Discussione INFN su Roadmap ECFA Detector R&D

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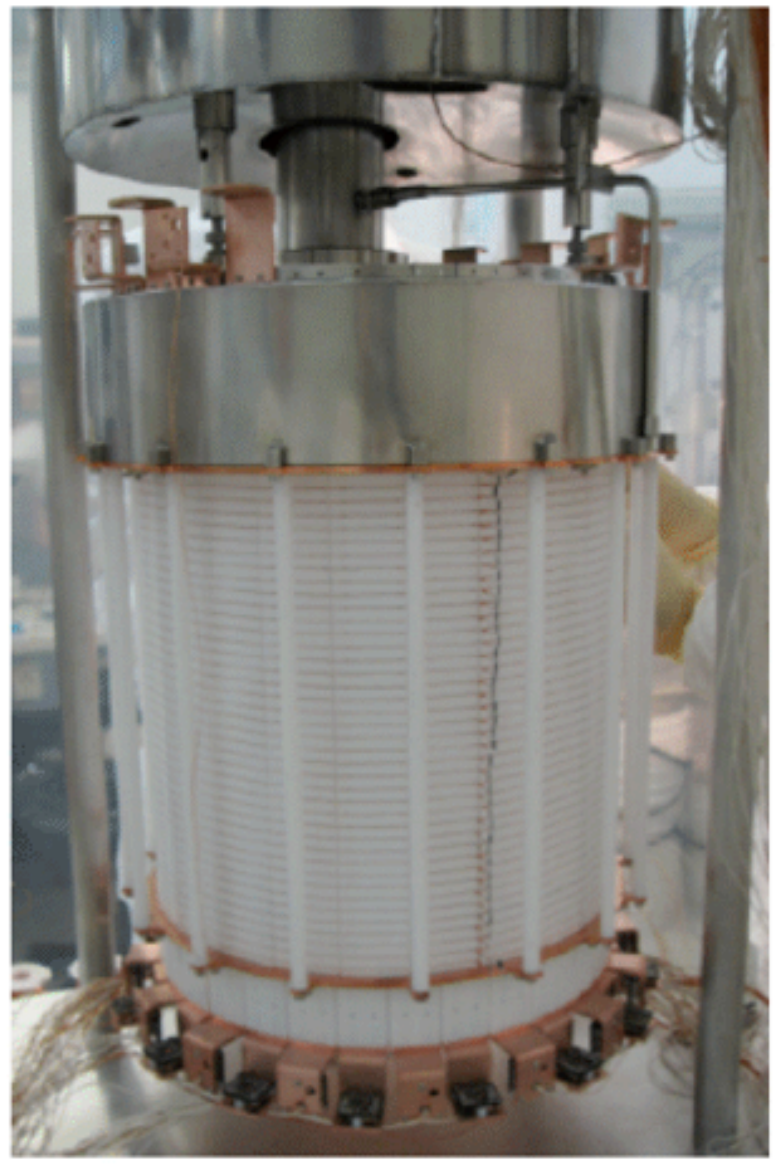
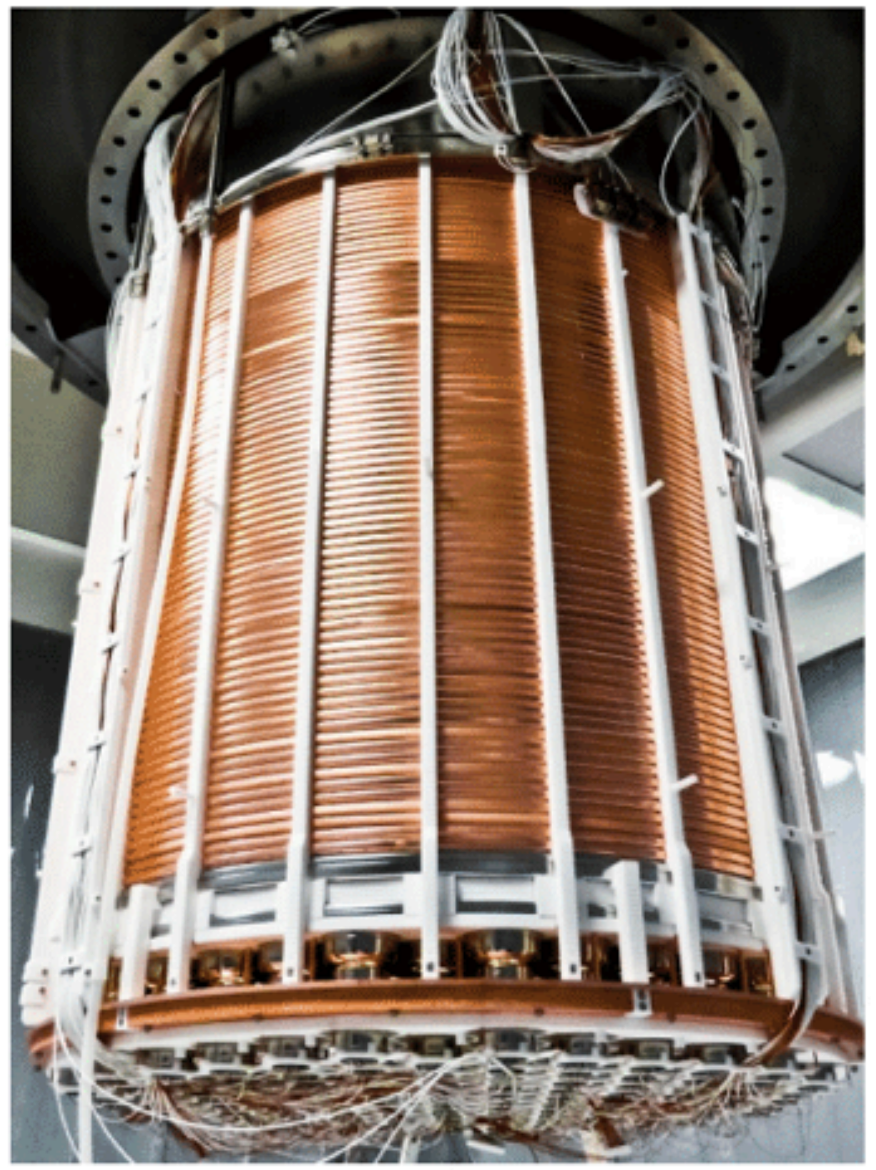
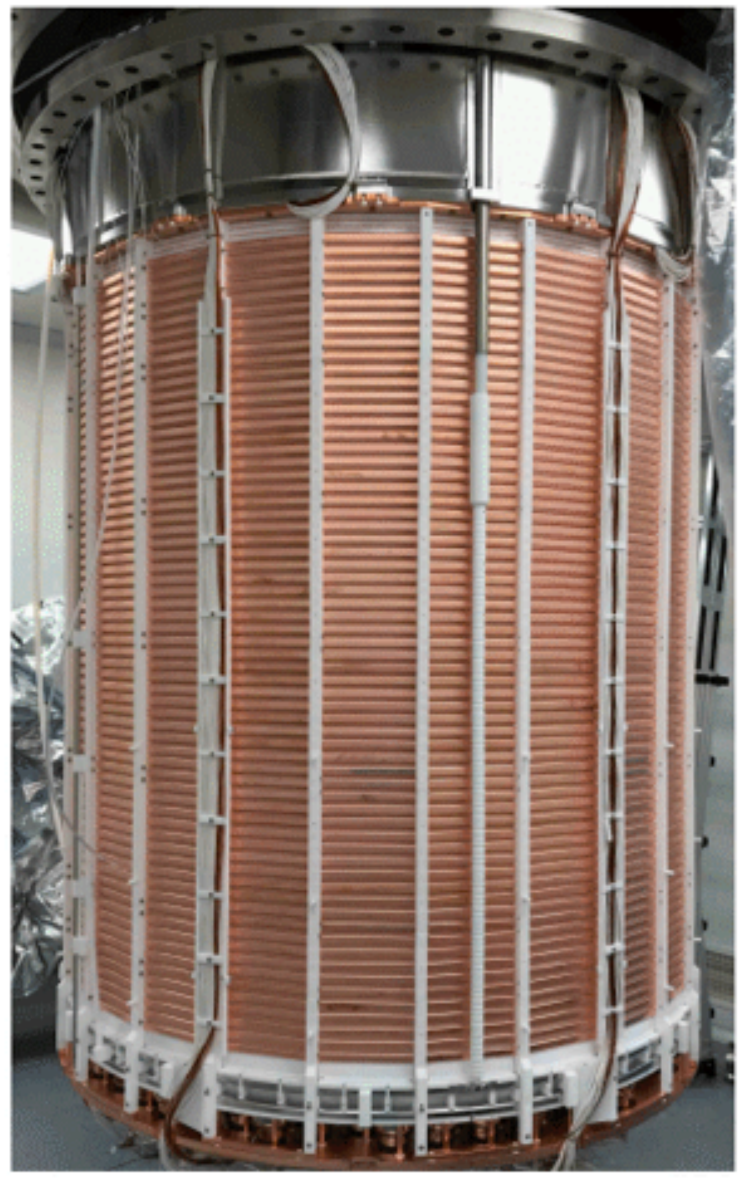
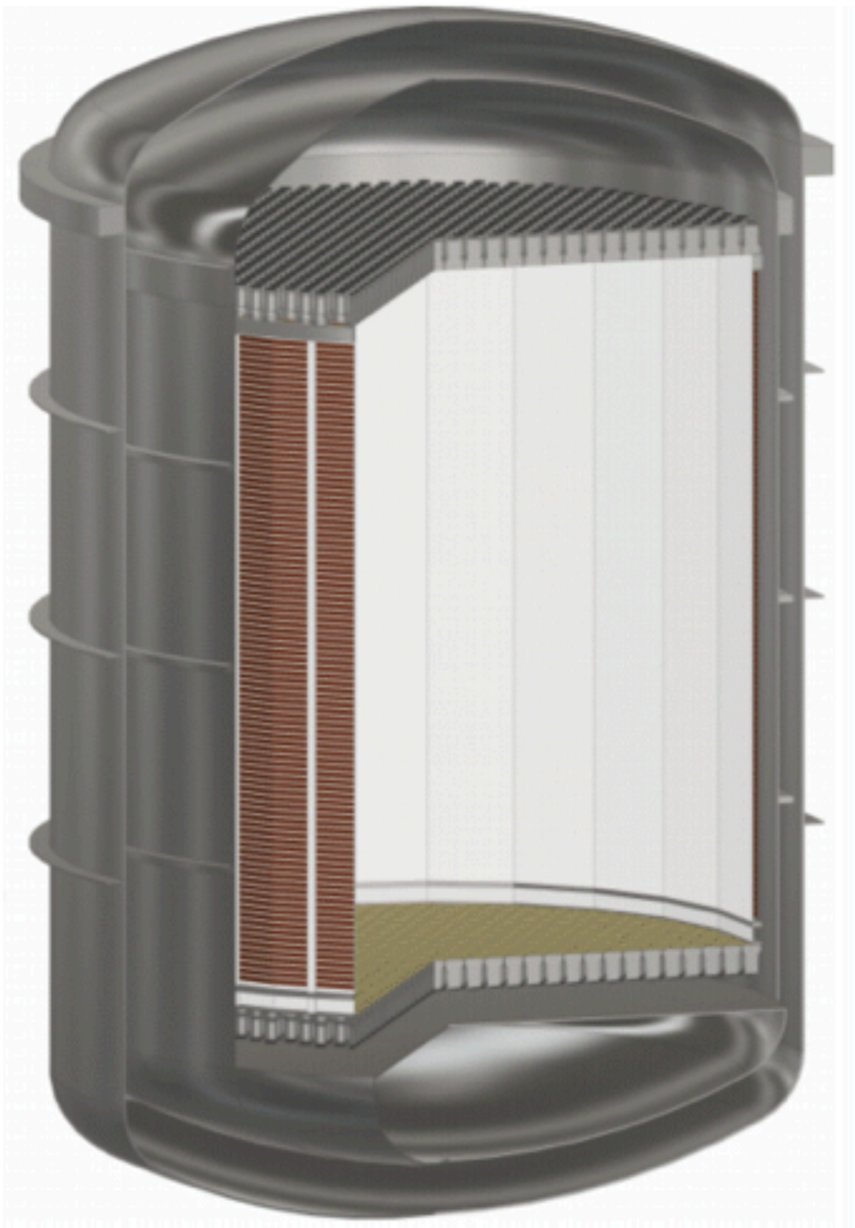
per i gruppi **XENON** INFN
(Bo, Fe, LNGS & Aq, Na, To)

15 marzo 2021

the XENON project @LNGS

XENON10	XENON100	XENON1T	XENONnT	DARWIN
2005-2007	2008-2016	2012-2018	2020-2025	2027–
15 kg	161 kg	3200 kg	8400 kg	50 tonnes
15 cm	30 cm	96 cm	150 cm	260 cm
~10^{-43} cm^2	~10^{-45} cm^2	~10^{-47} cm^2	~10^{-48} cm^2	~10^{-49} cm^2

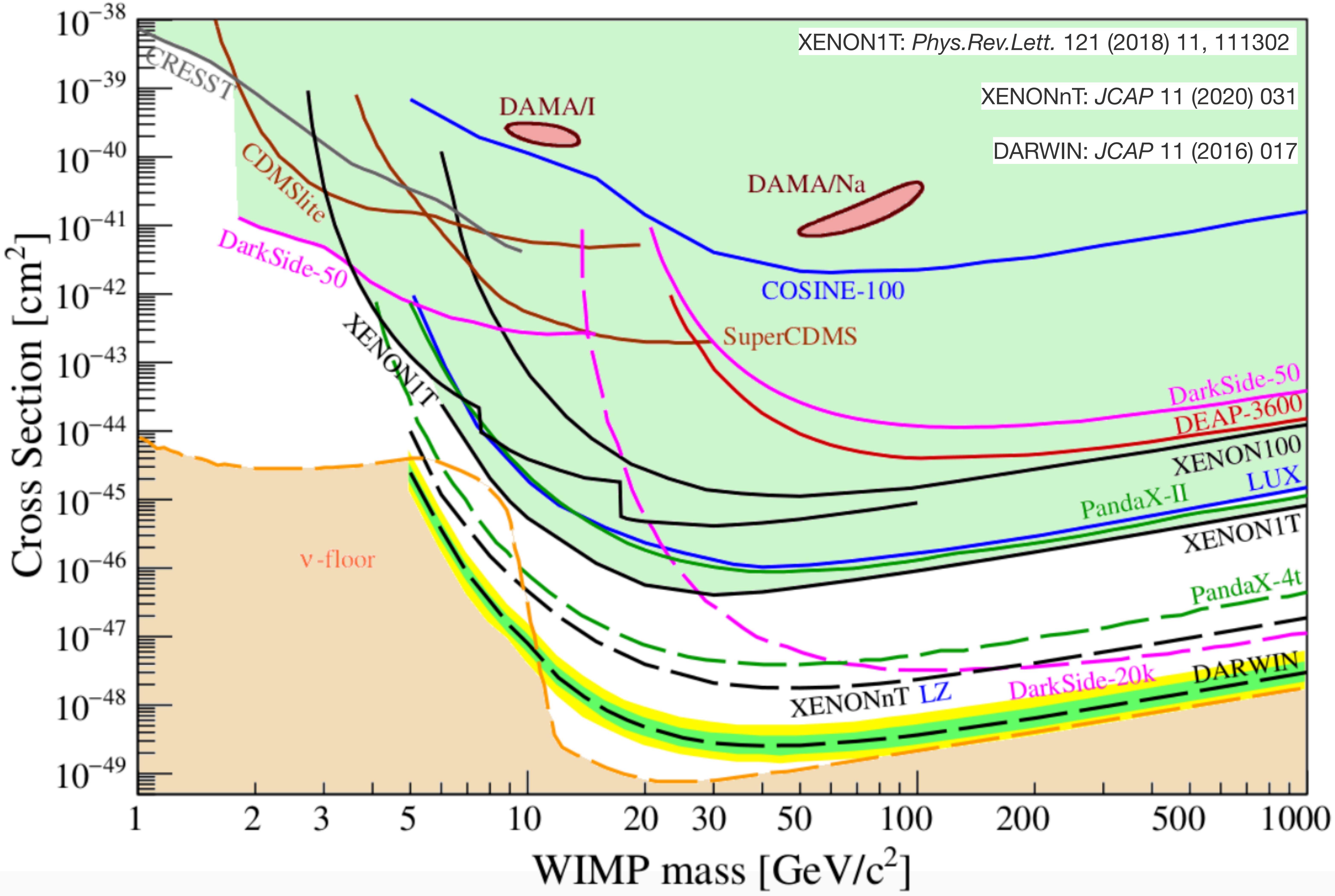
XENON1T @LNGS

E. Aprile et al.,
"The XENON1T Dark Matter Experiment",
EPJ C 77, 881 (2017).

XENON1T

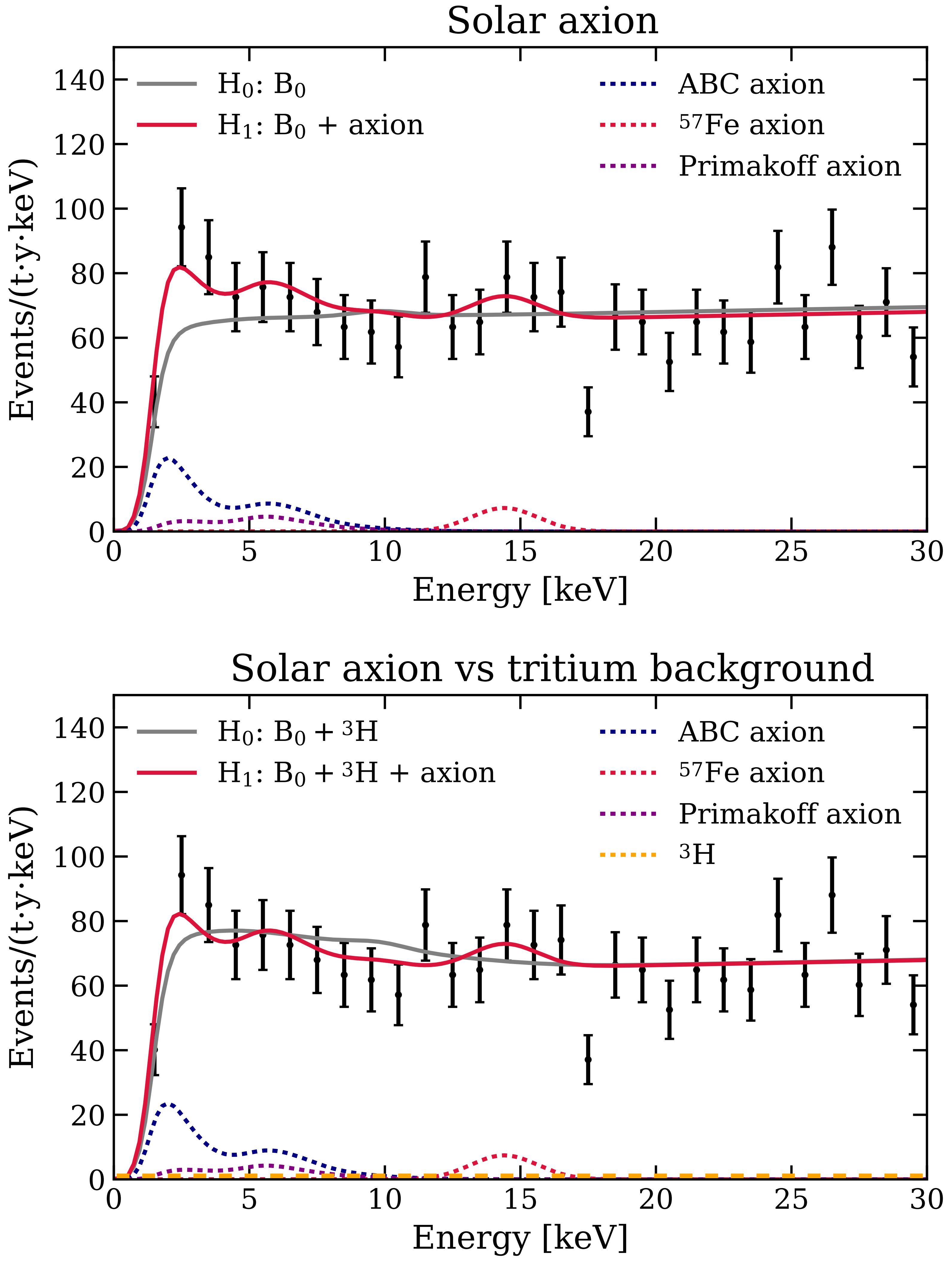
XENON1T world-best results

SI, elastic WIMP-nucleus



Excess Electronic Recoil Events in XENON1T

Phys. Rev. D 102, 072004 (2020)



current phase: XENONnT installed in 2020

E. Aprile et al.,
"The XENON1T Dark Matter Experiment",
EPJ C 77, 881 (2017).

XENON1T

XENONnT

+

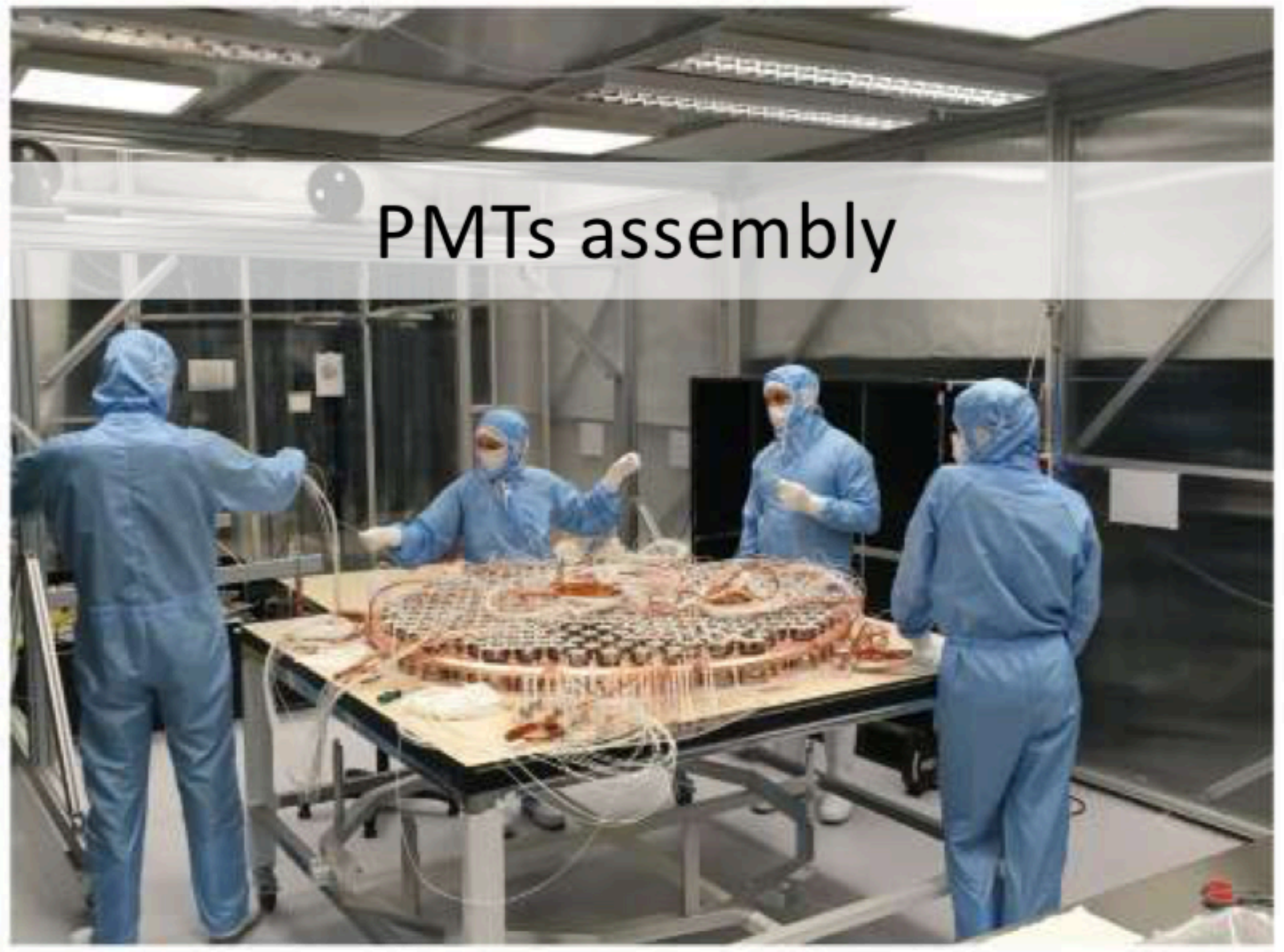
Larger TPC

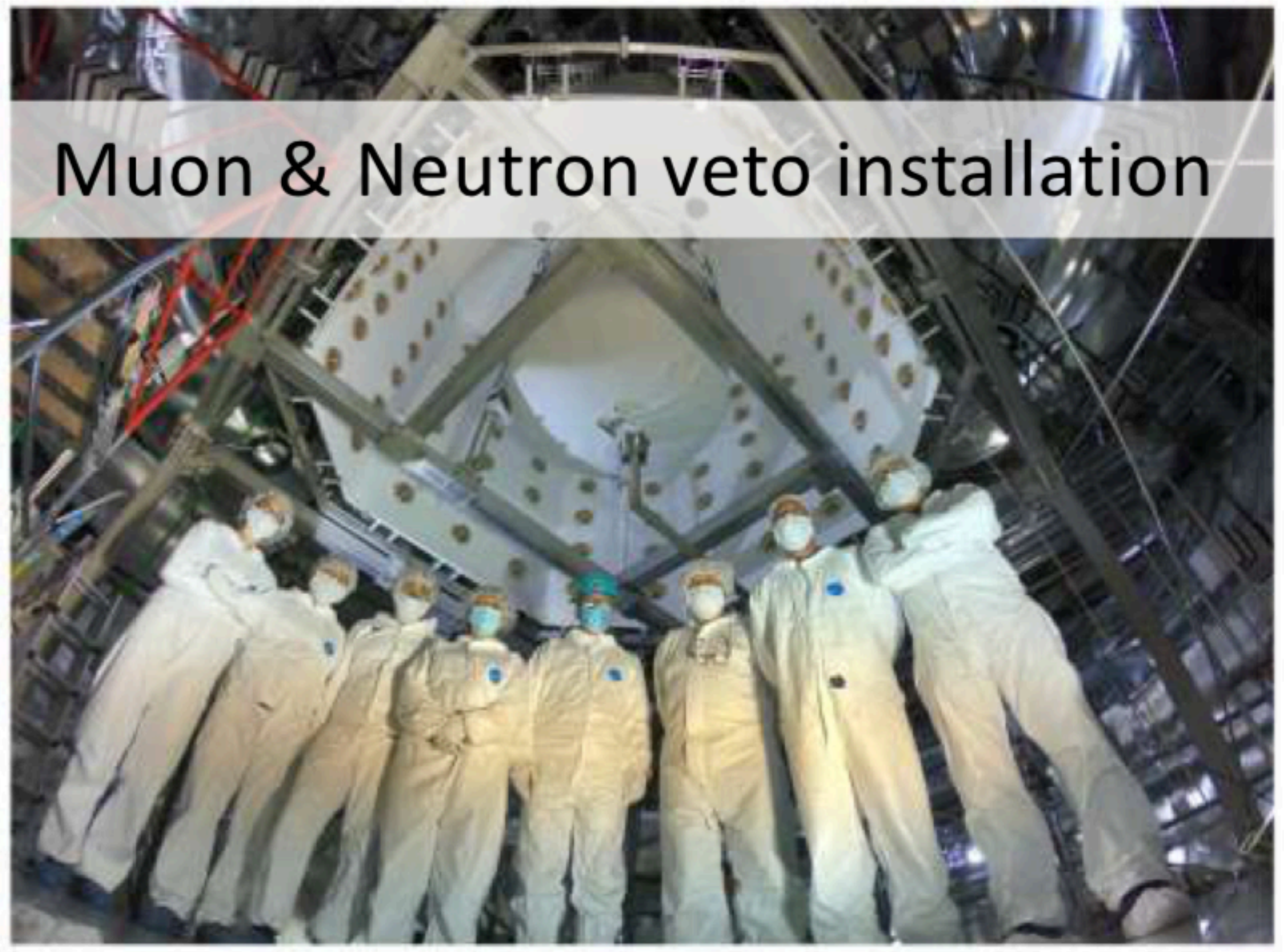
Neutron veto

222Rn distillation

LXe purification

current phase: XENONnT installed in 2020

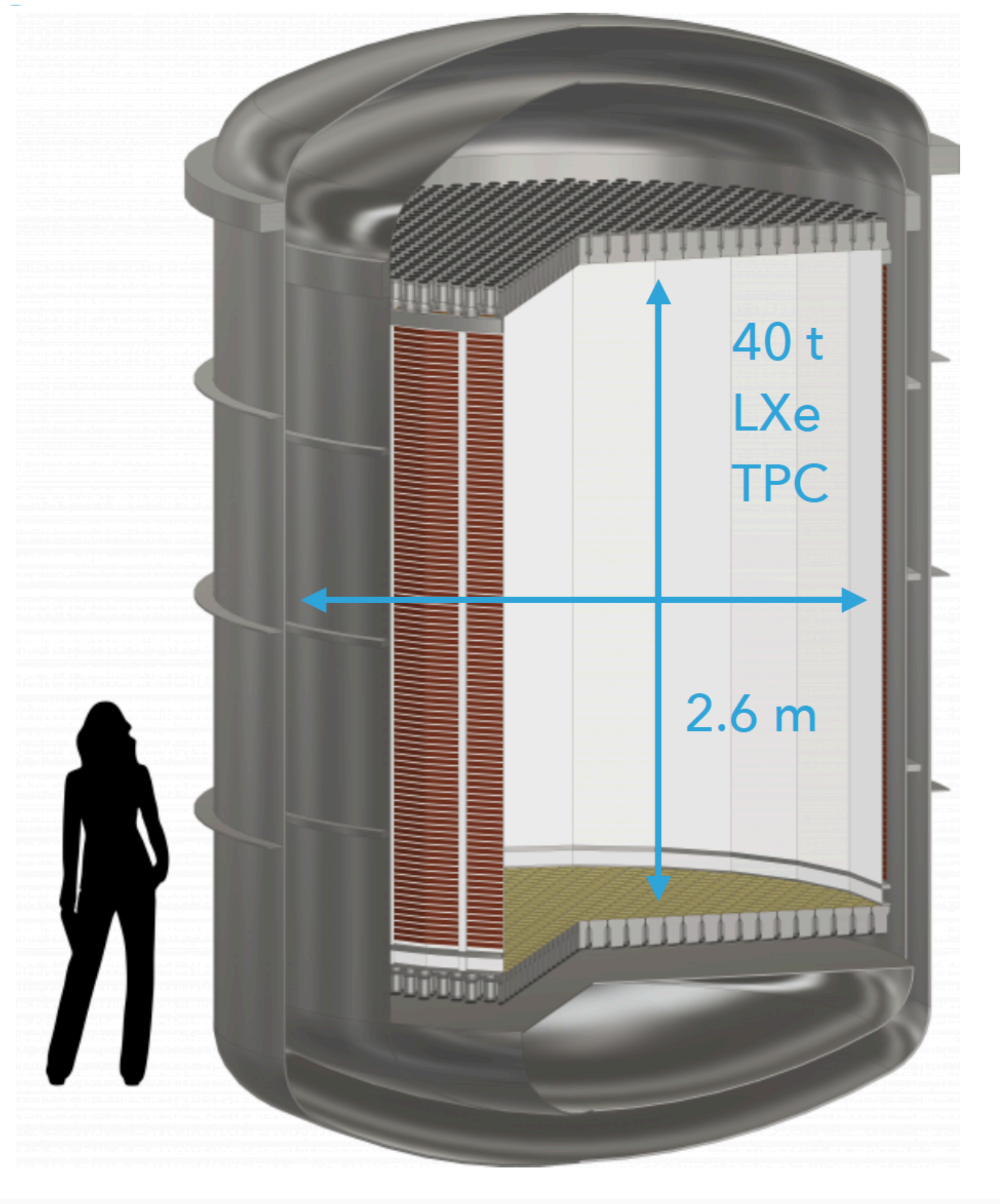




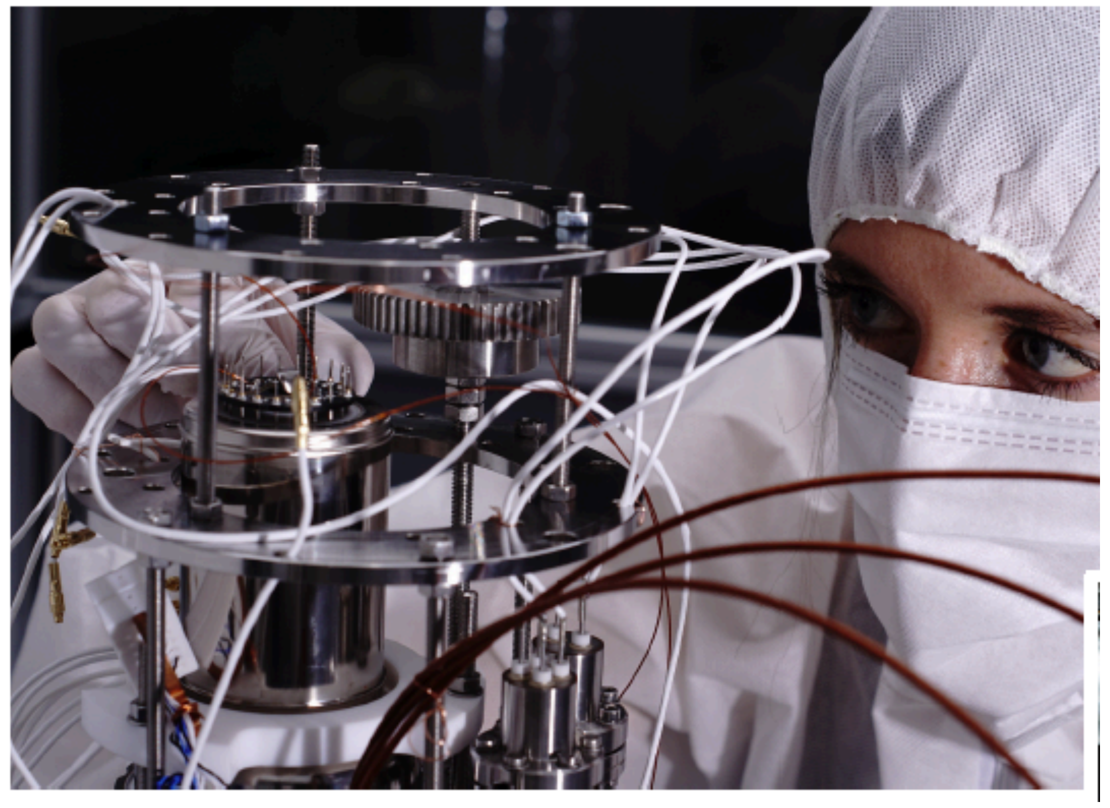
next phase: DARWIN

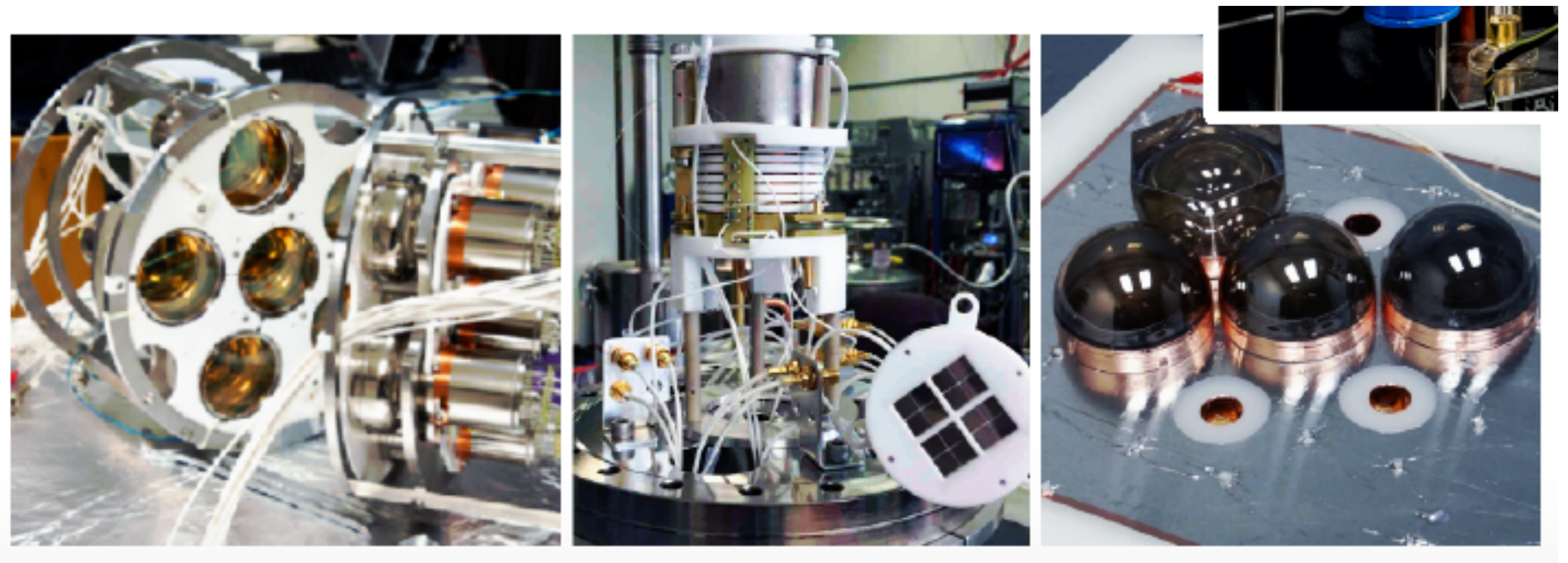
(just an option, so far)

DARWIN LXe TPC

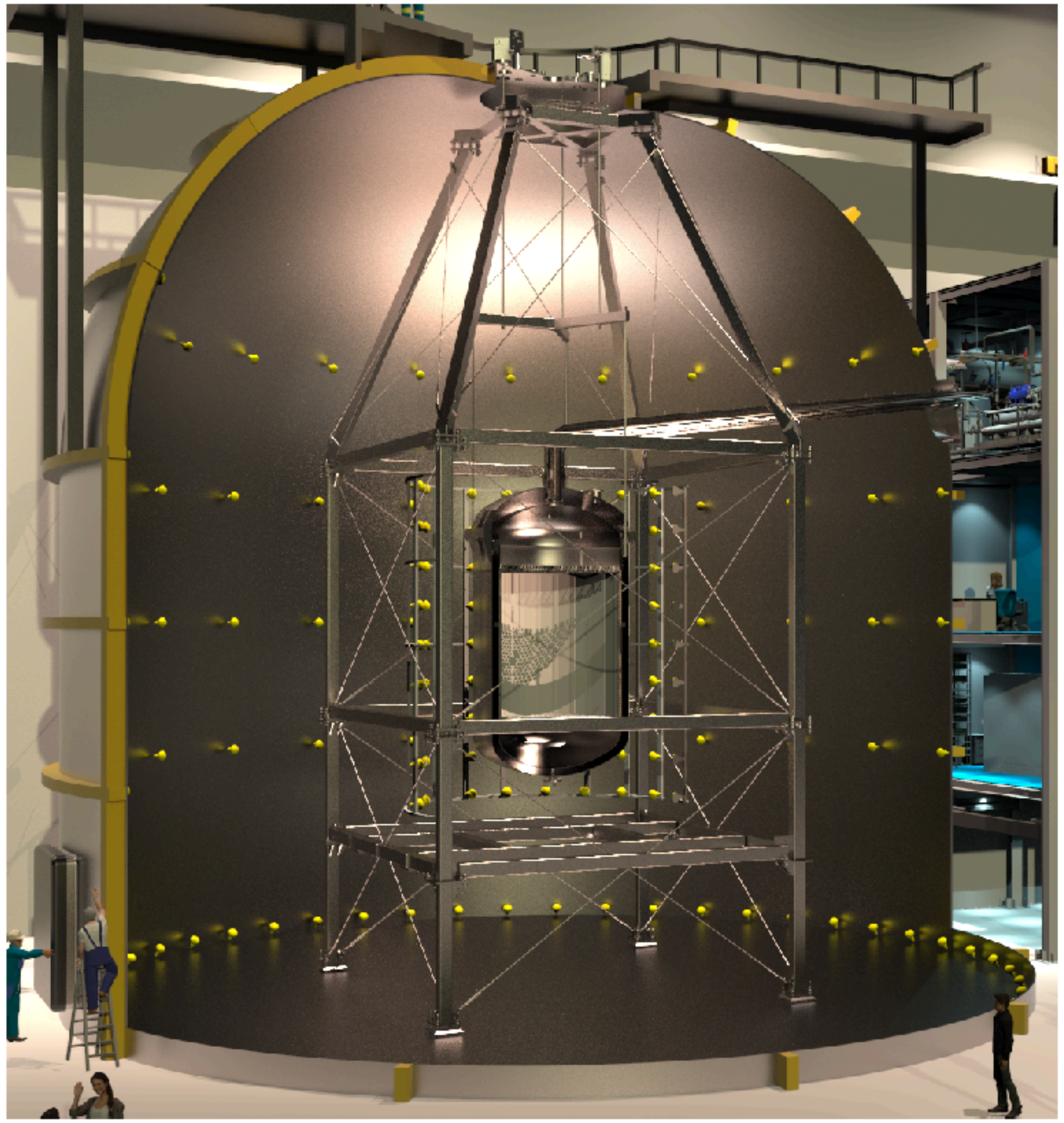


R&D on Photosensors



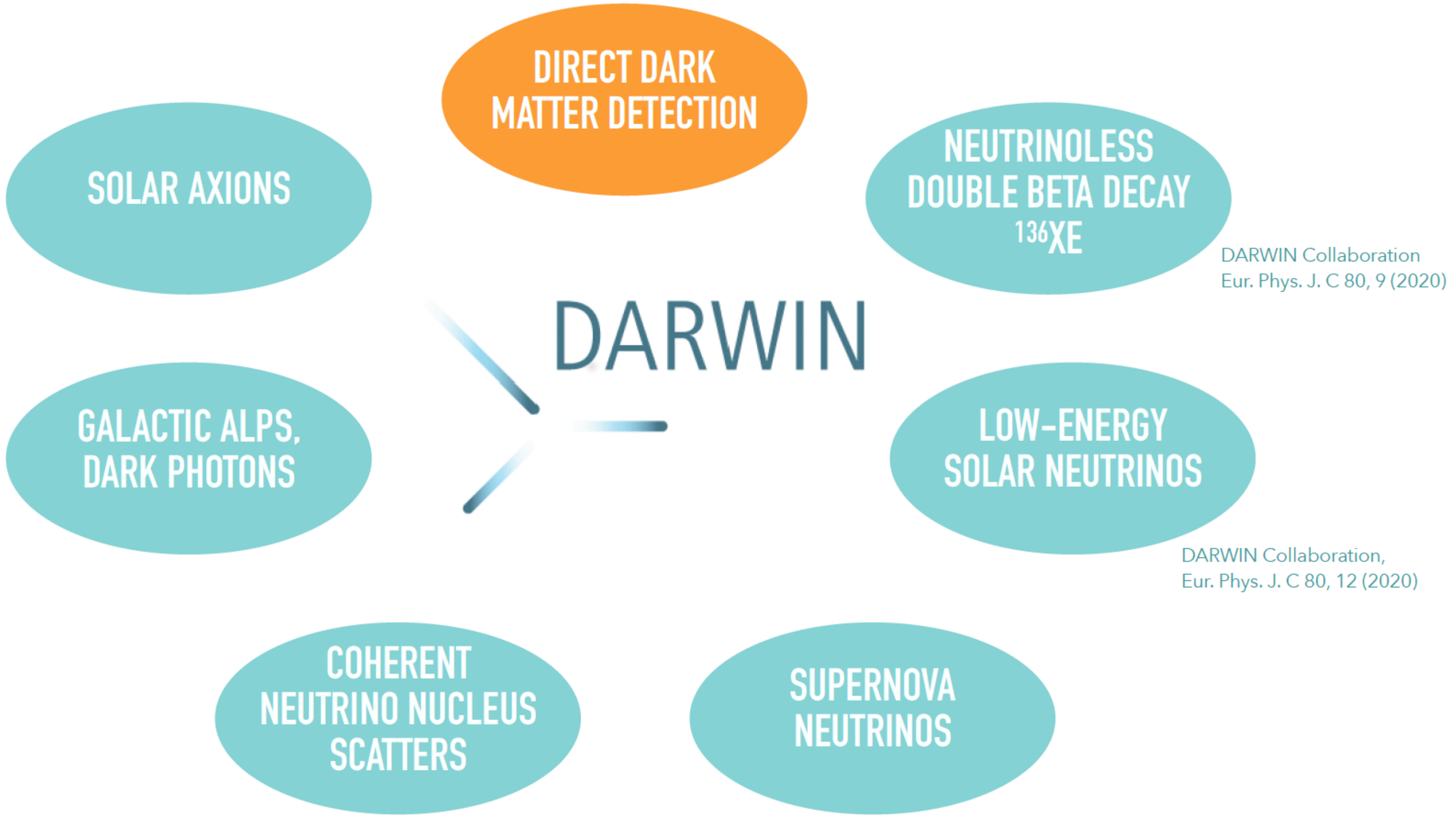


Visualisation of DARWIN in Borexino WT



next phase: DARWIN

DARWIN SCIENCE PROGRAMME

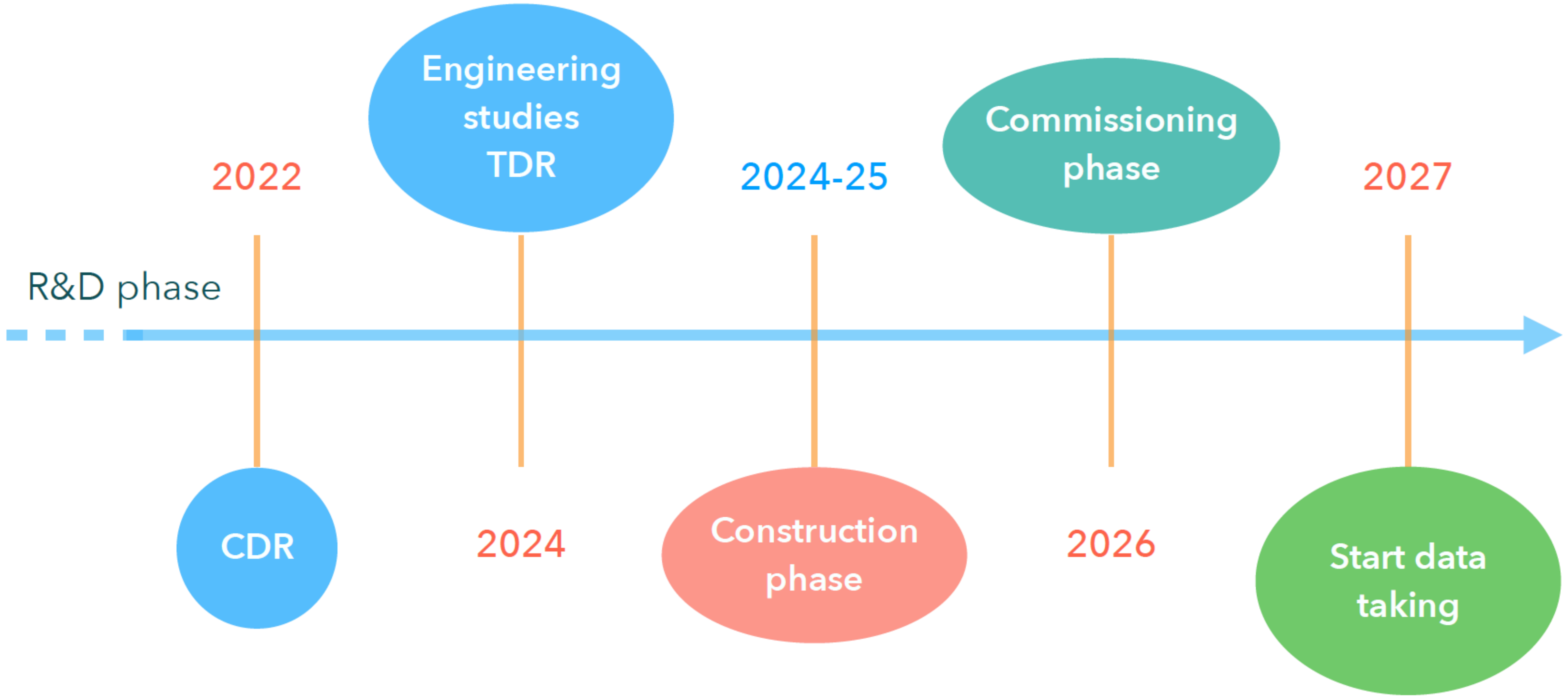


DARWIN Collaboration
Eur. Phys. J. C 80, 9 (2020)

DARWIN Collaboration,
Eur. Phys. J. C 80, 12 (2020)

darwin-observatory.org

DARWIN TIMESCALE



LETTER OF INTENT TO LNGS

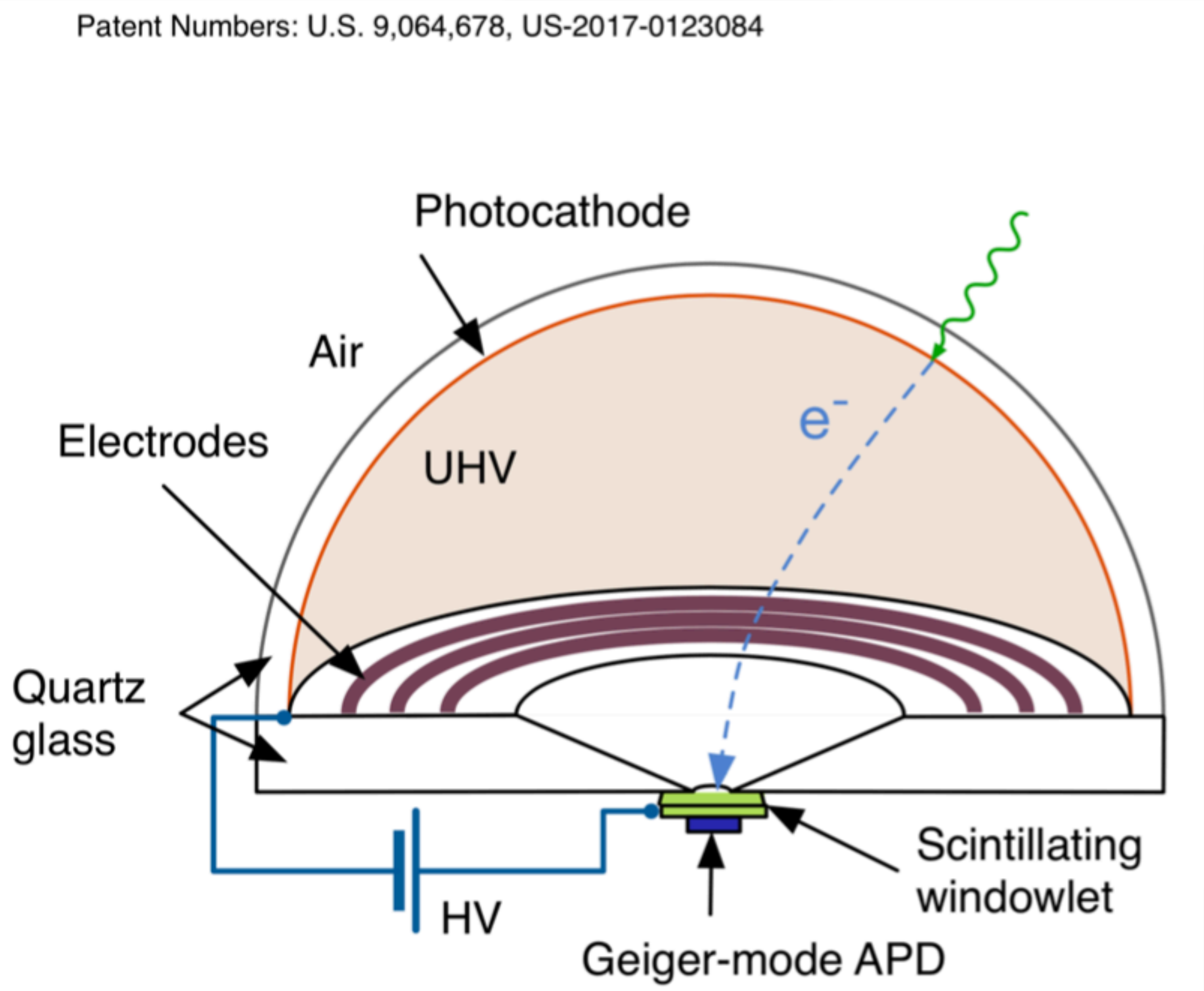
DARWIN

The DARWIN astroparticle physics observatory

Letter of Intent to the Gran Sasso Underground Laboratory of INFN

August 23, 2019 (v2)

R&D on Photosensors: ABALONE



Glass-glass sealing

- Indium-based evaporated seal
  - major advantage over Quasar & HPD

Principle

- p.e. accelerated towards scintillator windowlet (LYSO)
  - $L_0 \approx 32\,\gamma/\mathrm{keV} \rightarrow$
- Readout using SiPM (G = $\sim 10^6$)
  - @ 25 kV, assuming collection efficiency $\eta = 10\% \rightarrow \sim 80$ p.e.
  - Total gain: $\gtrsim 10^8$

Major advantages

- all UHV-components are evaporated
  - production can be fully automated
- field-shaping electrodes work as getter
- good timing
- good pulse height separation

R&D on Photosensors: ABALONE

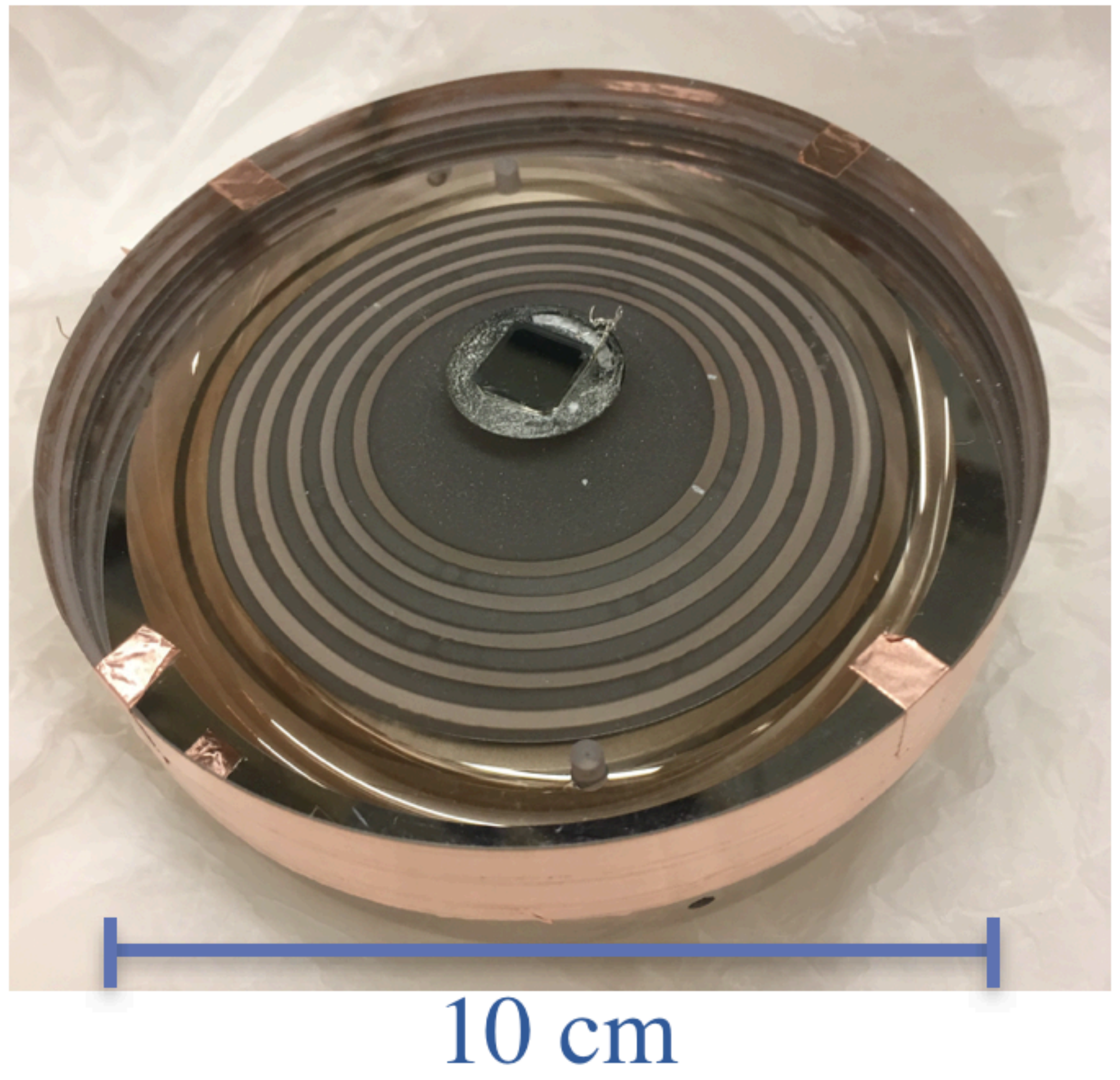
- Consists of 3 monolithic glass components: base, dome and windowlet (industrially pre-fabricated)
- Bonding with a thin-film alloy using specific thin-film vacuum-sealing technique
- Absence of metal in ultra high vacuum
- High electric field (~25 kV)
- Sensor like SiPM needed to detect photon signal coming from the scintillator (windowlet)
    - Area gain: $1m^2$ -> $1cm^2$

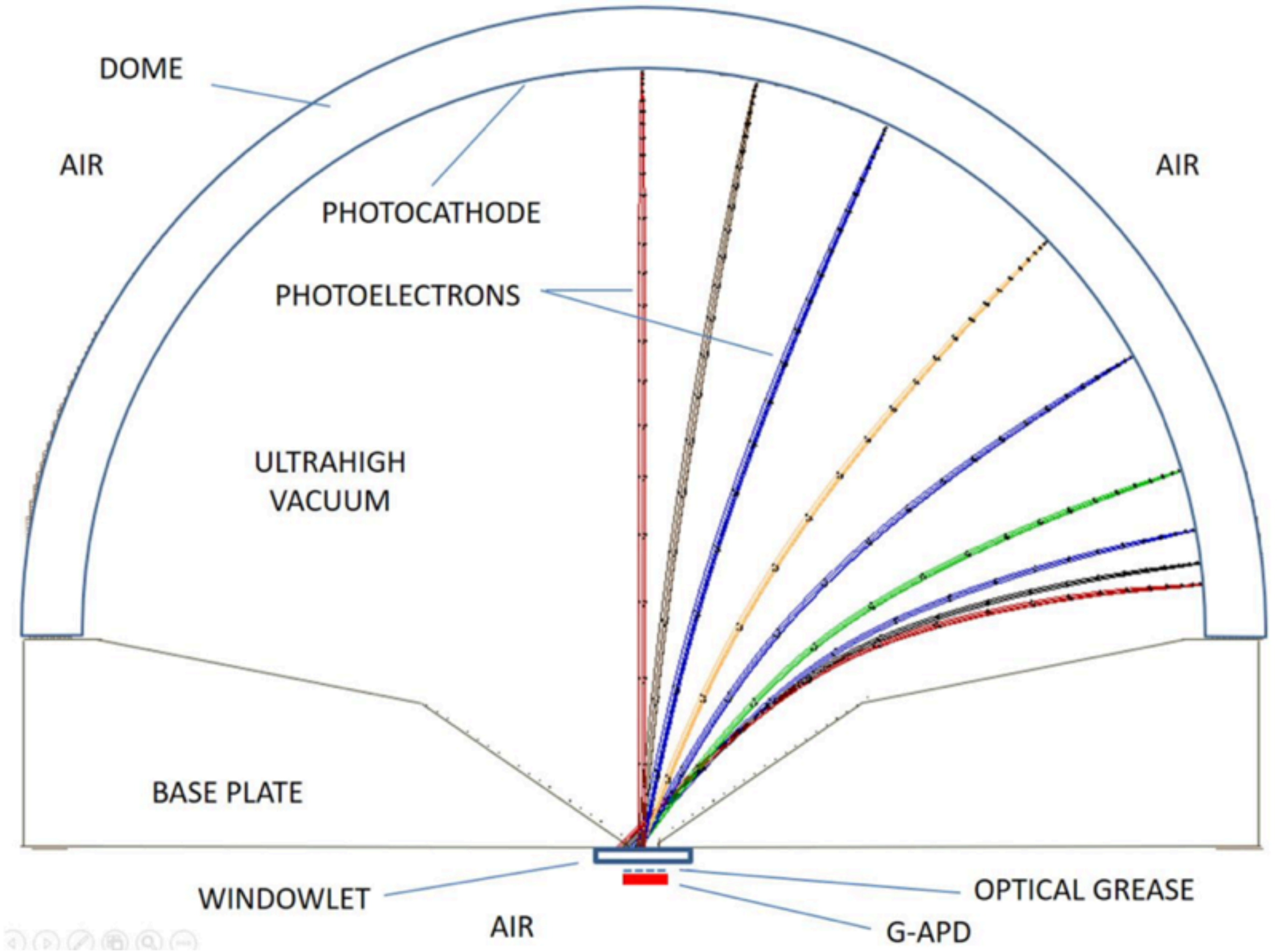
https://arxiv.org/pdf/1703.04546.pdf

Developed by Daniel Ferenc and produced by PhotonLab, Inc.

https://arxiv.org/pdf/1810.00280.pdf

Ferenc… **Ferella**, et al.





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R&D on Photosensors: ABALONE

Pro	"Con"
Low costs once in mass production (Goal: < 5000$ / m^2)	New technology: Needs be tested under different conditions
Low level of radioactivity due to absence of metal parts	High electric field required (High voltage of 25kV, but similar to TPC)
Low after pulse rate due to high field —> lower ionisation cross section (AP rate of $5*10^{-3}$ ions per pe)	Has to be combined with another light detector like a SiPM
Very low dark count rate	Lower energy resolution than a SiPM but better than a PMT

	R11410-20 PMT	VUV-SIPM	ABALONE
Sensitive area [mm^2]	3216	100	9503
Dark count rate / mm^2 [Hz]	0.02	1	0.001
Operating voltage [V]	1.5×10^3	25	25×10^3
Gain at operation voltage	5×10^6	1×10^6	1×10^8
Quantum efficiency [%]	35	15-18	35

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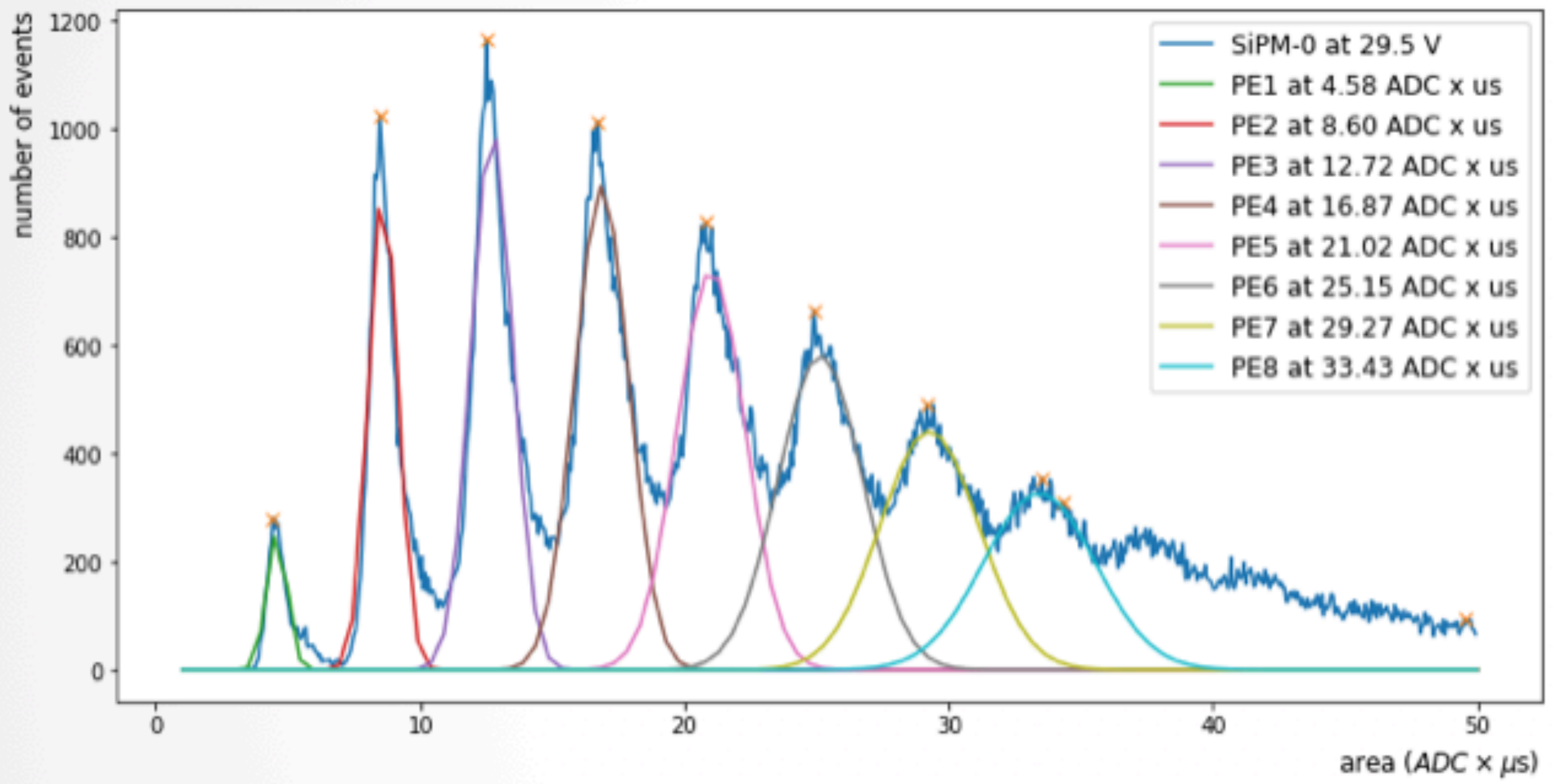
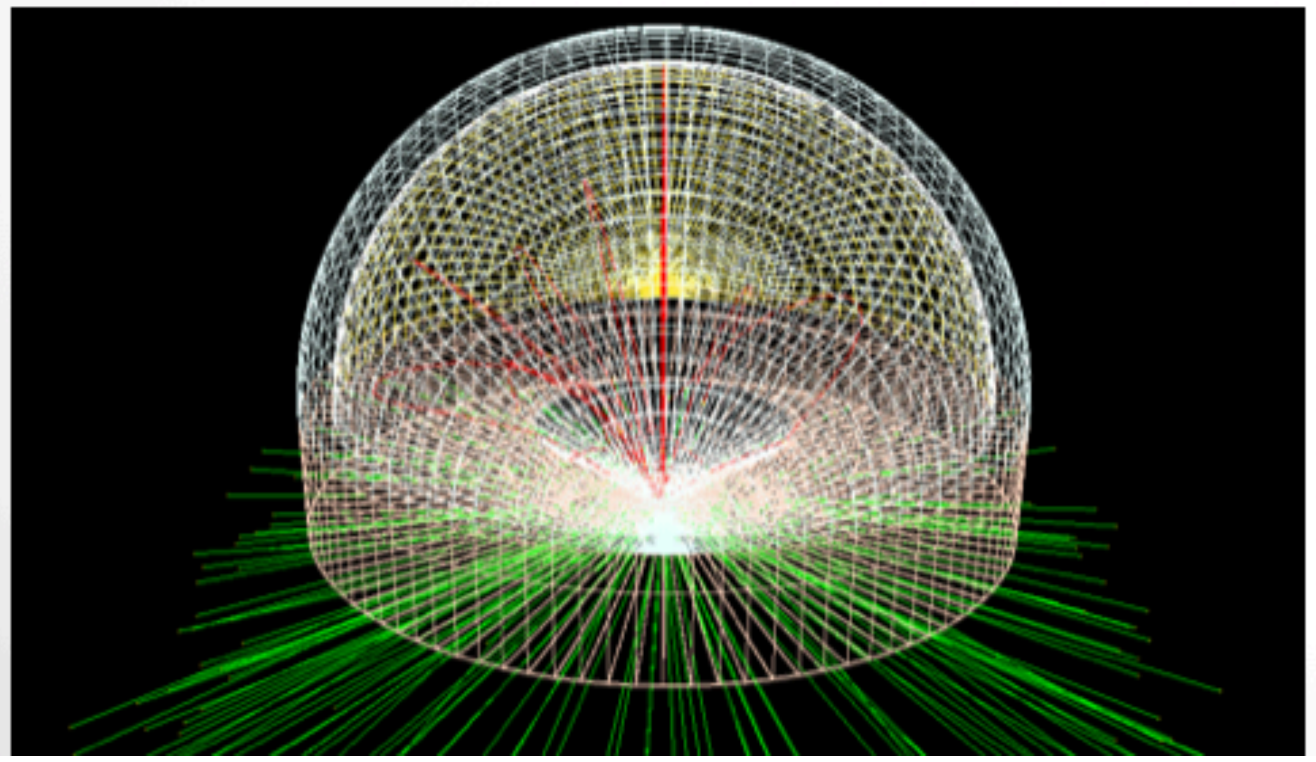
R&D on Photosensors: ABALONE

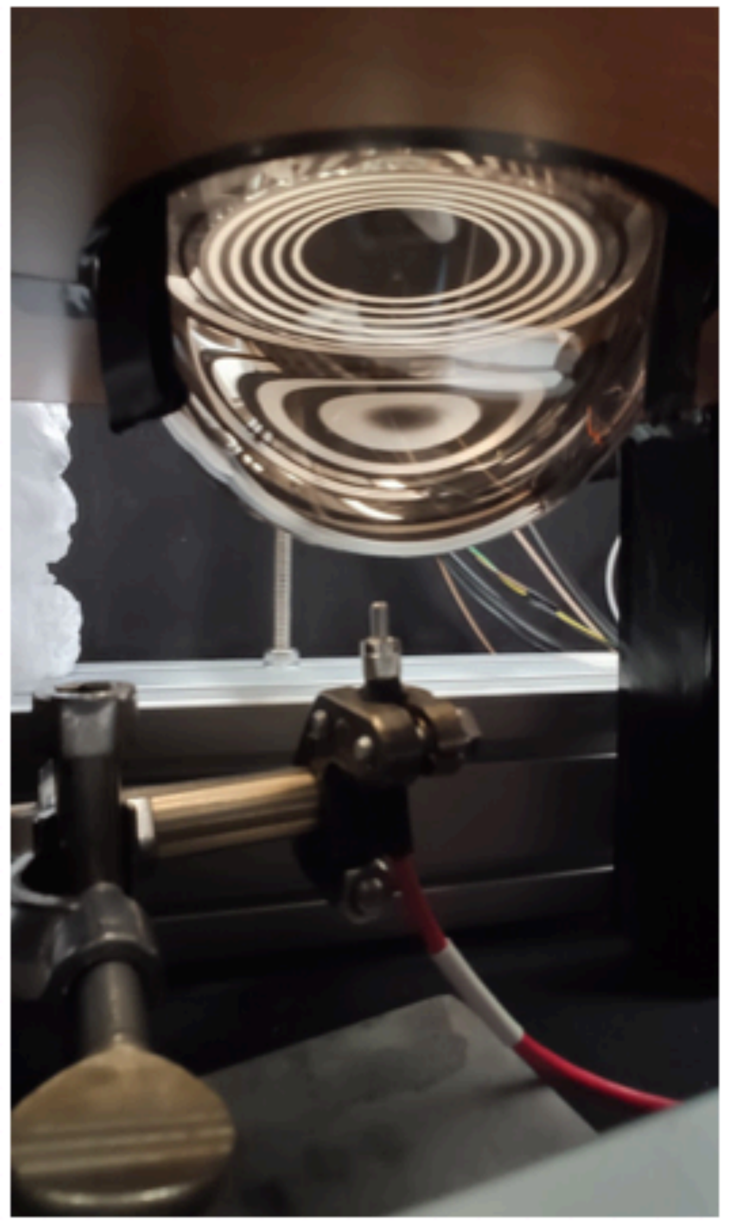
SiPM Tested and calibrated (DAQ ready)

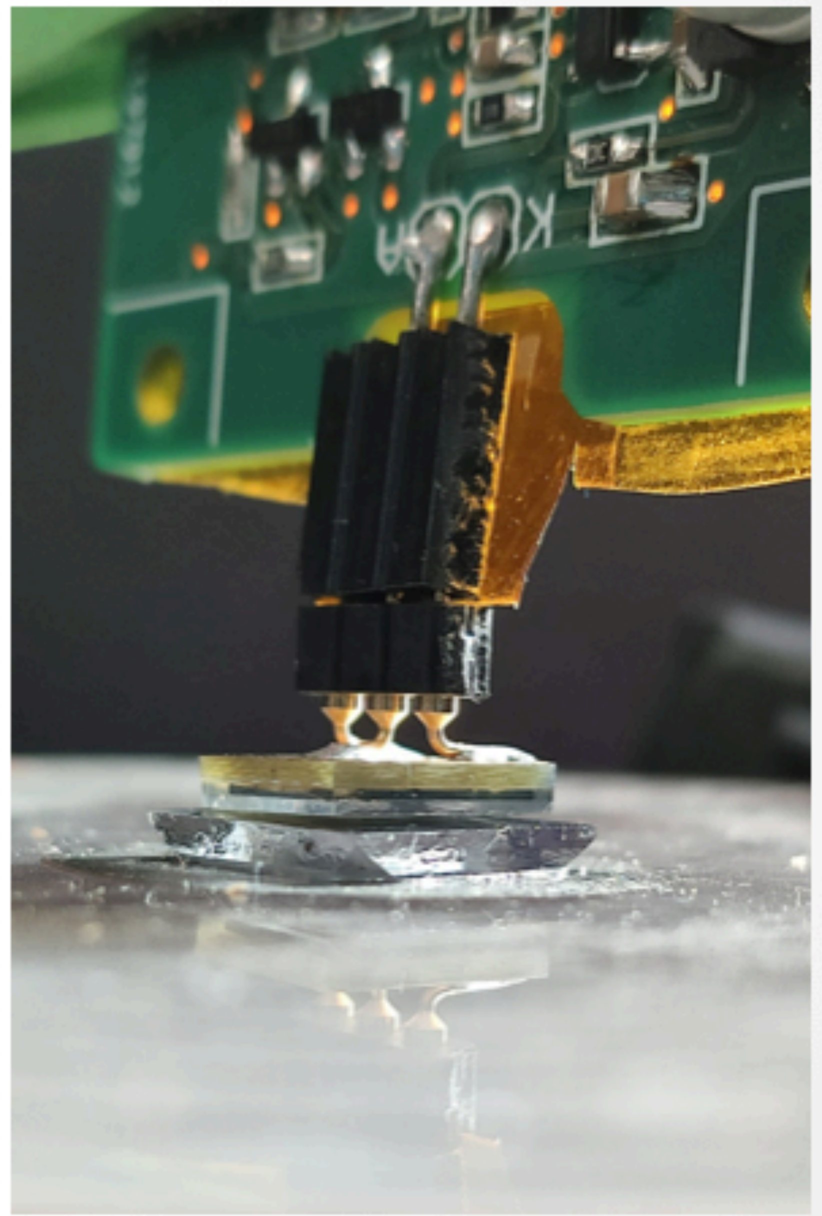


MC simulation to fully characterise and improve sensor are ongoing



SiPM coupled and optical fibre installed
READY to start extensive tests!





R&D activity carried out in collaboration with SU

Stockholm University

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R&D on Photosensors: ABALONE

- The ABALONE is proposed as the light detector for DARWIN
- Proposed also for the DeepCore extension (IceCube)
- Simulations and tests at room temperature in advanced stage
- Liquid xenon tests are planned (as soon as funds materialise)
- Strategies to improve TPC electrodes with new concepts are in-line with such sturdy photo-sensor properties

People involved:

- Ferella A.D. (UnivAq) alfredo.ferella@aquila.infn.it
- Fulgione W. (INAF/INFN-LNGS)
- **D'Andrea V.** (UnivAq), **Biondi R.** (INFN-LNGS)

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Sottomesso PRIN 2020 su questo R&D

Grant presso Stockholm University

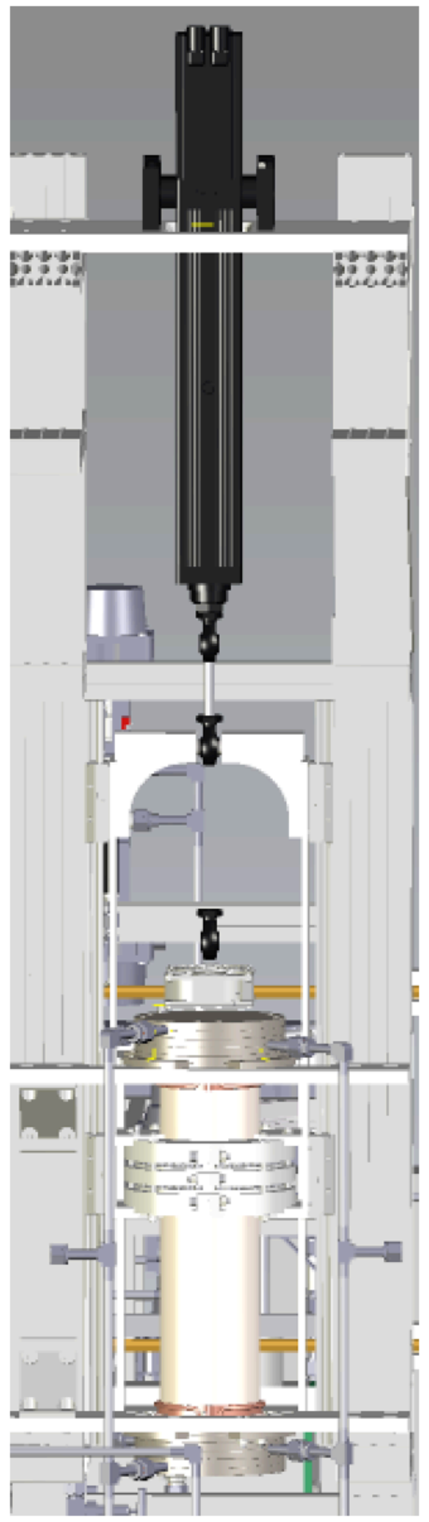
INFN funds:
not yet submitted/discussed for DARWIN

R&D on Xe purification

Magnetic Piston Pump:

efficiency Xe purification, low Rn emanation

3D drawing



In officina meccanica

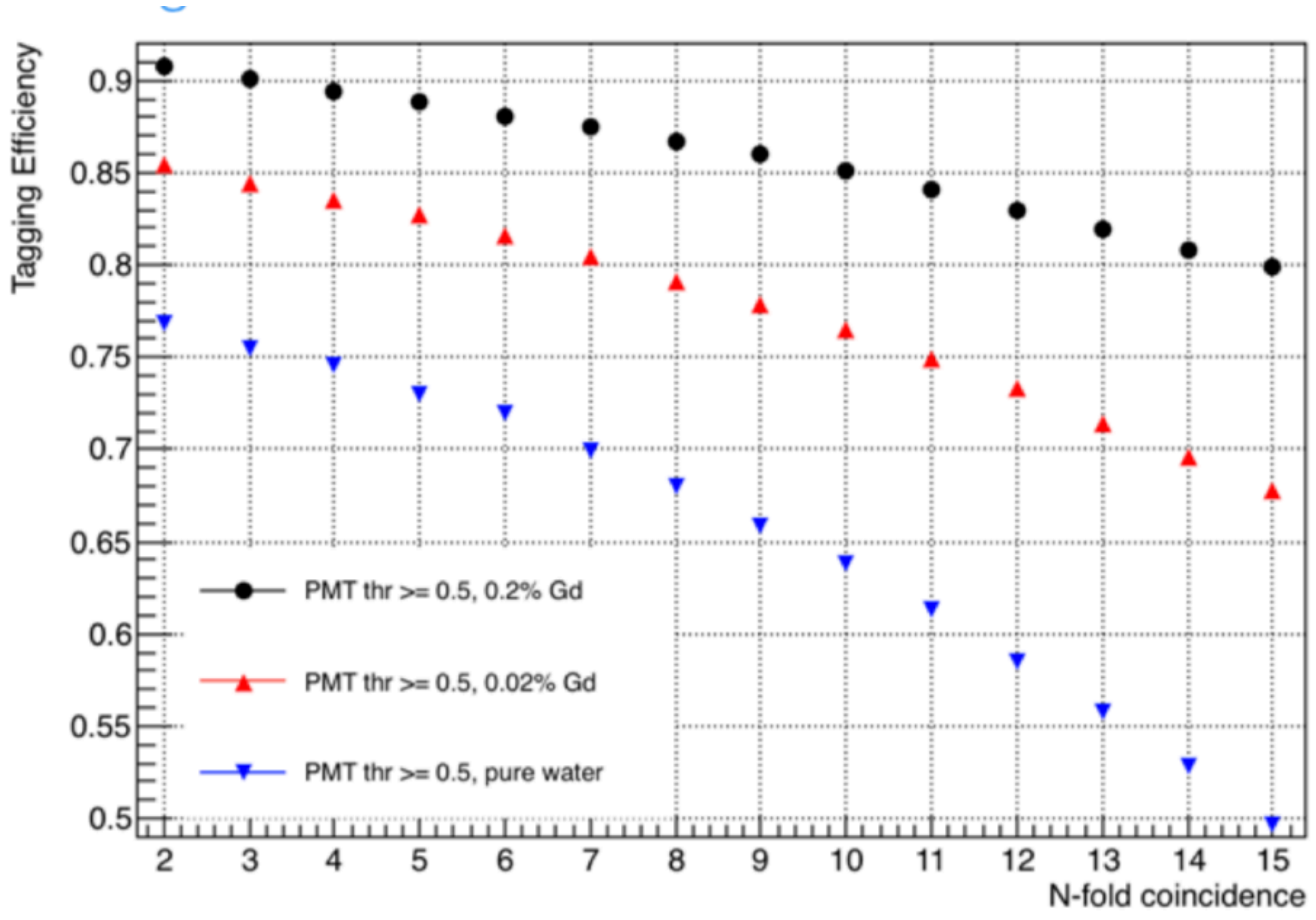
R&D on neutron veto

- Gd-loaded Water: 0.2% of Gd in mass -> 3.4 t of Gd-sulphate-octahydrate; (technology from EGADS-SK colleagues)

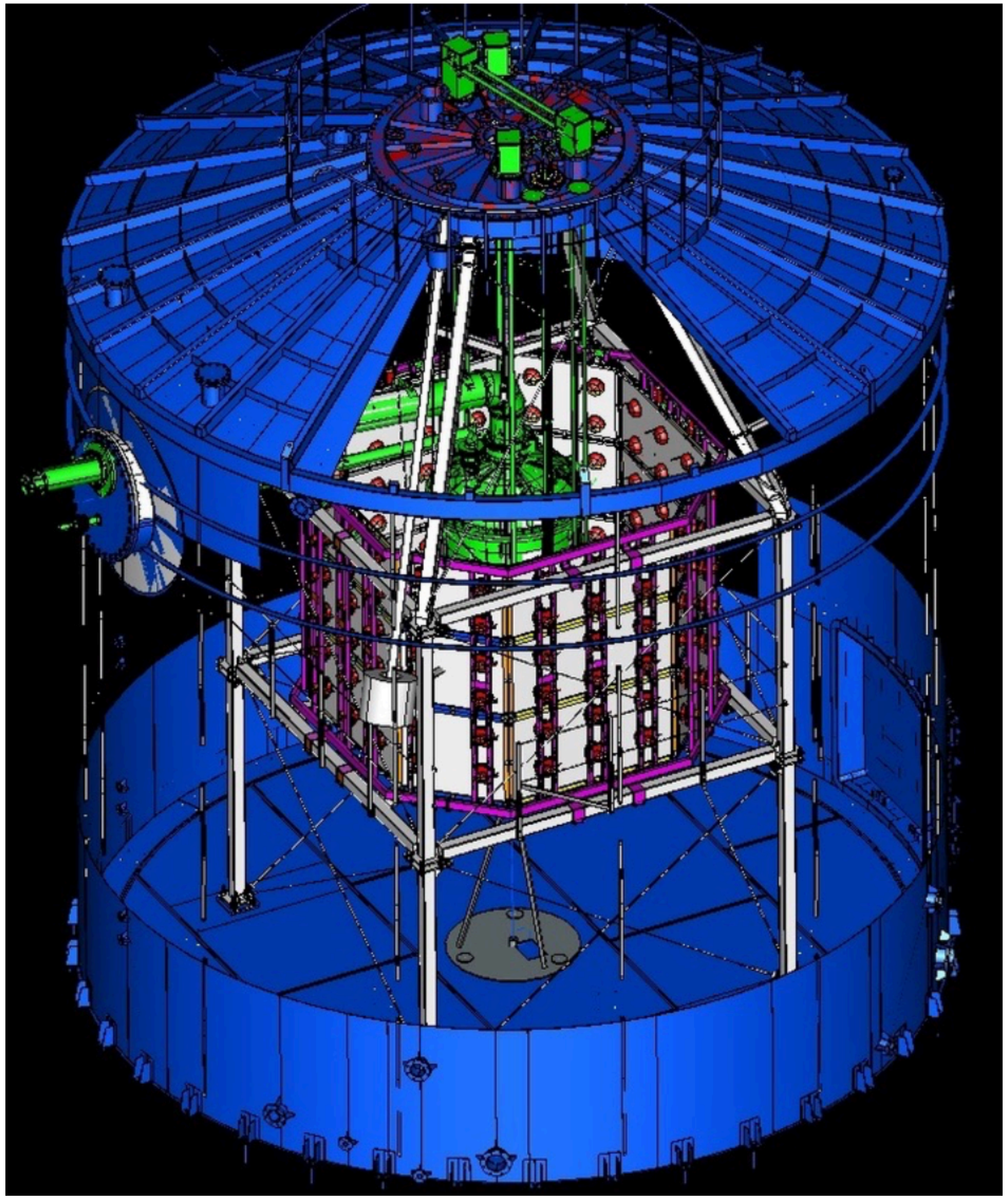
- Cerenkov light is seen by additional 120 PMTs placed in water around the cryostat;

- high-reflectivity foil to confine an inner nVeto region with high light collection efficiency.

XENONnT nVeto

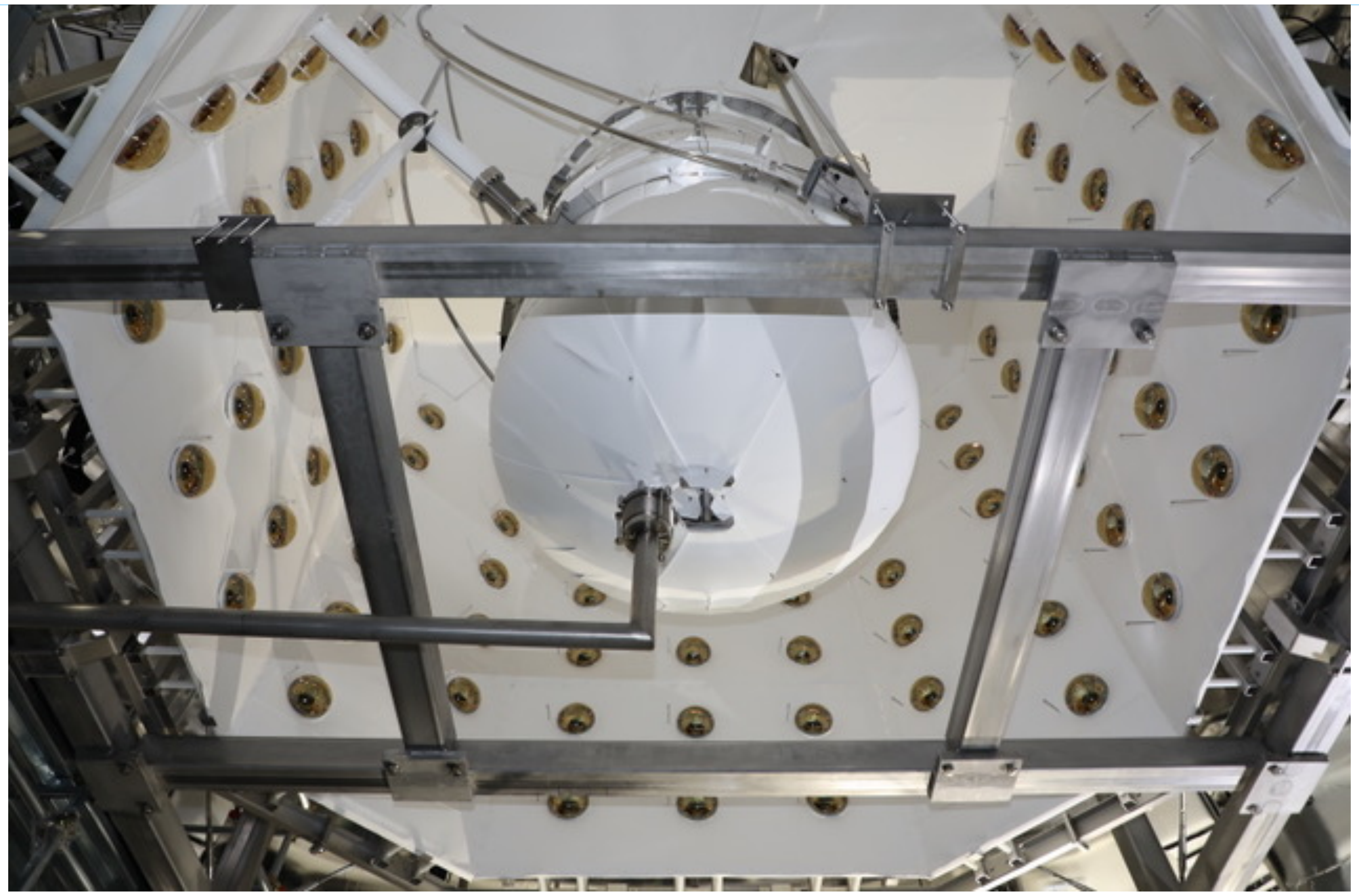


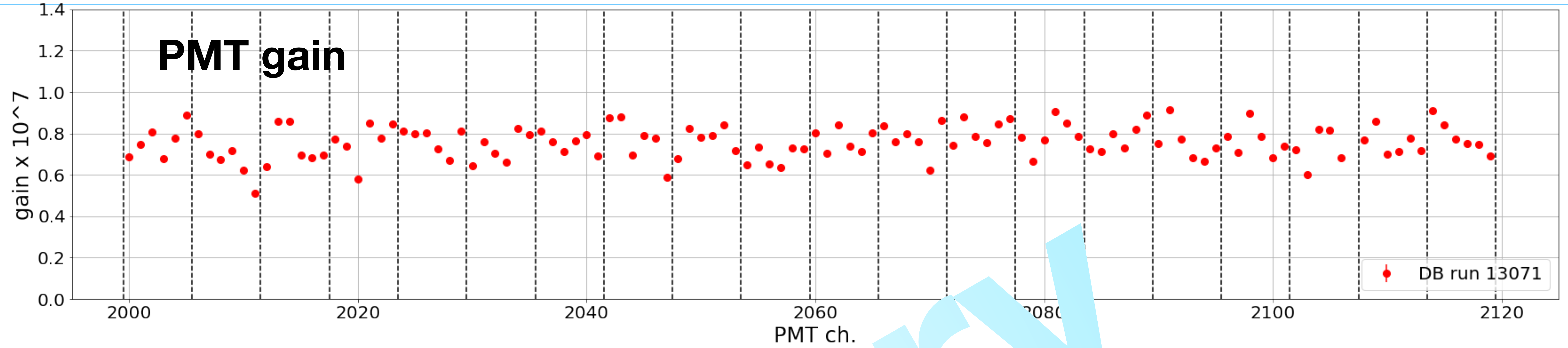
Neutron tagging efficiency:
85% with 0.2% Gd,
65% with pure water
(requiring a threshold of 10 PMTs in coincidence)

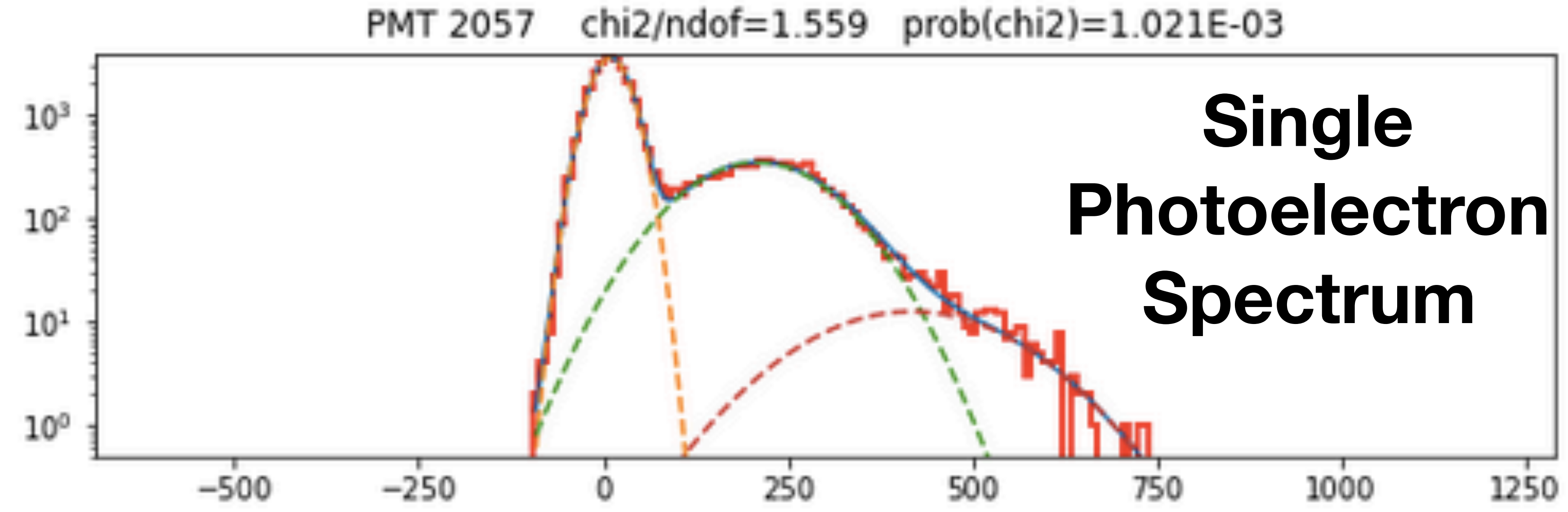


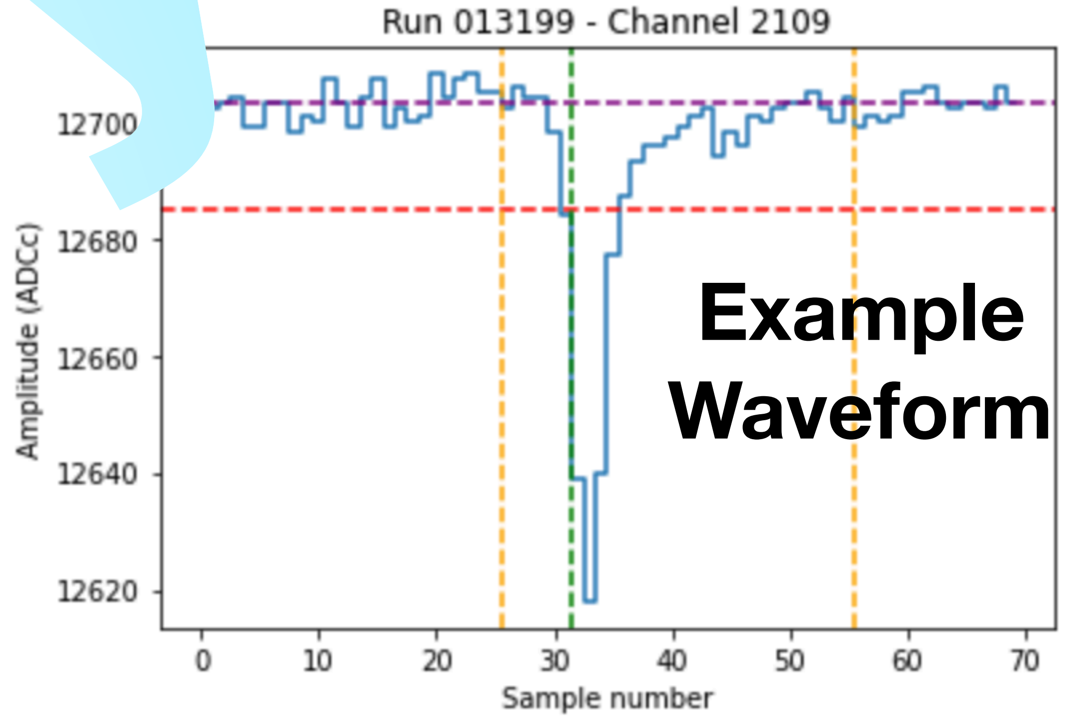
R&D on neutron Veto

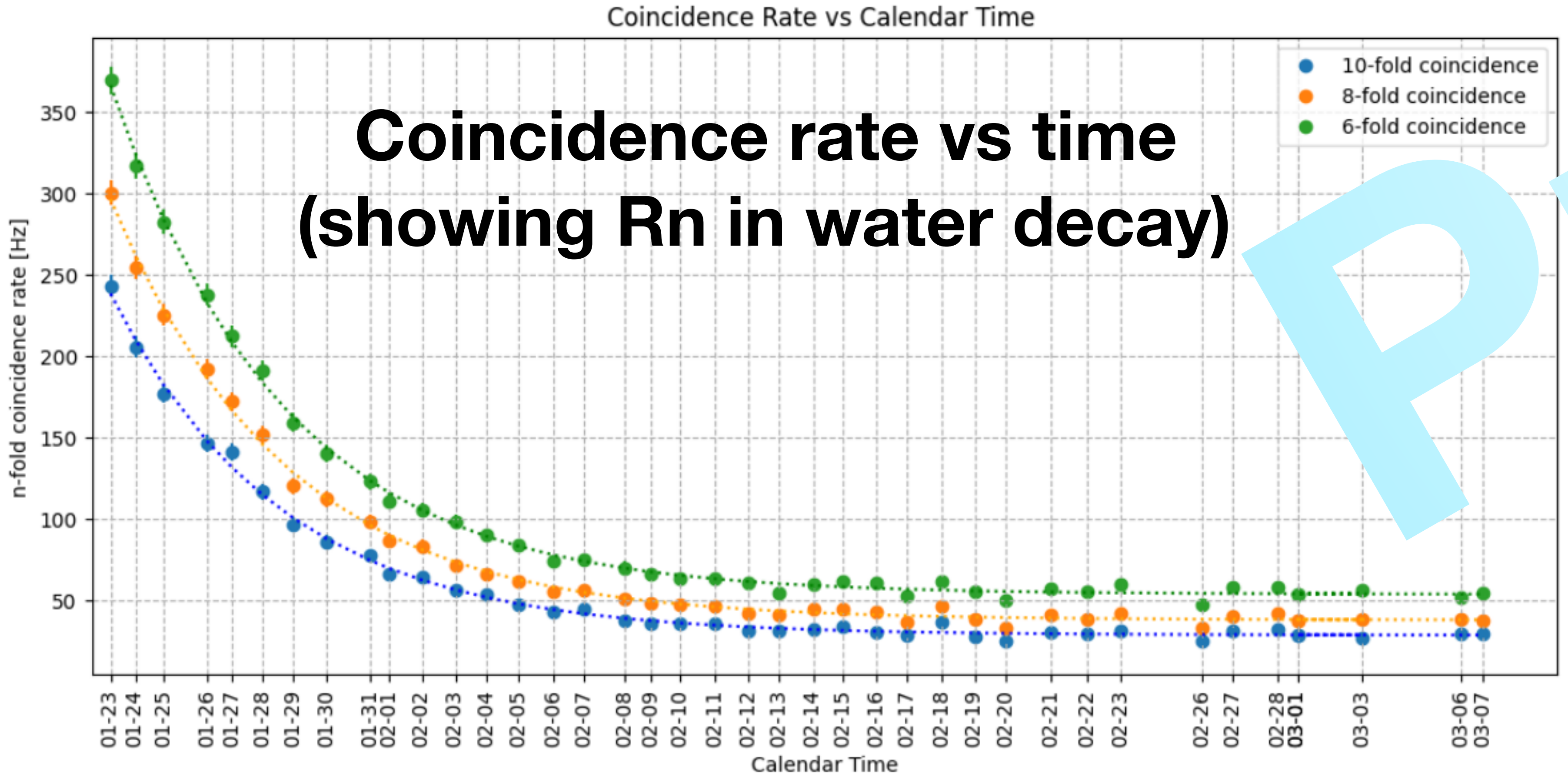
120 8” PMTs to detect Cerenkov light from n-capture, inside a high reflectivity volume around the cryostat.
Under commissioning since the tank has been filled with demi-water in December 2020.

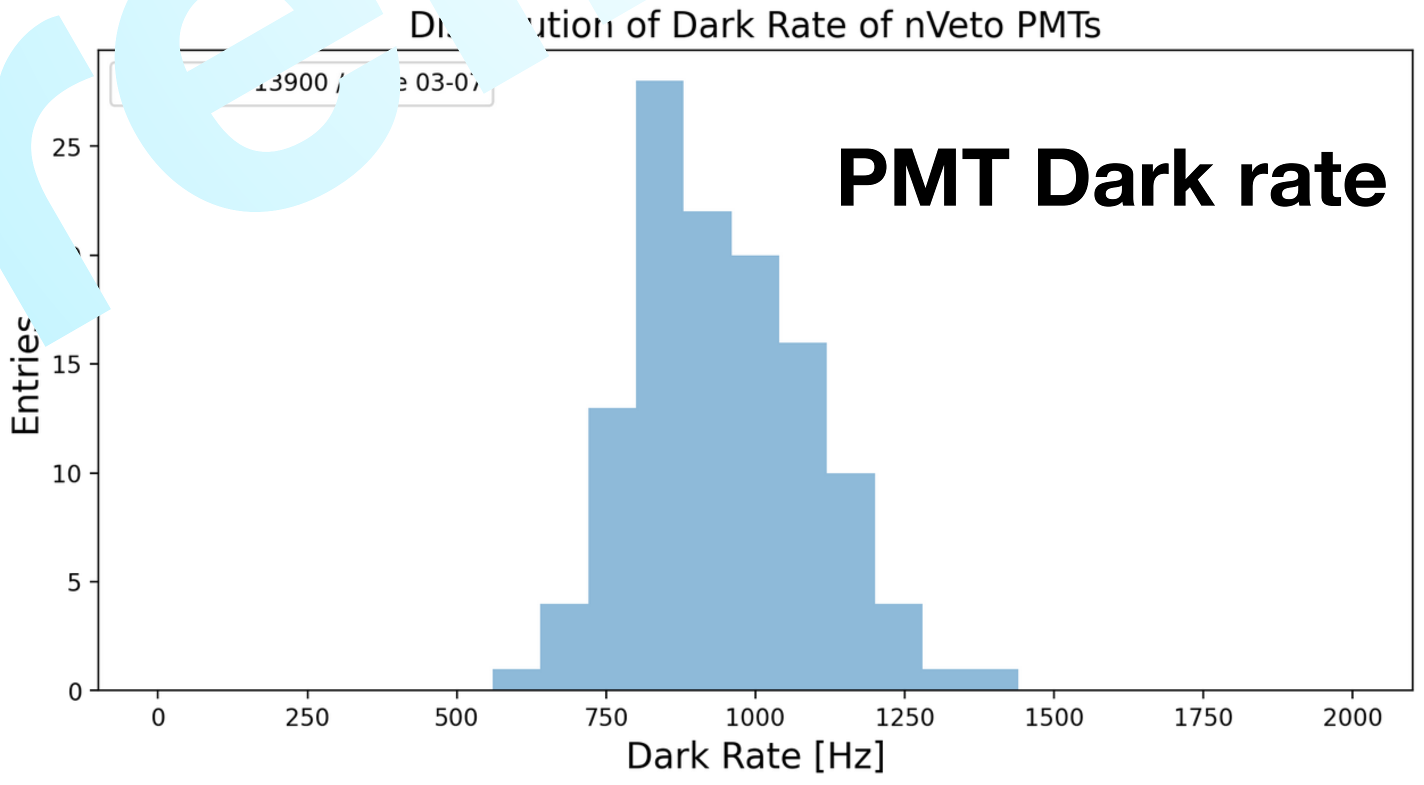




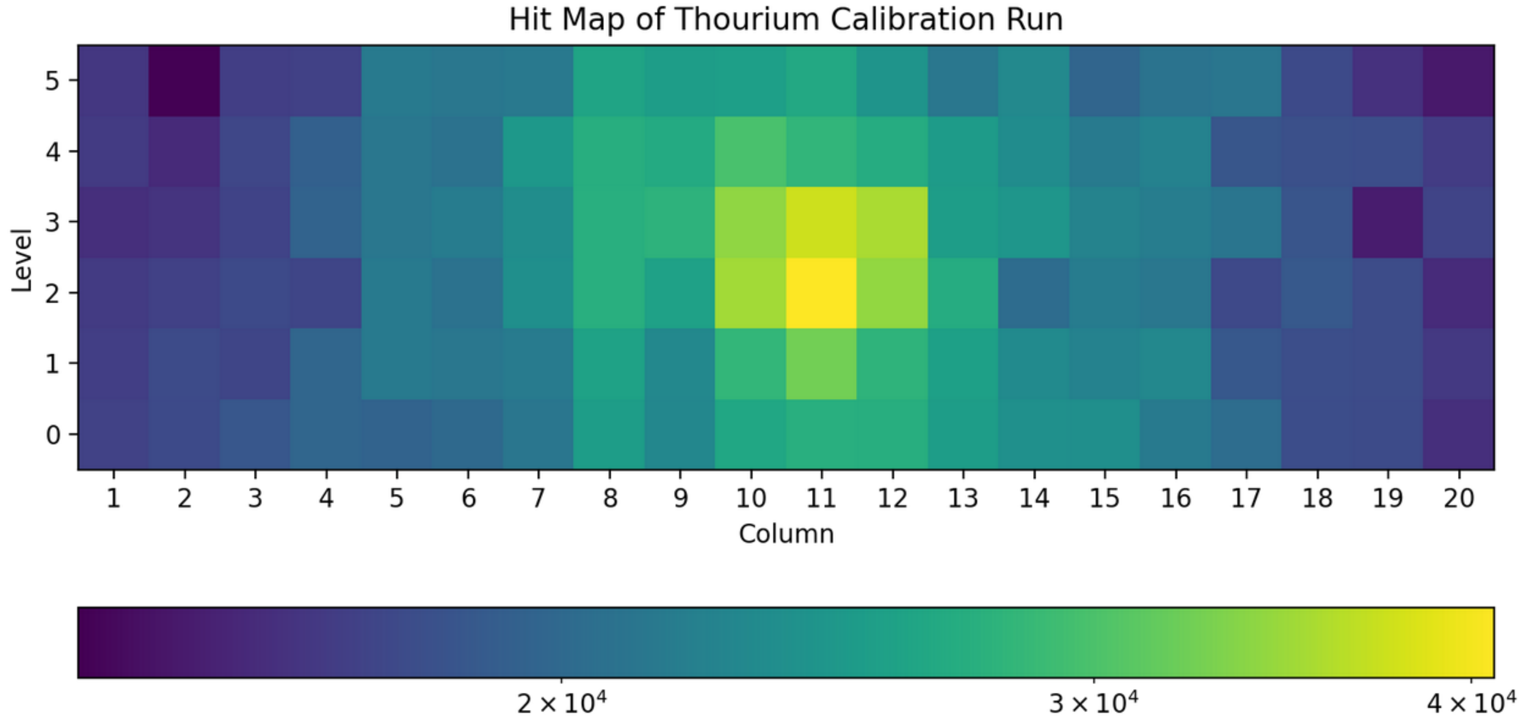








Calibration with Th source



Preliminary

R&D on neutron veto

Gd-loading:

- higher energy: 2.2 -> 8 MeV gammas
- shorter capture time: 200 us -> 20 us
- higher n-capture and detection efficiency
- lower rate of fake coincidences

Gd-Water purification plant:

Goal: maintain a large water transparency without removing the precious GdSalt.

Easier from the environmental point of view (at least with respect to organic liquid scintillators).

Primary responsibility of INFN groups.

R&D for future projects (e.g. DARWIN):

Develop tools to further concentrate GdSalt

Improve photosensors: QE, radioactivity, timing.

Fast (1ns sampling ?) Readout Electronics