A. Konovalov on behalf of the νGeN collaboration

Looking for CEvNS with the νGeN experiment

Joint Institute for Nuclear Research, Dubna

Institute of Experimental and Applied Physics, Czech Technical University in Prague

Lebedev Physical Institute of the Russian Academy of Sciences, Moscow

Magnificent CEvNS, ADEIT

June 12 2024

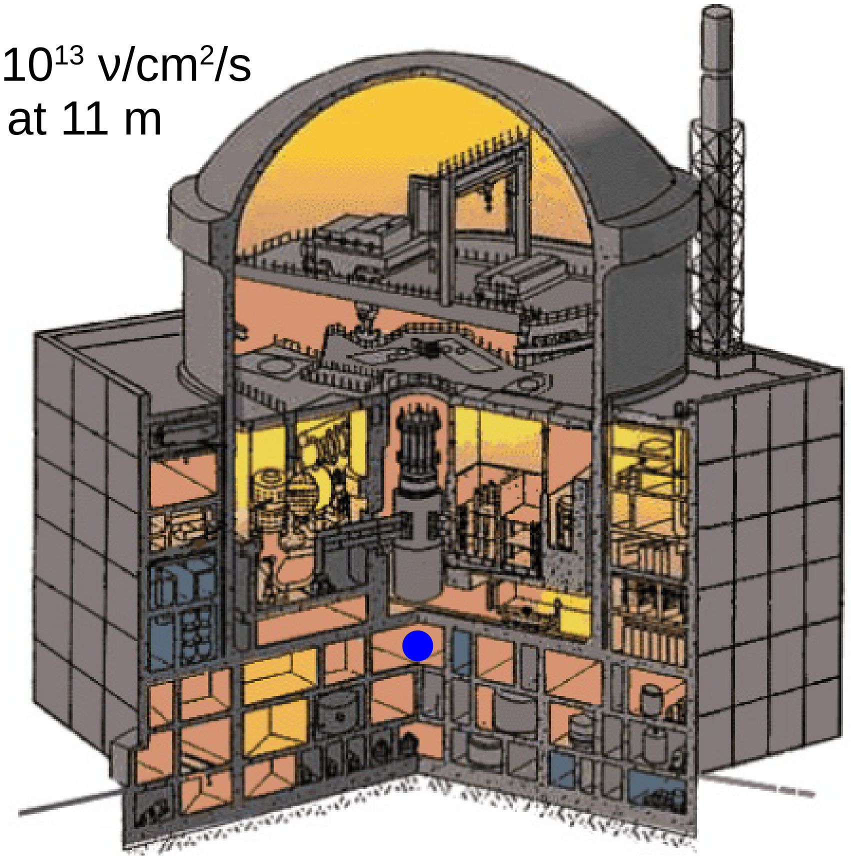
Neutrino experiments at Kalinin NPP

Four neutrino experiments at the same nuclear power plant!

4 WWER-1000 reactors, 3.1 GW_{th} each

Typically 18 months ON, 45 days OFF

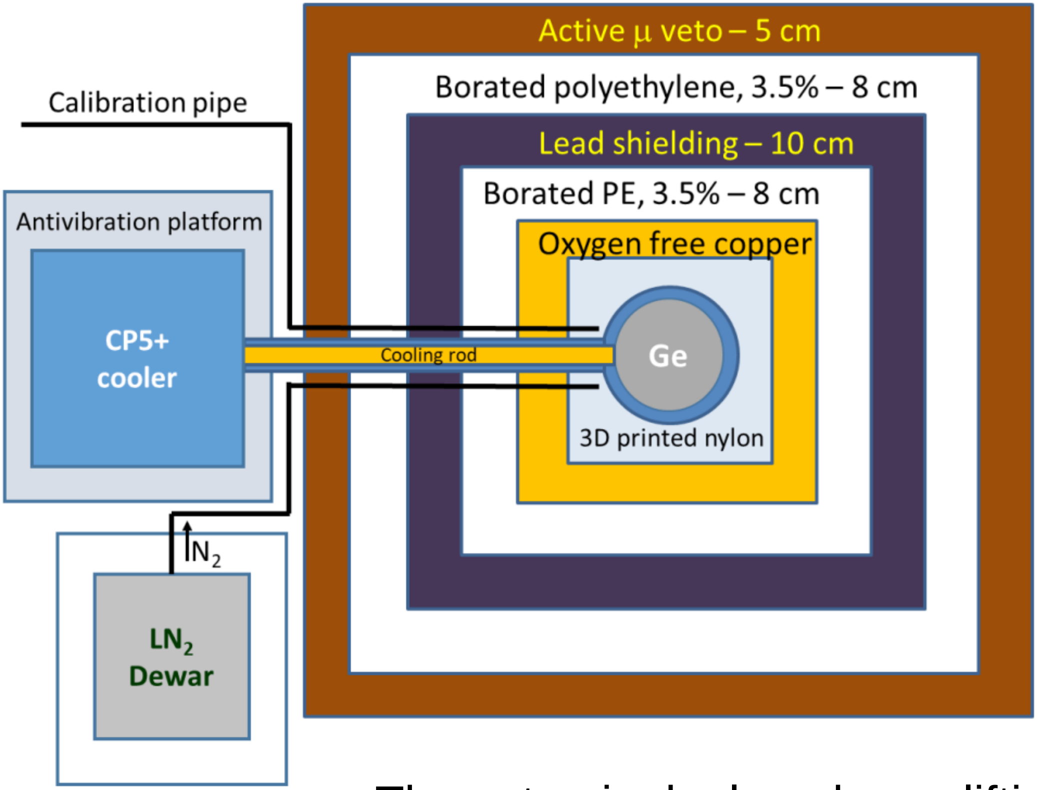
$4.4 \cdot 10^{13}$ ν/cm²/s at 11 m

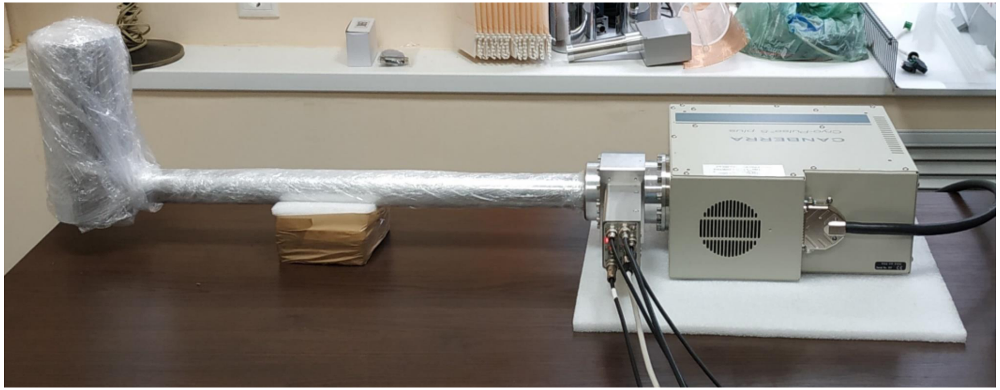


50 m.w.e. of materials above

The νGeN setup

The multi-layered shielding protects the Ge detector



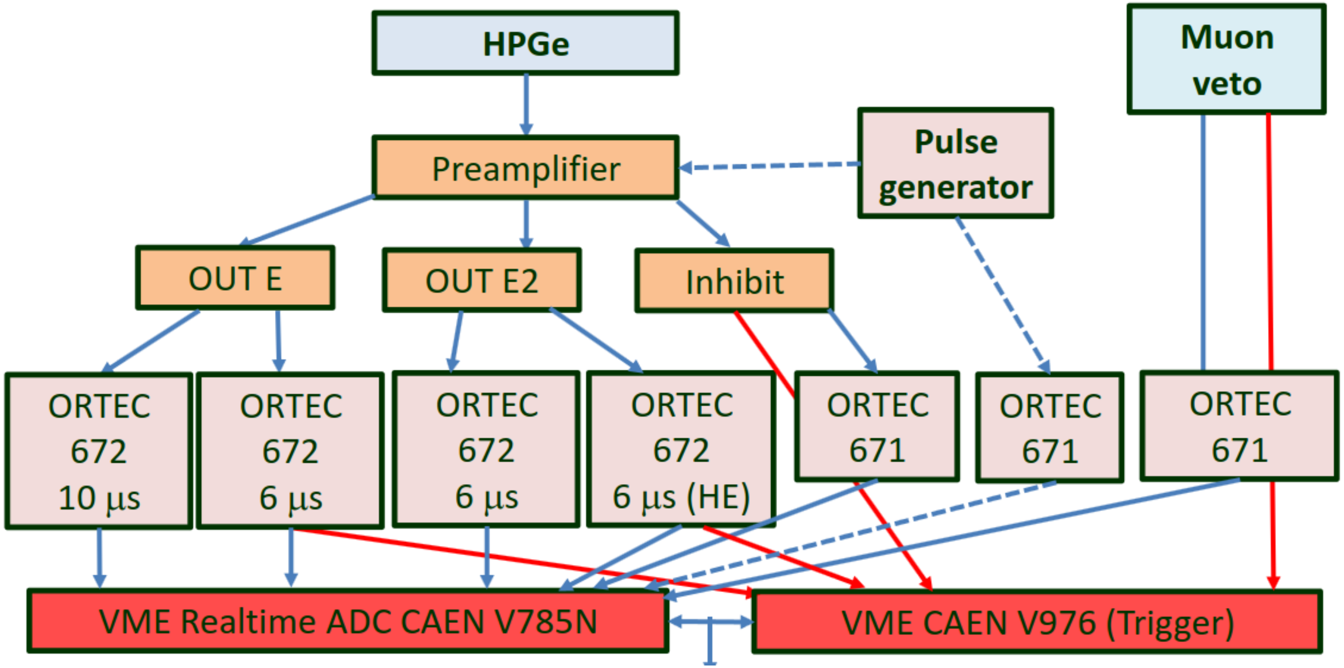


CANBERRA (Mirion, Lingosheim) detector

- HPGe PPC, 1.4 kg active mass
- low T by a cryocooler
- reset preamplifier
- pulser FWHM of 102 eV at KNPP

The setup is deployed on a lifting mechanism (L = 12.5 -> 11.0 m), the shielding is on an anti-vibration platform

Electronics & DAQ



- Reset preamplifier
- Shaping amplifiers / no WFs
- Noise supression:
  - OUT E to E2, same τ_{sh}
  - 6 μs to 10 μs for OUT E
- For selections and veto:
  - «inhibit» reset signal
  - muon veto

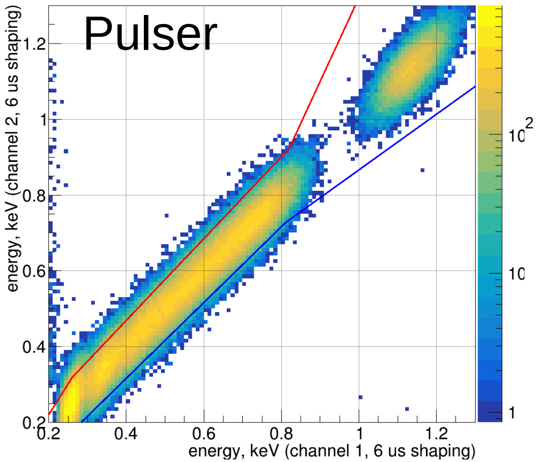
Dynamic range:

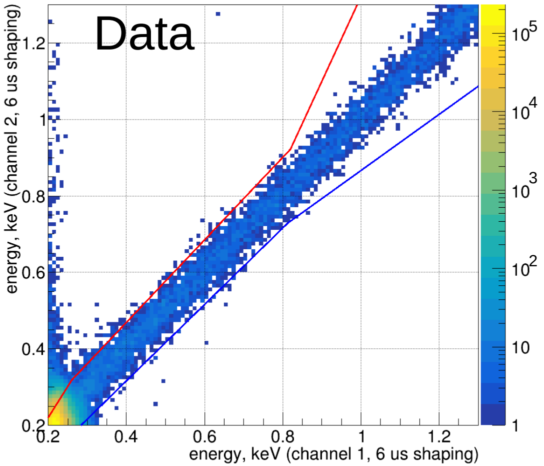
1. «Low energy»: ~0.2 to 16 keV
2. «High energy»: 16 keV to ~1 MeV

Total exposition: more than 1500 kg×d up to 2024, but different noise and BG conditions

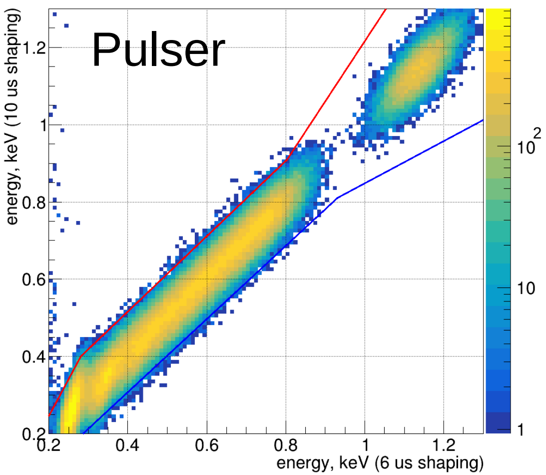
Selections

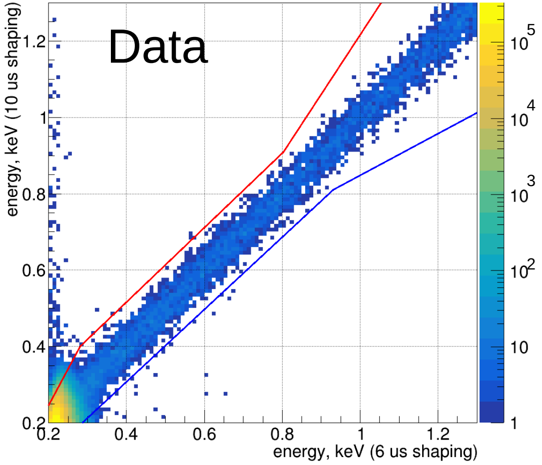
Correlation of two channels with the same τ_{sh}





Comparison of a channes with different with τ_{sh}

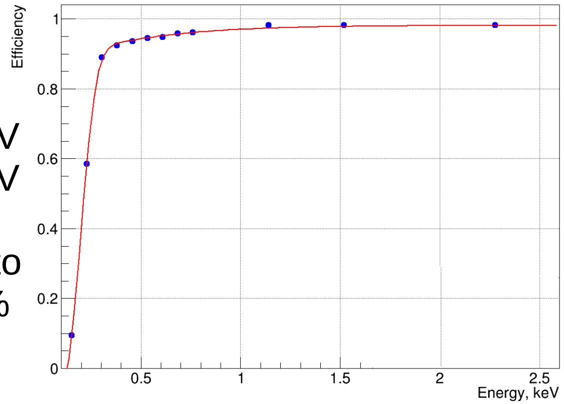




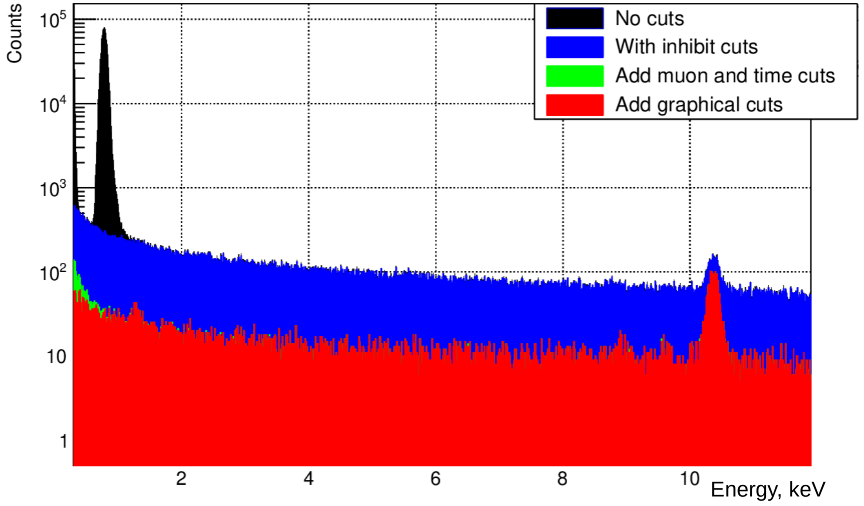
Eff-cy of a trigger +graphical cuts:

~45% for 0.2 keV
~85% for 0.3 keV

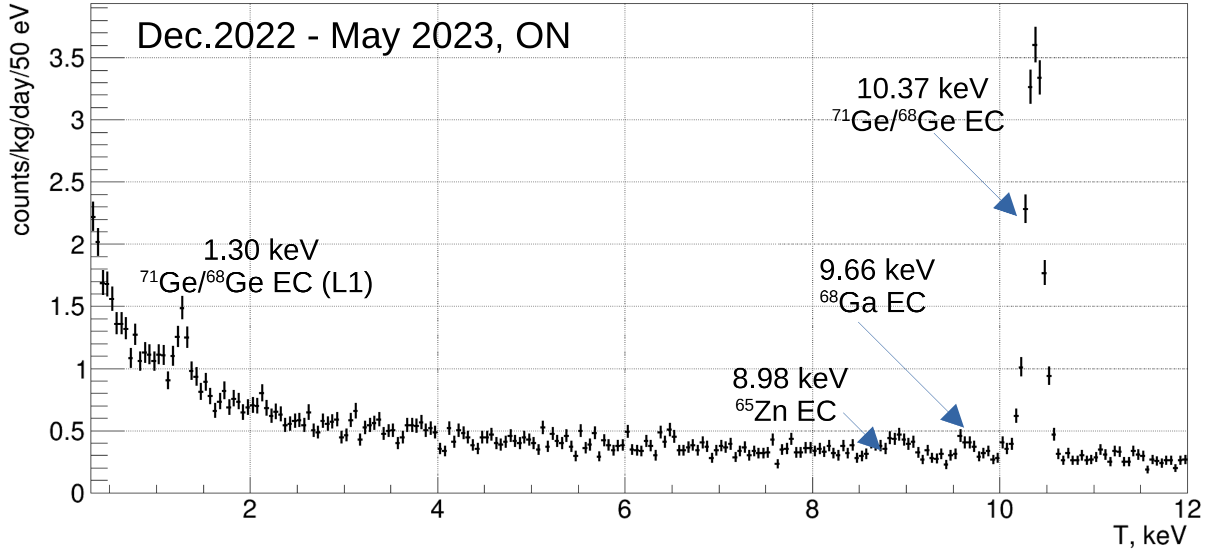
Inhibit and μ veto
Introduce ~10%
dead time total



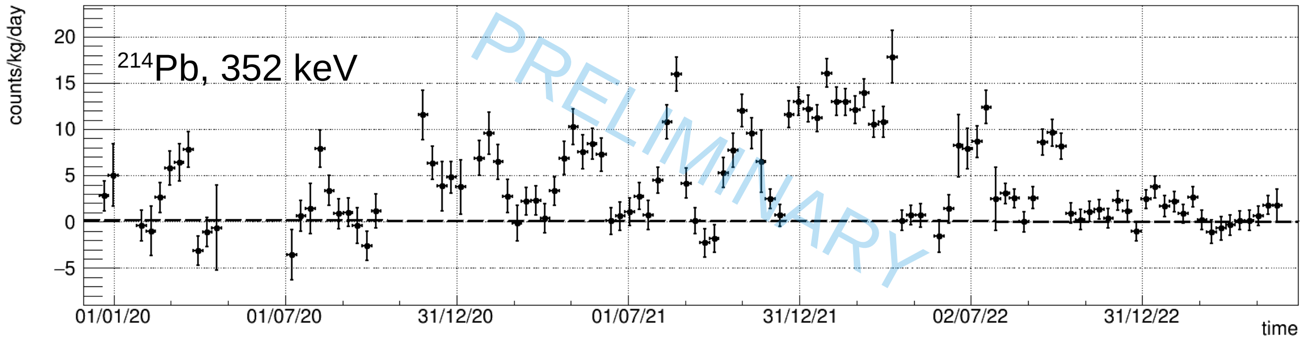
BG reduction by the selections



BG and its stability



Fluctuations of Rn affect the whole range, including CEvNS ROI



+ slow general decrease of the BG substrate count rate

E, keV	Source	Rate, $(kg\times d)^{-1}$
1.30	$^{71}Ge/^{68}Ge$ EC (L1)	$\sim1.3^{\times}$
8.98	^{66}Zn EC	$\sim0.7^{\times}$
9.66	^{68}Ga EC	$\sim0.5^{\times}$
10.4	$^{71}Ge/^{68}Ge$ EC (K)	$14.8^{\times}$
46.5	^{210}Pb	1.1
66.7	$^{72}Ge(n,\gamma)^{73m}Ge$	6.1*
140	$^{74}Ge(n,\gamma)^{75m}Ge$	1.8
198	$^{70}Ge(n,\gamma)^{71m}Ge$	1.7
242	^{214}Pb (^{222}Rn)	0−3.2
295	^{214}Pb (^{222}Rn)	0−7.8
352	^{214}Pb (^{222}Rn)	0-13.2
511	annihilation	11.6
609	^{214}Bi (^{222}Rn)	0−9.5
662	^{137}Cs	5.9
1173	^{60}Co	3.5

PRELIMINARY

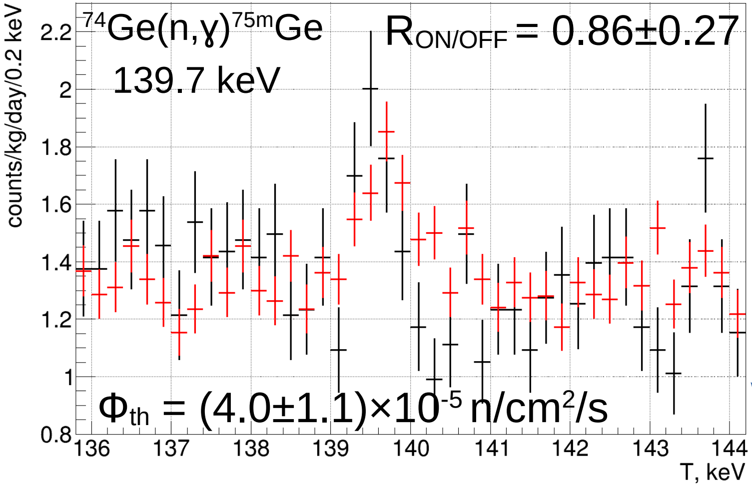
+ Pb, Bi X-rays

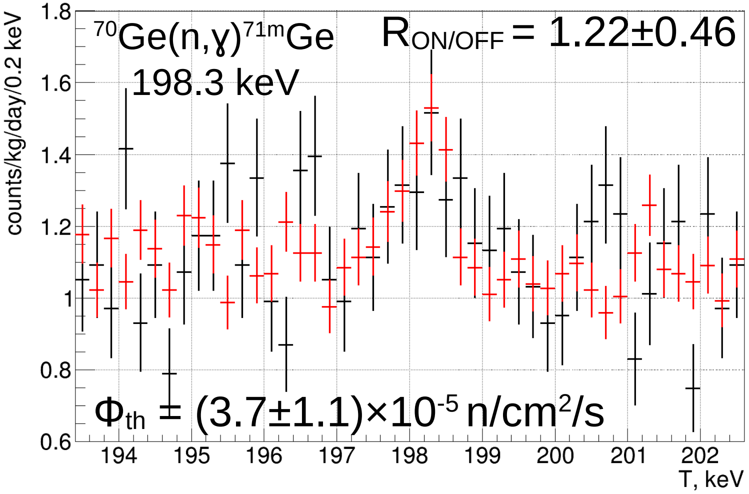
* - [53.4+13.3] keV, affected by τ_{sh}

× - as of Dec. 2022- May 2023

Neutron background characterization

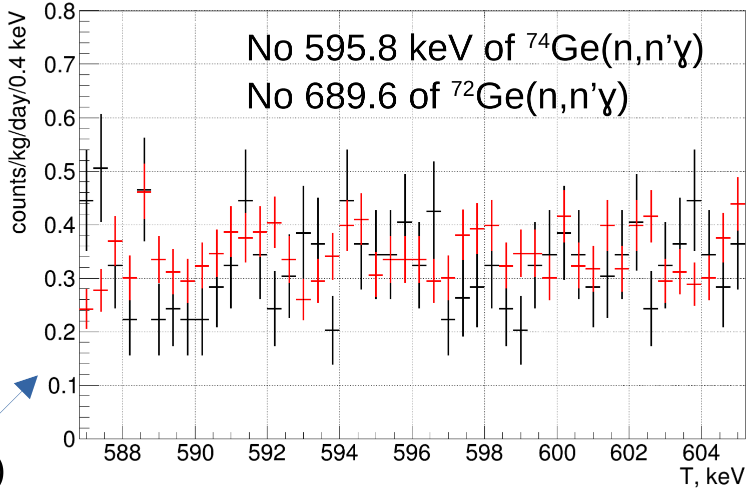
Thermal neutrons





Plots for
OFF: 38 d (black)
ON: 137 d (red)

Absense of peaks from inelastics



Ongoing simulations and a measurement for verification: ^{252}Cf in the lab with a similar HPGe

Fast neutron flux measurements

Measurements with the Bicron LS cell (PSD) at KNPP, both ON and OFF periods

Approach to the quenching problem

<u>Ongoing discussion</u>

Dresden-II

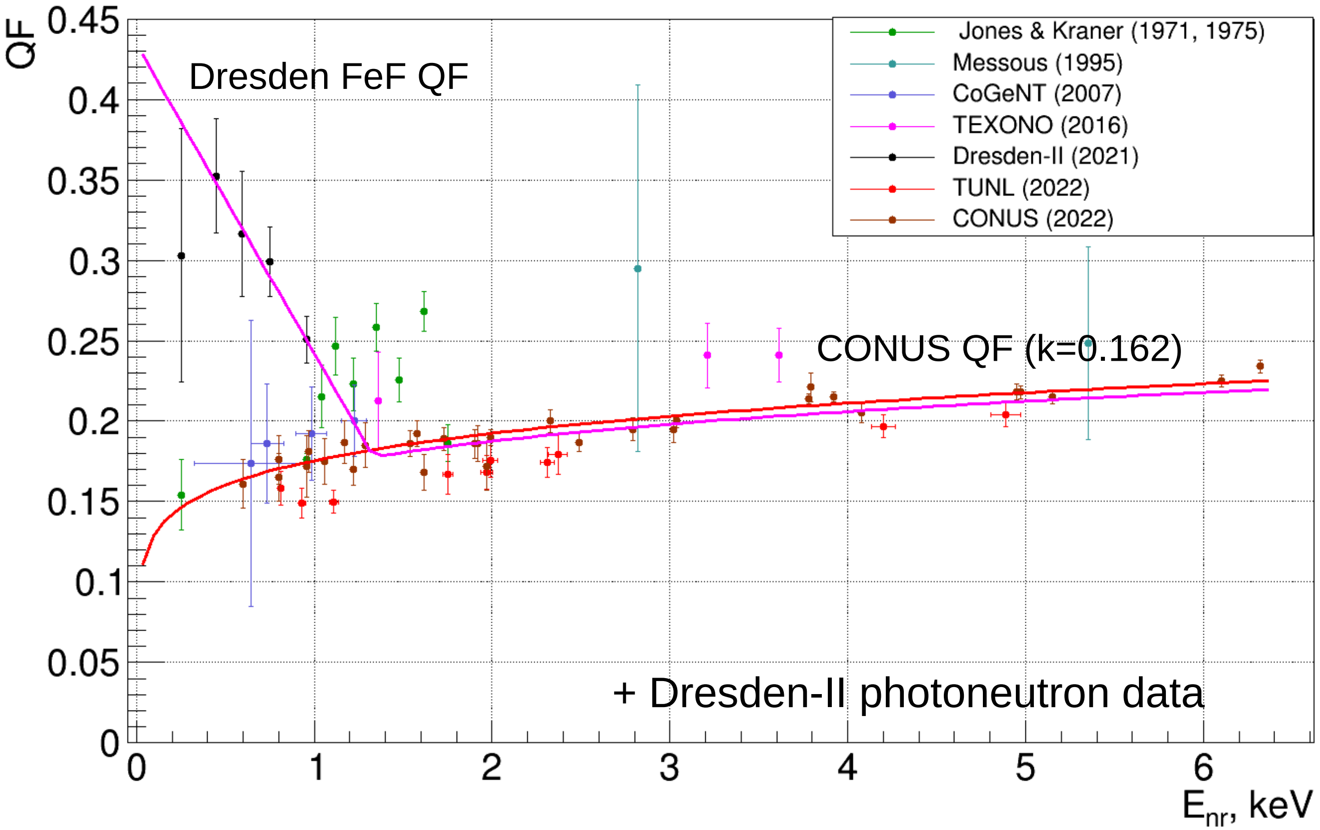
Phys. Rev. D 103, 122003 (2021)

TUNL, L. Li, PhD thesis (2022)

https://hdl.handle.net/10161/25153

CONUS

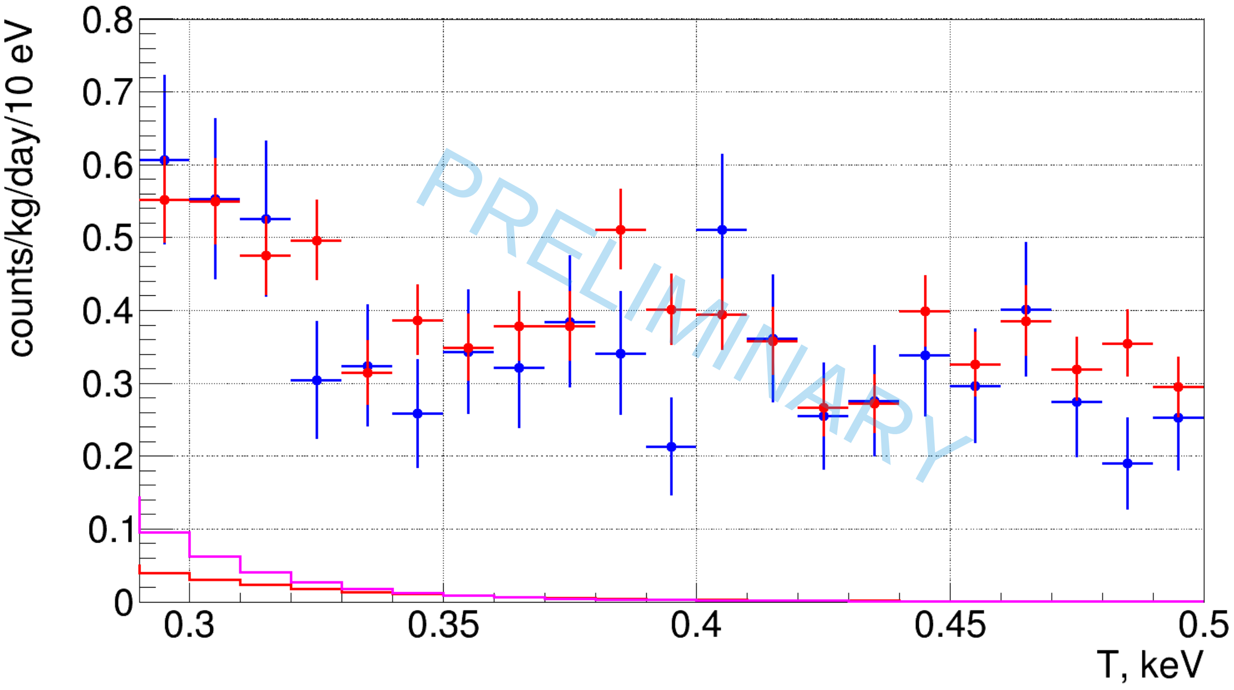
Eur. Phys. J. C (2022) 82:815



We consider two cases: CONUS QF (Lindhard k=0.162), Dresden QF (FeF, mod. k=0.157)

Dataset

Collected October 2022 — May 2023 at 11.1 m from the reactor core



OFF (blue): 38 days
ON (red): 137 days

Prediction (SM2018 spectra):

CONUS QF — red line
Dresden QF — magenta line

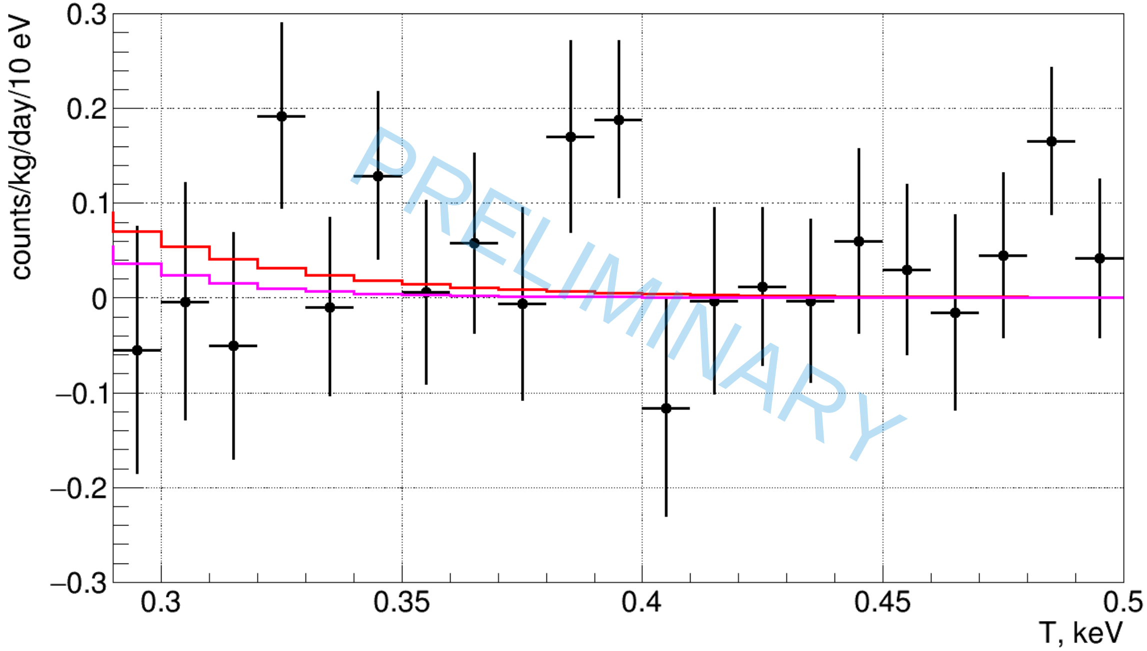
Analysis ROI: 0.29-0.4 keV

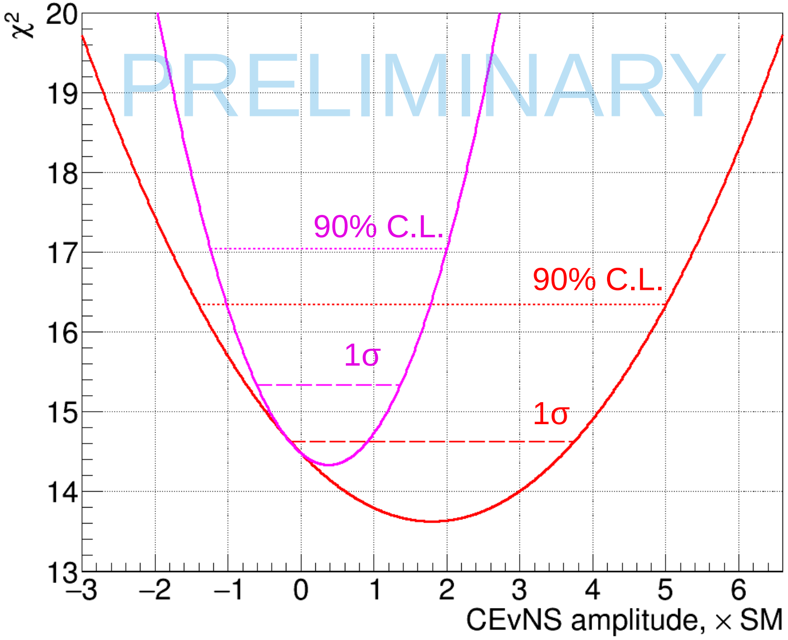
0.29 keV — stability considerations
0.40 keV — provides <1% loss of the sensitivity

QF	Prediction, ev./kg/day	Sensitivity, ×SM	68% expectation for a 90% C.L. limit, ×SM
CONUS	0.159	4.1	2.3-6.0
Dresden	0.278	2.6	1.6-3.6

Fit and results

Best fits and χ^2 profiles: CONUS QF(red line), Dresden QF (magenta line)



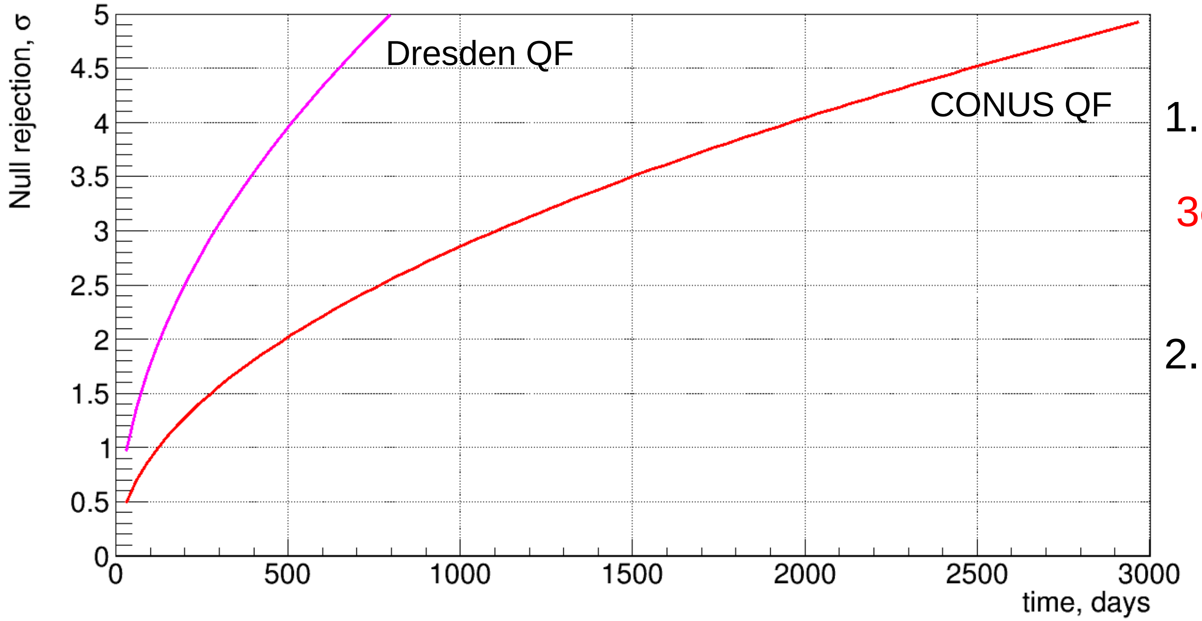


QF	Prediction, ev./kg/day	Sensitivity, ×SM	68% expectation for a 90% C.L. limit, ×SM	Best fit, ×SM	90% C.L. limit
CONUS	0.159	4.1	2.3-6.0	1.80	5.0
Dresden	0.278	2.6	1.6-3.6	0.38	2.0

Sensitivity extrapolation

Given the measured BG rate and currently achieved threshold we can extrapolate the sensitivity studies

Null rejection significance under assumption of SM



Two scenarios:

1. Direct ON - OFF: time = OFF, ON = 11×OFF

3σ at ~300 / 1100 days OFF depending on QF
- unrealsitic for a current E_{th}

2. ON - BG model (no syst.): time = ON

3σ at ~1 / 3 years, 5σ at 2.5 / 8 yeads

Need to:

1. Deconvolve the BG -> full BG model: studies and simulations ongoing

2. Improve threshold / reduce BG -> modifications and upgrades

Sensitivity to NMM

The best limit at reactors is set by GEMMA — $\mu_\nu < 2.9\cdot10^{-11}\ \mu_B$ (90% C.L.)

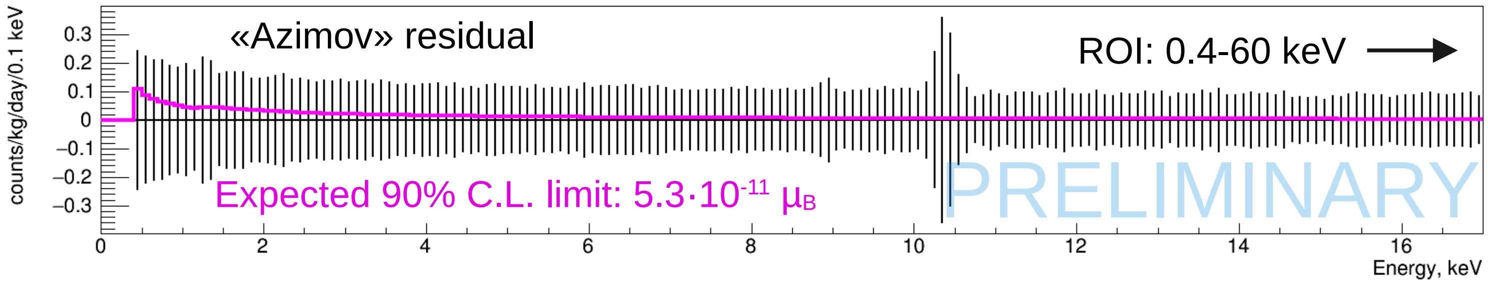
Experiment	Mass, kg	ν flux, $cm^{-2}s^{-1}$	E_{th}, keV_{ee}	Reference
GEMMA	1.5	$2.7\cdot10^{13}$	2.8	Adv.High Energy Phys. 2012
νGeN	1.4	$4.4\cdot10^{13}$	0.2-0.3	Phys.Rev.D 106 (2022)
COνUS	3.7	$2.3\cdot10^{13}$	0.2-0.3	Eur.Phys.J.C 82 (2022)
Dresden-II	2.9	$4.8\cdot10^{13}$	0.2-0.3	JHEP 09 164 (2022)

LZ dark matter experiment (solar ν) — $\mu_{\nu e} < 1.5\cdot10^{-11}\ \mu_B$ (90% C.L.)
Astrophysical considerations — $\mu_\nu < 3.0\cdot10^{-12}\ \mu_B$ (90% C.L.)

Phys. Rev. D 107, 053001 (2023)

Astrophys. Journal, 365 559 (1990)

Sensitivity studies: OFF – 69.2 d (same dataset, loose cuts), ON (est.) – 140.2 d



For 900 d ON + BG model

Median exp. limit: $\sim2.5\cdot10^{-11}\ \mu_B$
68% in $[1.8,3.3]\cdot10^{-11}\ \mu_B$

More sensitive to stability and BG systematics due to large ROI and statistics

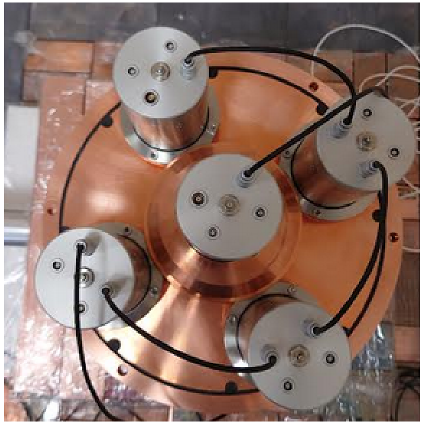
Upgrades and modifications

Noise & BG reduction tests in the JINR lab:

1. «Compton veto» — set of NaI crystalls to supress multiple scattering events

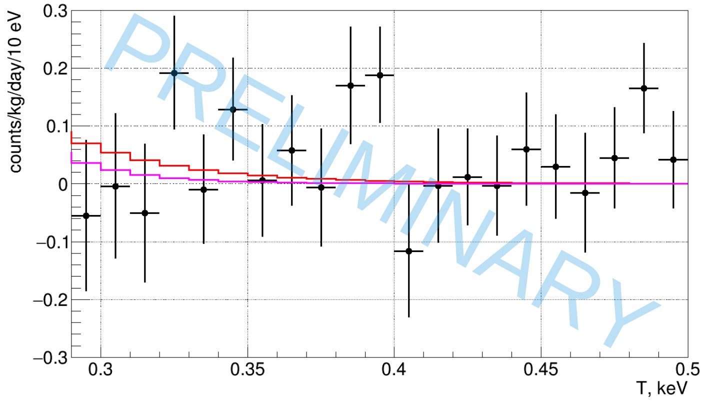
2. Modifications of the cryocooler to reduce its power consumption

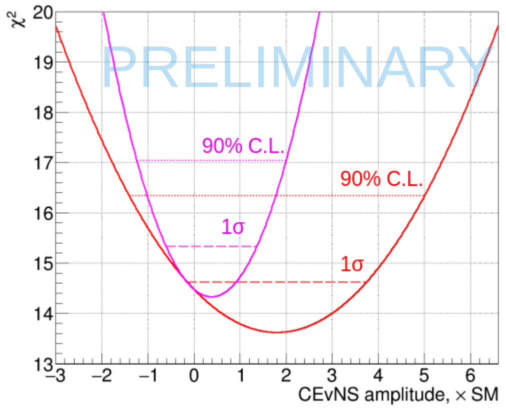
3. DAQ tests for a better discrimination of noise and surface events



Summary

- We set the 90% C.L. limit on the CEvNS rate: 5.0/2.0 ×SM depending on QF





- We continue the data analysis and simulations to use all available statistics (more than 1500 kg×d total)

- We perform lab tests of the modifications to reduce BG and improve the threshold

Thank you for your attention!