A. Konovalov on behalf of the νGeN collaboration

Status of the νGeN neutrino experiment at Kalinin NPP

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ICPPA-2024, Moscow

October 23 2024

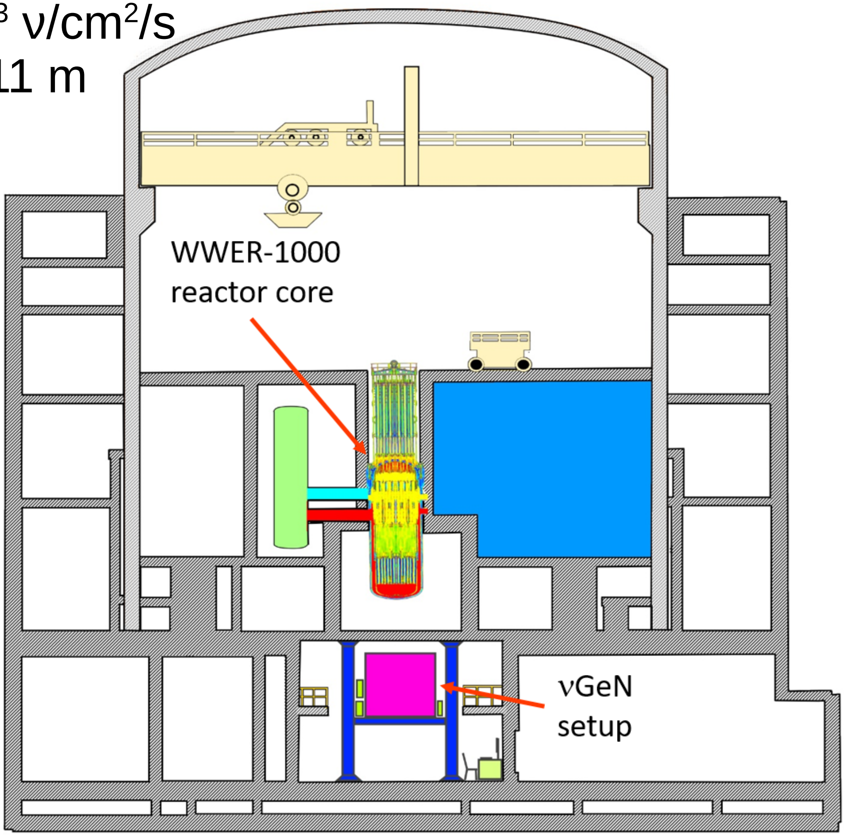
Neutrino experiments at Kalinin NPP

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

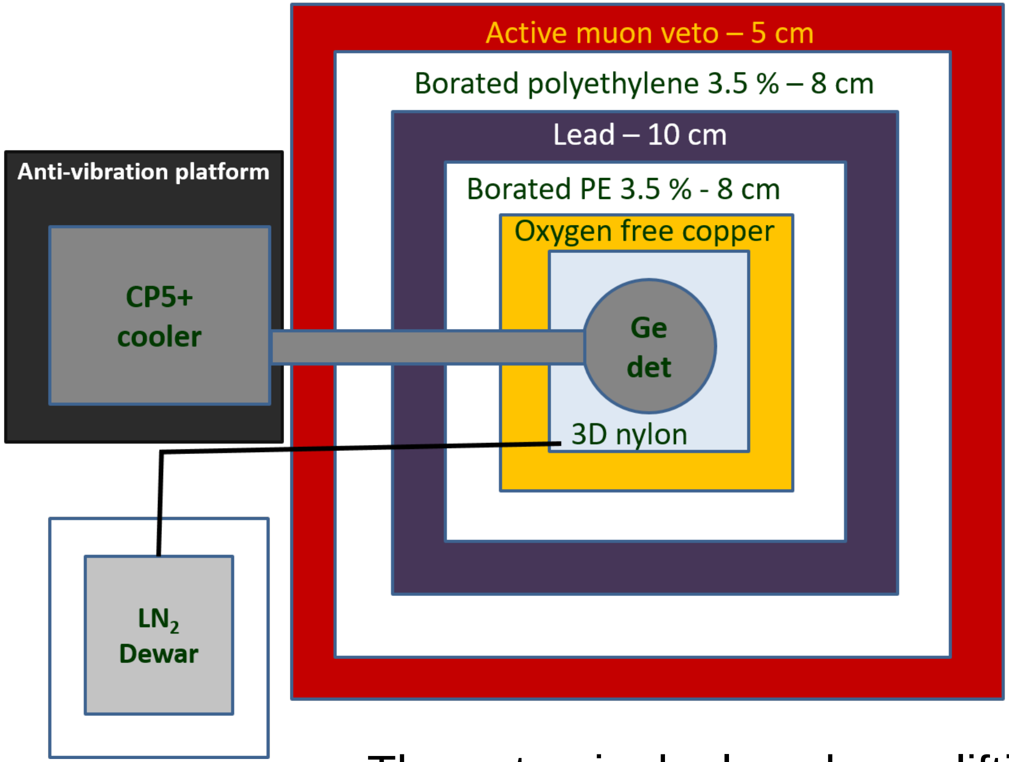


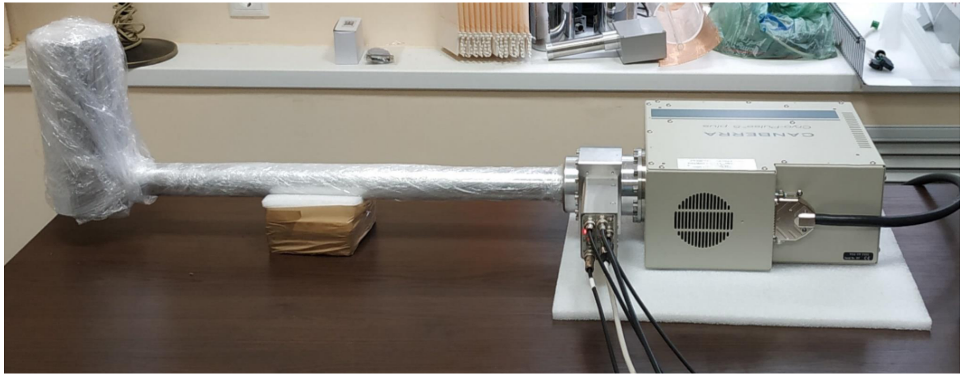
50 m.w.e. of materials above

See also talks by O. Razuvaeva (RED-100), I. Alekseev (DANSS), A. Oralbaev (iDREAM)

The νGeN setup

The multi-layered shielding protects
the Ge detector



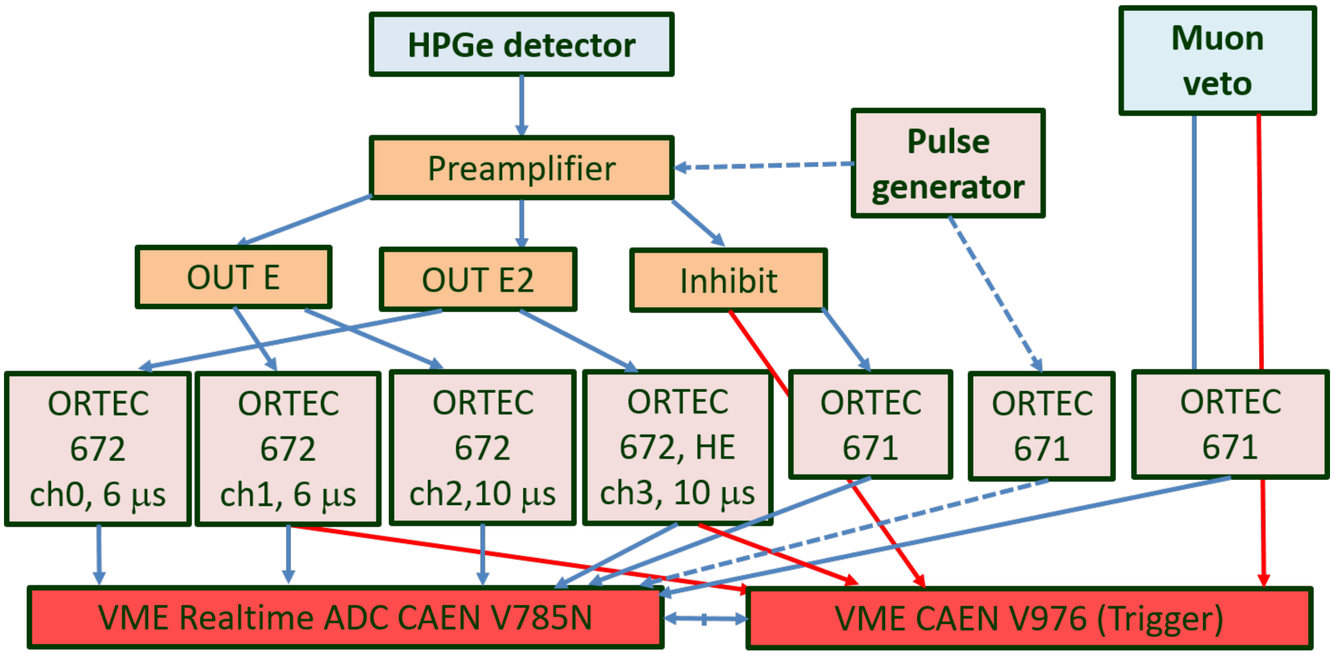


CANBERRA (Mirion, Lingosheim) detector

- 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

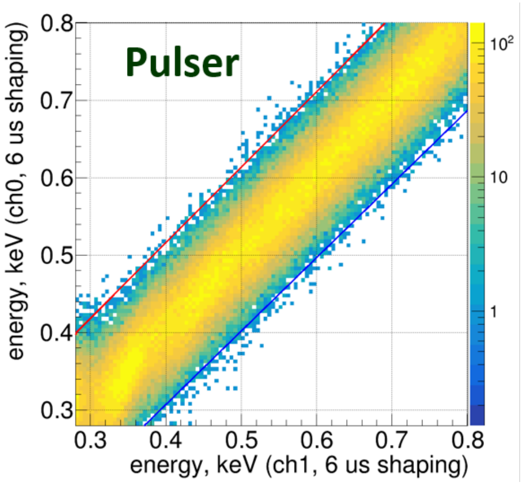
Dynamic range:

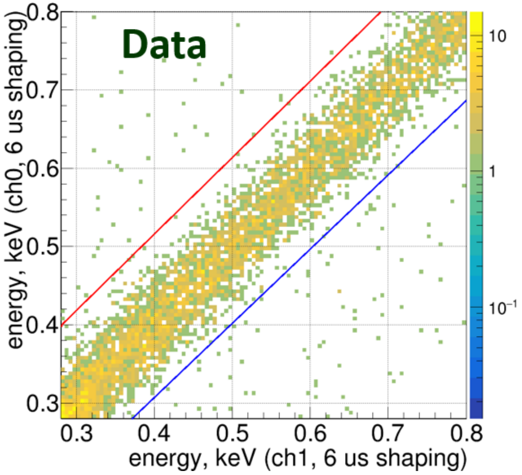
1. «Low energy»: ~0.2 to 17 keV
2. «High energy»: 17 keV to ~1 MeV

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

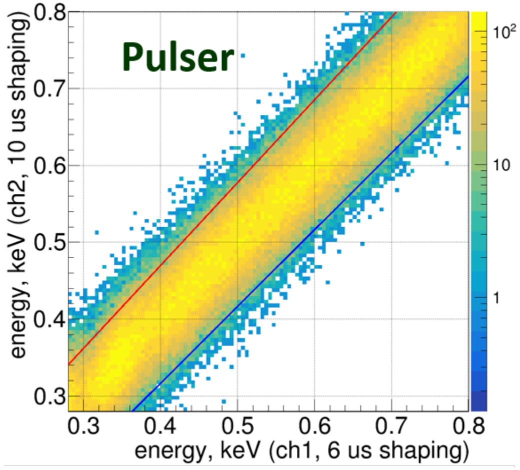
Selections

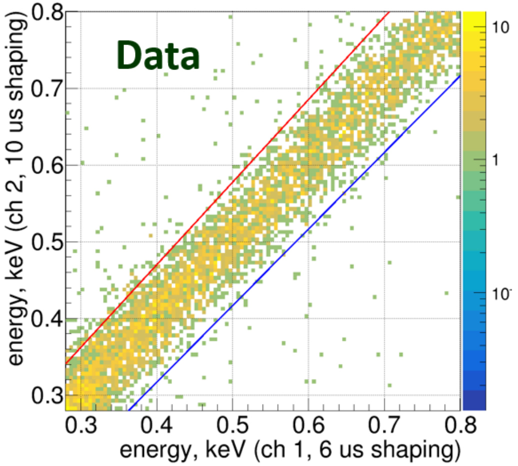
Correlation of two channels with the same τ_{sh}





Comparison of channels with different τ_{sh}

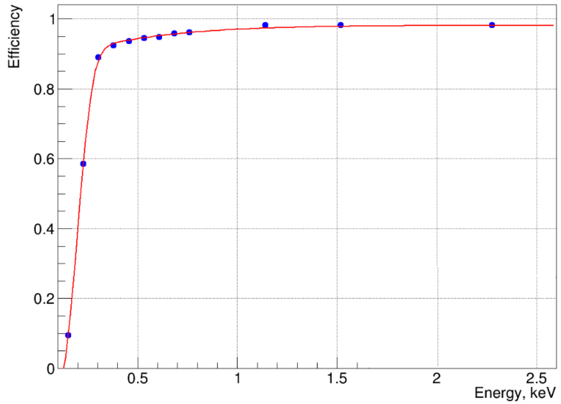




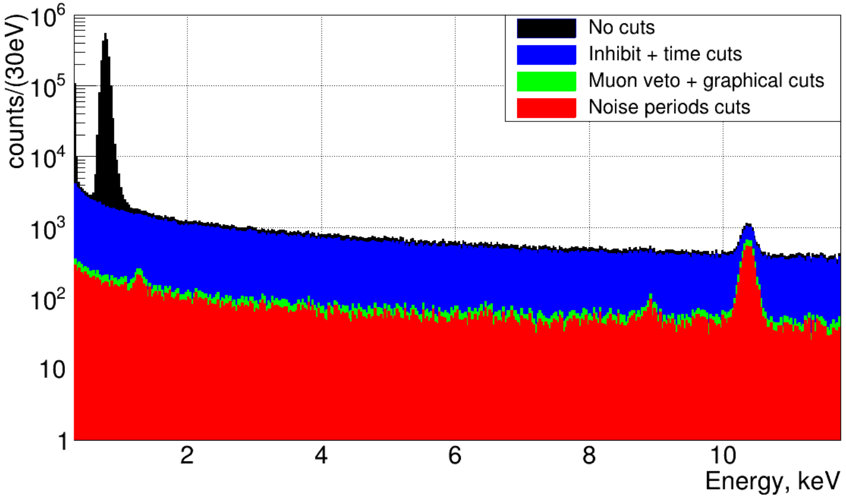
Eff-cy of a trigger + graphical cuts:

~45% for 0.2 keV
~90% for 0.3 keV

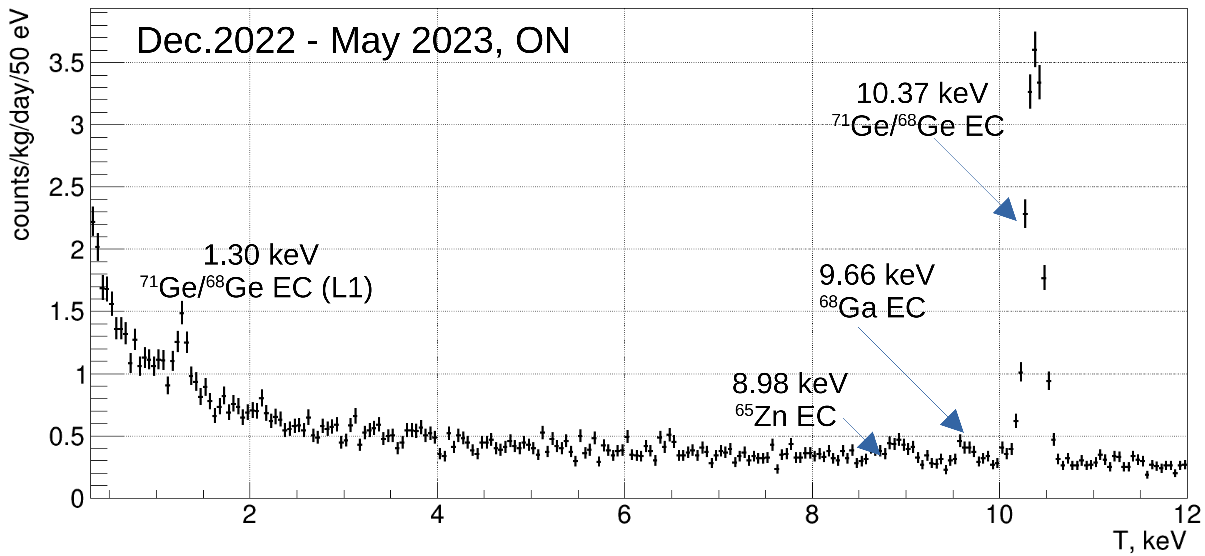
Inhibit and μ veto Introduce ~10% dead time total



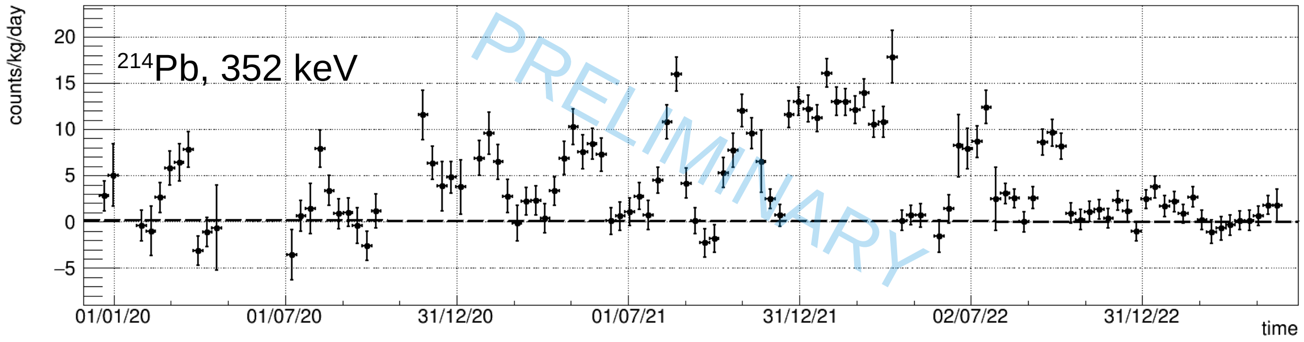
BG reduction by the selections



BG and its stability



Fluctuations of Rn affect the whole range, including CEvNS ROI



+ slow general decrease of the BG substrate count rate

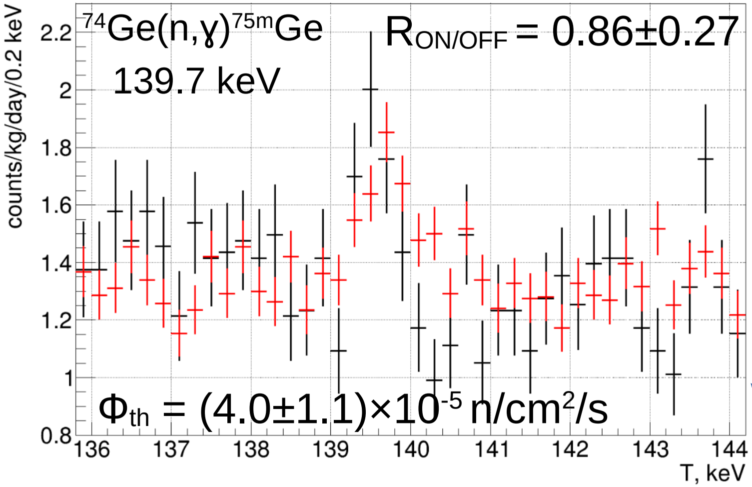
E, keV	Source	Rate, (kg×d)$^{-1}$
1.30	^{71}Ge/^{68}Ge EC (L1)	~1.3$^{×}$
8.98	^{66}Zn EC	~0.7$^{×}$
9.66	^{68}Ga EC	~0.5$^{×}$
10.4	^{71}Ge/^{68}Ge EC (K)	14.8$^{×}$
46.5	^{210}Pb	1.1
66.7	^{72}Ge(n,ɣ)^{73m}Ge	6.1*
140	^{74}Ge(n,ɣ)^{75m}Ge	1.8
198	^{70}Ge(n,ɣ)^{71m}Ge	1.7
242	^{214}Pb (^{222}Rn)	0−3.2
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

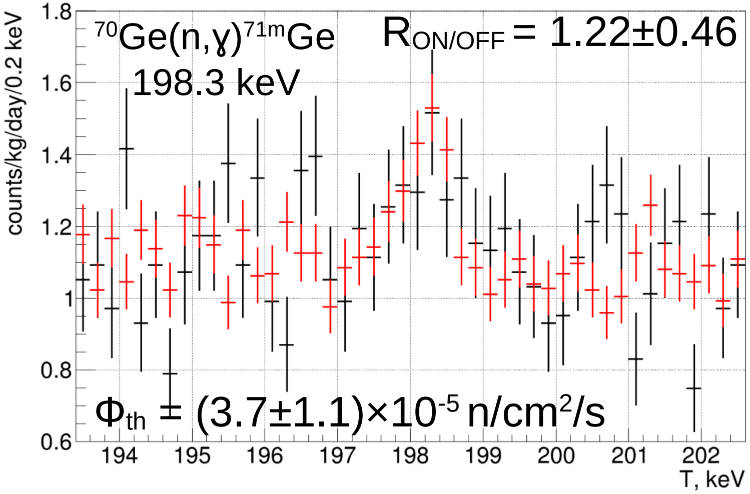
+ Pb, Bi X-rays

* - [53.4+13.3] keV, affected by τ_{sh}
× - as of Dec. 2022- May 2023

Neutron background characterization

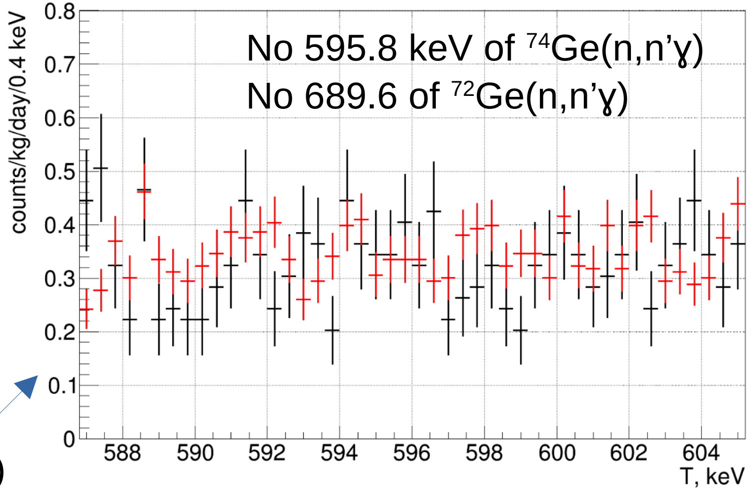
Thermal neutrons





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

Absense of peaks from inelastics

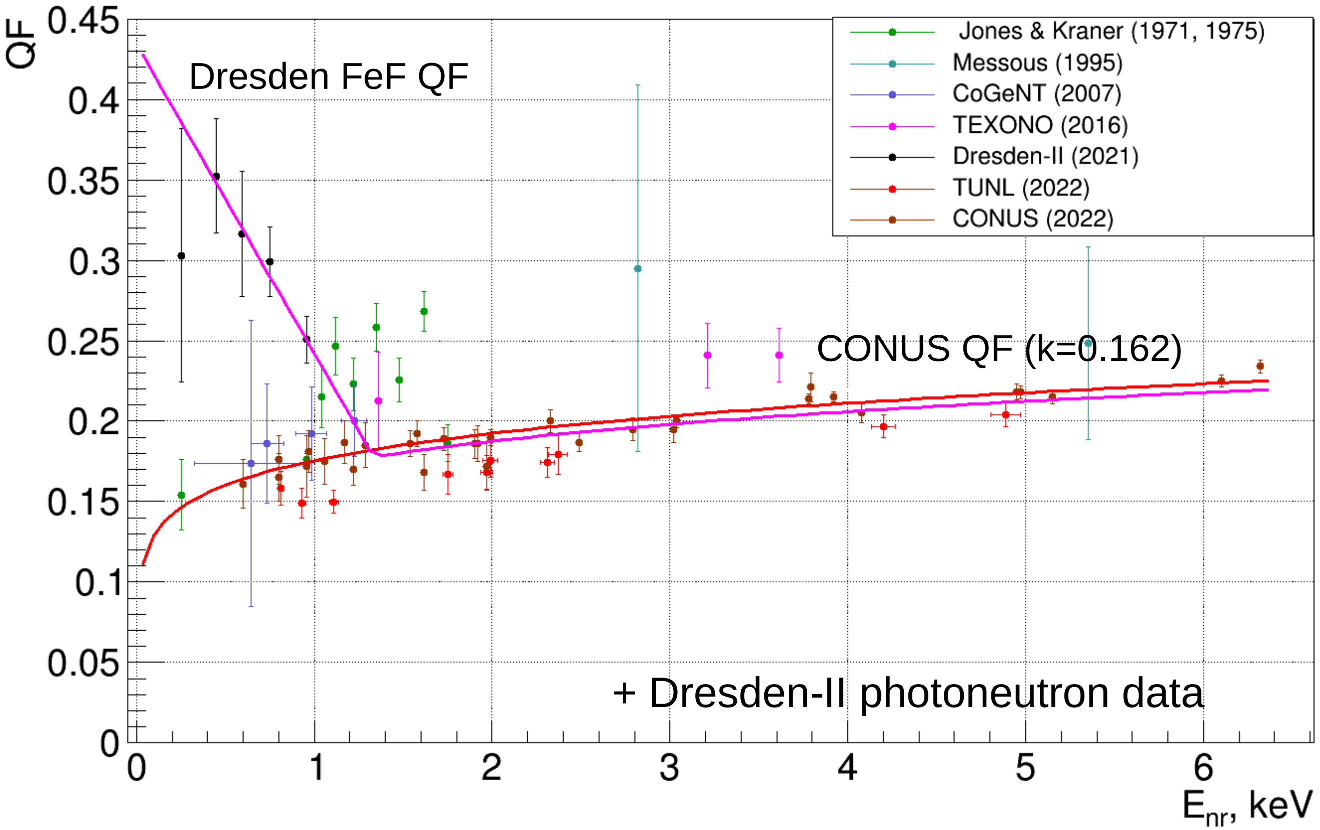


Ongoing simulations and a measurement for verification: ^{252}Cf in the lab with a similar HPGe

Fast neutron flux measurements

Measurements with the Bicron LS cell (PSD) in March-July 2024 at KNPP, both ON and OFF. Ongoing analysis.

Approach to the quenching problem



Ongoing discussion

Dresden-II

Phys. Rev. D 103, 122003 (2021)

TUNL, L. Li, PhD thesis (2022)

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

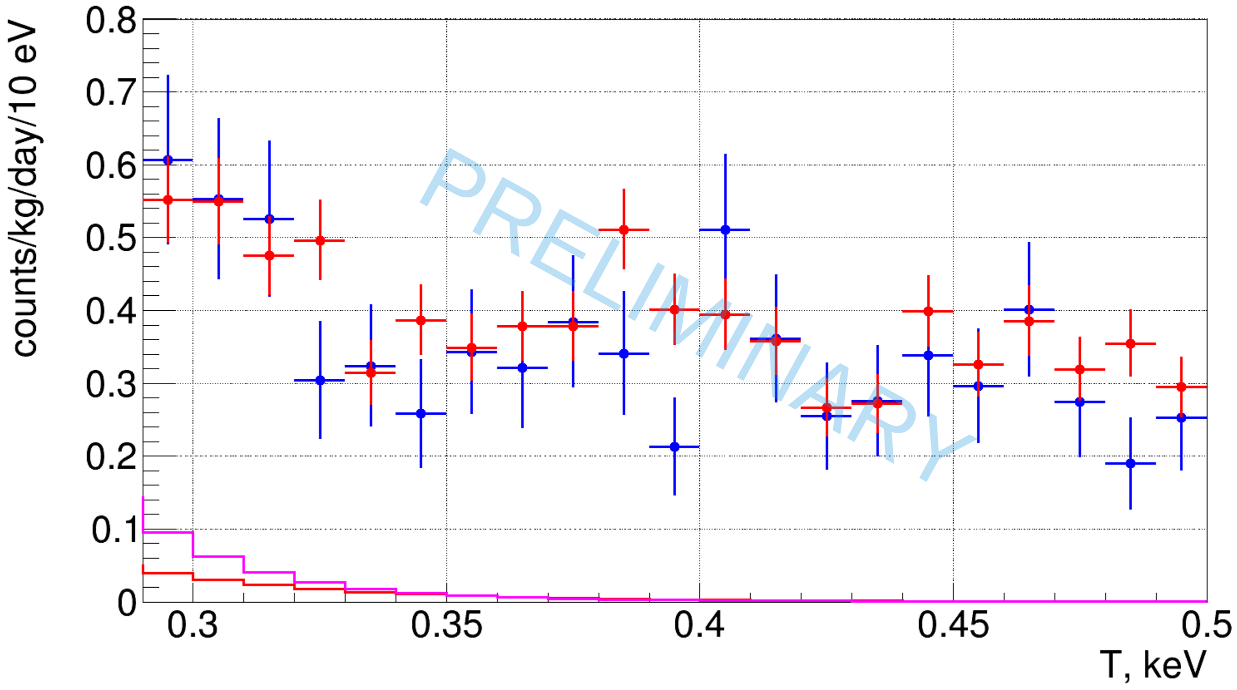
CONUS

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

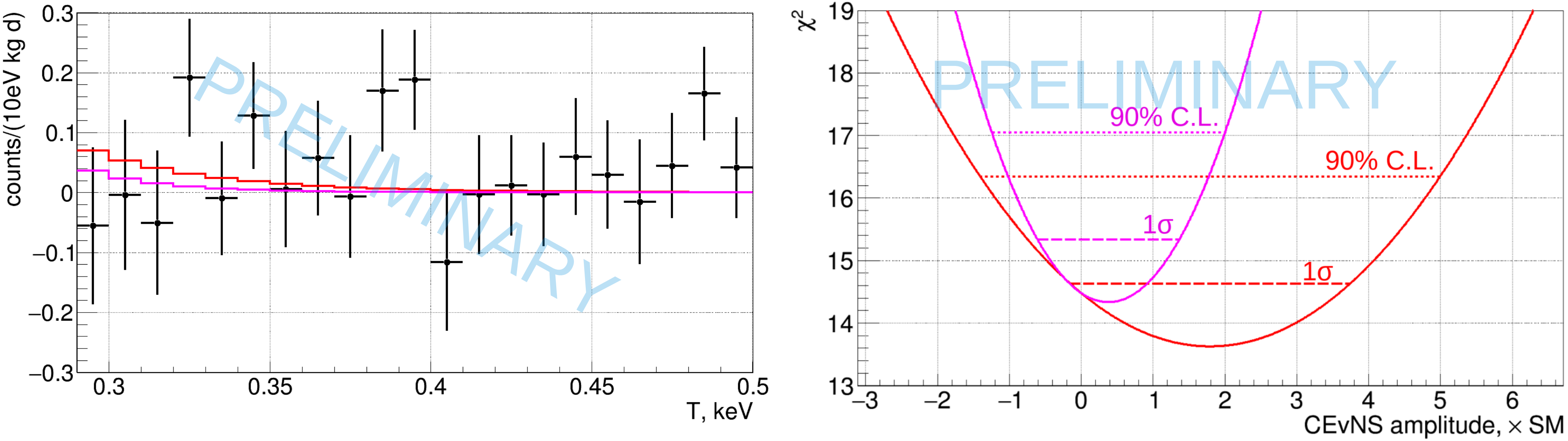
Analysis ROI: 0.29-0.4 keV

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)

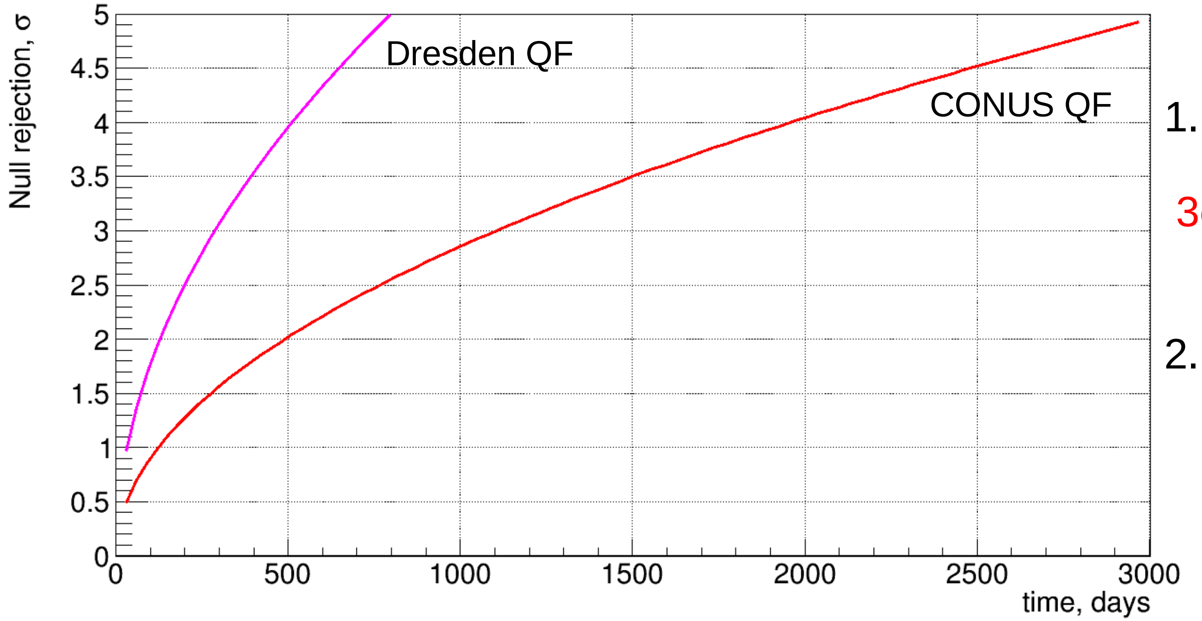


QF	Prediction, ev./kg/day	Sensitivity, ×SM	68% expectation for a 90% C.L. limit, ×SM	Best fit, ×SM	90% C.L. limit
CONUS	0.159	4.1	2.3-6.0	1.8 ± 1.9	5.0
Dresden	0.278	2.6	1.6-3.6	0.4 ± 1.0	2.0

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

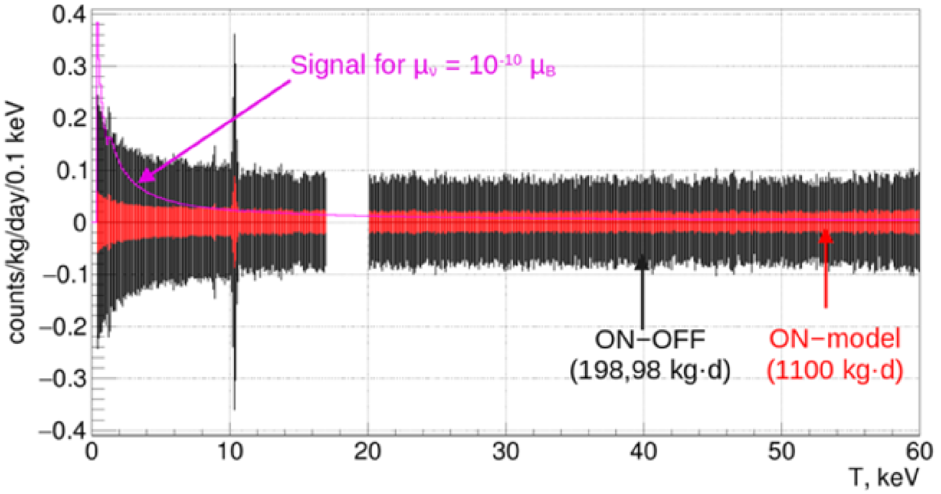
Need to:

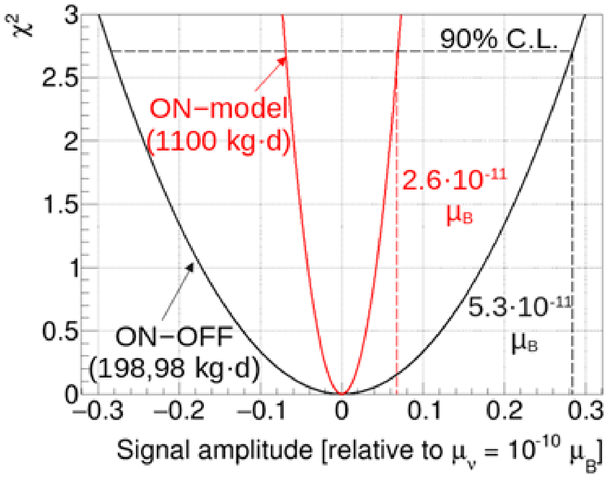
1. Deconvolve the BG -> full BG model: studies and simulations ongoing
2. Improve threshold / reduce BG -> modifications and upgrades

Sensitivity to neutrino EM properties

The best NMM limit at reactors is set by GEMMA in 2013 — $\mu_\nu < 2.9 \cdot 10^{-11}\ \mu_B$ (90% C.L.)

Experiment	Mass, kg	ν flux, $cm^{-2}s^{-1}$	E_{th}, keV_{ee}	Reference
GEMMA	1.5	$2.7 \cdot 10^{13}$	2.8	Adv.High Energy Phys. 2012
νGeN	1.4	$4.4 \cdot 10^{13}$	0.2-0.3	Phys.Rev.D 106 (2022)
COνUS	3.7	$2.3 \cdot 10^{13}$	0.2-0.3	Eur.Phys.J.C 82 (2022)
Dresden-II	2.9	$4.8 \cdot 10^{13}$	0.2-0.3	JHEP 05 037 and JHEP 09 164 (2022)





νGeN is capable of stricter NMM limits for the exposition same to GEMMA

See more details RE NMM and the sensitivity to ν millicharge in the poster by G. Ignatov (MIPT,LPI)!

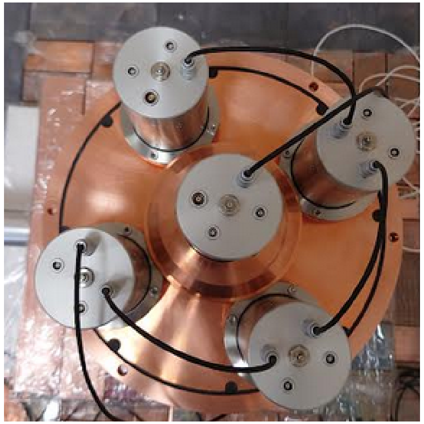
Upgrades and modifications

Noise & BG reduction tests in the JINR lab:

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

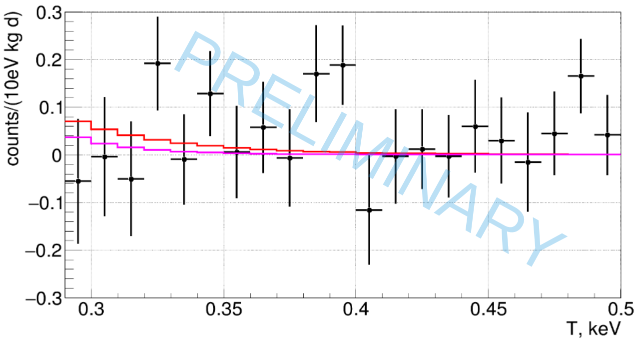
2. Modifications of the cryocooler to reduce its power consumption

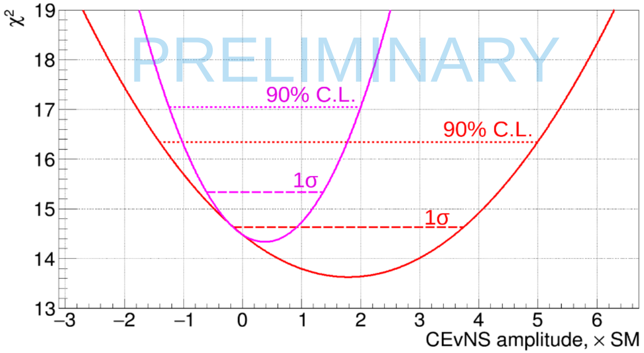
3. DAQ tests for a better discrimination of noise and surface events



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!

This work was supported by RSF grant #24-72-10089