Crylin

CRYstal calorimeter with Longitudinal INformation

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Calorimeter and jet reconstruction @ Muon Collider

Muon Collider: Ecal

- The present Ecal in the simulation framework is based on 1.9 mm W + silicon pad layers:
  - 40 layers
  - 5x5 mm^2 cells
  - 22 $X_0 + 1\ \lambda_I$
  - barrel (with dimension 4 m x 3 m) + 2 endcap

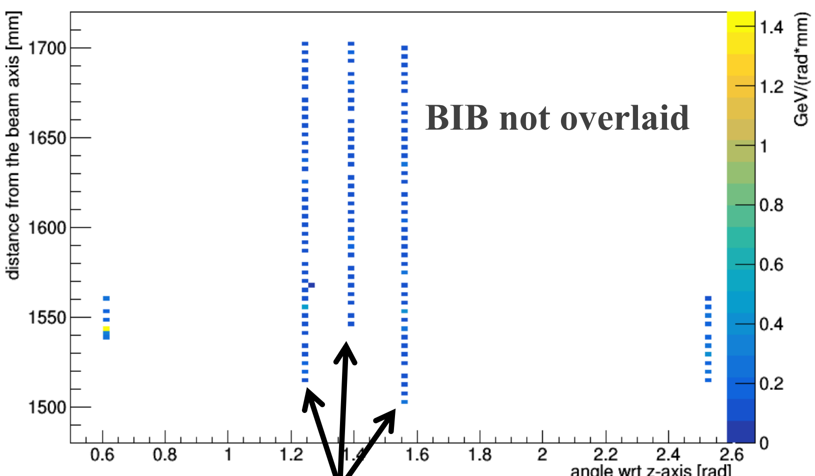
  - ➢ Very expensive, huge amount of channels
  - ➢ Low time resolution

- However, this high segmentation allows setting the requirement for the calorimeter

  → Lets see an example

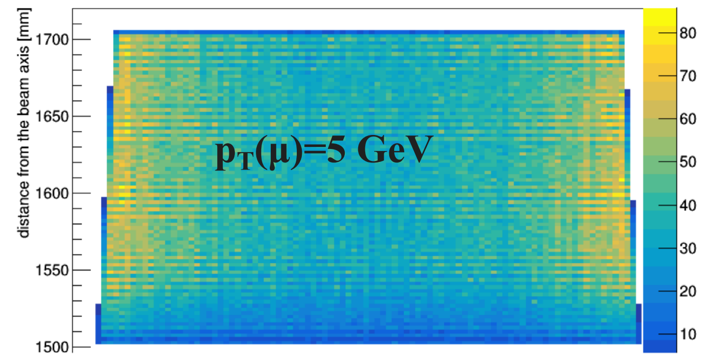
Muon ID with the calorimeter -1-

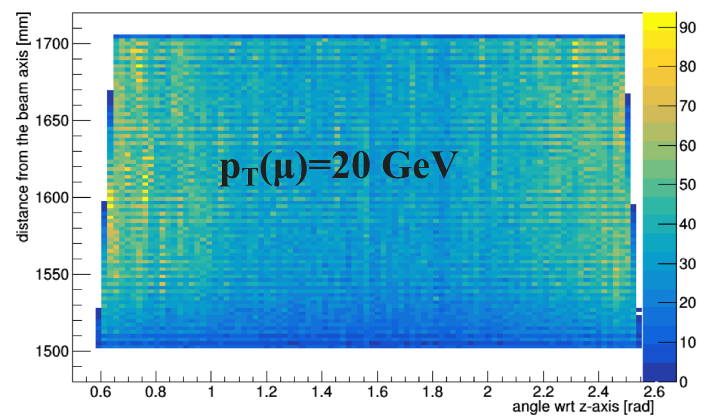
- The identification of high p_T muons could be difficult with just the Muon Detector → the calorimeter can be used to improve it.
- For such purpose, the longitudinal segmentation is important to reconstruct muon tracks in the calorimeter.



prompt muon tracks in ECAL barrel

Energy released in ECAL barrel by uniformly distributed prompt muons in the (θ,φ) space

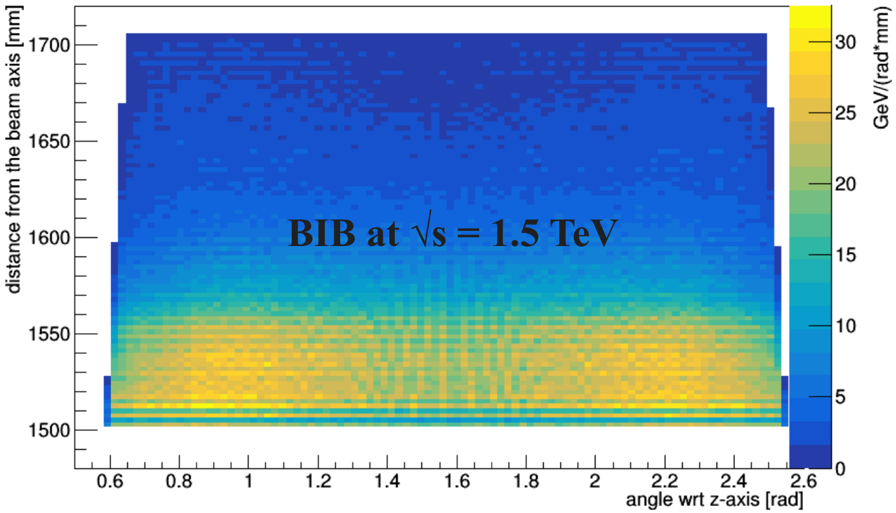




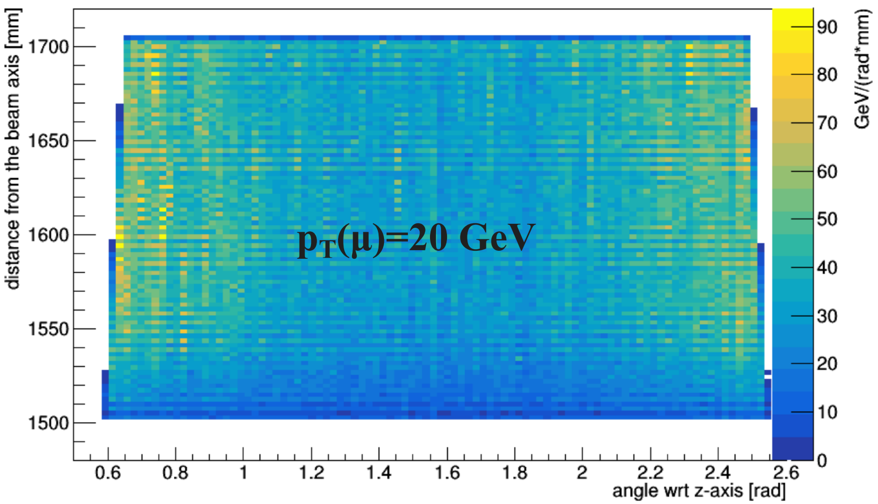
Muon ID with the calorimeter -2-

- The distributions of the energy released in ECAL by the beam-induced background (BIB) and prompt muons are different;
- The BIB must be subtracted in the proper way to reconstruct the muon tracks;
- In particular the energy released as a function of the longitudinal coordinate is very different btw BIB and muons, and the longitudinal measurement can be exploited to perform the subtraction.

Energy released in ECAL barrel by one BIB bunch crossing



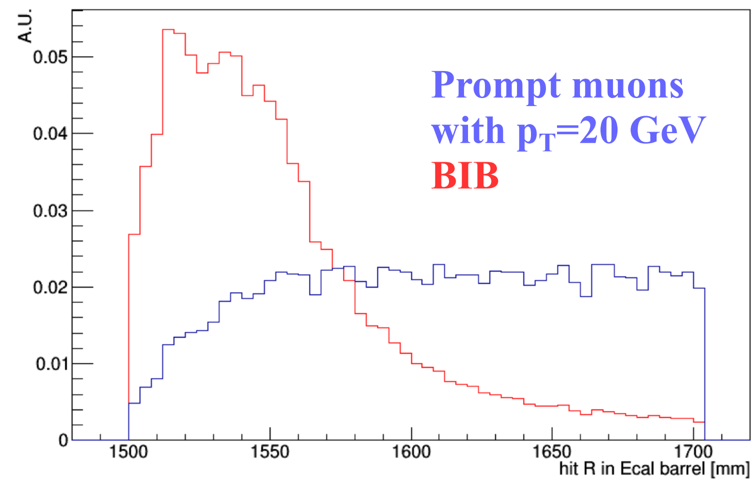
Energy released in ECAL barrel by uniformly distri buted prompt muons in the (θ,φ) space



Muon ID with the calorimeter -3-

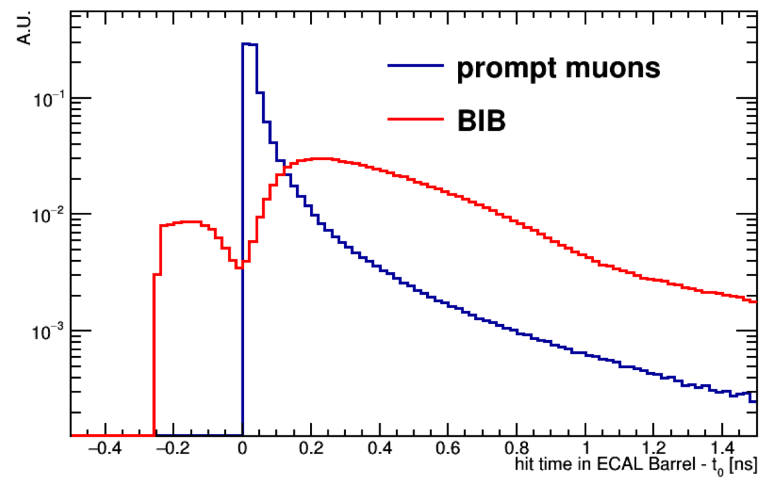
- The BIB produces most of the hits in the first layers of the calorimeter;
- The muons produce a constant density of hits after the first calorimeter layers.

hit longitudinal coordinate distribution



- The BIB hits in the calorimeter are out-of-time wrt the bunch crossing;
- **A measurement of the hit time performed cell-by-cell can be used to remove most of the BIB.**

hit time distribution (t0 is the time of arrival of prompt photons)



A Crystal Calorimeter with Longitudinal information

- The proposed R&D has the goal to build a crystals calorimeter, faster, cheaper, and with a granularity (both transversal that longitudinal) tuned on MC observations.
- Proposal: a Cherenkov, semi-homogeneous, calorimeter based on PbF_2 crystals and SiPM.

PbF_2 active medium

SiPM read out

Cell of 11x11x50 mm^3 (5.4 X0 – 0.5 M_R)

Cherenkov Light → to be fast

High density material, low X0 → easy integration in the experiment

Good light yield 9.3 MeV/cm → To be tested!

5-10 euro/cc per big quantities → relative cheap

Array of 9 SiPMs 3x3 mm^2

Pixel of 50 um → fast, high QE

Fast adder amplifier → signal width of ~10 ns (as done in g-2)

~ 3 p.e MeV → ~70% geom. coverage.+ Teflon wrapping

~ 200 euro per array → cheap

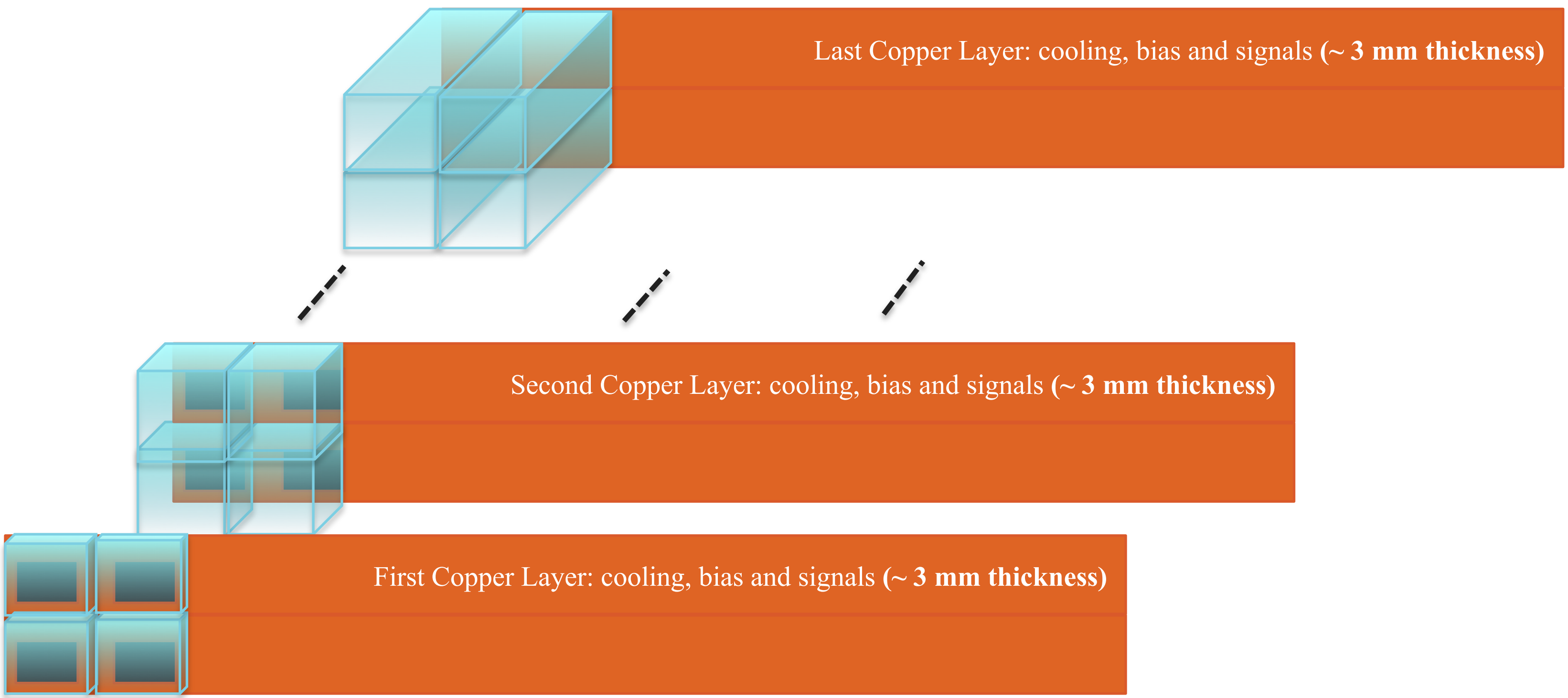
From Padme experience (SAC cal.)

N p.e. ~ 1.5 p.e./MeV with R13478UV PMT (40% coverage) and Tedlar wrapping

80 ps time resolution in an energy range of 100 - 450 MeV

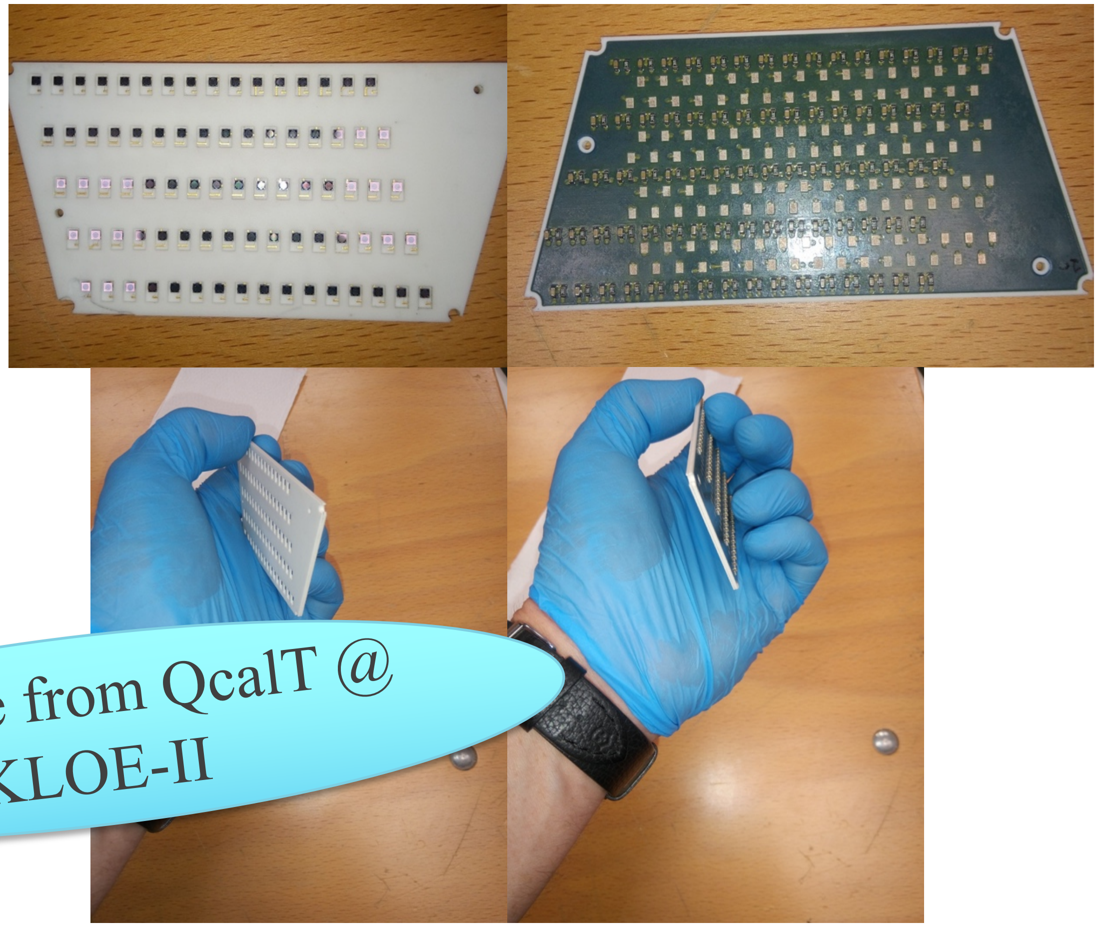
A quasi-homogeneous calorimeter

- Calorimeter Layout: **the calorimeter can be segmented longitudinally** as a function of the energy of the particles and the background level.



- A reduced first layer used as active pre-shower for timing → PbF2 or LYSO (5÷10 mm).

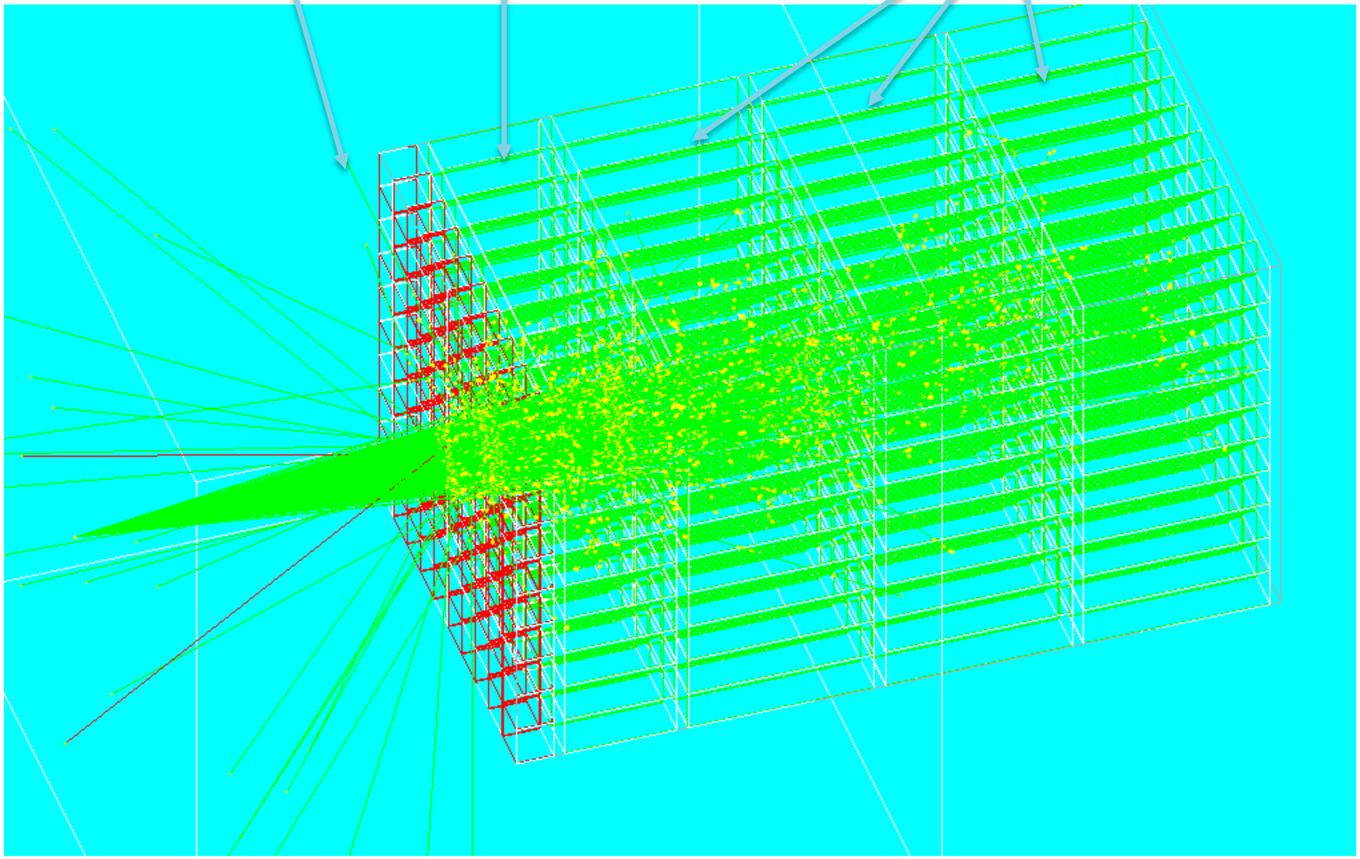
Starting from the experience with QcalT calo: Alumina holder with cooling and first bias-FEE of the SiPMs



Example from QcalT @ KLOE-II

Geant4 simulations -1-

- A first look at a possible configuration:
  1 cm of LYSO (for timing) + 3 cm of PbF2 (to stop the BIB) + **3**x 5 cm of PbF2 + **5**x3 mm copper bias layers



Geant4 simulations -1-

- A first look at the response:
  BIB parametrized as 1.7 MeV photons – 300 particles/cm^2 per event
  1 π^0 with p = 30 GeV per event
  1 μ^- with p = 30 GeV per event

- Consideration: 1 cm of LYSO almost useless → negligible deposit for the π^0
- 3 cm of PbF2 not enough to shield the BIB
- 5 cm length is too much for the energy deposited by the π^0 in the cell. Problem of linearity..

→ THE CALO has been redesigned

New Design

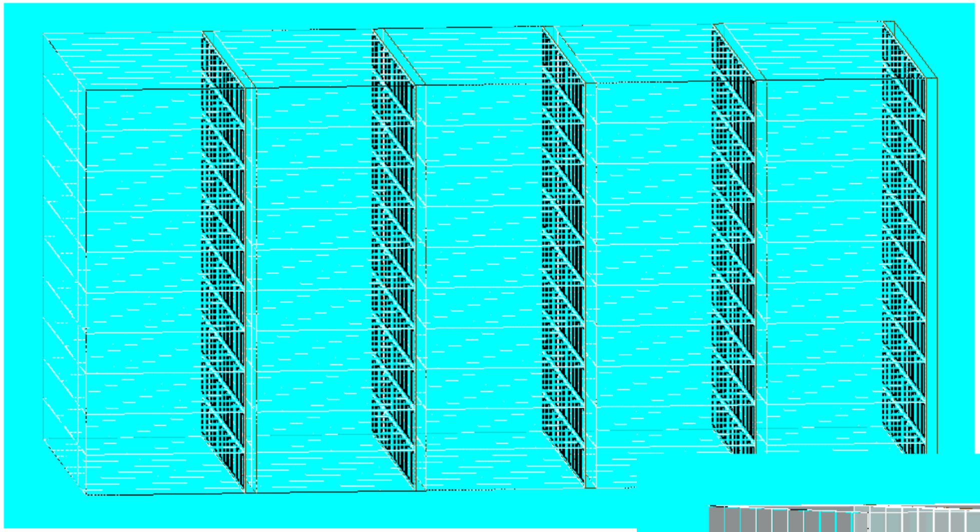
- Hamamatsu can provide SiPM for PET of 4x4 mm^2, in a way to have:
  - good quantum efficiency for Cherenkov thanks to the silicon resin (of topic: I would like try to open next year a "Gruppo5 sigla" to improve the PDE of SiPMs at the level of 60-80%, for Cherenkov light detection)
  - bonding in a middle hole to maximize the active area without TSV technology. Cheapest technology developed for Positron Emission Tomography.

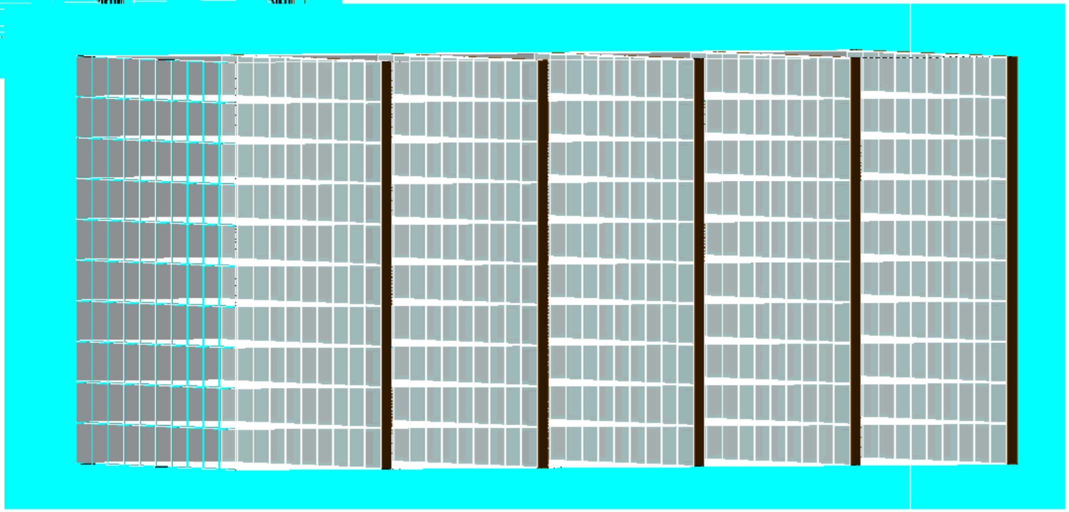
- PbF2 crystals with dimension 1x1x4 cm^3

- readout with a matrix (2x2) of 4 SiPMs per crystal → coverage of 64% of the area

Geant4 simulations -2-

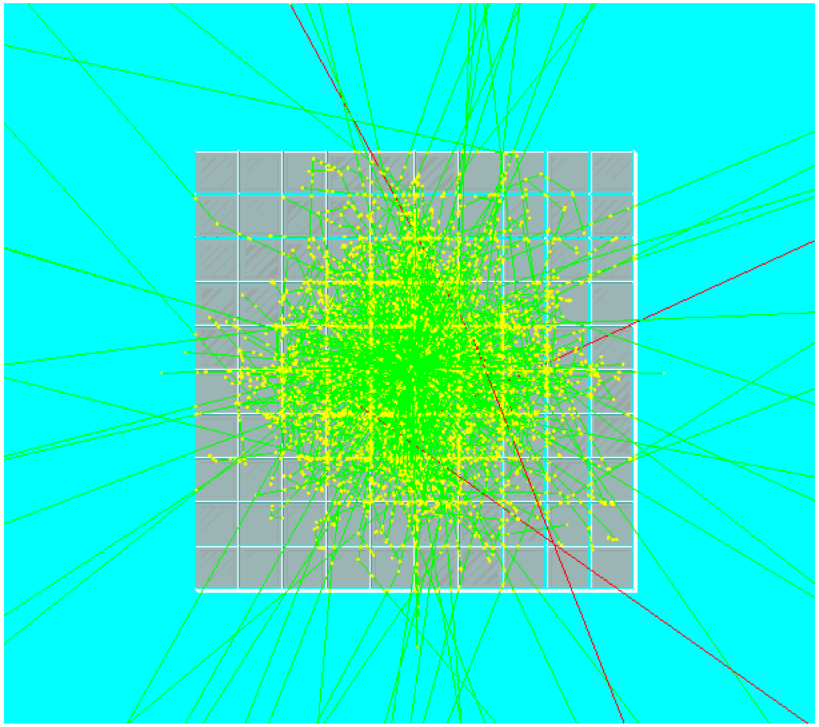
- A second look at a possible configuration:
  5x 4 cm of PbF2

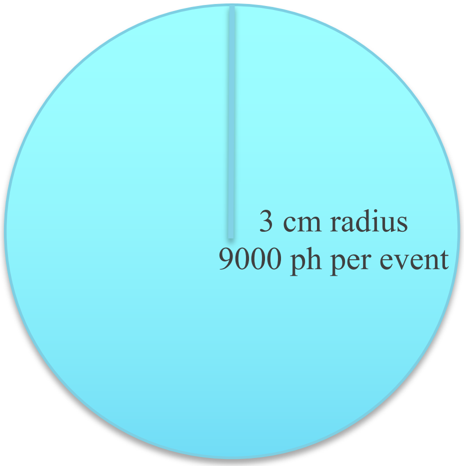




Geant4 simulations -2-

- A second look at the response:
  BIB parametrized as 1.7 MeV photons – 300 particles/cm^2 per event

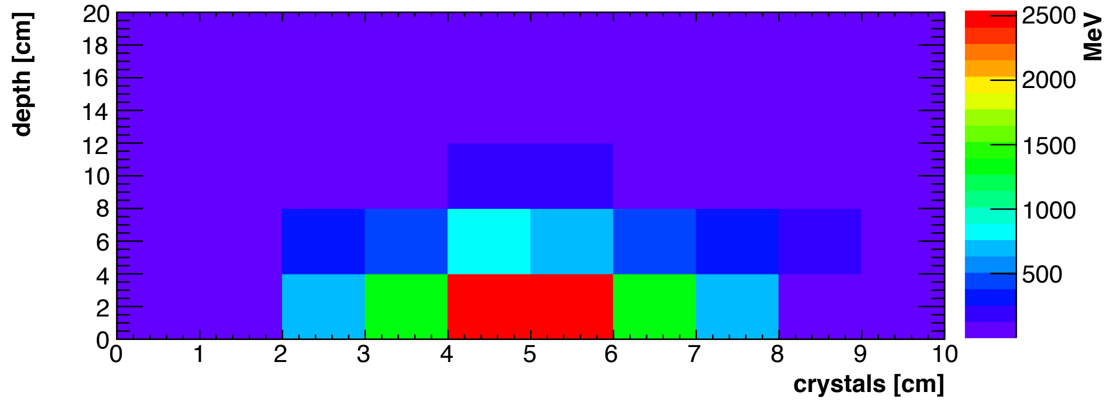




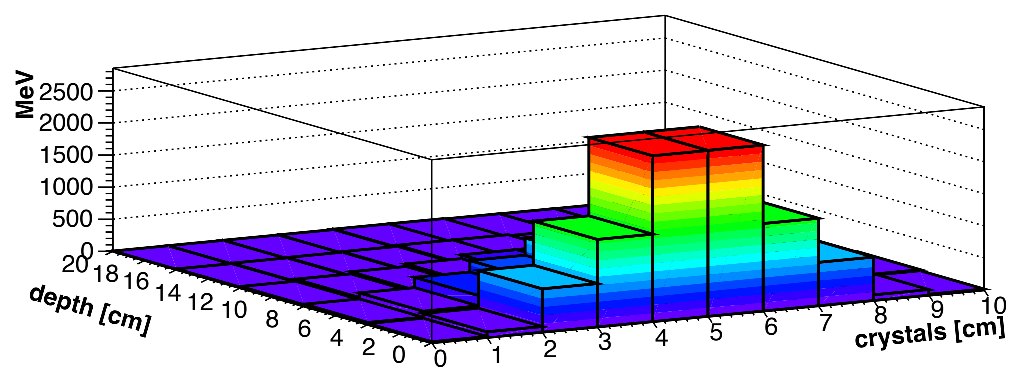
Geant4 simulations -2-

- A second look at the response:
  BIB parametrized as 1.7 MeV photons – 300 particles/cm^2 per event

Single Event



Average of 1000 events



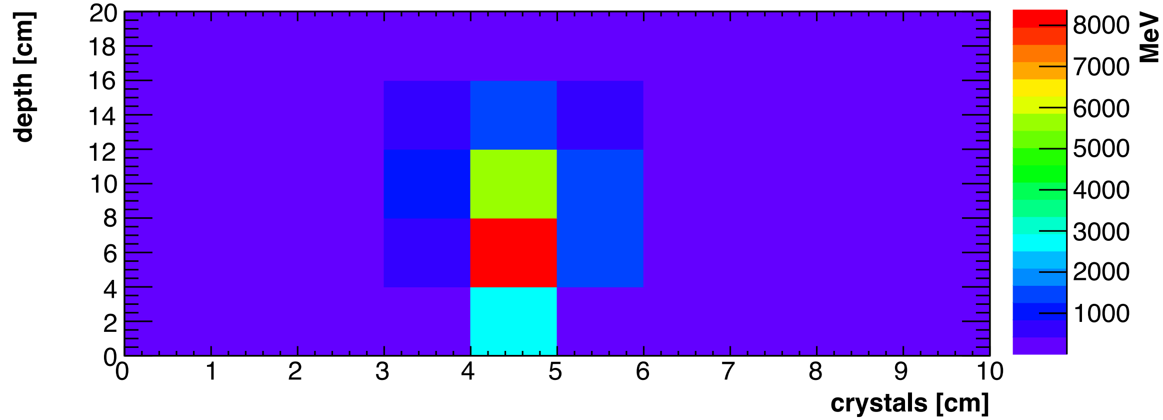
M. Casarsa, F. Happacher, D. Lucchesi, S. Miscetti, N. Pastrone, I. Sarra, L. Sestini

Geant4 simulations -2-

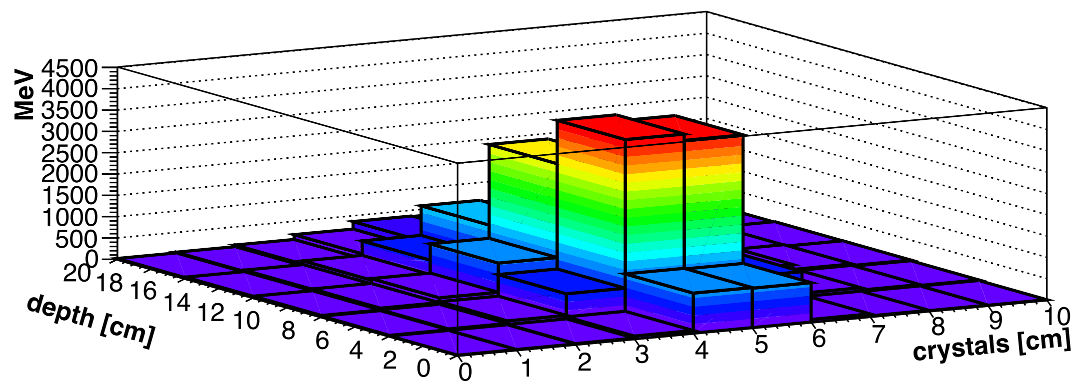
- A second look at the response:
  1 π^0 with p = 30 GeV per event

1 cm radius
1 π^0 per event

Single Event



Average of
1000 events

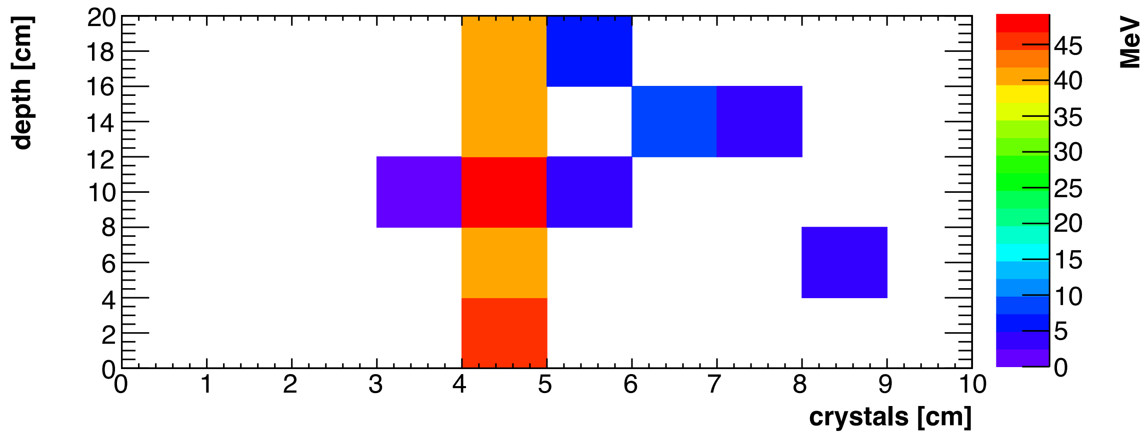


Geant4 simulations -2-

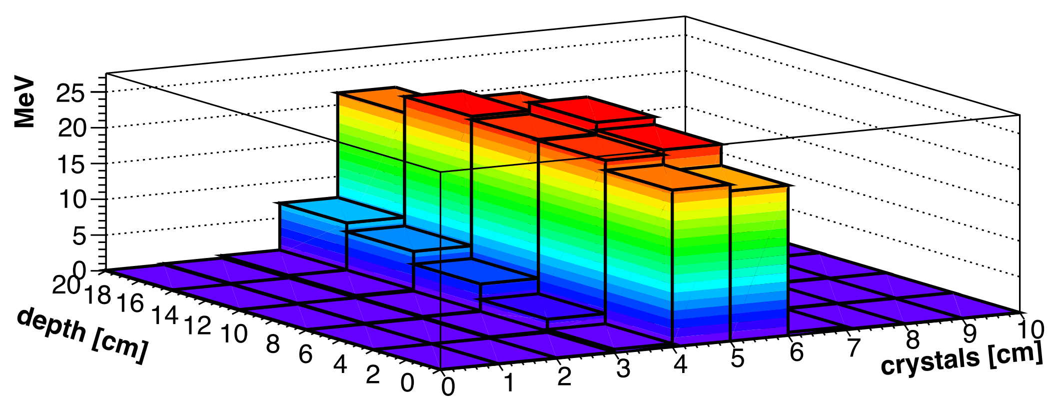
- A second look at the response:
  1 μ^- with p = 30 GeV per event

1 cm radius
1 μ^- per event

Single Event



Average of
1000 events



Geant4 simulations -2-

- A second look at the response:

  1) the timing plays an important rule on the reduction of the BIB:

     → a factor 10 of reduction using a 200 ps cut considering (BIB uniformly distributed in 2 ns).

  2) high occupancy on the first layer

Things to do:

- try a to reconstruct muon and pion over the BIB with clustering and timing;
- change the energies of the particles and repeat the exercise.

News.. Good

- Using leftovers of the year we placed orders for:
  - 100 SiPMs 4x4 mm^2 → thanks to Nadia
  - 18 PbF_2 1x1x4 cm^3 crystals → thanks to Gruppo1 Frascati
  - 32 channel of Electronics (HV, adc and tdc) → thanks to Research Division Frascati

- We are working to arrange a dedicated lab here in Frascati (joint venture with Mu2e Frascati)

- What is missing
  - Alumina PCBs (a PhD student and myself are already working on that)
  - Micro coax cables (18 ch x 2 meter each)
  - Mechanics (next year)

Goal: to mount a small calorimeter prototype composed by 2 layer of 3x3 crystals each and test it with cosmic rays .. (? before April ?).

STAY TUNED

SPARES