H1 and Sampling Calibration for Jets

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Ideal detector would measure interacting particles (e.g., not ν) perfectly. Define jet calibration relative to such ideal detector.

ATLAS calorimeter has $e/h \sim 1.3$ so jet response at EM scale less than true energy. Also effects of dead material, B field,....

Since $X_0 \ll \lambda$, EM showers are denser and shorter than hadronic ones. Session devoted to two approaches — based on Monte Carlo:

1. "H1" calibration, based mainly on CaloCell E/V.

2. Sampling calibration, based mainly on shower depth.

Physics measurements (e.g. m_t) require additional analysis.

Session outline, with contributions from many people:

- Calibration implementation.
- H1 calibration from QCD dijets.
- H1 performance for other samples.
- Status of sampling calibration.
- Ideas for improvements.
- Towards tests with data.

Implementation

Jets are found at EM scale. Then cell/layer weights are applied to minimize difference between reconstructed and nearest truth jet found using same algorithm.

Use `JetSampling` [Gupta, Salvachua] to accumulate relevant data for many jets. Store sums of `CaloCell` energies in bins of E/V for each `CaloSampling`. E.g., EMB is divided at $\eta = 0.8$, where Pb thickness changes. Then minimize

$$\chi^2 = \sum_{\text{jets } j} \left(\frac{\sum_{\text{cells } c} w_c E_{T,\,cj}}{E_{T,\,\text{match truth}}} - 1 \right)^2$$

Default H1 calibration combines some layers. Sampling calibration fits in $\Delta\eta = 0.1$ bins combining calorimeter technologies and summing over E/V.

Reduce H1 parameters with polynomial in $\log E/V$ index for w_c. Will discuss alternative fits and parameterizations later.

Add jet scale correction: polynomial in $1/\log E_T$ in $\Delta\eta = 0.1$ bins. Originally from profile plots – gave $\sim 2\%$ fluctuations at sample boundaries. Since 15.0.0 from numerical inversion.

Can apply numerical inversion without additional calibration. Gives comparable improvement of resolution at low E_T.

`QGSP_BERT` fits test beam better. Switching to it from `QGSP_EMV` changed jet scale by $\sim 5\%$. Geometry is also important.

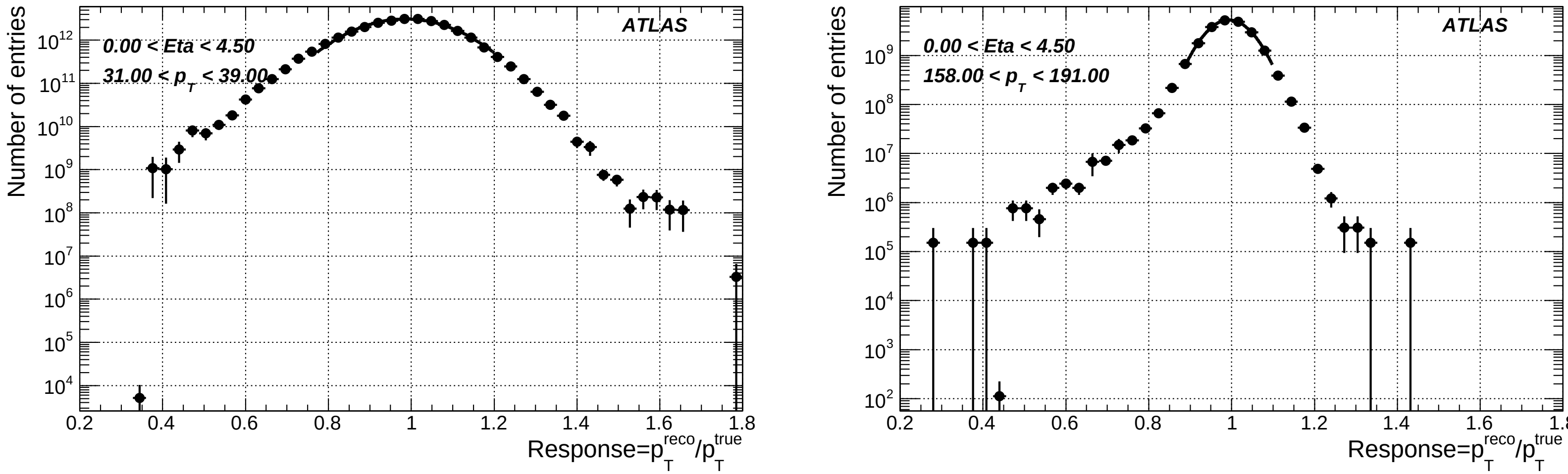
H1 Calibration for QCD Jets

Have refit H1 weights for AntiKt algorithm with $R = 0.4$ and 0.6 with various inputs:

H1TopoJets	Jets from EM-scale 4-2-0 `TopoClusters` with H1 cell weighting plus numerical inversion.
H1TowerJets	Jets from EM-scale `CaloTowers` with H1 cell weighting plus numerical inversion.
H1TopoTower	Jets from `CaloTowers` from cells in `TopoClusters` with H1 cell weighting plus numerical inversion.
LC TopoJets	Jets from 4-2-0 `TopoClusters` with local hadron cluster calibration plus numerical inversion.

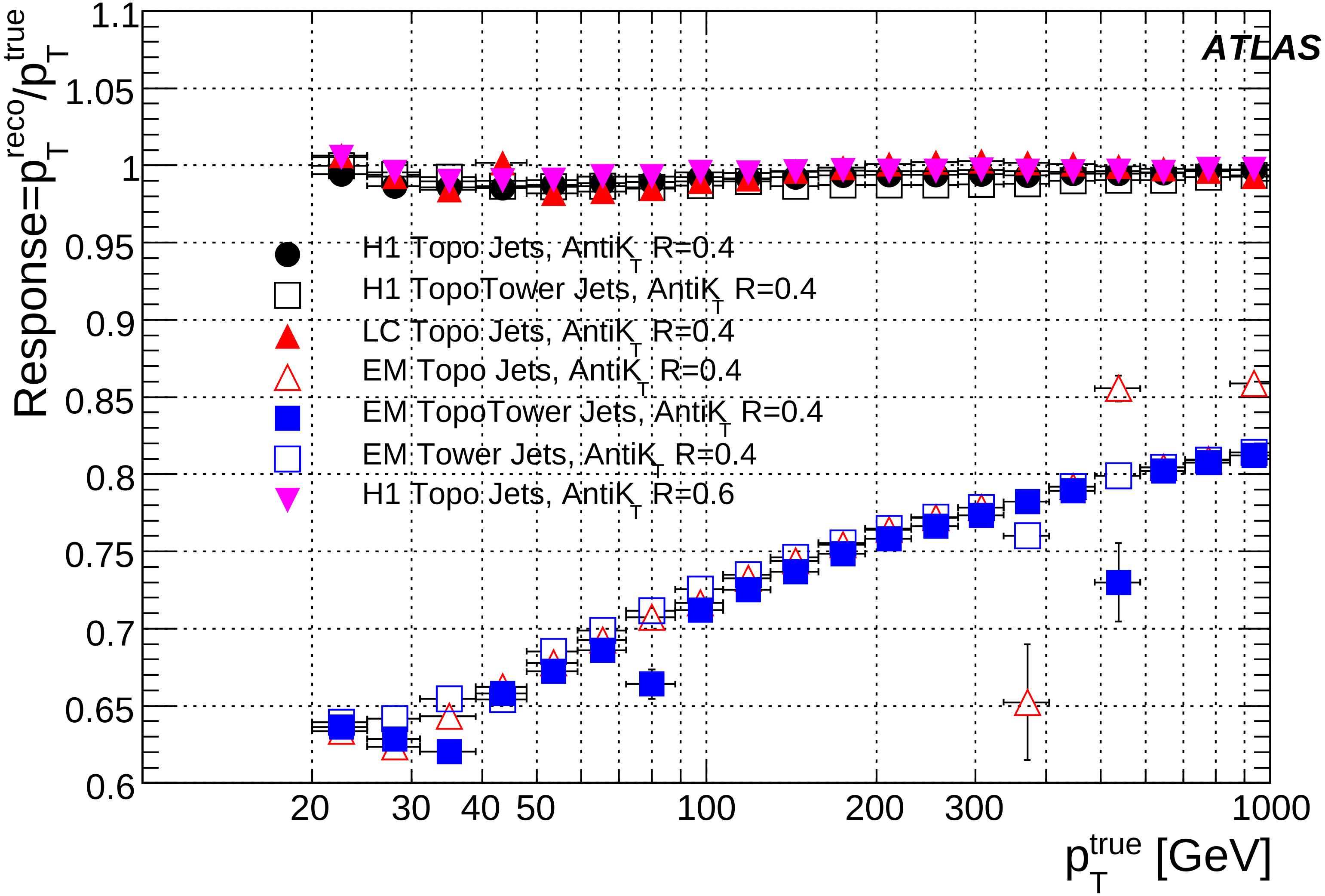
Compare with jets at EM scale using similar inputs.

Resolution distributions $p_{T,\text{reco}}/p_{T,\text{truth}}$ for two AntiKt4H1TopoJet p_T bins, 31–39 GeV and 158–191 GeV [K. Lohwasser]:

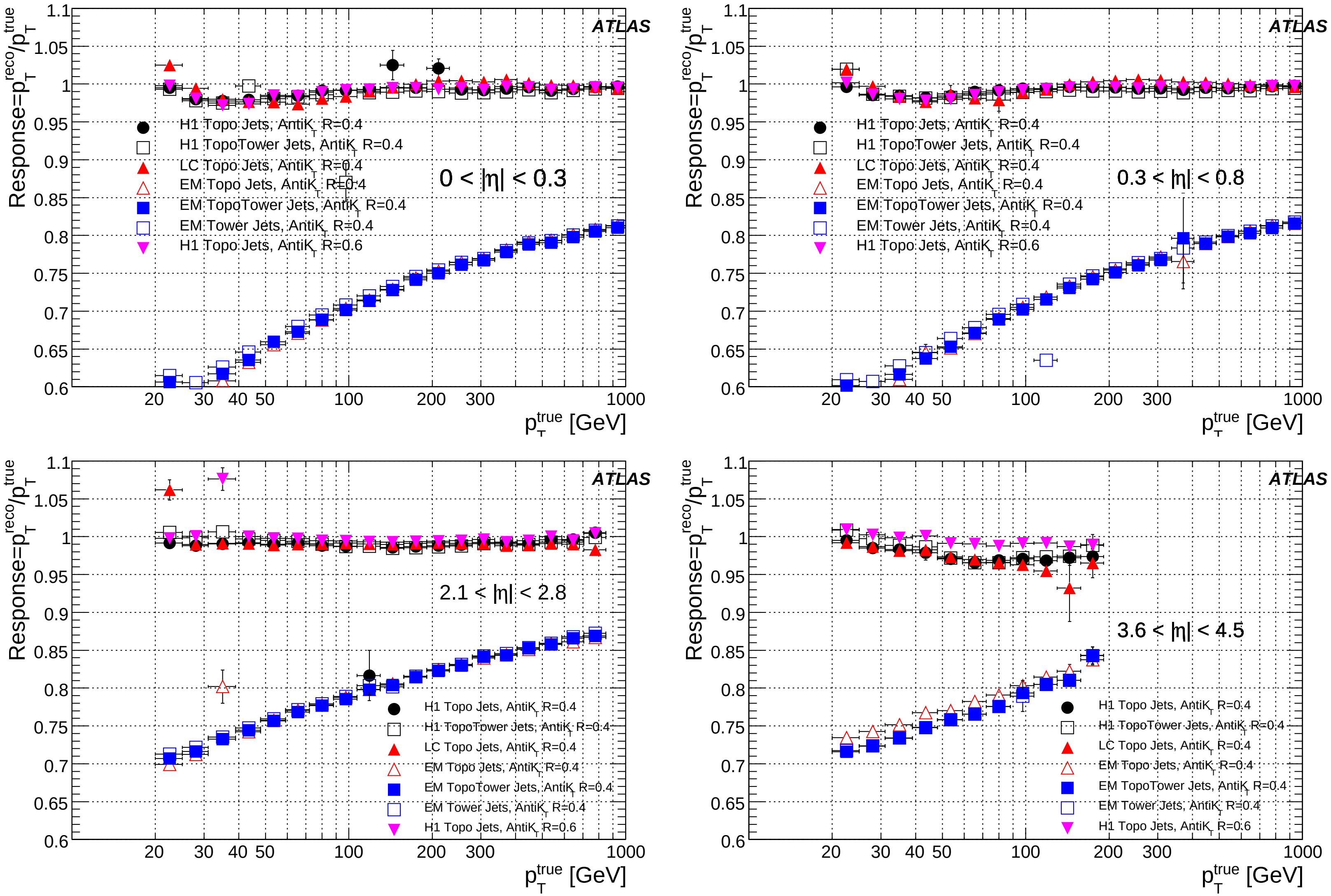


Plots are integrated over all η and so include tails from crack regions. Linearity and resolution plots below made from such distributions with additional cuts as indicated.

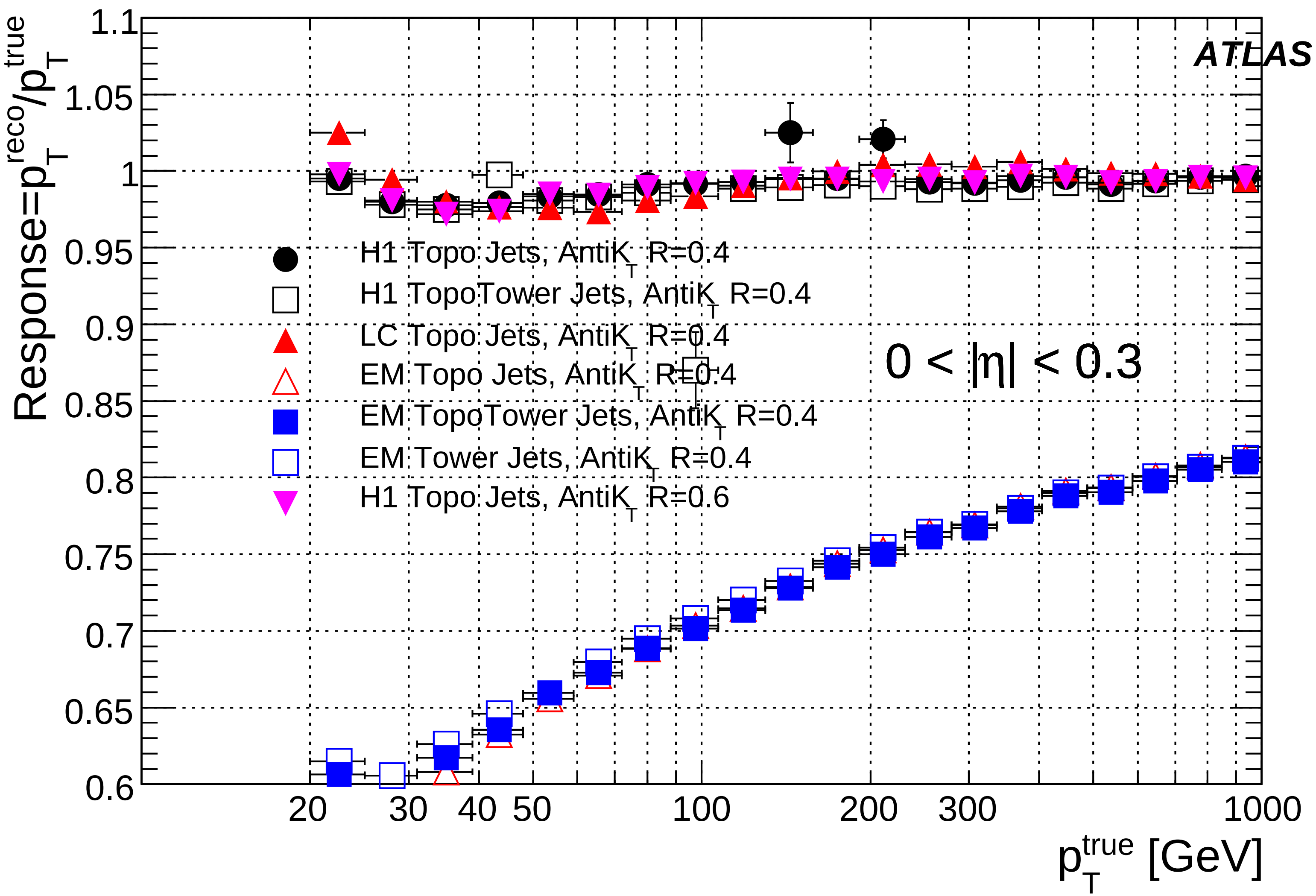
Linearity result integrated over η [C. Doglioni]:

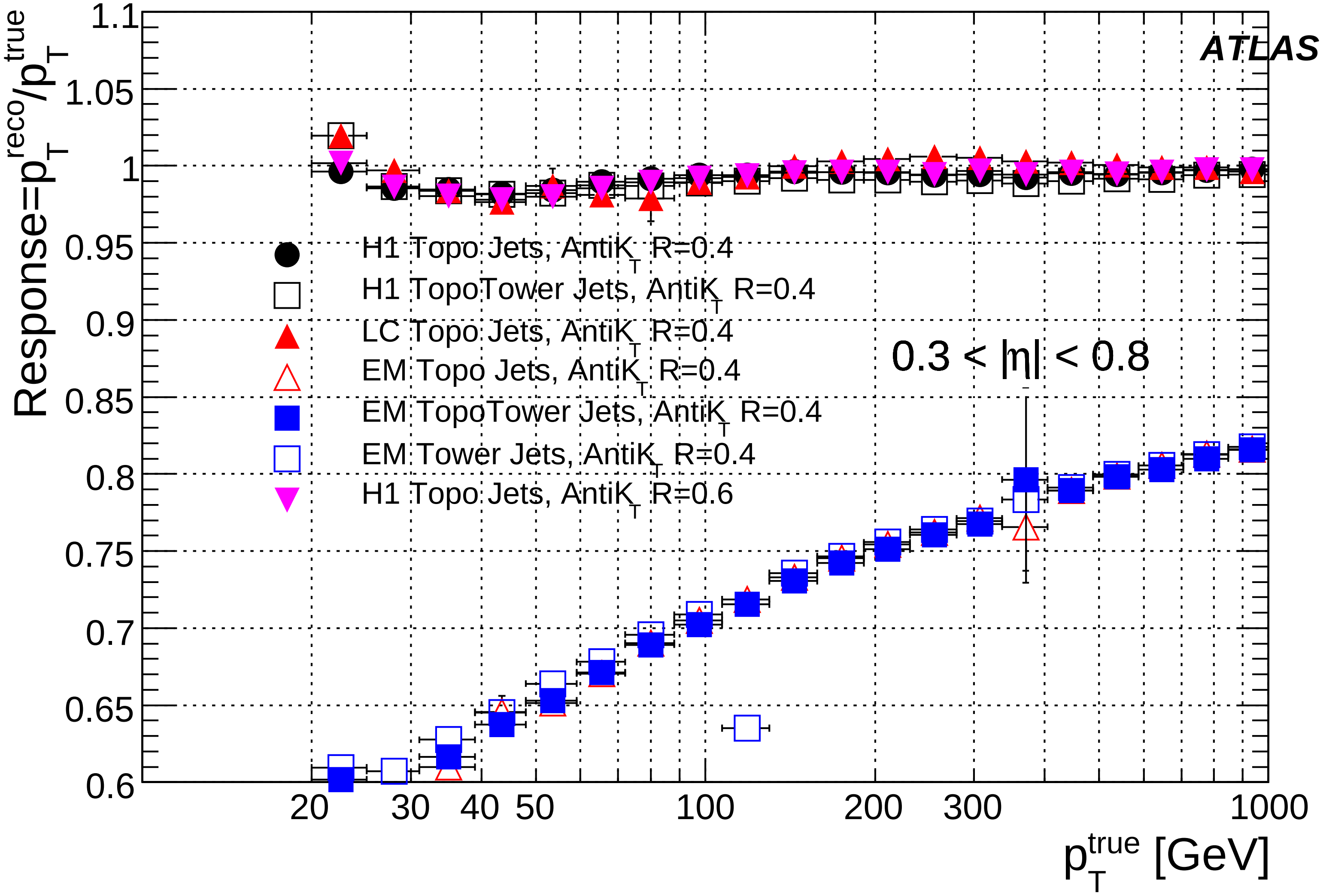


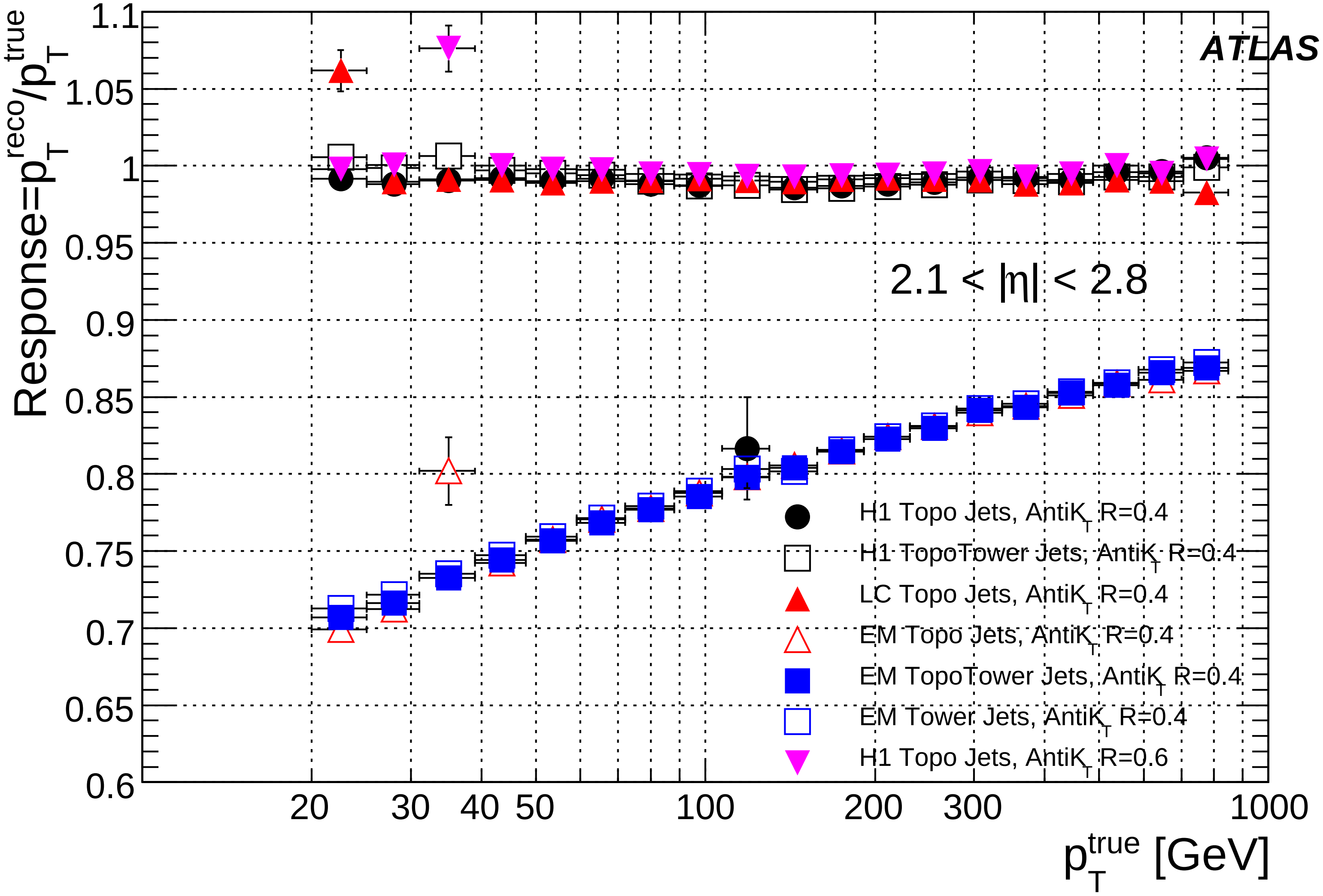
Linearity in η bins:

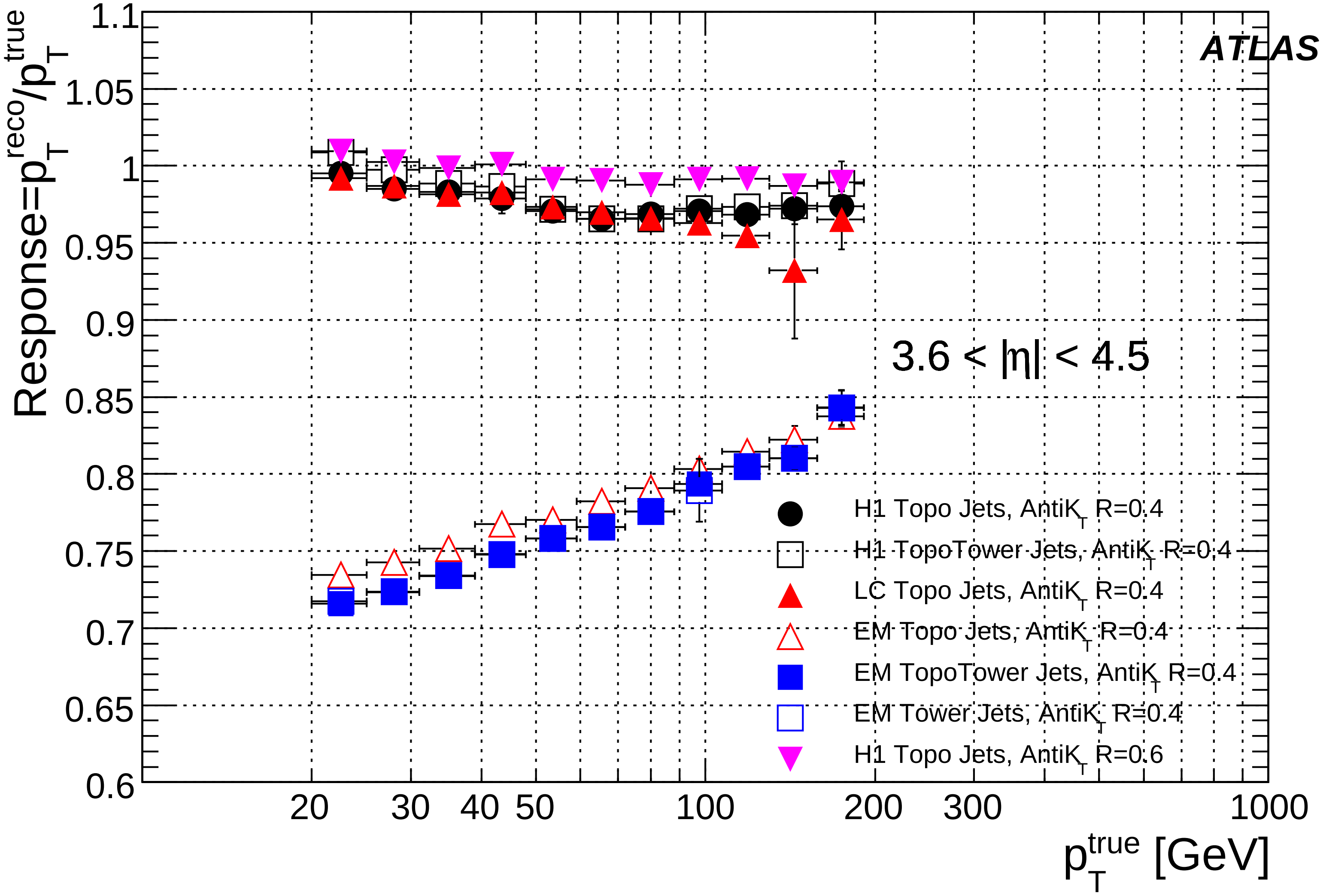


Same plots on expanded scale:



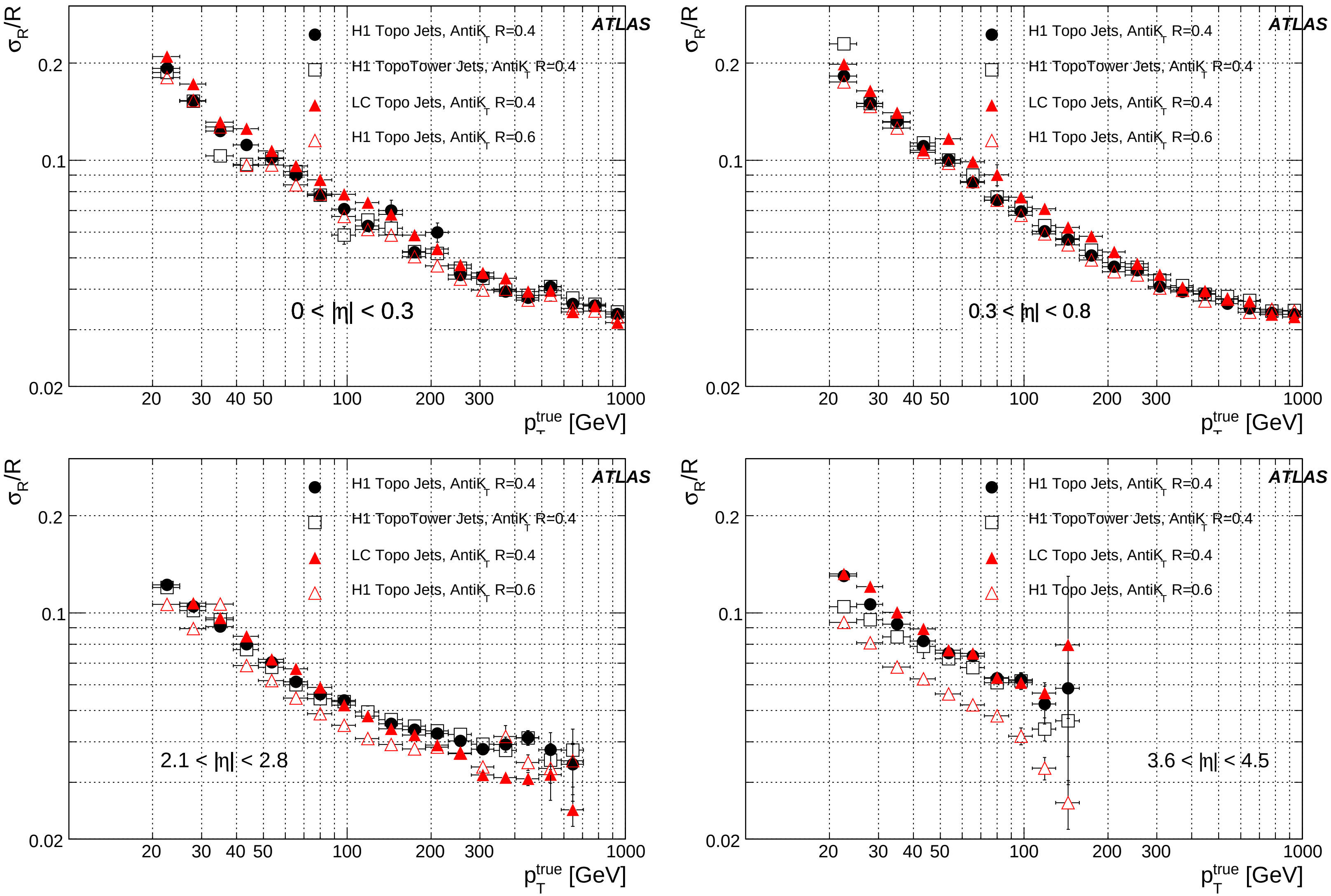

ATLAS
Response=p_T^{reco}/p_T^{true}
p_T^{true} [GeV]
H1 Topo Jets, AntiK$_T$ R=0.4
H1 TopoTower Jets, AntiK$_T$ R=0.4
LC Topo Jets, AntiK$_T$ R=0.4
EM Topo Jets, AntiK$_T$ R=0.4
EM TopoTower Jets, AntiK$_T$ R=0.4
EM Tower Jets, AntiK$_T$ R=0.4
H1 Topo Jets, AntiK$_T$ R=0.6
0.3 < |η| < 0.8
1.1
1.05
1
0.95
0.9
0.85
0.8
0.75
0.7
0.65
0.6
20
30
40
50
100
200
300
1000


ATLAS
2.1 < |η| < 2.8
Response=p_T^{reco}/p_T^{true}
p_T^{true} [GeV]
H1 Topo Jets, AntiK$_T$ R=0.4
H1 TopoTower Jets, AntiK$_T$ R=0.4
LC Topo Jets, AntiK$_T$ R=0.4
EM Topo Jets, AntiK$_T$ R=0.4
EM TopoTower Jets, AntiK$_T$ R=0.4
EM Tower Jets, AntiK$_T$ R=0.4
H1 Topo Jets, AntiK$_T$ R=0.6

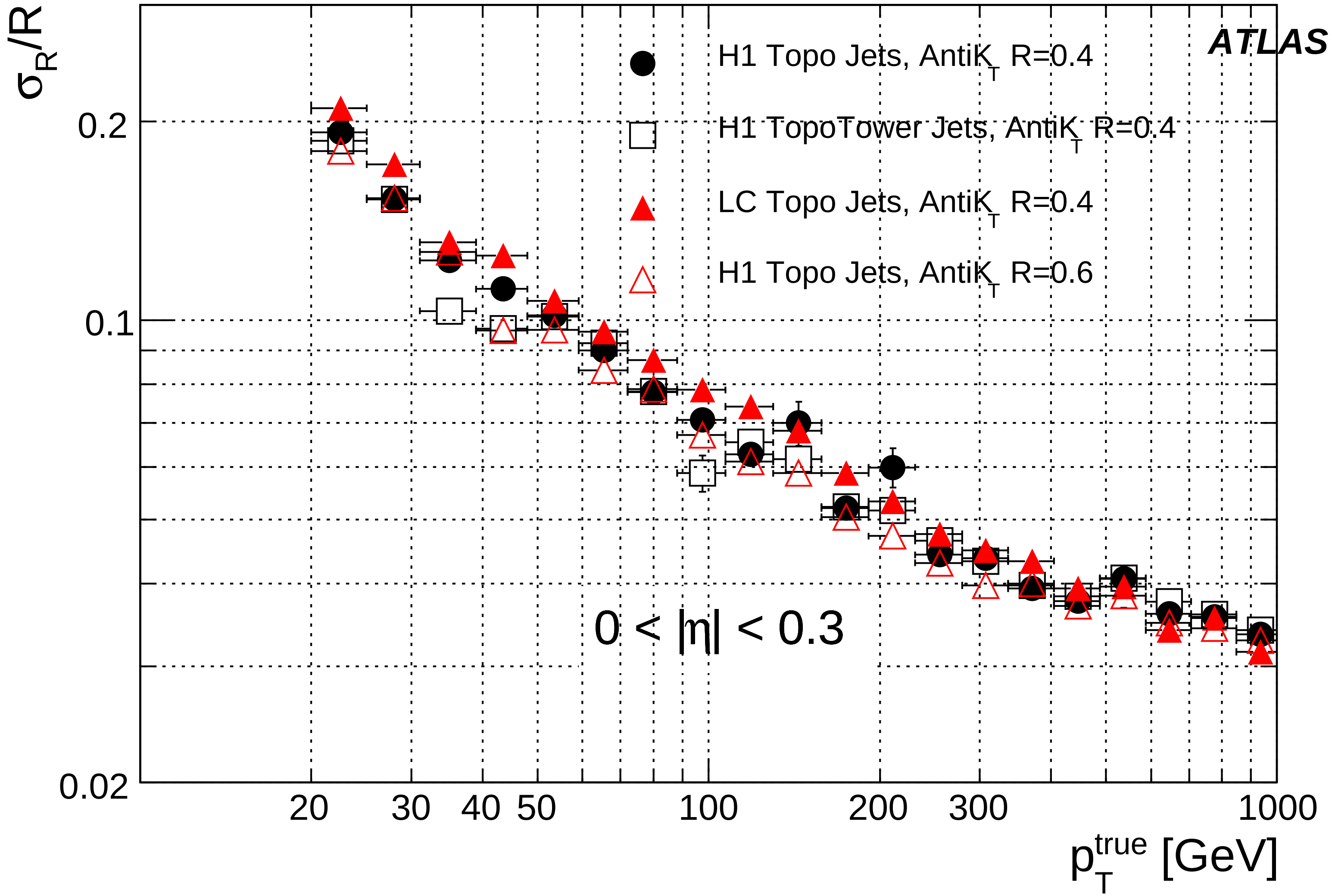


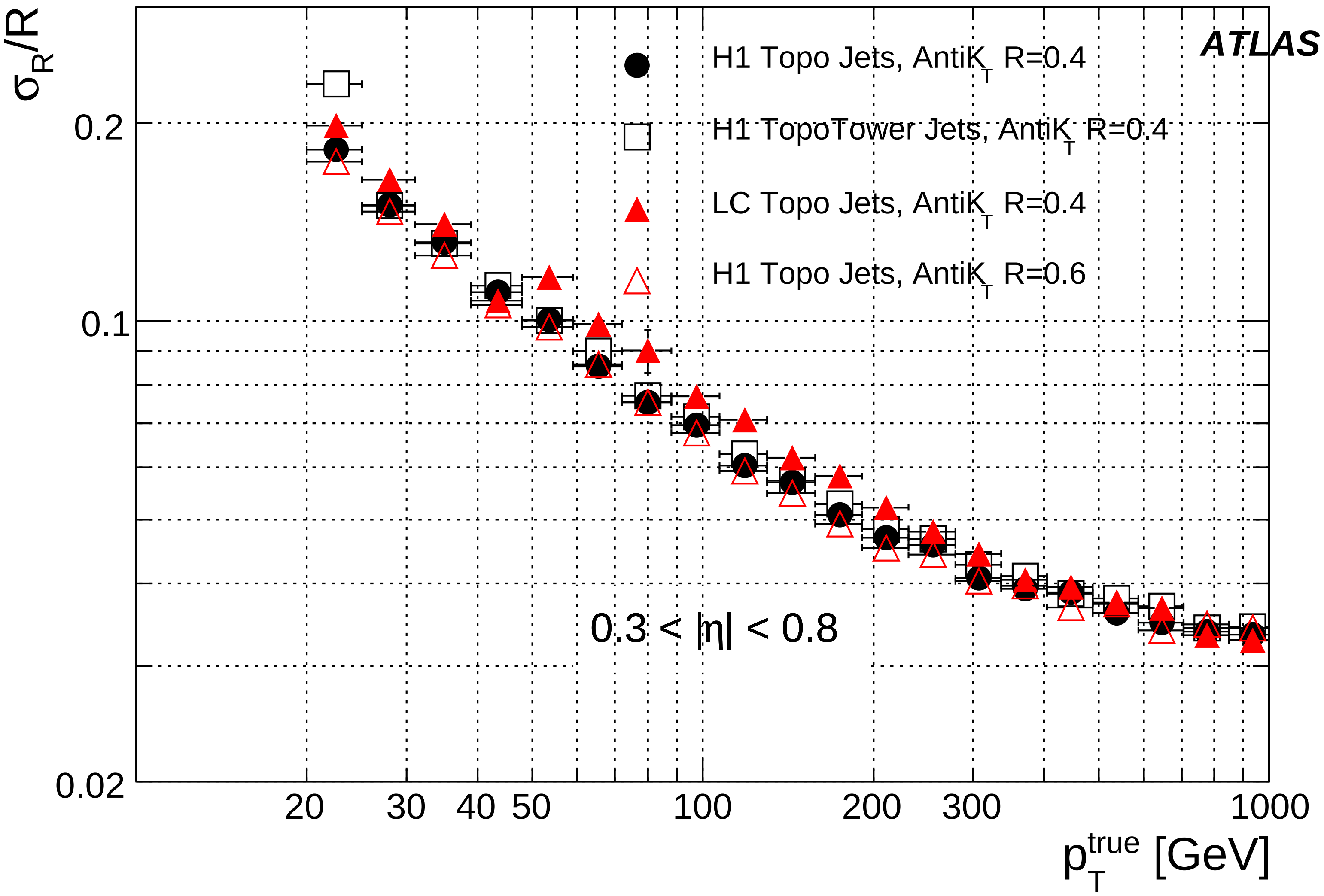
ATLAS
3.6 < |η| < 4.5
H1 Topo Jets, AntiK_T R=0.4
H1 TopoTower Jets, AntiK_T R=0.4
LC Topo Jets, AntiK_T R=0.4
EM Topo Jets, AntiK_T R=0.4
EM TopoTower Jets, AntiK_T R=0.4
EM Tower Jets, AntiK_T R=0.4
H1 Topo Jets, AntiK_T R=0.6
Response=p_T^reco/p_T^true
p_T^true [GeV]

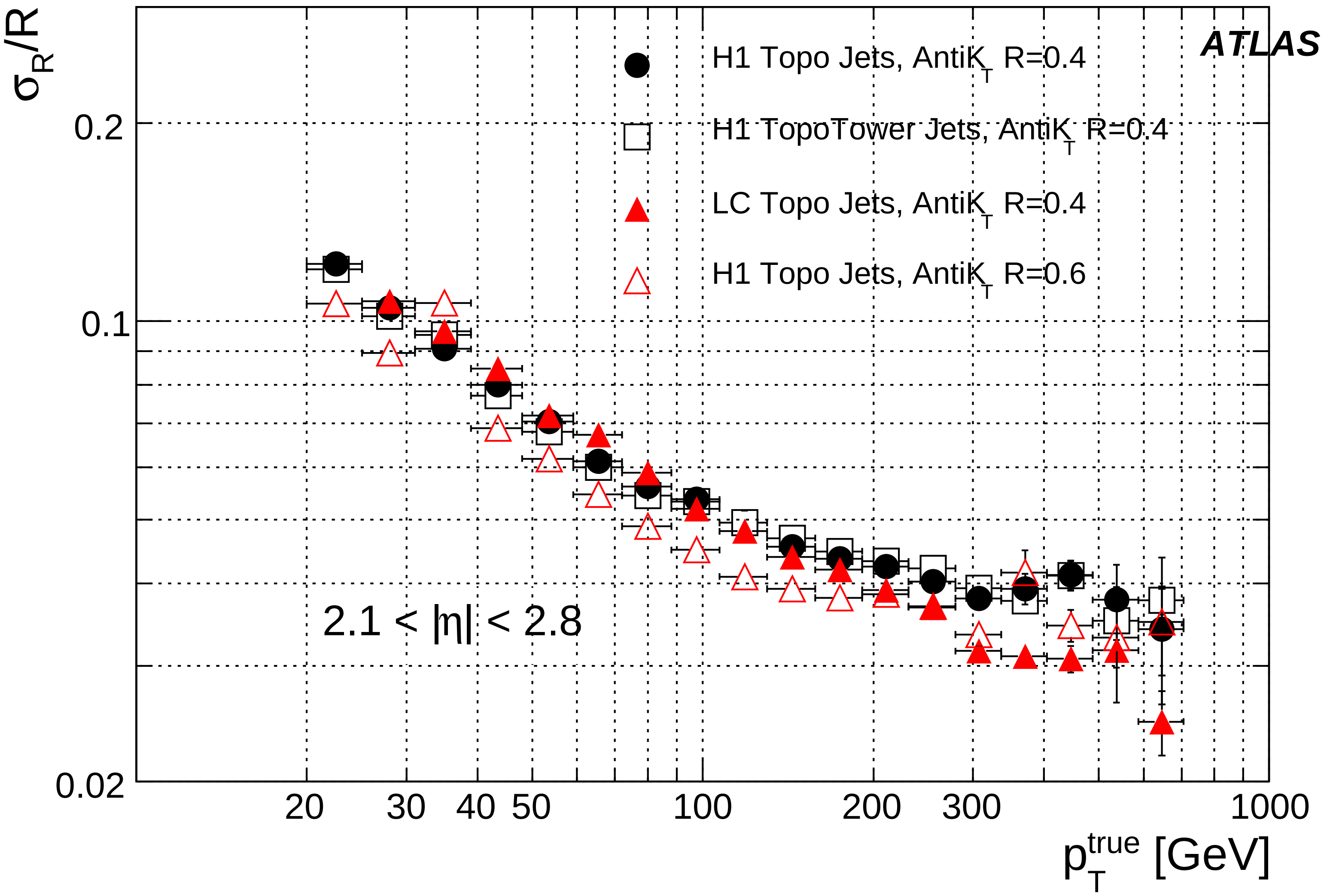
Resolution in η bins:

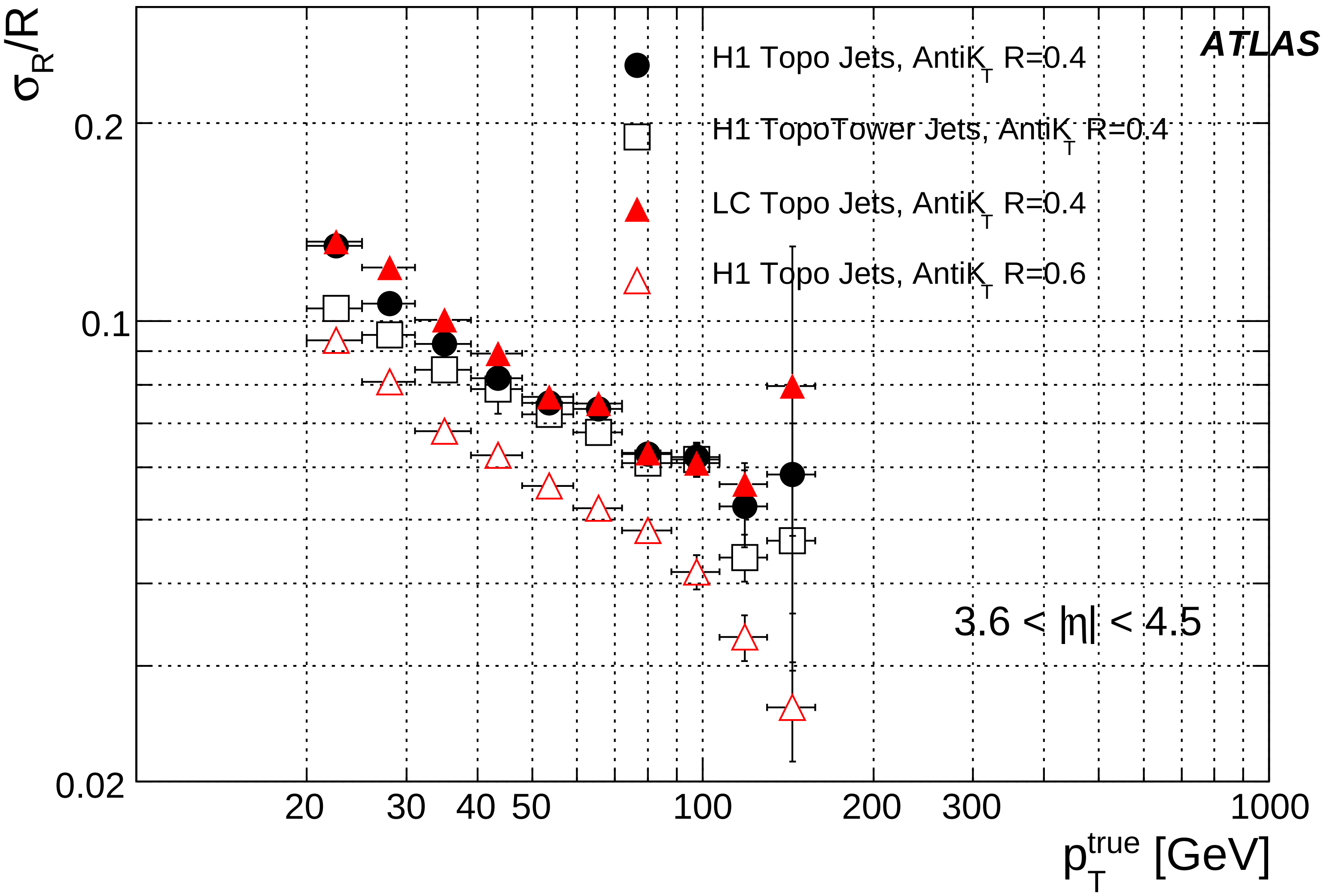


Same plots on expanded scale:




ATLAS
H1 Topo Jets, AntiK$_T$ R=0.4
H1 TopoTower Jets, AntiK$_T$ R=0.4
LC Topo Jets, AntiK$_T$ R=0.4
H1 Topo Jets, AntiK$_T$ R=0.6
0.3 < |η| < 0.8
σ_R/R
0.2
0.1
0.02
20
30
40
50
100
200
300
1000
p_T^{true} [GeV]


ATLAS
H1 Topo Jets, AntiK_T R=0.4
H1 TopoTower Jets, AntiK_T R=0.4
LC Topo Jets, AntiK_T R=0.4
H1 Topo Jets, AntiK_T R=0.6
2.1 < |η| < 2.8
σ_R/R
0.2
0.1
0.02
20
30
40
50
100
200
300
1000
p_T^true [GeV]



ATLAS
H1 Topo Jets, AntiK_T R=0.4
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LC Topo Jets, AntiK_T R=0.4
H1 Topo Jets, AntiK_T R=0.6
3.6 < |η| < 4.5
σ_R/R
0.2
0.1
0.02
20
30
40
50
100
200
300
1000
p_T^true [GeV]

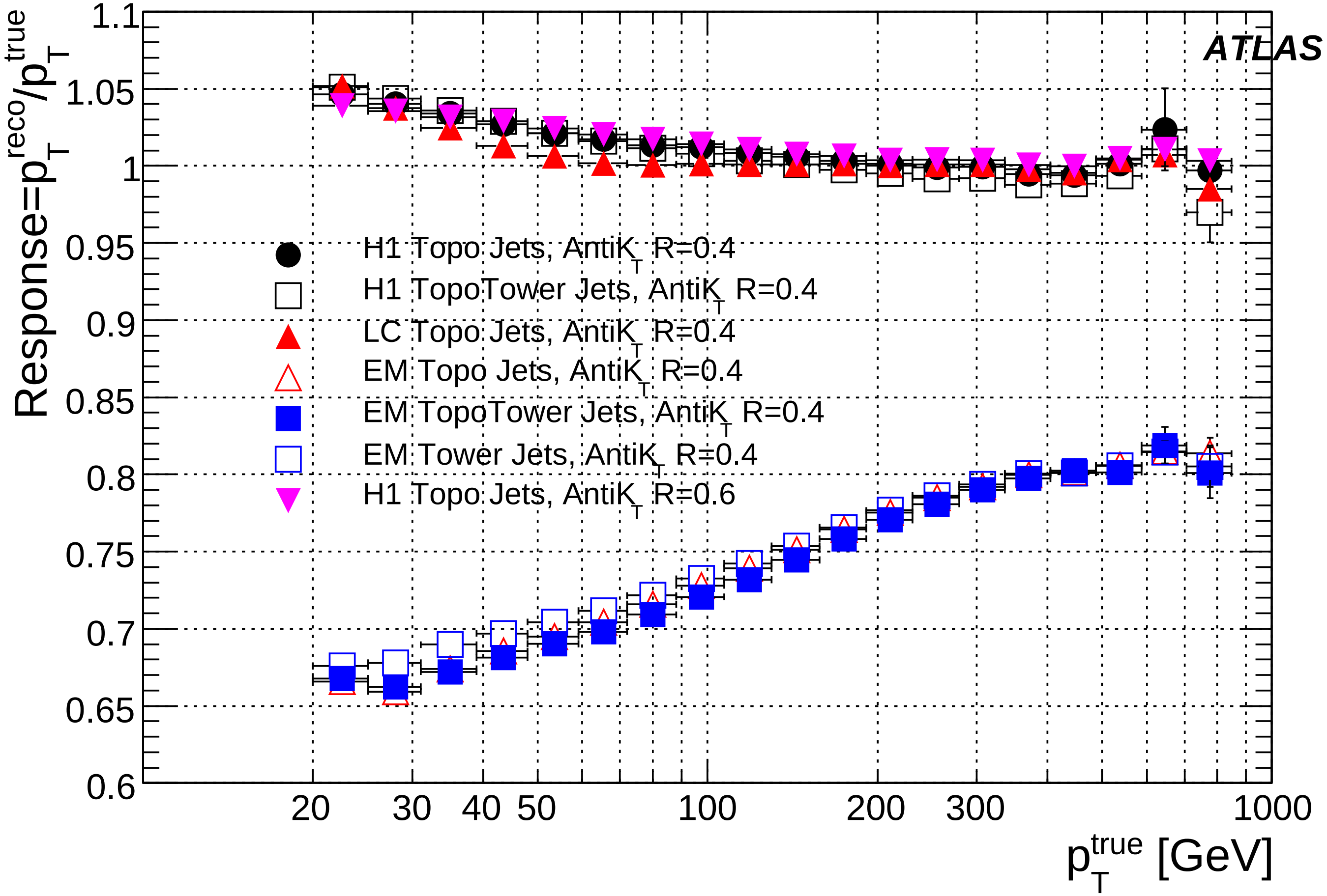
Linearity is good as expected: numerical inversion is not perfect, but deviations smaller than effect of different samples.

Linearity and resolution similar for all H1 inputs and LC.

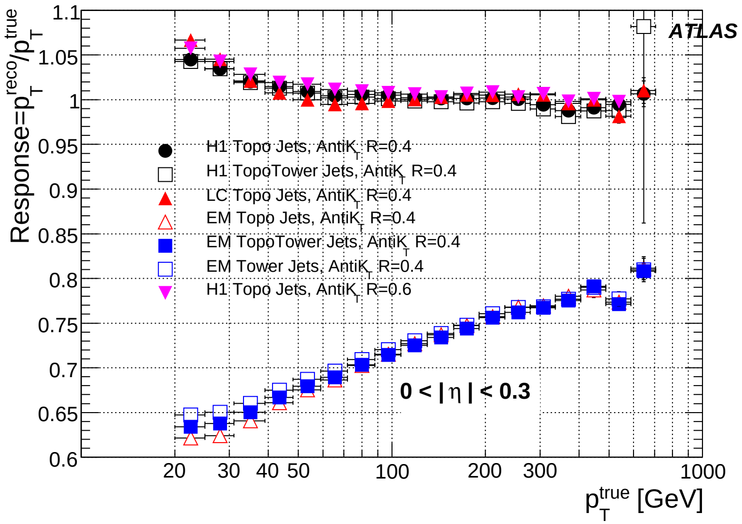
High-p_T FCAL resolution for AntiKt6 H1 seems better than constant term. RMS larger than Gaussian fit but still small. Hadronic shower size in FCAL $\Rightarrow$ do expect better resolution for larger R [P. Loch].

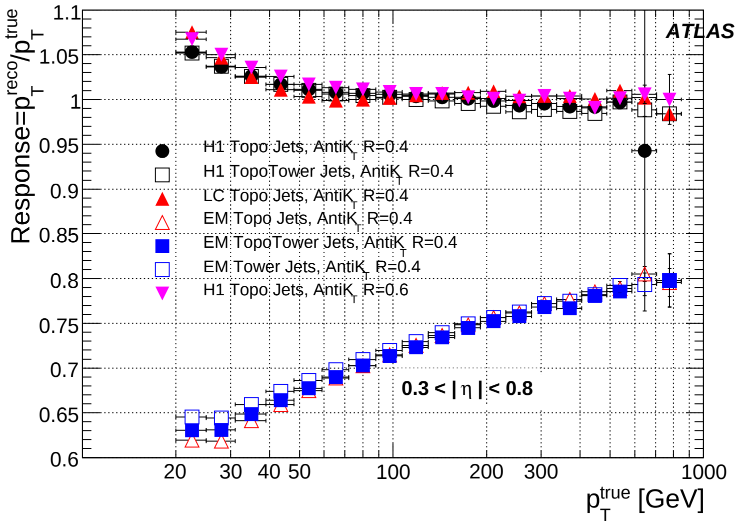
Comparison with Other Samples

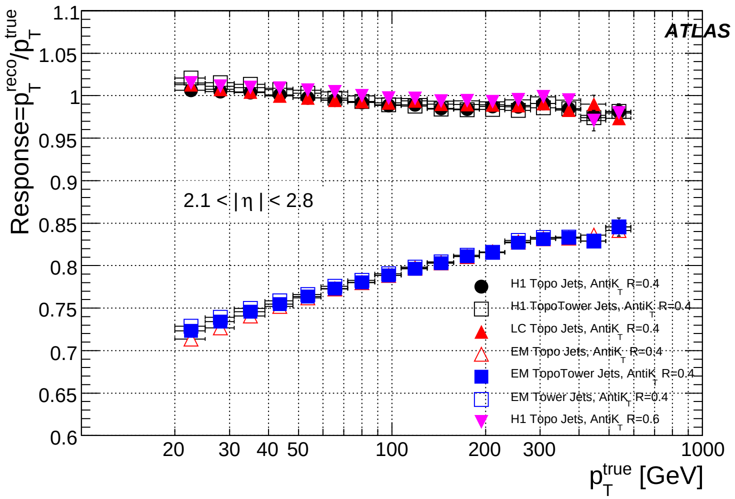
Crucial! Can achieve perfect scale — even perfect resolution — for specific sample with enough parameters. Linearity for $t\bar{t}$ [C. Doglioni]:

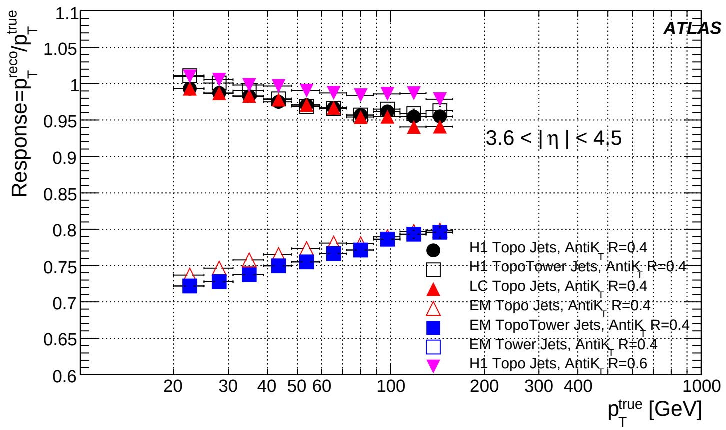


Linearity for $t\bar{t}$ in η bins after e removal:

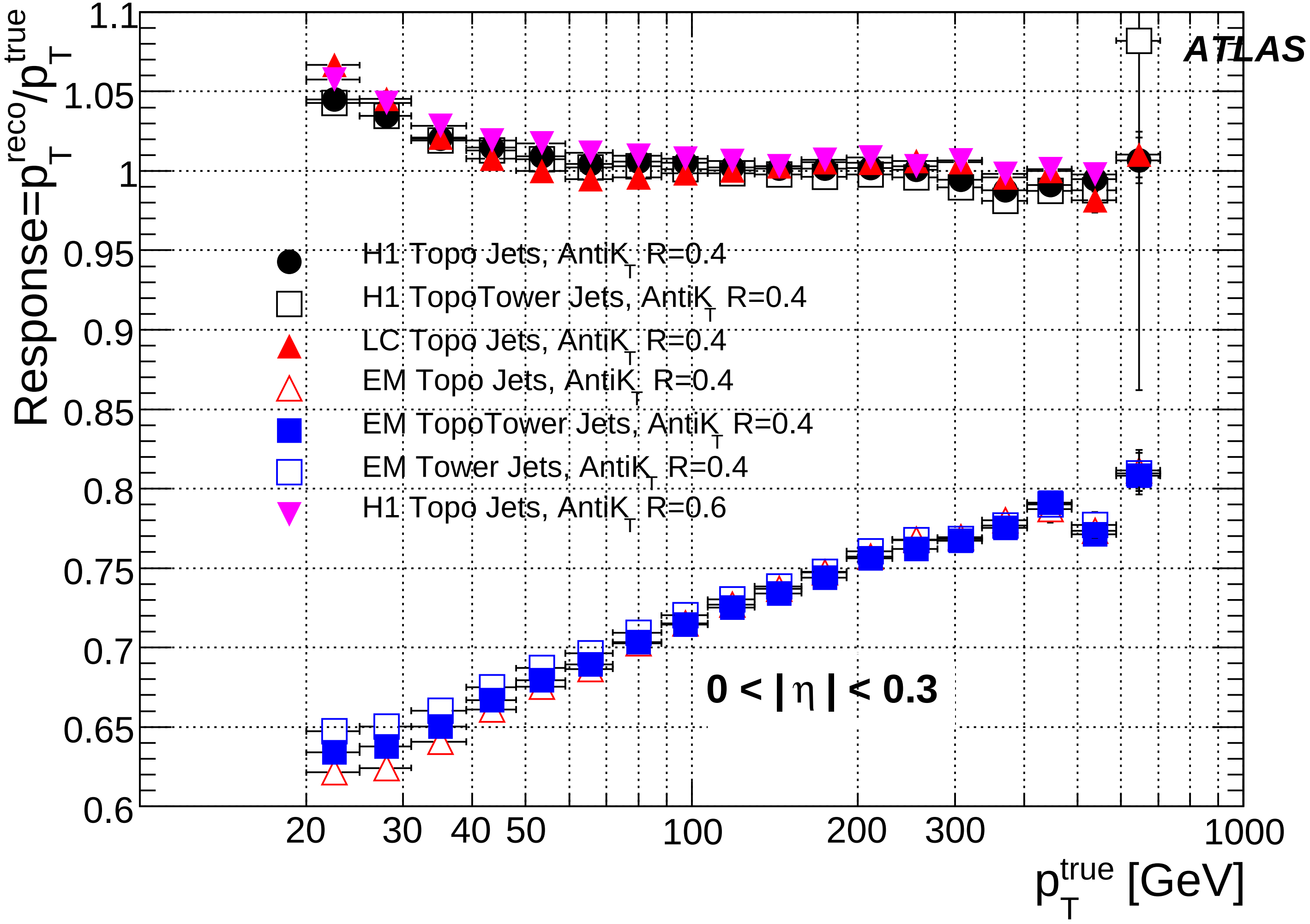


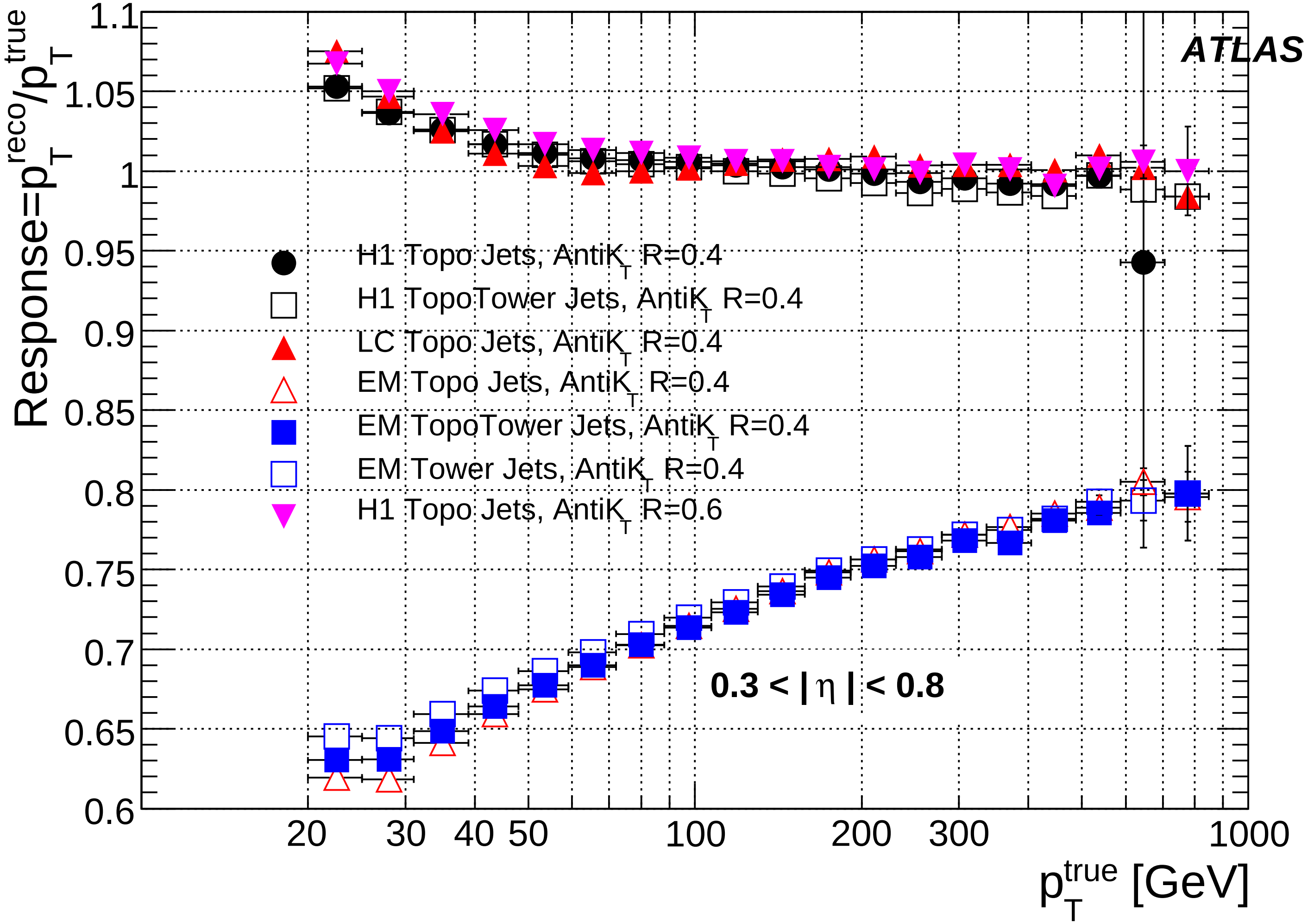






Same plots on expanded scale:

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p_T^{true} [GeV]
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EM Tower Jets, AntiK$_T$ R=0.4
H1 Topo Jets, AntiK$_T$ R=0.6
0.3 < | η | < 0.8
1.1
1.05
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0.65
0.6
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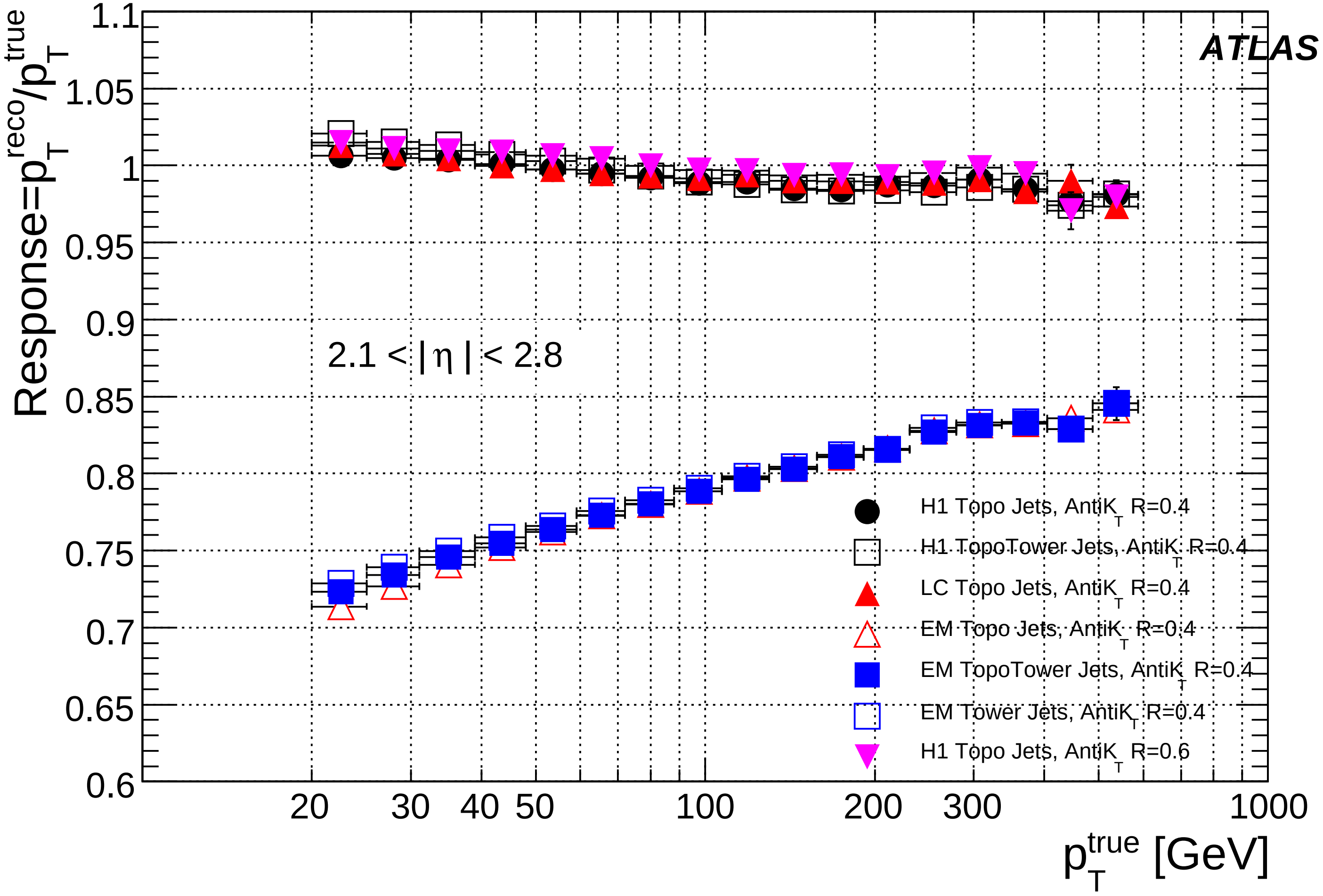

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p_T^{true} [GeV]
2.1 < |η| < 2.8
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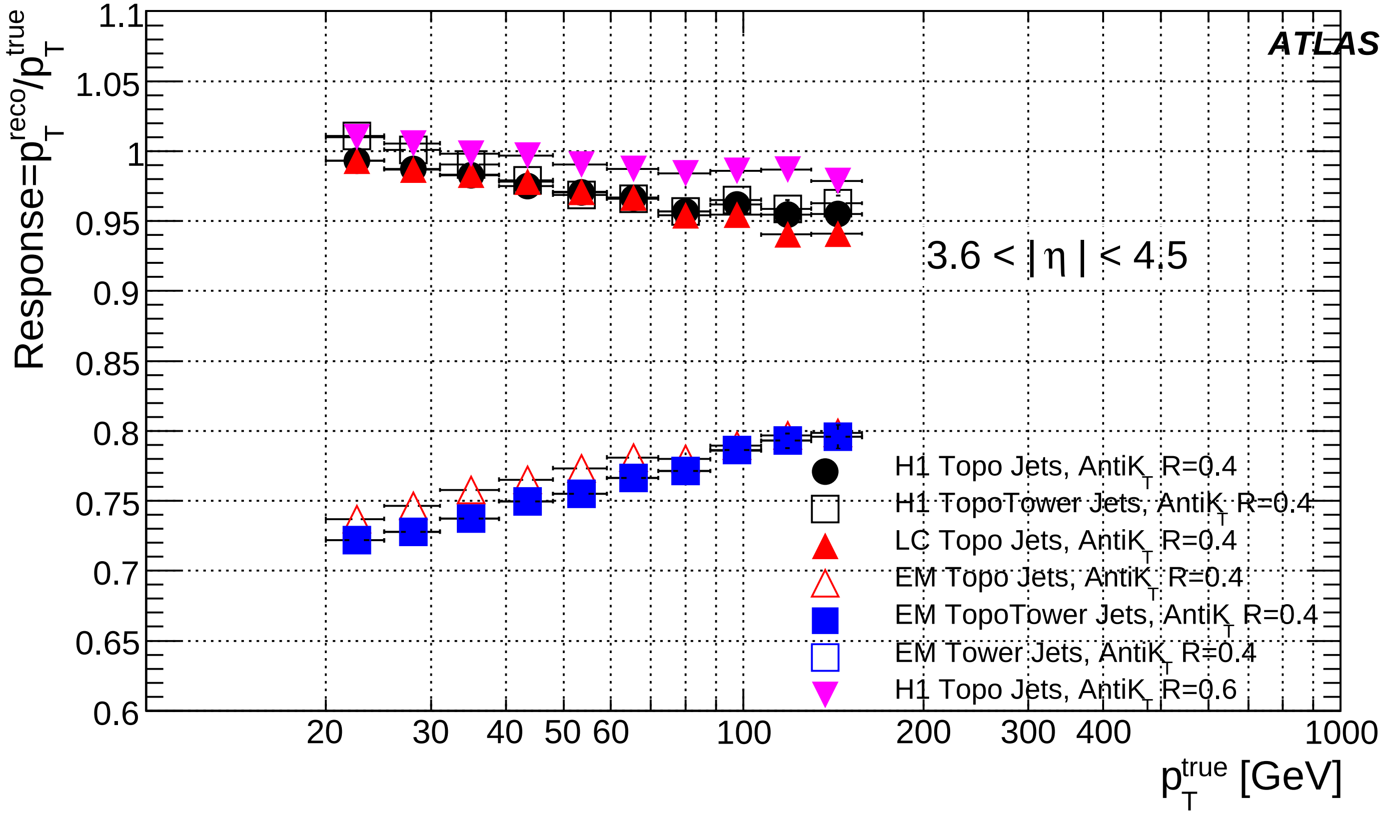
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EM Tower Jets, AntiK$_T$ R=0.4
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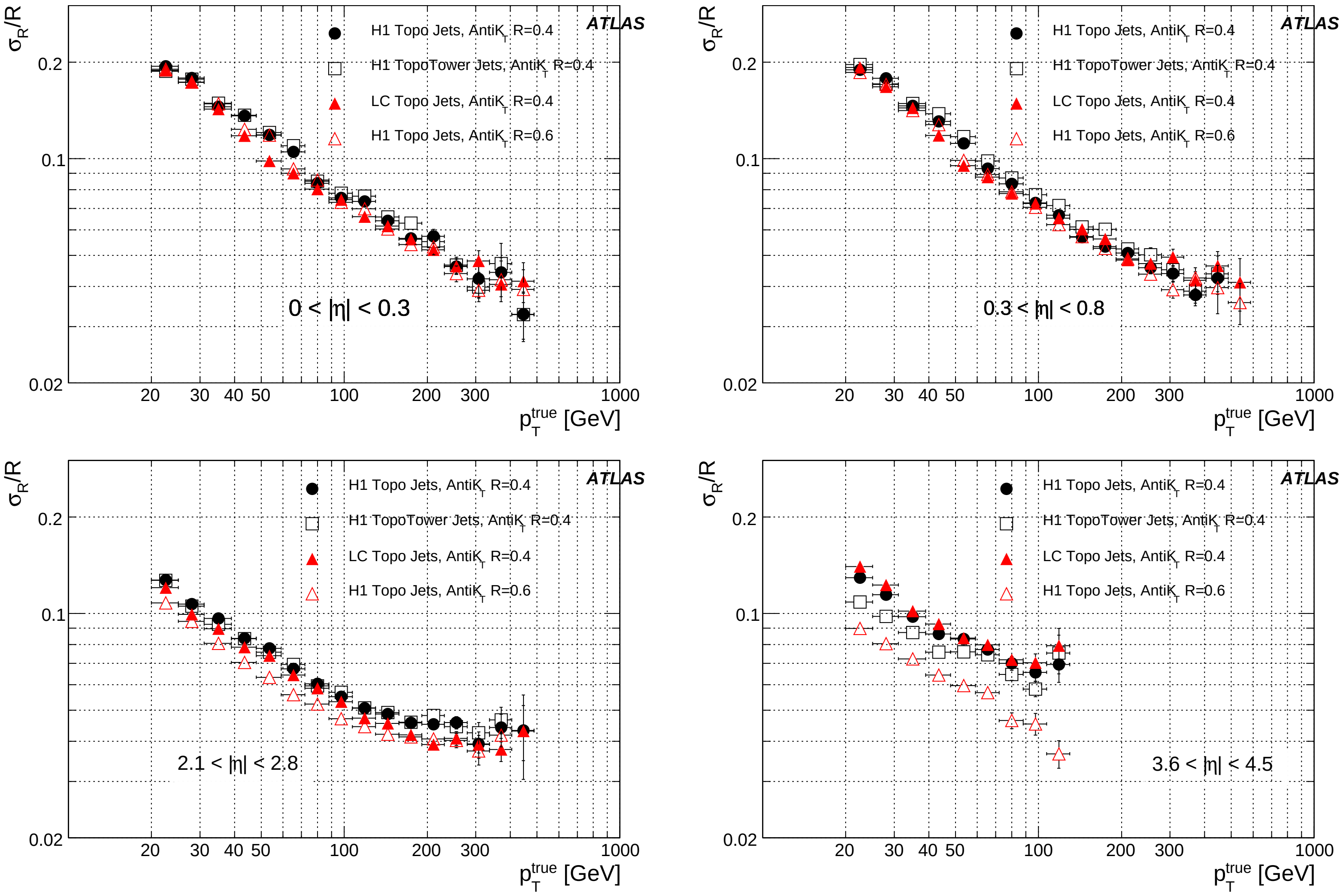
Resolution for $t\bar{t}$ in η bins:



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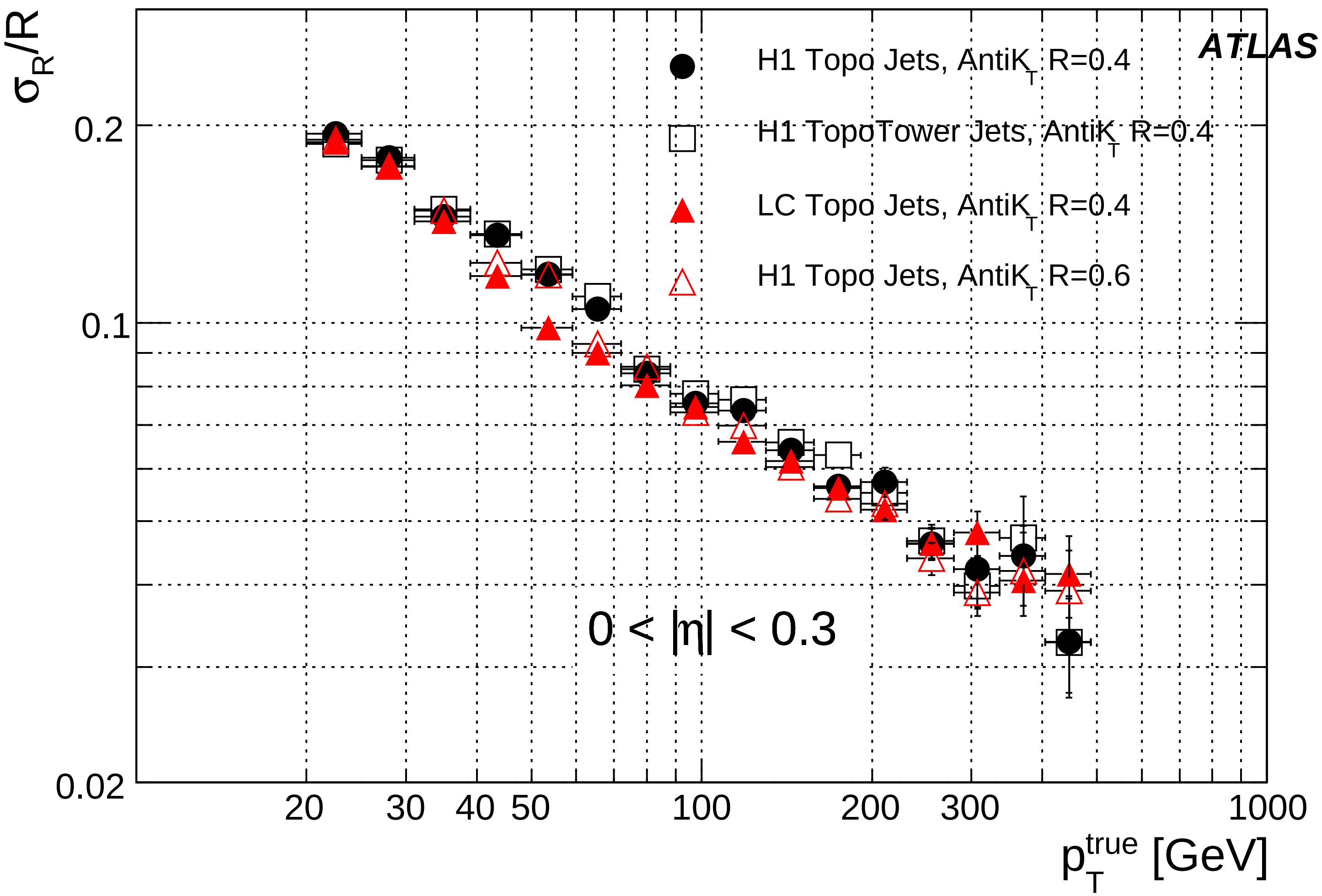

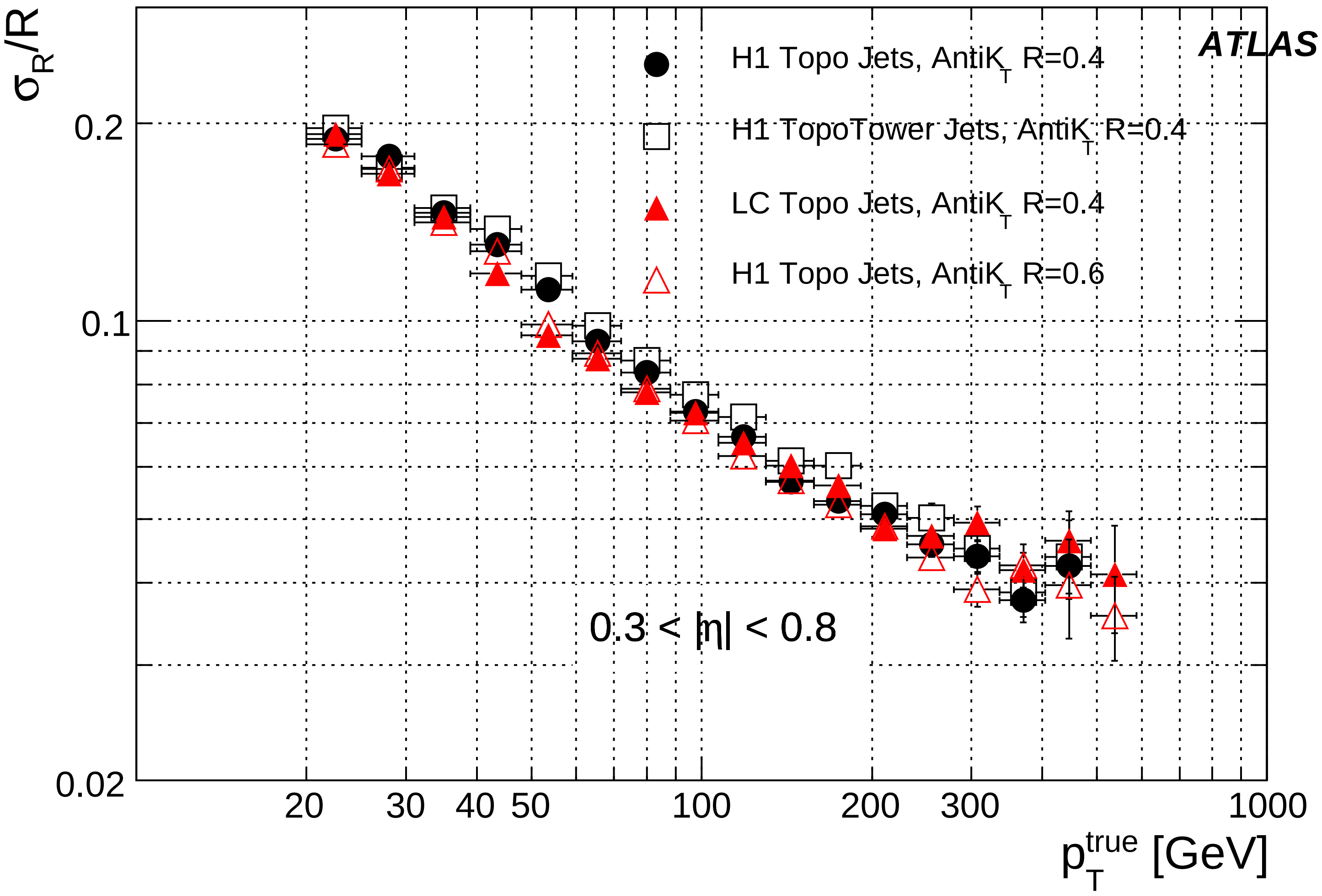
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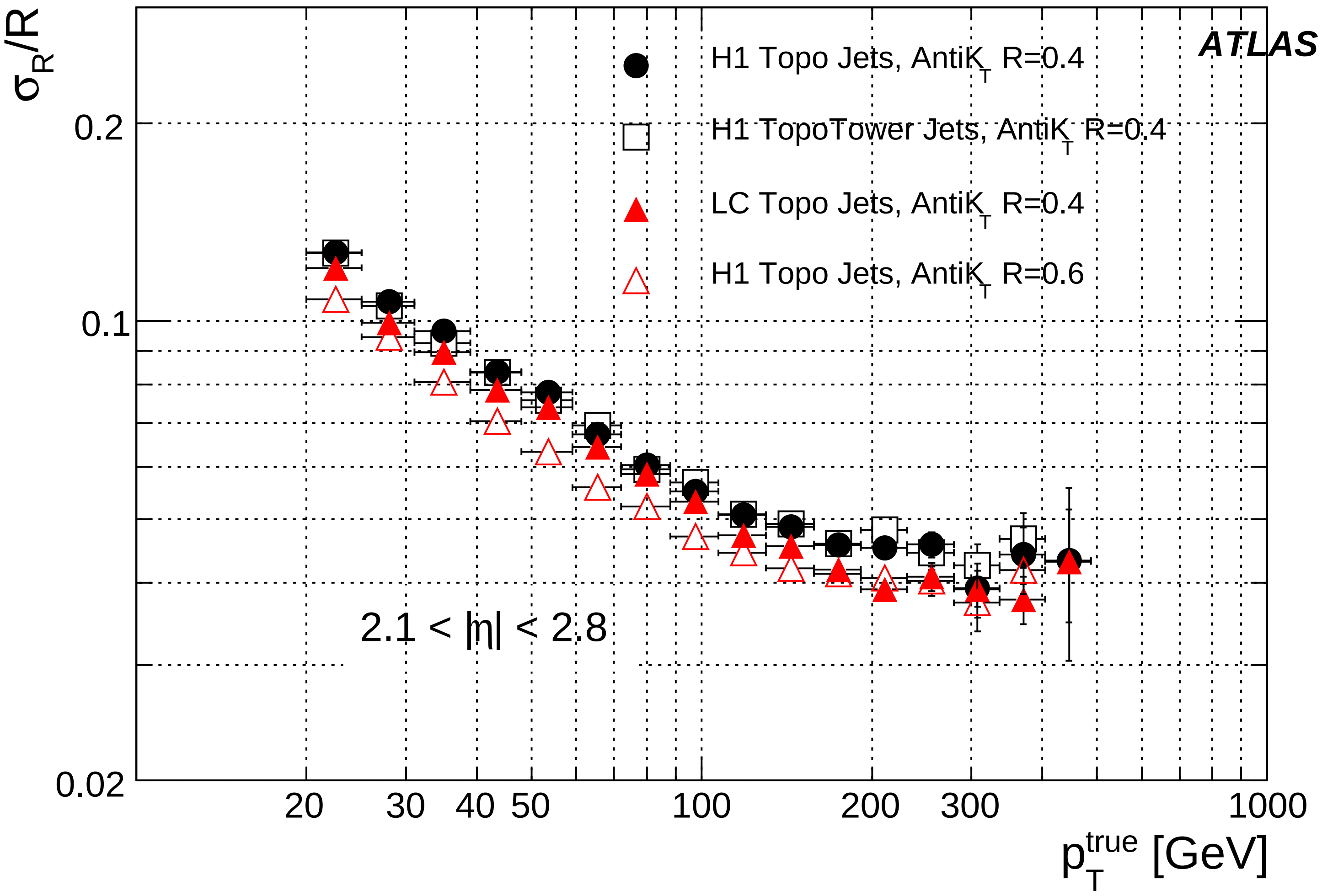
H1 Topo Jets, AntiK$_T$ R=0.6
0.3 < |η| < 0.8
σ_R/R
0.2
0.1
0.02
20
30
40
50
100
200
300
1000
p_T^{true} [GeV]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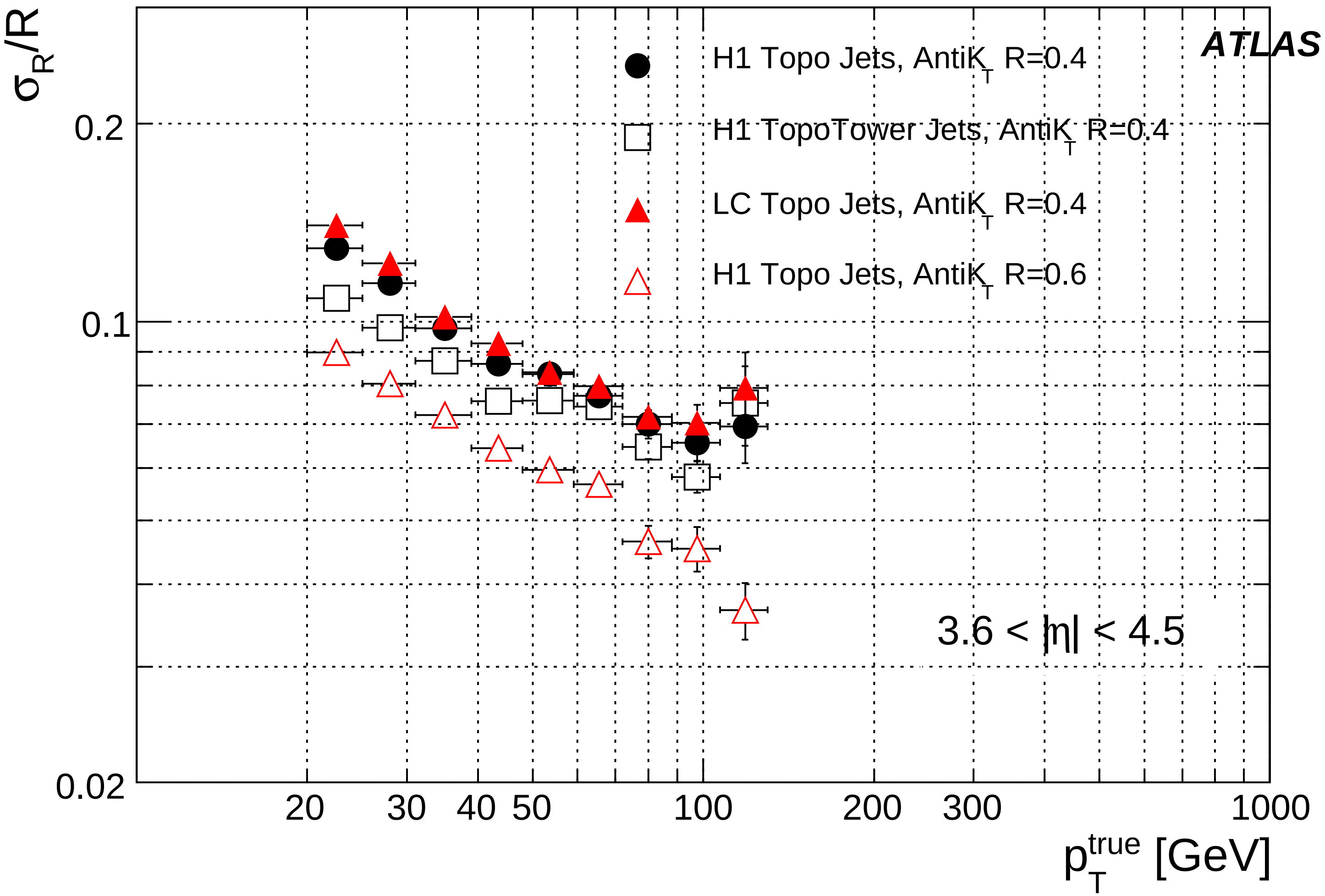
p_T^true [GeV]



σ_R/R
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0.1
0.02
ATLAS
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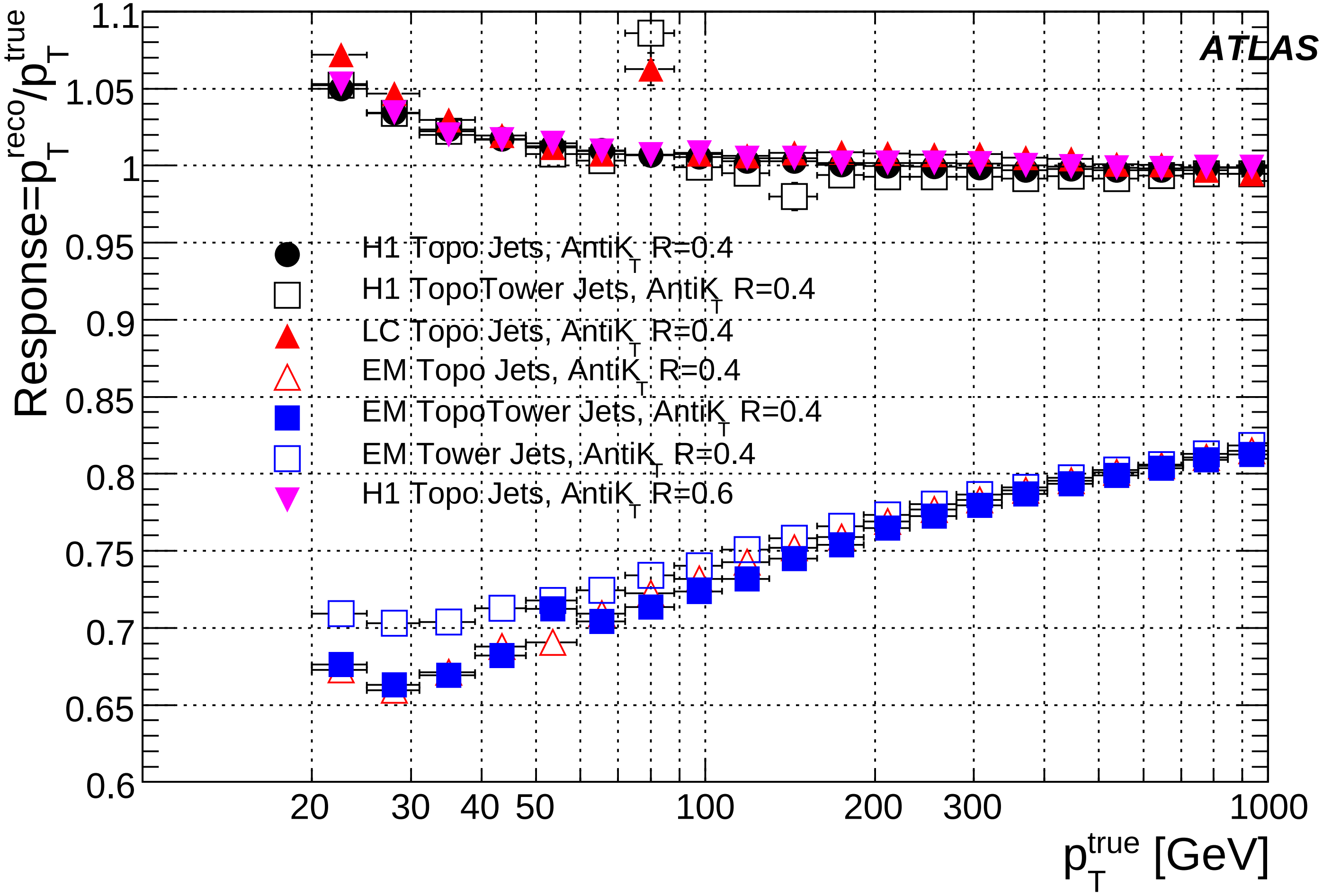
H1 TopoTower Jets, AntiK$_T$ R=0.4
LC Topo Jets, AntiK$_T$ R=0.4
H1 Topo Jets, AntiK$_T$ R=0.6
3.6 < |η| < 4.5
20
30
40
50
100
200
300
1000
p_T^{true} [GeV]

Linearity for QCD jets with 450 ns pileup:



Linearity for $t\bar{t}$ — mainly quark jets from MCNLO/Herwig — within $\sim 5\%$ for $E_T > 25\,\text{GeV}$ and $\sim 2\%$ for $E_T > 50\,\text{GeV}$.

No significant difference among H1 and LC results. (LC somewhat better before e removal.) Jet resolutions for $t\bar{t}$ and QCD jets also similar.

Linearity with pileup looks similar. Might expect opposite shift, since pileup adds more soft particles, while $t\bar{t}$ quark jets are harder.

Should make subtraction for additional events with pileup. More discussion in other sessions.

DISCUSSION

What is realistic goal for Monte-Carlo based jet energy scale?

What do we need for early physics? Perhaps (verified) $\sim 5\%$ — corresponding to $\sim 20\%$ for cross sections?

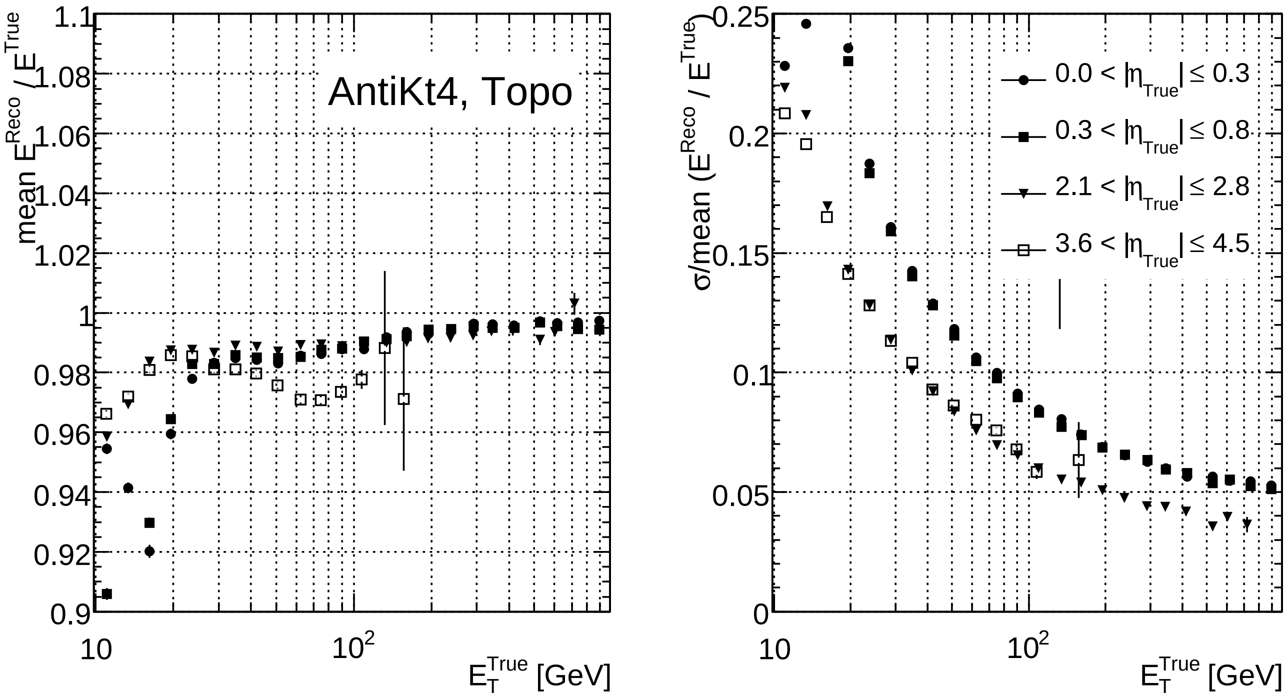
Should we apply calibration (H1 or LC) before finding jets?

What are the relevant criteria for selecting one or more schemes to use with early data? Parametric simplicity? Physics simplicity? Fundamental physics understanding? Ease of tuning with data?

Defer main discussion to Saturday.

No Calibration

Can just find jets at EM scale and apply numerical inversion. Scale and resolution for AntiKt4 jets from TopoClusters [S. Eckweiler]:

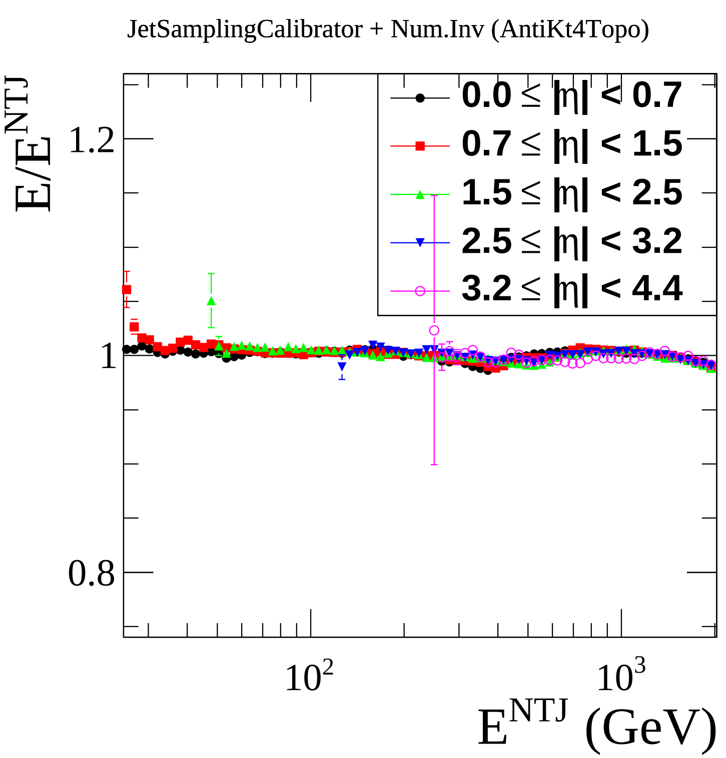


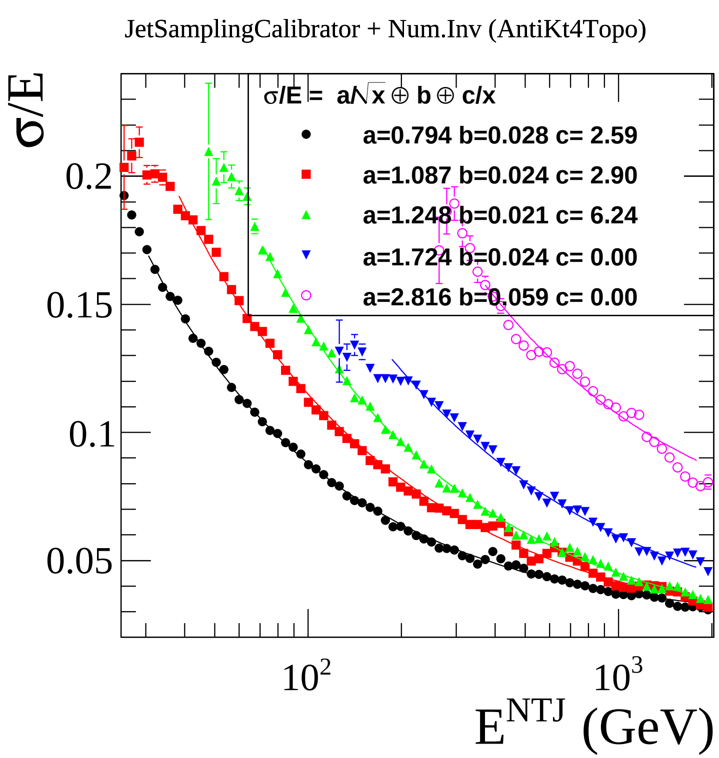
Should test with other samples, e.g., $t\bar{t}$.

Sampling Calibration

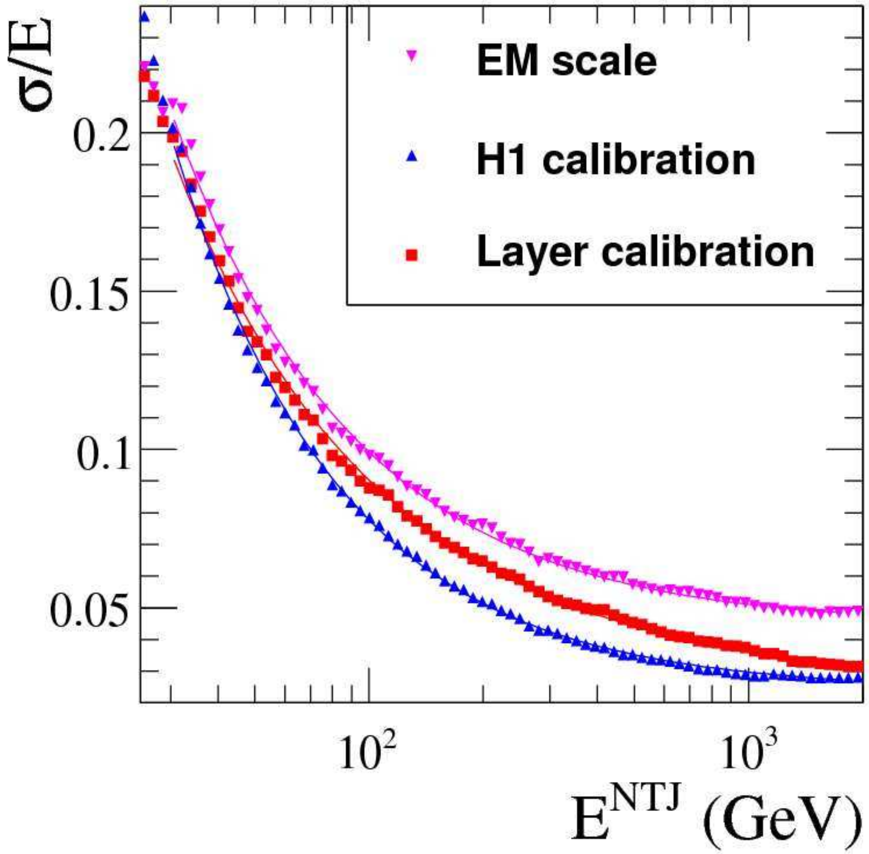
Somewhat simpler than H1: fit each η bin using just sampling layer information. Combine different technologies in same sampling.

Weights refit using current simulation [B. Salvachua]. Results:





Comparison with EM and H1 resolutions (Cone4 jets):



Sampling clearly better than EM scale. Not quite as good as H1 but simpler.

DISCUSSION

Same questions for EM and sampling calibrations as for H1.

Ideas for Improvements

Current calibration probably better w.r.t. Monte Carlo truth than uncertainties in event and detector simulation. But algorithmic improvements still useful.

More H1 Sampling Layers

Default H1 calibration combines, e.g., all Tile and all HEC layers. Originally motivated by reducing number of parameters.

Have tried treating each layer separately using information stored in standard `JetSampling`. Improvement seems small compared to increase in number of parameters.

Including all layers allows common data format for H1 and sampling calibrations.

Better Weight Parameterization

Currently use polynomial in $\log E/V$ index to parameterize weights. Tile/HEC cells with large E/V have low statistics; EM cells with low E/V have low weight. Currently use common range for all.

Expect e/h and dead material effects to decrease with higher E_{jet}. Parameterization should reflect this.

Should choose parameterization which approaches constant for large E/V. To avoid instability, exclude E/V values for each sampling with low contributions [Duxfield]. "Inverse polynomial" and "exponential" forms seem better than polynomial.

Needs more study.

Lagrange Multiplier

Can add Lagrange multiplier, i.e.,

$$\chi^2 = \sum_{\text{jets } j} \left[\left(\frac{\sum_{\text{cells } c} w_c E_{T,\,cj}}{E_{T,\,\text{truth}}} - 1 \right)^2 - \lambda \left(\frac{\sum_{\text{cells } c} w_c E_{T,\,cj}}{E_{T,\,\text{truth}}} - 1 \right) \right]$$

Cannot minimize with Minuit, but can solve analytically if w_i are linear functions of parameters p_i. (So incompatible with some w_i parameterizations.)

Reduces bias, especially at low E_T.

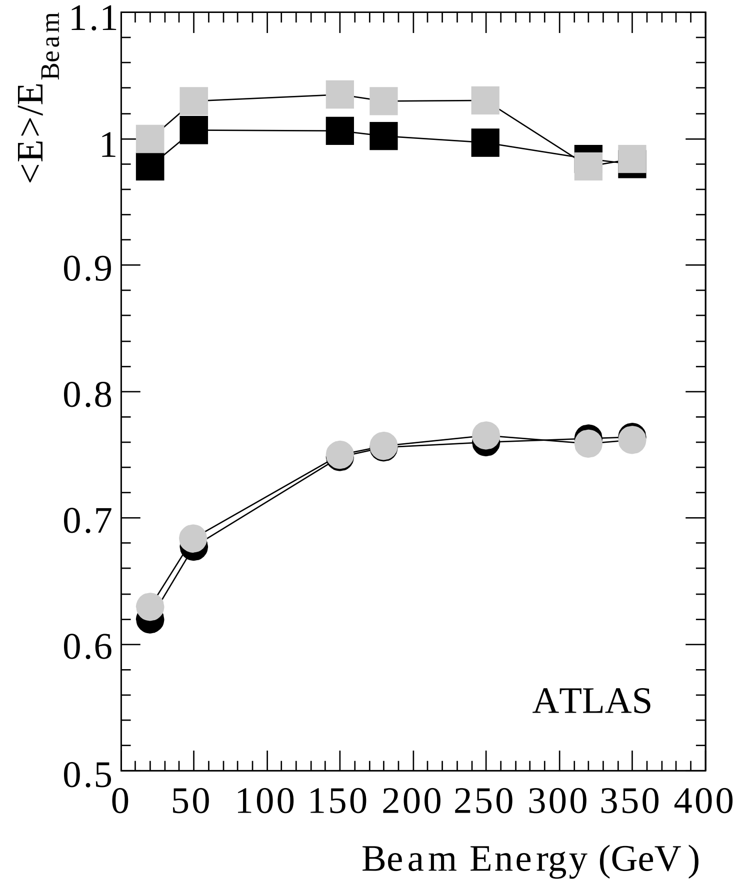
DISCUSSION

What changes/improvements seem most promising?

Several ideas look good, but we need effort to implement them.

Tests with Data

Test beam results (grey) agree pretty well with simulation (black) [CSC Book, p. 308]:



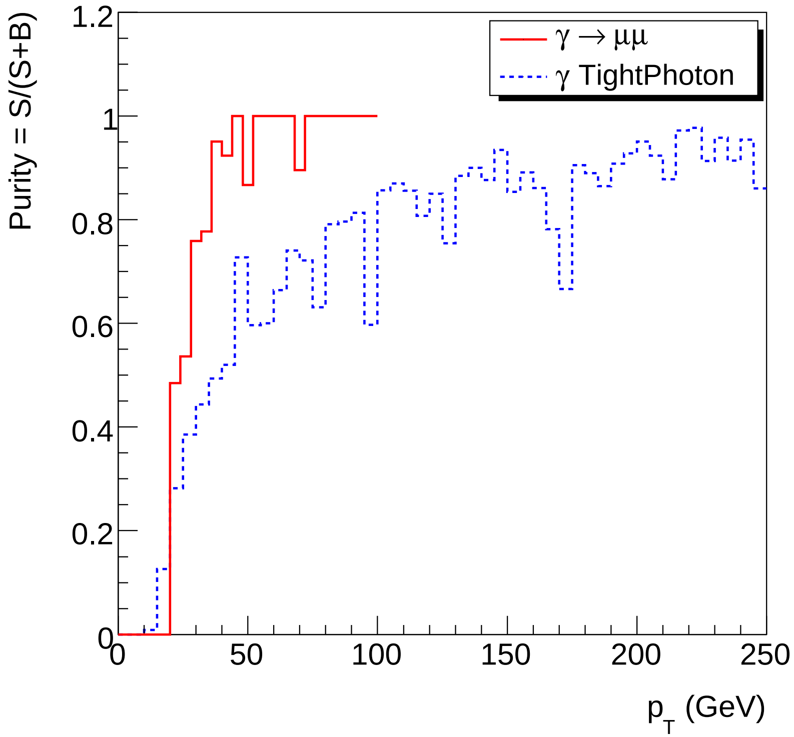
Must test with real jets. Probably $\gamma + \text{jet}$ is best for early data with limited luminosity.

Do not expect perfect balance! Parton shower should be good approximation but must test it. Handles for extra jets ("ISR"):

- $\Delta\phi(\gamma, j)$.
- Calorimeter jet distributions — sensitive to calibration.
- Track jet distributions — limited to $\eta \lesssim 2.5$.
- Underlying event measurements.

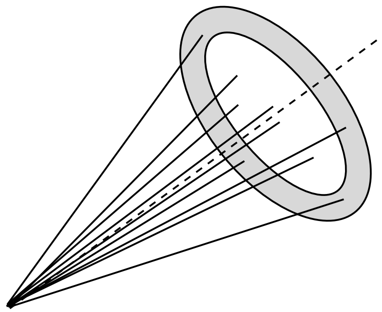
How well do these constrain jet scales? Need sample(s) with different ISR parameters to assess variations? (Possible Iowa State student, K. Yamanaka.)

Reconstructed **TightPhoton** from QCD dijets gives purity of 60–80% for $p_T = 50–100\,\text{GeV}$. Not problem for calibration *if* background is pure π^0's:



Should also consider $W \rightarrow e\nu$ background with missed track.

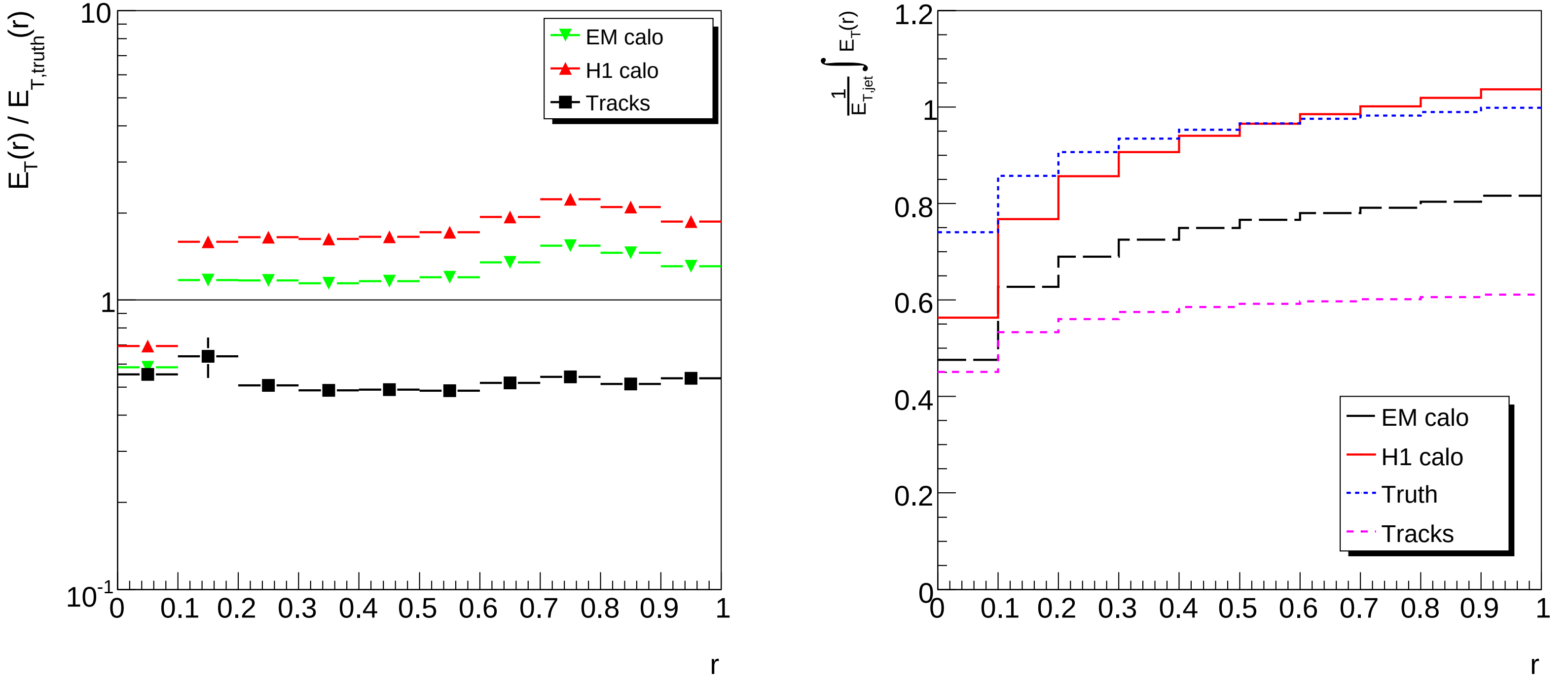
Jet shape affects p_T balance. Can measure using $\sum p_T$ of tracks and cells in annular rings around jet axis:



For tracks require $p_T > 1\,\text{GeV}$, 2 pixel and 7 pixel+SCT hits, and impact parameter cuts w.r.t. primary vertex. Normalize to $\sum p_T$ for truth particles with $p_T > 1\,\text{GeV}$ in same annular regions.

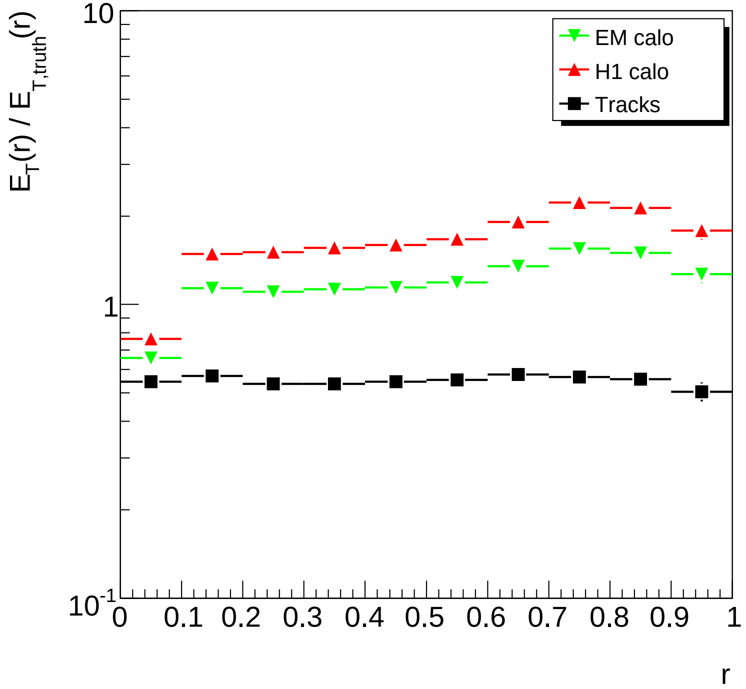
Discard occasional bad tracking ($\sum p_T = 1.8 \times 10^6\,\text{GeV!}$) by requiring $\sum p_T < 2E_{T,\text{jet}}$. Then get good measure from tracks with `e344_s479_r635`.

Results for $p_T = 140\text{–}280\,\text{GeV}$ $\gamma + \text{jet}$ bin:



Calorimeter shape distorted by shower spreading and depends on linearity. But integrated distribution (right) looks OK.

Also OK for QCD J5 sample, 280–560 GeV:



Needs more detailed study. But much better than 13.0.40 results.

DISCUSSION

What do we need to do to make an estimate of the scale uncertainty from $\gamma +$ jet or other samples?

What uncertainty is needed for early physics?

Many jet measurements could be good thesis topics for students wanting to graduate with early data. Should facilitate this.

Scale and Resolution in EDM?

Users need estimates of scale uncertainty and expected resolutions.

Should at least provide average scale uncertainty and resolution as functions of p_T and η.

Would optimally like scale and resolution including everything relevant — cells, tracks, underlying event, vertices, luminosity, . . . — for each jet in each event.

Is this possible? What EDM structure would be required?