Revealing low energy neutrinos: the NUCLEUS experiment

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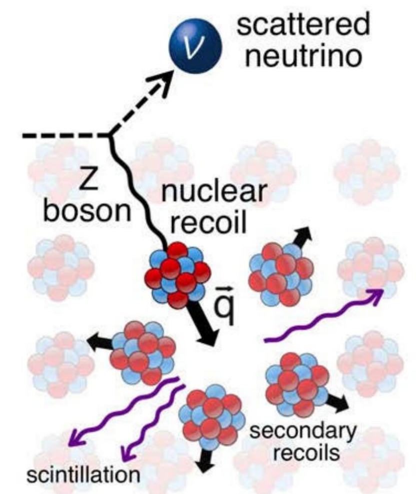
The physics: CEνNS

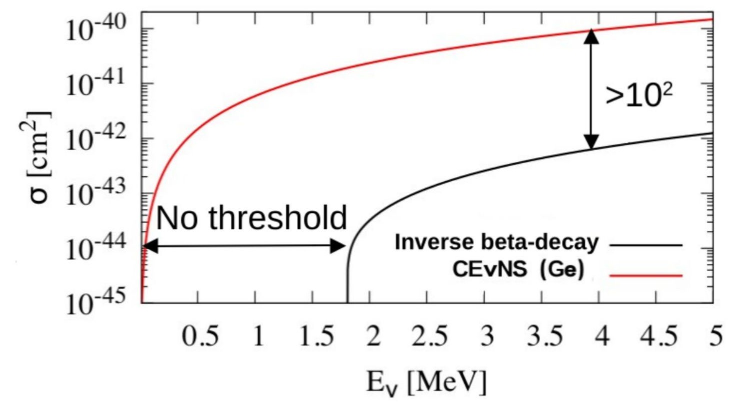
Coherent **E**lastic **ν**-eutrino **N**ucleus **S**cattering



- **Elastic scattering** between a neutrino and an entire atomic nucleus.
- **Most probable interaction** for a low energy neutrino with matter.
- Can reveal neutrinos with **arbitrarily low energy**.
- **Tiny nuclear recoil** (the observable): CEνNS took 43 years to be detected.

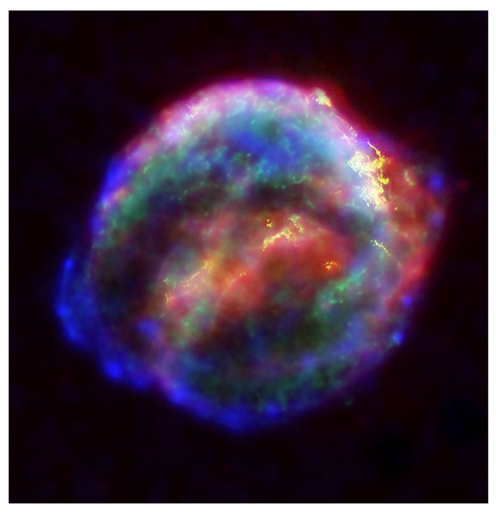
Standard model cross section:

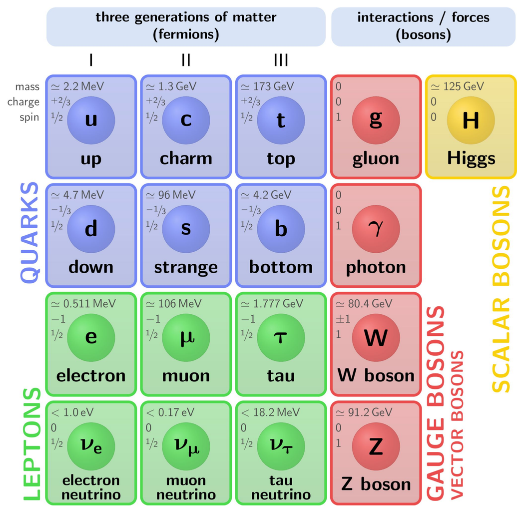
$$\sigma_{\mathrm{CE}\nu\mathrm{NS}} = \frac{G_F^2}{4\pi} E_\nu^2 Q_W^2 \left(1 - \frac{2E_\nu}{M_A}\right) F^2(q^2)$$



Physical applications

- Physics beyond standard model: **non standard neutrino interactions**, **Weinberg angle** at low momentum.
- Measurements of the nuclear **Form Factor**.
- Monitoring of **nuclear power plants** and **spent nuclear fuel**.
- **Supernova** detection.





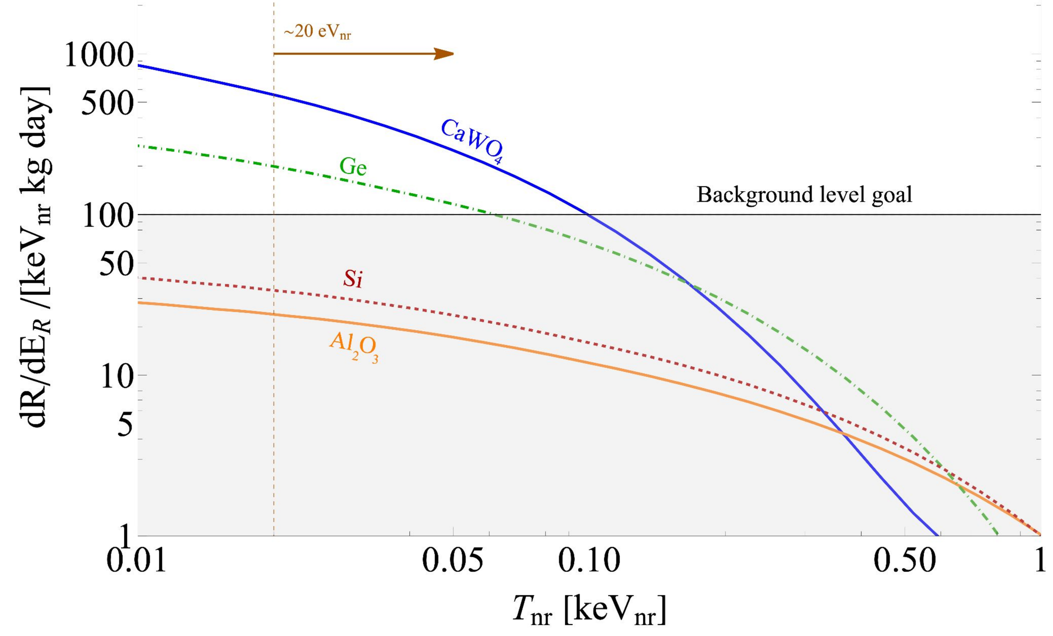
Need for a **precision measurement** of the CEνNS cross section.

NUCLEUS strategy

NUCLEUS will measure **CEνNS from antineutrinos** produced by the reactor cores of the Chooz nuclear power plant in France.

- **Very near site**: 24 m^2 room, 72 m and 102 m from the two 4.25 GW$_{th}$ reactor cores.
- **Neutrino flux**: $1.7 \cdot 10^{12}$ ν/cm^2/s.

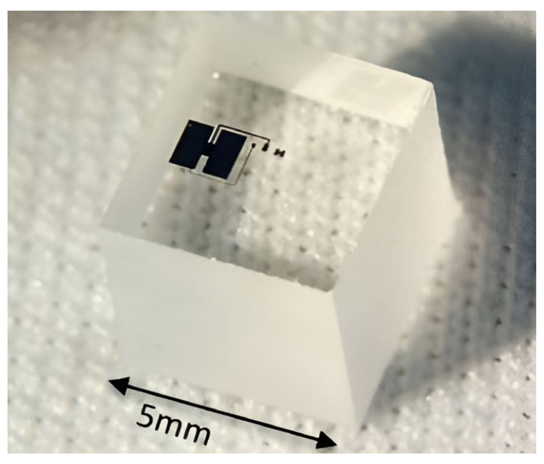
CaWO$_4$ and Al$_2$O$_3$ target crystals, as neutrino detectors.
Reconstruct the **nuclear recoil energy spectrum** from neutrino interactions.
Look for an **excess signal** above the background.



NUCLEUS collaboration:
~ 50 scientists, from 9 institutions and 8 countries.
Website and **comic**!
(credit: Chloé Goupy)

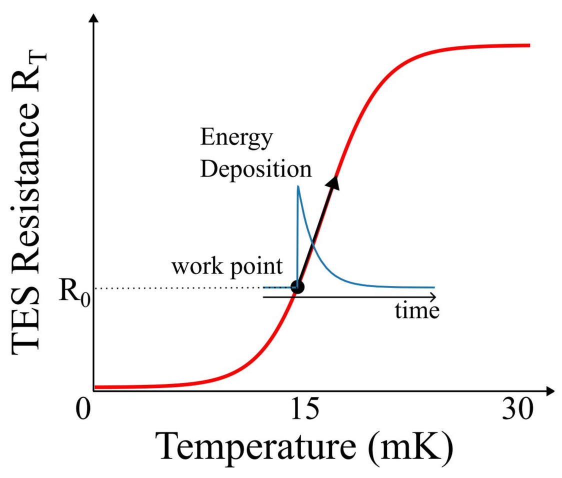
The target detector

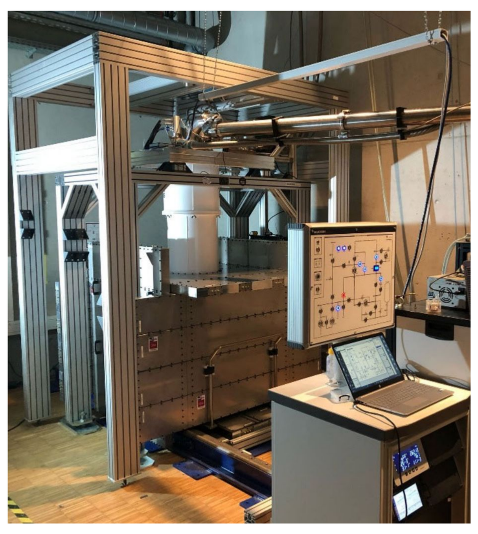
- CaWO$_4$ and Al$_2$O$_3$ target crystals, **kept at 10 mK.**
- When a neutrino interacts, heat is produced, and the rise in temperature is read out by an **extremely sensitive TES termometer**.



Cryogenic cube with equipped with TES

TES: superconductive on the transition curve





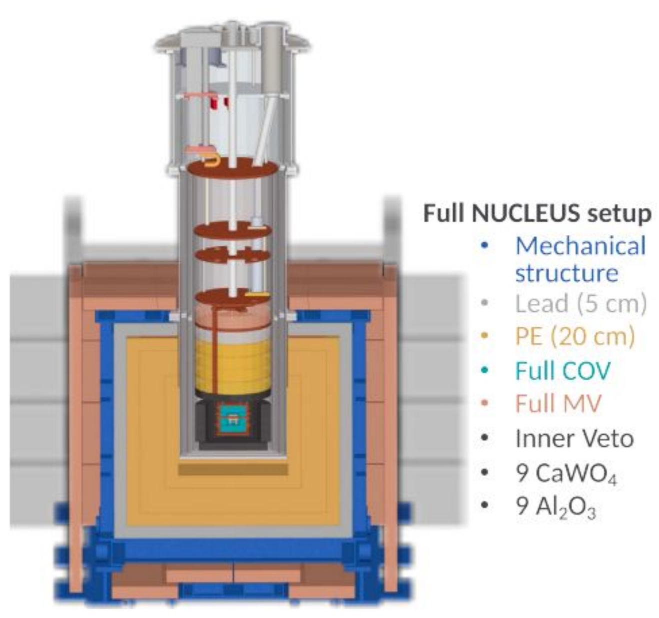
cryostat to keep the detector near the absolute zero

Cryogenic calorimeters with **very low energy threshold** (~ 10 eV).

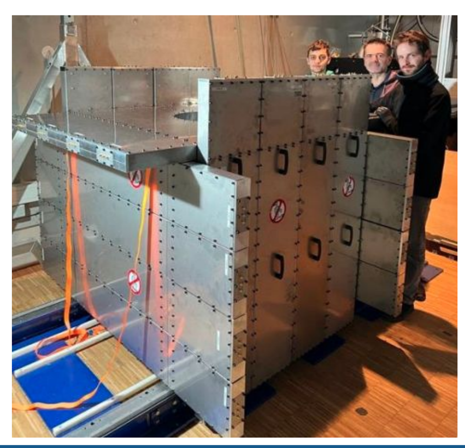
Veto detectors

- Several **active and passive shieldings** to reach a background level of 100 d.r.u.
- Different target detectors for a model independent **background subtraction**.

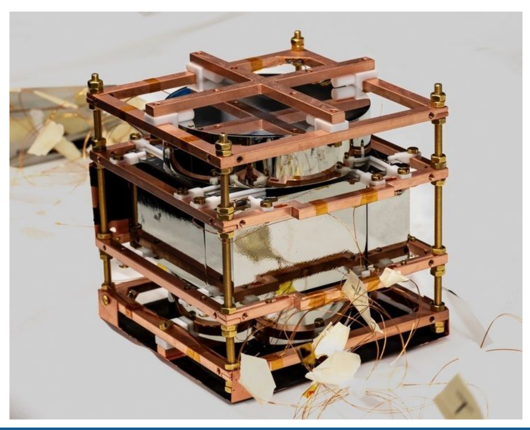
inner veto



muon veto

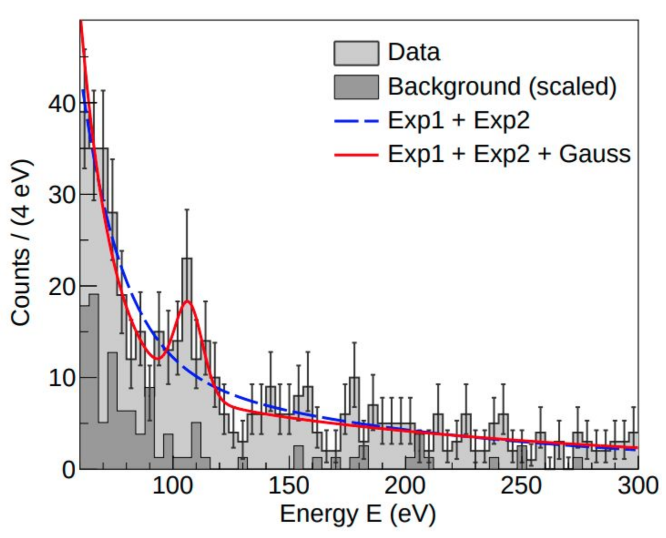


COV to reduce γ



Status and perspectives

- Milestones:
  - Observed a **nuclear recoil** at 100 eV energy scale. Perfect **calibration** method.
  - Operated **all active detectors together** during the commissioning phase at TUM.

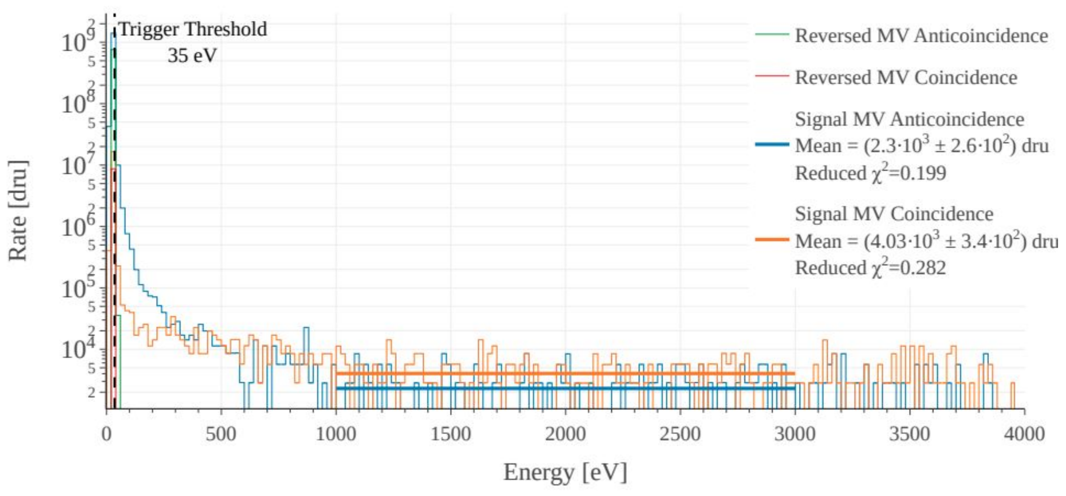


- Currently:

Relocation at Chooz for **NUCLEUS phase 1** (10 g detector, 10% cross section measurement).

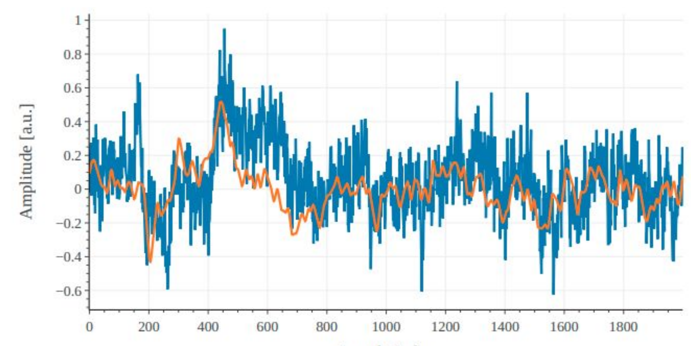
- Perspectives:

Scale up the detector mass for **NUCLEUS phase 2** (1 kg detector, 1% cross section measurement).



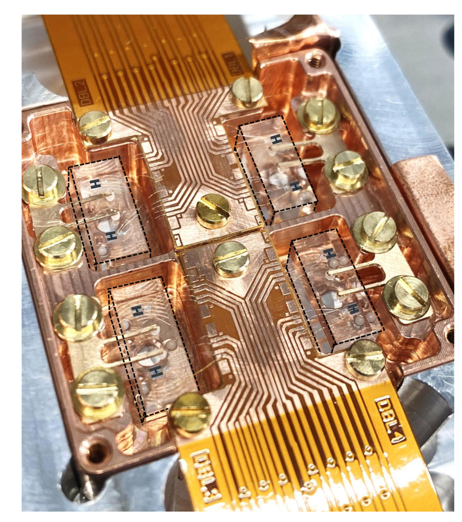
What you can do

- You can work on:
  - Particle physics in the **low energy regime**, **rare event searches**.
  - **Cryogenic physics** at mK temperatures.



- NUCLEUS activities:
  - Data analysis: from **signal processing** to high level **sensitivity studies**.
  - Hardware: **detectors R&D** in Munich.

⚠ **First data taking at Chooz coming soon!**



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