

qqH \rightarrow 2tau analysis with Particle Flow

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Outline

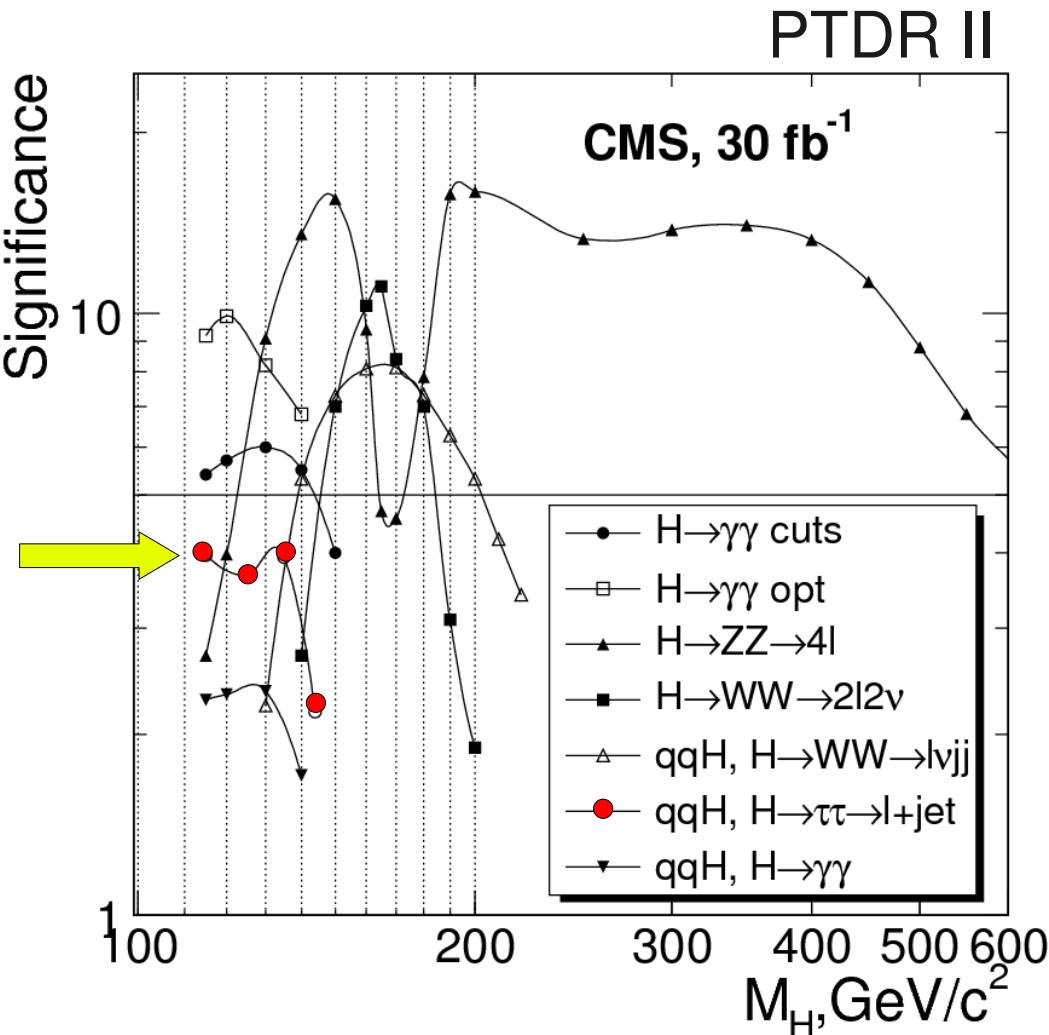
- ◎ VBF $H \rightarrow 2\tau$ analysis

- The process
- Event selection: base ideas

- ◎ First results with Particle Flow

- Jets
- Taus
- MET
- Mass reconstruction

SM Higgs Boson at low mass

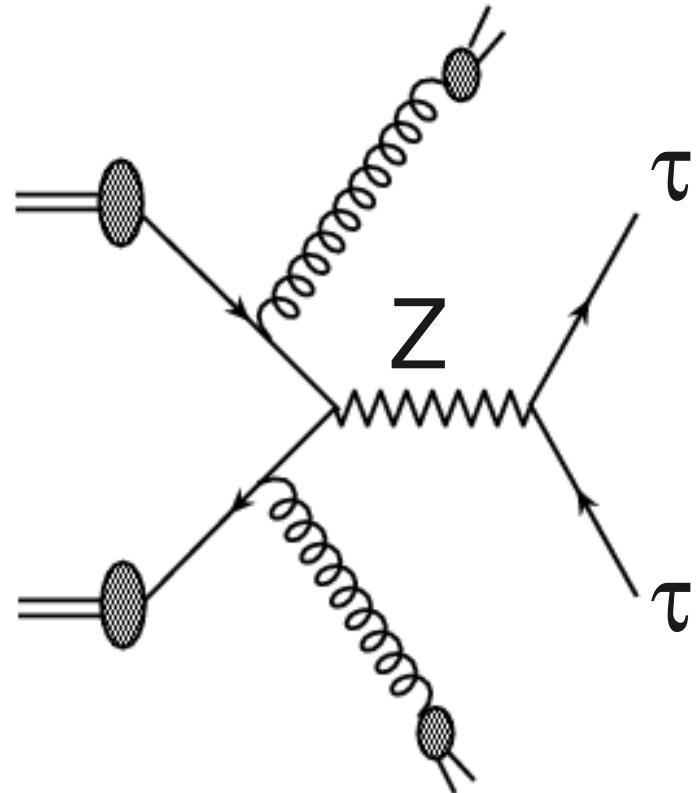
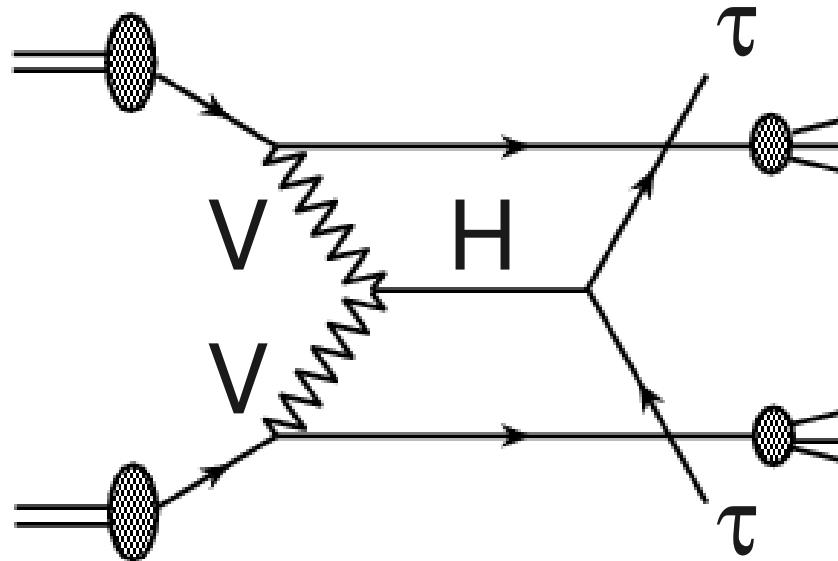


- ④ Decays to VV difficult for m_H much below threshold
- ④ Next available decays:
 - bb – overwhelming $gg \rightarrow bb$ background
 - Higgs production in association with $t\bar{t}$
 - $\tau\tau$ – overwhelming $qq \rightarrow Z \rightarrow \tau\tau$ background
 - Production by Vector Boson Fusion (VBF)
- ④ VBF $qqH \rightarrow \tau\tau$ similar to SUSY $bb/ggH \rightarrow \tau\tau$

Goal: to reach significance for $qqH \rightarrow \tau\tau$ similar to this for $H \rightarrow \gamma\gamma$
($4\sigma \rightarrow 5\text{-}6\sigma$ for a cut-based analysis)

VBF qqH \rightarrow 2tau

- ◎ VBF process characterized by two energetic forward jets



- ◎ Signal: no color exchange between the 2 protons
- ◎ Rapidity gap between the 2 jets (region w/o hadron activity)

- ◎ Main irreducible background: QCD Z \rightarrow tau tau + jets
- ◎ No rapidity gap

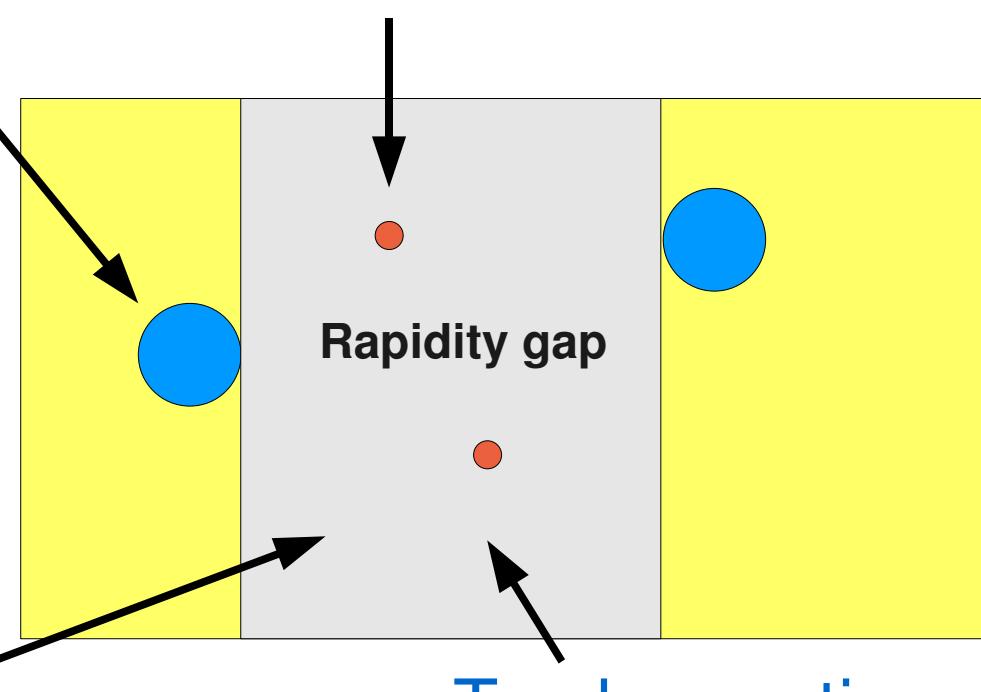
Event selection, base

◎ 2 forward tagging jets

- $p_T > 40 \text{ GeV}$
- Opposite eta
- $\Delta\eta > 4$
- $M_{jj} > 1000 \text{ GeV}$

◎ 2 taus

- Leptonic, for trigger (**MET**)
- **Hadronic (MET)**



◎ Central jet veto

- No jet with $p_T > p_{T,\min}$ in the central region

◎ Track counting veto

- Count the number of tracks (**particles?**) in the central region
- Set an upper limit on N

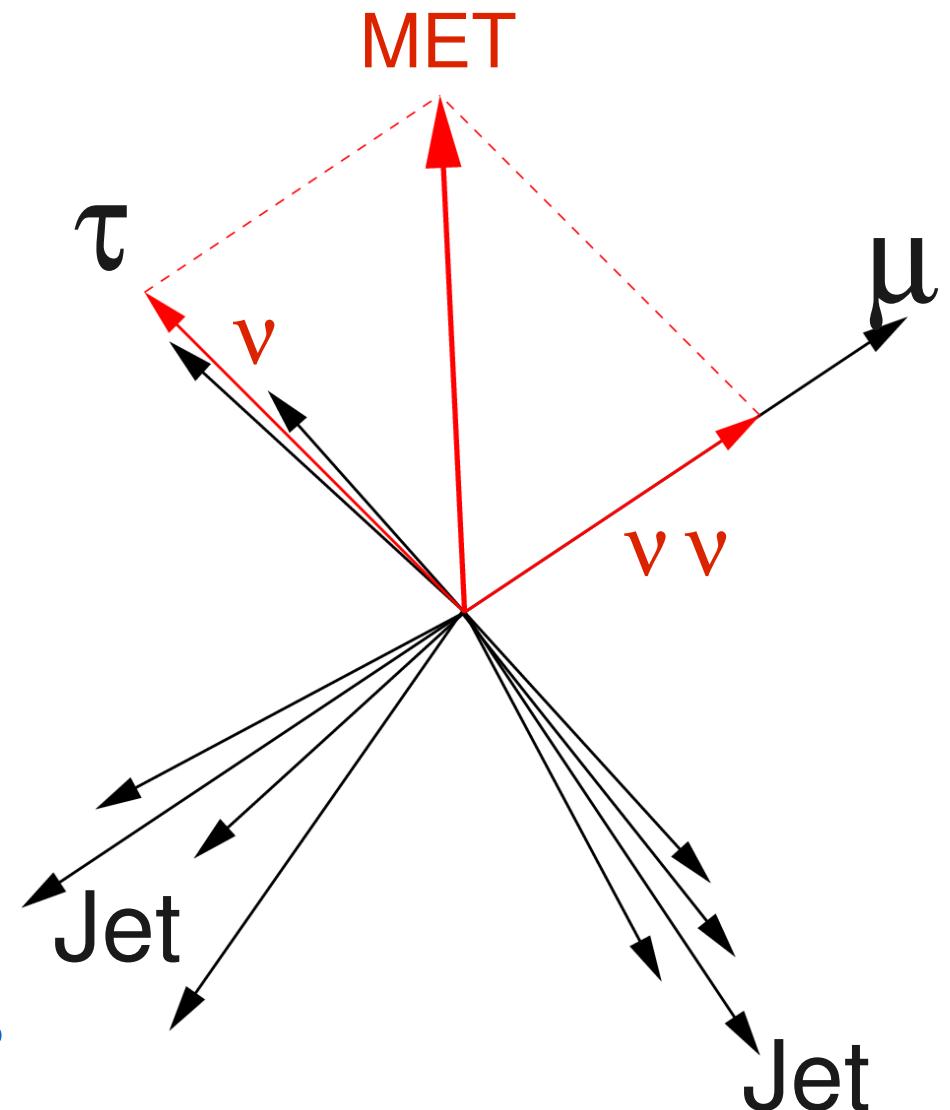
Mass reconstruction

- ◎ Collinear approximation
- ◎ Reconstruction of the Higgs mass dominated by the MET.



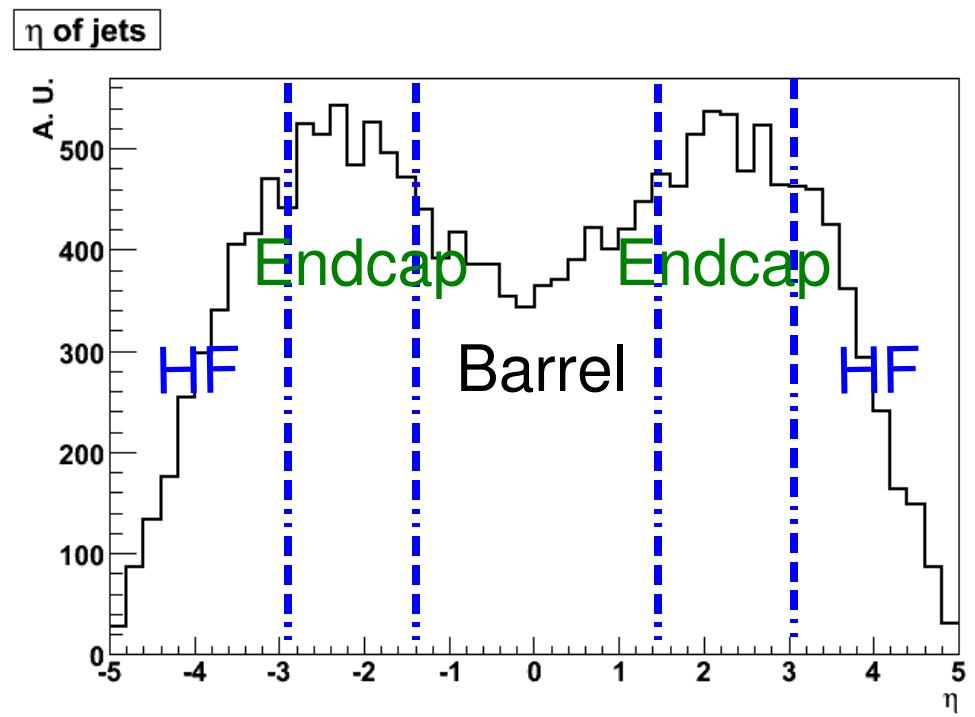
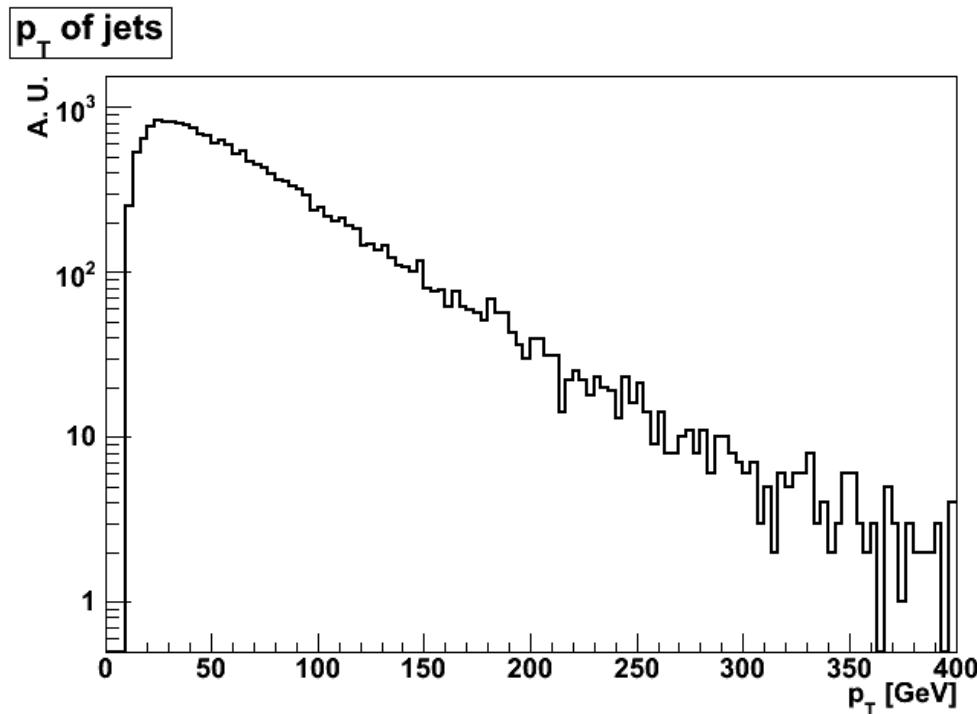
$$\overrightarrow{\text{MET}} = - \sum_{i=0}^{N_{\text{particles}}} \vec{E}_T^i$$

- depends on taus ...
 - ... and on tagging jets
- Tagging jets mostly forward
 - No tracker for PFlow
- Marginal gain on mass resolution?
- Let's first check the inputs



Jets in the signal sample

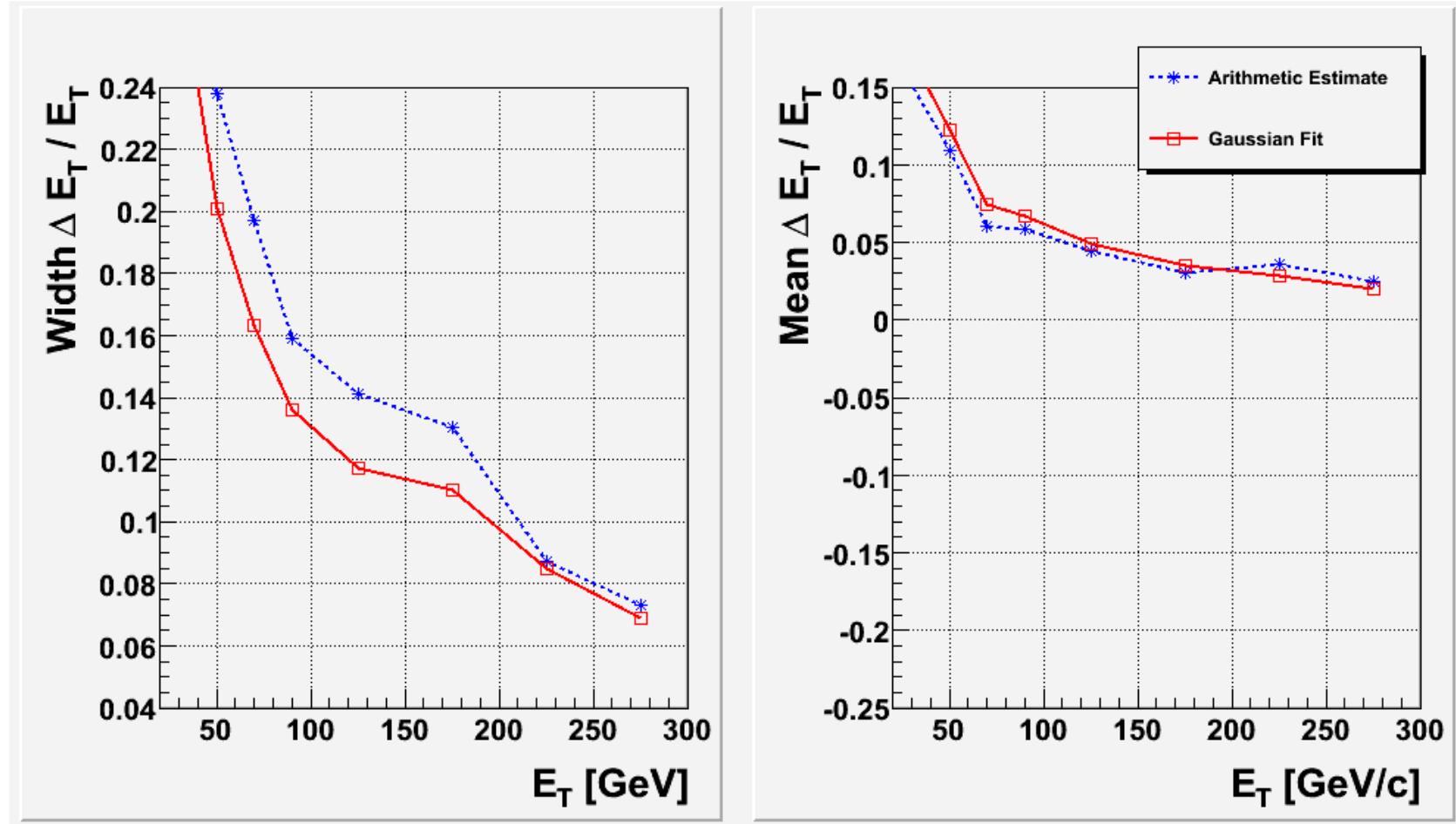
◎ Compare PFJets and CaloJets



- 3 regions:
- Barrel
 - Endcap
 - HF

Tagging jets, barrel (1/2)

- Signal, Barrel ($0 < |\eta| < 1.2$)
 - CaloJets** ($q\bar{q}H \rightarrow \tau\tau \rightarrow \tau\text{-jet}, \mu$, 1 reco-tau required)

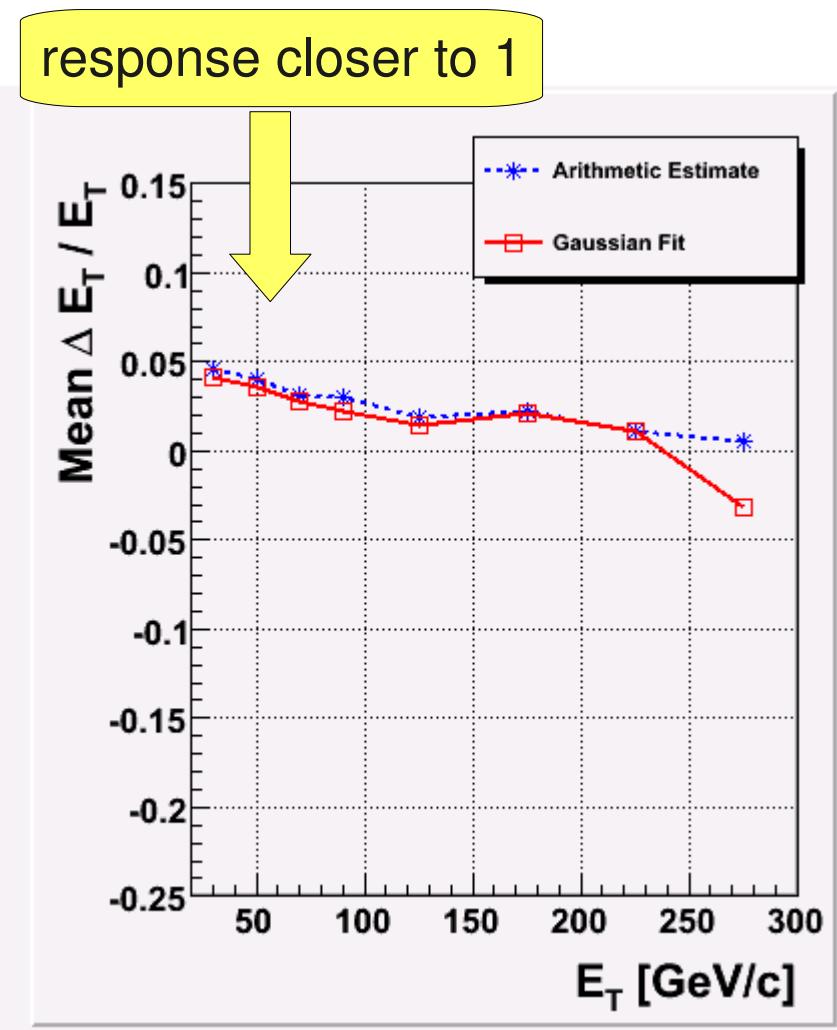
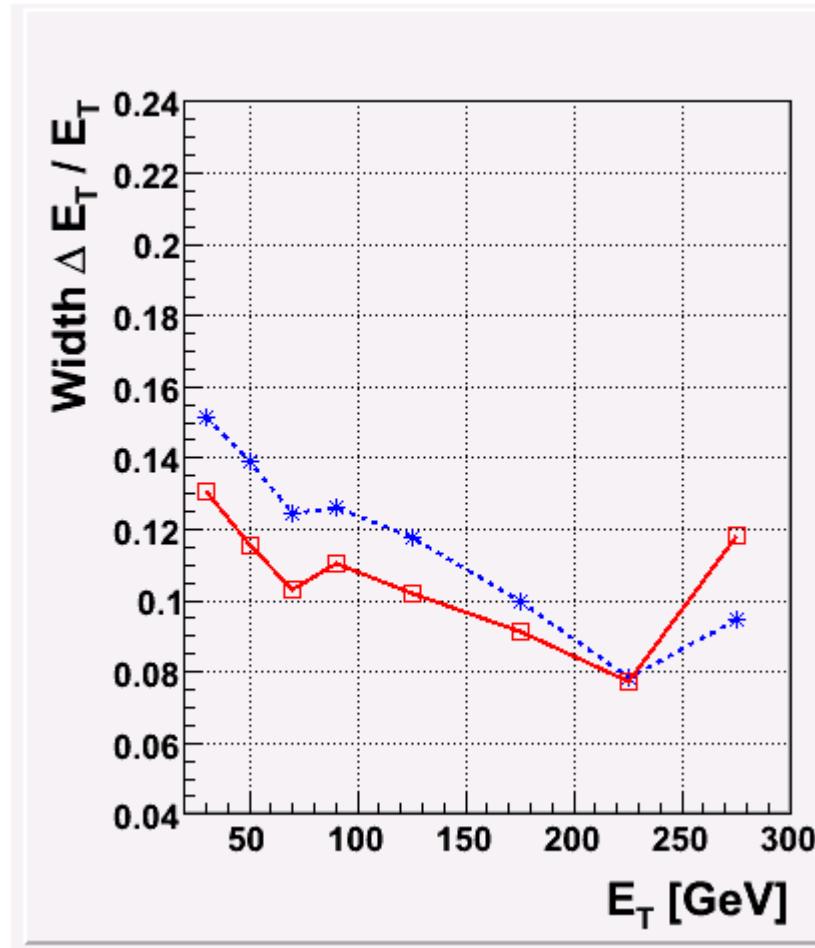


Overcorrected by 5% - not visible in QCD events:
QCD jets mostly gluon jets, while tagging ones are quark-jets

Tagging jets, barrel (2/2)

- Signal, Barrel ($0 < |\eta| < 1.2$)

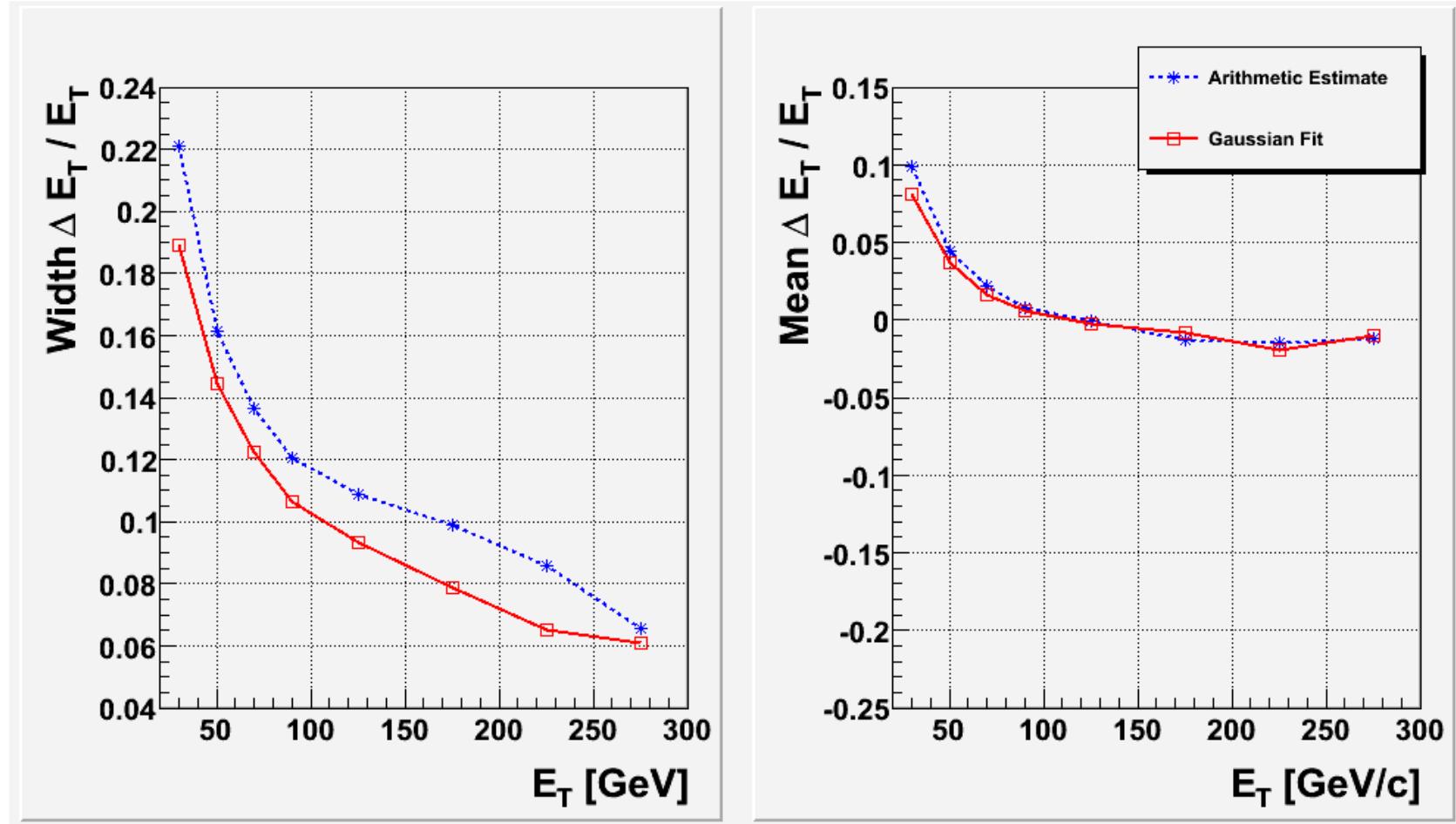
- PFJets**



Corrected PFJets in Barrel have better resolution than Calo ones
More accurate response

Tagging jets, endcap (1/2)

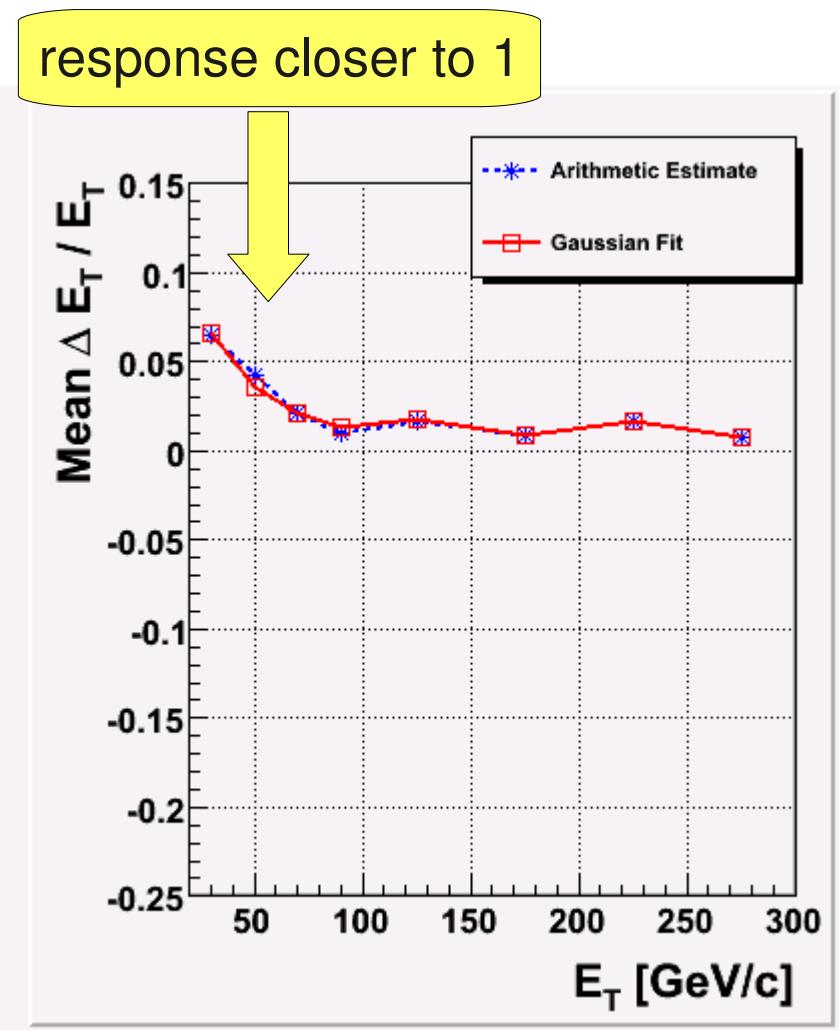
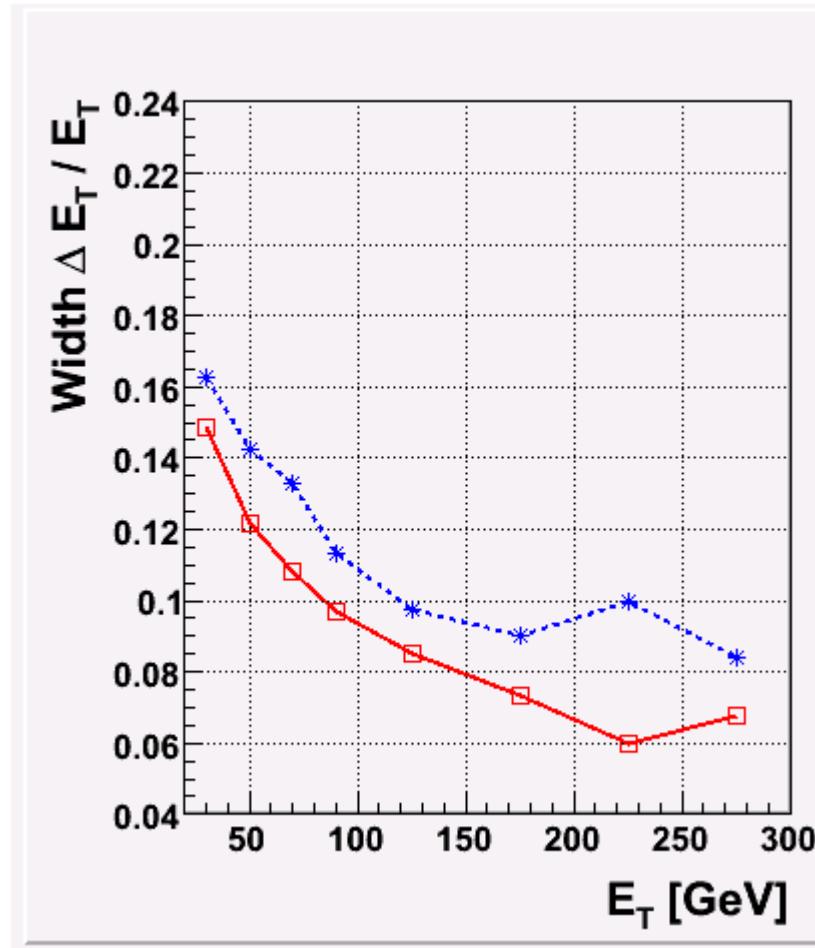
- Signal, Endcaps ($1.6 < |\eta| < 2.8$)
 - CaloJets** ($q\bar{q}H \rightarrow \tau\tau \rightarrow \tau\text{-jet}, \mu$, 1 reco-tau required)



Tagging jets, endcap (2/2)

- Signal, Endcaps ($1.6 < |\eta| < 2.8$)

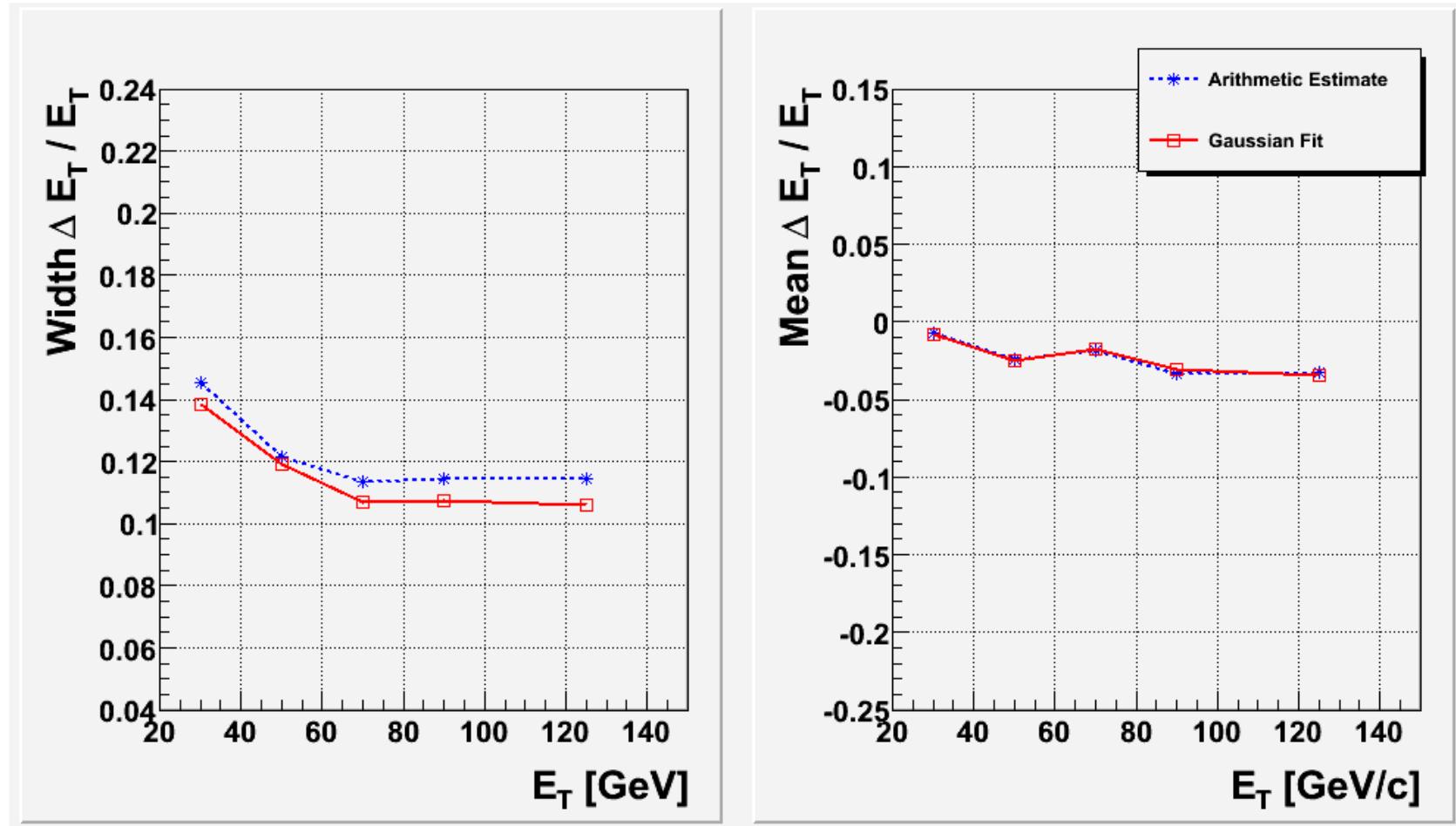
- PFJets**



Less difference in resolution as in the barrel

Tagging jets, HF (1/2)

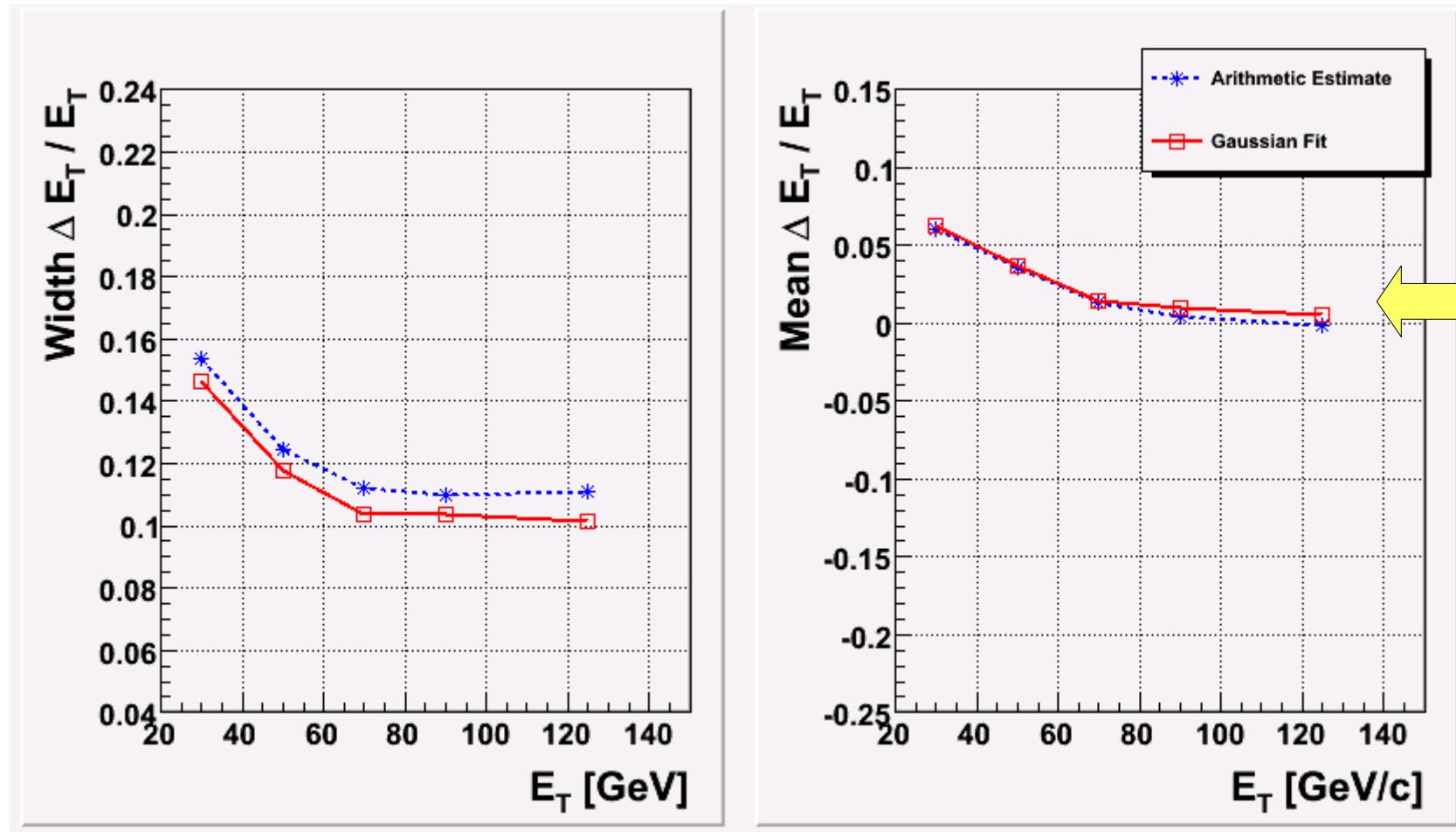
- ◎ Signal, HF ($3.2 < |\eta| < 4.5$)
 - **CaloJets** ($q\bar{q}H \rightarrow \tau\tau \rightarrow \tau\text{-jet}, \mu$, 1 reco-tau required)



Tagging jets, HF (2/2)

- Signal, HF ($3.2 < |\eta| < 4.5$)

- PFJets**

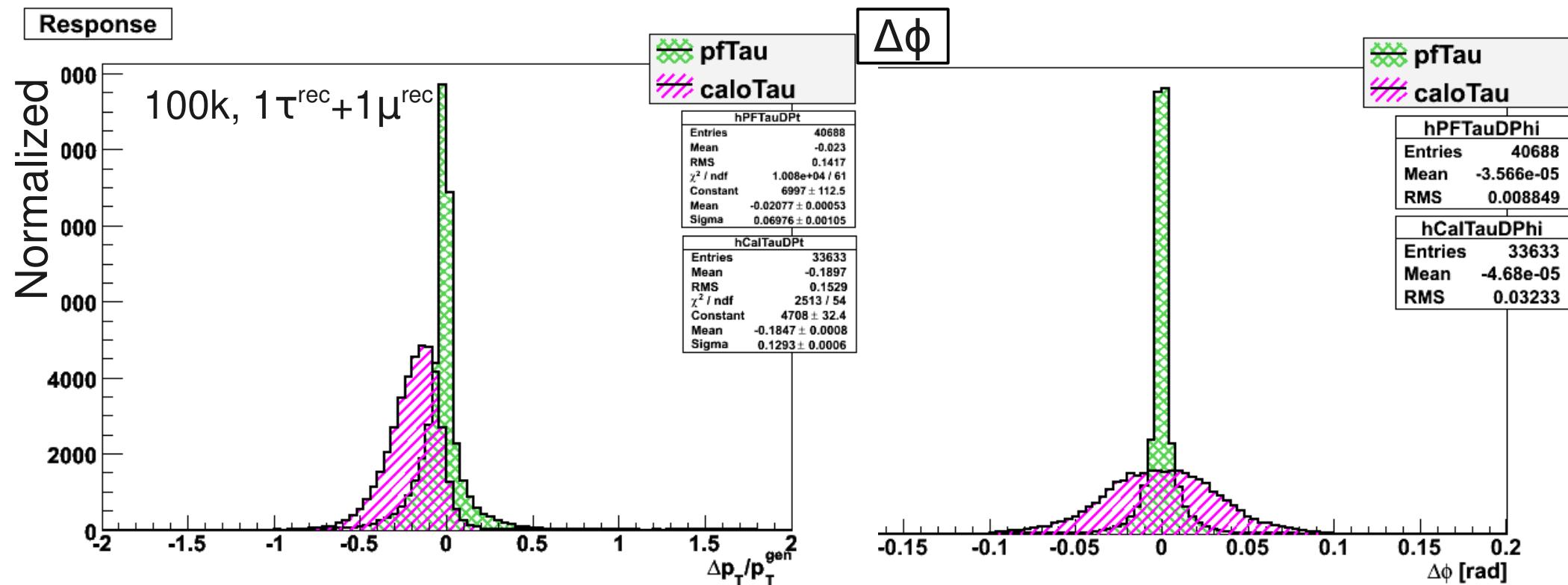


Resolution of PFJets and CaloJets in HF is the same
PFJets at low E_T overcorrected by $\sim 5\%$

Jets, Sub-summary

- JES correction with two leading jets with multi-jet QCD sample i.e. gluon-jets applied for VBF jets i.e. quark jets
 - Tagging jets are overcorrected
- JES correction for PFJets smaller than for CaloJets
 - especially in the barrel region
 - PFJets more robust against not (completely) proper JES corrections
- Resolution of PFJets better than CaloJets
 - especially in the barrel region, but also in endcap
- Better response of PFJets (esp. for $E_T < 50$ GeV)
- Big improvement of PFJets reconstruction especially in the endcap region in 31X

Compare PFTau with CaloTau



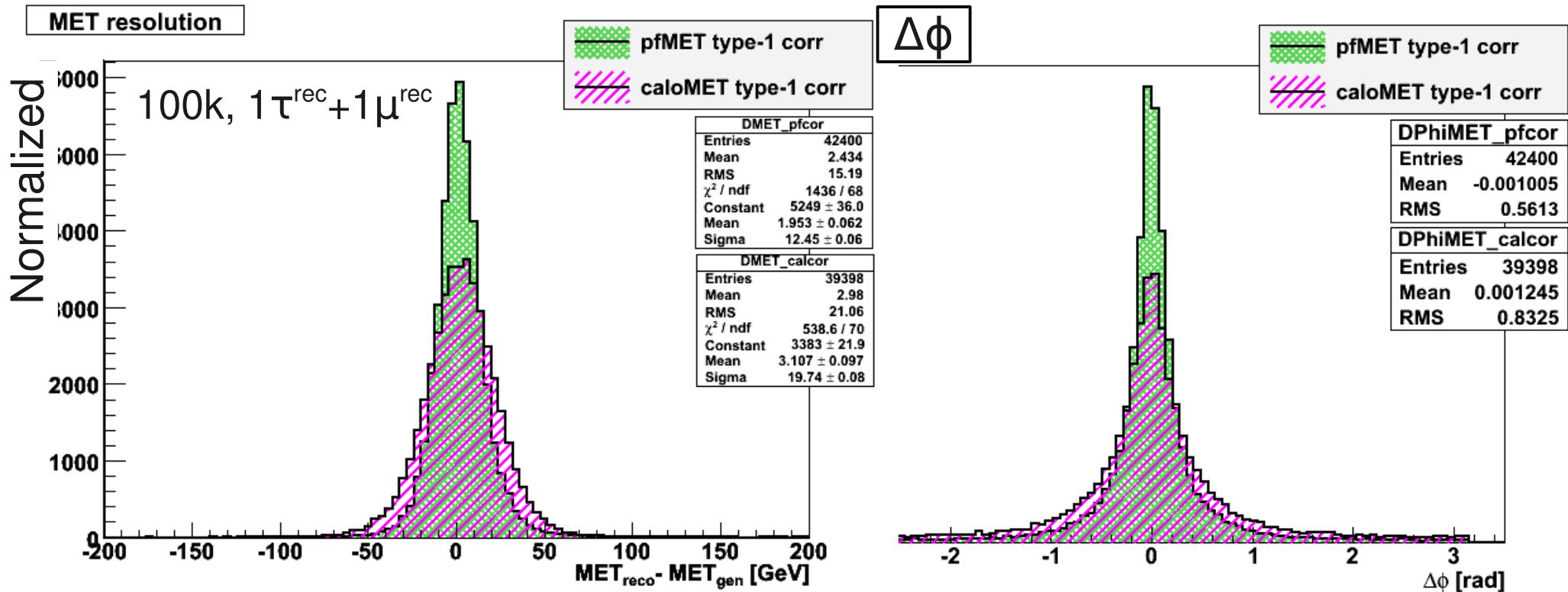
- PFTaus provide response close to 1, while caloTaus underestimate energy
- Better resolutions of PFTaus

Compare PFMET with CaloMET (for signal sample)

- ◎ Type-1 corrections - JES (L2+L3) correction applied to MET
 - Compute ΔE_x , ΔE_y for each jet and add it to MET
 - where $\Delta E = E_{\text{cor}} - E_{\text{RAW}}$
 - Jets with $E_{\text{TRAW}} > 20 \text{ GeV}$ used:
 - for CaloMET all jets with $\text{EMF} < 0.9$ (to exclude e-; tau-jets included)
 - for PFMET jets after particle-based cleaning by PF2PAT
 - L2+L3 correction with the “Winter09” production
JetMETCorrections.Configuration.L2L3 Corrections_Winter09_cff
- ◎ CaloMET have to be corrected for muons
 - not needed for PFMET, since all particles including muons are used in the computation of PFMET

Calo vs PFMET

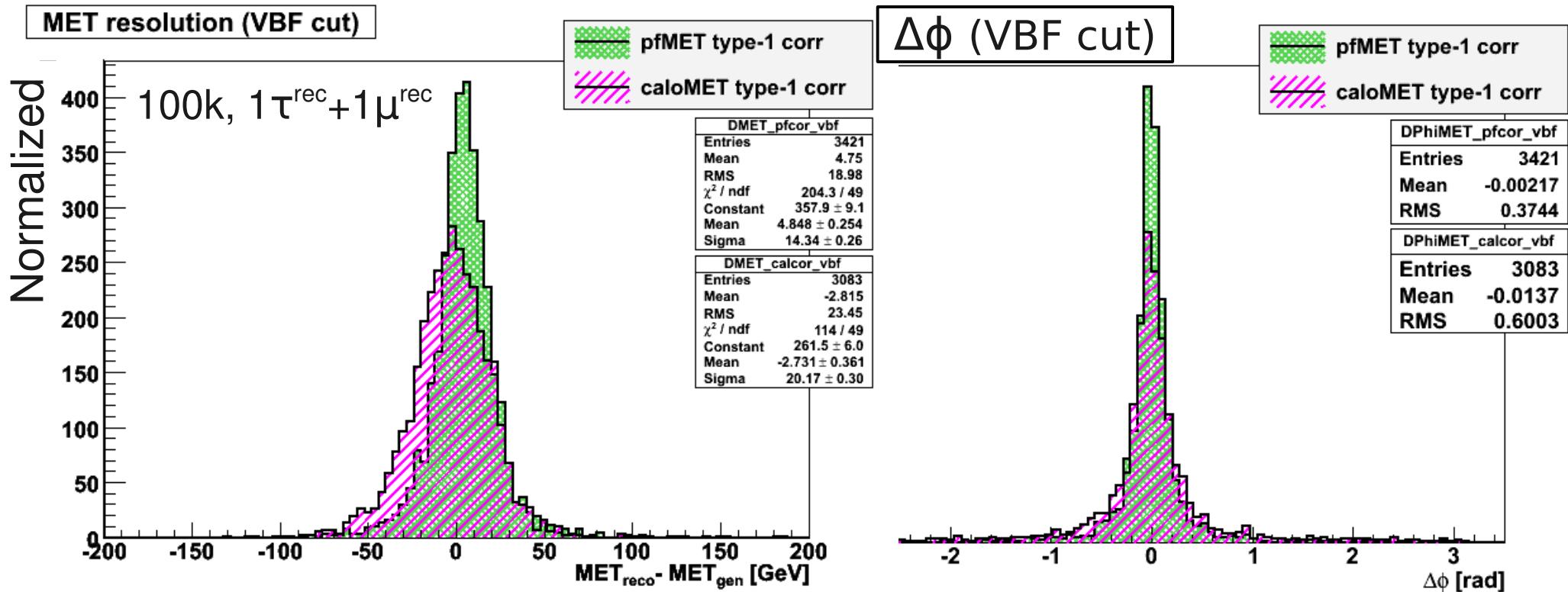
- ④ PFMET vs CaloMET (type-1 corrected) without VBF cut



- ◉ Both METs a bit overcorrected
 - Same level for both
 - ◉ Better resolutions of PFMET

Calo vs PFMET (VBF cut)

- ⑤ PFMET vs CaloMET (type-1 corrected) after VBF cut

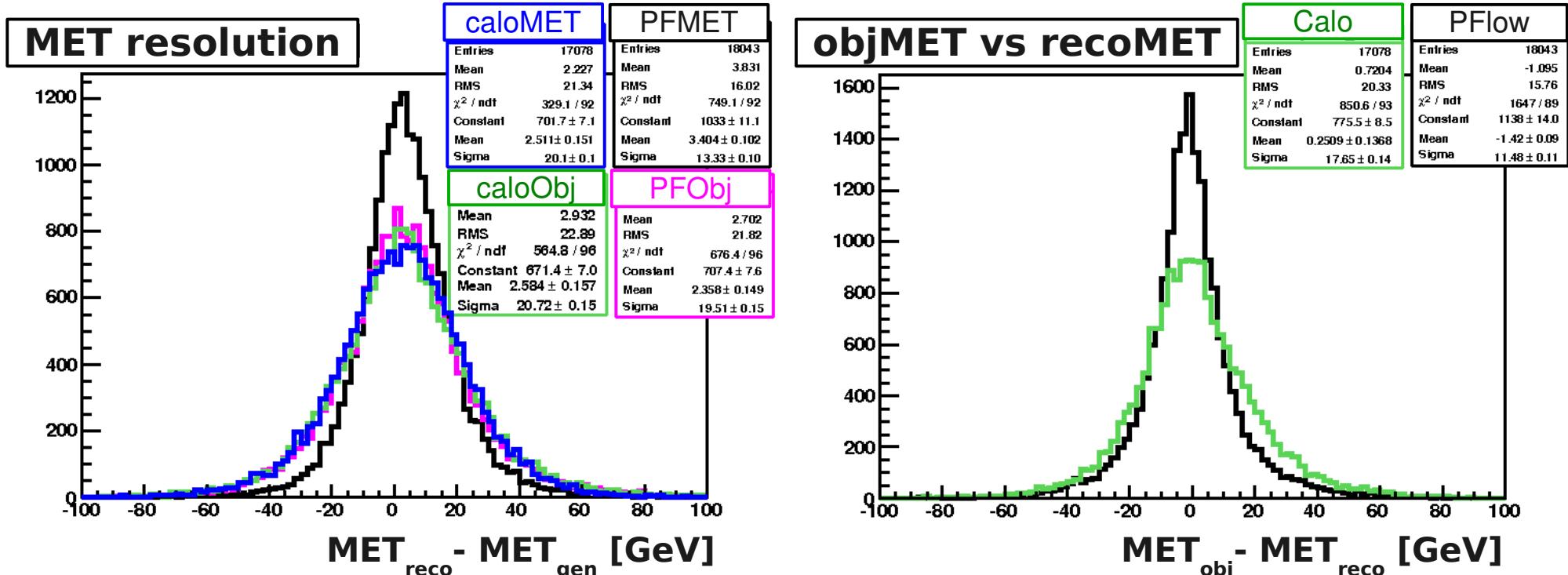


- ◉ PFMET a bit overcorrected, while caloMET undercorrected
 - Same level for both
 - ◉ Better resolutions of PFMET remains

High-pT-objects MET

- To understand better why PFMET is better let's reconstruct MET with four high-pT-objects:

- Muon, $p_T > 15$ GeV (globalMuon), Tau, $p_T > 15$ GeV (PFTau)
- Two jets, $E_T > 40$ GeV (Calo or PFlow ones)
- $\vec{\text{MET}}_{\text{Obj}} = -(\vec{p}_T^\mu + \vec{p}_T^\tau + \vec{E}_T^{\text{jet}1} + \vec{E}_T^{\text{jet}2})$



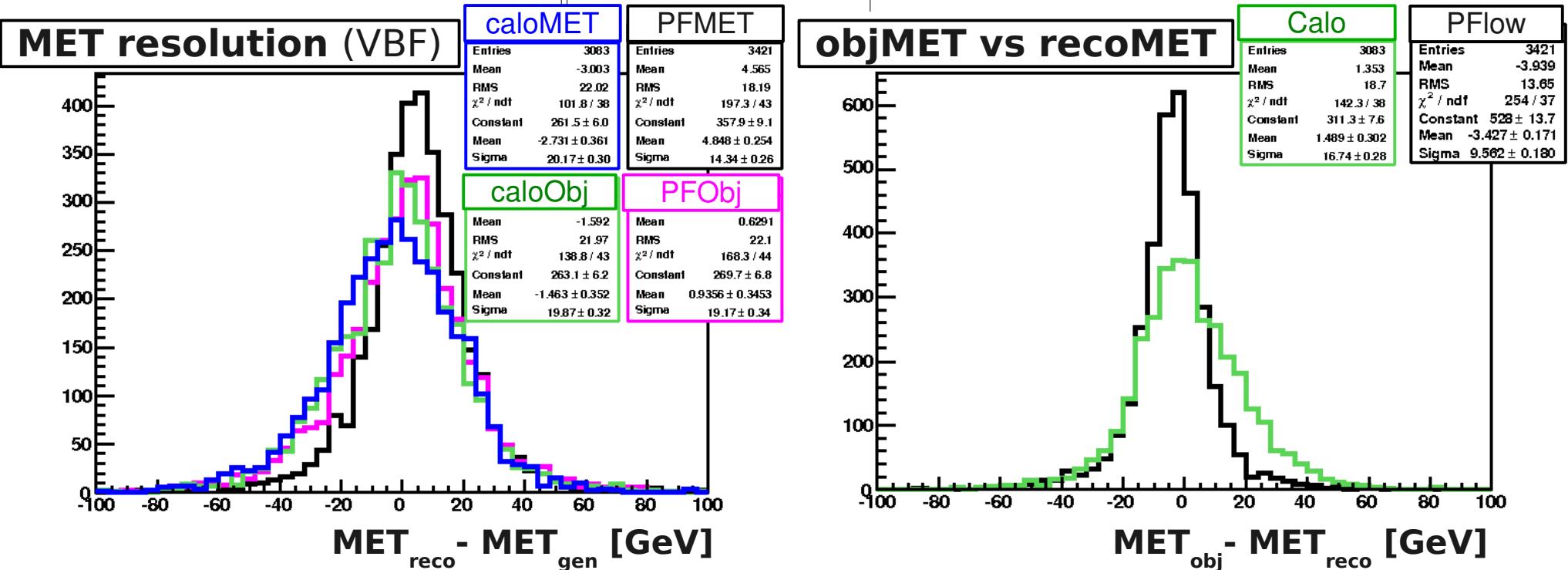
- Resolution of objMETs same as caloMET, and worse than PFMET
- Difference between objMETs and recoMET in the same order as wrt genMET

High-pT-objects MET

High-pT-objects MET after VBF cut

- Probability of tagging jet within tracker acceptance (after VBF):

	$ \eta_{\text{trk}} < 2.4$	$ \eta_{\text{trk}} < 2.1$
≥ 1 fwd jet in trk	$51 \pm 1\%$	$35 \pm 1\%$
2 fwd jet in trk	$1.3 \pm 0.2\%$	—



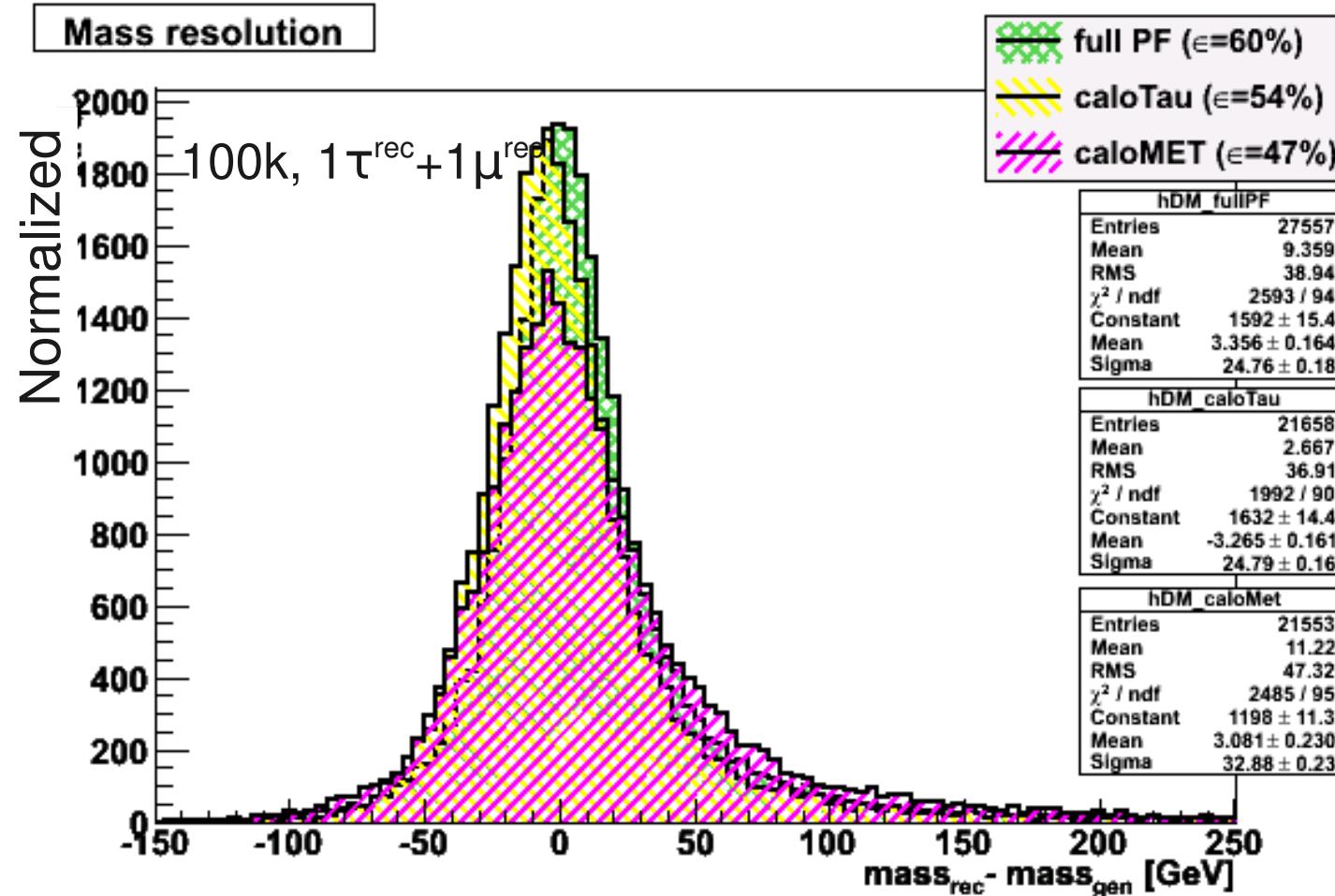
- Same behavior as before VBF cut
- Particles not associated to high-pT objects play important role !?

MET, Sub-summary

- Much better energetic and angular resolutions of PFMET vs CaloMET, even when the VBF cut is applied
- Response of uncorrected PFMET close to 1
 - uncorrected PFMET can be used instead of corrected one?
- The improvement looks not come from high- p_T objects (jets) – reconstruction of non-associated energy looks important
- **Note:** A careful work on jet cleaning before MET correction could improve the calorimeter-based reconstruction

Mass reconstruction

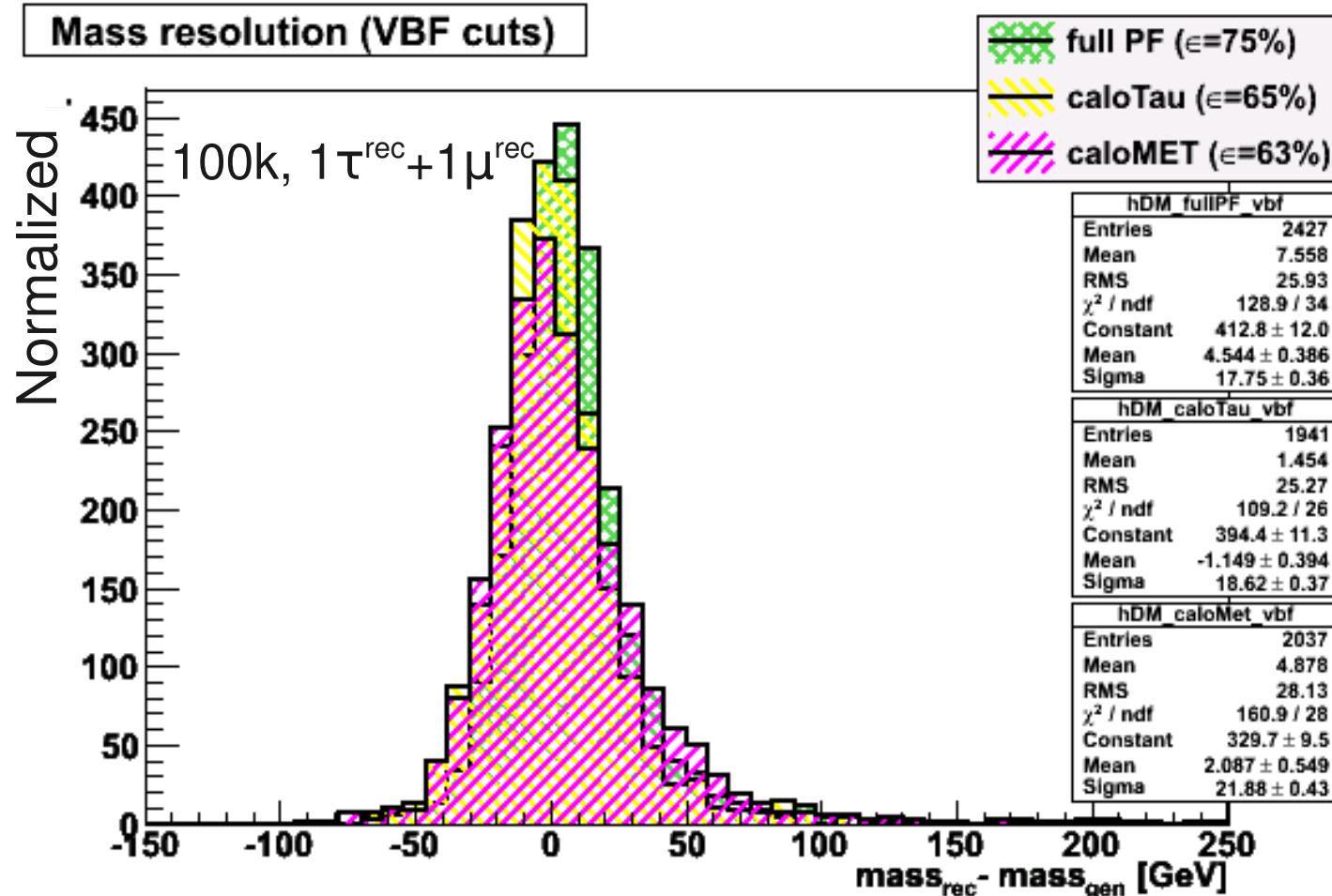
◎ Collinear approximation (without VBF cut)



- ◎ Mass resolution dominated by MET (full-PF vs PF+caloMET)
- ◎ Mass reconstruction with all PF-objects (full-PF) provides the best resolution and highest efficiency of approximation.

Mass reconstruction

◎ Collinear approximation (after VBF cut)



- ◎ Mass resolution dominated by MET (full-PF vs PF+caloMET)
- ◎ Mass reconstruction with all PF-objects (full-PF) provides the best resolution and highest efficiency of approximation.

Summary

- PFlow provides much better energetic and angular resolutions of reco objects than reconstruction based on calorimetry
 - Particle Flow is still improved (CMSSW 3_1_X vs 2_2_X)
- These improvements translate to the reconstruction of di-tau resonances with the collinear approximation, and improve the significance of the VBF, $H \rightarrow \tau\tau$, $\tau\tau$ channel
- Still a lot to do:
 - Study the rapidity gap: jet and particle vetoes
 - Study background
 - Prepare to the first period of data taking (2009/10)
 - PFlow commissioning
 - Background from data ...