Laboratoire d'Annecy-le-Vieux
de Physique des Particules

Simulation study of a DHCAL with various absorber materials

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Introduction

Motivation:

- Better understanding of digital calorimetry generally
- First qualitative view on DHCAL global performance

Study performed:

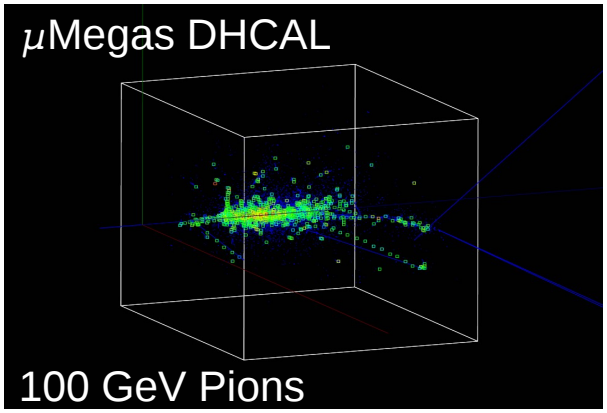
- Study of the main calorimeter characteristics such as:
  - Response
  - Linearity
  - Energy resolution
  - Shower shape
  - Containment
- Comparison of various absorber materials
- Comparison of analog and digital readout
- Dependency on the readout threshold

Generated data: π^-: 3, 10, 50, 100, 150, 200 GeV

Simulation tools:

- SLIC (Geant4) simulation tools with LHEP physics list
- lcsim.org analysis framework

Calorimeter configuration



Calorimeters description:

- Sampling calorimeter with 80 layers (9 λ)
- 1x1 cm^2 cell size
- Readout: - analog (deposited energy)
  - digital (number of hits)

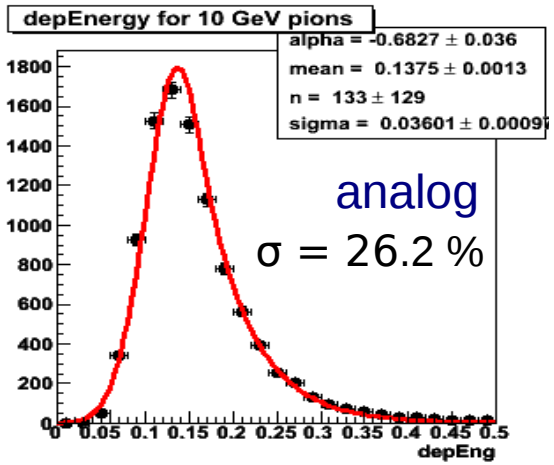
Calorimeter with Fe absorber:

- Passive material: 1.9 cm Fe including 4 mm thick steel cover (total 9 λ: 154 cm Fe)
- Active layer: 6 mm (3 mm of gas + 3 mm detector materials)
- Dimension: 200 x 200 x 200 cm^3

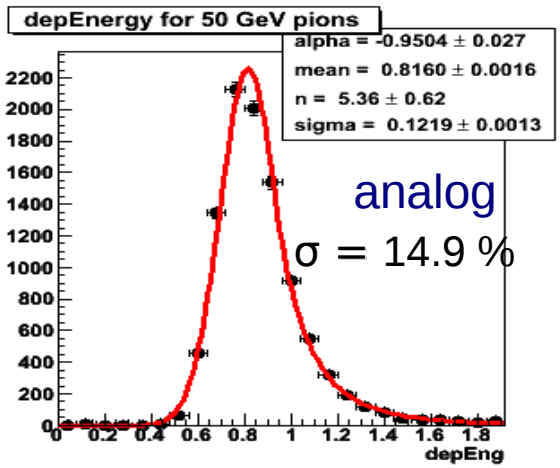
Calorimeter with W and Pb absorbers:

- Passive materials: 1.13 cm W or 1.99 cm Pb (total 9 λ: 90 cm W and 159 cm Pb)
- Active layer: 6 mm (3 mm of gas + 3 mm detector materials) + 4 mm of Al cover
- Dimensions: - W: 200 x 200 x 170.16 cm^3
  - Pb: 200 x 200 x 239.44 cm^3

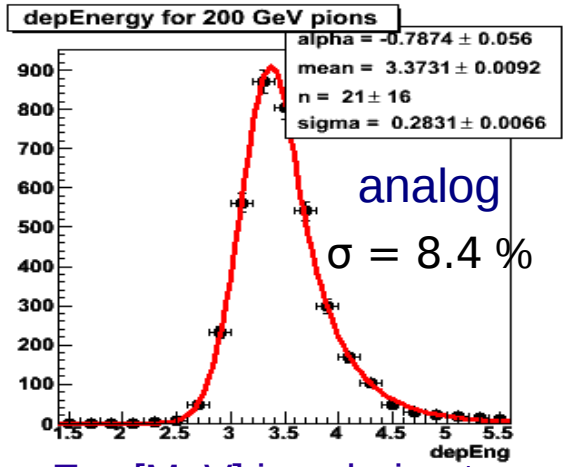
Analog vs digital readout, W abs.



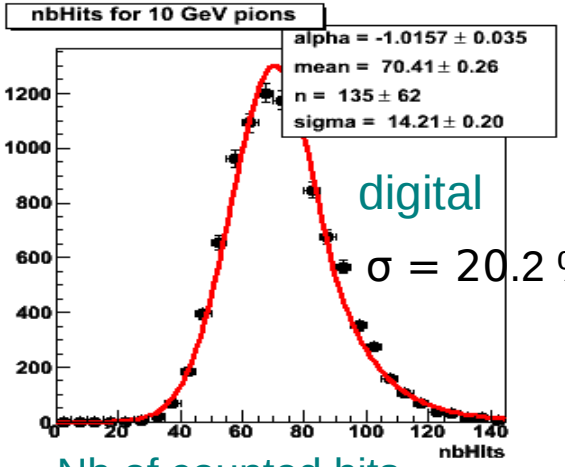
E_{dep} [MeV] in calorimeter



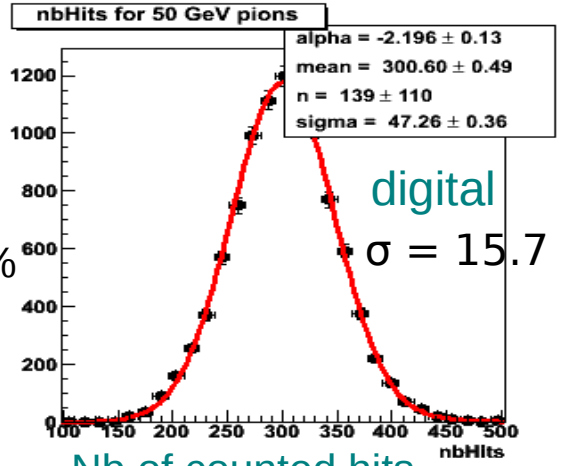
E_{dep} [MeV] in calorimeter



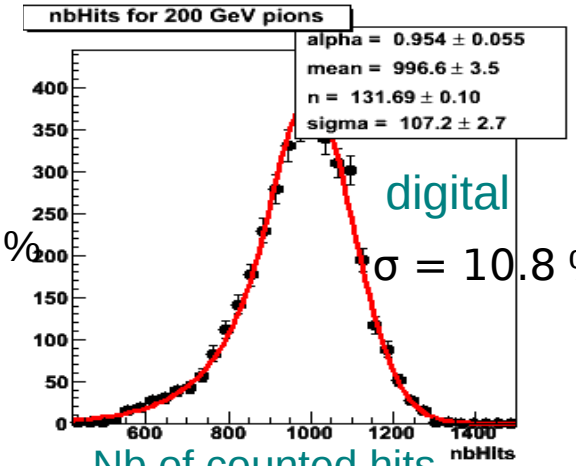
E_{dep} [MeV] in calorimeter



Nb of counted hits

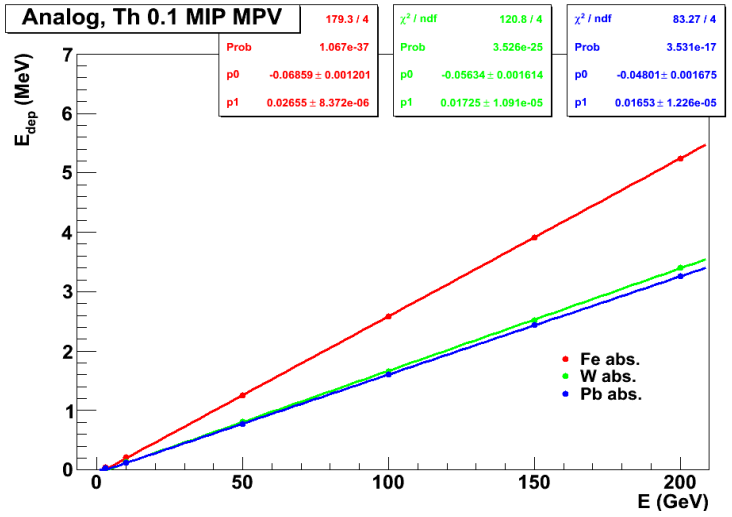


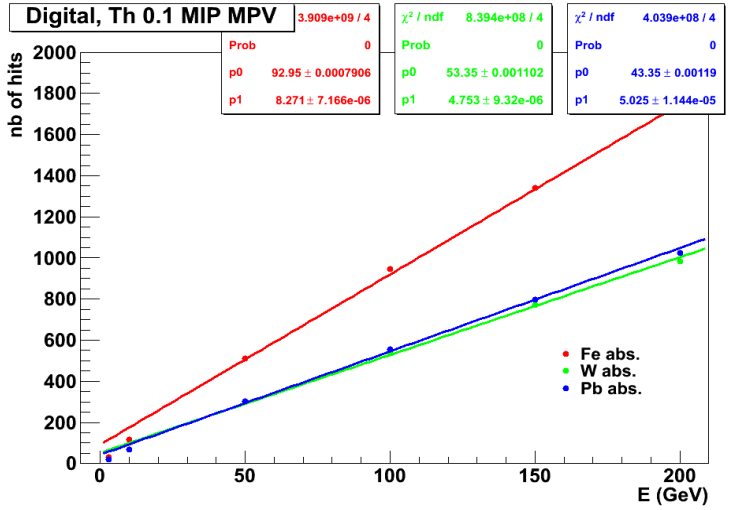
Nb of counted hits

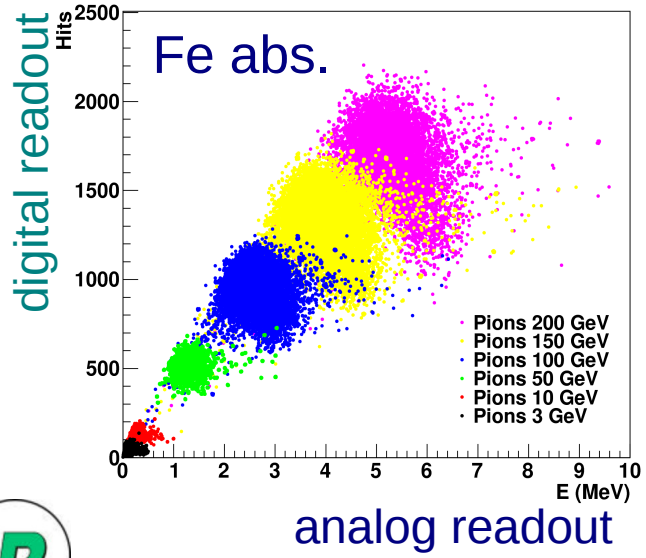


Nb of counted hits

Response for various abs.

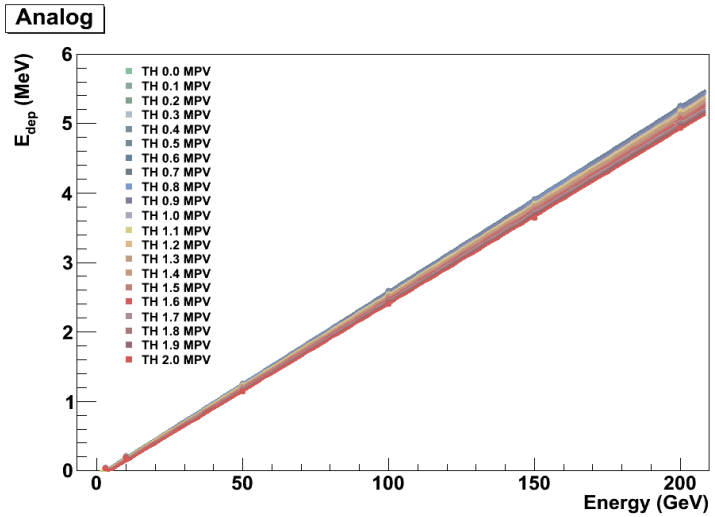


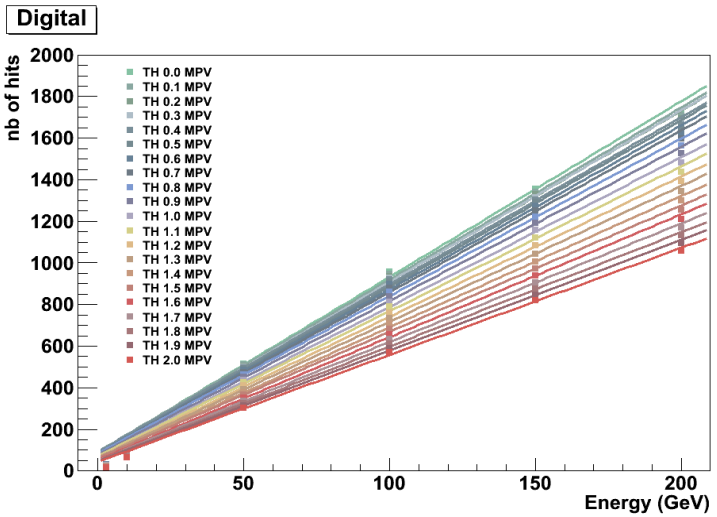


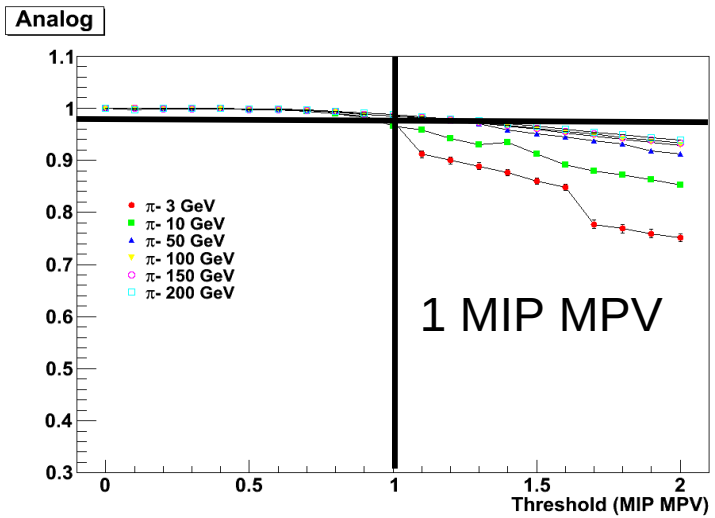


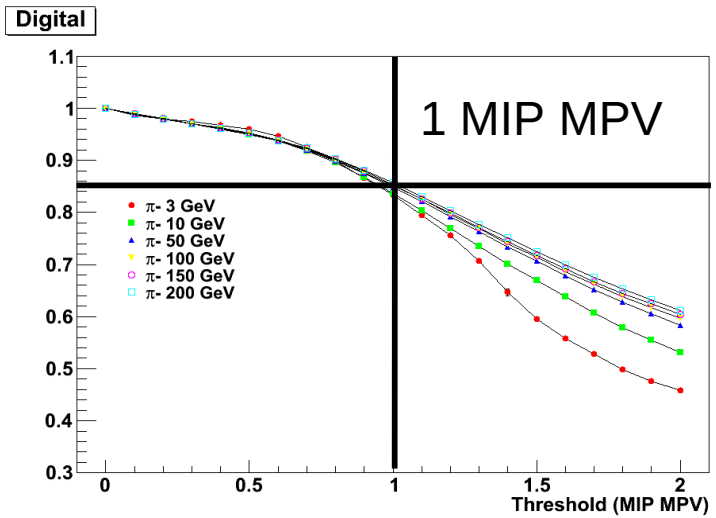
- More visible energy is for the Fe due to its longer X_0 and R_M in comparison with W and Pb absorbers
- Number of counted hits is well correlated with E_{dep}. Digital readout can be used in a wide energy range
- The saturation effect is seen for higher energy → semi-digital readout should be considered

Response vs threshold, Fe abs.





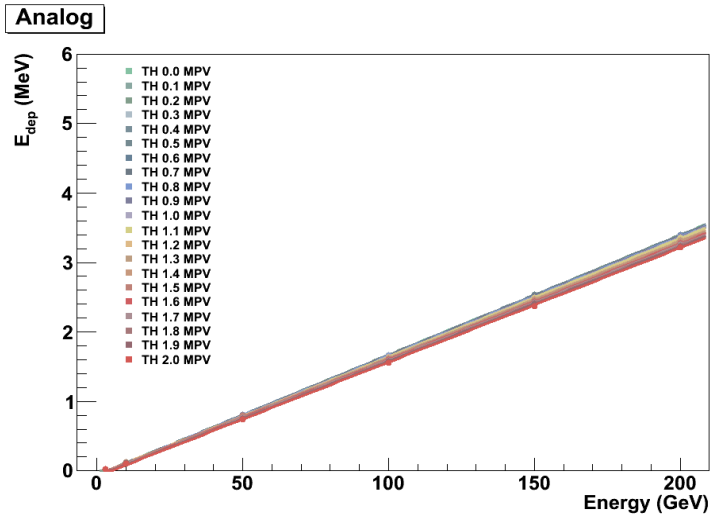


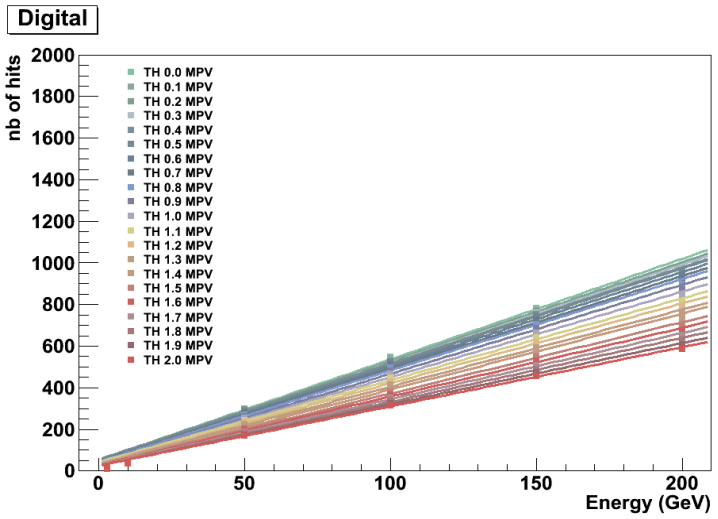


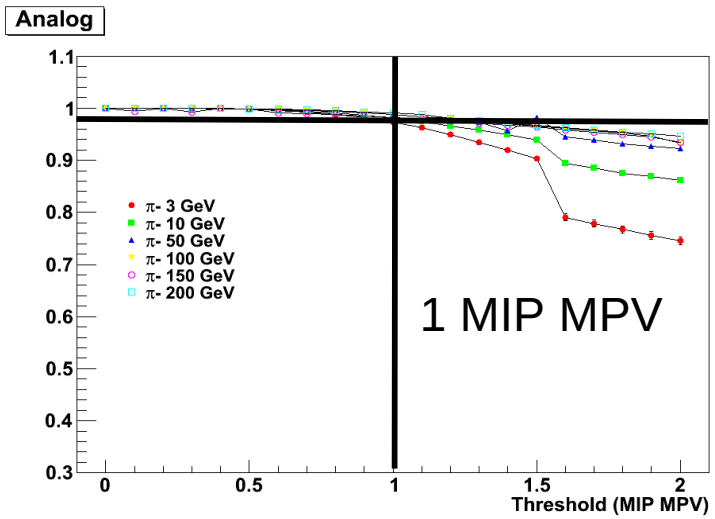
15%

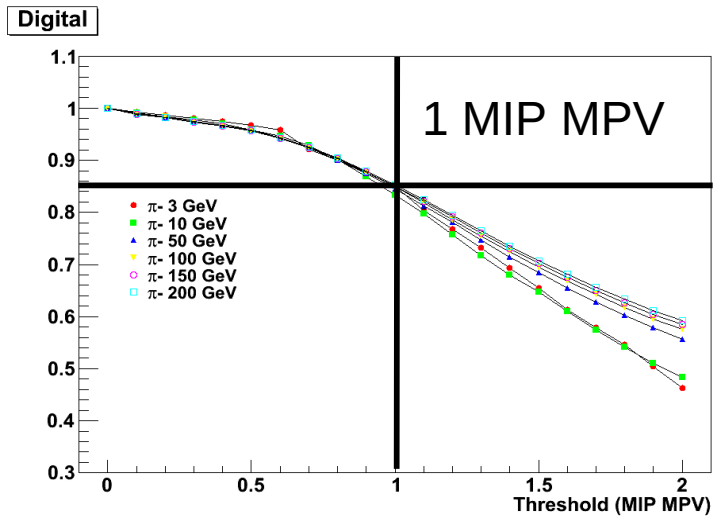
Number of hits has decreased by 15 % for 1 MIP threshold

Response vs threshold, W abs.





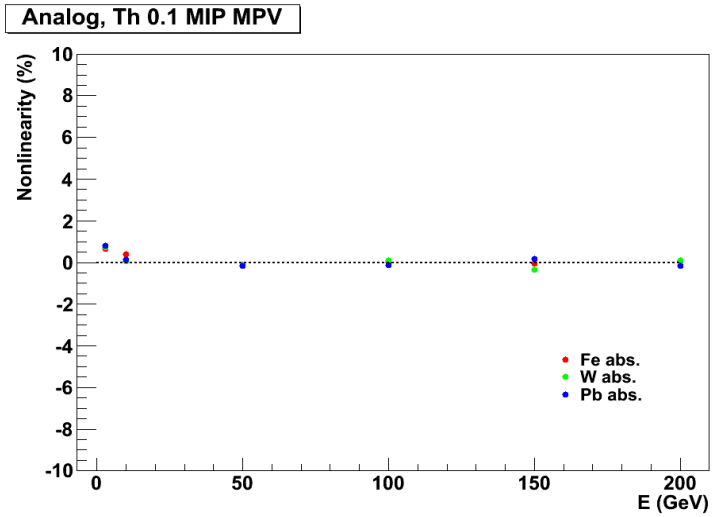


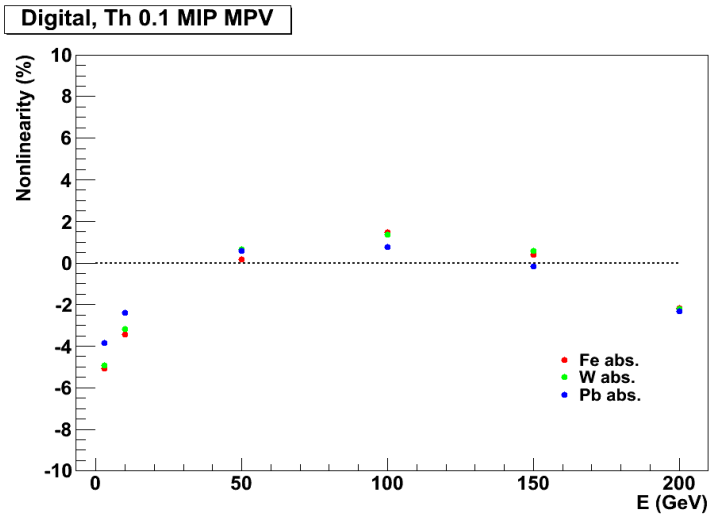


15%

Number of hits has decreased by 15 % for 1 MIP threshold

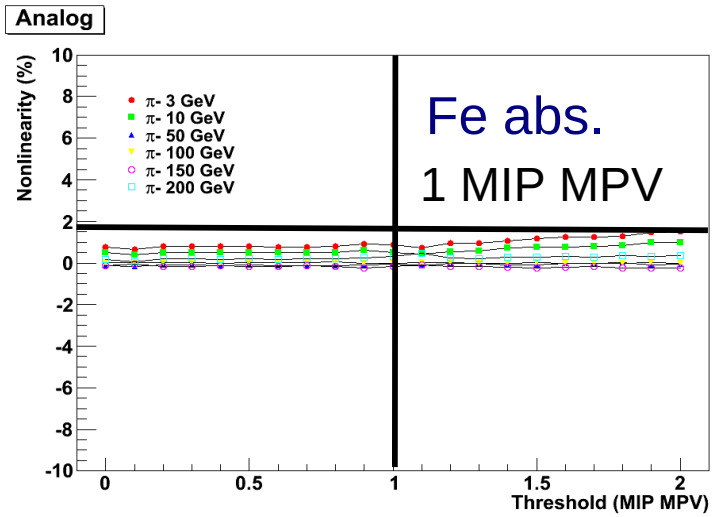
Calorimeter linearity

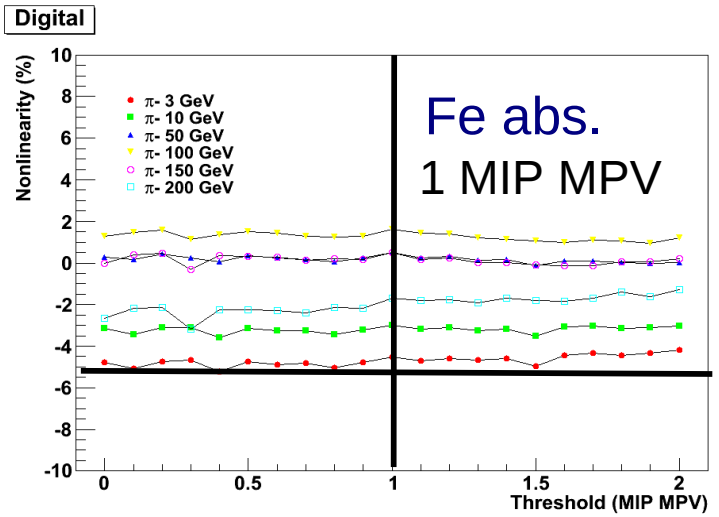


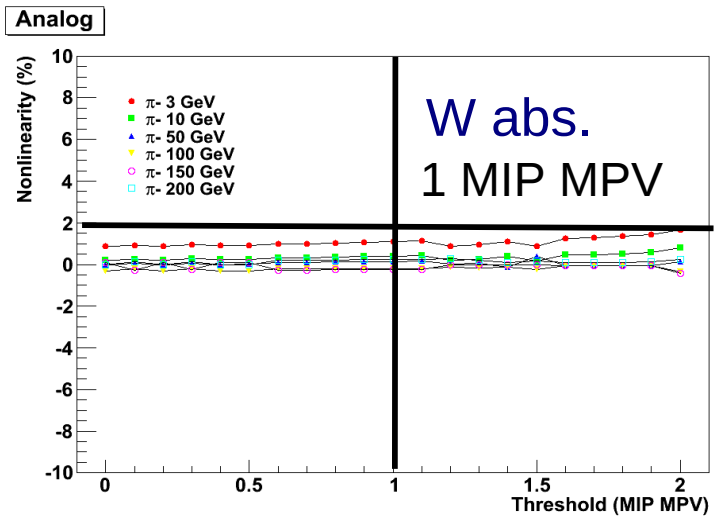


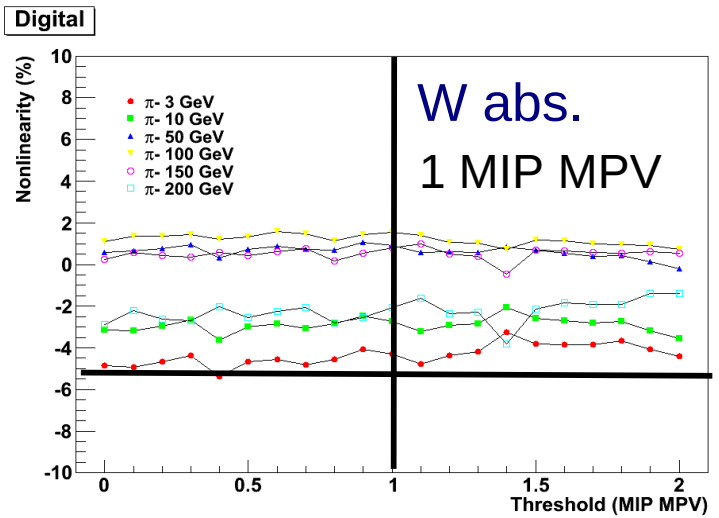
- Similar behavior observed for all three absorvers and for both readouts
- For analog readout, the full-scale linearity is within ± 1 %
- In case of digital readout, full-scale linearity is ± 5 % due to the saturation for higher energy

Linearity vs threshold



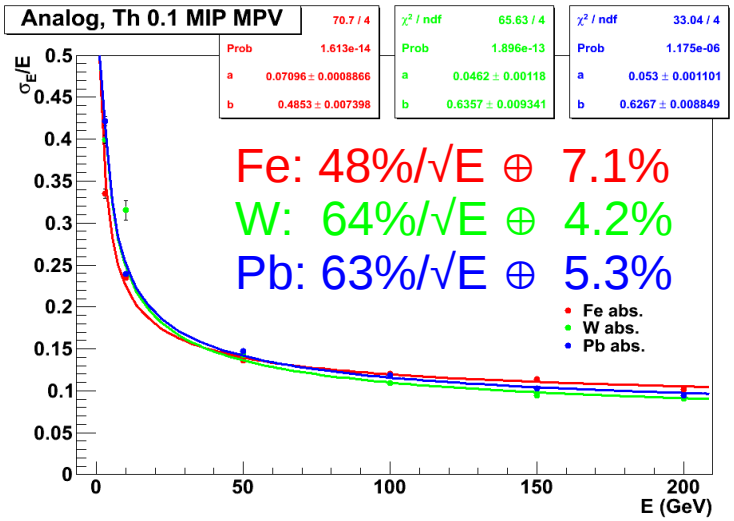


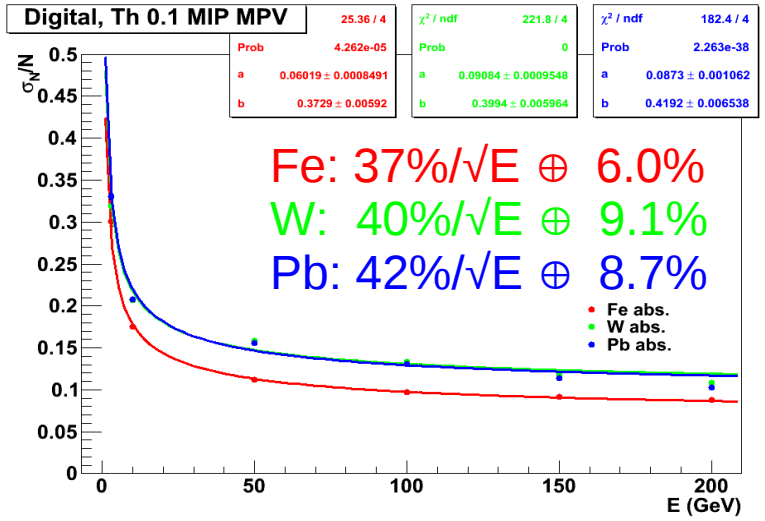


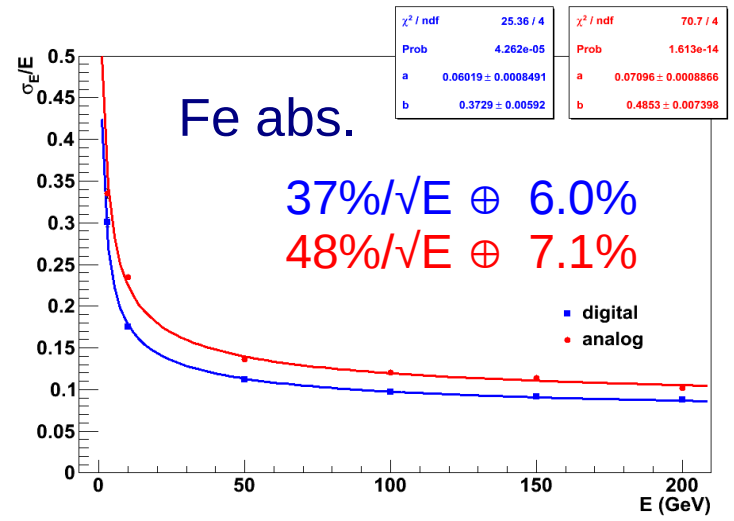


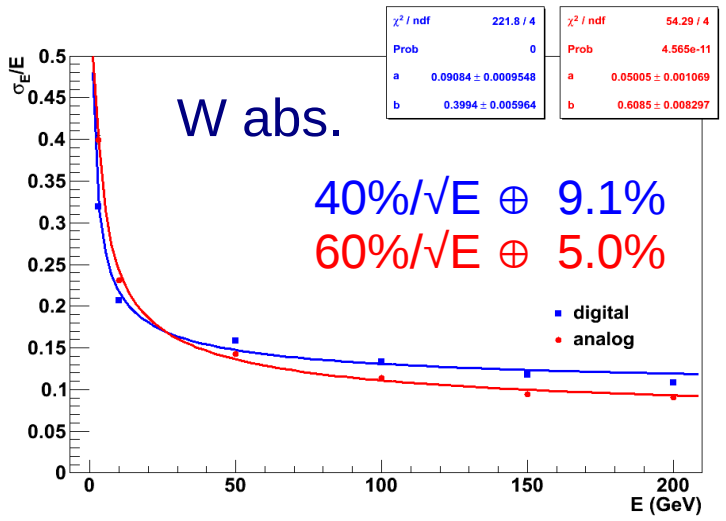
Very small improvement of linearity for digital readout

Energy resolution

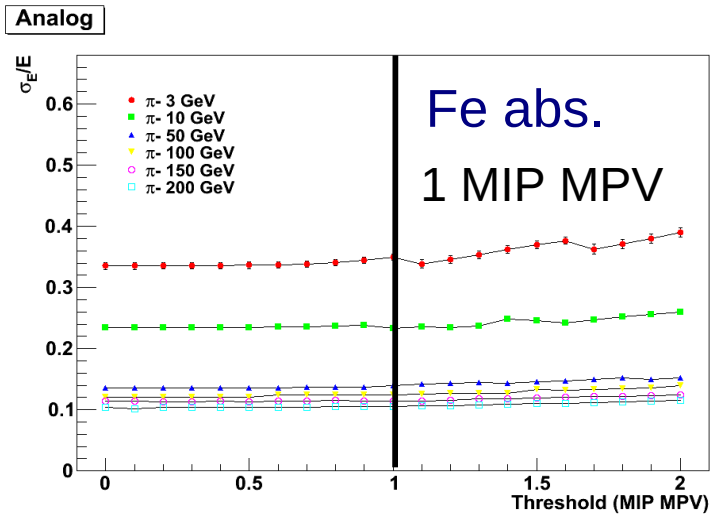


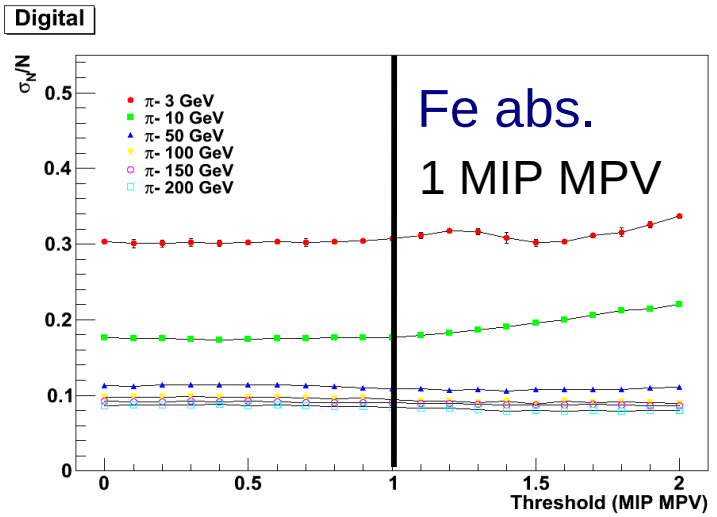


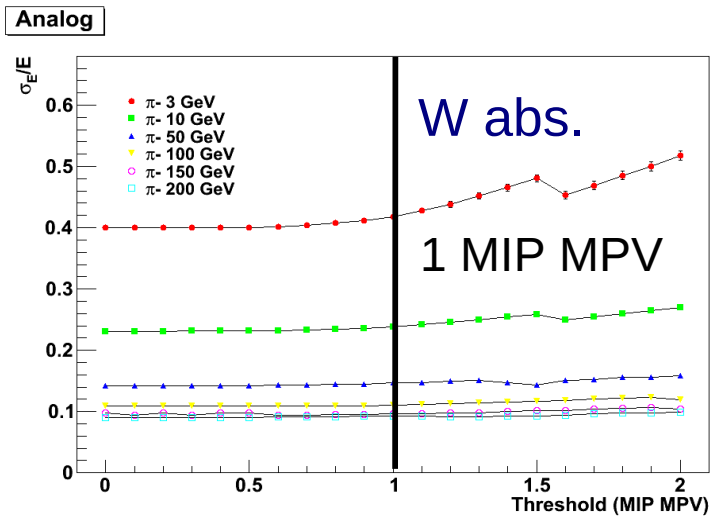


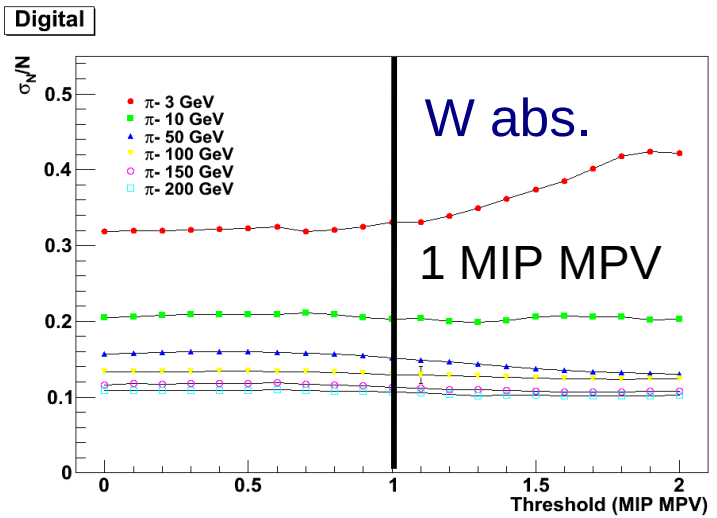


Resolution vs threshold



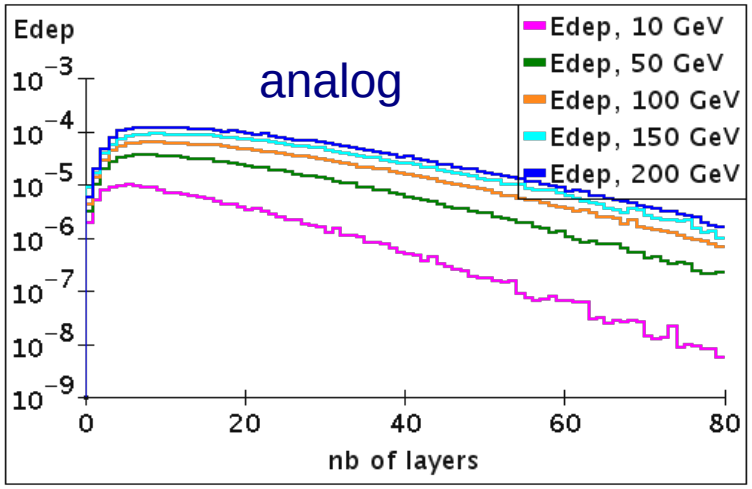


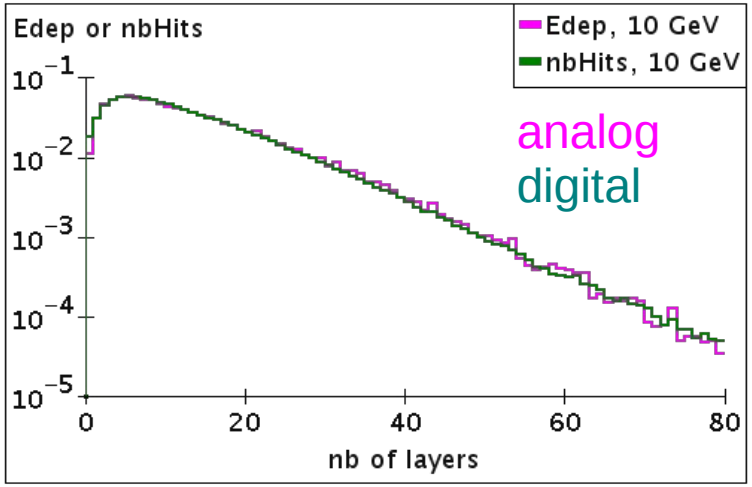


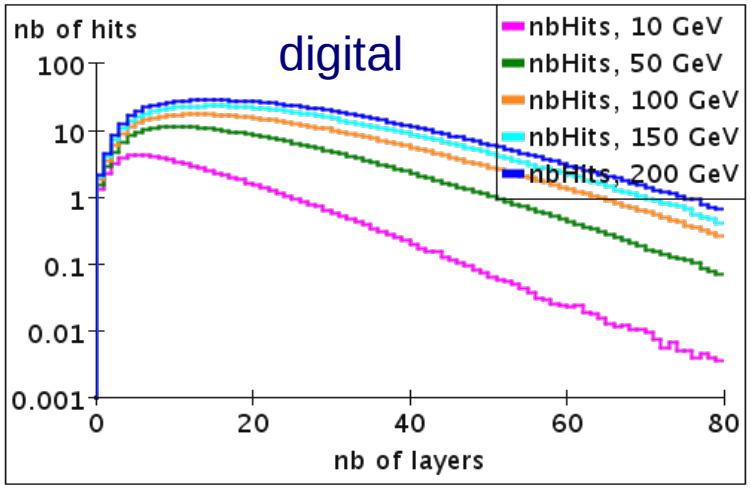


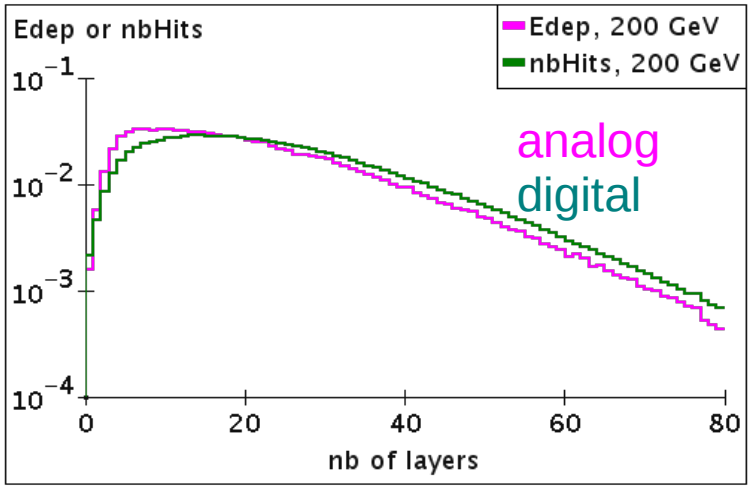
No degradation of the energy resolution up to 1 MIP threshold

Long. shower profiles, W abs.



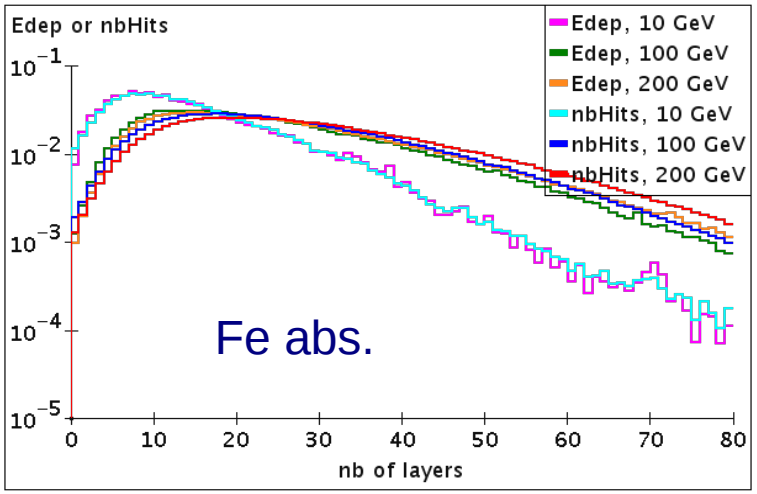


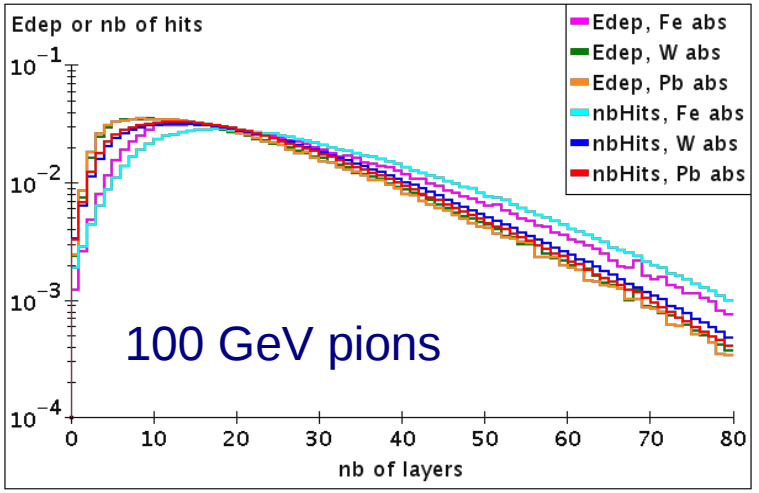


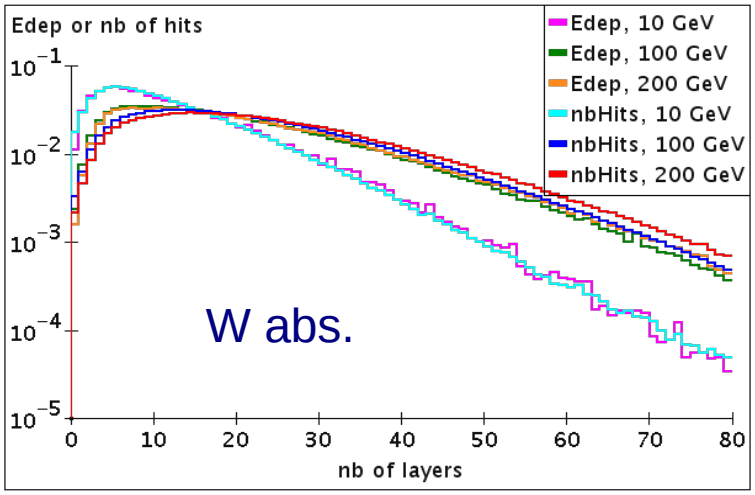


N.B. Threshold 0.1 MIP MPV

Longitudinal shower profile

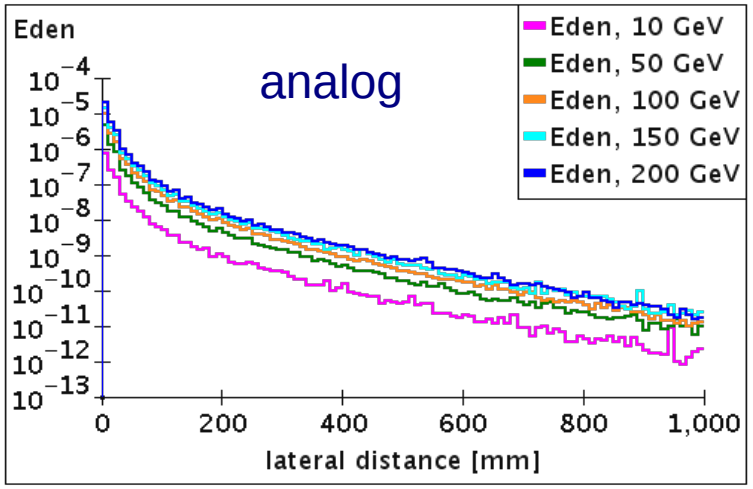


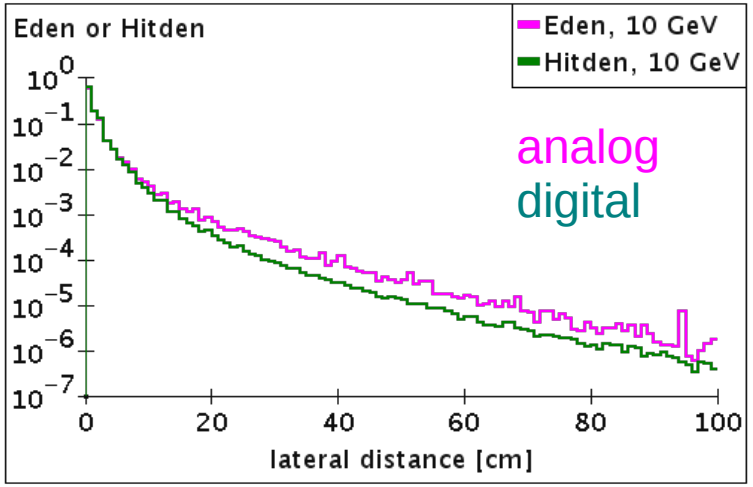


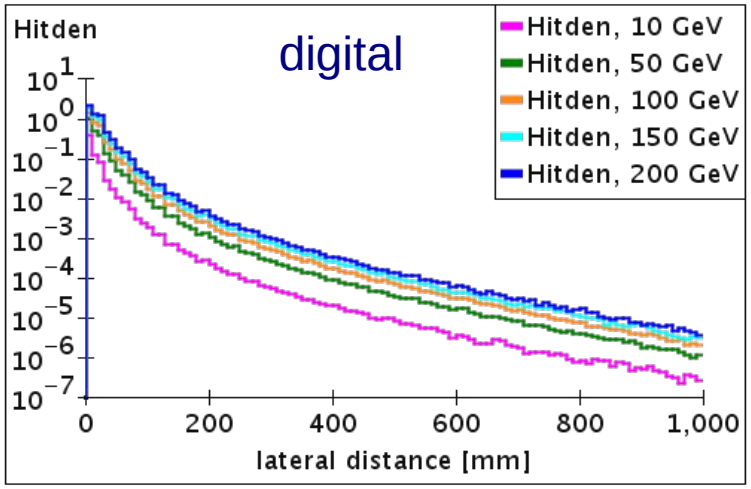


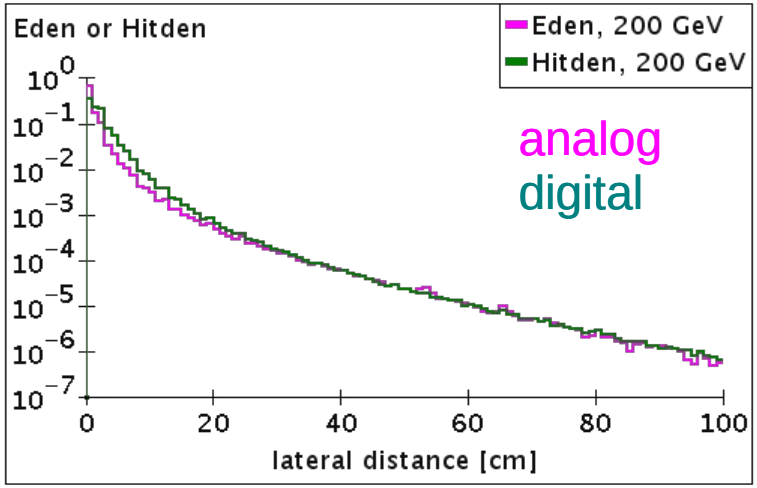
- Shower profile behaves as expected for different absorbers
- Analog and digital readouts have almost identical shower profile in a low energy range
- The shift between analog and digital shower profiles increase with energy

Lateral shower profiles, W abs.



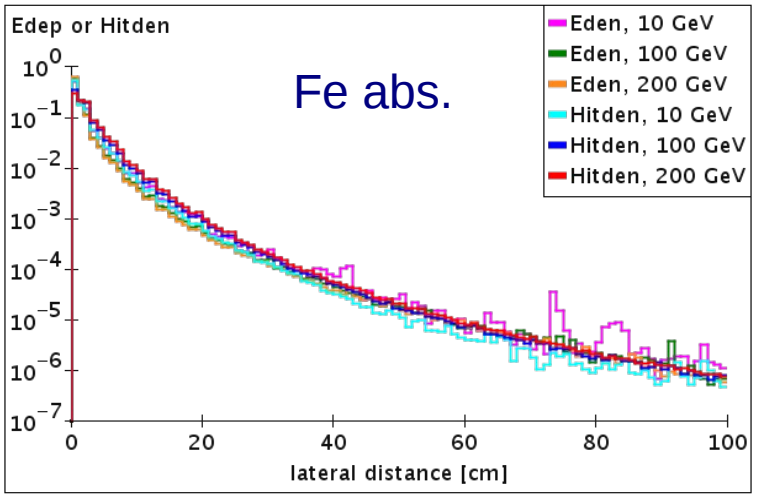


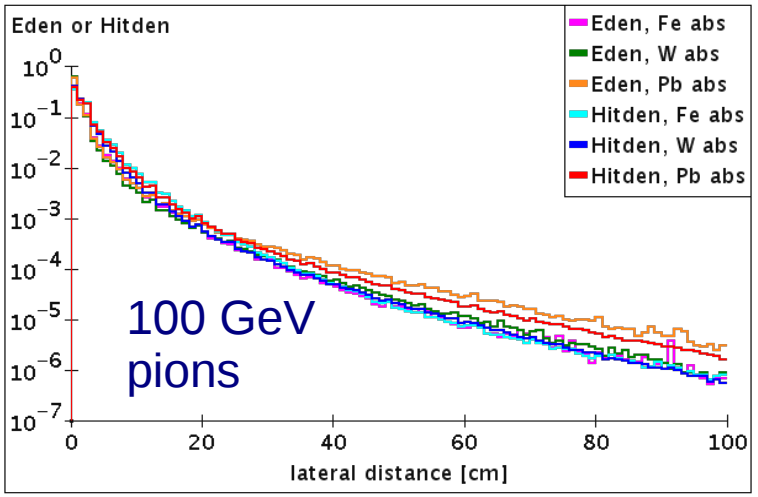


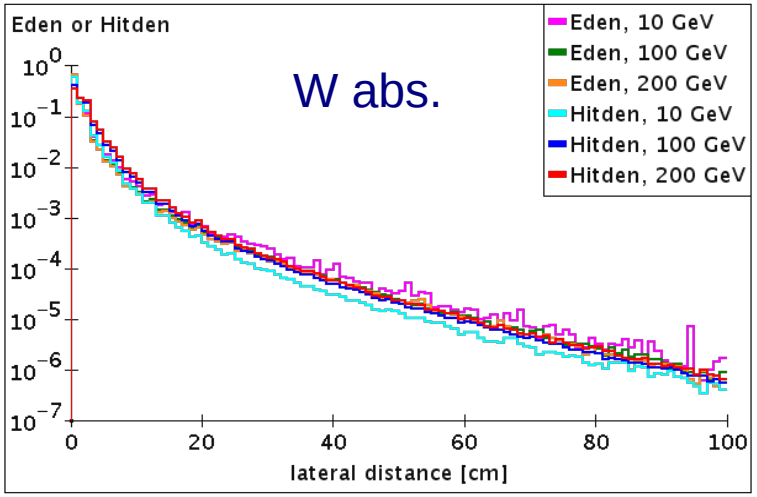


N.B. Threshold 0.1 MIP MPV

Lateral shower profile

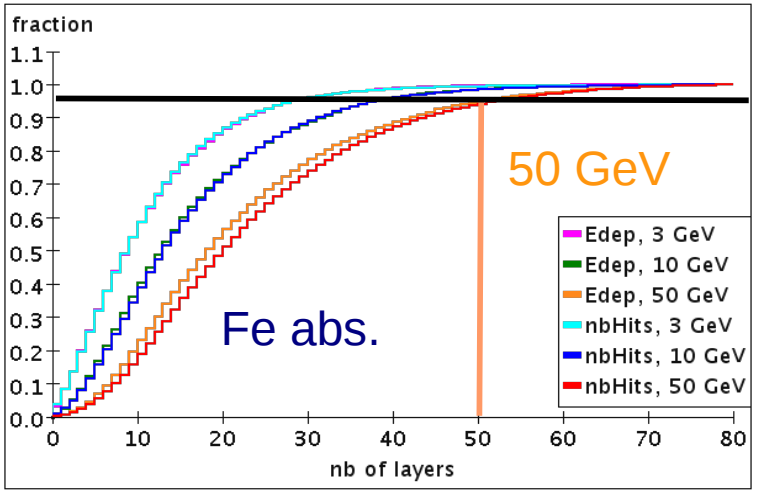


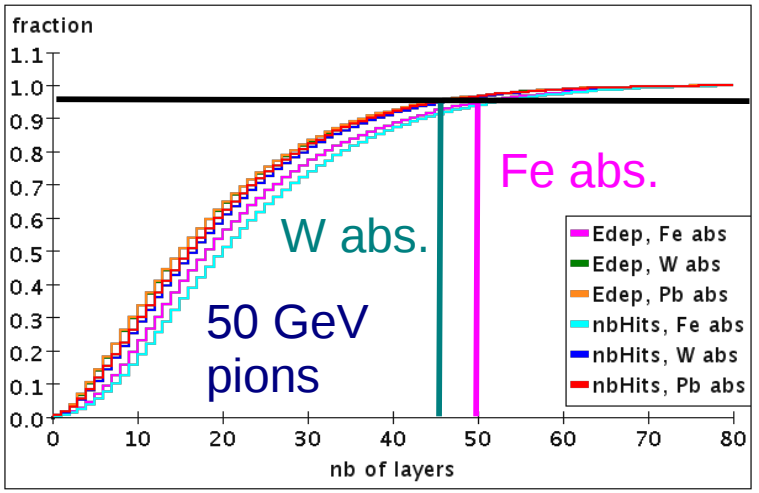


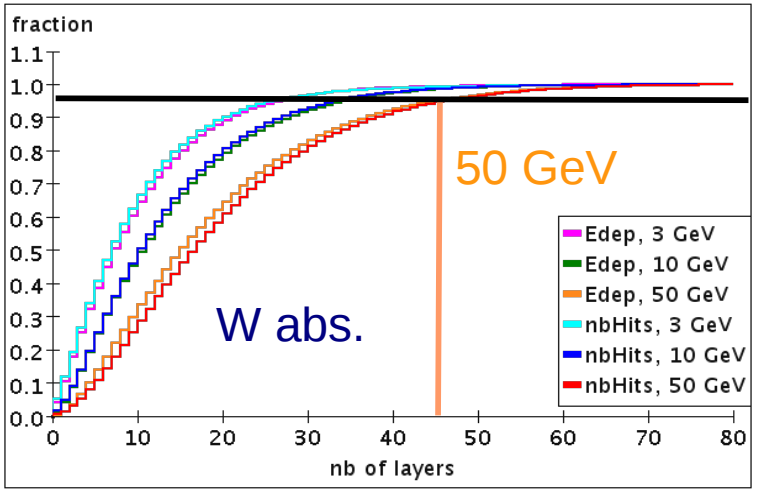


- Difference between analog and digital readout is seen for all energies
- More hits in comparison with deposited energy are counted in the core and less in the tail
- The difference is significantly larger in case W in comparison with Fe absorber

Longitudinal containment

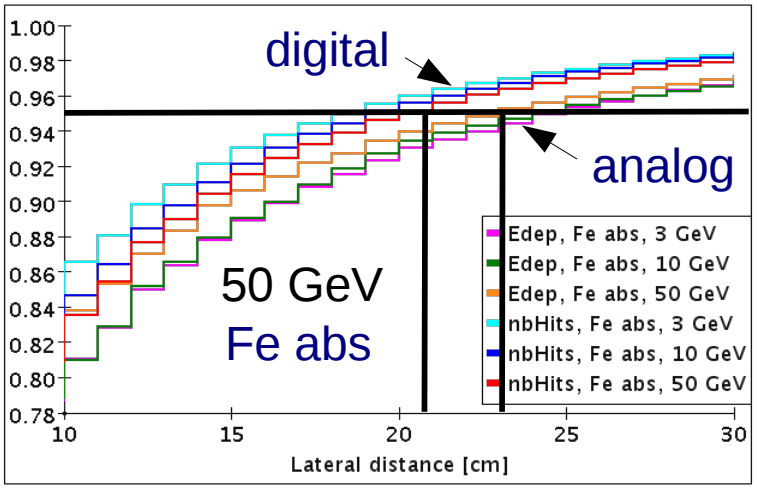


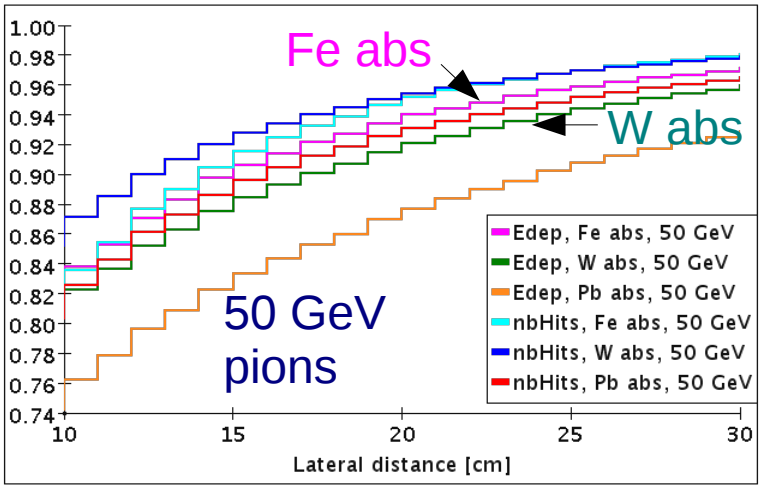


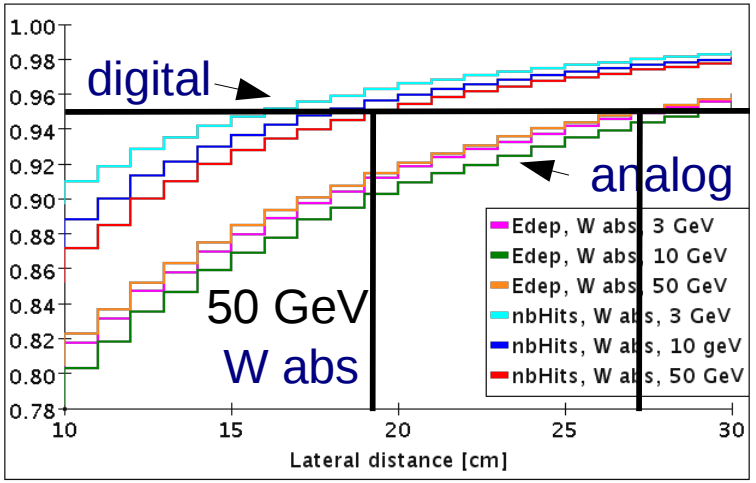


- For Fe absorber, 95 % energy is contained in 50 layers (~5.6 λ) for 50 GeV pions
- In case of W absorber, 95 % energy is contained in 45 layers (~5 λ) for 50 GeV pions
- As a consequence, the W absorber needs less λs for the same containment

Lateral containment







- Large difference in containment is seen between analog and digital readout
- For analog readout, 95 % is contained in a radius 23 (27) cm for Fe (W) absorber for 50 GeV pions
- In case of digital readout, 95 % is contained in a radius of ~21 (19) cm for Fe (W) absorber for 50 GeV pions

Summary and conclusions

Linearity has been found similar for all three absorbers and is within 1 % for analog and 5 % for digital readout.

The best energy resolution, over whole energy range, has been found for Fe absorber. The degradation of the resolution up to 1.0 MIP MPV for both readouts

The difference in longitudinal and lateral shower profiles has been found between analog and digital readout. The difference can lead to incorrect estimation of the calorimeter dimension if only digital information is considered

A difference in performance between analog and digital approaches has been identified and will be a subject of further investigation.

The study will be also extended from digital (1 bit) to semi-digital (2 bit) readout.

Spare slides

Properties of absorbers

absorber	Z	ρ [g.cm^{-3}]	X_0 [cm]	λ [cm]	R_M [cm]	1 abs. [cm]	80 planes [cm]
Fe	26	7.87	1.76	16.78	1.77	1.9	200
W	74	19.30	0.35	9.97	0.92	1.127	170.16
Pb	82	11.35	0.56	17.6	1.60	1.993	239.44