WP4
Calorimeter Software
State of art

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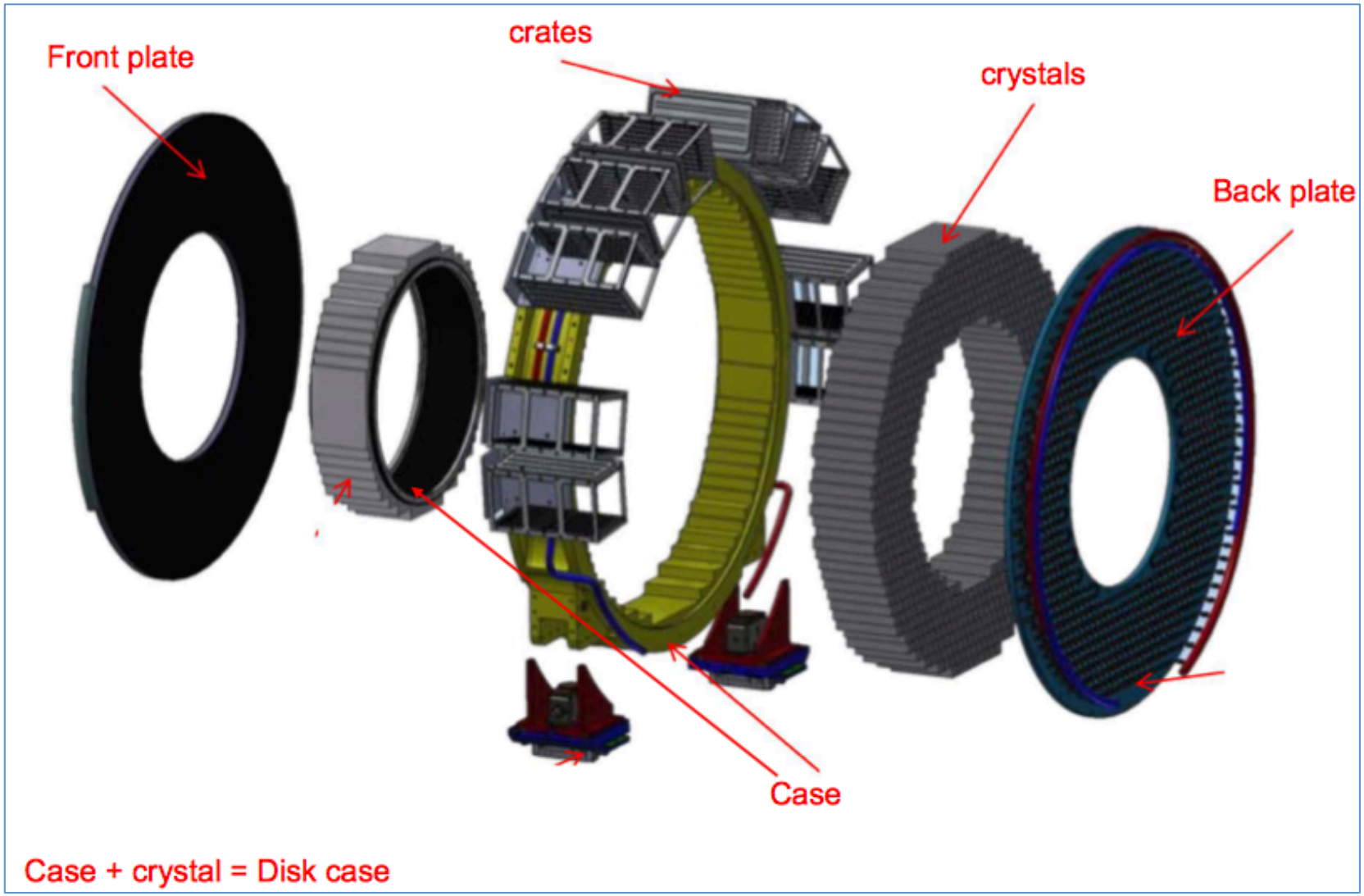
Main tasks

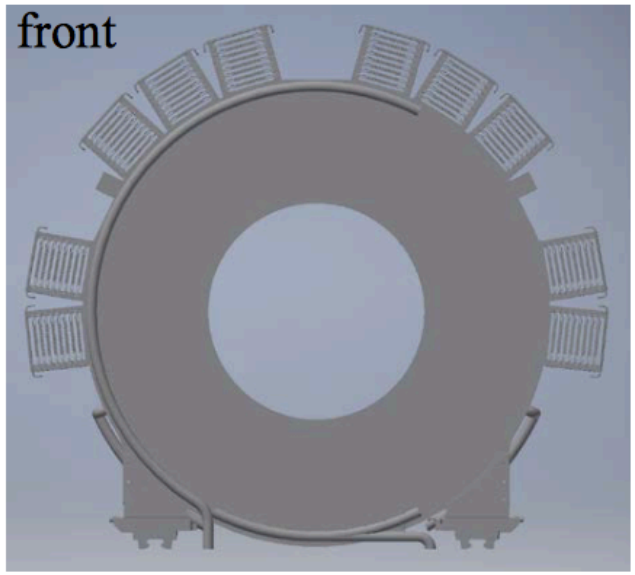
- Improvement in calorimetry geometry description
  - Following CAD files
  - Good state achieved
  - Code clean up, few things missing
- Summary of Module-0 TB data analysis
  - New test to check CR based calibration
- Cosmic rays calorimeter calibration
  - new Module-0 test

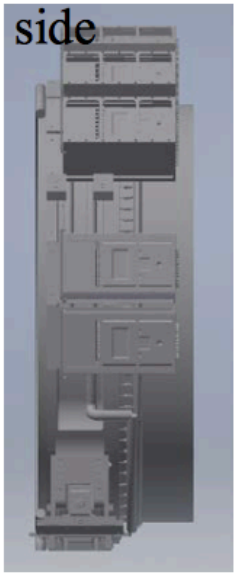
Calorimeter geometry

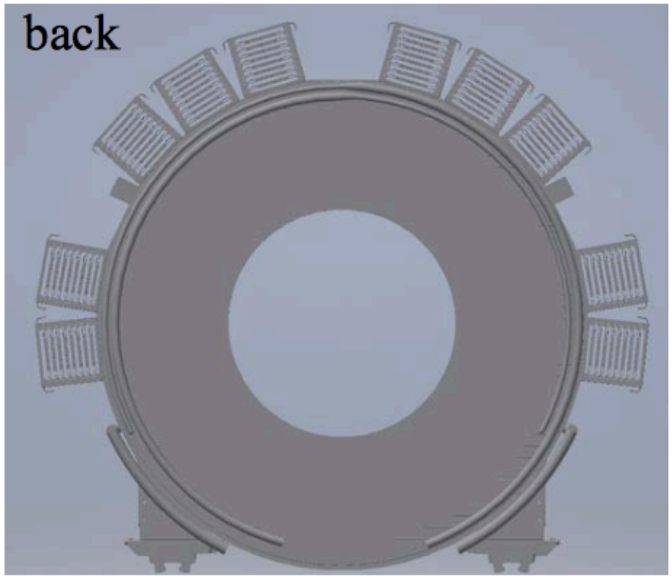


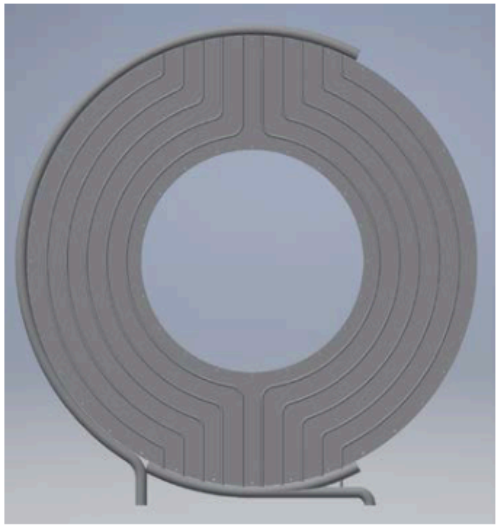
Calorimeter geometry

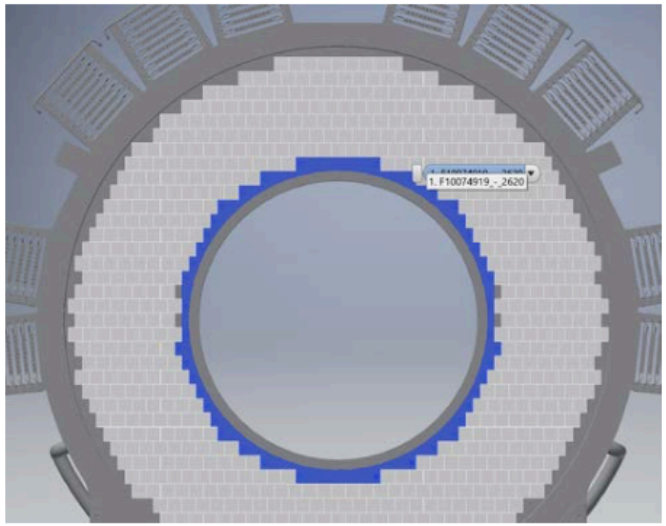
CAD drawing

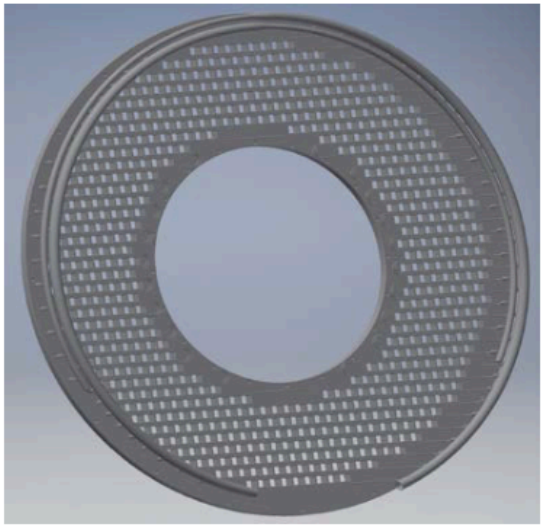






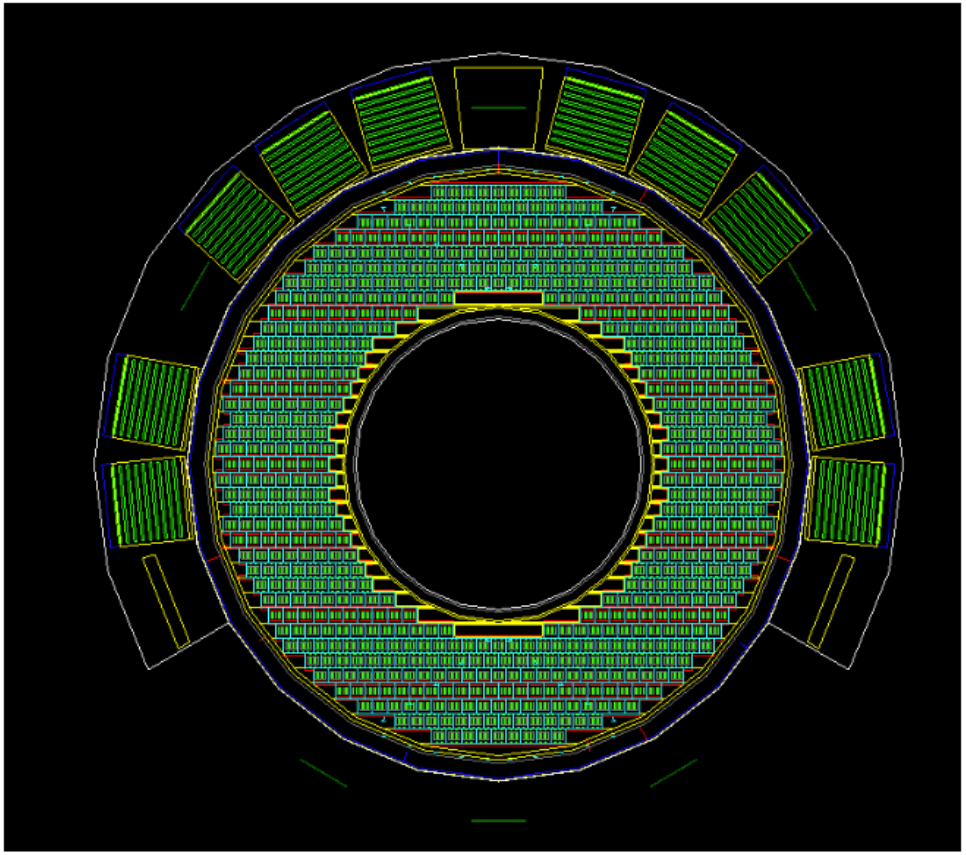


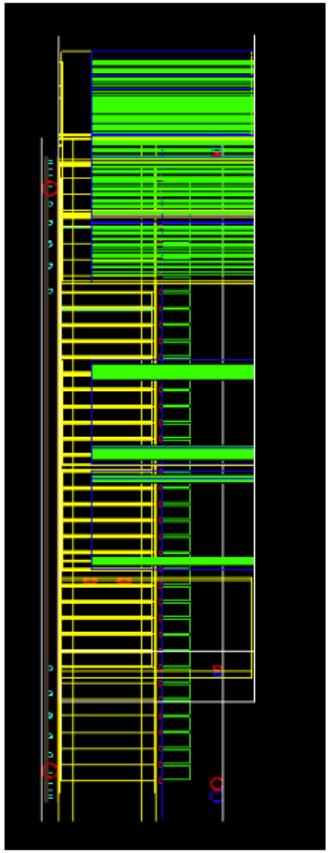


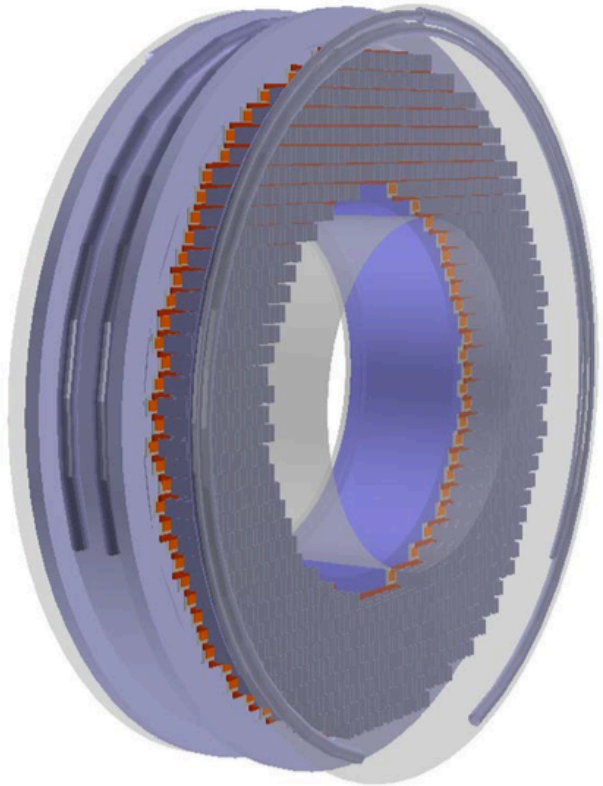


Geometry improvement

Geant 4



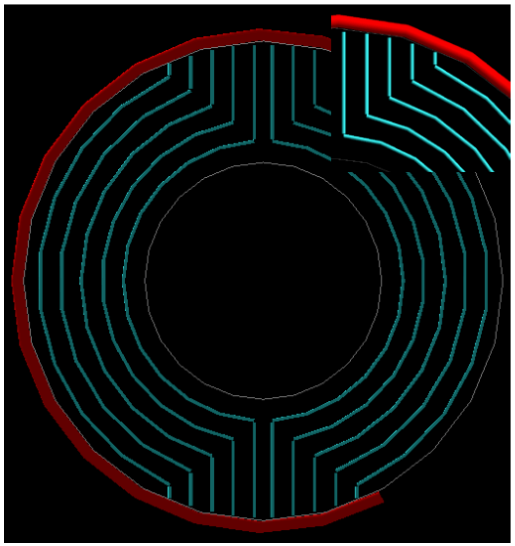


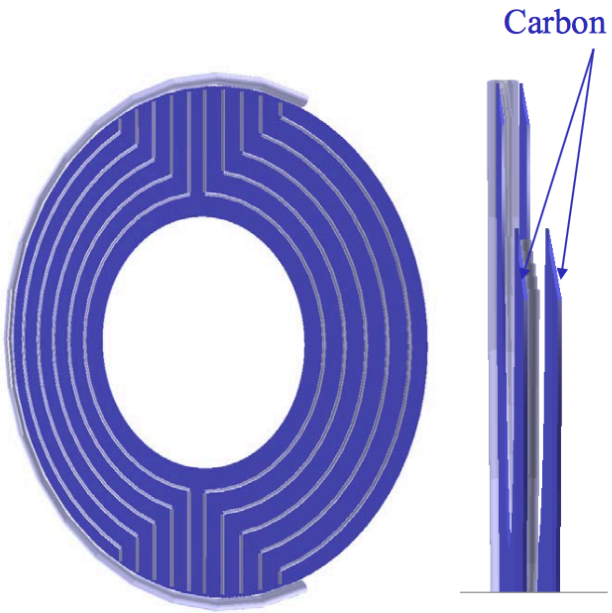


Full disk separated in four components:

front plate + crystal case + back plate + crates

Geometry improvement





Front plate is composed of the following layers:
- carbon fiber cover
- aluminum foam
- carbon fiber cover

The aluminum pipes are inside the foam, the manifold is outside (dimensions/positions taken from CAD file)

Crystal case

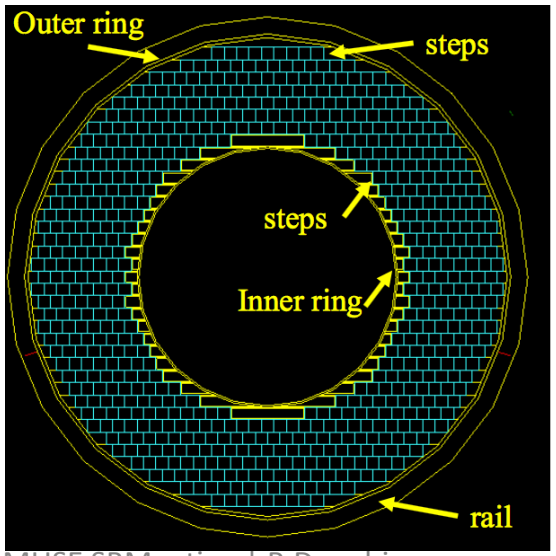
Inner ring, steps (hollow), crystals, steps, outer ring and outer rails

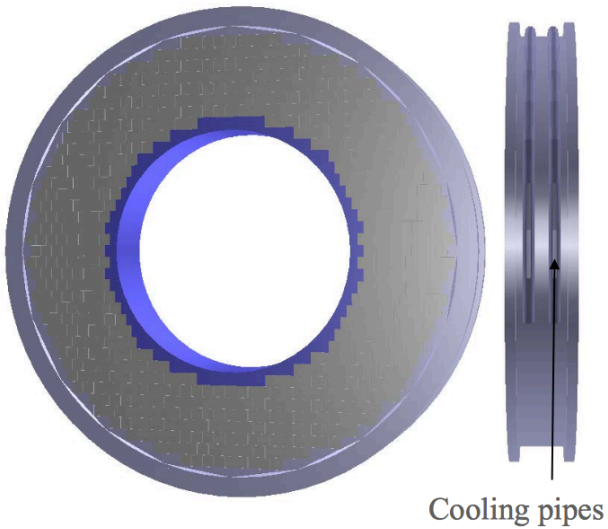
Inner steps are hollow, outer steps are plain

Two cooling pipes outside the outer ring

Crystal unit = Crystal + wrapper + plastic ring at both ends

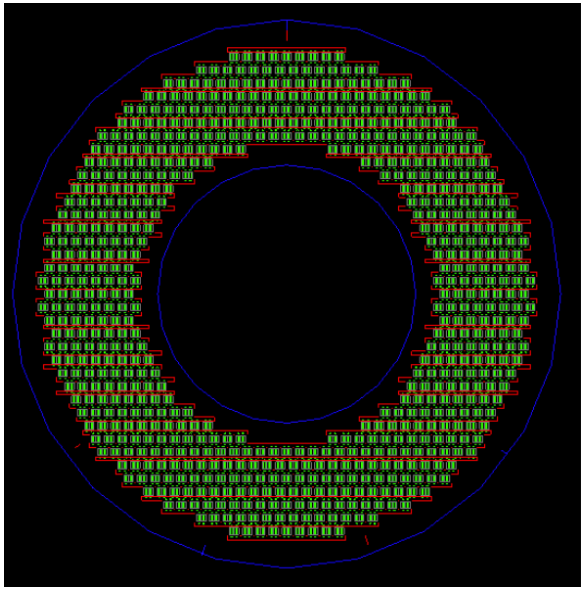
Ideal crystal size/position, realistic size/ location as upgrade later

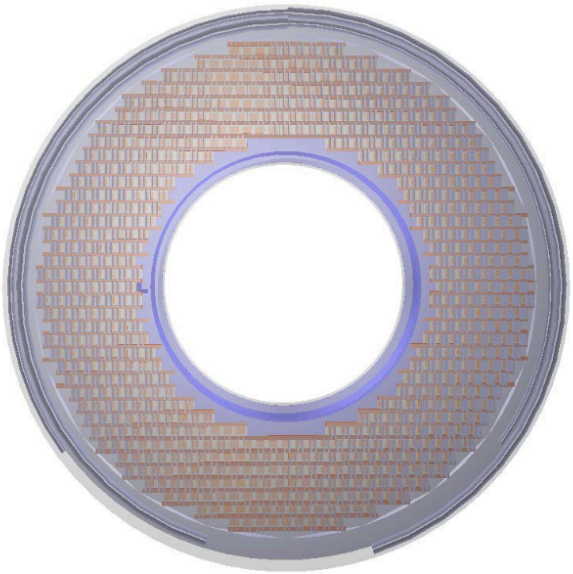


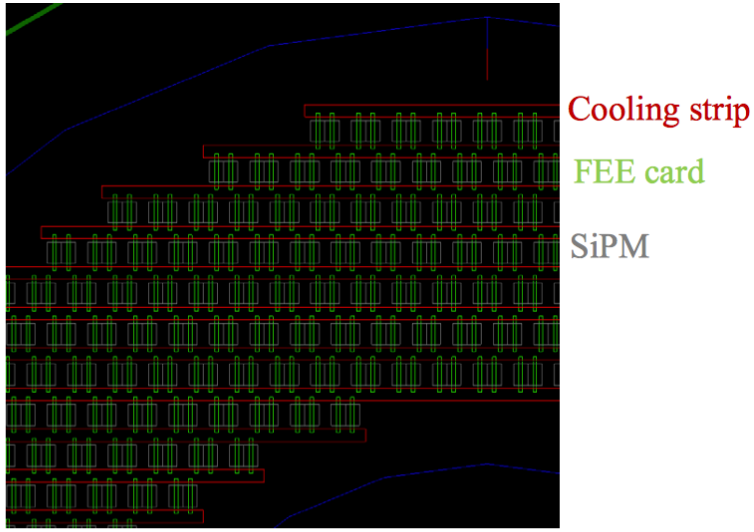


Geometry improvement

Back plate

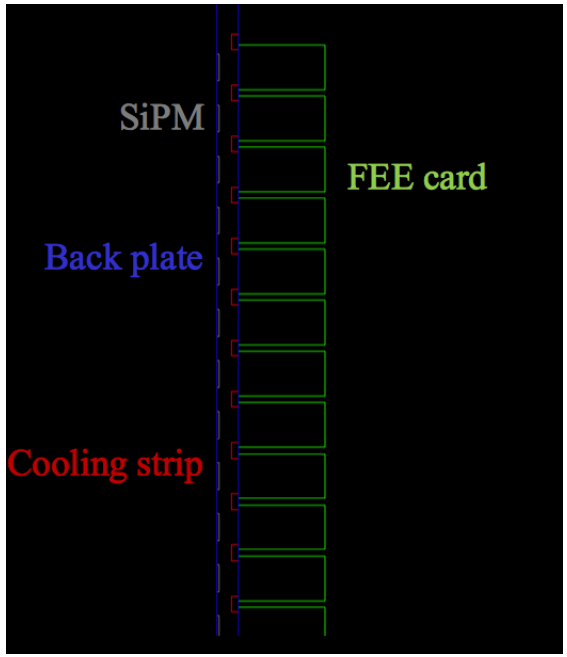






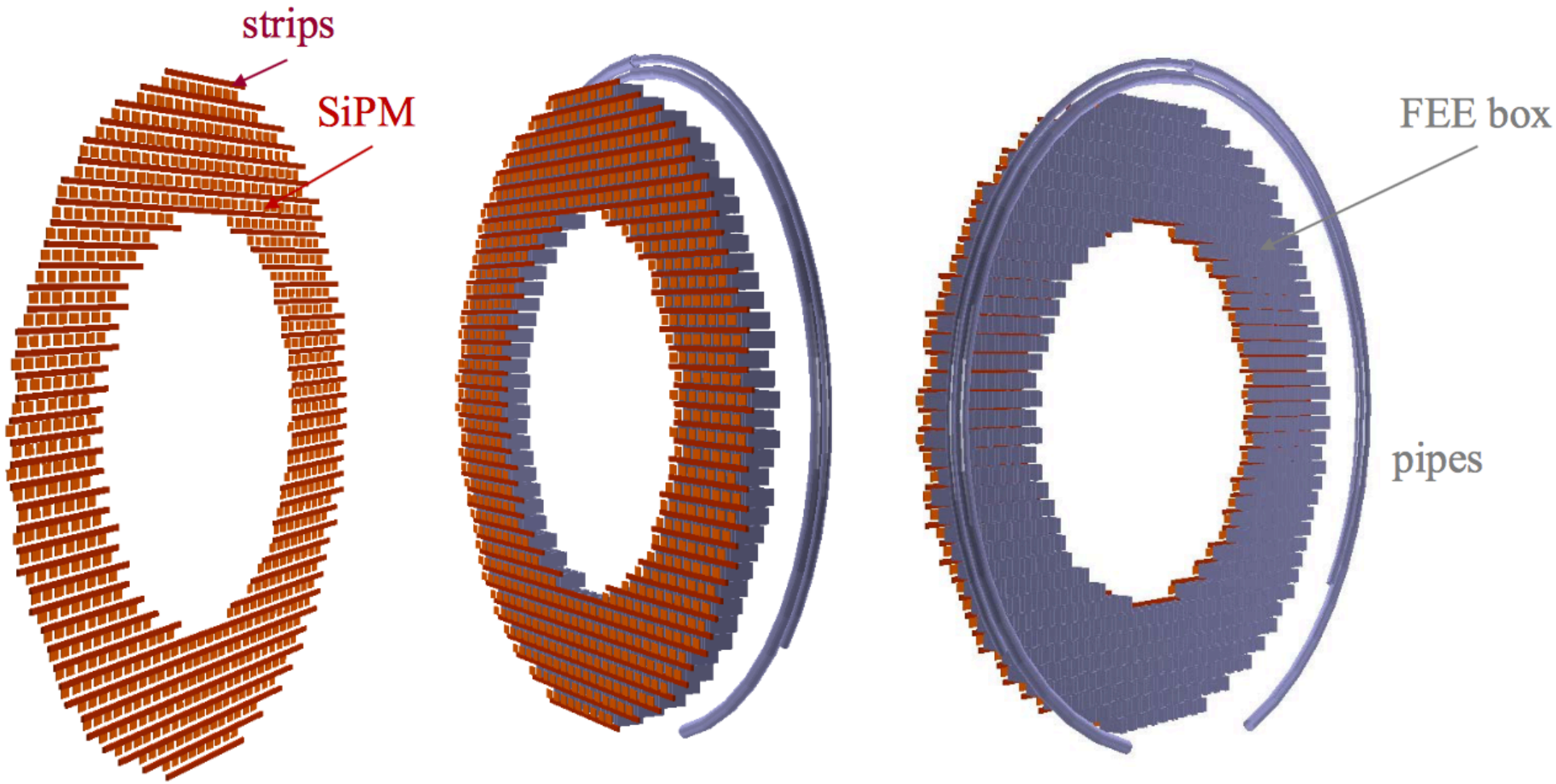
<u>Back plate</u> has holes with SiPM inside
Cooling strips, FEE cards and copper box at the back
Main cooling pipes (no connectors between strips and cooling pipe)

A lot of small pieces are not included (part of FEE card in hole, small connectors), but this should have a minimal impact on the simulation



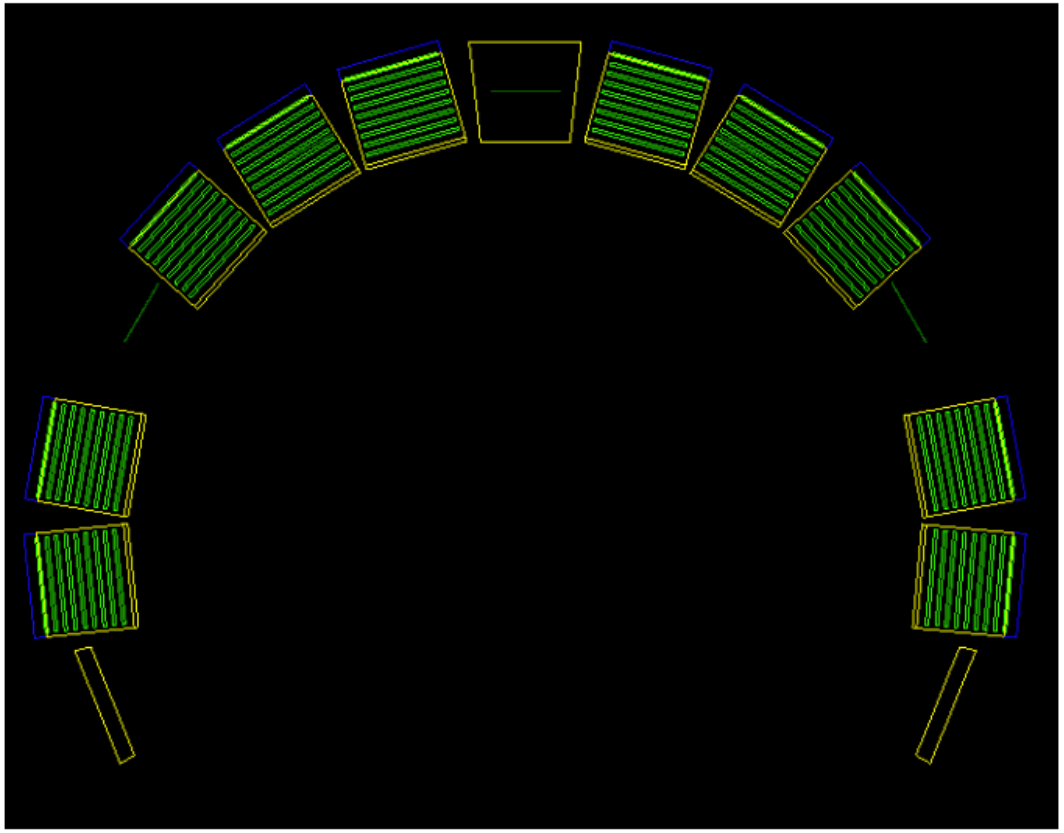
Geometry improvement

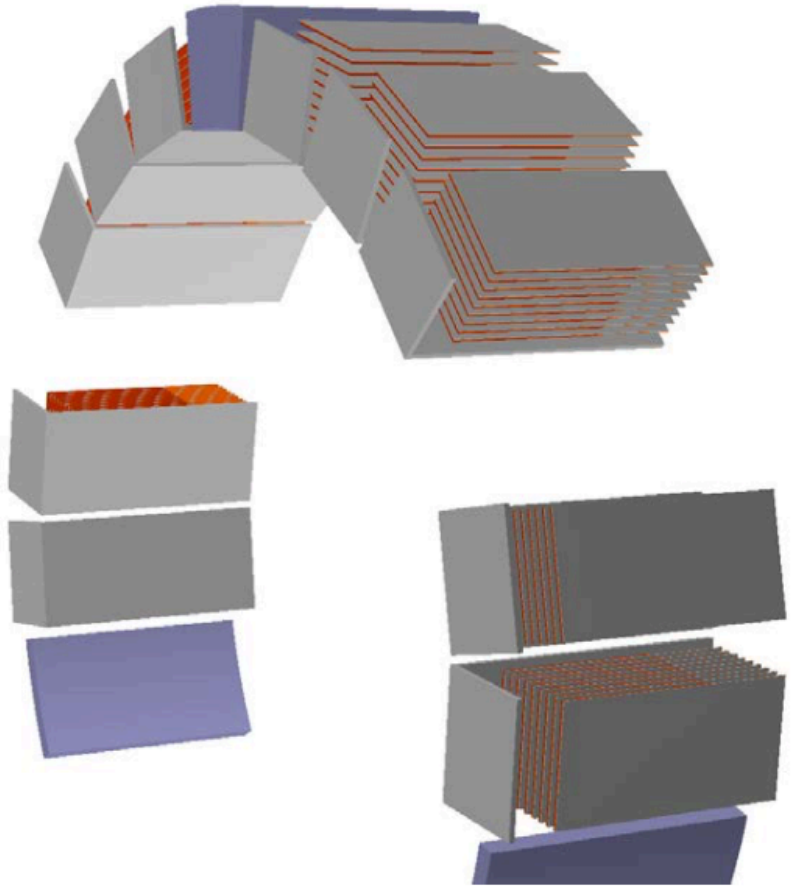
Back plate (2)



Geometry improvement

Crates





Crates around disk, following CAD drawing specifications: front/bottom shield, electronics,

Geometry improvement

Summary

- 5 mm thick Carbon-fiber **inner ring**
- **Inner step-margins** made of Al honeycomb
- **source-plate**: sandwich of 2 Carbon-fiber panels 3mm thick+21.75 mm thick Al honeycomb for supporting the Al pipes
- Al **manifolds** for the source plate
- 100 mm thick Al **outer ring+outer margins** made of Al
- **back-plate** 15 mm thick made of PEEK (with holes for SiPMs)
- SiPM front-end **cooling lines**->Cu bars 5mm thick
- **Faraday cages** for the FEE boards, made of 0.7 mm thick Cu
- Fixed material composition of the crate shields

New dose estimates study

Background source simulated:

✓ **electrons** from μ decay in orbit in the stopping target (DIO)

✓ **deuterons** from the stopping target (DEUTERON)

✓ **neutrons** from the stopping target (NEUTRON)

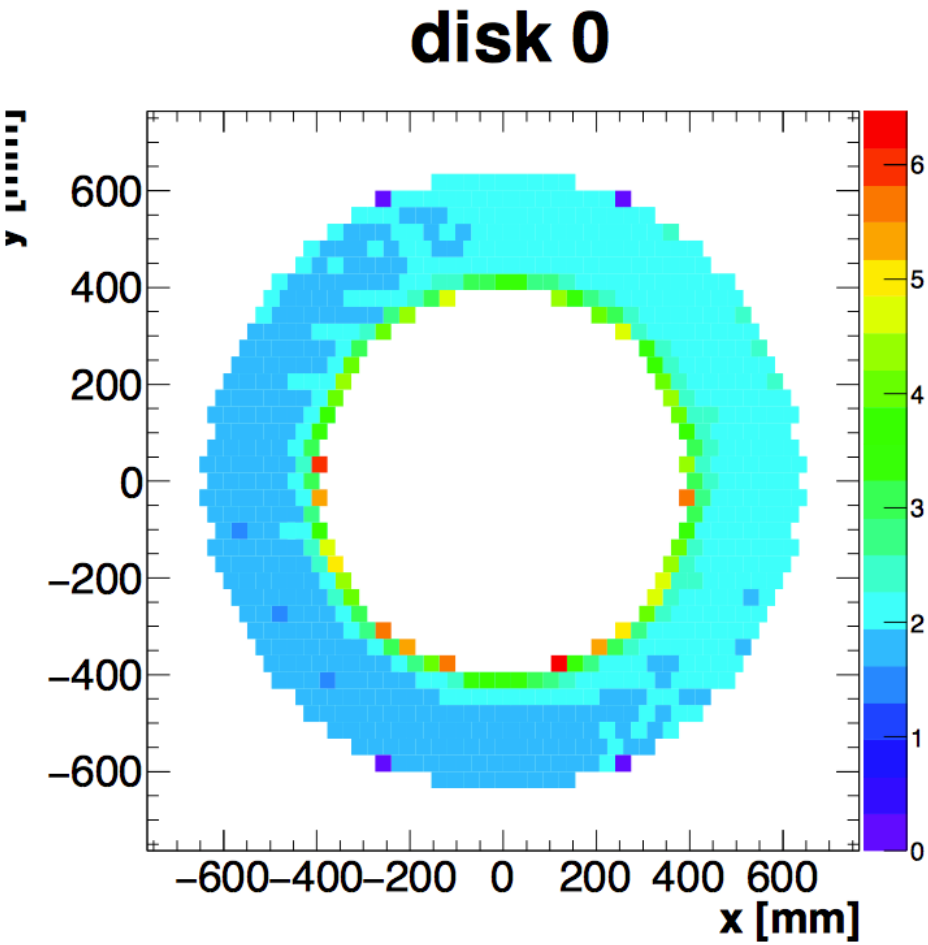
✓ **photons** form the stopping target (PHOTON)

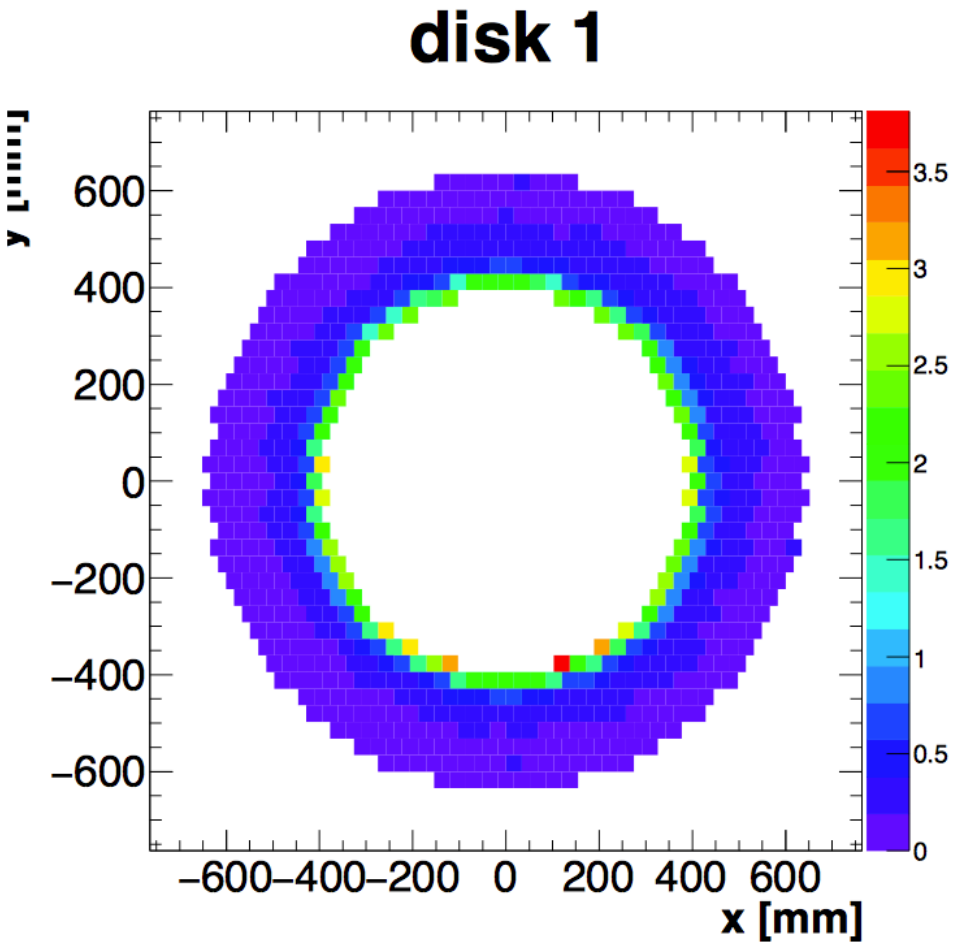
✓ **beam flash** (FLASH)

✓ **μ out-of-target** (OOT)

✓ **protons** from the stopping target (PROTONS)

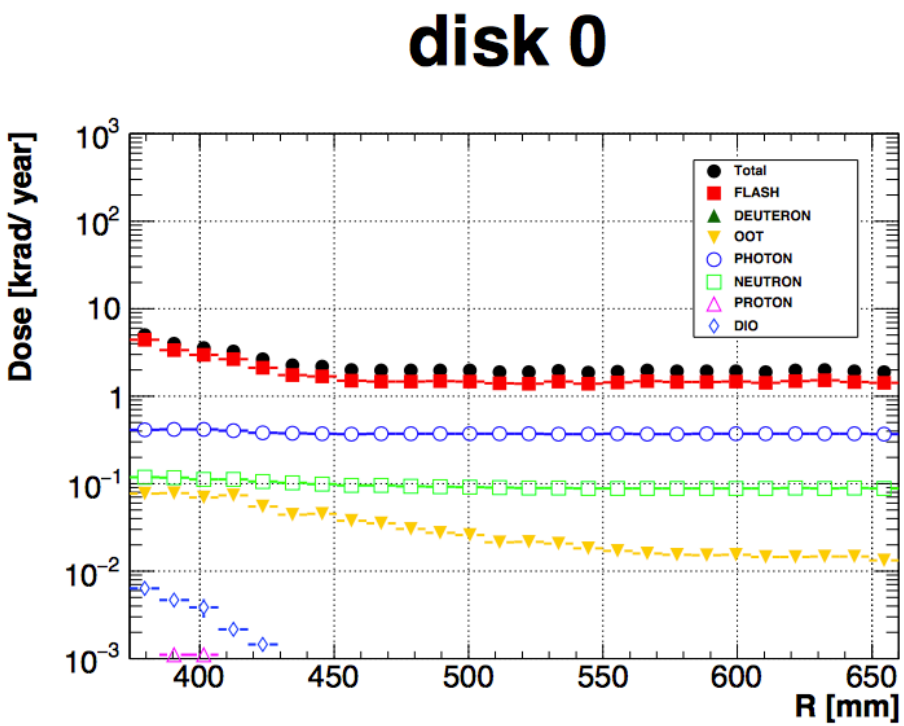
Dose: crystals

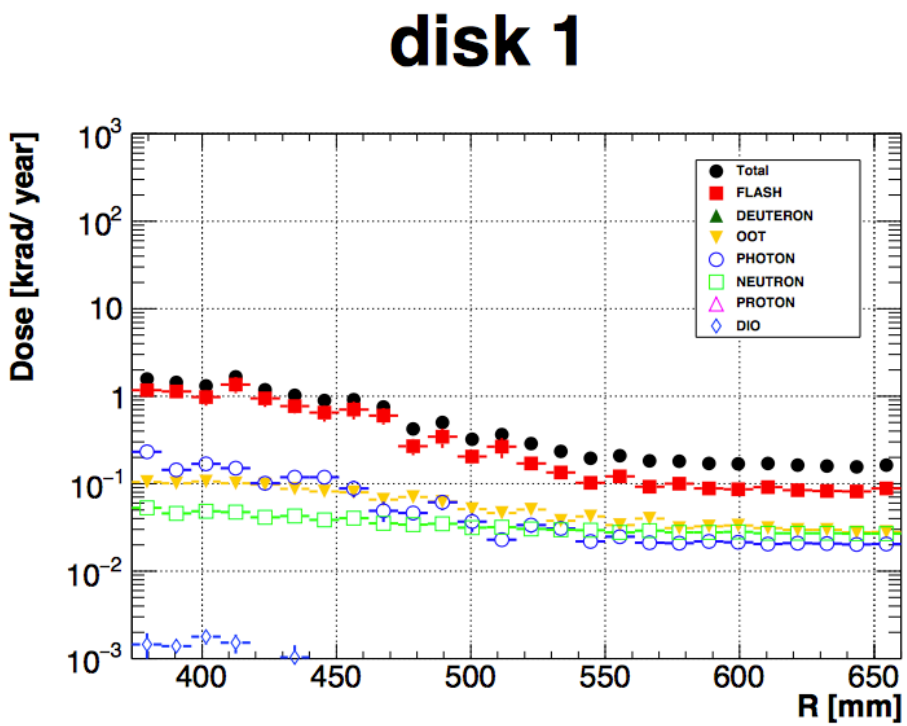




Estimated dose [krad] in the crystals assuming 1 year of run

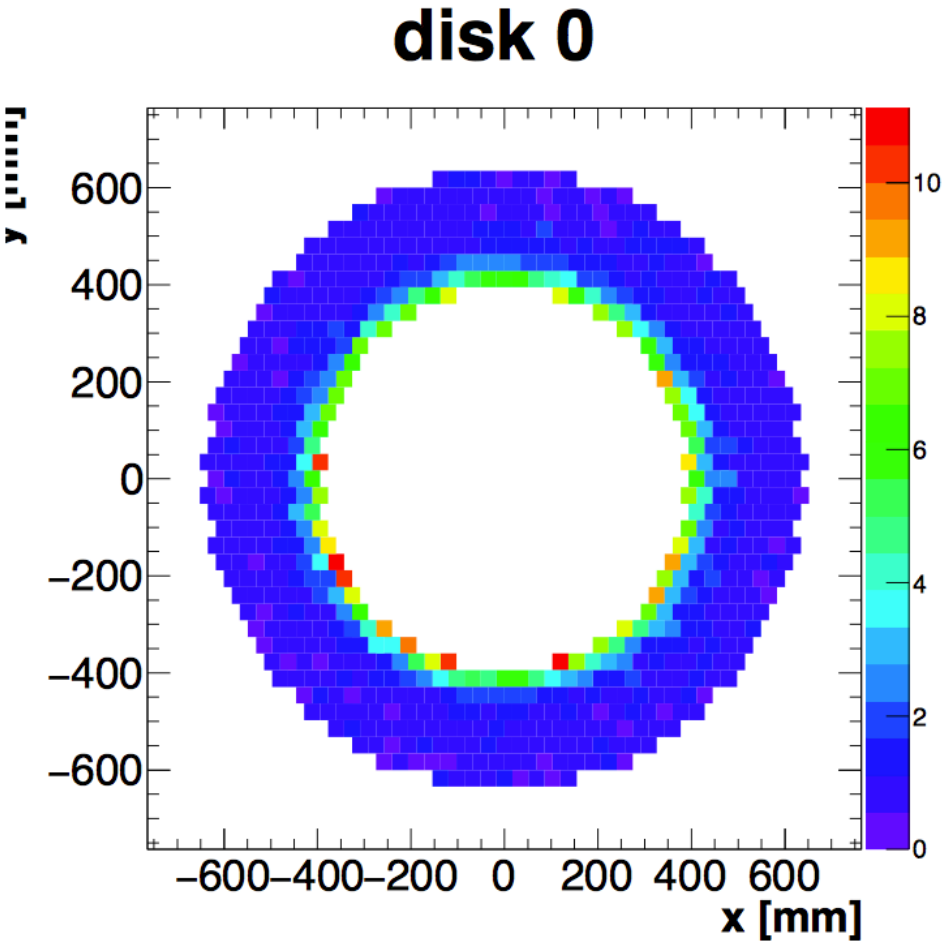
Dose: crystals

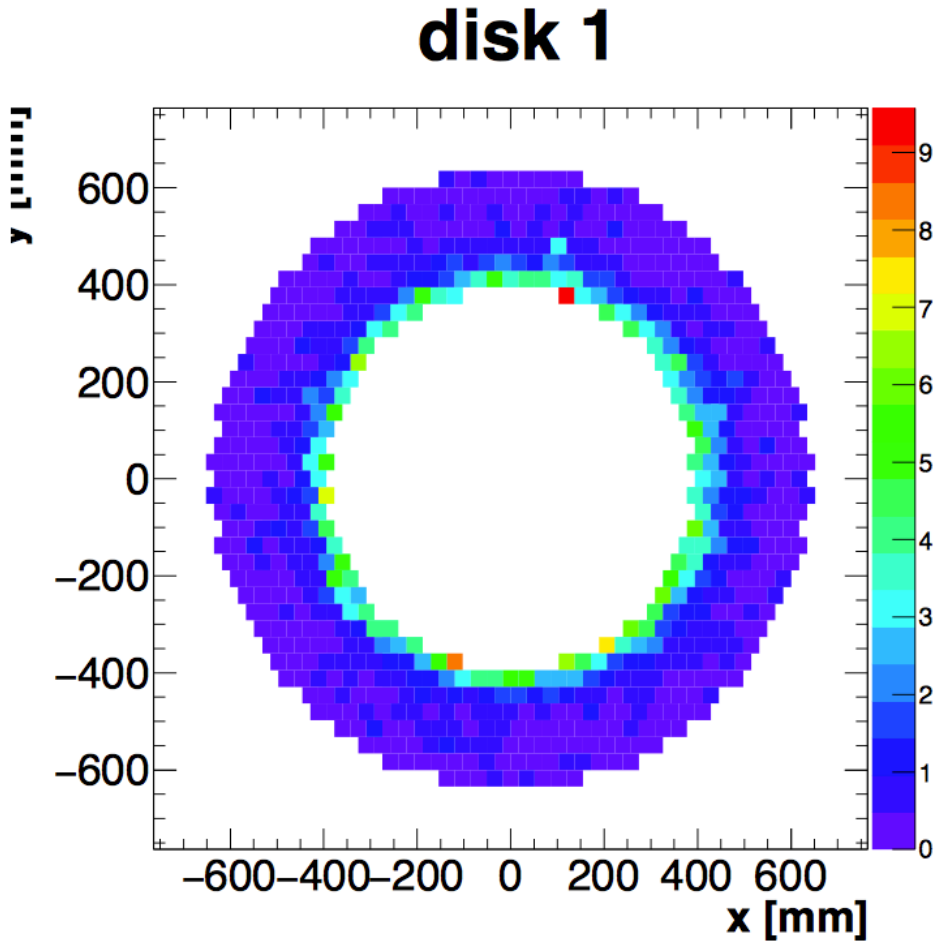




Estimated dose [krad] in the crystals assuming 1 year of run

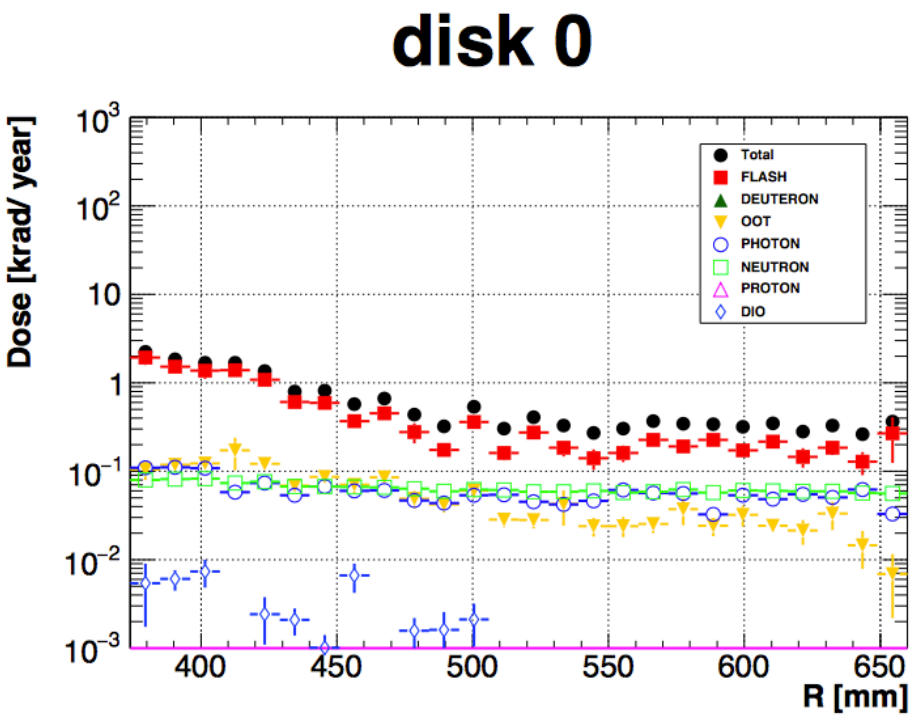
Dose: SiPM

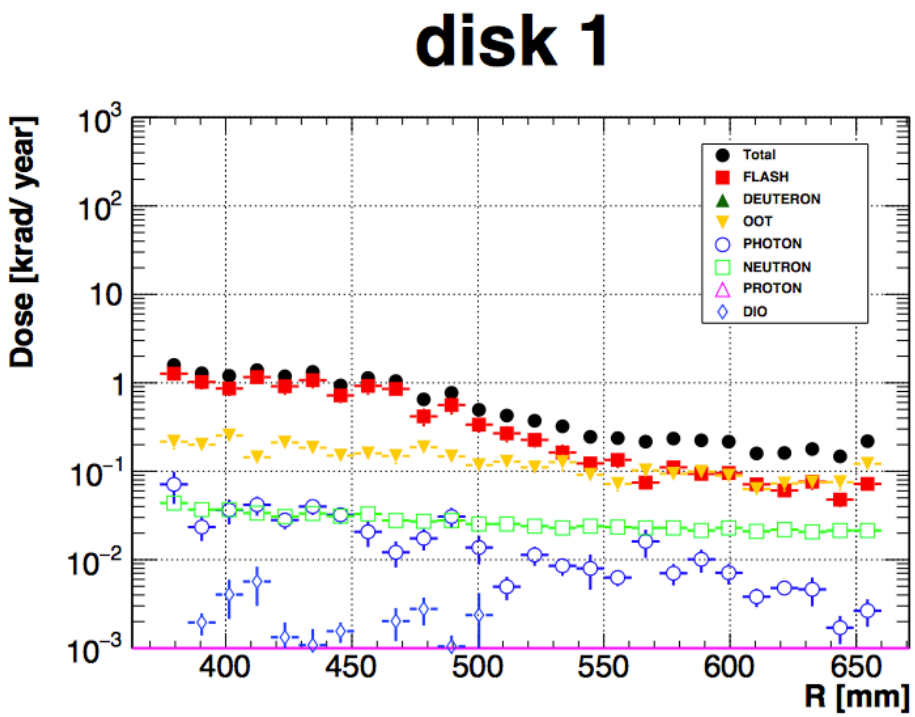




- **scale down by a factor around 2 the estimated dose on crystals**

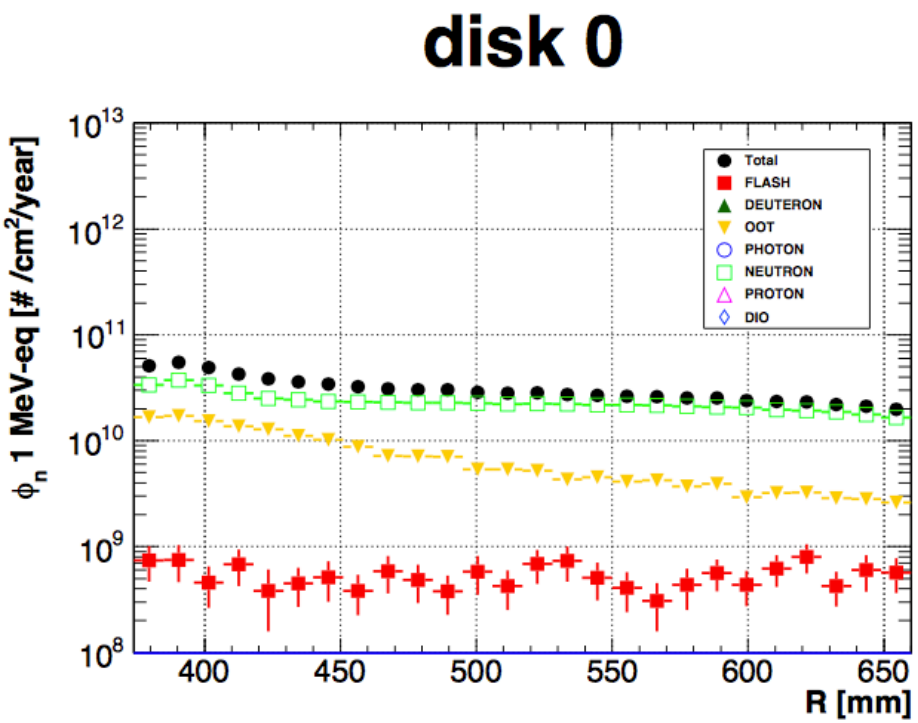
Dose: SiPM

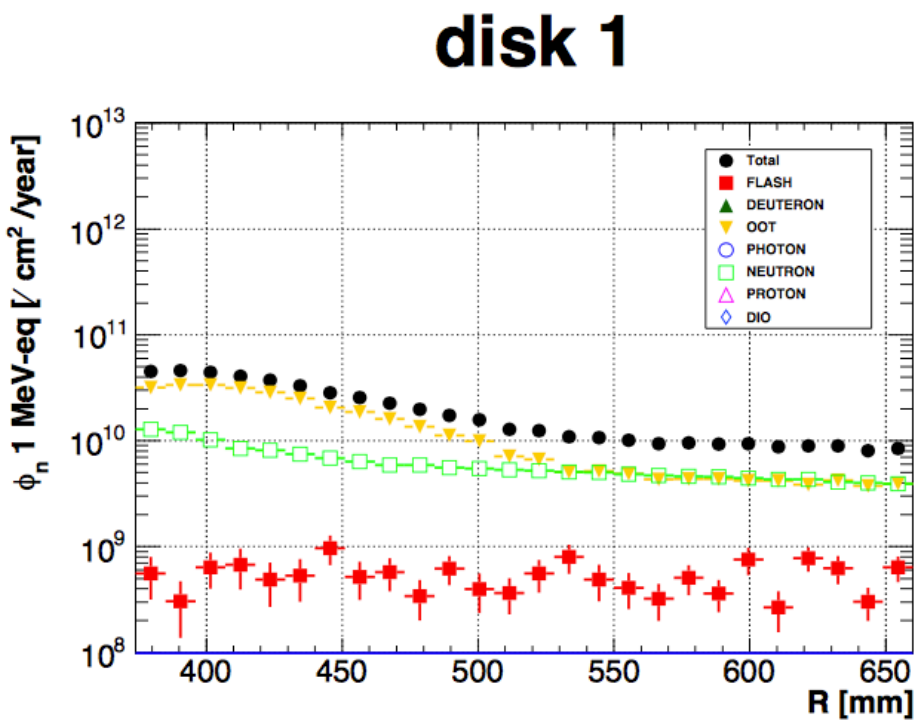




Estimated dose [krad] on SiPMs assuming 1 year of run

Neutron: SiPM





Expected neutron fluence at 1-MeV equivlent energy in the SiPM region

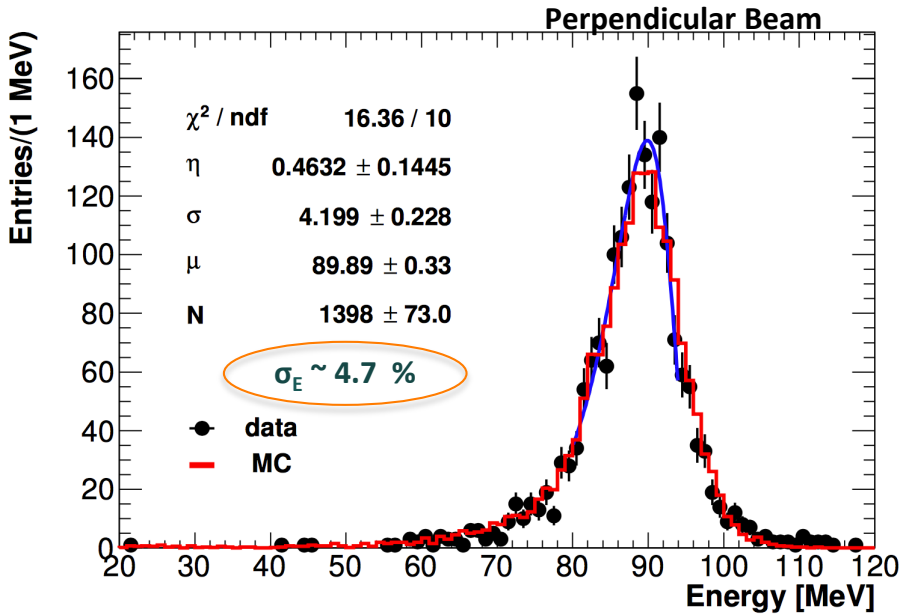
Dose: Summary

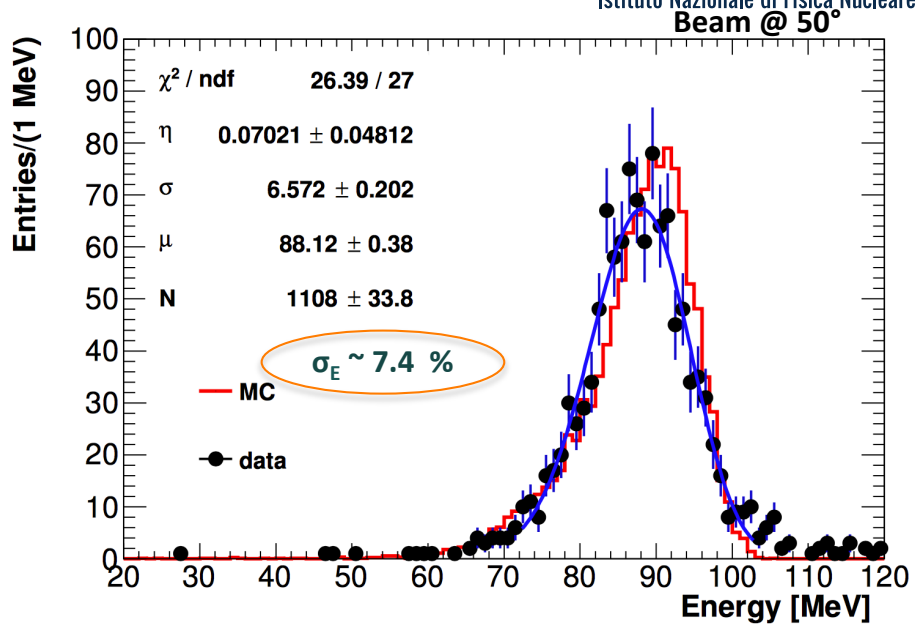
The expected dose and neutron flux was evaluated for all the calo active components using the latest calorimeter model in the simulation:

	Max dose [krad/year]
crystal	6
SiPM	5
FEE	5
DIRAC	0.5
Mezzanine	0.2

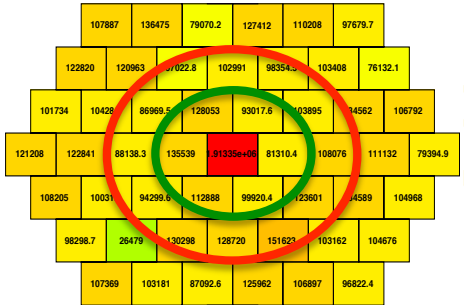
Module0 TB (1)

Data analysis concluded – Energy resolution

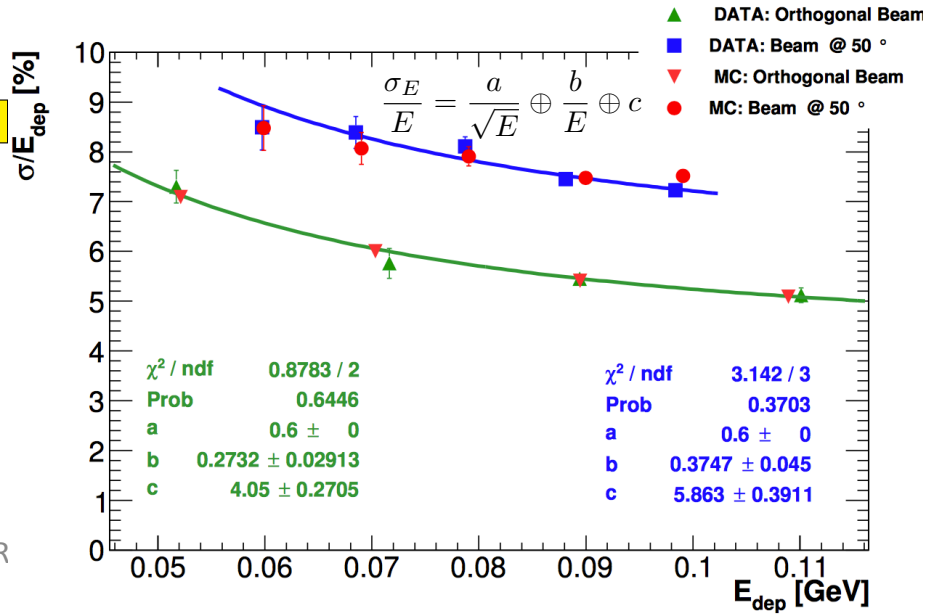




- Single particle selection

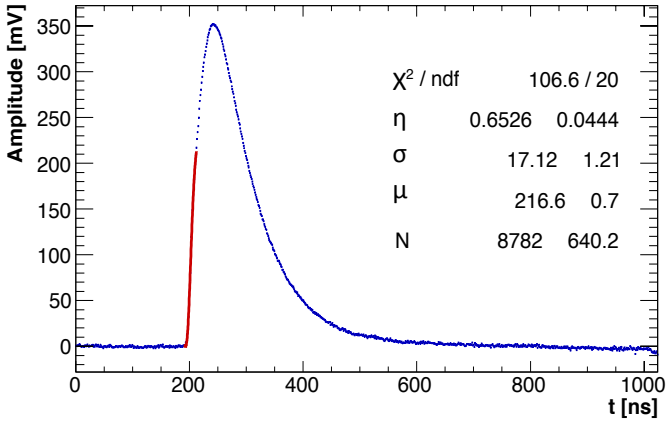


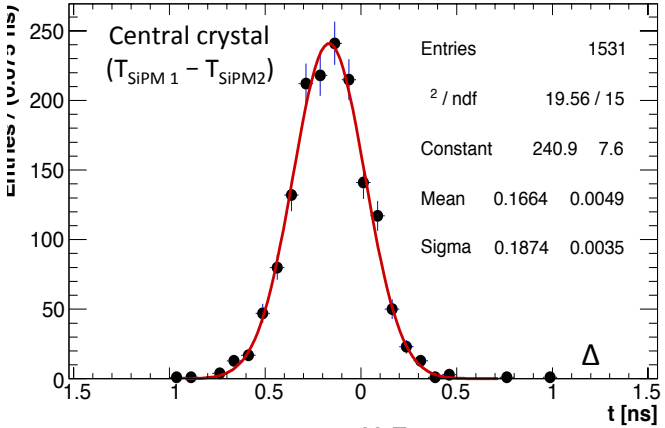
- Calibration
  - MIPs
  - 100 MeV e⁻ beam, up to ring **2**
- Threshold applied after noise run @ 3 σ

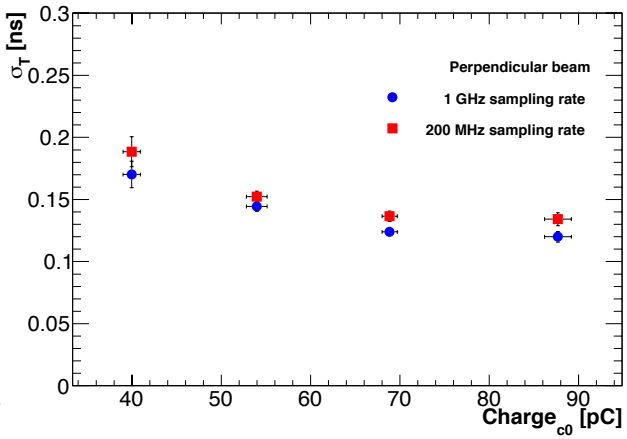


Module0 TB (2)

Data analysis concluded – Time resolution

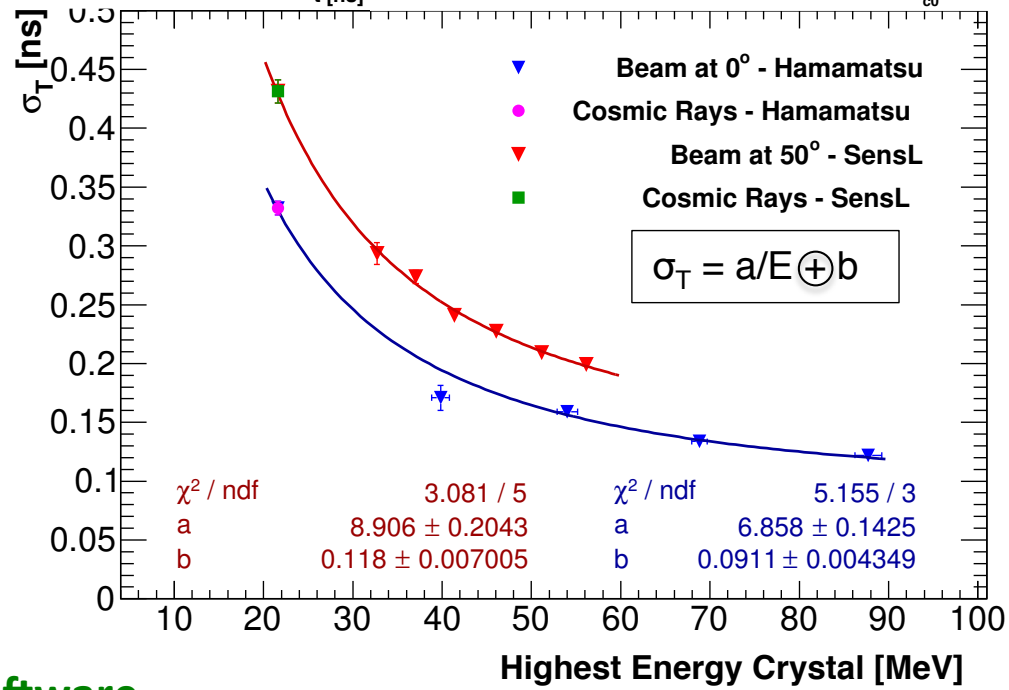






- Selection on single particle
- Log-Normal fit on leading edge
- Constant Fraction method used
  → CF = 5%

σ (T1-T2)/√2 ~ 132 ps
@ E_{beam} = 100 MeV



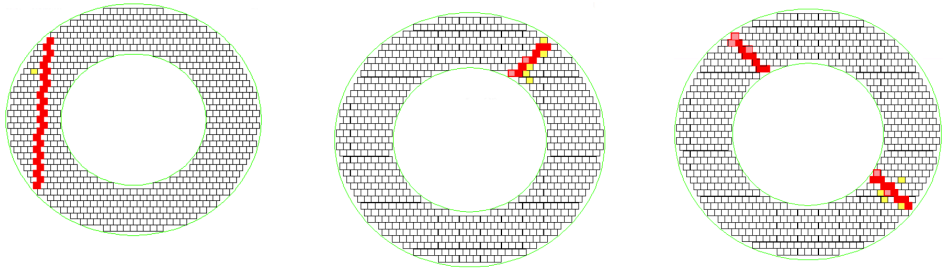
Next step: integrate these reults in Mu2e software

Calorimeter calibration

Cosmic Rays - simulation

Muons generated on a plane at ~11 m above the calorimeter

- 0.5 GeV < E < 500 GeV
- 0°< θ < 90°;

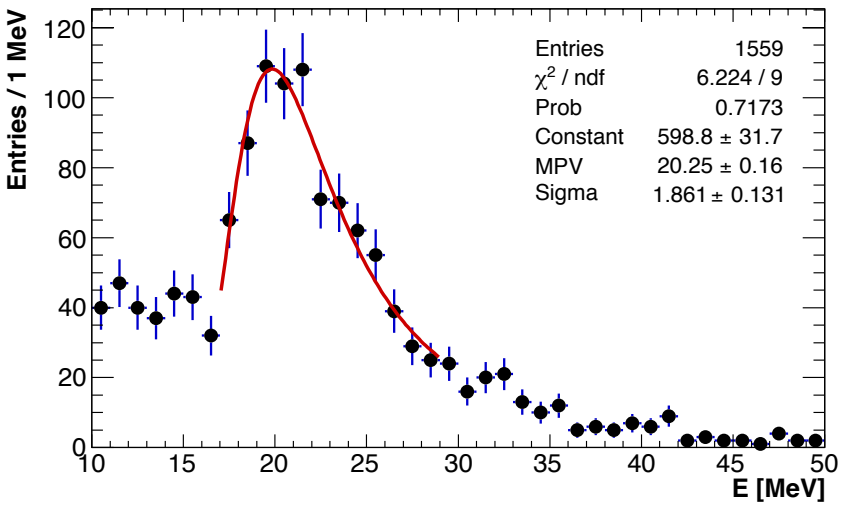


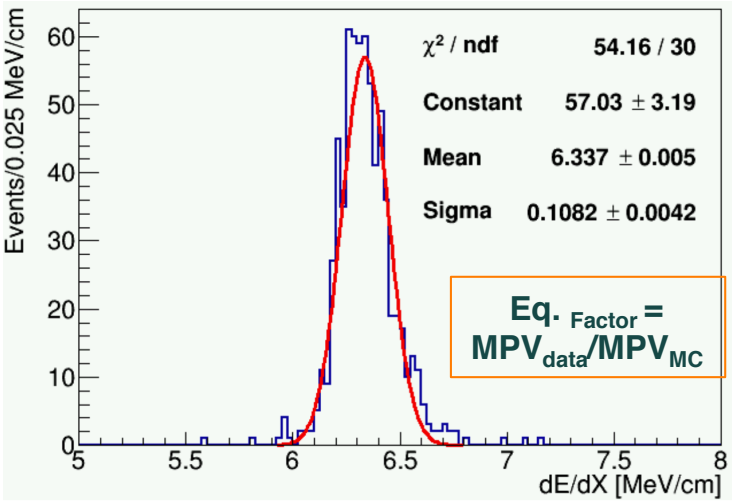
Trigger (15 Hz):

- at least 3 crystals with E_{tot} > 6 MeV
- energy deposit above 1 MeV for clustering

Muon trajectory

- Linear fit in the transverse plane, energy weighted **least square method**
- 0.6 < χ^2/ndof < 1.4

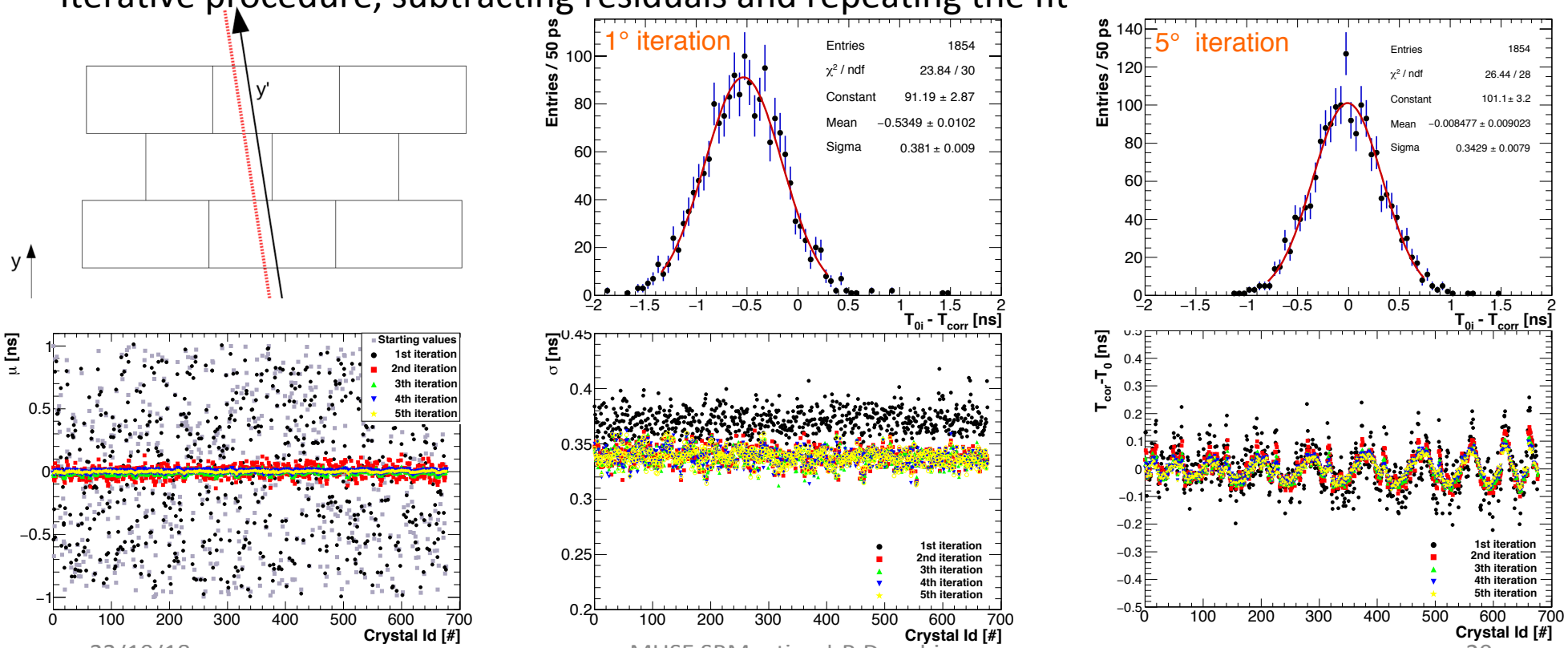




Calorimeter calibration

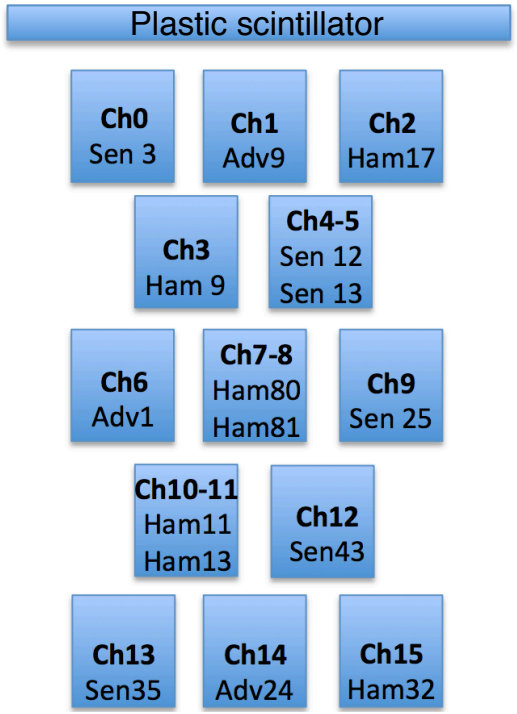
Cosmic Rays - simulation

- Same TRG
- For each event, **linear fit** to time vs relative distance of the cells, imposing light velocity. **Common T0 subtracted to all cells**
- Gaussian fit on residuals of each channel
- Extract first calibration set from the fit (Tcorr)
- Iterative procedure, subtracting residuals and repeating the fit



Calorimeter calibration

Cosmic Rays - Data



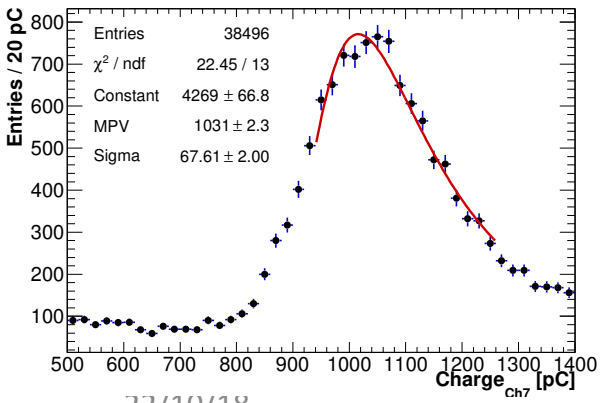
Cosmic ray run using **16 channels of the Module-0**

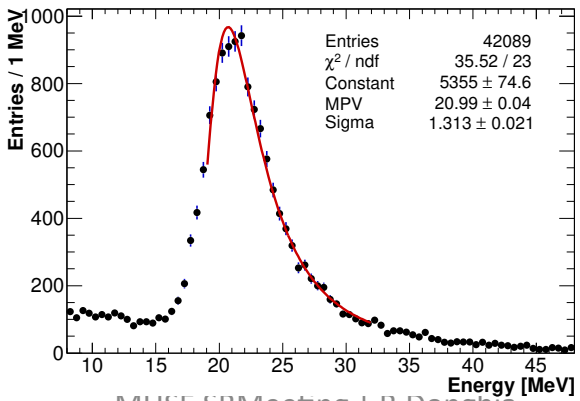
- 13 crystals, 3 with double readout
- **New DAQ system!**
- TRG:
  - plastic scintillators counters
  - Offline: cut on top layer energy deposit

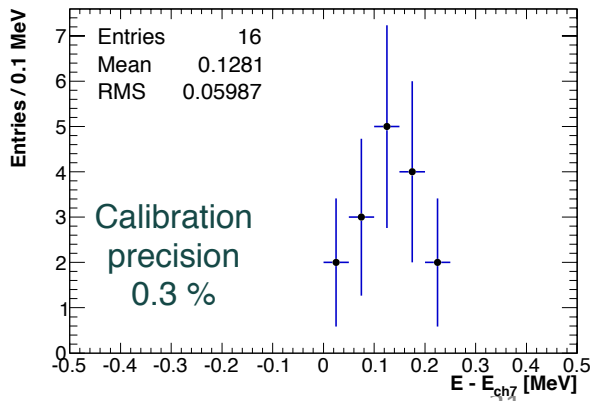
Same TB analysis and same MC procedure

- Charge: wf integration in a 250 ns range

Plastic scintillator





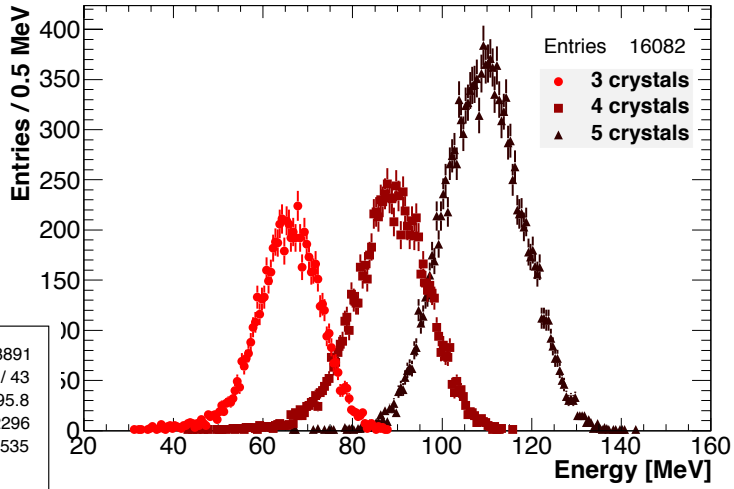


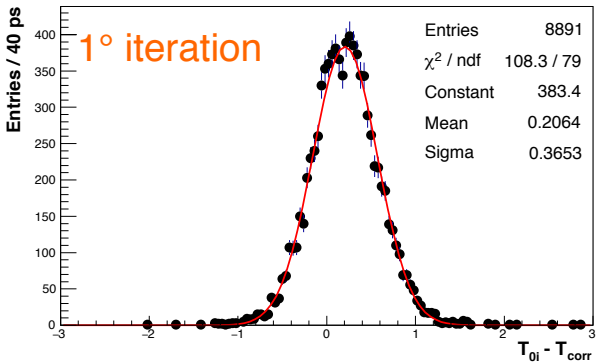
Calorimeter calibration

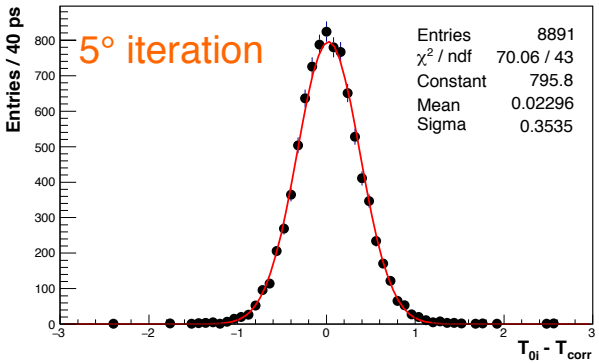
Cosmic Rays - DATA

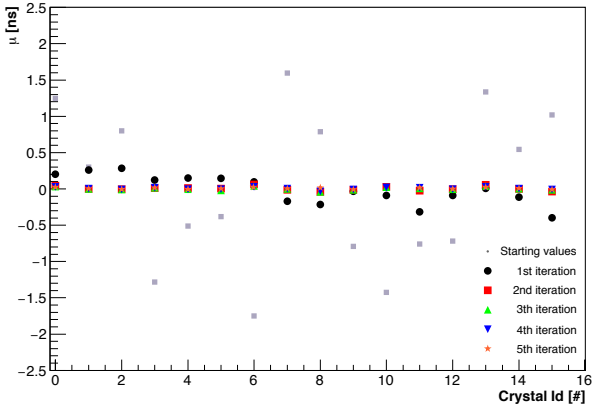
Same TB analysis and same MC proceedure

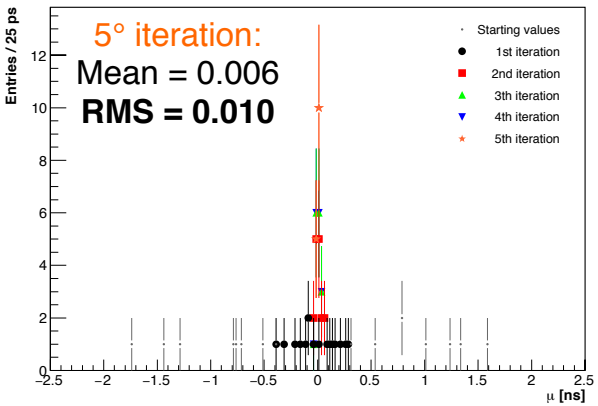
- Time reconstruction: logn fit + CF method
- Same TRG
- Linear fit on CR trace

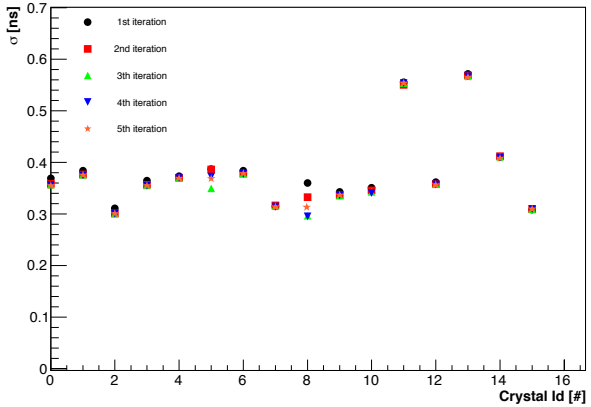








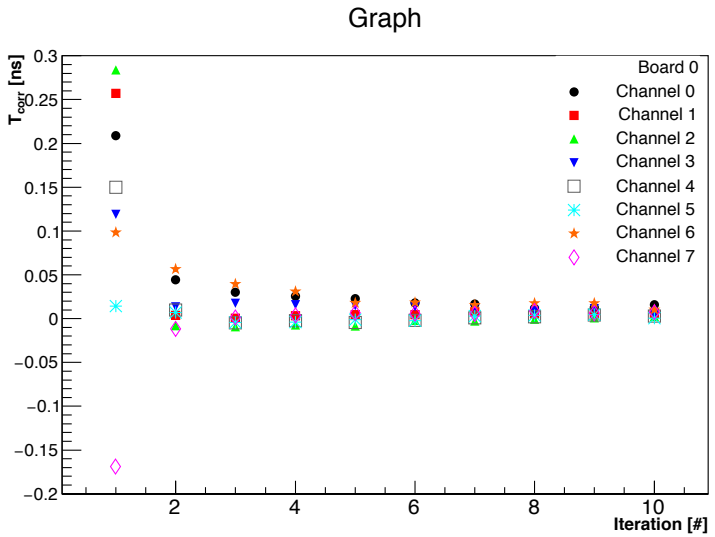


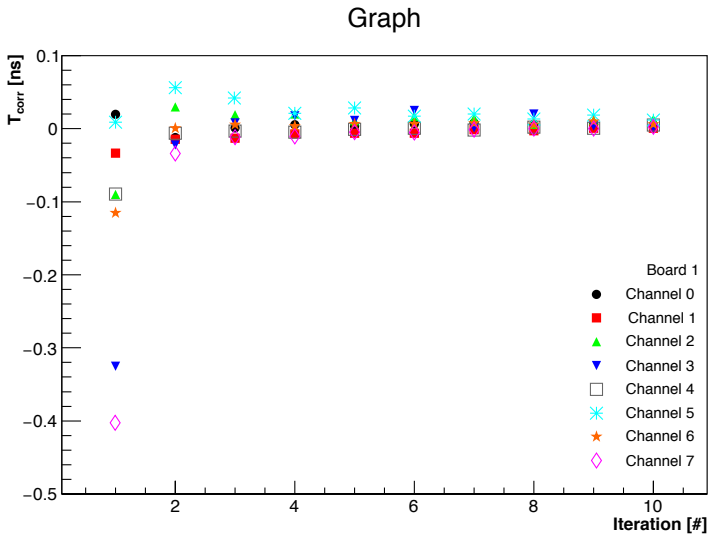


Calorimeter calibration

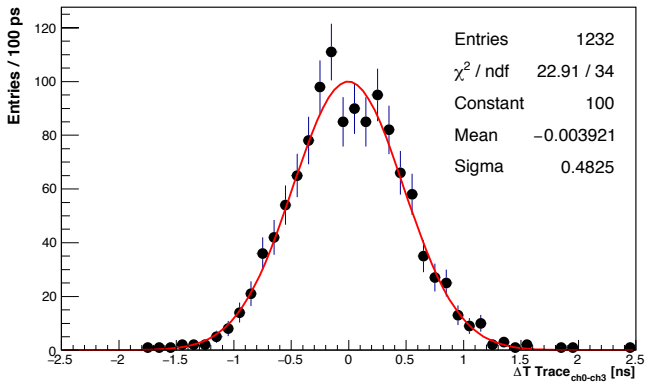
Cosmic Rays - data

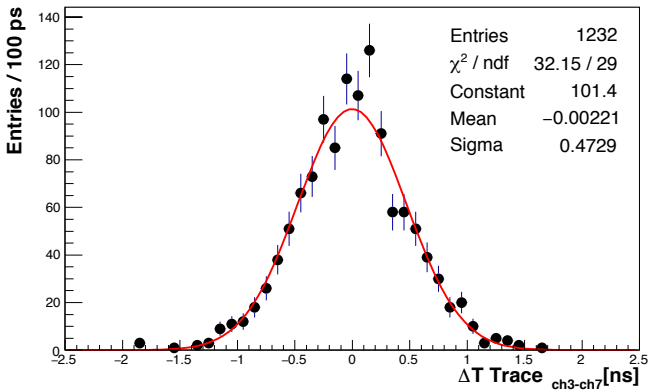
After 5 iterations the correction is comparable with zero

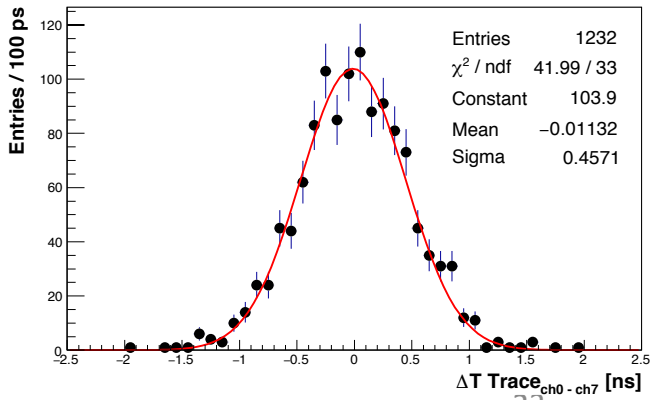




Time resolution neighboring crystals:

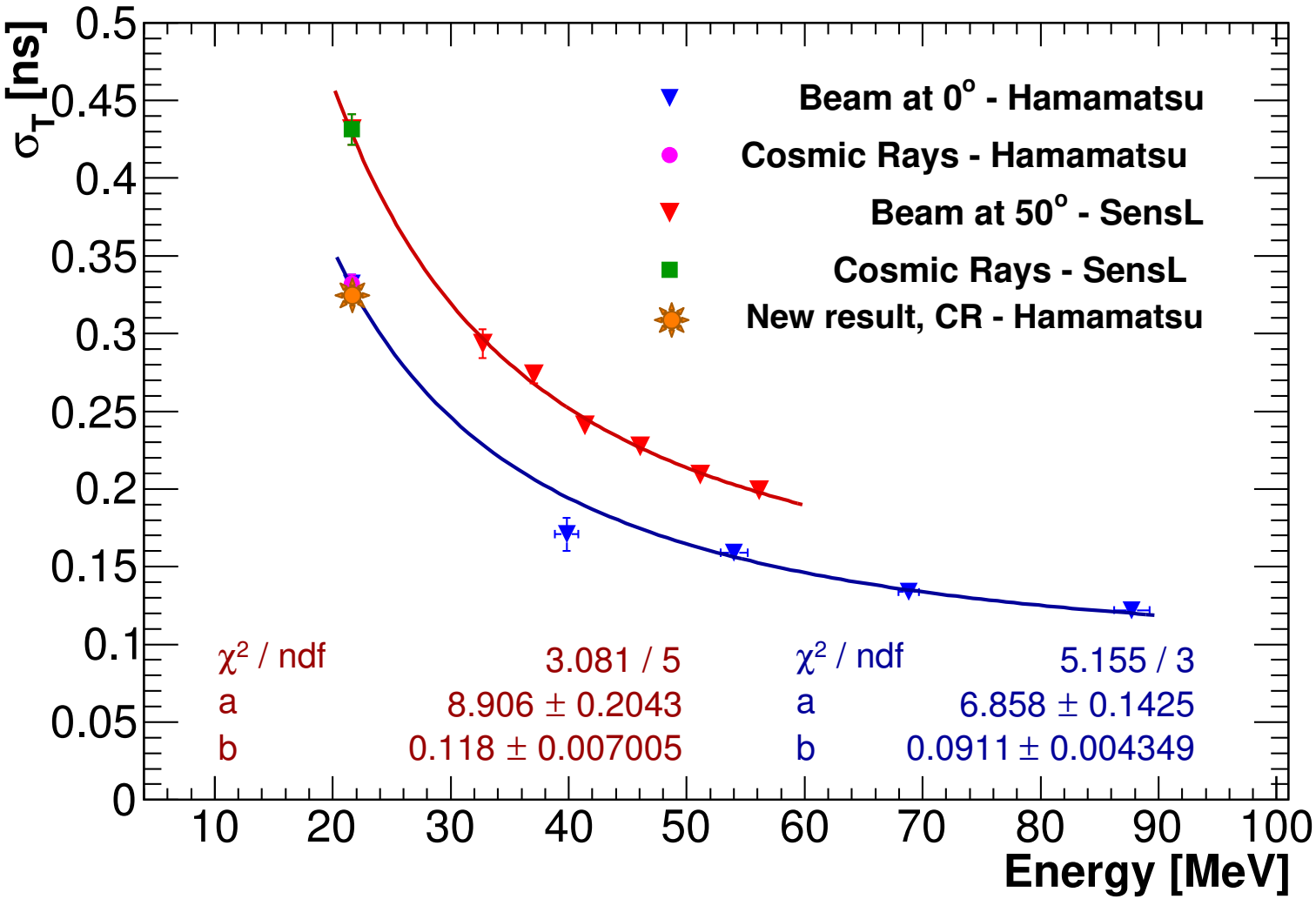






Calorimeter calibration

Cosmic Rays - data



Offline filters study

There has been substantial improvements in the pure track and track-calo triggers:

- **Track trigger**: latest improvements have decreased **running time around 3 ms**
- **Dual track – calo trigger**: on-going work to merge sequences with track / calo triggers
- **Calorimeter trigger**: current algorithm is fast (<1 ms) with ~90% efficiency

Additional physics trigger → ΔL=2, calibration, monitor, off-spill

Dual Calo TRG
Quick review

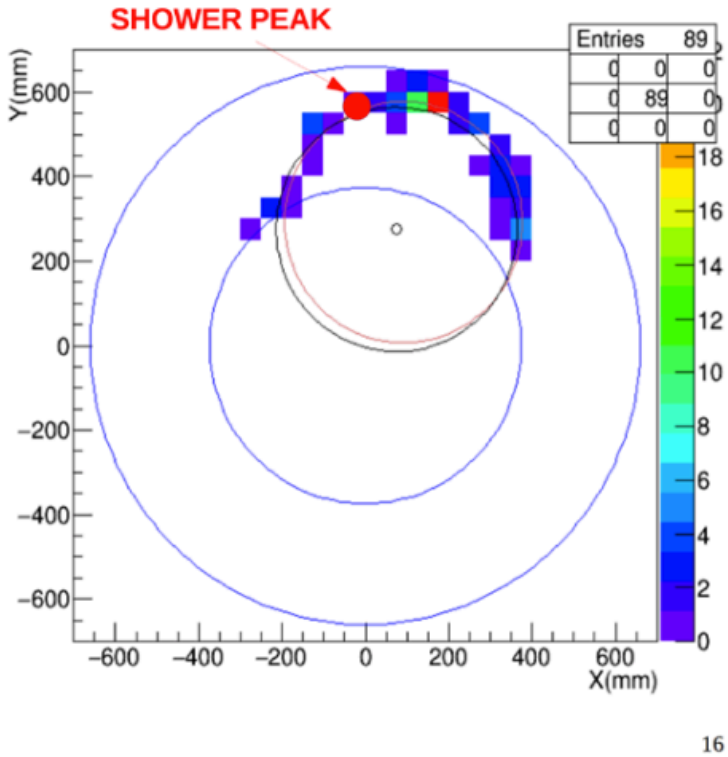
Select tracker hit based on the calorimeter cluster time / position and try to reconstruct the track using a semi-analytical model

CE MIXED TRACKER-CALORIMETER TRIGGER PROPOSAL (doc-db 15369)

QUICK REVIEW:

8) Select the hits on the circle (distance<50 mm)

Doc-db 15962



CE MIXED TRACKER-CALORIMETER EFFICIENCY vs REJECTION

preselection	CE efficiency	BKG rejection
Good tracks	90.9±0.1%	102±2
Good tracks matching a cluster with E>50 MeV	96.2±0.1% 95.3±0.1%	570±30 1030±70

TIME PERFORMANCE

TimeTracker printout (ms)	Min	Avg	Max
makeSH:StrawHitReco	0.4	1.3	2.3
FilterEcalMixedTrigger	1.0	2.1	5.7

10000 events on mu2ebuild01
Average Total: 3.5 ms

Subtracting
Straw Hit position reconstruction (1.3 ms) and ECAL waveform peaks search (1.4 ms)
We should able to reach ~0.7 ms

Summary and conclusion

Good progress done on the calorimeter simulation

- Most of the components included in geometry simulation
  - Few small pieces missing (connectors, FEE pin hole…)
- New dose study performed
  - Waiting fro tracker shielding/geometry updates
- Module0 data anlysis concluded
  - It is needed to include the results in Mu2e framework
  - Additional cosmic ray test performed to validat the calorimeter calibration procedure
- Offline filters/triggers study ongoing