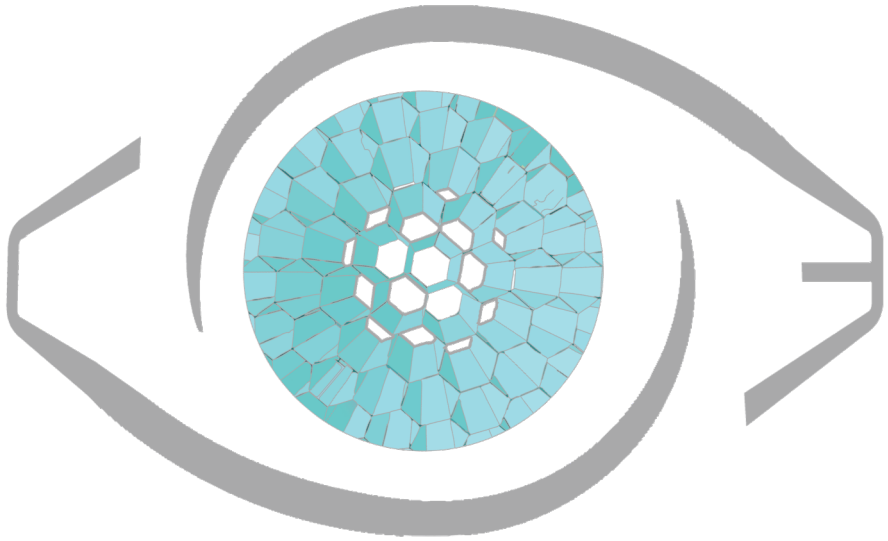


The Crystal Eye X and gamma ray detector for space missions

GRAN SASSO SCIENCE INSTITUTE
SCHOOL OF ADVANCED STUDIES
Scuola Universitaria Superiore

UNIVERSITÀ DEGLI STUDI DI NAPOLI FEDERICO II

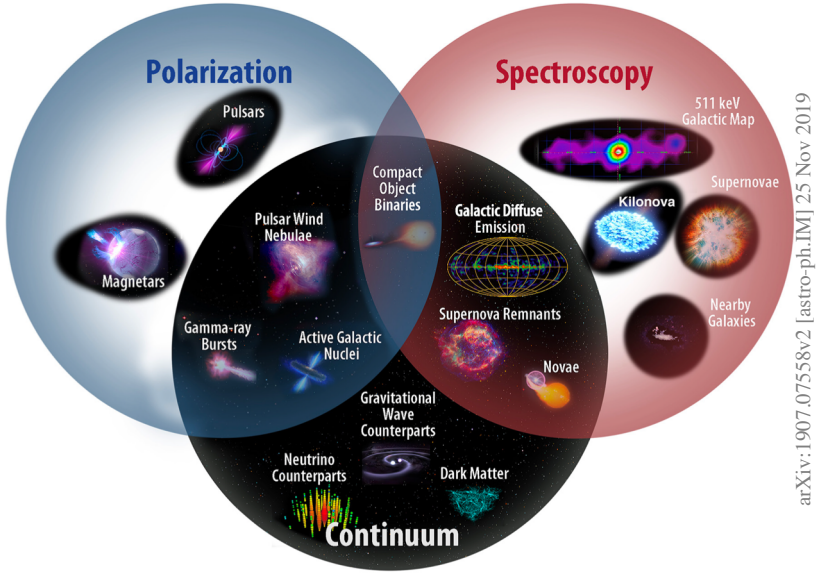
INFN Istituto Nazionale di Fisica Nucleare

THE MEDIUM/LOW ENERGY GAMMA RANGE

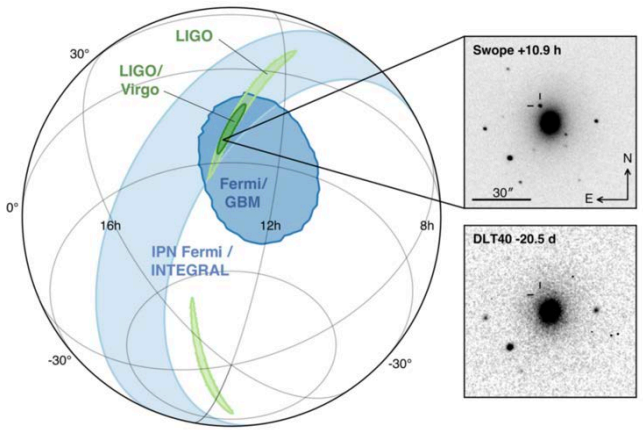
Wonderful experiments and results in the hard X-ray/low energy gamma ray range (E~10-200 keV) and high energy gamma rays range (E> 1GeV)

Medium energies still under-explored (E ~ MeV)

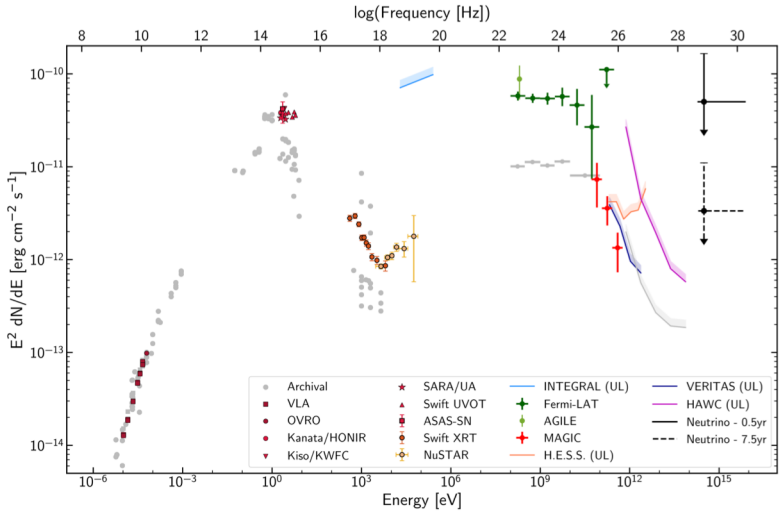
Powerful probes for the extreme Universe



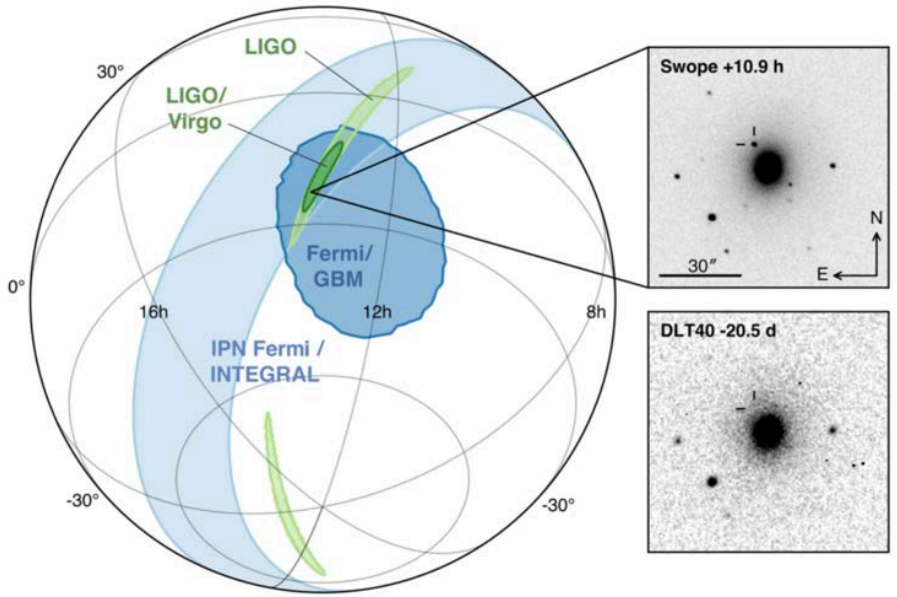
GW170817



TXS 0506+056



THE SCIENCE CASE: GRBs AND NS-GW



17-08-2017

- First NS merger observed in GW
- First detection of EM counterpart (GRB 170817A; AT 2017gfo)

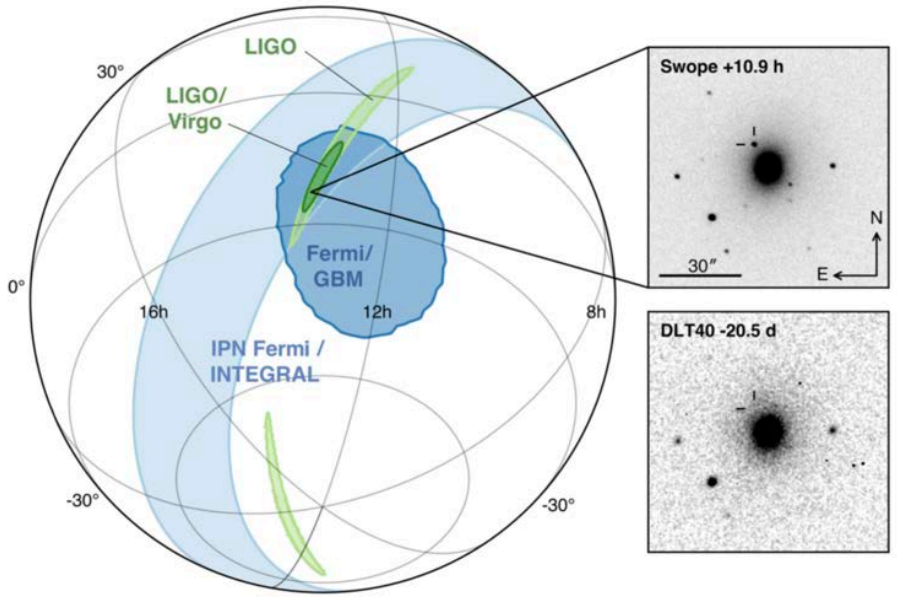
25-04-2019

- NS merger observed in GW
- EM counterpart (GRB 190425) detected only by INTEGRAL
- No follow-up by other experiments (probably due to the occultation by the Earth)

Primary Scientific Goal: Monitoring the electromagnetic counterpart of gravitational waves

We need to enhance the detection and localization capability of our instruments to *perform frontier science* and *enable new technologies*

THE SCIENCE CASE: GRBs AND NS-GW



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Primary Scientific Goal: Monitoring the electromagnetic counterpart of gravitational waves

We need to enhance the detection and localization capability of our instruments to *perform frontier science* and *enable new technologies*

Exploit a constellation of satellites

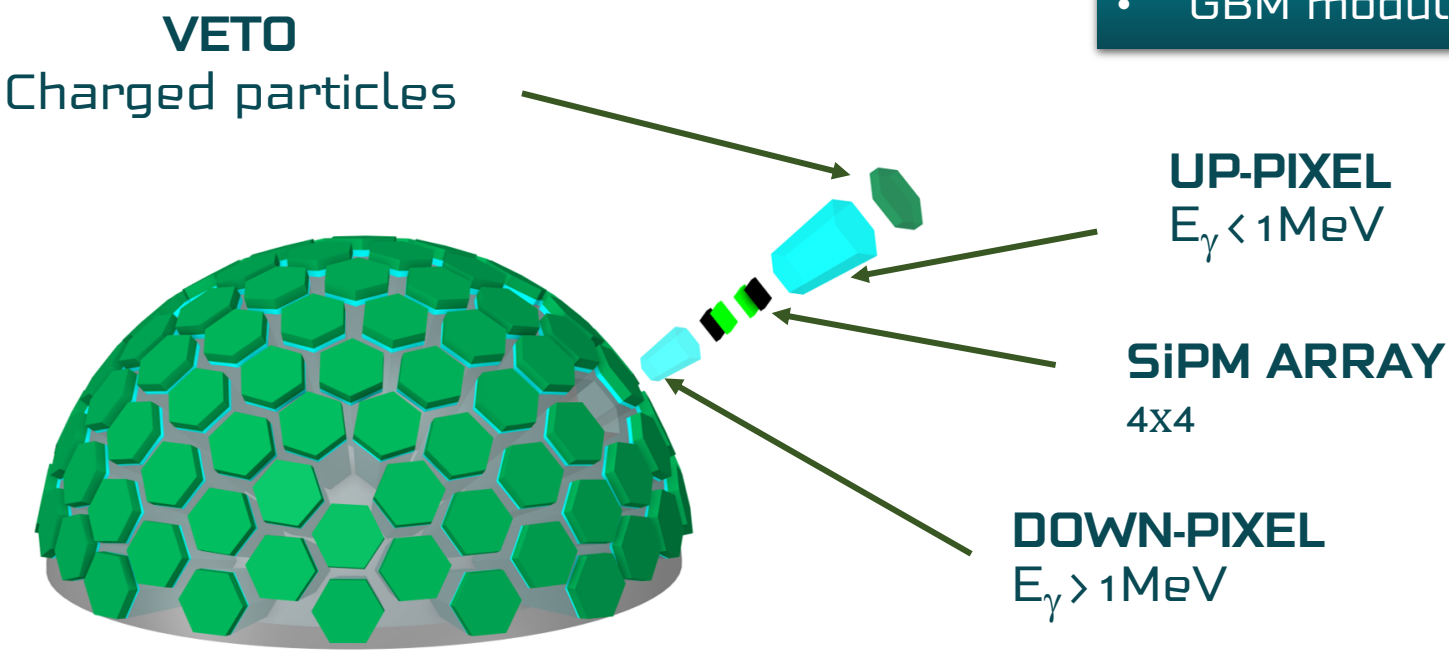
Change the detection method

THE CRYSTAL EYE METHOD

Compact to be portable by human flights
LYSO crystals read by SiPM-array

BORN TO BE:

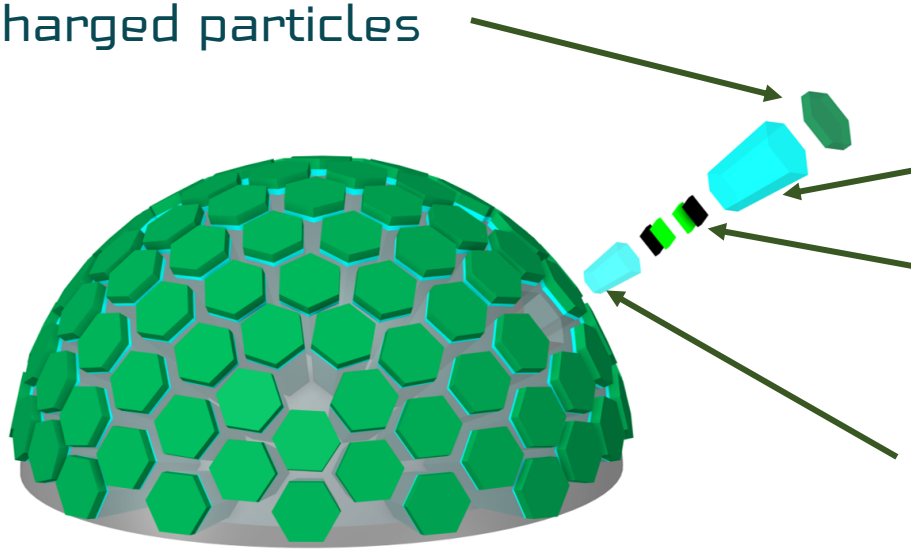
- Free-flyer
- Onboard of space stations
- GBM module of larger satellites



Radius: 17 cm
Energy range: 10keV -30MeV
Material: LYSO
Photodetectors: 4x4 Hamamatsu MPPC 3x3mm² 50μm
FOV: 6sr
Effective area: ~ 600 cm² @ 1MeV

THE CRYSTAL EYE METHOD

VETO
Charged particles

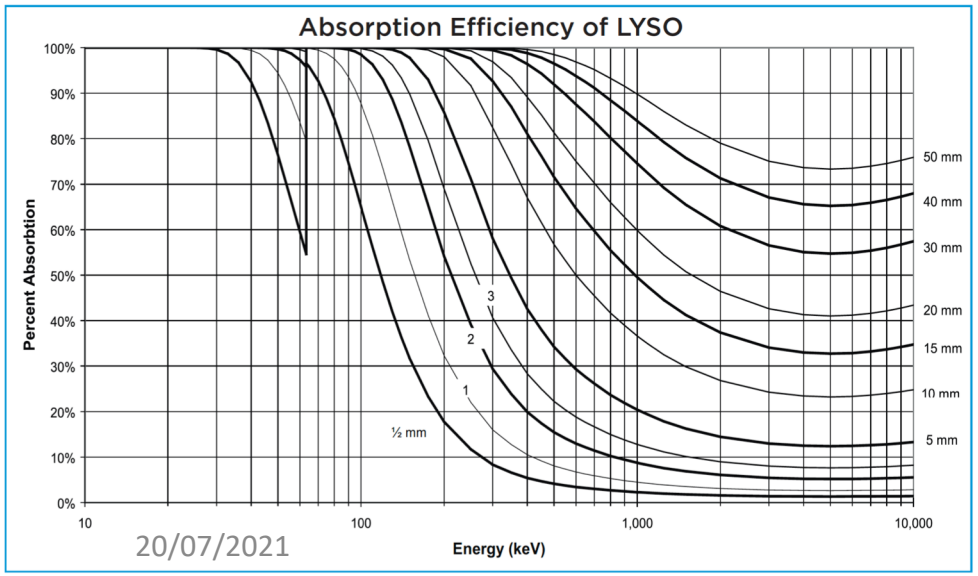


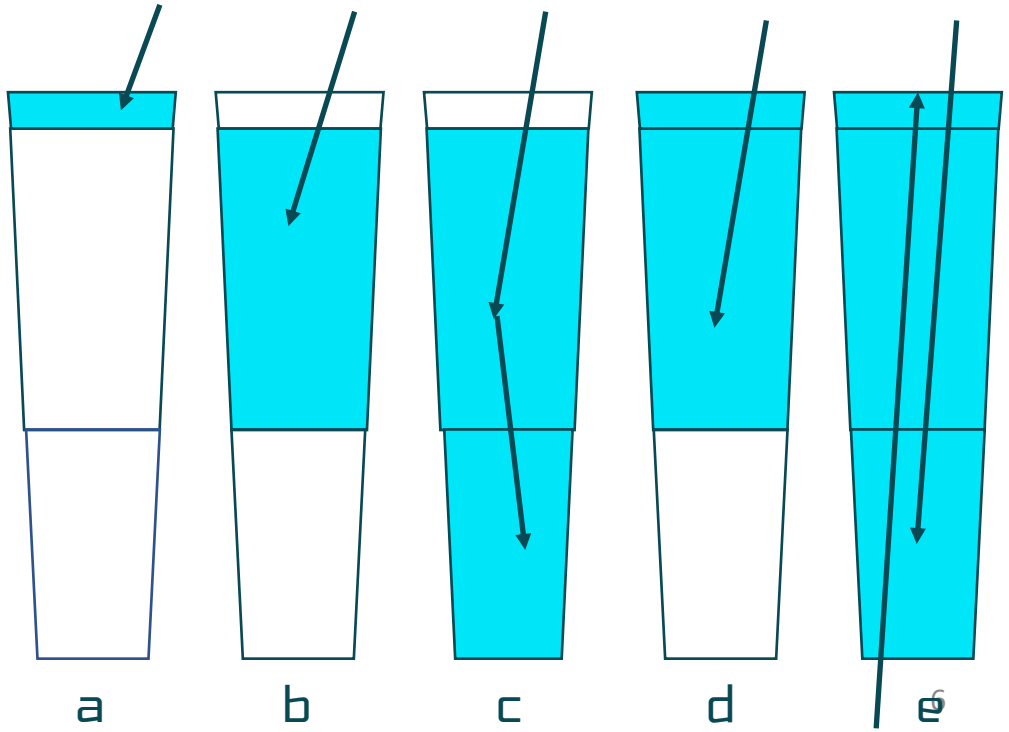
UP-PIXEL
$E_\gamma < 1MeV$

SiPM ARRAY
4X4

DOWN-PIXEL
$E_\gamma > 1MeV$

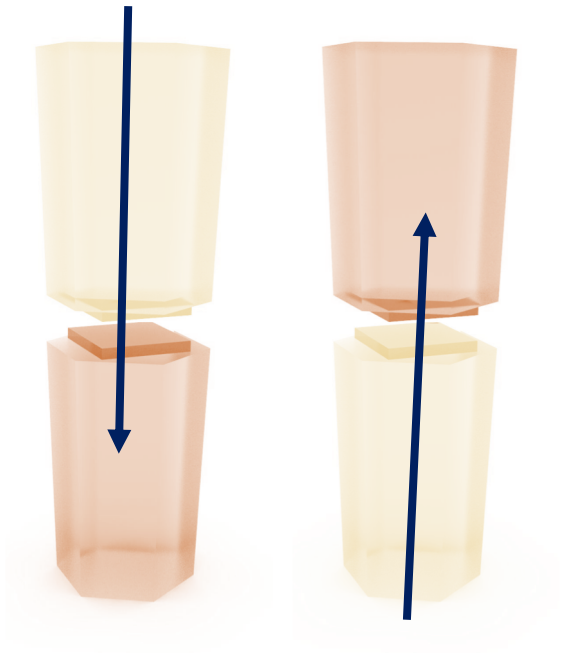
a – Down-going hard X-ray
b – Down-going LE γ-ray
c – Down-going ME γ-ray
d – Down-going LE charged particle
e – HE charged particle



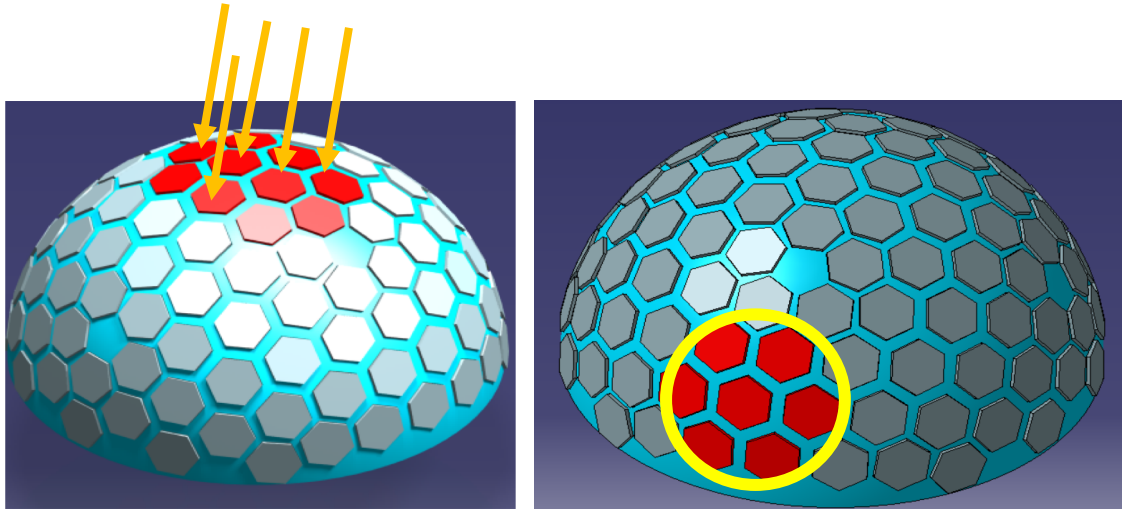


THE CHARGE DISTRIBUTION

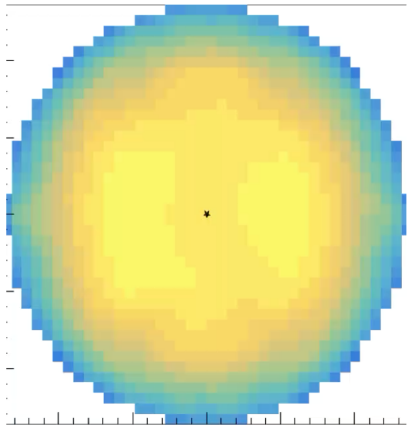
Different charge deposit in up-going or down-going events



(a) (b)

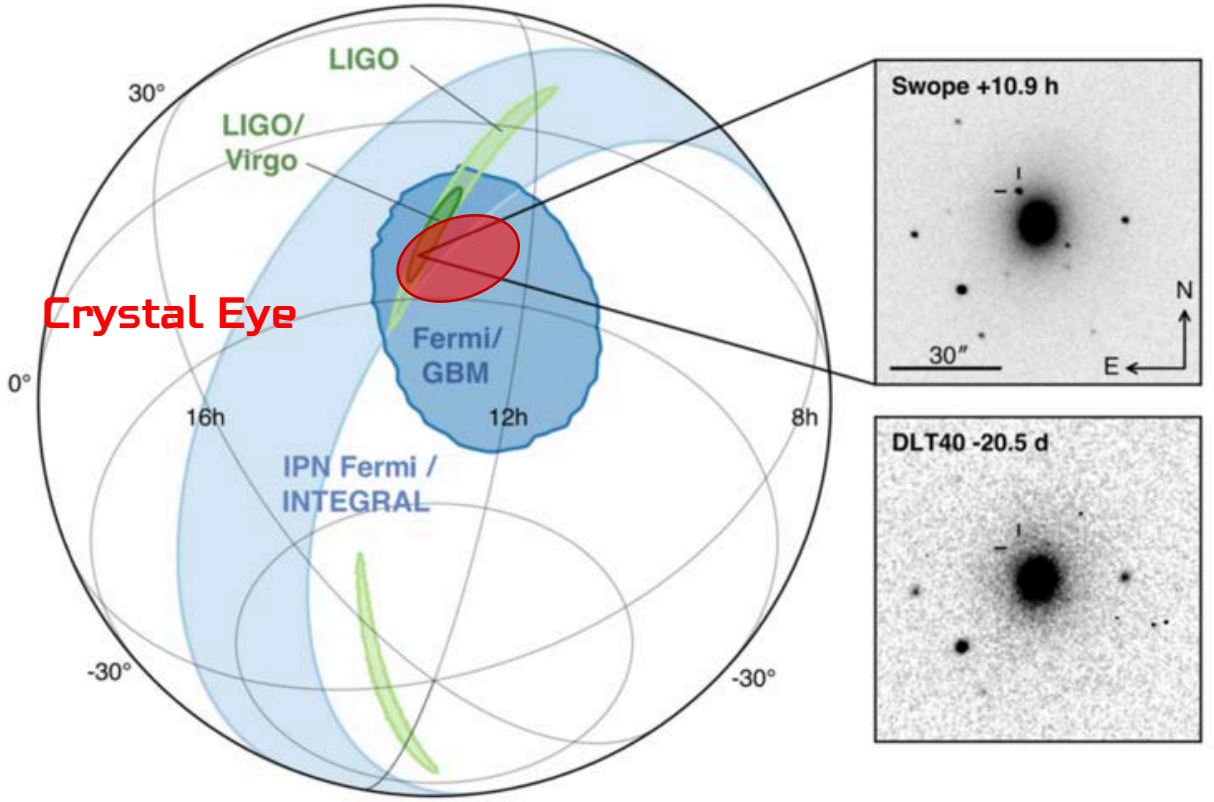


The localization is possible by following the charge distribution on the detector



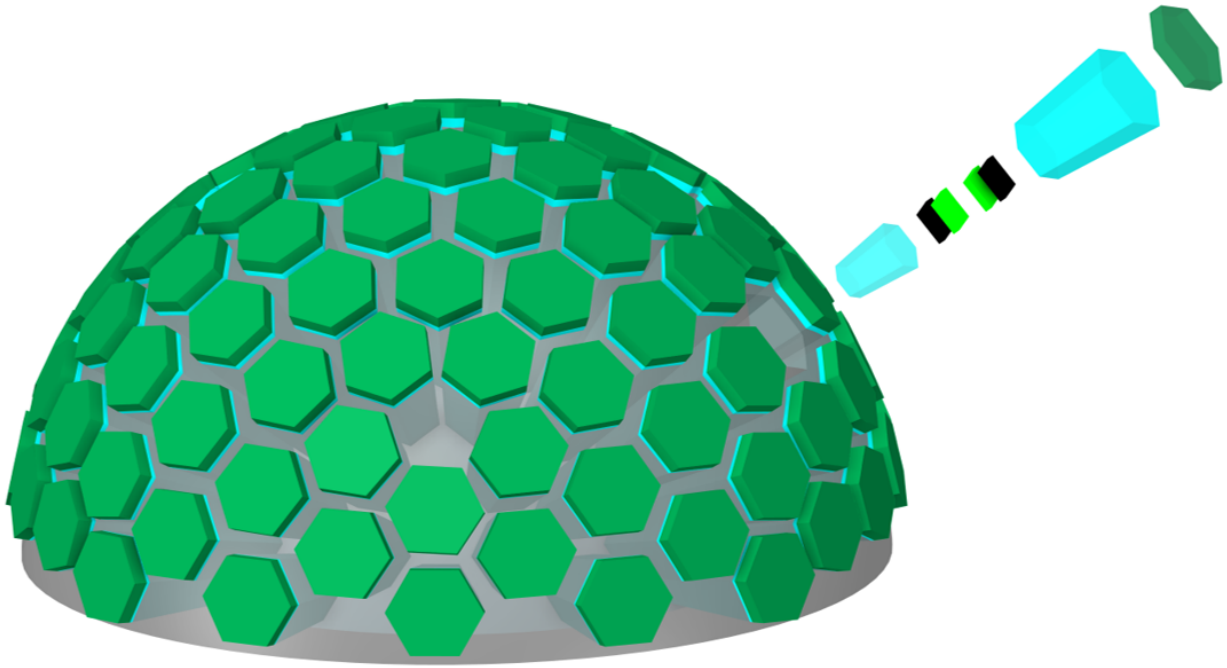
A FIRST STUDY

Localization capability more than 4 times better than Fermi-GBM with only **ONE** Crystal Eye



... Further improvements expected by triangulation of 3 Crystal Eyes

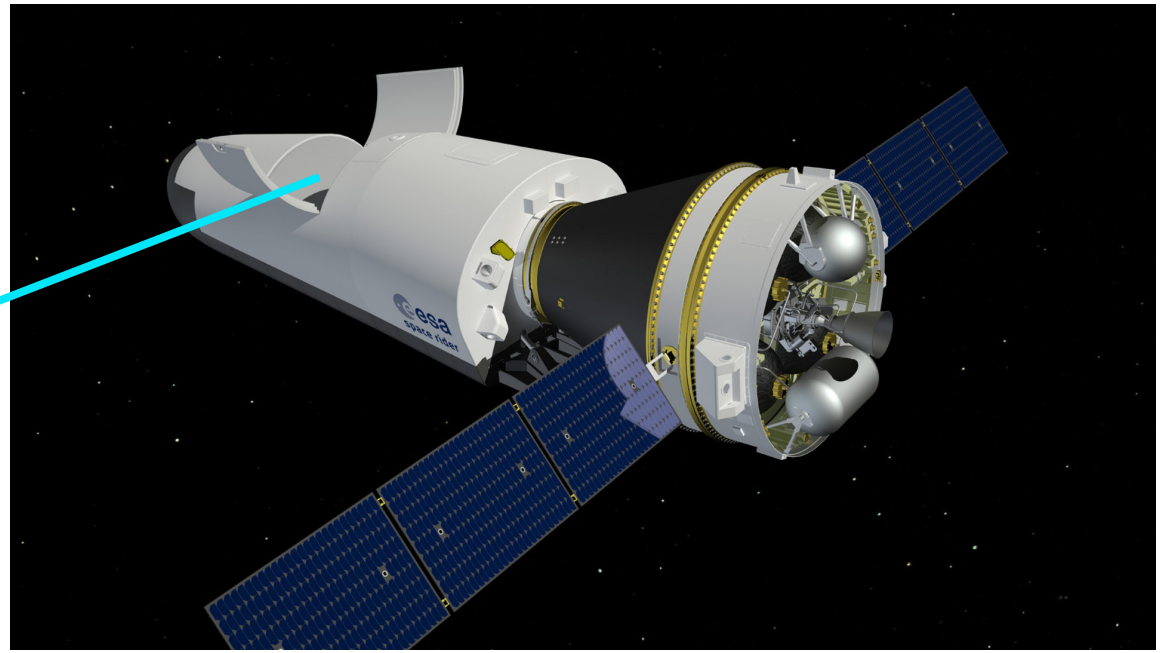
A SMART CONFIGURATION



The hemispherical double layer represents a smart configuration from several point of view

- Compactness
- Symmetry
- Thermal protection of the SiPMs
- Radioprotection of the SiPMs

FIRST GSSI SPACE MISSION: THE SPACE RIDER FLIGHT

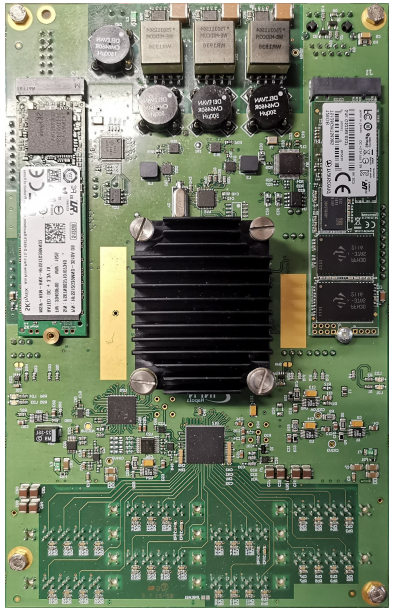


Technological pathfinder eligible for the Space RIDER launch by ESA in 2023

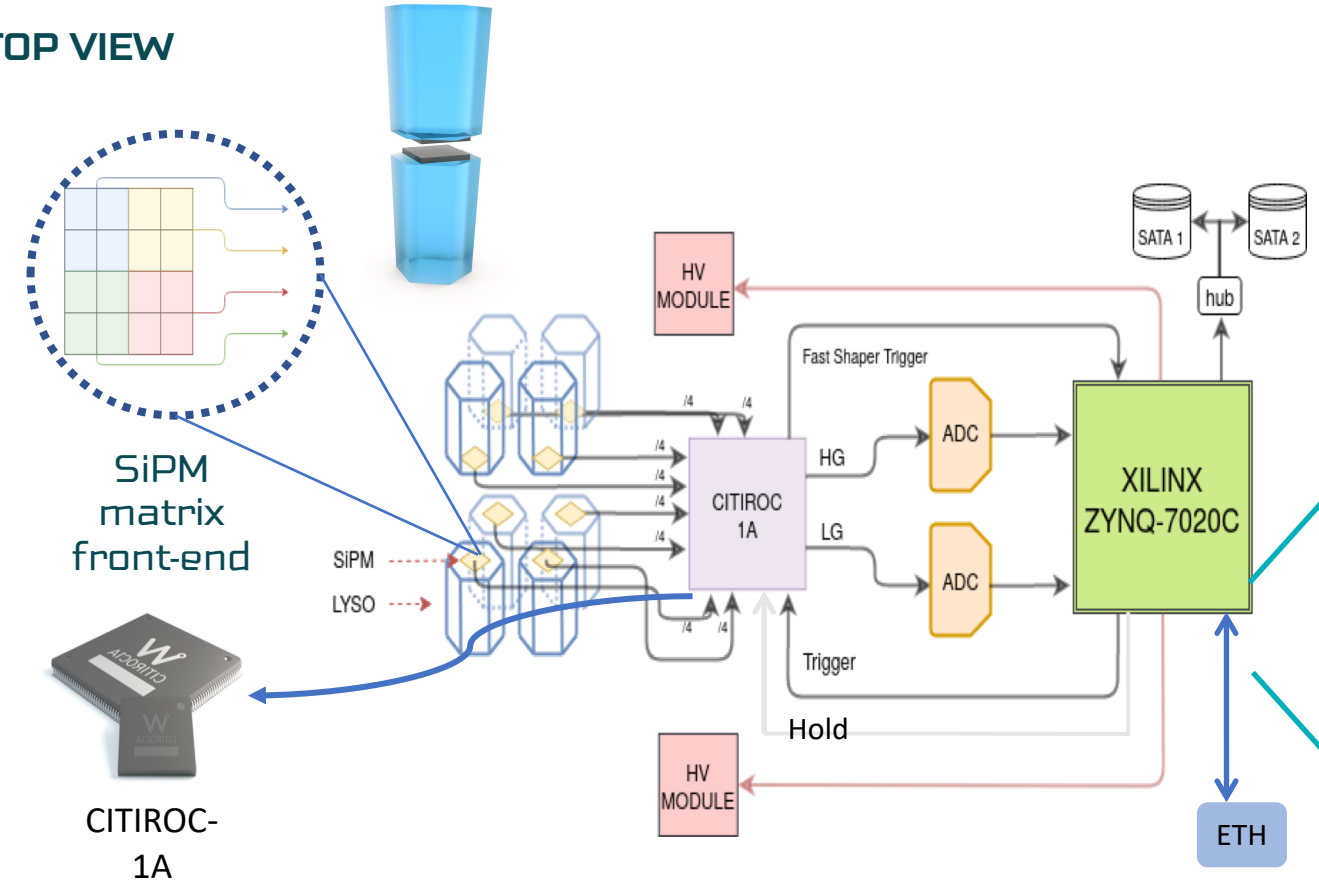
SCIENTIFIC GOAL : Background characterization

Number of pixels: 4
Material: LYSO/BGO
Photodetectors: 4x4 Hamamatsu MPPC 3x3mm² 50μm
Weight: 1.5kg
Power consumption: <10 W

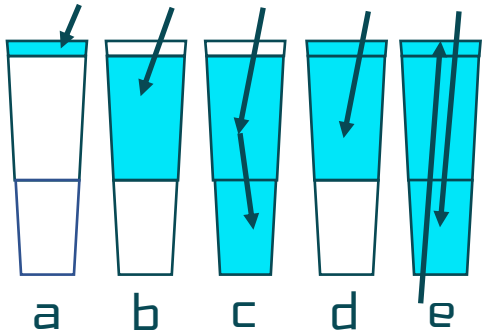
DAQ SYSTEM

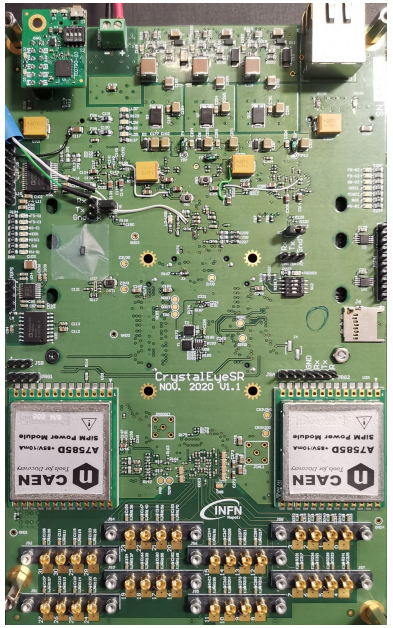


TOP VIEW



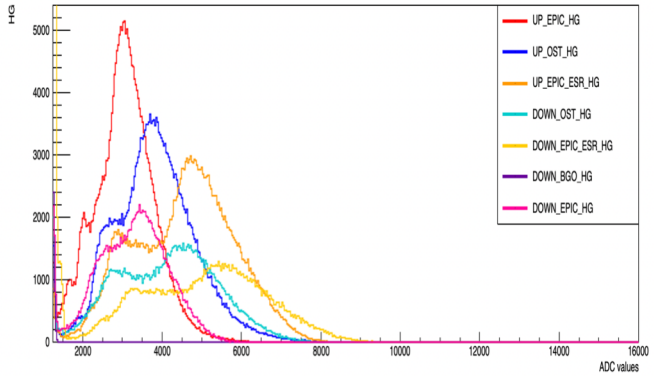
DATA MODE



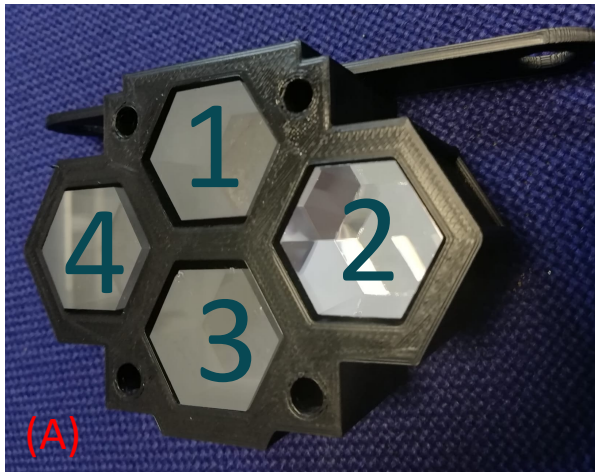


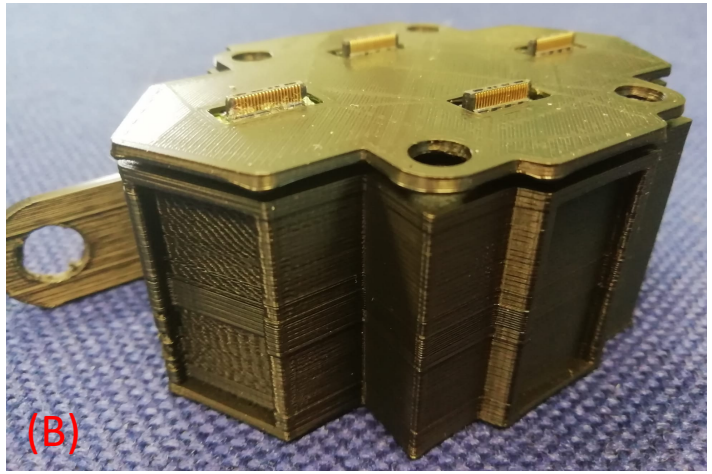
BOTTOM VIEW

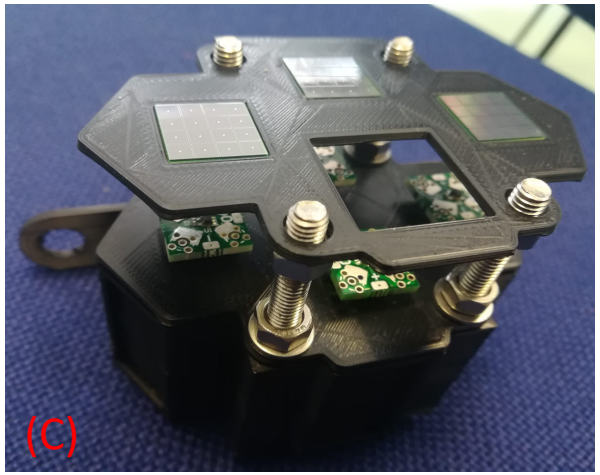
CALIBRATION MODE

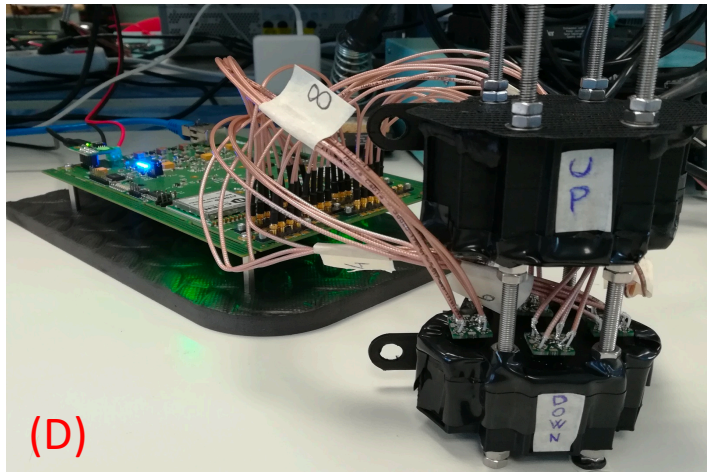


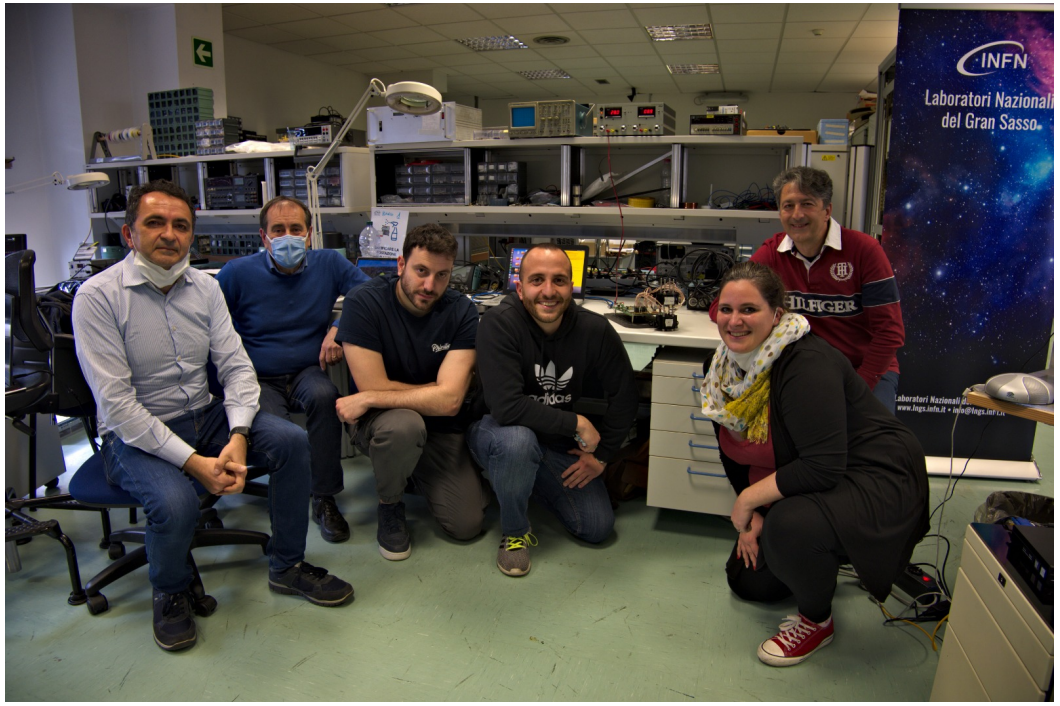
The prototype assembly





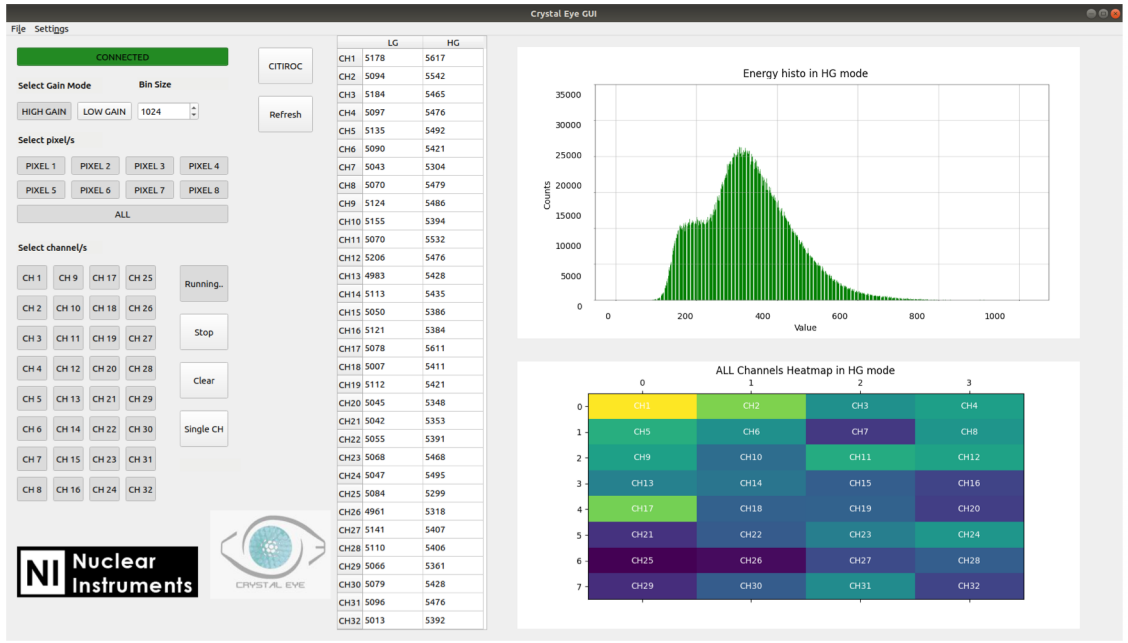


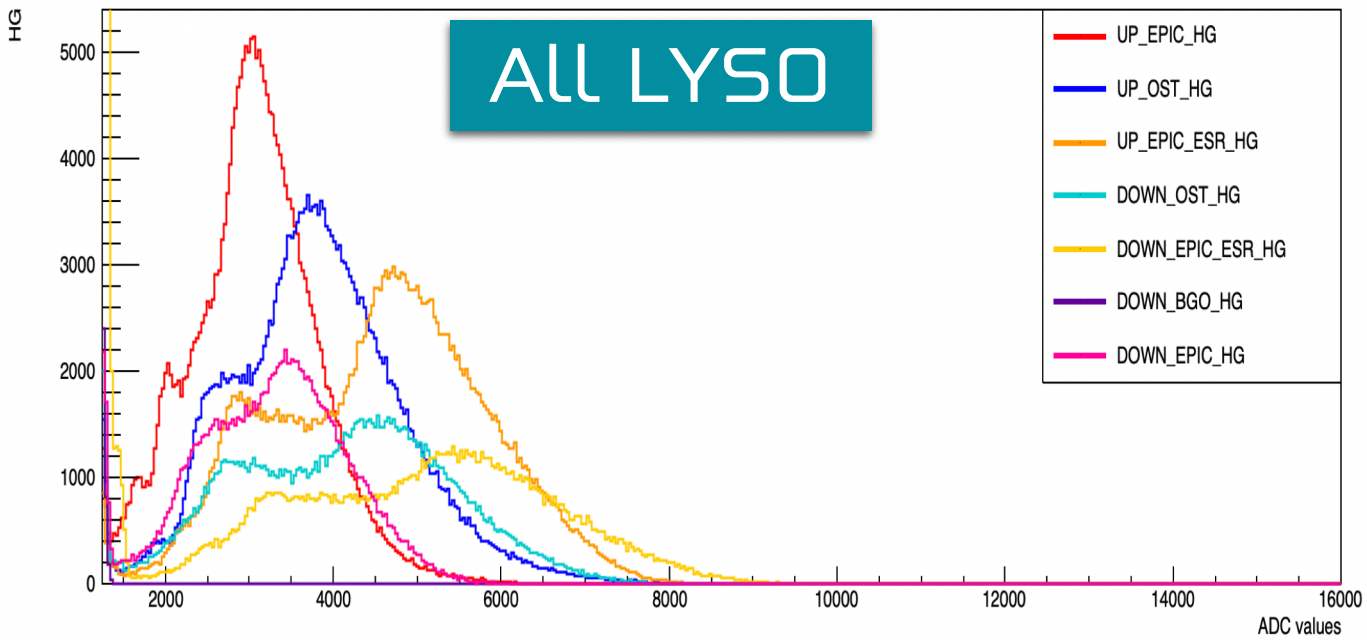


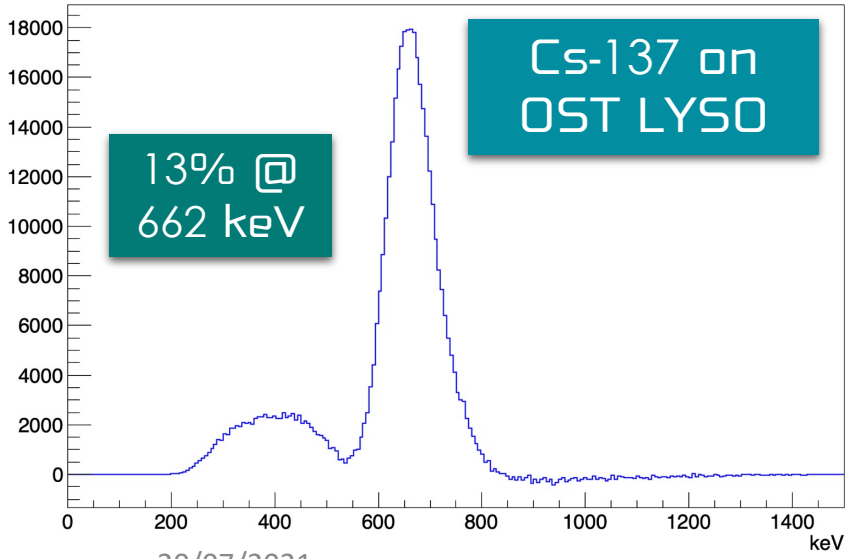


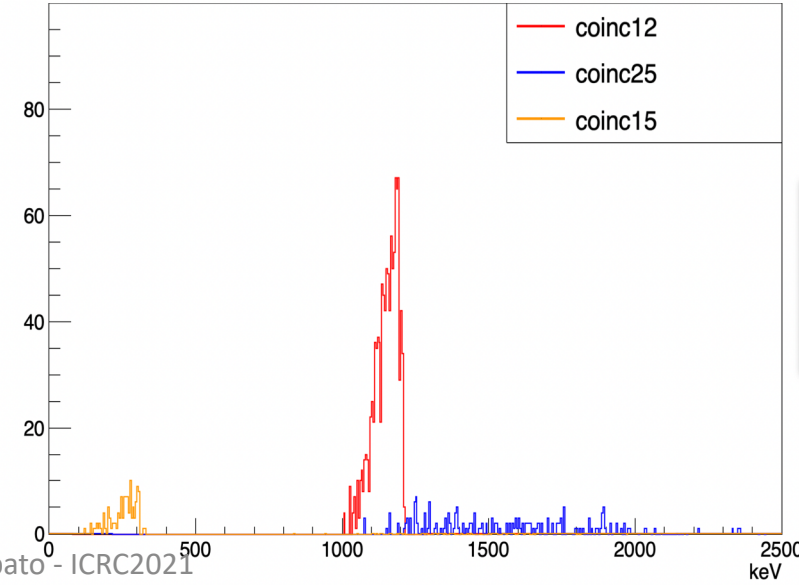
1 – LYSO by OST (ground surface)
2 – LYSO by EPIC Crystals (polished surfaces with ESR)
3 – BGO by OST (ground surfaces)
4 – LYSO by EPIC Crystals (ground surfaces)

PRELIMINARY CHARACTERIZATION TESTS







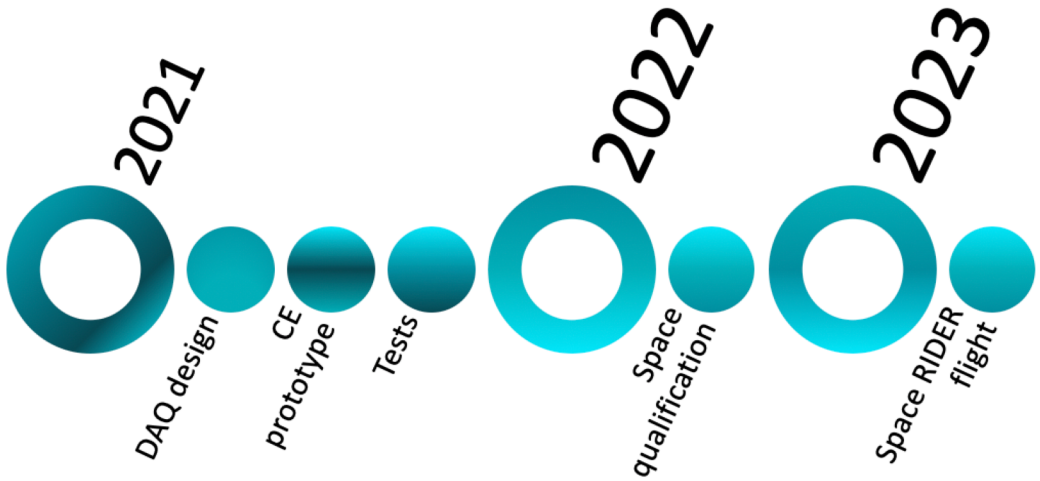


Co-60 reconstruction with AND logic

THANKS

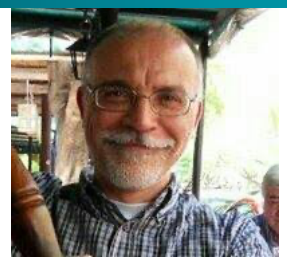
Bando STAR2018 – L1 Junior Principal Investigator (90 k€) + GSSI (70 k€)

F. Barbato
Principal Investigator

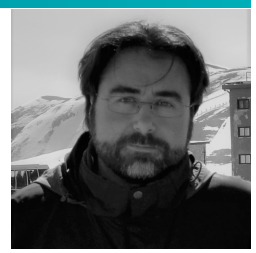


Physics

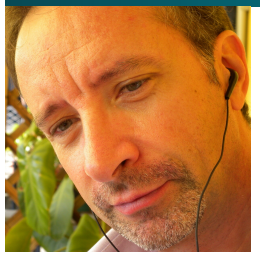

G. Barbarino

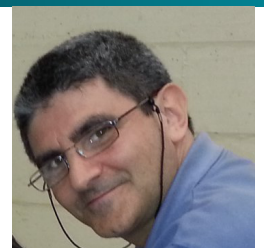

F. Guarino


F. Garufi


I. De Mitri

Electronics


R. de Asmundis


A. Boiano


A. Vanzanella


A. Abba

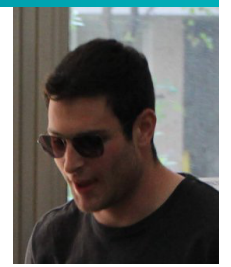

L. Ferrentino

Engineering


F. Renno


S. Papa


D. Marzullo


R. Guida

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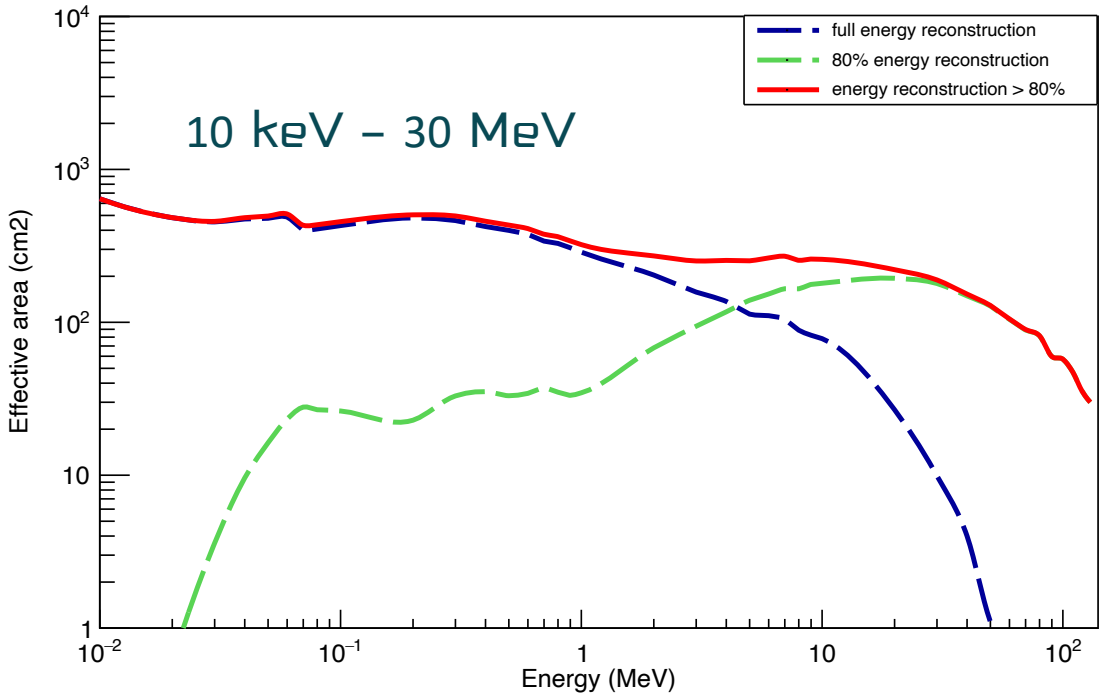
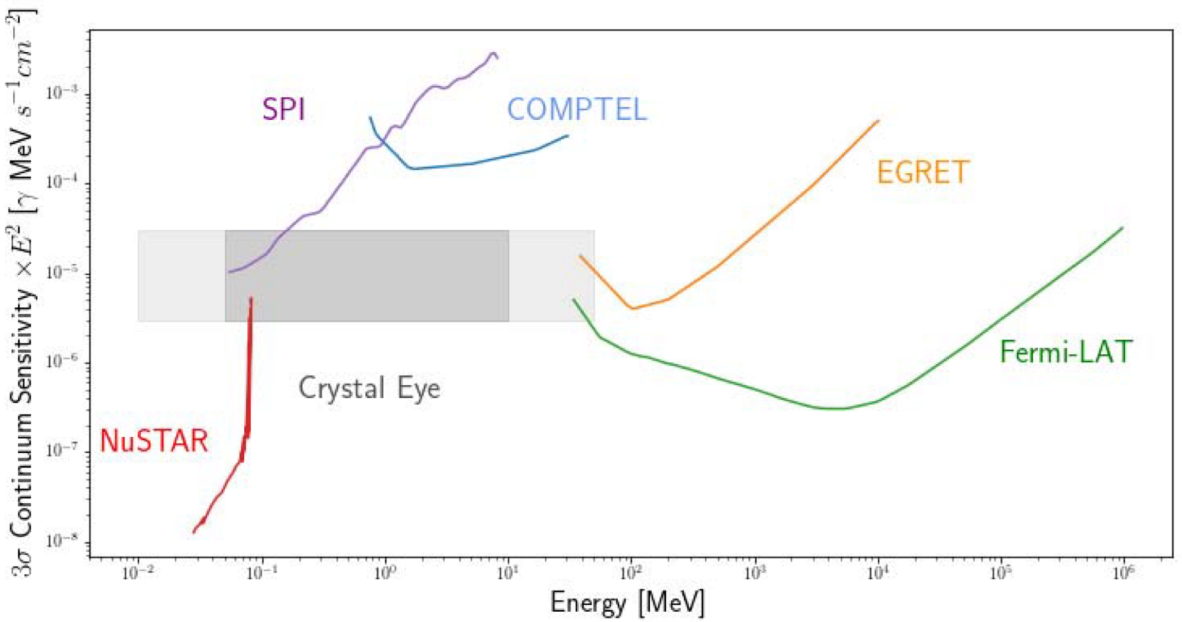
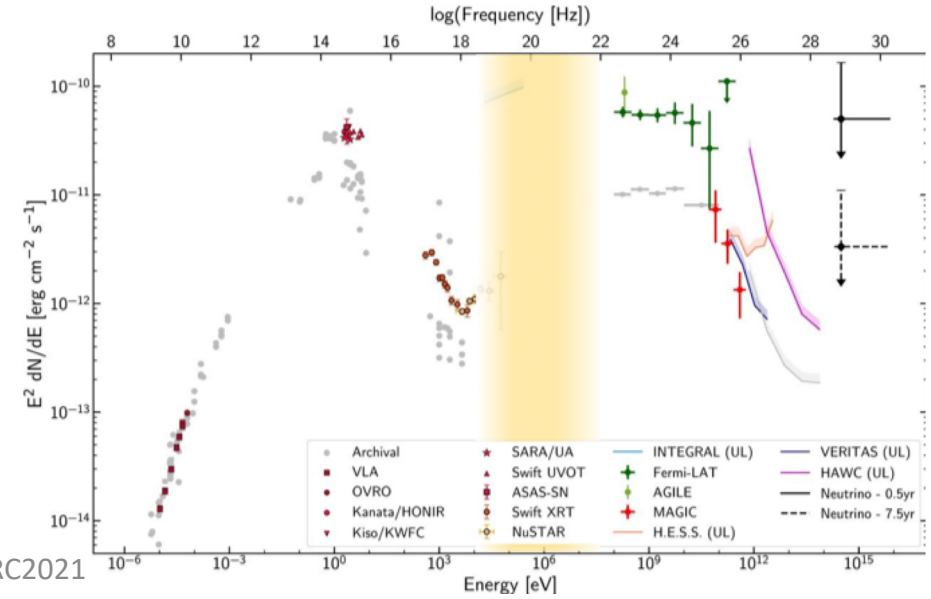
INFN Istituto Nazionale di Fisica Nucleare

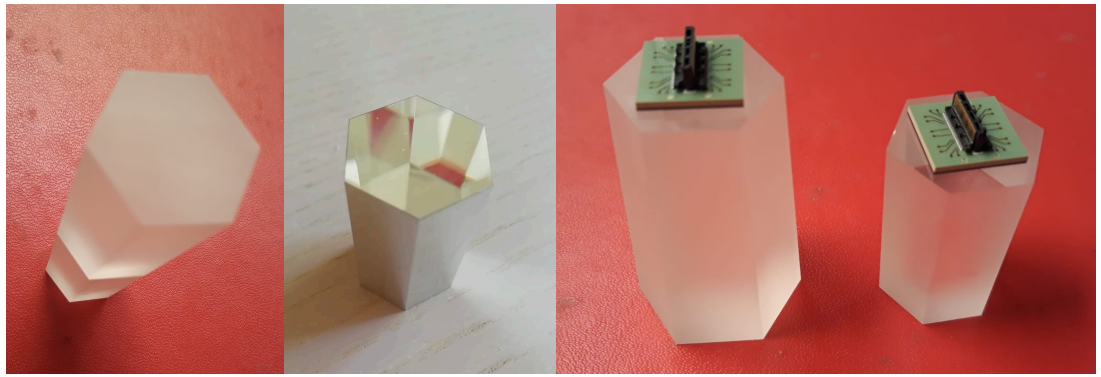
SOME NUMBERS ABOUT CRYSTAL EYE

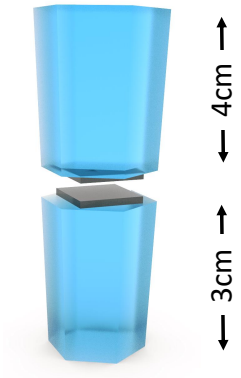




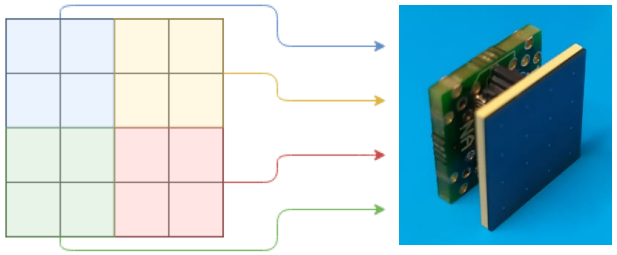


THE PIXELS

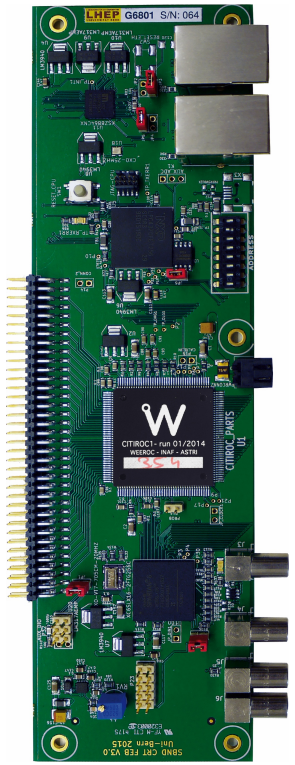




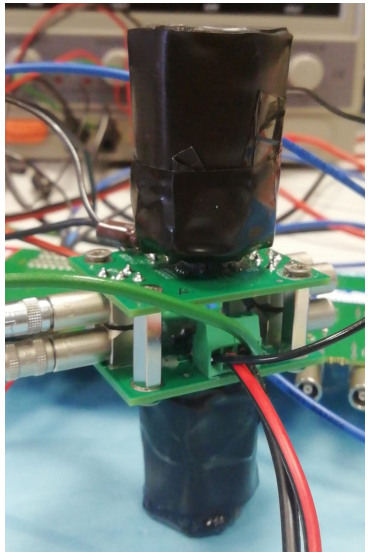
Array-Sum

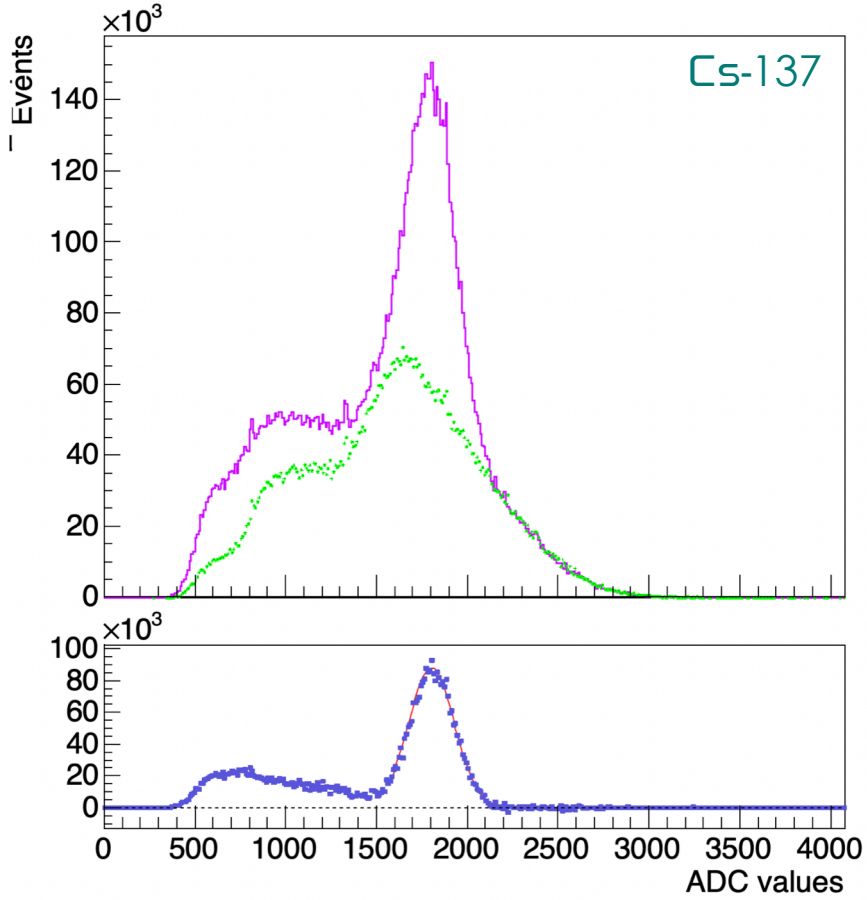


Front-end board



Temporary DAQ
(A1702 CAEN)

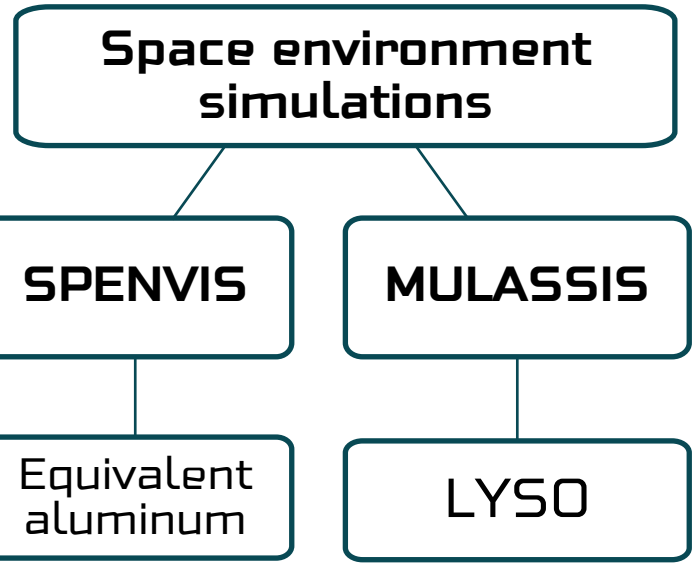


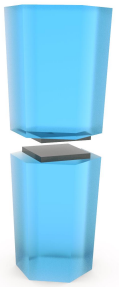


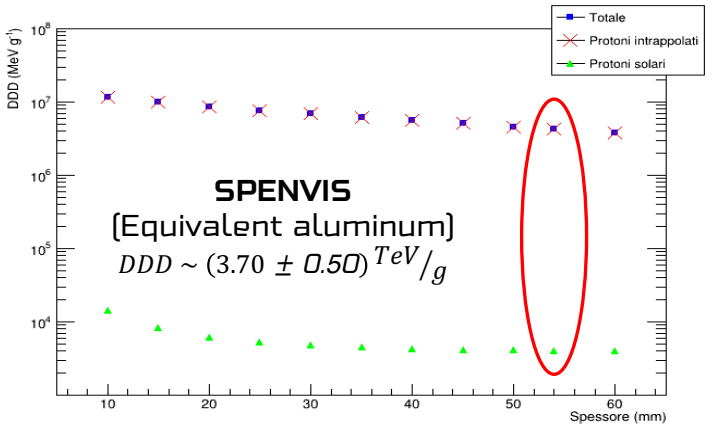
- Very High Light Yield (40 γ/keV)
- Fast response (36 ns)
- Self Calibration

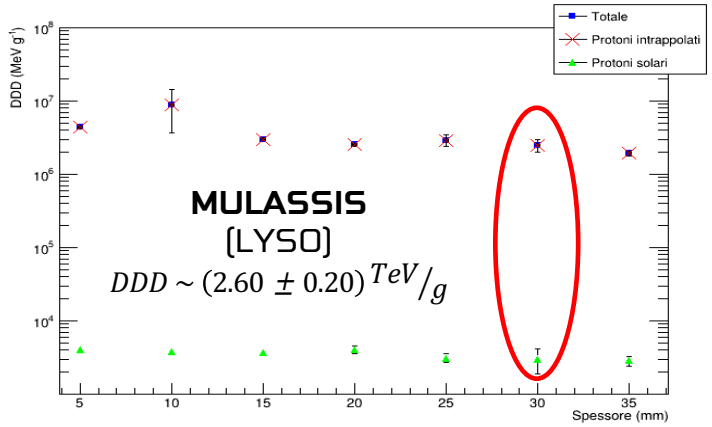
SPENVIS
The Space Environment Information System

Mission duration: 10 years
Mission start time: 01/01/2022
Orbits/dd: ~15
Low Earth Orbit: ~400 km









RADIATION HARDNESS

Neutron Beamline ChiPIR

@ Rutherford Appleton Laboratory

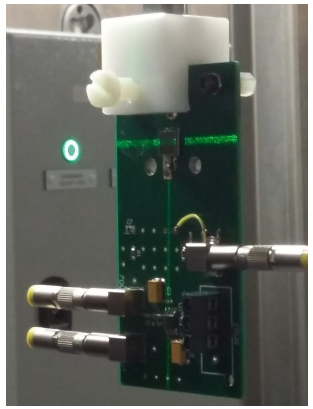
Flux: $4.0 \cdot 10^{6} cm^{-2} s^{-1}$

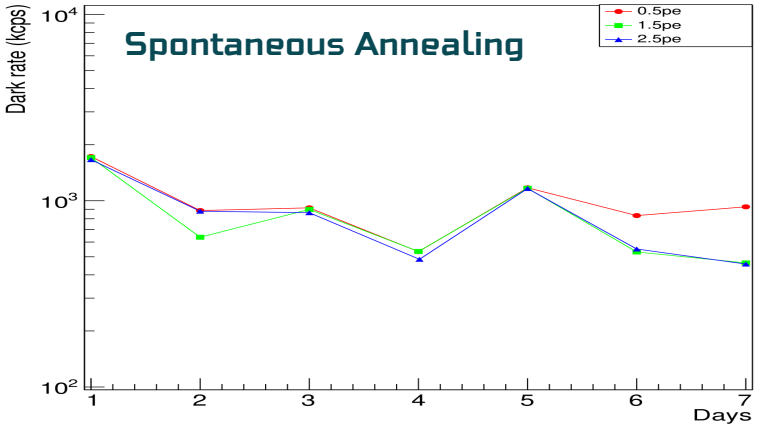
Test duration: $876\ s$

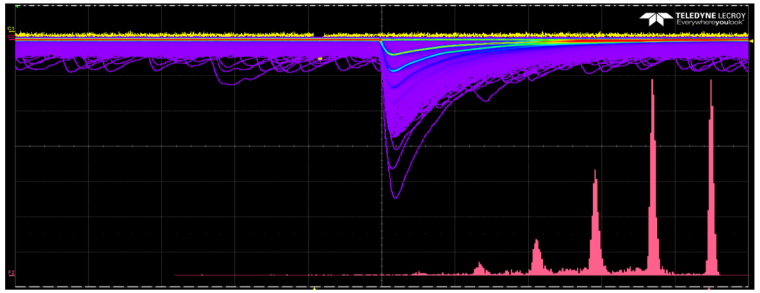
Fluence: $3.71 \cdot 10^{9} cm^{-2}$

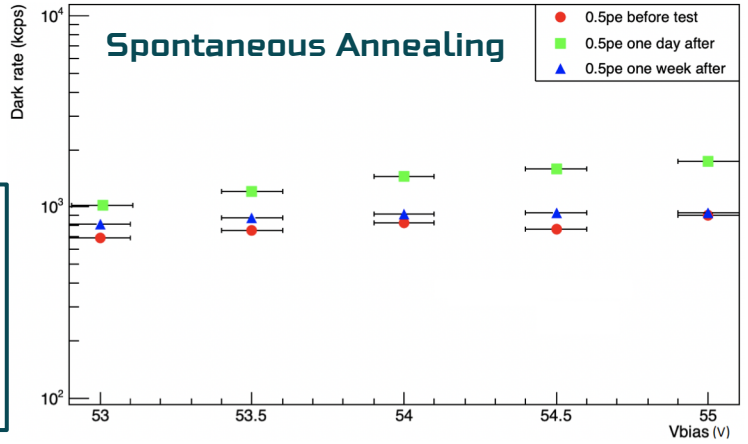
$$\mathrm{DDD} = 9.7\ \frac{TeV}{g}$$

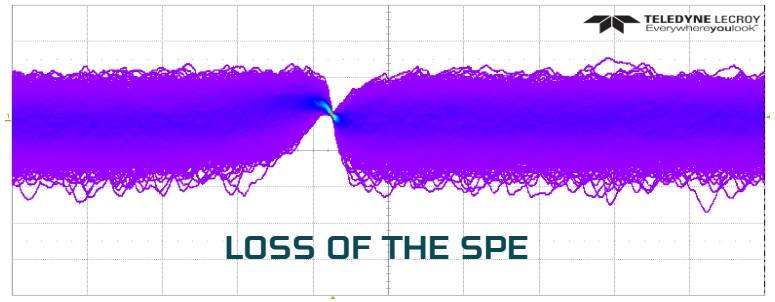
37 years equivalent











RESULTS

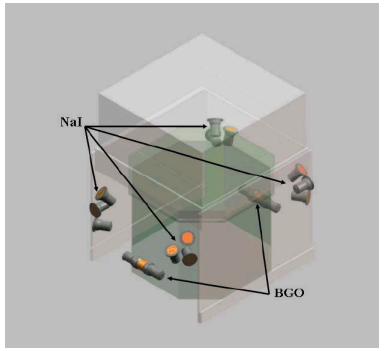
- Increment of DCR
- SPE loss
- LYSO Spectrum preserved

In 37 years each SiPM will loose only ~1% of the pixels

Shielding effect of the LYSO crystals

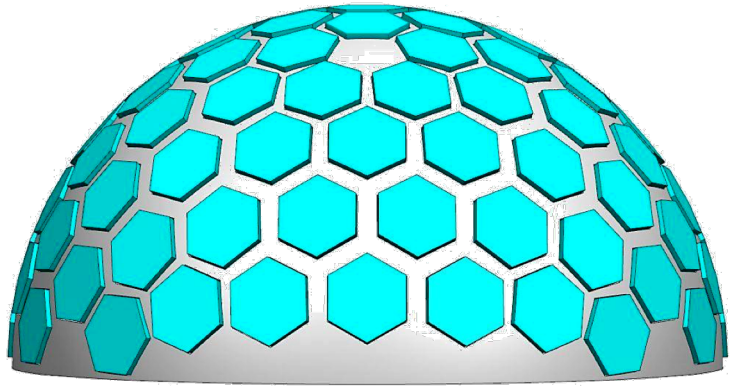
OUR PROPOSAL: FROM FERMI-GBM TO CRYSTAL EYE

Fermi-GBM



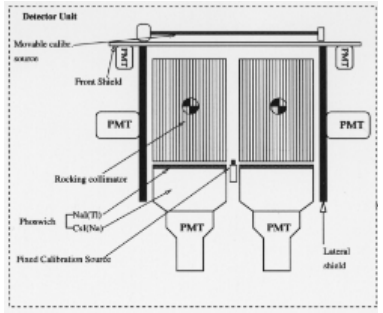
- Triangulation over 12 pixel (ø 12.7 cm)
- One module

Crystal Eye



- Charge distribution over 112 pixel (ø ~ 5cm)
- Three modules in orbit for a full time coverage

Beppo-Sax



- Phoswich technique with collimators
- One module

TIME IS NOW!