# BOOST 2022:
# EXPERIMENTAL SUMMARY

Cristina Mantilla Suarez & Experimentalists

Fermilab


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godzilla quito

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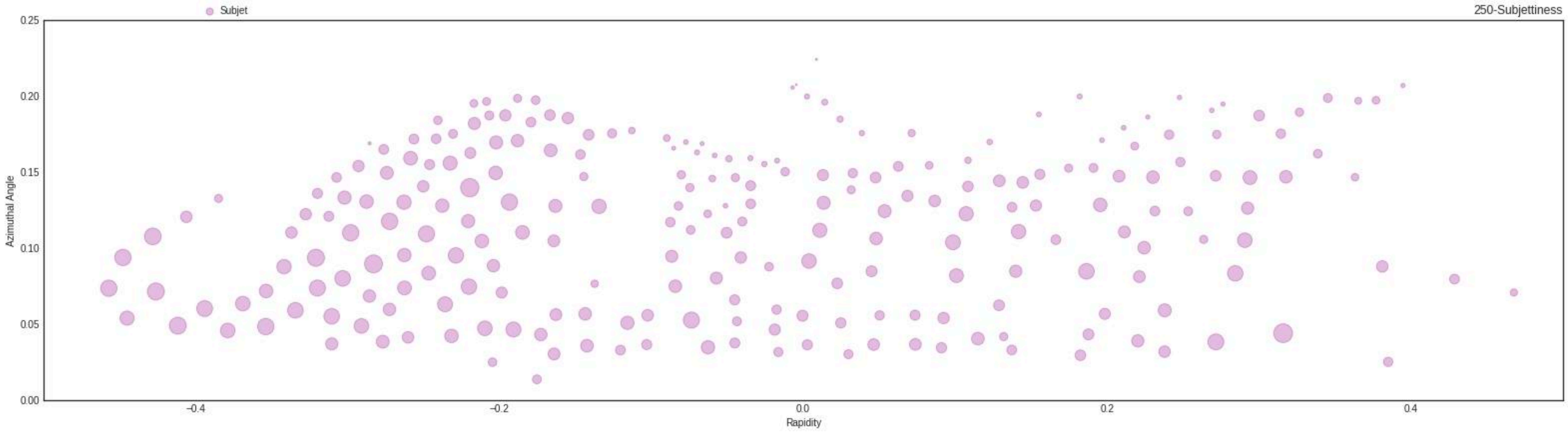
# #BOOSTZILLA


Gregor Kasieczka @GregorKasieczka · May 25
Sending out posters for the #BOOST workshop on jet substructure at @unihh+@desy.
See you in beautiful Hamburg, August 15-19.
Hope the conference will be marginally less catastrophic than the poster implies.
More details at indico.cern.ch/e/boost2022

# How much like boostzilla does my jet look like?




thanks to Rikhab Gambhir

# How much like boostzilla does my jet look like?


thanks to Rikhab Gambhir

My first BOOST was 2017 - at the edge of the start of Run-2: searches were somewhat rushed, measurements were just starting and theorists were impatient.

# From BOOST 2017 summary about H(bb)

- Turns out Hbb tagging is a good idea after all as we finally observe H—>bb decays

# From BOOST 2017 summary about ML

- The gains seem fantastic, what do we need to see to convince ourselves to use this everywhere? (can we make a list?)

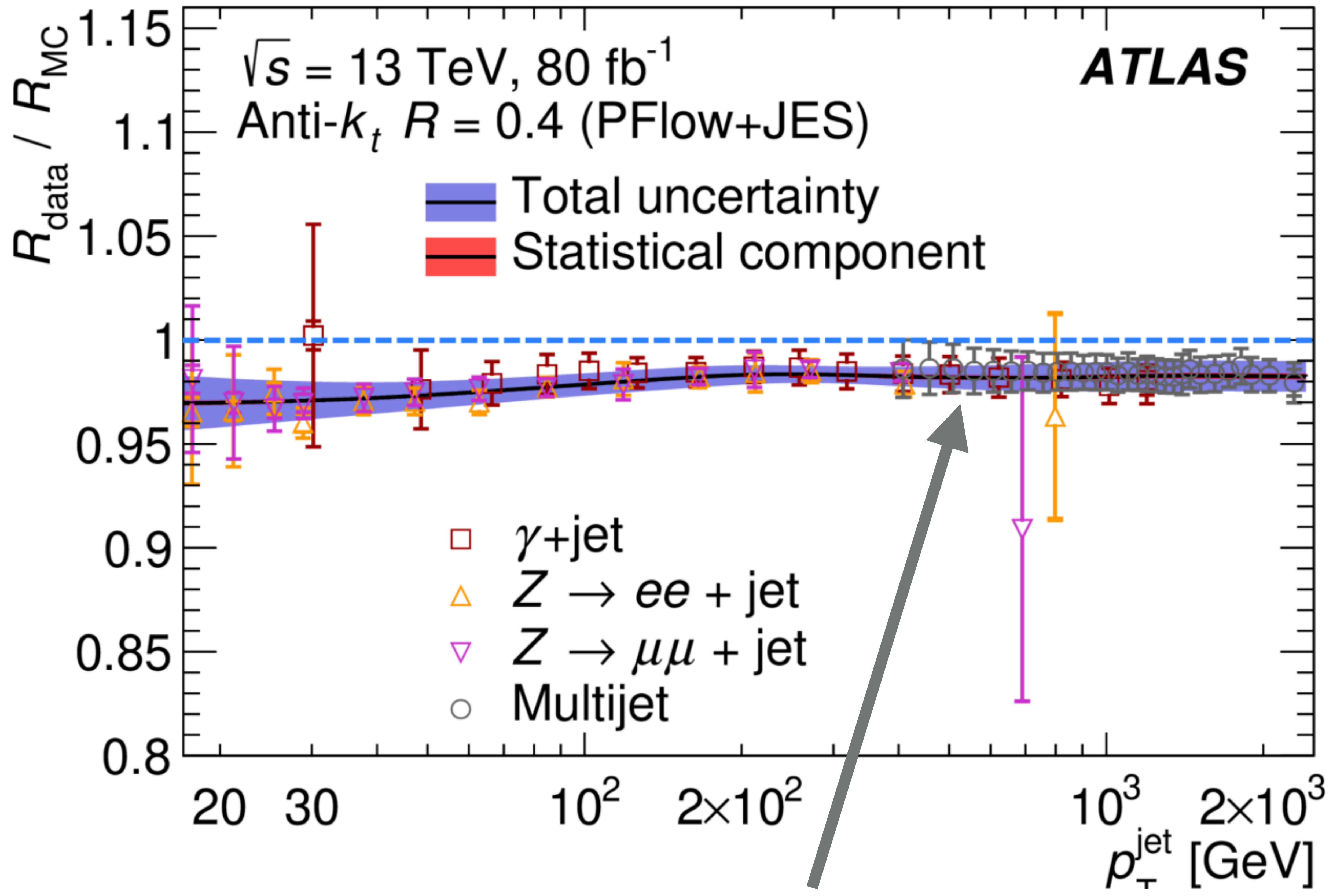
5 years later - searches are established, theorists got some of the measurements they asked for, and experimentalists are impatient.

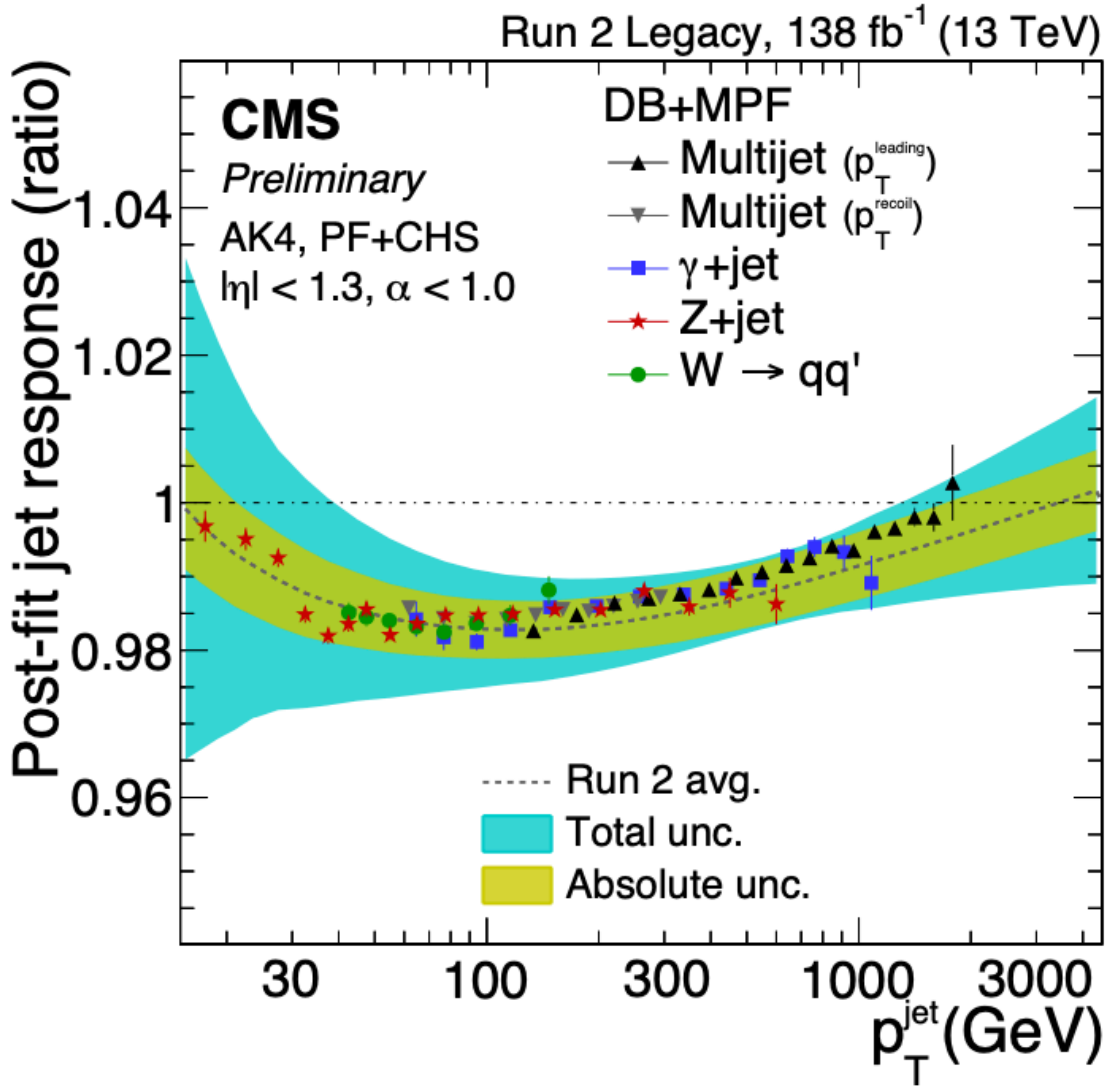
# JET INPUTS, RECONSTRUCTION AND TAGGING

# RECONSTRUCTING LARGE JETS AT THE END OF RUN-2

| | Inputs | Clustering | Pileup Mitigation | Grooming |
|---|---|---|---|---|
| ATLAS | **Unified Flow Clusters**<br>Calorimeter cell-level matching (low pT) + cluster-level matching (high pT) | **Anti-kT (R=1.0)** | **CS + SoftKiller/ CHS** | **SoftDrop (mMDT)** |
| CMS | **Particle Flow** | **Anti-kT (R=0.8)** | **PUPPI-tuned v15** | |

Dear ATLAS: I would like UFOs to be used everywhere now and to not hear of another acronym ever again (or until next BOOST)

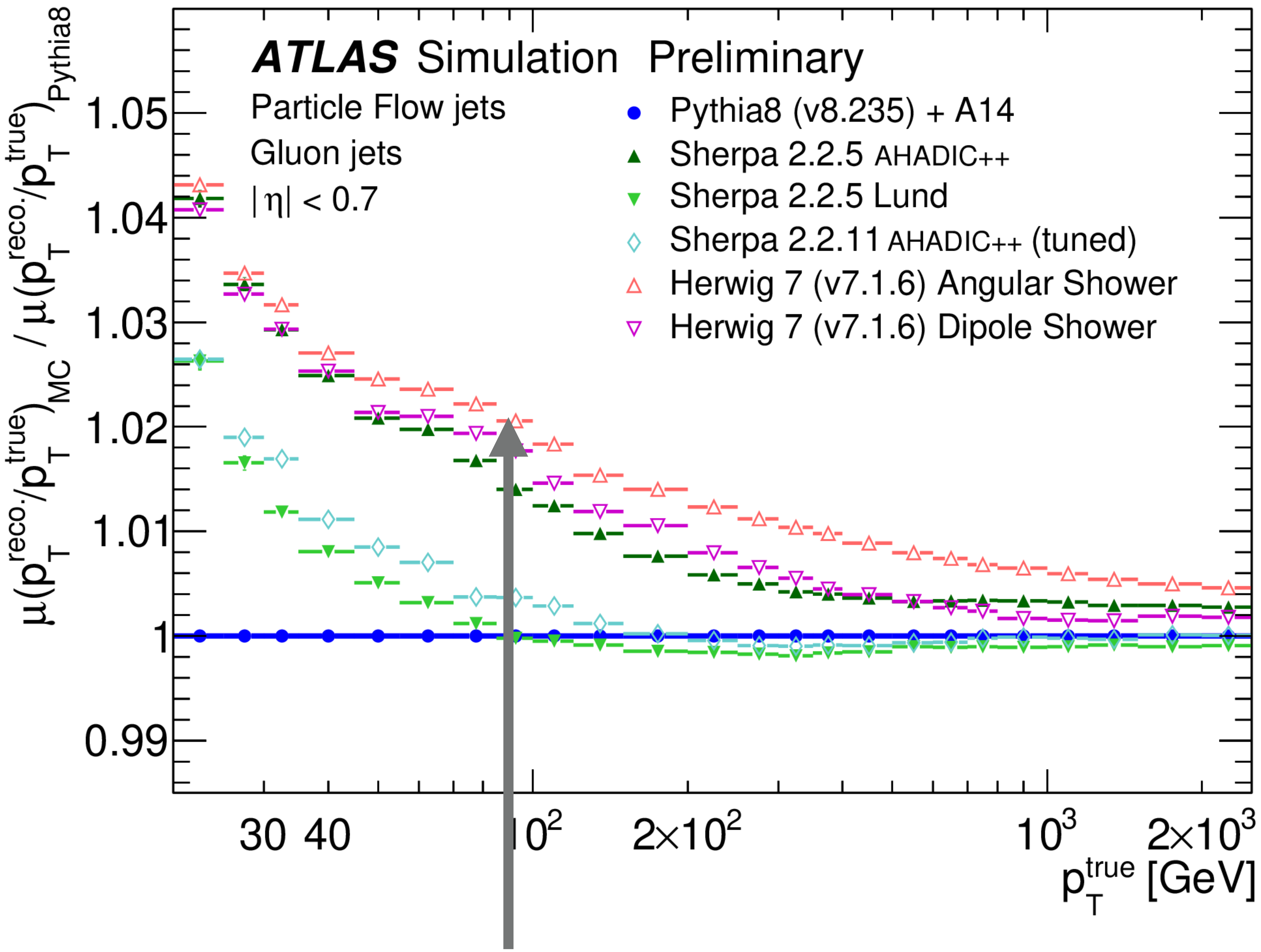



Shift by 2% in jet scale understood as originated from calorimeter response measurements (now measured in-situ in a $\pi^+$ sample)

**Have achieved <1% precision, can we go to 0.1%?**

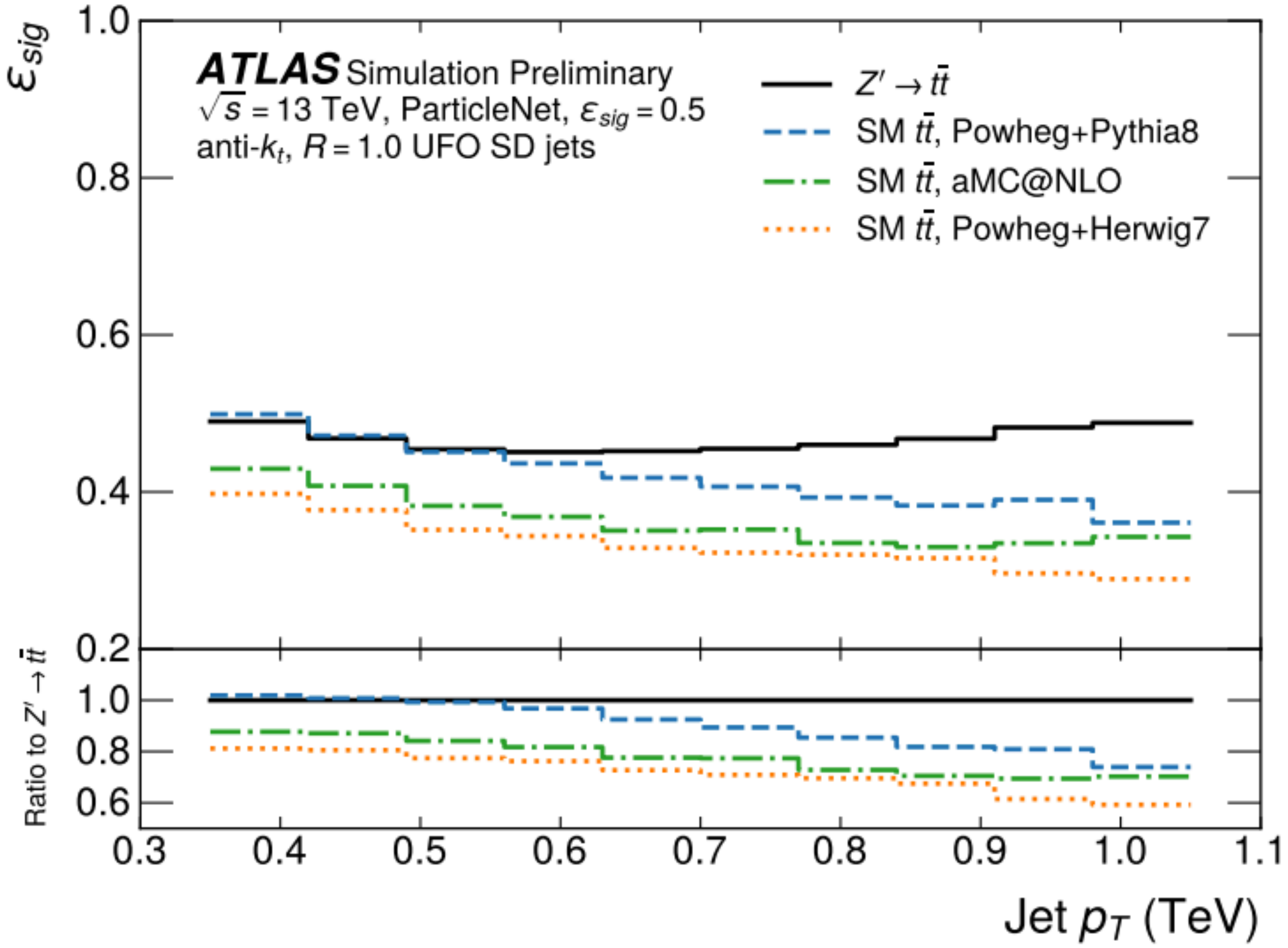
Garvita Arwal/Chris Young




**Understanding flavour responses is key to 0.1% precision:**

ATLAS made large strides by comparing the gluon jet response in many generators

# ATLAS TRIED PARTICLE NET (YAY!)



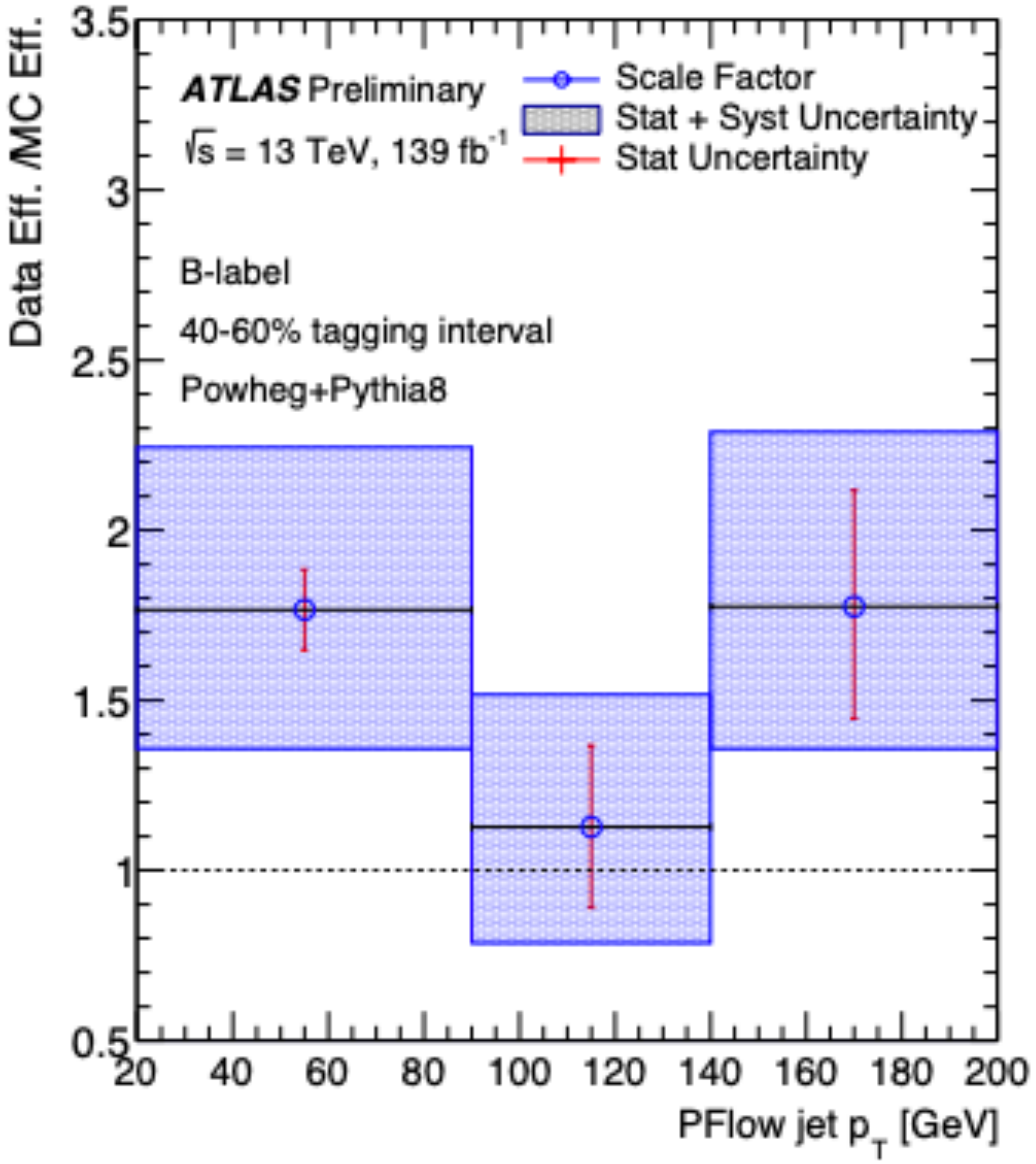

ROC curve matches expectations* but ParticleNet shows more model dependence than others (EFN/PFN)

**Is ParticleNet increasing or picking up the differences in PS/ hadronisation?**

*except perhaps on one comparison: ParticleNet way over ResNet50

Tobias Fitschen

# CHALLENGING TAGGING (1)



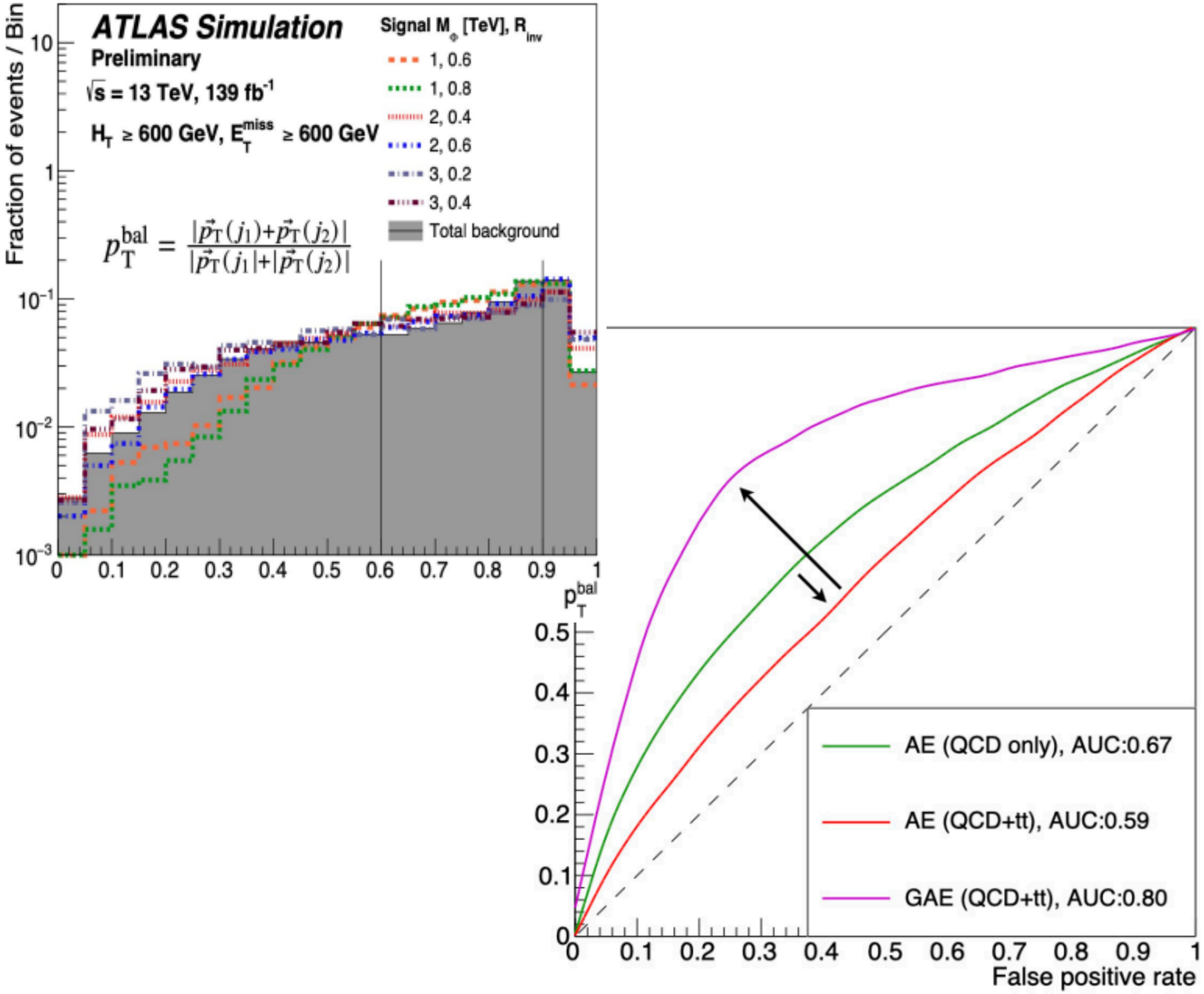

A *complete study (ROC to Scale Factor)* on **low $p_T$ bb tagging**

Data efficiency is too high: can we understand what is causing it and what is unique about this model?

**Can we understand what is uniquely beneficial for low vs high $p_T$ bb's?**

Yuan-Tang Chou/Sukanya Sinha/Jeremi Niedziela

# CHALLENGING TAGGING (2)




Studying dark showers with MET aligned in jets: kinematic imbalance vs ML

**How can we include realistic MET mis-reconstruction (and other detector effects) in our training?**

A ROC ~~is not telling me anything~~

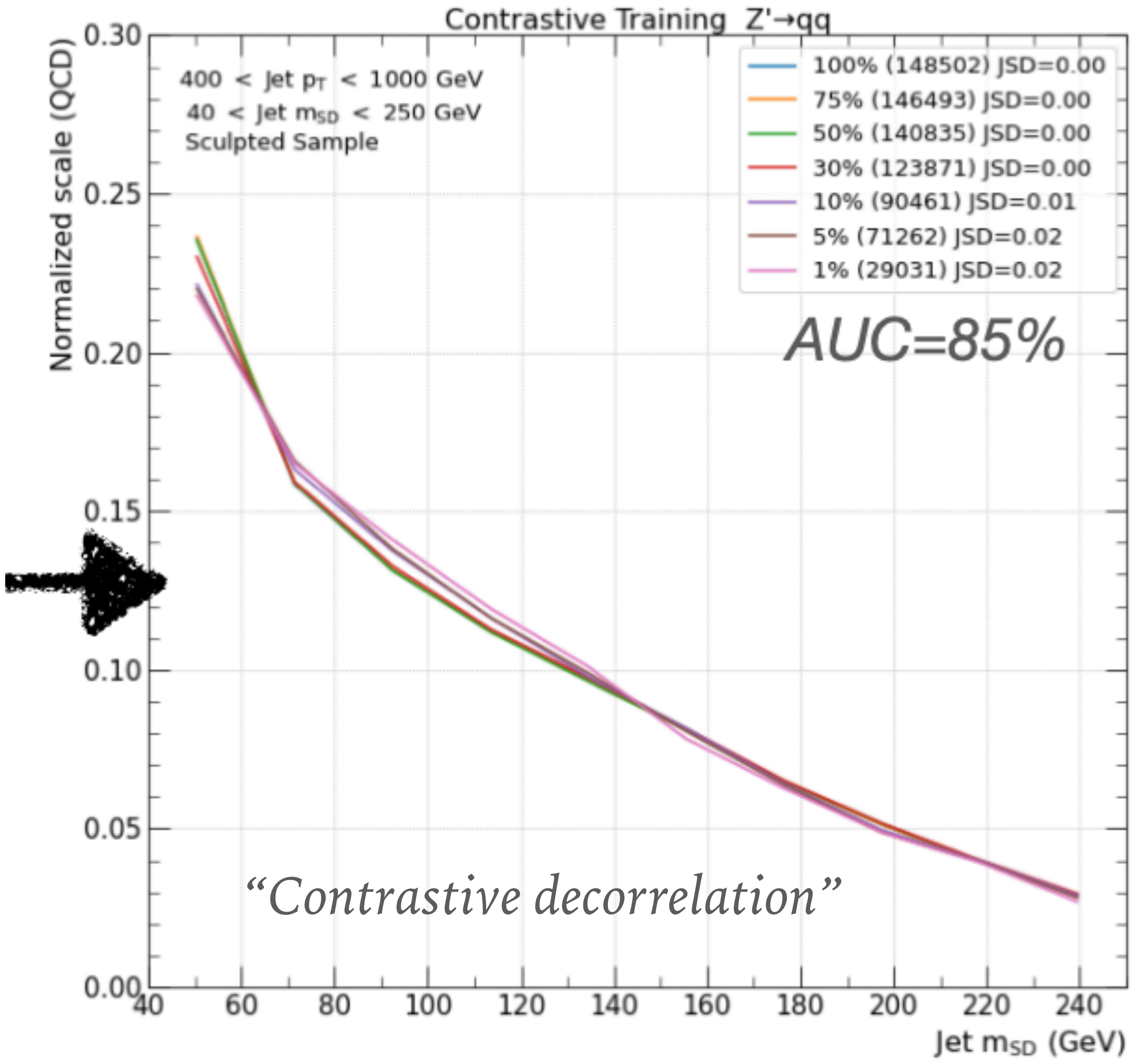
is not the full story (and we know this)

# 2016 Beyond the ROC: the mass decorrelation

We now have ways to address this:

DDT/KNN/DisCo/MoDe/Modify loss term/Tune input mass

**Can we challenge ourselves to decorrelate to a very tight level of background rejection < 1%?**




Jeff Krupa

# 2022 Beyond the ROC:

the mass decorrelation

the model independence

the IRC safety

the $p_T$ stability

the stability with resonance masses

the data/MC (dis-)agreement

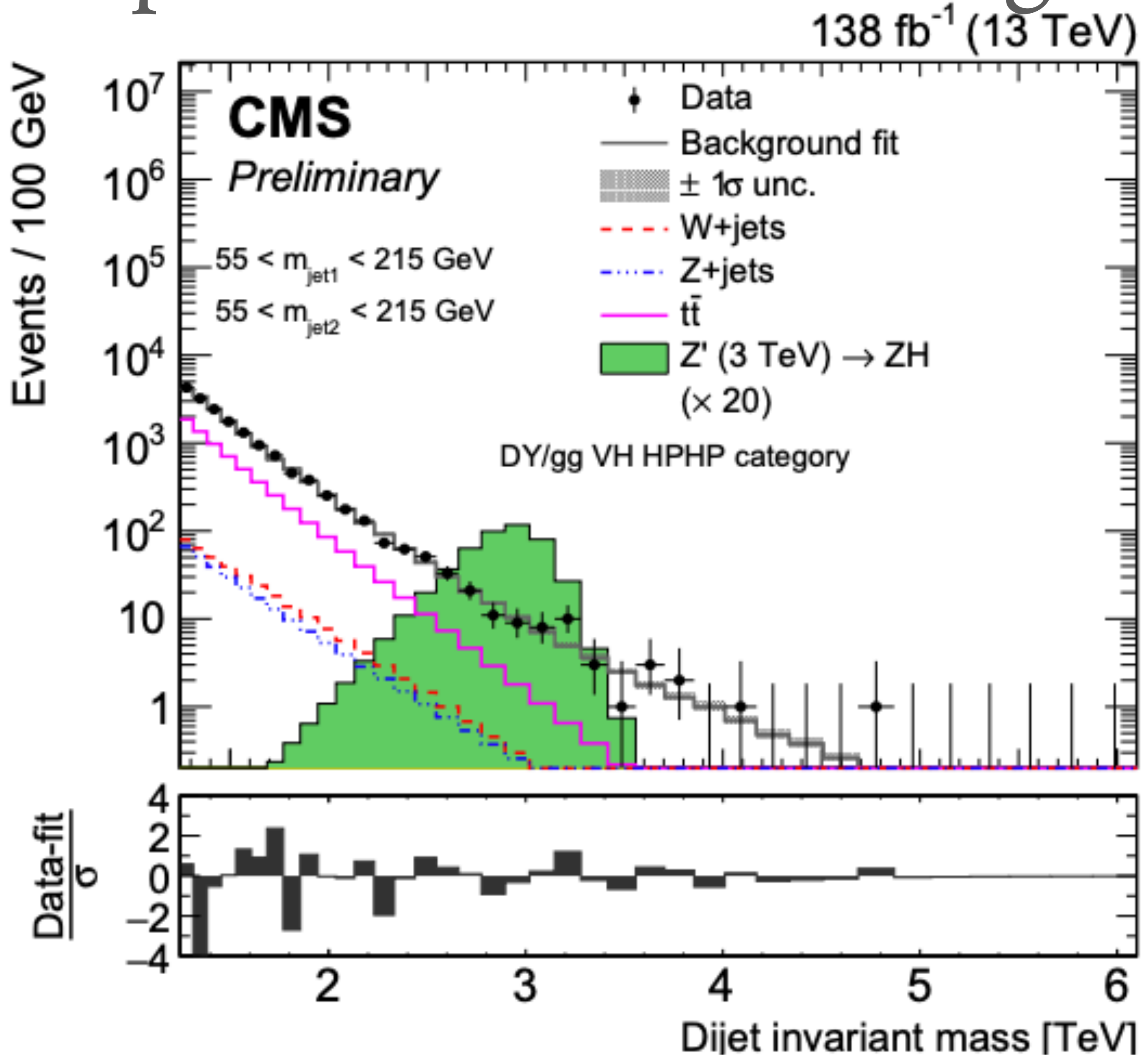
the lack of a real proxy in data

the uncertainty on your not-so-real proxy

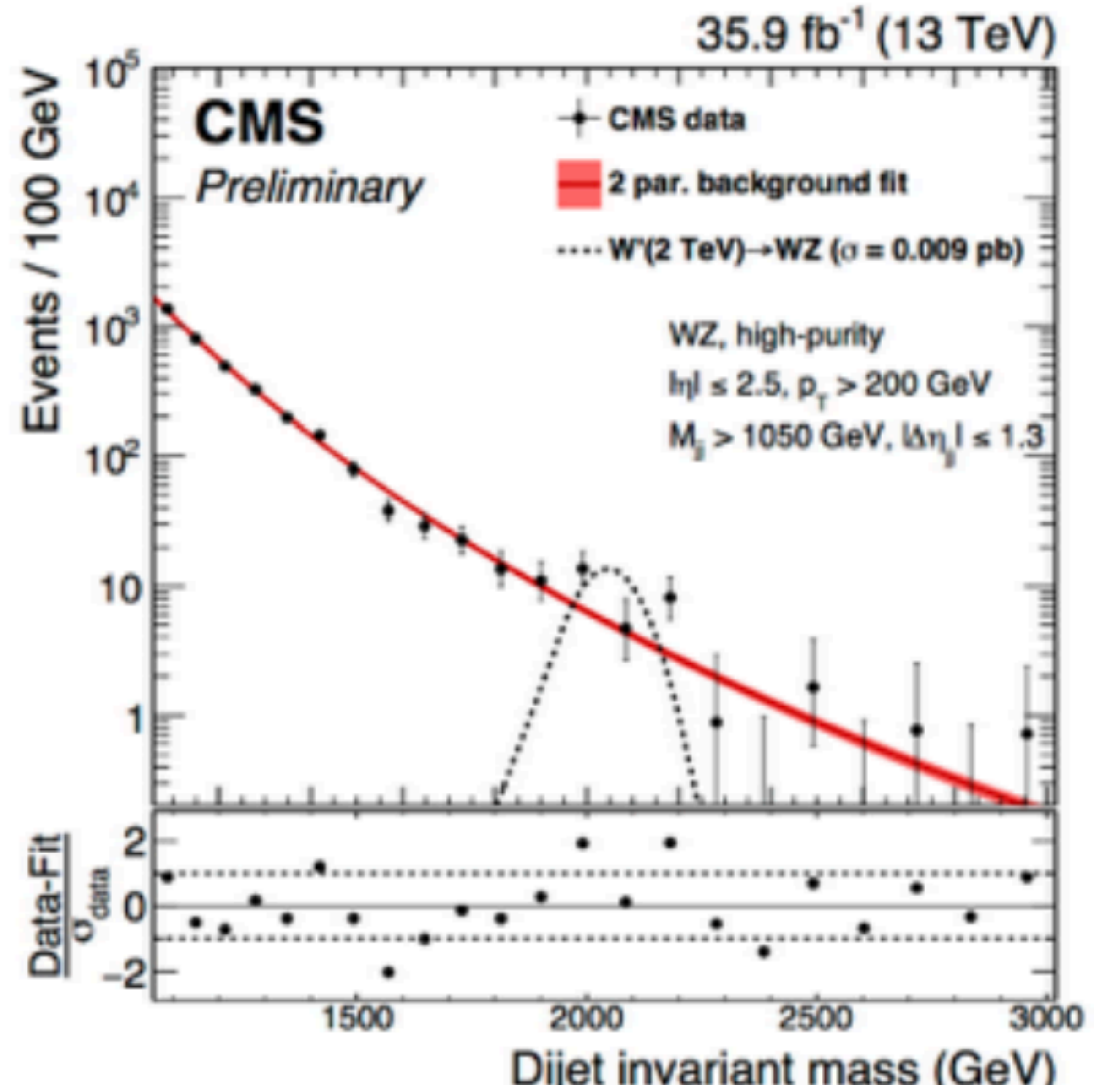
ALL OF THESE THINGS REALLY MATTER FOR A SEARCH

# E.G PROGRESS SINCE 2017 (DIBOSONS)

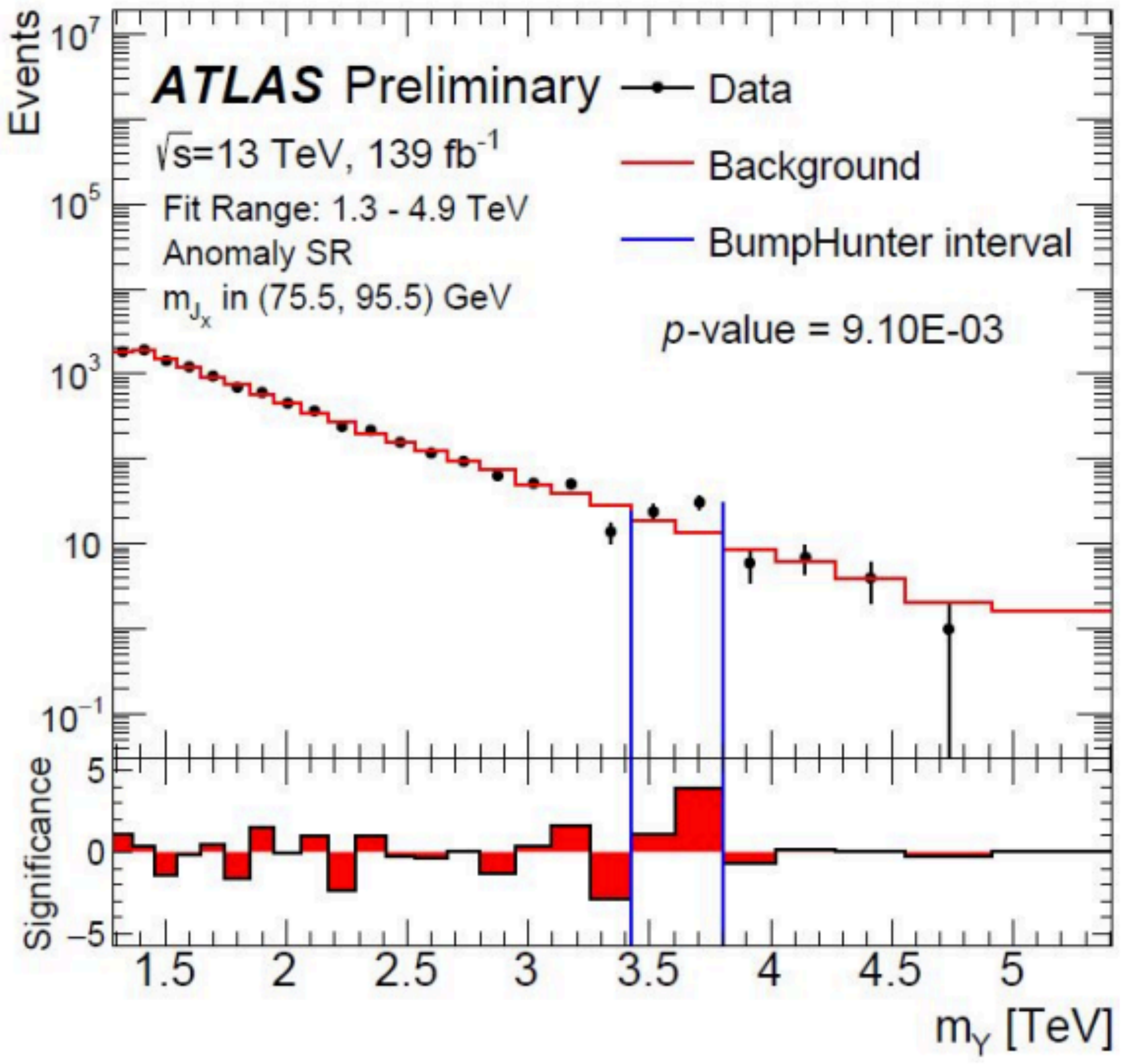
Sophisticated 3D background fit




2017: 1D fit



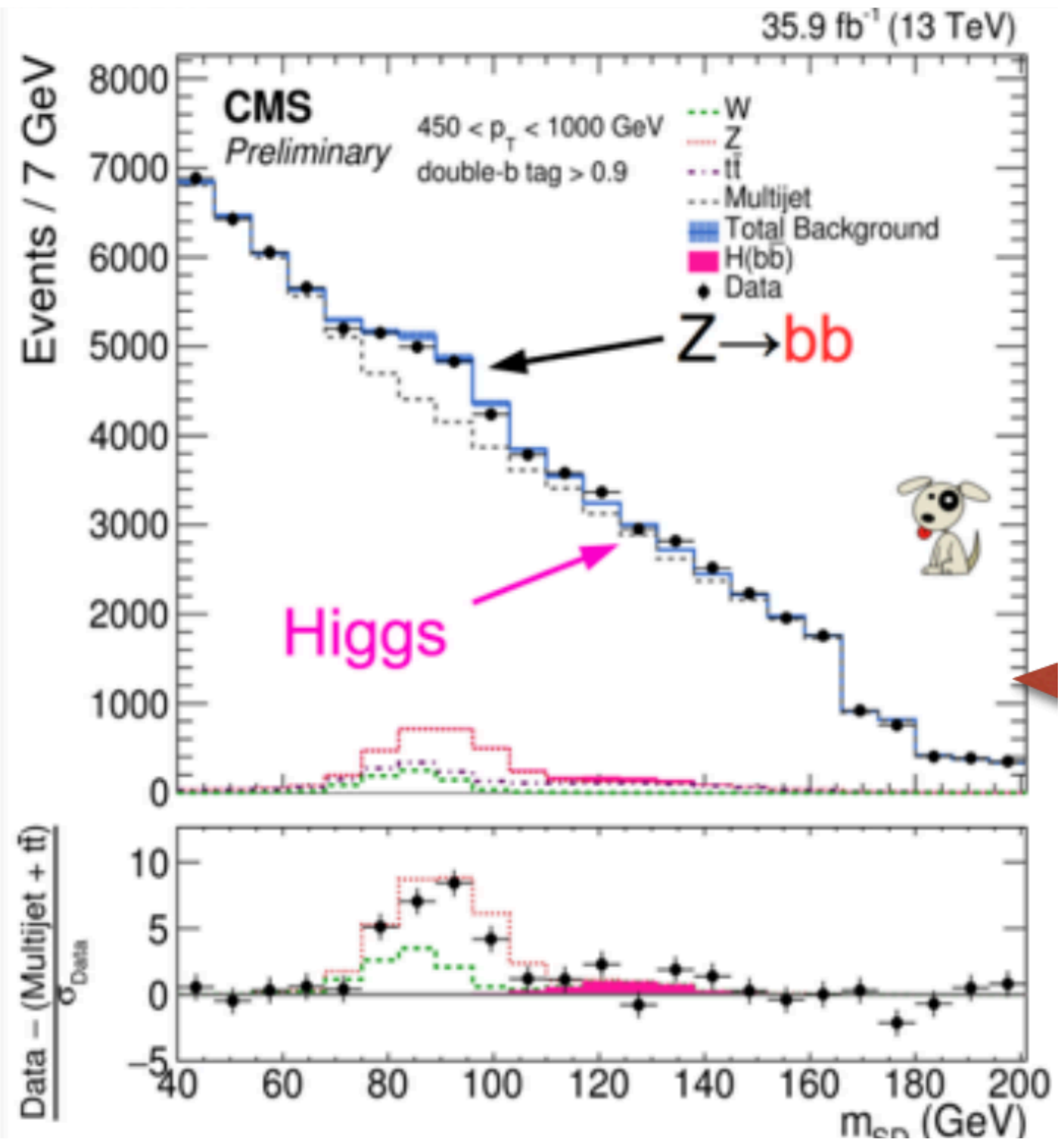

Including anomaly signal region



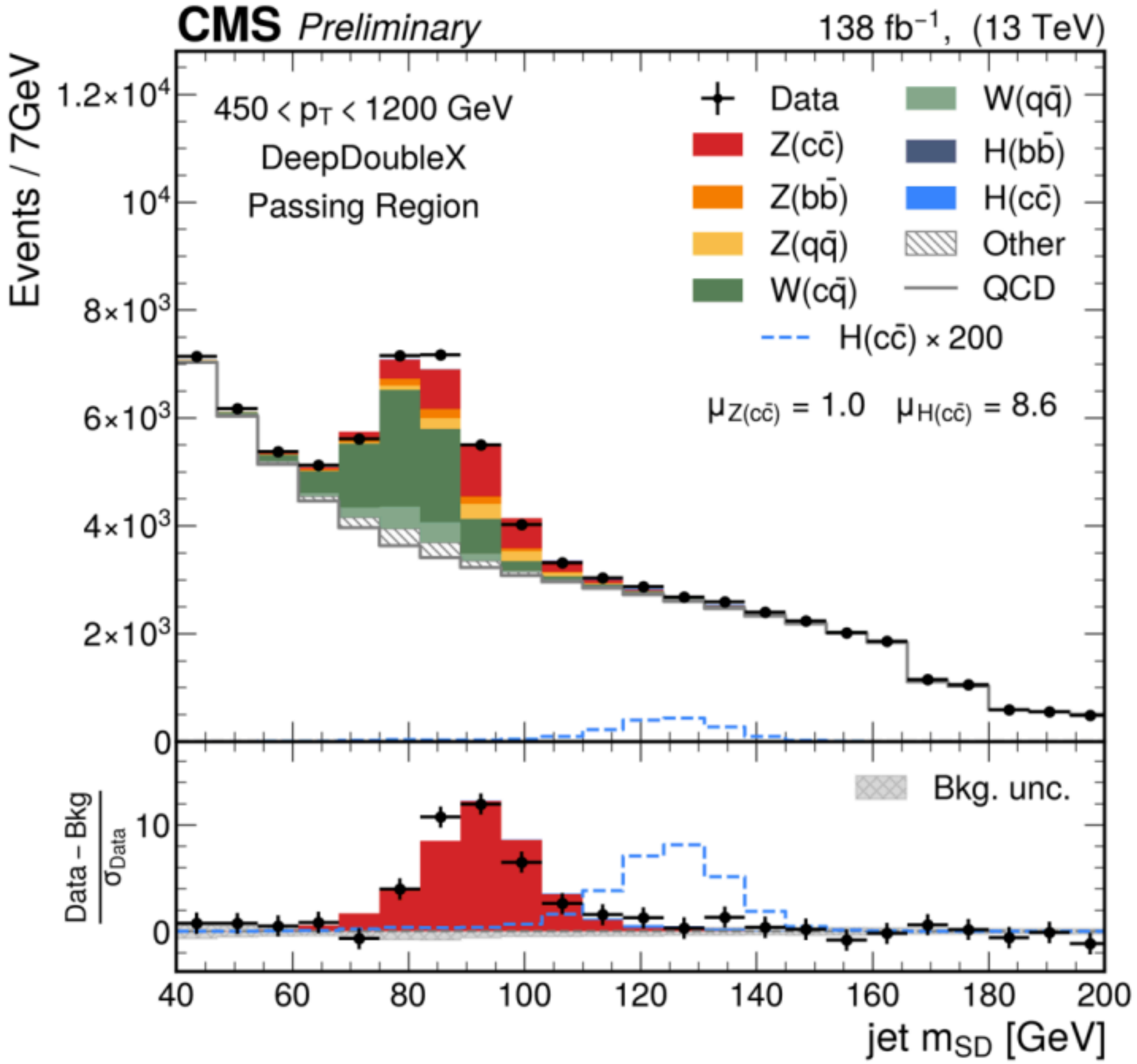

Lars Henkelmann/Denis Rathjens/
Sotiroulla Konstantinou/Ali El Moussaouy

# E.G PROGRESS SINCE 2017 (HIGGS IN ONE JET)

2017: Z(bb)

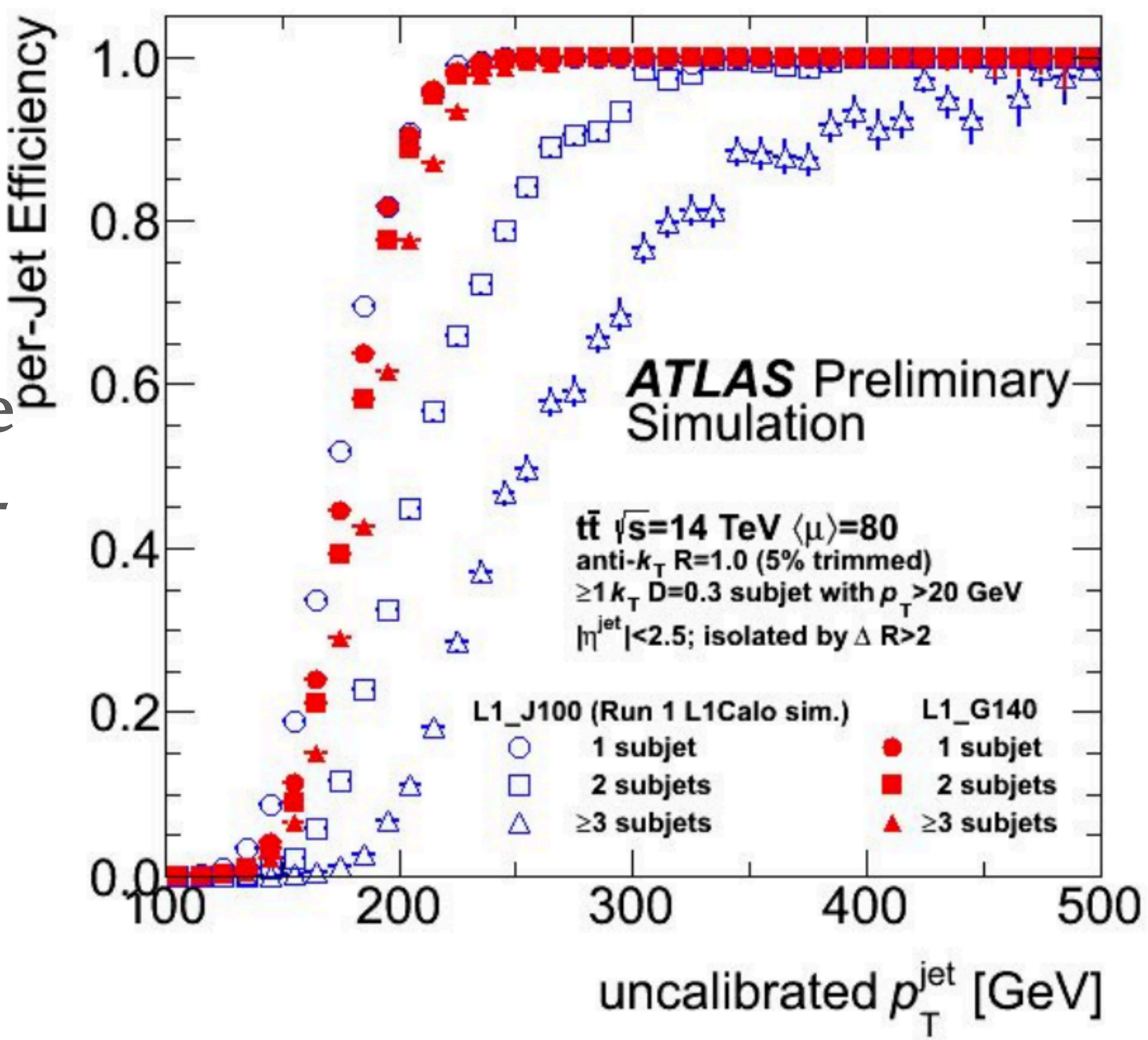



2022: Z(cc)



# LOOKING FOR SUBSTRUCTURE AT THE LEVEL-1 TRIGGER

How will these **improvements translate to HLT and our trigger-limited searches?**

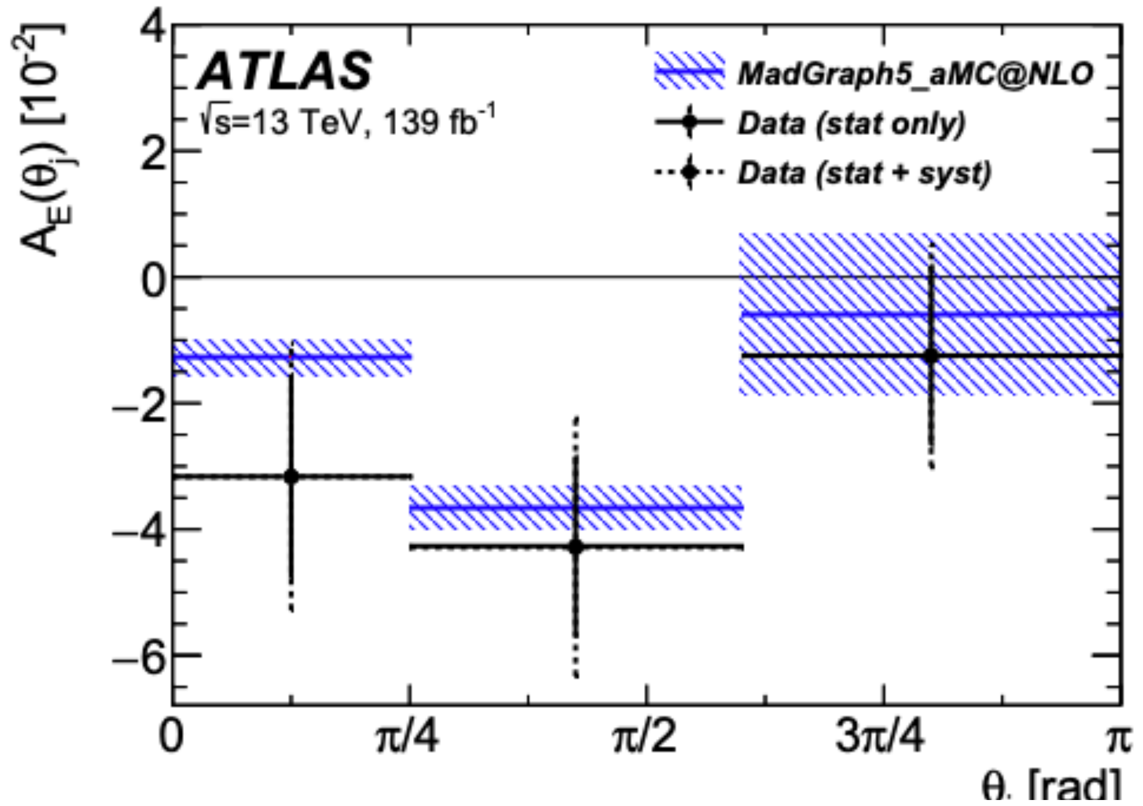


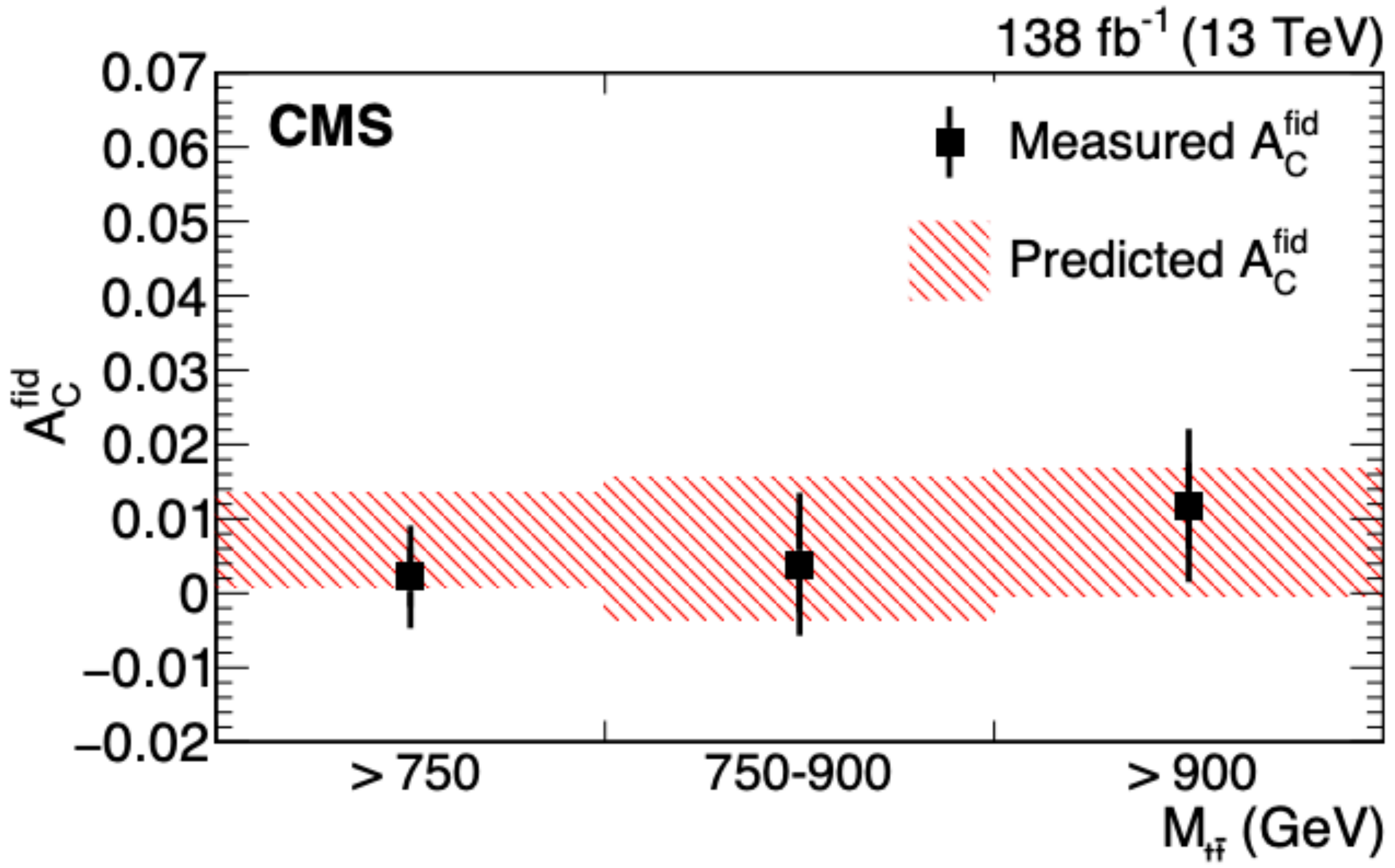
- We have a basis of jet reconstruction and tagging and we are ready for Run 3. This should not stop us from being innovative.
- As new data approaches here are a few signatures that we should start *boosting for*: semi-visible jets, dark showers, flavour and color jets, anomalous densities of events, more Higgs!
- We should start *boosting with* detector upgrades that will happen in Run 4 and will revolutionize our jet reconstruction: e.g. HGCAL, the new inner trackers and the trigger upgrades.

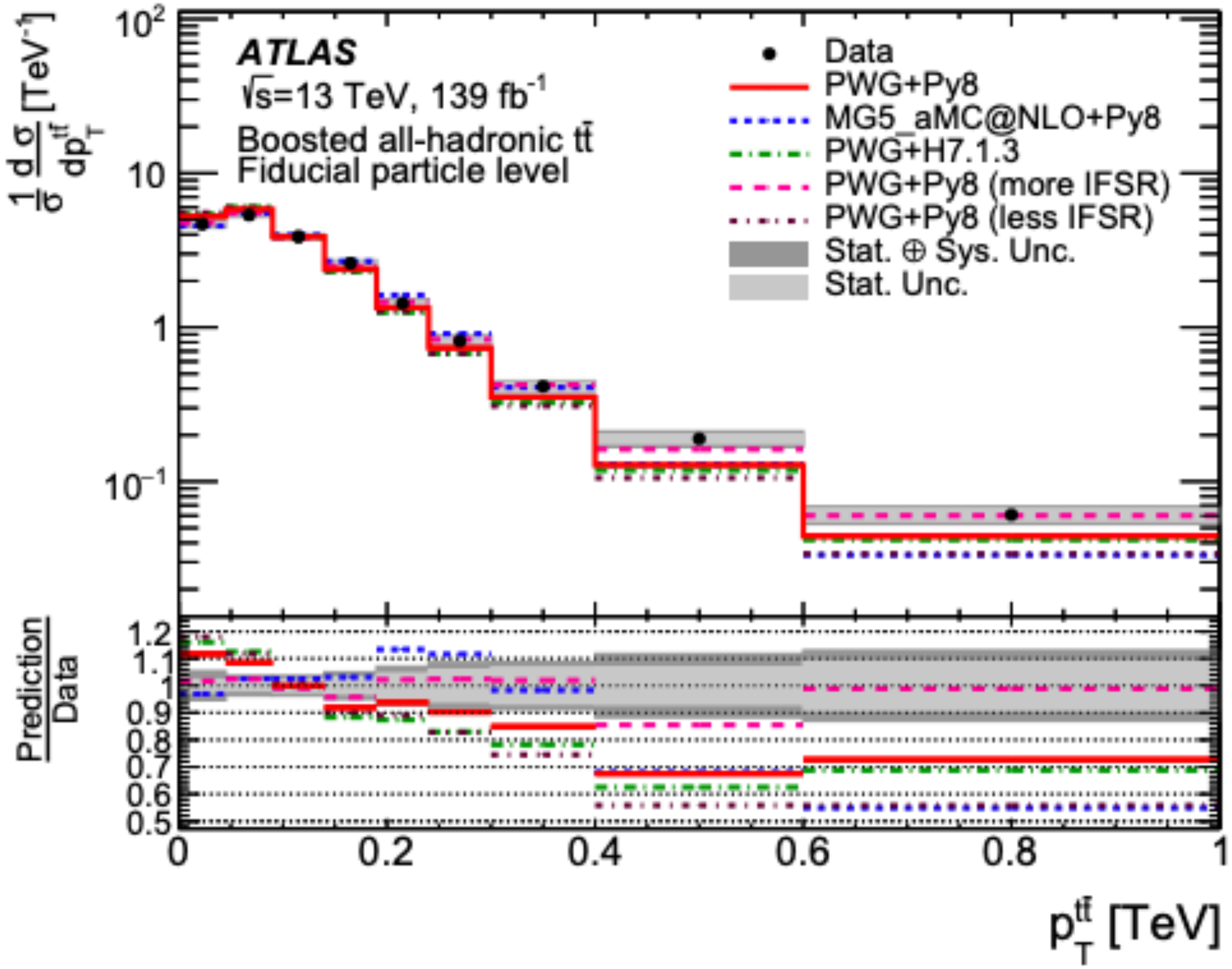
# QCD AND QGP MEASUREMENTS

# TOP MEASUREMENTS WITH BOOST

Charge and energy asymmetry



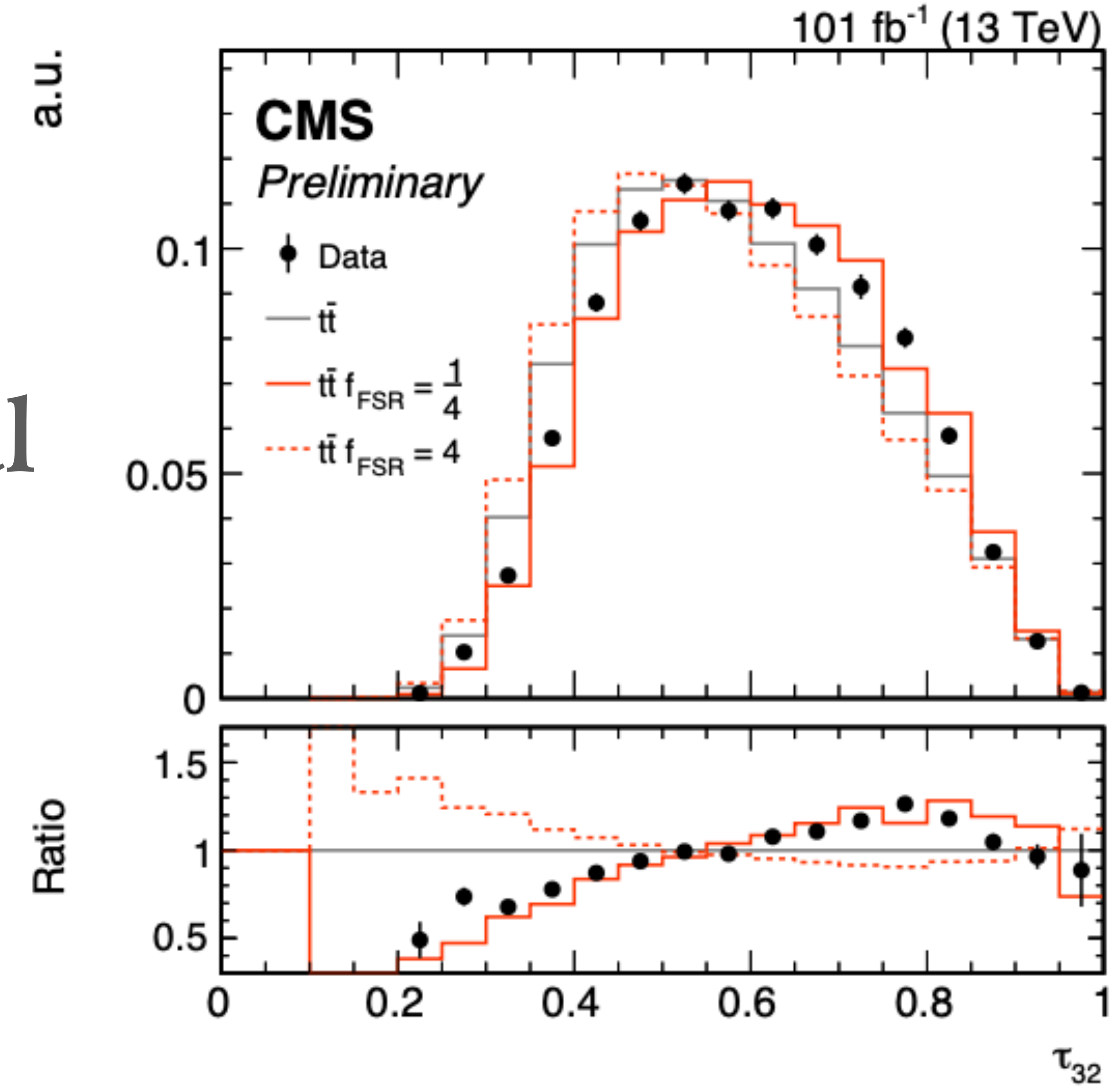

NNLO provides the best agreement but an increase on FSR provides an even better agreement

# WE CAN INCREASE THE TOP MASS PRECISION BY 1 GEV

$$m_{\text{top}} = 172.6 \pm 2.5 \text{ GeV} \rightarrow \boxed{m_{\text{top}} = 172.76 \pm 0.81 \text{ GeV}}$$

$$\Delta m_t(\text{FSR}) = 1.5 \rightarrow \boxed{\Delta m_t(\text{FSR}) = 0.02 \text{ GeV}}$$

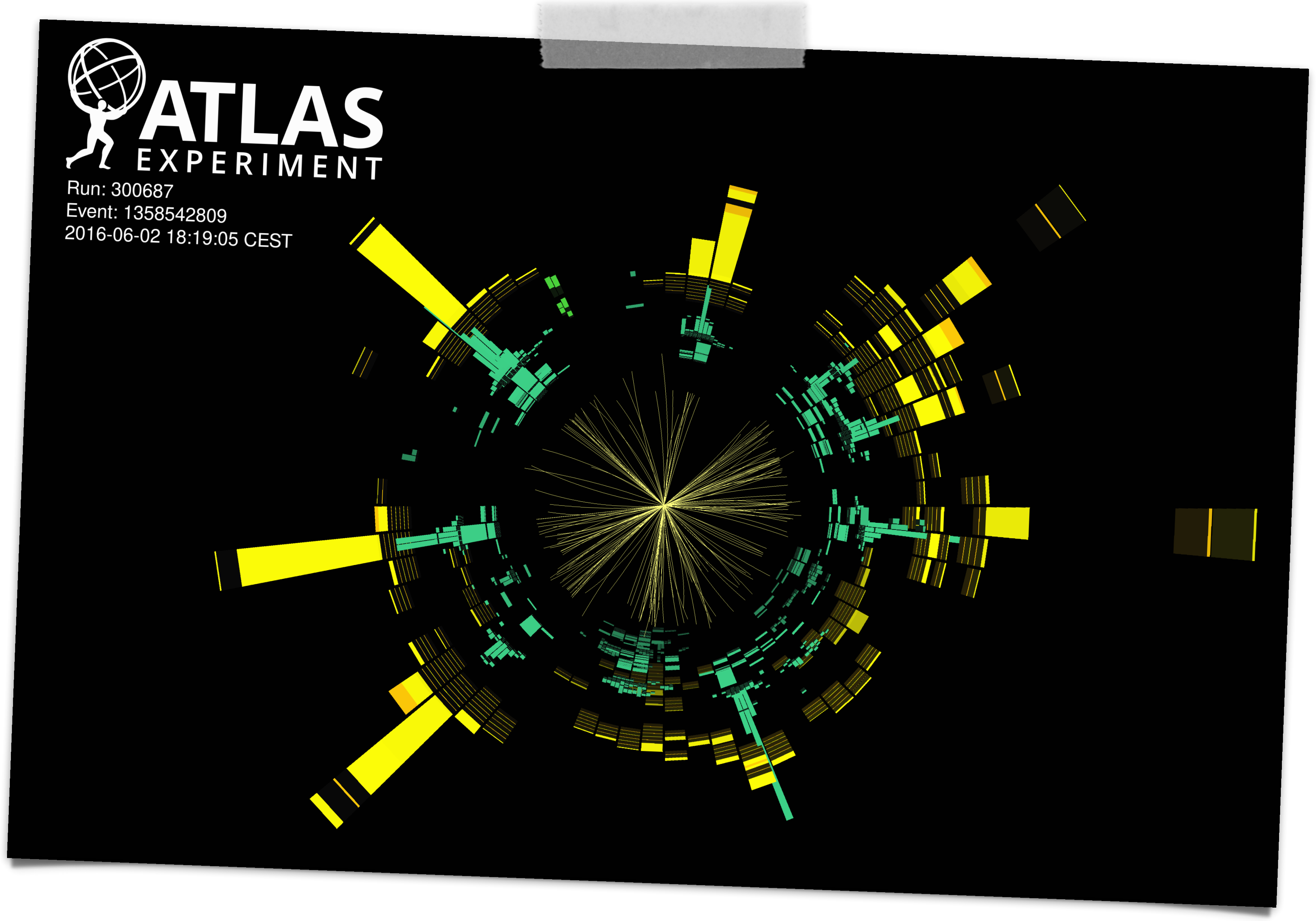
(Part of) the large improvement came from a **better retune of additional final state radiation** in fiducial region

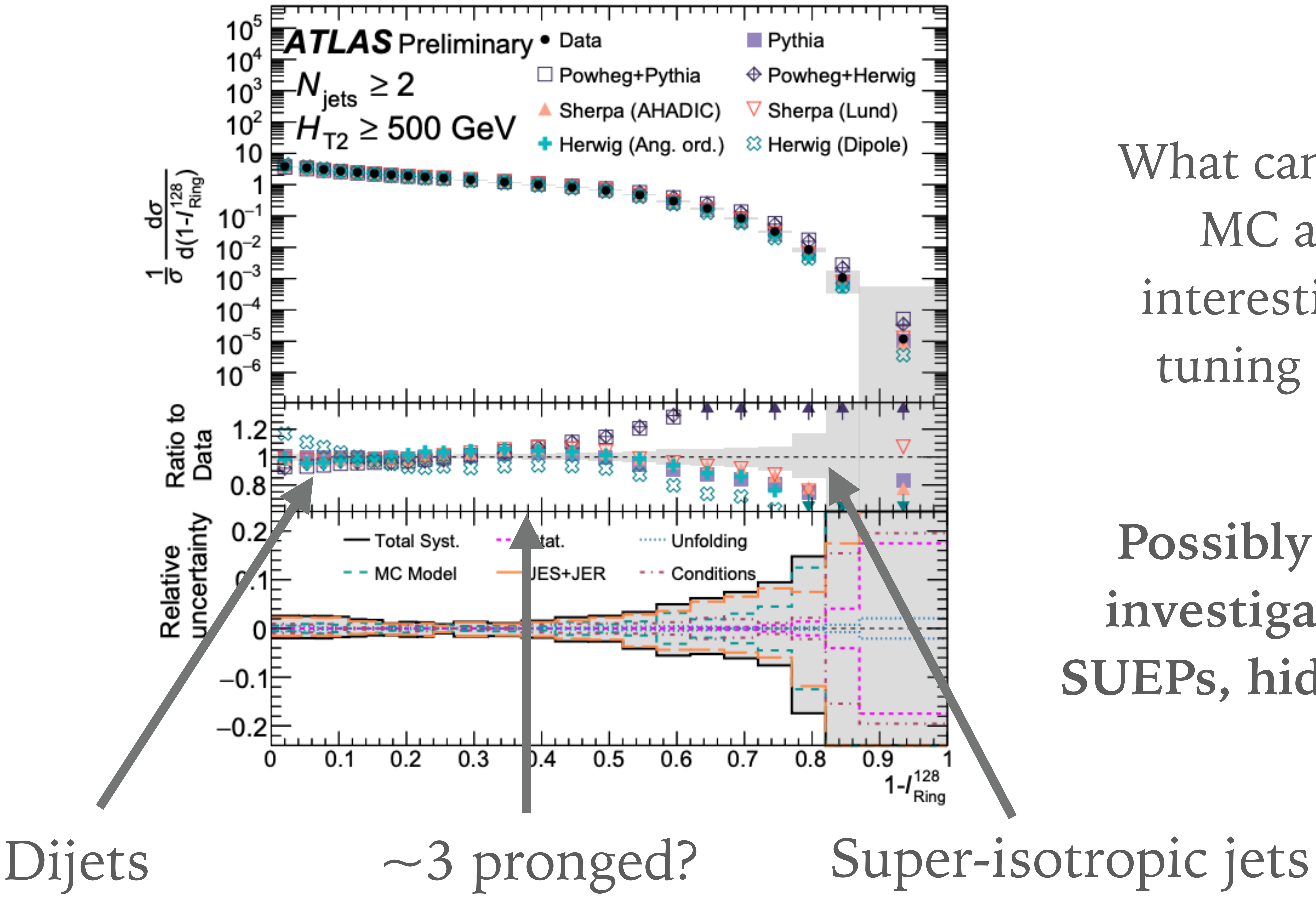


# How should we tune our QCD modeling?

# WE CAN CHARACTERIZE THE TOPOLOGY OF COLLISION EVENTS

Measuring how far an event is from (~~a symmetric~~) any radiation pattern.

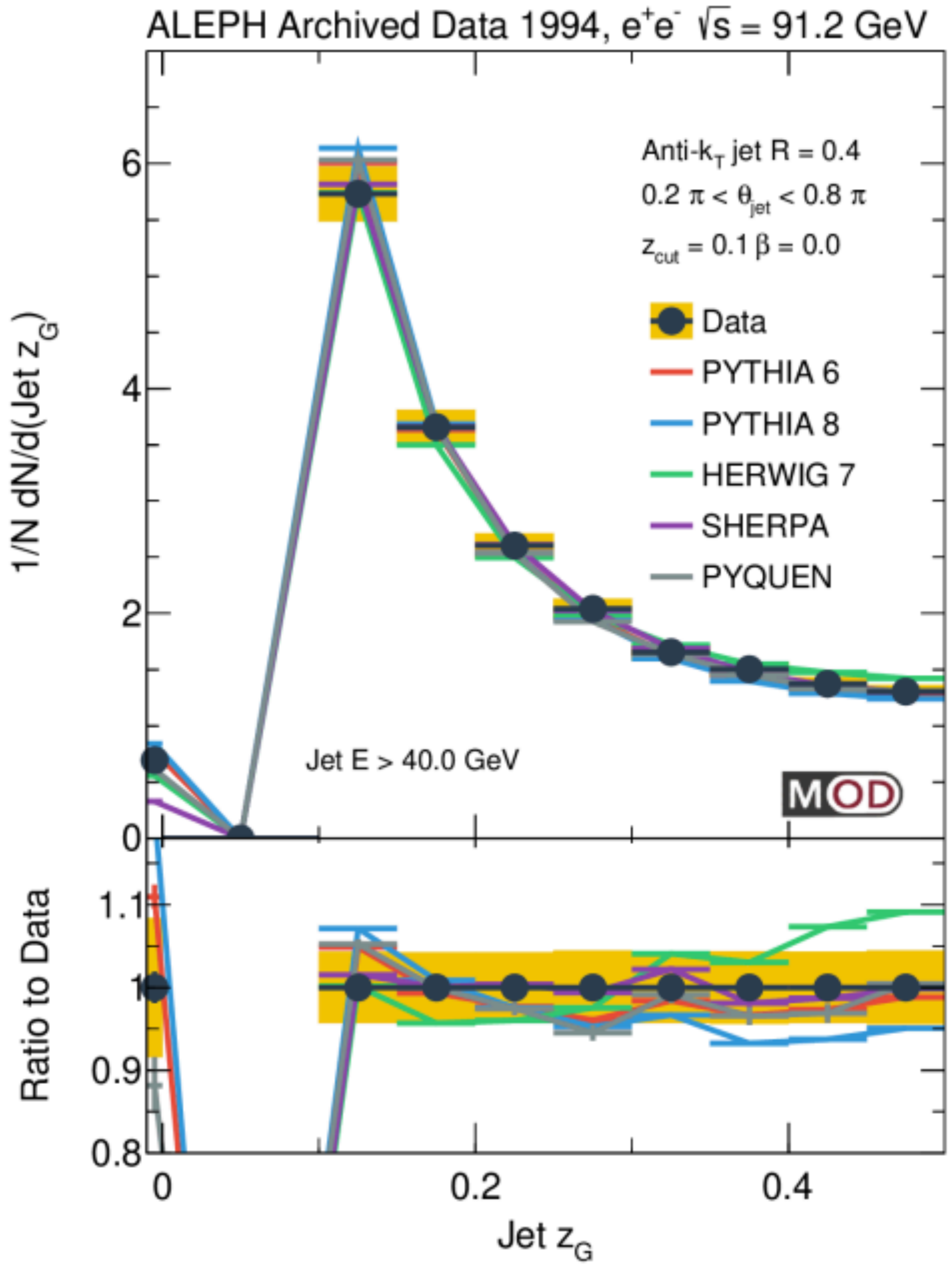



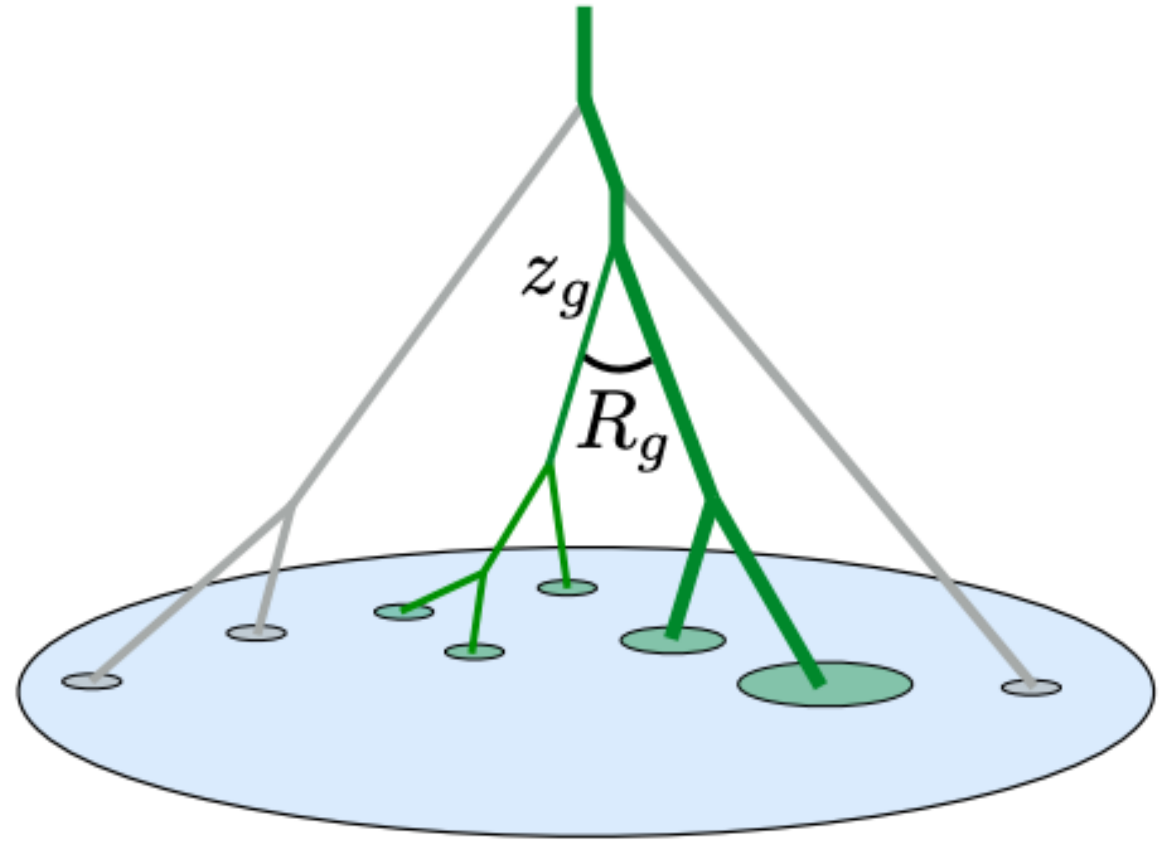



What can be said beyond data/MC agreement (already interesting by itself) and MC tuning at high multiplicity?

**Possibly use observables to investigate QCD instantons, SUEPs, hidden valley scenarios?**

# WE CAN RE-EXPLORE DATA IN A CLEAN ENVIRONMENT




ALEPH **e+e-** data measurements at high energy of energy splitting ($z_G$) and angle ($R_G$) have *similar behavior* to the LHC

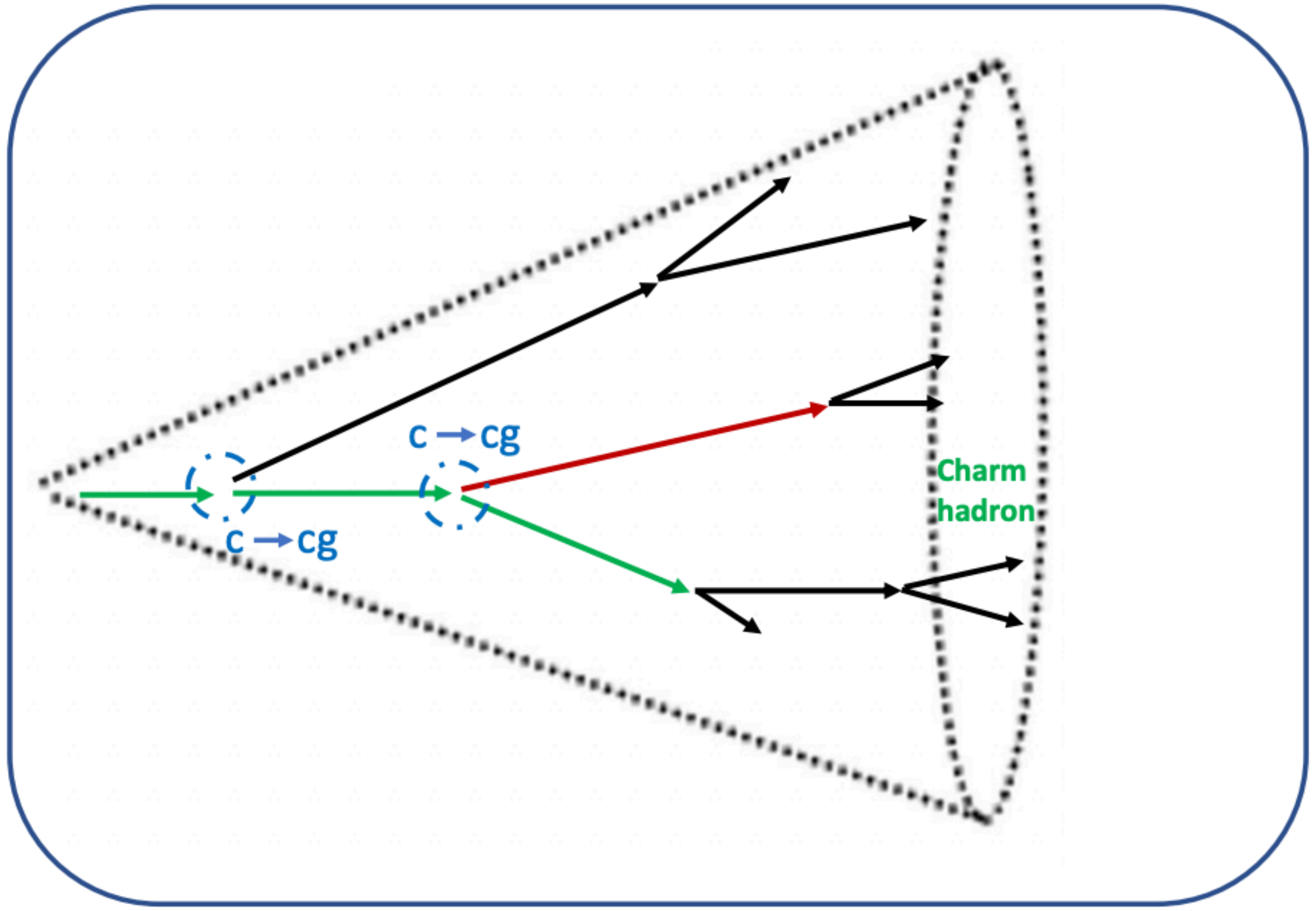
**e+e- data can give us input to improve modeling**

Yi Chen

# The rise of heavy flavor

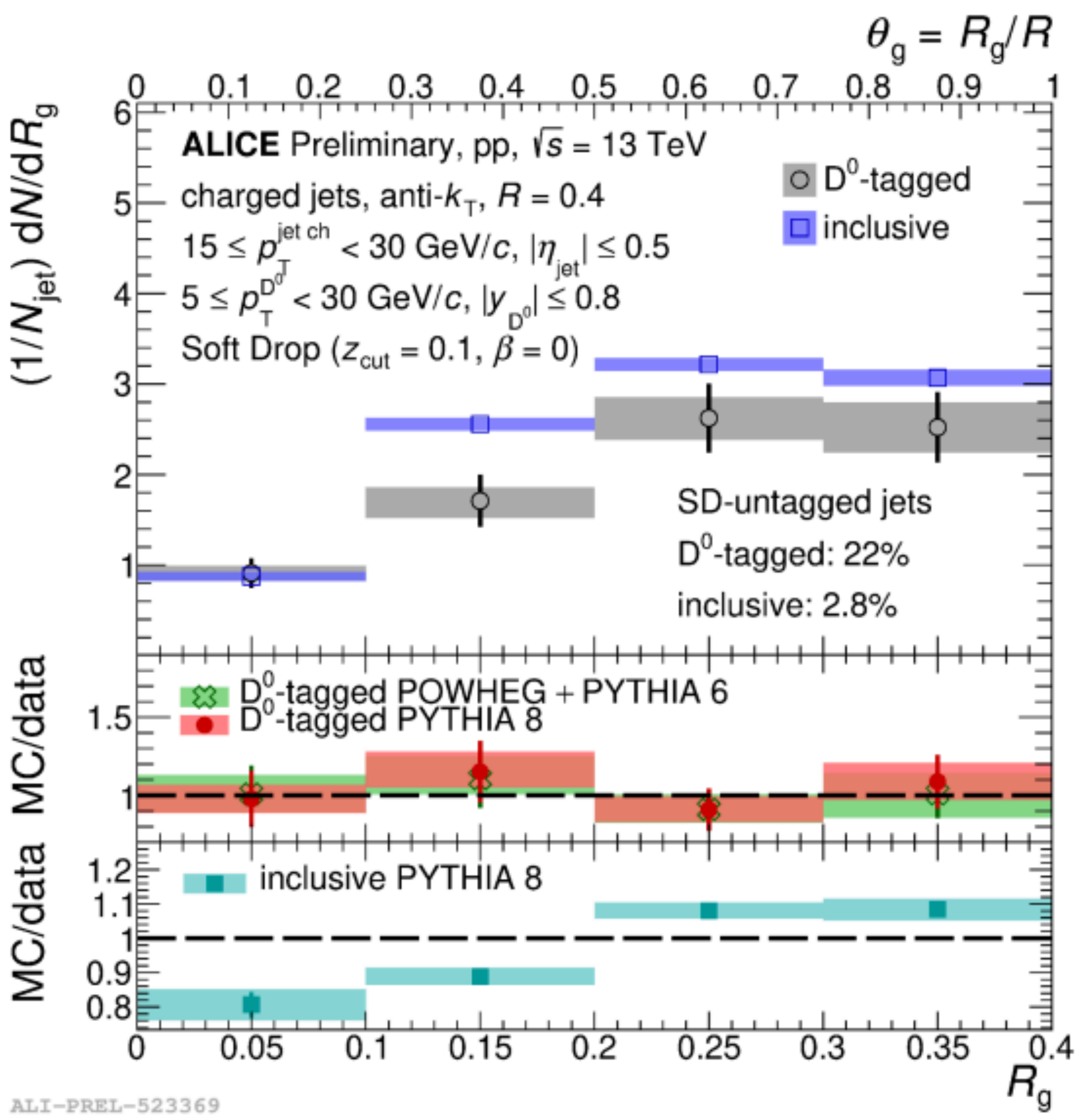
# WE CAN EXPLORE CHARM QUARK SUBSTRUCTURE IN PP

ALICE's excellent Particle ID + Run-2 data + Dynamic reconstructing the parton shower




**Identified charm quarks from $D^0$s**, b-quark substructure is next and only stats are limiting!

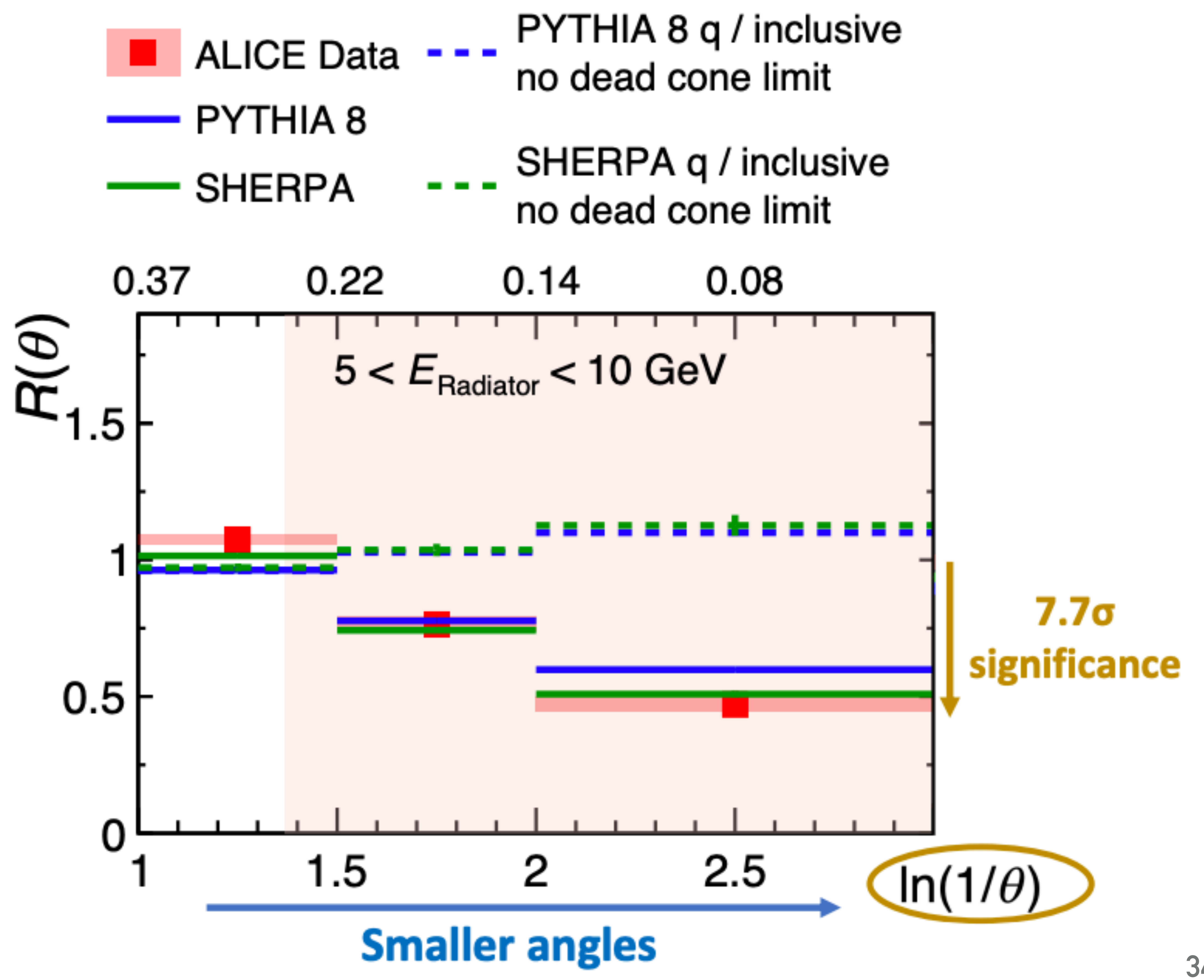
# MEASURING RG/ZG/ANGULARITIES WITH HEAVY FLAVOR




Learned that **for charm quarks fragmentation is harder and wide emissions are suppressed** when compared to light+gluon jets (among other things)

# ALICE TAKING IT TO THE NEXT LEVEL WITH THE DEAD CONE

**Clear suppression at smaller angles** when comparing charm-quark emissions with those from light quarks and gluons

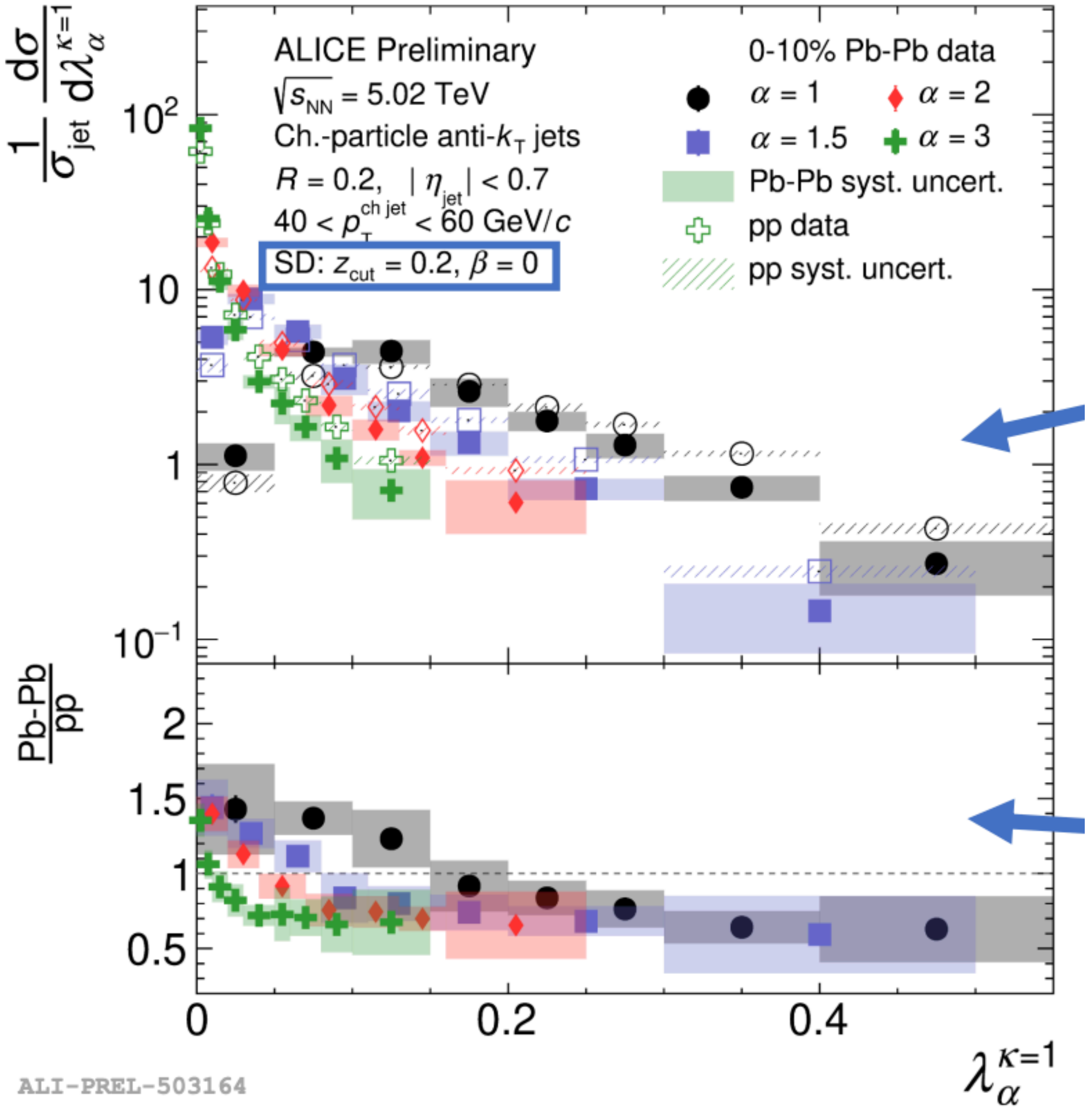



Nima Zardoshti

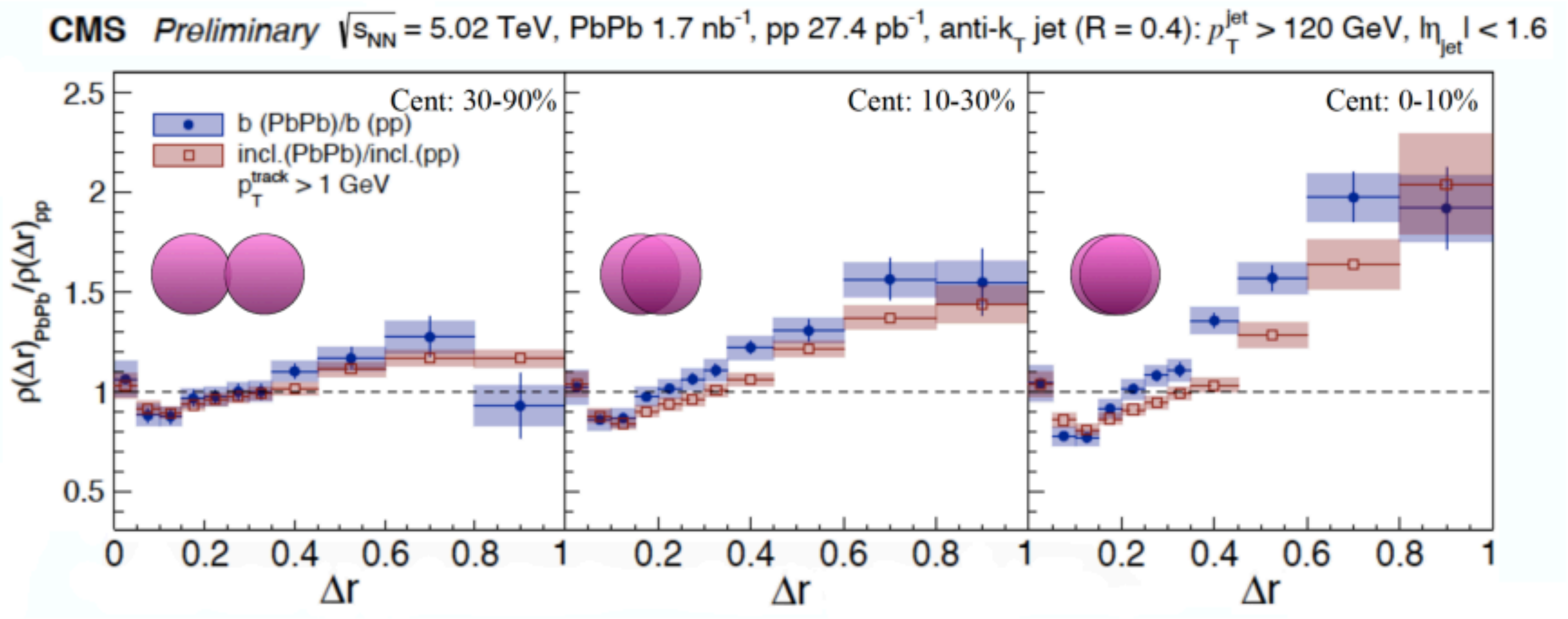
# How do jets propagate in the QGP medium?

# EFFECT ON PT DISTRIBUTION OF TRACKS WITHIN JETS

Jet angularities show **narrower $p_T$ distribution in PbPb** than pp and **grooming reveals strongest quenching**



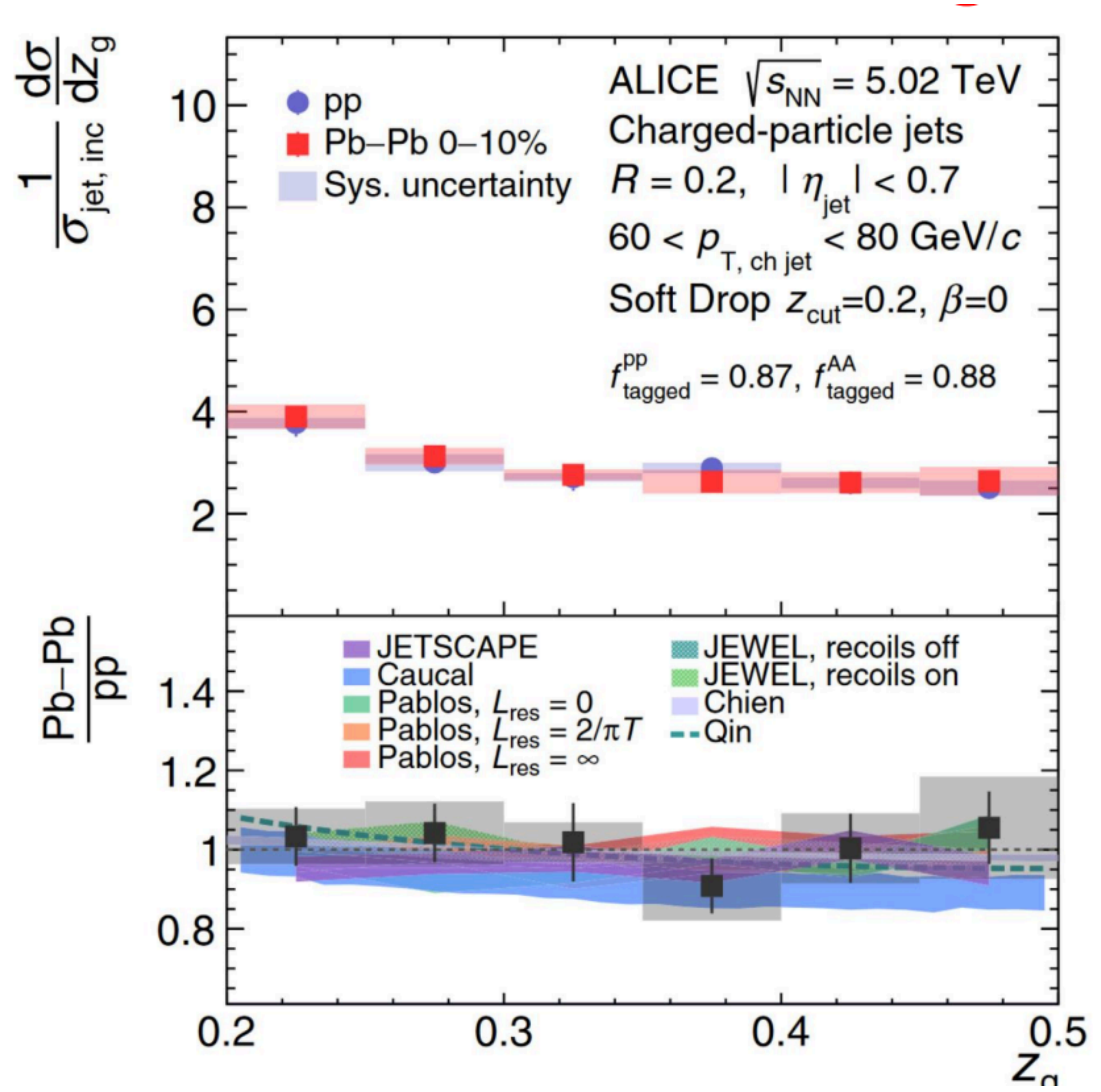
# TOWARDS HEAVY FLAVOR IN PBPB

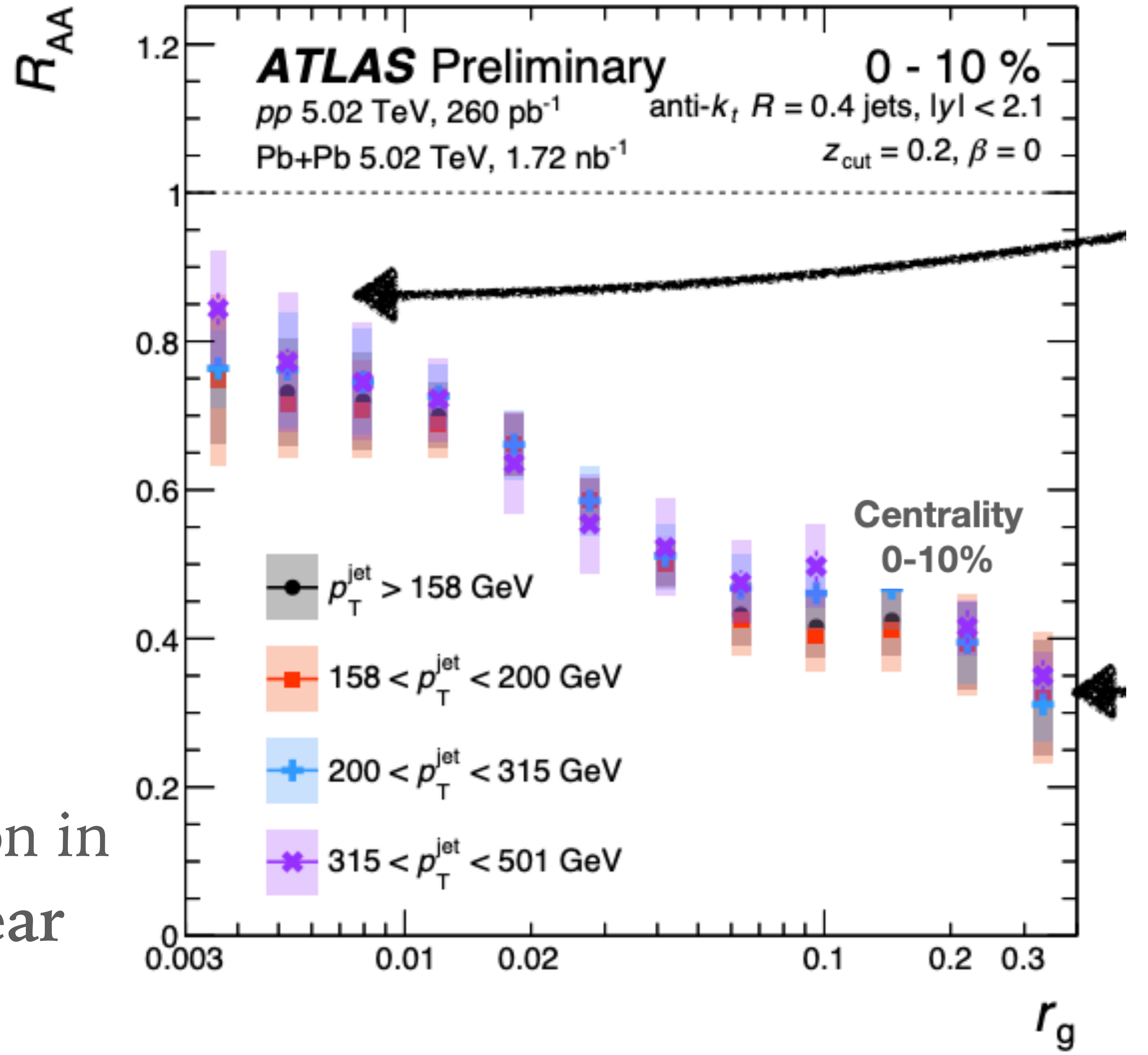



Increasing nuclei overlap

First comparisons of b-jet shapes with inclusive-jet shapes (tell us about the momentum flow in jets). Sensitive to mass effects, dead cone..

# CHARACTERIZING AT WHICH CRITICAL ANGLE JET QUENCHING APPEARS




$z_G$ measurement does not show any modification in the medium but $R_G$ **measurement shows clear dependence of jet energy suppression**

Ezra Lesser/Dhanush Hanga

# CONCLUDING REMARKS

The final states we all explore are *all about the boost*

- The statement is valid whether you are doing pp or PbPb, a measurement or a search, whether you are using ML or not.
- BOOST is fun. We cannot let our efforts disperse or let this community die: especially as we move towards more LHC data (and other data), better detectors and better theory observables and predictions.

BOOST 2010: These aren’t your daddy’s jets
BOOST 2011: “First” data
BOOST 2012: Kids in a candy store
BOOST 2013: Bringing substructure into the mainstream
BOOST 2014: if you ain’t boostin’ you ain’t livin’
BOOST 2015: What a difference five years makes
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**BOOST 2022: we are all about that boost**

(no treble) ♫

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**BOOST 2022: we are all about that boost (no treble)** ♫

Go watch: https://www.youtube.com/watch?v=zsUIDOn6nJk

And Nhan Tran’s summary talk on 2014

boost~~a~~mos!

(it’s spanish for “let’s boost”)

Boostemos is Spanish for “let’s boost”

Thanks!