The CUORE-CUPID cryostat: current performance and future upgrades

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Abstract: The **CUORE** (**C**ryogenic **U**nderground **O**bservatory for **R**are **E**vents) experiment is a ton-scale bolometric detector[1], operating at a cryogenic temperature of about 10 mK, searching for neutrinoless double-beta decay and other rare events. It owns one of the today's most powerful milli-Kelvin infrastructure in the world[2].

We envision an upgrade of the CUORE cryostat in order to host the new **CUPID** (**CU**ORE **U**pgrade with **P**article **ID**entification) detector array and read-out system, that will account for about 3 times higher thermal load coming from the wiring with respect to CUORE[3].

In this contribution the cryogenic upgrades of the CUORE cryostat from the perspective of the CUPID experiment will be mainly introduced, with an insight on the enhancement of the Pulse Tube system and on suppression of the vibration noise[4].

References

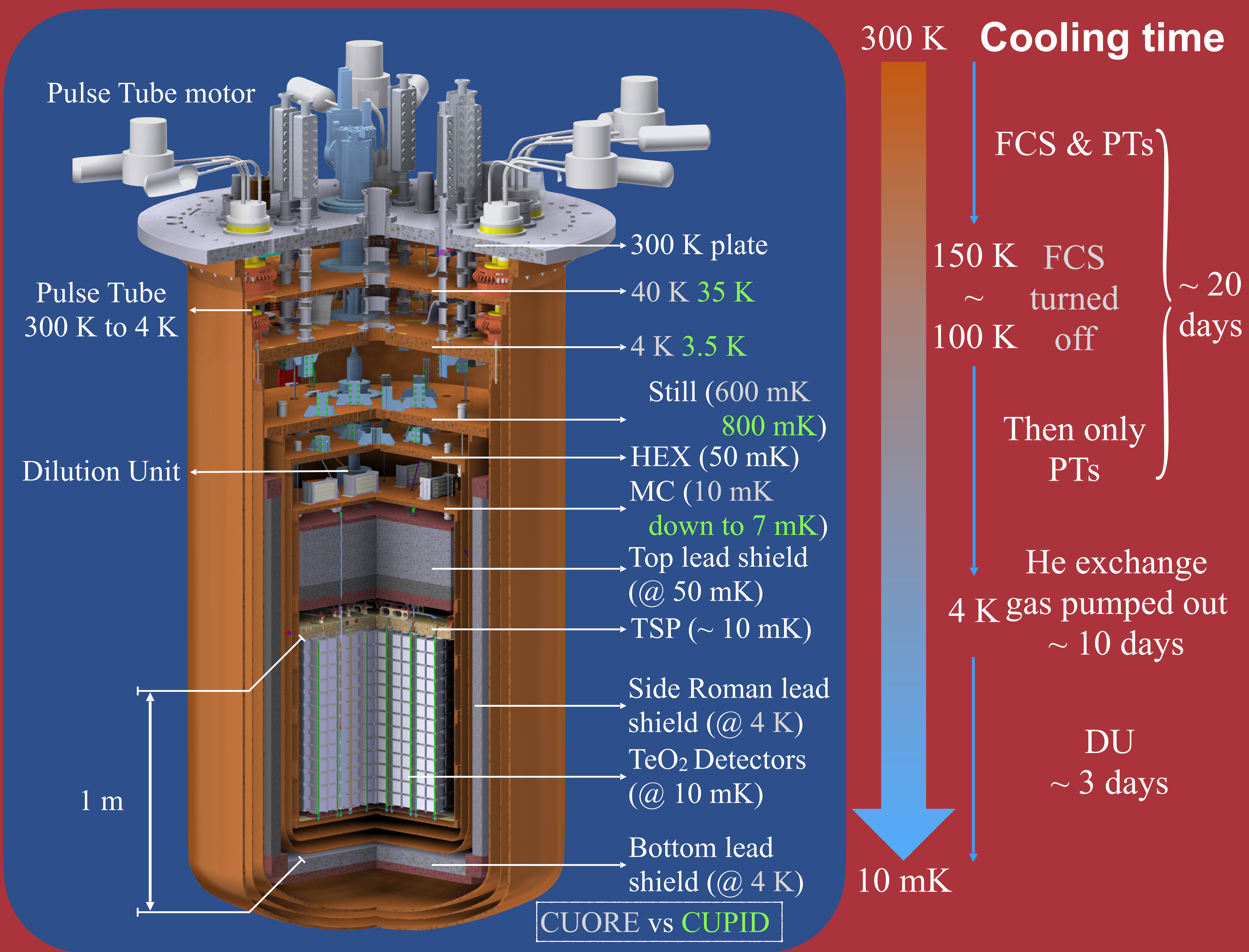
[1]: D. Q. Adams *et al*. "CUORE opens the door to tonne-scale cryogenics experiments". Progress in Particle and Nuclear Physics 122, 103902 (2022)

[2]: C. Alduino *et al*. "The CUORE cryostat: An infrastructure for rare event searches at millikelvin temperatures". Cryogenics 102, 9-21 (2019)

[3]: The CUPID Interest Group, "CUPID pre-CDR". arXiv:1907.09376

[4]: A. D'Addabbo *et al*. "An active noise cancellation technique for the CUORE Pulse Tube cryocoolers". Cryogenics 93, 56-65 (2018)

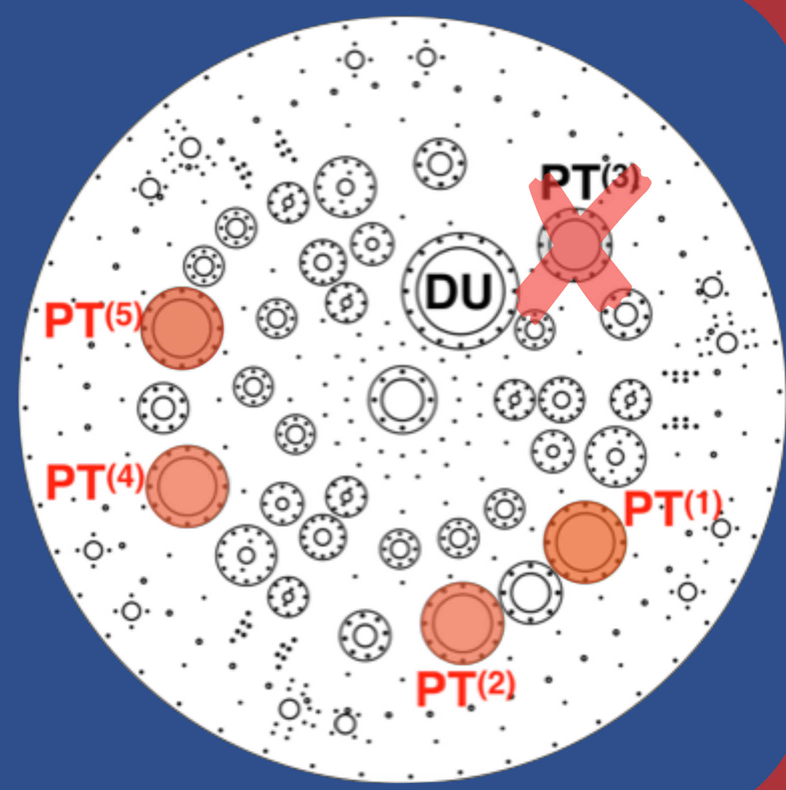
The CUORE Cryostat



Top View of 300 K Plate

Foreseeing to reduce 1 PT in CUPID

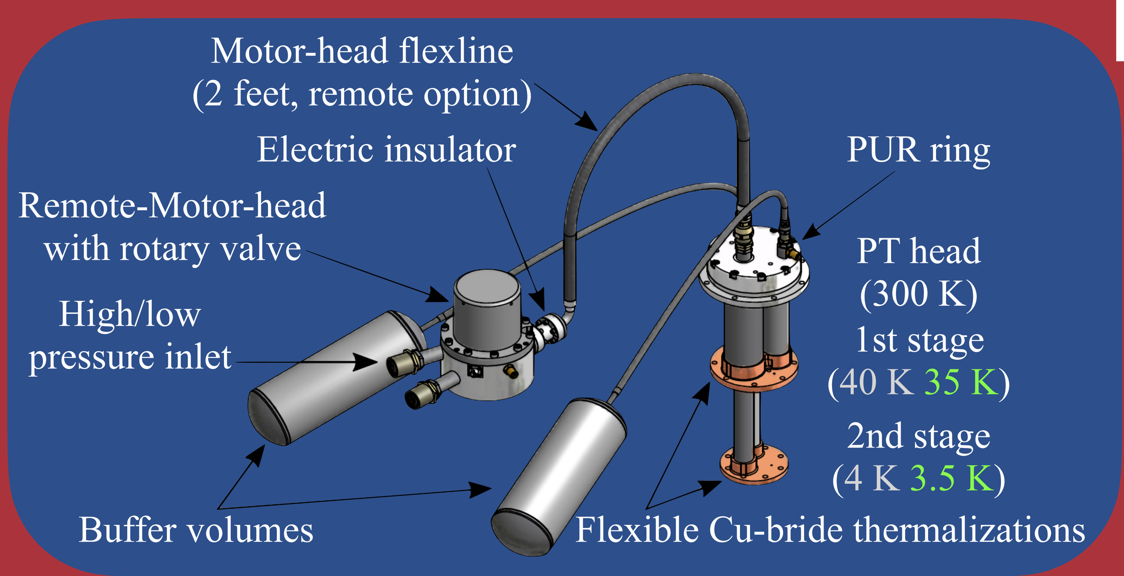
(This green color represents CUPID in this poster)

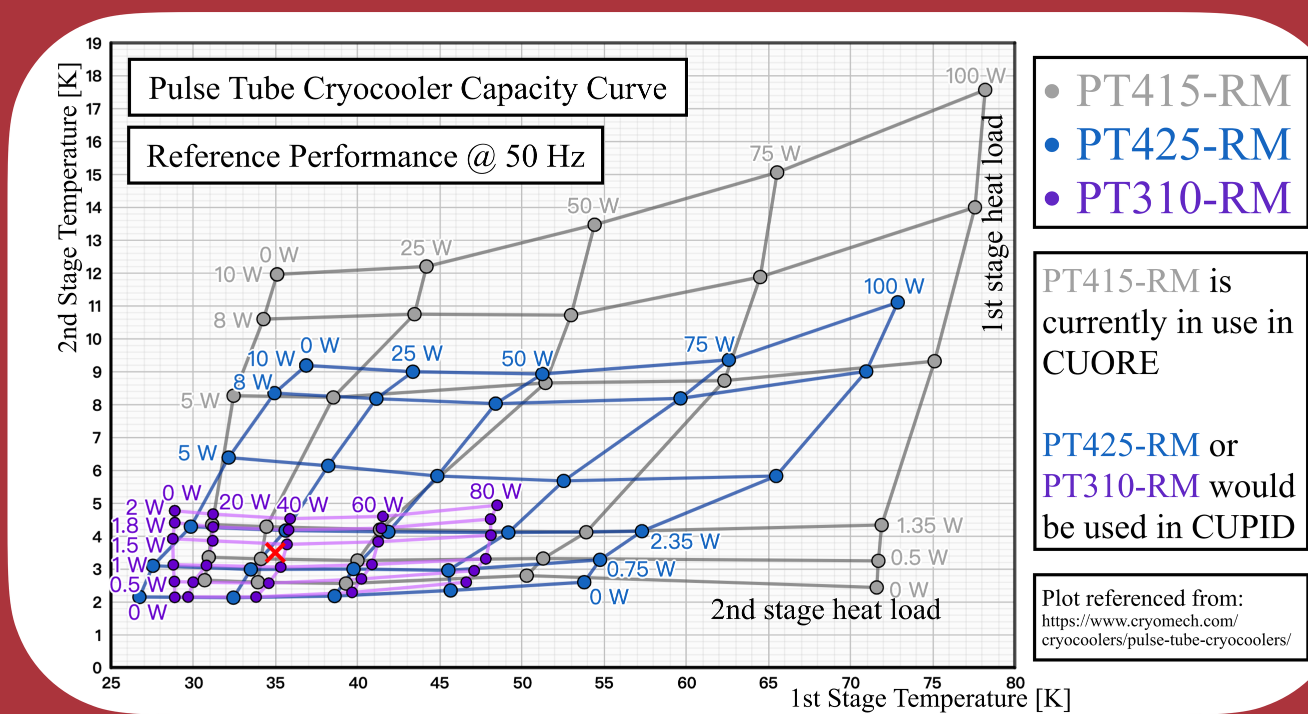


The multistage refrigerator

- Fast Cooling System (FCS) down to ~ 50 K
  - Cooling power: 1800 W @ 300 K; 350 W @ 50 K
- Pulse Tubes (PTs) down to ~ 4 K (~ 3.5 K)
  - 4 PTs plus 1 backup (Cryomech 415-RM)
  - 3 PTs plus 1 backup (Cryomech 425-RM)
  - Cooling power: (4 × 32 W) - 16 W = 112 W @ 45 K;
    - (4 × 1.2 W) - 0.6 W = 4.2 W @ 4 K
    - (3 × 45 W) - 22.5 W = 112.5 W @ 45 K;
    - (3 × 2.35 W) - 1.175 W = 5.875 W @ 4.2 K
- Dilution Unit (DU) down to ~ 10 mK (down to 7 mK)
  - Cooling power: 2 mW @ 120 mK; > 4 μW @ 10 mK

Pulse Tube Cryocoolers Preliminary





Cooling Power Estimation

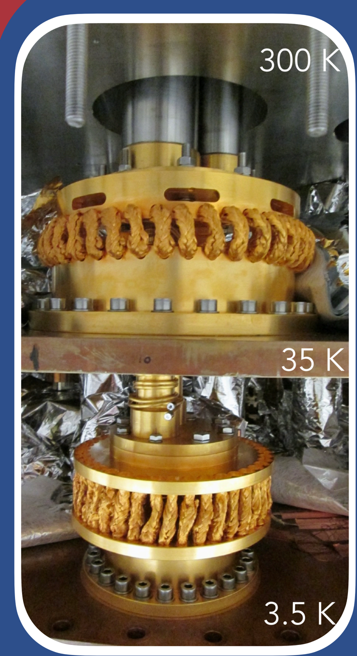
- PT415-RM (4 PTs + 1 backup)
- 28 W @ 35 K (98 W)
- 0.6 W @ 3.5 K (2.1 W)

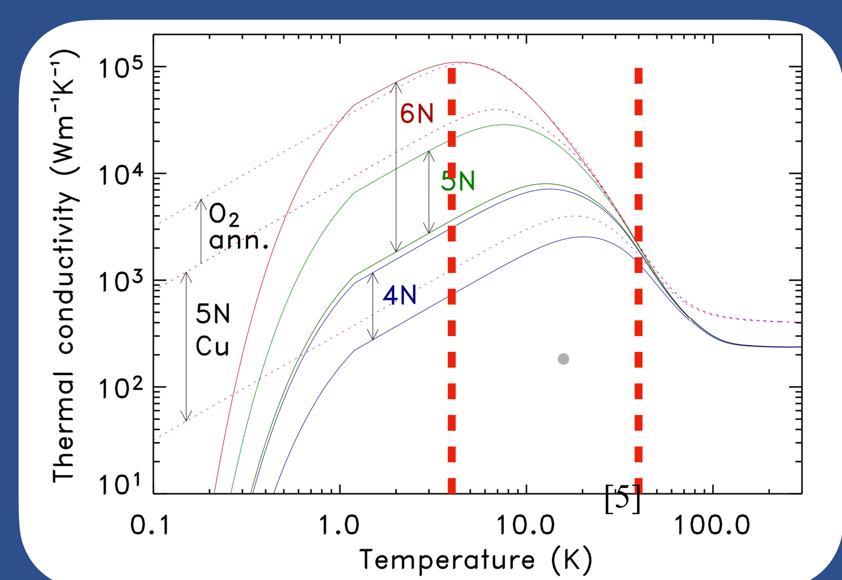
- PT425-RM (3 PTs + 1 backup)
- 27 W @ 35 K (67.5 W)
- 1.4 W @ 3.5 K (3.5 W)
  - ≥ 150% @ 3.5 K

- PT310-RM (3 PTs + 1 backup)
- 37 W @ 35 K (92.5 W)
- 1.3 W @ 3.5 K (3.25 W)
  - ≥ 150% @ 3.5 K

The above estimates are based on 2-feet Remote Motor option.

Pulse Tube Thermalization





- Good thermal conductivity
- Strong mechanical coupling
- More flexible
- Forsee vibration transmission reduction

[5]: Adam L. Woodcraft, "Recommended values for the thermal conductivity of aluminium of different purities in the cryogenic to room temperature range, and a comparison with copper". Cryogenics 45, 626-636 (2005)

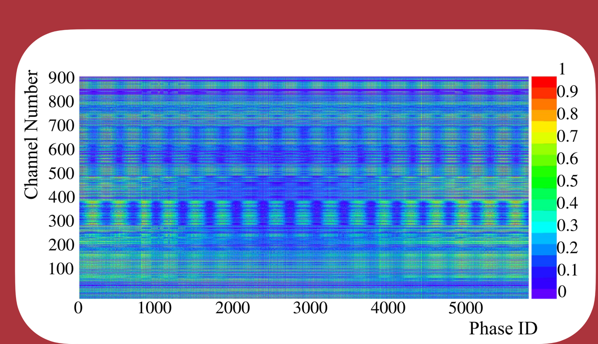
PT Noise Mitigation Strategy

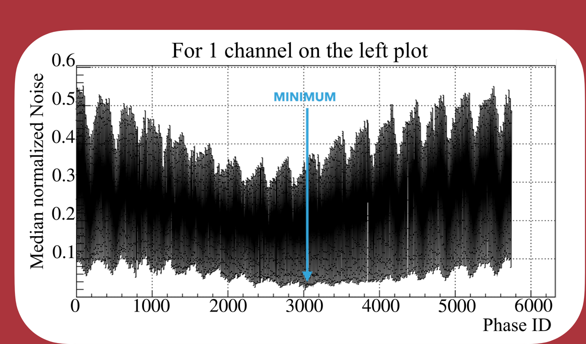
PT passive noise suppression

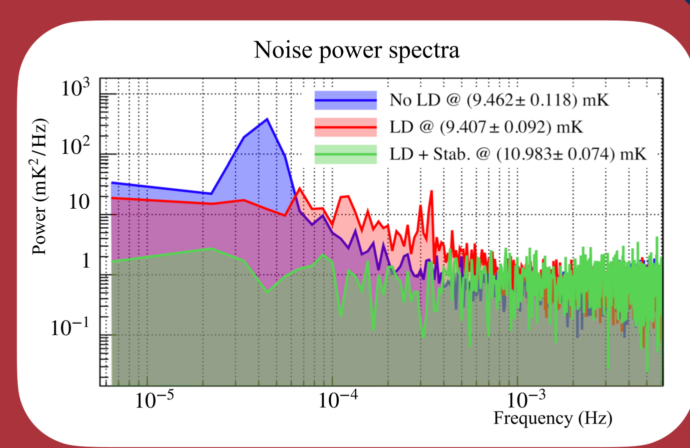
- 1.4 Hz working frequency and related harmonics from PTs remote motor and rotary valve
  - Which will vary, e.g. : 1.27 Hz for PT310-RM
- Polyurethane (PUR) ring decouple PT head
- Sandbox absorb vibration from inlets
- Cu-bridge as mechanical decouplers

PT active noise cancellation

- Linear driver to suppress beating noise
- Control the phases of running PTs
- PT Phase Scan to find the best phase configuration







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