tightly linked to **LiquidO**, **AM-OTech/CLOUD**, and **SuperChooz** collaborations/consortia & specially **EDF**

SUPERCHOOZ

European Innovation Council

International Conference on the Physics of the Two Infinities
29th March 2023 — Kyoto, Japan

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

IJCLab Irène Joliot-Curie
cnrs
université PARIS-SACLAY
FACULTÉ DES SCIENCES D'ORSAY
Université de Paris
cnrs
eDF

~50 years of neutrino oscillations…

huge experimental/theory effort

[discovery⊕establishment ⇔ Nobel 2015]

status on neutrino oscillation knowledge…

Standard Model(3 families)
[leptons & quarks]
&
PMNS$_{3x3}$(θ_{12},θ_{23},θ_{13})
&
$\pm\Delta m^2$ & **$+\delta m^2$**

no conclusive sign of any extension so far!!
(inconsistencies vs uncertainties)

must measure all parameters→characterise & test (i.e. over-constrain) ***Standard Model***

	today		
	best knowledge		global
θ_{12}	3.0 %	SK⊕SNO	2.3 %
θ_{23}	5.0 %	NOvA+T2K	2.0 %
θ_{13}	1.8 %	DYB+DC+RENO	**1.5 %**
$+\delta m^2$	2.5 %	KamLAND	2.3 %
$\|\Delta m^2\|$	3.0 %	T2K+NOvA & DYB	1.3 %
Mass Ordering	**unknown**	SK et al	NO @ **~3σ**
CPV	**unknown**	T2K	3/2π @ **≲2σ**

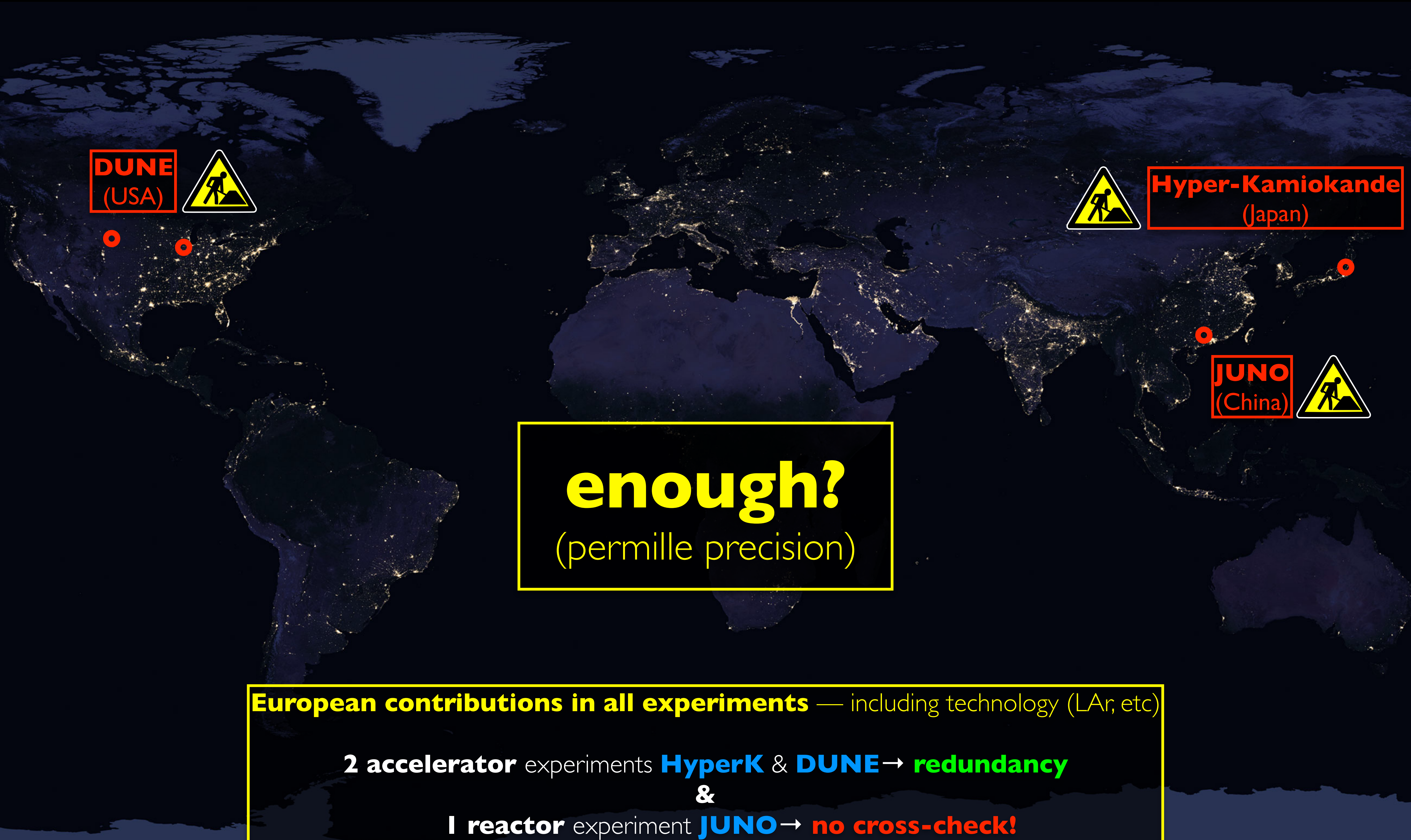
(**now**)

(reactor-beam)

JUNO⊕DUNE⊕HK will lead precision in the field→**Mass Ordering** & **CPV** **except θ_{13}!**

ORCA⊕PINGU⊕IceCube complementary for Mass Ordering & Δm^2 measurements

flagship neutrino experiments…



enough?

(permille precision)

European contributions in all experiments — including technology (LAr, etc)

2 accelerator experiments **HyperK** & **DUNE**→ **redundancy**

&

1 reactor experiment **JUNO**→ **no cross-check!**

neutrinos oscillation : standard picture (SM)

[today's signal = tomorrow's background]

neutrinos to probe BSM $\longrightarrow$ discoveries?

beyond today's paradigm!

our rationale…

neutrino unique in Standard Model… **more discoveries?**

SUPERCHOOZ

the new opportunity…

somewhere in the middle of Europe, there is Chooz…

maybe Chooz?

Chooz *is tiny cute little village in the Ardennes*

Chooz = powerful reactor(s) ⊕ overburden

the reactor (source)...

Chooz-B nuclear reactor plant: 2x N4 reactors [4.2GW$_{\text{thermal}}$ each]

civil-construction near a reactor?

upon **DoubleChooz** underground **laboratories limitations**…

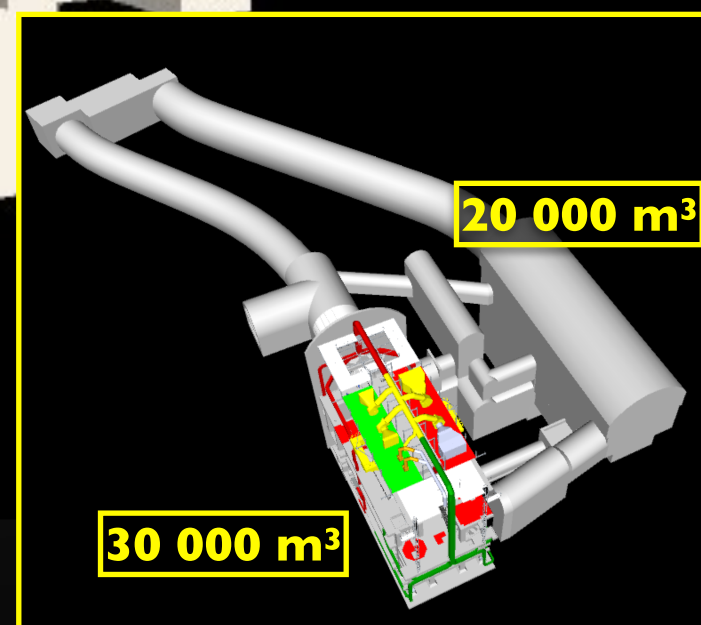
- **too small!**
- **too shallow!** (to today's technology capability)

lesson: don't…!

Chooz: **any future?**

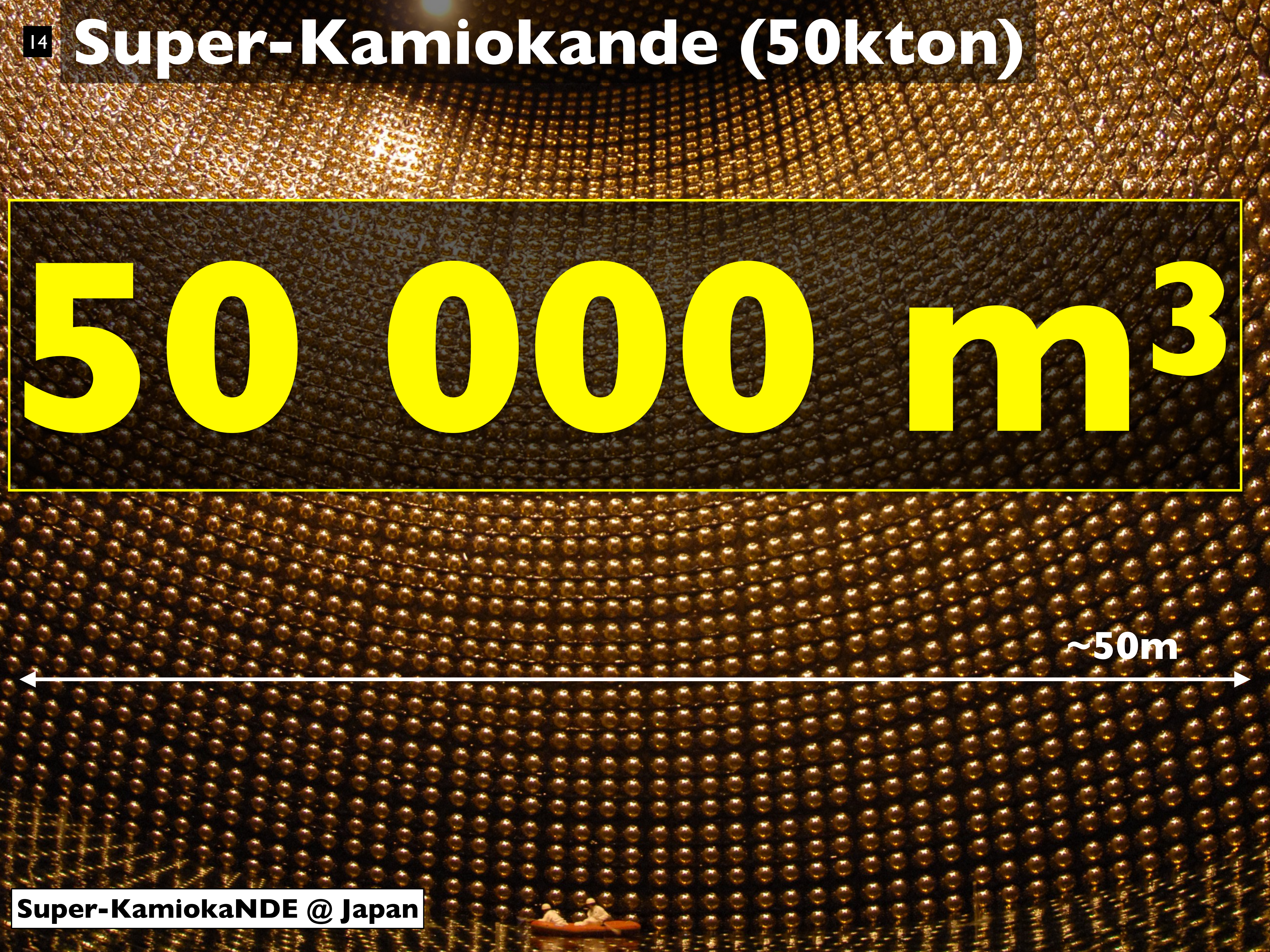
an underground **unknown**…

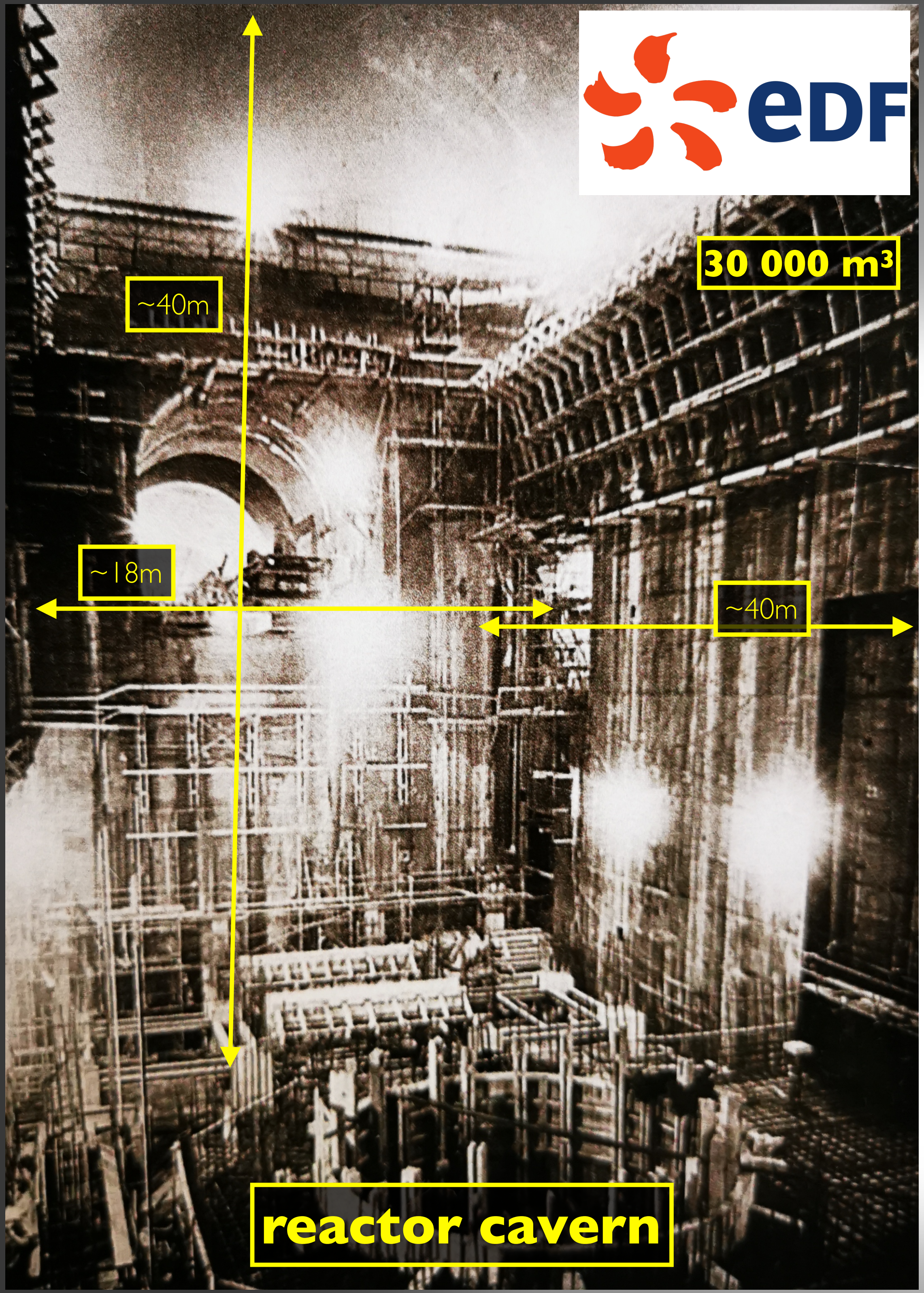
huge caverns (already built) of the **size of Super-Kamiokande** right next to **Chooz reactors!**
(unique site in France-Belgium / Europe / World?)



Chooz-A for science?

Super-Kamiokande (50kton)





construction caverns [1962-1967]

Anatael Cabrera (CNRS-IN2P3) — IJCLab / Université Paris-Saclay (Orsay)

SuperChooz cavern is built (60's)…

historical opportunity!! one of the largest underground laboratories in Europe — built!!

Anatael Cabrera CNRS-IN2P3 / IJCLab (Orsay) - LNCA (Chooz) Laboratories

IJCLab⊕Subatech teams — Octobre 2020

CNRS/IN2P3 direction — March 2022

EDF⊕CNRS exploring (2018)…

(despite COVID)

SUPERCHOOZ

experimental scenario…

SuperChooz
@Superchooz

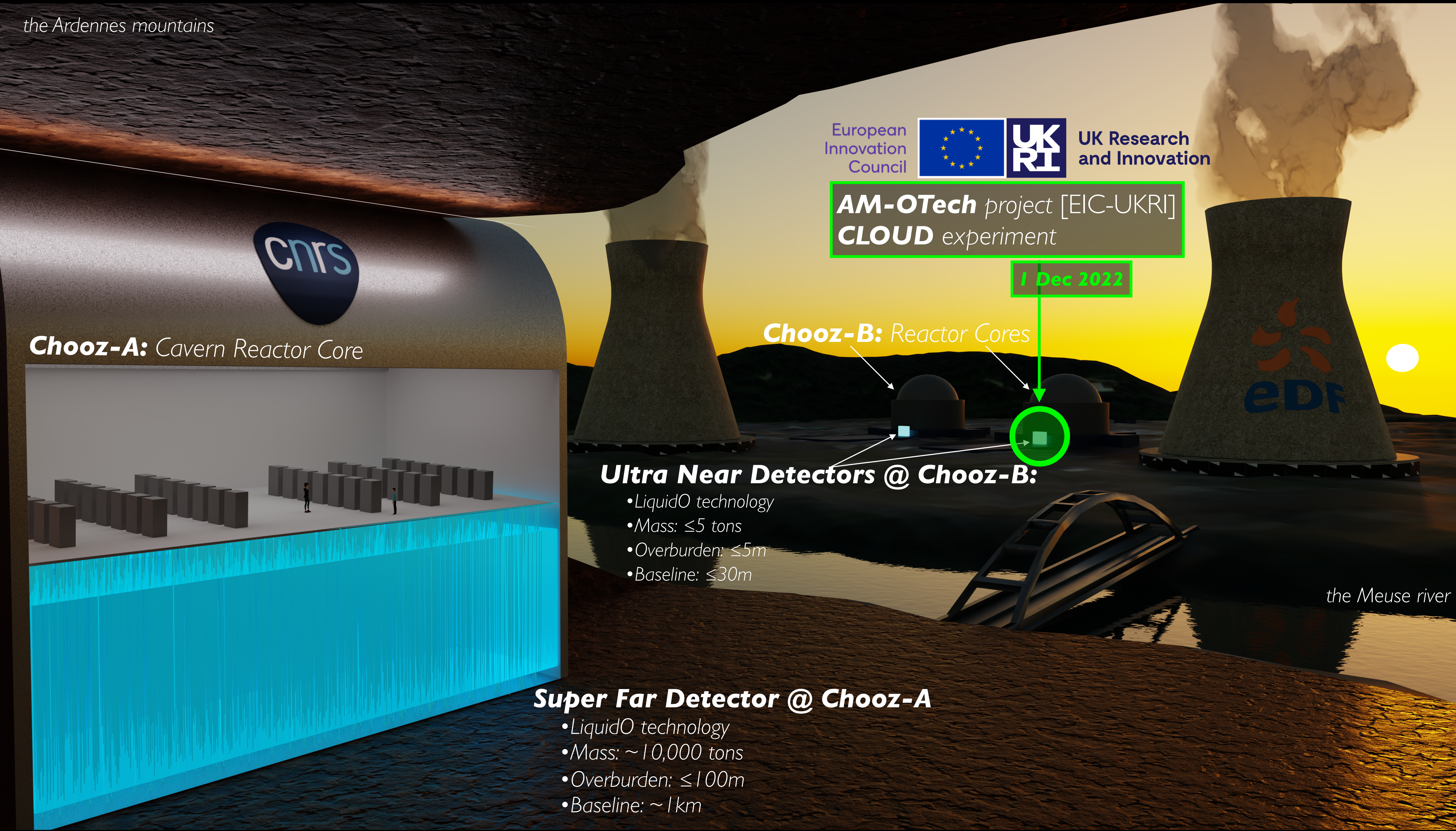
We are delighted to announce that the #SuperChooz agreement between @EDFofficiel and @CNRS directions was signed on the 7th Sept 2022 (twitter.com/IN2P3_CNRS/sta...), thus officially starting the so-called "SuperChooz Pathfinder" exploration era.

S U P E R C H O O Z

pathfinder [2022-2028]

exploration is now official...

SuperChooz experimental setup…



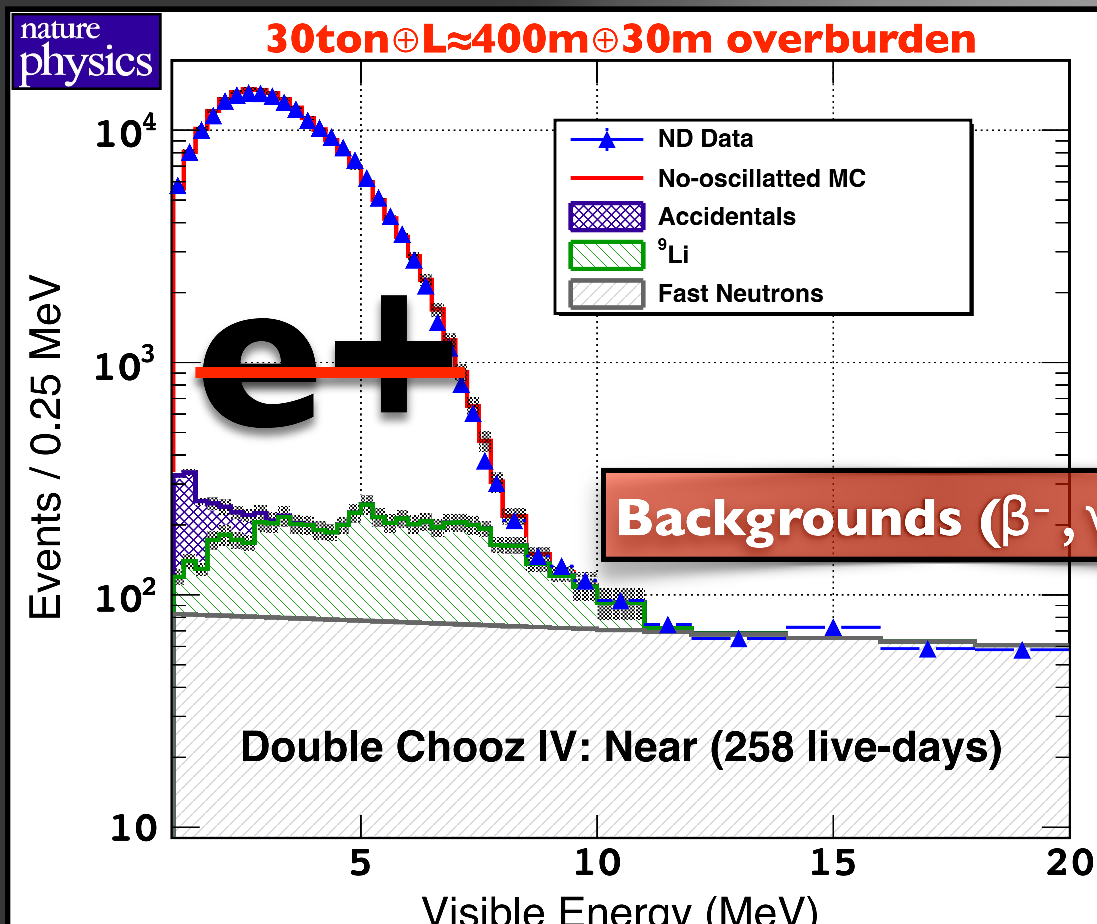
SuperChooz → new laboratory facilities — beyond the existing **LNCA** (key support!)

Anatael Cabrera (CNRS-IN2P3) — IJCLab / Université Paris-Saclay (Orsay)

S U P E R C H O O Z

experimental demonstration

experimental demonstration I



Article | Published: 20 April 2020

Double Chooz θ_{13} measurement via total neutron capture detection

The Double Chooz Collaboration

Nature Physics **16**, 558–564 (2020) | Cite this article

- **no Gd** needed a priori — simpler
- extreme precision **single/multi-detector(s)**
  ⟹simpler detectors (avoid multi-volumes)
- control of **all systematics at per mille**
- **geometrical full flux cancellation systematic**
  ⟹**fewer reactors sites** is better!
- exquisite **energy control absolute/relative**
- Chooz site **full background knowledge**

DC-ND:
Signal ≈ 816 ν/day (average over cycle)
BG(β⁻,α,γ,p) ≈ 39 day⁻¹ ("*some per day*")

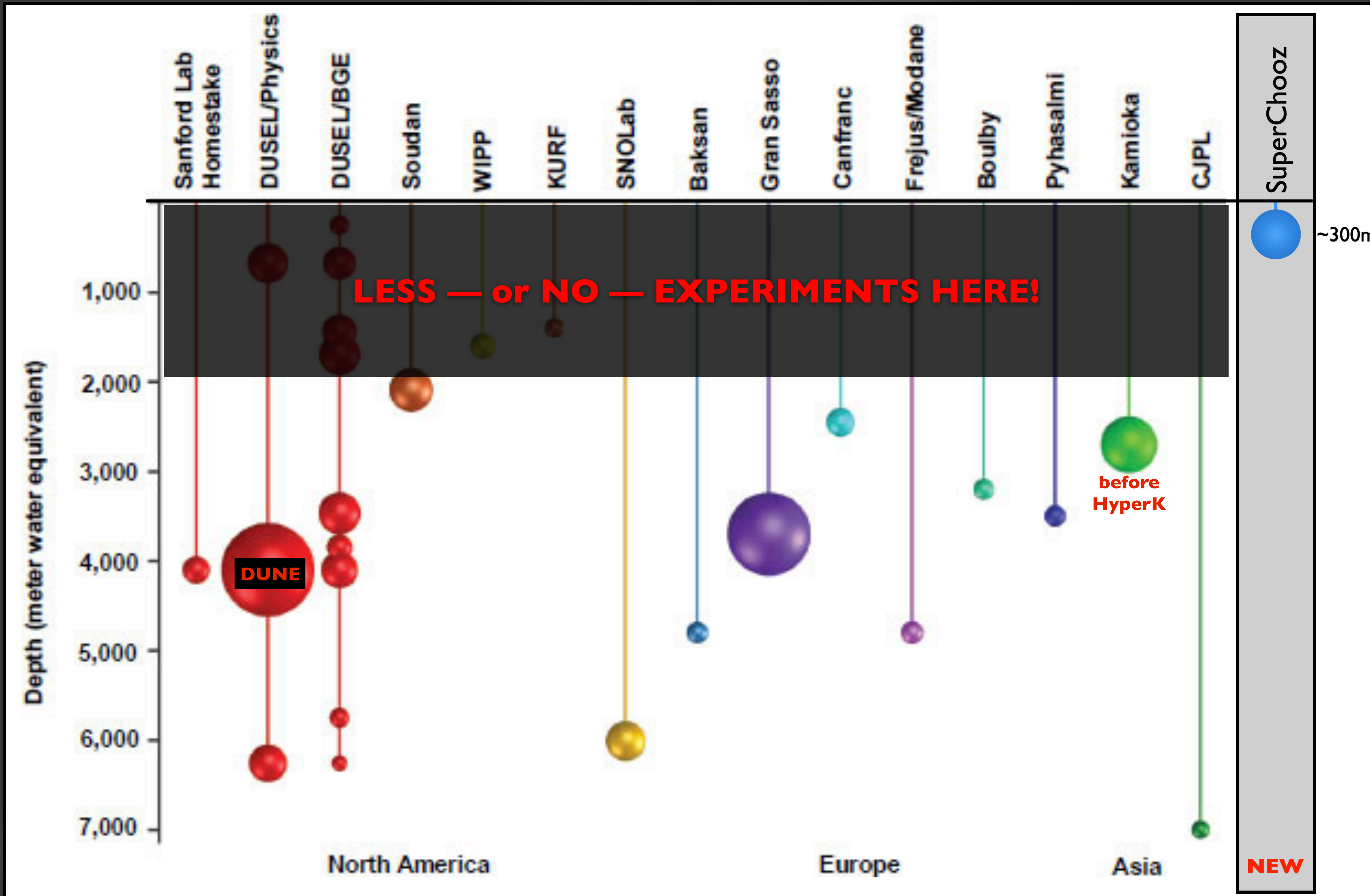
Signal/BG ≈ 21→30 within IBD region [0.5,9.0]MeV

systematics can be controlled: ~0.1% (each)
[flux, background, detection]

energy control: ≲0.5%

enough?

DoubleChooz data & expertise…



ISSUE!!! overburden <100m rock (or <300 mwe)

world underground volume…

Anatael Cabrera (CNRS-IN2P3) — IJCLab / Université Paris-Saclay (Orsay)

experimental demonstration II

L I Q U I D

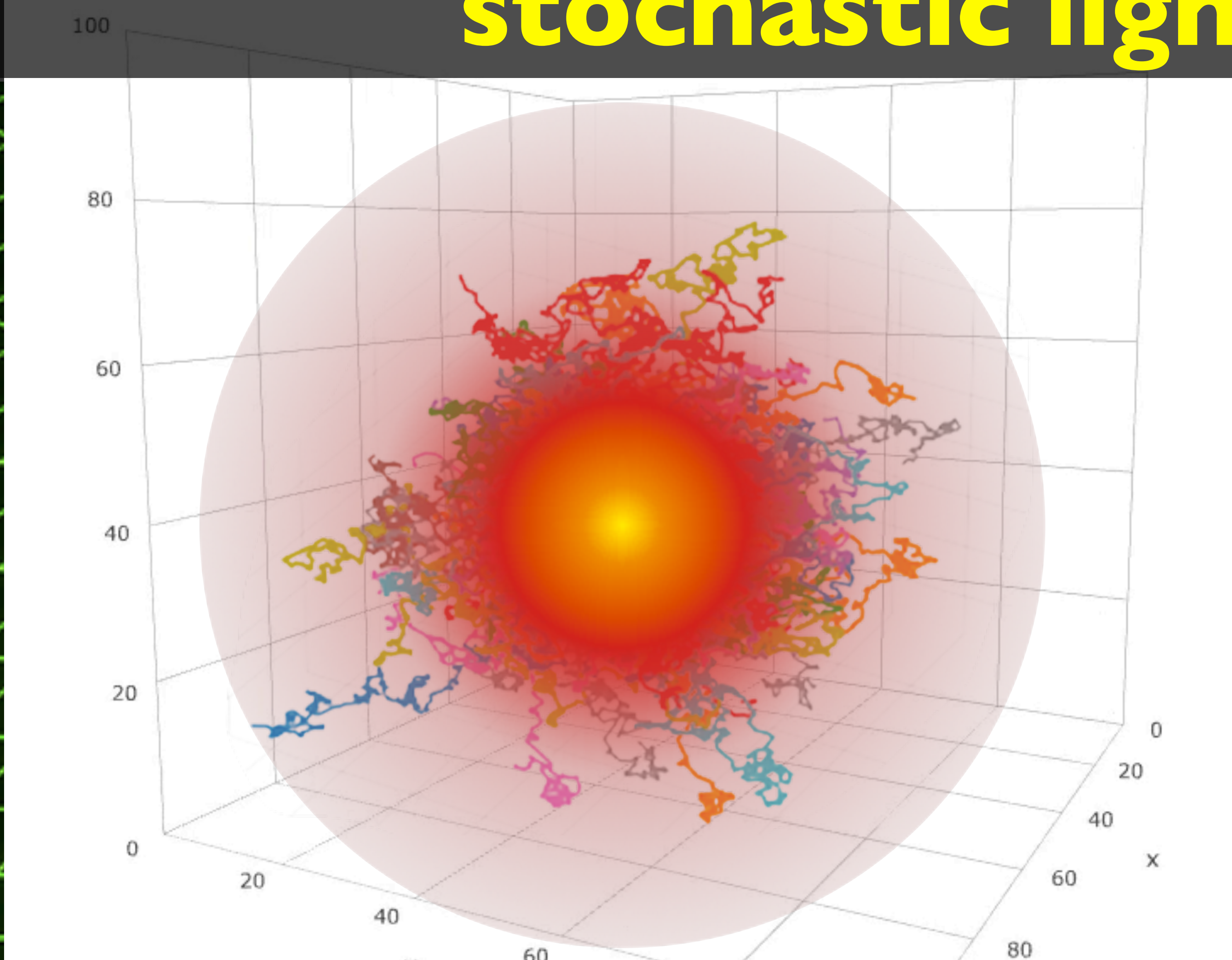
new technology — the breakthrough

today's liquid scintillator technology: transparent. . .

extremely low overburden→ new technology needed

CTF @ Gran Sasso
(Borexino R&D)

stochastic light confinement



LiqudiO→ photon's "random walk" (self-confinement)

- **scattering→random walk→light ball** [order 1cm]
  - scattering mean-free-path order 1mm: x10^{-4} smaller than usual
- **lossless (elastic) light scattering:**
  - **Mie scattering:** achromatic & tiny losses ["cloudy" touch]
  - **Rayleigh scattering:** chromatic & lossless
  - **Internal Reflection** (Snell's law lossless)
  - **warning:** avoid reflection (losses @ order ~1%/reflection)

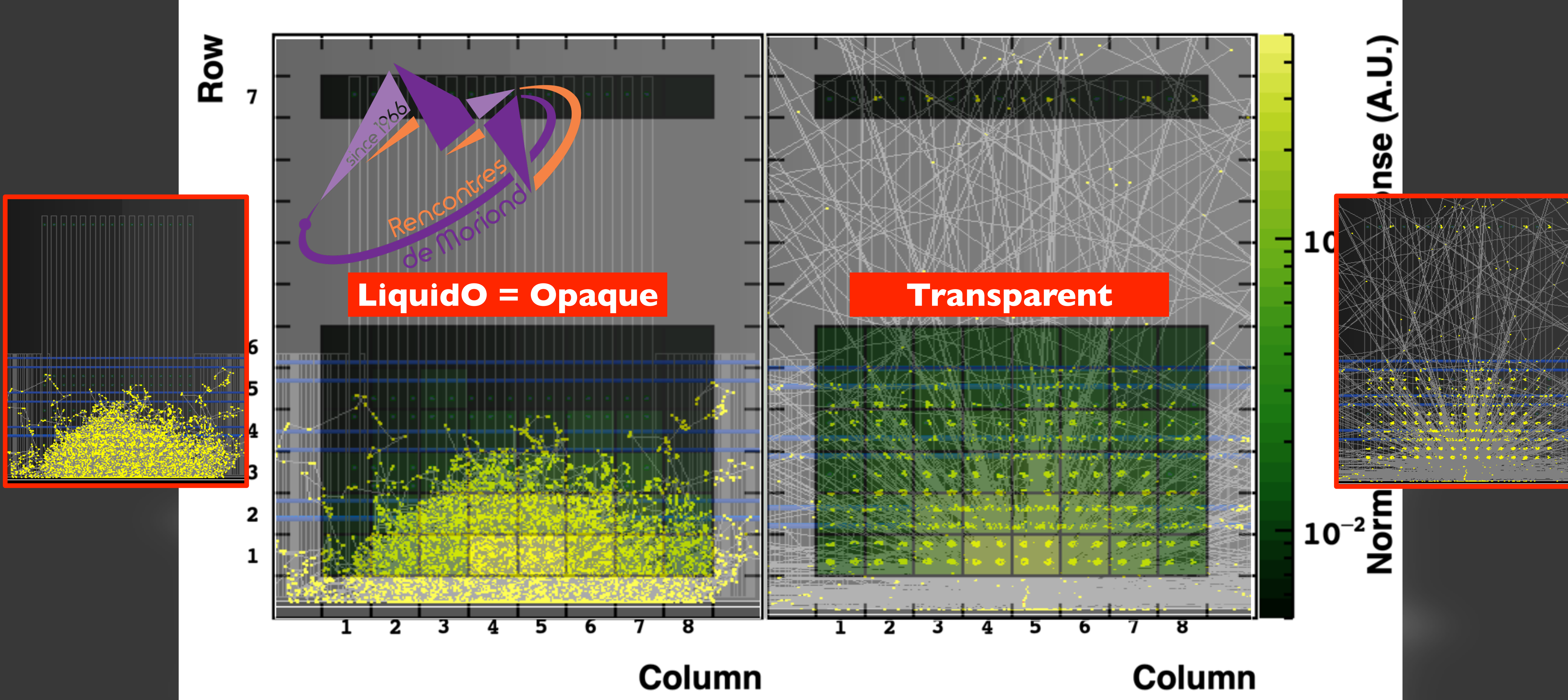
LiquidO ⇔ unique stochastic light confinement

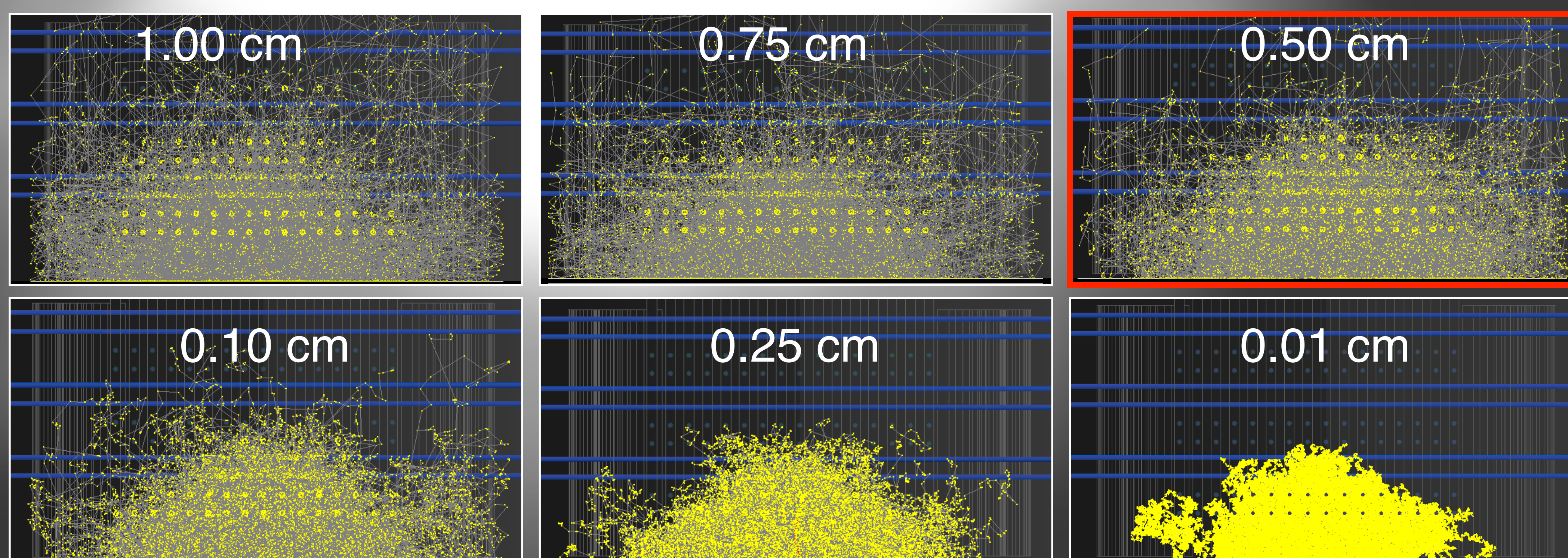
⟹ **must NOT be transparent!!**

Transparency
λ(scattering)≥10m

Rayleigh & Mie Scattering
λ(scattering)≤1cm

inducing light to a point (lossless)...





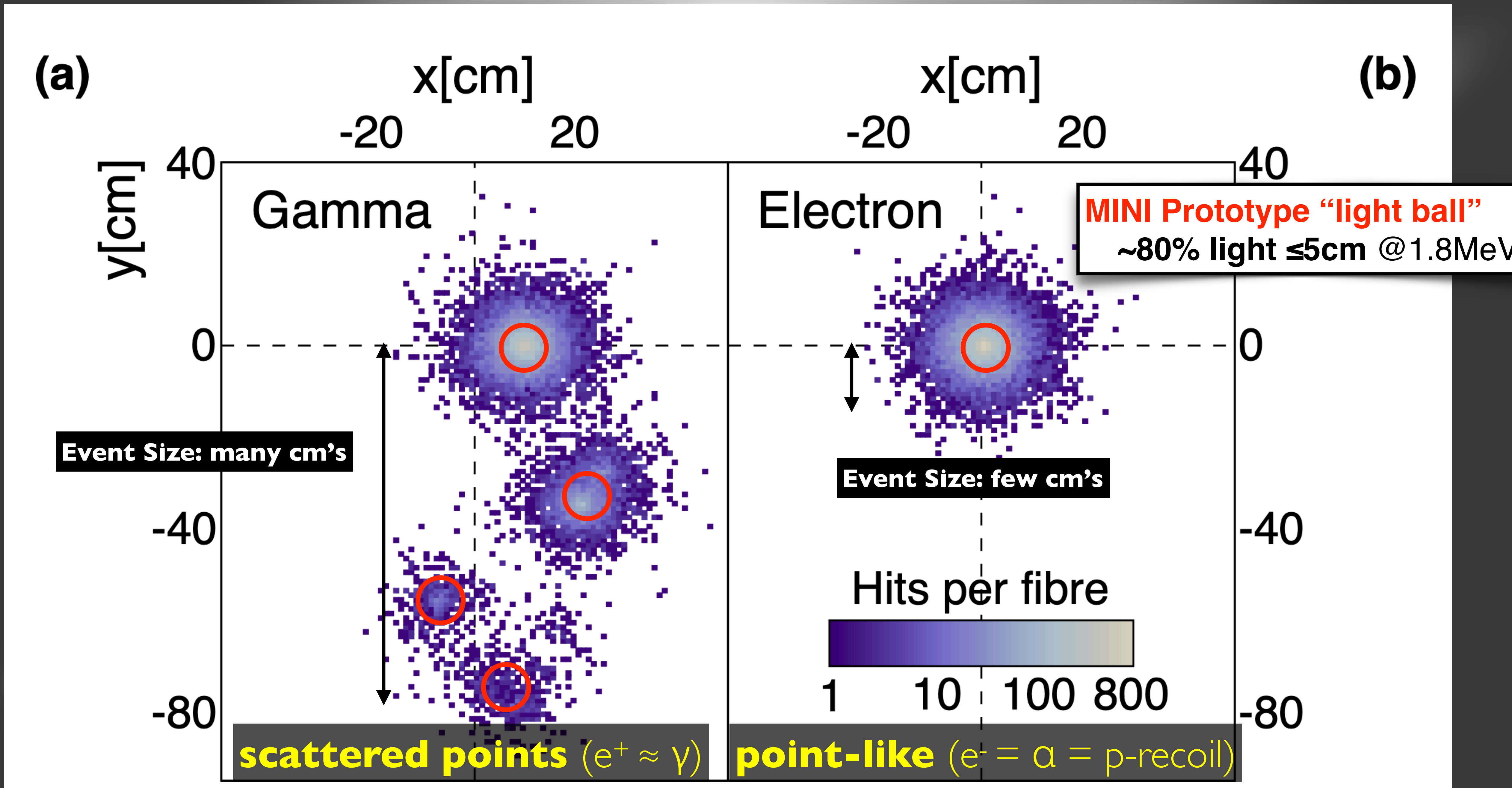
Geant4 Simulation (under tuning)

"light ball" size:

- scattering: λ_s
- # fibres
- absorption?

topology's PID (no timing)…

PID e/γ should be ≥100:1 rejection @ ≥90%
(**γ** resembles more **e+** = **e-** + **2γ**)



Neutrino physics with an opaque detector

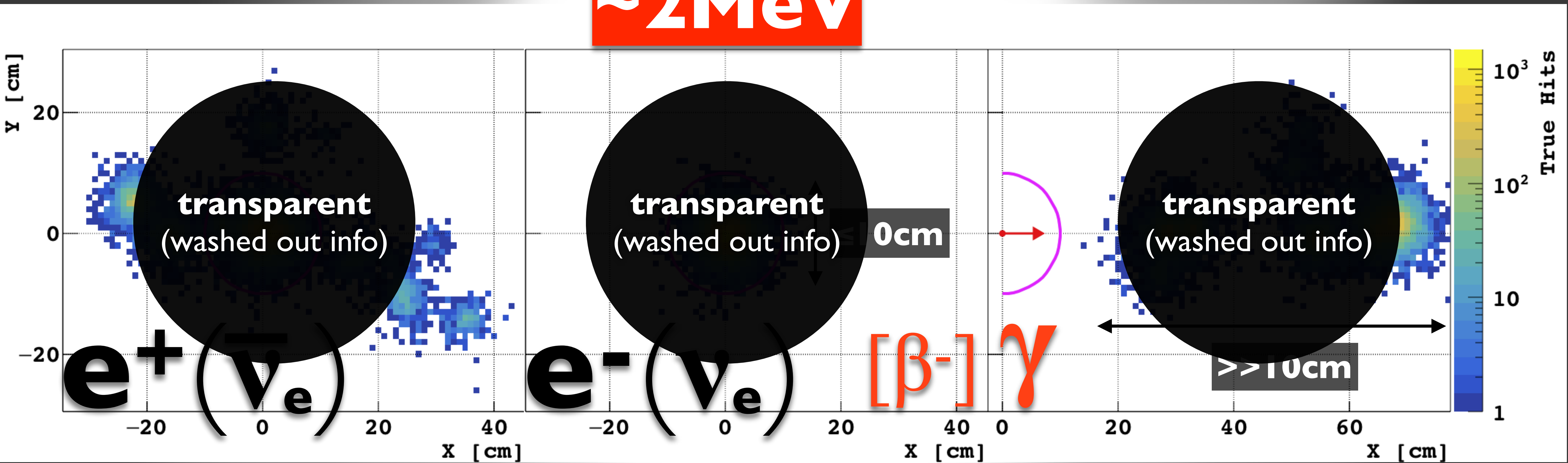
LiquidO Consortium

Communications Physics **4**, Article number: 273 (2021) | Cite this article

unprecedented PID@MeV…

potential: reduce overburden/shielding

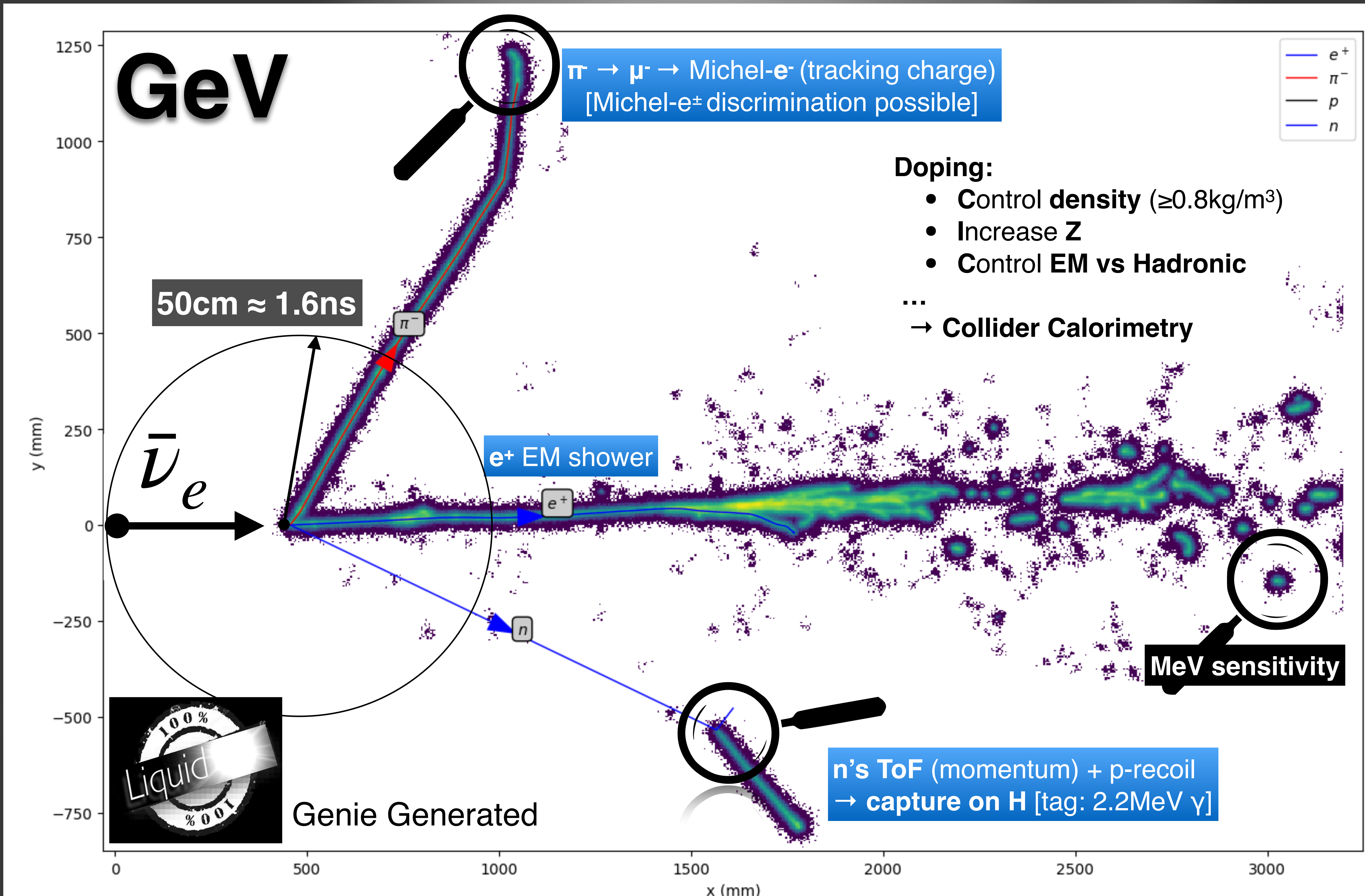
~2MeV



opacity→ (native) self-segmentation

needless segmentation: problematic @ 1MeV (pollution, cost⊕complex, etc)

~1MeV: reactor, geoneutrino, solar, etc



Stochastic calorimetry order 0.1% [~10^5 PE/GeV] — excellent control of non-stochastic

≥100MeV: accelerator, atmospheric, p-decay, etc

experimental demonstration III

a priori no showstopper

SuperChooz : ~9 700 m³

some **common technology** but **not methodology**

- scintillator: ✓ (improvement)
- fibres ✓ (improvement)
- ~~segmentation~~ ✗ (simplification, cheaper, less BG)
- light collection: ✓ (improvement expected)
- photo-detector: ✓ (simplicaition with SiPM)
- MeV optimisation→**Scaling R&D [≥2024]**

SuperChooz (~10kton) similar dimensions as **NOvA (~14kton)** & one module of **DUNE (~10kton)**

First Release at CERN July 2019 (detector seminar)

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

nature communications physics

Article | Open Access | Published: 21 December 2021

Neutrino physics with an opaque detector

LiquidO Consortium

Communications Physics **4**, Article number: 273 (2021) | Cite this article

Abstract **COVID delayed**

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

latest experimental results @ **Neutrino 2022** (June 2022)

DOI 10.5281/zenodo.6697273

https://zenodo.org/record/6697273#.Y4DDdezMLfv

proof-of-concept: *simulation* & data [**μ-LiquidO**]

physics potential — appetiser

latest prototype detector results [mini-LiquidO]

physics potential — more precision

LiquidO Official WEB: **https://liquido.ijclab.in2p3.fr/**

LiquidO Consortium*

J. dos Anjos[a], L. Asquith[r], J.L. Beney[q], T.J.C. Bezerra[r], M. Bongrand[q], C. Bourgeois[fα], D. Brasse[g], D. Breton[fα], M. Briere[fα], J. Busto[b], A. Cabrera[†fα], A. Cadiou[q], E. Calvo[c], H. Carduner[q], V. Chaumat[fα], E. Chauveau[h], M. Chen[n], P. Chimenti[e], F. Dal Corso[kα], A. Dahmane[g], J.-F. Le Du[fα], S. Dusini[kα], A. Earle[r], C. Frigerio-Martins[e], J. Galán[s], J.A. García[s], R. Gazzini[fα], A. Gibson-Foster[r], D. Giovagnoli[g], P. Govoni[jα,jβ], M. Grassi[kβ], W.C. Griffith[r], F. Haddad[q], J. Hartnell[r], A. Hourlier[g], G. Hull[fα], I.G. Irastorza[s], L. Koch[iα], P. Laniéce[fα,fβ], C. Lefebvre[n], F. Lefevre[q], P. Loaiza[fα,fβ], G. Luzón[s], J. Maalmi[fα], F. Mantovani[dα,dβ], C. Marquet[h], M. Martínez[s], L. Ménard[fα,fβ], D. Navas-Nicolás[fα], H. Nunokawa[m], M. Obolensky[fα,fβ], J.P. Ochoa-Ricoux[o], C. Palomares[c], P. Pillot[q], J.C.C. Porter[r], M. S. Pravikoff[h], M. Roche[h], B. Roskovec[l], M.L. Sarsa[s], S. Schoppmann[iβ], A. Serafini[kα,kβ], W. Shorrock[r], L. Simard[fα], M. Sisti[jα], D. Stocco[q], V. Strati[dα,dβ], J.-S. Stutzmann[q], F. Suekane[‡p], M.-A. Verdier[fα,fβ], A. Verdugo[c], B. Viaud[q], A. Weber[iα], and F. Yermia[q]

LiquidO-Contact-L@in2p3.fr

[a]Centro Brasileiro de Pesquisas Físicas (CBPF), Rua Xavier Sigaud 150, Rio de Janeiro, 22290-180, Brazil
[b]Université d'Aix Marseille, CNRS/IN2P3, CPPM, Marseille, France
[c]CIEMAT, Centro de Investigaciones Energéticas, Medioambientales y Tecnológicas, Av. Complutense 40, E-28040 Madrid, Spain
[dα]INFN, Ferrara Section, Via Saragat 1, 44122 Ferrara, Italy
[dβ]Department of Physics and Earth Sciences, University of Ferrara, Via Saragat 1, 44122 Ferrara, Italy
[e]Departamento de Física, Universidade Estadual de Londrina, Rodovia Celso Garcia Cid, PR 445 Km 380, Campus Universitário Cx. Postal 10.011, CEP 86.057-970, Londrina – PR, Brazil
[fα]Université Paris-Saclay, CNRS/IN2P3, IJCLab, 91405 Orsay, France
[fβ]Université de Paris Cité, CNRS/IN2P3, IJCLab, 91405 Orsay, France
[g]Université de Strasbourg, CNRS, IPHC UMR 7178, F-67000 Strasbourg, France
[h]Université de Bordeaux, CNRS, LP2I Bordeaux, UMR 5797, F-33170 Gradignan, France
[iα]Johannes Gutenberg-Universität Mainz, Institut für Physik, Staudingerweg 7, 55128 Mainz, Germany
[iβ]Johannes Gutenberg-Universität Mainz, Detektorlabor, Exzellenzcluster PRISMA+, Staudingerweg 9, 55128 Mainz, Germany
[jα]INFN, Sezione di Milano-Bicocca, I-20126 Milano, Italy
[jβ]Dipartimento di Fisica, Università di Milano-Bicocca, I-20126 Milano, Italy
[kα]INFN, Sezione di Padova, via Marzolo 8, I-35131 Padova, Italy
[kβ]Dipartimento di Fisica e Astronomia, Università di Padova, via Marzolo 8, I-35131 Padova, Italy
[l]Institute of Particle and Nuclear Physics Faculty of Mathematics and Physics, Charles University, V Holešovičkách 2 180 00 Prague 8, Czech Republic
[m]Department of Physics, Pontifícia Universidade Católica do Rio de Janeiro, C.P. 38097, 22451-900, Rio de Janeiro, Brazil
[n]Department of Physics, Engineering Physics & Astronomy, Queen's University, Kingston, Ontario K7L3N6, Canada
[o]Department of Physics and Astronomy, University of California at Irvine, 4129 Frederick Reines Hall, Irvine, California 92697, USA
[p]RCNS, Tohoku University, 6-3 AzaAoba, Aramaki, Aoba-ku, 980-8578, Sendai, Japan
[q]Subatech, CNRS/IN2P3, Nantes Université, IMT-Atlantique, 44307 Nantes, France
[r]Department of Physics and Astronomy, University of Sussex, Falmer, Brighton BN1 9QH, United Kingdom
[s]Centro de Astropartículas y Física de Altas Energías (CAPA), Universidad de Zaragoza, Calle Pedro Cerbuna 12, 50009 Zaragoza, Spain

invention/conception 2012-2013 — since 2016 consortium (~20 institutes & 10 countries)

SuperChooz's pilot project

C L O U D

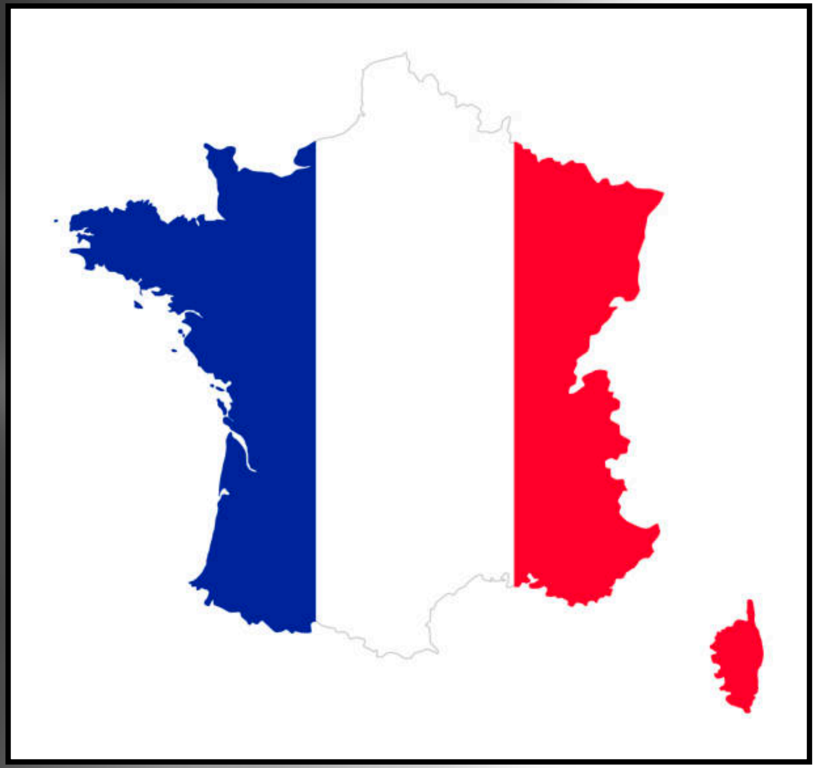
European Innovation Council

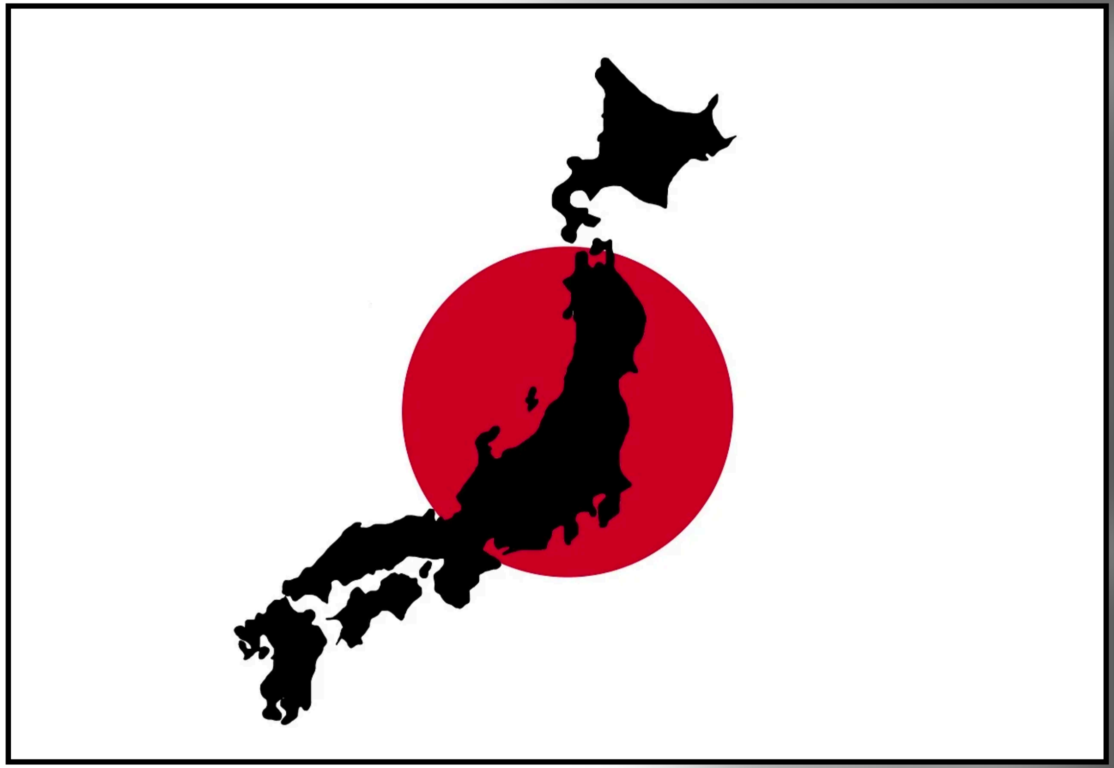
UK Research and Innovation

project: "**AntiMatter-OTech**"

first LiquidO-based experiment...

CLOUD = "**C**hooz **L**iquid**O** **U**ltranear **D**etector"





(✓) **DoubleChooz** → (✓) **LiquidO** → (✓ starting) **CLOUD** → (exploring) **SuperChooz**

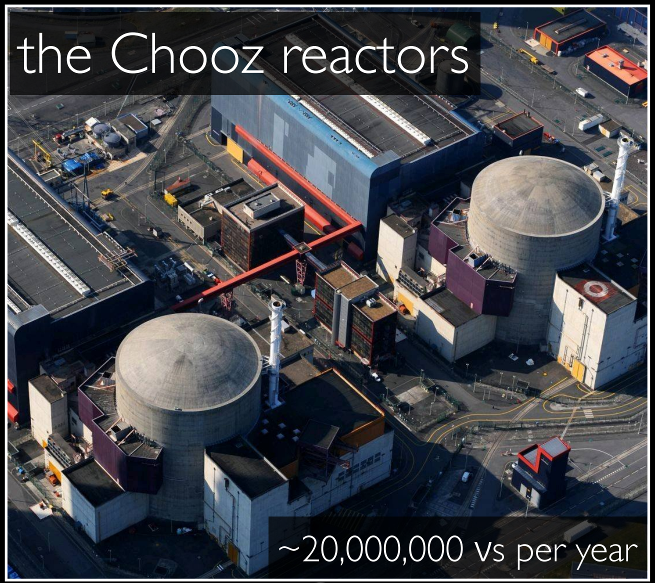
~20 years of collaboration…

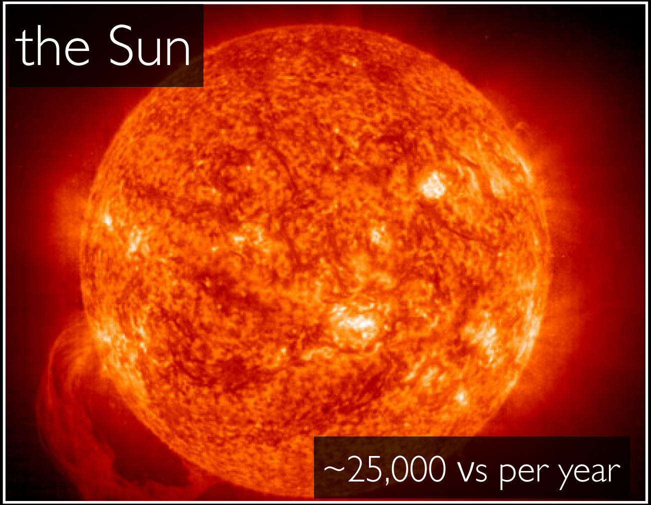
SUPERCHOOZ

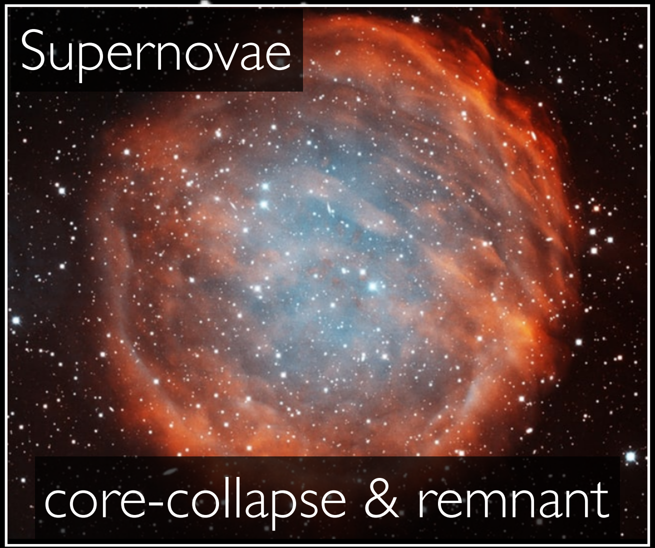
scientific programme…(so far)

neutrino sources…

large **SuperChooz** detector→ **vast physics programme!**







…also **atmospherics**!!

geoneutrino? yes, but huge irreducible background by reactor neutrinos!!

Anatael Cabrera (CNRS-IN2P3) — IJCLab / Université Paris-Saclay (Orsay)

SuperChooz rates…

10 years exposure

Antineutrino Reactor (@1.1km):

- $\phi \approx 6\ \nu \bullet \mathrm{day}^{-1} \bullet \mathrm{ton}^{-1}$ [→**DC-FD**]
- $\phi \approx 20\mathrm{M}\ \nu \bullet \mathrm{year}^{-1}$ [~**10kton**]
- **$\phi \approx$ 220M ν's** [exposure: 100,000 ton•year]

Neutrinos Sun:

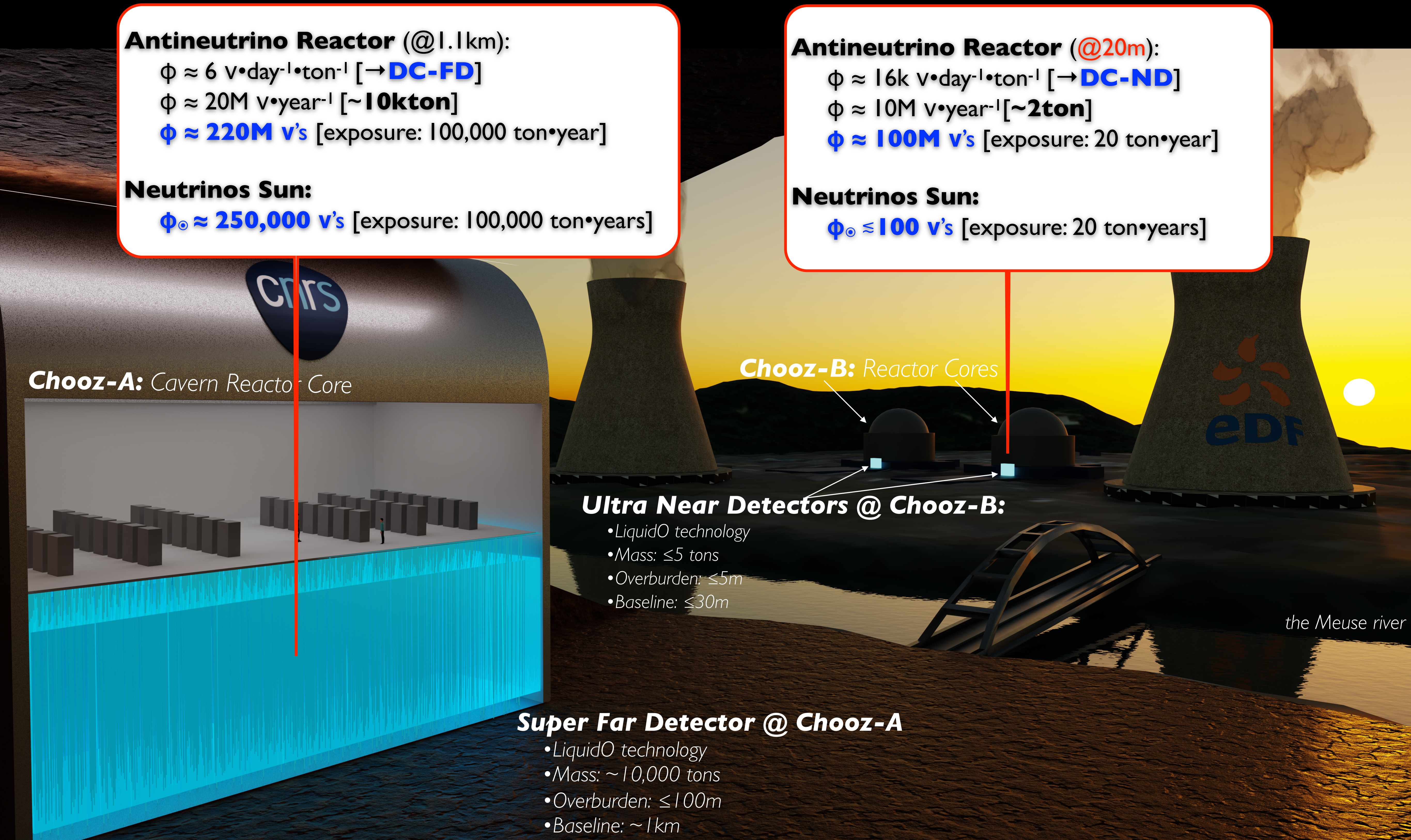
- **$\phi_\odot \approx$ 250,000 ν's** [exposure: 100,000 ton•years]

Antineutrino Reactor (@20m):

- $\phi \approx 16\mathrm{k}\ \nu \bullet \mathrm{day}^{-1} \bullet \mathrm{ton}^{-1}$ [→**DC-ND**]
- $\phi \approx 10\mathrm{M}\ \nu \bullet \mathrm{year}^{-1}$[~**2ton**]
- **$\phi \approx$ 100M ν's** [exposure: 20 ton•year]

Neutrinos Sun:

- **$\phi_\odot \lesssim$ 100 ν's** [exposure: 20 ton•years]



Anatael Cabrera (CNRS-IN2P3) — IJCLab / Université Paris-Saclay (Orsay)

detection: all about coincidences…

the power of coincidences

low energy (≤3MeV) neutrinos interactions benefit by interactions leading to coincidences

Reines et al 1956

(neutrino discovery)

CC: $\bar{\nu}_e + p \rightarrow e^+ + n$

($\tau \approx 220\mu s$ for only H⊕C)

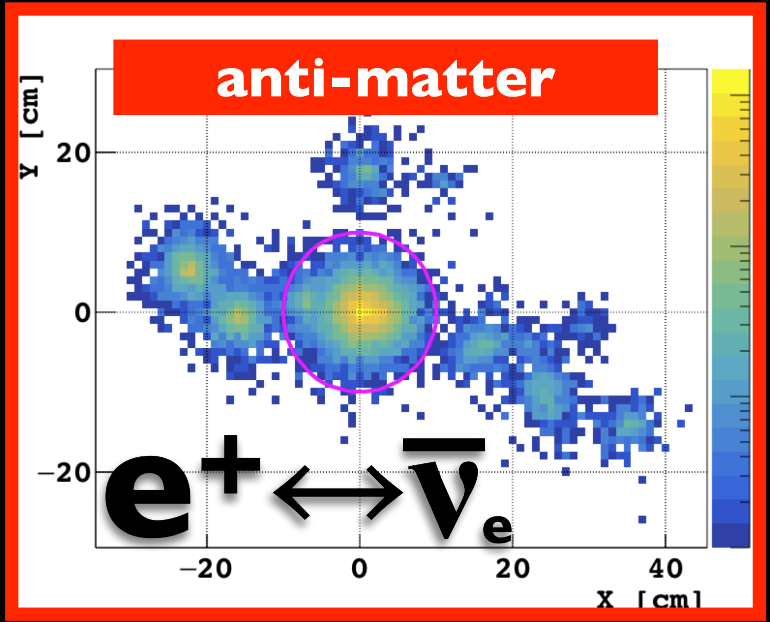
Raghavan et al 1977

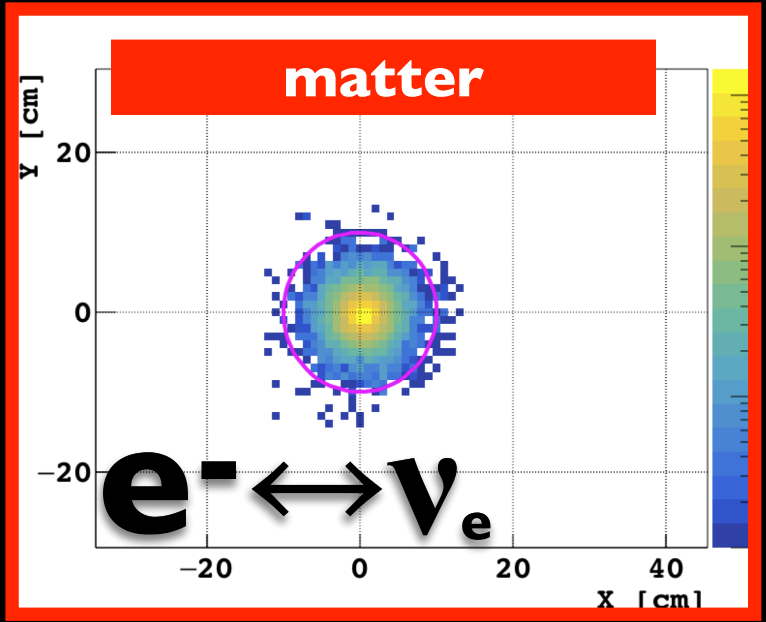
(pp solar neutrino — unobserved)

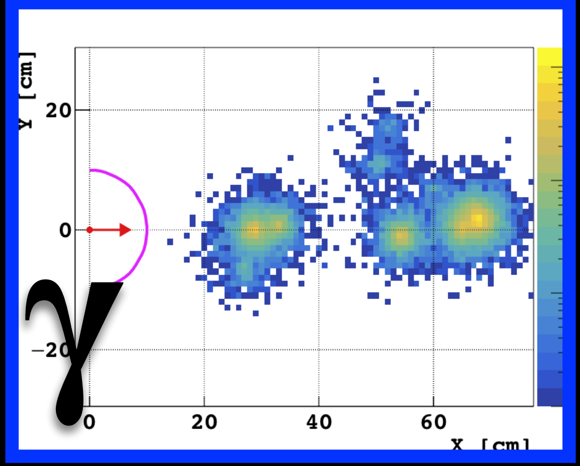
CC: $\nu_e + {}^{115}In \rightarrow e^- + \gamma + \gamma/e^-$

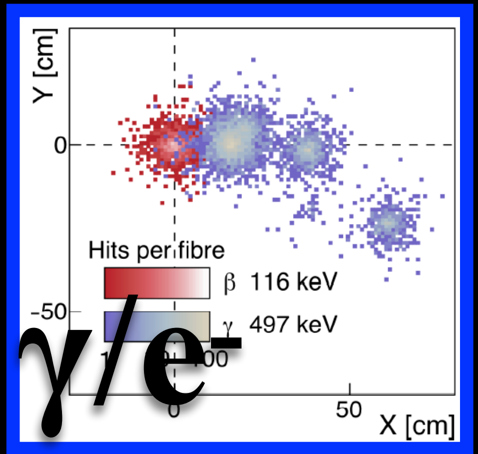
($\tau \approx 4.7\mu s$ decay of **Sn***)

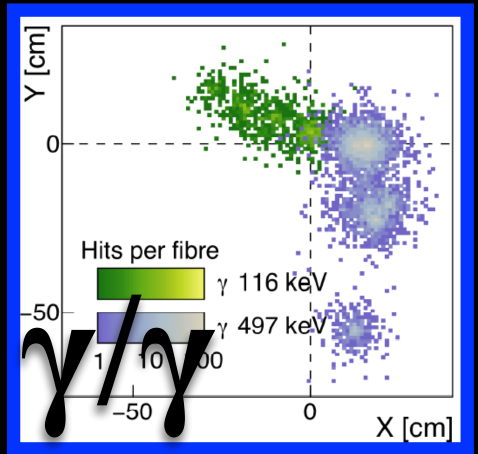
major **R&D** by **LENS** *et al* [many years]











Anatael Cabrera (CNRS-IN2P3) — IJCLab / Université Paris-Saclay (Orsay)

SUPERCHOOZ

preliminary physics programme…

rationale...

- high precision SM's neutrino oscillation

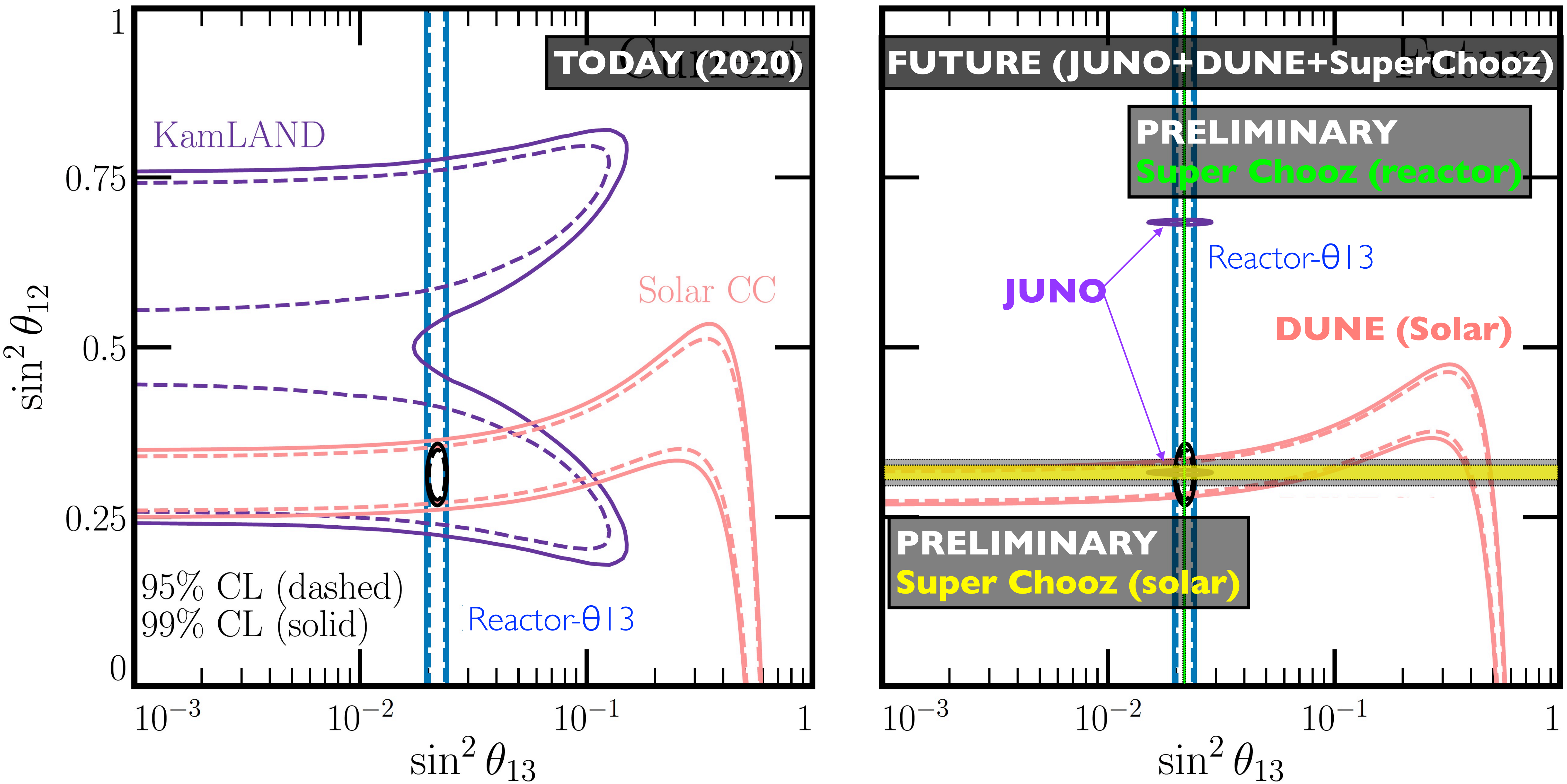
$\Longrightarrow$ synergise with JUNO & HK$\oplus$DUNE

- neutrinos probing BSM $\longrightarrow$ discoveries?

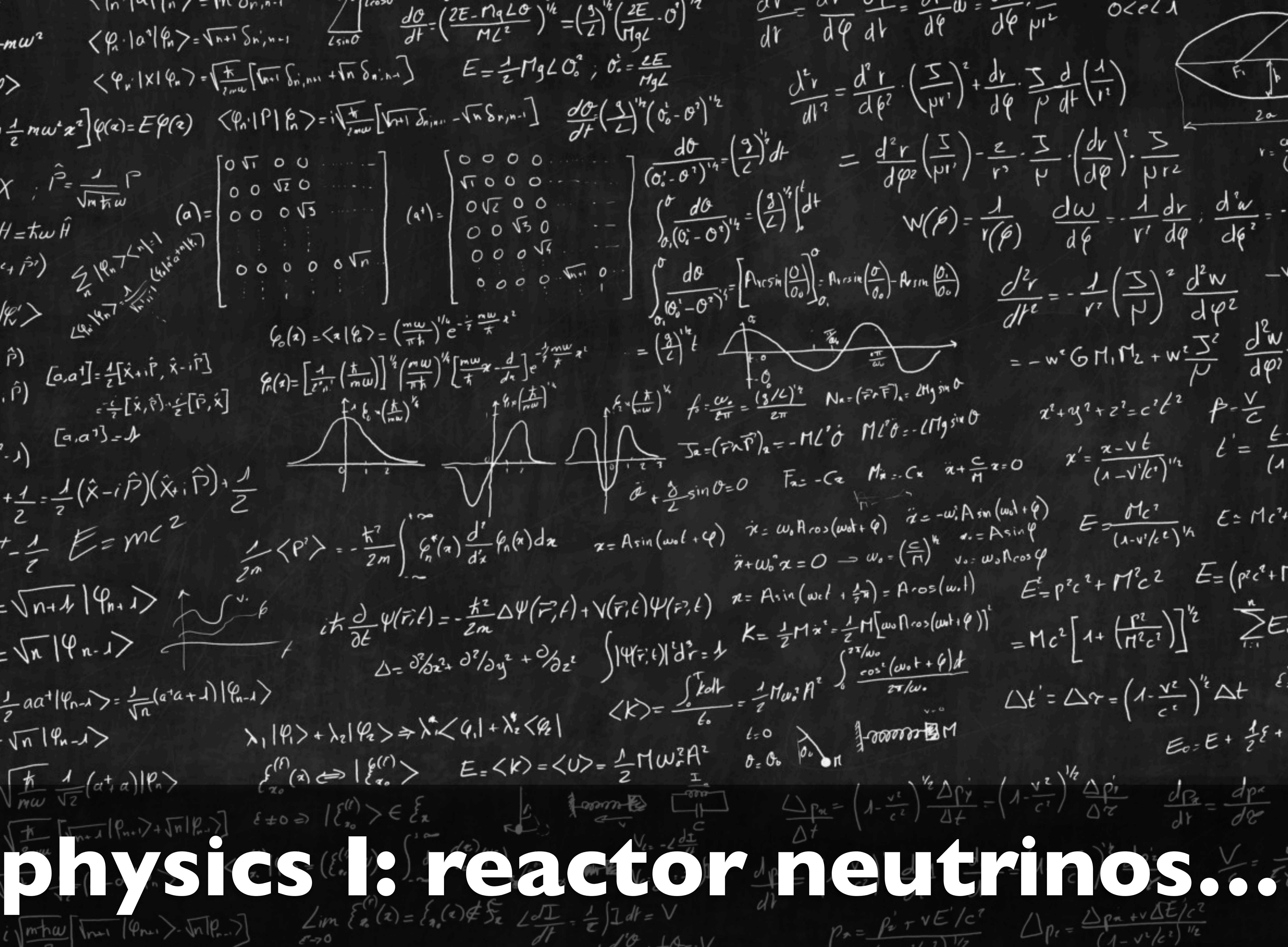
$\Longrightarrow$ beyond today's paradigm?

Super Chooz potential under investigation…

Plot: hacked version from original in ***Ellis, Kelly & Weishi-Li at arXiv:2008.01088***

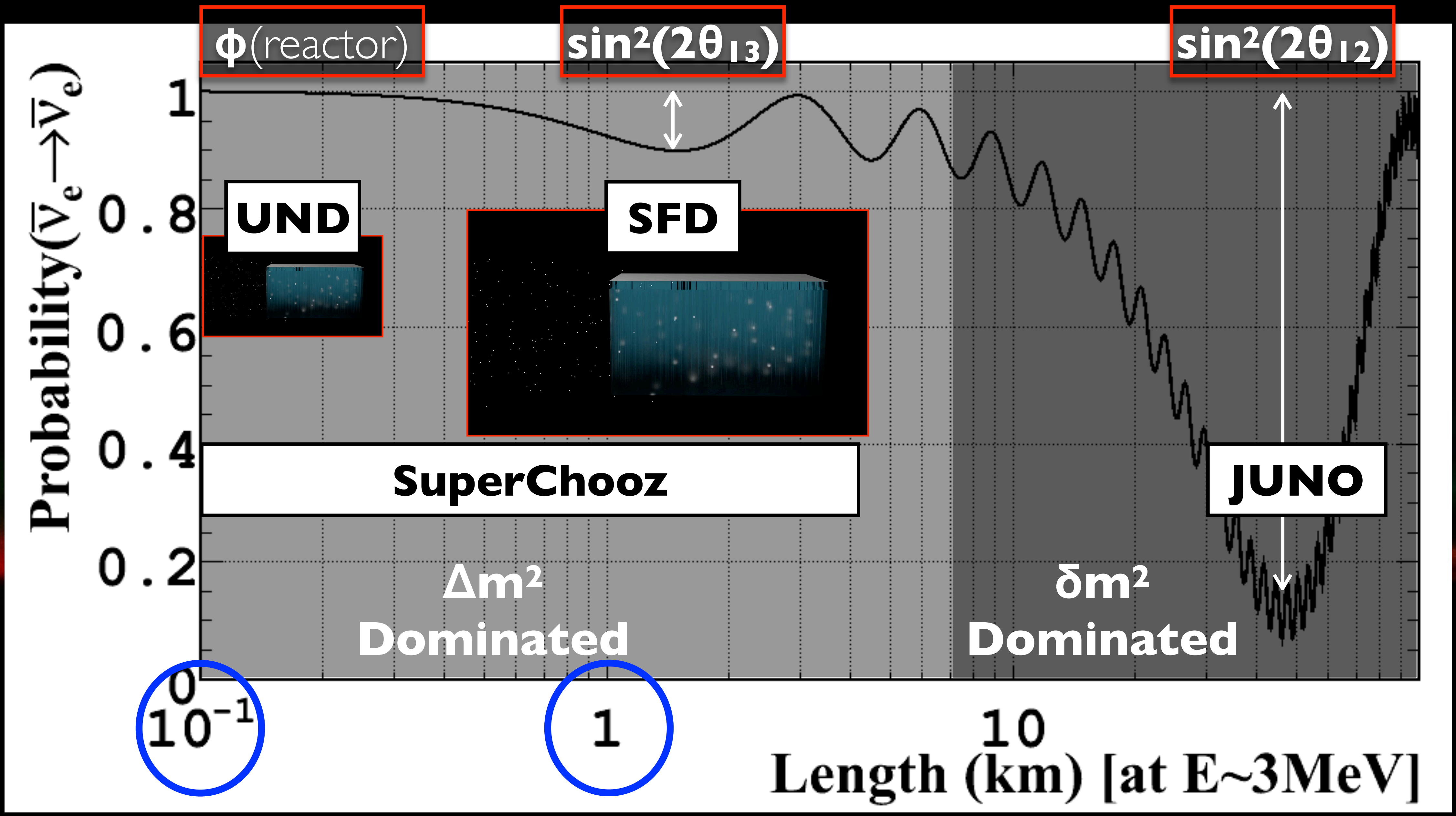


Super Chooz: the smallest but powerful…



physics I: reactor neutrinos…

experimental setup…

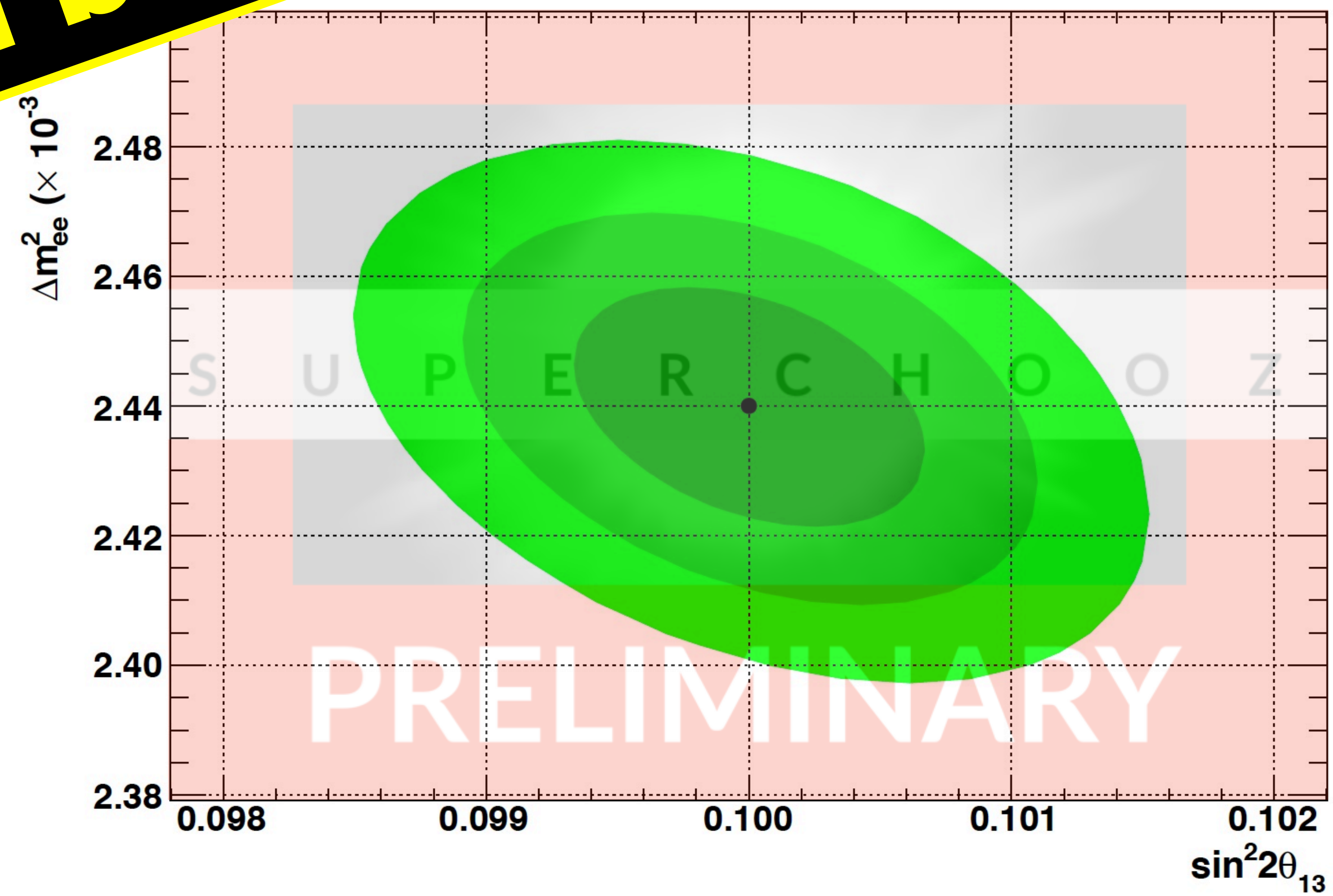


- **reactor:** extreme source of neutrino (commercial→1GW≈2x10[20]/s) — no running cost.
- **3 measurement regimes:** depending on baseline (L):
  - [**UND**] **zero-baseline** (L→~0km): **φ(reactor)** — and **new physics: Unitarity violation?**
  - [**SFD**] **short-baseline** (L→~1km): **θ13⊕Δm²** [multi-detector: ~~**φ(reactor)**~~]
  - [**JUNO**] ~~**long baseline** (L→≳50km): **θ12⊕δm²** and **θ13⊕Δm²**, if enough resolution~~

overall θ13⊕Δm²(ee) sensitivity…

Input Δm^2_{ee} unc.	Output Δm^2_{ee} unc.	$\sin^2 2\theta_{13}$ unc.
1% Free	≤0.5%	≤0.5%

world best | **≥3x** | **≥6x**



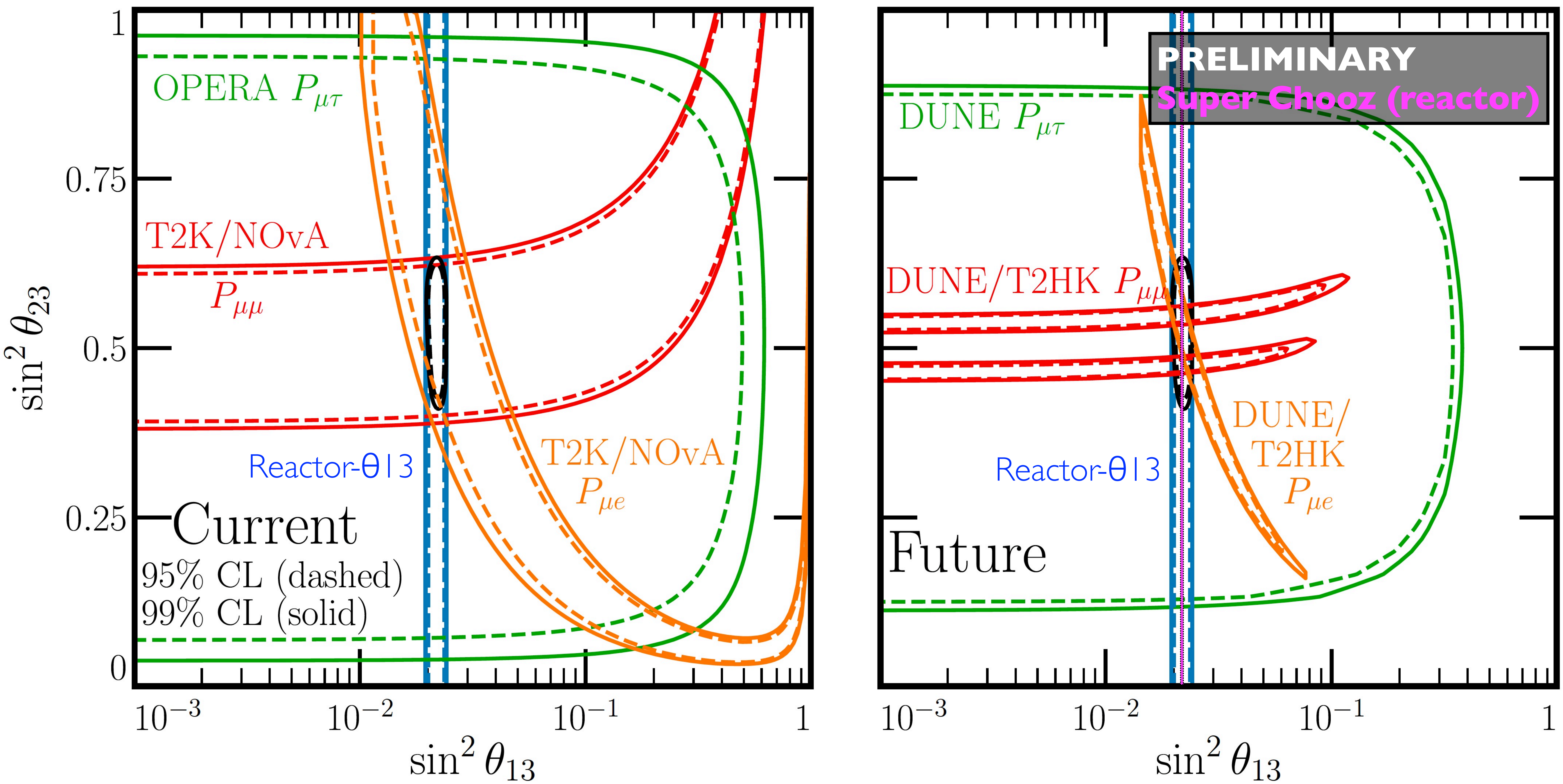
[first time] sub-percent measurement of θ13⊕Δm²(ee)

why θ_{13} & $|\Delta m^2|$? (reactor)

- world most precise θ_{13}!! [permille precision]
  - (unique) cross-check JUNO's Δm^2
- PMNS' shape: the smallest term
- synergies: extra precision on
  - HyperK⊕DUNE's CP violation
    - (simultaneously) resolve octant-θ_{23}?
    - PMNS' shape: the largest term!
  - JUNO's Mass Ordering (oscillation)

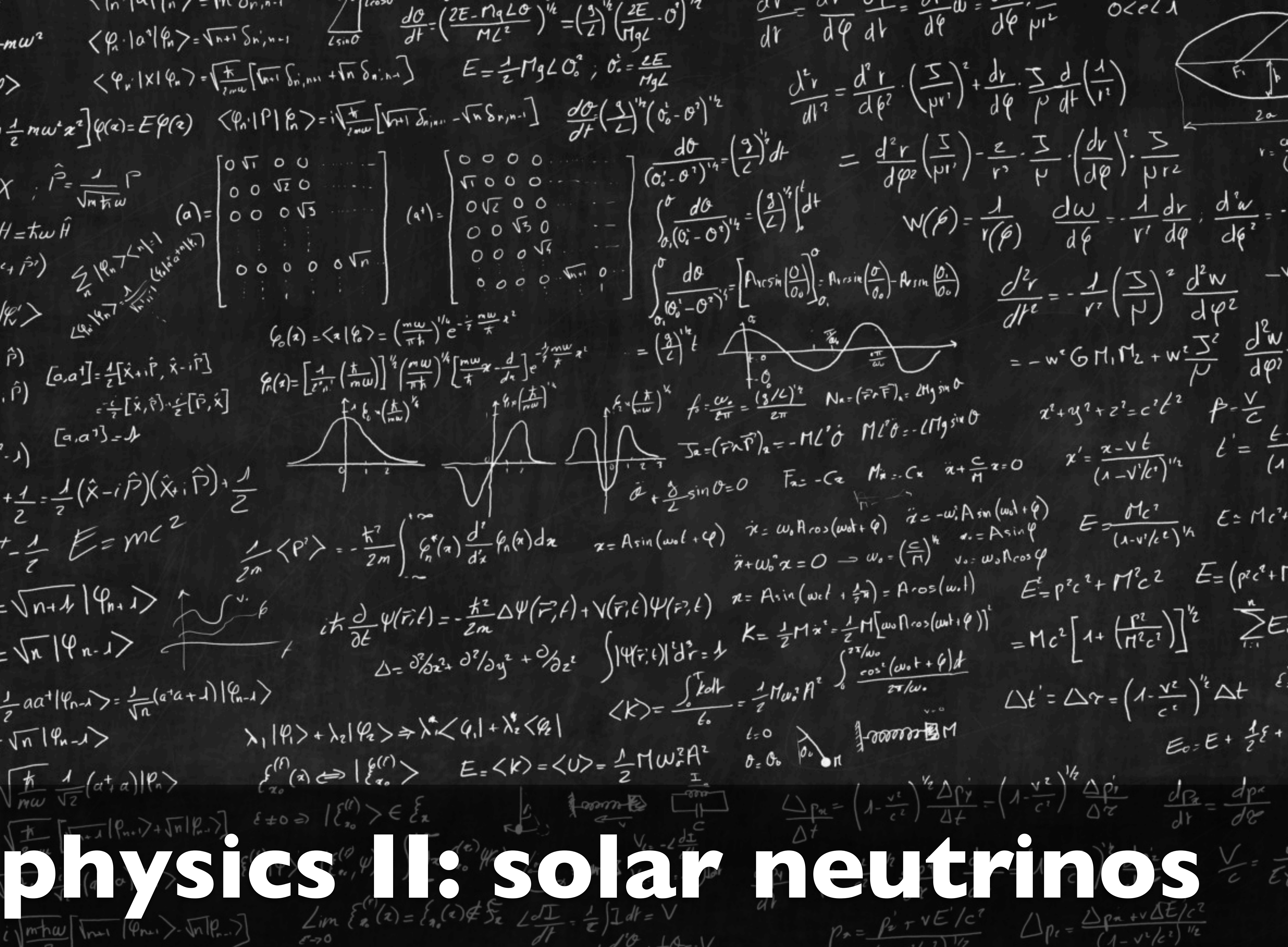
Super Chooz potential under investigation…

Plot: hacked version from original in ***Ellis, Kelly & Weishi-Li at* arXiv:2008.01088**



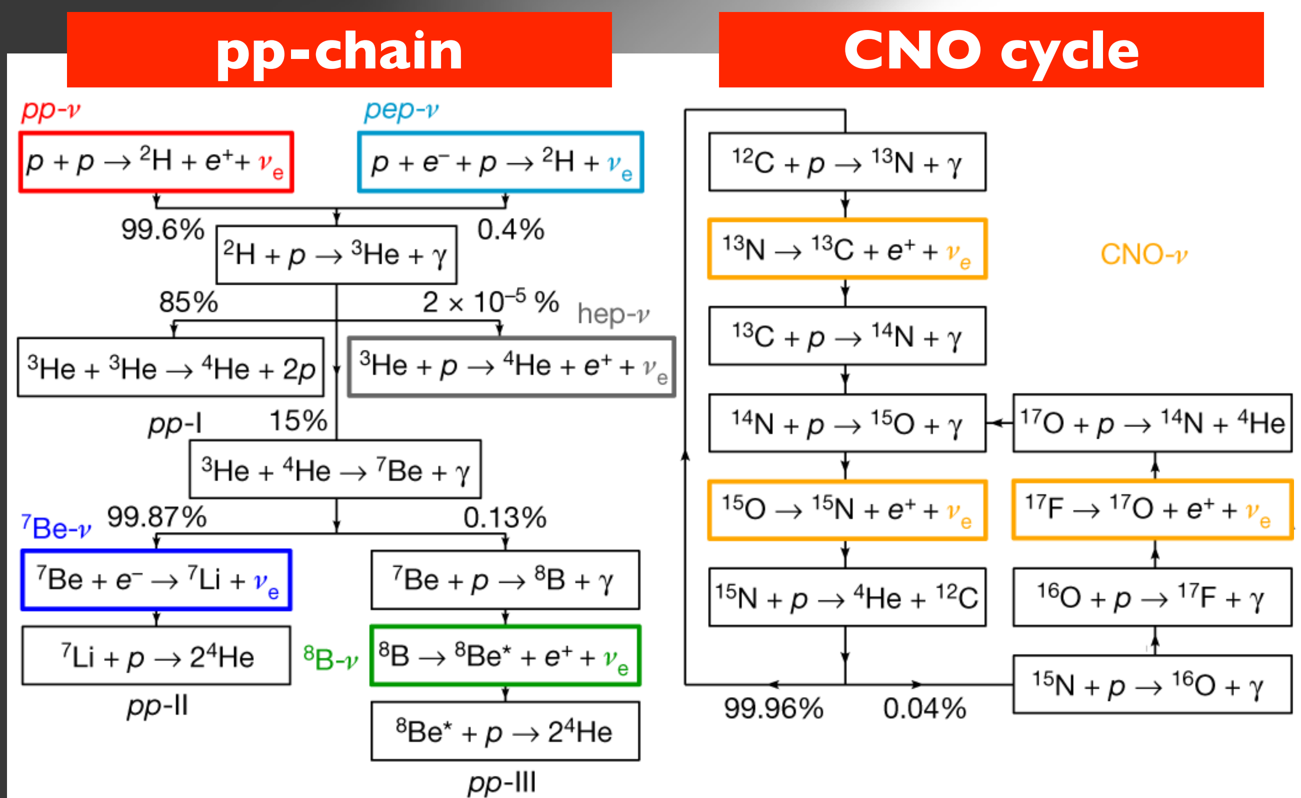
synergy: SC θ13 may help to resolve the "θ23 octant" ambiguity
(HK and DUNE) measured the combined effect of θ13⊕θ23 (harder to disentangle)

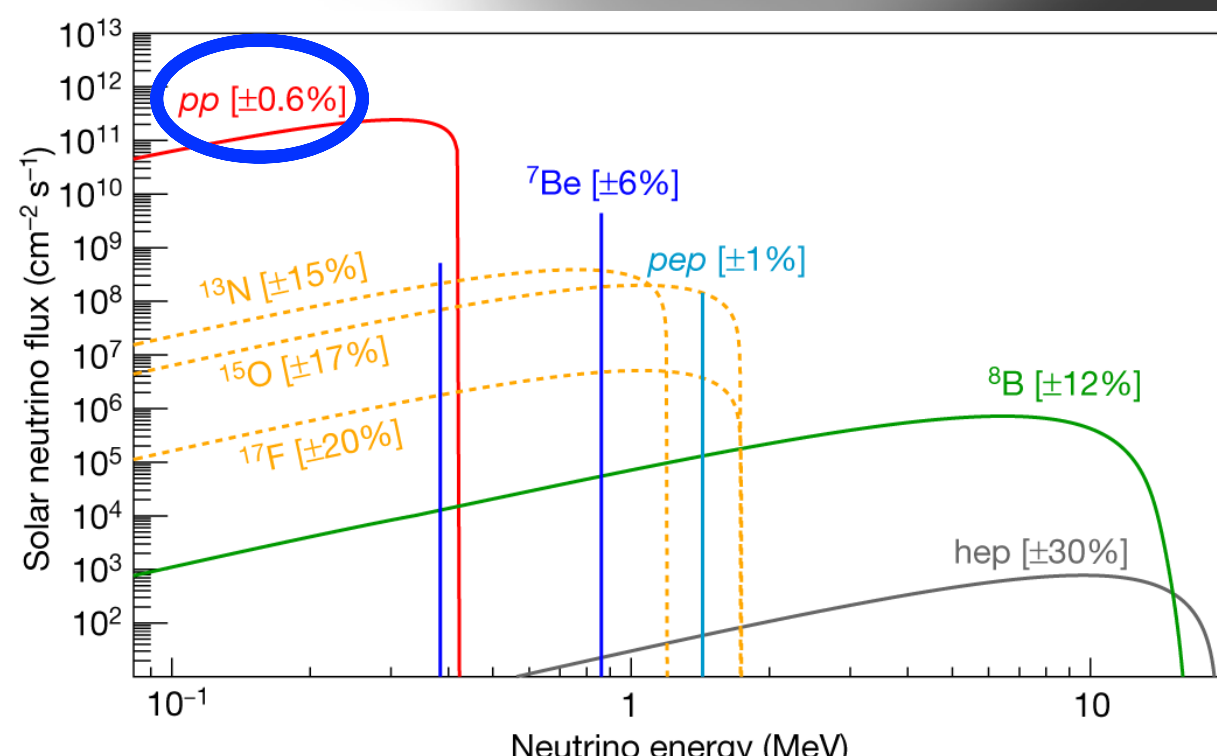
Super Chooz: the smallest but powerful…



physics II: solar neutrinos

Sun's inner-most insight…



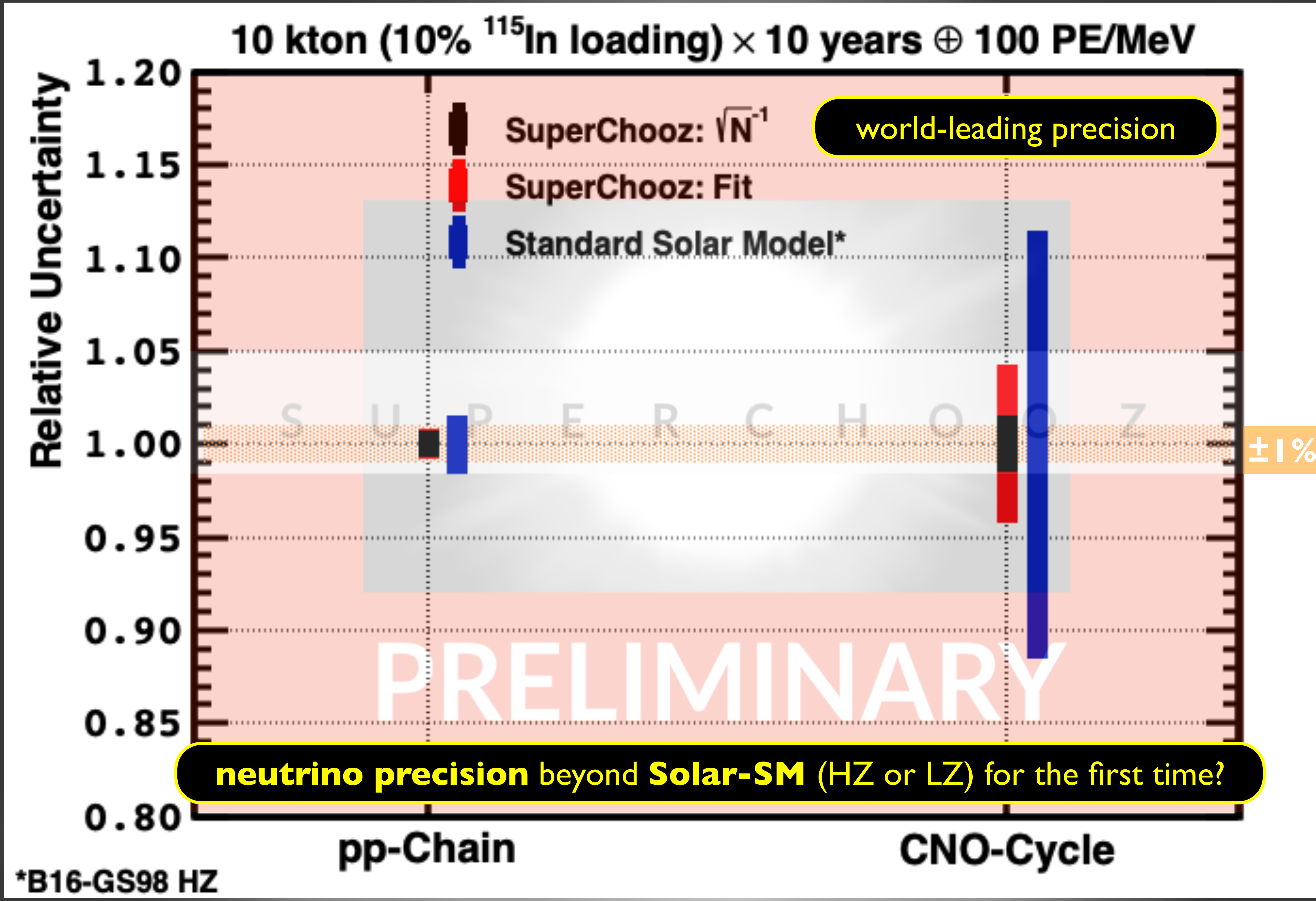


2 main reactions…

- **pp Chain** (dominant in Sun, still)
- **CNO Cycle** (most stars dominant)

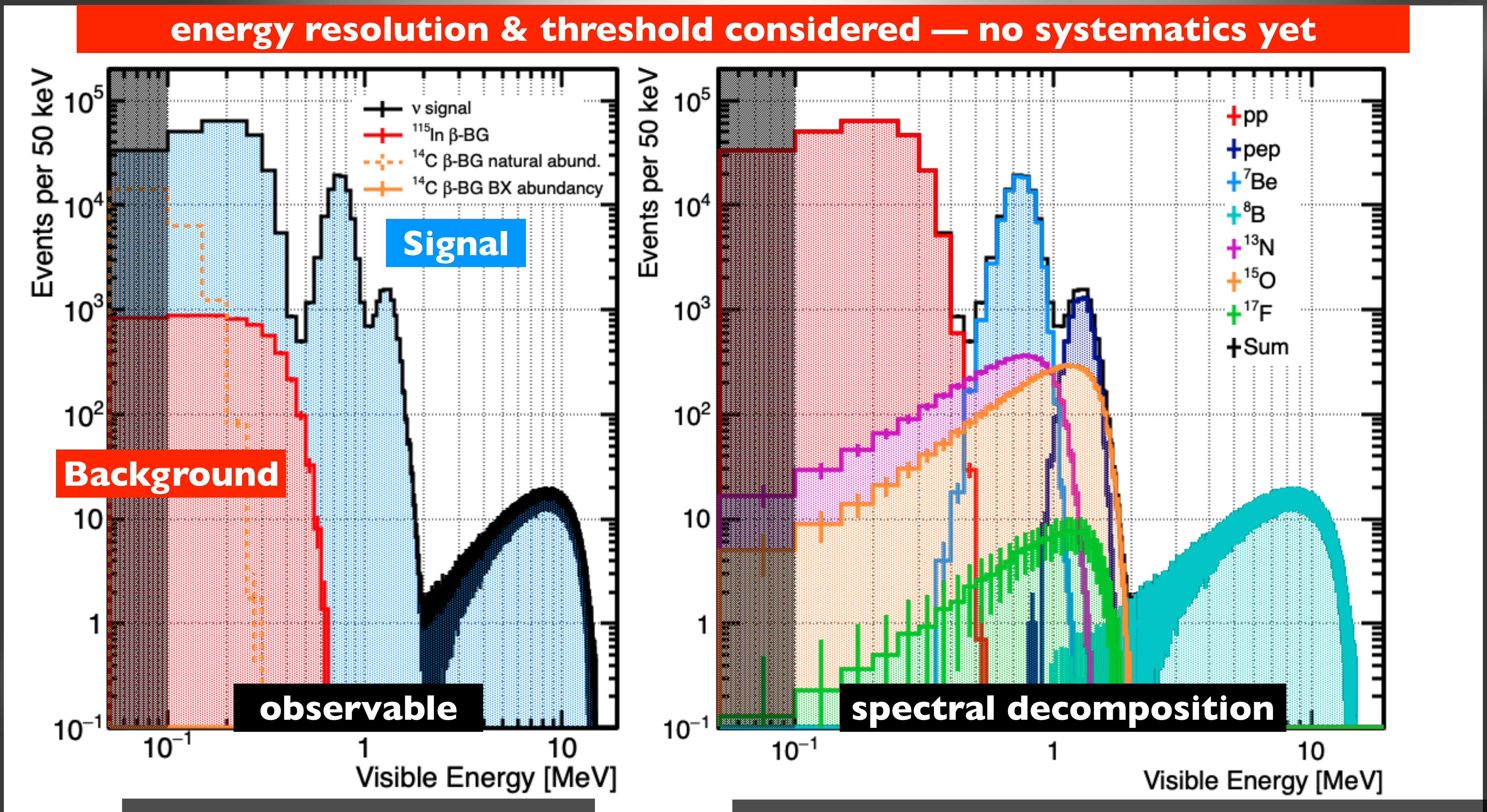
spectral precision "Solar-SM" (SSM)

- **SuperChooz** up to sub-% precision on everything
- probe **beyond-SSM** & **beyond-SM?**



highest precision solar physics…

solar spectra extraction…



Signal to BG ≥10x

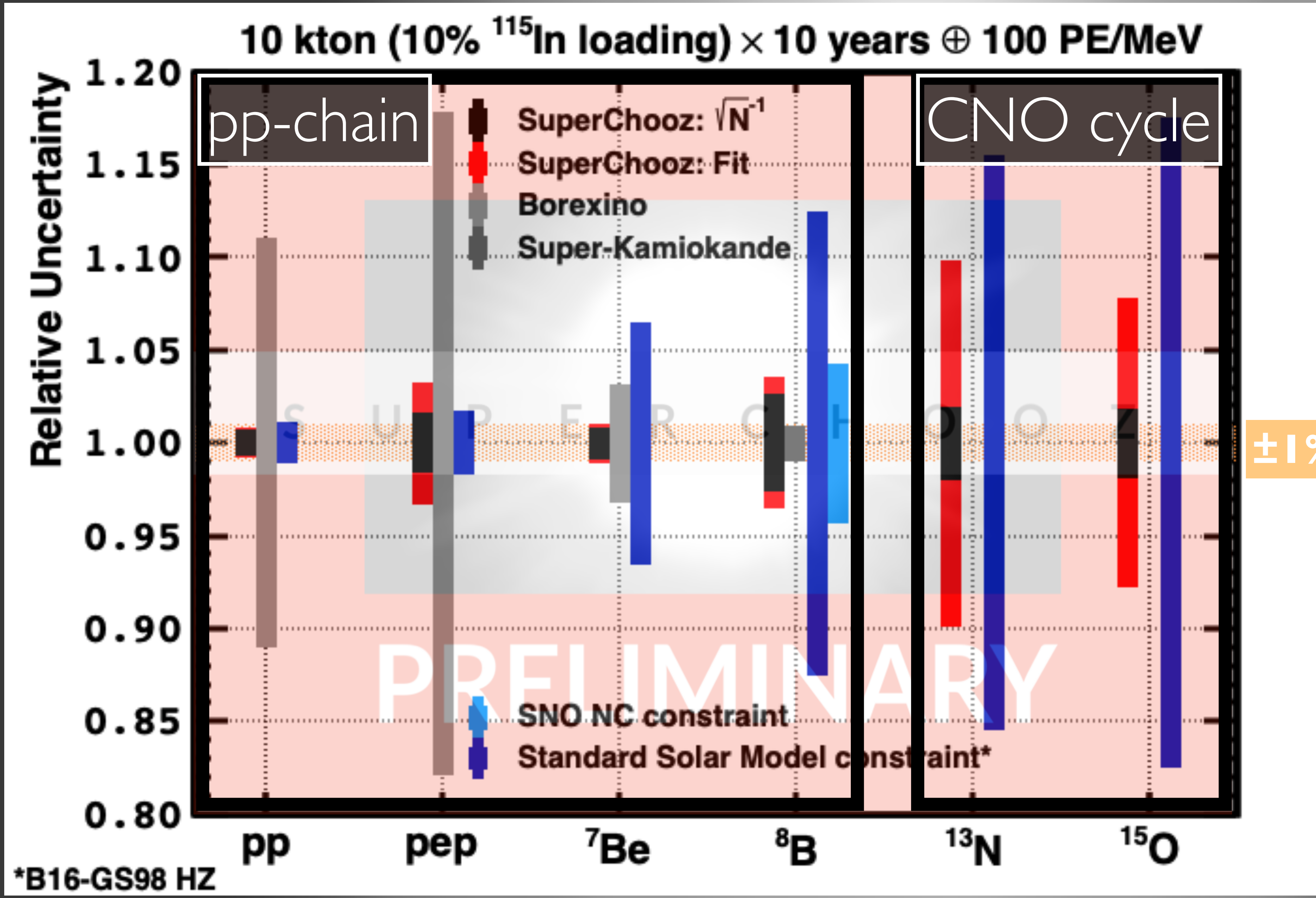
Background-less ≥0.5MeV
[LENS *et al.*]

Full Spectral Information:

- Neutrino Energy (CC interaction)
- High Statistics: **10%** (In loading) x **10 years**
- Light level: **≥100PE/MeV** (thershold: 0.1MeV)

Anatael Cabrera (CNRS-IN2P3) — IJCLab / Université Paris-Saclay (Orsay)

ultimate solar spectra knowledge?



Event Rates (10% load)
- **pp: ~250,000** [0.2%]
- **pep: ~7,700** [1.1%]
- **^{7}Be: ~85,000** [0.3%]
- **CNO: ~9,700** [<2%]
- **^{8}B: ~2,200** — good by SK!
- **hep: ~4** — unlikely

→**30%** loading**?** **~3x stats?**

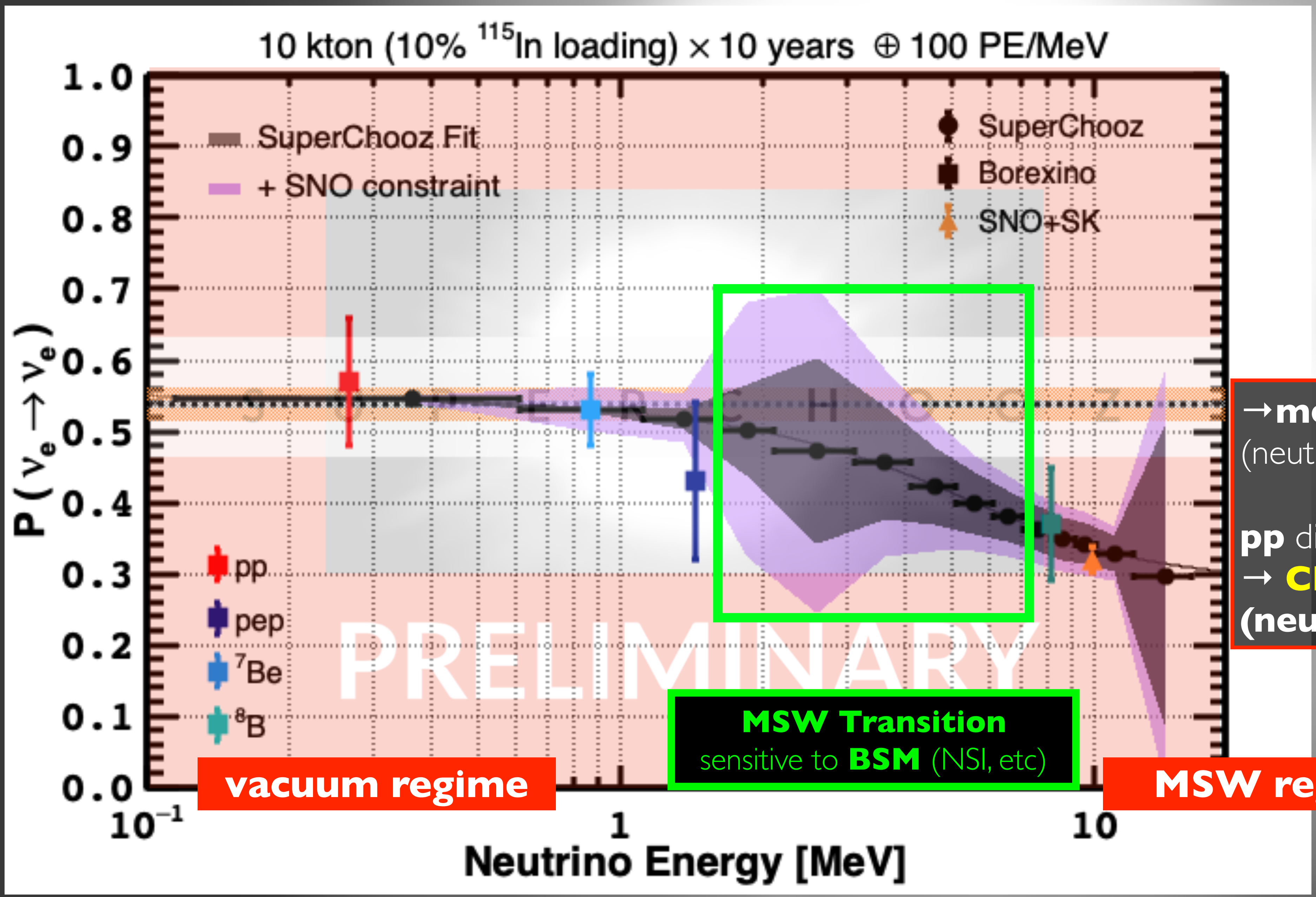
Flux Information:
- **SSM prediction**
- **SNO-NC** for **ϕ(^{8}B)**

low systematics (fiducial volume, efficiency, energy, In-fraction, etc)→ **under final evaluation**

ISSUE: exclusive Indium cross-section knowledge? Possible ~1%? [a la Ga]

neutrino oscillation transition…

In-interaction: neutrino energy scan (impossible for elastics scattering)



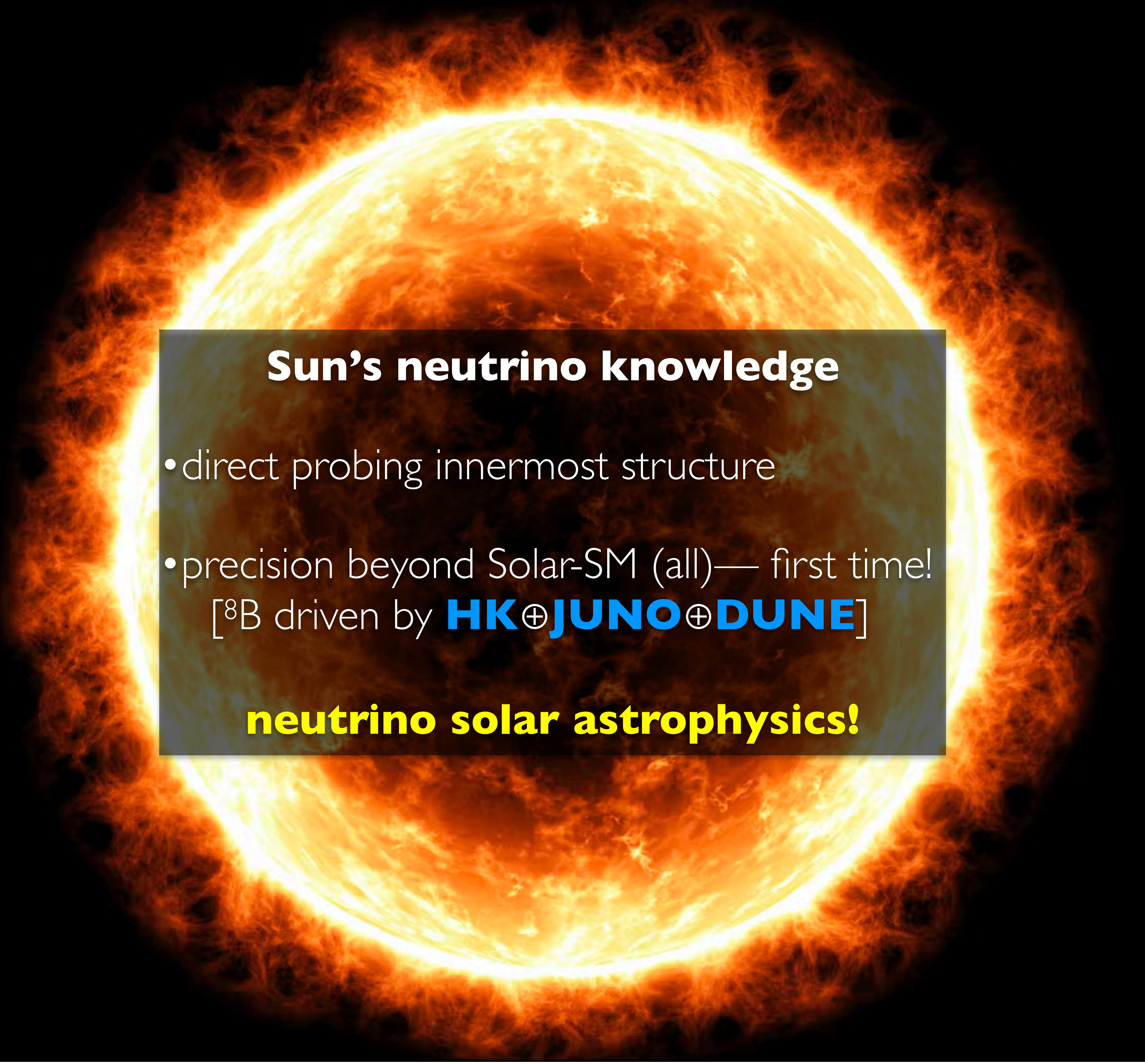
today's precision on θ_{12}

→**measure θ12 & δm²** (neutrino)

pp direct comparison with **JUNO**[≤0.5%]
→ **CPT violation?**
(neutrino vs anti-neutrino)

solar neutrinos: longest baseline neutrino with few % precision→ new physics?

use ϕ(SNO-NC) for ^{8}B control [1.5,10] MeV — ultimate limitation?



Sun's neutrino knowledge

- direct probing innermost structure
- precision beyond Solar-SM (all)— first time!
  [^{8}B driven by **HK⊕JUNO⊕DUNE**]

neutrino solar astrophysics!

why θ_{12} & δm^2 ? (solar)

- world most precise neutrino θ_{12} & δm^2
  - unique cross-check of JUNO
- first time: neutrino precision better SSM
  - all pp-chain: pp to $\leq$1% potential
  - (first) all CNO-cyle: to few %

$\Longrightarrow$ neutrino info driving SSM precision?

- first time: mapping MSW shape (few %)

$\Longrightarrow$ deviations? new interactions [BSM]

Anatael Cabrera (CNRS-IN2P3) — IJCLab / Université Paris-Saclay (Orsay)

(historically) **symmetries crucial in neutrino manifestation**

neutrino oscillation implied…

→ no need of the **lepton-flavour number** (**L_i**)

→ discrepancies in flux normalisation — **unitarity violation?**

⟹ **new phenomenology** manifesting as **symmetry violation**

physics III: fundamental symmetries

Anatael Cabrera (CNRS-IN2P3) — IJCLab / Université Paris-Saclay (Orsay)

beyond-SM neutrino oscillations (L$_i$)

CP Violation? [SM ⟶ foreseen in CKM and PMNS]

- (indirectly) HyperK⊕DUNE knowledge on θ_{13}

⟶ extra precision on θ_{23} ? [backup]

Unitarity Violation? [BSM]

discovery potential

- @UND: reactor absolute flux (up to 0.5%?) — CLOUD
- @SFD: solar-pp absolute flux (up to 0.6%?)

CPT Violation? [BSM]

discovery potential

- θ_{12} by both SuperChooz⊕JUNO — difference?

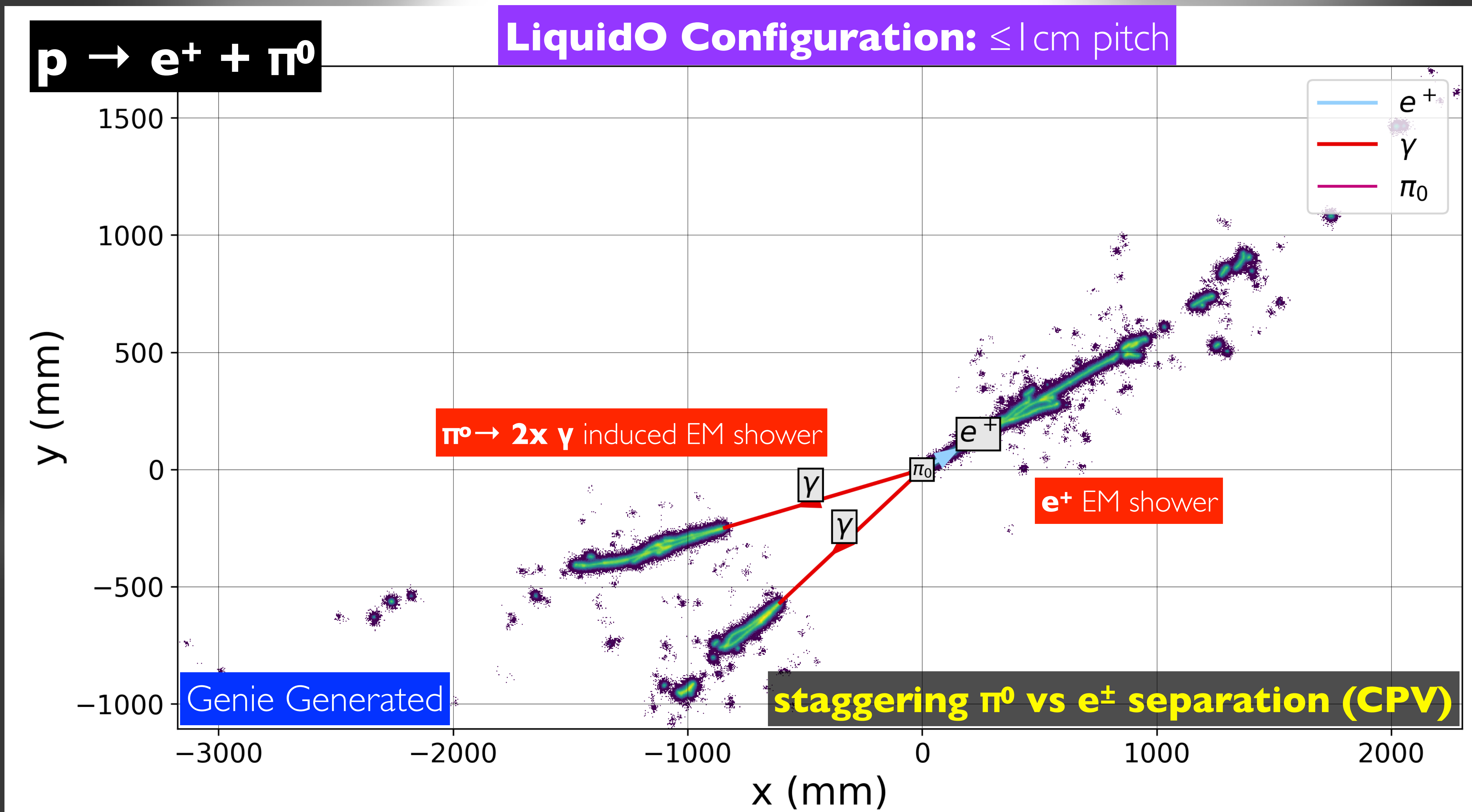
Baryon# Violation? proton-decay [multi-mode]

discovery potential

discovery channels too…

m(proton)**~1GeV**

free-H per unit of mass:
water: ~10%
scintillator: up to 20%



SUPERCHOOZ

main conclusions…

neutrinos back to Europe?

(high precision)

historical opportunity for Europe's neutrino science (fundamental & innovation)…

Anatael Cabrera CNRS-IN2P3 / IJCLab (Orsay) - LNCA (Chooz) Laboratories

status on neutrino oscillation knowledge…

SuperChooz is designed cover the full ***SM picture*** (3 families) [synergy]

SuperChooz explore the ***SM***'s consistency/completeness→ **BSM discovery?**

SuperChooz = SC

	today				≥2030		
	best knowledge		global	foreseen	dominant	source
θ_{12}	3.0 %	SK⊕SNO	2.3 %	≤0.5%	JUNO⊕**SC**	reactor⊕solar
θ_{23}	5.0 %	NOvA+T2K	2.0 %	≲1.0%?	DUNE⊕HK [**SC**]	beam (octant)
θ_{13}	1.8 %	DYB+DC+RENO	1.5 %	**≤0.5%**	**SC**	reactor
$+\delta m^2$	2.5 %	KamLAND	2.3 %	<0.5%	JUNO⊕**SC**	reactor⊕solar
$\|\Delta m^2\|$	3.0 %	T2K+NOvA & DYB	1.3 %	<0.5%	JUNO⊕DUNE⊕HK⊕**SC**	reactor⊕beam
Mass Ordering	**unknown**	SK et al	NMO @ ≤3σ	@5σ	JUNO⊕DUNE⊕HK	reactor⊕beam
CP	**violation?**	T2K+NOvA	3/2π @ ≤2σ	**@5σ?**	DUNE⊕HK [**SC**]	beam driven
CPT	**violation?**	—	—	**<1%?**	**SC**	reactor⊕solar
Unitarity	**violation?**	—	—	**<1%?**	**SC**	reactor⊕solar
Baryon#	**violation?**	—	—		JUNO⊕DUNE⊕HK⊕**SC**	

reactor⊕solar main channels of **SC**, but low energy **atmospherics under study…**

Anatael Cabrera (CNRS-IN2P3 @ LAL - LNCA)

thanks to **EDF** teams & support,
LiquidO consortia,
AM-OTech consortia,
CLOUD collaboration,
and **SuperChooz** team.

Дякую…
thanks…
merci…
고맙습니다…
ありがとう…
danke…
obrigado…
спасибі…
grazie…
谢谢…
hvala…
gracias…
شكرا…

S U P E R C H O O Z

new **flagship neutrino physics** project in based **Europe** [>2030]**?**
(once **JUNO⊕HyperK⊕DUNE** are **running**)

new detector [**LiquidO**] ⊕ **new site** [Chooz-A] ⊕ **new physics**

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

anatael@in2p3.fr

Anatael Cabrera (CNRS-IN2P3) — IJCLab / Université Paris-Saclay (Orsay)

HEP-European Physics Society
(July 2019 @ Ghent Belgium)

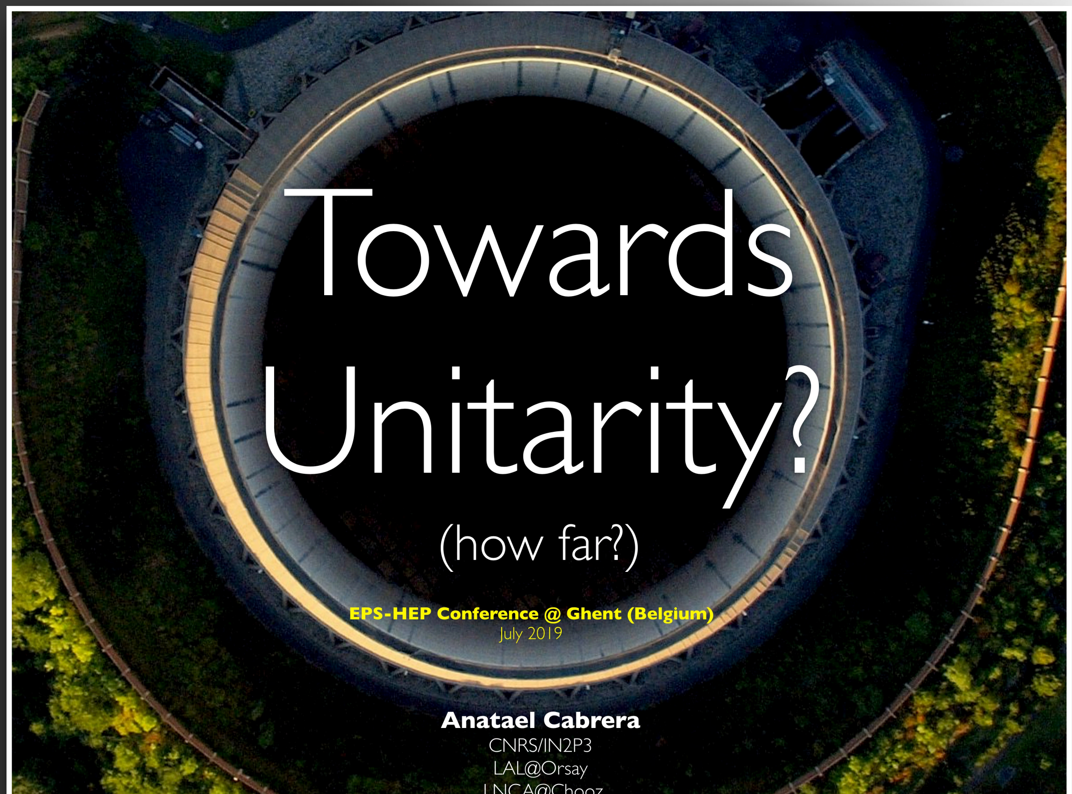
EP Seminar

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)



R C

https://indico.cern.ch/event/577856/contributions/3421609/

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

https://zenodo.org/record/7504162

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

since 2018...