Neutrino properties from short baseline reactor experiments

Igor Alekseev (NRC KI & LPI RAS)

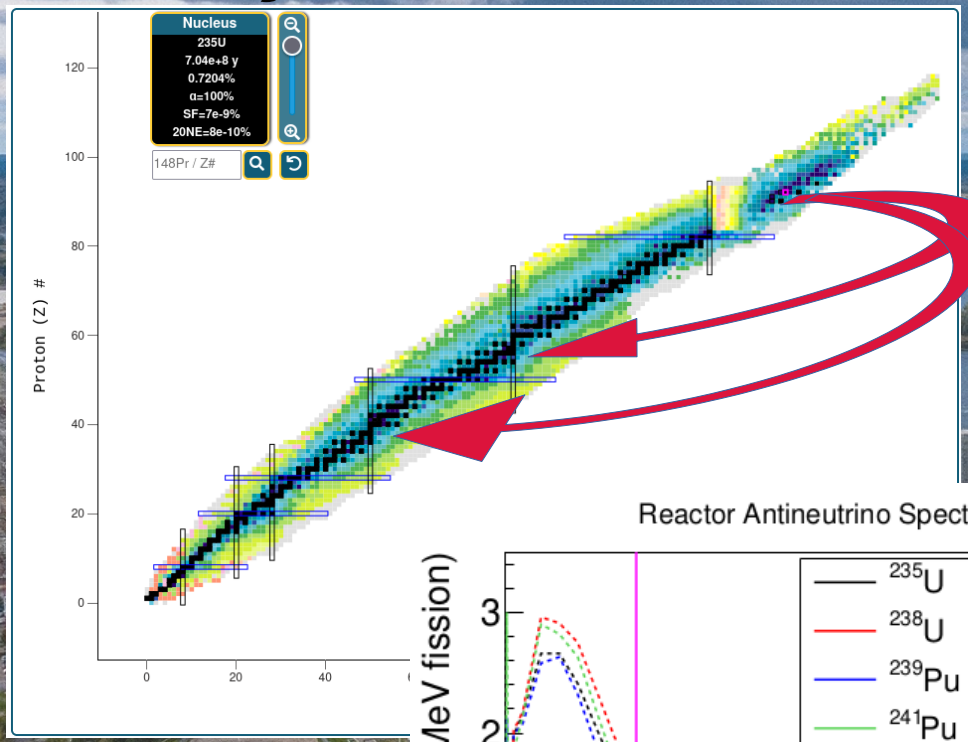


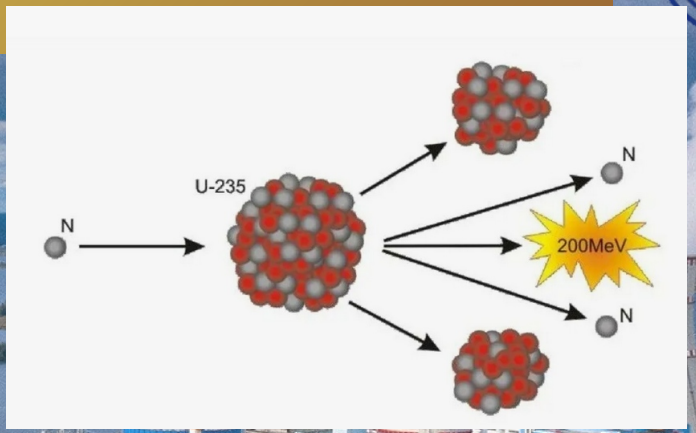
The 8th International Conference on Particle Physics and Astrophysics (ICPPA-2026)
Moscow, October 27-30, 2026

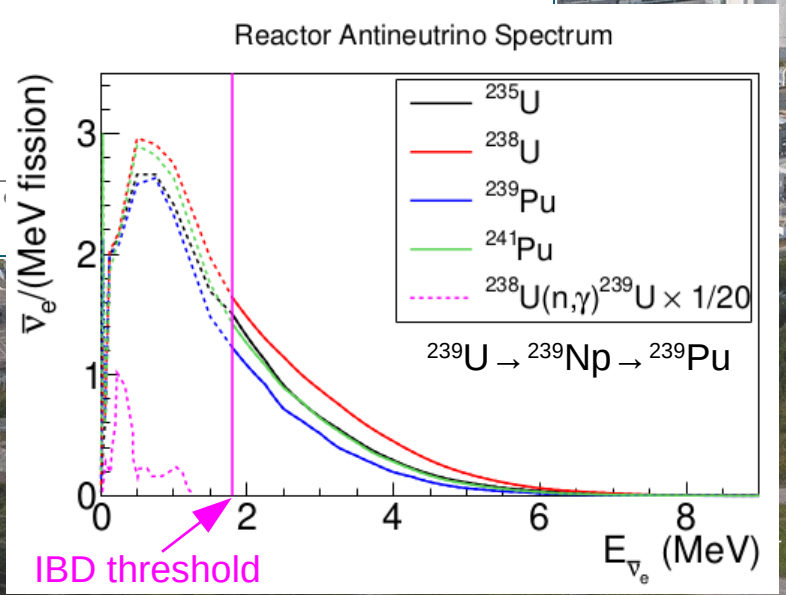
Outline

- ✔ Reactor antineutrinos
- ✔ Search for sterile neutrinos
- ✔ Search for Large Extra Dimensions
- ✔ Coherent elastic neutrino-nucleus scattering
- ✔ Search for neutrino magnetic moment
- ✔ Search for neutrino millicharge
- ✔ Reactor monitoring with antineutrinos

Reactors are very intense pure sources of antineutrinos







Fission produces neutron-rich nuclides and neutrons, which undergo a series of β-decays, producing **antineutrinos**

Reactors — are very pure sources of antineutrinos.

Average energy per fission ≈ **200 MeV**

==> 1 GW ≈ **$3 \cdot 10^{19}$** fissions / s

1 fission ≈ **6** antineutrinos

1 GW_{th} ≈ **$2 \cdot 10^{20}$** antineutrino / s

Neutrino flux @ **10 m** from the reactor core ≈ **$1.6 \cdot 10^{13}$ $cm^{-2}s^{-1}GW_{th}^{-1}$**

Neutrino oscillations are already well established and measured with a percent level precision:

$|\Delta m^2_{31}| = (2.455 \pm 0.028) \cdot 10^{-3}\ eV^2$ ==> L/E ~ 500 km/GeV (m/MeV)

$\Delta m^2_{12} = (7.53 \pm 0.18) \cdot 10^{-5}\ eV^2$ ==> L/E ~ $1.6 \cdot 10^4$ km/GeV (m/MeV)

Number of neutrino flavors in SM is limited from Z-width measurements 2.9963 ± 0.0074

There are several indications of oscillations at short distances with L/E ~ 1 km/GeV (m/MeV). One of the explanations lays in introduction of the 4th neutrino flavor – "sterile", which is revealed only in oscillations. The idea of sterile neutrinos is very old (Pontekorovo 1958): S. M. Bilenky and S. T. Petcov, **Rev. Mod. Phys. 59, 671 (1987)**

Appearance anomaly – when electron neutrinos appear in the beam of primarily muon neutrinos. LSND + MiniBooNE – **6.1σ** combined result. **Phys.Rev.Lett. 121, 221801 (2018)**

Disfavored by MicroBooNE measurements – **Nature 648 64-69 (2025).**

JSNS² 2022 and 2024 runs (1.95×10^{22} POT): Observation : 8 events, Bkg. Only : 6.1±1.0, Bkg+LSND : 8.9 ± 1.6. 10 times more data expected. **Dongha Lee @ Neutrino 2026**

Gallium anomaly (GA) – a deficit of electron neutrinos from a neutrino source measured with gallium using reaction $\nu_e + {}^{71}Ga \rightarrow {}^{71}Ge + e^-$. GALLEX+SAGE+BEST – **4.6σ** combined result.

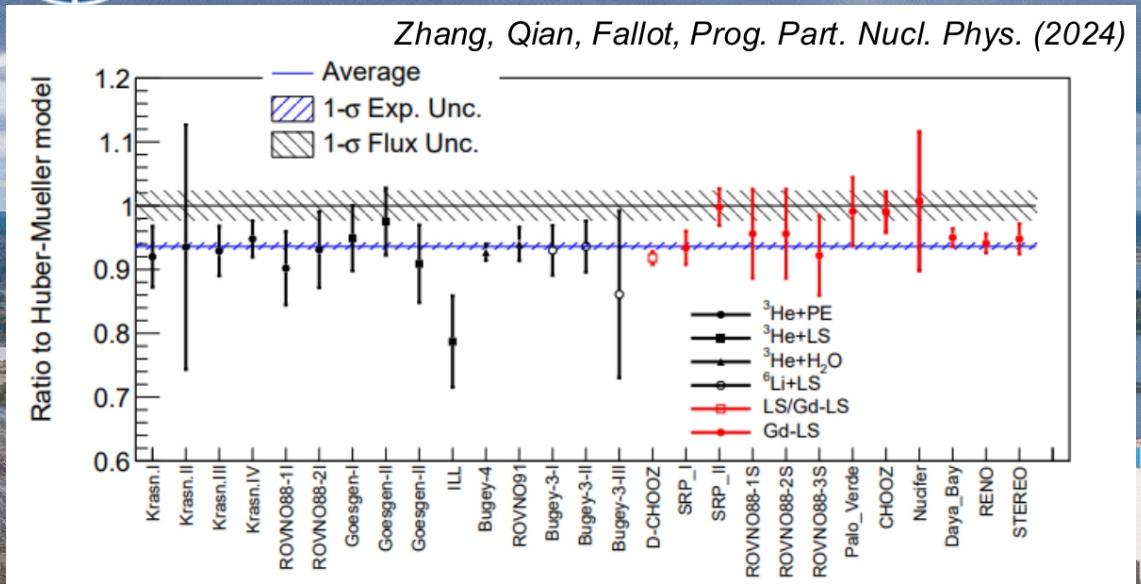
Phys.Rev.Lett. 128 (2022) 232501; Phys.Rev.C 105 (2022) 065502

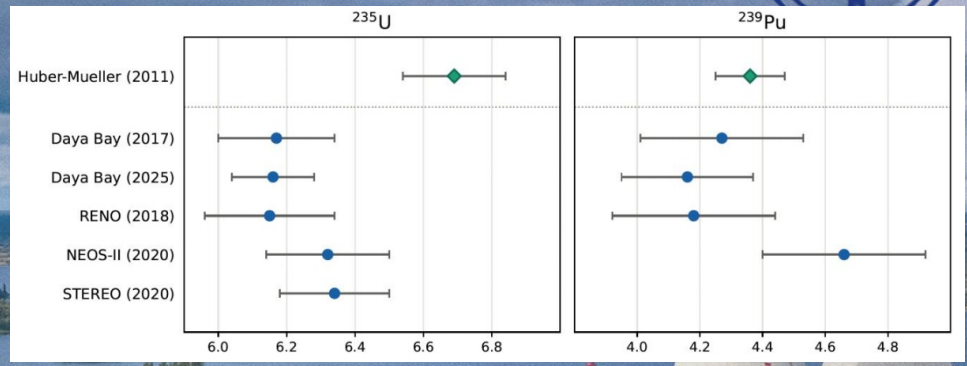
GA is the only anomaly where all experiments performed so far observe it.

Giunti et al.: arXiv:2507.13103v4 [hep-ph] 👍, arXiv:2512.20560v4 [hep-ph] 👎

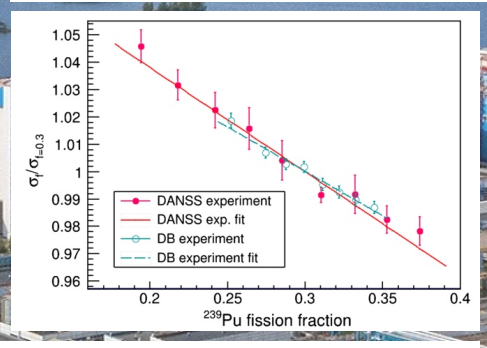
Reactor antineutrino anomaly (RAA) – deficit of electron antineutrinos from reactors.

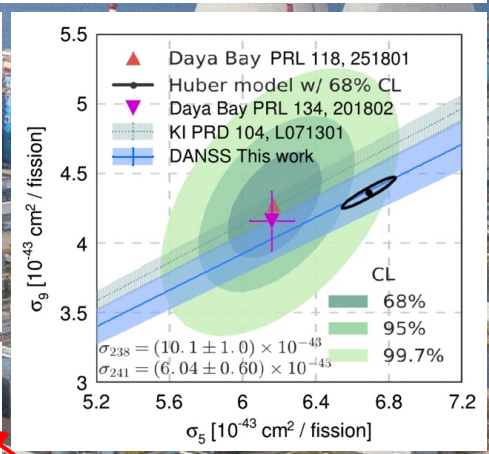
G. Mention et al. **Phys.Rev. D 83, 073006 (2011) –** deficit of 5.7% (2.5σ) in combined analysis of existing reactor data.



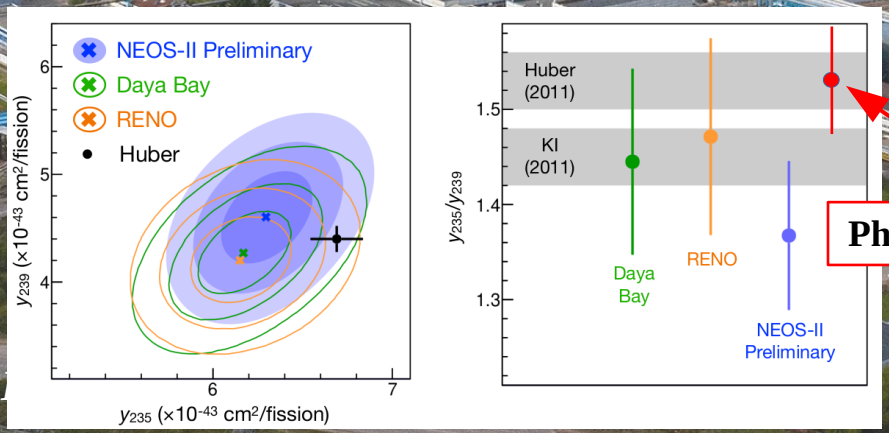


$$\bar{R} = 0.936^{+0.024}_{-0.023} \approx 0.936 \pm 0.005\ (\text{exp.}) \pm 0.023\ (\text{model})$$





Reactor spectra at ICPPA 2026:
V. Zaitsev, poster session
S. Ingerman, poster session
P. Sushkova, poster session
I. Zhutikov, poster session
V. Sinev, 28.10 16:50 Hall 4
V. Vakulenko, 28.10 17:05 Hall 4

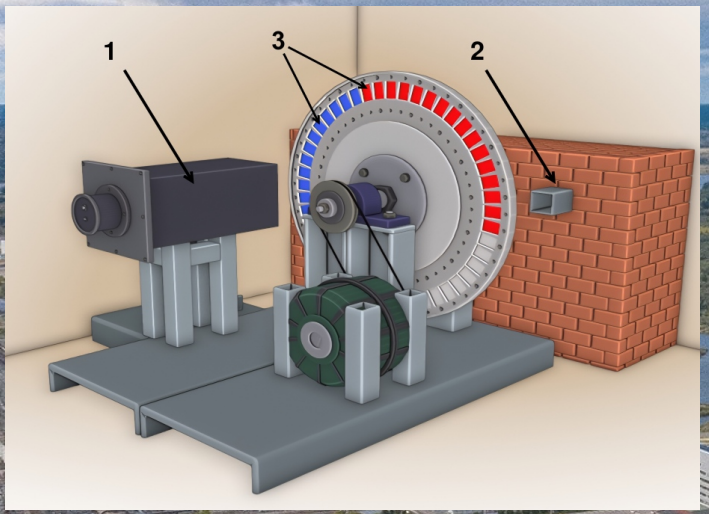


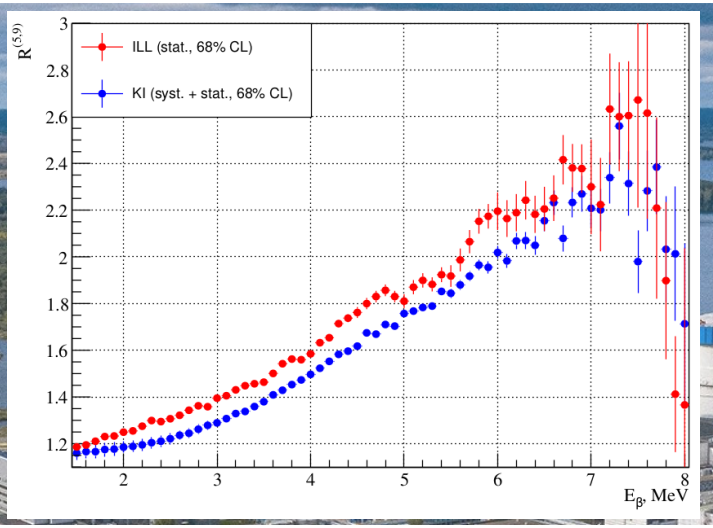
DANSS: 1.529±0.057

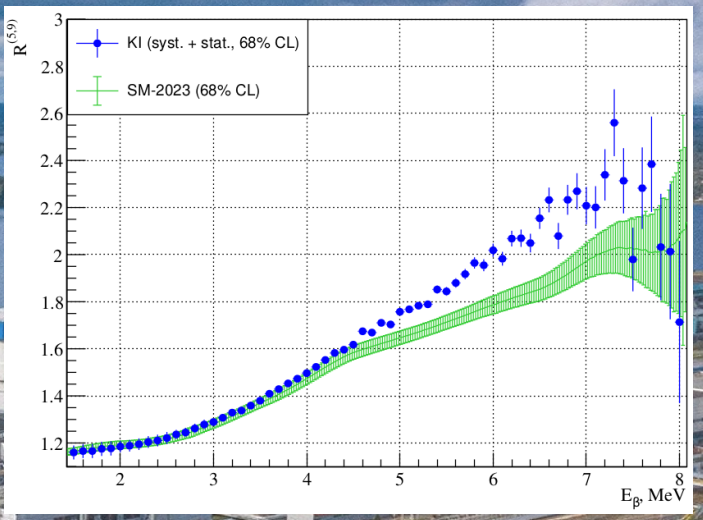
Phys.Rev. D 112, 112005 (2025)

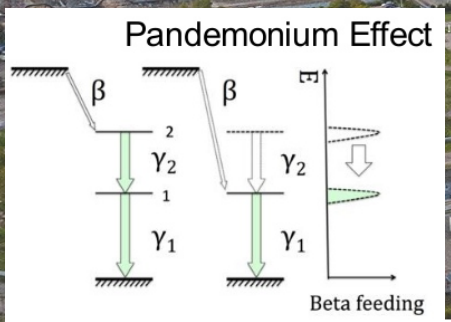
HM – conversion model, based on 40 years old ILL data. There are hints that in these works normalization of neutron flux for ^{235}U measurements was based on wrong $^{207}Pb(n,\gamma)$ cross section.

New measurements by KI group repeat the experiment done a few years ago:
JETP Letters 124, 164–169 (2026)









Phys. Lett. B 71, 307 (1977)

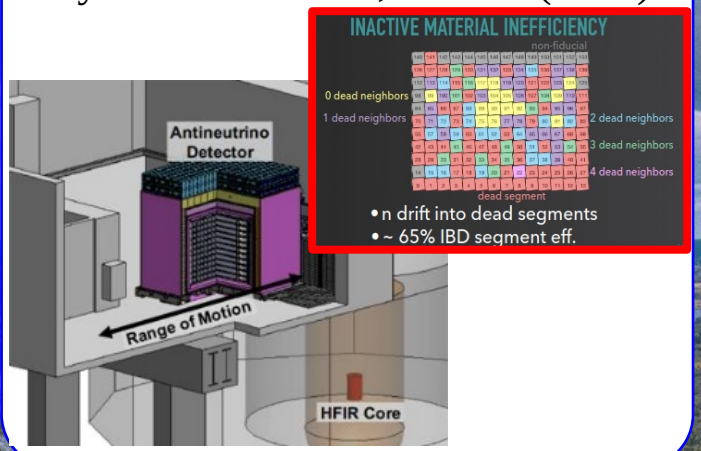
KI to ILL difference in 2-7 MeV electron energy range (6.9±0.3)%
Good agreement with BESTIOLE-2023 (**PRC 108 (2023) 055501**) summation model till 4.5 MeV

Total Absorption Gamma-ray Spectroscopy (TAGS) to improve summation models
Two ongoing TAGS campaigns (in Europe and in US)

PROSPECT — HFIR (HEU)

85 MW, 7-12m, segmented, ^{6}Li-LS

Phys. Rev. Lett. 134, 151802 (2025)



Neutrino4 — SM-3 (HEU)

90 MW, 6-12m, movable, Gd-LS

Phys. Rev. D 104, 032003 (2021)



DANSS — Kalininskaya NPP (LEU)

3.1 GW, 10.9-12.9m, movable, Gd-PS

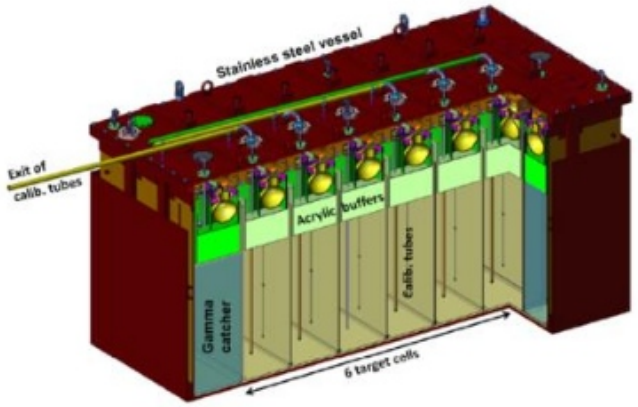
Phys. of Atomic Nucl. 88, 406 (2025)



STEREO — ILL (HEU)

58 MW, 9-11m, 6-cell, Gd-LS

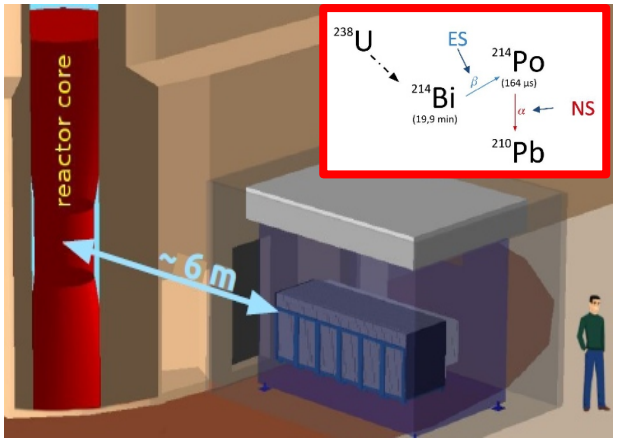
Nature 613, 257 (2023)



SoLid — BR2 (HEU)

50-80 MW, 6-9m, ^{6}LiF:ZnS + PVT

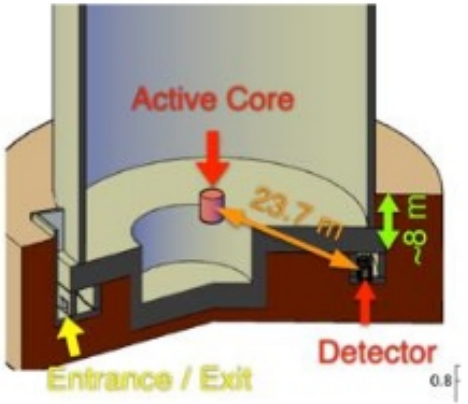
Phys. Rev. D 111, 072005 (2025)



NEOS — Hanbit (LEU)

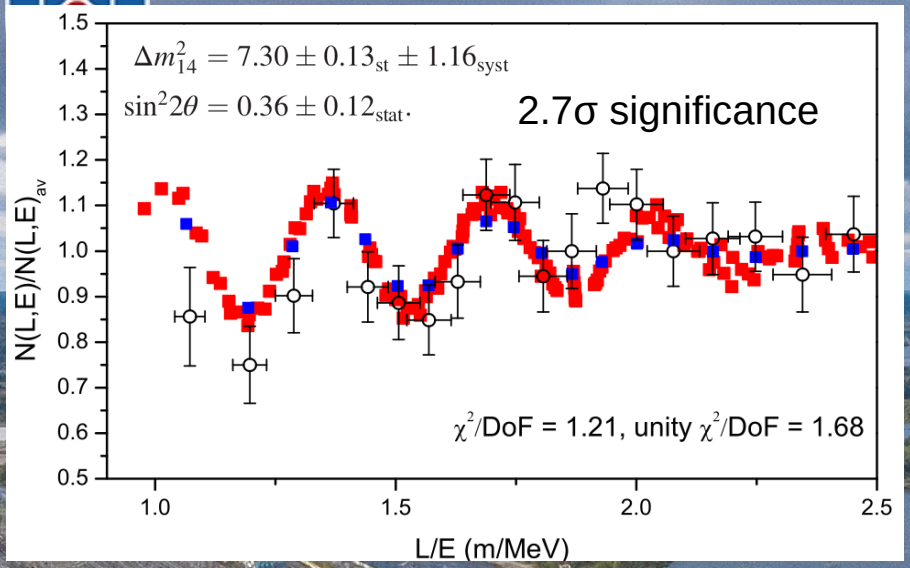
2.8 GW, 23.7m, RENO norm., Gd-LS

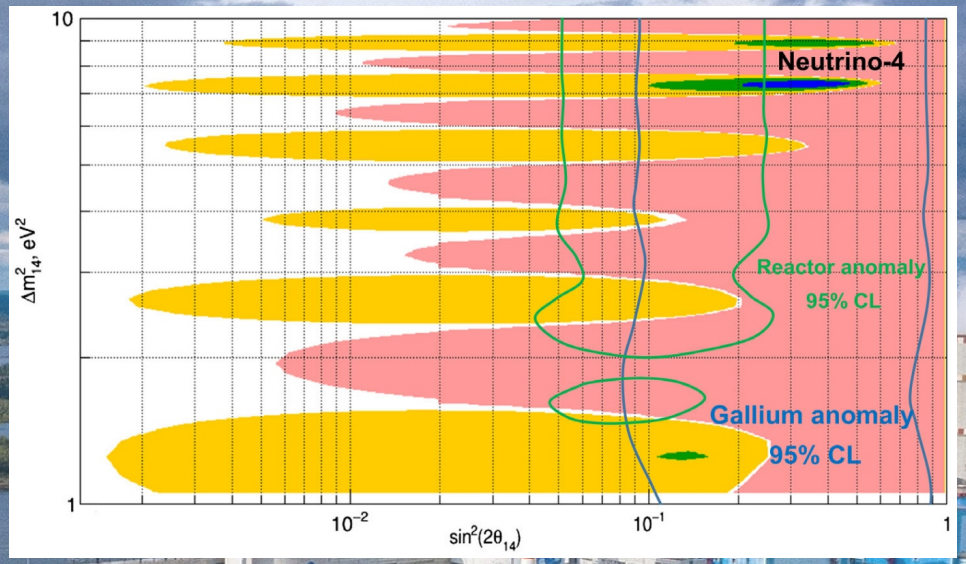
Phys. Rev. D 105, L111101 (2022)



Neutrino-4 – the only positive indication

Phys. Rev. D 104, 032003 (2021)

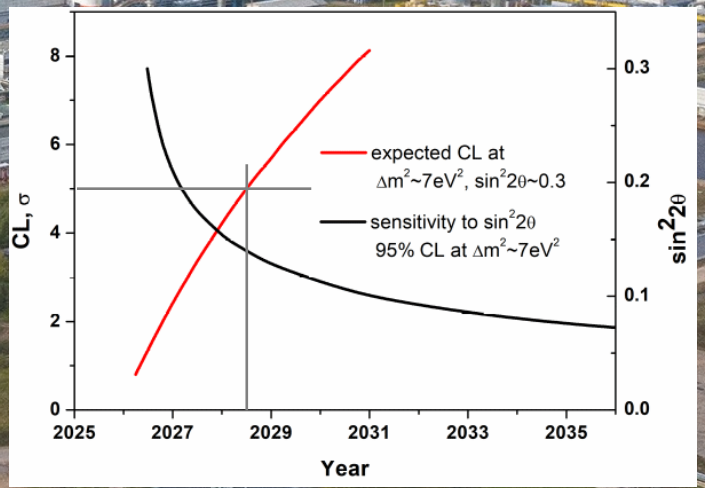




New detector (another lab @ SM-3) to start data taking this December

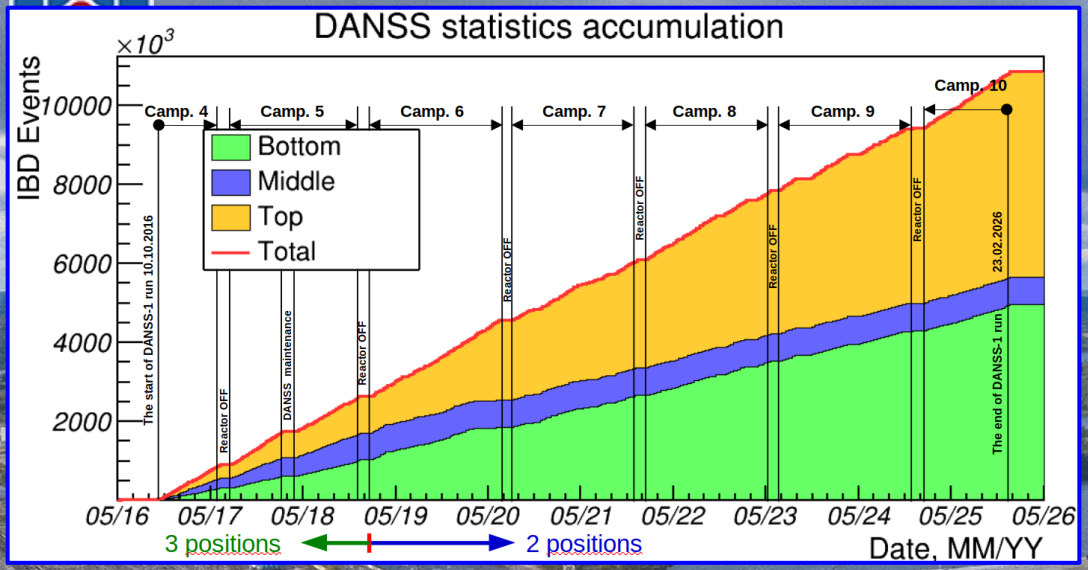


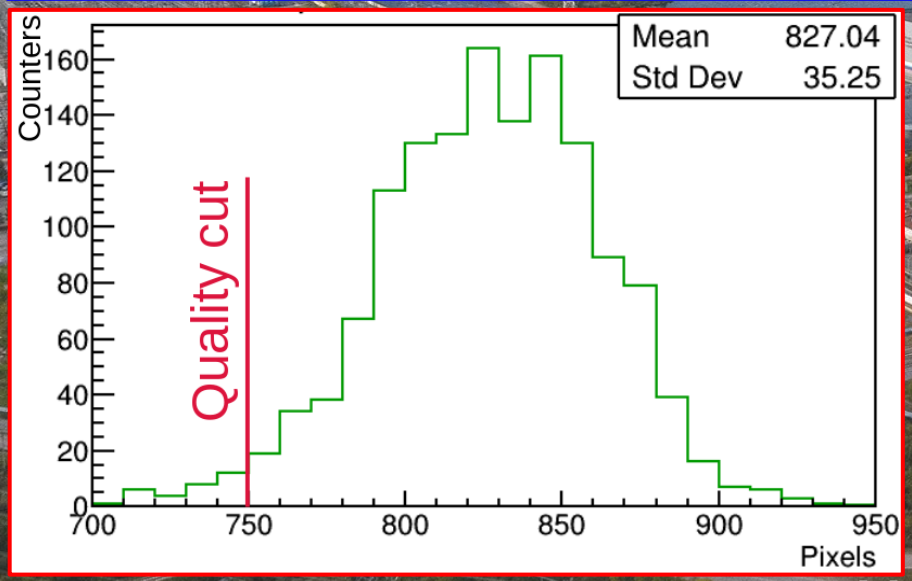
5 σ confirmation of Neutrino-4 best point by mid-2028

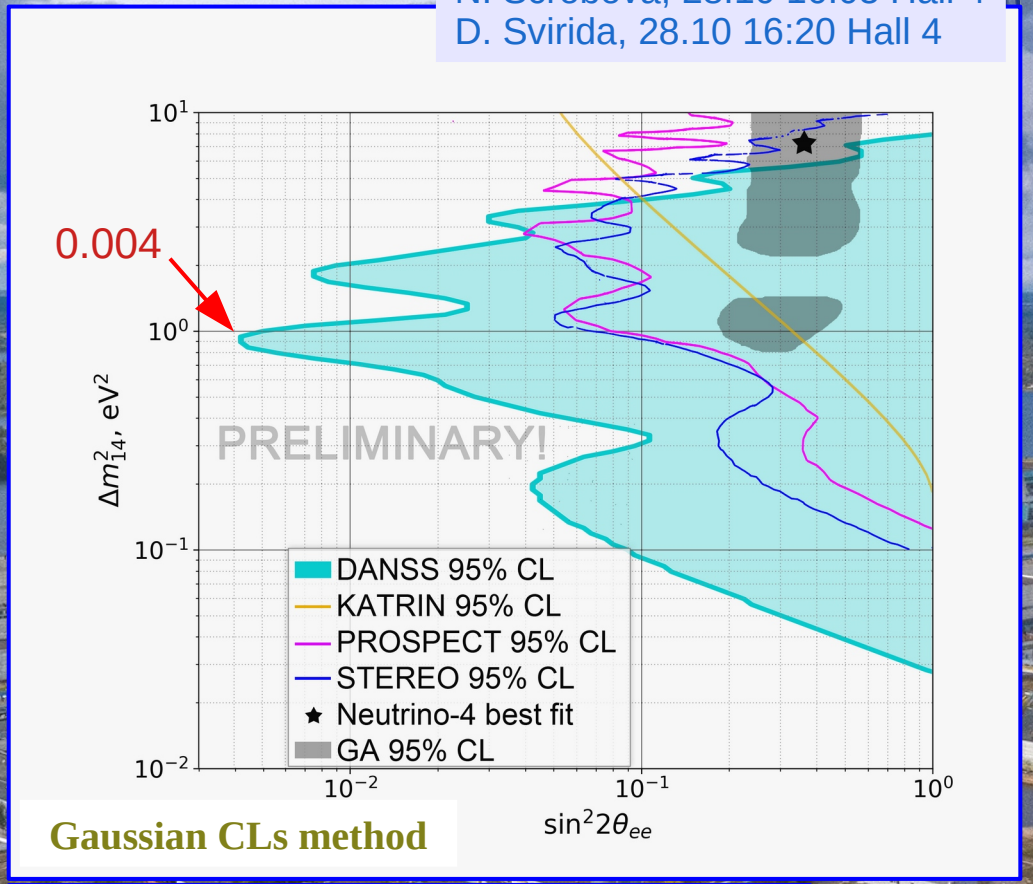


DANSS-I run completed – 10.9 M IBD events

D. Ilyushkin, poster session
N. Scrobova, 28.10 16:05 Hall 4
D. Svirida, 28.10 16:20 Hall 4







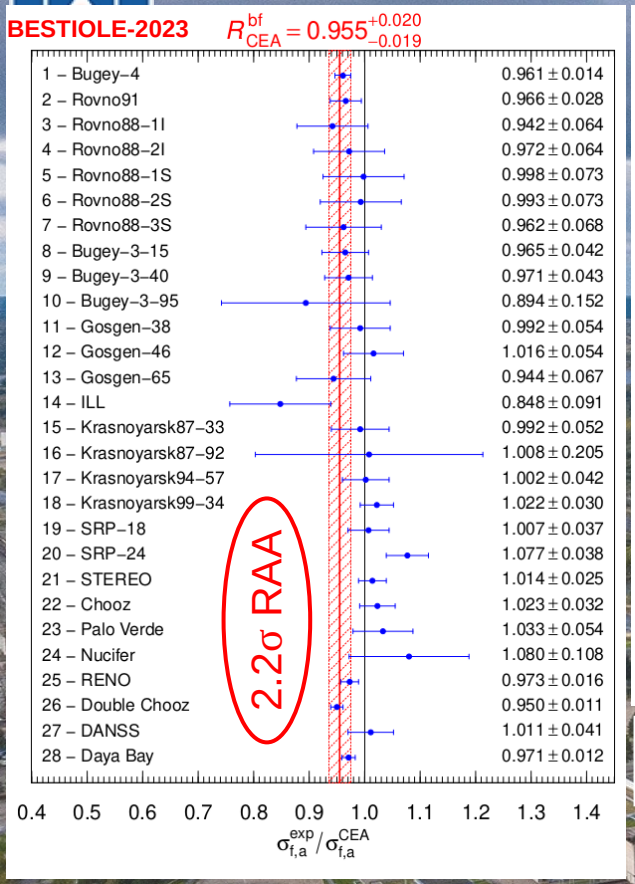
Gaussian CLs method

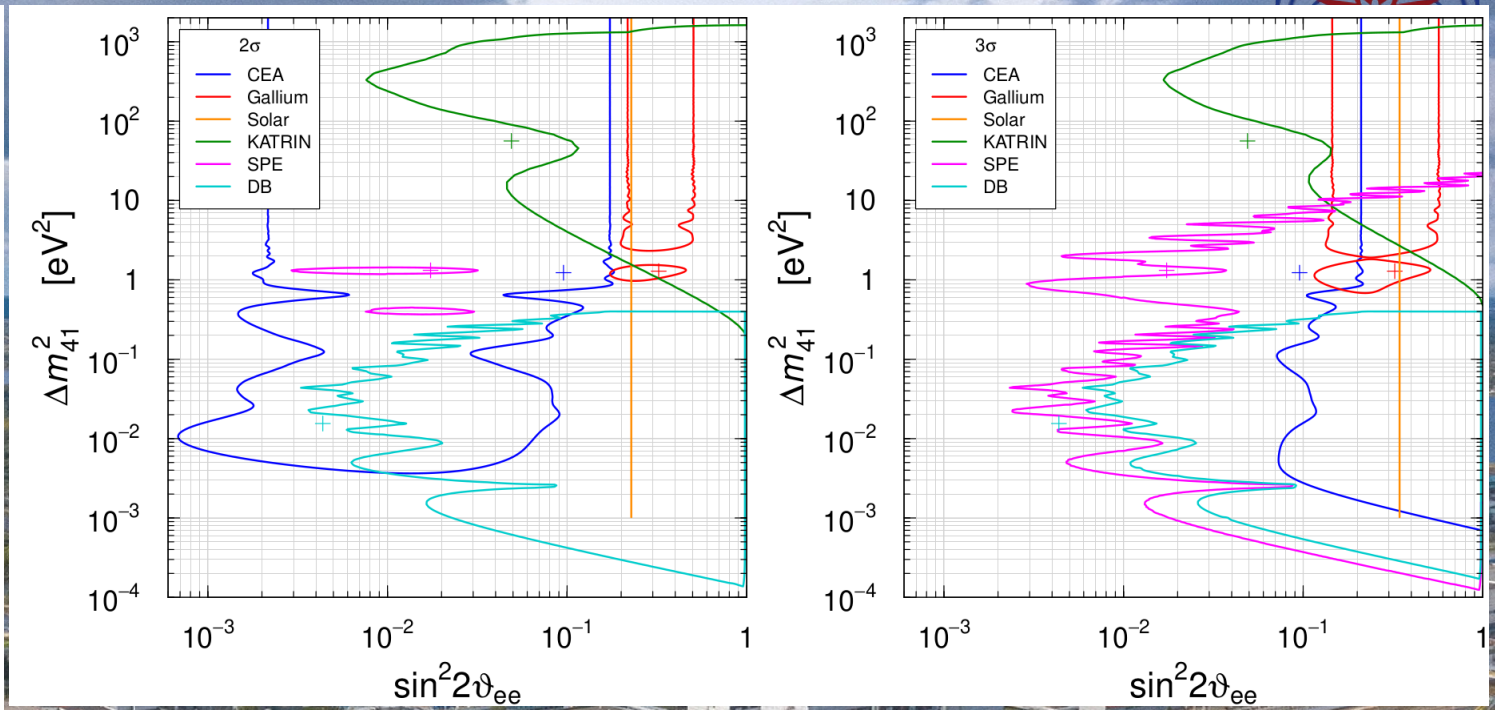
DANSS-I result with whole statistics

DANSS-II 1456 counters are manufactured and tested. Light yield > 200 ph.c./MeV. Detector assembly will start early next year.

Revival of the Reactor Antineutrino Anomaly

C. Giunti et al. **arXiv:2605.10353 [hep-ph]**





CEA = BESTIOLE-2023 summation model
SPE = DANSS+(NEOS+RENO)+PROSPECT+STEREO

Common fit in 3+1 ν_e-ν_s model of all data with 3.8 times enlarged GA uncertainties has only 1.3σ tension.

Recent experiments show no evidence of sterile neutrinos.
Nevertheless, this is still one of the statistically strongest indications of the New Physics.

Large Extra Dimensions (LED)

- Another way to explain RAA и GA
- Two parameters: size of the extra dimension a and mass of the lightest neutrino m_0

P. A. N. Machado et al. Phys. Rev. D 84, 013003

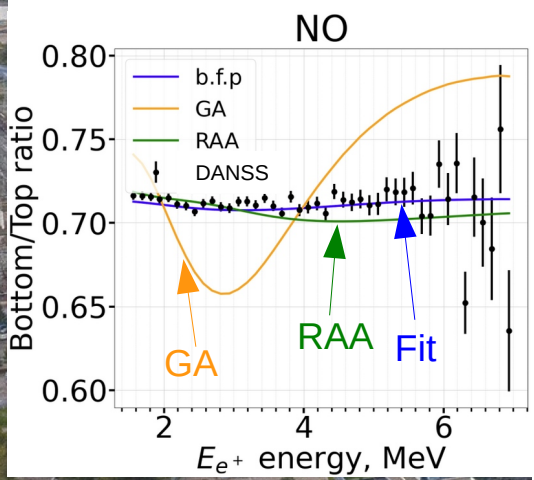
Survival amplitude of neutrino mass m_i:

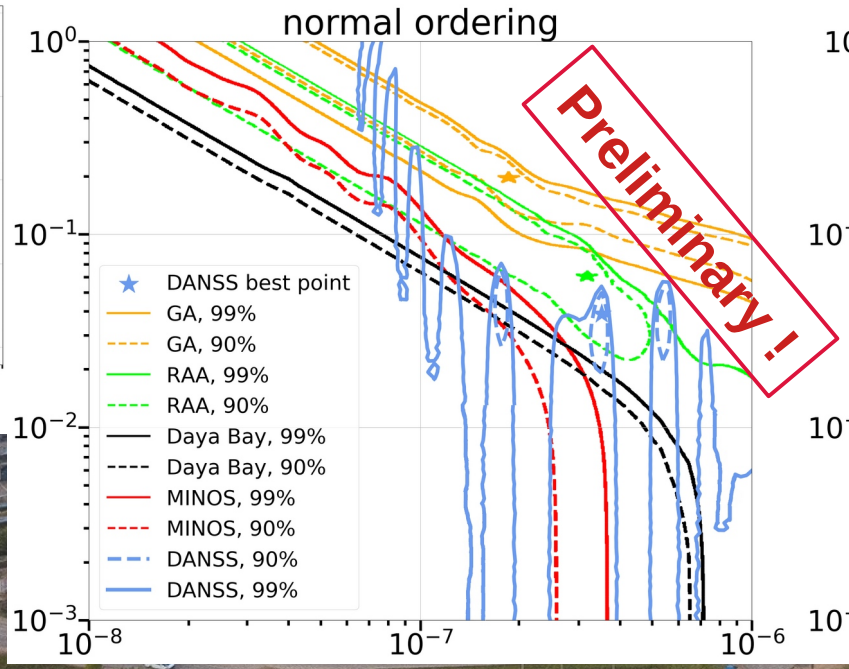
$$A_i = \left(1 - \frac{\pi^2}{6} m_i^2 a^2\right)^2 \exp\left(i \frac{m_i^2 L}{2E}\right) + 2 m_i^2 a^2 \exp\left(i \frac{m_i^2 L}{E}\right) \sum \frac{\exp\left(i \frac{n^2 L}{2Ea^2}\right)}{n^2}, ma \ll 1$$

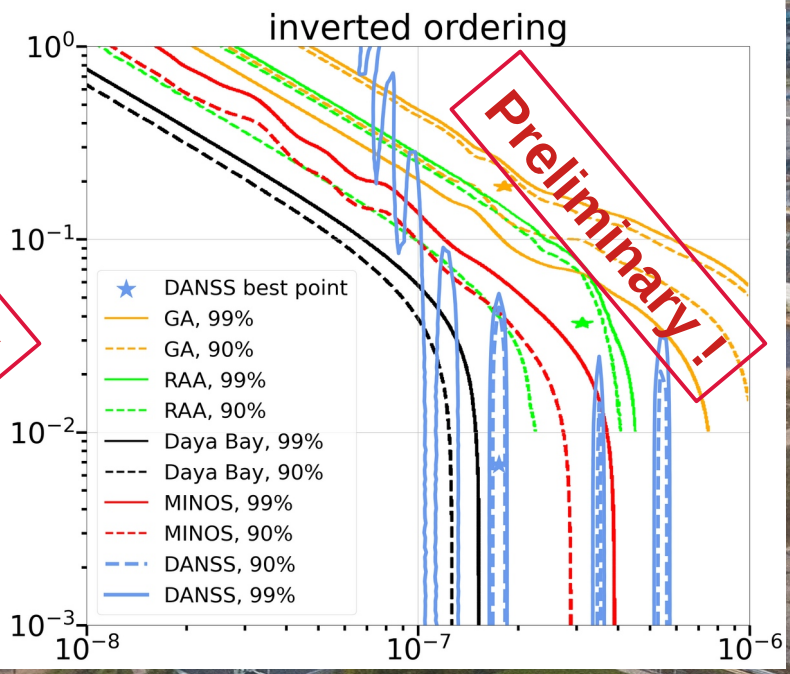
Survival probability of ν_e: $P_{ee} = \left| \sum |U_{ei}|^2 A_i \right|^2$

$|U_{e1}| \sim 0.8$
$|U_{e2}| \sim 0.5$
$|U_{e3}| \sim 0.1$

D.V. Forero et al. Phys.Rev.D 106 (2022) 3, 035027



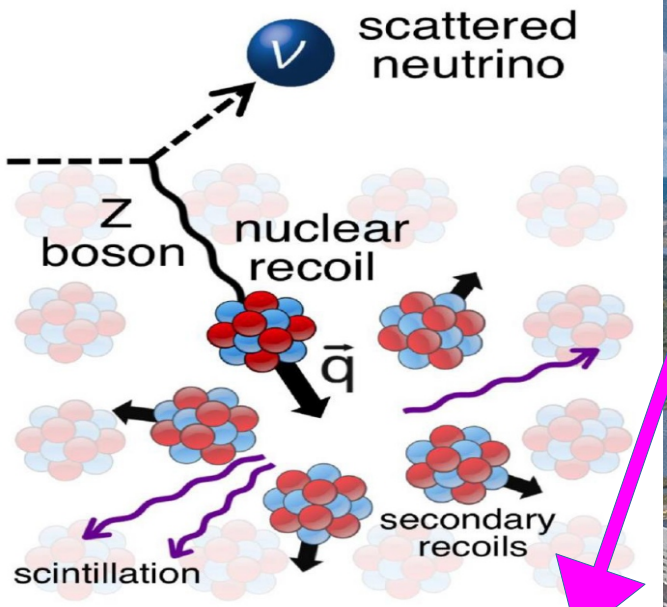


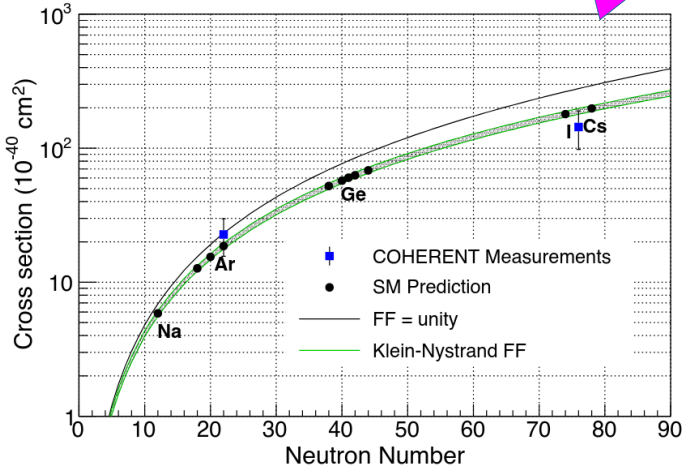


- GA and RAA best points exclusion significance > 5σ.
- DANSS best points significance 2.5σ.

DANSS: JETP Letters 122 (2025) 1

Coherent elastic neutrino nucleus scattering (CEvNS)





- Standard model weak interaction, flavor blind, **no energy threshold**
- Predicted in 1974:
  - V.B. Kopeliovich and L.L. Frankfurt, **JETP Lett. 19 4 (1974) 236**
  - D. Freedman, **Phys.Rev. D 9 (1974) 1389**
- First observed by COHERENT: **Science 357, 1123, 2017**

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

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

- ✔ Total cross section ~ N² (N — number of neutrons)
- ✔ Dominating process at low neutrino energies
- ✔ No threshold unlike IBD
- ✗ Tiny recoiled energy

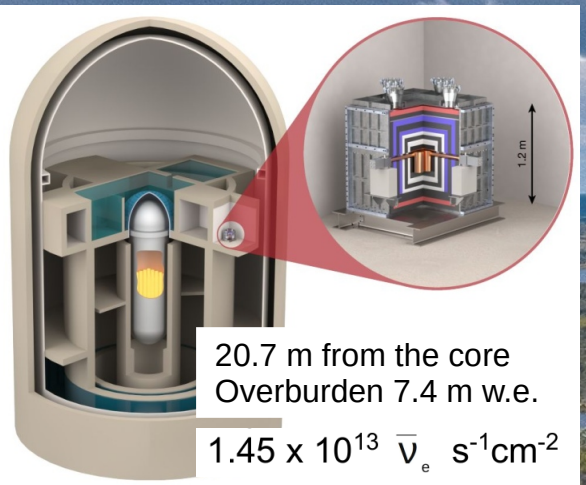
COvUS+

4 p-type point contact HPGe:

- Total active mass: 3.74 kg (7.9 kg).
- Pulser resolution (FWHM) ~50eVee.
- Liquid cooling system for cryocooler
- Radiopure components.

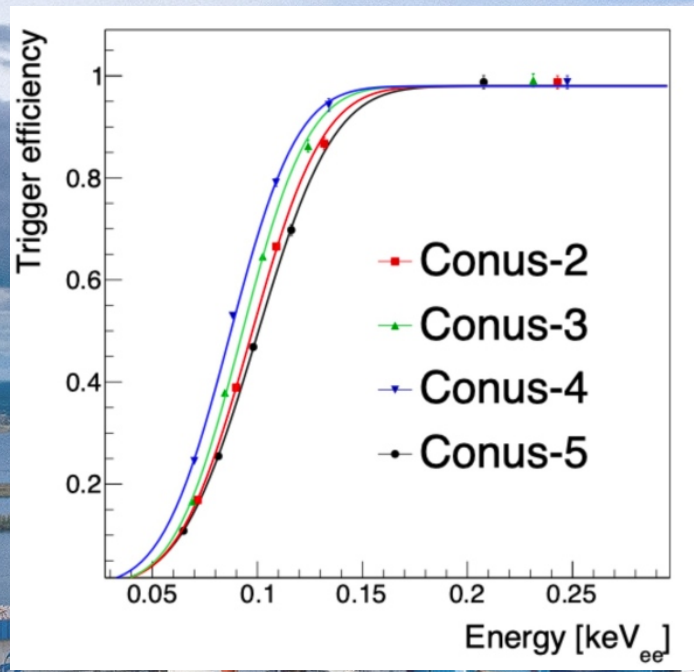
Active + passive shielding:

- Low ^{210}Pb lead.
- Borated and pure PE.
- Two layers active μ-veto (plastic scintillator).
- Flushing against airborne radon.

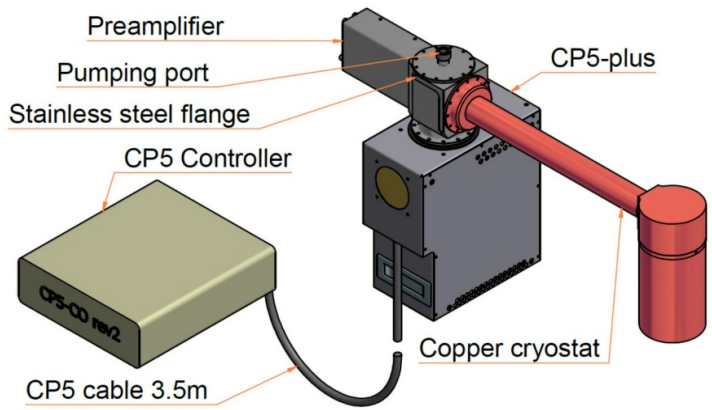


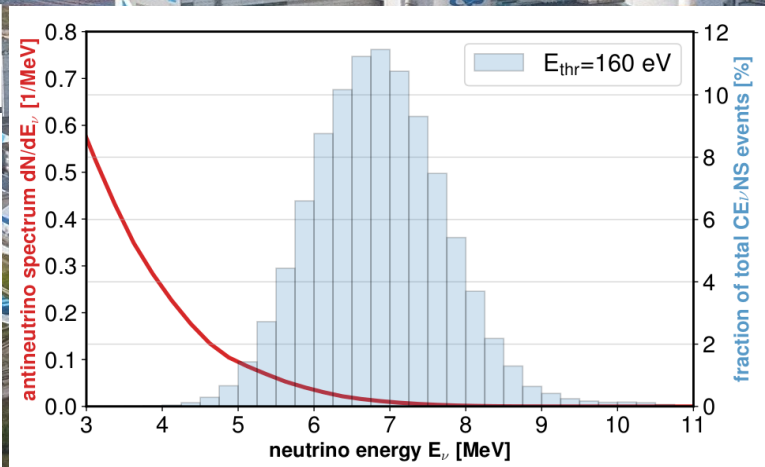
20.7 m from the core
Overburden 7.4 m w.e.

1.45 x 10^{13} $\bar{\nu}_e$ $s^{-1}cm^{-2}$



3.6 GW_{th} LEU reactor KKL power plant (Leibstadt, Switzerland)





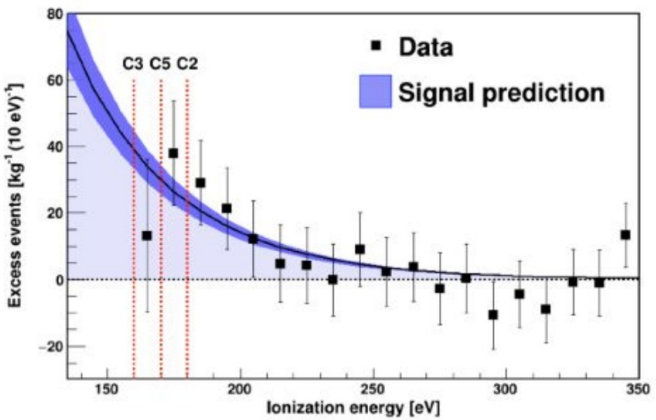
Detector	Threshold [eV_{ee}]	Predictetd CEvNS counts
C5	170	116 (+20/-18)
C2	180	96 (+16/-14)
C3	160	135 (+23/-20)
COMBINED	-	345 (+34/-30)

Exposure: 327 (kg d) reactor on and 60 (kg d) reactor off

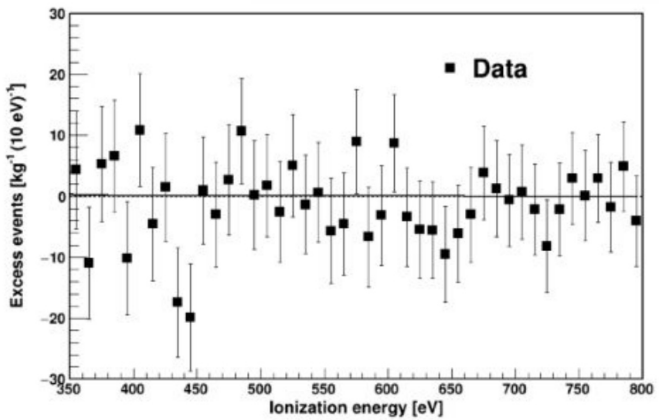
Signal events from combined fit 395±106

Data/SM prediction: 1.14±0.36

Excess below 350 eV_{ee} !!



No excess above 350 eV_{ee} !!



Detector	Threshold [eV_{ee}]	CEνNS counts fit	SM prediction
C5	170	117 +- 57	116 +- 20
C2	180	69 +- 47	96 +- 16
C3	160	186 +- 66	135 +- 23
Combined		395 ± 106	347 ± 34

Experiment	Target	Source	Neutrino energy	Flux [$cm^{-2}s^{-1}$]	Data [counts]	Data/ SM prediction	Significance of null hypothesis rejection
COHERENT	Cs	Accelerator	10 – 50 MeV	$5 * 10^7$	306^{+20}_{-20}	$0.90^{+0.14}_{-0.14}$	11.6 σ
COHERENT	Ar	Accelerator	10 – 50 MeV	$5 * 10^7$	140^{+40}_{-40}	$1.22^{+0.49}_{-0.49}$	3.5 σ
COHERENT	Ge	Accelerator	10 – 50 MeV	$5 * 10^7$	21^{+7}_{-6}	$0.59^{+0.26}_{-0.24}$	3.9 σ
XENONnT	Xe	Sun (^{8}B)	< 15 MeV	$5 * 10^6$	11^{+4}_{-2}	$0.90^{+0.65}_{-0.67}$	2.73 σ
PandaX-4T	Xe	Sun (^{8}B)	< 15 MeV	$5 * 10^6$	4^{+1}_{-1}	$1.25^{+0.69}_{-0.69}$	2.64 σ
CONUS+	Ge	Reactor	< 10 MeV	$1.5 * 10^{13}$	395^{+106}_{-106}	1.14^{+036}_{-036}	3.7 σ

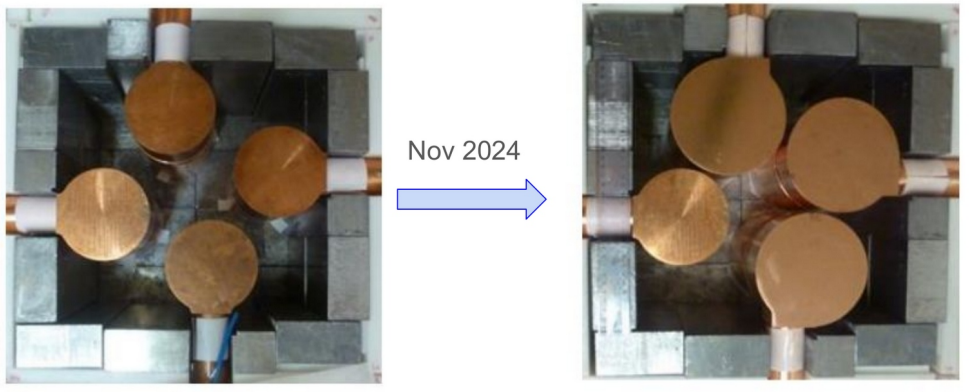
✔ **Null hypothesis rejected at 3.7 σ**

✔ **First CEνNS detection at reactor**

Nature 643,(2025), 1229-1233

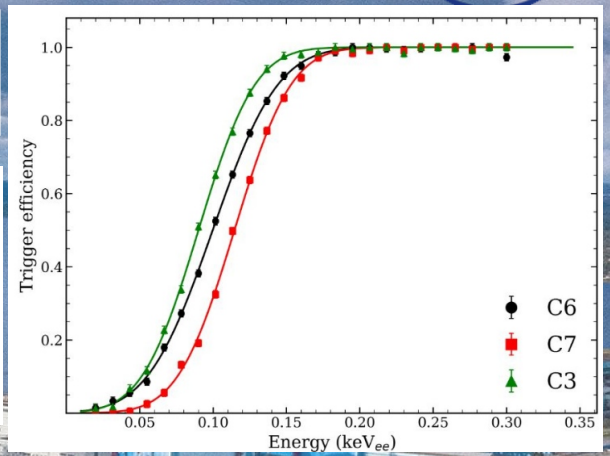
Run 2

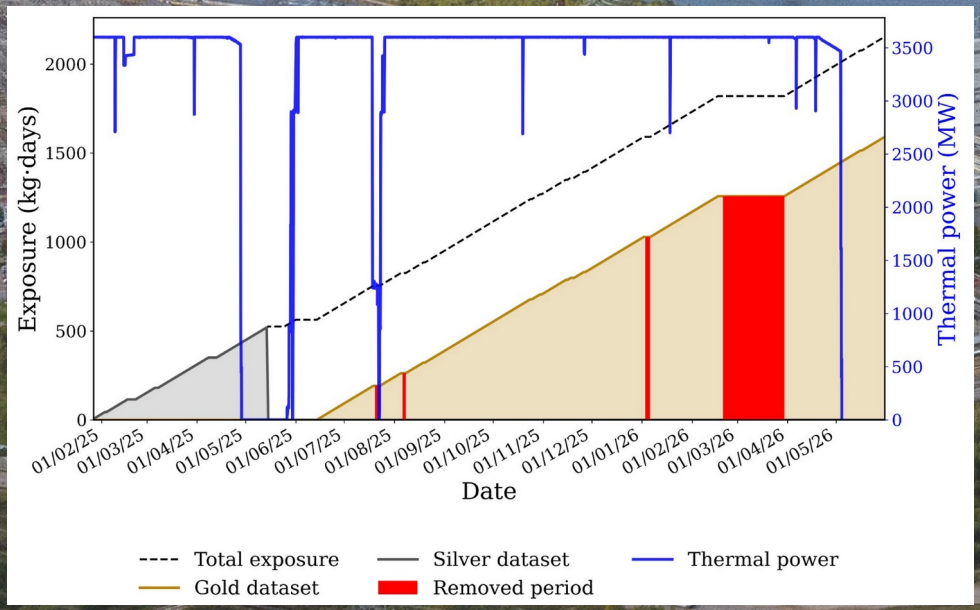
E.S. García @ Magnificent CEvNS-2026



3 detectors repalced with new 2.4 kg

Detector	Threshold [eV_{ee}]
C6	160
C3	170
C7	140





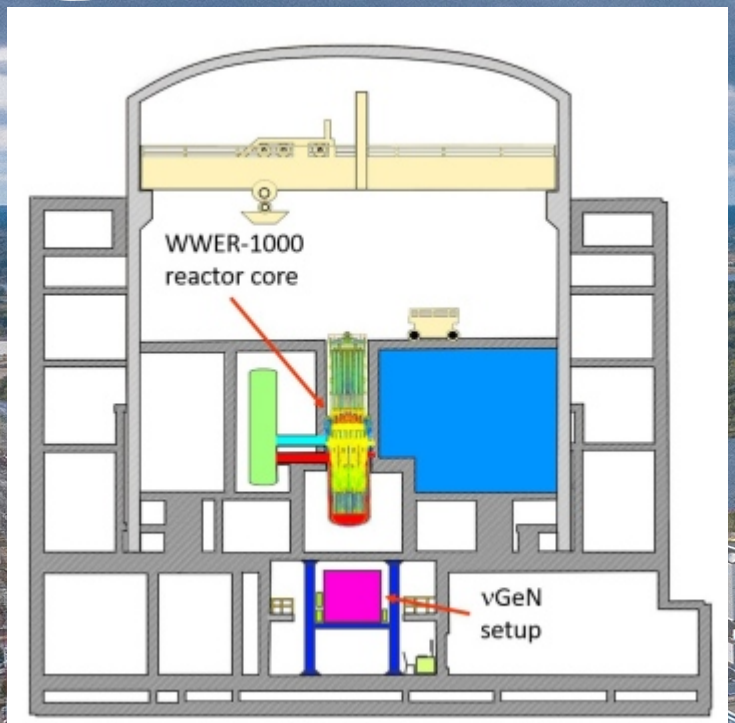
- Performance of new 2.4 kg detector better than previous generation.
- Run-2 exposure almost 4 times larger than Run-1. Very good stability.
- Mainly cosmic background events: reactor power uncorrelated!
- Expected significance for Run-2 measurement above 8 σ.
- Unblinding of CEvNS data-set ongoing. Stay tuned for new results coming soon!!

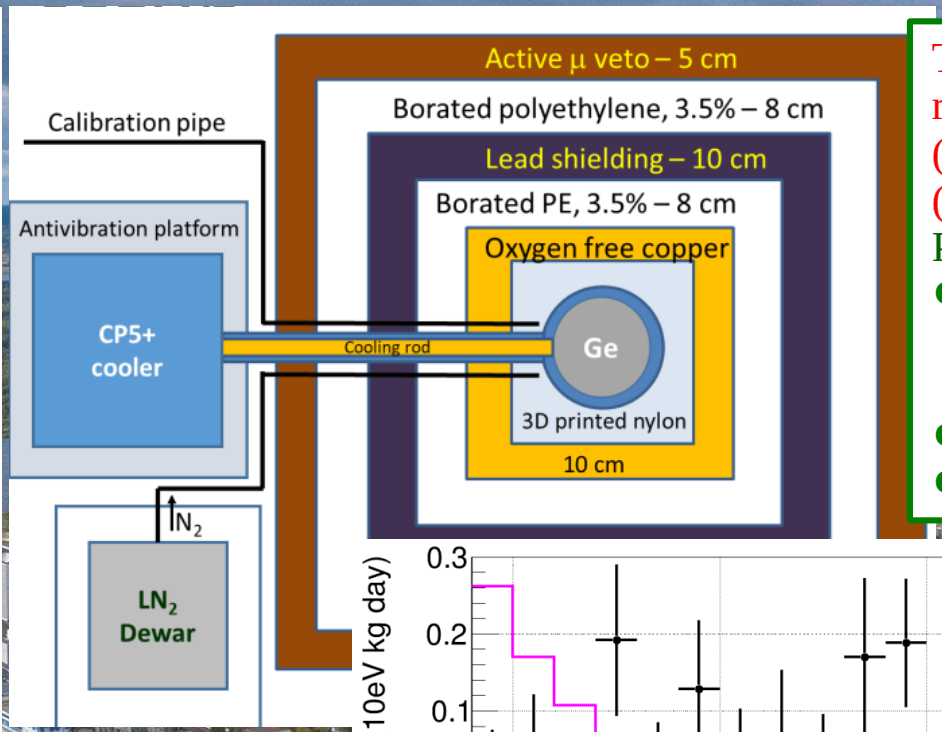
vGeN

3d reactor unit of Kalinin. NPP, 3.1 GW_{th}

Chin. Phys. C 49 053004 (2025)

B. Degtyarev, poster session
D. Ponomarev, 29.10 16:55 Hall 1
D. Sautner, 29.10 17:10 Hall 1



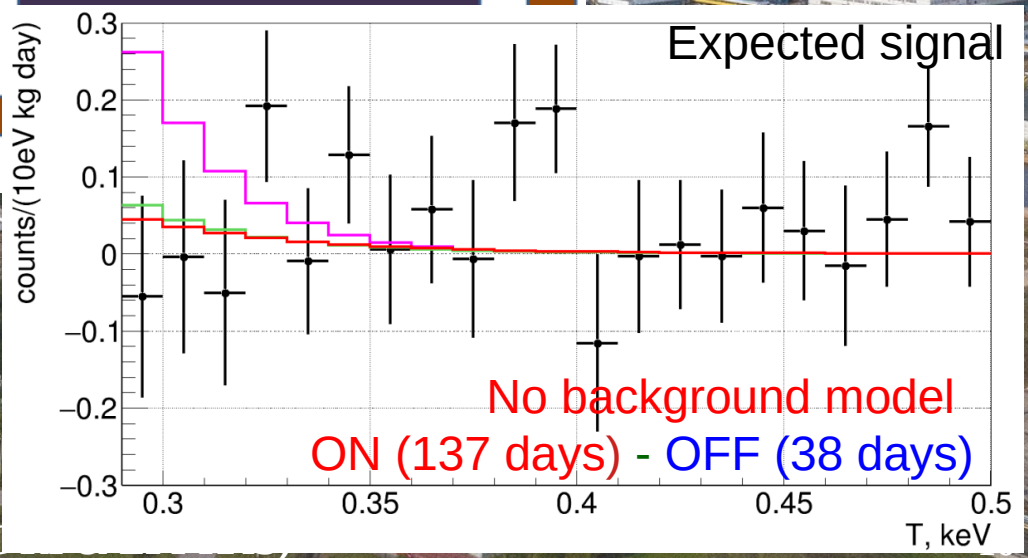


The limit on the CEνNS rate for the Lindhard (k=0.162) QF is **4.3**×SM (90% CL)

Plan:

- Use DAQ with WFD to lower the E_{th} to 200-240 eV
- Process more data
- Background model

- 1.4 kg p-type point contact HPGe
- 11.1 m to the core center, ~$4.4 \cdot 10^{13}$ ν $cm^{-2}s^{-1}$
- overburden ~ 50 m w.e.
- Total collected statistics > 2200 kg*day
- Threshold 290 eV



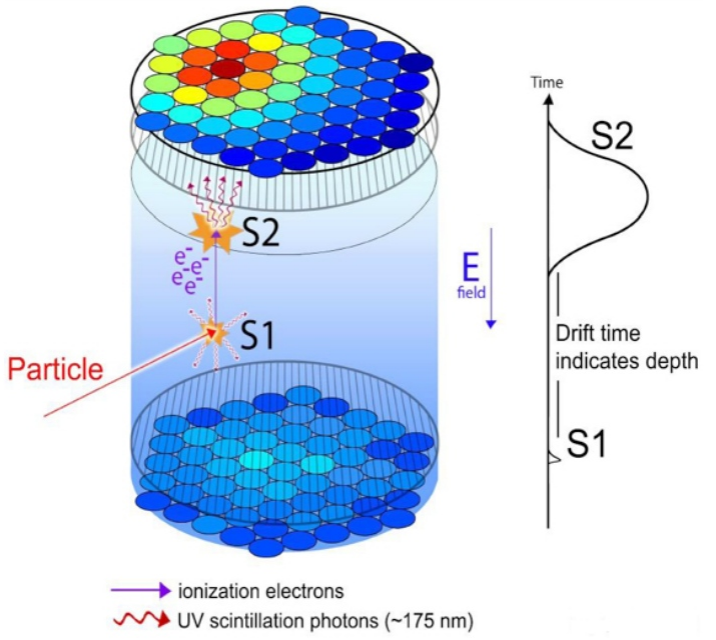
Igor Alekseev (NRC

RED
RUSSIAN EMISSION DETECTOR

4th reactor unit of Kalininskaya NPP, 3.1 GW_{th}

Two-phase emission detector with liquid xenon/argon

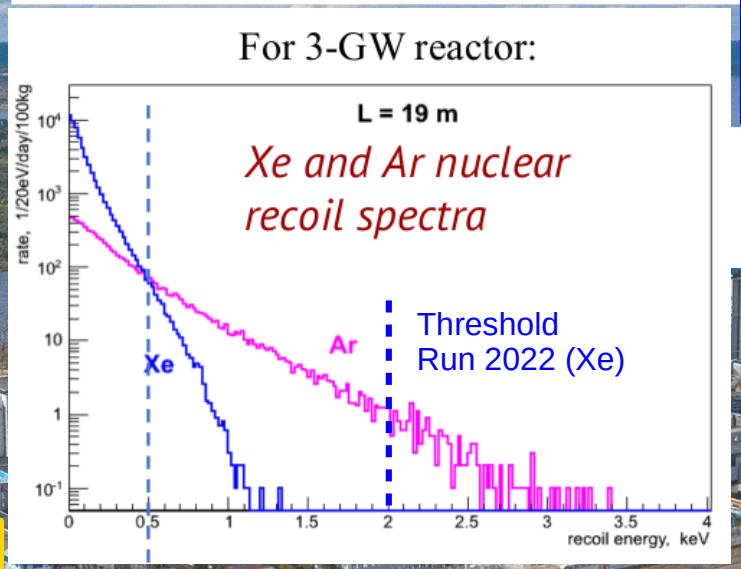
Run 2022:
T_{ON} = **2.63** days
T_{OFF} = **0.88** days



~200/100 kg LqXe/Ar (≈126/62 kg active volume)
19 m from the reactor core center
Sensitivity to single electrons

Phys.Rev. D 111 (2025) 072012

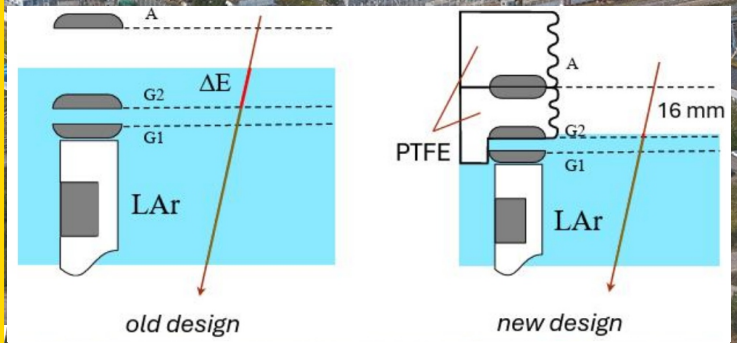
Threshold ≈4 ionization electrons, extraction efficiency 32.8 ± 2.8%
=> E_{th} ~ **2keVnr** (~0.2keVee) .



Run 2022 result in SM units:

sensitivity: 58^{+24}_{-15}, ***limit:*** 63^{+26}_{-16}





Suppression of muon signal and larger $U_{A\text{-}G2}$

Ar vs Xe:
- ✔ 100% extraction efficiency vs 33%
- ✔ ~ 3x recoil energy

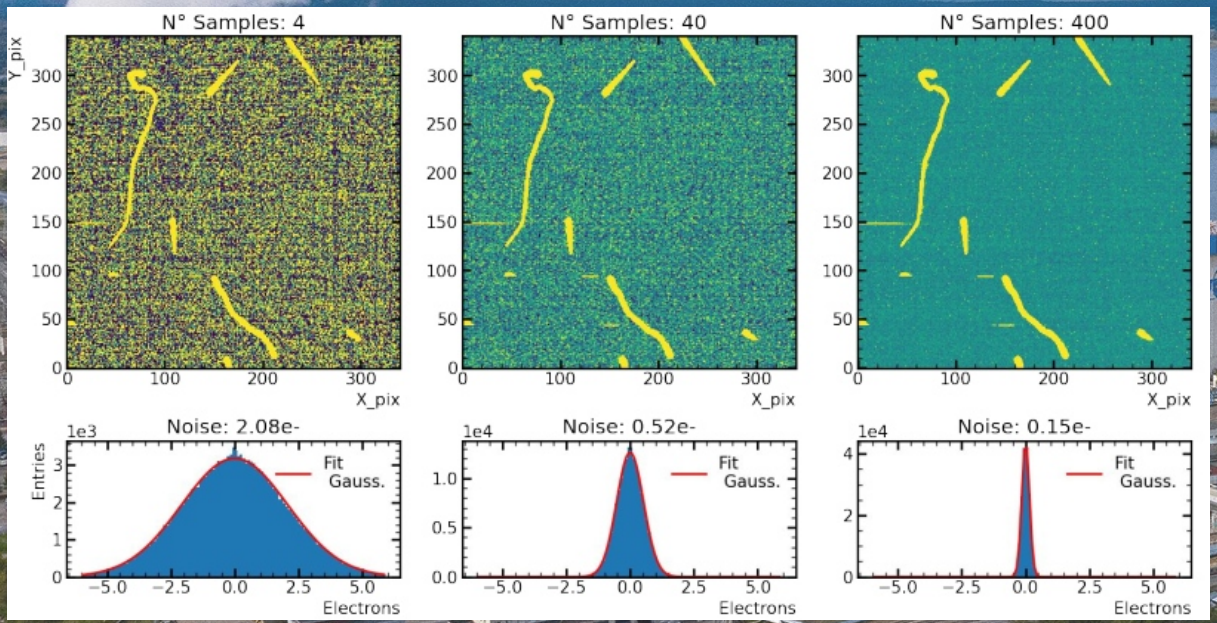
But:
- ✗ ~12x smaller cross section
- ✗ ^{39}Ar (β-decay) ~1 Bk/kg
- ✗ Lower boiling point and shorter wavelength

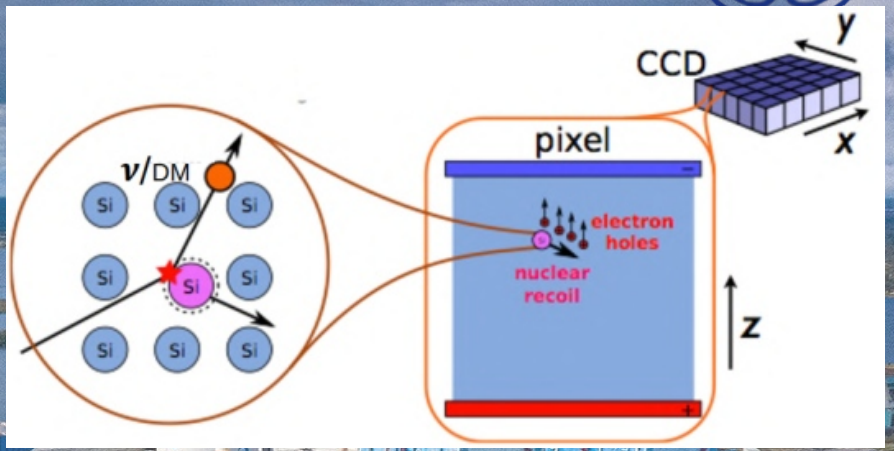
Running test at MEPhI to evaluate E_{th}

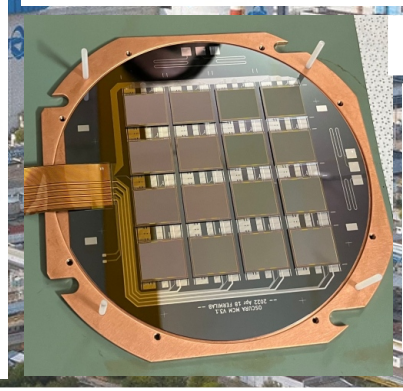
A. Bolozdynya, 28.10 17:00 Hall 3
A. Golovanov, 30.10 19:00 Hall 5

Skipper-CCD technology

- A floating gate amplifier allows multiple independent, uncorrelated samples of the pixel charge;
- Gaussian readout noise goes with $\sigma = \frac{\sigma_1}{\sqrt{N}}$ → **Single-electron resolution;**







Phys.Rev.D 113 (2026) 092017

243 days (**14.9** g-day) Reactor on, **57** days (**3.5** g-day) Reactor off
95% CL on observed CEvNS rate is **76**x the Standard Model predicted rate

- 30 m from the 3.95 GW_{th} Angra2 reactor in Angra, Brazil, antineutrino flux ≈7.8×10^{12} s^{-1} cm^{-2};
- 16 Skipper CCDs sensors on the same module;
- 1278x1058 pixels each 725 μm thick; total active mass: 8g;
- 15 eV threshold;
- Reactor-ON and OFF data have been collected (5k images) and are currently being analyzed.

Pedro Ventura@ICHEP 2026
Nicolas Avalos@Magnificent CevNS 2026

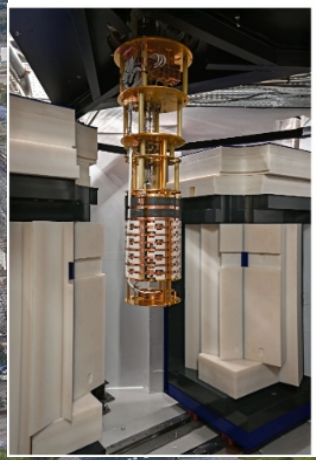
More CEνNS experiments

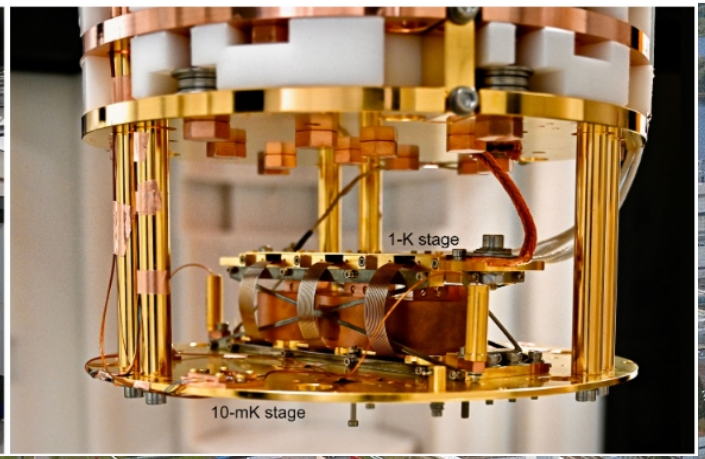
RICOCHET

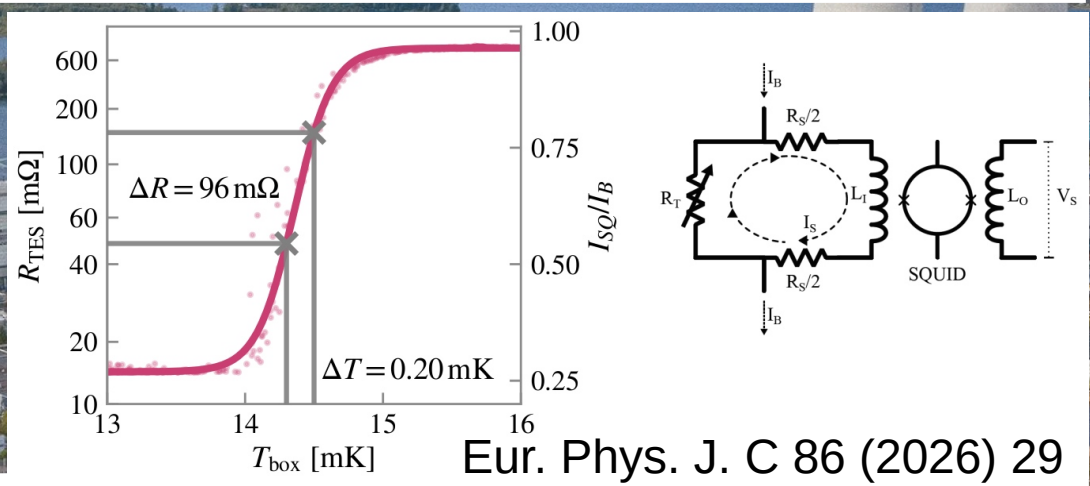
- ILL research reactor, Grenoble, France, 58 MW_{th}, 8.8m from the core, 15 m w.e. overburden
- recoil-incuded temperature change in gram-sized crystals
- Prototype 2 x 42 gr **Ge** with with heat and ionization readout
- baseline resolution: Ionization: **40 eV**, Phonon: **50-80 eV**
- Physics run with 18 detectors started July 2025

$$E_r = E_{\text{ph}} - E_{\text{ion}} \frac{q \cdot V}{\epsilon}$$

Phys. Rev. D 112, 112019 (2025)







Eur. Phys. J. C 86 (2026) 29

nucleus EXPERIMENT

- Chooz NPP, France, 4.25 GW_{th}, 70m from cores
- 3 m w.e. overburden
- Gram scale cryogenic detectors Al_2O_3, $CaWO_4$, E_{th} < **20 eV**
- 7 gr of **$CaWO_4$** surrounded by 6 germanium veto detectors
- Start data collection by the end of 2026

More CEvNS experiments



NEON (**N**eutrino **E**lastic-scattering **O**bservation with **N**aI)

- Hanbit NPP (Reactor 6), Korea, 2.8 GW_{th}, 23.7m from the core
- 20 m w.e. overburden, total 16 kg **NaI(Tl)** in 6 crystals
- Operation started from April 2022 (~18000 kg*day collected)
- Aimed threshold for CEvNS detection 5 PE => ~**200 eVee**
- Going to decommission in September 2026
- **CEvNS** search is on-going

In-Soo Lee@Magnificent CevNS 2026

TEXONO (Taiwan EXperiment On NeutrinO)

- Kuo-Sheng NPP (Reactor 1), Taiwan, 2.9 GW_{th}, 28m from the core
- 30 m w.e. overburden, 1.957 kg **HPGe** in 2 crystals, **200 eVee** threshold
- Data collected Sept. 2019 - Apr. 2023. ON(OFF): 404(813.7) kg*days
- The limit on the CEvNS rate for the Lindhard (k=0.162) QF is **2.0**×SM (90% CL)

arXiv:2606.16864v1

- Sanmen NPP Taizhou, China, 3 GW_{th}, 25m from the core
- 62kg **LXe** in total, plan: Energy ROI: **[0.3,1] keVnr**
- Prototype tested

Eur.Phys.J. C 86 (2026) 4, 348

Neutrino magnetic moment (NMM)

Elastic neutrino scattering on electrons (EνES) and nuclei (CEνNS)

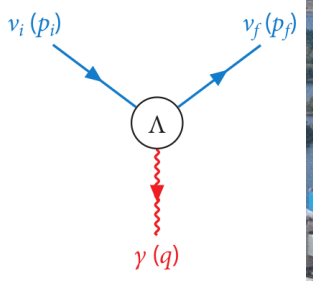
Minimum SM extension: Annu. Rev. Nucl. Part. Sci. 2025. 75:1–33

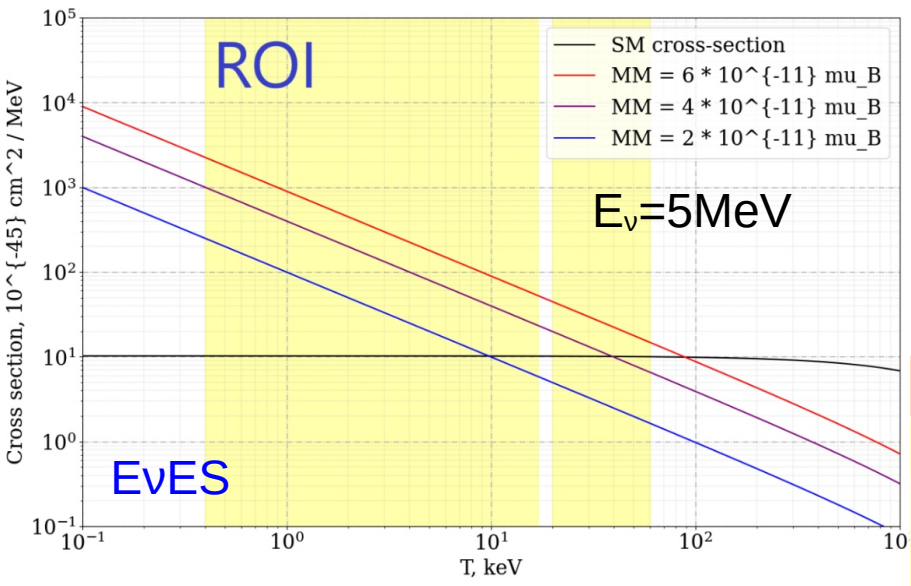
Konovalov@NuFact2026

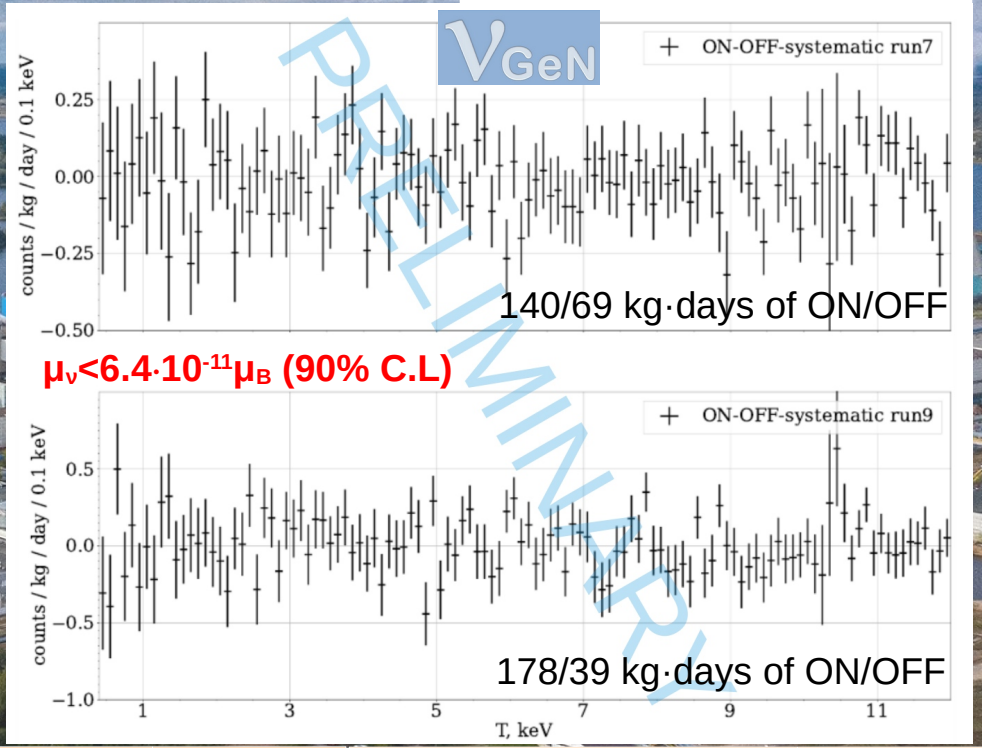
$$\mu_\nu = \frac{3eG_F m_\nu}{8\sqrt{2}\pi^2} \approx 3.2 \times 10^{-19} \left(\frac{m_\nu}{1eV}\right)\mu_B$$

Cross section (no interference with SM):

$$\frac{d\sigma(\mu_\nu)}{dT} = C\frac{\pi\alpha^2}{m_e^2}\left(\frac{1}{T} - \frac{1}{E_\nu}\right)\frac{\mu_\nu^2}{\mu_B^2}$$

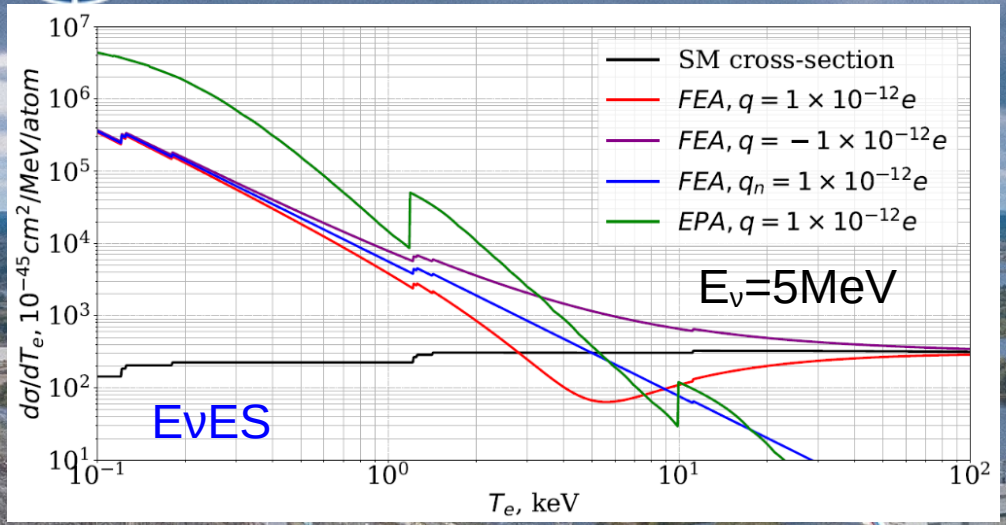






Experiment, EνES	L, $10^{-11}\mu_B$	Experiment, other	L, $10^{-11}\mu_B$
GEMMA (2016)	**2.9**	TEXONO (2026) CEνNS	**59**
COνUS+ (2026)	**5.2**	XENONnT (2022) sol.	**0.6**
TEXONO (2007)	**7.4**	Astrophysical	**~0.1**

Neutrino millicharge (NMC)



Experiment	Limit, 10^{-12}e
TEXONO (2014) [MCPPRA]	**2.1**
GEMMA (2016) [FEA]	**2.7**
COνUS+ (2026) [EPA]	**0.6**
COνUS+ (2026) [FEA]	**1.76**
νGen (2026) [EPA]	**0.53**
νGen (2026) [FEA]	**1.5**
LUX-ZEPLIN (2023) solar	**0.224**

Reactor $\bar{\nu}$, Ge

Limit on diagonal NMC from NMM [FEA]:

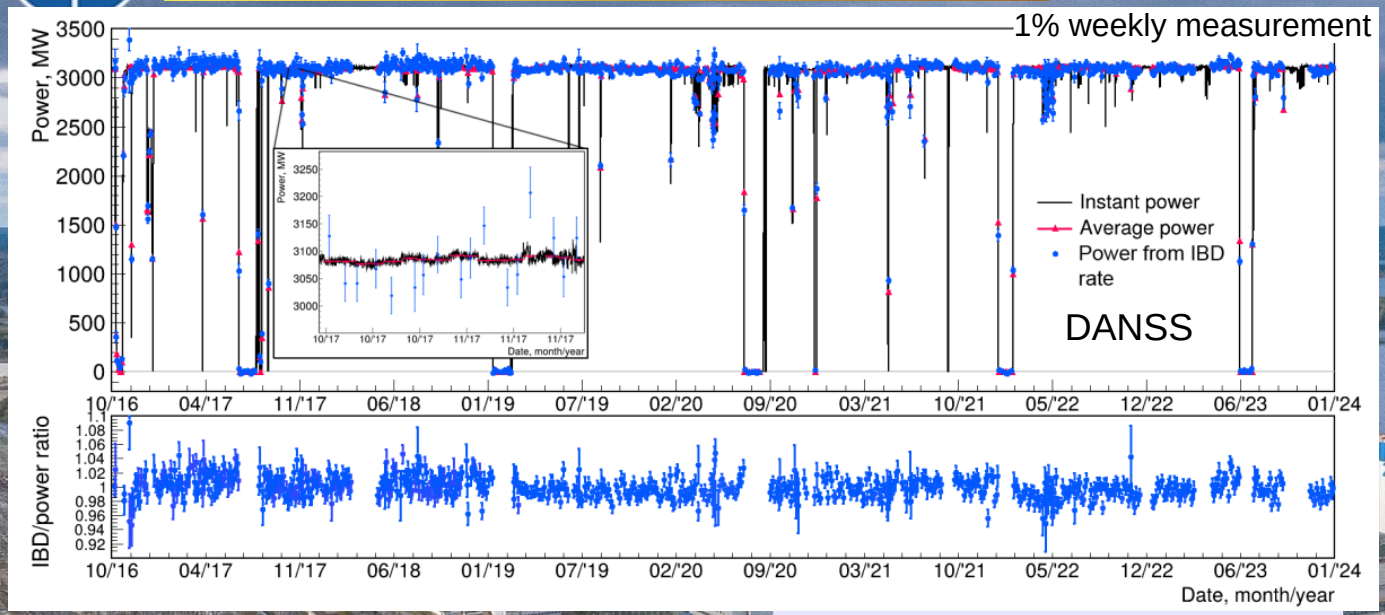
$$|Q_{\nu_\ell}| \lesssim \sqrt{\frac{T_e^{\rm th}}{2m_e}} \left(\frac{\mu_{\nu_\ell}^{\rm up}}{\mu_{\rm B}}\right) e$$

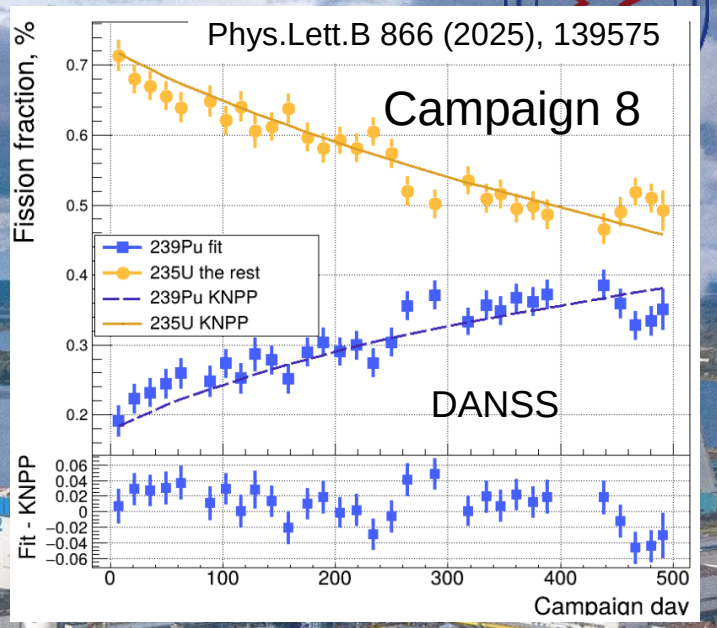
Astrophysics ~10^{-14} e
Matter neutrality ~10^{-21} e

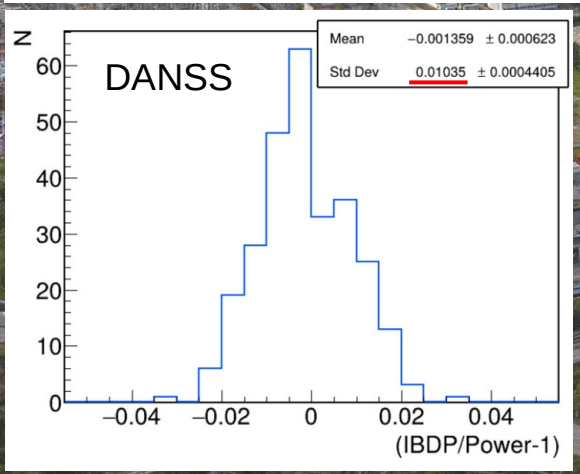
[FEA] – free electron approximation
[EPA] – equivalent photon approximation
[MCRRPA] – Multi-Configuration Relativistic Random-Phase Approximation

Reactor monitoring

Another detector for reactor monitoring:
R. Biktimirov, poster session

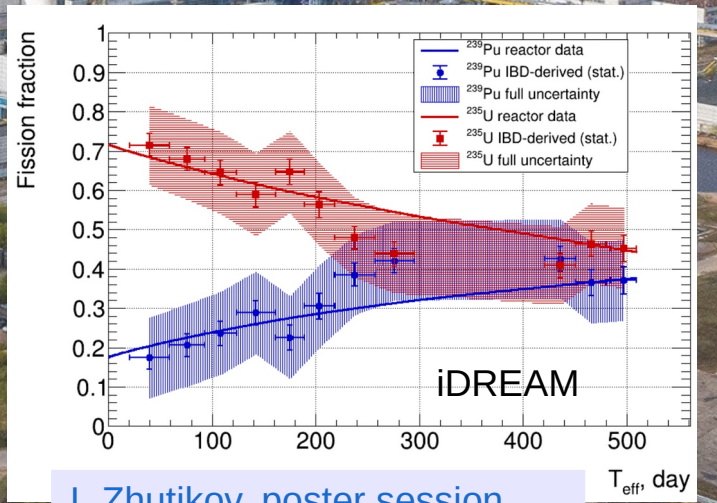






DANSS: N. Scrobova, 28.10 16:05 Hall 4

- ✔ Average statistical precision of weekly measurement **0.67**%. σ of the difference with conventional methods **1.04**% => systematic uncertainty **0.8**%. It includes DANSS systematics as well as systematics of conventional methods.
- ✔ Determination of fission fractions from $\bar{\nu}$ flux better than **3**%.
- ✔ The precise agreement provides confidence in validity of both approaches.



I. Zhutikov, poster session
I. Zhutikov, 28.10 16:35 Hall 4

Conclusions

- Reactors are the most intense terrestrial flavor pure sources of electron antineutrinos with intensities up to $5 \cdot 10^{13} \bar{\nu}\ s^{-1} cm^{-2}$ – great place for experiments.
- CEνNS was for the first time observed with reactor antineutrino by COνNUS+ (2025). Many experiments are aimed to repeat the success (νGen, TEXONO, RED100, RELICS, NEON) and new results from COνNUS+ Run2 are coming soon. Breakthrough with very low CEνNS threshold like with Skipper-CCD technology (COνNIE) or with gram scale cryogenic detectors (RICOCHET and NUCLEOUS) could overcome 1.8 MeV IBD threshold in reactor antineutrino measurements.
- The signal of light sterile neutrinos becomes weaker and weaker, though anomalies (GA in the first place) are still unexplained and experimental activity is very high. In the reactor based experimental field we are awaiting new results from JUNO-TAO, Neutrino-4+, DANSS-II, PROSPECT-II.
- A lot of activity in measuring neutrino electromagnetic properties (magnetic moment, millicharge, charge radius, etc), though experimental limits are still far from theoretical predictions.
- New precision era of reactor monitoring with its antineutrino flux: 1% precision in power and 3% in fission fractions (DANSS).

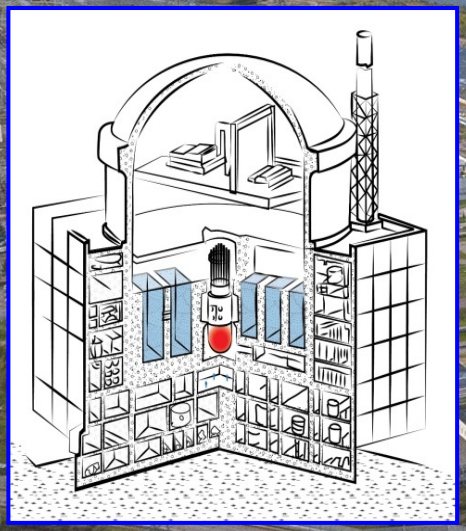
We are awaiting a lot of new interesting results soon. Stay tuned !


Thank you for
GEMMA
νGen
DANSS
iDREAM
RED100
your attention !

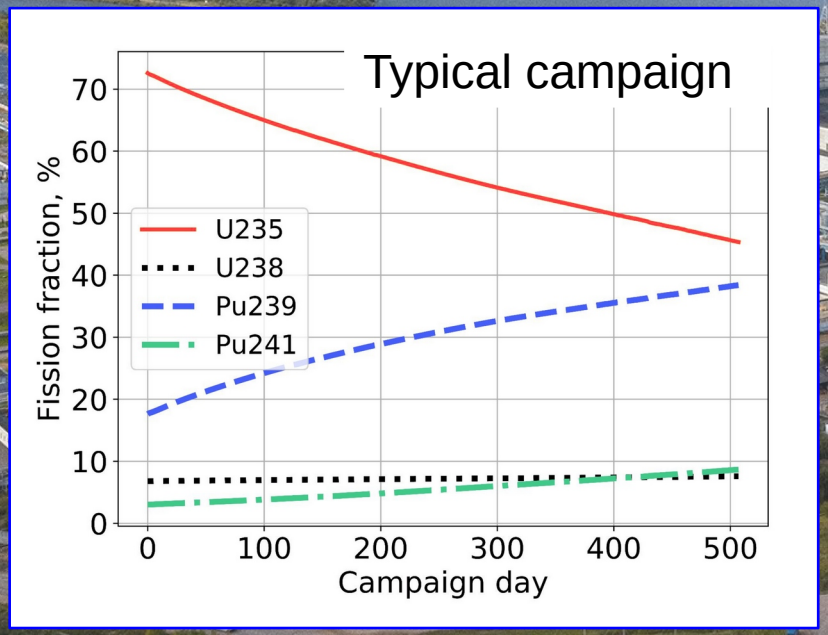
Reactor types

Power commercial reactors

- Large power 3-4.5 GW_{th} => large flux
- Large core ~ 3 m diameter x 3 m height
- Low Enriched Uranium (LEU) ~5% of ^{235}U:
  4 fission nuclides: ^{235}U, ^{238}U, ^{239}Pu, ^{241}Pu
- 1-1.5 years campaign with ~ 1.5 month off for fuel replacement

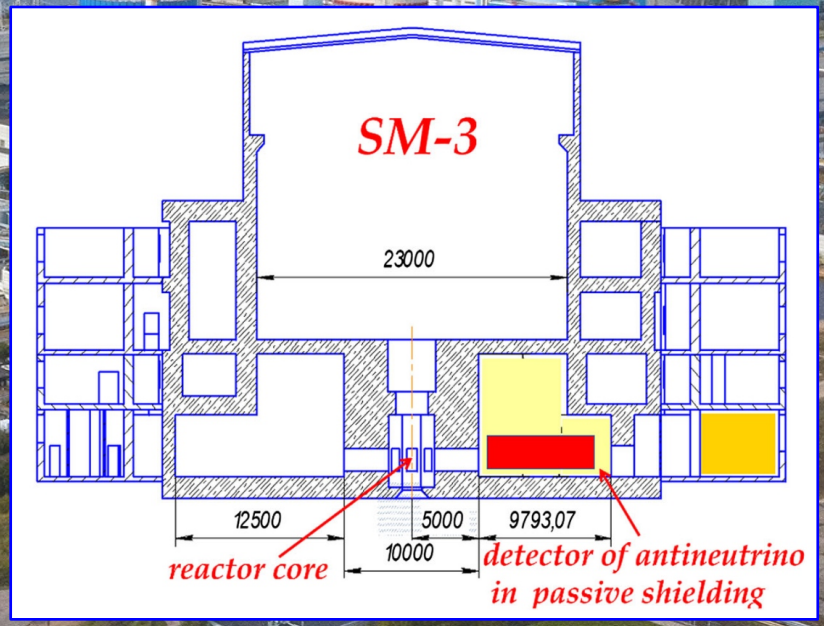


WWER-1000



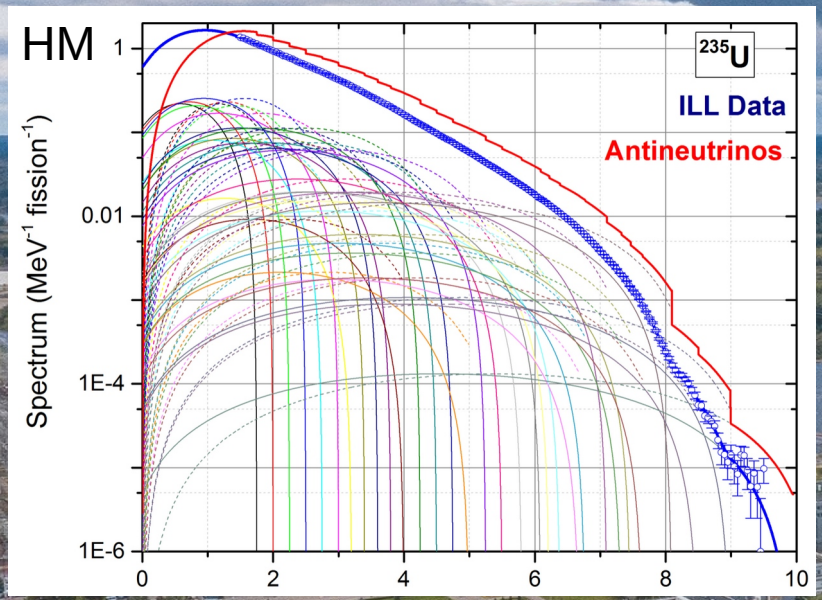
Research reactors

- Small power < 100 MW_{th}
- Compact core ~ 0.5 m diameter x 0.5 m height
- Highly Enriched Uranium (HEU) ^{235}U fission only
- Short cycle with approximately equal On/Off times

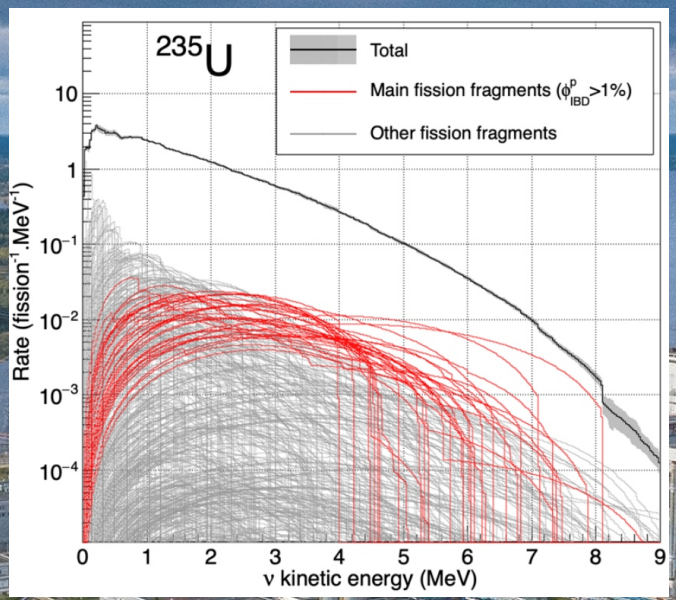


Reactor antineutrino flux models

Conversion



Summation



C. Giunti et al., PLB 829 (2022) 137054

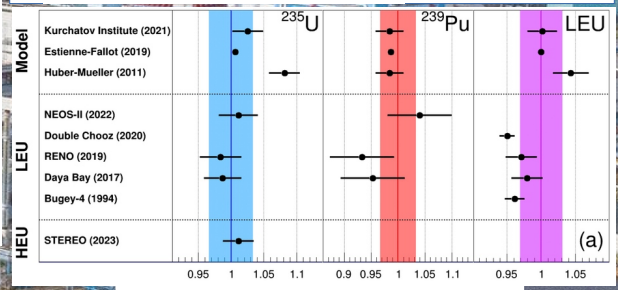
$$\overline{R}_{EF} = 0.960^{+0.033}_{-0.031}$$

$$\overline{R}_{HKSS} = 0.925^{+0.025}_{-0.023}$$

$$\overline{R}_{KI} = 0.975^{+0.022}_{-0.021}$$

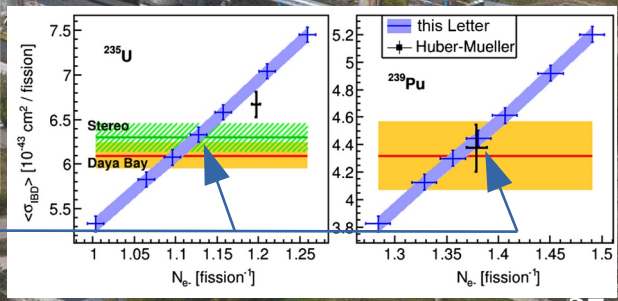
$$\overline{R}_{HKSS-KI} = 0.964^{+0.023}_{-0.022}$$

$$\overline{R}_{HM} = 0.936^{+0.024}_{-0.023}$$



Ratio to **BESTIOLE**

L. Hayen et al., PRC 100 (2019) 054323 — conversion model **HKSS**
M. Estienne et al., PRL 123 (2019) 022502 — summation model **EF**
V. Kopeikin et al., PRD 104 (2021) L071301 — conversion model **KI**
L. Perissé et al., PRC 108 (2023) 055501 — summation model **BESTILOE**
A. Letourneau et al., PRL 130 (2023) 021801 — summation model with emperical estimation of beta-decays absent in the database



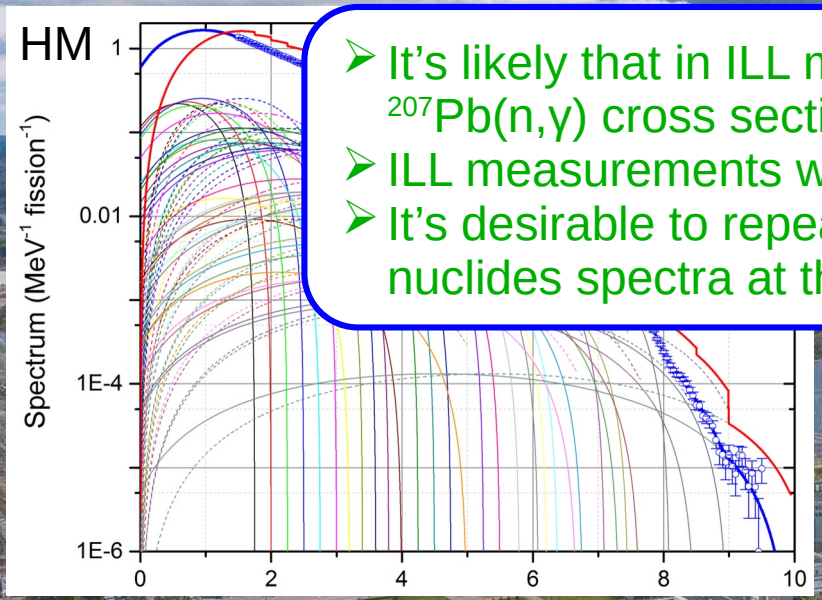
Center value of the model parameter

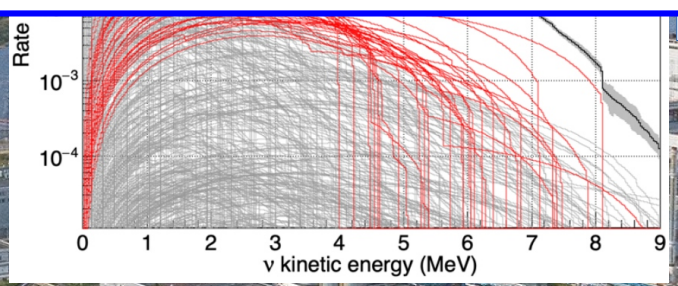
Reactor antineutrino flux models

Conversion

Summation

- It's likely that in ILL measurements of ^{235}U wrong (larger) ^{207}Pb(n,y) cross section was used
- ILL measurements were completed 40 yaers ago
- It's desirable to repeat measurements of the main nuclides spectra at the modern level of precision





C. Giunti et al., PLB 829 (2022) 137054

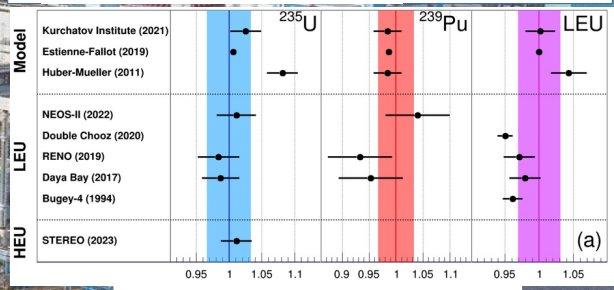
$\overline{R}_{\cdot\cdot} = 0.960^{+0.033}_{-0.031}$

$_{SS} = 0.925^{+0.025}_{-0.023}$

$= 0.975^{+0.022}_{-0.021}$

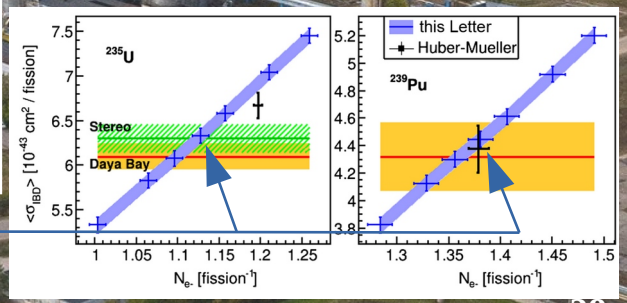
$_{S-KI} = 0.964^{+0.023}_{-0.022}$

$_{HM} = 0.936^{+0.024}_{-0.023}$



Ratio to **BESTIOLE**

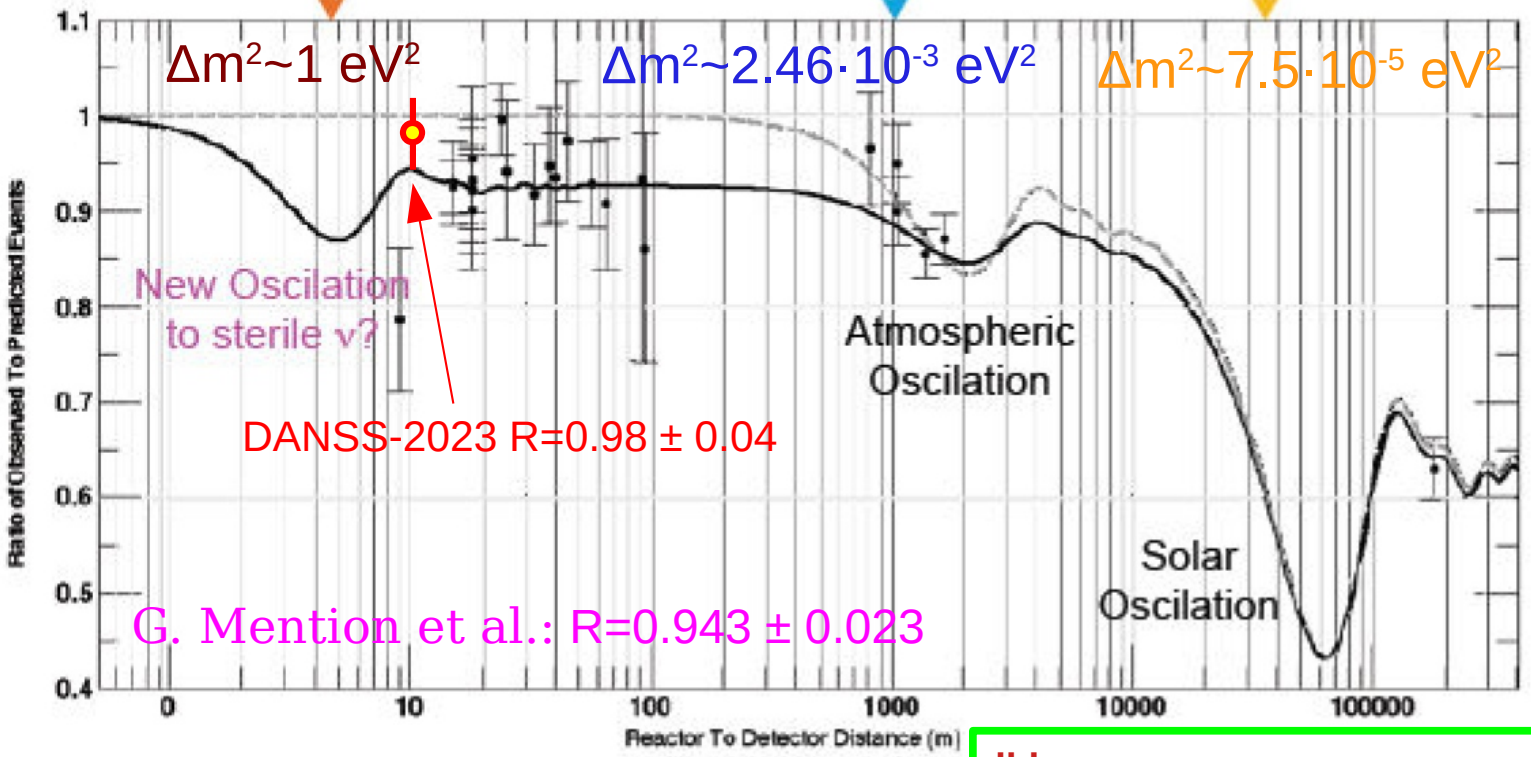
L. Hayen et al., PRC 100 (2019) 054323 — conversion model **HKSS**
M. Estienne et al., PRL 123 (2019) 022502 — summation model **EF**
V. Kopeikin et al., PRD 104 (2021) L071301 — conversion model **KI**
L. Perissé et al., PRC 108 (2023) 055501 — summation model **BESTILOE**
A. Letourneau et al., PRL 130 (2023) 021801 — summation model with emperical estimation of beta-decays absent in the database



Center value of the model parameter

Reactor Antineutrino Anomaly (RAA)

$$P_{\bar{\nu}_e \to \bar{\nu}_e} = 1 - \sin^2 2\Theta_{14} \sin^2 (1.27 \Delta m^2_{41} \frac{L}{E}) - c^4_{14} \sin^2 2\Theta_{13} \sin^2 (1.27 \Delta m^2_{31} \frac{L}{E}) - c^4_{14} c^4_{13} \sin^2 2\Theta_{12} \sin^2 (1.27 \Delta m^2_{21} \frac{L}{E})$$



RAA: G. Mention et al., Phys. Rev. D 83 (2011) 073006
^{238}U: Th. A. Mueller et al., Phys. Rev. C 83 (2011) 054615
^{235}U, ^{239,241}Pu: Patrick Huber, Phys. Rev. C 84 (2011) 024617

ILL:
W. Mampe et al., NIM 154 (1978) 127
F. von Feilitzsch et al., PLB 118 (1982) 162
K. Schreckenbach et al., PLB 160 (1985) 325
A. A. Hahn et al., PLB 218 (1989) 365

Inverse beta-decay (IBD)

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

H. Bethe and R. Peierls 1934.

F. Reines and C. L. Cowan 1953-56

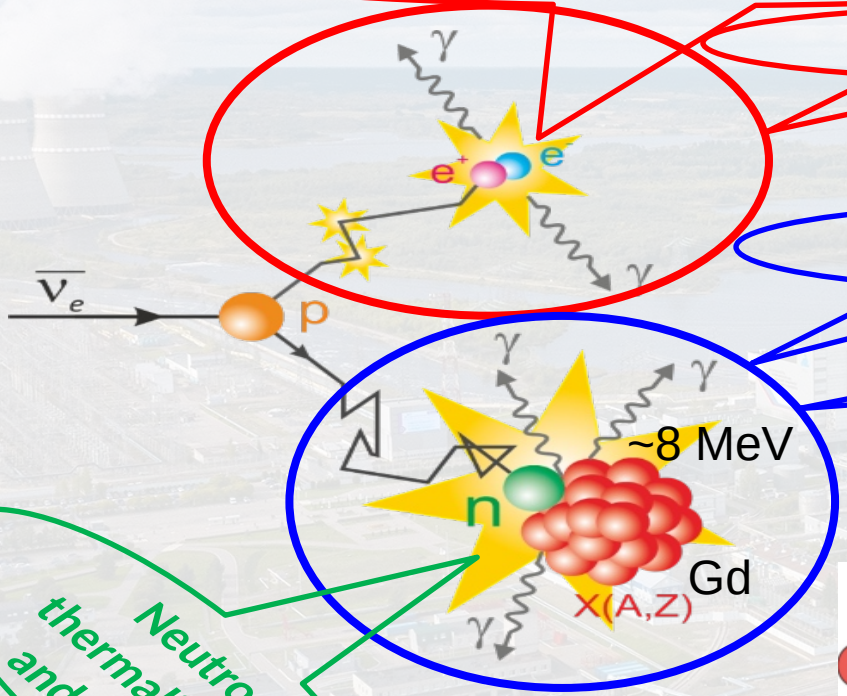
Continuous ionization cluster

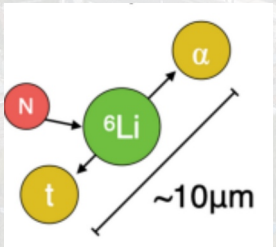
Fast (prompt) signal

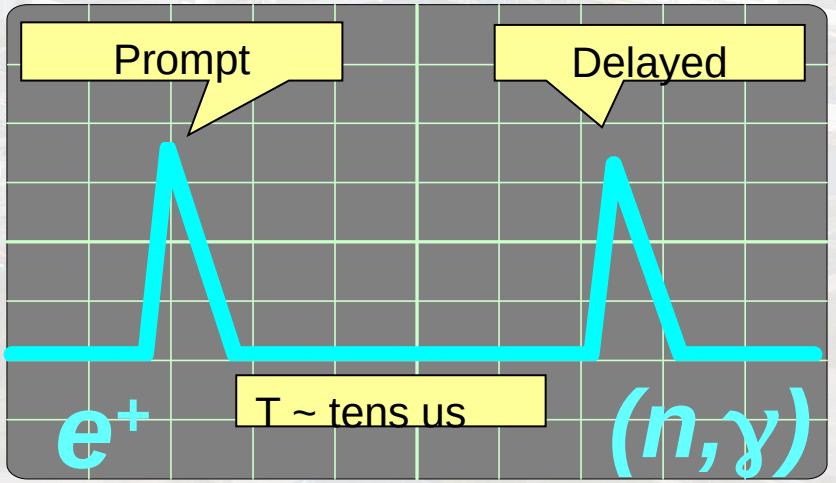
$E_e \approx E_\nu$ – 1806 MeV

Delayed signal

Gamma flush in the whole detector







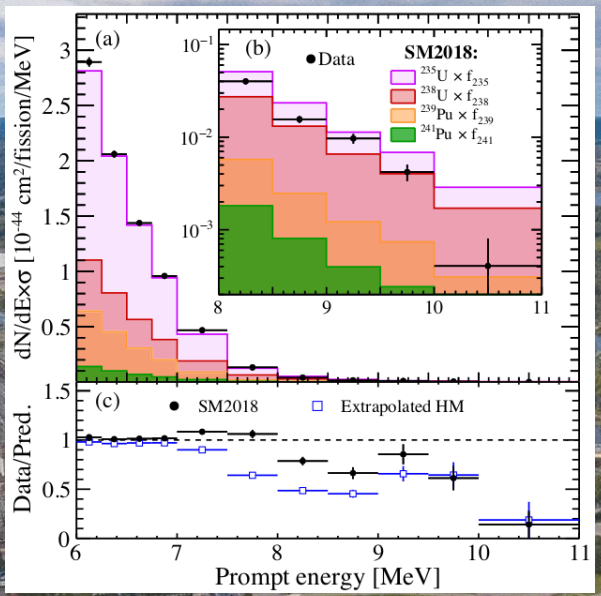
Neutron thermalization and capture

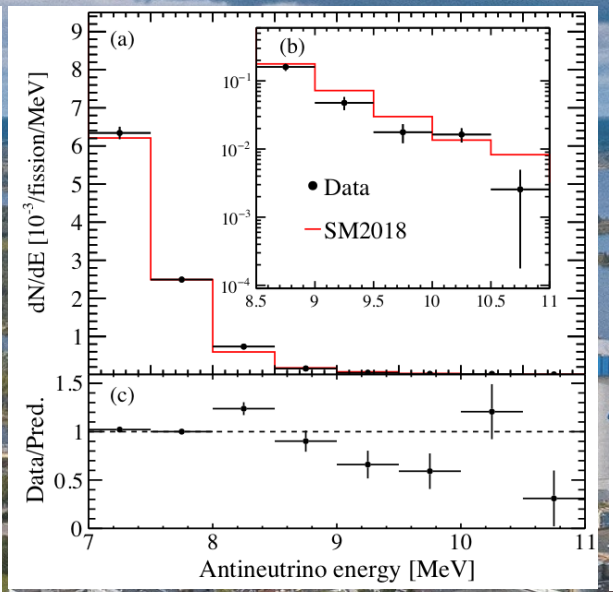
n+p→d+γ(2.3 МэВ)

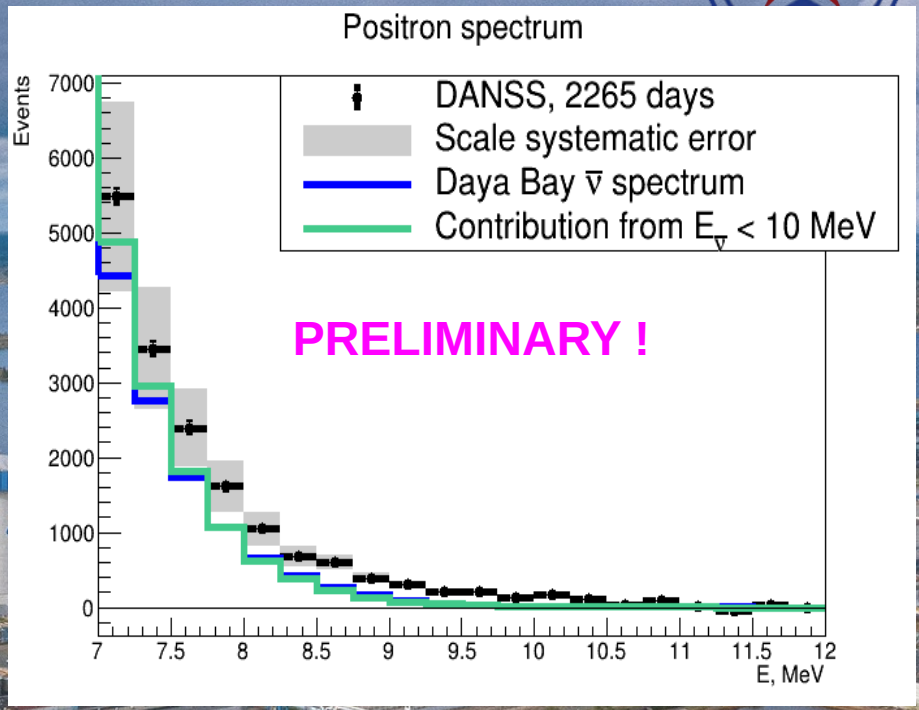
High energy tail of the neutrino spectrum

Daya Bay

Phys.Rev.Lett. 129, 041801 (2022)







The hypothesis of no reactor antineutrinos with energy above 10 MeV is rejected with a significance of 6.2σ.

DANSS observes antineutrino with energy > 10 MeV: **$1797 \pm 169_{stat} \pm 189_{sys}$ ev. (7.1σ)**

Fraction of IBD events with antineutrino energy > 10 MeV:

$$(1.48 \pm 0.14_{stat} \pm 0.16_{sys}) \cdot 10^{-4}$$

CEνNS around the world

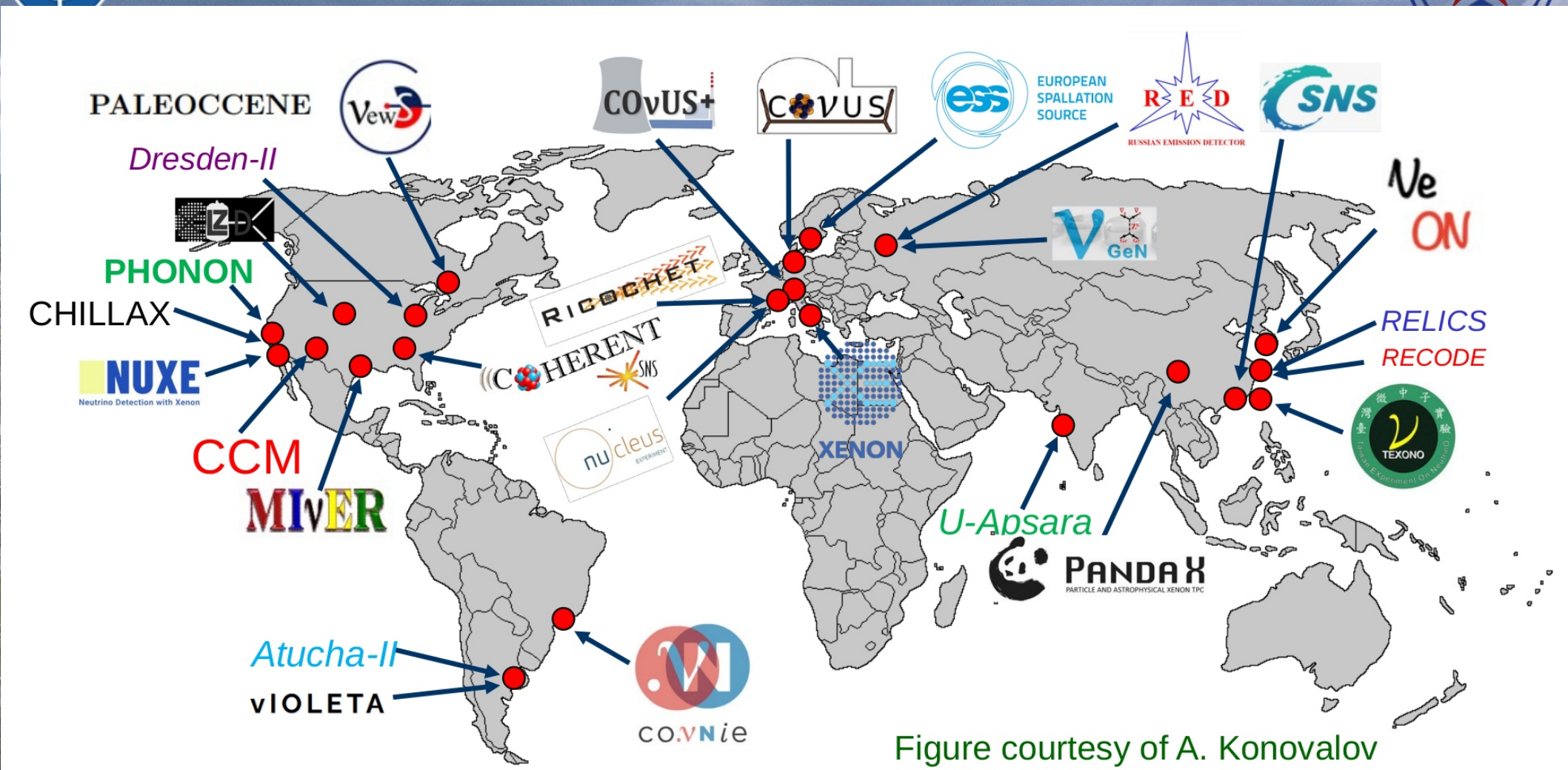


Figure courtesy of A. Konovalov

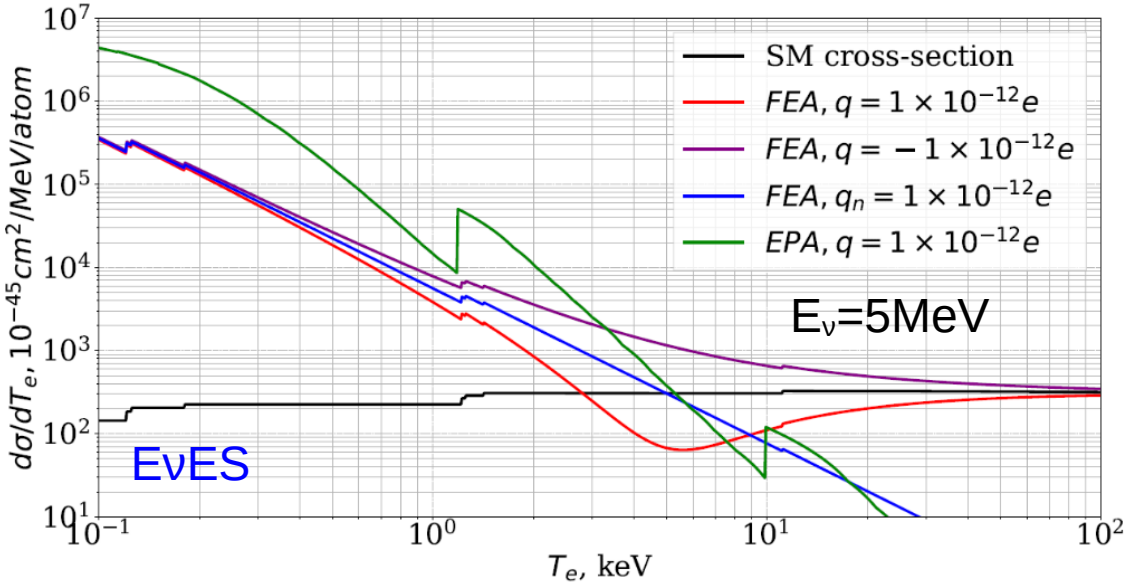
Neutrino millicharge (NMC)

For free electron SM cross section:

Annu. Rev. Nucl. Part. Sci. 2025. 75:1–33

$$\frac{\mathrm{d}\sigma^{\mathrm{E}\nu\mathrm{ES,SM}}_{\nu_\ell-\mathcal{A}}}{\mathrm{d}T_\mathrm{e}}(E_\nu, T_\mathrm{e}) = Z^{\mathcal{A}}_{\mathrm{eff}}(T_e)\,\frac{G_\mathrm{F}^2 m_e}{2\pi}\left[\left(g_V^{\nu_\ell}+g_A^{\nu_\ell}\right)^2+\left(g_V^{\nu_\ell}-g_A^{\nu_\ell}\right)^2\left(1-\frac{T_e}{E_\nu}\right)^2-\left((g_V^{\nu_\ell})^2-(g_A^{\nu_\ell})^2\right)\frac{m_e T_e}{E_\nu^2}\right]$$

With diagonal electric charge: $g_V^{\nu_\ell} \to g_V^{\nu_\ell} - \frac{\sqrt{2}\pi\alpha}{G_\mathrm{F} m_e T_e}\left(\frac{Q_{\nu_\ell}}{e}\right)$ (interference with SM)



Non-diagonal electric charge:

[FEA] $\frac{d\sigma}{dT_e} \approx \frac{\pi\alpha^2}{m_e T_e^2}\delta_n^2$

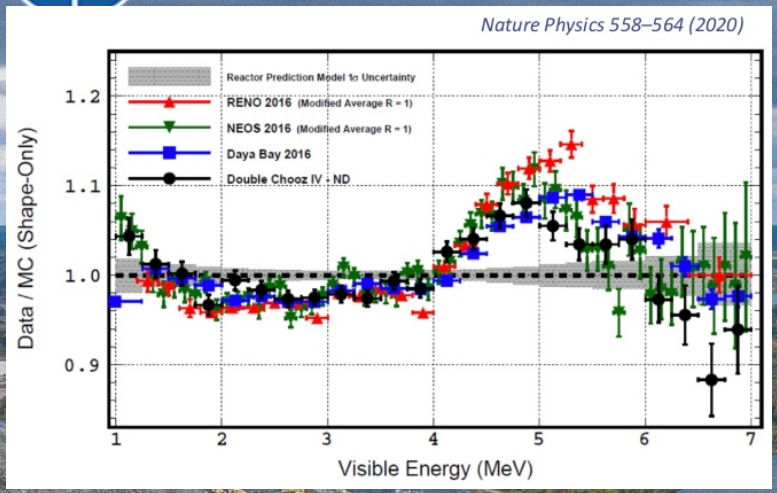
[EPA] $\frac{d\sigma}{dT_e} = \frac{2\alpha}{\pi}\frac{\sigma_\gamma(T_e)}{T_e} log\frac{E_\nu}{m_\nu}\delta_n^2$

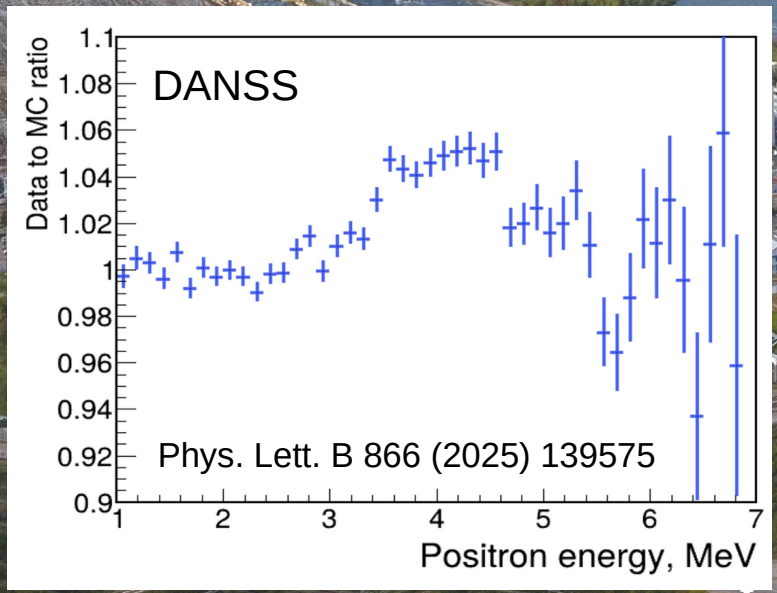
[FEA] – free electron approximation
[EPA] – equivalent photon approximation
$\sigma_\gamma(T_e)$ – photoelectric effect cross section
[MCRRPA] – Multi-Configuration Relativistic Random-Phase Approximation

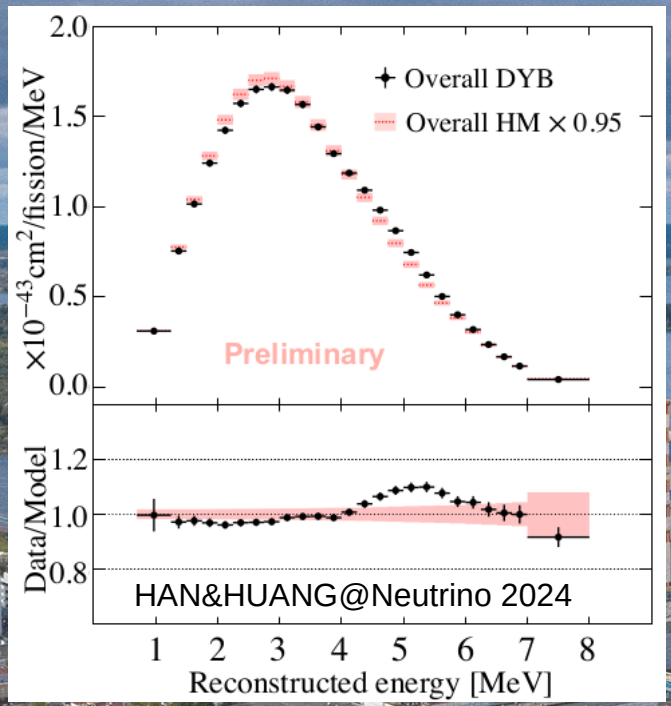
Limit on diagonal NMC from NMM [FEA]:

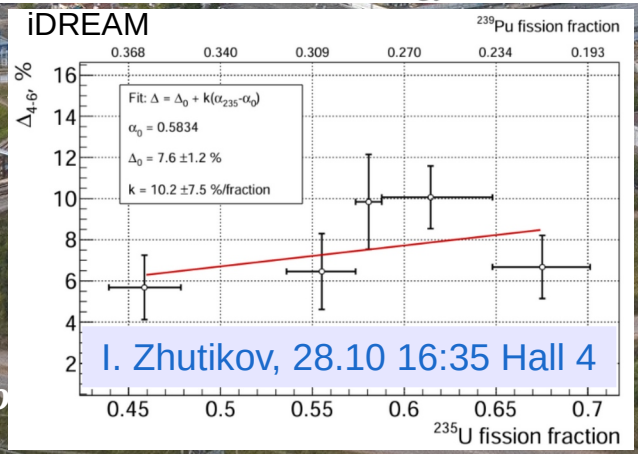
$$|Q_{\nu_\ell}| \lesssim \sqrt{\frac{T_e^{\mathrm{th}}}{2m_e}}\left(\frac{\mu_{\nu_\ell}^{\mathrm{up}}}{\mu_\mathrm{B}}\right)e$$

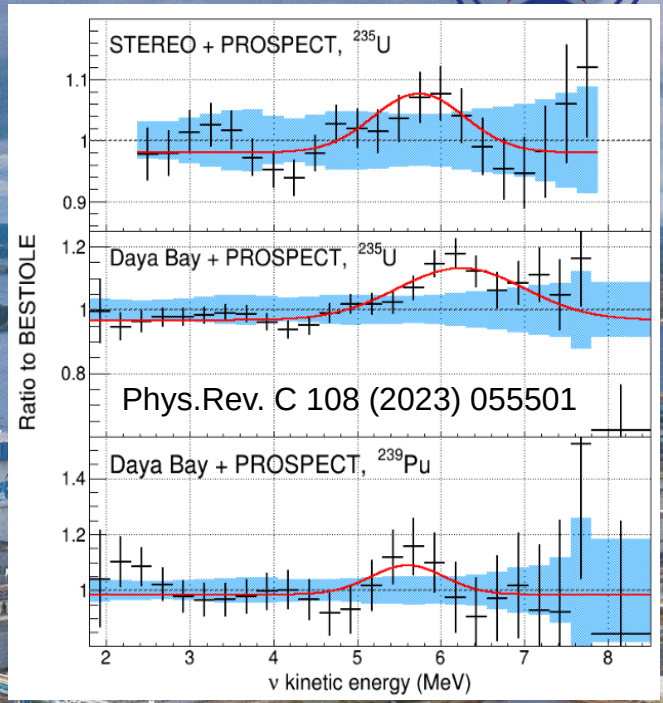
Spectrum shape anomaly- "Bump"











Shape anomaly is seen in the most of the experiments, but not reproduced in reactor antineutrino flux models including BESTIOLE