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Outer Veto prototype for the CEvNS detection at nuclear reactors

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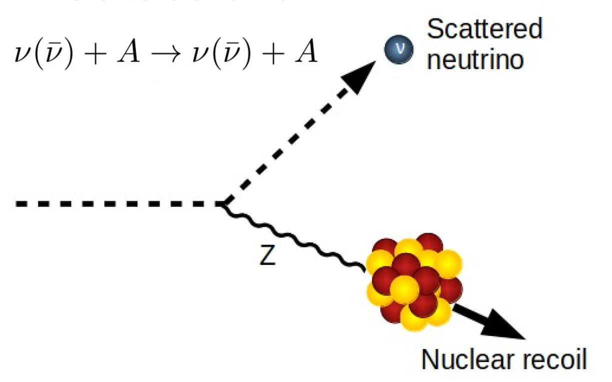
The Coherent Elastic Neutrino Nucleus Scattering (CEvNS) process

- 1974: Freedman's CEvNS prediction
- 2017: first CEvNS observation on CsI by the COHERENT Collaboration
- 2020: second observation on Ar



- Assuming momentum transfer sufficiently low, the neutrino scatters off the target nucleons as a whole
- Signature: **unique nuclear recoil** with typical energy range 10's eV to few 10's keV
- **Cross section**: 10 to 1000 times greater compared to the standard neutrino detection channels
  - → cross section proportional to the square of the neutrons number of the target nucleus
  - → **10's g to kg** detectors
- new way to prove **physics beyond the Standard Model**

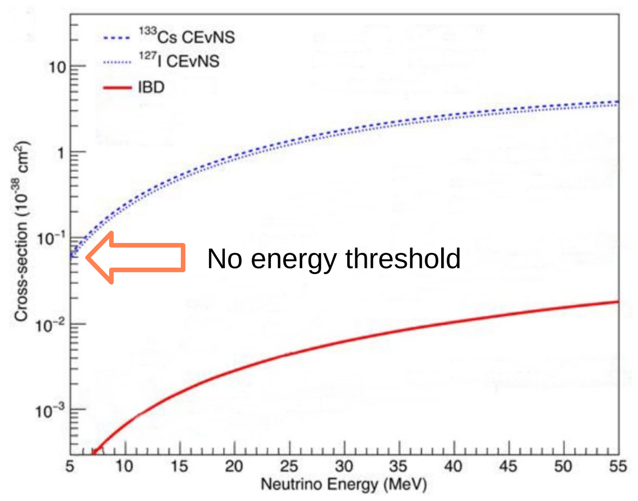
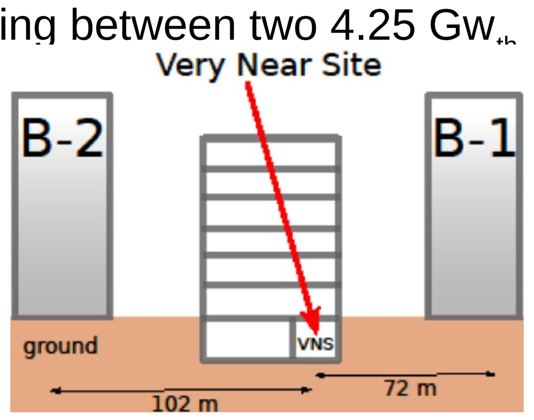


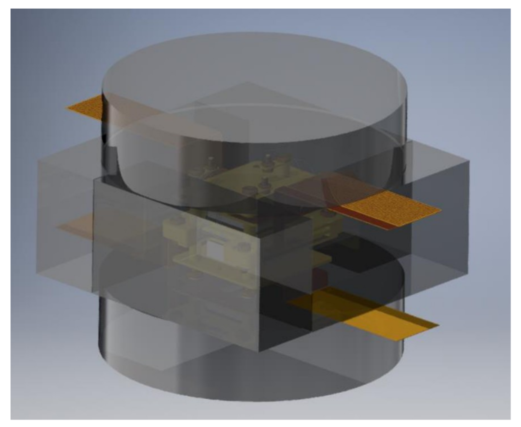
Figure from D. Akimov et al., Observation of coherent elastic neutrino-nucleus scattering, Science 357 (6356), 1123-1126 (2017)

The NUCLEUS experiment in a nutshell

- **Experimental Site at CHOOZ Nuclear Power Plant (France)**
  - Very Near Site: 24 m² basement room in administrative building between two 4.25 Gw$_{th}$ reactors
  - Baseline: 72 m to B1 and 102 m to B2
  - ϕ_ν~1.7 x 10^{12} ν/cm²/s, E_ν<10 MeV



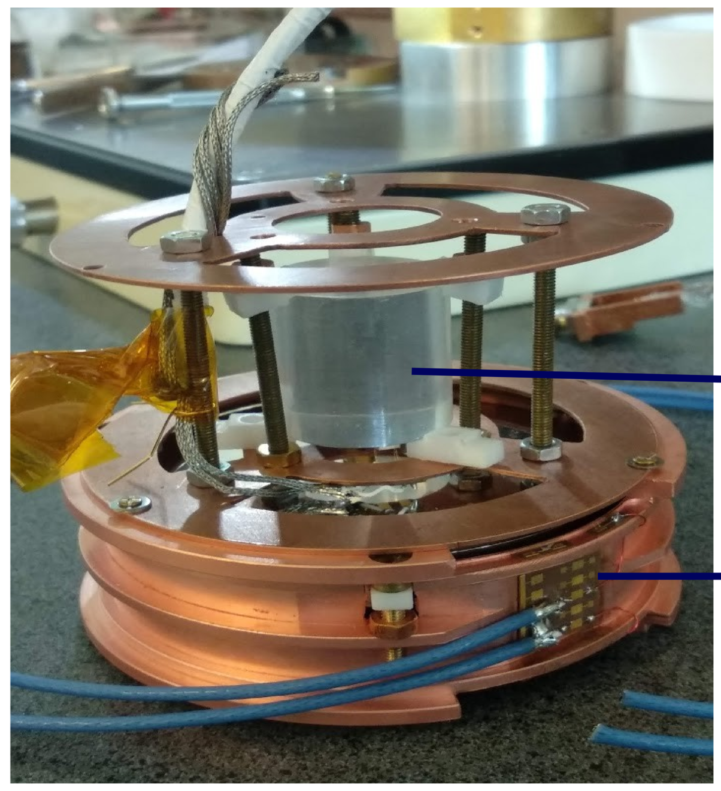
- **Target detectors**
  - Gram-scale cryogenic calorimeters based on CRESST technology
  - 3x3 $CaWO_4$ array + 3x3 Al_2O_3 array
  - Coupled to thin-film tungsten Transition Edge Sensors as thermometers
  - Ultra-low energy threshold: demostrated with NUCLEUS-1g: 20 eV
  - Active vetos and shielding against the background
- **NUCLEUS Outer Veto (OV): final configuration**



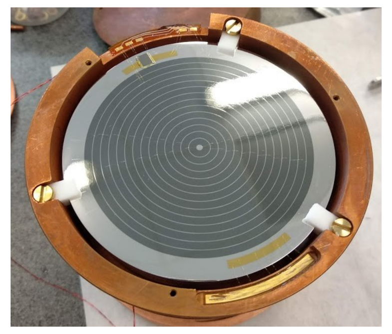
- For an efficient reduction of background events induced by ambient ɣ's and neutrons
- 6 HPGe crystals with 2.5 cm thickness
- Active ionizing detectors
- Hosting the target detectors
- Working in anti coincidence with the target detectors

NUCLEUS Outer Veto prototype

2 tests performed at IJCLab (Orsay, France)

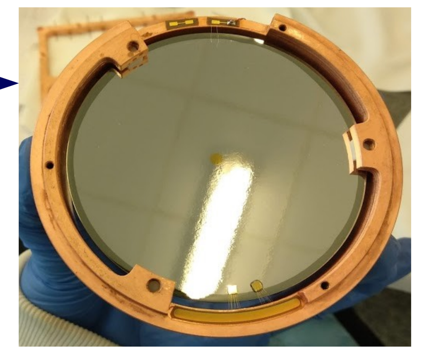


Ist test: Ge with planar electrodes

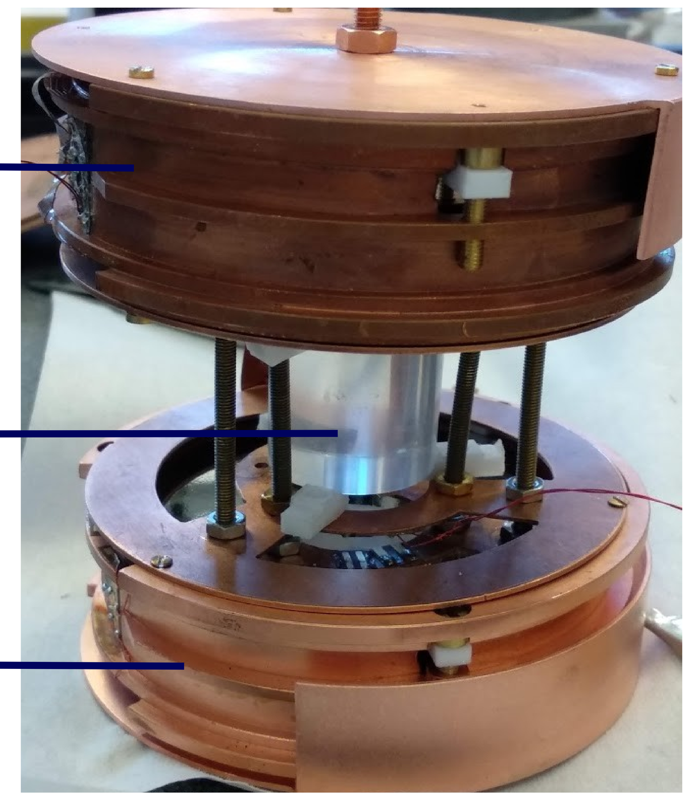


HPGe crystal (Interdigit Detector, ID)
- d=7cm, h=2cm, m=400g
- impurity density < 10^{10} cm^{-3}
- Electrodes: inter-leaved geometry (concentric rings)

BASKET detector as target detector (Li_2WO_4+ Neutron Transmutation Doped sensor)



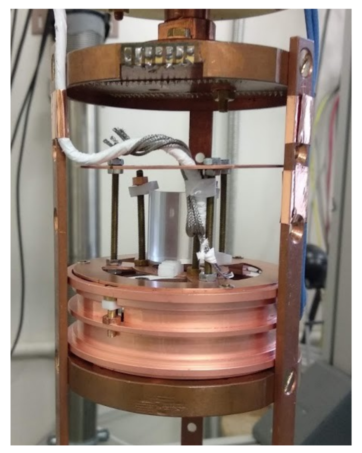
HPGe crystal
- d=7cm, h=2cm, m=400g
- impurity density<10^{10} cm^{-3}
- electrodes: full Al layer (co-planar geometry) on both sides



2nd test : Ge with planar electrodes + ID

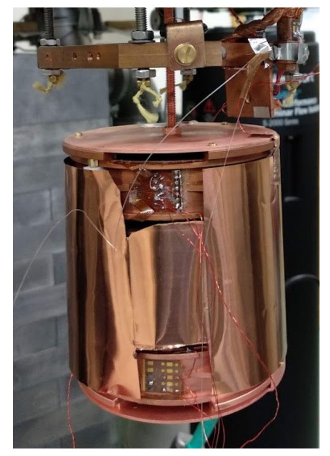
1st test: 1h acquisition in Actuator cryostat at 17 mK

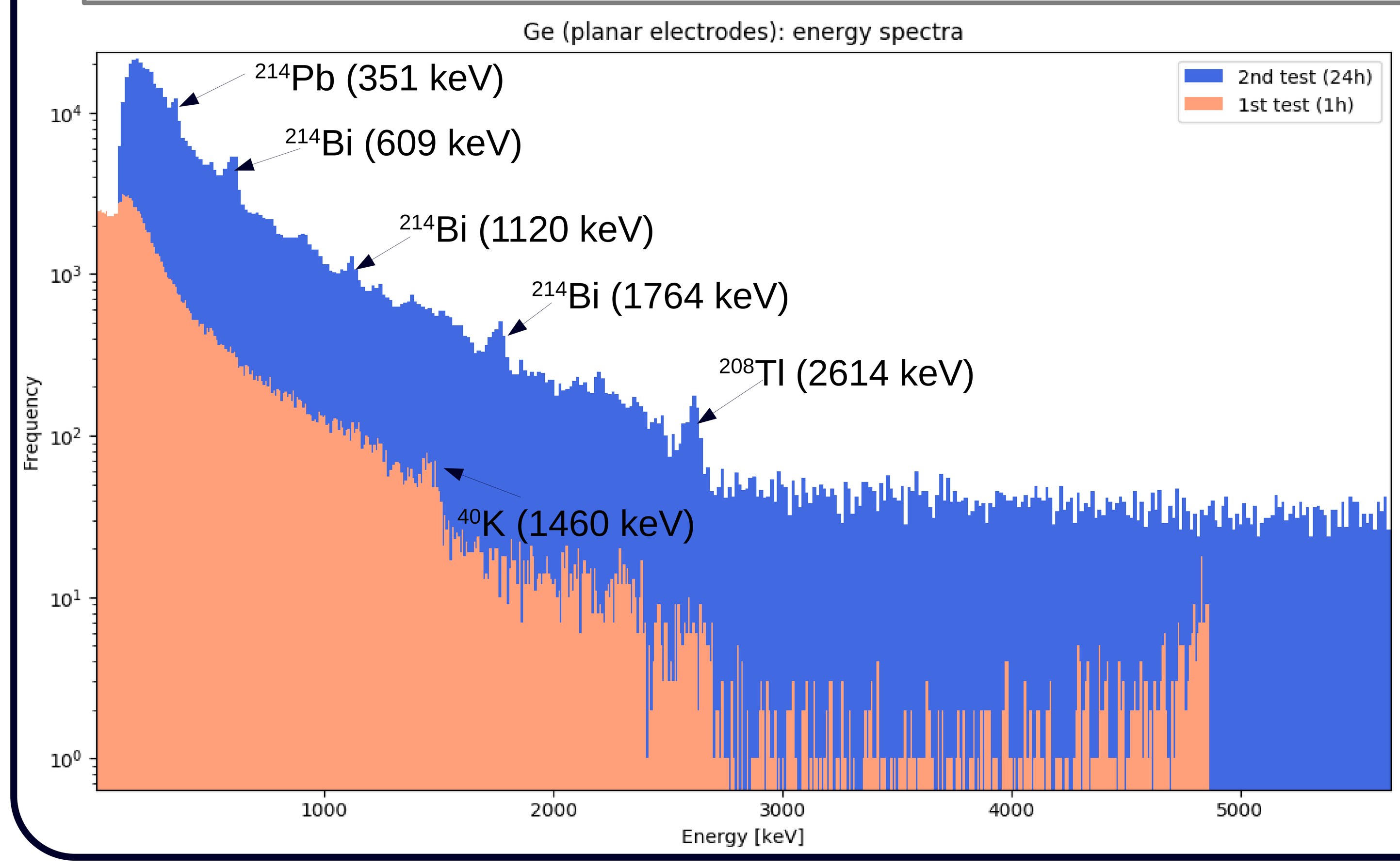
- Cold electronics
- Capacitance on which the charge is integrated: 90 pF
- Current amplifiers
- No lead shield
- Electrodes bias: 0V and 1.5V
- Butterworth high-pass filter (1 kHz) + optimum filter



2nd test: in Ulisse cryostat at 20 mK

- Room temperature electronics (not optimized for ionization measurements)
- Capacitance on which the charge is integrated > 500 pF
- Low noise voltage amplifier
- 10 cm thickness lead shield
- Electrodes bias: 0V and 10V for both the Ge detectors
- Butterworth band-pass filter (20 Hz, 250 Hz) + optimum filter





	1st test: Ge planar electrodes	2nd test: Ge planar electrodes	2nd test: ID
Energy resolution (FWHM)	71±28 keV @ 1460 keV	52.6±5 keV @ 2614 keV	38±2 keV @ 2614 keV
Energy Threshold (5σ)	2.3 keV *	45 keV	55.7 keV
Bsl resolution (FWHM)	1.1 keV	21.3 keV	26.2 keV
Sensitivity	842 nV/keV	94.7 nV/keV	83 nV/keV
Rise-time	2 us	107 us	118 us

* in not optimized cryogenic conditions

Conclusions

- NUCLEUS requirements satisfied in the 1st test
- 2nd test shows:
  - a cold electronics is indispensable
  - strong pile-up reduction due to the lead shield
- 3rd test ongoing:
  - same detector used in 2nd test
  - in the Actuator cryostat (cold electronics!)
  - with additional lead shield
  - in optimized cryogenic conditions
  - preliminary results: very promising. Stay tuned!
- In future: 2nd test OV prototype will be used to test the NUCLEUS electronics in Munich

References

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