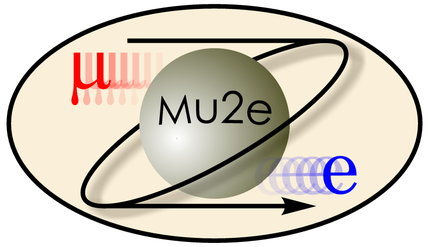
Master's Thesis Proposals from the Mu2e and Crilin (RD_MUCOL) LNF Groups



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19/06/2025

The Crilin Electromagnetic Calorimeter

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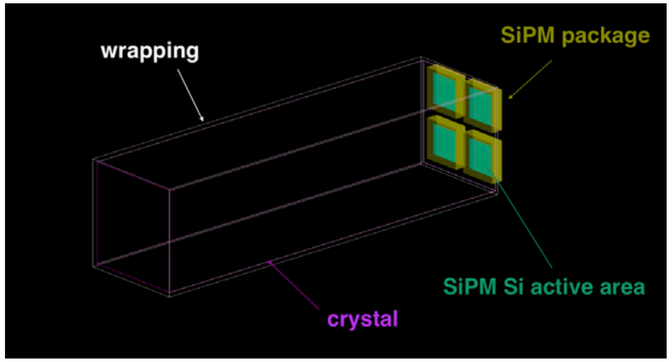
The Crilin Calorimeter

Crilin (crystal calorimeter with longitudinal information): electromagnetic calorimeter R&D for the future high-energy collider

Semi-homogeneous ECAL made of **crystal matrices** interspaced and read out by 2 series of 2 UV-extended **SiPMs**



Key assets:

- **fine granularity**
- good **resistance to radiation**
- modular architecture → **longitudinal segmentation**
- excellent **timing** (<100 ps)

Crystal choice:

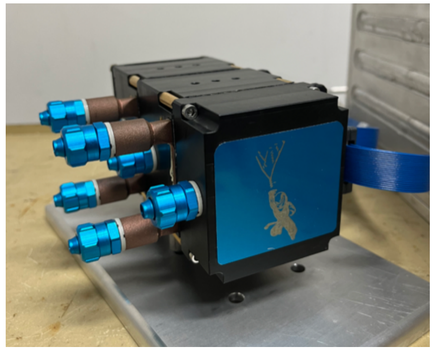
- **high density** → compact
- **fast response**
  - **PbF_2** (high-density Cherenkov crystal), with **PWO-UF** and **LYSO** as possible alternatives

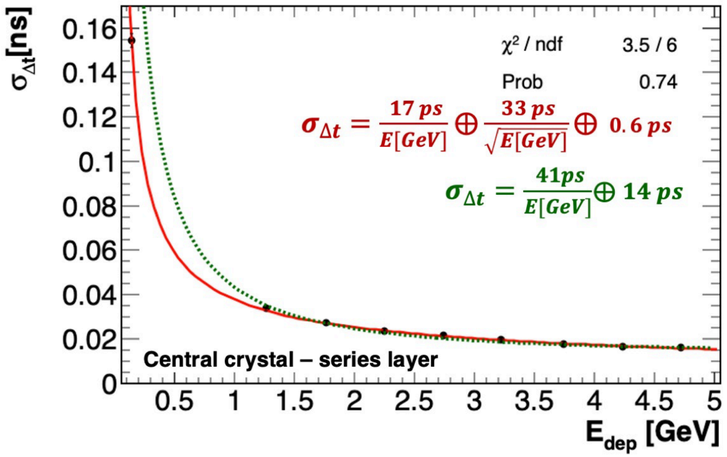
Peculiar features:

- **semi-homogeneous** (exploits the strengths of both sampling and homogeneous calorimeters)
- **flexibility** to adjust crystal size for tailored solutions

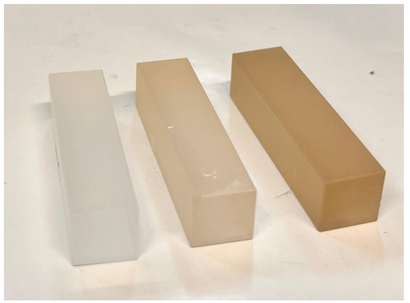
What has been done up to now?

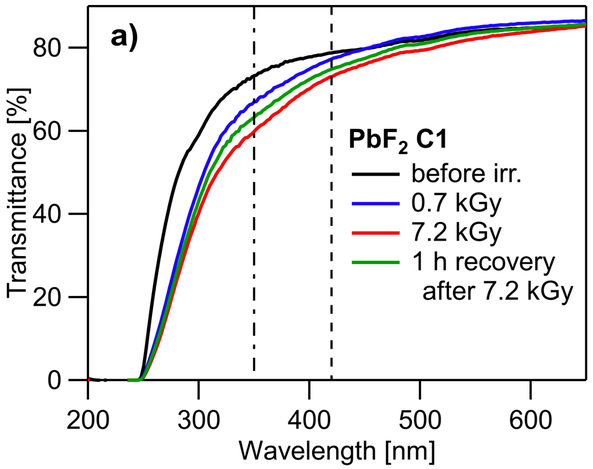
✓ **Built/tested** a two-layer module (Proto-1)



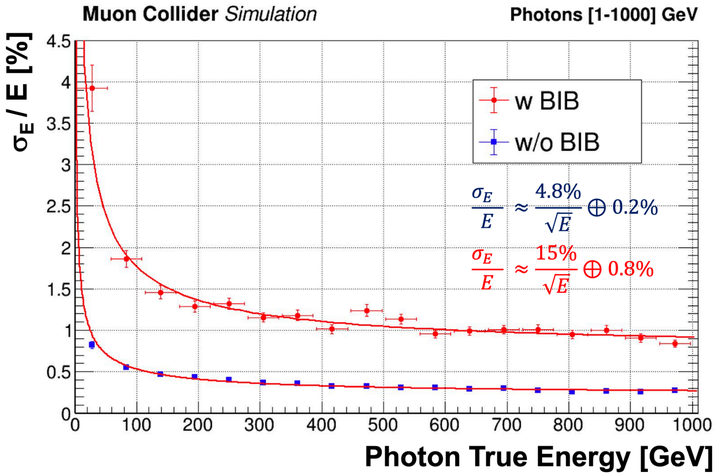


✓ **Irradiation** of single crystals and Proto-1

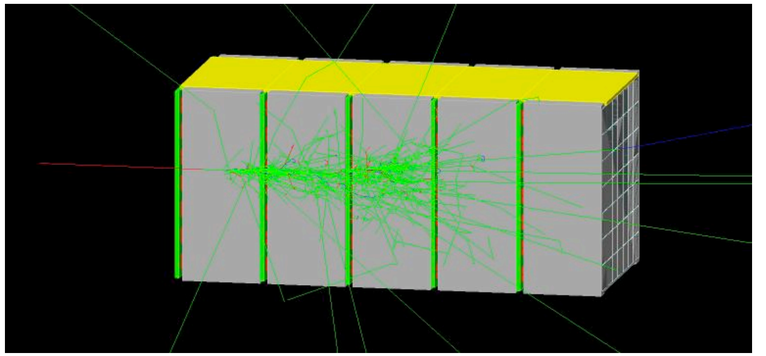




✓ **Simulations** in the Muon Collider framework



✓ **Design** of a full-scale prototype



What's Next?

Next big step: construction, operation and testing of a **full-scale prototype** able to contain high-energy electromagnetic showers!

Design/electronics changes will be validated with a beam test on a smaller prototype (similar to Proto-1)

→ September 2025 beam test (Thesis Proposal #1)

Also, in order to have conclusive data on the effect of **high dose on SiPMs and crystals** (decoupling the two effects), a complex irradiation campaign is foreseen

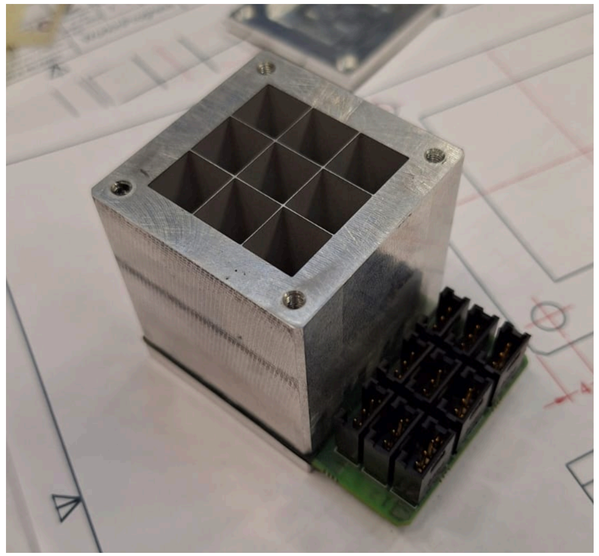
→ irradiation campaign (Thesis Proposal #2)

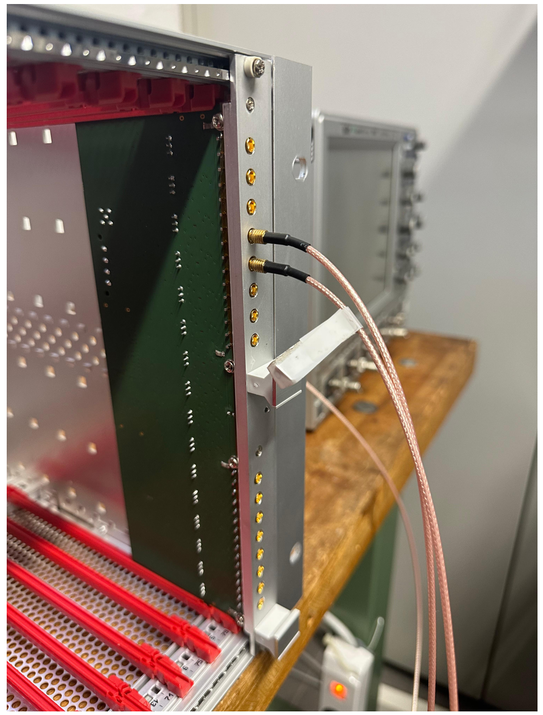
The R&D will have its **final milestone** during the full-scale prototype beam test

→ March 2026 beam test (Thesis Proposal #3)

Thesis proposal #1: Sept 2025 beam test

Test of the **new mechanics** (super-thin aluminum matrix, new crystal dimension + reflective varnish) and the **new electronics** (custom-made + picoTDC discriminator for timing)





- **What you will do:**

  take part in the beam test (help setting up the apparatus, live monitoring of the acquired data, operating the Crilin prototype and our custom-made MIP trackers, see how the DAQ works)

  analyse the acquired data (time resolution, light yield studies, position reconstruction)

- **What you will learn:**

  how to work with the **full hardware/electronics setup**

  basics of scientific programming using **python/ROOT**

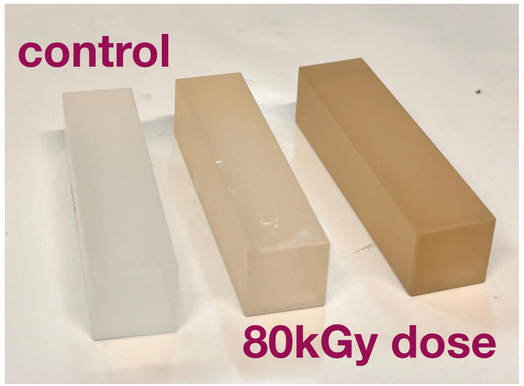
- **Indicative start date:** early Fall 2025

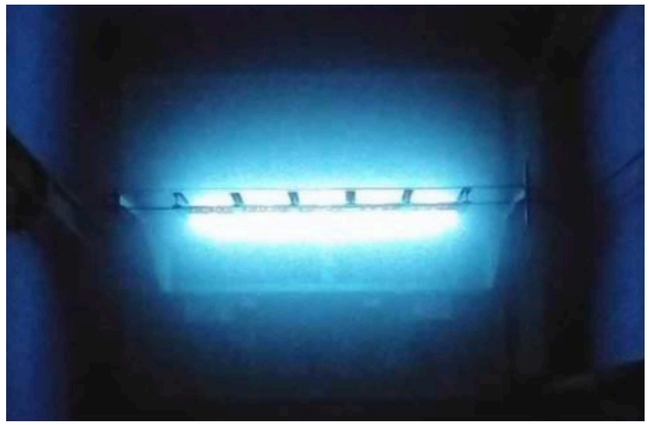
- Chance to participate to a week-long beam test at **CERN**

Thesis proposal #2: irradiation campaign

The previous irradiation test was performed on the full module (mechanics + SiPMs + crystals)

New test to disentangle the various contributions: acquire data in **two configurations** (SiPM vs crystal+SiPM) using a laser source, for various irradiation levels





^{60}Co source

- **What you will do:**

  take part in the irradiation test (help setting up the apparatus, live monitoring of the acquired data, using the laser system..)

  analyse the acquired data (energy response to a laser source for different ionising doses, crystal transparency loss, SiPM dark count rate..)

- **What you will learn:**

  how to work with the **hardware/electronics setup**, and how the setup reacts to **heavy doses of radiation**

  how a DAQ works and how to **handle real-life data taking**

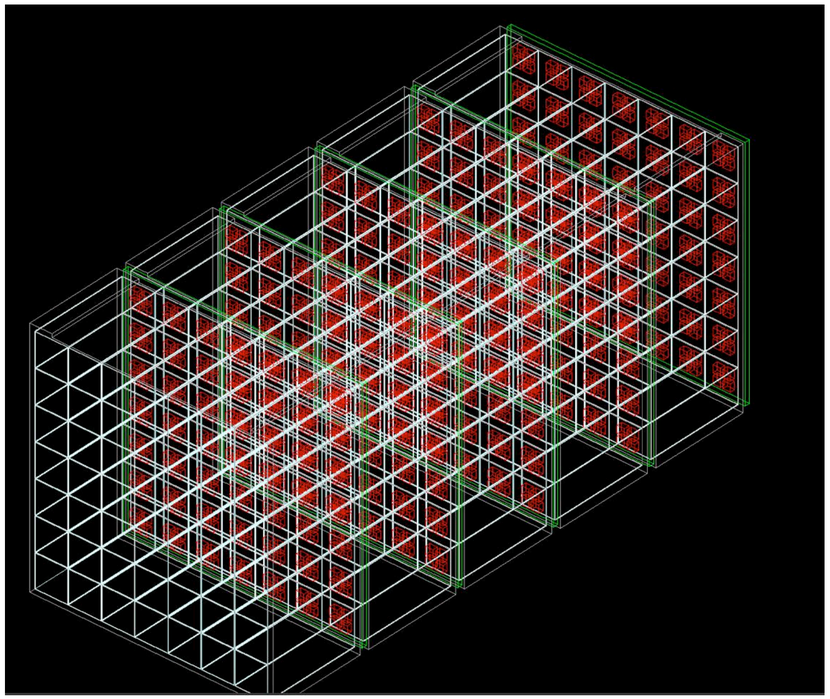
  basics of scientific programming using **python/ROOT**

- **Indicative start date: Winter 2026**

- Chance to participate to a complex irradiation campaign using a ^{60}Co source @ Calliope (ENEA Casaccia)

Thesis proposal #3: March 2026 beam test

Test of the **full-scale prototype**, with finalised design and electronics. Will give a final assessment of the calorimeter's performances (we expect $\sigma_E/E \sim 7\%/\sqrt{E}$)!



- **What you will do:**

  take part in the beam test (help setting up the apparatus, live monitoring of the acquired data, operating the detector..)

  optimise the online DAQ system (understand the DAQ logic, synchronise the acquisition of the electronics boards for 250 read-out channels..)

  analyse the acquired data (time and energy resolution, position reconstruction..)

- **What you will learn:**

  how to work with the **full hardware/electronics setup**

  how a DAQ works and how to **handle real-life data taking**

  basics of scientific programming using **python/ROOT**

- **Indicative start date:** late Winter/Spring 2026

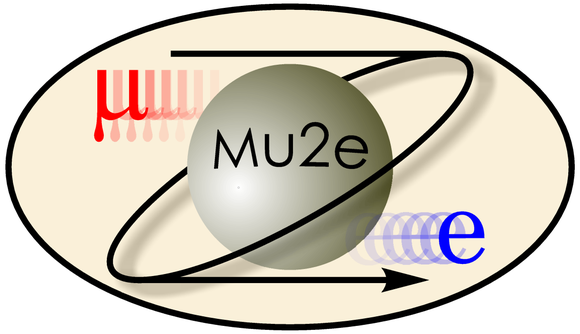
- Chance to participate to a week-long beam test at **CERN**

So… Why Crilin?

If you want to pursue a Master's thesis in the Crilin LNF group you will:

- enter a **young working group**, where you will be aided by 1 PhD student (me) and 2 PostDocs
- find yourself in a **"man-sized" R&D**, i.e. you can contribute to all decisional and experimental steps
- have a **lab** here (building 36), where you can work on the setup/DAQ
- have the chance to present your work in physics **conferences** such as SIF
- be able to **publish** an article describing your results with us!

The Mu2e Electromagnetic Calorimeter



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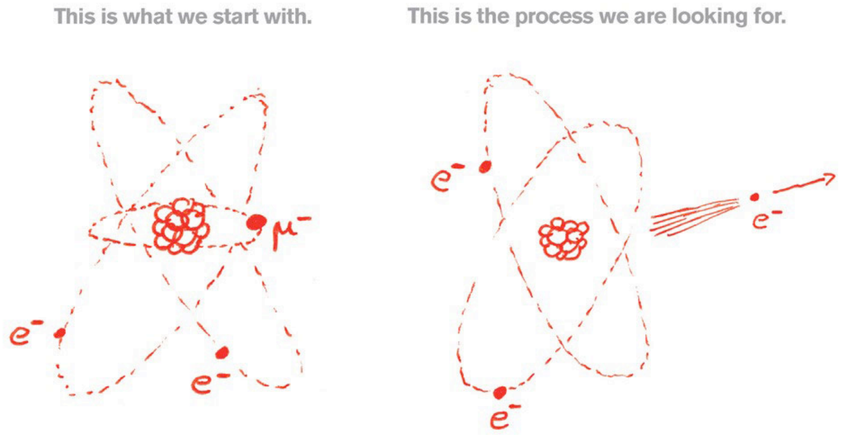
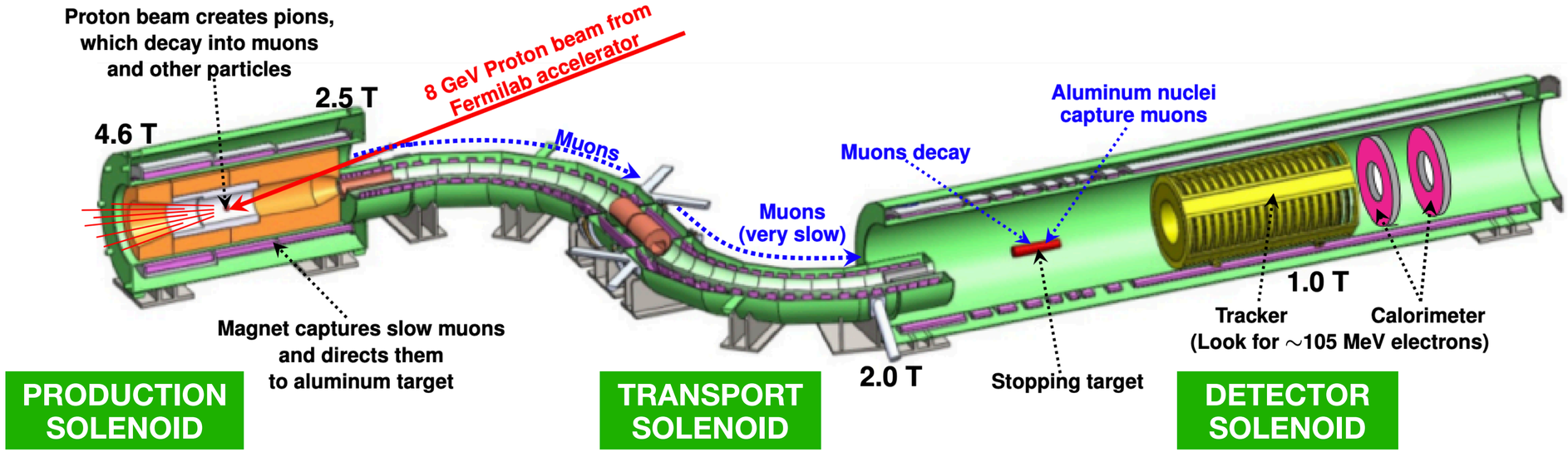
The Mu2e experiment

Mu2e will search for **charged lepton flavour violation**: conversion of a muon into an electron in the field of an Al target

The experiment is based in **Fermilab**, where the experimental apparatus is now being put together piece by piece → **data taking** foreseen in the **next few years**!



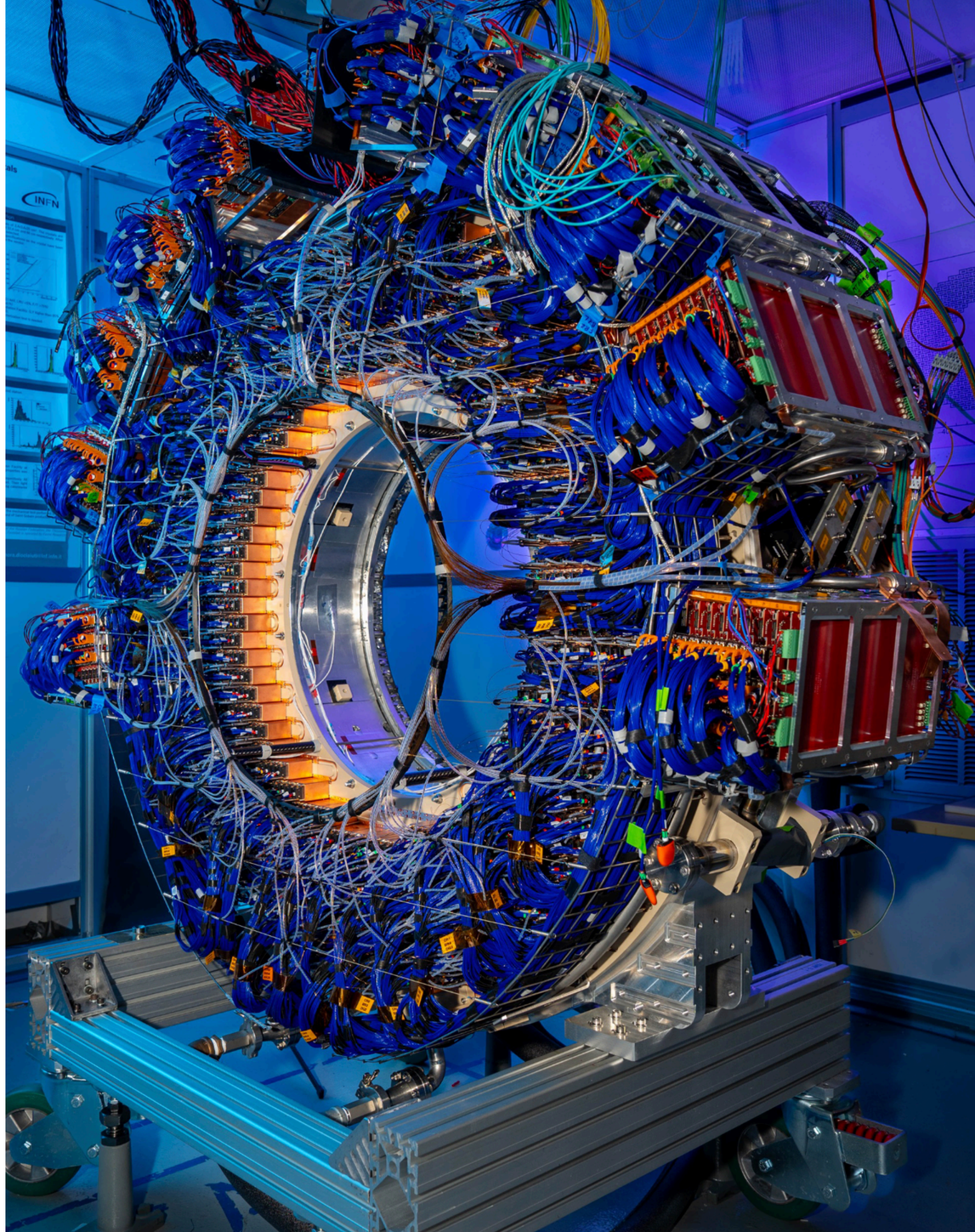


The Mu2e calorimeter

- Two annular disks, each made of 674 pure **CsI** crystals with 2 **SiPM** readout
- Primary importance for **particle identification** (muons vs electrons), independent **trigger** information w.r.t. tracker, and energy/position **reconstruction**
- Disks are being **calibrated** (cosmic rays, laser system, activated liquid source)
- Disks will be transferred to the Fermilab Mu2e **experimental hall** in a few weeks!

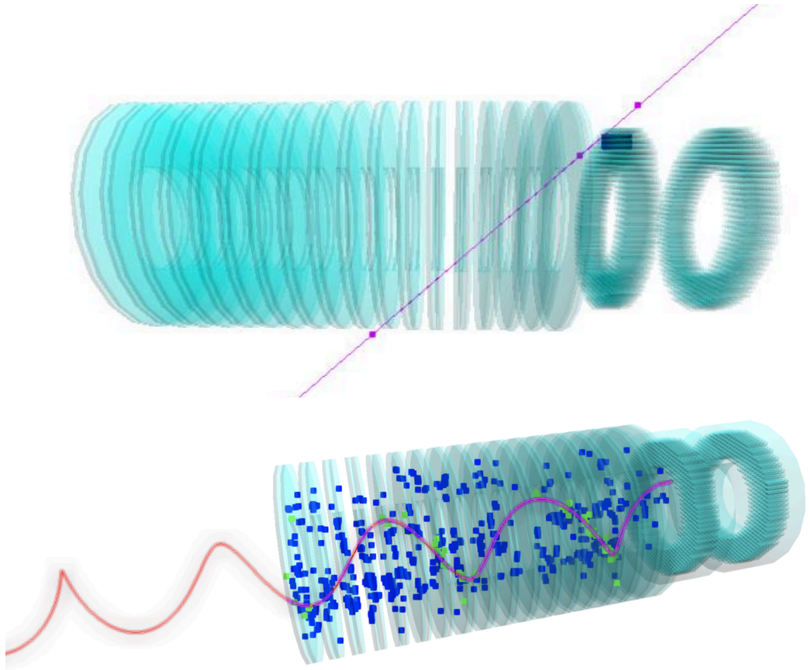
→ Particle ID studies (Thesis Proposal #4)

→ CAPHRI detector (Thesis Proposal #5)



Thesis proposal #4: Particle ID studies

Particle ID (muons vs electrons) is central for **background exclusion** in the search for rare events: you will work with **cosmic ray data** and through **simulations** (taking into account the B-field of the solenoids)



- **What you will do:**

  take part in the data taking process (monitoring of the data acquired by tracker and calorimeter, see how the DAQ works)

  analyse the acquired data (cosmic ray reconstruction - track, energy, time - in tracker and calorimeter)

  simulate possible background events (cosmic rays that escape the veto and are assumed to be physics signal)

- **What you will learn:**

  basics of scientific programming using **python/C++/ROOT**

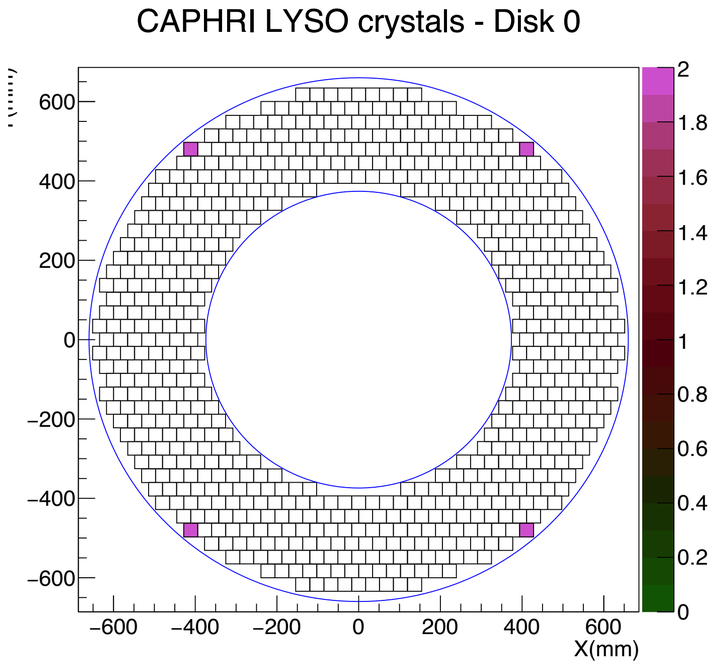
  basics of **Monte Carlo simulation** in the Mu2e framework

- **Indicative start date:** Spring 2026

Thesis Proposal #5: CAPHRI detector

CAPHRI (Calorimeter Precise High-Resolution Intensity detector) is a real-time, fast monitor of **muon capture**, crucial for having an independent measurement of

$$R_{\mu e} = \frac{\Gamma(\mu^- + N(A,Z) \rightarrow e^- + N(A,Z))}{\Gamma(\mu^- + N(A,Z) \rightarrow all\ captures)}$$



- **What you will do:**

  take part in the data taking process (monitoring of the data acquired by the calorimeter, see how the DAQ works)

  analyse the acquired data (energy and time reconstruction of CAPHRI hits, beta-decay spectrum for LYSO crystals)

  simulate the expected response during Run-1 (find the muon capture rate detected by CAPHRI and compare it to the expected one)

- **What you will learn:**

  basics of scientific programming using **python/C++/ROOT**

  basics of **Monte Carlo simulation** in the Mu2e framework

- **Indicative start date:** Spring 2026

So… Why Mu2e?

If you want to pursue a Master's thesis in the Mu2e LNF group you will:

- enter a **very active working group**, with people that play important roles in the collaboration
- get yourself involved in an experiment that plans to **start data taking in the next years**
- find yourself in a **medium-size collaboration** (~300 people), where you will get a feel of the main parts of a complex experiment
- have the chance to go to **Fermilab** (Chicago) to get some on-site experience
- have the chance to present your work in physics **conferences** such as SIF/APS
- be able to **publish** an article describing your results with us!

Thank you for your attention!