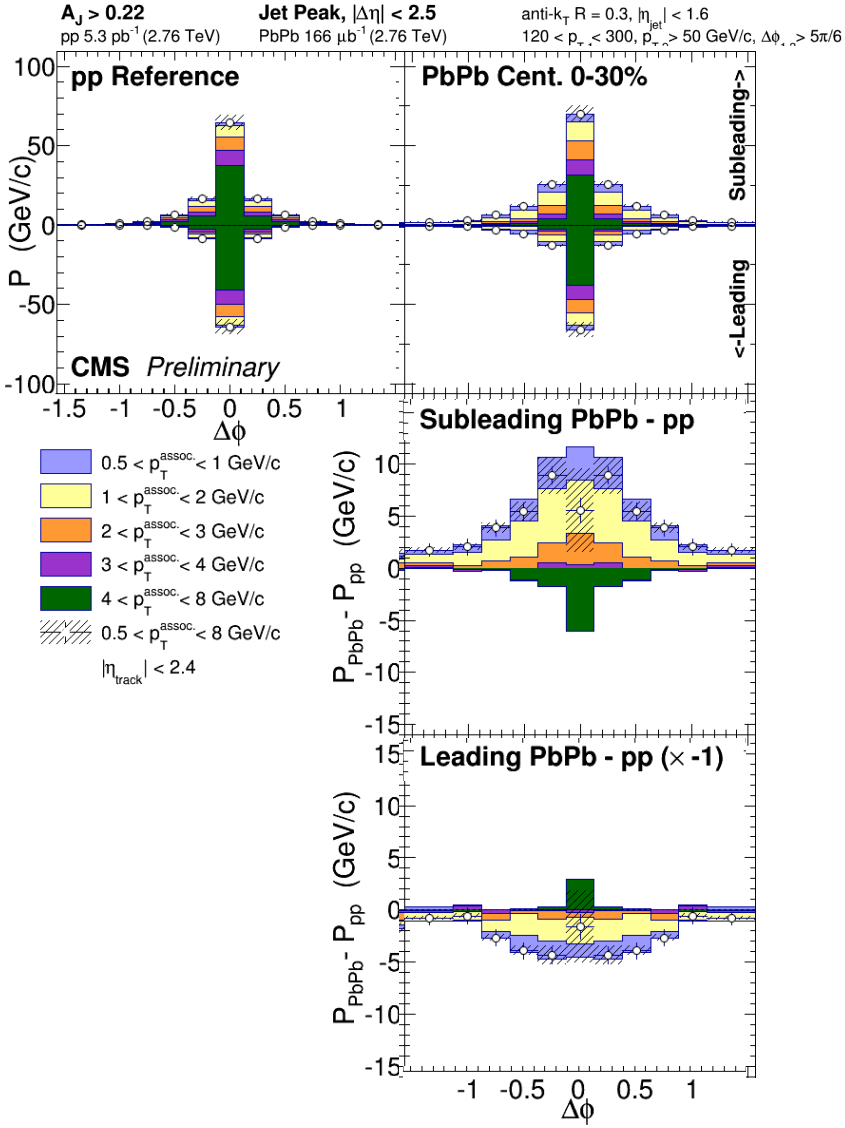
- Leading jet peak
- Subleading jet peak
- Overall subleading-to-leading long range asymmetry (measured on 1.5<|Δη|<2.5, Δη-independent)



Decomposing Energy Balance: Jet Peaks

Jet peak contributions for balanced dijets:

- Enhancement of momentum carried by low-p_T tracks about both leading and subleading jets
- Follows expectations from correlated yield studies



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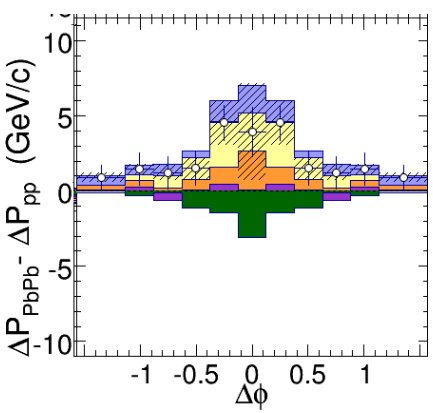
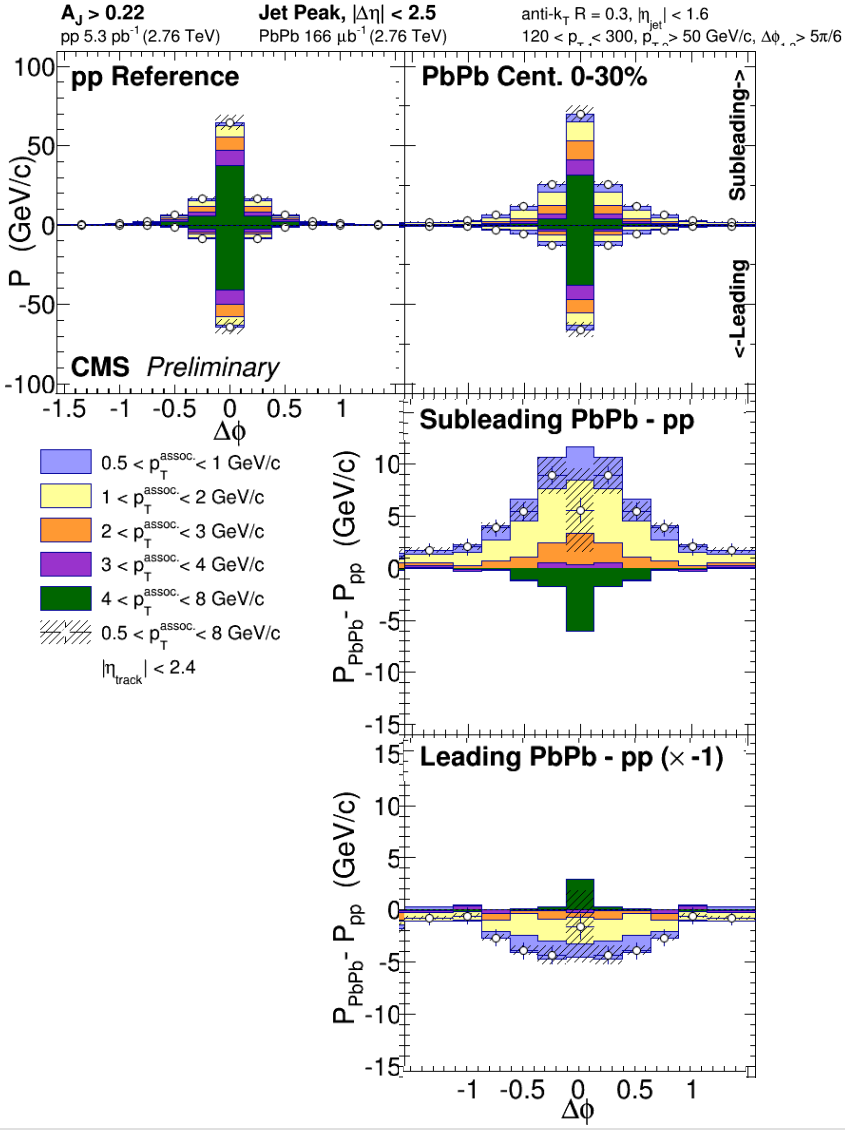
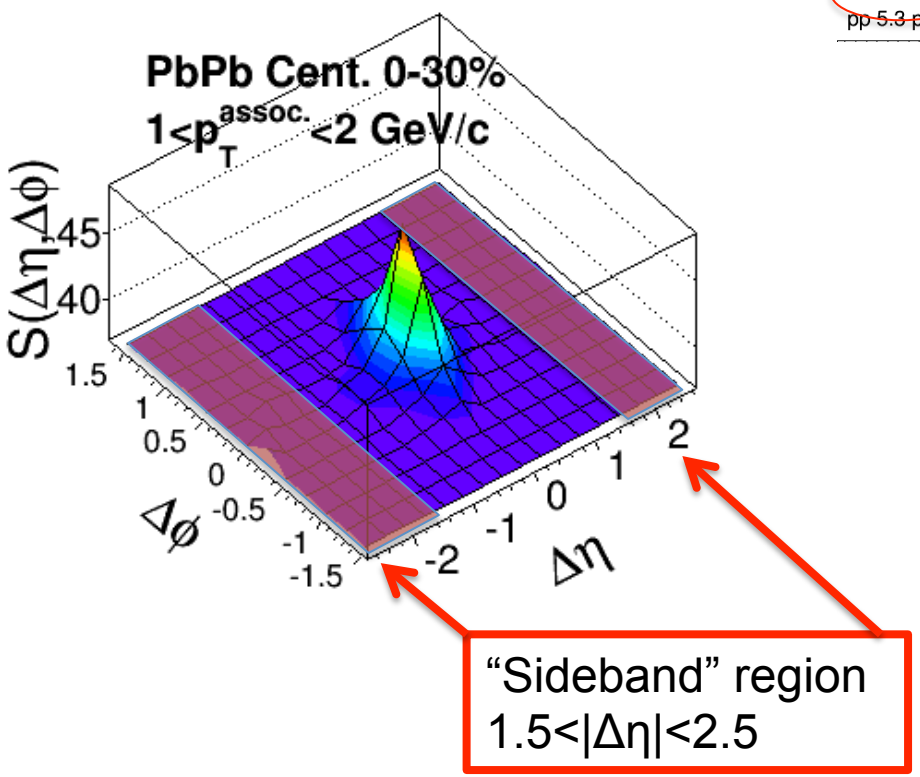
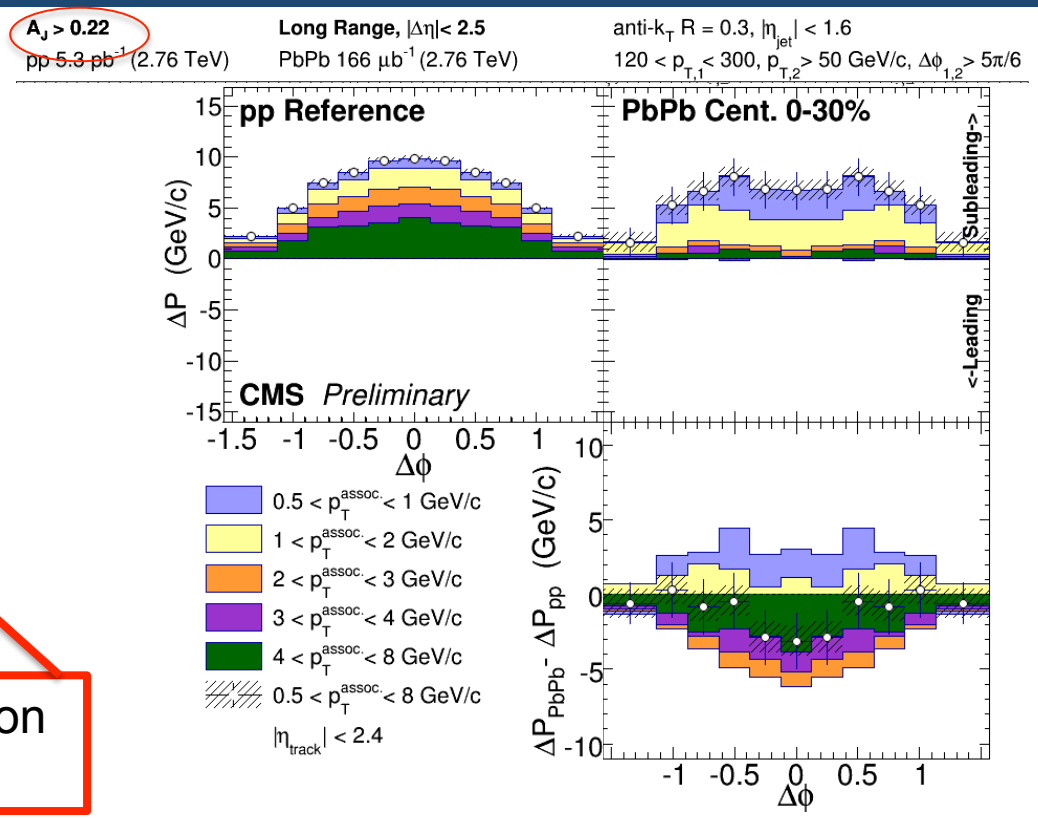
PbPb – pp, subleading – leading gives contribution to hemisphere balance:





Decomposing Energy Balance: Long Range





- **In pp:** <u>unbalanced</u> dijets are accompanied by a long range excess of yield on the subleading side (momentum conservation/ 3-jet events)
- **In central PbPb:** disappearance of high-p_T long range asymmetry, growth of low-p_T long range asymmetry

Summary

- **Three contributions to hemisphere momentum imbalance:**
  - Leading jet peak
  - Subleading jet peak
  - Long range Δη-independent asymmetry

- **Jet peaks:**
  - Excess momentum carried by soft particles (p_T<2 GeV) in central PbPb relative to pp
  - Suggests both leading and subleading jets are quenched

- **Long range asymmetry:**
  - pp: Δφ-correlated excess of high-p_T (4-8 GeV) associated particles, attributed to additional jets as required by momentum conservation in unbalanced dijet events
  - PbPb (central): unbalanced jet selection includes more quenched 2-jet events and as 3rd jets present in this selection are quenched