December 1 2022, ICPPA-2022

The COHERENT experiment

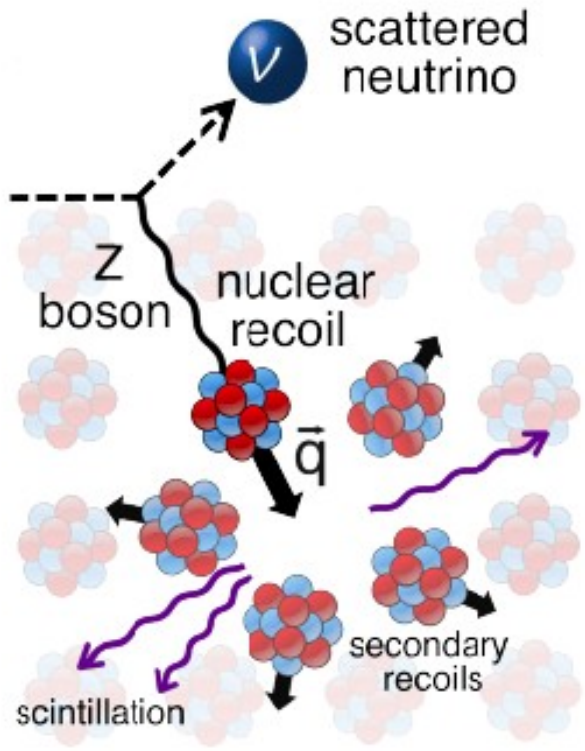
Alexey Konovalov (MEPhI)

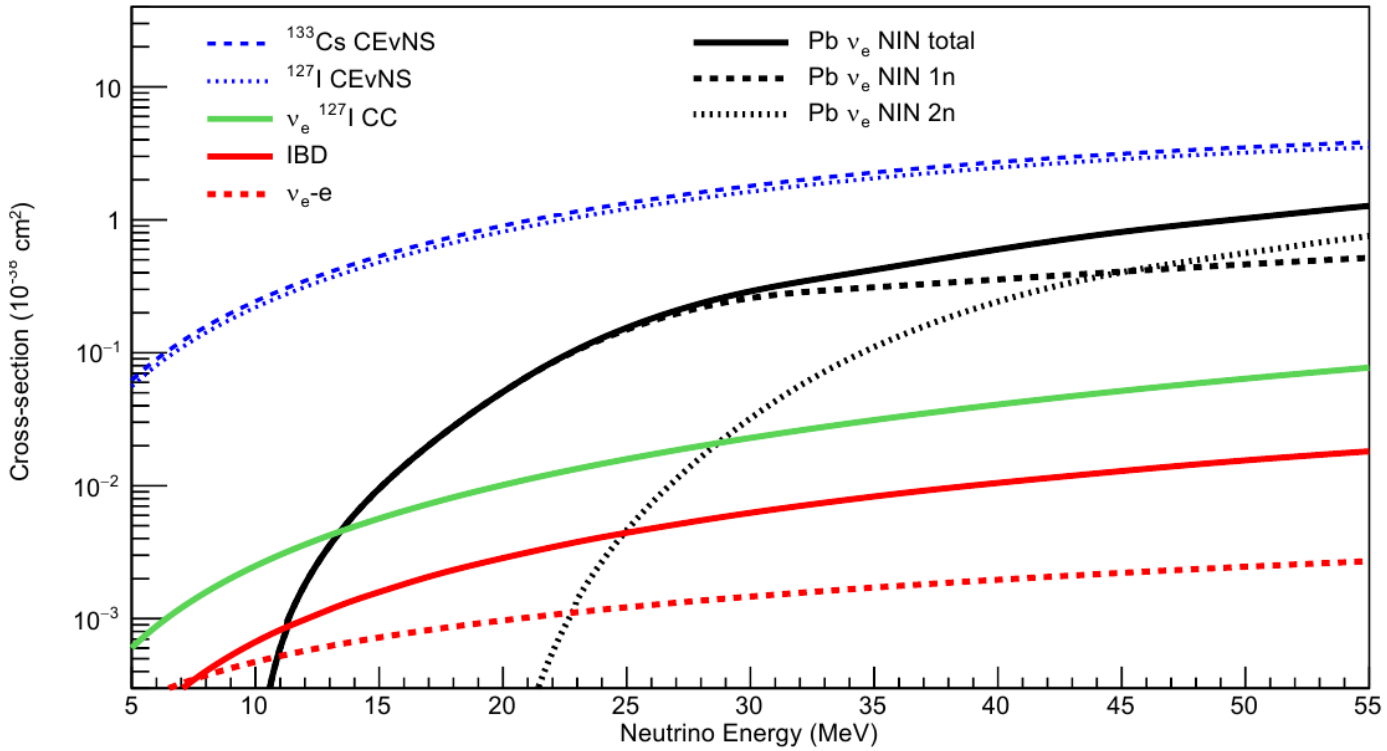
Coherent elastic neutrino-nucleus scattering (CEvNS)

Predicted in

"Coherent effect of a weak neutral current", D. Freedman, PRD v.9, n.5 (1974)

"Isotopic and chiral structure of neutral current", V.Kopeliovich, L. Frankfurt, ZhETF. Pis. Red., v.19 n.4 (1974)





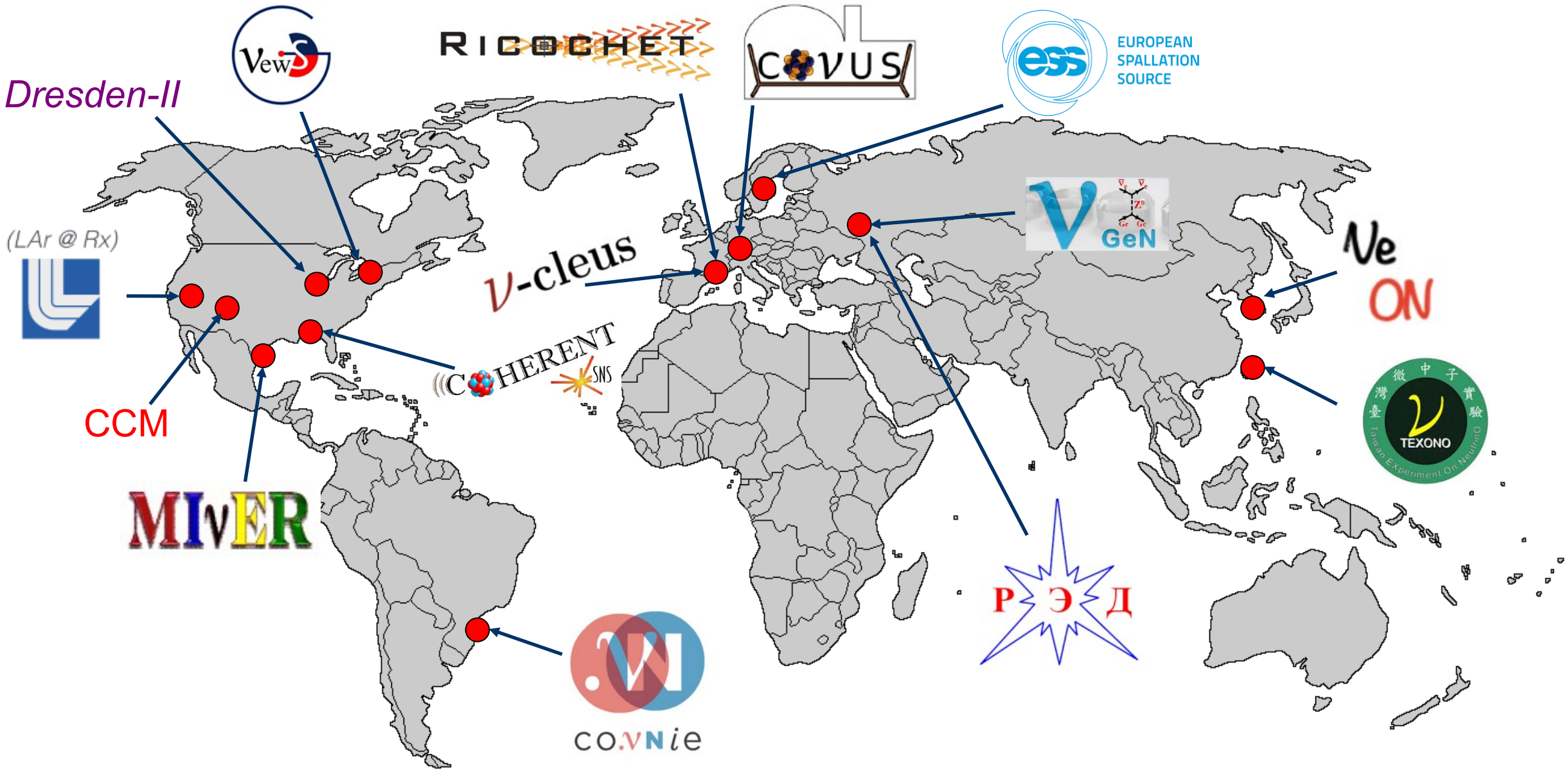
CEvNS cross section in the SM:

$$\frac{d\sigma}{dT} = \frac{G_F^2 M}{4\pi}\Big([1-4\sin^2\theta_W]Z - N\Big)^2\Big[1-\frac{T}{T_{max}}\Big]F_{nucl}^2(q^2)$$

$$T_{max} = 2E_\nu^2/(M+2E_\nu)$$

Nucleus	T_{max}, keV (E_ν =5 MeV)	T_{max}, keV (E_ν =30 MeV)
^{12}C	4.44	159.0
^{23}Na	2.32	83.2
^{40}Ar	1.33	47.9
^{74}Ge	0.72	25.9
^{133}Cs	0.40	14.4

CEvNS search and study around the world

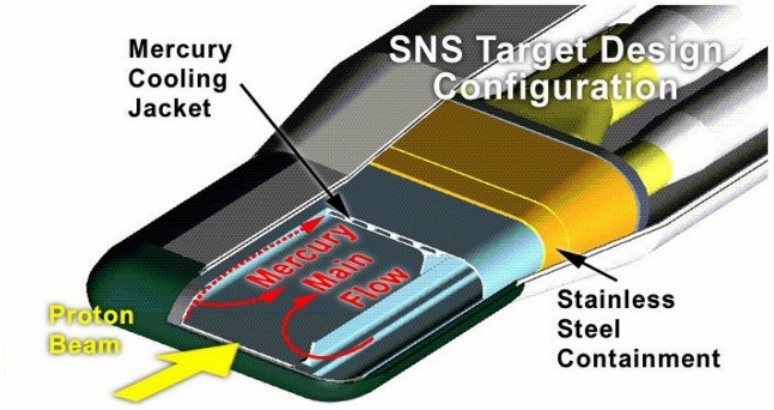


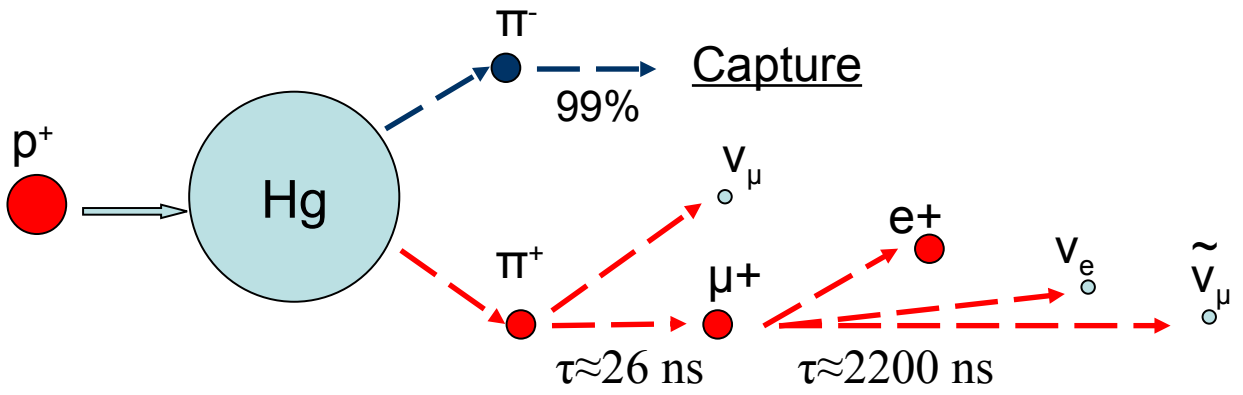
SNS facility at ORNL

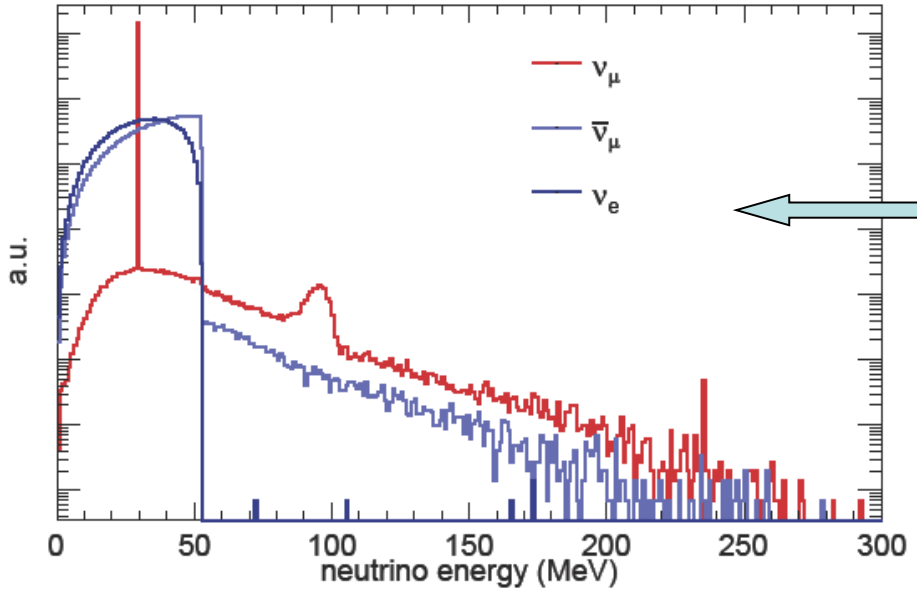
Bunches of ~1 GeV protons on the Hg target with 60 Hz frequency

Proton bunch time profile with FWHM of ~350 ns

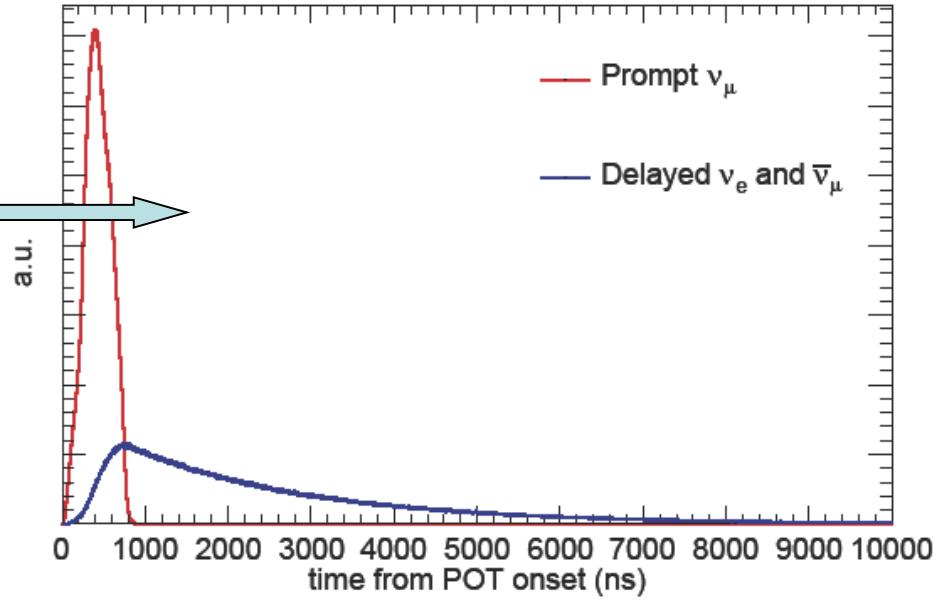
Total neutrino flux of $4.3 \cdot 10^7$ $cm^{-2} * s^{-1}$ at 20m







ν energy and timing suit well for CEvNS search



COHERENT CEvNS detectors: pioneers

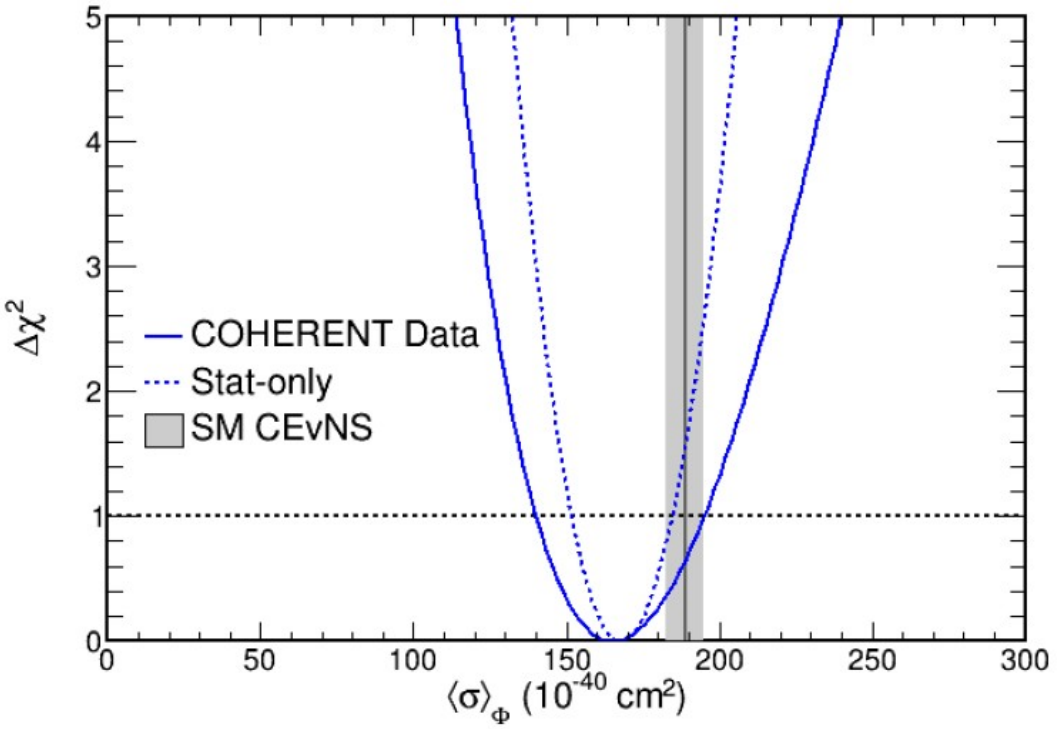
CsI[Na], 14.6 kg

2015-2017: Science vol. 357 iss. 6456 (2017)

6.7σ first observation

2015-2019: PRL vol. 129 081801 (2022)

11.6σ at full statistics



The end of exposure in 2019

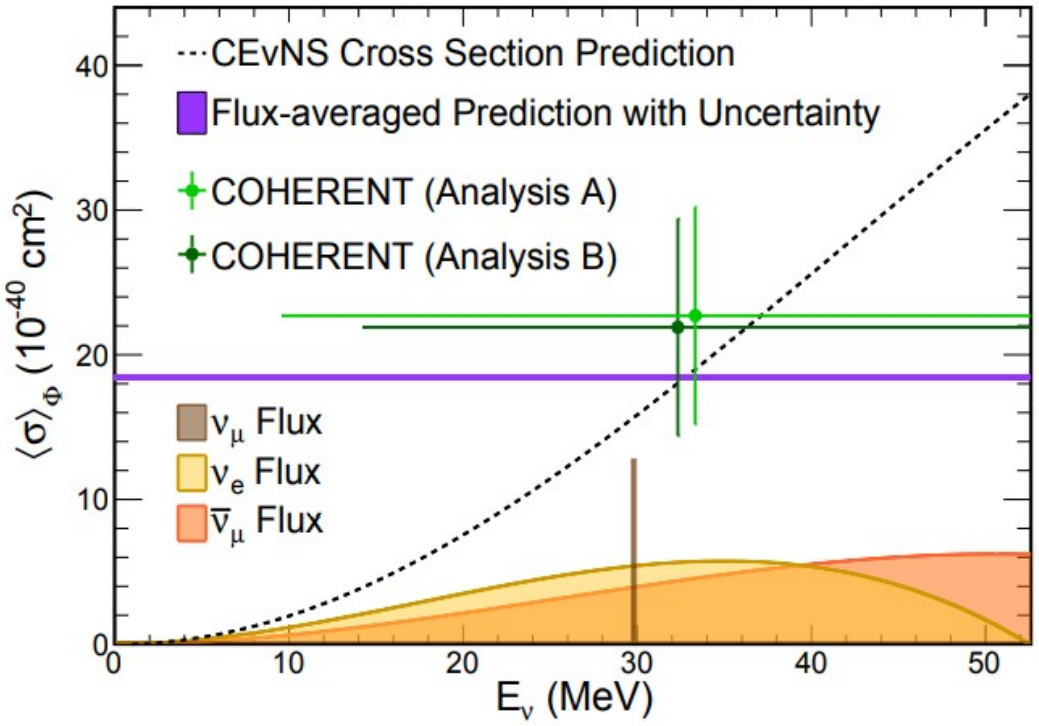
LAr, 24 kg (CENNS-10)

2017: PRD vol. 100 115020 (2019)

limit ~4 times SM (90% CL)

2017-2018: PRL vol. 126 012002 (2021)

observation at 3.1σ



The full data (2017-2021) analysis ongoing

COHERENT CEvNS detectors: newcomers

Ge, 18 kg (I)→50 kg (II)

Detectors: 8x2.2 kg PPC HPGe, $E_{thr} < 5\ keV_{nr}$

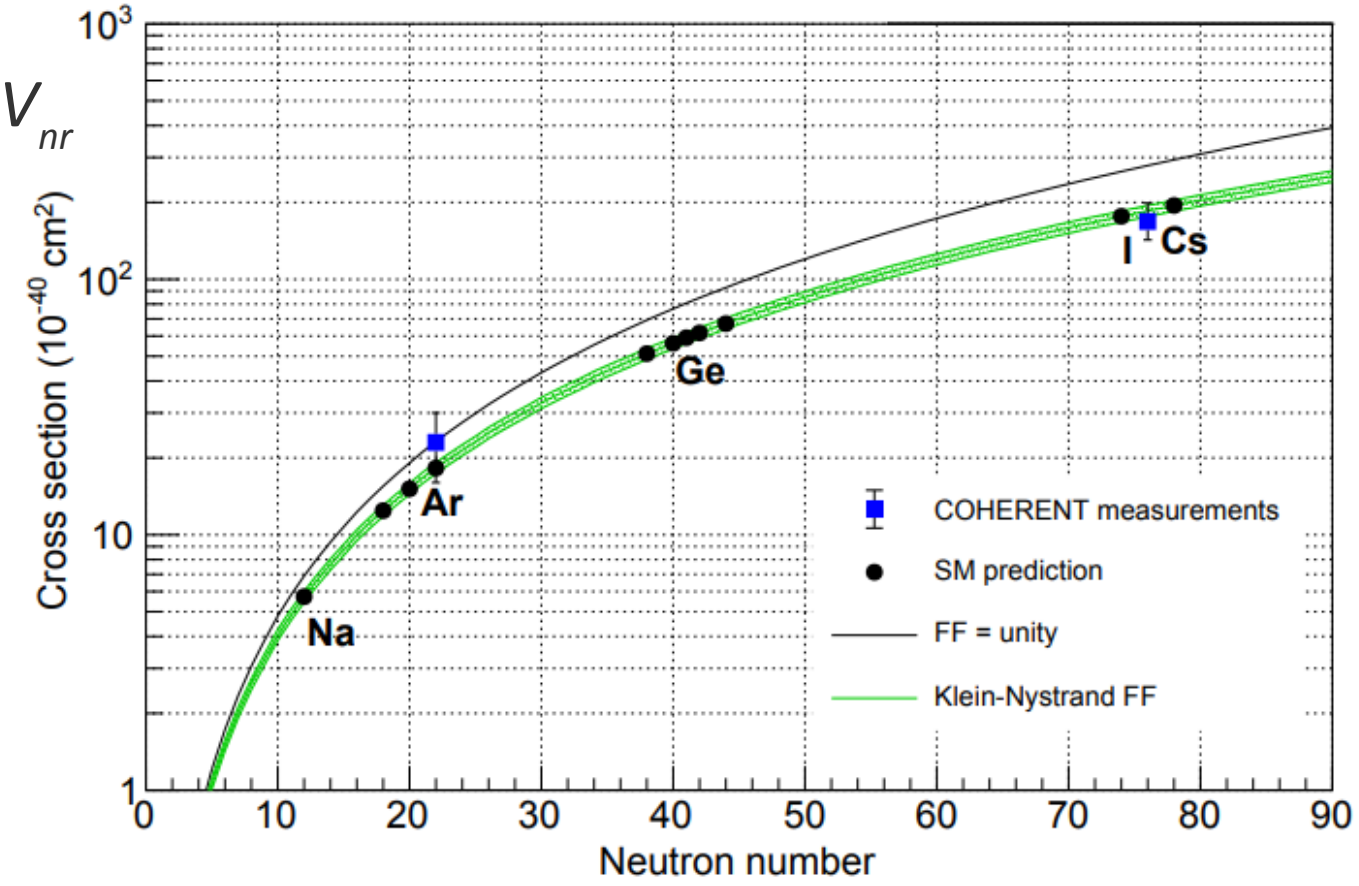
Status: deployment/cooldown

NaI[Tl], 185 kg→2.4T→3.4T

Detectors: 7.7 kg crystals, $E_{thr} = 13\ keV_{nr}$

Status: deployment

Sensitivity: 3σ per year for 3.4 T



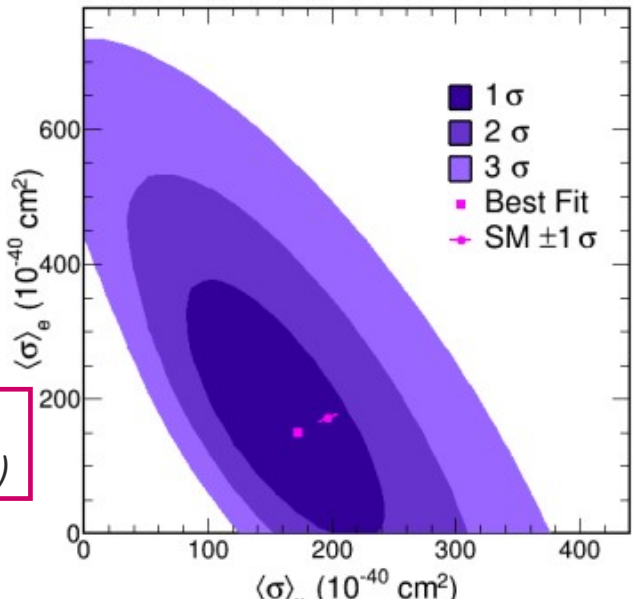
Successors (R&D): 610 kg of LAr and around 10 kg of undoped cryogenic CsI

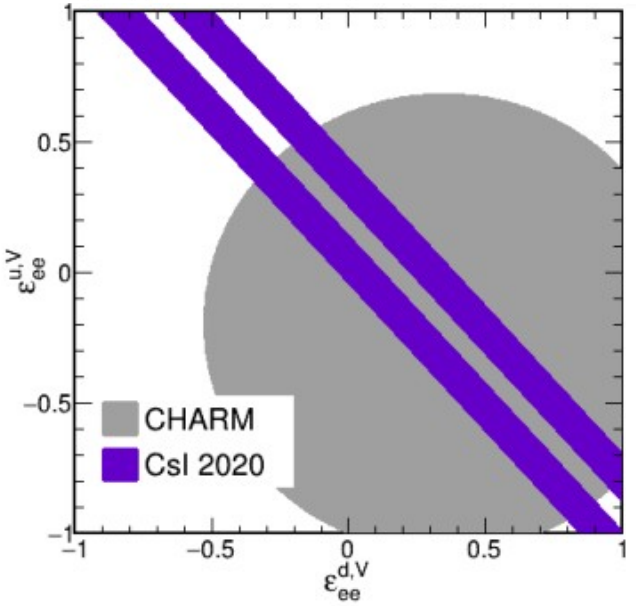
Physics reach: non-standard neutrino-quark interactions

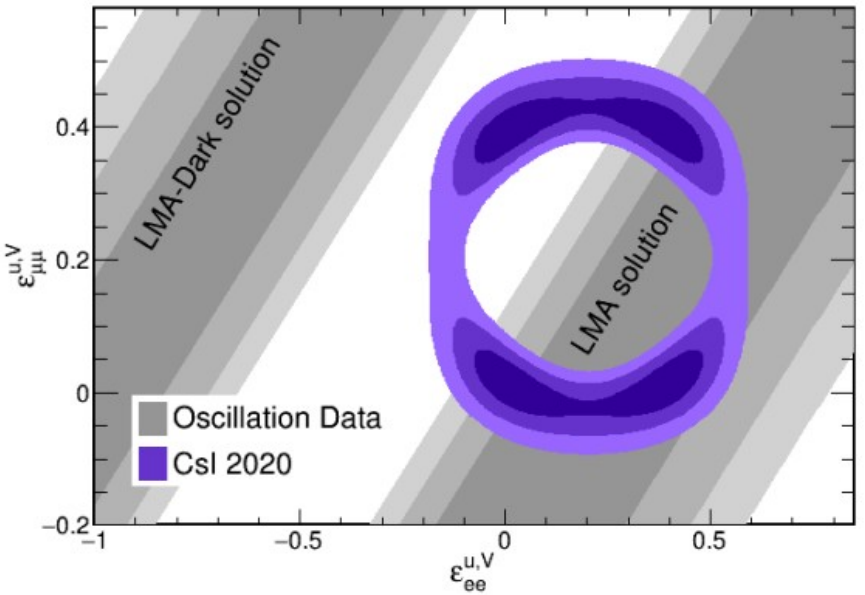
vector-like ν-quark NSI, $Q_\alpha^2 = \left[Z\left(g_p^V + 2\varepsilon_{\alpha\alpha}^u + \varepsilon_{\alpha\alpha}^d\right) + N\left(g_n^V + \varepsilon_{\alpha\alpha}^u + 2\varepsilon_{\alpha\alpha}^d\right)\right]^2$*, see JHEP 12 (2005) 021 for formalism*

CsI[Na] (2022)

PRL vol. 129 081801 (2022)

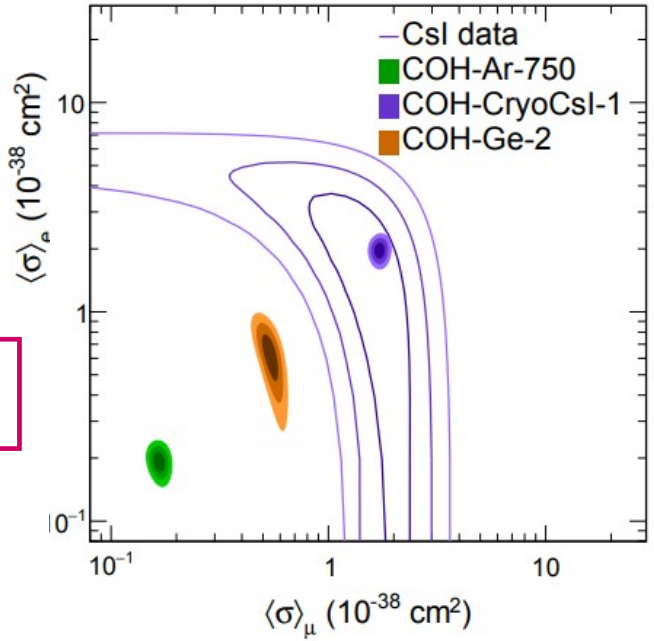


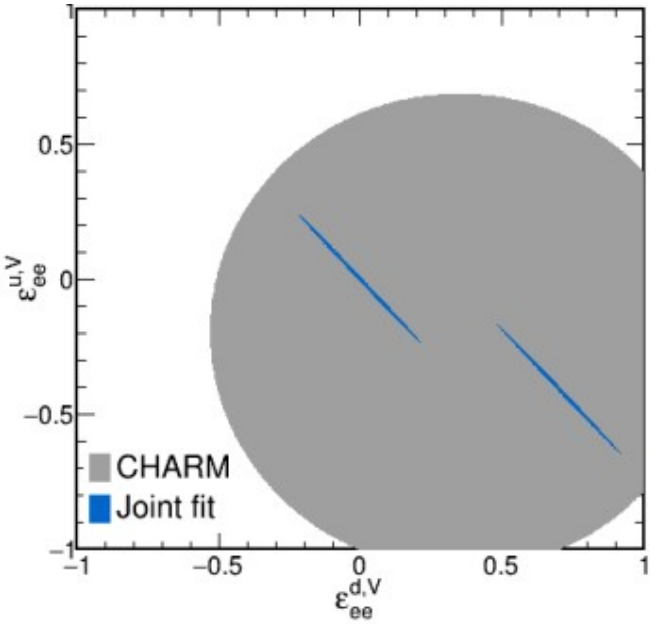


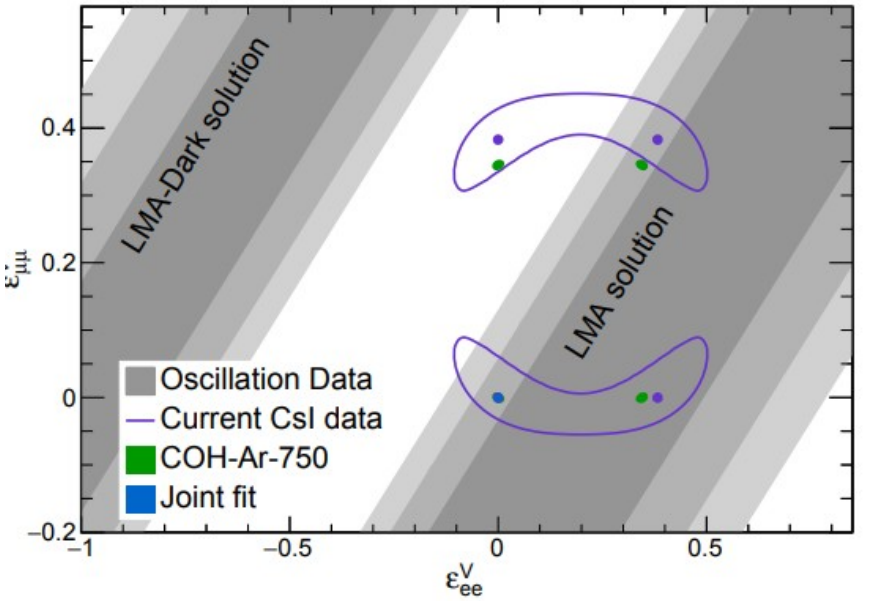


Future

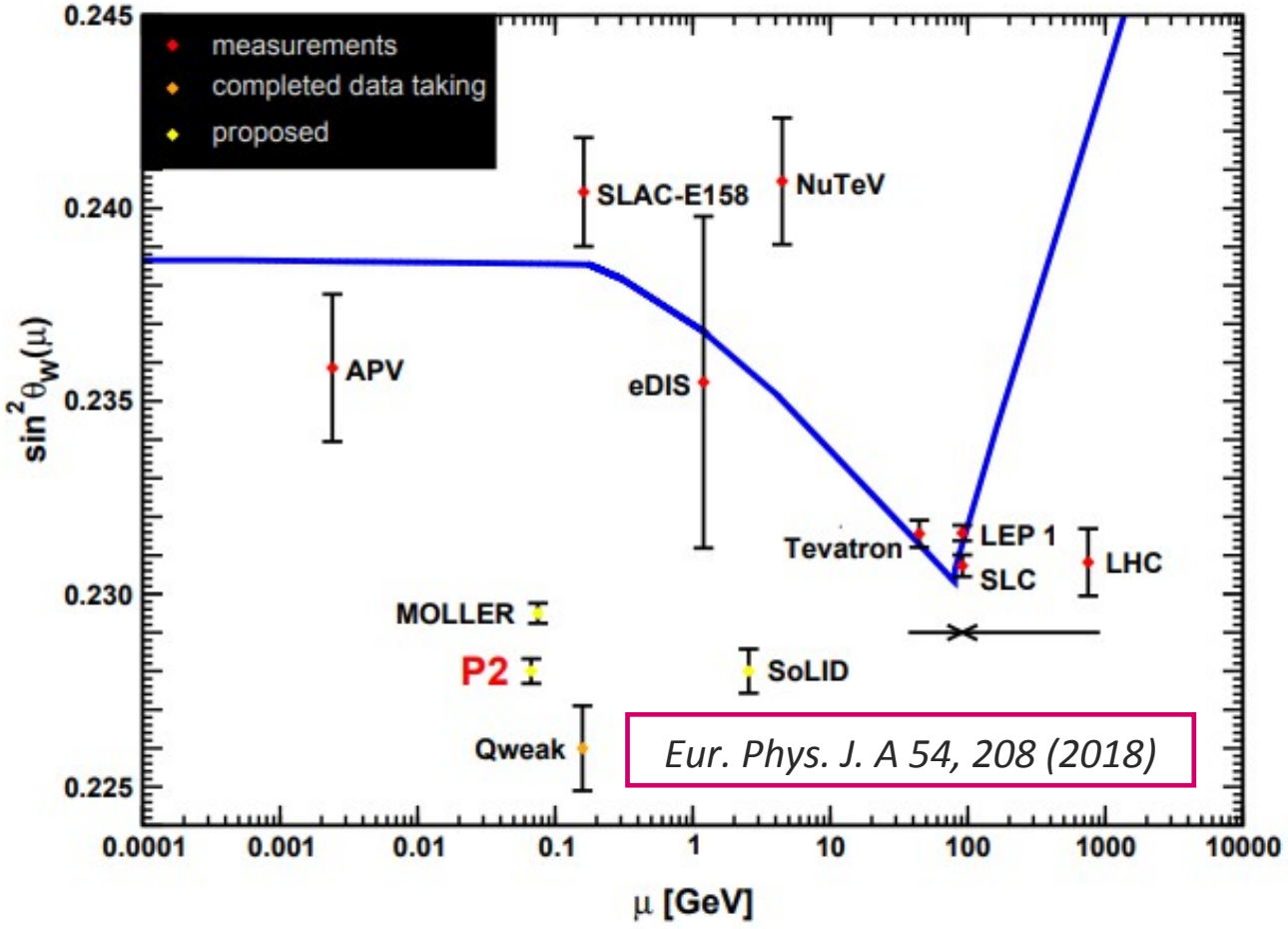
arXiv: 2204.04575







Physics reach: $\sin^2\theta_W$

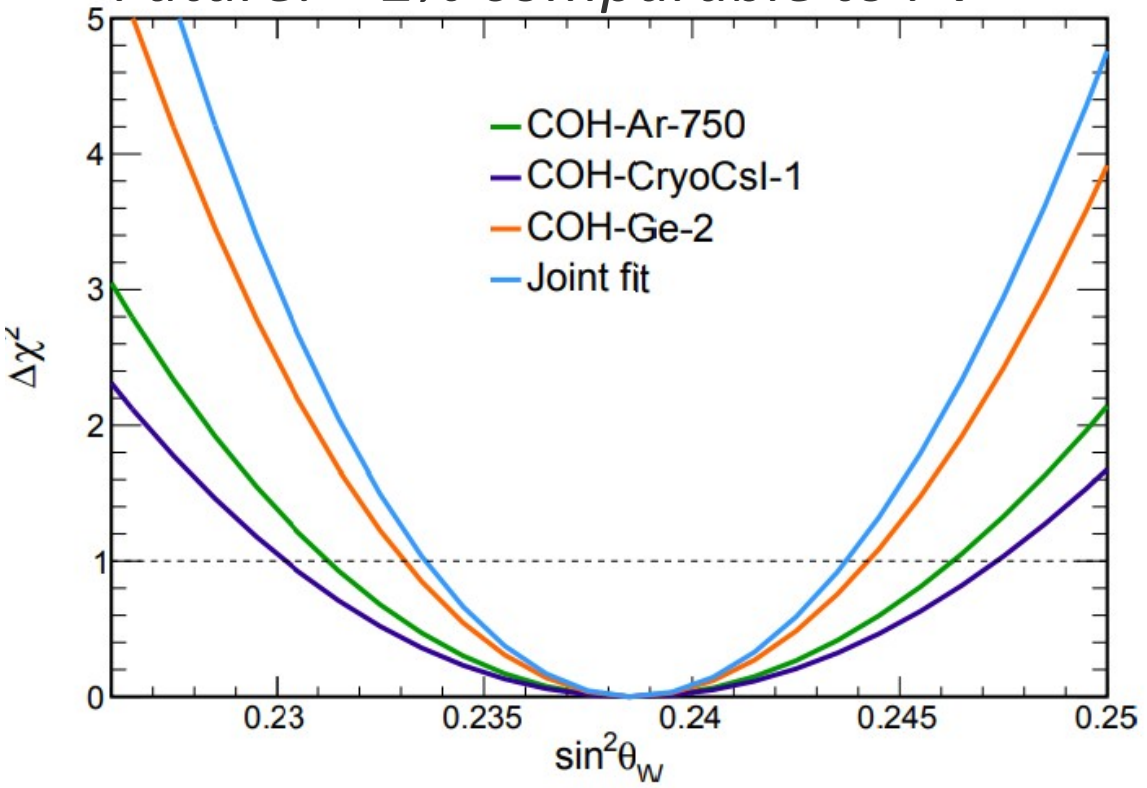


EW couplings running with the scale

From CsI[Na]

$$\sin^2\theta_W = 0.220^{+0.028}_{-0.026}$$

Future: ~2% comparable to PV

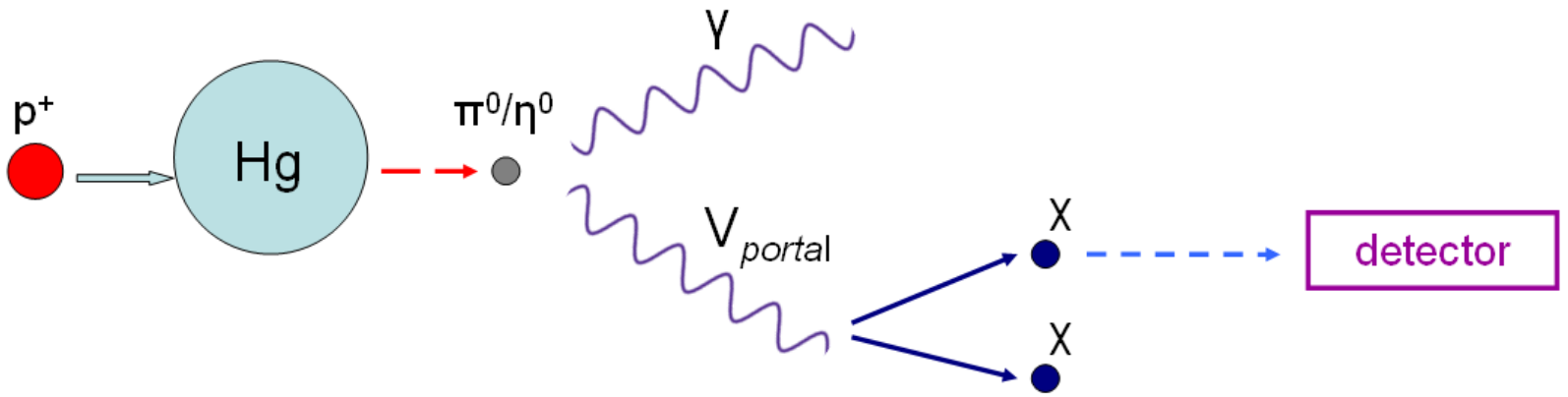


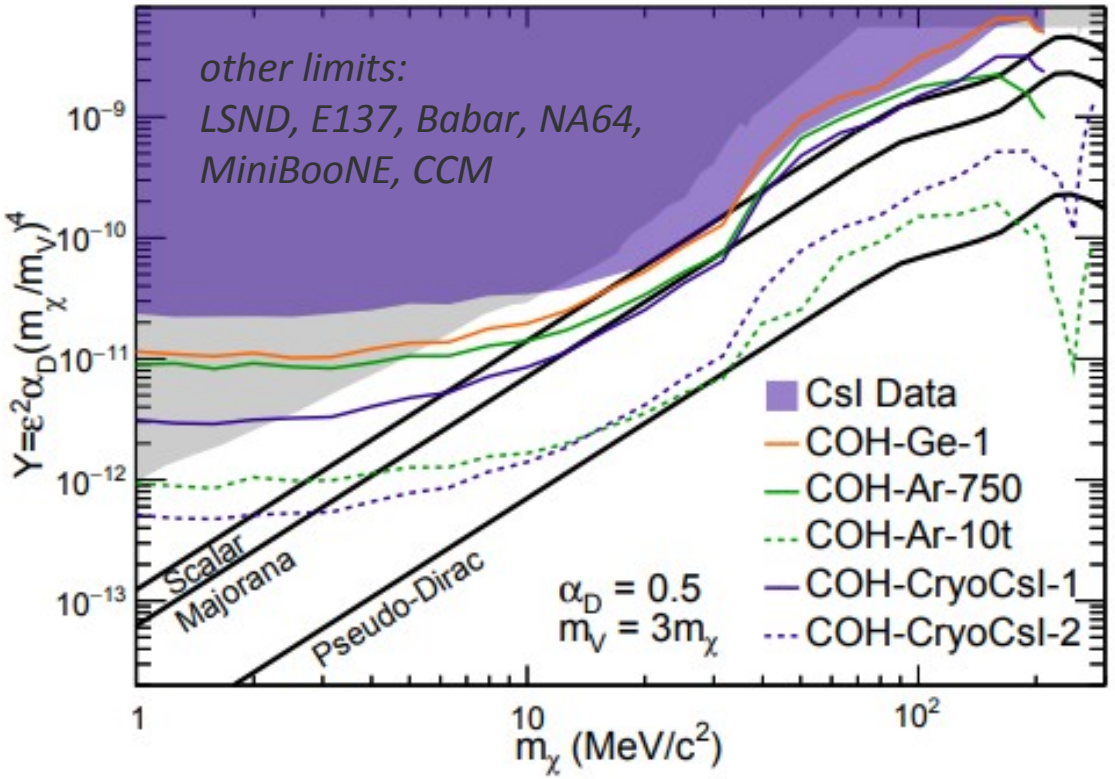
«V kinetic mixing with γ»

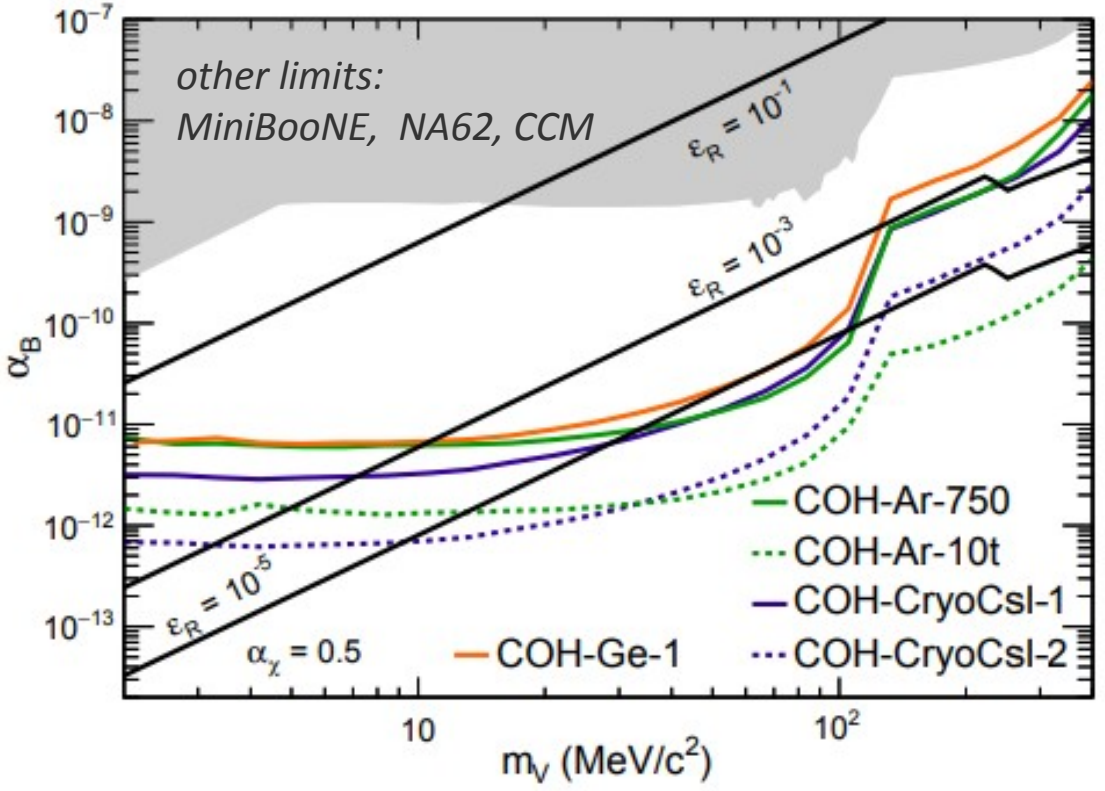
arXiv: 2110.11453

«leptophobic»

PRD 106, 052004 (2022)







Consider disappearance:

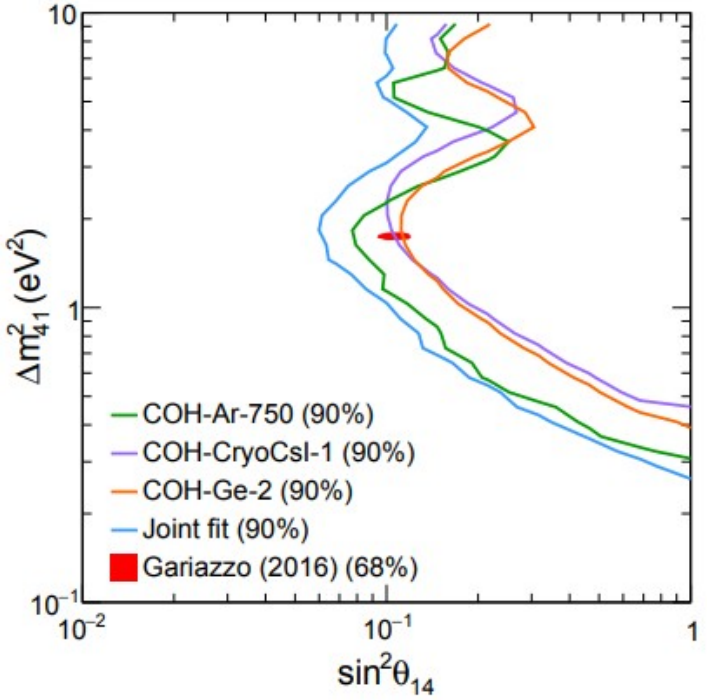
$$1 - P(\nu_e \to \nu_s) = 1 - \sin^2 2\theta_{14} \cos^2 \theta_{24} \cos^2 \theta_{34} \sin^2 \frac{\Delta m^2_{41} L}{4E}$$

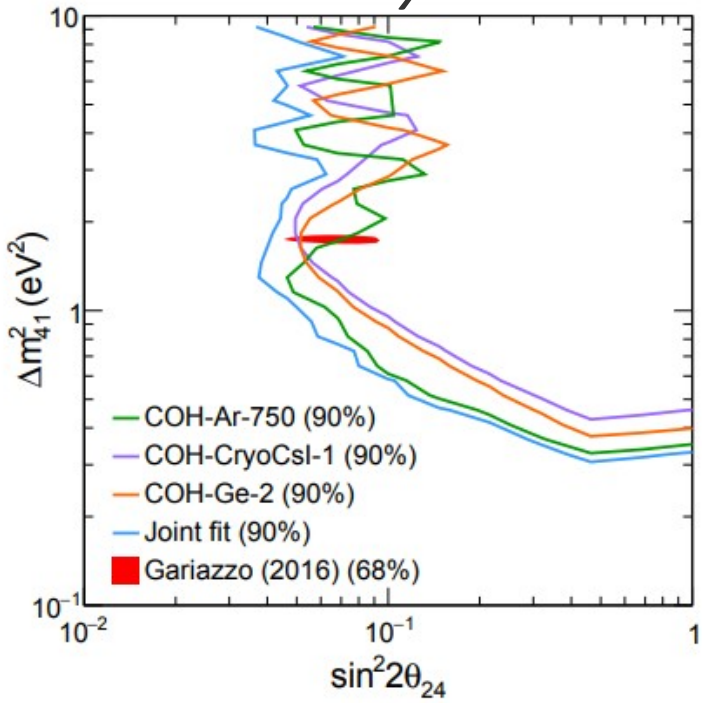
$$1 - P(\nu_\mu \to \nu_s) = 1 - \cos^4 \theta_{14} \sin^2 2\theta_{24} \cos^2 \theta_{34} \sin^2 \frac{\Delta m^2_{41} L}{4E}$$

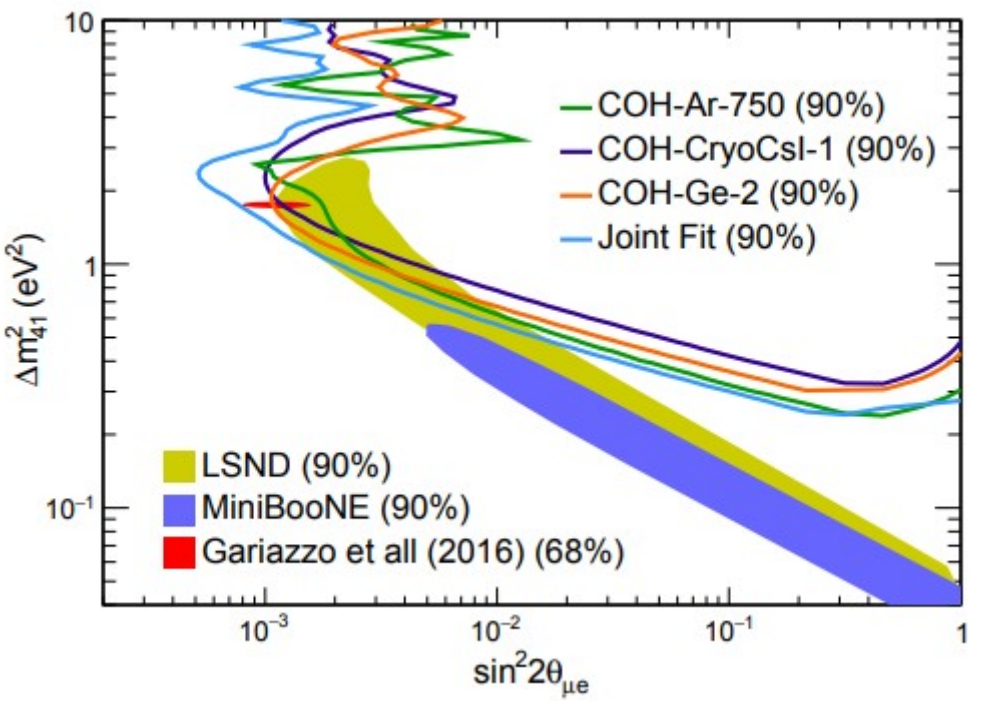
We need a prior constraint on θ_{34}, take from 3-flavor oscillations

Neutrino energy from 10 to 53 MeV, distances from 19 to 28 m ➡ Δm^2_{41} between 0.4 and 3.4 eV^2

Sensitivity estimates



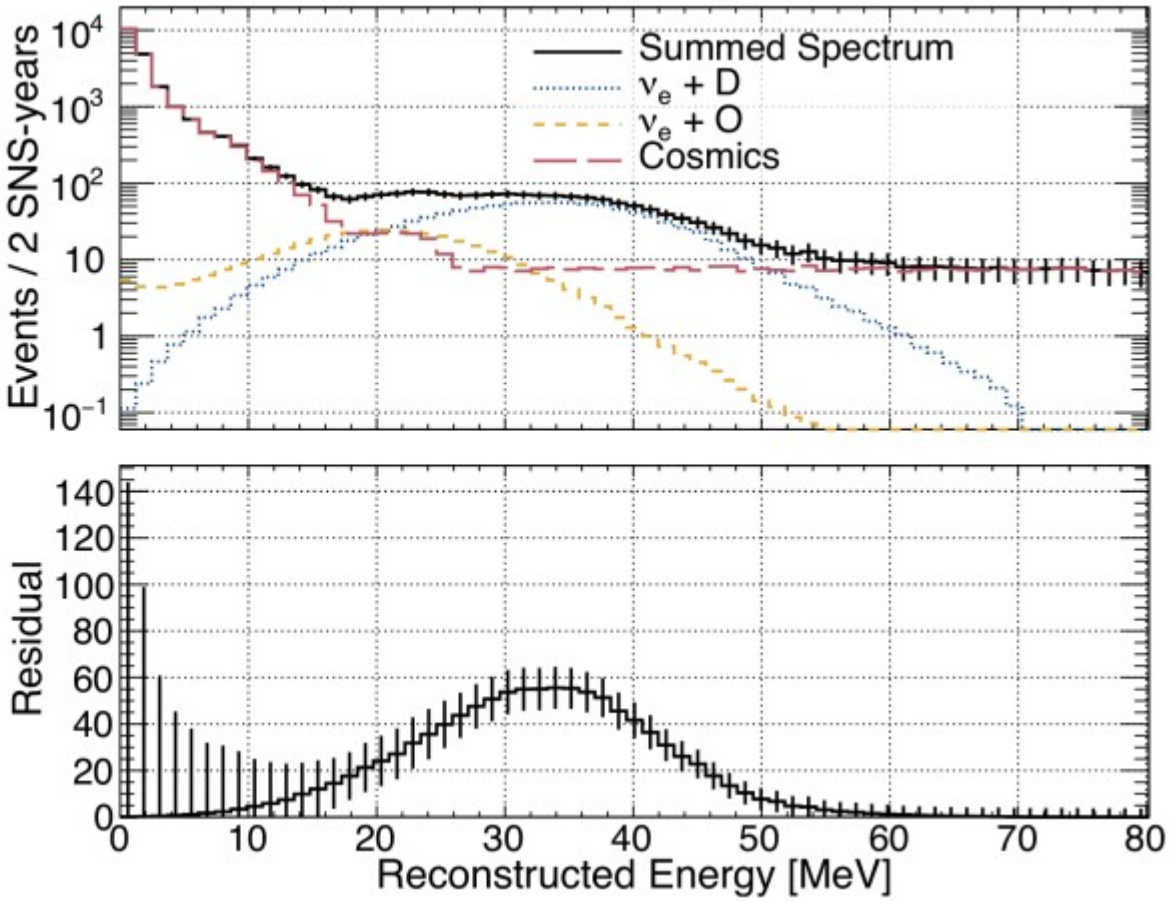




D_2O: pushing down the systematics

Leading syst. right now: ±10% on the neutrino flux
Idea: measure flux with $\nu_e + d \rightarrow p + p + e$

PRD 106, 032003 (2022)



Two modules,
592 kg D_20 each

Down to ~5% flux unc-ty with a single module for 2 SNS-years of operation

Status: deployment of the first module

JINST 16 P08048 (2021)

Bonus: charge current (CC) on oxygen for supernova ν in Super/Hyper-Kamiokande

Inelastic neutrino interactions

Neutrino-induced neutrons:

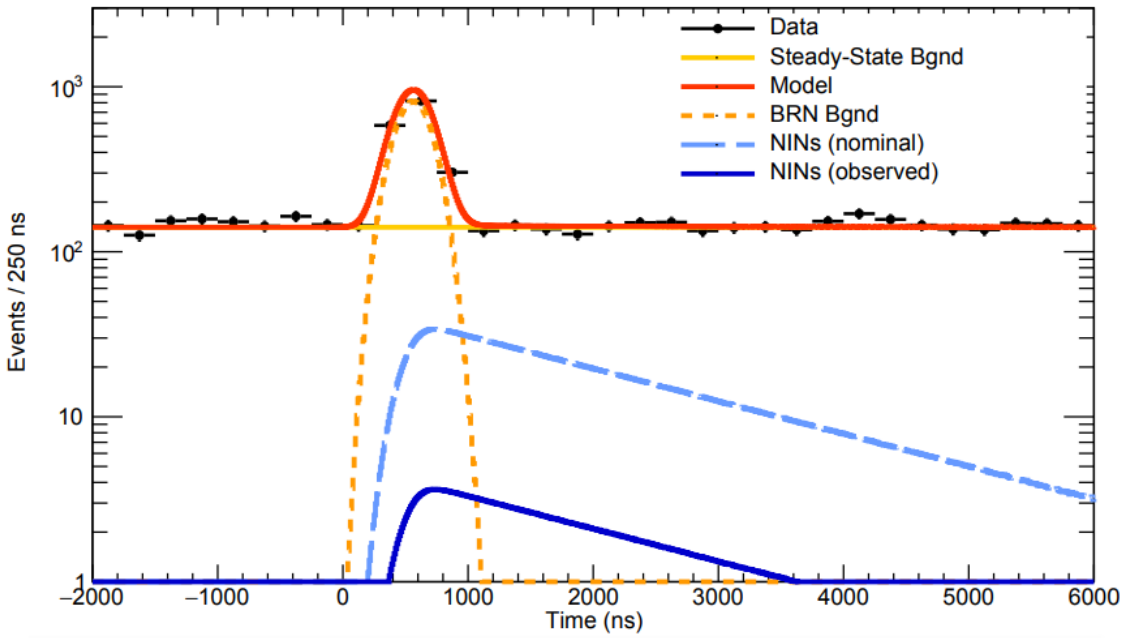
$\nu_e + {}^{208}Pb \rightarrow e^- + {}^{208}Bi,$

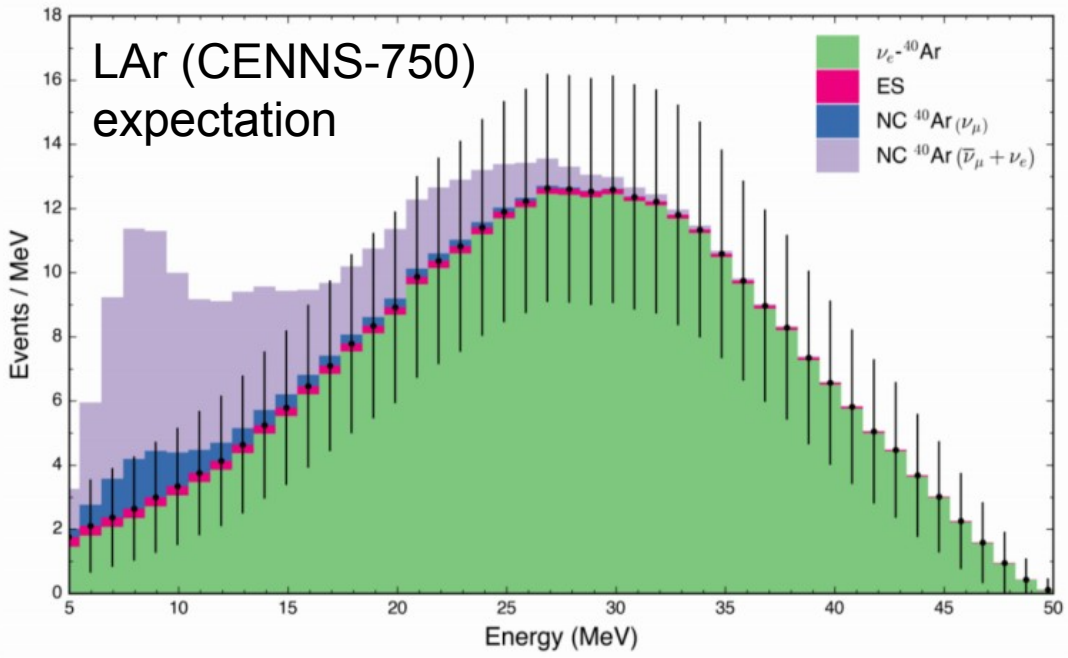
$\nu + {}^{208}Pb \rightarrow \nu + {}^{208*}Pb$

+ decay of a nucleus with neutrons in the final state

Measure final state neutrons with LS (EJ-301) cells surrounded by 900 kg led

Observed $0.29^{+0.17}_{-0.17}$ *times prediction, preprint to be out soon!*



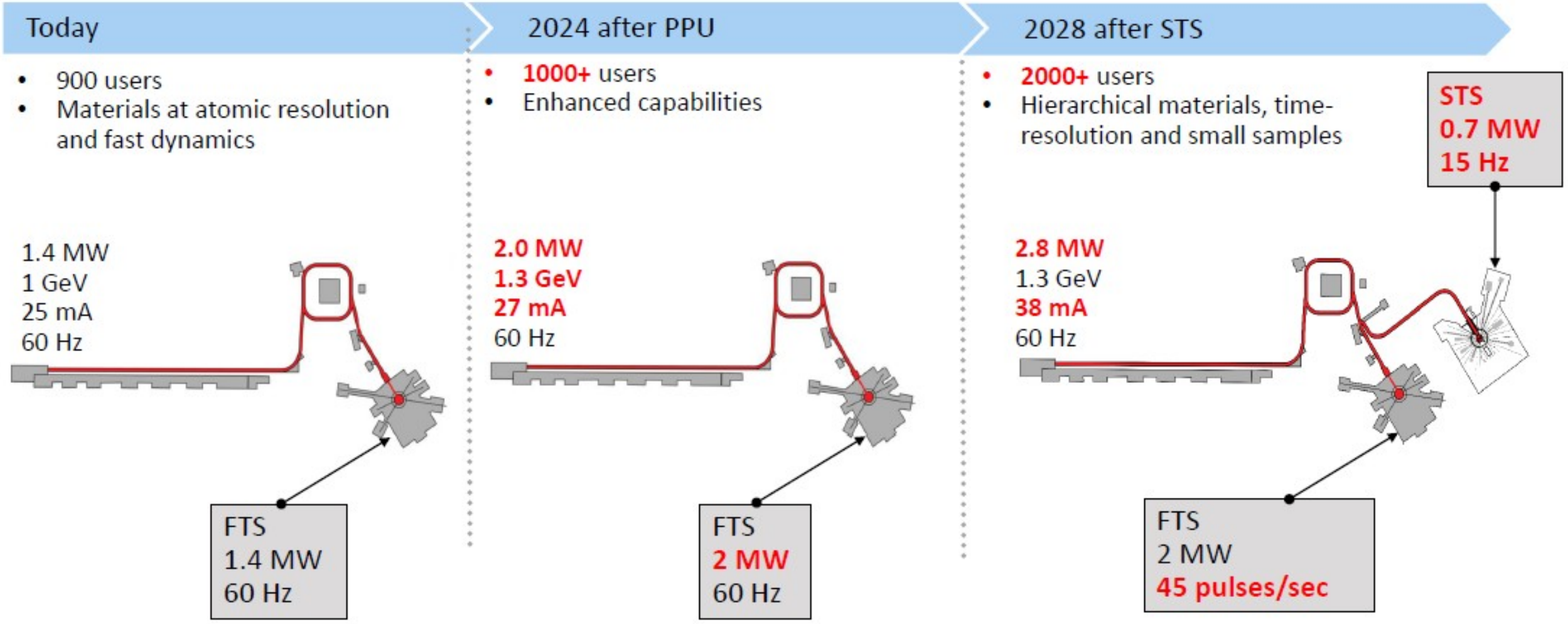


Inclusive ν_e CC on ^{127}I from 185 kg NaI[Tl] to be publicly presented soon

Future: ν CC (~340/SNS year) and NC (~100/SNS year) from CENNS-750

LAr TPC is considered, useful for DUNE

Upgrades



The Second Rarget Station (STS) provides more dedicated neutrino physics space
COHERENT is in contact with ORNL on this matter (space/background level optimization)

Summary

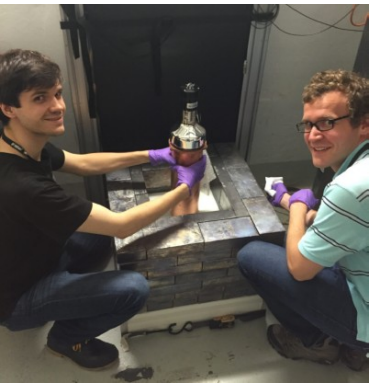
arXiv:2204.04575

Collaboration operates multiple detectors in the «Neutrino Alley» at SNS

Wide physics reach

- *CEvNS*
- *Neutrino-quark NSI*
- $sin^2\theta_W$
- *Accelerator-produced DM*
- *Nuclear physics (FF)*
- *Inelastic ν interactions (CC, NC)*
- *Steriles*

Neutrino alley virtual tour





Thank you for attention!