



Axion searches with a **RES-NOVA** prototype cryogenic detector

Laura Trombetta
l.trombetta7@campus.unimib.it



www.res-nova.unimib.it

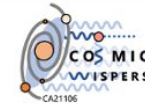
1st BiCoQ Conference - 16/06/2026

RES-NOVA experiment

- RES-NOVA comes from latin and means “new thing”
- Main goal: detection of astrophysical neutrinos, primarily from supernovae (SN)

Besides neutrinos, RES-NOVA can also potentially detect dark matter interactions, making it a versatile tool for astrophysical research.

→ Use of cryogenic detectors based on archaeological lead!

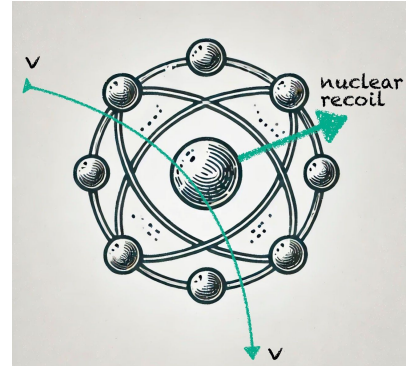


RES-NOVA neutrino detection - I

Coherent Elastic Neutrino-Nucleus Scattering (CEvNS)

CEvNS is a process in which low-energy neutrinos scatter off entire atomic nuclei coherently.

- equally sensitive to all ν -flavors
- high interaction cross-section



Archeological lead detector

→ as shielding

→ in the production of PbWO_4 crystals

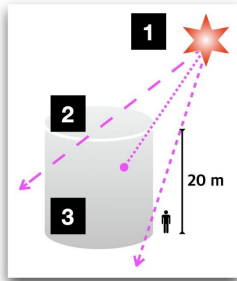
- high statistics (largest cross-section)
- ultra-low-background

$$\sigma_{CE\nu NS} \propto N^2$$

neutron number

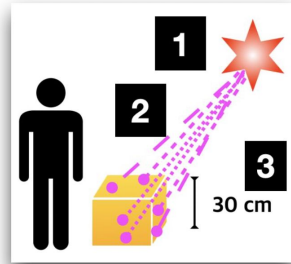
RES-NOVA neutrino detection - II

→ new experimental approach with cm-scale neutrino detector



Status quo:

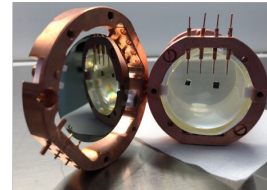
- 1** detection of $\sim 1/6$ SN flux
- 2** small cross-section
- 3** large volume detectors



Opportunities:

- 1** detection of full SN ν flux
- 2** highest cross-section
- 3** cm-scale ν telescope

RES-NOVA CRYOGENIC DETECTORS



4 cm

TRADITIONAL NEUTRINO DETECTOR

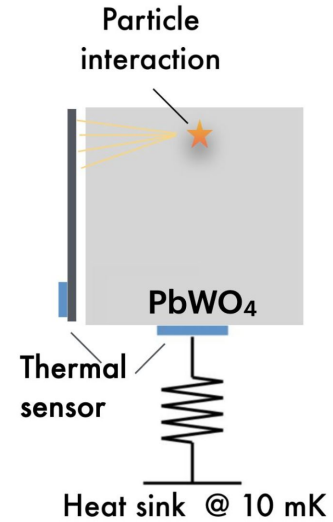


20 m

RES-NOVA is designed for operating in the [Gran Sasso National Laboratory](#)
→ the natural shielding reduces background interference from cosmic rays

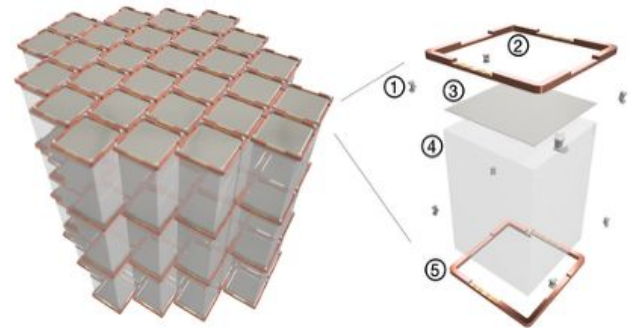
RES-NOVA technology

- Low-temperature calorimeters based on PbWO_4 crystals
- TES (Transition Edge Sensors) used as thermal sensor
- Double read-out (heat + light signal) for particle identification



RES-NOVA demonstrator:

- 1 keV energy threshold
- 84 PbWO_4 modules (crystal + Ge light detector)
- Total mass of 170 kg
- Target bkg rate in the ROI: 10^{-3} c/keV/ton/s



Solar axion fluxes - production

- Primakoff flux and longitudinal plasmon (LP) flux → interaction of axions with the electromagnetic fields in the solar plasma

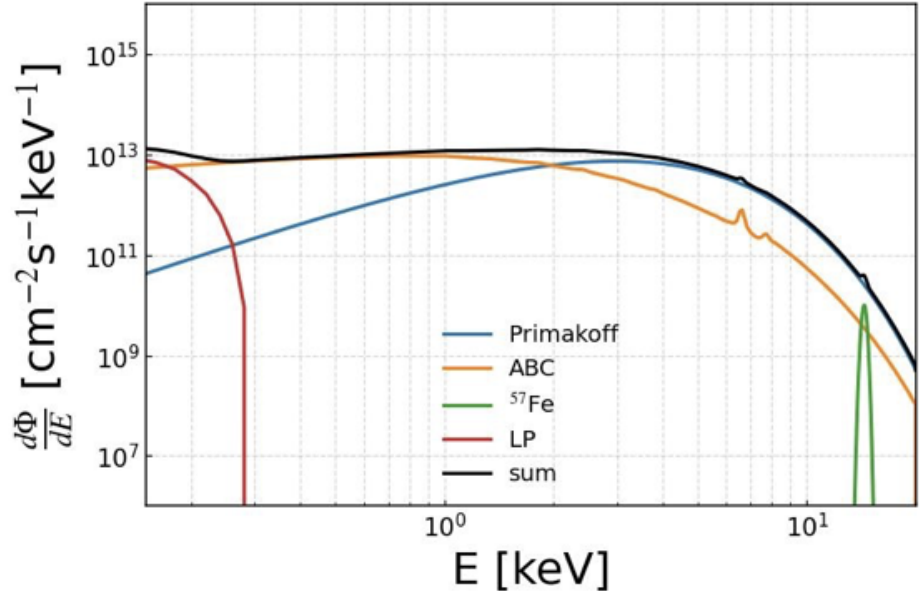
g_{ay}

- ABC flux → atomic recombination and de-excitation (A), Bremsstrahlung (B) and Compton scattering (C)

g_{ae}

- Monochromatic ^{57}Fe flux → M1 nuclear transition of ^{57}Fe at 14.4 keV

g_{aN}



Inverse Primakoff effect - detection

Conversion of axions coupled to photons into photons in the Coulomb field of atoms.

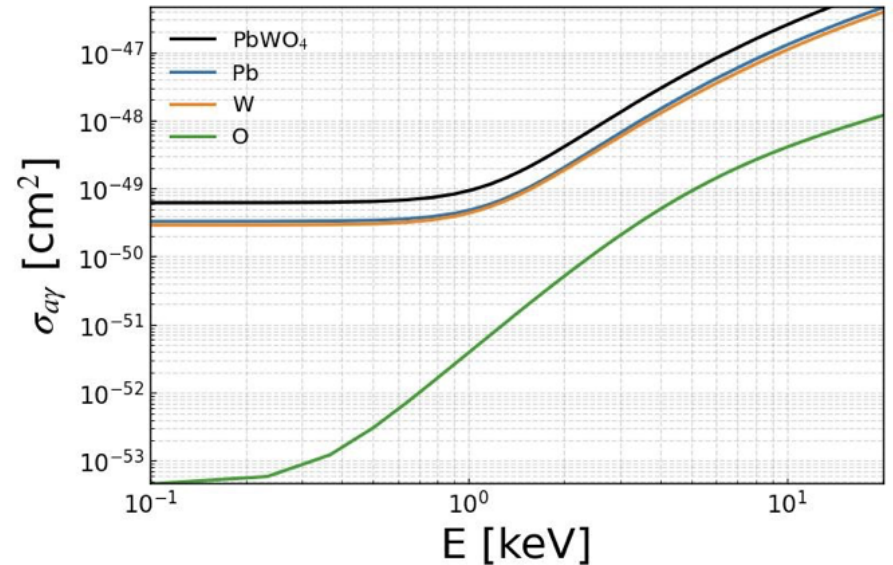
This channel provides a relevant detection mechanism in high-Z materials such as PbWO_4 .

$$\frac{d\sigma_P}{d\Omega} = \frac{\alpha g_{a\gamma}^2}{16\pi} \frac{\sin^2\theta}{(1 - \cos\theta)^2} |Z - F(q)|^2$$

form factor $\rightarrow F(q)$

scattering angle of the outgoing photon $\rightarrow \theta$

momentum transfer $\rightarrow q$



(plot assuming $g_{a\gamma} = 1 \cdot 10^{-10}$)

Axioelectric effect - detection

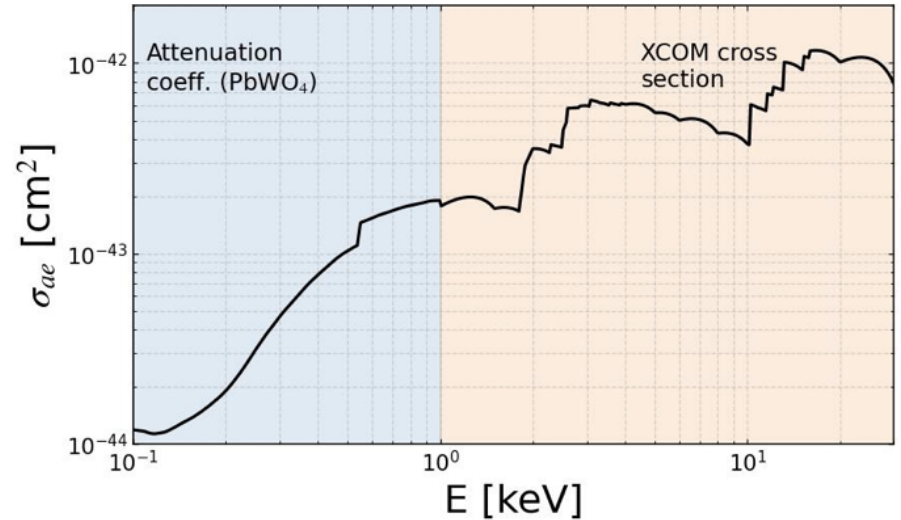
Absorption of an axion by a bound electron in an atom, resulting in the ejection of the electron.

It is a correction to the photoelectric cross-section (σ_{pe}).

$$\sigma_{ae}(E_a) \simeq \sigma_{pe}(E_a) \frac{g_{ae}^2}{\alpha} \frac{3E_a^2}{16\pi m_e^2} \left(1 - \frac{\beta_a^{2/3}}{3}\right)$$

\uparrow
 $\sim Z^n$ ($n \sim 4-5$)

In this work, we use values from the NIST XCOM database for energies above 1 keV. At lower energies, the cross section is reconstructed from X-ray mass attenuation coefficients.

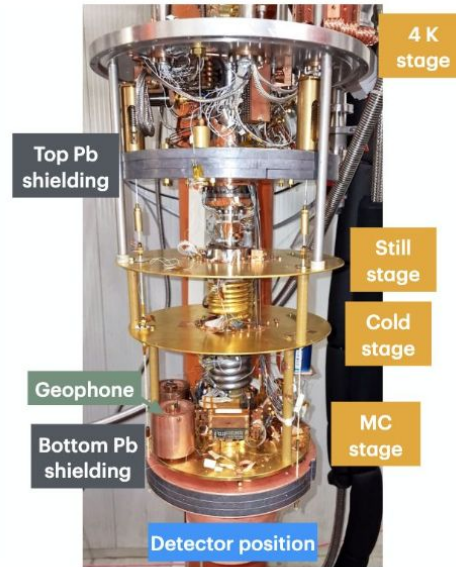


(plot assuming $g_{ae} = 5 \cdot 10^{-11}$)

Constraints with the Yellin's method - I

We present the constraints in the $(g_{\text{oe}}, g_{\text{ay}})$ parameter space derived from a RES-NOVA prototype.

- The crystal had a mass of 13 g and dimensions of $0.7 \times 0.7 \times 4 \text{ cm}^3$
- The measurement was performed in IETI, a pulse-tube assisted dilution refrigerator at LNGS
 - Not optimized for ultra-low-background measurements
 - Optimized for mechanical stability and vibrational isolation



TOTAL EXPOSURE

32.4 g·day

AN. THRESHOLD

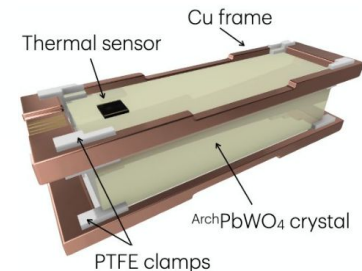
2.5 keV

EN. RESOLUTION

0.2 keV

THERMAL SENSOR

NTD



Constraints with the Yellin's method - II

Given the absence of any background model for the measurement we utilized the optimum-interval method, commonly referred as the Yellin's method.

This approach allows one to derive exclusion limits without relying on an explicit background prediction, and is particularly well suited for low-statistics datasets.

IDEA:

if the expected signal has a given energy distribution model, and the data show intervals that are “too empty” compared to that distribution, then that certain model of the signal can be excluded.

Constraints with the Yellin's method - III

STEPS:

1. Compute the theoretical differential rate dR/dE for different pair $(g_{ae}, g_{a\gamma})$

$$\frac{dR}{dE} = \left\{ [g_{a\gamma}^2 g_{ae}^2 h_P(E) + g_{ae}^4 h_{ABC}(E)] f_{AE}(E) + [g_{a\gamma}^4 h_P(E) + g_{a\gamma}^2 g_{ae}^2 h_{ABC}(E)] f_{IP}(E) \right\} \frac{N_A}{M_{mol}}$$

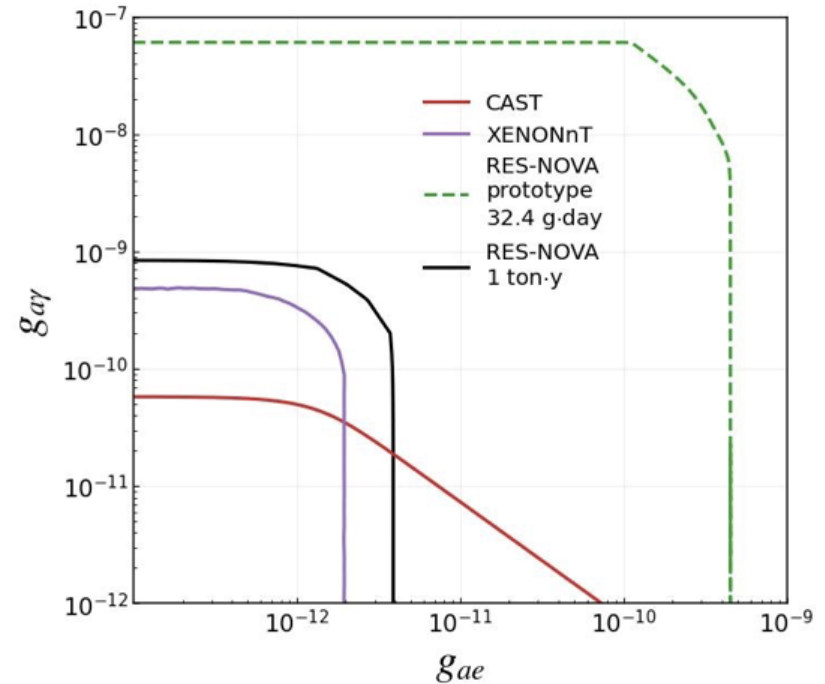
- h_P and h_{ABC} denote the Primakoff and ABC axion flux components
 - f_{AE} and f_{IP} encode the energy-dependent cross-sections for the two detection channels
- } with the corresponding couplings factored out

2. Integrate it to obtain the total expected number of events $\mu(g_{ae}, g_{a\gamma}) = N_{tot}$ and to calculate the normalized CDF of the expected signal. Map each event into a uniform variable $x \in [0; 1]$

Constraints with the Yellin's method - IV

XENONnT Collaboration -
arxiv 2207.11330

- Given the value to the Yellin's algorithm it computes the maximum value of events we expected to have for a specific confident level (here **90% CL**) $\rightarrow N_{\text{sup}}$
- Compare N_{tot} with N_{sup} to define an exclusion curve in the $(g_{\text{ae}}, g_{\text{ay}})$ parameter space (2D grid of μ -values).
 \rightarrow Exclusion contour (green curve) defined by the condition: $\mu(g_{\text{ae}}, g_{\text{ay}}) = N_{\text{sup}}$



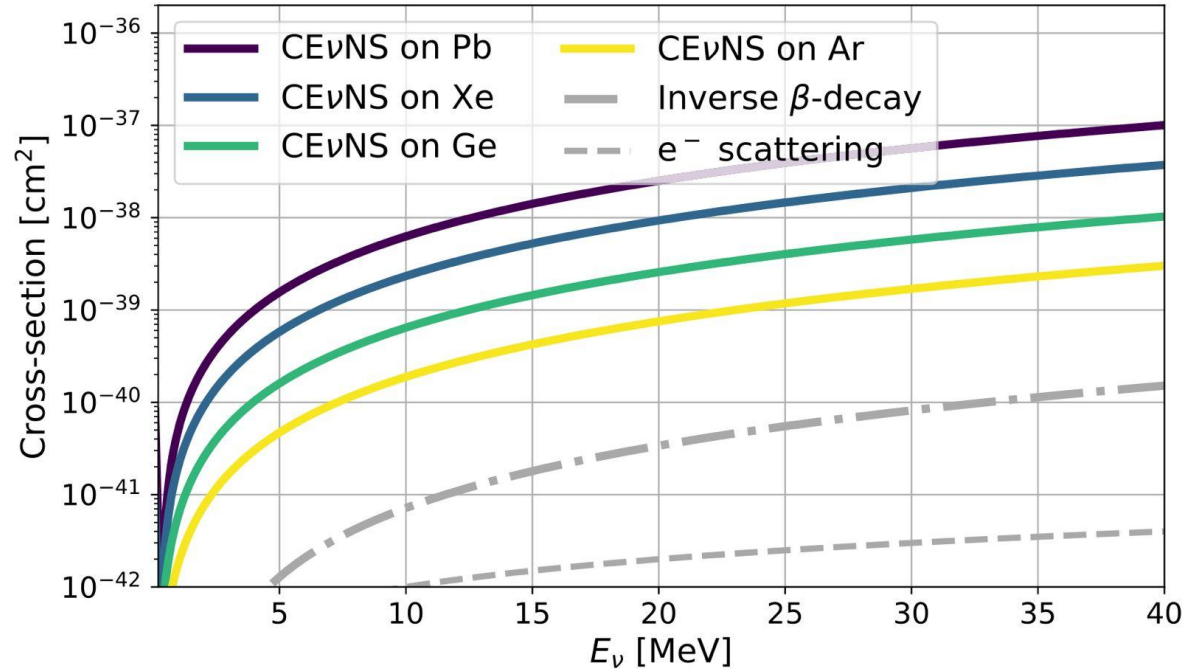
Even if this constraint not competes with the strongest XENONnT limits, it already probes an interesting region of the $(g_{\text{ae}}, g_{\text{ay}})$ parameter space!

Conclusion

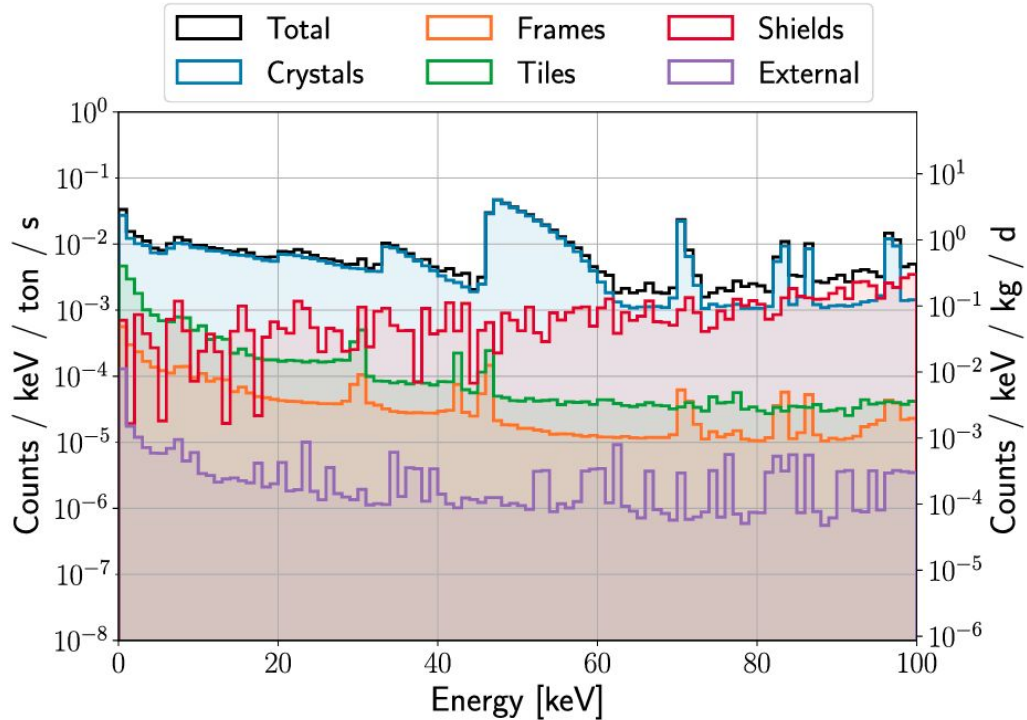
- We successfully operated a cryogenic detector prototype based on a PbWO_4 crystal grown from archaeological lead
- Although the current sensitivity is not yet competitive with state-of-the-art experiments, the measurement provides a clear proof of concept of the detector technology
- Significant improvements are expected in future setups employing optimized low-background conditions and TES sensors instead of Ge-NTD thermistors.
- The experiment represents an **ideal platform for axion searches** thanks to its intrinsic characteristics
- Even with a 13 g prototype, we were able to set an interesting limit on the axion coupling parameter space!

Thank you for the attention!

CE ν NS cross-section



Background prediction

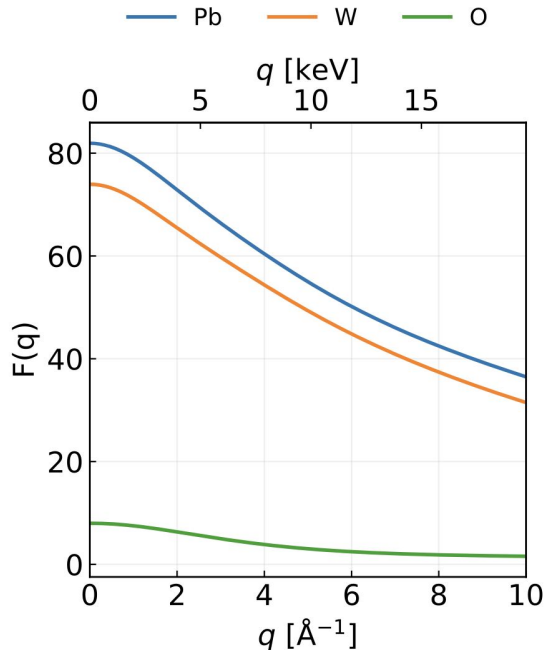


Simulations indicate that bulk contaminations in the crystal are the dominant background source

The collaboration is currently working on benchmarking and optimizing the PbWO_4 crystal production line

Inverse Primakoff effect - form factor

In this work, we model the atomic form factor $F(q)$ using relativistic Hartree-Fock calculations.



$$F(q) = \sum_i a_i \exp \left[-b_i \left(\frac{q}{4\pi} \right)^2 \right] + c$$

where the coefficients (a_i , b_i , c) are specific to each atomic species (Pb, W, O)