Sampling Fluctuations and Their Contribution to Hadron Energy Resolution

A. Para, February 20, 2007

Motivation

- Homogenous calorimeter with dual readout (Cherenkov + ionization) offers a prospect of high resolution hadron calorimetry.
- Natural implementation of a dual readout concept: two-component calorimeter (for example lead glass/scintillator). In such a calorimeter both components are sampled, hence undergo sampling fluctuations
- The target energy resolution is very good, hence the contribution of sampling fluctuations must be well understood.

Goal

- Develop a phenomenological model of contribution of sampling fluctuations to the hadron energy resolution as a function of the detector geometry: sampling frequency (absorber thickness) and the active detector thickness.

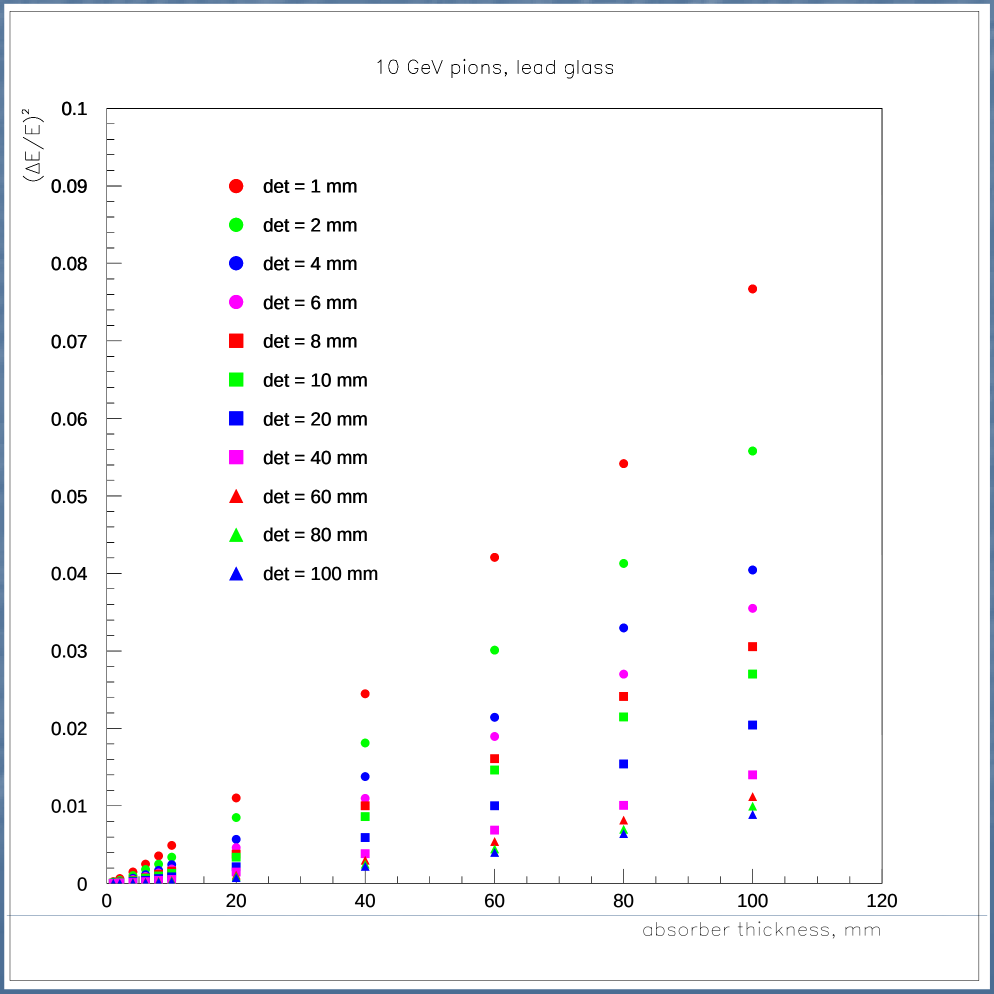
Method

- Use a sample of 10 GeV pion-induced showers simulated in a large calorimeter with 10,000 layers of 1 mm thick lead glass. By convenient grouping of thin layers one can effectively simulate the sampling calorimeter with different thicknesses of 'absorber' (i.e. inactive) and 'active' materials.
- Analyze the ionization energy deposits only. The energy resolution is dominated by non-compensated effects of nuclear energy loss. Remove these effects by studying the resolution defined as the RMS of:

$$\frac{\Delta E}{E} = \frac{\frac{t_{abs} + t_{act}}{t_{act}} \sum E_{act}}{\sum E_{act} + \sum E_{abs}}$$

Energy Resolution (10 GeV) as a Function of Absorber Thickness

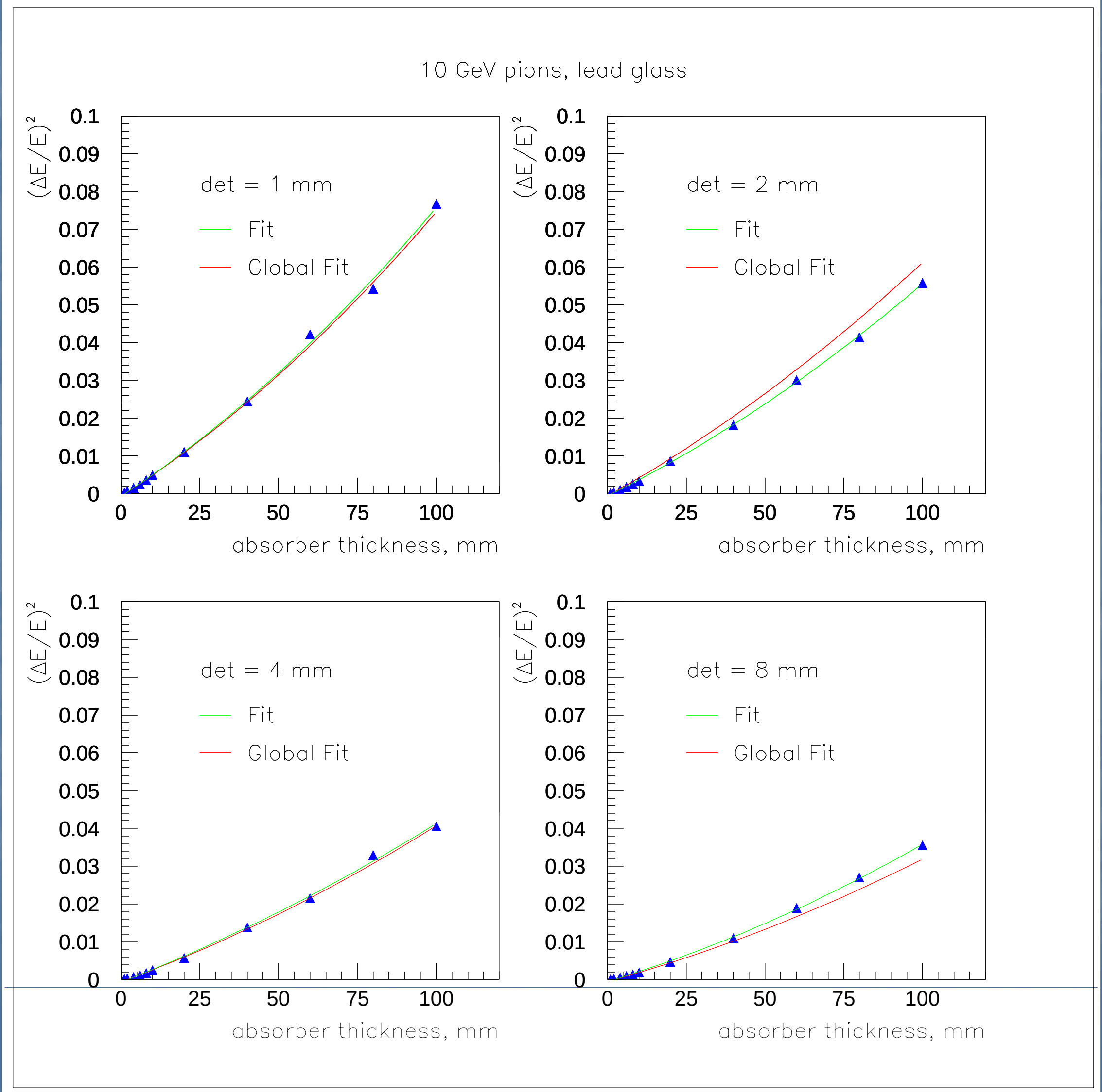
- Expectation: $\Delta E/E \sim \sqrt{t_{abs}}$, hence plot $(\Delta E/E)^2$ as a function of t_{abs}
- $(\Delta E/E)^2$ is not a straight line, but straight line is a decent approximation
- But the slope of the straight line depends on the thickness of the active layer
- Sampling fraction (ratio of active to absorber) is not the only relevant variable. Compare (1,1), (20,20) and (100,100) configuarations



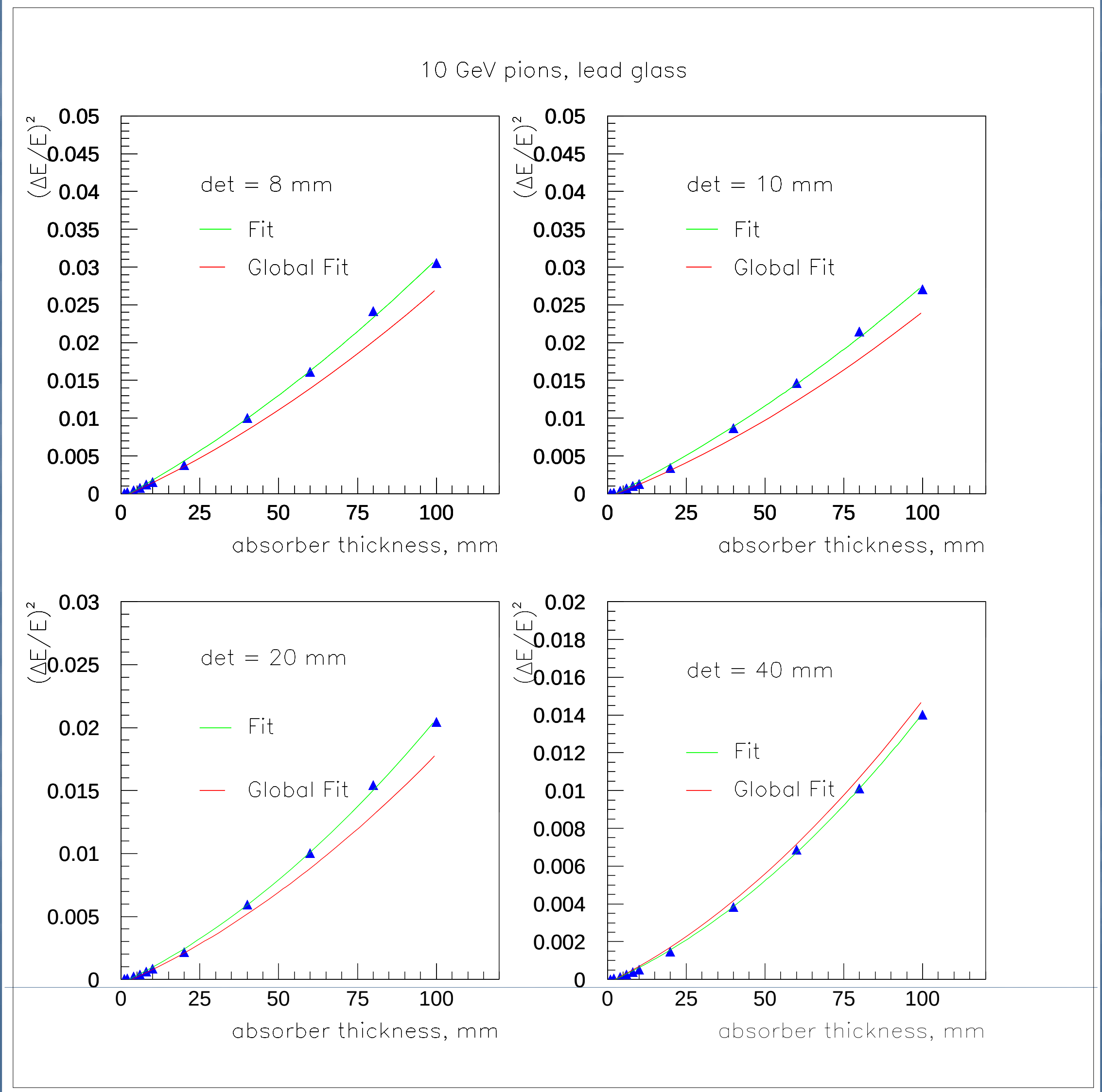
Strategy

- The previous plot is too busy to analyze. Try to find an effective description in three steps:
  - Fit $(\Delta E/E)^2$ as a quadratic function of t_{abs} (green line in the forthcoming plots)
  - Parameterize the coefficients (constant, linear and quadratic term) as a quadratic function of the t_{act} (or $1/t_{act}$)
  - Parameterize (red line in the forthcoming plots):
  - $(\Delta E/E)^2(t_{abs},t_{act}) = A(t_{act})t_{abs}^2 + B(t_{act})t_{abs} + C(t_{act})$
- Note: the above ansatz is a crude guess. Fitting separate coefficients is not a good recipe, as they are usually correlated. It may not work very well. Better approximations can be found.

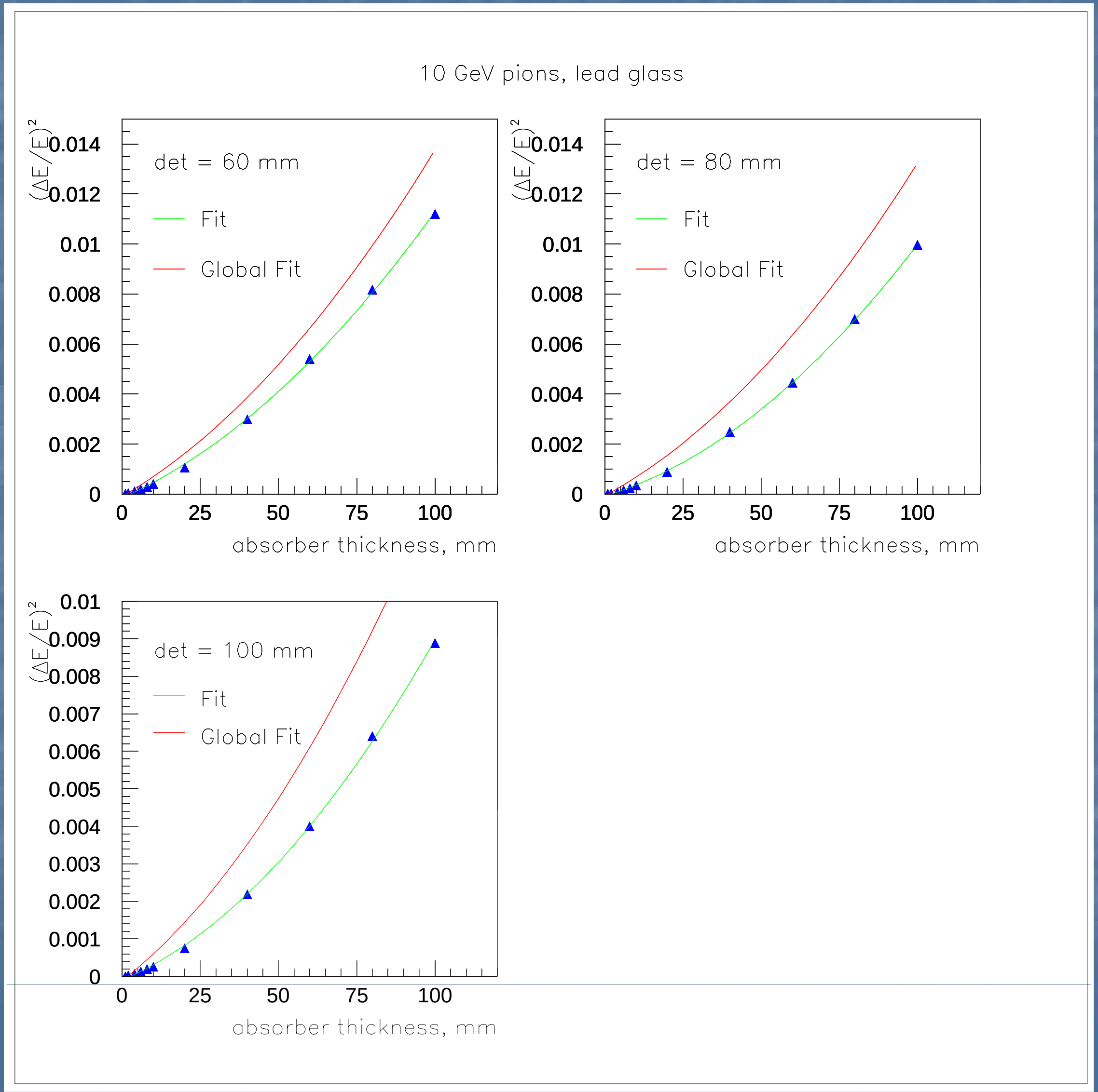
Active layers 1 - 8 mm



Active layers 10 - 40 mm

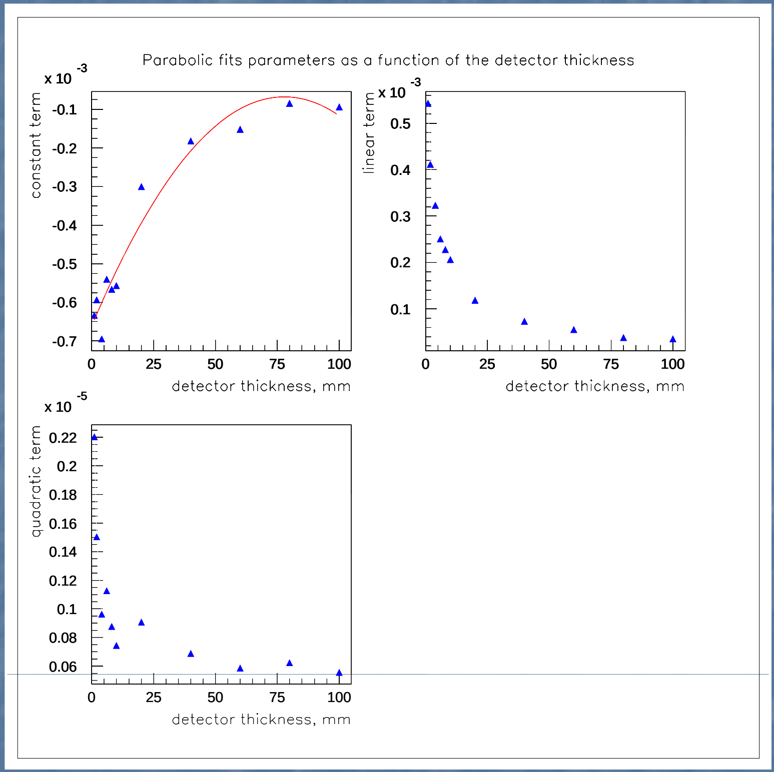


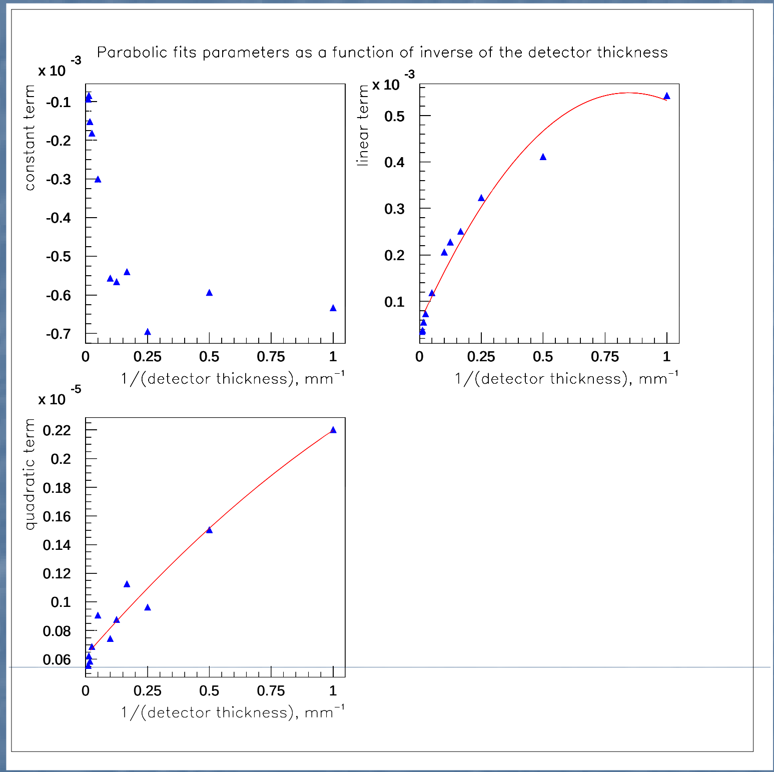
Active layers 60 - 100 mm



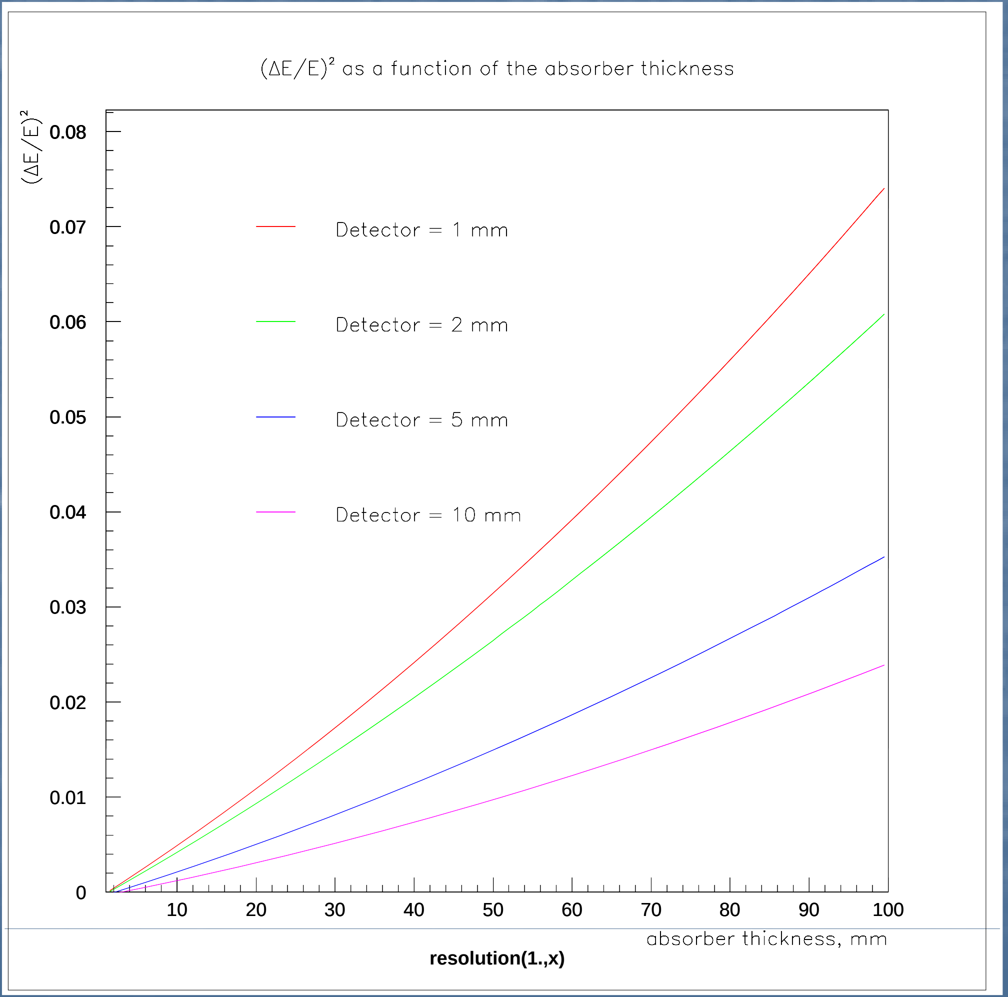
- 'Global' fit not a very good description for very thick active layers (deficiency of the coefficients parameterization)

Fitting the Coefficients





Sampling Fluctuations as a Function of the Absorber Layer



- $(\Delta E/E)^2$ 'almost linear' in t_{abs}
- But the slope (resolution) grows very rapidly for thin active layers