Jet R_{AA}: How to make meaningful comparisons of experiment to theory?

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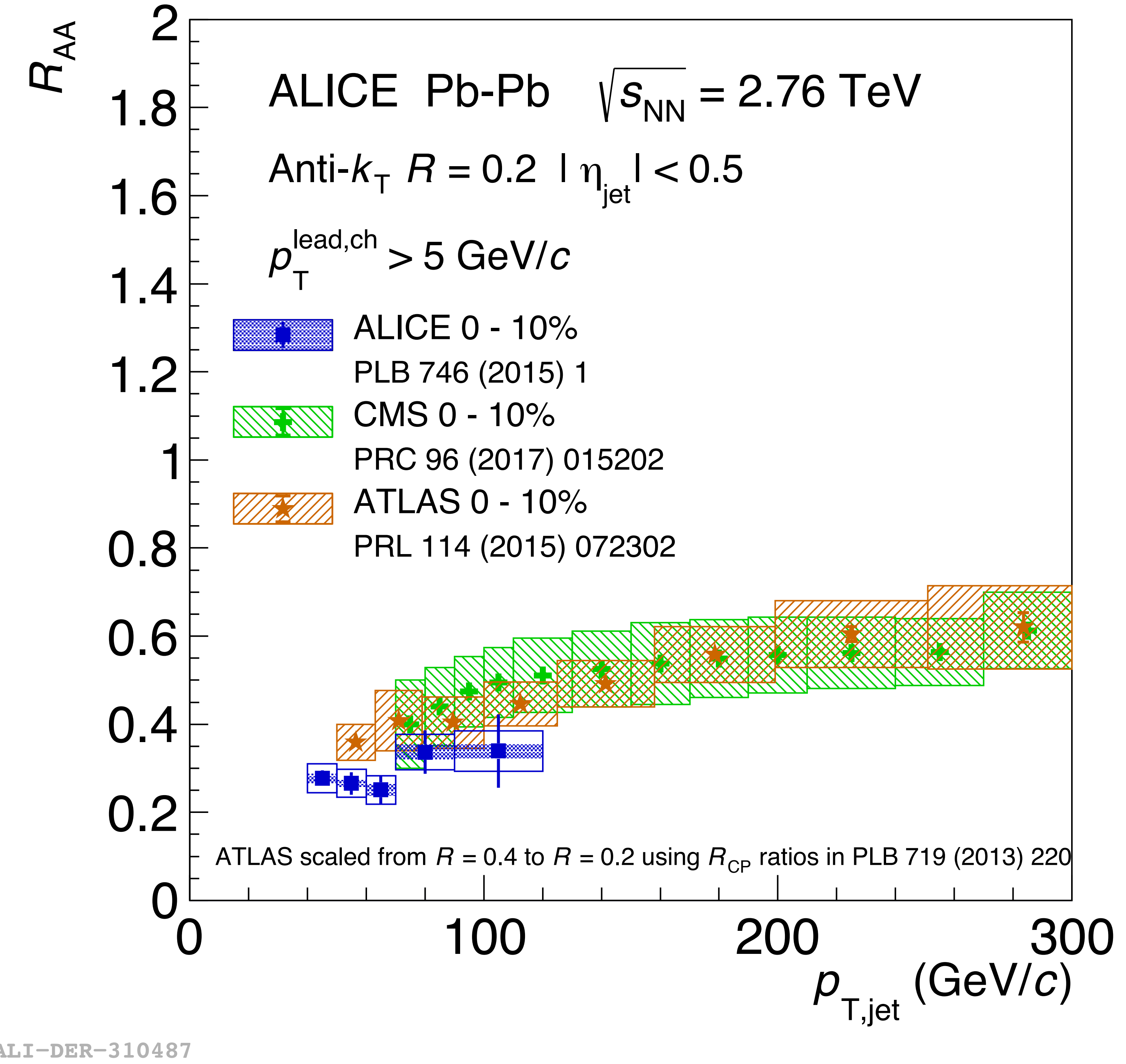
Comparing experiment to theory

In any experimental result or theoretical calculation, one must report (accurate) uncertainties.

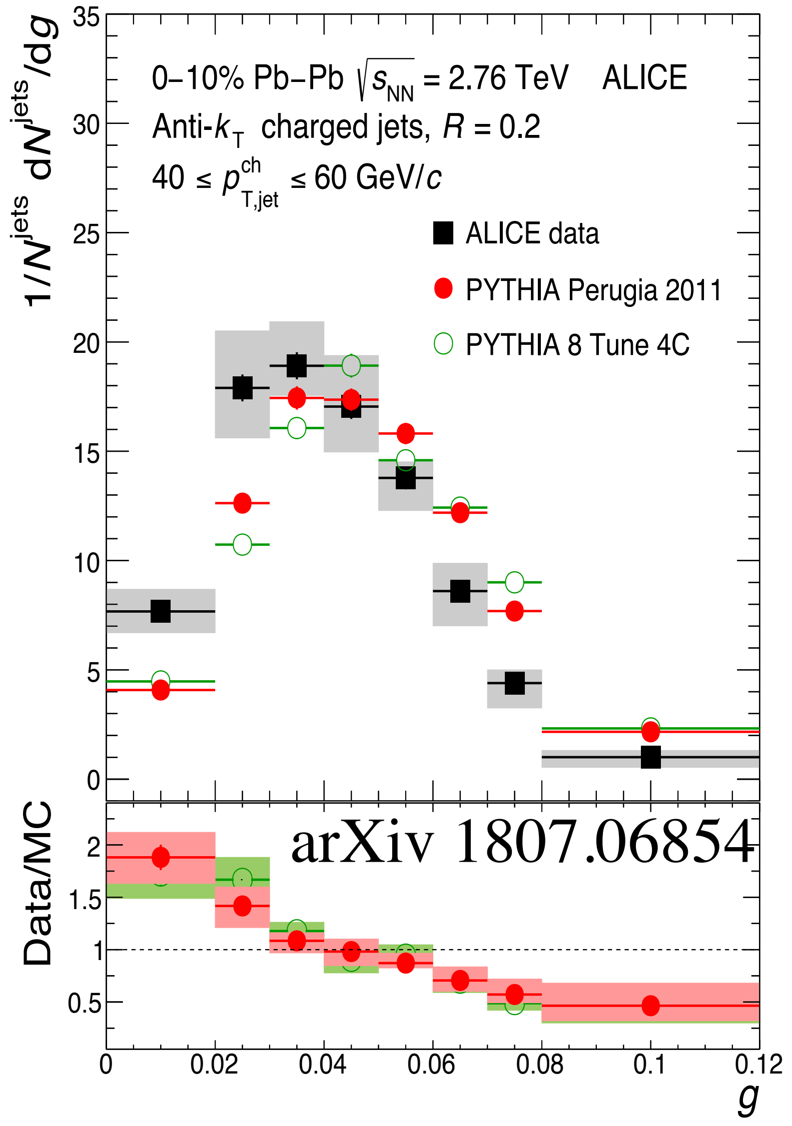
For the discovery phase of the QGP, “qualitative” comparisons sometimes sufficed, since there were several observables with very large modifications.

For example:
- Jet R_{AA} was observed to be strongly suppressed.
- Models with deconfined QCD roughly predicted this.
- Models without deconfined QCD don’t predict this.

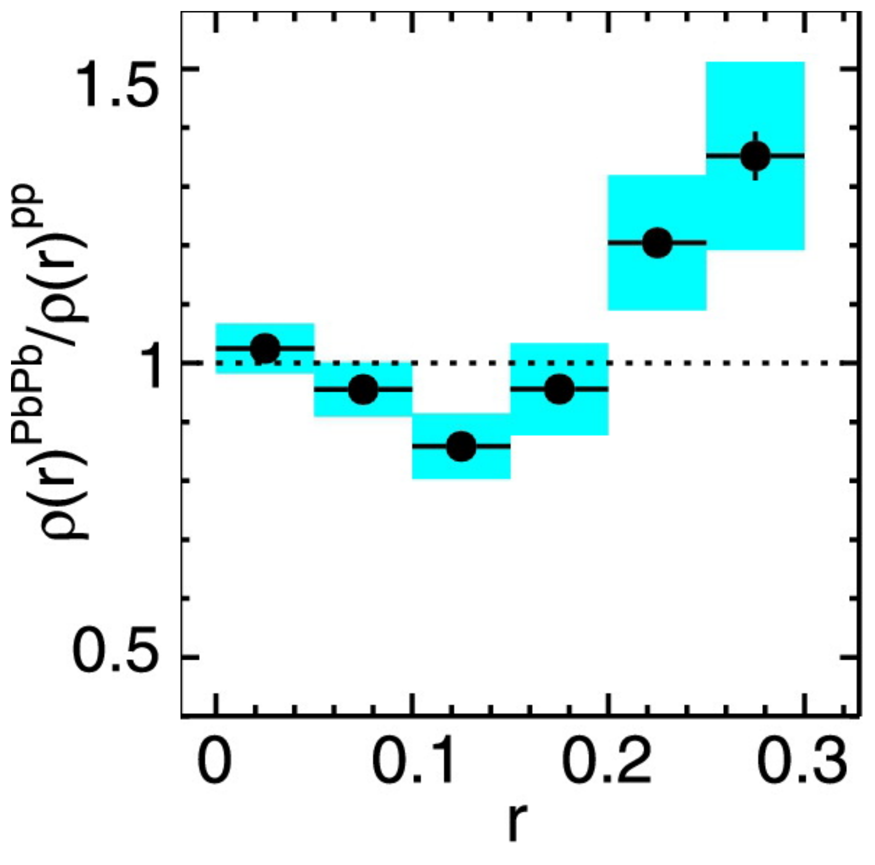
But to really get at the interesting physics that we are all after now, **we will need precision**.



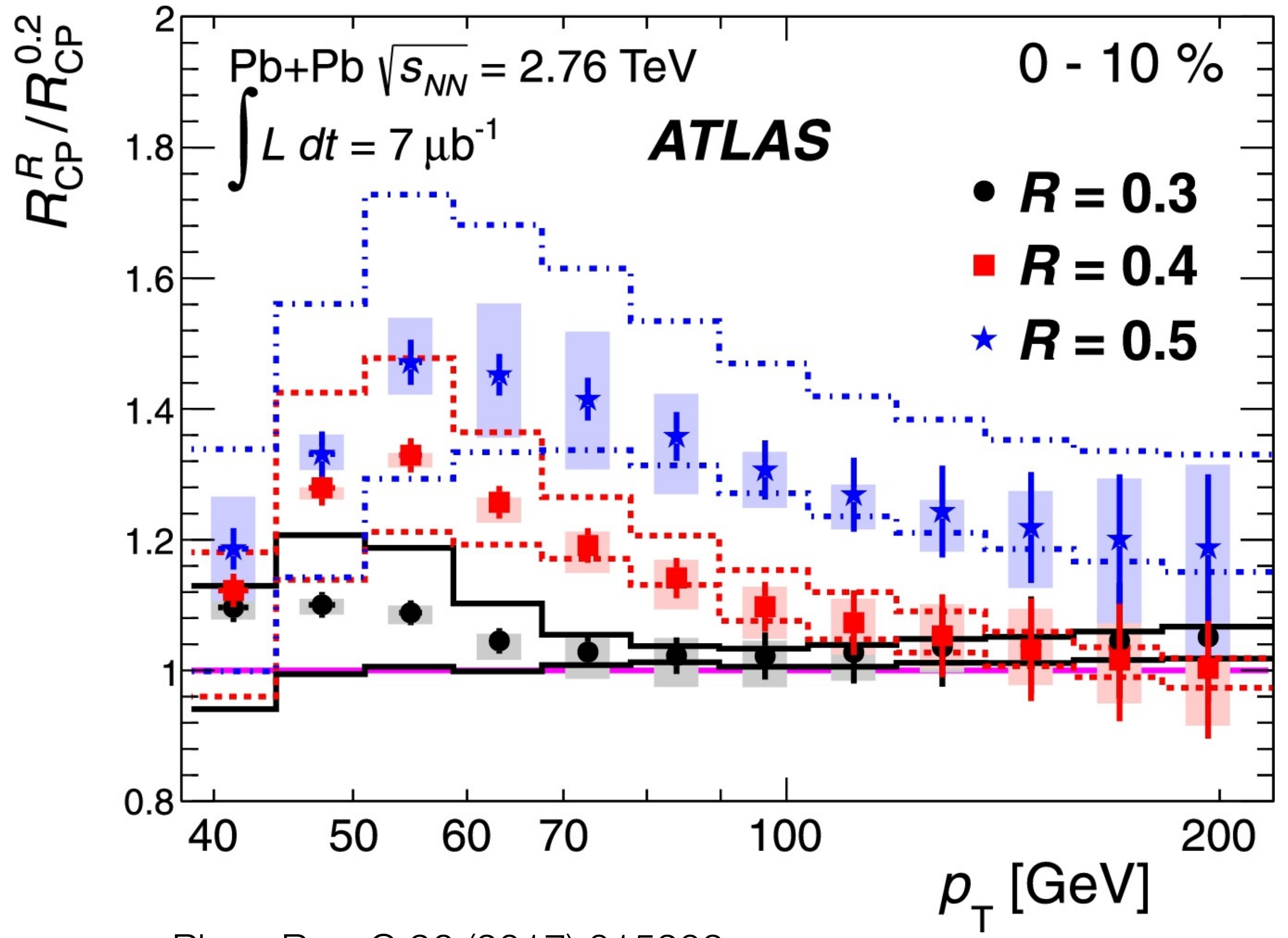
Example: How is the jet radial shape modified?

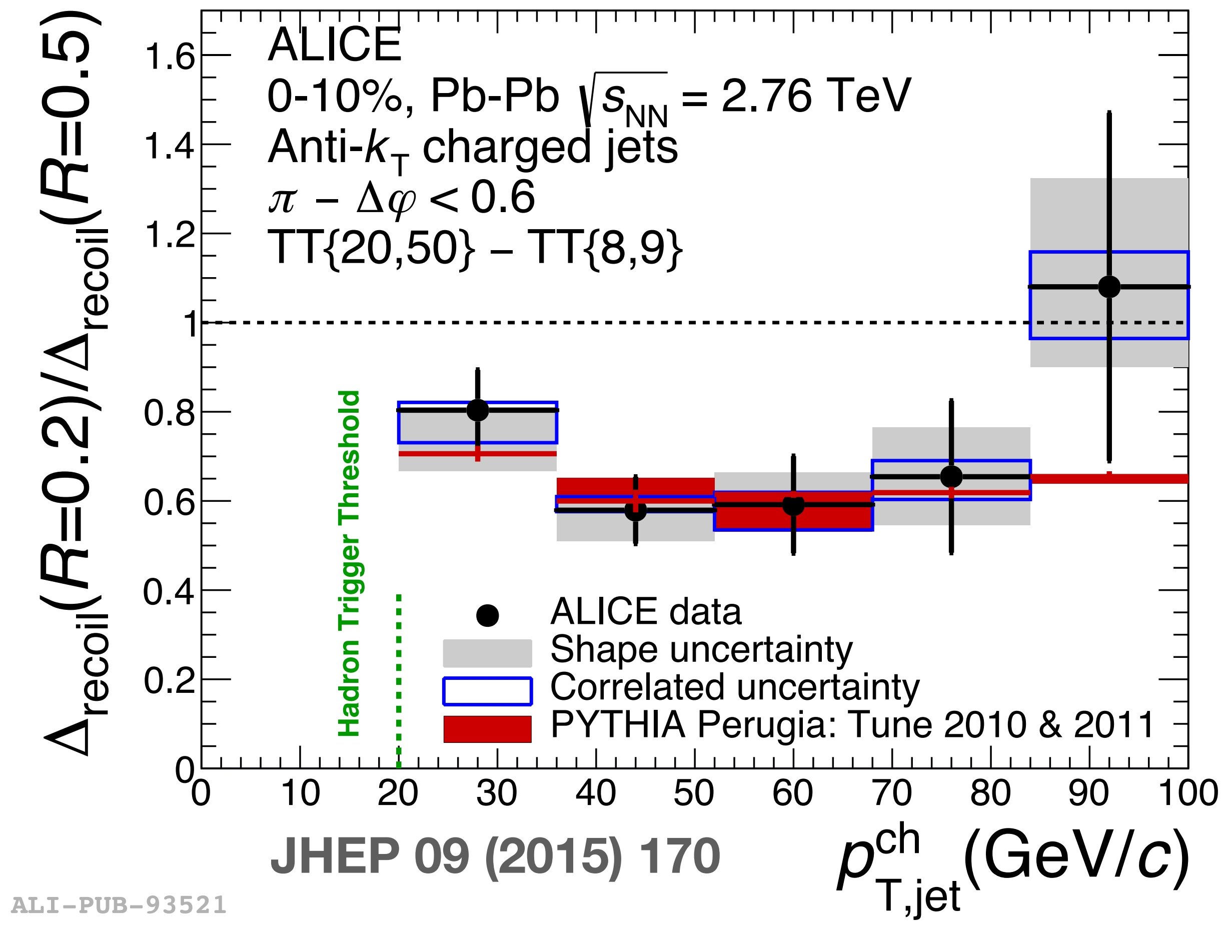


PLB 730 (2014) 243-263

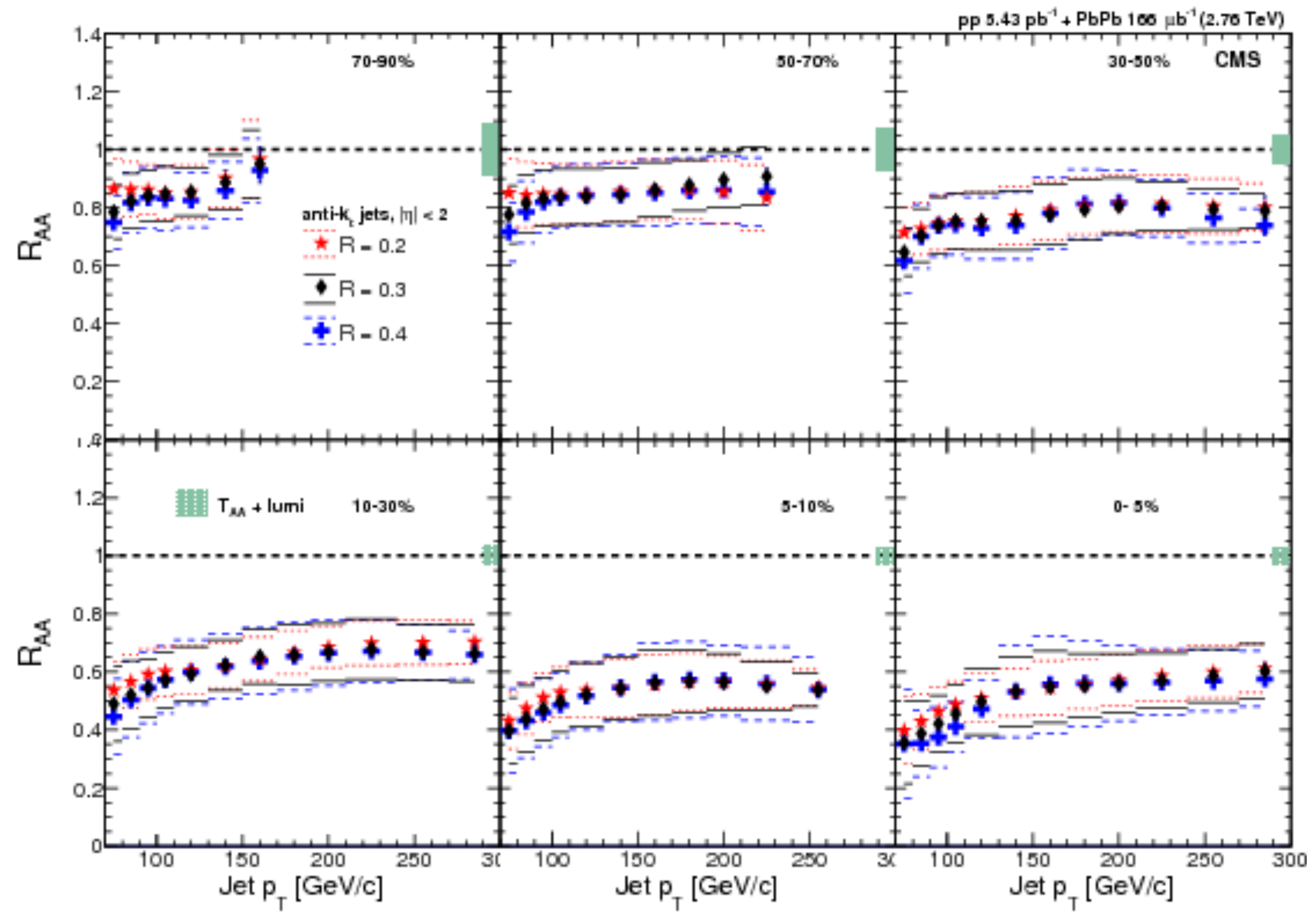


Phys. Lett. B 719 (2013) 220-241





Phys. Rev. C 96 (2017) 015202



Comparing experiment to theory

One way to be more rigorous in interpreting the data is with global analyses…

But instead let's consider the simplest possible case: A single observable

Comparing experiment to theory

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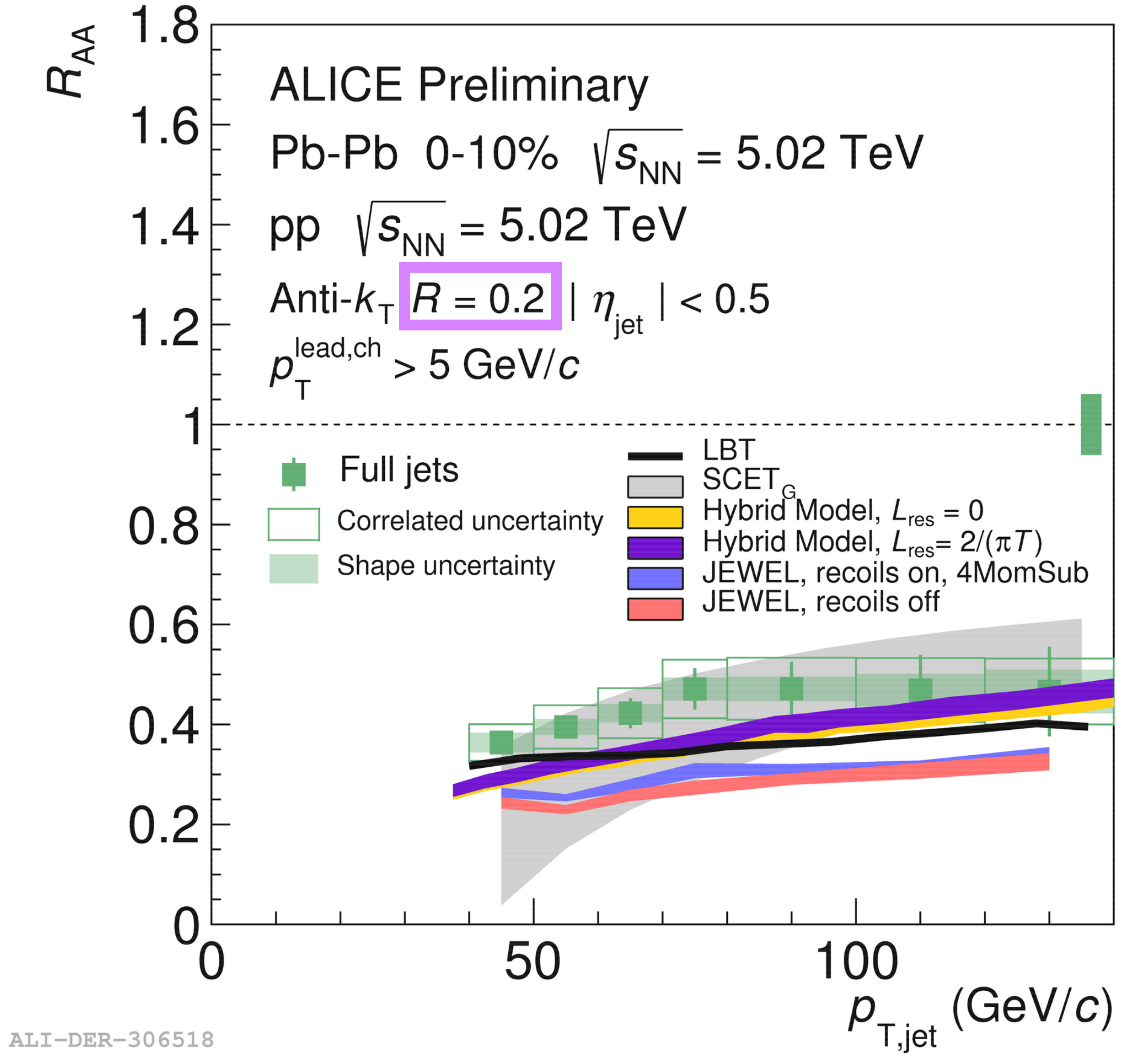
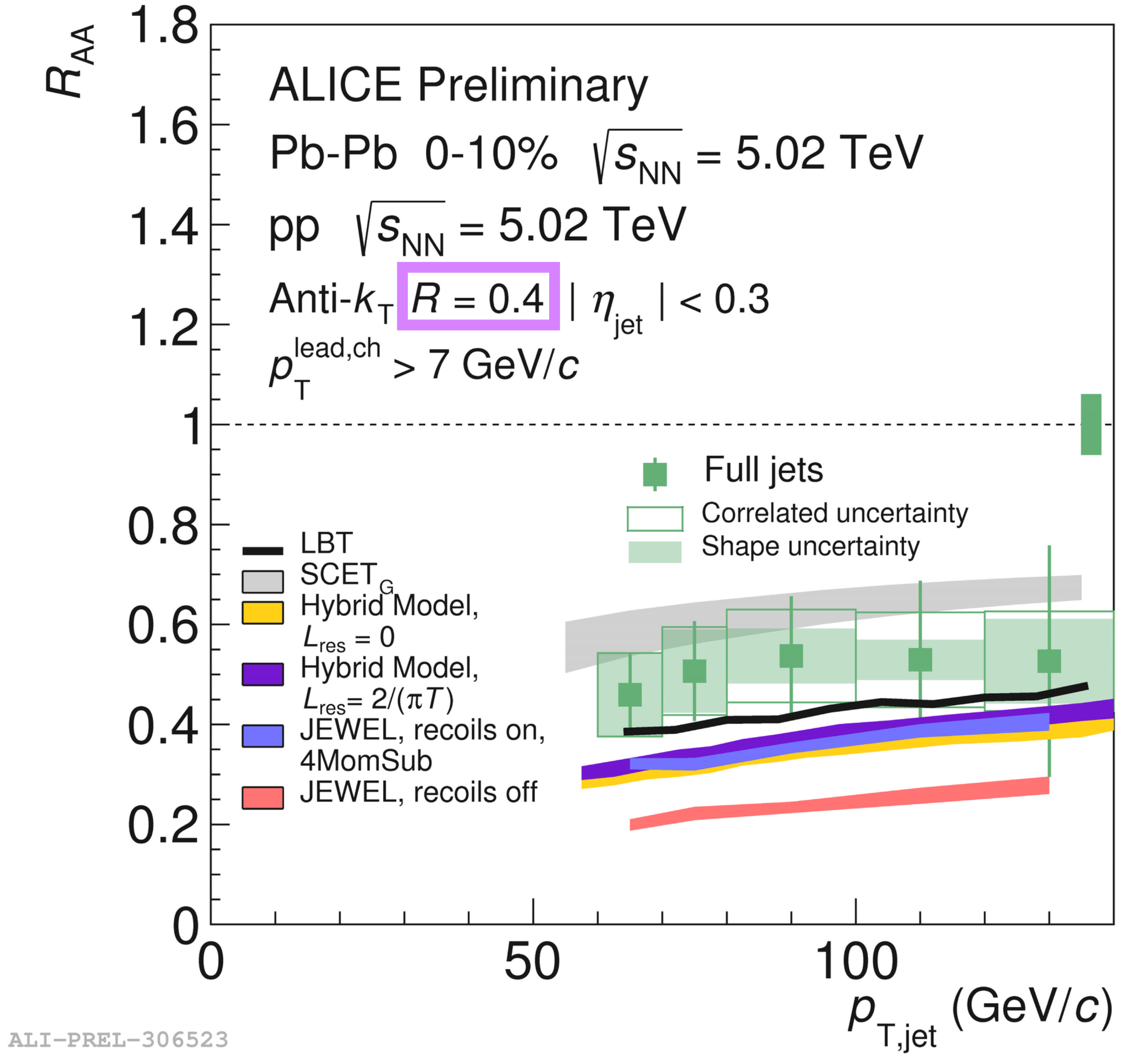
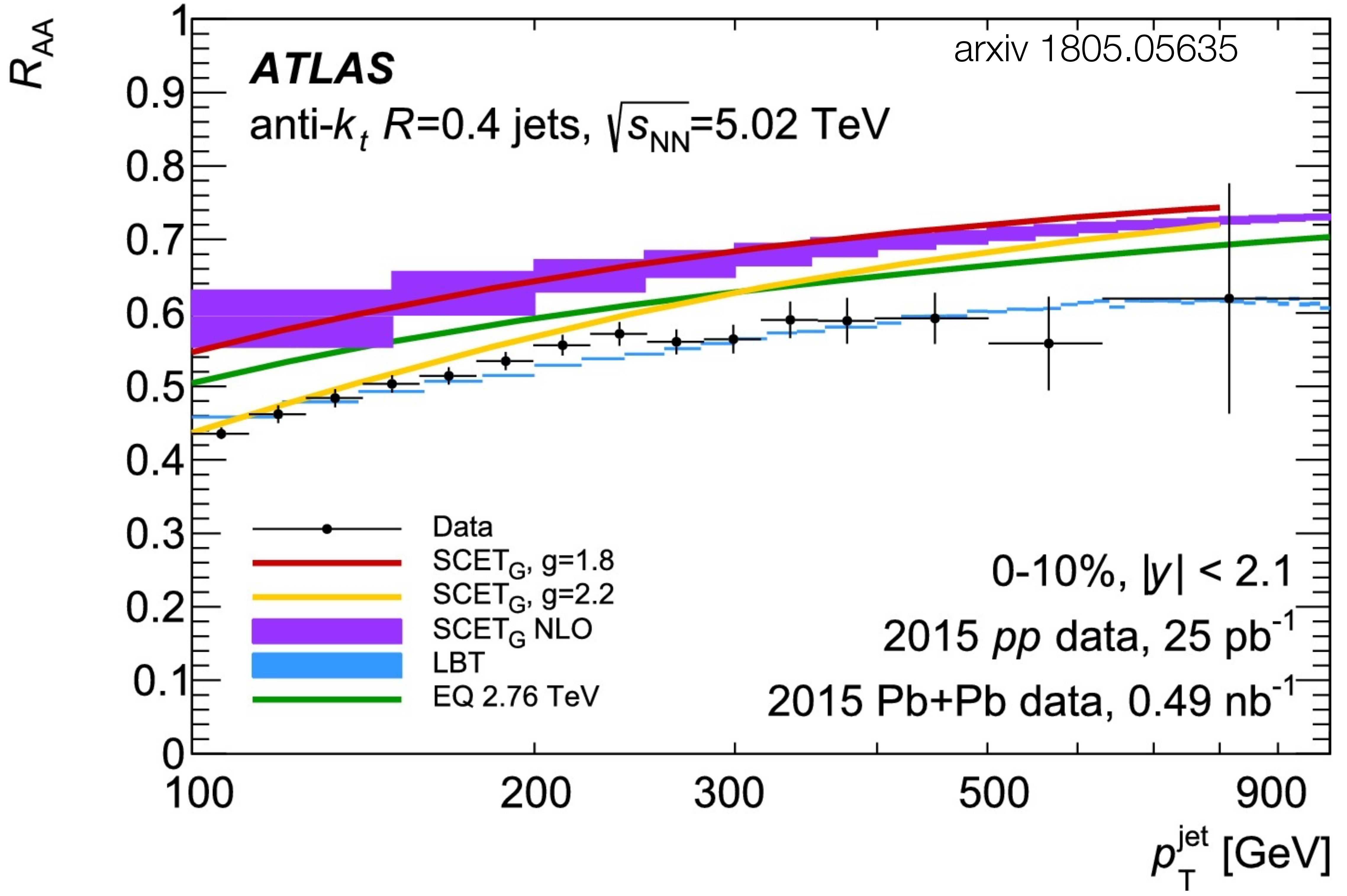
But instead let's consider the simplest possible case: A single observable

Is it possible, now or in the future, to rule out a prediction by quantitative comparison to the measured jet R_{AA}?

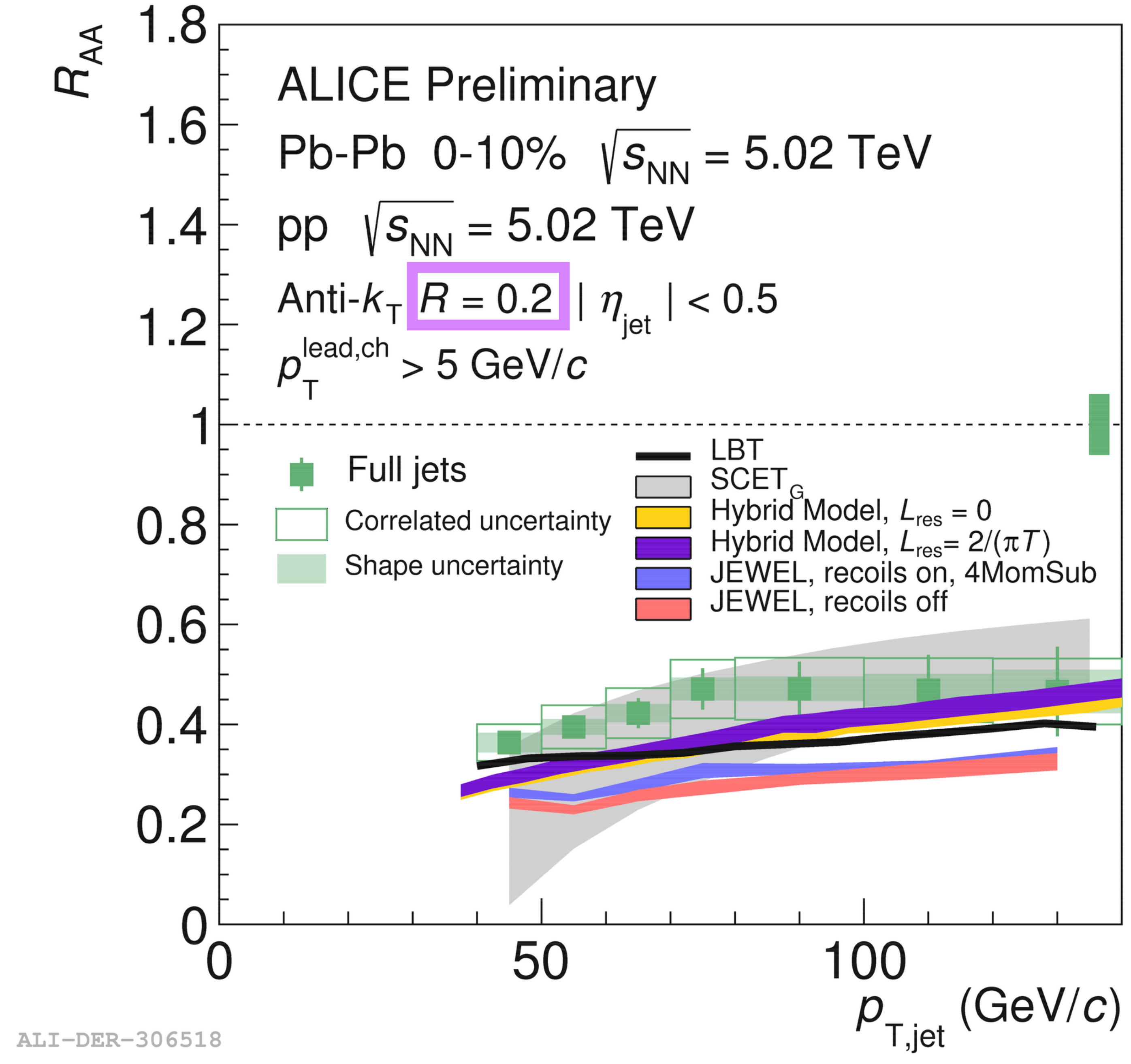
Jet R_{AA}

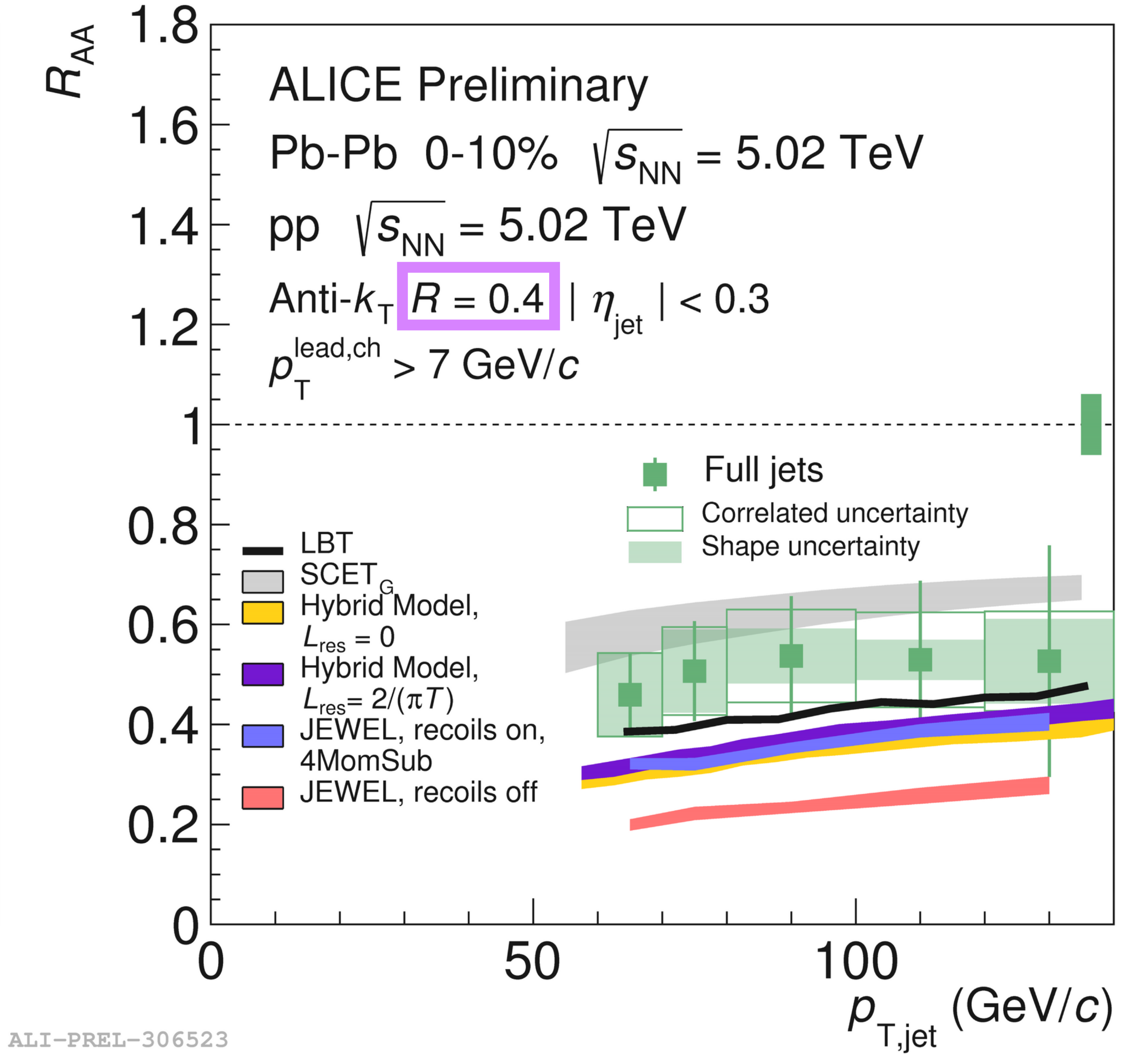

ALICE Preliminary
Pb-Pb 0-10% $\sqrt{s_{NN}}$ = 5.02 TeV
pp $\sqrt{s_{NN}}$ = 5.02 TeV
Anti-k_T R = 0.2 | η_{jet} | < 0.5
$p_T^{lead,ch}$ > 5 GeV/c
Full jets
Correlated uncertainty
Shape uncertainty
LBT
SCET$_G$
Hybrid Model, L_{res} = 0
Hybrid Model, L_{res}= 2/(πT)
JEWEL, recoils on, 4MomSub
JEWEL, recoils off
R_{AA}
$p_{T,jet}$ (GeV/c)
ALI-DER-306518

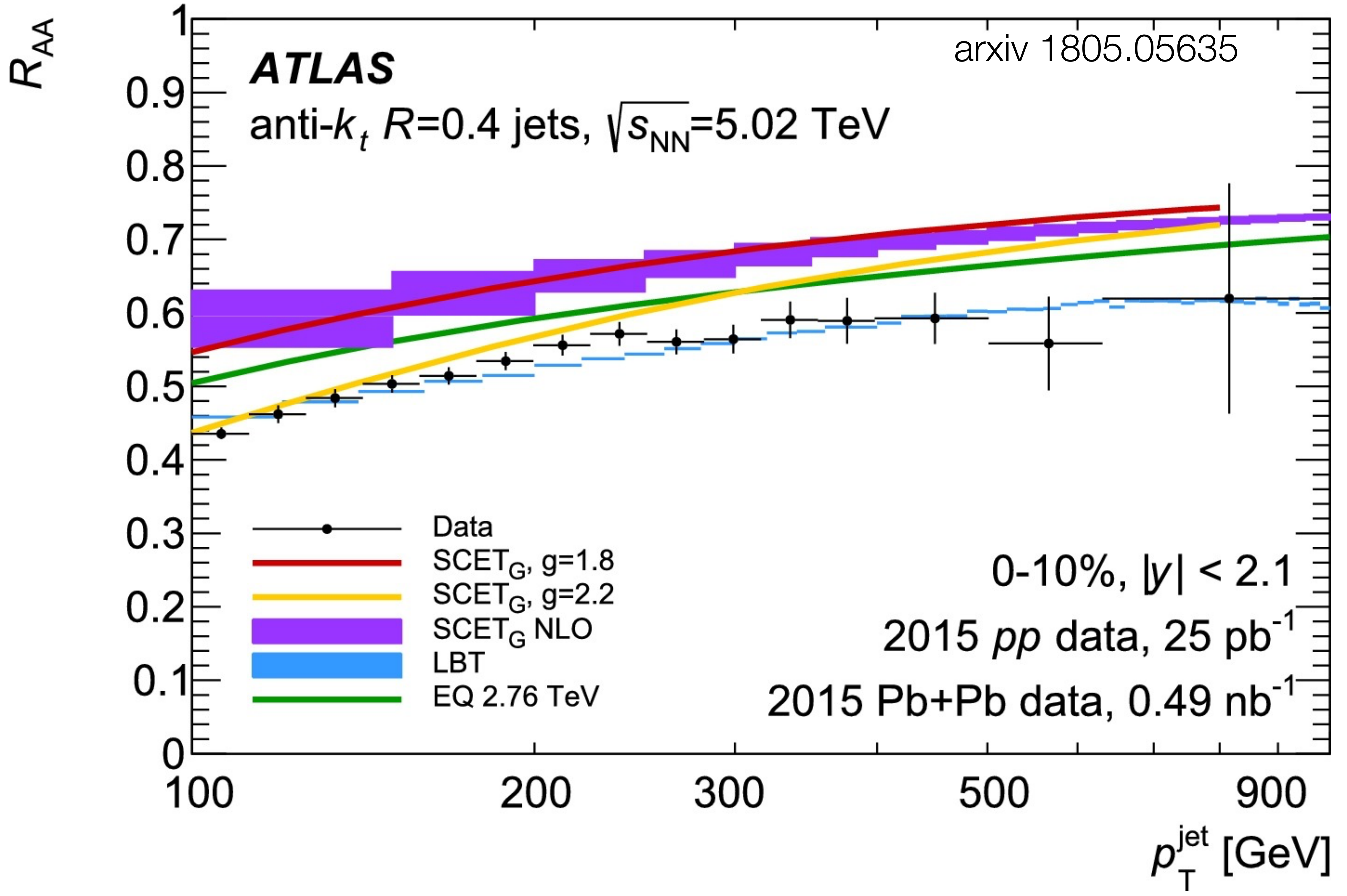

ALICE Preliminary
Pb-Pb 0-10% $\sqrt{s_{NN}}$ = 5.02 TeV
pp $\sqrt{s_{NN}}$ = 5.02 TeV
Anti-k_T R = 0.4 | η_{jet} | < 0.3
$p_T^{lead,ch}$ > 7 GeV/c
Full jets
Correlated uncertainty
Shape uncertainty
LBT
SCET$_G$
Hybrid Model, L_{res} = 0
Hybrid Model, L_{res}= 2/(πT)
JEWEL, recoils on, 4MomSub
JEWEL, recoils off
R_{AA}
$p_{T,jet}$ (GeV/c)
ALI-PREL-306523


arxiv 1805.05635
ATLAS
anti-k_t R=0.4 jets, $\sqrt{s_{NN}}$=5.02 TeV
Data
SCET$_G$, g=1.8
SCET$_G$, g=2.2
SCET$_G$ NLO
LBT
EQ 2.76 TeV
0-10%, |y| < 2.1
2015 pp data, 25 pb^{-1}
2015 Pb+Pb data, 0.49 nb^{-1}
R_{AA}
p_T^{jet} [GeV]

What can be learned from jet R_{AA}?







Can we distinguish the low-p_T behavior of models?

Can we distinguish the high-p_T behavior of models?

Can we distinguish the R-dependence of models?

What can be learned from jet R_{AA}?

R_{AA} is an observable that is well-suited for comparison to theory.

Two issues that make it difficult to compare theoretical models:

(1) Precision of measurement

(2) Accuracy of error bars for (a) Theory, (b) Experiment

The theory side

There is a lack of uniformity in the non- jet energy loss part of the calculations

Different predictions use different initial state, medium evolution, hadronization, pp reference spectrum

In general, systematic uncertainties on theory calculations are either absent or incorrect

When systematics are included in predictions, they tend to ignore uncertainties in the initial state, medium evolution, hadronization, pp reference spectrum

It is difficult to compare predictions from the "same" theoretical models that are supplied to different experimental results

Private codes are evolving, the free parameters may be fixed differently, etc.

The experimental side

Uncertainties in experimental results are not always provided in a clear way to theorists

E.g. systematic uncertainties are divided into multiple types ("correlated uncertainties", "shape uncertainties"); covariances are generally not supplied

Biases in experimental results are not always clearly communicated or evaluated

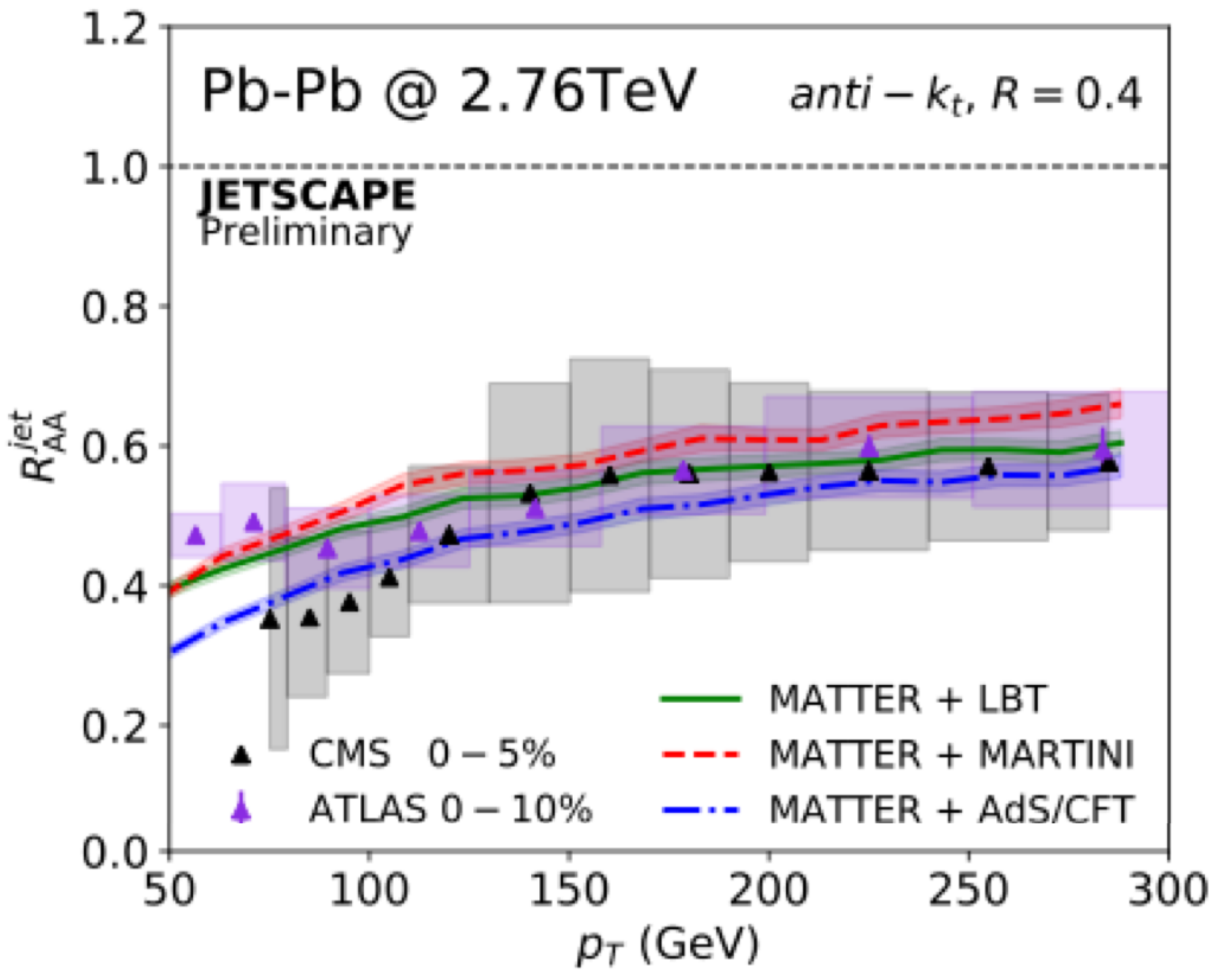
For example, leading hadron requirement to suppress combinatorial jets

JETSCAPE

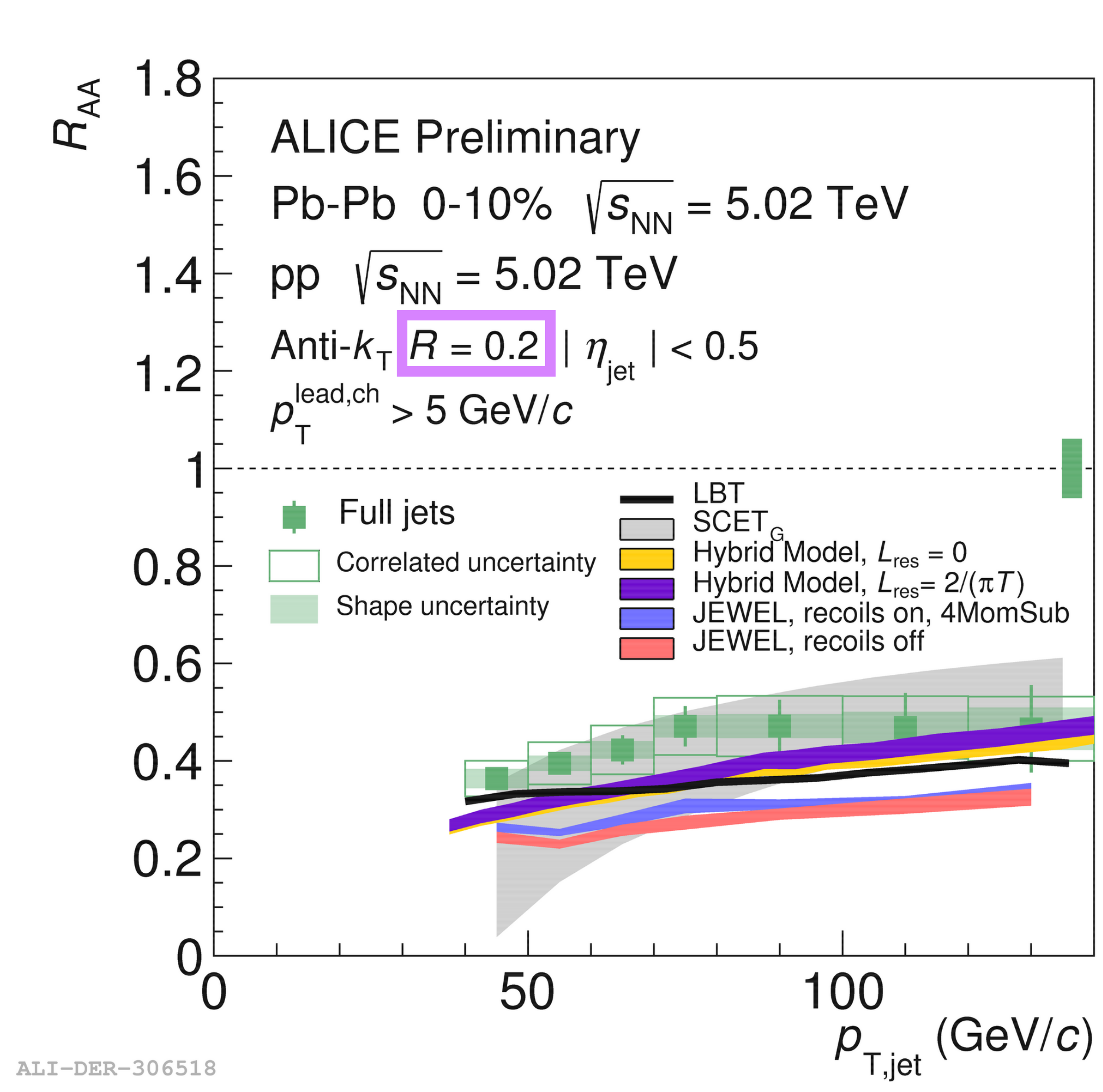
JETSCAPE will allow us to solve some of these problems

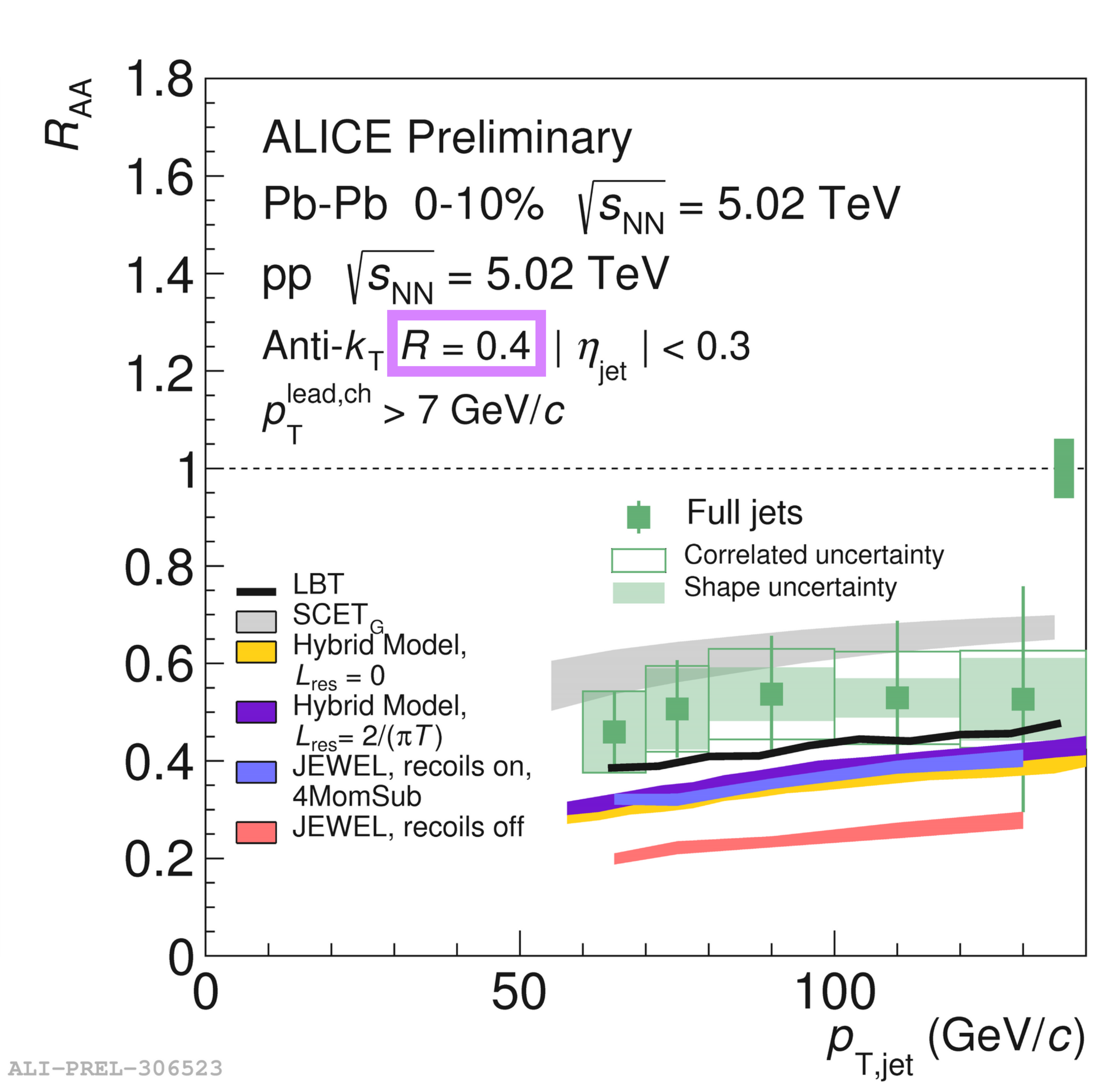
1. Study differences between model predictions by fixing the non- jet energy loss part of the calculation

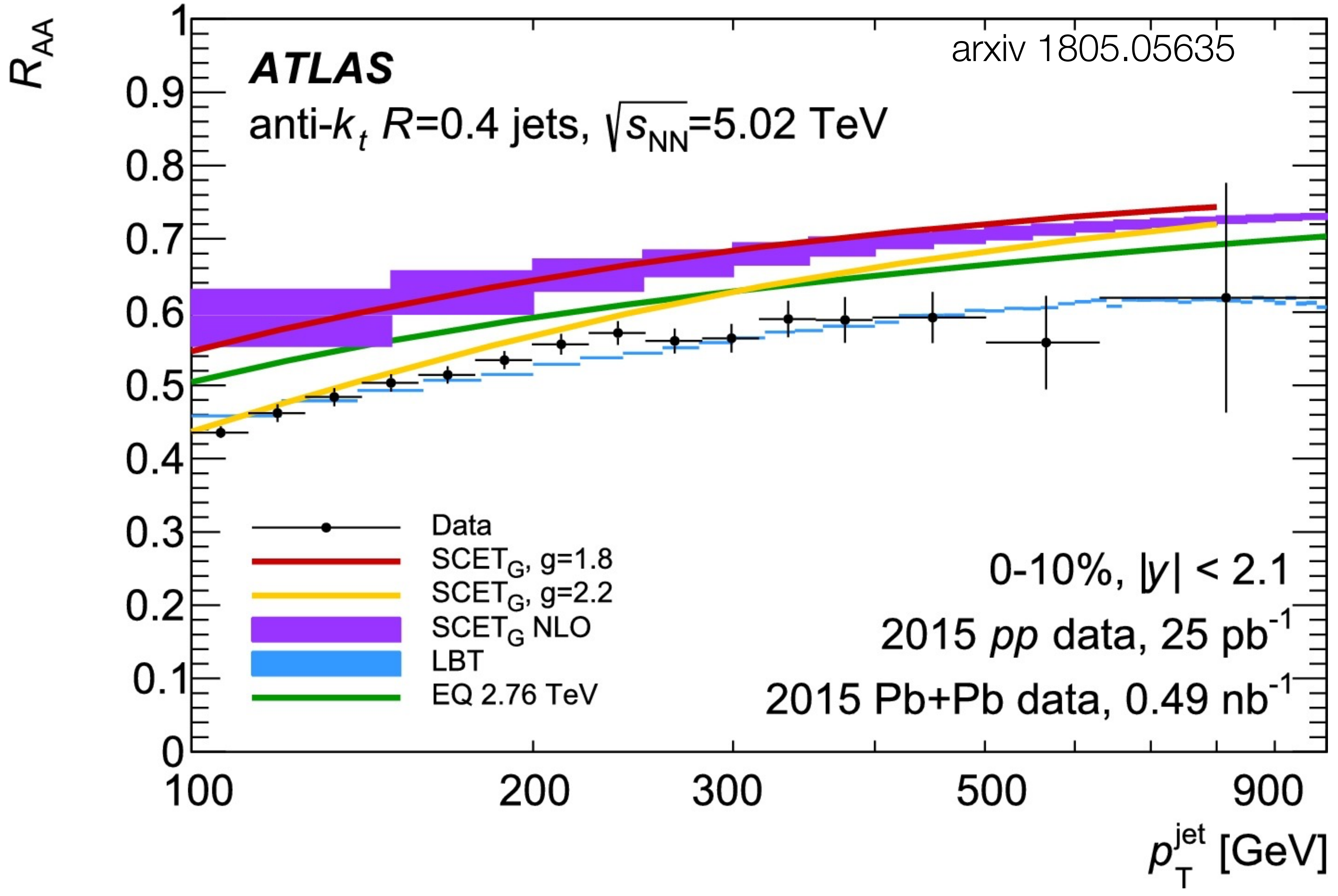
2. Study the agreement between experiment and theory by evaluating systematic uncertainties on the theory predictions which include the non- jet energy loss part of the calculation, by varying the non- jet energy loss modules



What can be learned from jet R_{AA}?







Can we distinguish the low-p_T behavior of models?

Maybe…depends on experimental improvements and size of theory systematics

Can we distinguish the high-p_T behavior of models?

Likely yes — with proper theory systematics

Can we distinguish the R-dependence of models?

Likely yes — ATLAS (CMS?) can achieve sufficient precision at high-p_T