Impact of marine microseisms on the response of the CUORE cryogenic calorimeters

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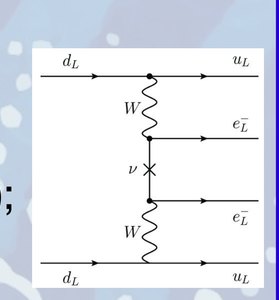
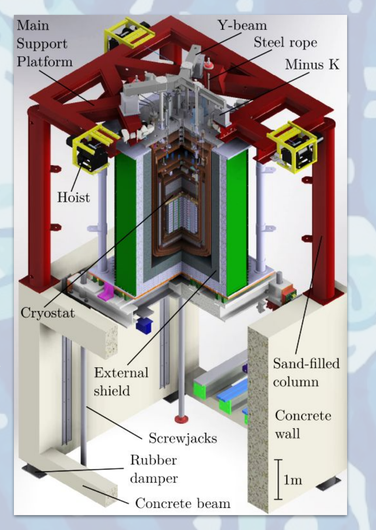
1. CUORE experiment

- CUORE searches for $0\nu\beta\beta$ decay of ^{130}Te:
  - rare process: $T_{1/2}^{0\nu}(^{130}\text{Te}) > 2.2 \cdot 10^{25}$ yr;
  - BSM process (lepton number violation ΔL=2);
  - if detected ➡ majorana neutrinos ($\nu \equiv \bar{\nu}$).



- CUORE:
  - 988 low-T calorimeters at T ~ 15 mk;
  - TeO_2 crystals + Ge-NTD thermistors;



- Frequency band of thermal pulses: ~ 0-5 Hz

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importance of understanding sources and time evolution of sub-Hz noise (seismic noise, marine microseisms) to improve noise-reduction techniques and energy resolution.

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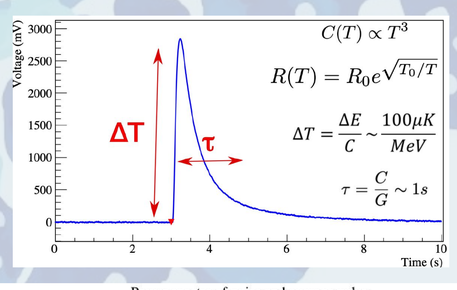
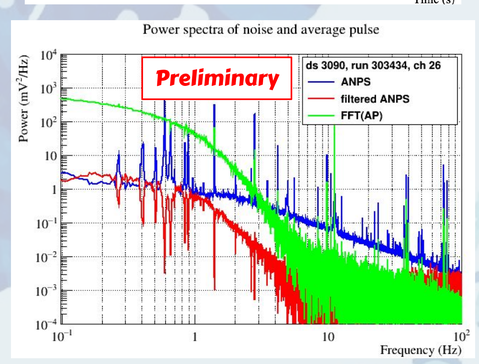
sensitivity to $0\nu\beta\beta$ decay:

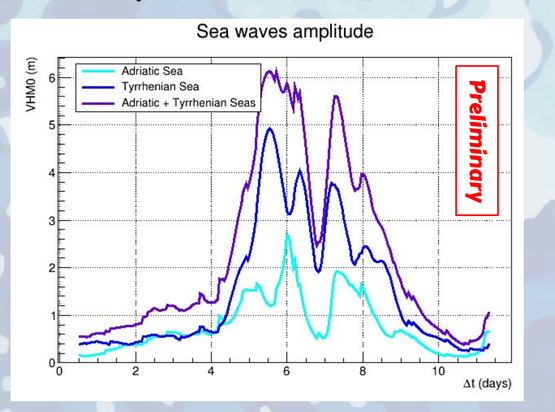
$$S^{0\nu} \propto \sqrt{\frac{M\,T}{\Delta E\,B}}$$

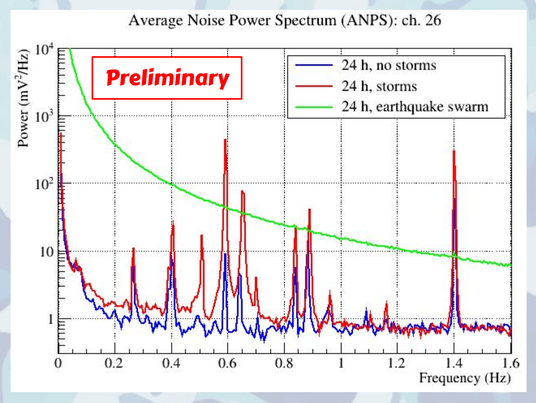




2. Multi-detector approach

- Study correlation between CUORE low-frequency noise and marine microseisms in Mediterranean Sea.
- Multi-detector approach:
  - **E.U. Copernicus Marine Service**: identify storms and evaluate wave amplitude (VHM0);
  - **seismometers**: detect and reject earthquakes;
  - **CUORE detectors:** study low-frequency noise.
- 21st September 2020 - 1st October 2020:



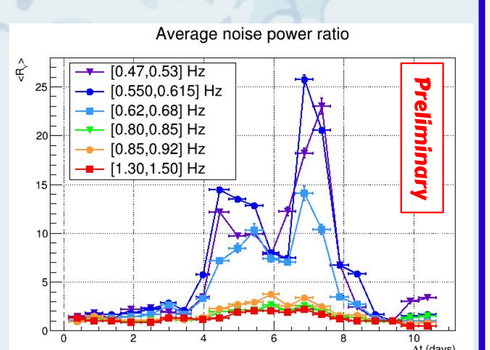


➢ Marine microseisms excite noise at sub-Hz frequencies.

3. Storms-induced low-ν noise

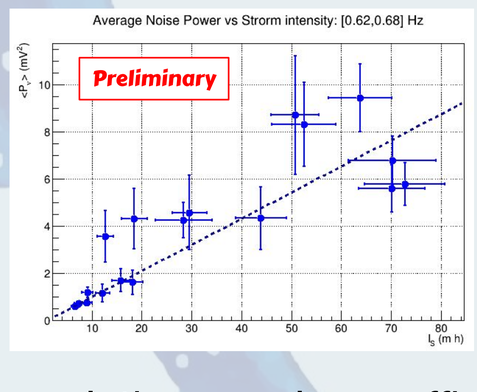
3.1 Time evolution of low-frequency noise

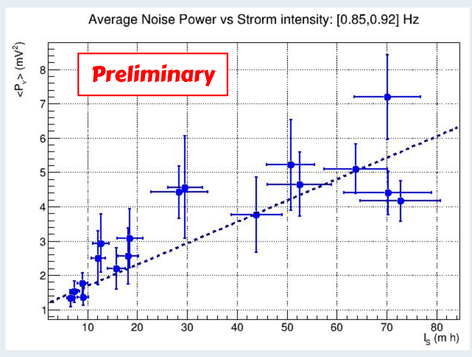
- Power of a ν-component of the noise: $P_\nu = \int_{\nu_1}^{\nu_2} ANPS(\nu) d\nu$
- Noise power ratio: $R_\nu = \frac{P_{i,\nu}}{P_{ref,\nu}}$
  - ➢ average R_ν on ⅓ of CUORE detectors (the most sensitive);
  - ➢ noise increases during storm;
  - ➢ maximum variation at $\nu \sim 0.6$ Hz;
  - ➢ $\nu > 0.9$ Hz almost unaffected;
  - ➢ 1.4 Hz and harmonics almost unaffected (pulse tubes induced).



3.2 Sensitivity of low-ν noise to sea waves intensity

- Sea waves intensity: $I_S = \int_{t_i}^{t_f} [VHM0_A(t) + VHM0_T(t)] dt$
- Quantify noise variation as a function of sea waves intensity:





➢ The relative angular coefficient $m_\nu^{rel} = \frac{m_\nu}{min(<P_\nu>)}$ quantifies the **sensitivity of a noise ν-component to changes of sea waves intensity**.

➢ $\nu > 0.9$ Hz almost unaffected;

➢ maximum sensitivity at $\nu \sim 0.6$ Hz

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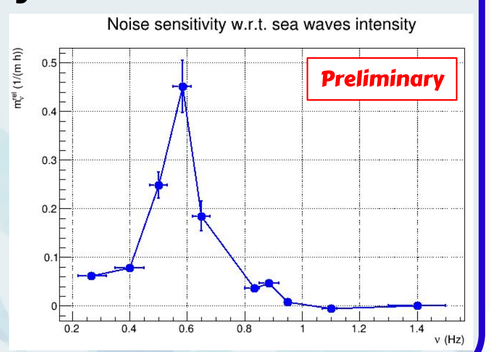
hint for identifying $\nu \sim 0.6$ Hz as a resonant mode of CUORE.



4. Next steps

- Ongoing:
  - ➢ extend analysis to other storms in different years;
  - ➢ extend analysis to all CUORE detectors, and search for position-dependent effects;
  - ➢ evaluate the impact on the detectors energy resolution.
- Possible outcomes:
  - ➢ studies to improve the seismic-decoupling system for CUPID (next-gen experiment for $0\nu\beta\beta$ decay search);
  - ➢ studies to improve the detectors low-energy threshold.

This study has been conducted using E.U. Copernicus Marine Service Information.