Status and latest results of the νGeN experiment at the Kalinin Nuclear Power Plant
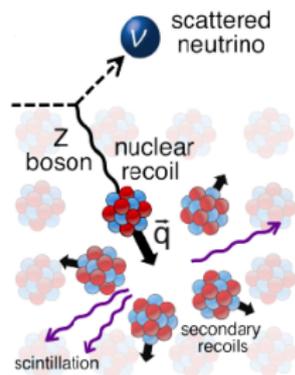
Ignatov Georgii for the νGeN collaboration

LPI RAS, MIPT

22.07.2025

21st Rencontres du Vietnam, Neutrino physics

CEνNS

- **C**oherent **E**lastic ν - **N**ucleus **S**cattering: was predicted in 1974[1,2] and observed for the first time in 2017[3]
- SM cross-section:

$$\frac{d\sigma}{dT} = \frac{G_F^2 M}{4\pi} \big([1 - 4\sin^2\theta_W]Z - N\big)^2 \big(1 - \frac{T}{T_{max}}\big) F^2(q^2)$$

$$T_{max} = \frac{2E_\nu^2}{M + 2E_\nu}$$

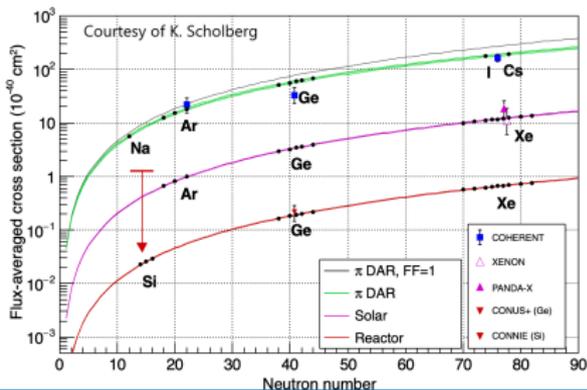| Nucleus	T_{max}, keV (E_ν =5 MeV)	T_{max}, keV (E_ν =30 MeV)
^{12}C	4.44	159.0
^{23}Na	2.32	83.2
^{40}Ar	1.33	47.9
^{74}Ge	0.72	25.9
^{133}Cs	0.40	14.4

Motivation:

- NC ν-q NSI / SM test
- Nuclear FF
- BG for DM search
- Supernova dynamics
- Reactor monitoring

[1] D. Freedman, PRD v.9, iss.5 (1974)

[2] V.Kopeliovich, L. Frankfurt, ZhETF. Pis. Red., v.19 n.4 (1974)

[3] Akimov, D., et al. Science 357.6356 (2017): 1123-1126.

CEνNS search

Ge CEvNS tension

- Dresden-II (2022): observation claim for D1/D2 QF

- COHERENT (2024/2025): 2σ below SM prediction

- CONUS+ (2025): observation claim for C QF

νGeN experiment

- KNPP unit 3 ($\sim$50 m.w.e. overburden).
- ≈ 11 distance from the center of the reactor core.
- antineutrino flux $- 4.4 \times 10^{13}$ cm^{-2} s^{-1}.
- Reactor cycle: 16.5 months ON, 45 days OFF.
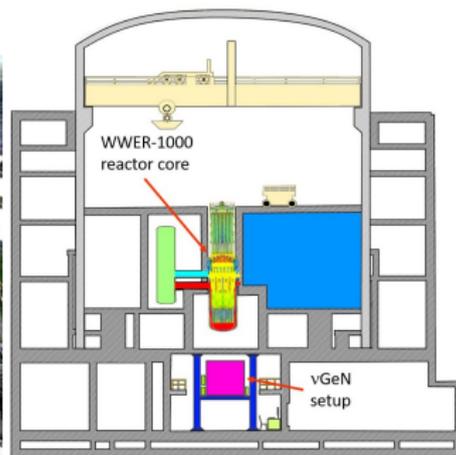
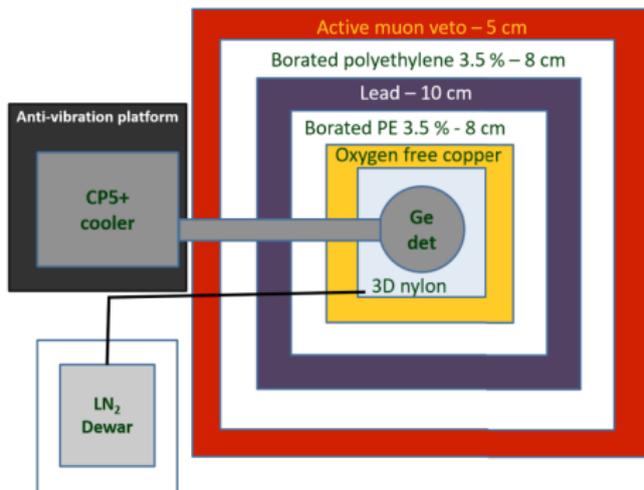Main goals of the νGeN experiment:
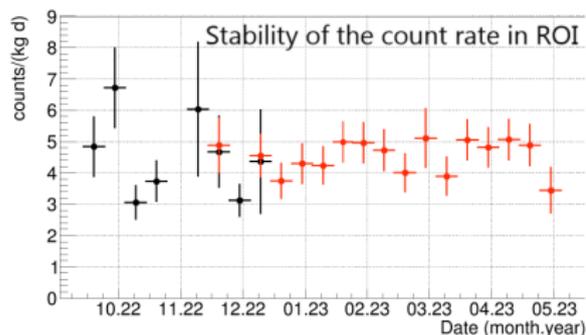- CEvNS measurement
- neutrino EM properties search

νGeN setup

- 1.4 kg active mass HPGe PPC.
- 102 eV FWHM from pulser.
- 0.29 keV threshold.
- Cooled by cryocooler.

- Multi-layered shielding + muon veto.
- Anti-vibration platform.
- Comparison of amplifiers with different shaping times allows noise discrimination.
- Total exposition: $\sim$ **2000 kg $\times$ d** up to 2025, but different conditions.
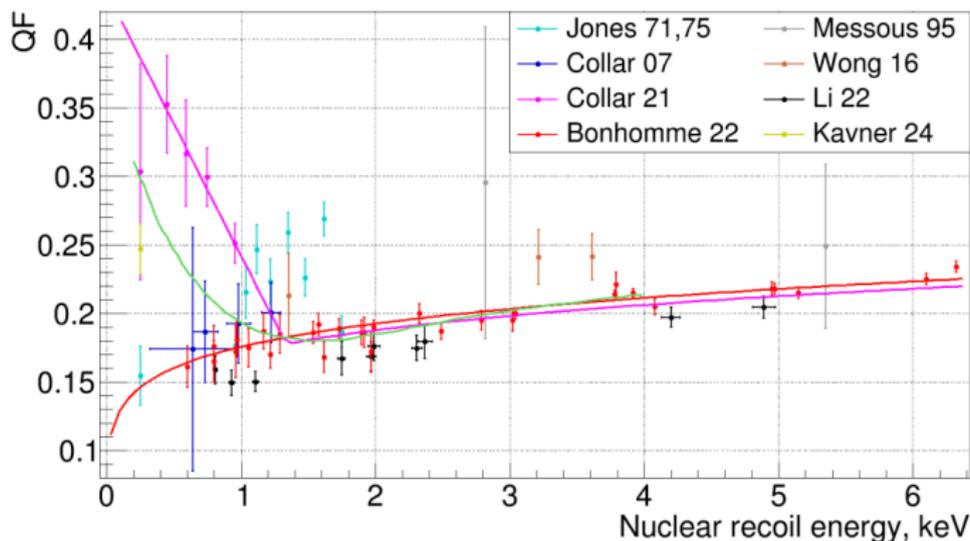
Dataset & stability

- Data collected from October 2022 to May 2023.
- 38 d OFF (black) & 137 d ON (red).
- Stability checked by the intensity of Rn/neutron-induced lines, cosmogenic lines and total count rate in ROI.
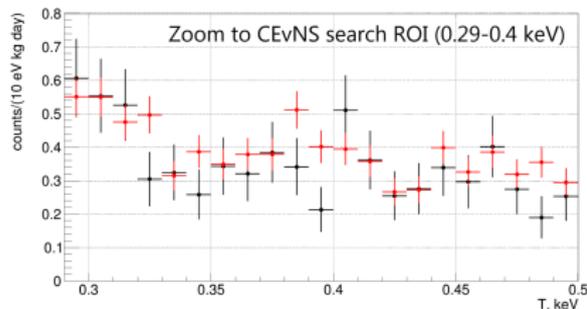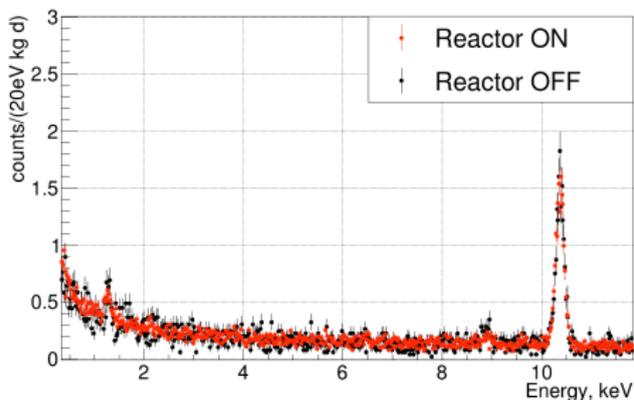
Quenching factor (QF)

$$QF(T_{nr}) = \frac{E_{det}(T_{nr})}{E_{det}(T_{er})}\bigg|_{T_{nr}=T_{er}}$$
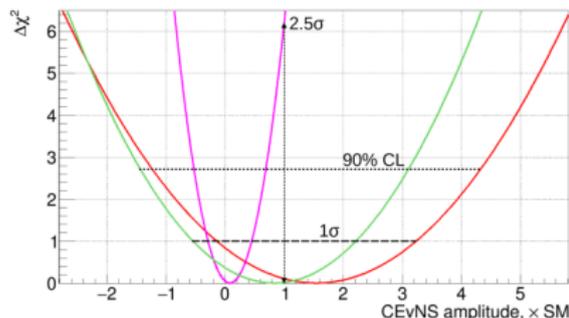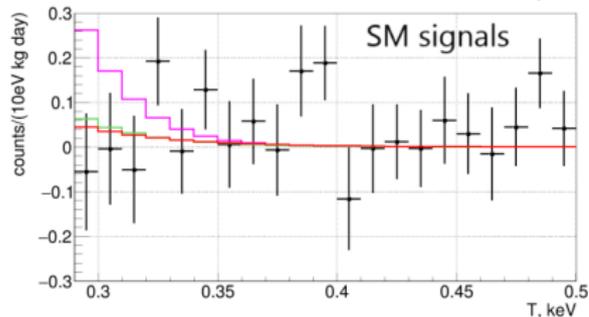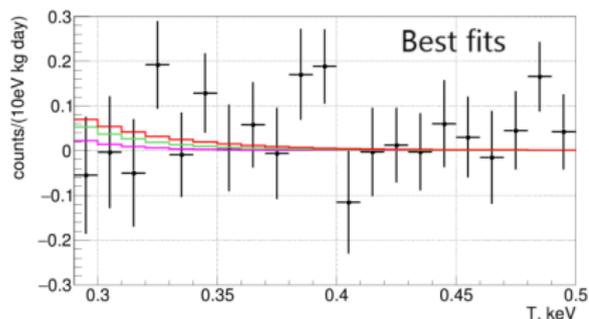
Discrapences in measurements of QF for low energies:

3 scenarios: CONUS (C), Dresden FeF-based (D1) and photo-neutron based (D2).

Fit & results

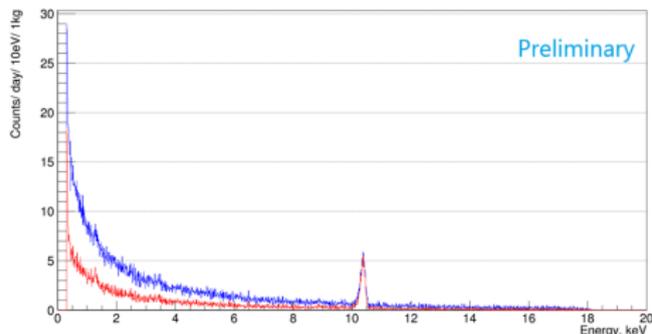QF scenarios: C – red, D1 – magenta, D2 – green.

QF	$A_{best} \pm \sigma_A$, $\times$SM	χ^2_{best} (ndf=10)	S,$\times$SM	L,$\times$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

Sensetivity: Full statistics + BG model →
null-hypothesis rejection at $\sim 5\sigma$.

- Upper limit (90% C.L.):
  $4.3\times$ SM (C QF)
- Tension with D1 QF

νGeN modifications
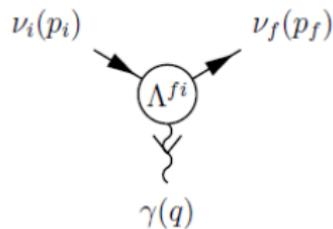
"Compton veto": ~ 30 kg NaI

More than 2 times BG supression in the lab with shielding & μ veto. Now tests at the Baksan underground laboratory.

- DAQ modification: waveform analysis $\rightarrow$ noise / surface events rejection.
- Cryocooler modification: reduce power consumption $\rightarrow$ less vibrations $\rightarrow$ less noise.

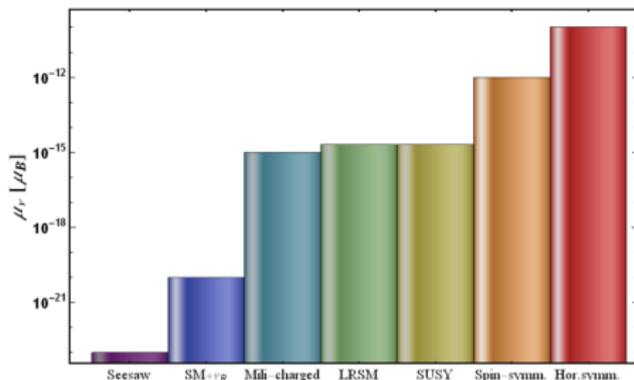# ν EM properties

ν-γ vertex:
$$\Lambda_\mu(q) = F_Q(q^2)\gamma_\mu - F_M(q^2)i\sigma_{\mu\nu}q_\nu + F_E(q^2)\sigma_{\mu\nu}q_\nu\gamma_5 + \\ + F_A(q^2)(q^2\gamma_\mu - q_\mu q_\nu\gamma_\nu)\gamma_5$$
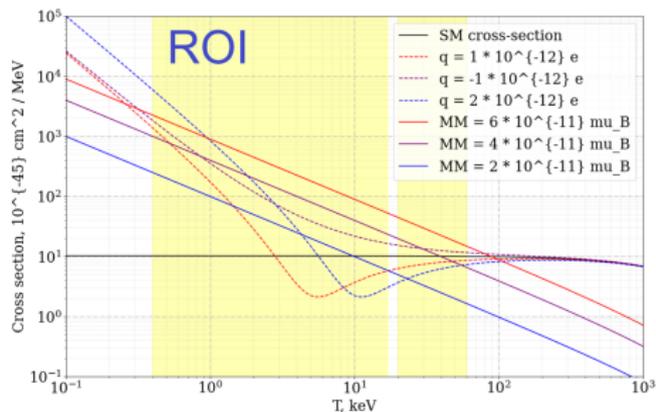
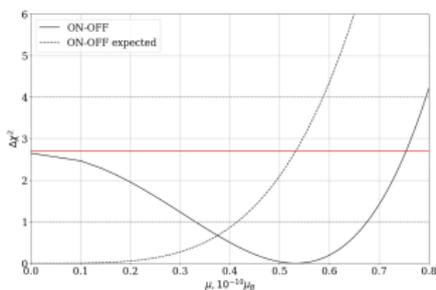Observables: Magnetic Moment (MM), (milli)charge, charge radii.

NMM in SM extansions*:

*SJ, PoS(DISCRETE2020-2021)037

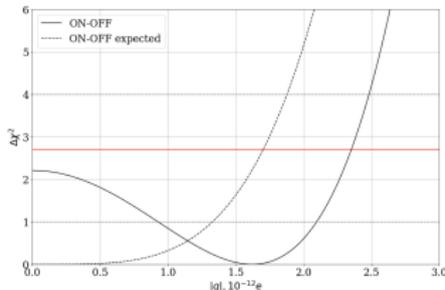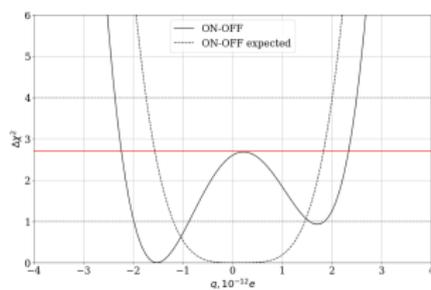ν-electron CS for $E_\nu = 5$ MeV:

Limits on ν EM properties

All limits are given for 90% C.L.; ROI: [0.4,17] keV & +[20,60] keV for NMM.

$\mu_\nu < 7.5 \times 10^{-11} \mu_B$

$q_{ij} < 2.4 \times 10^{-12} e$

$q_{ii} \in (-2.2, 2.3) \times 10^{-12} e$

Limit, $10^{-11} \mu_B$	Experiment
7.5	CONUS
7.5	νGeN
7.4	TEXONO
2.9	GEMMA
0.64	XENONnT

Limit, $10^{-12} e$	Experiment
2.7	GEMMA
1.2	TEXONO
2.4 (0.9)	νGeN
0.6	CONUS+
0.224	LZ

Astrophys.: $\mu_\nu < 1.2 \times 10^{-12} \mu_B$

Cosmology: $q_\nu < 10^{-35} e$

Summary

CEvNS search [V. Belov et al. Chinese Phys. C 49 053004 (2025)]:

- Limit on the CEvNS count rate at $4.3 \times$ SM (C QF).
- Tension with Dresden-II QF and CEvNS claim.

Limits on ν EM properties:

- $\mu_\nu < 7.5 \times 10^{-11} \mu_B$.
- $q_\nu < 2.4\,(0.9) \times 10^{-12} e$ for FEA (EPA) CS.

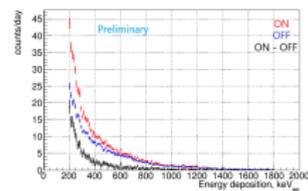+ Ongoing analysis to use full statistics (~ 2000 kg$\times$d) and upgrades to reduce BG + lower threshold.
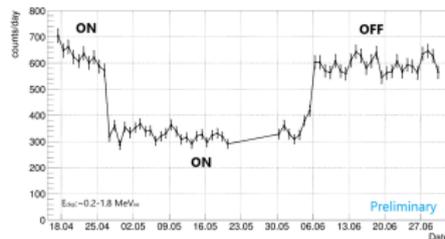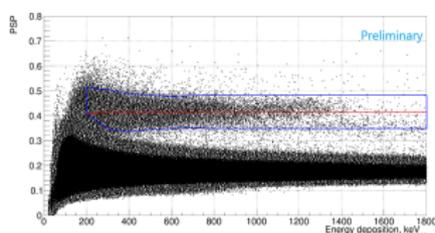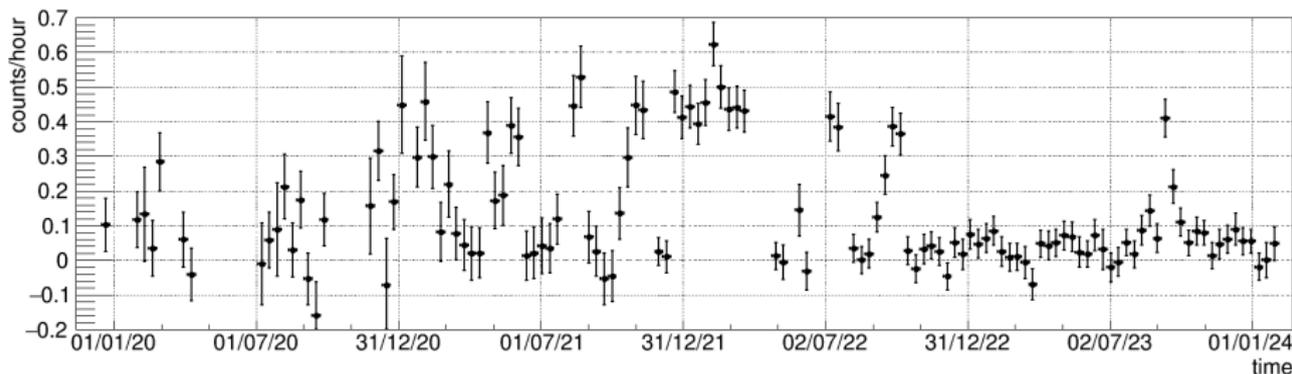
Thank you for your attention!

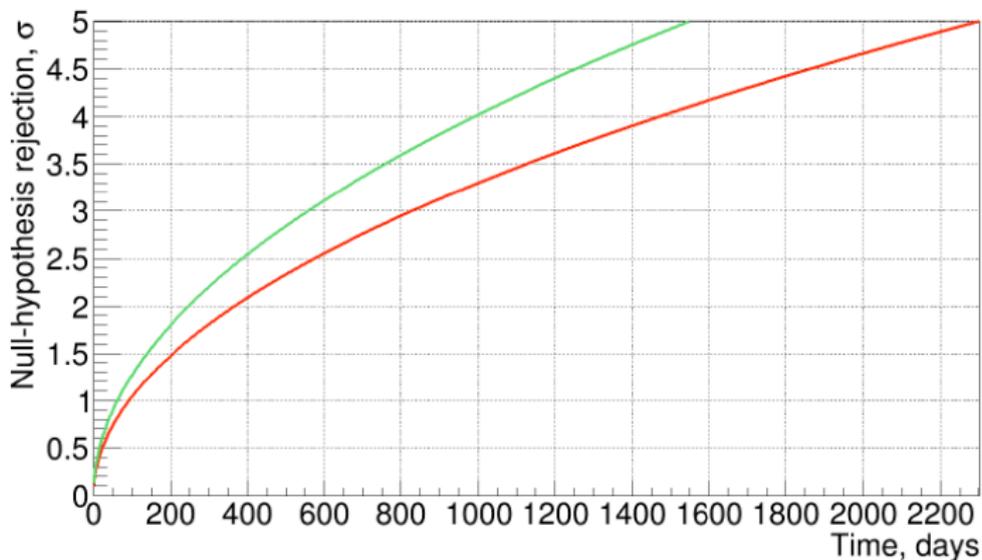# Backup

Stability: neutrons, Rn

Neutrons in BC501A LS outside shielding: First estimation: $\sim 10^{-2}$ of BG rate.

Rn by ^{214}Bi 609 keV line:

Sensitivity estimation

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