Electromagnetic Calorimeter optimization through G4MICE simulation

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(special thanks to V.Grichine)

Spaghetti calorimeter

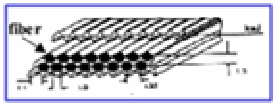
A reminder of the calorimeter design:
from L.T.'s presentation at CERN on 29/03/03

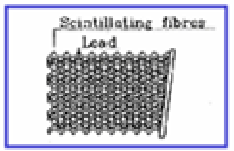
Fine Grained Calorimeter Option for Electron Identifier

The construction technique consists in embedding 1 mm diameter polystyrene based blue scintillating fibers between thin grooved lead plates, obtained by plastic deformation of 0.5 mm thick lead foil.

Fibers are glued to the lead plates and run parallel to each other with a pitch of 1.35 mm and are mostly orthogonal to the entering particles.

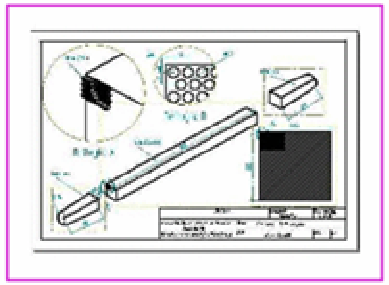
The Construction Technique of KLOE EmCal

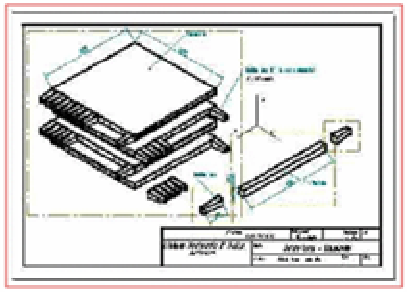


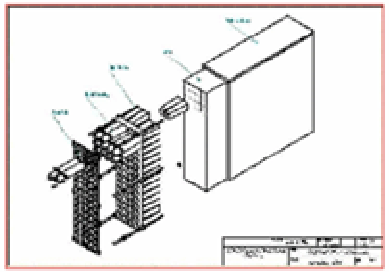


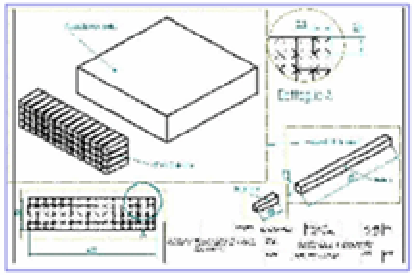
Density ≈ 5 g/cm³
Sampling fraction for mip ≈ 15%
Radiation length ≈ 1.5 cm

NIM A 482 (2002) 363-385









Readout: square (or rectangular) cells connected to PMT photocatode by light guides shaped as Winston cones

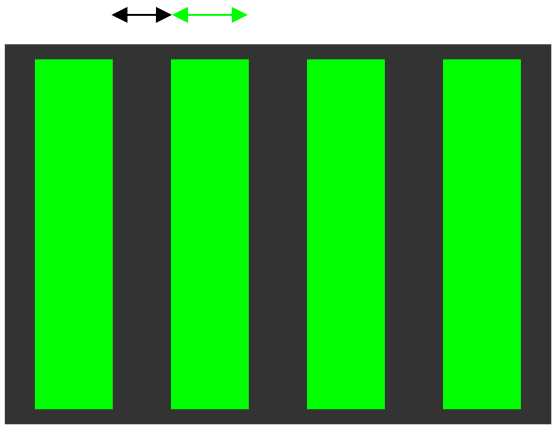
EMCAL in G4MICE

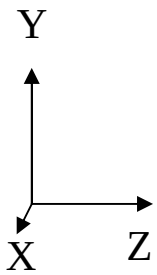
Geometry:

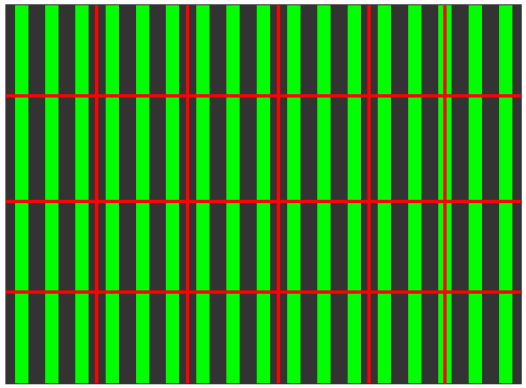
- Choice between “Lasagna” and “Spaghetti” geometry
  - “spaghetti” is actually simplified: thin layers of lead and scintillator
- Variable thickness of lead and scintillator (=fiber) layers

Digitization:

- Definition of readout cells and of other parameters







G4MICE: EMCAL Geometry DataCards

- **`EMCalUseSpaghetti`** =1 for “Spaghetti” (default)
  =0 for “Lasagna”

for “Lasagna”:

- **`EMCalNumberOfSlices`** number of scint. layers (4)
- **`EMCalFiberLeadRatio`** ratio of scintillator/fiber thickness (2)

for “Spaghetti”

- **`EMCalFiberDiameter`** fiber diameter (1.0 mm)
- **`EMCalLeadThickness`** lead layer thickness (0.5 mm)

G4MICE: EMCAL Digitization

- Propagate the energy deposited by each hit to the end of the calorimeter, with exponential attenuation (along X)
- Assign ach hit to one readout cell

  `EmCalDigits::Process`
- Add up the energies of all the hits in the same cell
- Create one digit for each cell with signal

  `EmCalEvent::Process`
- Multiply energy by Winston cone efficiency light collection
- Compute expected number of photoelectrons
- Fluctuate according to Poisson distribution around expectation
- Multily by PMT gain => PMT signal (in a.u.)

  `EmCalFinalDigits constructor`
- Output to Digits.out : Zcell, Ycell, Amplitude

  `EmCalEvent::Print`

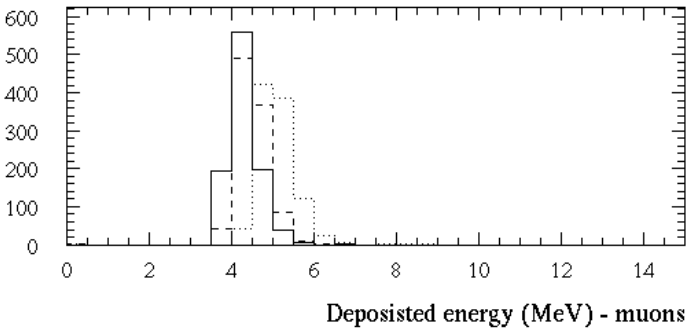
G4MICE: EMCAL Digitization DataCards

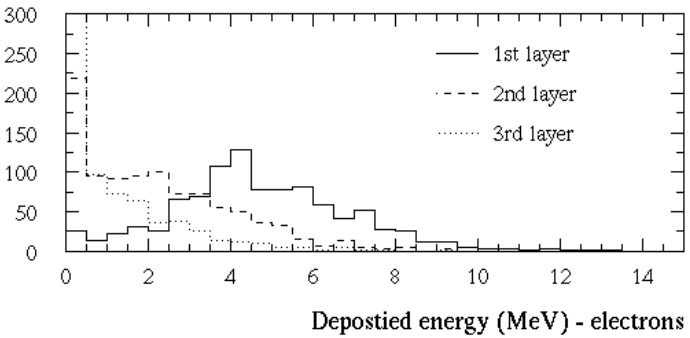
- ► **`EMCalAttLength`** attenuation length for light propagation in fibers (3500 m)
- ► **`EMCalLightCollectionEff`** efficiency for light collection in Winston cone (0.8)
- • **`EMCalEnergyPerPhotoElectron`** energy giving 1 p.e. at the PMT (0.5 MeV)
- • **`EMCalAmplificationCof`** gain factor ($5x10^5$)
- • **`EMCalAmplificationFluct`** gain fluctuation (10^3)
- ► **`EMCalCellDepth`** size of readout cells in Z (32.5 mm)
- ► **`EMCalCellWidth`** size of readout cells in Y (32.5 mm)

(►= NEW)

Calorimeter signal, efficiency definition

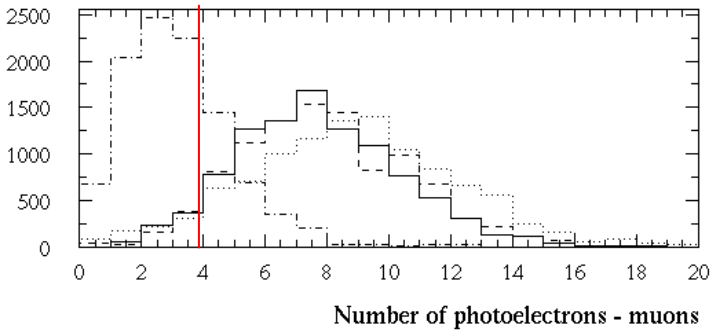
Energy deposit

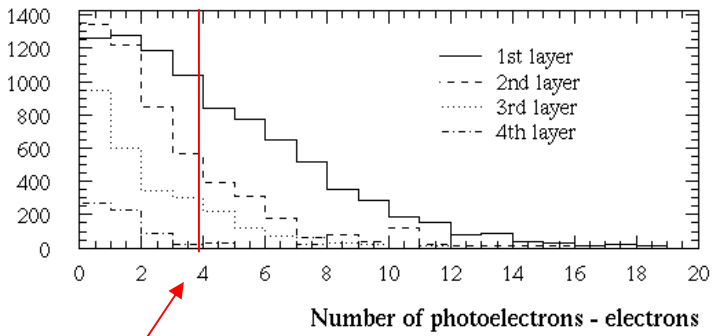




"digitization":
- Light attenuation along fibers
- Winston cone collection efficiency
- Photocatode quantum efficiency

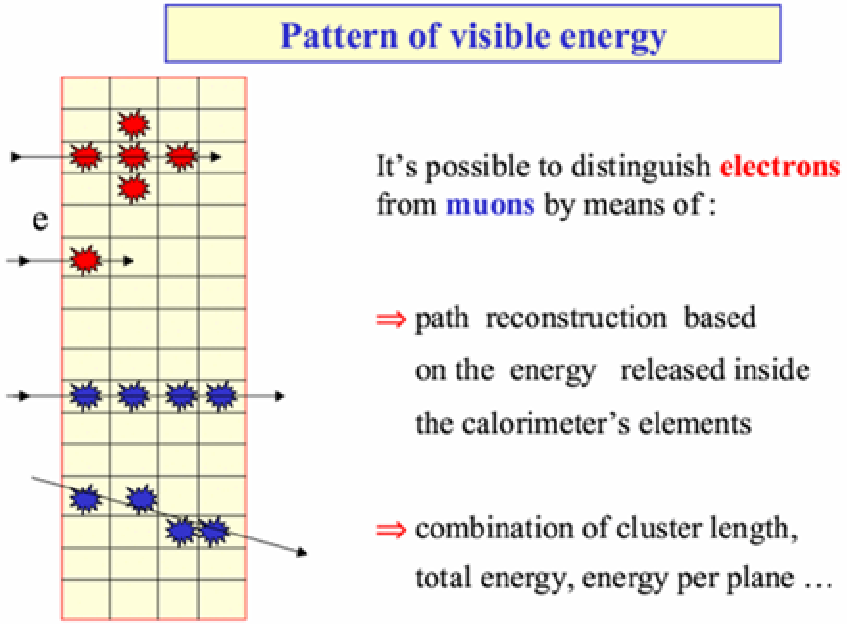
PMT signal





Detection efficiency is defined by a cut on signal above noise threshold: 3-4 p.e.

Muon vs electron identification



We only consider a "pattern-based" identification algorithm, i.e. detection efficiency in layers >1

We have carried out simulation studies in G4MICE to optimize the muon/electron separation capabilities by varying:

- sampling fraction, i.e. **lead layer thickness**: 0.5-0.2 mm
- readout segmentation, i.e. **cell size**:
  3.75x3.75 cm^2, 3.25x3.25 cm^2, 2.5x2.5 cm^2, 2.5x4.0 cm^2

One caveat

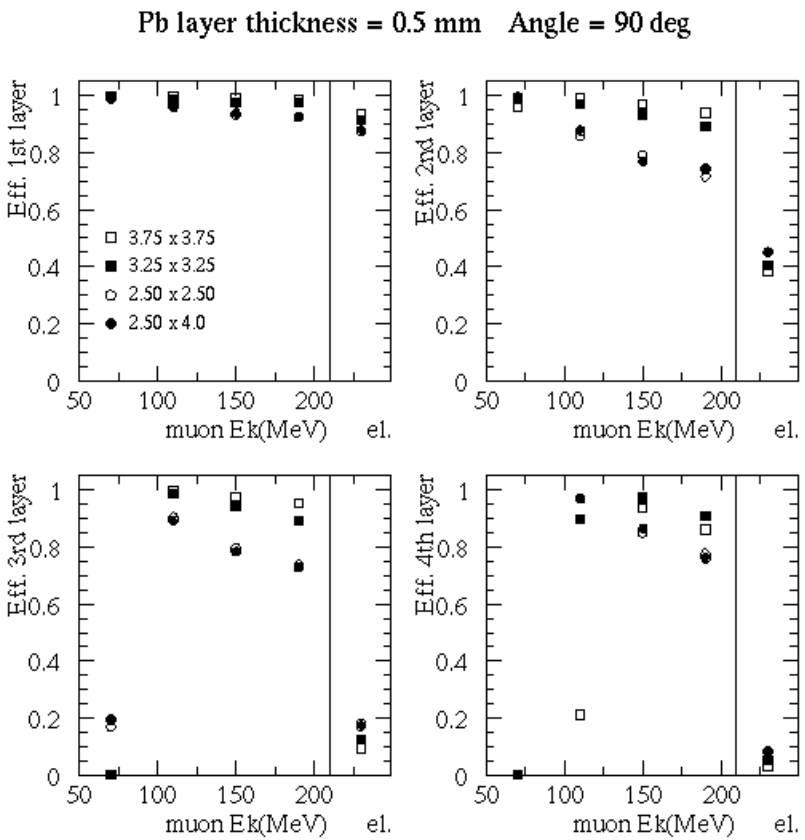
We don't know the "final" beam profile at calorimeter entrance yet

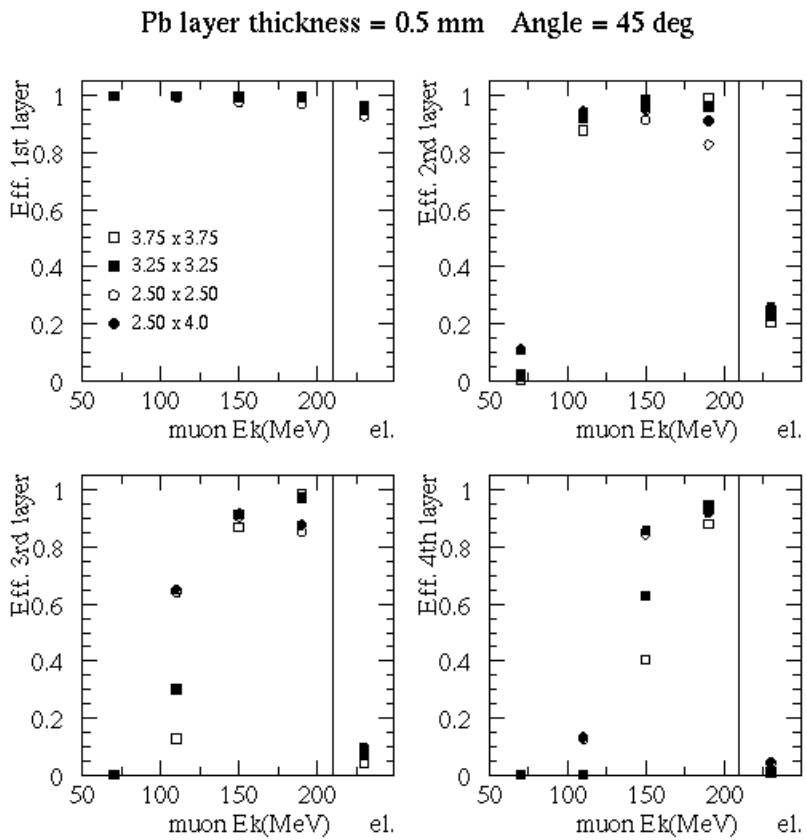
➔ We cannot define the detector transverse size. Maximum possible height is about 60 cm.

➔ The optimization cannot be concluded: we will show the results as a function of muon energy and angle, which will have to be convoluted with the actual beam shape

Simulated samples of 1000 particles just in front of the detector, with fixed energy (muons Ek=70,110,150,190 MeV, electrons Ek=190MeV) and angle (90°,45°)

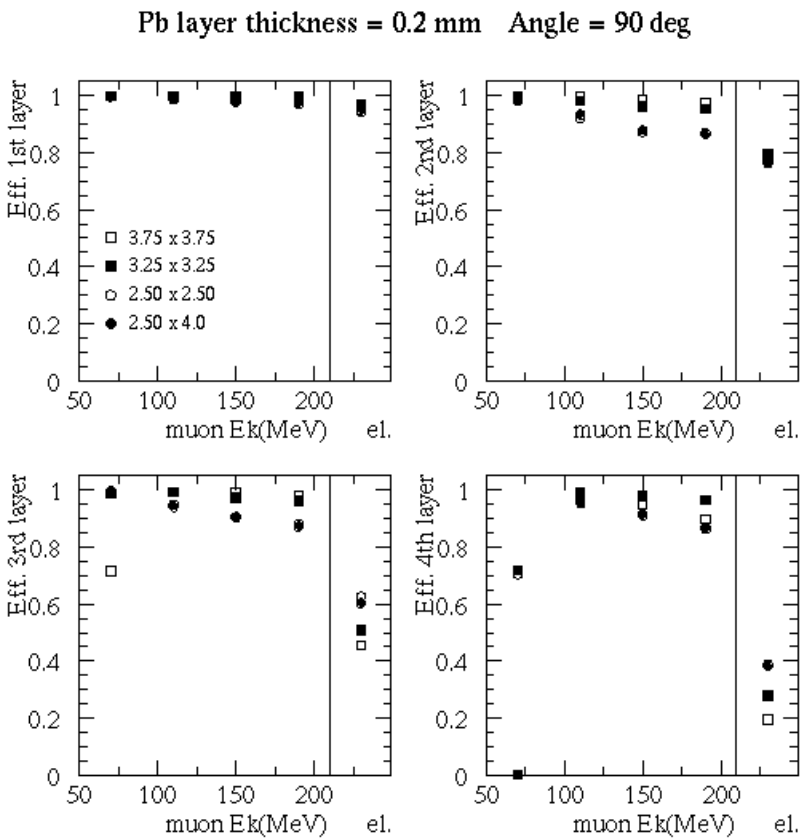
Lead layer thickness = 0.5 mm

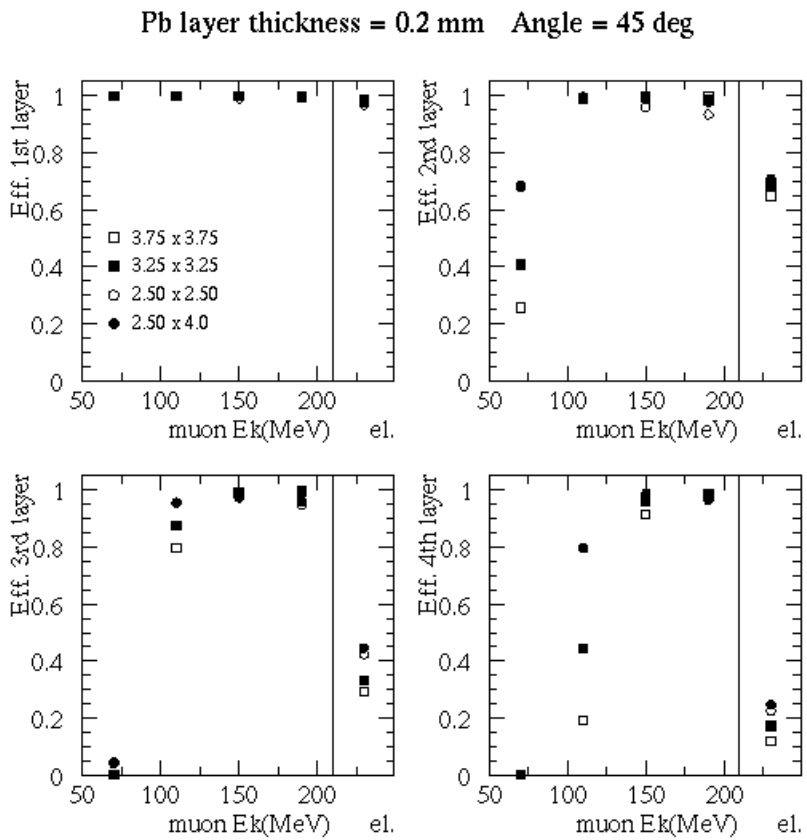




- Small cells give too small collected light (essential for timing information!)
- Efficiency for detecting low energy muons in layers >2 is low
- Rectangular cells increase efficiency for particles impinging at an angle

Lead layer thickness = 0.2 mm





- Efficiency for detecting low energy muons in layers >2 increases reducing lead thickness, but so does efficiency for electrons

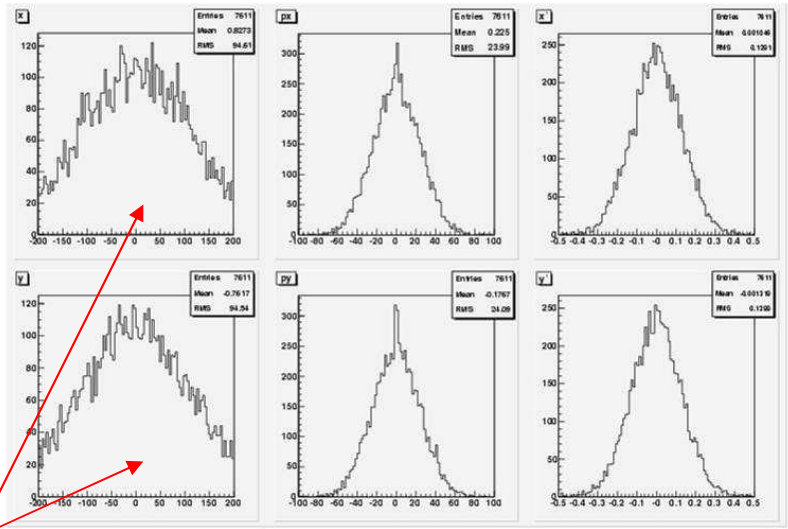
Beam as in H.Wilson's report on 30/07/03

Preliminary!

Beam upstream of calorimeter (H.W.)

Iron shield in front of Cherenkov

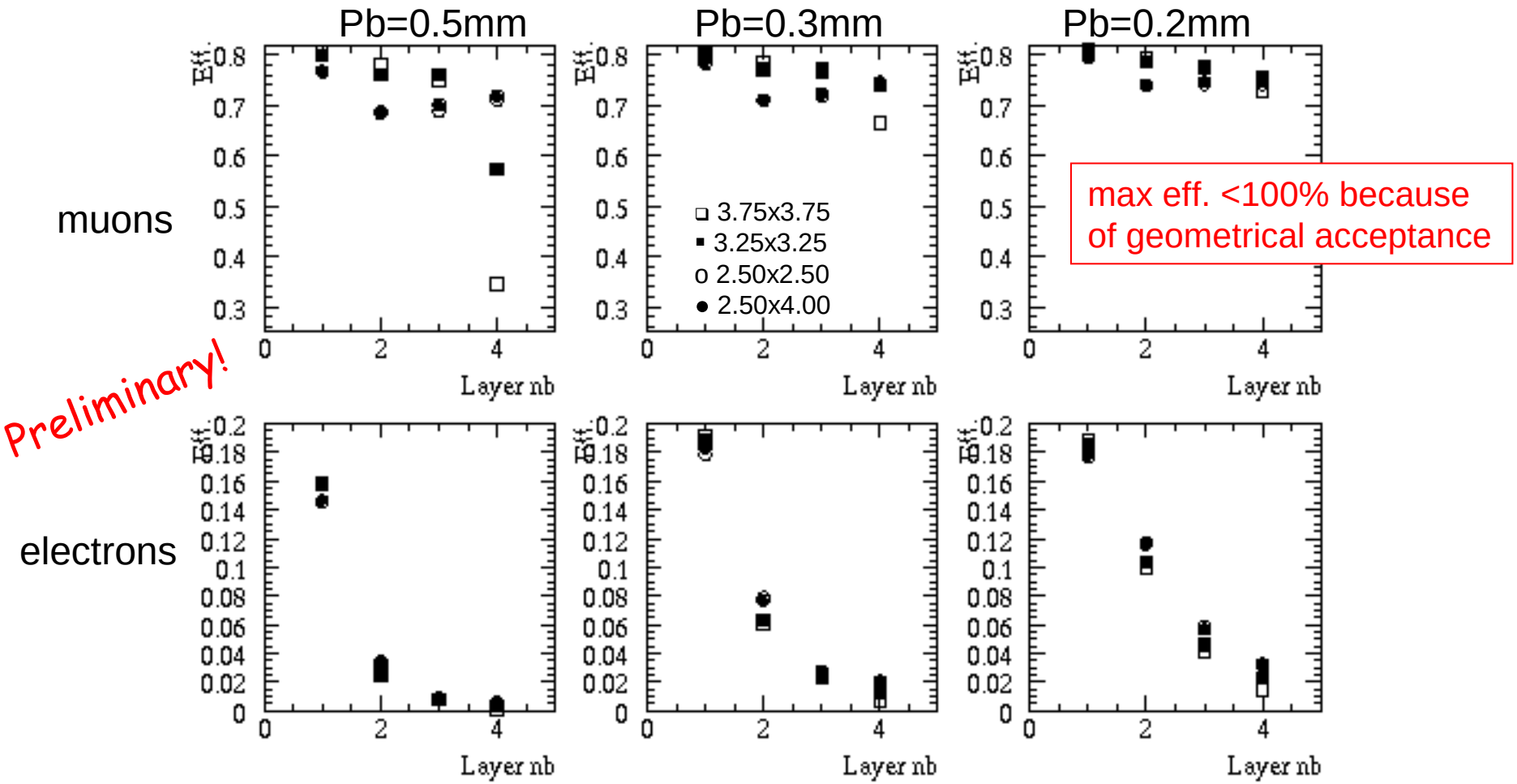
is not included in the simulation



X and Y distributions: RMS=9.5cm, axis range +/- 20cm => issue of EMCal transverse size !

```
numEvts       5000
RunMode       Normal
#SolDataFiles useFiles
rfCellType    none
AbsorberType  none
ZOffsetStart  -5400
SigmaX         50.
SigmaXPrime    0.15
BunchLength    30.
DeltaEoverE    0.1
AverageKineticEnergy 120.5
NominalKineticEnergy 120.5
TrackerOffsetZ 0.
#muDoDecay      1
BeamProtonFraction 0.
BeamPionFraction   0.
BeamElectronFraction   0.  (or 1.)
SciFiMode Off
TPGMode On
TOF1Mode Off
TOF2Mode Off
TOF3Mode On
Ckov1Mode Off
Ckov2Mode On
EMCalMode On
VirtualMode On
EMCalUseSpaghetti 1
EMCalFiberDiameter 1.0
EMCalLeadThickness 0.5    (0.3, 0.2)
EMCalMotherLength 150
EMCalMotherRadius 300
EMCalSliceRadius 300
```

Beam as in H.Wilson's report on 30/07/03



Summary and outlook

- We have carried out a simulation of the EMCAL in G4MICE to study the optimization of the design for best muon/electron separation:
  - Sampling fraction (lead layer thickness)
  - Readout segmentation (cell size)
- Only pattern has been considered: better identification algorithm should be studied (baricenter depth, etc.)
- Conclusions can be drawn when the beam description is available
- Detector transverse size is also a critical issue