Liquid

novel neutrino detection

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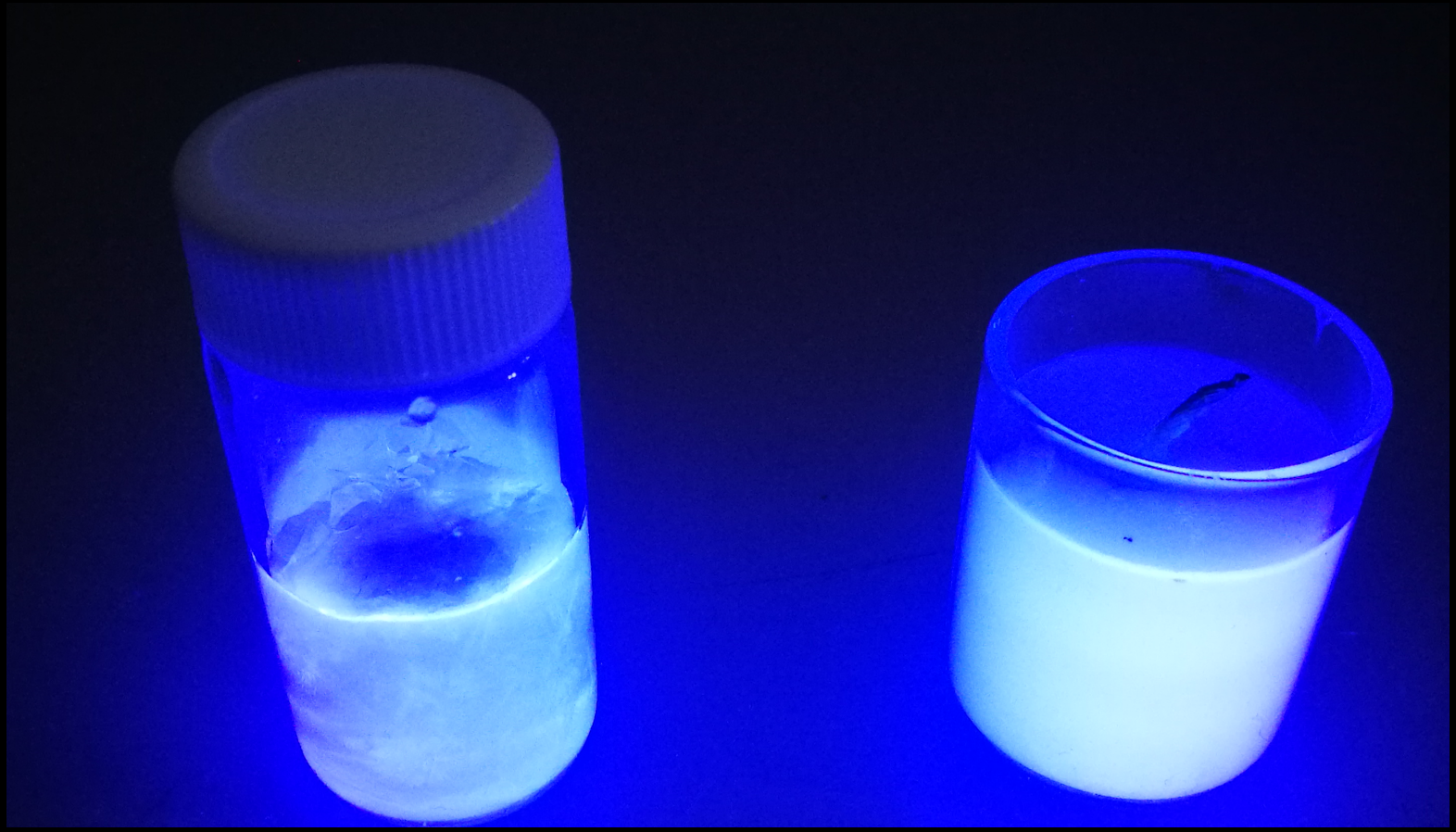
What is LiquidO? → O is for “Opaque”

R&D towards a new “liquid” scintillator detection technique



How to readout an "opaque" scintillator?

grid of wavelength-shifting fibres

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

Z info: timing along fibre (~cm resolution)

SiPM fibre readout (photon counting)

(everybody ❤️ SiPMs these days)

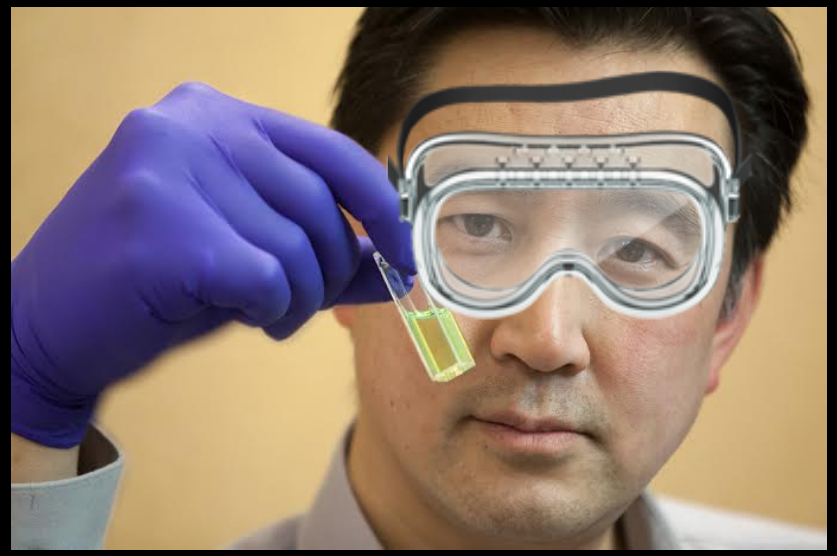
"It's like a light TPC or photon drift chamber"

Image: CDF central tracker

Why LiquidO?

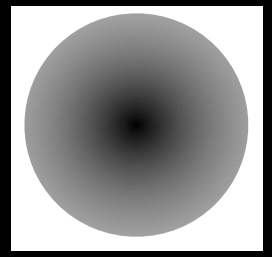
- spatial and temporal event ID and pattern information provides **strong background rejection**

- relaxing the scintillator transparency requirement opens many doors for liquid scintillator design options

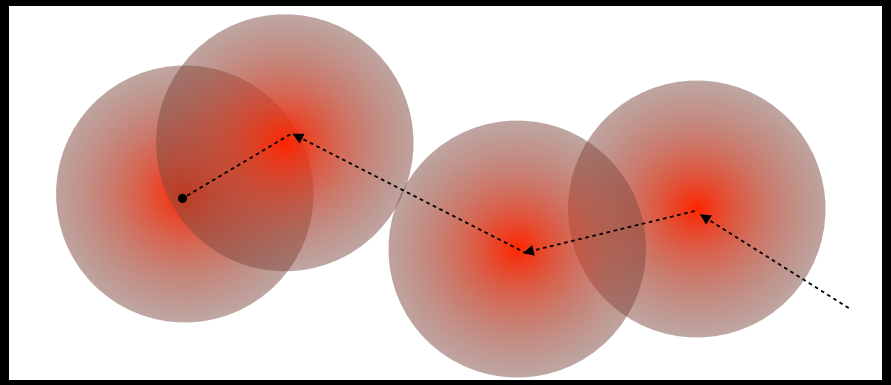


Event Identification

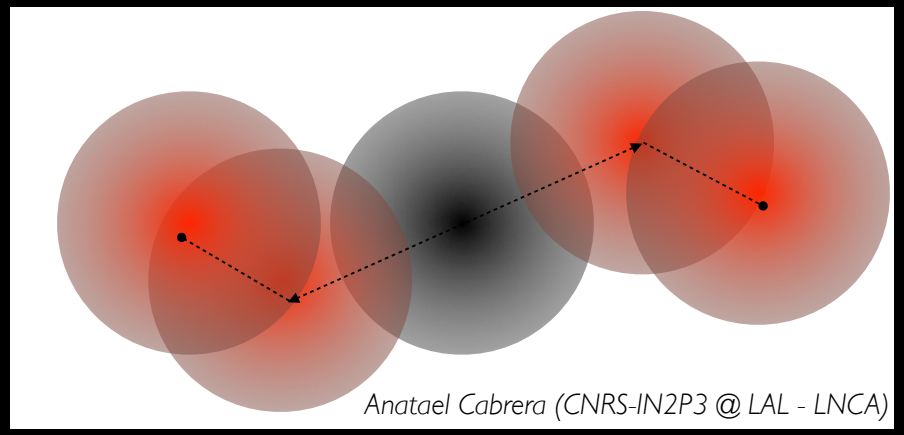
- Single Site (electrons, alphas, proton recoils)



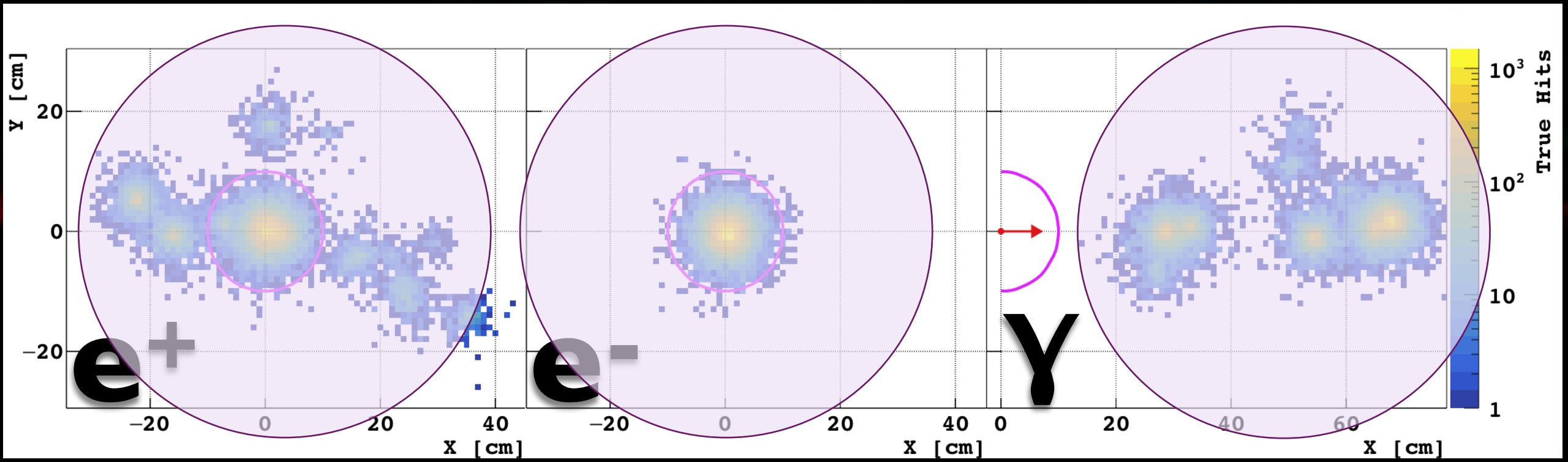
- Multi Site (gammas)



- Positrons!



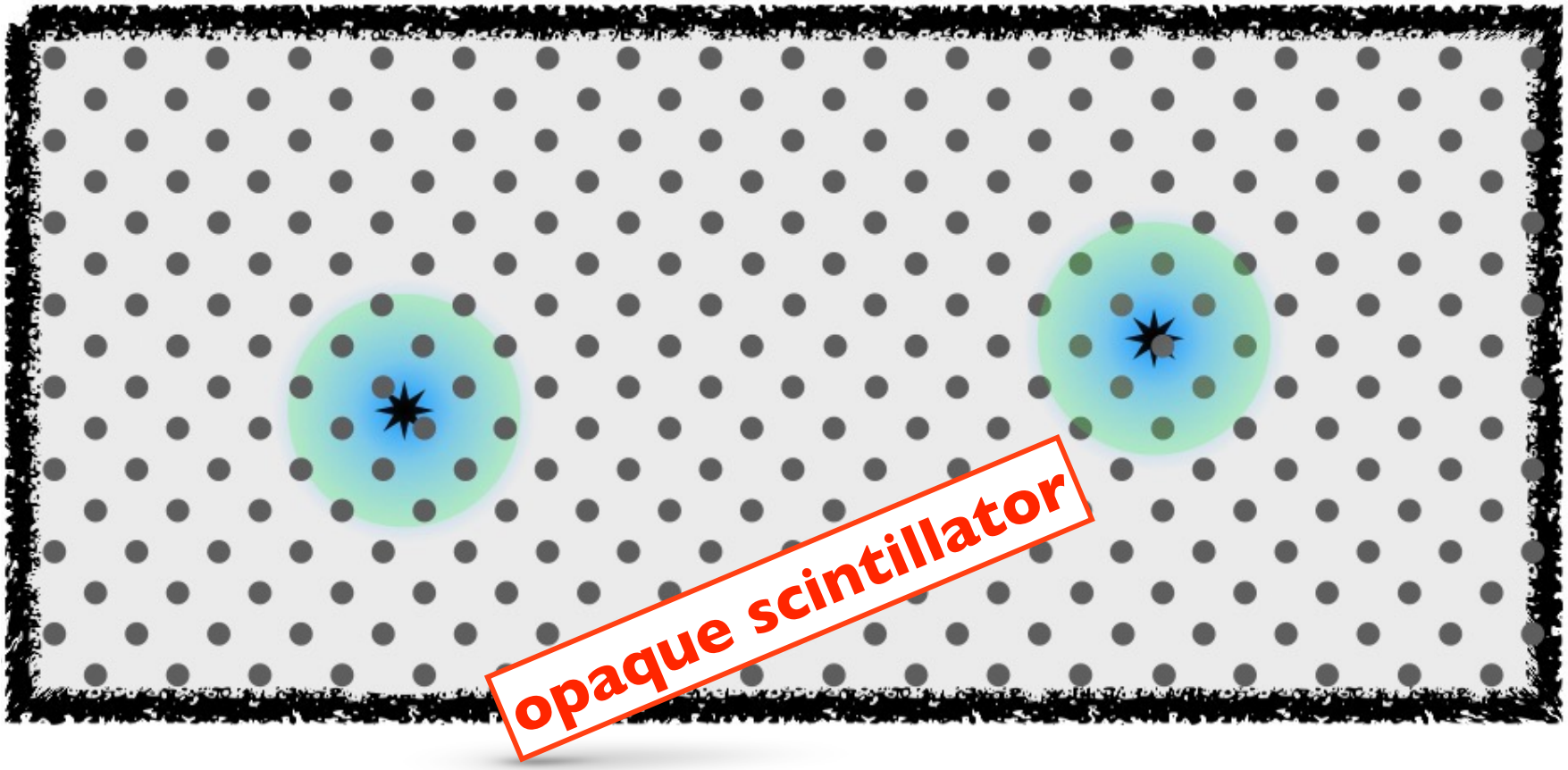
LiquidO Simulations – 2 MeV



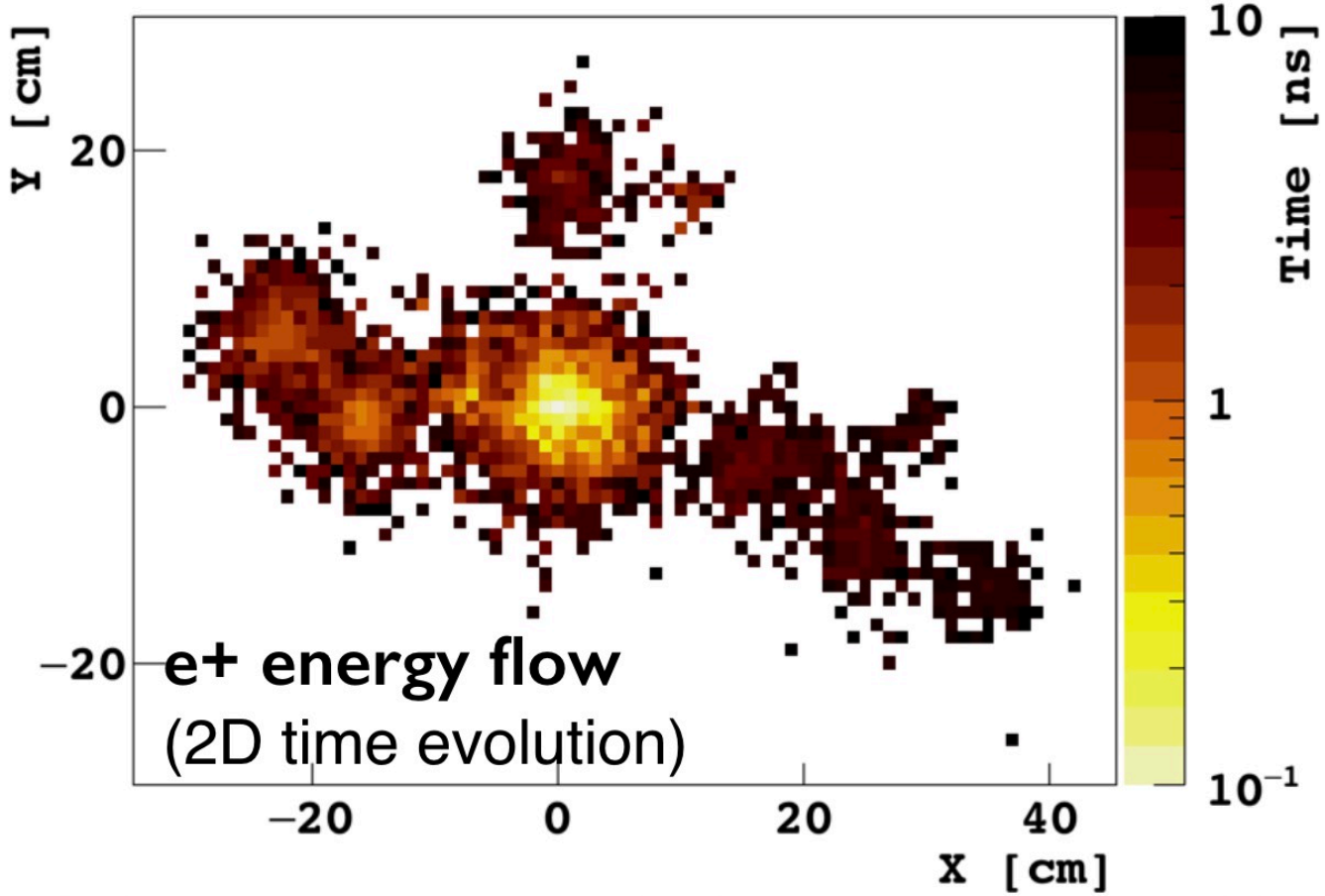
In contrast: how do PMTs from far away see such events?
…as mostly indistinguishable large balls of light!

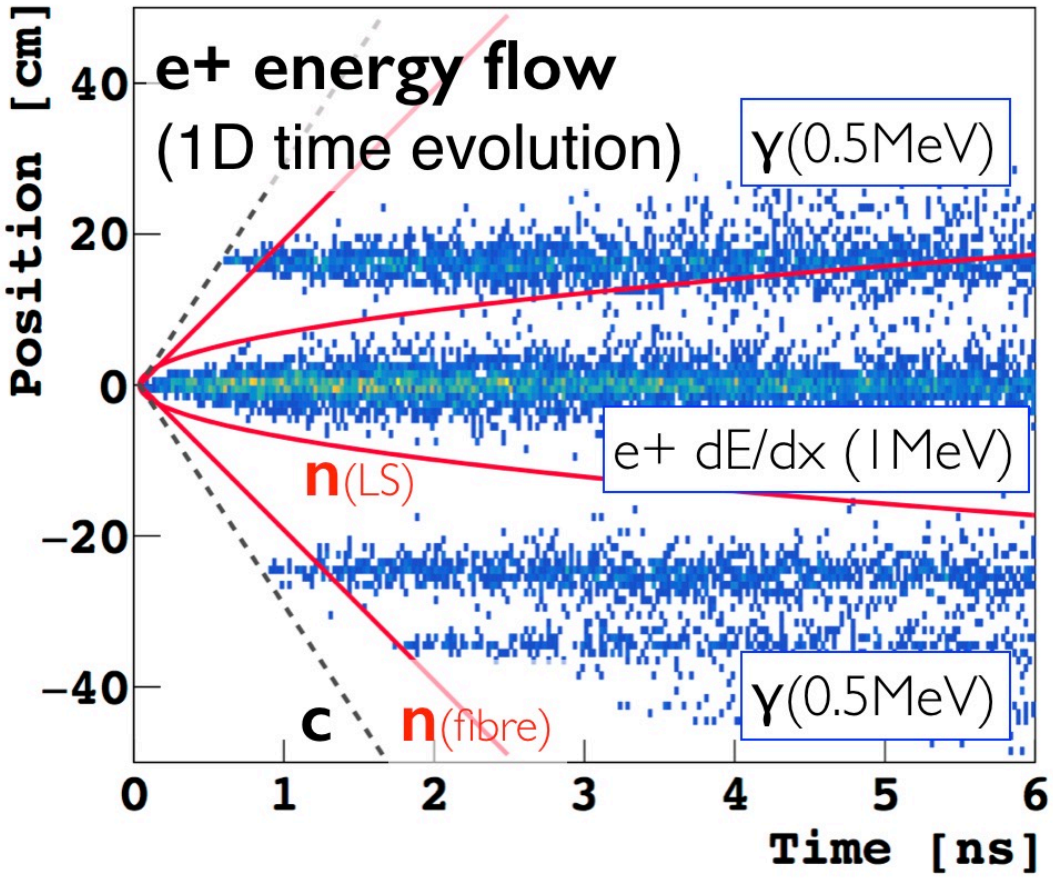
Light Confinement – opaqueness helps

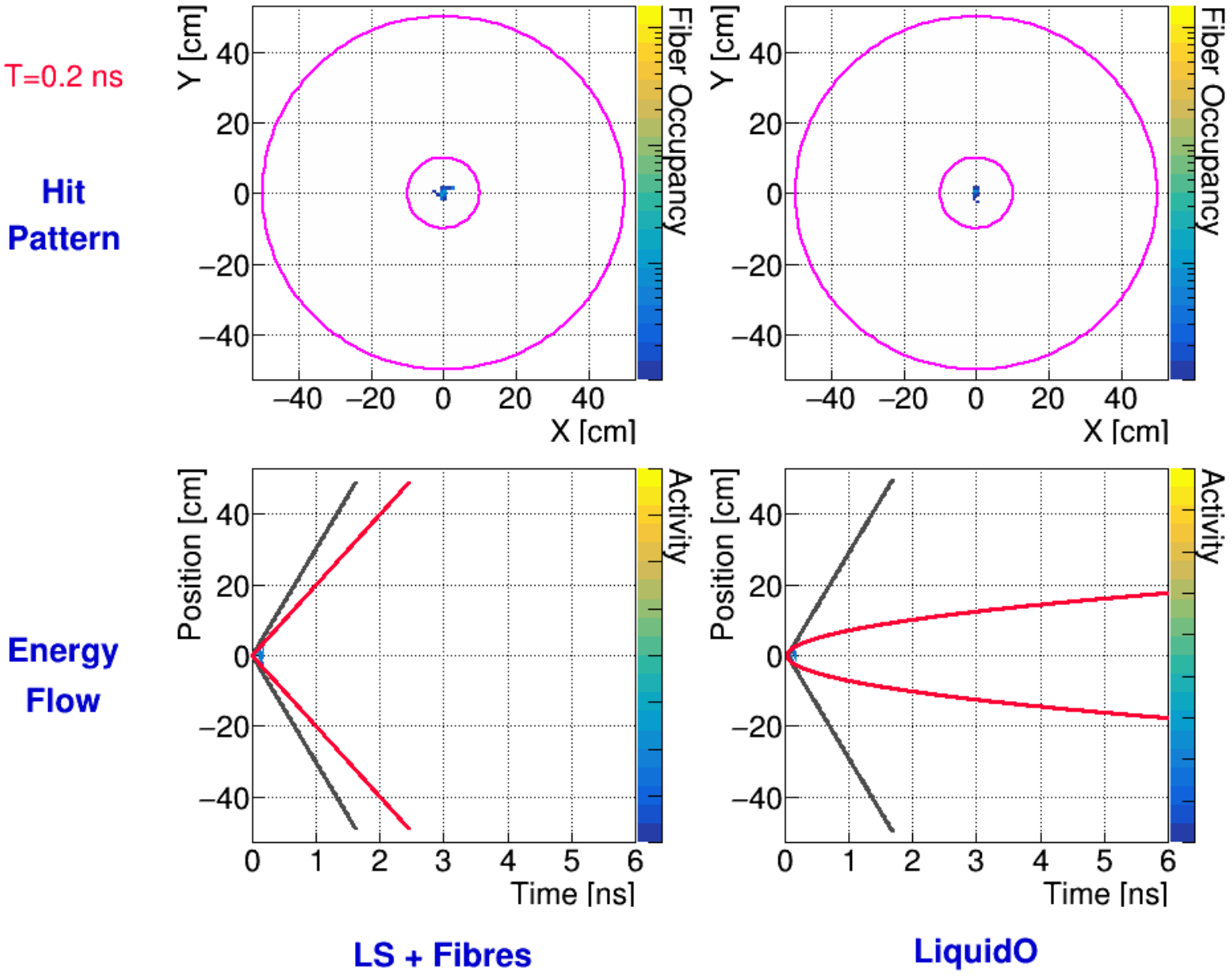
confine energy deposition locally → freeze information



“Energy Flow”

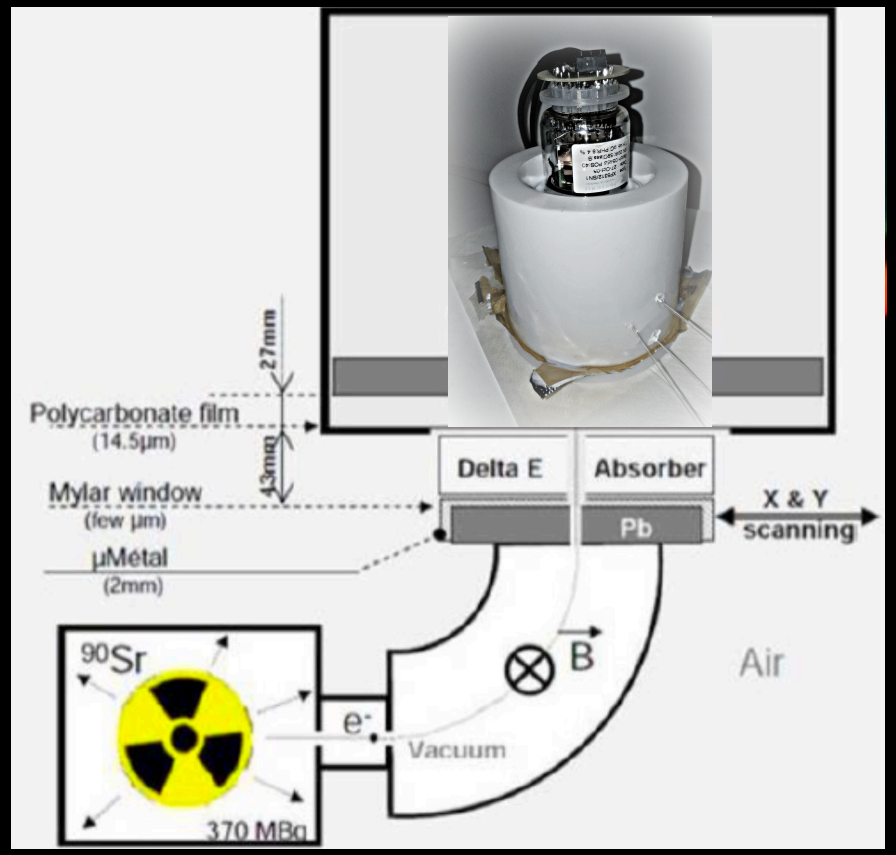

e+ energy flow
(2D time evolution)
Y [cm]
X [cm]
Time [ns]
20
0
−20
−20
0
20
40
10
1
10^{-1}


e+ energy flow
(1D time evolution)
γ(0.5MeV)
e+ dE/dx (1MeV)
γ(0.5MeV)
n(LS)
n(fibre)
C
Position [cm]
Time [ns]
40
20
0
−20
−40
0
1
2
3
4
5
6

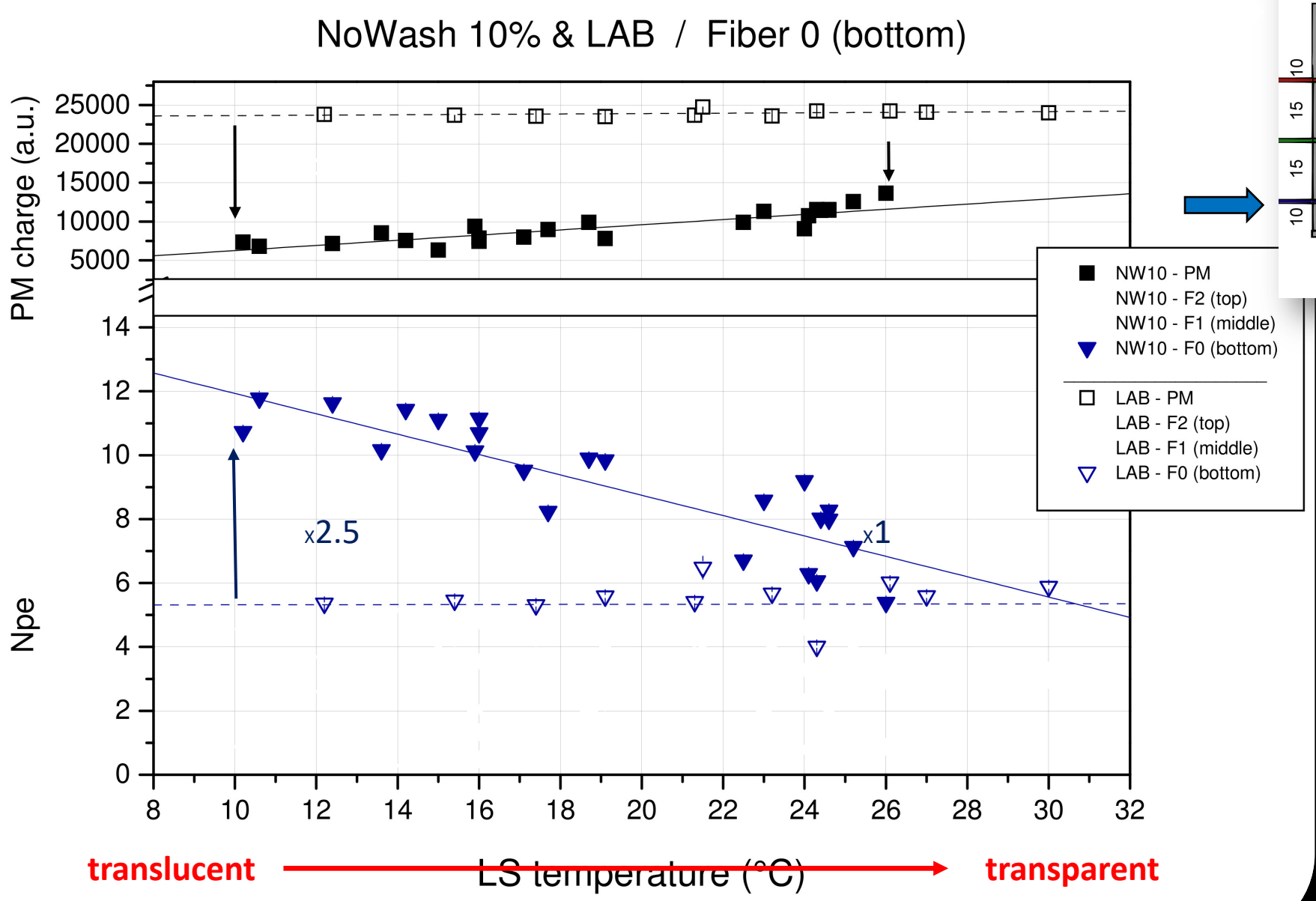


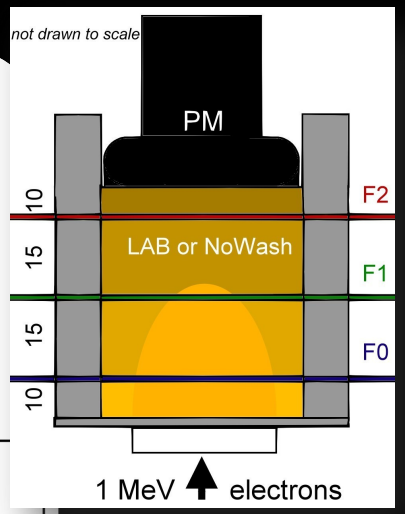
Light “confinement” establishes strong space-time event pattern

Does it actually work? YES! μ-LiquidO



electron beam from SuperNEMO R&D


NoWash 10% & LAB / Fiber 0 (bottom)
PM charge (a.u.)
25000
20000
15000
10000
5000
Npe
14
12
10
8
6
4
2
0
8
10
12
14
16
18
20
22
24
26
28
30
32
x2.5
x1
NW10 - PM
NW10 - F2 (top)
NW10 - F1 (middle)
NW10 - F0 (bottom)
LAB - PM
LAB - F2 (top)
LAB - F1 (middle)
LAB - F0 (bottom)
translucent
LS temperature (°C)
transparent


not drawn to scale
PM
LAB or NoWash
F2
F1
F0
10
15
15
10
1 MeV
electrons

Advantages of Large Volume Liquid Scintillator
viewed by PMTs far away

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

Image: SNO+

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 is still low background
- added background component: fibres

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

GERDA fibres shown as an example

Image: GERDA fibre curtain

Examples of LiquidO Neutrino Physics

- Reactor Antineutrinos: $\bar{\nu}_e + p \rightarrow e^+ + n$
  - Unmistakable positron signature
- Neutrinoless Double Beta Decay
  - Very highly loaded translucent liquid scintillator (i.e. SNO+ Te *on steroids*)
  - Powerful single-site/multi-site background rejection
- …and much more!

Summary

- Who – LiquidO Proto-Collaboration
  - ~45 scientists, 20 institutions
  - Brazil, Canada, Chile, China, France, Germany, Italy, Japan, Spain, UK, USA
- What – (Slides 2-3)
- Why – (Slides 4-9, 13-14)
- When and Where – *coming soon to an underground lab near you!*