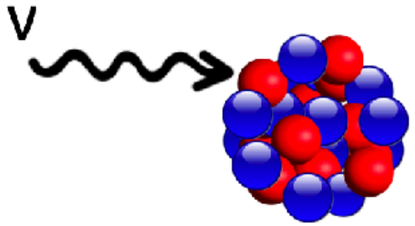
Instrumentation for the future of particle, nuclear and astroparticle physics and medical applications in Spain

F. Monrabal on behalf of nuESS

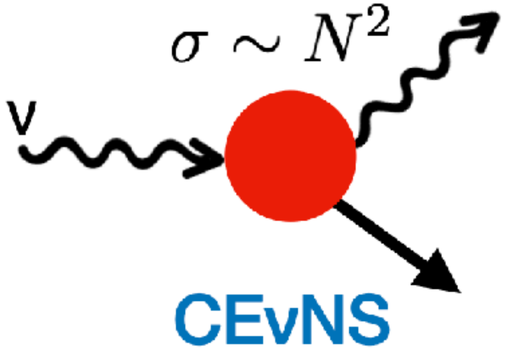
European Research Council

7th March 2023-Barcelona

Coherent Elastic Neutrino-nucleus scattering



Long wavelength, "sees" all nucleons simultaneously

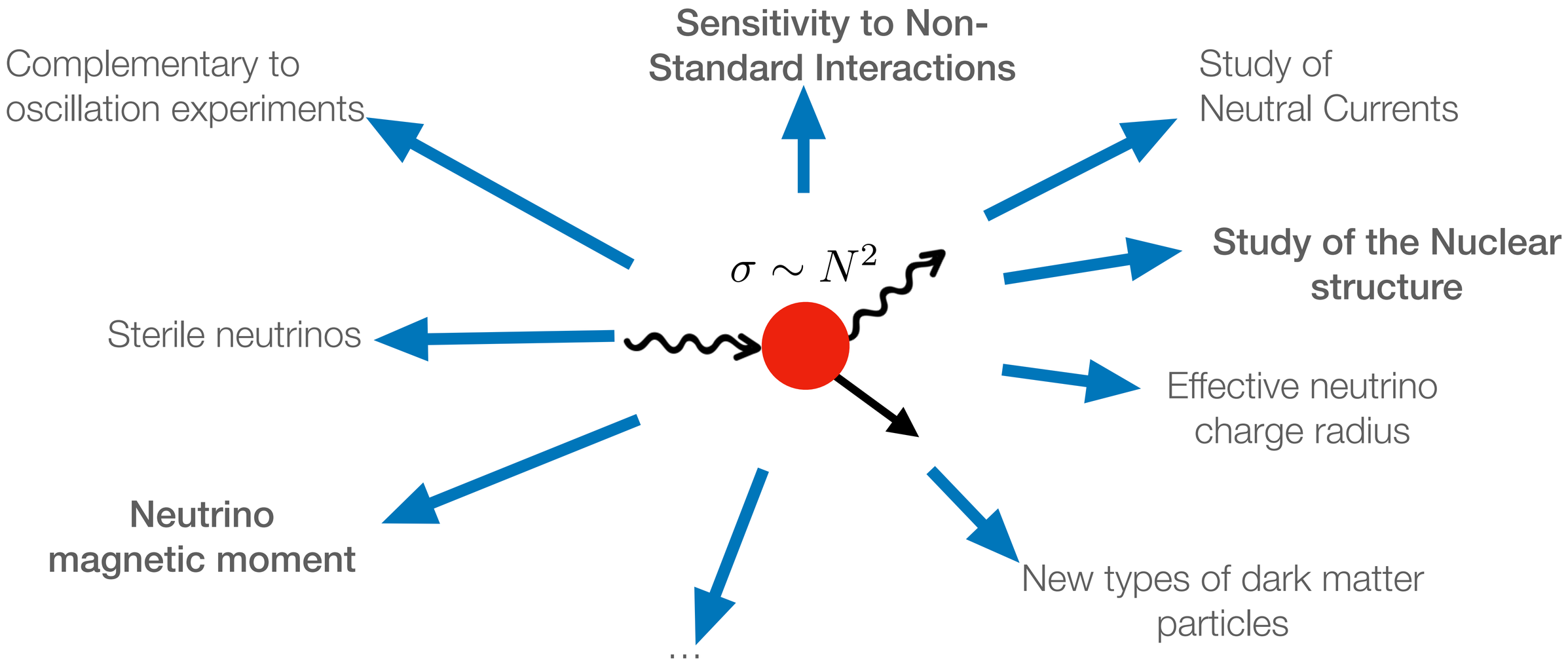


Cross section increases as N^2. Four orders of magnitude increase for large nucleus!

First observation published only 4 years ago.

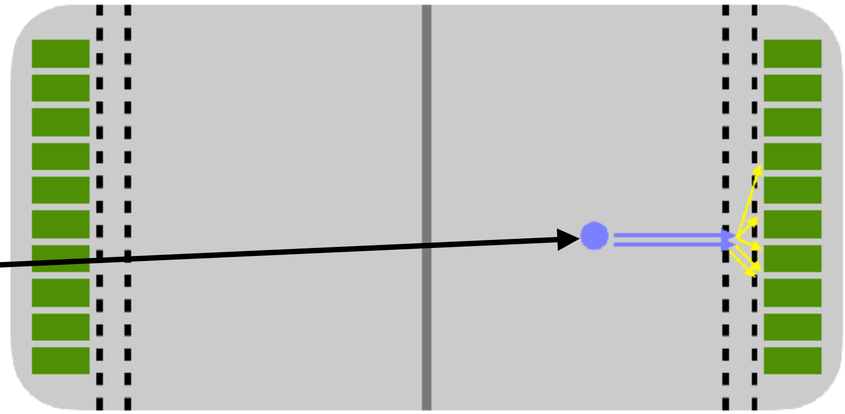
Coherent Elastic Neutrino-nucleus scattering

Very rich physics



Detecting CEvNS

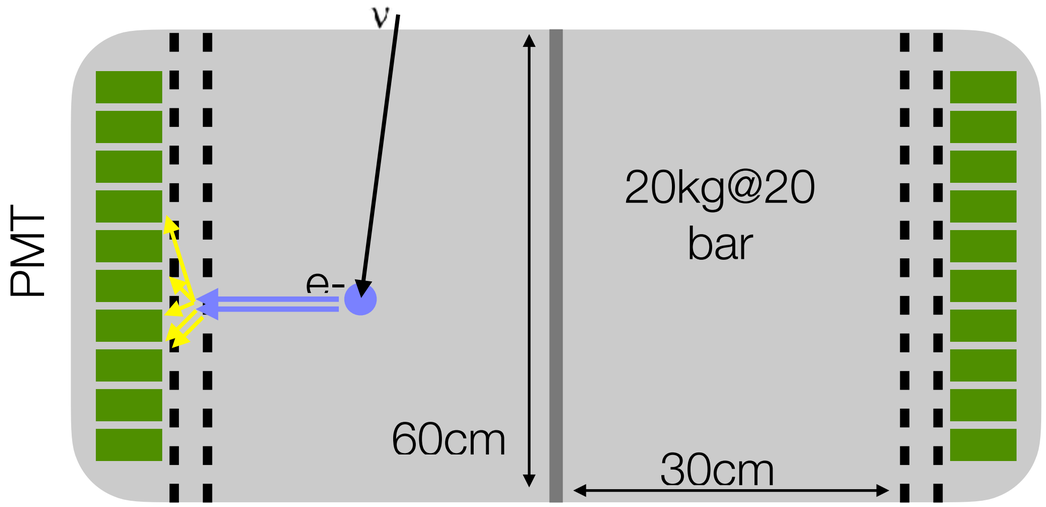
CEvNS sources, must be sufficiently intense in yield, and low enough in neutrino energy so the coherence condition can be satisfied.

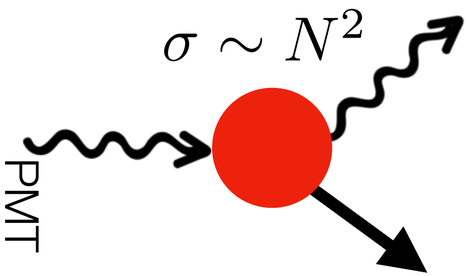


~10 kg size detectors.

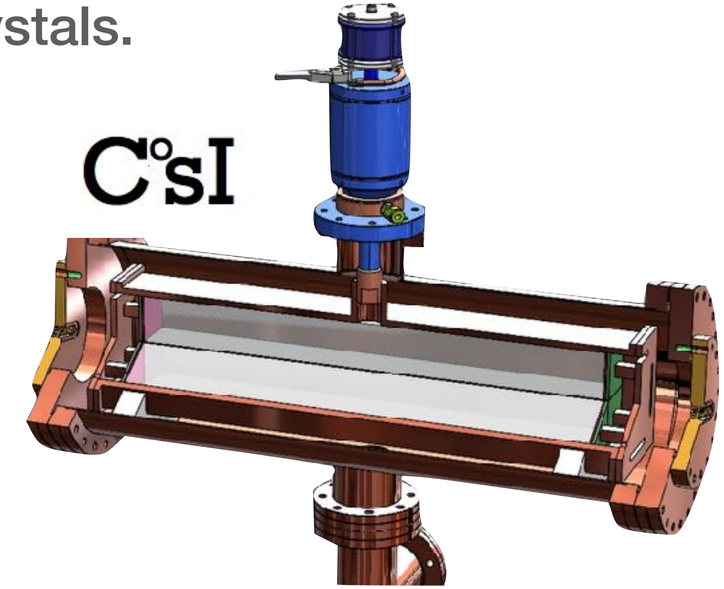
nuNESS project

The GanESS detector: decking coherent interaction with gaseous detectors

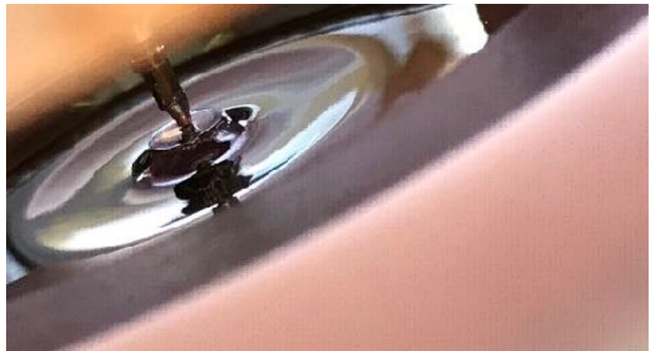




Cosi: Cryogenic undated CsI crystals.



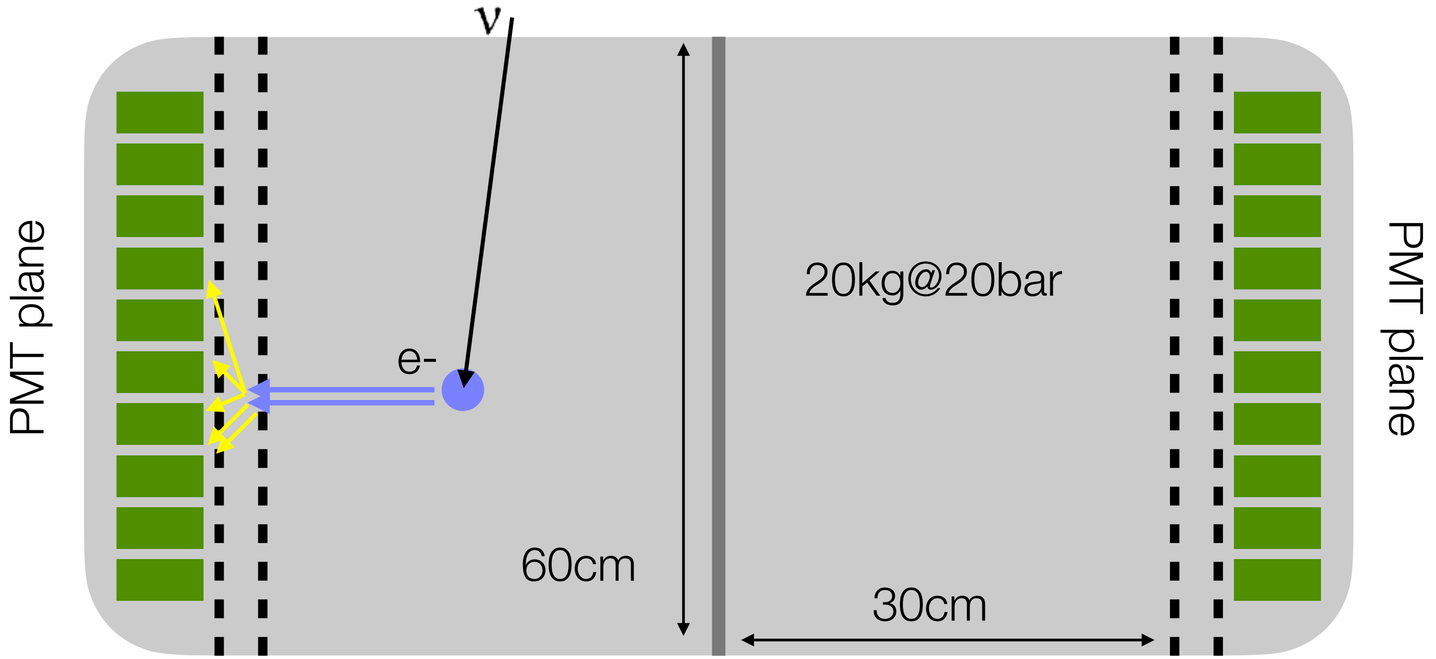
PPC type Germanium detectors



GaNESS project

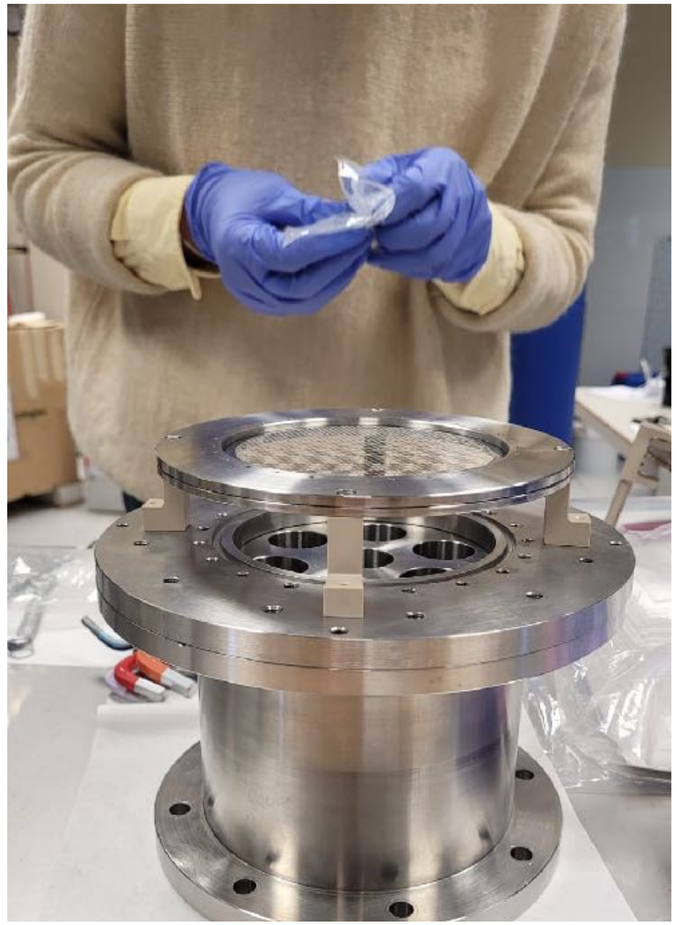
The GanESS detector

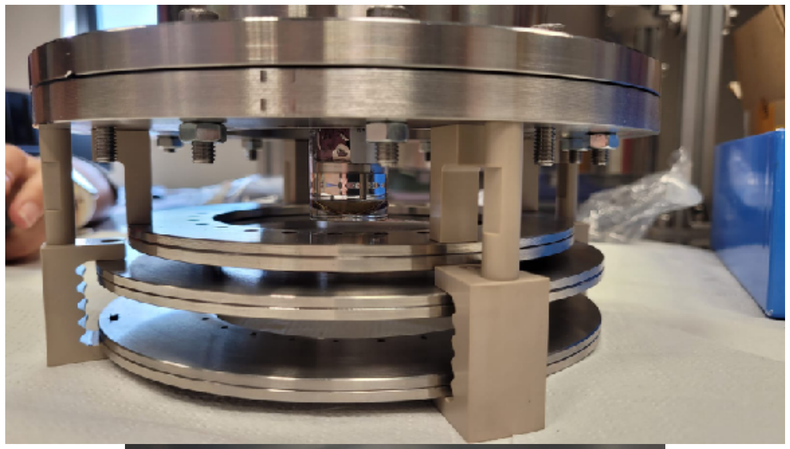
- Optimised for **reduced threshold**.
- Operation with **different gases**.

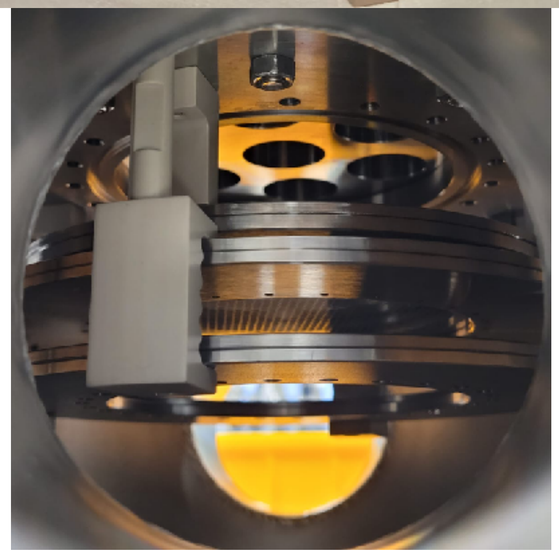


R&D topics: Amplification structures

Amplification system





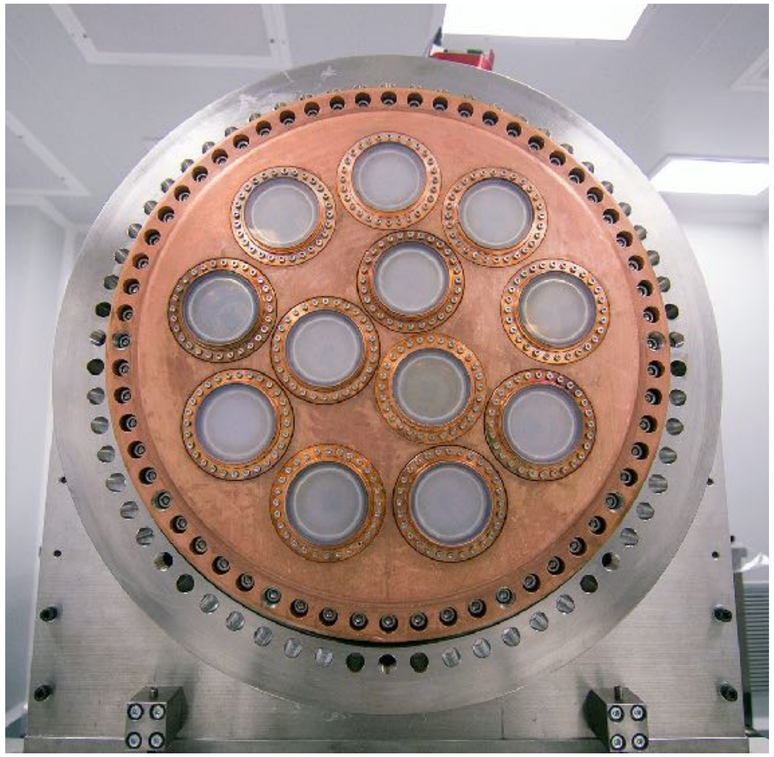


- Going to high pressures implies larger electric fields and possible deformation of the amplification structures due to large electric field.

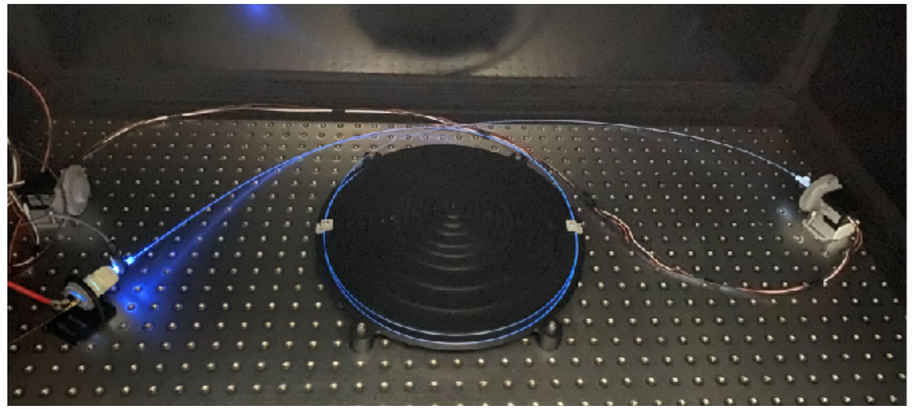
- New ways of creating these structures, maintaining radioactivity low, are needed.

R&D topics: Light collection systems

Amplification system



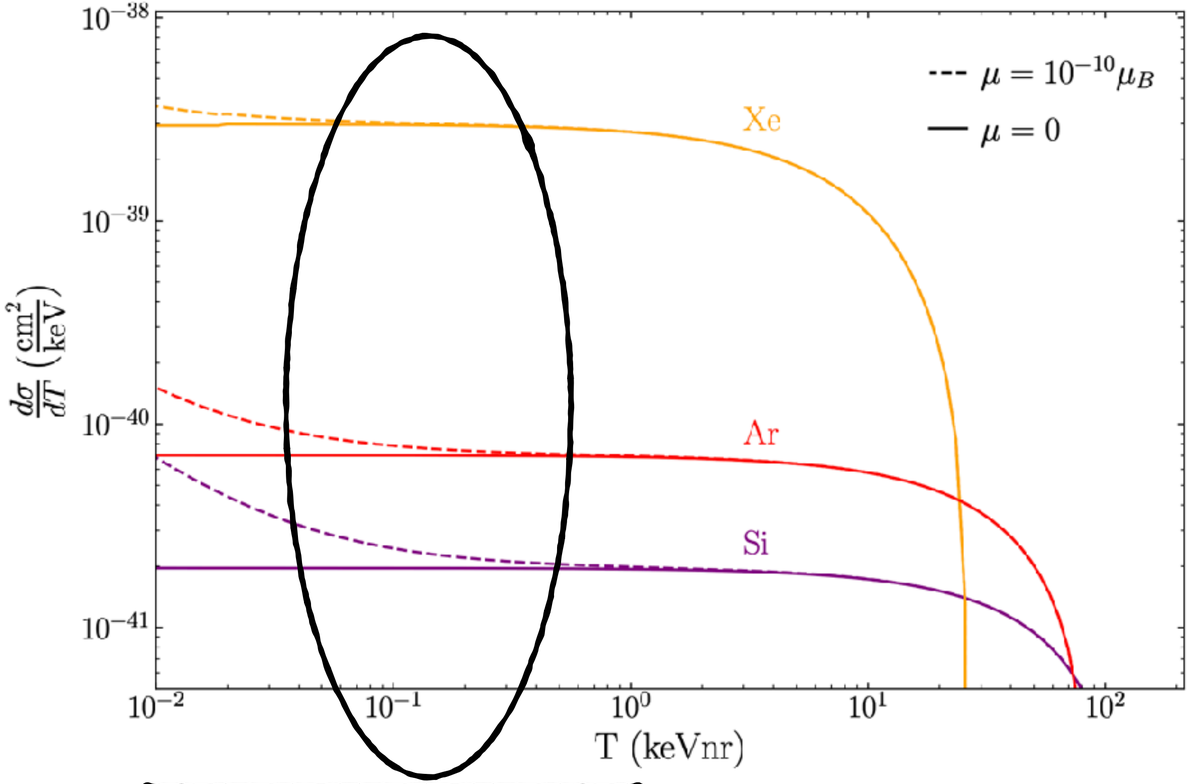
- Current solutions is to use PMTs protected with windows.
- Hard to apply to higher pressures.



- Exploring a combination of SiPMs plane with WLS.
- No need of measuring S1 simplifies the problem.

R&D topics: FPGA programming

Neutrino magnetic moment, new physics!



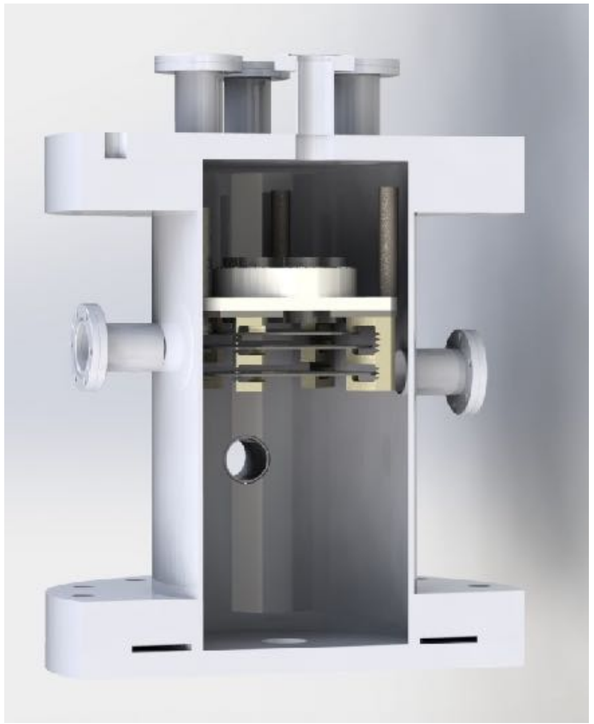
Ultra low energy threshold is crucial

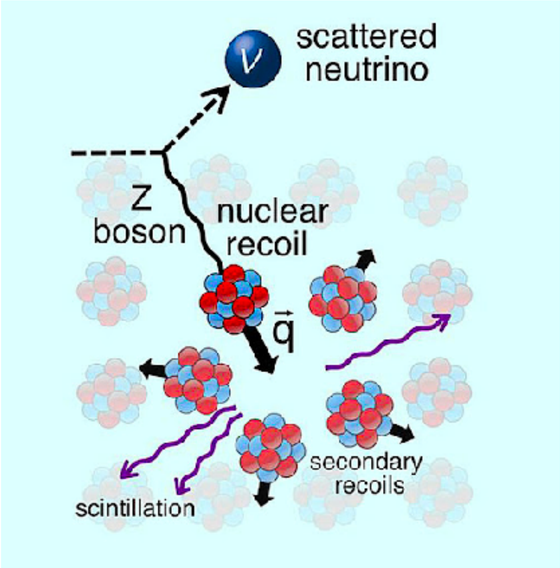
- Interesting physics concentrates at low energies.
- Development of trigger systems capable to be efficient at very low energy levels.
- Triggers based on FPGA are being explored with capabilities for a on-line pre-classification of the events.

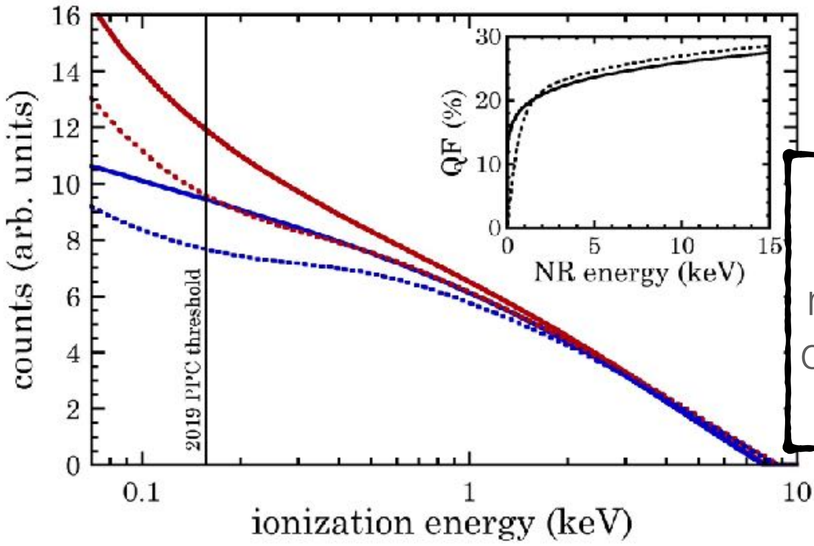
GaNESS project

The Gaseous Prototype (GaP) system

- Test for high pressure (up to 50 bar) and operation with different gases.
- Characterisation of the **response to nuclear recoil** at low energies.
- Small set-up for testing different technical solutions.
- Physics goal: Measurement of quenching factor at different conditions and gases



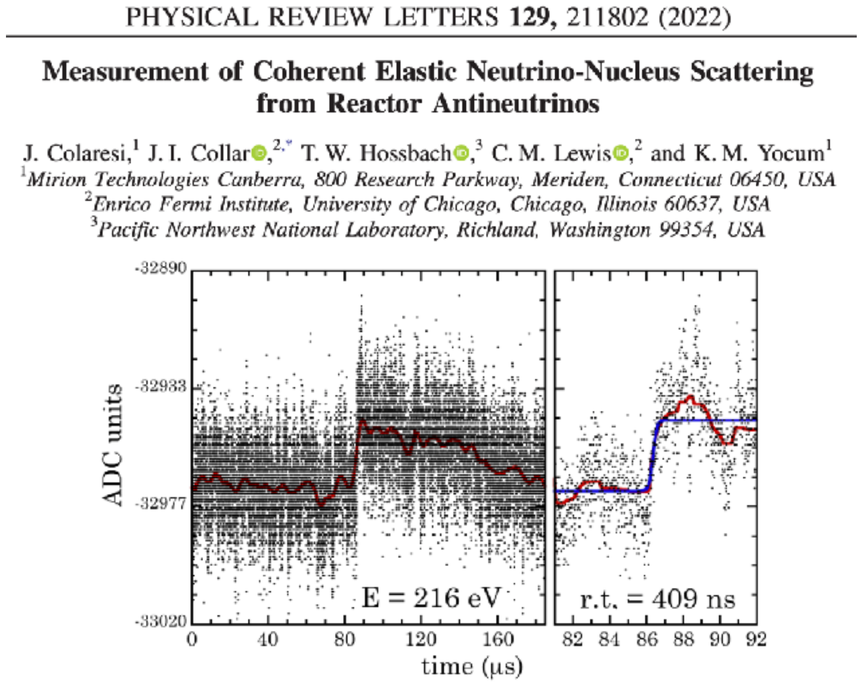




Expected number of events for different values of the neutrino magnetic moment (blue-red) and different models of the quenching factor (solid-dashed)

Next-generation Ge PPC for CEνNS (reactor and later ESS)

- x2-3 reduction in energy threshold to < 100 eV via ASICs front-end and FPGA DAQ (ultra-compact 3 kg PPC).
- Drastic reduction in background (30 m.w.e. tendon gallery) for >> 20 signal/background (presently ¼).
- Precision (high-statistics) measurement: reactor monitoring via CEνNS (daily signal rates proportional to Rx power).


PHYSICAL REVIEW LETTERS **129,** 211802 (2022)

Measurement of Coherent Elastic Neutrino-Nucleus Scattering from Reactor Antineutrinos

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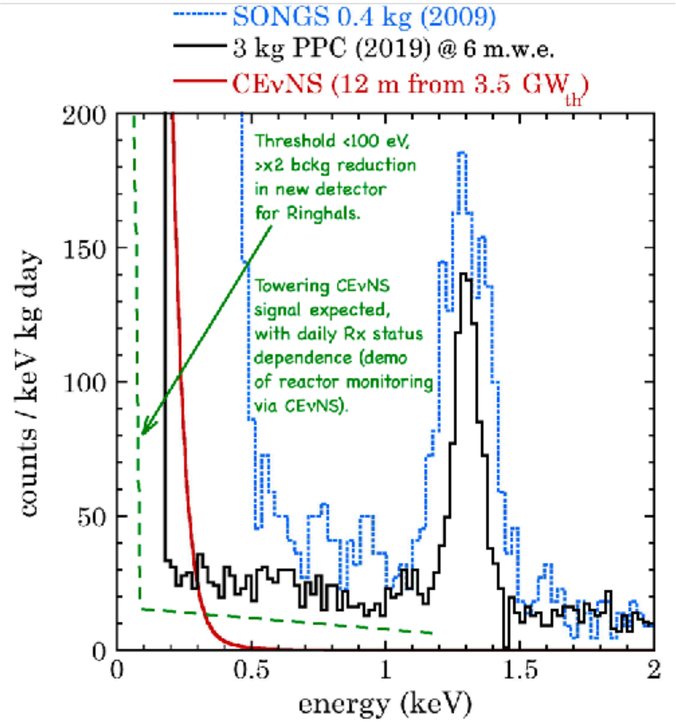
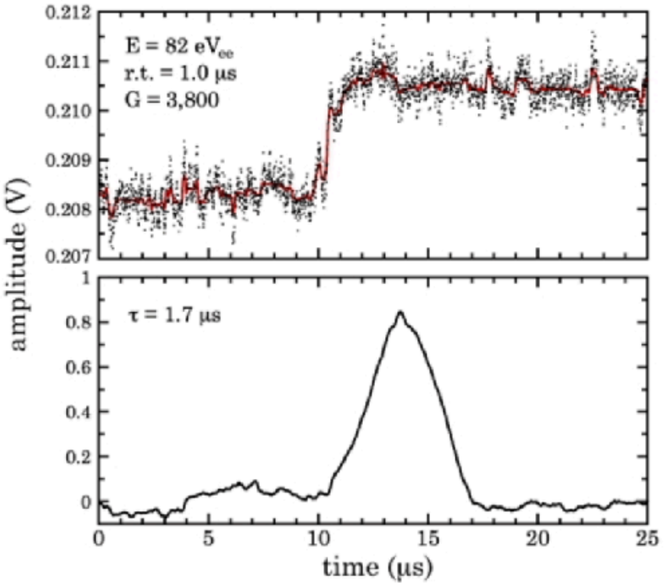


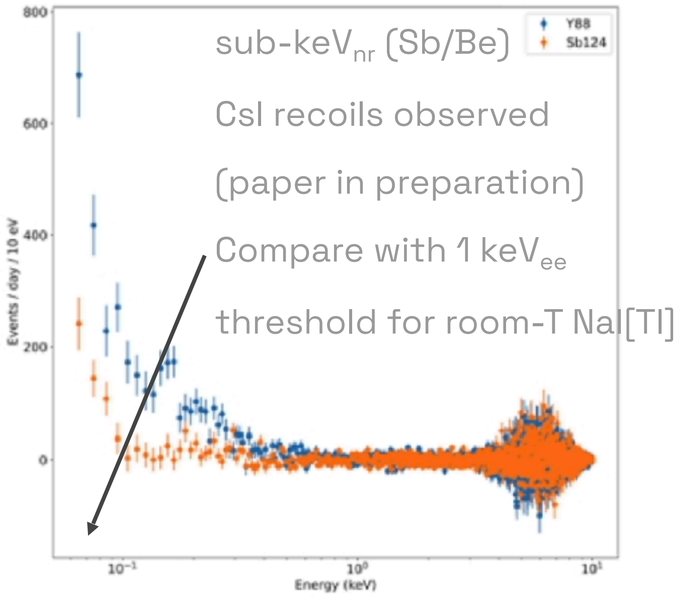
Cryogenic undoped CsI for CEνNS @ ESS (~1 keV$_{nr}$ threshold)

NOL-9 waveshifter exit plate illuminated by 360 nm UV LED.

(see arXiv:1911.00762)

- In-house development of low-noise, low-bckg LAAPDs (>25 cm2).
- Use of NOL-9 waveshifter (>80% QE on Si LAAPD).
- 80K pure CsI yields 100 ph/keV: ~60eV$_{ee}$ threshold, sub-keV$_{nr}$ sensitivity demonstrated.
- Further progress possible (presently limited by LAAPD charge-trapping noise).
- 32 kg array ERC-funded for operation at ESS: high-statistics precision CEνNS measurement (> 10,000 events/yr).





NEXT R&D: People involved

Summary of people involved per institution.

	Researchers	Engineers	Technicians
DIPC	5	2	1

- Researchers:
  - 3 Ikerbasque
  - 1 Marie-Curie
- Engineers:
  - 2 Mechanical engineer.
  - Open position for Electronic engineer.

- Electromechanical technician providing support in the lab.
- 2 PhD students.

nuESS Summary

- CEvNS detection opens a **new avenues in the search of physics beyond the Standard Model**.
- **ESS** will become the largest low-energy neutrino source. Perfect facility to study this process.
- Different detector technologies will be used to fully exploit the physics of the process
- The **GanESS project** will produce a gaseous detector to observe the process at the ESS with a variety of nuclei.
- Development of cryogenic undoped CsI crystals and ultra-low threshold Ge detectors.