

# SABRE North @ LNGS

11th Astroparticle Physics Science Fair 2024/2025: Underground Physics

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# SABRE

(Sodium-iodide with Active Background RejEction)

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- **Scientific motivation:** verify the longstanding modulation effect shown by DAMA/LIBRA @ LNGS
  - ✓ determination of modulation amplitude and phase with a background equal or better than that of DAMA/LIBRA
  - ✓ this modulation finds possible justification in models of dark matter regardless of its interaction with the detector
- Framework
  - ✓ Observed annual modulation is of order 0.01 cpd/kg/keV (1 dru) in ROI [1,6]keV
  - ✓ Background in ROI is of order of 1 dru (cpd/kg/keV)

# Strategy in SABRE

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- High signal-to-background ratio by **ultra-high purity NaI(Tl) crystals**
  - ✓ aim to 0.1-0.5 dnu in ROI (challenge!)
- **North-South «twin» experiments** at LNGS(Italy) and SUPL(Australia) underground labs
  - ✓ Rule out seasonal effects
- **Proof-of-Principle (PoP) at LNGS --- DONE!**
  - ✓ Exploit active background rejection with a liquid scintillator
  - ✓ Test crystals radio-purity
- Build a full scale experiment: 2025-2027

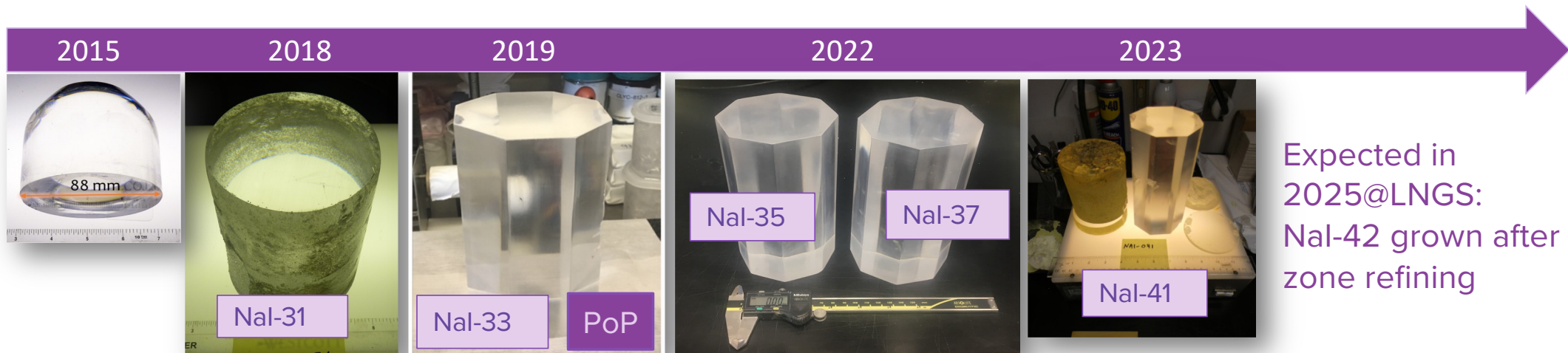
# NaI(Tl) crystal production for SABRE

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- Crystals are grown from **Astro Grade NaI powder** (developed in the framework of SABRE)
  - ✓ a few ppt in U, Th and a few ppb in K and Rb
- The **Bridgman vertical method** has been selected to mitigate the risk of contamination during growth
  - ✓ molten material is sealed inside a cleaned crucible
- **Zone refining purification** of the powder is performed before growth in collaboration with the industrial partner MELLEN
- **Crystal growth** is performed by the industrial partner Radiation Monitoring Devices (RMD)
  - ✓ some quality controls are performed prior to underground counting

# The SABRE crystals R&D

- Several crystals grown to understand and improve radio-purity



- Nal-33: background  $\sim 1$  cpd/kg/keV  $\rightarrow$  close to DAMA/LIBRA Phase 1
- Nal-35, Nal-37: reproducibility within factor 2
- Nal-41: **grown from chunks rather than powder**  $\rightarrow$  demonstrated same optical quality

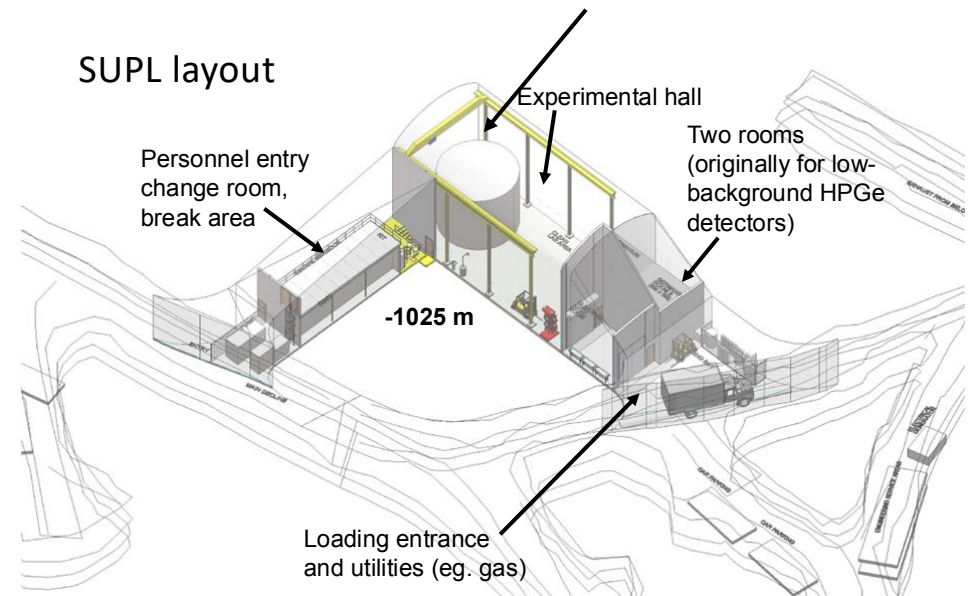
# A two-site experiment

- 45 kg of NaI(Tl) at LNGS for SABRE North
- 35-49 kg of NaI(Tl) at SUPL (1 km.w.e. overburden) for SABRE South

SABRE North area @ LNGS

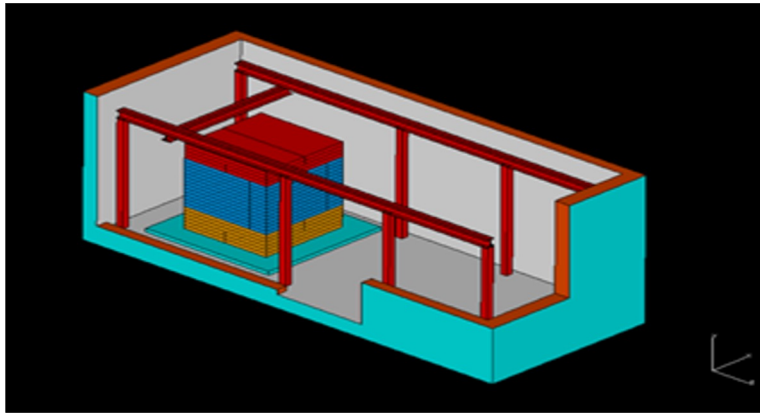


SABRE South @ SUPL

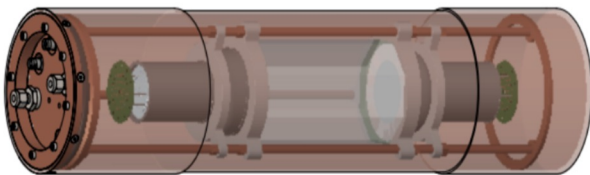


# SABRE North

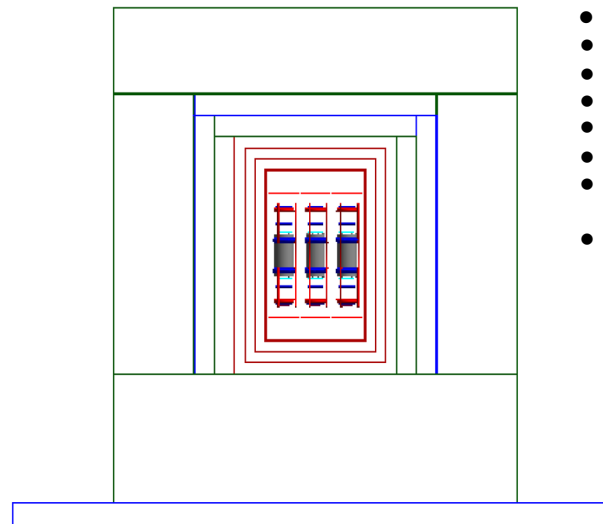
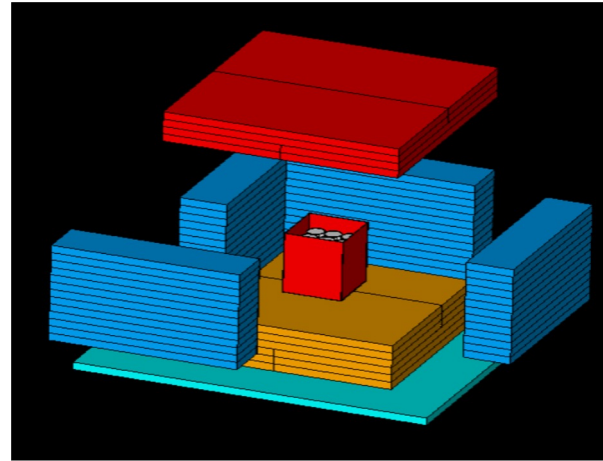
Experimental area under refurbishment



Crystal enclosure with one 5 kg crystal and 2 3-inch PMTs



Detector passive shielding with PE and Cu



- Array of 9 x 5kg crystals
- Each crystal in a Cu enclosure
- All crystals inside a Cu box 5mm thick
- 3 cm Cu layers with decreasing radiopurity
- One 10 cm thick PE U-shaped layer
- One 10 cm thick Cu U-shaped layer from OPERA
- Outer PE slabs 40 cm on top and sides and 60 cm on the bottom
- 10 cm of Cu 3m x 3m underneath

# Future activities

- In collaboration with COSINE100 a 5 kg crystal is being grown with purified powder from South Korea
  - March 2025: crystal expected at LNGS for underground characterization
- Zone refining of Astro Grade powder for SABRE 1st crystal
  - June 2025: crystal expected at LNGS for underground characterization
- Start crystal production (x9 5kg crystals)
  - Fall 2025



# Activities for interested students

- Crystal production, assembly and characterization
- DAQ development and commissioning
- Analysis tools development and crystal characterization
- MC simulations and testing
- Given the scale of the experiment a multi-item choice is reasonable

# References

- M. Antonello, et al., Eur. Phys. J. C 79 (2019) 363
- M. Antonello et al., Eur. Phys. J. C 81 (2021) 4, 299
- M. Antonello, et al., Astroparticle Physics, 106 (2019) 1-9
- F. Calaprice et al., Phys. Rev. D 104 (2021) L021302
- B. Suerfu, F. Calaprice and M. Souza, Phys. Rev. Appl. 16 (2021) 014060

# Grown crystals underground at LNGS

- **NaI-31** at LNGS since April 2019
- **NaI-33** since August 2019, assembled in Princeton
- **NaI-35** since May 2022, assembled at RMD
- **NaI-37** since March 2022, naked and encapsulated at LNGS
- **NaI-41** since December 2023, assembled at RMD and grown from chunks

