

European
Innovation
Council



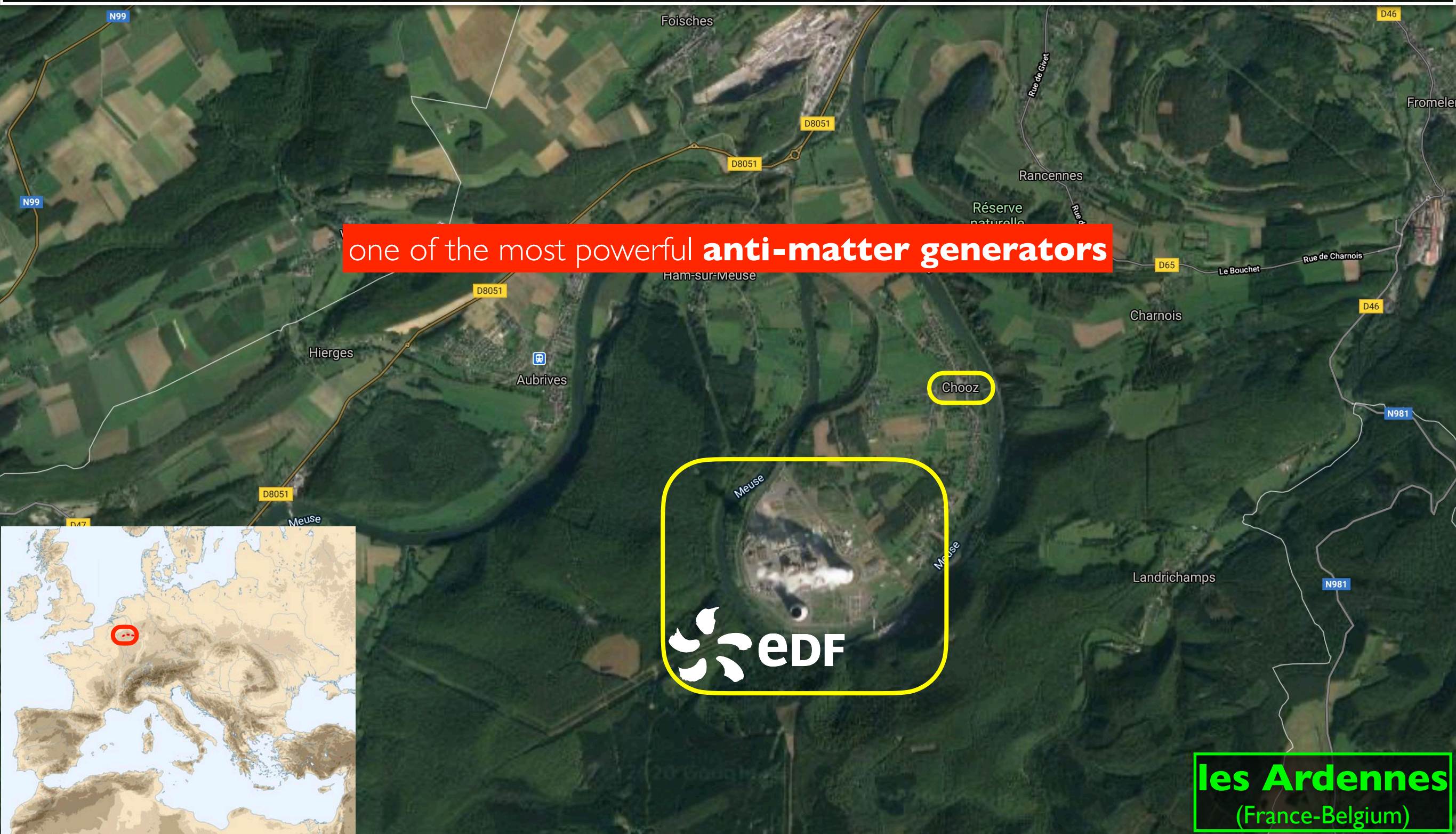
UK Research
and Innovation

C L O U D

solving the reactor puzzle(s) at Chooz?

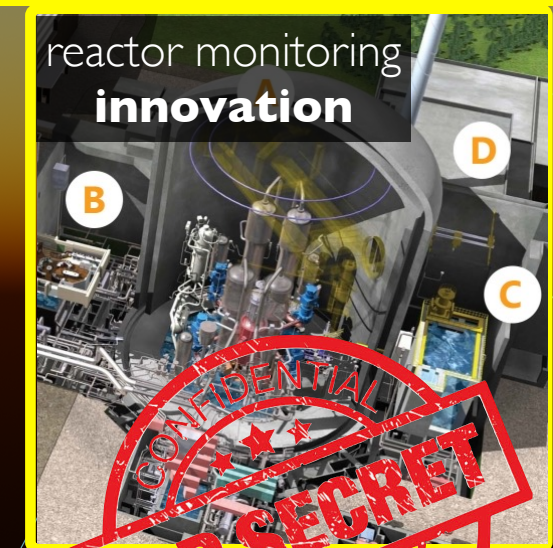
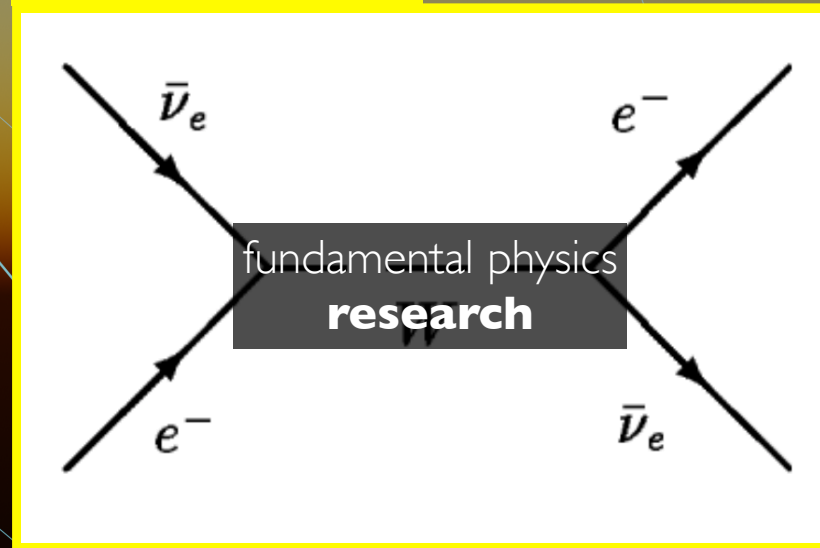
CPNR Workshop 2025 “Neutrino & Physics Beyond SM”
26 October 2025 — CNU (South Korea)

in the **middle of central Europe** (between France-Belgium): **Chooz** [meeting point with Germany, Luxembourg, Netherlands]



Europe's most powerful reactor site...

3rd generation of reactor neutrino experiments @ Chooz



antineutrino (neutrino?): $\sim 10^{21}$ v/s per core

Chooz-B: Nuclear Reactor Cores

the most powerful source on Earth

experimental setup...

- Detector Mass: $\sim [5, 10]$ ton — **LiquidO** technology
- Overburden: ~ 3 mwe
- Baseline: ≥ 30 m (**Ultra Near Detector** site @ Chooz)
- Rate: $\sim 25,000$ anti- ν per day — $\sim 10M$ anti- ν per year

CLOUD vs AntiMatter-OTech...

on behalf of the **AntiMatter-OTech consortium...**

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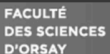
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AntiMatter  Tech
project's first release

 **IAEA**
International Atomic Energy Agency

3rd IAEA Technical Workshop on Antineutrino
SNU, Seoul (South Korea) — April 2025

Anatael Cabrera
CNRS / Université Paris-Saclay — IJCLab (Orsay) / LNCA (Chooz)
France
Scientific collaboration @ Institute of Astrophysics of the Canaries,
Spain

    Université
de Paris



(co)spokesperson:
• DoubleChooz
• LiquidO
• CLOUD — AntiMatter-OTech (EIC)
• SuperChooz Pathfinder

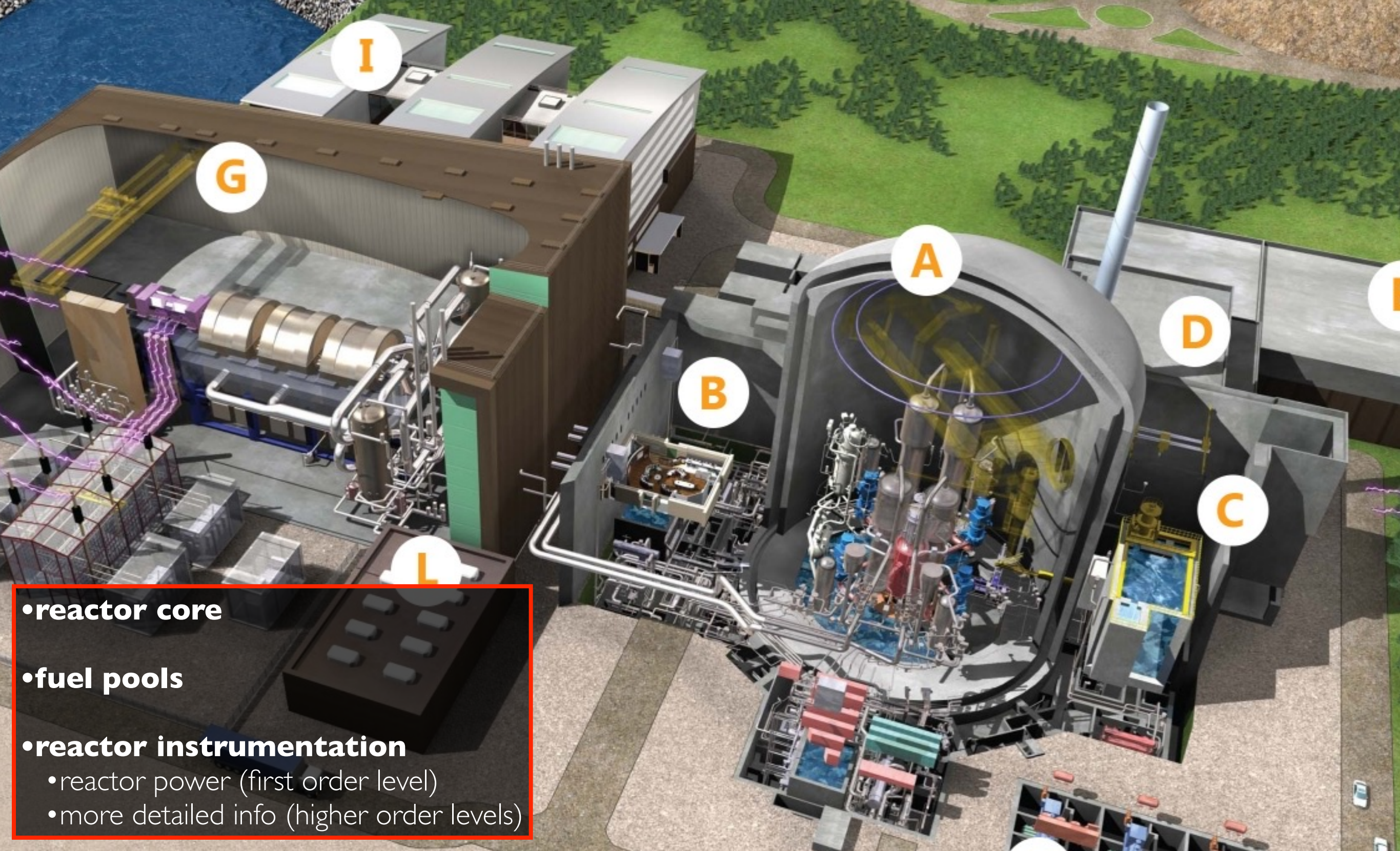
<https://doi.org/10.5281/zenodo.15198757>

AntiMatterOTech first release...

C L O U D

reactor neutrinos **experimental methodology largely similar** for the last **~70 years** (Reines et al.)
powerful framework so far, but **good enough for discoveries ≥ 2025 ?**

on the shoulders of giants...



- **reactor core**

- **fuel pools**

- **reactor instrumentation**

- reactor power (first order level)
- more detailed info (higher order levels)

nuclear reactors...

powerful experimental framework

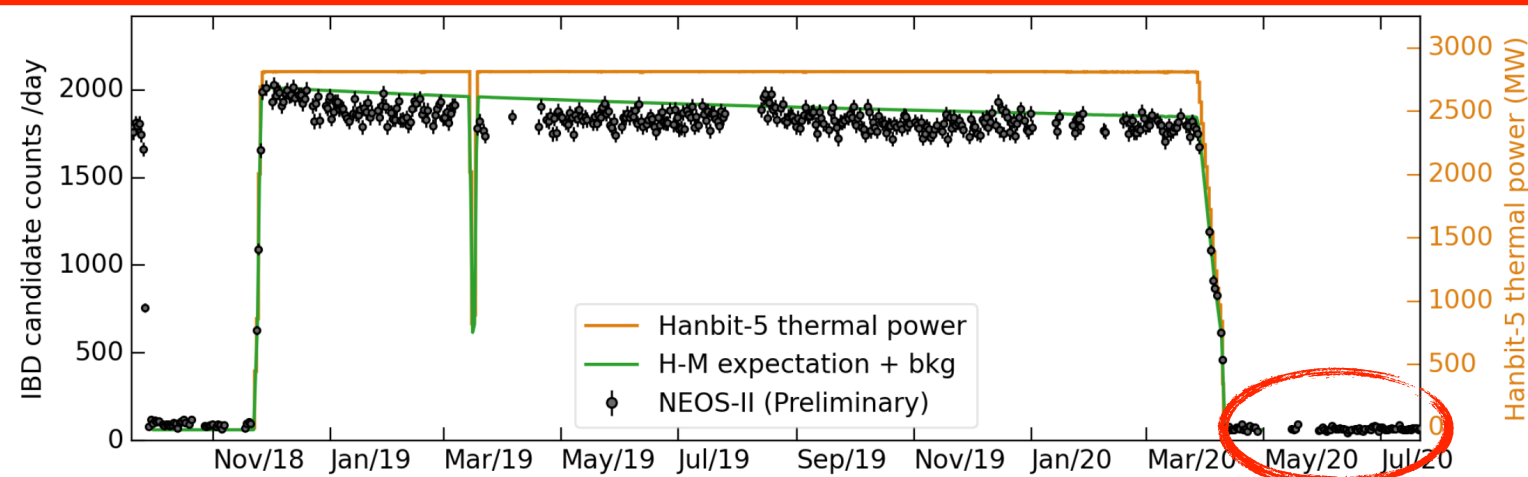
• **IBD(p)**: one interaction (**CC**)

→ **NC** still very difficult

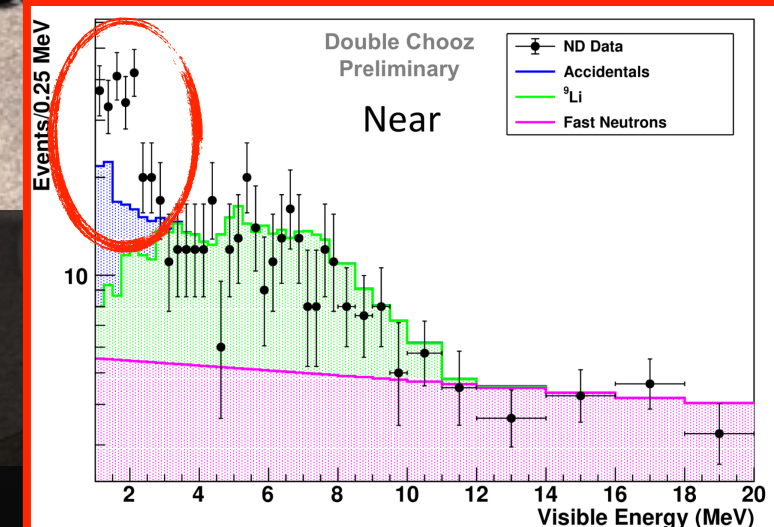
• **flux**: **several issues!**

status: **issues vs physics?**

NEOS-II data (rate ≈ 2000 IBD per day)



DC-ND data



nuclear reactors...

future: discoveries?

today's BG: *standard neutrino oscillation*

neutrino+weak-interaction remains **bizarre feature** in the **SM** (Majorana, etc)...

- new neutrino **phenomenology**? [ex. mixing and masses]
- new neutrino **interactions**?
- new neutrino **states**? [assume: “3+1 sterile” is largely ruled out]

C L O U D

a probe to the future?
(let's try)

the experiment...

today, **most experiments** bypass (whenever possible) the **absolute flux knowledge** — complex!
relative knowledge (ex. multi-detector, etc.) well suited to **extract “known model” parameters**



confront **absolute flux knowledge** for **new neutrino physics** via “*flux bias explorations*”

- **extreme signal** (to BG) rates — unprecedented
- *must*: the **best-known cross-section**(s) today ($\leq 1\%$)
- **extreme energy control** ($\leq 1\%$) — avoid spectral distortions ($\rightarrow$ flux biases)
- **much redundancy** — as much as Nature kindly allows...

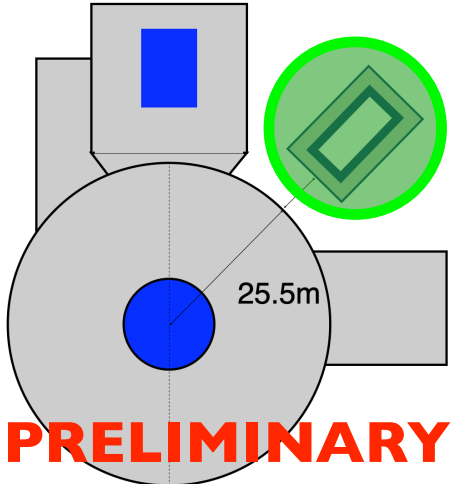
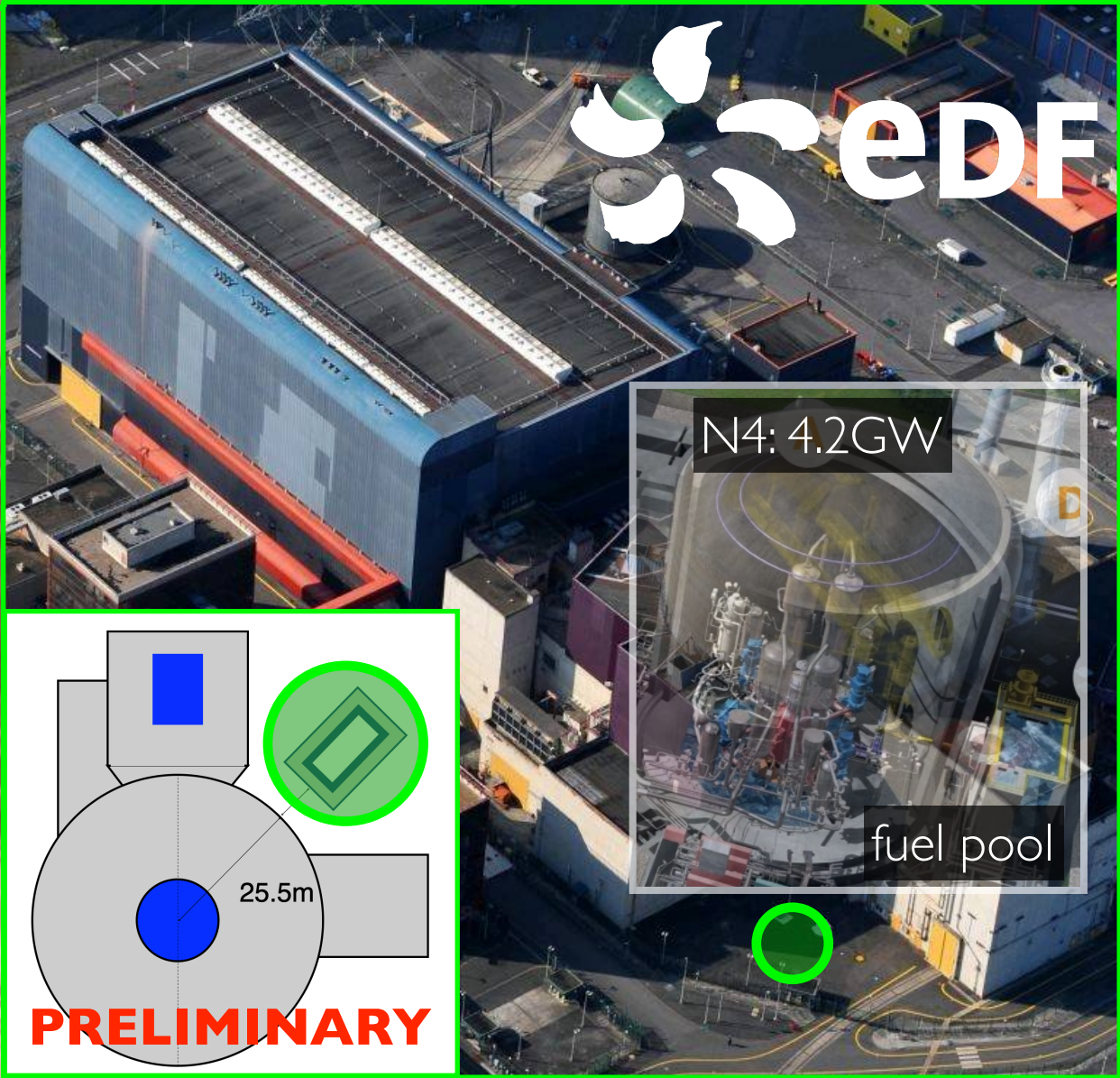
Chooz-B Power Station

- facility: EDF CNPE
- location: Chooz (France)
- reactor cores: 2x PWR AREVA-N4
- thermal power: 8.4GW (total)

Double Chooz
Near Detector

LNCA-Hall (CNRS)

Ultra Near Detector (UND) sites



ON

OFF

N4: 4.2GW

fuel pool

PRELIMINARY

due to global warm → more frequent reactor-OFF (2022: several months)

CLOUD = "Chooz Liquid **U**ltraneur **D**etector"

Double Chooz
Far Detector

Europe's best reactor-V site...

Water Pool [20,40]cm thick

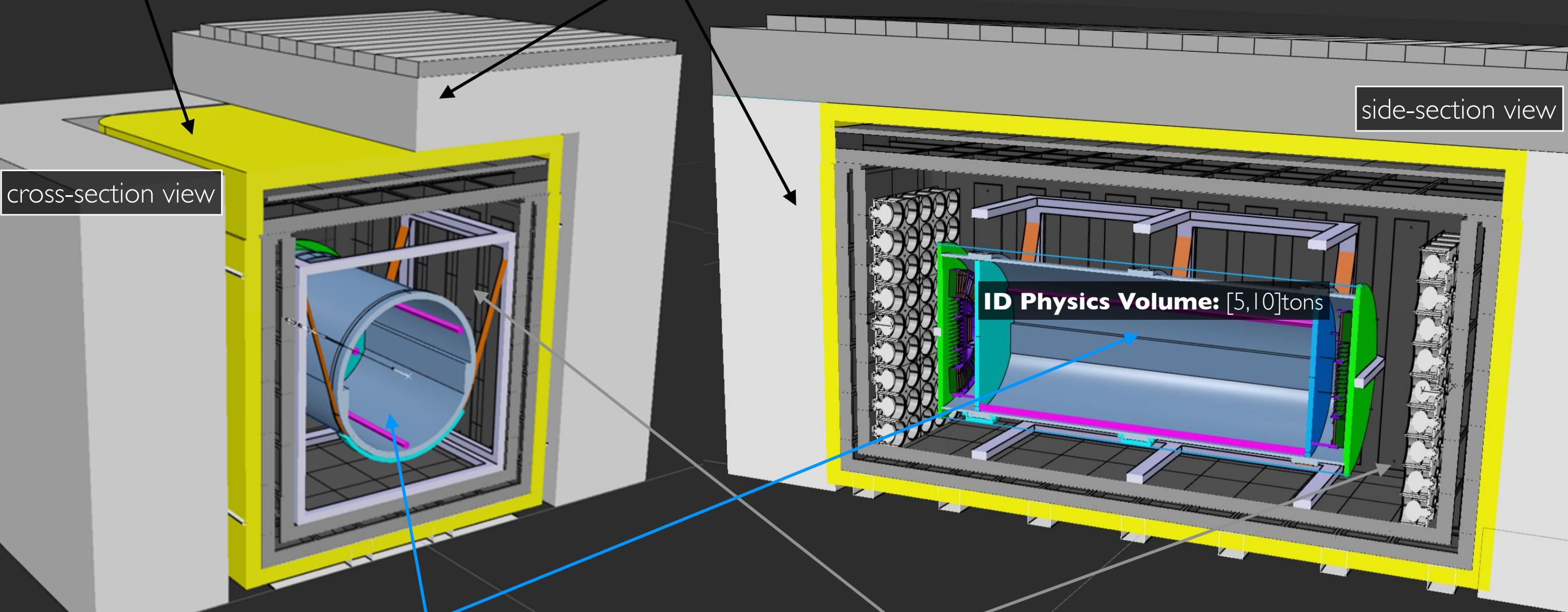
- 4π shield & neutron moderator
- controllable thermal-bath

IGLOO [~ 3 mwe]

- concrete **bunker** (with boron?)
- DC's iron steel shield (15cm thick)

Redundant “surface neutron” layers...

- **IGLOO** (absorption) — passive
- **Water** (moderator $\oplus$ absorption) — passive
- **Armour** (veto $\oplus$ moderator $\oplus$ absorption) — **OD**
- **Tracker** (PID $\oplus$ moderator) — **ID**



LiquidO-Tracker (or **inner-detector**) [≤ 10 tons fiducial]

- opaque scintillator — new formulation(s) [more on this soon]
- **$\sim 10,000$ fibres $\oplus$ SiPM** readout channels (GHz waveforms)
- designed light level: ≥ 200 pe/MeV

ARMOUR (or **outer-detector**) [~ 0.5 m thickness]

- transparent scintillator (LAB $\oplus$ PPO $\oplus$ Bis-MSB)
- **≤ 180 DC-PMTs** & highly reflecting walls
- designed light yield ≥ 400 pe/MeV

CLOUD detector...

experimental setup...

- Detector Mass: $\sim [5, 10]$ ton — **LiquidO** technology
- Overburden: ~ 3 mwe
- Baseline: ≥ 30 m (**Ultra Near Detector** site @ Chooz)
- Rate: $\sim 25,000$ anti- ν per day — ~ 10 M anti- ν per year

our collaboration...

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CLOUD

CLOUD International collaboration

- **EDF** (France) — **first time in neutrino science**
- **Brookhaven National Laboratory** (USA)
- **Charles University** (Czechia)
- **CIEMAT** (Spain)
- **IJCLab** / Université Paris-Saclay (France)
- **Imperial College London** (UK)
- **INFN-Padova** (Italy)
- **Instituto Superior Técnico** (Portugal)
- **Johannes Gutenberg Universität Mainz** (Germany)
- **Pennsylvania State University** (USA)
- **Pontifícia Universidade Católica do Rio de Janeiro** (Brazil)
- **Queen's University** (Canada)
- **Subatech / Nantes Université** (France)
- **Tohoku University / RCNS** (Japan)
- **Universidad de Zaragoza** (Spain)
- **Universidade Estadual de Londrina** (Brazil)
- **University of California Irvine** (USA)
- **University of Michigan** (USA)
- **University of Sussex** (UK)

⇒ 19 institutions in 11 countries

Spokespersons:

- A. Cabrera — IJCLab / Université Paris-Saclay (France)
- J. Hartnell — Sussex University (UK)

IB Chair:

- M. Chen — Queen's University (Canada)

Webs:

<https://antimatter-otech.ijclab.in2p3.fr/> [AMOTech]

<https://liquido.ijclab.in2p3.fr/nucloud> [via LiquidO]

powered by...

L I Q U I D



First Release at CERN July 2019 (detector seminar)

<https://indico.cern.ch/event/823865/>

nature communications physics

Article | [Open access](#) | Published: 21 December 2021 **COVID delayed**

Neutrino physics with an opaque detector

[LiquidO Consortium](#)

[Communications Physics](#) 4, Article number: 273 (2021) | [Cite this article](#)

10k Accesses | 29 Citations | 27 Altmetric | [Metrics](#)

Publication “LiquidO-Zero”

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.

www.nature.com/articles/s42005-021-00763-5

Neutrino 2022

(June 2022)

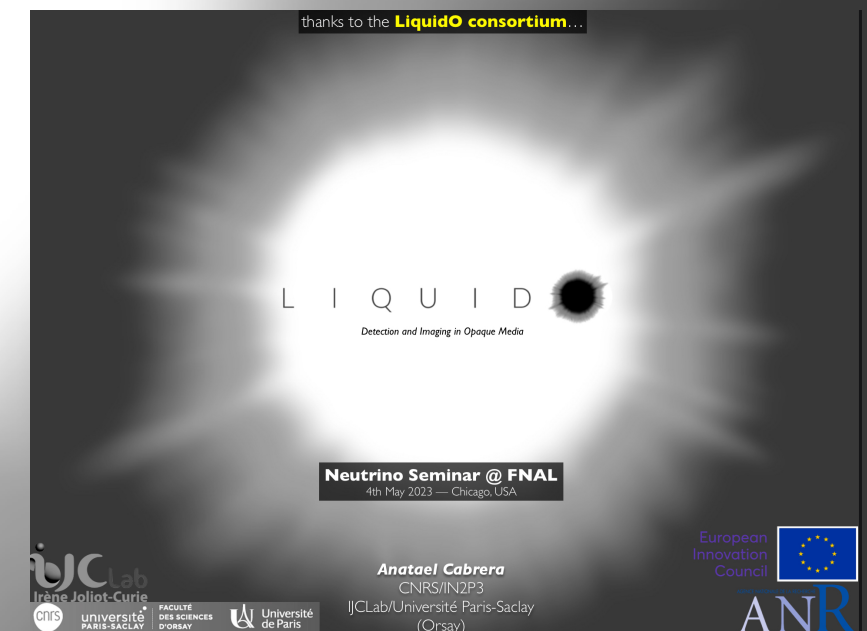


<https://zenodo.org/record/6697273>

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FNAL Seminar 2023

(May 2023)

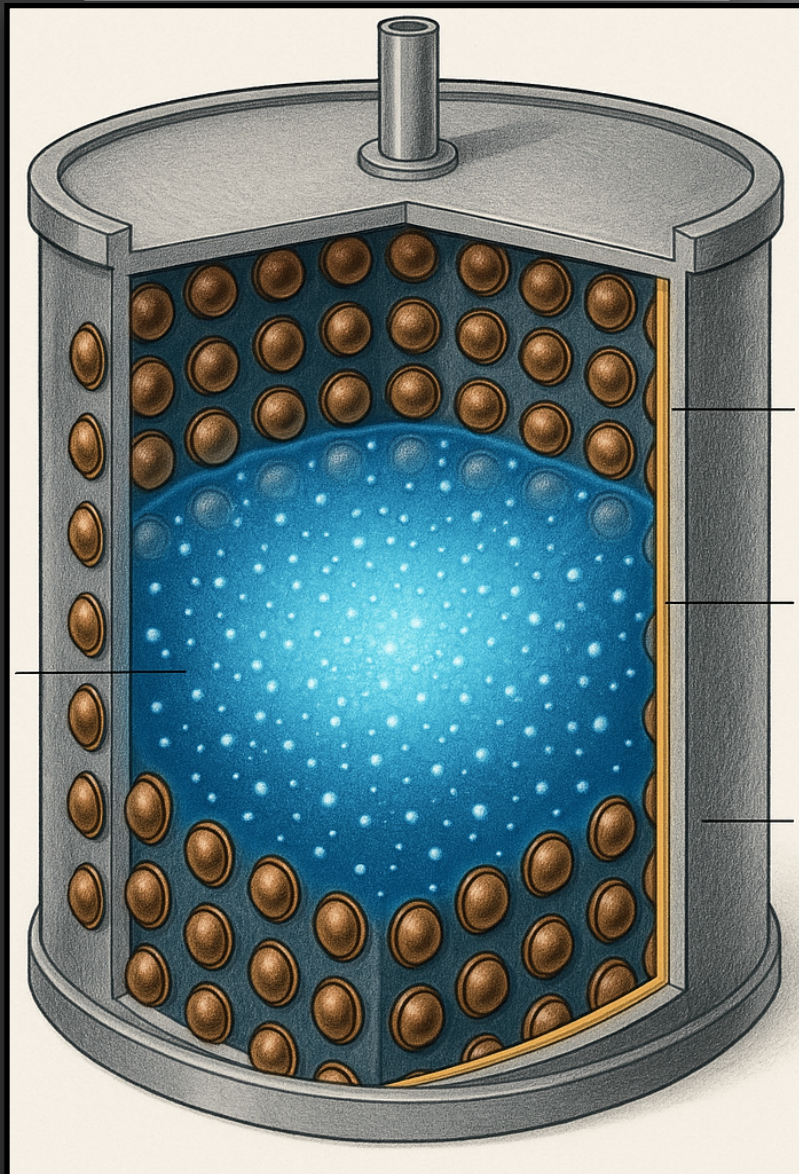


<https://zenodo.org/records/7922021>

LiquidO Official WEB: <https://liquido.ijclab.in2p3.fr/>

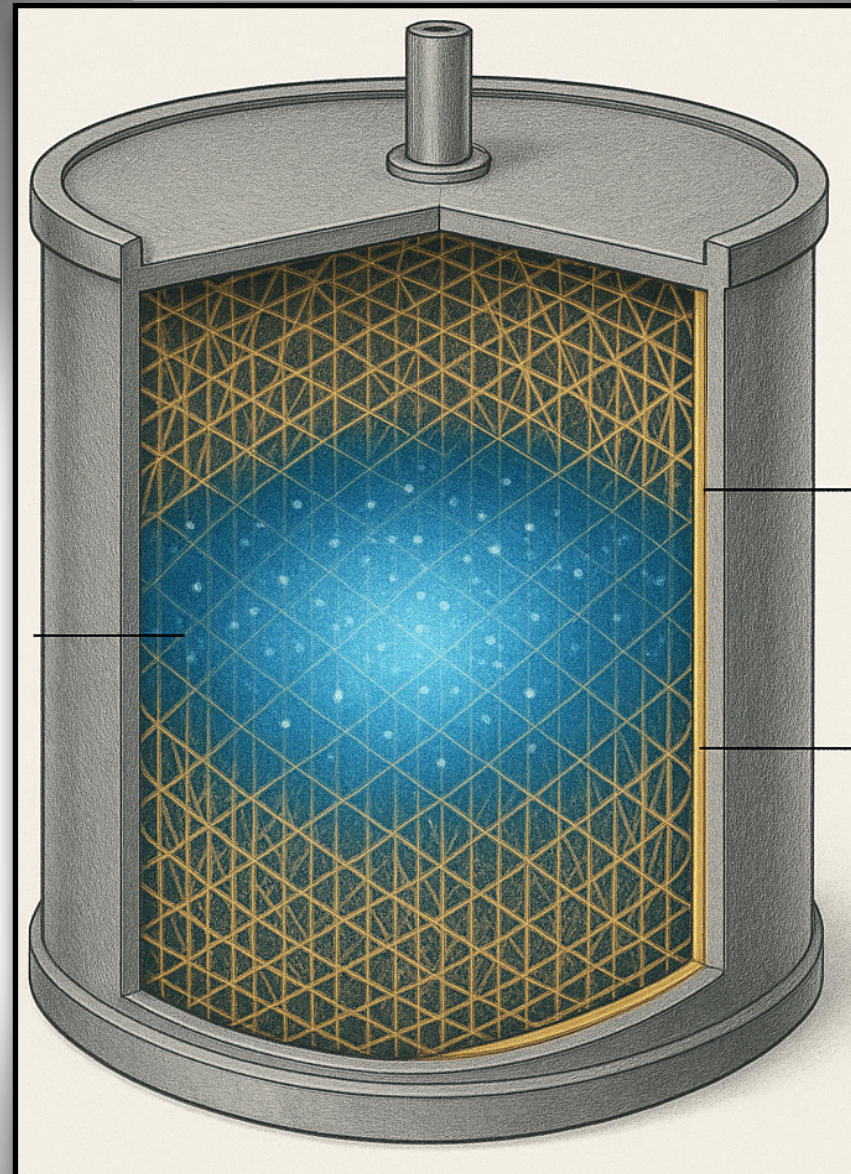
peripheral PMTs are **superseded/useless (opaque)** $\Rightarrow$ **fibres $\oplus$ SiPM**

today's technology



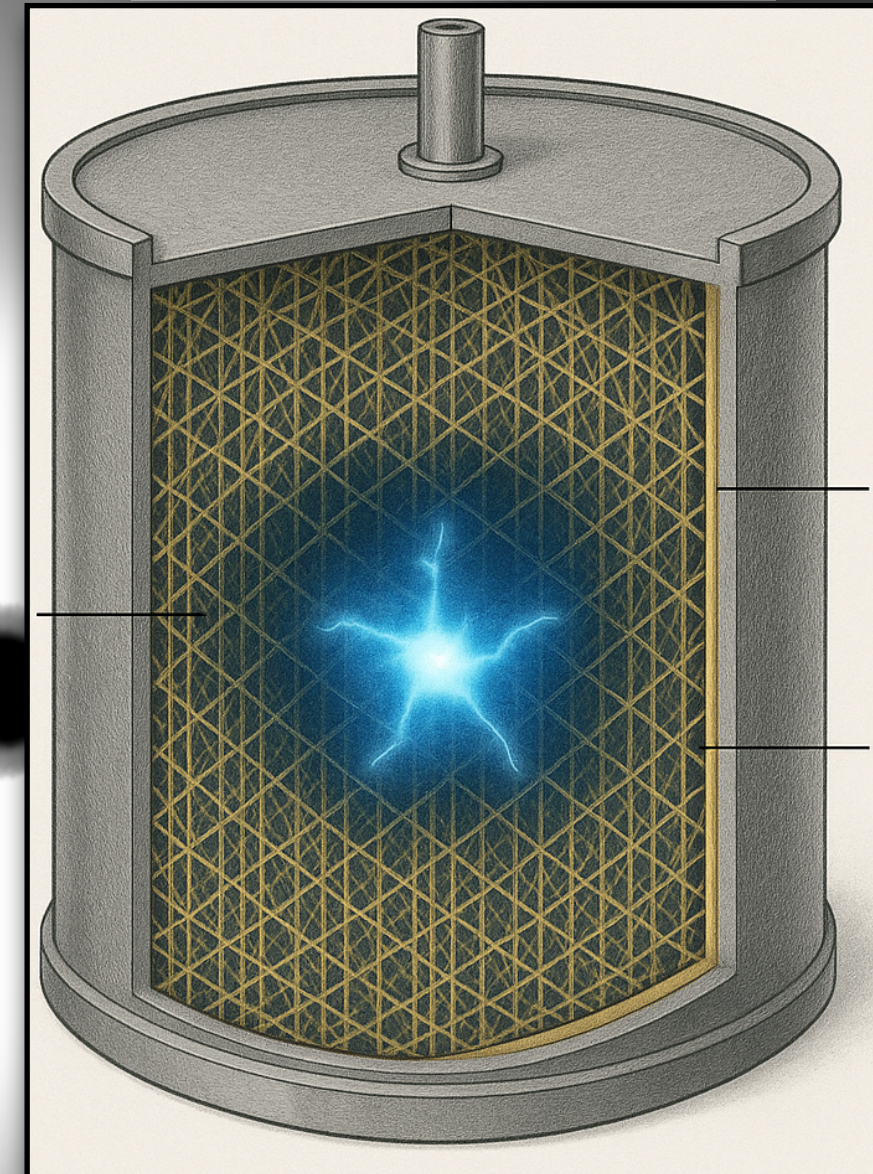
no topology $\Leftrightarrow$ **shielding**
(segmentation)

intermediate stage



no topology $\Leftrightarrow$ **shielding**
(segmentation)

LiquidO technology



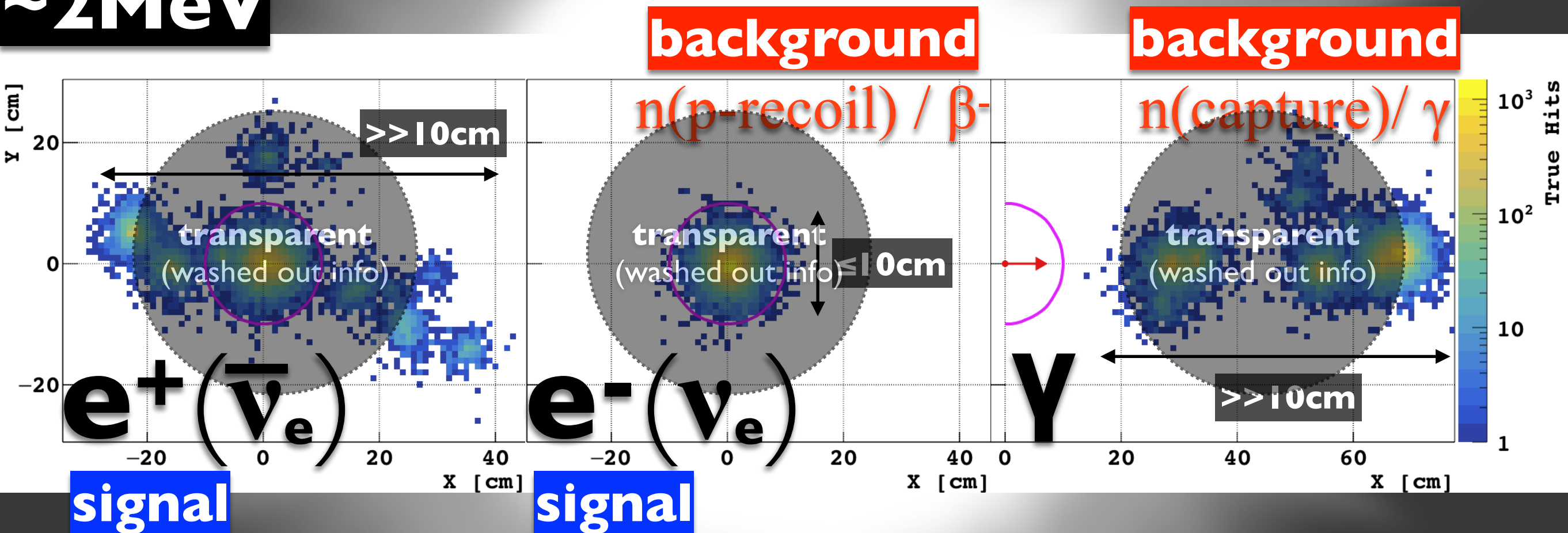
topology $\Leftrightarrow$ less **shielding**

no buffer ($\rightarrow$ precious underground volume) & **topology** ($\rightarrow$ extremeBG control)

unprecedented MeV imaging...

reduce overburden/shielding

~2MeV

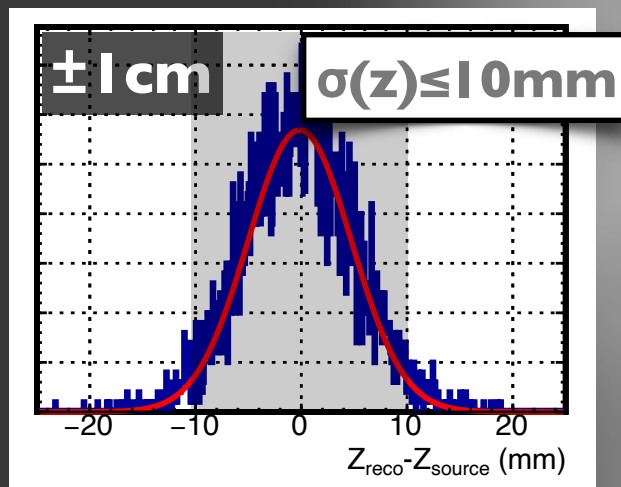
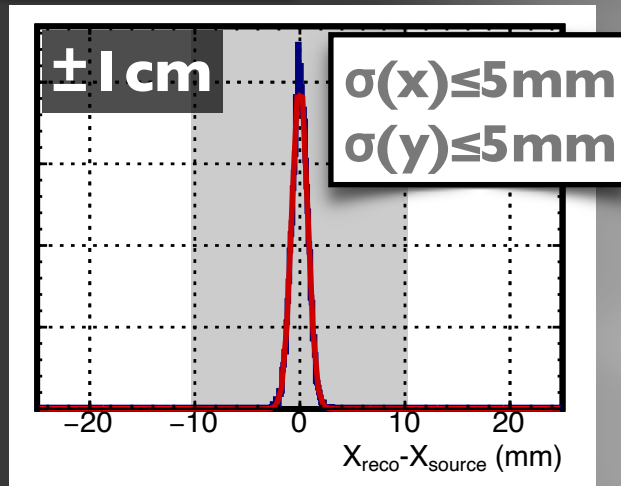


LiquidO: stochastic confinement (NO segmentation)

LiquidO $\leftrightarrow$ stochastic light confinement

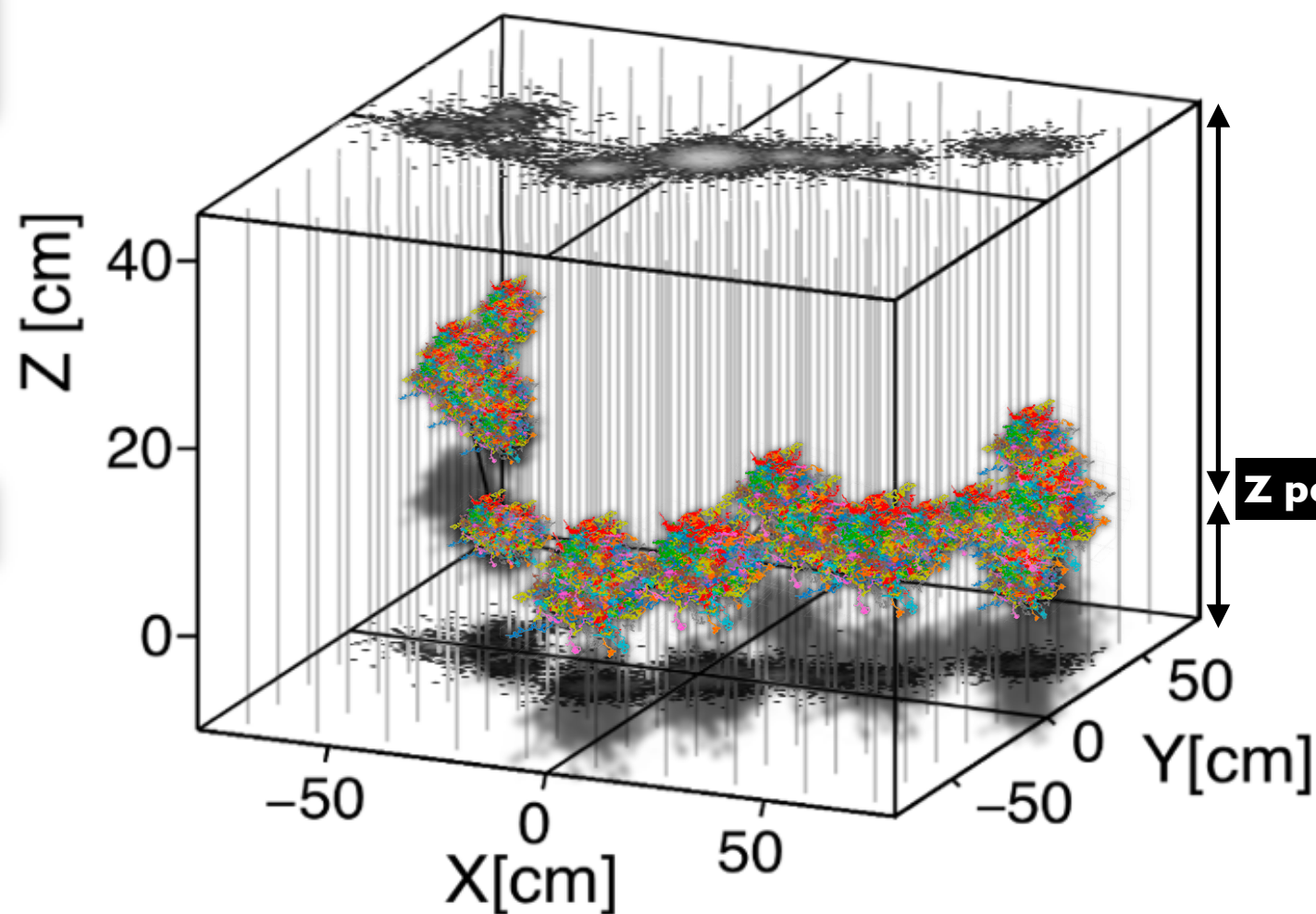
Topology (X,Y) direct & native (PID) $\rightarrow$ possible sub-mm vertex precision

$\sim 1.0\text{MeV}$

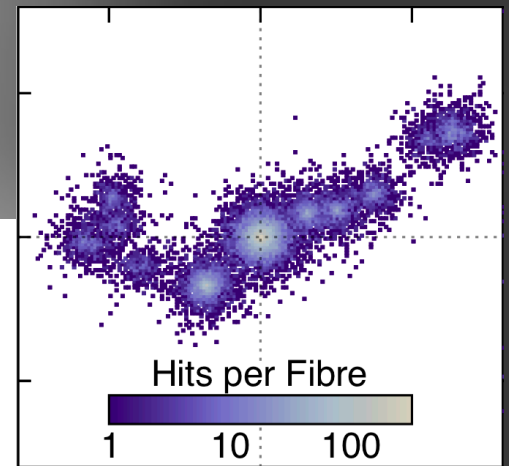


Vanilla LiquidO: 1D lattice (fibres along Z-axis only)

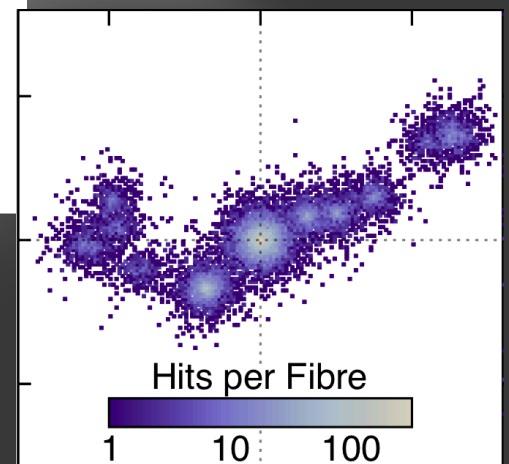
TOP VIEW: (X,Y) Projection $\rightarrow$ direct readout



BOTTOM VIEW: (X,Y) Projection $\rightarrow$ direct readout



Z position: Δt (time difference)



LiquidO can have up to 3 orthogonal fibre lattice orientations (3D)

latest results — March 2025

The Stochastic Light Confinement of LiquidO

LiquidO Collaboration^{(a-z)*}

Publication “LiquidO-I”

J. Apilluelo^{1,z}, L. Asquith^b, E. F. Bannister^b, N. P. Barradas^{kα}, J. L. Beney^p, M. Berberan e Santos^{kβ}, X. de la Bernardie^p, T. J. C. Bezerra^{id^b}, M. Bongrand^p, C. Bourgeois^q, D. Breton^q, C. Buck^{id¹}, J. Bustonⁿ, K. Burns^q, A. Cabrera^{id^{q,c,2}}, A. Cadiou^p, E. Calvo¹, E. Chauveau^f, B. J. Cattermole^b, M. Chen^h, P. Chimentiⁱ, D. F. Cowen^{xα,xβ}, S. Dusini^{id^{rα}}, A. Earle^b, M. Felizardo^{kα}, C. Frigerio Martinsⁱ, J. Galán^z, J. A. García^z, R. Gazzini^q, A. Gibson-Foster^b, C. Girard-Carillo^{mα}, B. Gramlich¹, M. Grassi^{2,rβ}, W. C. Griffith^b, J. J. Gómez-Cadenas^u, M. Guitière^p, F. Haddad^p, J. Hartnell^b, A. Holin^d, I. G. Irastorza^z, I. Jovanovic^{id^a}, A. Kling^{kα}, L. Koch^{id^{mα}}, P. Lasorak^b, J. F. Le Du^{q,c}, C. Lefebvre^h, F. Lefevre^p, P. Loaiza^q, J. A. Lock^b, G. Luzón^z, J. Maalmi^q, J. P. Malhado^j, F. Mantovani^{eα,eβ}, J. G. Marques^{kα}, C. Marquet^f, M. Martínez^z, D. Navas-Nicolás^{id^{q,1}}, H. Nunokawa^t, M. Obolensky², J. P. Ochoa-Ricoux^{id^g}, T. Palmeira^{kβ}, C. Palomares¹, B. Pedras^{kβ}, D. Petyt^d, P. Pillot^p, A. Pin^f, J. C. C. Porter^b, M. S. Pravikoff^{id^f}, N. Rodrigues^{kβ}, M. Roche^f, R. Rosero^y, B. Roskovec^s, N. Roy^q, M. L. Sarsa^z, S. Schoppmann^{id^{mβ,1}}, A. Serafini^{rα,rβ}, C. Shepherd-Themistocleous^d, W. Shorrock^{id^b}, M. Silva^{kγ}, L. Simard^q, S. R. Soleti^u, H. Th. J. Steiger^{mα,mβ}, D. Stocco^p, V. Strati^{eα,eβ}, J. S. Stutzmann^p, F. Suekane^v, A. Tunc^{mα}, N. Tuccori^{id^b}, A. Verdugo¹, B. Viaud^p, S. M. Wakely^{id^{mα}}, A. Weber^{id^{mα}}, G. Wendel^{xβ}, A. S. Wilhelm^{id^a}, M. Yeh^y, and F. Yermia^p

[arXiv:2503.02541](https://arxiv.org/abs/2503.02541) — under publication

latest results — July 2025

Muon tracking in a LiquidO opaque scintillator detector

Publication “LiquidO-II”

LiquidO Collaboration

J. Apilluelo,^z L. Asquith,^b E. F. Bannister,^b N. P. Barradas,^{kα} C. L. Baylis,^b J. L. Beney,^p
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F. Lefevre,^p P. Loaiza,^q J. A. Lock,^b G. Luzón,^z J. Maalmi,^q J. P. Malhado,^j
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D. Petyt,^d P. Pillot,^p A. Pin,^f J. C. C. Porter,^b M. S. Pravikoff ,^f S. Richards,^d
N. Rodrigues,^{kβ} M. Roche,^f R. Rosero,^y B. Roskovec,^s M. L. Sarsa,^z S. Schoppmann ,^{mβ}
A. Serafini,^{rα,rβ} C. Shepherd-Themistocleous,^d W. Shorrock ,^b M. Silva,^{kγ} L. Simard,^q
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A. Verdugo,^l B. Viaud,^p S. M. Wakely ,^{mα} A. Weber ,^{mα} G. Wendel ,^{xβ} A. S. Wilhelm
,^a A. W. R. Wong,^{b,d} M. Yeh,^y F. Yermia^p

[arXiv:2507.13864](https://arxiv.org/abs/2507.13864) — under publication

DRD2@CERN WORKSHOP

OPAQUE SCINTILLATION

Anatael Cabrera (CNRS / Université Paris-Saclay - IJCLab@Orsay / LNCA@Chooz)

<https://doi.org/10.5281/zenodo.10629927>

pioneering **opaque scintillation...**

IFAE just joined...

LiquidO Collaboration^{(a-z)*}

J. Apilluelo^z, L. Asquith^b, E. F. Bannister^b, N. P. Barradas^{k α} , C. L. Baylis^b, J. L. Beney^p, M. Berberan e Santos^{k β} , X. de la Bernardie^p, T. J. C. Bezerra^b, M. Bongrand^p, C. Bourgeois^q, D. Breton^q, J. Bustoⁿ, A. Cabrera^{q,c}, A. Cadiou^p, E. Calvo^l, M. de Carlos Generowicz^b, E. Chauveau^f, B. J. Cattermole^b, M. Chen^h, P. Chimentiⁱ, D. F. Cowen^{x α ,x β} , S. Kr. Das^b, S. Dusini^{r α} , A. Earle^b, M. Felizardo^{k α} , C. Frigerio Martinsⁱ, J. Galán^z, J. A. García^z, A. Gibson-Foster^b, C. Girard-Carillo^{m α} , W. C. Griffith^b, J. J. Gómez-Cadenas^u, M. Guitière^p, F. Haddad^p, J. Hartnell^b, A. Holin^d, I. G. Irastorza^z, I. Jovanovic^a, A. Kling^{k α} , L. Koch^{m α} , P. Lasorak^b, J. F. Le Du^{q,c}, F. Lefevre^p, P. Loaiza^q, J. A. Lock^b, G. Luzón^z, J. Maalmi^q, J. P. Malhado^j, F. Mantovani^{e α ,e β} , J. G. Marques^{k α} , C. Marquet^f, M. Martínez^z, J. T. Moffat^{x β} , D. Navas-Nicolás^l, H. Nunokawa^t, J. P. Ochoa-Ricoux^g, T. Palmeira^{k β} , C. Palomares^l, D. Petyt^d, P. Pillot^p, A. Pin^f, J. C. C. Porter^b, M. S. Pravikoff^f, S. Richards^d, N. Rodrigues^{k β} , M. Roche^f, R. Rosero^y, B. Roskovec^s, M. L. Sarsa^z, A. Serafini^{r α ,r β} , C. Shepherd-Themistocleous^d, W. Shorrock^b, M. Silva^{k γ} , L. Simard^q, M. Sisti^o, S. R. Soleti^u, D. Stocco^p, V. Strati^{e α ,e β} , J. S. Stutzmann^p, F. Suekane^v, N. Tuccori^b, A. Verdugo^l, B. Viaud^p, S. M. Wakely^{m α} , A. Weber^{m α} , G. Wendel^{x β} , A. S. Wilhelm^a, A. W. R. Wong^b, M. Yeh^y, and F. Yermia^p

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^{k γ} IDMEC, Instituto Superior Tecnico, Universidade de Lisboa, Lisbon, Portugal

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^yBrookhaven National Laboratory, Upton, NY, USA

^zCentro de Astropartículas y Física de Altas Energías (CAPA), Universidad de Zaragoza, Zaragoza, Spain

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- F. Suekane — Tohoku University / RCNS (Japan)

Contact: LiquidO-Contact-L@in2p3.fr

Web: <https://liquido.ijclab.in2p3.fr/>

Chooz (most powerful reactor) $\oplus$ **UND** ($\geq 25\text{m}$ baseline) $\oplus$ **LiquidO** (BG rejection)
[**EDF** within the team — unprecedented]

C L  U D
I - II - III

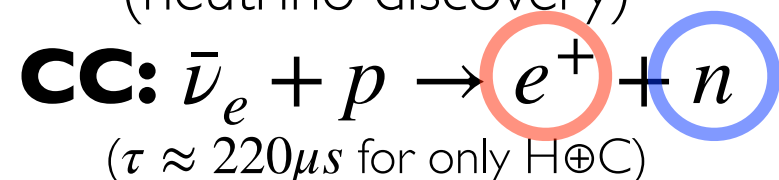
CLOUD's sequence...

the power of coincidences

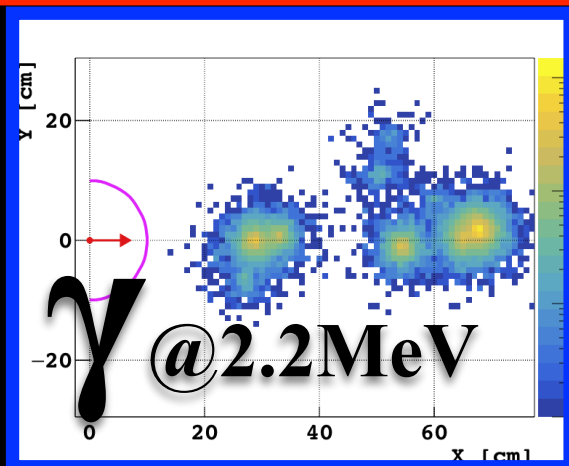
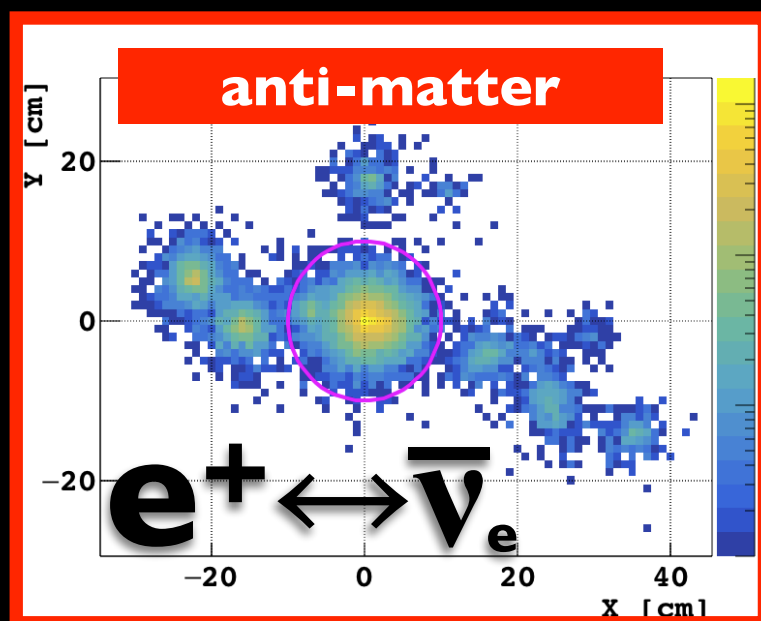
being at **the right “place & time & energy & PID” — huge rejection(s)**

Reines et al ‘50s

(neutrino discovery)

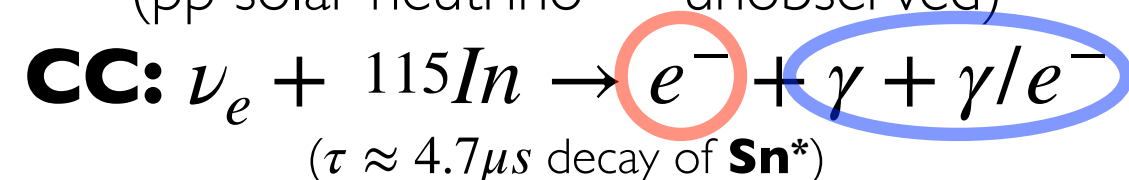


(anti)neutrino **discovery** [τ_n & $\Delta m_{p\sim n}$]

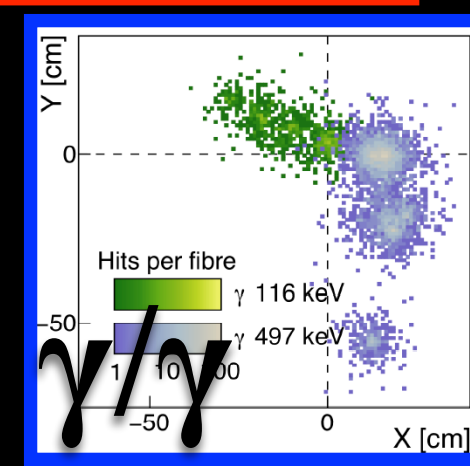
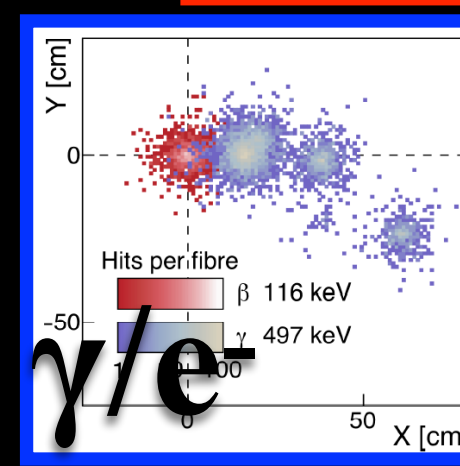
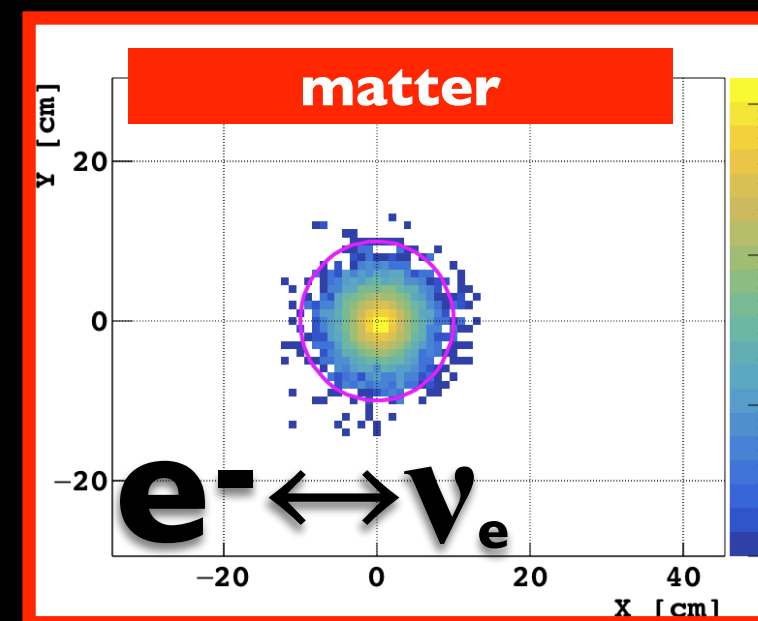


Raghavan et al ‘70s

(pp solar neutrino — unobserved)



major **R&D** [~ 2 decades] by **LENS** *et al.*



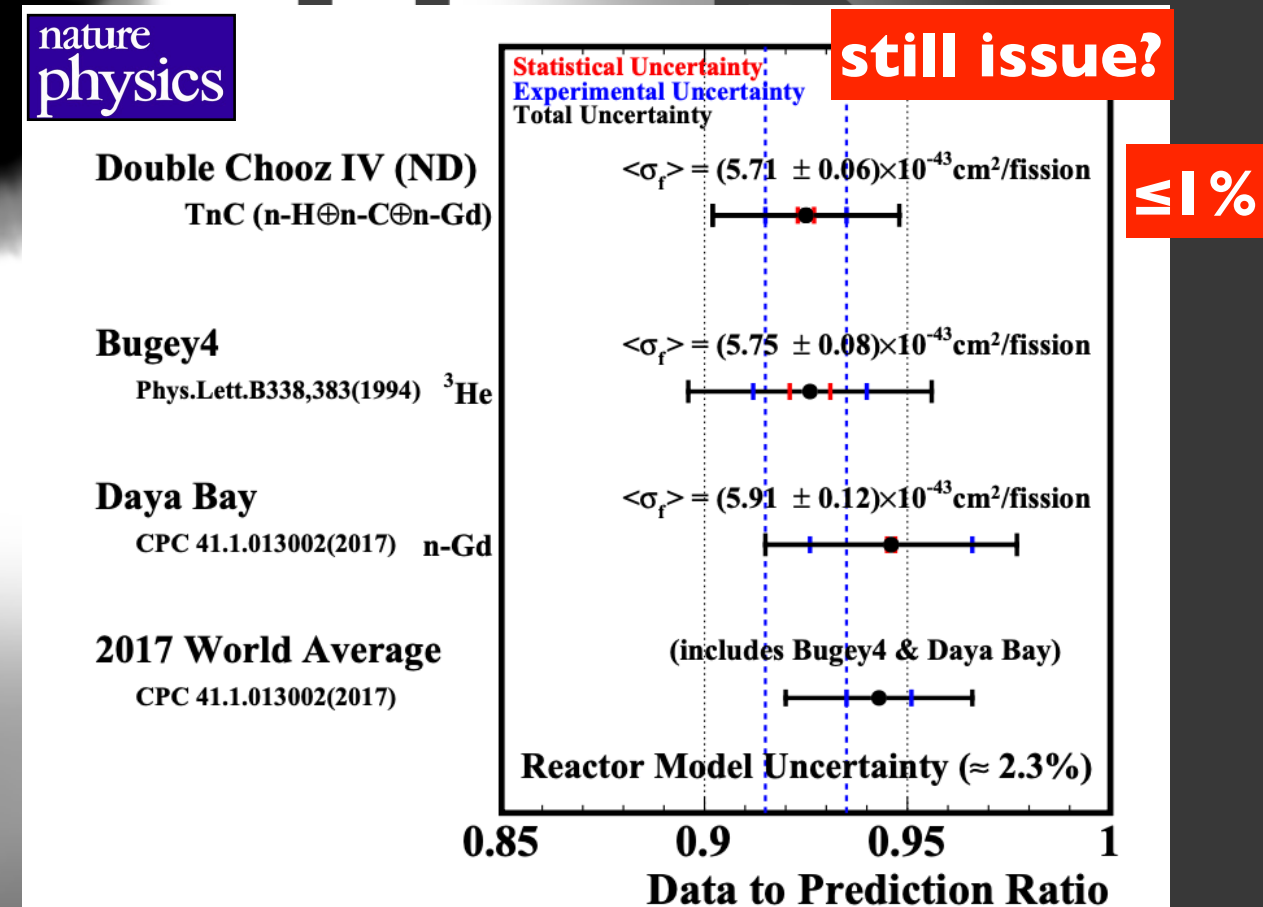
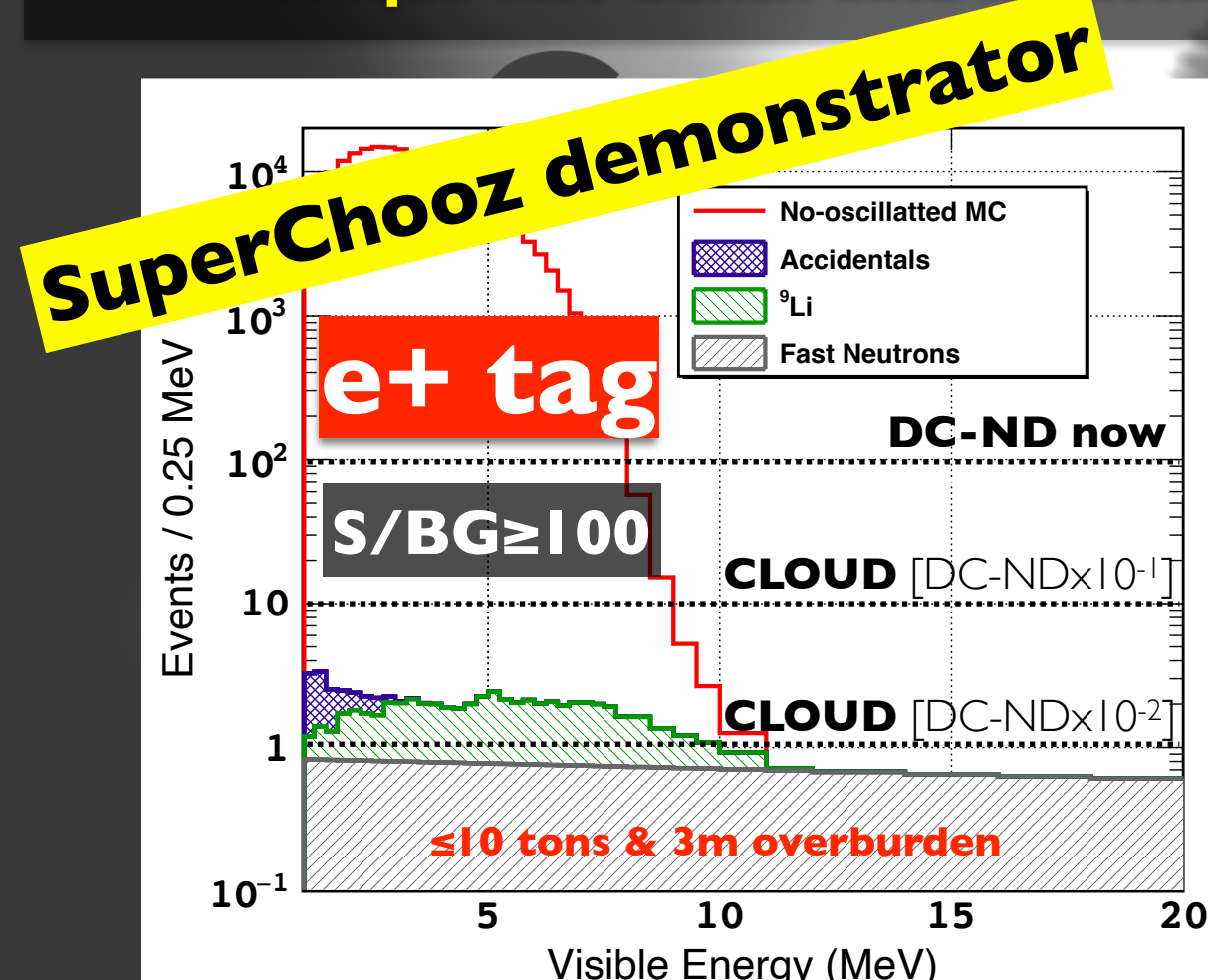
C L  U D

AntiMatter-OTech — synergy
SuperChooz's antineutrino golden channel **demonstration** — byproduct

antineutrino CC & NC? (~~doping~~)...

CLOUD-I physics programme: **IBD@p...**

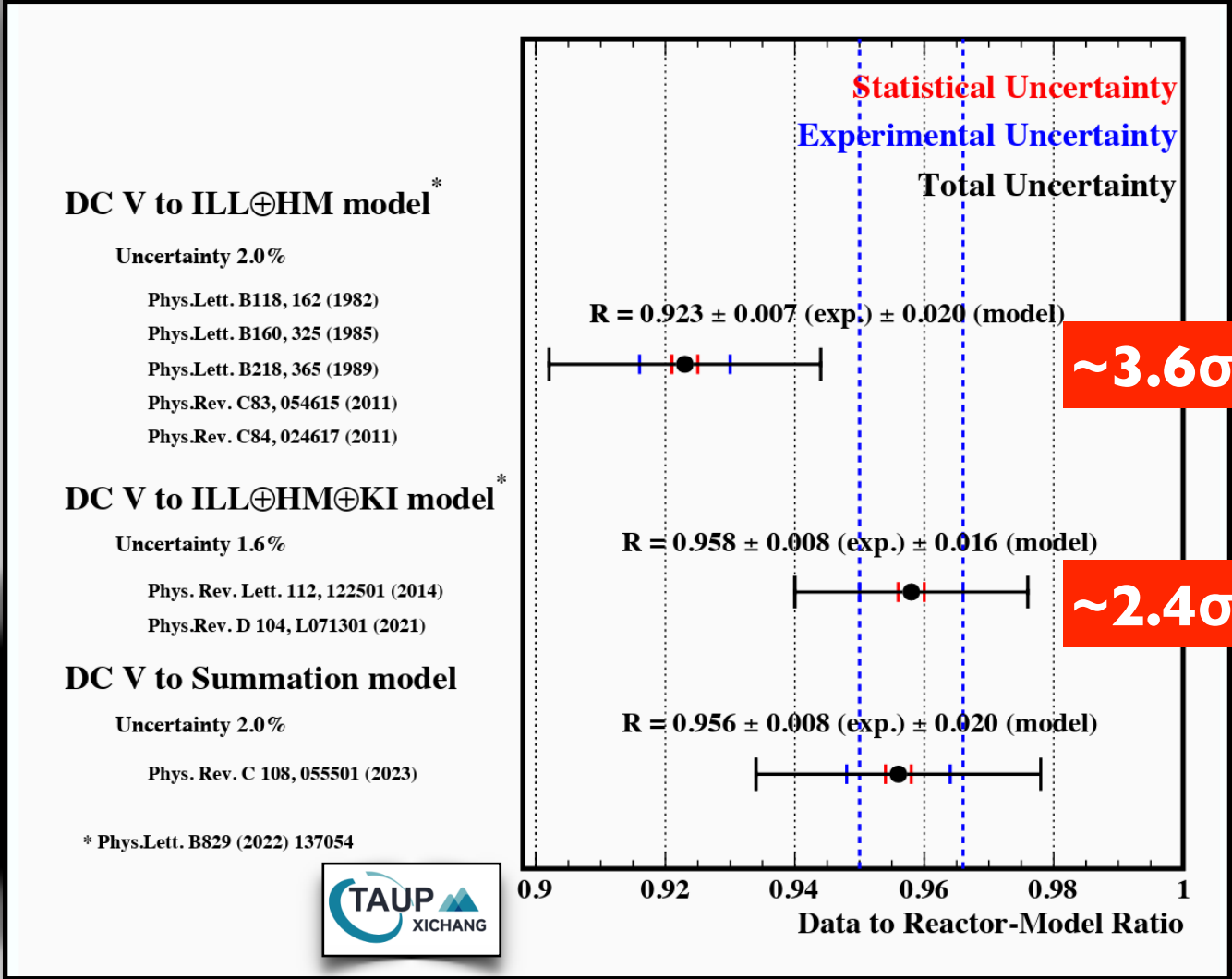
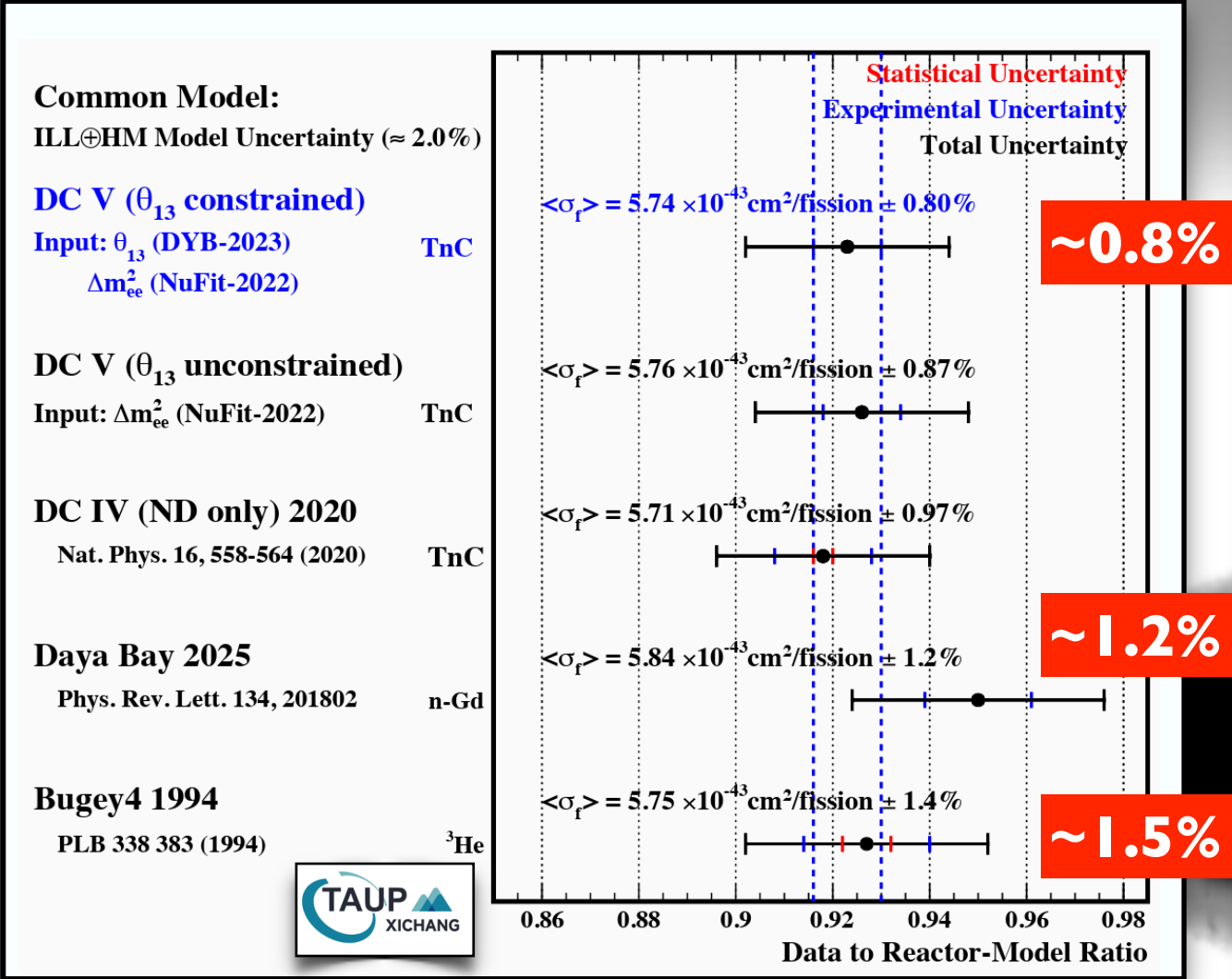
- **IBD@p** (anti-ν CC): **$\geq 10,000$** interactions per day in **10 tons** [**$\geq 3M$** interactions per year]
- **LiquidO** reach a **background-less** regime — improve **$\geq 3x$** today's BG control (ex. DC-ND)
- **Signal(ON)-to-BG ≥ 100** — unprecedented high precision reactor characterisation
 - dominant **$\sim 0.5\%$ (thermal power) uncertainty** & accurate **U/Pu composition**
- **Signal(OFF)-to-BG ≥ 1** — unprecedented **reactor-fuel monitoring**
 - accurate monitoring of **transitions OFF-ON-OFF** — interesting physics too
- **unique test-bench data for accurate prediction** — validate uncertainties, too?



CLOUD precision $\geq 0.6\% \Rightarrow$ Unitarity Violation? (if predictions are improved)!

world's most precise reactor data

reactor's prediction (i.e. no neutrino data)



consistent within **1.2 σ** (only experimental uncertainties)
[common prediction $\Rightarrow$ strong correlations]

Reactor Flux Prediction
ILL⊕Hubber⊕Muller & new Kopeikin et al.
DC: $\sim 3.6\sigma$ to $\sim 2.4\sigma$ [^{235}U correction]
[alternative **summation method: similar**]

DC V world's most precise ϕ^{reactor} ...

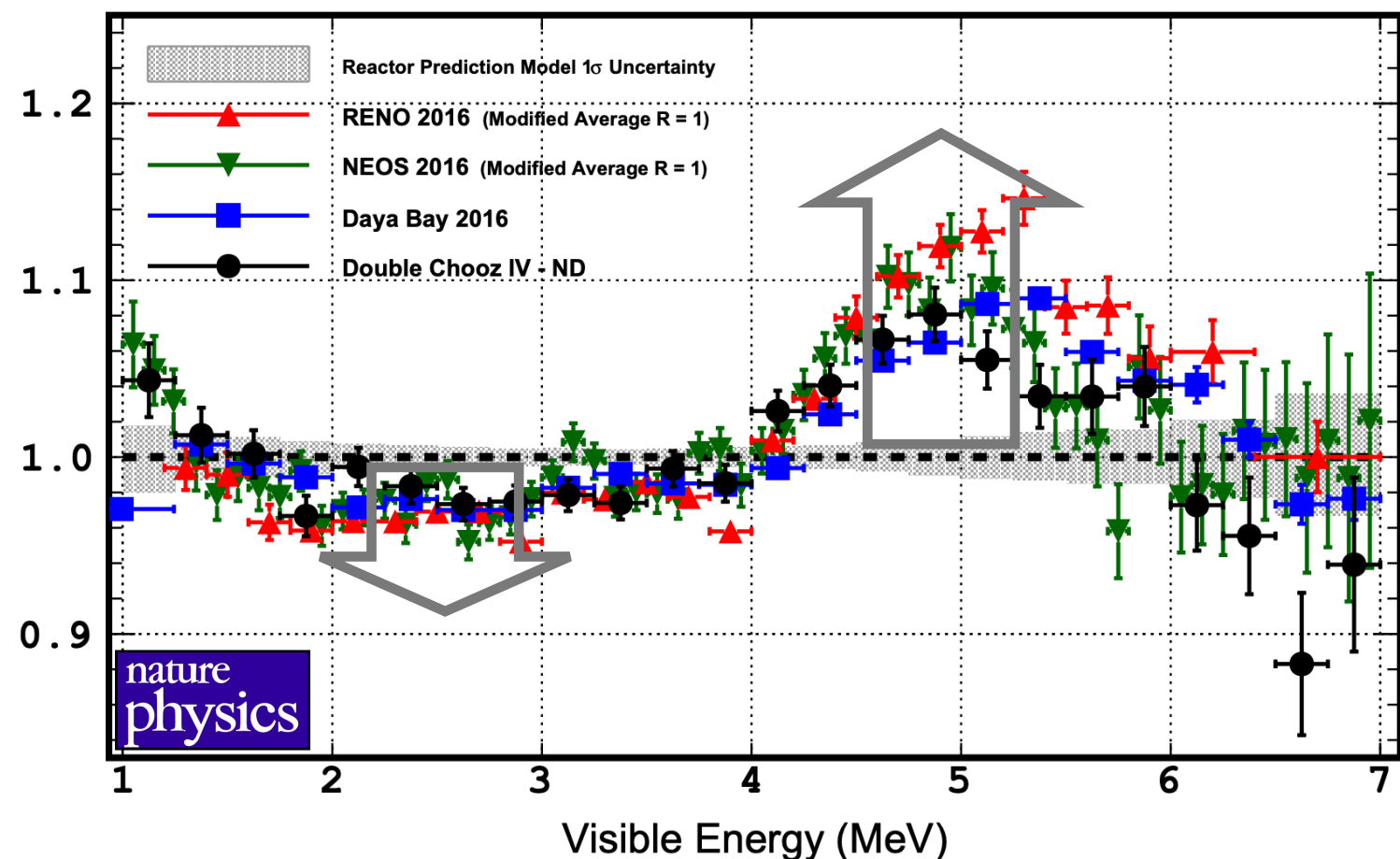
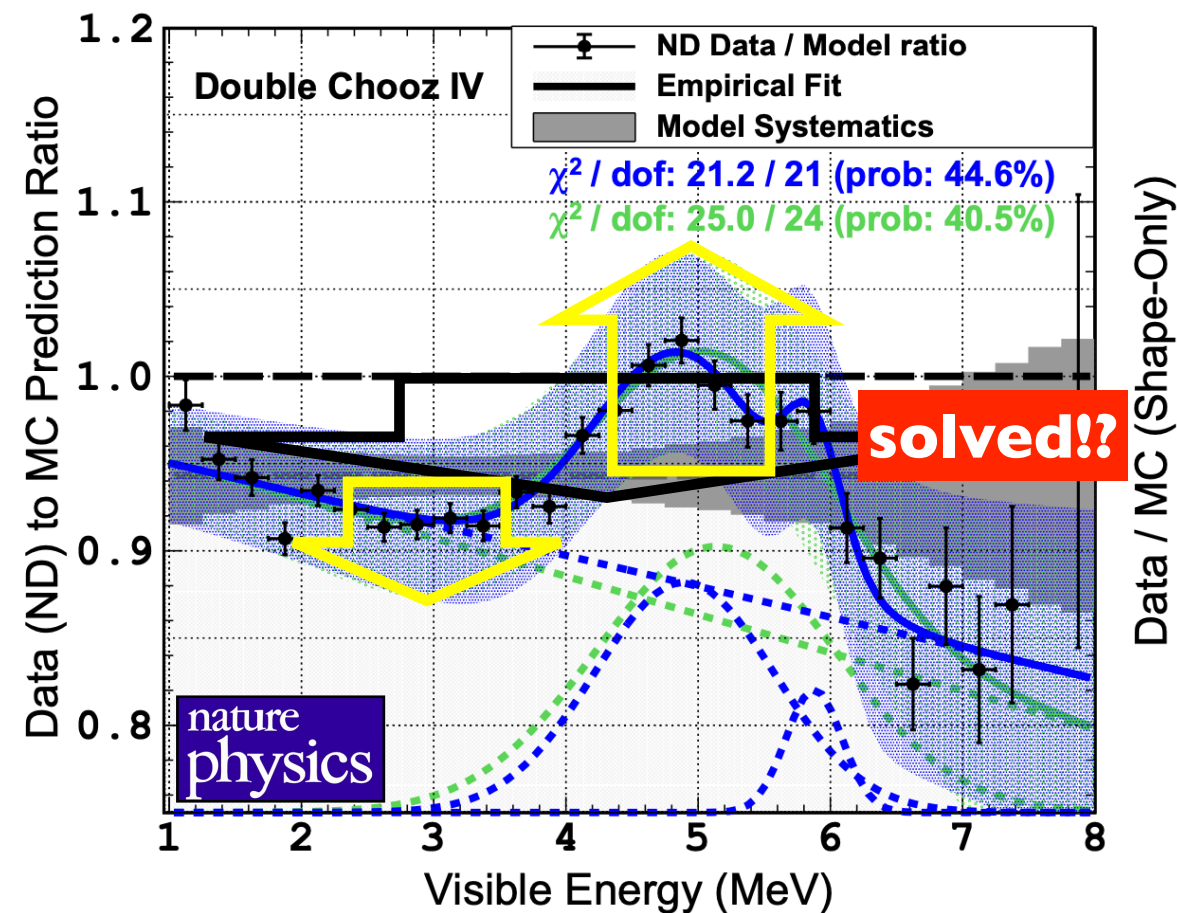
sterile- ν : disfavoured...

C L  U D

many experiments worldwide...

still issues to be resolved — beyond the sterile neutrino hypothesis (disfavoured)

all experiments consistent — except **Bugey3??**



ABSOLUTE FLUX: the future of reactor-antineutrino physics

we must solve this “mess” $\Rightarrow$ the reward **possible new physics!**
(if so, prediction should not use neutrino input $\Rightarrow$ **no** new physics)

must understand flux $\leq 1\%$...

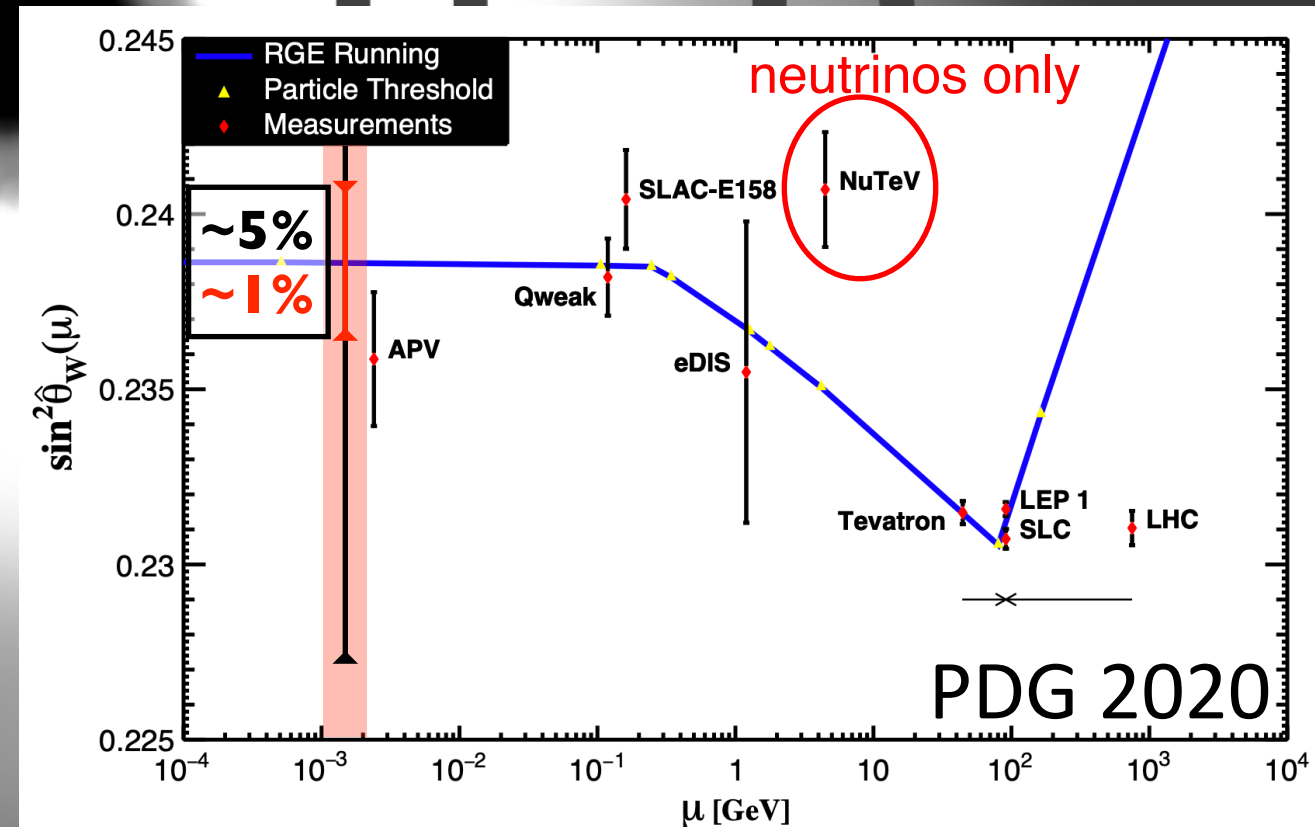
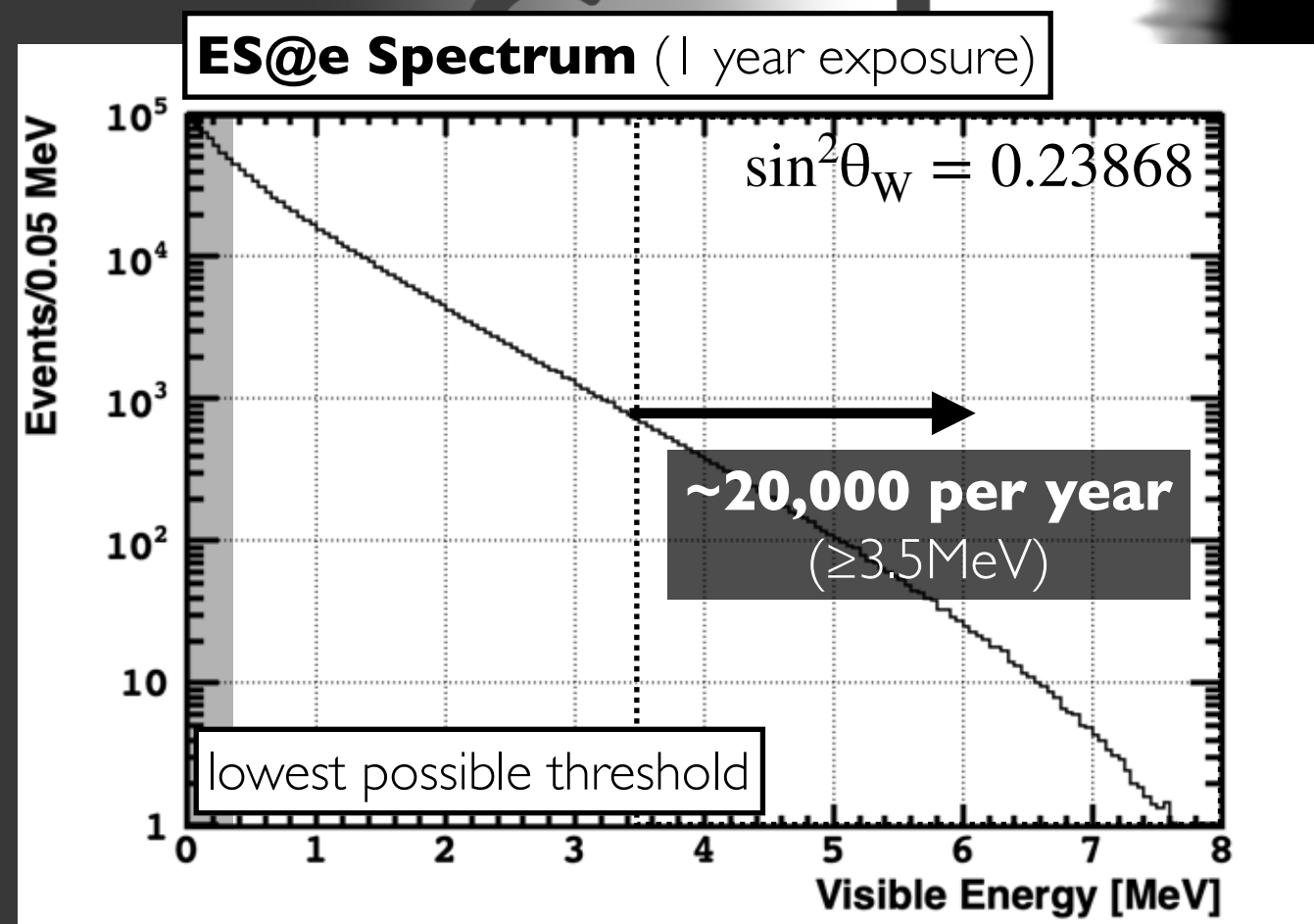
- LiquidO's event **PID** e^+ ?
- NC component: **$\phi(CC) \approx \phi(NC)$** ?



CLOUD's complementarity?

CLOUD-I physics programme: **ES@e...**

- **eES** (anti- ν CC $\oplus$ NC): **$\leq 5,000$** interactions per day for **10tons ID** [$\approx 2M$ interactions per year]
 - interference CC & NC — different for neutrino (easier) and antineutrino (harder)
 - measure θ_w or use to **decompose the NC flux** component
 - PDG-2022's $\sin^2\theta_w \approx [0.231, 0.239]$ — running due to SM's renormalisation
- **major challenge: LiquidO** isolate “e-like” **PID** and exploit **high-rate reactor modulation**
 - likely strong **fiducial volume** & **higher energies** — reduce detected rate drastically
 - **$\leq 10\%$ precision** ($\geq 5\sigma$ observation) tolerates much BG but **$\leq 1\% \Rightarrow S/BG \geq 2(!!)$ impossible?**



R.L. Workman et al. (Particle Data Group), Prog. Theor. Exp. Phys. 2022, 083C01 (2022)

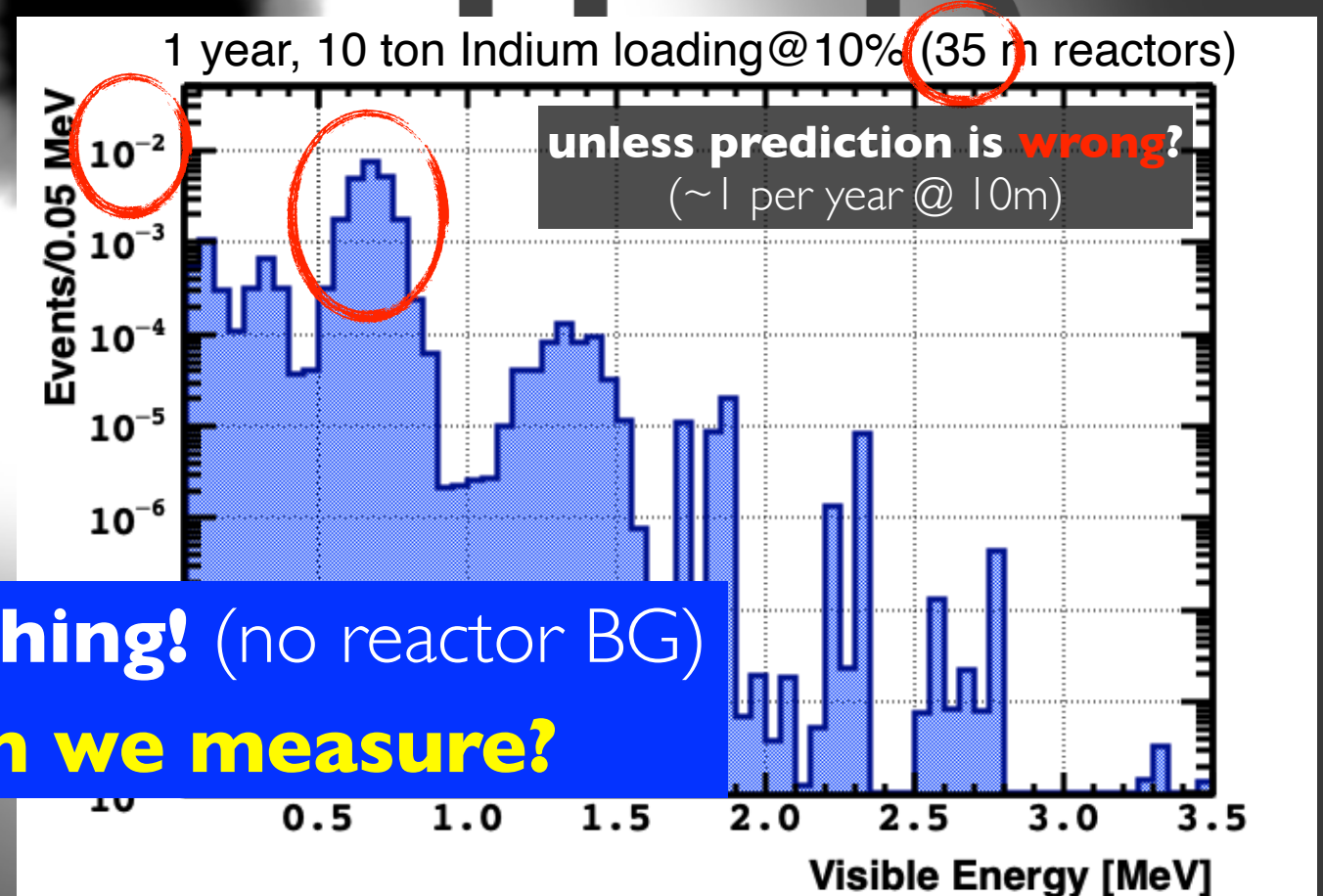
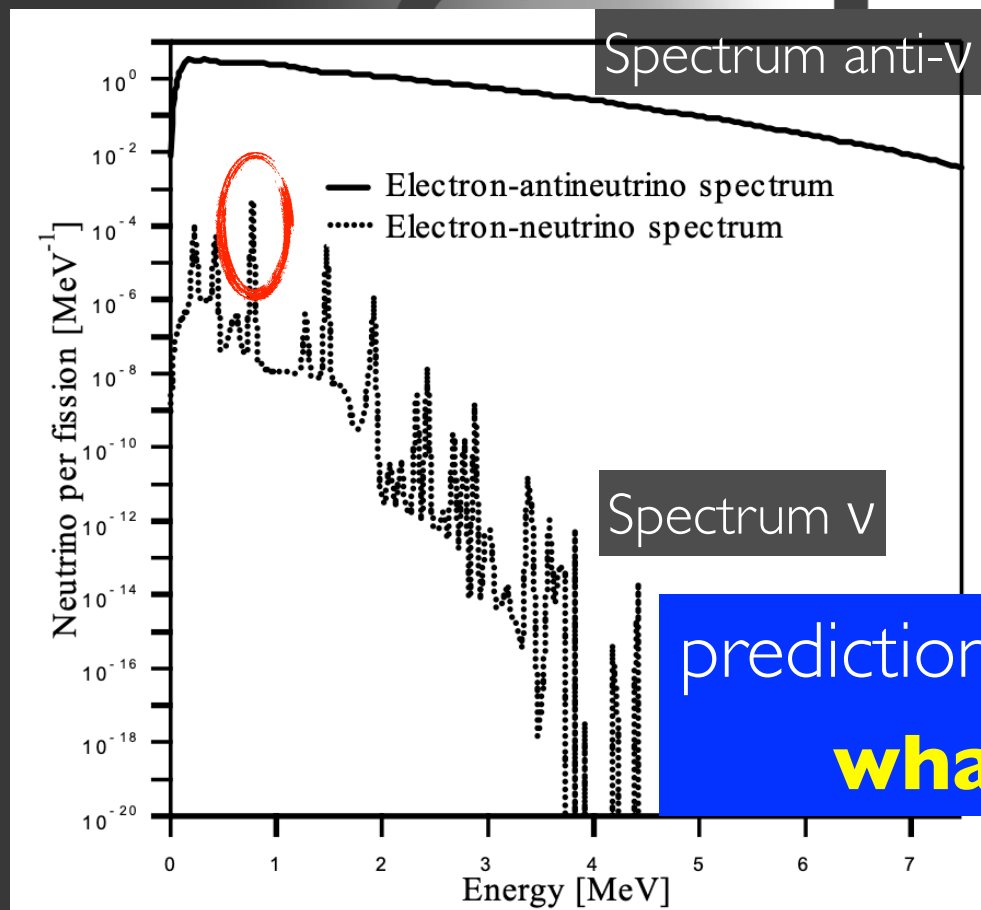
CLIU D

SuperChooz's neutrino golden channel **demonstration** — byproduct

neutrino CC (doping)...

CLOUD-II physics programme: **neutrino**...

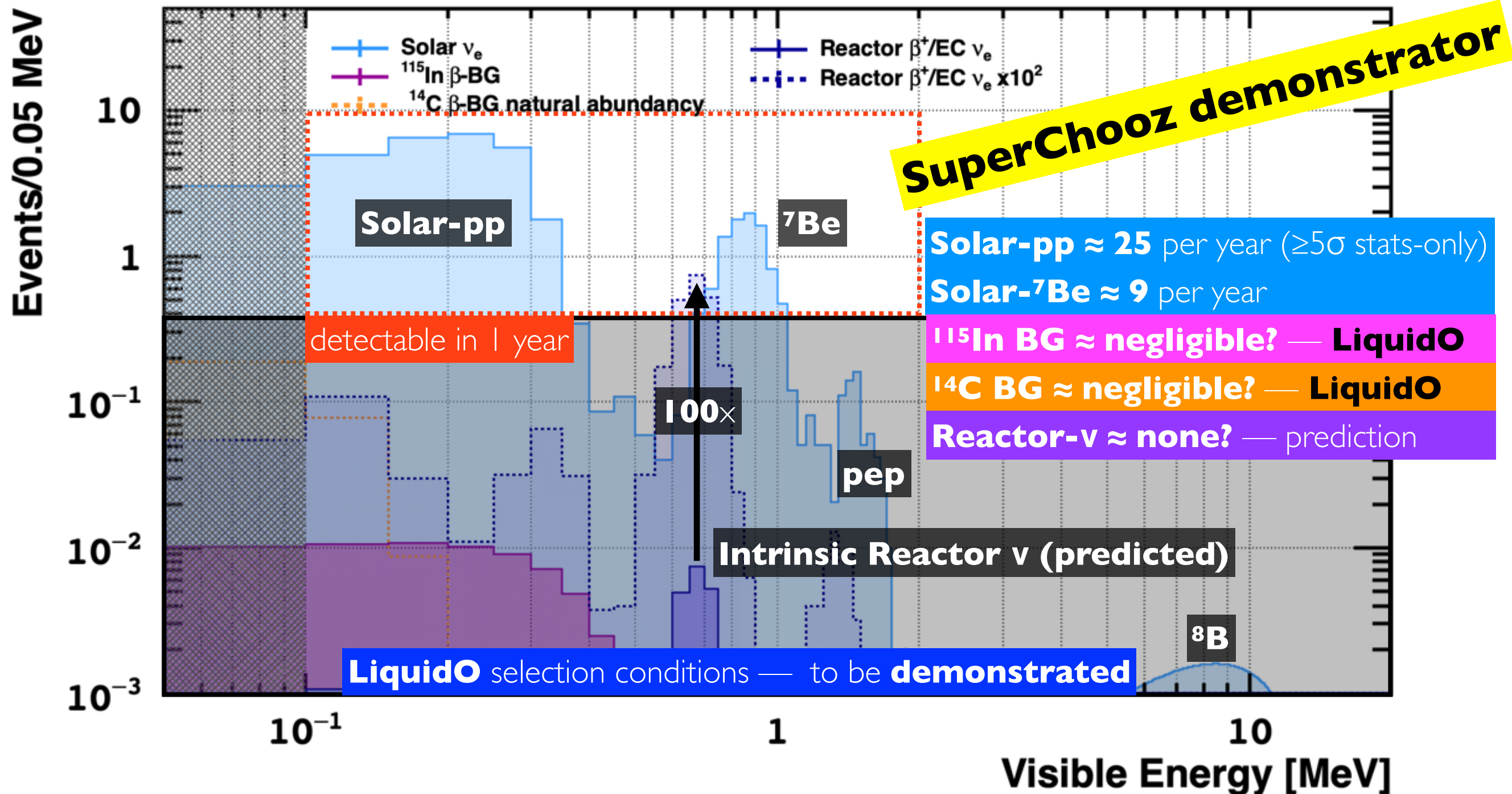
- loading **indium** on the detector — **unique strong coincidence $\geq 114\text{keV}$** (“solar-pp” in mind)
 - low threshold $\oplus$ high natural-abundance $\oplus$ high-ish cross-section $\oplus$ BG-killer (coincidence)
 - CC interaction: $\nu_e + {}^{115}\text{In} \rightarrow e^- + {}^{115}\text{Sn}^*$ [$\tau: 4.8\mu\text{s}$ decay: $\gamma/e(116\text{keV}) + \gamma(496\text{keV})$]
 - reactor neutrino **modulate with the reactor power** — no ambiguity whatsoever
- why to detector neutrinos close to a reactor?
 - **reactor neutrinos** (from β^+/EC): **rate(ν) $\approx 10^{-5}$ rate(anti- ν)** — prediction (both correlated)
 - could **reactors be the missing MeV neutrino source?** [otherwise impractical]



the big picture of neutrinos @CLOUD...

assuming the **LENS “BG model”** — valid at **overburden ~3m?** (to be demonstrated)

1 year, 10 ton Indium loading @10% (35 m reactors)



SuperChooz demonstrator

Solar-pp ≈ 25 per year ($\geq 5\sigma$ stats-only)

Solar- ^7Be ≈ 9 per year

^{115}In BG $\approx$ negligible? — **LiquidO**

^{14}C BG $\approx$ negligible? — **LiquidO**

Reactor- ν $\approx$ none? — prediction

100×

Intrinsic Reactor ν (predicted)

LiquidO selection conditions — to be demonstrated

detectable in 1 year

detection **solar-pp neutrinos** on a **10ton** detector **almost on surface** right **next a nuclear reactor?**

CLIU D

R&D for low energy reactor-fuel monitoring & geoneutrino ^{40}K discovery — demonstration

new antineutrino CC (doping)...

Probing Earth's Missing Potassium using the Unique Antimatter Signature of Geoneutrinos

A. Cabrera^{*12 α ,2,a}, M. Chen^{†6}, F. Mantovani^{‡3 α ,3 β} , A. Serafini^{§3 α ,3 β ,13 α ,13 β} , V. Strati^{*3 α ,3 β} , J. Apilluelo¹⁸, L. Asquith¹, J.L. Beney¹¹, T.J.C. Bezerra¹, M. Bongrand¹¹, C. Bourgeois^{12 α} , D. Breton^{12 α} , M. Briere^{12 α} , J. Busto¹⁰, A. Cadiou¹¹, E. Calvo⁸, V. Chaumat^{12 α} , E. Chauveau⁴, B.J. Cattermole¹, P. Chimenti⁷, C. Delafosse^{12 α} , H. de Kerret^{†a}, S. Dusini^{13 α} , A. Earle¹, C. Frigerio-Martins⁷, J. Galán¹⁸, J. A. García¹⁸, R. Gazzini^{12 α} , A. Gibson-Foster¹, A. Gallas^{12 α} , C. Girard-Carillo^{9 α} , W.C. Griffith¹, F. Haddad¹¹, J. Hartnell¹, A. Hourlier¹⁷, G. Hull^{12 α} , I. G. Irastorza¹⁸, L. Koch^{9 α} , P. Lanièce^{12 α ,12 β} , J.F. Le Du^{12 α ,2}, C. Lefebvre⁶, F. Lefevre¹¹, F. Legrand^{12 α} , P. Loaiza^{12 α} , J. A. Lock¹, G. Luzón¹⁸, J. Maalmi^{12 α} , C. Marquet⁴, M. Martínez¹⁸, B. Mathon^{12 α} , L. Ménard^{12 α ,12 β} , D. Navas-Nicolás^{12 α} , H. Nunokawa¹⁵, J.P. Ochoa-Ricoux⁵, M. Obolensky^a, C. Palomares⁸, P. Pillot¹¹, J.C.C. Porter¹, M.S. Pravikoff⁴, H. Ramarijaona^{12 α} , M. Roche⁴, P. Rosier^{12 α} , B. Roskovec¹⁴, M.L. Sarsa¹⁸, S. Schoppmann^{9 β} , W. Shorrocks¹, L. Simard^{12 α} , H.Th.J. Steiger^{9 α ,9 β} , D. Stocco¹¹, J.S. Stutzmann¹¹, F. Suekane^{16,a}, A. Tunc^{9 α} , M.-A. Verdier^{12 α ,12 β} , A. Verdugo⁸, B. Viaud¹¹, S. M. Wakely^{9 α} , A. Weber^{9 α} , and F. Yermia¹¹

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⁵ Department of Physics and Astronomy, University of California at Irvine, Irvine, CA, USA

⁶ Department of Physics, Engineering Physics & Astronomy, Queen's University, Kingston, Canada

⁷ Departamento de Física, Universidade Estadual de Londrina, Londrina, Brazil

⁸ CIEMAT, Centro de Investigaciones Energéticas, Medioambientales y Tecnológicas, Madrid, Spain

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¹⁶ RCNS, Tohoku University, Sendai, Japan

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^a Université de Paris Cité, CNRS, APC, Paris, France

(LiquidO Consortium)

⁴⁰K geoneutrino new methodology → good enough for discovery?

C L O U D

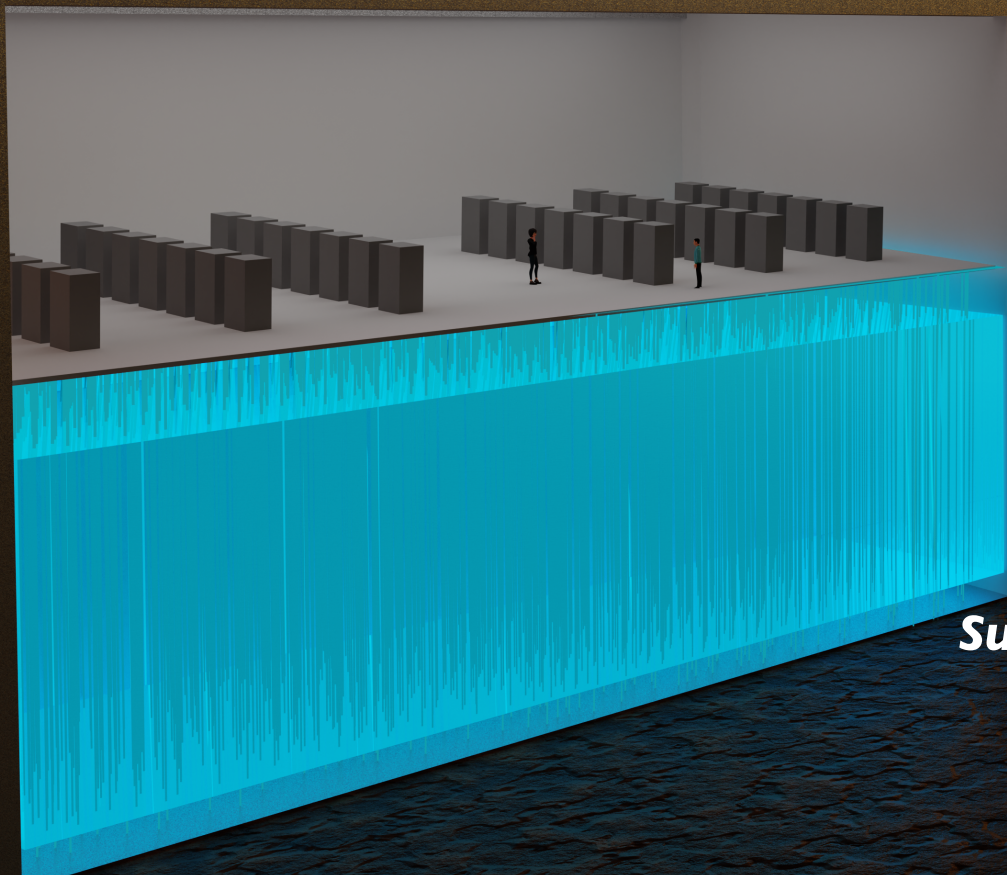
a long story short...

SuperChooz exploration...

flagship neutrino oscillation experiment in Europe?

the Ardennes mountains

Chooz-A: Cavern Reactor Core



European
Innovation
Council



UK Research
and Innovation

AM-OTech project [EIC-UKRI]
CLOUD experiment

1 Dec 2022

Chooz-B: Reactor Cores

Ultra Near Detectors @ Chooz-B:

- LiquidO technology
- Mass: ≤ 5 tons
- Overburden: ≤ 5 m
- Baseline: ≤ 30 m

Super Far Detector @ Chooz-A

- LiquidO technology
- Mass: $\sim 10,000$ tons
- Overburden: ≤ 100 m
- Baseline: ~ 1 km

the Meuse river



<https://zenodo.org/record/7504162>

<https://indico.cern.ch/event/1215214/>

S U P E R C H O O Z

EP Seminar

The Superchooz Experiment: Unveiling the Opportunity

by Dr Anatael CABRERA (IJCLab - IN2P3/CNRS)

 Tuesday 29 Nov 2022, 11:00 → 12:00 Europe/Zurich

 222/R-001 (CERN)

exploring since 2018...

- **CLOUD** demonstrator for **LiquidO's (anti)neutrino detection capabilities** — **a revolution?**
 - byproduct to **new reactor monitoring capability?** [a dream since '70s]
- **CLOUD-I: approved & funded [AM-OTech]** **plan: data by 2025**
 - **goal:** possible **background-less regime?** [→ LiquidO]
 - **most precise absolute CC-antineutrino flux** — **new physics?**
 - possible **first NC-(anti)neutrino flux** — **new physics?**
- **CLOUD-II: under feasibility study** (→ new **indium**-loaded opaque scintillator)
 - (first) **absolute CC-neutrino flux reactor** — **new physics?**
 - **measure solar-pp ($\geq 5\sigma$)** in a “tiny detector” almost on the surface? ⇒ **a breakthrough?**
- **CLOUD-III: under feasibility study** (→ new **copper**-loaded opaque scintillator)
 - probe **reactor flux at low energies?** — **surprises?** [first time ever below 1.8MeV]
 - demonstration for **^{40}K detection methodology** — **a discovery one day?**

an even vaster future of reactor (anti)neutrinos ahead?

conclusions...

SuperChooz demonstrator