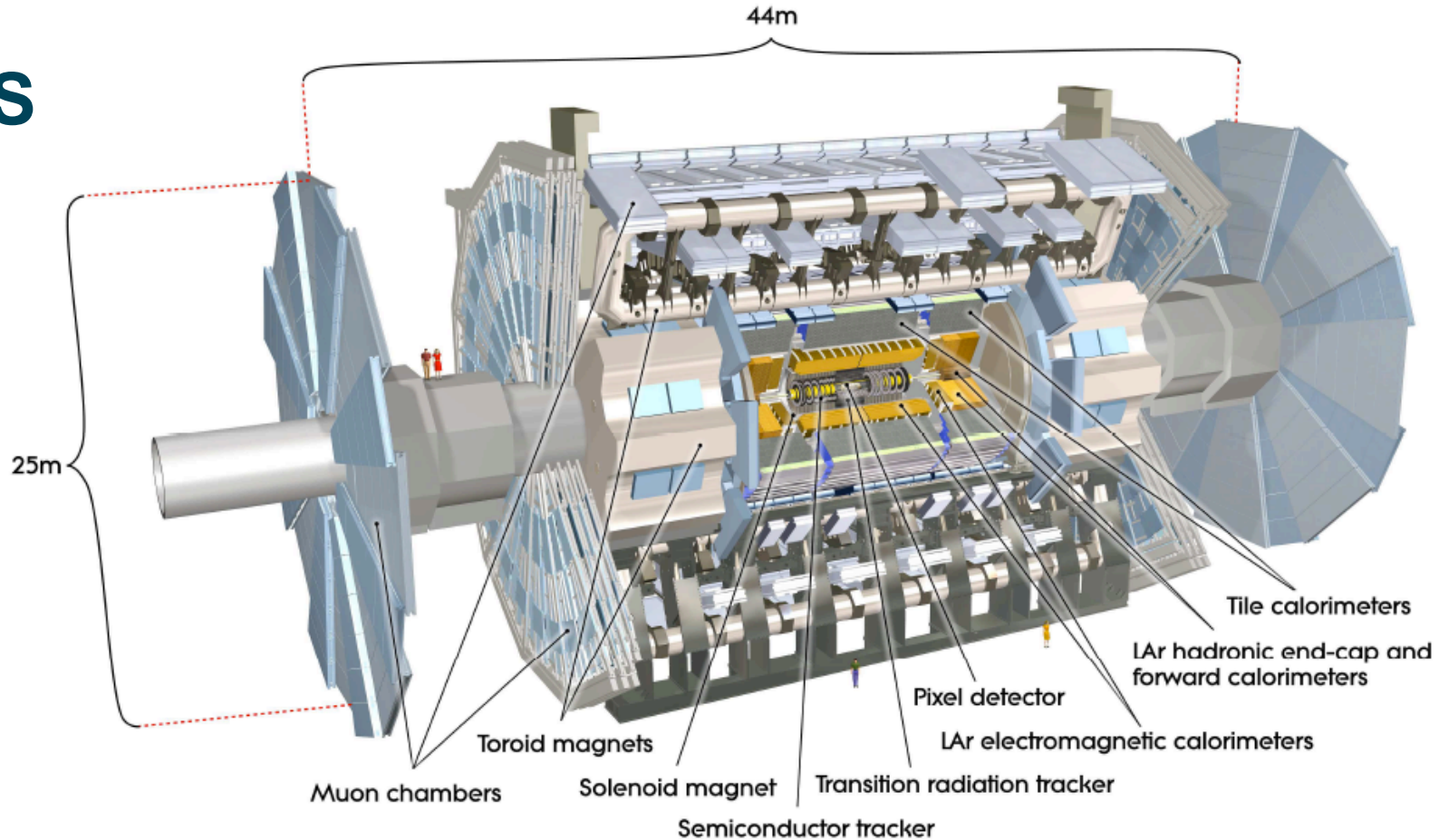


Measurements of Jet Substructure at ATLAS

**Adam Davison
for the ATLAS Collaboration**



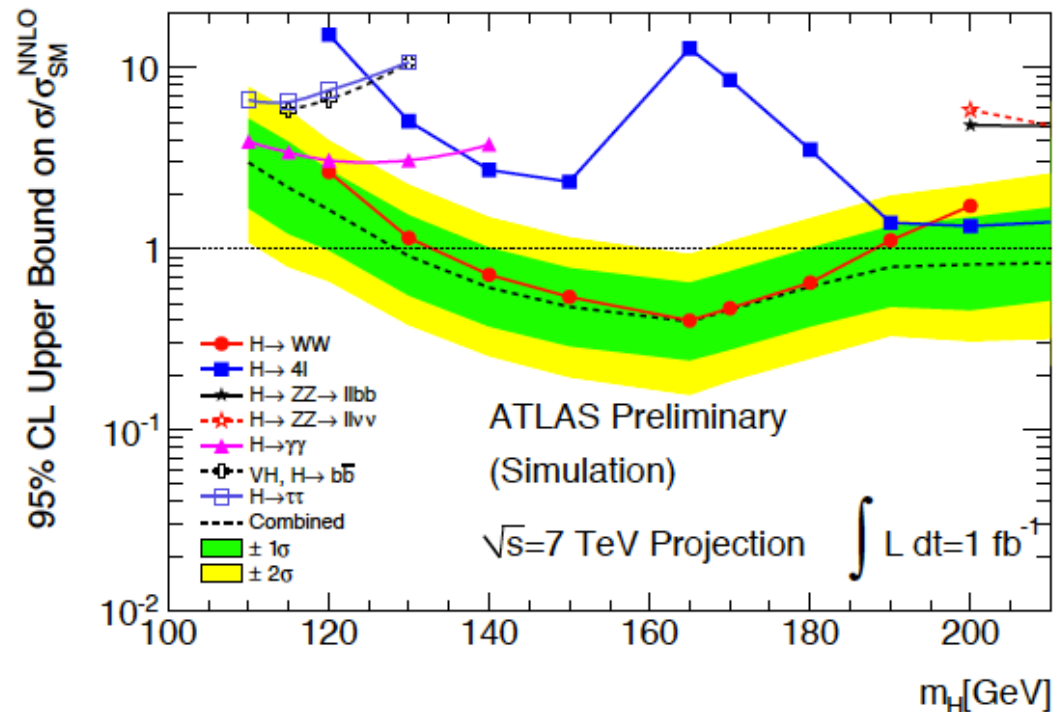
ATLAS



- High granularity calorimeter (down to 0.025×0.025)
- Recorded 43 pb^{-1} of 7 TeV proton-proton collisions in 2010

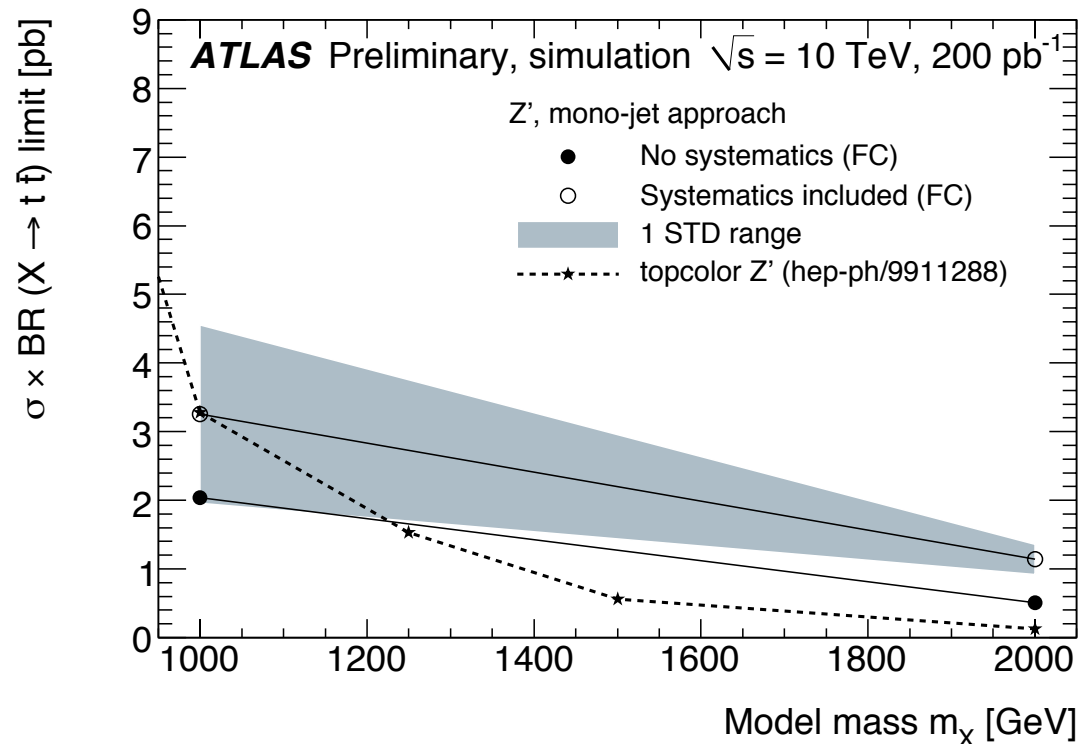
ATLAS in 2011 – $H \rightarrow bb$ Search

- Traditional approaches to WH/ZH/ttH not competitive
- But bb branching ratio important for Higgs discovery claim
- Boosted WH/ZH and C-A splitting/filtering currently offers best $H \rightarrow bb$ sensitivity
- ATL-PHYS-PUB-2008-088
- ATL-PHYS-PUB-2010-015



ATLAS in 2011 (2) – Boosted Top

- Many models have high mass resonances decaying to top
- These tops will be boosted
- High p_T top tagging important to maximise sensitivity in this region
- See M. Villaplana
- **ATL-PHYS-PUB-2010-008**

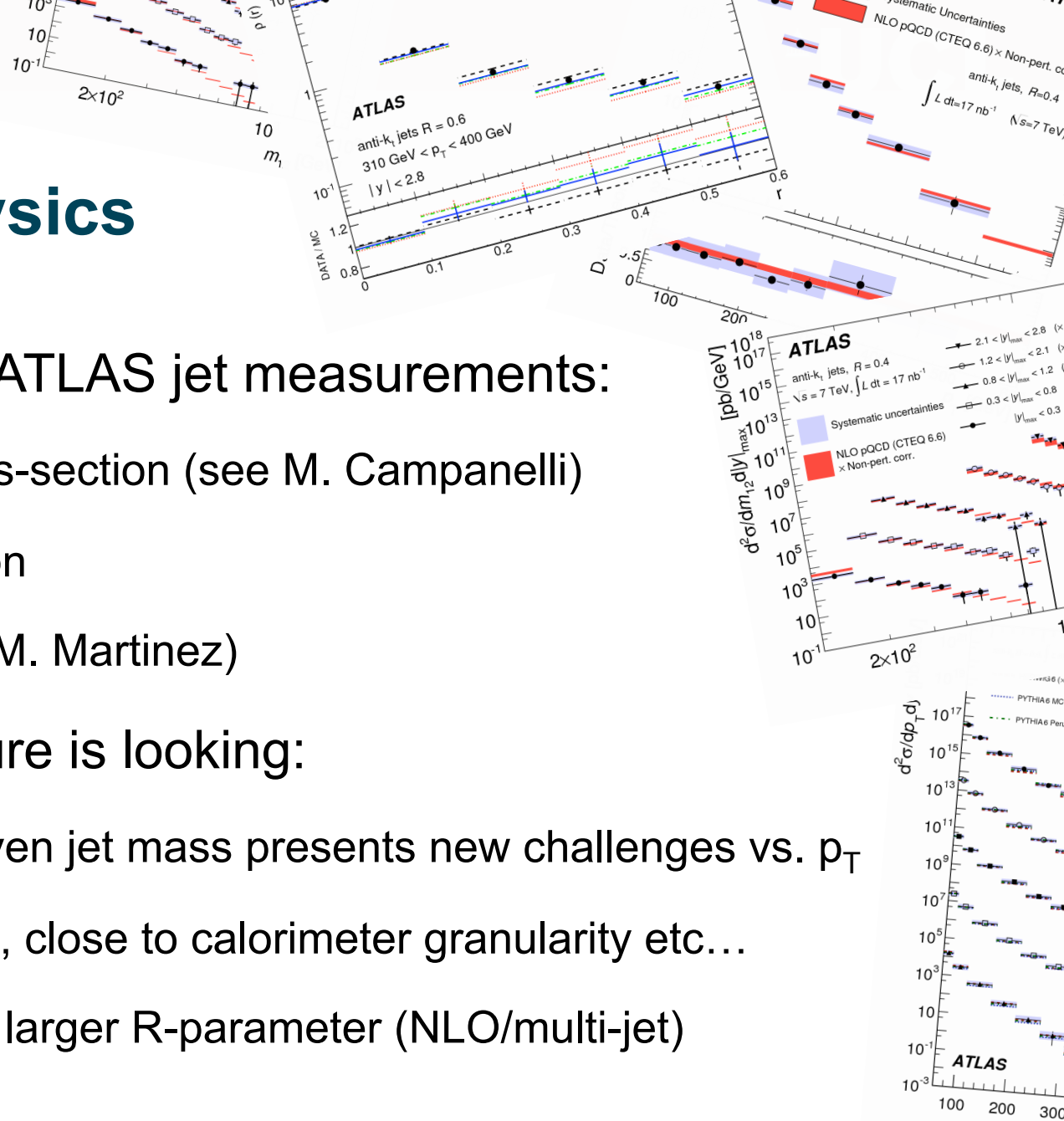


Jet Substructure at ATLAS

- Jet substructure is a key part of 2011 ATLAS physics
- Enables new analyses and enhances old ones
- However jet substructure largely untested in real data
- Important to use the 2010 dataset to build experimental confidence and understanding of these techniques

ATLAS Jet Physics

- Lots of excellent ATLAS jet measurements:
 - Inclusive jet cross-section (see M. Campanelli)
 - Dijet cross-section
 - Jet shapes (see M. Martinez)
- But jet substructure is looking:
 - In more detail, even jet mass presents new challenges vs. p_T
 - At smaller scales, close to calorimeter granularity etc...
 - At bigger scales, larger R-parameter (NLO/multi-jet)



ATLAS Substructure Results

- **ATLAS-CONF-2011-073**
- Inclusive QCD jets are abundant in the 2010 dataset
- Can require one primary vertex required (~20% of events)
- ATLAS has measured some key quantities
 - Anti- k_t $R=1.0$ jet mass and $\sqrt{d_{12}}$
 - Cambridge-Aachen $R=1.2$ jet mass before and after filtering
- Full systematics
- Corrected for detector effects

Variables

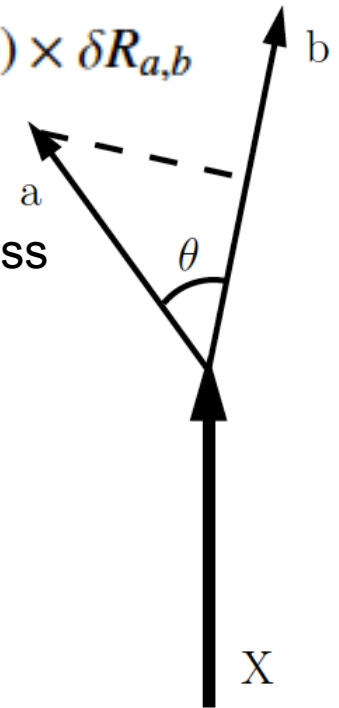
$$\sqrt{d_{12}} = \min(p_{T a}, p_{T b}) \times \delta R_{a,b}$$

d_{12} (a.k.a. k_T splitting scales, y -scale, y_2)

Add-on variable usable to enhance analyses using jet mass
 Measure of hardness of final k_T splitting in a jet

J.M. Butterworth, B.E. Cox, J.R. Forshaw **Phys. Rev. D** **65** (2002)

M. H. Seymour **Z Phys** **C62** (1994) 172

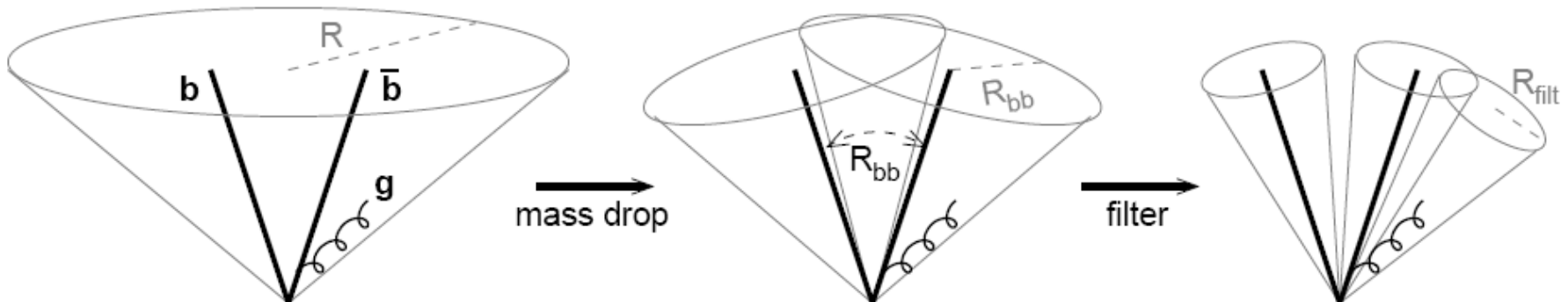


Splitting and Filtering (a.k.a. BDRS filtering, C-A filtering)

Take jets and search for symmetric splittings with large mass drop, recluster filtering out large angle radiation. Yields new jets which can be treated as heavy particle candidates.

Include additional cut $R_{qq} > 0.3$ here.

J. M. Butterworth, AD, M. Rubin and G. P. Salam **Phys. Rev. Lett.** **100**, 242001 (2008)

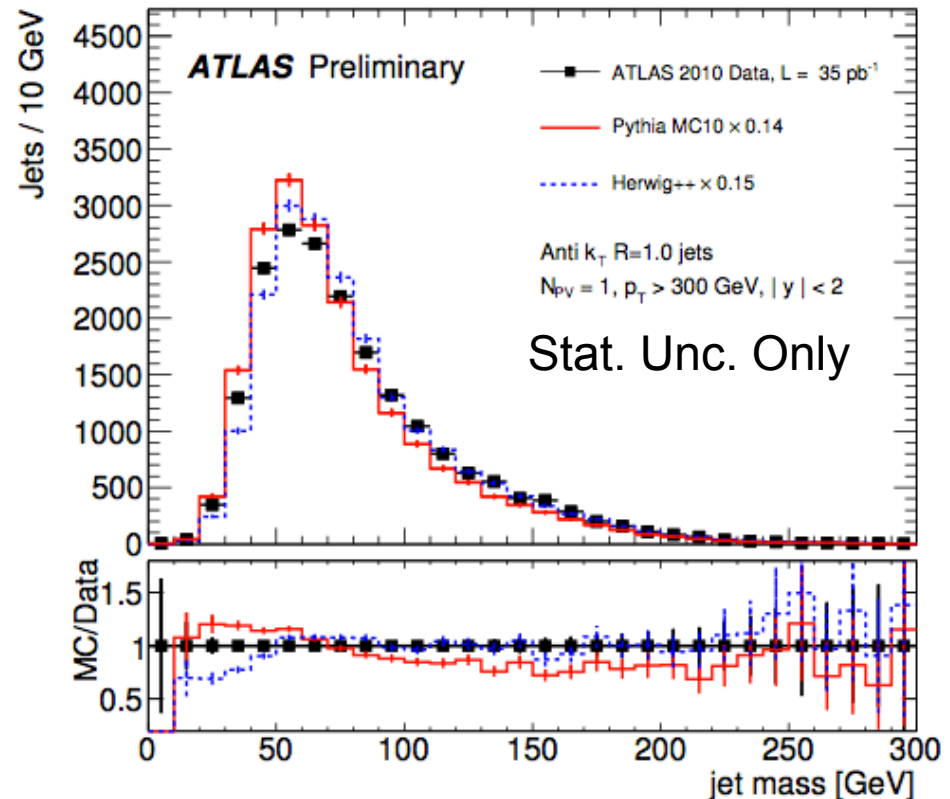
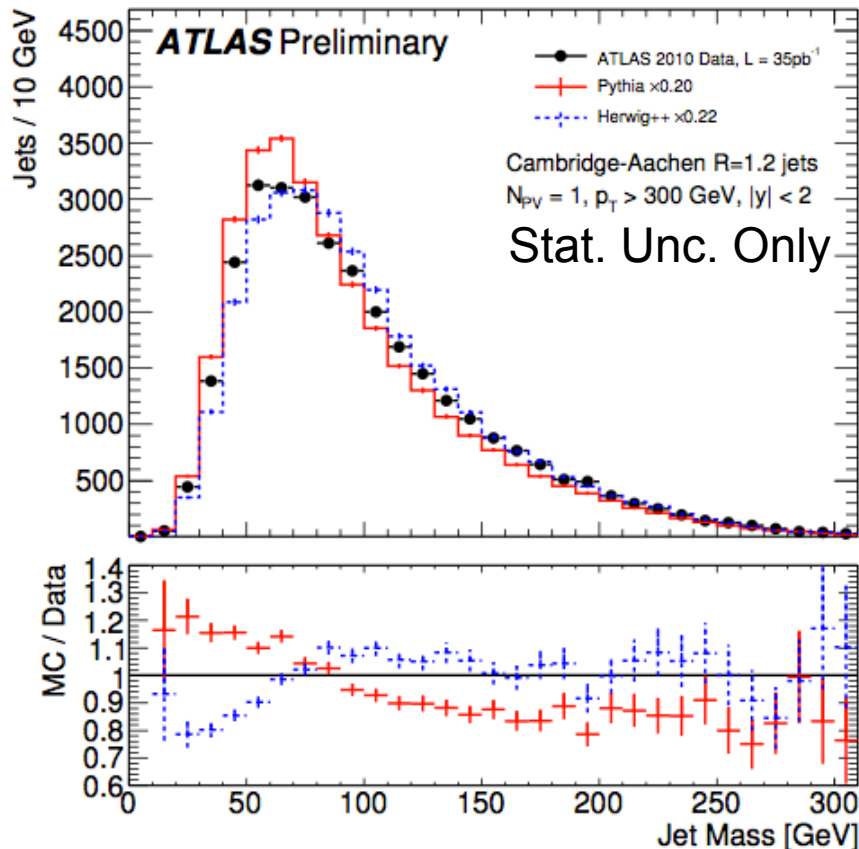


ATLAS Substructure Results

- Jets are built from “locally calibrated topological clusters”
- Monte Carlo based calibration applied to correct scale
- Events cleaned for detector noise and non-collision bkgd.
- Require one primary vertex
- Look at jets $p_T > 300$ GeV and $|y| < 2$

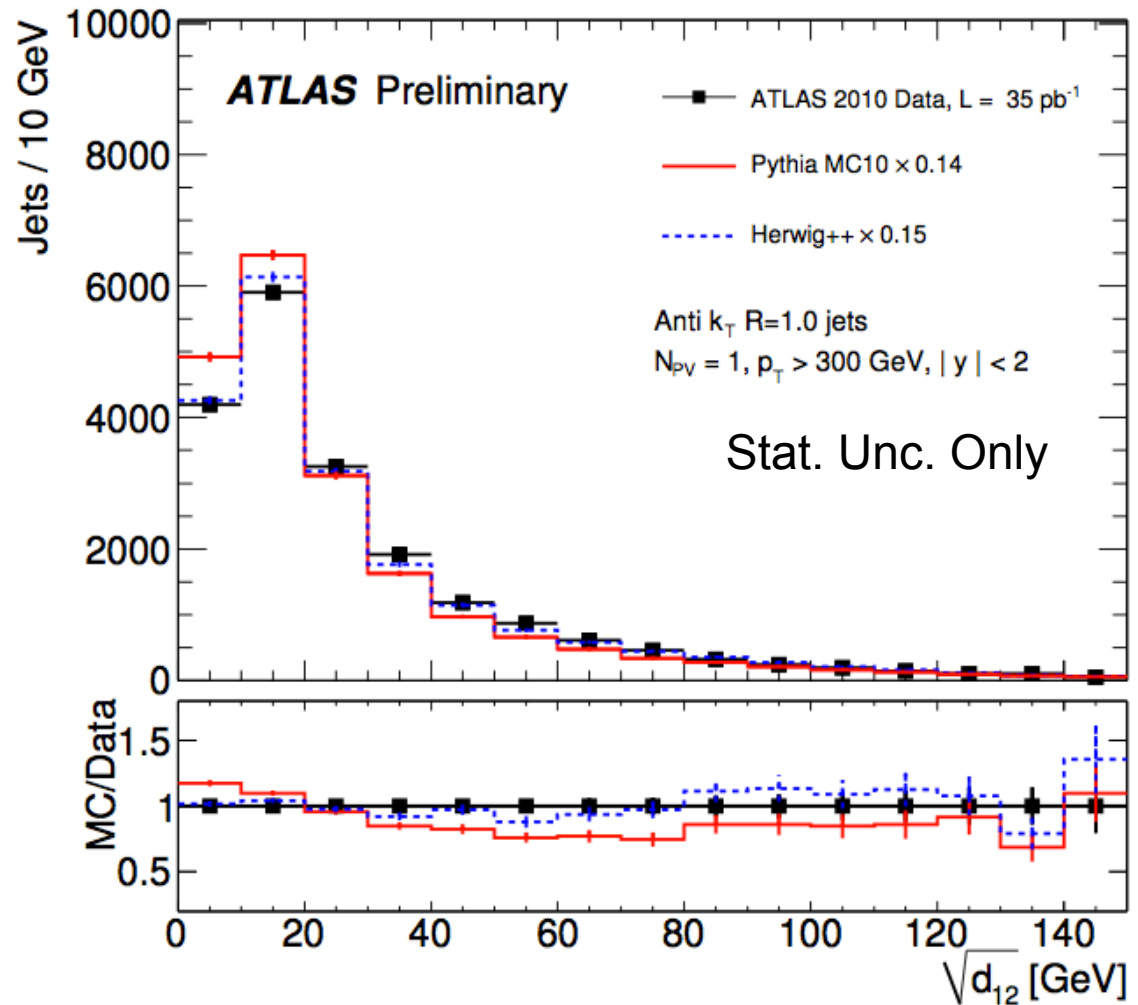
Raw Mass Spectra

- Description of mass shape is reasonable in MC samples



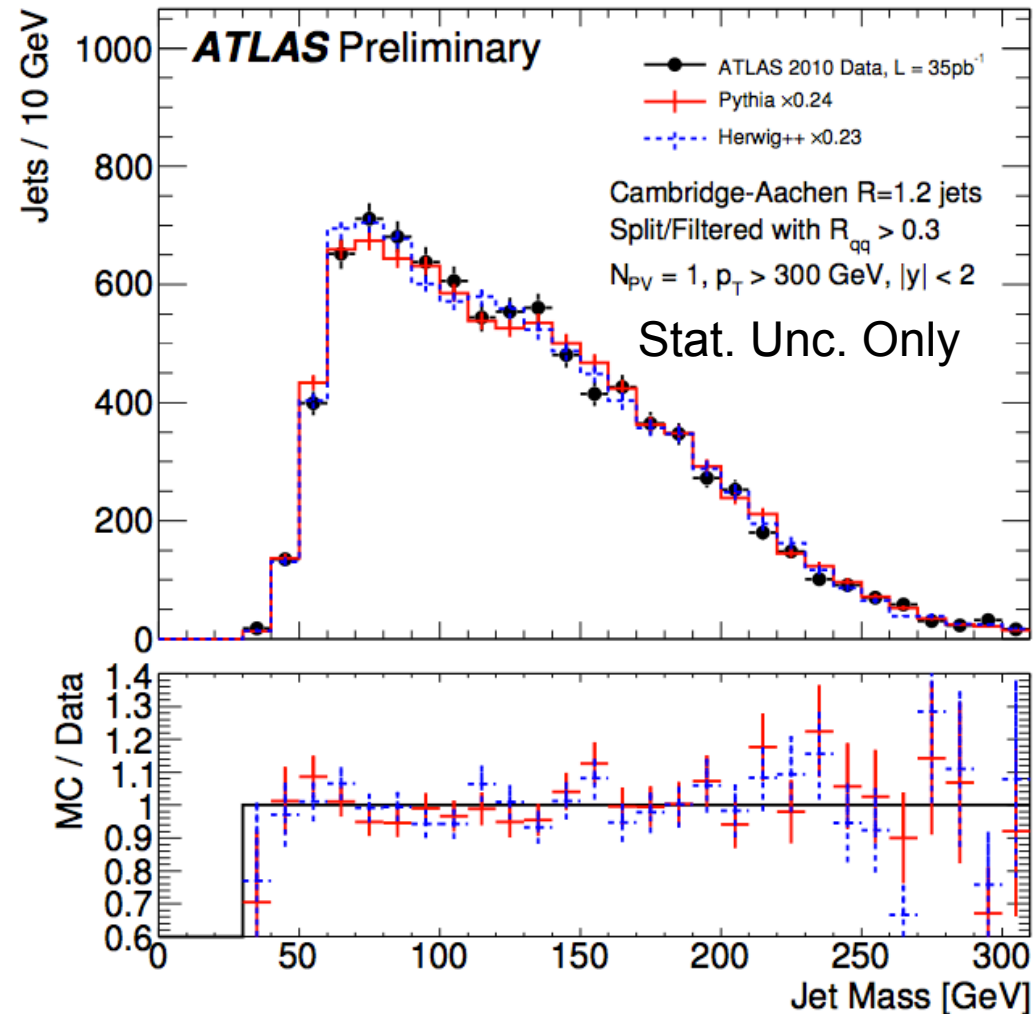
$\sqrt{d_{12}}$ Spectrum

- Again reasonable agreement with LO parton shower Monte Carlo



Filtered Mass Spectrum

- Basic description appears to be very good here



Systematics

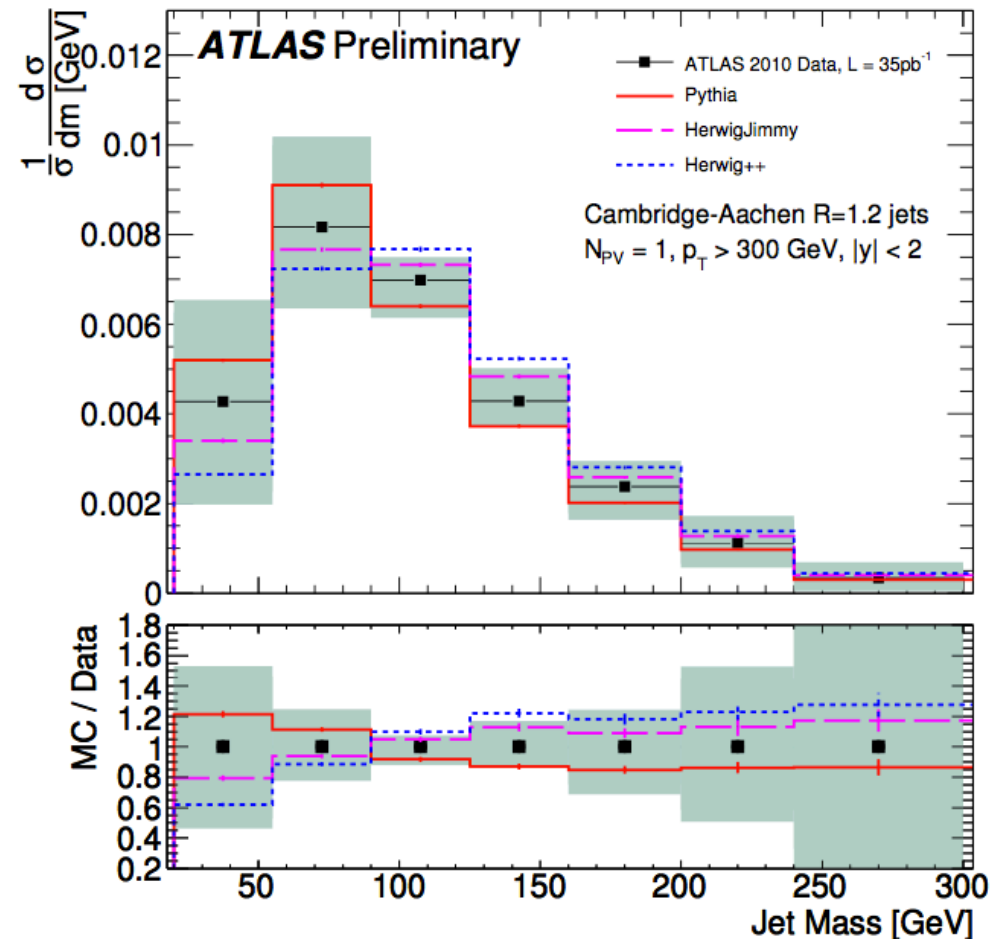
- Perform a Monte Carlo-based calibration
- Validated primarily in-situ using the inner detector
 - See L. Asquith
- Have the following (correlated) systematics:

Jet Algorithm	JES	JMS	JER	JMR
anti- k_t $R = 1.0$	5%	7%	20%	30%
Cambridge-Aachen $R = 1.2$	5%	6%	20%	30%
Cambridge-Aachen Filtered $R = 1.2$	6%	7%	20%	30%

	Scale	Resolution
$\sqrt{d_{12}}$	15%	30%

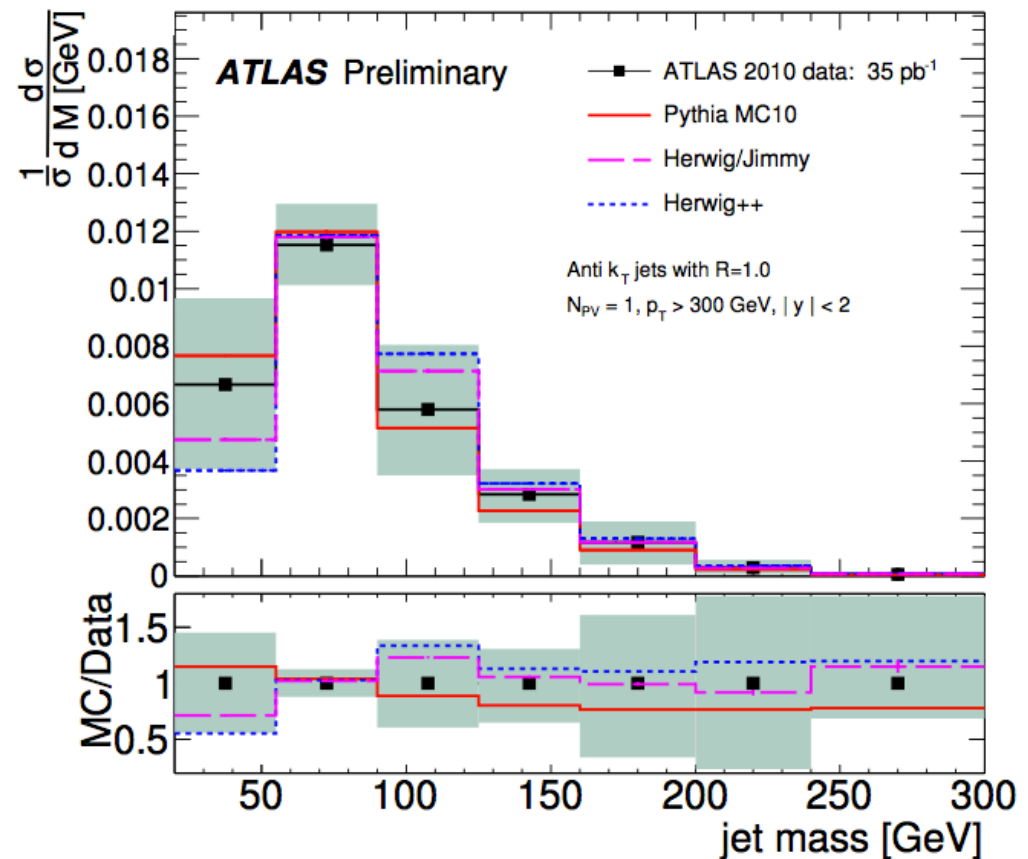
Cambridge-Aachen R=1.2 Jet Mass

- Dividing by total cross-section
- Systematics are the shaded green band
- Corrected with bin-by-bin unfolding procedure
- Comparable to particle-level generator predictions



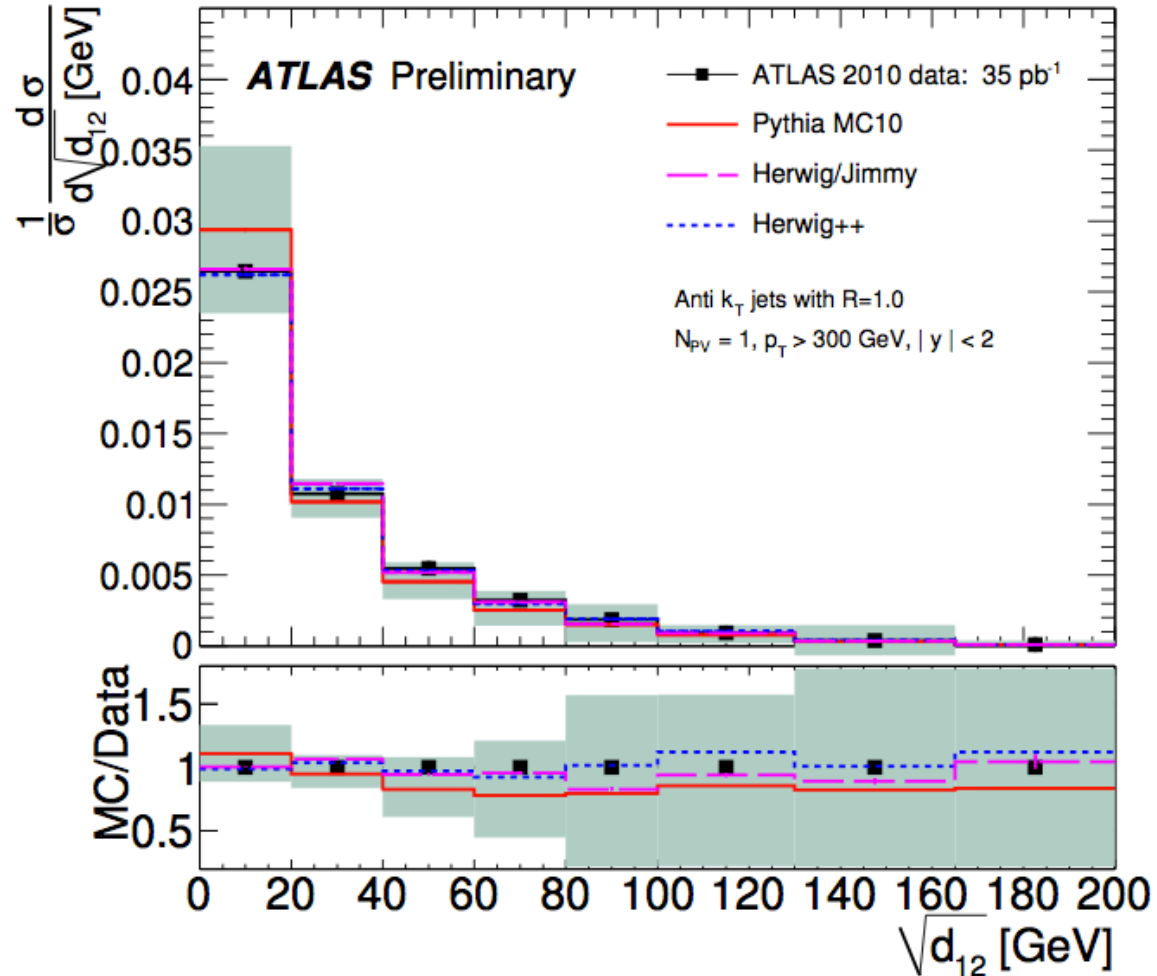
Anti- k_t R=1.0 Jet Mass

- As Cambridge-Aachen
- All predictions compatible with ATLAS data here



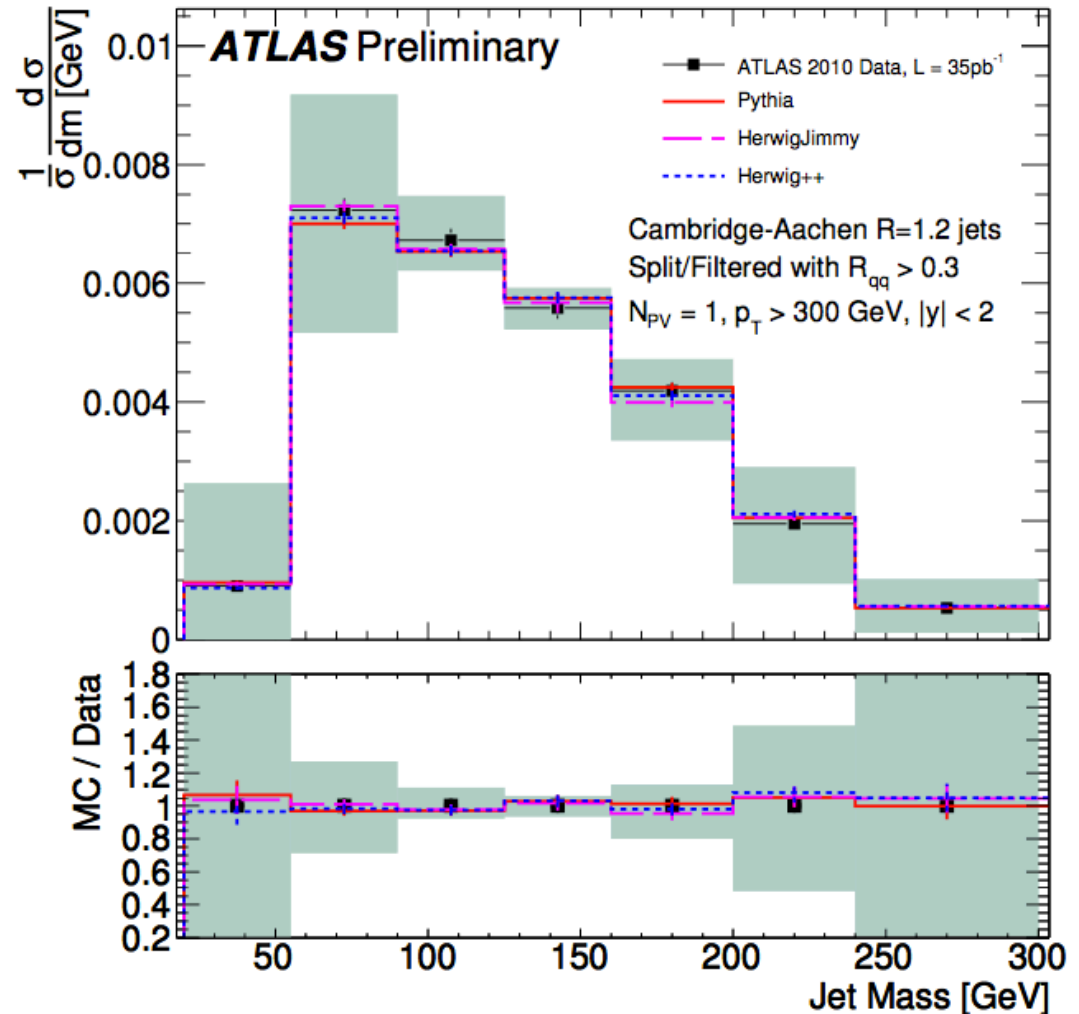
Anti- k_t $R=1.0$ $\sqrt{d_{12}}$

- Again fully corrected for detector effects
- All generators in agreement to within systematics



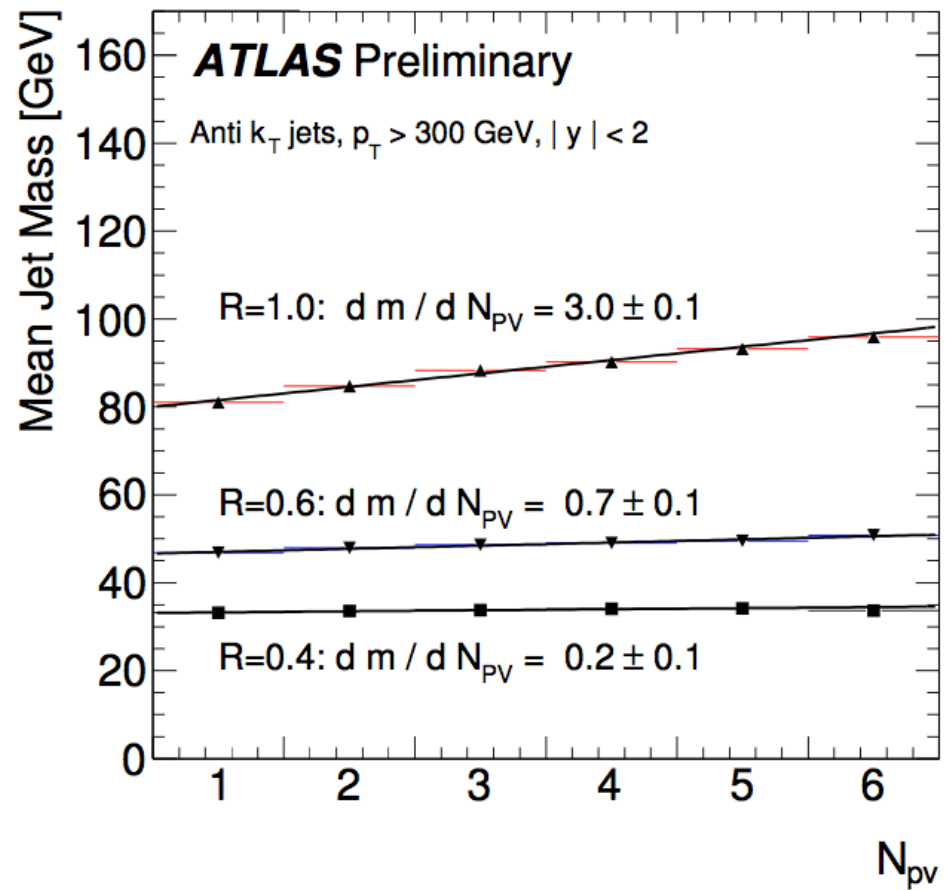
Cambridge-Aachen R=1.2 Filtered Mass

- Very good agreement with all three Monte Carlos shown here
- MC predictions converge on data compared to unfiltered jet mass



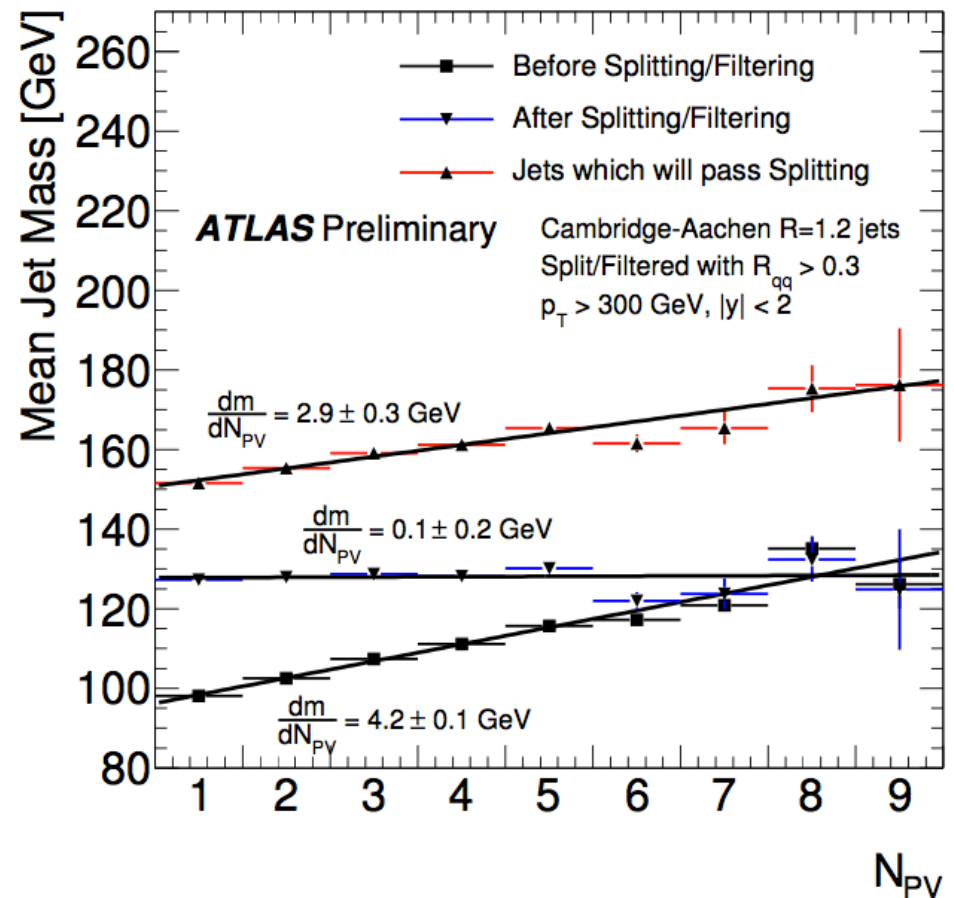
Pile-up

- Pile-up effects a big concern for future analyses
- Need to be sure we understand the effects
- Here find expected scaling of mean mass with number of primary vertices
- Also expected R^3 dependence of slope



Pile-up (2)

- Filtering reduces effective jet area
- Should therefore reduce pile-up dependence
- Slope in fact consistent with zero after filtering



Jet Substructure Results Summary

- ATLAS has made first measurements of these quantities
- Generally well modelled by LO parton showers
- ATLAS lives up to our expectations from simulation
- Area dependence of pile-up effects matches predictions
- Filtering performance against pile-up is excellent

Jet Substructure in 2011

- These results will be finalised and published
 - Rivet routine + HEPDATA will also be provided once final
- Expect more Standard Model measurements
- This experience propagated to new physics searches

Conclusions

- ATLAS is measuring jet substructure
- See **ATLAS-CONF-2011-073**
- Luminosity already rising in 2011
- Expect to see many more exciting results

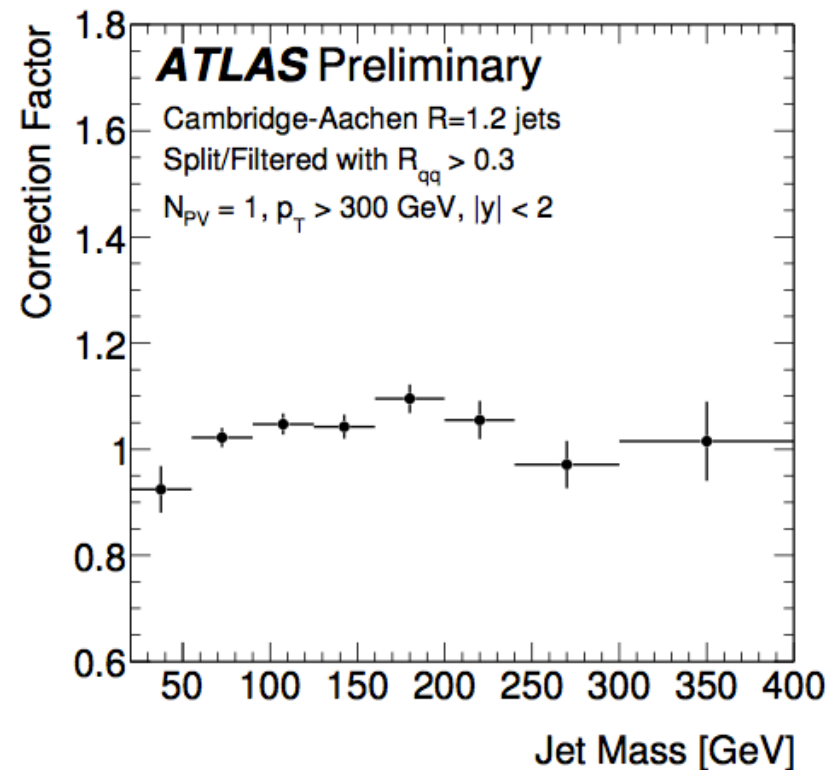
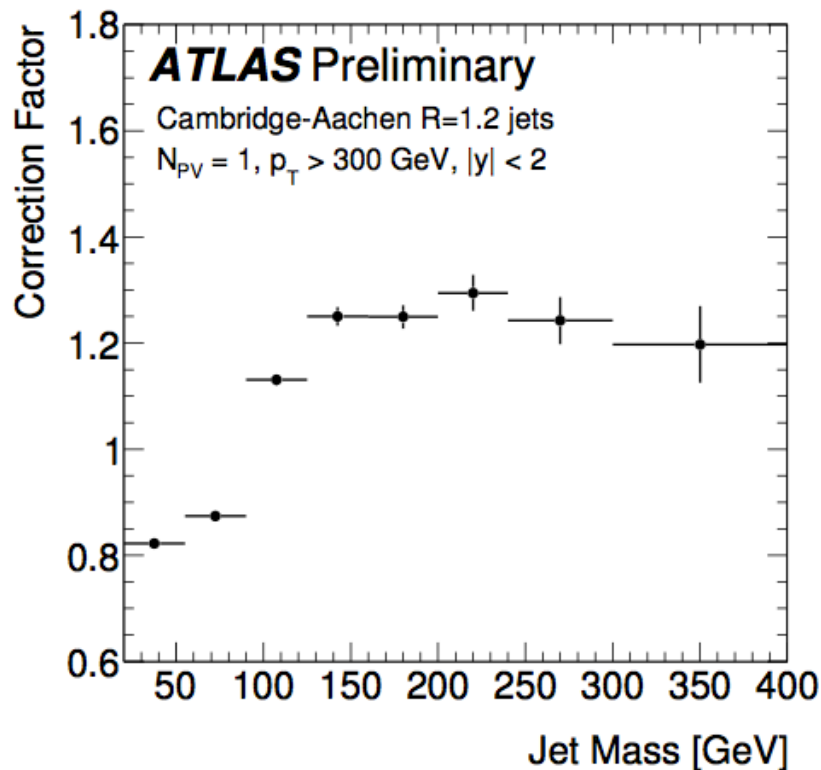
Backup

MC Tunes

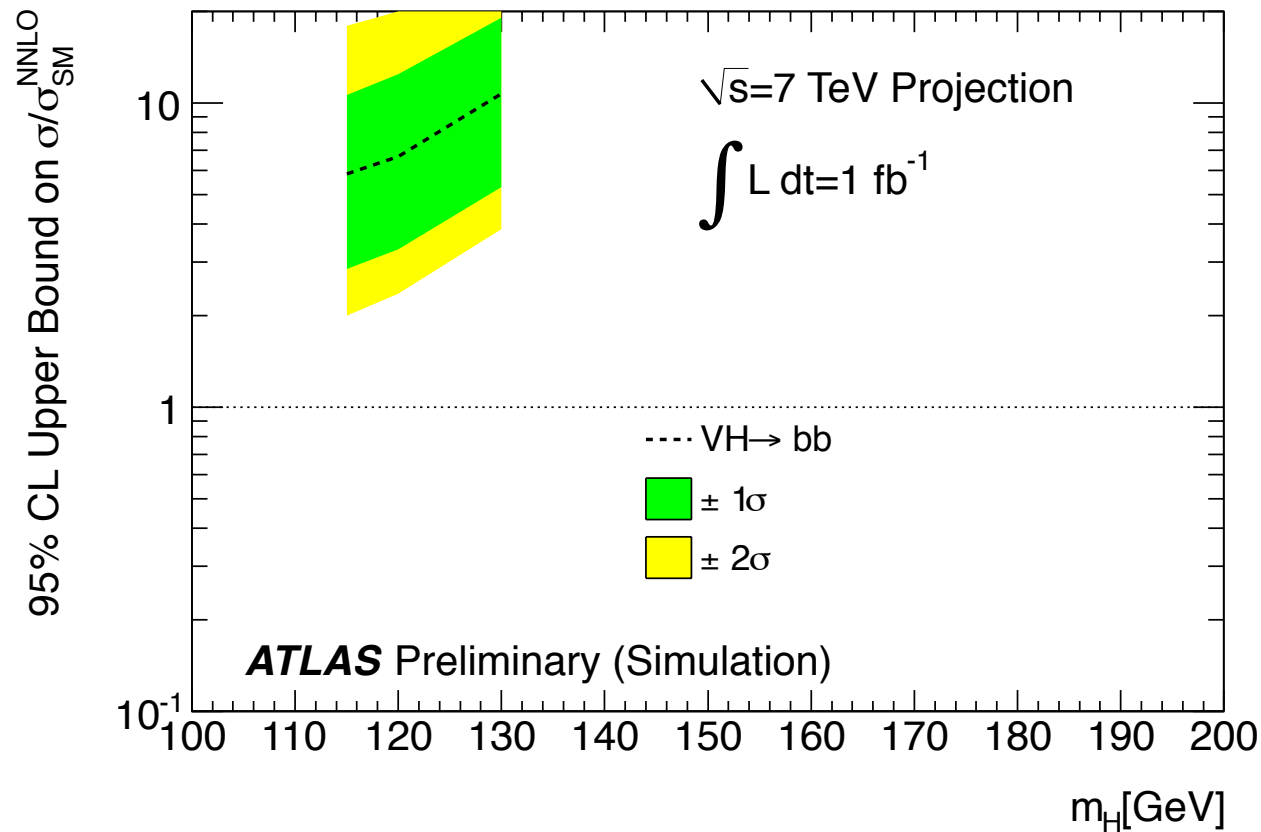
- PYTHIA 6.423 with AMBT1
- HERWIG 6.510 and JIMMY 4.31 with AUET1
- HERWIG++ 2.4

Unfolding

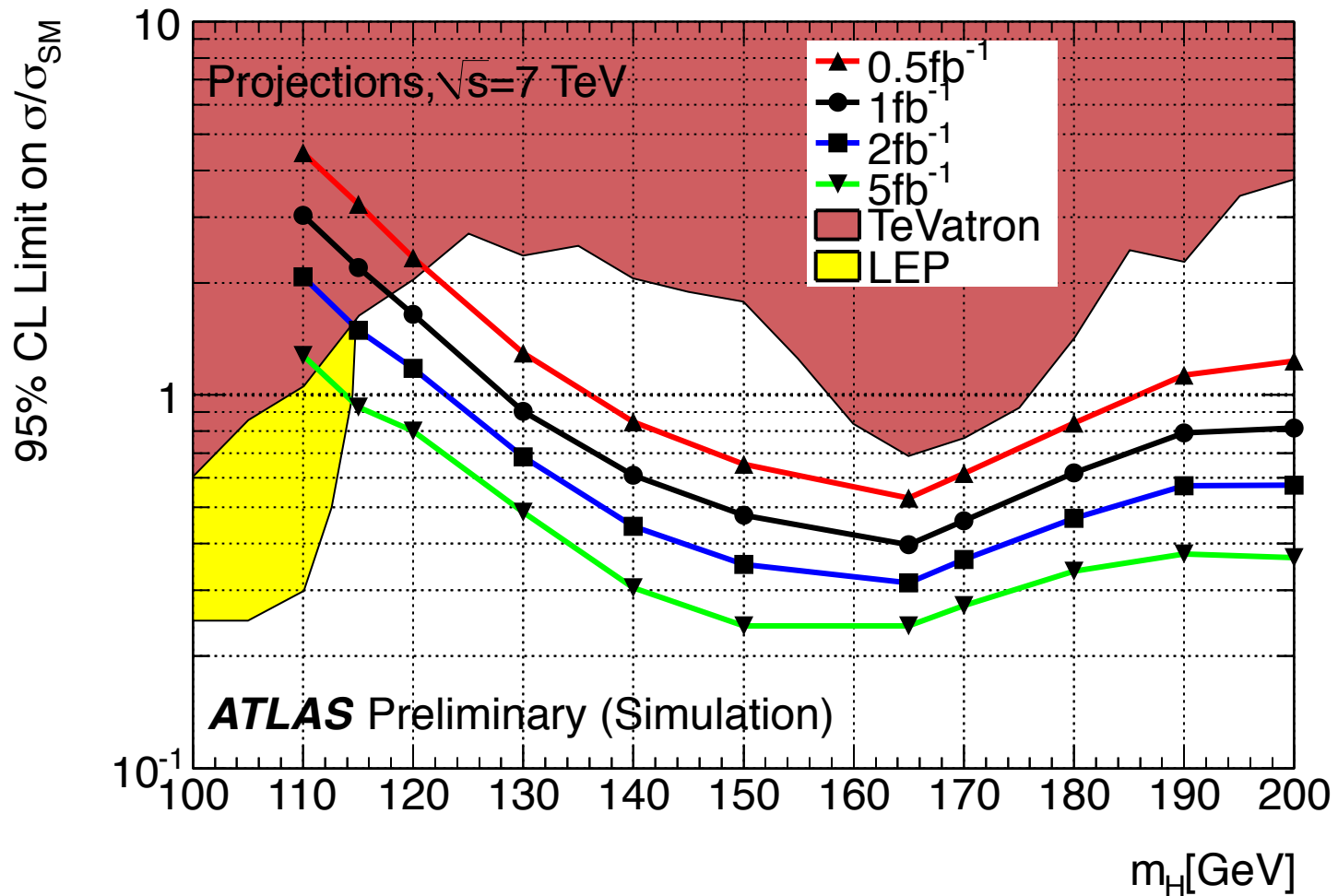
- Bin-by-bin correction
- Forces the use of wide bins to contain migrations



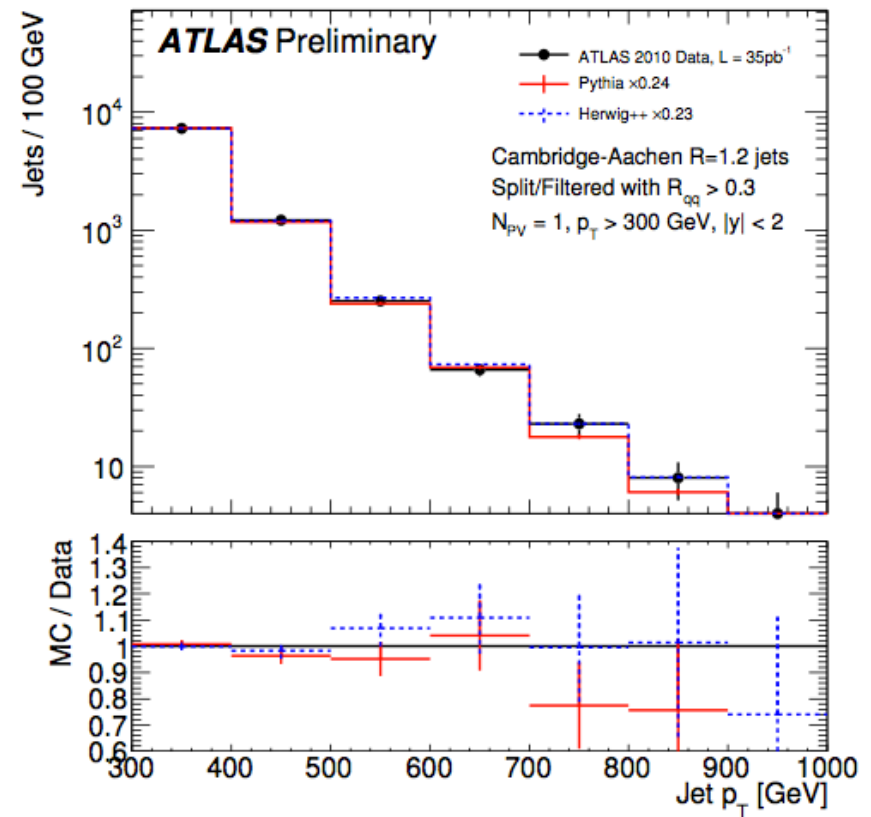
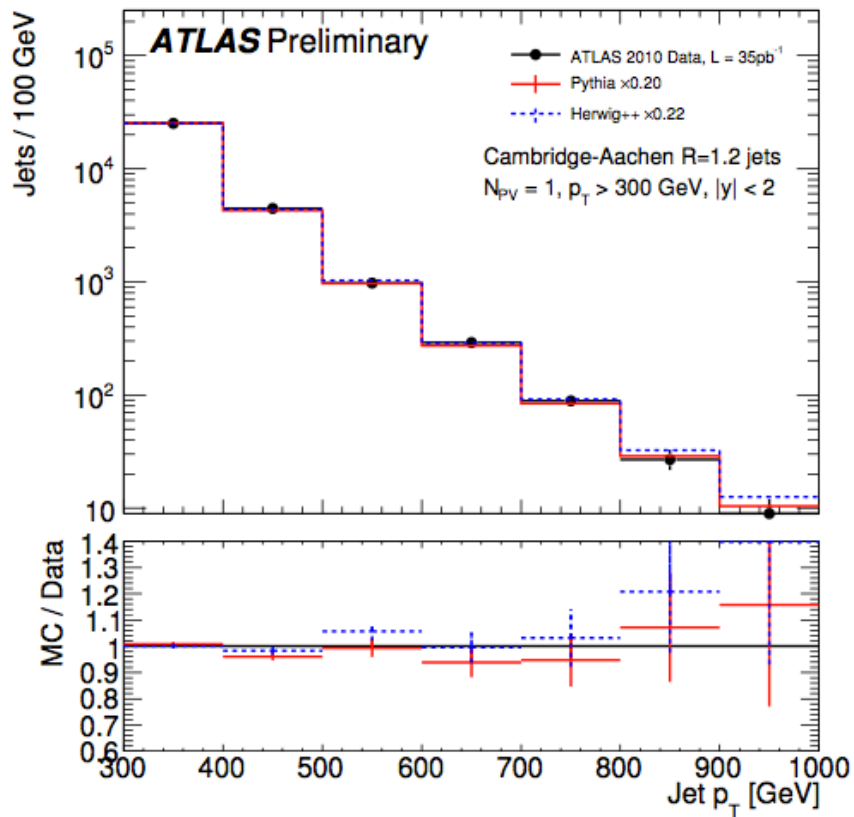
Boosted VH Limit



Higgs Luminosity



p_T Spectra



Rapidity

