The CRILIN technology: an optimised calorimeter solution for a future Muon Collider

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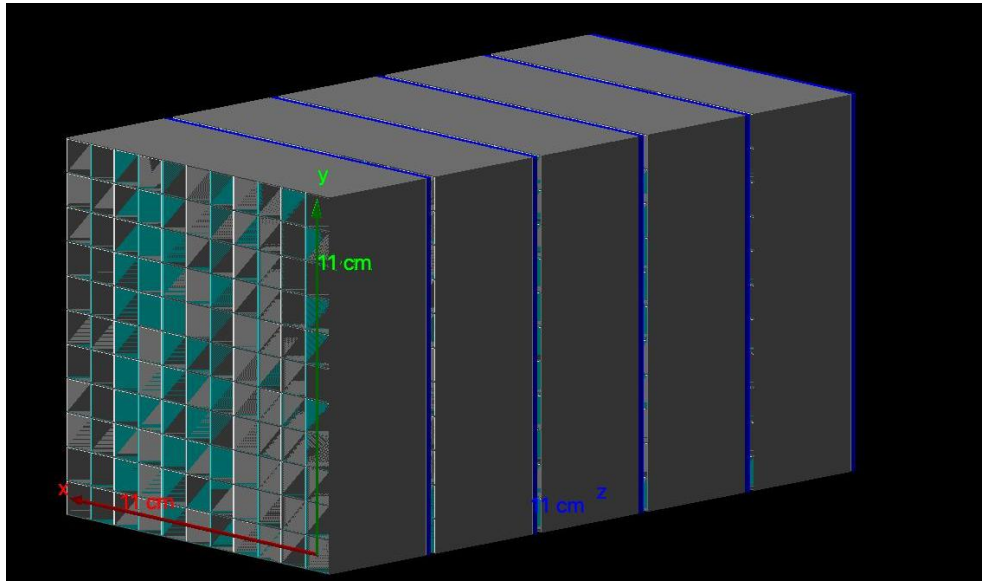
The CRILIN calorimeter

- ECAL design optimized for a Muon Collider → need to cope with the Beam Induced Background (BIB)
- **Semi-homogeneous, compact** and **flexible** ECAL made of **Cherenkov (PbF_2) crystal matrices** interspaced and readout by **SiPMs**
- Able to adapt to any Collider environment by changing the crystal/SiPM model choice



Key Features:

Excellent timing: (< 50 ps) to reject the BIB out- of-time hits and for good pileup capability.

Longitudinal segmentation: allows to recognize fake showers from the BIB.

Fine granularity: reduced hit density in a single cell and distinguish the BIB hits from the signal.

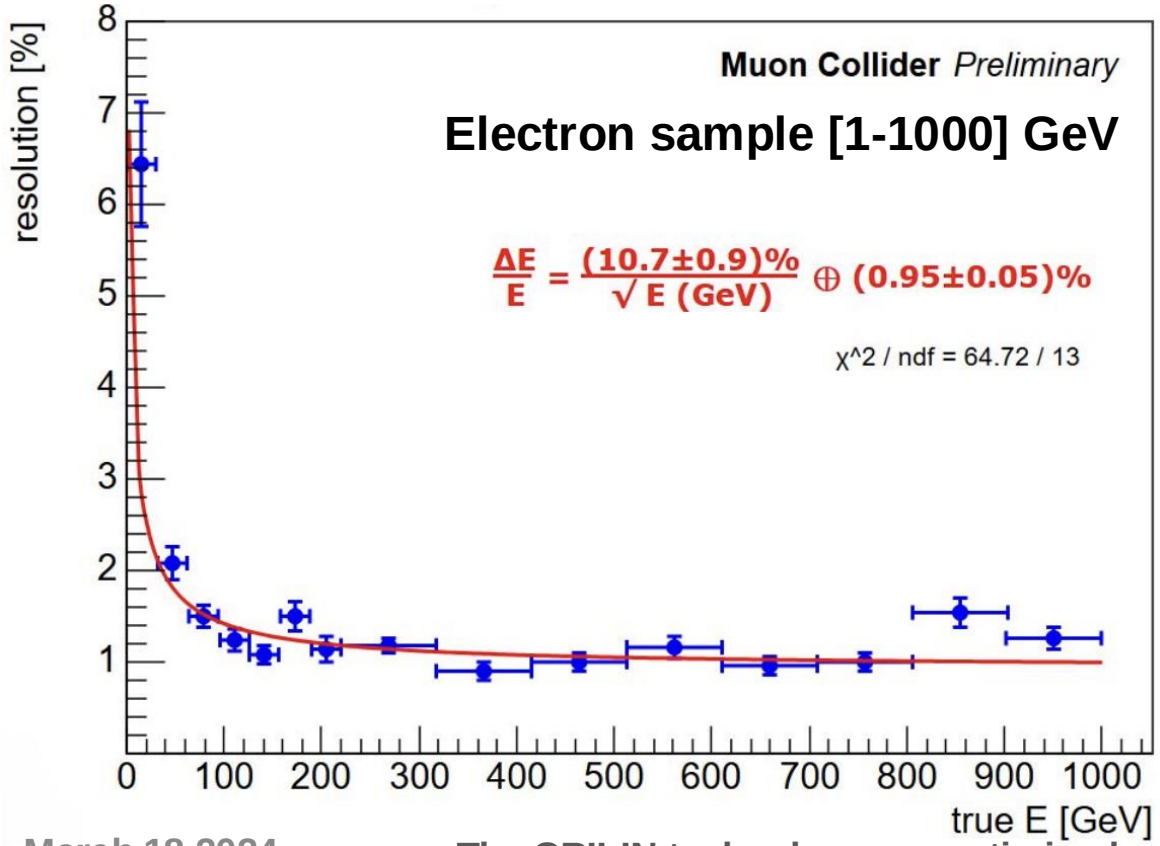
Good resistance to radiation: good reliability during the experiment

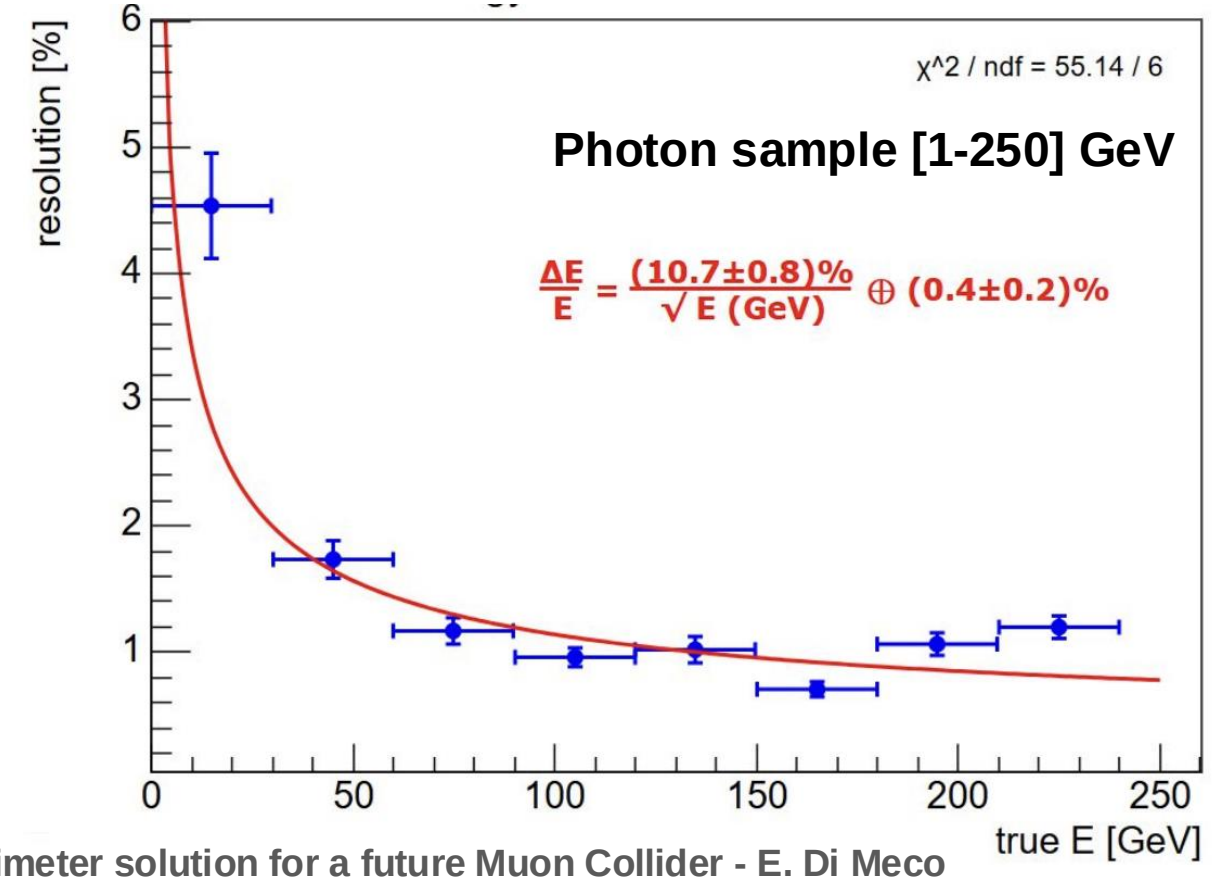
Energy resolution: targeting a level of $\sigma_E/E \sim 10\%/\sqrt{E}$, MC confirmed

*S. Ceravolo et al 2022 JINST **17** P09033*

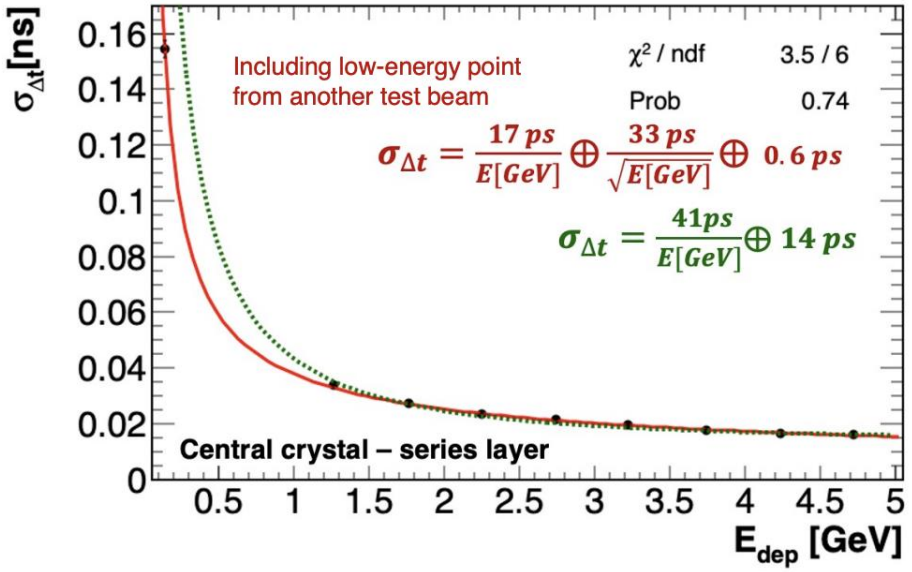
Simulated performances

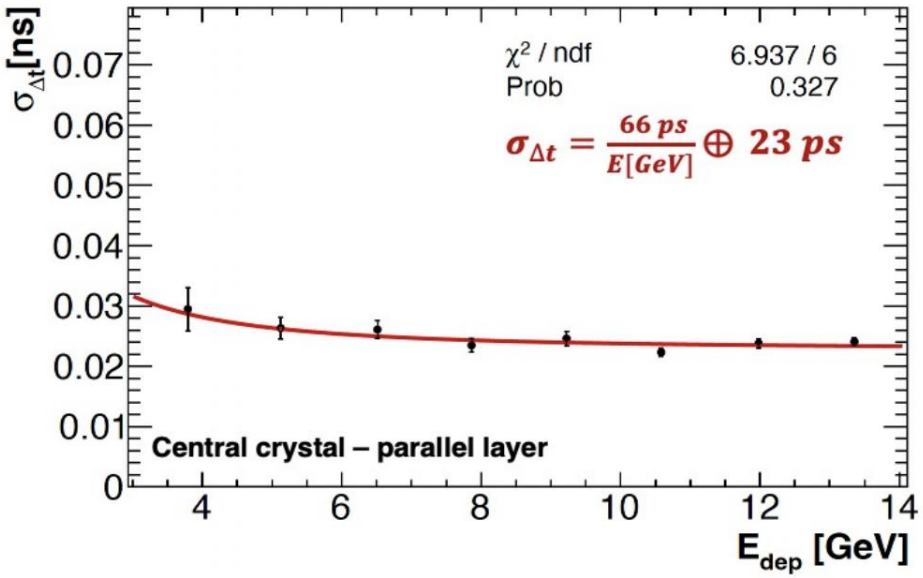
- The CRILIN calorimeter was implemented in the Muon Collider detector **MUSIC** (MUon System for Interesting Collisions) geometry.
- Performance studies based on the Muon Collider simulation framework using MC **particle gun samples** of **photons** and **electrons,** including the **beam induced background contribution**.





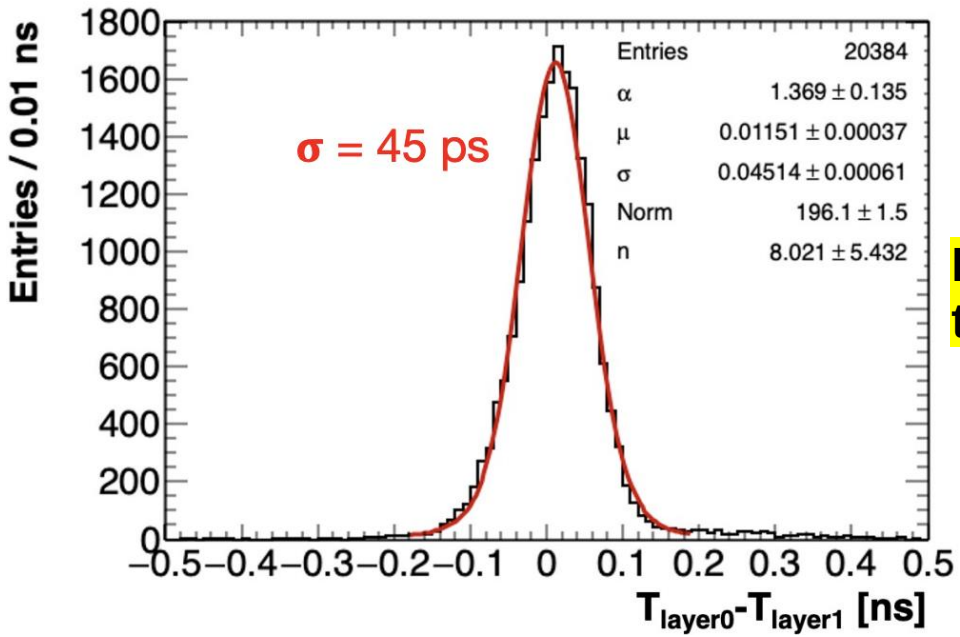
Timing results





Dedicated test beam at SPS-H2 (e^- 120 GeV) for time resolution evaluation on the **3x3x2 prototype (Proto-1)**.

- **Outstanding time resolution** of **O(20 ps)** for E_{dep} > 1 GeV was achieved in both the case of the **both layers**.
- **Excellent results** using central crystals of **different layers** with **σ_t=45ps**. Time resolution dominated by the 2 SiPM board **synchronization jitter O(32ps)**.



Result in agreement with the ECAL requirements!

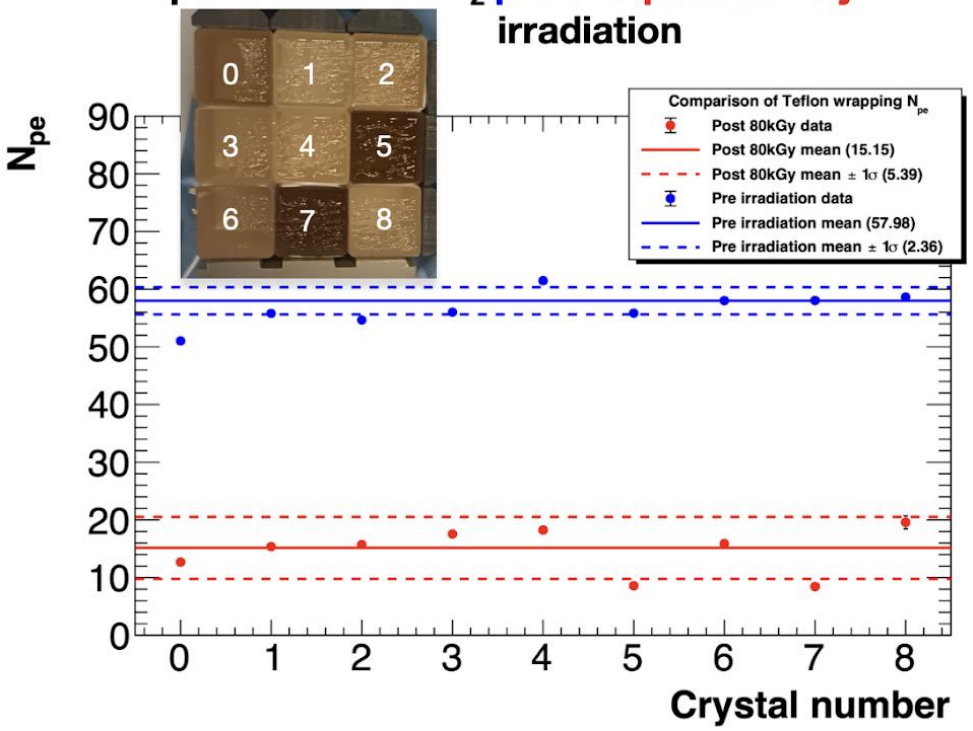
Radiation hardness

Dedicated Test Beam at BTF (e^- 450 MeV) in single particle mode to test the **LY loss due to TID**

- Different wrapping tested → **Teflon sensibly damaged**
- Crystals evident loss of transparency → **still good amount of light detectable**
- **SiPM dark counts increases significantly** with the absorbed dose
- New tests planned to evaluate SiPMs PDE loss and optical grease degradation

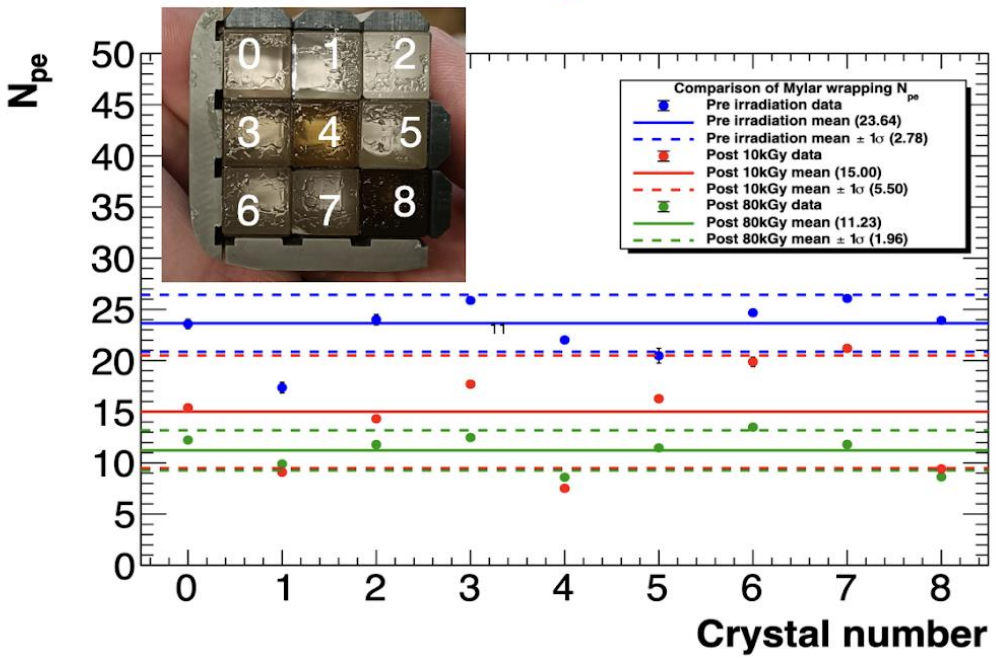
Telfon wrapping

Npe values of PbF_2 pre and post 80 kGy irradiation



Mylar wrapping

Npe values of PbF_2 pre, after 10 kGy and after 80 kGy irradiation



Summary

- **Time resolution**: < 40 ps for single crystals, for E_{dep} > 1 GeV
- **Radiation resistance:** transmittance PbF_2($PbWO_4$-UF) robust to > 35(200) Mrad and SiPMs validated up to 10^{14} n_{1MeV}/cm^2 displacement-damage eq. fluence → LY loss test beam showed a strong non uniformity in response between different crystals

- *Use PbWO-UF in the first calorimeter layer.*
- *Conduct new irradiation tests and monitor Cherenkov light variations with a blue laser.*
- *Simultaneously test crystals with SiPM and SiPM alone*

DRD6-WP3 2025

➢ Expanding prototype to a 7x7x5(layers) configuration, with a target of 2 M_R – 22 X_0.

- Two beam test weeks approved for 2025 to test the new FEE and DAQ options
- Final test beam scheduled for 2026