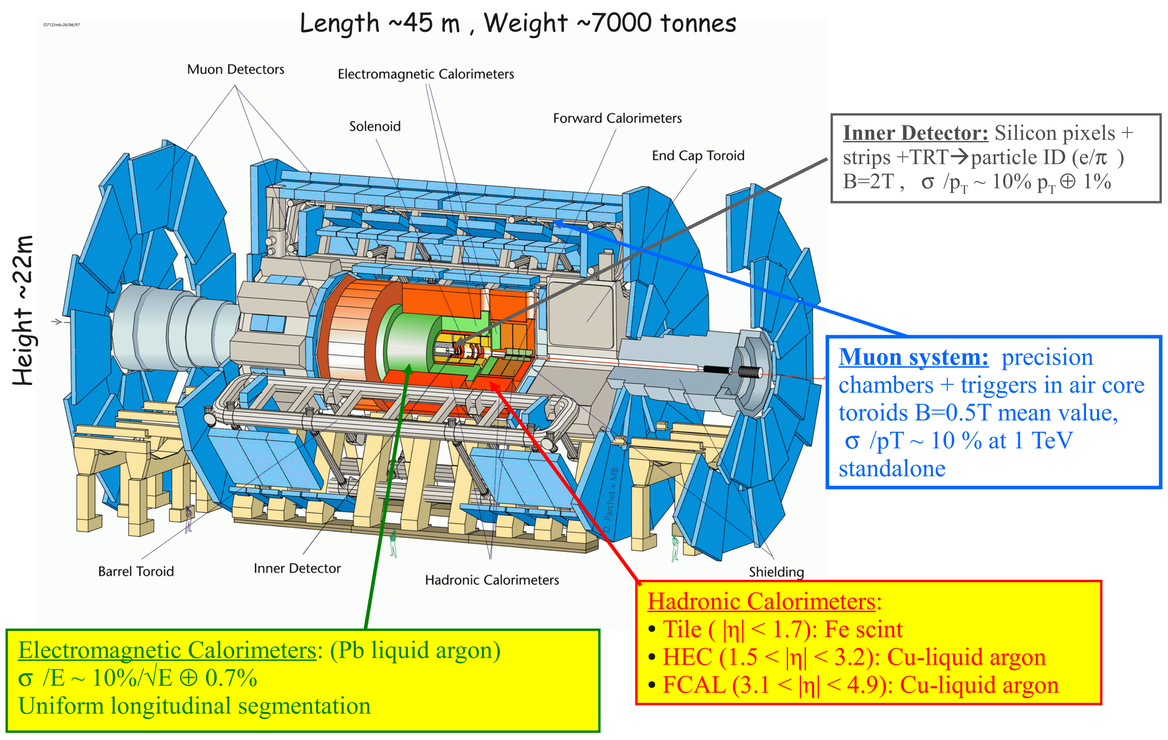
TrackInCaloTools: a package for measuring muon energy loss and calorimetric isolation in ATLAS

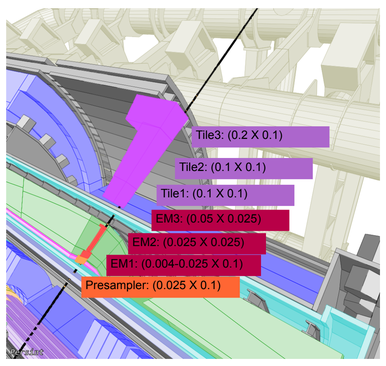
Samira Hassani, Bruno Lenzi and Rosy Nikolaidou for the ATLAS Collaboration
CEA - Saclay

1. The ATLAS Detector

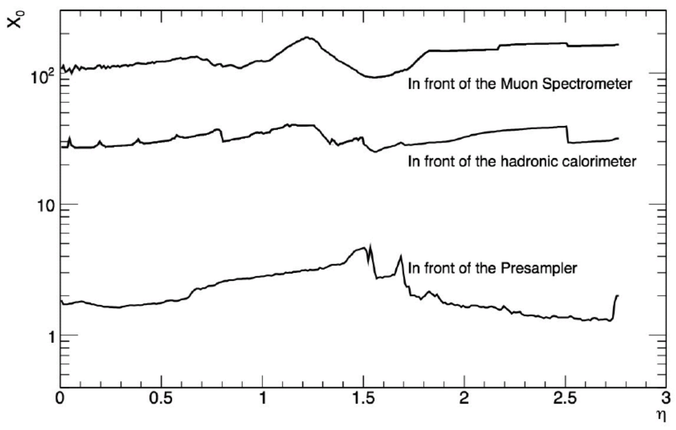


Energy-scale: e/γ~0.1%, μ~0.1%, Jets~1%

- Muons measured by Inner Detector (ID) and Muon Spectrometer (MS)
  - Combined tracks: matching beetwen ID and MS (very low fake rates)
- More than 100 radiation lengths (X_0) before the MS
  - 80% of the material is instrumented by the calorimeters



(a) Calorimeter segmentation and granularity ($\Delta\eta \times \Delta\phi$) in the barrel ($|\eta| < 1.7$)

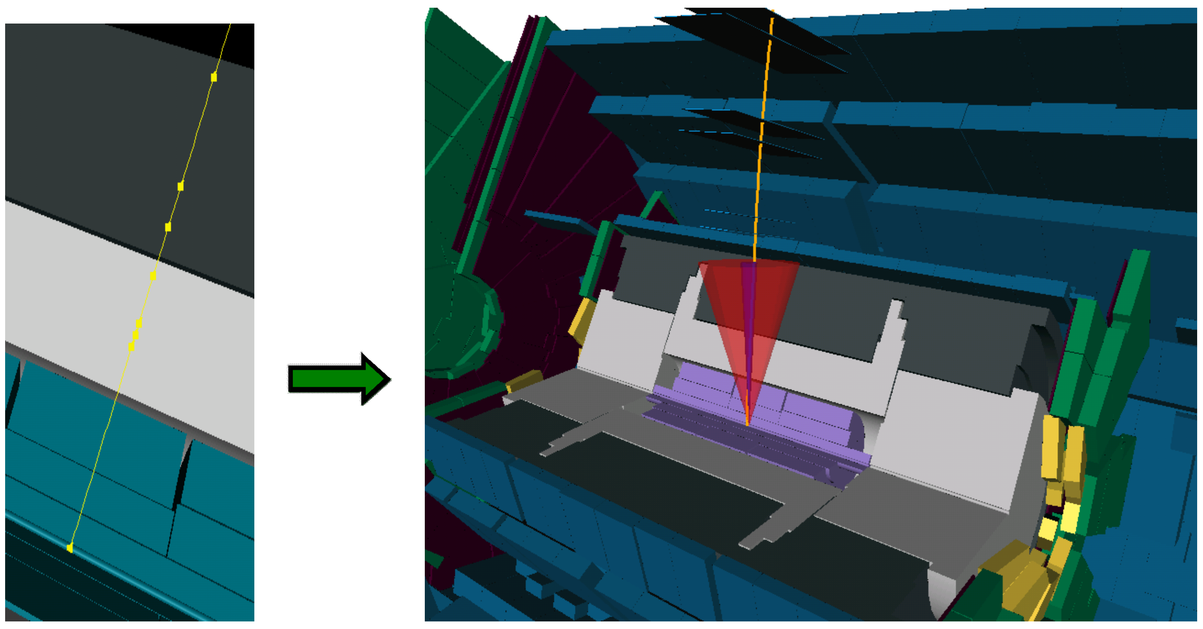


(b) Material distribution vs. η

3. Muon isolation using calorimeter information

Principle

- Track is extrapolated from perigee to each layer of the calorimeters
- Cells are collected around a given cone of $dR = \sqrt{\Delta\eta^2 + \Delta\phi^2}$
  - Selected according to noise threshold



- TrackInCaloTools provides default isolation variables for muons: **etcone**
- Inner cone of dR = 0.05 is supposed to contain muon energy loss
- Difference between the energy in outer and inner cone used for isolation
  - Default sizes for outer cone: 0.1, 0.2, 0.3, 0.4

$$etconeY = \sum E_T^{dR=Y} - \sum E_T^{dR=0.05}$$

2. Muon energy loss

- Muons reconstructed at MS are back-tracked to perigee and combined with ID tracks
  - By default, parametrization is used to account for energy loss
- Energy loss fluctuations become important for high-pT
  - Impact on resolution and efficiency for combined reconstruction
- Calorimeter measurement can be combined with parametrization (bayesian method)

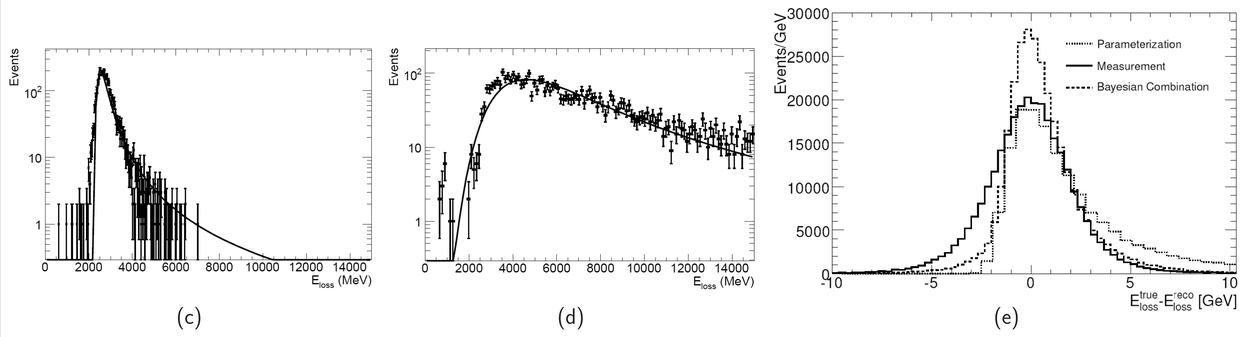
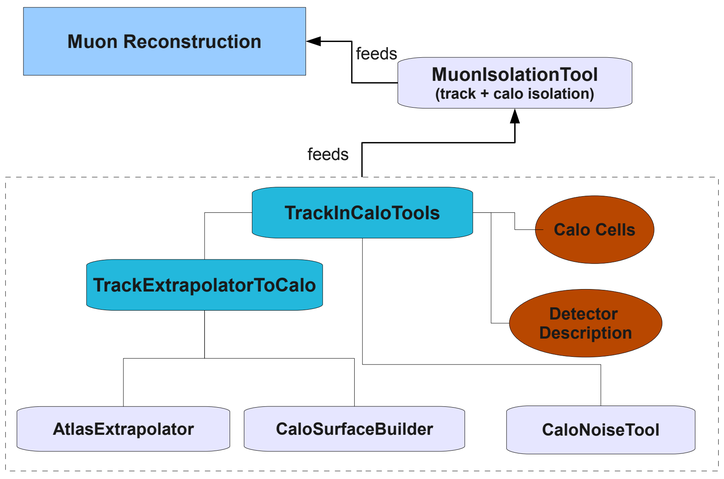


Figure: Energy loss distributions in the calorimeters for 10 GeV (left) and 1 TeV muons (center) for $|\eta| < 0.15$. On the right, the difference between true energy loss and the one used in reconstruction for the parametrization, the measurement and their combination.

4. Framework

- TrackInCaloTools is integrated in the Atlas framework (ATHENA) via MuonIsolationTool, that feeds Muon Reconstruction
  - Provides energy loss measurement and isolation information
- TrackExtrapolatorToCalo is the part of the package that handles the extrapolations



Functionalities

- TrackInCaloTools
  - Energy measured per layer for given cone
  - Cells around track
  - Cells crossed by the track
- TrackExtrapolatorToCalo
  - Extrapolation positions
  - Path lenghts on each layer

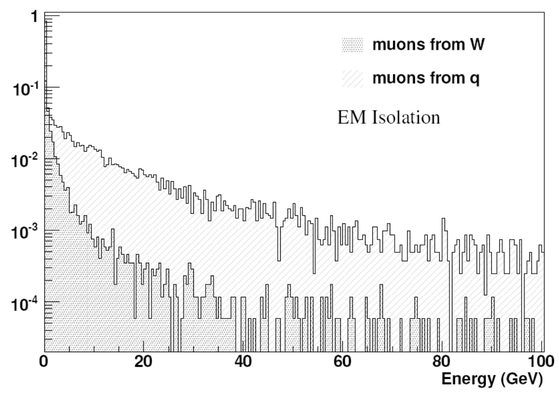
Speeding up

- Extrapolations and cells selected for the last given track are kept and reused

5. Calorimetric isolation in physics analysis

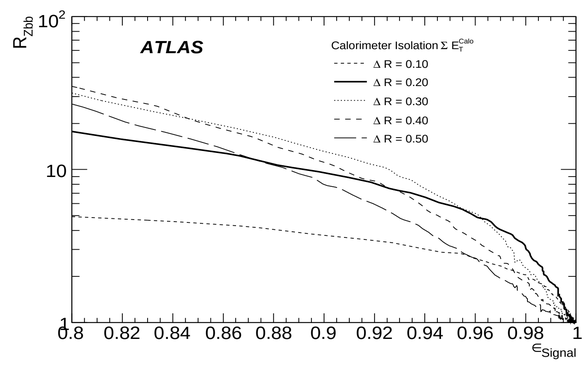
Calorimetric isolation used in Higgs searches, Standard Model analysis and beyond

$t\bar{t}$ analysis



(a) Isolation energy in the electromagnetic calorimeter of muon from a $t\bar{t}$ sample

Higgs → 4 lepton analysis



(b) Zbb rejection versus H → 4μ efficiency for various calorimetric isolation cone sizes.

6. Monitoring and ongoing work

- **Monitoring:** checking distance between cells and extrapolations in single muon simulations
- **Ongoing work:** Defining minimum cell content to include muon energy loss
  - Goal 1: improve isolation and energy loss measurement
  - Goal 2: define when to use measurement, parametrization and their combination

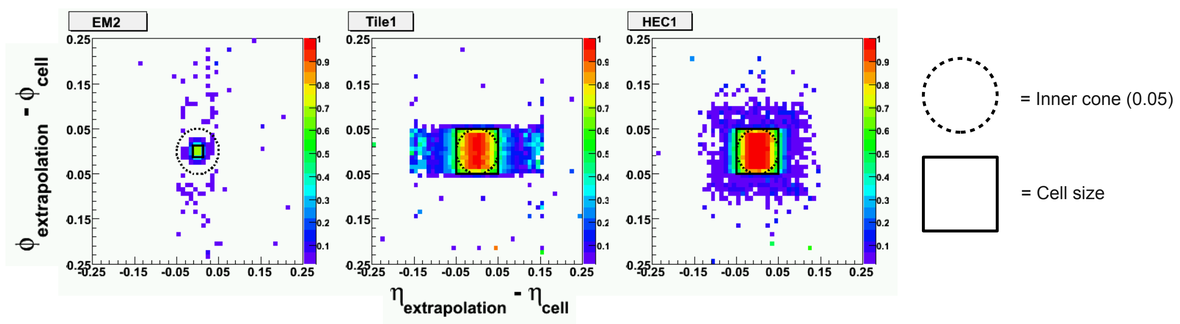


Figure: Distance between extrapolation and energy deposits weighted by average $E_T / \sum E_T$ for three calorimeter layers.

This work is partially supported by the European Commission through the ARTEMIS Research Network, contract number MCRTN-CT-2006-035657.