Simulation of the HERMES Lead Glass Calorimeter using a LUT

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On behalf of the HERMES Collaboration

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Outline

1. Introduction
   - The HERMES Experiment
   - Design of the HERMES Lead-Glass Calorimeter
2. Simulation of the Lead Glass Calorimeter
   - Description of the Simulation
   - Implementation of the Algorithm
3. Results of the Simulation
   - Different particles and observables

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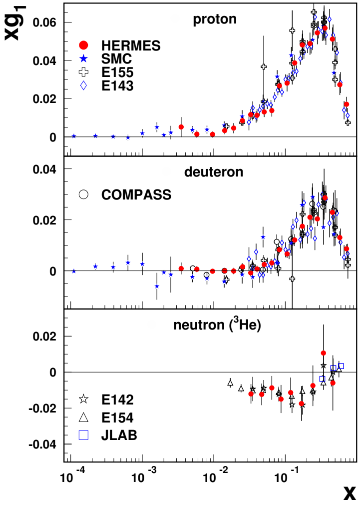
The HERMES Experiment

⇒ **HER**A **ME**asurement of **S**pin

- Spin like Charge fundamental property
- Experiment at DESY Hamburg
- 27,5 GeV longitudinally polarised $e^{\pm}$ from HERA accelerator
- Running since 1995

1. Inclusive Physics:
   $e + p \rightarrow e + X$
   $\Rightarrow x \cdot g_1(Q^2, x)$
2. Semi-Inclusive Physics:
   $e + p \rightarrow e + \pi^{\pm}/K^{\pm} + X$
   $\Rightarrow x \cdot \Delta q(Q^2, x)$
3. Exclusive Physics:
   $e + p \rightarrow e + \gamma + p$
   $\Rightarrow J^q(x, Q^2)$



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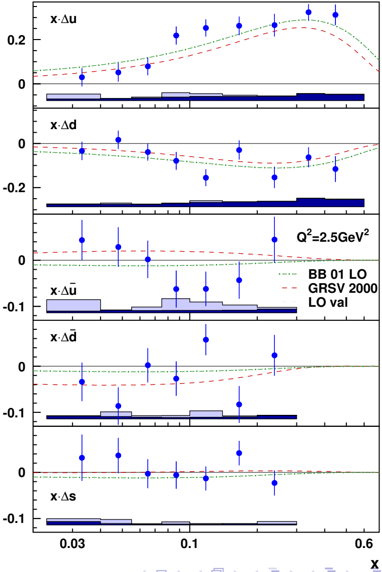

HERMES Physics
A Very Short Overview

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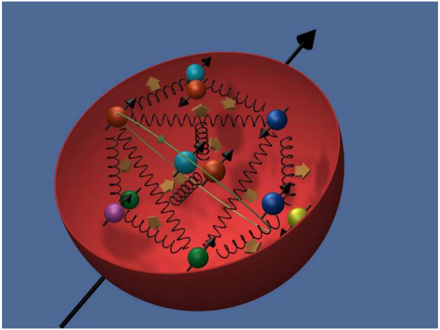
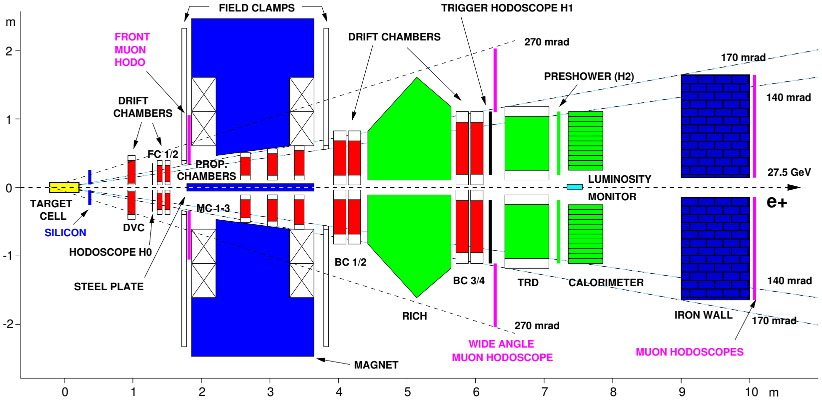


$$\frac{1}{2} = \Delta\Sigma + L_q + J_g$$

The HERMES Spectrometer



- Internal Polarized Gas Target
- Magnet Momentum measurement
- Tracking Chambers $\Delta P/P \sim 2\%$

- Lepton/Hadron Separation with $\epsilon > 99\%$
- RICH to separate pion,kaon,proton
- Calorimeter

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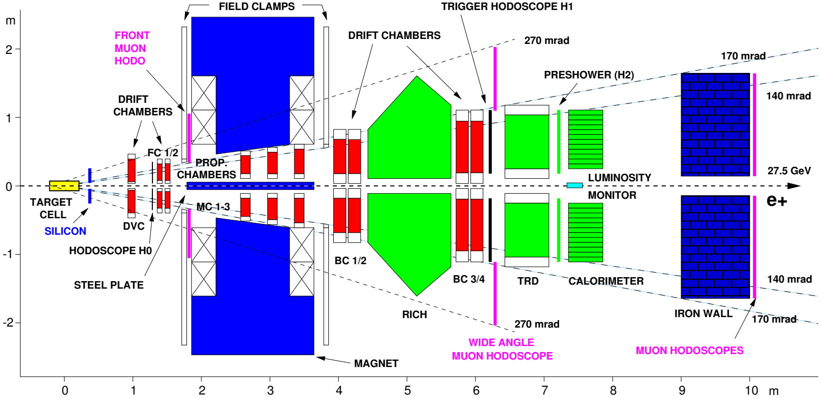

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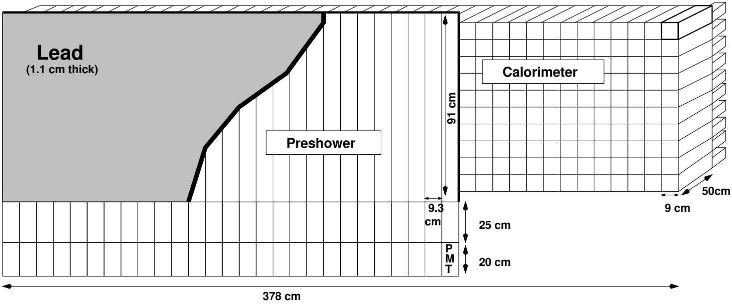
Preshower - Calorimeter combination



- Serves as a first level trigger
- Electron/Hadron Separation (preshower removes π background)
- Identify π^0 through its decay in $2\gamma's$
- Give a coarse position estimation

Design of the HERMES EM Calorimeter

- Calorimeter was build by LNF,NIKHEF, and YPI.
- Build out of $2 \times 42 \times 10$ Lead Glass F101 blocks (Rad. Hard)
- Block Surface of 9×9 cm ($>$ 90% of lateral shower profile)
- Block Length of 50 centimeter ($\sim 18\times$ Radiation length)

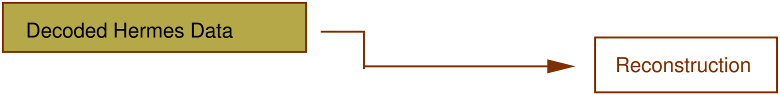
Chemical Composition F101	weight %
PB_3O_4	51.23
SiO_2	41.53
K_2O	7.0
Ce	0.2

Radiation Length	2.78 cm
Critical Energy	17.97 MeV
Refraction index	1.65
Molière Radius	3.28 cm

Outline

Calorimeter in the HERMES Monte Carlo

- New physics requires a better simulation



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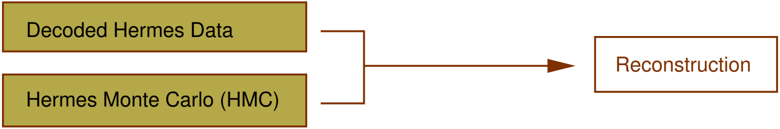

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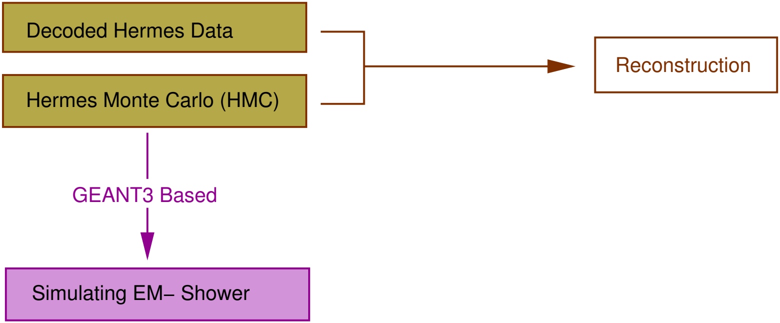

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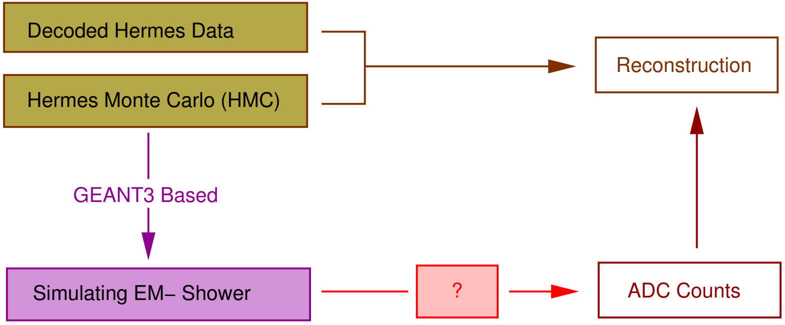

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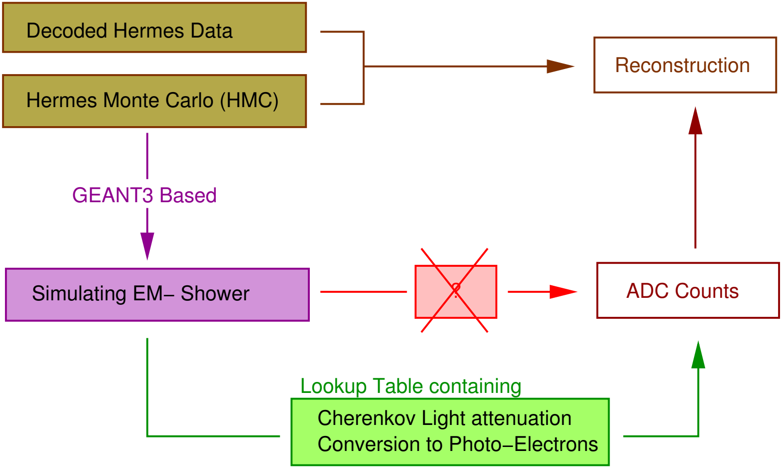
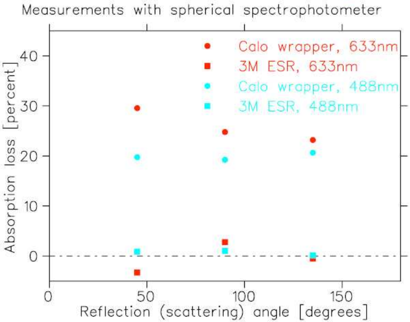


Effects to the Cherenkov Light

From Cherenkov Light To Photo-Electron

- Reflectivity of the foils
- Transparancy of the Lead Glass
- Reflection at all surfaces (including glue)
- Quantum Efficiency PMT

Measurements at U. Hamburg



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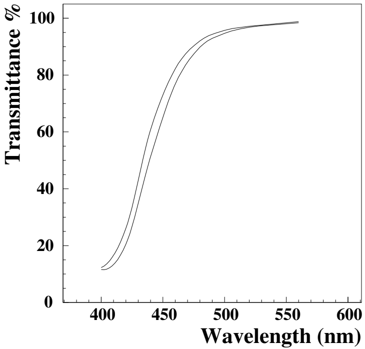

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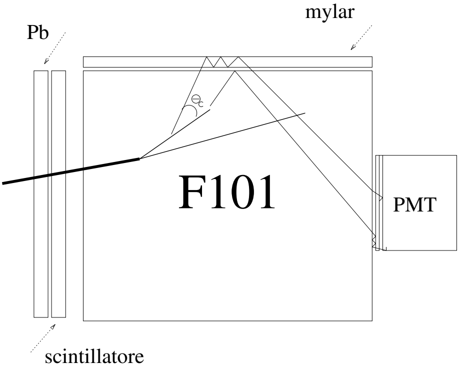

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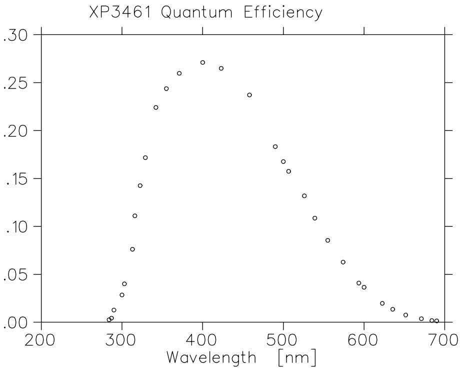

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$\Rightarrow$

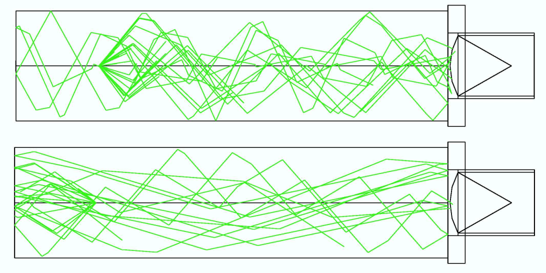
Stand Alone (G4 Based) Monte Carlo

$\Downarrow$

Lookup Table

Determining the LUT dimensionality

- Cherenkov angle $\cos(\theta_c) = \frac{1}{\beta \cdot n}$ is velocity dependent
- Cherenkov radiation forward **and** backward
- Amount of Reflections dependent on the (x, y) position



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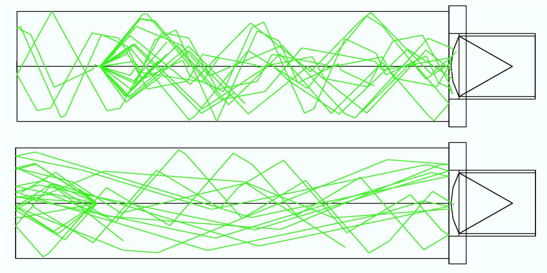
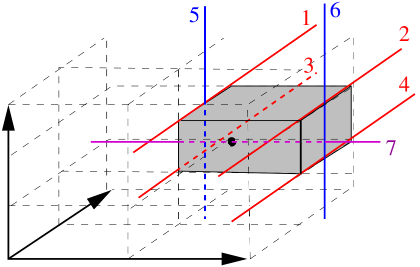


$\Rightarrow$ 6 DIMENSIONAL LUT CONTAINING $PE(x, y, z, p_\theta, p_\phi, \beta)$

Outline

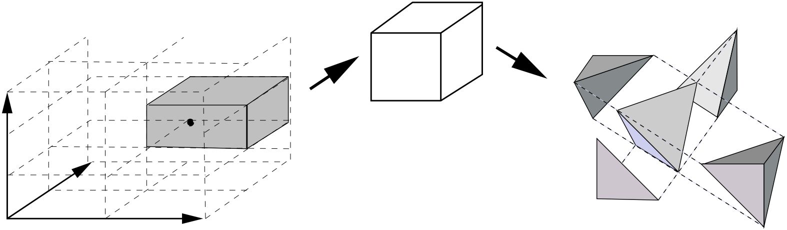
Interpolating the Table

- Having a $10 \times 10 \times 16 \times 40 \times 10 \times 16$ grid, we want the right number of PE (per mm e^- track length) for any $(x_1 \cdots x_6) \in$ the grid
- The most simple case is to extend a linear algorithm to 6 dimensions, yielding $2^6 - 1$ interpolations.



- The CERNLIB FINT algorithm based on linear interpolation has been extended to 6 dimensions.

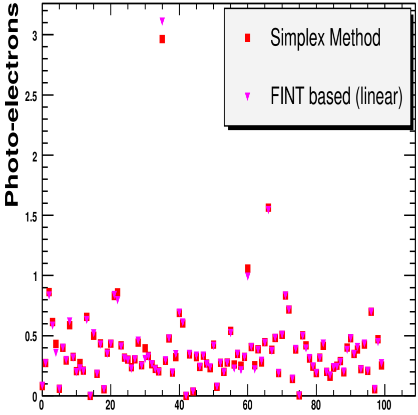
- Another method is the simplex method. Supposedly the fastest method possible[1].
- A hypercube around the point x_i is normalized to the $n-$dimensional unit cube
- The unit cube then can be further divided into simplexes. An $n-$simplex is a $n-$dimensional analogue of a triangle, eg a tetrahedron.



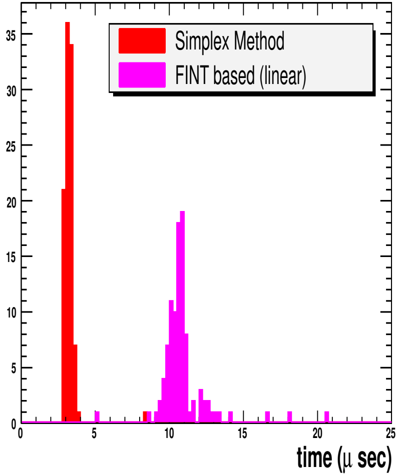
- Problem reduced to find the right simplex and $n+1$ function evaluations.

Interpolation Comparison
FINT-SIMP

Interpolated value from 100 random vectors



Time Poli on a 1 GHz P3



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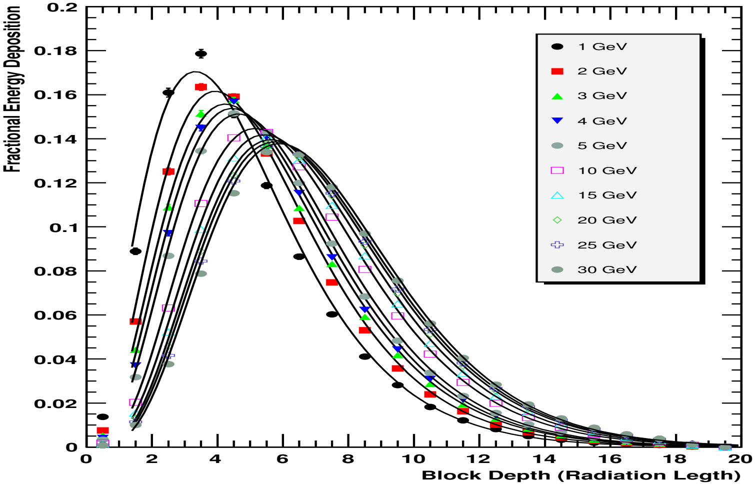
Electron initiated showers in the Calorimeter only

– Longitudinal Energy Deposition for perpendicular incidence –



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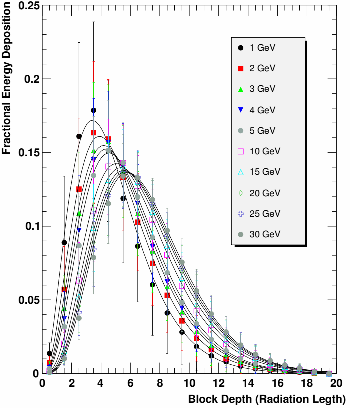
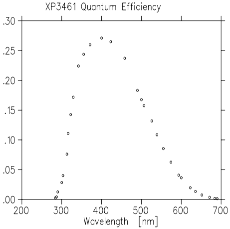
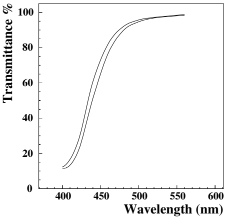


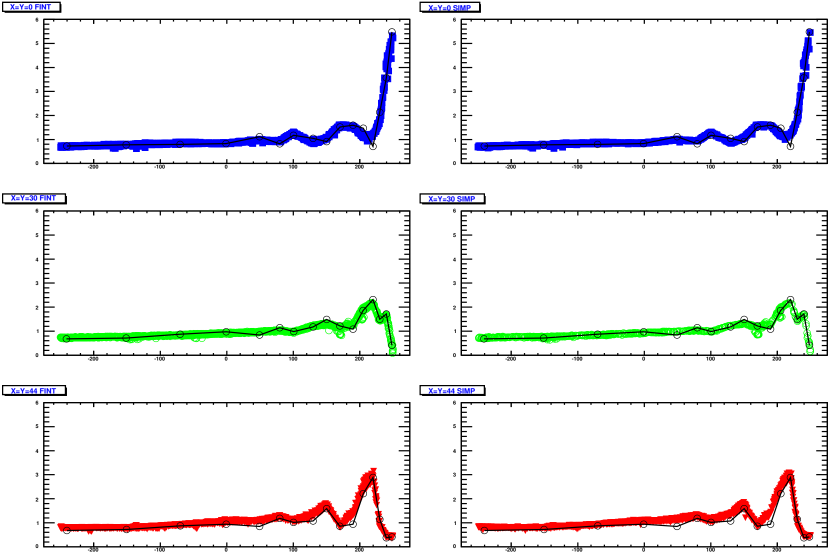
- Error bars = RMS of distribuition
- Resolution limited by shower fluctuations !
- NIM157 (1978) 455-460 reports an improved resolution when using a blue filter !





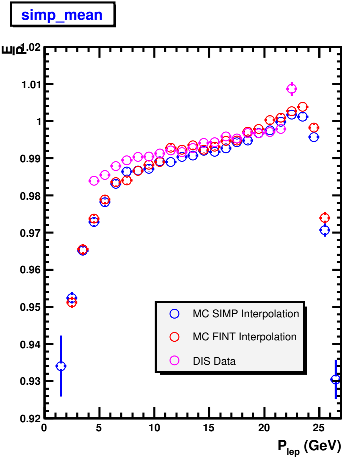
Checking the interpolation

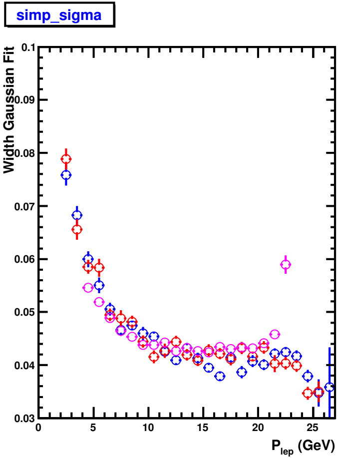
– Generating 100 GeV muons at different (x, y) positions $\perp$ incidence –



Comparing to data: E/P leptons

– Generating e^- from the vertex –

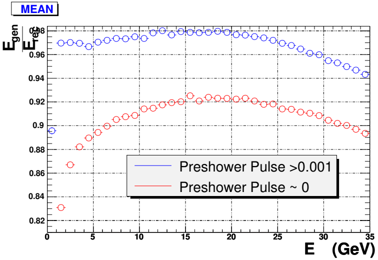




- a ~ 5% difference at 5 GeV
- Tracking in MC not perfect !

Comparing to data: Photons

– Generating γ from the vertex –



- No data to compare with !
- Falloff due to cubic correction for the preshower !

Comparing to data: Photons

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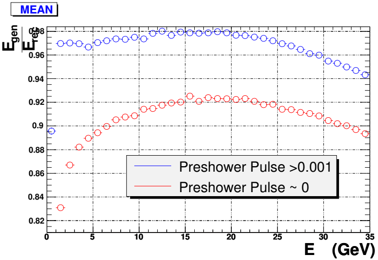

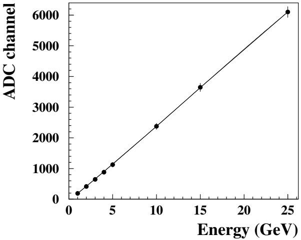

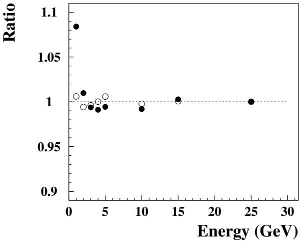

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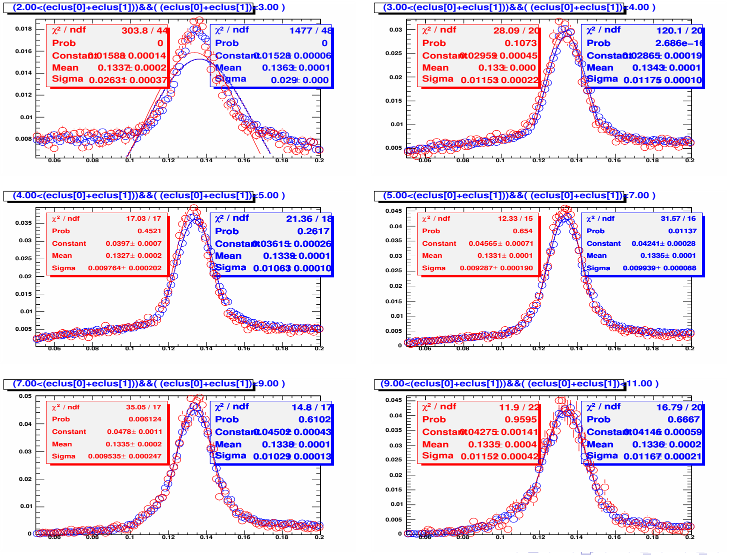
Comparing to data: π^0

– Blue: data, Red: MC –



Comparison HMC/G3 - Standalone G4

Not everything perfect !

- G4 and HMC/G3 simulation give a good overall agreement for muons
- For electrons HMC/G3 gets about 13% more photo-electrons than G4, while getting about 6% more Cherenkov Photons
- A difference in escaping energy between G4 and HMC/G3 has been observed
- Total shower track length is different as well

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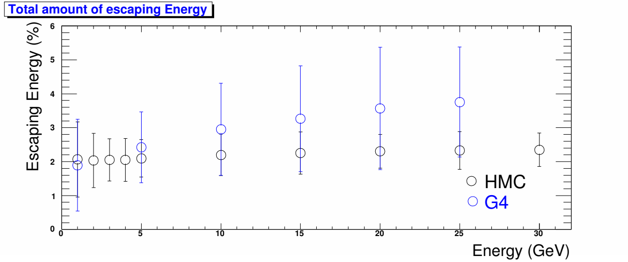

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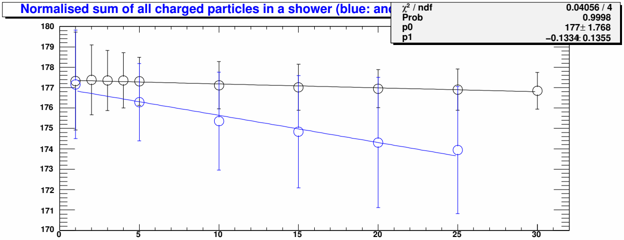

Summary

- The HERMES electromagnetic calorimeter has been simulated using a 6 dimensional LUT generated by a standalone G4 MC
- Comparison with data shows a good agreement for E/P electrons and π^0 invariant mass spectrum
- Differences between G4 and HMC/G3 observed

For Further Reading I

R. Ravotti et al.
'A Geometric Apporach to Maximum-Speed n-Dimensional Continuous Linear Interpolation in Rectangular Grids'
IEEE Trans. on Comp. Vol 47 (1998), 894-899

H. Avakian et al.
'Performance of the electromagnetic calorimeter of the HERMES *experiment'*
NIM A417 (1998), 69-78