The OREO (ORiEnted calOrimeter) project

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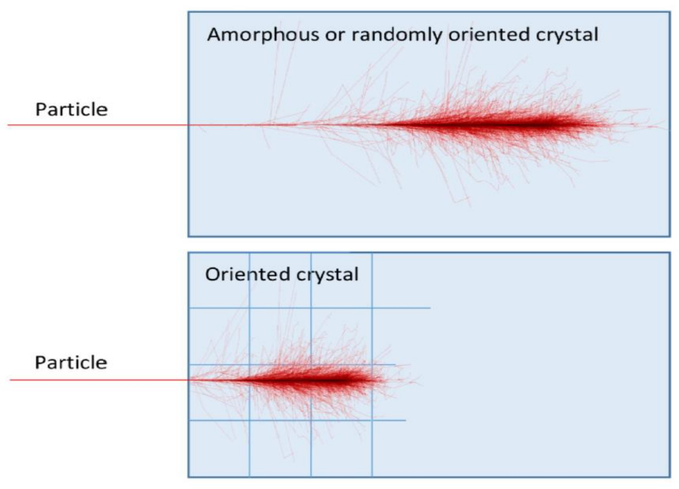
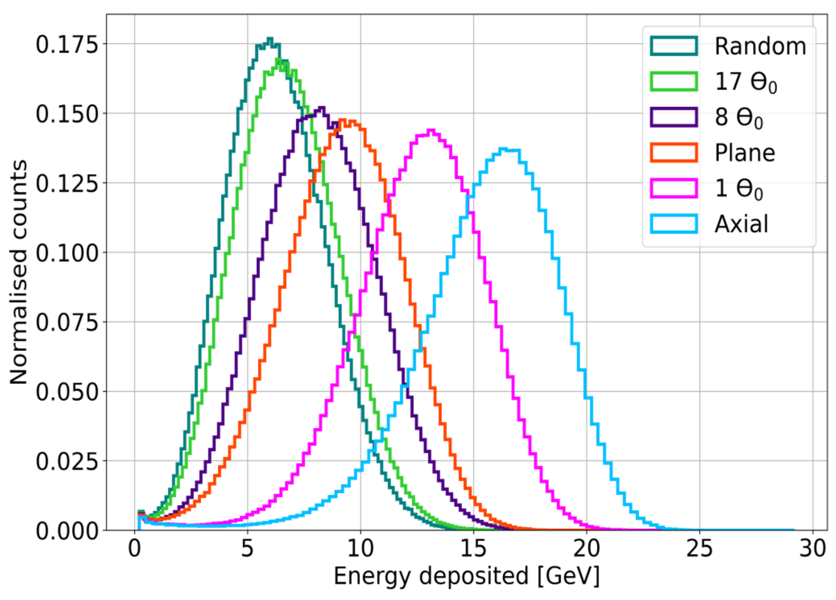
The ORiEnted calOrimeter (OREO) project intends to assemble and test an **electromagnetic calorimeter prototype based on oriented crystals.** The calorimeter will consist of a 3x3 matrix of 5 X_0 **oriented PWO-UF (Ultra-Fast) crystals readout by SiPMs**, followed by non oriented crystals. The most challenging aspect of the design is to keep the crystals aligned when arranged in a matrix structure. The results obtained with a 3x1 and a 2x2 matrix of PWO-UF oriented crystals during the Oreo 2023 beamtests with 6-15 GeV/c electrons on the T9 beamline at the CERN PS and with 20-150 GeV/c electrons on the H2 beamline at the CERN SPS, demonstrate **for the first time ever the possibility to align a layer of crystals along the same crystallographic direction**, opening a new technological path towards the **development of a highly compact calorimeter**. The **particle identification** capability of such a system is also explored: since the nuclear interaction length is unaffected by the lattice orientation, the calorimeter oriented crystal layer is an **instrument that is sensitive to photons and blind to hadrons**. These features make such a calorimeter of interest for high energy physics experiments (forward calorimeter in fixed target experiments) but also for space-borne γray telescopes.

The Strong Field (SF) regime

When a high energy (>10 GeV) $e^{\pm}/\gamma$ **moves close to one of the axes** (strings) **of atoms in a crystal lattice** it experiences an **intense electromagnetic field** (i.e. the **Strong Field regime**) [1].
The coherent sum of the single-atom contributions along the string direction leads to:

- An **enhancement** of the bremsstrahlung and pair production **cross-sections** [2].
- An **acceleration of the electromagnetic shower development** with respect to the case of a randomly oriented medium [3].





The **relative angle** between the incidence direction and the crystallographic axis, needed for **the SF shower development acceleration** to be achieved is

$$\theta \leq \Theta_0 = \frac{U_0}{511\ \text{keV}} \sim 1\ \text{mrad}$$

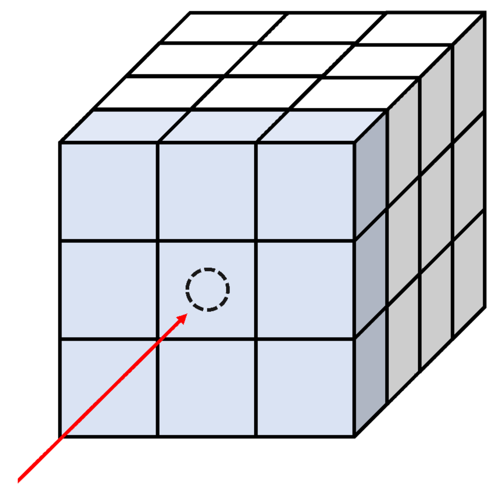
where U_0 is the depth of the potential well associated to the axial field.

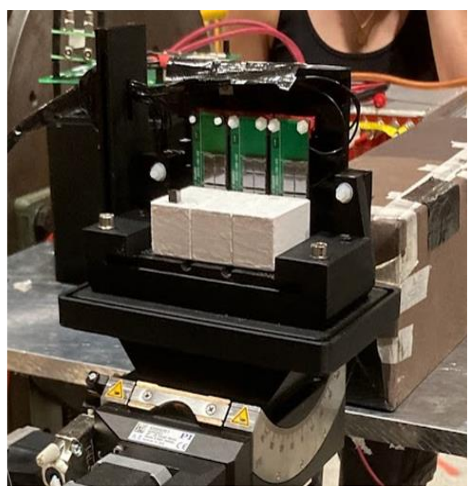
It has been observed an acceleration in the e.m. shower development for θ up to 1°

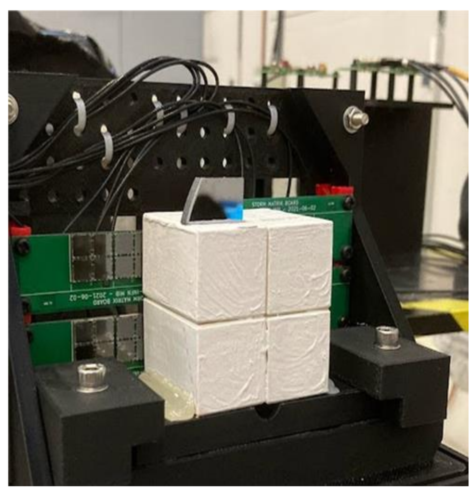
The OREO calorimeter

The ORiEnted calOrimeter (OREO) project intends to assemble and test a 3x3 matrix of **PWO-UF crystals** read out by SiPMs [4,5], with:

- An **oriented layer** of $\sim 5\ X_0$
- A non-oriented layer of $\sim 10\ X_0$



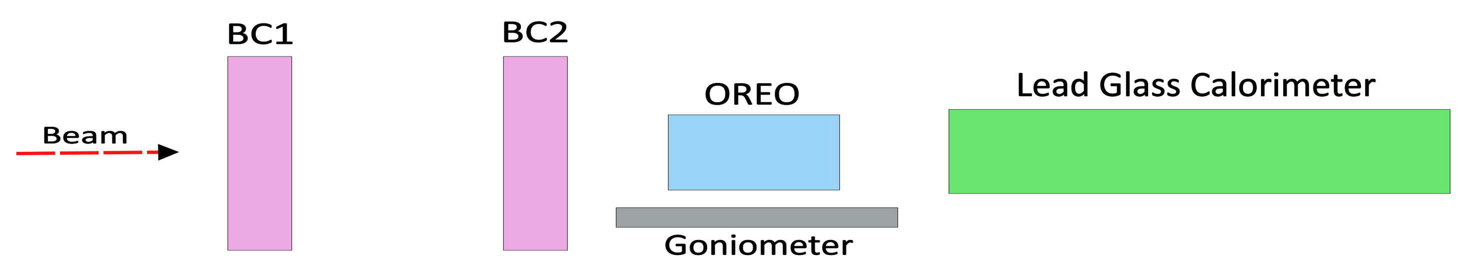




In 2023 **two prototypes** of the first oriented layer have been developed: **a 3x1 and a 2x2 matrix of oriented crystals** of 2.5x2.5x4 cm^3 read out by SiPMs.

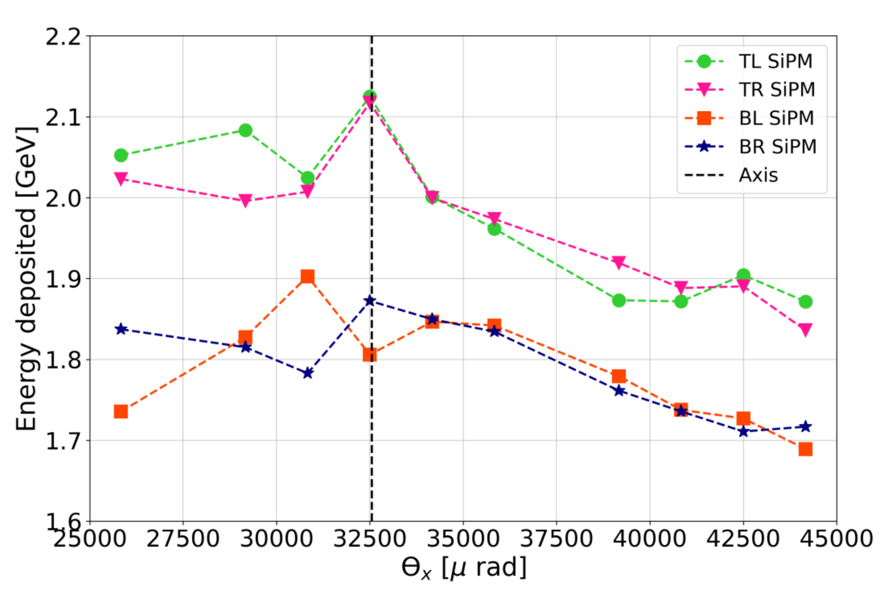
The beamtest experimental setup

The experimental setup consists of **two silicon microstrip beam chambers** (BC) for the particle tracking, a **high-resolution goniometer** to orient the crystals with respect to the particle beam and **one lead glass homogeneous calorimeter** with a length of $\sim 25\ X_0$.



Experimental results on the T9 and H2 beamline at CERN

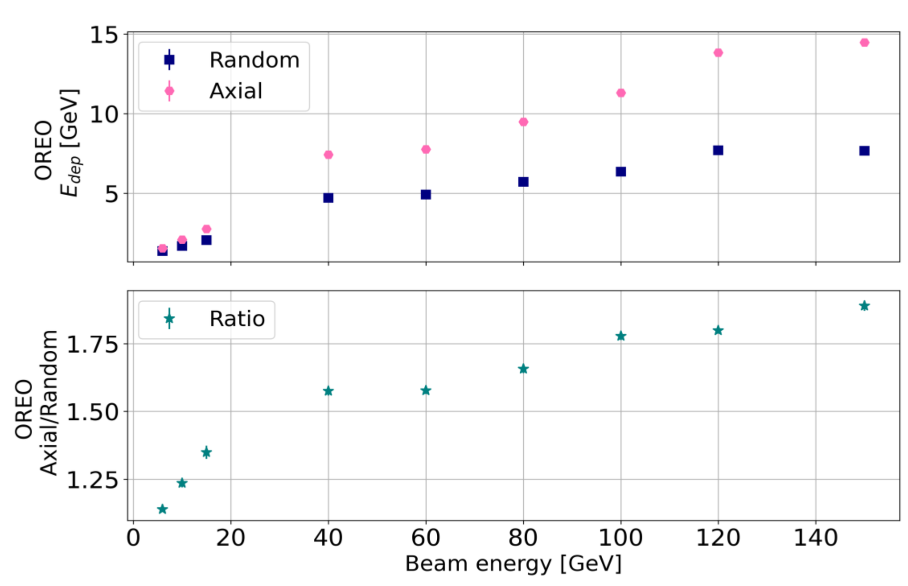
Crystal inter-alignment



Mean values of the energy deposited inside each crystal of the 2x2 matrix as a function of the rotational angular stage (Θ_x) of the goniometer, during a **horizontal scan** near the **axis coordinate**.

These results indicates that the crystals were well inter-aligned along the same crystallographic direction.

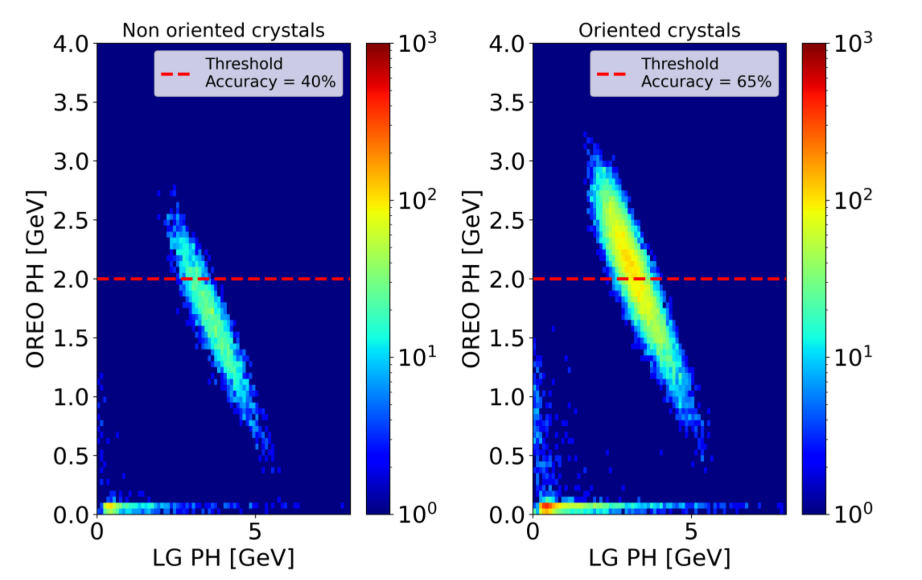
Energy deposit in OREO



Energy deposit distribution in the axial and random orientations as a function of the incident energy. In the **axial orientation** there is an **enhancement of the energy deposited** due to the **Strong Field effects**.

The ratio between the mean energy deposited in the axial and random orientations increases to a value of ~ 2.

Particle Identification



Preliminary measure on **the Particle Identification** (electrons vs hadrons) with 6 GeV electron-pion beam on the T9 beamline, with a **threshold on the energy deposited in OREO**.

In an oriented crystal the accuracy in the identification of an electron increases.

Future developments

Planned activities for 2024:

- Characterization of the **final prototype** of OREO
- Development of the front-end electronics and the OREO mechanics.
- Beamtest on the CERN/LNF beamlines.

OREO is a calorimeter of **interest for high energy physics experiments** (forward calorimeter in colliders experiment and fixed target experiments) but also for **space-borne γray telescopes**.

Bibliography

[1] 10.1103/RevModPhys.77.1131
[2] 10.1103/PhysRevLett.121.021603
[3] 10.1140/epjc/s10052-023-11247-x
[4] 10.3389/fphy.2023.1254020
[5] 10.1016/j.nima.2018.07.085

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