Novel opaque scintillator technology for antineutrino detection

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Thiago Bezerra, for the LiquidO Consortium

Applied Antineutrino Physics Workshop @ York

19th September 2023

Quick review on scintillators

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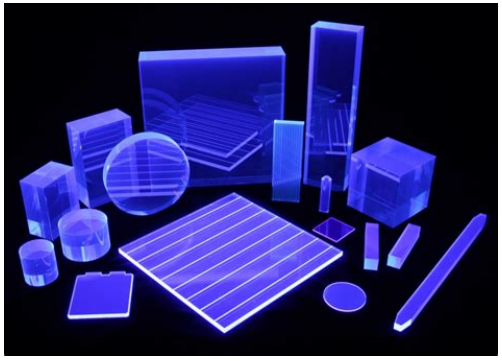
→ **Radiation detection with scintillators, 80 years "business"**

→ **Converts deposited energy into light**

→ **Light converted to electric signals**

→ Detection and calorimetry

→ ***Transparent media for light propagation***



The *novel* opaque scintillation technique

Two types of opacity

Short *absorption* length
Short scattering length

Long *absorption* length
Short scattering length

Light paths

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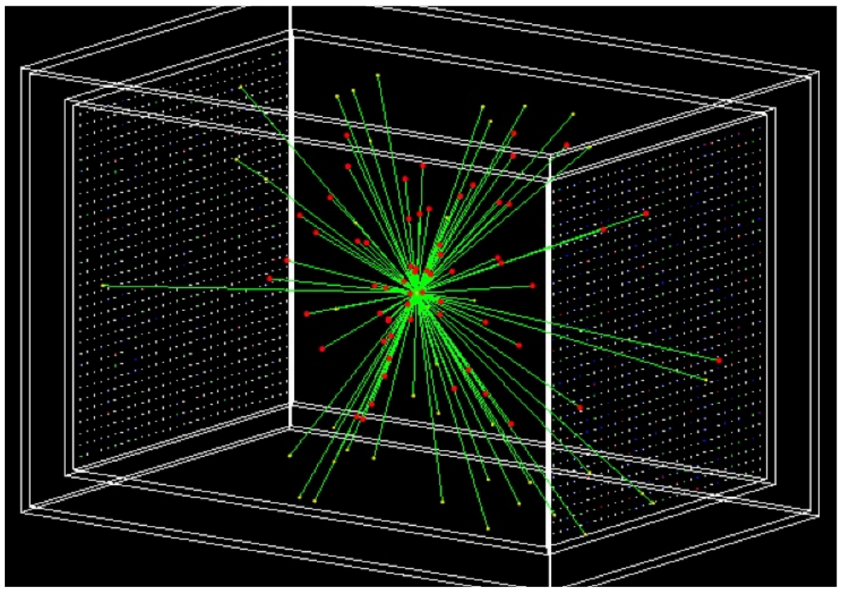
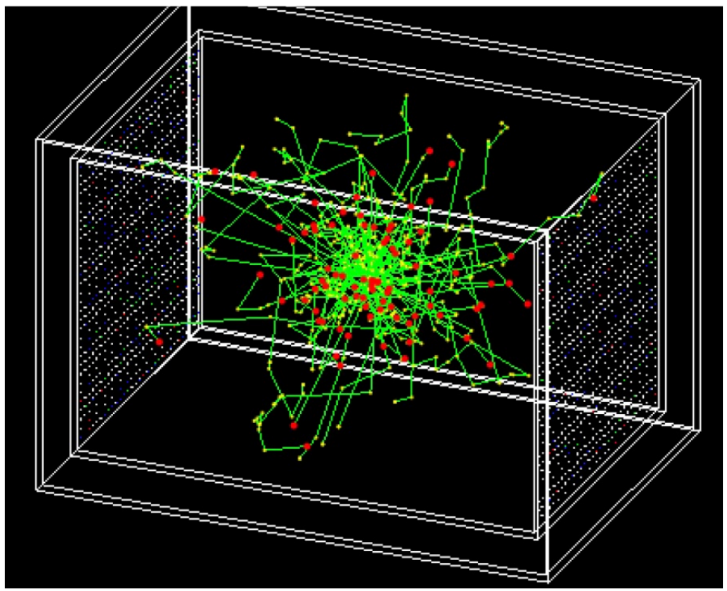
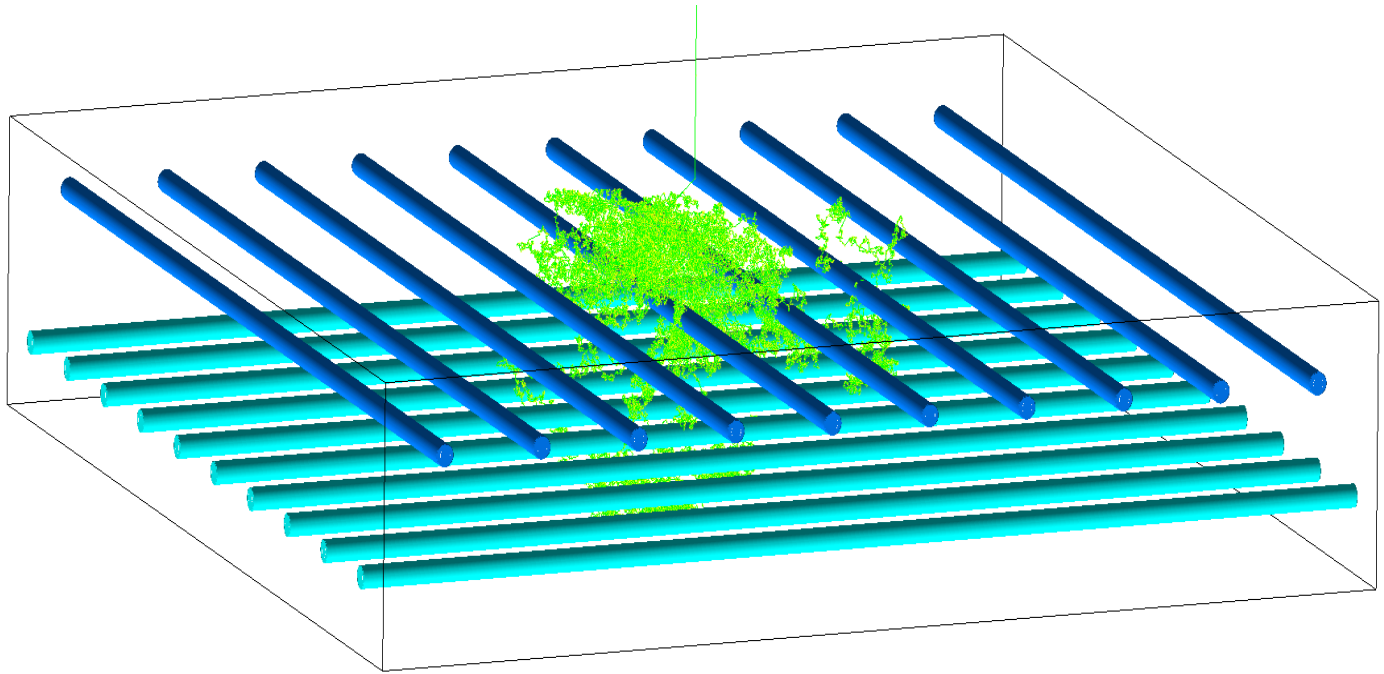


Transparent scintillator
Straight paths

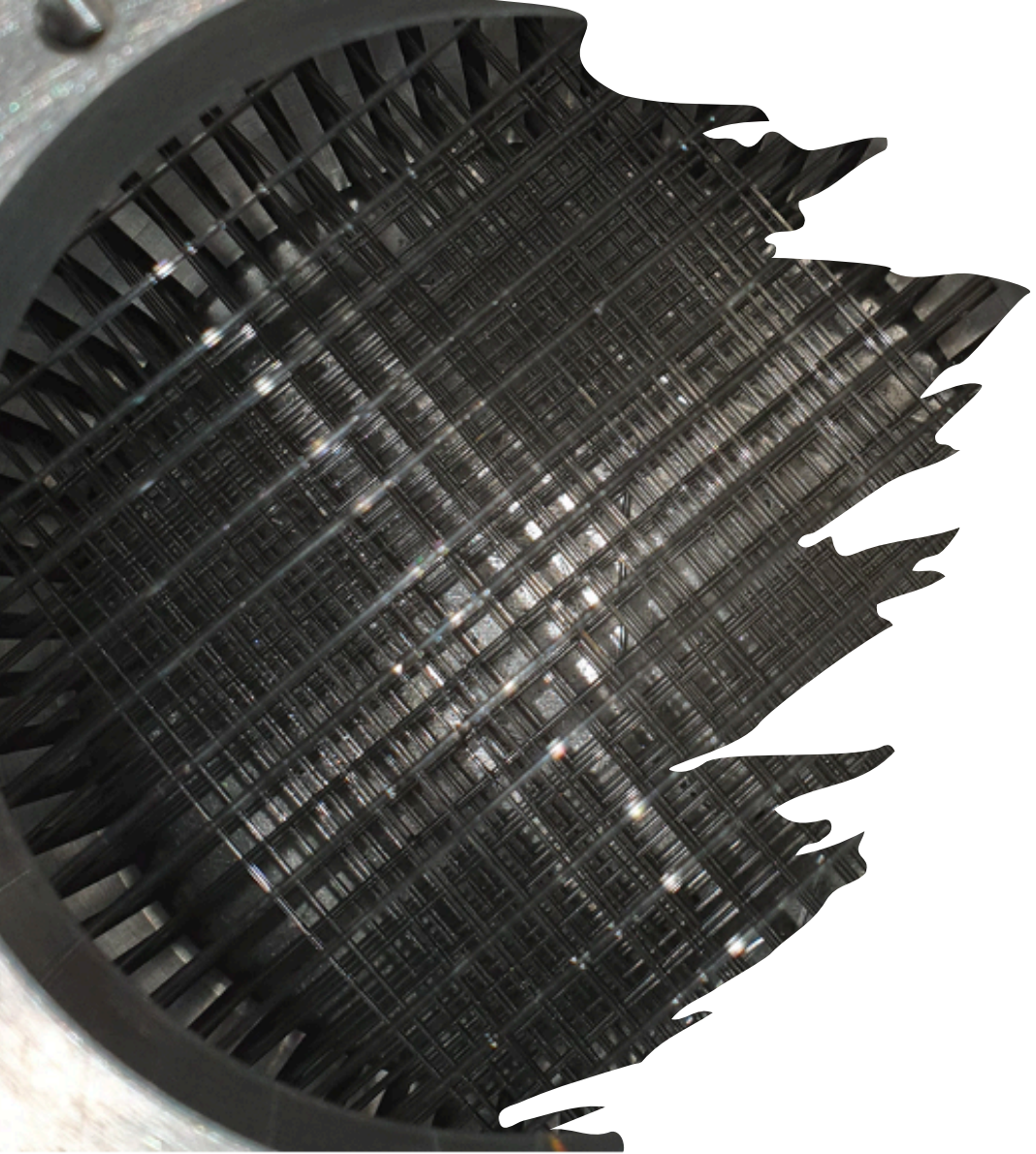


Opaque scintillator
Random walk

Confine energy deposition locally



Readout: wavelength shifting fibres + SiPMs



How is it compared to traditional particle detection?

A new approach!

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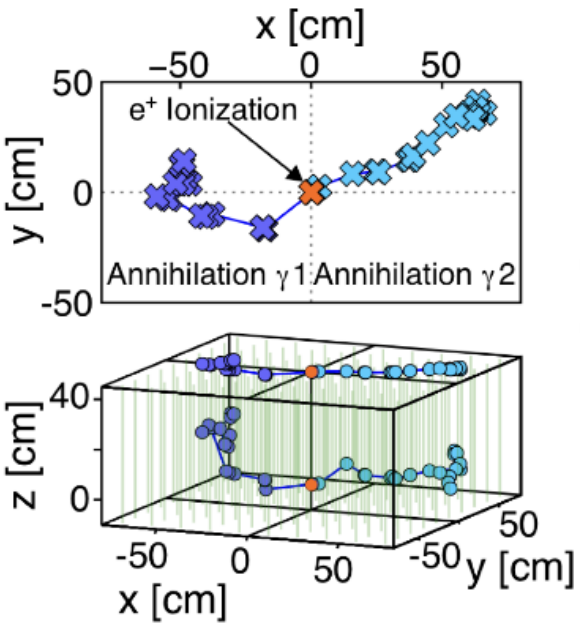
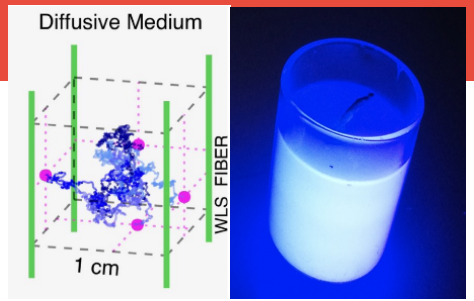
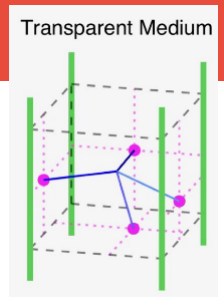
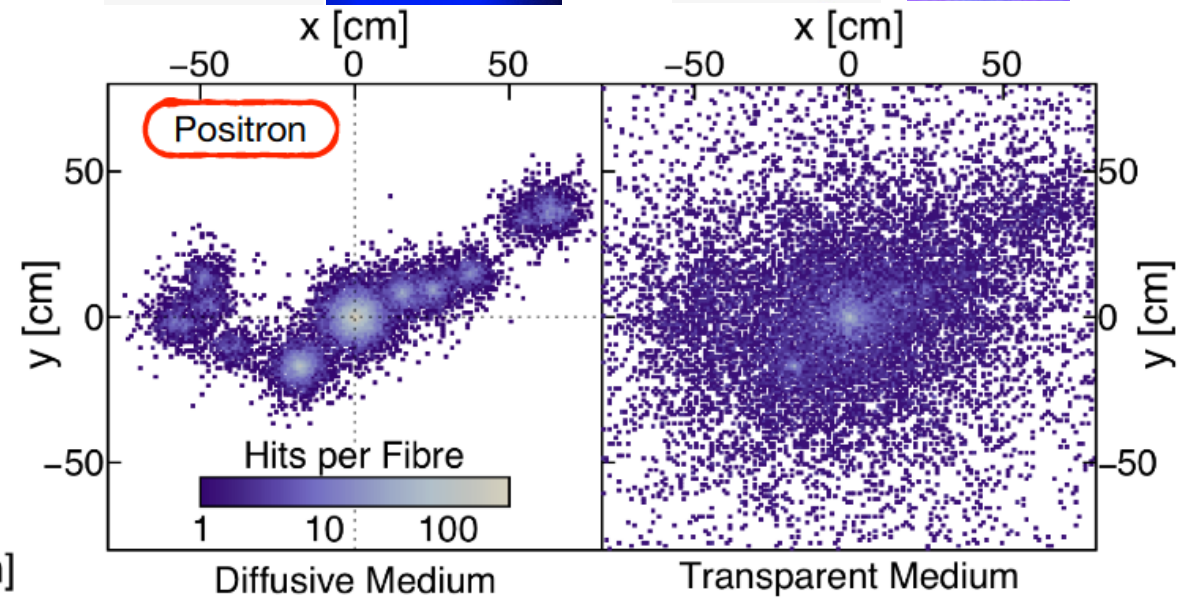
e^+ of 1 MeV

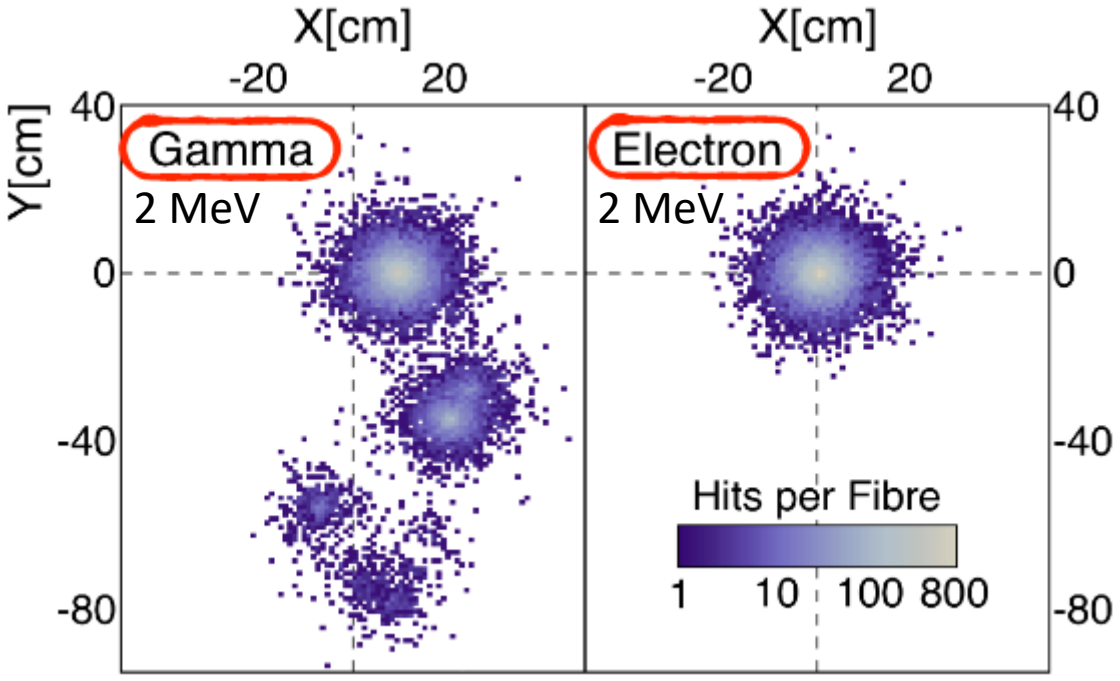


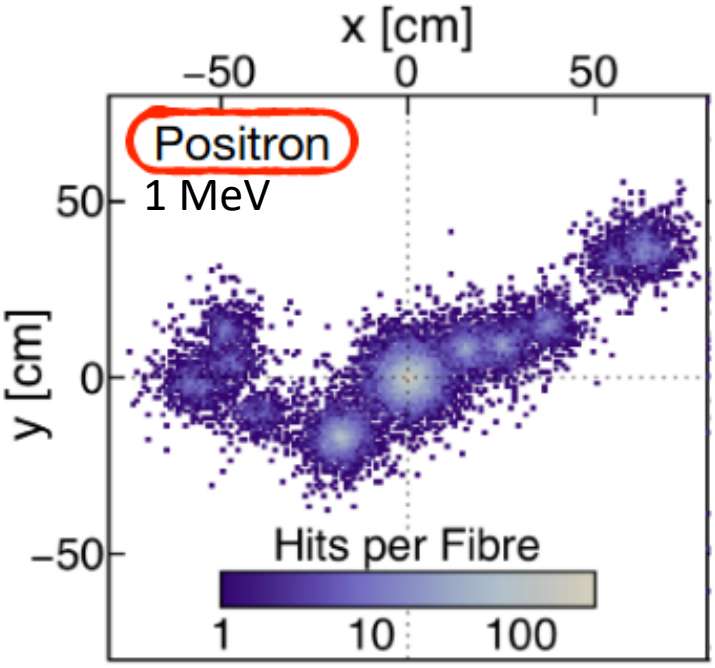






Powerful particle identification

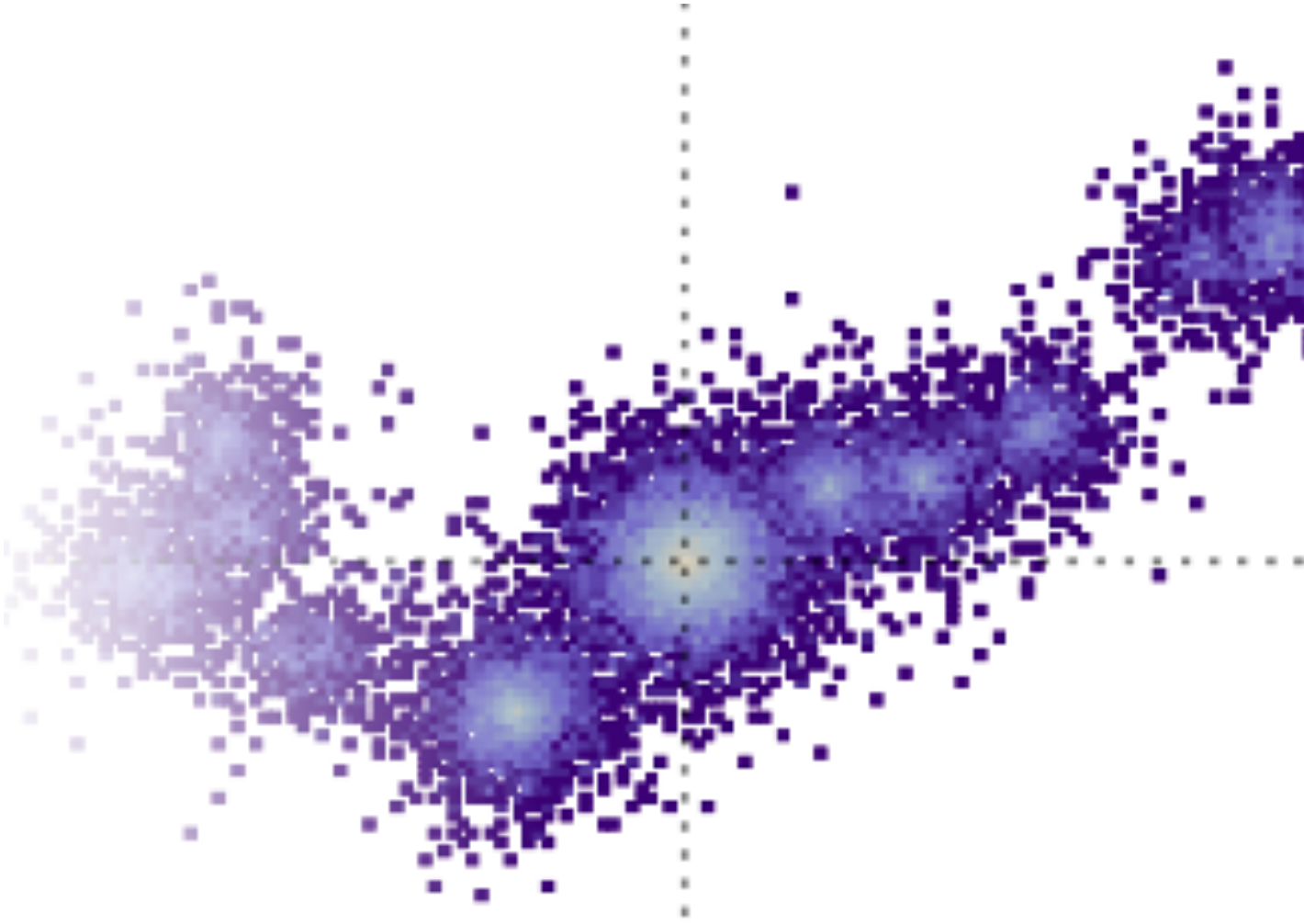




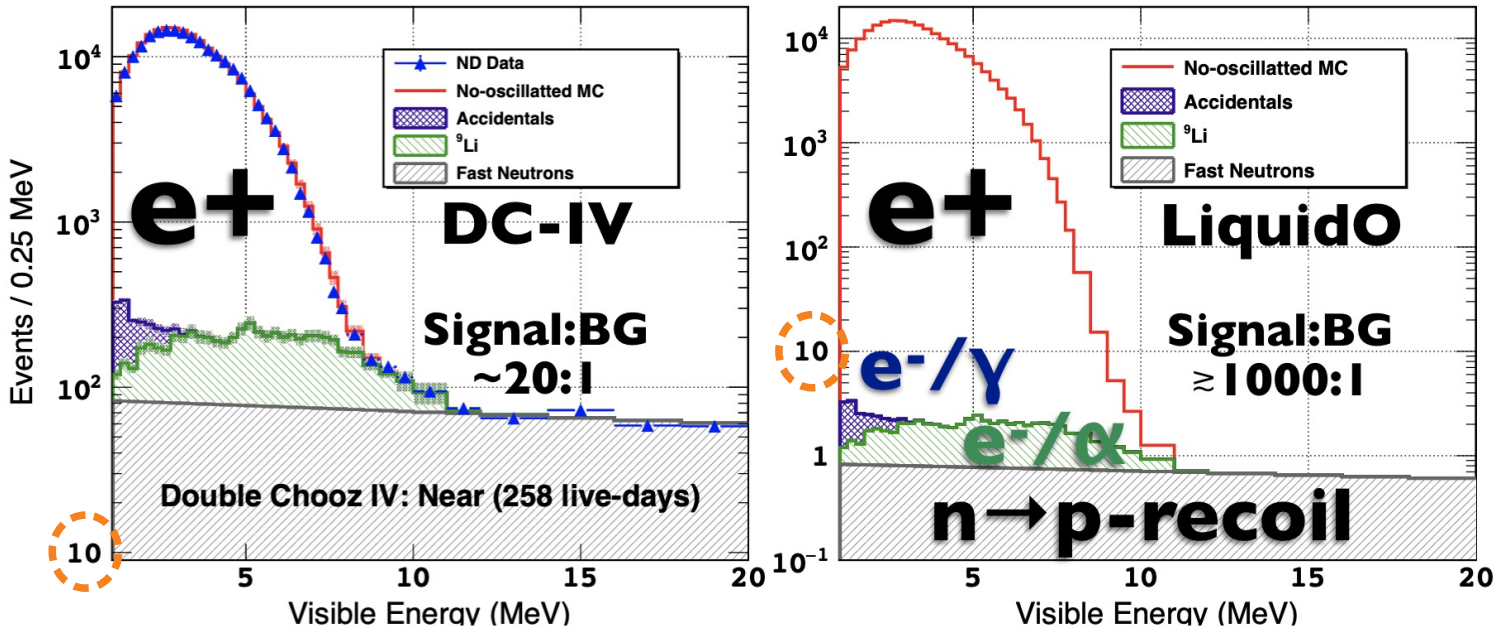
Cannot separate these 3 on an event-by-event basis with transparent scintillator!

unless segmented

Implications of High Resolution Imaging



Impact on IBD (e^+) detection



Applying expected PID for BG rejection (100:1)

Expensive way to veto backgrounds

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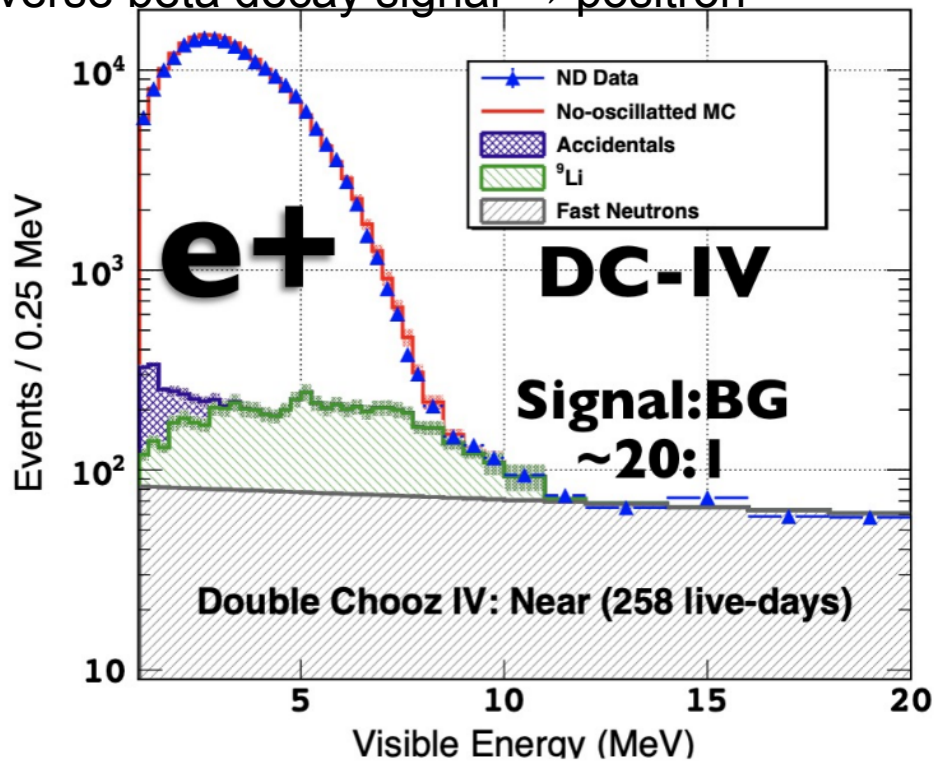
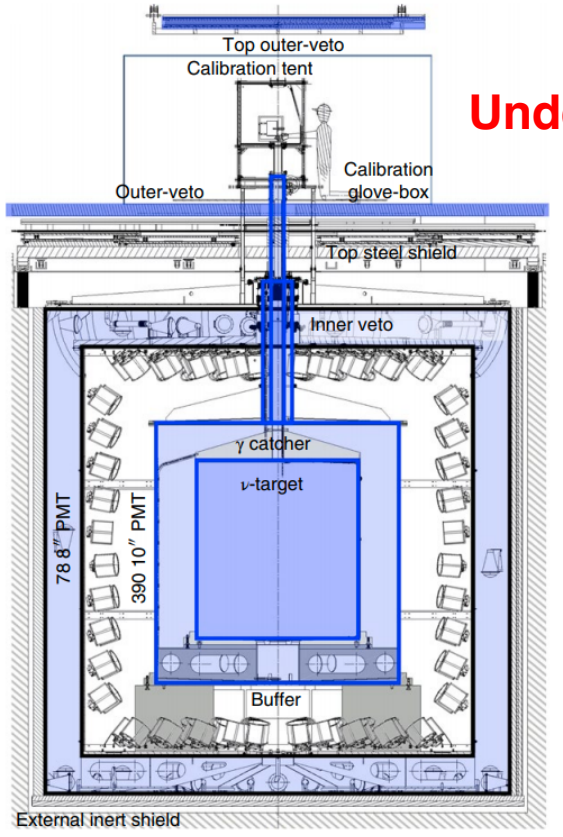
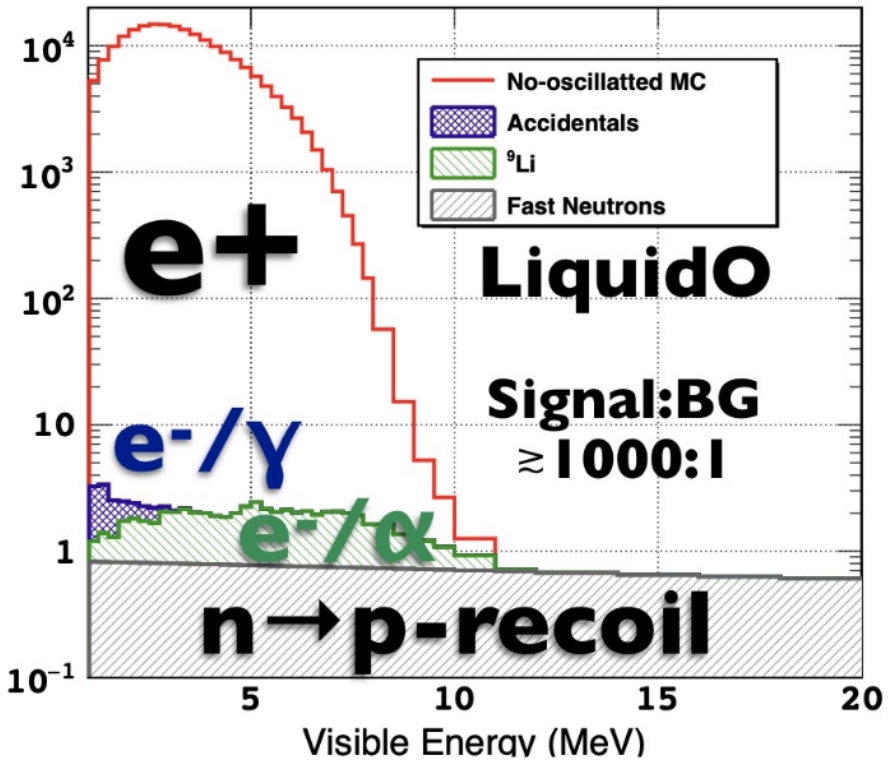
Inverse beta decay signal → positron

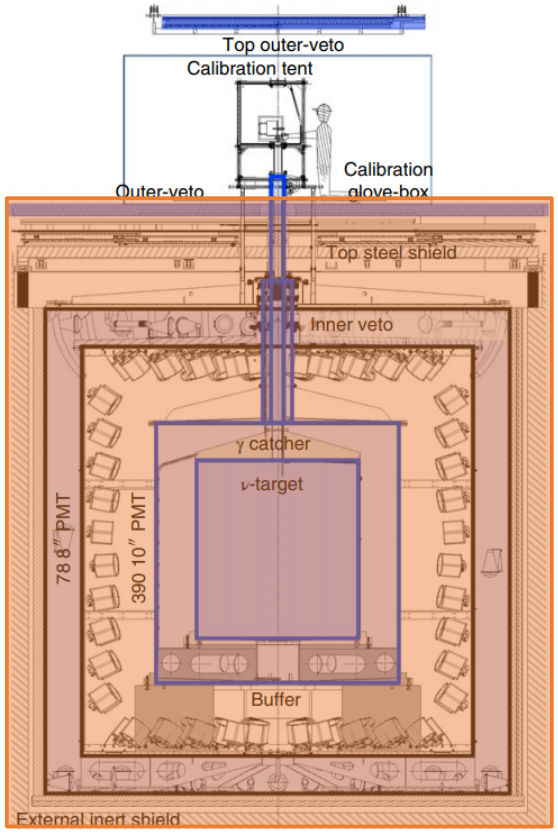




Underground

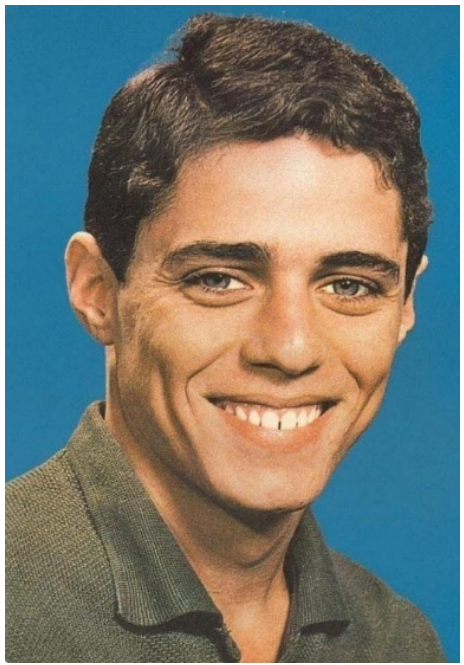
Simpler way to veto backgrounds



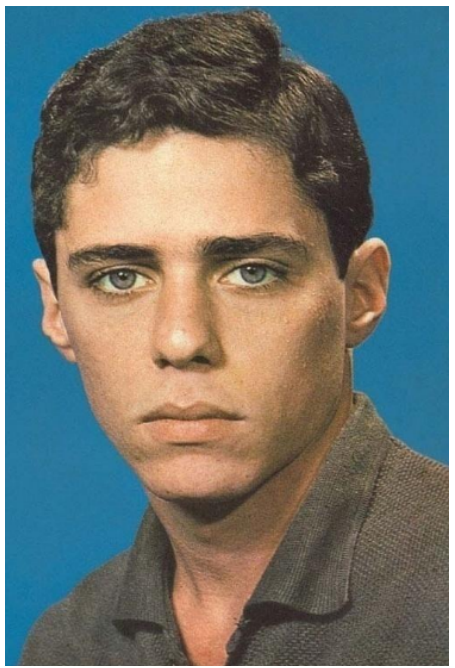


All available space as target

10 fold increase!

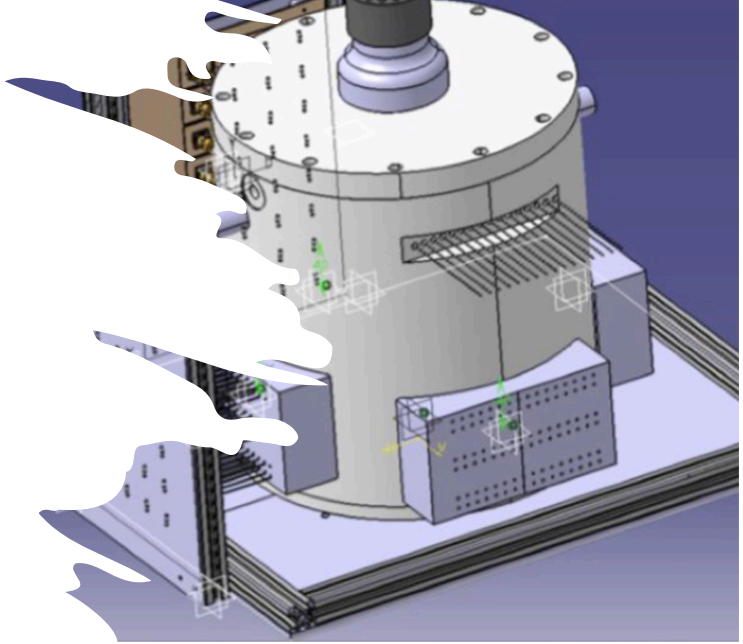


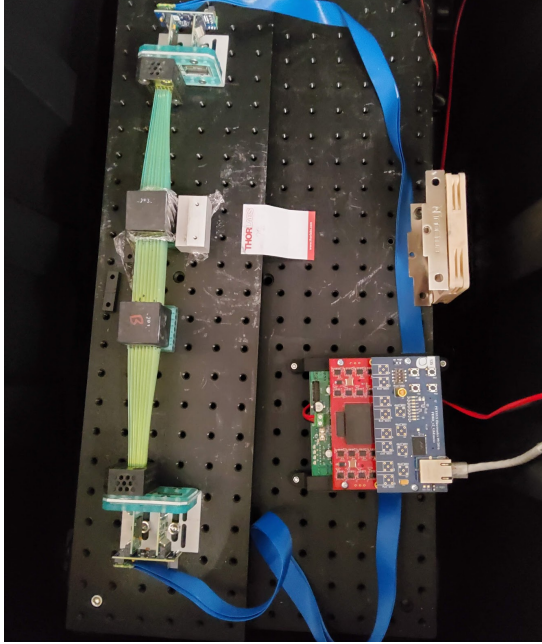
Very nice MC plots!

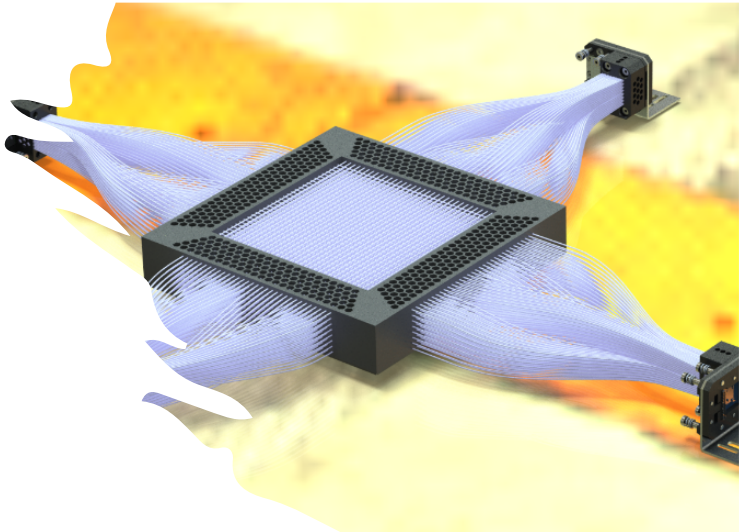


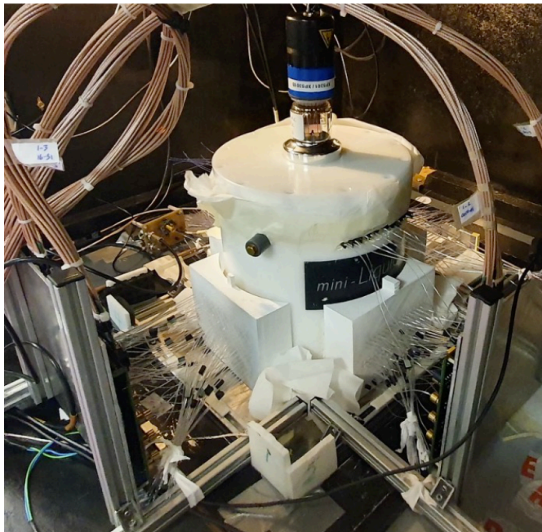
Does it work?

LiquidO Prototypes









MINI-LiquidO Prototype

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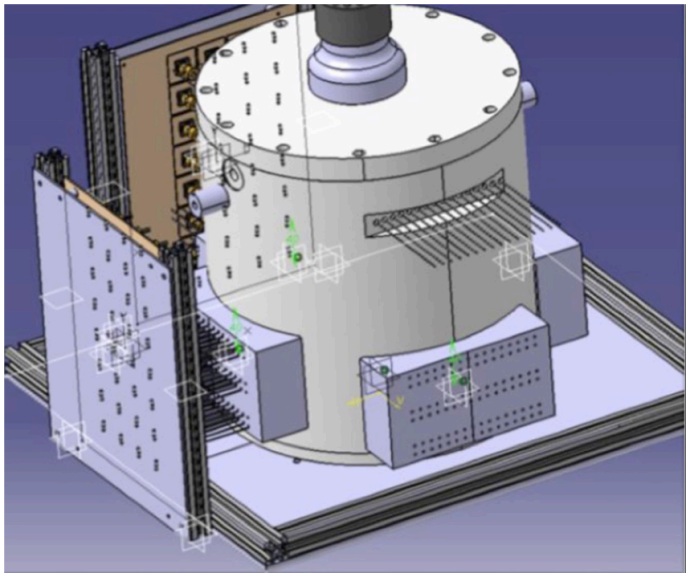
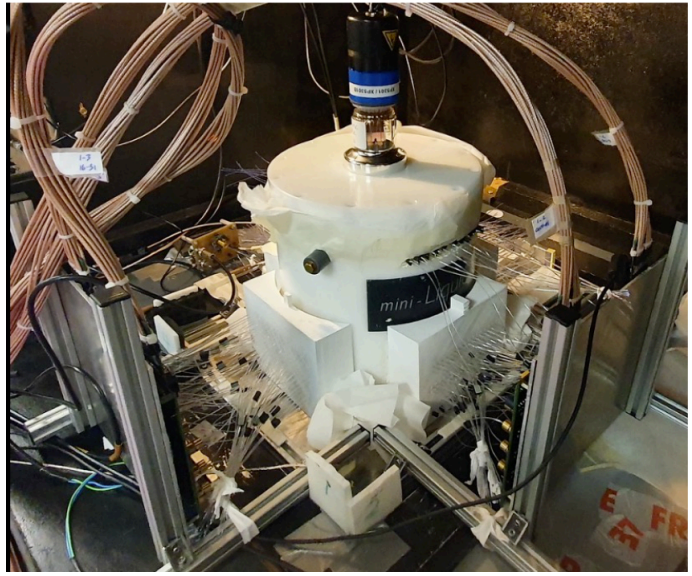


10 L and 64 readout fibres
3” PMT on top
Very fast electronics
Temp. control system [5, 40]^{o}C
Runs with:

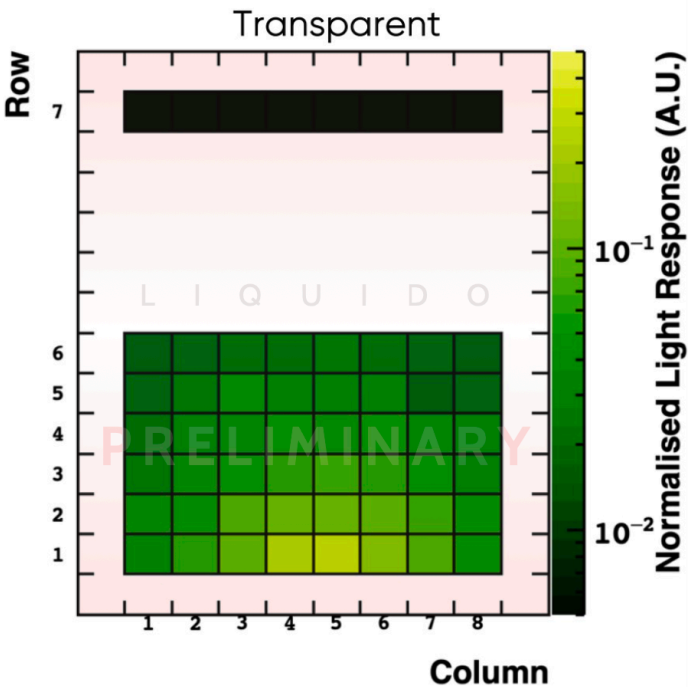
- Opaque LS (NoWash20)
- LAB (+PPO)
- Water

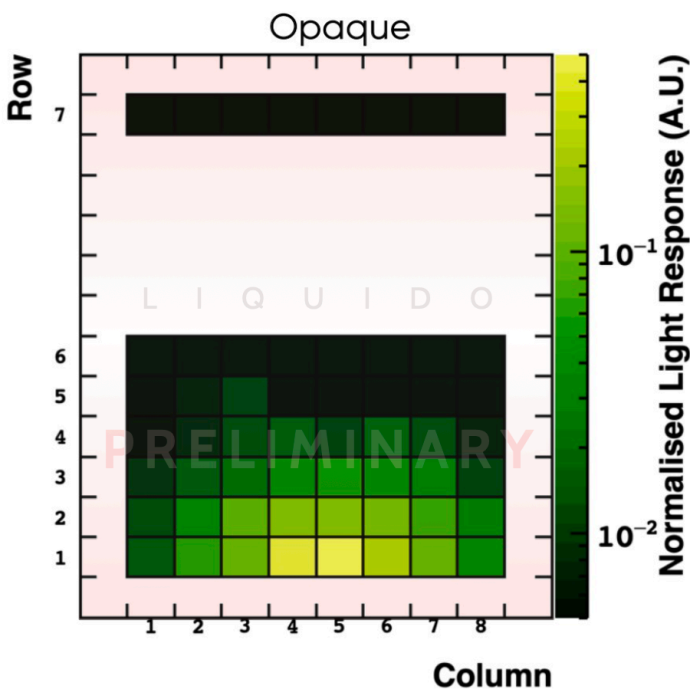
e^{-} beam [0.4, 1.8] MeV
Operated @ LP2i Bordeaux

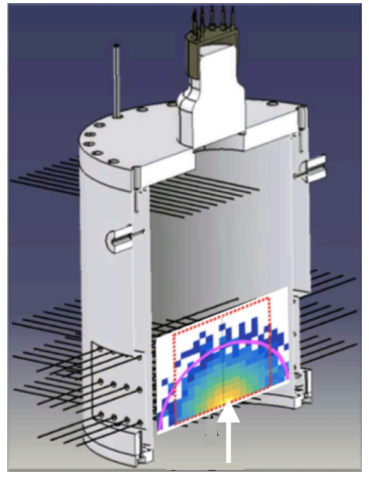


Goal: demonstrate stochastic light confinement

MINI-LiquidO Prototype: Results







MINI-LiquidO Prototype: Results

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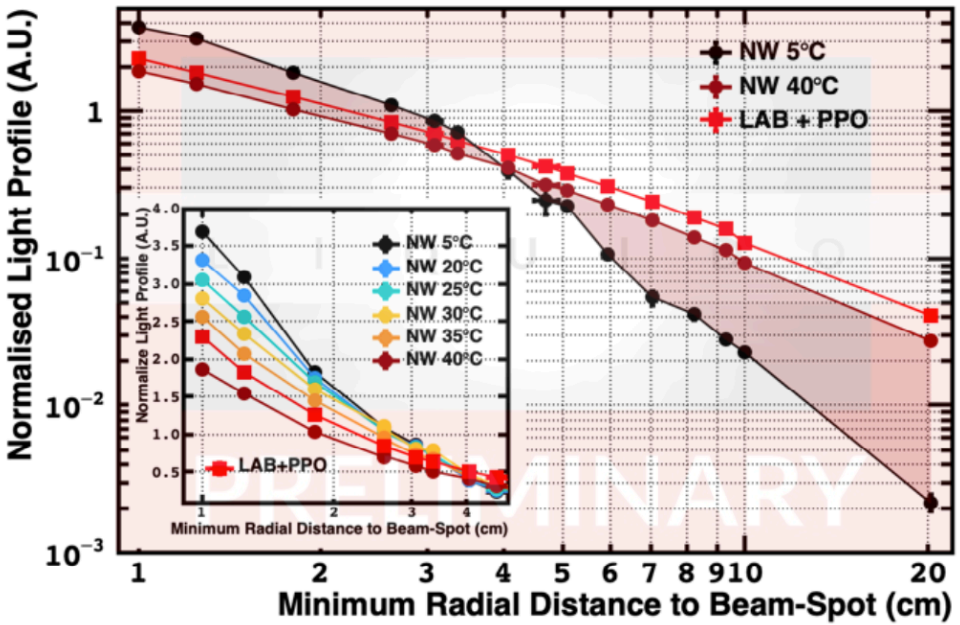
Transparent vs Opaque



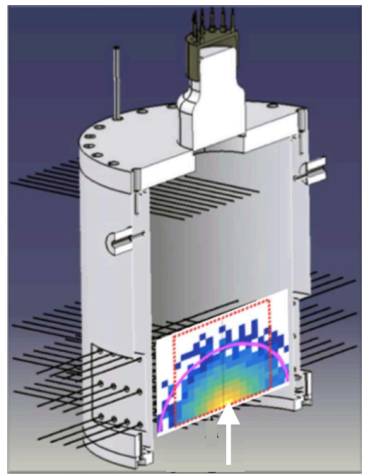
NW at 40°C → transparent
similar to LAB+PPO

NW at 5°C → Opaque

Light ball formation at ~4cm

Stochastic light confinement!

Major demonstration of the LiquidO technology



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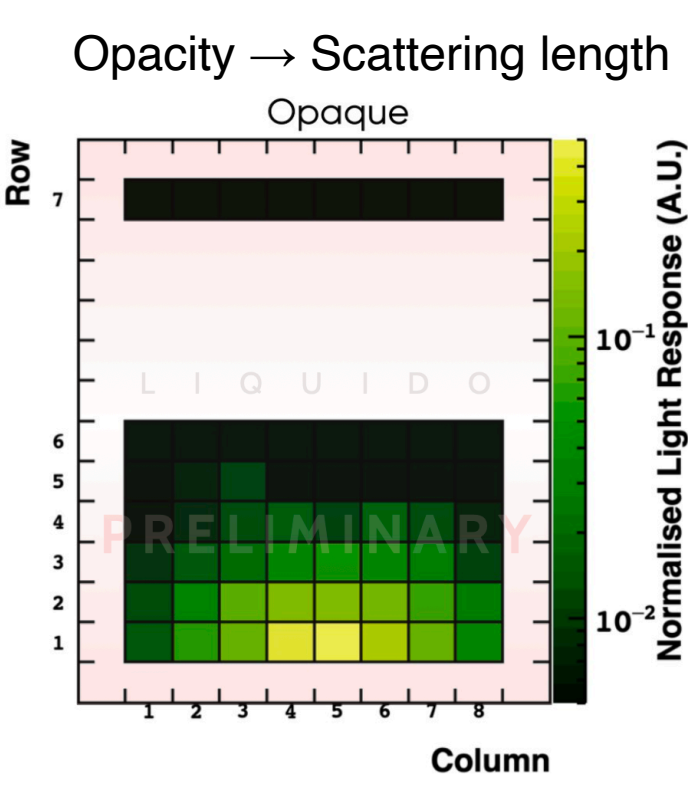
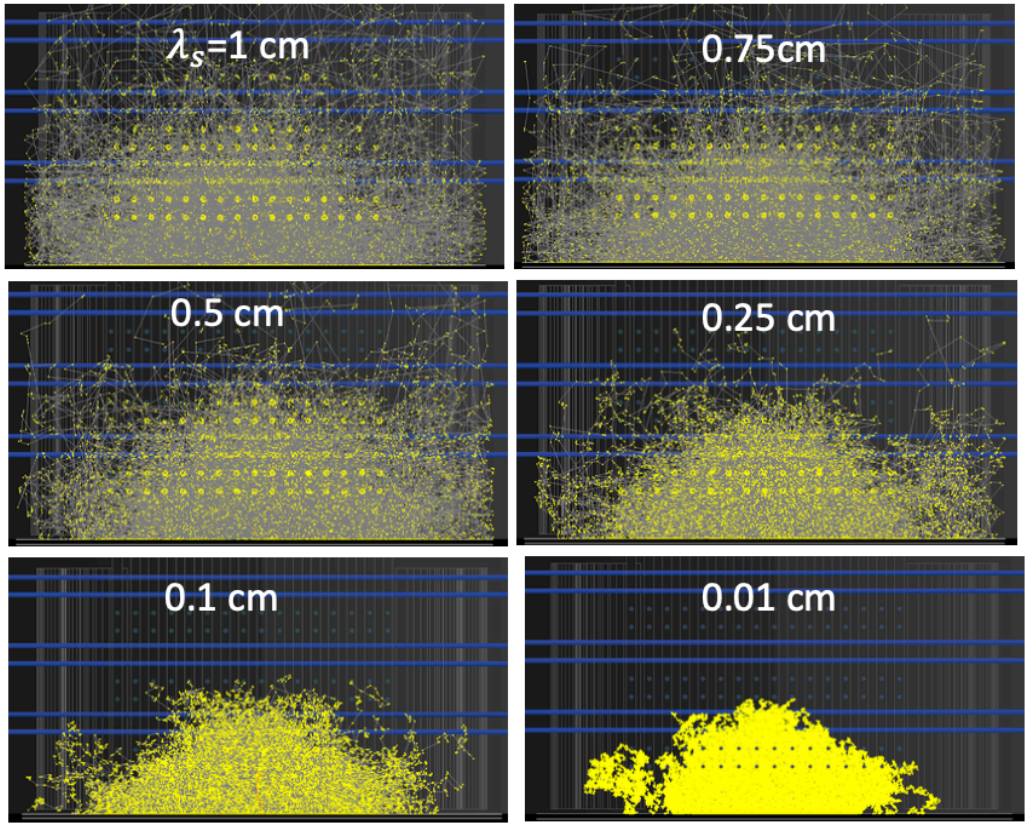
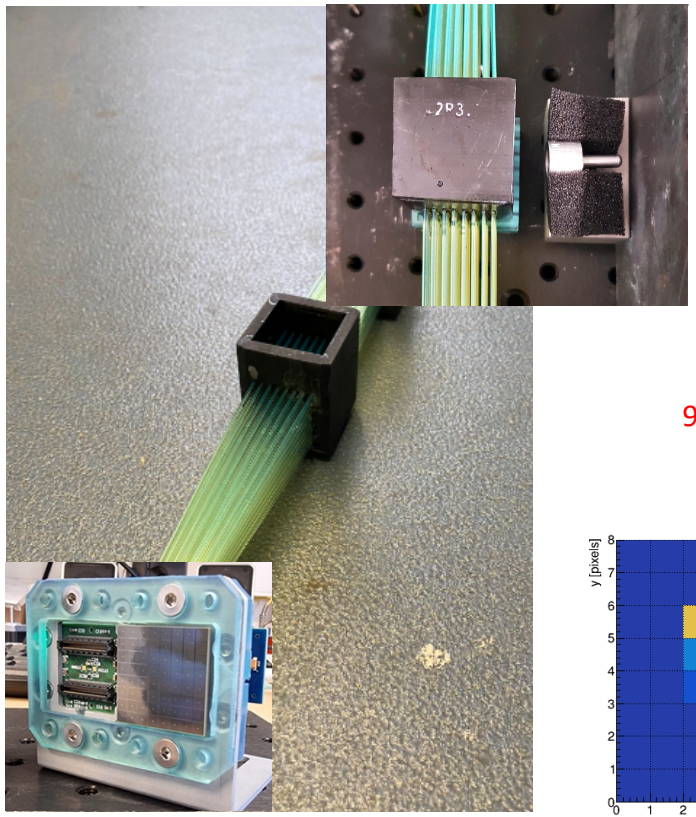
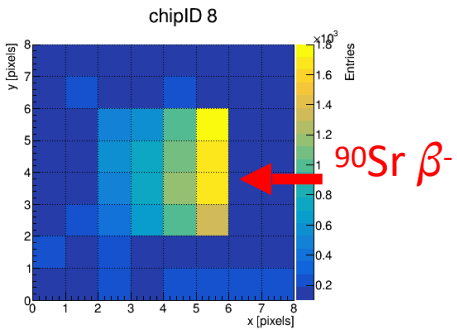
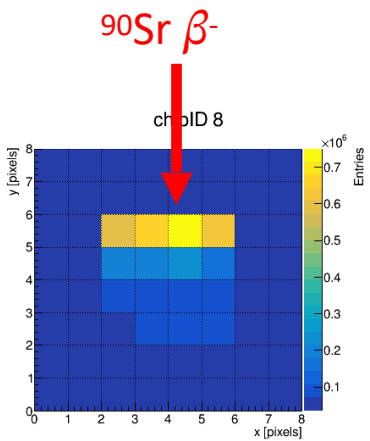




On going developments at Sussex



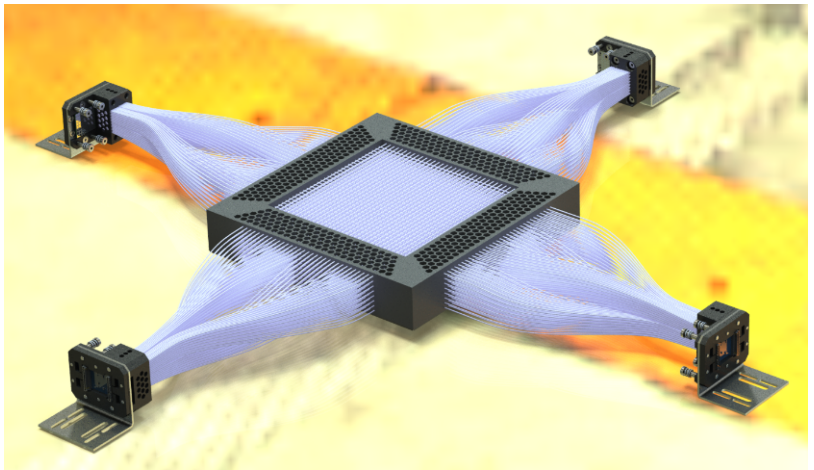


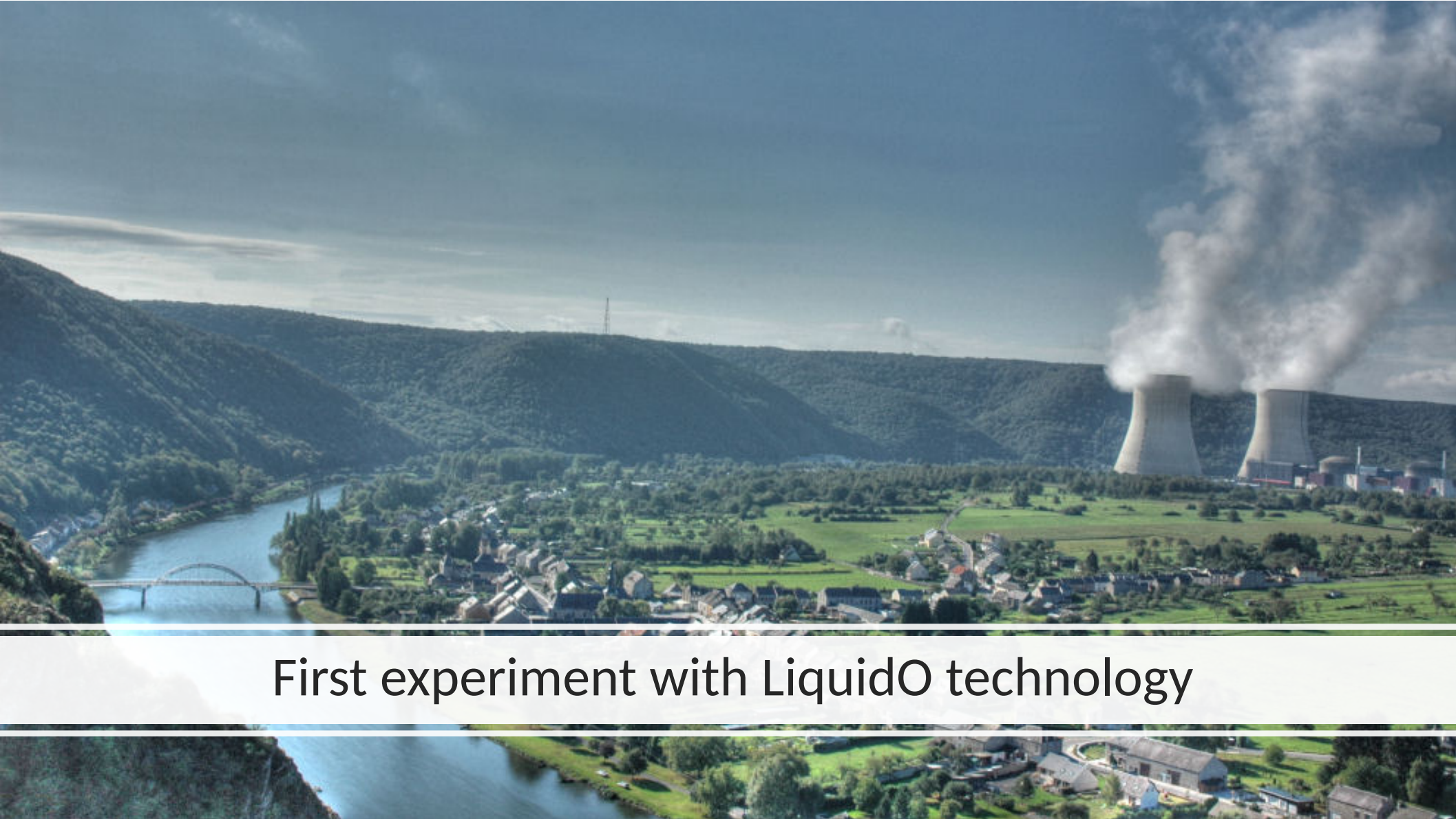


Goals:

→ Highest Light Yield possible

→ Muon tracking capability

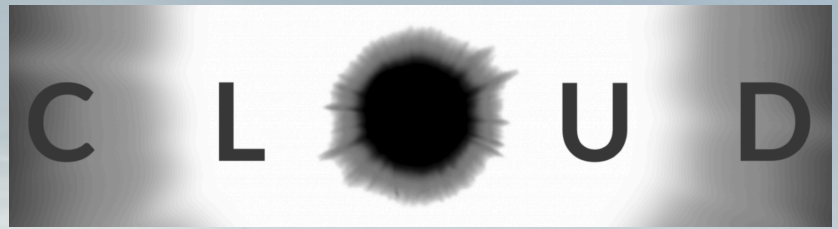




First experiment with LiquidO technology

European Innovation Council

UK Research and Innovation



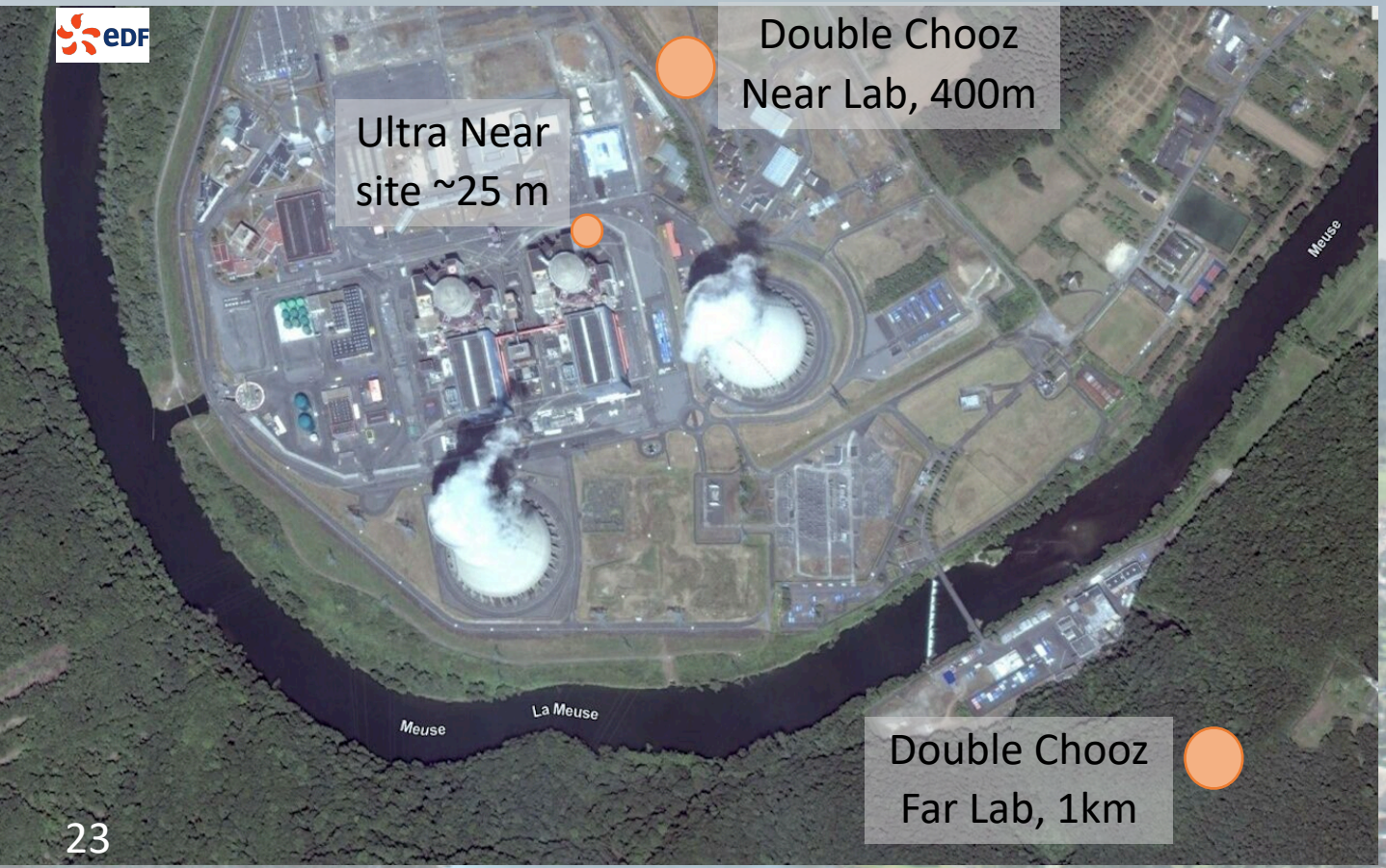
Innovation Programme + Fundamental Science Programme

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

BNL (USA)
Charles University (Czech Republic)
INFN-Padova (Italy)
Penn Stat (USA)
PUC-Rio (Brazil)
Queen's University (Canada)
Universidade Estadual de Londrina (Brazil)
UC-Irvine (USA)
University of Michigan (USA)
University of Zaragoza (Spain)
Tohoku University/RCNS (Japan)

European Innovation Council

UK Research and Innovation



>5-ton LiquidO detector
@ Chooz reactors site

Innovation (2023-26)
- Reactor Monitoring

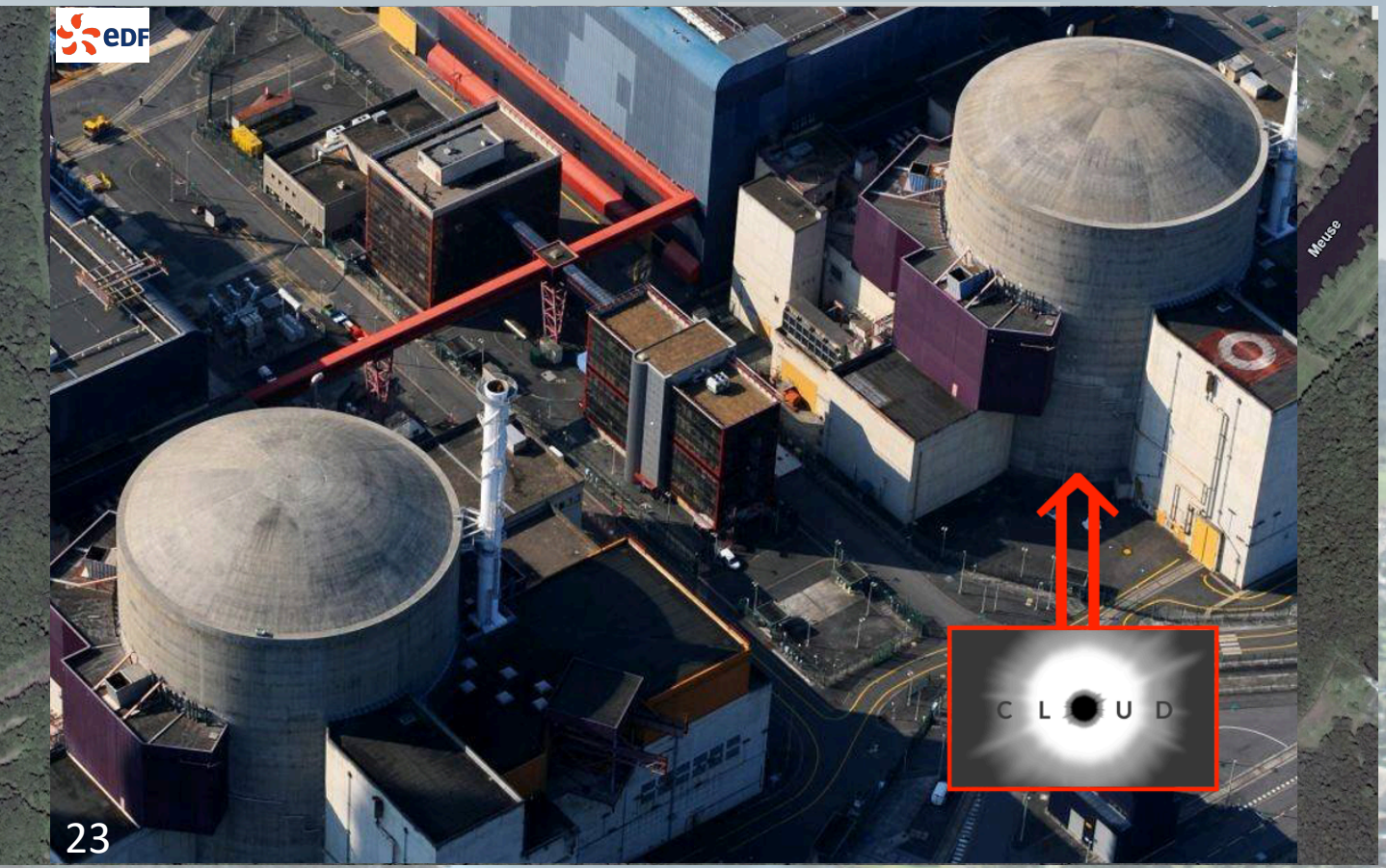
Fundamental Science (>2023)
- LiquidO capability for
Low-E physics

> 10,000 IBDs / day

High-resolution imaging to
beat down backgrounds

European Innovation Council

UK Research and Innovation



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Summary

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→ Opacity: novel and counter-intuitive way to use scintillator

→ Light-based “TPC”; uniform calorimeter; imaging (PID); ToF;

→ Doping: a powerful by-product

→ LiquidO R&D progressing rapidly and steadily

→ New **CLOUD** experiment will find technical solutions and verify LiquidO capabilities for reactor antineutrino detection at surface in the next years

First Publications

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communications physics

arXiv:1908.02859

ARTICLE

https://doi.org/10.1038/s42005-021-00763-5 OPEN

Neutrino physics with an opaque detector

LiquidO Consortium*

In 1956 Reines & Cowan discovered the neutrino using a liquid scintillator detector. The neutrinos interacted with the scintillator, producing light that propagated across transparent volumes to surrounding photo-sensors. This approach has remained one of the most widespread and successful neutrino detection technologies used since. This article introduces a concept that breaks with the conventional paradigm of transparency by confining and collecting light near its creation point with an opaque scintillator and a dense array of optical fibres. This technique, called LiquidO, can provide high-resolution imaging to enable efficient identification of individual particles event-by-event. A natural affinity for adding dopants at high concentrations is provided by the use of an opaque medium. With these and other capabilities, the potential of our detector concept to unlock opportunities in neutrino physics is presented here, alongside the results of the first experimental validation.

arXiv:1908.03334

Jinst

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Novel opaque scintillator for neutrino detection

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Abstract: There is rising interest in organic scintillators with low scattering length for future neutrino detectors. Therefore, a new scintillator system was developed based on admixtures of paraffin wax in linear alkyl benzene. The transparency and viscosity of this gel-like material can be tuned by temperature adjustment. Whereas it is a colorless transparent liquid at temperatures around 40°C, it has a milky wax structure below 20°C. The production and properties of such a scintillator as well as its advantages compared to transparent liquids are described.

Keywords: Detector design and construction technologies and materials; Neutrino detectors; Scintillators, scintillation and light emission processes (solid, gas and liquid scintillators)

ArXiv ePrint: 1908.03334

2019 JINST 14 P11007

LiquidO Consortium

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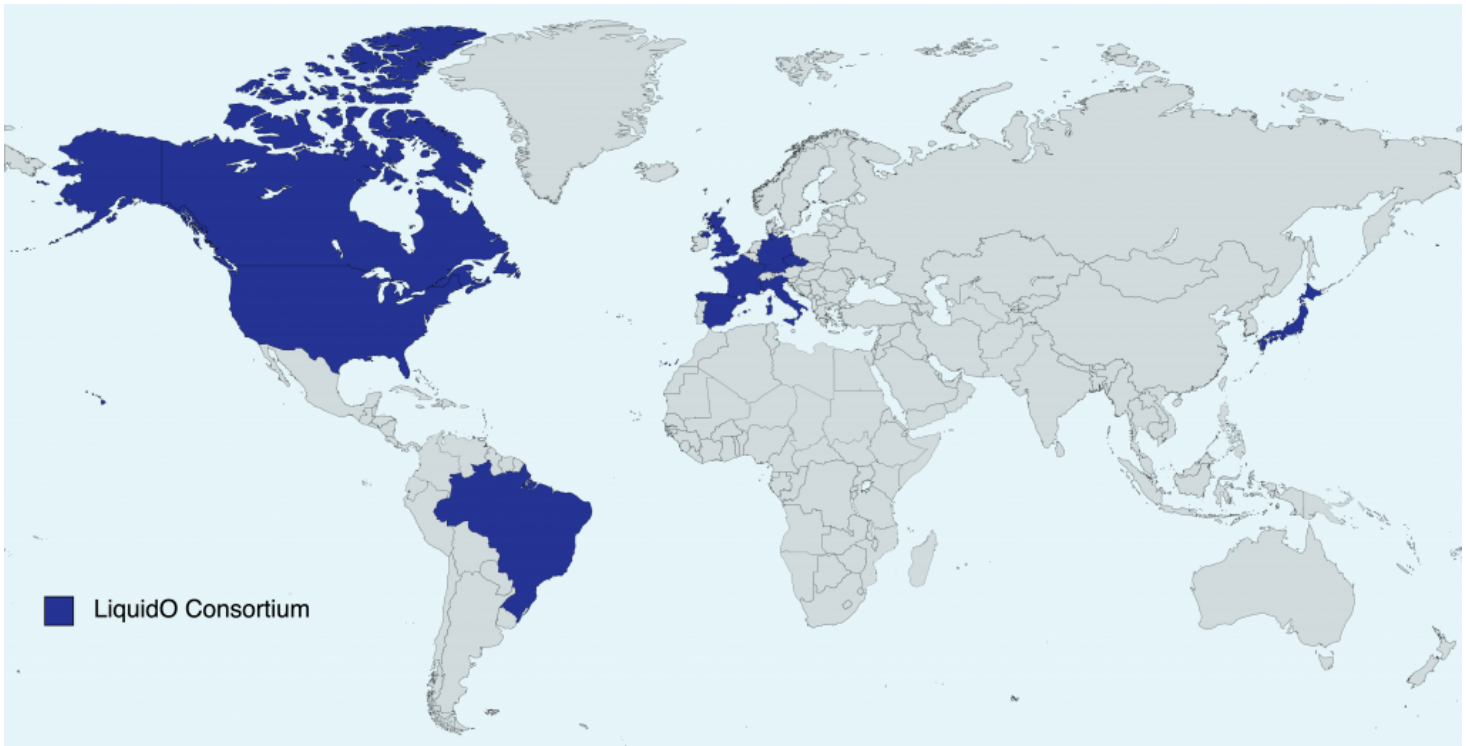
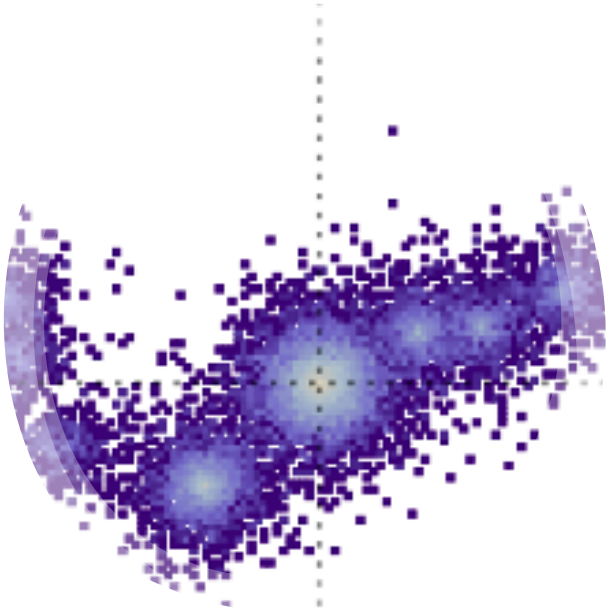
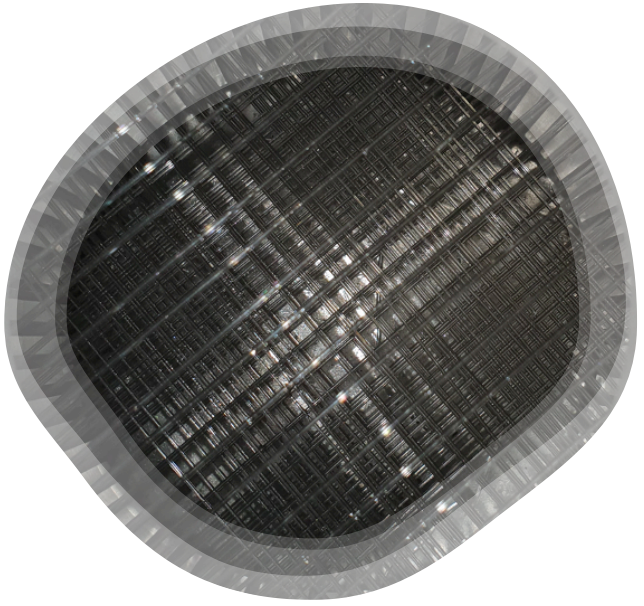


- 90 scientists
- 26 institutions
- 11 countries

https://liquido.ijclab.in2p3.fr/





Thank you!