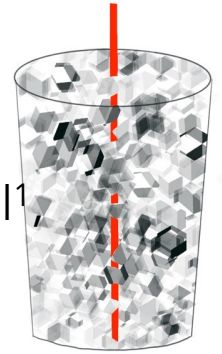
The GRAiNITA project: status report with a focus on the cosmic test bench



S. Barsuk[1],). Beschyko[4], D. Breton[1], A. Boyarintsev[2], I. Boyarintseva[2,1], H. Chanal[3], A. M. Dubovik[2], G. Hull[1], A.Kotenko[4], J. Lefrancois[1], S. Monteil[3], M-H Schune[1], N.Semkiv[4] , I. Tupitsyna[2], M. Yeresko[3]

[1] *Université Paris-Saclay, CNRS-IN2P3, IJCLab, Orsay, France*
[2] *Institute of Scintillation Materials of the National Academy of Science of Ukraine, Kharkiv, Ukraine*
[3] *Université Blaise Pascal, CNRS-IN2P3, LP-Clermont, Aubiere, France*
[4] *Kyiv National Taras Shevchenko University Ukraine*

+ Carlos Dominguez Goncalves, Brice Geoffroy, Miktat Imre, Bernard Mathon, Sebastien Olmo, Denis Reynet (Mechanics)

The overall idea (in a nutshell)

Inspired by LiquidO technique for neutrino detector
(A. Cabrera et al. LiquidO Commun Phys 4, 273 (2021))

Typical sampling calorimeters:

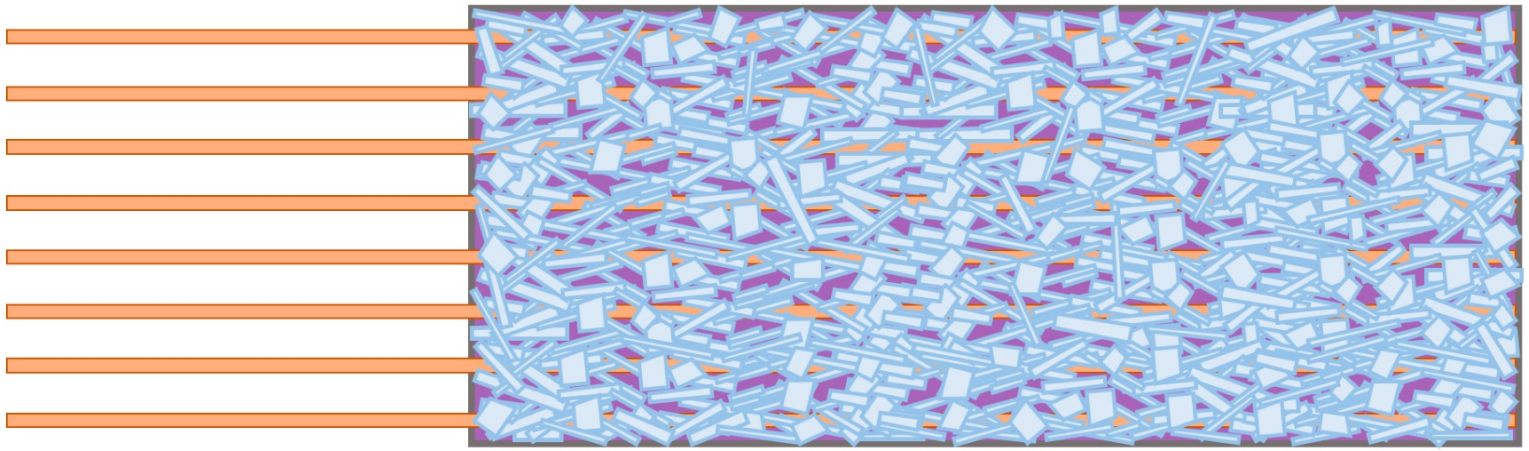
$$\frac{\sigma_E}{E} \sim \frac{10\%-15\%}{\sqrt{E}}$$

Crystal calorimeters :

$$\frac{\sigma_E}{E} \sim \frac{1\%-2\%}{\sqrt{E}}$$

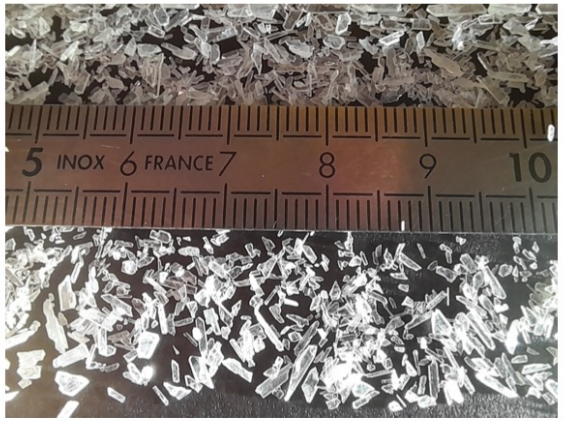
Requirements:

- fine sampling
- scintillation light locally contained



A possible candidate: $ZnWO_4$

	BGO	$ZnWO_4$
Effective Z	74	61
Density (g/cm^3)	7.13	7.87
Refractive index	2.15	2.0 - 2.3
Light yield (photons/MeV)	~ 9000	~ 9000
Peak emission wavelength (nm)	480	480
Decay time (μs)	0.3	20
Radiation length (cm)	1.12	1.20
Molière radius (cm)	2.26	1.98



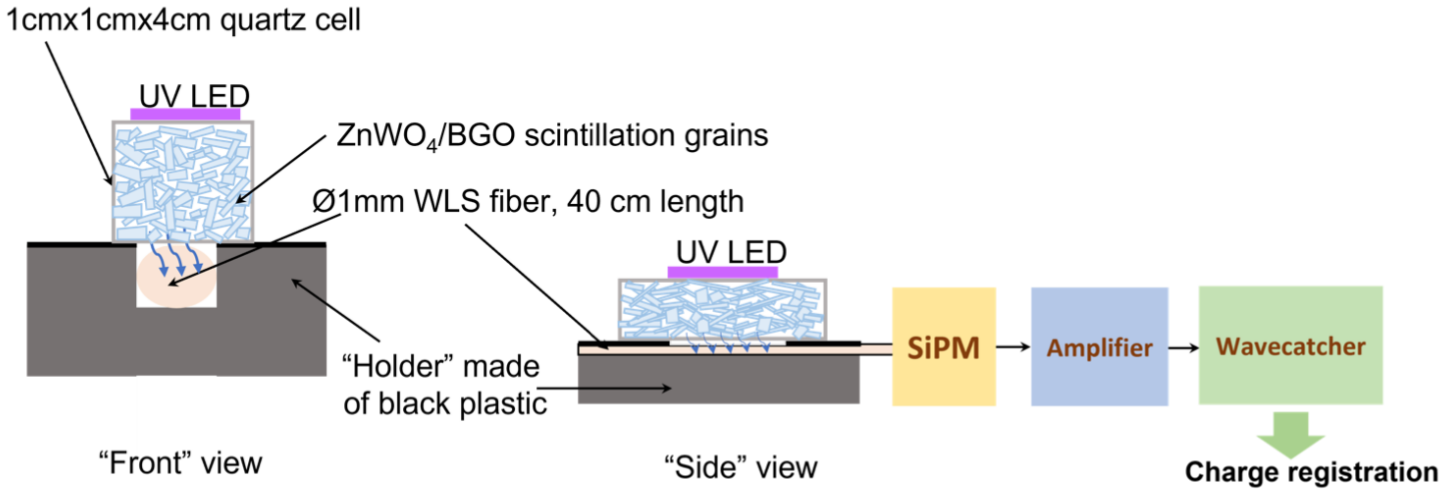
ISMA has done specific R&D and has produced grains & plates of $ZnWO_4$

- "flux method" production of $ZnWO_4$ is under control

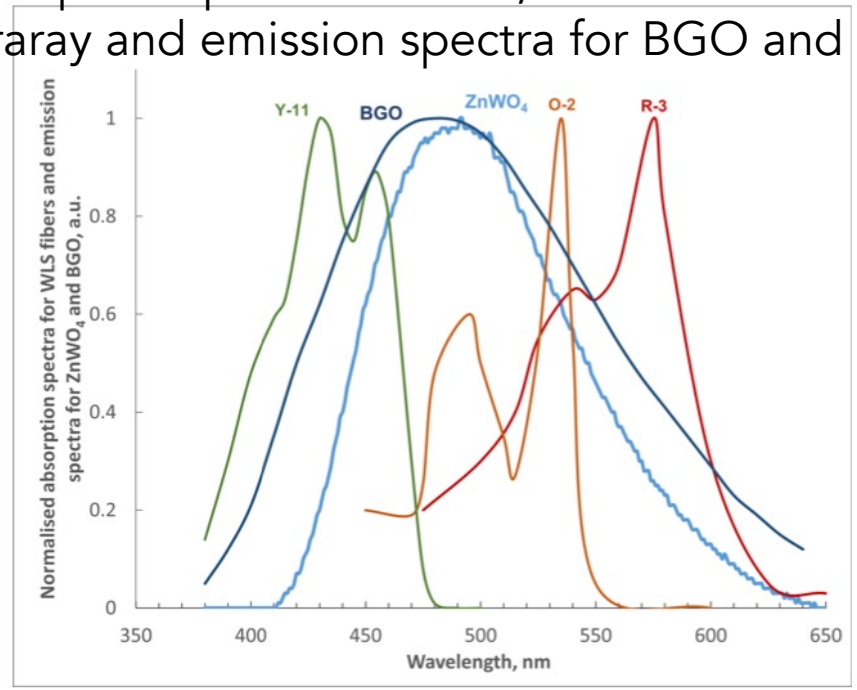
- ~ 1kg of $ZnWO_4$
- grains of BGO (200 g)
- small plates of BGO & of $ZnWO_4$

Price reduction ~ 2.5 for ZnWo4 wrt crystal

WLS fiber selection



Absorption spectra for Y-11, O-2 and R-3 fibers from Kuraray and emission spectra for BGO and $ZnWO_4$

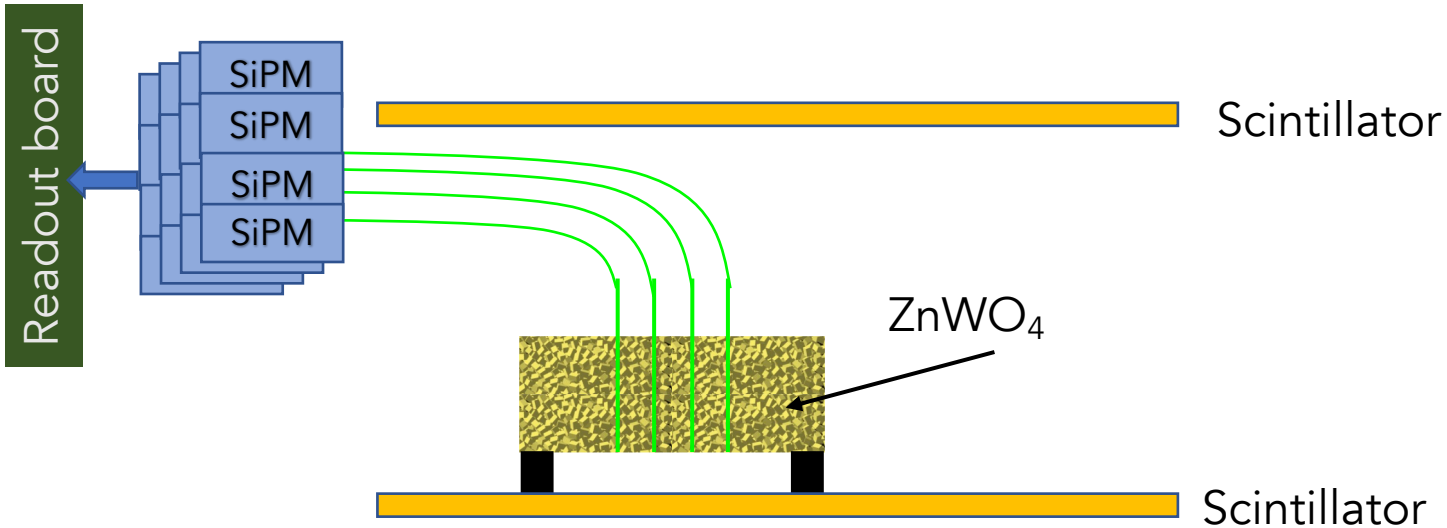


	Relative efficiency (%)	
Fiber type	$ZnWO_4$ grains (~ 9 mm)	BGO grains (~ 9 mm)
O-3(300)	100	100
O-2(200)	104	104
Y-11(200)	44	98
R-3(100)	60	n.a.

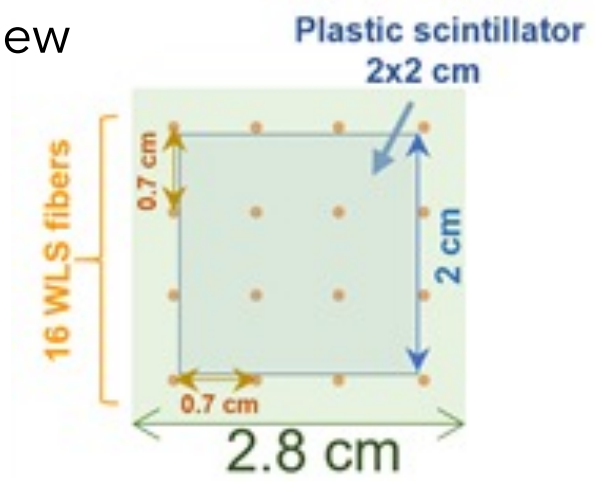
preferred choice

Cosmic rays test bench

determine the number of photo-electrons

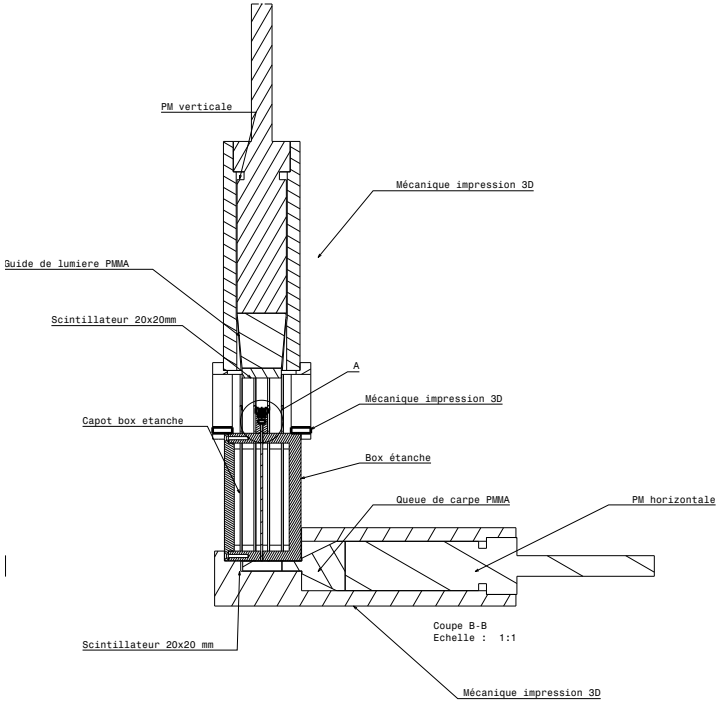


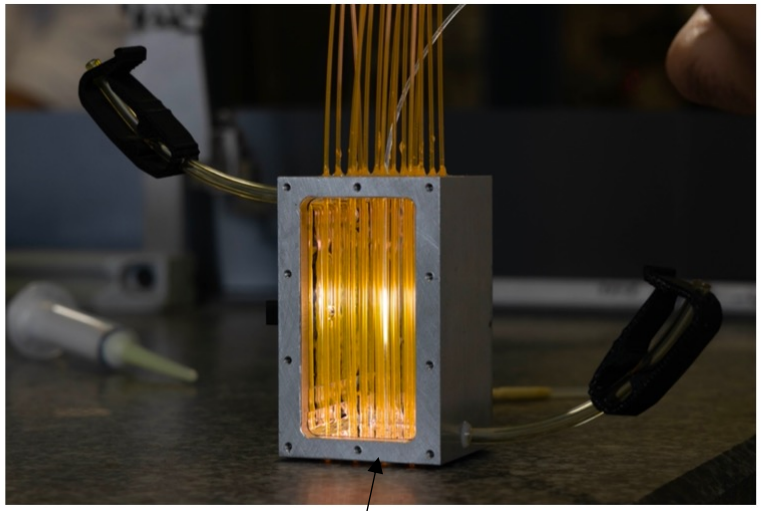
top view

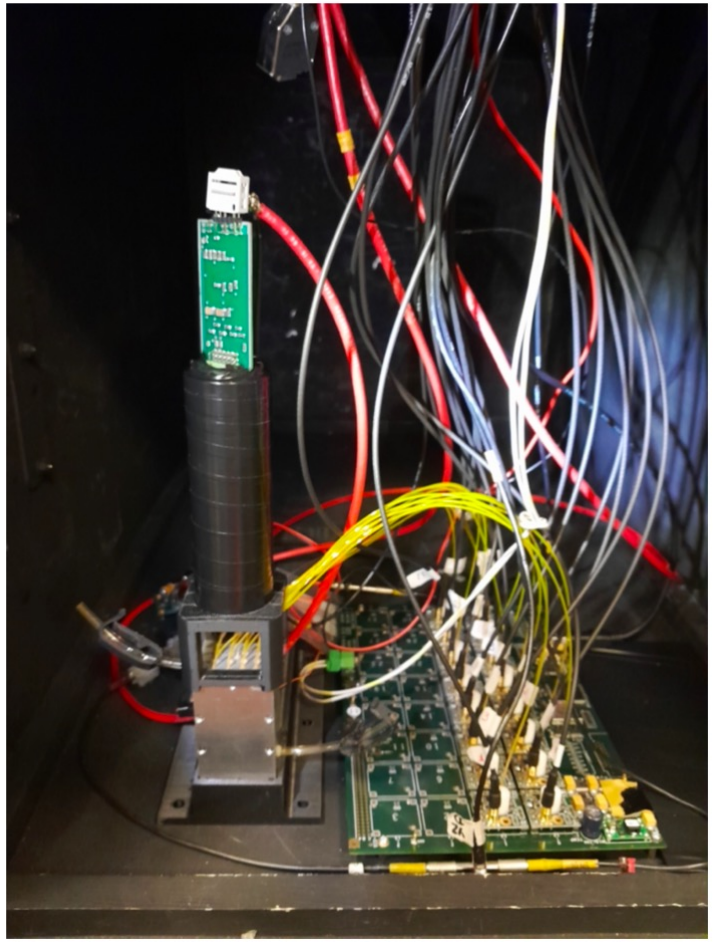


- Active volume = 2.8 x 2.8 x 6 cm^3 (~200 g of $ZnWO_4$)
- Fibers spacing: 7 mm
- 16 fibers read-out by SiPM
- Possibility to repeat the study with BGO
- Blue/Green LED injected in the middle
- Cosmic rays triggering

Real object and test bench !







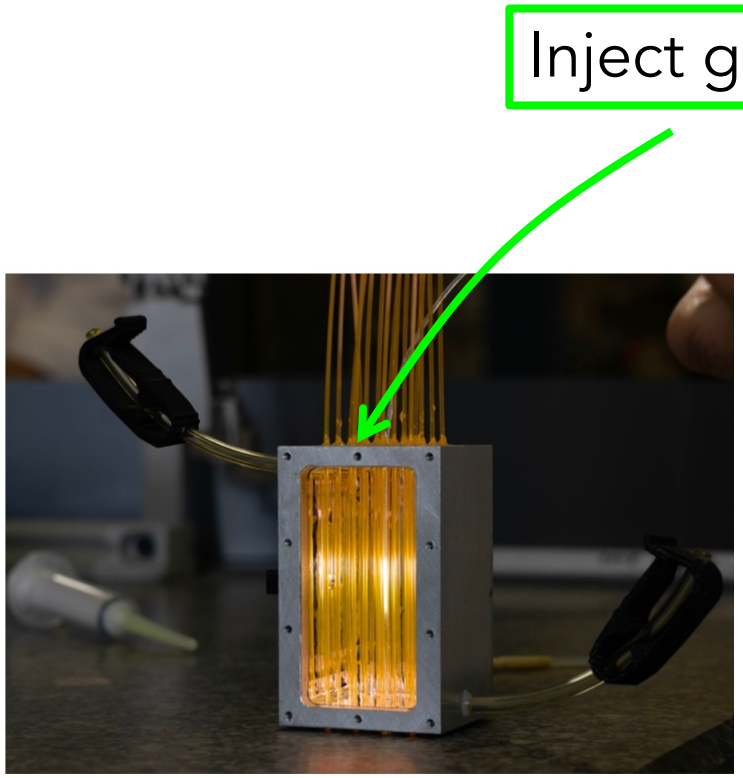
No reflective material at the end of the fibers

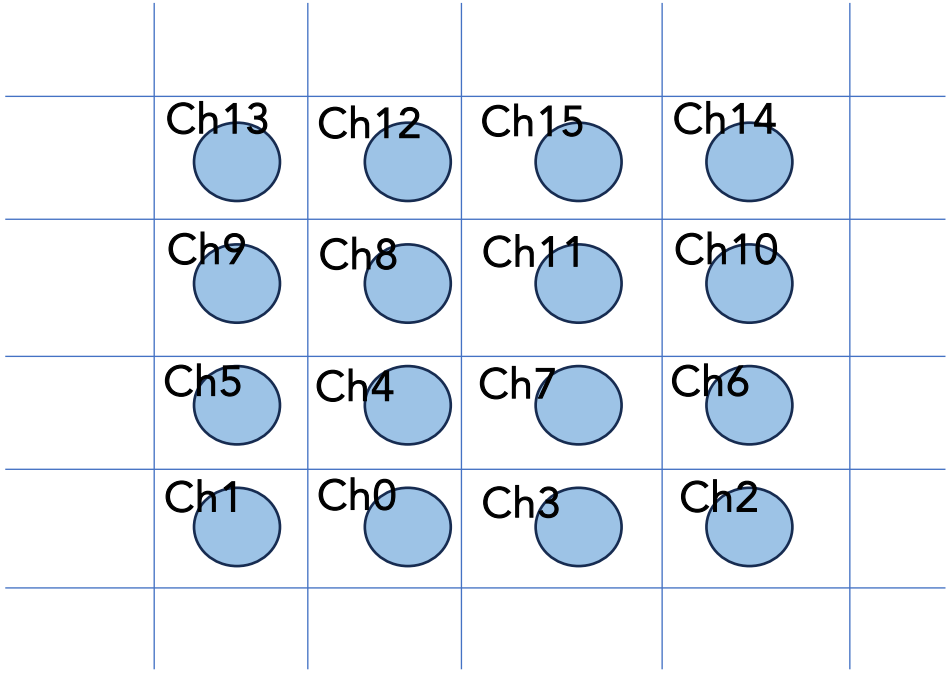
Prototype characterization

$ZnWO_4$

$ZnWO_4$ + H_2O

$ZnWO_4$ + EGL



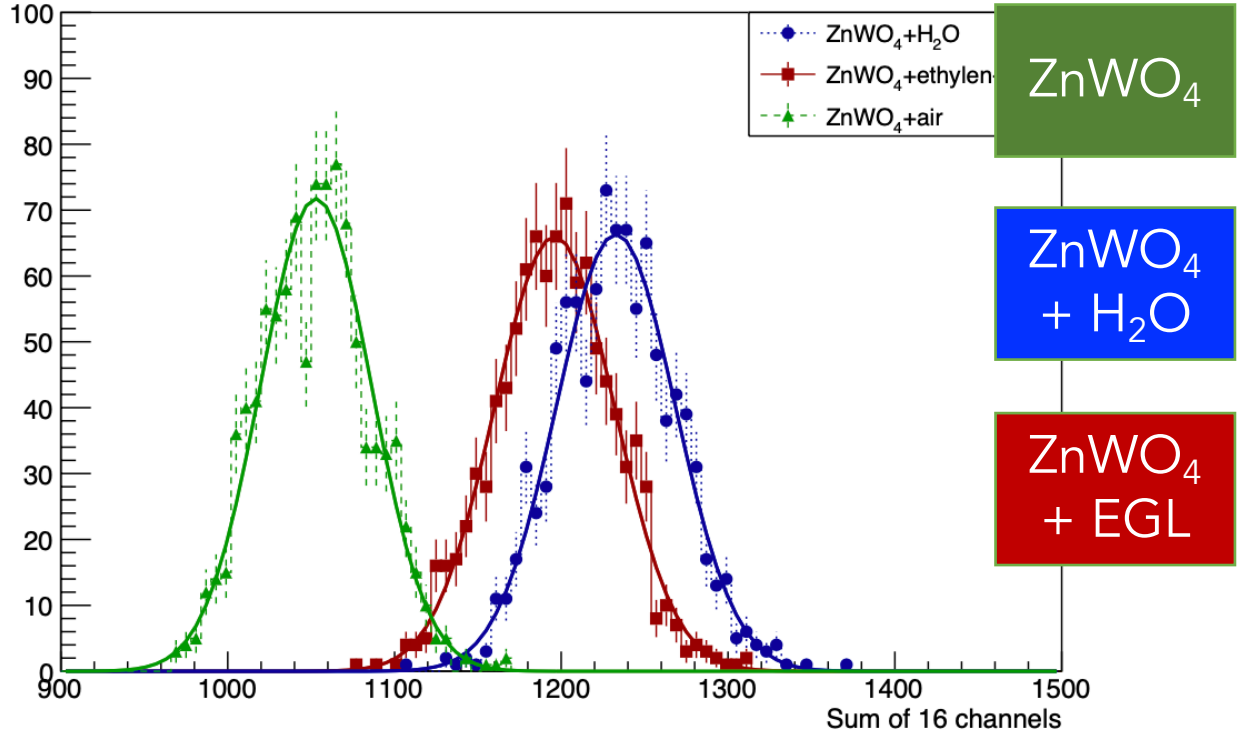


$$\text{Sum} = \sum_{i=0}^{16} Ch_i$$

$$\text{Centrality} = \frac{4\ central\ channels}{Sum}$$

dark current noise subtracted (about 2% for the central fibers)

Sum



$ZnWO_4$

$ZnWO_4$ + H_2O

$ZnWO_4$ + EGL

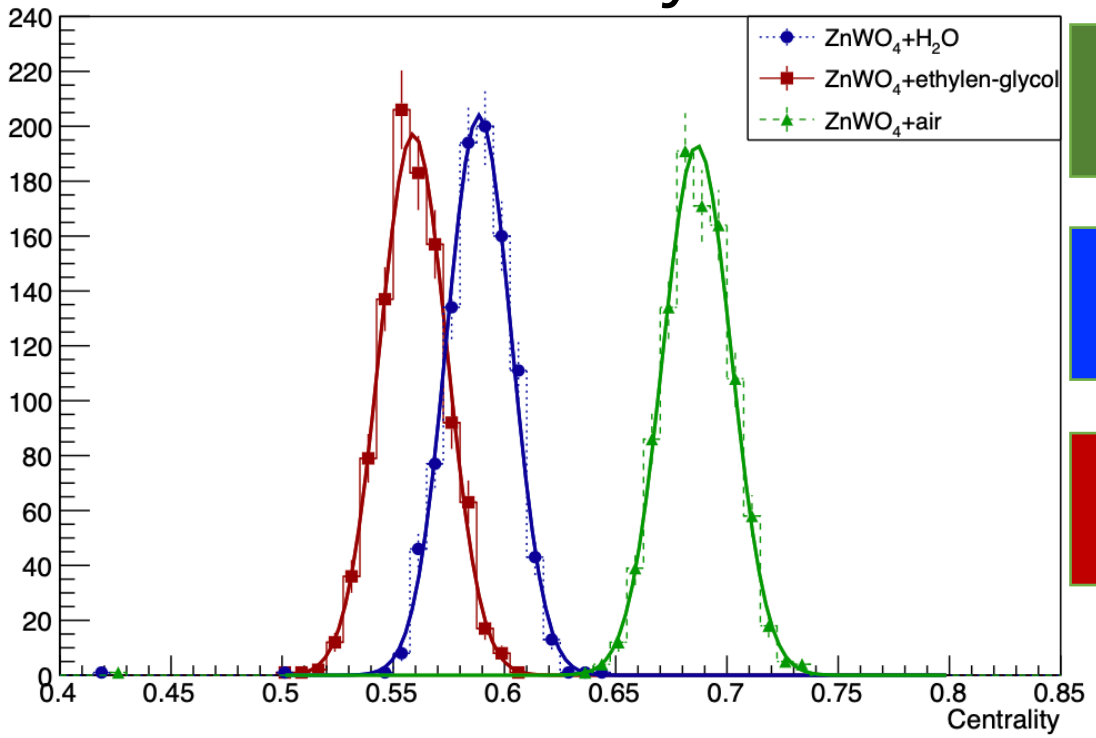
External medium	Mean (Sum)
Air (n=1)	1052.9 ± 1.1
Water (n=1.33)	1232.8 ± 1.1
Ethylene-glycol (n=1.43)	1196.1 ± 1.1

- Larger signal with liquids
- Small difference between EGL & H2O is of no concern for the cosmic test

Total signal depends upon :

- amount of light emitted by the depolished part of the fiber (measured to be lower with liquids than in air)
- better matching between the medium and the ZnWO4 refractive indices → smaller impact of the absorption in the grains
- efficiency of the WLS fibers for the signal collection varies with the medium refractive index.

Centrality



$ZnWO_4$

$ZnWO_4$ + H_2O

$ZnWO_4$ + EGL

External medium	Mean (Centrality)
Air (n=1)	0.6866 ± 0.0005
Water (n=1.33)	0.5886 ± 0.0005
Ethylene-glycol (n=1.43)	0.5590 ± 0.0005

ZnWO4 and medium refractive indices more different → light is more confined
(the photons have higher probability to bounce back and to stay closer of the emission point)

First cosmic rays results

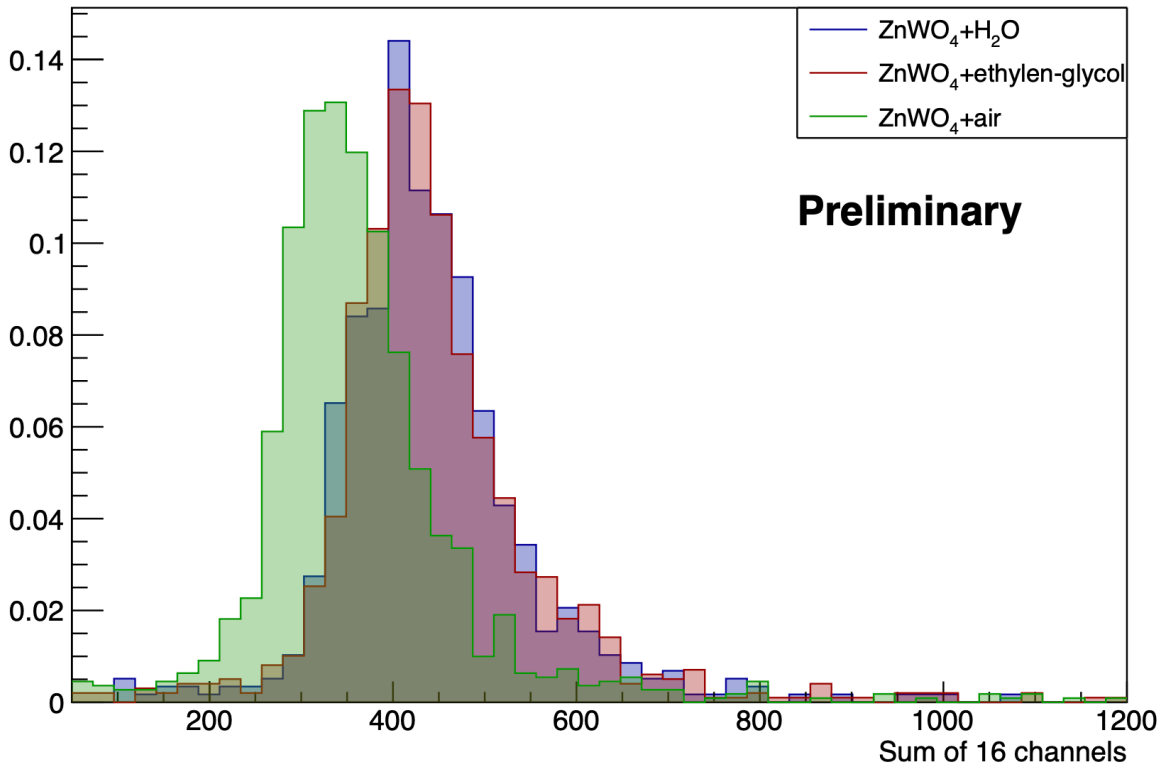
$ZnWO_4$

$ZnWO_4$ + H_2O

$ZnWO_4$ + EGL

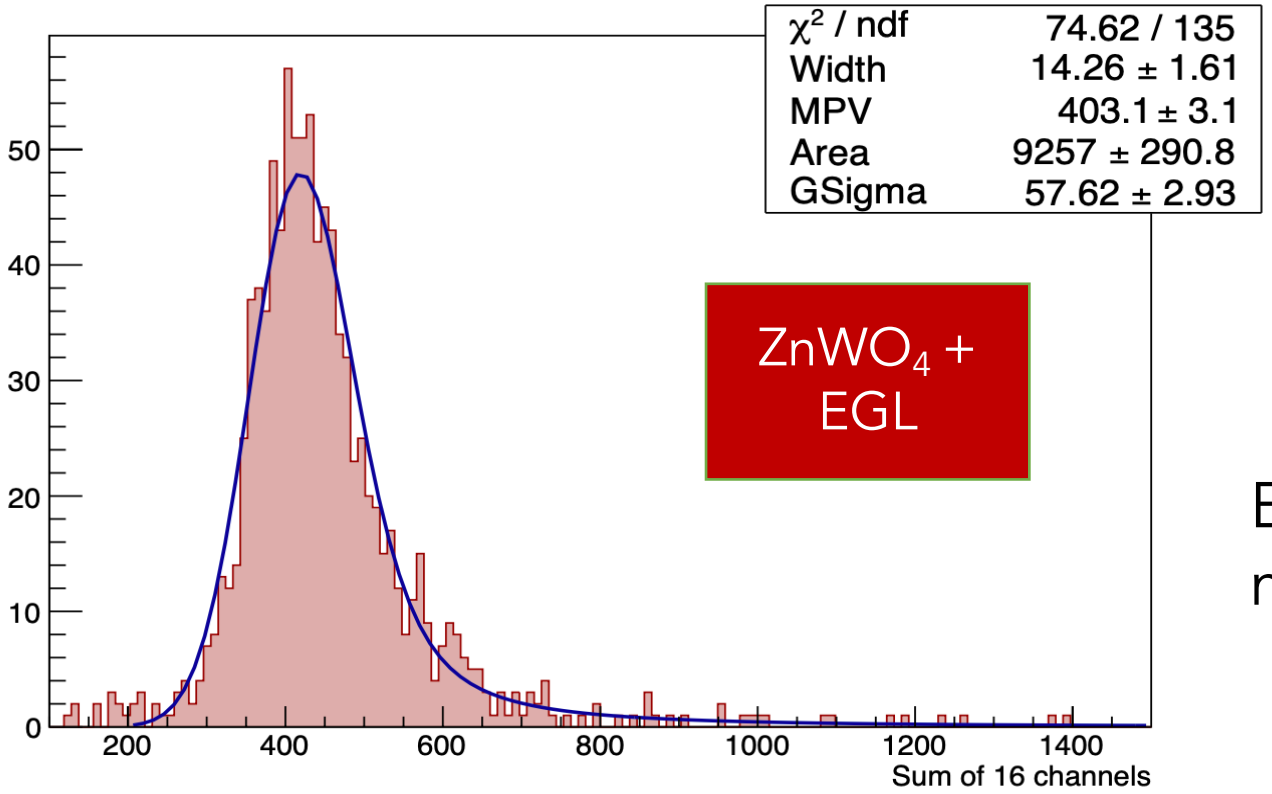
Rate is low (~4 cosmics per hour)

Sum



Larger signal when the refractive index is better matched with ZnWO4

Sum



Fit : G⊗Landau

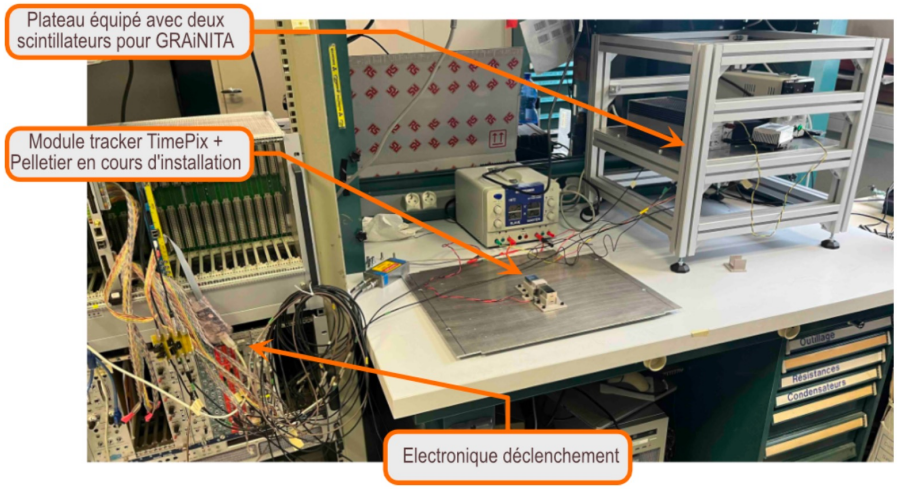
Expected energy deposit by a cosmic muon in this 6 cm high device: 40 MeV

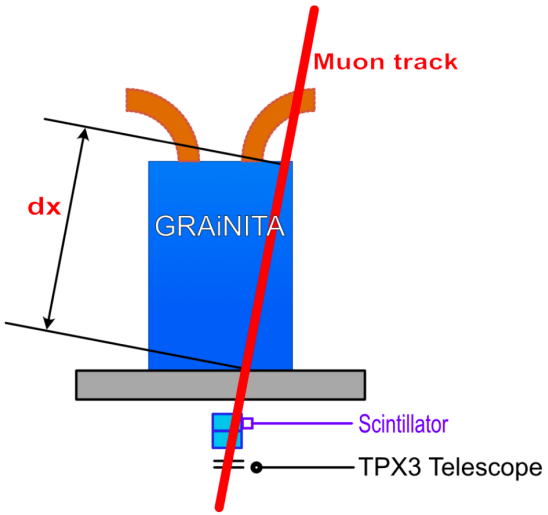
Publication in preparation

→ ~ 10 000 photo-electrons/GeV
opens the road to a statistical fluctuation of 1% /sqrt(E) due to photon statistics

What's next ?

- Study of the heavy liquid
- Similar study with BGO
- Another test bench to characterize the uniformity of response (μ close to a fiber or half-way) and the angular dependence of response. Constant term in the energy resolution





- Test beam with muons
- A full-size module demonstrator (17 × 17 × 40 cm3) (25X0 in depth)