Studies of Jet-Track Correlations in PbPb collisions with CMS

Hard Probes 2015

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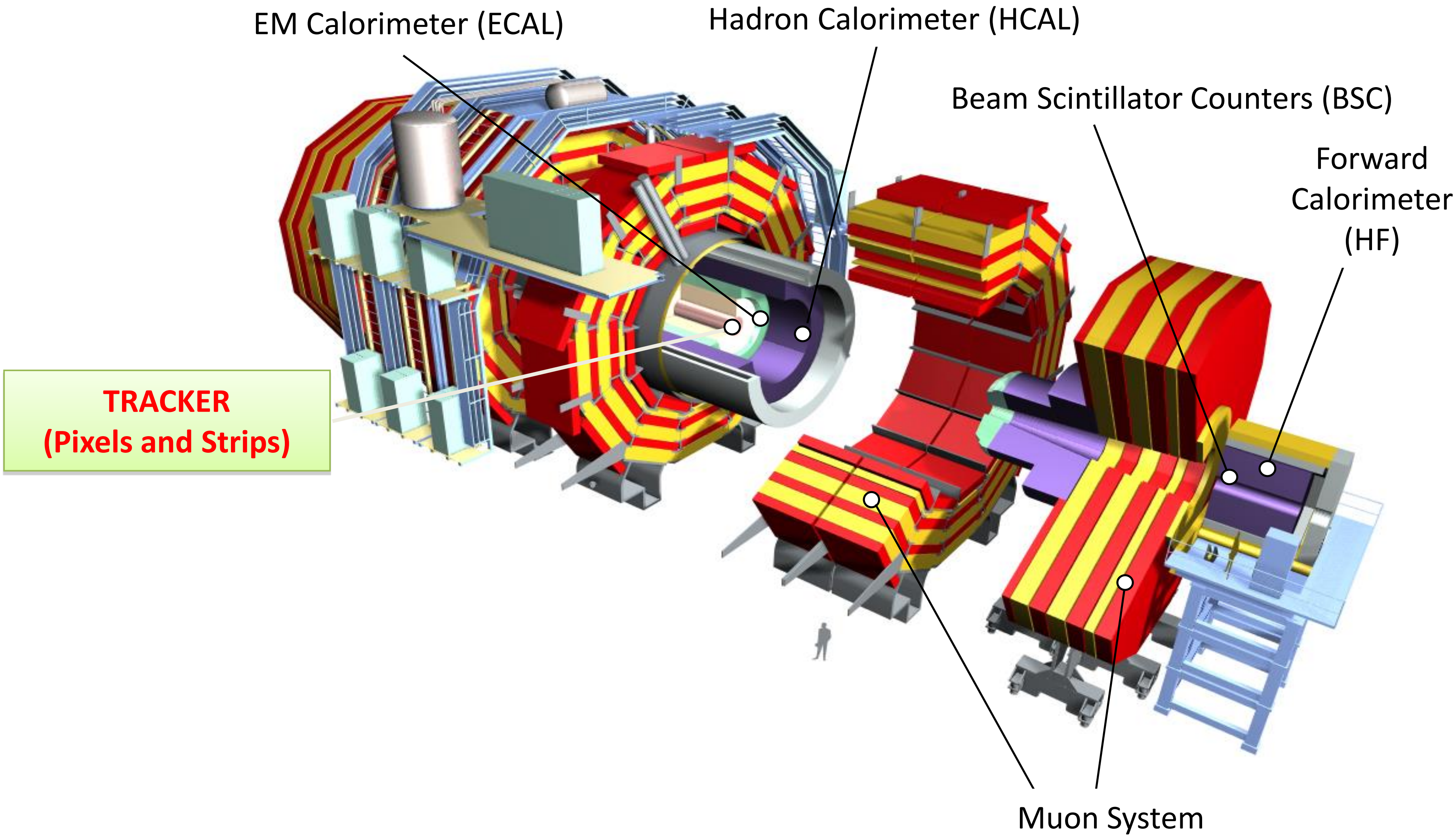
for the CMS Collaboration

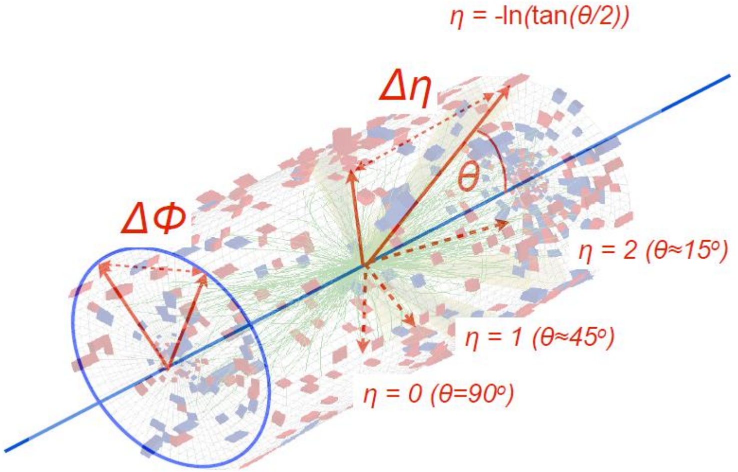
Questions this talk will address

- How are charged particles distributed around jets?
- What happens to these distributions when we compare leading and subleading jets?
- How many particles are there around these jets as a function of p_T and centrality ?
- What are effects of the QGP medium created in PbPb collisions that doesn't appear in pp?

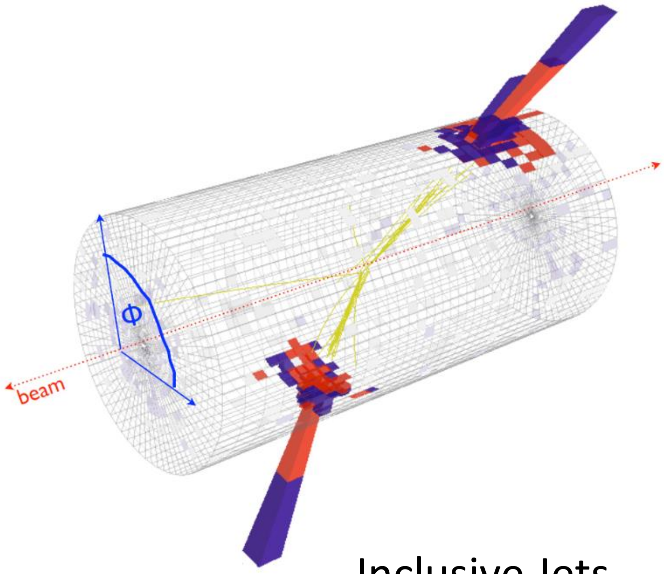
Compact Muon Solenoid



Jets and tracks



Tracks



Inclusive Jets

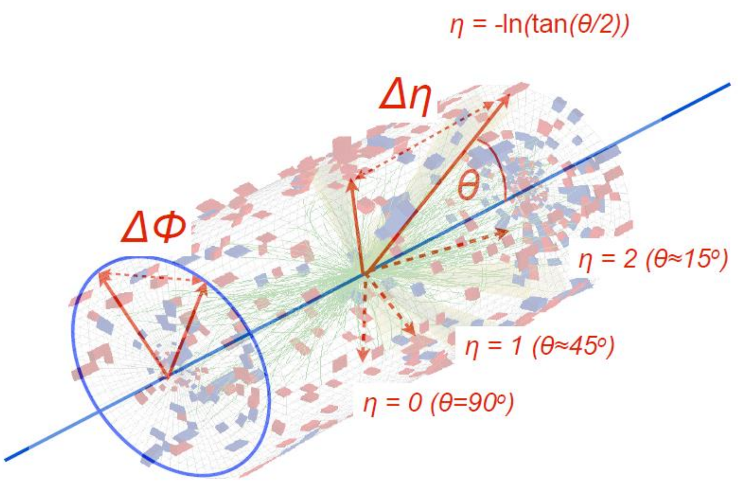
Standard CMS HI track selection

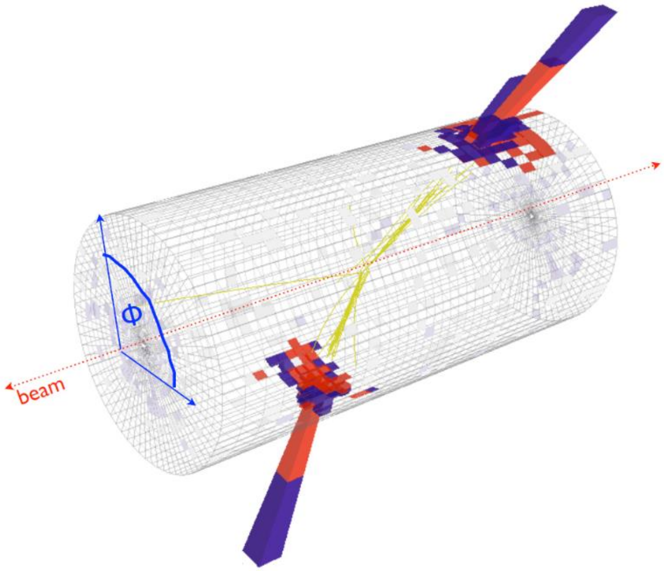
- $|\eta|<2.4$
- $1.0 > p_T > 2.0$ GeV/c
- $2.0 > p_T > 3.0$ GeV/c
- $3.0 > p_T > 4.0$ GeV/c
- $4.0 > p_T > 8.0$ GeV/c

Standard CMS HI jet selection

- Anti k_T jets with R = 0.3
- $|\eta|<1.6$
- Jet $p_T > 120$ GeV/c
- Fully efficient from a triggered dataset corresponding to 166 ub^{-1}

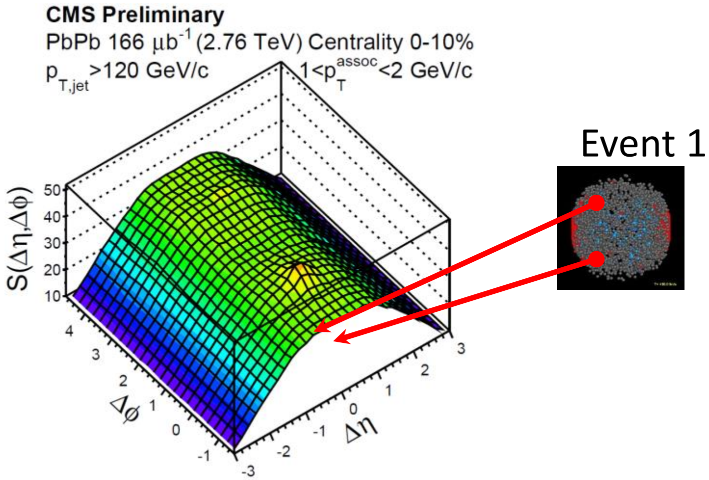
Jet-track correlations





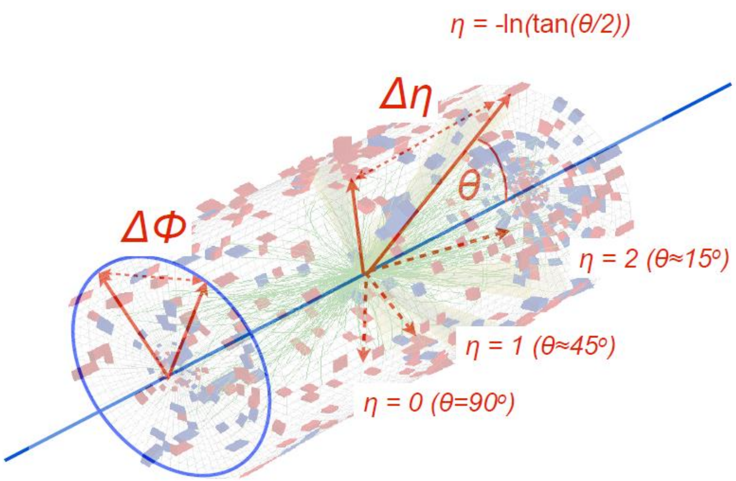
Signal pair distribution:

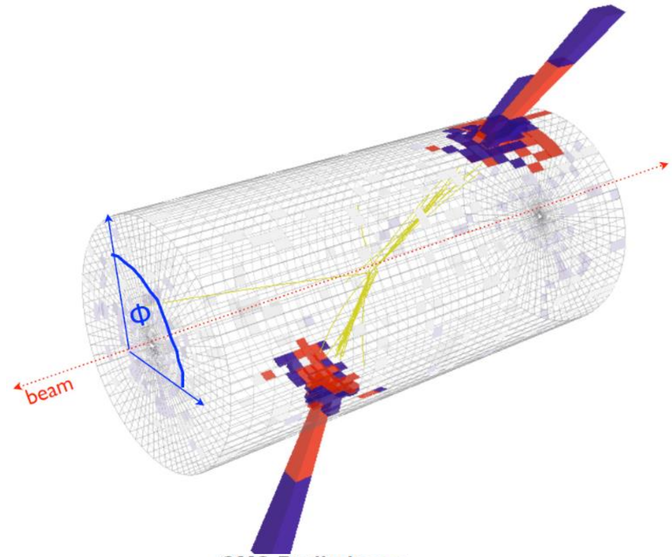
same event pairs



$$S(\Delta\eta, \Delta\phi) = \frac{1}{N_{trig}} \frac{d^2 N^{same}}{d\Delta\eta d\Delta\phi}$$

Jet-track correlations





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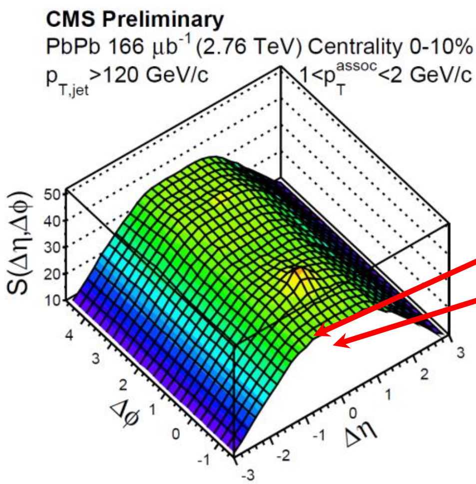
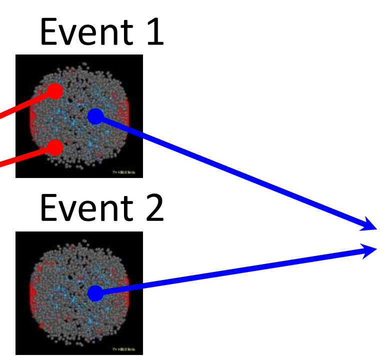
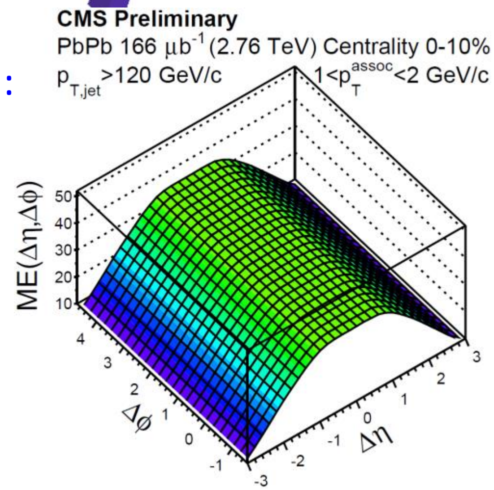




Mixed event pair distribution:



mixed event pairs

$$S\left(\Delta\eta,\Delta\phi\right) = \frac{1}{N_{trig}}\frac{d^2N^{same}}{d\Delta\eta d\Delta\phi}$$

$$ME\left(\Delta\eta,\Delta\phi\right) = \frac{1}{N_{trig}}\frac{d^2N^{mix}}{d\Delta\eta d\Delta\phi}$$

Jet-track correlations

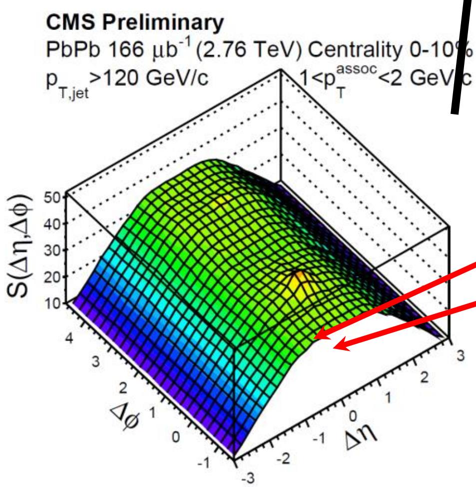
Divide Signal by Mixed Event

Associated hadron yield per trigger:

$$\frac{1}{N_{trig}}\frac{d^2N^{pair}}{d\Delta\eta d\Delta\phi} = ME(0,0)\times\frac{S(\Delta\eta,\Delta\phi)}{ME(\Delta\eta,\Delta\phi)}$$

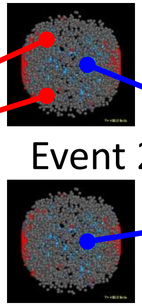
Signal pair distribution:

same event pairs

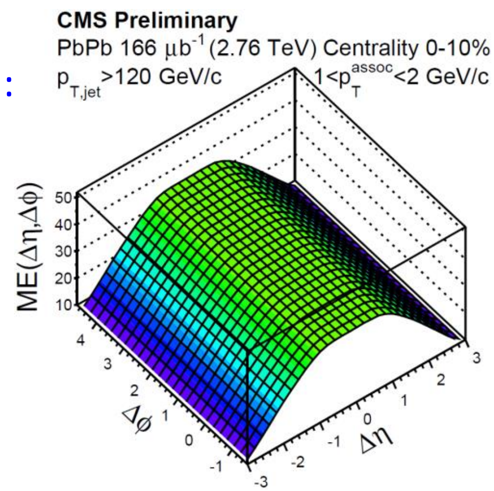


Event 1

Event 2



Mixed event pair distribution:

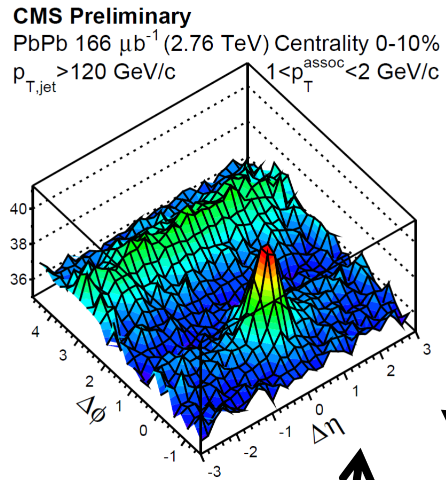


mixed event pairs

$$S(\Delta\eta,\Delta\phi) = \frac{1}{N_{trig}}\frac{d^2N^{same}}{d\Delta\eta d\Delta\phi}$$

$$ME(\Delta\eta,\Delta\phi) = \frac{1}{N_{trig}}\frac{d^2N^{mix}}{d\Delta\eta d\Delta\phi}$$

Jet-track correlations

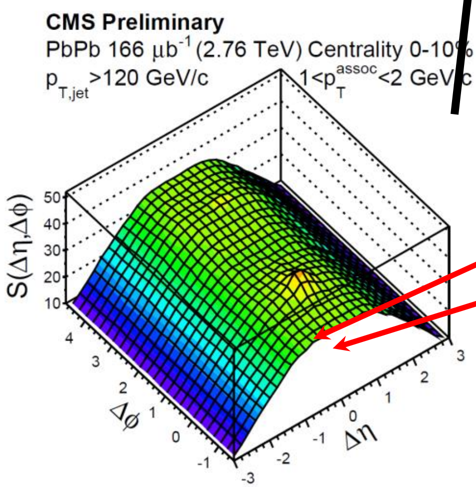


Associated hadron yield per trigger:

$$\frac{1}{N_{trig}}\frac{d^2N^{pair}}{d\Delta\eta d\Delta\phi} = ME(0,0) \times \frac{S(\Delta\eta,\Delta\phi)}{ME(\Delta\eta,\Delta\phi)}$$

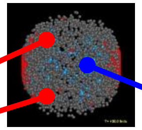
Signal pair distribution:

same event pairs

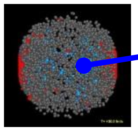


$$S(\Delta\eta,\Delta\phi) = \frac{1}{N_{trig}}\frac{d^2N^{same}}{d\Delta\eta d\Delta\phi}$$

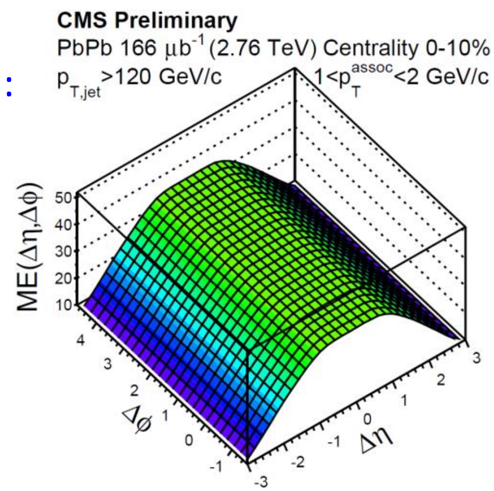
Event 1



Event 2



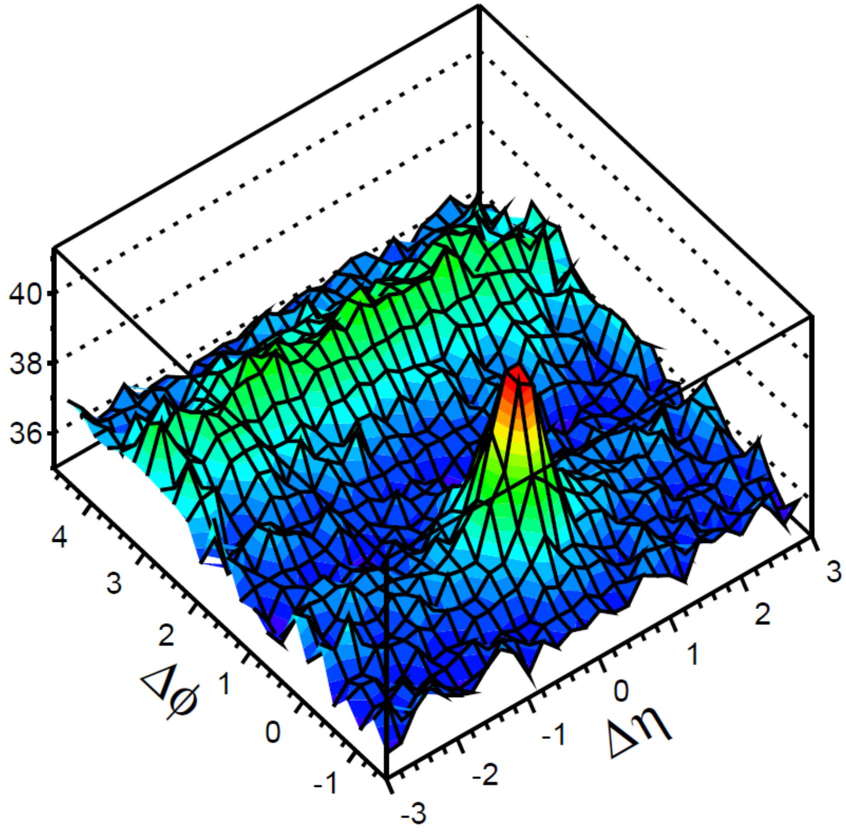
Mixed event pair distribution:



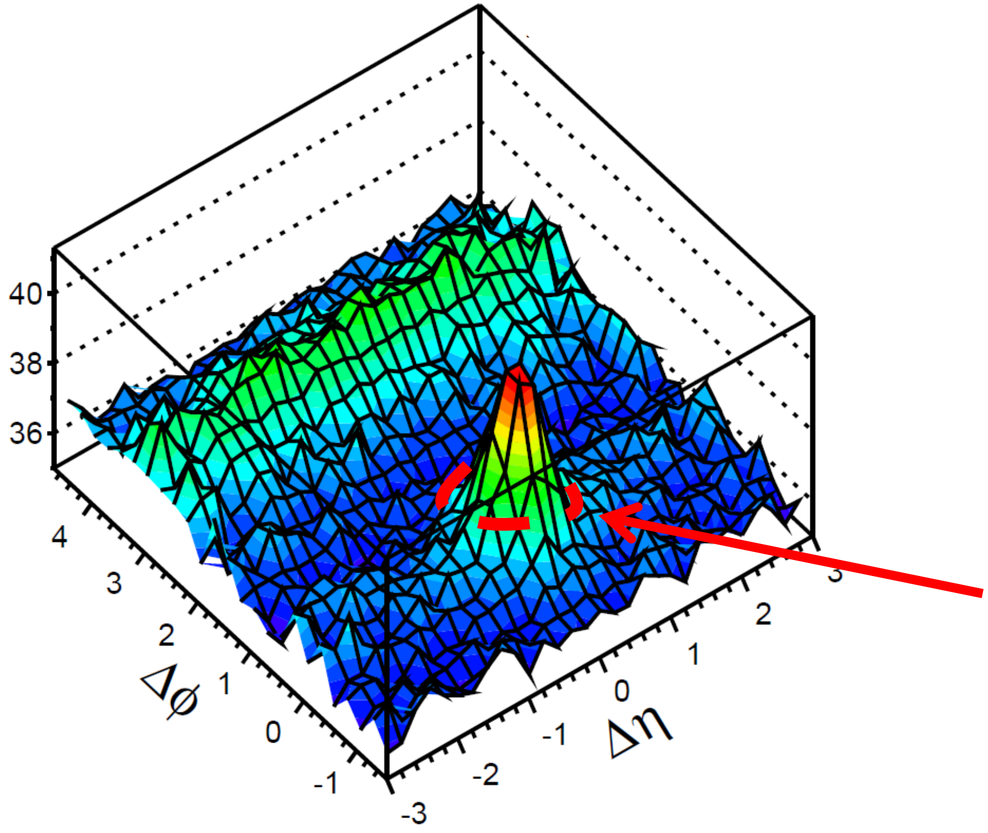
mixed event pairs

$$ME(\Delta\eta,\Delta\phi) = \frac{1}{N_{trig}}\frac{d^2N^{mix}}{d\Delta\eta d\Delta\phi}$$

Jet track correlation topology



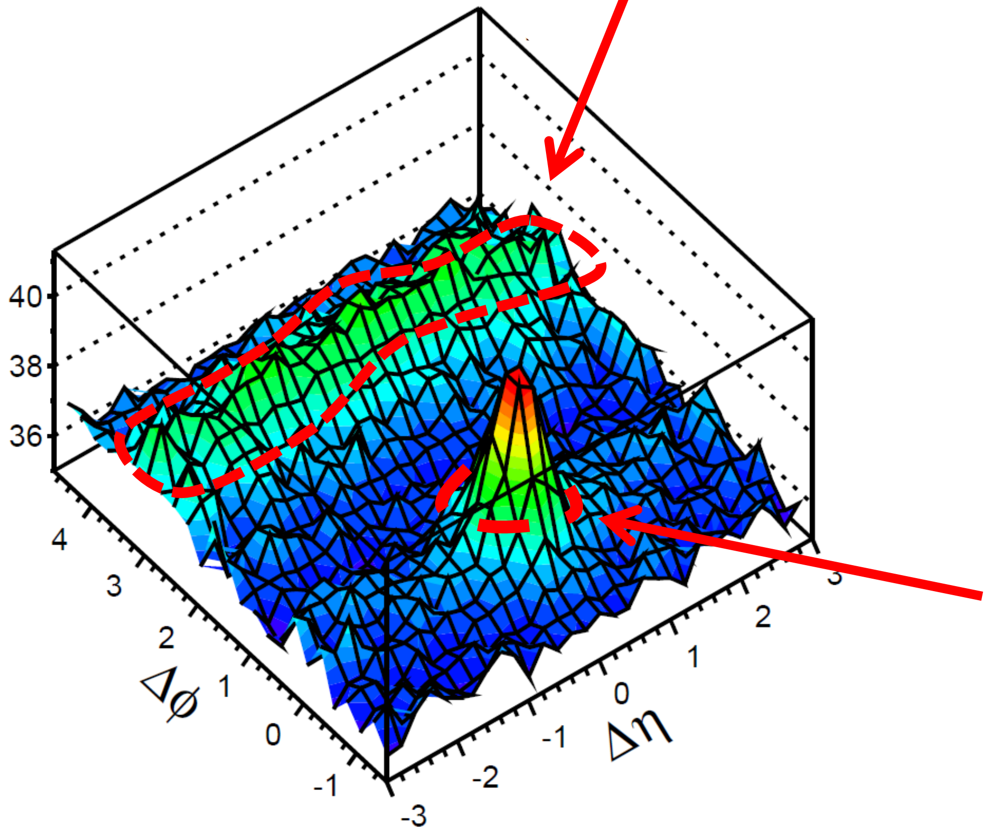
Jet track correlation topology



"Near-side" (Δφ, Δη ~ 0) correlations from particles around a jet

Jet track correlation topology

“Away-side” ($\Delta\phi \sim \pi$) correlations from particles around the other jet

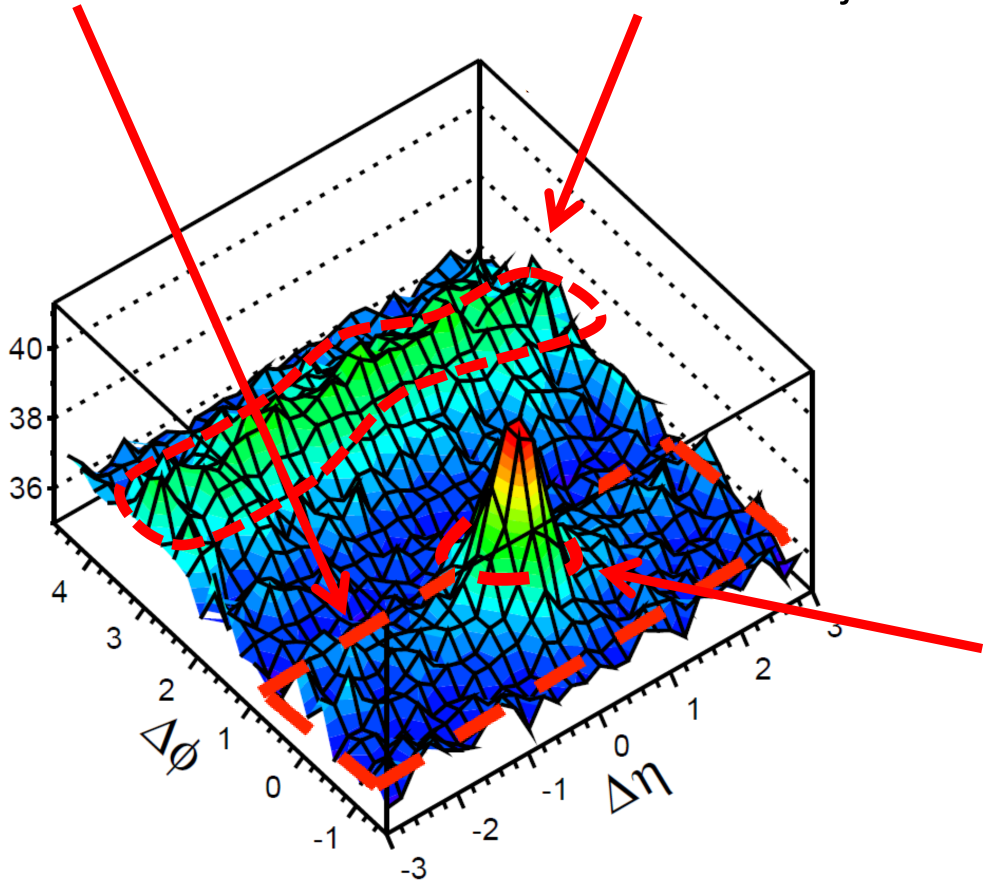


“Near-side” ($\Delta\phi$, $\Delta\eta \sim 0$) correlations from particles around a jet

Jet track correlation topology

Long range nearside jet correlations (weak in this example)

"Away-side" ($\Delta\phi \sim \pi$) correlations from particles around the other jet

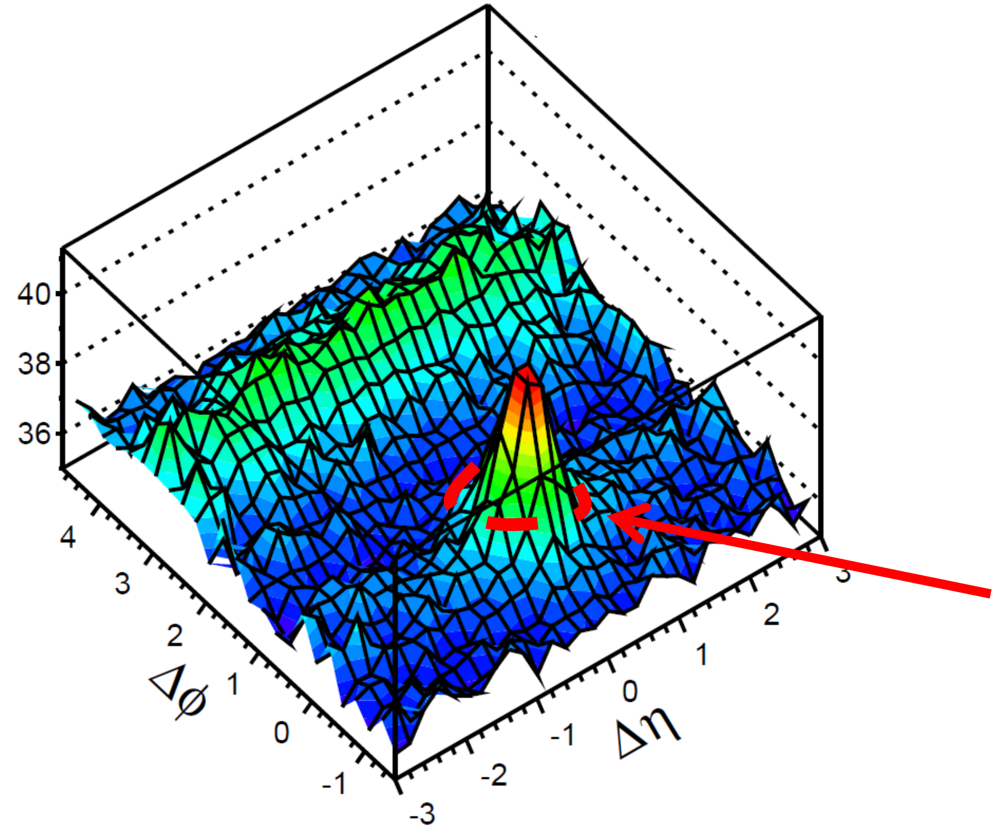


"Near-side" ($\Delta\phi$, $\Delta\eta \sim 0$) correlations from particles around a jet

Study the jet peak

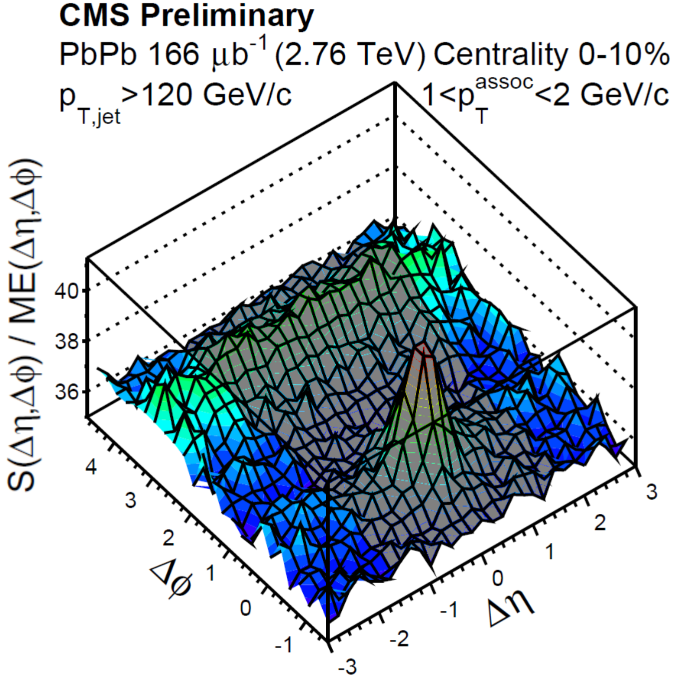
Long range nearside jet correlations (weak in this example)

"Away-side" ($\Delta\phi \sim \pi$) back-to-back jet correlations



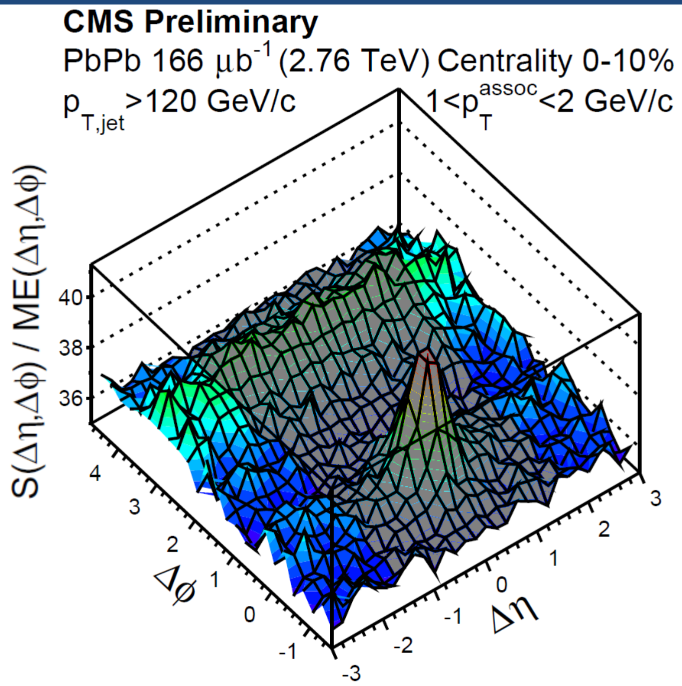
"Near-side" ($\Delta\phi$, $\Delta\eta \sim 0$) correlations from particles around a jet

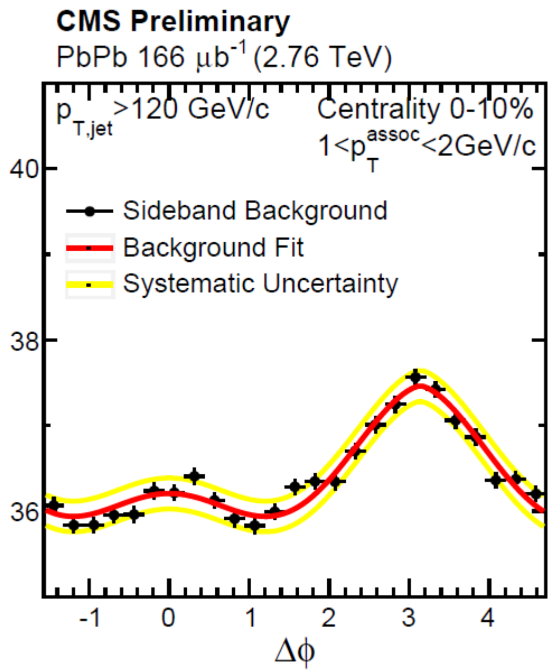
Subtract combinatorial and long range bkg



Construct the |Δϕ| projection from the correlation region $1.5 < |\Delta\eta| < 3.0$

Subtract combinatorial and long range bkg



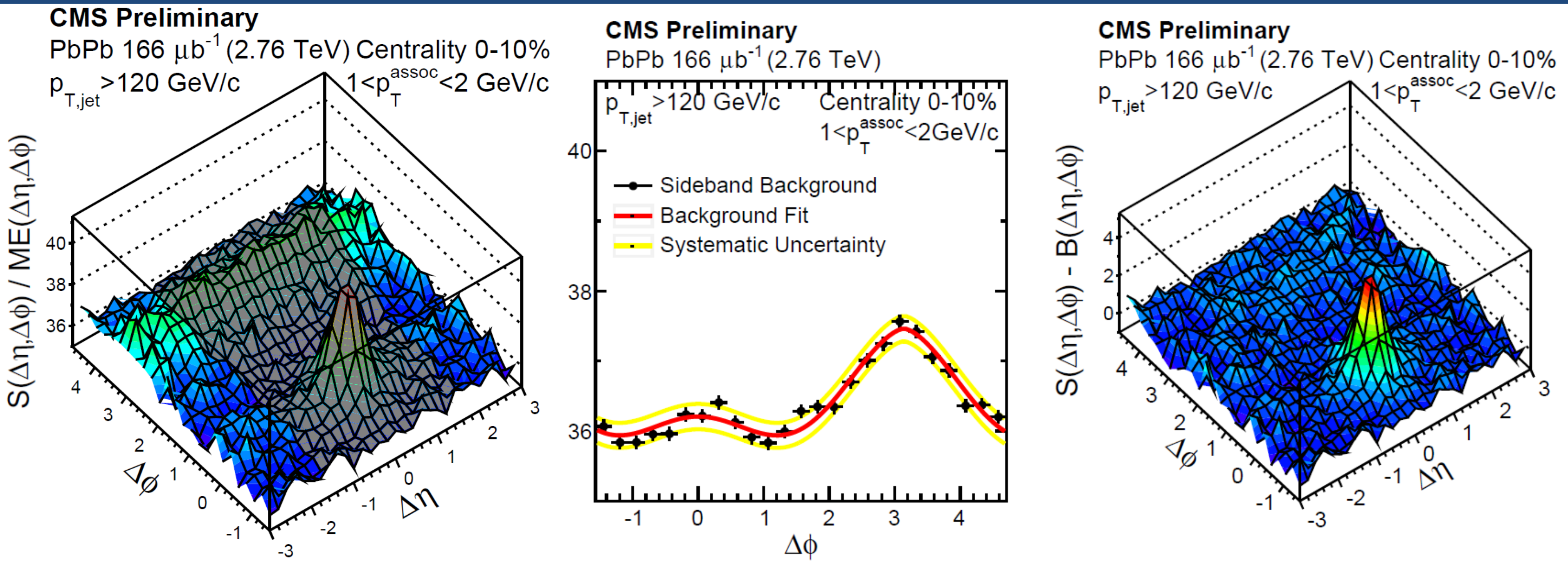


Subtract it from the original correlation function

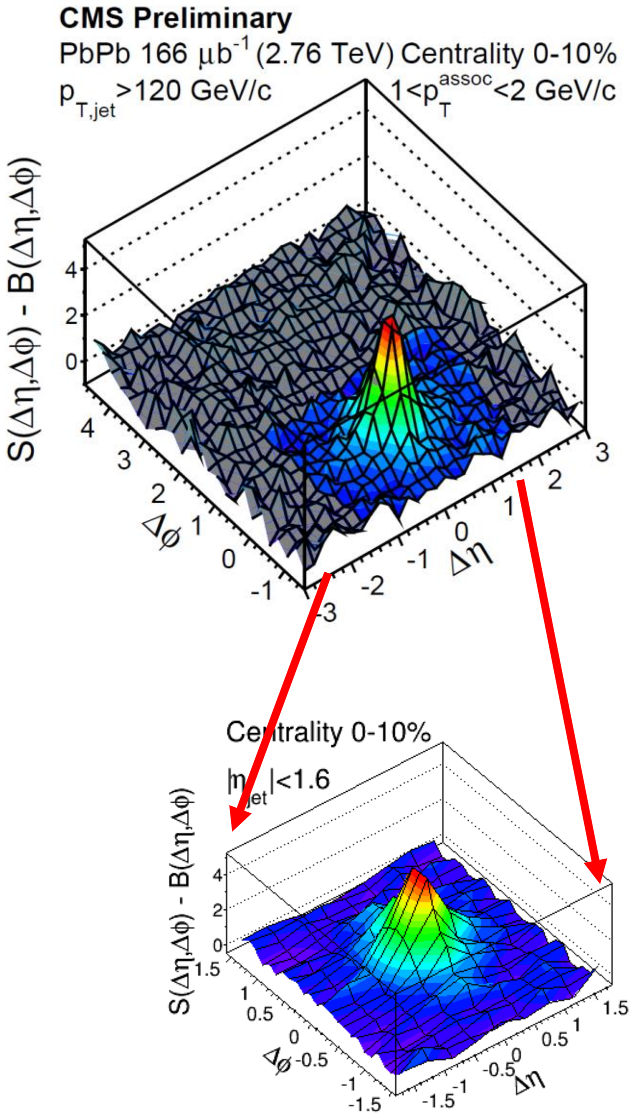
Fit a constant + the first 2 Fourier cosine terms and a Gaussian for the away side

$$B(\Delta\phi) = B_0\left(1 + 2V_1\cos(\Delta\phi) + 2V_2\cos(2\Delta\phi) + A_{AS}\exp\left(-\left(\frac{|\Delta\phi| - \pi}{\alpha}\right)^{\beta}\right)\right)$$

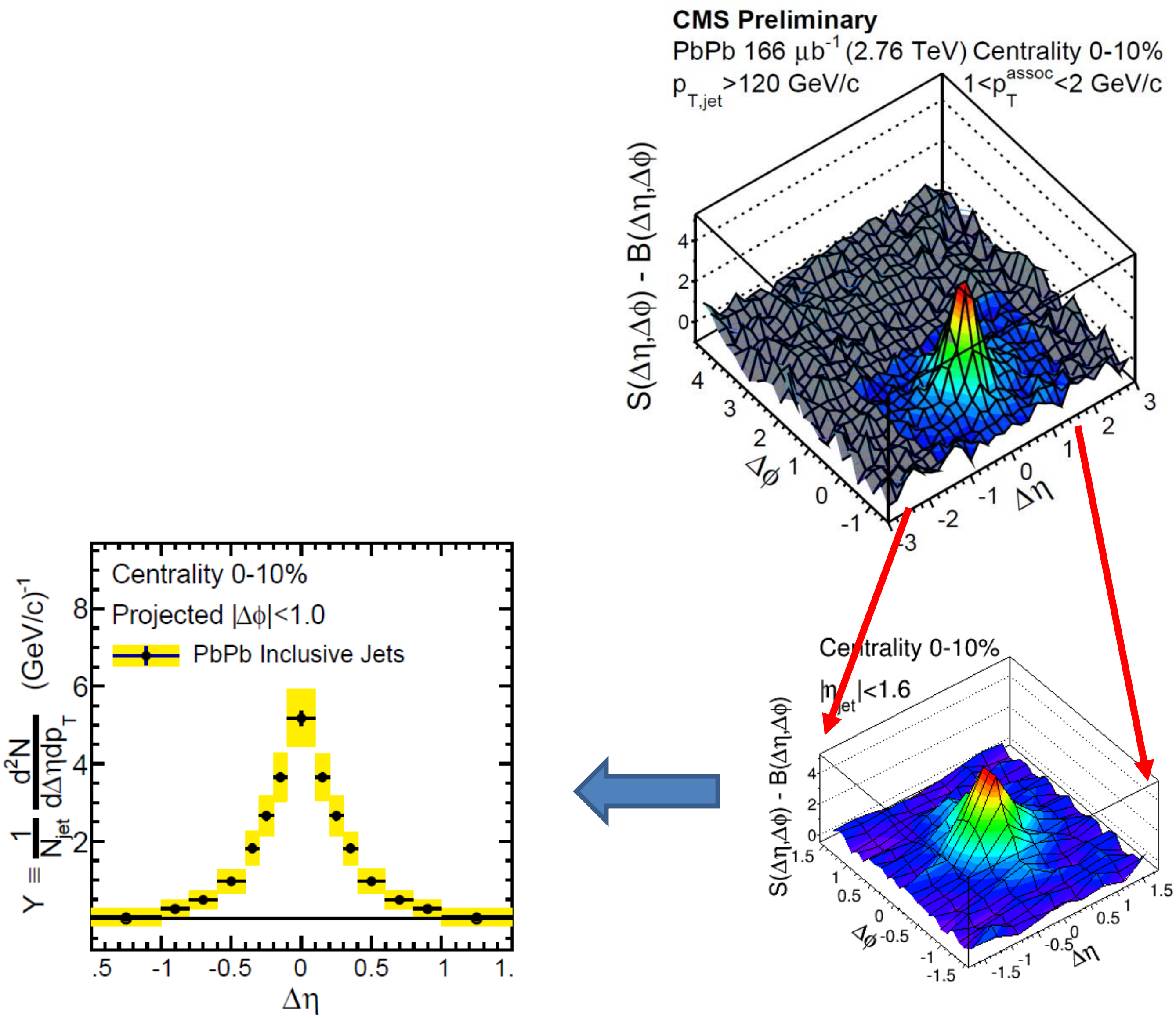
Subtract combinatorial and long range bkg



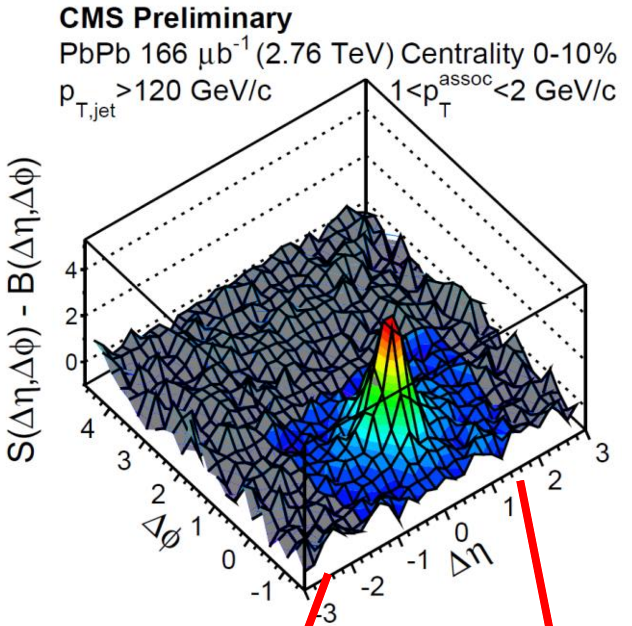
Zoom in on the jet peak after subtracting

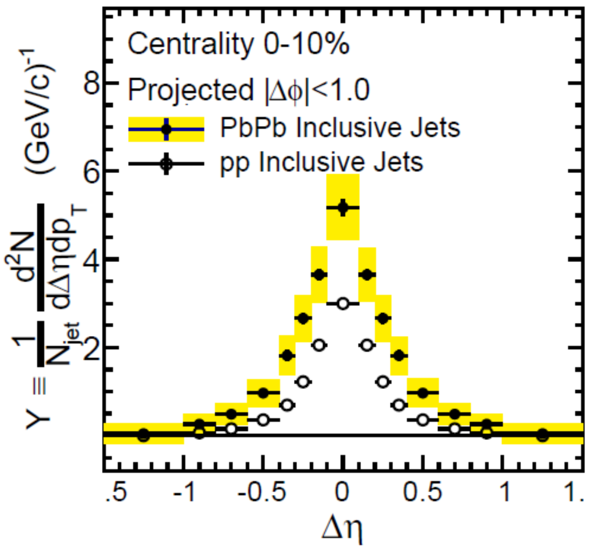


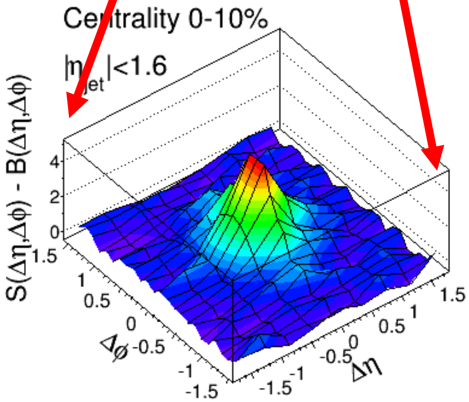
Project into Δη



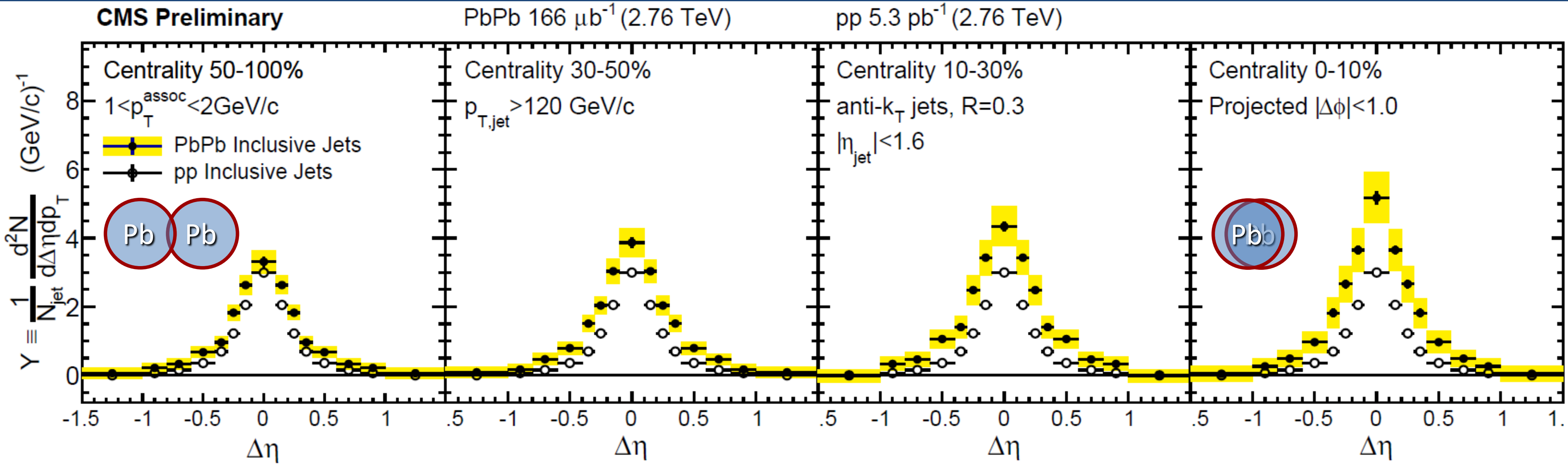
Repeat for pp



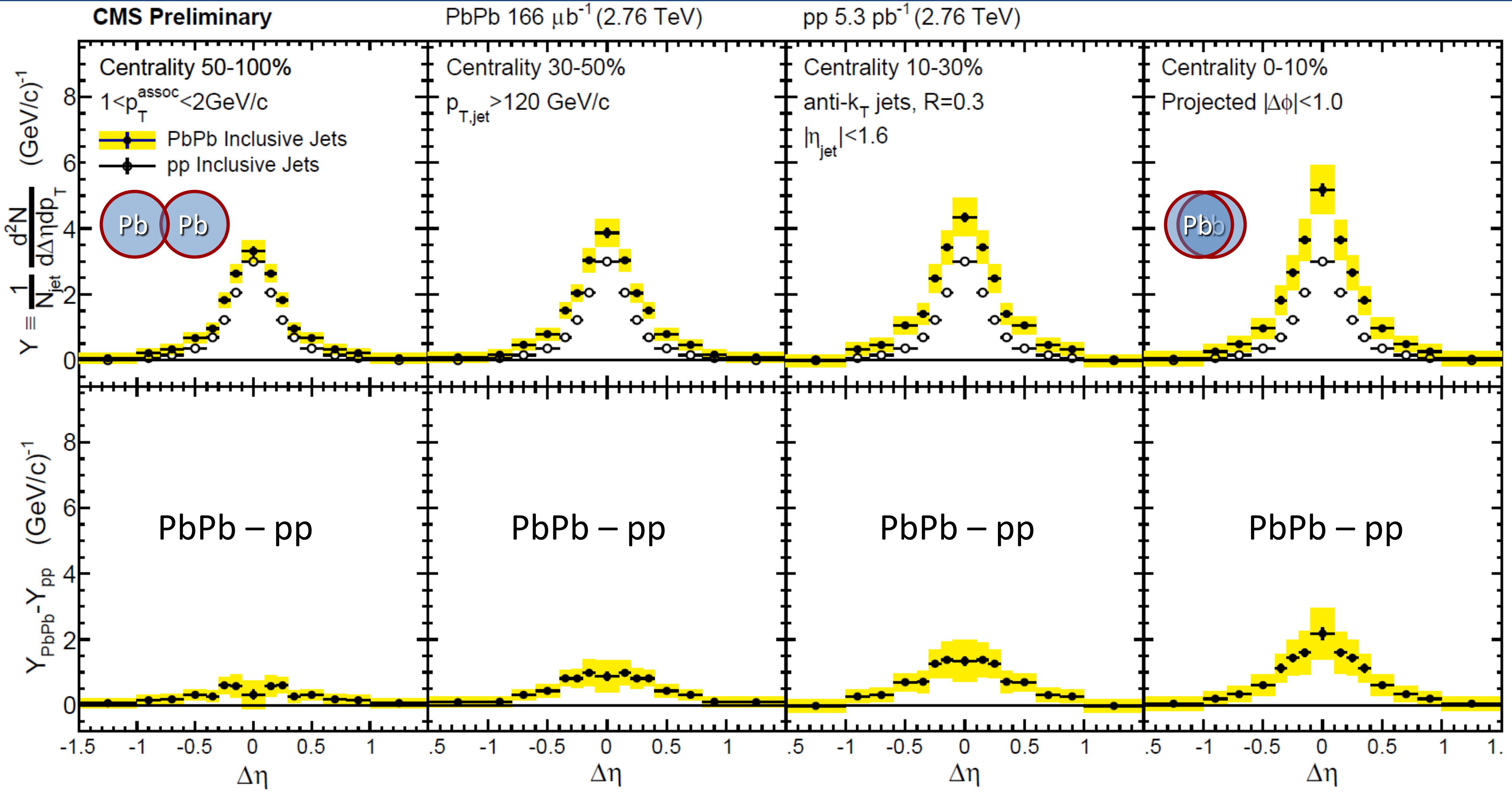




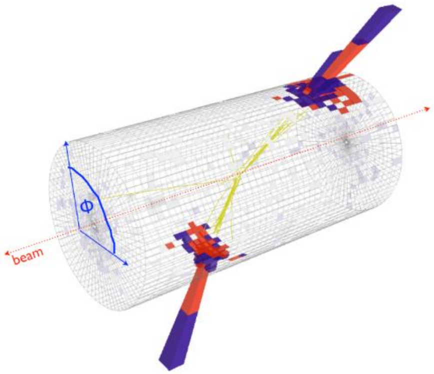
Δη versus Centrality



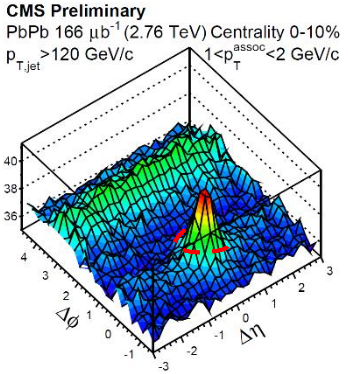
Subtract pp from PbPb



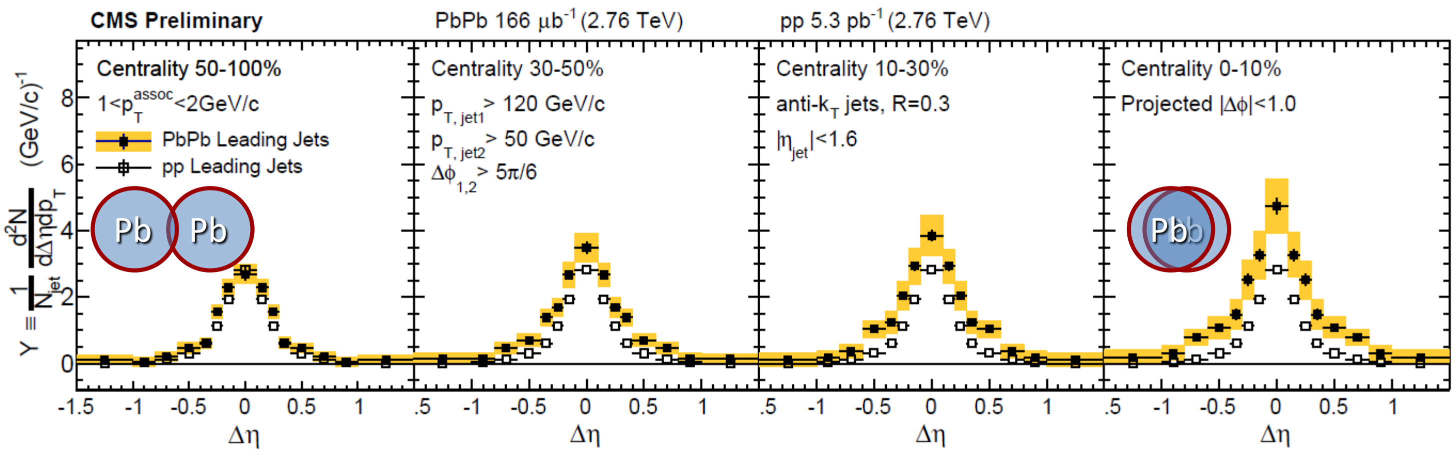
Leading vs Subleading



- Look at leading and subleading in dijet events
- Standard CMS HI dijet selection
  - Reconstruct all jets with $|\eta| < 2.0$
  - Leading and subleading reside $|\eta| < 1.6$
  - $|\text{dijet } \Delta\phi| > 5\pi/6$
  - Leading jet $p_T > 120$ GeV/c
  - Subleading jet $p_T > 50$ GeV/c

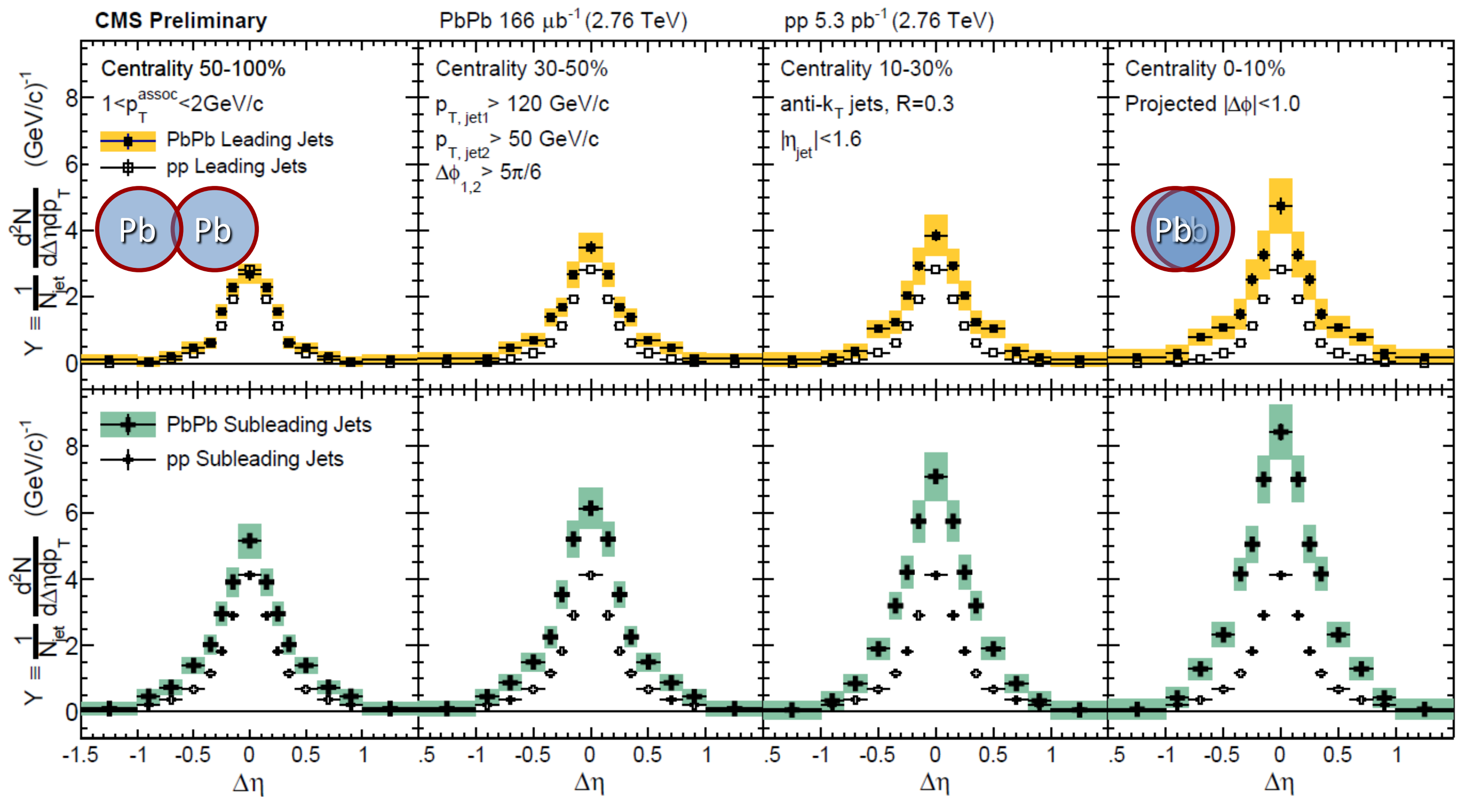


Vary centrality for Leading Jet



Leading

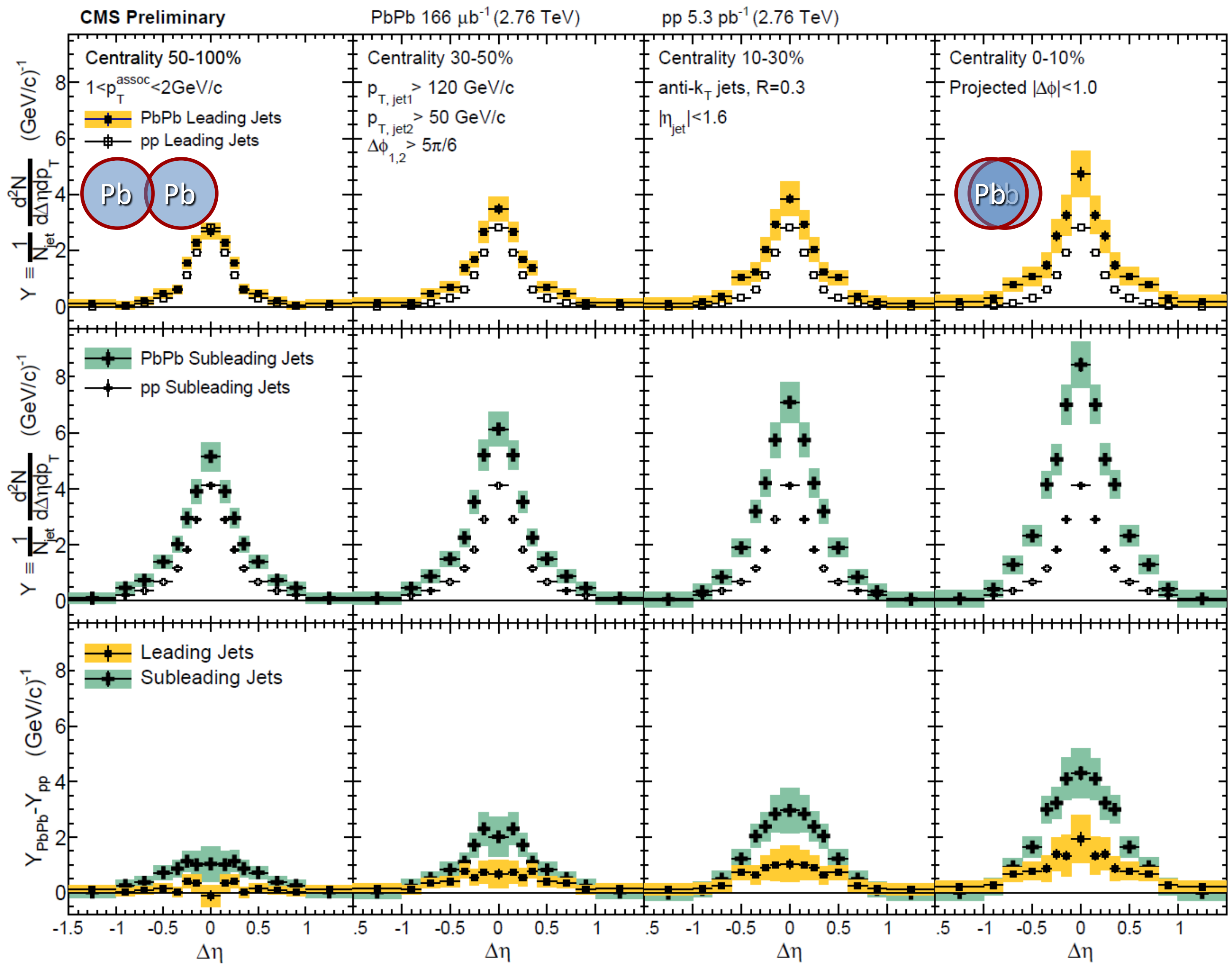
Vary centrality for Leading & Subl Jet



Leading

Subleading

Subtract pp from PbPb for Lead and Subl



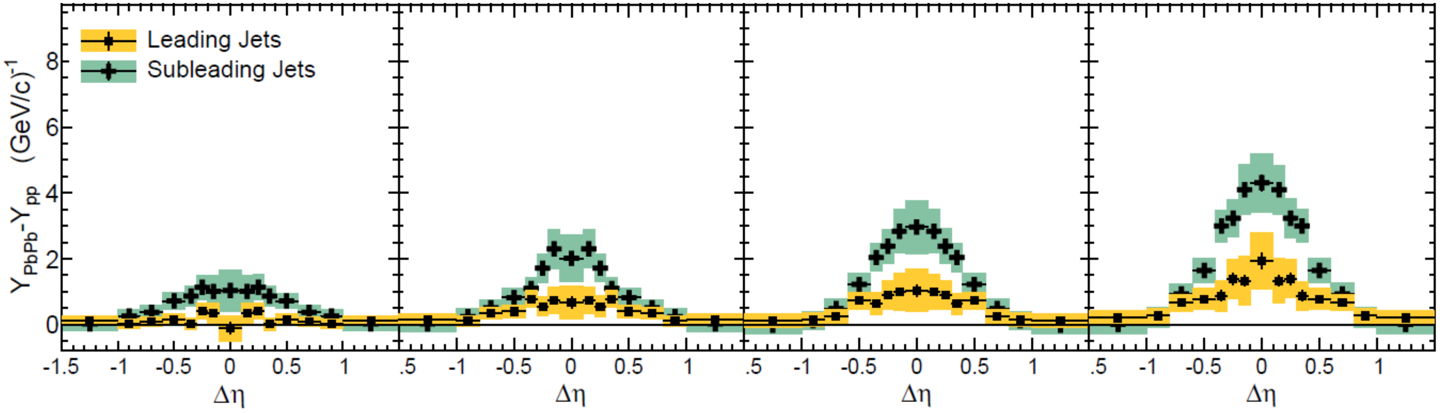
Leading

Subleading

PbPb – pp

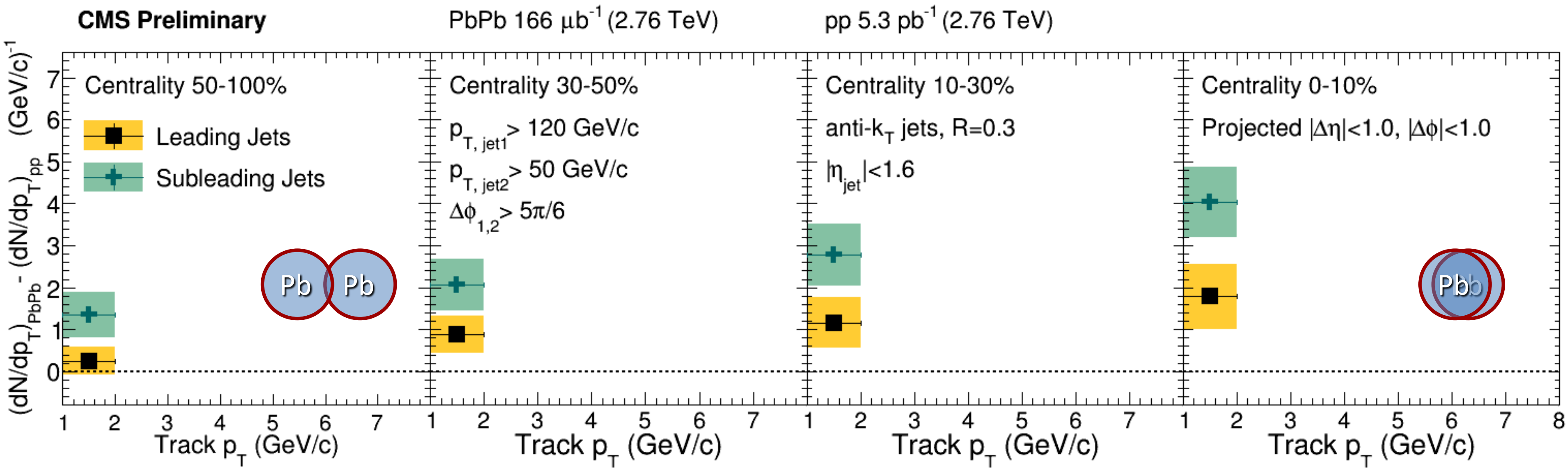
Yield in Leading vs Subleading Jets

Integrate to find excess yield



PbPb – pp

Yield in Leading vs Subleading Jets



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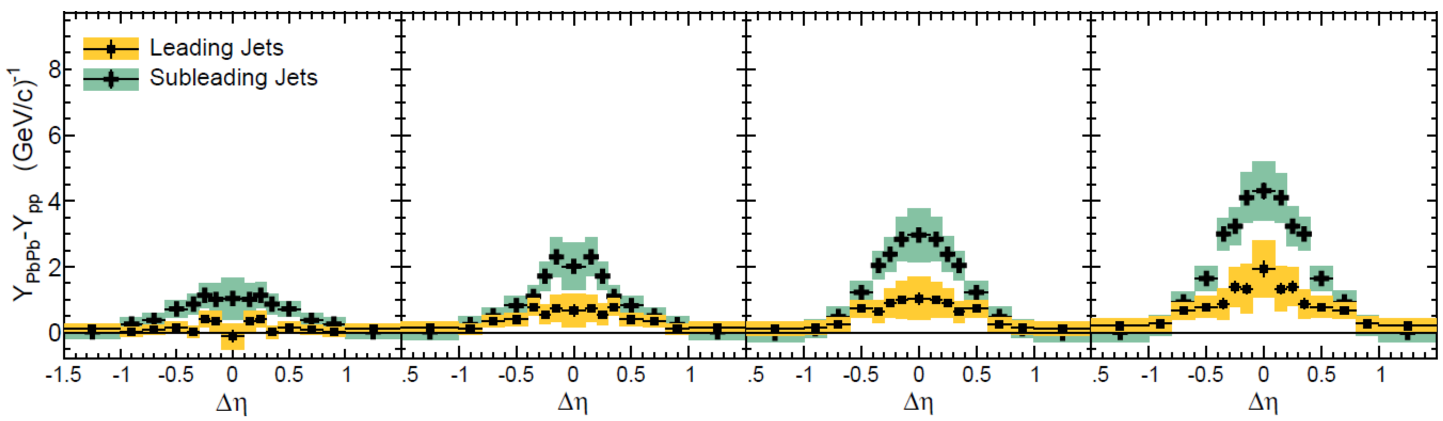
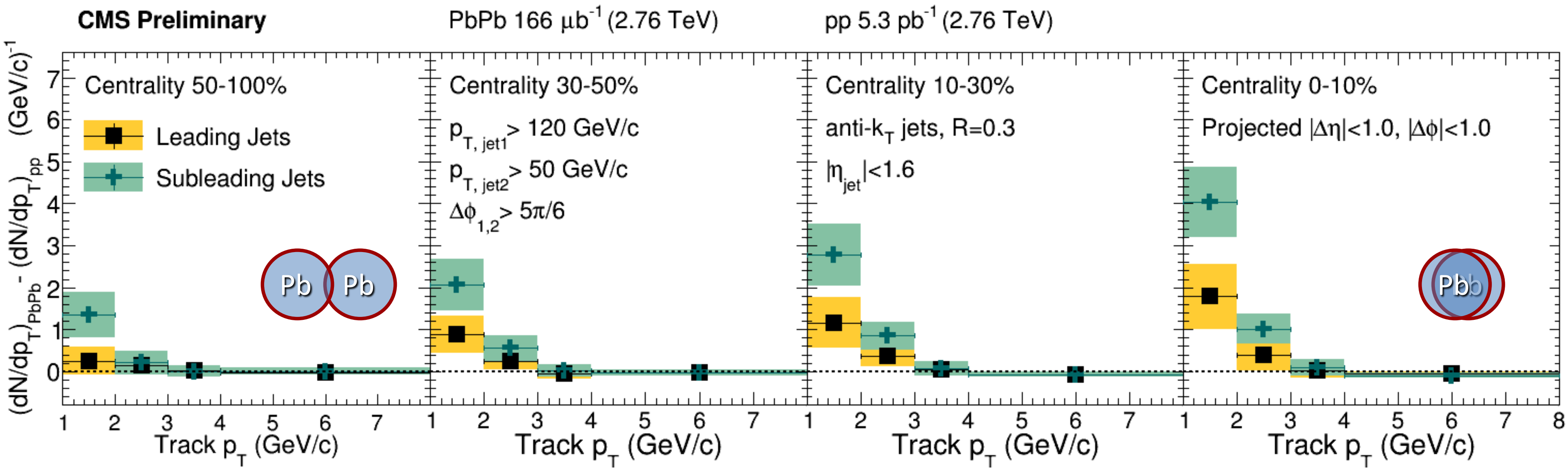


PbPb – pp

Yield in Leading vs Subleading Jets

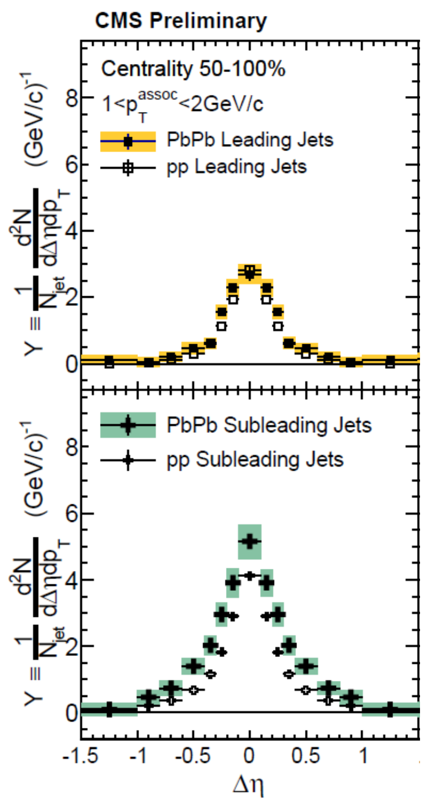


Vary associate track p_T :

- $1.0 > p_T > 2.0$ GeV/c
- $2.0 > p_T > 3.0$ GeV/c
- $3.0 > p_T > 4.0$ GeV/c
- $4.0 > p_T > 8.0$ GeV/c

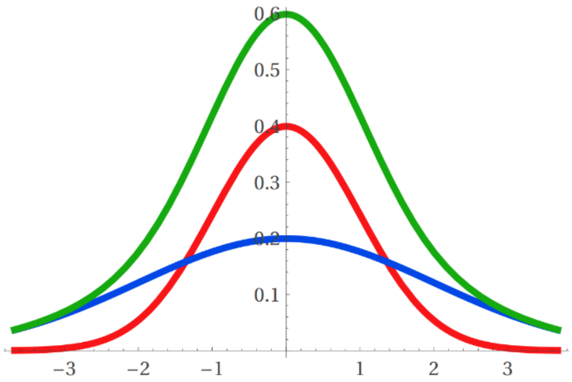
Less excess particles at higher p_T

Width of the Leading vs Subleading Jet



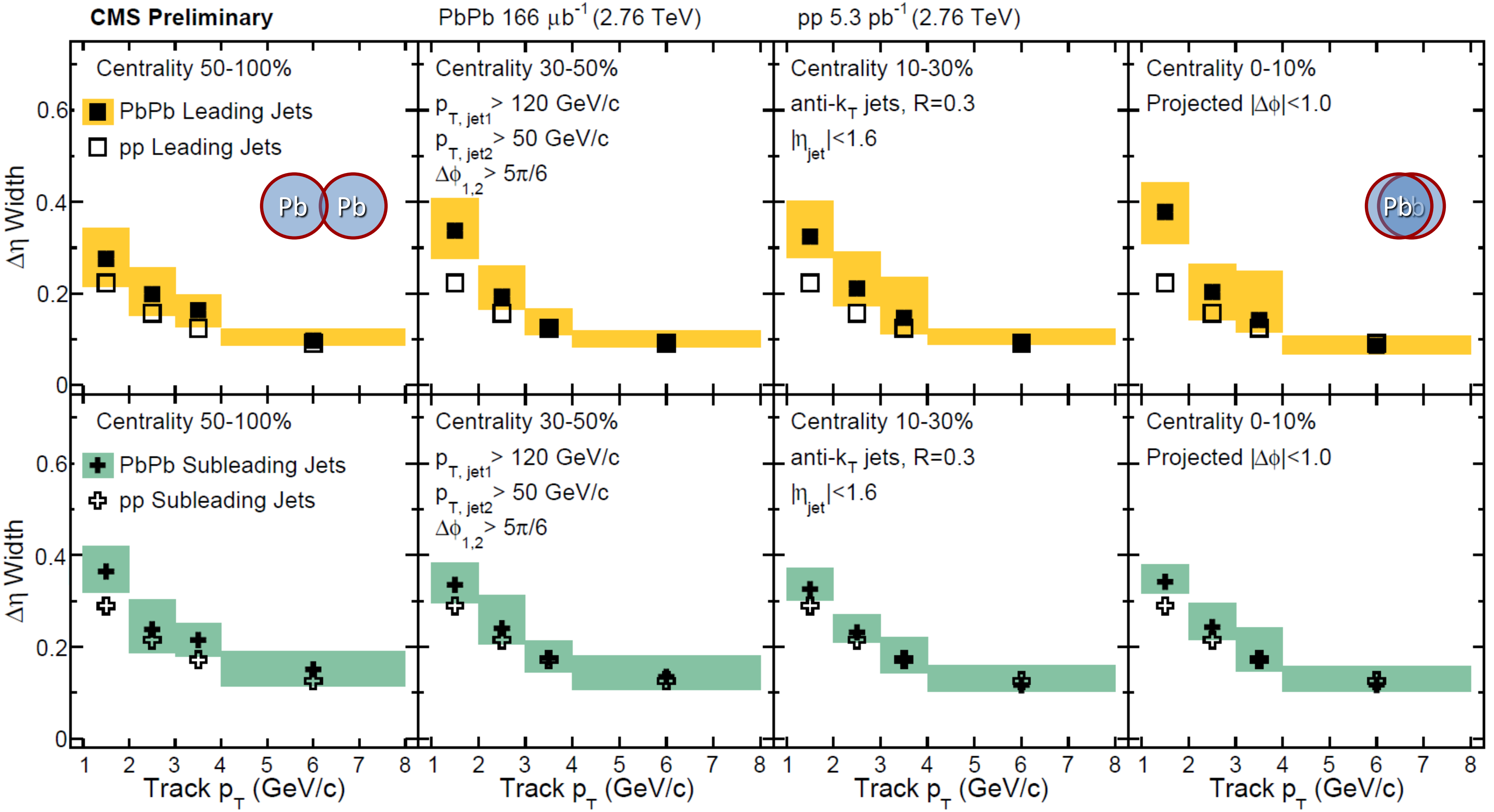
Fit the distribution with the sum of two Gaussians centered at zero

$$f(\Delta\eta) = a_1 \exp\left[\frac{-\Delta\eta^2}{2\sigma_1^2}\right] + a_2 \exp\left[\frac{-\Delta\eta^2}{2\sigma_2^2}\right]$$



Width ≡ |Δη| range that contains 67% of the total correlated yield

|Δη| Width Leading vs Subleading Jet

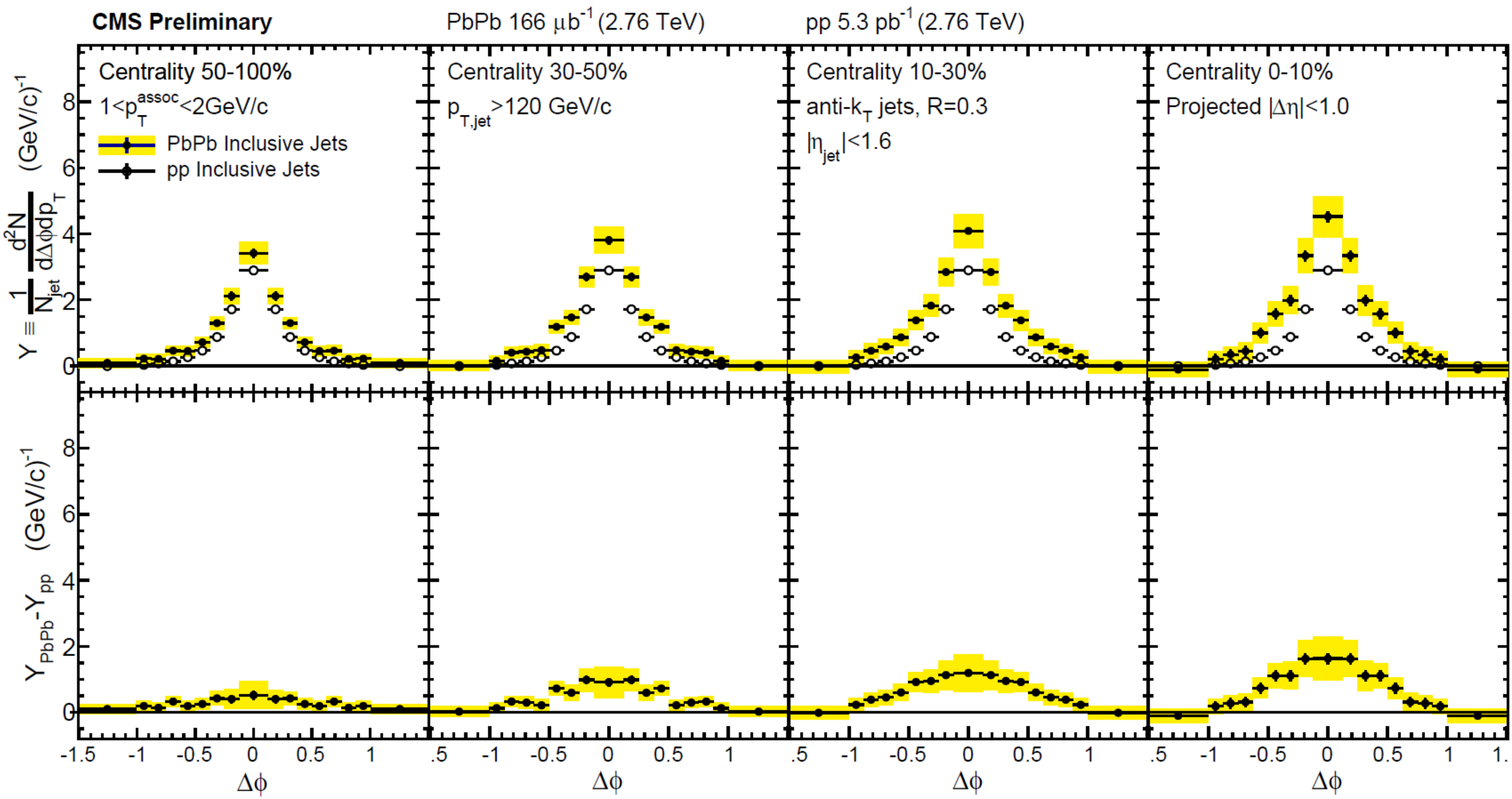


Summary

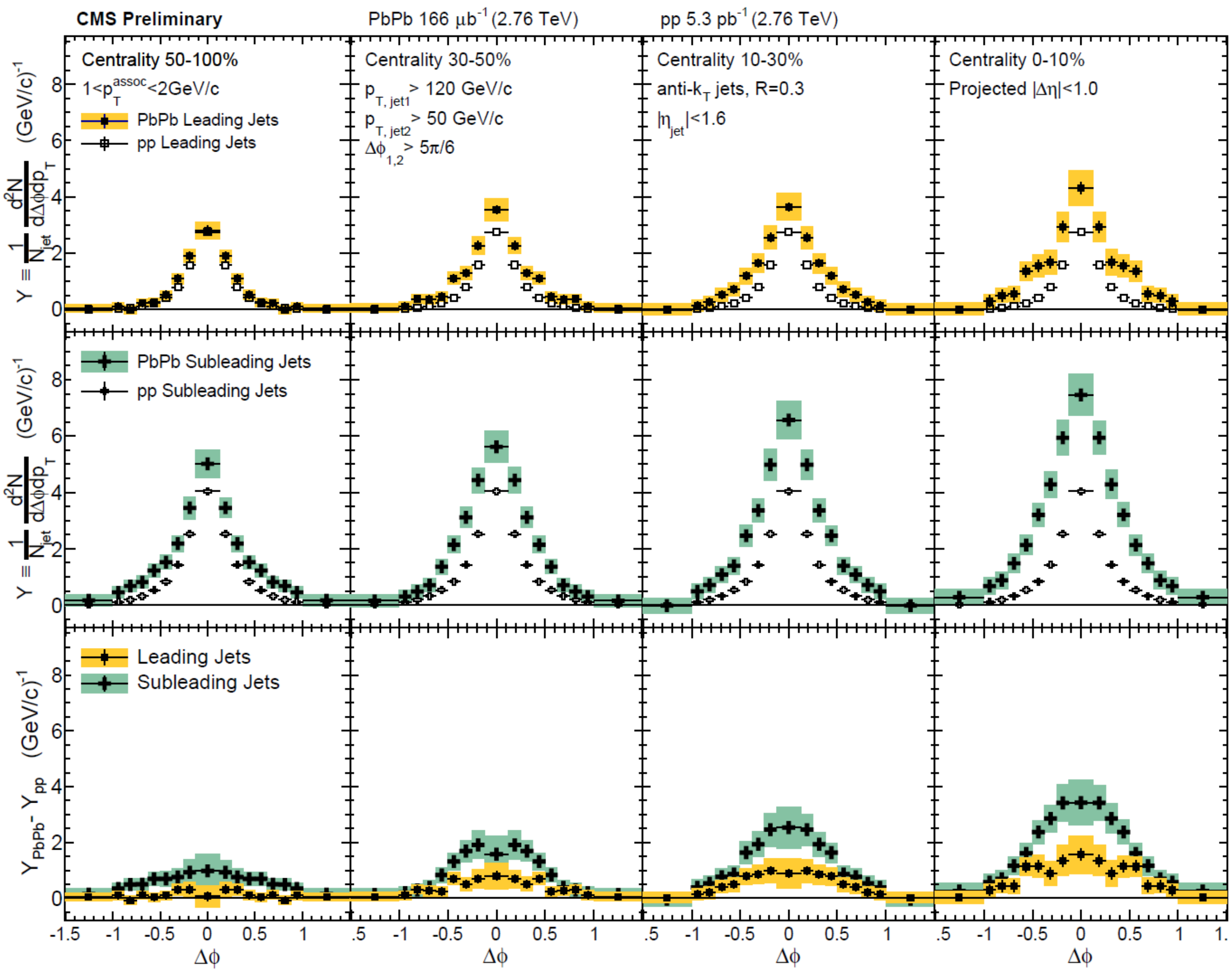
- Jet track correlations were measured for leading and subleading jets
- Inclusive jets are pp-like in peripheral collisions but have an excess yield in central collisions at low p_T
- Subleading jets have greater excess yield compared to pp than leading jets
- Leading and subleading jets in PbPb are broader for low track p_T compared to pp, effect goes away at high p_T, no strong centrality dependence

Backup

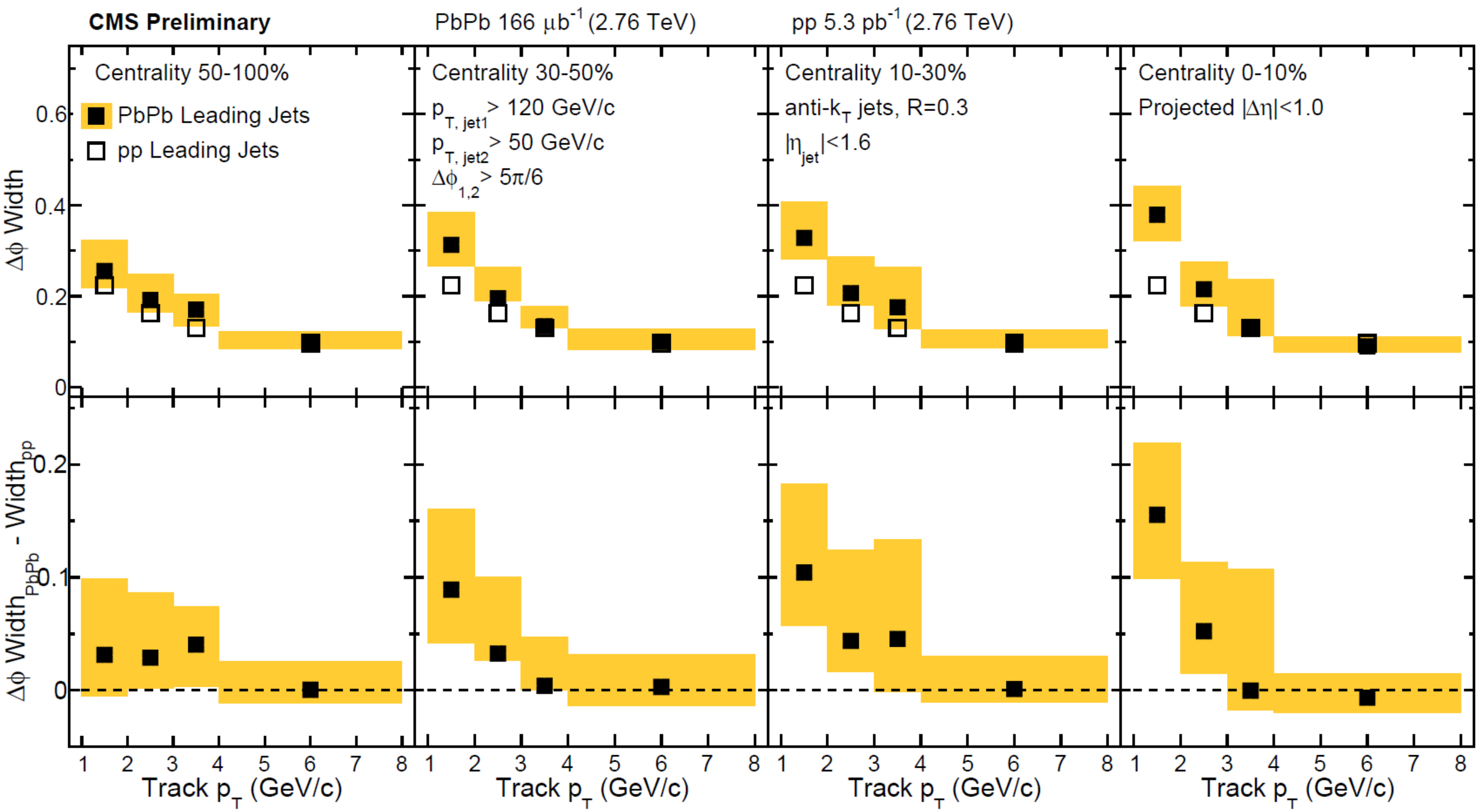
Vary Centrality |Δϕ|



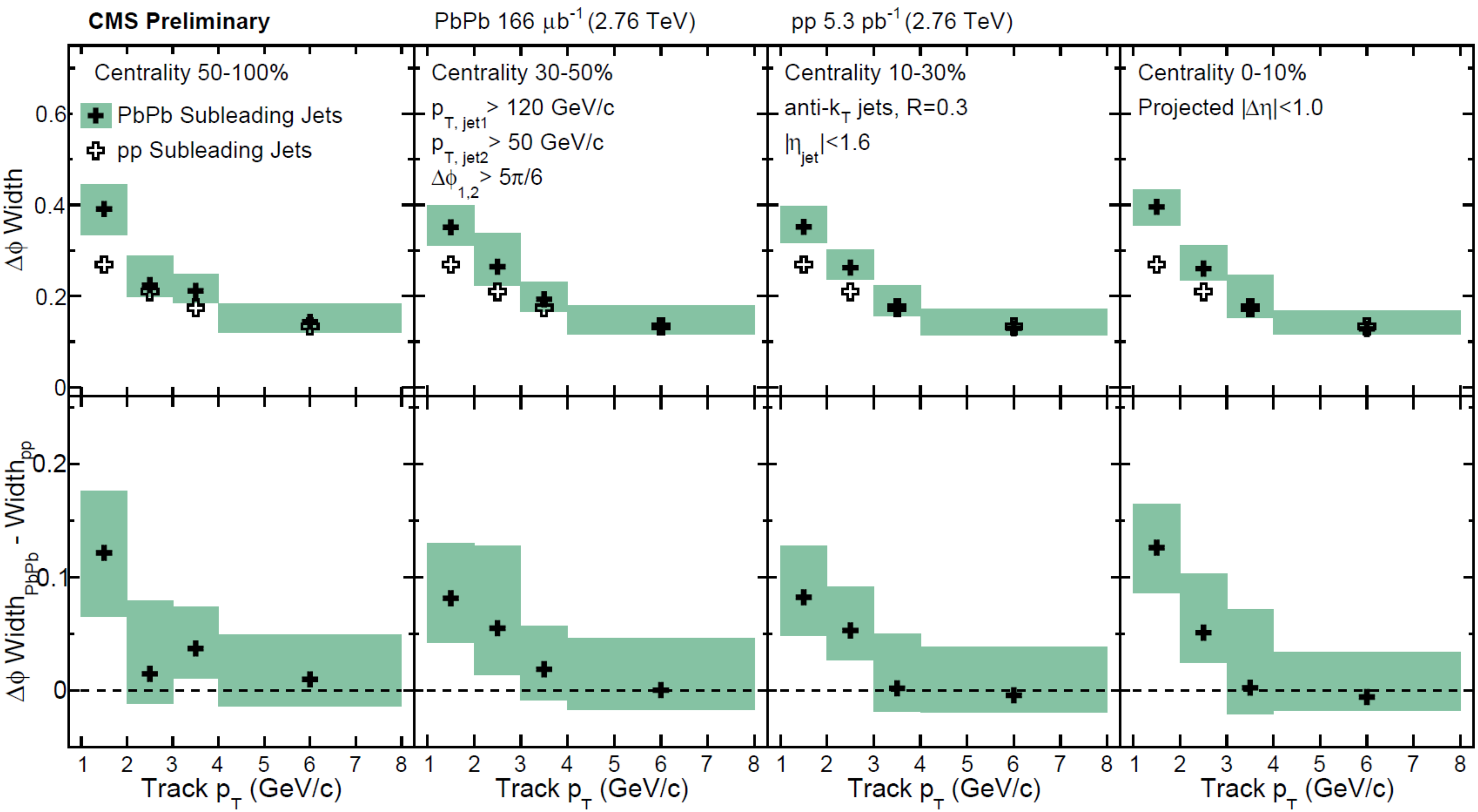
Vary Centrality Leading & Subleading |Δϕ|



Leading |Δφ| width

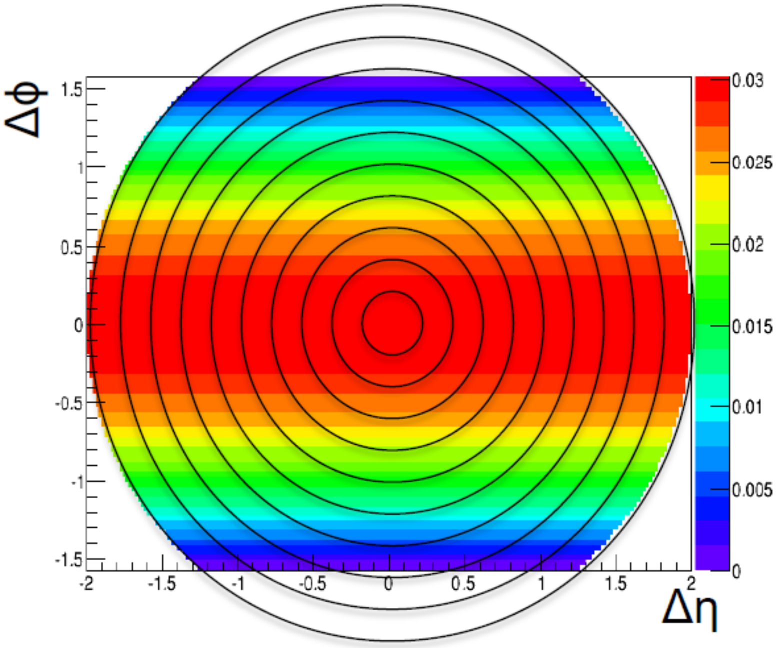


Subleading |Δϕ| width

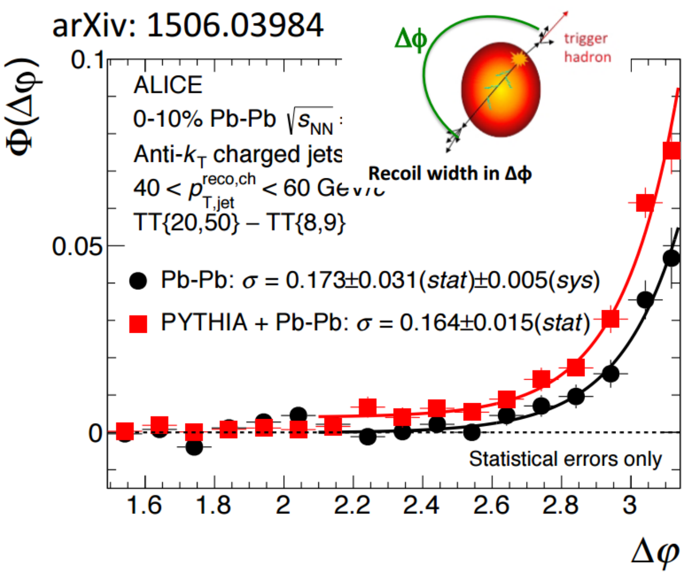


Missing p_T comparison

- Missing-pT analysis: projects all tracks onto average dijet axis, takes subleading minus leading hemispheres
- Jet-track analysis: could do the same from correlation—just weight by $p_T^{assoc}\cos(\Delta\phi)$
- **Cross-check shown perfect consistency between the two studies**
- Missing-p_T phase space:
  - Δη-Δϕ area integrated into each Δr bin (cartoon for illustration)
  - Last Δr bin shown is catch-all for Δr>1.8



ALICE Jet Broadening Statement



PLB 712 (2012) 176