Status and prospects on CEνNS

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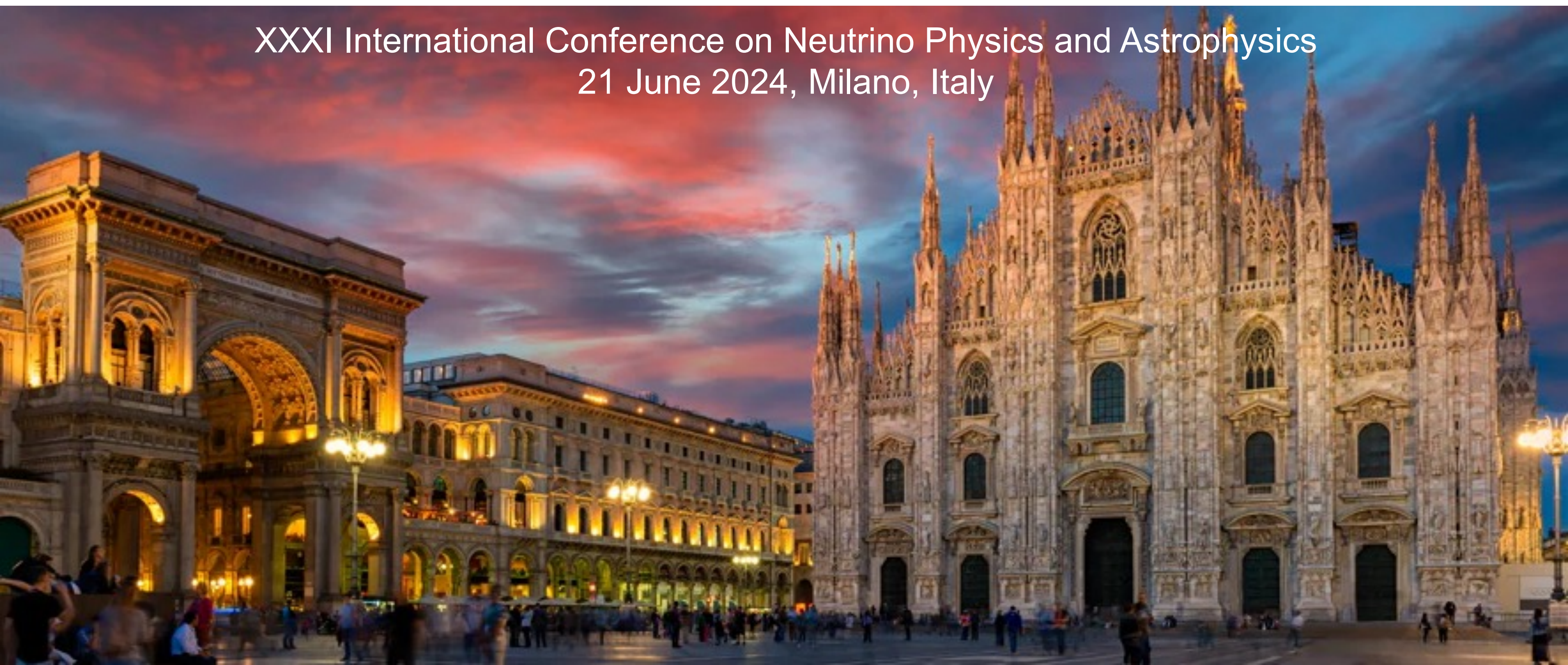
Based on the Magnificent CEvNS workshop 2024

XXXI International Conference on Neutrino Physics and Astrophysics
21 June 2024, Milano, Italy

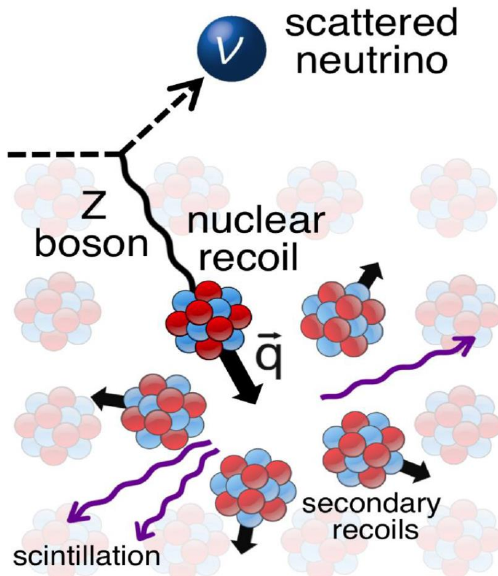


Coherent elastic νN scattering

- In the Coherent Elastic Neutrino-Nucleus Scattering (CEνNS) interaction, the neutrino scatters off the nucleus as a whole.
- Neutral-current interaction, all neutrino flavours.
- Predicted by two groups in 1974.
- Discovered by COHERENT in 2017.

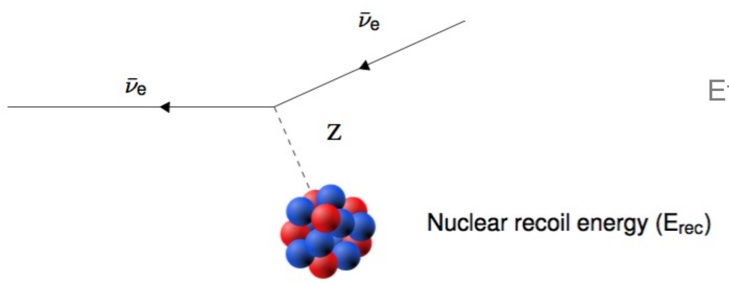
D. Freedman, Phys.Rev. D 9 1389 (1974)
V.B. Kopeliovich and L.L. Frankfurt, JETP Lett. 19 4 236 (1974)

Science 357, 1123, 2017

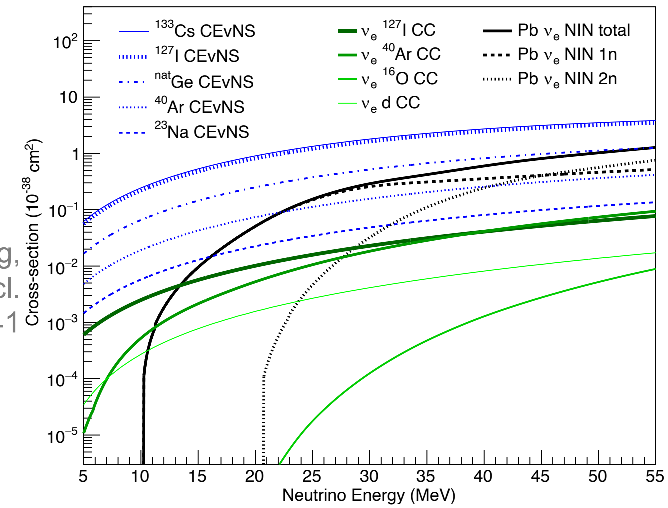


Coherent elastic νN scattering

- Coherent enhancement of the scattering cross-section at low energies: E_ν < 50 MeV.



Barbeau, Scholberg, Efremenko, Ann. Rev. Nucl. Part. Sci. 73 (2023) 41



mass of the nucleus — proton form factor — neutron form factor

$$\frac{d\sigma(E_\nu, E_{nr})}{dE_{nr}} = \frac{G_F^2 M_n}{\pi}\left(1 - \frac{M_n E_{nr}}{2E_\nu^2}\right)\left[g_V^p(\sin^2\theta_w) Z F_Z(|q^2|) + g_V^n N F_N(|q^2|)\right]^2$$

SM vector proton coupling — SM vector neutron coupling

θ_w= Weinberg angle,
Z = atomic number,
N = number of neutrons

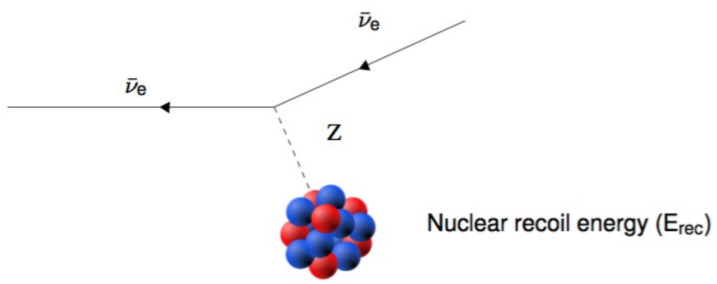
$$g_V^p = \frac{1}{2} - 2\sin^2\theta_w \cong 0.0227$$

$$g_V^n = -\frac{1}{2}$$

- The total cross-section is proportional to N^2.
- Nuclear form-factor is ≈ 1 in the coherence limit $(q^2 \to 0)$.
- CEνNS is the dominant interaction at low energies.

Coherent elastic νN scattering

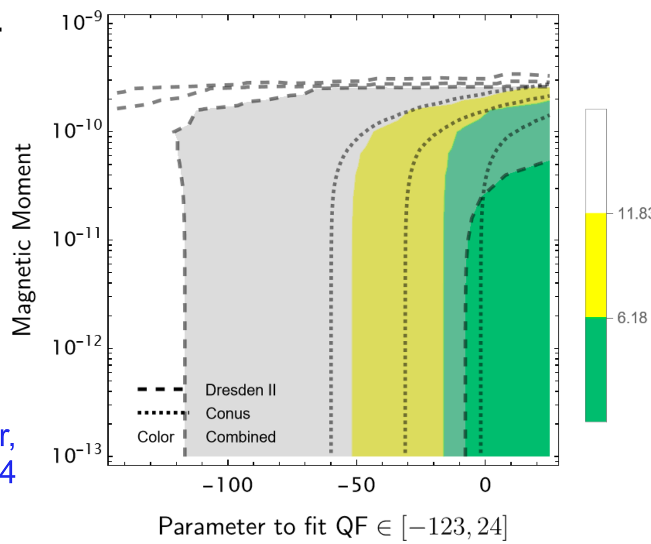
- Coherent enhancement of the scattering cross-section at low energies: E_ν < 50 MeV.



$$E_{nr} = \frac{q^2}{2M_n} = E_\nu - E_{\nu'}$$

Recoils can vary between 0 and $\dfrac{2E_\nu^2}{M_n + 2E_\nu}$

- Despite the large cross-section, the nuclear recoils are very small, $\lesssim$ keV.
  - New technological developments in low-threshold detection.
  - Low backgrounds.
- Ionisation signals are a fraction of recoils.
  - Quenching factor measurements are crucial.



Patrick Huber,
Magnificent CEvNS 2024

Physics with CEνNS

Slide from Valentina de Romeri, Magnificent CEvNS 2023

- EW precision tests
  - Weak mixing angle
- New neutrino interactions
  - Nonstandard interactions
  - Generalised interactions
  - New mediators
- Neutrino properties
  - Neutrino charge radius
  - Neutrino magnetic moments
- Nuclear physics
  - Nuclear form factors
  - Neutron radius and skin
- Supernovae
- Solar neutrinos
- Sterile neutrinos
- Dark matter

Brdar and Rodejohann, arXiv:1810.03626; Chang and Liao, arXiv:2002.10275; Li et al, arXiv:2005.01543; CONUS, arXiv:2110.02174; Cadeddu et al, arXiv:1710.02730, arXiv:2005.01645, arXiv:1908.06045; Aristizabal Sierra et al, arXiv:1902.07398; Huang and Chen, arXiv:1902.07625; Papoulias et al, arXiv:1903.03722, arXiv:1907.11644; Miranda et al, arXiv:2003.12050; Papoulias et al, arXiv:1711.09773, arXiv:1907.11644; Cadeddu et al, arXiv:1808.10202, arXiv:2005.01645, arXiv:1908.06045, arXiv:2205.09484; Huang and Chen, arXiv:1902.07625; Miranda et al, arXiv:1902.09036, arXiv:2003.12050; Khan and Rodejohann, arXiv:1907.12444; COHERENT, arXiv:2110.07730; Papoulias and Kosmas, arXiv:1711.09773; Blanco et al, arXiv:1901.08094; Miranda et al, arXiv:1902.09036, Cerdeño et al, arXiv:1604.01025; Farzan et al, arXiv:1802.05171; Aristizabal Sierra et al, arXiv:1806.07424; Khan and Rodejohann, arXiv:1907.12444; Aristizabal Sierra et al, arXiv:1910.12437; Miranda et al, arXiv:2003.12050; Aristizabal Sierra et al, JHEP 09 (2019) 069; Suliga and Tamborra, arXiv:2010.14545; CONUS, arXiv:2110.02174; Li and Xia, arXiv:2201.05015; Atzori Corona et al, arXiv:2202.11002; Liao et al, arXiv:2202.10622; Coloma et al, arXiv:2202.10829; Lindner et al, arXiv:1612.04150; Aristizabal Sierra et al, arXiv:1806.07424; Aristizabal Sierra et al, JCAP 01 (2022) 01, 055, ...

Physics with CEνNS

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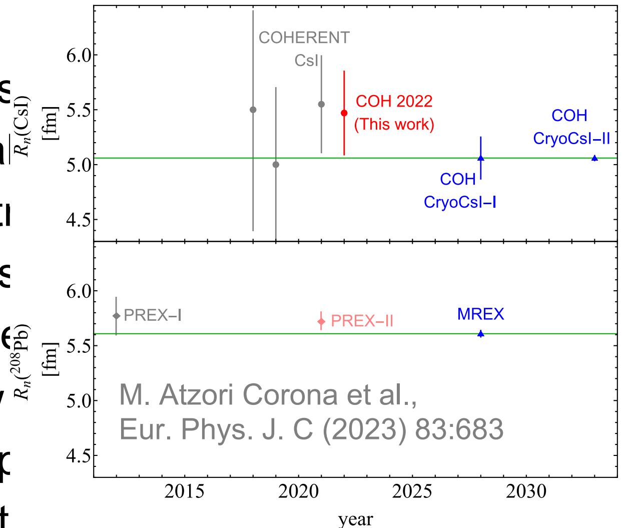
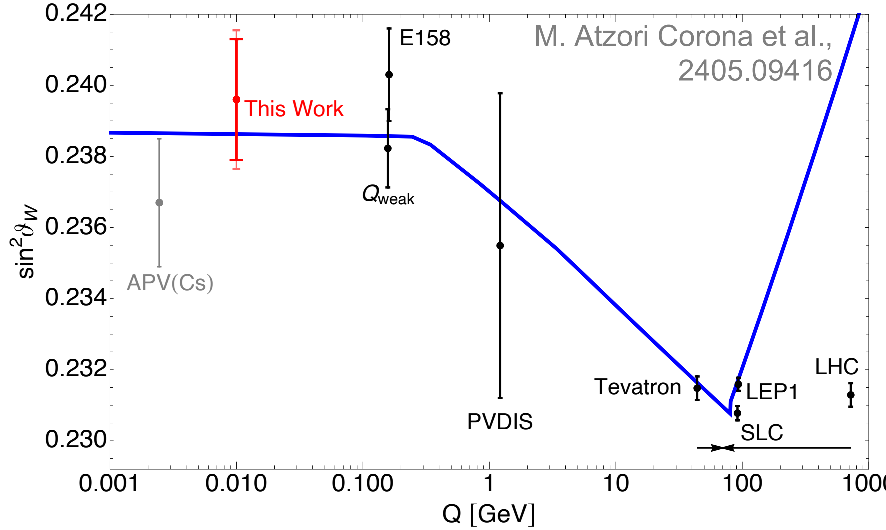
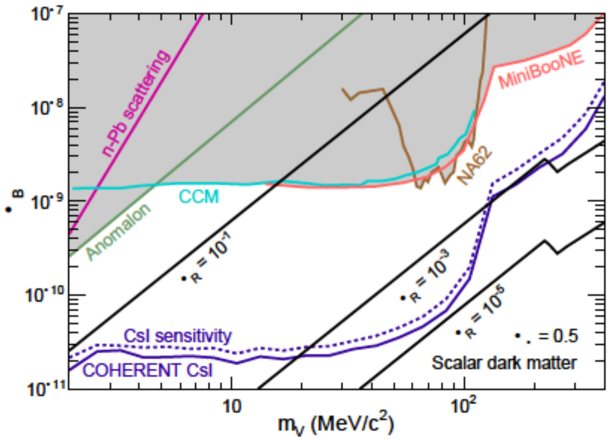
  - Nons
  - Gene
  - New
- Neutrino p
  - Neut

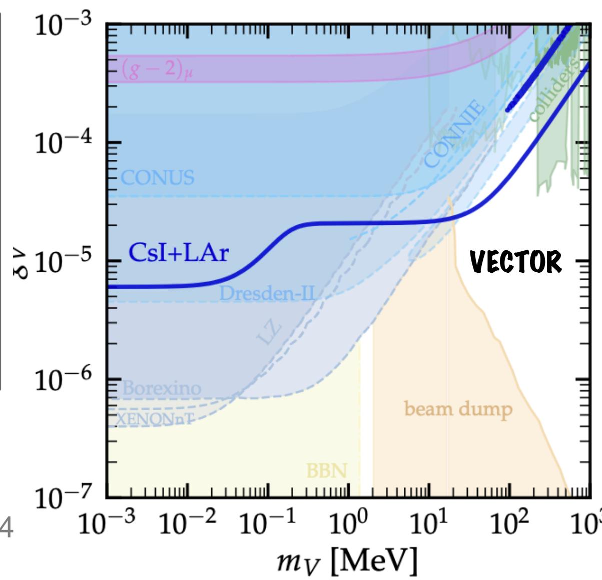


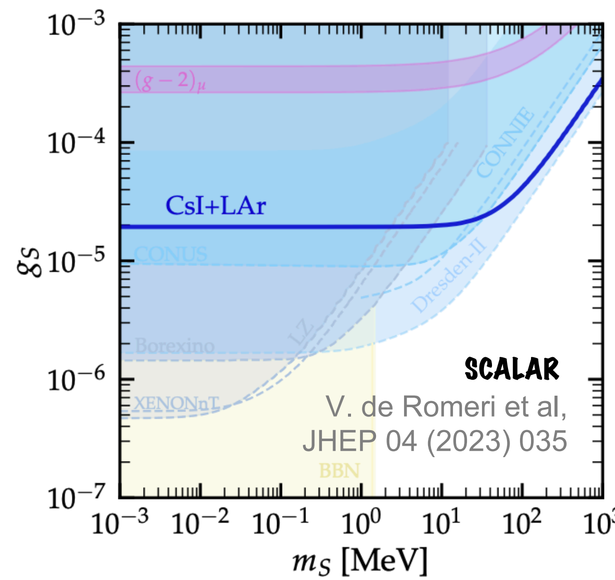




- Dark matter

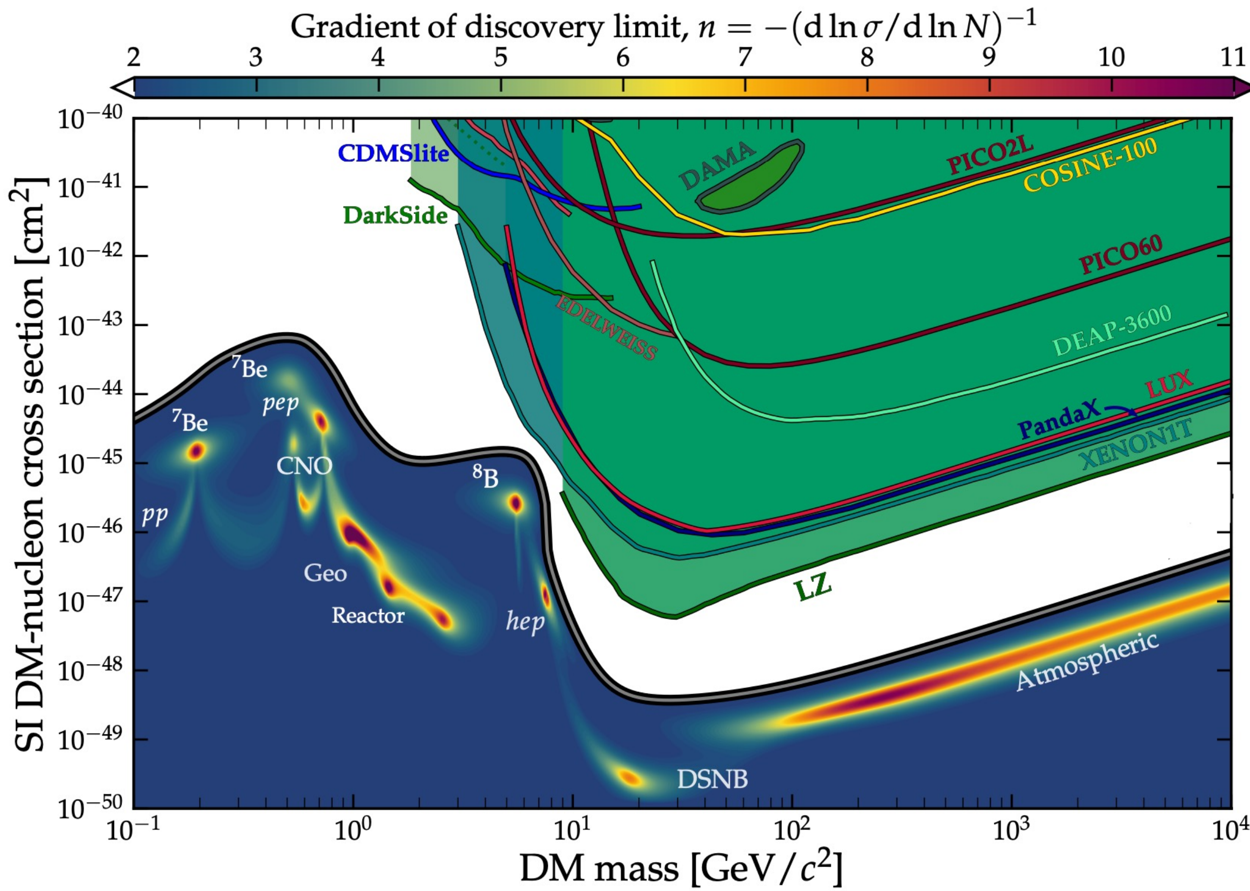
COHERENT collab., PRD106 (2022) 5, 052004





Physics with CEνNS

- CEνNS from solar, atmospheric and diffuse supernova neutrinos forms an irreducible background to direct Dark Matter searches.



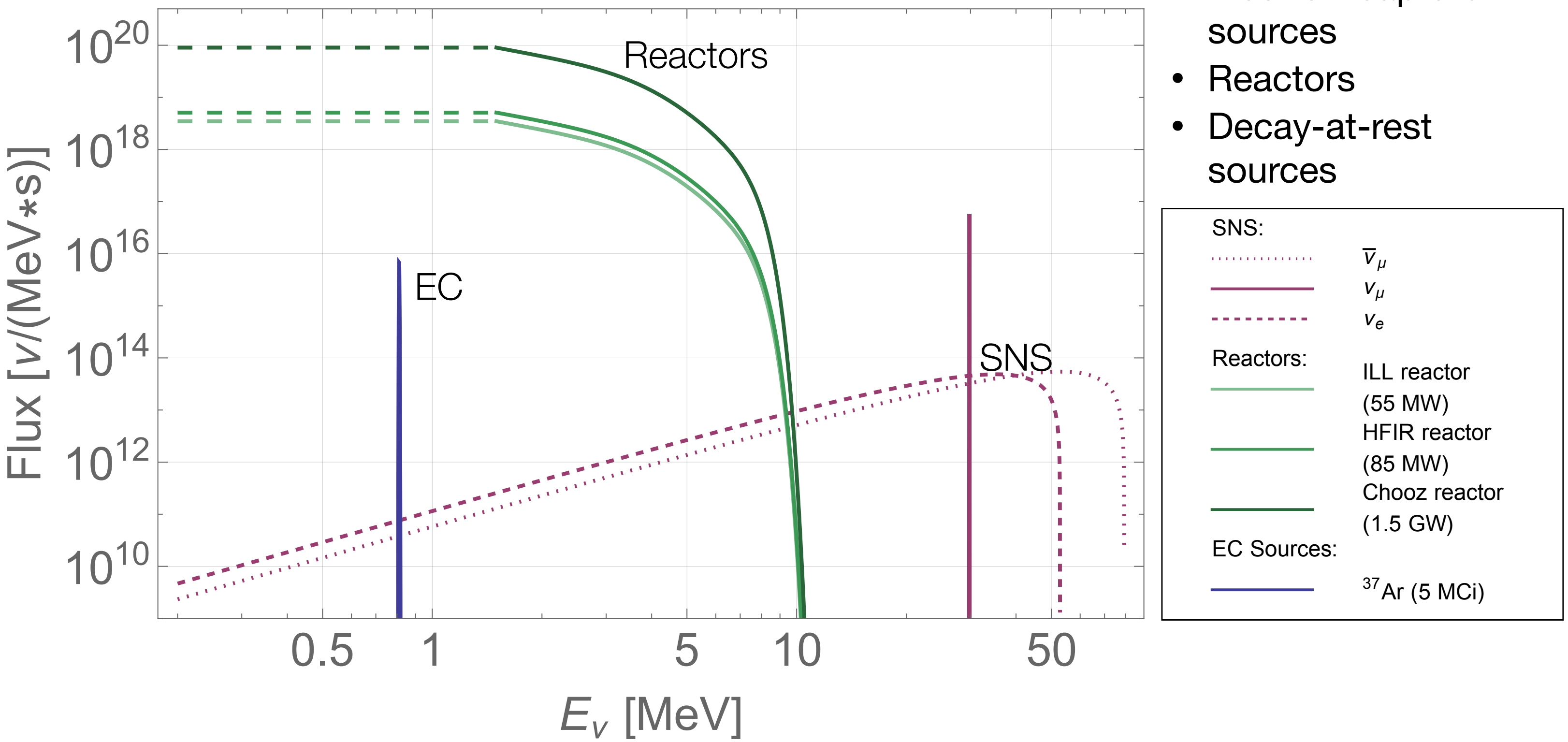
Neutrino fog

C. O'Hare, PRL 127 (2021) 25, 251802

Ciaran O'Hare, Magnificent CEvNS 2024

Neutrino sources

- Required: sources of low-energy neutrinos (E_ν < 50 MeV) with a high flux.

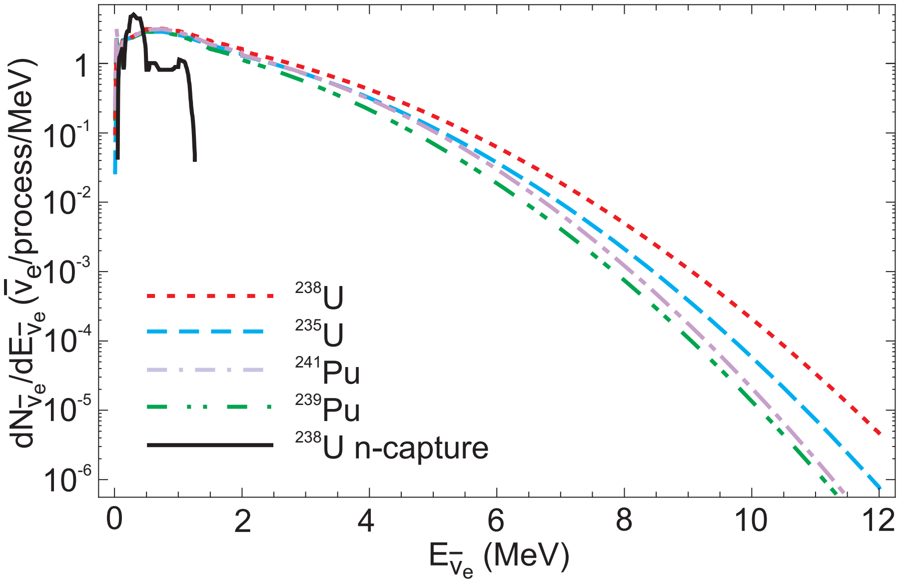


- Electron-capture sources
- Reactors
- Decay-at-rest sources

Enectali Figueroa, Magnificent CEvNS 2023

Neutrino sources

- Required: sources of low-energy neutrinos (E_ν < 50 MeV) with a high flux.
- Reactors.
  - High fluxes of $2*10^{20}$ s^{-1} per GW reactor power.
  - Reactor-off periods crucial for background measurement.
  - Energy range (0–10) MeV means full coherence.

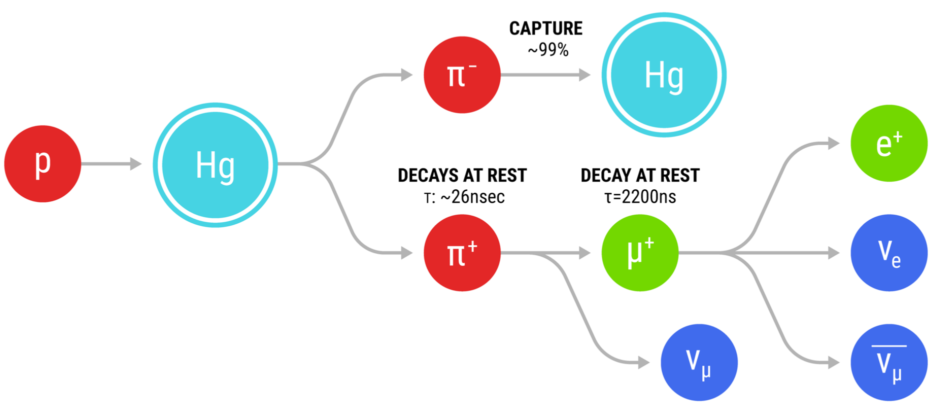


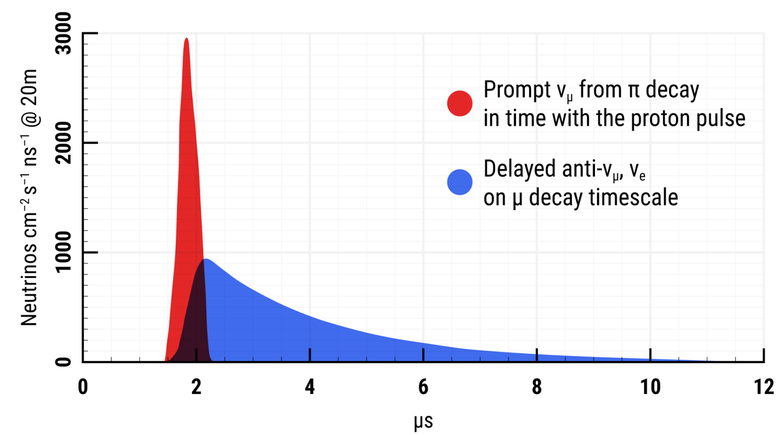
TEXONO collab., Phys.Rev. D75, 012001 (2007)

Neutrino sources

- Required: sources of low-energy neutrinos (E_ν < 50 MeV) with a high flux.

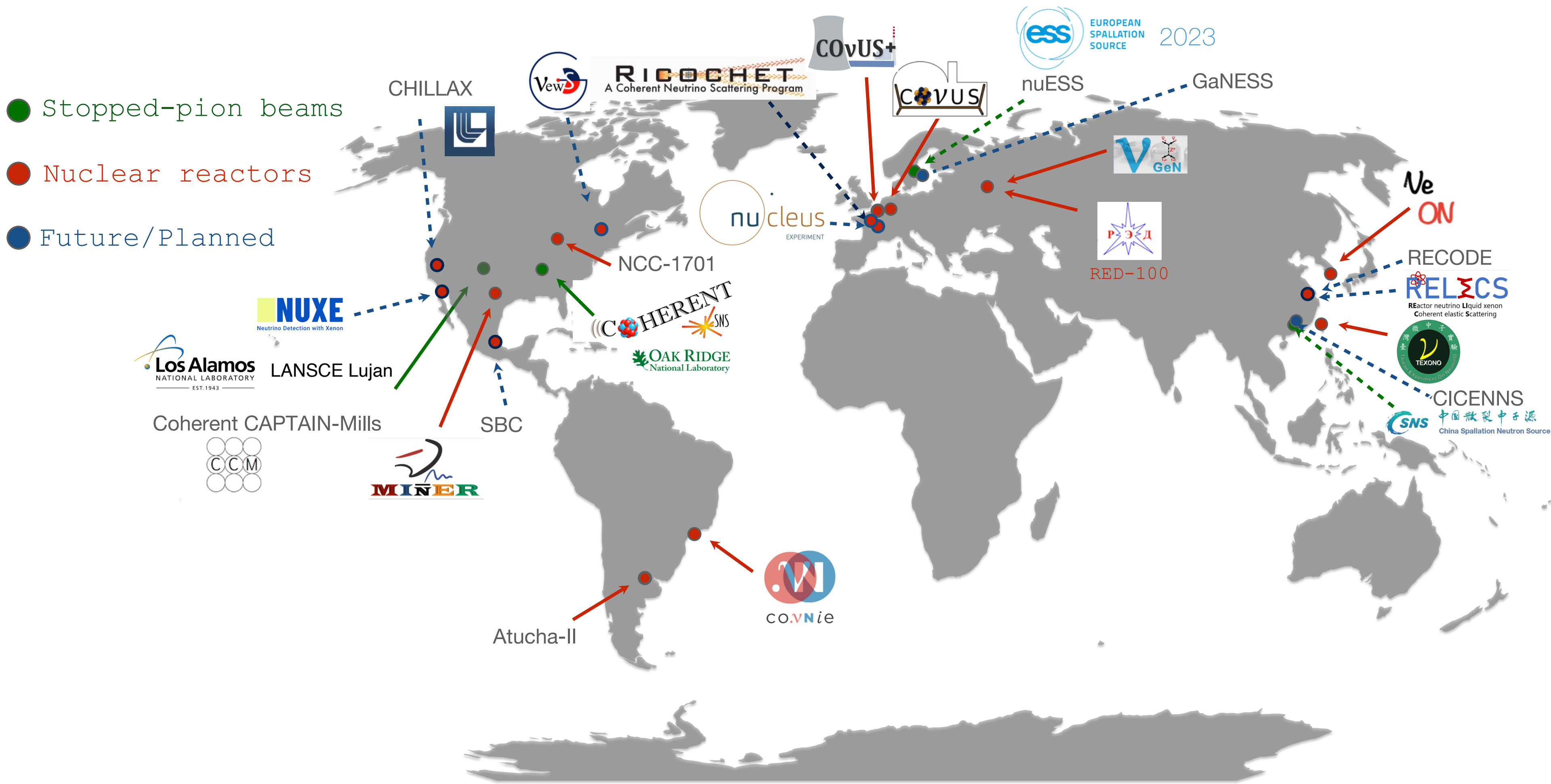
- Pion decay at rest (π-DAR).
  - Pulsed source of electron neutrinos and muon (anti)neutrinos.
  - Timing information crucial for background suppression.
  - Higher energy (10–50) MeV means partial coherence, but higher recoils.
- Several facilities with experiments.
  - Spallation Neutron Source (SNS) at Oak Ridge National Laboratory (USA).
  - Lujan center at Los Alamos Neutron Science Center LANSCE (USA).
  - China Spallation Neutron Source CSNS (China).
  - European Spallation Source (ESS) under construction (Sweden).





COHERENT

CEνNS experiments



Updated from C. Bonifazi, Neutrino 2022

CEνNS experiments

Experiment	Detector	Mass	Threshold	Reactor/ source	Distance to source	Thermal power	Neutrino flux ν/cm^2/s	Location
COHERENT	CsI, Ar, Ge, NaI	15-185 kg	6.5-20 keVnr	πDAR	19-28 m		4.3*10^7	USA
nuESS*	CsI, Ge, Xe, Ar			πDAR				Sweden
CICENNS*	CsI(Na)	300 kg	2 keVnr	πDAR	10.5 m		2*10^7	China
Atucha-II	Si CCDs	2.5 g	40 eVee	Atucha-II	12 m	2 GW$_{th}$	2*10^{13}	Argentina
BULLKID*	Si/Ge cryogenic	20 g	160 eV					Italy
CONNIE	Si CCDs	0.5 g	15 eVee	Angra-II	30 m	3.9 GW$_{th}$	7.8*10^{12}	Brazil
CONUS	HPGe	3.74 kg	210 eVee	Brokdorf	17 m	3.9 GW$_{th}$	2*10^{13}	Germany
CONUS+	HPGe	3.74 kg	150 eVee	Leibstadt	20.7 m	3.6 GW$_{th}$	1.45*10^{13}	Switzerland
MINER*	Ge, Si, Al_2O_3 cryogenic	1 kg	100 eVnr	TRIGA / HFIR*	2-10 m	1 MW$_{th}$	~1*10^{12}	USA
NCC-1701	HPGe	3 kg	200 eVee	Dresden-II	8 m	2.96 GW$_{th}$	8.1*10^{13}	USA
NEON	NaI(Tl)	16.7 kg	200 eVee	Hanbit	23.7 m	2.815 GW$_{th}$	~1*10^{13}	Korea
NEWS-G3*	Ar+2%CH4			tbc				Canada
NUCLEUS*	$CaWO_4$, Al_2O_3 cryogenic	10 g	20 eVnr	Chooz	77 m, 102 m	2x2.45 GW$_{th}$	1.7*10^{12}	France
NUXE*	LXe	10 kg		tbc				
nuGEN	HPGe	1.4 kg	200 eVee	Kalinin	11-12 m	3.1 GW$_{th}$	5.4*10^{13}	Russia
RED-100	LXe, Lar*	200 kg		Kalinin	19 m	3.1 GW$_{th}$	1.35*10^{13}	Russia
RECODE*	HPGe	1-2,10 kg	160 eVee	Sanmen	11, 22 m	3.4 GW$_{th}$	Up to 5.6*10^{13}	China
RELICS*	LXe	50 kg	1 keVnr	Sanmen	22 m	3.4 GW$_{th}$	1.4*10^{13}	China
Ricochet*	Ge, Zn, Al, Sn cryogenic	680 g	160 eVee, 300 eVnr	ILL-H7	8.8 m	58 MW$_{th}$	1.6*10^{12}	France
SBC*	Ar	10 kg	100 eVee	tbc				USA
TEXONO	HPGe	1.43 kg	200 eVee	Kuo-Sheng	28 m	2.9 GW$_{th}$	6.4*10^{12}	Taiwan

* in preparation

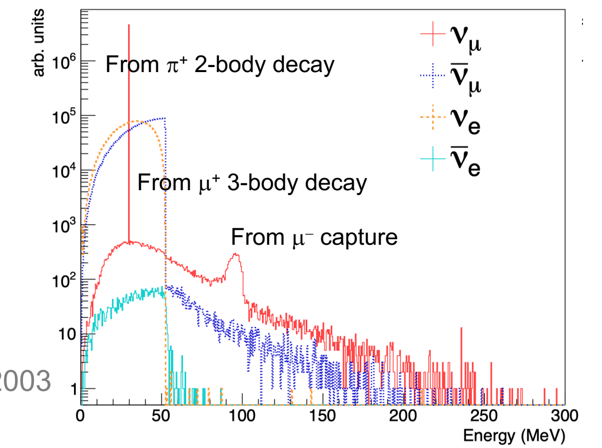
Germanium Silicon Noble gases Cryogenic Scintillator

(the list may be incomplete)

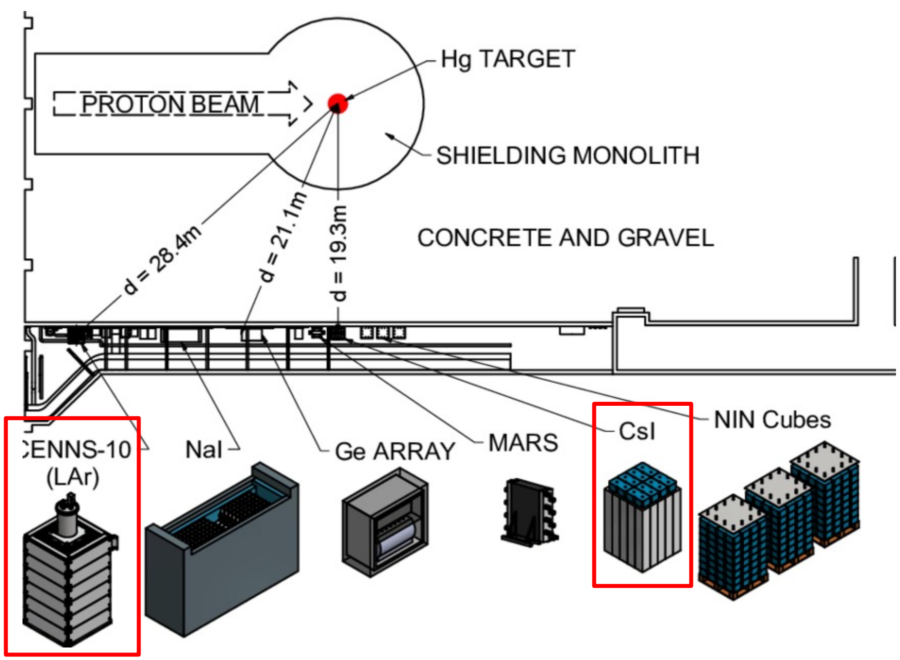
CEνNS at πDAR sources

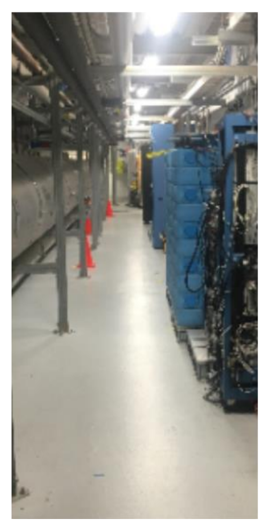
COHERENT

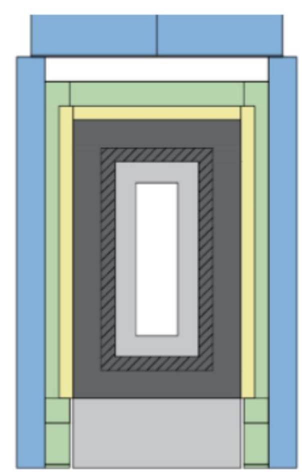
- Pulsed neutrino beam from pion decay at rest at Spallation Neutron Source (SNS).
- CsI[Na] detector was the world's smallest working neutrino detector.
  - 14.6 kg mass, 6.5 keV_{nr} threshold.
  - 19.3 m from the source.
  - Basement with 20+ m of gravel and concrete.
  - Muon vetoes and lead, water and plastic passive shielding.
  - Different neutrino flavours resolved using timing.

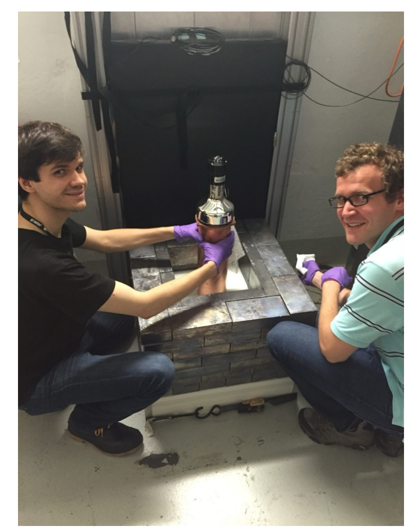


PRD 106 (2022) 032003



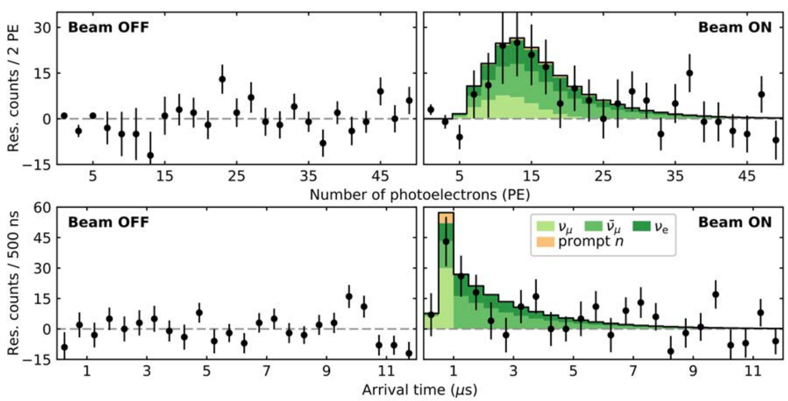






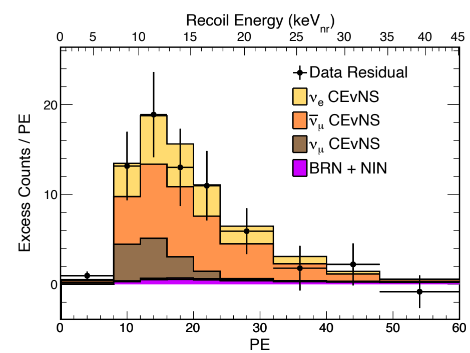
COHERENT CsI measurement

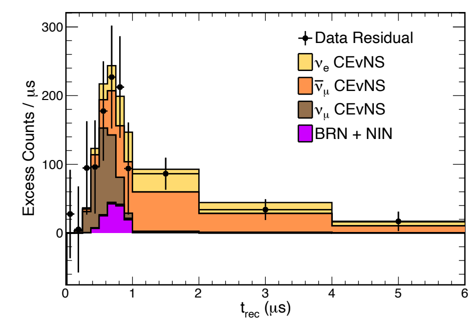
- First observation of CEνNS with the CsI[Na] detector in 2017.
- Full CsI[Na] dataset 2.2 times bigger, before decommissioning in 2019.
  - Updated scintillator response model, improved systematic uncertainties.
- Measurement of the CEνNS cross-section.
  - Compatible with the Standard Model prediction and most precise to date.
  - Limits on BSM physics.



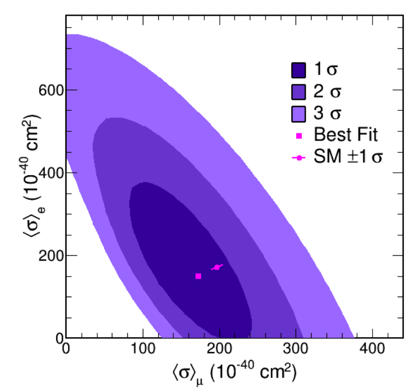
134 ± 22 events observed
173 ± 48 events predicted
6.7σ significance

Science 357, 1123, 2017





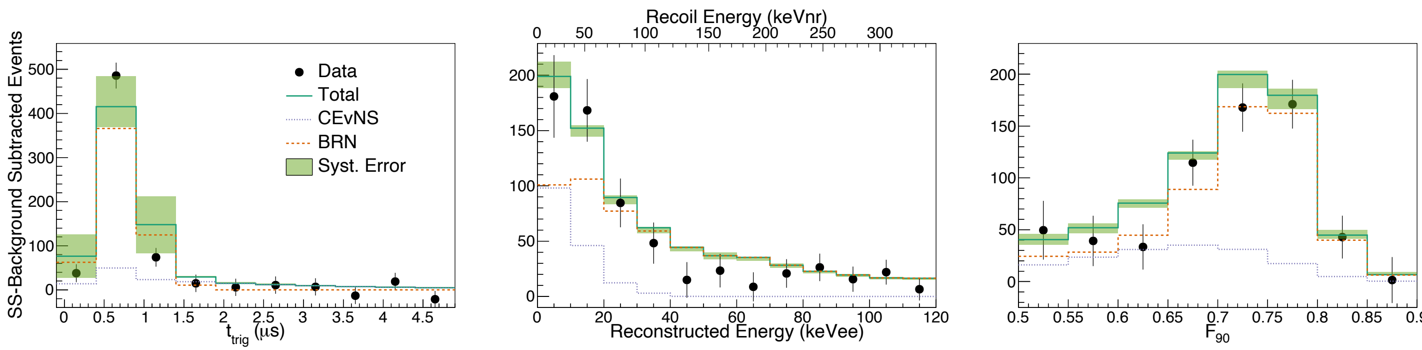
$$\langle\sigma\rangle_{\phi} = \left(165^{+30}_{-25}\right)\times 10^{-40}\ cm^{2}$$

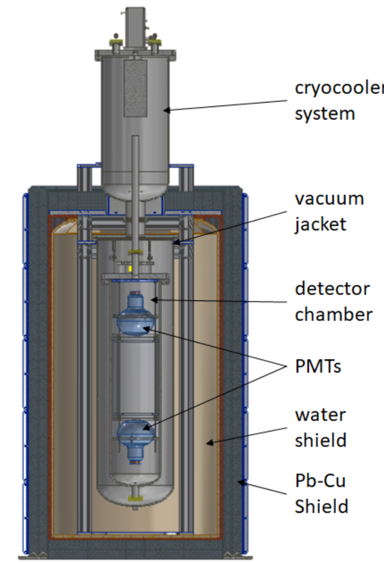


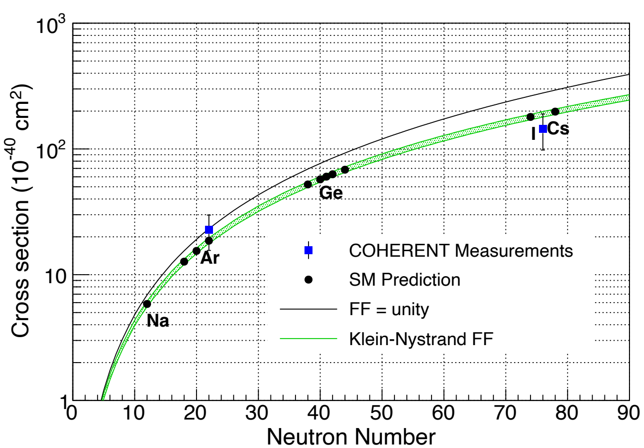
PRL 129 (2022) 8, 081801

COHERENT Ar measurement

- CENNS-10 Liquid Argon single-phase (scintillation) detector.
  - 24.4 kg mass, 20 keV_{nr} threshold.
  - CEνNS excess with 3.5σ significance.
- Measurement of the CEνNS cross-section on argon.
  - First confirmation of its N^2 dependence.







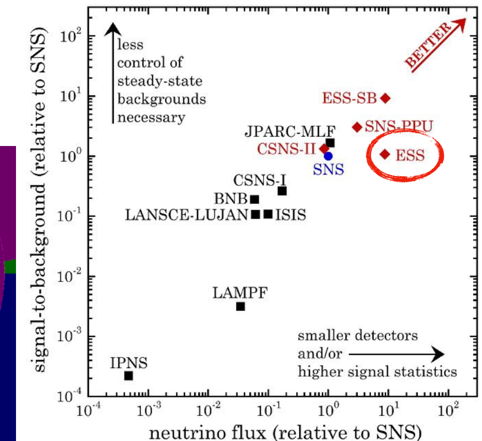
PRL 126 (2021) 1, 012002

See more in Matthew Green's talk next

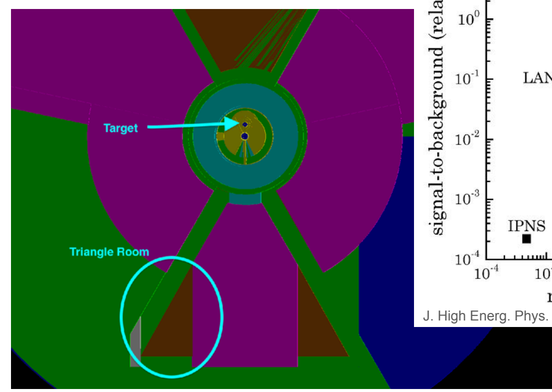
NuESS

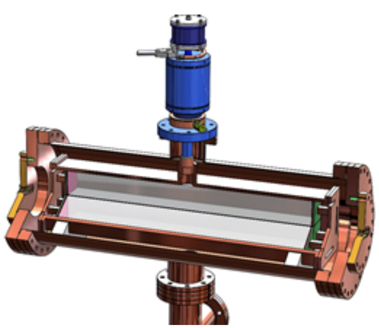
- New opportunities for CEνNS experiments at the European Spallation Source.
  - Flux 8.5 x 10^{22} ν/flavour/y, largest in the next-generation facilities.
- NuESS project combines several detector technologies.
  - Cryogenic undoped CsI.
  - PPC Ge.
  - High-pressure TPC (GanESS) with Ar, Kr, Xe.
- Experiment location identified.
  - Studies to measure and simulate neutrons.
- Ongoing detector development.
  - Operation expected in 2027.

Neutrino production at different facilities

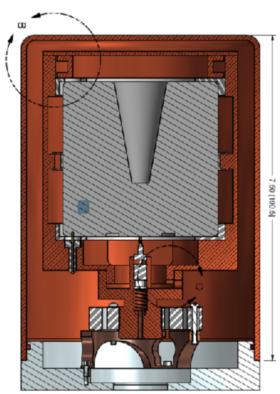


J. High Energ. Phys. **2020**, 123 (2020)

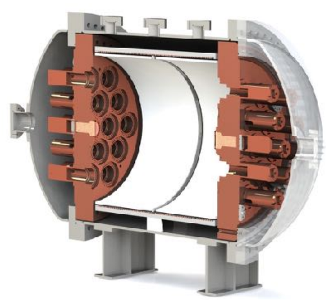




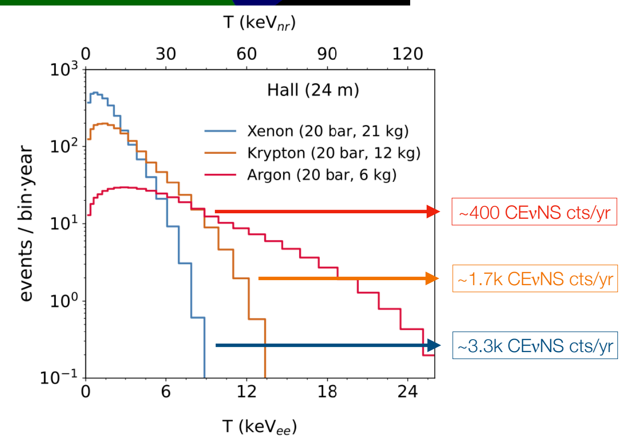
Cryogenic undoped CsI



p-type point contact Ge



high pressure gas TPC



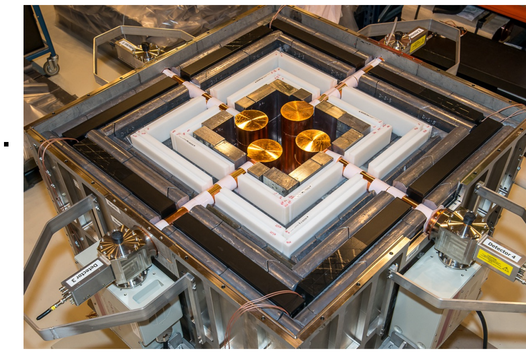
Francesc Monrabal, Magnificent CEvNS 2024

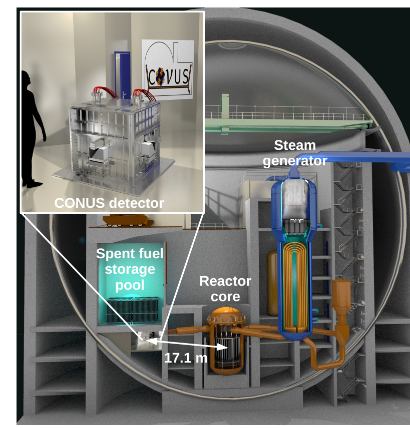
Leire Larizgoitia, poster #386

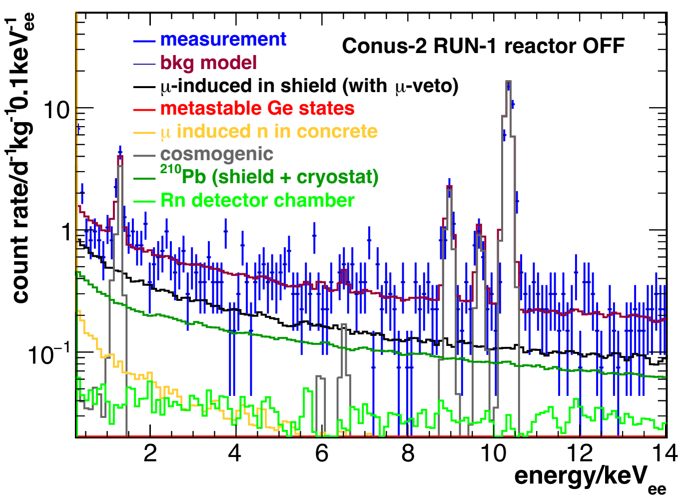
CEνNS at reactors

CONUS

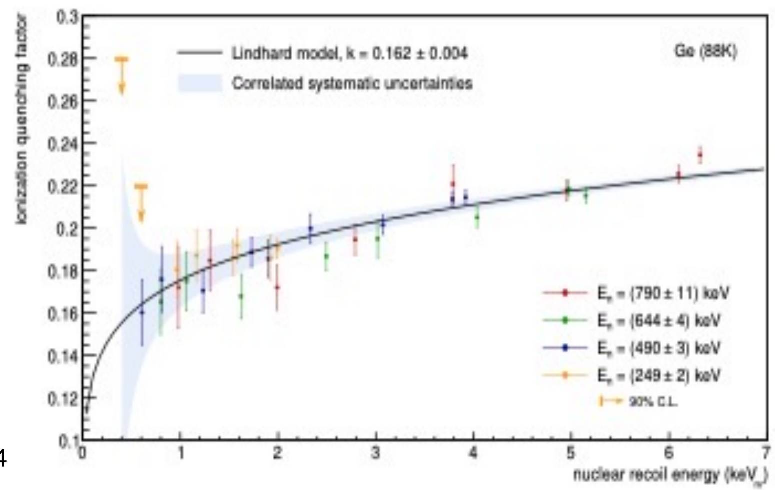
- Reactor neutrino experiment at 17 m from the 3.95 GW_{th} Brokdorf reactor in Germany.
  - Flux 2.3 x 10^{13} $\bar{\nu} s^{-1} cm^{-2}$.
  - Took data in 2018-2022.
- Four 1-kg p-type point contact High-Purity Germanium detectors.
  - 24 m.w.e overburden, muon veto and passive shielding.
  - Run 1 & 2 data with threshold 300 eV_{ee}.
- Complete background characterisation.
- Measurement of the quenching factor for Ge.







Eur. Phys. J. C 83, 195 (2023)



Eur. Phys. J. C 82, 815 (2022)

Lindhard theory
k = 0.162 ± 0.004

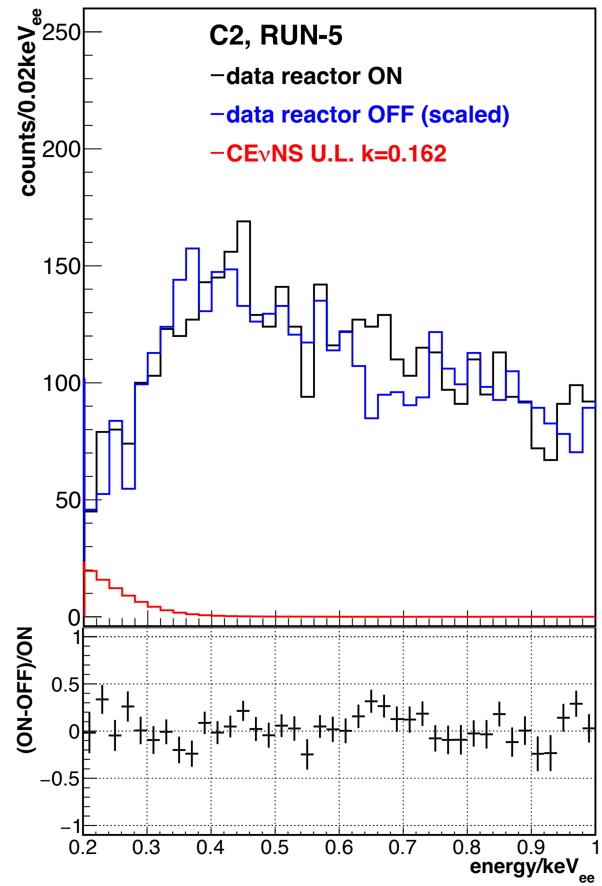
Janina Hakenmüller, Magnificent CEvNS 2024

CONUS

- Improvements in run 5 before decommissioning in 2022:
  - Improved trigger efficiency and temperature stability.
  - New pulse-shape discrimination.
  - Threshold down to 210 eV_{ee}.

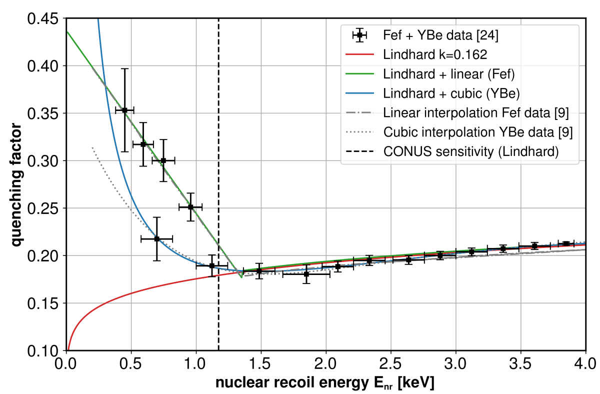
Eur.Phys.J.C 84 (2024) 139

- Best limit on CEνNS in the fully coherent regime using the full dataset at 2x the SM.
  - Good reactor-off exposure.
- Expect update on limits of Nonstandard Interactions.
- Quenching factor comparison.
  - NCC-1701 at Dresden-II QF in tension with CONUS result.



arXiv: 2401.07684

	Run-1/Run-2	Run-5
ON/kg*d	248.7	426
OFF/kg*d	58.8	272
threshold/eV_{ee}	296-348	210
Limit (k=0.162)	factor 17 > SM	factor 2 > SM

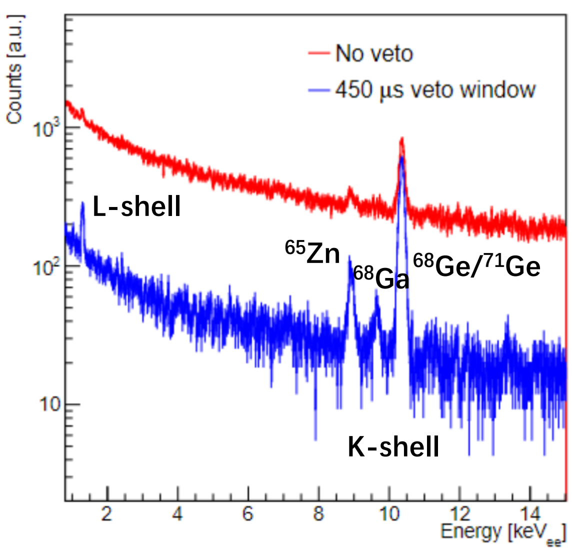


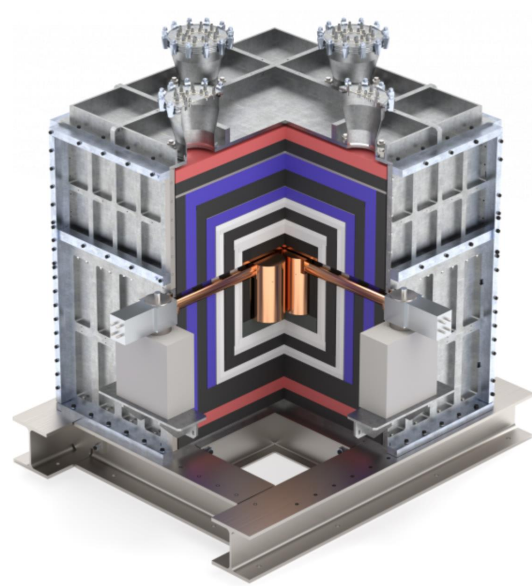
Dresden-II data: PRD 103 (2021) 122003

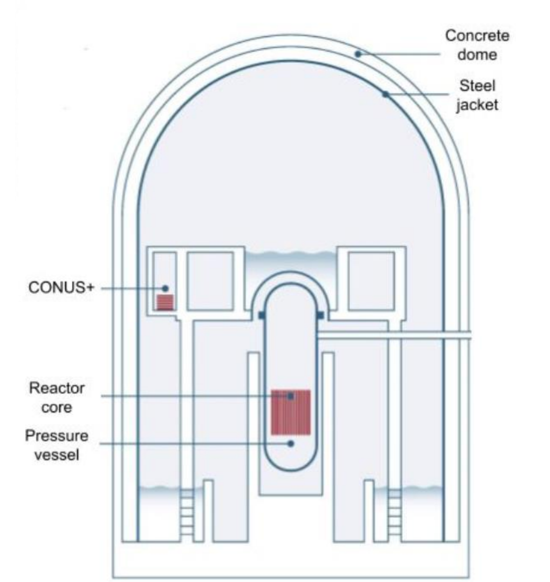
Manfred Lindner, poster #244

CONUS+

- CONUS moved to 20.7 m from the 3.95 GW_{th} Leibstadt reactor in Switzerland.
  - Flux 1.45 x 10^{13} $\bar{\nu} s^{-1} cm^{-2}$.
  - Started running in Nov 2023. First reactor-off data in May 2024.
- Detector, shielding and DAQ upgrade.
  - Threshold reduced to 150 eV_{ee}.
- Environmental background characterised.
- Working on full background modeling.
- Expect 10x larger signals than CONUS: 580 ν/det/y.





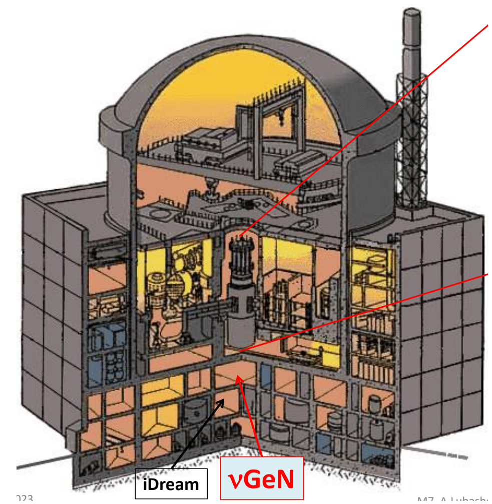


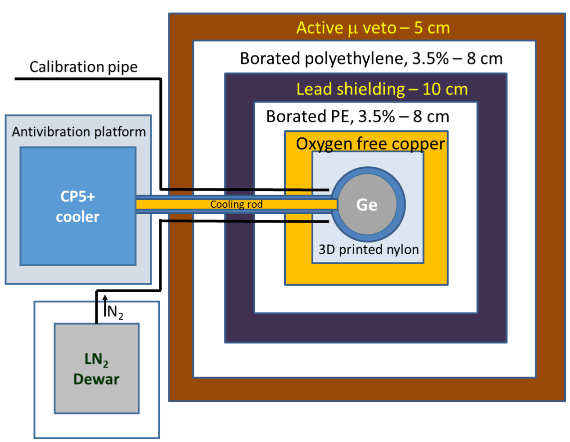
Edgar Sánchez García, poster #243

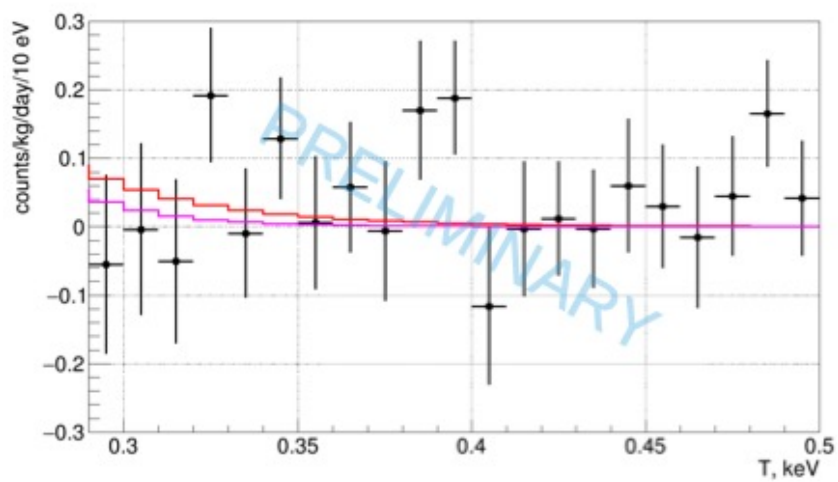
Kaixiang Ni, Magnificent CEvNS 2024

nuGeN

- Reactor neutrino experiment at 11 m from the 3.1 GW_{th} Kalinin reactor in Russia.
  - Flux up to 4.4 x 10^{13} $\bar{\nu} s^{-1} cm^{-2}$.
  - Distance to reactor can be varied 11-12.5 m.
- 1.5-kg p-type point contact High-Purity Germanium detector.
  - 50 m.w.e. overburden, muon vetoes, antivibration platform.
- Preliminary limits on CEνNS with 2022-2023 data.
  - Taking data with improved conditions since 2022.
  - Implementing modifications to reduce background at low energy.
  - Limits at 5x SM (if CONUS QF) or 2x SM (if Dresden QF).
  - Analysing 1500+ kd-days of data.
  - Plans to improve sensitivity: background model, threshold, DAQ.





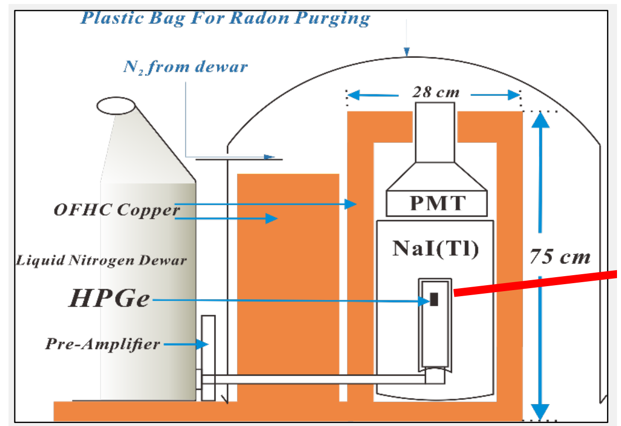


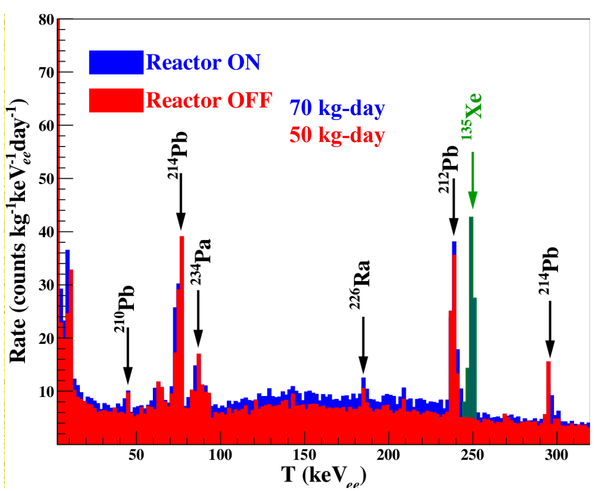
CONUS QF (Lindhard k=0.162)
Dresden QF (FeF, modified Linhard k=0.157)

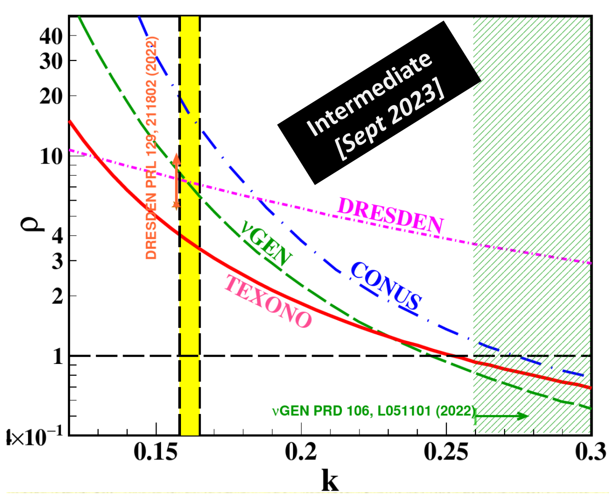
Alexey Konovalov, Magnificent CEvNS 2024

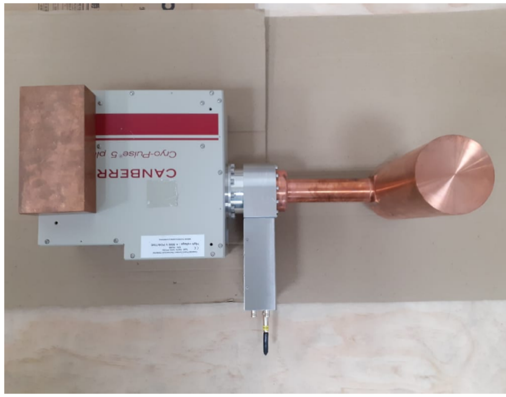
TEXONO

- Reactor neutrino experiment at 28 m from the 2.9 GW_{th} Kuo-Sheng reactor in Taiwan.
  - Flux 6 x 10^{12} $\bar{\nu}s^{-1}cm^{-2}$.
  - 24 m.w.e overburden, muon veto and passive shielding.
- Six p-type point contact High-Purity Germanium detectors.
  - Took data since ~2003.
  - 1.43 kg electro-cooled detector.
  - Threshold 200 eV_{ee}.
- Working on completing the analysis.
  - ^{135}Xe reactor-on background subtraction.
  - Preliminary limit at 4.2x SM for Lindhard QF k = 0.157.
- Long reactor-off period till 2025. 500/800+ kg-days of on/off data.





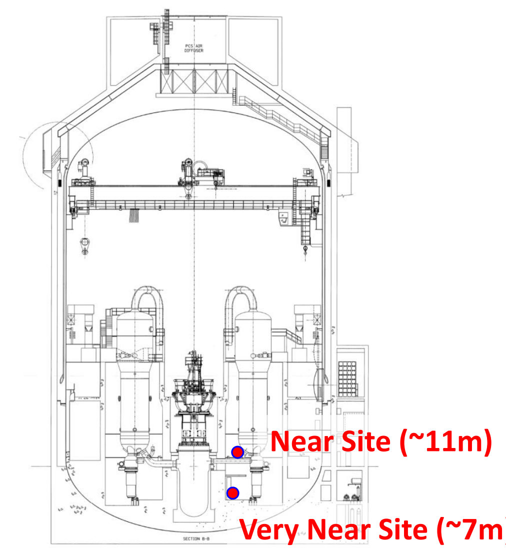




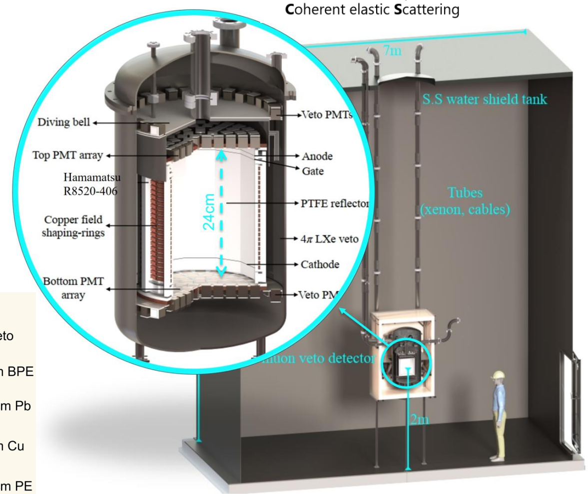
Henry Wong, Magnificent CEvNS 2024

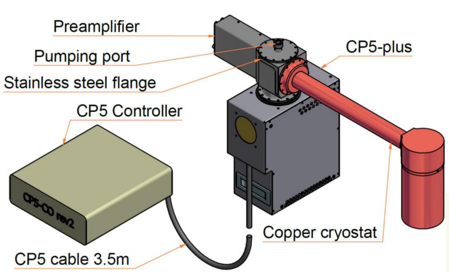
Sanmen reactor neutrino lab

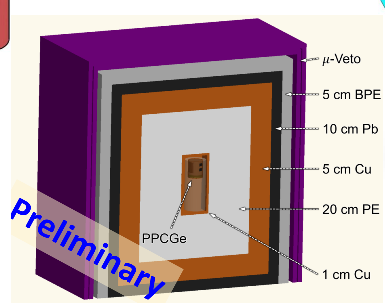
- A new reactor neutrino lab at the 3.4 GW_{th} Sanmen reactor in China.
  - Positions at 22 m / 11 m / 7 m.
  - Flux over 1.4 x 10^{13} $\bar{\nu} s^{-1} cm^{-2}$.
  - Possibility for near/far joint analysis.
  - Background measurements ongoing.
- RECODE experiment: PPCGe.
  - LN cooling (FS), electric cooling (NS/VNS).
  - 1/10 kg based on CDEX-1/10, 160 eV_{ee}.
  - First data in 2025.
  - Plans to measure Ge quenching factor.
- RELICS experiment: LXe TPC.
  - 32 kg fiducial mass, at FS.



RELICS
REactor neutrino LIquid xenon Coherent elastic Scattering



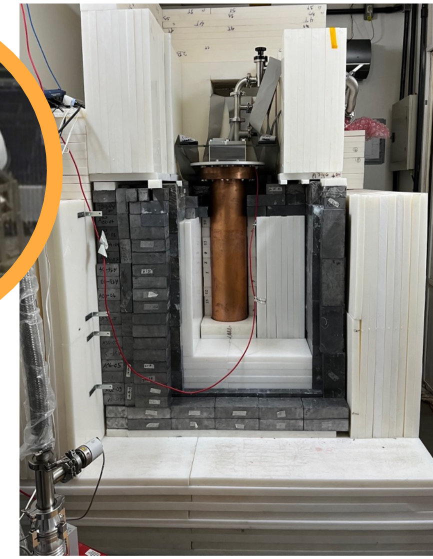


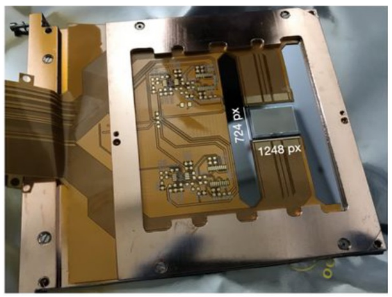


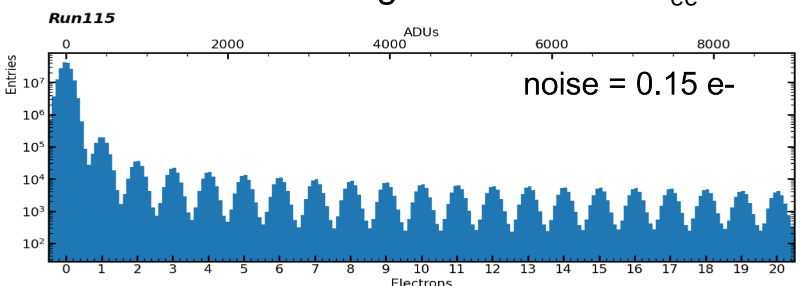
Litao Yang, Magnificent CEvNS 2024

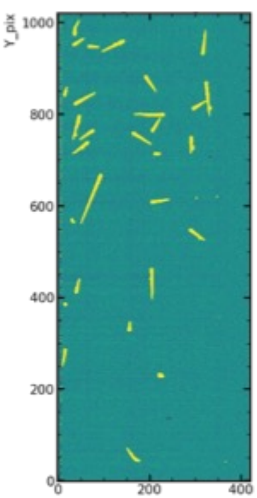
CONNIE

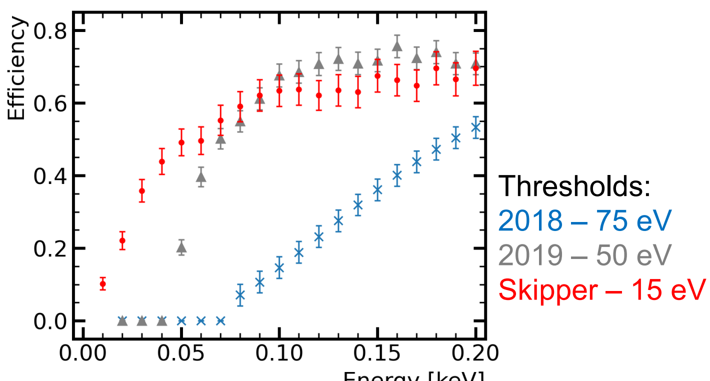
- Reactor neutrino experiment at 30 m from the 3.95 GW_{th} Angra 2 reactor in Brazil.
  - Flux $7.8 \times 10^{12}\ \bar{\nu} s^{-1} cm^{-2}$.
- Thick scientific silicon Skipper-CCD detectors.
  - Multiple non-destructive measurements of pixel charge.
  - 2 sensors of 0.5 g total mass.
  - Took data in 2021-2023.
  - Lower background and 15 eV_{ee} threshold.

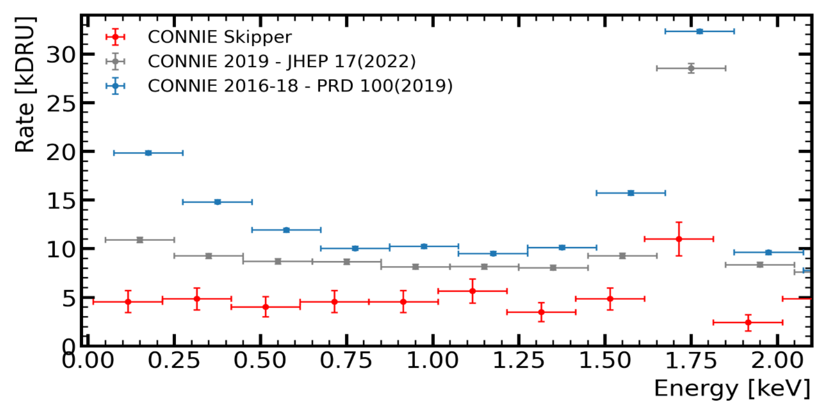








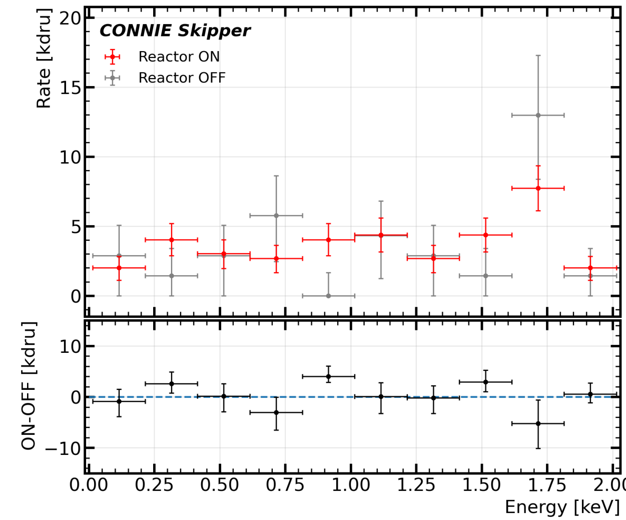




arXiv: 2403.15976

CONNIE

- Searches for CEνNS and BSM physics:
  - CEνNS limit at 76x SM with 18.4 g-days.
  - Limit on light vector mediator.
  - Limit on DM direct detection by diurnal modulation.
  - World leading limit on millicharged particle production – joint analysis with the Atucha-II experiment.
- Multi-chip-module installed in May 2024, 32x more mass.



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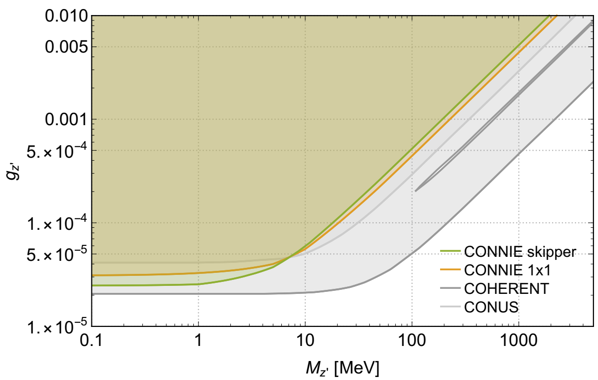

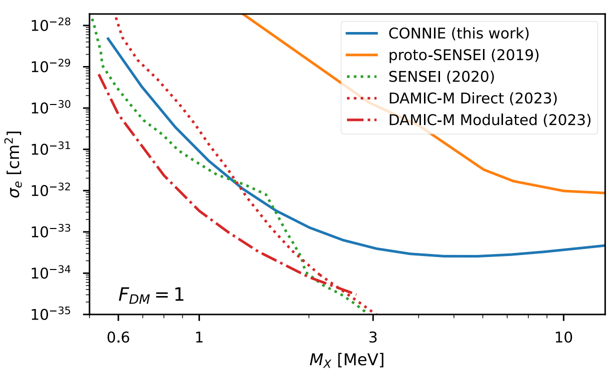

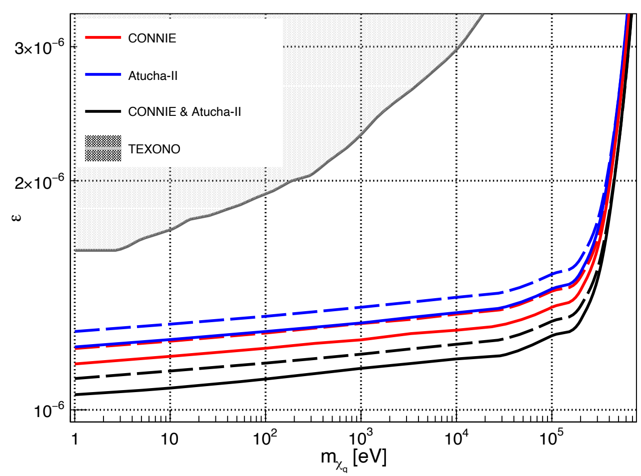

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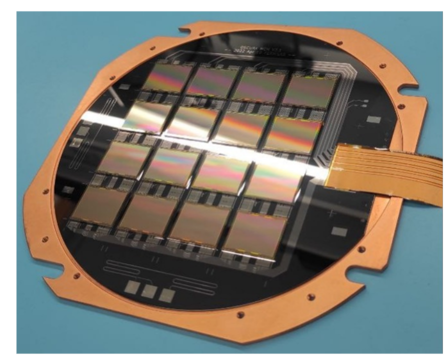
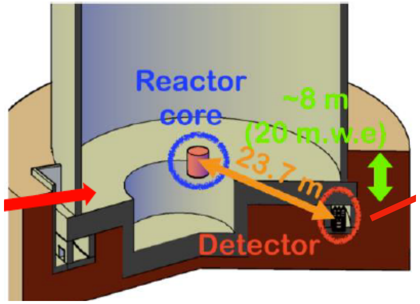
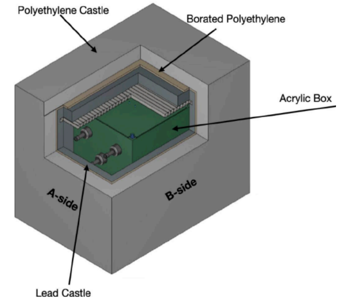


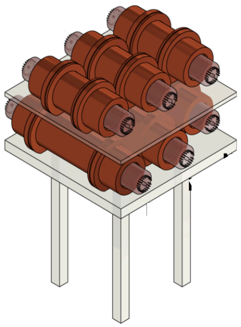
poster #410

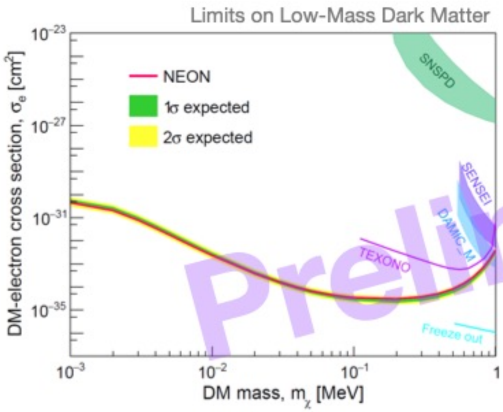
NEON

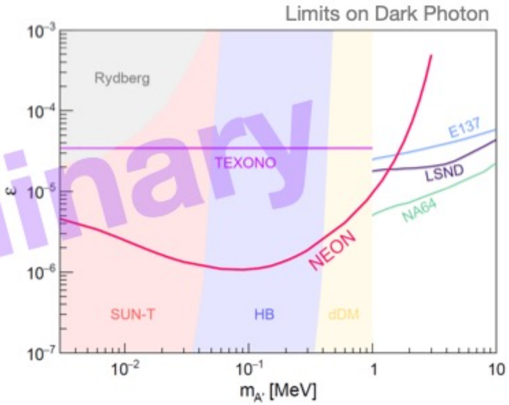
- Reactor neutrino experiment at 23.7 m from the 2.8 GW_{th} Hanbit 6 reactor in Korea.
  - Flux $7.1 \times 10^{12}\ \bar{\nu} s^{-1} cm^{-2}$.
- 16.7-kg scintillator NaI[Tl] detectors.
  - Lower cross-section but higher recoils in Na, 24 PE/keV yield.
  - Passive and active shielding, detector improvements.
  - Energy threshold 200 eV_{ee}.
- Taking data since Apr 2022.
  - Preliminary limits on ALPs and DM.
  - ML for background reduction.
  - Tests with multiple-hit events, will be applied to single-hit.

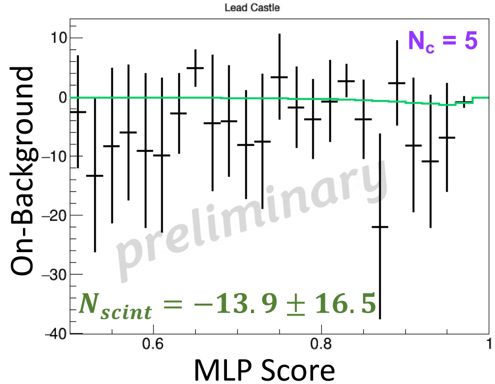










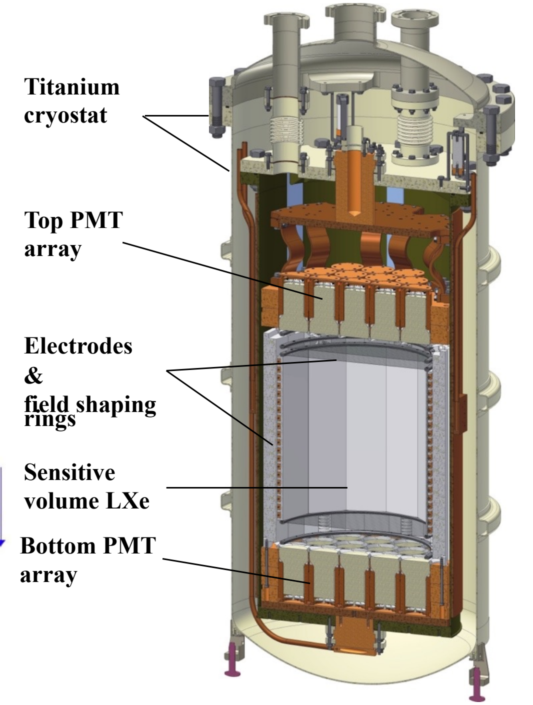


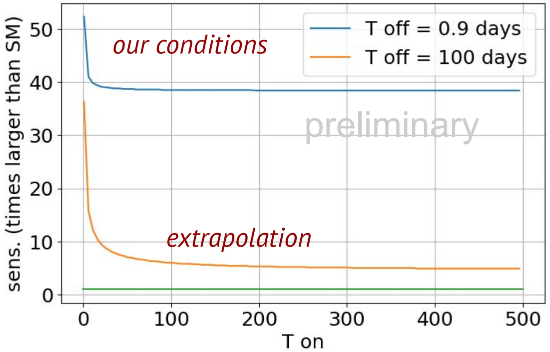
Young Ju Ko, Magnificent CEvNS 2024

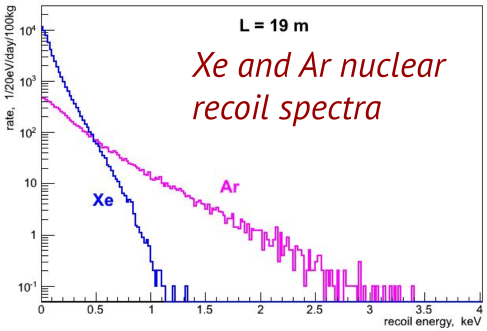
Byoung-cheol Koh, poster #493

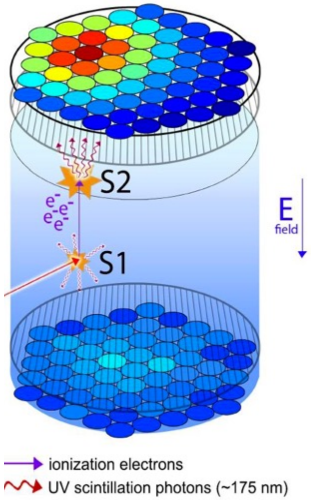
RED-100

- Reactor neutrino experiment at 19 m from the 3.1 GW_{th} Kalinin reactor in Russia.
  - Flux 1.35 x 10^{13} $\bar{\nu} s^{-1} cm^{-2}$.
  - 65 m.w.e. overburden.
- 200-kg liquid Xenon two-phase emission detector.
  - Sensitive to single ionisation electrons SE.
- Data analysis will be completed soon.
  - Background characterisation and detector calibration.
  - Investigating background excess, threshold 4.5 SE.
  - Sensitivity depends strongly on charge fluctuation model.
- Plans to substitute LXe for LAr, higher recoil energies.









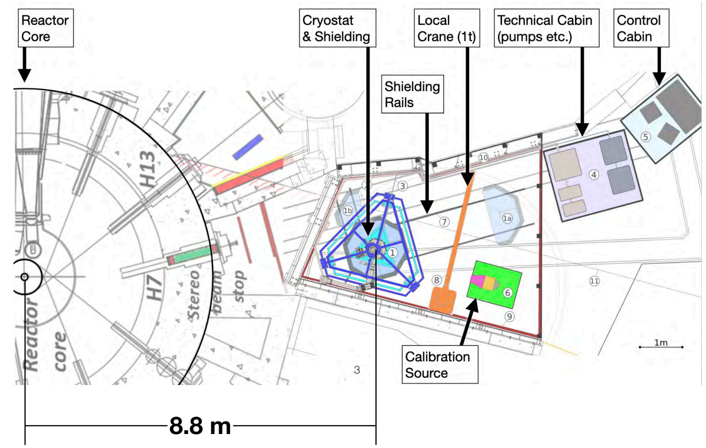
Olga Razuvaeva, Magnificent CEvNS 2024

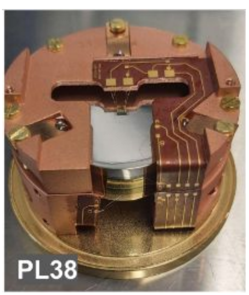
O. Razuvaeva, poster #582

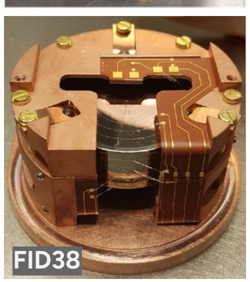
Ricochet

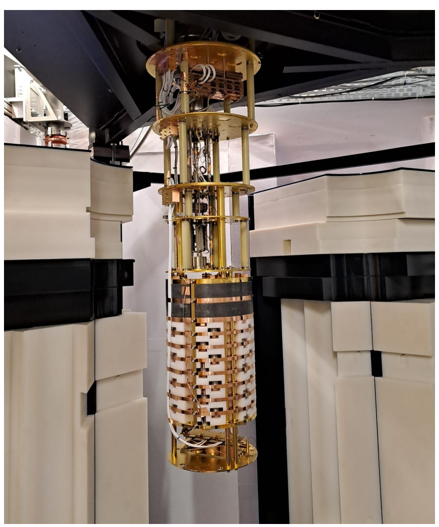
RICOCHET
A Coherent Neutrino Scattering Program

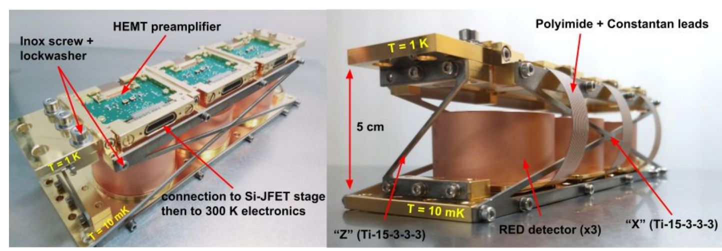
- Reactor neutrino experiment at 8.8 m from the 58 MW_{th} ILL reactor in France.
  - Flux $1.6 \times 10^{12}\ \bar{\nu} s^{-1} cm^{-2}$.
  - 15 m.w.e. overburden.
- Two types of cryogenic calorimeter detectors.
  - CryoCube: Ge crystals with ionisation and heat readout.
  - Particle ID based on ionization/heat ratio.
  - Q-Array: Superconducting crystals with TES, R&D.
- Started commissioning run at the ILL reactor in 2024.
  - Expect to start neutrino run in spring 2025 with 680 g.
  - Predicted S/B = 1 and 7 on-off cycles nominal exposure.



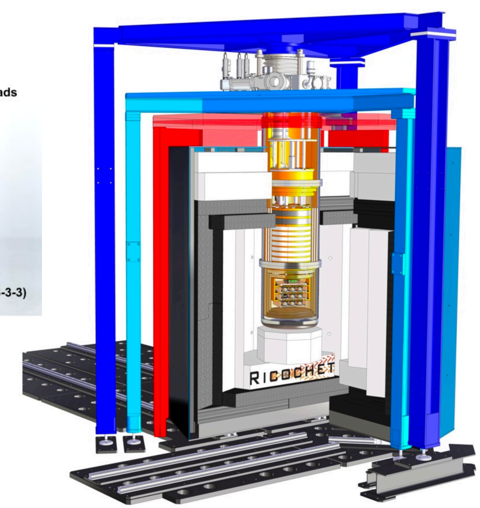








MiniCryoCube of 3 Ge bolometers at 1 K, 38 g each

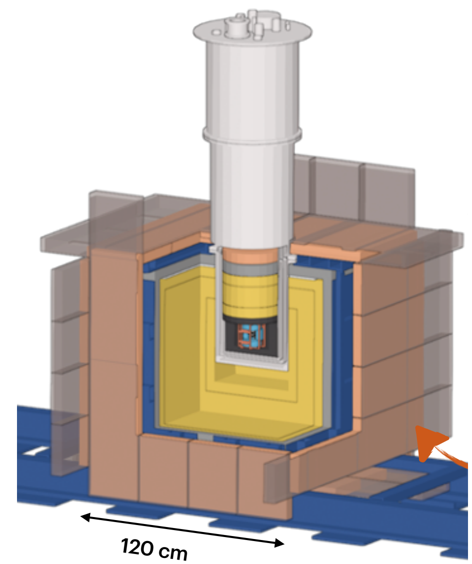


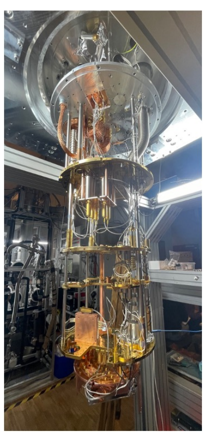
Jiatong Wang, poster #614
Valentina Novati , poster #339

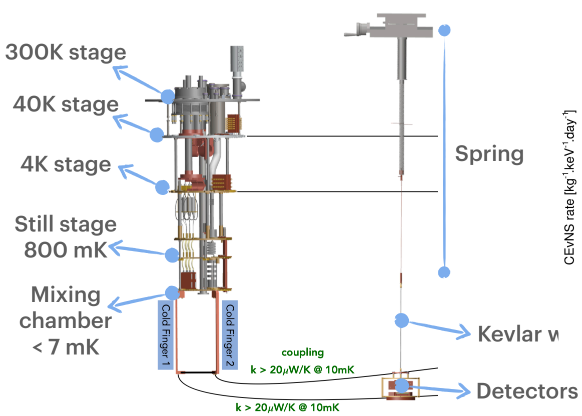
Nicolas Martini, Magnificent CEvNS 2024

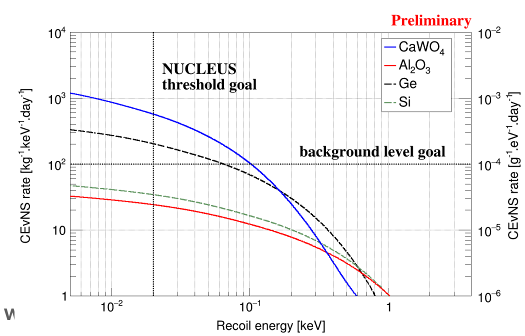
NUCLEUS

- Reactor neutrino experiment at 72, 102 m from the 2x4.5 GW_{th} Chooz reactors in France.
  - Flux $1.7 \times 10^{12}\ \bar{\nu} s^{-1} cm^{-2}$ in a basement room in Very Near Site.
- Two types of cryogenic calorimeter detectors with TES readout.
  - Al_2O_3 for background, $CaWO_4$ for CEνNS, 10 g, from 20 eV.
  - Silicon wafers with TES inner veto, HPGe outer veto, muon veto.
  - External shielding (Pb, PE, B_4C) commissioned, inner ongoing.
- Ongoing target + vetoes commissioning at TUM.
  - Full background model in simulations, low-energy calibration.
  - Double TES readout and PSD for low-energy backgrounds.
  - Move to Chooz for engineering run in 2025.
  - Predict S/B = 1 and 5σ in 150 days.

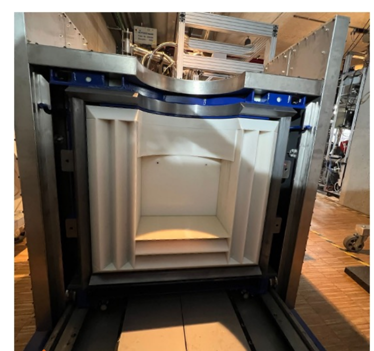


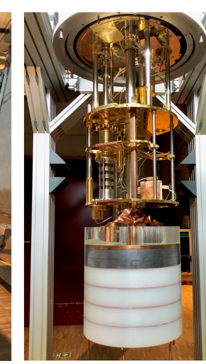






Elisabetta Bossio, Magnificent CEvNS 2024





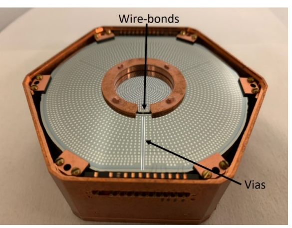
External shielding fully commissioned and in place
Full thermalisation of internal shielding (~50 kg of PE, Pb, Cu, CMV) achieved within 11 days.

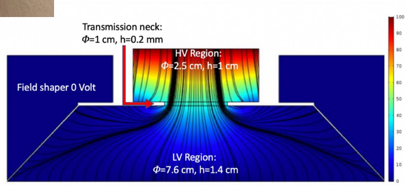
Giorgio Del Castello, poster #432

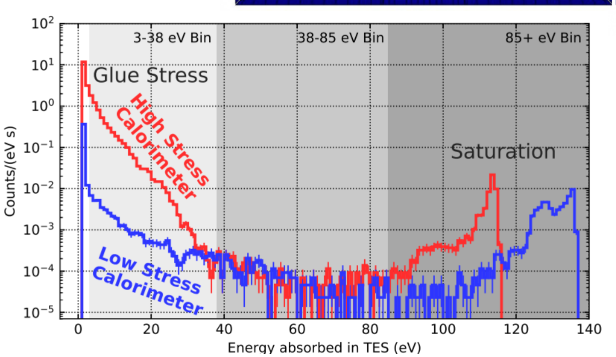
New technologies

MINER:

- Based on iZIP cryogenic detector for SuperCDMS: Si, Ge, Al_2O_3.
- New hybrid HV detectors for ER/NR detection, 100 eV thr.
- Background from stress relaxation.
- Possible deployment in HFIR.

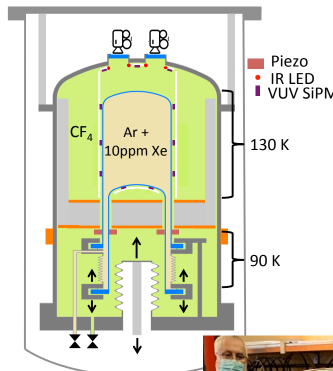






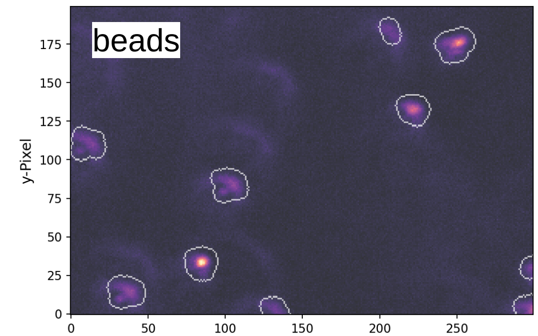
Scintillating Bubble Chamber:

- 10 kg LAr Bubble Chamber.
- Calibrations, 100 eV_{nr} threshold.
- Insensitive to ER.
- Possible deployment in ININ or Laguna Verde reactors.



Paleoccene:

- Colour centre passive detectors.
- Identification in LiF using light sheet microscope.



+ CEνNS for SN detection in LZ and XENONnT
+ CEνNS via ^{12}C recoils in LS in JUNO
+ NR imaging in Ar TPC in LArCADe
+ ...

Summary

- CEνNS is a very active field, with many developments and new/improved techniques.
  - Lower thresholds.
  - Lower backgrounds.
  - Higher fluxes.
  - Higher masses.
- COHERENT is leading the field of CEνNS measurements.
- Reactor experiments are getting closer to detection.
  - Expect some definitive measurements soon.
  - Quenching factor measurements are crucial for interpreting the data.
- We can look forward to exciting results.