NUCLEUS: cryogenic calorimeters to detect coherent nuclear scattering of reactor antineutrinos

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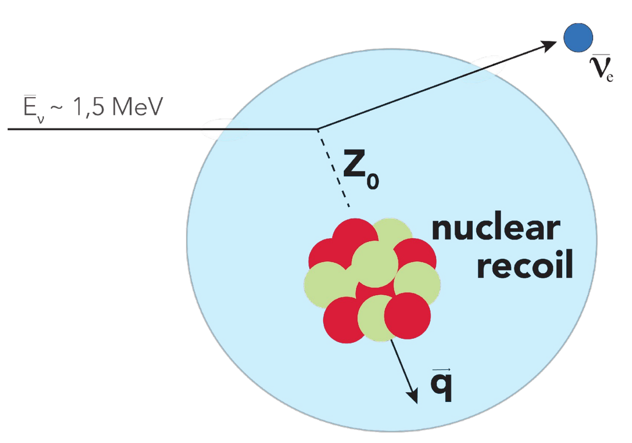
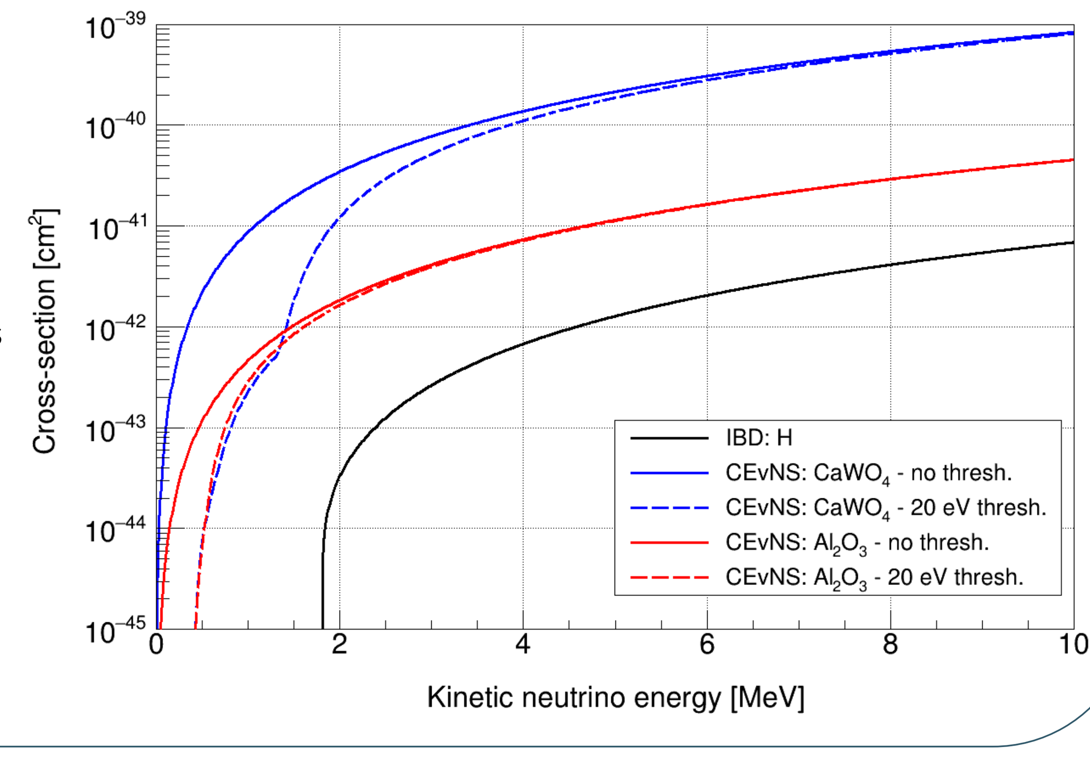
COHERENT NEUTRINO NUCLEUS SCATTERING (CEvNS) WITH REACTOR NEUTRINOS



Fully coherent scattering for low neutrino energies (e.g. reactor neutrinos)

- neutral-current neutrino interaction - coupling of neutrinos to quarks through Z-boson exchange
  → **flavor-independent process**
- Prediction of elastic neutrino-nucleus scattering in 1974 [1]
  → **no energy threshold**
- small momentum transfer: coherent interaction of nucleons
  → **strong enhancement of cross-section**
- First experimental detection in 2017 [2]
  → **new neutrino interaction channel**

the beauty: **high cross section**
$\sigma_{CEvNS} \sim 10^3 \cdot \sigma_{IBD}$
the challenge: **small recoil energies**,
e.g. $E_{CEvNS,\,Tungsten} \sim O(10 - 100\ eV)$



PHYSICS POTENTIAL

NUCLEUS 10g

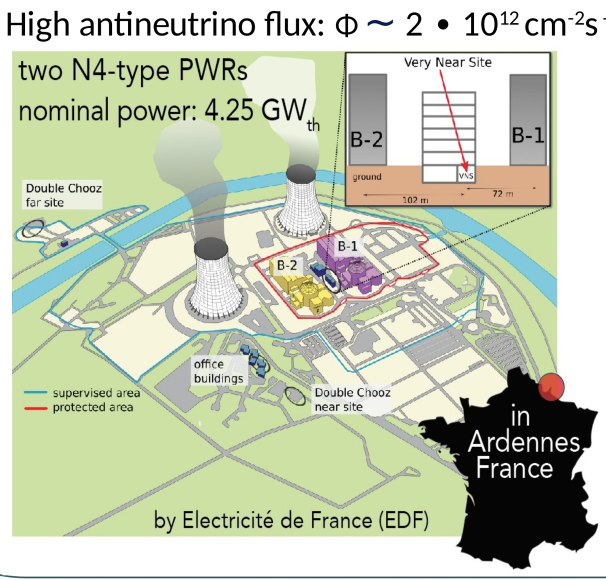
- 5σ observation of CEvNS achievable after less than 1 year of data taking
- New measurement of weak mixing angle at low momentum transfer
- Constrain electronic neutrino NSI parameters
- Limited at 10% statistical uncertainty over measurement-time

Significant detection of CEvNS using reactor neutrinos
→ extending the frontier of low-energy neutrino physics

THE EXPERIMENTAL SITE AT THE CHOOZ NUCLEAR POWER PLANT

"Very Near Site" - VNS

- 24m² basement room in administrative building
- Baseline: 72 m to B-1 & 102 m to B-2
- High antineutrino flux: $\Phi \sim 2 \cdot 10^{12}\ cm^{-2}s^{-1}$

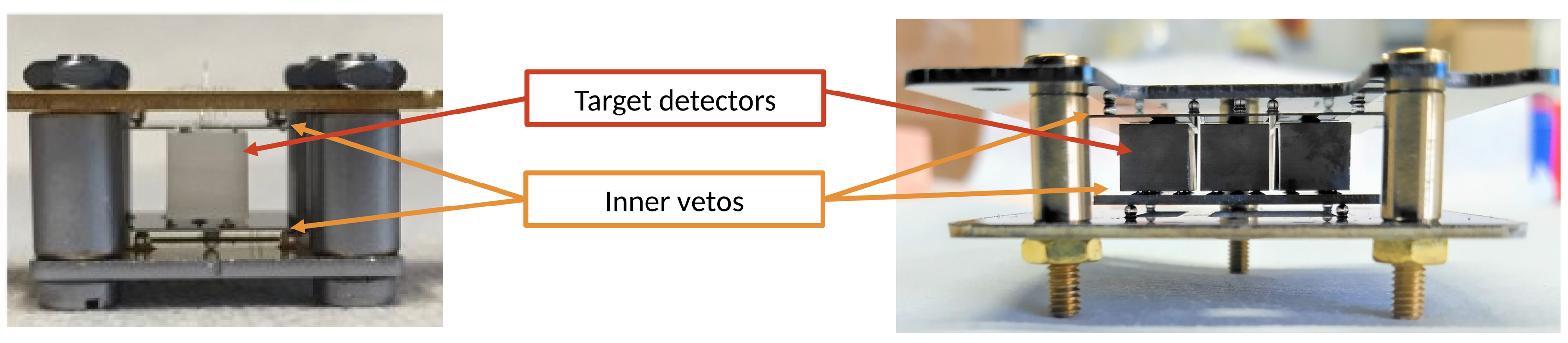


NUCLEUS DETECTOR CONCEPT

Multi-target approach ($CaWO_4$ & Al_2O_3) allows **in-situ background characterization**:
9 detectors of ∼6g $CaWO_4$ for CEvNS detection and 9 detectors of ∼4g Al_2O_3 for background characterization
→ First science phase: **Total target mass of ∼10g** & Ultra-low **threshold goal of 20 eV_{nr}**

Detector performance for 1 detector of 1g target mass demonstrated:

Detector concept of for 2*9 detectors with 10g total target mass demonstrated:



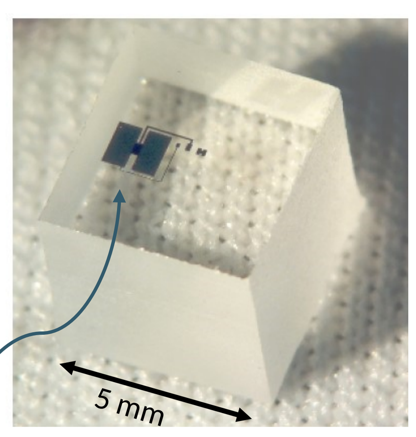
Target detector with ultra-low energy threshold of 20 eV_{nr}

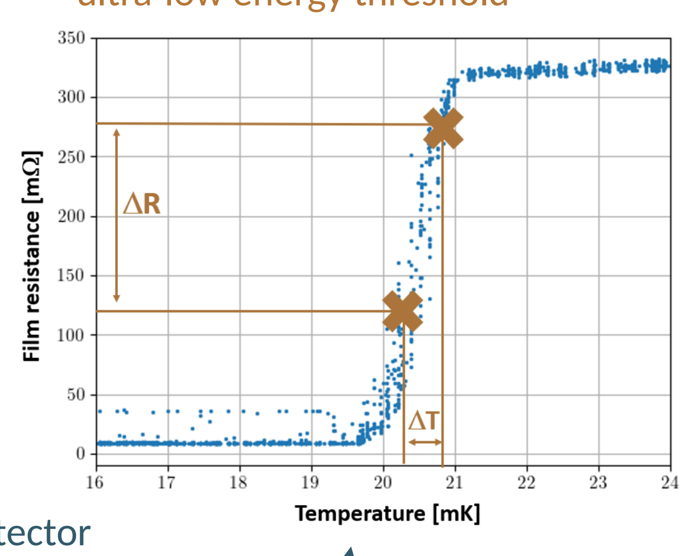
Simultaneous operation of target detector & inner vetos

Mechanical set-up verified at room & cryogenic temperatures
Scalable cryogenic technology allows target-mass upgrade from NUCLEUS-10g to NUCLEUS-1kg

TARGET DETECTORS

Gram-scale cryogenic detectors with ultra-low energy threshold



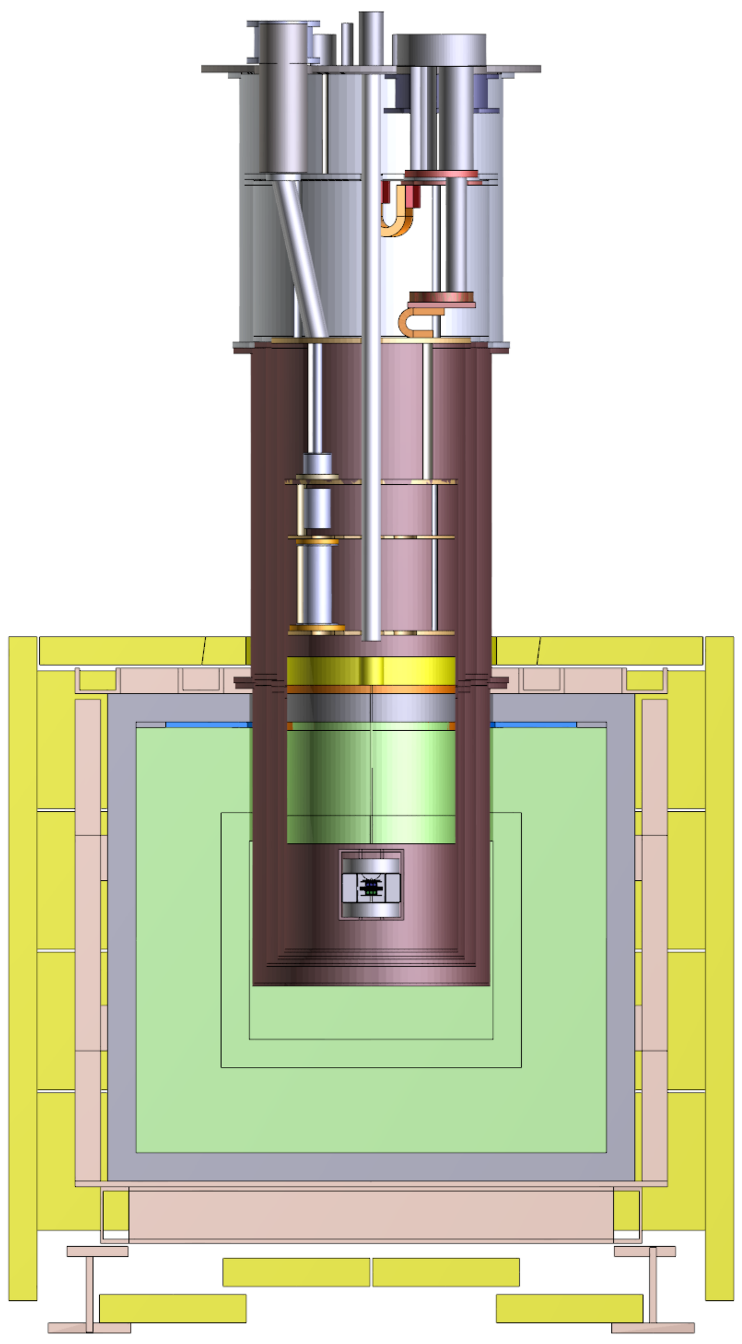


W-TES on first CaWO4 detector show transition at T~21 mK

Temperature sensors on the detector's surface are based on **superconducting thin tungsten films** and are operated at a temperature in between of the normal to superconducting phase transition = **Tungsten Transition Edge Sensors** (W-TES)

Target detectors will be individually **calibrated** by a **LED System**

Measuring the pulse height and width of LED bursts allow for in-situ absolute energy calibration of the 18 target detectors [5]



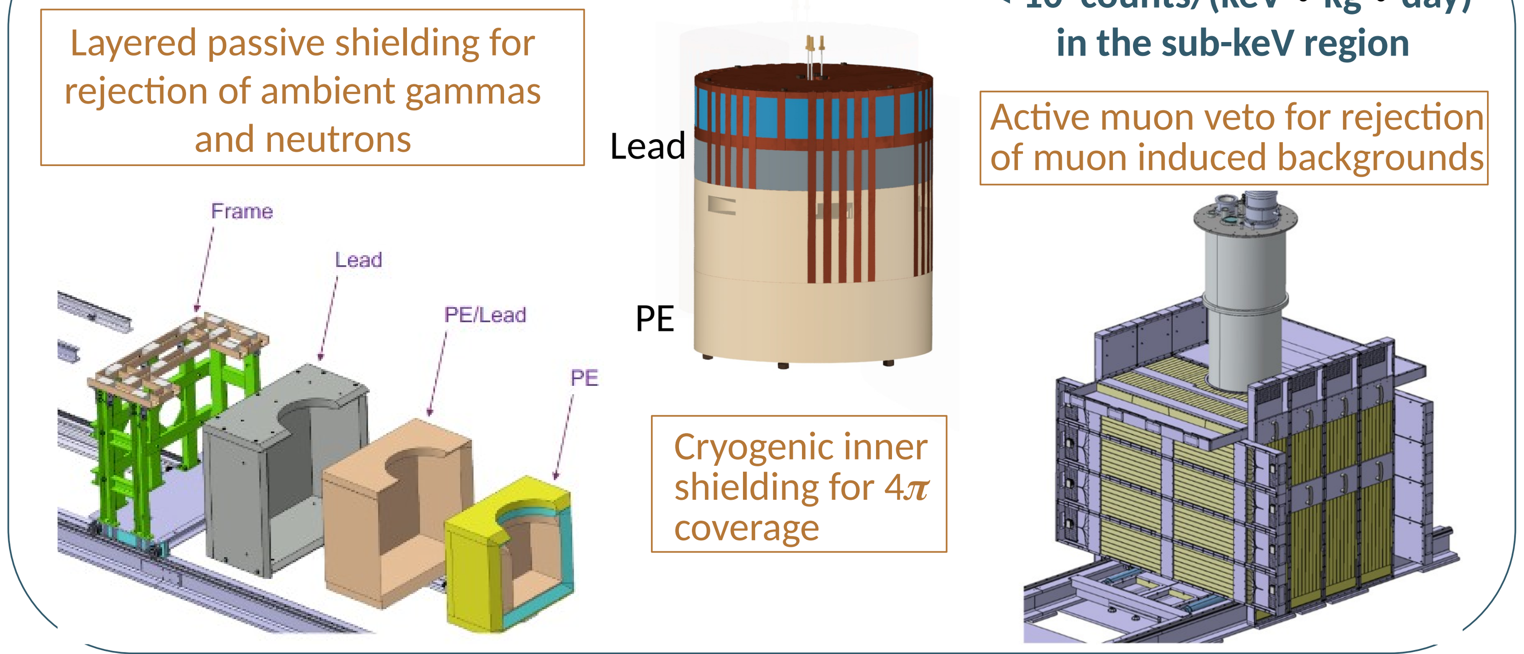
ACTIVE AND PASSIVE SHIELDING [7]

Goal: background rate < 10^2 counts/(keV • kg • day) in the sub-keV region

Layered passive shielding for rejection of ambient gammas and neutrons

Active muon veto for rejection of muon induced backgrounds

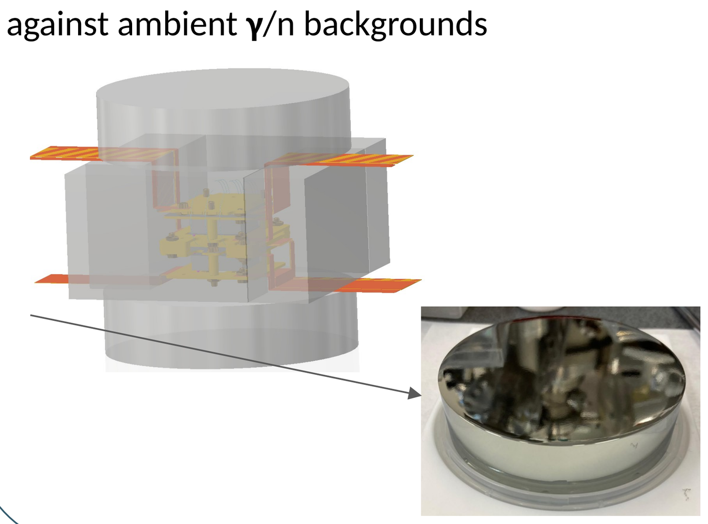
Cryogenic inner shielding for 4π coverage

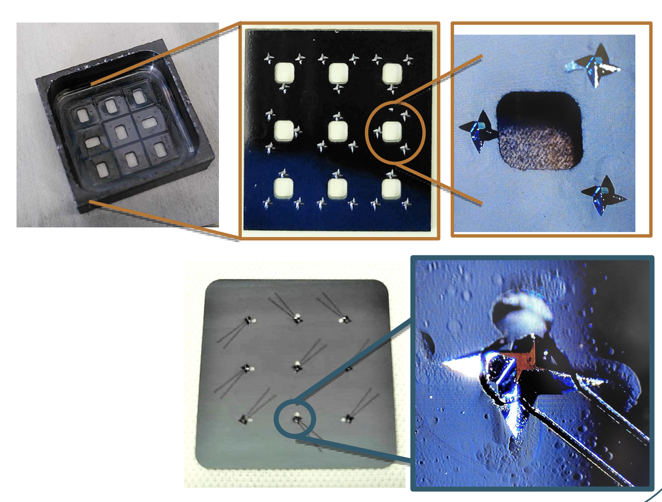


CRYOGENIC VETO SYSTEMS

Outer veto [6]: Ge charge readout detectors against ambient γ/n backgrounds

Inner veto:
1. supports target detectors
2. 4π coverage of targets with sub-keV threshold





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