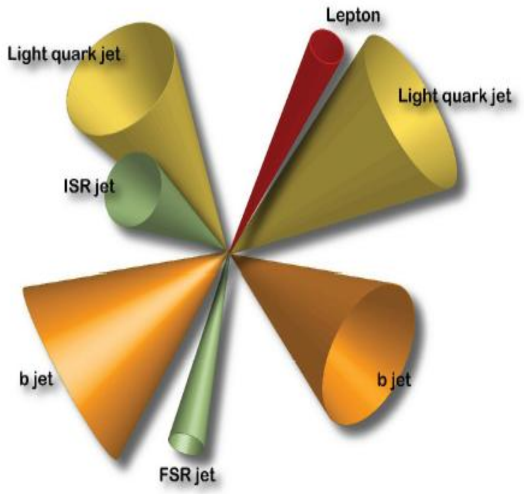
Top mass determination studies using MC08 10 TeV simulated data

Valencia aTOPe, June 23



María José Costa (IFIC-Valencia)
Carlos Escobar (IFIC-Valencia)
Salvador Martí (IFIC-Valencia)
María Moreno Llácer (IFIC-Valencia)

23/06/2009

Talk outline

Outline

- Introduction
- Data samples and software
- Reconstruction of physics objects (in the semi-leptonic channel)
  - Electron reconstruction performance
  - Muon reconstruction performance
  - Missing transverse energy
  - Jet calibration studies
  - Jets reconstruction performance
- Event Selection
- First results from the kinematic fit

Introduction

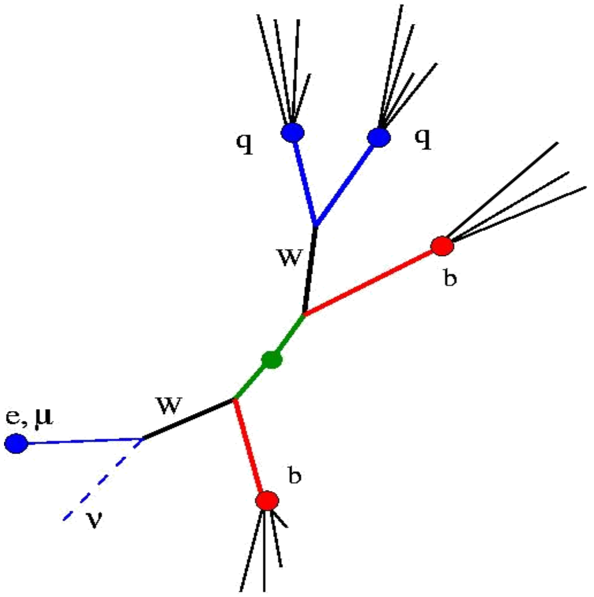
Goal:

- Contribute to the studies of the ATLAS potential to measure the top quark mass.

How:

- Use the **semi-leptonic channel** (electron, muons or taus decaying leptonically + jets), σtt ~ 139 pb @ 10 TeV (golden channel).

  – Final state objects:
    - **1** (high pT) **isolated electron/muon**
    - 1 neutrino → **MET**
    - **2 light jets** (neglecting ISR and FSR)
    - **2 b jets**



Introduction

- From a kinematic fit using a χ^2 based on the entire final state:

$$\chi^2 = \sum_{\substack{4\,jets\\+lepton}} \left(\frac{E_i^{reco} - E_i^{fit}}{\sigma_{E_i}}\right)^2 + \left(\frac{M_{jj} - M_W^{PDG}}{\Gamma_W^{PDG}}\right)^2 + \left(\frac{M_{l\nu} - M_W^{PDG}}{\Gamma_W^{PDG}}\right)^2 + \left(\frac{M_{jjb_H} - M_{top_H}^{fit}}{\sigma_{top_H}}\right)^2 + \left(\frac{M_{l\nu b_L} - M_{top_L}^{fit}}{\sigma_{top_L}}\right)^2$$

(additional terms could be added in the future)

- Fit parameters: E_{fit} (for jets and lepton) and m_{top}.
- The $\chi 2$ minimization is done using a Global $\chi 2$ method

→ Essential to determine first:

• E resolutions for jets and leptons

• For jets:

the jet calibration effects are removed by performing a jet calibration to the parton level using MC information. This allows jet calibration to be disentangled from other effects on the top mass measurement (selection, reconstruction,…).

• And in general to study the ATLAS performance for reconstructing electrons, muons, jets and missing Et.

→ And then the kinematic fit can be done to determine the top mass and the jets and lepton energies.

Data samples and software used

Simulation: **@ 10 TeV, m_t = 172.5 GeV**
ATLAS-GEO-02-01-00

→ Hits G4 →

Digitization & reconstruction (release 14.2.25.8):
- ATLAS-GEO-02-00-00 (same as ATLAS-GEO-02-01-00 but diff. conditions)
- OFLCOND-SIM-00-00-06

→ Misaligned ID
→ Beam spot displaced from (0, 0, 0) to (1.5, 2.5, -9) [mm]
→ Detector conditions as Sept. 08 (Pixel and LAr dead channels and modules)

↓

AOD
Dataset: mc08.**105200**.T1_**McAtNlo**_Jimmy.merge.AOD.e357_s462_r635_t53

↓

ARATopQuarkAnalysis (Our modifications are in tag 00-00-76)
- Running a private jobOptions on the Grid using Ganga.

→ D3PD → ROOT

Known problems:
There is a problem in the treatment of standalone muons in the MET computation.

Reconstruction and selection of physics objects

- Physics objects studied: electrons, muons, jets and missing Et (MET).
- Efficiencies, purities, resolutions, linearities and uniformities have been studied for the signal ttbar semi-leptonic events.

$$\varepsilon(\Delta R) = \frac{\#\,matches\ of\ truth\ e/\mu/\ jets\ with\ reconstructed\ e/\mu/\ jets\,(\Delta R)}{\#\,truth\ e/\mu/\ jets}$$

$$P(\Delta R) = \frac{\#\,matches\ of\ reconstructed\ e/\mu/\ jets\ with\ truth\ e/\mu/\ jets\,(\Delta R)}{\#\,reconstructed\ e/\mu/\ jets}$$

$$Energy\ linearity = \frac{E_{reco} - E_{truth}}{E_{truth}}\ \ Vs.\ E_{reco}$$

$$Energy\ uniformity = \frac{E_{reco} - E_{truth}}{E_{truth}}\ \ Vs.\ \eta_{reco}\ or\ \phi_{reco}$$

$$Energy\ resolution = \sigma\left(\frac{E_{reco} - E_{truth}}{E_{truth}}\right)\ \ Vs.\ E_{reco}\ or\ \eta_{reco}$$

Electron reconstruction performance

Electron reconstruction and selection

- **Truth electrons**: electrons coming from the W leptonic decay.
- **Reconstructed electrons**:

- The medium identification cuts have been used: based on information from EM calorimeters and tracking variables (egamma isEM ElectronMedium)
- author=1 or author=3
- pT>25 GeV
- $|\eta| < 2.5$ (and outside crack region: $1.37<|\eta|<1.52$)
- Isolation cut based on calorimeter energy: the additional Et in a cone with radius $\Delta R=0.2$ around the electron < 6 GeV.

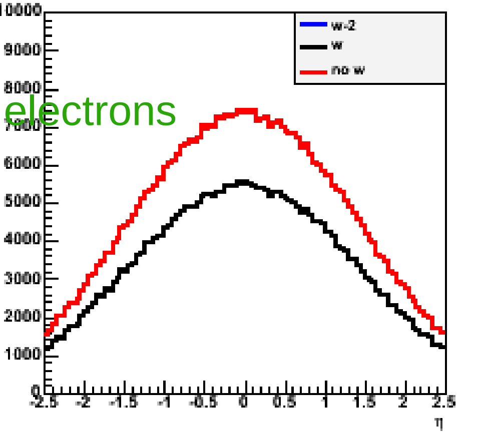
$$MATCHING \quad CRITERIA: \quad \Delta R = \sqrt{(\phi_{reco} - \phi_{truth})^2 + (\eta_{reco} - \eta_{truth})^2} < 0.05$$

How to calculate efficiencies?

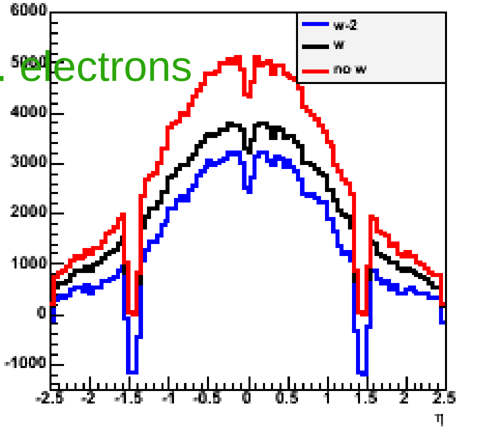
MC@NLO samples have event weight, which is +1 or -1.

* How to deal with events with:
- 1 truth electron with EventWeight@NLO= -1
- no reconstructed electron

η of truth electrons



η of reco. electrons

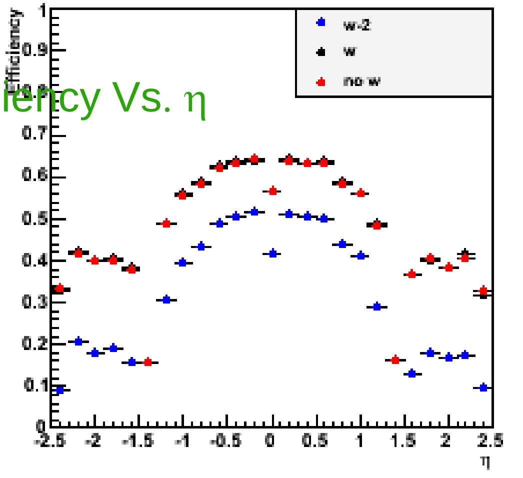


→Option A (w-2):
Fill truth and matched reco. histograms using EventWeights and in case no electron is found and EventWeight = -1, fill reco histo with EventWeight= -2.

→Option B (Akira use this one):
Fill truth histograms with its EventWeight and if a reco electron is matched then fill reco histo with its weight.

→ Option C (no w):
do not use EventWeights to calculate efficiencies or purities.

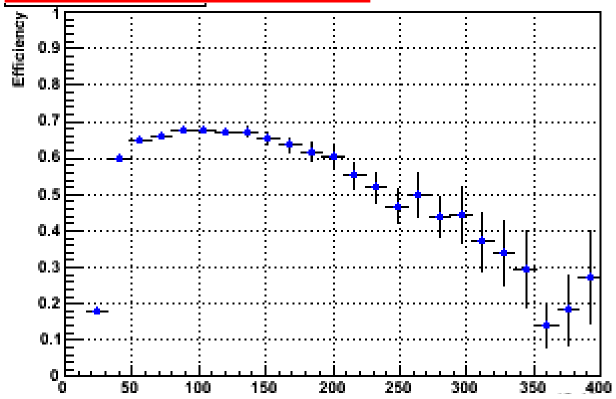
Efficiency Vs. η



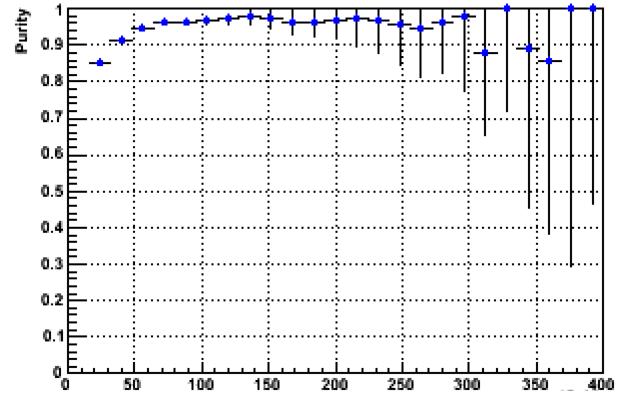
- About 12% of events have negative weight.
- Similar efficiencies obtain when using method B and C.
- Decide to use (from now on) **method C**,
(under discussion with the cross section note authors)

Efficiency and purity

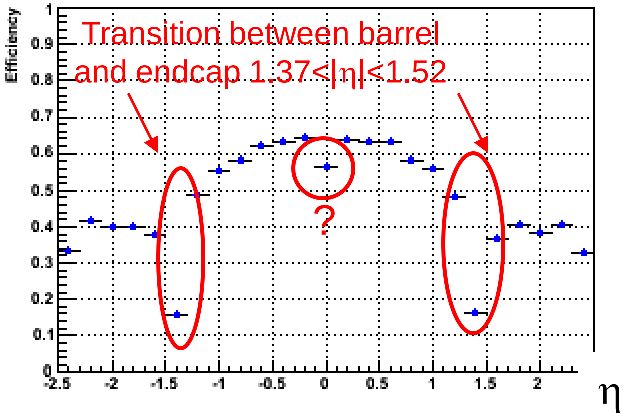
Efficiency Vs. pT



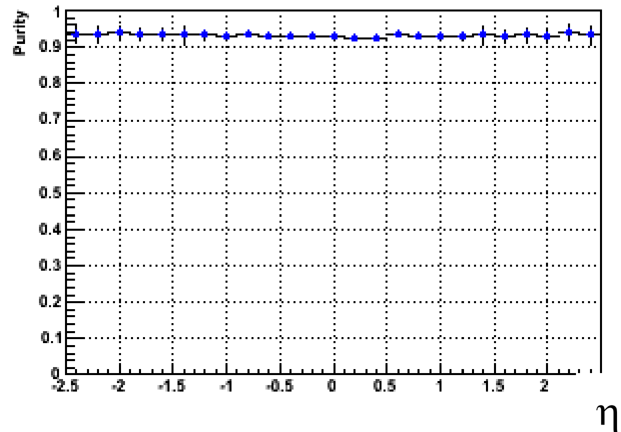
Purity Vs. pT



Efficiency Vs. η



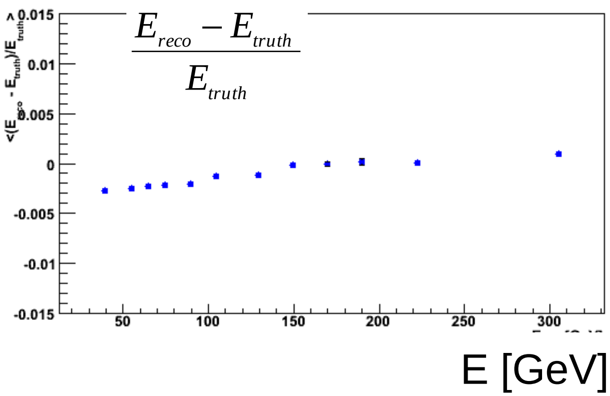
Purity Vs. η



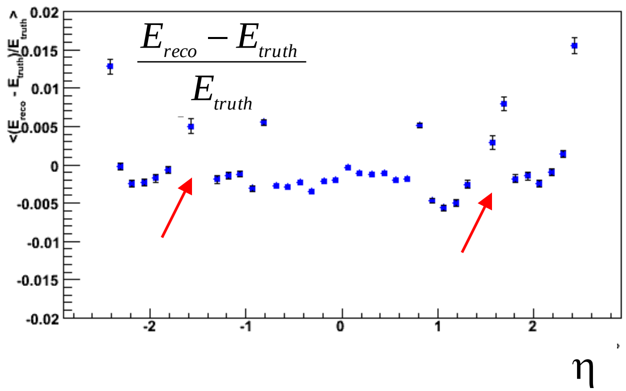
- Efficiency of electron reconstruction reaches 70% except for:
  - low pT and large |η|,
  - the overlap region between barrel and endcap calorimeters (cracks): 1.37<|η|<1.52,
  - |η|>1.52 (calorimeter endcaps).
- The contamination is ~5% (purity: ~95%, increases with pT).

Linearity, uniformity and resolution

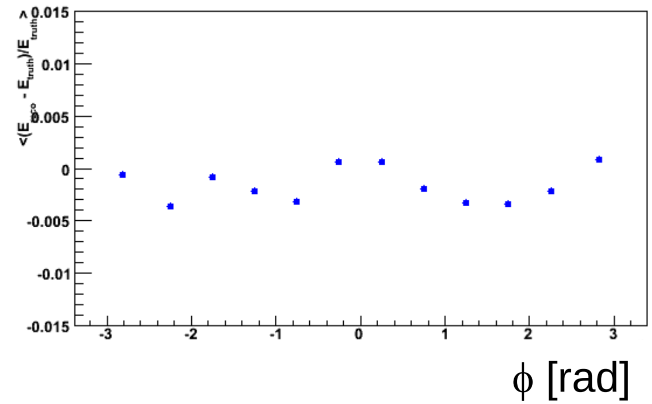
Energy linearity



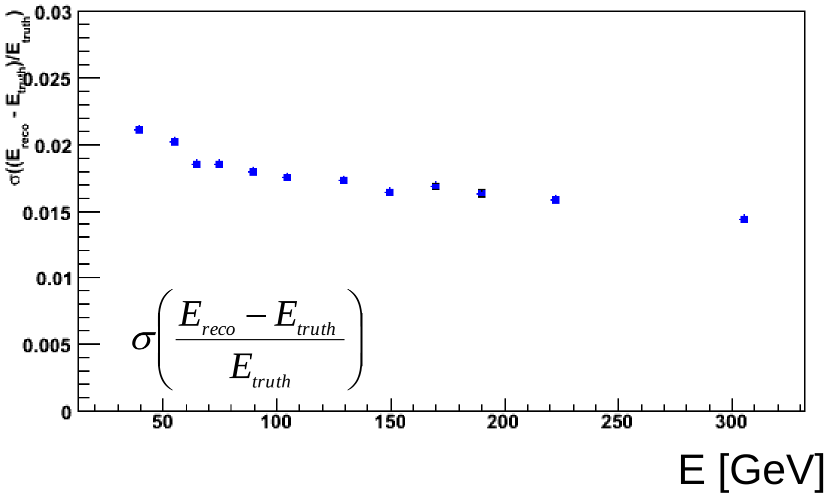
Energy uniformity in η



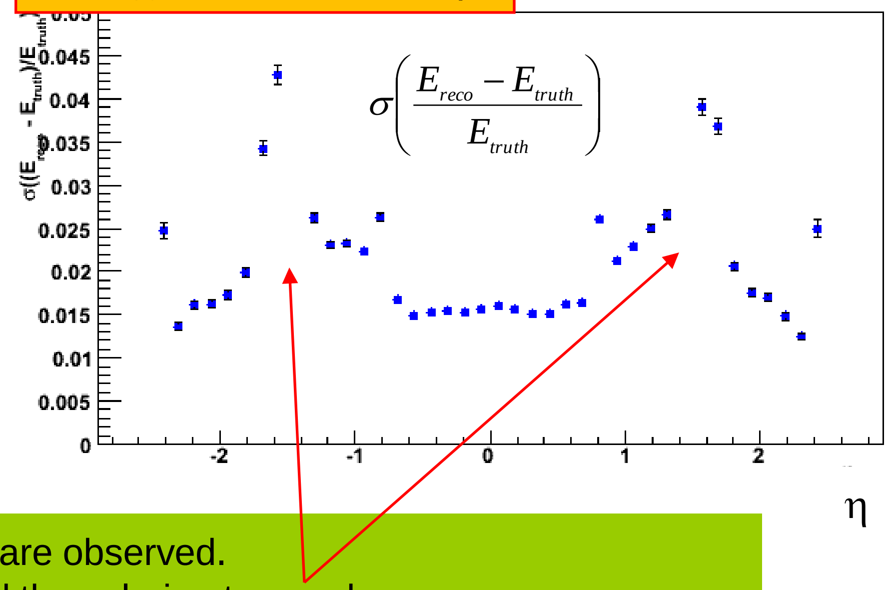
Energy uniformity in ϕ



Energy resolution Vs E



Energy resolution Vs η

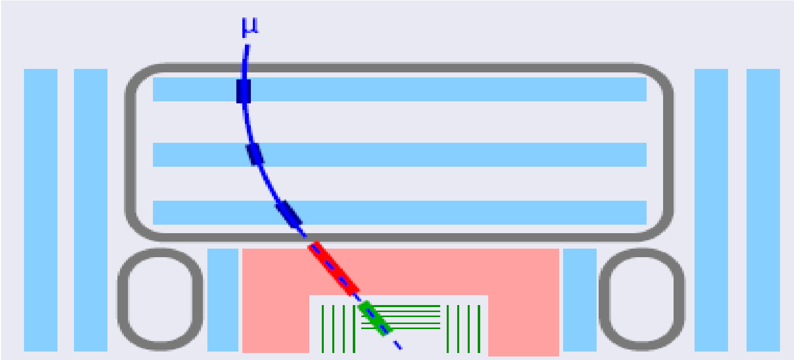


- A small departure from linearity and non-uniformities are observed.
- Resolution is better for high energy and worse around the calorimeter cracks.

Muon reconstruction performance

Muon reconstruction and selection

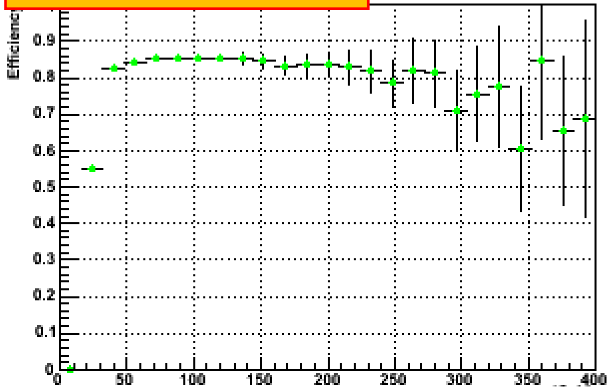
- **Truth muons**: muons coming from the W leptonic decay
- **Reconstructed muons**:
  - Muon signature: Muon track passes through the ID, the calorimeters material (minimum ionizing energy deposits) and the MS.
  - Muon reconstruction by STACO algorithm: ID + MS tracks→ $\chi 2$ match.
  - Cuts:
    - STACOmuons
    - isCombined=True
    - pT>20 GeV
    - $|\eta| < 2.5$
    - Isolation cut: the additional Et in a cone with radius $\Delta R=0.2$ around the muon <6 GeV
    - remove muons if there is a good jet within $\Delta R = 0.3$.



$$MATCHING \quad CRITERIA: \quad \chi^2 = \sqrt{\left(\frac{\phi_{reco} - \phi_{truth}}{0.005}\right)^2 + \left(\frac{\eta_{reco} - \eta_{truth}}{0.005}\right)^2 + \left(\frac{\Delta p_T / p_T}{0.03}\right)^2} < 100$$

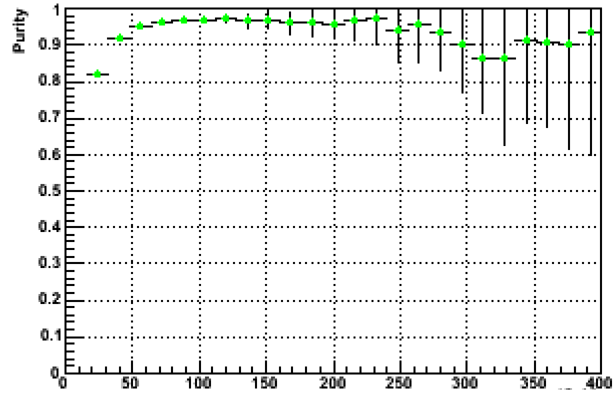
Efficiency and purity

Efficiency Vs. pT



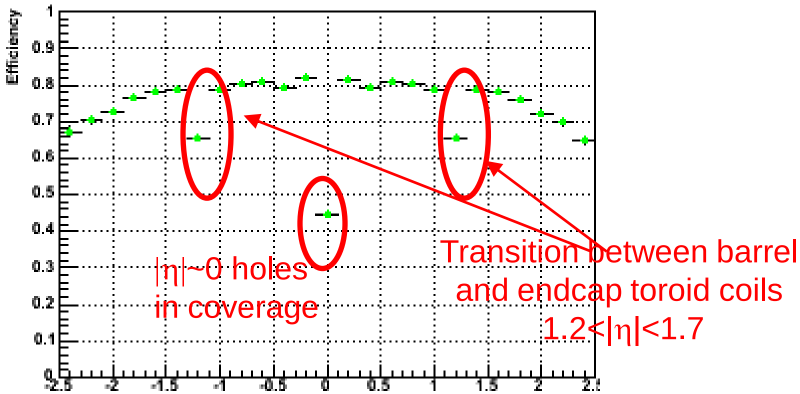
pT [GeV]

Purity Vs. pT



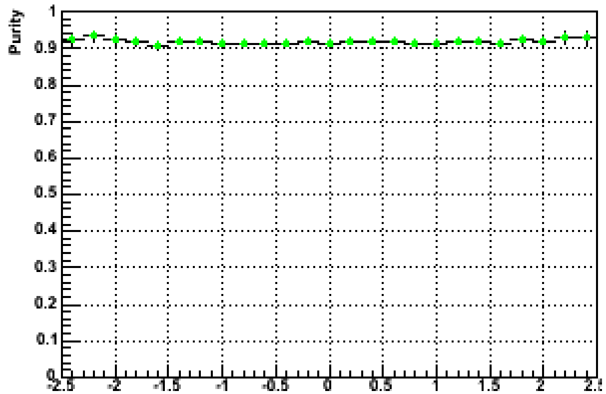
pT [GeV]

Efficiency Vs. η



η

Purity Vs. η

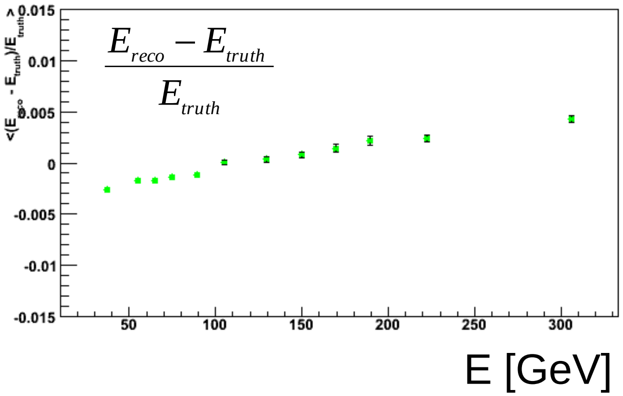


η

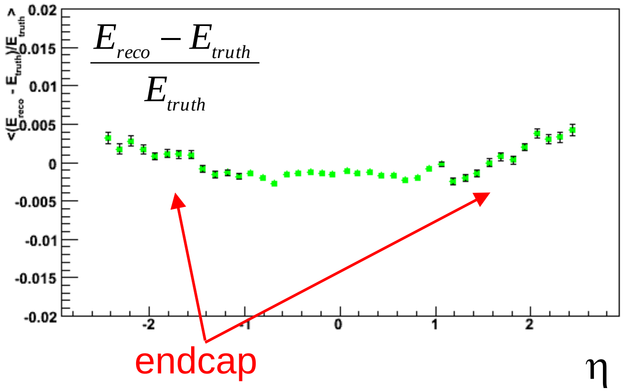
- Efficiency reaches 85% except for:
  - low pT region,
  - near $\eta \sim 0$ and intermediate region $1.2<|\eta|<1.7$.
- The purity is near 95%.

Linearity, uniformity and resolution

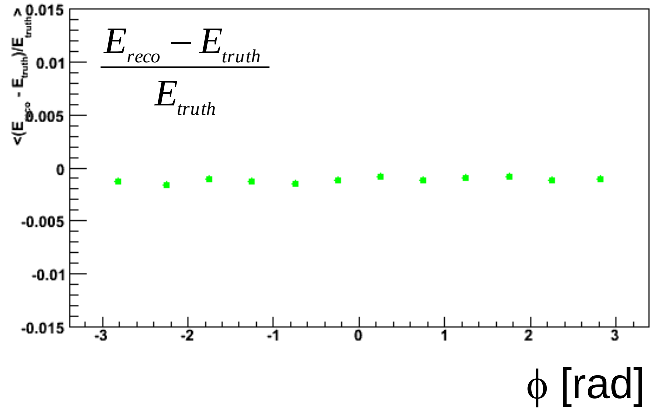
Energy linearity



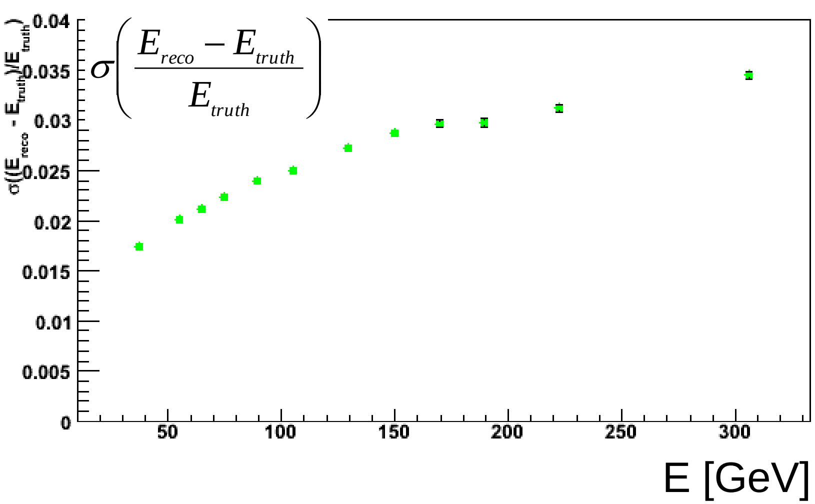
Energy uniformity in η



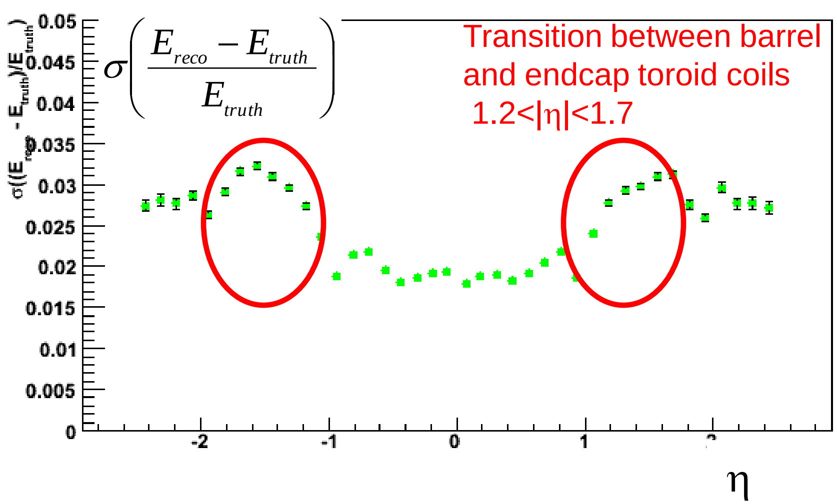
Energy uniformity in ϕ



Energy resolution Vs E



Energy resolution Vs η



- Good linearity and uniformity in ϕ. Small non-uniformities observed in endcap region.
- Resolution is better for low energy muons and is worse in the transition region 1.2<|η|<1.7.

MET reconstruction performance

MET reconstruction

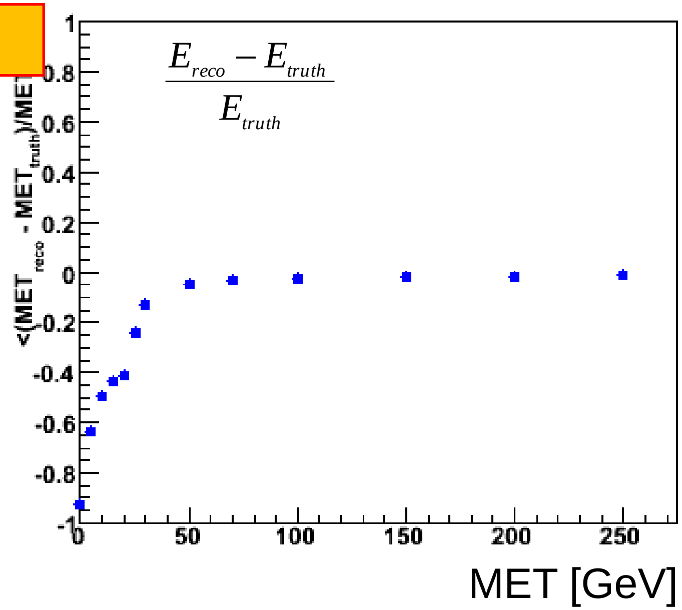
- The MET is used as an estimate of the neutrino transverse momentum.
- **Truth MET**: contribution from all stable and non-interacting particles in the final state.
- **Recontructed MET**:
    - Reconstructed by the RefMET algorithm (cell based):

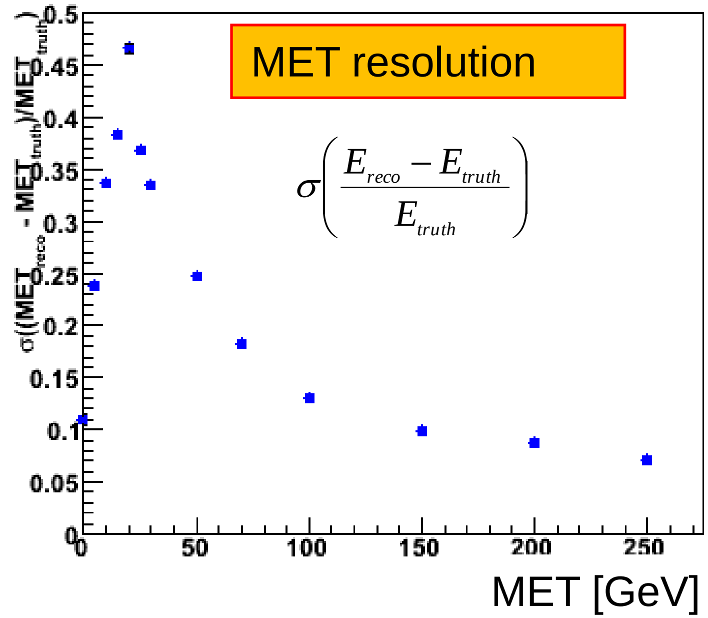
$$\not{E}_{x,y}^{Final} = MET_{x,y}^{Final} = MET_{x,y}^{Calo} + MET_{x,y}^{Cryo} + MET_{x,y}^{Muon}$$

The μ are not added in MET calculations
since there are standalone μ which are mostly fake.

MET performance

MET linearity



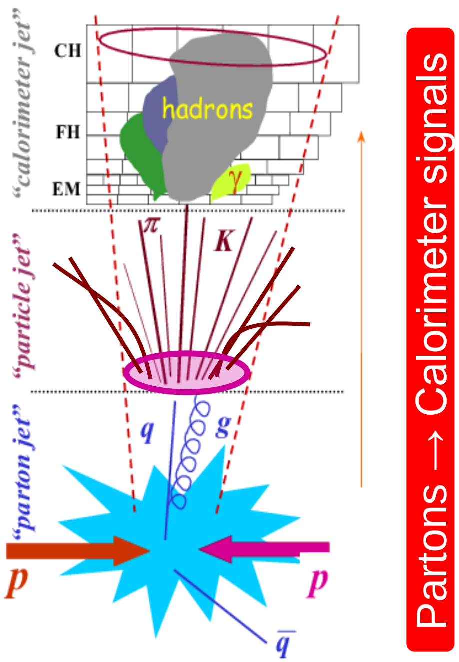


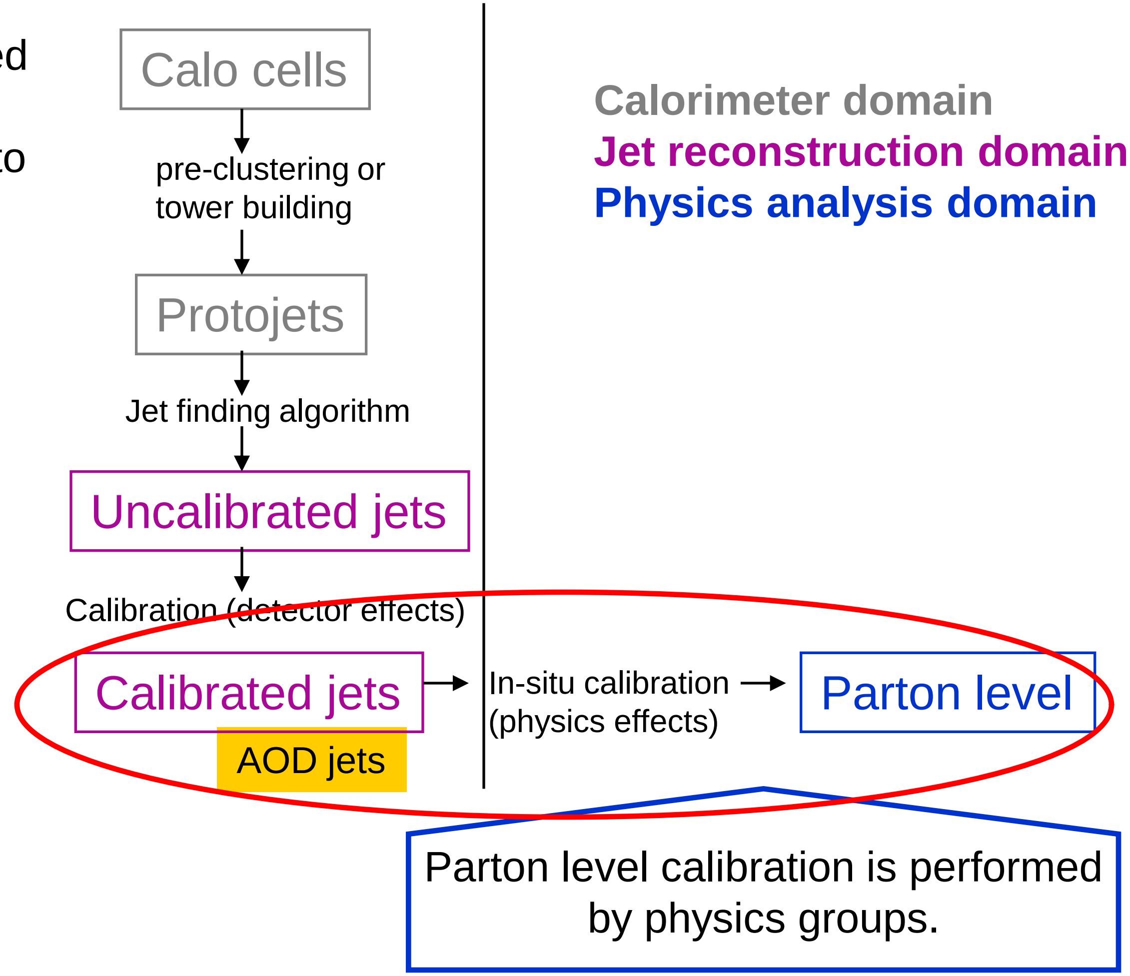
- Departure from linearity due to the fact that muons contributions are not included.
- The resolution is better for higher MET.
- A resolution of about 12 GeV is obtained, in agreement with what is expected.

Jet calibration

Jet calibration to quark level

The signals in the detector produced by the calorimeters must be reconstructed and calibrated back to parton level in order to study the physics of the event.





• **Goal:**
- compute correction factors to go from reconstructed jets calibrated by detector effects to quark level
- compute jet energy resolutions

Jet reconstruction and selection

- The ATLAS implementation of the fixed cone jet finder algorithm (Cone4TowerJets) with Rcone = 0.4 was used to build jets.
- Jets are defined at 3 levels:

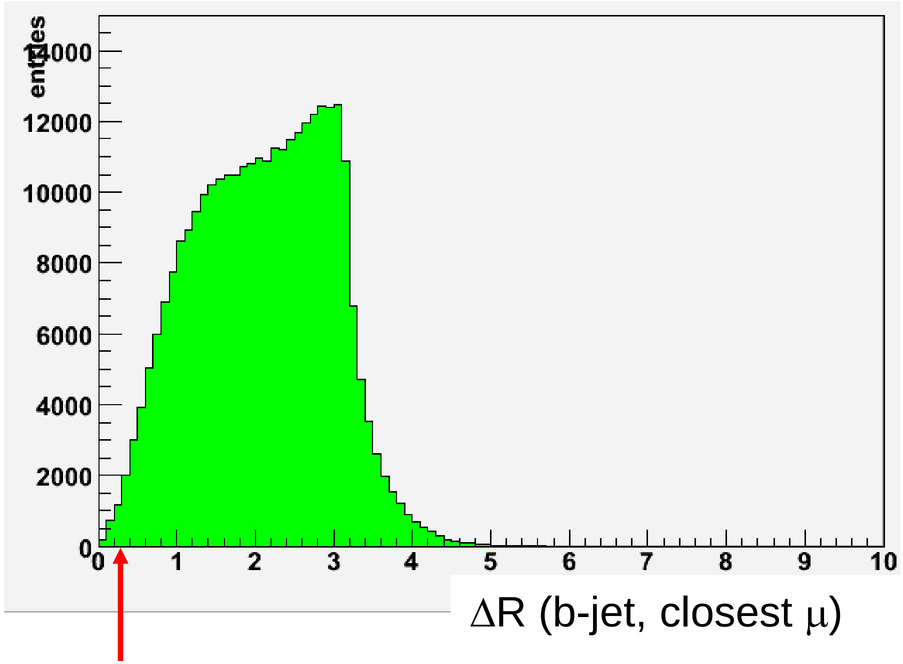
- **Quark level**: each quark is taken as a different jet
- **Truth Particle jets**: built from stable particles
  (neutrinos and muons generated in the collisions are excluded)
- **Reconstructed jets**: built from calorimeter towers defined as massless pseudo-particles
  (corrected by detector effects)
  - Cuts applied:
    - pT > 40 GeV (for top mass measurement) and pT>20 GeV (for jet calibration)
    - $|\eta|< 2.5$
    - Jets coinciding within $\Delta R<0.2$ with reconstructed electrons are removed.

- Matching criteria:
  - Jets at different levels are associated based on the minimum ΔR and requiring:

$$\Delta R = \sqrt{(\phi_{reco} - \phi_{truth})^2 + (\eta_{reco} - \eta_{truth})^2} < 0.3$$

Jet clasification

- 3 types of jets have been considered separately:
  - **light jets**
  - **b-jets not close to a reconstructed muon**
  - **b-jets close to a reconstructed muon** (i.e. ΔR(jet,muon)<0.2)



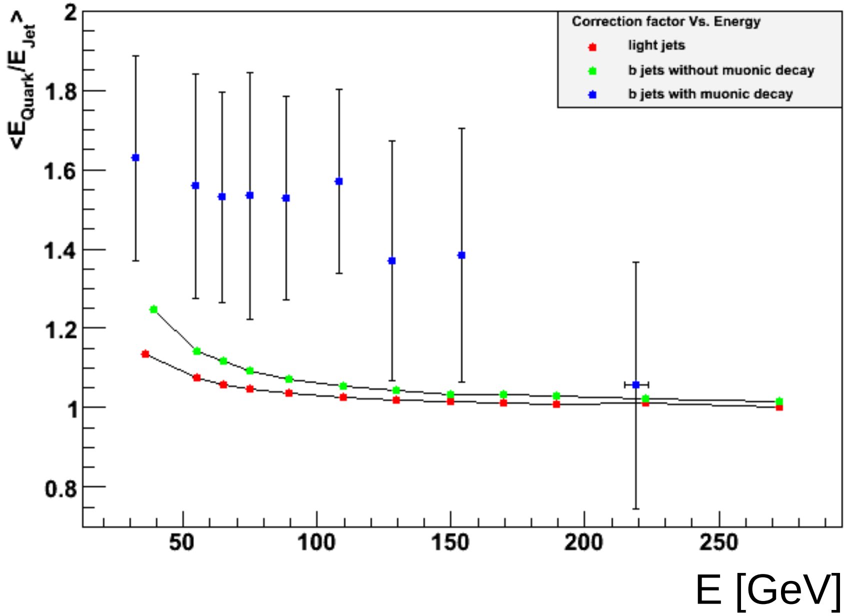
- at reconstruction level the IP3D + SV1 b-tagging algorithm was used to tag b-jets (weight > 6)

Correction factors and resolutions

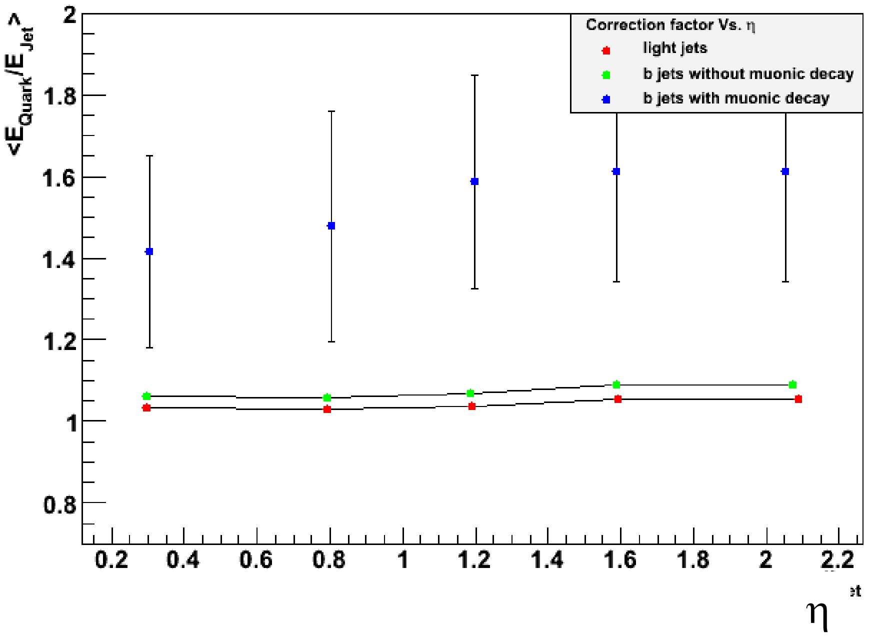
- Correction factors (E_{quark}/E_{jet}) and energy resolutions ($\sigma(E_{quark}-E_{jet})$)
-depend on the jet energy and γ.

Correction factors

Vs. Energy



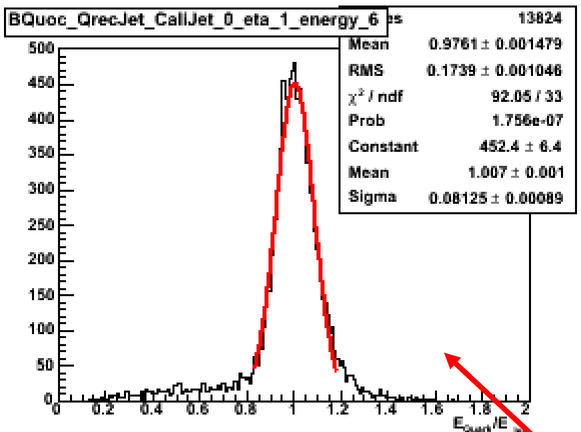
Vs. η



- Energy scale depends on the type of jets
- Correction factors are higher for b-jets with muonic decay (since the energy of the muon is not reconstructed in the jet)..

Correction factors and resolutions

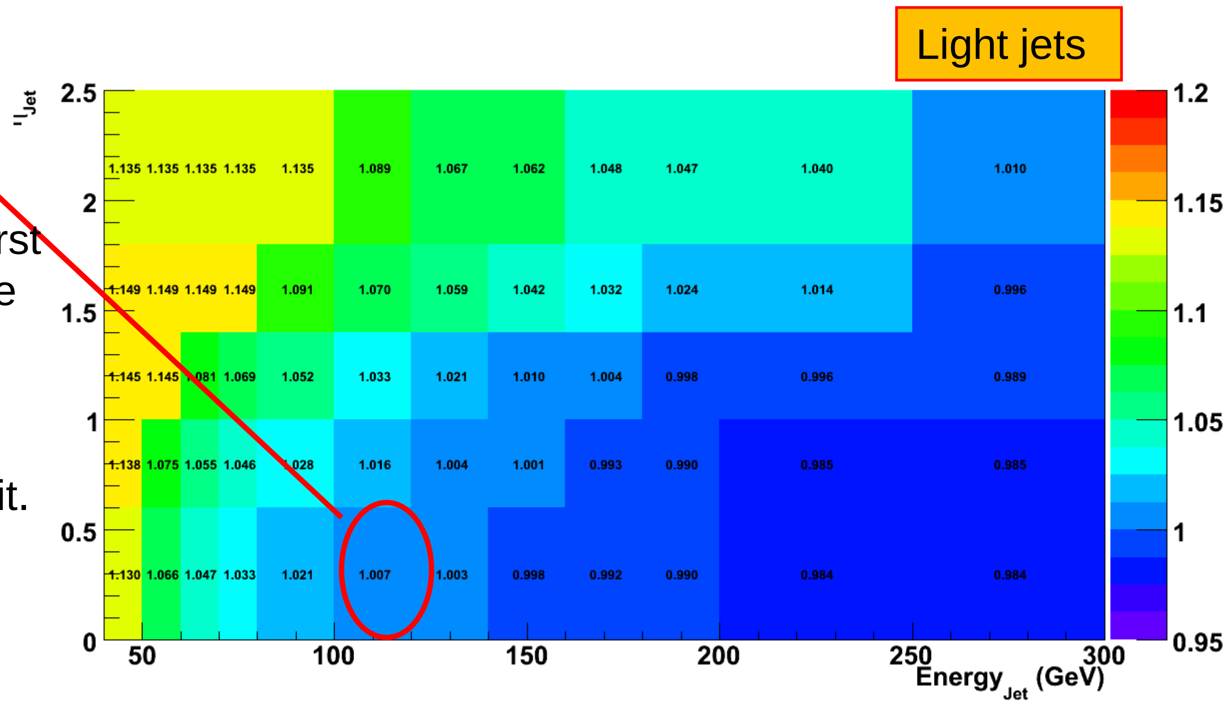
- Correction factors (E_{quark}/E_{jet}) and energy resolutions ($\sigma(E_{quark}-E_{jet})$) are computed for different energy and η regions.



$100<|E_{jet}| \leq 120$

$0 \leq |\eta_{jet}| < 0.6$

To make the fit more stable, a first Gaussian was fitted between the mean of the histogram ±2 times the RMS. A second fit is then perform in the same way using the mean and width of the first fit.

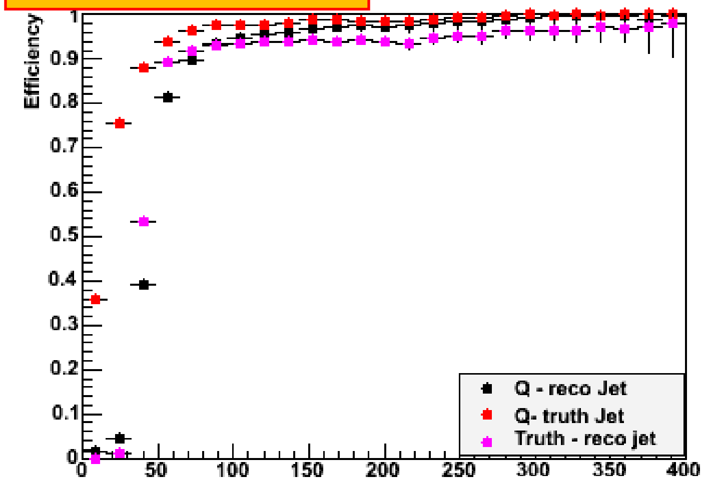


Jets reconstruction performance

Once jets are calibrated, …

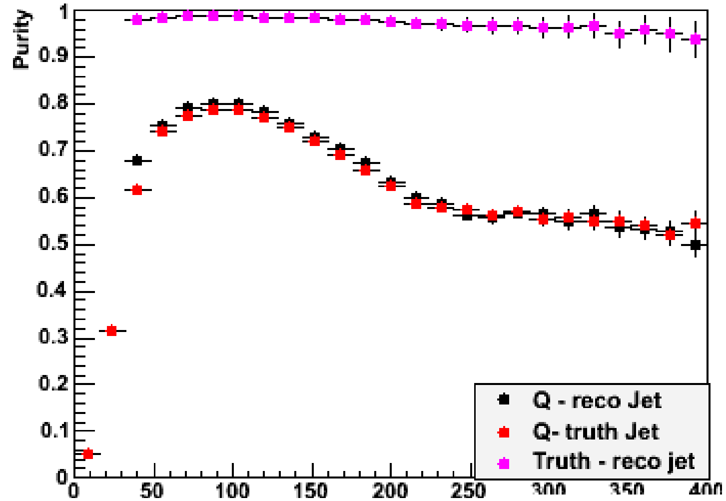
Efficiency and purity

Efficiency Vs. pT



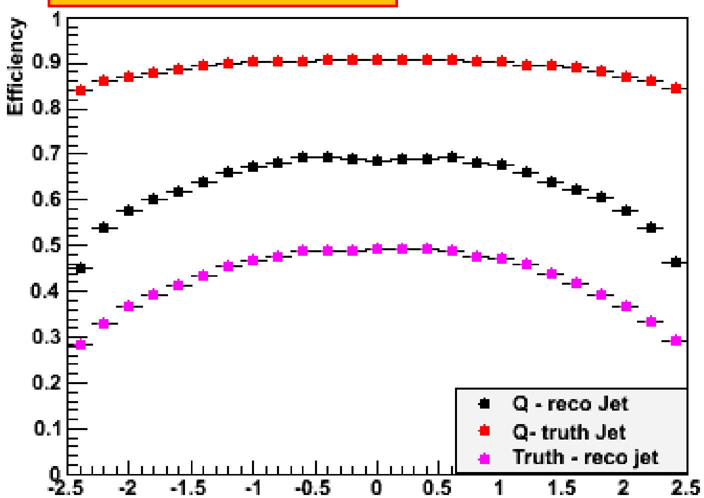
pT [GeV]

Purity Vs. pT



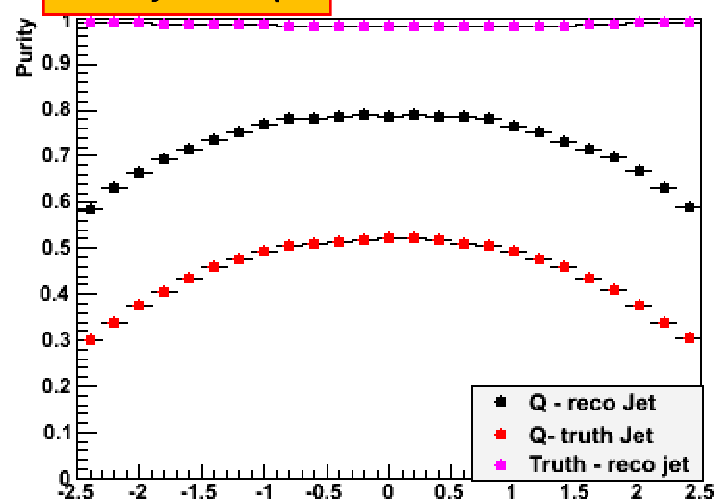
pT [GeV]

Efficiency Vs. η



η

Purity Vs. η



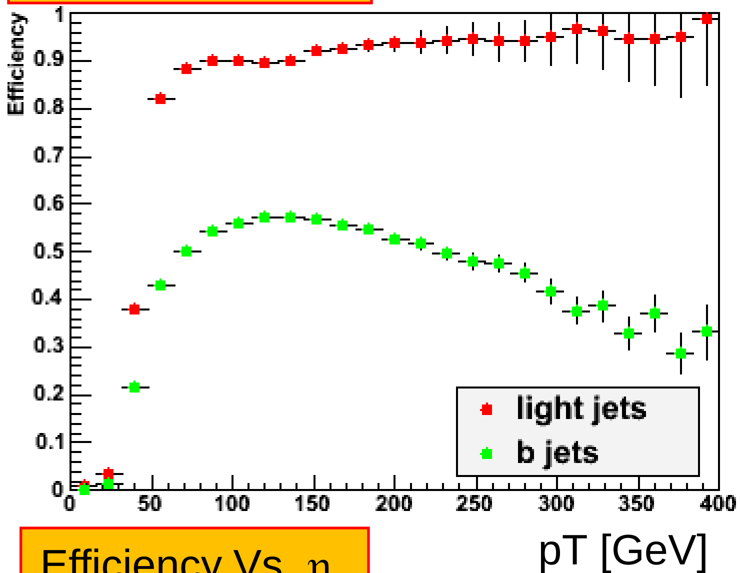
η

- Efficiencies are higher when comparing quarks-truth jets.
- Purity is near 1 when comparing truth and reco jets; while the others are lower due to effects of the hadronization.

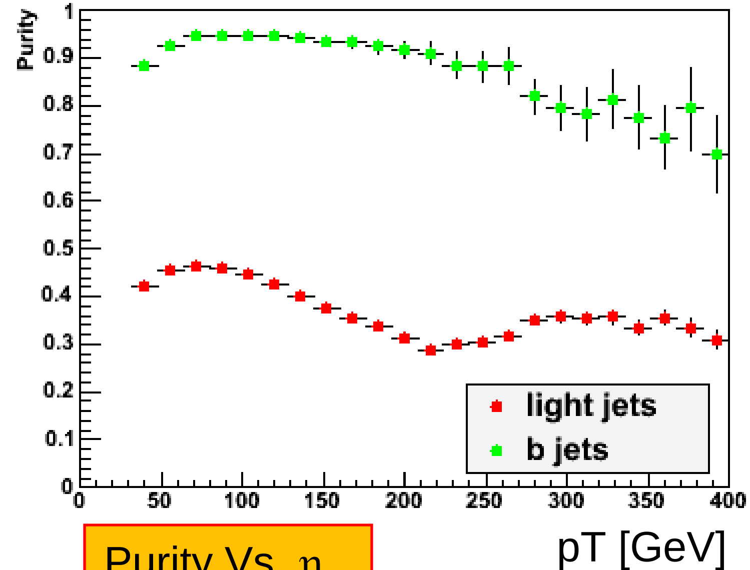
Efficiency and purity

Q-reco jet

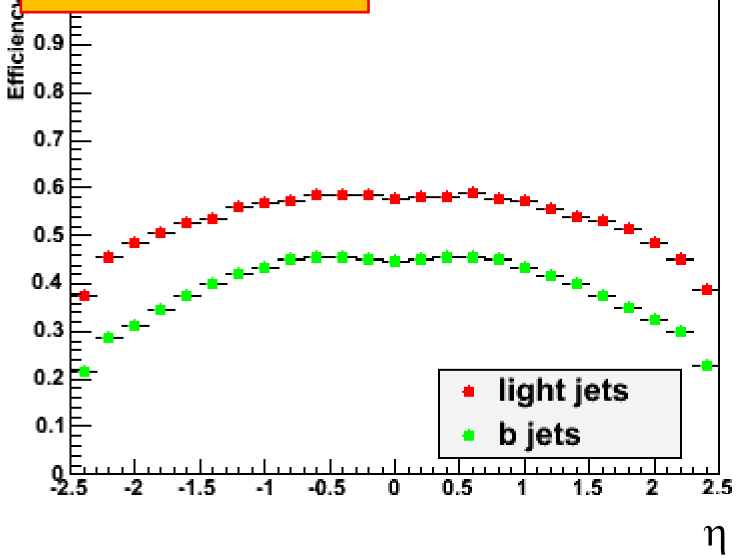
Efficiency Vs. pT



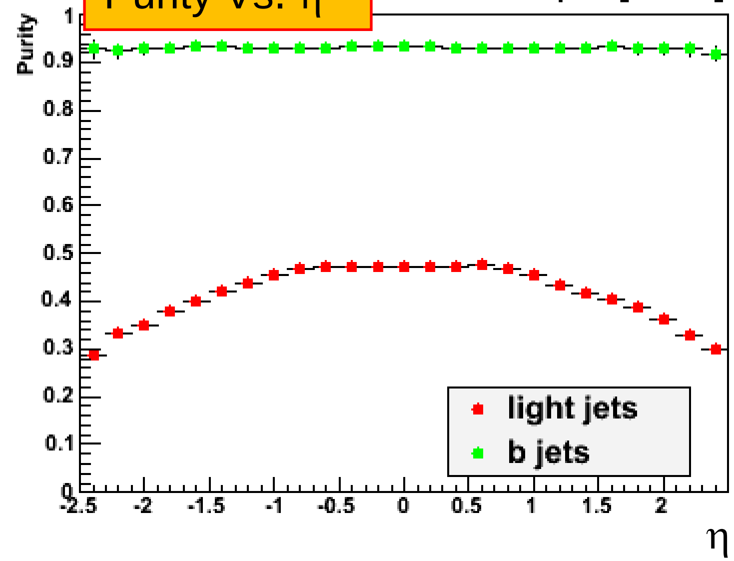
Purity Vs. pT



Efficiency Vs. η



Purity Vs. η

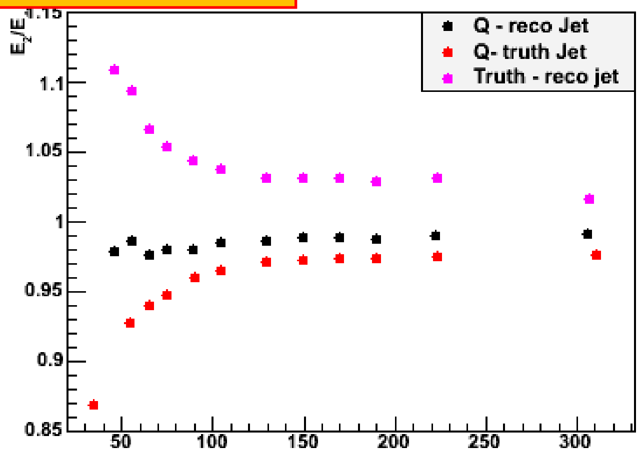


- Efficiency is higher for light jets than for b-jets while the purity is lower.

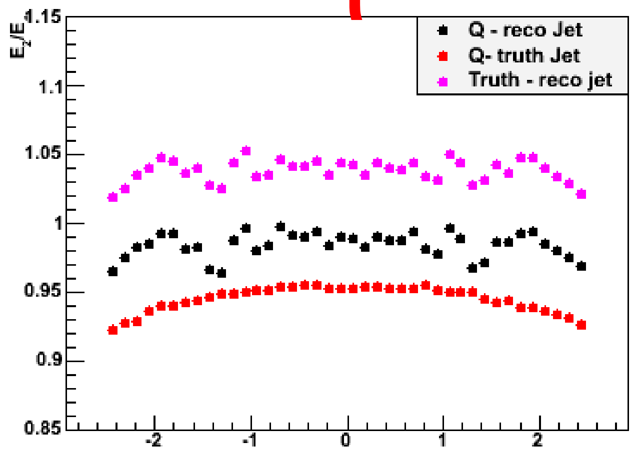
Linearity, uniformity and resolution

Energy scale

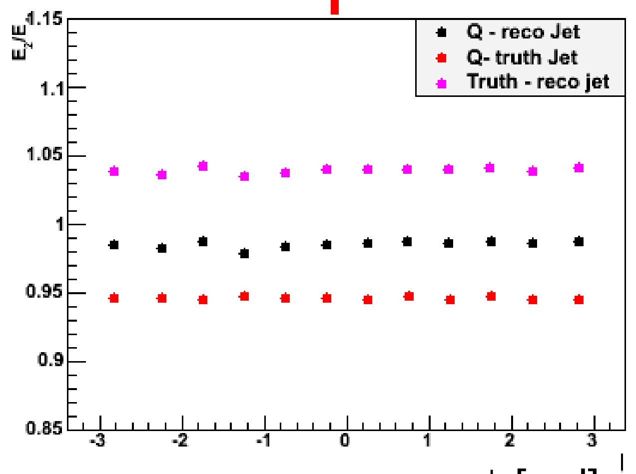
Vs E



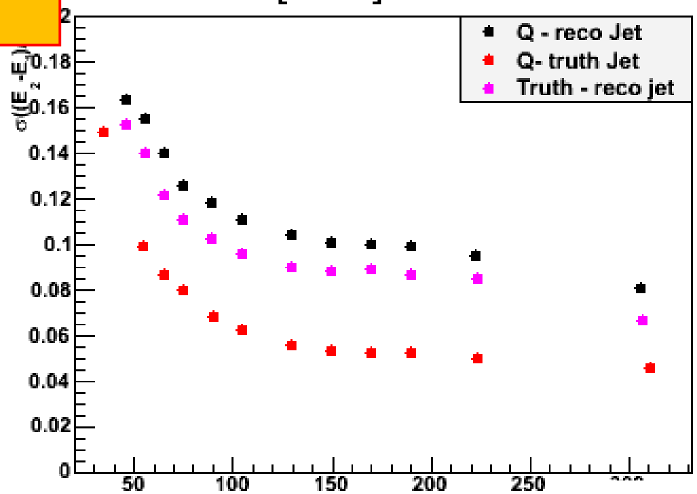
Vs η

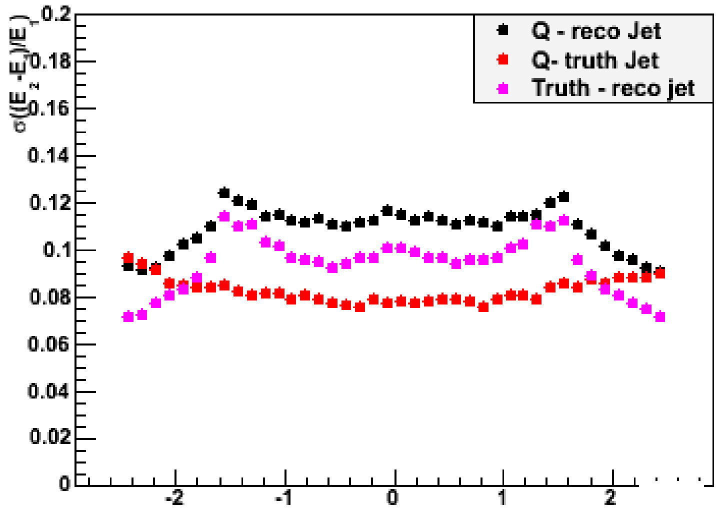


Vs ϕ



Resolution



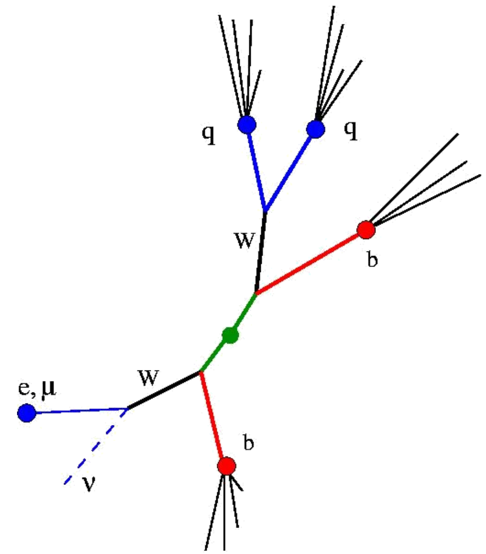


- Departures from linearity when comparing Q-truth jets or truth – reco jets.
- After jet calibration (from reco jets to quarks) the linearity is near 1.
- Resolution increases for higher energies and is worse when comparing Q-reco jets.

Event selection

- **Semi-leptonic channel** (electron, muons or taus decaying leptonically + jets), :

- **1 lepton (e or μ) isolated, P_T > 25 (20) GeV , |η| < 2.5**
- **MET> 20 GeV**
- **Jet energy calibration**
- **Jets selection**
  - **→ ≥ 4 jets, p_T > 40 GeV, |η| < 2.5**
  - **→ 2 of the jets tagged as b-jets**



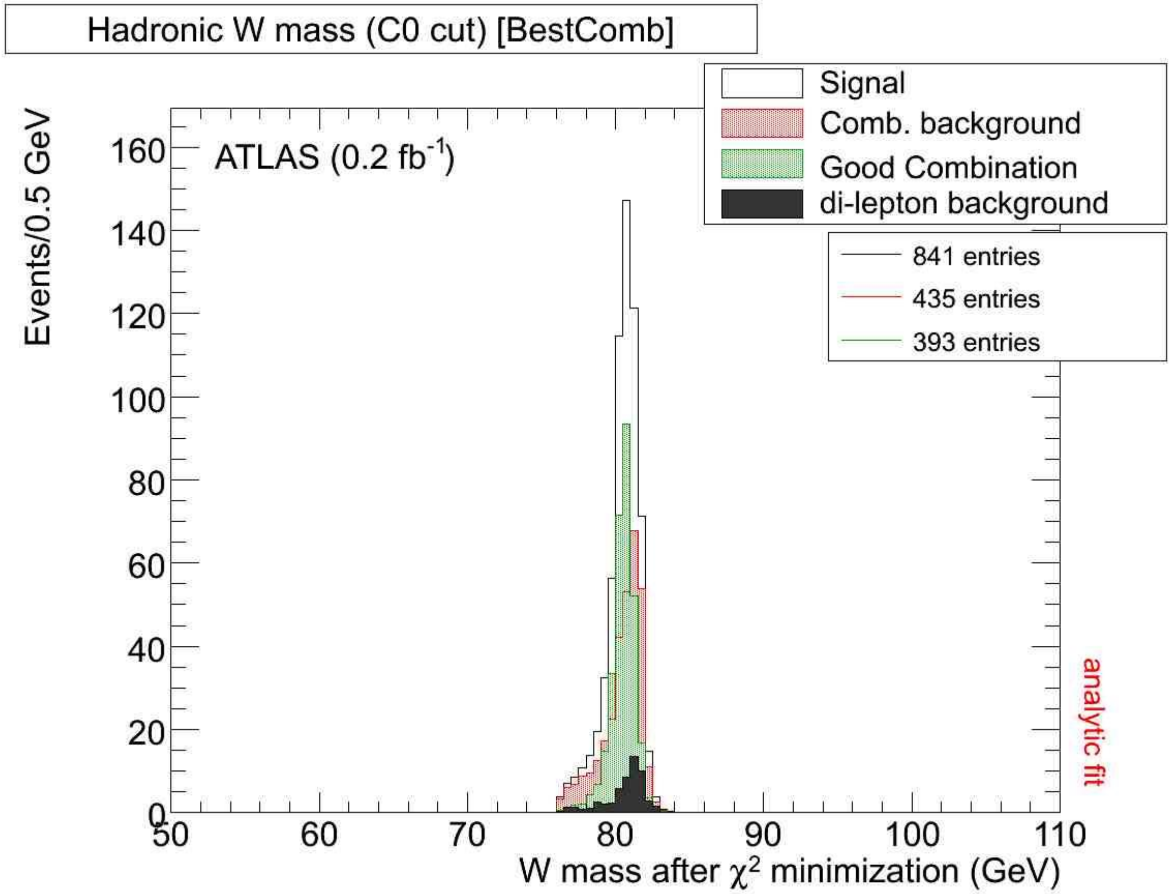
L=200 pb^{-1} @ 10 TeV

Process	Number of events	1 isolated lepton pT>20(25) GeV	MET>20 GeV	>= 4 jets pT>40 GeV	= 2b-jets pT>40 GeV
Signal	**27831**	**14602 (52%)**	**13061 (47%)**	**4971 (18%)**	**1191 (4%)**
Di-leptonic	8882	4312 (49%)	4054 (46%)	663 (7%)	175 (2%)
τ+jets	7698	44 (0.6%)	40 (0.5%)	10 (0.14%)	2 (0.02%)

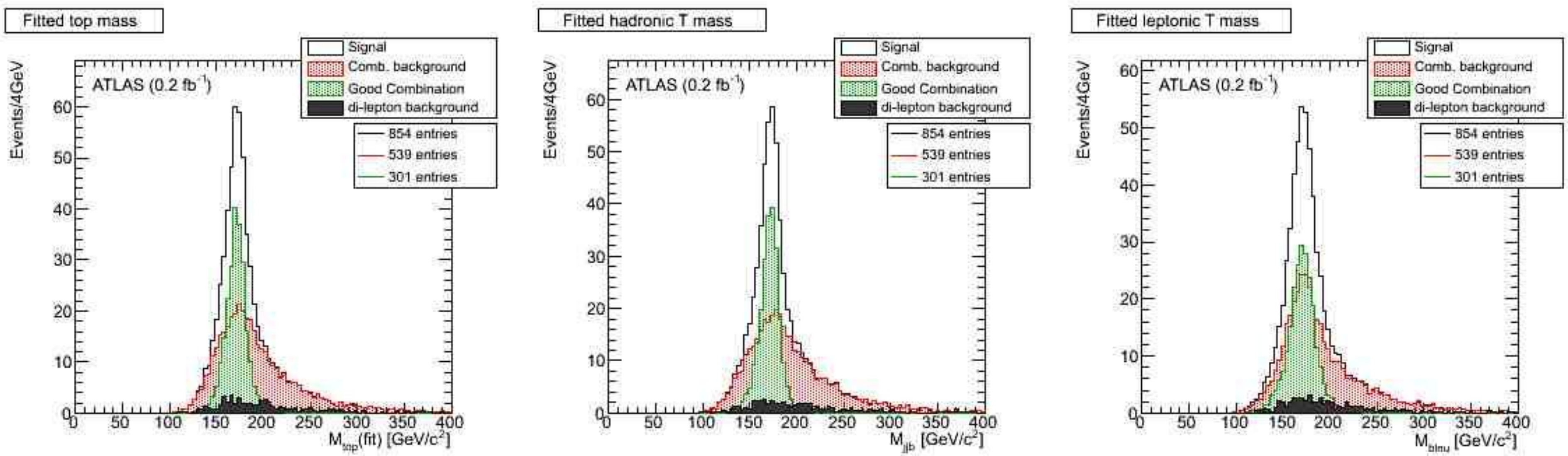
- About 4 % of the signal events pass all cuts (similar to the result obtained with TopView ntuples @ 14 TeV).
- Acumultaive efficiencies after each cut are shown.

First results from the kinematic fit

Top mass results: Hadronic W



Top mass results: fitted top mass



Conclusions

• The analysis code has been modified to read both TopView ntuples (to compare with CSC results) and D3PDs.
• D3PDs are produced from AODs in Athena (ARATopQuarkAnalysis) using the Grid (Ganga).

• Only dataset 105200 has been studied so far; need to look to backgrounds.

• The performance of the reconstruction of final state objets of the semi-leptonic channel: electrons, muons, jets and missing Et has been studied using MC08.

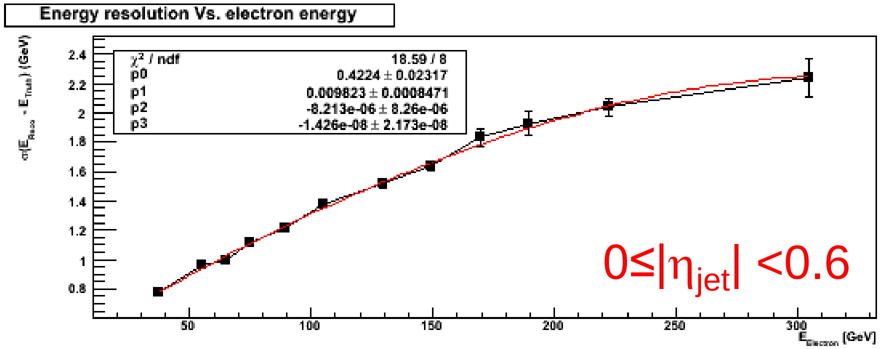
• Energy resolutions have been provided for leptons and jets, in order to use them in the χ^2 function used to determine the top mass.
For jets, a calibration to correct reconstructed jets energy to parton level has been provided.

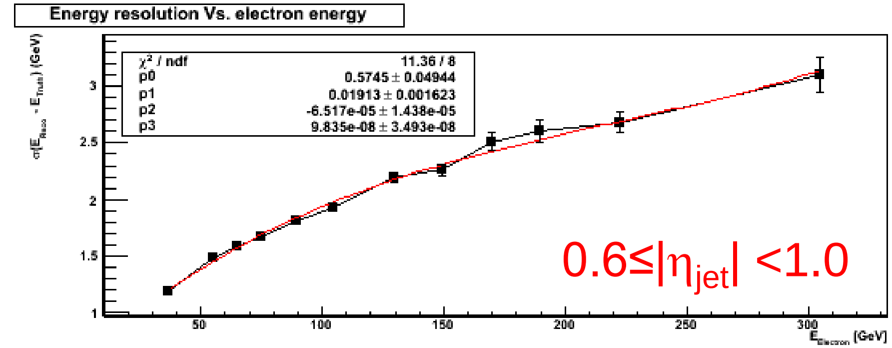
• First look at kinematic fit results leads to reasonable results.

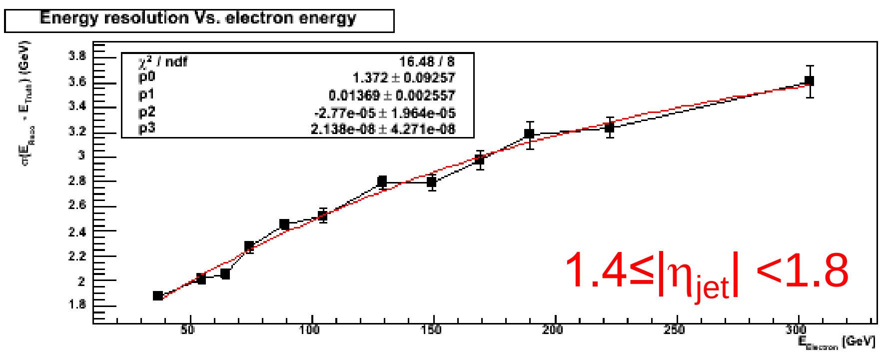
BACK-UP SLIDES

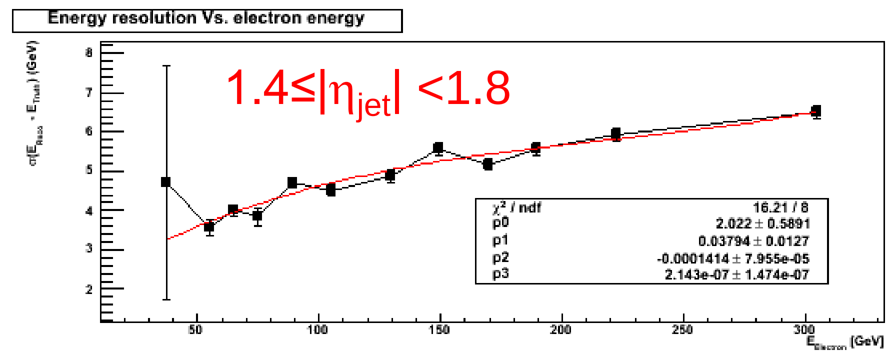
Resolution $\sigma(E_{reco} - E_{truth}) = p0 + p1 \cdot E_{reco} + p2 \cdot E_{reco}^2 + p3 \cdot E_{reco}^3$

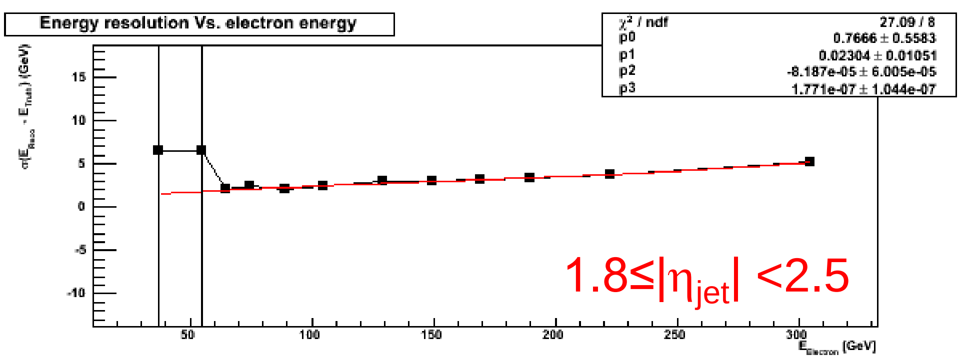
Electrons





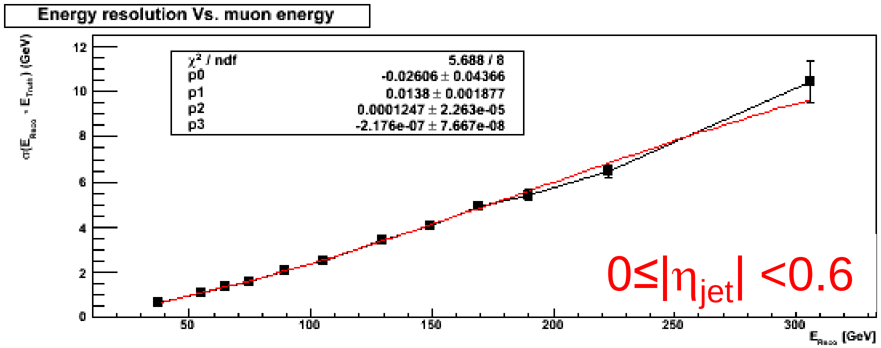


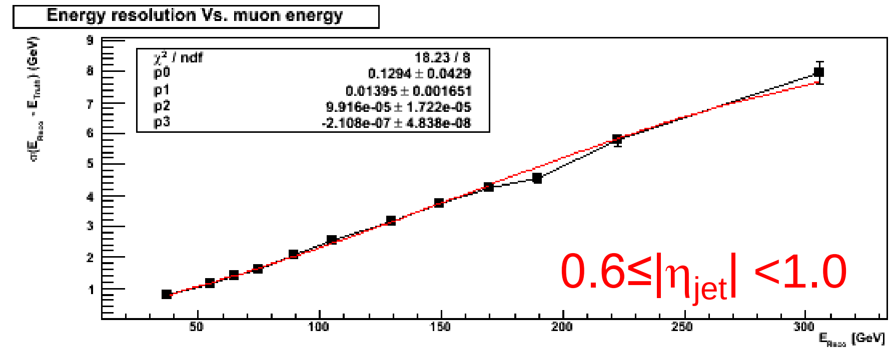


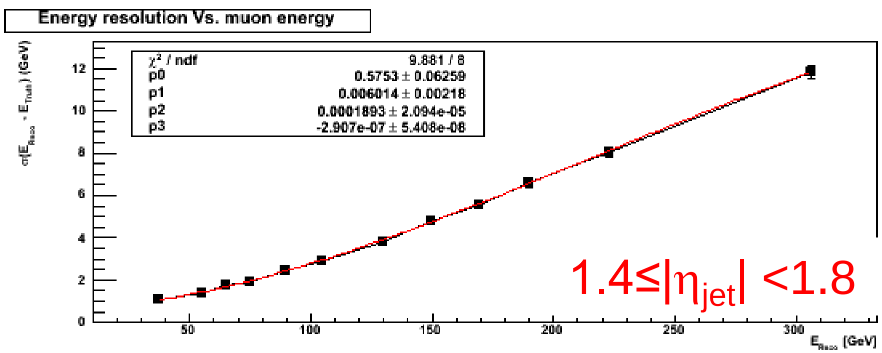


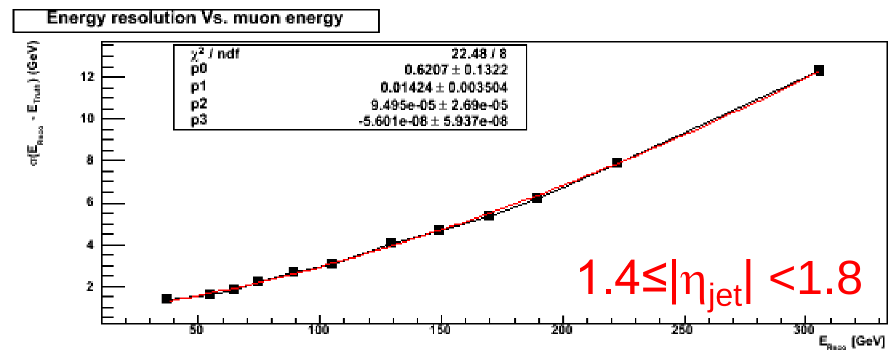
Resolution $\sigma(E_{reco} - E_{truth}) = p0 + p1 \cdot E_{reco} + p2 \cdot E_{reco}^2 + p3 \cdot E_{reco}^3$

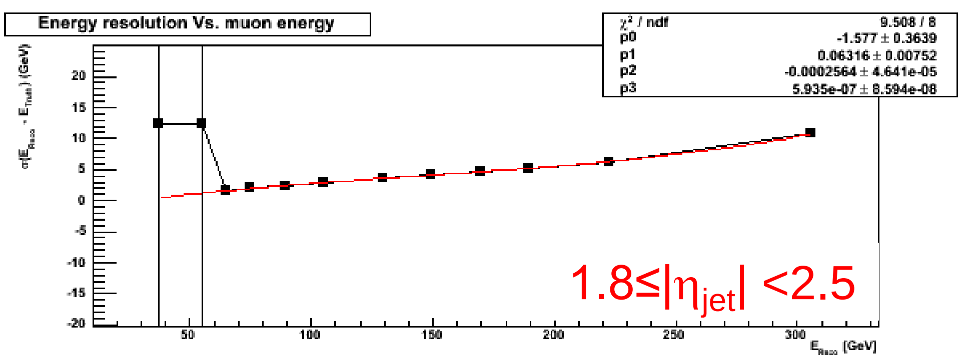
Muons





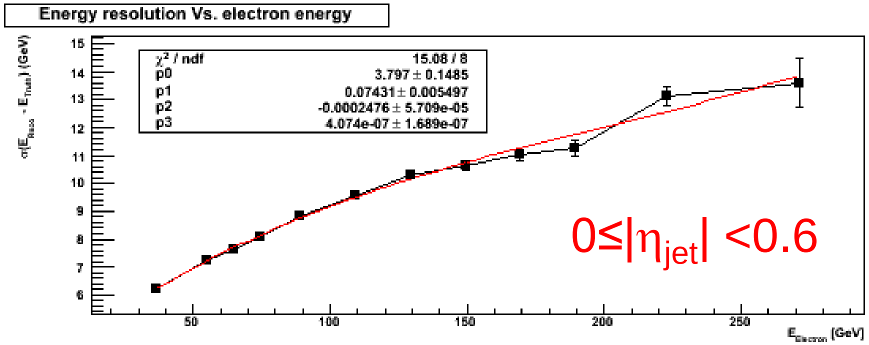


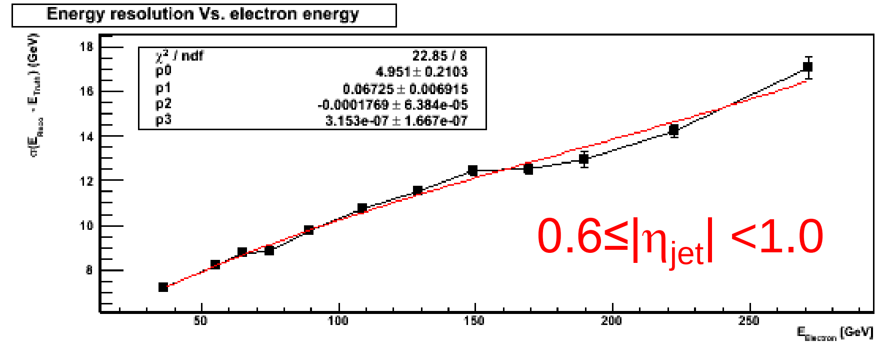


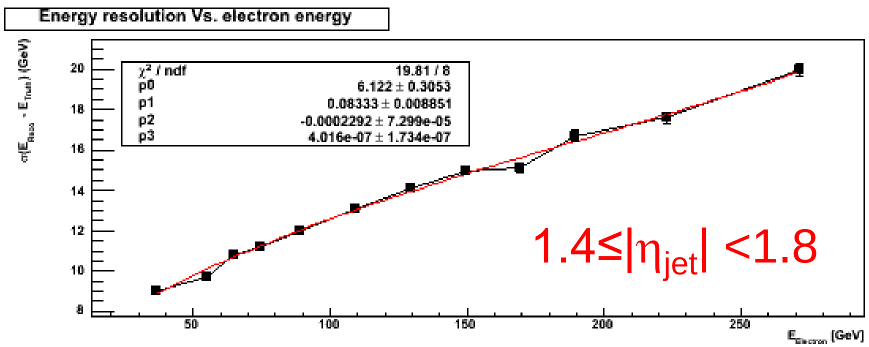


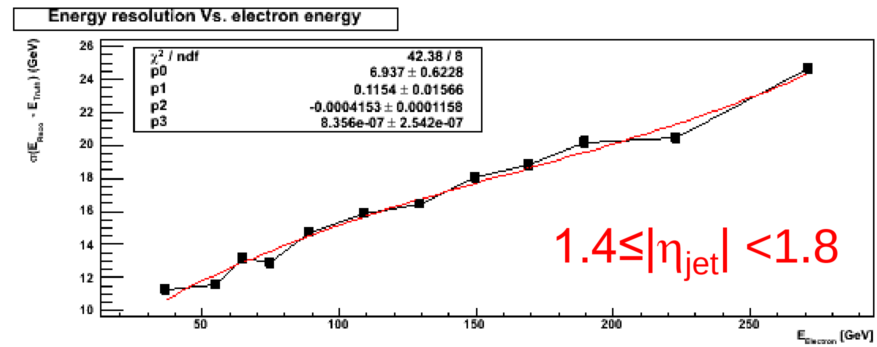
Resolution $\sigma(E_{reco} - E_{truth}) = p0 + p1 \cdot E_{reco} + p2 \cdot E_{reco}^{2} + p3 \cdot E_{reco}^{3}$

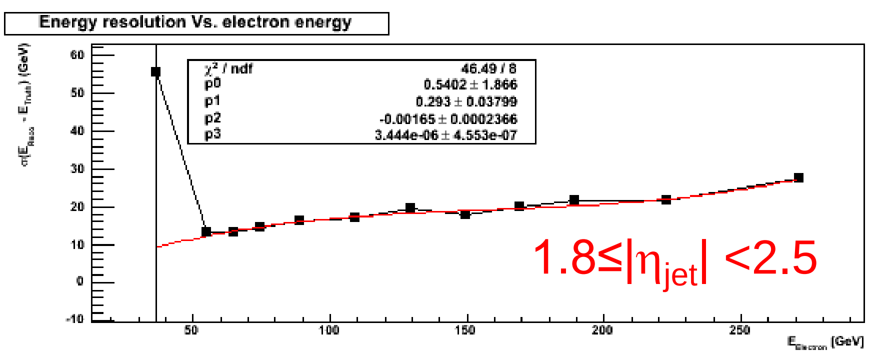
Light jets





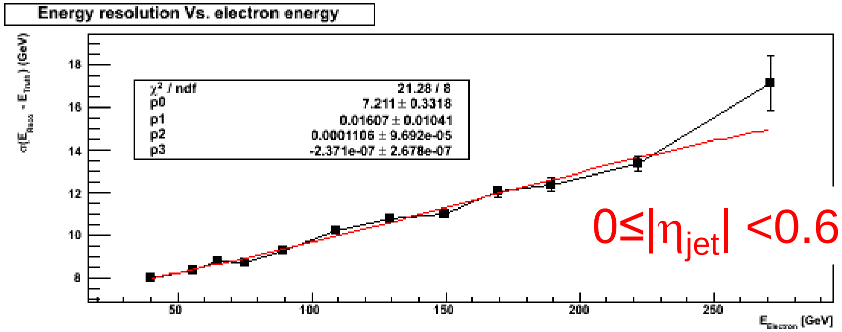


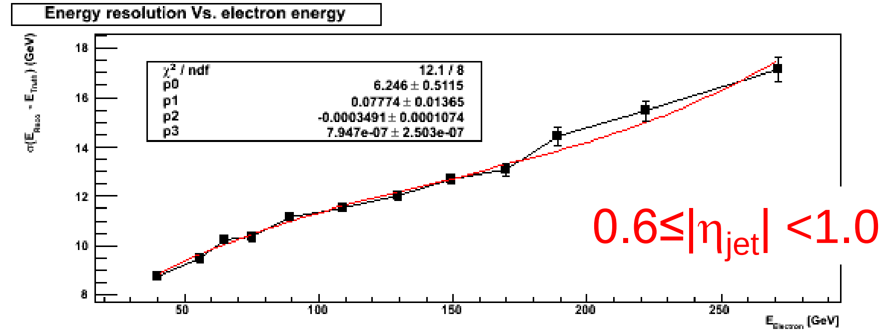


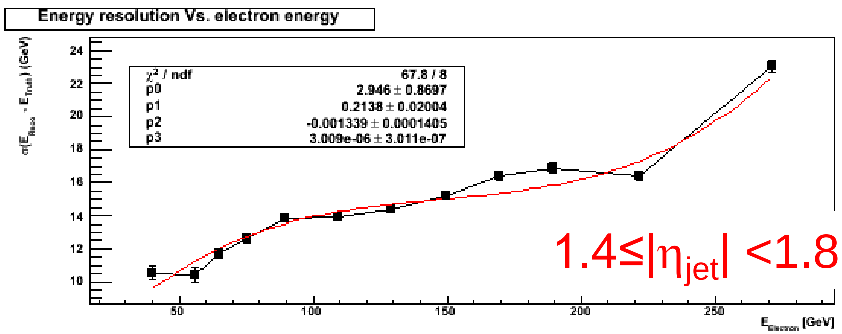


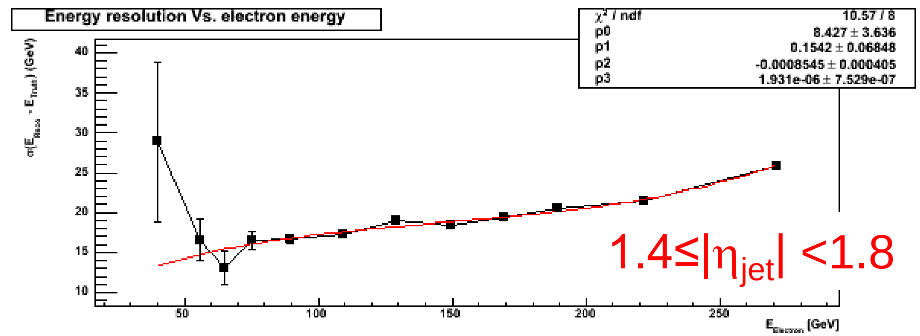
Resolution $\sigma(E_{reco} - E_{truth}) = p0 + p1 \cdot E_{reco} + p2 \cdot E_{reco}^2 + p3 \cdot E_{reco}^3$

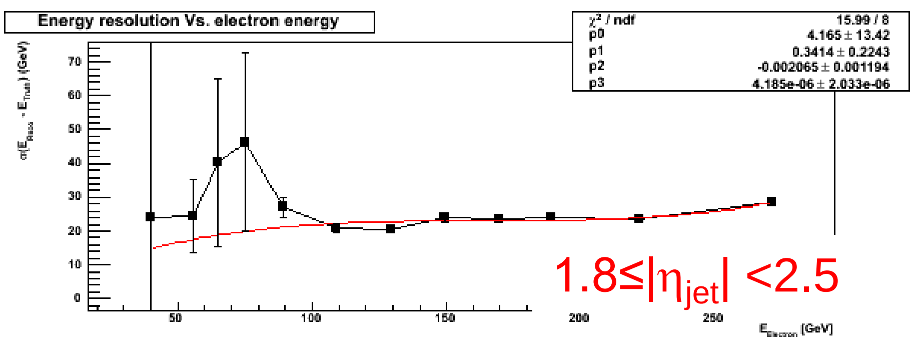
b jets (non muonic decay)











TOP decays

- **Production**: σtt(@10TeV) ~400 pb
- **Final states:** depending on the W decay channel

1) Fully-leptonic (1/9): 2l + 2v + 2 jets
2) Fully-hadronic (4/9) 6 jets
3) Semi-leptonic (4/9): 1l + 1v + 4 jets → *Golden channel*: 2.5 million ev/year

Category	Decay Mode	BR	
Dilepton	tt-bar →evb evb	1/81	4/81 (5%)
	tt-bar →μvb μvb	1/81	
	tt-bar →evb μvb	2/81	
τ-Dilepton	tt-bar →evb τvb	2/81	5/81 (5%)
	tt-bar →μvb τvb	2/81	
	tt-bar →τvb τvb	1/81	
Lepton+jets	tt-bar →evb qqb	12/81	24/81 (30%)
	tt-bar →μvb qqb	12/81	
	tt-bar →τvb qqb	12/81	
All-hadronic	tt-bar →qqb qqb	36/81	36/81(44%)

Top Pair Decay Channels