Jet substructure for precision physics/QCD in ATLAS

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What does *precision* mean?

This is not the W mass measurement (0.01%) but it is also not a search (10-100%). We are aiming for 1-10% uncertainties in various differential cross-section spectra and SM parameter measurements.

N.B. it is likely that we will be systematics limited for many measurements. Therefore, the goal is not to combine ATLAS + CMS but to compare / harmonize (also with theory) for the best precision + cross-check.

Why now? ATLAS, CMS, theory, (and ALICE/ LHCb!) are making 1-10% measurements / predictions of various jet substructure quantities!

Achieving precision: uncertainties

Precision requires that everyone (ex **and** ph) has a detailed estimate of the uncertainty

ATLAS

For all inputs:

-Efficiency
-Fake/pileup rate
-Parameter scale/resolution
-Density effects (inside jets)
…

Unfolding: *modeling, priors, …*

So far in Run 2:
“bottom up” approach

(used a mix of both approaches in early Run 1)

CMS

So far in Run 2:
“top down” (search-like) approach

Theory

NP corrections

PS MC/Shape functions?

Perturbative scales

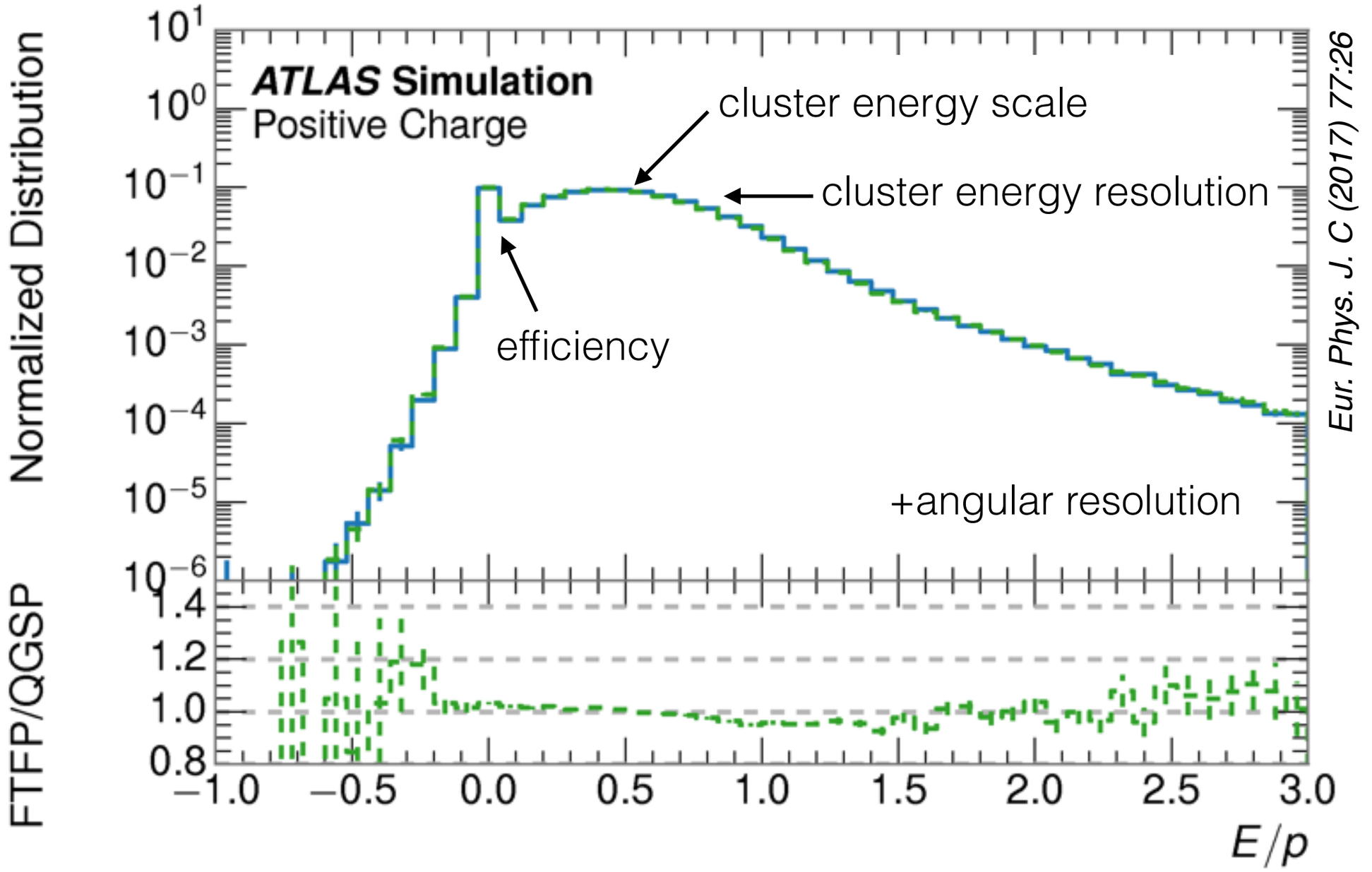
Matching

additive/multiplicative

Resummation terms

naming conventions - number of L’s including NGLs? R resummation?

“Bottom up” uncertainties: calorimeter



We match calorimeter-cell clusters to tracks extrapolated from our inner detector.

“Bottom up” uncertainties: tracks

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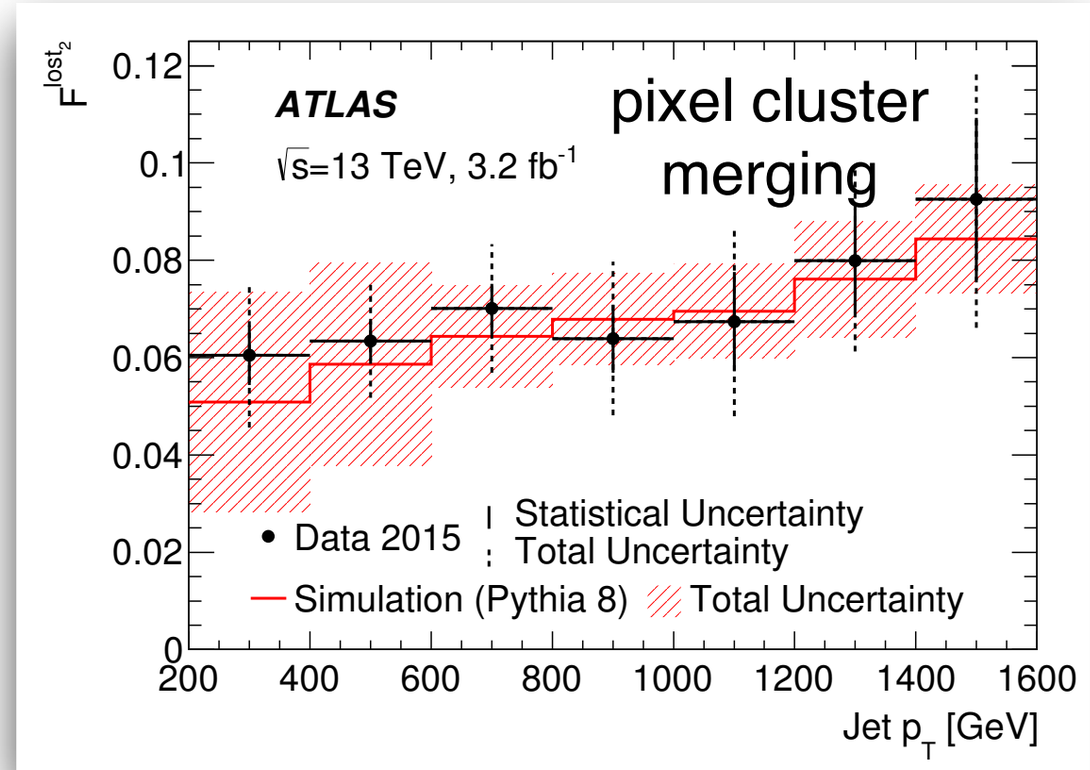

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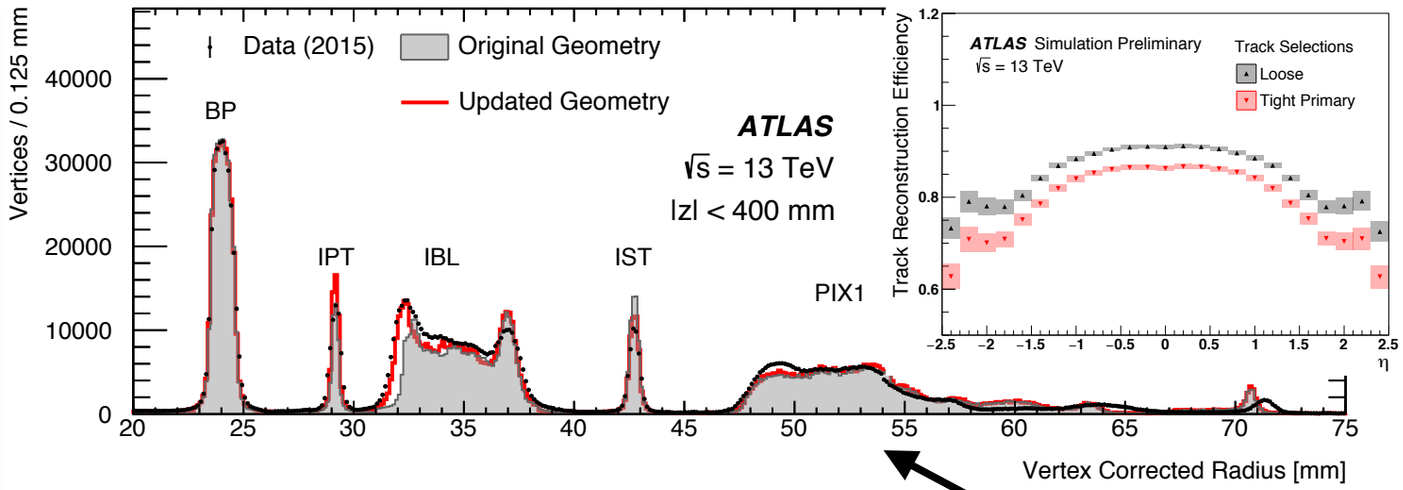
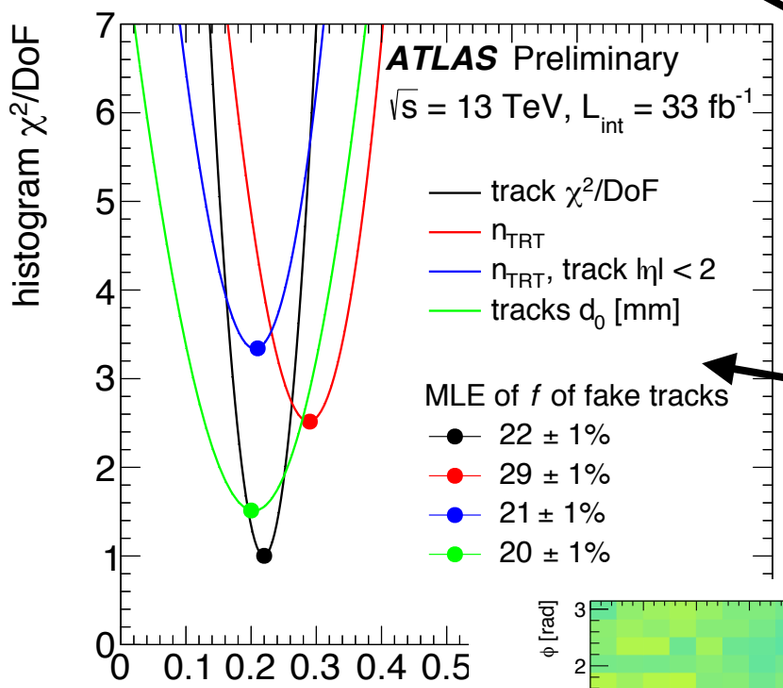


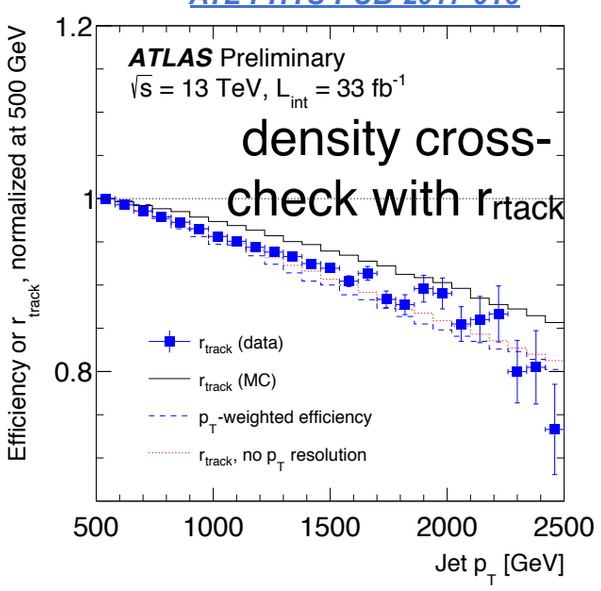
Geometry uncertainty => Inclusive efficiency uncertainty

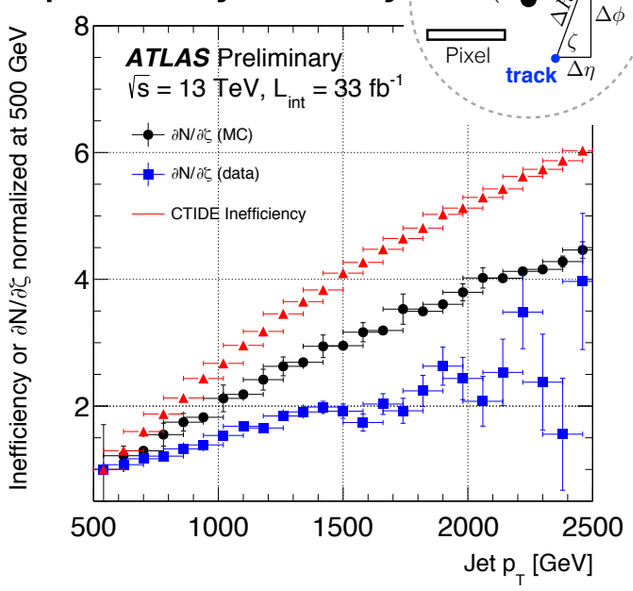


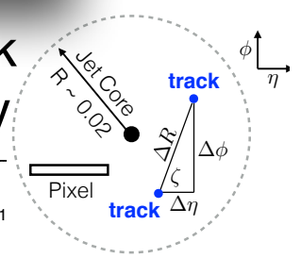
Fake rate inside jets (in a control region)

ATL-PHYS-PUB-2017-016

density cross-check w/ pixel asymmetry







Sagitta bias using Z->μμ

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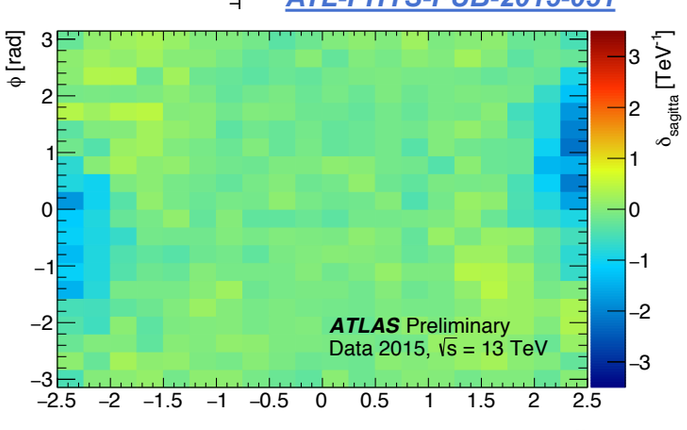
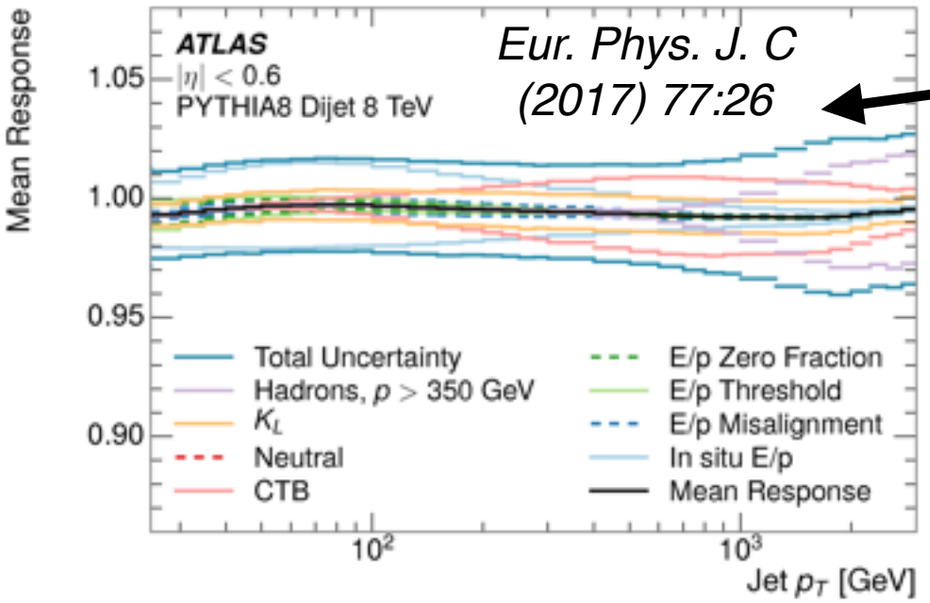
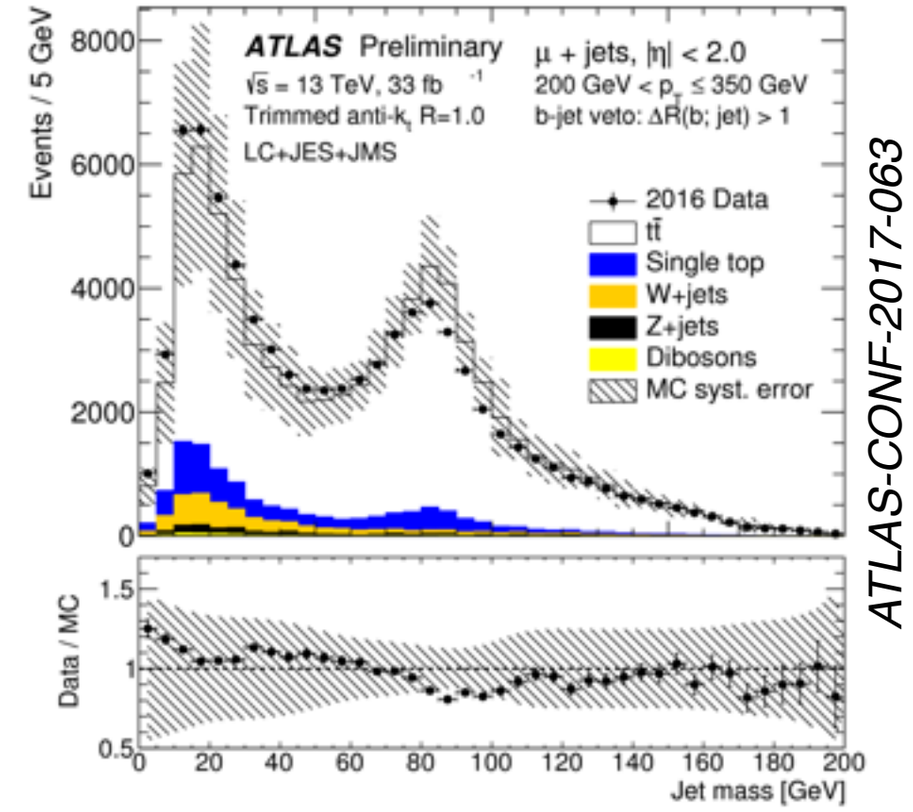


“Bottom up” uncertainties: validation

Many cross-checks to ensure that the “bottom up” approach is valid (not spoiled by collective effects)

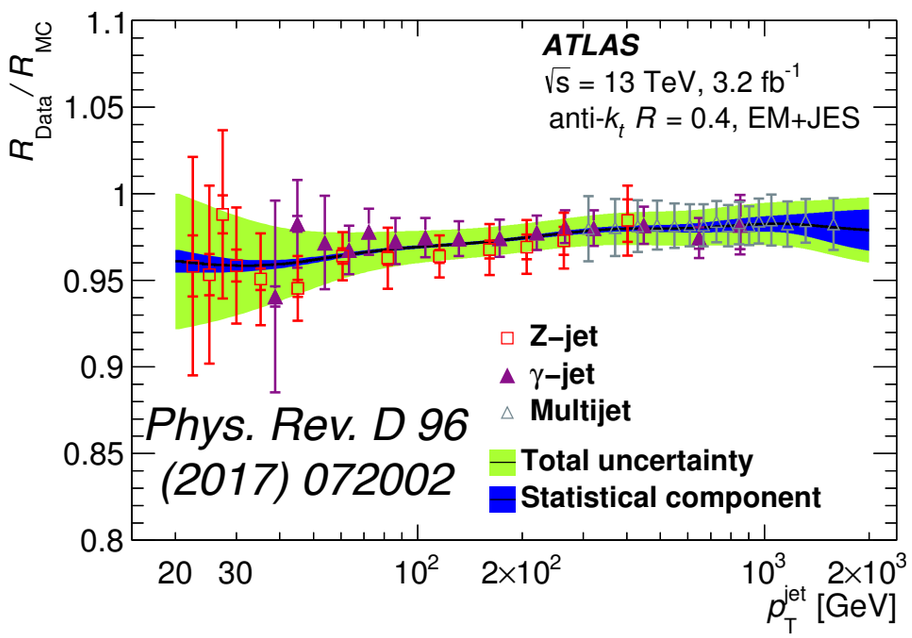


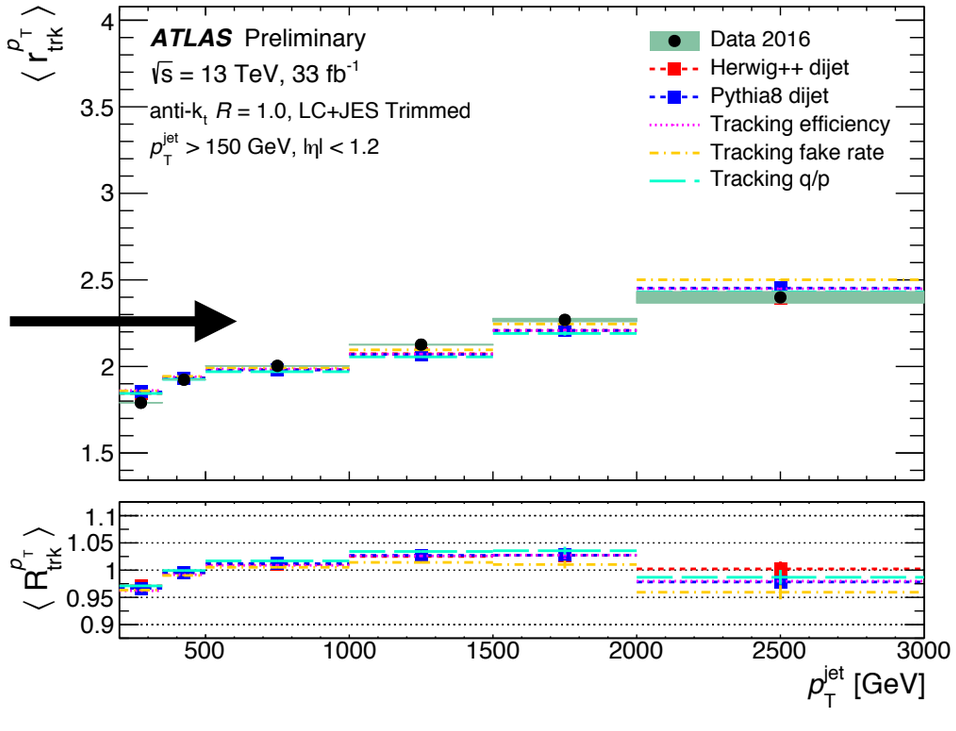
Energy scale by comparing to Z +jet balance



Mass resolution from W peak

Mass scale by comparing with track jets





Physics Program of Precision JSS

(1) Measure fundamental parameters of the SM

α_s, m_{top}, others? [Andreassen & Schwartz, '17] [Hoang et al., '17] [CMS, '17] [Les Houches 2017]

(2) BSM searches using small deviations from SM

Running of α_s, EFTs, others? [Kaplan & Schwartz, '08] [Becciolini et al., '15] [Llorente & Nachman, '18]

(3) Quantum properties of inherently exciting emergent phenomena

interference (N^XLO/LL), entanglement (NGLs), dead cone, … [Larkoski & Moult, '15] [Larkoski, Moult, Neill, '15] [Maltoni, Selvaggi, Thaler, '16]

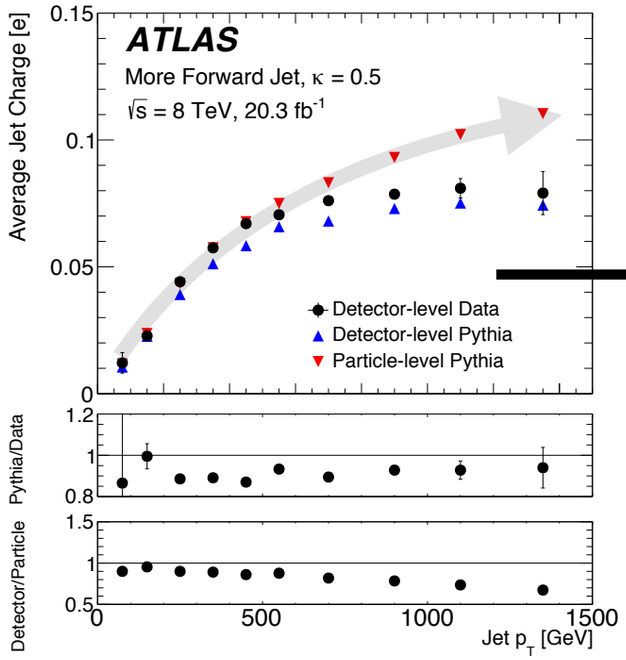
(4) Develop models to empower searches

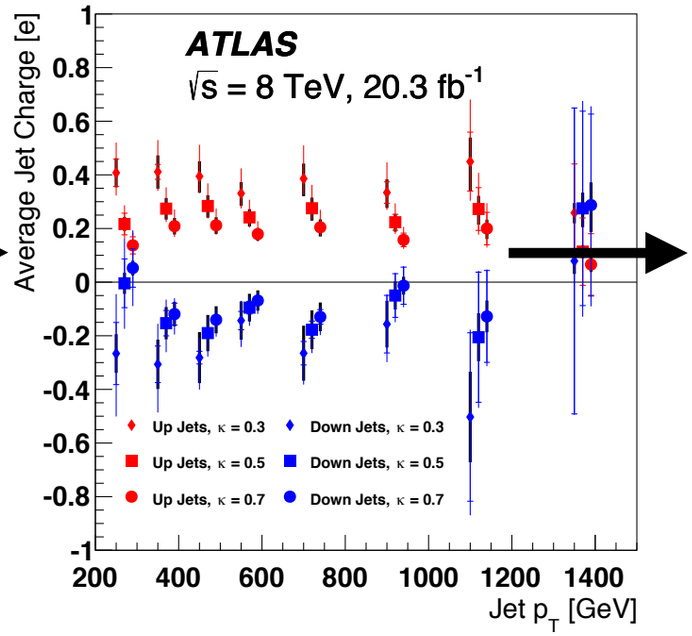
MC tuning, higher-order corrections, … [ATLAS, '14] [CMS, '18] [Hoche & Prestel, '17]

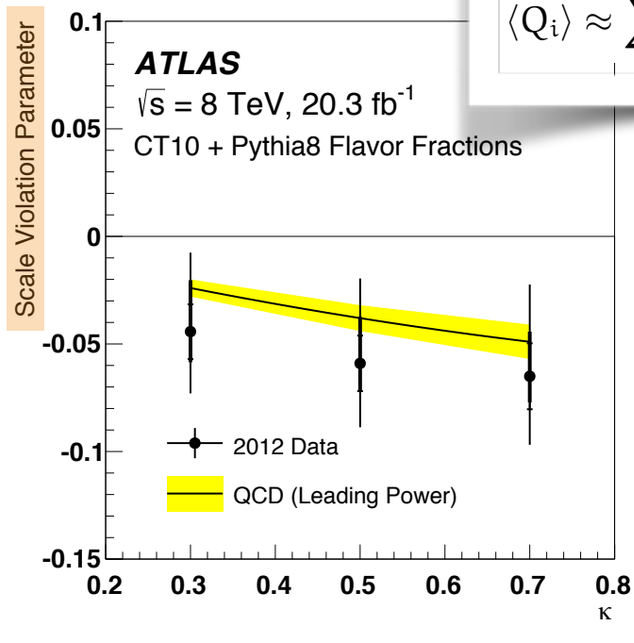
(5) Heavy Ions [Chien & Vitev, '16] [CMS, '18] [Mehtar-Tani & Tywoniuk, '16] [Milhano, Wiedemann, Zapp, '17] [ALICE, '18] [ATLAS, '18]

Precision JSS in ATLAS at 8 TeV

Jet Charge: Phys. Rev. D 93 (2016) 052003



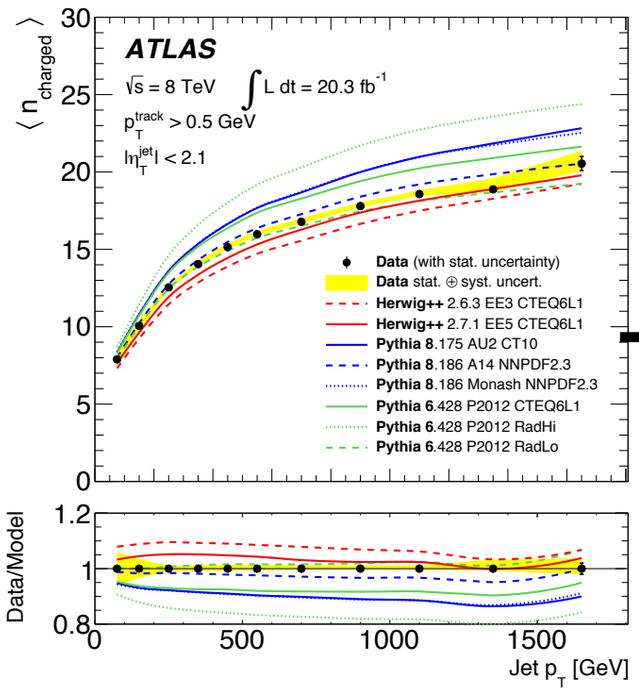


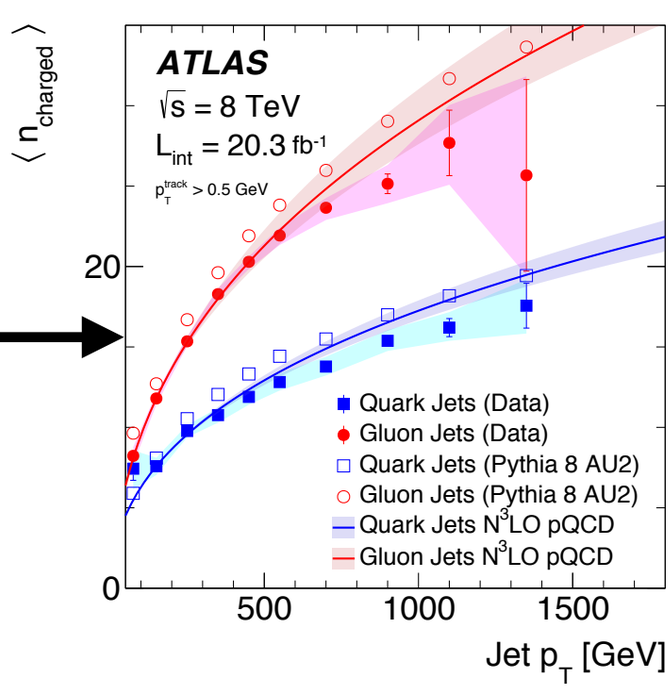


$$\langle Q_i \rangle \approx \sum_f \beta_{f,i} \bar{Q}_f (1 + c_\kappa \ln(p_{T,i}/\bar{p}_T))$$

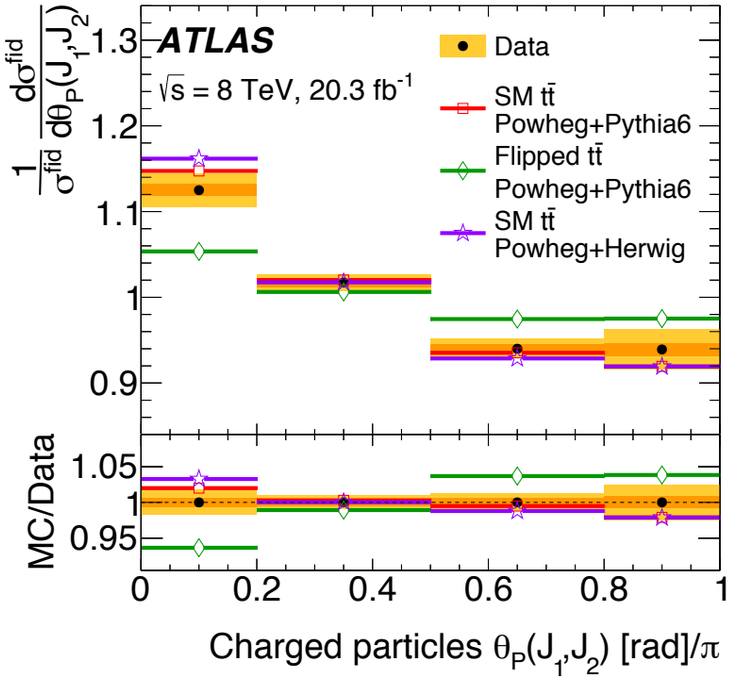
N.B. comparisons to pQCD calculations **AND** MC predictions!

Multiplicity: Eur. Phys. J. C76 (2016) 1



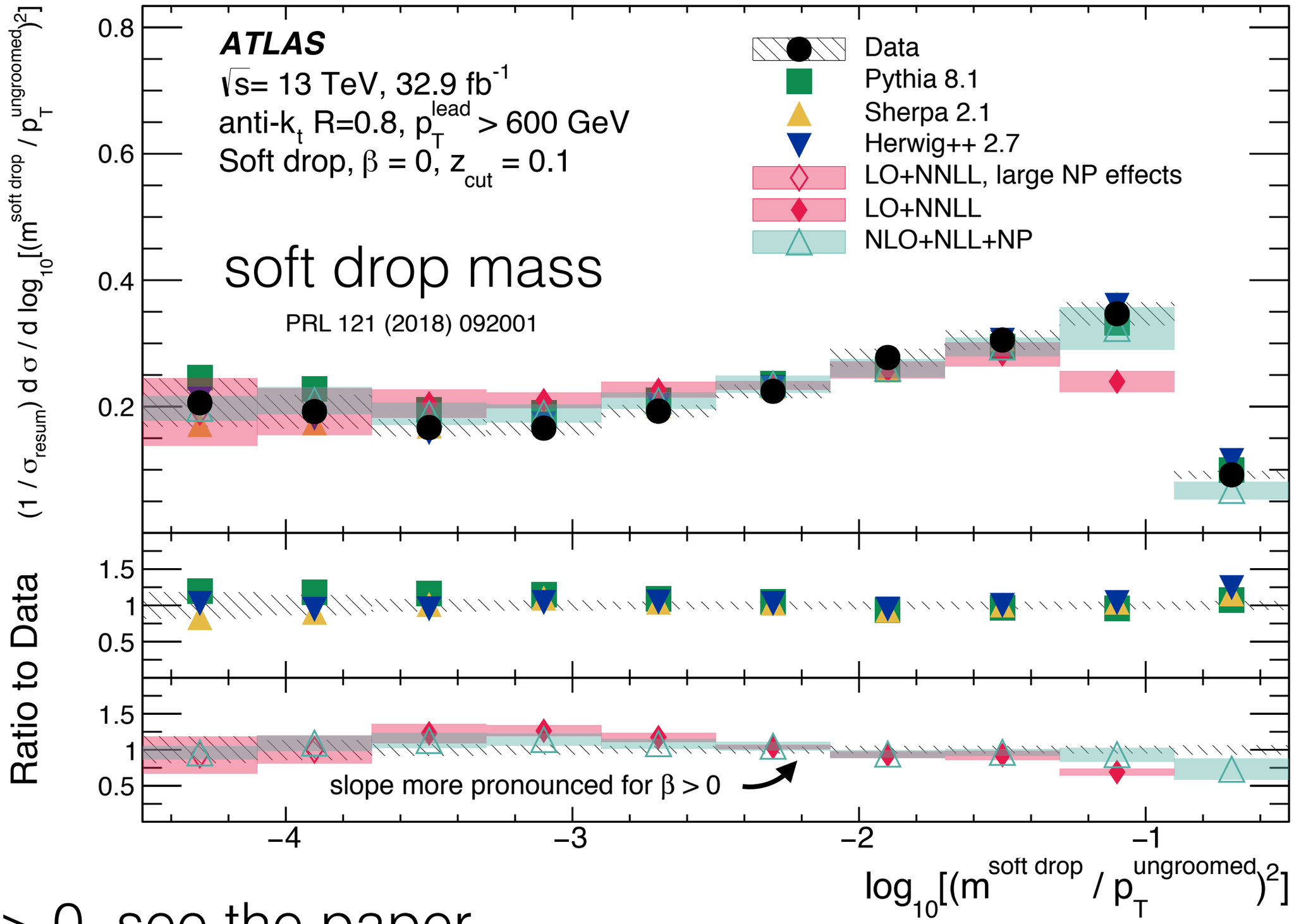


Colorflow: PLB (2015) 475



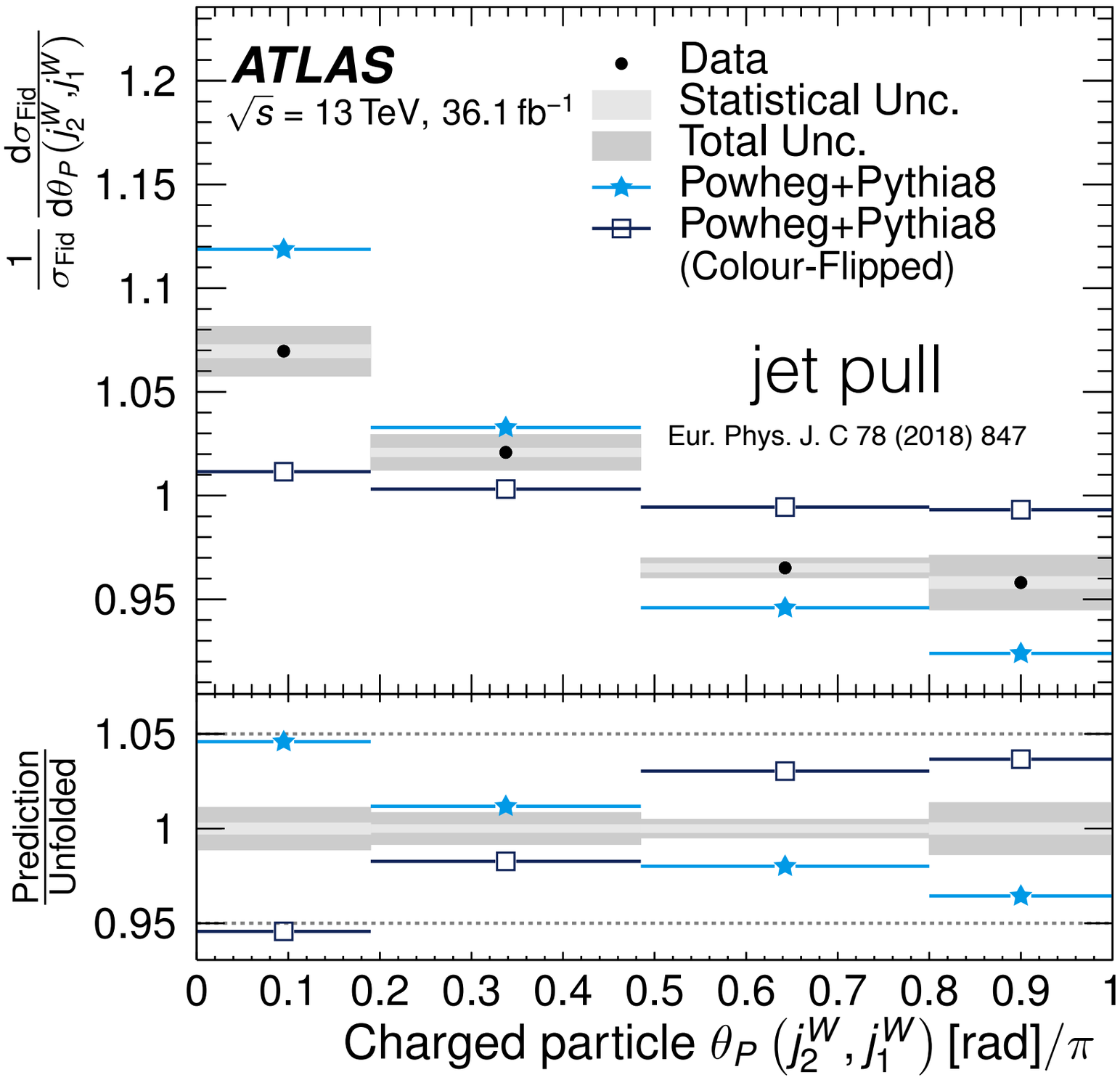
(+more results at 7 TeV not mentioned here)

Precision JSS in ATLAS so far in Run 2



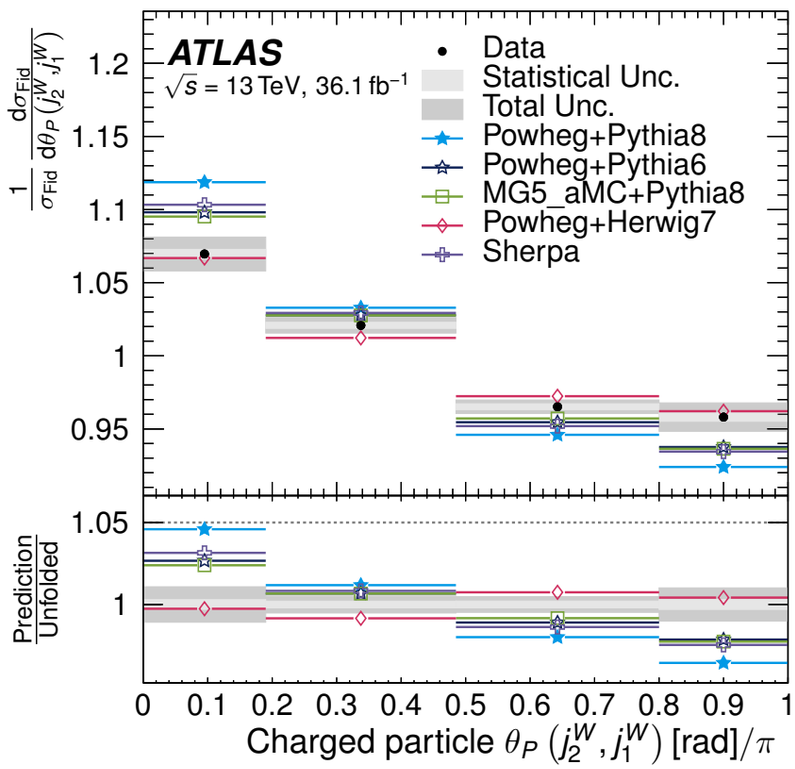
for $\beta > 0$, see the paper.

Precision JSS in ATLAS so far in Run 2



Severe mis-modeling observed in Pythia and Sherpa. Can <u>analytics</u> help?

(hint: Herwig7 is spot on!)



How we would like to use this forum

Would be great to work toward a measurement or measurements that can be directly compared between experiments (same lumi, p_T, binning).

Top group has used their WG to decide on standard uncertainty prescriptions for e.g. (fragmentation) modeling (e.g. variations and tunes). Can we do the same as we both become more sophisticated in this important source of uncertainty?

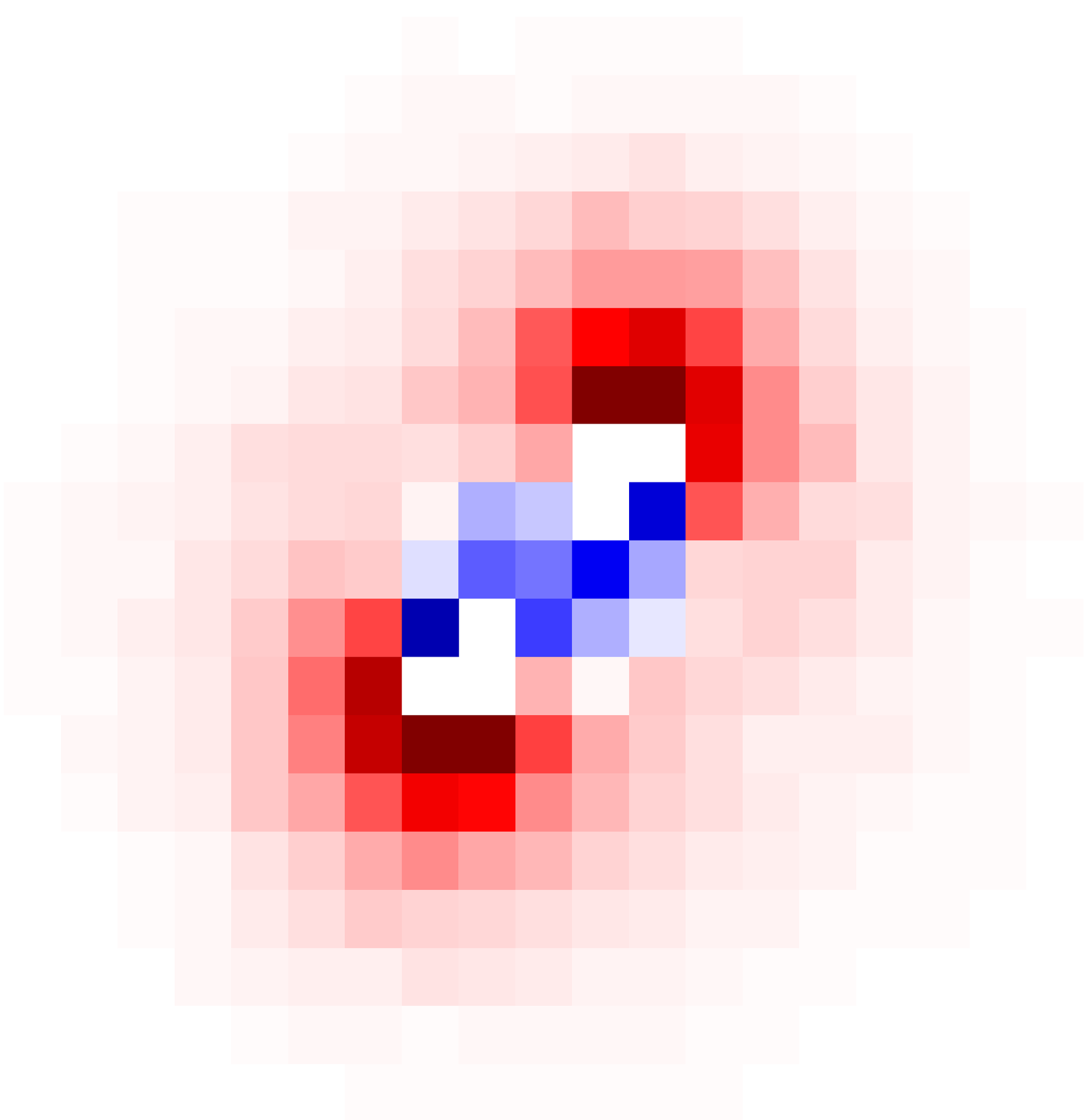
We can also use this forum to work with the theory community (pQCD + MC) to discuss how to best achieve the goals of precision JSS goals. We can set common targets for all parties in terms of observables.

How we would like to use this forum

For the next meeting, it would be nice to have enough advanced notice that we could have an in-person meeting at CERN. Ideally this would be before BOOST (by a ~few months and maybe also just before). We could also try to ask the organizers to help facilitate a discussion at BOOST 2019.

Would be good to have a calendar of topics.

We should not meet just to meet and ideally the meetings will be infrequent but useful!



Fin.