Physics Modeling

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For the ATLAS Collaboration
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General Notes

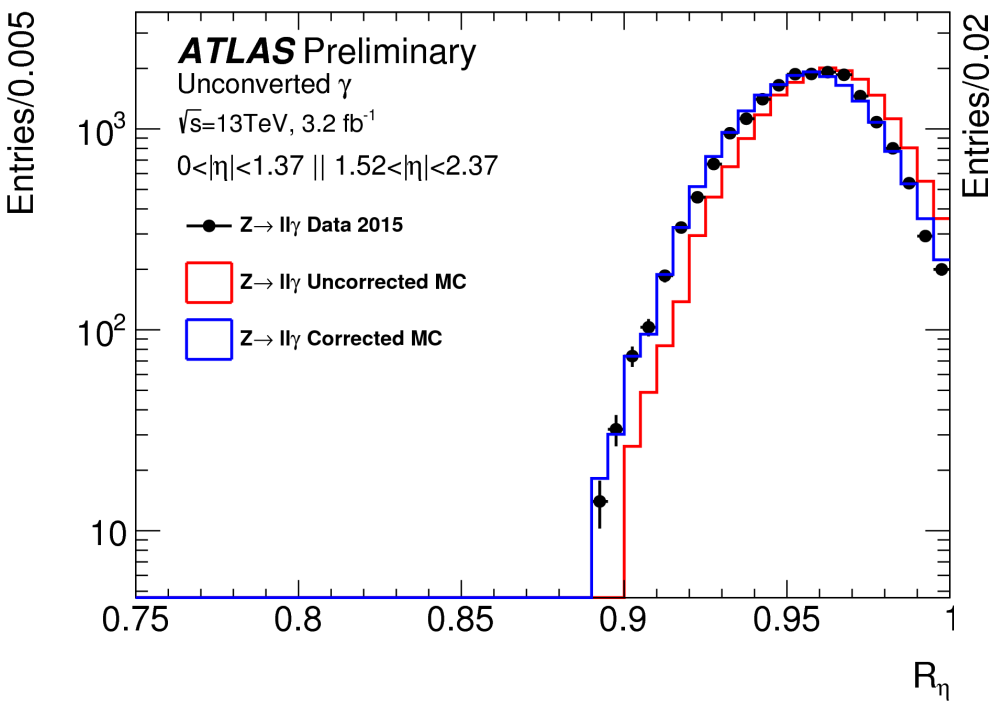
- We do know of some mis-modeling in our simulation
  - For the most part, we deal with these via scale-factors in analysis

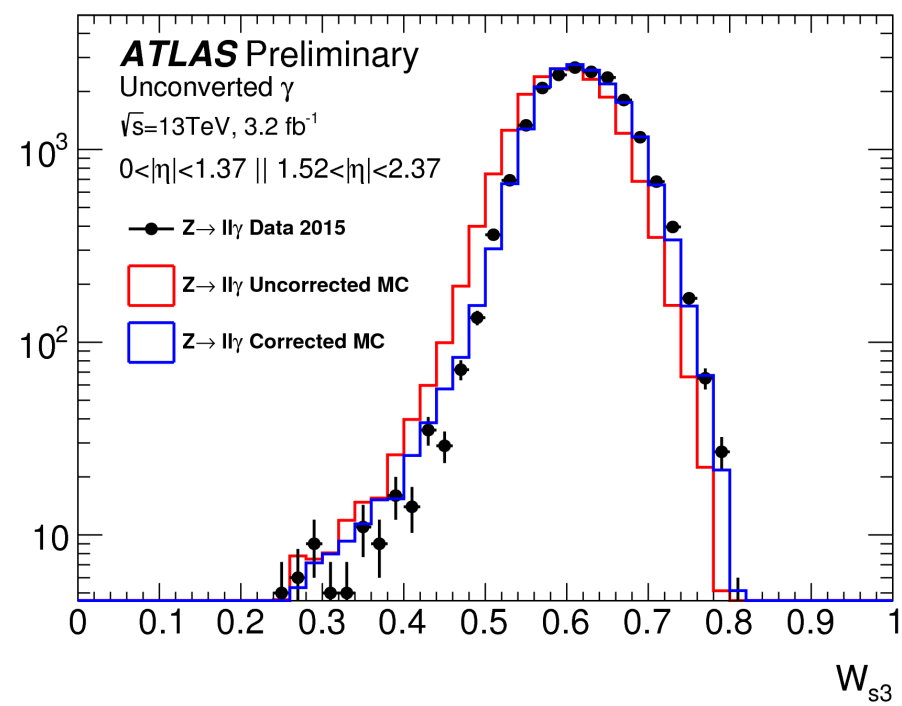
- It can be *extremely* difficult to disentangle detector effects and Geant4 physics modeling effects

- We have done a lot of work to understand the detector material, so we don't believe the issues I'm showing you are to do with material

EM Shower Shapes

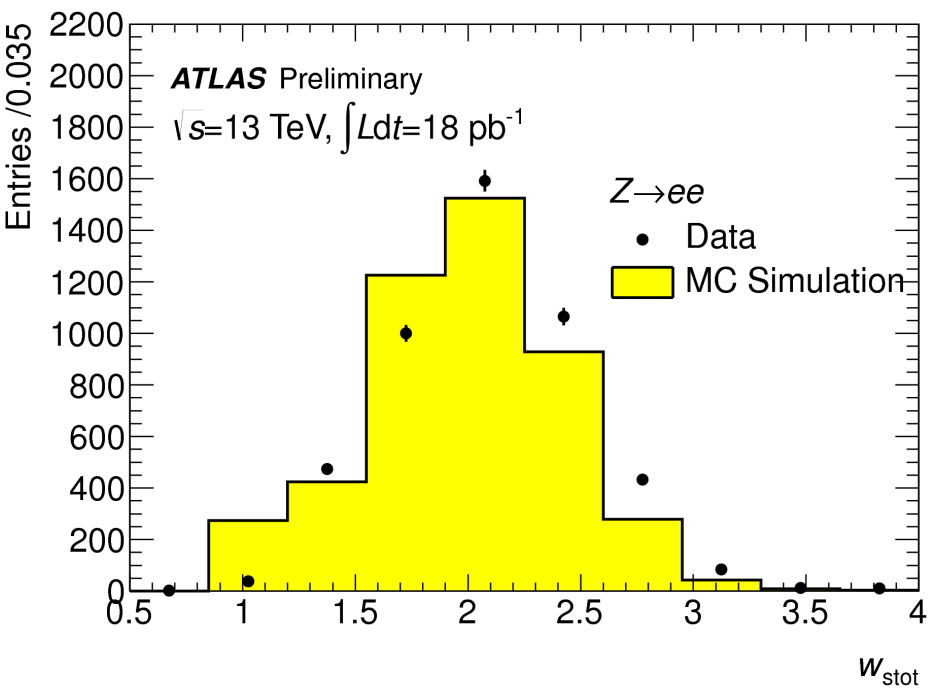
- One of the best-known disagreements in ATLAS simulation
- Below two examples for unconverted photons
  - R_η: Ratio of 3x7 to 7x7 shower (in η-ϕ) energy
  - W_{s3}: Shower width calculated from three strips around the strip with max energy deposit
- Detailed investigations suggest that this is not a material issue

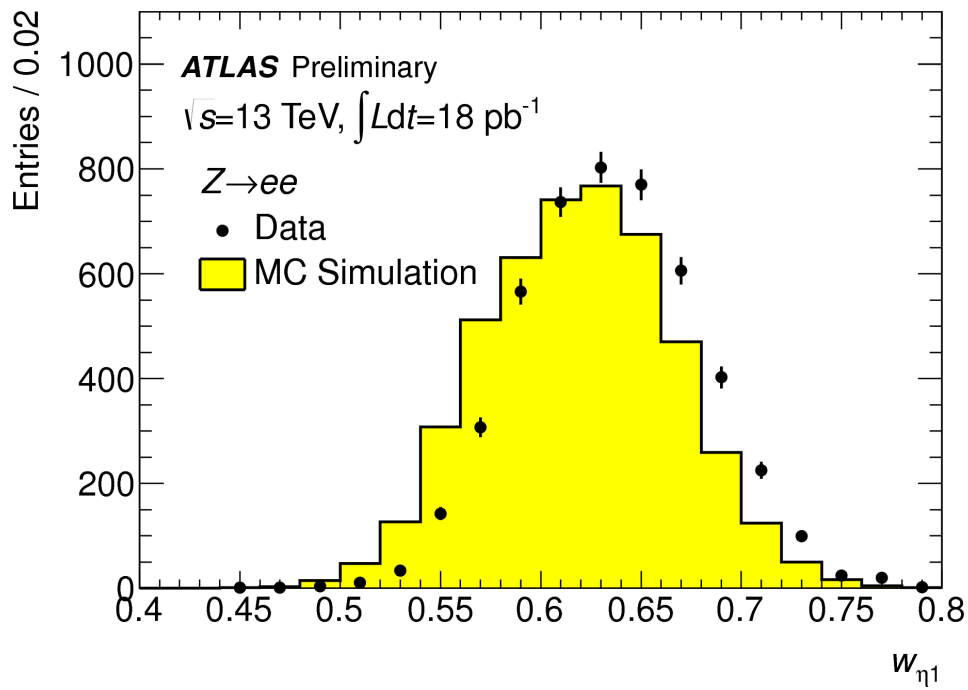




EM Shower Shapes (II)

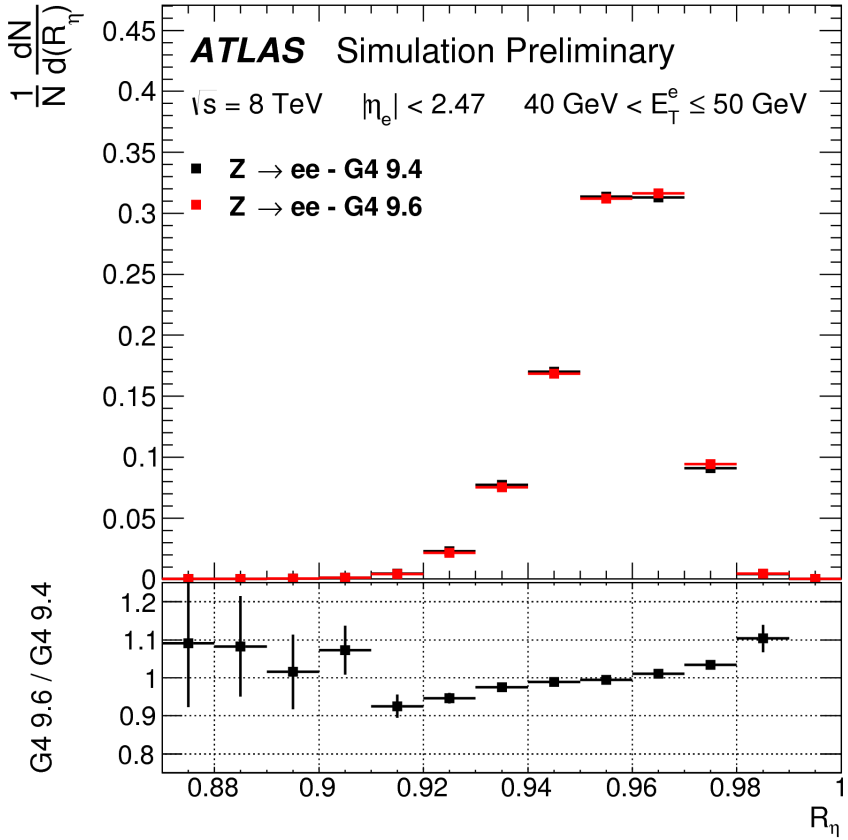
- Similar story for electron shower shapes
  - W_{stot}: Total shower width in the EM calorimeter front
  - $W_{\eta 1}$: Shower lateral width in EM first layer

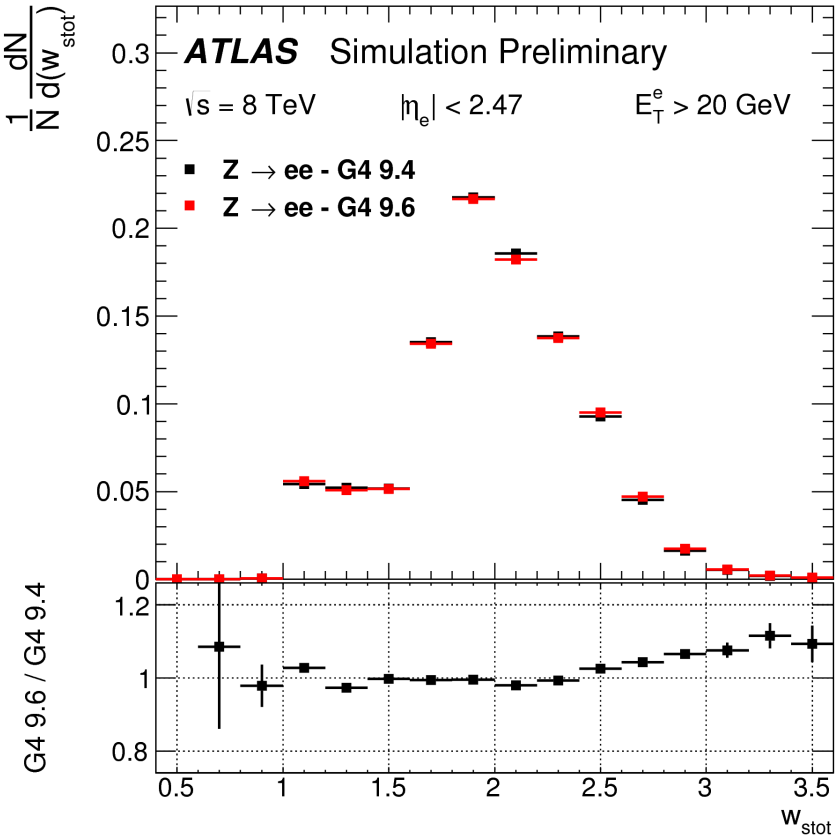




EM Shower Shapes (III)

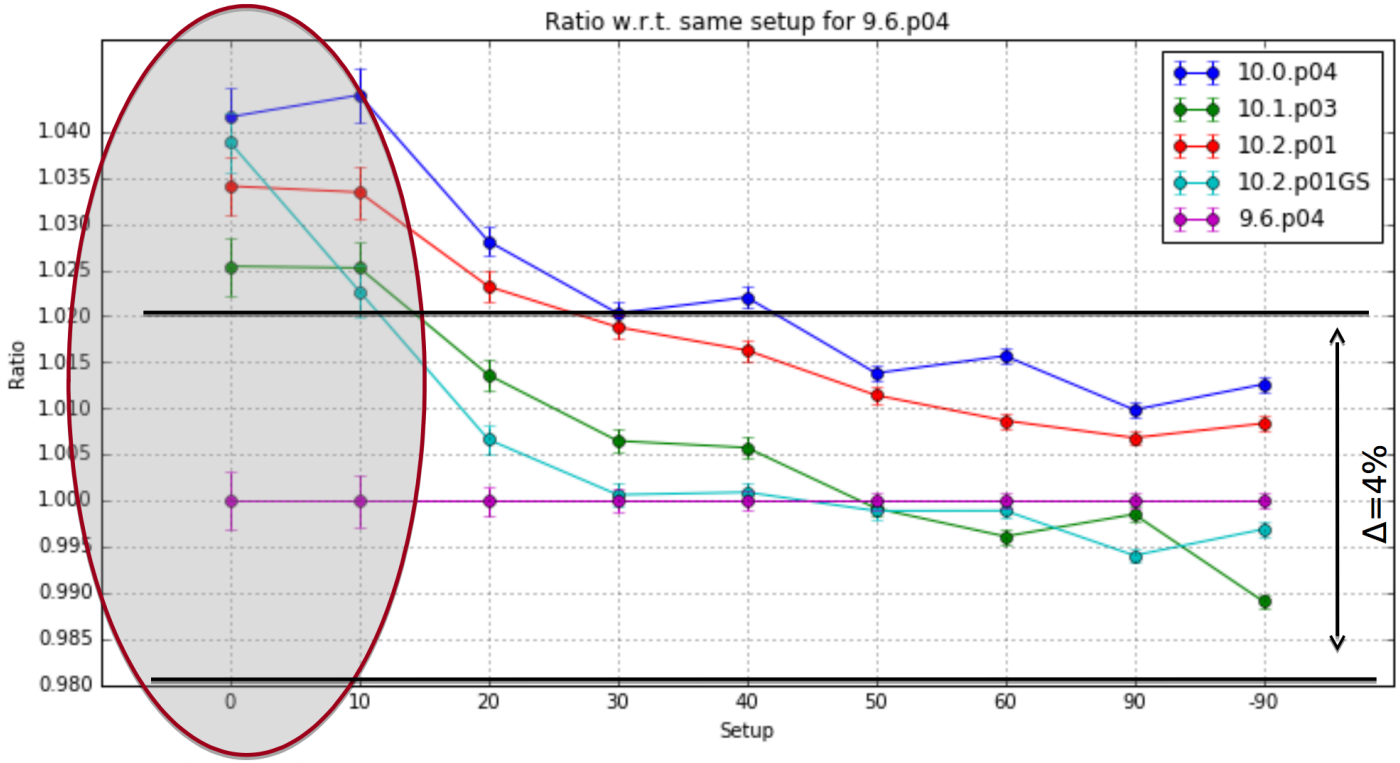
- Did some exploration of Geant4 variations
  - https://atlas.web.cern.ch/Atlas/GROUPS/PHYSICS/PUBNOTES/ATL-PHYS-PUB-2014-003/
- Small differences there; expect an update of this soon





Sampling Fractions

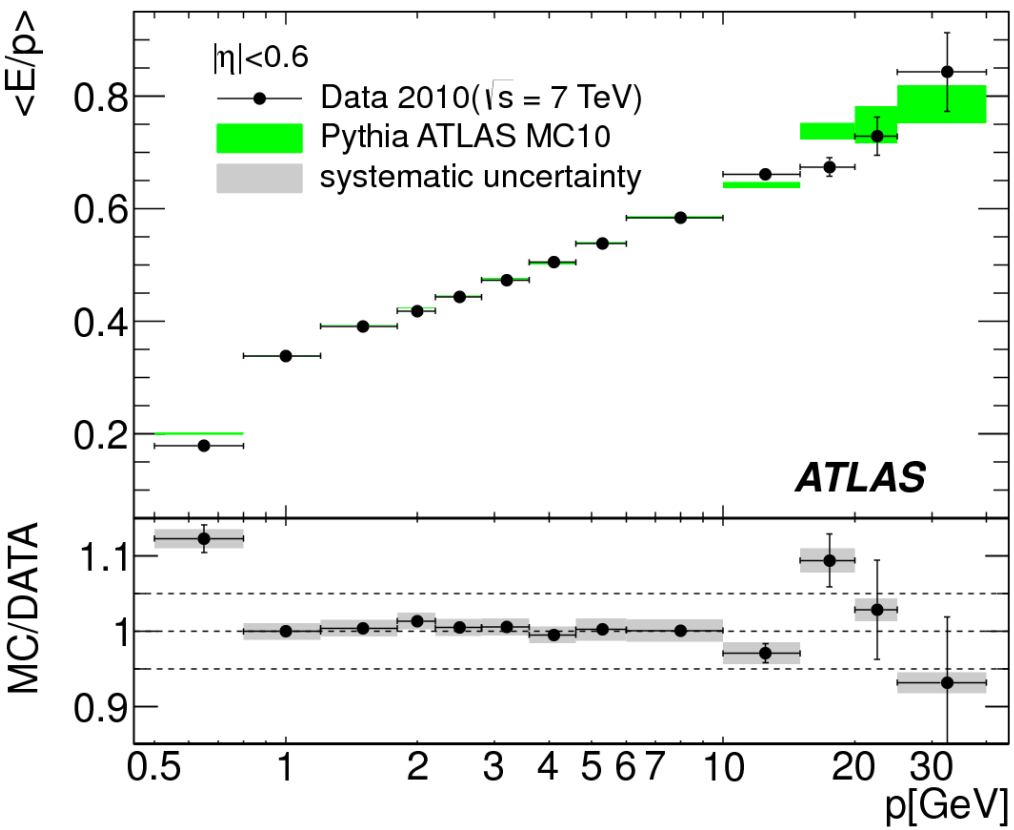
- Angular dependence of sampling fraction is much larger in G4 10+; confirmed by the Geant4 team (A. Dotti), who did some nice investigations
- Change mostly due to a 50um layer of glue in the tile geometry
  - Precision models suggest 9.6 was 'more correct' in this case
  - Emphasized that G4 tests should be more complex (e.g. including thin layers)

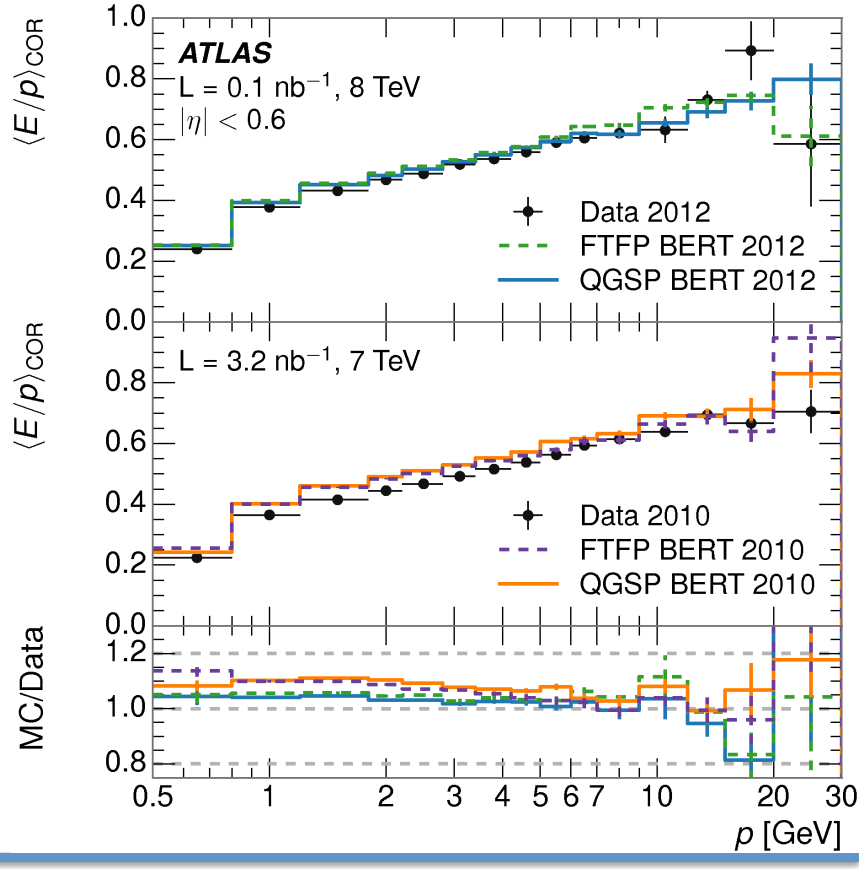


Non-gaussian regime, do not consider

Hadronic Response

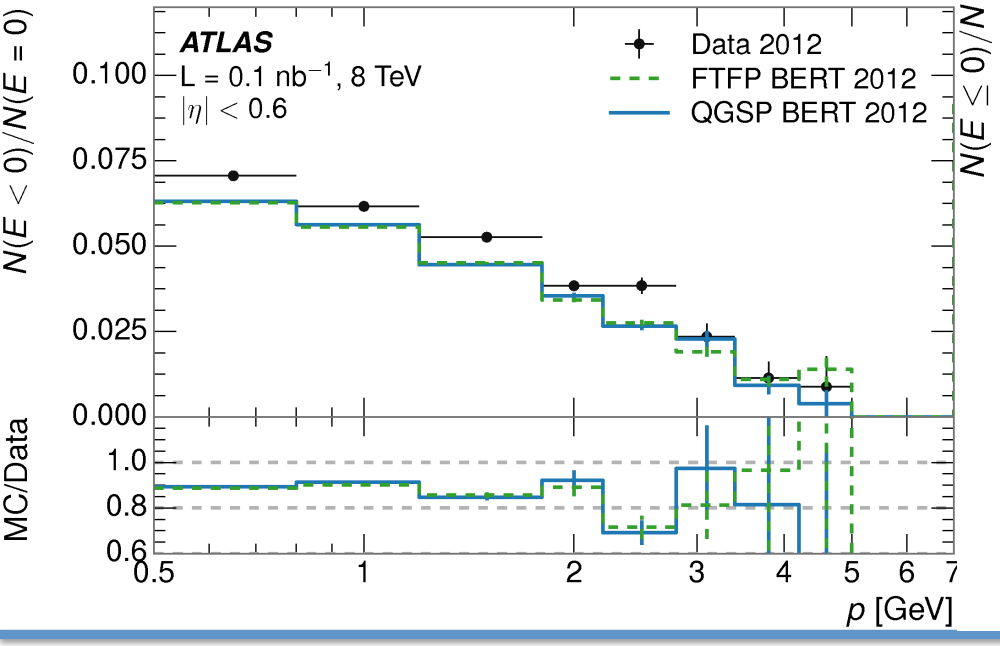
- A couple of long papers on single particle response
  - https://arxiv.org/abs/1607.08842 and https://arxiv.org/abs/1203.1302
- Excellent agreement in early days, not as good in ~2016

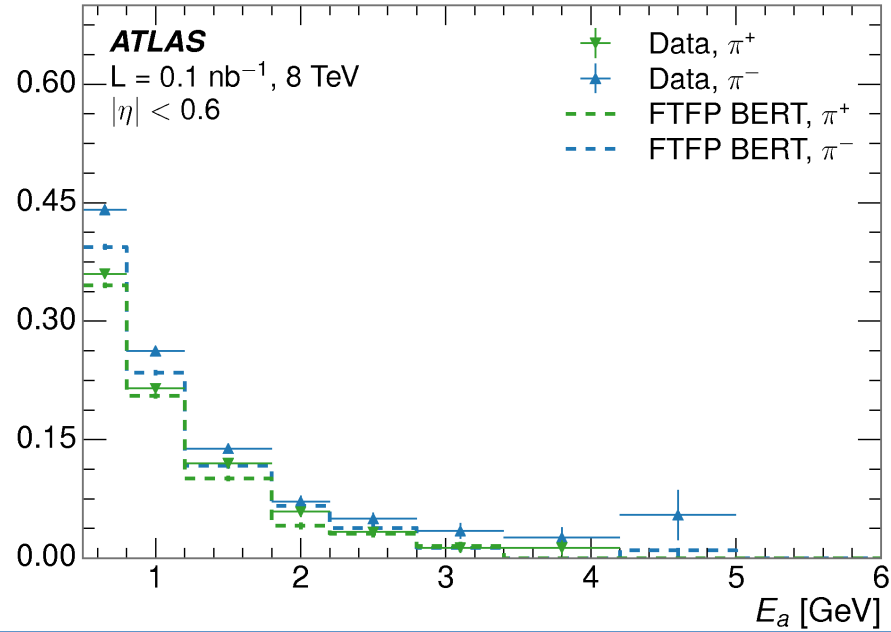




Hadronic Response (II)

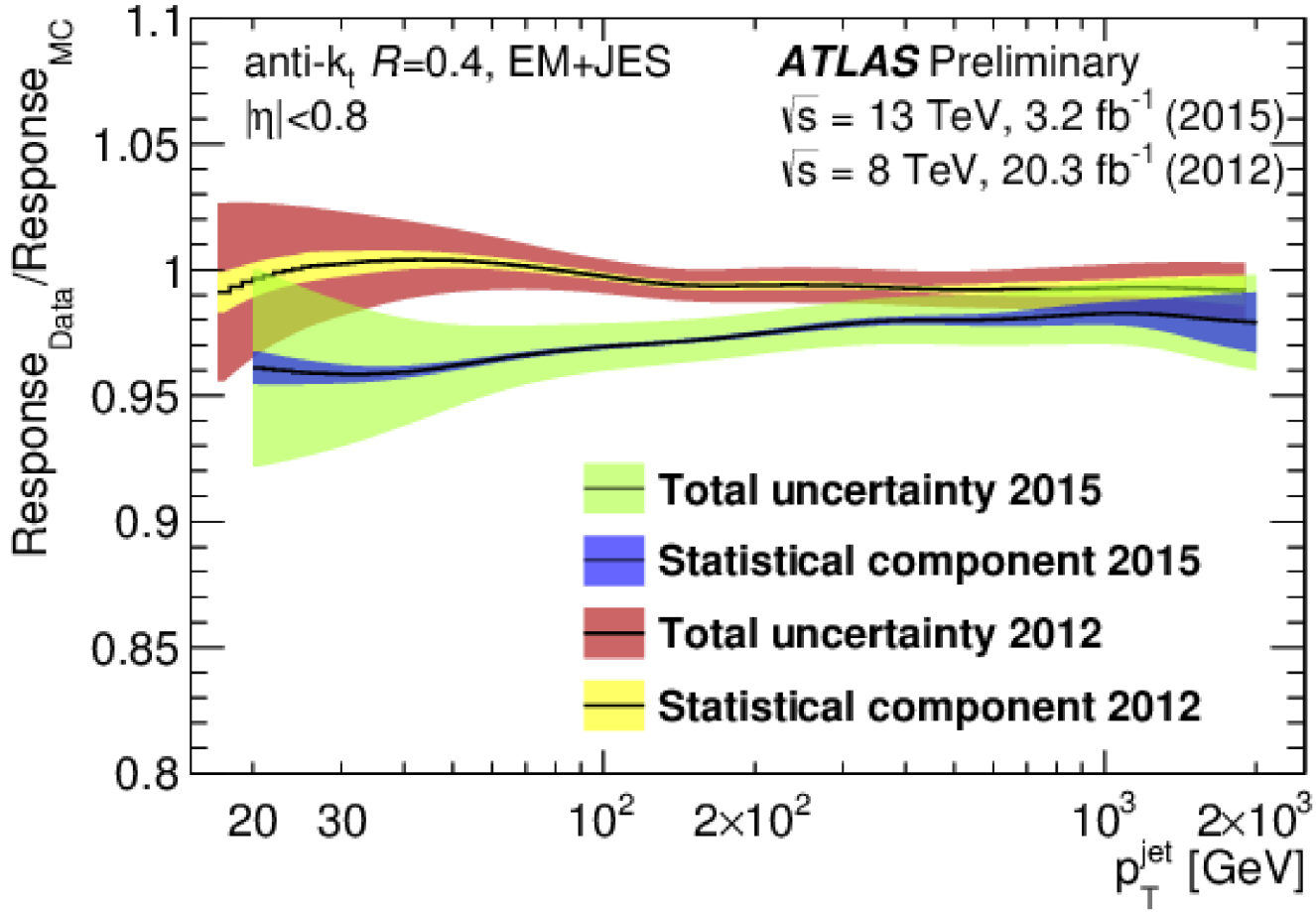
- One of the standard difficulties is the fraction of tracks that do not match a cluster in the calorimeter
  - Could be particles destroyed in nuclear interactions, for example
  - Could also be related to the rate of charged secondaries from interactions, or leading secondary momentum





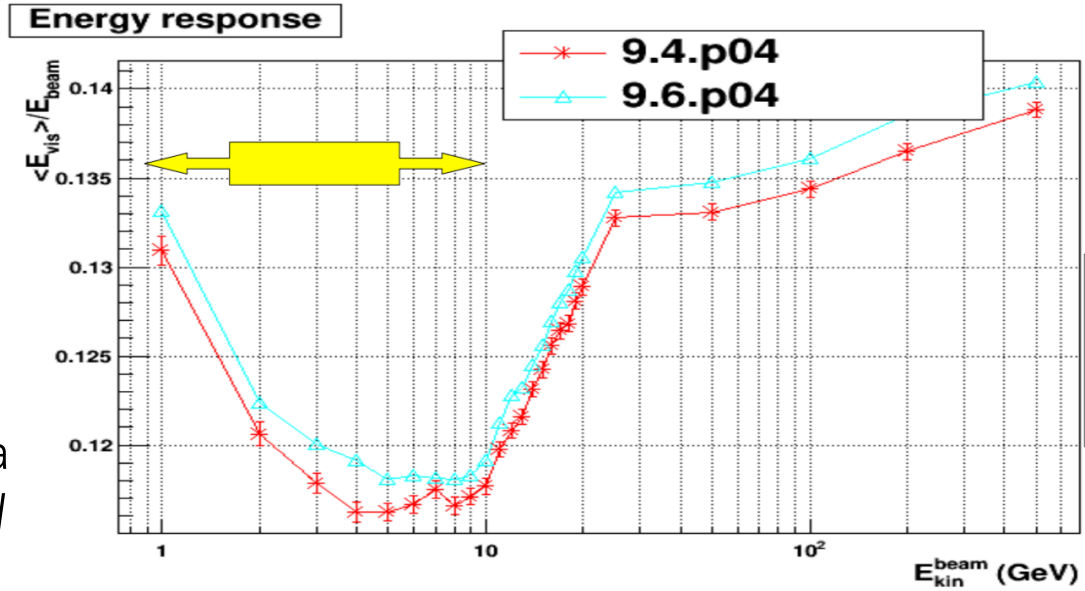
Hadronic Response (III)

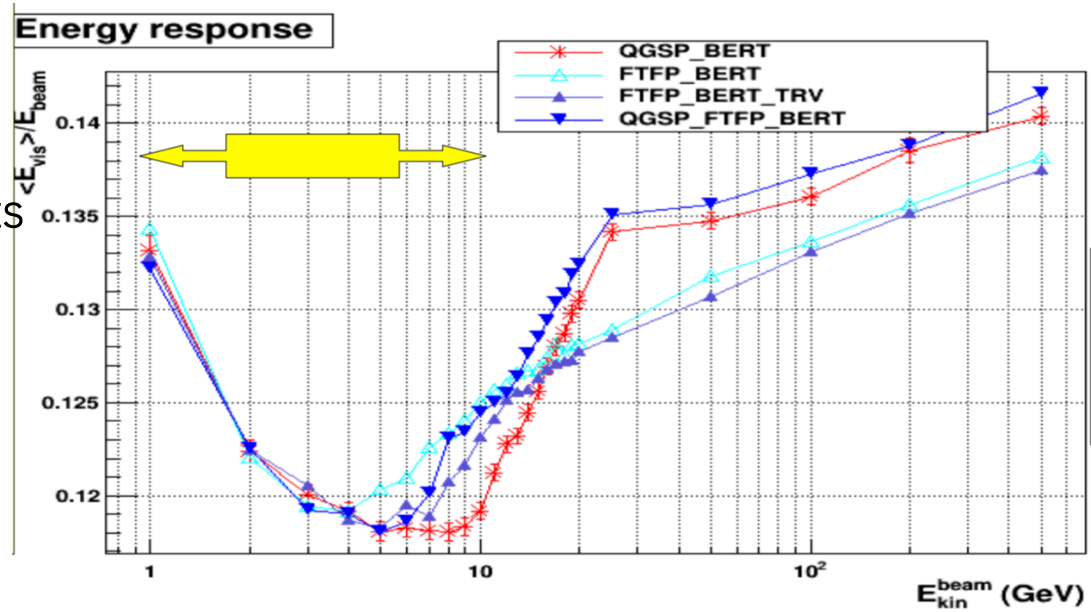
- Change in jet response (esp. at low p_T) between 2012 and 2015
  - Similar changes seen in CMS – points to a Geant4 issue



Hadronic Response (IIII)

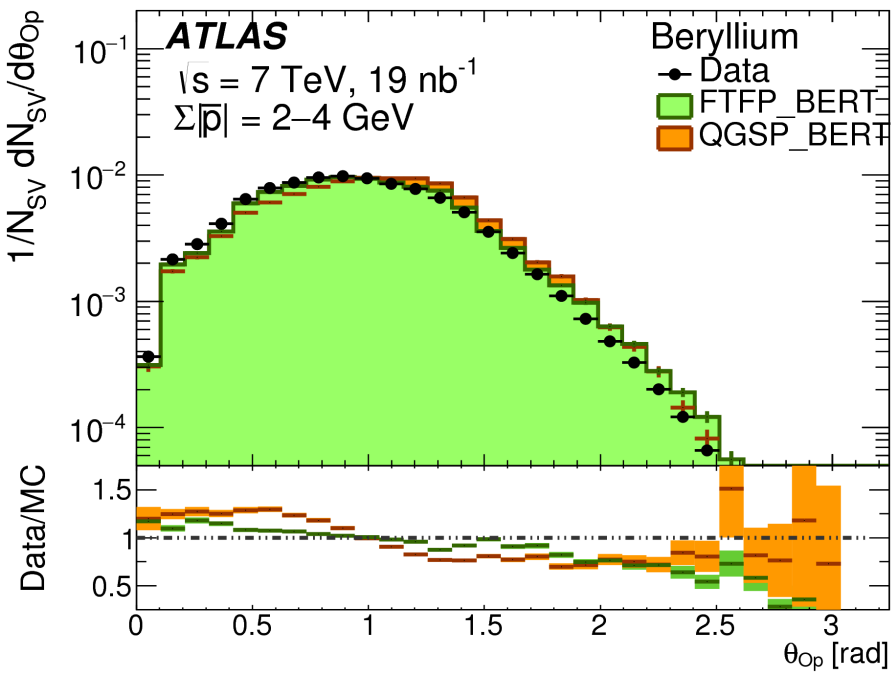
- Here response for π^+ on a simplified Pb+LAr calorimeter from Alberto Ribon
- Change in releases (G4 9.4 to 9.6) caused a 1-2% change in scale at low energy
- Change in physics lists caused a change in scale of an *additional* 4-5% at low (7-9 GeV) energy
- Together, these may have caused our JES shift!
- Created a physics lists that shifts the transition to FTFP from 4-5 GeV to 9-12 GeV: FTFP_BERT_ATL

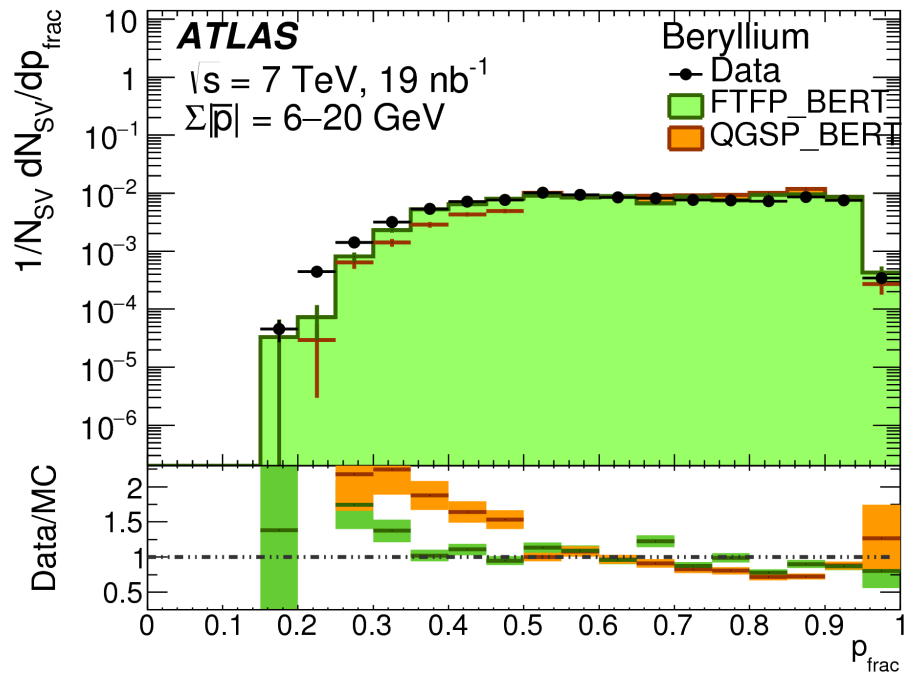




Hadronic Interactions

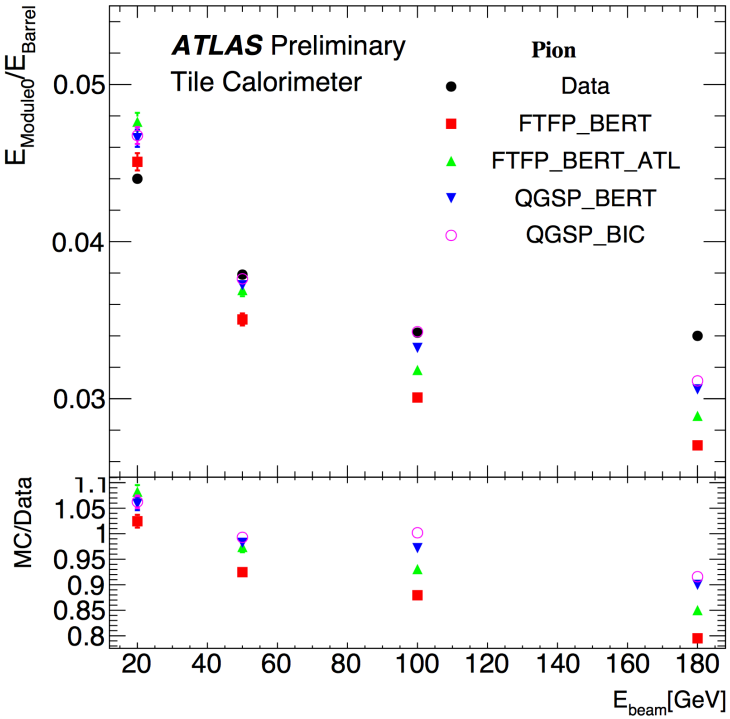
- New paper on hadronic interactions in the inner detector
  - https://arxiv.org/abs/1609.04305
- Lots of nice cases of what we can do with nuclear interactions
- Also shows our ability to isolate specific materials

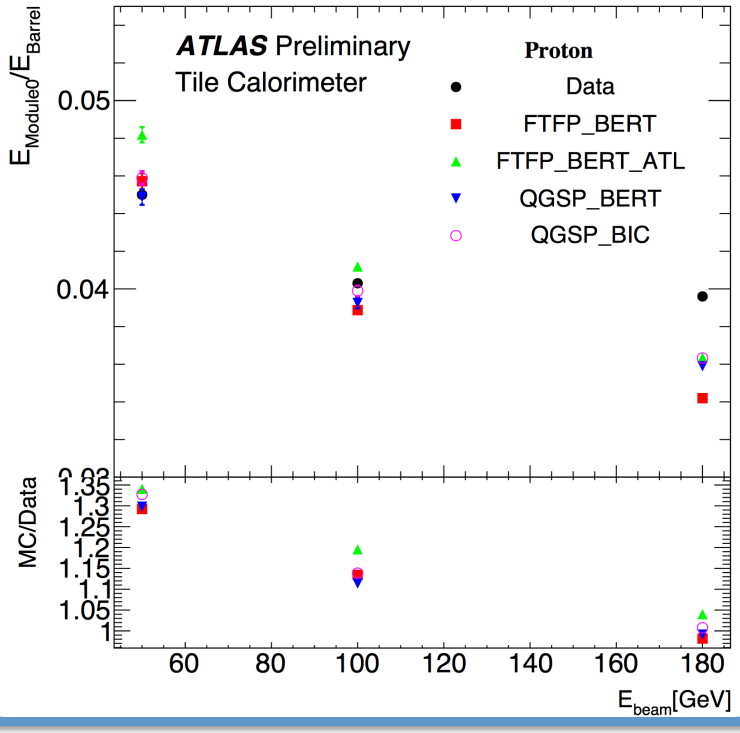




Test Beams

- We are in the process of updating some test beam studies
  - Both using new MC and collecting new data (upgrade detectors)
  - https://twiki.cern.ch/twiki/bin/view/AtlasPublic/ApprovedPlotsTileTestBeamResults
- One way to look at shower width – too narrow in MC
  - Could be related to resolution differences





Summary

- Mis-modeling in EM and hadronic shower shapes
  - Long-standing, still working on a variety of tests
  - This does cause scale-factors and some analysis issues – mostly worried about whether we understand the problem and how it extrapolates into different physics selections
- Recently solved (maybe?) mis-modeling of hadronic response
  - Final tests to come in the next month or two
- Trying to update some test beam studies to check various other hadronic issues
  - Shower shapes and resolution can be studied better in isolation there
  - Can be a little tricky to study these issues in situ
- Modeling of cavern background is a work in progress
  - Low energy neutron physics is not something we're used to in ATLAS
  - Getting the detector response to low energy neutrons right is tough

EXTRAS

Hadronic Resolution

- Historically we have some discrepancy in jet resolution
- *Very* difficult to understand where this is coming from, though
- Also varies from analysis to analysis