

LiquidO

Seeing through the fog to find new physics

Mark Chen

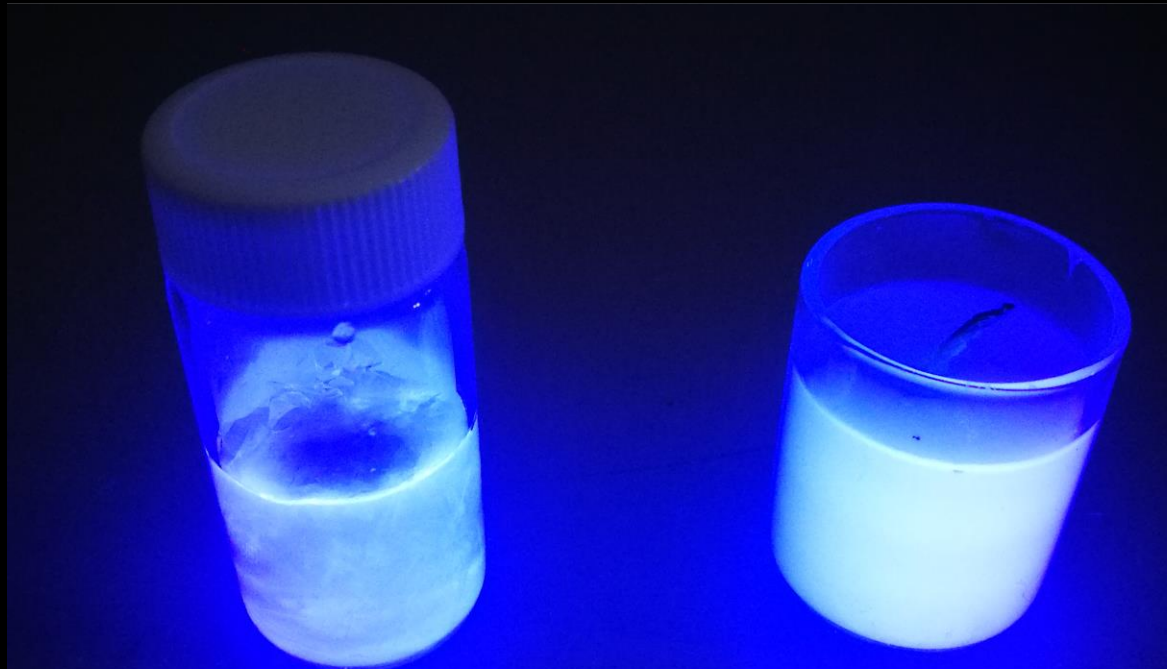
*Queen's University and the Canadian Institute for
Advanced Research*

Summer Particle Astrophysics Workshop 2024

What is LiquidO? → O is for
“Opaque”



R&D towards a novel liquid scintillator detection
technique that uses an opaque medium



What is a Liquid Scintillator?

It's a material that gives off light when excited by particles/radiation

- inorganic crystals, organic liquids, noble gases and liquids, plastic scintillators

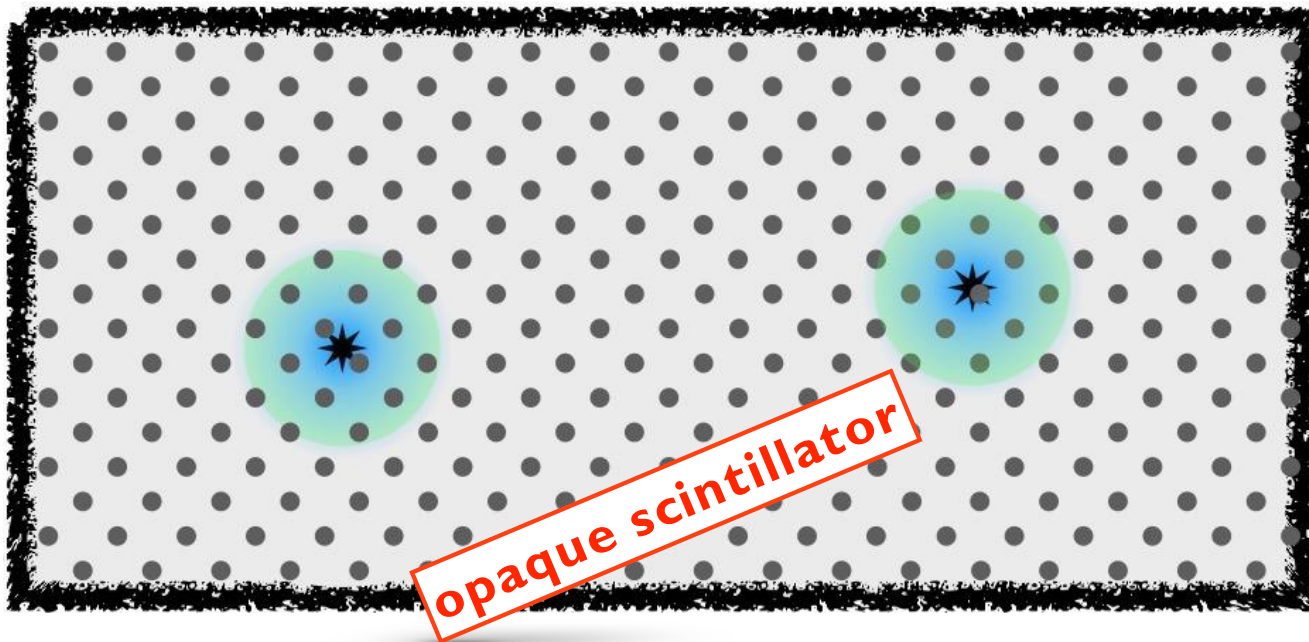
Right: the SNO+ neutrino detector is filled with liquid scintillator; light is detected by photomultipliers (PMTs)



Light Confinement

using high scattering medium (with low absorption) to **preserve** energy deposition information

confine energy deposition locally → freeze information



How to readout an “opaque” scintillator?

grid of wavelength-shifting fibres

X, Y info: ~1-cm fibre grid spacing (~mm imaging)

Z info: timing along fibre (~cm resolution)

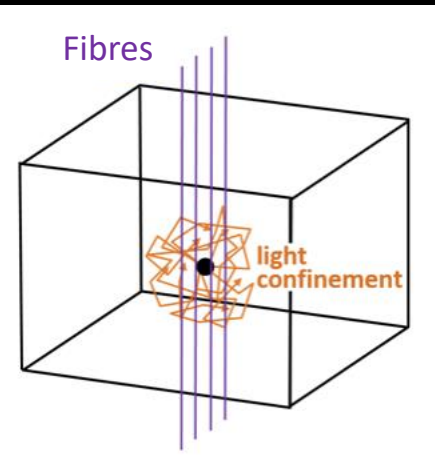
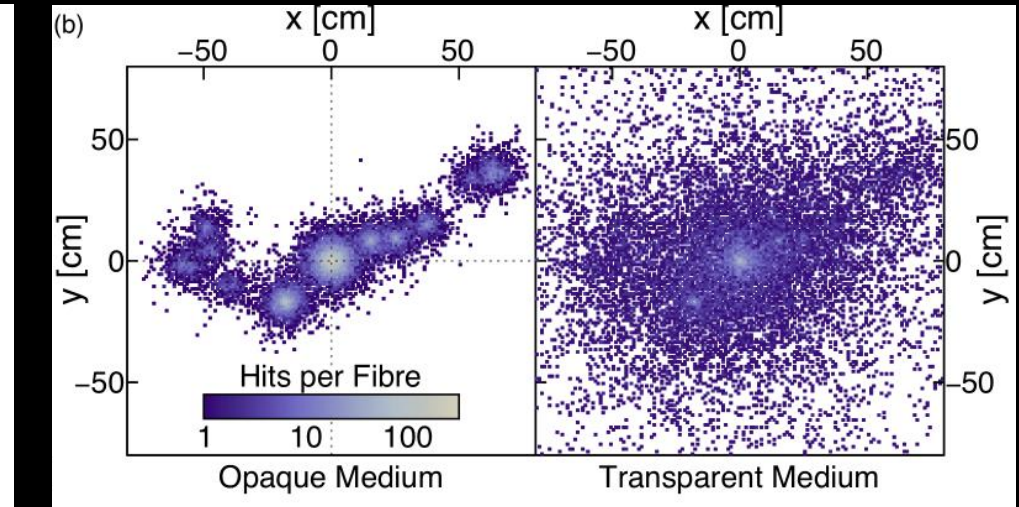
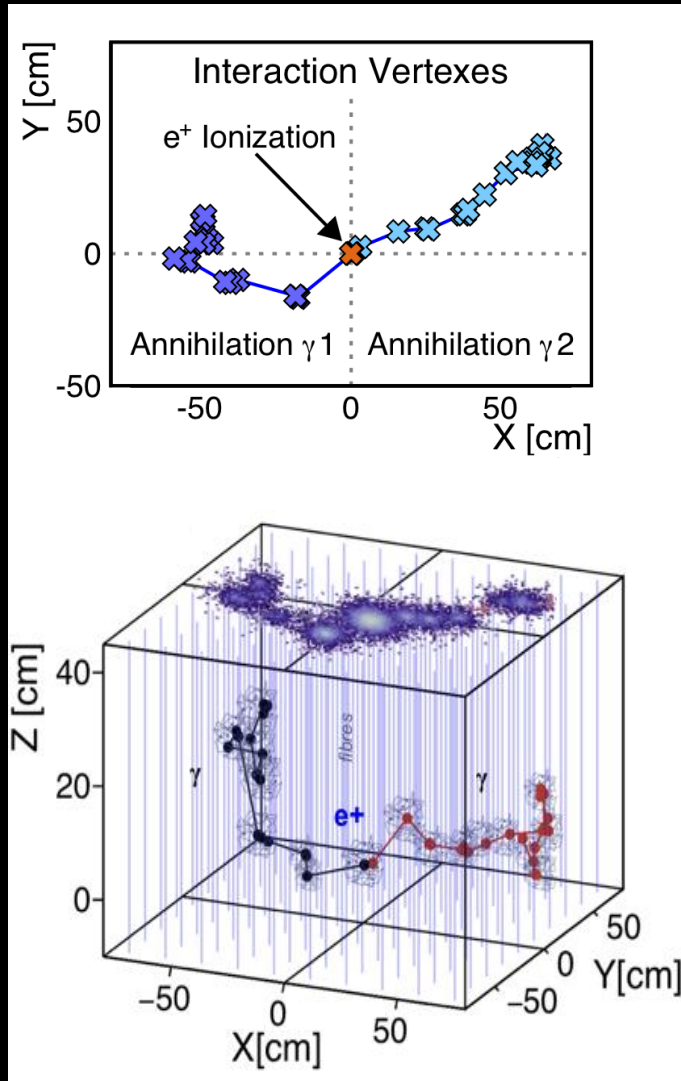
SiPM fibre readout (photon counting)

(everybody ♥ SiPMs these days)

It's like a light TPC or photon drift chamber!

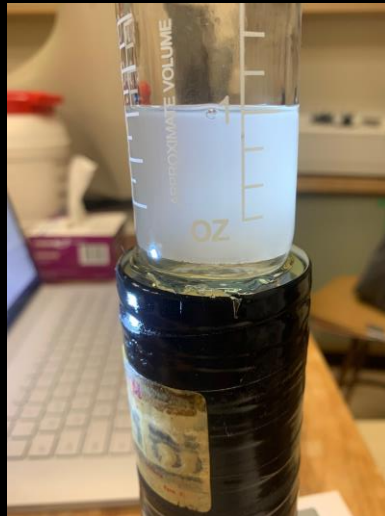
Image: CDF central tracker

Scintillation light from energy deposition is confined stochastically... scattering *enables* imaging!



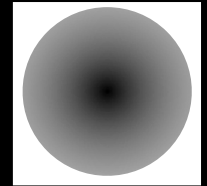
LiquidO Features & Advantages

- spatial and temporal event ID and pattern information → **powerful background rejection**
- **relaxing the scintillator transparency requirement** opens many doors for liquid scintillator design options

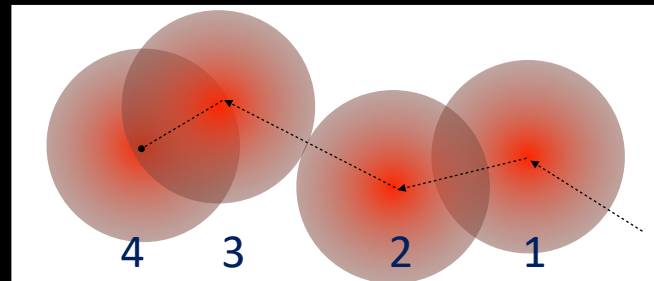


Event Identification @MeV energies

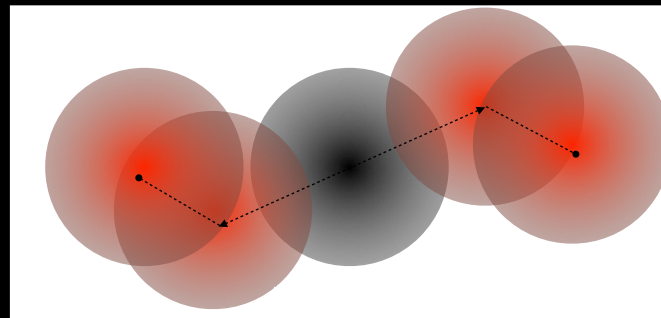
- Single Site (electrons, alphas, proton recoils)



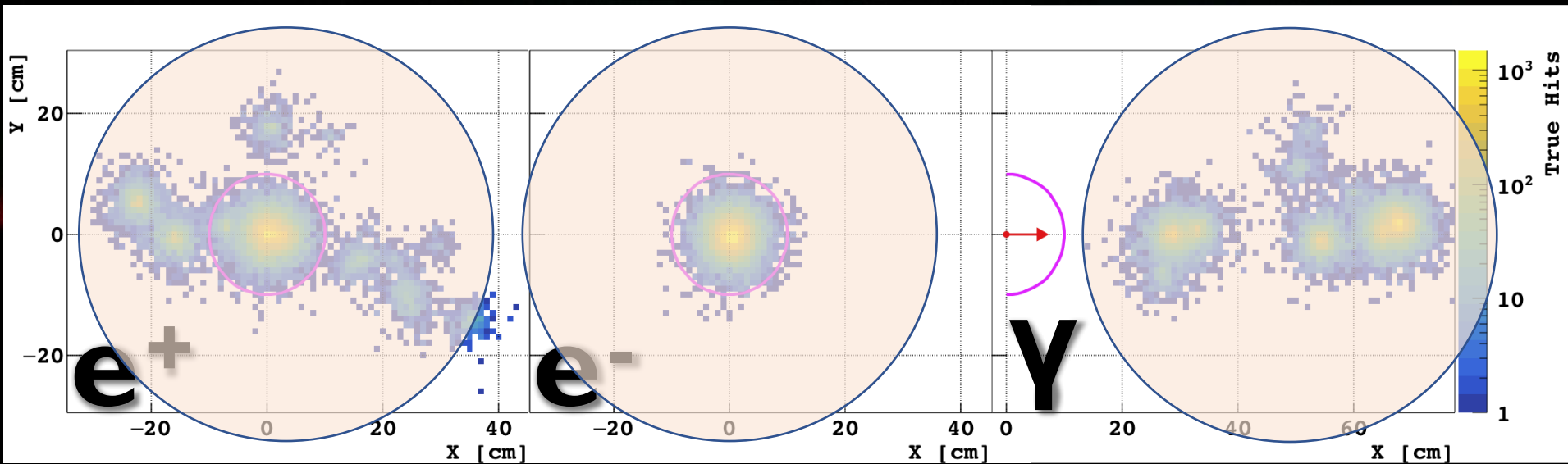
- Multi Site (gammas)



- Positrons!

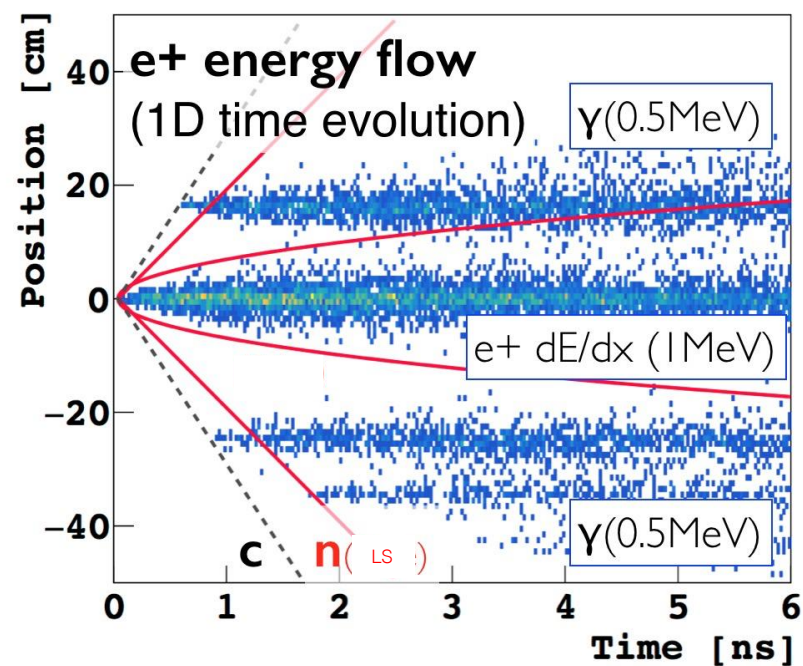
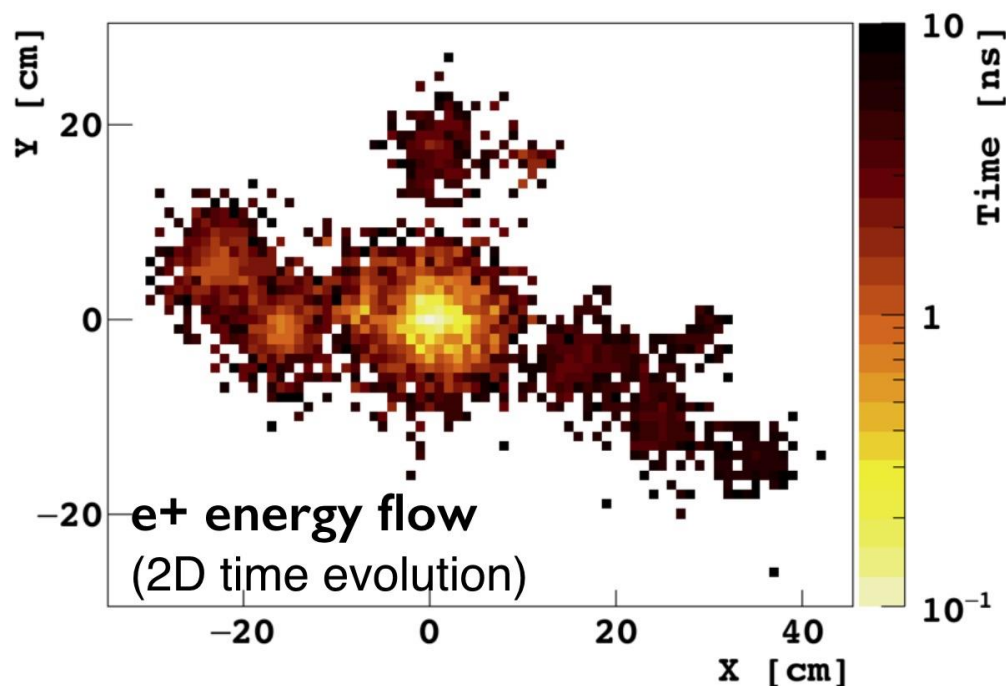


LiquidO Simulations – 2 MeV



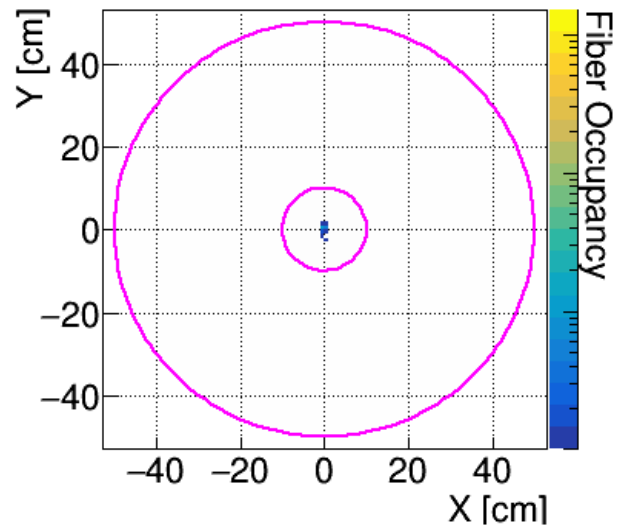
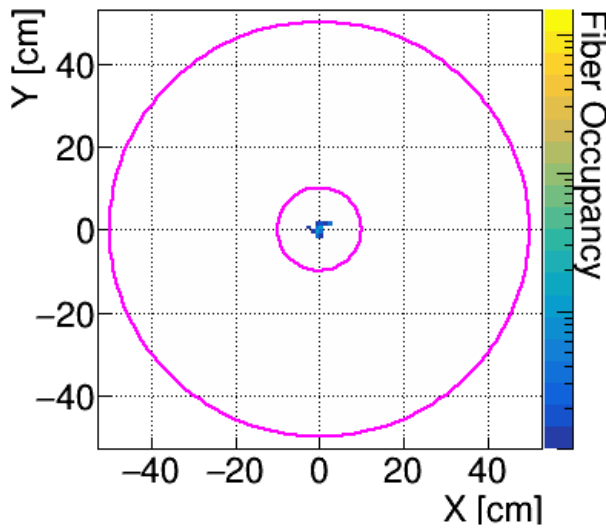
In contrast: how do PMTs from far away see such events?
...as mostly indistinguishable large balls of light!

“Energy Flow” – Time Information

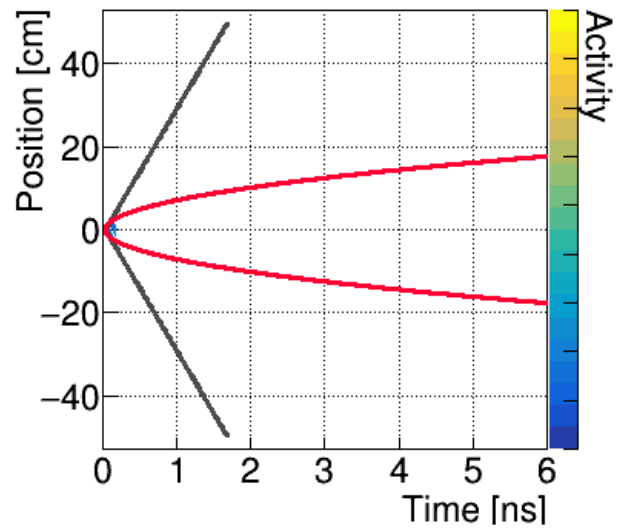
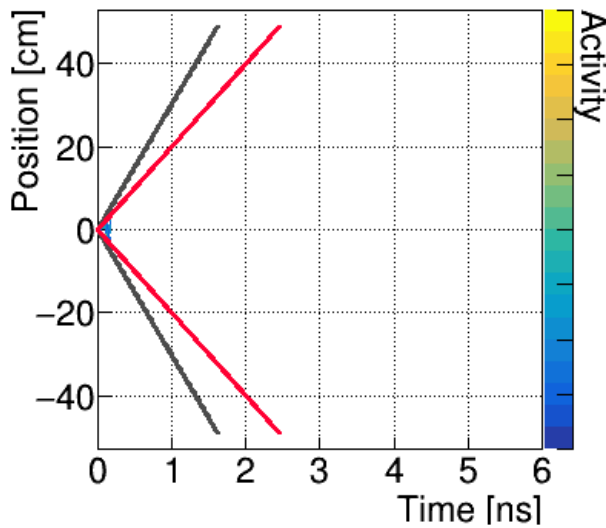


$T=0.2$ ns

Hit
Pattern



Energy
Flow

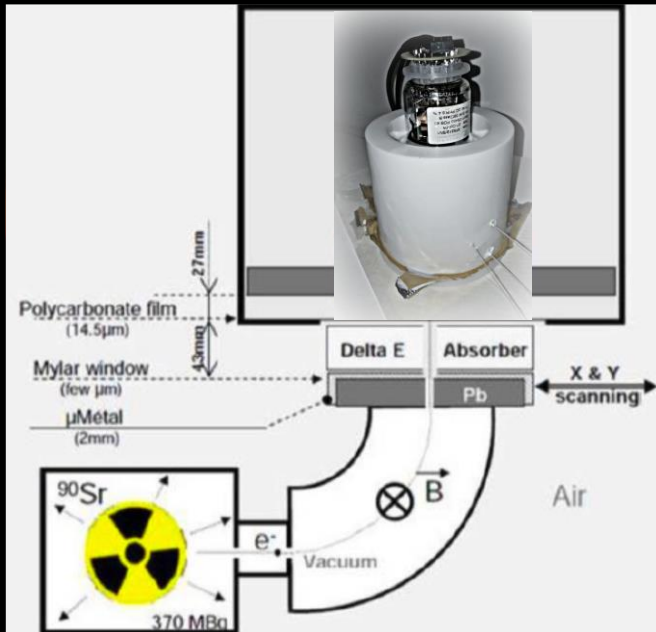


LS + Fibres

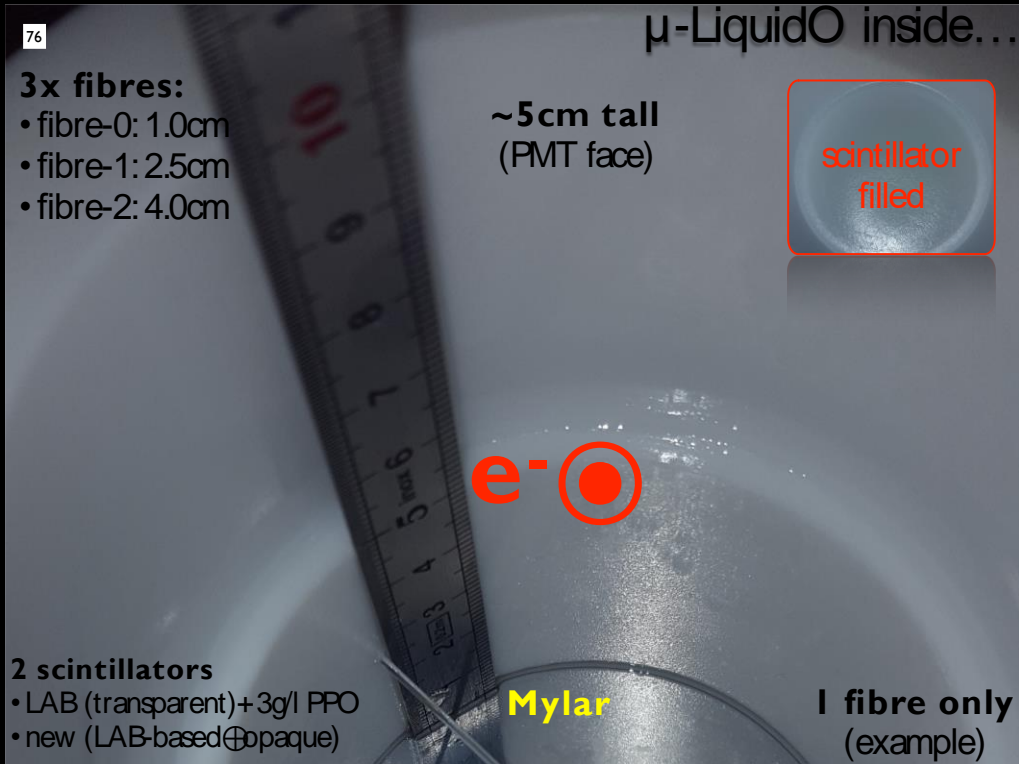
LiquidO

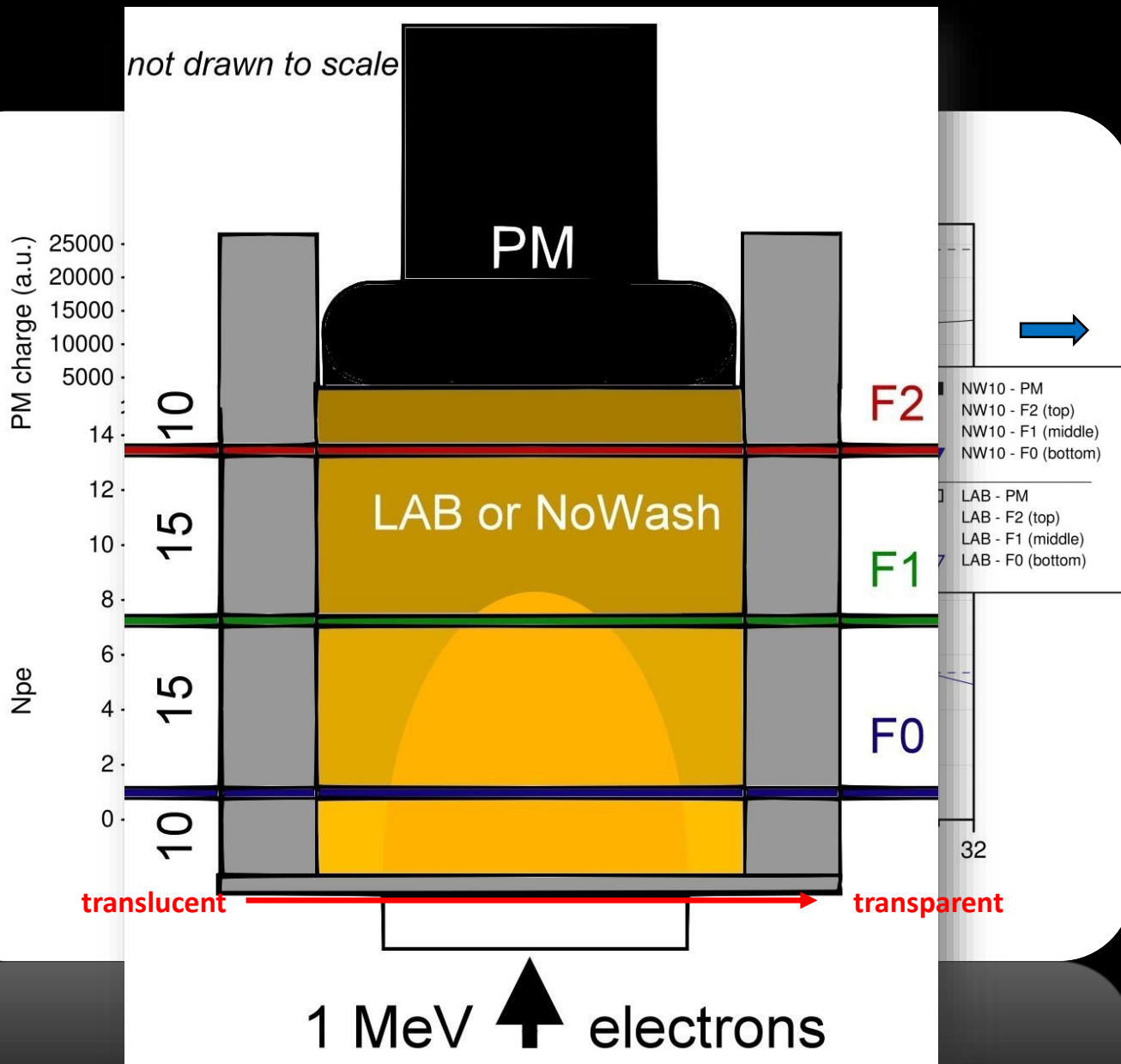
Light "confinement" establishes strong space-time event pattern

Does stochastic light confinement work? YES! μ -LiquidO

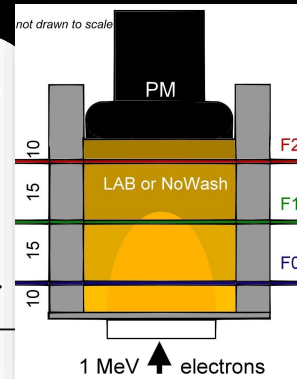
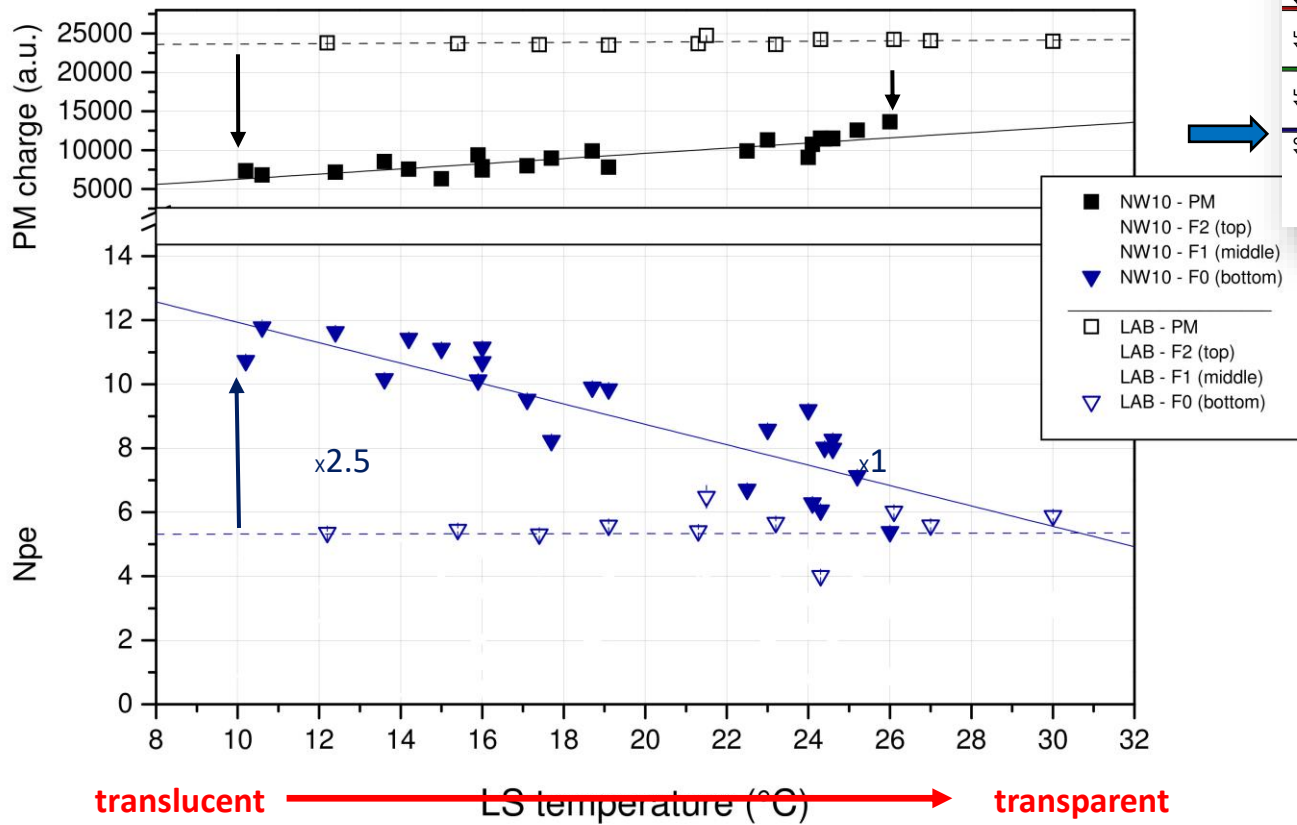


electron beam from SuperNEMO R&D





NoWash 10% & LAB / Fiber 0 (bottom)



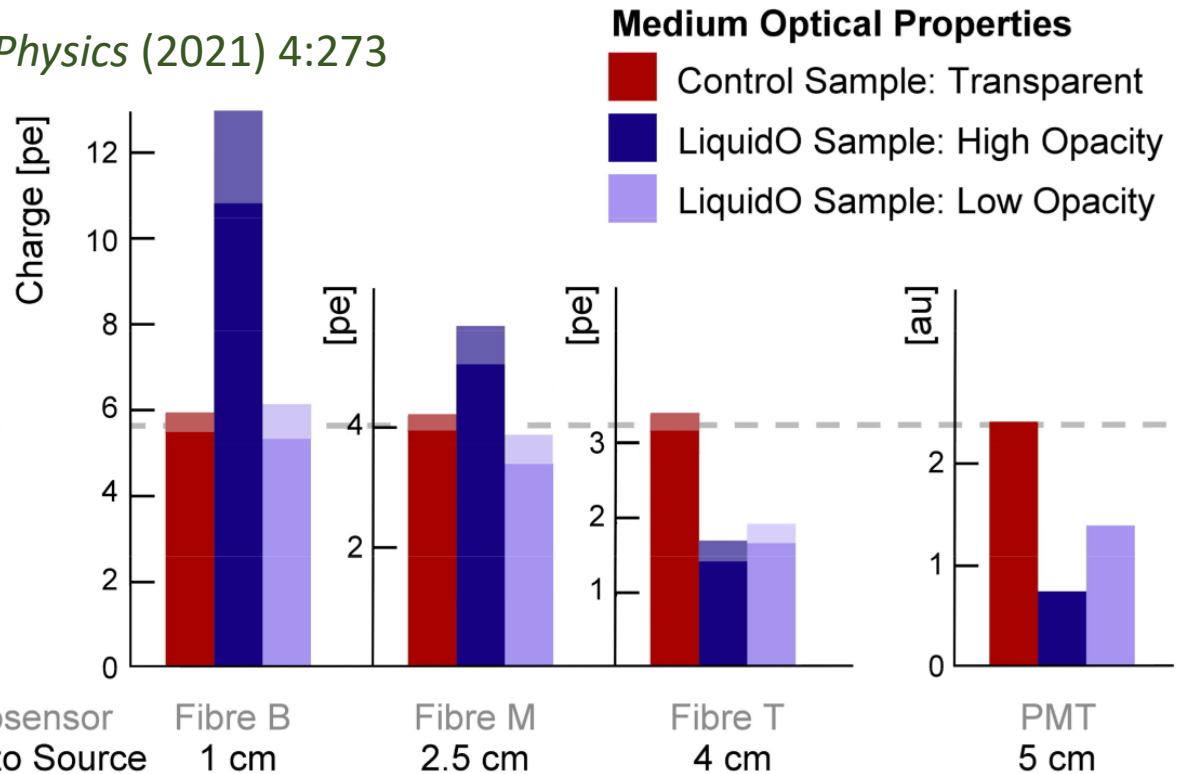
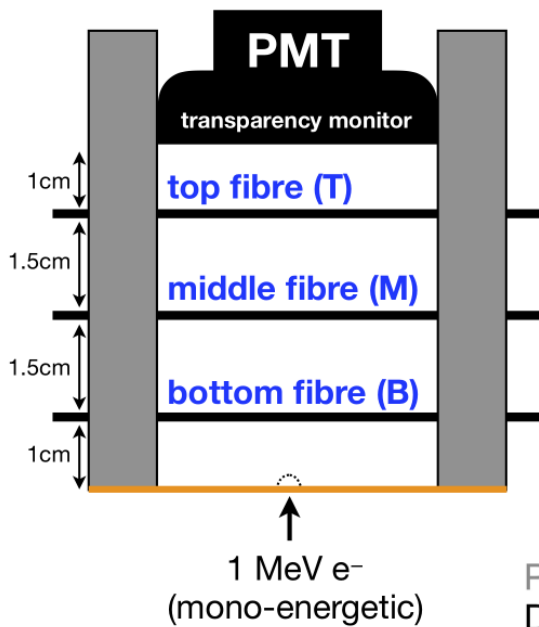
LS temperature (°C)

8 10 15 14 16 18 20 22 24 26 28 30 32

0

Summary of μ -LiquidO demonstration of opacity light confinement

in *Nature's Communications Physics* (2021) 4:273



Review

Advantages of Large Volume Liquid Scintillator viewed by PMTs far away

- Homogeneous volume
- Low background
- Fiducial volume cut to reduce external backgrounds
- *Passive buffer volume needed to shield from PMT radioactivity*

Image: SNO+

negatives in pink

Review

Scintillating, wavelength-shifting fibres can be radiopure and are *active*

GERDA fibre curtain as an example

Advantages of LiquidO Technique readout by fibres+SiPMs

- Active background rejection
- Powerful single-site/multi-site discrimination
- External SiPMs don't require passive buffer
- Fiducial cut includes active detector rejection of external backgrounds
- Liquid scintillator can still be low background
- Added background component: fibres

negatives in pink

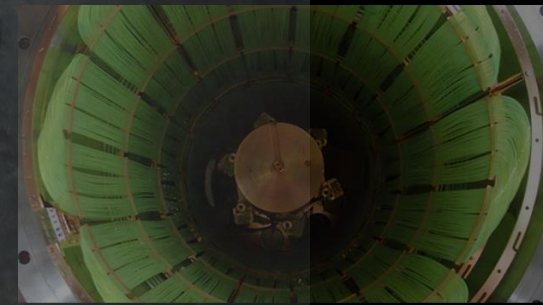
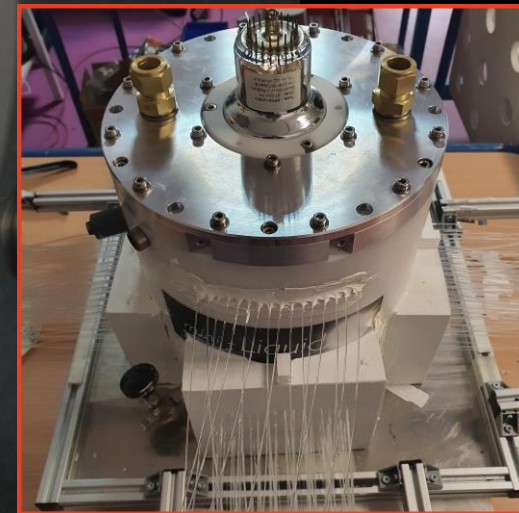


Image: GERDA fibre curtain

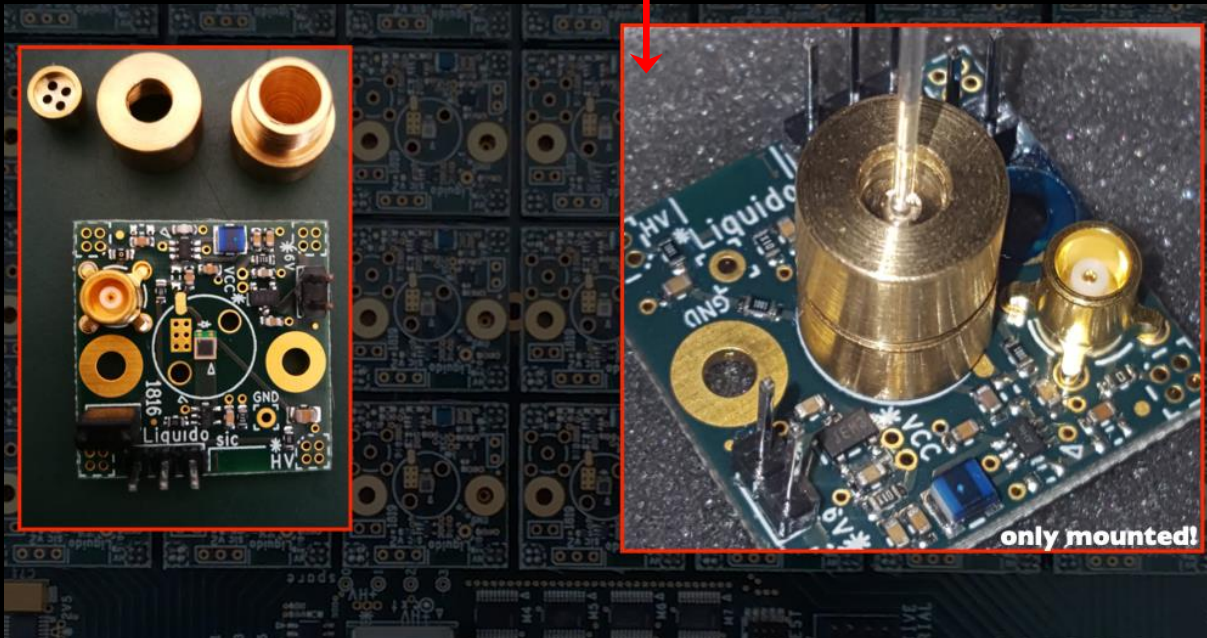
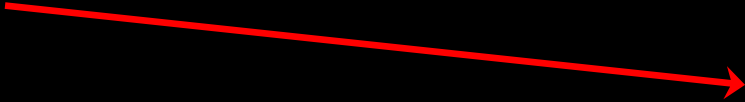


Images: Mini-LiquidO

Next Steps for LiquidO

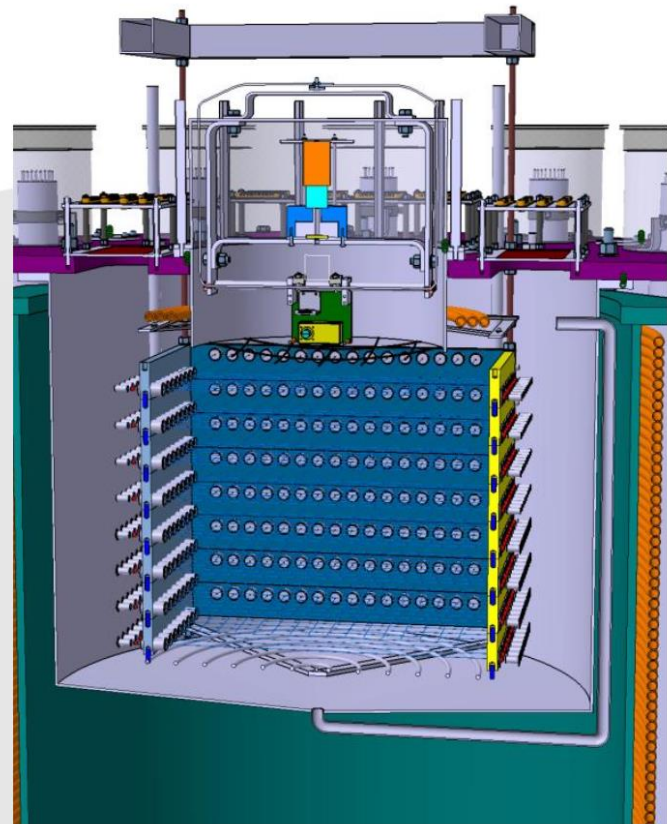
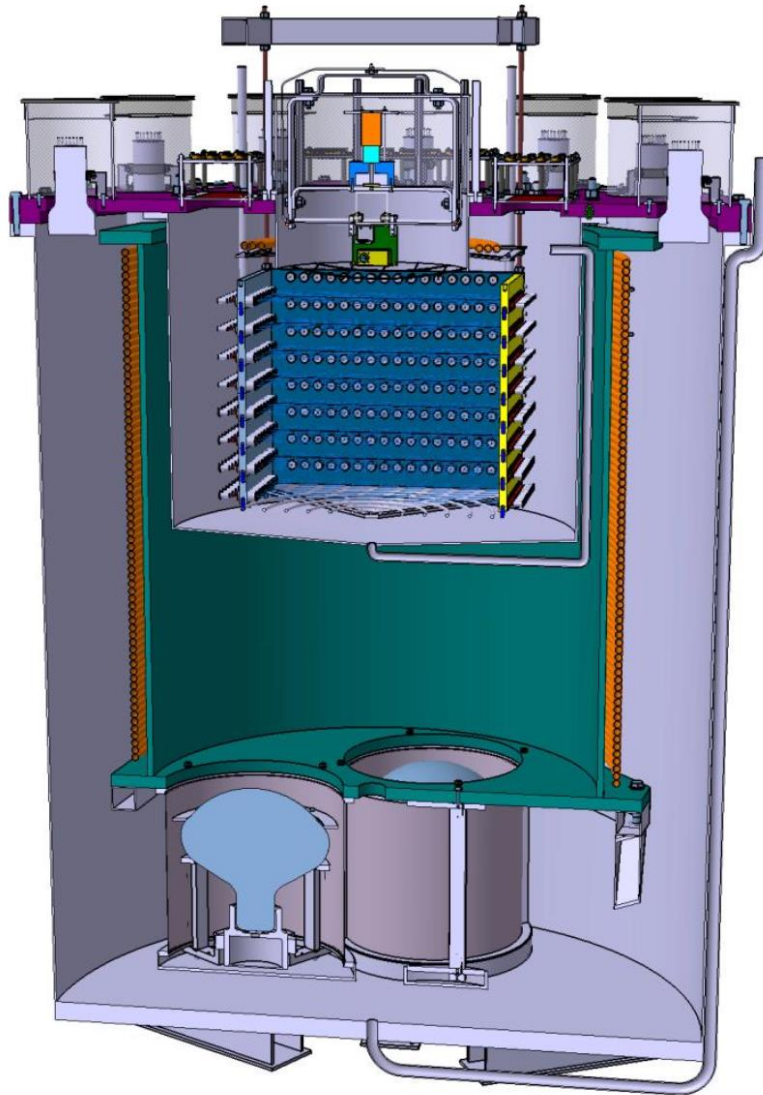
Mini-LiquidO
(has taken data)

w/fast SiPM electronics readout



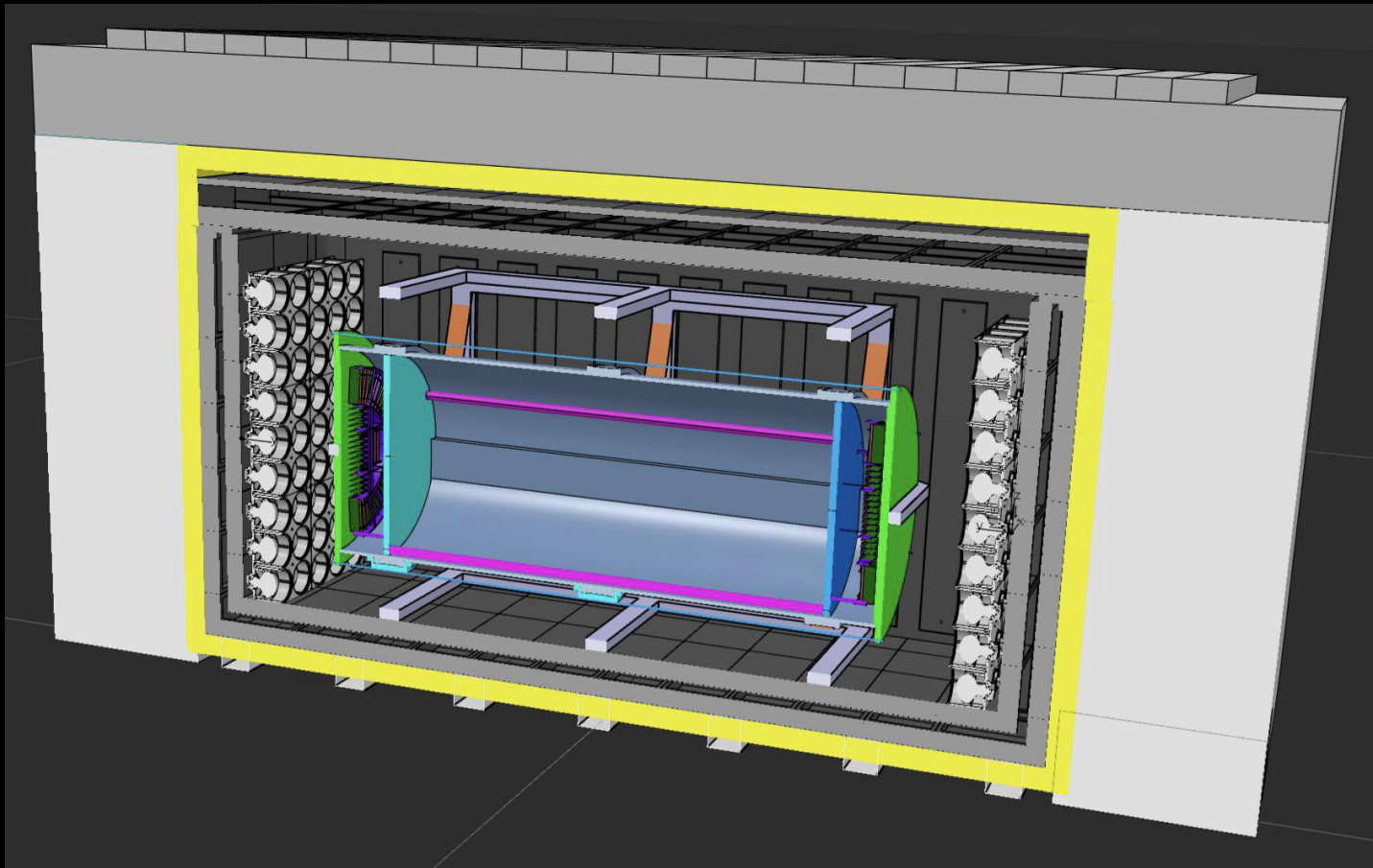
Le détecteur MiniGamma

161 L opaque LS
1021 L transparent LS



~10-ton LiquidO at Chooz

~10,000 fibres+SiPM readout channels (GHz waveforms)



Chooz LiquidO Ultra-near Detector

CLOUD



Baseline: ~ 30 m
Overburden: ~ 3 mwe



IBD antineutrino rate:
 ~ 15 events/minute

Summary

*LiquidO is a novel approach for liquid scintillator
neutrino detection*

Exciting neutrino physics potential

EVENT ID \oplus RELAXED LS REQUIREMENTS

Thanks!