Jet and photon measurements with ***ATLAS***

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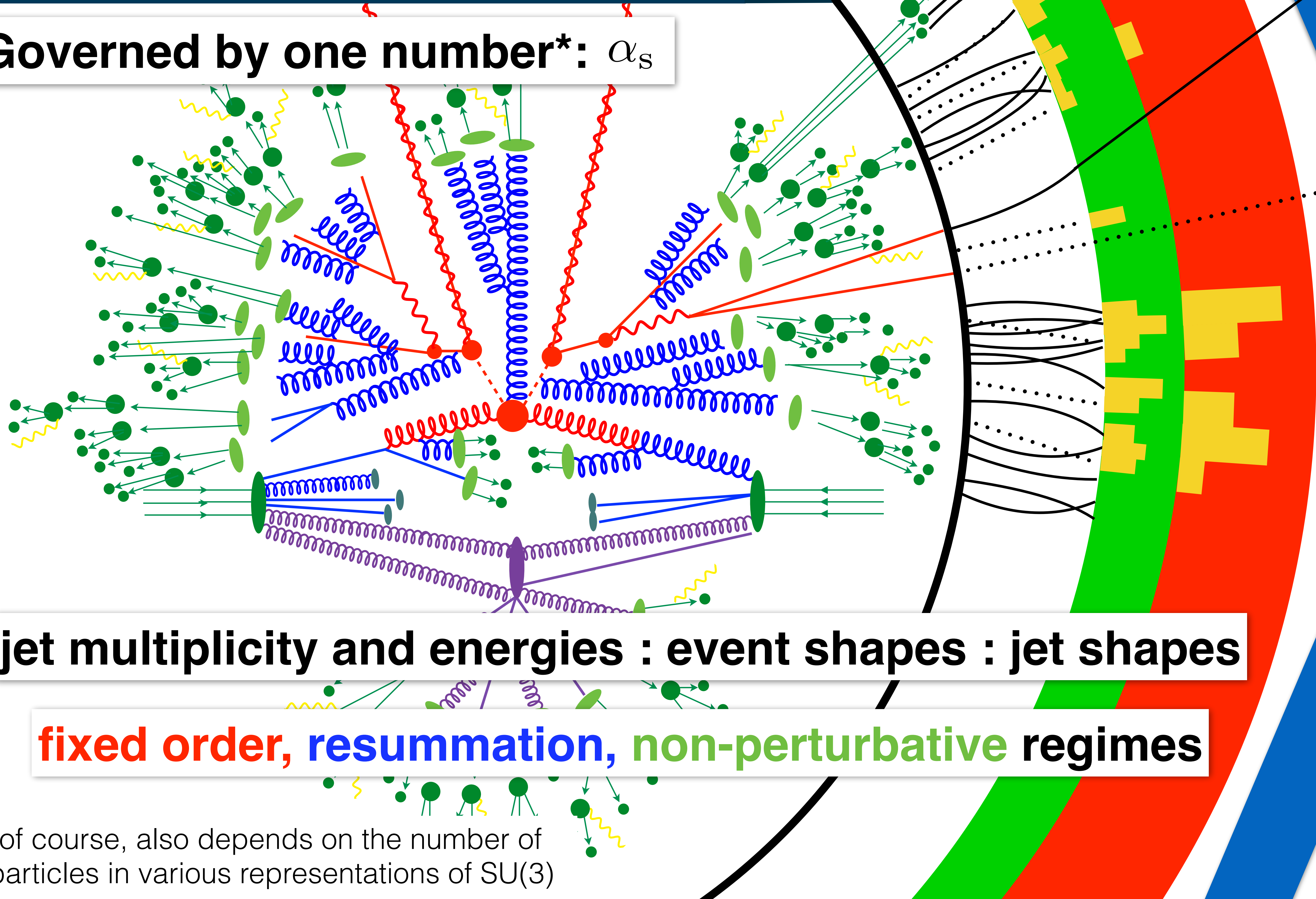
LHCP 2017

Outline: Jet cross-sections ⇢ Photon highlights ⇢ Jet Event Shapes ⇢ Jet substructure

Quantum Chromodynamics (QCD)

Governed by one number*: α_{s}



jet multiplicity and energies : event shapes : jet shapes

fixed order, resummation, non-perturbative regimes

*of course, also depends on the number of particles in various representations of SU(3)

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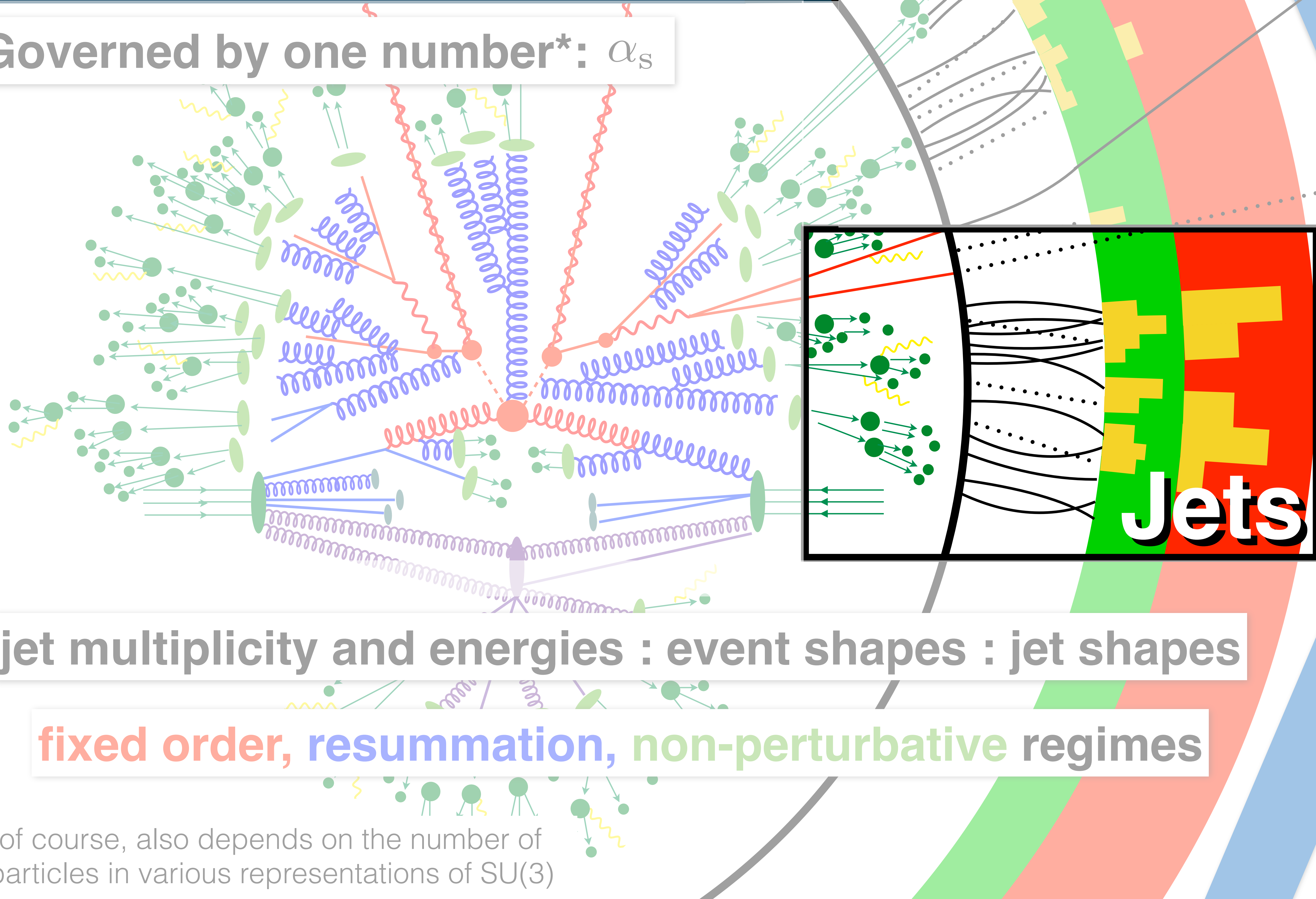
Governed by one number*: α_s



jet multiplicity and energies : event shapes : jet shapes

fixed order, resummation, non-perturbative regimes

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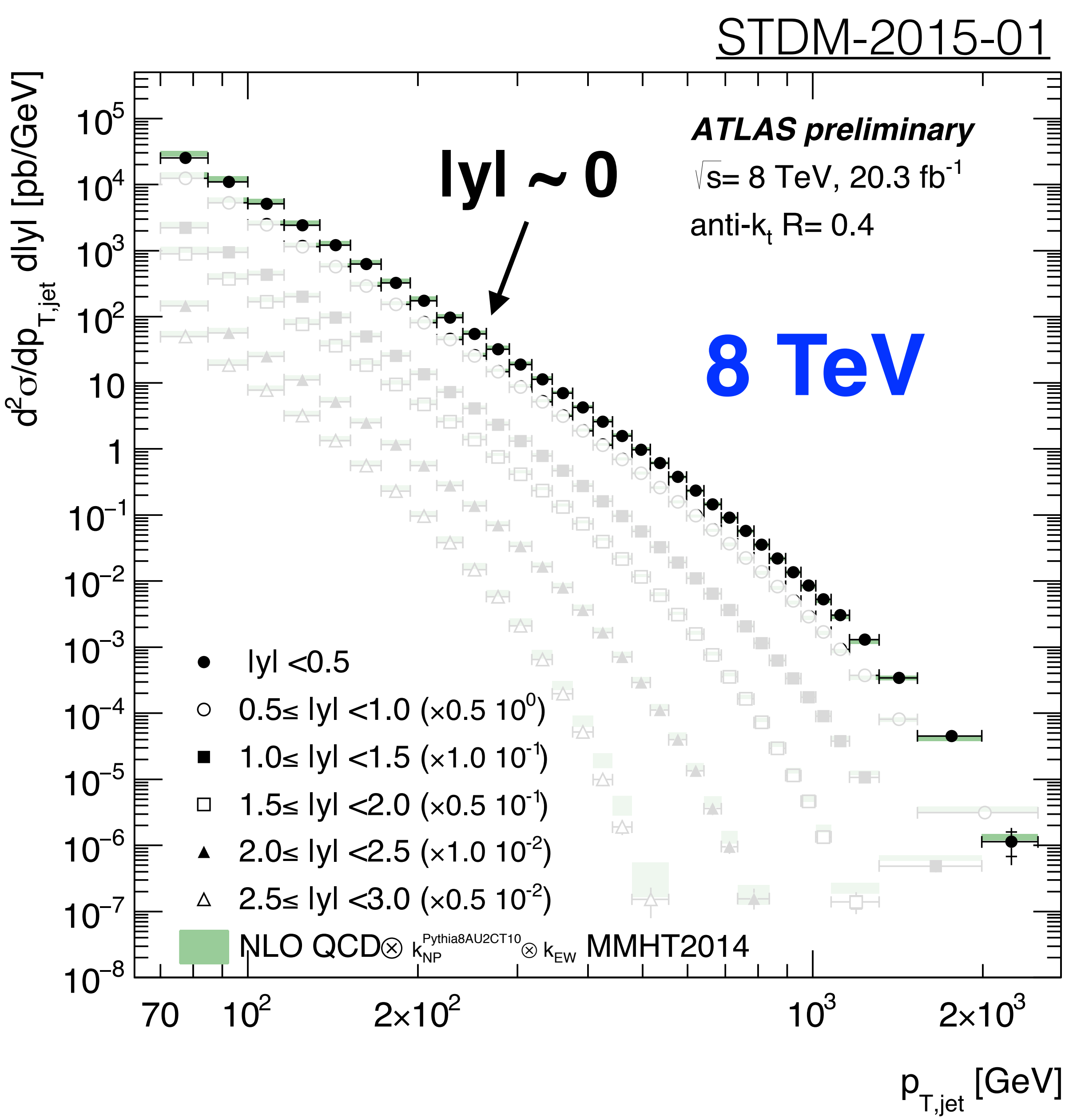
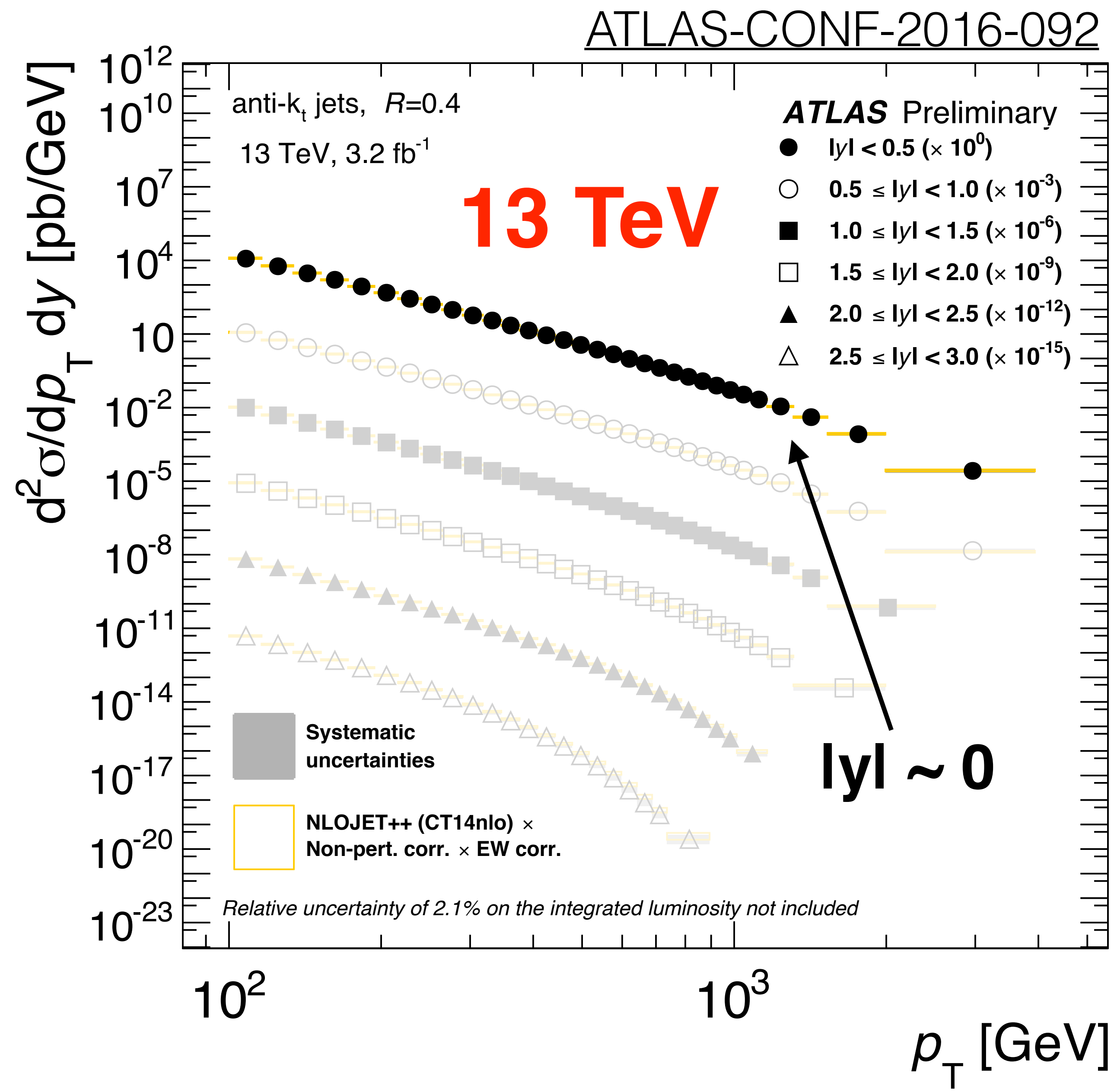
Part I: Jet Multiplicity and Energies





Reach: **~2 TeV @ 20.3 fb^{-1}** **~3 TeV @ 3.2 fb^{-1}**

Inclusive anti-k_t Jet Cross-Sections

(binned in rapidity, *y*)

NLO is accurate over many orders of magnitude (slight trend - see backup)

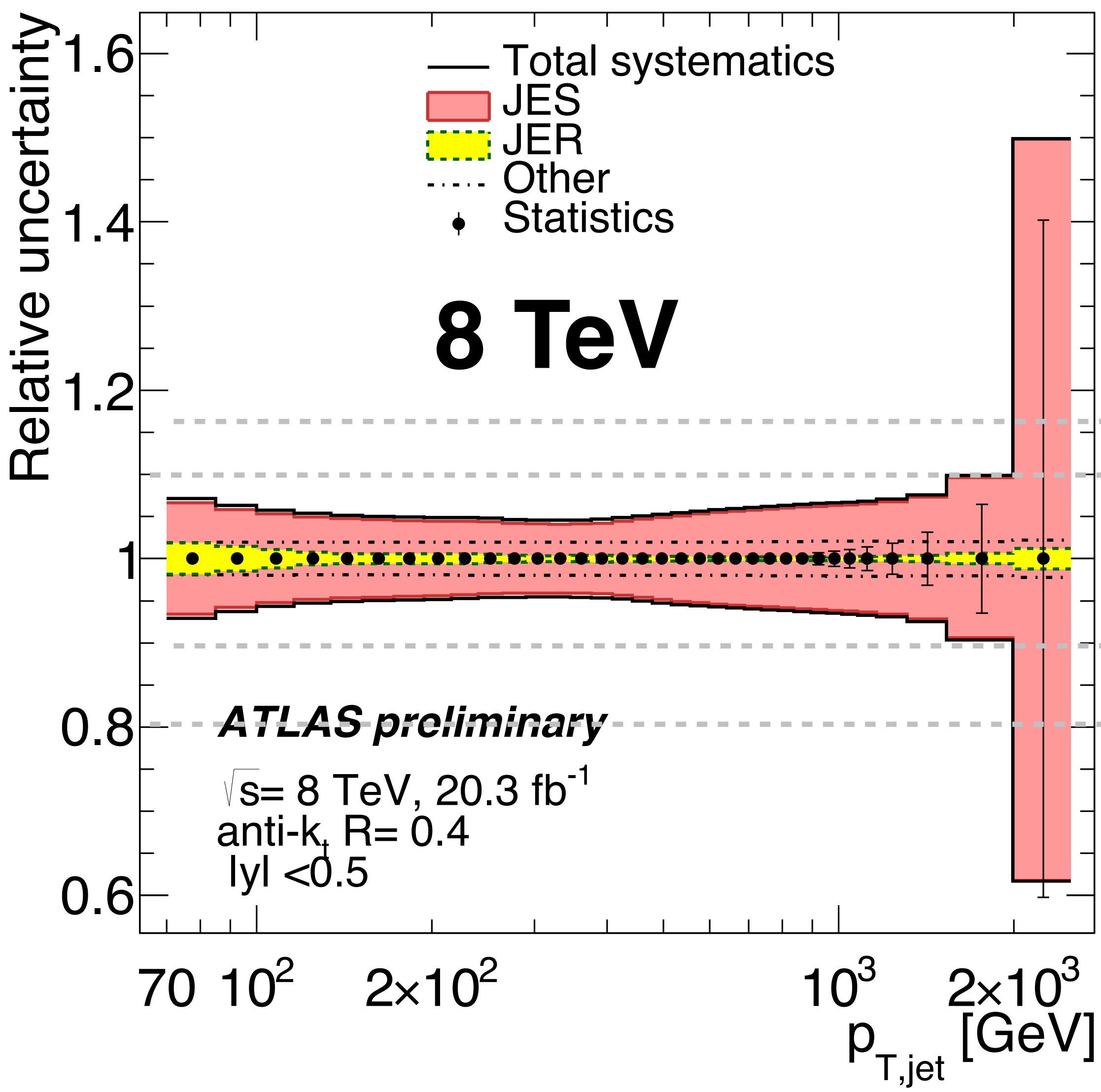
STDM-2015-01 ATLAS-CONF-2016-092

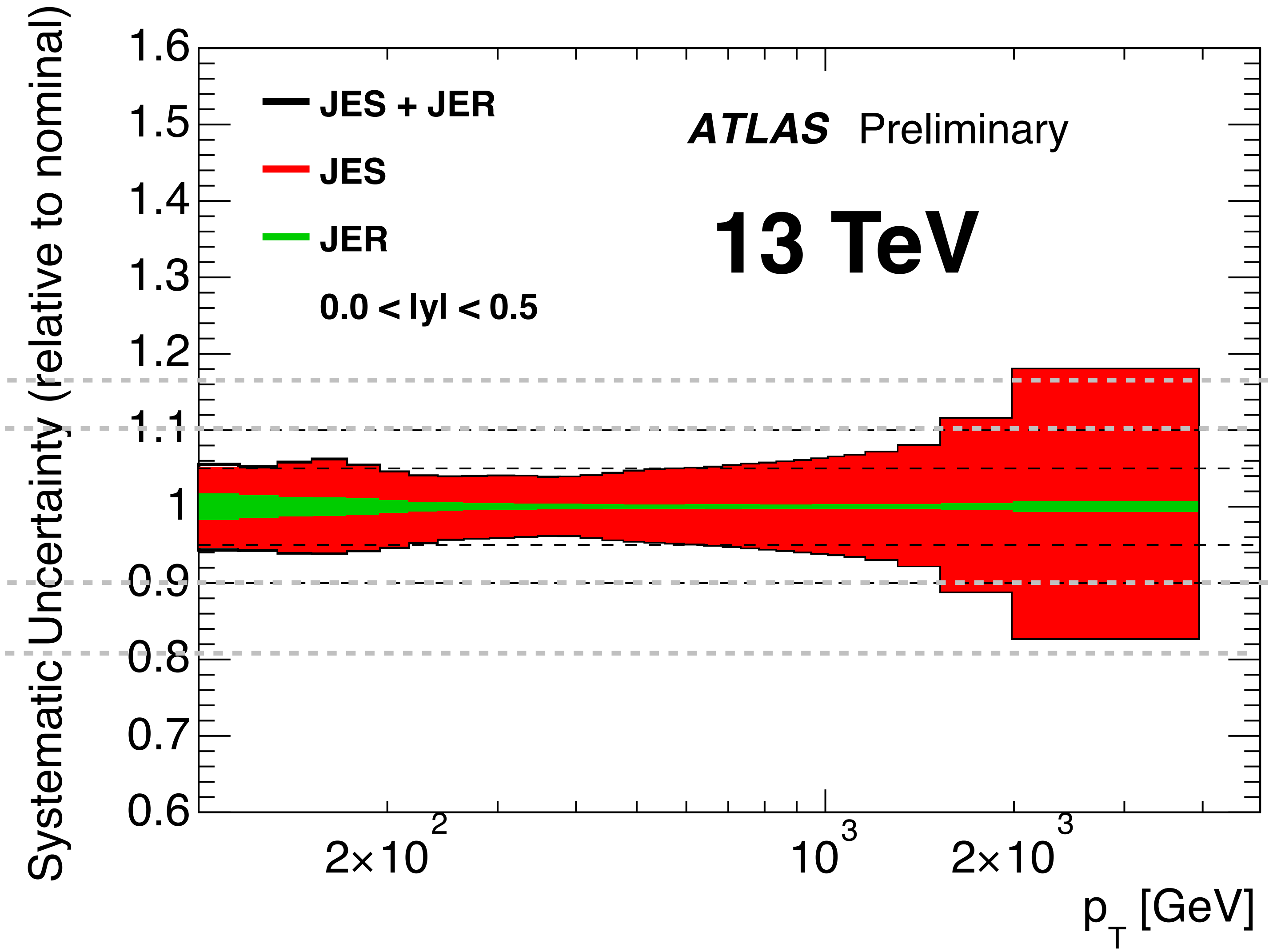
Already reaching/surpassing 8 TeV precision!

very important for probing proton structure, in particular the gluon PDF

JES = jet energy scale (bias)

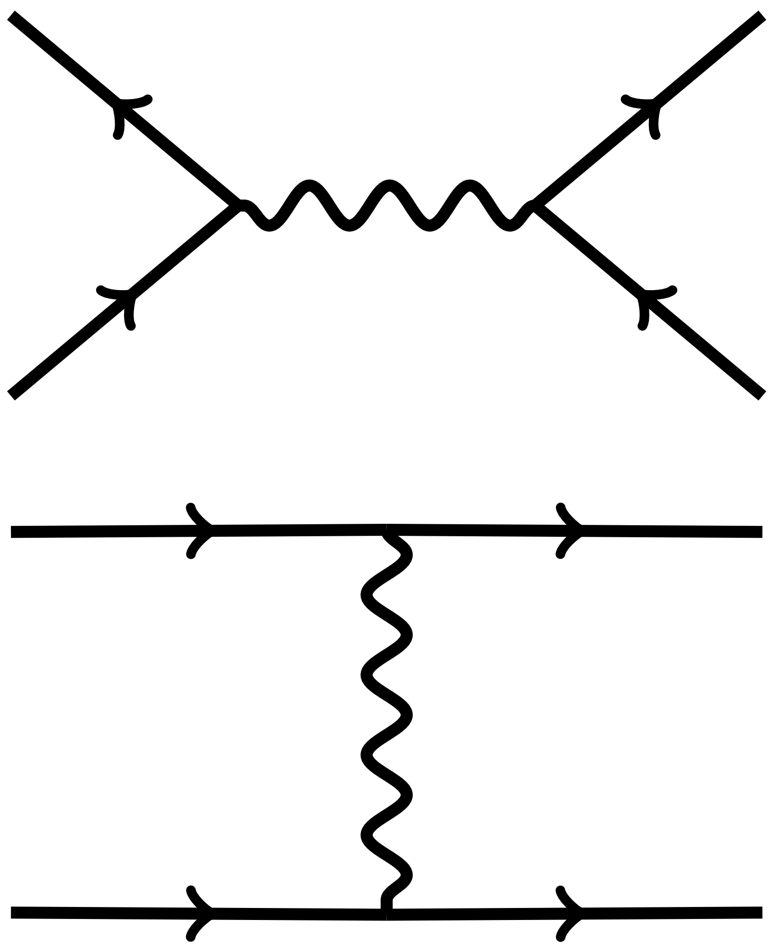
JER = jet energy resolution (standard deviation)



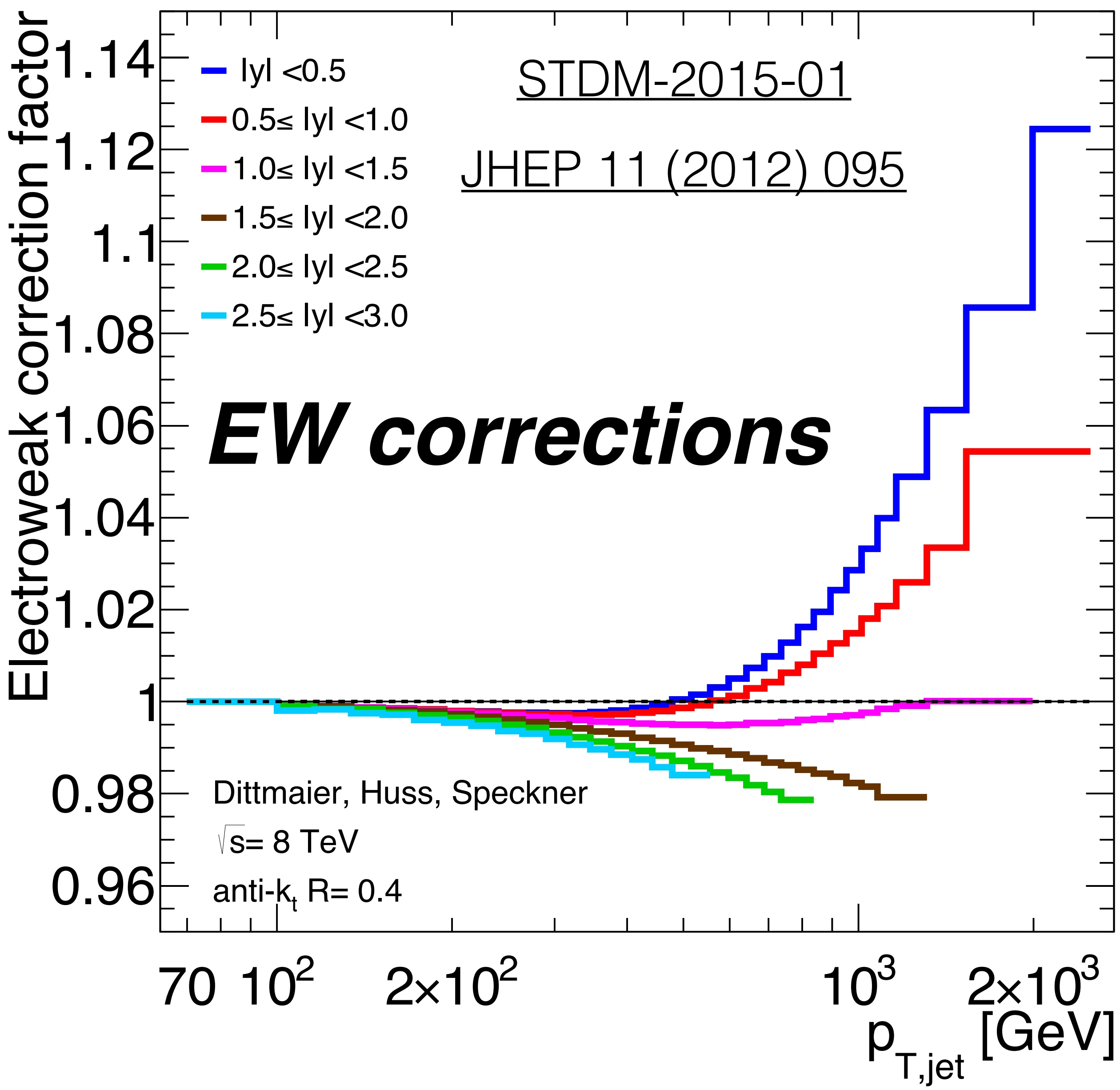


We are probing a regime where NP effects are negligible.

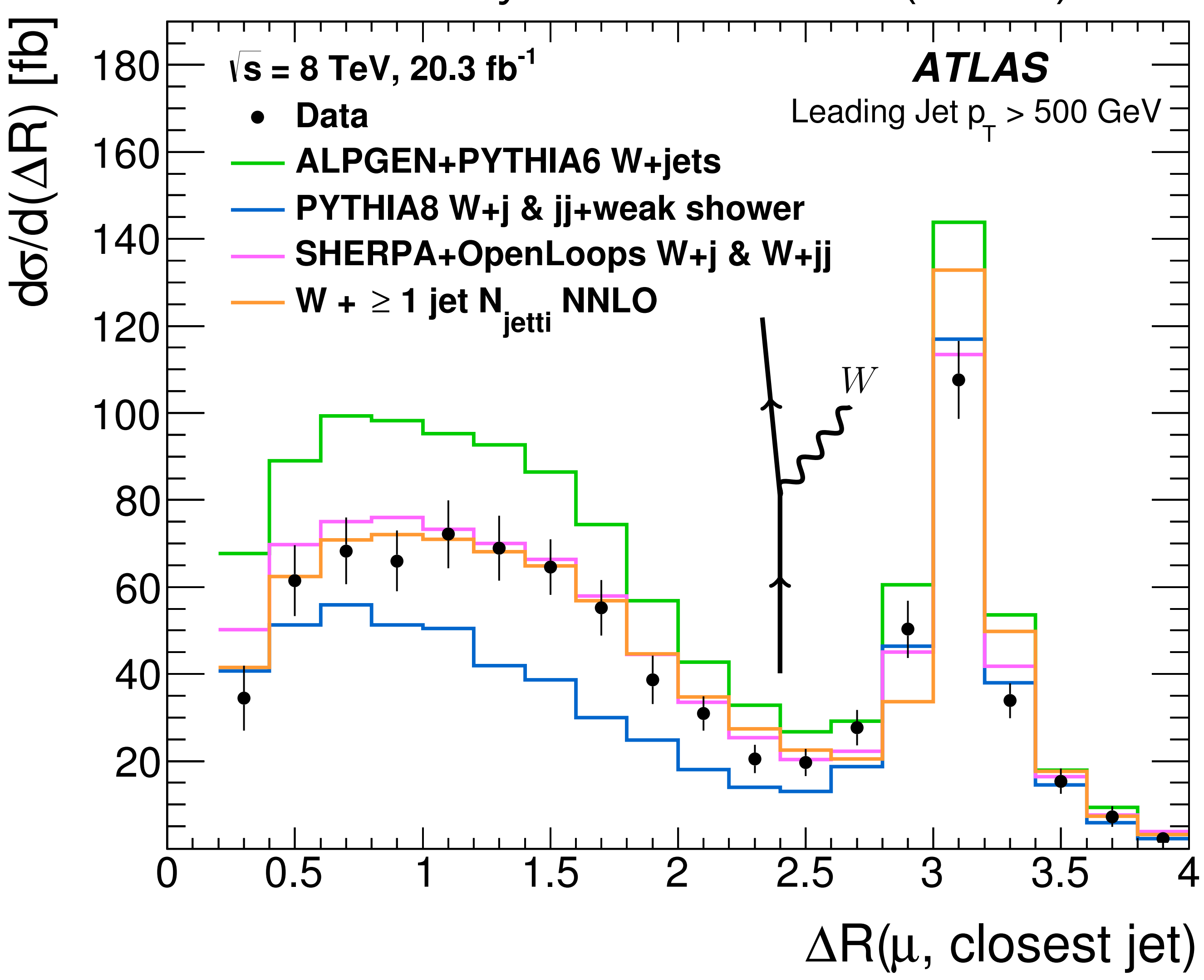
…but electroweak corrections are not small!



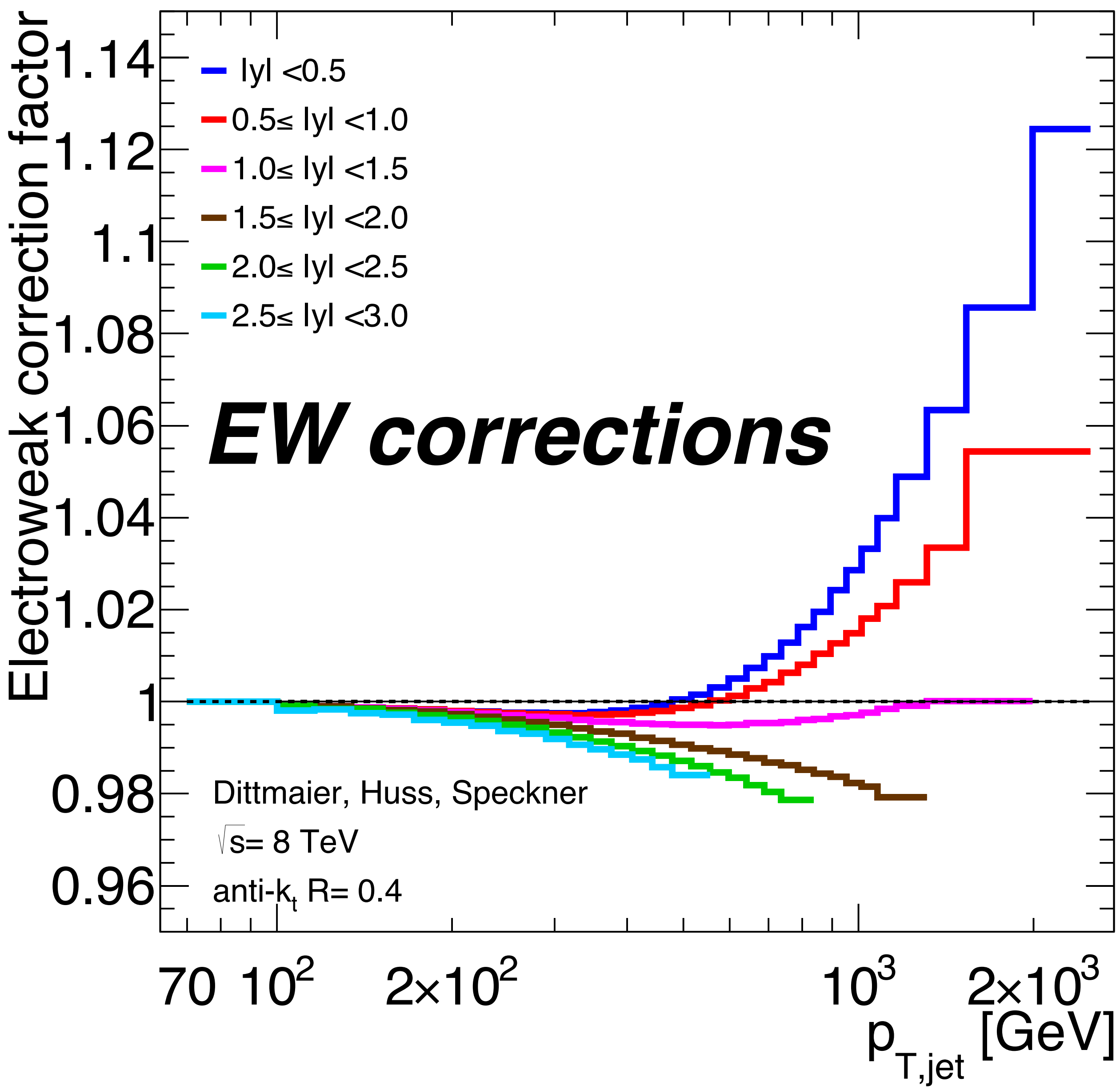
(LO diagrams)



Phys. Lett. B 765 (2017) 132



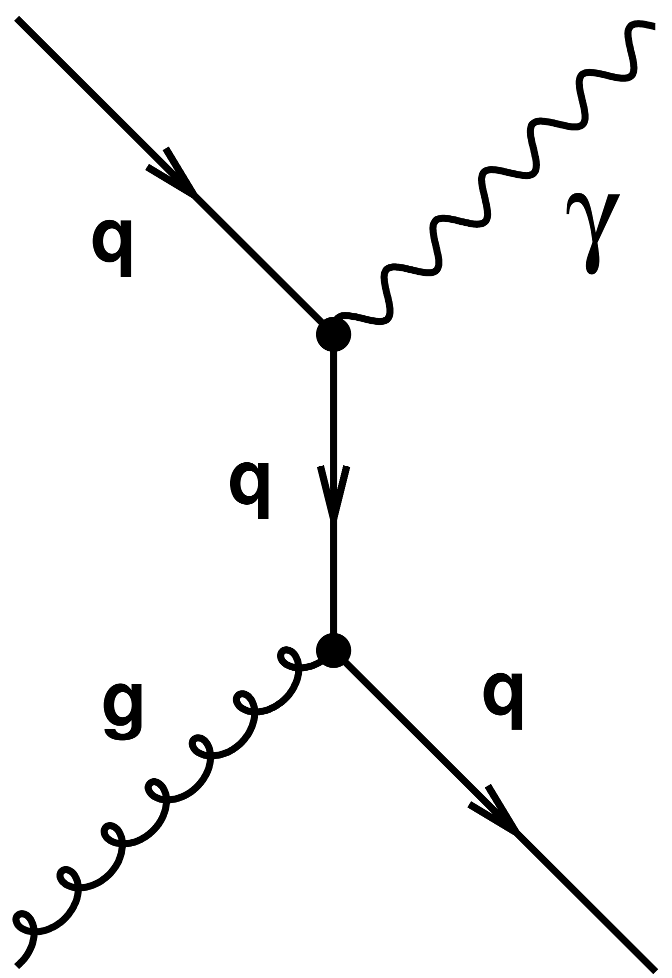
STDM-2015-01



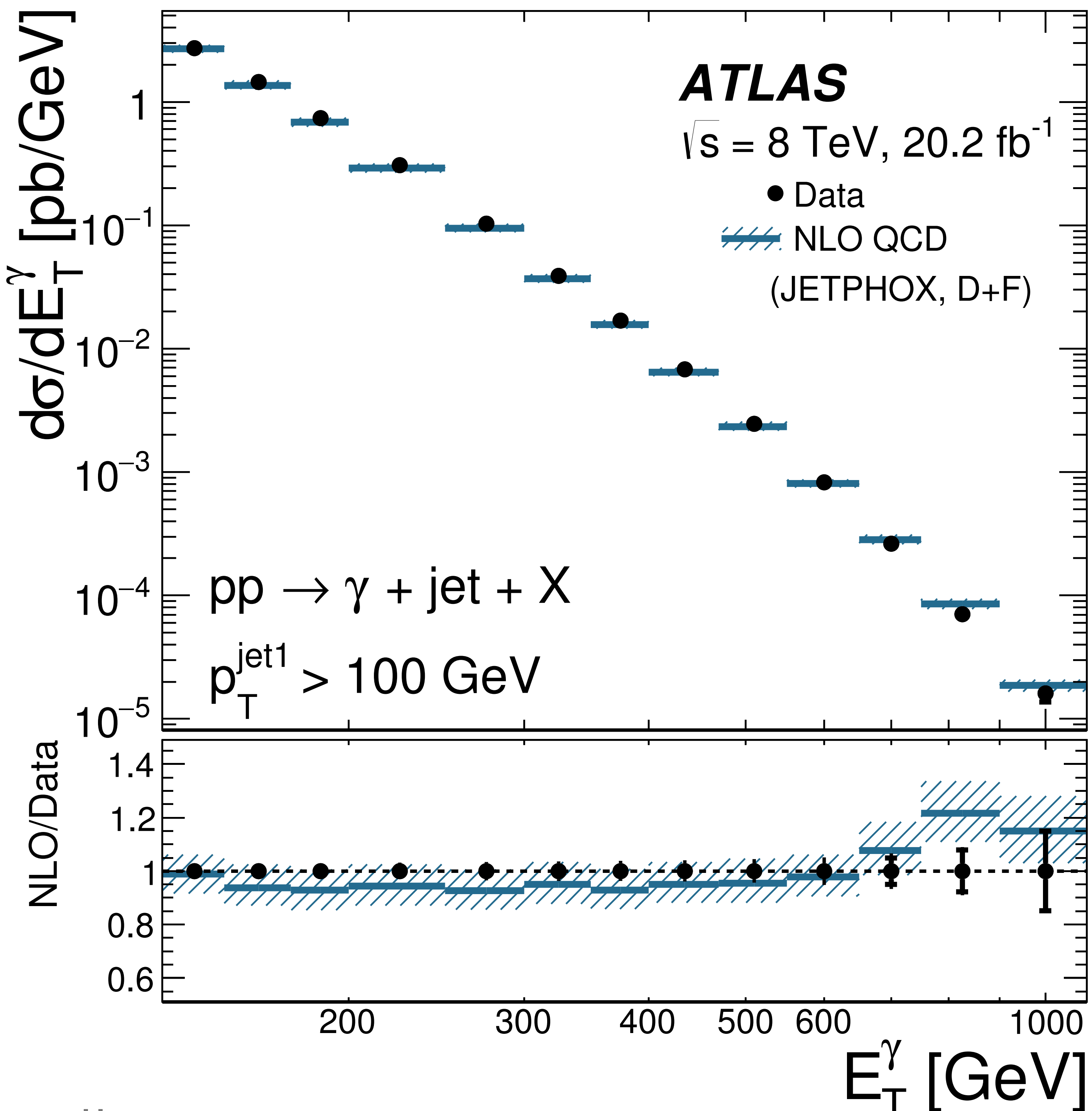
In fact, real EW emissions are measurable!

Not well-modeled by all setups, including dedicated weak shower

A related process has also been measured with isolated photons



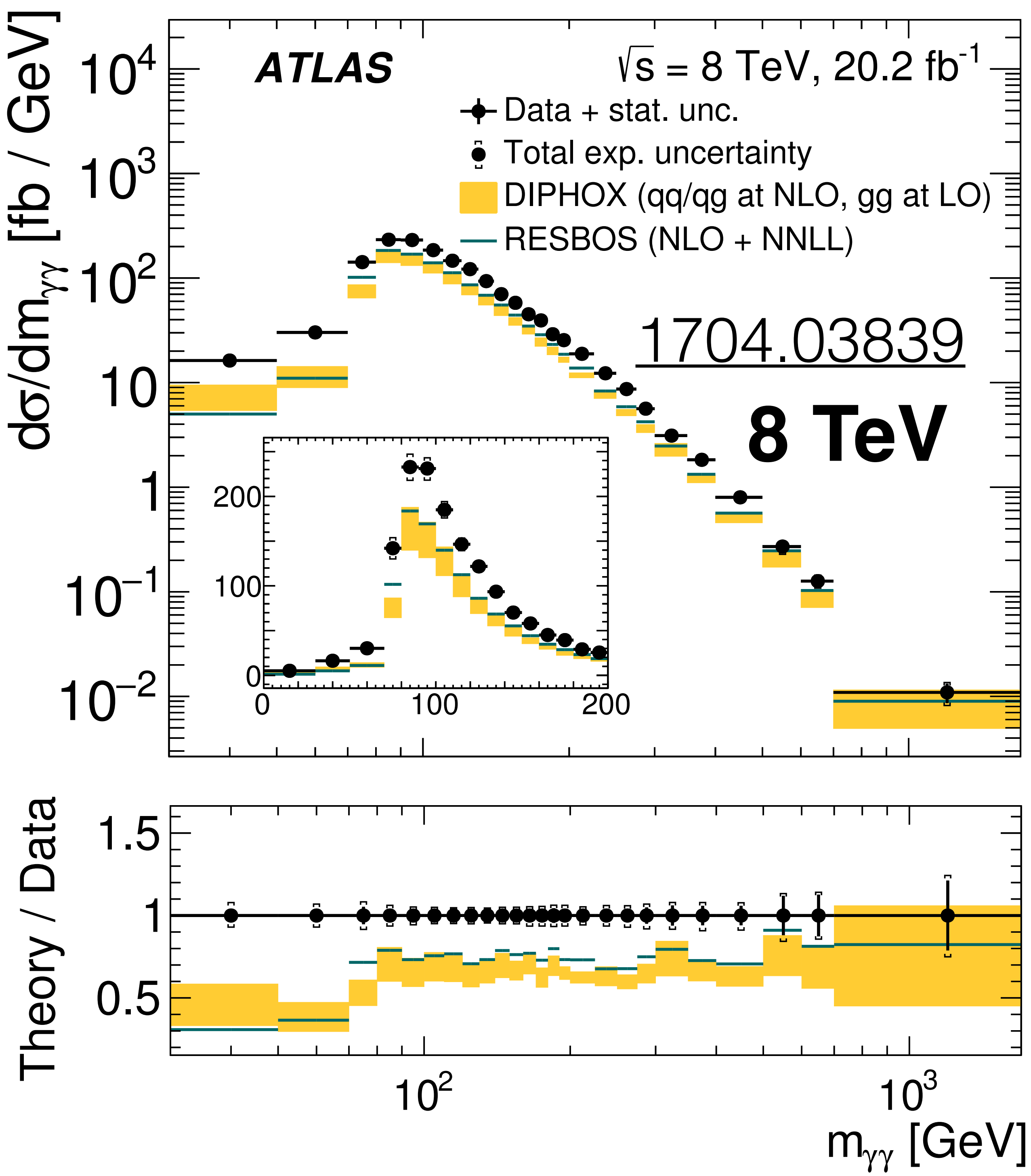
1611.06586



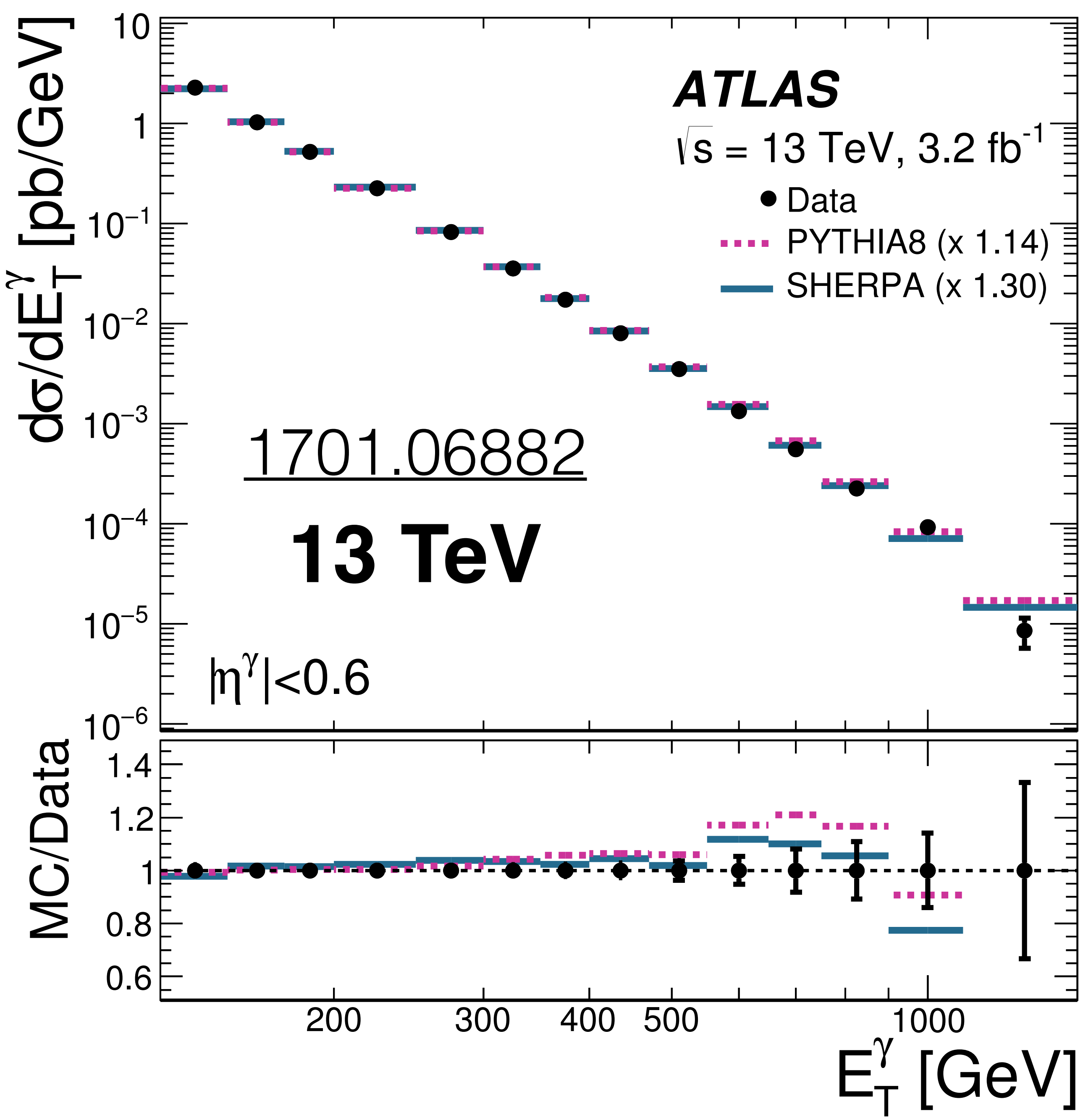
NLO QCD captures the shape well

Brief interlude: more photon results

photon-pairs

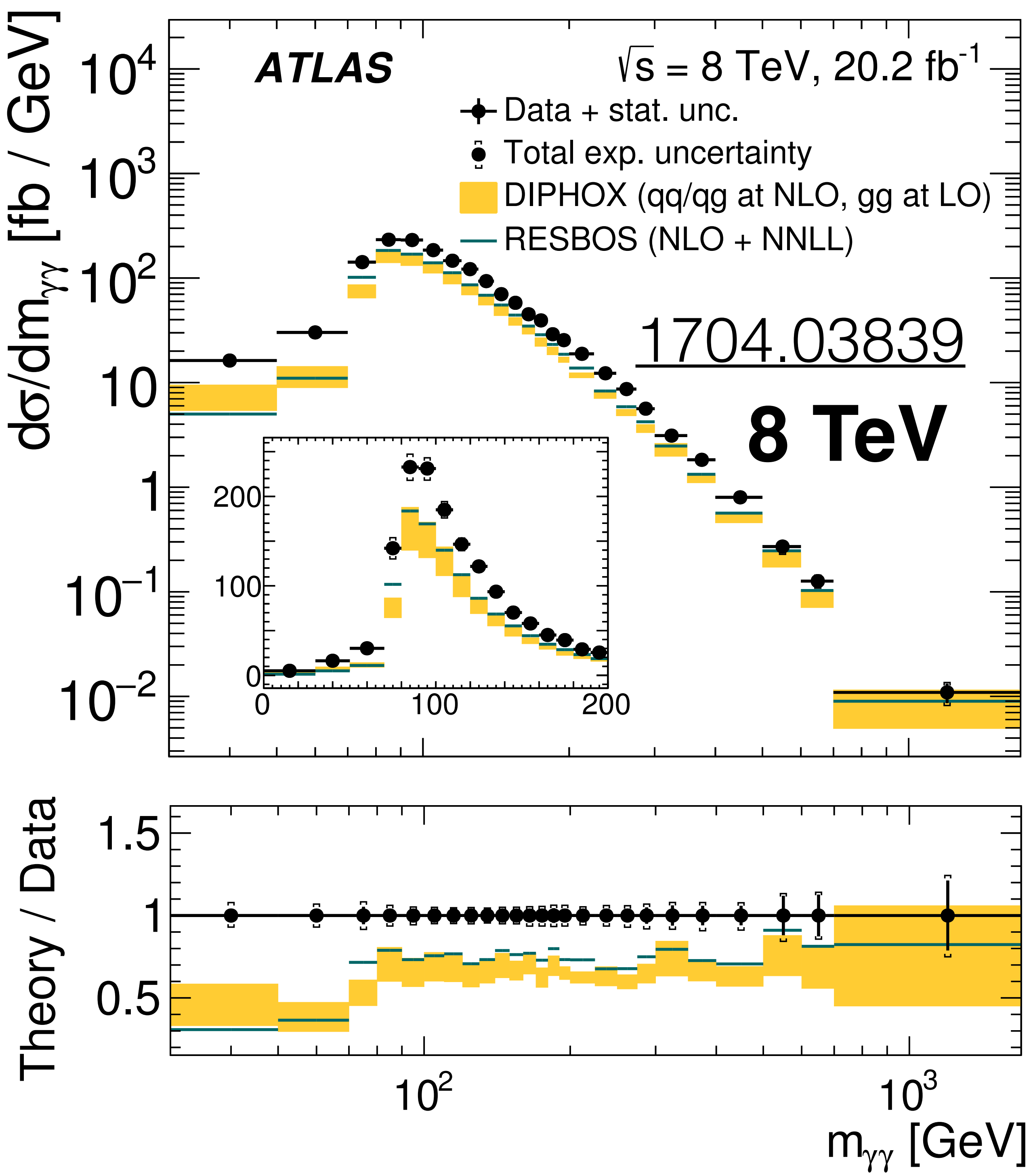


inclusive photons

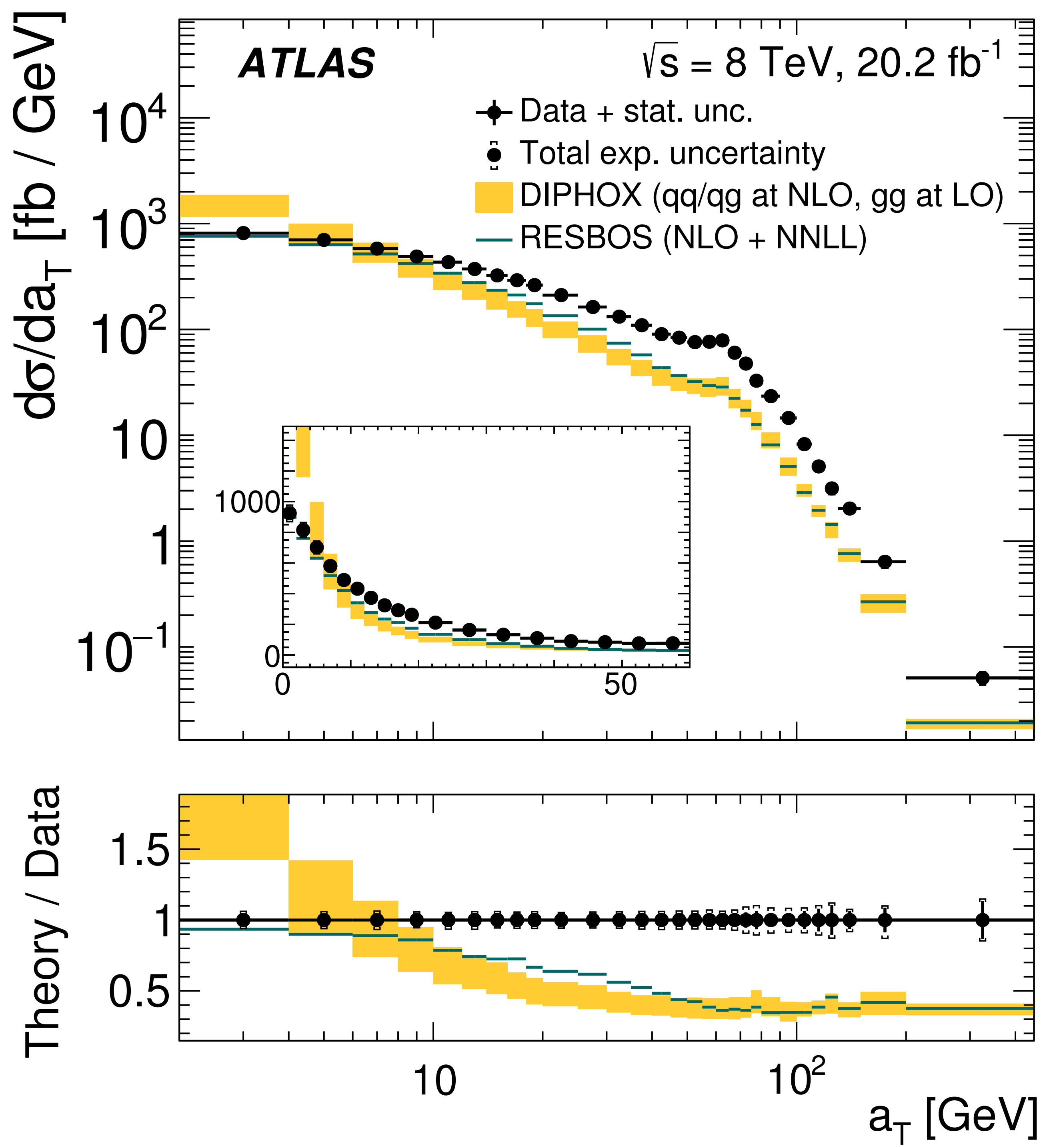


Single photon is well-described; not the case for photon-pairs.

γγ invariant mass

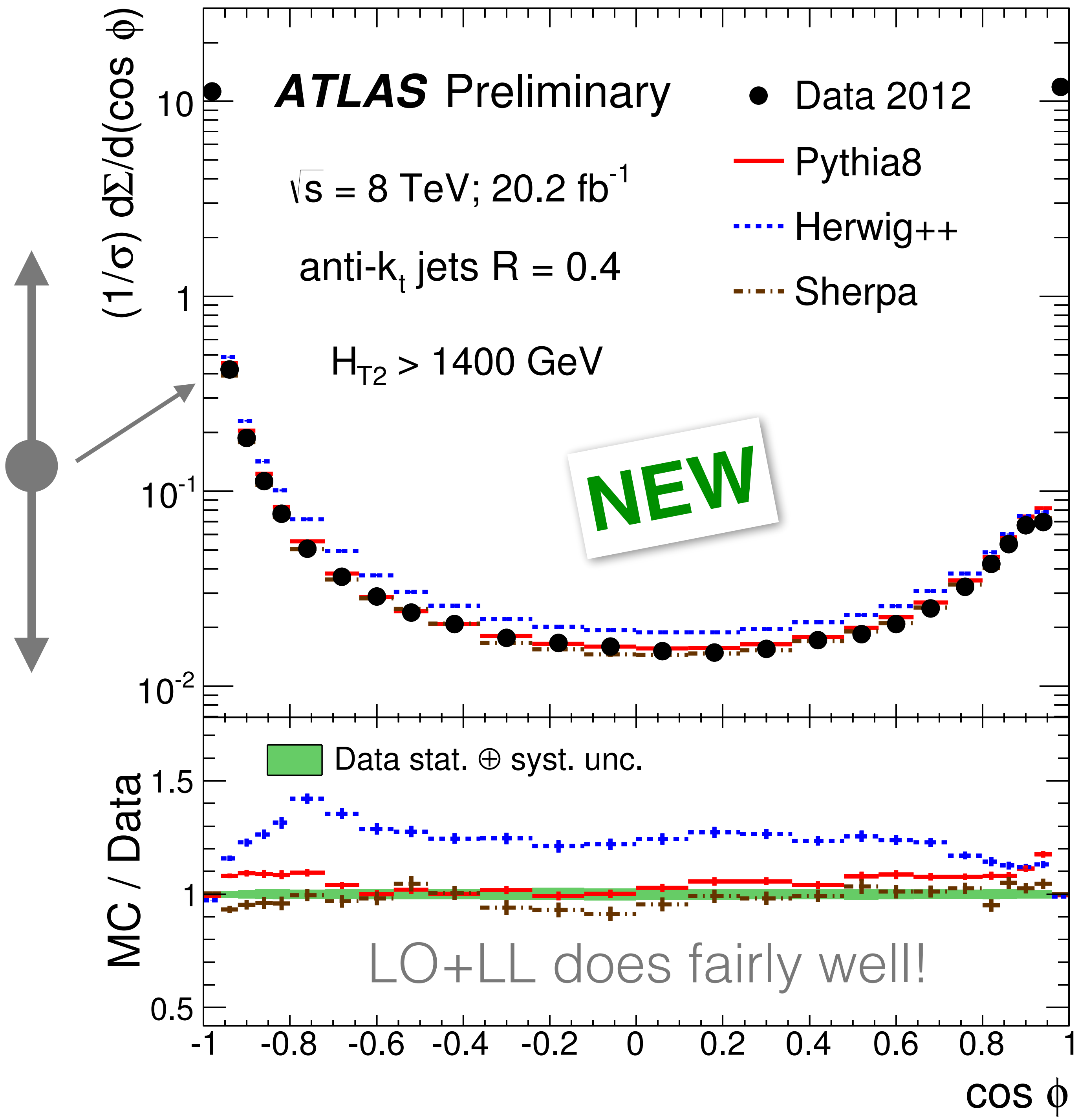


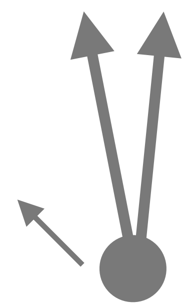
p_T perp to transverse thrust axis



Resummation works well to describe the soft gluons.

STDM-2016-10





Event shapes played a key role in precision QCD at e^+e^-

One observable is the **Transverse Energy-Energy Correlation Function** (TEEC)

$H_{T2} = p_{T1} + p_{T2}$

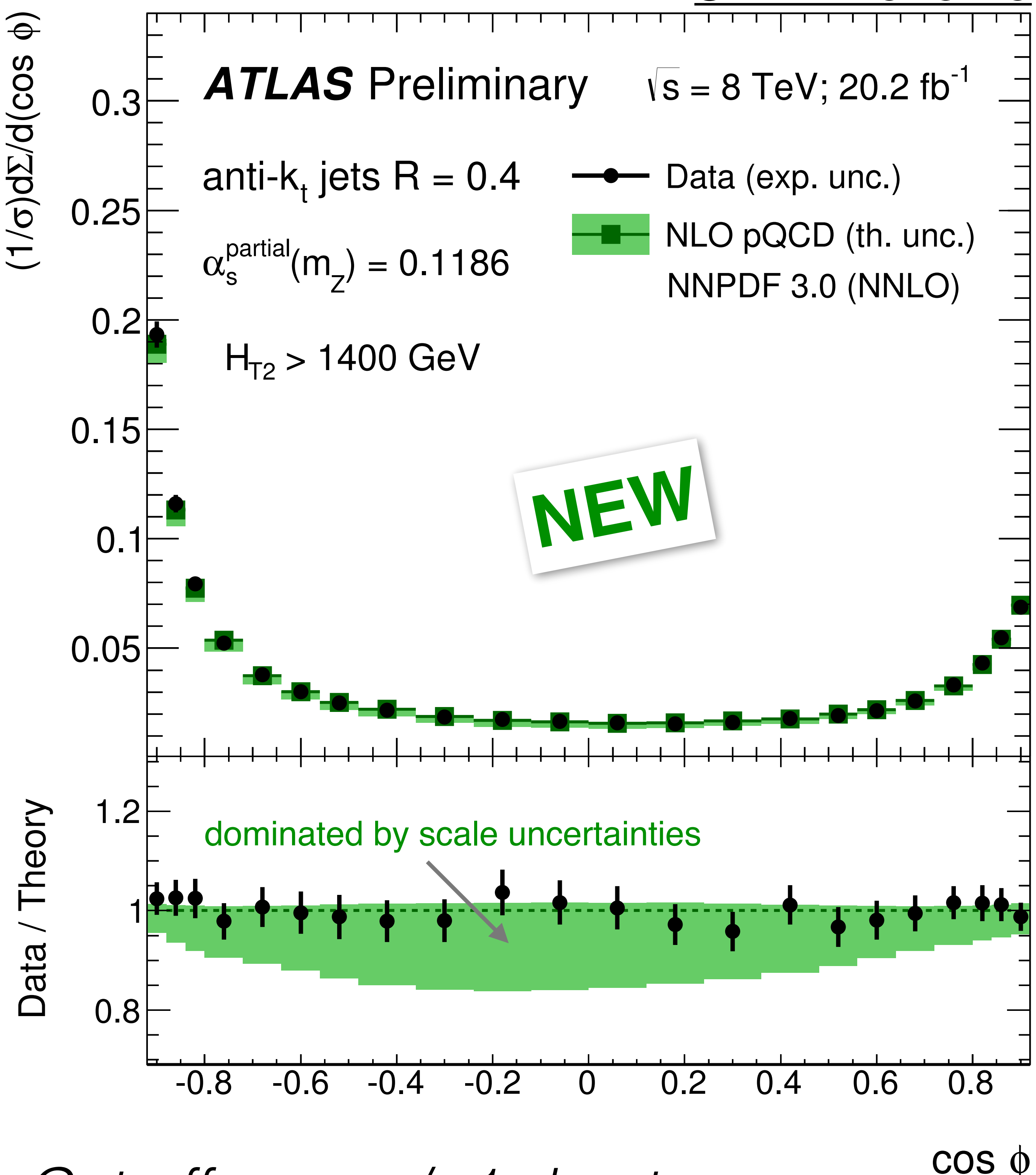
(sets the hard scale)

$$\frac{1}{\sigma}\frac{d\Sigma}{d\cos\phi}(\cos\phi) = \sum_{\text{events}}\sum_{i,j=1}^{n_{\text{jets}}}\frac{E_{T,i}E_{T,j}}{\left(\sum_{k=1}^{n_{\text{jet}}}E_{T,k}\right)^2}\delta(\cos\phi - \cos\phi_{ij})$$

(defined as dimensionless cross-section)

Part II: Event Shapes

STDM-2016-10

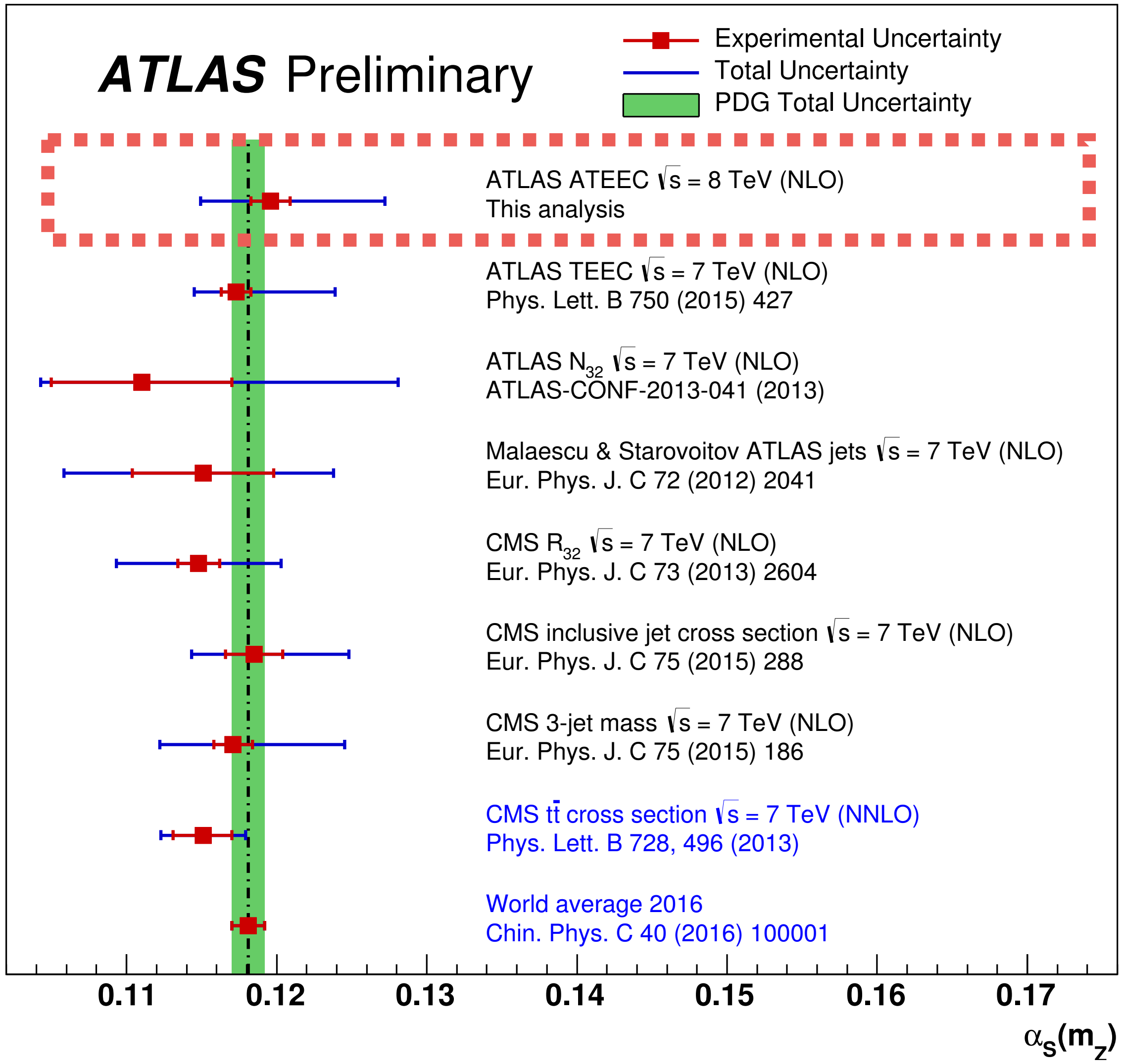


Cut off near +/- 1 due to resummation sensitivity

χ^2 fit for α_s

using unfolded data

(N.B. LO $= \mathcal{O}(\alpha_s^3)$)



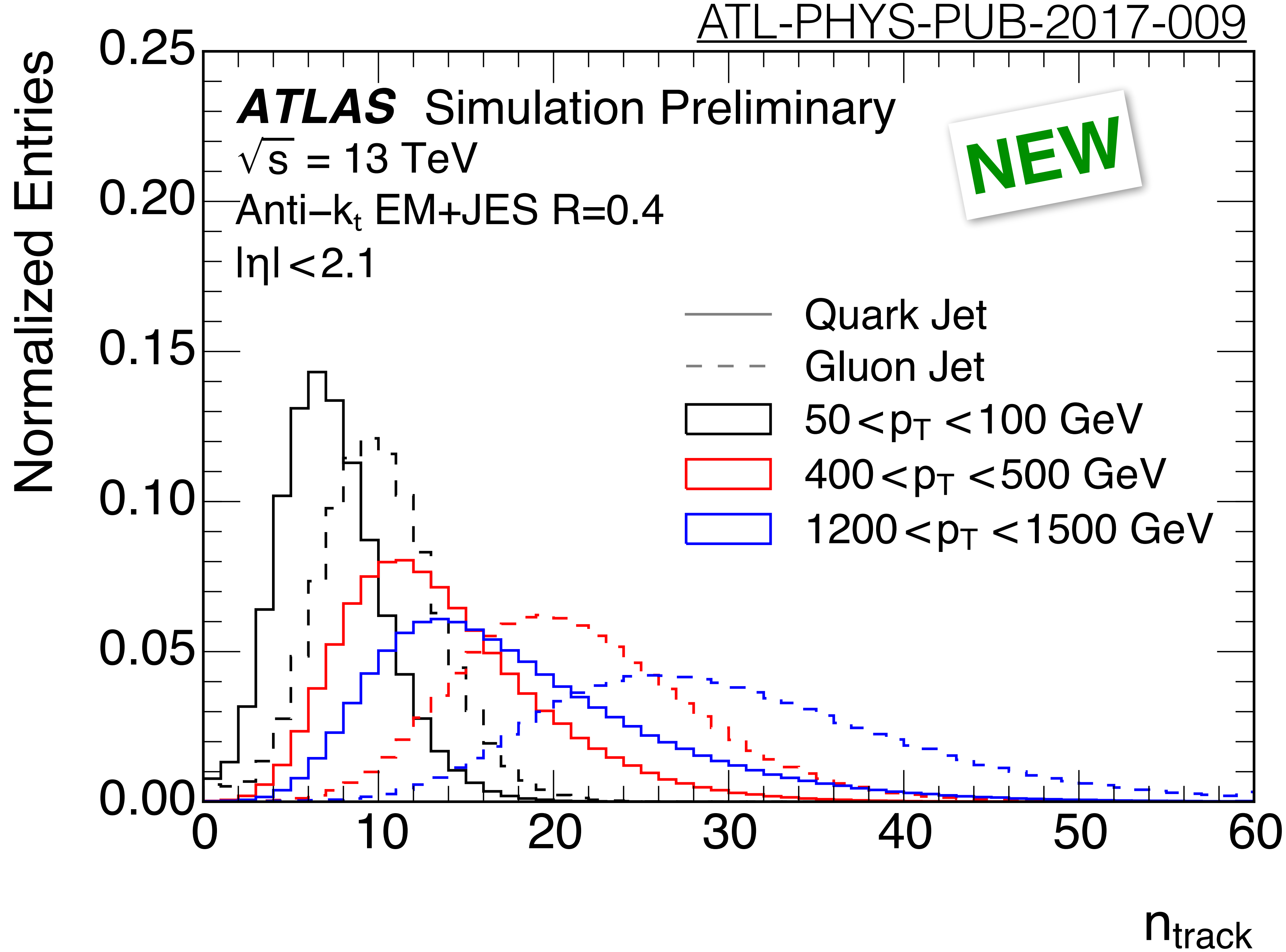
consistent with other *pp* jet extractions

The radiation pattern inside jets probes a different regime of QCD

The most basic of all observables is particle multiplicity

Charged particle tracks are our proxy for particles

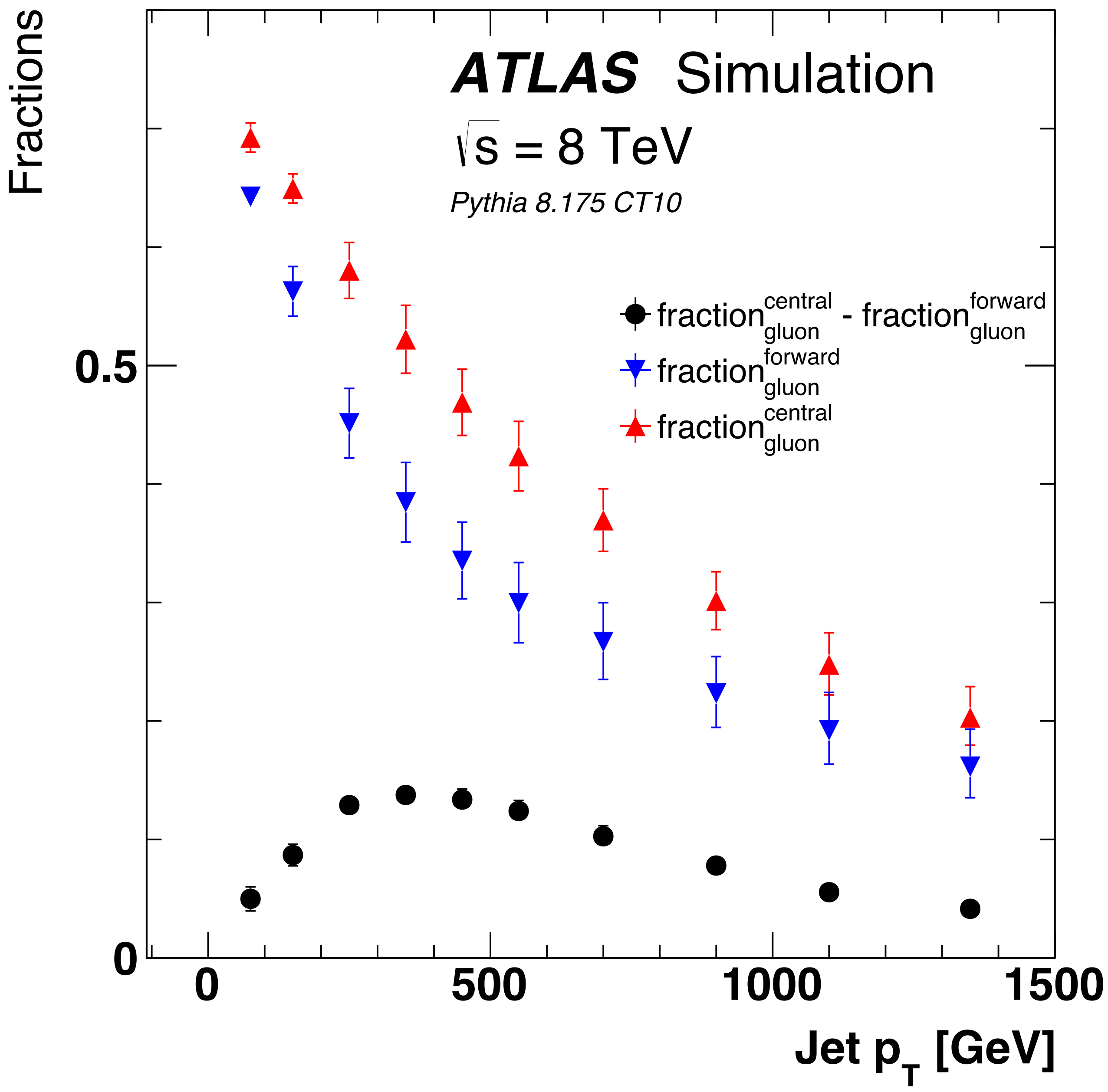
ATL-PHYS-PUB-2017-009



Multiplicity scales with the color charge (C_F/C_A): useful for distinguishing q/g!

We have re-cast a precision QCD measurement to calibrate a q/g tagger for Run 2

Eur. Phys. J. C76(6), 1-23 (2016)



$$\langle n^{\mathrm{f}}_{\mathrm{charged}}\rangle = f^{\mathrm{f}}_{\mathrm{q}}\langle n^{q}_{\mathrm{charged}}\rangle + f^{\mathrm{f}}_{\mathrm{g}}\langle n^{g}_{\mathrm{charged}}\rangle$$

$$\langle n^{\mathrm{c}}_{\mathrm{charged}}\rangle = f^{\mathrm{c}}_{\mathrm{q}}\langle n^{q}_{\mathrm{charged}}\rangle + f^{\mathrm{c}}_{\mathrm{g}}\langle n^{g}_{\mathrm{charged}}\rangle$$

q/g multiplicity separately measured by exploiting rapidity

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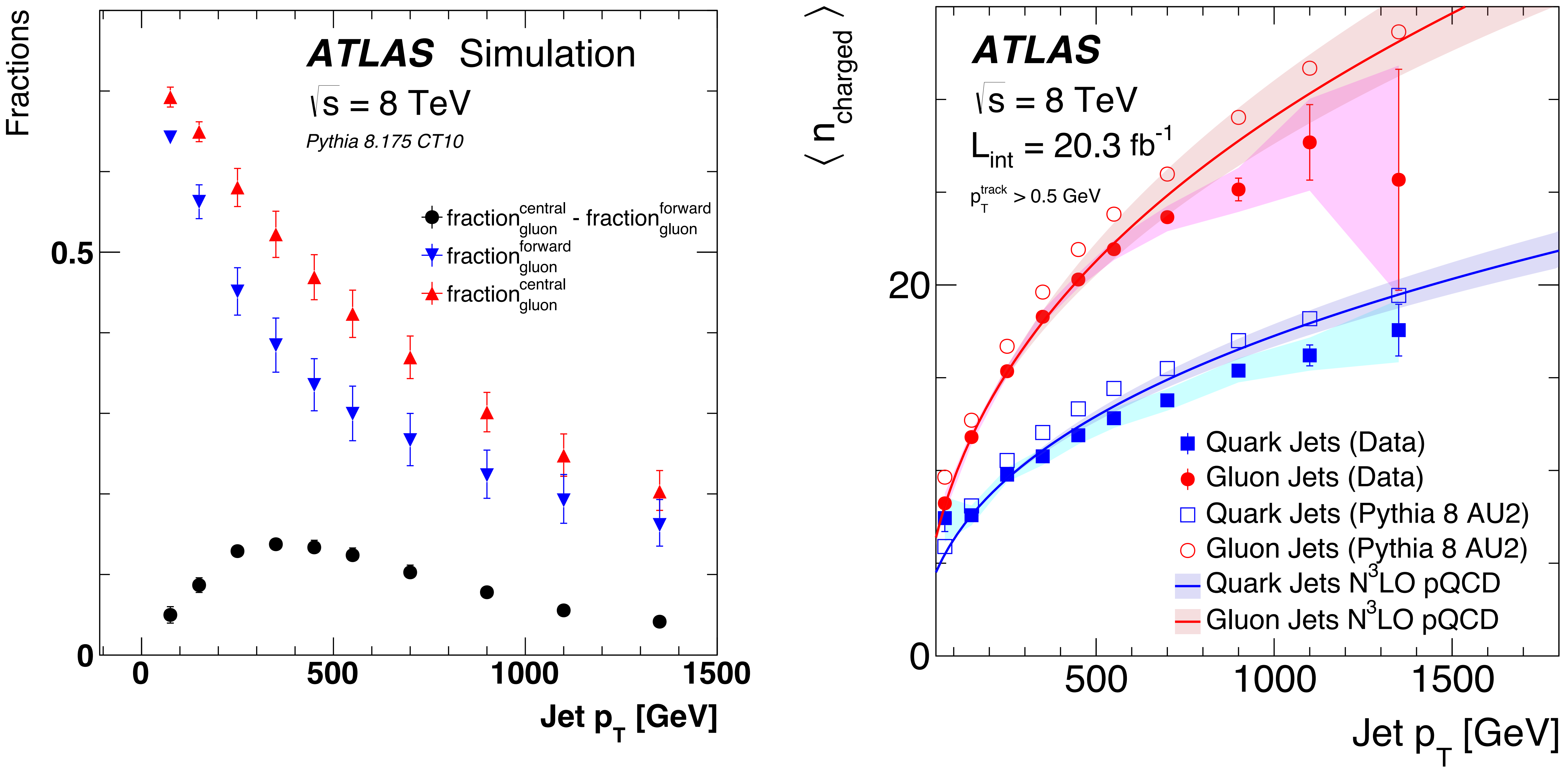
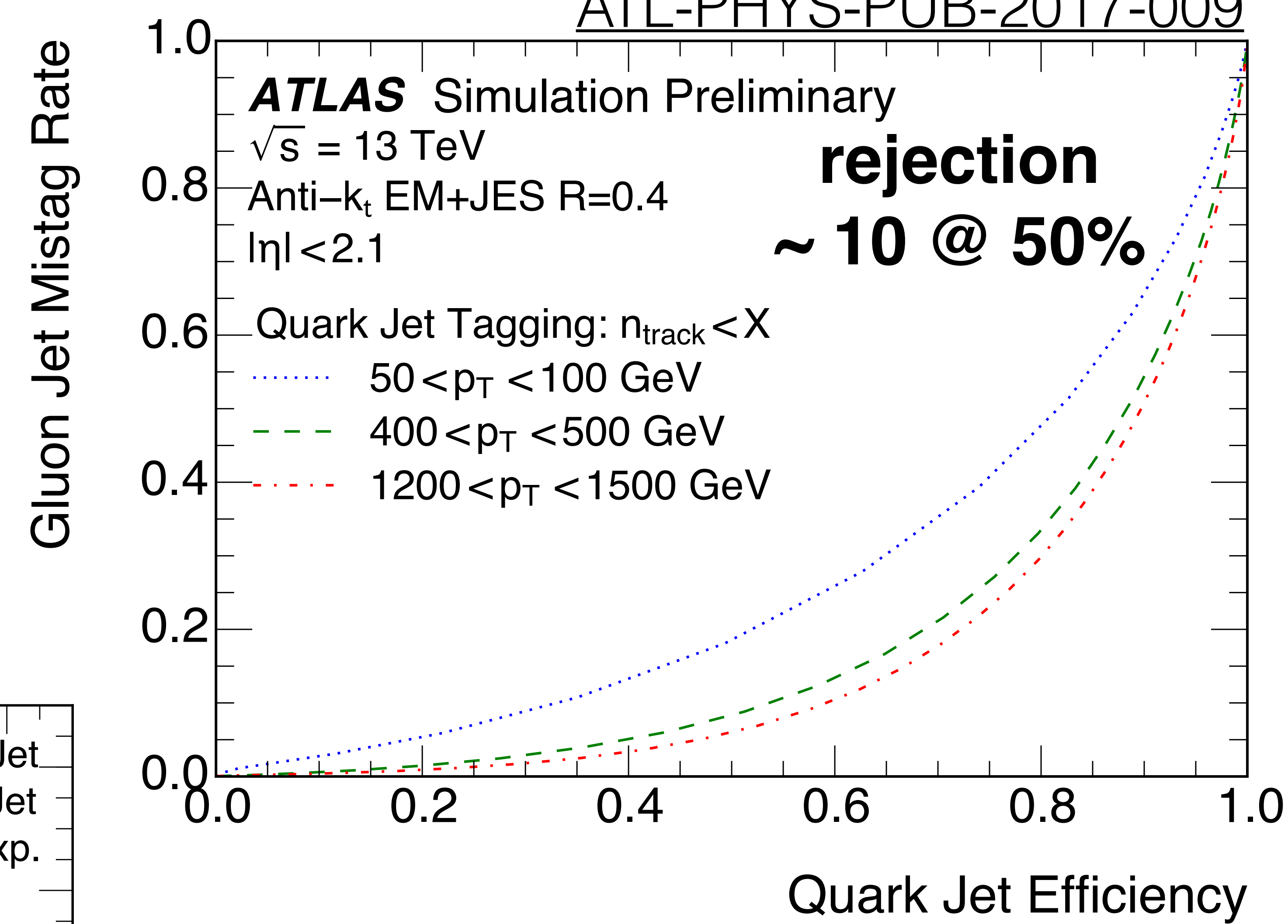


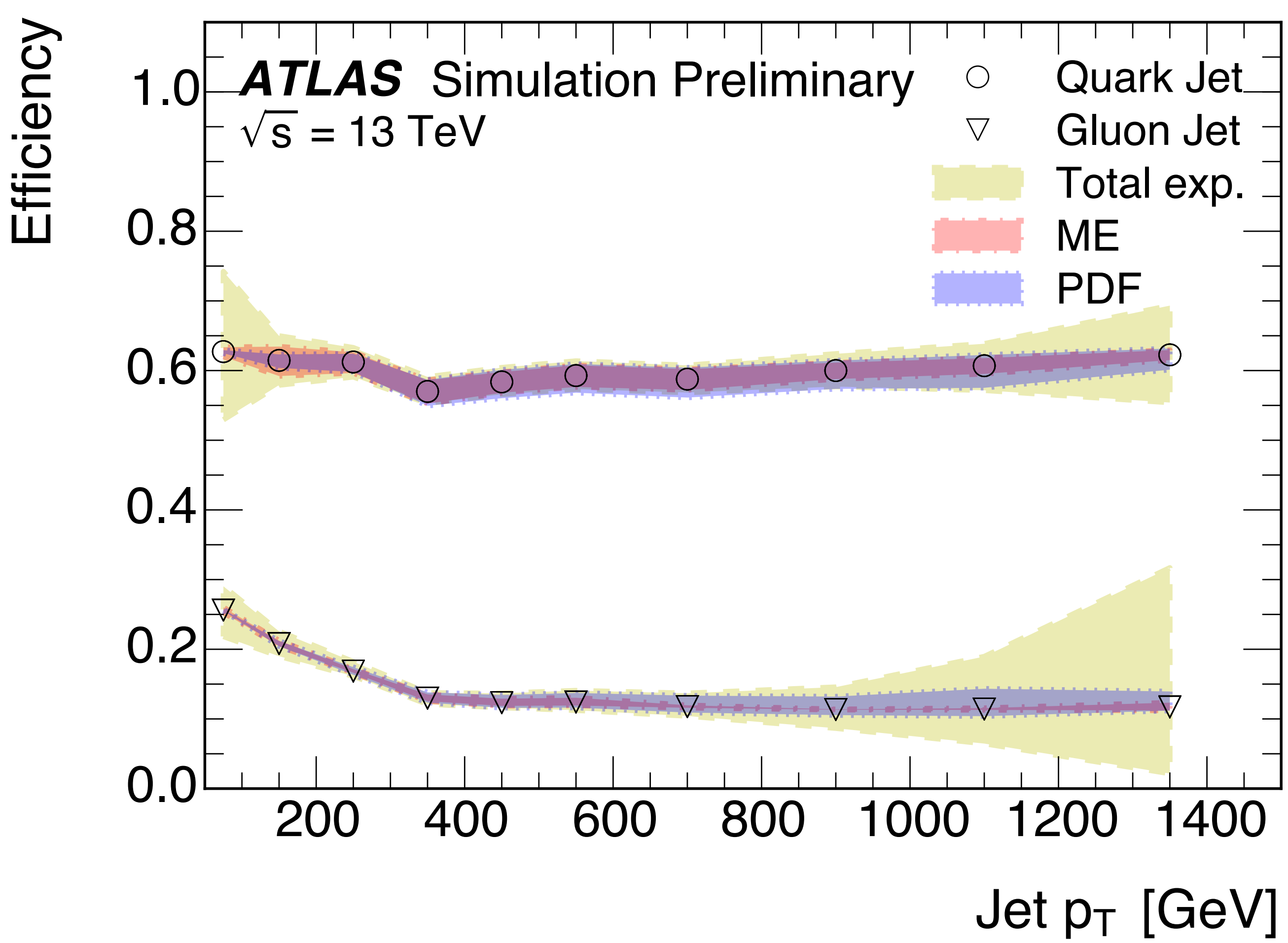
q/g multiplicity separately measured by exploiting rapidity

ATL-PHYS-PUB-2017-009

q/g tagging performance

modeling uncertainties from precision measurement





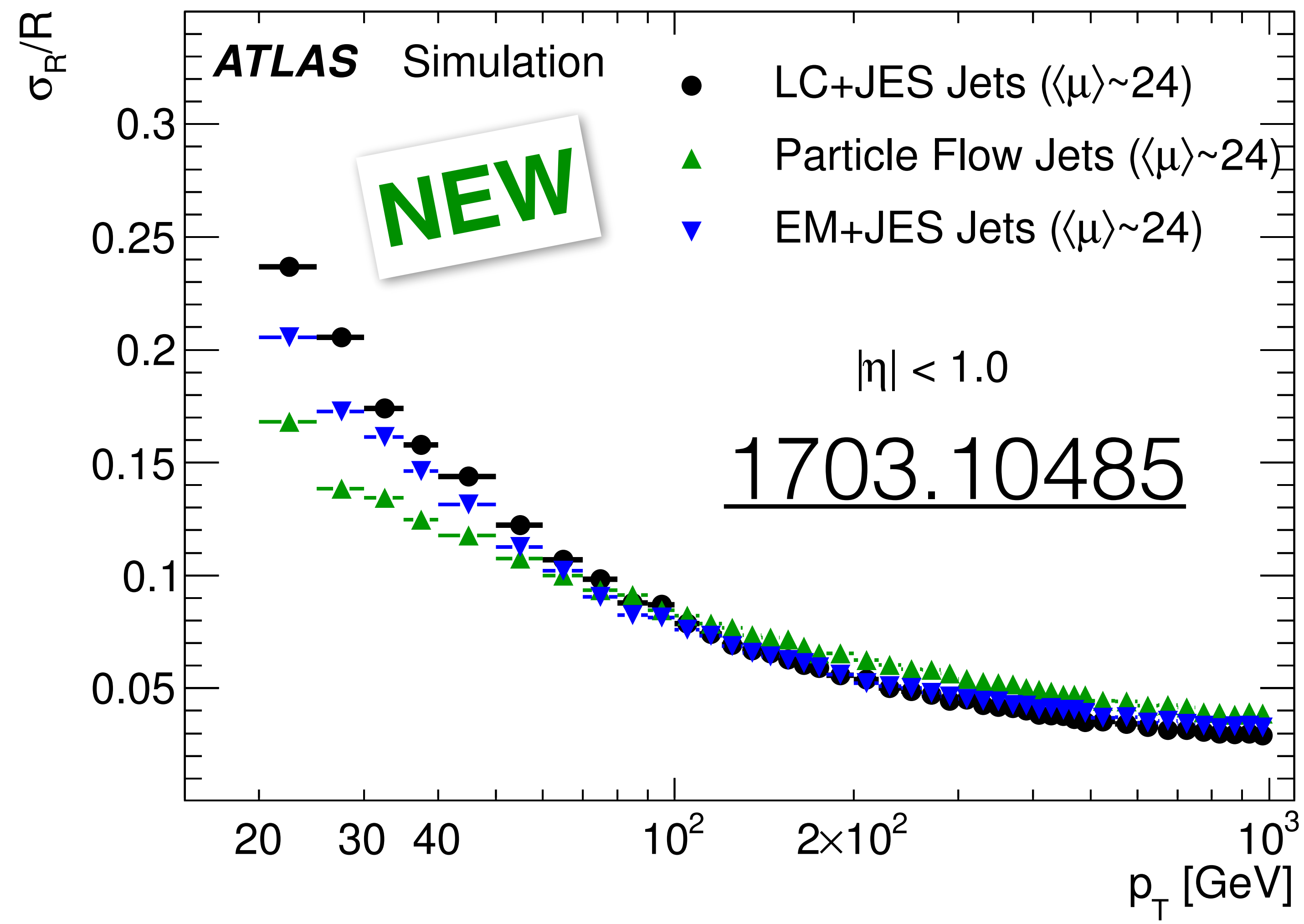
transport to 13 TeV with experimental tracking uncertainties

~5% uncertainties across a wide range of p_T

Future outlook

The ATLAS jet program is probing all aspects of the rich structure of QCD

There are exciting new opportunities in the near future; in particular with **tracking inside jets**!



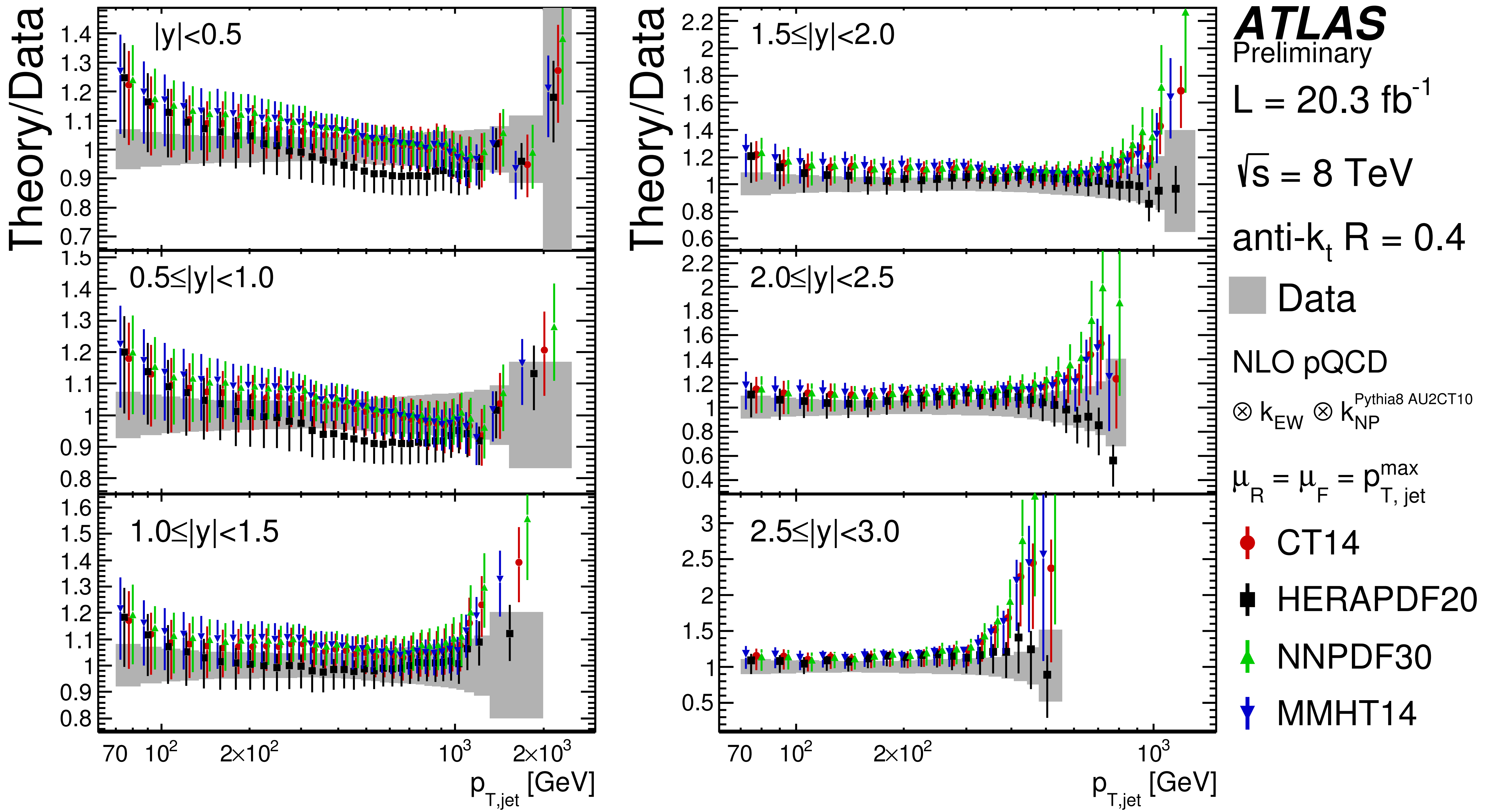
improvements to jet calibration (including particle flow) and tracking inside dense environments

for the latest results on jet and photon physics, please see

https://twiki.cern.ch/twiki/bin/view/AtlasPublic/StandardModelPublicResults

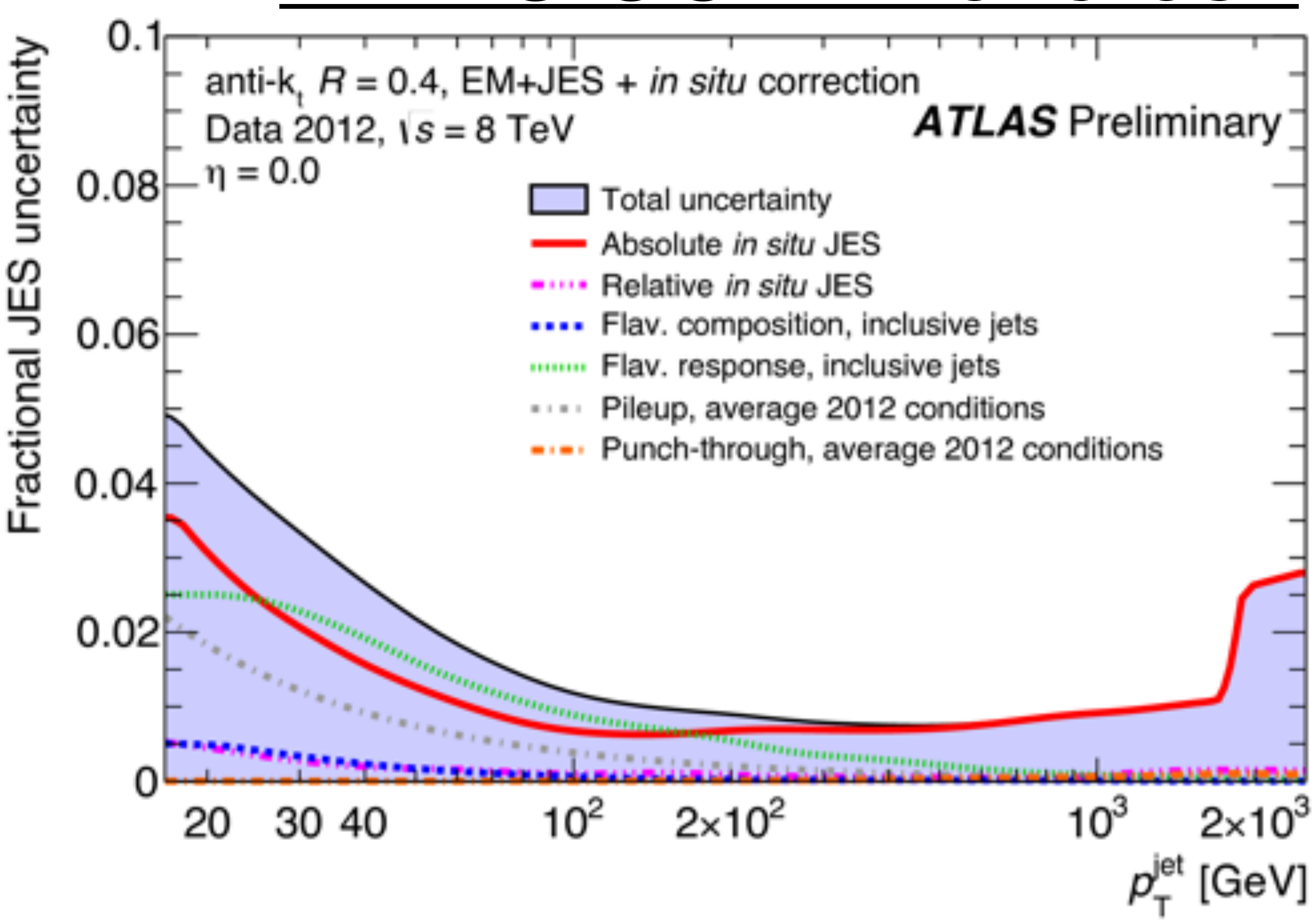
Backup

Jet Cross-sections

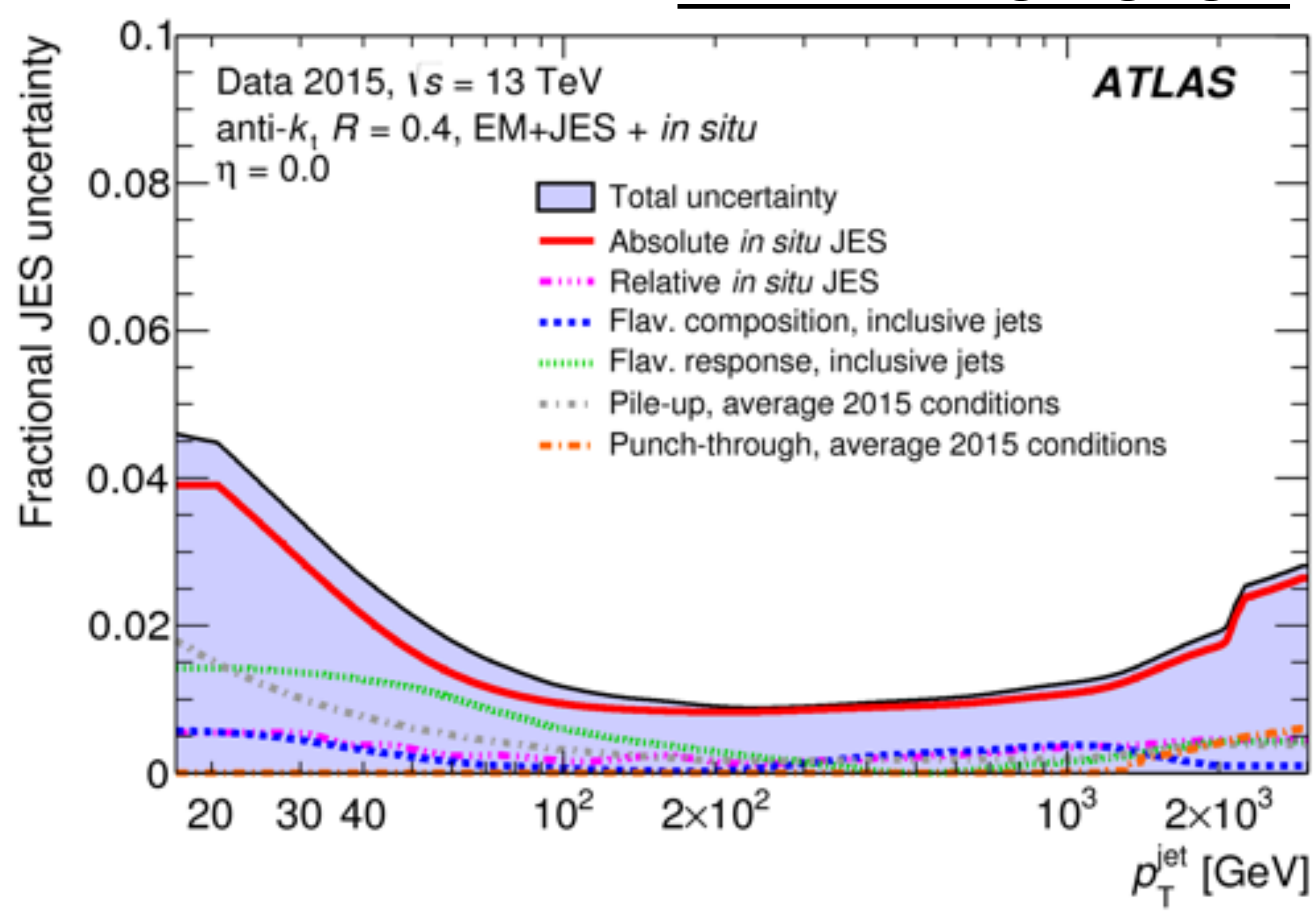


Jet Energy Scale Uncertainty

ATLAS-CONF-2015-037



PERF-2016-04



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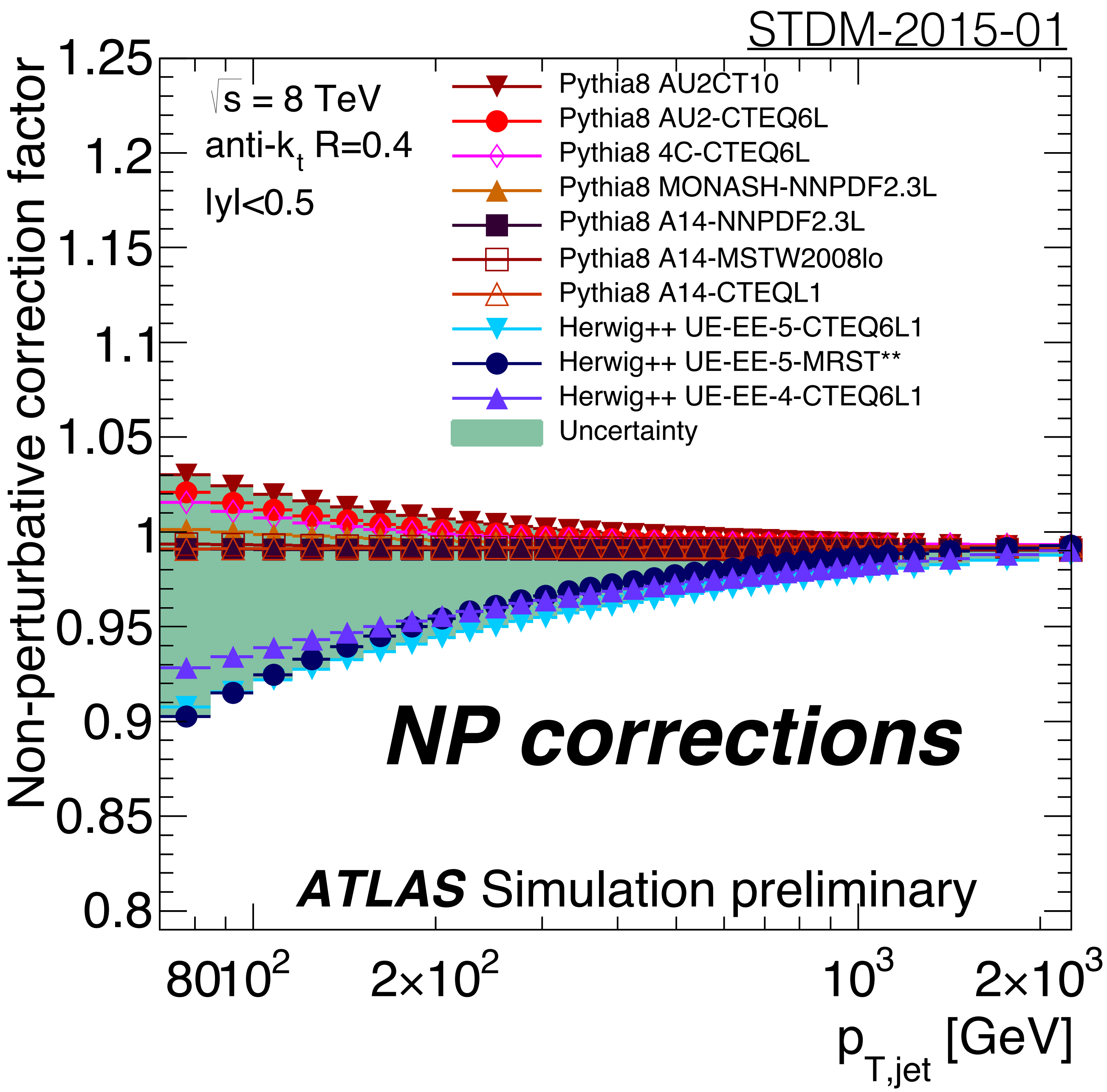
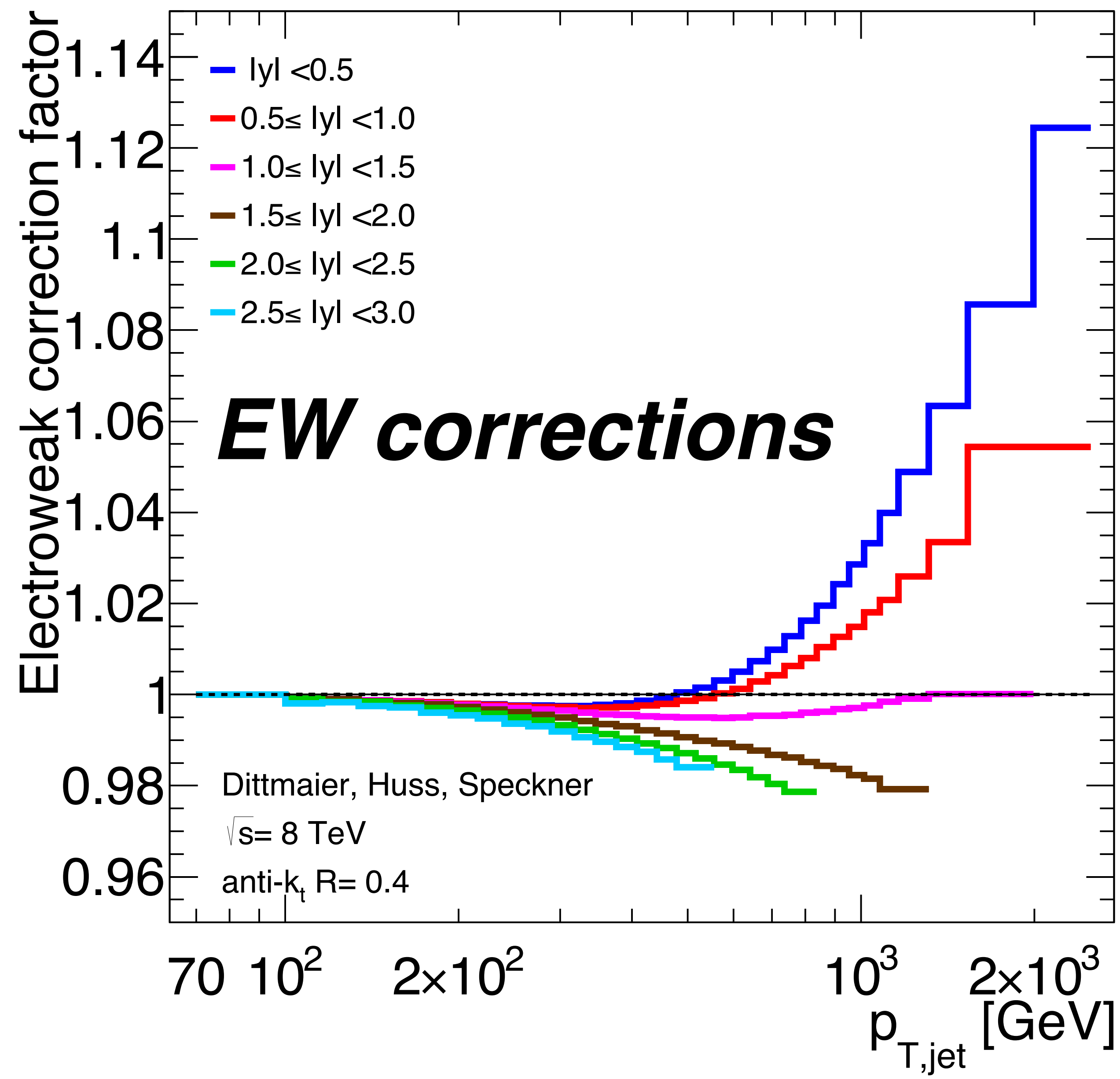


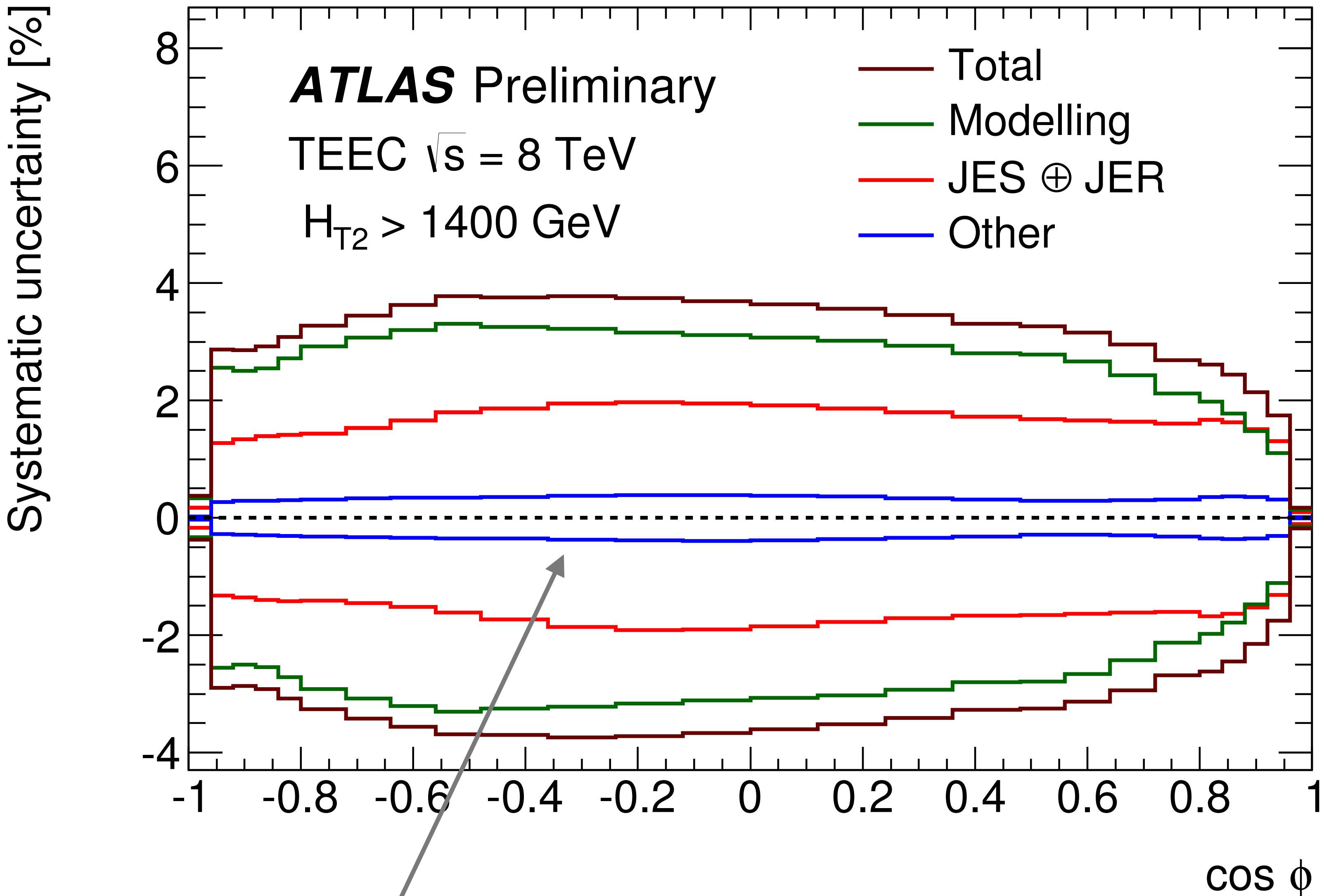


But electroweak corrections are not small!

Part II: Energy-energy correlation uncertainties

NEW

STDM-2016-10

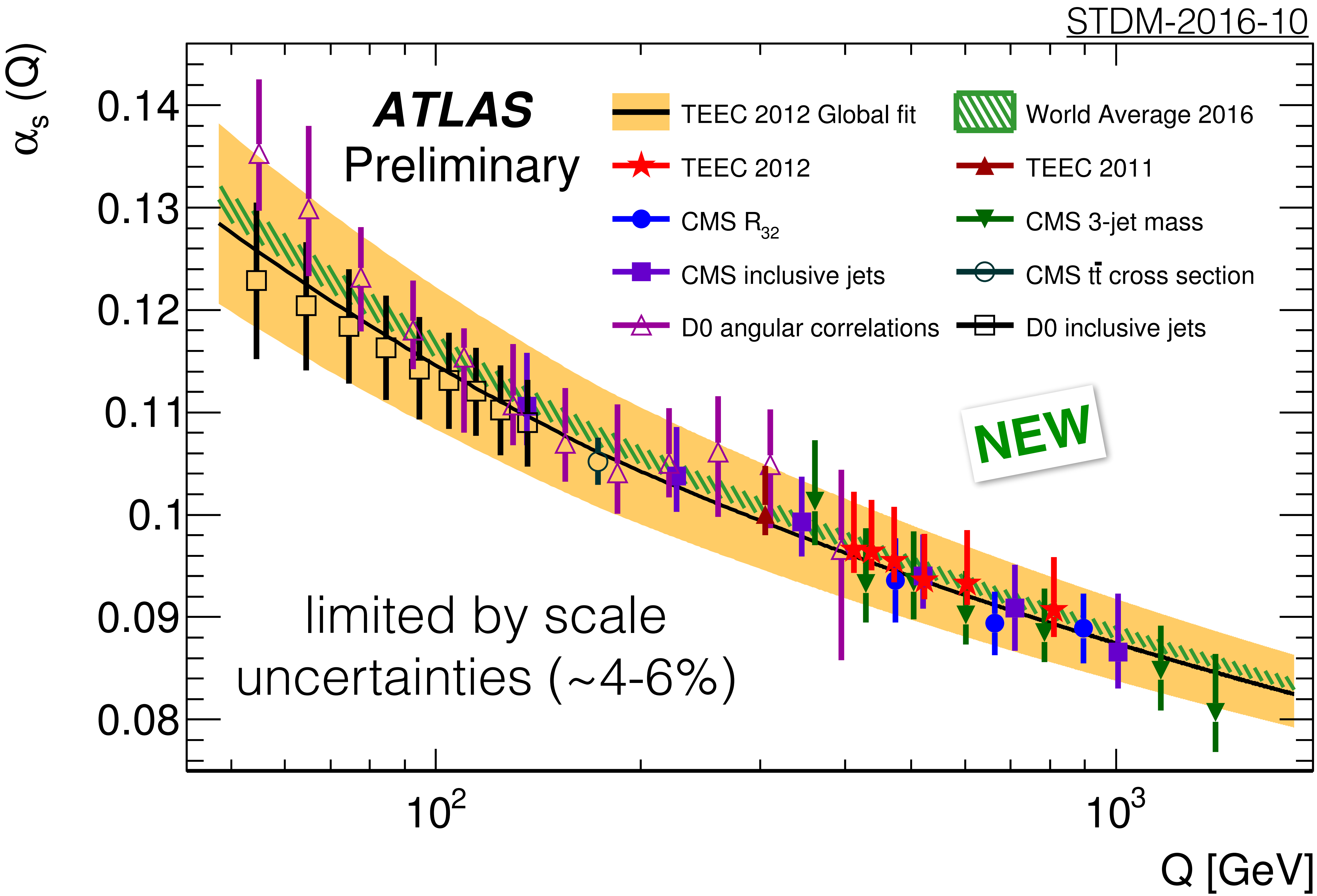


jet angular resolution

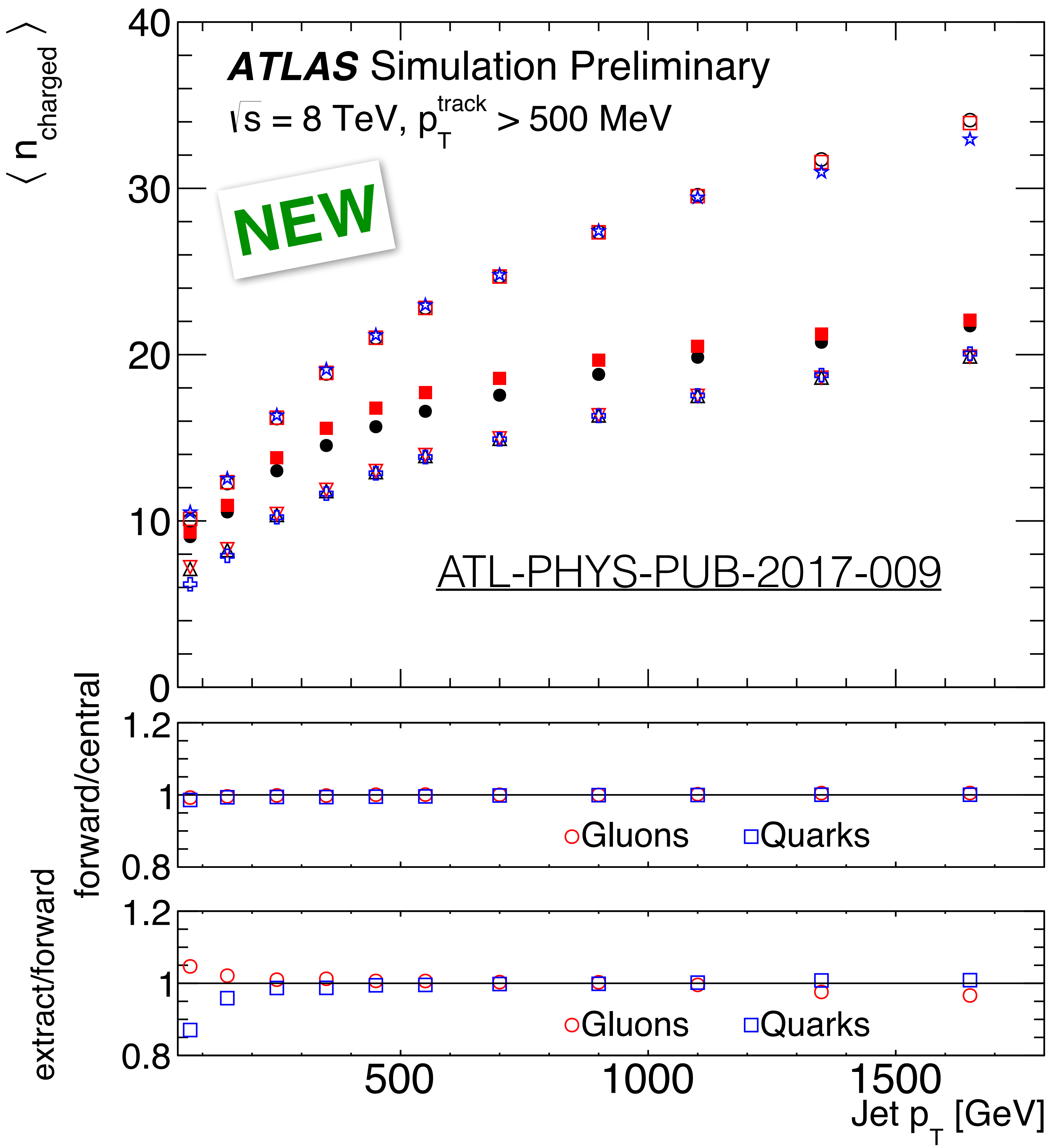
By construction, designed to be less sensitive to JES

(~5% for the xs measurement for comparable energy)

More sensitive in the middle to do softer gluon radiation


STDM-2016-10
ATLAS
Preliminary
TEEC 2012 Global fit
World Average 2016
TEEC 2012
TEEC 2011
CMS R32
CMS 3-jet mass
CMS inclusive jets
CMS tt̄ cross section
D0 angular correlations
D0 inclusive jets
NEW
limited by scale
uncertainties (~4-6%)
αs (Q)
0.14
0.13
0.12
0.11
0.1
0.09
0.08
10^2
10^3
Q [GeV]

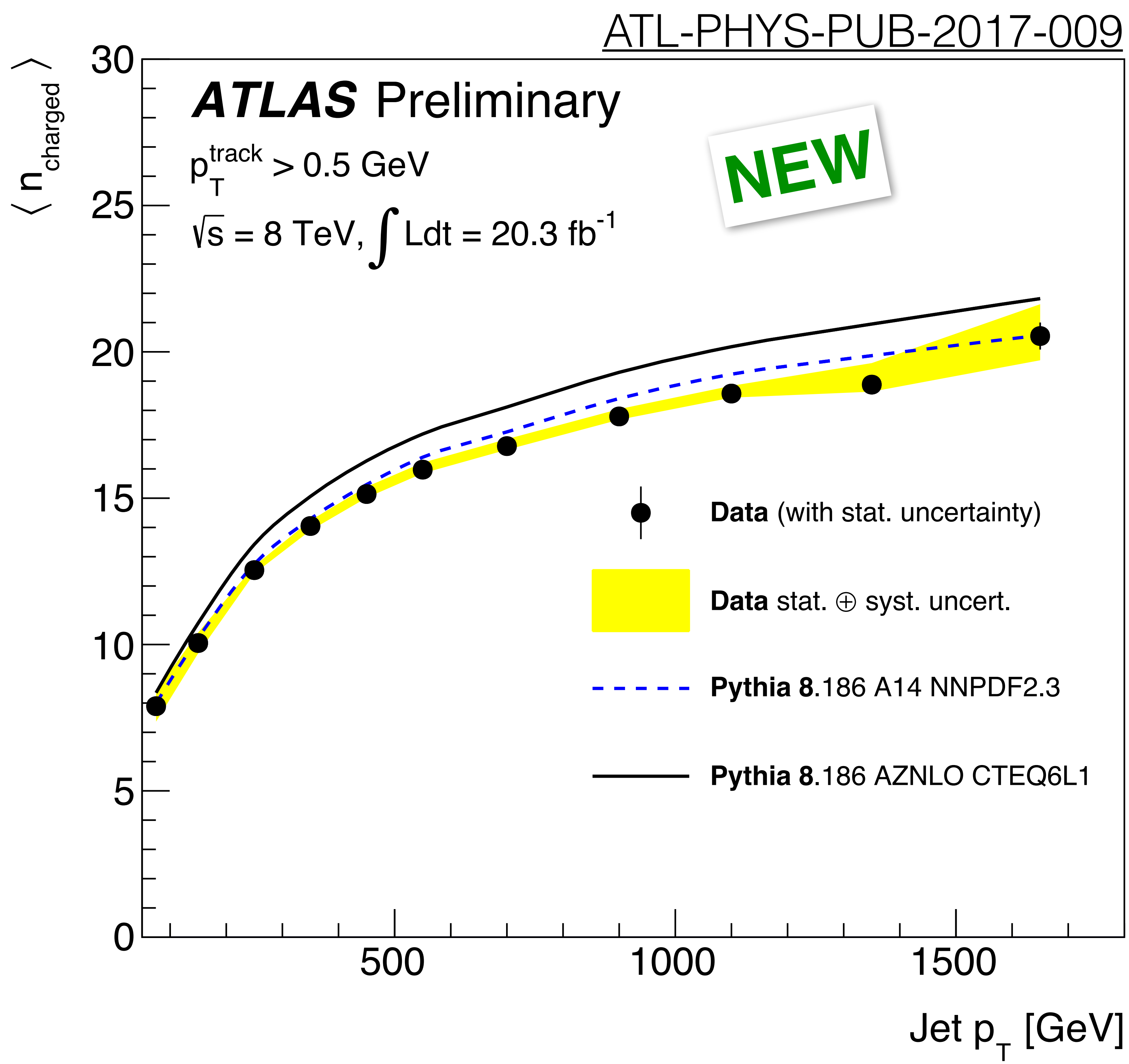
Part III: Multiplicity Extraction Closure



Closure Test

- More central jet (inclusive)
- More central jet (gluons)
- More central jet (quarks)
- Quarks (extracted)
- More forward jet (inclusive)
- More forward jet (gluons)
- More forward jet (quarks)
- Gluons (extracted)

Part III: Multiplicity with various UE tunes



difference: alpha FSR 10% smaller

As part of this effort, we have also studied UE tuning

The ATLAS **A14 tune** is a better model than the Pythia 8 default (Monash) and the ATLAS **AZNLO tune** used for many Higgs analyses

This is a key challenge for the Hep-ex and Hep-ph communities!