Status and perspectives of the OREO (ORiEnted calOrimeter) project

Alessia Selmi
On behalf of the OREO project
aselmi@uninsubria.it

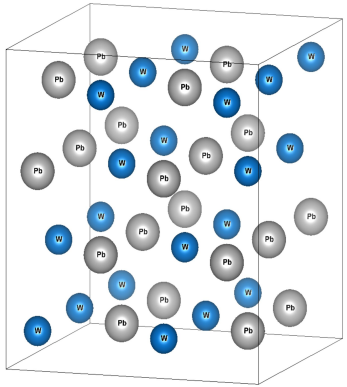
ICHEP 2024
Prague, July 18-24 2024

INFN

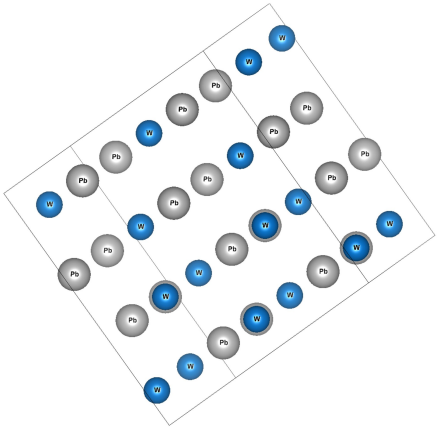
UNIVERSITÀ DEGLI STUDI DELL'INSUBRIA

OREO - ORiEnted calOrimeter

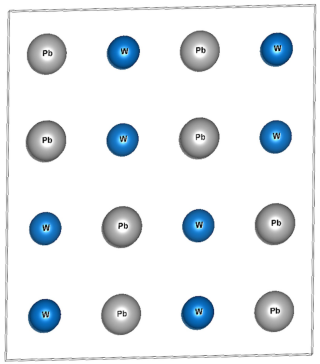
Randomly oriented crystal



Oriented crystals



Planar orientation



Axial orientation

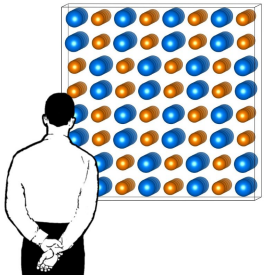
Bethe-Heitler bremsstrahlung and standard pair production

Coherent mechanisms →

Modification of the electromagnetic processes

Relativistic particle incident on atomic string

STRONG FIELD REGIME



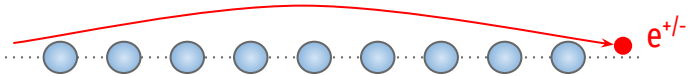
Lorentz factor

$$\chi = \frac{\gamma E}{E_0} > 1$$

Field experienced by the electron in its rest frame

QED critical electric field $\sim 1.3 \cdot 10^{18} \frac{V}{m}$

The particle experiences an **intense field** that can be considered **constant** along the string

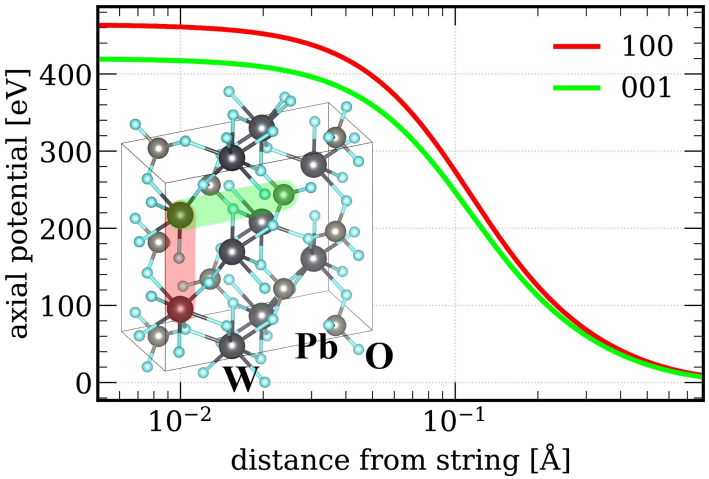


Coherent interactions all over the string of atoms

Shift of bremsstrahlung spectra towards higher energies and enhancement of pair production cross section

Strong field regime

The angle between the particle incidence direction and the crystallographic axis must be smaller than:

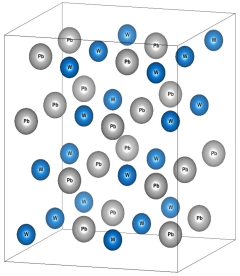


$$\Theta_0 = \frac{U_0}{mc^2}$$

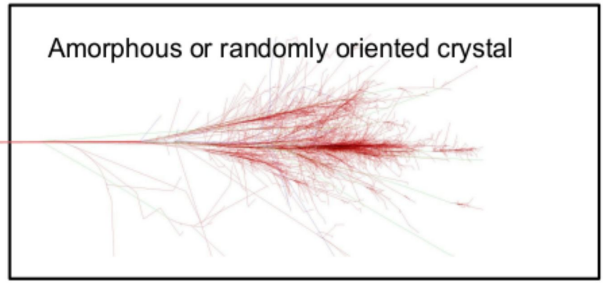
Depth of the potential well associated to the axial field

Axial	Θ_0 [mrad]
W <111>	1.2
$PbWO_4$ <001>	0.82

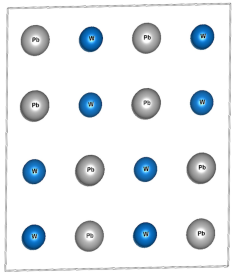
Randomly oriented crystal



Particle



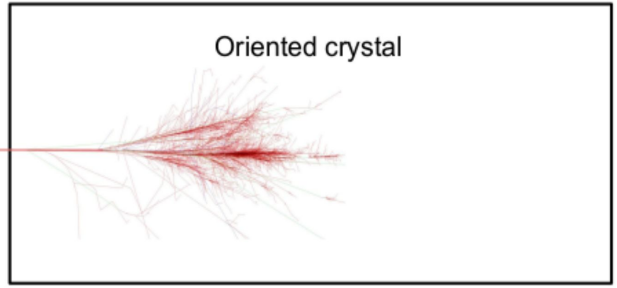
Oriented crystals



Axial orientation

Strong Field

Particle



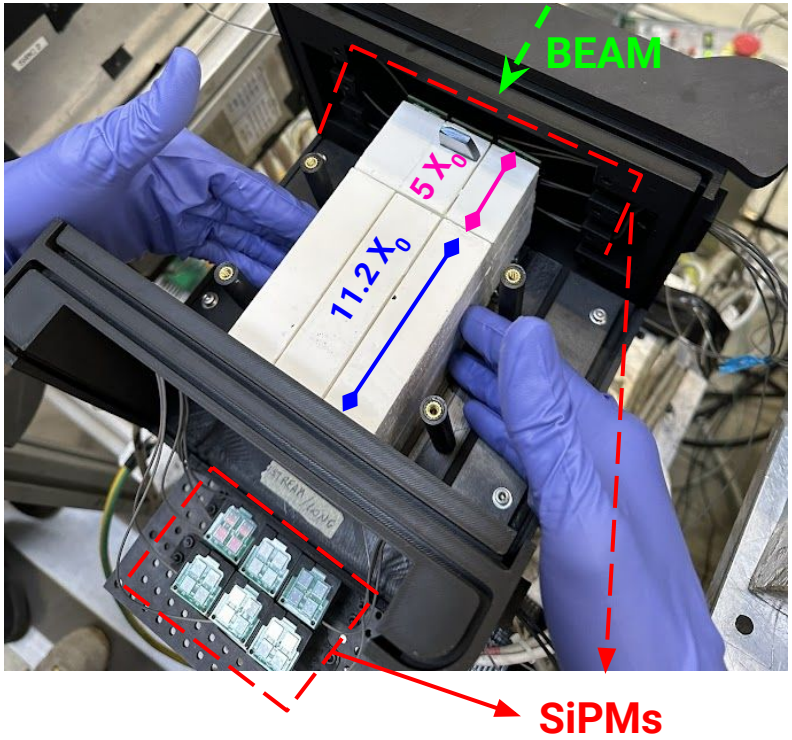
Enhancement of the bremsstrahlung and pair production cross section

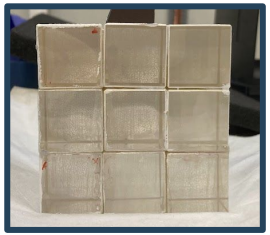
Acceleration of the electromagnetic shower

Enhancement in the energy deposited per unit thickness, in the early stage of the shower

OREO - ORiEnted calOrimeter → Prototype of compact crystal based calorimeter

National Coordinator
Laura Bandiera, INFN FE





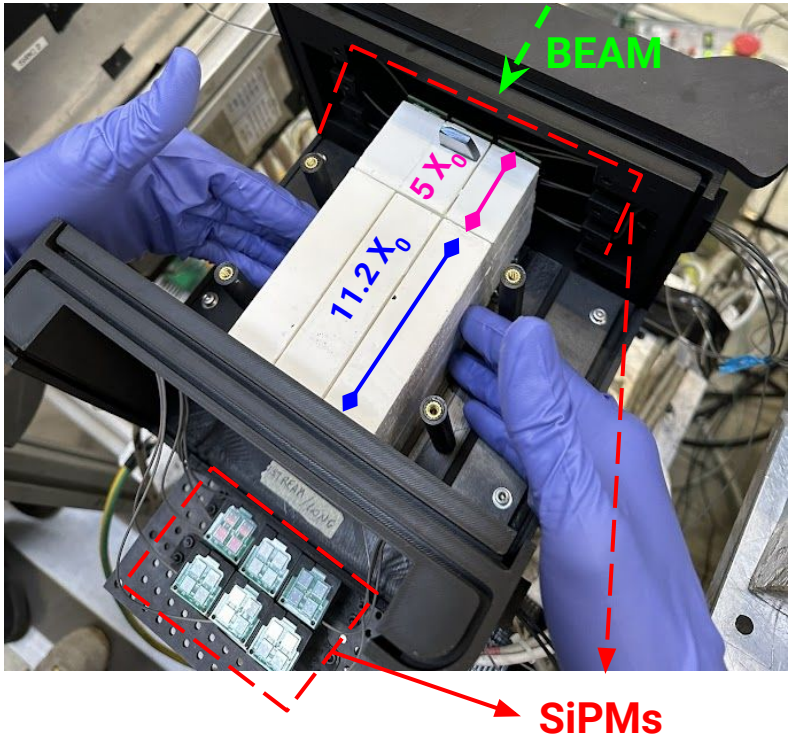
Front face

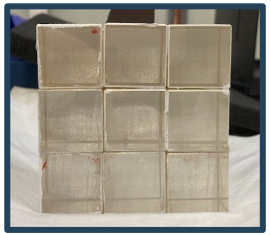
3x3 matrix of **oriented $PbWO_4$** (PWO) readout by SiPMs with:

- An **oriented layer of 5 X_0**
- A non oriented layer of 11.2 X_0

OREO - ORiEnted calOrimeter → Prototype of compact crystal based calorimeter

National Coordinator
Laura Bandiera, INFN FE





Front face

GOAL

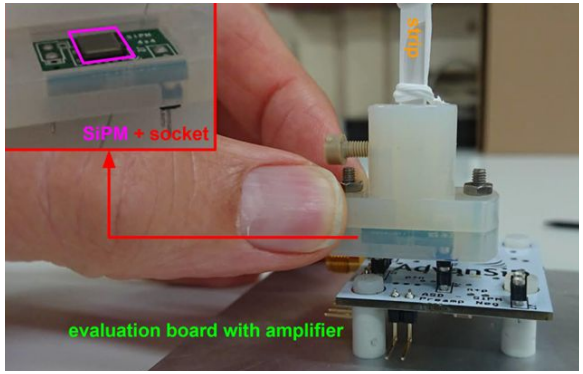
1. Demonstrate the possibility to **align a layer of crystals along the same crystallographic direction**
2. Prove that it's possible to **contain e.m. showers in a reduced volume/weight** and cost

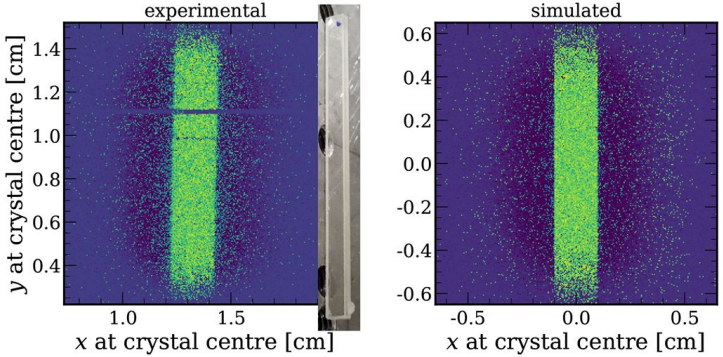
Experimental investigation of the Strong Field effects in oriented $PbWO_4$:

samples under test

2017-19 — 2021 — 2022 ▶

0.45 X_0





Probed with:
120 GeV/c e− @ CERN SPS H2
5.6 GeV/c e− (no SiPMs) @ DESY T21

SiPM: AdvanSiD ASD-NUV4S-P
Soldani et al. (2022)

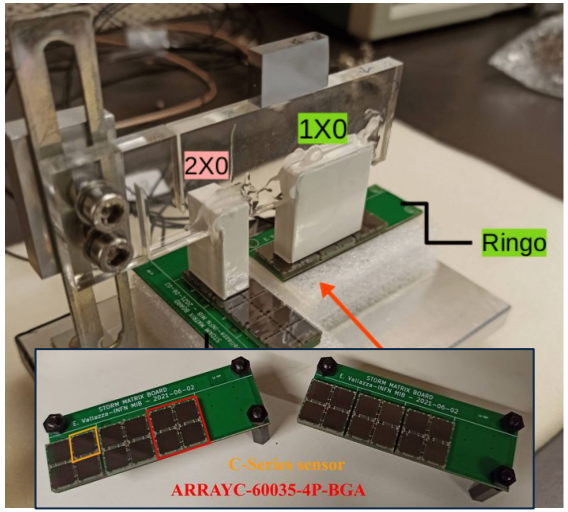
First observation of Strong Field effects to radiation in oriented PWO
Bandiera et al. (2018)

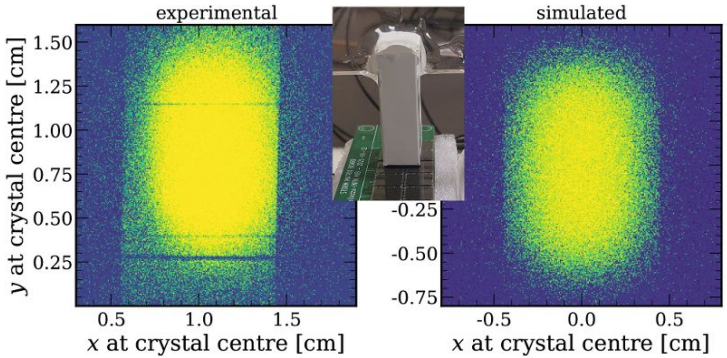
Experimental investigation of the Strong Field effects in oriented $PbWO_4$:

samples under test

2017-19 — 2021 — 2022

1-2 X_0





Probed with:
120 GeV/c e− @ CERN SPS H2
1-100 GeV/c γ @ CERN SPS H2

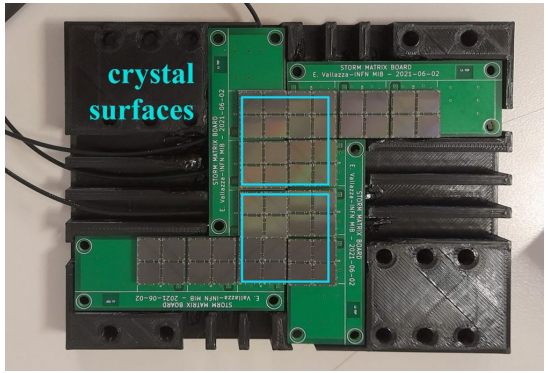
SiPM: [onsemi ARRAYC-60035-4P-BGA arrays]

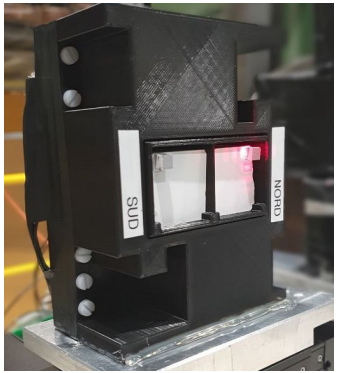
Experimental investigation of the Strong Field effects in oriented $PbWO_4$:

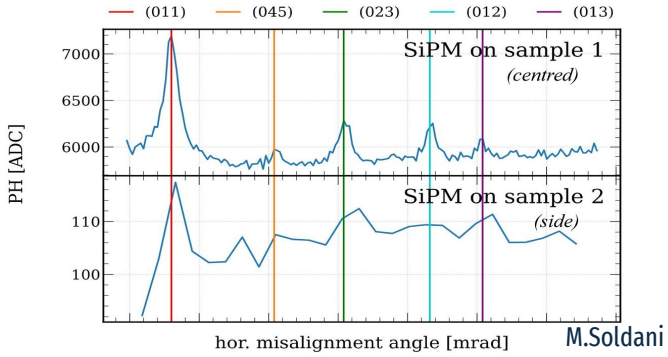
samples under test

2017-19 — 2021 — 2022

4.6 X_0







Probed with 100, 120 GeV/c e– @ CERN SPS H2

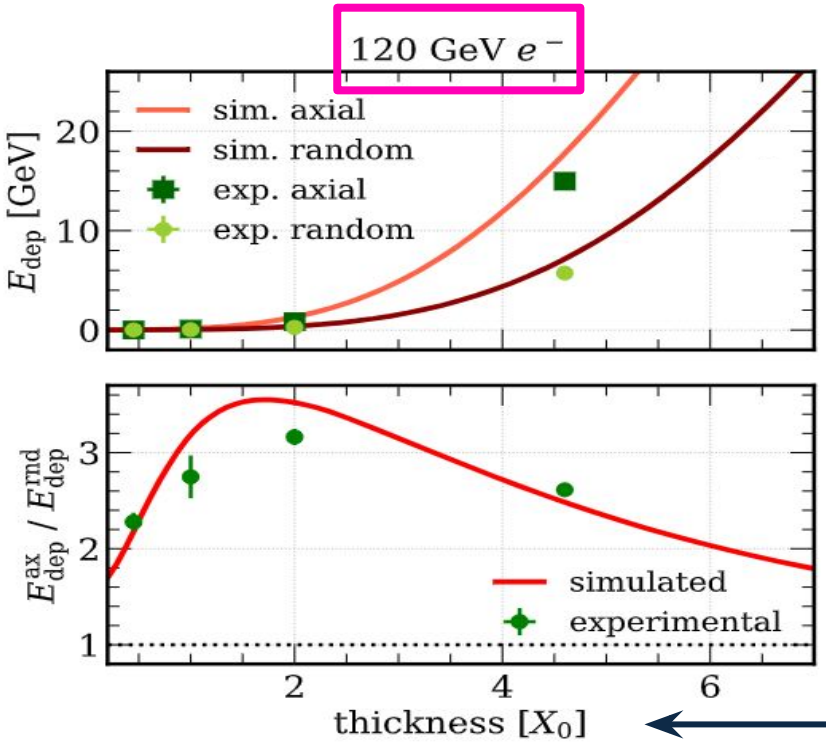
SiPM: [onsemi ARRAYC-60035-4P-BGA arrays]

Preliminary test of (purely mechanical) mutual alignment between 2 identical samples and shower sharing

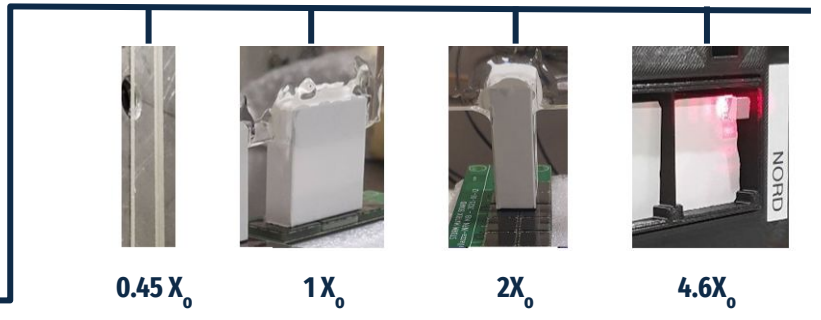
Experimental investigation of the Strong Field effects in oriented $PbWO_4$:

Results: shower acceleration → enhancement of the effective thickness !

Soldani et al.



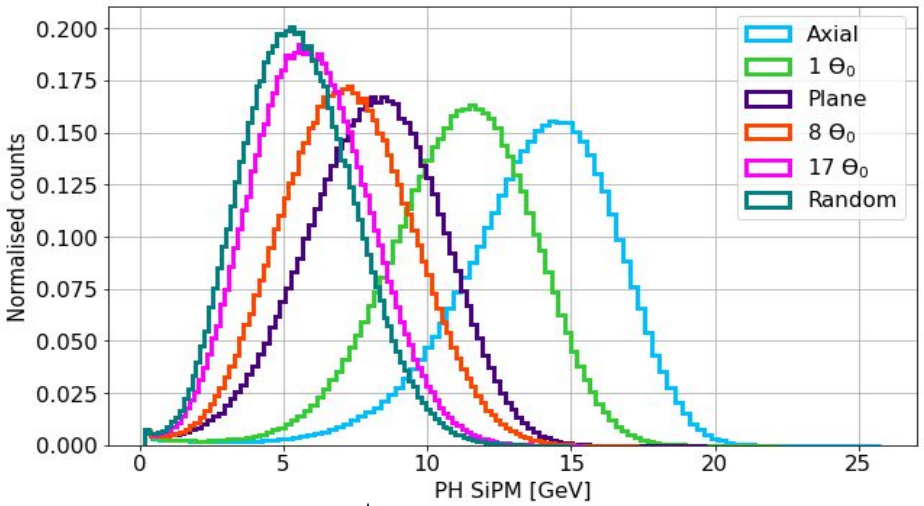
thickness [X_0]	effective thickness [X_0]	thickness enhancement [%]
0.45	0.745	165.48
1	1.520	151.98
2	2.923	146.17
4.6	6.208	134.96



Experimental investigation of the Strong Field effects in oriented $PbWO_4$:

Results: angular range

Soldani et al.



$$\Theta_0 = \frac{U_0}{mc^2}$$

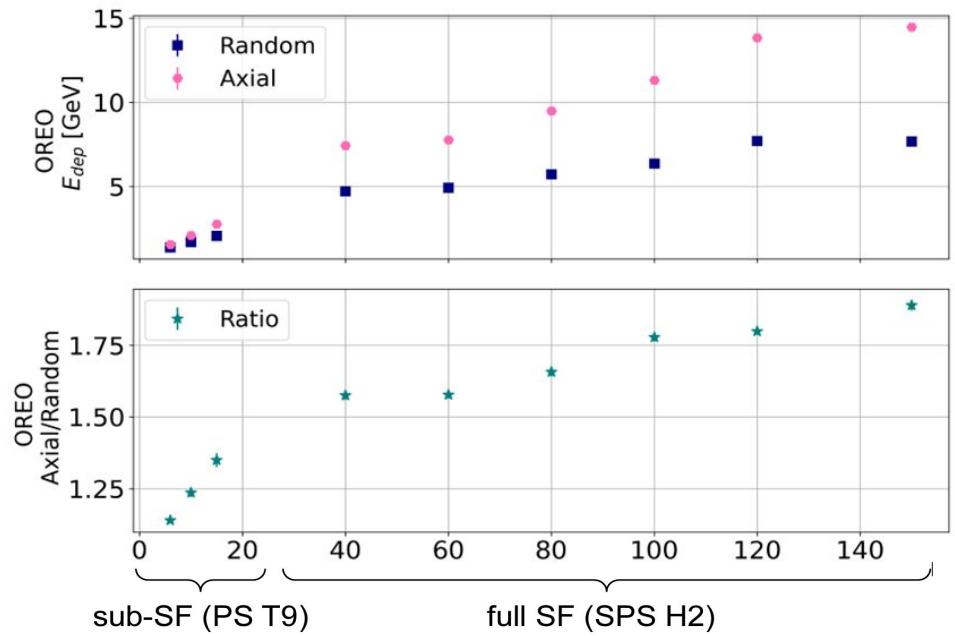
For $PbWO_4$ axis <001>
Θ_0 ~ 0.82 mrad

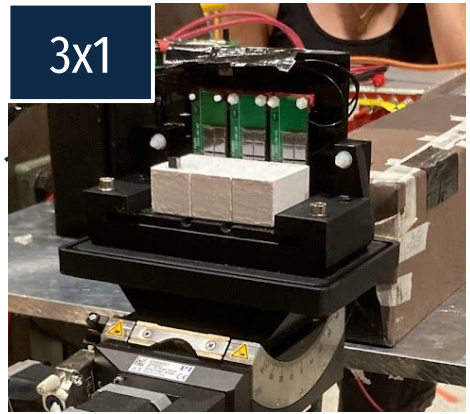
Acceleration in the e.m. shower development is visible **for an incident angle Θ up to 1°** (17 mrad)

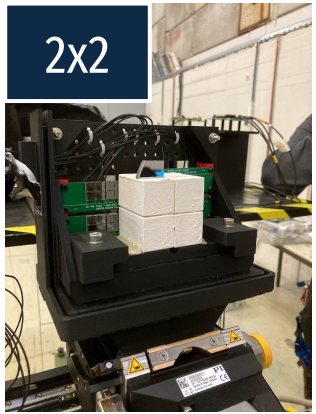
4.6X$_0$

120 GeV/c e− @ CERN SPS H2

2023 → 5 X_0 PWO arrays





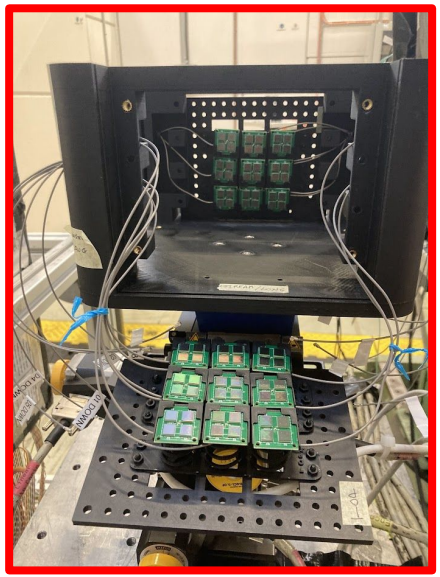


Axis-random **enhancement grows** with the incident **electron energy**

2024 → OREO!

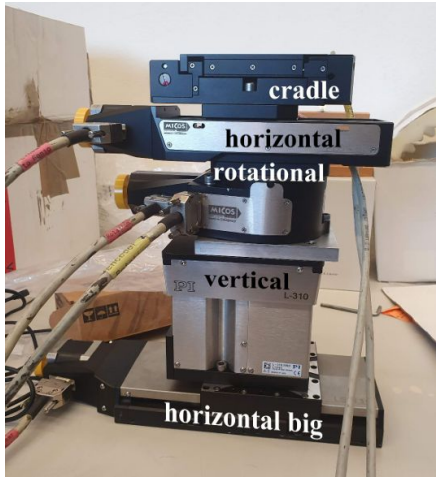
3x3 matrix of **oriented $PbWO_4$** (PWO) readout by SiPMs with:

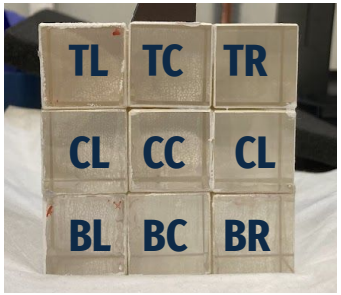
- An **oriented layer of 5 X_0**
- A non oriented layer of 11.2 X_0



SiPM: Hamamatsu MPPC

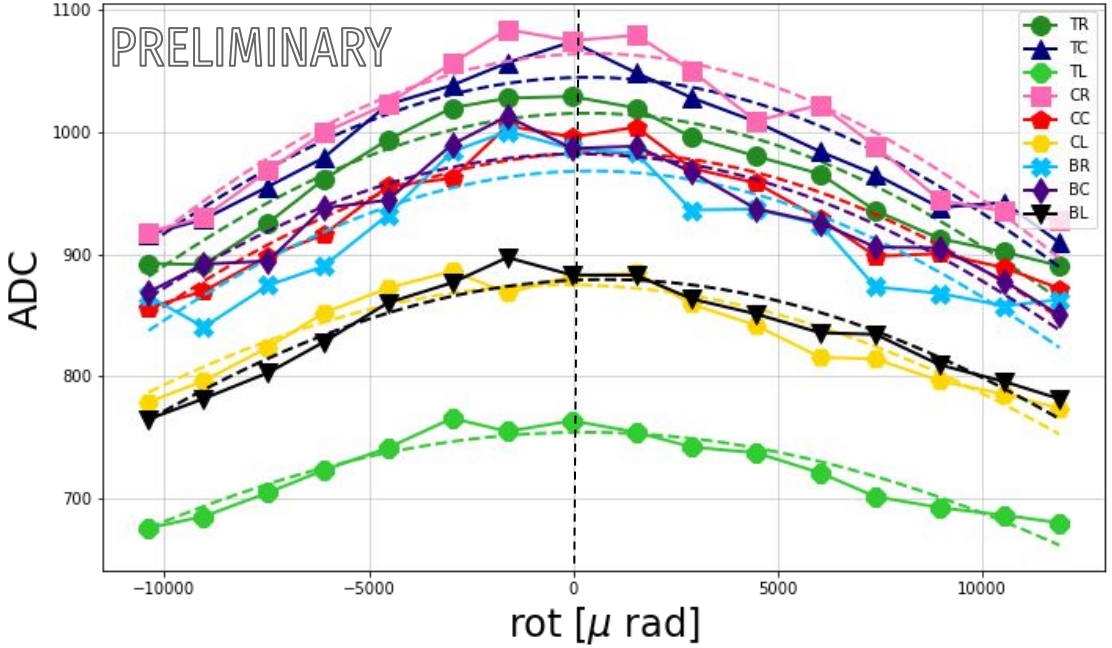
Goniometer





Preliminary results @ T9 CERN PS

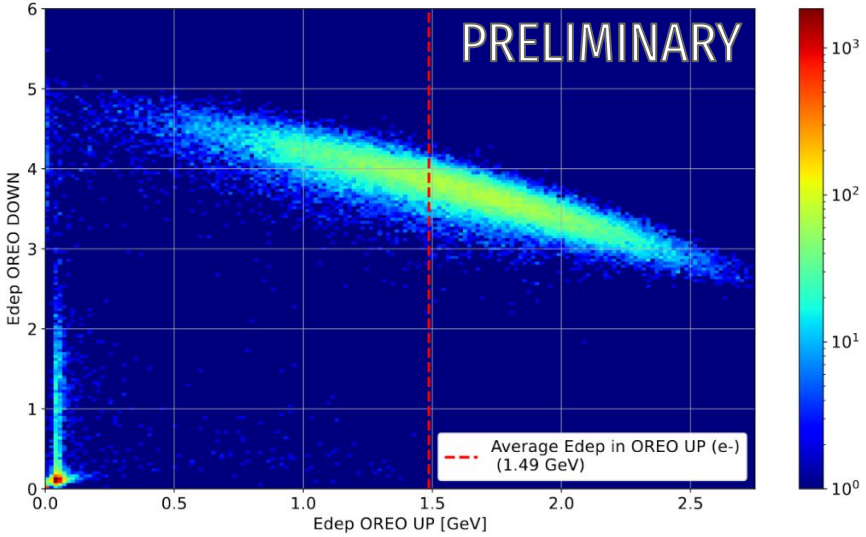
The crystals are well inter-aligned!



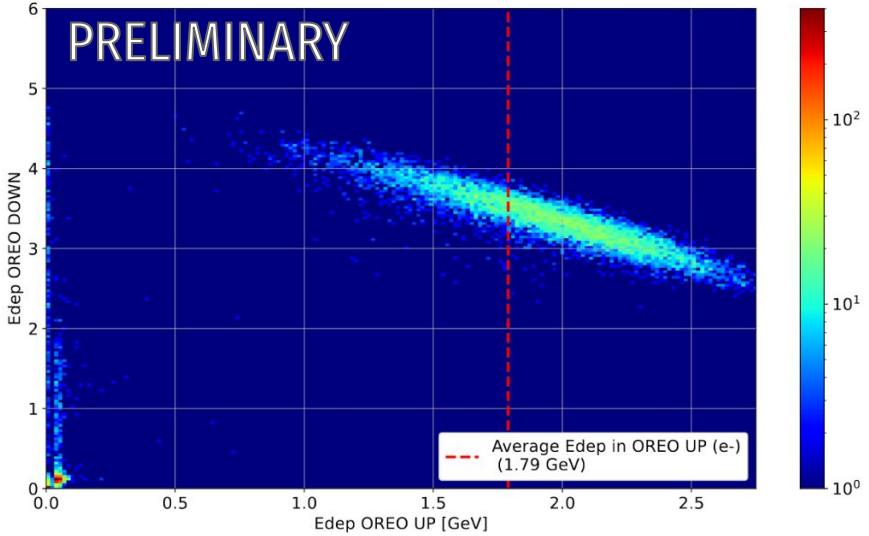
electrons / hadrons discrimination

6 GeV mixed beam, T9 beamline @ CERN PS

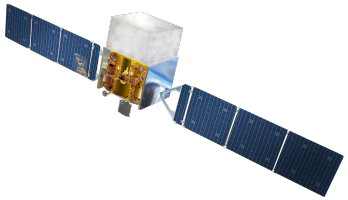
RANDOM



AXIAL



The axial strong field modifies only the electromagnetic processes:
the hadrons are unaffected by the lattice orientation.



ORiEnted calOrimeter for...

space-borne γ-ray (VHE/UHE) detectors with pointing systems e.g. Fermi LAT

- reduced thickness
- improved shower containment with less longitudinal leakage
- higher γ efficiency
- better γ/hadron discrimination

⋮

Bandiera, CRIS-MAC 2024
Bandiera et al.

forward-geometry accelerator-based experiments

fixed-target collider forward region

- improved shower containment and energy resolution
- higher γ efficiency: ideal for γ vetoes
- better γ/hadron discrimination: ideal for γ/n in small-angle calorimeters on neutral hadron beamlines

⋮

Monti-Guarnieri et al.

Thanks for the attention