Advanced jet modification observables explored with Monte Carlo models

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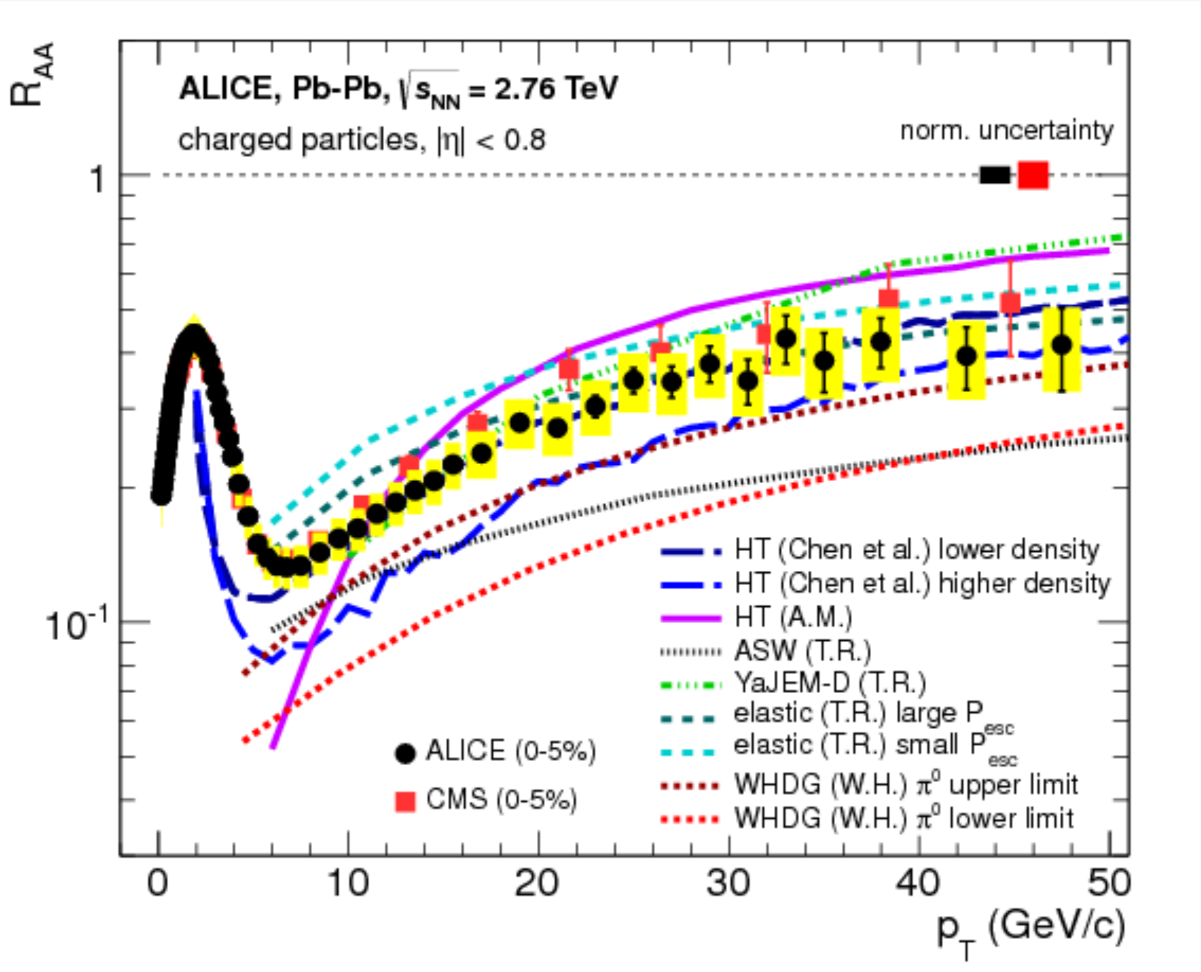
Introduction: R_{AA} and beyond



arxiv:1301.5285

- R_{AA} can be described well by a variety of models
- Explore the sensitivity of other observables
- Focus of this talk:
  - Jet-hadron correlations

  (soft large-angle radiation)
  - Jet substructure

  (hard splittings within a jet)
- Use YaJEM and JEWEL models

Models

JEWEL — explicit pQCD treatment of hard partons scattering on the quasi-free partons of the medium (recoils can be kept or discarded before hadronization)

K. Zapp *et al.* JHEP 1303 (2013) 080, EPJC C60 (2009) 617

YaJEM-DE — scattering on QGP constituents is not modeled explicitly

Hard parton acquires additional virtuality from the medium:

$$\Delta Q^2 = \kappa \int \epsilon^{3/4}(\xi)\, d\xi$$

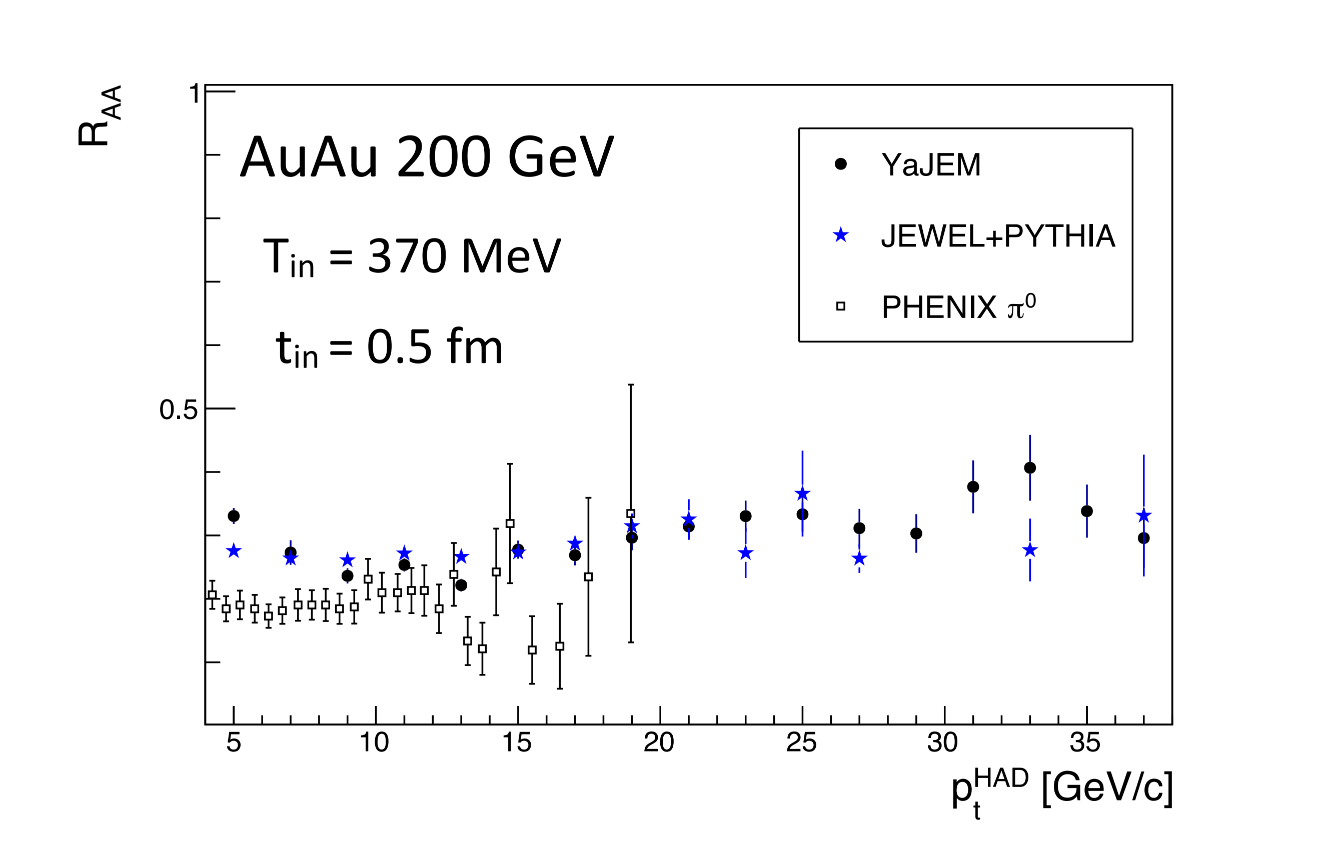
enhanced radiation ⇒ broadening and softening of the shower

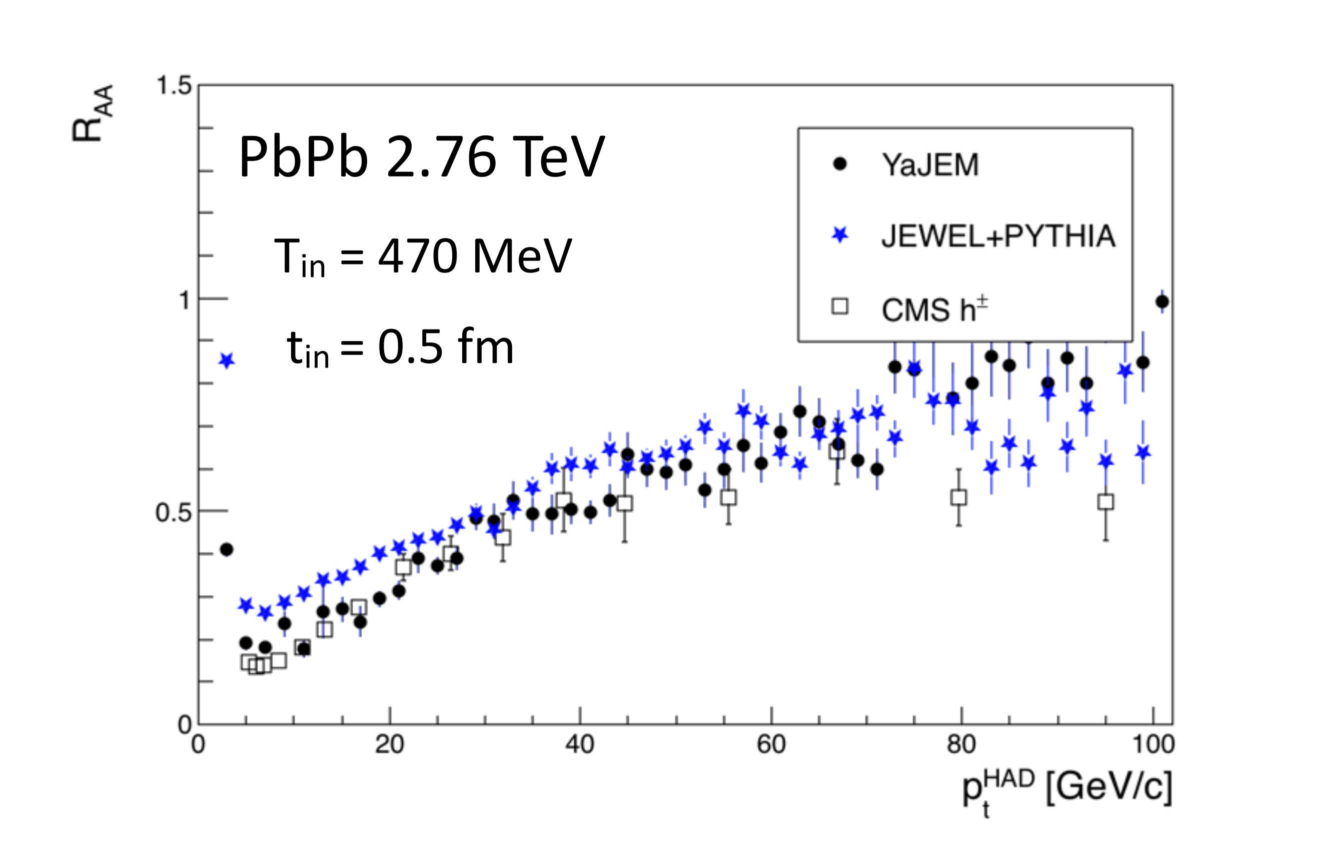
Free parameter κ must be tuned to reproduce exp. data (R_{AA})

T. Renk, Phys. Rev. C 84 (2011) 067902 and refs therein

- This study: run both models using the same hydro (1D Bjorken-type) to isolate the implementations of jet quenching

First step: hadron R_{AA}





- Model parameters fixed at RHIC energy
- YaJEM tuned to reproduce hadron R_{AA} at RHIC, $\kappa \sim 2$
- JEWEL — default parameters v2.0.2

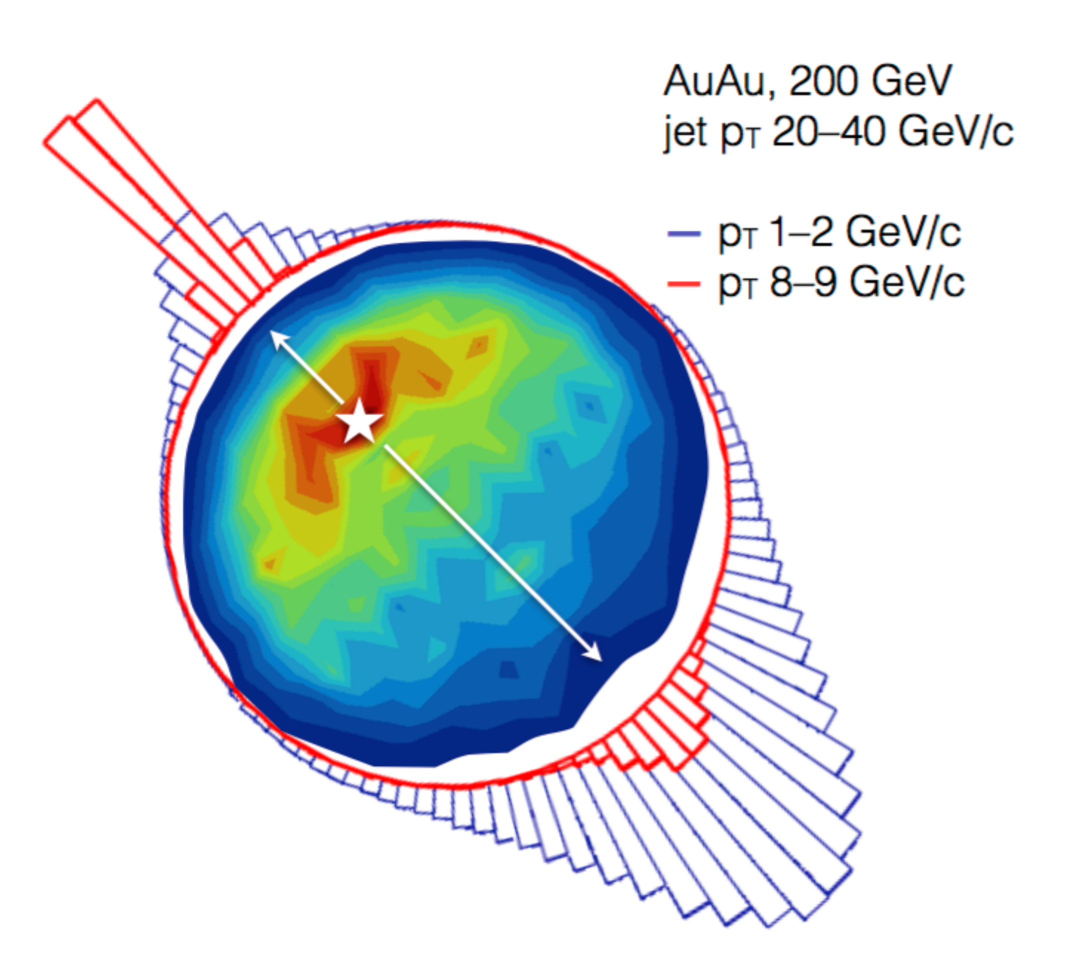
Jet-Hadron Correlations

Azimuthal distribution of hadrons in jet-triggered events

Near-Side Peak:

- surface biased

(trigger conditions)



Away-Side Peak:

- longer in-medium path
- shower broadening
- softening of the FF

Reference:

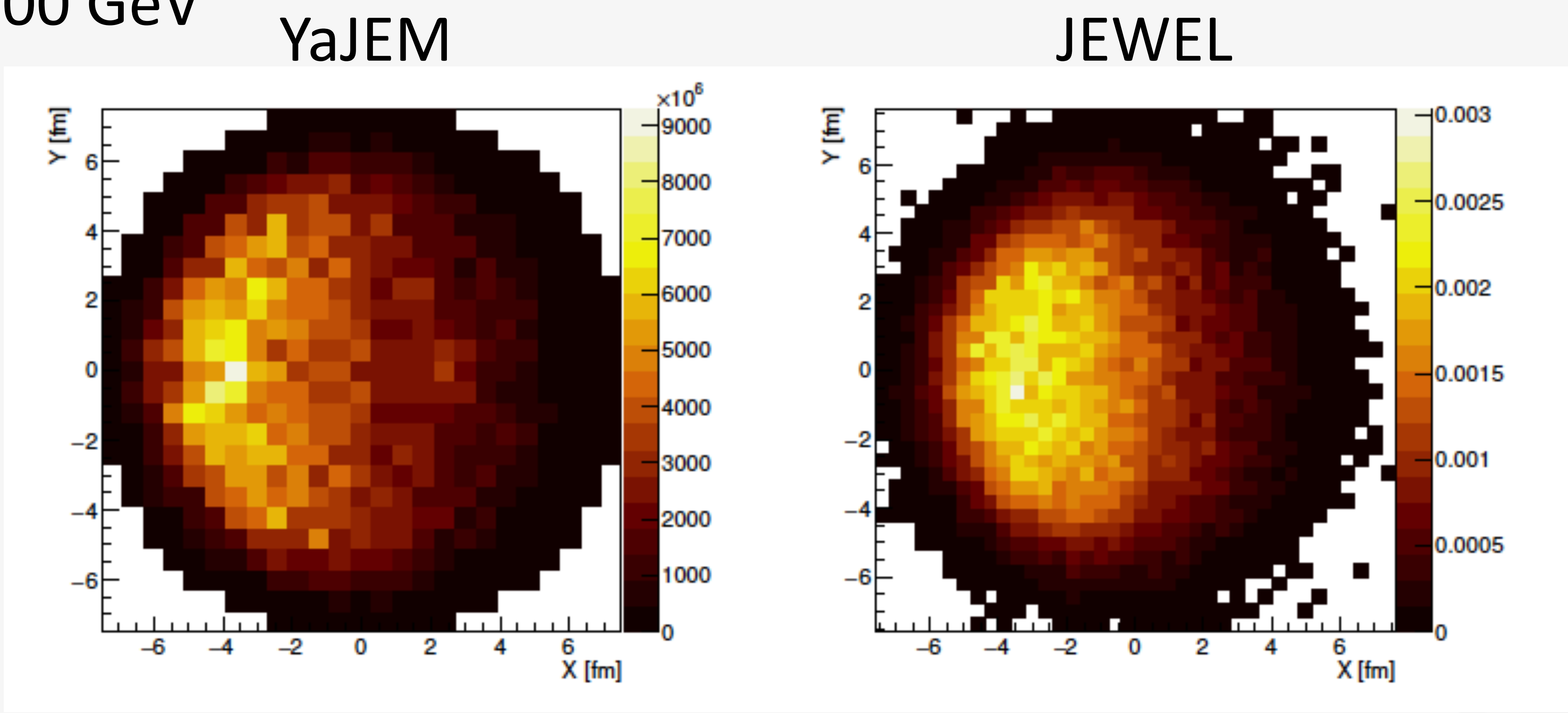
“vacuum” AS peak,

measured in pp collisions

Surface bias with jet trigger

AuAu at 200 GeV

trigger jet direction



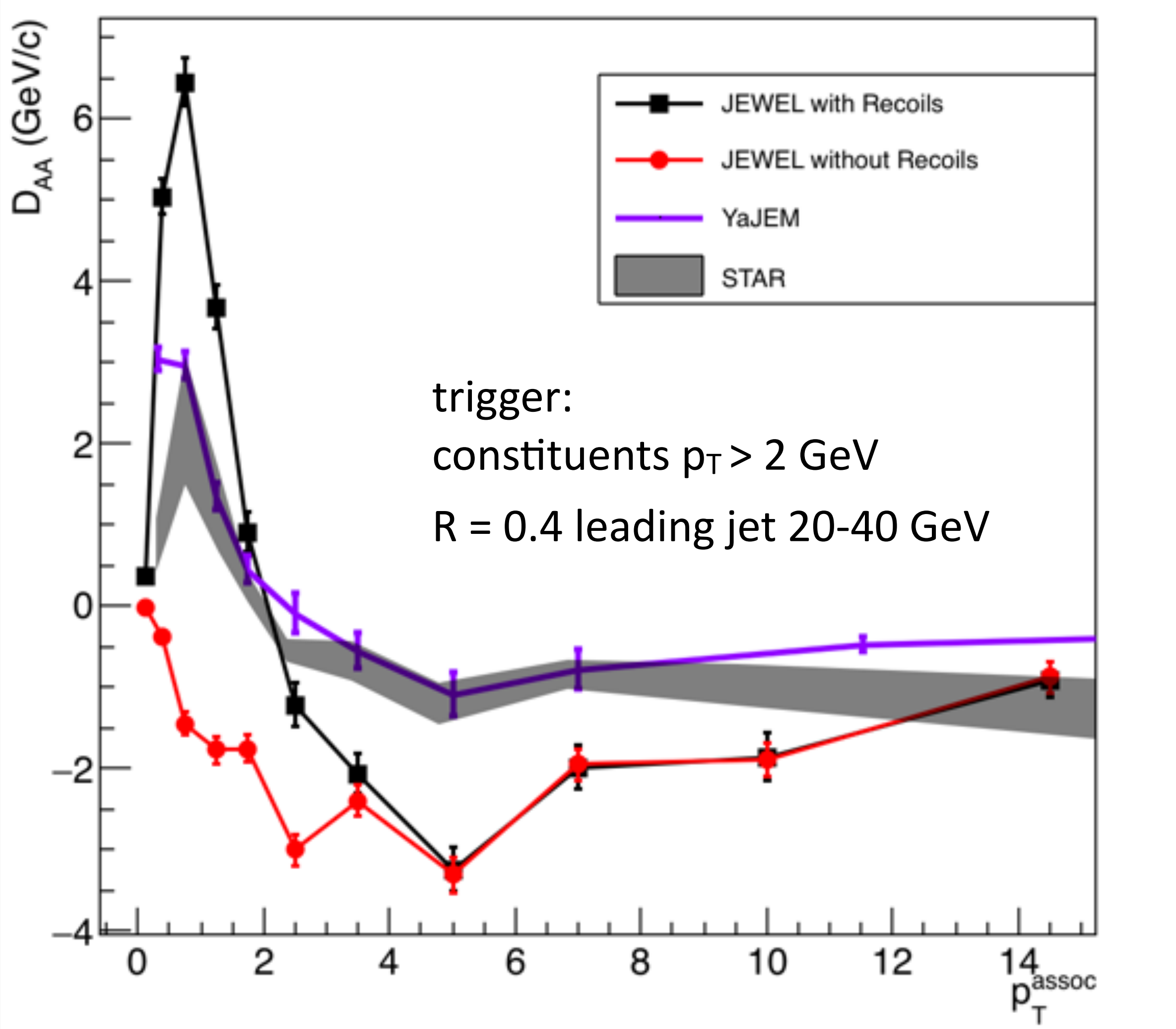
constituents $p_T > 2$ GeV
R = 0.4 leading jet 20-40 GeV
(Kinematic selection used by STAR for j-h correlations)

- Large surface bias in AuAu 200 GeV
- Very similar results using YaJEM and JEWEL
- Trigger jet is pp-like

D_{AA} AuAu 200 GeV JEWEL vs YaJEM

$$D_{AA}(p_T^{assoc}) \equiv Y_{Au+Au}(p_T^{assoc}) \cdot \langle p_T^{assoc} \rangle_{Au+Au} - Y_{p+p}(p_T^{assoc}) \cdot \langle p_T^{assoc} \rangle_{p+p}.$$

away side



STAR data: Phys. Rev. Lett. 112 (2014) 12, 122301

- qualitatively similar results by YaJEM and JEWEL with recoils (**φ**-uniform background subtracted)
- lost energy redistributed to soft particles $p_t < 2$ GeV
- JEWEL without recoils — energy balance not restored

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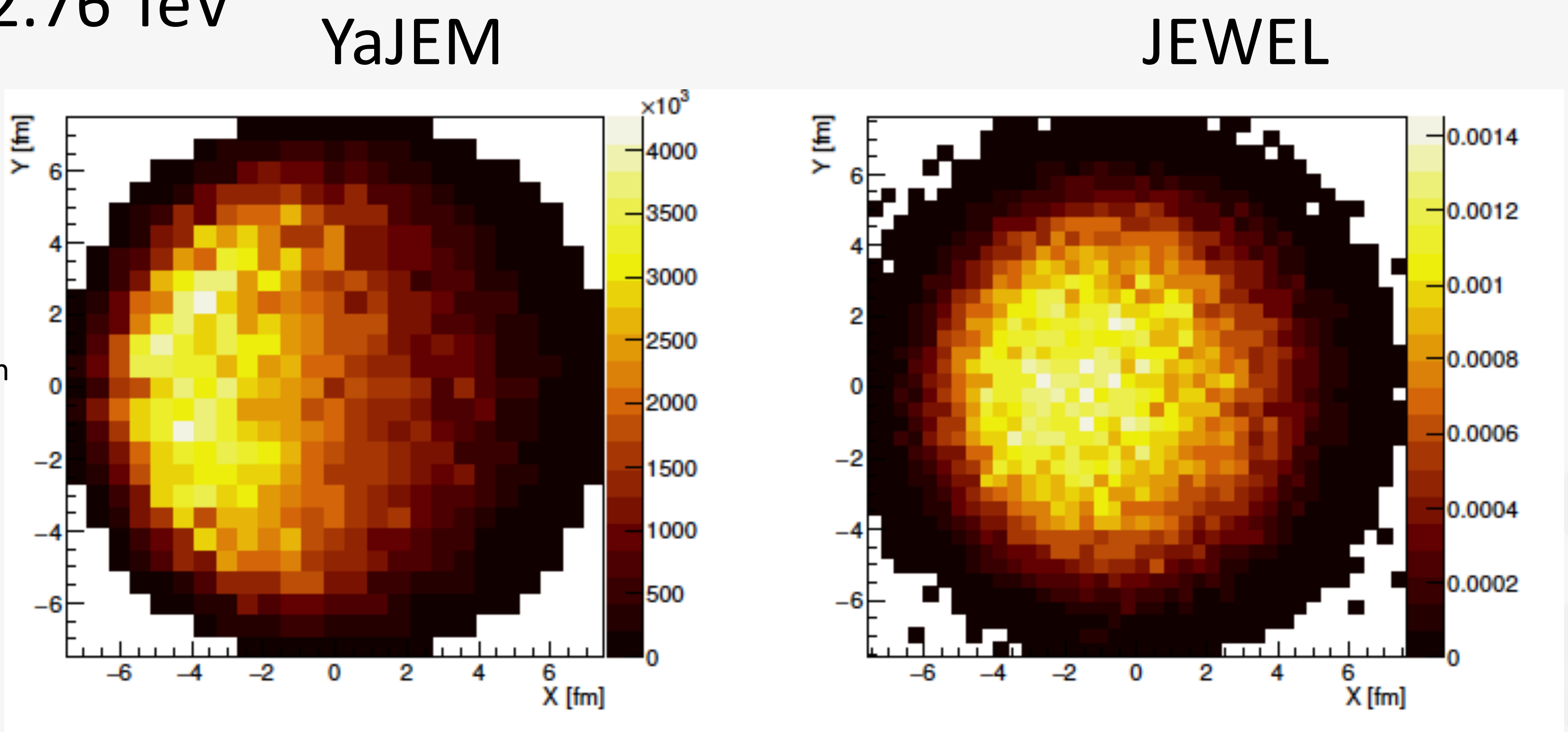
Surface bias with jet trigger

PbPb at 2.76 TeV

trigger jet direction



constituents $p_T > 3$ GeV

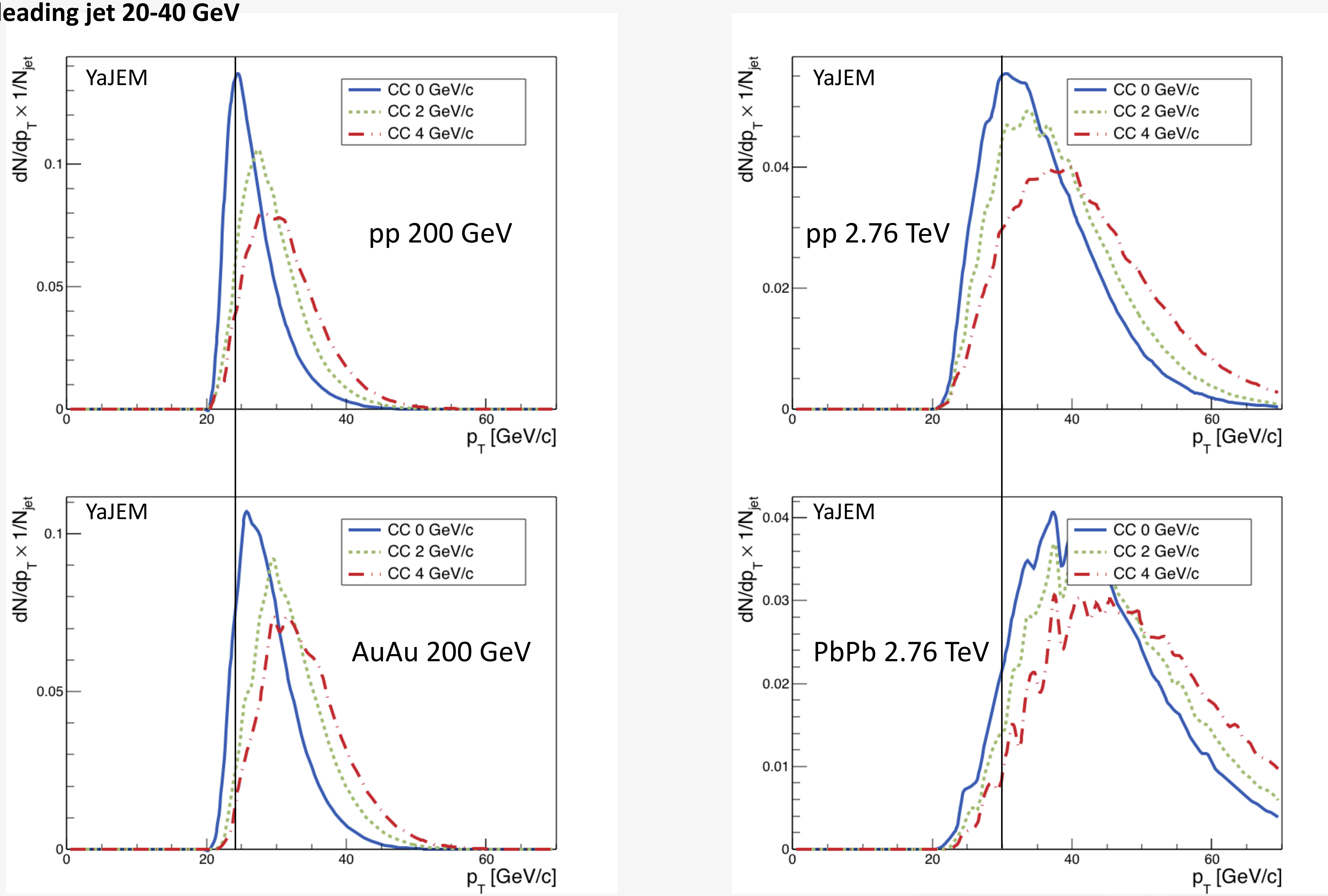
R = 0.2 leading jet 20-40 GeV

(Kinematic selection relevant for ALICE)

- YaJEM (1D hydro): still significant surface bias at LHC
- JEWEL: much smaller surface bias
- However, both models predict larger energy losses by the trigger jet compared to RHIC, hampers comparison with pp-collisions

Jet-parton p_t correlation

leading jet 20-40 GeV



Jet true energy mismatch 5-10 GeV for PbPb 2.76 TeV

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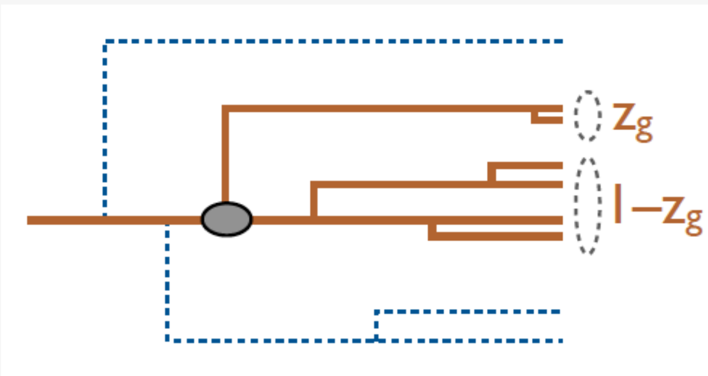
Hard Jet Splitting probed with Soft Drop

A. J. Larkoski, S. Marzani, G. Soyez, J. Thaler JHEP 05 (2014) 146

A. J. Larkoski, S. Marzani, J. Thaler PRD 91, 111501(R)



$$\frac{\min(p_{T1}, p_{T2})}{p_{T1}+p_{T2}} > z_{\mathrm{cut}}$$

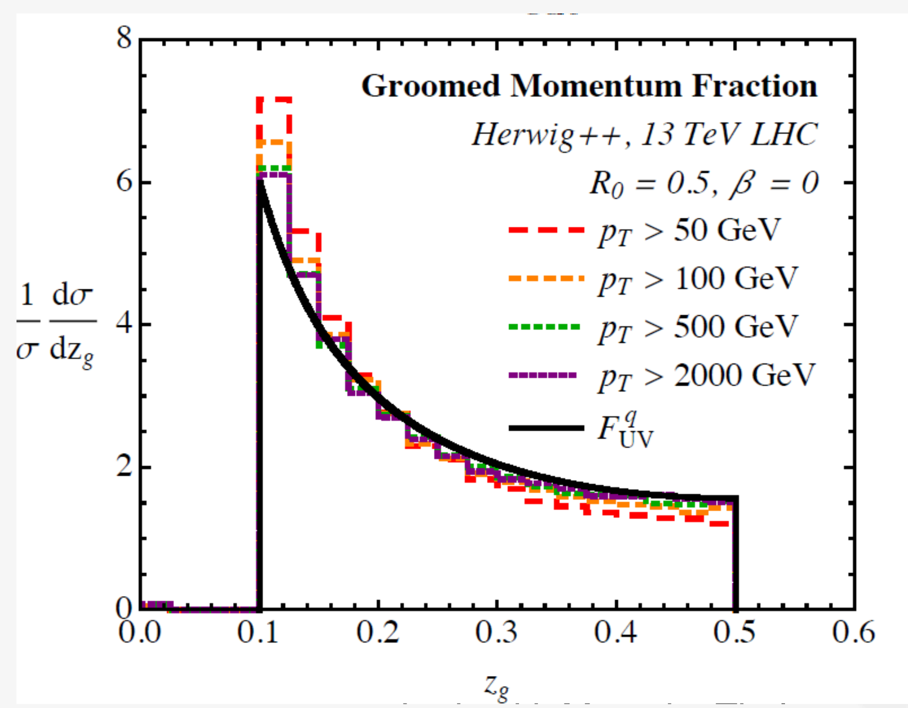
recursively removes soft subjets, until a hard splitting is identified

$$z_g = \frac{\min(p_{T1}, p_{T2})}{p_{T1}+p_{T2}}$$

groomed momentum fraction

$$p(z_g) = \frac{\overline{P}_i(z_g)}{\int_{z_{\mathrm{cut}}}^{1/2} dz\, \overline{P}_i(z)} \Theta(z_g - z_{\mathrm{cut}})$$

$$\overline{P}_i(z) = P_i(z) + P_i(1-z)$$

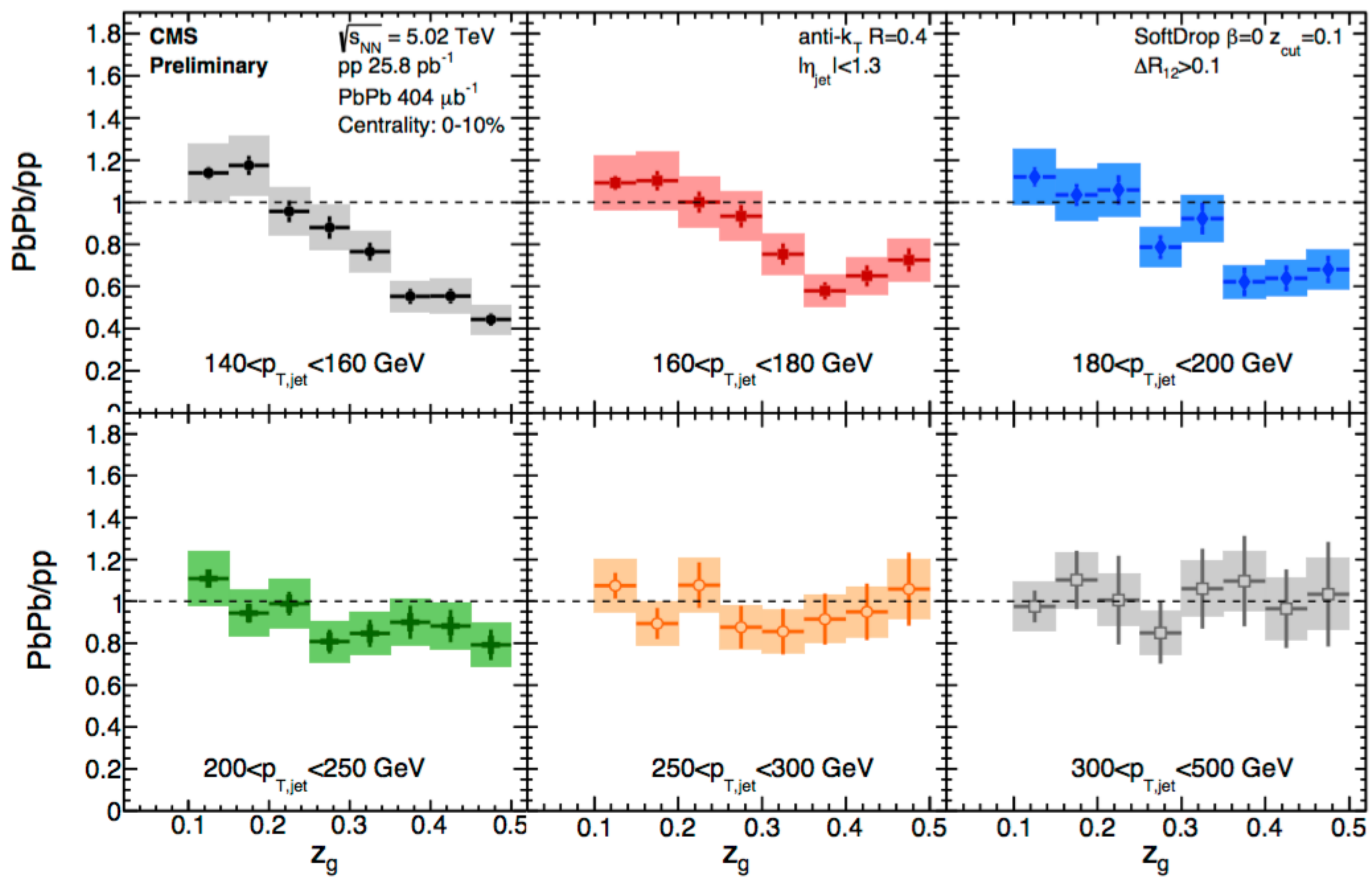


$p(z_g)$ is approx. independent of:
- jet p_t and radius
- α_S
- collision energy

What MC including jet quenching effects predicts?

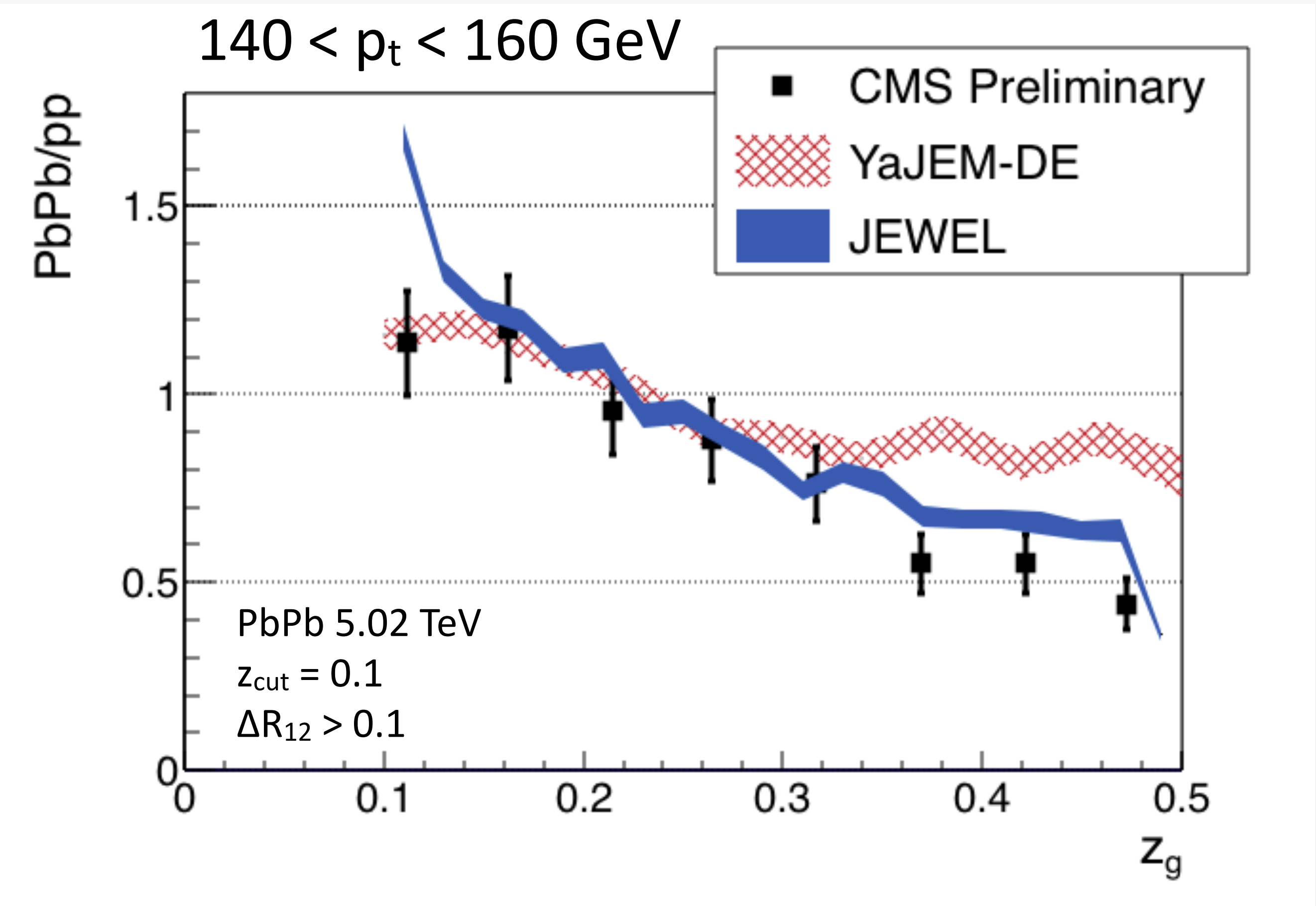
Experimental data

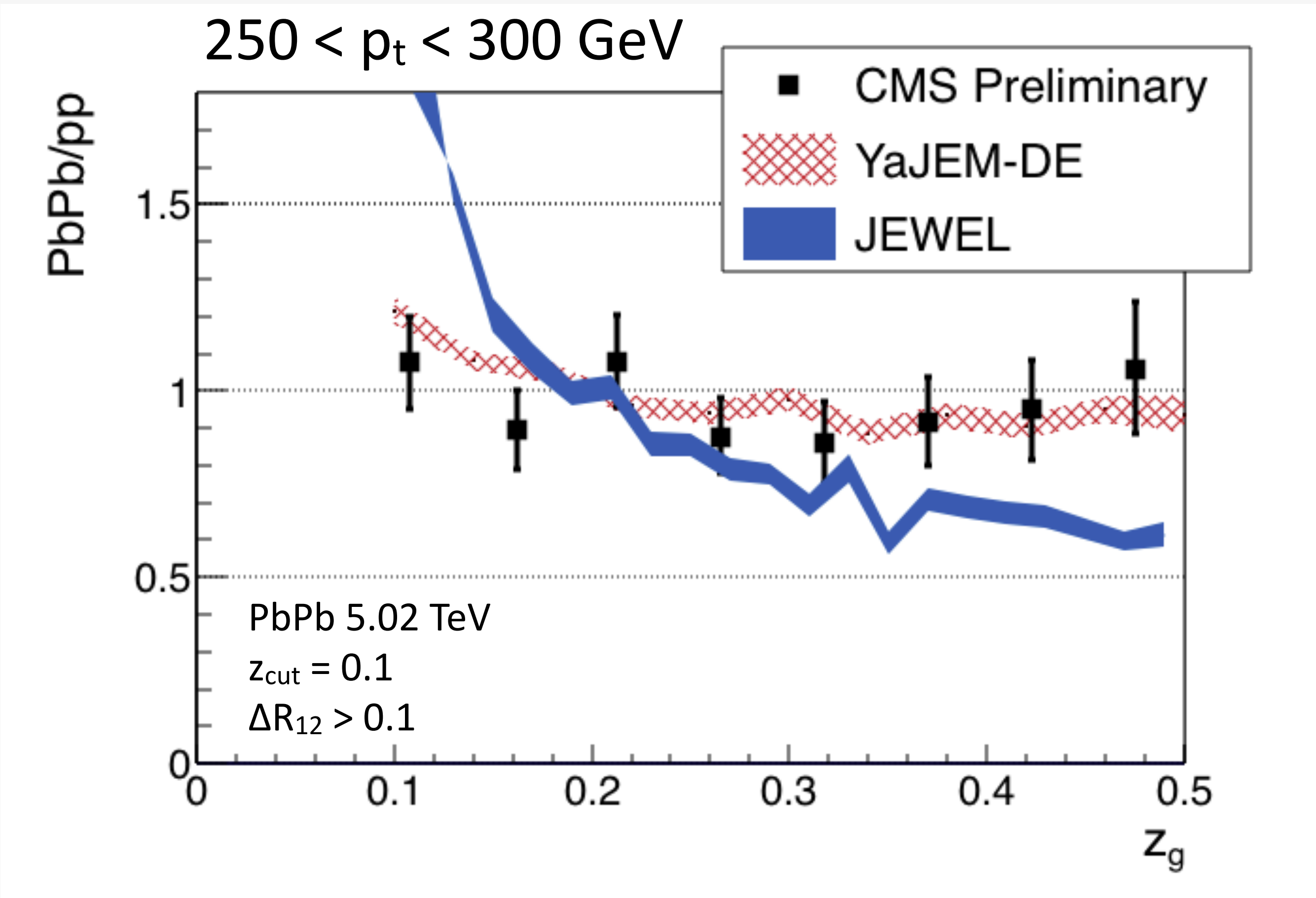
CMS PAS HIN-16-006



- Significant effect observed in the lowest p_t bin
- Momentum-dependent behavior

z_g: Data vs. Models





- Good discriminating potential of the z_g observable
- Momentum dependence is not described well
- Both models (YaJEM-DE and JEWEL) incorporate unmodified splitting functions

K. Zapp, Phys.Lett. B735 (2014) 157-163

Is z_g sensitive to a modified P(z)?

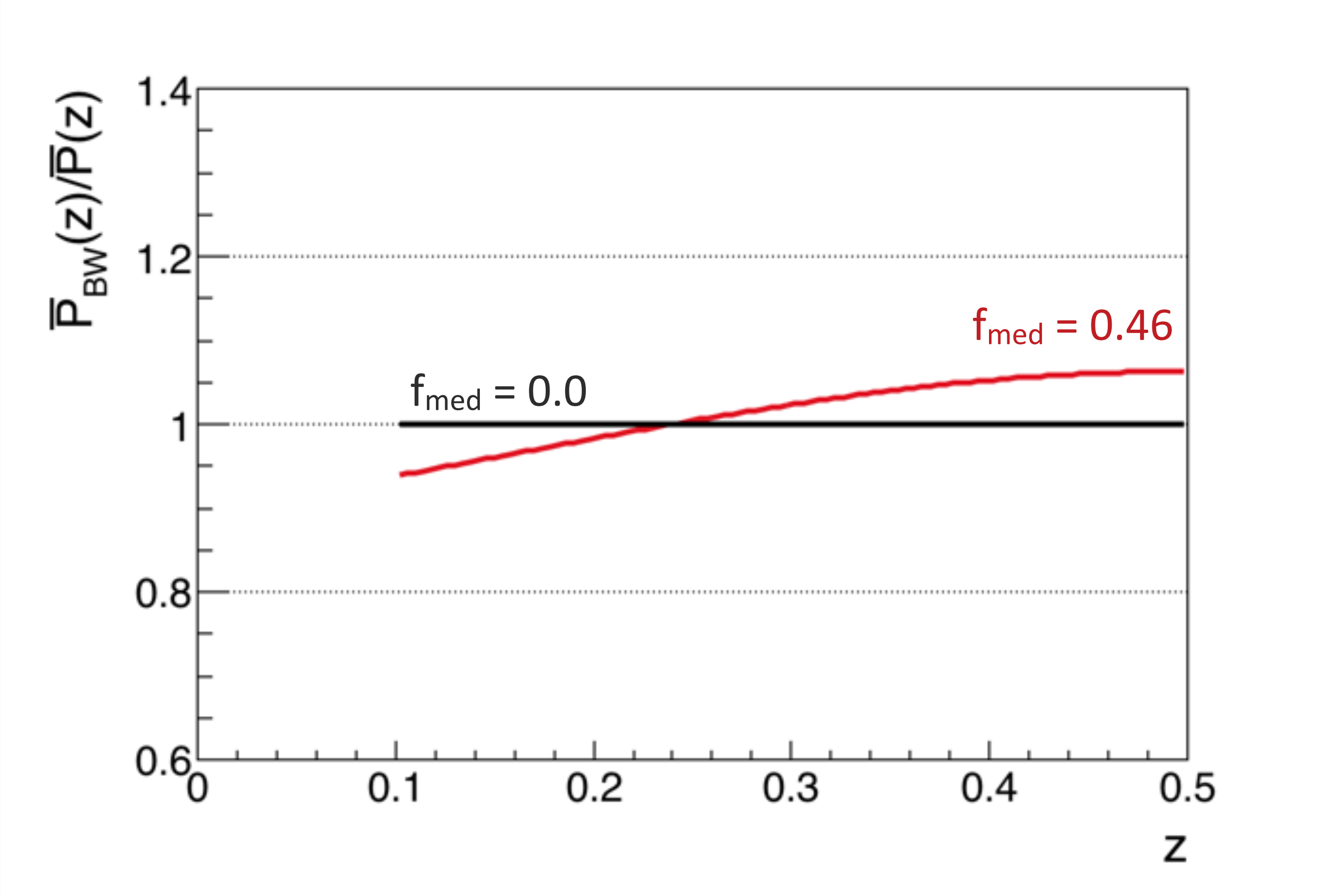
YaJEM-BW

Does an explicit modification of the splitting function propagate to the z_g observable?

YaJEM-**BW:** $$P_{q\to qg} = \frac{4}{3}\frac{1+z^2}{1-z} \Rightarrow \frac{4}{3}\left(\frac{2(1+f_{\mathrm{med}})}{1-z} - (1+z)\right)$$

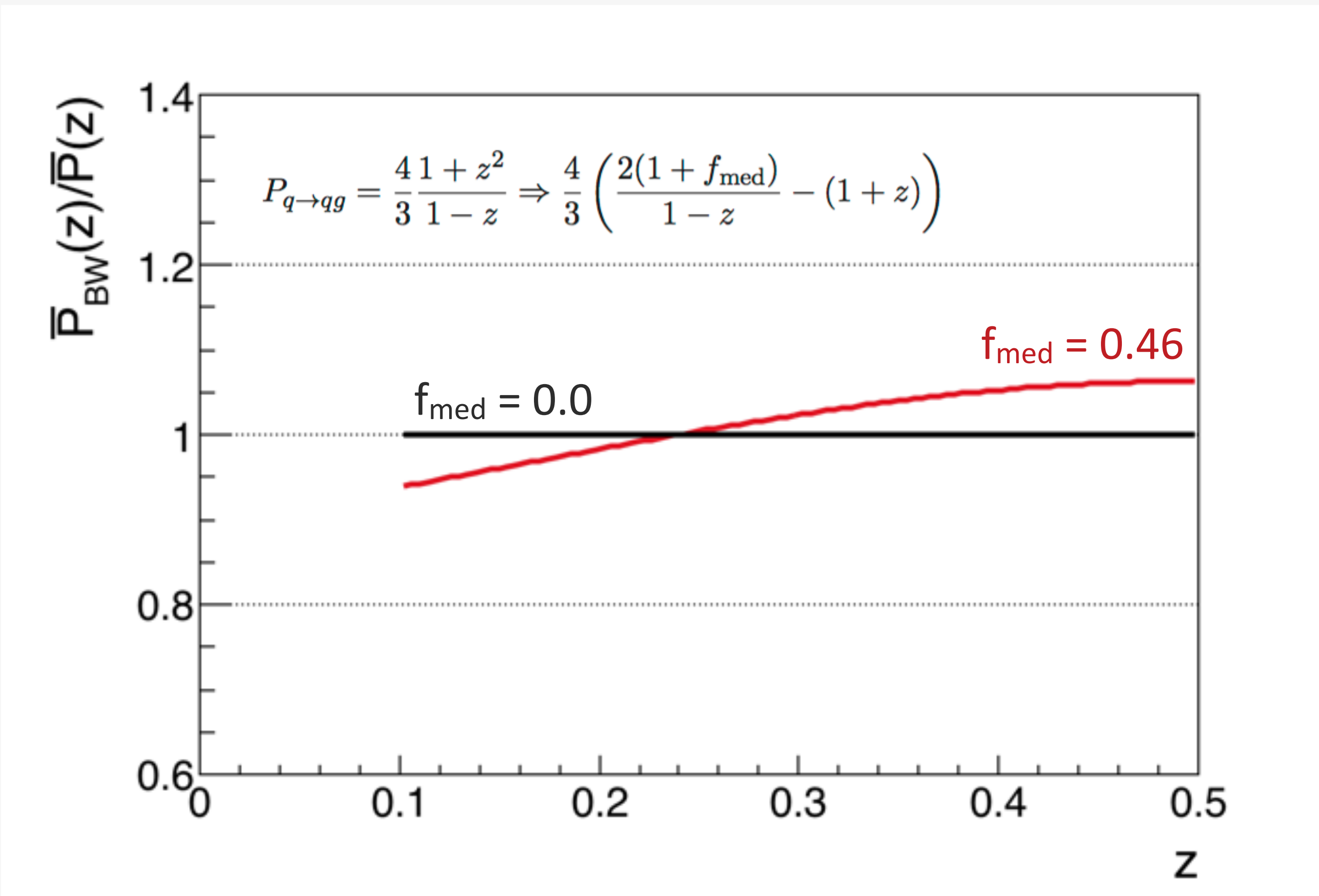
$$p(z_g) = \frac{\overline{P}_i(z_g)}{\int_{z_{\mathrm{cut}}}^{1/2} dz\, \overline{P}_i(z)} \Theta(z_g - z_{\mathrm{cut}})$$

$$\overline{P}_i(z) = P_i(z) + P_i(1-z)$$

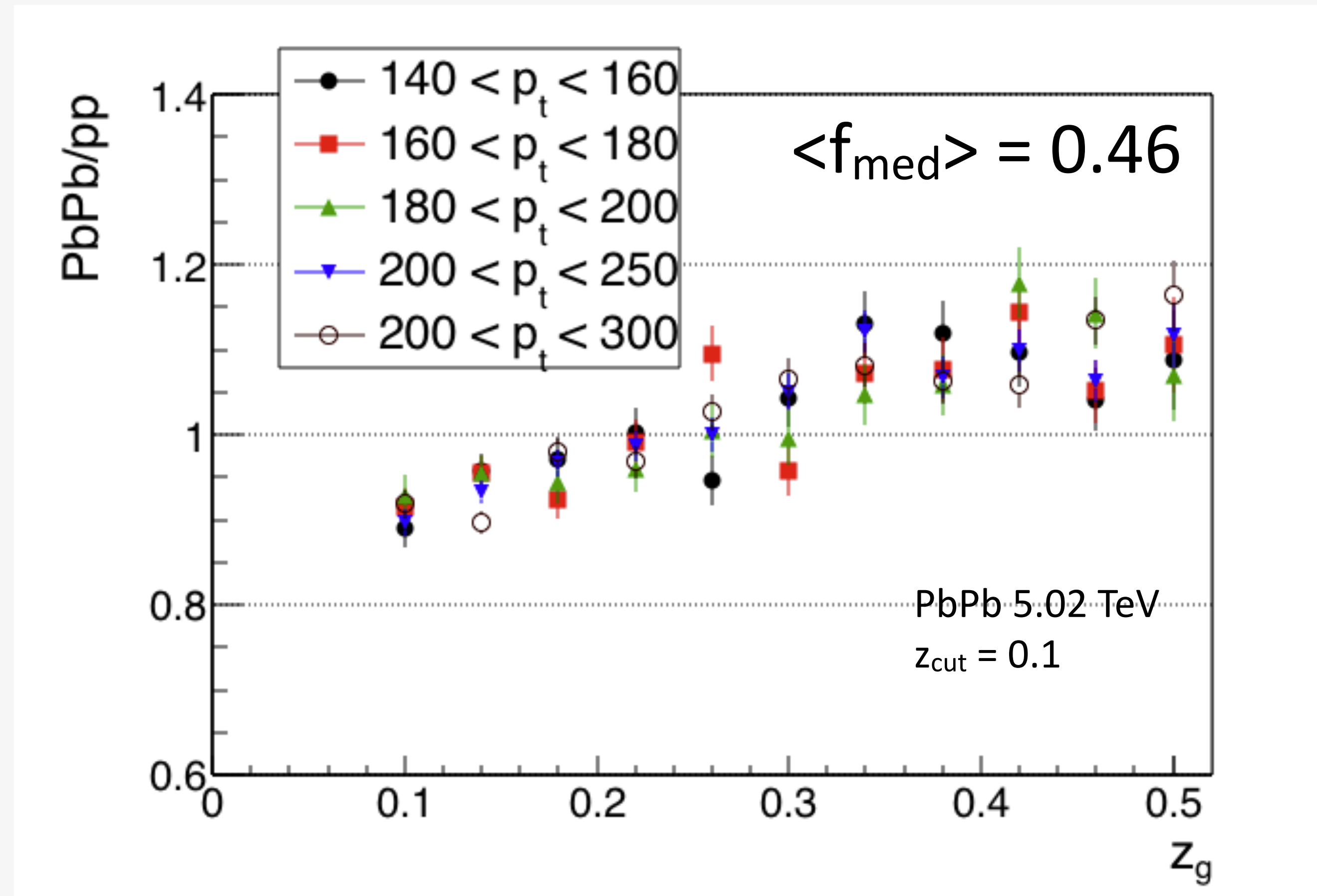


YaJEM-BW results

MC input: modified P(z)



MC ouput: modified $p(z_g)$



- YaJEM-BW: modification of the P(z) is directly propagated to the measurable z_g

Conclusions

- Jet-hadron correlations:
  - D_{AA}: qualitatively similar results by YaJEM and JEWEL with recoils
  - JEWEL without recoils fails to describe D_{AA}
  - Energy loss by the trigger jet is not negligible for LHC

- Hard intra-jet structure probed with Soft Drop:
  - z_g discriminates between YaJEM-DE and JEWEL models
  - Models show approx. p_t-independent behavior
  - z_g is sensitive to explicit P(z) modification (YaJEM-BW), but also to other aspects of in-medium parton showers (YaJEM-DE, JEWEL)

Backup slides

- Run Monte Carlo model with appropriate settings, kinematic regions, weighting
- Apply experimental cuts (rapidity, pt); based on ALICE capabilities.
- Run anti-KT, calculate $\Delta\phi$ jet-track correlations.
- Fit to a function with a nearside and awayside peak and constant background.
- Subtract nearside peak + background from correlations, take integral (Yield), RMS (width) of awayside.
  - This minimizes dependence on the chosen fit function.
  - Here, use sum of two Gaussians for nearside peak, generalized gaussian for wayside peak
- Calculate $D_{AA} = Y_{AA}(p_{T,AA}^{assoc})\langle p_{T,AA}^{assoc}\rangle - Y_{pp}(p_{T,pp}^{assoc})\langle p_{T,pp}^{assoc}\rangle$