Recent results from the νGeN experiment

D. Medvedev on behalf of νGeN collaboration

TWENTY- SECOND LOMONOSOV CONFERENCE ON ELEMENTARY PARTICLE PHYSICS, August, 21-27, 2025

Scientific motivation

- Coherent elastic neutrino-nucleus scattering (CEνNS)
- $\sin^2\theta_W$ at low energies
- Nuclear form factor
- Applied physics possibility: nuclear power reactor monitoring using compact Ge detectors based on CEνNS
- Neutrino electromagnetic properties
    - Magnetic moment
    - Millicharge
- New physics
    - Dark photons
    - (Pseudo)scalar dark bosons
    - Sterile neutrinos

CEνNS

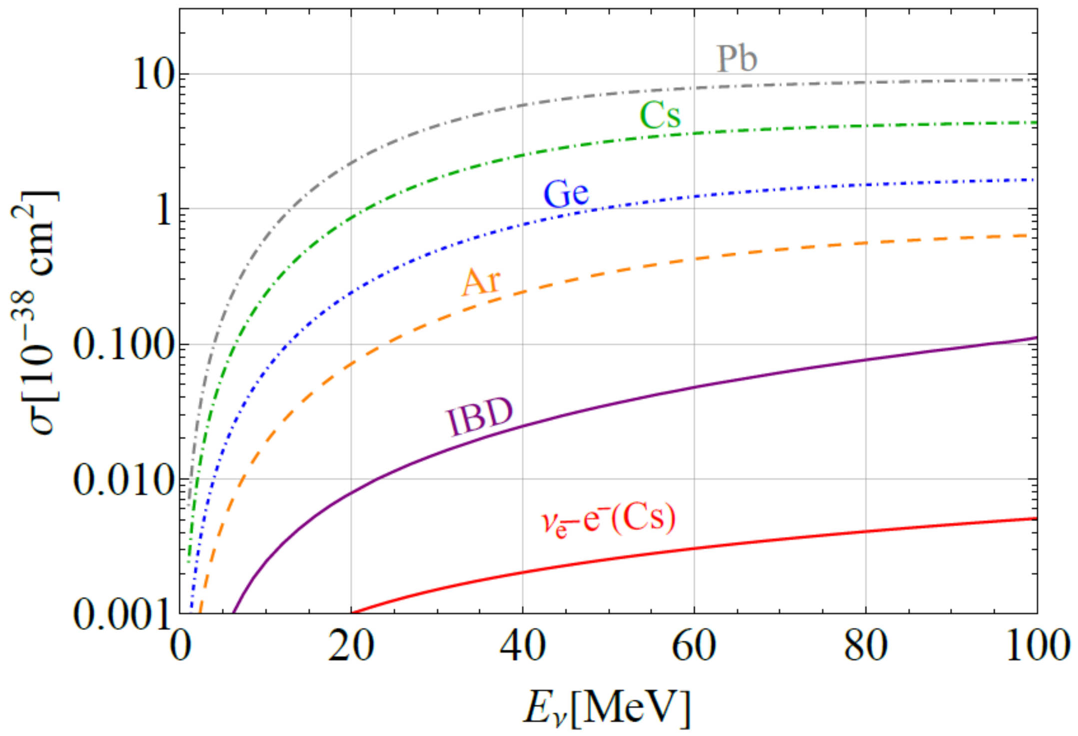
- Allowed by SM

«Coherent effect of a weak neutral current», D. Freedman, PRD v.9, iss.5 (1974)

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

$$\left(\frac{d\sigma}{dT}\right) = \frac{G_F^2}{4\pi} Q_W^2 M \left[1 - \frac{MT}{2E_\nu^2}\right] F^2(Q^2)$$

- No reaction threshold
- The cross-section is enhanced in comparison with other cross-sections at the same energy
- Detectors with small mass (~1 kg) can be used
- Challenges:
    - Strong source
    - Low threshold
    - Low background



Magnetic moment

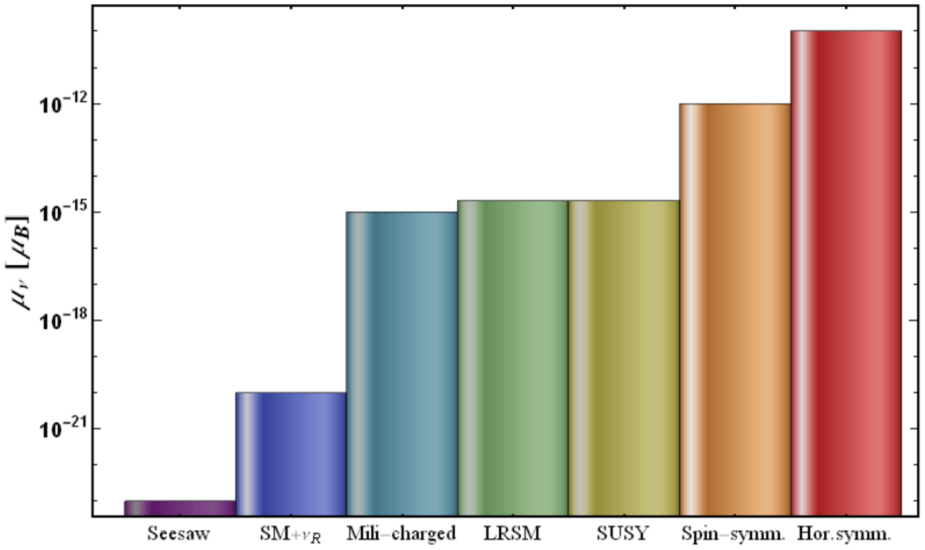
SM prediction: $\mu_\nu \sim 10^{-19}\,\mu_B \times (m_\nu\,/\,1\mathrm{eV})$

$$\frac{d\sigma}{dT} = \frac{\pi\alpha^2}{m_e^2}\left[\frac{1}{T_e} - \frac{1}{E_\nu}\right]\left(\frac{\mu_\nu}{\mu_B}\right)^2 \quad \text{(electron)}$$

$$\frac{d\sigma}{dT} = \frac{\pi\alpha^2}{m_e^2}\left[\frac{1}{T_{nr}} - \frac{1}{E_\nu}\right]Z^2F_Z^2(|q|^2)\left(\frac{\mu_\nu}{\mu_B}\right)^2 \quad \text{(nucleus)}$$

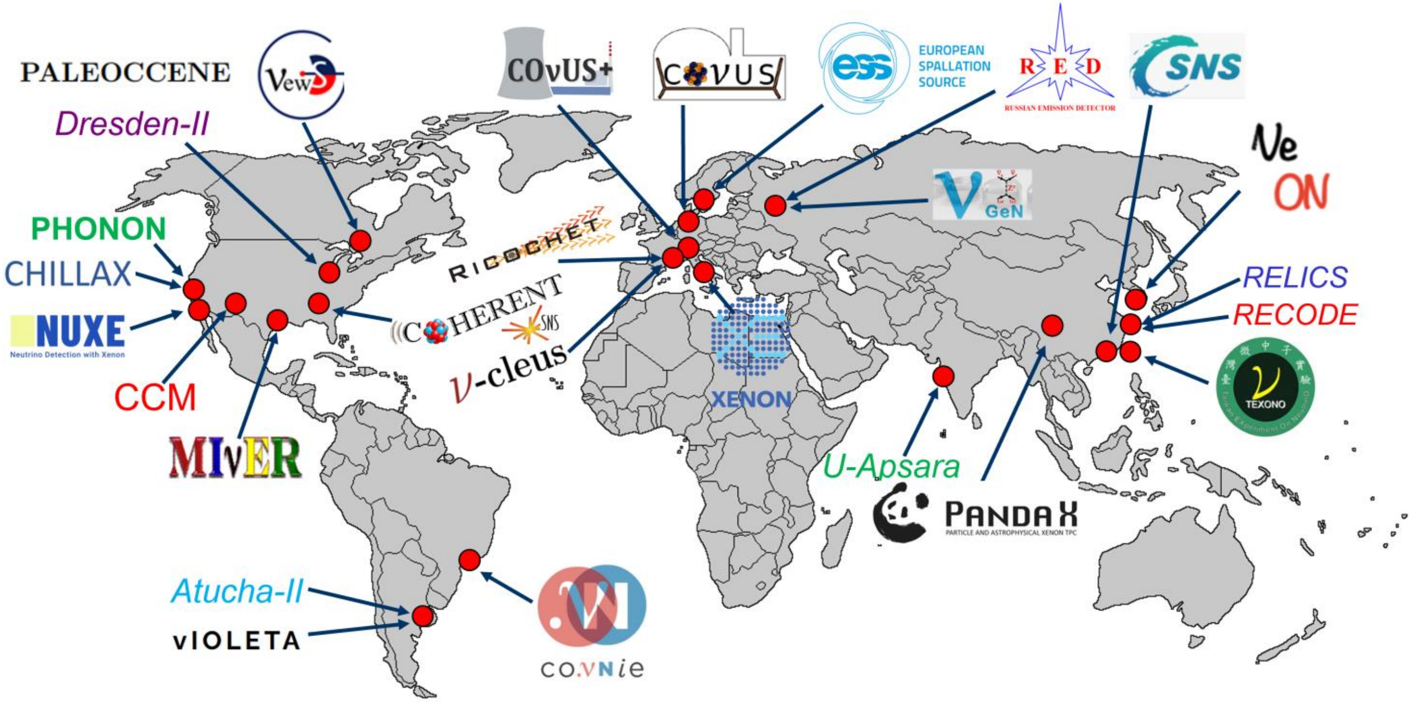
Observation of $\mu_\nu \sim 10^{-11}$-$10^{-12}\,\mu_B$ will:

- give a hint of neutrino nature
- allow to feel the scale of Λ
- set the restrictions on the number of astrophysical models



*SJ, PoS(DISCRETE2020-2021)037

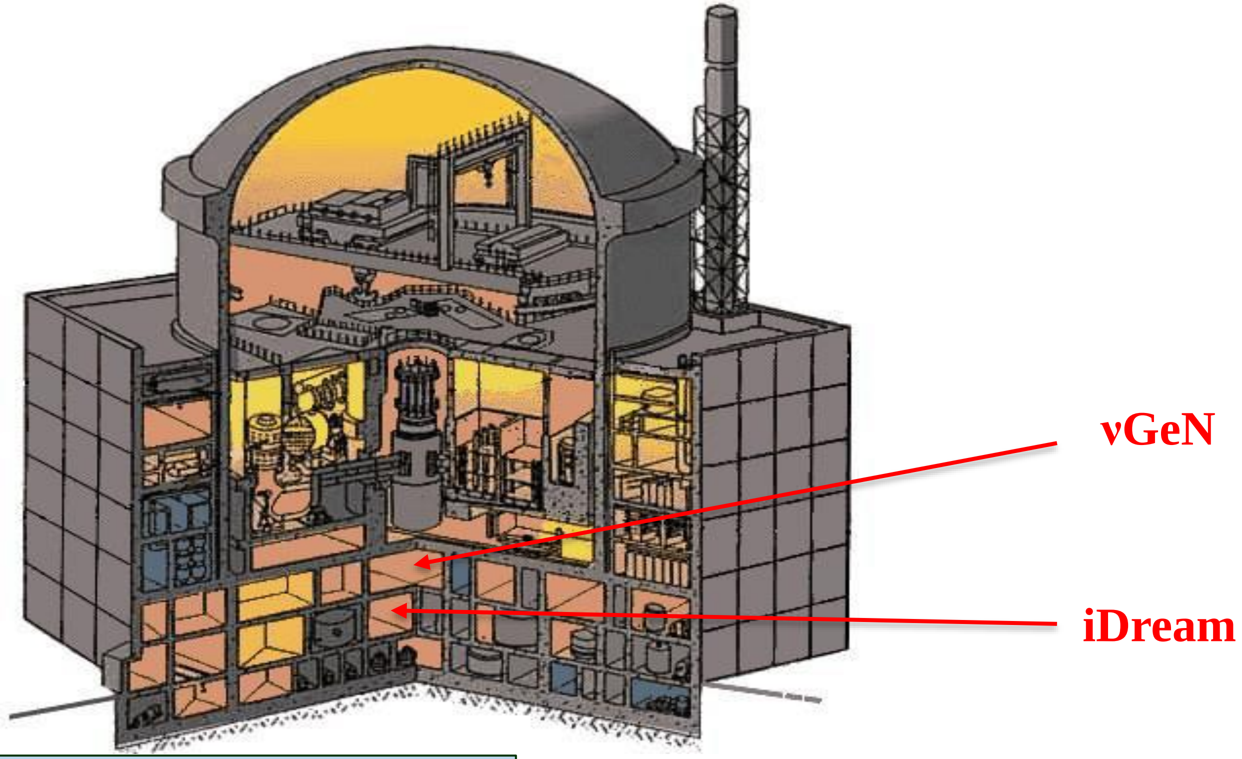
Experiments searching for CEνNS



Ge CEνNS tension

- Dresden-II (2022): observation claim for D1/D2 QF (reactor)
- COHERENT (2024/2025): 2σ below SM prediction (accelerator)
- CONUS+ (2025): observation claim for C QF (reactor)

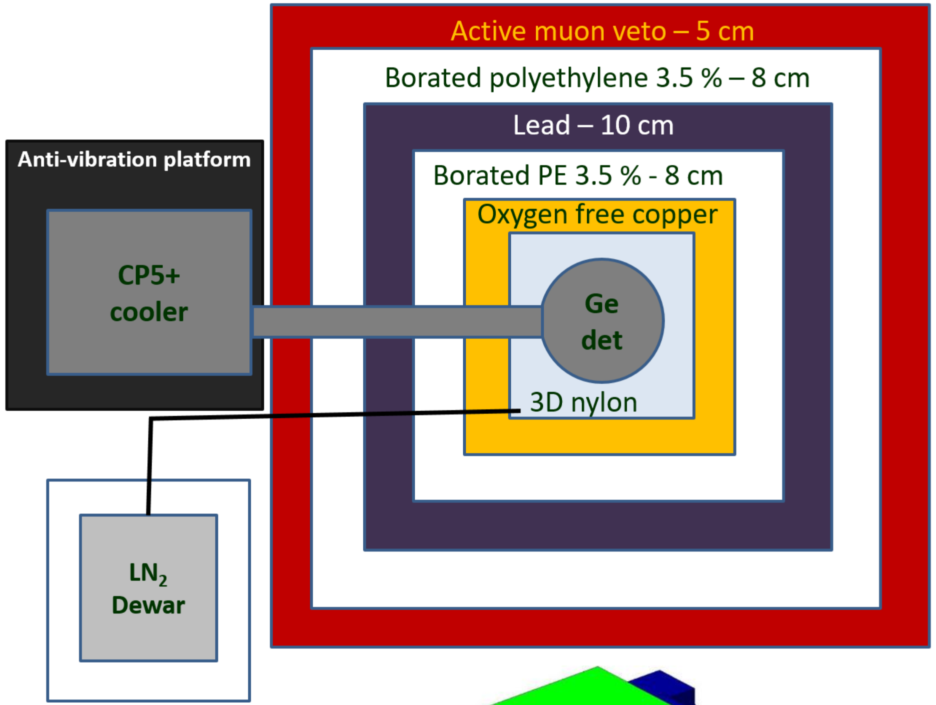
Experimental site

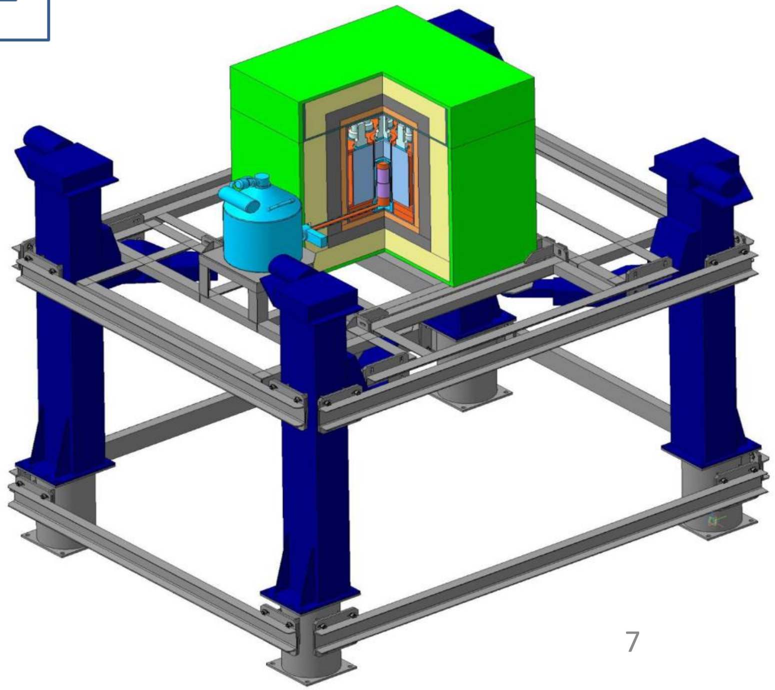


- **νGeN** is located under reactor unit #3 of KNPP (WWER-1000, thermal power – 3.1 GW)
- Antineutrino flux @11.1 m is **4.4 × 10^{13}ν/(s × cm^2)**
- Overburden ~ 50 m w.e.

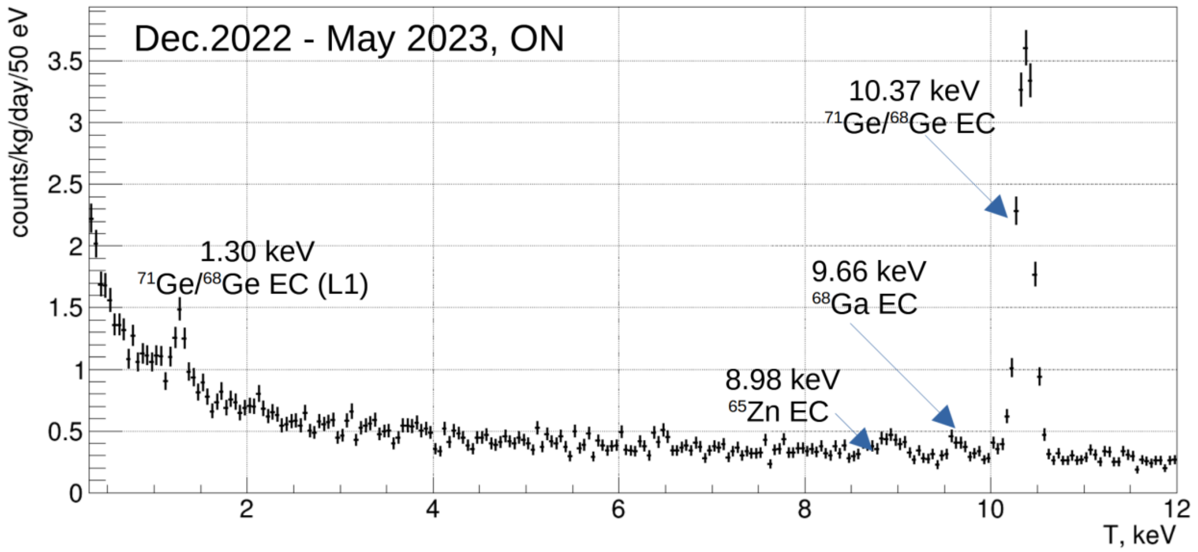
Experimental setup

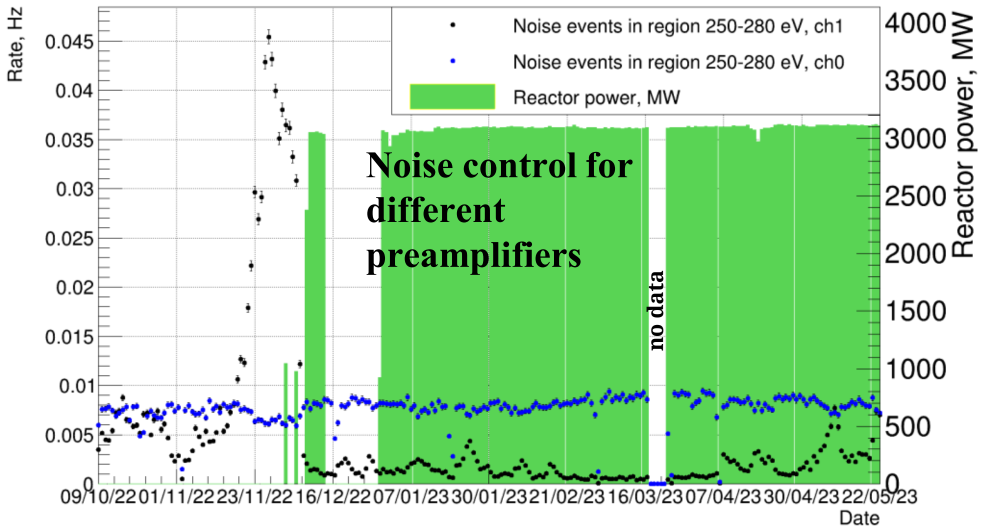
- CANBERRA (Mirion, Lingosheim) detector HPGe PPC, 1.4 kg active mass
- reset preamplifier
- low T by a cryocooler
- Multilayer passive + active shielding
- Lifting mechanism (distance from detector to the center of reactor core: from 11.1 m to 12.5m)
- pulser FWHM of 102 eV at KNPP
- Data taking via spectroscopic shaping amplifiers – comparison of different preamplifier outputs with various shaping times provides noise discrimination capability

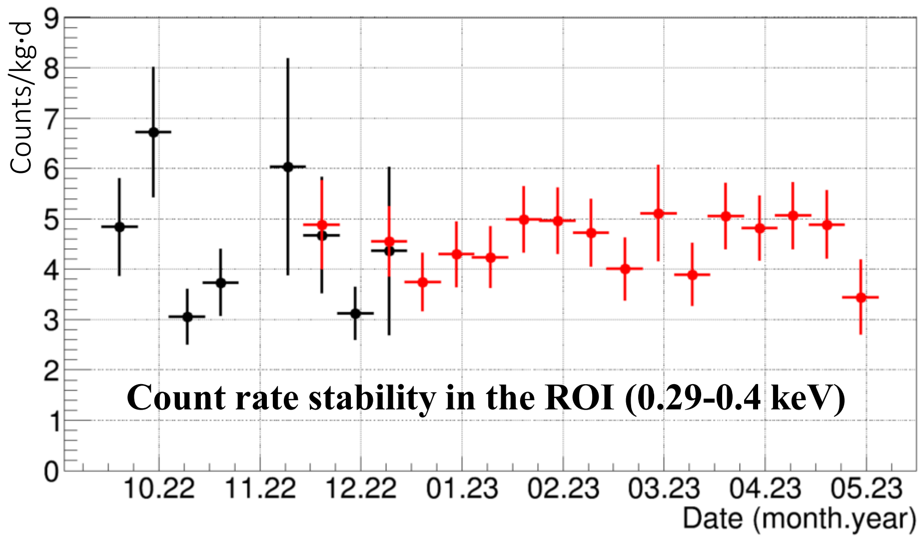




Data analysis







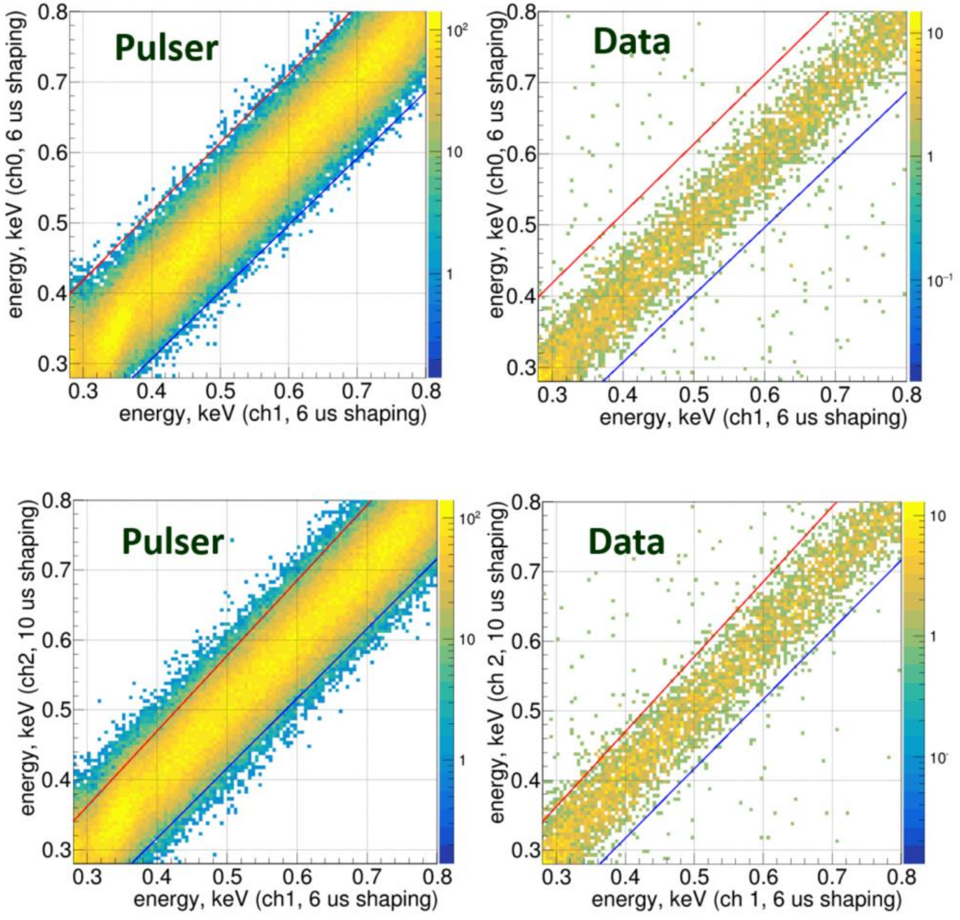
Since 2019 over **1500 days (2100 kg·d)** of statistics have been accumulated.

Data acquired from October 2022 till May 2023 @11.1 m from the center of reactor core are considered in this analysis

reactor ON – 137 days (195.5 kg·d)
reactor OFF – 38 days (54.6 kg·d)

Background suppression

Applying different amplifiers with various shaping times to suppress noise events

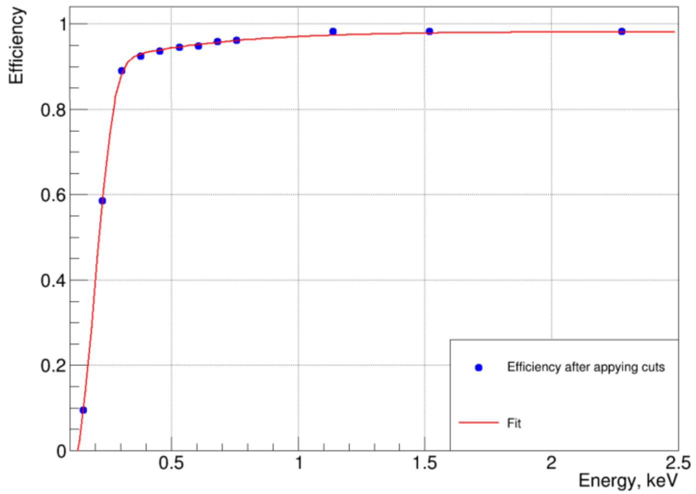


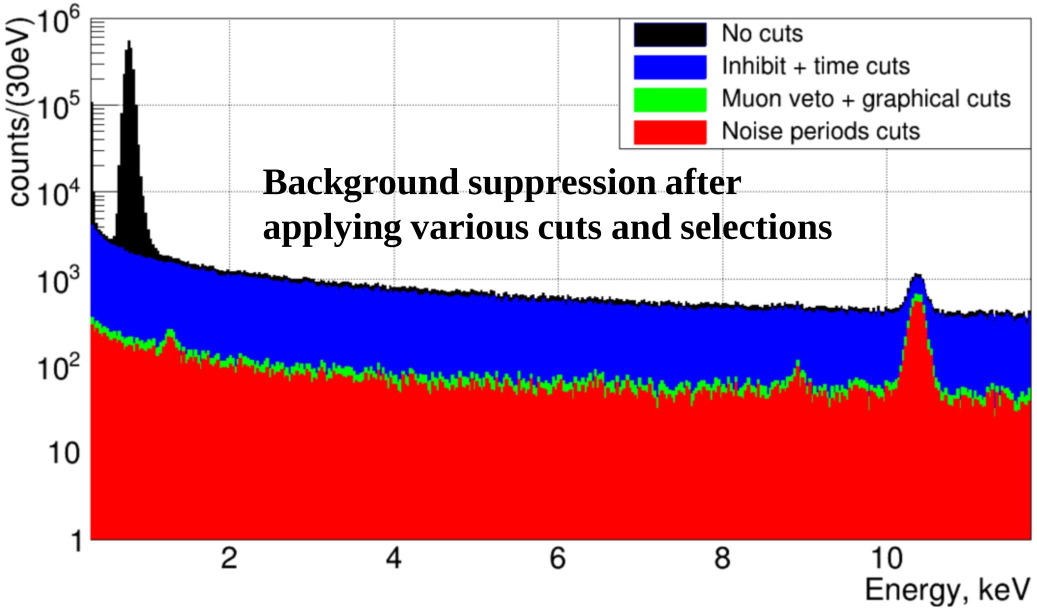
Trigger effectiveness after all cuts:

~40% for 0.2 keV

~80% for 0.3 keV

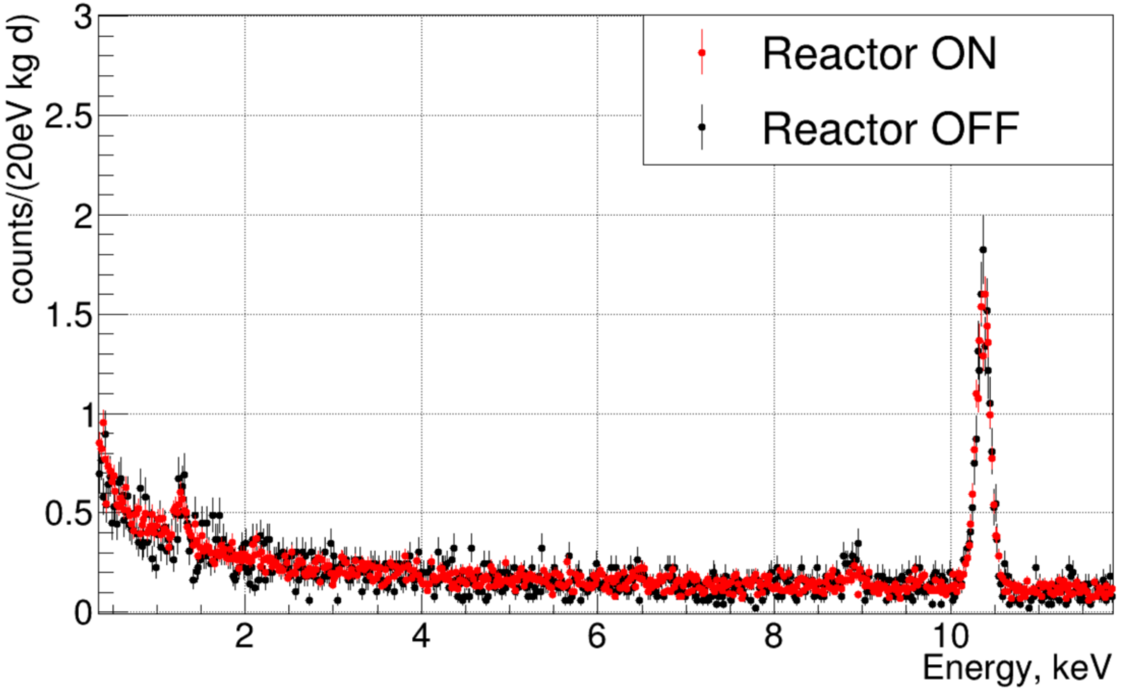
Event rejection from preamplifier reset and from muon veto leads to **dead time of ~10%**



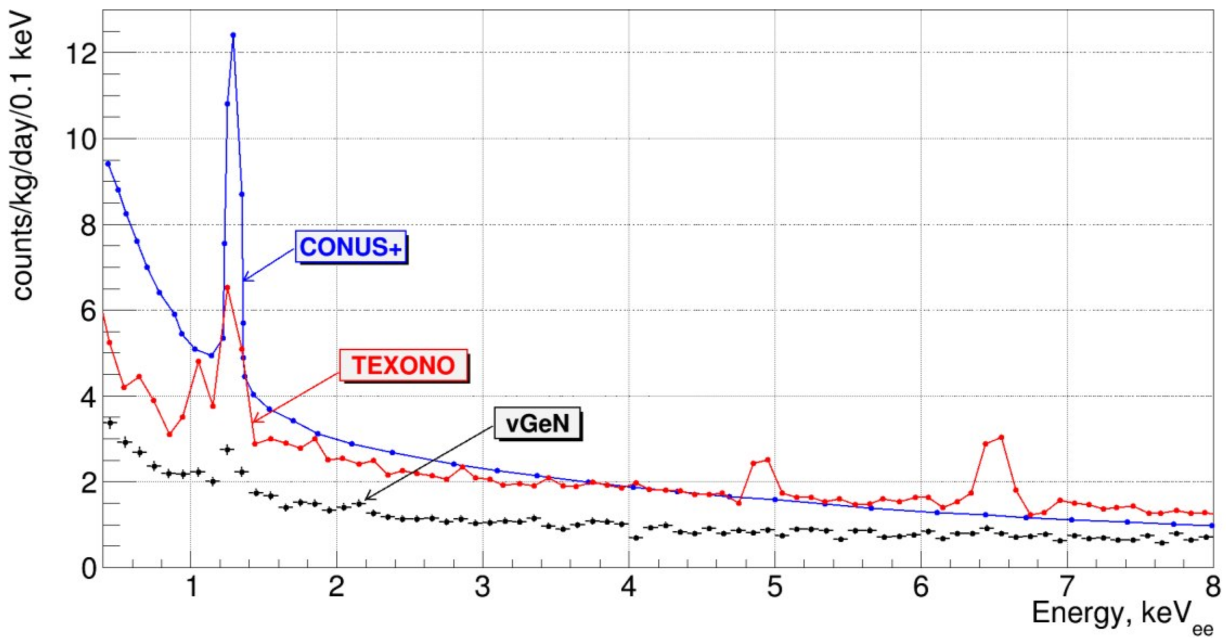


Resulting spectra

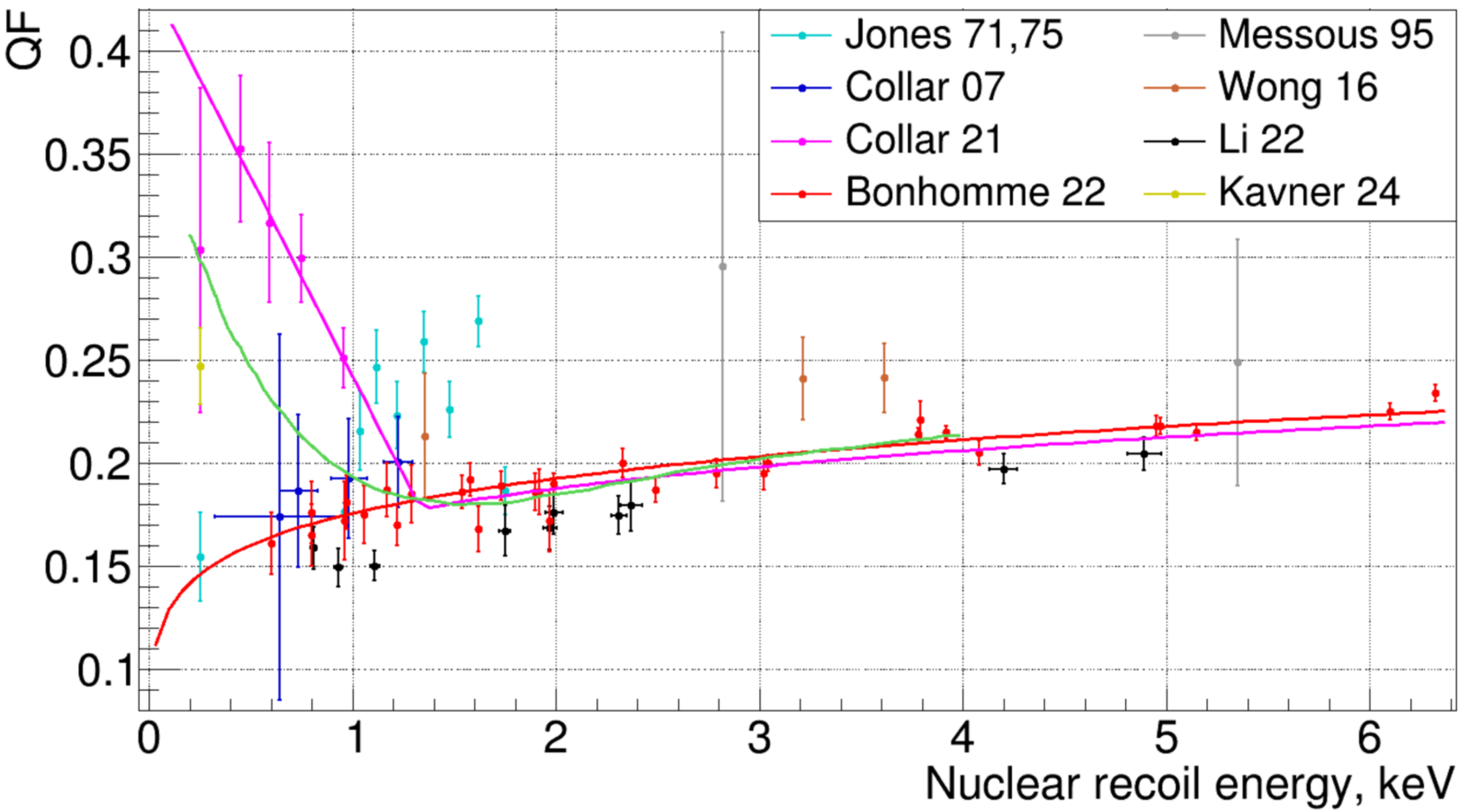
Comparison of normalized
ON (195.5 kg × d) and OFF **(54.6 kg × d)** spectra



Background level comparison for different experiments



Quenching factor (QF) problem



$$QF = \frac{E_{detected}}{E_{Nuclear\ recoil}}$$

Lindhard model (used in CONUS/CONUS+) – C

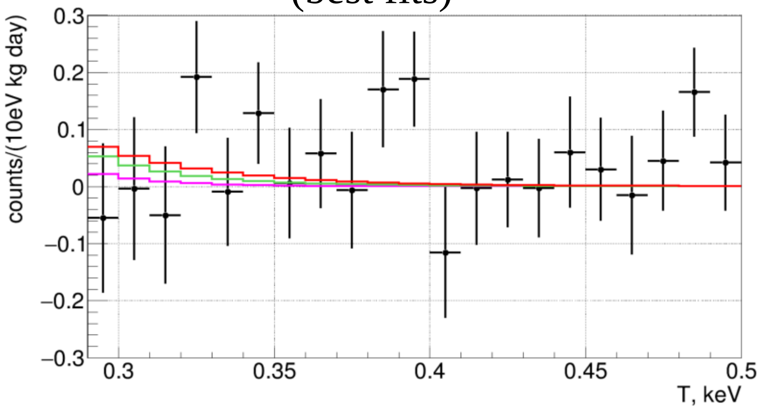
Dresden-II model – D1

Dresden-II model – D2

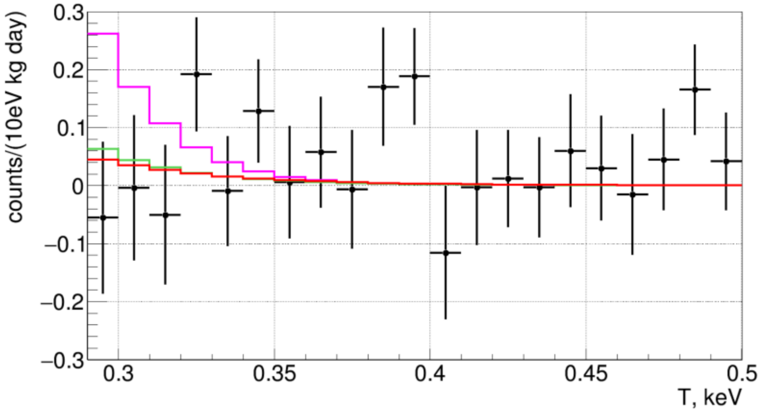
Results on CEνNS

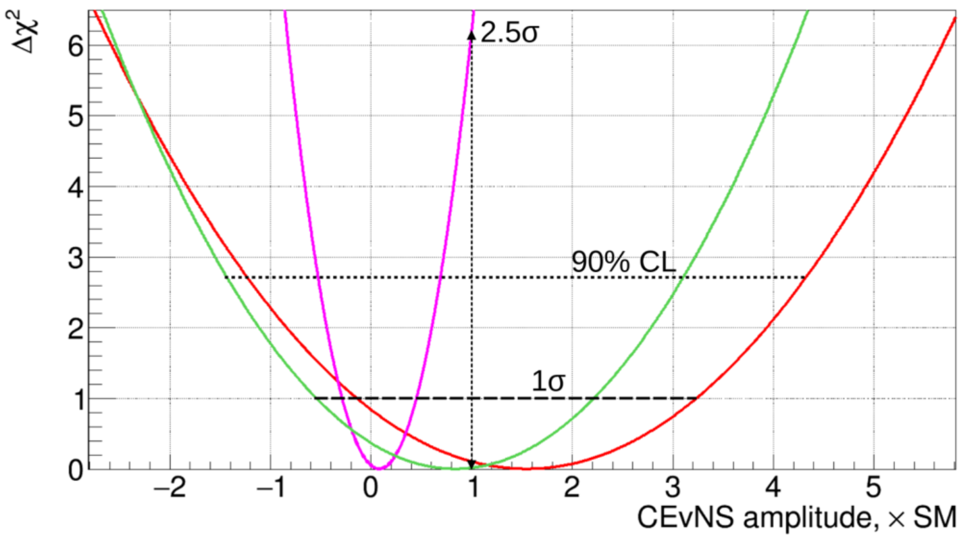
Quenching models:
C, D1, D2

Effect estimation based on ON-OFF data (best fits)



ON-OFF vs expected effect





Sensitivity and upper limits (90% CL)

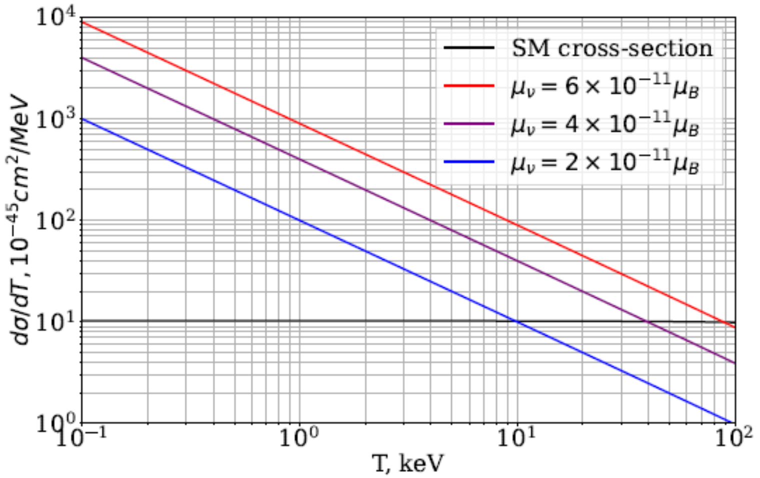
QF	$A_{best} \pm \sigma_A$, ×SM	χ^2_{best} (ndf=10)	S, ×SM	L, ×SM
C	1.5 ± 1.7	13.6	3.8	4.3
D1	0.1 ± 0.4	14.4	1.6	0.7
D2	0.8 ± 1.4	14.1	3.3	3.1

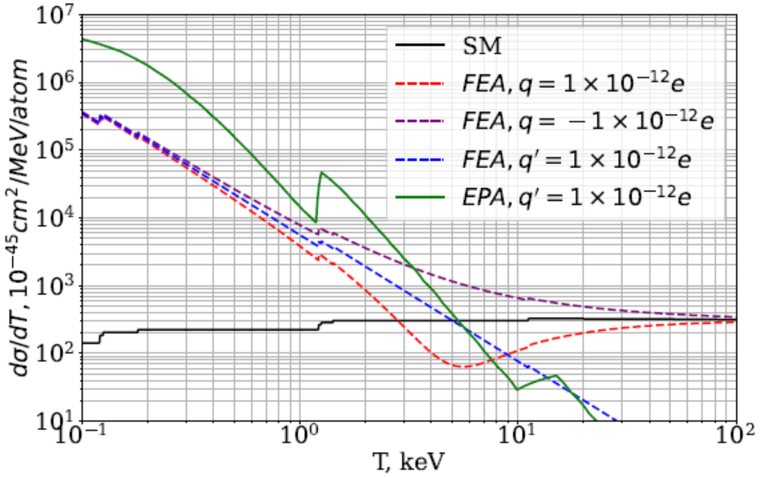
Upper limit (90% CL) at 4.3 times above SM (C QF)

Tension with **D1**-scenario

(*preliminary results*)

Results on electromagnetic properties of neutrino





Magnetic moment

Limit, $10^{-11}\mu_B$	Experiment	Type	Comment
7.5	νGeN	reactor	ON-OFF
7.4	TEXONO	reactor	ON-OFF
5.2	CONUS	reactor	ON-OFF
2.9	GEMMA	reactor	ON-OFF
0.64	XENONnT	solar	ON only

Astrophys.: $\mu_\nu < 1.2\times10^{-12}\mu_B$ [F. Capozzi, 2022]

Millicharge

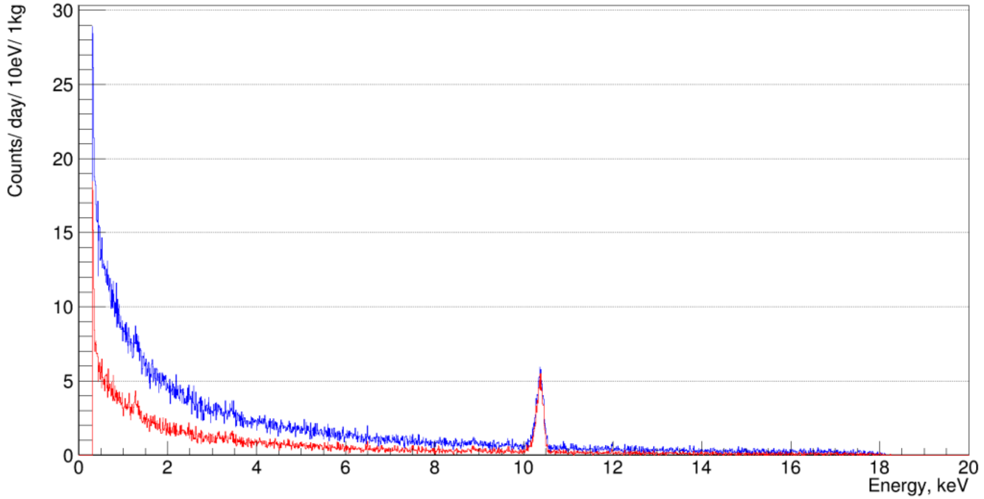
Limit, 10^{-12} e	Experiment	Type	Comment
2.7	GEMMA	reactor	FEA
1.2	TEXONO	reactor	EPA
2.4 (0.9)	νGeN	reactor	FEA (EPA)
0.6	CONUS+	reactor	EPA
0.224	LZ	solar	MCRRPA

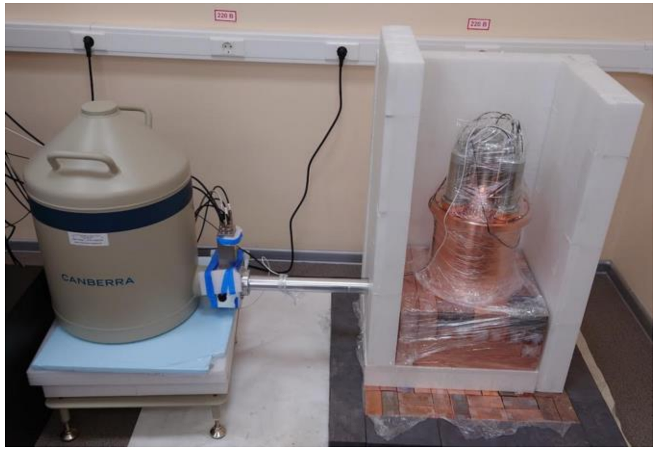
Matter neutrality: $q_\nu^{lim} \sim 10^{-35}$ [C. Caprini, 2003]

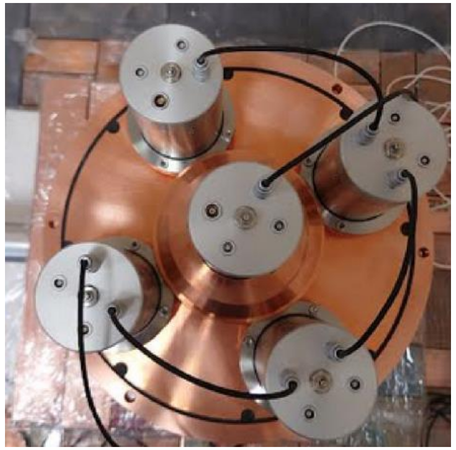
(*preliminary results*)

Future plans

Test measurements with 1 kg HPGe detector.
The effectiveness of applying NaI Compton veto







- Mounting 30 kg NaI Compton veto. Now - tests at the Baksan underground laboratory (overburden – 4800 m w.e.)
- Cryocooler modification: reduce power consumption → less vibrations→ less noise.
- DAQ modification: waveform analysis → noise / surface events rejection (see poster by D. Sautner)
- **The goal of all modifications:**
    - ***reduce the background level in the ROI***
    - ***Lower the effective threshold down to 150 – 200 eV***

Conclusions

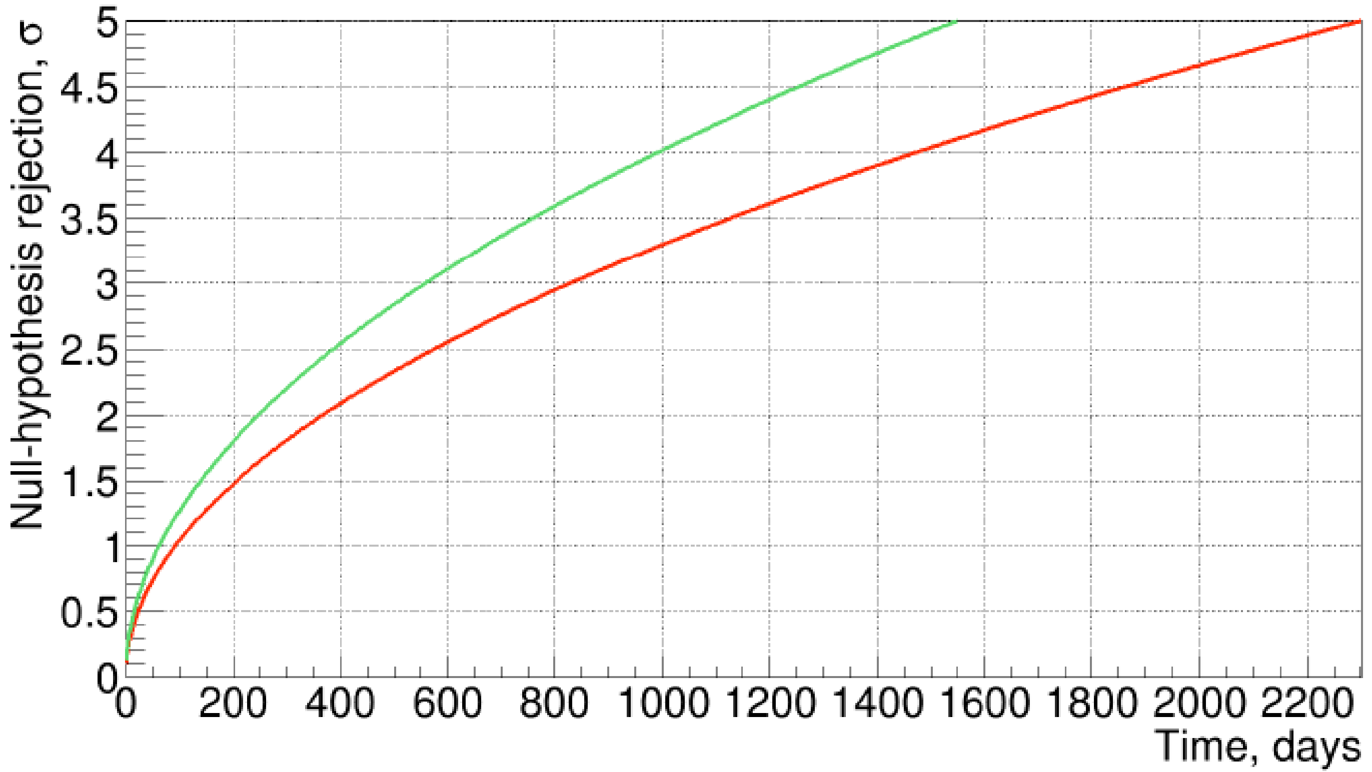
- Direct comparison of ON and OFF statistics without applying any background models/simulations has been made.
- Limit on the CEvNS count rate at 4.3×SM (C QF).
- Tension with Dresden-II (D1 QF) and νGeN result claim.
- Limits on electromagnetic properties: $\mu_\nu < 7.5 \times 10^{-11}\mu_B,\ q_\nu < 2.4\ (0.9) \times 10^{-12}e$ for FEA (EPA) cross-section scenario.
- The upgrade is planned to be in 2026. The goal is to reduce the background level in the ROI and Lower the effective threshold down to 150 – 200 eV.
- More data (>2100 kg*d) are being analyzed.
- The works on background model are ongoing.
- The results are published: **V. Belov et al. Chinese Phys. C 49 053004 (2025).**
- The data set on KNPP is ongoing.

Latest collaboration meeting in JINR

Thank you for your attention!

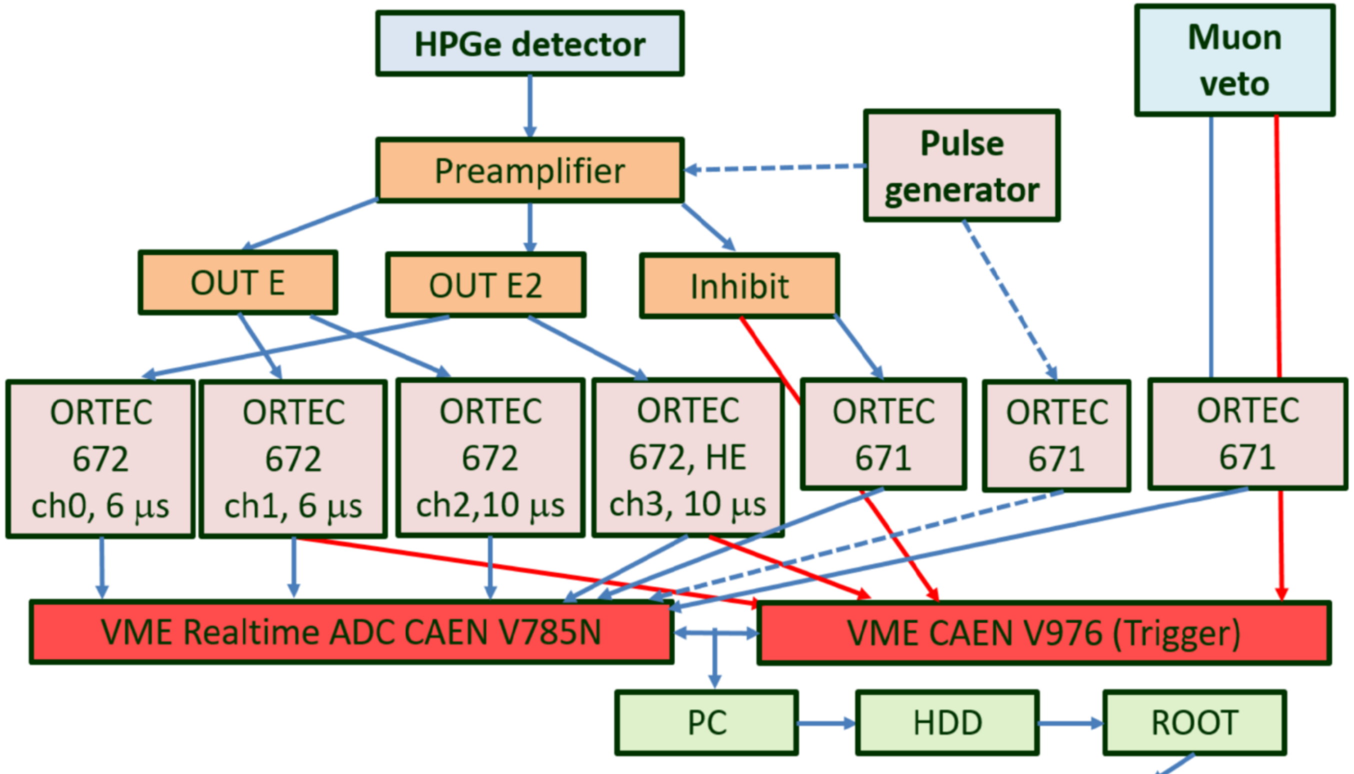
Backup slides

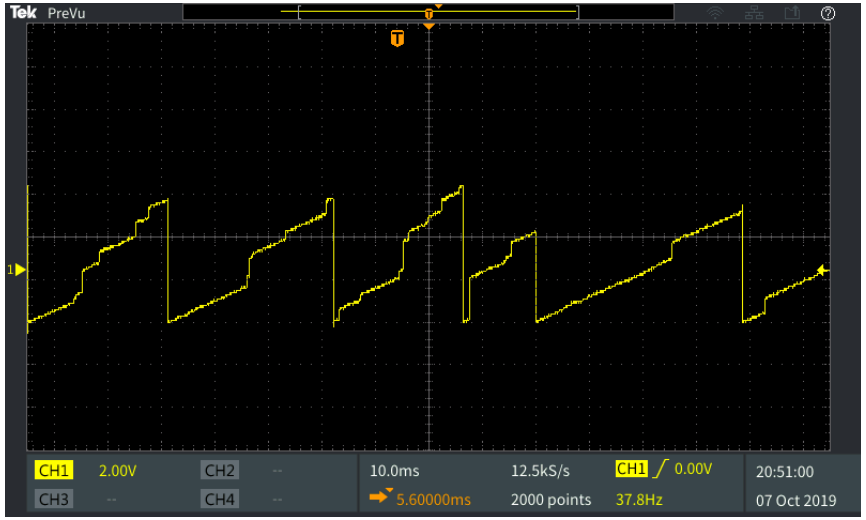
Sensitivity estimation



«Time» corresponds to ON / OFF statistics depending on the analysis strategy.

DAQ system





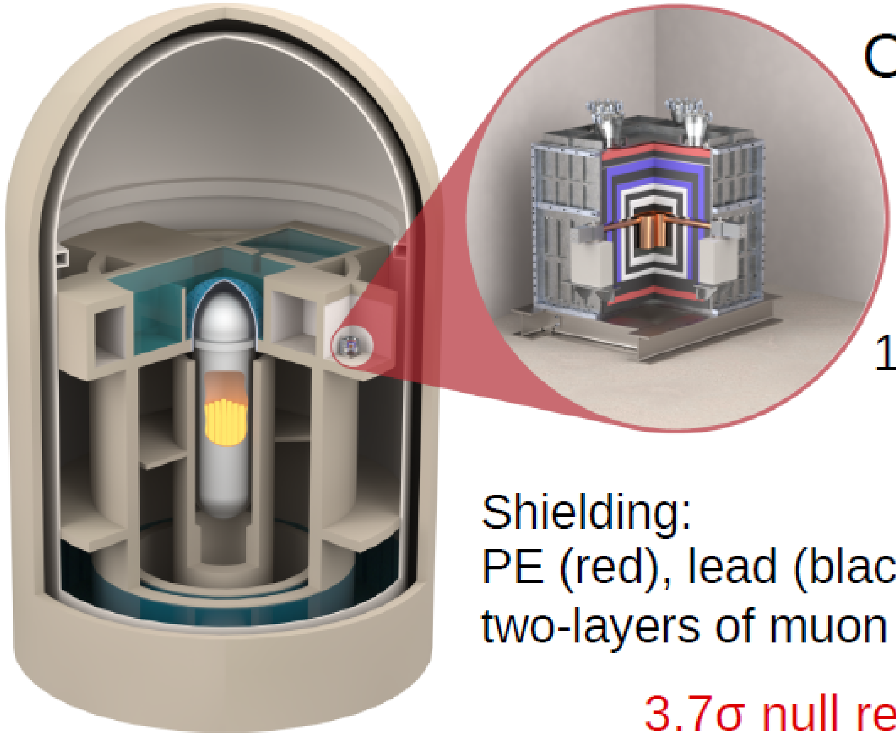
Reset preamplifier is used. Typical reset frequency is 5-30 Hz. Inhibit signal is used for identification of nonphysical signals caused by reset.

Real time signal processing is realized using VME electronics together with amplifiers with different shaping times.
Two energy regions:
low energies: 0.2 – 17 keV
high energies (HE): 17 – 1700 keV

Reactors: CONUS+

Nature v.643, 1229–1233 (2025)

Predecessor: CONUS at Brokdorf NPP, 4 HPGe,
3.7 kg tot. mass, E_{th}≈210 eV, 2024: limit of 1.6 times above SM



CONUS+ at Leibstadt

3.6 GW reactor
7.4 mwe overburden

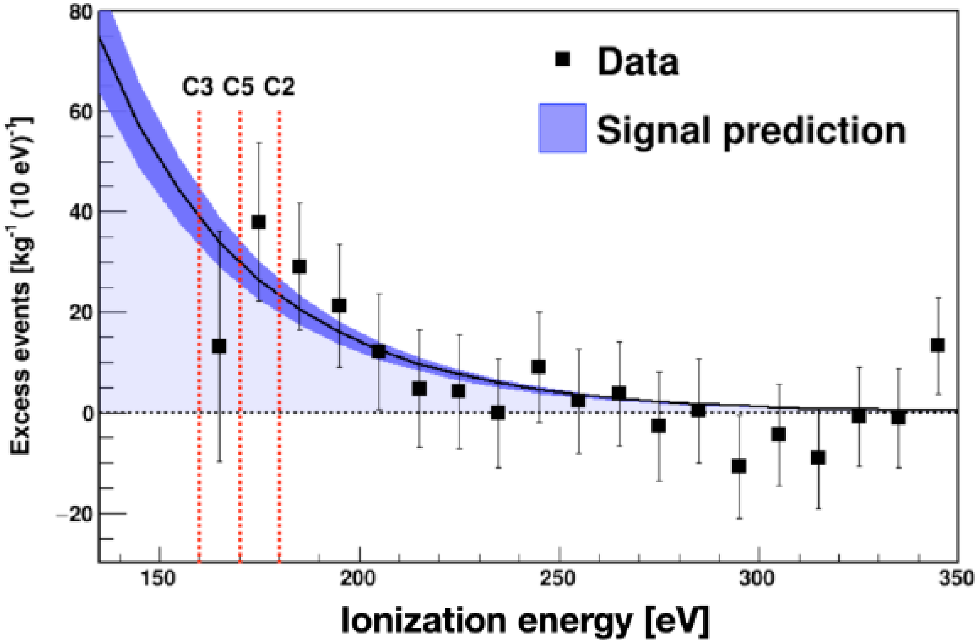
1.5×10^{13} ν/cm^2/s at 20.7 m

Shielding:
PE (red), lead (black) and B-doped PE (white), two-layers of muon veto panels (blue)

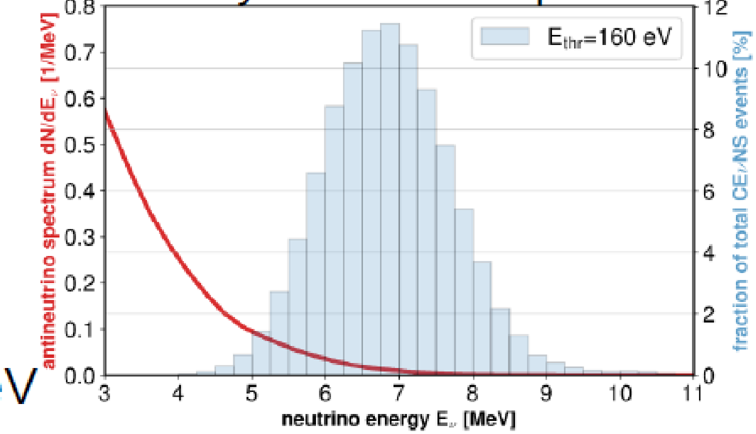
3.7σ null rejection!

Detector	E_{th} [eV$_{ee}$]	mass (kg)	live time	signal data	prediction	ratio
C2	180	0.95 ± 0.01	117.1 days	69 ± 47	96 ± 16	0.72 ± 0.50
C3	160	0.94 ± 0.01	109.9 days	186 ± 66	135 ± 23	1.38 ± 0.54
C5	170	0.94 ± 0.01	119.5 days	117 ± 75	116 ± 20	1.01 ± 0.67
combined		2.83 ± 0.02		395 ± 106	347 ± 59	1.14 ± 0.36

Analysis approach: comparison of ON spectrum with data driven BG model.



Sensitivity to reactor ν spectrum

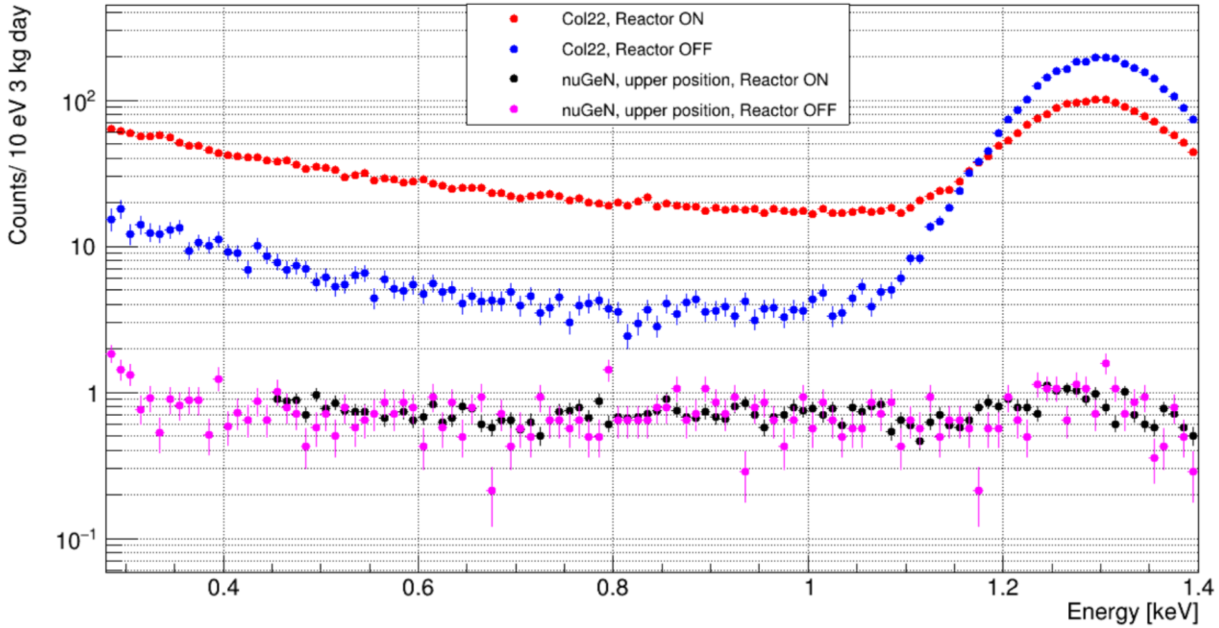


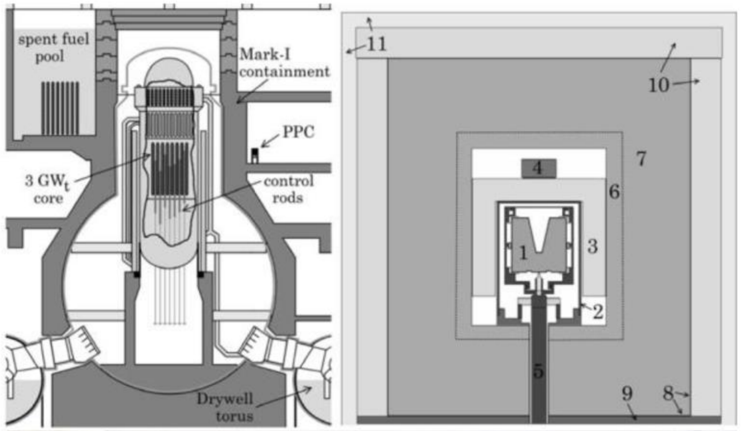
Now new 2.4 kg HPGe, plans for a O(100 kg) HPGe array and E_{th} ~100 eV

Comparison with DRESDEN-II

PHYSICAL REVIEW LETTERS 129, 211802 (2022)

- 1 HPGe detector, ~3 kg
- Data: 96.4 days ON, 25 days OFF
- Energy resolution >160 eV (FWHM)
- Big difference between ON and OFF
- Different shielding
- Almost no shieling against fast neutrons





COHERENT: results

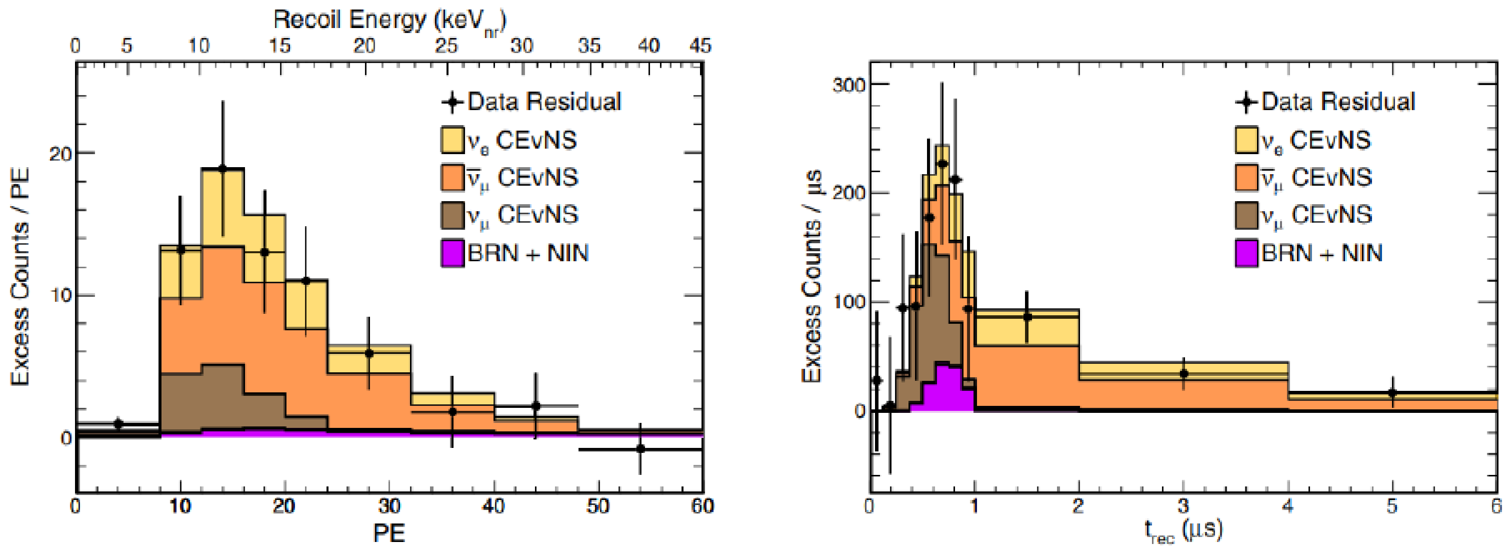
CsI[Na], 14.6 kg

2015-2017: 6.7σ | $\sigma_{meas}/\sigma_{SM} = 0.77 \pm 0.25$

Science vol. 357 iss. 6456 (2017)

2015-2019: 11.6σ | $\sigma_{meas}/\sigma_{SM} = 0.87^{+0.16}_{-0.13}$

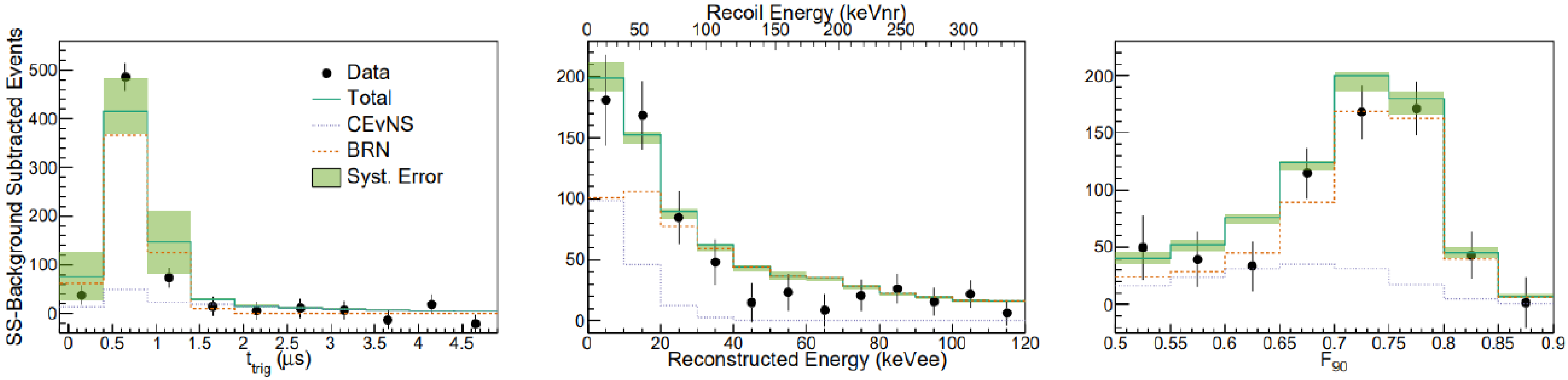
PRL vol. 129 081801 (2022)



LAr, 24 kg (CENNS-10)

2017-2018: ~3σ $\sigma_{meas}/\sigma_{SM} = 1.28 \pm 0.39$

PRL vol. 126 012002 (2021)

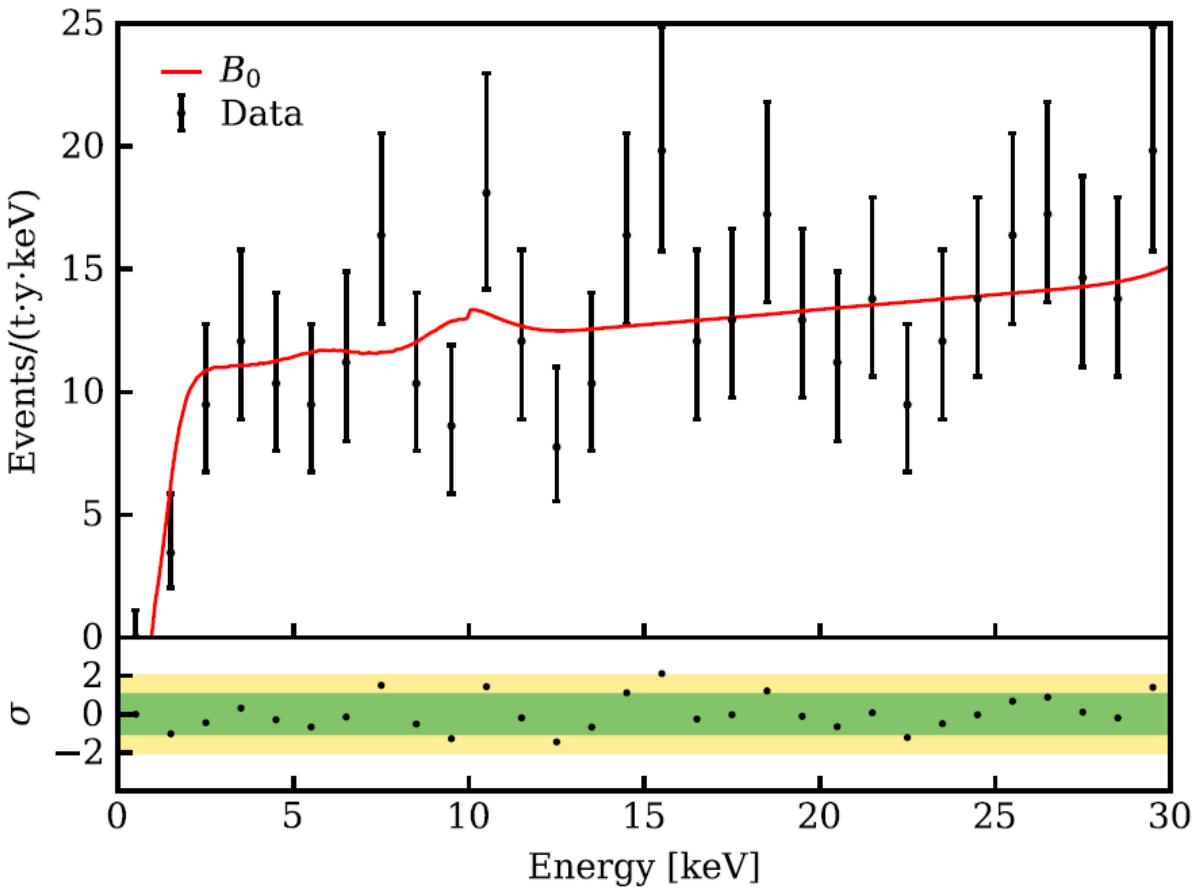


Soon: full statistics of 2017-2021, ~5σ null-rejection expected

XENONnT

PHYSICAL REVIEW LETTERS 129, 161805 (2022)

- m = 5.9 ton (liquid Xe)
- ROI: 1 – 30 keV
- Bkg: 15.8 1/(ton × year × keV)
- 1.16 ton*years statistics
- $\mu_\nu < 6.4 \times 10^{-12}\ \mu_B$



LZ

(PHYSICAL REVIEW D 108, 072006 (2023))

- Dual phase Xe TPC
- t = 60 days
- m = 5.5 ton
- $q_\nu < 2.24 \times 10^{-13}\ e$