Muon identification in the HCAL MC confronted with real data

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The aim of the study

The aim of this study is to develop a muon identification technique including the hadron calorimeter information.

- Study of the muon interaction with the calorimeter in detail
  - Total energy deposited
  - Geometrical information (electromagnetic clusters around muon tracks)
- Likelyhood Method for muon ID
  - It merges all the observables identified in the point above.
  - Mu/pi separation ?

The data collected within the CALICE collaboration are at the moment a unique opportunity to test the method also in the real prototype and not only in simulations

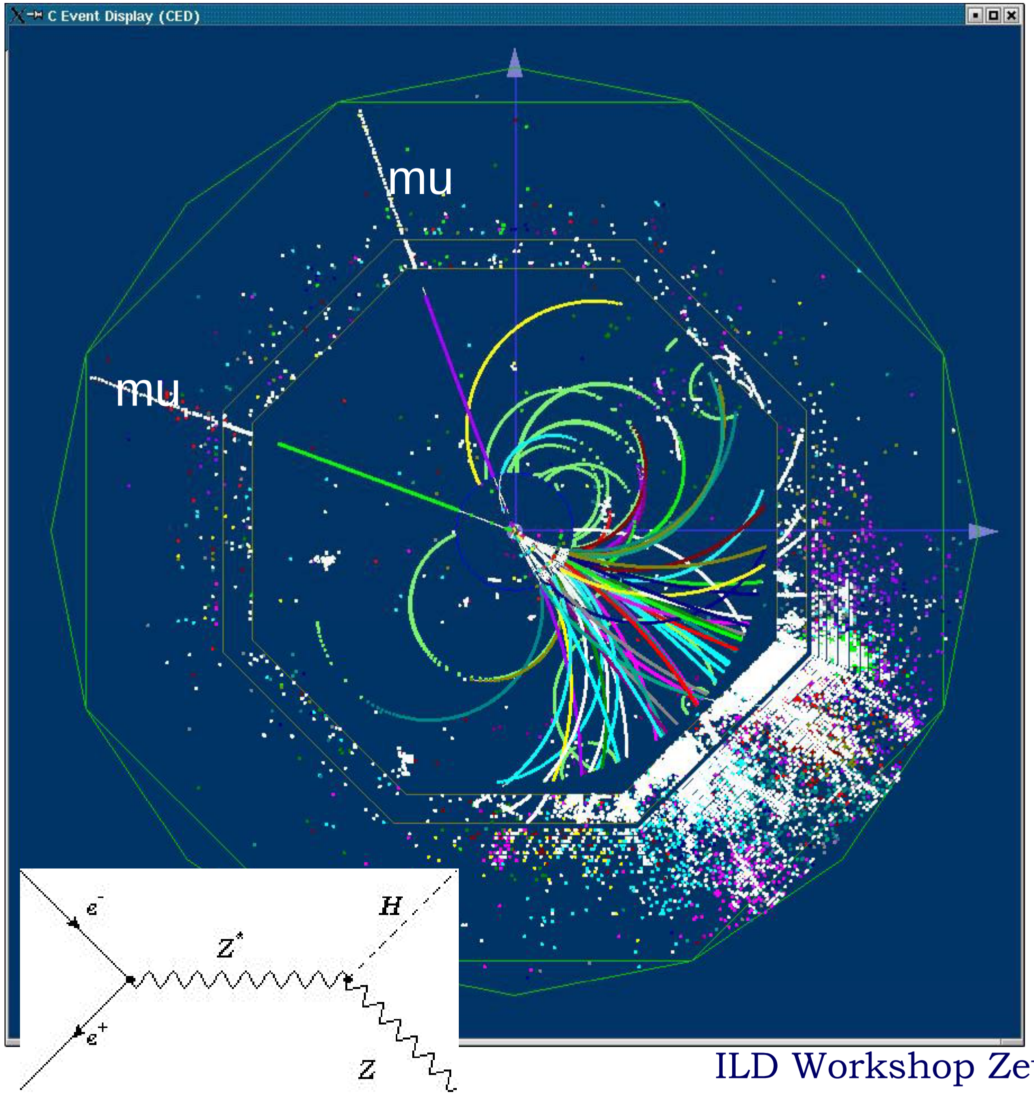
- All the HCAL technical characteristics are fully included and treated in the analysis.

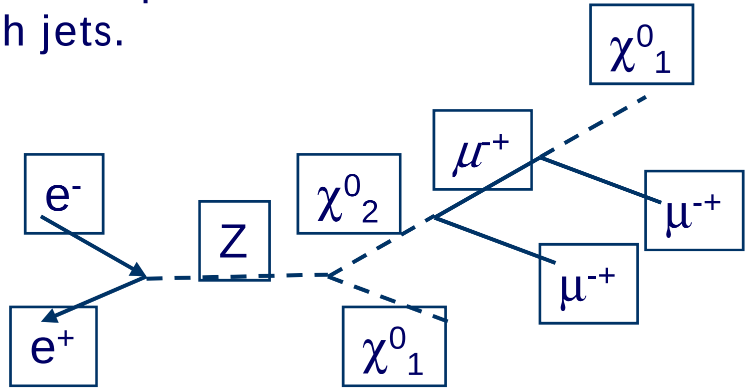
Linear collider studies: arxiv-ph/0609018

The ATLAS collaboration performed a deep investigation of this topic: starting point for this study

Muon identification and ILC physics

The muon identification plays an important role in the ILC physics program.
Many precise measurement channels present muon pair final state,
both isolated and mixed with jets.





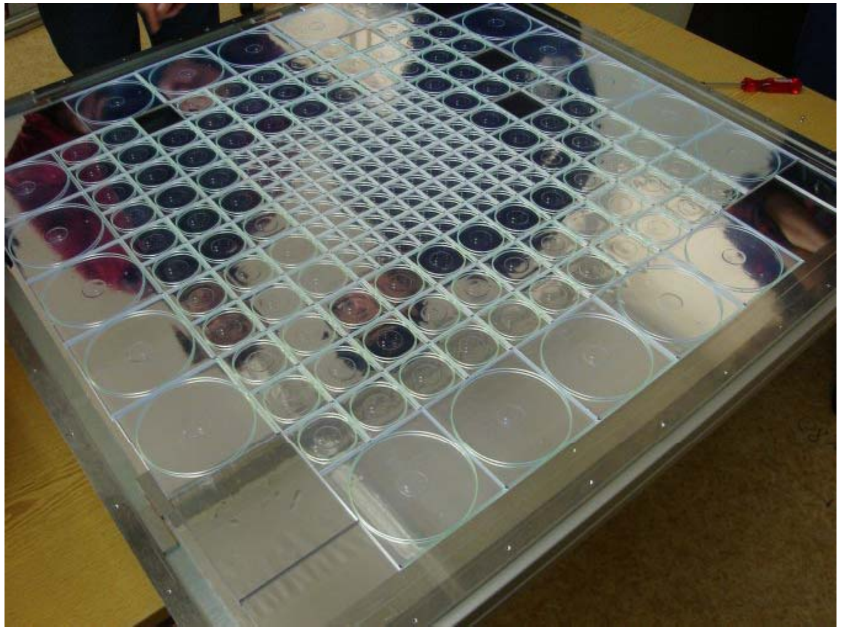
The muon ID is mostly done by the **muon chamber**. The muon momentum is measured by the tracker. The connection between tracker and muon chamber needs to be well reconstructed.

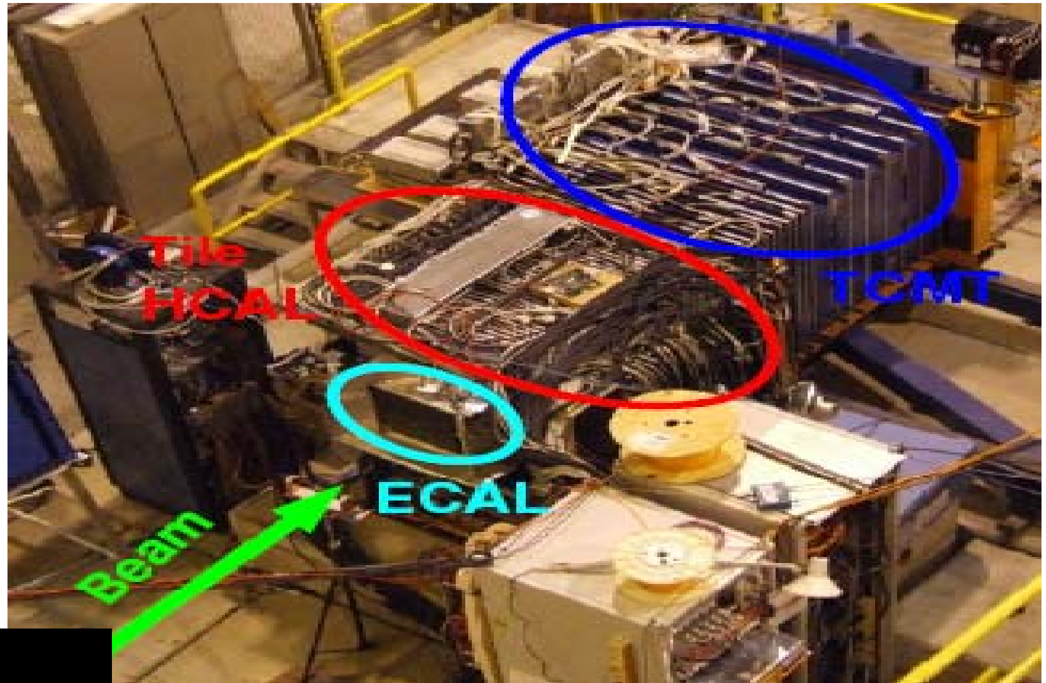
- ECAL
- HCAL
- MAGNET!!!!

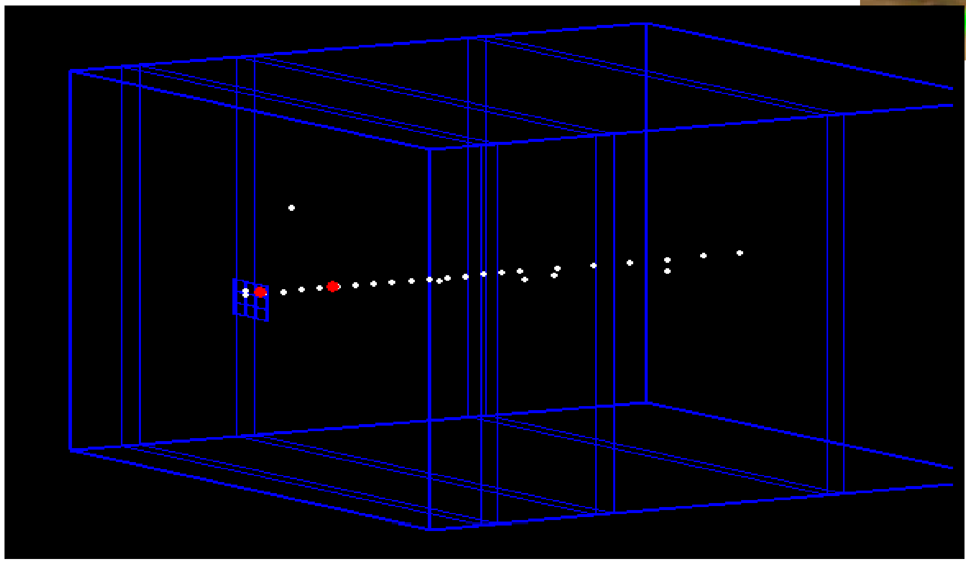
The muon response of the HCAL needs to be studied in detail, in order to understand the interplay between calorimeter and muon chamber.

1) *Muon Identification of high energetic muons*
2) *Soft muons which don't pass through the magnet*

HCAL test beam setup







HCAL in August-October 2006 Test Beam:

1. 23 high granular fully equipped layers
2. ECAL and Tail Catcher fully operative

120 GeV muons

Muon trigger : 1m x 1m scintillator in front and behind the setup

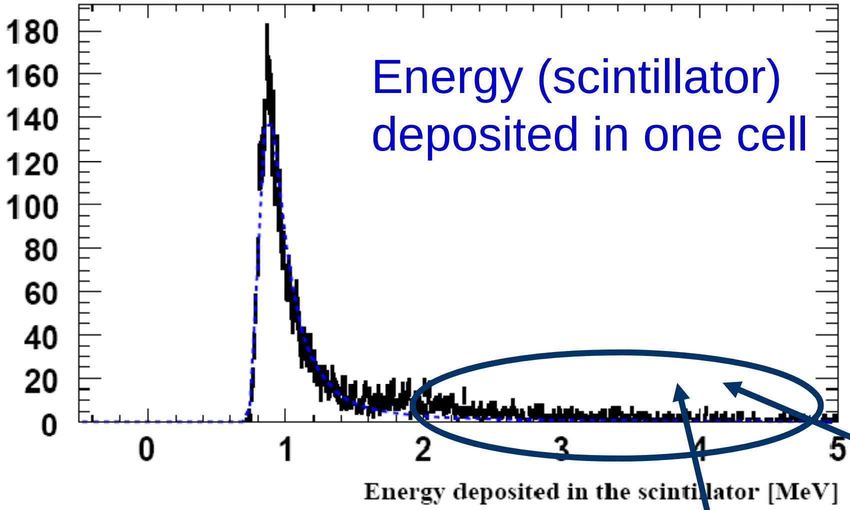
See F. Sefkow talk for more information…

Data and Montecarlo samples: event selection

1. Number of hits in the track >16
2. Hits in ECAL>20
   1. Only tracks in the core of the detector are selected (lateral leakage and high granularity)
3. Only 1 track found (double particle rejection)
4. Only the first 17 modules are used:
   1. fully equipped and low noise. Module 1,2,7 are in the alternated equipped part of the detector
5. Newest calibrations (+-1.5 %)

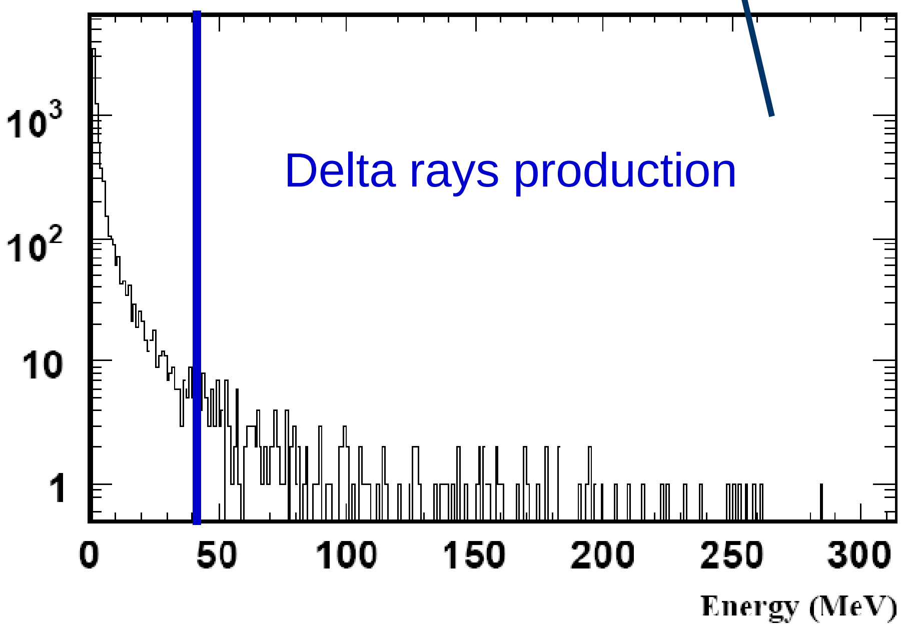
1. Mokka Plugin for full Geant4 information.
   1. It provides the full physics information, with a granularity of 1cm x 1cm, both in the absorber and in the scintillator.
2. Muon 120 GeV, 50000 events generated.
3. October 2006 Test Beam configuration

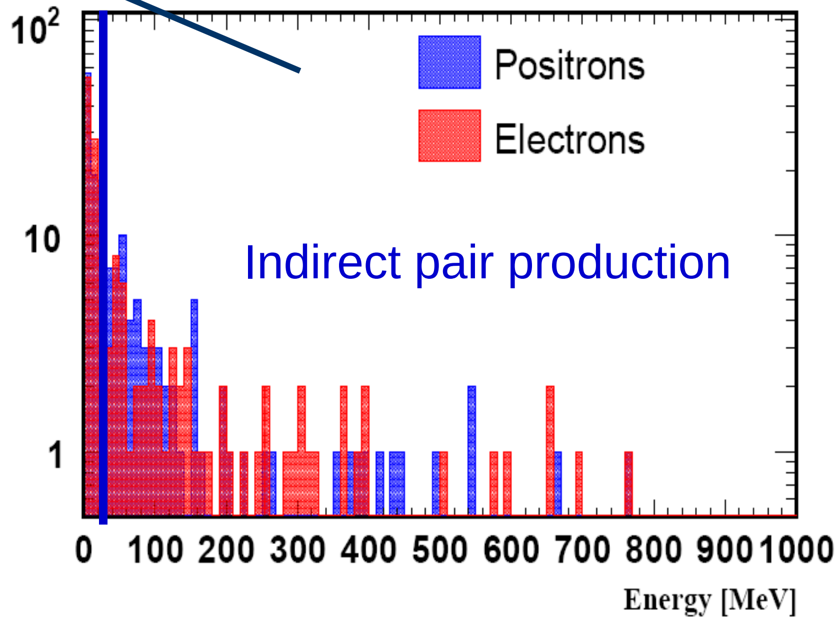
Muon interaction with the matter



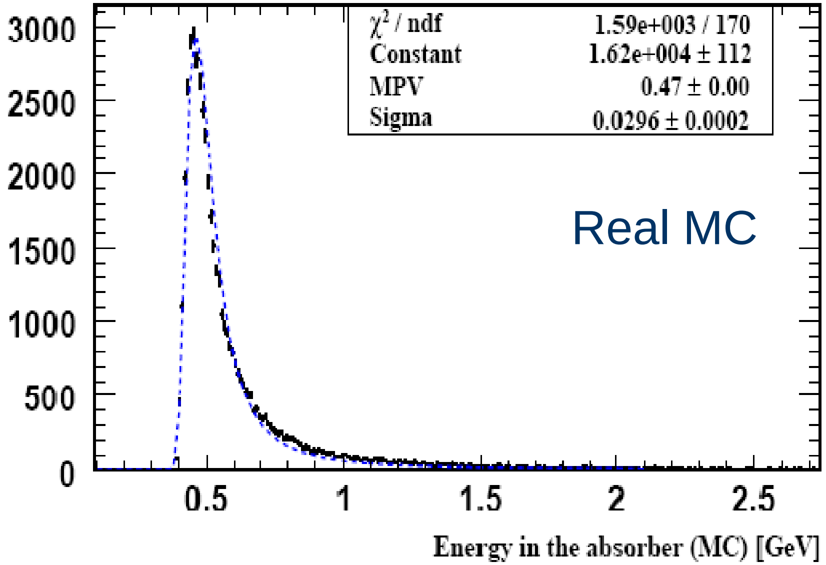
What is observable in the hadron calorimeter?

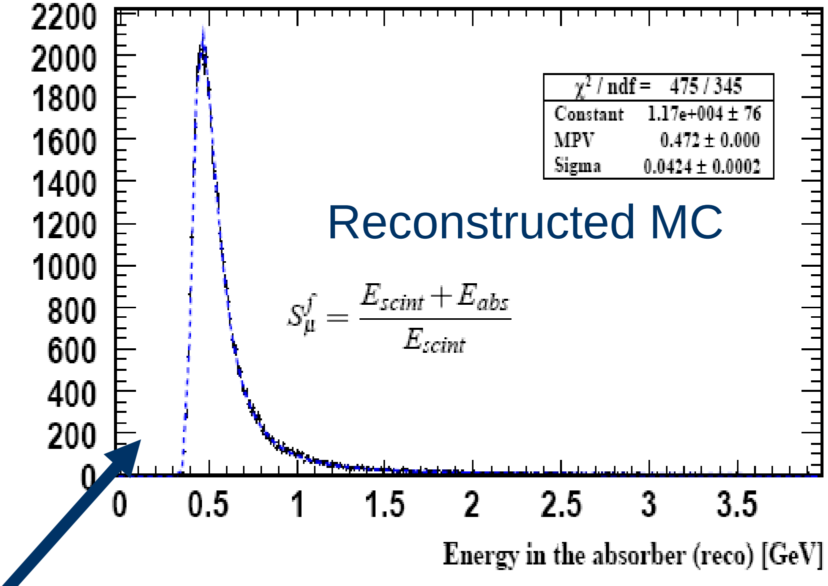
- Electrons with energy more than 28 MeV generate little electromagnetic showers:
  - X0 ~ 2 cm
  - 98 % transversal containment in ~ 12 cm
  - 98 % radial containment ~ 4 cm

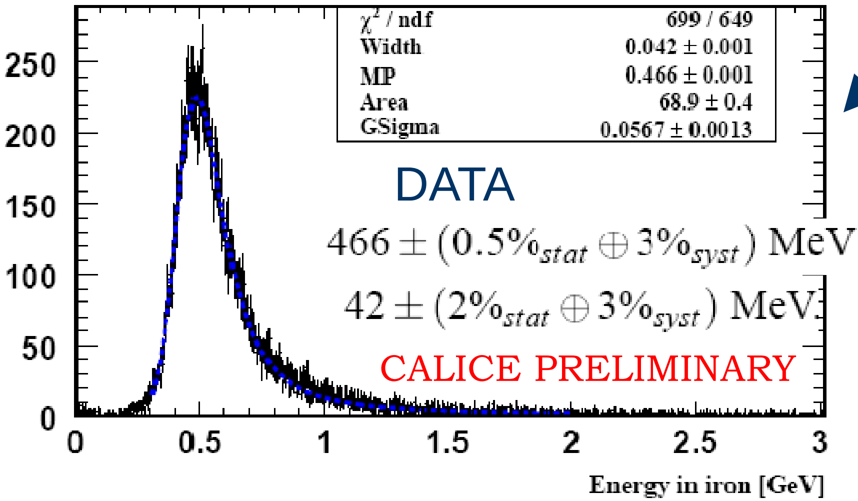




Reconstruction using the sampling fraction



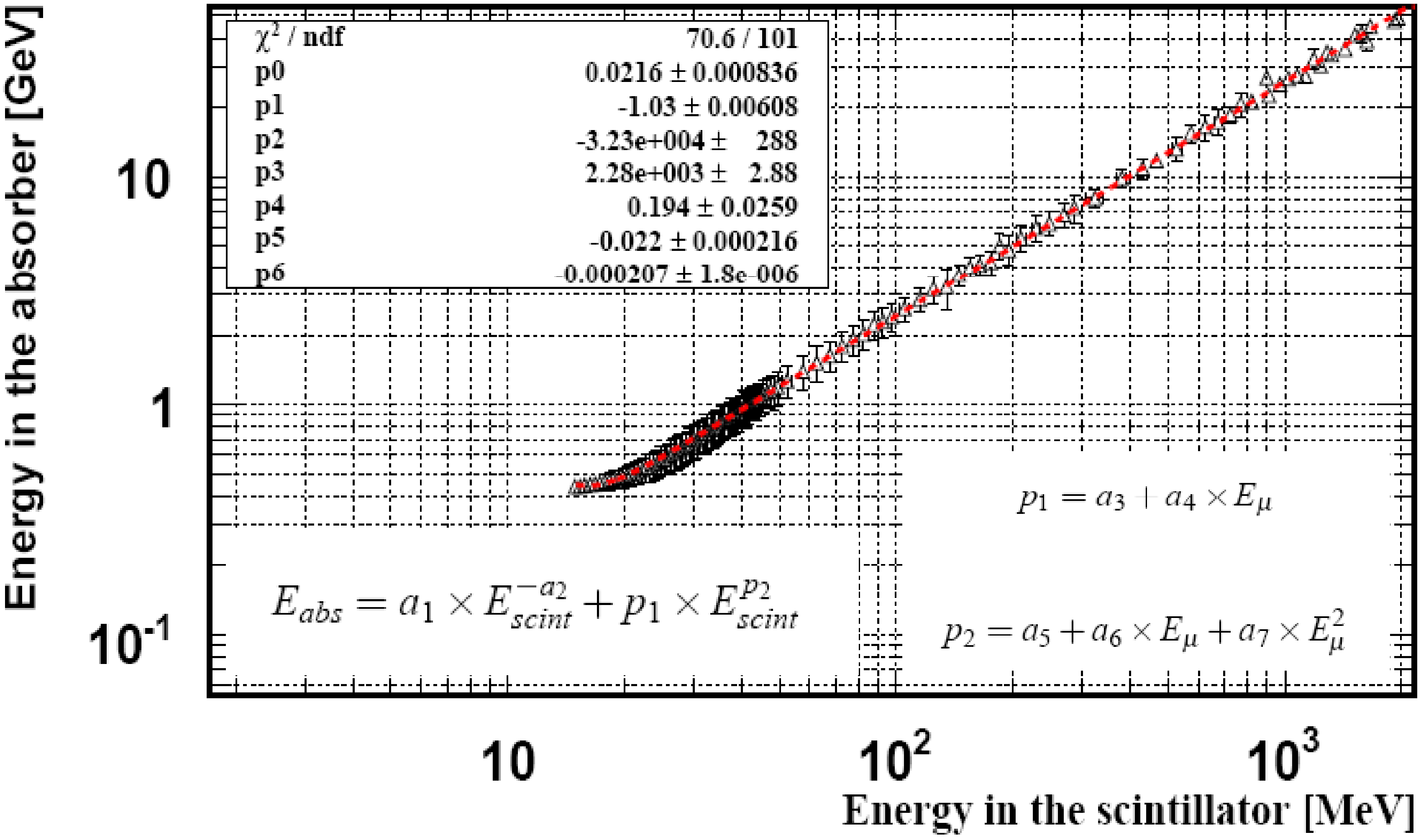




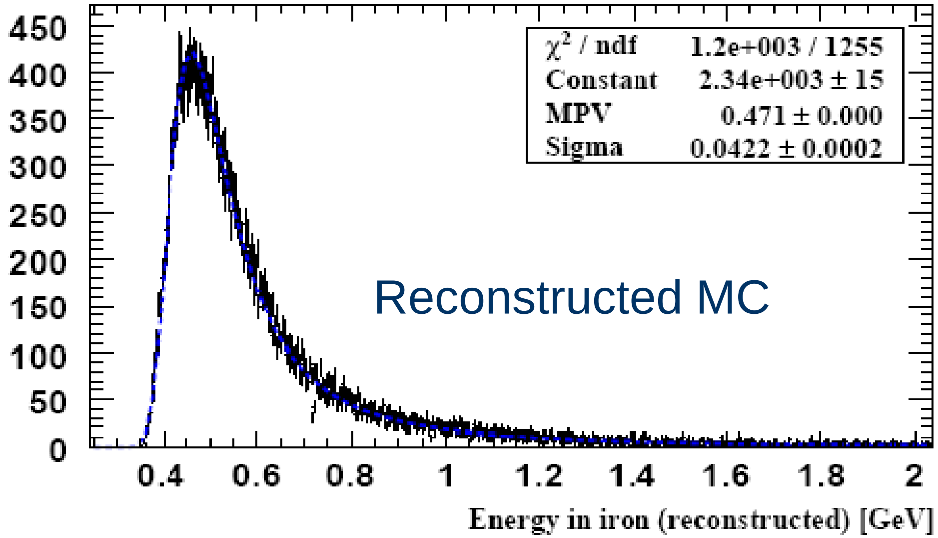
The application of the reconstruction widens the width of the energy distribution inside the absorber 29.6 MeV (1) --> 42.4 MeV (2)

The physics signal can be easily extracted from the data, using a landau convoluted with gaussian fit. The gaussian models the smearing of the detector response.

Parametrization of the energy deposit



Hybrid reconstruction

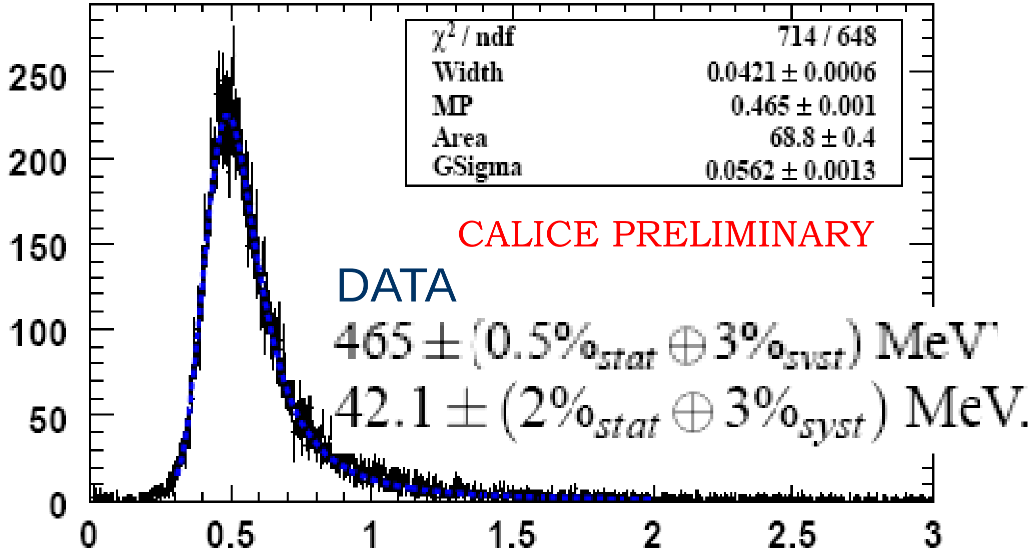


$$E_{scint} > 30 MeV$$

$$E_{abs} = a_1 \times E_{scint}^{-a_2} + p_1 \times E_{scint}^{p_2}$$

$$E_{scint} < 30 MeV$$

$$E_{abs}\big|_{reco} = Sf_{\mu} E_{scint} - E_{scint}$$

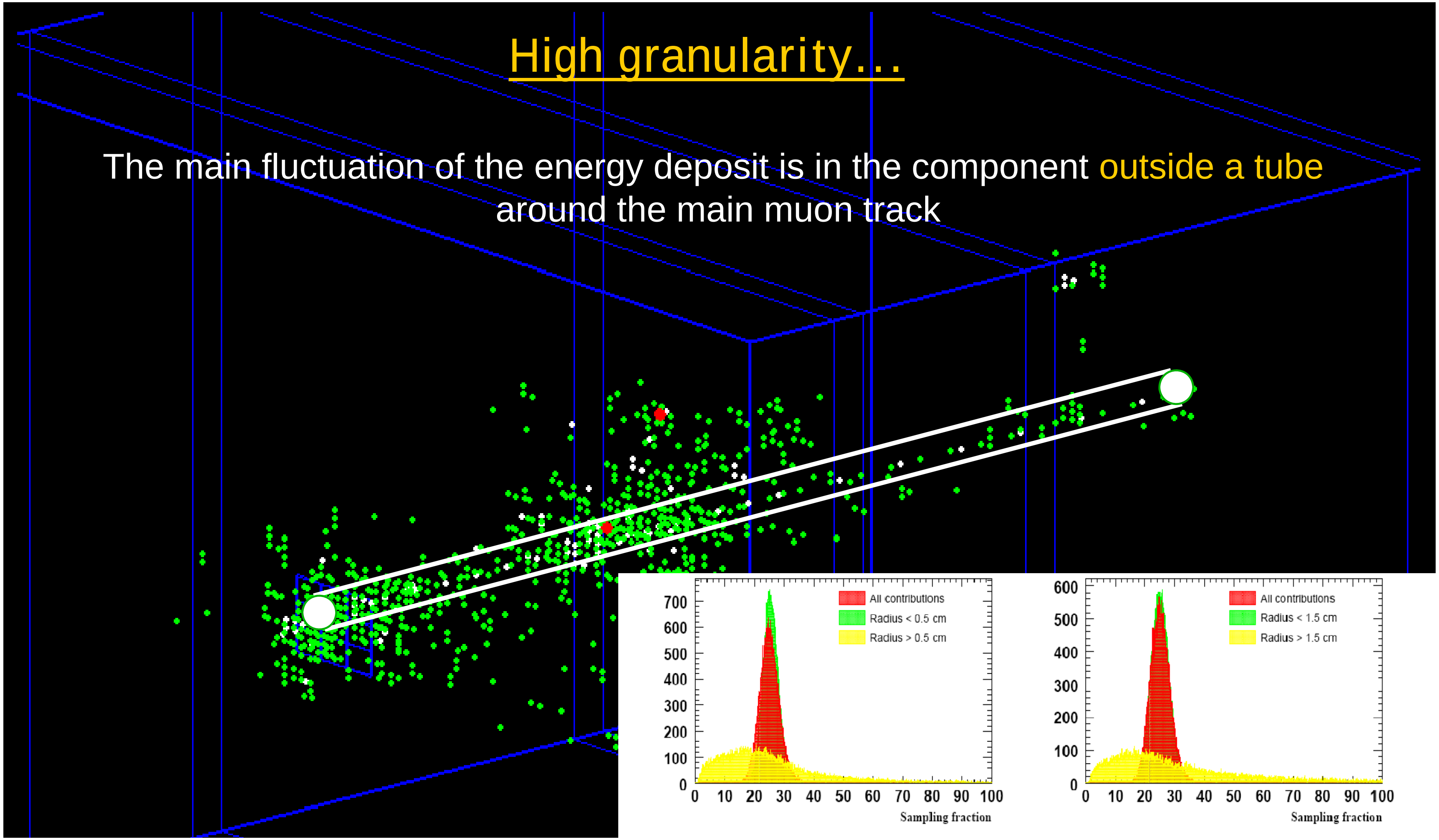


The data represent very well the behaviour of the muon response. The agreement with the MC is very good!

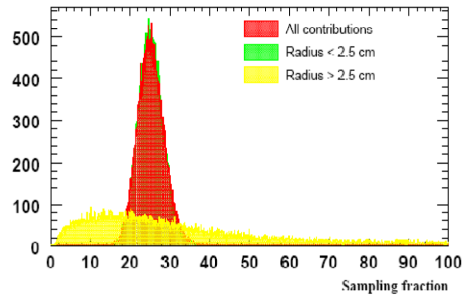
A deeper study of the properties of the HCAL response to muons is possible!

High granularity…

The main fluctuation of the energy deposit is in the component outside a tube around the main muon track



	Hit inside tube			Hit outside tube		
Radius	Sf_{mu}	σ	$\sigma\ Sf_{mu}$	Sf_{mu}	σ	$\sigma\ Sf_{mu}$
0.5 cm	25.33 ± 0.02	2.51 ± 0.02	10%	18.74 ± 0.08	10.98 ± 0.09	58%
1.5 cm	25.03 ± 0.02	2.97 ± 0.03	11.8%	17.82 ± 0.08	13.57 ± 0.09	76%
2.5 cm	24.99 ± 0.02	3.07 ± 0.03	12.3%	17.58 ± 0.08	13.69 ± 0.09	76%

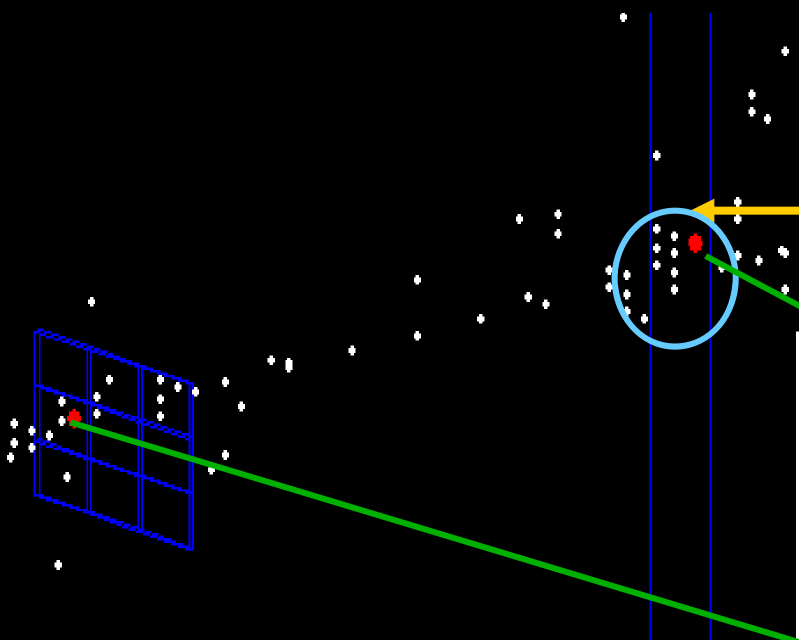


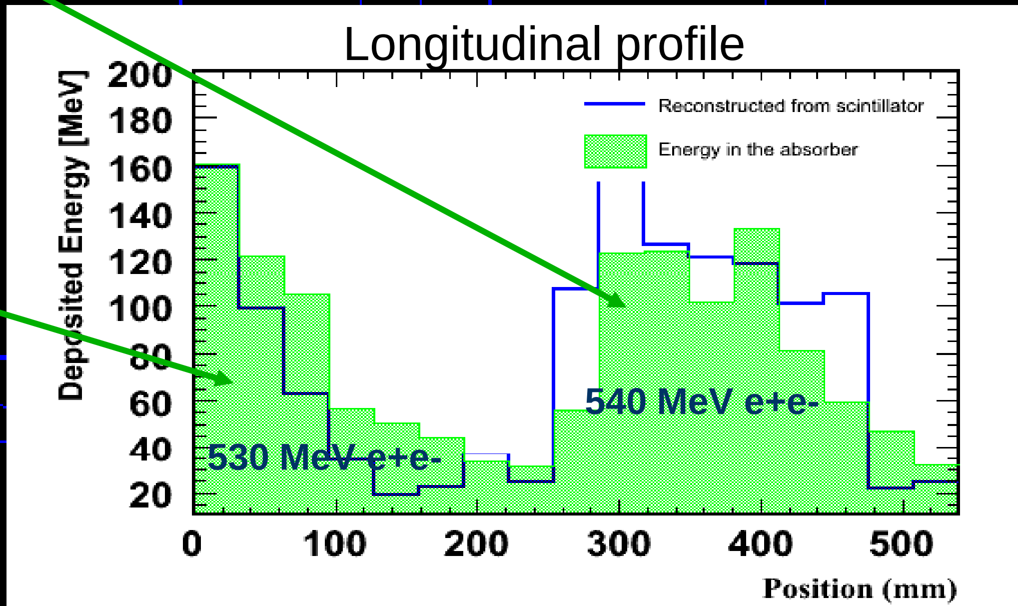
Reconstruction of the elements around the track

1. The **longitudinal distance** between two hits has to be less than 2 X0 (3.6 cm)
2. The radial distance between two hits is within 2 moliére radius (3.6 cm)

$$\bar{\rho} = \frac{\sum E_i r_i}{E_{seed}} \qquad \bar{\sigma} = \frac{\sum E_i(\bar{\rho} - r_i)}{E_{seed}}$$

1. Seeds within 12 cm in z and 2 moliére radius are grouped together
2. Isolated seeds are associated to the nearest found cluster
3. **Electromagnetic clusters found**





1. The reconstructed energy is not so different from the real one: fluctuations needs a deeper study
2. The method allows to recognize events with higher electromagnetic activity. It can be used as "VETO".

Conclusions and outlook

- Data and Montecarlo are in good agreement in the description of the integral parameterers of the muon response
- A reconstruction method for the showering particles around the muon track was developed
  - Application on the DATA will follow soon
- The full study will converge in a proposed statistical description of the muon in the ILD detector (likelyhood etc…)

The interplay between the hadron calorimeter and the muon detector is an interesting topic of investigation, in terms of detector optimization of the muon chamber design.

The test beam data are very useful in the direction of testing the method to be applied in the future ILD detector.