Timing performance of the ATLAS calorimeters

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Preliminary study for Master's thesis.

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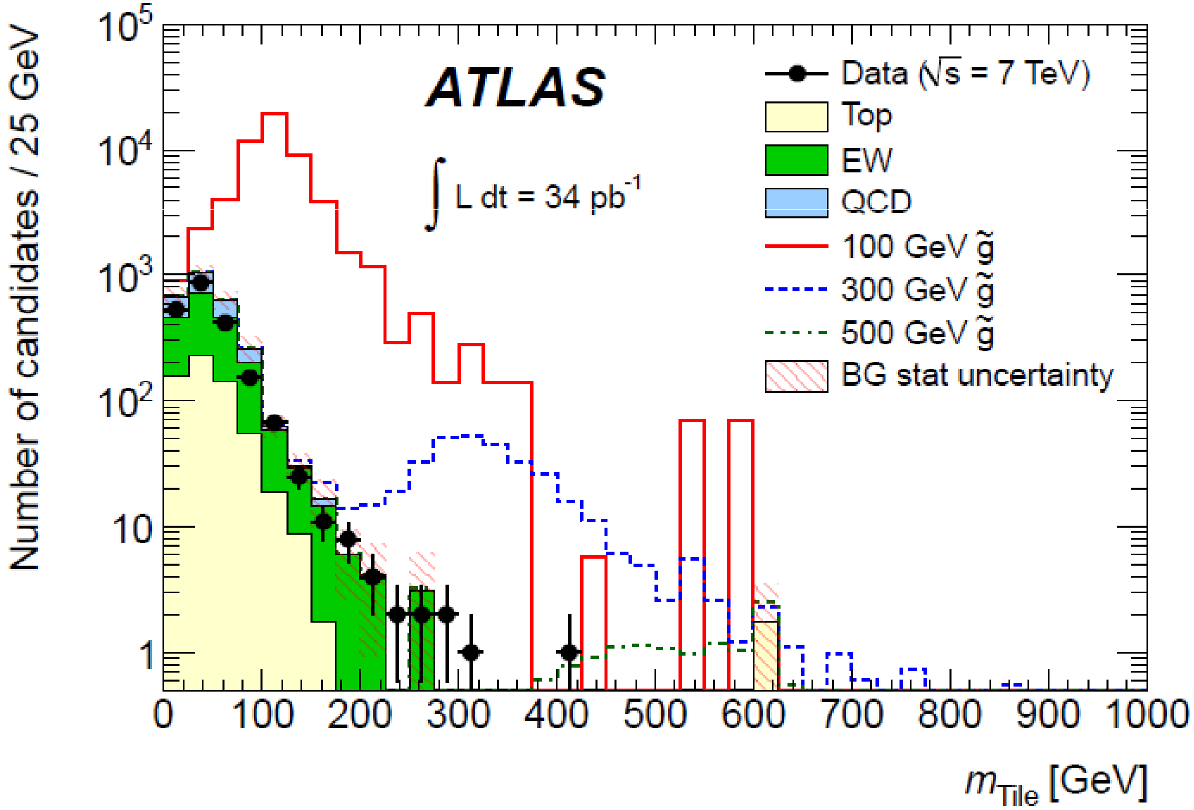
Timing performance of the ATLAS calorimeters

Motivation:

- Search for stable massive particles (R-hadrons)
- Speed measurements
- Mass exclusion limits

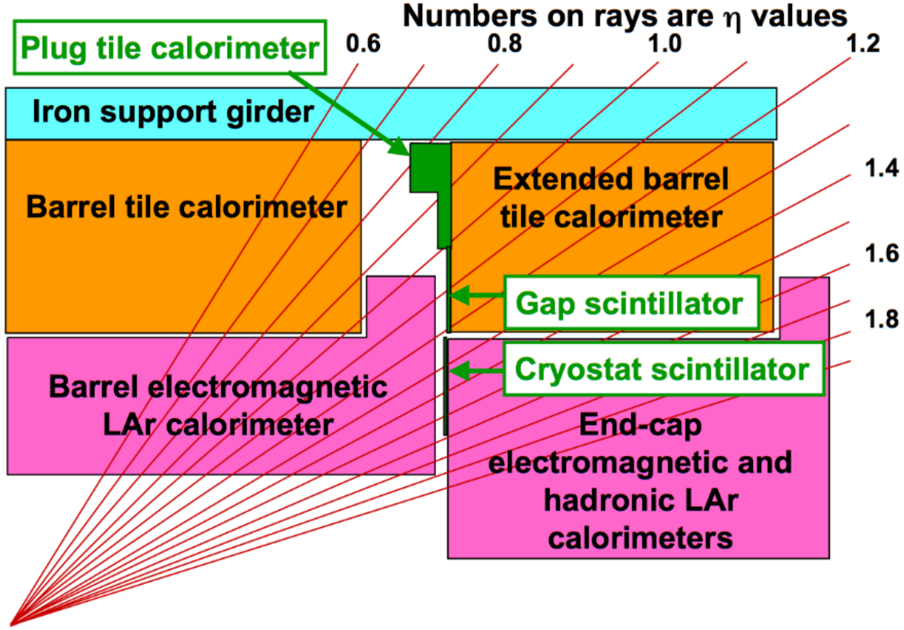


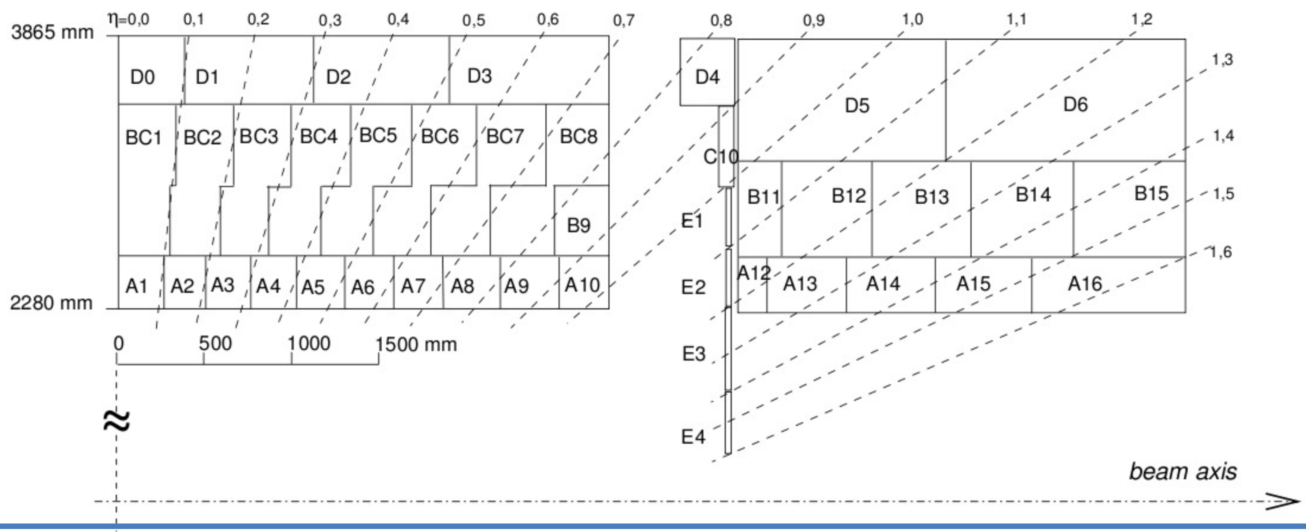
Mass reconstruction:

$$m_{\mathrm{SMP}} = \frac{p}{\beta\gamma} = p\frac{\sqrt{1-\beta^2}}{\beta}$$

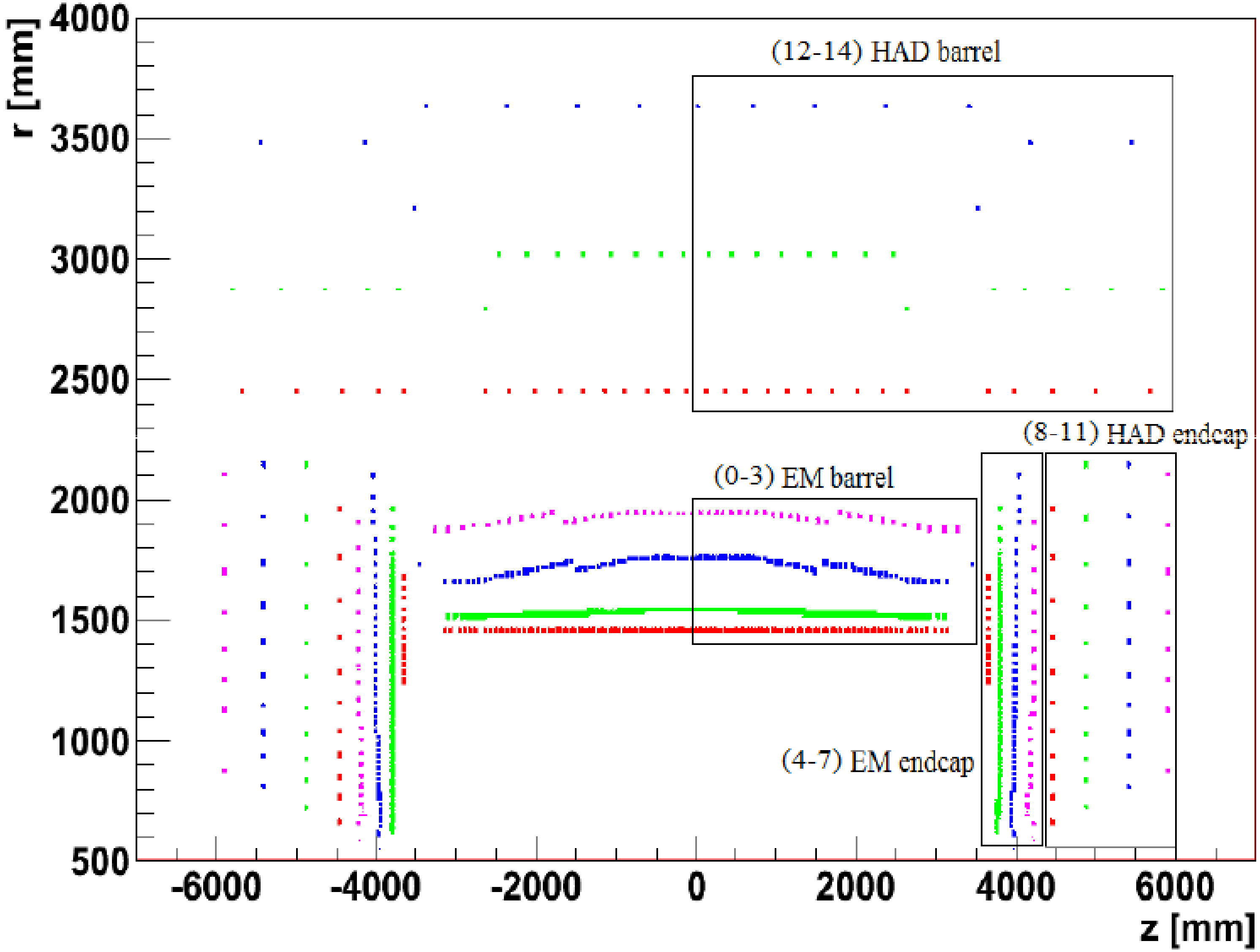
Plot from The ATLAS Collaboration: arXiv:1103.1984v1

Overview of the ATLAS calorimeters





Overview of the ATLAS calorimeters



Strategy of the analysis

• Calorimeters need calibration → Obtain calibration constants vs. energy.

• Calculate beta-values and find optimal combination of measurements for the same reconstructed track.

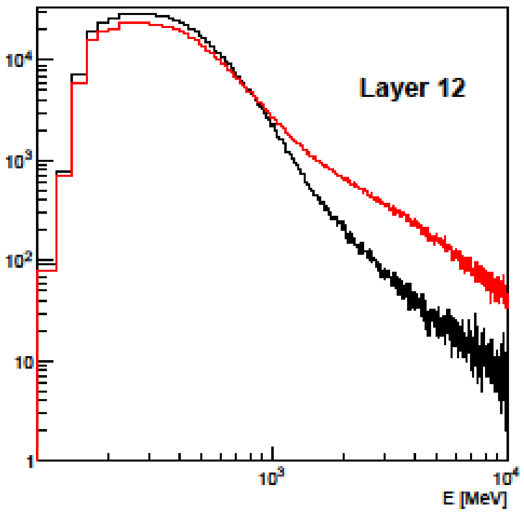
• R-hadrons not observed, so we need to choose which particles to use when measuring detector response. Largest background stems from muons. Hard to separate from R-hadrons, so maybe they have similar response?

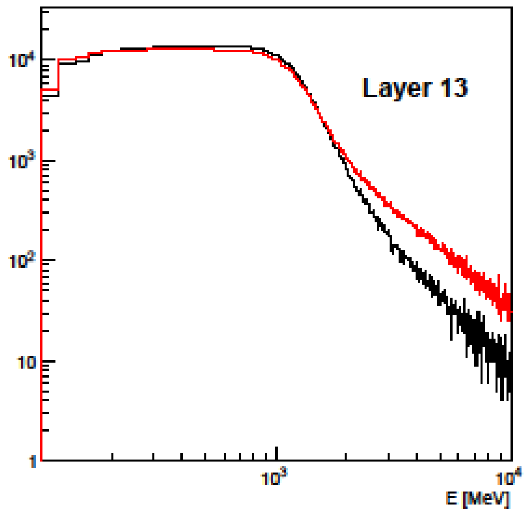
• Investigate jets and compare their response to muons. Is there a difference? (Not in detail here)

• Apply data reduction to increase accuracy while retaining high efficiency.

• Perform cross-check between calculated errors and the width of the distribution of combined beta-values.

Energy distributions in TileCal

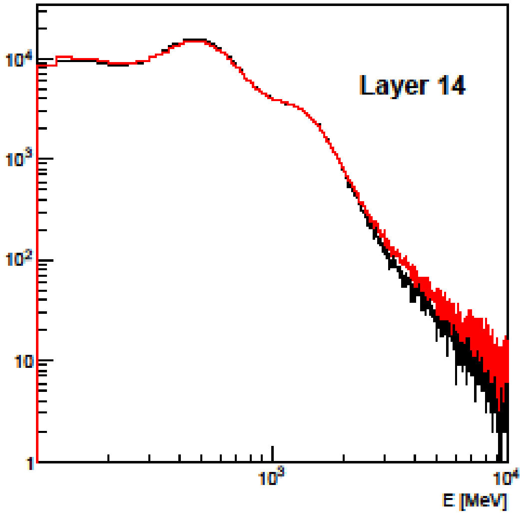


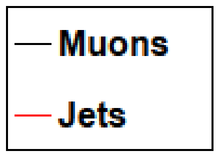


$Z \to \mu\mu$ data.

Jet distributions are rescaled to match integral of muon dist.

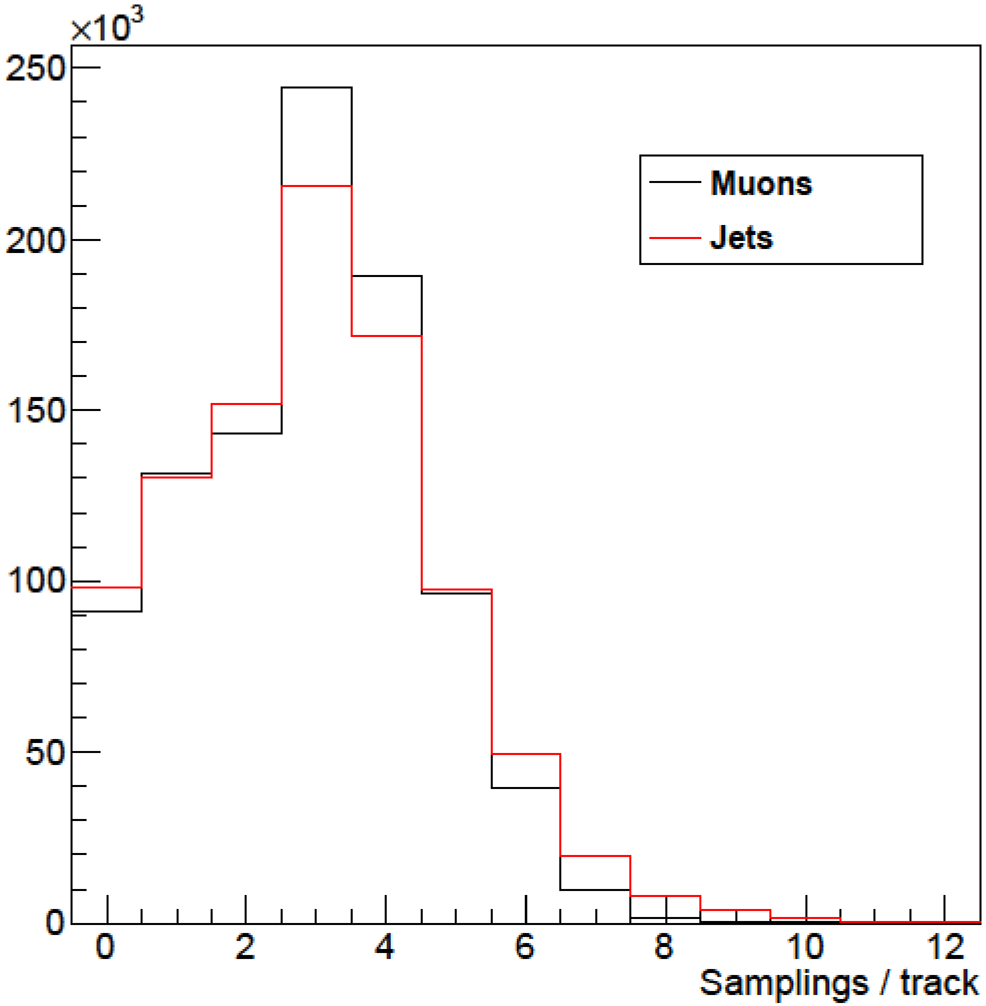
Jets shifted slightly towards higher energies. We expect more samplings for jets.





	Muons	Jets
Common cuts	Pixel hits ≥ 1 SCT hits ≥ 6	
Selection	$\|M_{Z,\text{reco}} - M_Z\| < 5.0$ GeV	$dR_{\text{jet}} < 0.2$

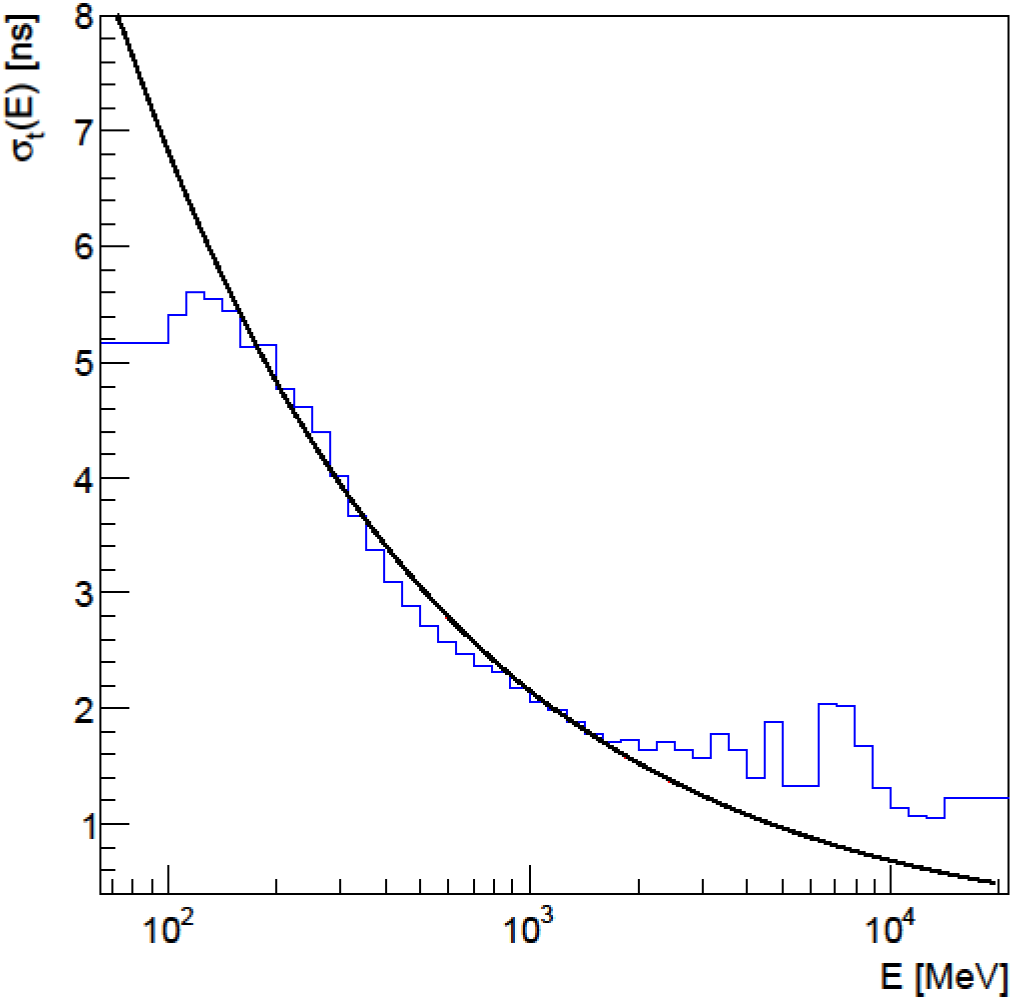
Samplings for muons and jets



Jet distribution is rescaled to fit integral of muon dist.

Larger tail towards higher number of samplings for jets.

Energy dependence of timing errors



Energy dependence usually described by:

$$\sigma_t(E_i) = \sqrt{\left(\frac{p_0}{\sqrt{E_i}}\right)^2 + \left(\frac{p_1}{E_i}\right)^2}$$

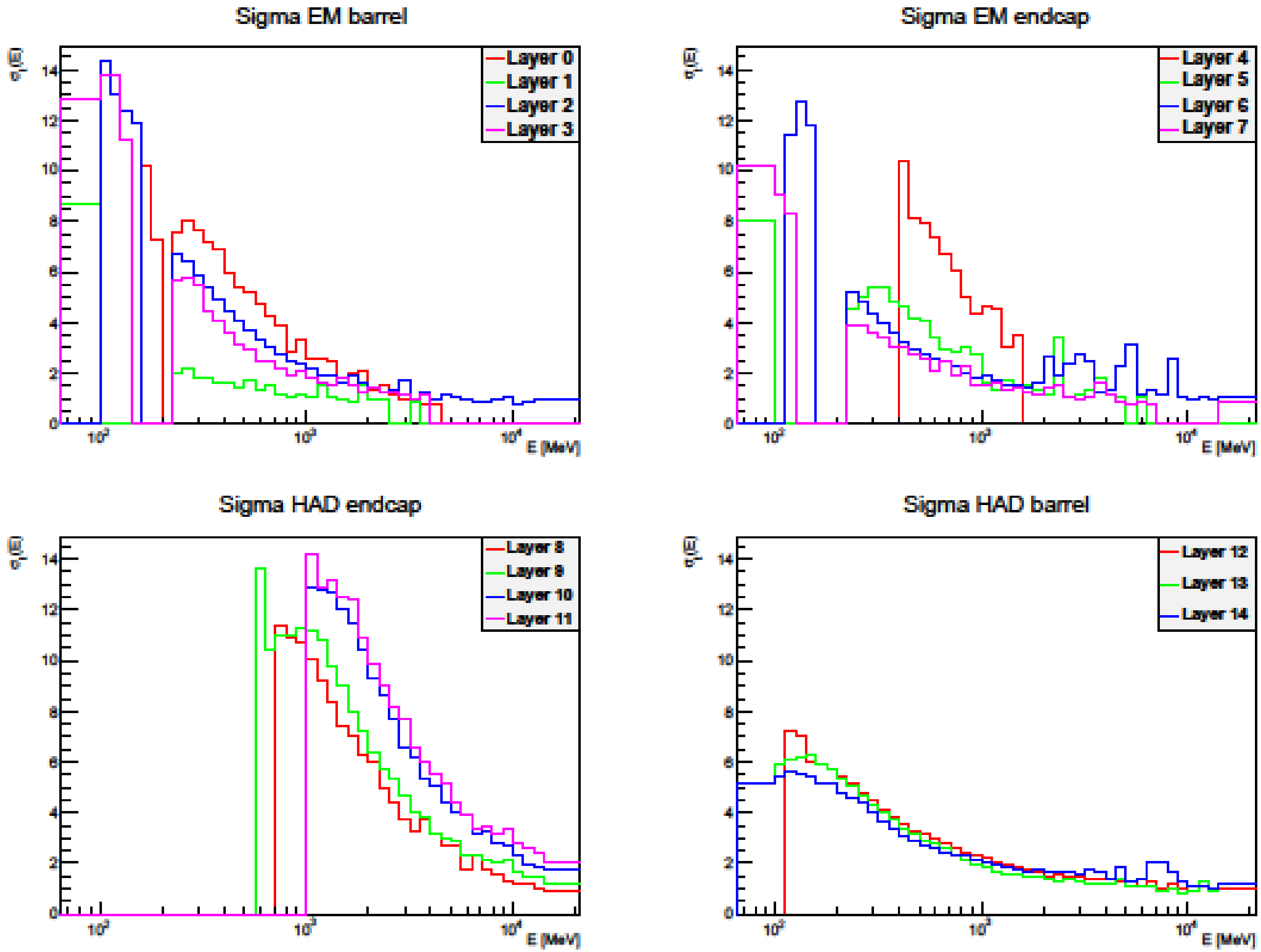
However, poor fit to data (layer 14 shown).

Notice:

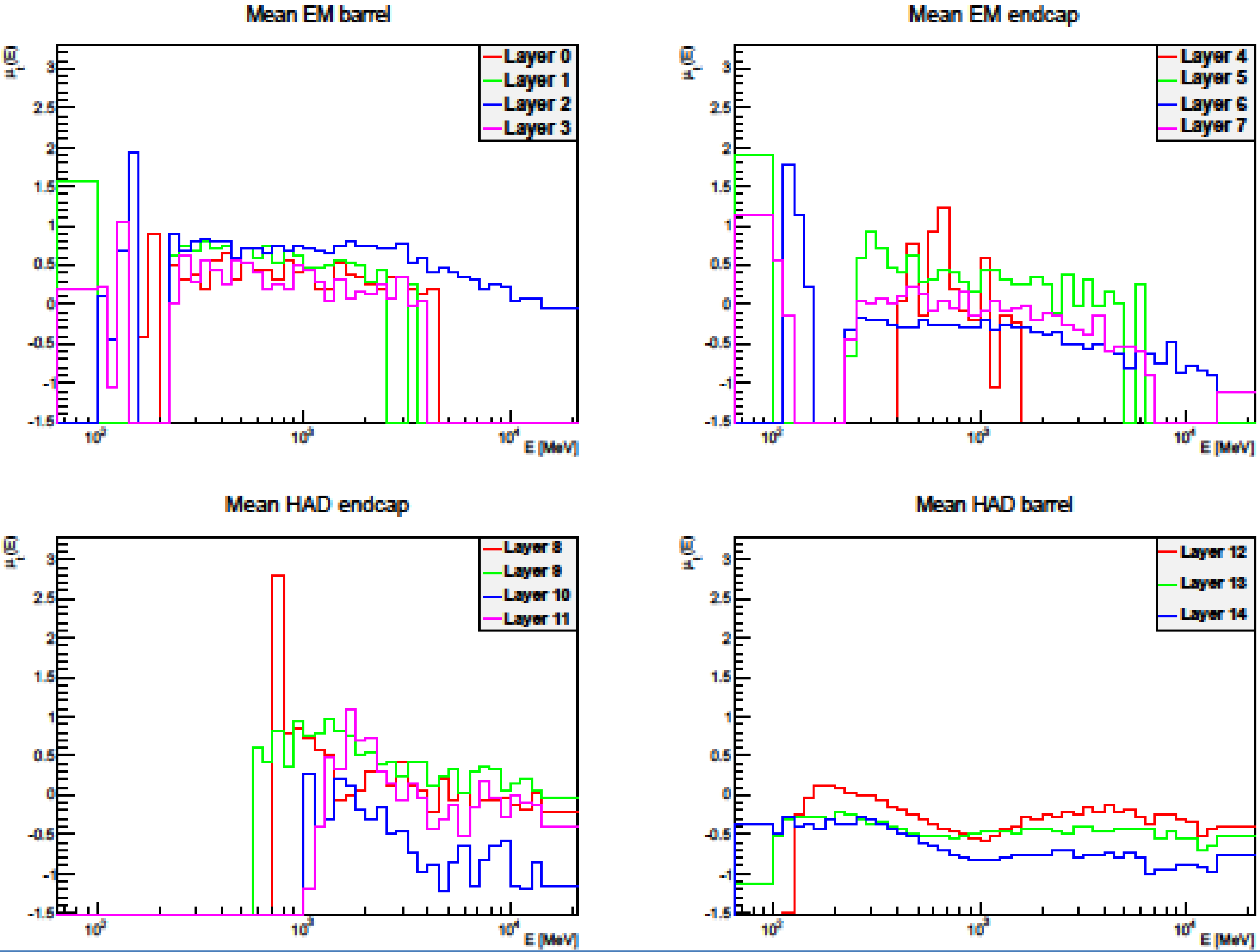
$$t_{\text{reco}} = t - d / c$$

$\Rightarrow$ distribution centered at zero for relativistic particles

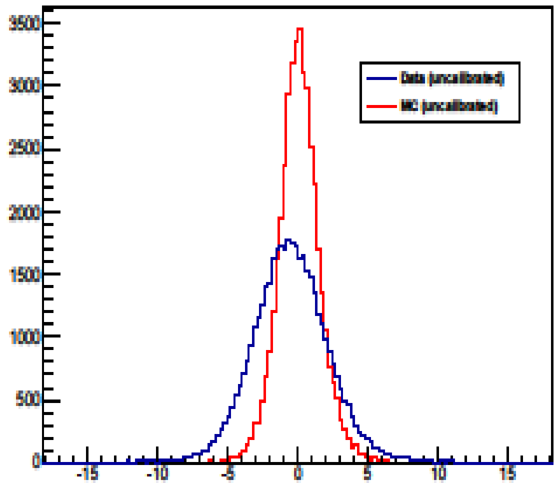
σ_t vs. energy



μ_t vs. energy



Calibration of data and MC

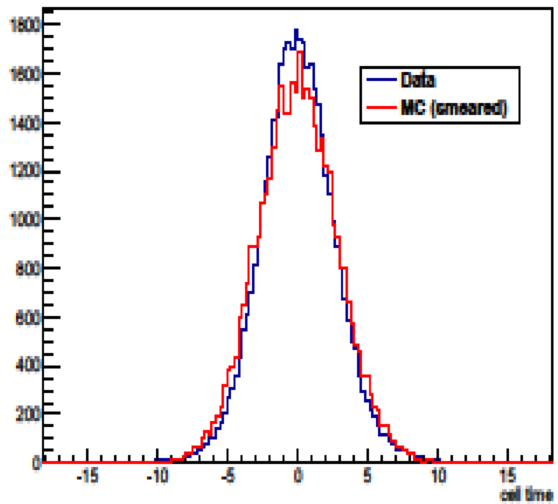


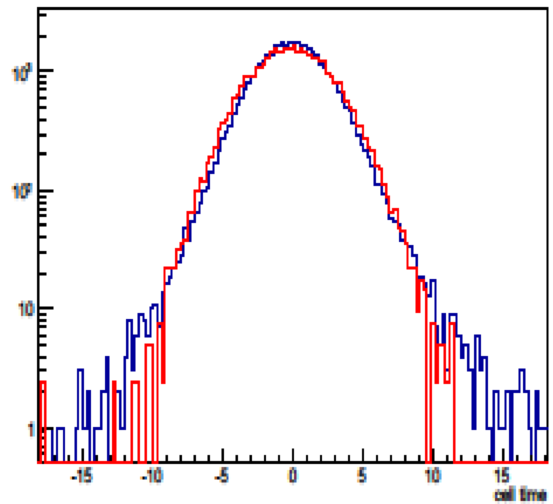
Calibration:

$$\text{Data}: \quad t_{i,\text{reco}}^{\text{cal}} = t_{i,\text{reco}} - \mu_{\text{data}}(E_i)$$

$$\text{MC}: \quad t_{i,\text{reco}}^{\text{cal}} = t_{i,\text{reco}} - \mu_{\text{MC}}(E_i) + r.Gaus(0.0, \sigma_{\text{smear}})$$

$$\sigma_{\text{smear}} = \sqrt{\sigma_{\text{data}}(E_i)^2 - \sigma_{\text{MC}}(E_i)^2}$$





$400 \text{ MeV} \leq E \leq 450 \text{ MeV}$

Calculation and combination of beta values

$$\beta_i = \frac{v}{c} = \frac{d_{\text{cell}}}{tc} = \frac{d_{\text{cell}}}{(t_{\text{reco}} + \frac{d_{\text{cell}}}{c})c} = \frac{d_{\text{cell}}}{t_{\text{reco}}c + d_{\text{cell}}}$$

t_{reco} assumed to be Gaussianly distributed.

$\beta^{-1} \propto t_{\text{reco}} \Rightarrow \beta^{-1}$ is Gaussianly distributed

β^{-1}-measurements are combined using weighting factor $w_i (= E \text{ or } 1/\sigma^2_{\beta^{-1}})$:

$$\beta^{-1}_{\text{comb}} = \frac{\sum_{i=0}^{N} w_i \beta_i^{-1}}{\sum_{i=0}^{N} w_i} = \frac{\sum_{i=0}^{N} \beta_i^{-1} / \sigma^2_{\beta_i^{-1}}}{\sum_{i=0}^{N} 1/\sigma^2_{\beta_i^{-1}}}$$

$$\sigma^2_{\beta^{-1}_{\text{comb}}} = \frac{1}{\sum_{i=0}^{N} 1/\sigma^2_{\beta_i^{-1}}}$$

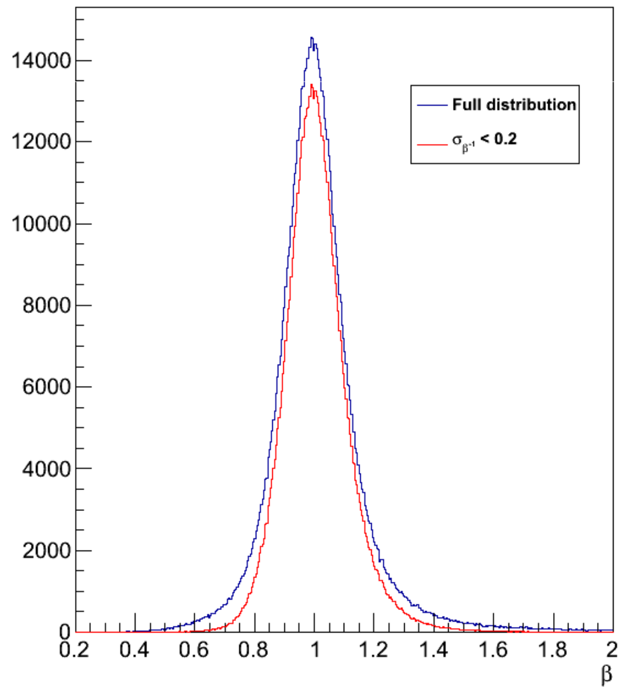
Data reduction

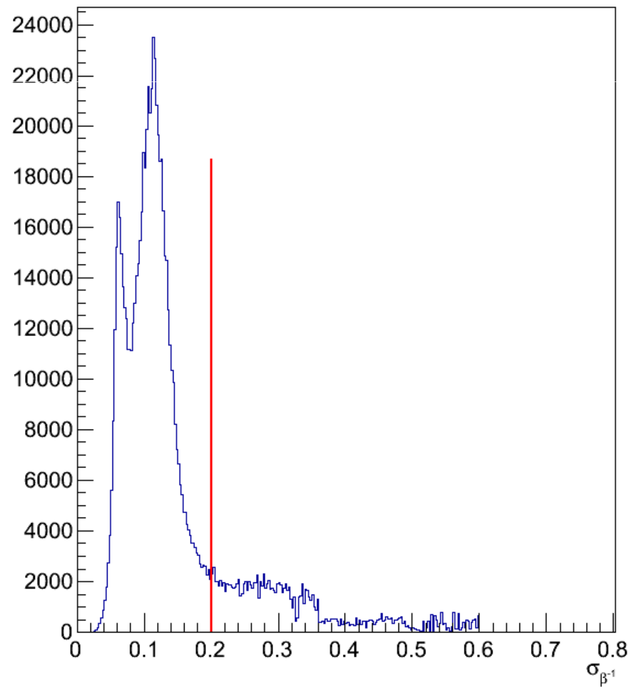
- How to retain high efficiency with lowest possible contamination of R-hadron sigal?

- Look at fraction of beta-measurements for muons or jets below 0.8, where the R-hadrons are situated.

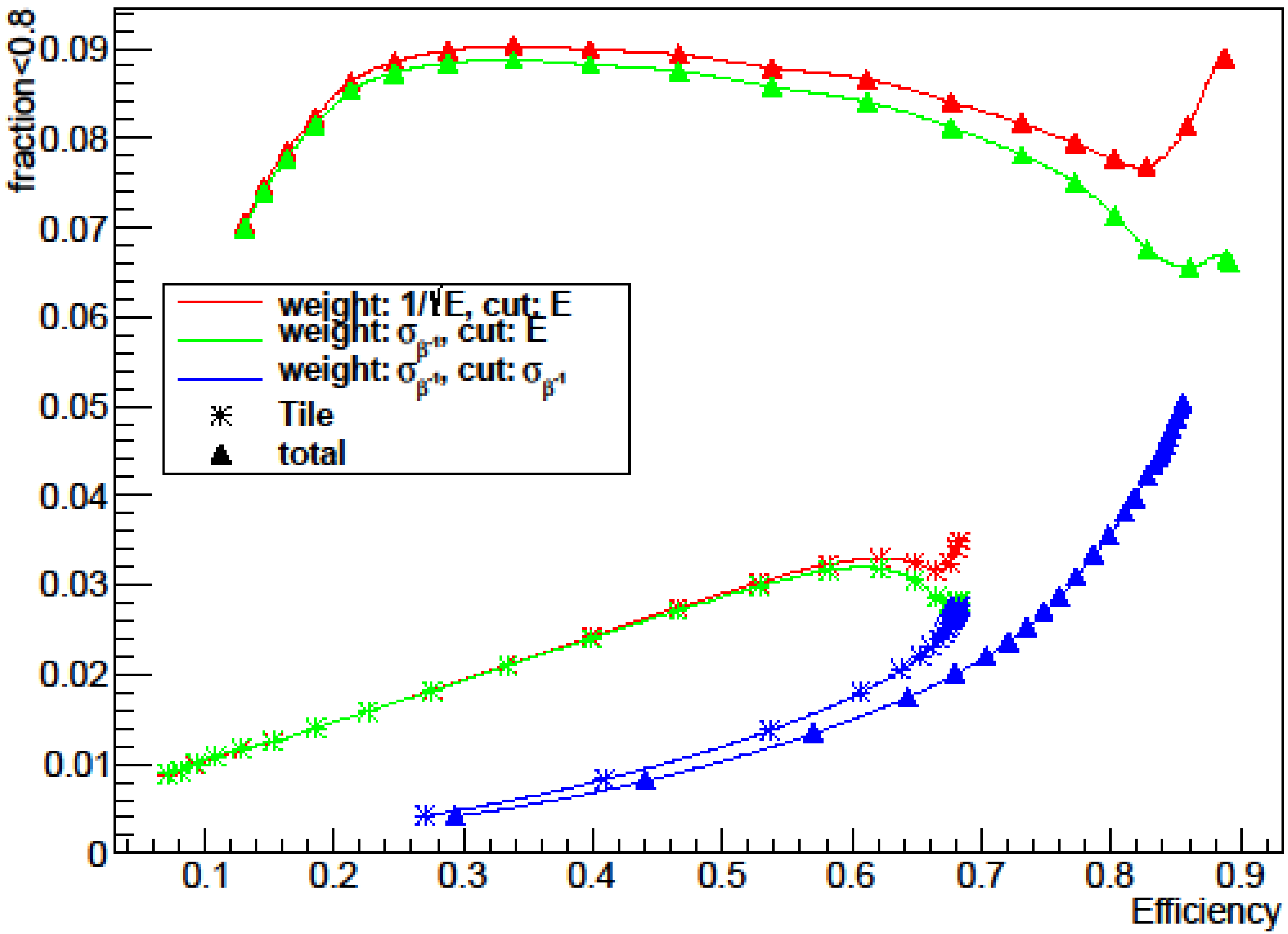
Methods investigated:

Weighting	Cut
E	E
$\sigma_{\beta^{-1}}$	E
$\sigma_{\beta^{-1}}$	$\sigma_{\beta^{-1}}$

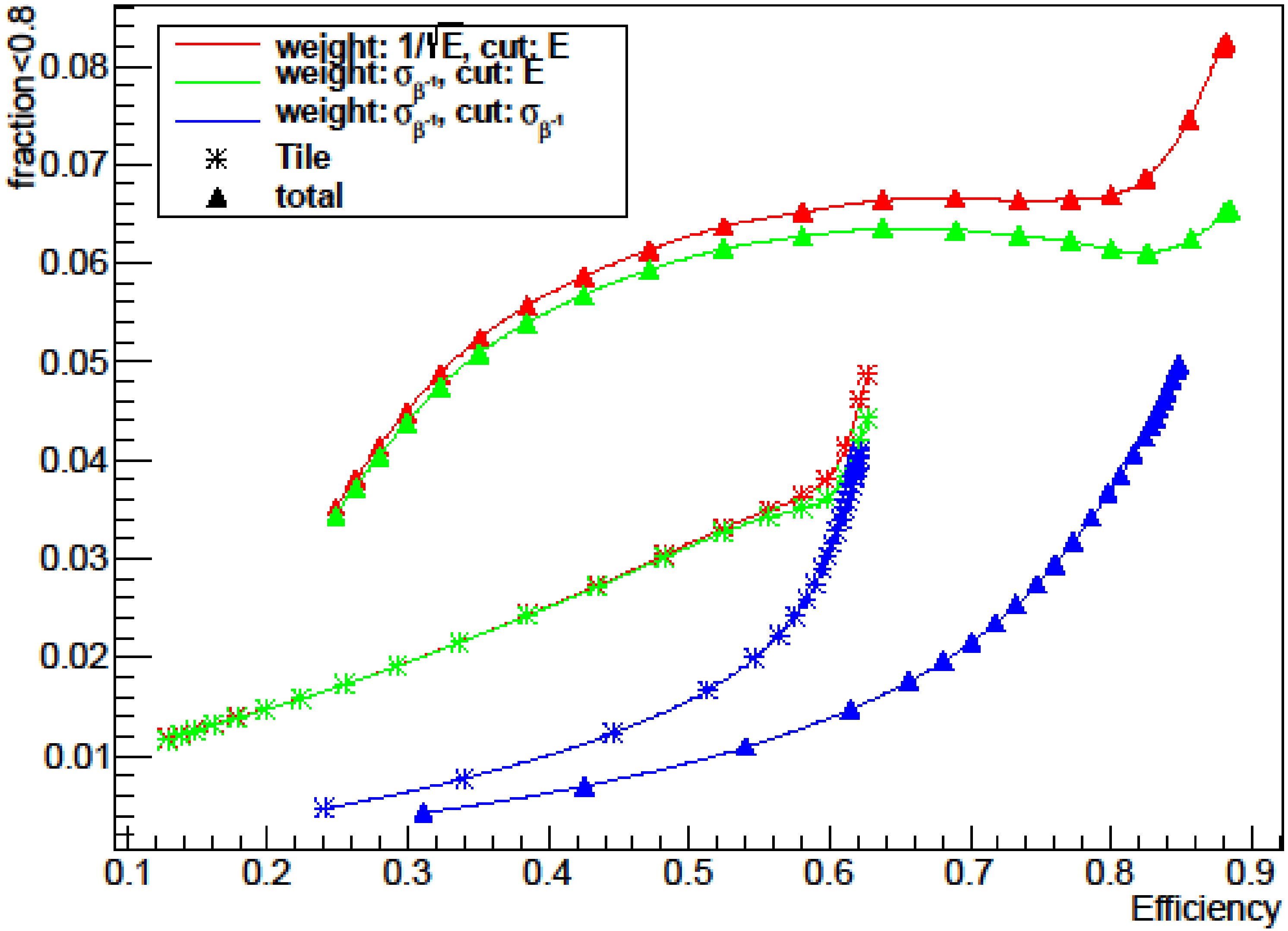




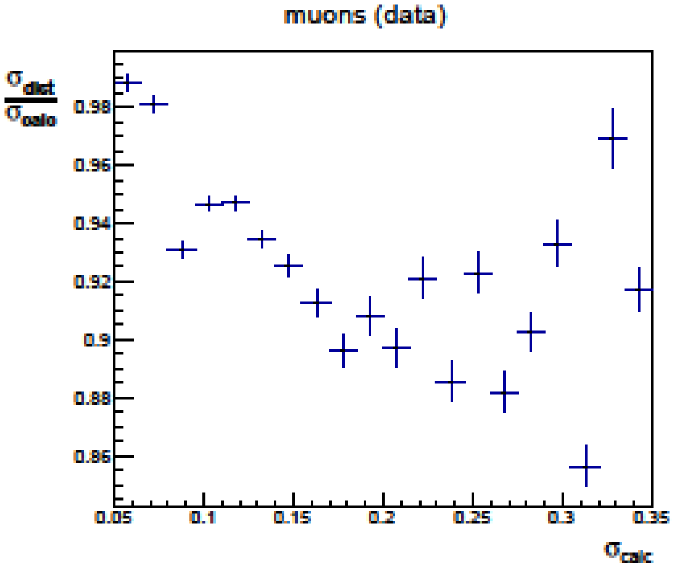
f<0.8 vs. efficiency for muons

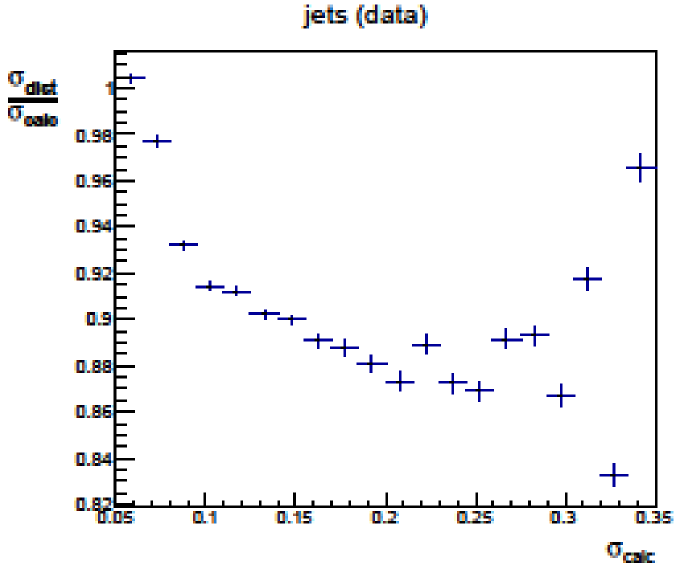


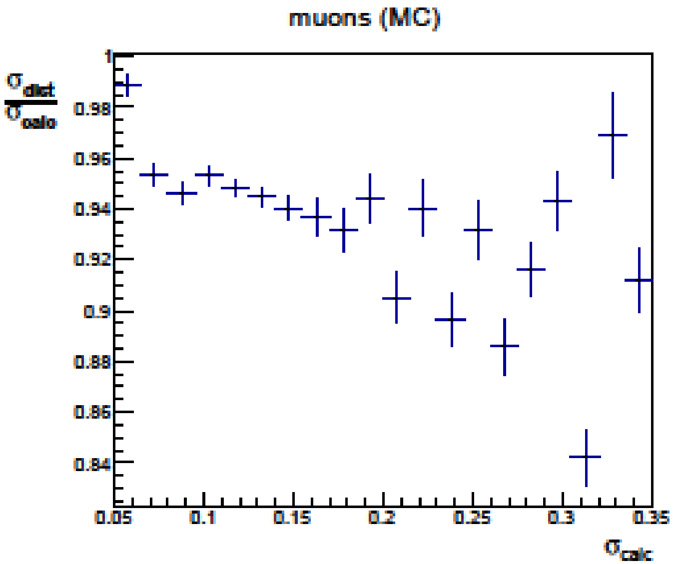
f<0.8 vs. efficiency for jets

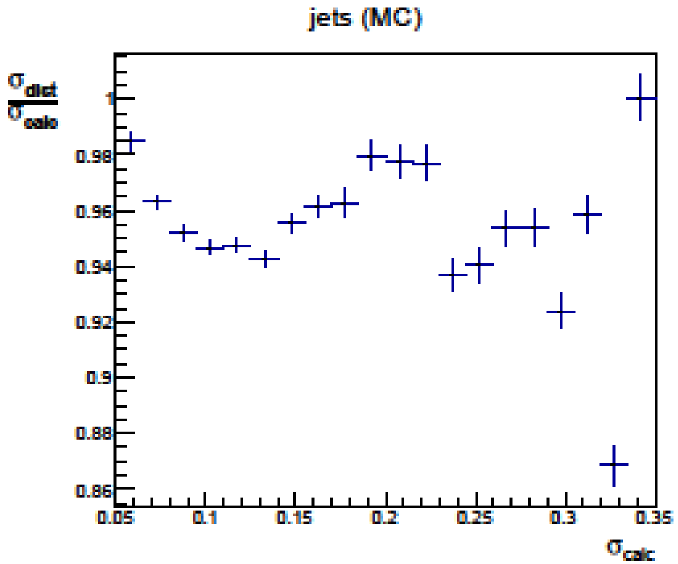


Precision of combined errors vs. sigma

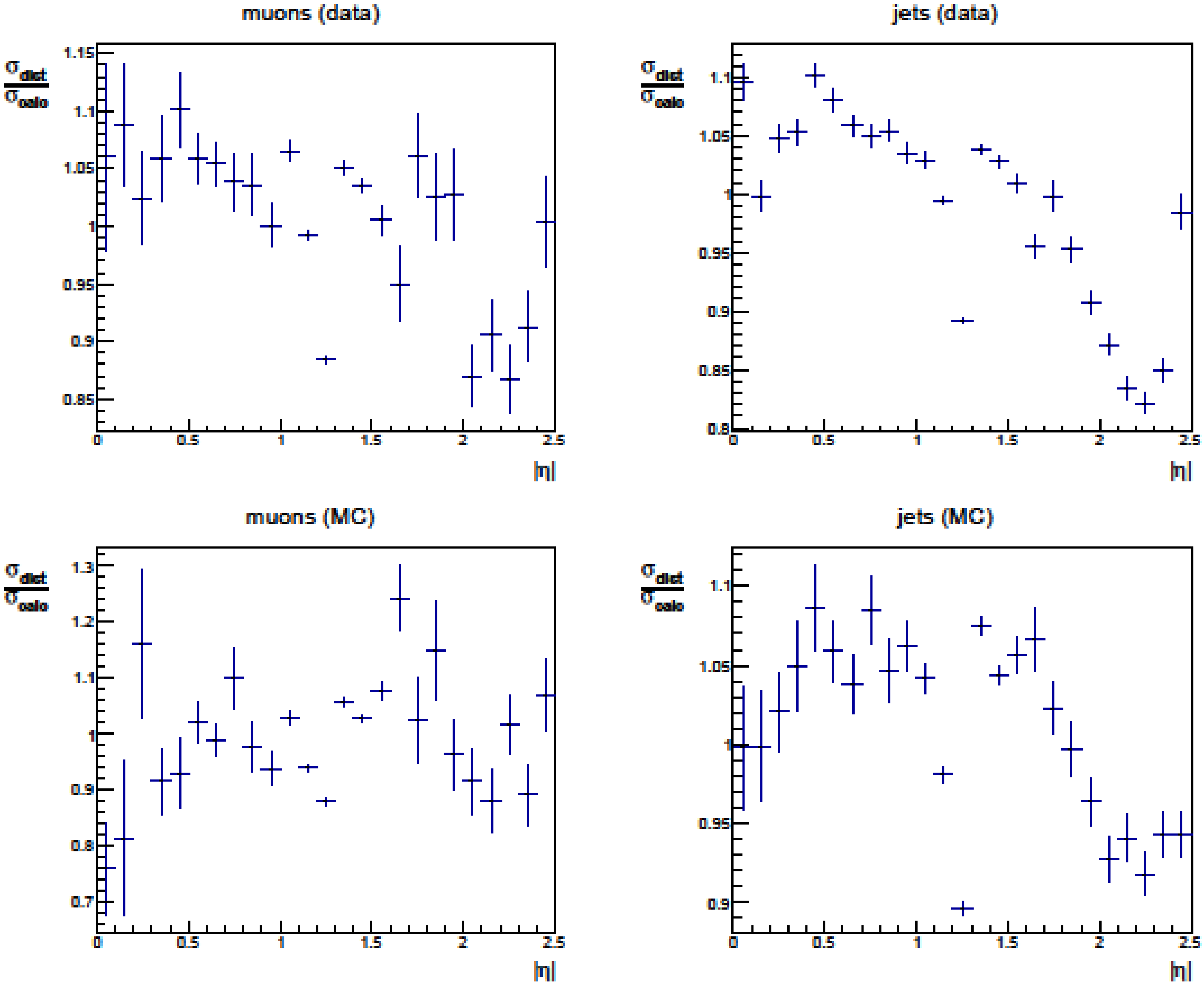




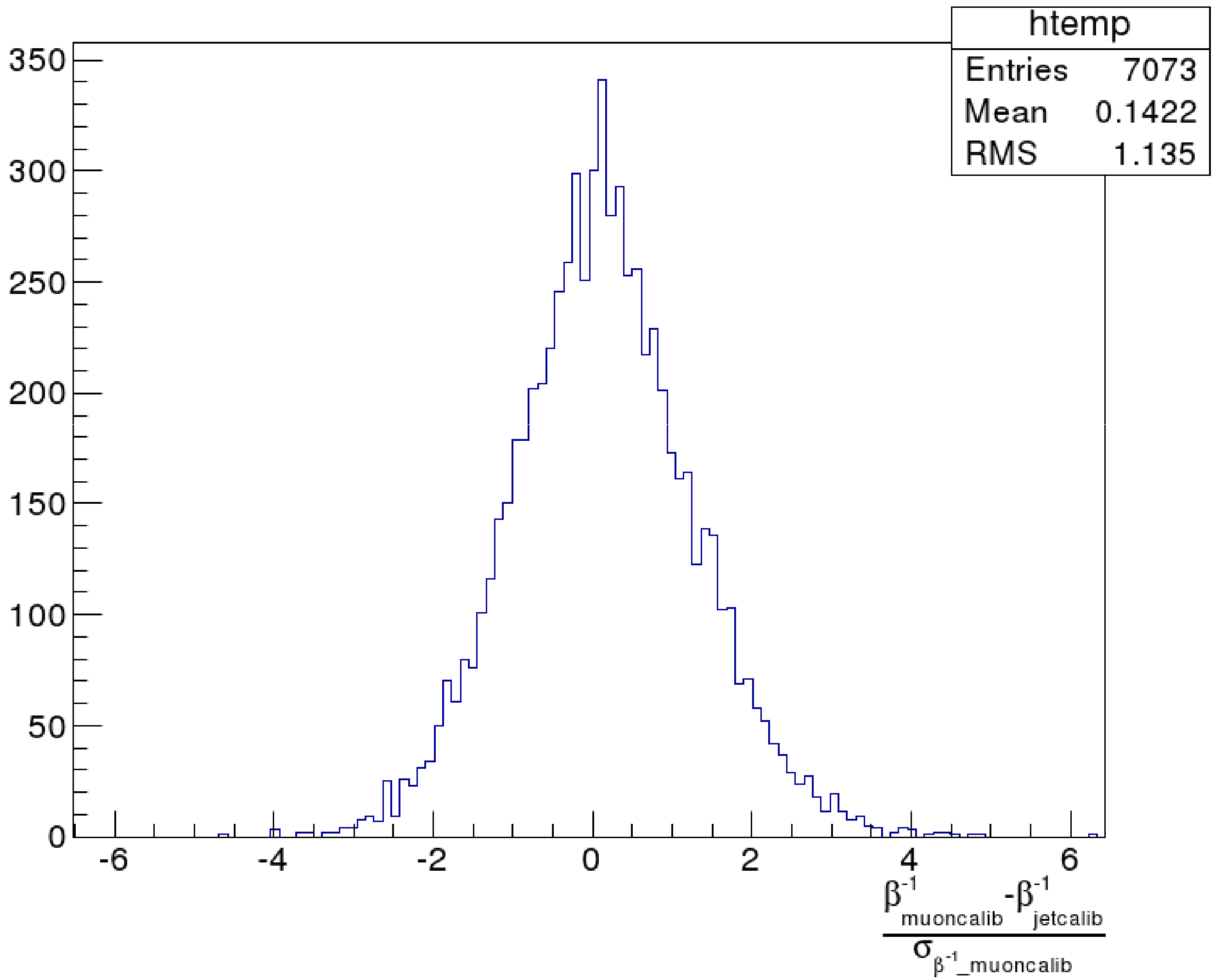




Precision of combined errors vs. eta



Does the type of R-hadron calibration matter?



Thank you for your attention!