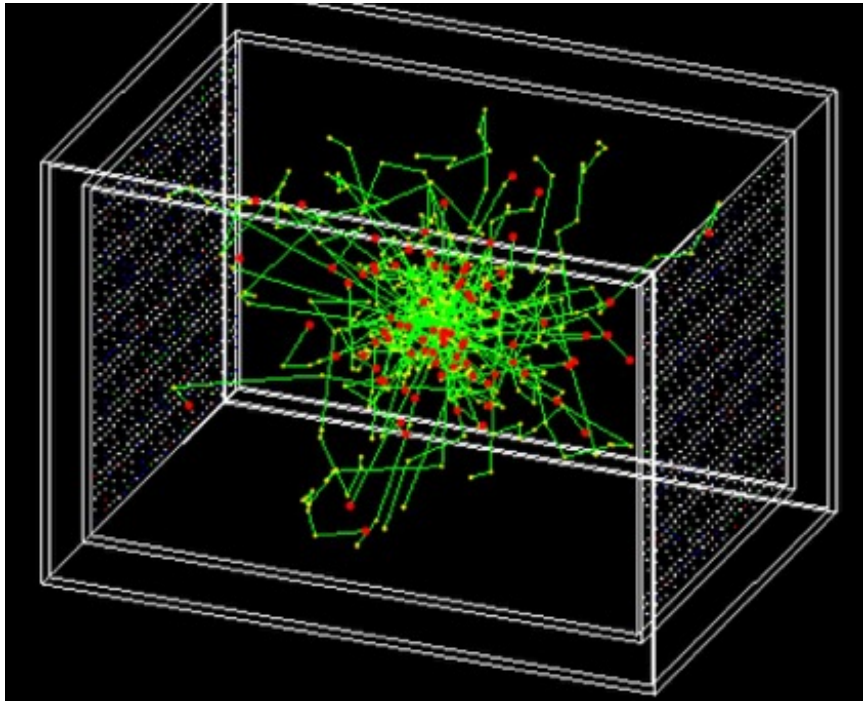
LIQUID

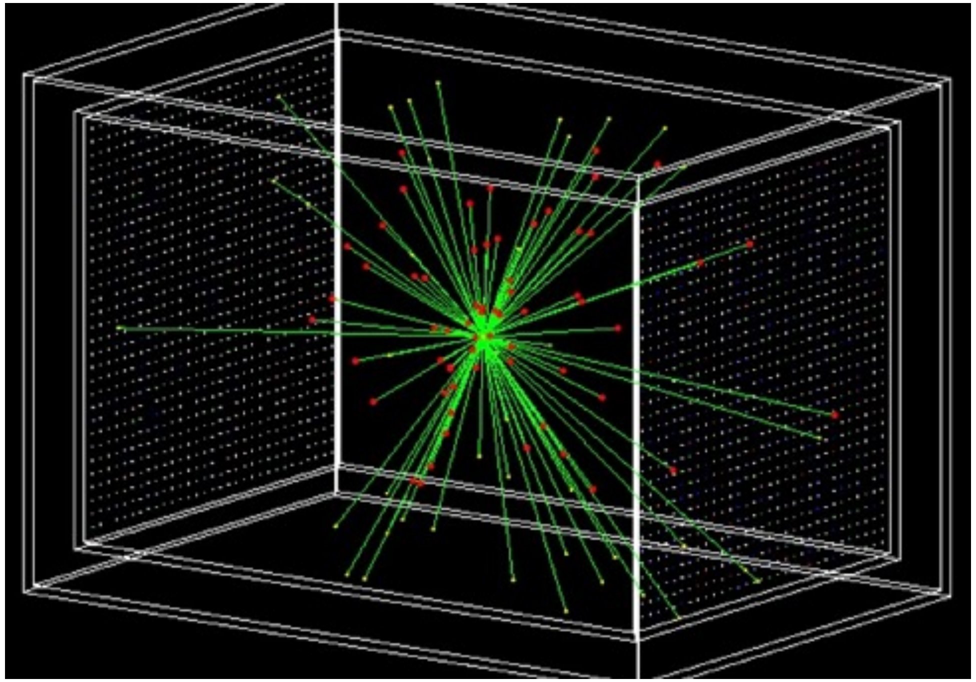
C. Palomares on behalf of U. Zaragoza and CIEMAT

LiquidO is an R&D Project on Opaque Scintillator Detectors for Neutrino research and Rare events experiments

Opaque Scintillator Short Scattering length
Mie & Rayleigh scattering



Transparent Scintillator



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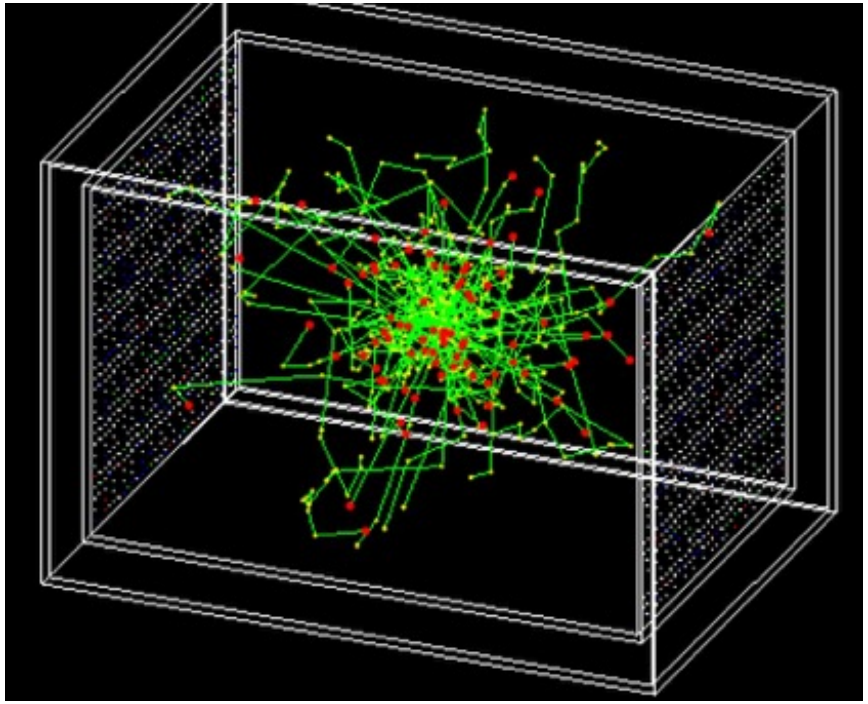
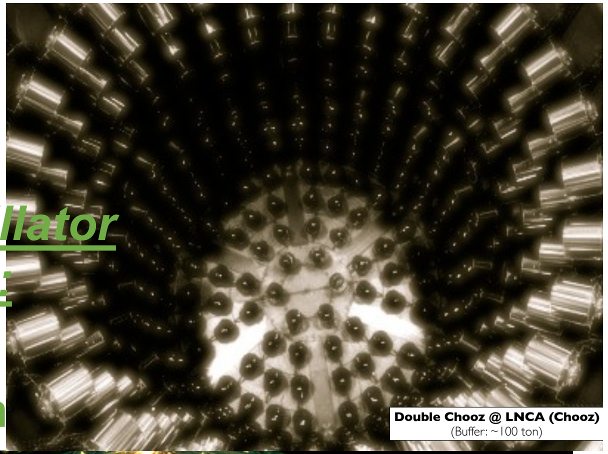
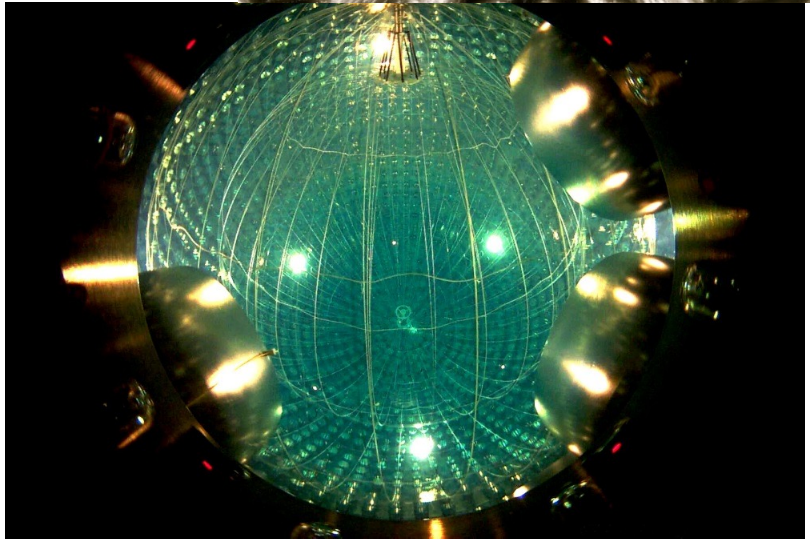


Transparent Scintillator

Traditional Liquid Scintillator in neutrino experiments:

Absorption length ~20m
Scattering length ~35m



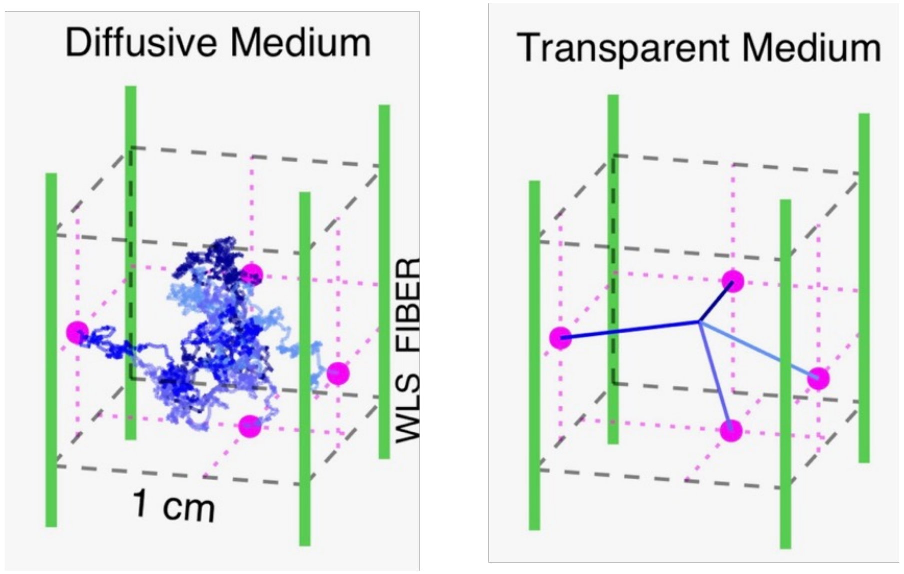


LiquidO approach: Auto-segmented scintillator detector

Liquid ⟶ *O* is for Opaque

<u>**Liquid scintillator detection technique using an opaque medium**</u>

Main purpose: stochastically confine light near its creation point to preserve the topological information of particle interactions



The right <u>scintillator for LiquidO</u>:

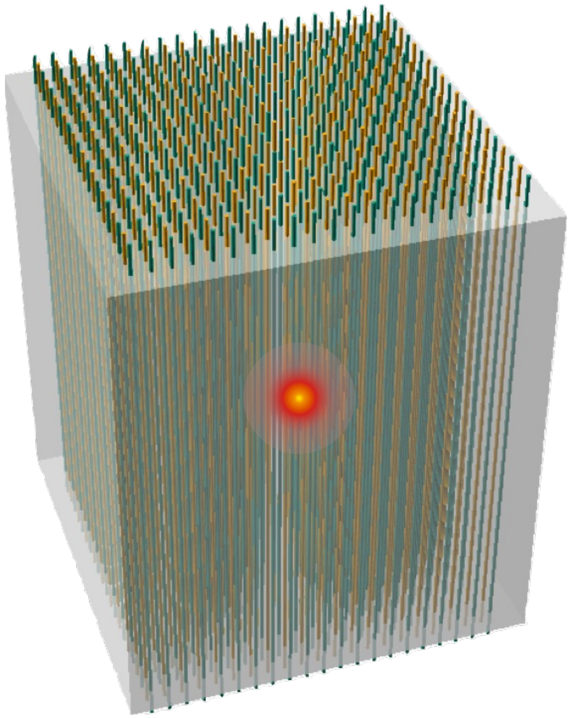
- short scattering length
- moderate absorption length

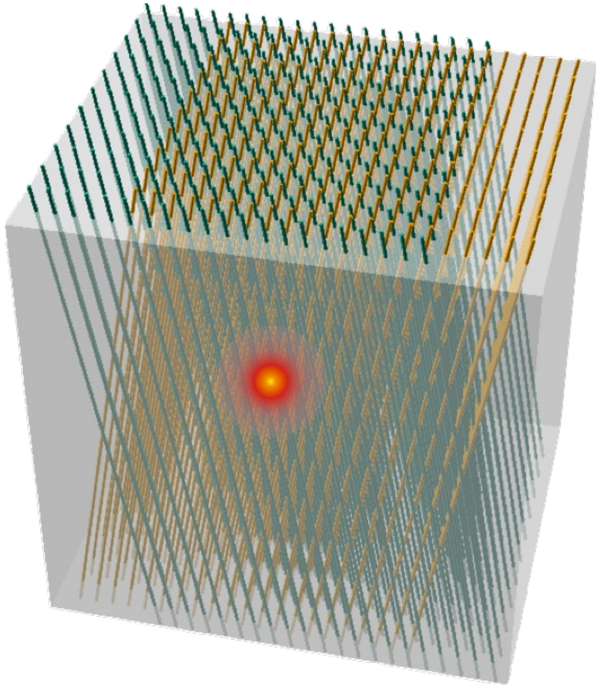
LiquidO approach: High resolution imaging

Light collection with a dense WLS fibre array running in at least one direction

Main purpose:
collect light near its creation point,
to get precise vertex and track reconstruction (fibre pitch)

LiquidO relies on well-understood, commercially available and relatively inexpensive technology!

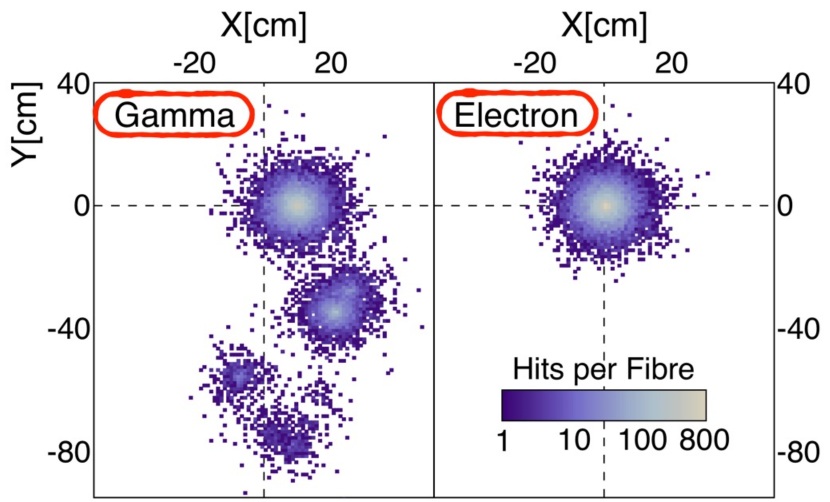




SiPMs are a great choice to readout the fibres (low background, high efficiency, ~0.1ns time resolution)

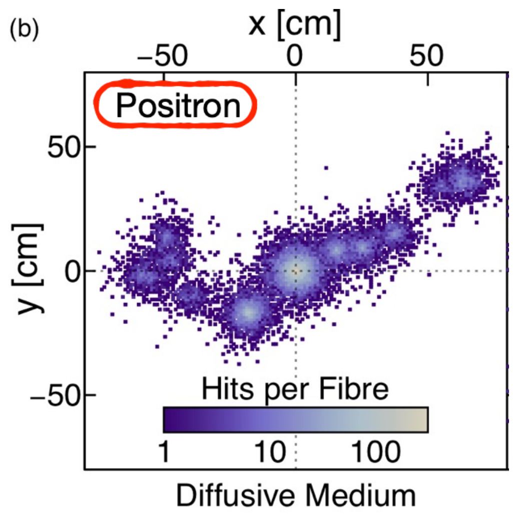
LiquidO approach: Game-changing technology in neutrino physics

The result:
- Powerful background rejection capability
- Possibility of doping at high concentrations



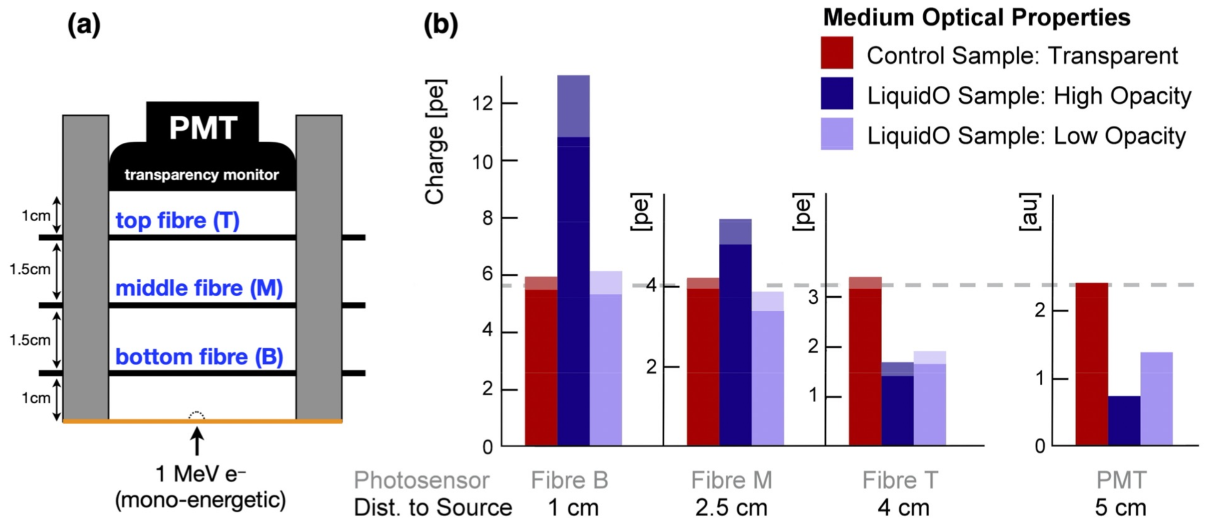
Detector concept with the potential to break ground in various frontiers of neutrino physics

Opportunities in MeV-scale:
- Reactor neutrinos (anti-neutrino identification)
- Solar neutrinos (Indium loading)
- $\beta\beta 0\nu$ (high isotope concentration. No enrichment required)



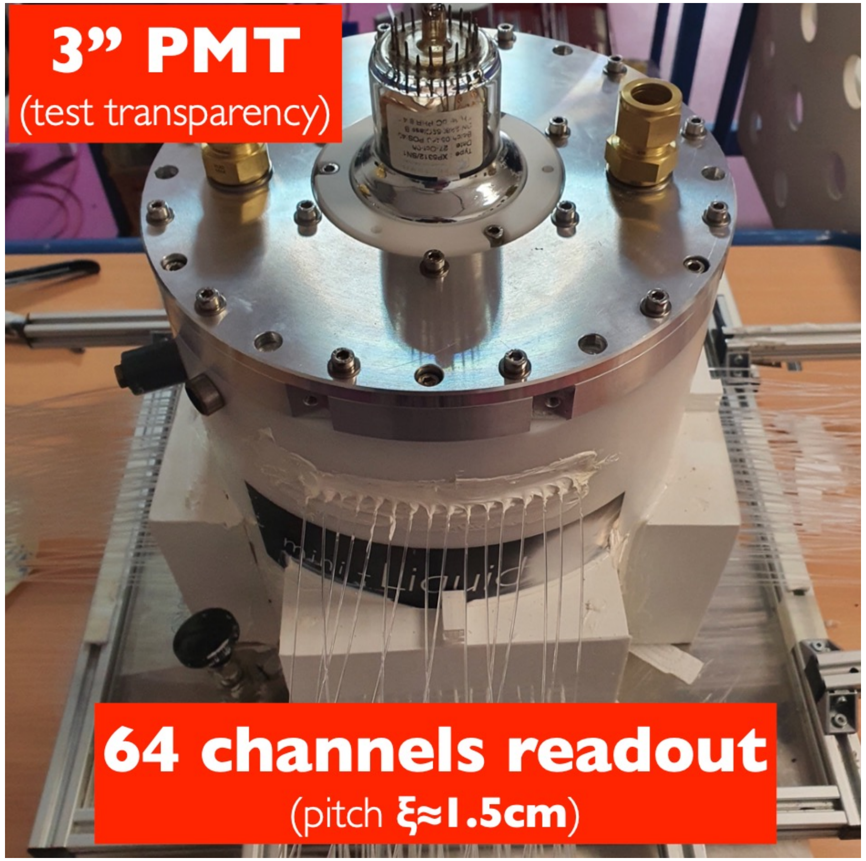
PROTOTYPING

MICRO-LiquidO. Operated at CENBG (Bordeaux) 2019



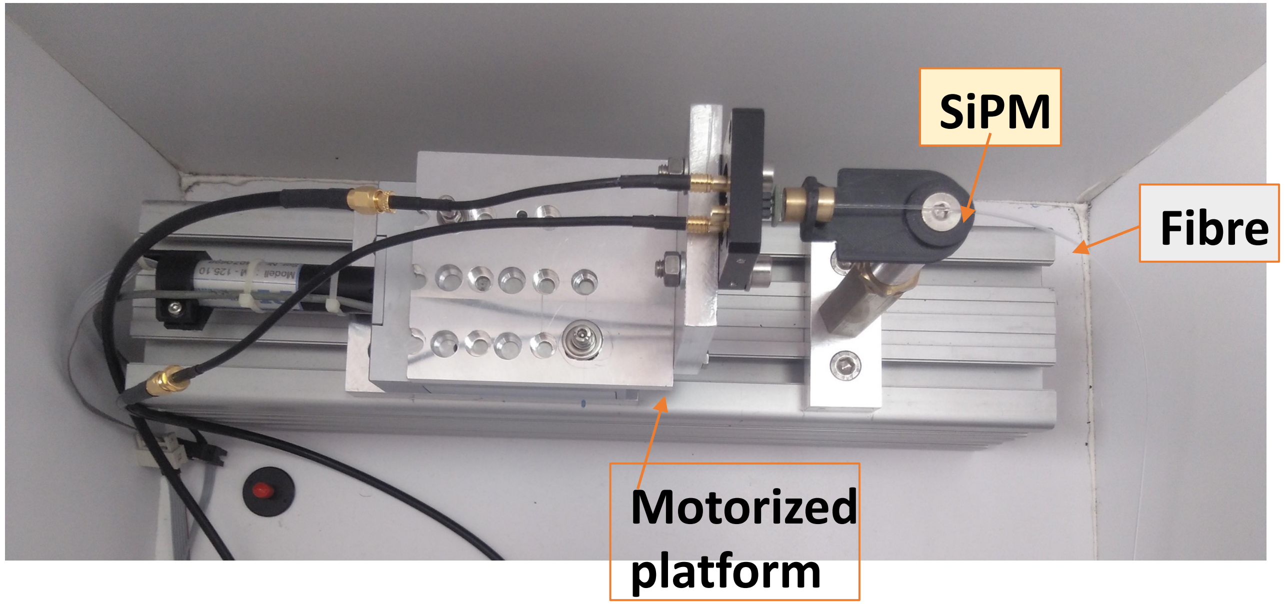
***Nature Commun. Phys.* 4 (2021) 273**
(arXiv:1908:02859)

MINI-LiquidO. Monoenergetic electron beam
Operated at CENBG (Bordeaux) since 2020



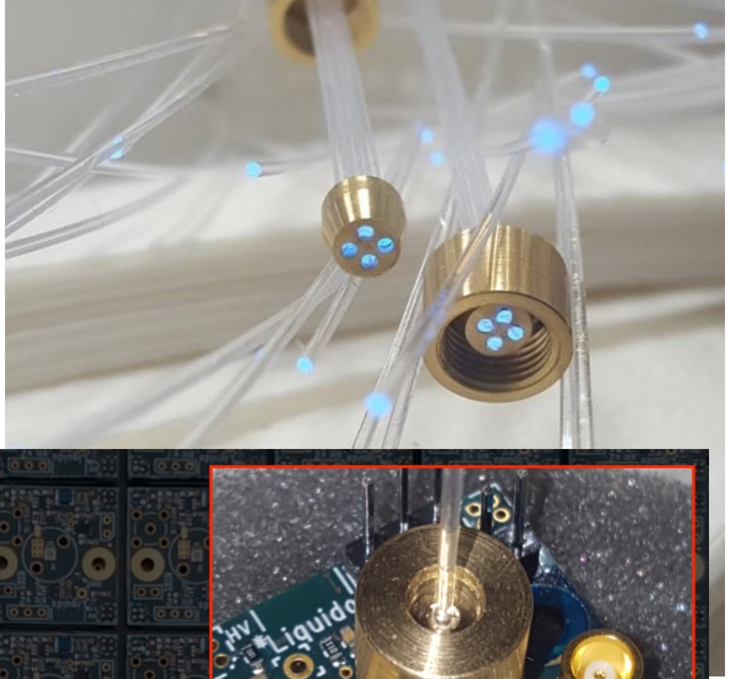
PROTOTYPING

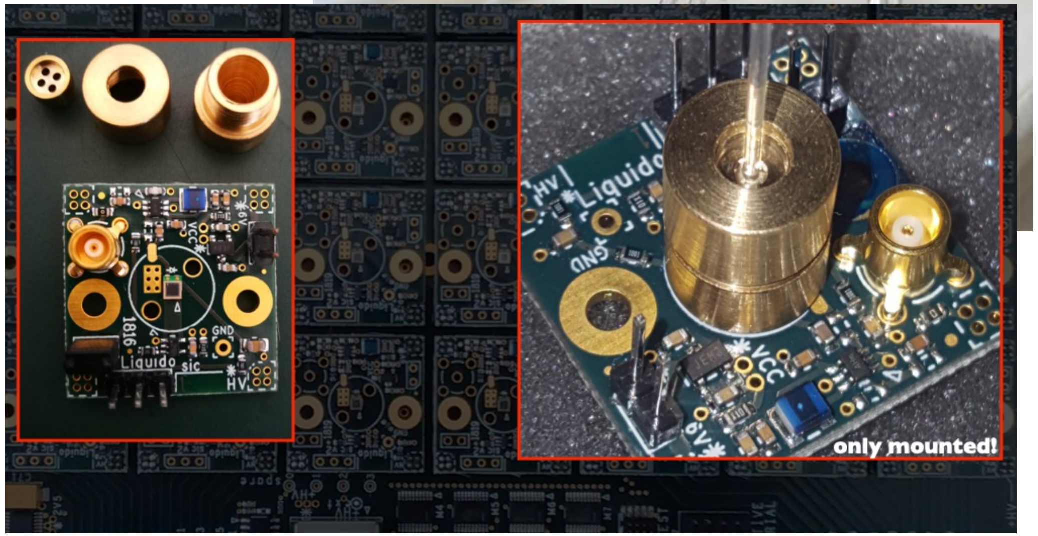
CIEMAT participation in MINI-LiquidO



Light-collector for optimum fibre-SiPM coupling

Designed, manufactured and tested at CIEMAT.

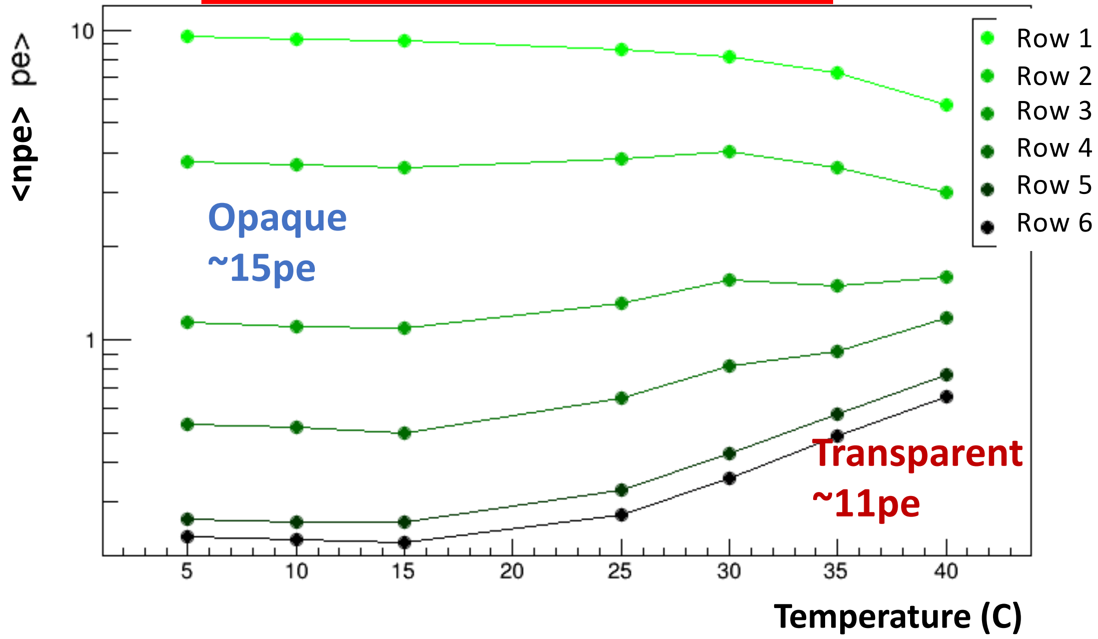




PROTOTYPING

CIEMAT participation in MINI-LiquidO

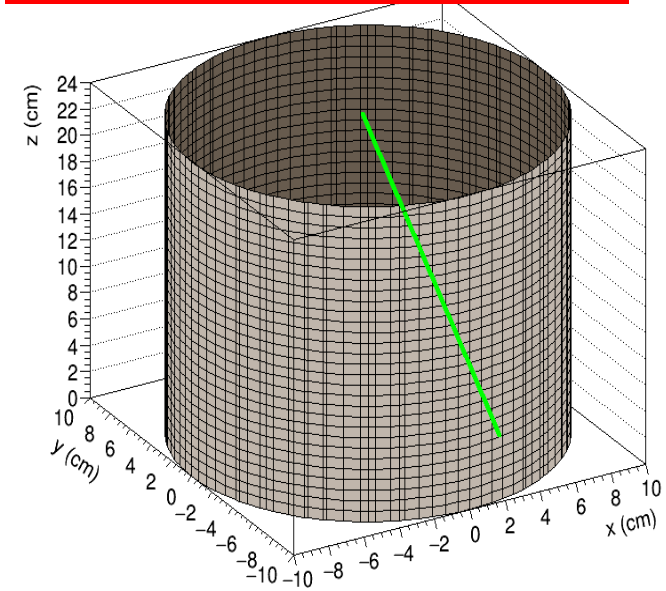
Detected light vs Temperature
1.8 MeV e-



Data Analysis

TFM J. Apilluelo (CIEMAT)

Cosmic muons reconstruction



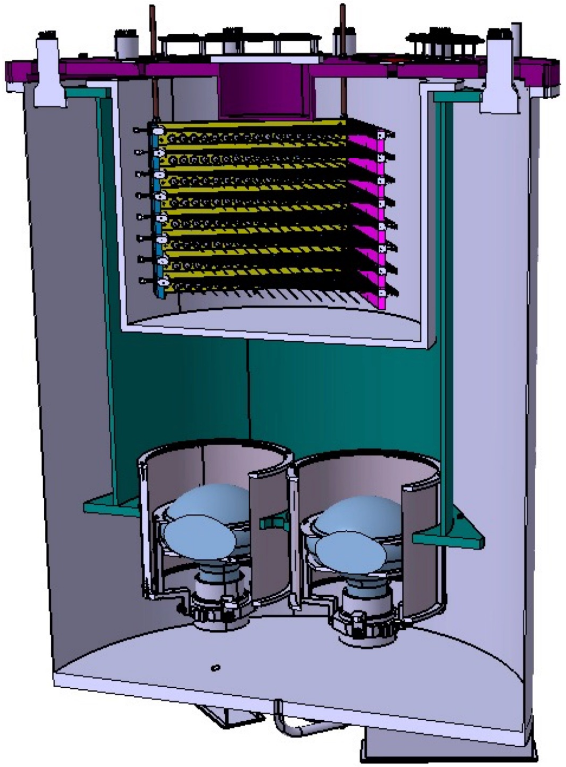
Paper in preparation

Confinement of the light - Most of the light collected by fibres of first row

More efficient light collection for opaque LS

NEXT-PROTOTYPES

MINI-gamma
for study of Compton-scattering of gammas
will be operated at IJCLab from summer 2023



MINI-gamma will also test the technical solutions proposed for AM-Otech:

- Fibre support
- Fibre-SiPM connector
- New Liquid Scintillator

MINI-Zaragoza
Joint R&D effort CIEMAT – U. Zaragoza
for Neutron detection study

Based on MINI-gamma design.
Test-bench accessible to both groups

MINI-Zaragoza will also test:
Scintillator doping in terms of light yield (sensitivity to $\beta\beta0\nu$)

AM- Tech

HORIZON-EIC-2021-PATHFINDEROPEN-01
1 – Dec – 2022 30 – Nov - 2026

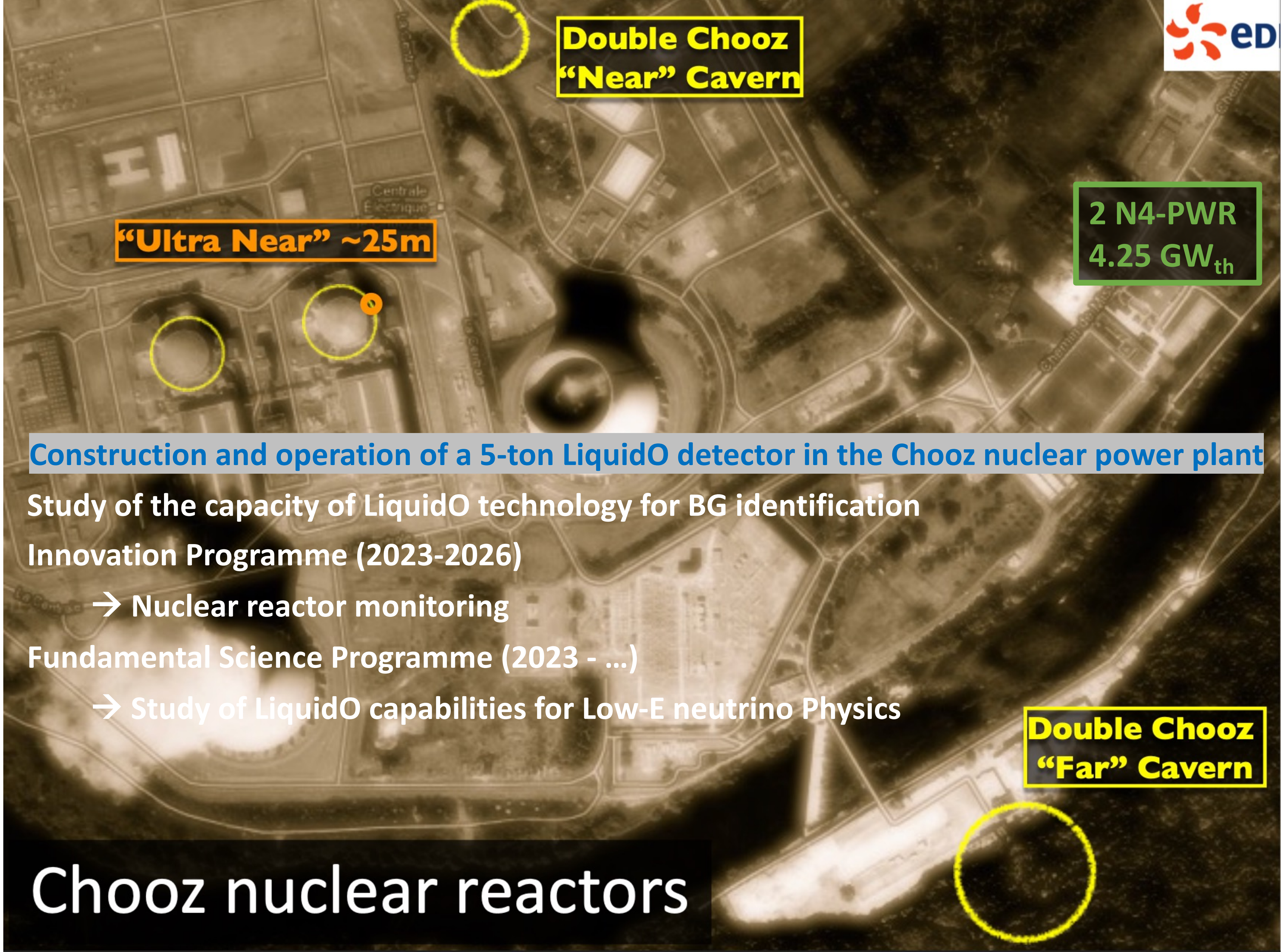
Co-funded by the European Union

Goal: **Development of a new instrumentation to use anti-neutrinos as a direct probe of the functioning of industrial nuclear reactors**

- IJCLAB / CNRS - Université Paris-Saclay (France)
- Subatech / CNRS – Université Nantes (France)
- J-G Universität Mainz (Germany)
- CIEMAT (Spain)
- Sussex University (UK)
- EDF (France)

UKRI Innovate UK

Chooz nuclear reactors



Construction and operation of a 5-ton LiquidO detector in the Chooz nuclear power plant

Study of the capacity of LiquidO technology for BG identification

Innovation Programme (2023-2026)

→ Nuclear reactor monitoring

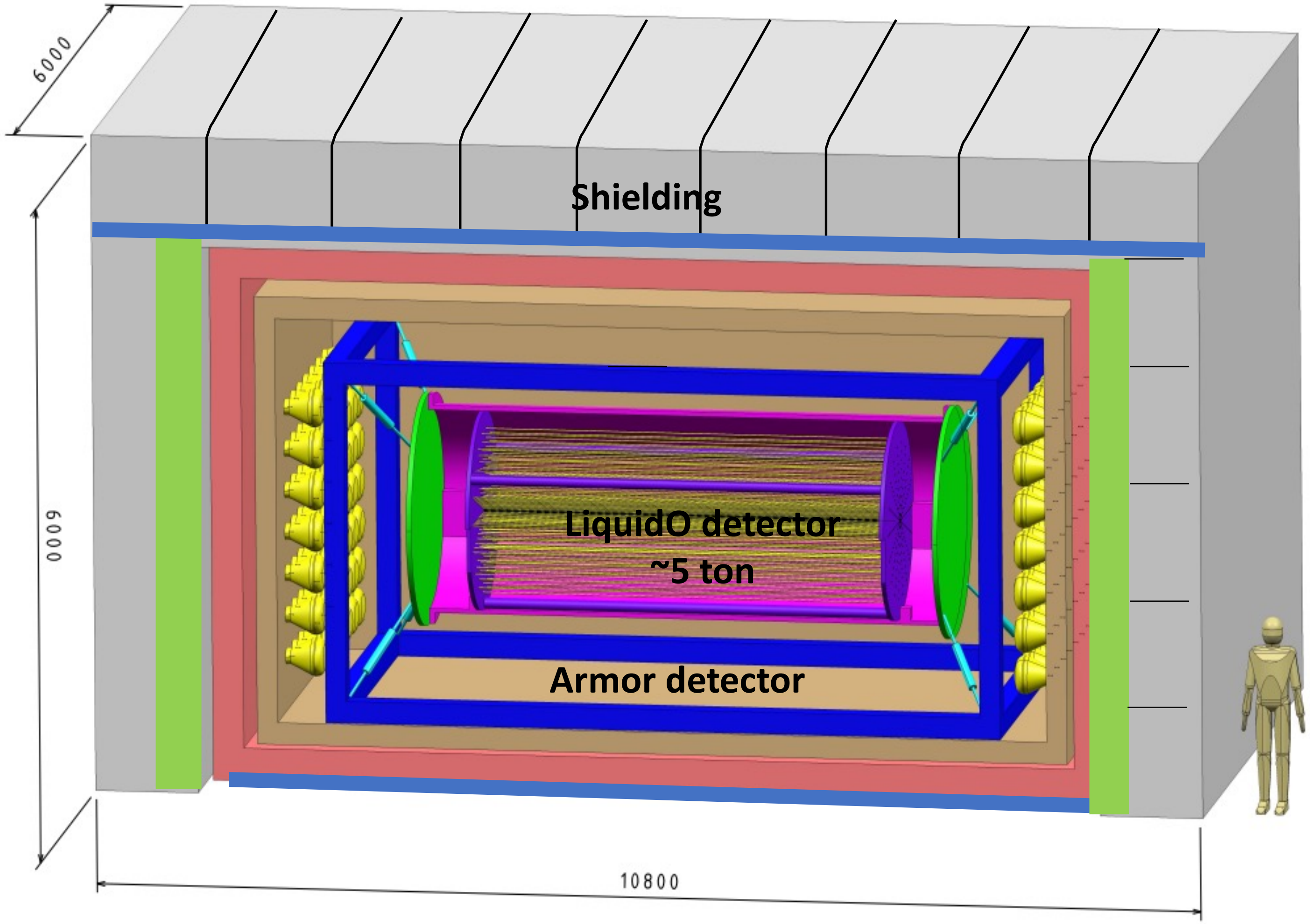
Fundamental Science Programme (2023 - …)

→ Study of LiquidO capabilities for Low-E neutrino Physics


European Innovation Council
UK Research and Innovation
CLOUD
Innovation Programme + Fundamental Science Programme
•EDF (France) — first time in neutrinos!
•CIEMAT (Spain)
•IJCLab/Université Paris-Saclay (France)
•J-G Universität Mainz (Germany)
•Subatech/Nantes Université (France)
•Sussex University (UK)
—
•Charles University (Czech Republic)
•INFN-Padova (Italy)
•UC-Irvine (US)
•Universidade Estadual de Londrina (Brasil)
•PUC-Rio de Janeiro (Brasil)
•Queen's University (Canada)
•University of Zaragoza (Spain)
•Tohoku University / RCNS (Japan)
CLOUD collaboration (EDF⊕13 institutions over 10 countries)

AM-OTech - CLOUD

Requirements:
- Operate on surface
- Minimizing shielding
- As compact as possible



CIEMAT:
- Responsible of Shielding design and construction
- Coordination of detector commissioning data analysis
- Participation in detector operation and exploitation of data.

U. ZARAGOZA:
- Software development
- Participation in detector operation and exploitation of data.

Work-force and funding resources

CIEMAT
Researches: 2 FTE + 1 PhD student
Engineers: 1/4 FTE
Expertise in Neutrino Physics experiments
- **Reactor** and accelerator **neutrinos**
- **Liquid scintillator** and Liquid Argon

Funded by AM-OTech project (2023-2026)

U. Zaragoza
Researches: 0.5 FTE + 0.5 PhD student
Engineers: 0.1 FTE
Expertise in Rare events physics
- $\beta\beta0\nu$ and dark-matter
- Scintillators and gaseous detectors

Funds from "PLANES COMPLEMENTARIOS PLAN DE RECUPERACIÒN, TRANSFORMACION Y RESILIENCIA-MRR / CCAA de Aragón"

The two groups have **Equipped Laboratories**
- With test-benches for:
  - SiPM testing
  - Fibre Characterization
  - Materials radiopurity screening
- Prototypes construction and operation

Detector R&D Themes of interest

Liquid Detectors

- DRDT 2.3 Improve the material properties of target and detector components in liquid detectors

→ Development of Liquid Scintillator in terms of light-yield, opacity (scattering length) and doping capability.

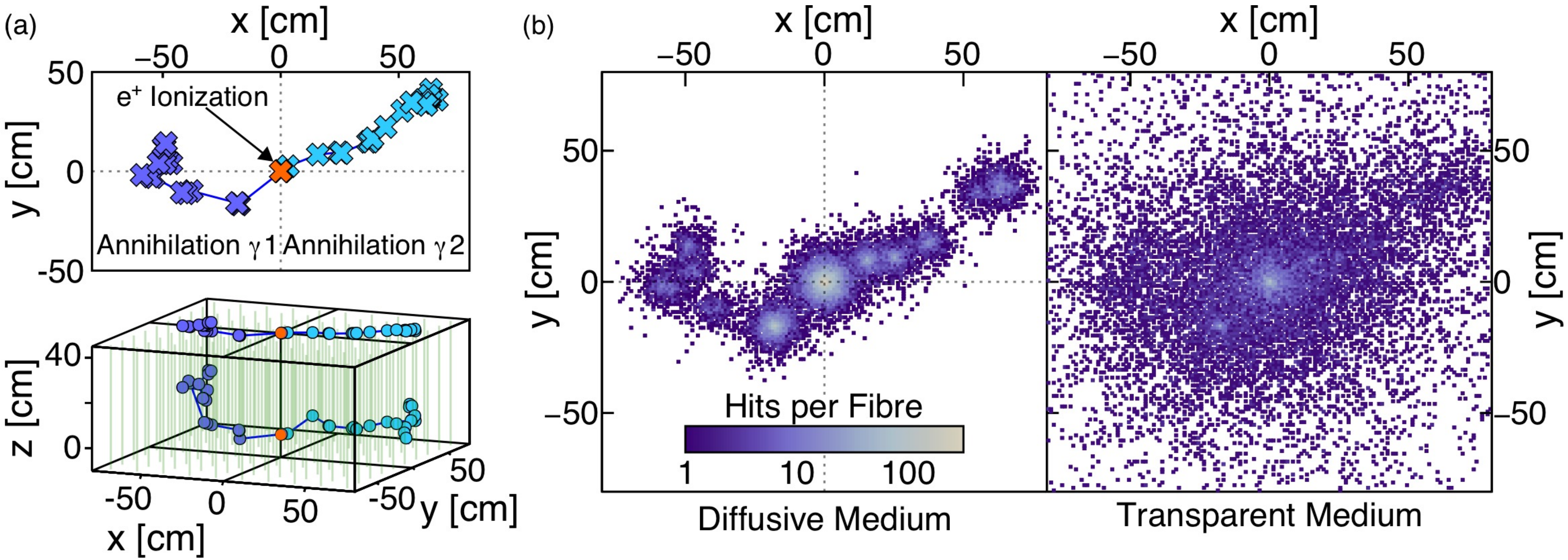
- DRDT 2.4 Realise liquid detector technologies scalable for integration in large systems

→ Prototyping programme to prove LiquidO technology capabilities for next generation experiments in neutrino and rare event physics

BACKUP

Developed for its application in low-energy neutrino physics

Powerful Identification of individual particles event-by-event

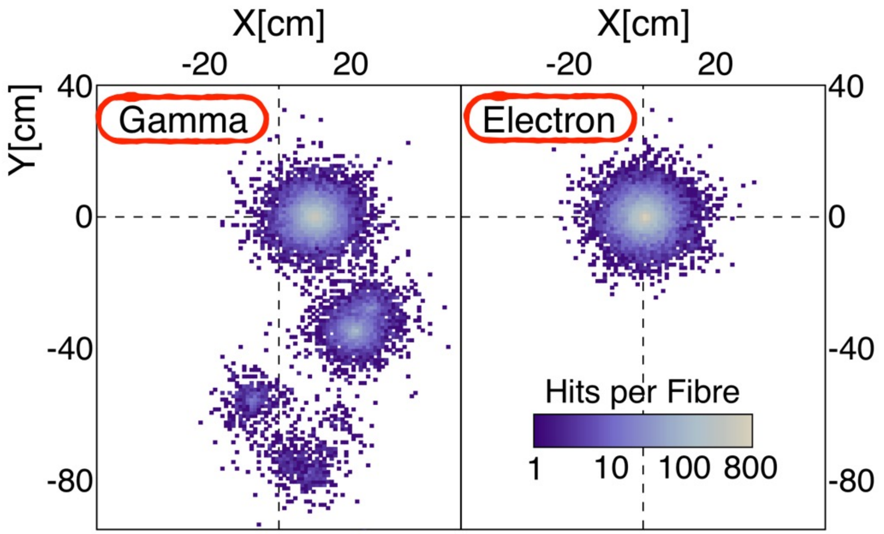


Geant4 simulation of **1 MeV positron** in a LiquidO detector with fibres running along z direction with a 1 cm pitch. The scintillator has a 5 mm scattering length. Each pixel corresponds to a fibre. The colour scale shows all true hits per fibre

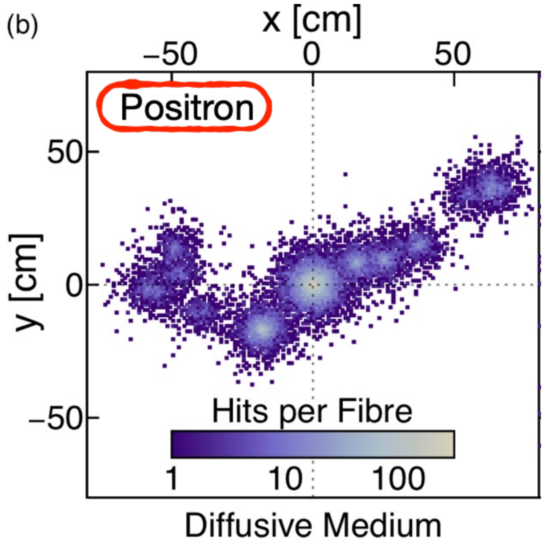
Developed for applications in low-energy neutrino physics

1) Imaging and Particle Identification

Using reasonable assumptions we can discriminate electrons from gammas with efficiency > 85% and contamination ~10^{-3}
Impossible in conventional Liquid Scintillator detectors



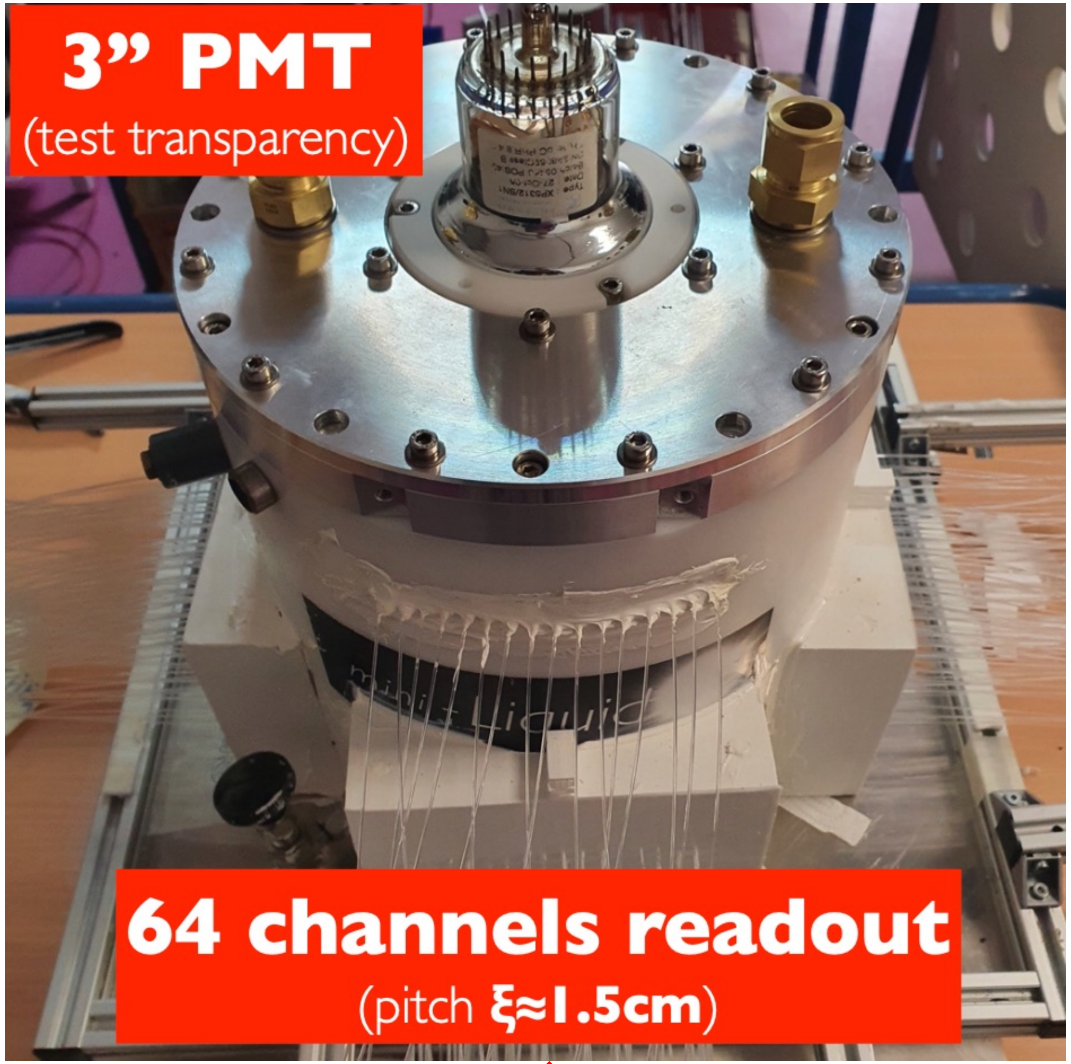
(b)



2) Elemental Doping Loading at high concentration thanks to the relaxation in transparency requirements

Opening new opportunities in neutrino research

Status: Operating a 10 L prototype

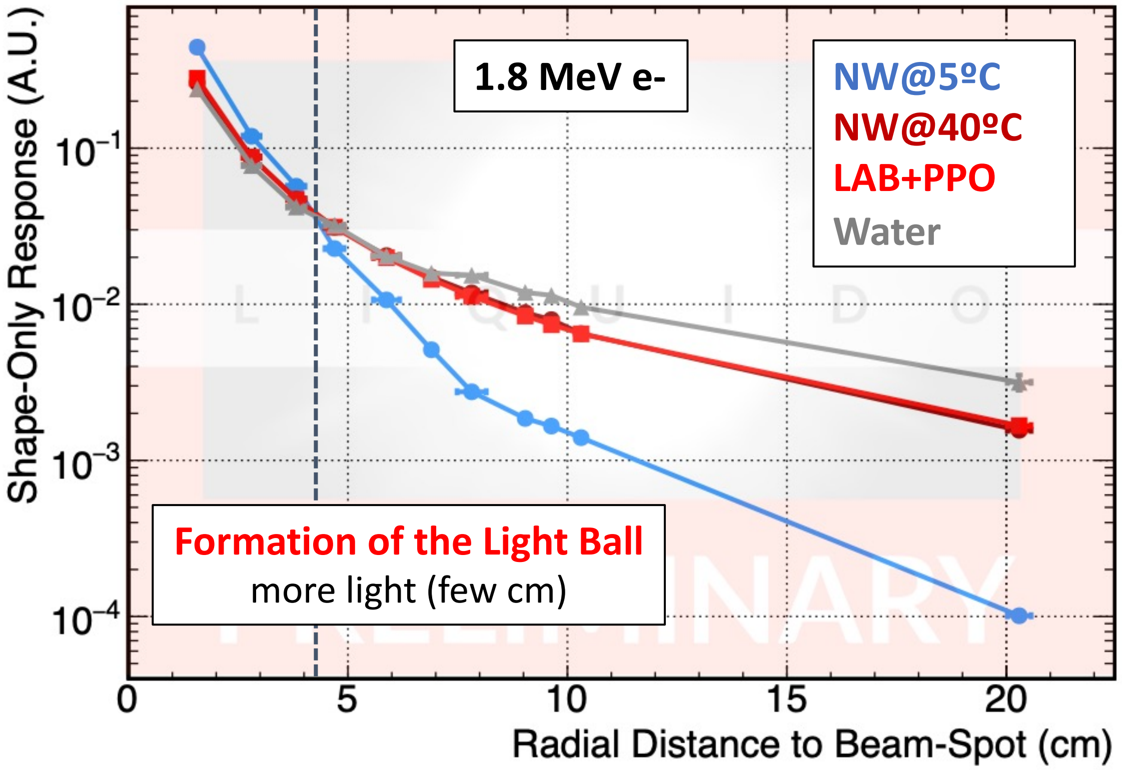


e^- beam

WATER

LAB+PPO

NoWash (LAB+PPO+PARAFIN): Opacity controlled through Temp. (arXiv:1908.03334)



CIEMAT TEST-BENCHES for fibre characterization