γ-jet balance

Contribution to the Hadronic Calibration Workshop

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with discussions and help from

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&

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Introduction

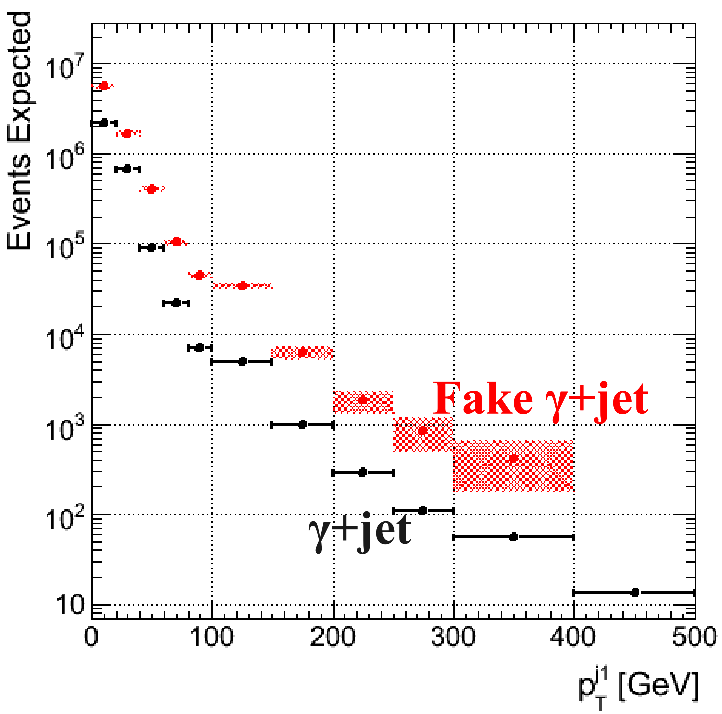
- We use "clean" γ-jet events to construct an estimator of p_T^γ, given p_T^j. The hope is that $p_T^\gamma \approx p_T^{j,Truth}$. If so, then we are essentially using data to derive an estimator of the truth-level energy.Caveat:
  - $p_T^{j,Truth} \approx p_T^\gamma$ + underlying event – 'out-of-cone' ± radiated soft jets.
- This estimator is expected more precise in clean γ-jet events than in other final states, because
  - jets in γ-jet are typically quark-jets,
  - the underlying event may depend on the hard-process,
  - jet reconstruction is influenced by how "busy" the event is.
- The estimator is based on Numerical Inversion.
- The performance is examined in 2 ways:
  - Closure test: does the estimator return p_T^γ in the γ-jet events with which it was built?
  - The real battle: does the estimator return $p_T^{j,Truth}$ in QCD events?

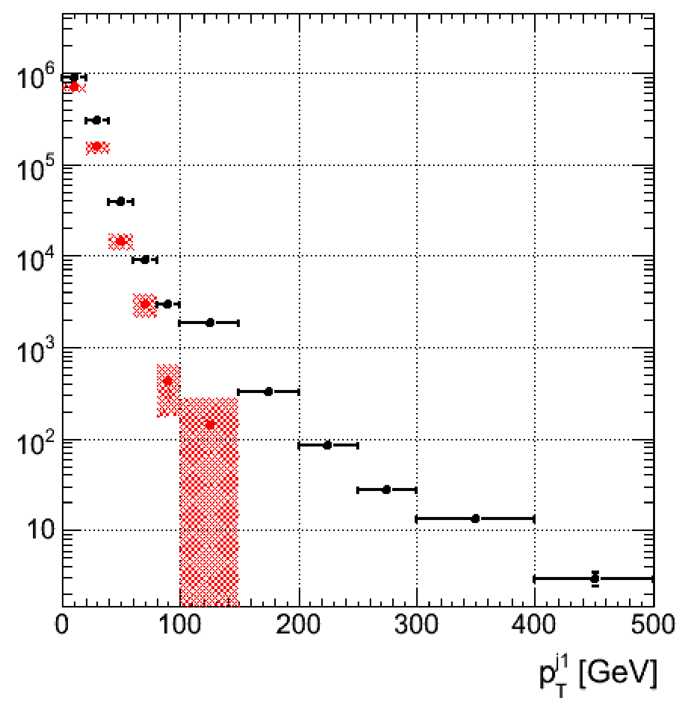
A disclaimer

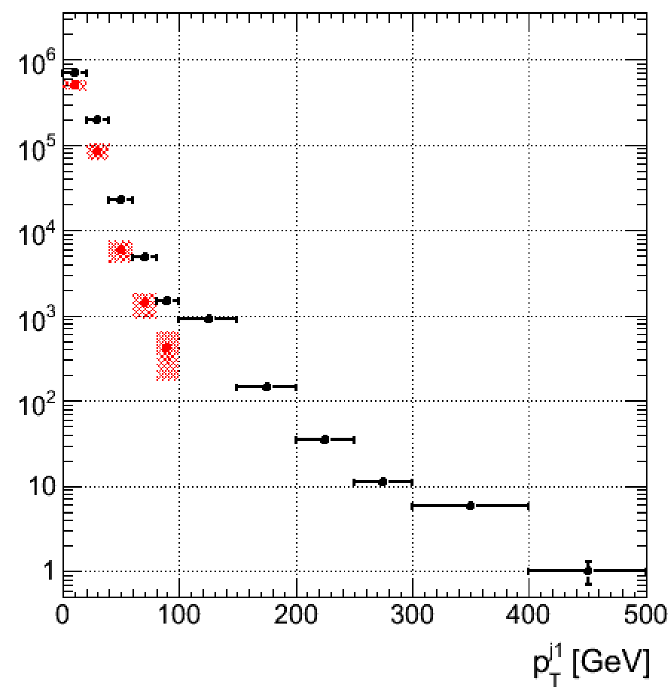
- This is a somewhat optimistic presentation.
  - QCD contamination of the γ-jet finals state has been studied, but MC statistics are not enough yet for very nice results, so we left QCD out of the game.
  - Pile-up is also out of the game, due to technical reasons that threw us off schedule.
- We always apply the dijet η-intercalibration. When we say "EM-scale", we mean "η-equalized EM-scale". Same for all 6 jet collections shown here.
  Thanks to Pavel Weber.

Expected data statistics

- In the following plots we use our full MC sample (Koji's D2PDs). At least, let's show how many γ-jet events we expect:







L=100 pb^{-1}
Events with a tight γ>20 GeV and a leading jet in |η|<5.

L=100 pb^{-1}
Tight γ>20 GeV.
No tracks within ΔR<0.2.
No Ecal>10% within ΔR<0.2
j2 pT < 15 GeV.
Δφ>2.9
Leading jet in |η|<3.

cuts of choice

L=100 pb^{-1}
Tight γ>20 GeV.
No tracks within ΔR<0.2.
No Ecal > 10% within ΔR<0.2
j2 pT **< 7 GeV** (= no j2 at all).
Δφ>2.9
Leading jet in |η|<3.

Construction of the estimator using Numerical Inversion

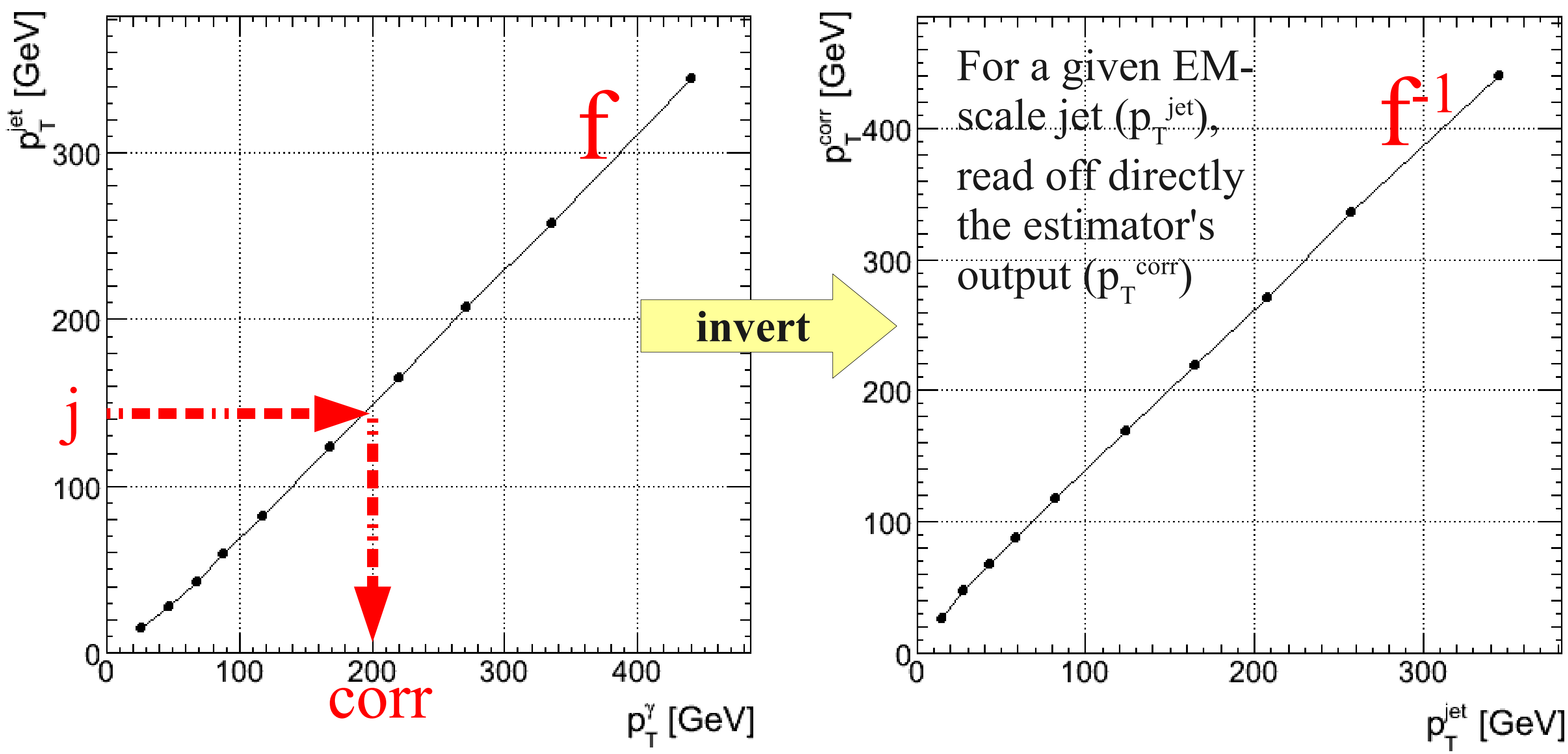
notation

$\gamma = p_T^{\gamma}$

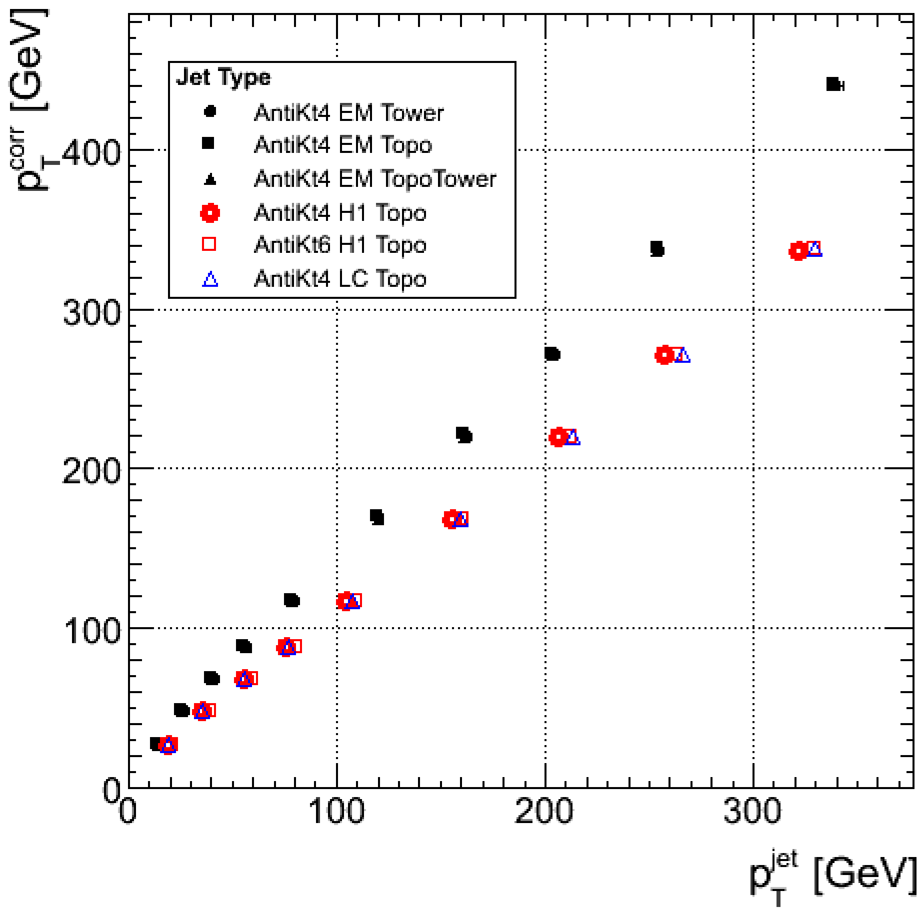
$j = p_T^{jet}$

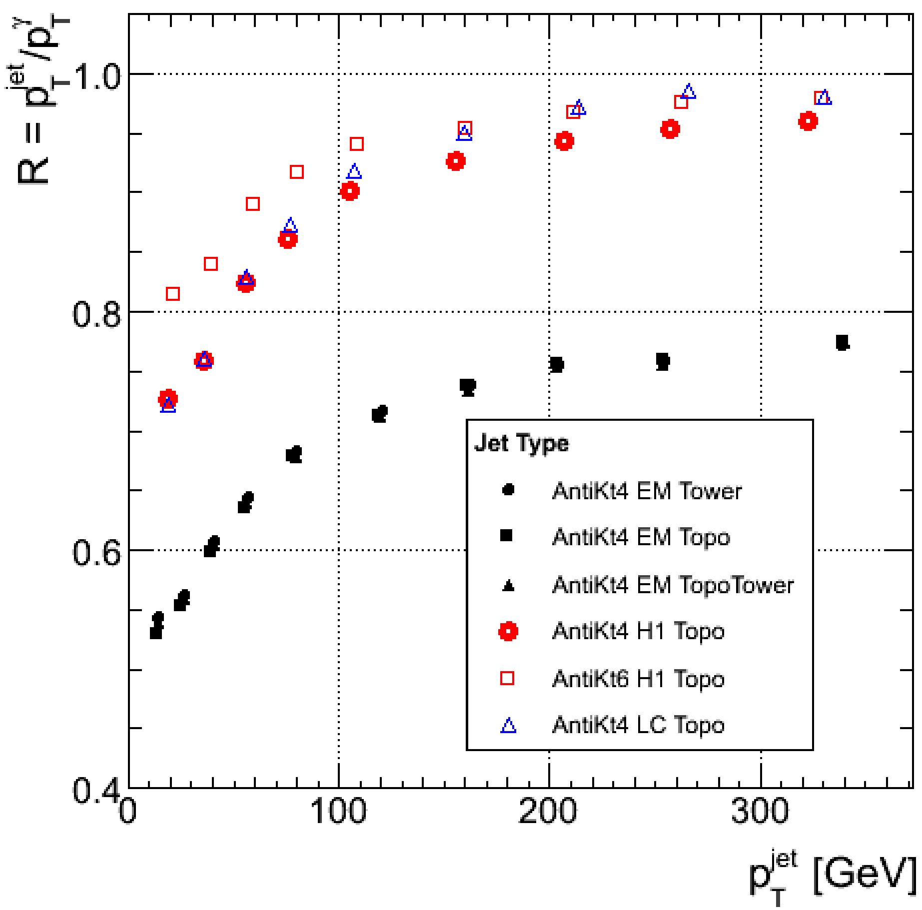
$corr = p_T^{corrected}$

We find average j and γ in bins of γ, and draw the line on the left.
By construction, $\langle j \rangle_{\gamma} = f(\langle \gamma \rangle_{\gamma})$. I define the estimator (corr) like this: f(corr)=j.
This has the property:
$\langle corr \rangle_{\gamma} = \langle f^{-1}(j) \rangle_{\gamma}$ → ***IF*** $f^{-1}(x)$ has the linear property: $\langle f^{-1}(x) \rangle = f^{-1}(\langle x \rangle)$, then
$\langle corr \rangle_{\gamma} = f^{-1}(\langle j \rangle_{\gamma}) = f^{-1}(f(\langle \gamma \rangle_{\gamma})) = \langle \gamma \rangle_{\gamma}$.
So, Numerical Inversion gives unbiased prediction in bins of γ, **provided that** $f(\langle \gamma \rangle)$ is a straight line. Otherwise, there is bias. This may be good to remember generally.



The correction (with Num. Inv.)





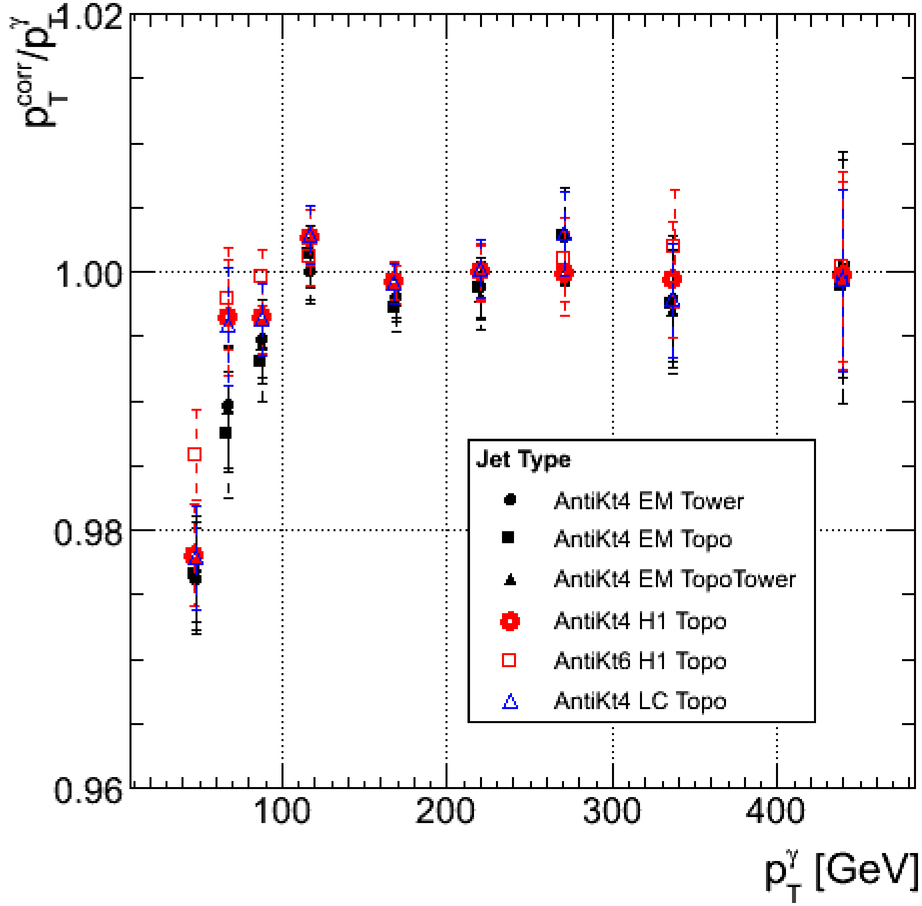
These two plots contain the same information.

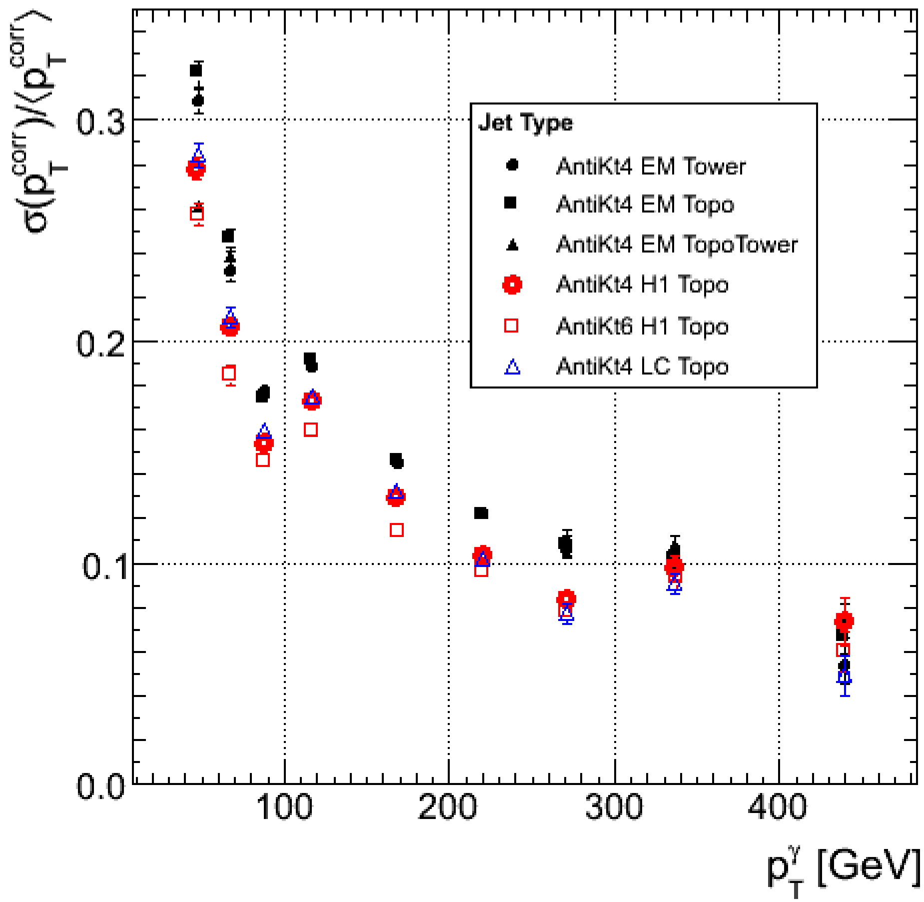
Left : Transposed calibration curve. jet(γ) → γ(jet), and p_T^{Corr} (jet)= γ(jet), which is shown here.

Right: Response curve. $R(p_T^{jet})$ = jet / γ, and $p_T^{corr} = p_T^{jet} / R(p_T^{jet})$.

Closure test

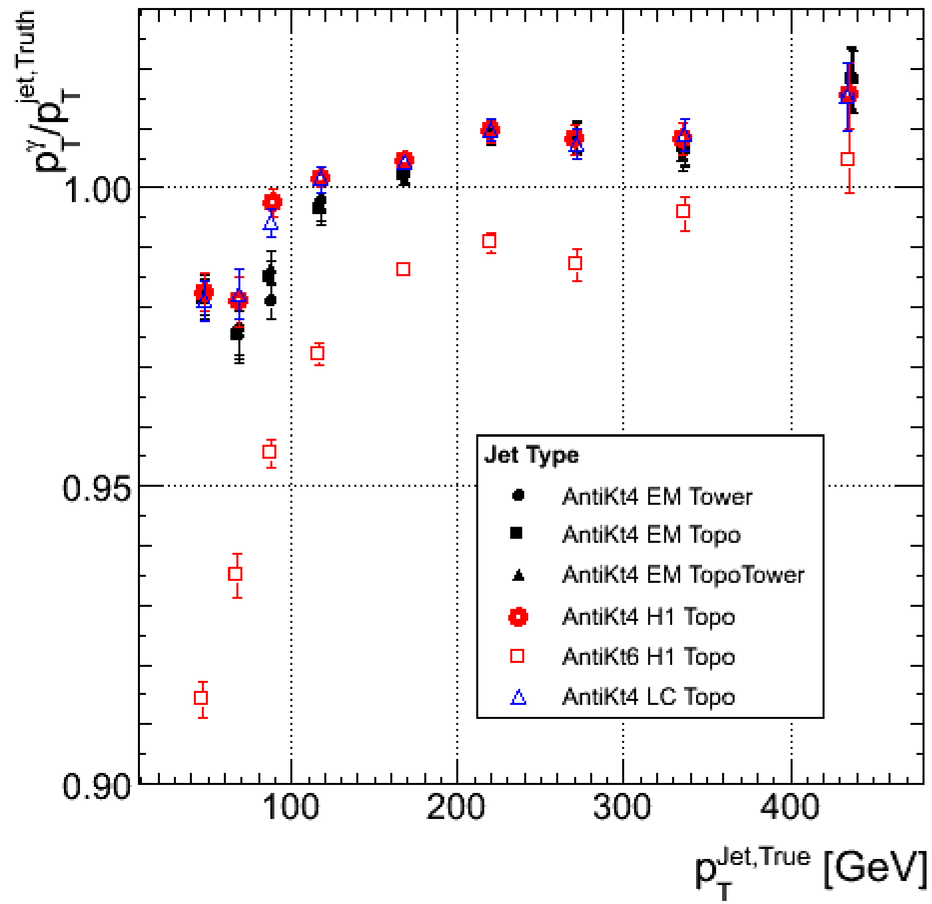
*All σ's used in resolution plots are RMSs.





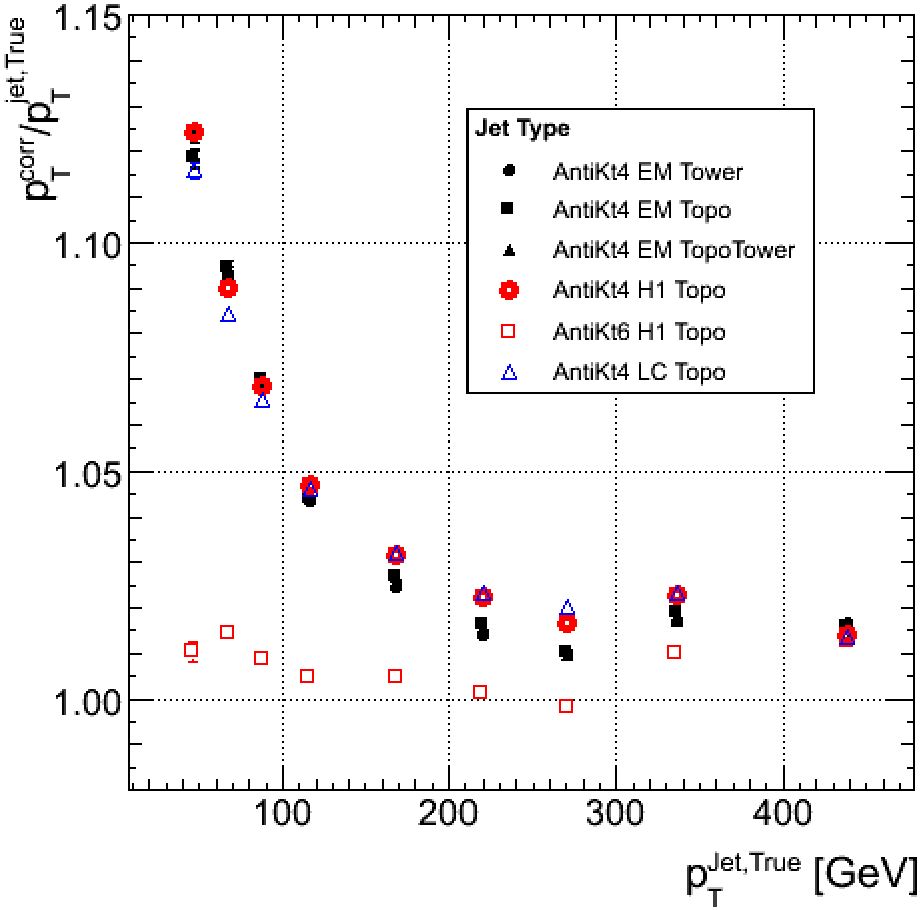
Low p_T deviation is because f(<γ>$_{\gamma}$) bends there. (see previous page).
It bends, because of PYTHIA cut at p_T^{hat} 17 GeV. This is artificial.
Such threshold effects are expected also in the real data. They are enhanced by selecting of p_T^{jet} > 20 GeV for example.

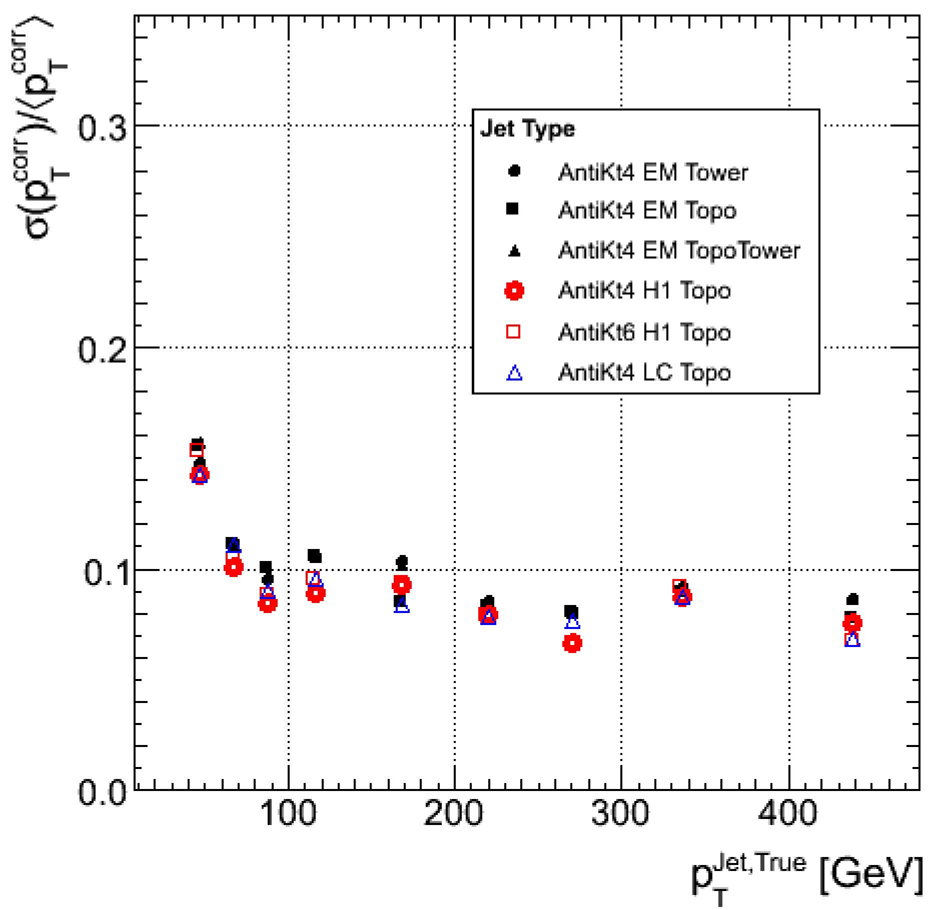
True Balance between γ and jet



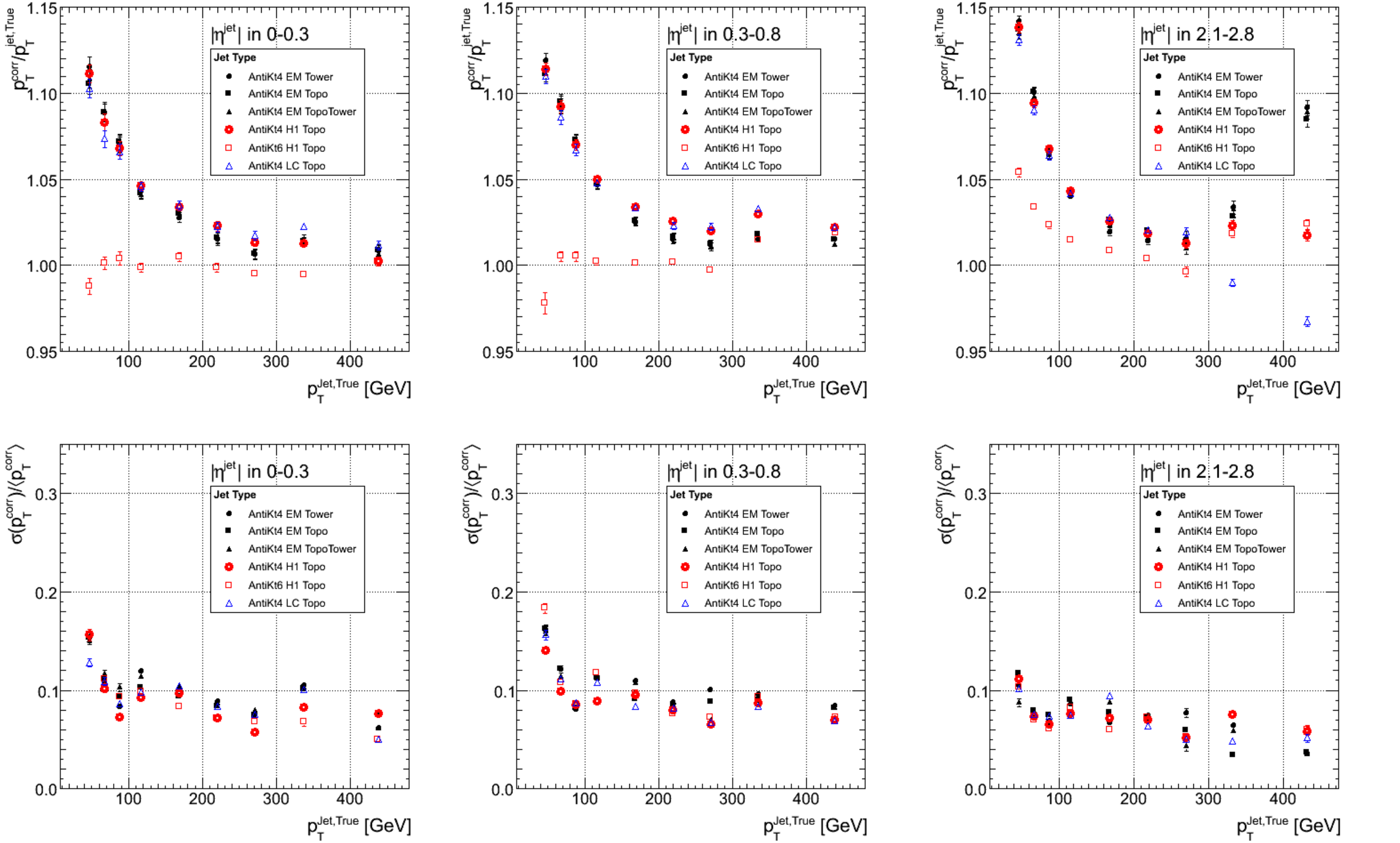
Truth-level balance between p_T^γ and $p_T^{jet,Truth}$ in γ+jet events. Since the γ+jet balance technique tries to estimate $p_T^{jet,Truth}$ by estimating p_T^γ, this plot shows how well it can possibly perform in the γ+jet final state, if there was an *ideal* estimator returning the exact p_T^γ opposite to each jet.

Application in QCD



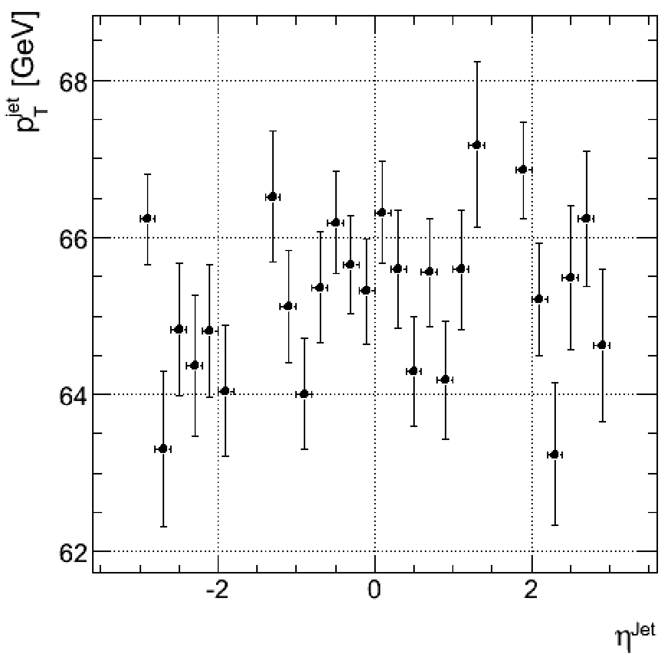


Application in QCD, in $|\eta^{jet}|$ slices

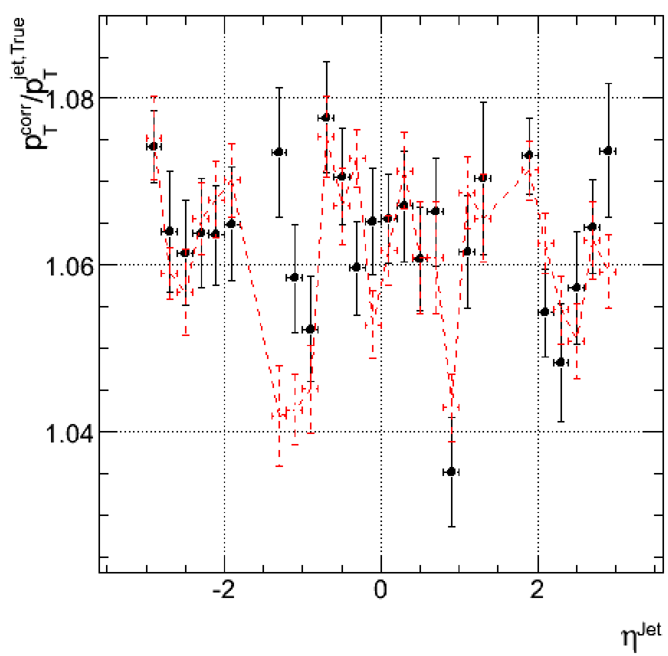


Application in QCD for

AntiKt 4 EM Tower jets of p_T^{Truth} in [80,120] GeV

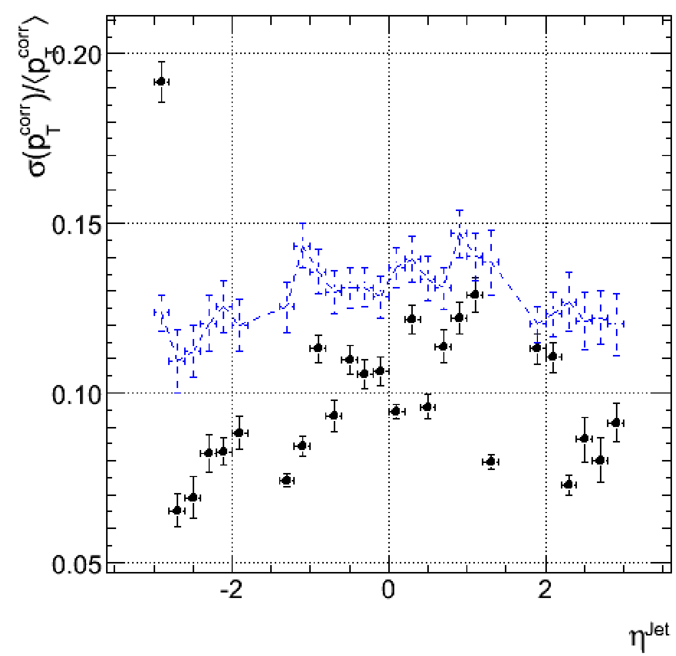


EM-scale vs η.
Intercalibration worked well.



(corrected p_T / truth p_T) vs η.
Flat in η.

black = means
red = gaussian means



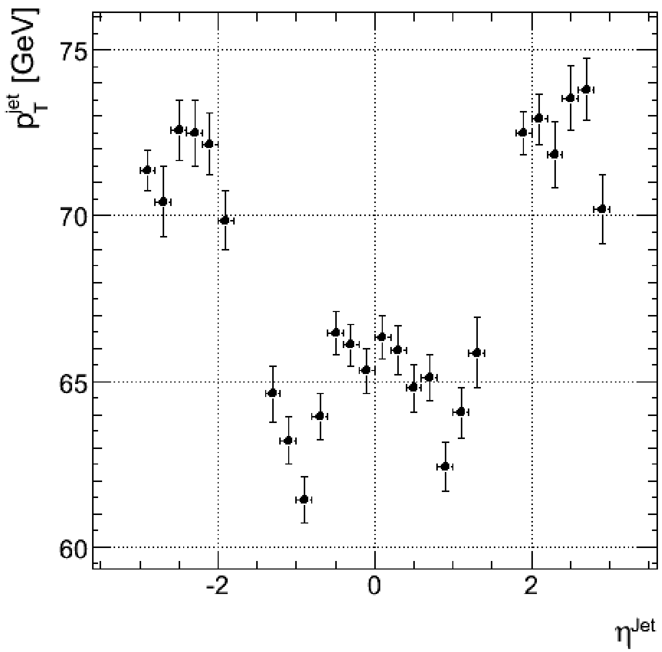
Resolution
Flat in η.

blue = RMS
black = gaussian σ

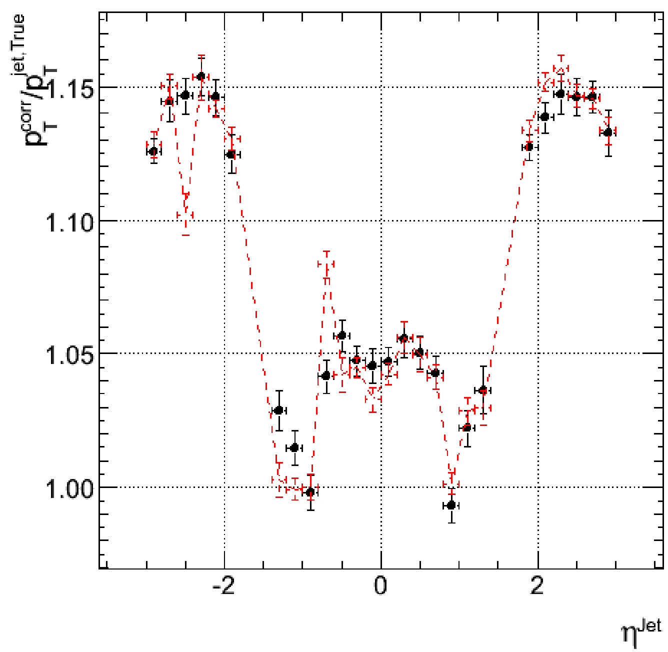
Application in QCD for

AntiKt 4 EM Tower jets of p_T^{Truth} in [80,120] GeV

This is what we ***would*** get just from γ-jet ***if we didn't have intercalibration.***

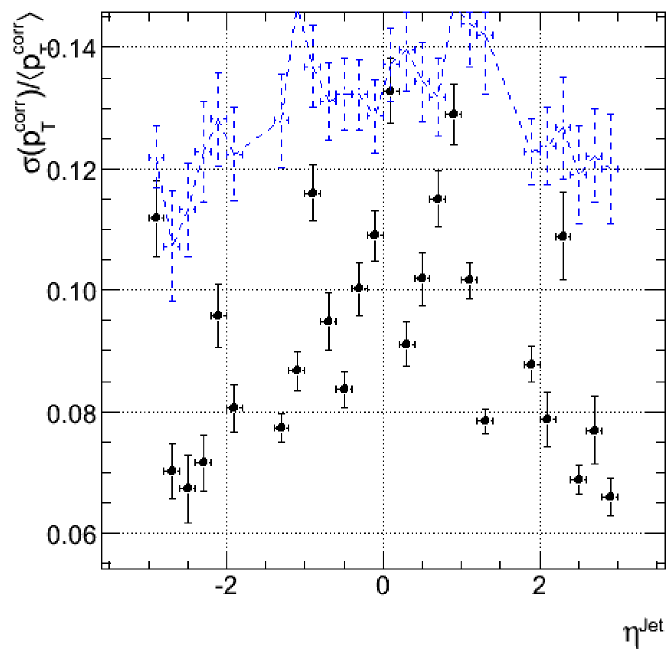


EM-scale vs η.



(corrected p_T / truth p_T) vs η.

black = means
red = gaussian means



Resolution vs η

blue = RMS
black = gaussian σ

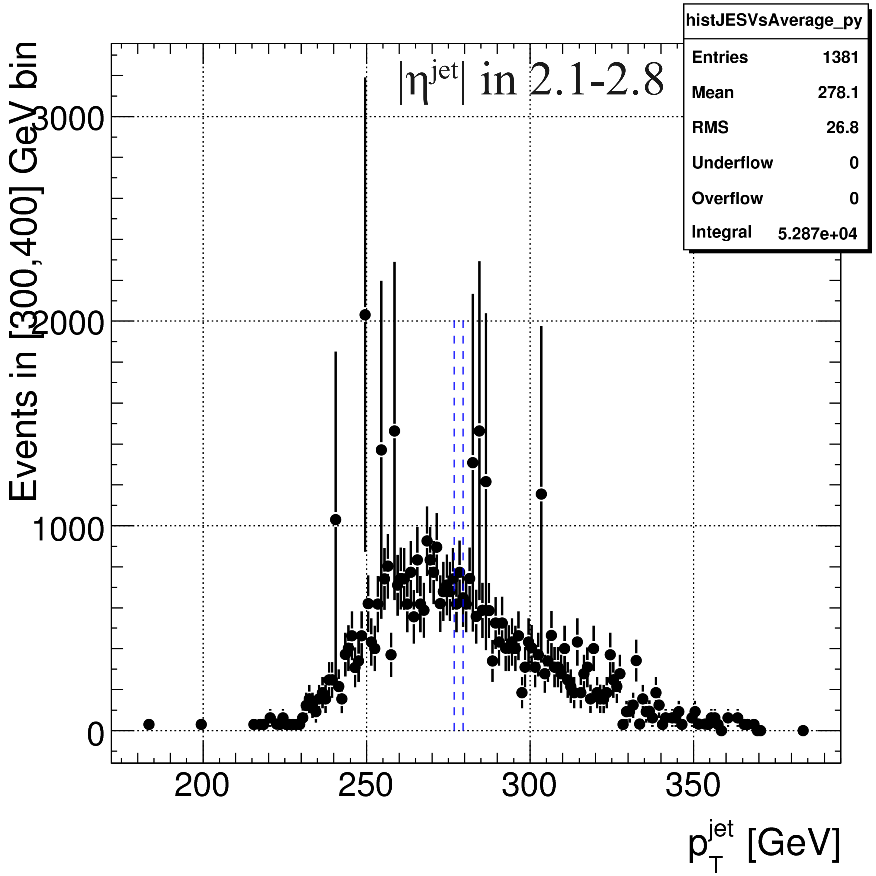
Summary

- Derived correction without QCD or pileup.
- Used Numerical Inversion, wishing to have no bias in bins of p_T^{γ}. That depends on $\langle j\rangle_{\gamma}=f(\langle\gamma\rangle_{\gamma})$ being a straight line. So, Numerical Inversion is not a panacea. If you want a really unbiased estimator, that is only possible in bins of uncorrected p_T^{jet}, which is the observable used by the correction.
- In closure test, the correction we get with Num. Inv. is (almost) unbiased in bins of p_T^{γ}.
- Applied it on QCD. For small jets, we get the energy right to ~5% above 100 GeV. For large jets, it's better.
- Performance does not depend much on η, thanks to intercalibration of calorimeter response.

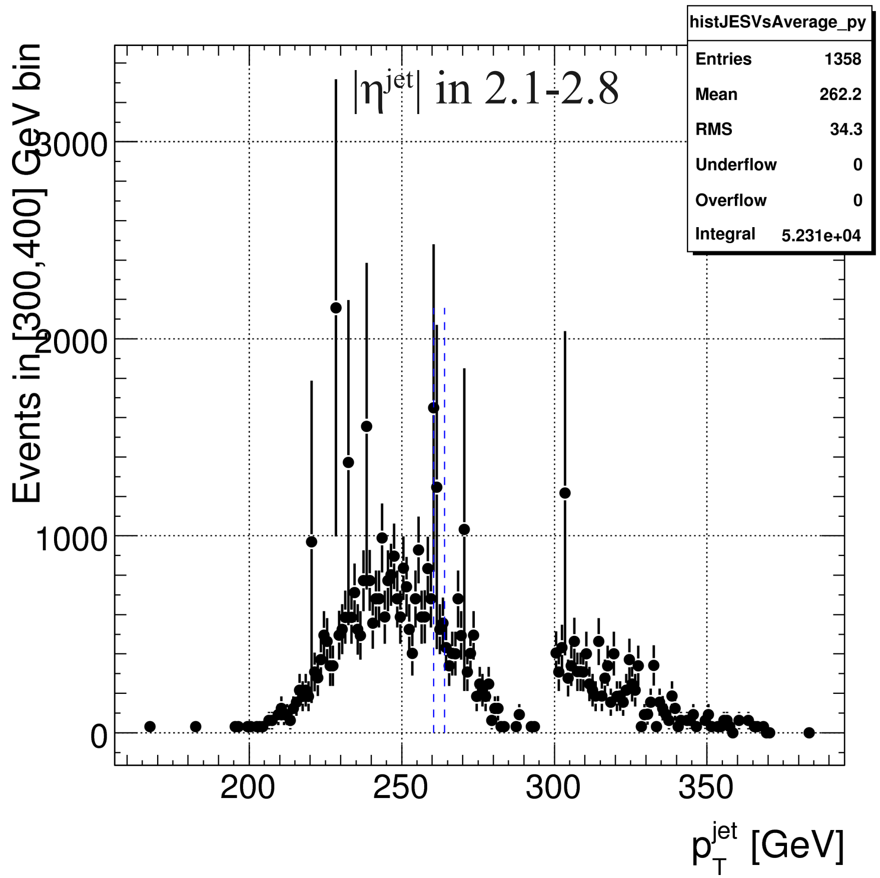
Backups

What is that funny behavior above 300 GeV, especially in resolution plots?

No intercalibration



intercalibration



Distribution of EM-scale jet p_T for jets that have truth-p_T between 300 and 400 GeV.

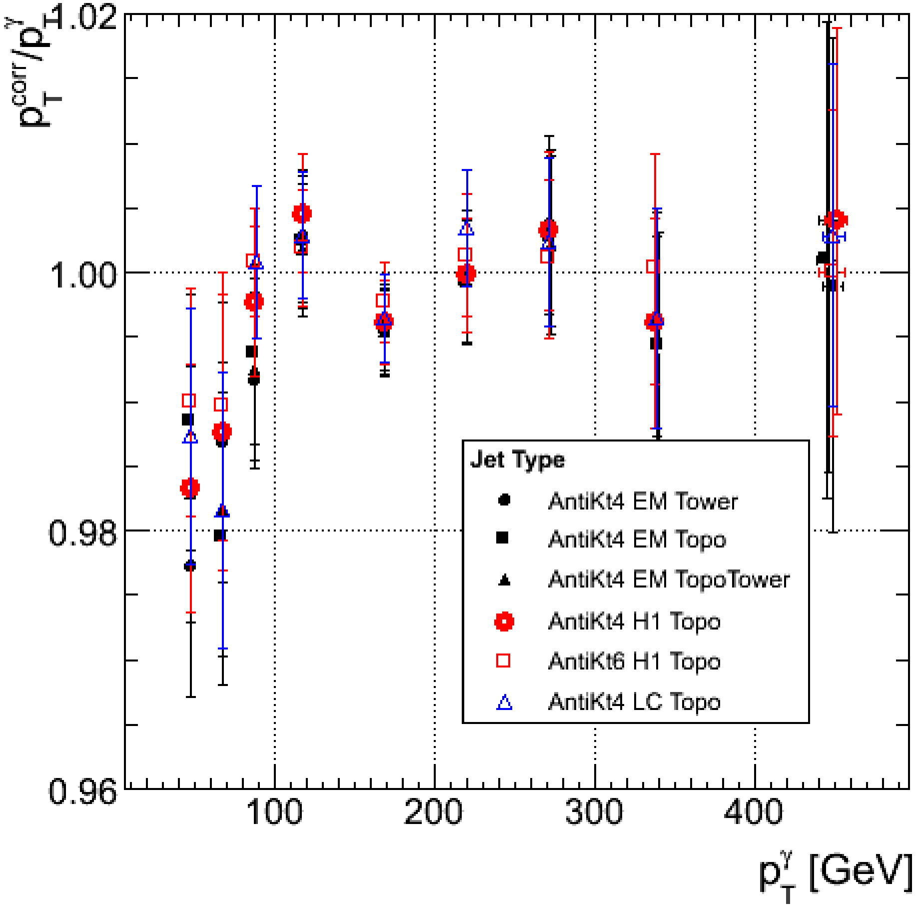
Intercalibration stops at 300 GeV, so those jets above 300 GeV are left untouched.

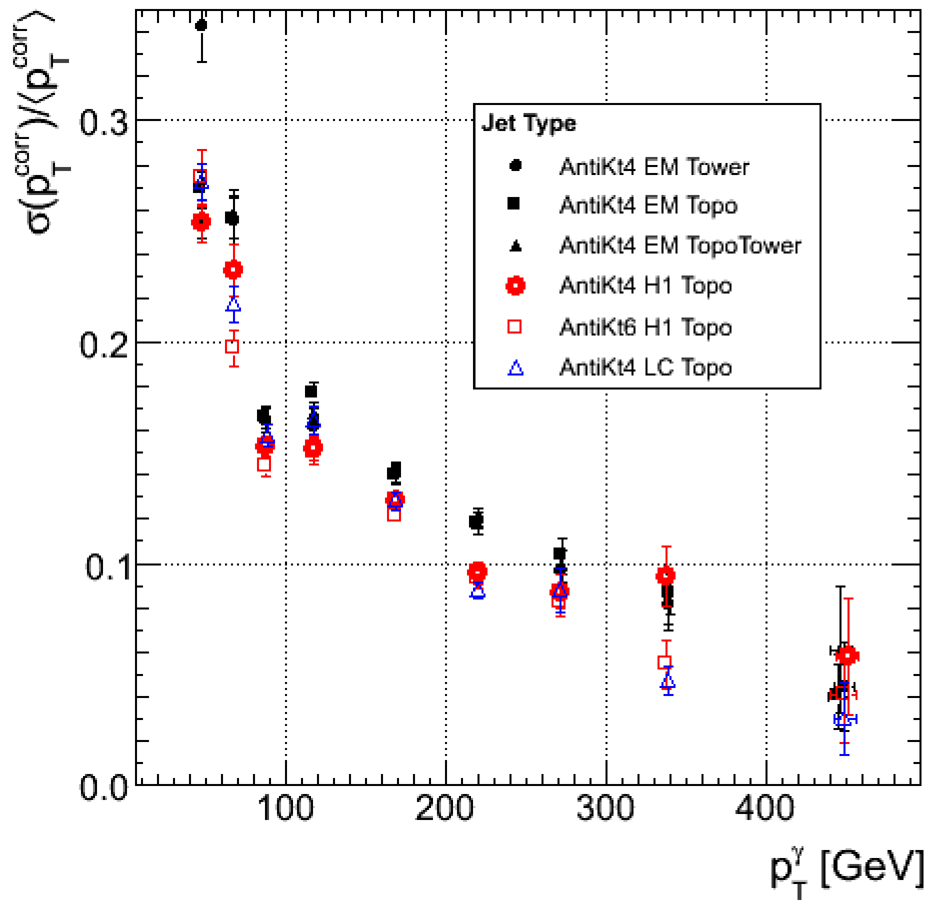
That causes the discontinuity on the left plot.

That makes RMS larger, and has also a slight effect on the mean.

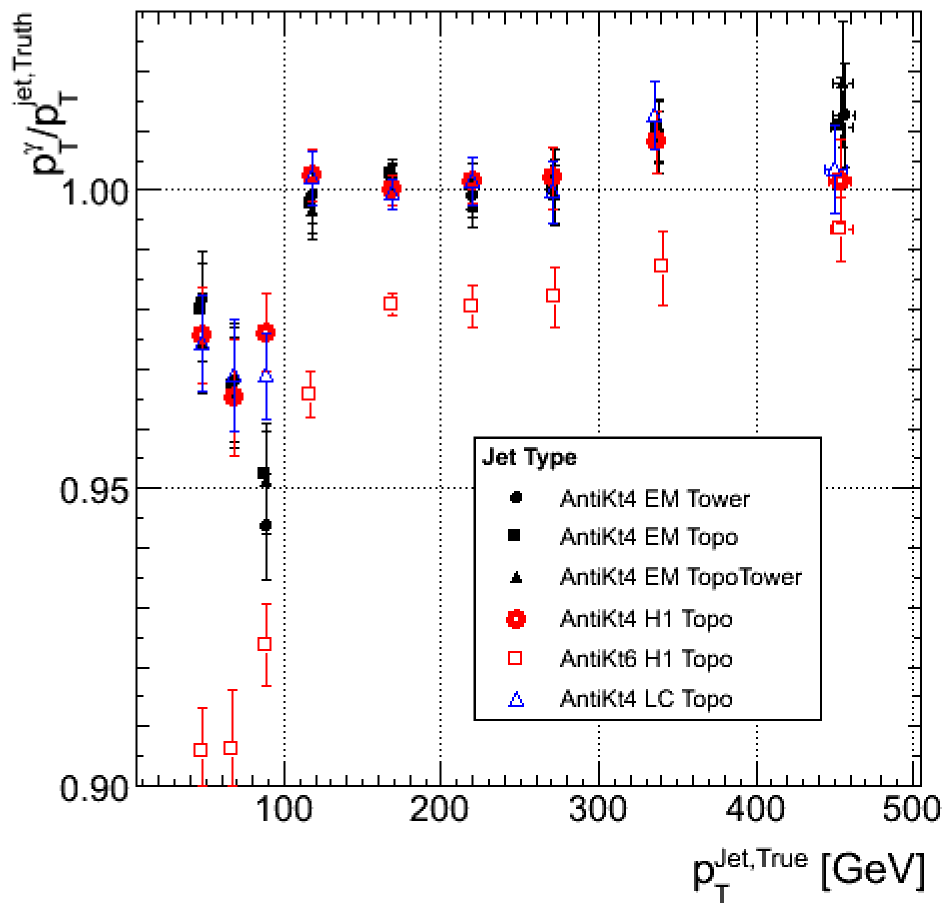
The following plots are like the previous, but $|\eta_{jet}|<0.3$

Closure test

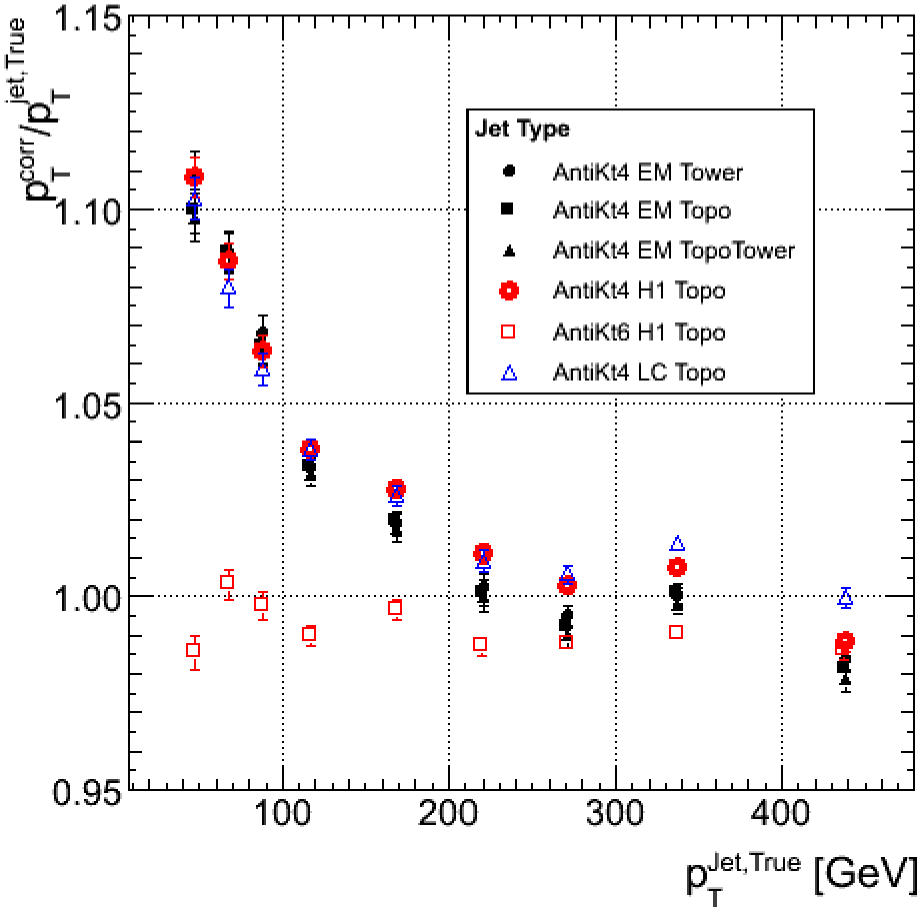


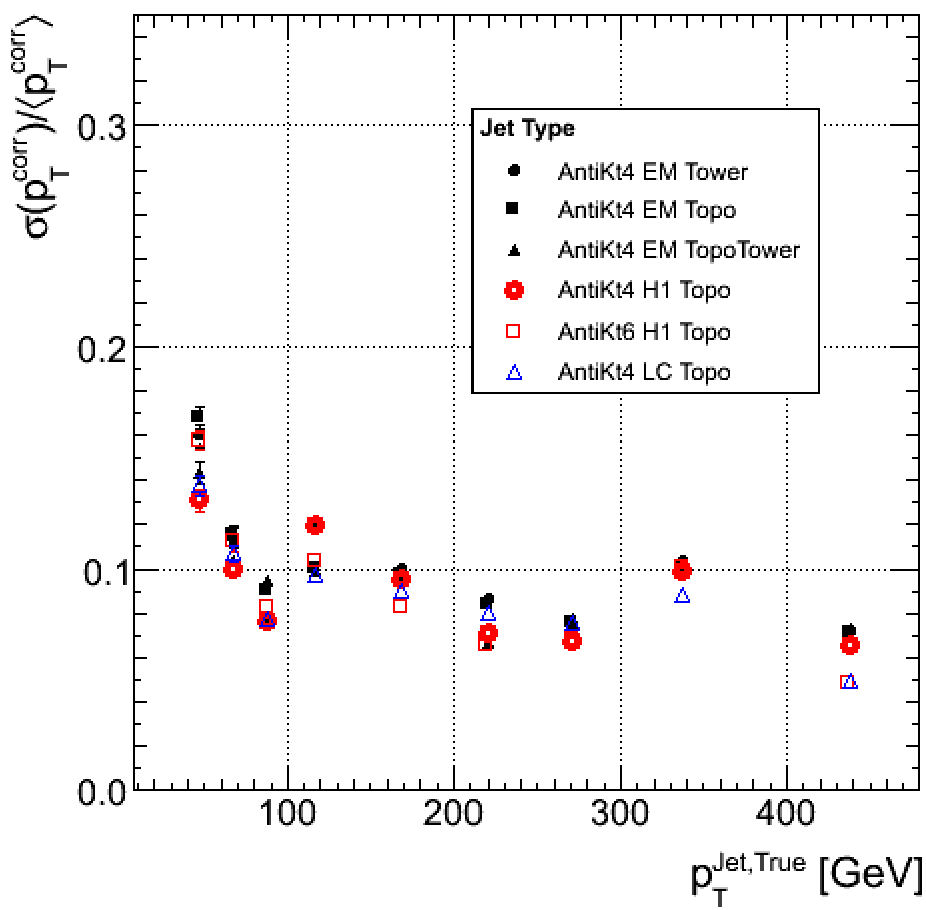


True Balance between γ and jet

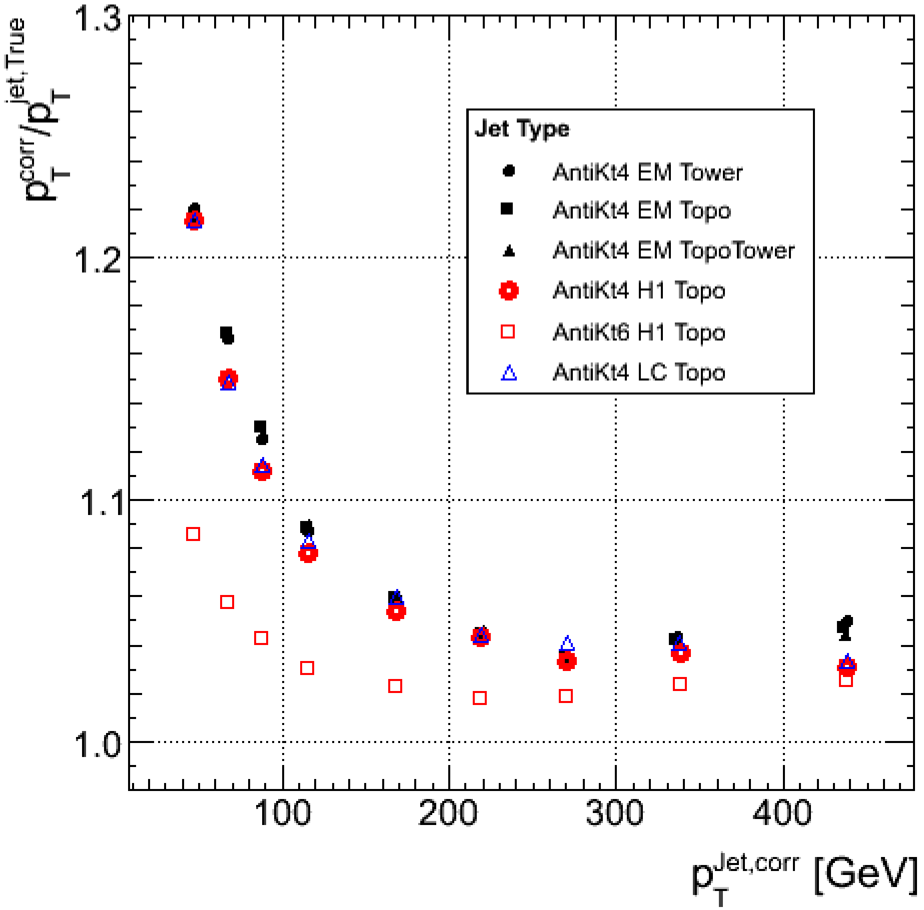


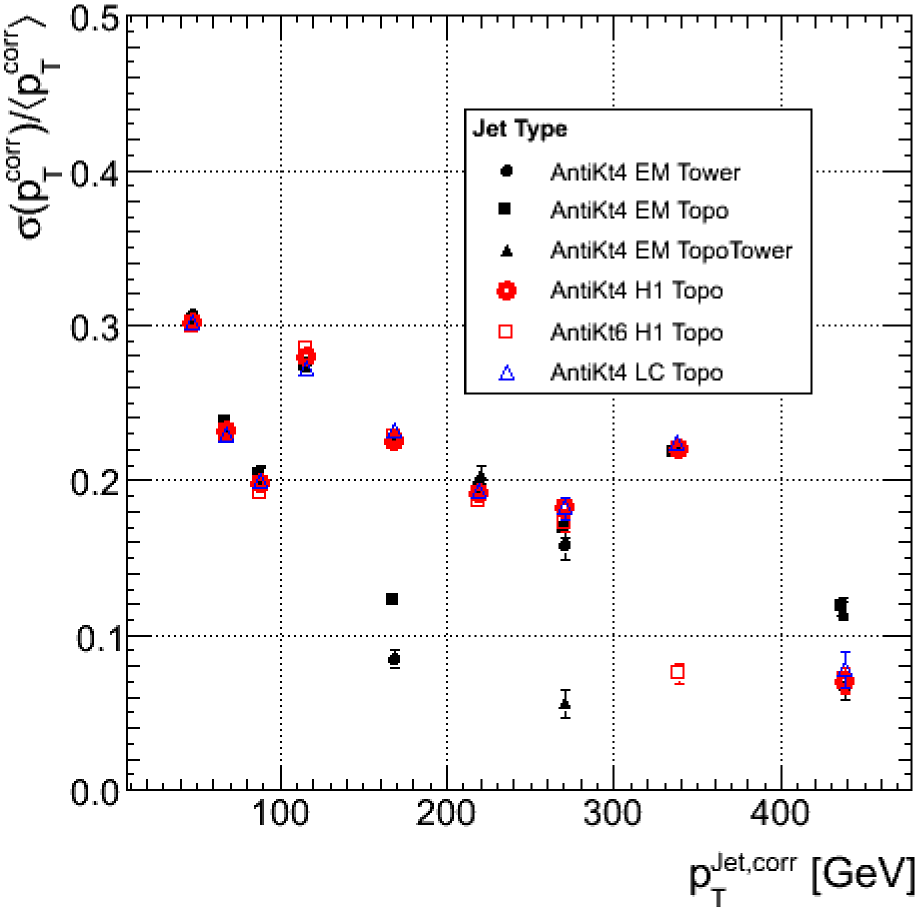
Application in QCD





Application in QCD vs corrected pT





includes $|\eta| < 3$