

A NOVEL ELECTROMAGNETIC CALORIMETER BASED ON ORIENTED CRYSTALS

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The **OREO - ORiEnted calORimeter** - project aims at assembling and testing an ultra-compact homogeneous electromagnetic calorimeter based on oriented crystals. It is approved by INFN CSN5 and the DRD Calo Collaboration.

The OREO calorimeter prototype consists in two matrices of **PWO-UF** crystals and it is built in order to create a multi-layer-crystal system, in which the first layer is completely interaligned and oriented with the direction of the incoming particles and it is followed by a layer of non oriented crystals. Both matrices are readout by **SiPMs**.

In the last years, this prototype has been tested to study the acceleration of the development of the electromagnetic shower in the oriented layer, that leads to an improvement in the performances of the calorimeter in terms of **linearity** and **energy resolution**.

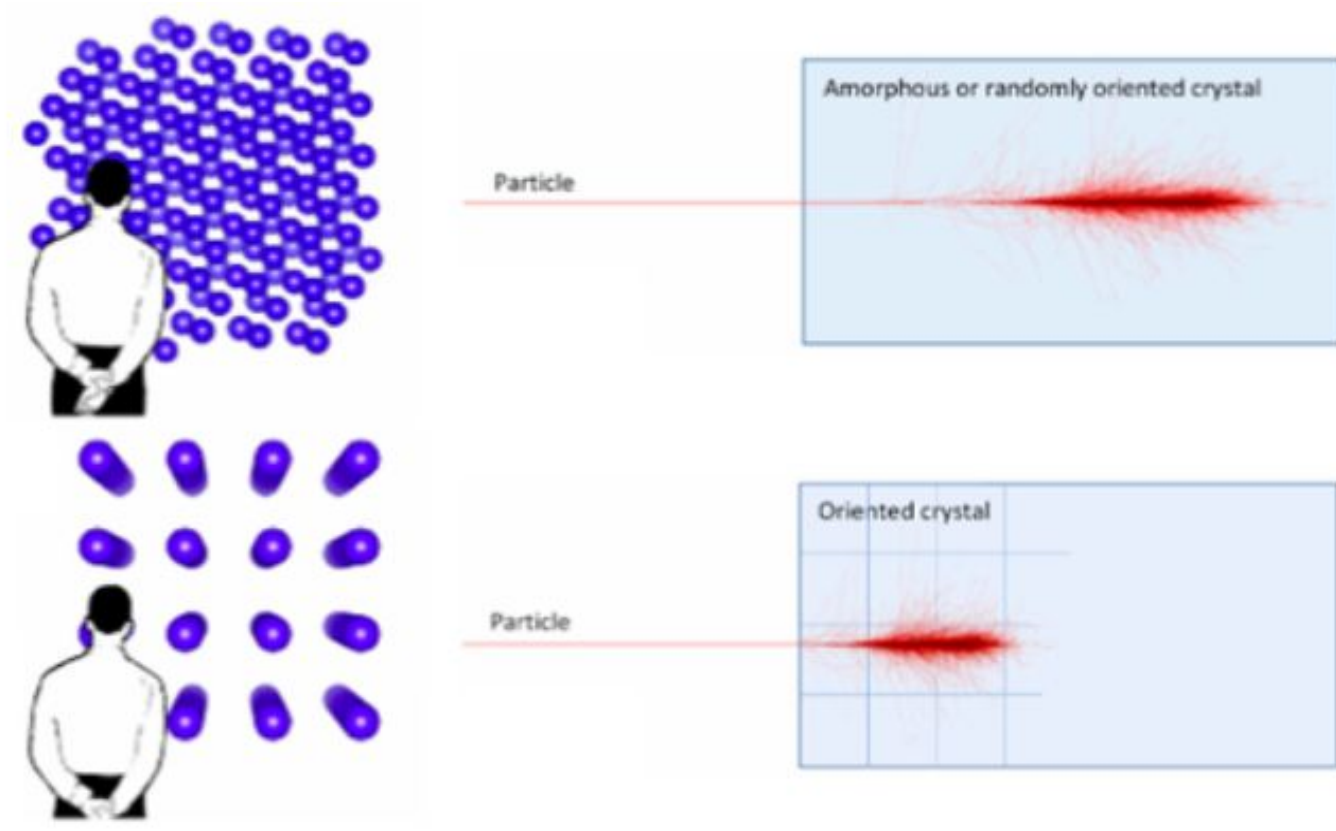
Such a calorimeter can be interesting for **high energy physics experiments**, in particular for forward calorimeter in colliders and fixed target experiments, but also for **space-borne γ -ray telescopes**.

The Strong Field effect

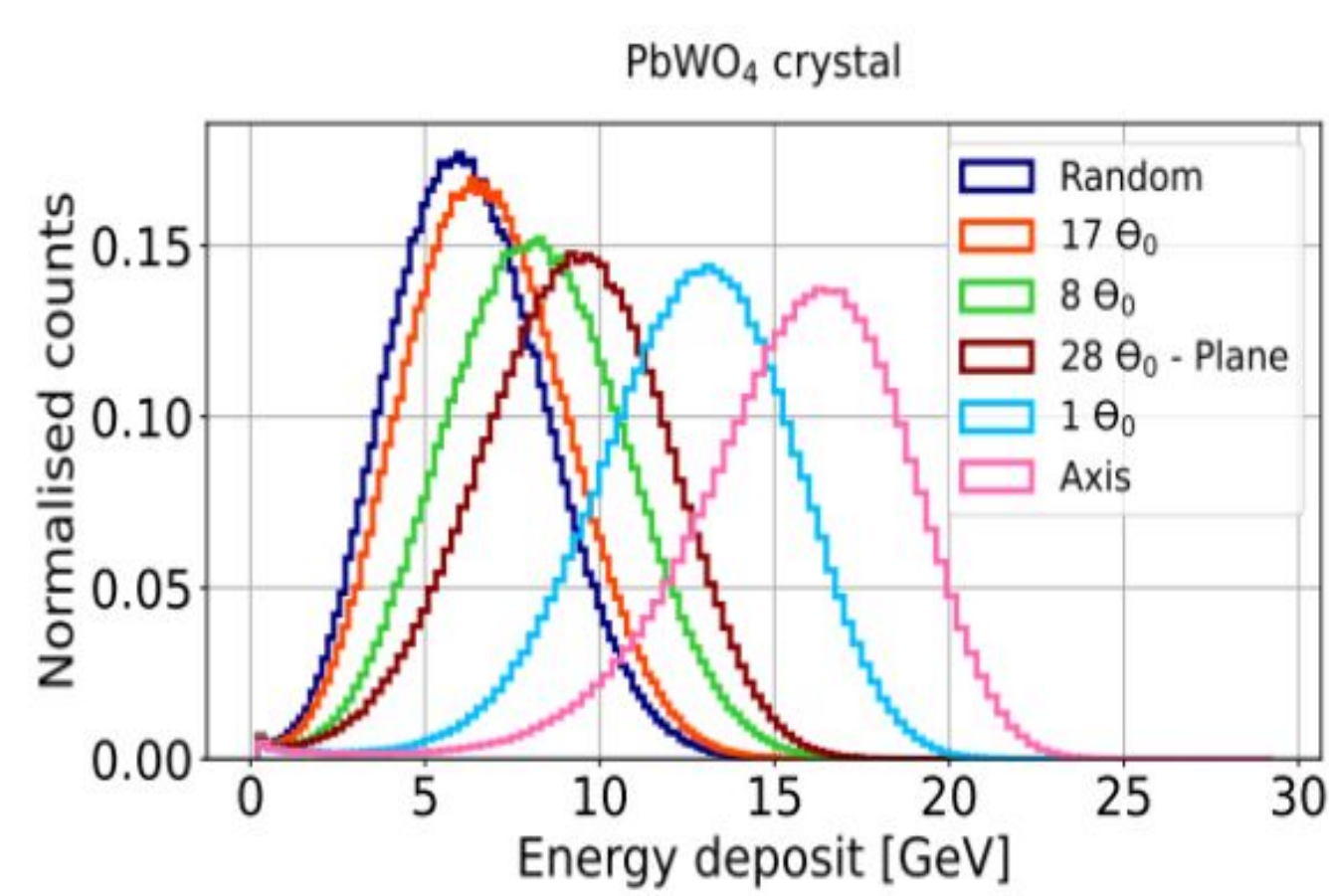
When a high energy (>10 GeV) e^+/e^- or γ impinges on a crystal with a misalignment angle θ , between the incidence direction and the crystallographic axis, smaller than a critical angle θ_0 , it experiences an intense electromagnetic field (i.e. the Strong Field (SF) regime) [1].

$$\theta < \theta_0 = \frac{U_0}{mc^2} \approx 1 \text{ mrad}$$

where U_0 is the depth of the potential well associated to the axis field and θ_0 is the **critical angle** [1].



The coherent sum of the single-atom contributions along the string directions leads to an enhancement of the **bremsstrahlung** and **pair production** cross sections. This leads to an **acceleration of the electromagnetic shower** development with respect to a non oriented medium [2,3].



The OREO calorimeter

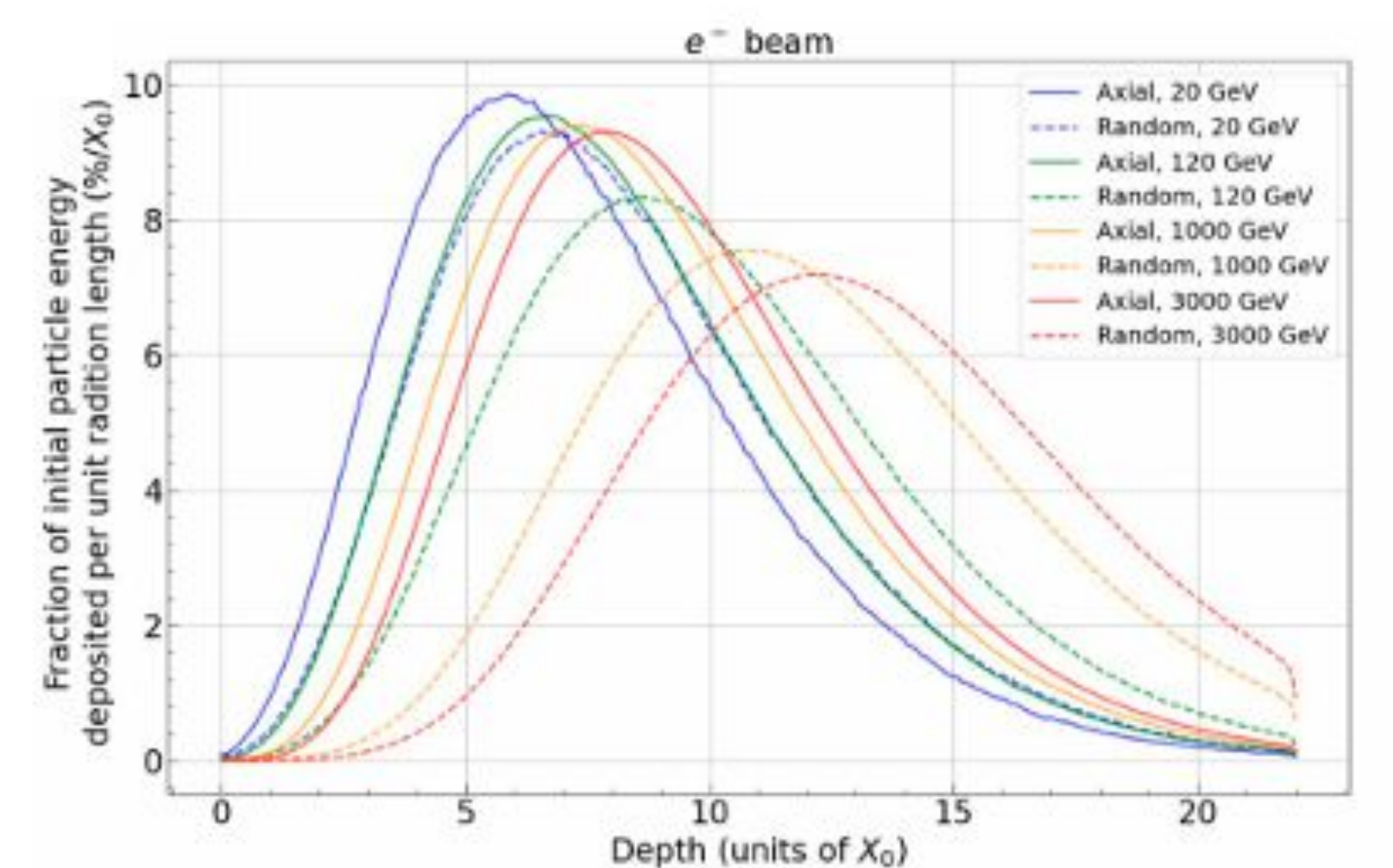
The OREO calorimeter consists of two 3x3 matrices of **PWO-UF** crystals:

- an **oriented** layer of 5 X_0
- a **non oriented** layer of 11.2 X_0

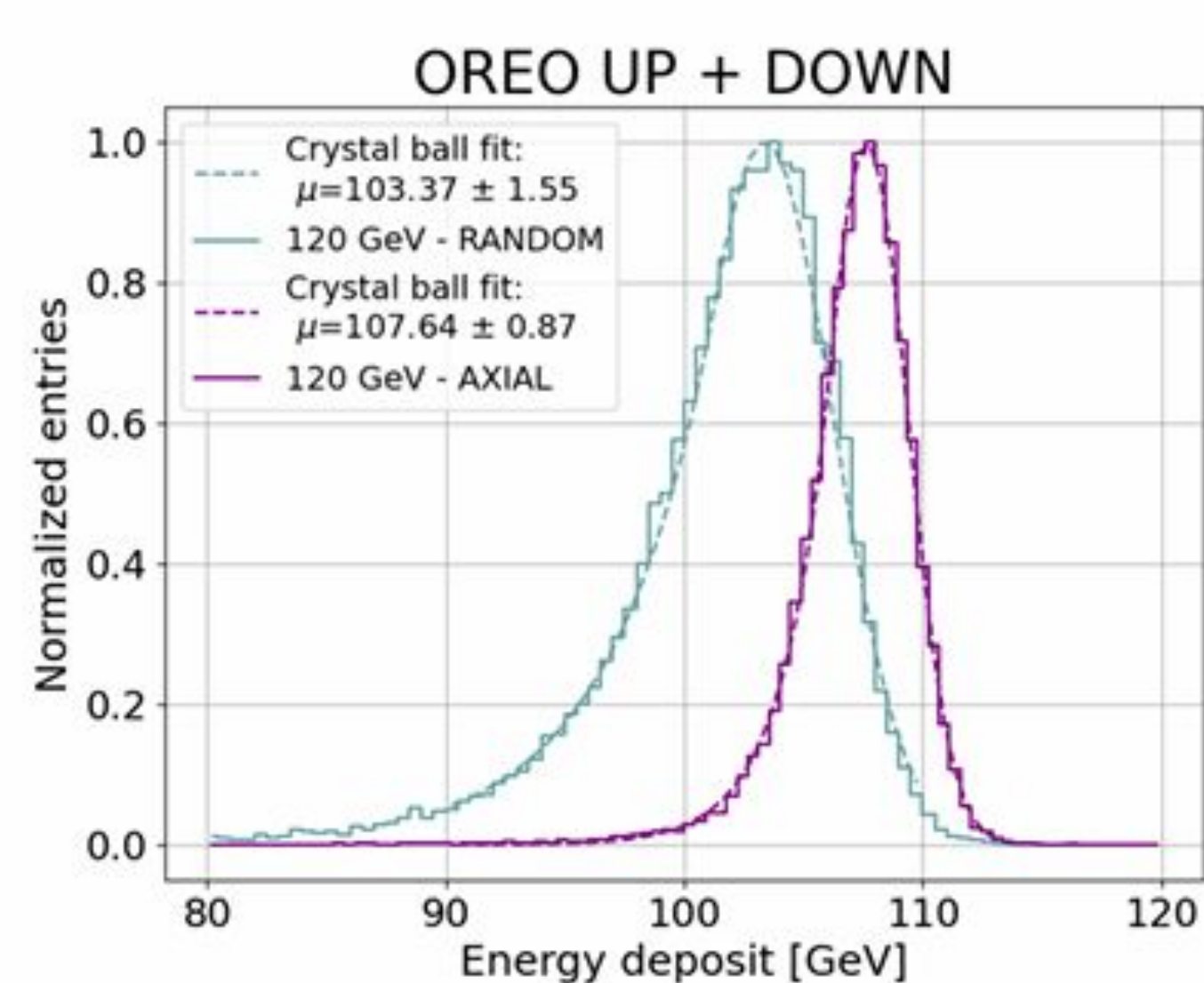
The first prototype of the calorimeter was assembled in 2024: the oriented layer crystals are 2.5x2.5x4.5 cm^3 , the non oriented layer ones are 2.5x2.5x10 cm^3 .

Each crystal is readout by **SiPMs** [4,5].

To evaluate the enhancement of the energy deposit in the axial configuration, the collaboration developed numerical **simulations** for the interaction of particles inside crystals, using Geant4 [5].

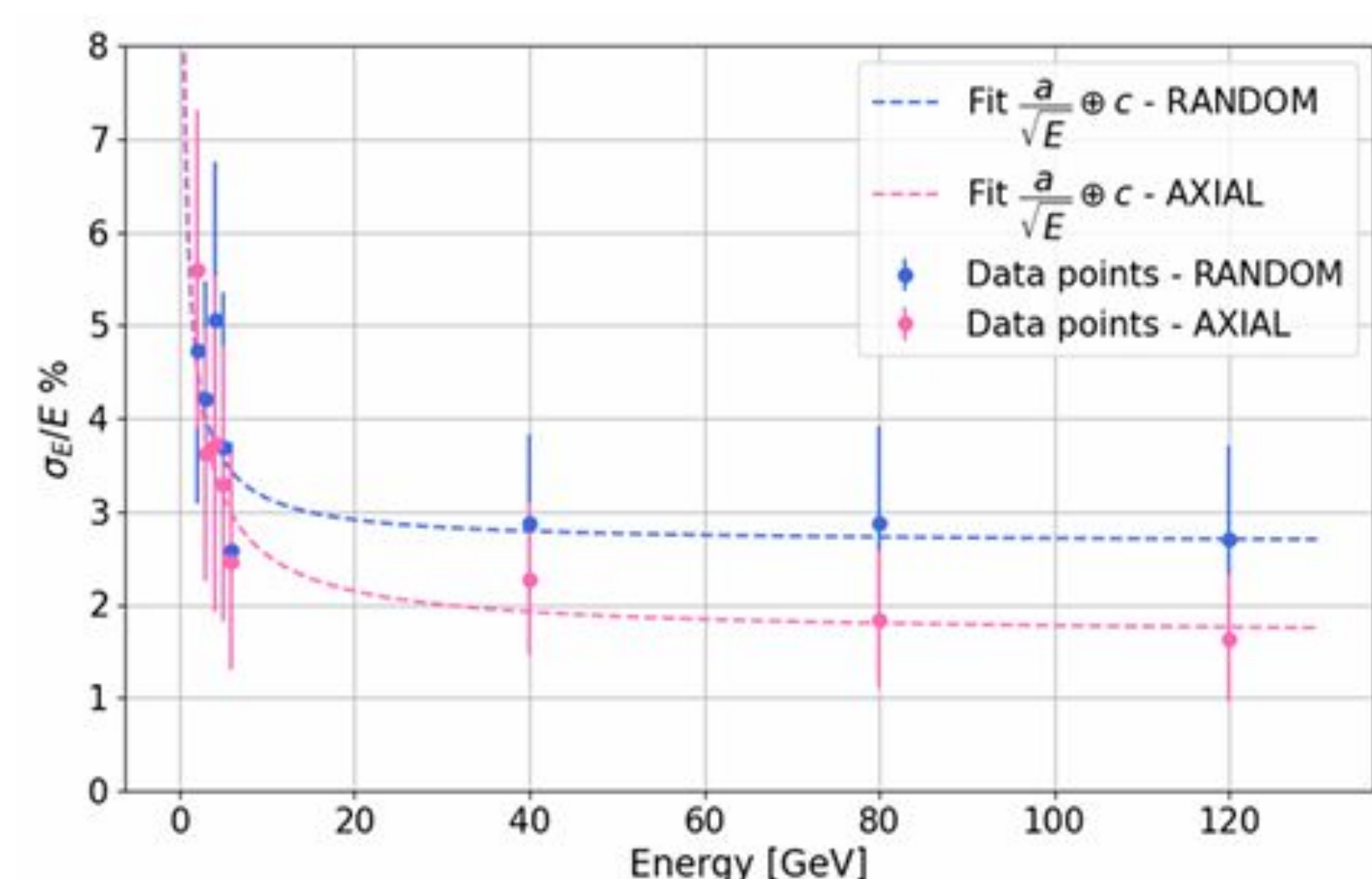


Experimental results on the T9 and H4 beamlines at CERN (2024)



Energy deposit distribution of the OREO calorimeter in axial and random configuration for a 120 GeV beam.

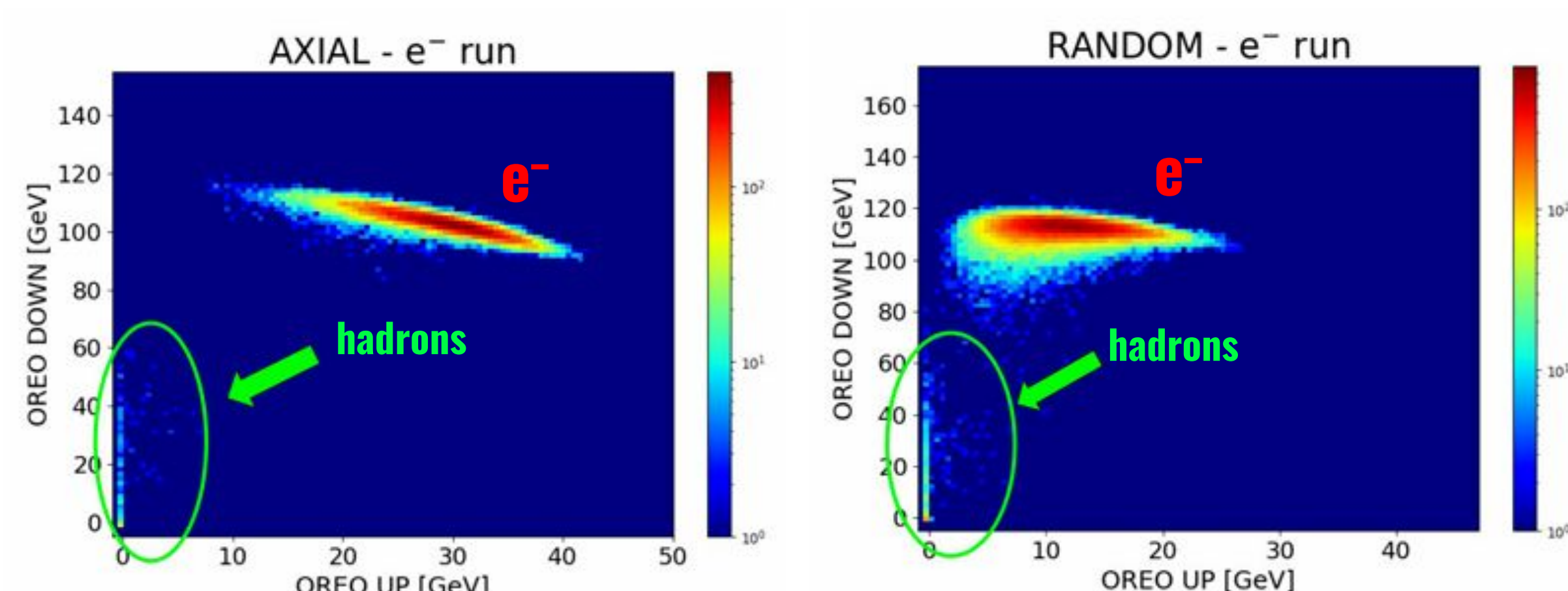
In the axial orientation it is observed an enhancement in the **energy deposit** due to the Strong Field effect.



Energy resolution of the OREO calorimeter as a function of the beam energy in axial and random configuration.

Orientation	a [% · $\sqrt{\text{GeV}}$]	c [%]
Random	5.28 ± 1.87	2.66 ± 0.61
Axial	6.02 ± 1.47	1.67 ± 0.49

In the axial orientation there is an improvement in the **energy resolution** of the OREO calorimeter.

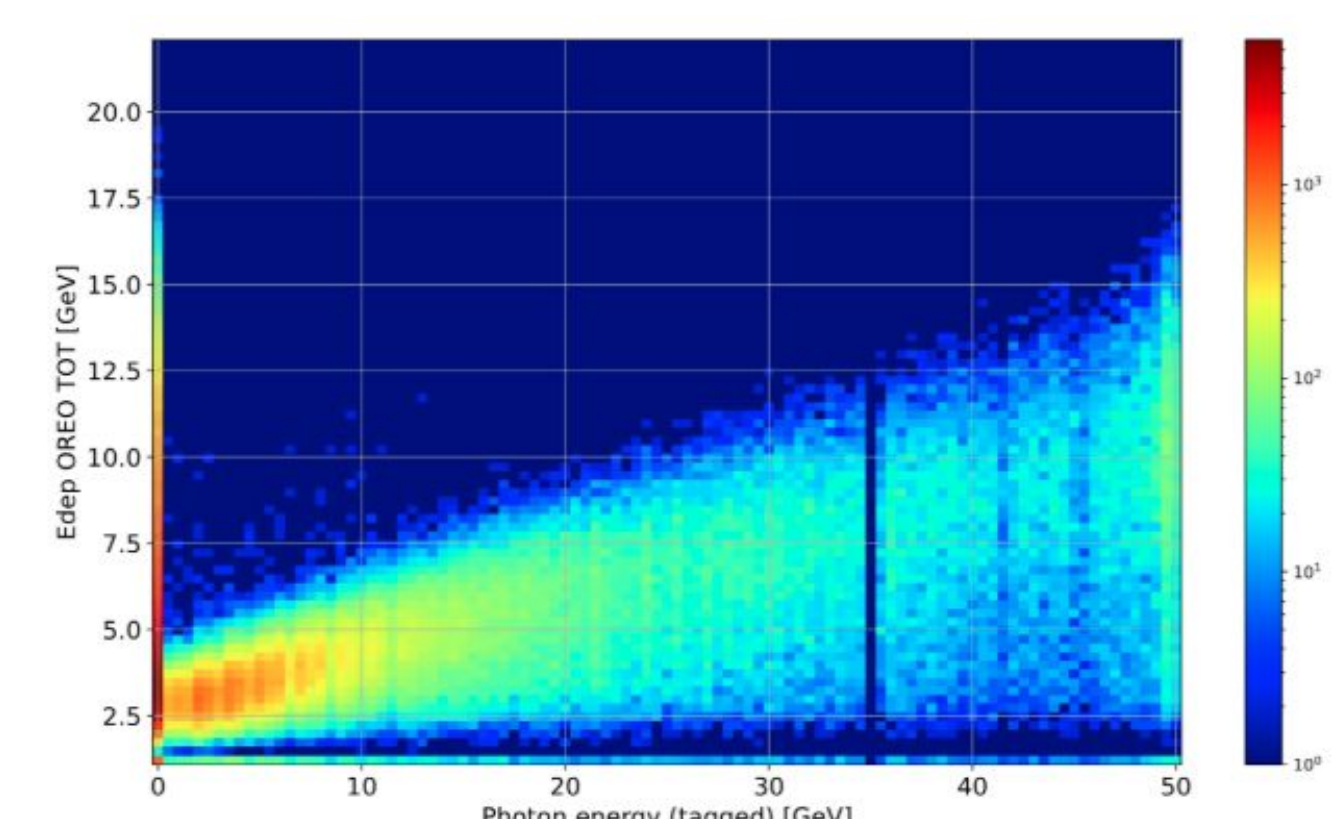


Preliminary measurement on the **Particle ID** (electron - hadrons) with a 150 GeV electron beam on the H4 beamline in axial and random orientation.

Further studies have been performed.

In **2025**, the central crystal of the non oriented layer was also axially oriented to better investigate the SF effects and evaluate the particle ID capabilities of the calorimeter.

In **2026**, the studies performed in 2024 and 2025 with electron beams have been replicated with a **photon tagged beam**.



Bibliography

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

