Status of the SABRE NaI(Tl) Dark Matter Experiment

Sodium-iodide with **A**ctive **B**ackground **RE**jection

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on behalf of SABRE Collaboration

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Acknowledgment

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Australian Research Council

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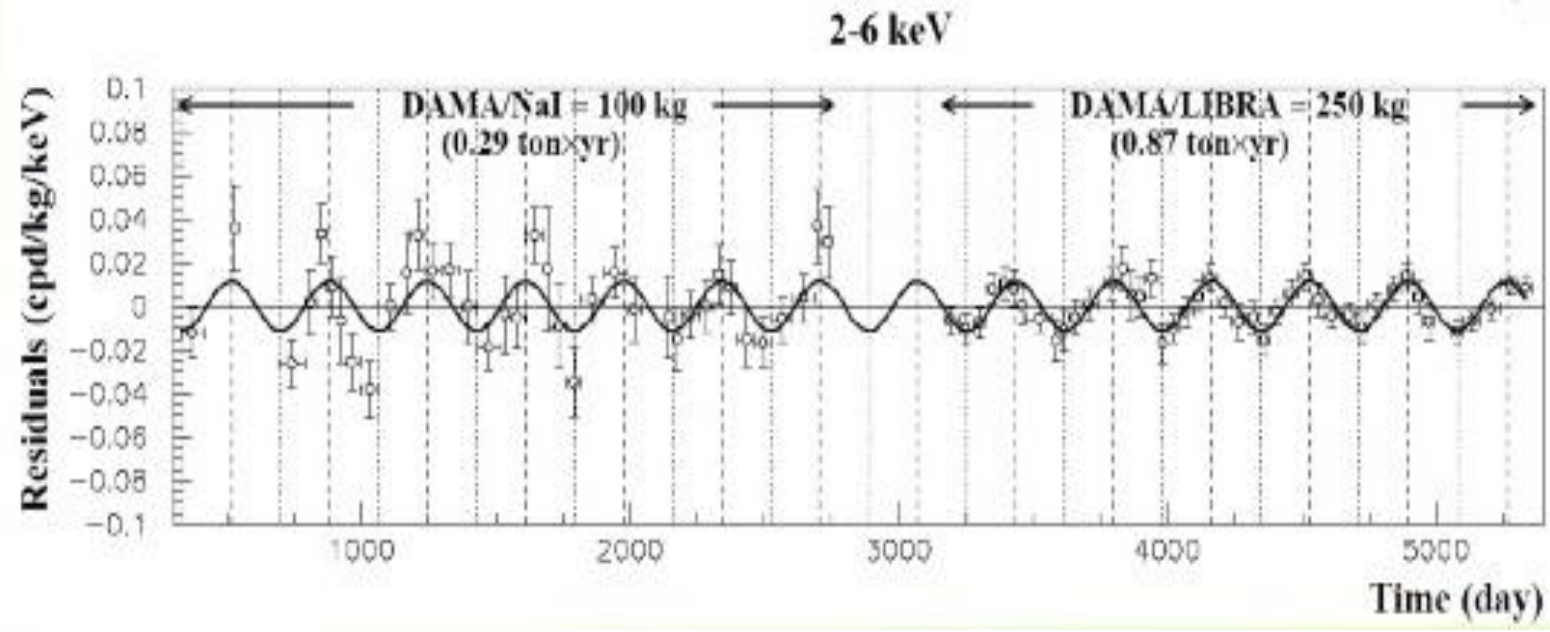
Motivation of SABRE

DAMA/LIBRA annual modulation

- 250-kg high-purity NaI(Tl) array
- collected data for 14 solar cycles
- observed **~0.01 cpd/kg/keV** modulation in 2 - 6 keV energy range
- over 9 σ stat. significant



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- Interpretation as WIMP in tension with other experiments
- Need an independent experiment with
  - **The same target material**
  - **Lower background**

Motivation of SABRE

SABRE aims to answer this question by

- **ultra high-purity NaI(Tl) crystal**
  - ➢ higher signal-to-background ratio
- N**orth-South twin-experiment**
  - ➢ rule out potential seasonal effects

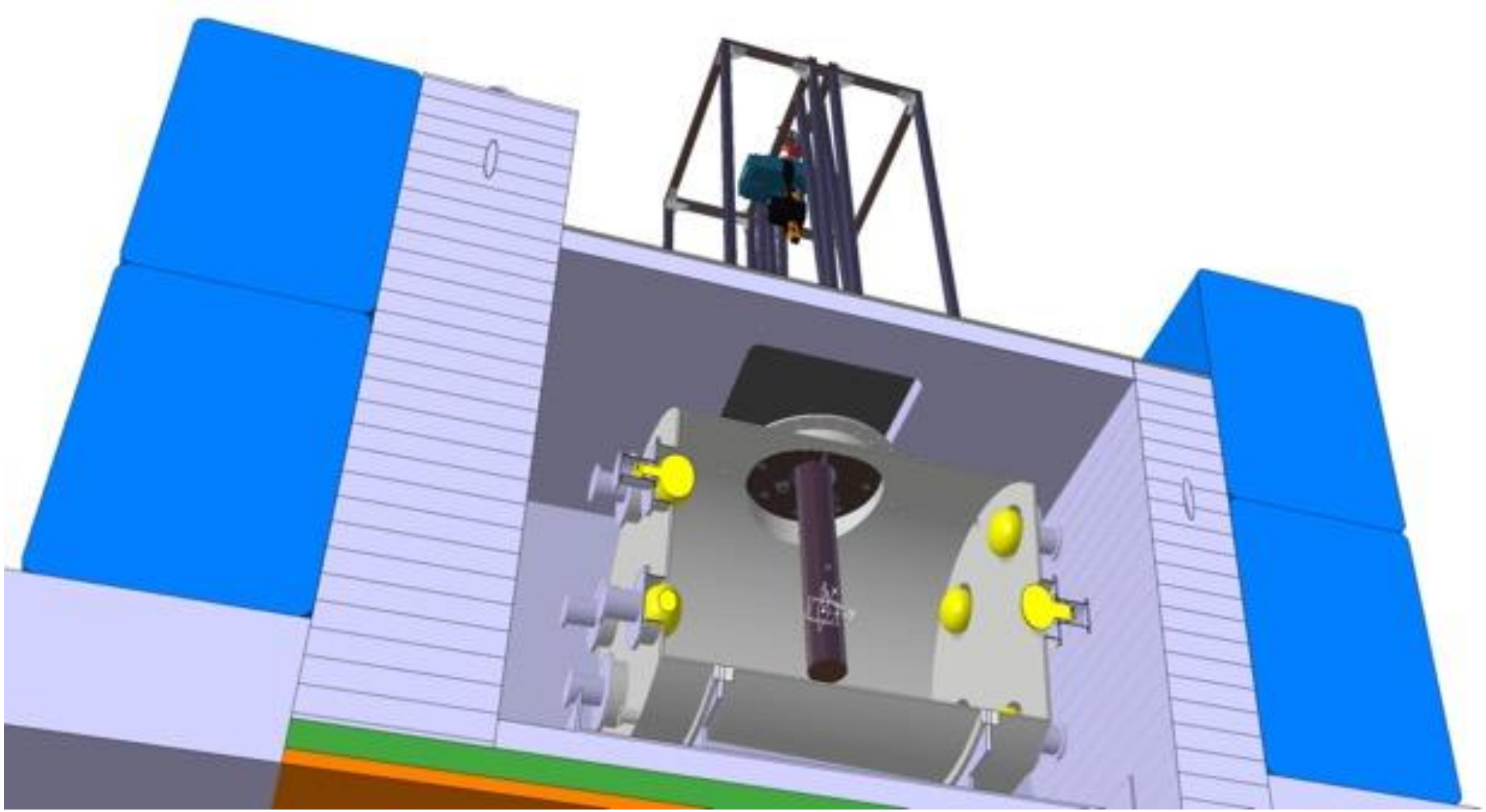
SABRE Proof-of-principle (PoP):

- to demonstrate ultra low-background NaI(Tl) crystal via underground counting at LNGS, Italy

SABRE Full-scale experiment:

- to search for modulation via NaI(Tl) crystal arrays in both northern and southern hemisphere

Overview of SABRE Proof-of-principle

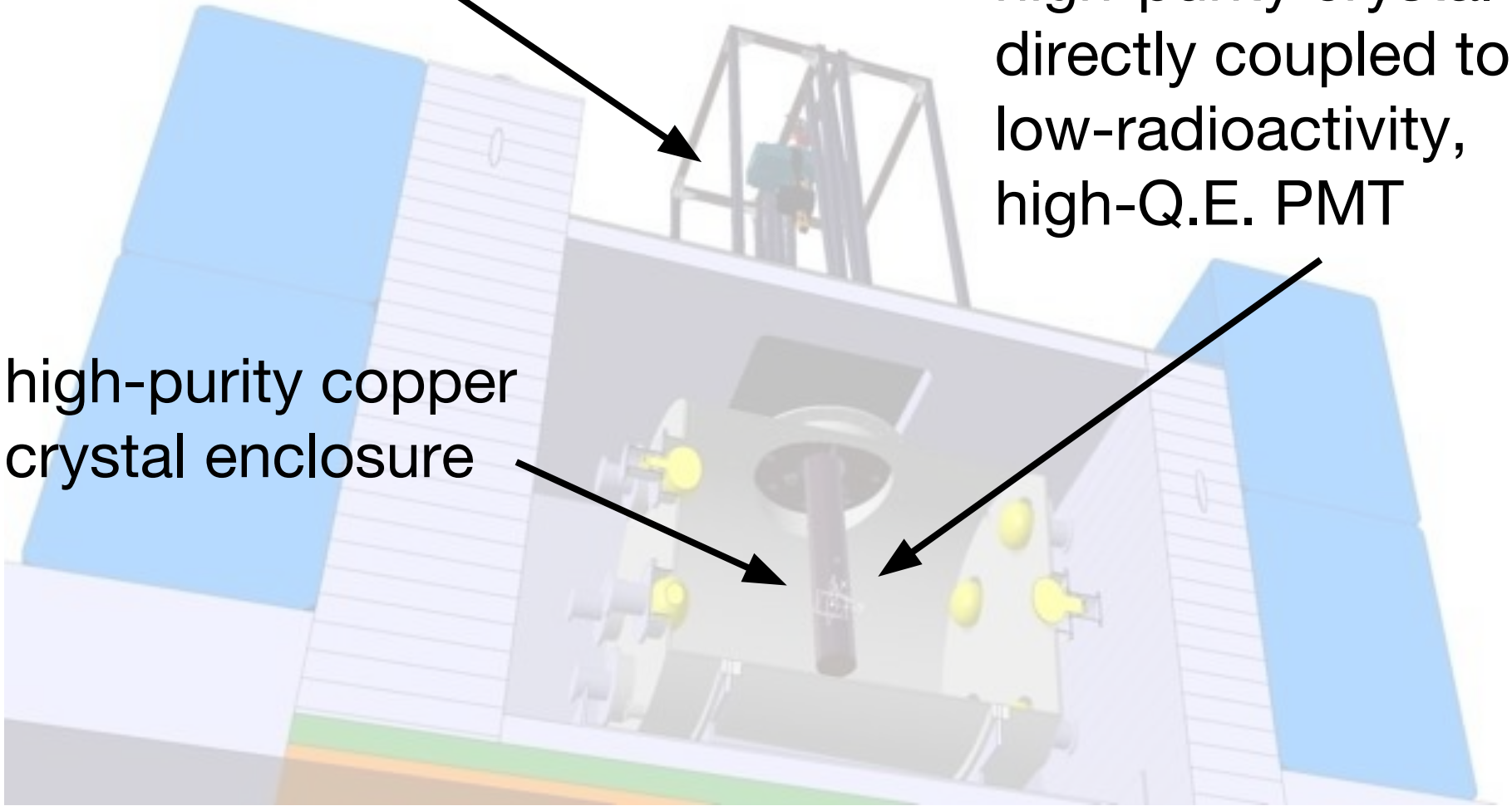


Overview of SABRE Proof-of-principle

crystal insertion system

5-kg ultra
high-purity crystal
directly coupled to
low-radioactivity,
high-Q.E. PMT

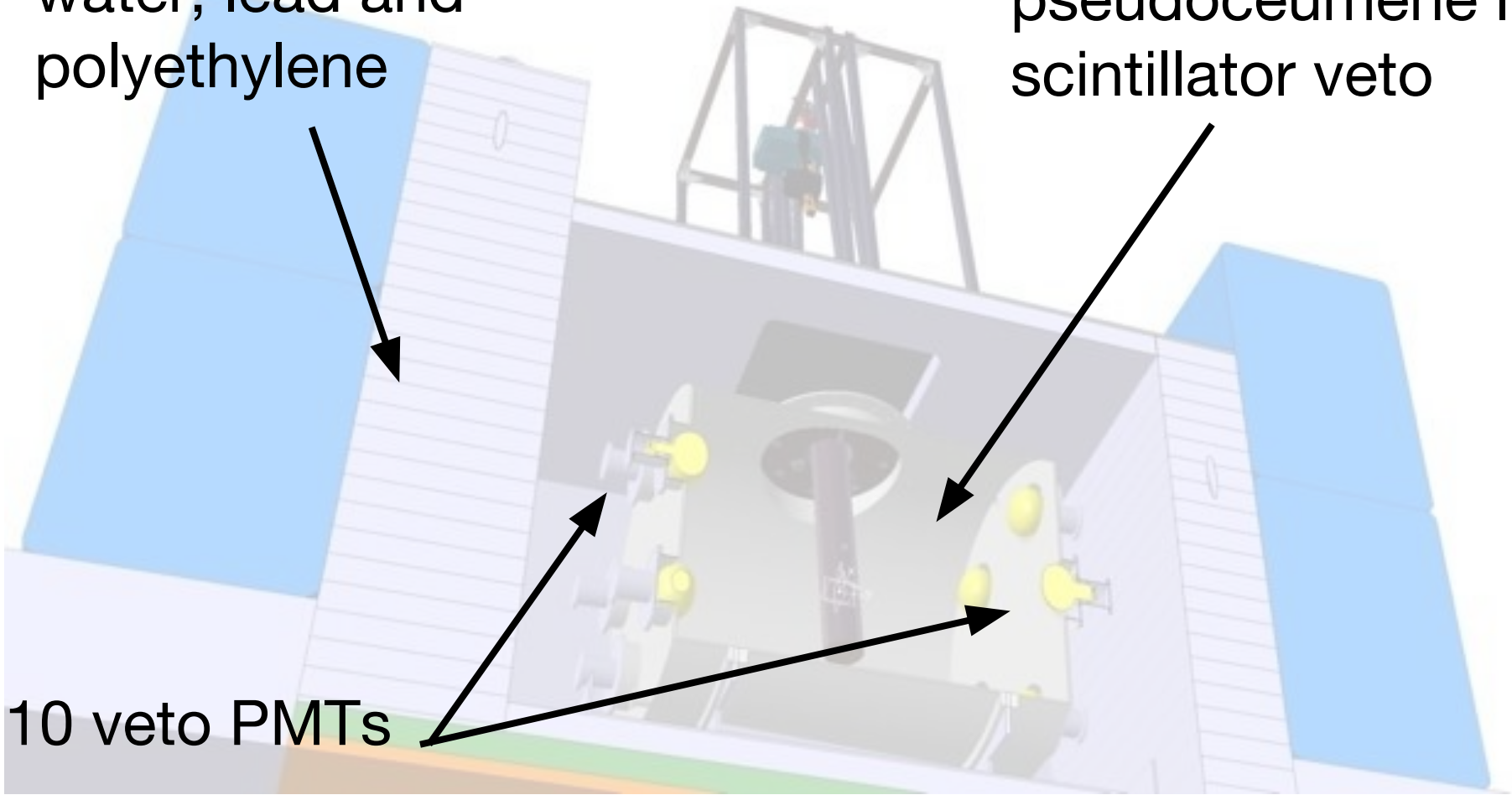
high-purity copper
crystal enclosure



Overview of SABRE Proof-of-principle

passive shielding of water, lead and polyethylene

1.4 m ∅ x 1.5 m L pseudoceumene liquid scintillator veto

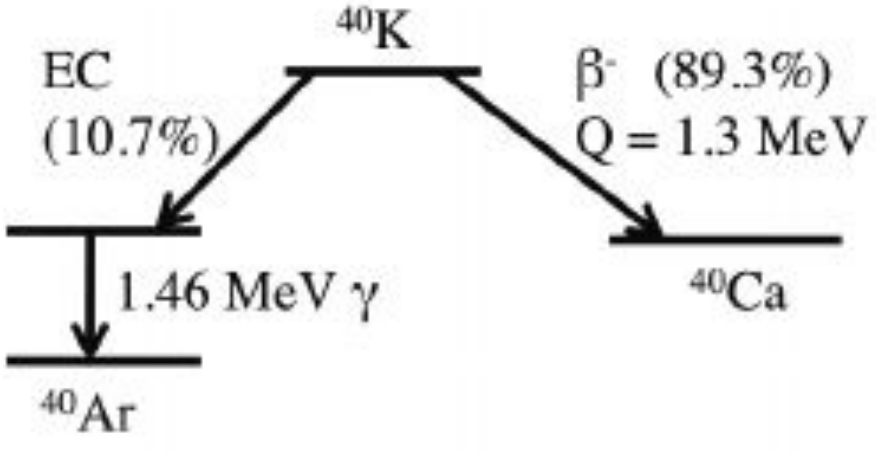


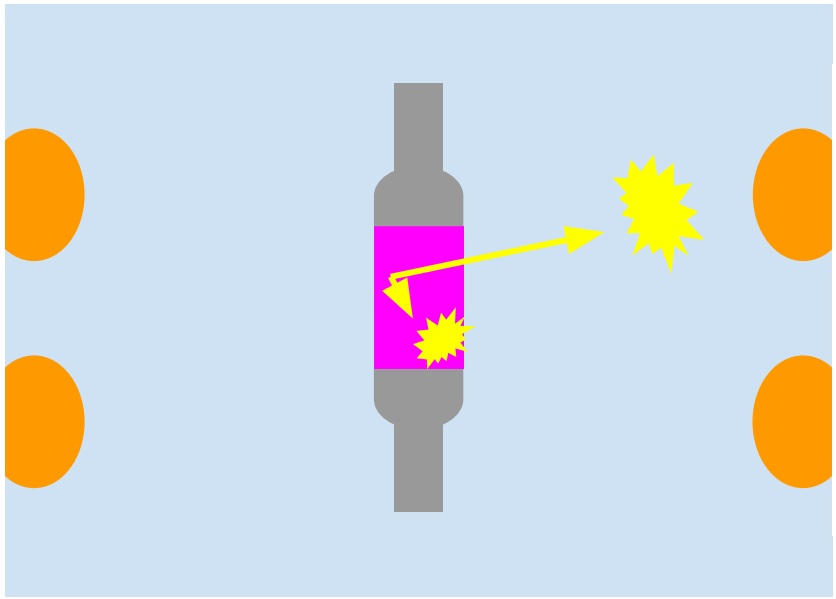
10 veto PMTs

Role of active veto

One of the most dangerous impurity is K

- ^{40}K decay by e^- capture (11%)
- 3-keV X-ray/Auger + 1.46 MeV γ-ray
- If the γ-ray escapes the crystal, the de-excitation becomes a background in the ROI (2-6 keV)
- Active veto can efficiently detect the γ-ray and veto such events.





Role of active veto

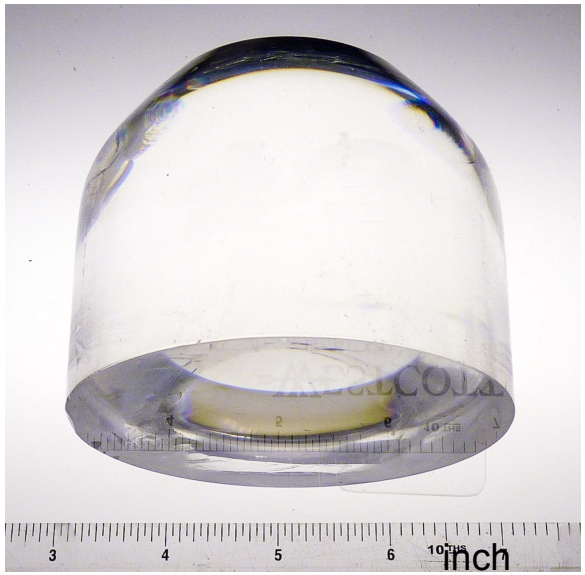
Veto helps reduce background from:

- radioactivities in the crystal that emit γ-rays:
  - ^{40}K, ^{22}Na, ^{238}U, etc.
  - ^{3}H, ^{87}Rb
- γ-rays from PMTs, enclosure, crystal insertion system, and vessel
- γ-rays and neutrons from experimental hall
- Cosmic-rays and induced γ-rays and neutrons

SABRE crystal growth

High-purity crystal growth succeeded in 2015

- Sigma-Aldrich “Astrograde” NaI powder
- 2-kg, 88-mm diameter
- ICP-MS showed good purity
  - [K] = 9 ppb



Faced new challenges in scaling up crystal size

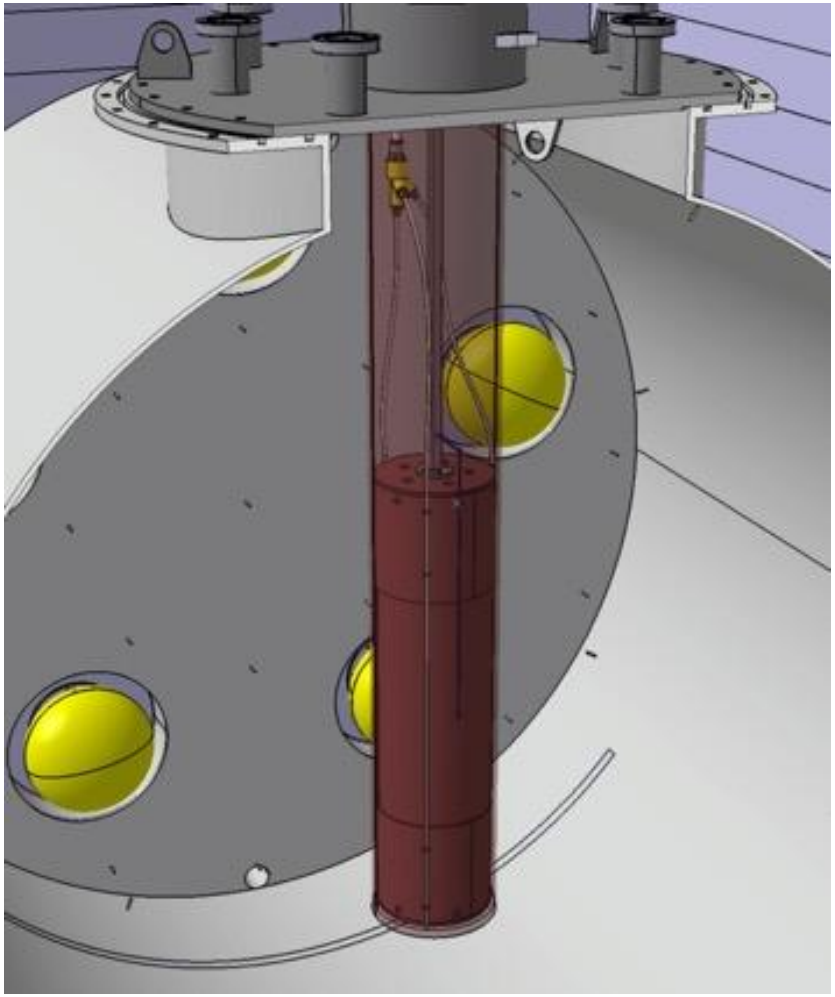
- making good progress
- currently in the process of growing 5-kg crystal
- unfortunately no data to report at this stage

SABRE crystal enclosure

- made out of high-purity copper and teflon
  - ➢ radioactivity assayed by HPGe counting
- used to insulate and protect crystal
  - ➢ allows continuous purge with nitrogen to suppress radon and moisture
- manufactured in LNGS and tested with a mock-up crystal

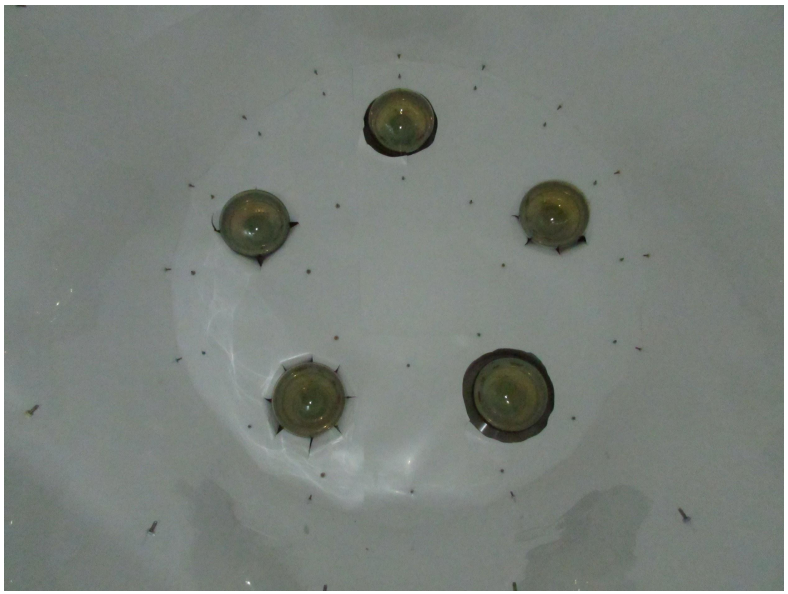
SABRE crystal insertion system

- high-purity copper tube to insert crystal enclosure without exposing PC
- allows continuous purge with nitrogen to suppress radon and insertion of calibration sources
- main components and auxiliary supporting structures tested at LNGS



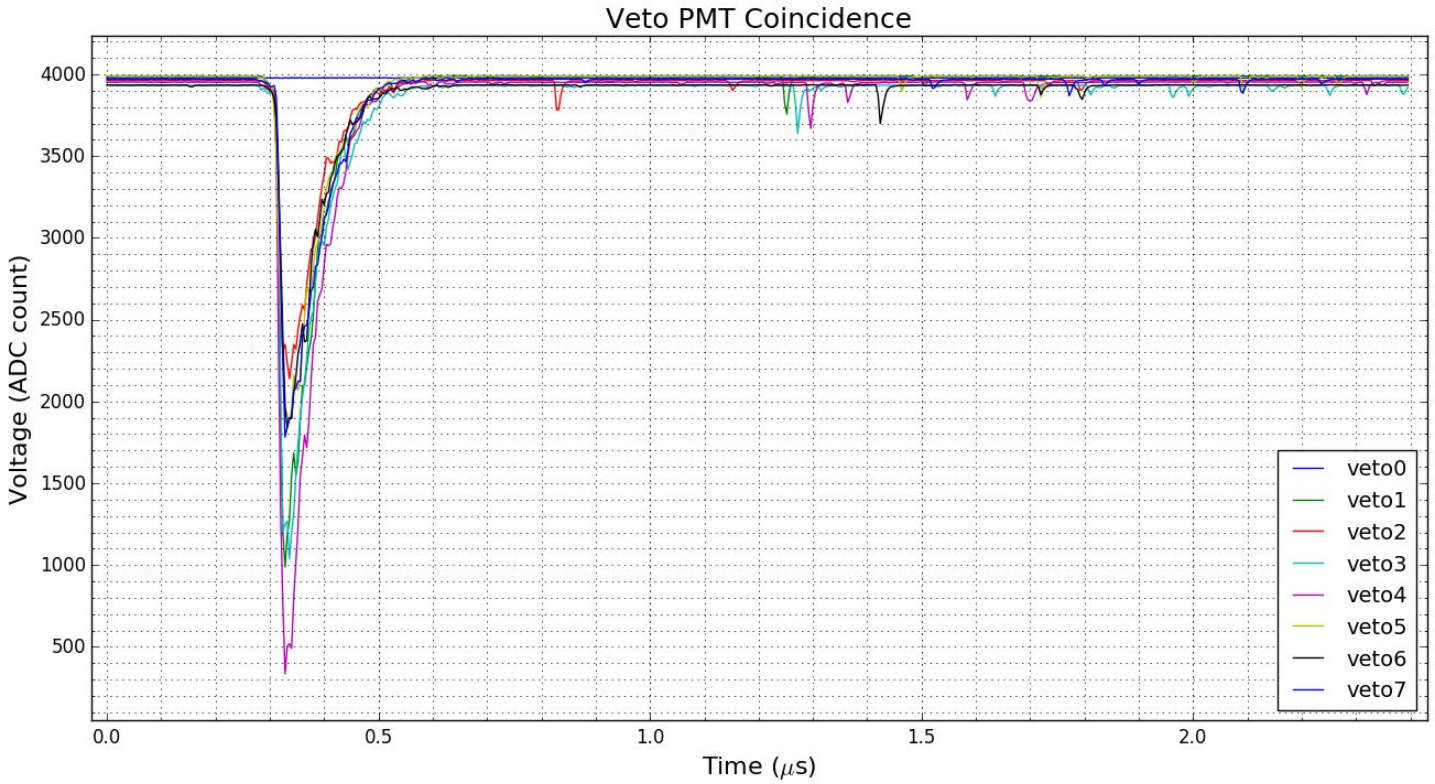
SABRE veto vessel

- Currently in LNGS Hall B.
- Interior coated with Lumirror
- All veto PMTs installed and tested
- Agreement to use liquid scintillator from Borexino



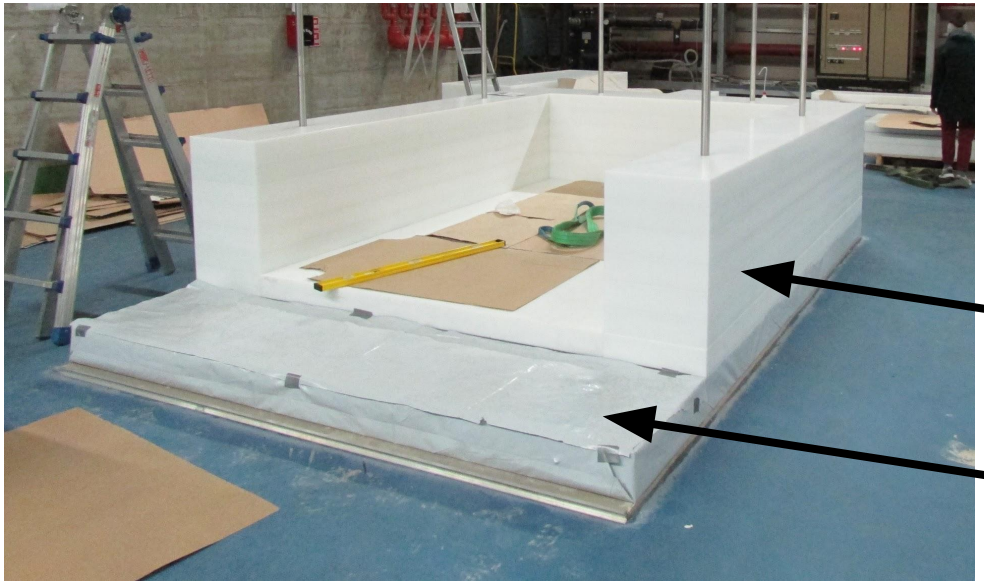
SABRE trigger & DAQ

- Trigger firmware implemented and tested with liquid scintillator majority trigger mode
- DAQ software finished and tested



SABRE shielding

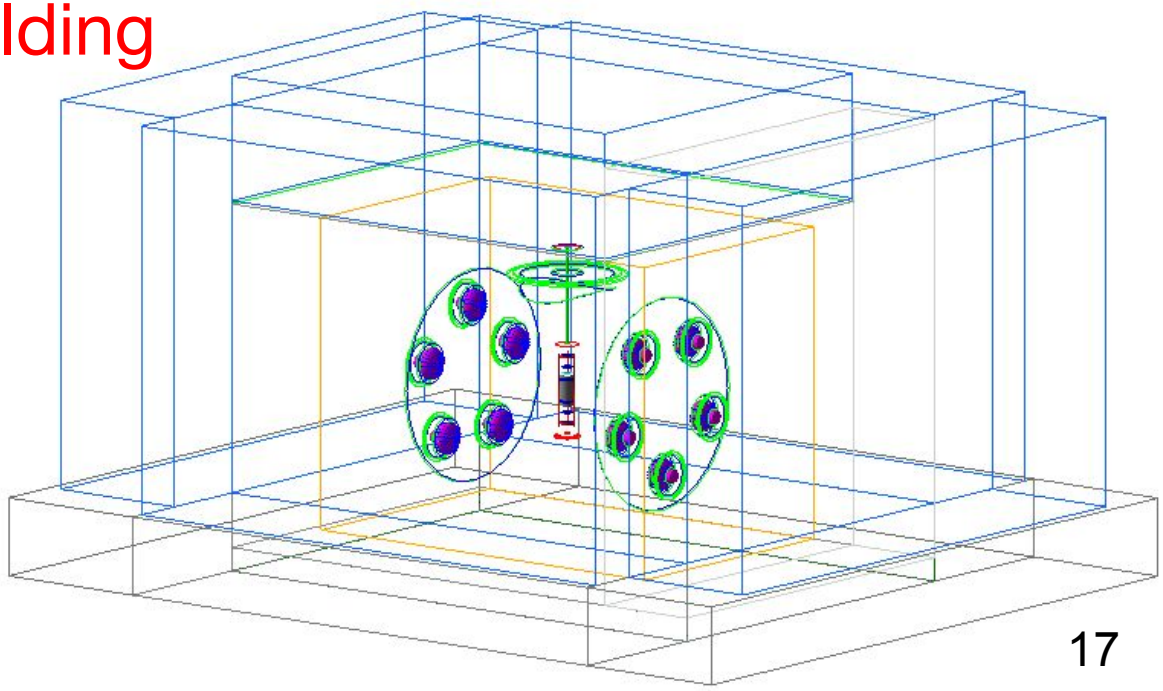
- passive shielding of lead, water and polyethylene
- Installation of shielding in LNGS Hall C has started.



SABRE Monte-Carlo simulation

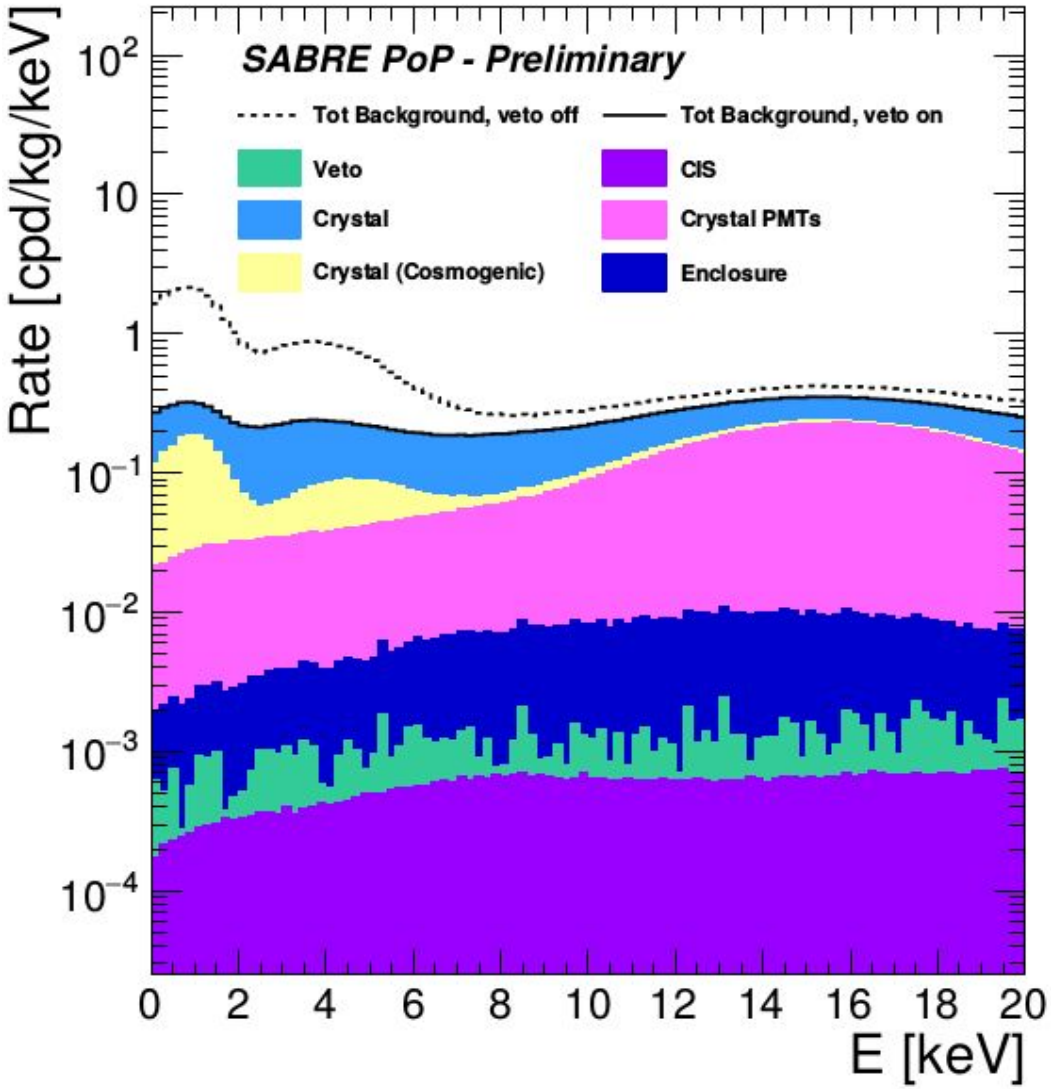
A comprehensive simulation including:

- crystal, crystal PMTs, reflector
- crystal enclosure, crystal insertion system
- veto vessel, veto PMTs, liquid scintillator
- calibration sources
- radioactivity in the shielding
- external gammas
- radon
- cosmogenics



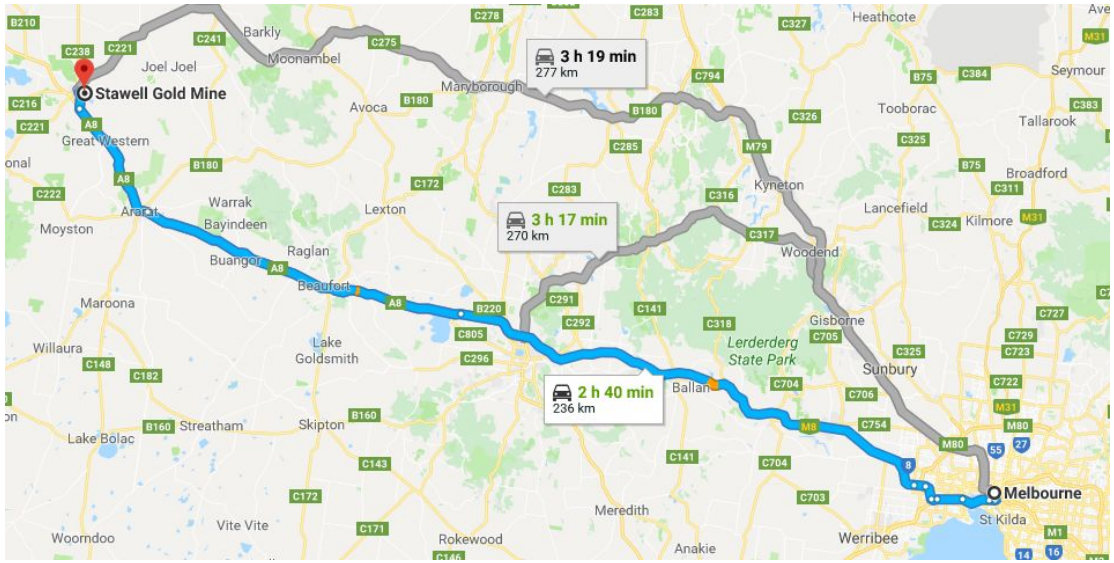
SABRE Monte-Carlo simulation

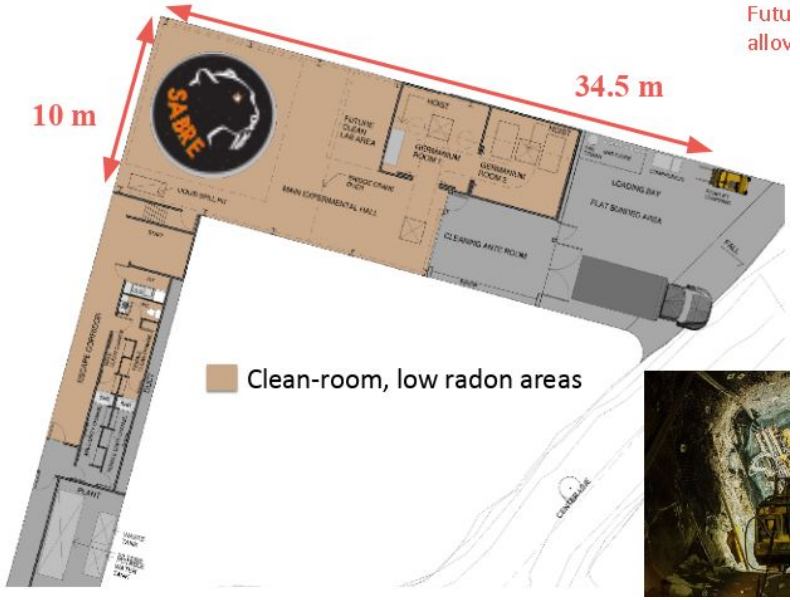
- intrinsic impurities in the crystal - biggest background
- Cosmogenics after 180 days
- Total background estimated to be: **0.23 cpd/kg/keV**



SABRE in the South

- Hosted in Stawell Underground Physics Laboratory
- 250 km from Melbourne
- 3000 m w.e.
- excavation expected to be finished in 2018
- lab ready in early 2019





SABRE in the South

- 50-kg ultra low-background NaI(Tl) crystal
- Liquid scintillator veto
- Lead shielding (not shown)
- vessel ready and start tests in 2018.

Conclusion

- SABRE is a dark matter direct detection experiment that features:
  - ultra low-background crystal
  - North-South twin setup

- Demonstrated ultra high-purity crystal via mass spectroscopy

- Currently in Proof-of-principle phase
  - enclosure, veto vessel, shielding etc.

- Expect to start taking PoP data in 2018

SABRE collaboration

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Thank you very much!