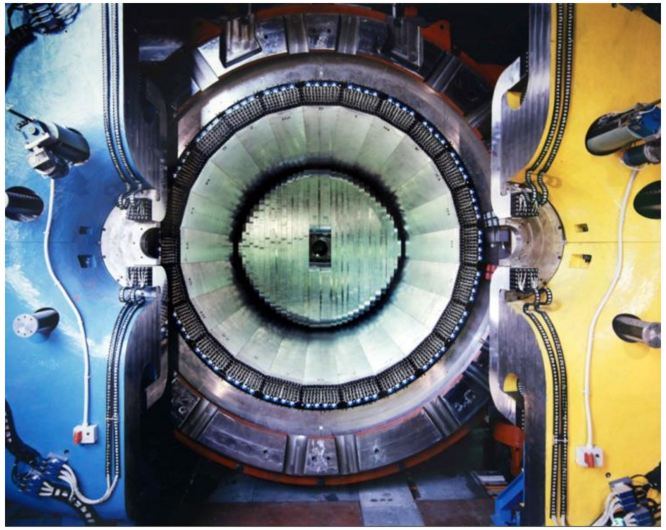

The KLOE EMCalorimeter

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on behalf of DUNE-IT

22th October, 2019 Near Detector Workshop at DESY

Overview

between past and future

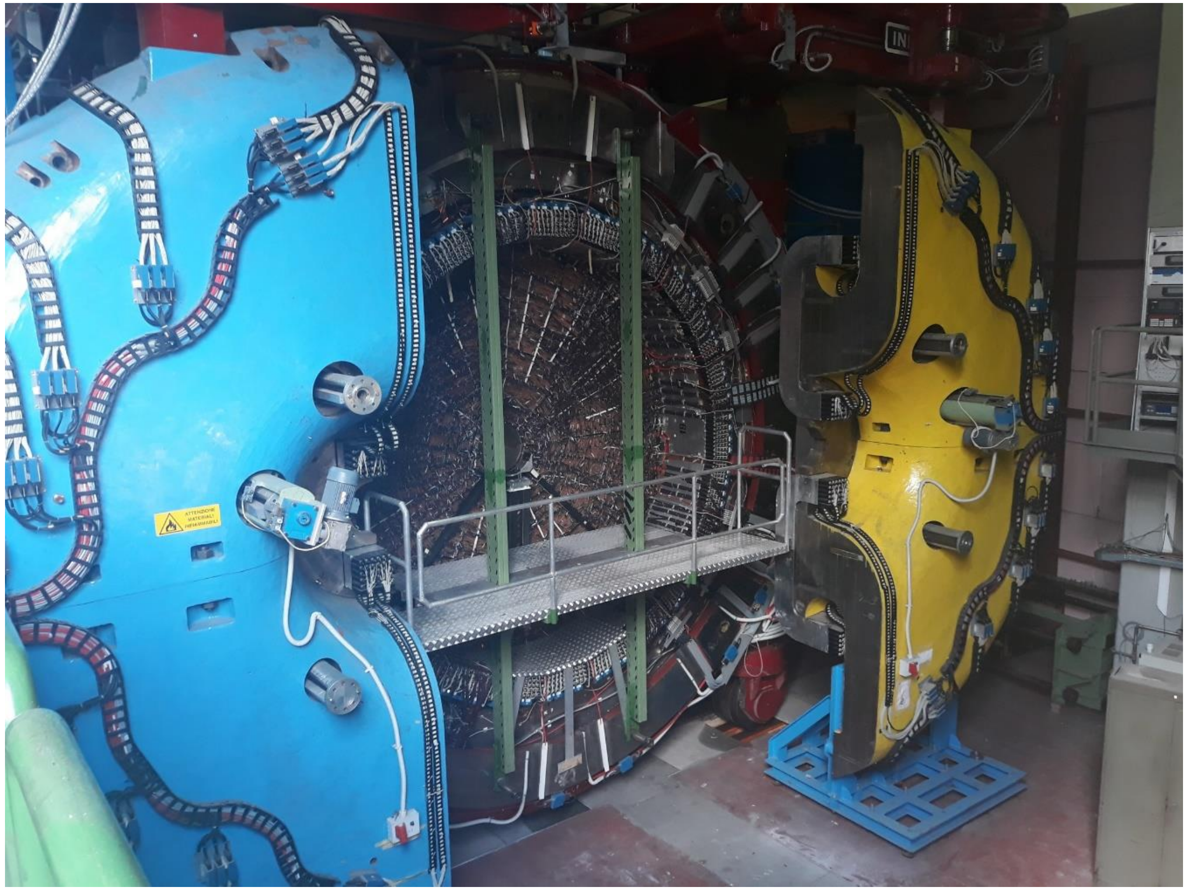
- General description
  - The geometry
  - The active detector
- The performances in KLOE experiment
- The KLOE calorimeter in the DUNE Near Detector
- Preliminary studies for DUNE
- Conclusions

Introduction

KLOE experiment run at Laboratori Nazionali di Frascati (Rome) Italy from 1999 until 2018

at DAΦNE e^+-e^- collider

for physics of K and Φ mesons.

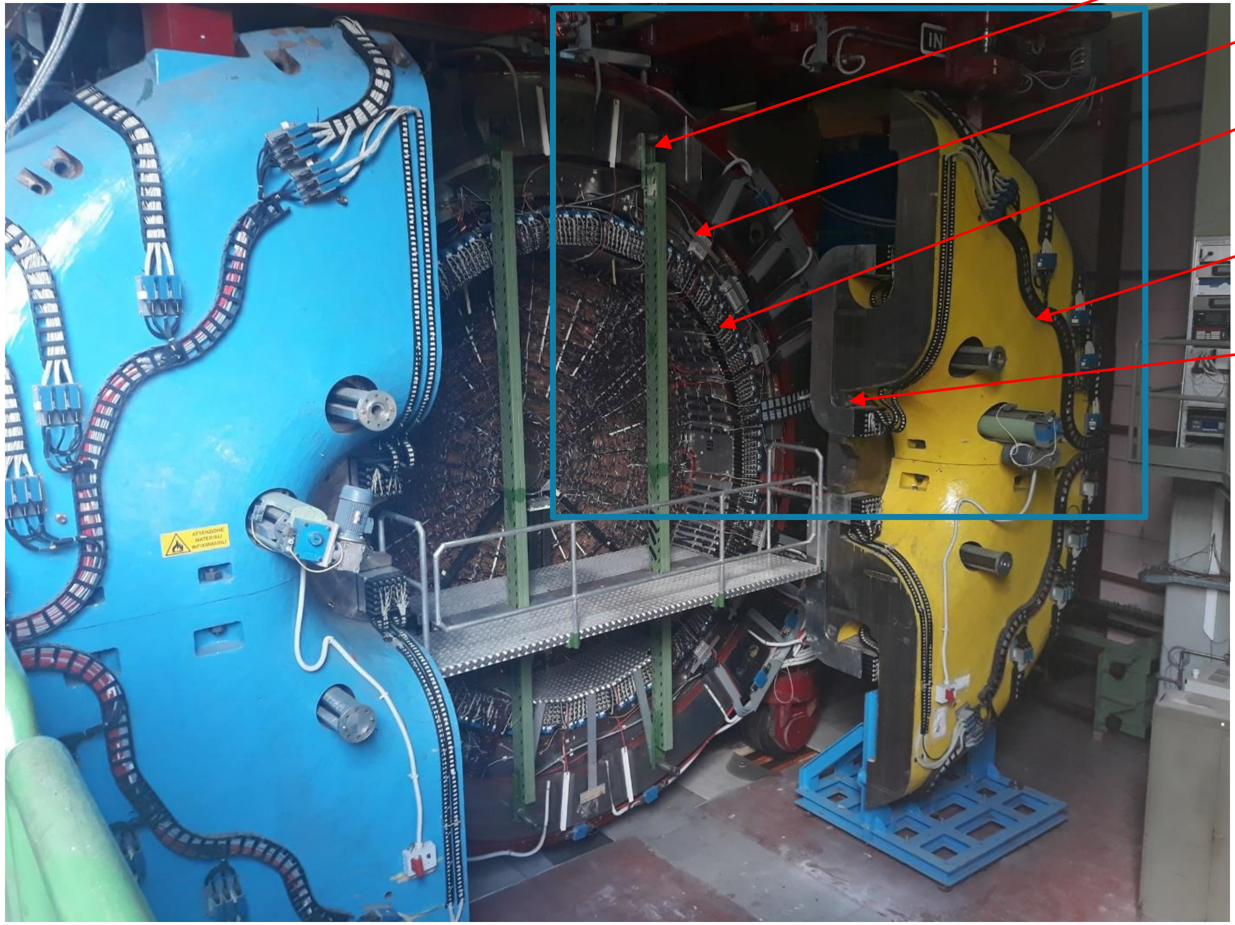


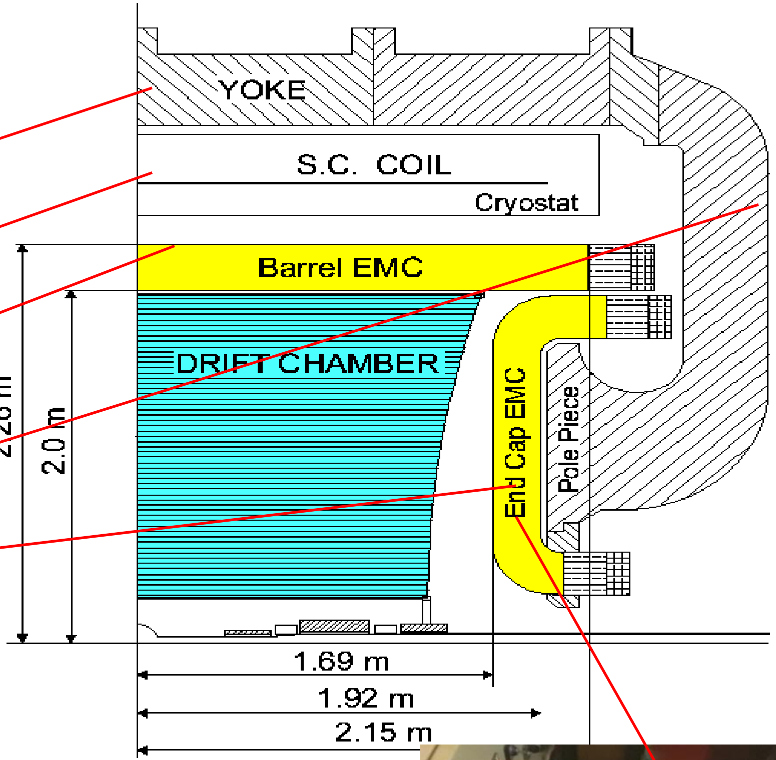
The apparatus is formed by:

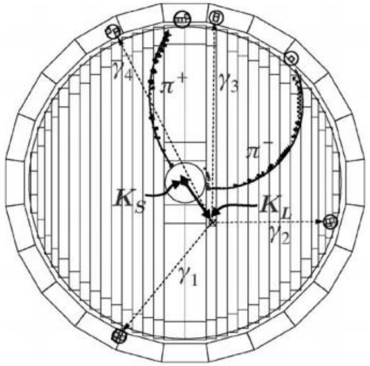
- **magnet**   B=0.52 T
- **electromagnetic calorimeter**
- drift chamber

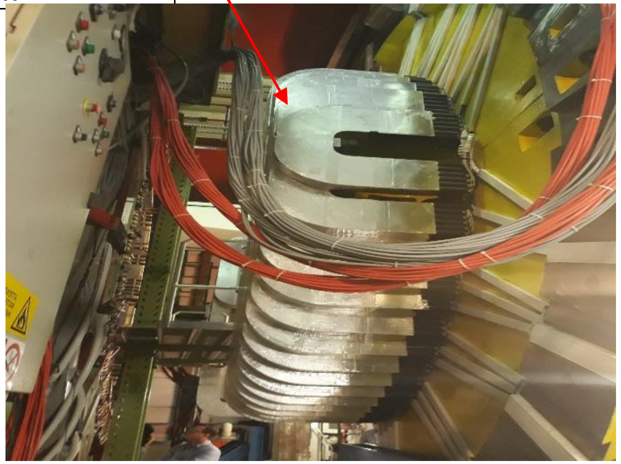
The geometry

magnet + calorimeter



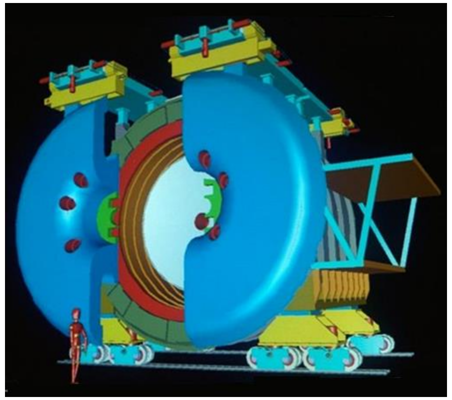






The geometry

the overall dimensions

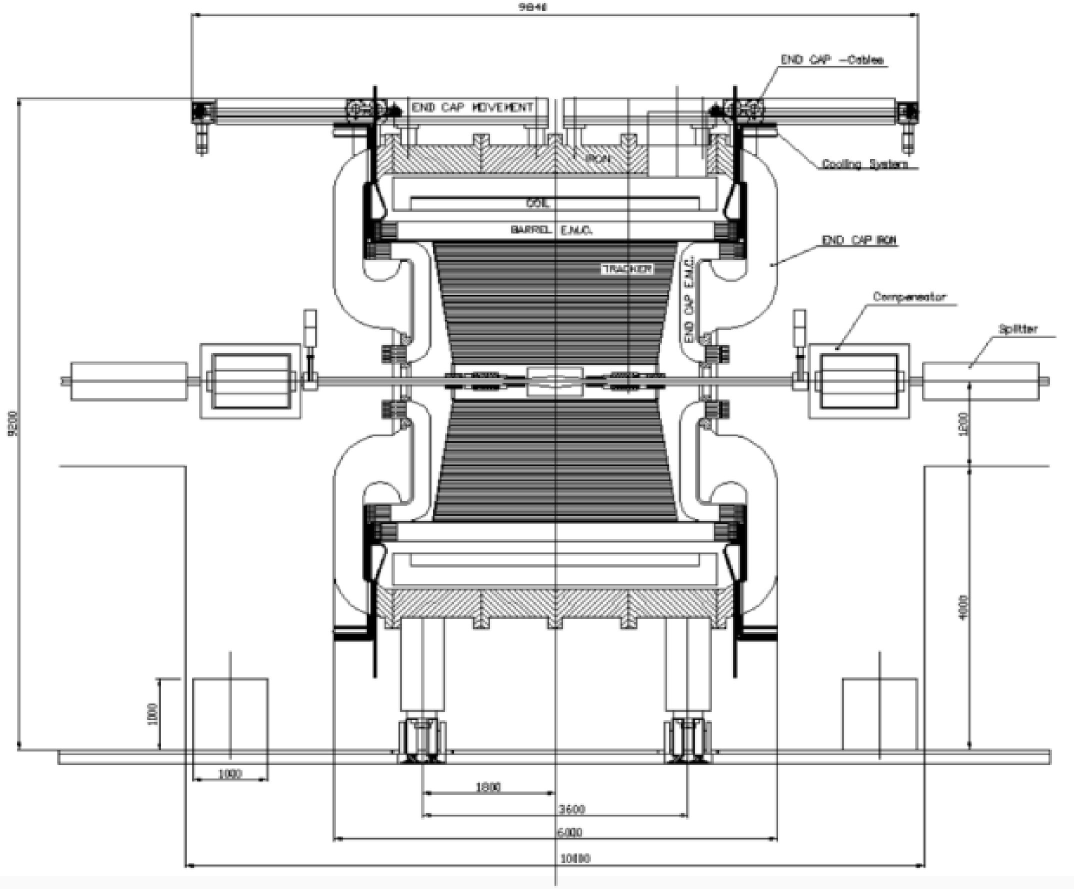


total length: ≈ 6 m
total height: ≈ 7 m

overall weight > 1500 tons
calorimeter weight >100 tons

in a compact and movable structure

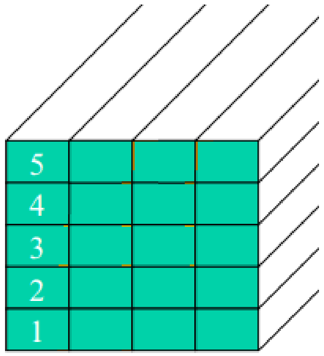
the endcap can be easily opened



The EM calorimeter

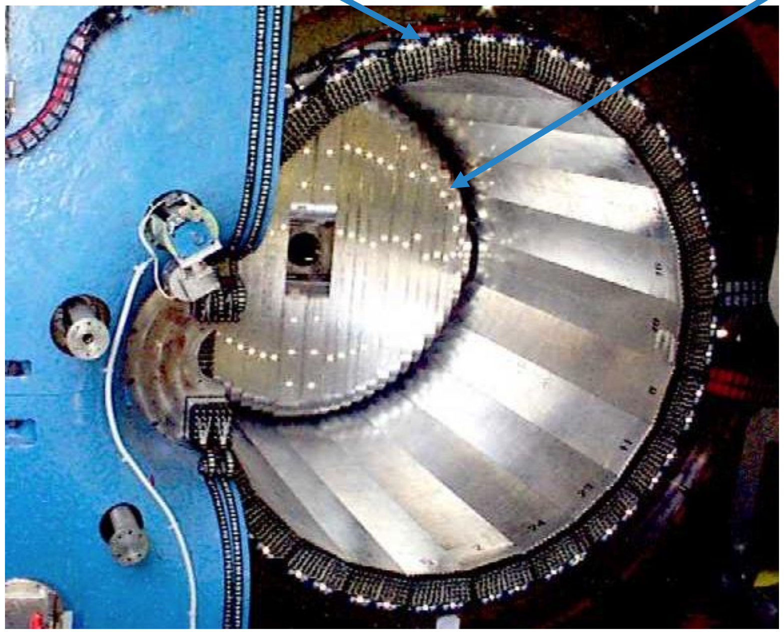
the barrel

24 modules
60 cells each
4.3m length
2880 channels



5 planes: height: 4.4 cm – 5.3 cm
wide: ≈ 4.4 cm

Calorimeter thickness = 23 cm

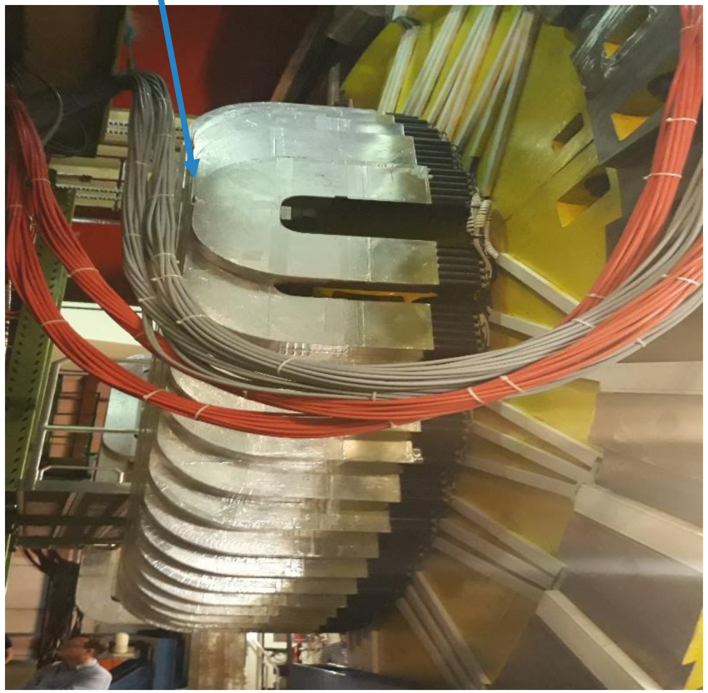


One PMT on each cell side

Total number of pmts: 4880

two endcaps

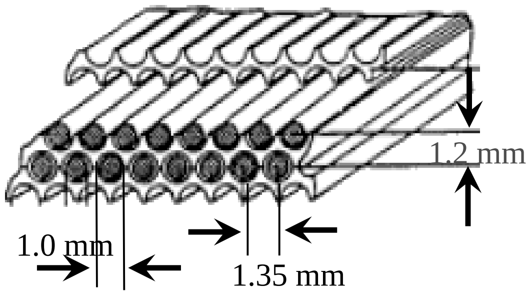
32 modules
10- 15-30 cells each
1000 channels

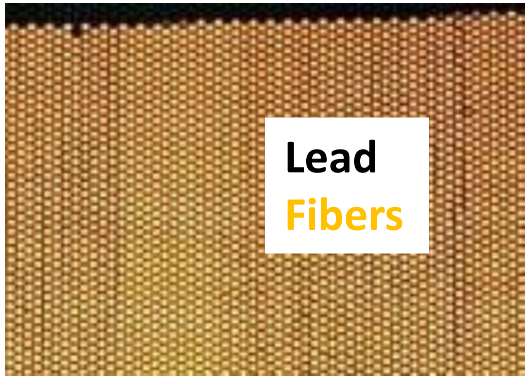


The inner structure

The active material:

- 1.0 mm diameter scintillating fiber
- (Kuraray SCSF-81, Pol.Hi.Tech 0046), λ_{Peak}<460nm
- Core: polystyrene, ρ=1.050 g/cm^3, n=1.6





The absorber material:

200 layers of 0.5 mm grooved lead foils

(95% Pb and 5% Bi).

Lead:Fiber:Glue volume ratio = 42:48:10

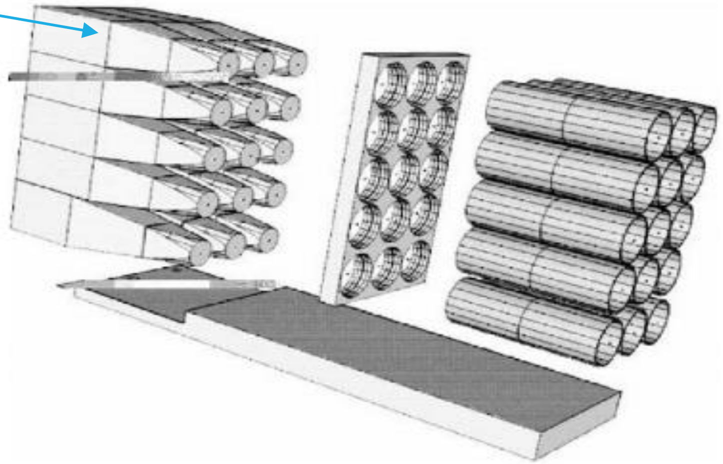
Average density: 5 g/cm^3
Radiation length: 1.5 cm
(thickness ≈ 15 radiation length)

Important parameters as measured after many calibrations:

- Birks effect parameters
- Scintillation decay time: 3 ns
- Attenuation length inside the fibers: 3- 5 m (two types of fibers)
- Number of p.e. : 25 * attenuated energy (MeV)

The readout

Light guides for matching with cylindrical pmts



4880 **Photomultiplier**

HAMAMATSU

PHOTOMULTIPLIER TUBE
R5946

Stable Operation in High Magnetic Fields beyond 1 Tesla
38mm(1–1/2 Inch) Diameter, Proximity Photocathode and Fine Mesh Dynodes

Very stable in low magnetic field
even if with 10% decreased gain

From each cell: two signals from the 2 pmts are acquired t^A, t^B

Reco-interaction time

$$t\ (\mathrm{ns}) = \frac{t^A + t^B}{2} - \frac{t_0^A + t_0^B}{2} - \frac{L}{2v}$$

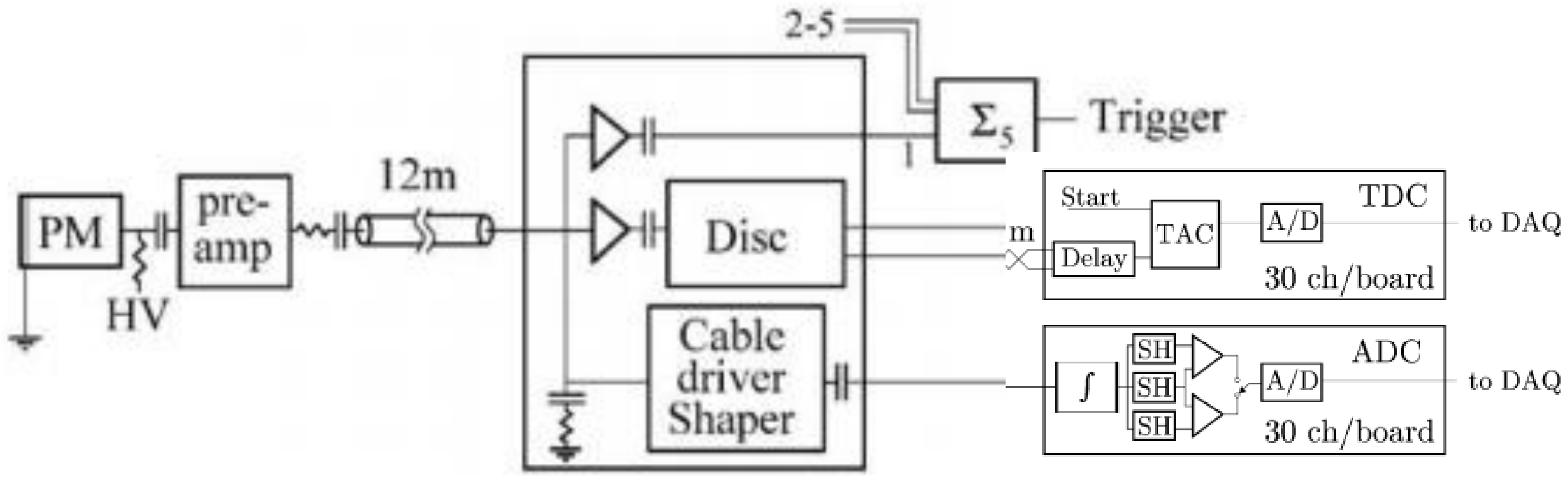
Reconstructed position along the cell

$$s\ (\mathrm{cm}) = \frac{v}{2}(t^A - t^B - t_0^A + t_0^B)$$

where L (cell length) is measured and t_0^A, t_0^B (time off-set) and v (light velocity in the fiber) are well calibrated with muons

The electronics

It should/may be improved….if it needs/if it is worth



12 bit TDC 53 ps/count
12 bit ADC 5 counts/MeV

TDC threshold: 4-5 mV (3-4 p.e) → (≈100 keV)

The calorimeter performances in KLOE

The ECAL main goals:

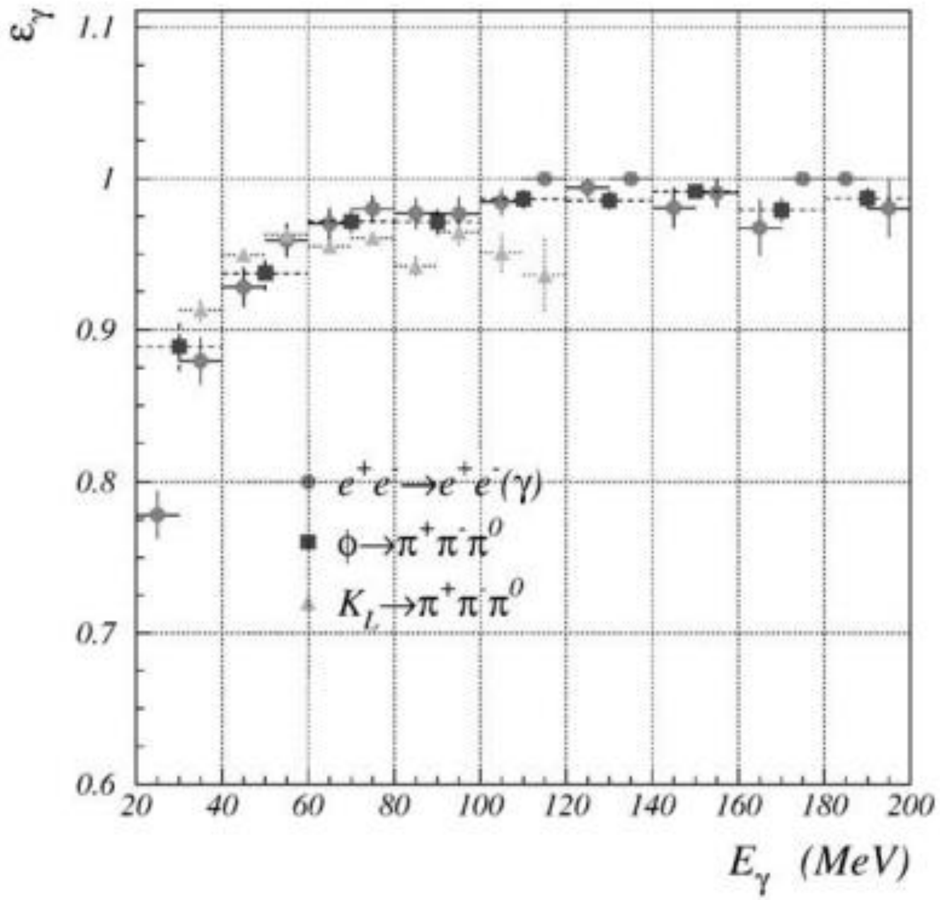
- full efficiency for gammas

- high **time resolution** (for K vertex reconstruction from gamma)

- high **energy resolution**

- shower vertex resolution (high granularity)

Gamma efficiency detection



The performances:

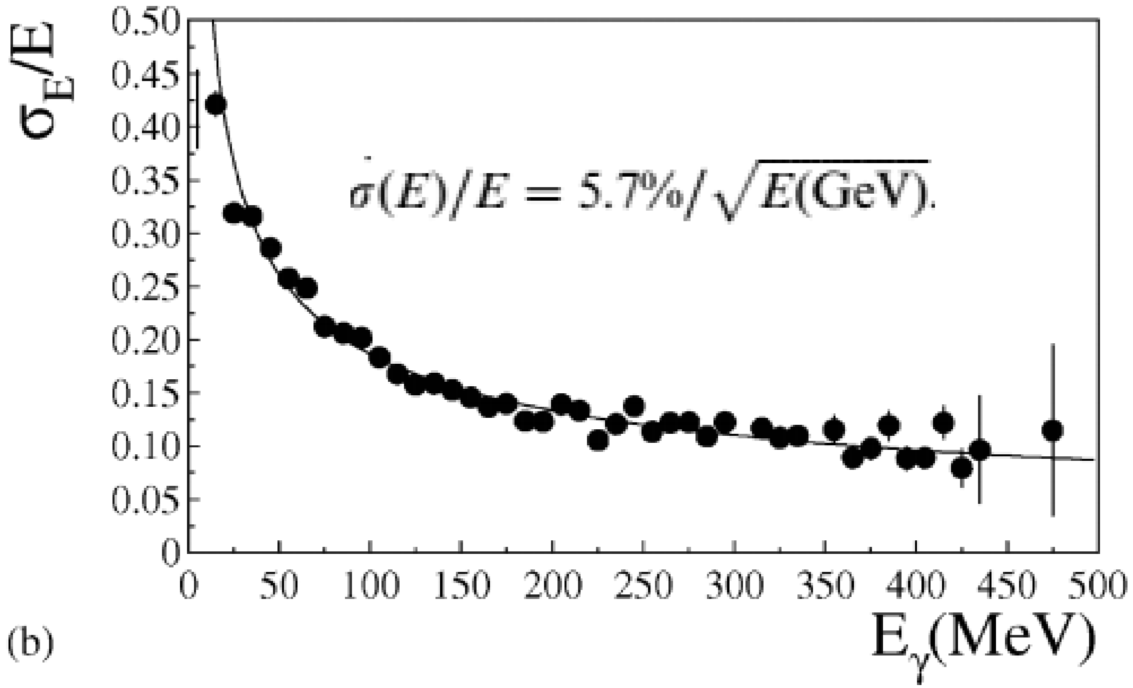
the energy resolution

Energy calibration with cosmic

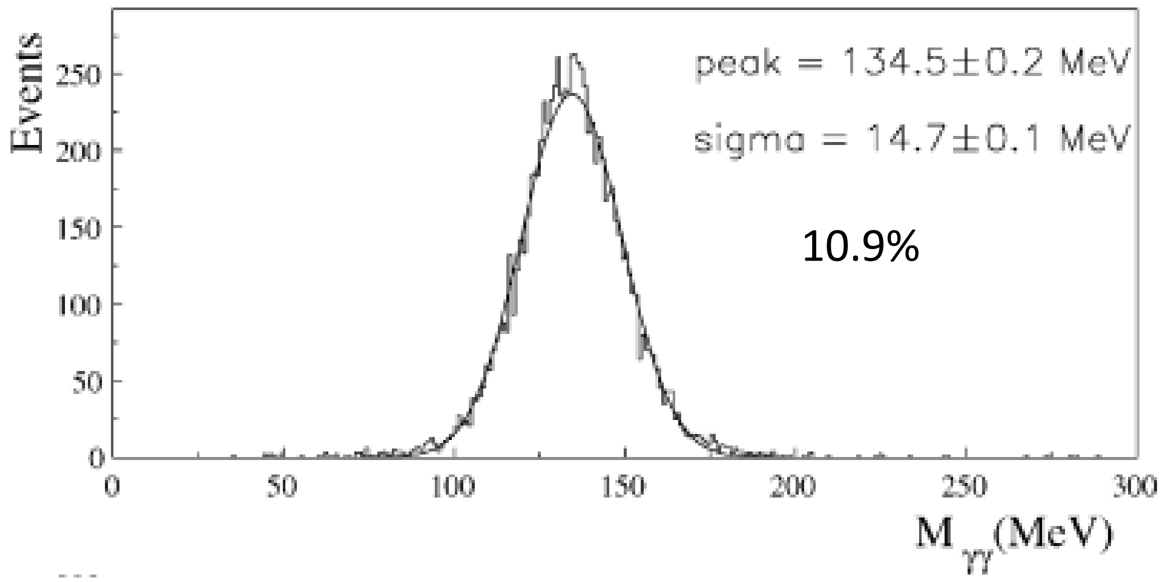
$$E_i^{A,B}\ (\text{MeV}) = \frac{S_i^{A,B} - S_{0,i}^{A,B}}{S_{M,i}} \times \kappa_E.$$

$S_{M;i}$ is the response for a minimum ionizing particle
kE gives the energy scale in MeV

Energy resolution for gamma



π^0 invariant mass



10.9%

NIM A 482 (2002) 364–386

The performances:

the time resolution

t_0^A, t_0^B (time off-set) were carefully measured with cosmic data calibration

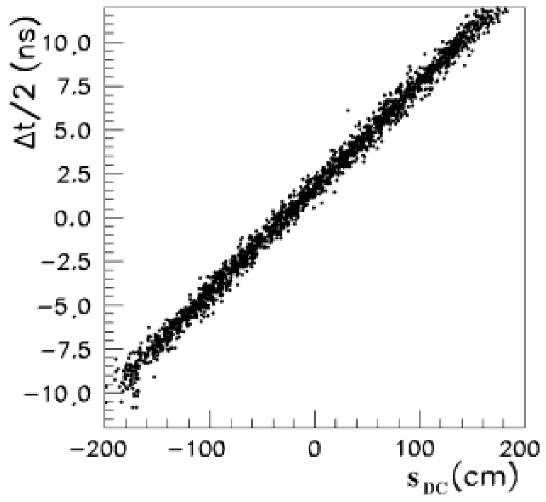


Fig. 25. $(t^A - t^B)/2$ vs. s_{DC} for a barrel cell.

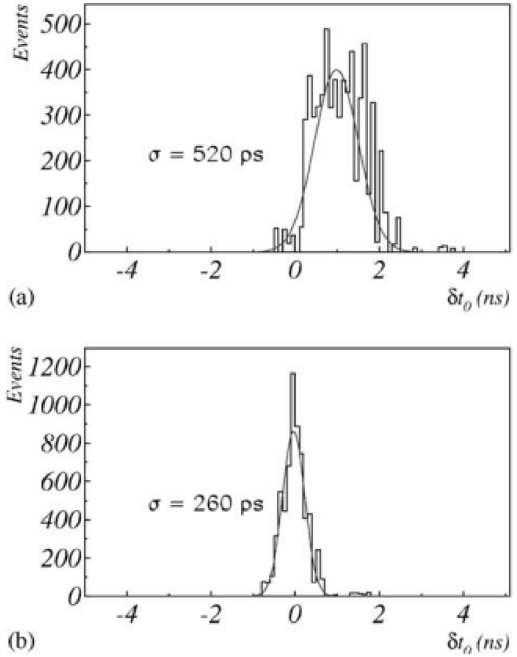
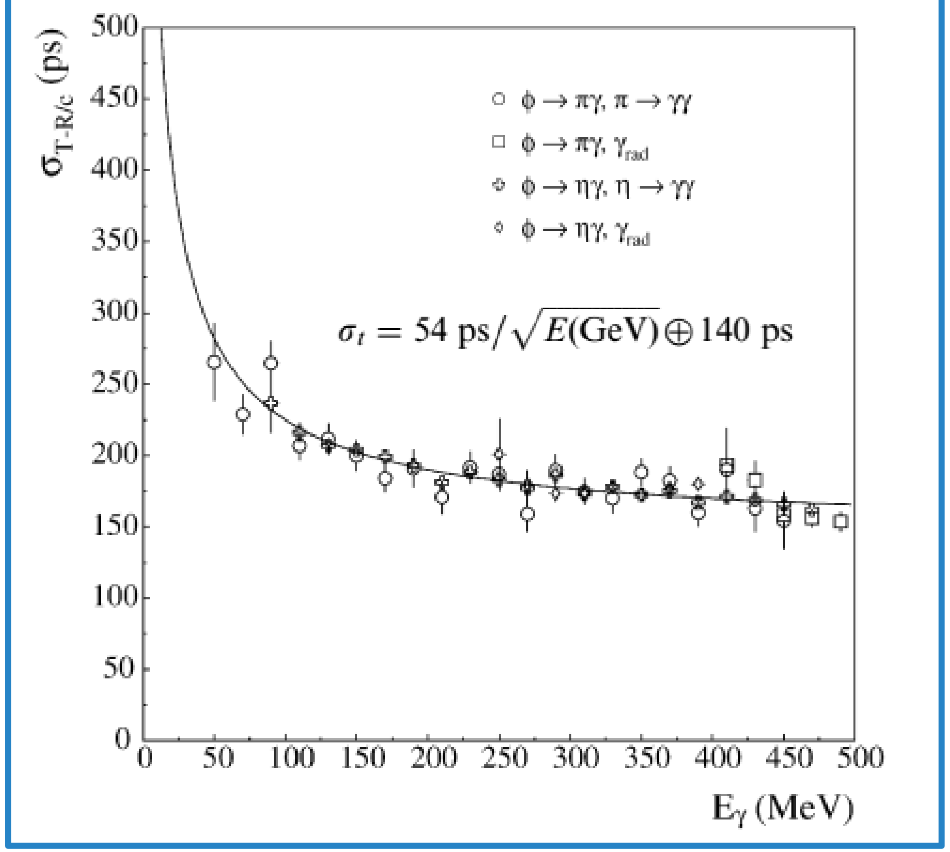


Fig. 29. Residual distributions before and after t_0 corrections using cosmic ray particles.



NIM A 482 (2002) 364–386

The calorimeter as

Time of flight detector

demonstrated for cosmic muon

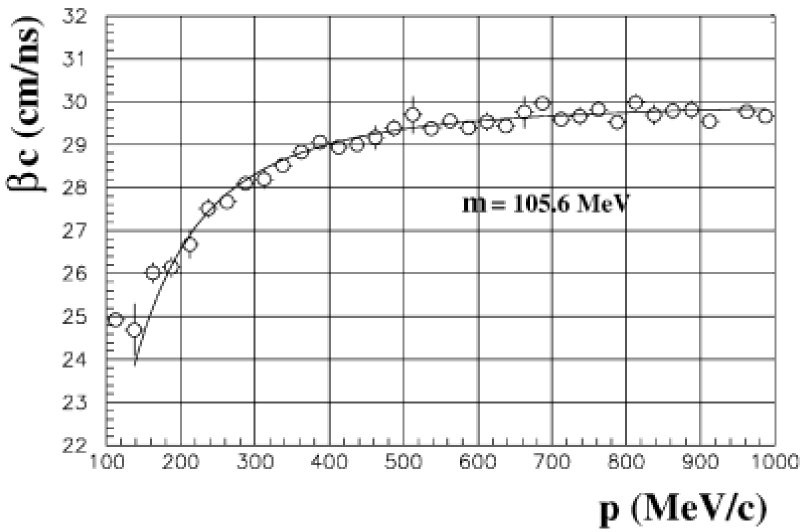
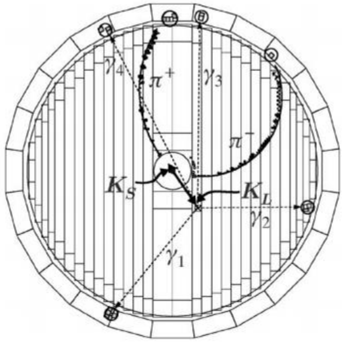


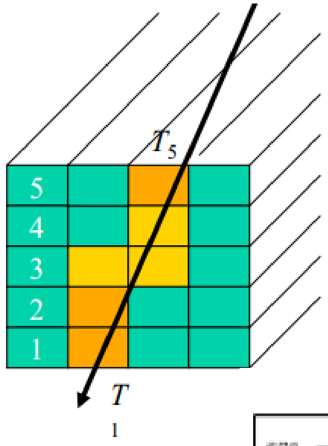
Fig. 31. Velocity as a function of track momentum for cosmic ray events.



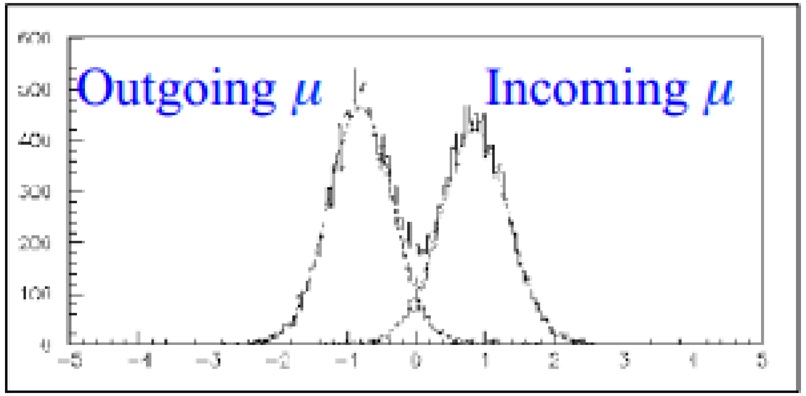
In combination with the tracker for having L and T0

$\beta = L/\Delta T$

External background tagger



T_1-T_5 distribution can distinguish incoming/outcoming events



T_1-T_5 (ns)

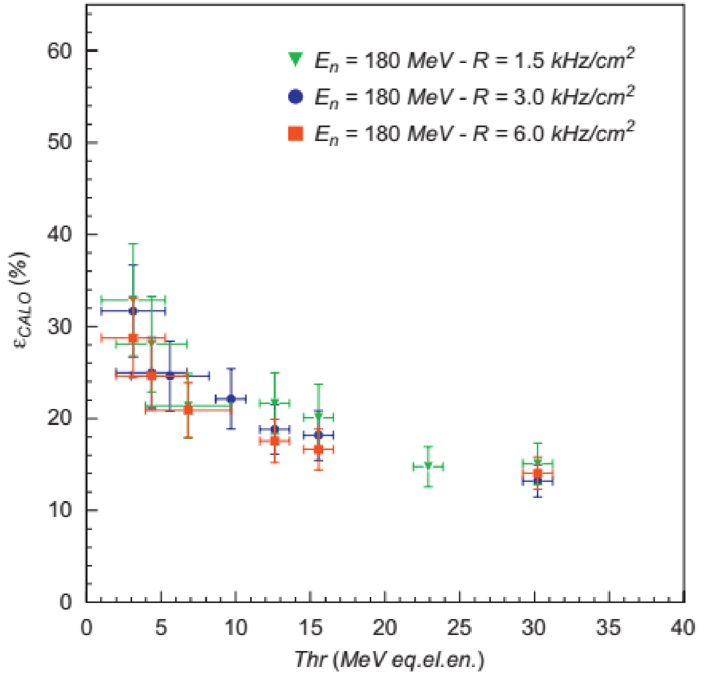
The neutron efficiency

NIM A 598 (2009) 244–247

Tested with a dedicated module $13 \times 65 \times 24\,\text{cm}^3$

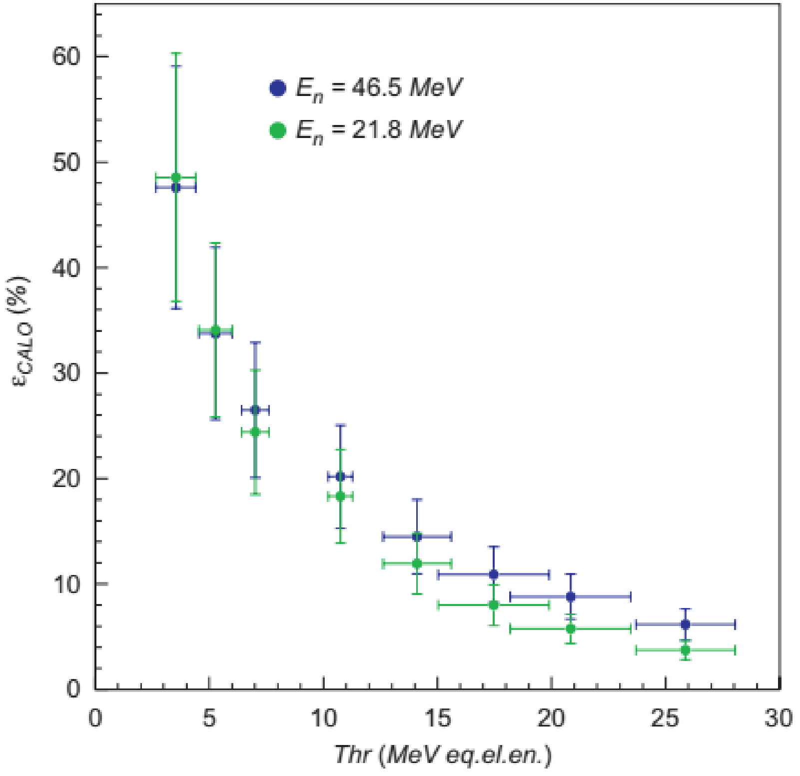
neutrons in 20-200 MeV energy

An efficiency considerably higher was measured



huge inelastic production of neutrons on the lead planes.

Secondary neutrons and protons and photons that contribute to the visible energy



The KLOE calorimeter in DUNE ND!

It will be **fundamental** for:

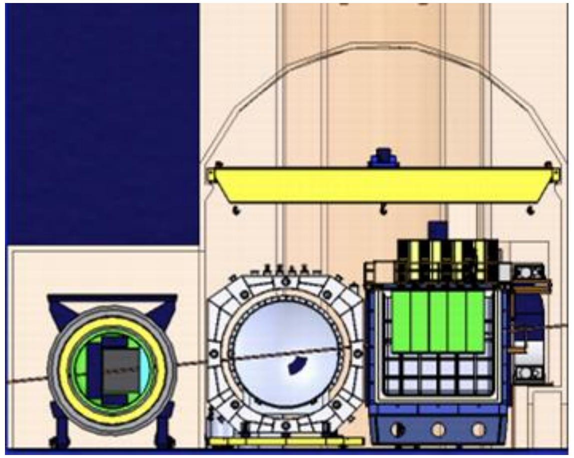
- gamma detection

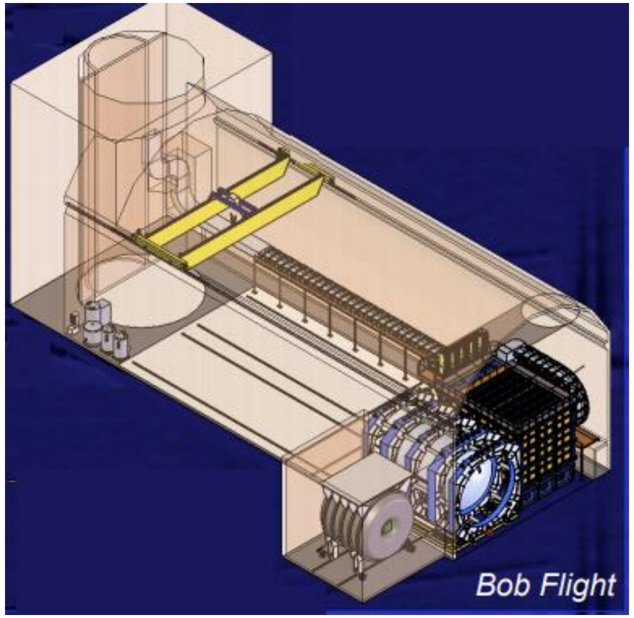
- neutron detection

It will be probably **useful** for:

- particle identification

- background rejection





A lot of these performances are well known….
…..others need deeper studies

Starting point:

full FLUKA simulations of fibers and lead and GEANT4 simulation were developed.

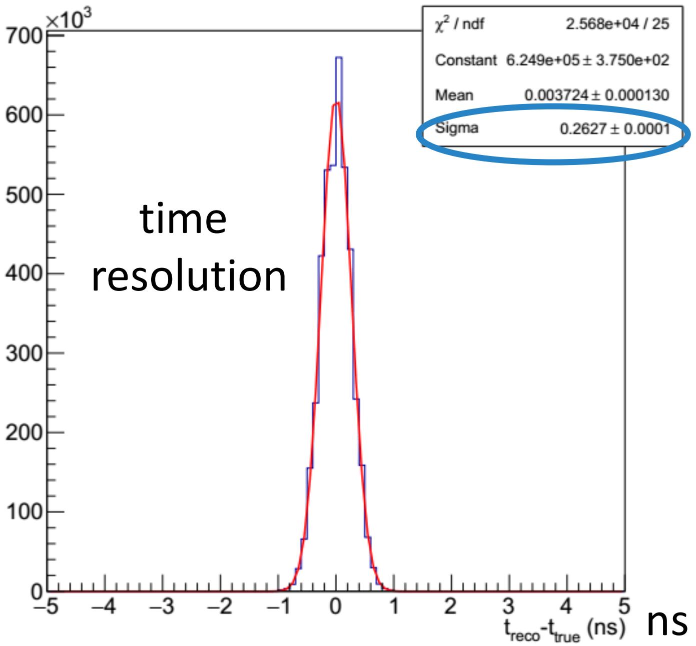
The old results were achieved with new simulations.

Next steps:

Further deeper studies and integration with the inner tracker design (see Guang talk on Wednesday)

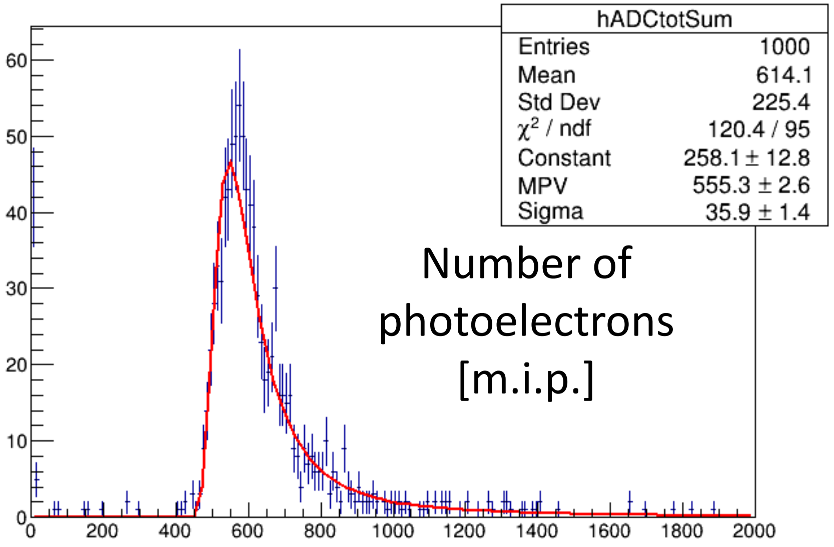
A full simulation

with FLUKA and GEANT 4



ns

260 ps for muons

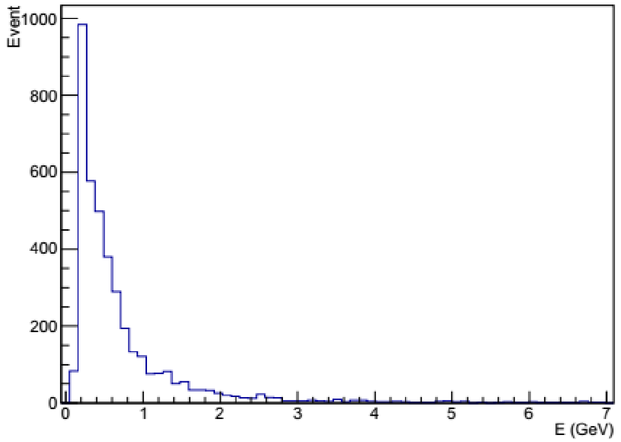


npe

The fundamental properties for energy resolution, time resolution and number of photoelectron have been obtained as in the published papers.

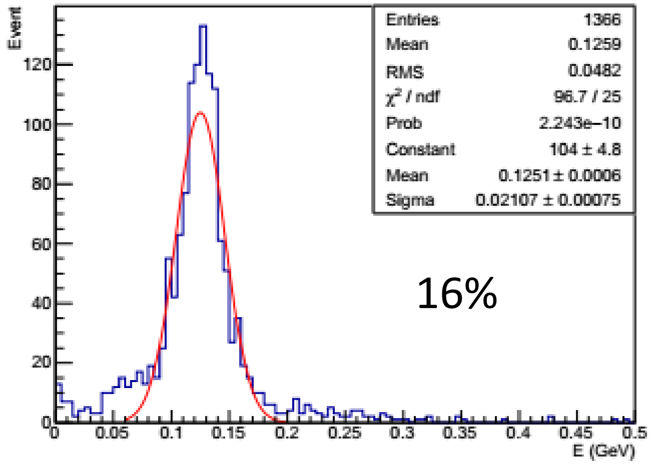
Preliminary results: π^0 detection from $\gamma\gamma$

From ν_μ CC interaction in the tracking volume



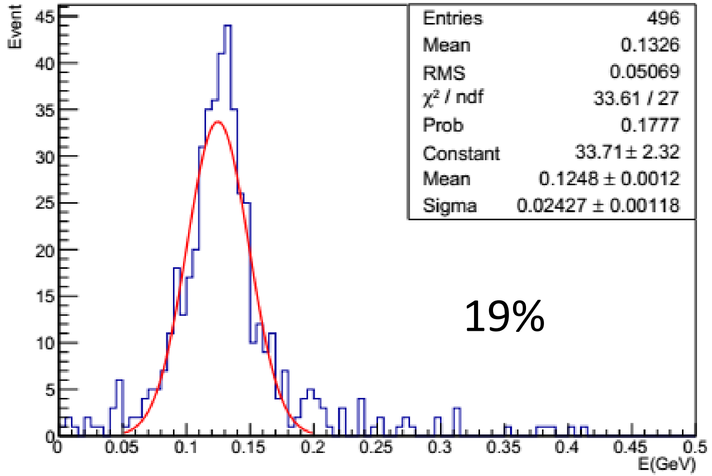
Number of π^0	Fraction %
0	63
1	26
2	7.4
3	1.7
4	0.55
> 5	0.13

Single π^0 two clusters event



16%

Two π^0, four clusters event



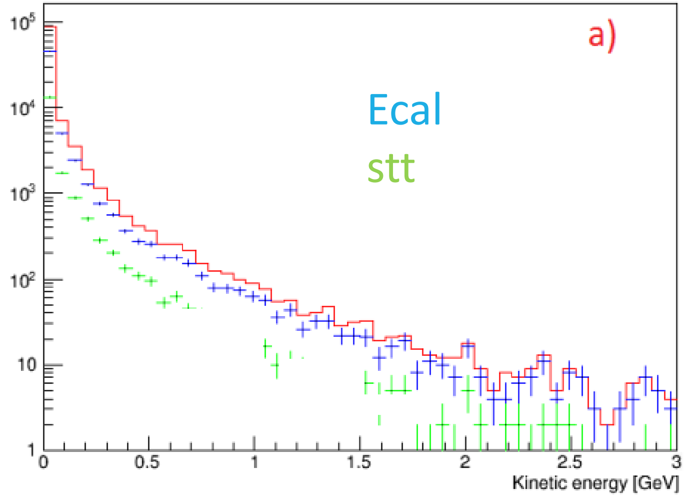
19%

obtained by minimizing $|m_1 - m_{\pi^0}| + |m_2 - m_{\pi^0}|$

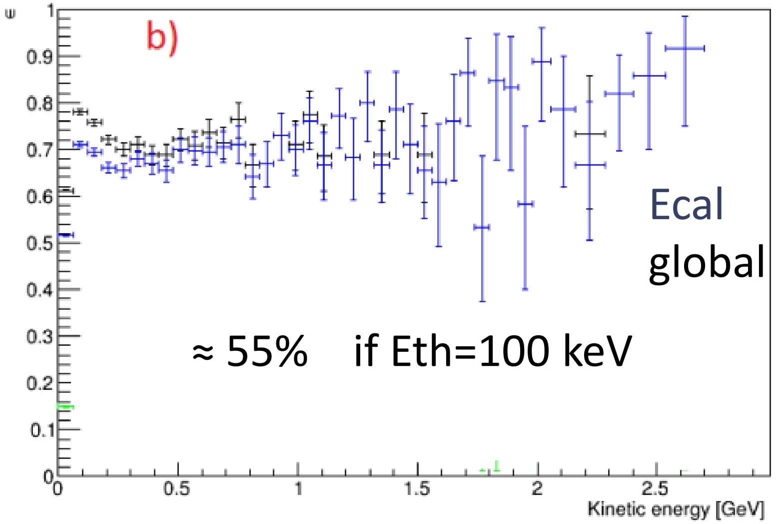
Preliminary results: neutron detection

Neutrons from ν_μCC interaction in "LAr target"

Neutron kinetic energy distribution

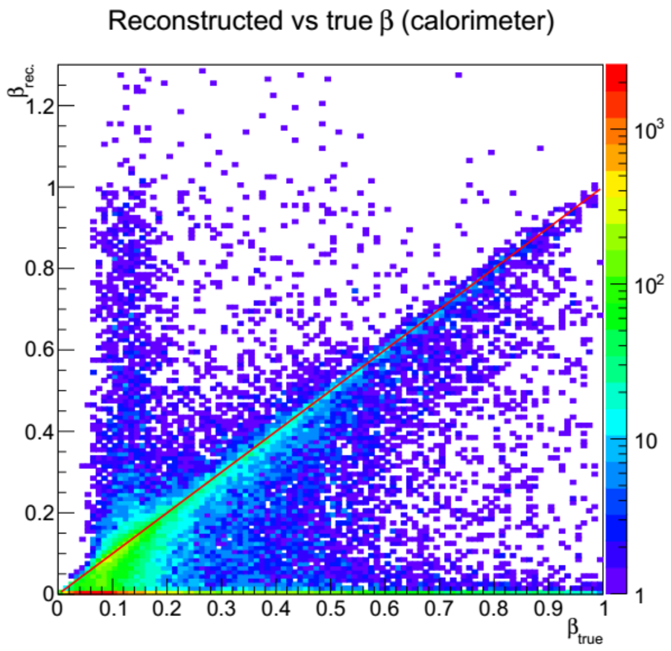


neutron detection **efficiency**



The detection efficiency strongly depends on the energy threshold

neutron **energy estimation**:
from time of flight technique

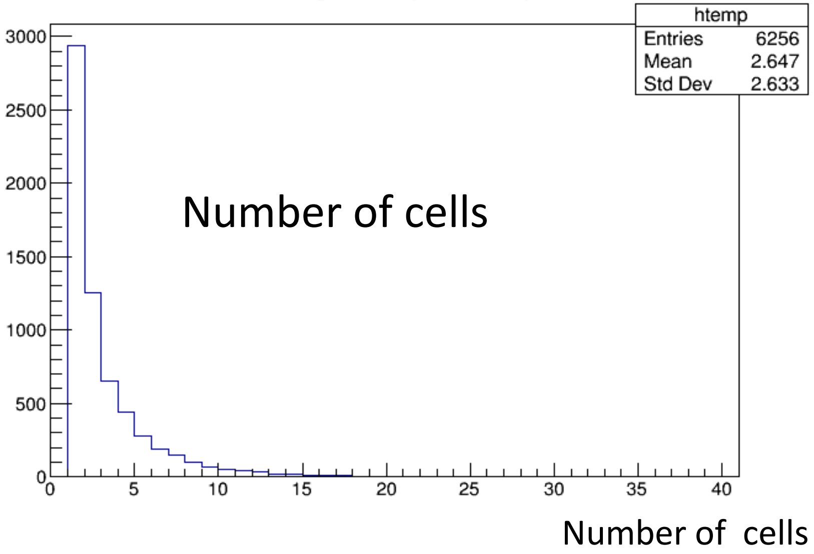


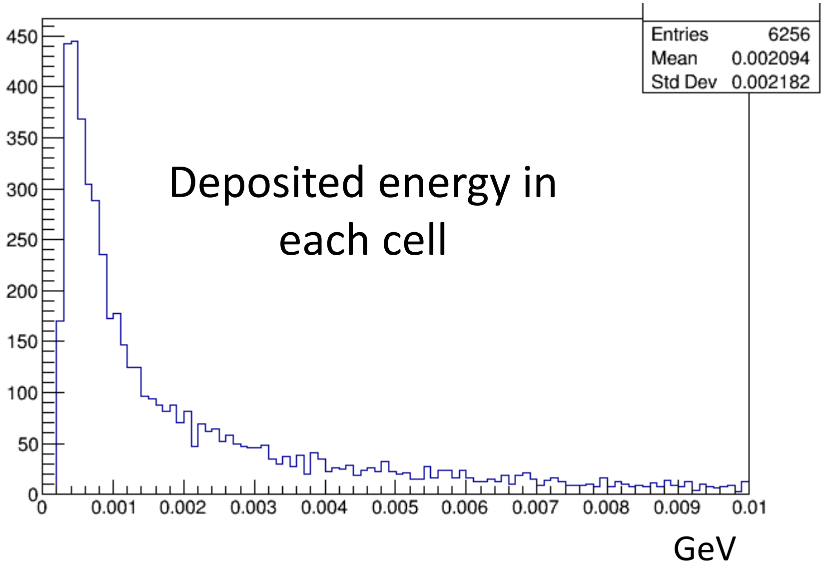
30% precision for about 28% of the detected neutrons

Next deeper studies

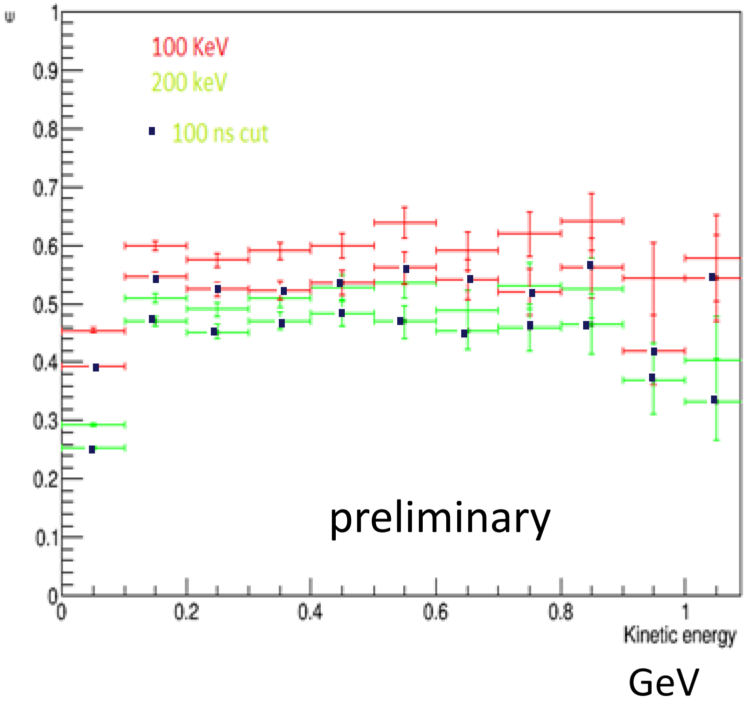
→ On neutron signal and minimum energy threshold

→ Energy estimation from calorimetric measurement





Neutrons from ν_μCC interaction in the tracker (STT)



→ On particle identification

→ On background rejection efficiency

Conclusions

between past and future

→The KLOE calorimeter showed superlative performances

→ Its properties are well known

→we have a full realistic and tuned simulation

NOW

→We have the possibility to improve it and adapt it to our goals

→ We can easily study the performances in DUNE integrating the ecal with the 3DST and tracker inside

NEXT STEPS

→Define what can/should be improved and optimized

→Check what has to be changed, replaced, renovated

→Integrate/adapt the DAQ with the DUNE ND DAQ

→Organize the dismounting/transportation/remounting

Thanks!