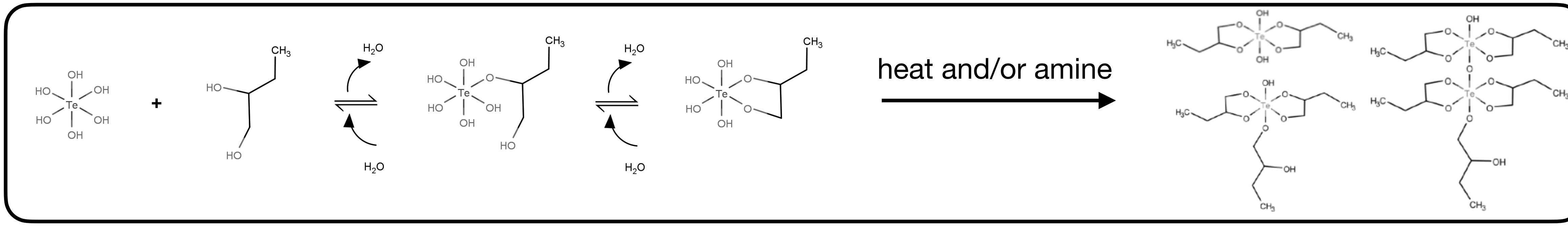
# Inputs from the Community

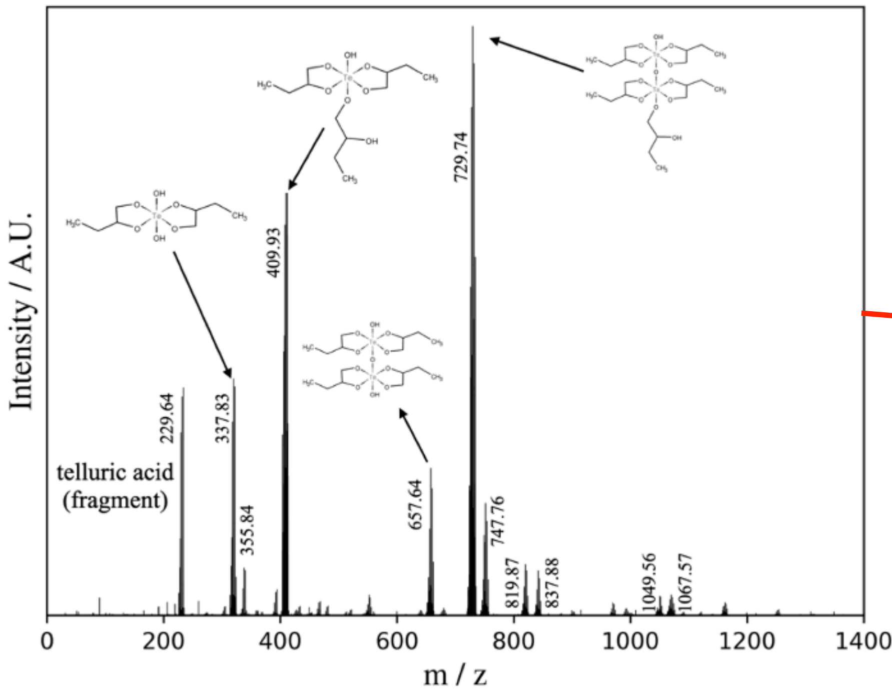
**https://docs.google.com/spreadsheets/d/1aHeFelYW37jVEFmBe-3V6CDHIUT2Rn0K/edit#gid=1842497237**

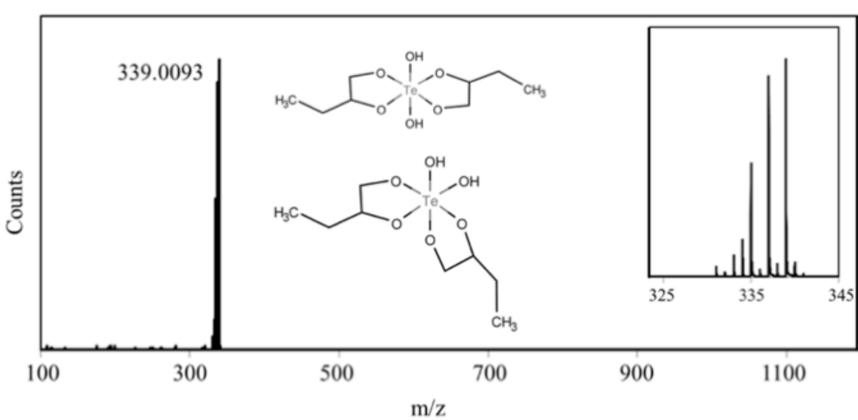
# Liquid Scintillators & Water Cherenkov

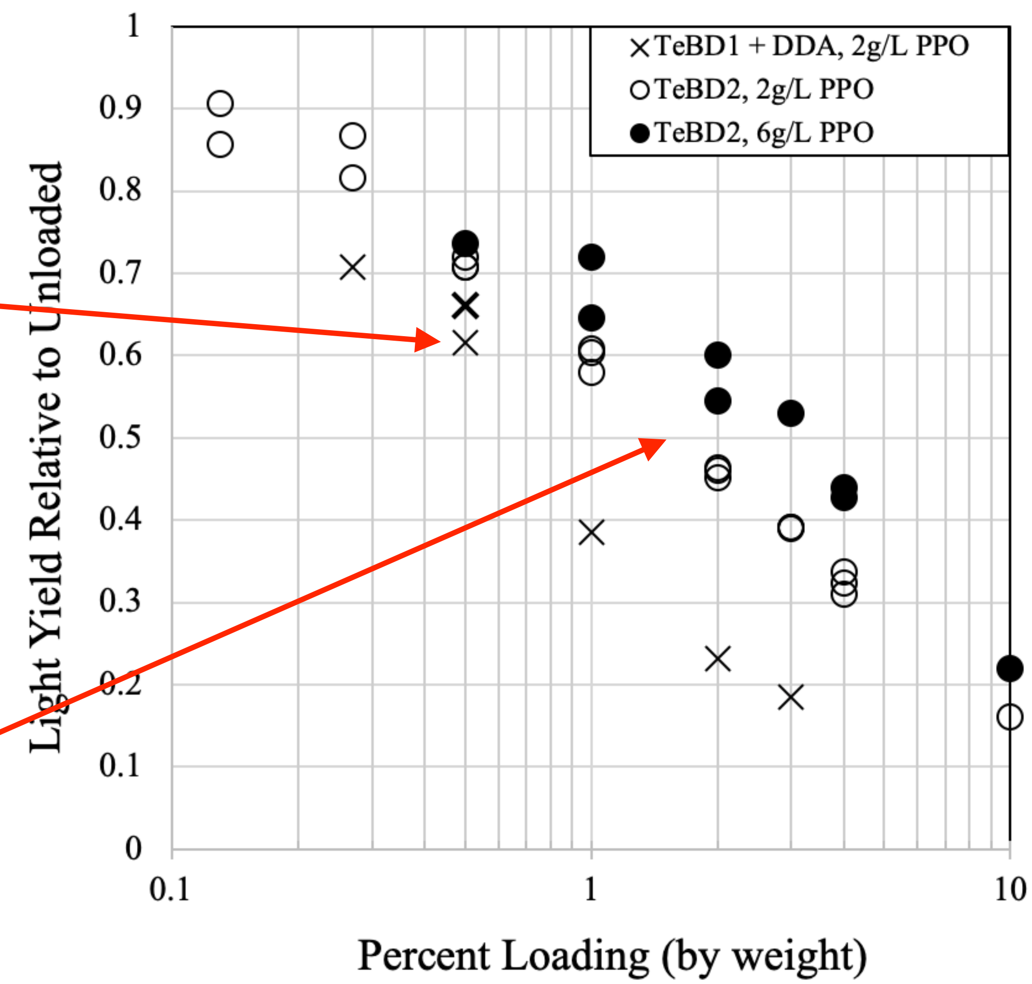
# Te Loading in Liquid Scintillator for 0νββ Experiments

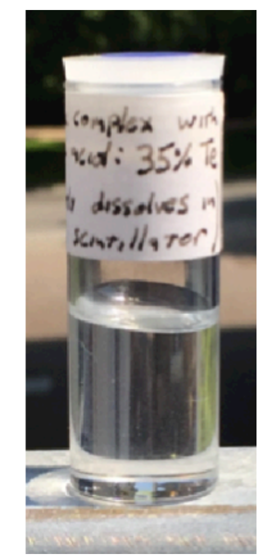
(submitted by S. Biller, Oxford - group technical paper in progress)



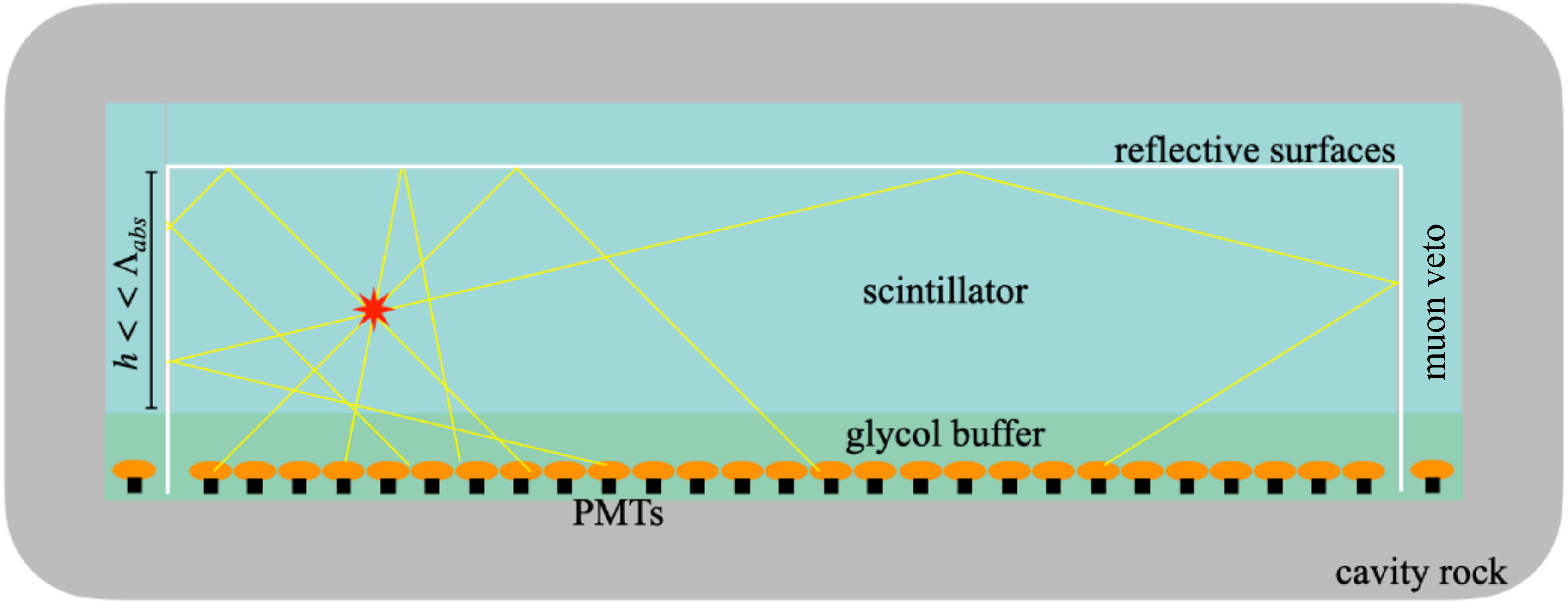
Currently being pioneered by SNO+, but also significant interest from possible future projects such as JUNO and THEIA

Lots of ongoing work: ideas for further improvements, new loading concepts, etc. - has high potential for game-changing impact. Aiming for a practical future NH experiment. Current loading costs equate to ~$1M per tonne of isotope… << most other 0νββ approaches.

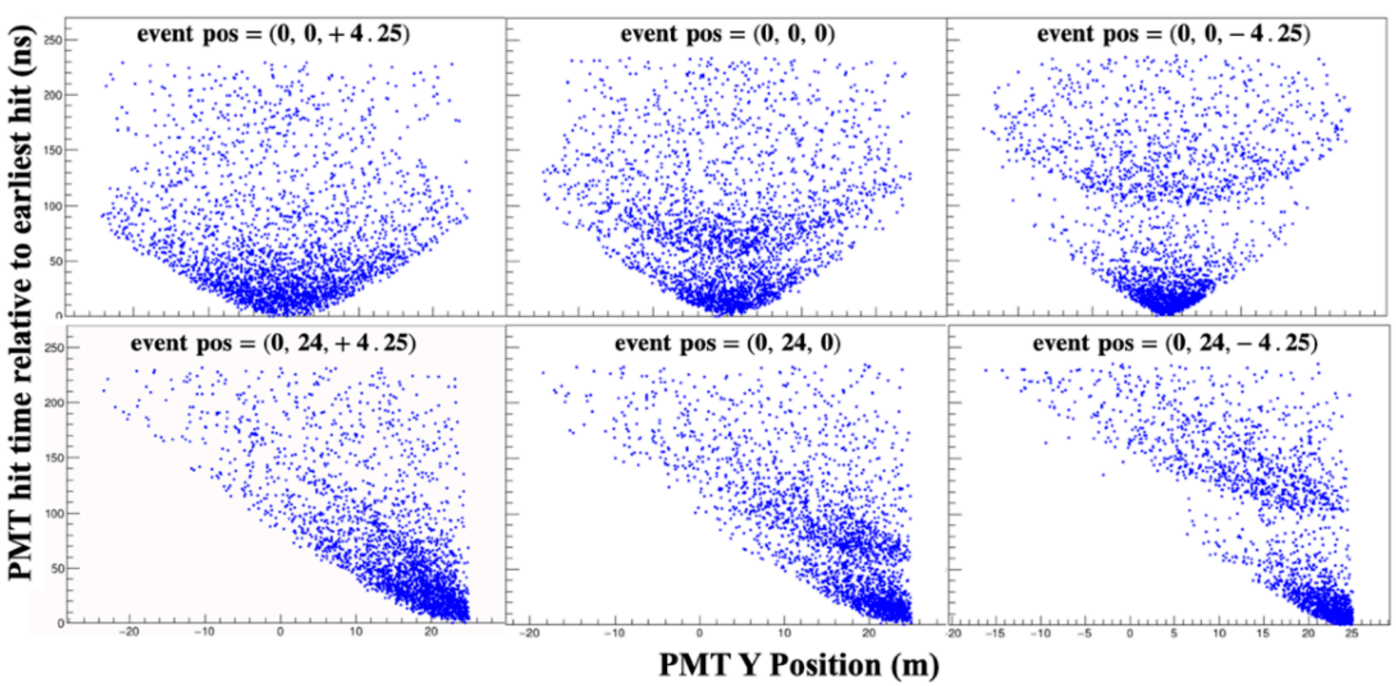
# New Design Concept for Large Scale LS Detectors: Stratified LIquid Plane Scintillator (SLIPS)

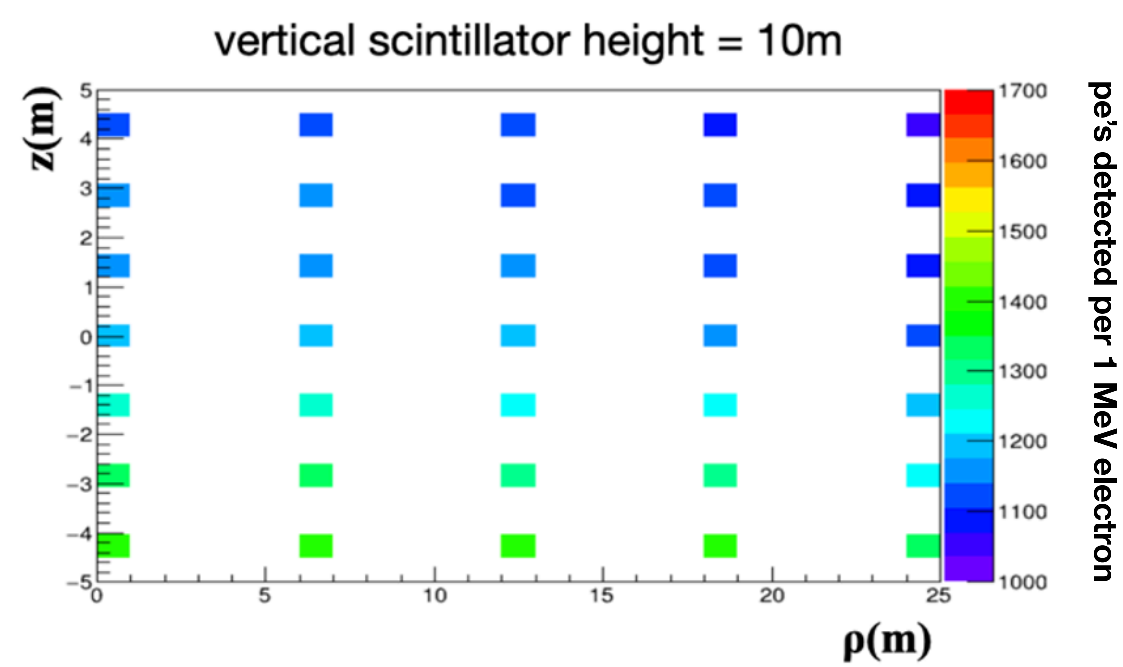
(S. Biller and I. Morton-Blake, Oxford - paper in progress)

Avoids complications related to separation of scintillation and buffer regions; allows for cleaner and more economical large-scale construction.



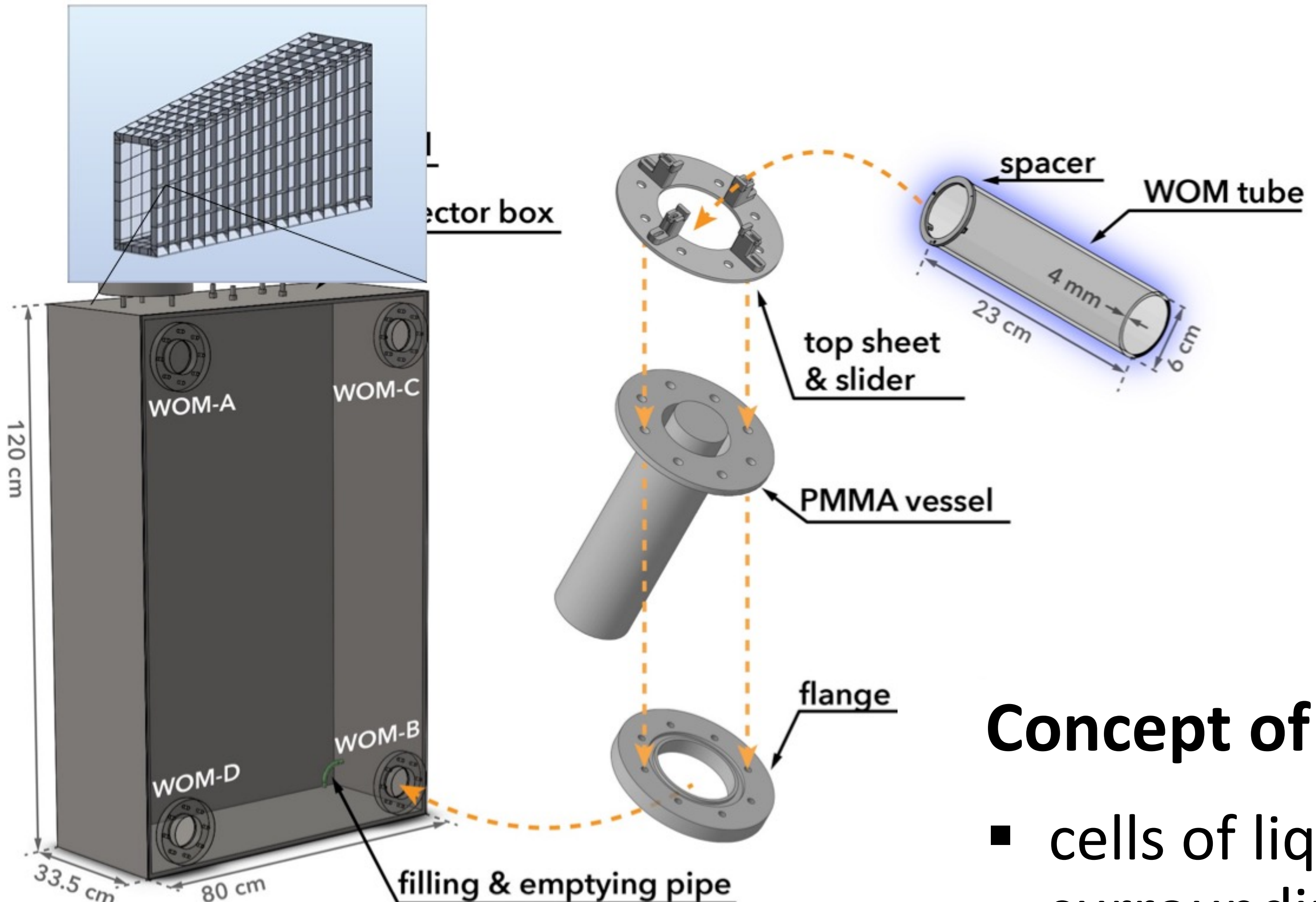

Currently simulation work, but looking to build small-scale prototype.

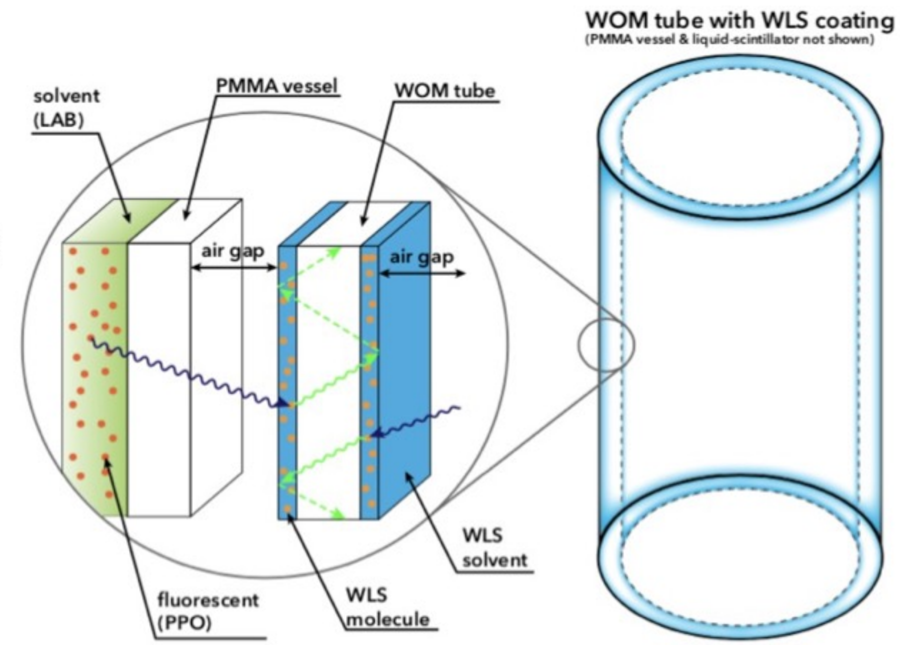



Implications for 0νββ, solar neutrinos, long baseline reactor neutrinos…

# Hermetic Scintillator Veto




## Concept of SHiP-SBT

- cells of liquid scintillator surrounding detection/decay volume
- light readout via Wavelength-shifting Optical Modules (WOMs) and SiPMs
- very high veto efficiency (>99.9%) and enlarged detector acceptance

**Contact Info:** Michael Wurm
<michael.wurm@uni-mainz.de>

# R&D on Gd-doped Water Cerenkov neutron veto

**Neutrons are one of the most dangerous backgrounds for WIMP DM experiments.**

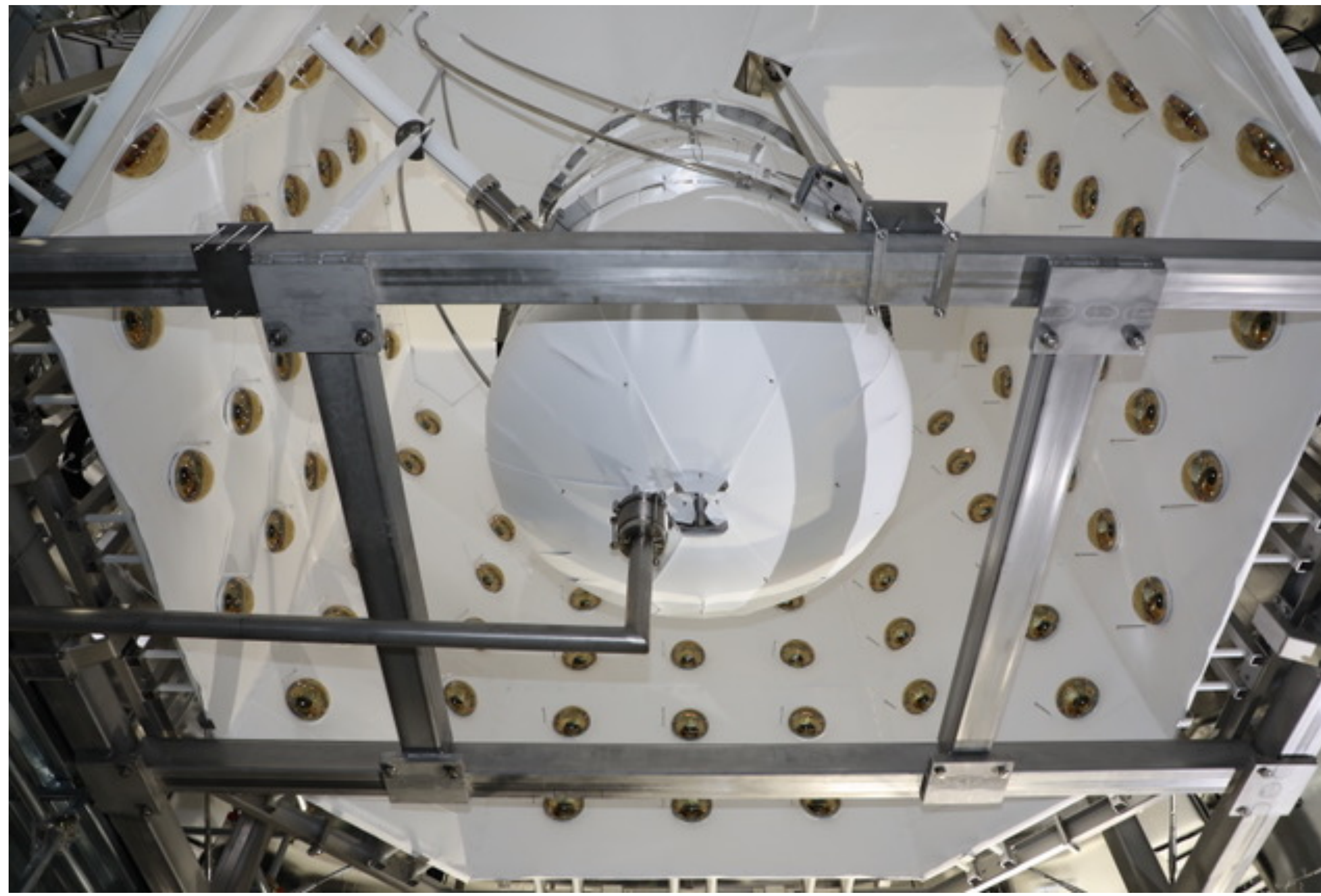
**Neutron veto based on:**

- Gd-loaded Water: 0.2% of Gd-sulphate-octahydrate; (technology from EGADS-SK)
- 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.

**Effective technology:**

- performances similar to Organic Liquid Scintillators,
- easier in terms of environmental constrains.

## XENONnT -> DARWIN



**Proponents**:

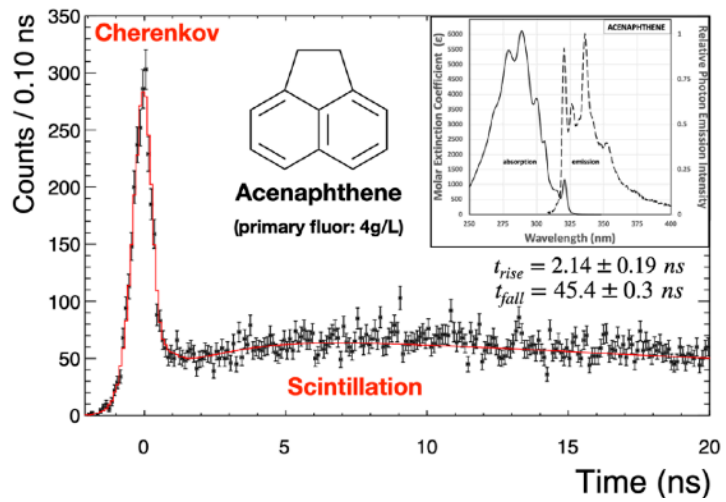
Marco Selvi - Uwe Oberlack
(INFN Bologna) (University of Mainz)
for the **DARWIN** experiment

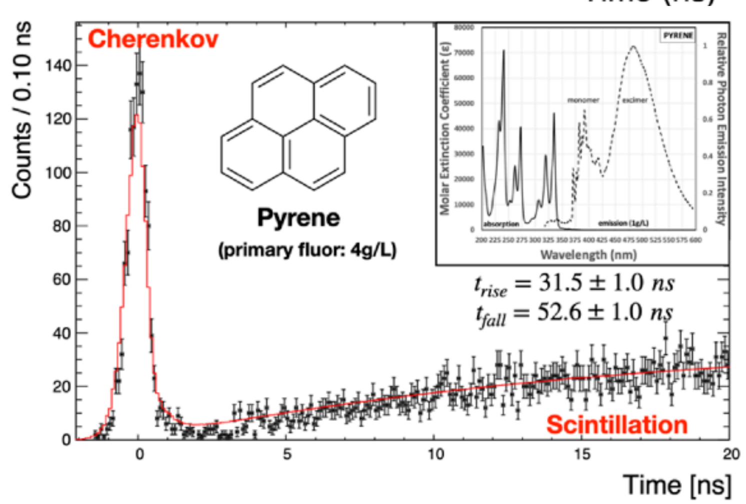
# Slow Fluors for Effective Separation of Cherenkov Light in Liquid Scintillators

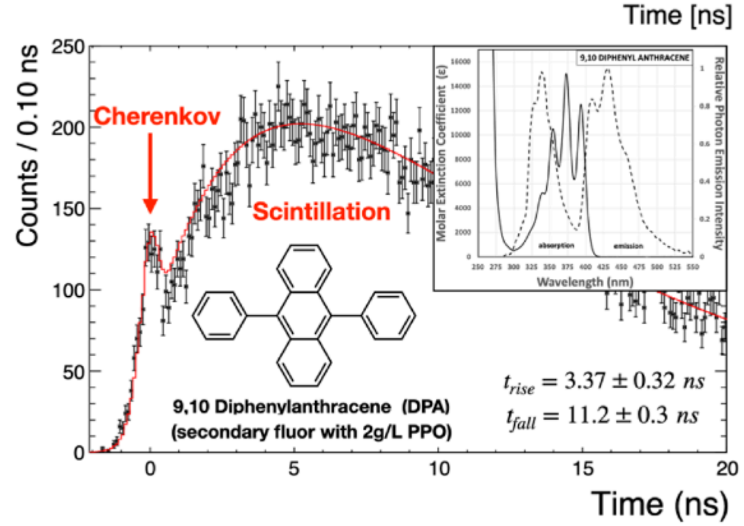
New detector concept: Allows directional and topological information from Cherenkov light plus excellent energy resolution from scintillation

(Biller, Leming and Paton, NIM A 972, 2020)

**Very clear Cherenkov separation with directionality experimentally demonstrated for sub-MeV electrons**



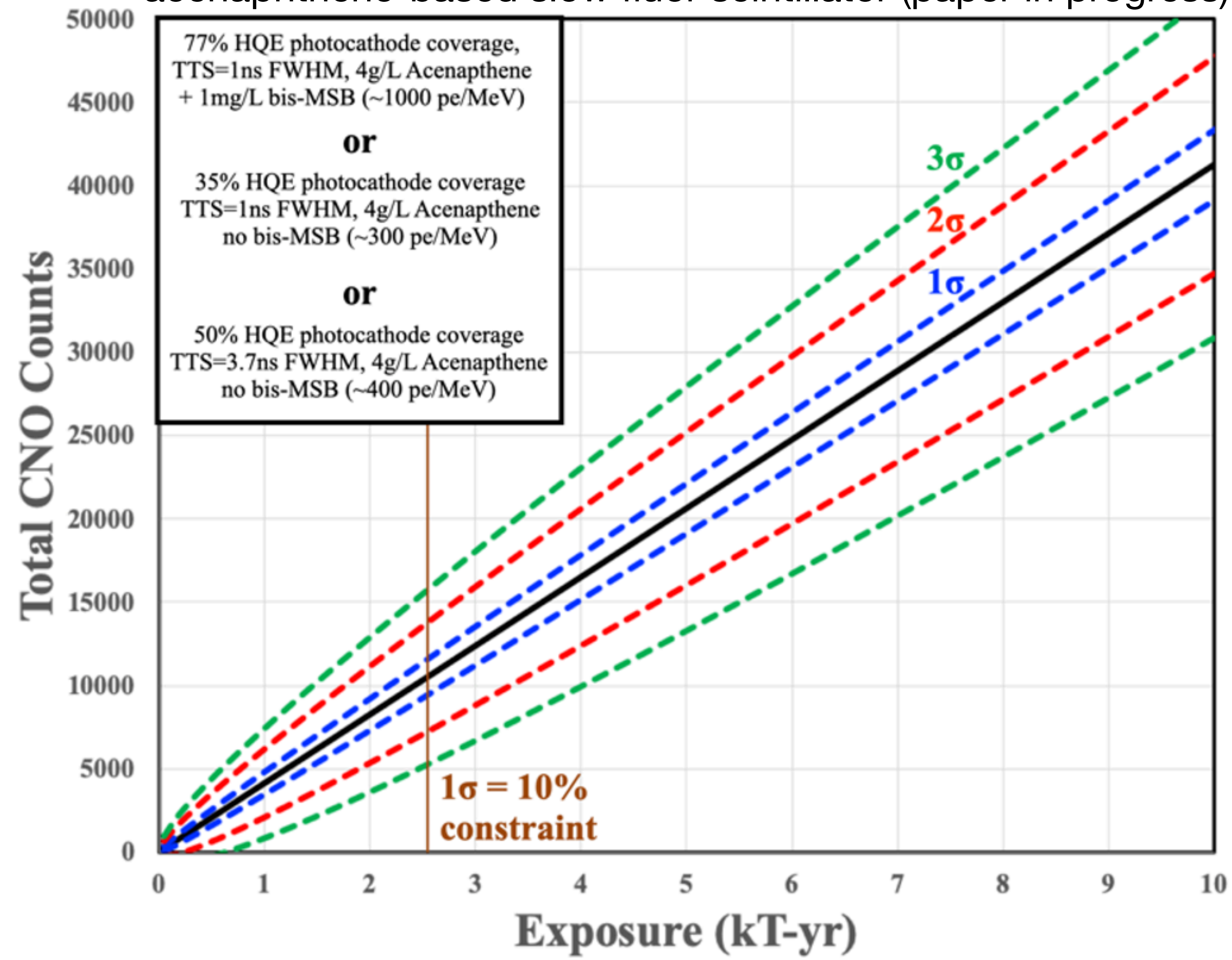




4 different slow fluors have been studied, 3 of which are shown here.

Currently the most effective and economical approach by far.

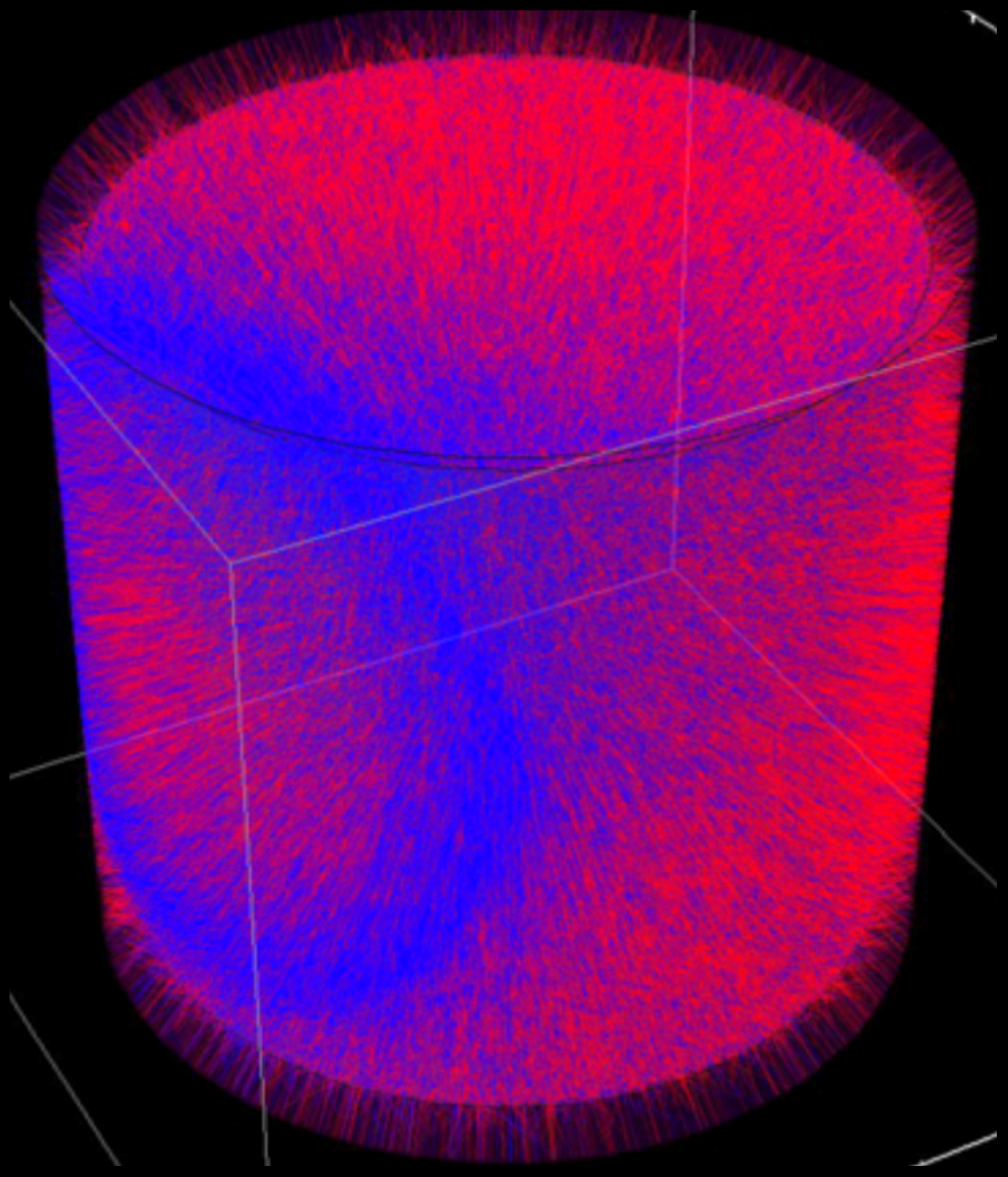
Simulation study of low energy CNO neutrino detection using acenaphthene-based slow fluor scintillator (paper in progress)




Possibly best way to do high-precision measurement of CNO neutrinos with inexpensive, "off-the-shelf" technology and a modestly sized detector. But many other potential applications as well, including possible suppression of $^{8}$B backgrounds in LS $0\nu\beta\beta$ experiments.

# Hybrid Optical Neutrino Detectors

- simultaenous detection of Cherenkov and scintillation light
- enhanced vertex reconstruction
  directionality, energy
- improved particle ID
  Cherenkov/scintillation ratio
- resolve complex final states at GeV energies
  ring counting, proton recoils
- target media:
  water-based or slow scintillators
- realization of large-volume neutrino detectors (Theia)



**Contact:** Michael Wurm <michael.wurm@uni-mainz.de>

# TAO - Taishan Antineutrino Observatory

**Measure reactor anti-neutrino spectrum with high resolution**

- provide **model-independent reference for JUNO**
- benchmark to **test nuclear databases**
- provides increased reliability in measured **isotopic antineutrino yields**
- improve nuclear physics **knowledge of neutron-rich isotopes**
- shed light on **reactor spectrum anomaly** (5 MeV bump)
- searching for **light sterile neutrinos** with a mass ~1 eV
- ~36 × JUNO statistics

**TAO Design Features:**

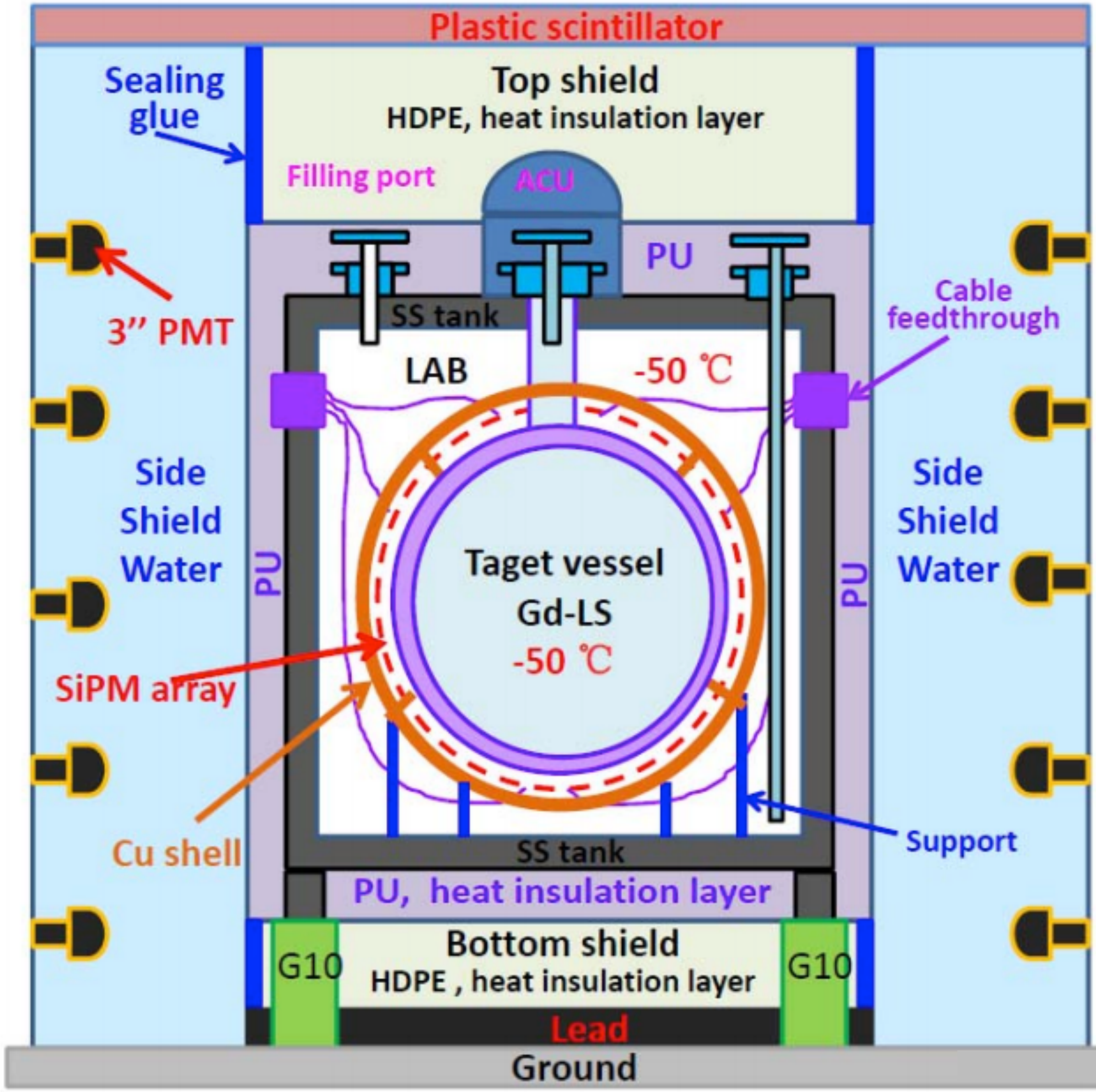
- **2.6 ton Gd-LS** as target material (1 ton fiducial mass)
- Detector placed at **30 m distance** from a **4.6 $GW_{th}$** reactor core
- *10 $m^2$ SiPM,* with *50% PDE, Coverage: > 95%*
- ***SiPMs and LS cooled down to -50 °C (-60 °C)***
- ***First ton-scale cooled LS detector with SiPM readout!***

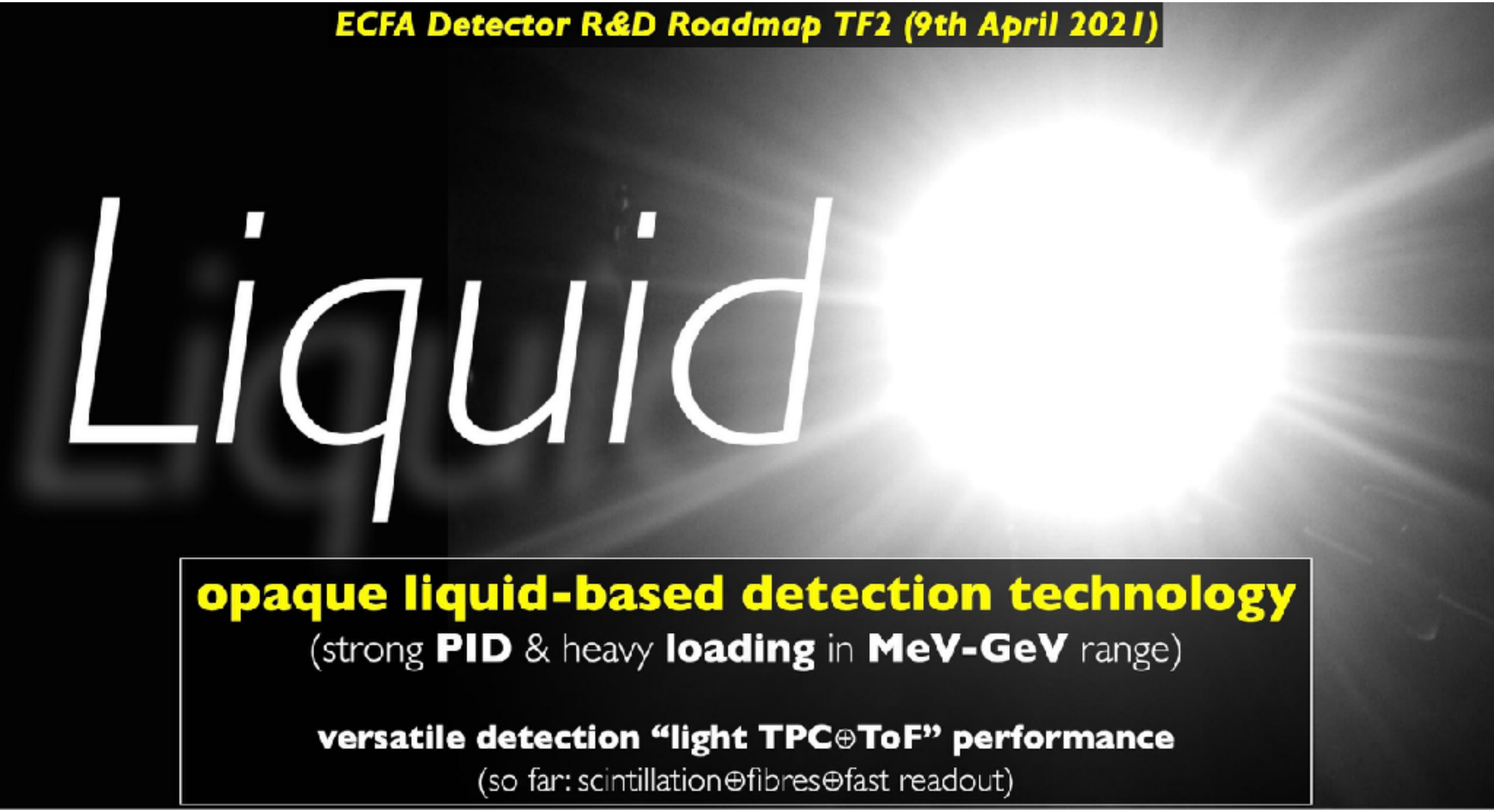
*Conceptual Design Report Released in May 2020! arXiv: 2005.08745v1*

**Expected Performance:**

- *~4500 p.e. / MeV* collected charge
- Energy Resolution*: ~1.7% @ 1 MeV, < 1.0% above 3 MeV*

**Planned to be online before the end of 2023!**




ECFA Detector R&D Roadmap TF2 (9th April 2021)
Liquid
opaque liquid-based detection technology
(strong PID & heavy loading in MeV-GeV range)
versatile detection "light TPC⊕ToF" performance
(so far: scintillation⊕fibres⊕fast readout)

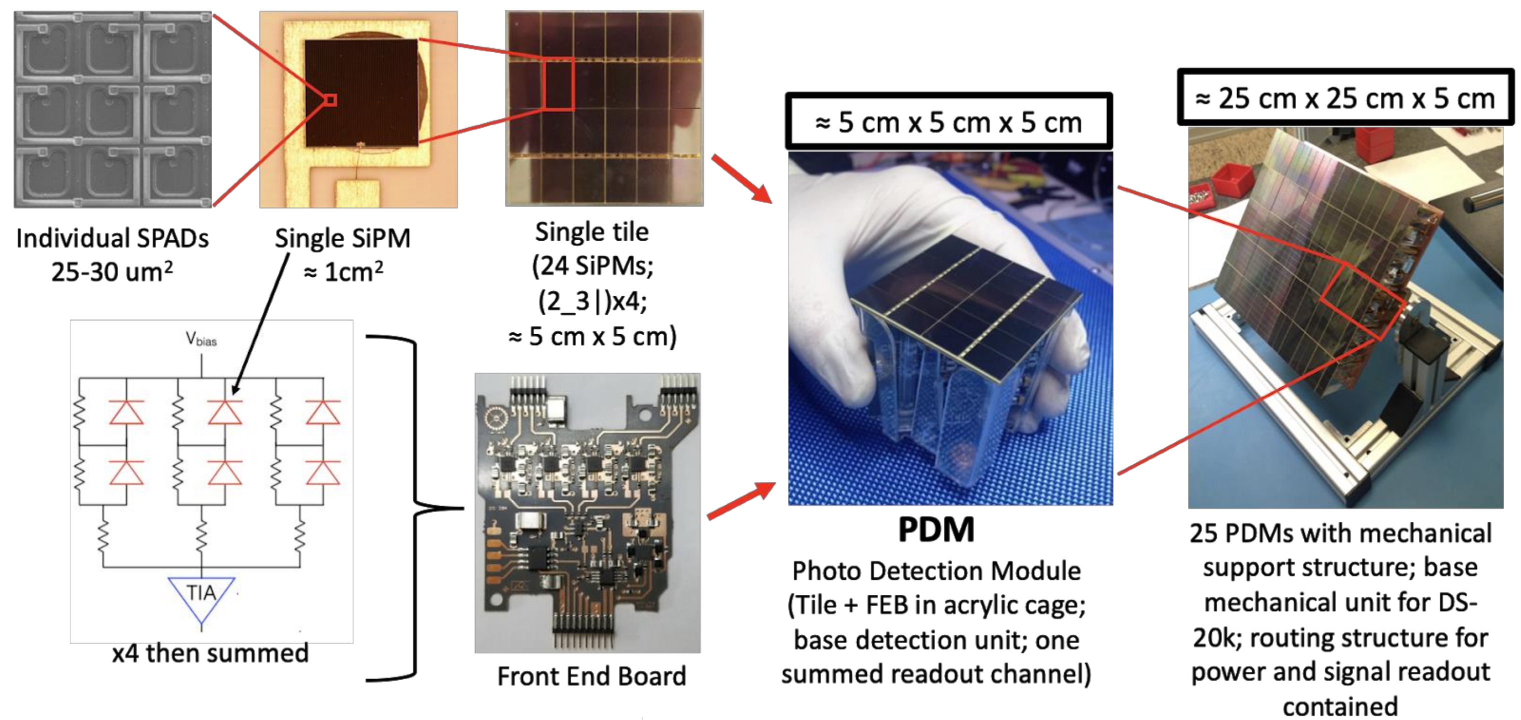
# Noble Liquid Signal Collections

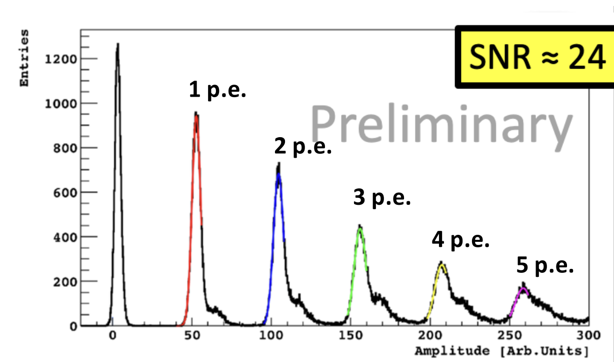
## (Light and charge)

# Improving Large Area SiPM Readouts for Next Generation Low Background Experiments

- **SiPM**-based readouts have many **advantages** over PMTs including higher radiopurity, compactness, magnetic insensitivity, and the ability to reach high gains at low bias voltages.
- **Large,** light detection **experiments** involved in **neutrino** and **dark matter** searches could all make use of SiPM-based readouts.
- SiPMs are typically produced with a **small sensitive area**, *O(mm²)*, so optimized **ganging strategies** are needed to produce working detector channels.
- Moving this line of research from the **R&D** phase into the **production** phase is crucial for outfitting any next generation detector with a SiPM-based readout.

## Darkside-20k ganging strategy




**PDM** single photoelectron spectrum

**Sources**


*IEEE Trans.Electron.Dev.* 64 2, 521-526
*IEEE Trans.Nucl.Sci.* 65 (2017) 1, 591-596
*IEEE Trans.Nuc.Sci. 65, no. 4, pp. 1005-1011, April 2018*
Sensors (Basel). 2019;19(2):308.
F.Acerbi et al.,IEEE Trans. Electron Dev. 64, 2, (2017), 521-526



Luigi Rignanese (INFN – Bologna) for the **GADMC**

Istituto Nazionale di Fisica Nucleare

# Development of Scalable Polyethylene Naphthalate (PEN) Wavelength Shifter (WLS) for Large Liquid Argon Detectors

M. Kuźniak (AstroCeNT/CAMK PAN) on behalf of the GADMC

## Motivation

- Next generation detectors, including Argo, will need up to thousands $m^2$ of WLS surfaces for efficient light collection
- Vacuum evaporated tetraphenyl butadiene (TPB) coatings are well proven but the production is challenging to scale up
- Polymeric foils based on PEN are among alternatives and subject of ongoing R&D:
  - Commercial (technical) grades have 30-60% of TPB WLS yield
  - Comparisons to TPB non-trivial (need 87 K and 128 nm excitation)
  - TPB absolute WLS yield itself is debated

## Goals

- Optimize PEN for high WLS yield in LAr (custom synthesis, production and storage/handling)
- Industrialize the production

## Needs

- Facility for absolute WLS yield characterization at 128 nm and at 87 K, time resolved measurements
- Keen industrial partner

**Bibliography**

1. Eur. Phys. J. C 79, 291 (2019)

2. Instruments 5, 4 (2021)

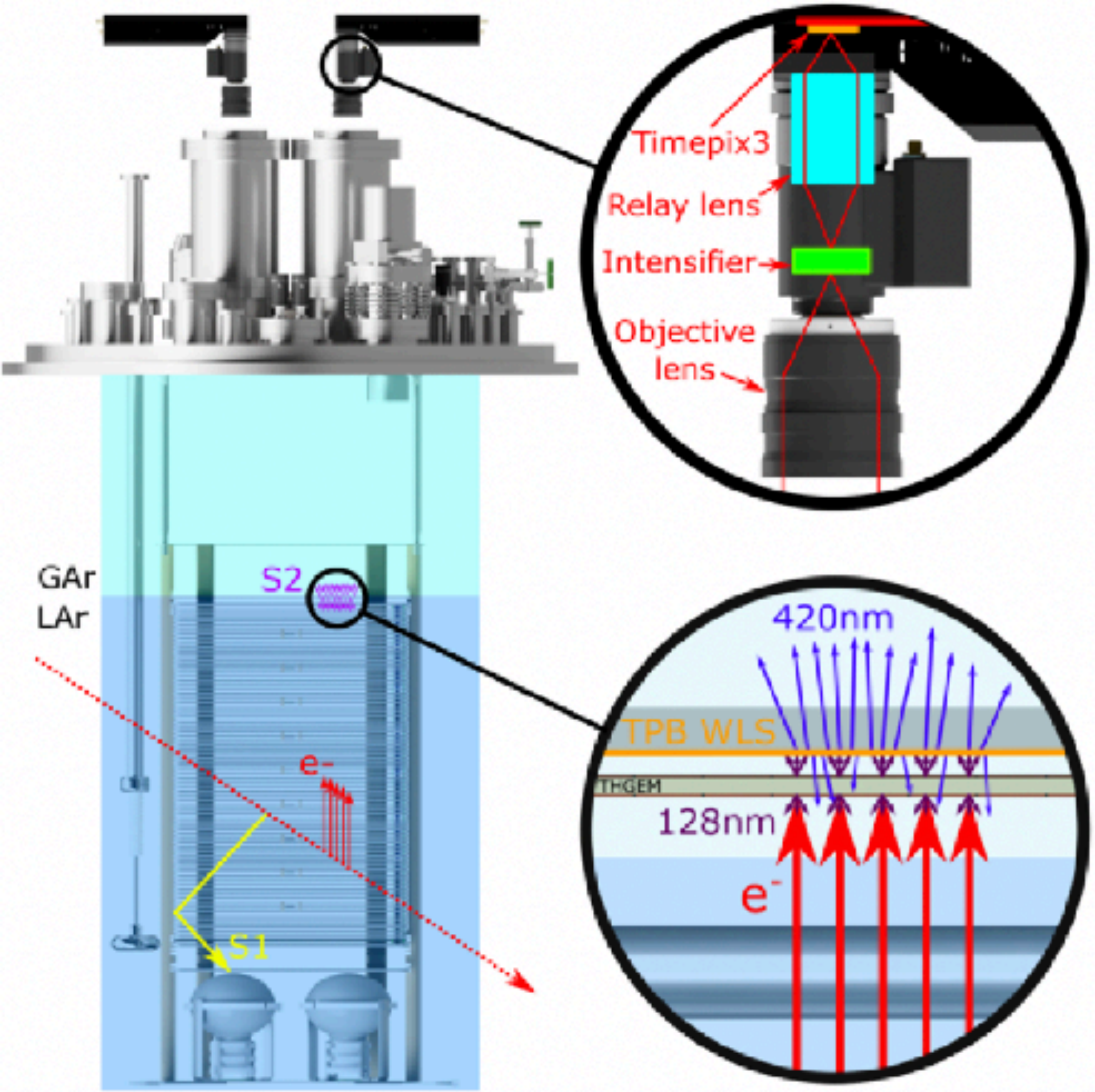
3. arXiv:2103.03232v2 (2021)

European Funds Smart Growth
Republic of Poland
FNP Foundation for Polish Science
European Union European Regional Development Fund
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 962480

# Optical LArTPC: ARIADNE

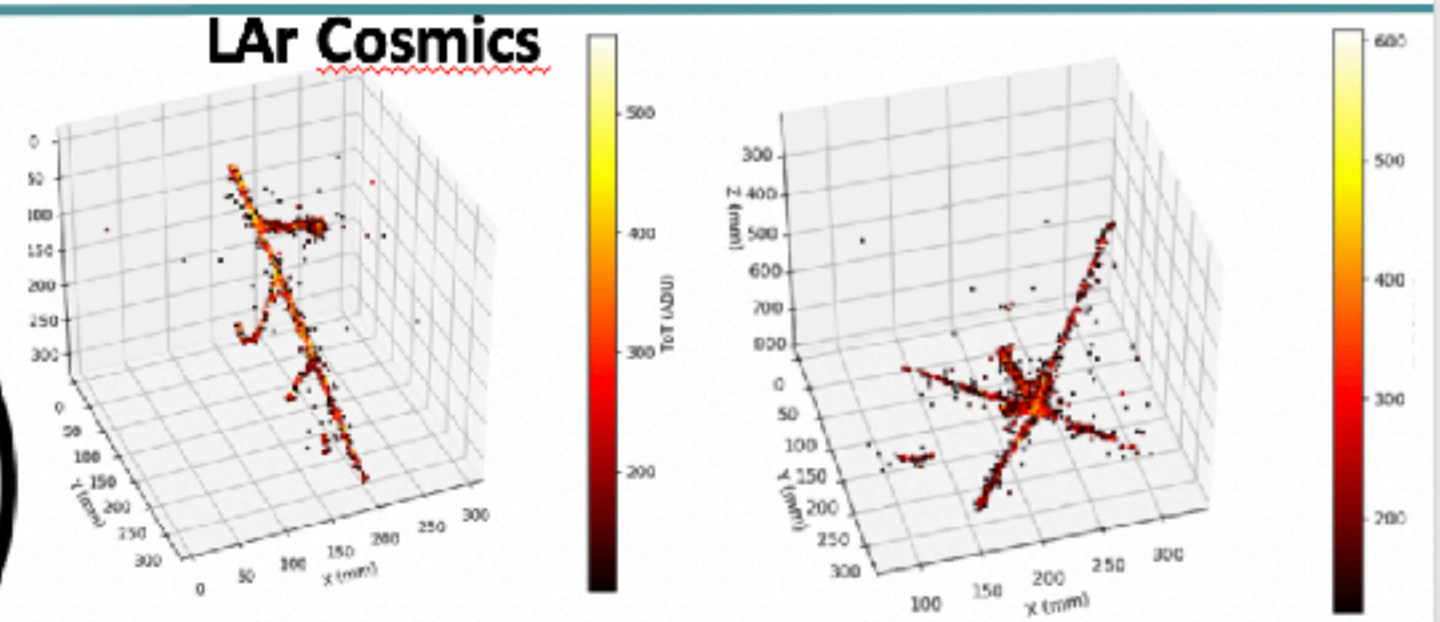
PI: Kostas Mavrokoridis

https://www.mdpi.com/2410-390X/4/4/35




Detection principle of dual phase optical TPC readout with TimePIX3 camera, first demonstrated in the ARIADNE detector.

**LAr Cosmics**

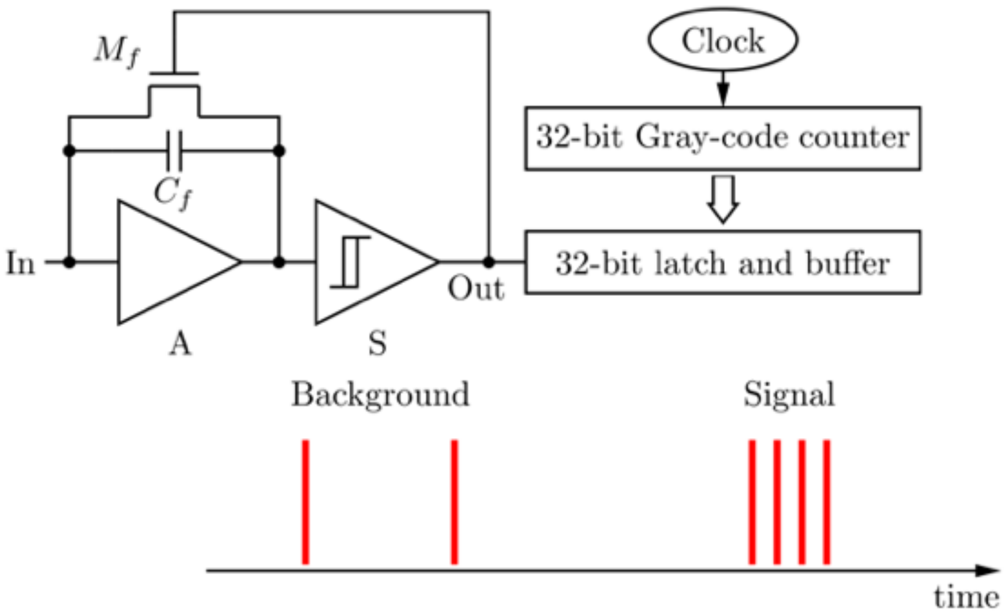


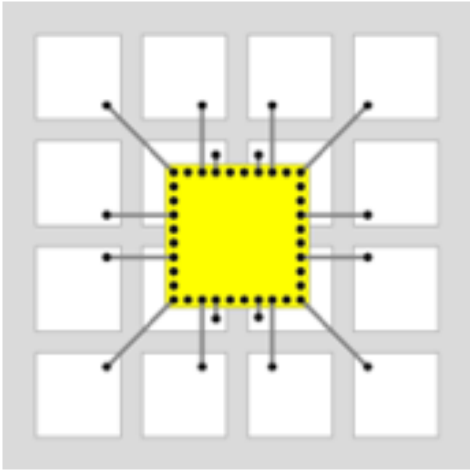
## TPX3Cam benefits:

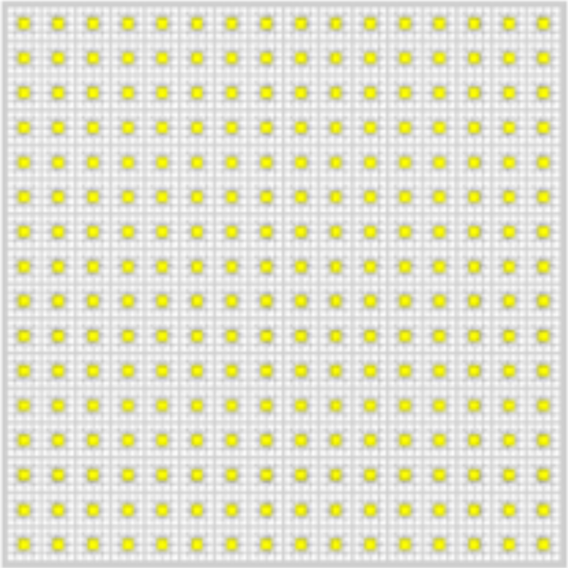
- Raw data is natively 3D
- Huge readout rates are possible (80MHits/s)
- Zero suppressed readout comes for free (~few KBytes per event)
- Physics sensor (Timepix) being used for a Physics application
- Relatively low cost
- Same readout is possible for two phase or gas TPCs

# QPIX: Pixelated LAr Detector

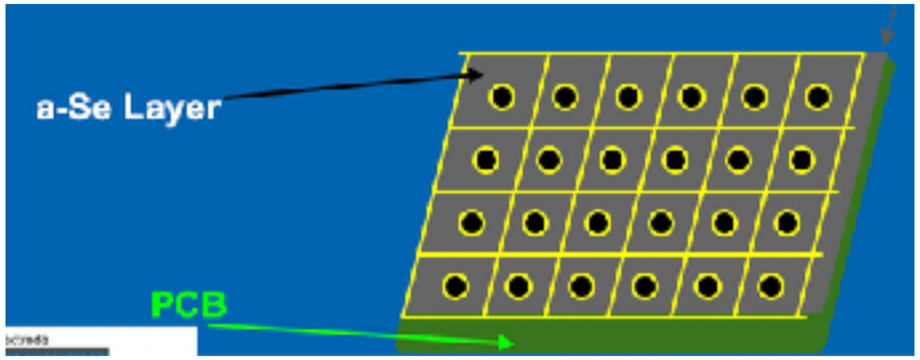
Reset Time Difference





**Light and charge readout combined?**




**Enhancing Neutrino Event Reconstruction with Pixel-Based 3D Readout for Liquid Argon Time Projection Chambers**

- JINST 15 P04009 / arXiv:1912.10133

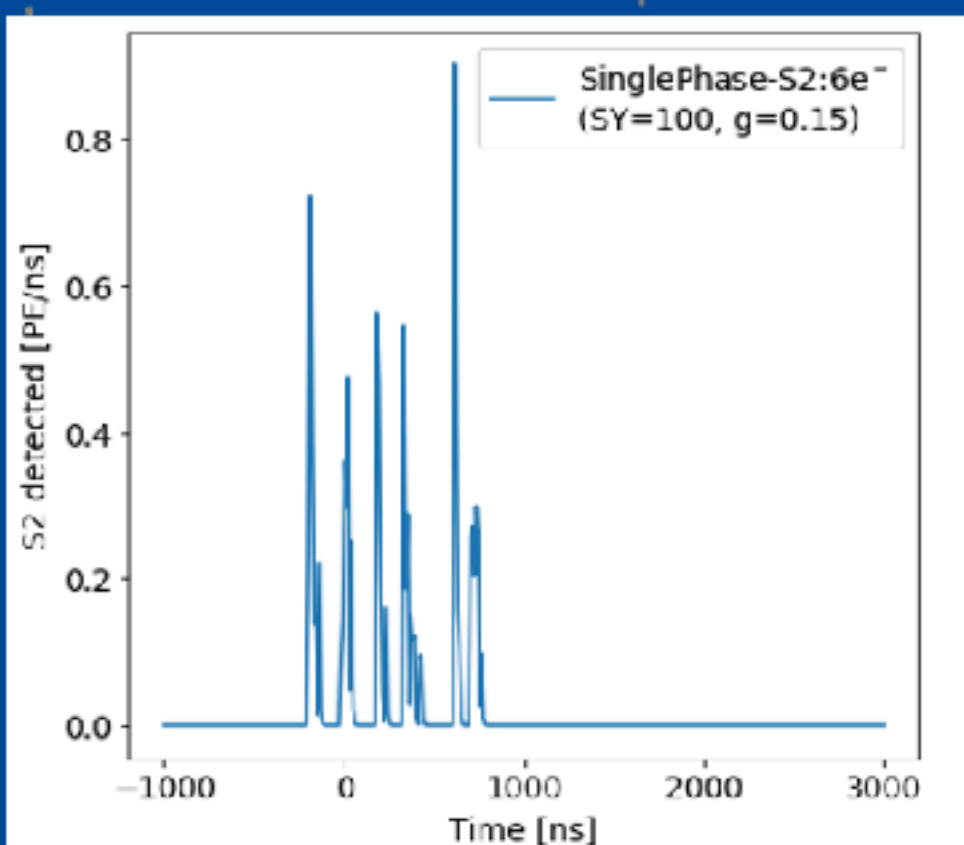
**Q-Pix: Pixel-scale Signal Capture for Kiloton Liquid Argon TPC Detectors: Time-to-Charge Waveform Capture, Local Clocks, Dynamic Networks**

- arXiv:1809.10213

Contact: Jonathan Asaadi (jonathan.asaadi@uta.edu) and Elena Graminelli (elenag@fnal.gov )

# Charge signal measurement by scintillation in liquid xenon

- maintains the successful principle of LXe TPCs
- obsoletes the gas phase + corresponding limitations
- exploits the fast signal generation per electron




➢ Potential to improve future LXe TPCs and expand their science reach

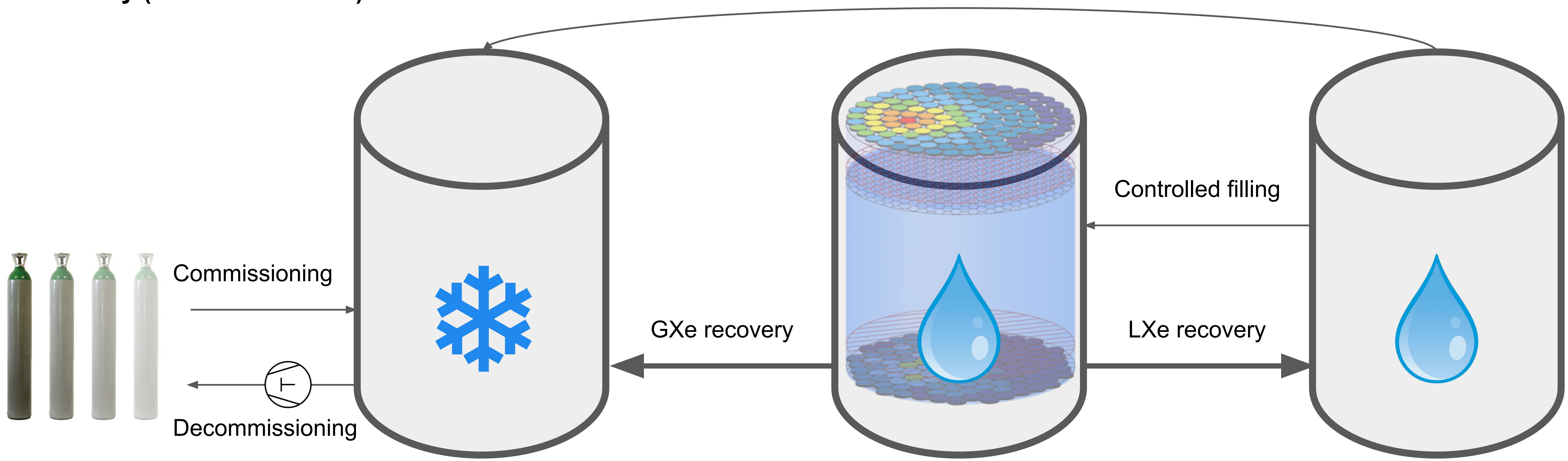
# Noble Liquid “Infrastructures”

## (Purification, HV, calibration…)

# Large-scale storage facilities for noble liquids

Julien Masbou (Subatech), Joaquim Palacio (MPIK), Luca Scotto Lavina (LPNHE)
*for the DARWIN Collaboration*

**Developing a storage facility capable of keeping safely the full xenon inventory of a pre-purified DARWIN inventory (50 tons of xenon).**




**Bottles**
- O(1000) bottles
- Low purity

**Warm/freeze storage**
- Cold on demand
- Fast gas recovery (1 ton/h)
- Cryo-pumping

**Cryostat**
- Stable data taking
- 50 ton LXe
- Overpressure hazard

**Cold storage**
- Always cold
- Stable PT conditions
- Fast liquid recovery (>>1 ton/h)

DARWIN

# Liquid noble gas purification from radioactive impurities at the multi ton-scale

**DARWIN**

- 50 t total (40 t active) LXe TPC
- WIMP search down to the “neutrino-floor”
- Multi-purpose experiment: Solar $\nu_e$, $0\nu\beta\beta$, axions,...
- Main backgrounds: radioactive impurities $^{85}Kr$, $^{222}Rn$
  $^{nat}Kr/Xe \leq 0.03$ ppt required (0.3 ppt in XENON1T)
  $^{222}Rn/Xe \leq 0.1$ µBq/kg required (4.5 µBq/kg in XENON1T)

**Background reduction**

- Removal of $^{85}Kr$ and $^{222}Rn$ by cryogenic distillation
- Screening of materials to avoid $^{222}Rn$

**Monitoring tools**

- $^{85}Kr$: Rare gas mass spectrometer
- $^{222}Rn$: Emanation measurements

# Cryogenic isotopic distillation (the Aria Collaboration)

Technology demonstrated with Aria in Sardinia, Italy,
h=280m d=30cm

Needs:

300t of argon for ARGO (dark matter, solar neutrinos) reducing $^{39}$Ar by 10

100t of xenon enriched in $^{136}$Xe for neutrinoless double beta decays

R&D

Need larger columns

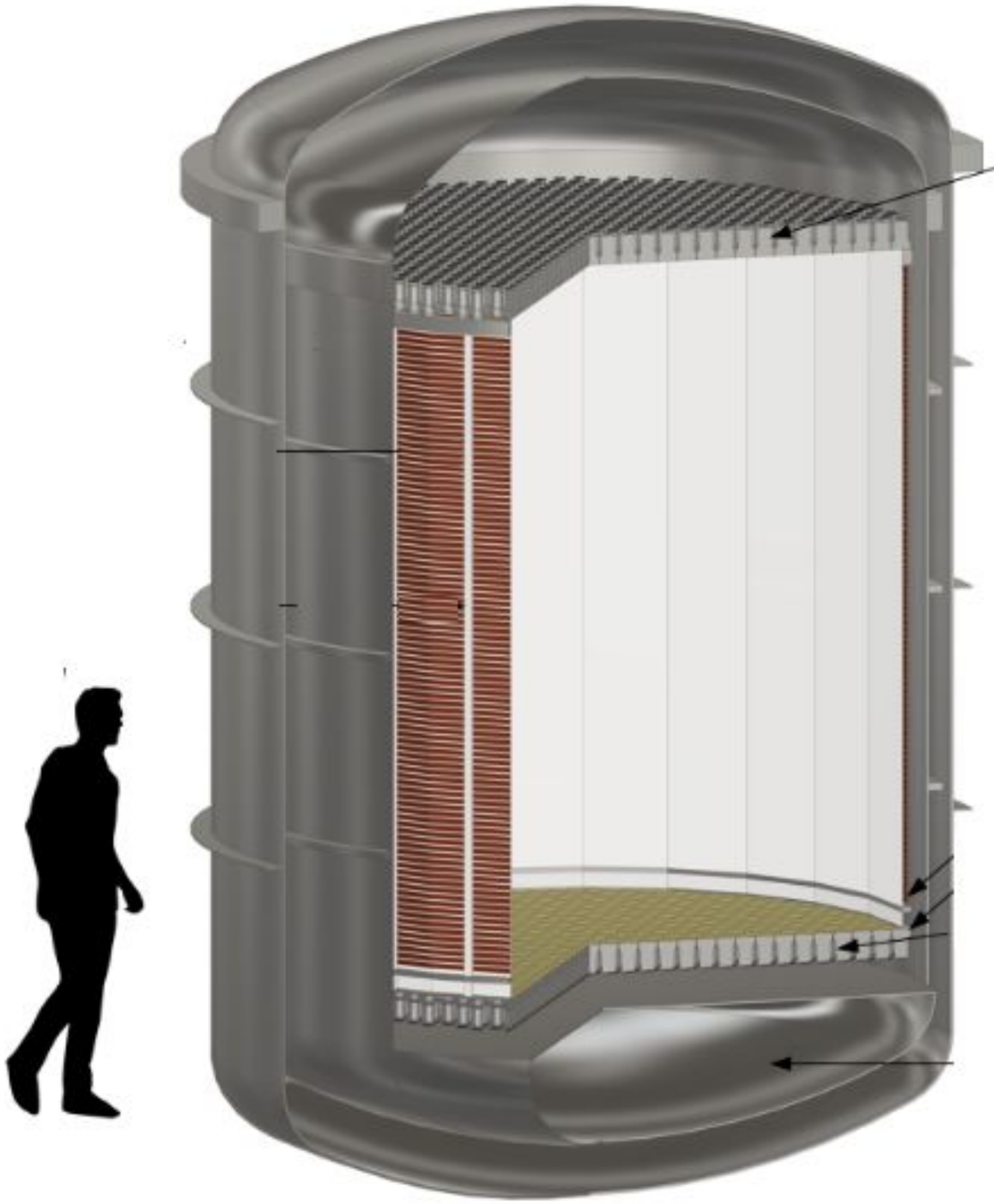
Need new packing with smaller HETP-->research

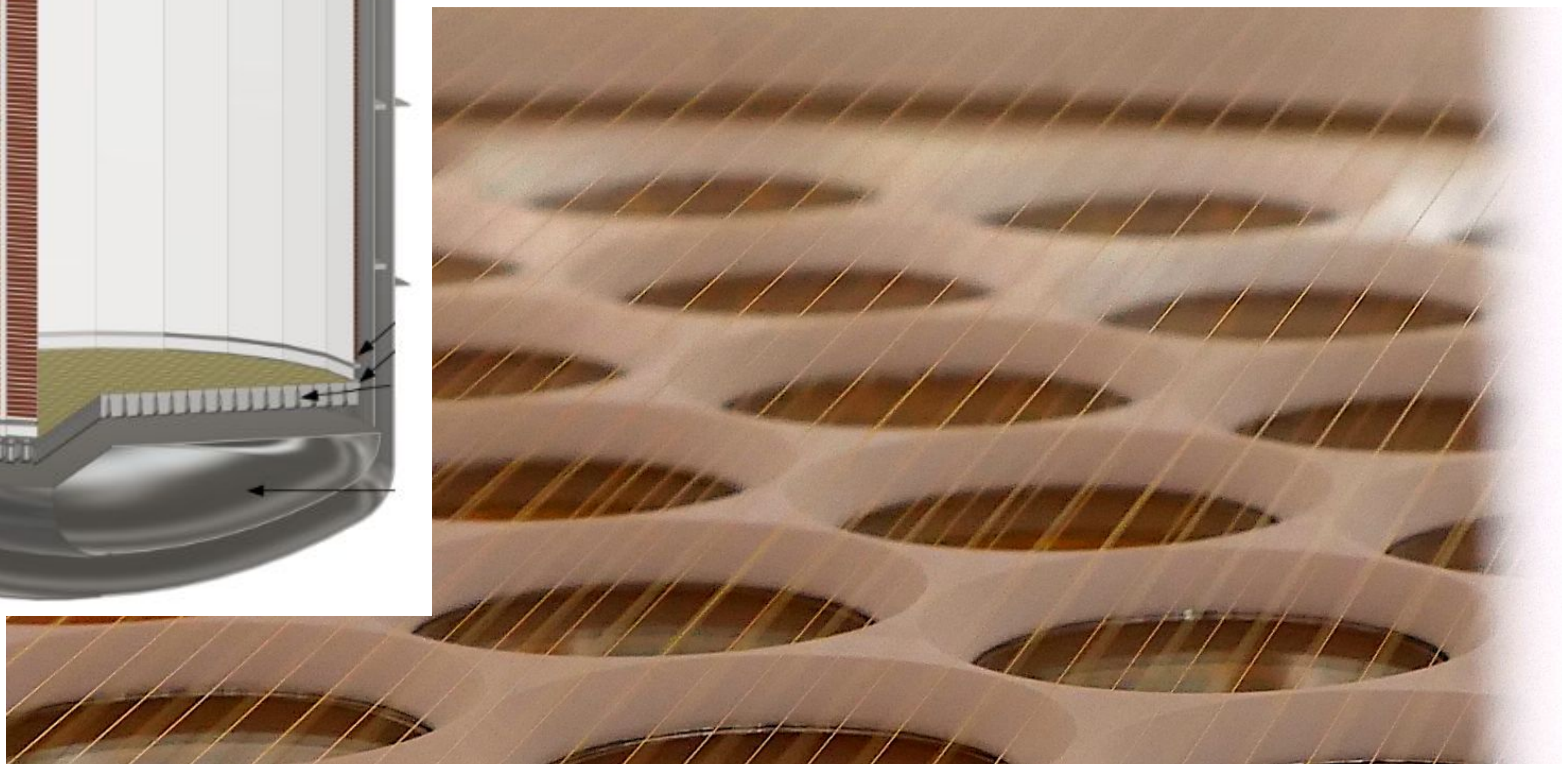
DARWIN

# Low-background, low-noise, cryogenic high-voltage systems for noble liquids

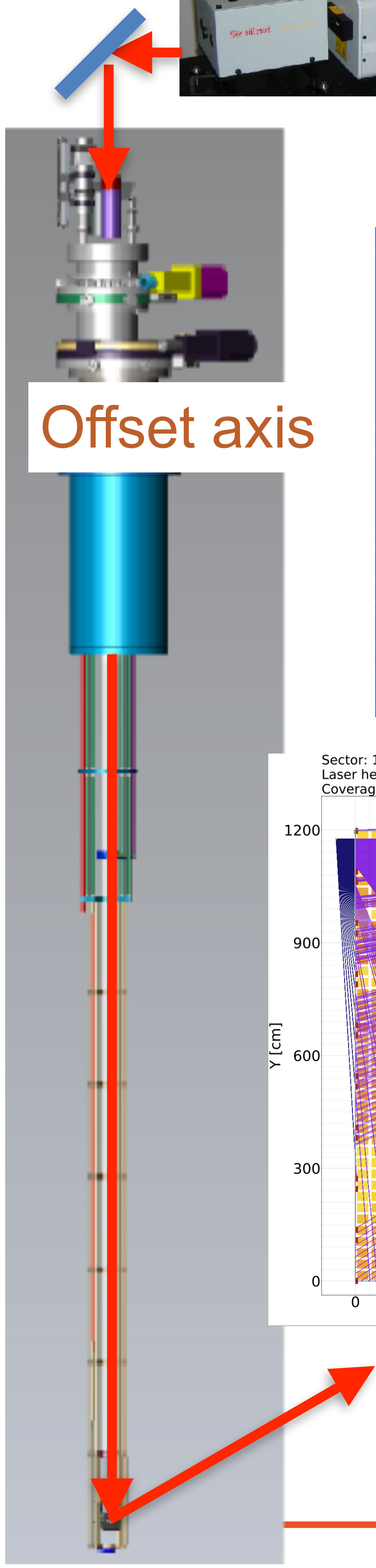
*Marc Schumann (U Freiburg) for the DARWIN collaboration*

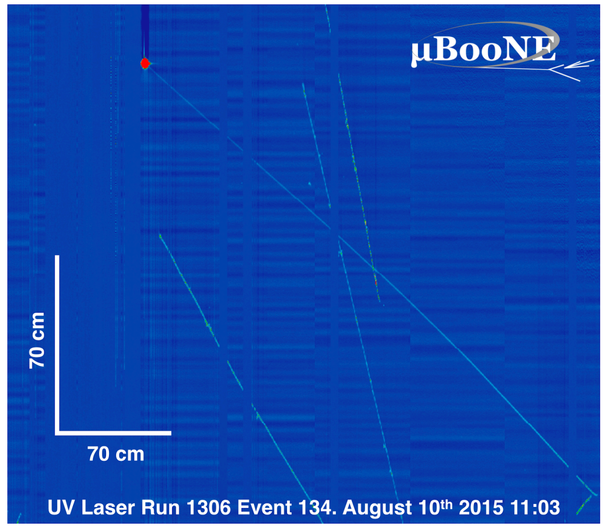
- find solutions to establish electric fields in LXe/LAr-filled dual-phase TPCs
- HV feedthroughs (~100 kV)
- electrodes (~3m diameter)
- low-background materials only
- no generation of light, single electrons

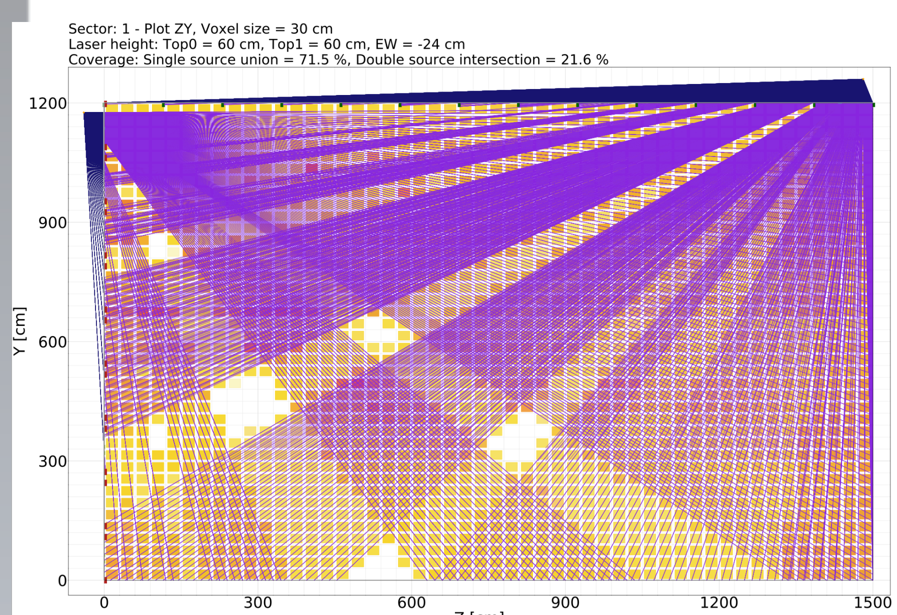




# Laser-based calibration of large underground LAr TPCs



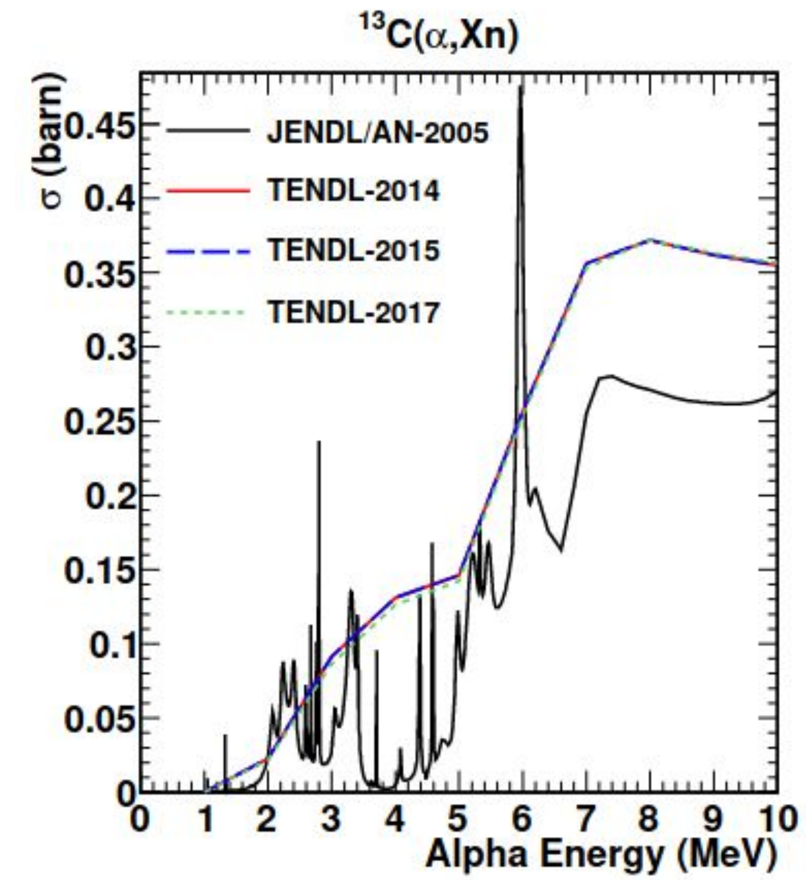

DUNE 1/16th module coverage simulations

- Intense UV laser beams cause MIP-like ionization tracks in LAr
- Two-“periscope” system used in Micro-BooNE to measure E field distortions
  - Challenges for DUNE:
    - wider coverage
    - precision at larger distances
    - charge-based measurements
  - New ideas for DUNE:
    - extra degrees of freedom in periscope/mirror motion
    - independent direction check
  - Tests at ProtoDUNE 2 and beyond

## Improving Neutron Background Estimates in Low Background Experiments

V. Pesudo (CIEMAT) for the GADM Collaboration

- **Radiogenic neutrons** are amongst the main sources of background for many low E rare event searches.
- This bkg is calculated using codes which have been validated in certain (α,Xn) reactions. **Far from being comprehensive**.
- **Discrepancies** between commonly used codes up to a factor 2.
- **Experimental data are scarce**.
- Specific **reaction** mechanisms mostly **unknown**: (α,n), (α,2n), (α,γn) are experimentally challenging to measure.




Can we have this bkg **estimated within the uncertainty** levels **needed for the next generation** of experiments?

Ciemat Centro de Investigaciones Energéticas, Medioambientales y Tecnológicas

# Other uses of Liquid Nobles

S. Degenkolb, P. Fierlinger, R. Georgii, R. Gernhäuser, W. C. Griffith, M. van der Grinten, and O. Zimmer

Ultracold neutron (UCN) detection with polarization-sensitivity, via applied magnetic fields partially cancelling the neutron-optical potential for one spin state. Various readout mechanisms to be explored.