Medium Recoils in JEWEL

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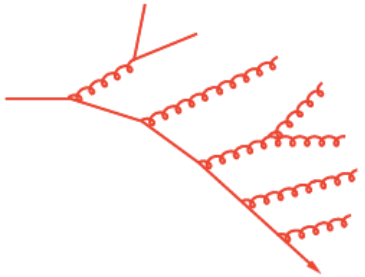
In Collaboration with Dr. Korinna Zapp (CERN)

What is JEWEL?

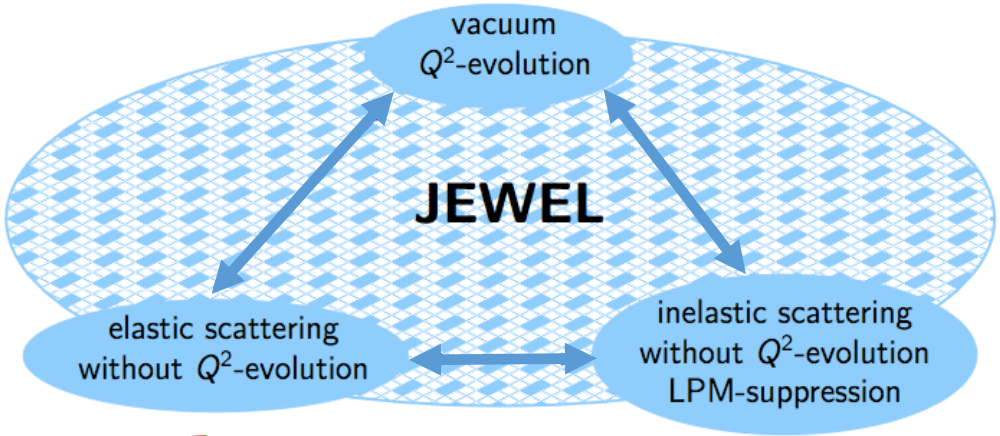
Korinna Zapp, EPJ C, Volume 74, Issue 2, 2014

- MC with in-medium jet energy loss implementation



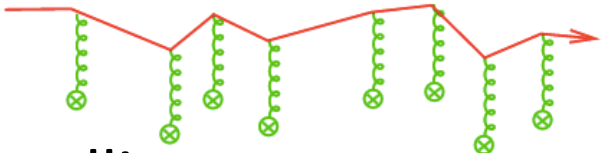
- NEW! Description of boson recoiling of jet ($\gamma, Z^0, W^{\pm}$ + jet)

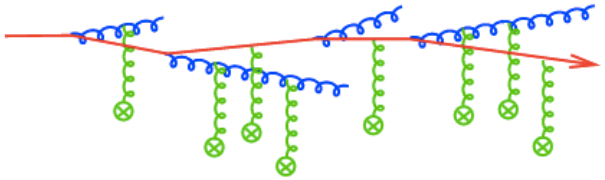
- Jet interacts with collection of quasi-free partons



- Consistent with all analytically known limiting cases

- LPM effect for collinear gluon splitting





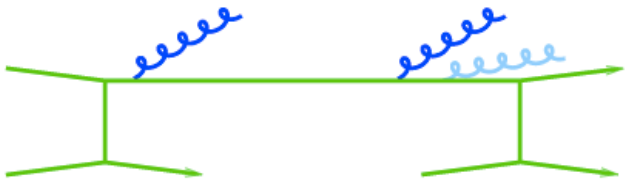
These are very good talks on JEWEL and its finer workings. Pictures taken from there. KZapp Talk1, Talk2,

Radiation in JEWEL

- Virtuality ordered parton shower
- Formation time for every gluon emitted

$$\tau \approx \frac{E}{Q^2} \approx \frac{2\omega}{k_\perp^2}$$

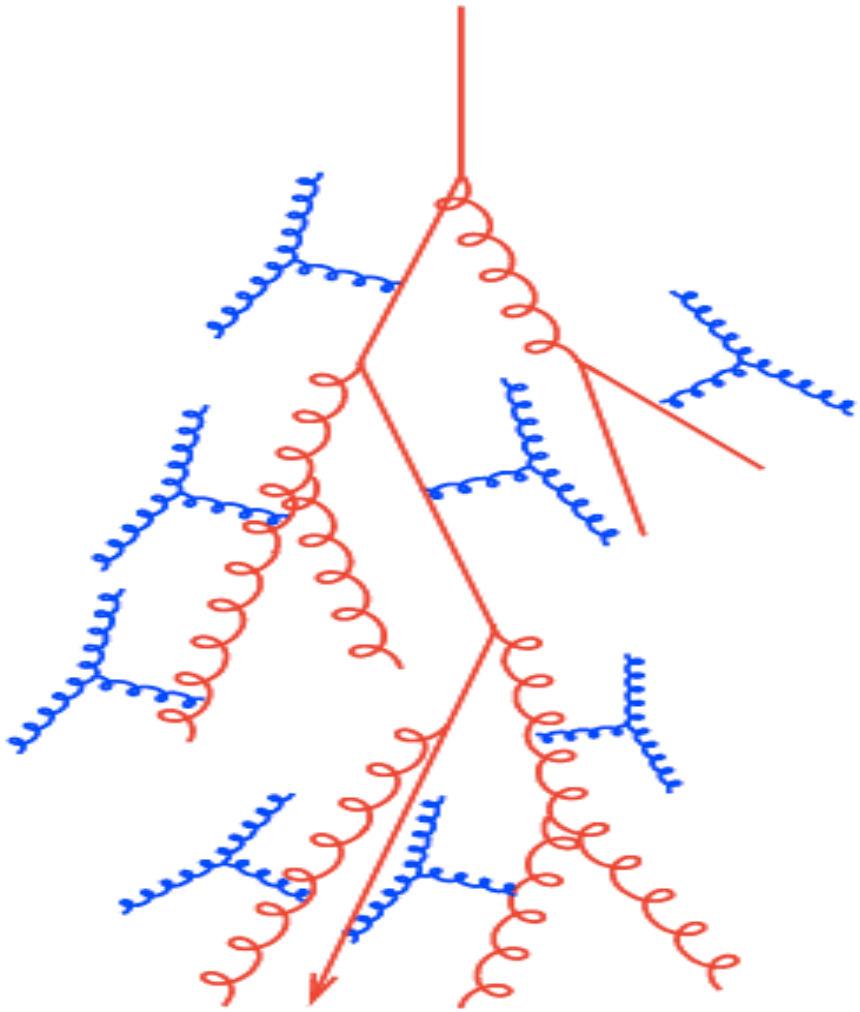
- In case of competing time, the shorter time one gets realized



- Elastic/inelastic scattering from the scattering centers
- At most one emission from ISR for medium scattering

Algorithm in MC

1. create gluon in inelastic process
2. check if scattering during t_f
3. If no gluon is formed
   - Back to 1
4. If yes: scattering after time $\Delta t < t_f$, re-evaluate formation time and back to 2



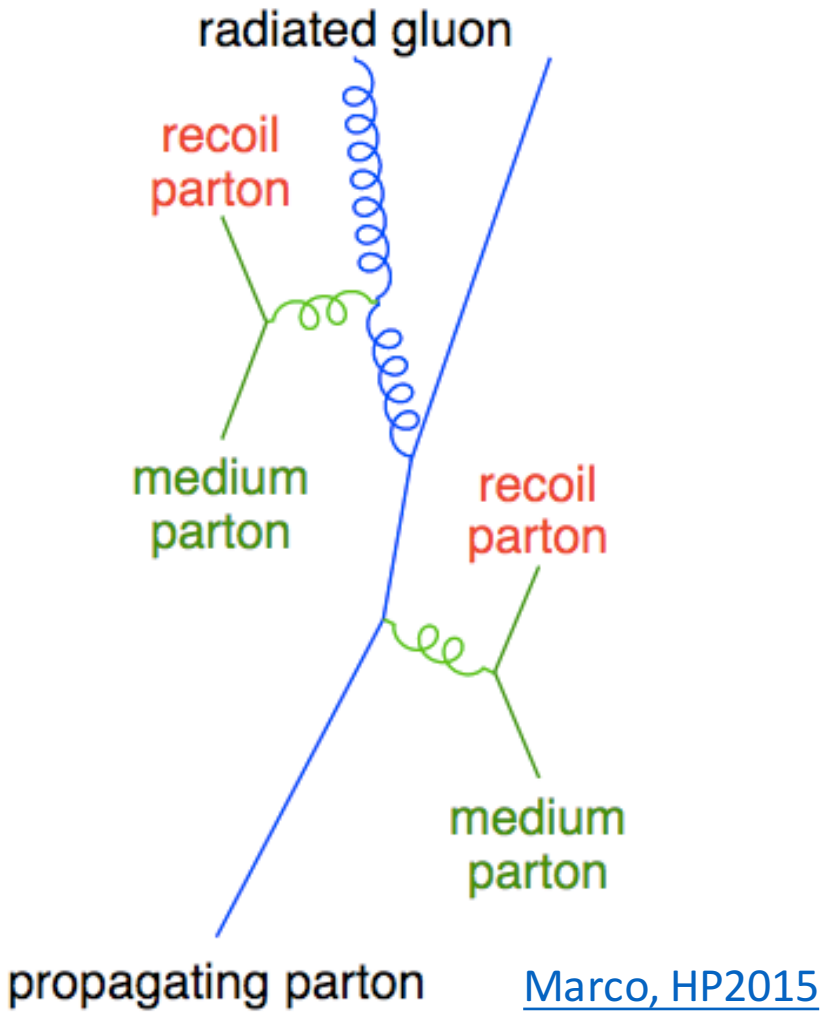
1212.1599

Treatment of Recoils

- Scattering centers realized from the interaction of the high energy parton propagating through the medium
- w/ Recoils, as soon as interaction happens and a gluon is emitted, it is stored in the event record.

1212.1599

Scattering centers drawn from a thermal distribution

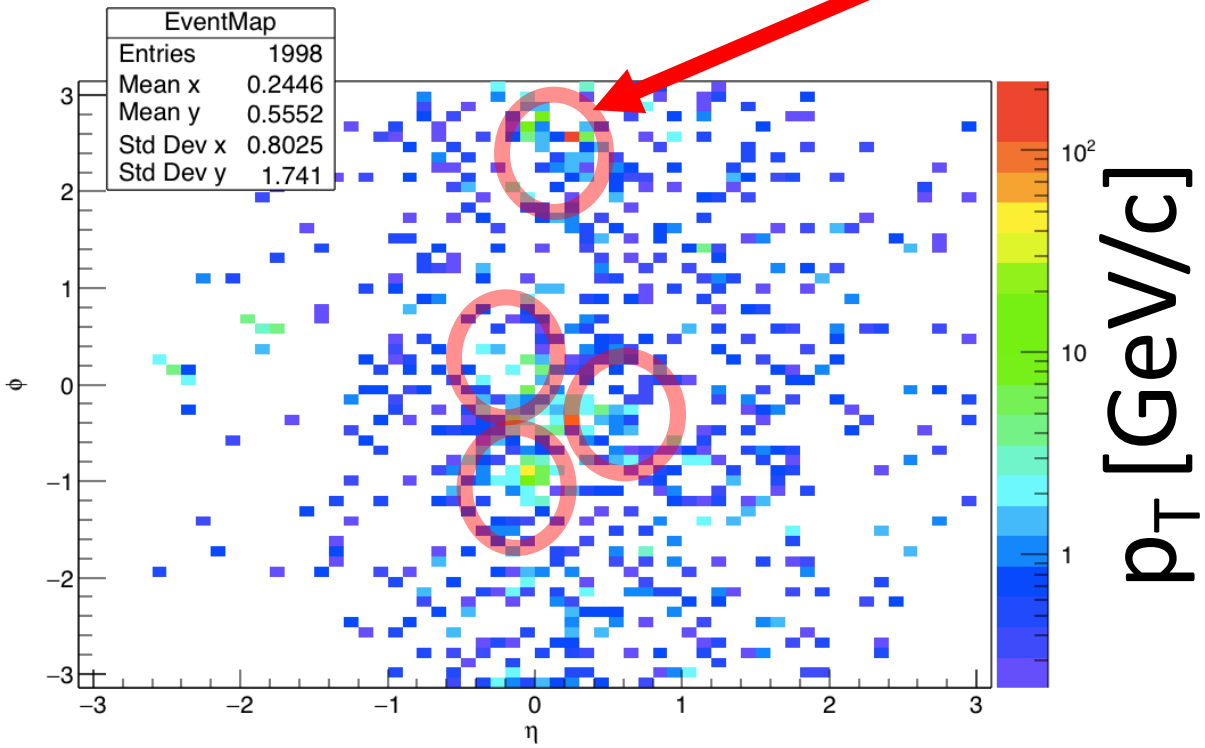


Marco, HP2015

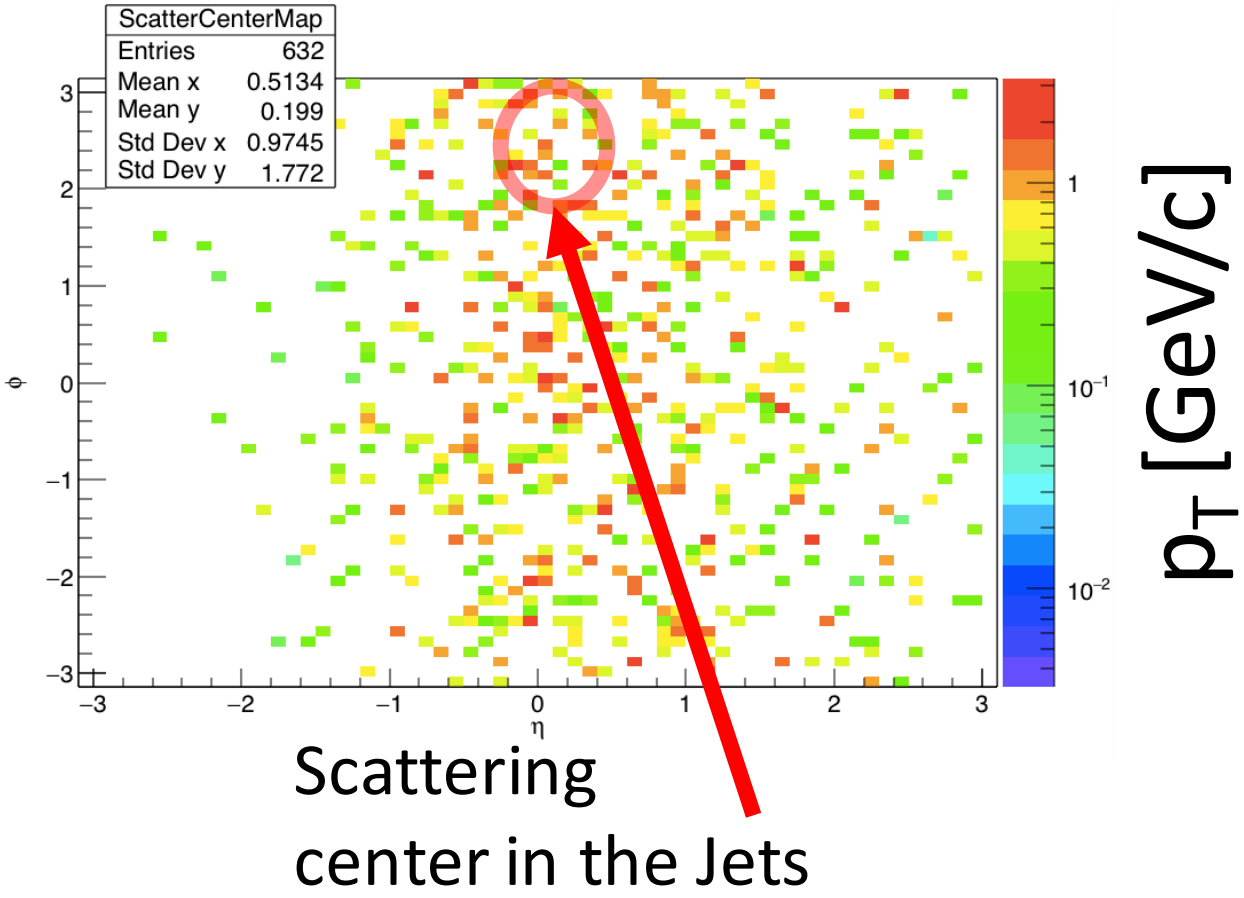
Using the scattering centers

NEW version of JEWEL!!
Will be public soon!

- Event Map

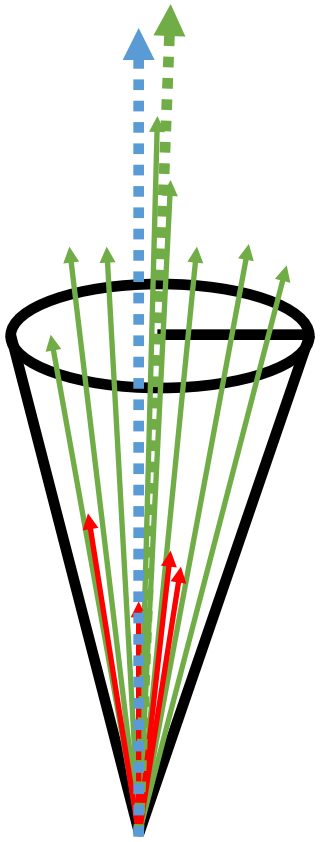


- Scattering centers Map



Background subtraction in JEWEL (two choices)

REAL (4MomSub)

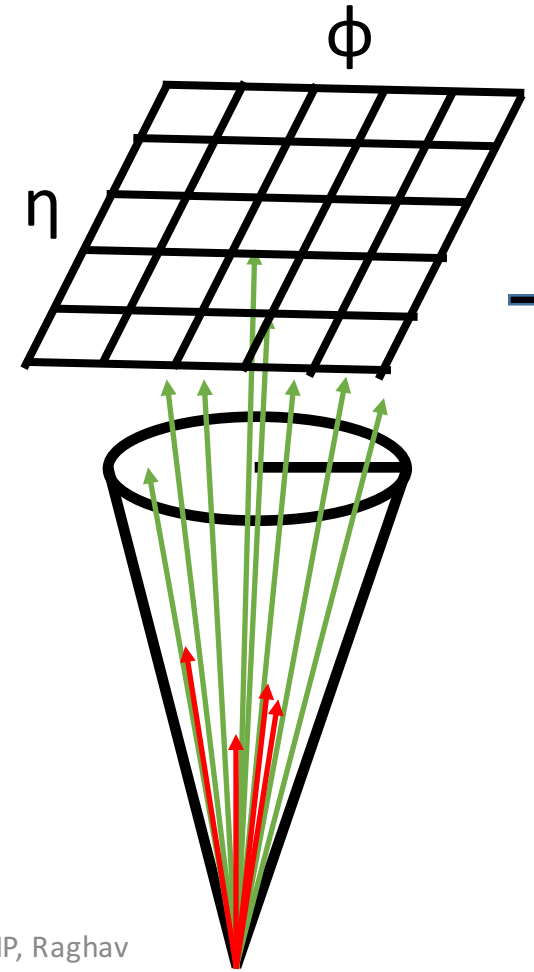


$$p^{\text{4MomSub}} = p^{\text{constituents}} - p^{\text{ScatCenter}}$$

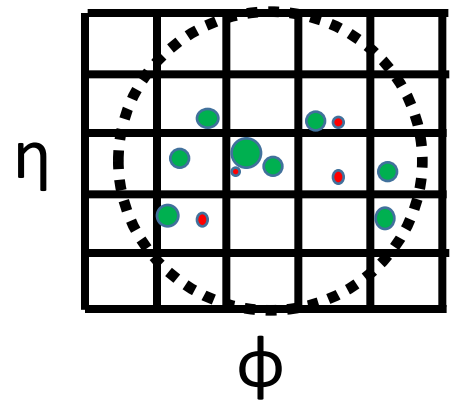
4vector manipulation

RKE, Korinna Zapp, Work in progress

DETECTOR-LIKE (GridSub)



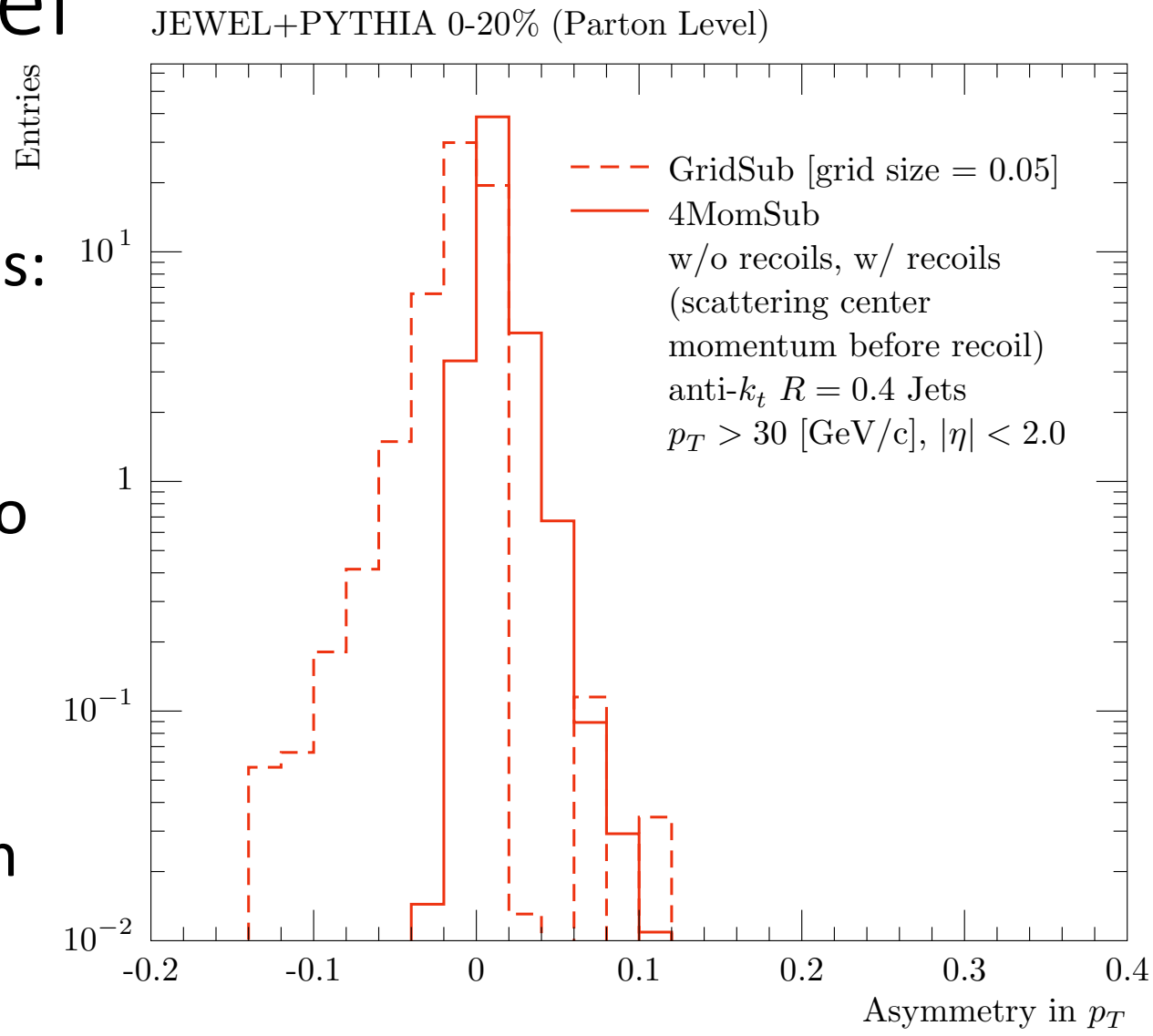
1. 4vector sum inside each box
2. Clustering with boxes as input



Systematic studies of the background subtraction

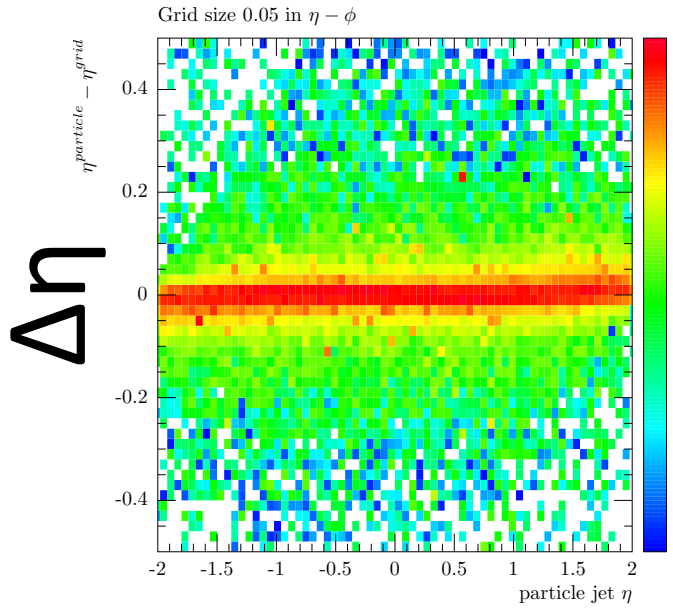
Recreating without recoils: jets at the parton level

- Scattering centers carry momentum from two sources:
  - Thermal distribution
  - Recoils
- Recreate (at parton level) w/o recoils jet p_T by removing its recoil momenta
- Asymmetry in jet p_T at parton level →



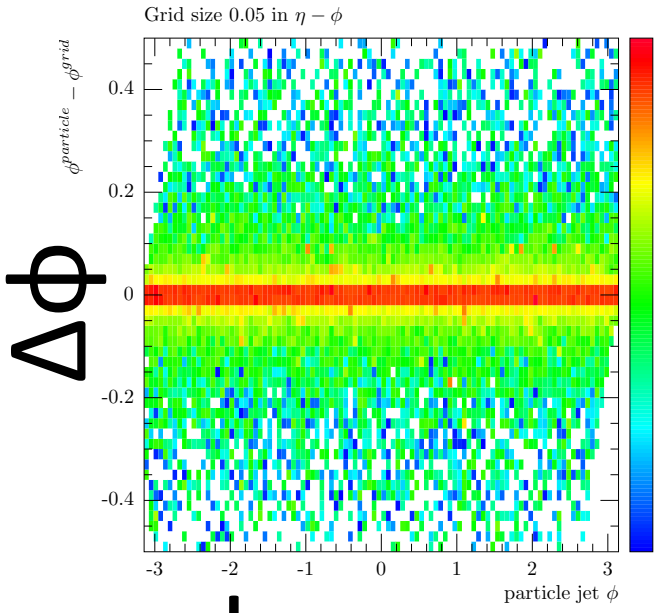
Smearing due to the grid

- For JEWEL w/o any recoils (no need of any background subtraction), the grid smeares the jet



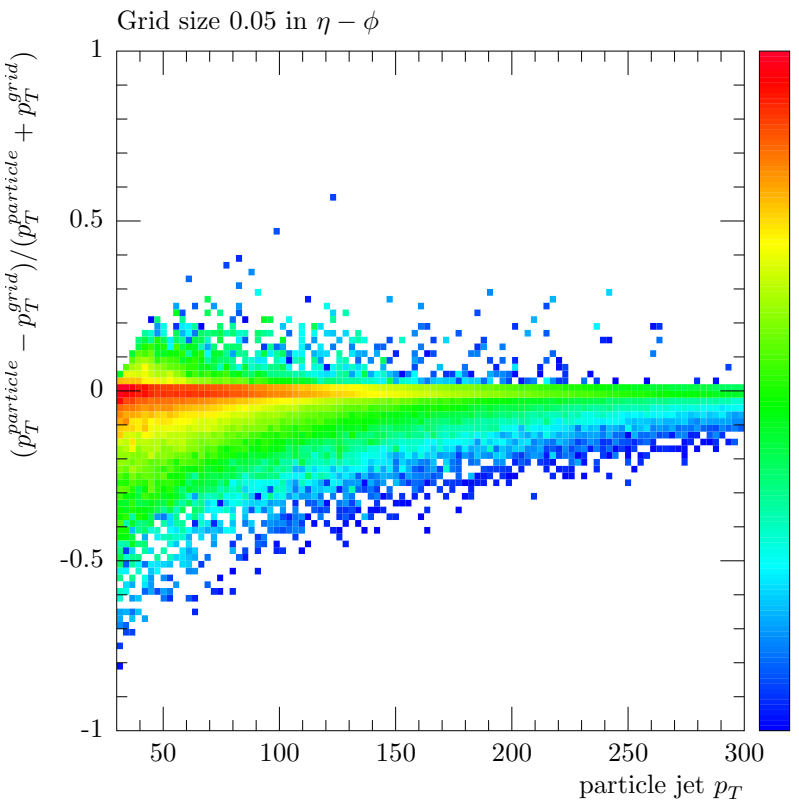
$\Delta\eta$

$\eta_{particle\ jet}$



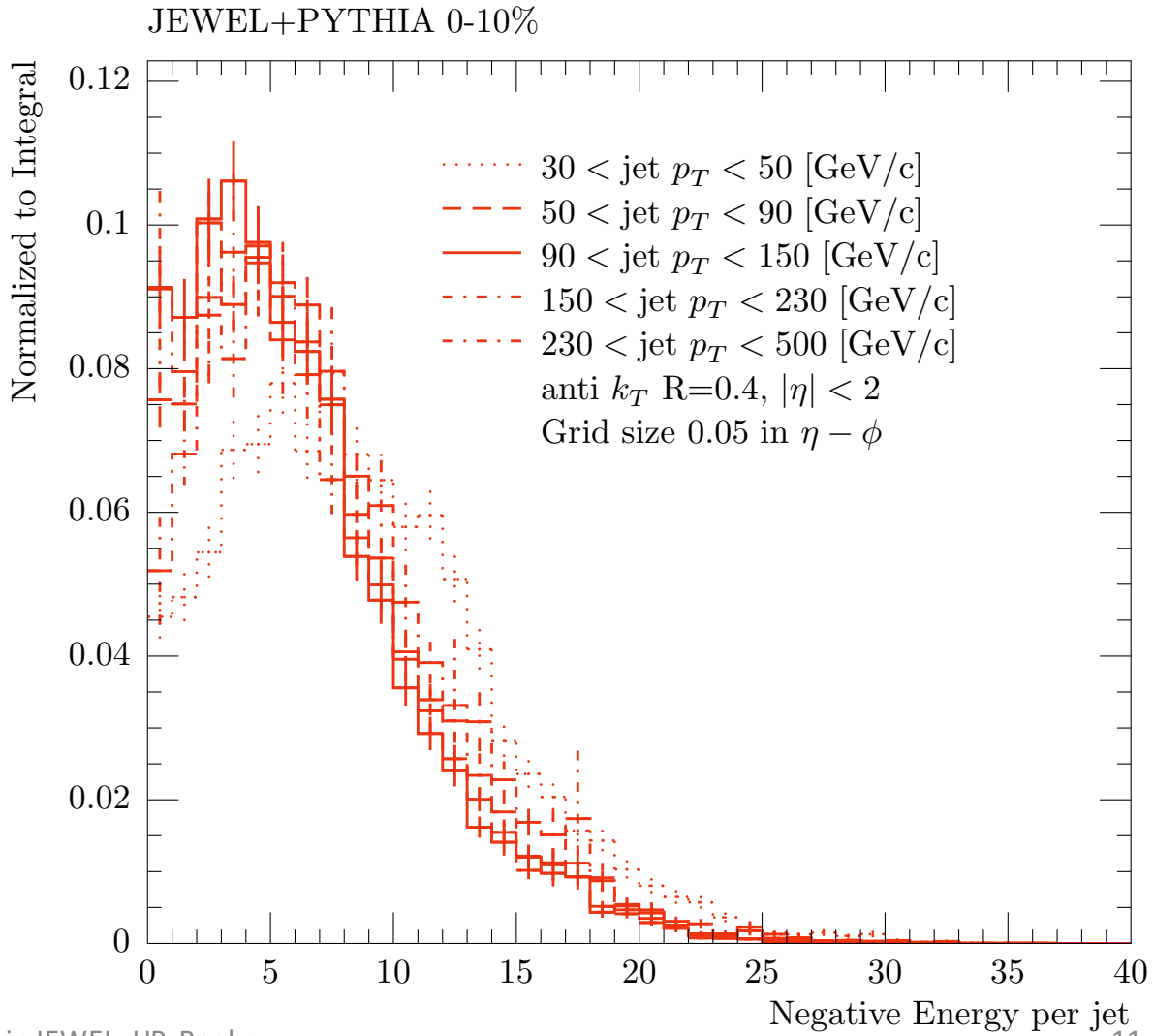
$\Delta\phi$

$\phi_{particle\ jet}$



Negative energy per jet due to the grid

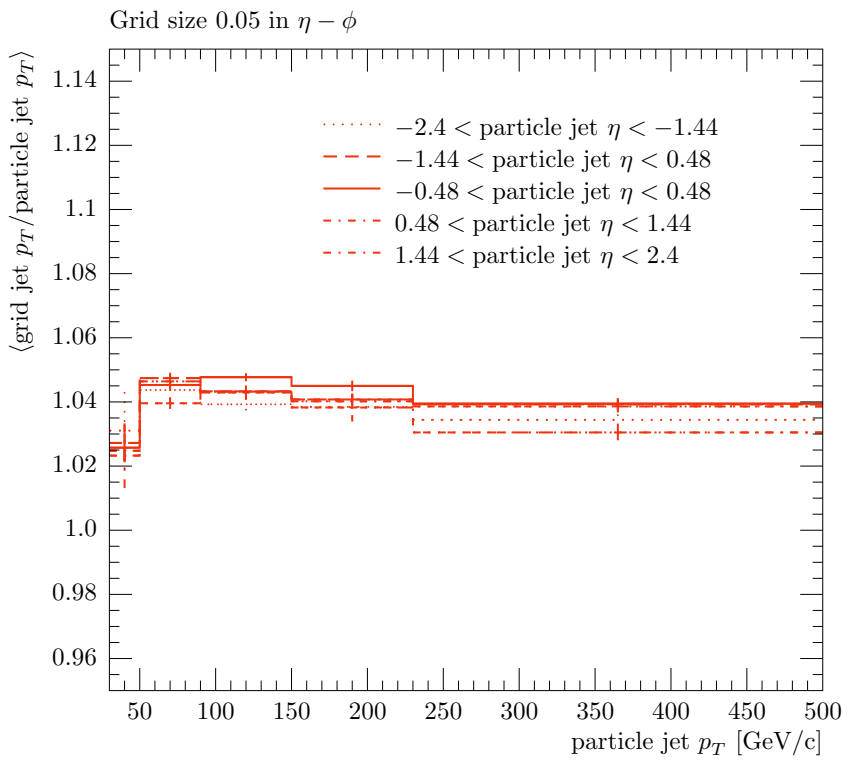
- Quantify the amount of energy not subtracted in a jet
- Expected behavior across the different grid sizes
- Contribution is quite small

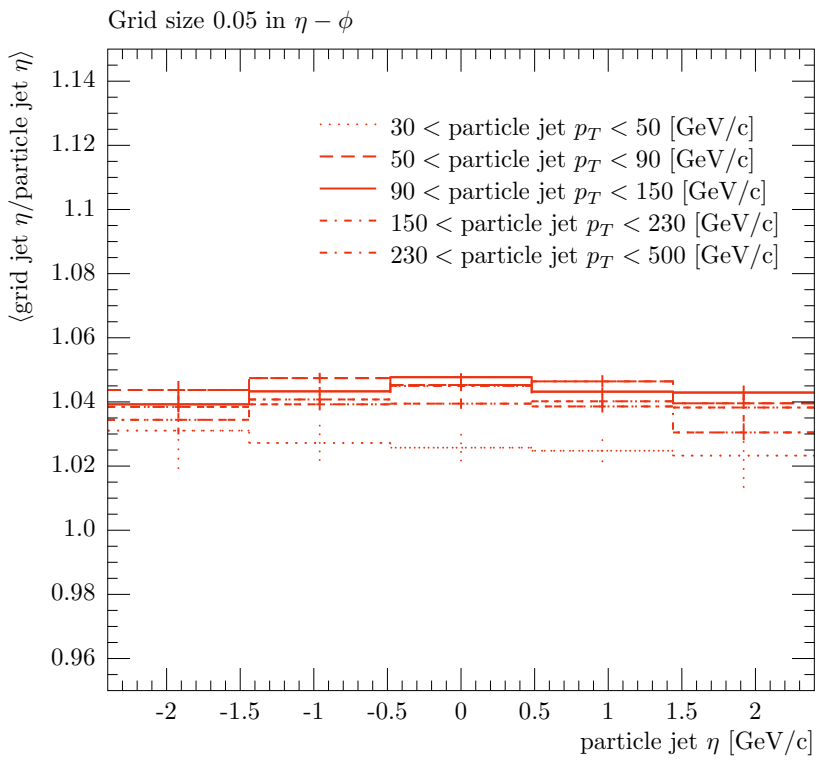


Jet Energy Closure

- particle jet p_T

particle jet η





- 3—5% closure (decent level and flat across jet eta)
- This is due to the grid, hence happens in both pp and PbPb

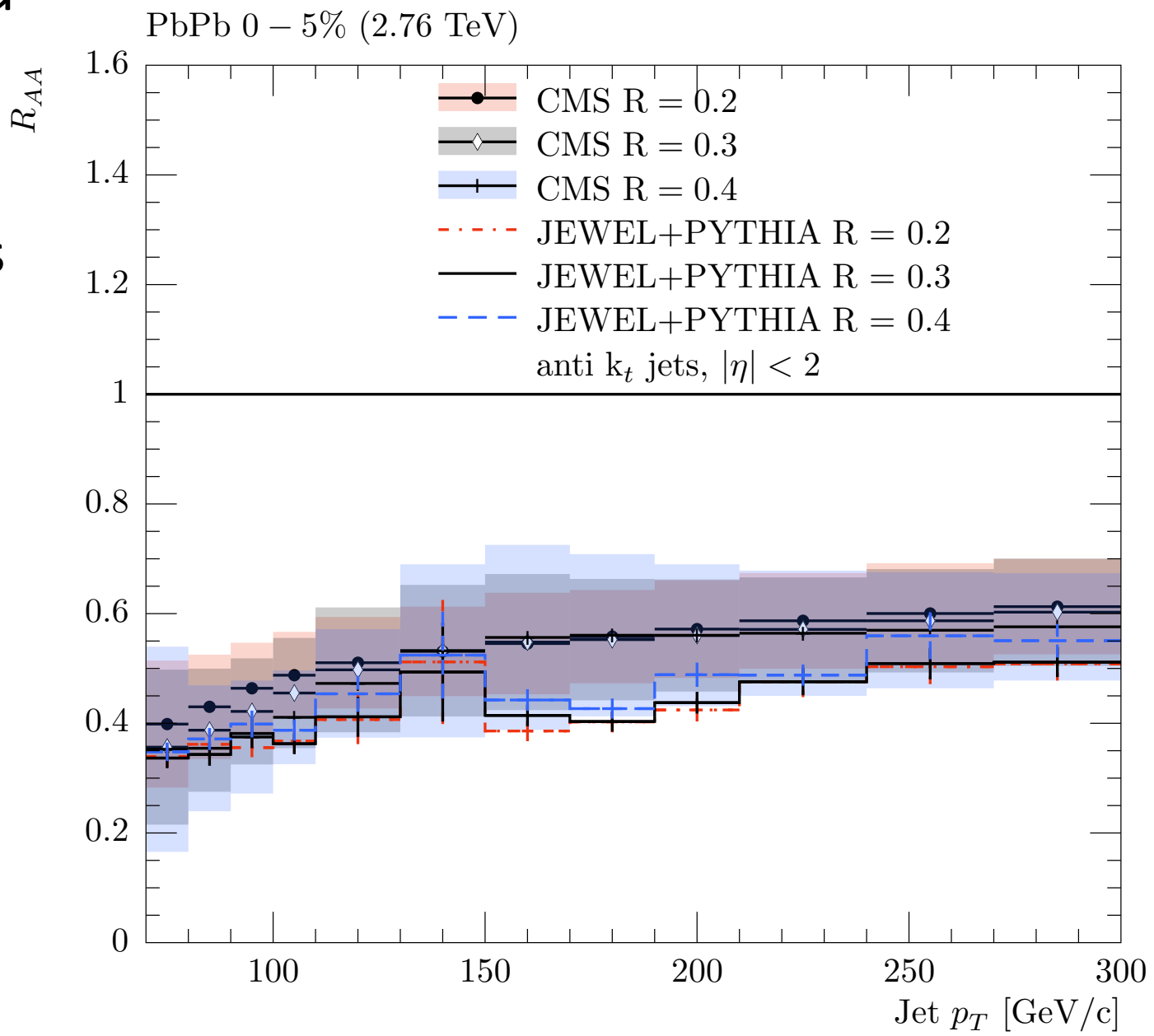

Results

Validation of background subtraction (Jet R_{AA})

See my poster

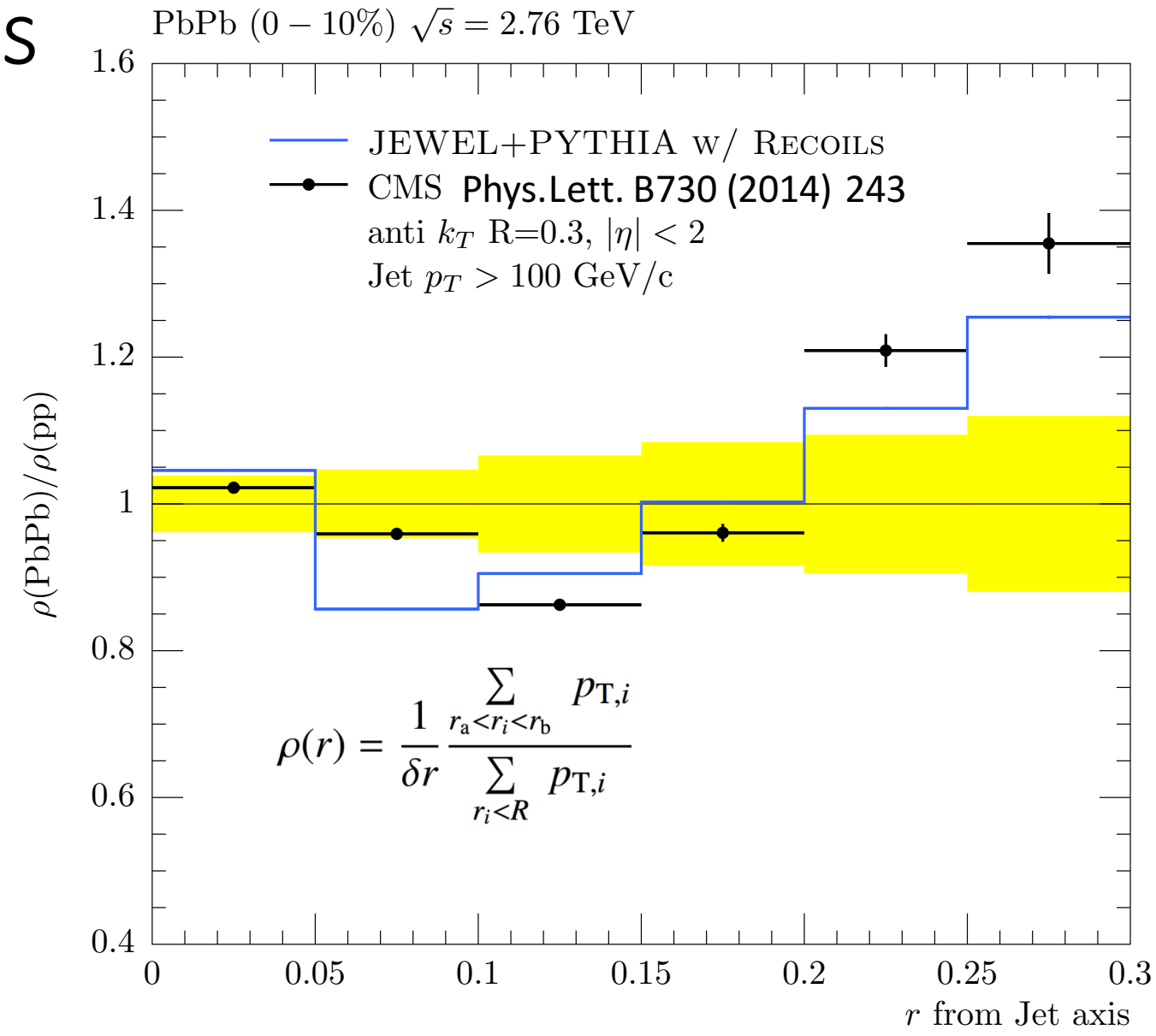
- Performing 4MomSub on jets
- Agrees with data across the kinematic range

- CMS Data (FINAL!) arxiv:1609.05383
- See my poster for more details ☺



Differential Jet Shapes

- Very good description of trend in data ☺
- Matches the collisional and radiative energy loss picture
- First MC capable of describing jet shape modification



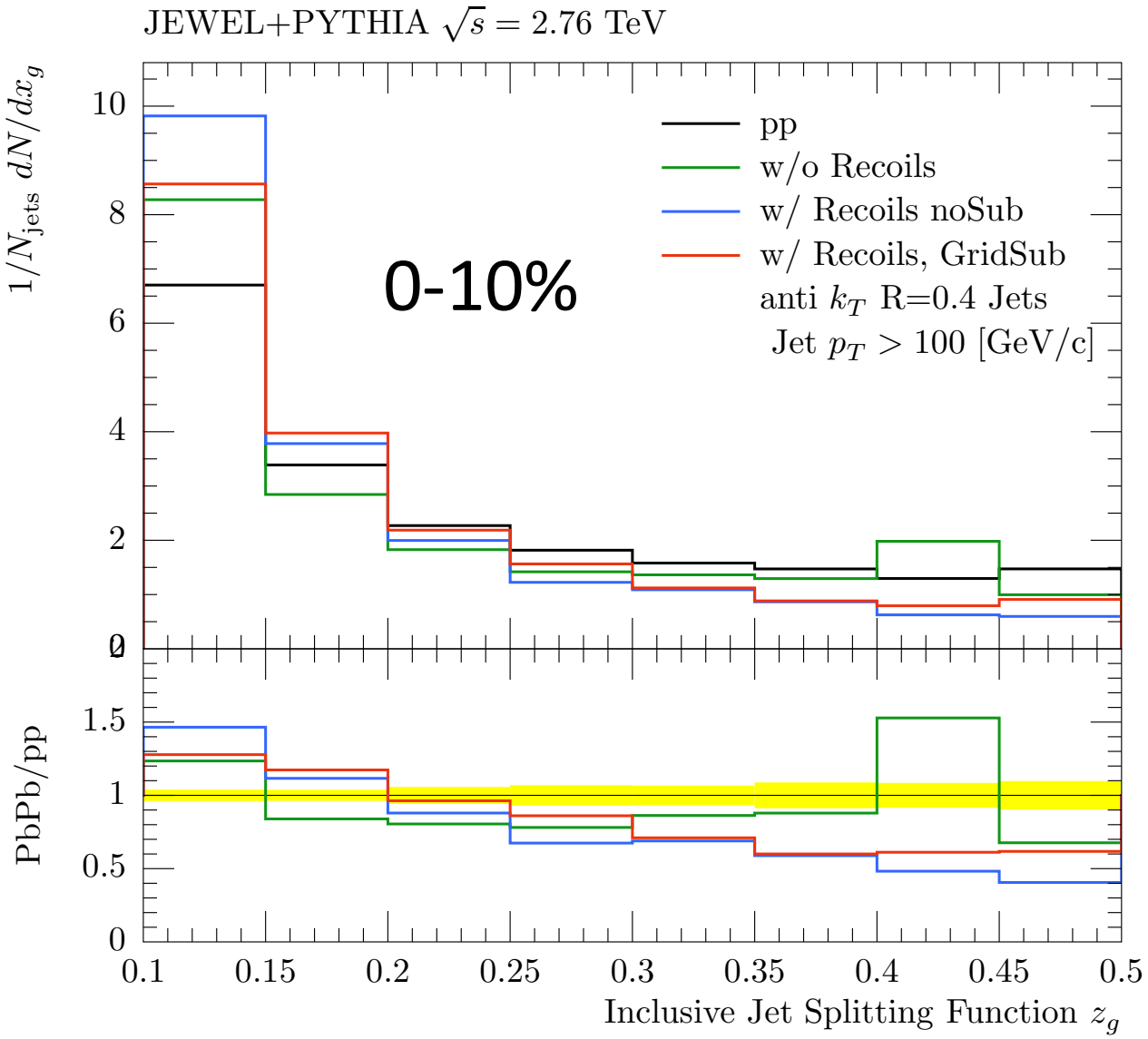
See talk by Marta Verweij

Structure of Jet splitting with JEWEL

- z_g (splitting function) :

$$\frac{\min(p_{T1}, p_{T2})}{p_{T1} + p_{T2}} > z_{\text{cut}} \left(\frac{\Delta R_{12}}{R_0} \right)^{\beta}$$

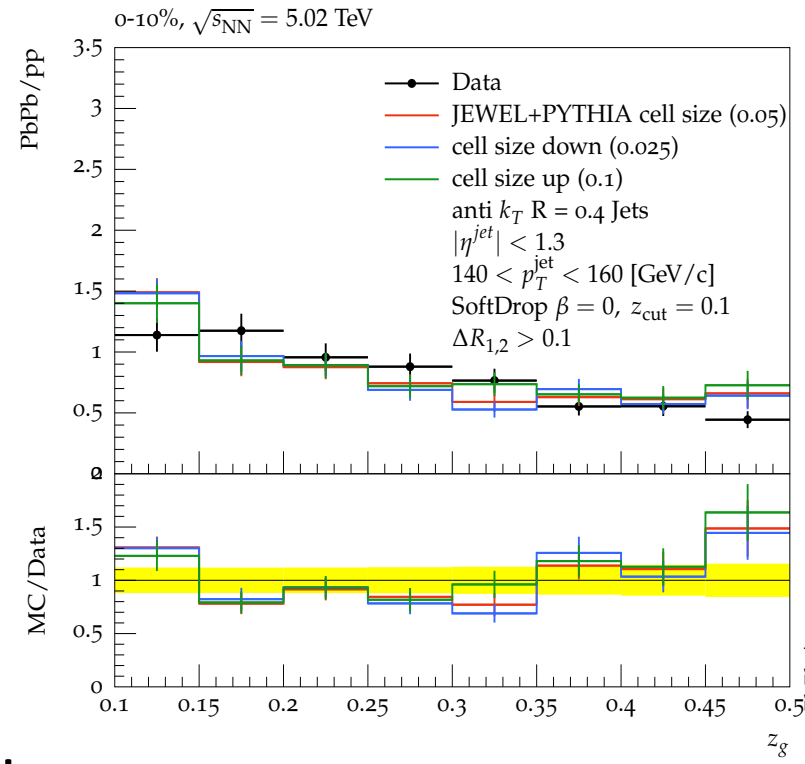
- z_{cut} = 0.1, β= 0
- Modifications to subjet splitting in the HIN environment: more asymmetric in PbPb
- w/o recoils, JEWEL doesn't store the information
- w/ recoils, need to subtract the background information to remove extraneous medium partons masquerading as splitting

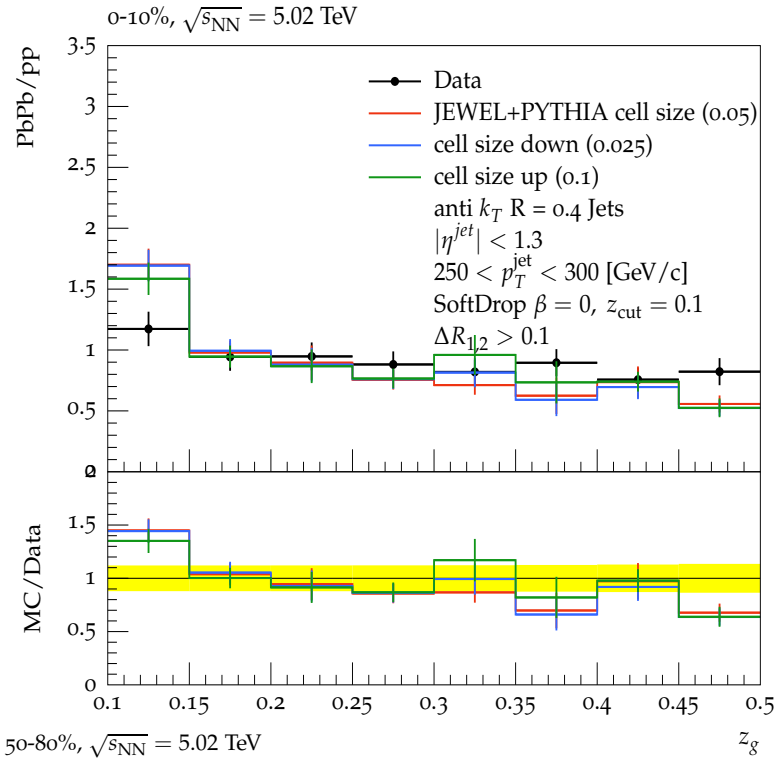


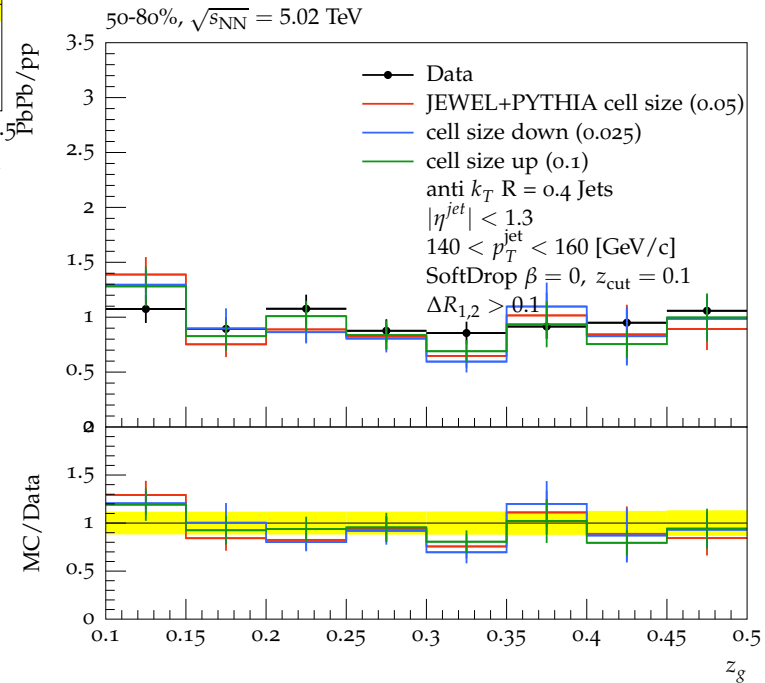
Comparing with Data

CMS-PAS-HIN-16-006

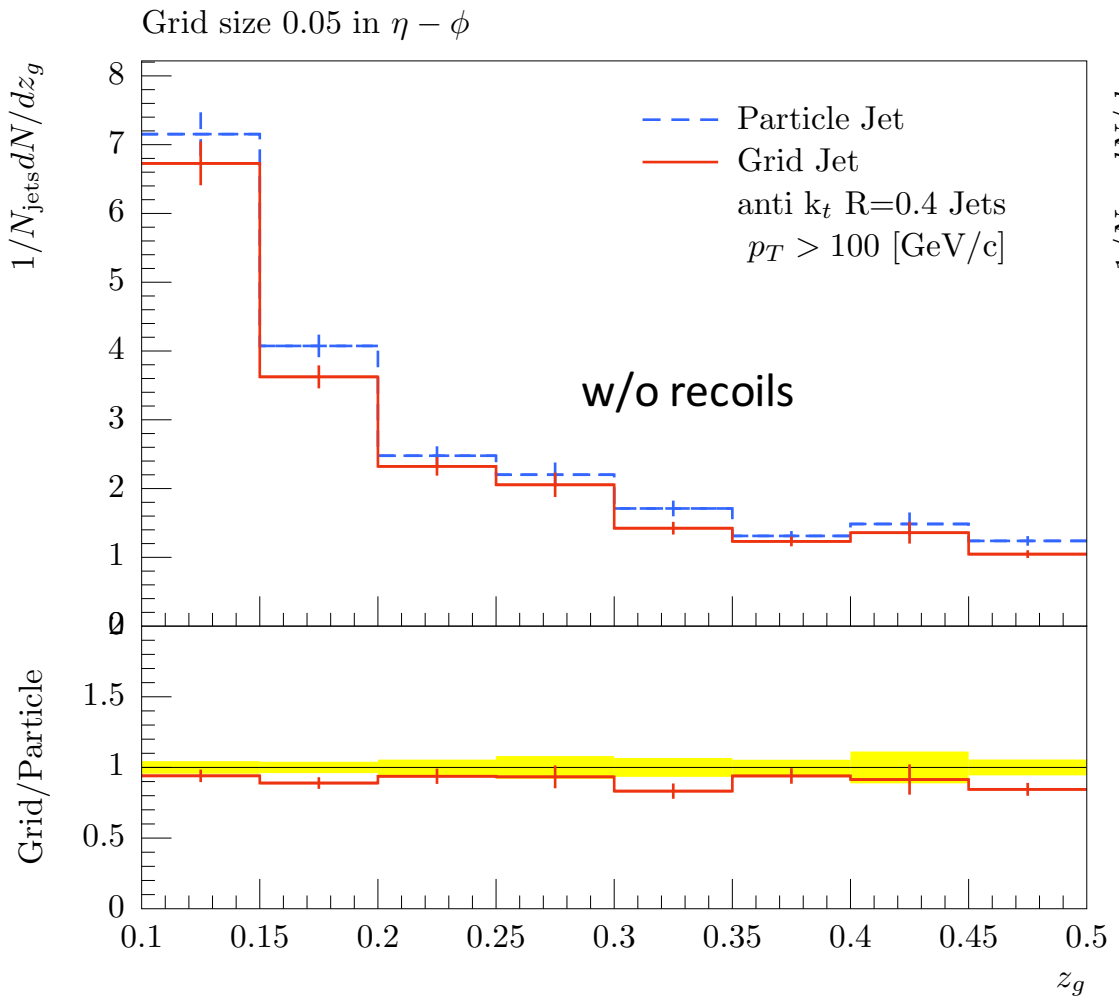
- Good description!
- The PbPb jets prefer to be more asymmetric as compared to pp (and general qcd) which features harder splitting

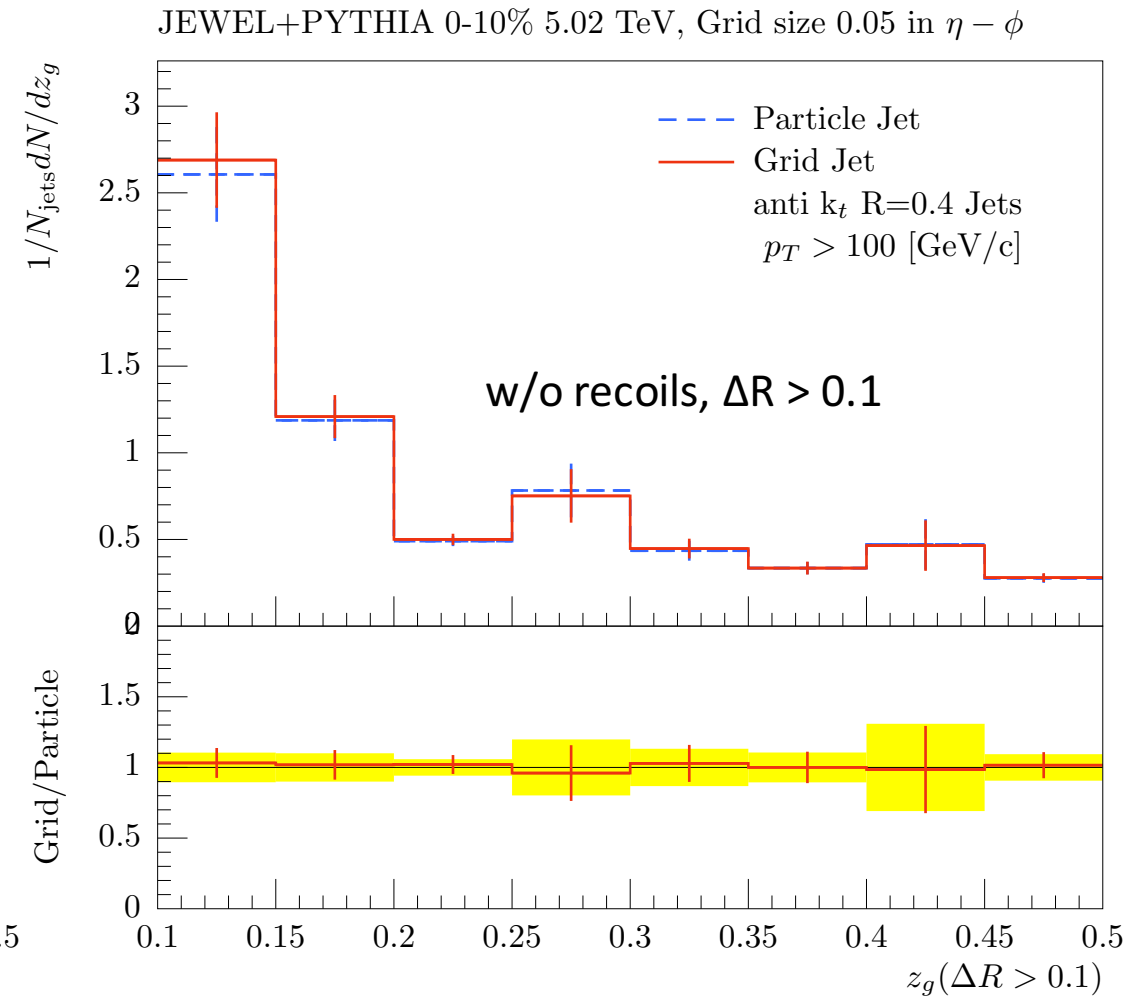






Any effect of the grid here?



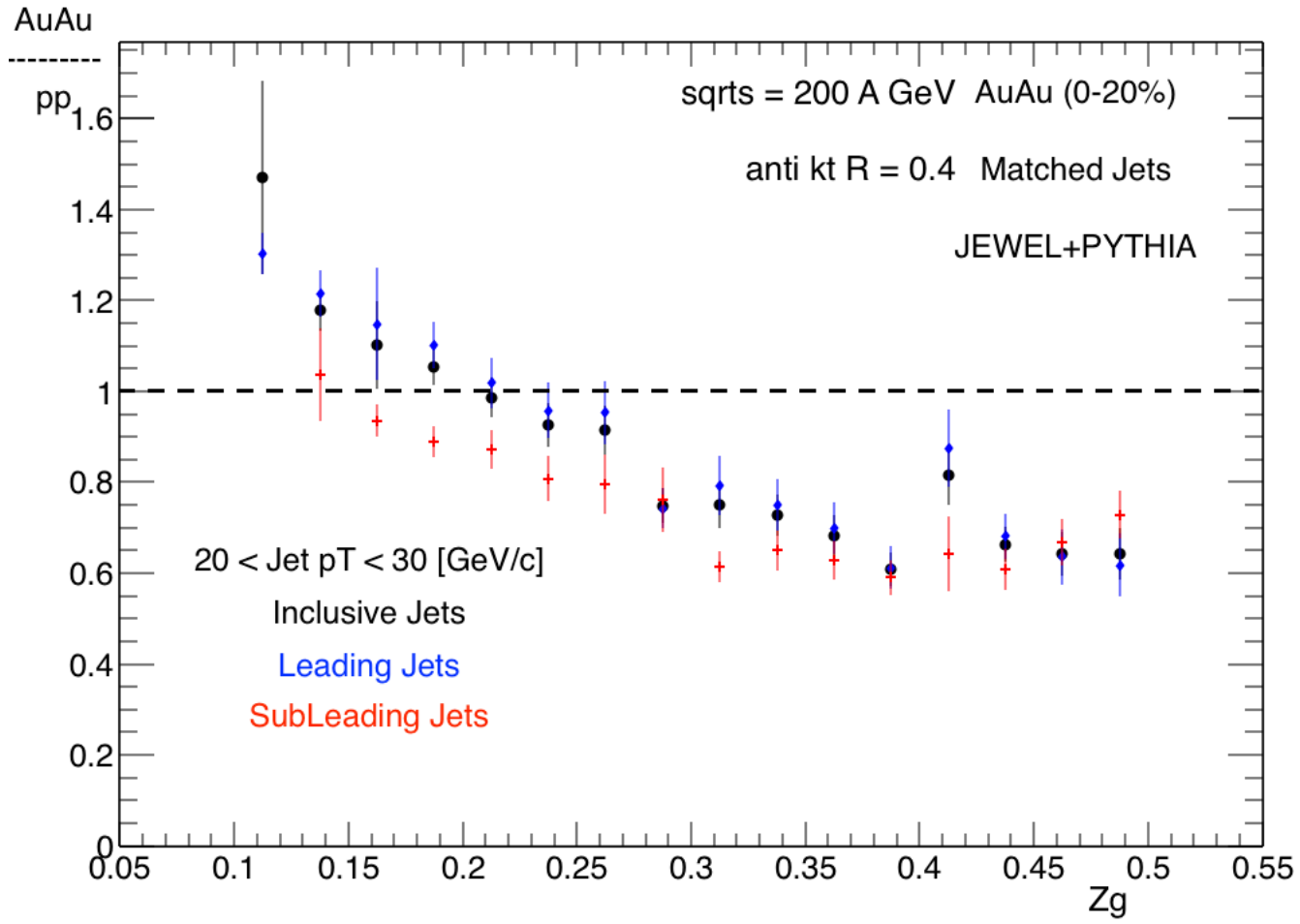


In the kinematic range, there are no issues caused by the grid.
BUT, the delta R cut off, affects the results!

See talk by Kolja Kauder

Splitting function at lower jet p_T @ RHIC

- Effectively the same behavior for very low p_T jets at RHIC energies
- Comparing leading vs sub-leading jets tells us that if any difference in the path length vs fluctuations
- Hints of sub-leading jets having a more symmetric splitting vs leading jets…
- Very interesting!

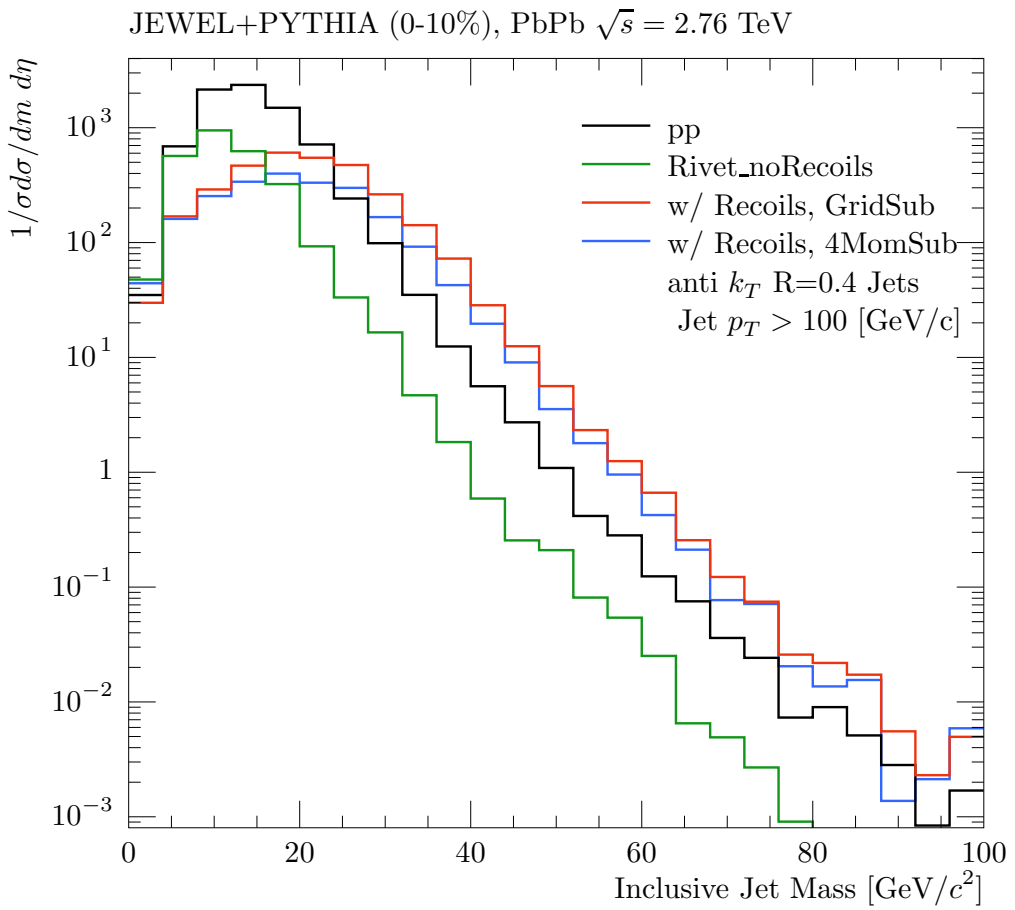


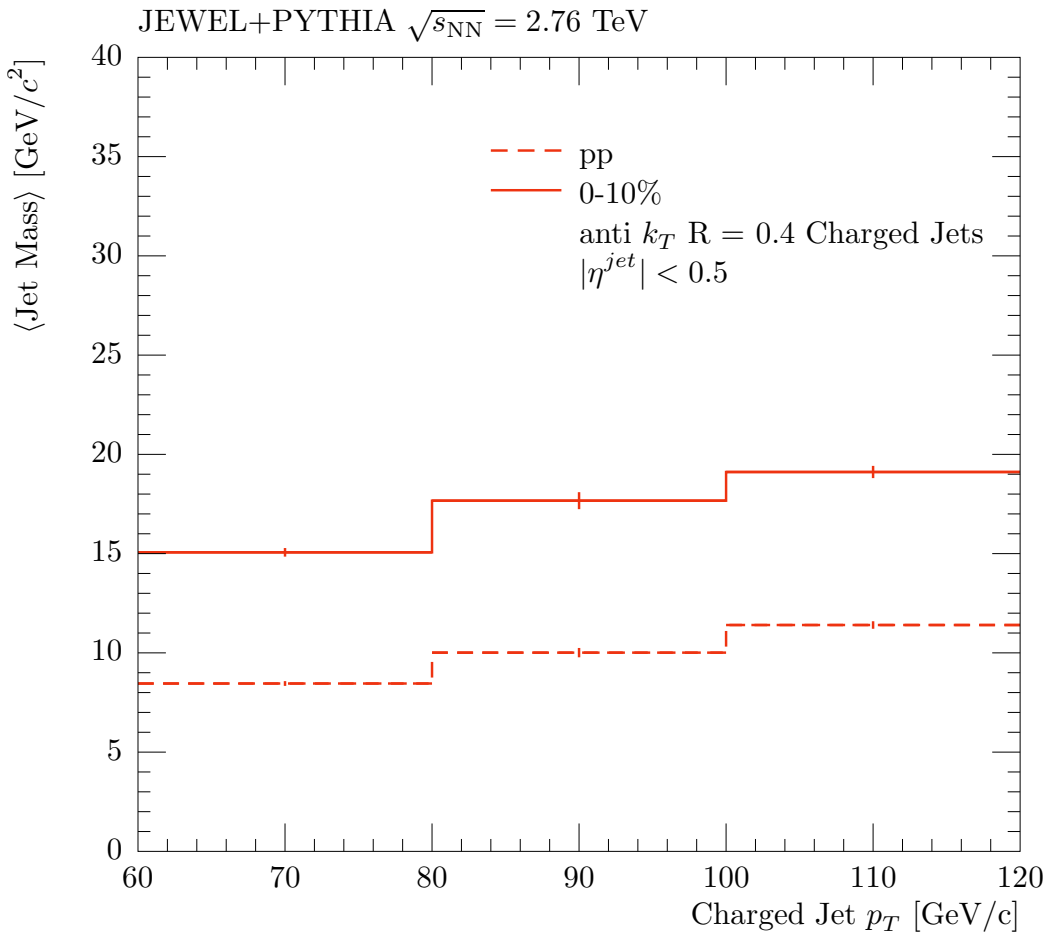
Jet Mass (NEW!!!)

See talk by Chiara Bianchin

Background subtracted JEWEL provides a shift in pp vs PbPb

Very interesting to understand the behavior of recoil limit here.





Conclusions

- JEWEL and its recoils reproduce jet structure modifications in the QGP
- Real physics is hidden in convolution of different observables: requiring more differential studies with MC support: JEWEL can provide that ☺
- Next generation of jet shapes observables: Mass, Radial moments, Angularity…
- Need to compare MC with results to gain more insights into the physics!

Thanks for your attention!

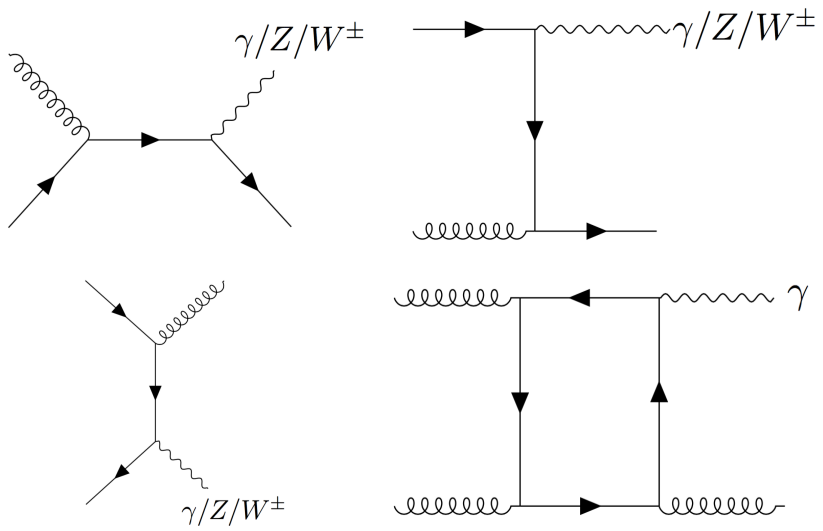
Backup

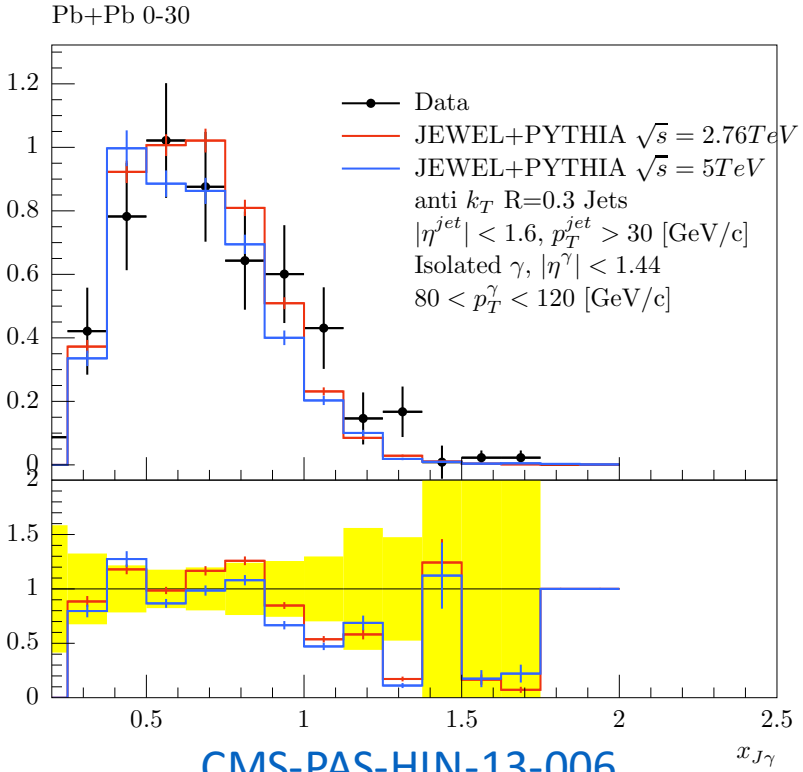
Is there tuning involved?

Parameters	200 GeV (Au+Au)	2.76 TeV (Pb+Pb)	5.02 TeV (Pb+Pb)
Initial (spatially averaged) Temperature	350 (260) MeV	485 (360) MeV iEBE package from Chen Shun	590 (440) MeV
Formation Time	0.4	0.6	0.4
Inelastic cross section	42 mb	64 mb http://dde.web.cern.ch/dde/glauber_lhc.htm	72mb
Debye mass factor This was to match hadron RAA at PHENIX	0.9	0.9	0.9

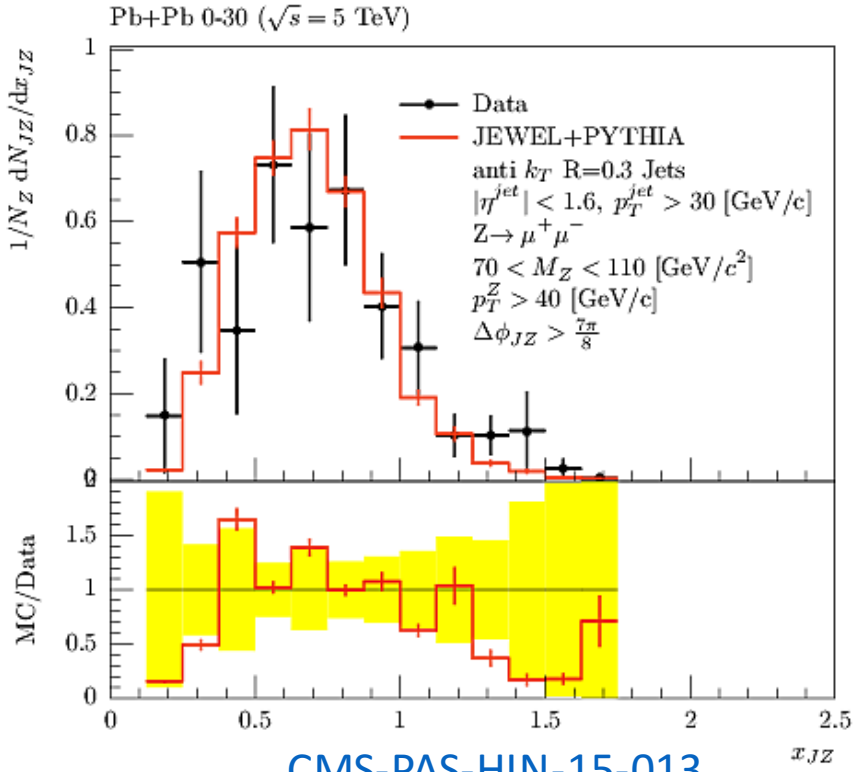
Recent addition to JEWEL – V+ Jet

- RKE, Korinna Zapp 1608.03099
  Submitted to EPJC
- Good description of medium modification to jets associated with γ and Z





CMS-PAS-HIN-13-006

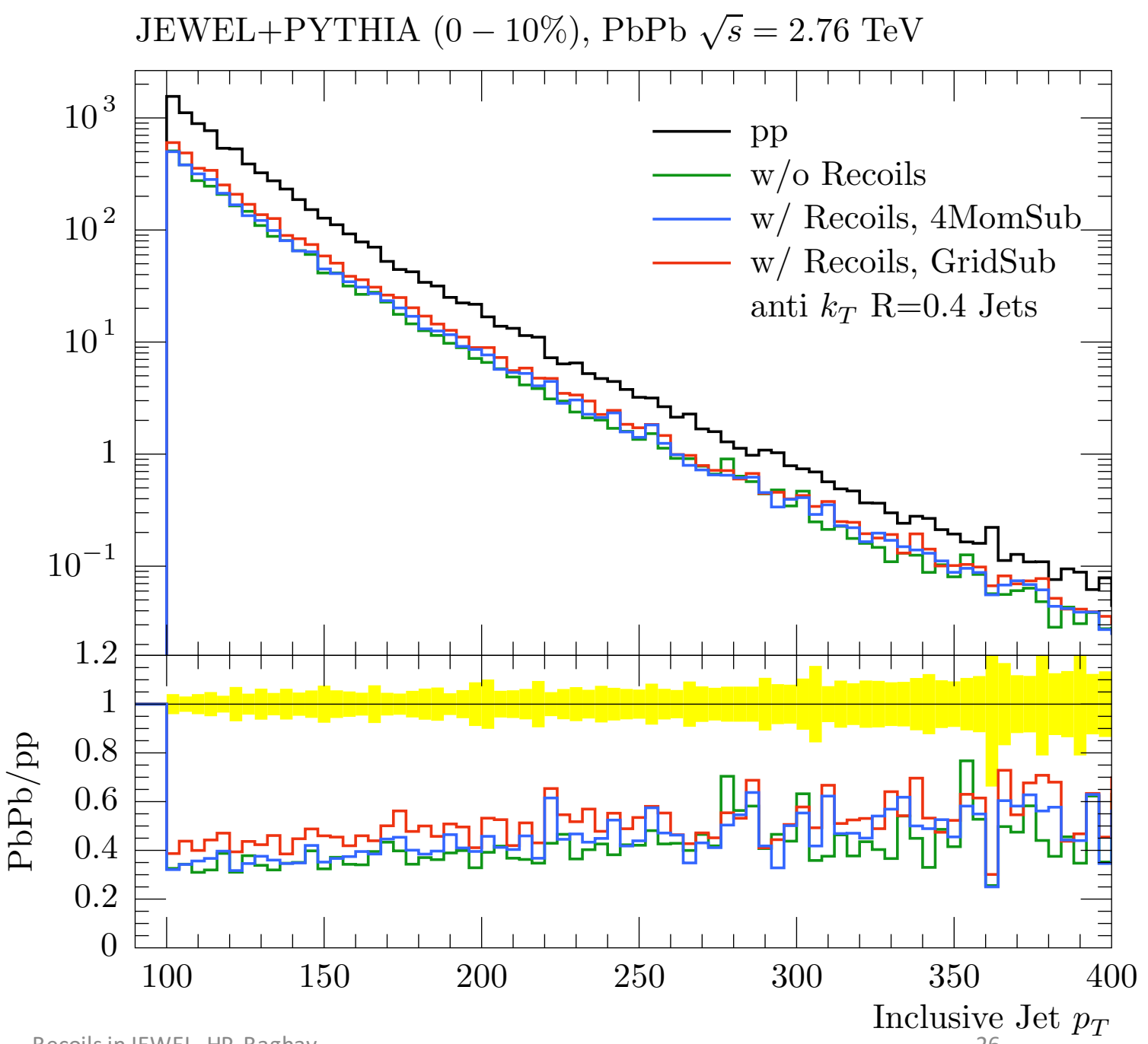


CMS-PAS-HIN-15-013

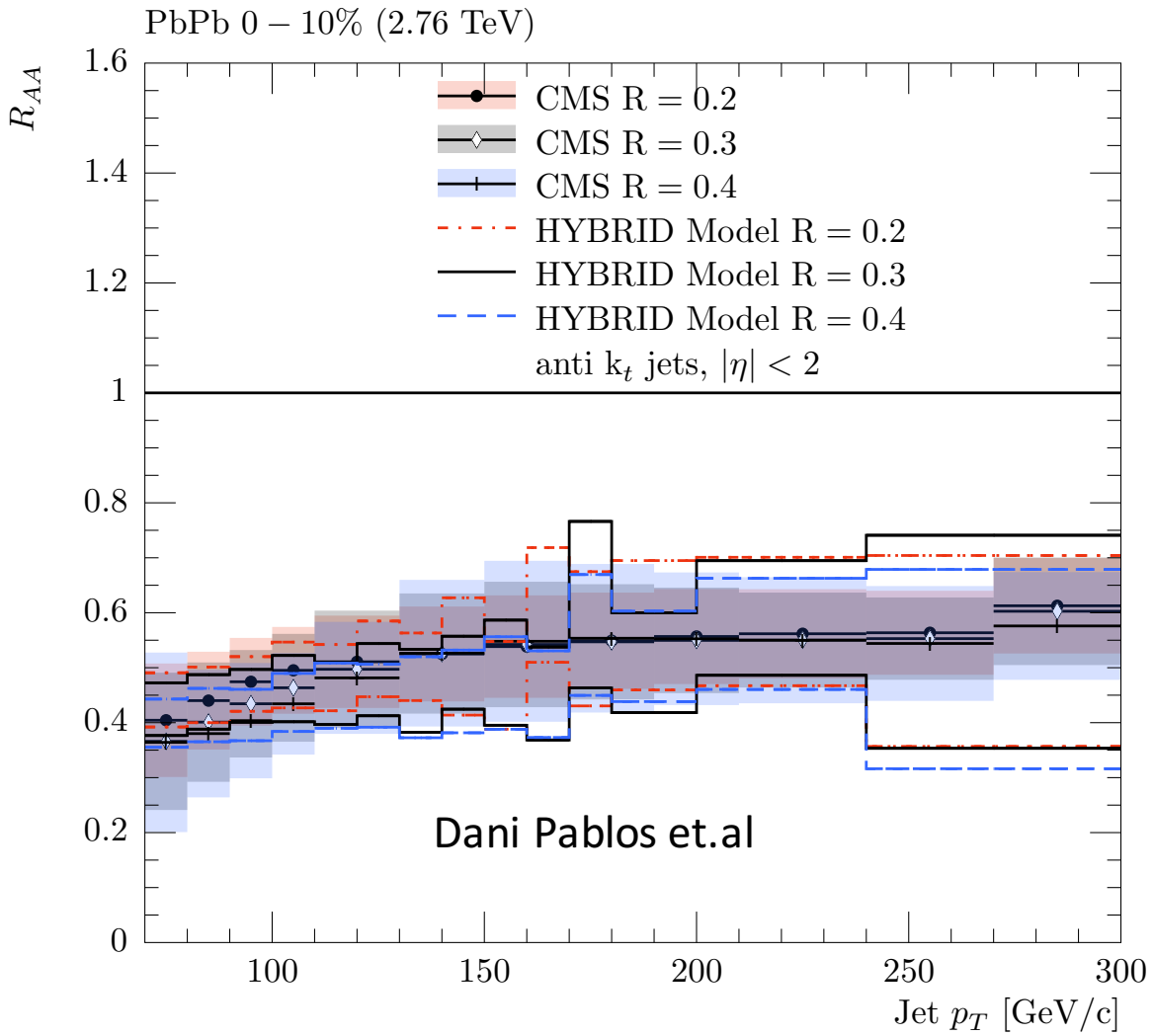
How does that look?

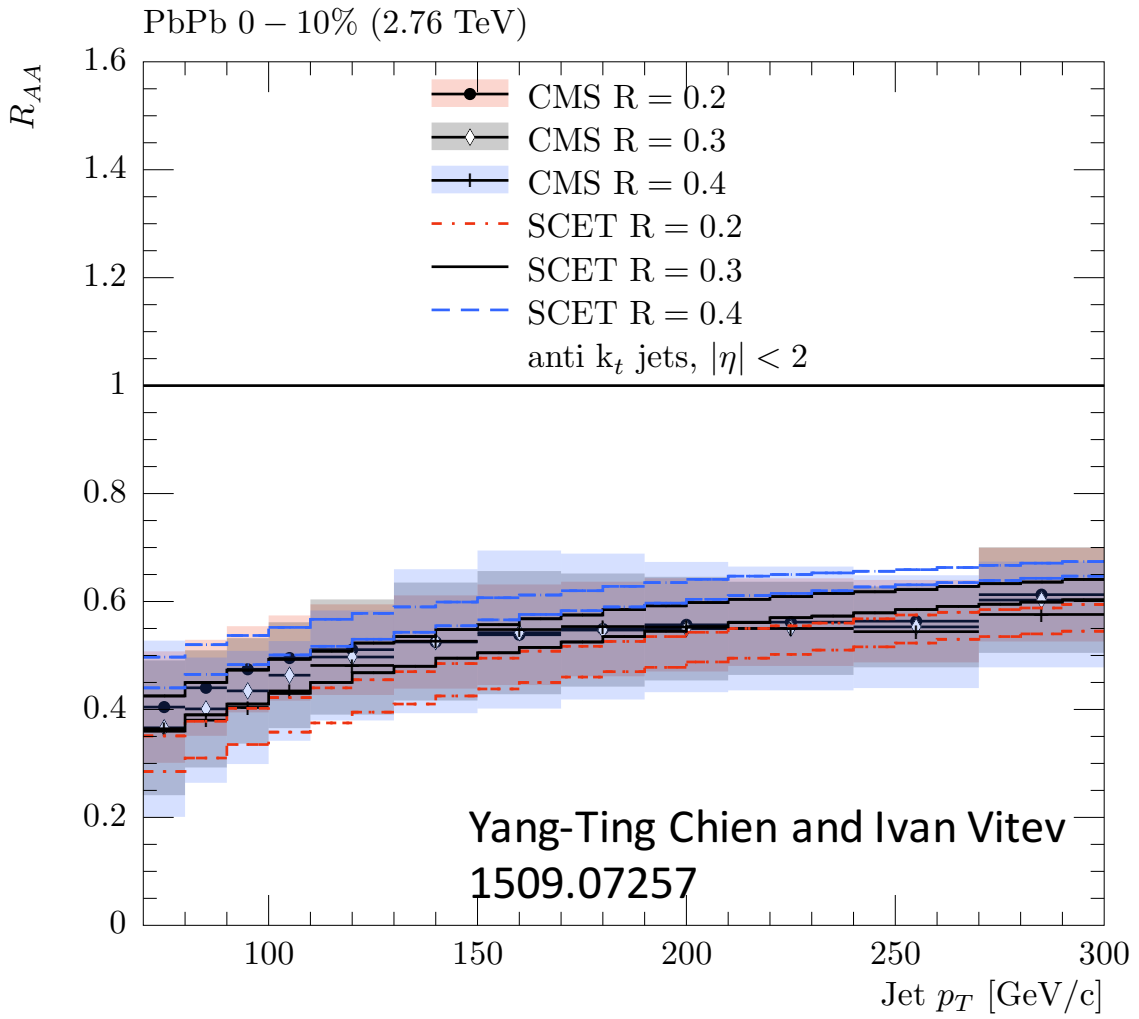
1. Perform 4 momenta subtraction from the scattering centers. For a given Jet or annuli (jet shapes). Should be used if possible

2. "Quantize" the event: Detector like finite resolution. Subtract the backgrounds (scattering centers) from the boxes. If box net sum < 0, then set to zero.



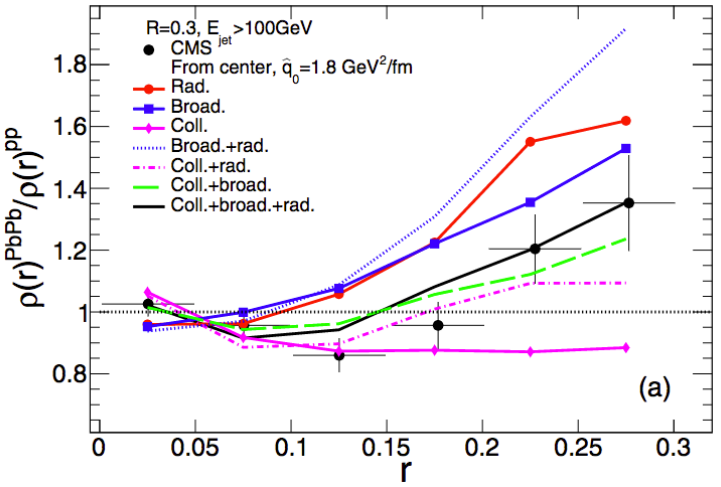
Jet RAA theory comparisons



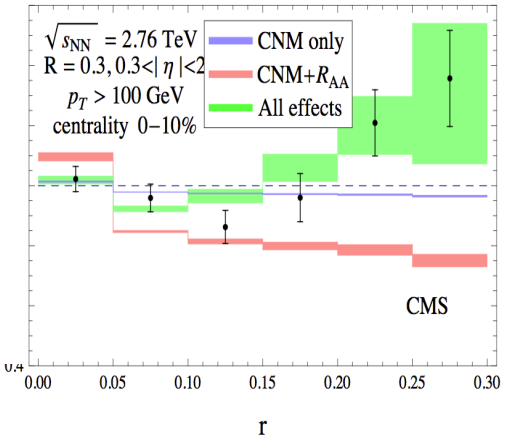


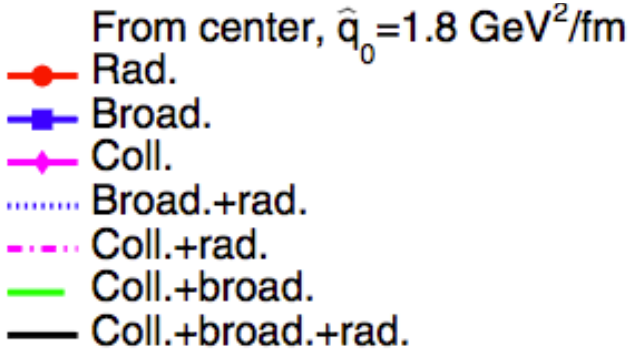
What's available on the market:

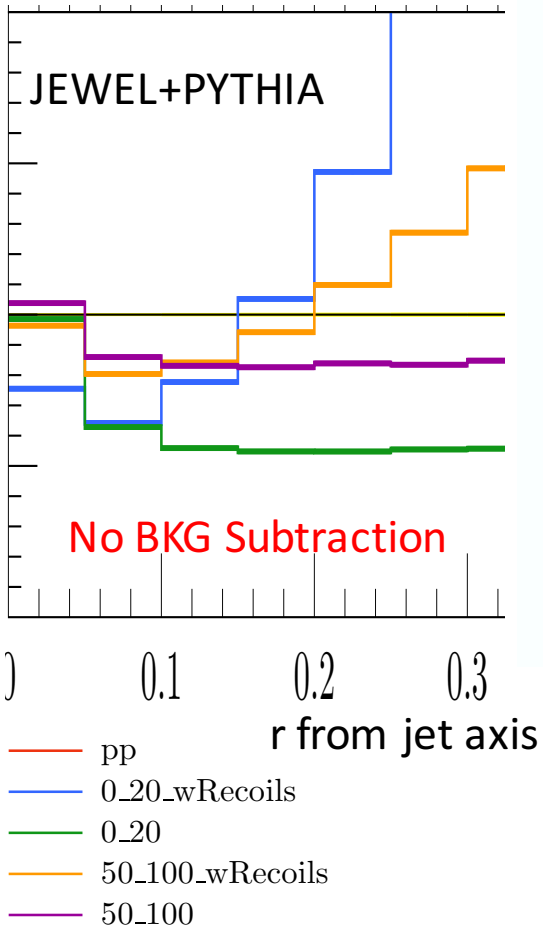
N-B Chang, G-Y Qin
Phys.Rev. C94 (2016) no.2, 024902



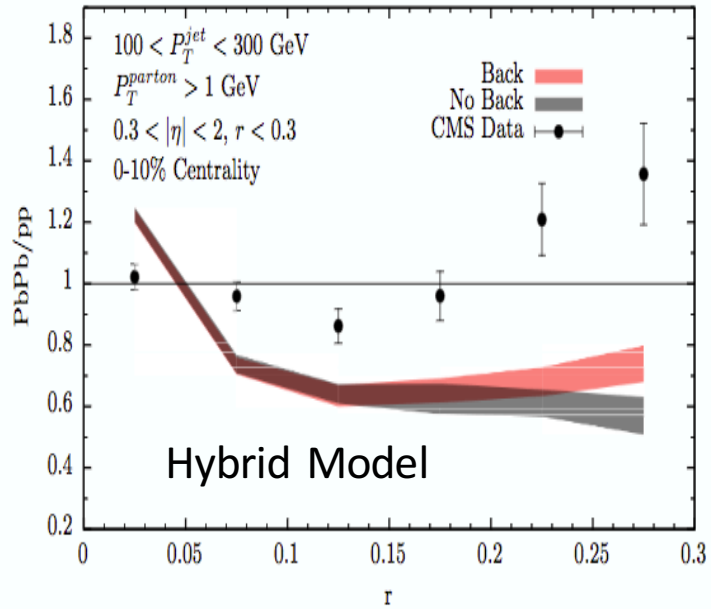
I Vitev, Y-T Chien
JHEP 1605 (2016) 023







Back Reaction not enough

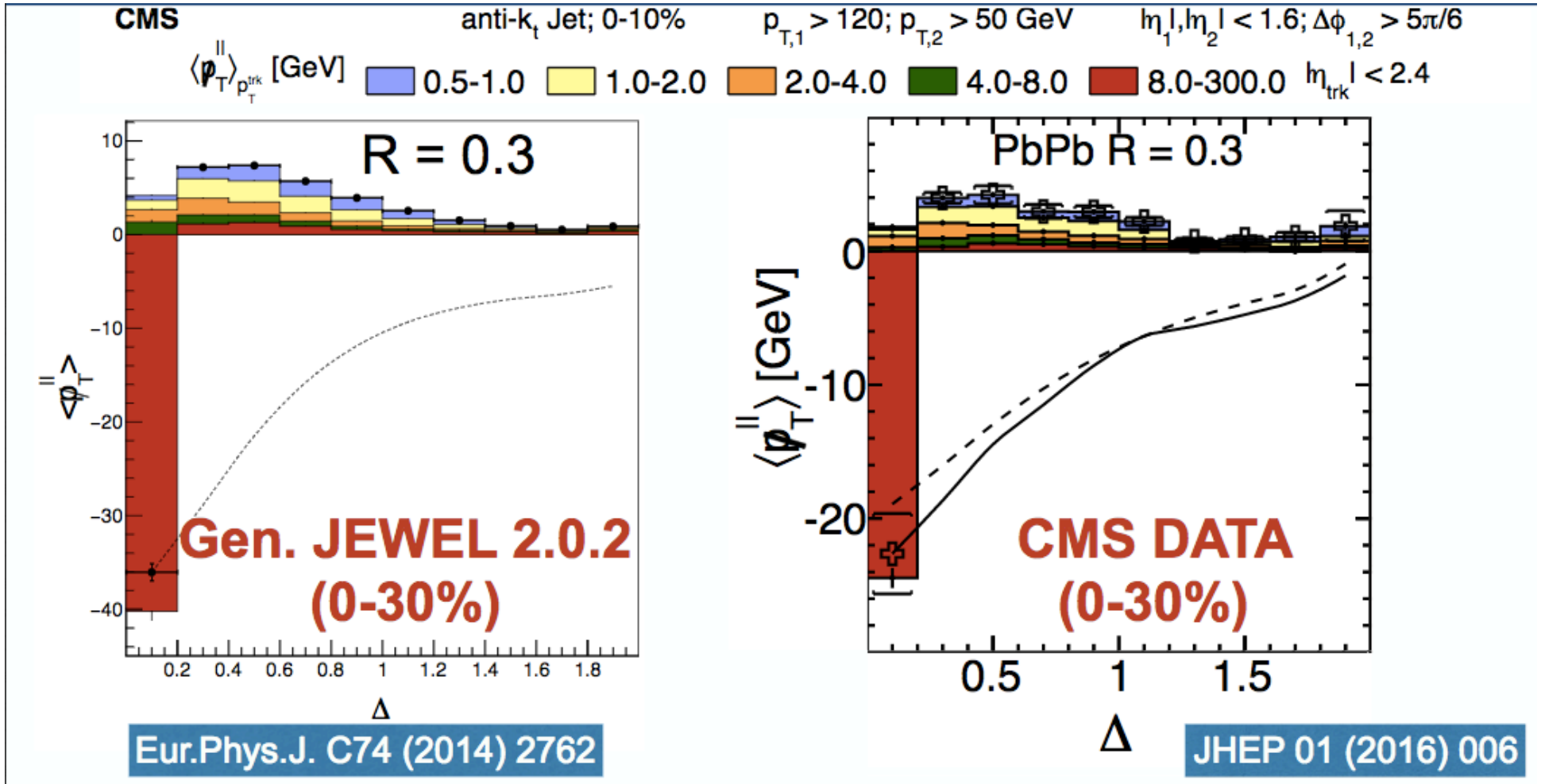


Casalderrey-Solana, J., Gulhan, D.C., Milhano, J.G. et al. J. High Energ. Phys. (2016) 2016: 53.

Is JEWEL recovering the lost energy?

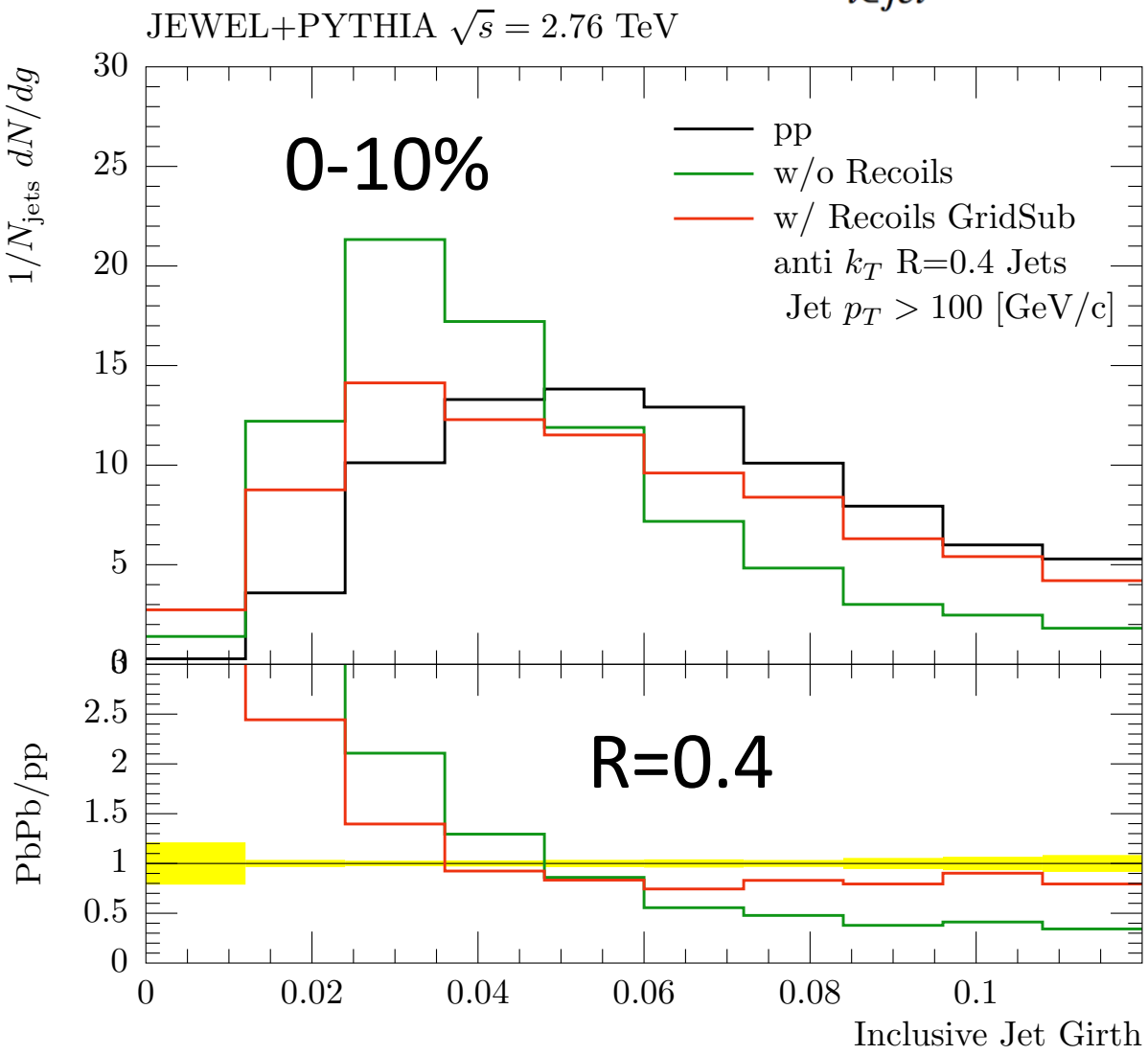
- Looks quite good. General trend is recovered but the scale is off.
- Note: No background subtraction in JEWEL and we are investigating it.

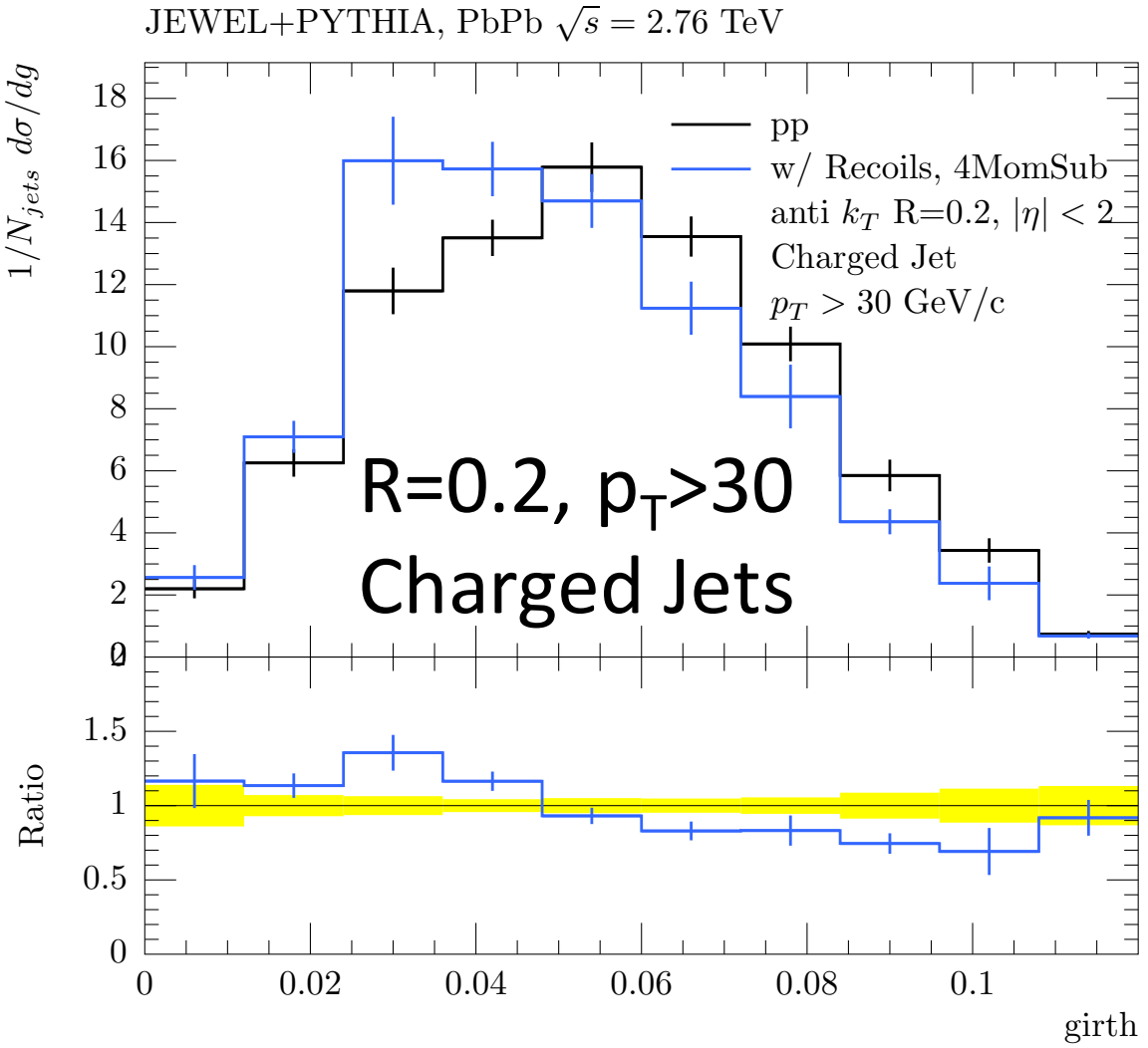
- Chris McGinn (MIT) shown during 4th HIN Jet Workshop



- Missing p_T curve using Gen. JEWEL w/ medium recoil, 0-30%, unsmeared
  - See backup for exact running parameters (here)

Radial Moment $g = \sum_{i \in jet} \frac{p_T^i}{p_{T,jet}} |\Delta R_{i,jet}|$





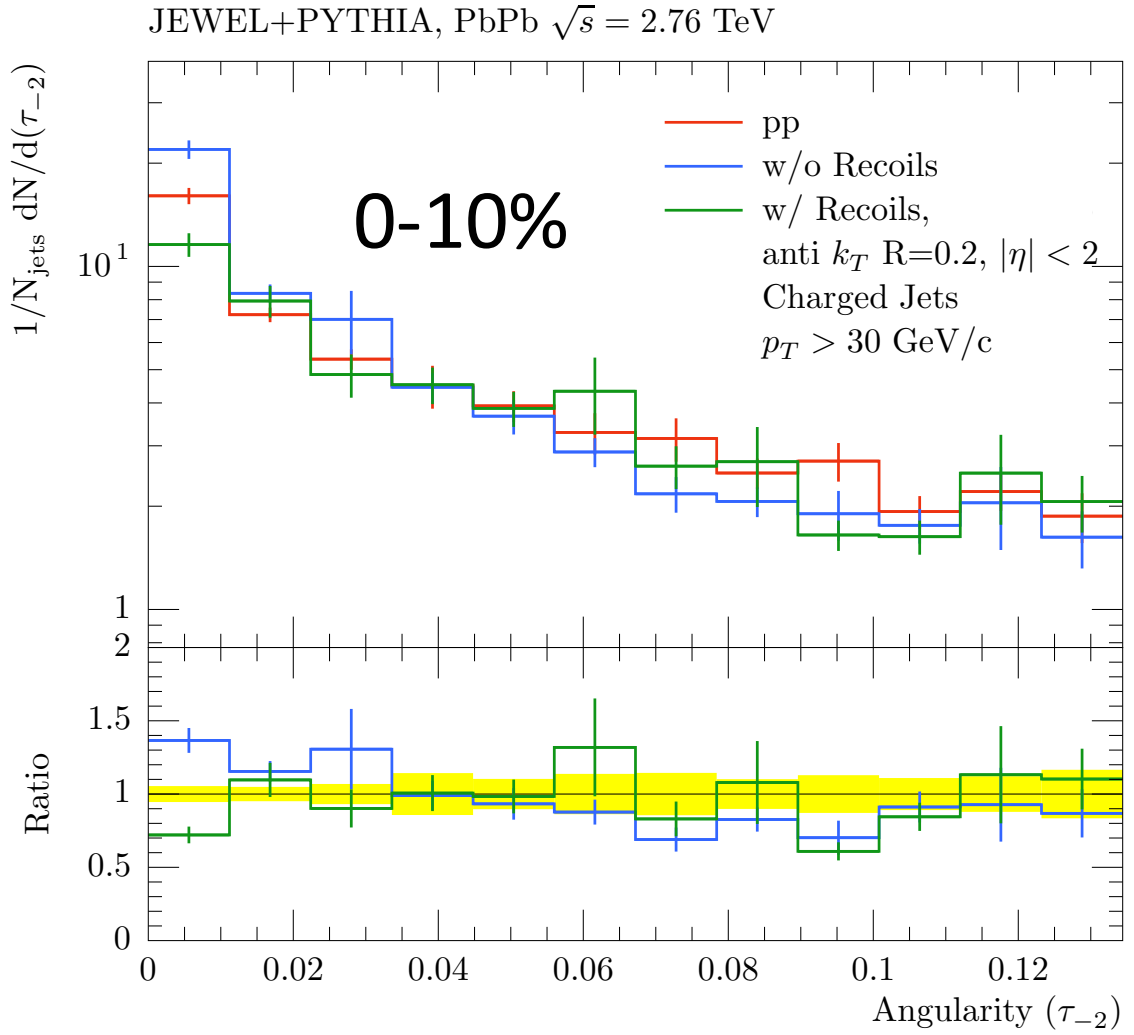
We see a very nice shift in the PbPb jet girth compared to pp. Jets are more evenly filled!

Another fancy measurement: Jet Angularity

$$\tilde{\tau}_a(R, p_T) = \frac{1}{m_J} \sum_{i \in jet} \omega_i \sin^a\left(\frac{\pi\theta_i}{2R}\right) \left[1 - \cos\left(\frac{\pi\theta_i}{2R}\right)\right]^{1-a}, \quad (7)$$

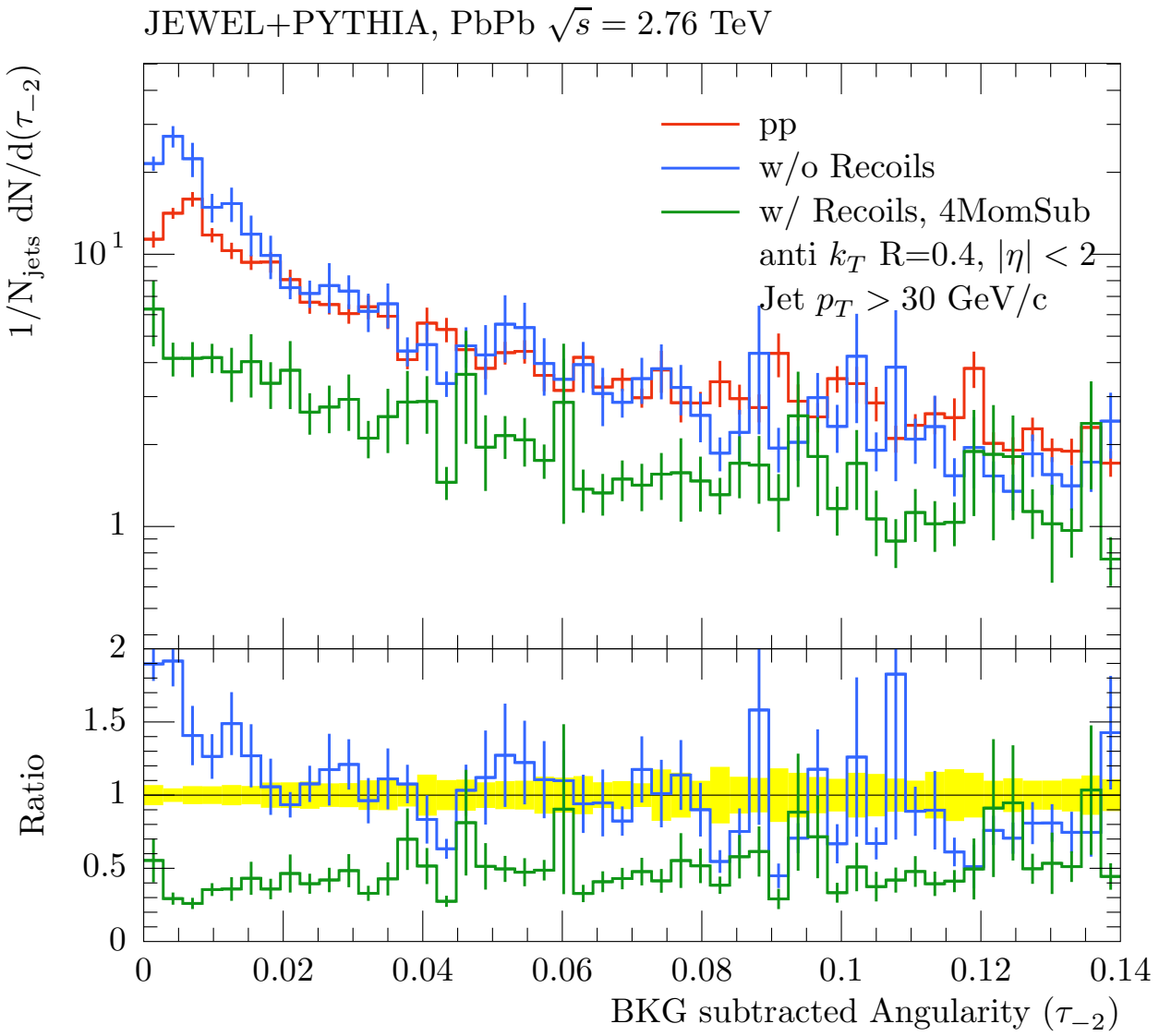
0807.0234

- Originally looked at in e^+e^- collisions in dijet events
- Thought useful for distinguishing boosted objects vs QCD
- Jet Shape quantity
- JEWEL seems to be insensitive to this (or is it??? Next page!)
- Expectation: would tell us that HIN jets are more broader than pp jets

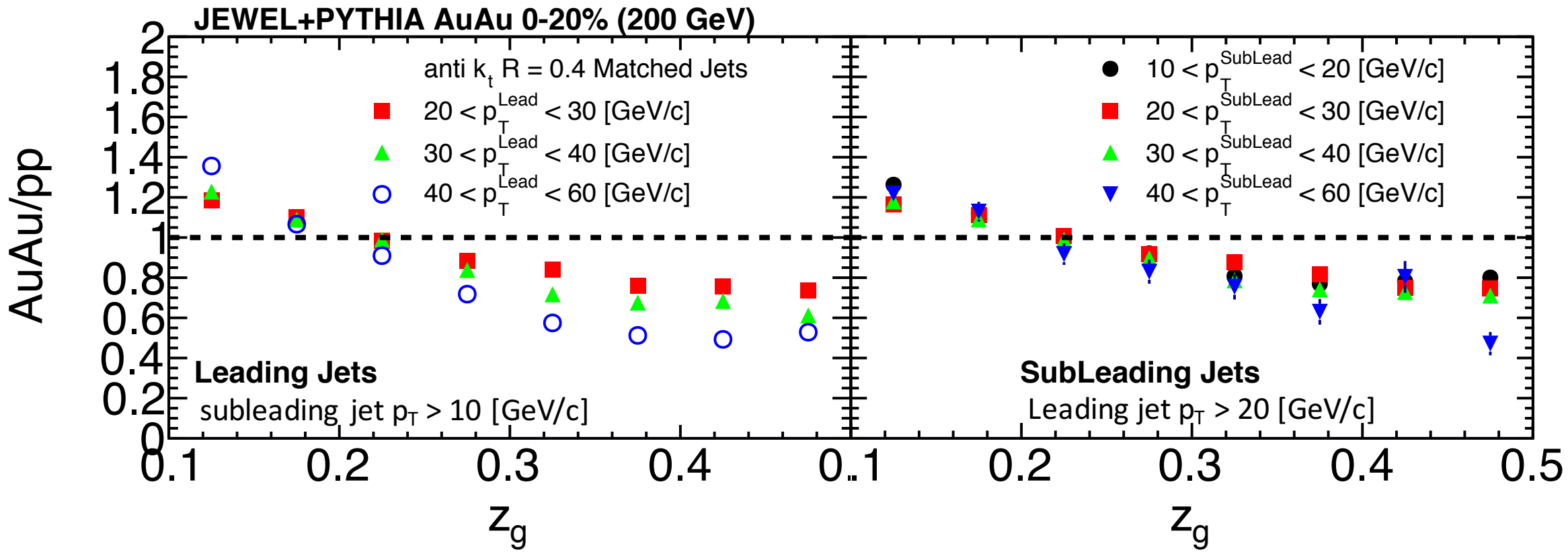


But wait! Inclusive jets at a larger radii?

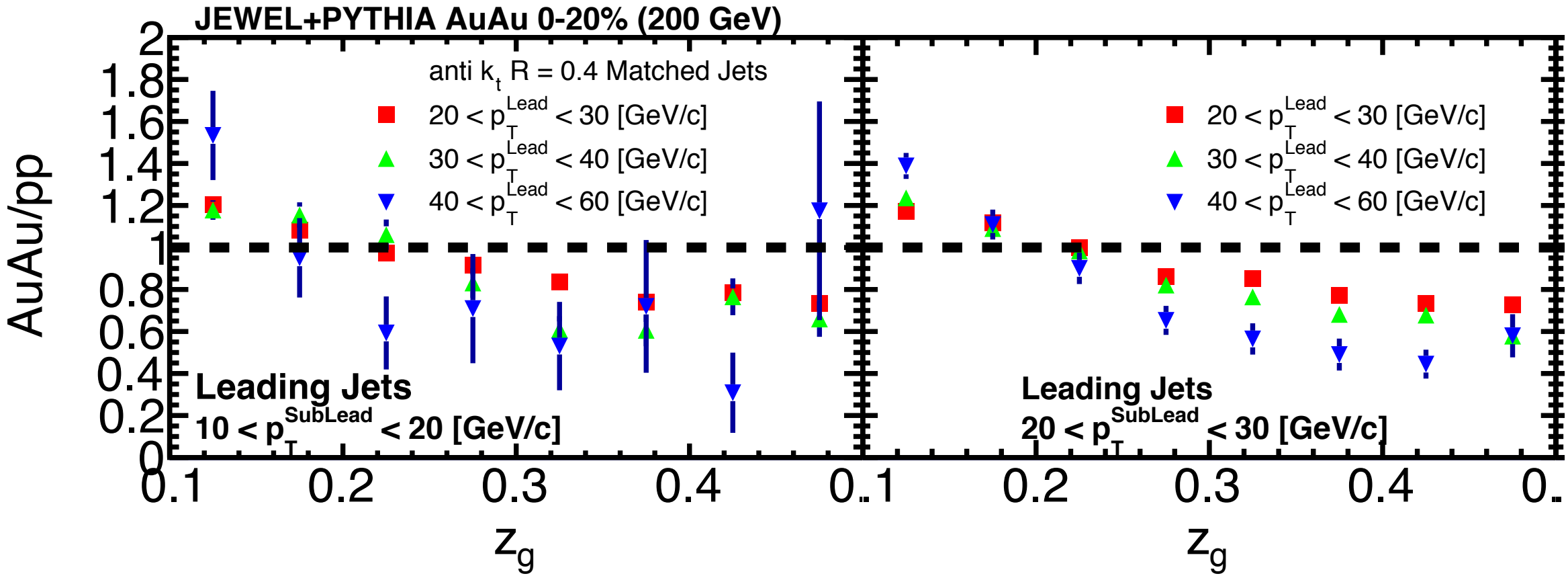
- This gives us the same picture that jets in PbPb are more broader than pp
- Background subtraction clearly shows an effect
- Is this the RAA?
  - (Again ☺)



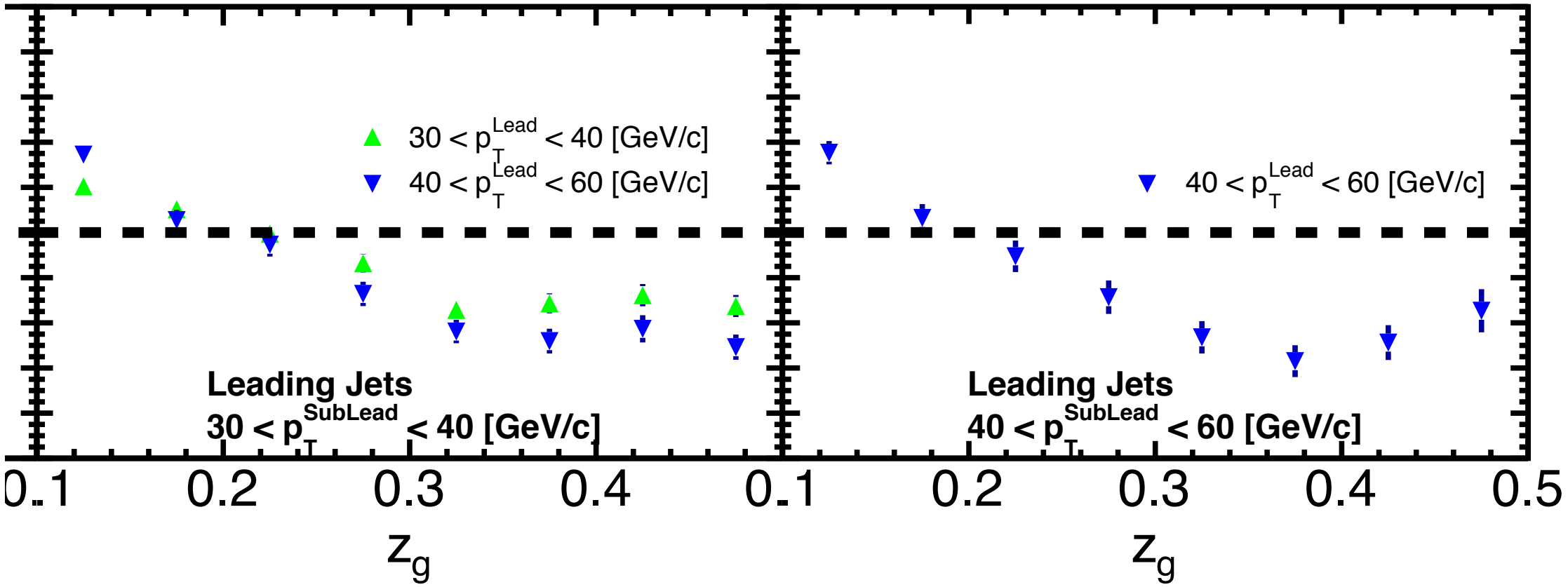
Splitting function in differential jet p_T bins



Leading jet splitting in asymmetric events



Leading jet splitting in asymmetric events



Splitting in sub-leading jets in asymmetric events