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What do we learn from the first EEC measurements in PbPb collisions by the CMS collaboration?

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for the CMS Collaboration

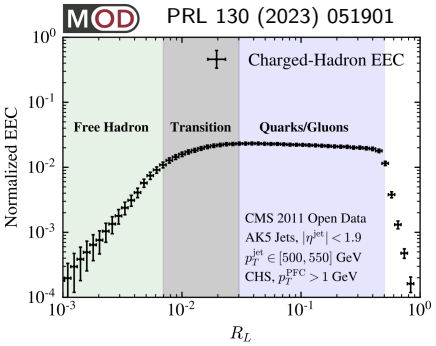
SoftJet 2024

Energy-energy correlator definition

$$\frac{\mathrm{d}\Sigma}{\mathrm{d}\theta} = \int \mathrm{d}\vec{n}_{1,2} \frac{\langle \epsilon(\vec{n}_1)\epsilon(\vec{n}_2)\rangle}{Q^2} \delta^2(\vec{n}_1 \cdot \vec{n}_2 - \cos(\theta))$$

- $\epsilon(\vec{n})$ = Energy flow to direction $\vec{n}$
- Q^2 = Hard scale of the process
- $\delta^2(\vec{n}_1 \cdot \vec{n}_2 - \cos(\theta))$ = Require angle θ between direction vectors

Komiske, Moult, Thaler, Zhu



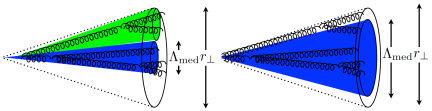
- Reasons to love energy correlators:
  - Scaling: Different time scales of jet evolution imprinted in different angular scales
  - Simplicity: No jet declustering needed, can be constructed using tracks
  - Control: Well understood pp baseline, medium modifications perturbatively calculable

Color coherence

Image credit: Jennifer James (Vanderbilt)

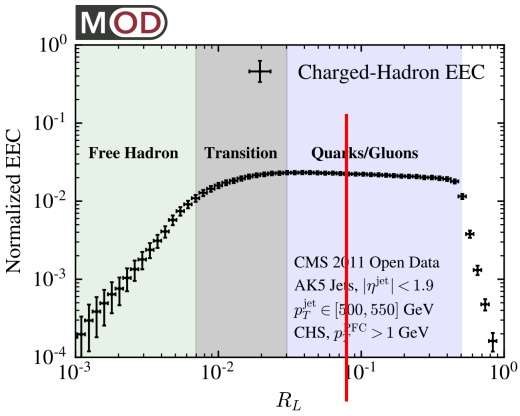
Casalderrey-Solana, Mehtar-Tani, Salgado, Tywoniuk

PLB 725 (2013) 357-360



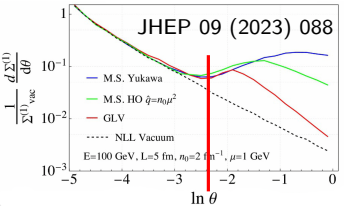
- Large angle emission: medium resolves emitted gluon as separate object
- Small angle emission: emitted gluon and emitter resolved as single object
- Critical angle: minimum separation where medium resolves separate objects

Color coherence effects to the correlator shape

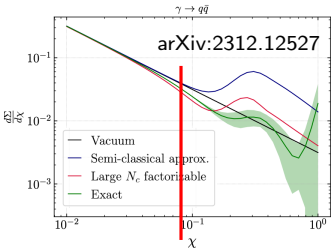


- Color coherence effects expected to change the shape at $\theta \gtrsim 0.08$

Andrés, Dominguez, Holguin, Marquet, Moult



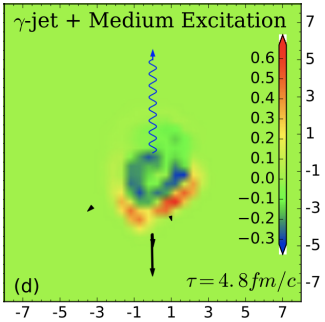
Barata, Caucal, Soto-Ontoso, Szafron



Jet wake

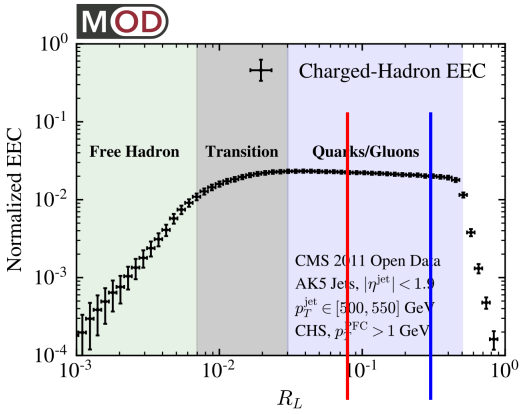
Image stolen from: Yen-Jie Lee (MIT)

Chen, Cao, Luo, Pang, Wang
PLB 777 (2018) 86



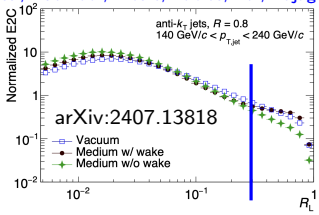
- Energetic parton pulls medium with it, leaving depletion behind

Jet wake effects to the correlator shape

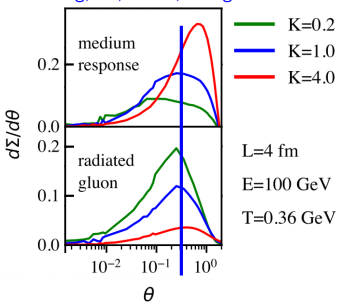


- Jet wake effects expected to change the shape at $\theta \gtrsim 0.3$

Bossi, Kudinoor, Moult, Pablos, Rai, Rajagopal

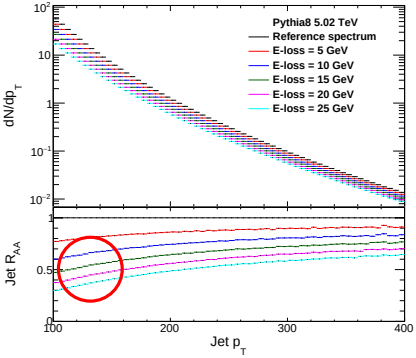


Yang, He, Moult, Wang

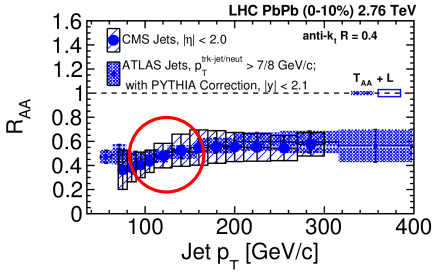


PRL 132 (2024) 1, 011901

Simple energy loss model: p_{T} spectrum shift in Pythia8

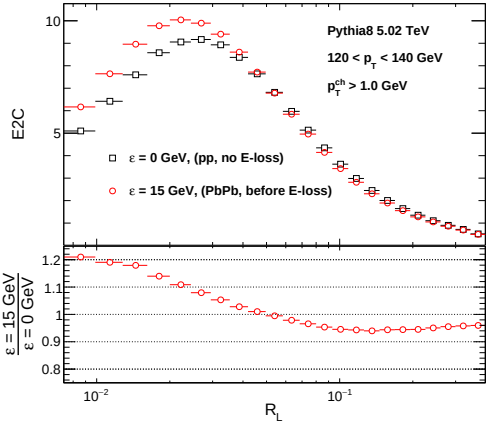


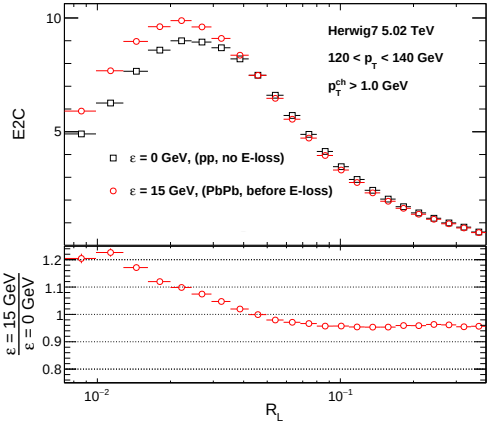
ATLAS: PRL 114 (2015) 072302
CMS: PRC 96 (2017) 015202



- Estimating energy loss effects in data
  - Shift the jet p_{T} spectrum in Pythia8
  - Find a shift that produces measured jet R_{AA} around $p_{\mathrm{T}} = 120\,\mathrm{GeV}$ ($\varepsilon = 15\,\mathrm{GeV}$)
  - Compare energy-energy correlators in shifted and reference p_{T} bins

Medium effects: jet p_{T} spectrum shift





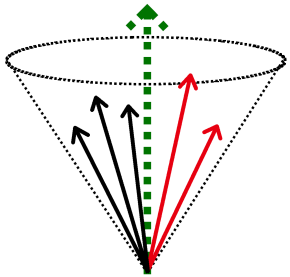
- Shift in peak position creates enhancement at small Δr region
- Simple energy loss does not modify large Δr region significantly

Energy-energy correlator definition for this analysis

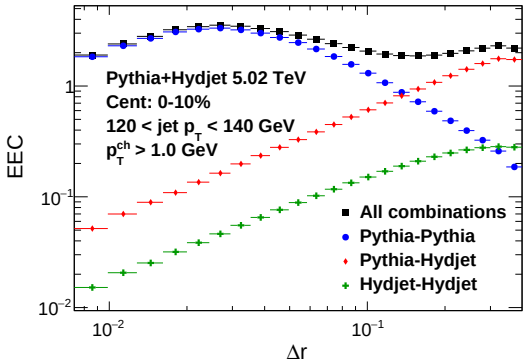
$$\frac{\mathrm{d}\Sigma}{\mathrm{d}\theta} = \int \mathrm{d}\vec{n}_{1,2} \frac{\langle \epsilon(\vec{n}_1)\epsilon(\vec{n}_2)\rangle}{Q^2} \delta^2(\vec{n}_1 \cdot \vec{n}_2 - \cos(\theta))$$

$$\mathrm{EEC}(\Delta r) = \frac{1}{W_{\mathrm{pairs}}} \frac{1}{\delta r} \sum_{\mathrm{jets} \in [p_{\mathrm{T},1}, p_{\mathrm{T},2}]} \sum_{\mathrm{pairs} \in [\Delta r_a, \Delta r_b]} (p_{\mathrm{T},i}\, p_{\mathrm{T},j})^n$$

- Normalize with weighted number of pairs W_{pairs}
- Bin width normalization: $\delta r = \Delta r_b - \Delta r_a$
- Hard scale appears only in jet p_{T} binning
  - Improves resolution, no need for unfolding
- Exponent values $n = 1$ and $n = 2$ used in this analysis
- Selects pairs within $R = 0.4$ from winner-take-all jet axis



Expected background in PbPb collisions



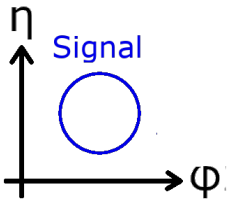
- Different pairings in the simulation
  - All pairs
  - Signal+signal pairs
  - Signal+background pairs
  - Background+background pairs
- Background contributions dominant at large Δr
- Background subtraction needed

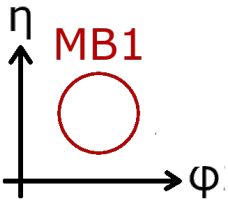
The good 

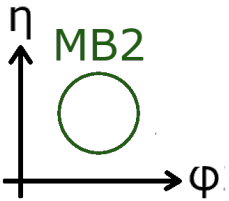
The bad 

The ugly 

Mixed cone background subtraction method



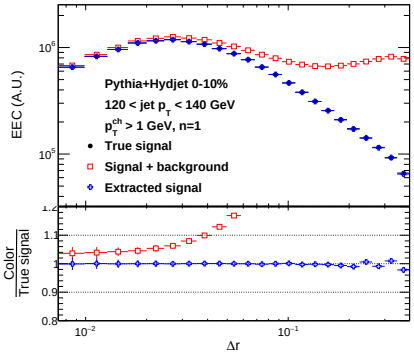




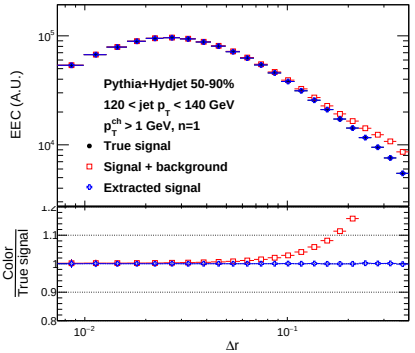
- Three cones are used in this method
  1. Signal cone: this is around the studied jet
  2. Minimum bias cone 1: same location as jet cone in minimum bias event
  3. Minimum bias cone 2: same location as jet cone in another minimum bias event
- Three different pairings are made from the cones
  1. $\mathrm{S} + \mathrm{M1}$: signal+fake together with mismodeled fake+fake
  2. $\mathrm{M1} + \mathrm{M1}$: properly modeled fake+fake
  3. $\mathrm{M1} + \mathrm{M2}$: mismodeled fake+fake
- Extract background: $\mathrm{BG} = (\mathrm{S} + \mathrm{M1}) + (\mathrm{M1} + \mathrm{M1}) - (\mathrm{M1} + \mathrm{M2})$

Signal extraction in Pythia+Hydjet

$C = 0 - 10\%$

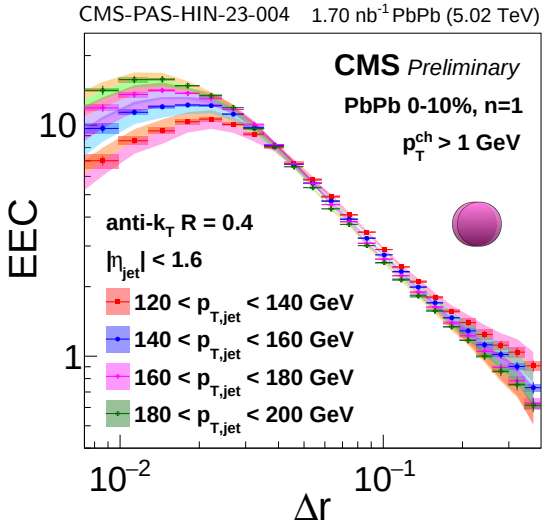


$C = 50 - 90\%$



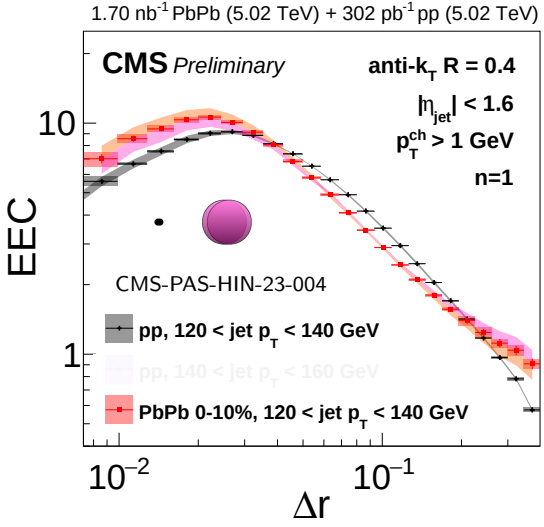
- Even with high background, signal can be very accurately extracted!

Energy-energy correlator distributions, PbPb 0-10%



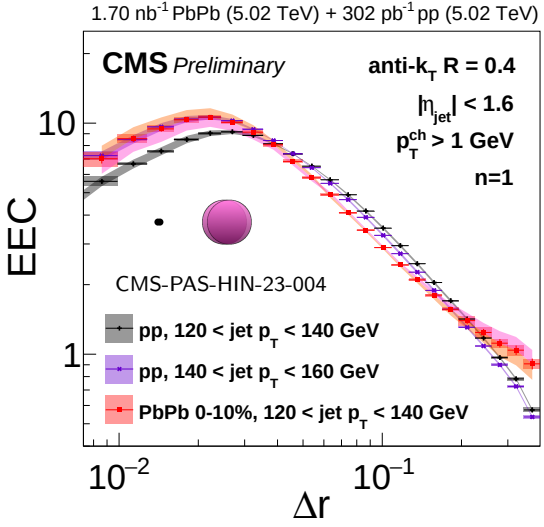
- PbPb distributions have the same features as previously seen in pp!
  - CMS: PRL 133 (2024) 071903
  - STAR: PoS HP2023 (2024) 175
  - ALICE: ALI-PREL-540213
- Low $\Delta r \rightarrow$ free hadrons
- Moderate $\Delta r \rightarrow$ transition
- High $\Delta r \rightarrow$ free quark/gluon
- Peak depends on jet p_{T}
- Lesson 1: Breaking of angular ordering does not break the general picture!

Medium modifications in energy-energy correlators



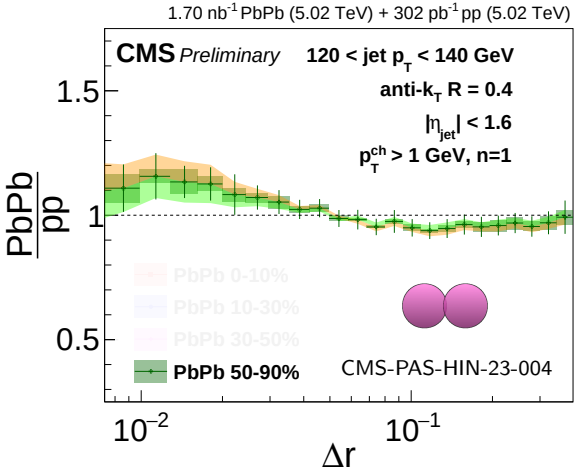
- The jet peak moves towards smaller Δr for more central collisions
- Energy loss effect $\rightarrow$ more central jets have higher initial virtuality
- Also the shape of the distribution at large Δr is modified!

Medium modifications in energy-energy correlators



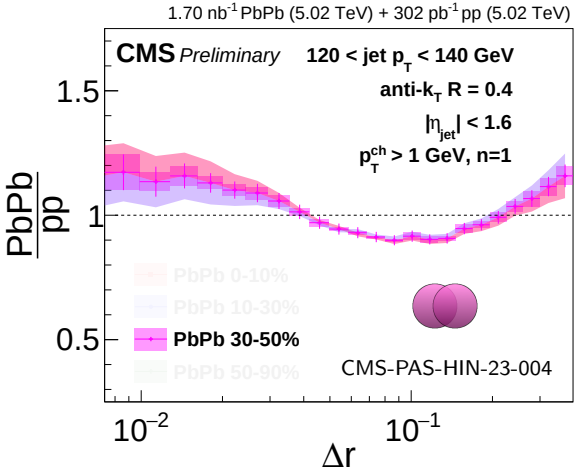
- The jet peak moves towards smaller Δr for more central collisions
- Energy loss effect $\rightarrow$ more central jets have higher initial virtuality
- Also the shape of the distribution at large Δr is modified!
- Lesson 2: Amount of energy loss proportional to shift in peak position!
- Lesson 3: Suppression of vacuum-like radiation in jet shower!

PbPb to pp ratio, centrality evolution



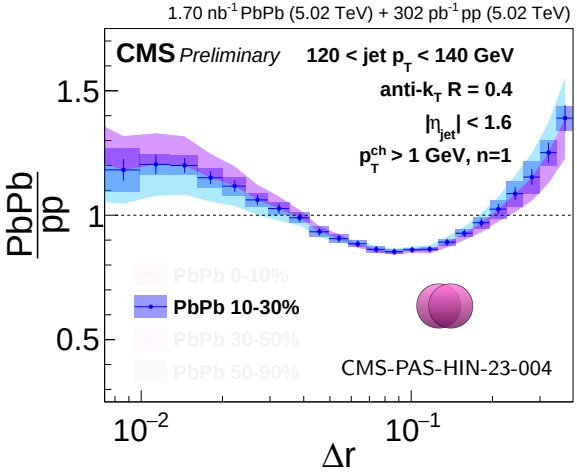
- Peripheral distribution shows only small modifications

PbPb to pp ratio, centrality evolution



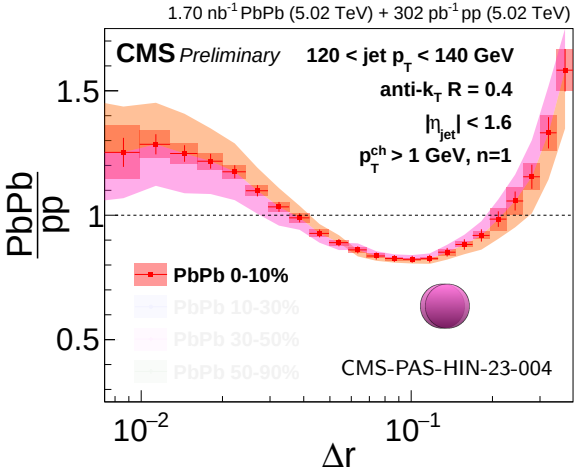
- Peripheral distribution shows only small modifications
- Enhancement at low Δr due to energy loss

PbPb to pp ratio, centrality evolution



- Peripheral distribution shows only small modifications
- Enhancement at low Δr due to energy loss
- Change in trend around $\Delta r \sim 0.1$ to enhancement at large Δr

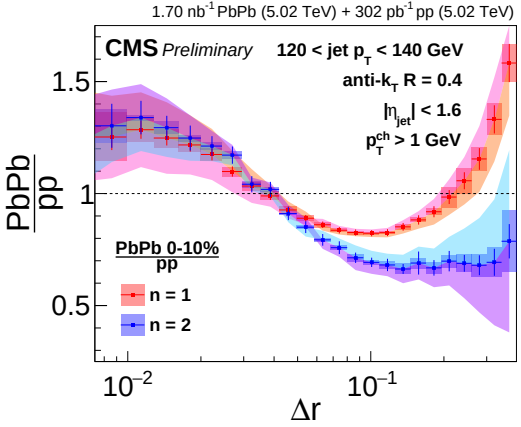
PbPb to pp ratio, centrality evolution

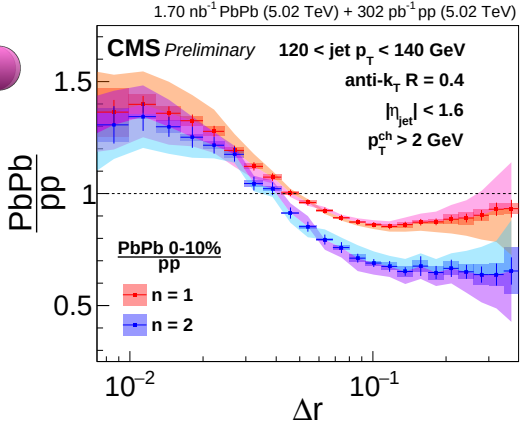


- Peripheral distribution shows only small modifications
- Enhancement at low Δr due to energy loss
- Change in trend around $\Delta r \sim 0.1$ to enhancement at large Δr
- Flat trend at few lowest Δr bins $\rightarrow$ Lesson 4: universal scaling for free hadrons!

PbPb to pp ratio and kinematic cuts

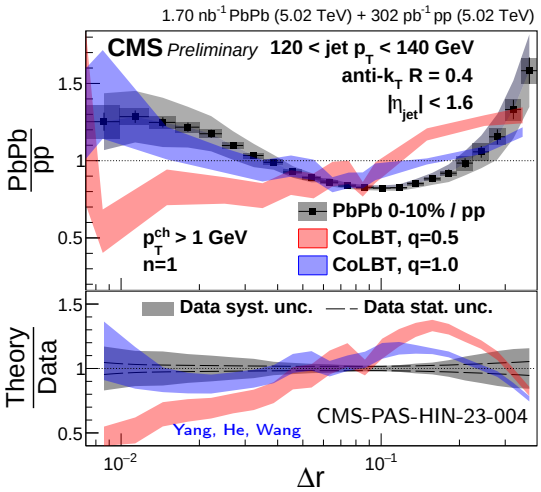
$p_{\mathrm{T}}^{\mathrm{ch}} > 1$ GeV CMS-PAS-HIN-23-004 $p_{\mathrm{T}}^{\mathrm{ch}} > 2$ GeV





- Lesson 5: Sensitivity to low p_{T} particles essential for large Δr enhancement!

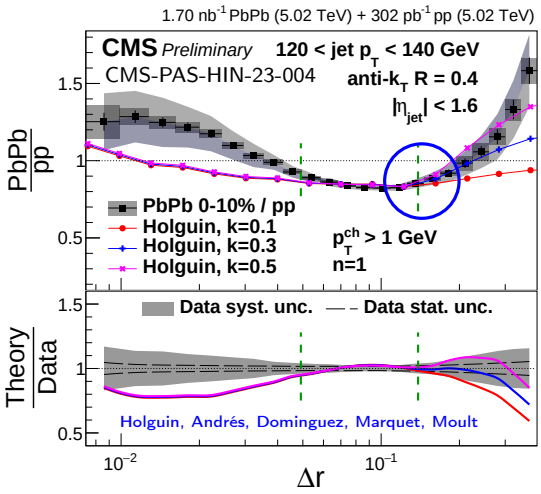
CoLBT model comparison for PbPb/pp ratio



- q-parameter in CoLBT[1] model describes the minimum virtuality for vacuum splittings
- $q = 0.5$ doesn't describe the data well
- $q = 1$ is better, but earlier turn-on and less enhancement than in data
- Enhancement at large Δr in CoLBT mainly coming from medium response
- There is also gluon radiation component

[1] PLB 777 (2018) 86, PLB 810 (2020) 135783, PRL 128 (2022) 2, 022302

Perturbative calculation with color coherence effects

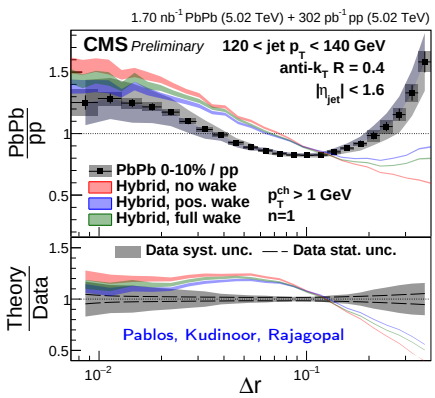


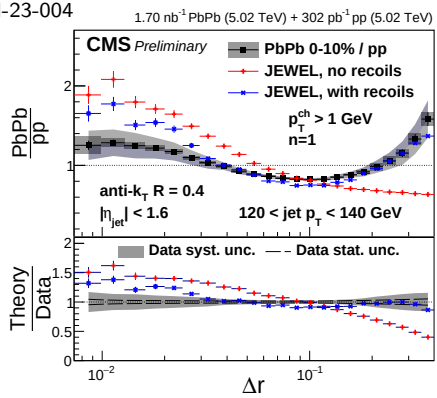
- Perturbative calculation by Holguin&co[4] includes color coherence
- Two free parameters: k and normalization
- Calculation normalized to data in region $0.042 < \Delta r < 0.126$
- Underprediction at large Δr
- Turn-on angle is similar in calculation and data

[4] arXiv:2407.07936

Jet wake in the Hybrid model and JEWEL

CMS-PAS-HIN-23-004



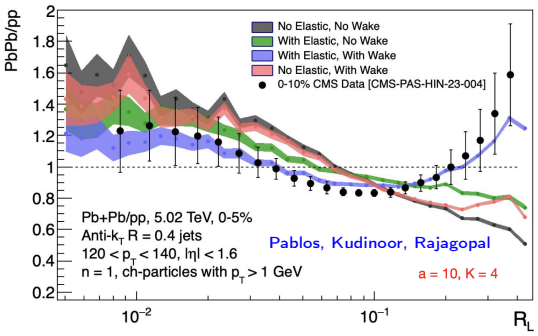


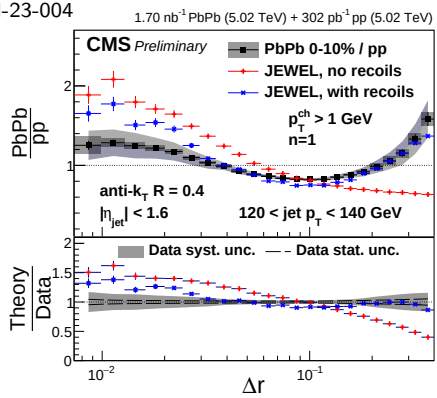
- Both Hybrid model[2] and JEWEL[3] only predict large Δr enhancement with wake included

[2] JHEP 09 (2015) 175, JHEP 03 (2017) 135 [3] EPJC 60 (2009) 617, JHEP 1707 (2017) 141

Jet wake in the Hybrid model and JEWEL

CMS-PAS-HIN-23-004



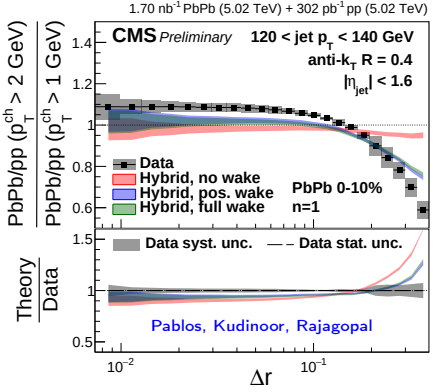


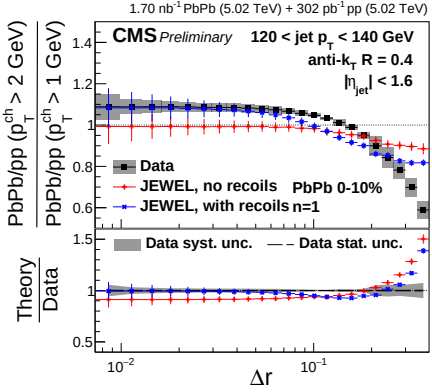
- Both Hybrid model[2] and JEWEL[3] only predict large Δr enhancement with wake included
- Elastic scatterings important to get good description of the data

[2] JHEP 09 (2015) 175, JHEP 03 (2017) 135 [3] EPJC 60 (2009) 617, JHEP 1707 (2017) 141

Hybrid model and JEWEL comparison for double ratio

CMS-PAS-HIN-23-004



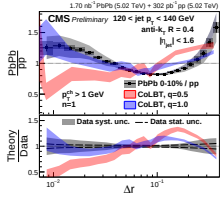


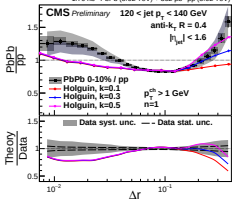
- Isolate the effects of soft-hard correlations with double ratio
- Interesting to see what elastic scatterings do for the double ratio

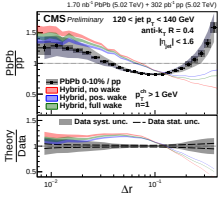
Conclusions from model comparisons

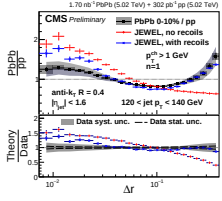
Double-edged lesson

- Color coherence, jet wake, elastic scattering predictions qualitatively agree with data
- Sensitivity to these effects!
- All in similar angular region $\Rightarrow$ difficult to disentangle









- Might be able to isolate (some) effects better with EEEC:s (see Arjun's talk, Sat 14:30)
- We could also be able to improve sensitivity to medium modifications

Improve sensitivity by reducing energy loss effects

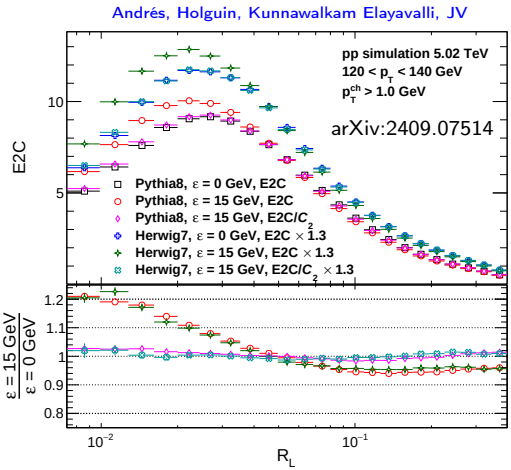
- Mitigate leading energy loss effects with cumulative distribution functions:

$$F_{\mathrm{ENC}}(R_{\mathrm{L}}, p) \equiv \int_0^{R_{\mathrm{L}}} (f_{\mathrm{ENC}}(R))^p \, \mathrm{d}R$$

$$C_p(R_{\mathrm{L}}) \equiv \left(\frac{F_{\mathrm{ENC}}^{\mathrm{AA}}(R_{\mathrm{L}}, p)}{F_{\mathrm{ENC}}^{\mathrm{pp}}(R_{\mathrm{L}}, p)} \right)^{\frac{2}{p+1}} - E_{\mathrm{peak}} \frac{p-1}{p+1}$$

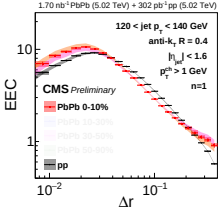
where E_{peak} is the energy loss evaluated at the peak

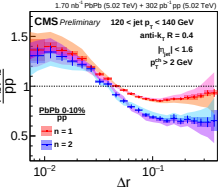
- See hadronization modifications?
- See medium modifications more clearly?
- See Carlota's talk at 16:40 for details

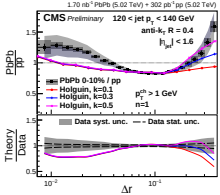


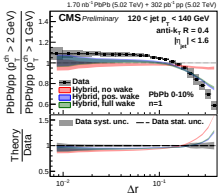
Summary

- The first EEC measurement teaches us several valuable lessons
- Free hadron, transition, and free quark/gluon regions visible in PbPb EECs
- Energy loss moves the peak in PbPb to smaller Δr, vacuum-like radiation suppressed
- Sensitivity to low p_{T} particles needed to see modifications at large Δr region
- Models with jet wake and color coherence show qualitatively similar behavior as data









This work is supported by the grant DE-FG05-92ER40712 from the US Department of Energy

Back-up

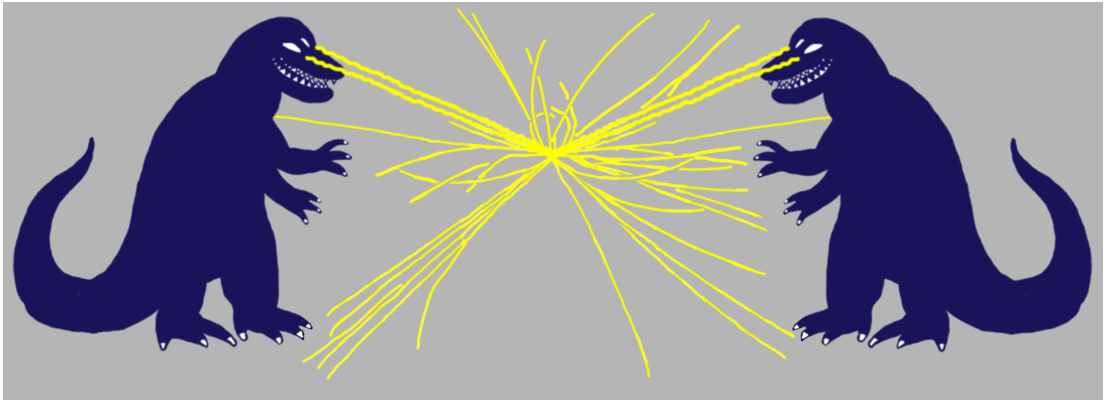
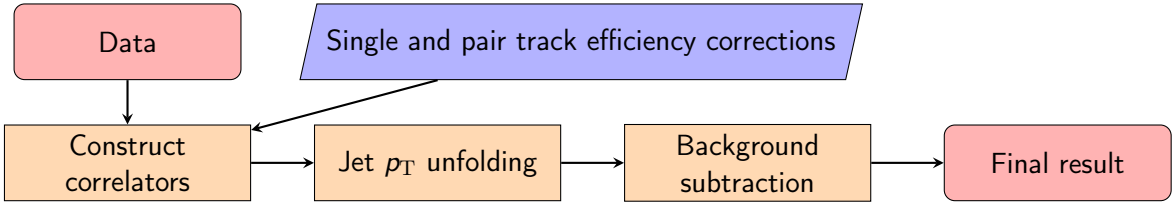


Image credit: BOOST 2022 conference logo

Jet p_{T} unfolding and tracking corrections



Result fully corrected to particle level!

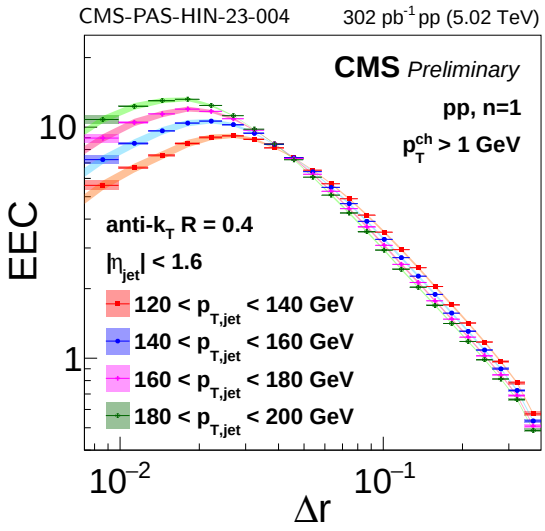
Sources of systematic uncertainty

Color coding for size of uncertainty

- Small, medium, large

- Jet energy scale
- Jet energy resolution
- Jet p_{T} prior for unfolding
- Number of iterations for unfolding
- Track selection
- Track pair efficiency
- Background subtraction
- Signal-to-background ratio scaling

Energy-energy correlator distributions, pp

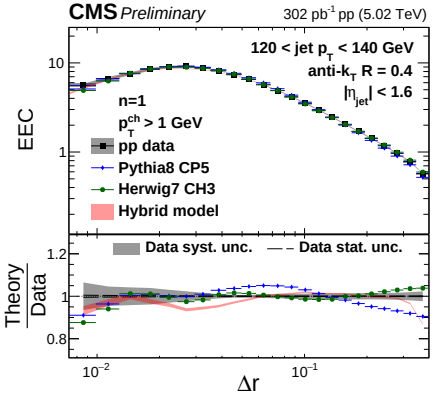


- pp results have consistent features with previous measurements
  - CMS: PRL 133 (2024) 071903
  - STAR: PoS HP2023 (2024) 175
  - ALICE: figure link
- Low $\Delta r \rightarrow$ free hadrons
- Moderate $\Delta r \rightarrow$ transition
- High $\Delta r \rightarrow$ free quark/gluon
- Peak depends on jet p_{T}

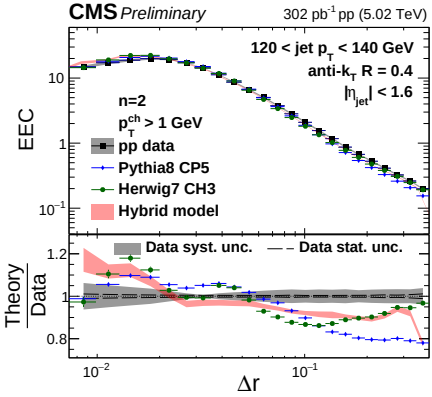
Model comparisons with pp distribution

CMS-PAS-HIN-23-004

$n = 1$



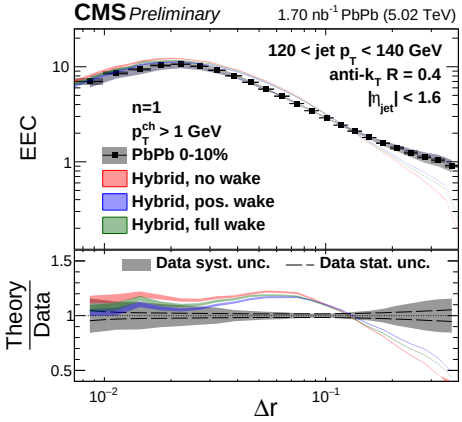
$n = 2$



- Models agree with pp data within $\sim 5\%$ for $n = 1$
- Models predict too narrow shape for $n = 2$
- Hybrid vacuum = Pythia8 with MPI off

Hybrid model comparison for PbPb 0-10%

CMS-PAS-HIN-23-004



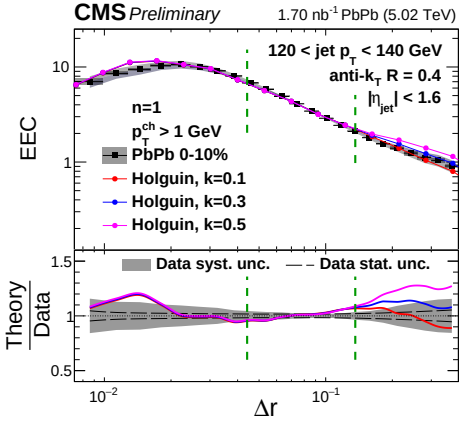
Pablos, Kudinoor, Rajagopal

- Hybrid model[1] with all three wake configurations underpredicts the data at large Δr
- Including wake brings prediction closer to data

[1] JHEP 09 (2015) 175, JHEP 03 (2017) 135, PRC 99 (2019) 5, 051901

Perturbative calculation comparison for PbPb 0-10%

CMS-PAS-HIN-23-004

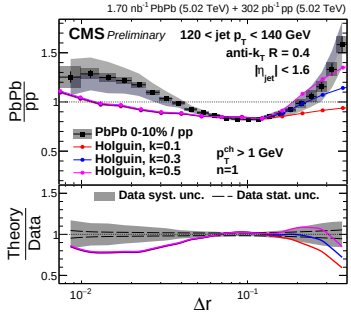


Holguin, Andrés, Dominguez, Marquet, Moult

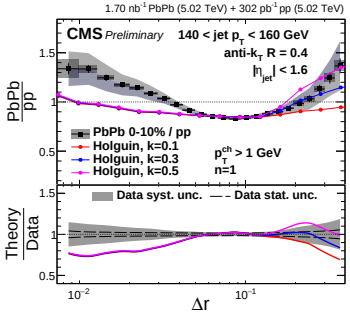
- Calculation with color coherence from Holguin + collaborators is normalized to data in region $0.042 < \Delta r < 0.126$
- k is constant of proportionality between hydro temperature and $\hat{q}$ of eikonalized scatters against the medium
- Shape at large Δr close to data for $0.1 \lesssim k \lesssim 0.3$

PbPb to pp ratio, Holguin, 0-10%, $p_{\mathrm{T}}^{\mathrm{ch}} > 1\,\mathrm{GeV}$, $n = 1$

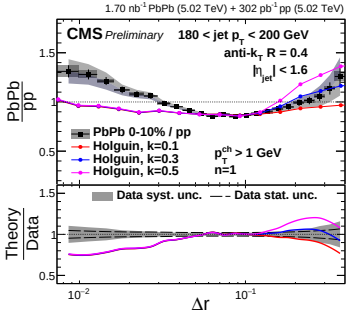
$120 < p_{\mathrm{T}}^{\mathrm{jet}} < 140\,\mathrm{GeV}$



$140 < p_{\mathrm{T}}^{\mathrm{jet}} < 160\,\mathrm{GeV}$



$180 < p_{\mathrm{T}}^{\mathrm{jet}} < 200\,\mathrm{GeV}$



- Data from CMS-PAS-HIN-23-004

PbPb distribution, Holguin, 0-10%, $p_{\mathrm{T}}^{\mathrm{ch}} > 1\,\mathrm{GeV}$, $n = 1$

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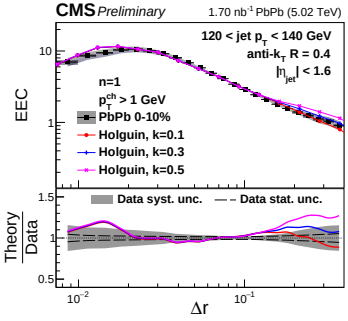
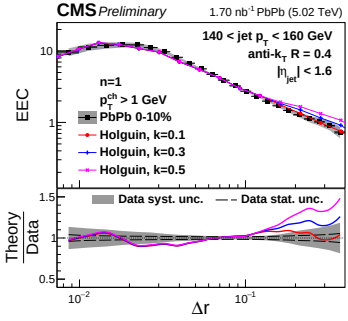


$140 < p_{\mathrm{T}}^{\mathrm{jet}} < 160\,\mathrm{GeV}$



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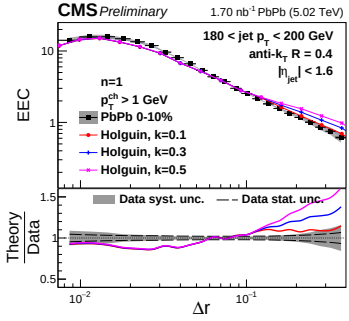

- Data from CMS-PAS-HIN-23-004
- Calculation by Holguin, Andrés, Dominguez, Marquet, Moult (arXiv:2407.07936)

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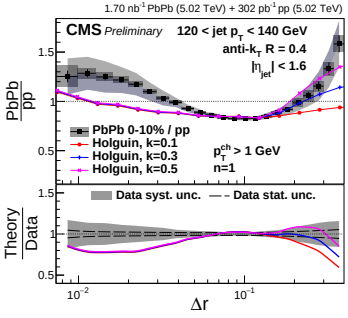
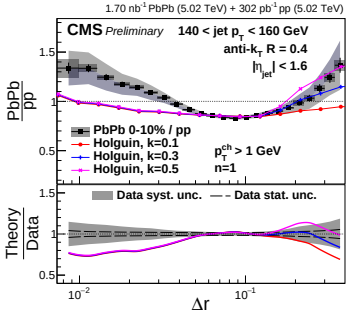


$140 < p_{\mathrm{T}}^{\mathrm{jet}} < 160\,\mathrm{GeV}$



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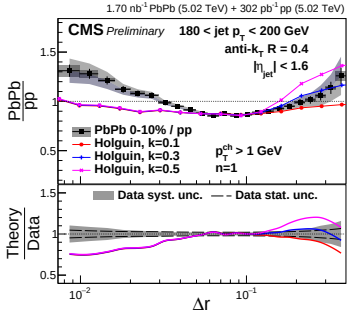

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PbPb distribution, Hybrid, 0-10%, $p_{\mathrm{T}}^{\mathrm{ch}} > 1\,\mathrm{GeV}$, $n = 1$

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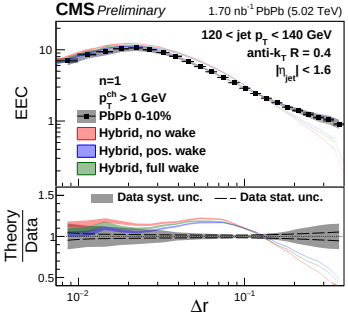
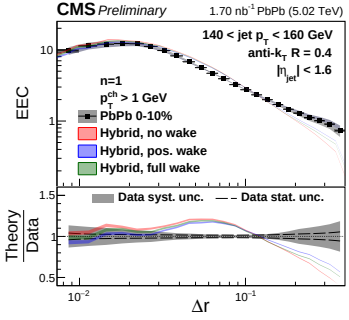


$140 < p_{\mathrm{T}}^{\mathrm{jet}} < 160\,\mathrm{GeV}$



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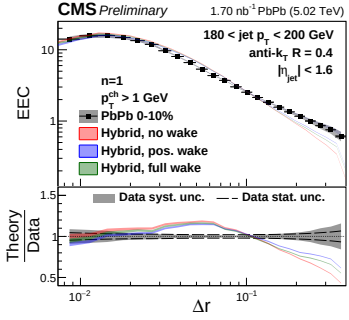

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PbPb distribution, Hybrid, 10-30%, $p_{\mathrm{T}}^{\mathrm{ch}} > 1\,\mathrm{GeV}$, $n = 1$

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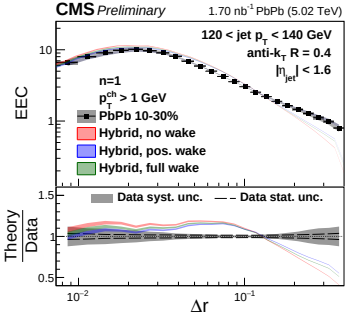

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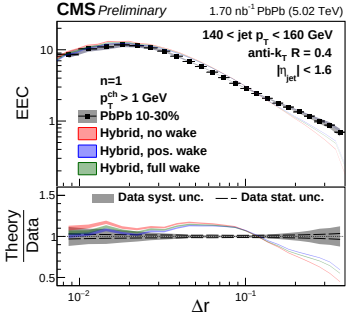

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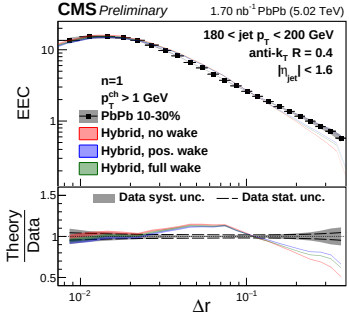

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PbPb distribution, Hybrid, 30-50%, $p_{\mathrm{T}}^{\mathrm{ch}} > 1\,\mathrm{GeV}$, $n = 1$

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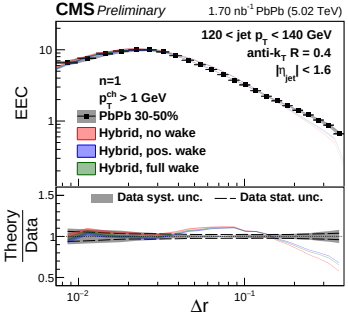

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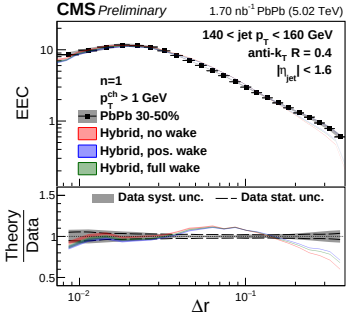

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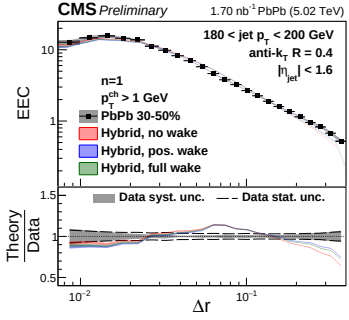

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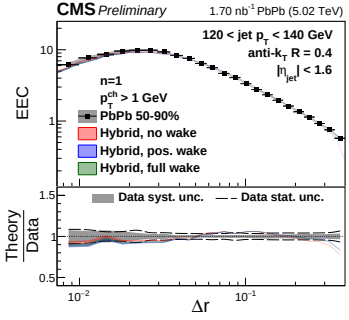

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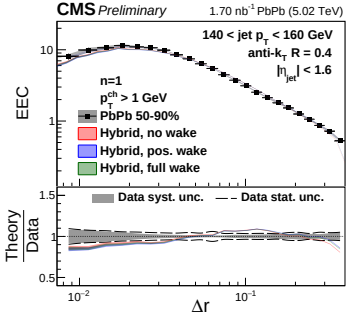

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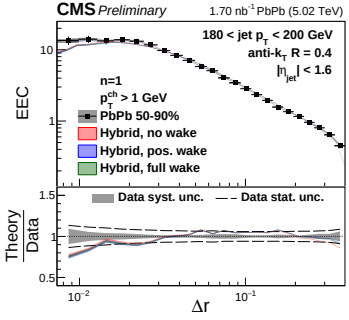

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PbPb distribution, Hybrid, 0-10%, $p_{\mathrm{T}}^{\mathrm{ch}} > 2\,\mathrm{GeV}$, $n = 1$

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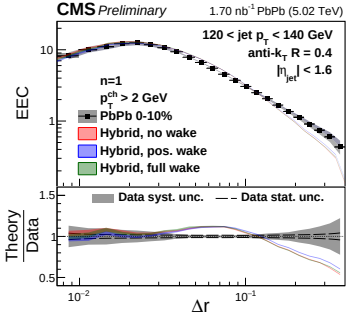

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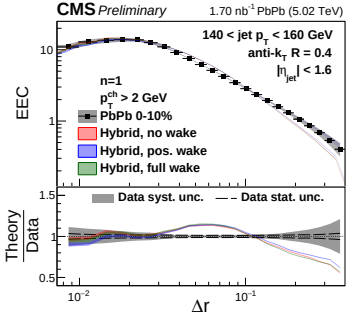

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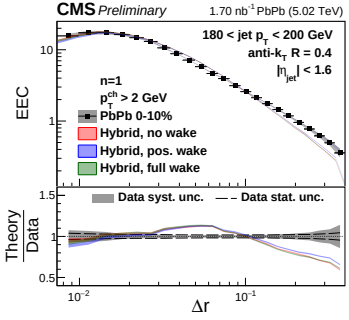

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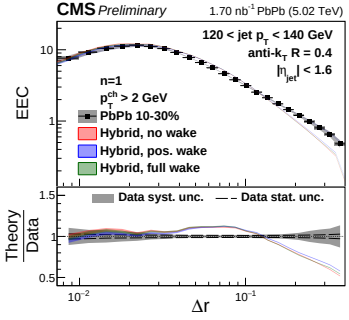

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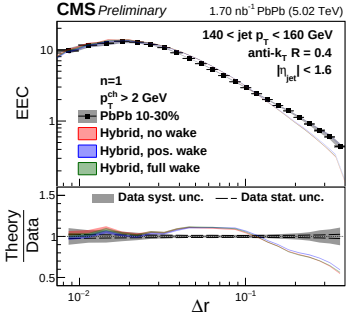

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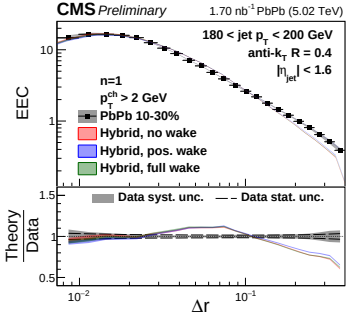

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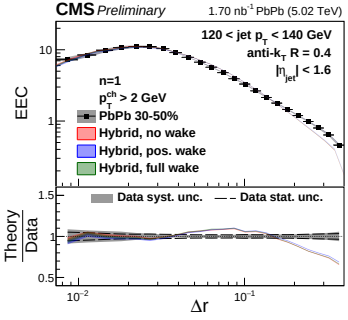

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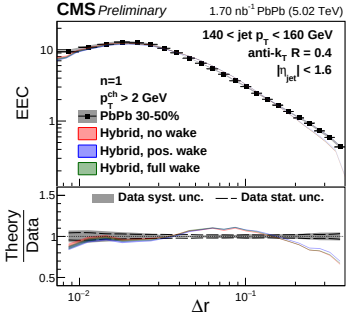

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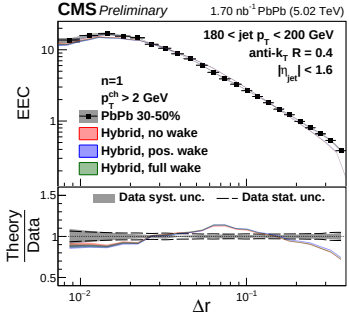

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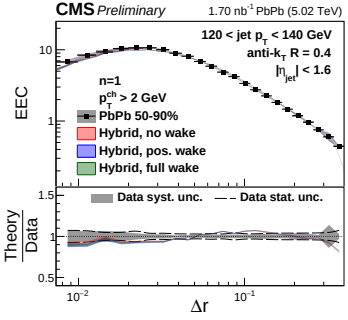

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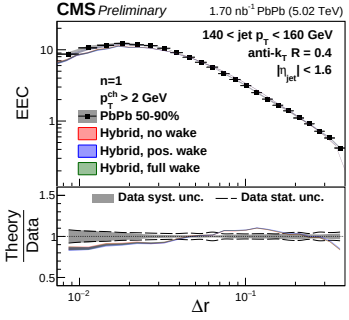

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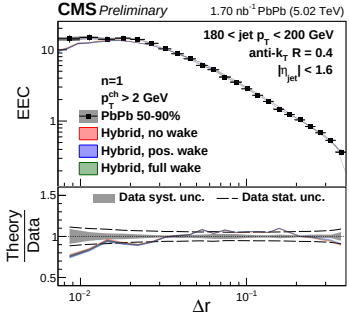

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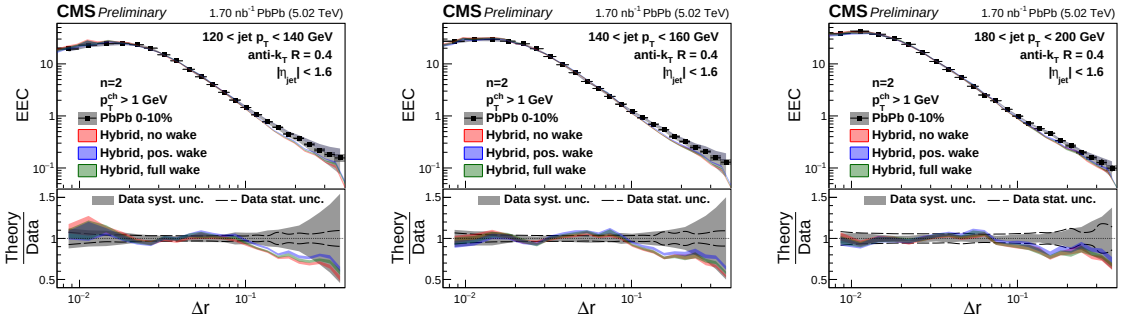
PbPb distribution, Hybrid, 0-10%, $p_{\mathrm{T}}^{\mathrm{ch}} > 1\,\mathrm{GeV}$, $n = 2$

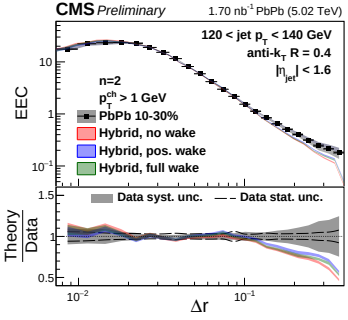
$120 < p_{\mathrm{T}}^{\mathrm{jet}} < 140\,\mathrm{GeV}$ $140 < p_{\mathrm{T}}^{\mathrm{jet}} < 160\,\mathrm{GeV}$ $180 < p_{\mathrm{T}}^{\mathrm{jet}} < 200\,\mathrm{GeV}$



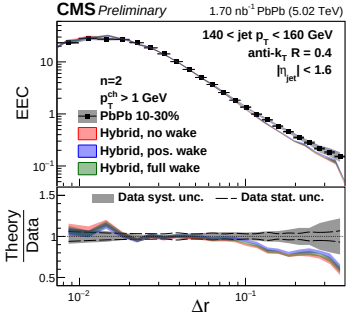
- Data from CMS-PAS-HIN-23-004
- Hybrid model prediction provided by Pablos, Kudinoor, Rajagopal

PbPb distribution, Hybrid, 10-30%, $p_{\mathrm{T}}^{\mathrm{ch}} > 1\,\mathrm{GeV}$, $n = 2$

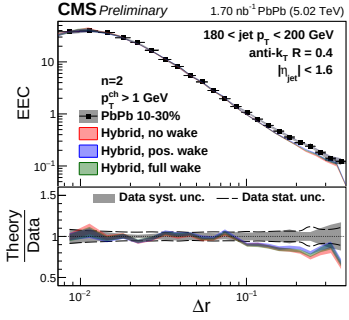
$120 < p_{\mathrm{T}}^{\mathrm{jet}} < 140\,\mathrm{GeV}$



$140 < p_{\mathrm{T}}^{\mathrm{jet}} < 160\,\mathrm{GeV}$



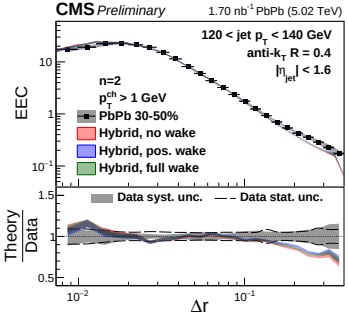
$180 < p_{\mathrm{T}}^{\mathrm{jet}} < 200\,\mathrm{GeV}$



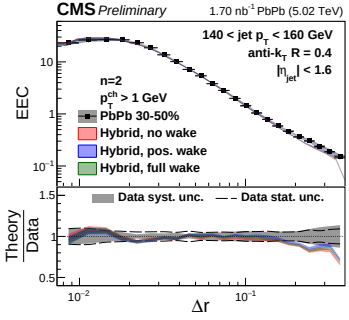
- Data from CMS-PAS-HIN-23-004
- Hybrid model prediction provided by Pablos, Kudinoor, Rajagopal

PbPb distribution, Hybrid, 30-50%, $p_{\mathrm{T}}^{\mathrm{ch}} > 1\,\mathrm{GeV}$, $n = 2$

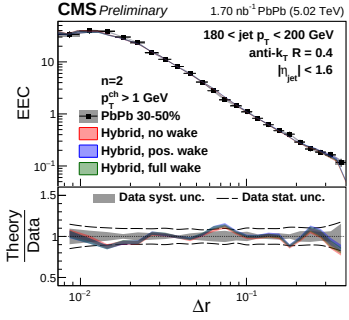
$120 < p_{\mathrm{T}}^{\mathrm{jet}} < 140\,\mathrm{GeV}$



$140 < p_{\mathrm{T}}^{\mathrm{jet}} < 160\,\mathrm{GeV}$



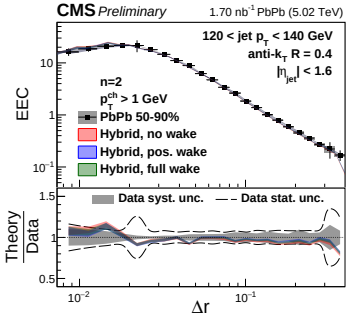
$180 < p_{\mathrm{T}}^{\mathrm{jet}} < 200\,\mathrm{GeV}$



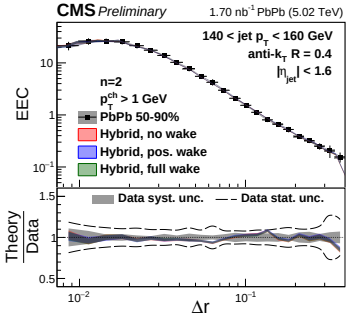
- Data from CMS-PAS-HIN-23-004
- Hybrid model prediction provided by Pablos, Kudinoor, Rajagopal

PbPb distribution, Hybrid, 50-90%, $p_{\mathrm{T}}^{\mathrm{ch}} > 1\,\mathrm{GeV}$, $n = 2$

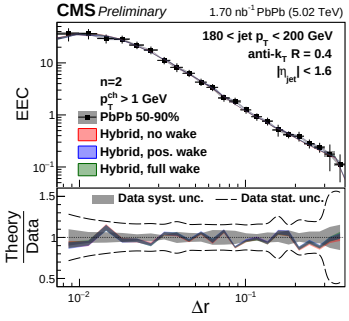
$120 < p_{\mathrm{T}}^{\mathrm{jet}} < 140\,\mathrm{GeV}$



$140 < p_{\mathrm{T}}^{\mathrm{jet}} < 160\,\mathrm{GeV}$



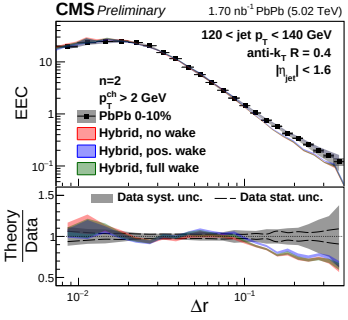
$180 < p_{\mathrm{T}}^{\mathrm{jet}} < 200\,\mathrm{GeV}$



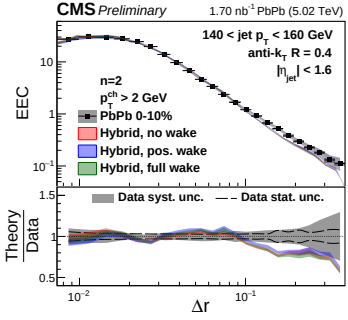
- Data from CMS-PAS-HIN-23-004
- Hybrid model prediction provided by Pablos, Kudinoor, Rajagopal

PbPb distribution, Hybrid, 0-10%, $p_{\mathrm{T}}^{\mathrm{ch}} > 2$ GeV, $n = 2$

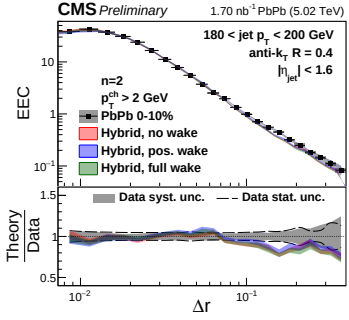
$120 < p_{\mathrm{T}}^{\mathrm{jet}} < 140$ GeV



$140 < p_{\mathrm{T}}^{\mathrm{jet}} < 160$ GeV



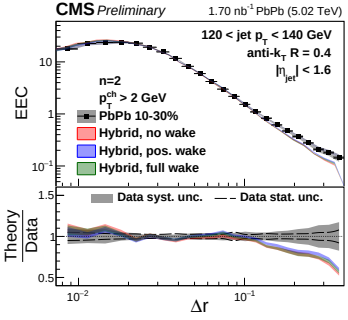
$180 < p_{\mathrm{T}}^{\mathrm{jet}} < 200$ GeV



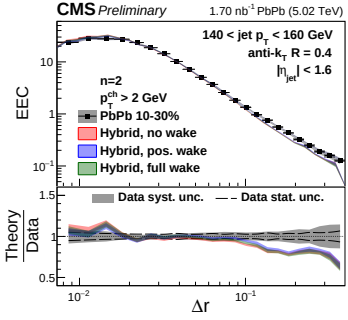
- Data from CMS-PAS-HIN-23-004
- Hybrid model prediction provided by Pablos, Kudinoor, Rajagopal

PbPb distribution, Hybrid, 10-30%, $p_{\mathrm{T}}^{\mathrm{ch}} > 2\,\mathrm{GeV}$, $n = 2$

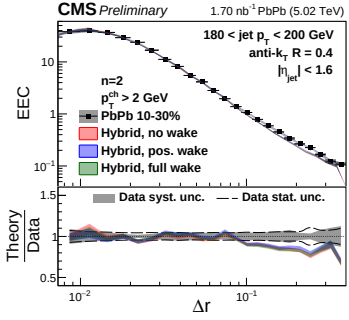
$120 < p_{\mathrm{T}}^{\mathrm{jet}} < 140\,\mathrm{GeV}$



$140 < p_{\mathrm{T}}^{\mathrm{jet}} < 160\,\mathrm{GeV}$



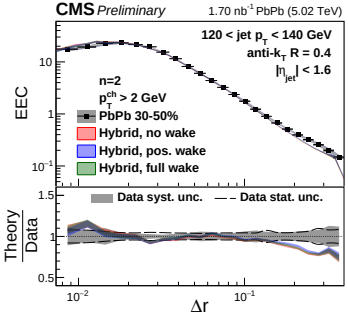
$180 < p_{\mathrm{T}}^{\mathrm{jet}} < 200\,\mathrm{GeV}$



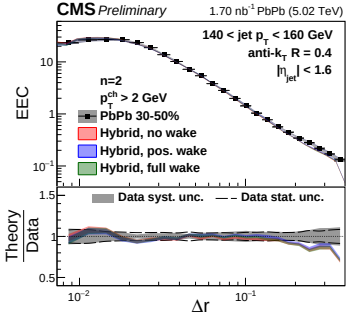
- Data from CMS-PAS-HIN-23-004
- Hybrid model prediction provided by Pablos, Kudinoor, Rajagopal

PbPb distribution, Hybrid, 30-50%, $p_{\mathrm{T}}^{\mathrm{ch}} > 2\,\mathrm{GeV}$, $n = 2$

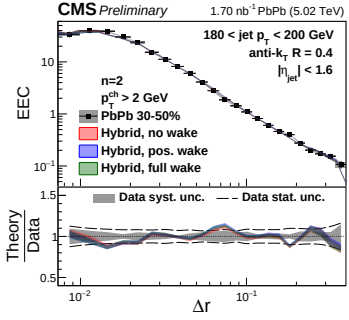
$120 < p_{\mathrm{T}}^{\mathrm{jet}} < 140\,\mathrm{GeV}$



$140 < p_{\mathrm{T}}^{\mathrm{jet}} < 160\,\mathrm{GeV}$



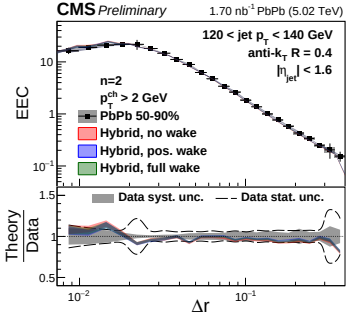
$180 < p_{\mathrm{T}}^{\mathrm{jet}} < 200\,\mathrm{GeV}$



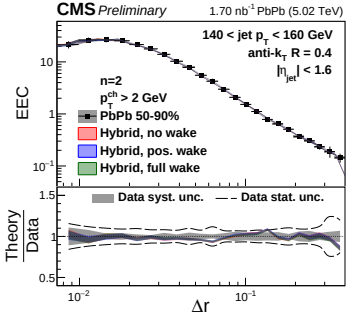
- Data from CMS-PAS-HIN-23-004
- Hybrid model prediction provided by Pablos, Kudinoor, Rajagopal

PbPb distribution, Hybrid, 50-90%, $p_{\mathrm{T}}^{\mathrm{ch}} > 2\,\mathrm{GeV}$, $n = 2$

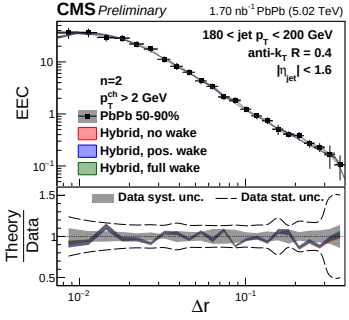
$120 < p_{\mathrm{T}}^{\mathrm{jet}} < 140\,\mathrm{GeV}$



$140 < p_{\mathrm{T}}^{\mathrm{jet}} < 160\,\mathrm{GeV}$



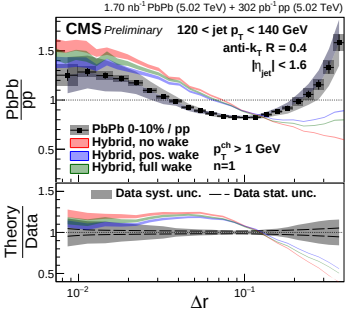
$180 < p_{\mathrm{T}}^{\mathrm{jet}} < 200\,\mathrm{GeV}$



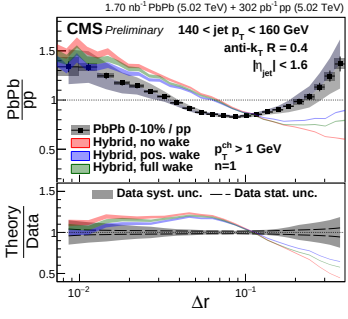
- Data from CMS-PAS-HIN-23-004
- Hybrid model prediction provided by Pablos, Kudinoor, Rajagopal

PbPb to pp ratio, Hybrid, 0-10%, $p_{\mathrm{T}}^{\mathrm{ch}} > 1\,\mathrm{GeV}$, $n = 1$

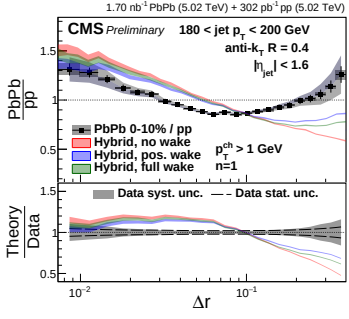
$120 < p_{\mathrm{T}}^{\mathrm{jet}} < 140\,\mathrm{GeV}$



$140 < p_{\mathrm{T}}^{\mathrm{jet}} < 160\,\mathrm{GeV}$



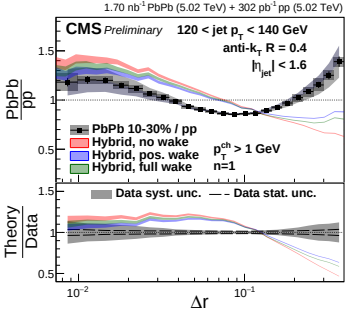
$180 < p_{\mathrm{T}}^{\mathrm{jet}} < 200\,\mathrm{GeV}$



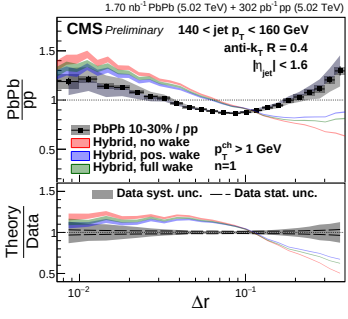
- Data from CMS-PAS-HIN-23-004
- Hybrid model prediction provided by Pablos, Kudinoor, Rajagopal

PbPb to pp ratio, Hybrid, 10-30%, $p_{\mathrm{T}}^{\mathrm{ch}} > 1\,\mathrm{GeV}$, $n = 1$

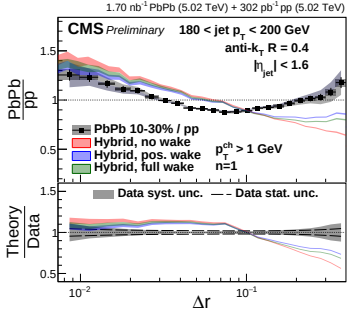
$120 < p_{\mathrm{T}}^{\mathrm{jet}} < 140\,\mathrm{GeV}$



$140 < p_{\mathrm{T}}^{\mathrm{jet}} < 160\,\mathrm{GeV}$



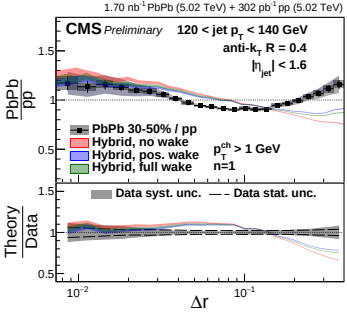
$180 < p_{\mathrm{T}}^{\mathrm{jet}} < 200\,\mathrm{GeV}$



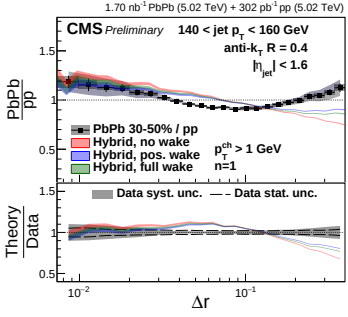
- Data from CMS-PAS-HIN-23-004
- Hybrid model prediction provided by Pablos, Kudinoor, Rajagopal

PbPb to pp ratio, Hybrid, 30-50%, $p_{\mathrm{T}}^{\mathrm{ch}} > 1\,\mathrm{GeV}$, $n = 1$

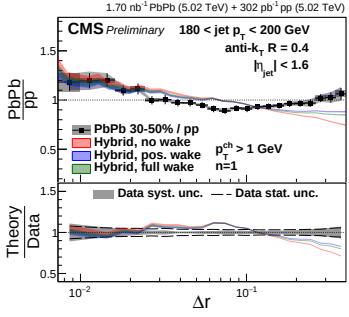
$120 < p_{\mathrm{T}}^{\mathrm{jet}} < 140\,\mathrm{GeV}$



$140 < p_{\mathrm{T}}^{\mathrm{jet}} < 160\,\mathrm{GeV}$



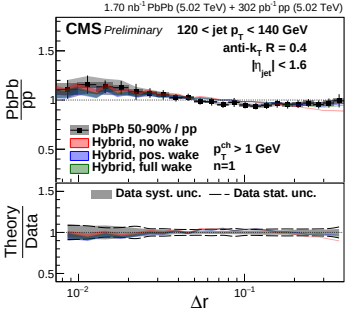
$180 < p_{\mathrm{T}}^{\mathrm{jet}} < 200\,\mathrm{GeV}$



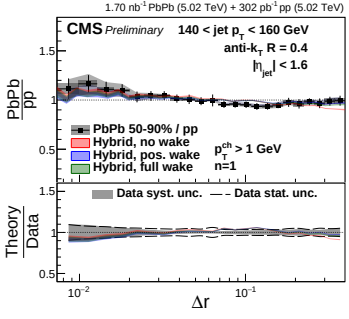
- Data from CMS-PAS-HIN-23-004
- Hybrid model prediction provided by Pablos, Kudinoor, Rajagopal

PbPb to pp ratio, Hybrid, 50-90%, $p_{\mathrm{T}}^{\mathrm{ch}} > 1\,\mathrm{GeV}$, $n = 1$

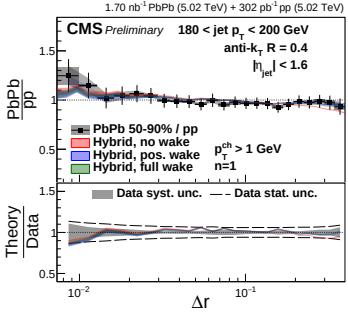
$120 < p_{\mathrm{T}}^{\mathrm{jet}} < 140\,\mathrm{GeV}$



$140 < p_{\mathrm{T}}^{\mathrm{jet}} < 160\,\mathrm{GeV}$



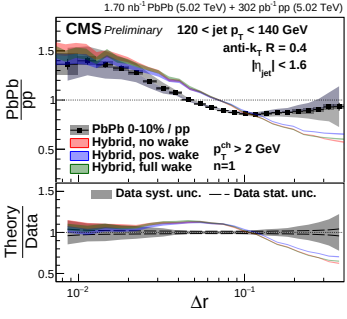
$180 < p_{\mathrm{T}}^{\mathrm{jet}} < 200\,\mathrm{GeV}$



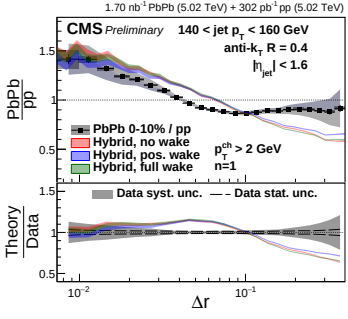
- Data from CMS-PAS-HIN-23-004
- Hybrid model prediction provided by Pablos, Kudinoor, Rajagopal

PbPb to pp ratio, Hybrid, 0-10%, $p_{\mathrm{T}}^{\mathrm{ch}} > 2\,\mathrm{GeV}$, $n = 1$

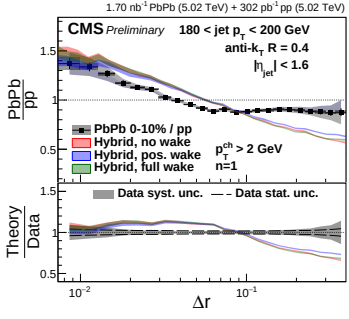
$120 < p_{\mathrm{T}}^{\mathrm{jet}} < 140\,\mathrm{GeV}$



$140 < p_{\mathrm{T}}^{\mathrm{jet}} < 160\,\mathrm{GeV}$



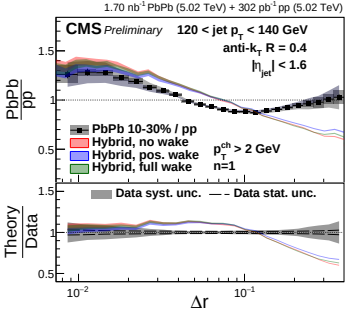
$180 < p_{\mathrm{T}}^{\mathrm{jet}} < 200\,\mathrm{GeV}$



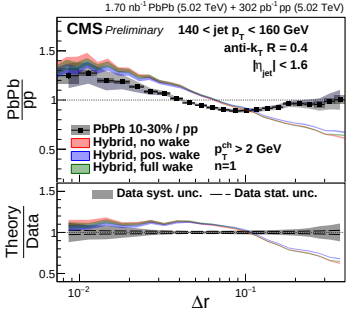
- Data from CMS-PAS-HIN-23-004
- Hybrid model prediction provided by Pablos, Kudinoor, Rajagopal

PbPb to pp ratio, Hybrid, 10-30%, $p_{\mathrm{T}}^{\mathrm{ch}} > 2\,\mathrm{GeV}$, $n = 1$

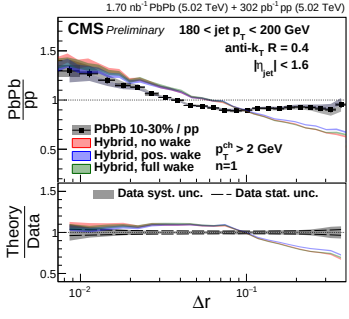
$120 < p_{\mathrm{T}}^{\mathrm{jet}} < 140\,\mathrm{GeV}$



$140 < p_{\mathrm{T}}^{\mathrm{jet}} < 160\,\mathrm{GeV}$



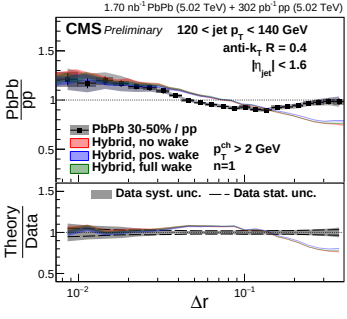
$180 < p_{\mathrm{T}}^{\mathrm{jet}} < 200\,\mathrm{GeV}$



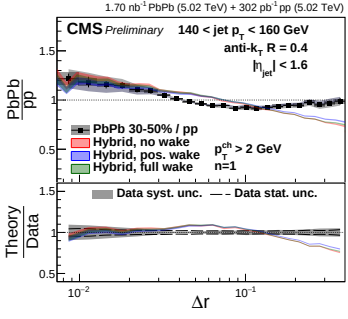
- Data from CMS-PAS-HIN-23-004
- Hybrid model prediction provided by Pablos, Kudinoor, Rajagopal

PbPb to pp ratio, Hybrid, 30-50%, $p_{\mathrm{T}}^{\mathrm{ch}} > 2\,\mathrm{GeV}$, $n = 1$

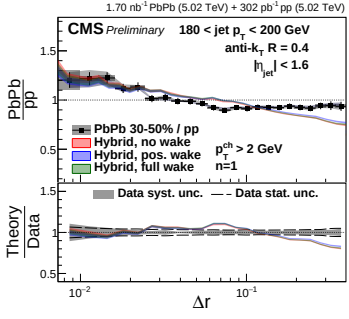
$120 < p_{\mathrm{T}}^{\mathrm{jet}} < 140\,\mathrm{GeV}$



$140 < p_{\mathrm{T}}^{\mathrm{jet}} < 160\,\mathrm{GeV}$



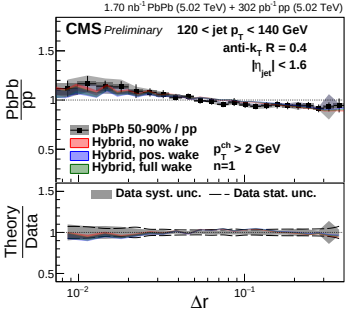
$180 < p_{\mathrm{T}}^{\mathrm{jet}} < 200\,\mathrm{GeV}$



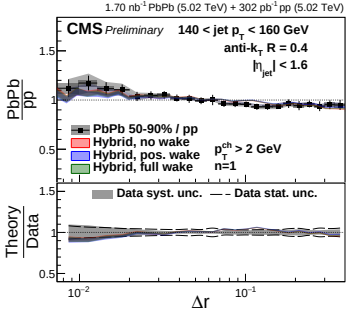
- Data from CMS-PAS-HIN-23-004
- Hybrid model prediction provided by Pablos, Kudinoor, Rajagopal

PbPb to pp ratio, Hybrid, 50-90%, $p_{\mathrm{T}}^{\mathrm{ch}} > 2\,\mathrm{GeV}$, $n = 1$

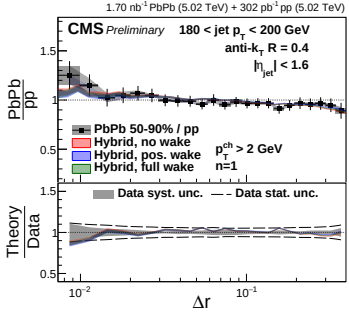
$120 < p_{\mathrm{T}}^{\mathrm{jet}} < 140\,\mathrm{GeV}$



$140 < p_{\mathrm{T}}^{\mathrm{jet}} < 160\,\mathrm{GeV}$



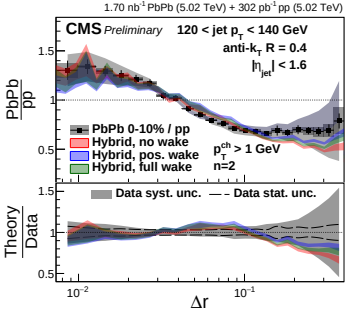
$180 < p_{\mathrm{T}}^{\mathrm{jet}} < 200\,\mathrm{GeV}$



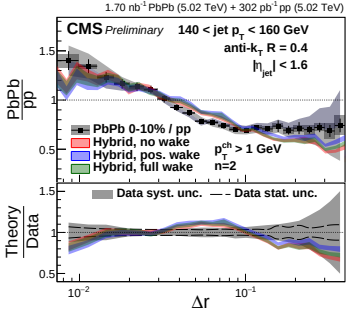
- Data from CMS-PAS-HIN-23-004
- Hybrid model prediction provided by Pablos, Kudinoor, Rajagopal

PbPb to pp ratio, Hybrid, 0-10%, $p_{\mathrm{T}}^{\mathrm{ch}} > 1\,\mathrm{GeV}$, $n = 2$

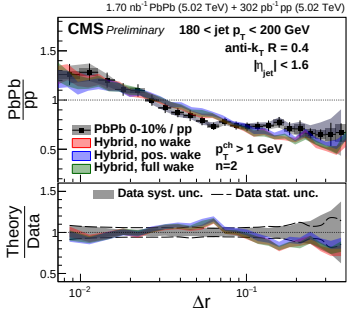
$120 < p_{\mathrm{T}}^{\mathrm{jet}} < 140\,\mathrm{GeV}$



$140 < p_{\mathrm{T}}^{\mathrm{jet}} < 160\,\mathrm{GeV}$



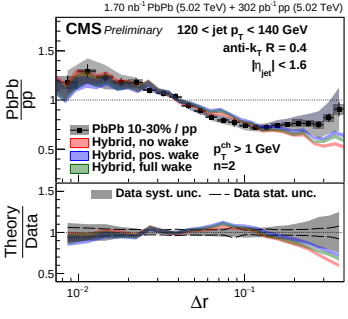
$180 < p_{\mathrm{T}}^{\mathrm{jet}} < 200\,\mathrm{GeV}$



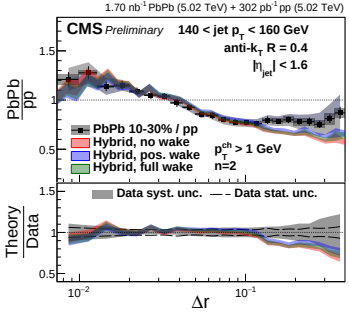
- Data from CMS-PAS-HIN-23-004
- Hybrid model prediction provided by Pablos, Kudinoor, Rajagopal

PbPb to pp ratio, Hybrid, 10-30%, $p_{\mathrm{T}}^{\mathrm{ch}} > 1\,\mathrm{GeV}$, $n = 2$

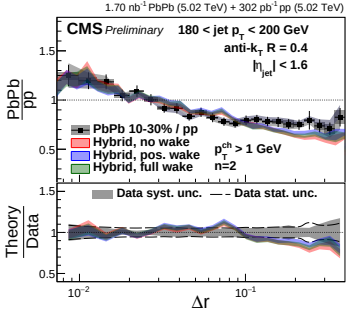
$120 < p_{\mathrm{T}}^{\mathrm{jet}} < 140\,\mathrm{GeV}$



$140 < p_{\mathrm{T}}^{\mathrm{jet}} < 160\,\mathrm{GeV}$



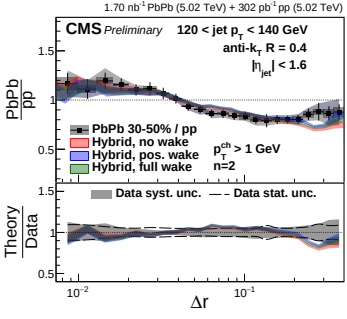
$180 < p_{\mathrm{T}}^{\mathrm{jet}} < 200\,\mathrm{GeV}$



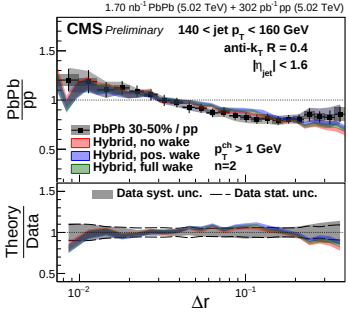
- Data from CMS-PAS-HIN-23-004
- Hybrid model prediction provided by Pablos, Kudinoor, Rajagopal

PbPb to pp ratio, Hybrid, 30-50%, $p_{\mathrm{T}}^{\mathrm{ch}} > 1\,\mathrm{GeV}$, $n = 2$

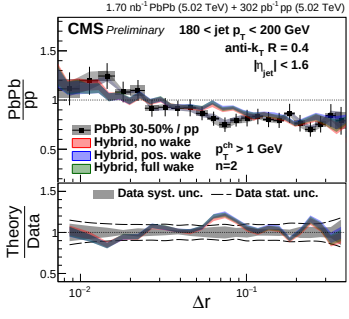
$120 < p_{\mathrm{T}}^{\mathrm{jet}} < 140\,\mathrm{GeV}$



$140 < p_{\mathrm{T}}^{\mathrm{jet}} < 160\,\mathrm{GeV}$



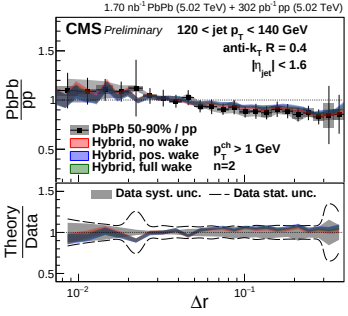
$180 < p_{\mathrm{T}}^{\mathrm{jet}} < 200\,\mathrm{GeV}$



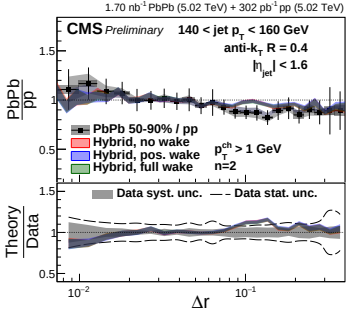
- Data from CMS-PAS-HIN-23-004
- Hybrid model prediction provided by Pablos, Kudinoor, Rajagopal

PbPb to pp ratio, Hybrid, 50-90%, $p_{\mathrm{T}}^{\mathrm{ch}} > 1\,\mathrm{GeV}$, $n = 2$

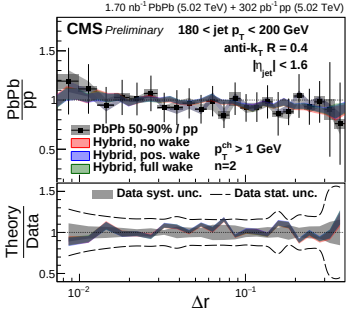
$120 < p_{\mathrm{T}}^{\mathrm{jet}} < 140\,\mathrm{GeV}$



$140 < p_{\mathrm{T}}^{\mathrm{jet}} < 160\,\mathrm{GeV}$



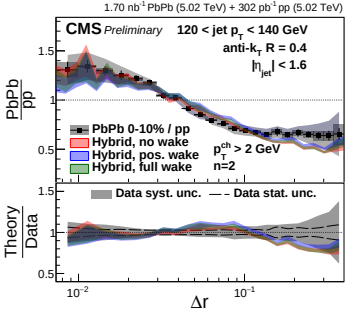
$180 < p_{\mathrm{T}}^{\mathrm{jet}} < 200\,\mathrm{GeV}$



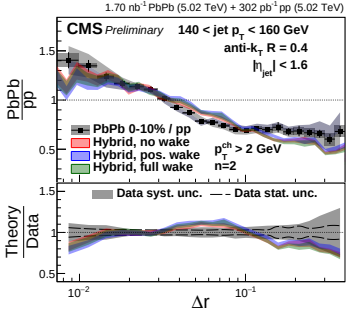
- Data from CMS-PAS-HIN-23-004
- Hybrid model prediction provided by Pablos, Kudinoor, Rajagopal

PbPb to pp ratio, Hybrid, 0-10%, $p_{\mathrm{T}}^{\mathrm{ch}} > 2\,\mathrm{GeV}$, $n = 2$

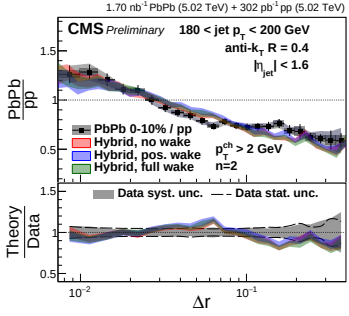
$120 < p_{\mathrm{T}}^{\mathrm{jet}} < 140\,\mathrm{GeV}$



$140 < p_{\mathrm{T}}^{\mathrm{jet}} < 160\,\mathrm{GeV}$



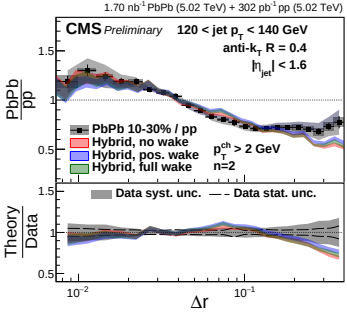
$180 < p_{\mathrm{T}}^{\mathrm{jet}} < 200\,\mathrm{GeV}$



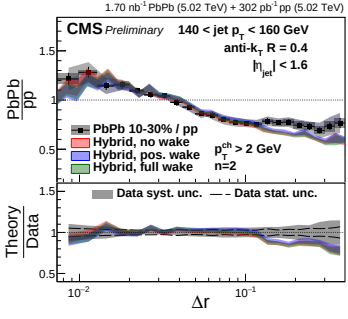
- Data from CMS-PAS-HIN-23-004
- Hybrid model prediction provided by Pablos, Kudinoor, Rajagopal

PbPb to pp ratio, Hybrid, 10-30%, $p_{\mathrm{T}}^{\mathrm{ch}} > 2\,\mathrm{GeV}$, $n = 2$

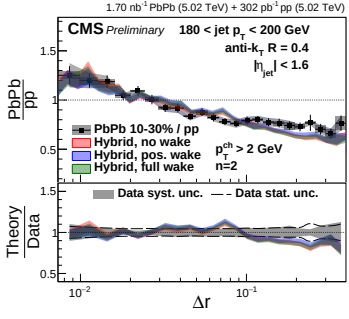
$120 < p_{\mathrm{T}}^{\mathrm{jet}} < 140\,\mathrm{GeV}$



$140 < p_{\mathrm{T}}^{\mathrm{jet}} < 160\,\mathrm{GeV}$



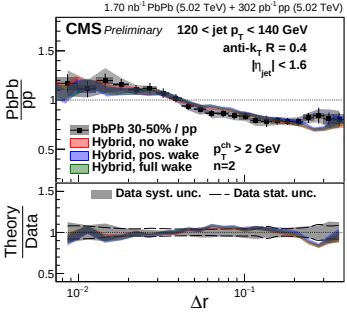
$180 < p_{\mathrm{T}}^{\mathrm{jet}} < 200\,\mathrm{GeV}$



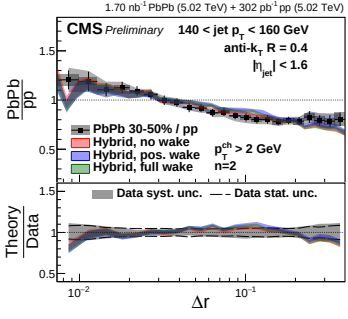
- Data from CMS-PAS-HIN-23-004
- Hybrid model prediction provided by Pablos, Kudinoor, Rajagopal

PbPb to pp ratio, Hybrid, 30-50%, $p_{\mathrm{T}}^{\mathrm{ch}} > 2\,\mathrm{GeV}$, $n = 2$

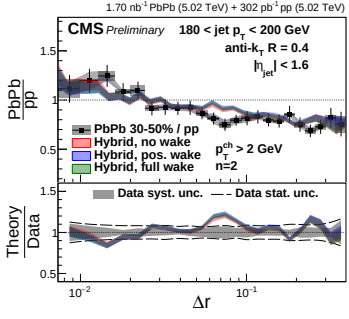
$120 < p_{\mathrm{T}}^{\mathrm{jet}} < 140\,\mathrm{GeV}$



$140 < p_{\mathrm{T}}^{\mathrm{jet}} < 160\,\mathrm{GeV}$



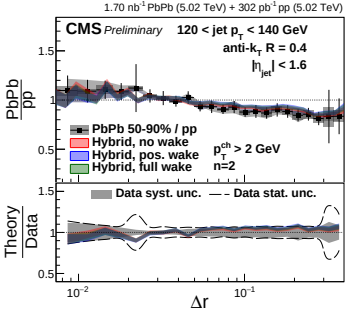
$180 < p_{\mathrm{T}}^{\mathrm{jet}} < 200\,\mathrm{GeV}$



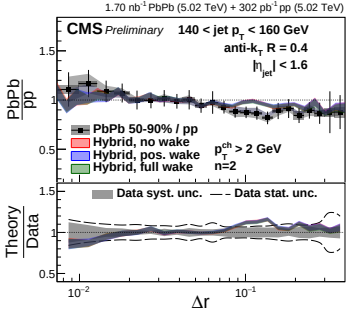
- Data from CMS-PAS-HIN-23-004
- Hybrid model prediction provided by Pablos, Kudinoor, Rajagopal

PbPb to pp ratio, Hybrid, 50-90%, $p_{\mathrm{T}}^{\mathrm{ch}} > 2\,\mathrm{GeV}$, $n = 2$

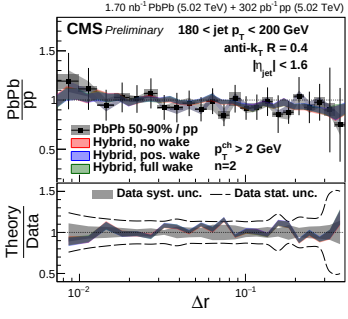
$120 < p_{\mathrm{T}}^{\mathrm{jet}} < 140\,\mathrm{GeV}$



$140 < p_{\mathrm{T}}^{\mathrm{jet}} < 160\,\mathrm{GeV}$



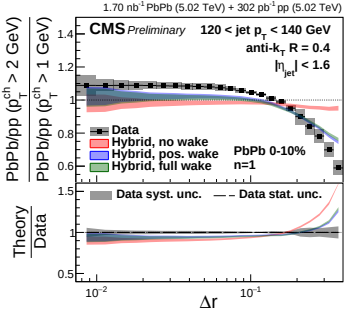
$180 < p_{\mathrm{T}}^{\mathrm{jet}} < 200\,\mathrm{GeV}$



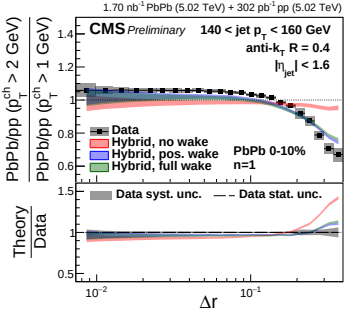
- Data from CMS-PAS-HIN-23-004
- Hybrid model prediction provided by Pablos, Kudinoor, Rajagopal

PbPb to pp double ratio, Hybrid, 0-10%, $n = 1$

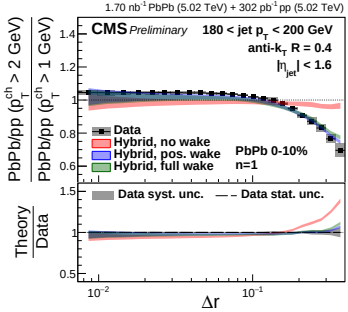
$120 < p_{\mathrm{T}}^{\mathrm{jet}} < 140$ GeV



$140 < p_{\mathrm{T}}^{\mathrm{jet}} < 160$ GeV



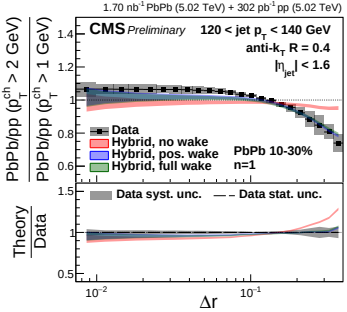
$180 < p_{\mathrm{T}}^{\mathrm{jet}} < 200$ GeV



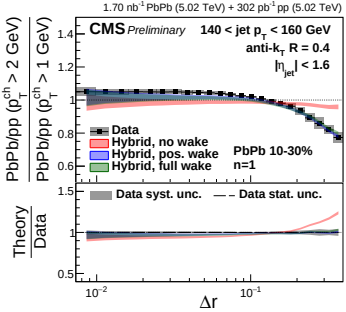
- Data from CMS-PAS-HIN-23-004
- Hybrid model prediction provided by Pablos, Kudinoor, Rajagopal

PbPb to pp double ratio, Hybrid, 10-30%, $n = 1$

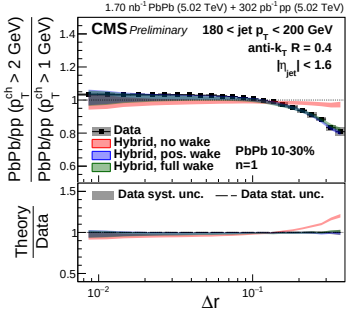
$120 < p_{\mathrm{T}}^{\mathrm{jet}} < 140$ GeV



$140 < p_{\mathrm{T}}^{\mathrm{jet}} < 160$ GeV



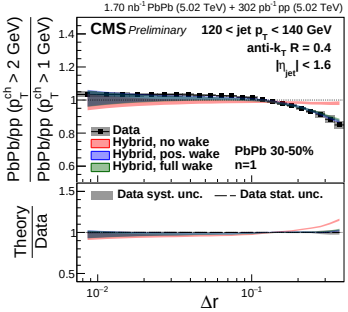
$180 < p_{\mathrm{T}}^{\mathrm{jet}} < 200$ GeV



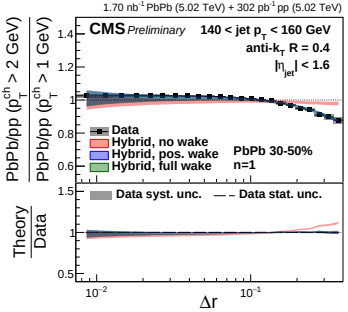
- Data from CMS-PAS-HIN-23-004
- Hybrid model prediction provided by Pablos, Kudinoor, Rajagopal

PbPb to pp double ratio, Hybrid, 30-50%, $n = 1$

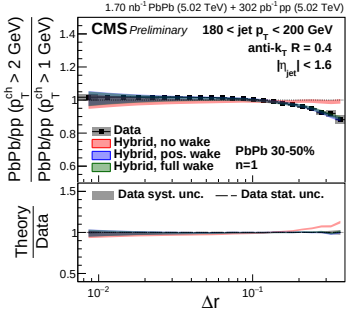
$120 < p_{\mathrm{T}}^{\mathrm{jet}} < 140$ GeV



$140 < p_{\mathrm{T}}^{\mathrm{jet}} < 160$ GeV



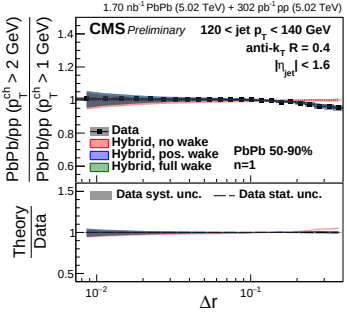
$180 < p_{\mathrm{T}}^{\mathrm{jet}} < 200$ GeV



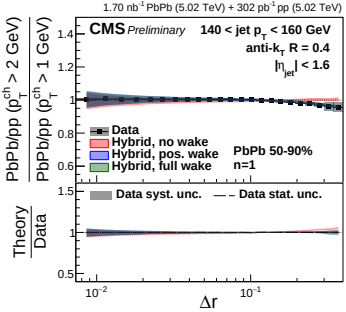
- Data from CMS-PAS-HIN-23-004
- Hybrid model prediction provided by Pablos, Kudinoor, Rajagopal

PbPb to pp double ratio, Hybrid, 50-90%, $n = 1$

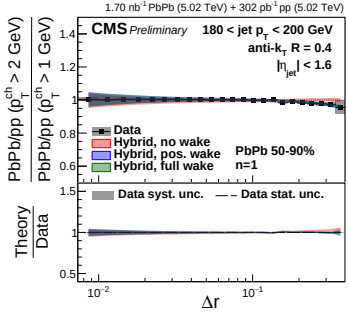
$120 < p_{\mathrm{T}}^{\mathrm{jet}} < 140$ GeV



$140 < p_{\mathrm{T}}^{\mathrm{jet}} < 160$ GeV



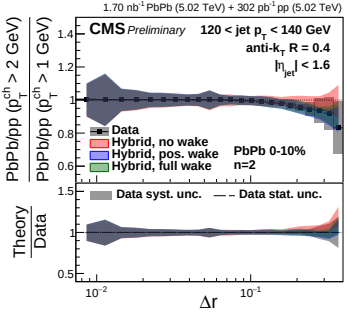
$180 < p_{\mathrm{T}}^{\mathrm{jet}} < 200$ GeV



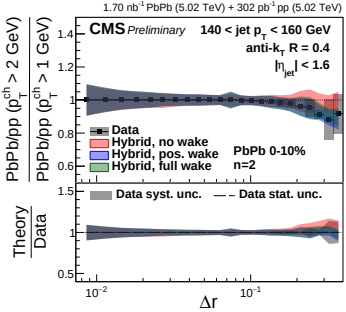
- Data from CMS-PAS-HIN-23-004
- Hybrid model prediction provided by Pablos, Kudinoor, Rajagopal

PbPb to pp double ratio, Hybrid, 0-10%, $n = 2$

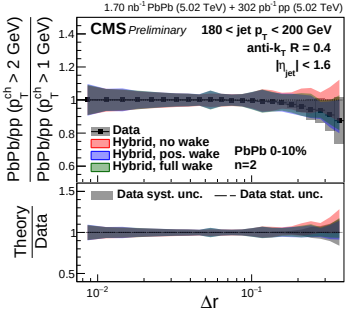
$120 < p_{\mathrm{T}}^{\mathrm{jet}} < 140$ GeV



$140 < p_{\mathrm{T}}^{\mathrm{jet}} < 160$ GeV



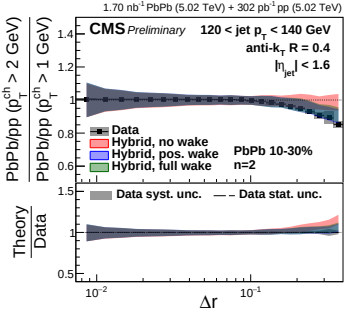
$180 < p_{\mathrm{T}}^{\mathrm{jet}} < 200$ GeV



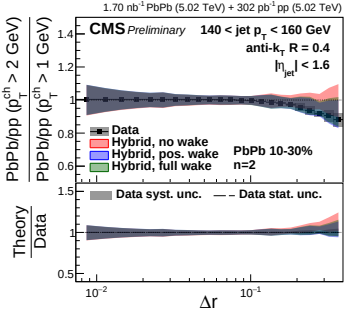
- Data from CMS-PAS-HIN-23-004
- Hybrid model prediction provided by Pablos, Kudinoor, Rajagopal

PbPb to pp double ratio, Hybrid, 10-30%, $n = 2$

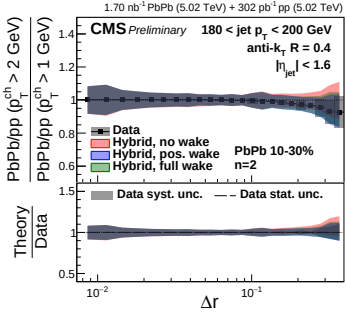
$120 < p_{\mathrm{T}}^{\mathrm{jet}} < 140$ GeV



$140 < p_{\mathrm{T}}^{\mathrm{jet}} < 160$ GeV



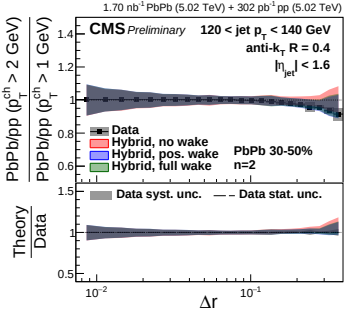
$180 < p_{\mathrm{T}}^{\mathrm{jet}} < 200$ GeV



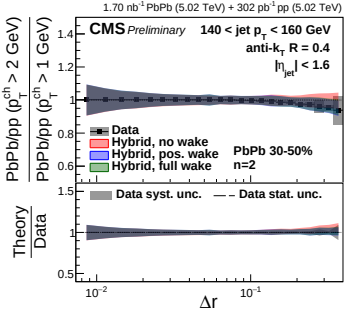
- Data from CMS-PAS-HIN-23-004
- Hybrid model prediction provided by Pablos, Kudinoor, Rajagopal

PbPb to pp double ratio, Hybrid, 30-50%, $n = 2$

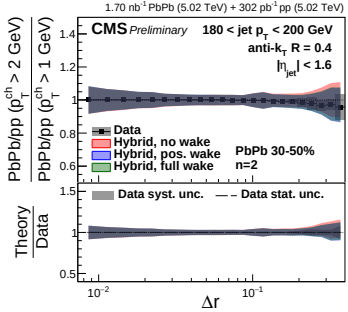
$120 < p_{\mathrm{T}}^{\mathrm{jet}} < 140$ GeV



$140 < p_{\mathrm{T}}^{\mathrm{jet}} < 160$ GeV



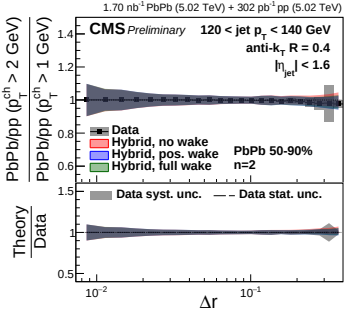
$180 < p_{\mathrm{T}}^{\mathrm{jet}} < 200$ GeV



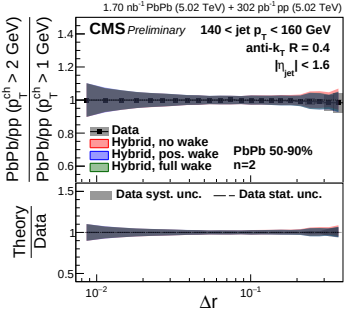
- Data from CMS-PAS-HIN-23-004
- Hybrid model prediction provided by Pablos, Kudinoor, Rajagopal

PbPb to pp double ratio, Hybrid, 50-90%, $n = 2$

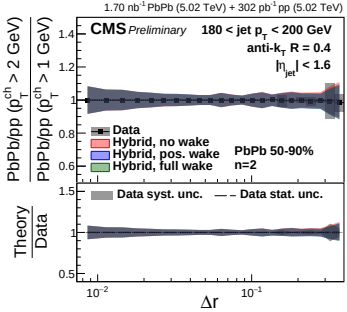
$120 < p_{\mathrm{T}}^{\mathrm{jet}} < 140$ GeV



$140 < p_{\mathrm{T}}^{\mathrm{jet}} < 160$ GeV



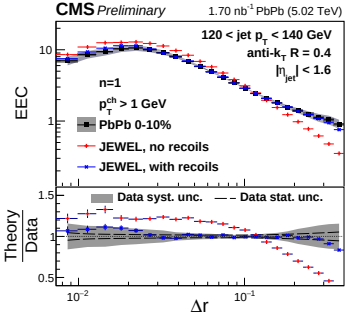
$180 < p_{\mathrm{T}}^{\mathrm{jet}} < 200$ GeV



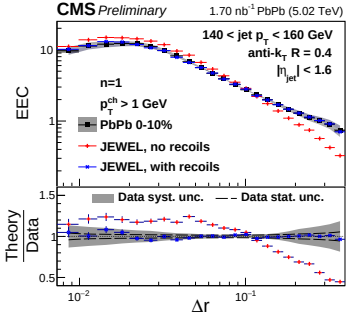
- Data from CMS-PAS-HIN-23-004
- Hybrid model prediction provided by Pablos, Kudinoor, Rajagopal

PbPb distribution, JEWEL, 0-10%, $p_{\mathrm{T}}^{\mathrm{ch}} > 1$ GeV, $n = 1$

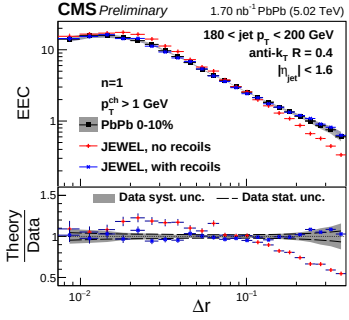
$120 < p_{\mathrm{T}}^{\mathrm{jet}} < 140$ GeV



$140 < p_{\mathrm{T}}^{\mathrm{jet}} < 160$ GeV



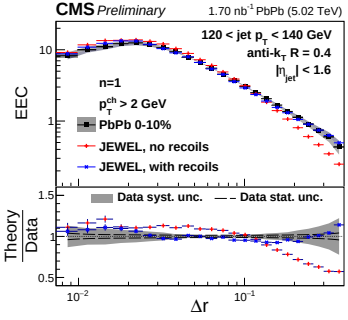
$180 < p_{\mathrm{T}}^{\mathrm{jet}} < 200$ GeV



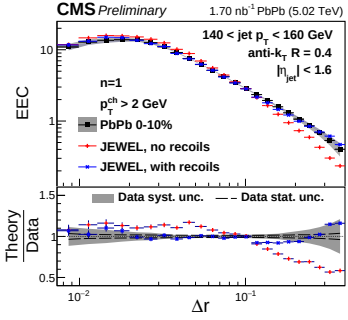
- Data from CMS-PAS-HIN-23-004
- JEWEL 2.4.0 simulation done by Sheng, Kunnawalkam Elayavalli

PbPb distribution, JEWEL, 0-10%, $p_{\mathrm{T}}^{\mathrm{ch}} > 2\,\mathrm{GeV}$, $n = 1$

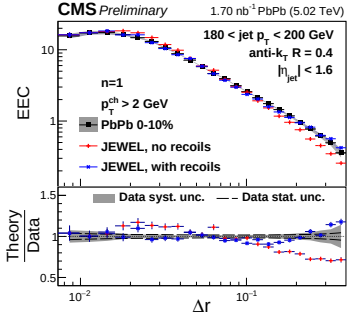
$120 < p_{\mathrm{T}}^{\mathrm{jet}} < 140\,\mathrm{GeV}$



$140 < p_{\mathrm{T}}^{\mathrm{jet}} < 160\,\mathrm{GeV}$



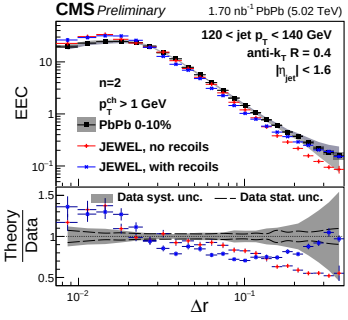
$180 < p_{\mathrm{T}}^{\mathrm{jet}} < 200\,\mathrm{GeV}$



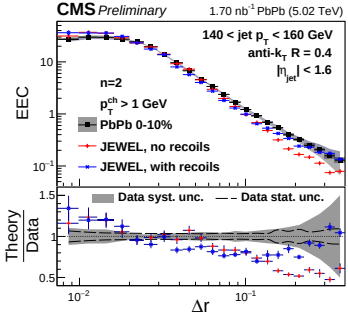
- Data from CMS-PAS-HIN-23-004
- JEWEL 2.4.0 simulation done by Sheng, Kunnawalkam Elayavalli

PbPb distribution, JEWEL, 0-10%, $p_{\mathrm{T}}^{\mathrm{ch}} > 1$ GeV, $n = 2$

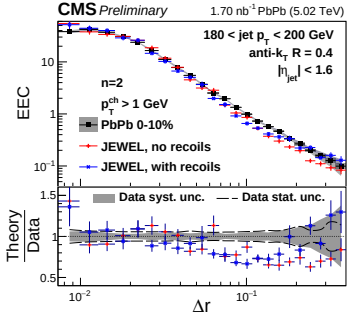
$120 < p_{\mathrm{T}}^{\mathrm{jet}} < 140$ GeV



$140 < p_{\mathrm{T}}^{\mathrm{jet}} < 160$ GeV



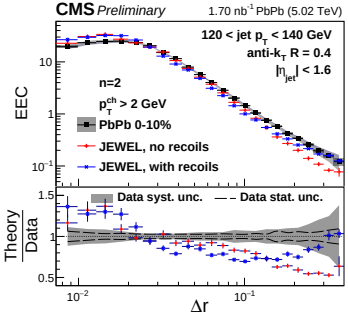
$180 < p_{\mathrm{T}}^{\mathrm{jet}} < 200$ GeV



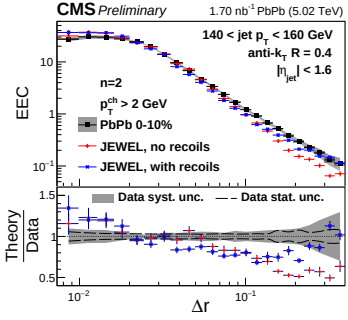
- Data from CMS-PAS-HIN-23-004
- JEWEL 2.4.0 simulation done by Sheng, Kunnawalkam Elayavalli

PbPb distribution, JEWEL, 0-10%, $p_{\mathrm{T}}^{\mathrm{ch}} > 2\,\mathrm{GeV}$, $n = 2$

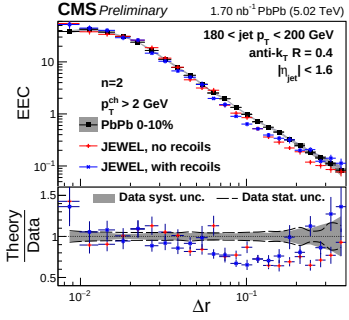
$120 < p_{\mathrm{T}}^{\mathrm{jet}} < 140\,\mathrm{GeV}$



$140 < p_{\mathrm{T}}^{\mathrm{jet}} < 160\,\mathrm{GeV}$



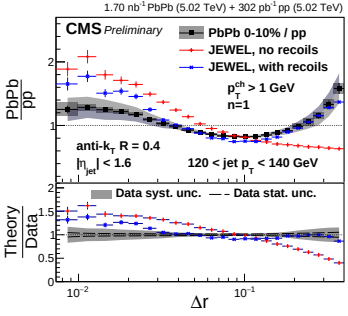
$180 < p_{\mathrm{T}}^{\mathrm{jet}} < 200\,\mathrm{GeV}$



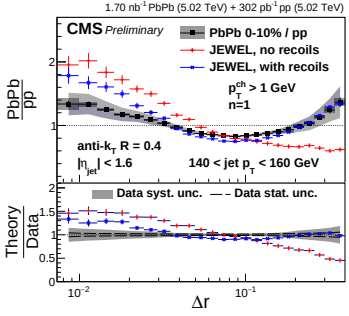
- Data from CMS-PAS-HIN-23-004
- JEWEL 2.4.0 simulation done by Sheng, Kunnawalkam Elayavalli

PbPb to pp ratio, JEWEL, 0-10%, $p_{\mathrm{T}}^{\mathrm{ch}} > 1\,\mathrm{GeV}$, $n = 1$

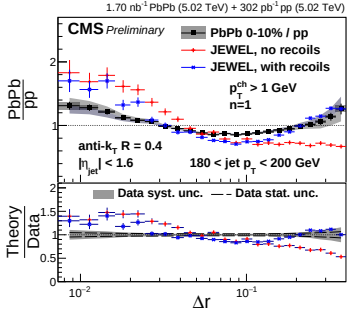
$120 < p_{\mathrm{T}}^{\mathrm{jet}} < 140\,\mathrm{GeV}$



$140 < p_{\mathrm{T}}^{\mathrm{jet}} < 160\,\mathrm{GeV}$



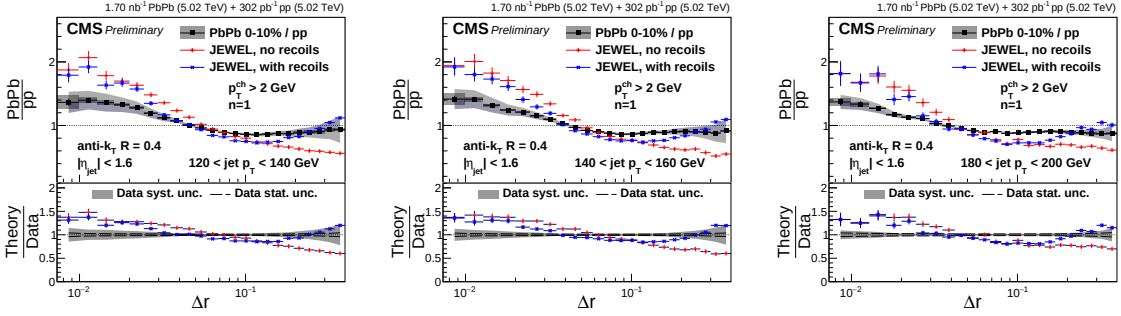
$180 < p_{\mathrm{T}}^{\mathrm{jet}} < 200\,\mathrm{GeV}$



- Data from CMS-PAS-HIN-23-004
- JEWEL 2.4.0 simulation done by Sheng, Kunnawalkam Elayavalli

PbPb to pp ratio, JEWEL, 0-10%, $p_{\mathrm{T}}^{\mathrm{ch}} > 2\,\mathrm{GeV}$, $n = 1$

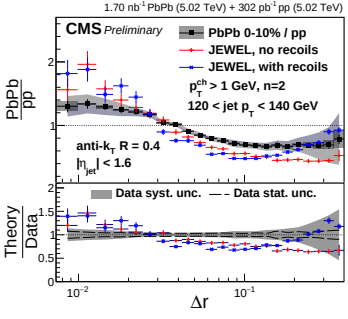
$120 < p_{\mathrm{T}}^{\mathrm{jet}} < 140\,\mathrm{GeV}$ $140 < p_{\mathrm{T}}^{\mathrm{jet}} < 160\,\mathrm{GeV}$ $180 < p_{\mathrm{T}}^{\mathrm{jet}} < 200\,\mathrm{GeV}$



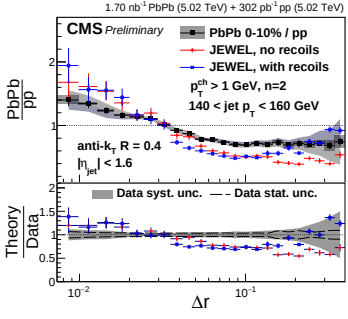
- Data from CMS-PAS-HIN-23-004
- JEWEL 2.4.0 simulation done by Sheng, Kunnawalkam Elayavalli

PbPb to pp ratio, JEWEL, 0-10%, $p_{\mathrm{T}}^{\mathrm{ch}} > 1\,\mathrm{GeV}$, $n = 2$

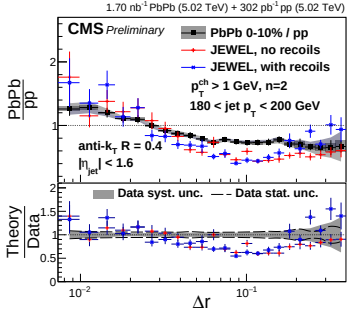
$120 < p_{\mathrm{T}}^{\mathrm{jet}} < 140\,\mathrm{GeV}$



$140 < p_{\mathrm{T}}^{\mathrm{jet}} < 160\,\mathrm{GeV}$



$180 < p_{\mathrm{T}}^{\mathrm{jet}} < 200\,\mathrm{GeV}$



- Data from CMS-PAS-HIN-23-004
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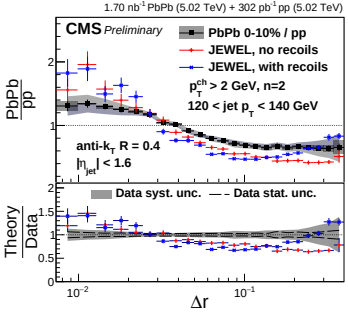
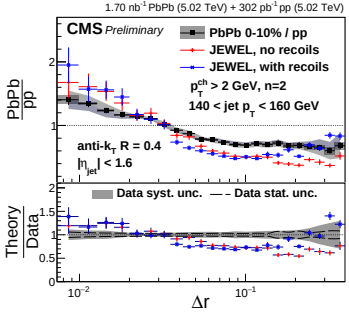
PbPb to pp ratio, JEWEL, 0-10%, $p_{\mathrm{T}}^{\mathrm{ch}} > 2\,\mathrm{GeV}$, $n = 2$

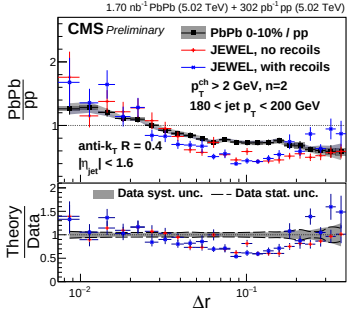
$120 < p_{\mathrm{T}}^{\mathrm{jet}} < 140\,\mathrm{GeV}$



$140 < p_{\mathrm{T}}^{\mathrm{jet}} < 160\,\mathrm{GeV}$



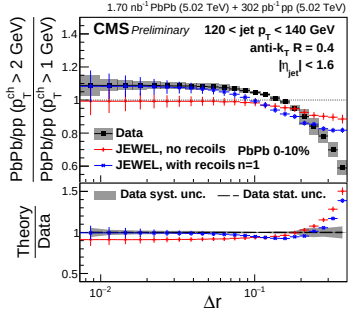
$180 < p_{\mathrm{T}}^{\mathrm{jet}} < 200\,\mathrm{GeV}$



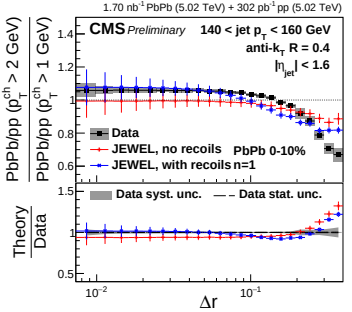
- Data from CMS-PAS-HIN-23-004
- JEWEL 2.4.0 simulation done by Sheng, Kunnawalkam Elayavalli

PbPb to pp double ratio, JEWEL, 0-10%, $n = 1$

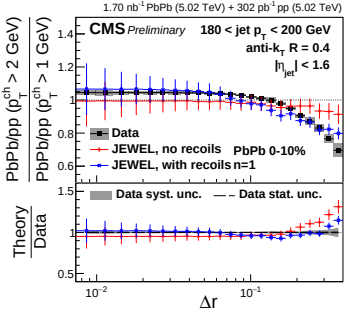
$120 < p_{\mathrm{T}}^{\mathrm{jet}} < 140$ GeV



$140 < p_{\mathrm{T}}^{\mathrm{jet}} < 160$ GeV



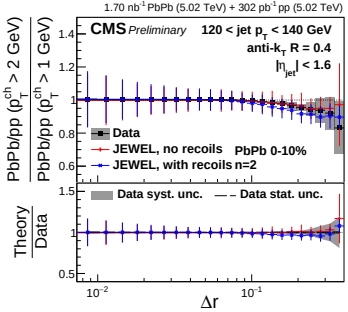
$180 < p_{\mathrm{T}}^{\mathrm{jet}} < 200$ GeV



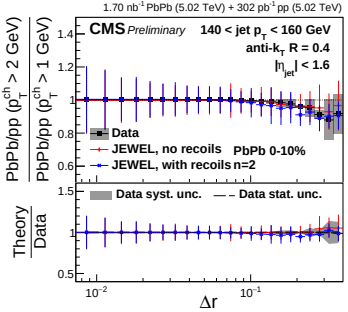
- Data from CMS-PAS-HIN-23-004
- JEWEL 2.4.0 simulation done by Sheng, Kunnawalkam Elayavalli

PbPb to pp double ratio, JEWEL, 0-10%, $n = 2$

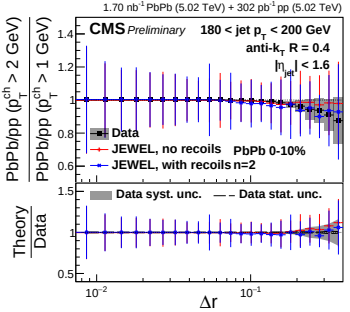
$120 < p_{\mathrm{T}}^{\mathrm{jet}} < 140$ GeV



$140 < p_{\mathrm{T}}^{\mathrm{jet}} < 160$ GeV



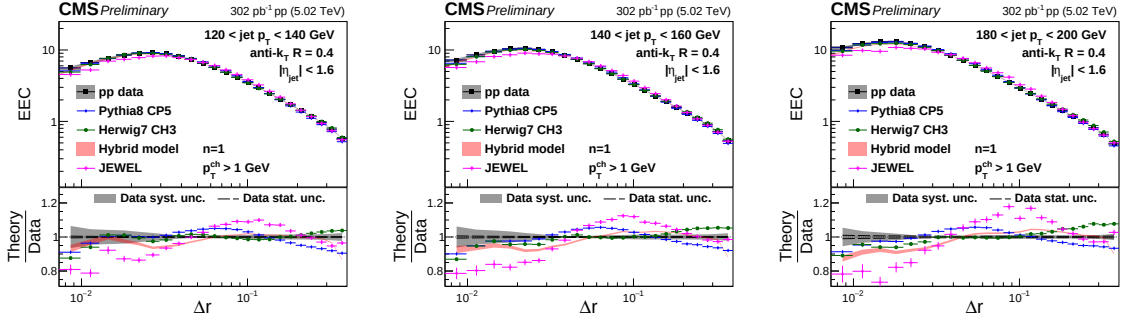
$180 < p_{\mathrm{T}}^{\mathrm{jet}} < 200$ GeV



- Data from CMS-PAS-HIN-23-004
- JEWEL 2.4.0 simulation done by Sheng, Kunnawalkam Elayavalli

pp distribution, $p_{\mathrm{T}}^{\mathrm{ch}} > 1\,\mathrm{GeV}$, $n = 1$

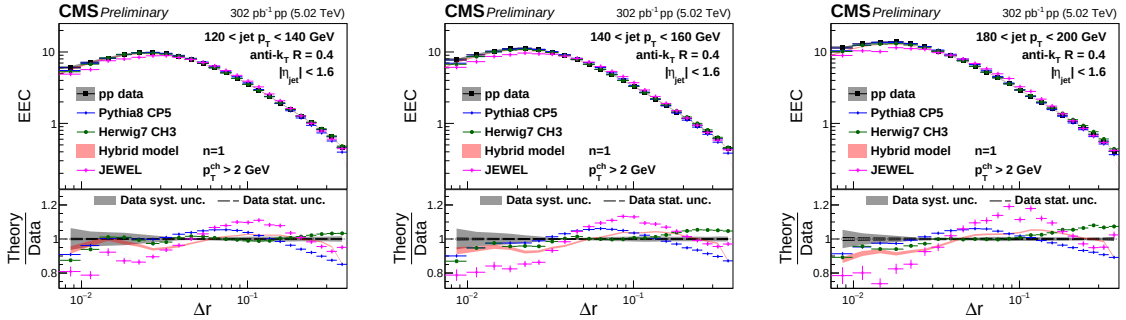
$120 < p_{\mathrm{T}}^{\mathrm{jet}} < 140\,\mathrm{GeV}$ $140 < p_{\mathrm{T}}^{\mathrm{jet}} < 160\,\mathrm{GeV}$ $180 < p_{\mathrm{T}}^{\mathrm{jet}} < 200\,\mathrm{GeV}$



- Data from CMS-PAS-HIN-23-004
- Hybrid model vacuum a specific Pythia8 tune, provided by Pablos, Kudinoor, Rajagopal
- JEWEL 2.4.0 simulation done by Sheng, Kunnawalkam Elayavalli

pp distribution, $p_{\mathrm{T}}^{\mathrm{ch}} > 2\,\mathrm{GeV}$, $n = 1$

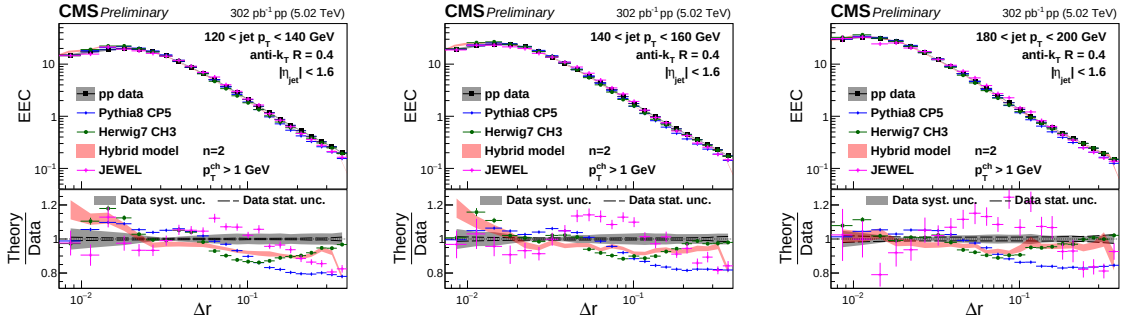
$120 < p_{\mathrm{T}}^{\mathrm{jet}} < 140\,\mathrm{GeV}$ $140 < p_{\mathrm{T}}^{\mathrm{jet}} < 160\,\mathrm{GeV}$ $180 < p_{\mathrm{T}}^{\mathrm{jet}} < 200\,\mathrm{GeV}$



- Data from CMS-PAS-HIN-23-004
- Hybrid model vacuum a specific Pythia8 tune, provided by Pablos, Kudinoor, Rajagopal
- JEWEL 2.4.0 simulation done by Sheng, Kunnawalkam Elayavalli

pp distribution, $p_{\mathrm{T}}^{\mathrm{ch}} > 1\,\mathrm{GeV}$, $n = 2$

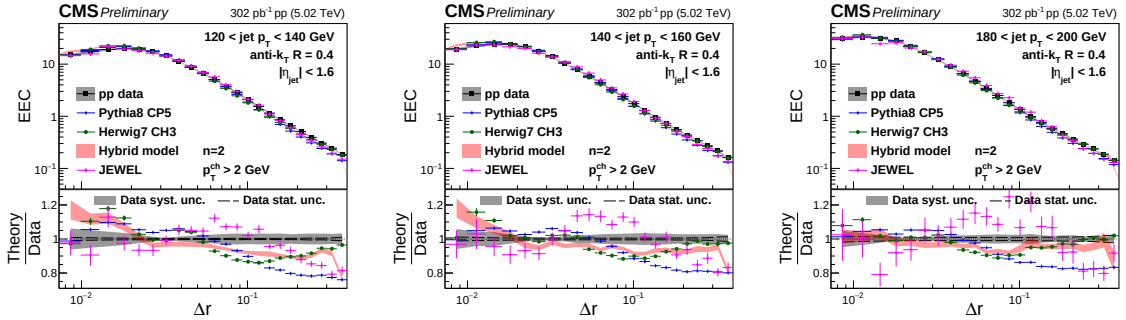
$120 < p_{\mathrm{T}}^{\mathrm{jet}} < 140\,\mathrm{GeV}$ $140 < p_{\mathrm{T}}^{\mathrm{jet}} < 160\,\mathrm{GeV}$ $180 < p_{\mathrm{T}}^{\mathrm{jet}} < 200\,\mathrm{GeV}$



- Data from CMS-PAS-HIN-23-004
- Hybrid model vacuum a specific Pythia8 tune, provided by Pablos, Kudinoor, Rajagopal
- JEWEL 2.4.0 simulation done by Sheng, Kunnawalkam Elayavalli

pp distribution, $p_{\mathrm{T}}^{\mathrm{ch}} > 2\,\mathrm{GeV}$, $n = 2$

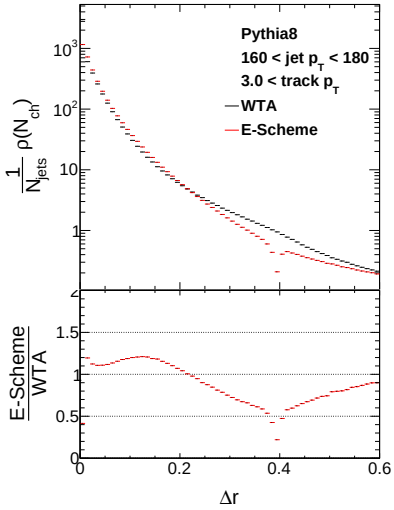
$120 < p_{\mathrm{T}}^{\mathrm{jet}} < 140\,\mathrm{GeV}$ $140 < p_{\mathrm{T}}^{\mathrm{jet}} < 160\,\mathrm{GeV}$ $180 < p_{\mathrm{T}}^{\mathrm{jet}} < 200\,\mathrm{GeV}$



- Data from CMS-PAS-HIN-23-004
- Hybrid model vacuum a specific Pythia8 tune, provided by Pablos, Kudinoor, Rajagopal
- JEWEL 2.4.0 simulation done by Sheng, Kunnawalkam Elayavalli

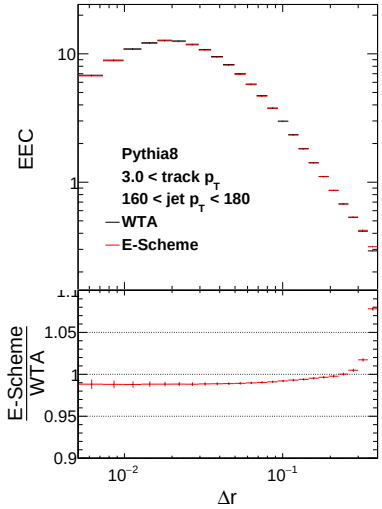
Particle density with respect to jet axis in Pythia8

- E-Scheme axis has a dip in particle density around jet radius
- In correlation measurements, good to avoid sharp structures like this



Energy-energy correlator axis comparison in Pythia8

- Most of the pairs are the same
- For e-scheme axis, strong enhancement with respect to WTA around the jet radius



Background estimation for systematics: reflected η cone

- Reflect jet η coordinate, require at least twice the cone radius distance from original axis to avoid overlapping cones
  - if $|\eta_{\text{jet}}| > R \Rightarrow \eta_{\text{reflected}} = -\eta_{\text{jet}}$
  - if $-R \leq \eta_{\text{jet}} < 0 \Rightarrow \eta_{\text{reflected}} = \eta_{\text{jet}} + 2R$
  - if $0 \leq \eta_{\text{jet}} \leq R \Rightarrow \eta_{\text{reflected}} = \eta_{\text{jet}} - 2R$
- The background estimation is constructed by pairing all particles from the signal cone with all particles in the reflected cone