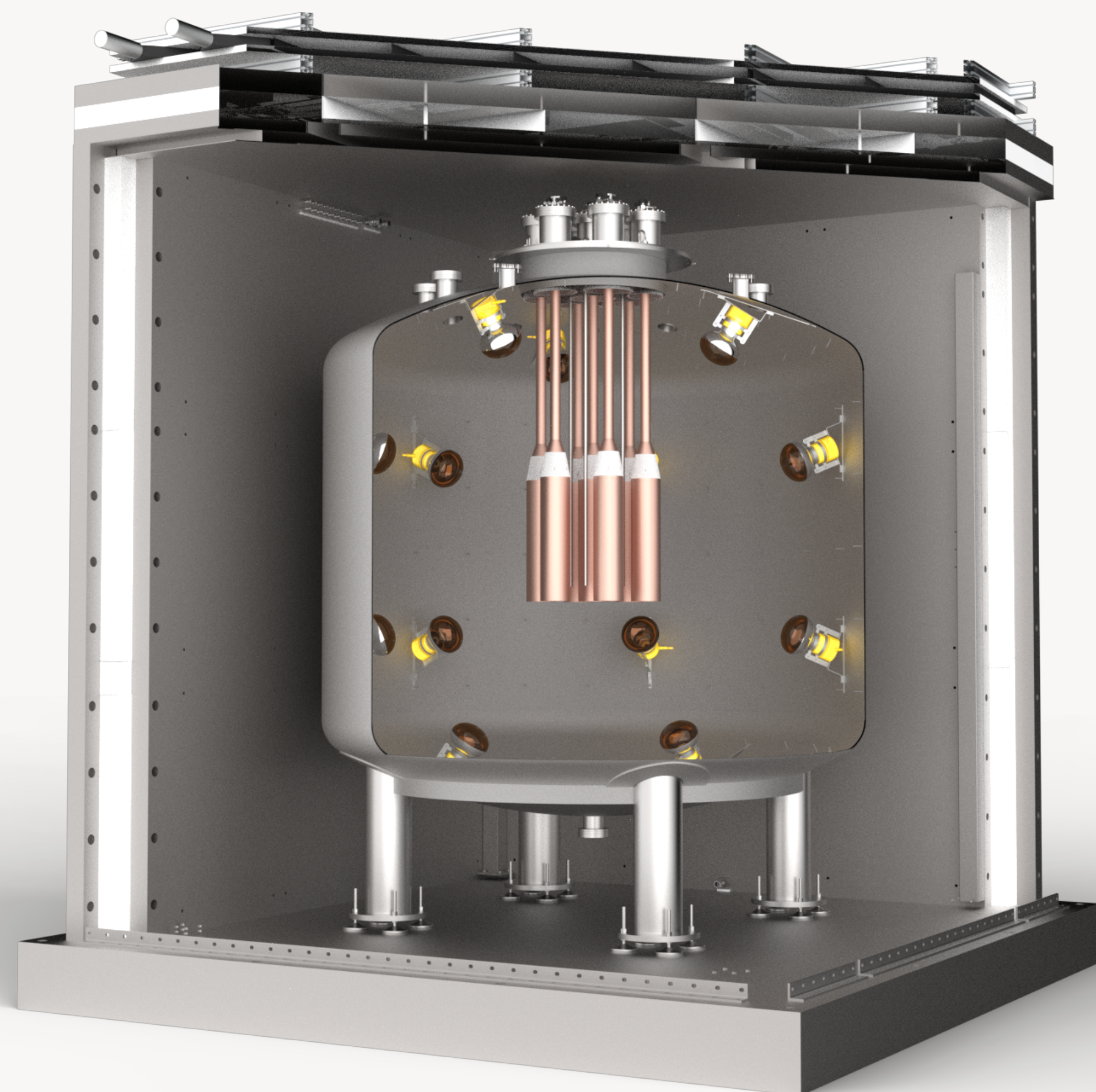




SABRE SOUTH

**AT THE STAWELL UNDERGROUND
PHYSICS LABORATORY**

LEONIE EINFALT
01/06/2026

ANNUAL MODULATION

Expected period of 1 year, peaking
June 2nd ($t_0 = 152.5$ days)

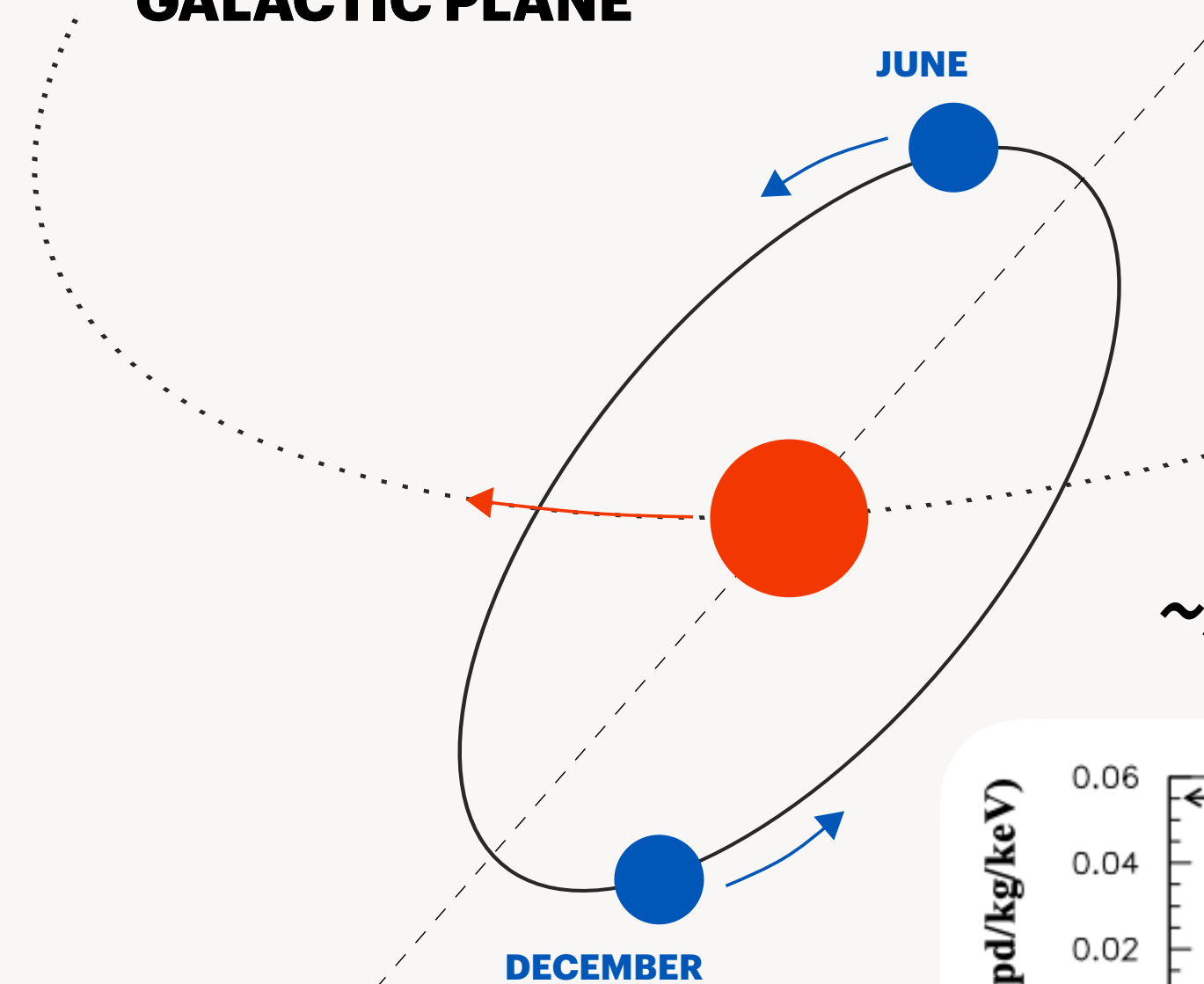
Rate (R_0) < 1 count/day/kg

Very low modulation amplitude
~0.01 cpd/kg/keV

$$R(t) = B + R_0 + R_m \cos(\omega(t - t_0))$$

Modulation amplitude
depends on target
nucleus

GALACTIC PLANE

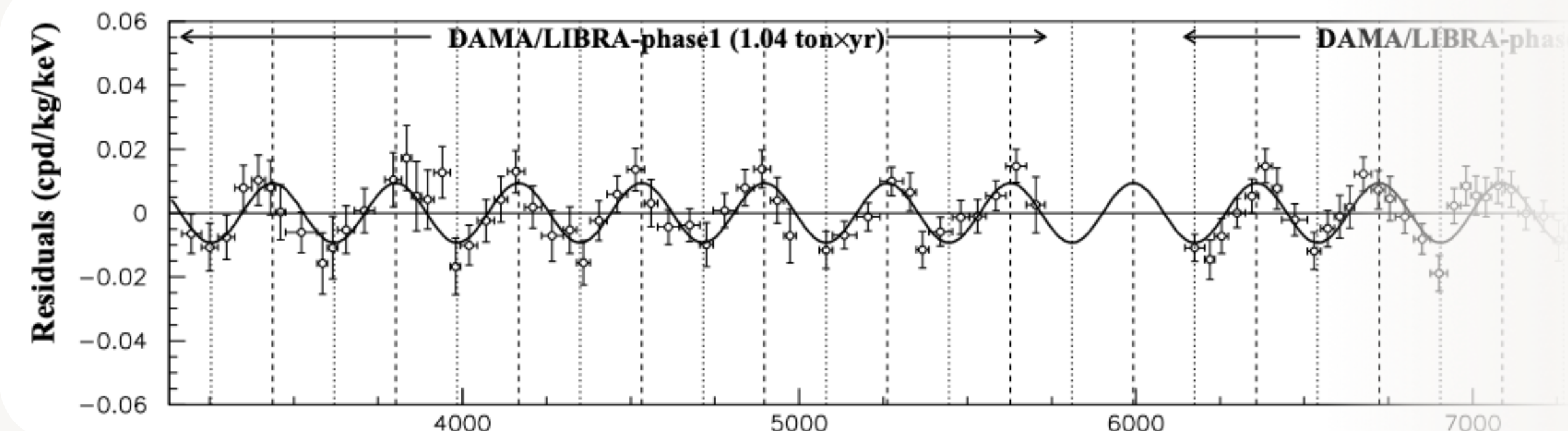


DAMA/LIBRA EXPERIMENT

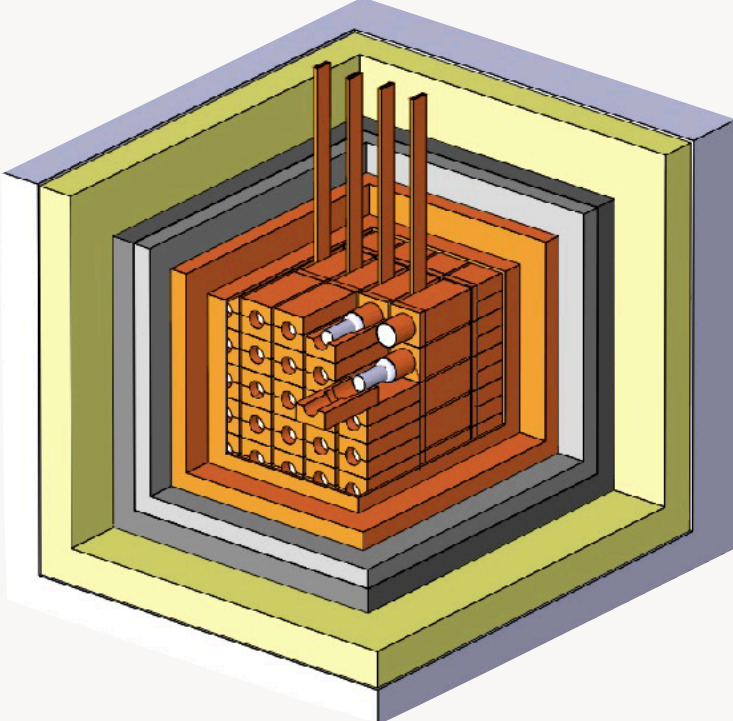
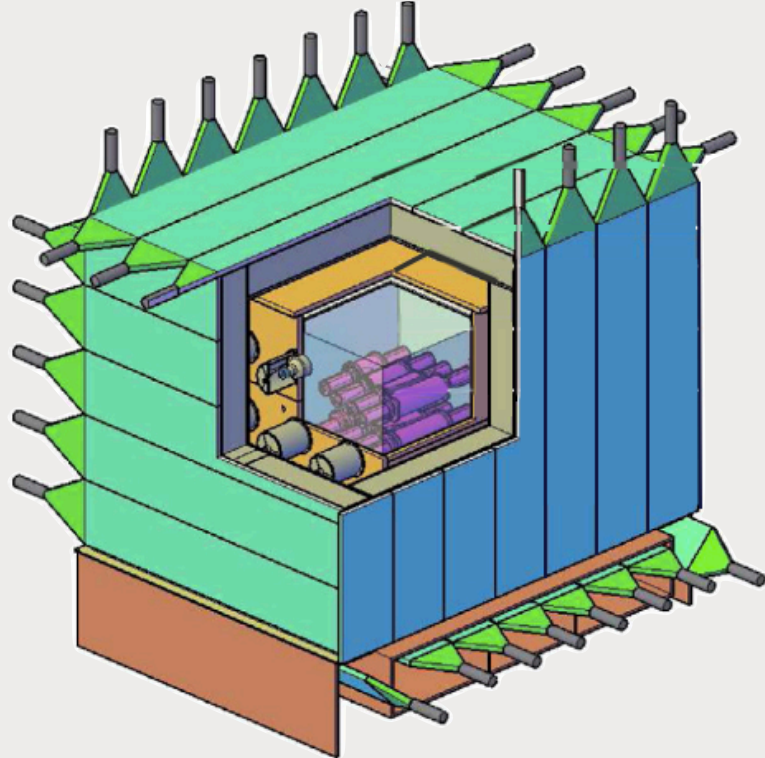
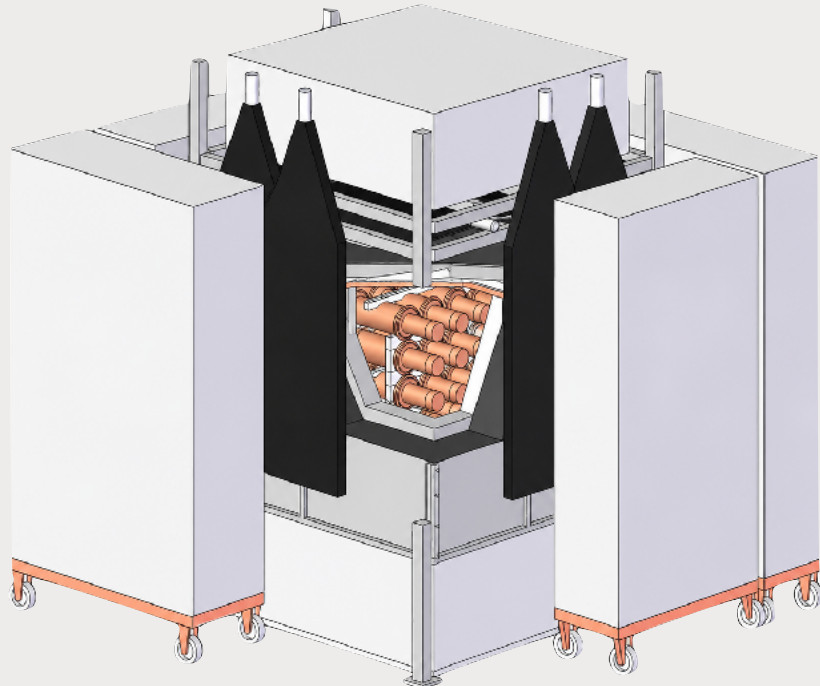
Direct detection experiment at LNGS
with 250 kg NaI(Tl) & PMT readout

Period: (0.998 ± 0.002)
& Phase: (145 ± 5) days (ROI 2-6 keV)

~20 years of operations → 13.6 σ CL significance*



NAI(TL) LANDSCAPE

decommissioned	taking data/upgrading		under construction
DAMA/LIBRA* LNGS, Italy 	COSINE-100~ Y2L, South Korea 	ANAIS-112** LSC, Spain 	SABRE COSINUS PICO-LON
Mass = 250 kg Bkg. = 0.8 dru	Mass = 61.3 kg Bkg. = 2-3 dru	Mass = 112.5 kg Bkg. = 2.0-4.7 dru	expected background <1 dru
$S_m, 1-6\text{ keV} = 0.0105 \pm 0.0011\text{ dru}$ $S_m, 2-6\text{ keV} = 0.0102 \pm 0.0008\text{ dru}$	$S_m, 1-6\text{ keV} = 0.0017 \pm 0.0029\text{ dru}$ $S_m, 2-6\text{ keV} = 0.0053 \pm 0.0031\text{ dru}$	$S_m, 1-6\text{ keV} = -0.0004 \pm 0.0025\text{ dru}$ $S_m, 2-6\text{ keV} = 0.0011 \pm 0.0025\text{ dru}$	

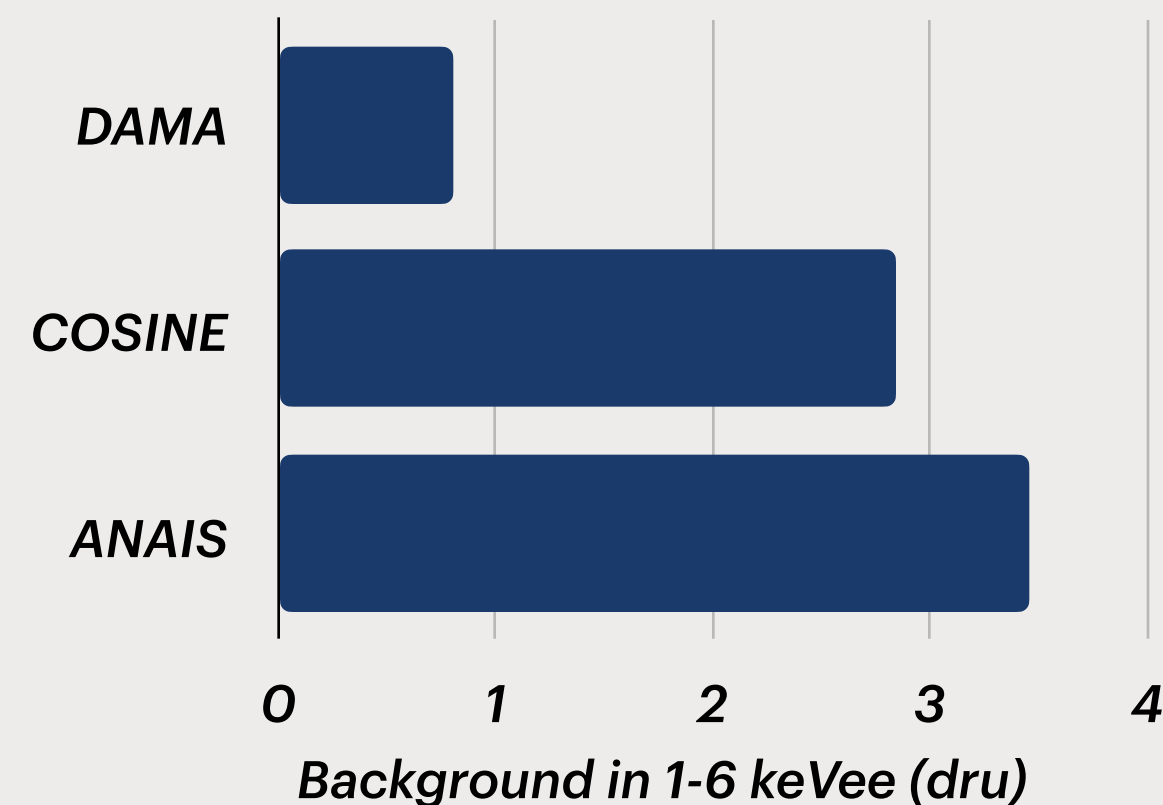
Region of interest (ROI)
1-6 keVee /2-6 keVee

OPEN QUESTIONS

4 / 18
*2021 JINST 16 P07034
~EPJ C 84, 484 (2024)
**arXiv:2408.08697

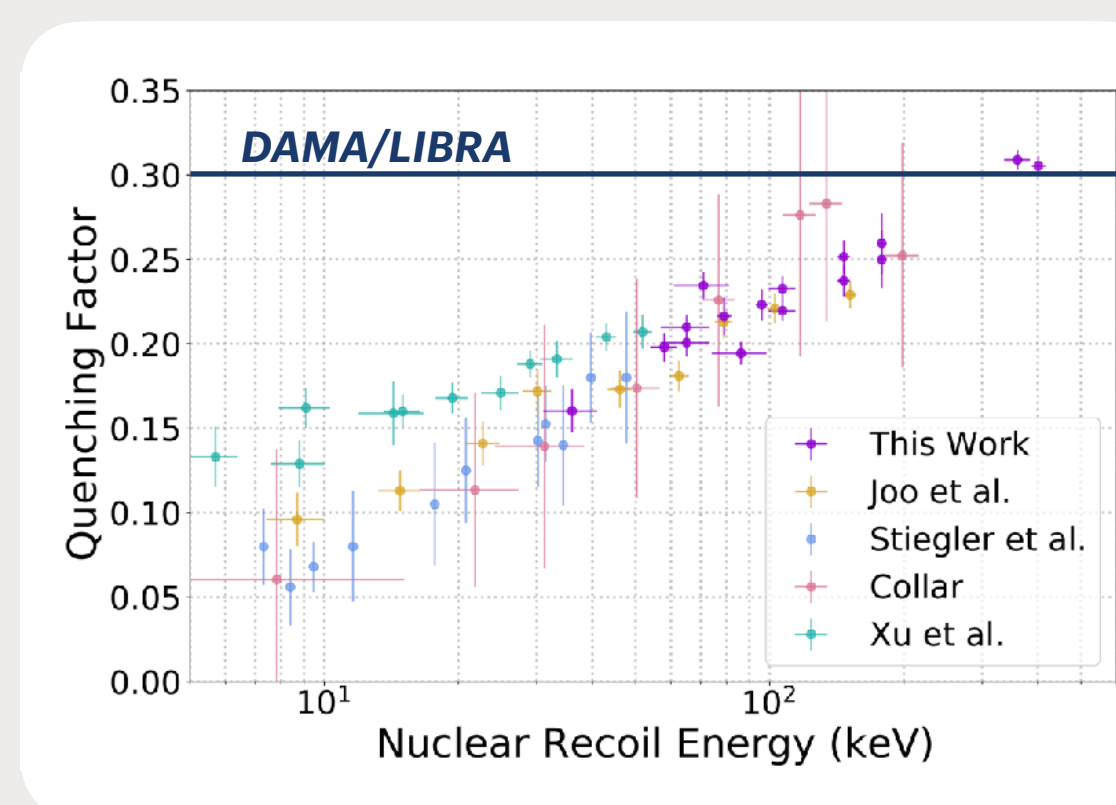
Varying background levels

Background rates varying by 3–4x between experiments **dwarf the modulation signal** itself, making systematic uncertainty estimation and rate comparisons unreliable



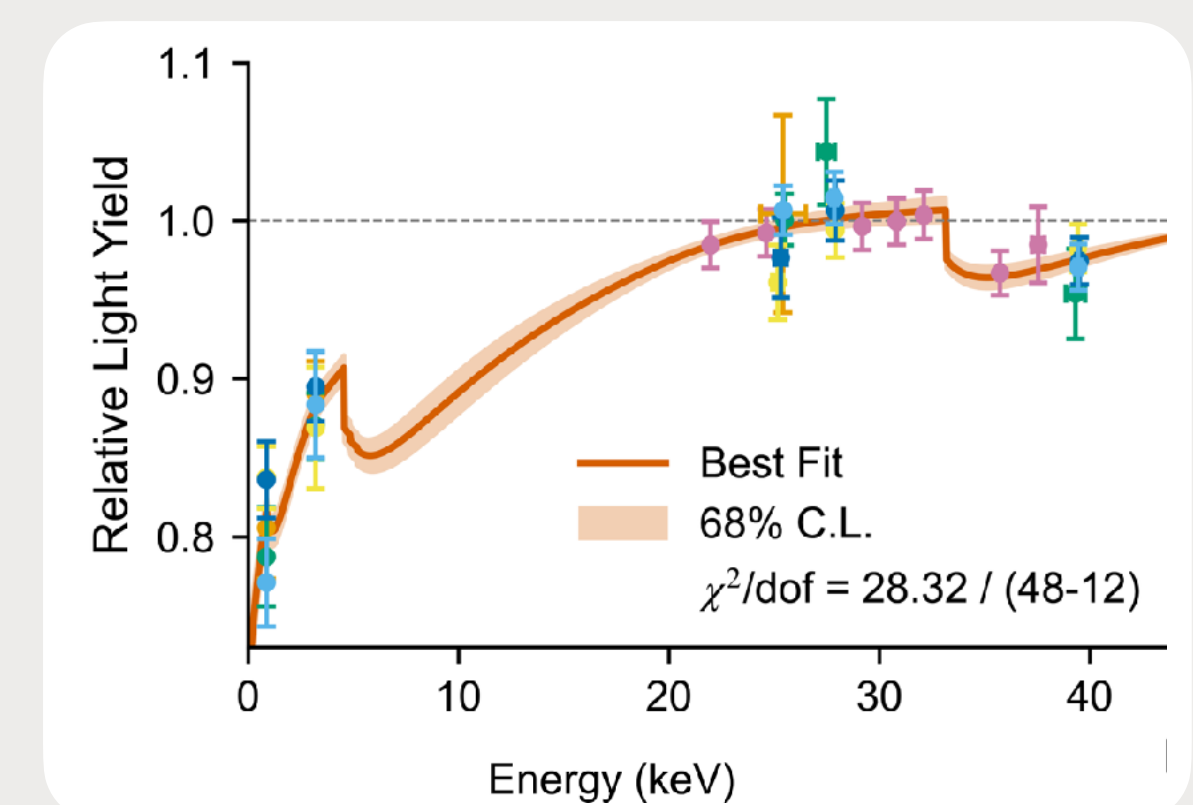
Nal quenching factors

QF varies significantly between crystals and growth methods, leading to **incompatible nuclear recoil energy windows** across experiments*



Scintillator non-proportionality

A non-linear scintillation response can introduce **uncertainties in energy calibration** and a systematic bias in the reconstructed modulation amplitude~



+ PMT noise at threshold · differences in analysis methods** · treatment of systematic uncertainties ...

THE SABRE COLLABORATION

SABRE NORTH

Laboratori Nazionali del Gran Sasso

- Astrograde NaI powder*
- Fully passive shielding*
- Zone refining in crystal production*

See also Claudia Tomei's talk in this session



SABRE SOUTH

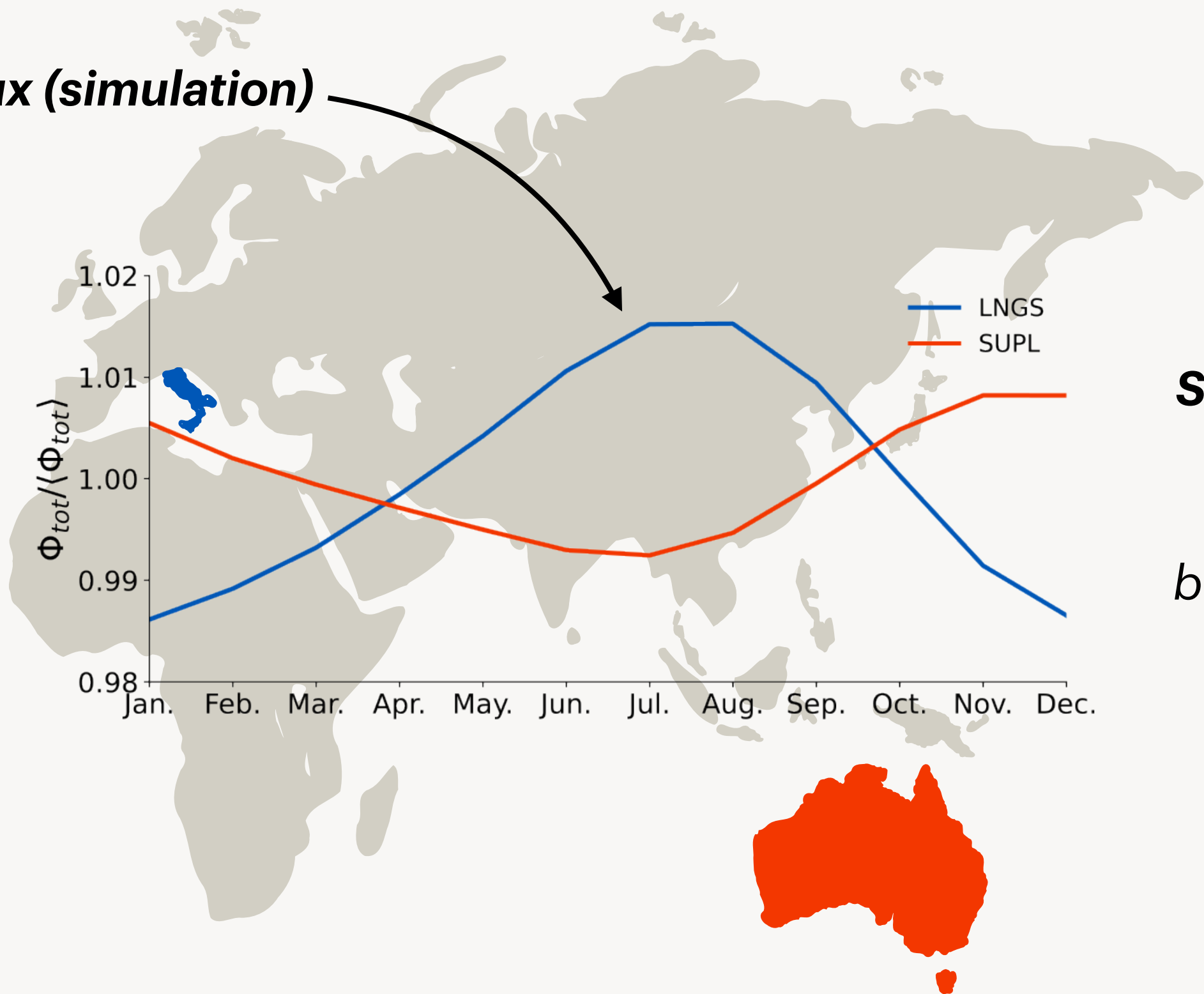
Stawell Underground Physics Laboratory

- Astrograde NaI powder*
- Passive shielding + background rejection with LAB-based veto*



THE SABRE COLLABORATION

Seasonal muon flux (simulation)



SABRE NORTH
Laboratori Nazionali del Gran Sasso
Astrograde NaI powder
Fully passive shielding
Zone refining in crystal production

See also Claudia Tomei's talk in this session



SABRE SOUTH
Stawell Underground Physics Laboratory
Astrograde NaI powder
Passive shielding + background rejection with LAB-based veto



SUPL

Stawell Underground Physics Laboratory

The first deep underground laboratory in the Southern Hemisphere, completed in 2023

LEONIE EINFALT
01/06/2026



6 / 20



Located in the **Stawell Gold Mine**, Victoria (Djabwurung country); 240 km west of Melbourne and 1km underground — equivalent to **2850 m.w.e. overburden**.

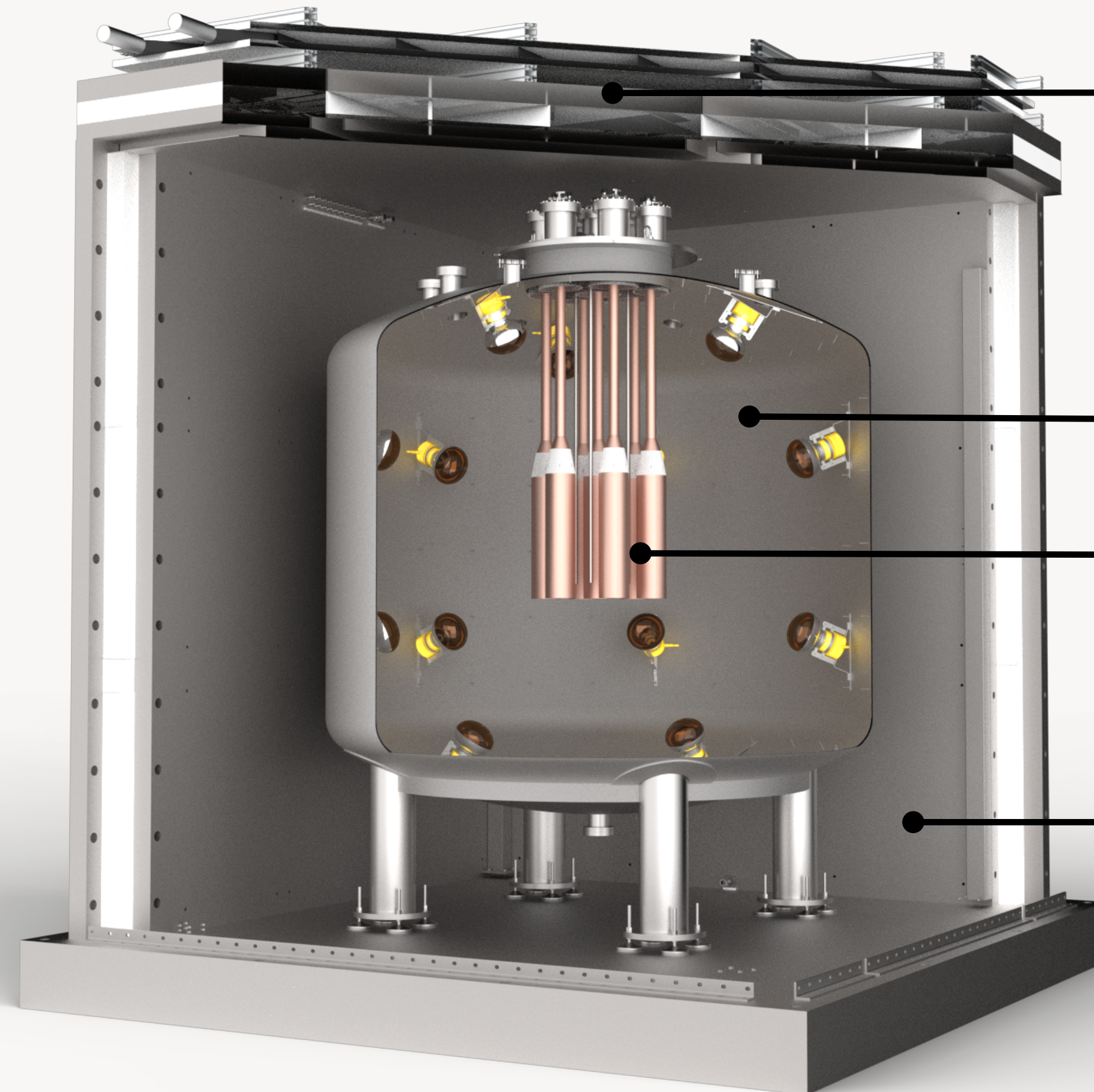
The main hall measures **10 × 26 × 12 m**, with SABRE South at its centre.

SUPL will **host other quantum and particle experiments**.



SABRE SOUTH

Combination 7 ultra-high-purity NaI(Tl) crystals with two active veto systems inside passive shielding



Muon veto system

9.6 m² x 5 cm EJ200
16x R13089 PMT

Liquid Scintillator Veto

12k litres Linear Alkyl Benzene
18-32x R5912 PMTs

Crystal Detector

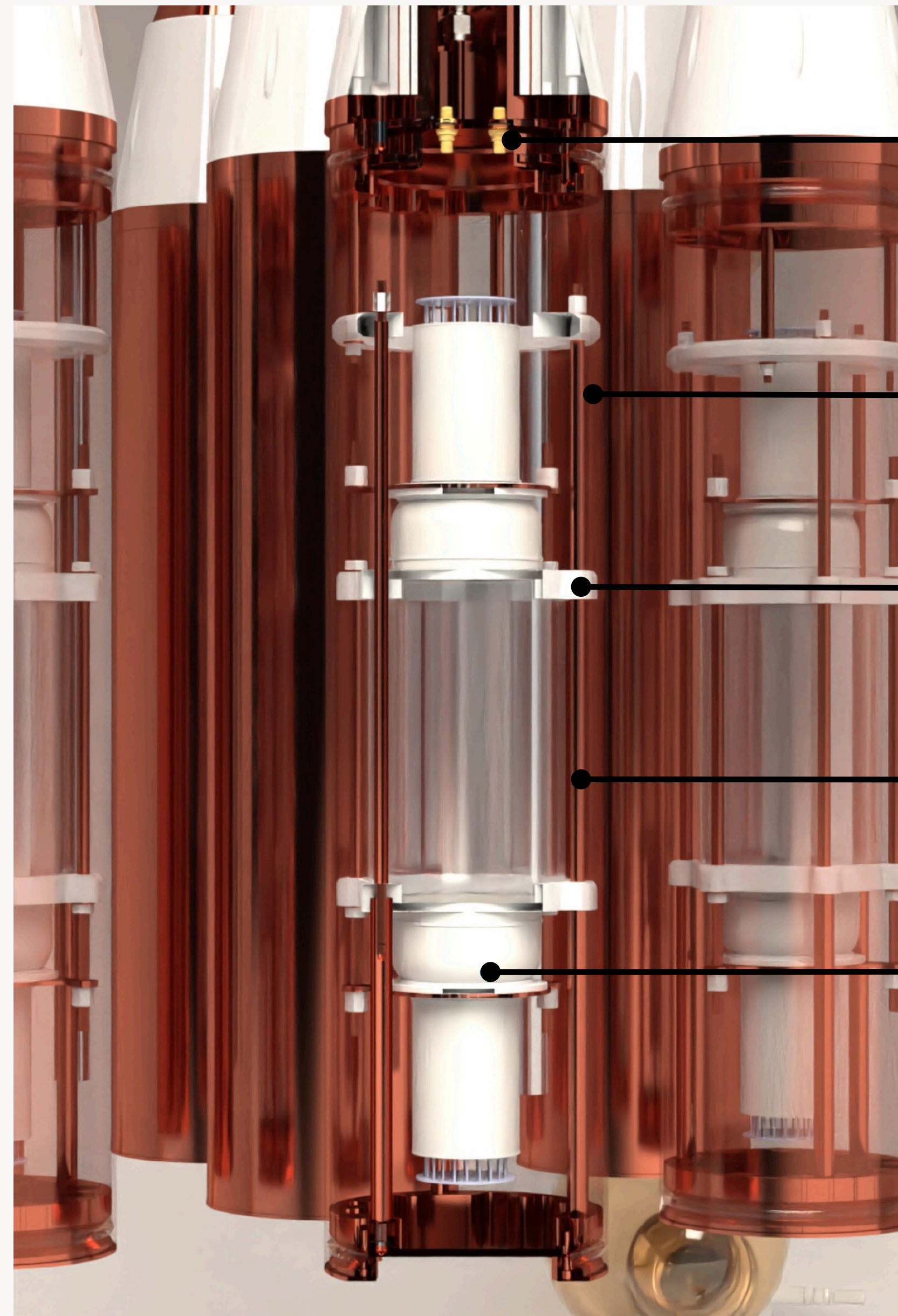
50 kg of NaI(Tl) Crystals in
7 modules, N₂ flushed,
14x R11065 PMTs

Passive shielding

80mm "new" steel +
100mm HDPE +
80mm "new" steel

CRYSTAL SYSTEM

7x7 kg crystals, directly coupled to two Hamamatsu R11065 PMTs in a sealed OFHC copper enclosure



Feedthrough plate

PTFE crystal/PMT holders

Copper enclosure
flushed with N₂

NaI(Tl) crystal
from Astrograde powder

R11065 Hamamatsu
76mm PMT

Active liquid scintillator veto

12 kL of **linear alkyl benzene (LAB)**
procured from JUNO, doped with PPO
and bisMSB

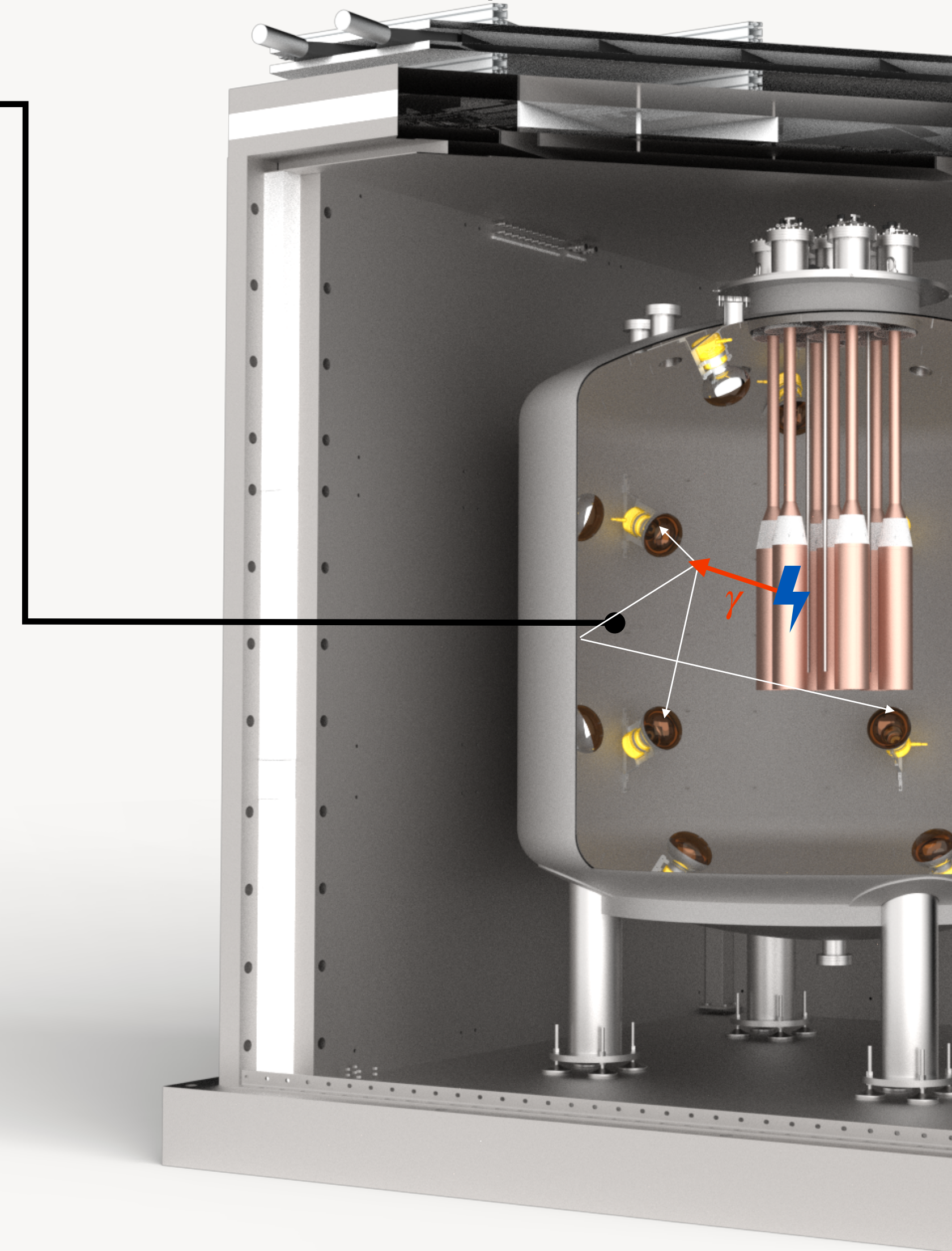
18 (+ 14 from Daya Bay) R5912 oil proof
PMTs sampled at 500 MS/s

Efficient tagging of secondary
particles created in decay process in-
and outside of the crystal modules

Veto reduces total background rate in
ROI to **0.72 cpd/kg/keVee***

VETO SYSTEMS

Two active veto systems tag and
reject coincident background and
muon-induced events

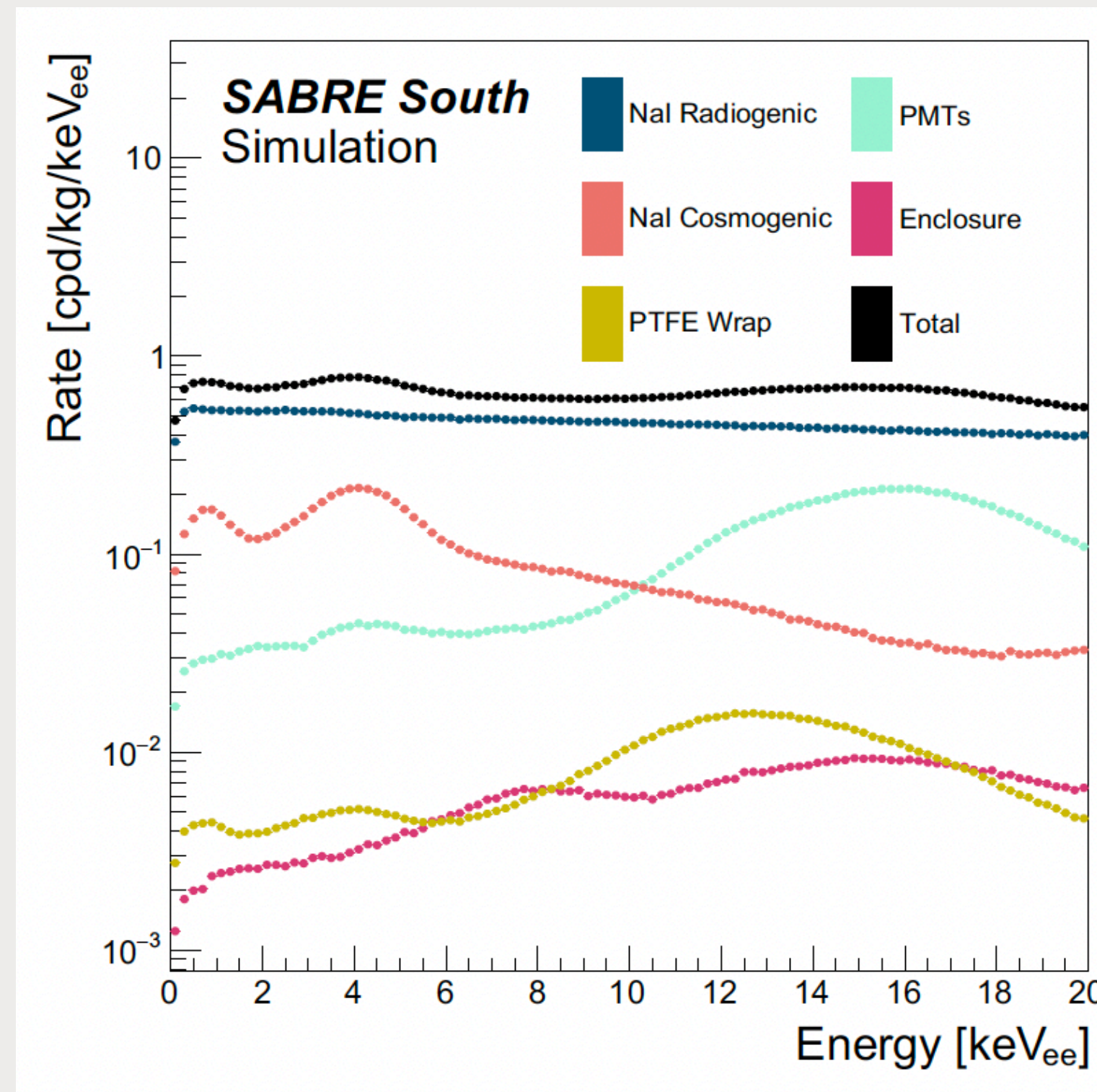


VETO SYSTEMS

Two active veto systems tag and reject coincident background and muon-induced events

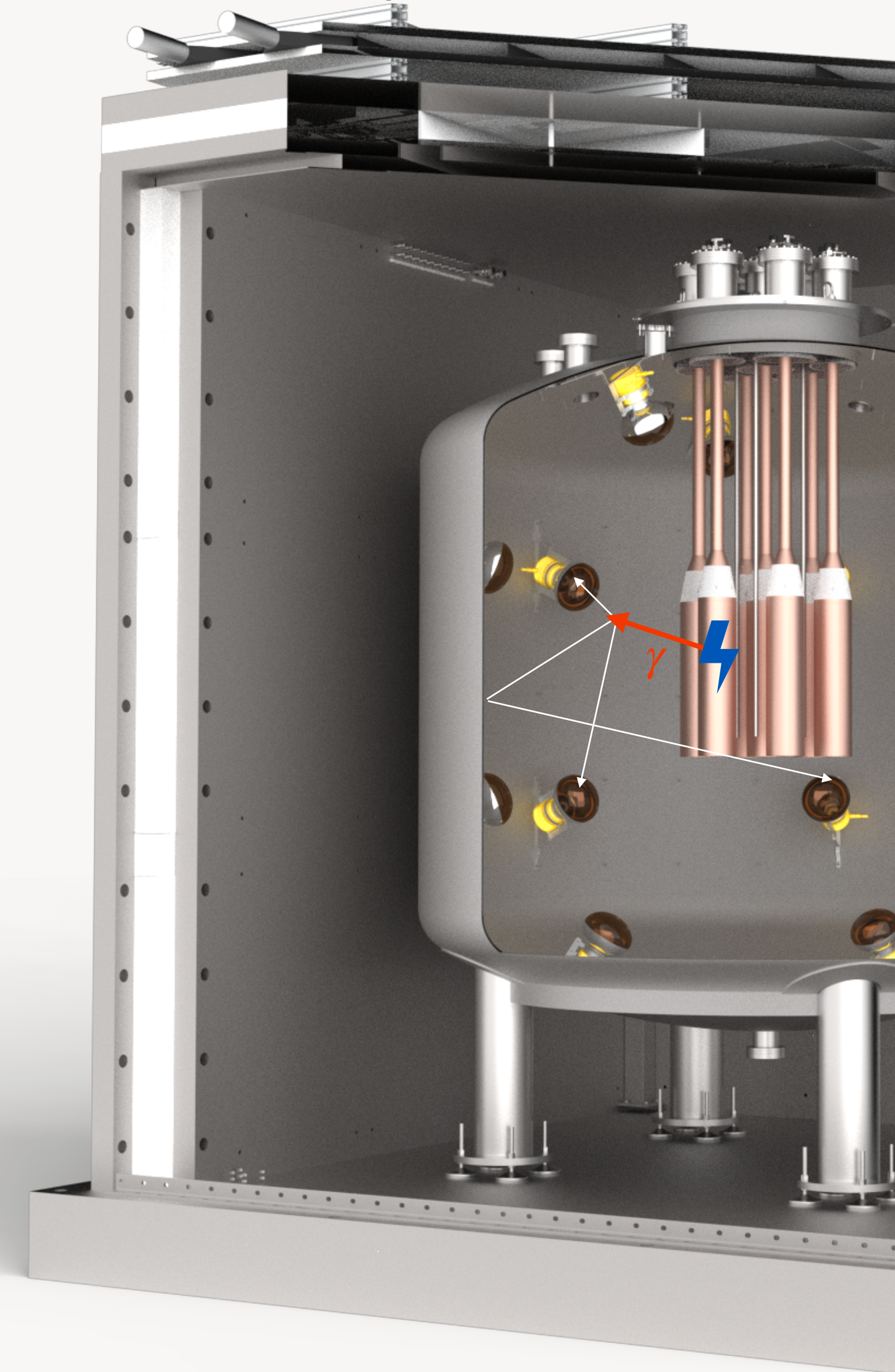
LEONIE EINFALT
01/06/2026

Expected Background



Full simulation based on SABRE proof-of-principle measurement*

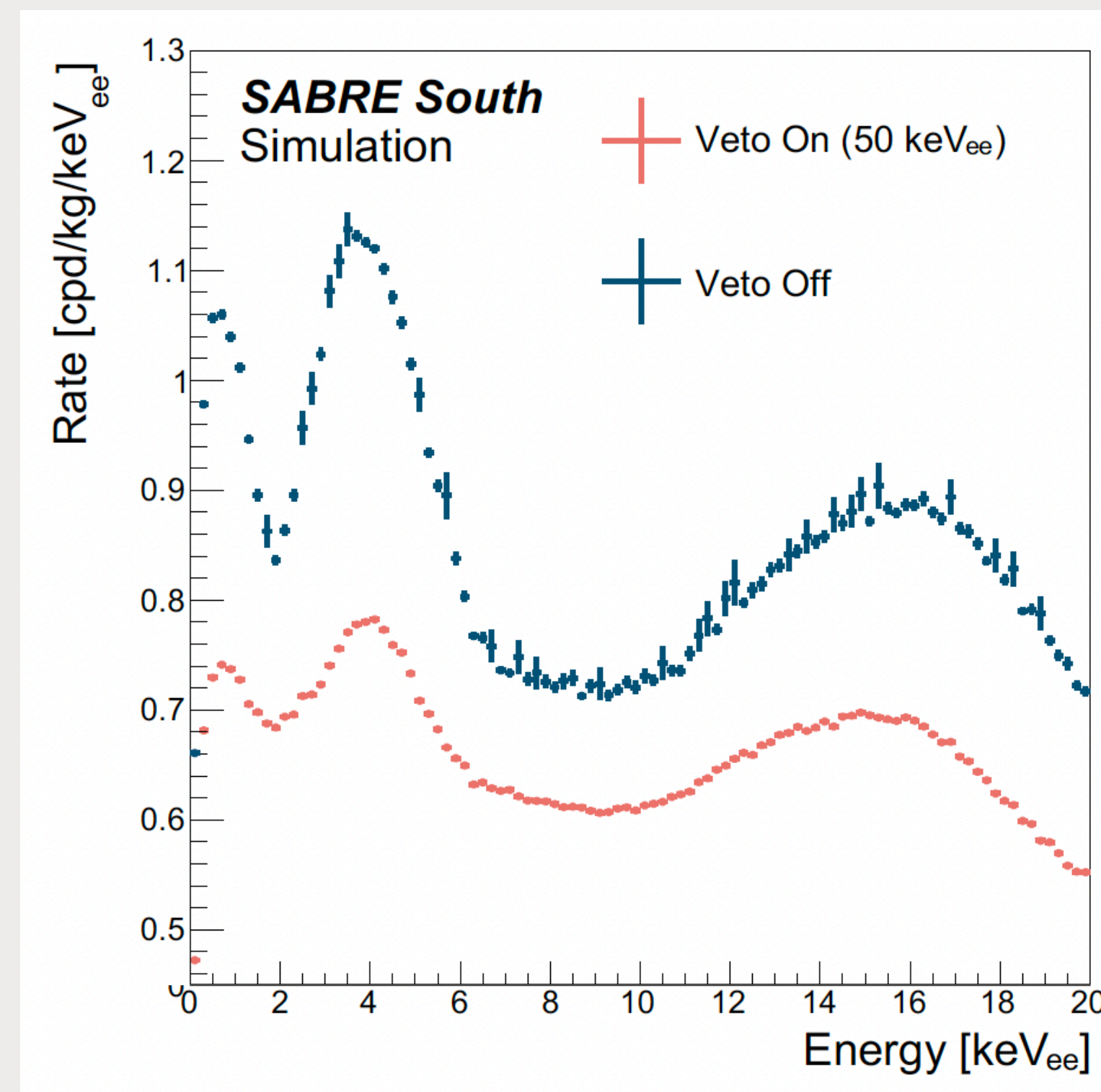
10 / 18
*Eur. Phys. J. C (2023) 83:878



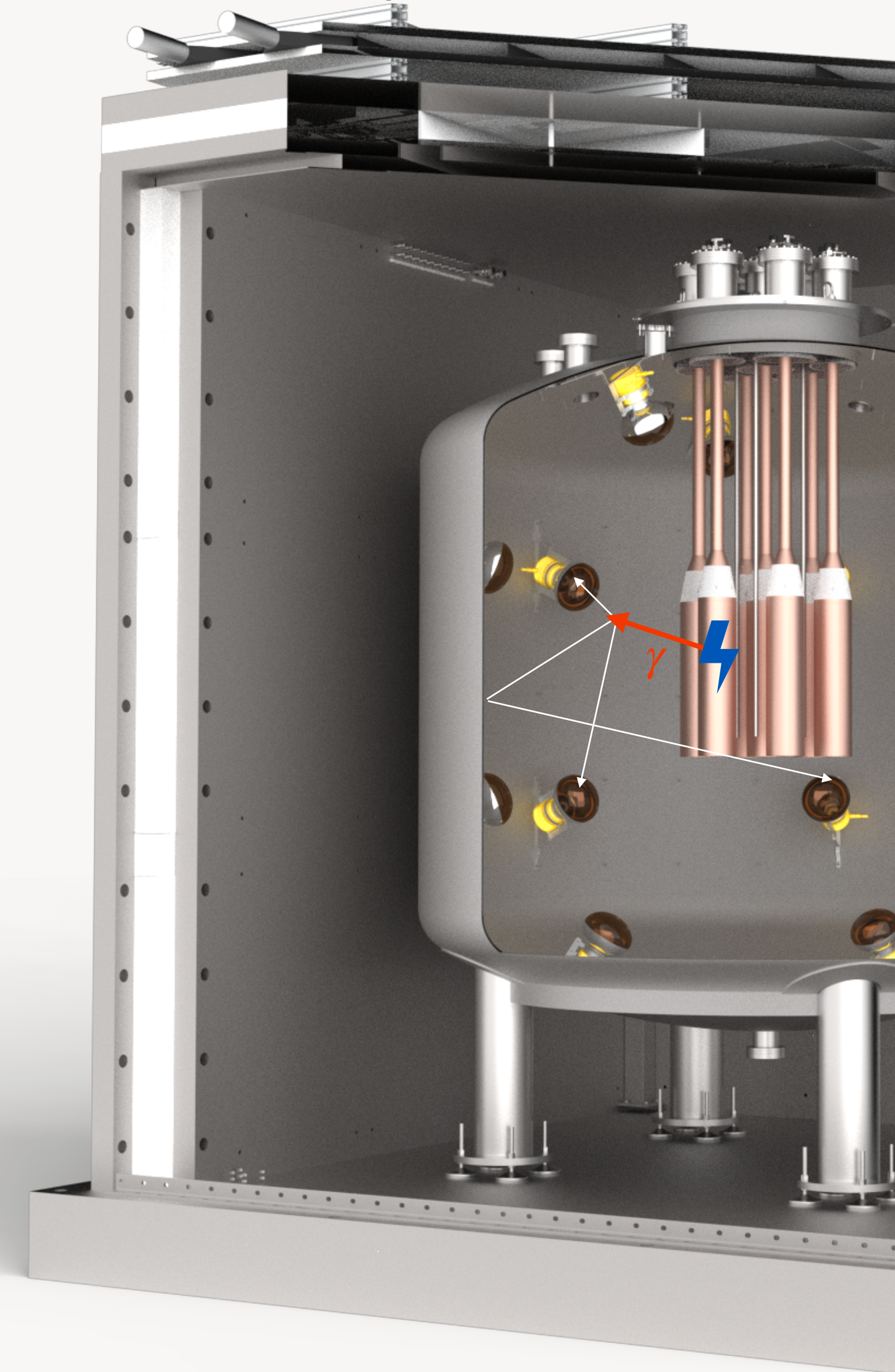
VETO SYSTEMS

Two active veto systems tag and reject coincident background and muon-induced events

Expected Background



Background reduction through tagging in LAB veto

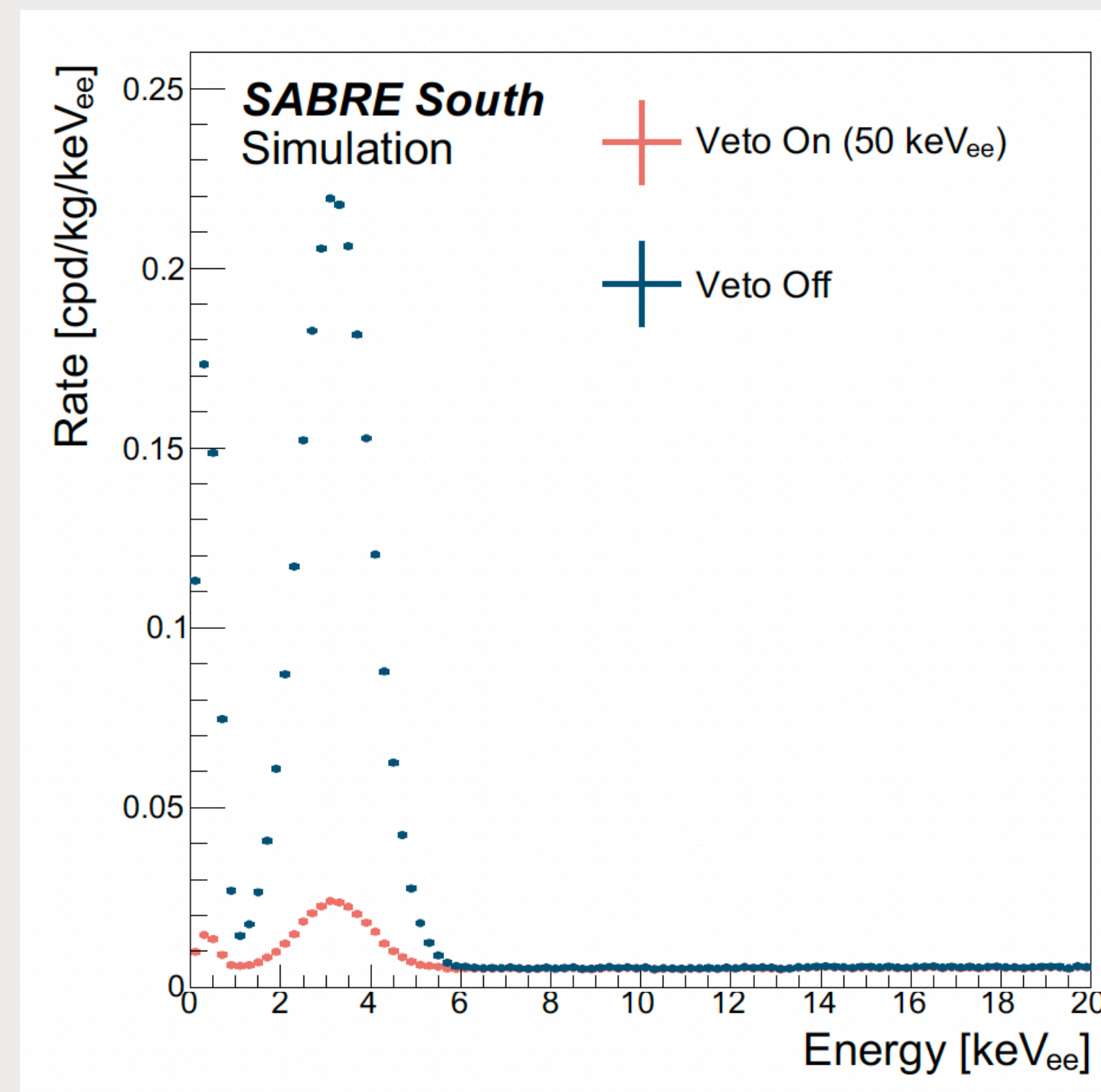


VETO SYSTEMS

Two active veto systems tag and reject coincident background and muon-induced events

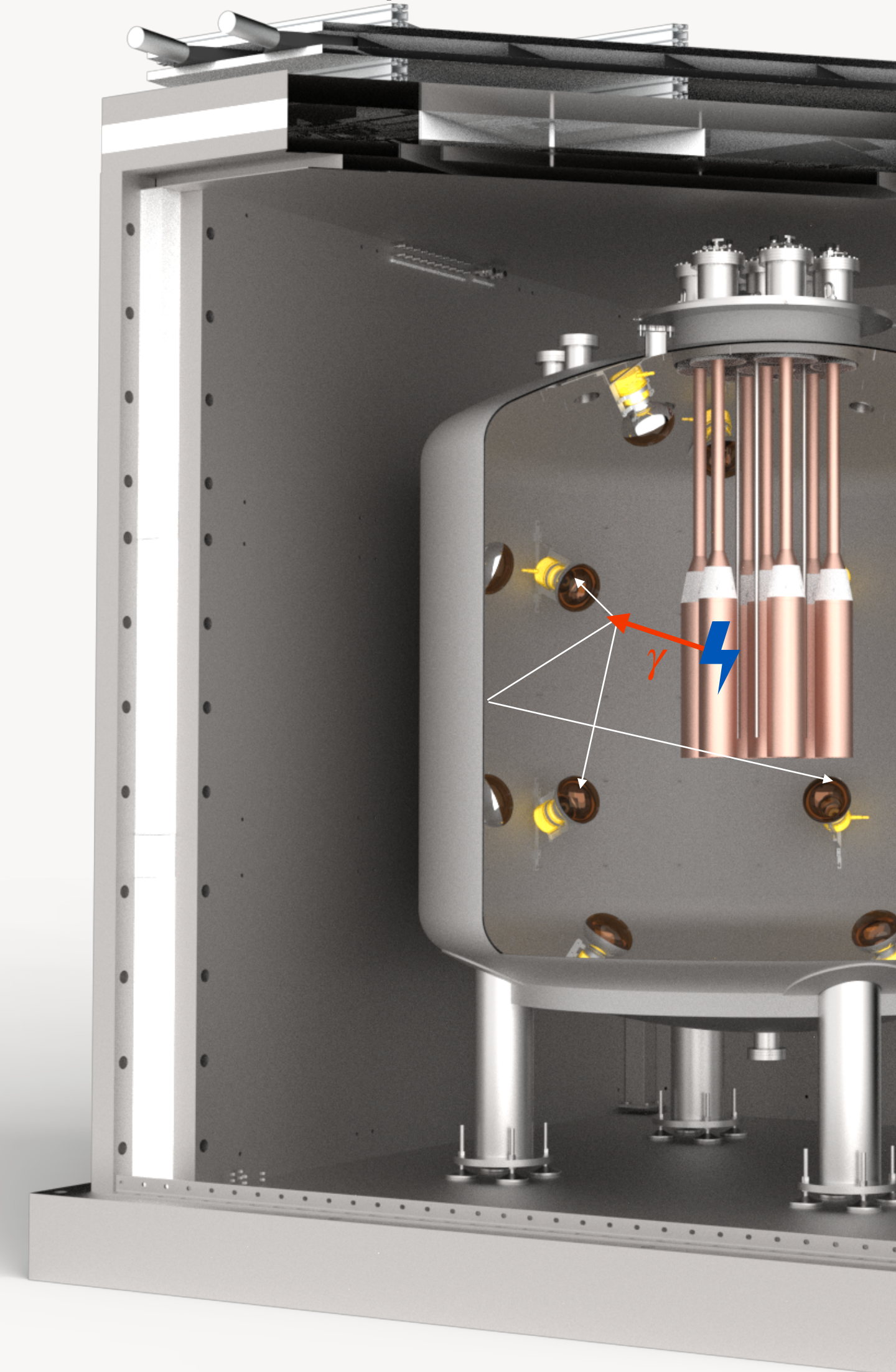
LEONIE EINFALT
01/06/2026

Expected Background



Veto especially efficient for tagging of events from crystal ^{40}K contamination

10 / 18
*Eur. Phys. J. C (2023) 83:878



Ongoing work above-ground

PMTS & CRYSTALS

11 / 18

*JINST 20 P07052 (2025)

**JINST 20 T04001 (2025)

Crystal PMTs

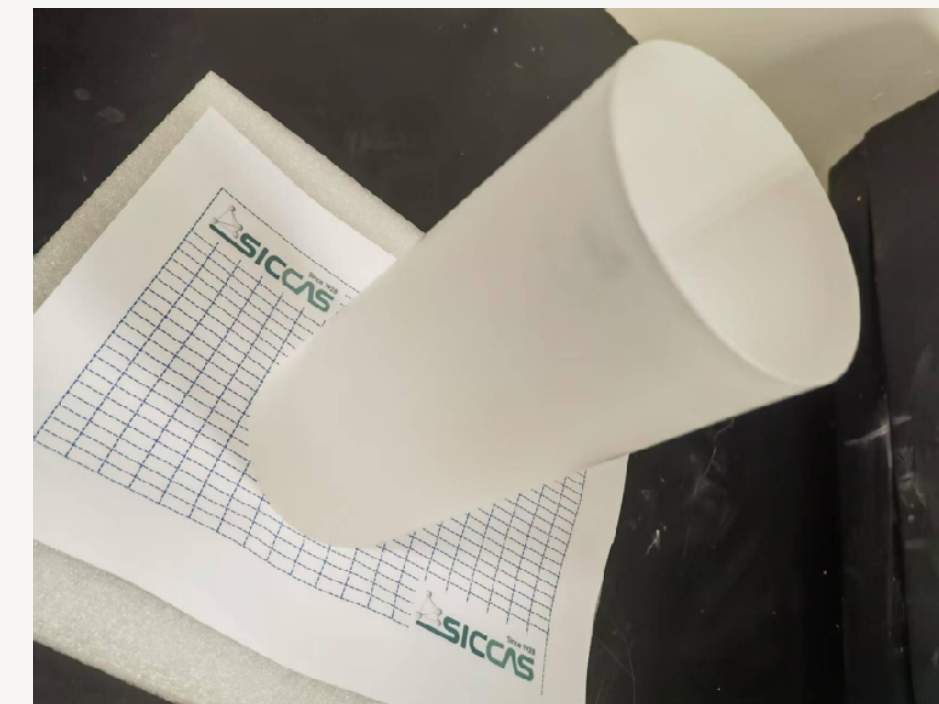
Low energy region at 1-3 keVee affected by **PMT noise** (potentially time-dependent background)



Developed **BDT-based noise rejection** to discriminate thermionic noise from genuine low-energy crystal events*

Veto PMTs

50 keVee veto threshold demonstrated for background discrimination with LAB veto**



Mech. test crystal
6.68 kg NaI(Tl) **crystal (SICCAS)** to be brought underground for **enclosure assembly tests and** cleaning procedure validation



Astrograde crystals

2x 0.5 kg Astrograde NaI(Tl) crystals will undergo **chemical and mechanical polishing** respectively to study impact on ^{210}Pb surface contamination

Ongoing work above-ground

PMTS & CRYSTALS

11 / 18

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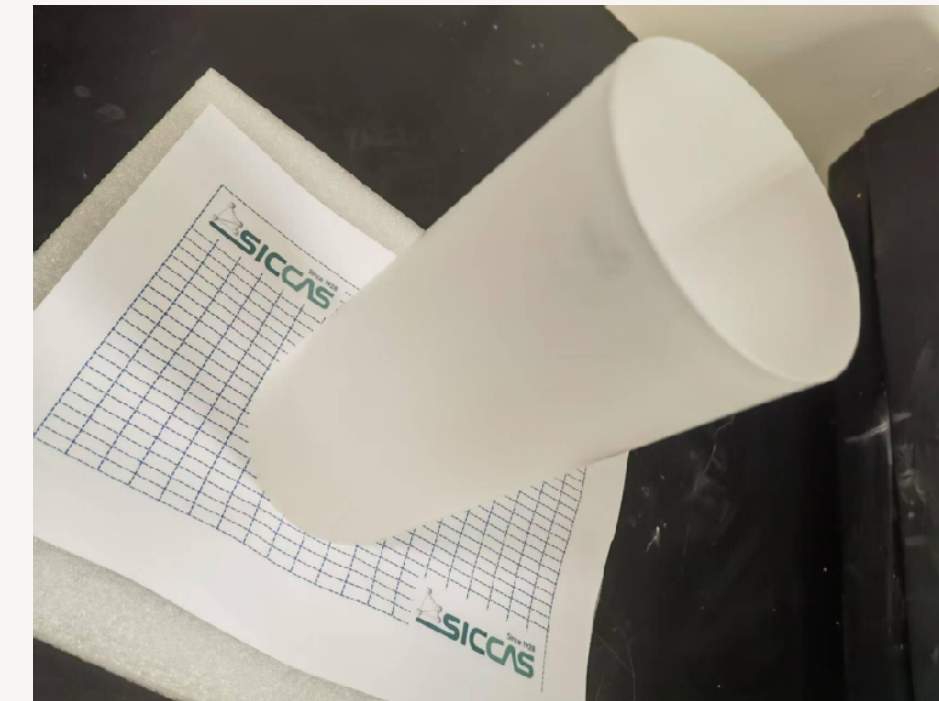
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Full characterisation of QE, SPE response, dark rate, gain, after pulsing etc.



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LEONIE EINFALT
01/06/2026

Ongoing work above-ground

PMTs & CRYSTALS

11 / 18

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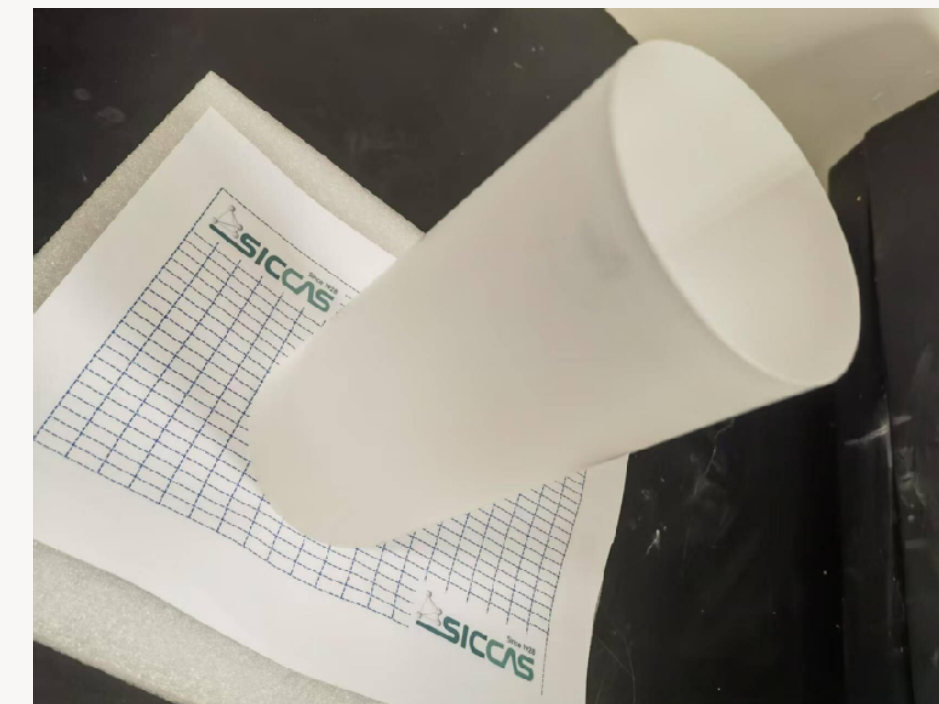


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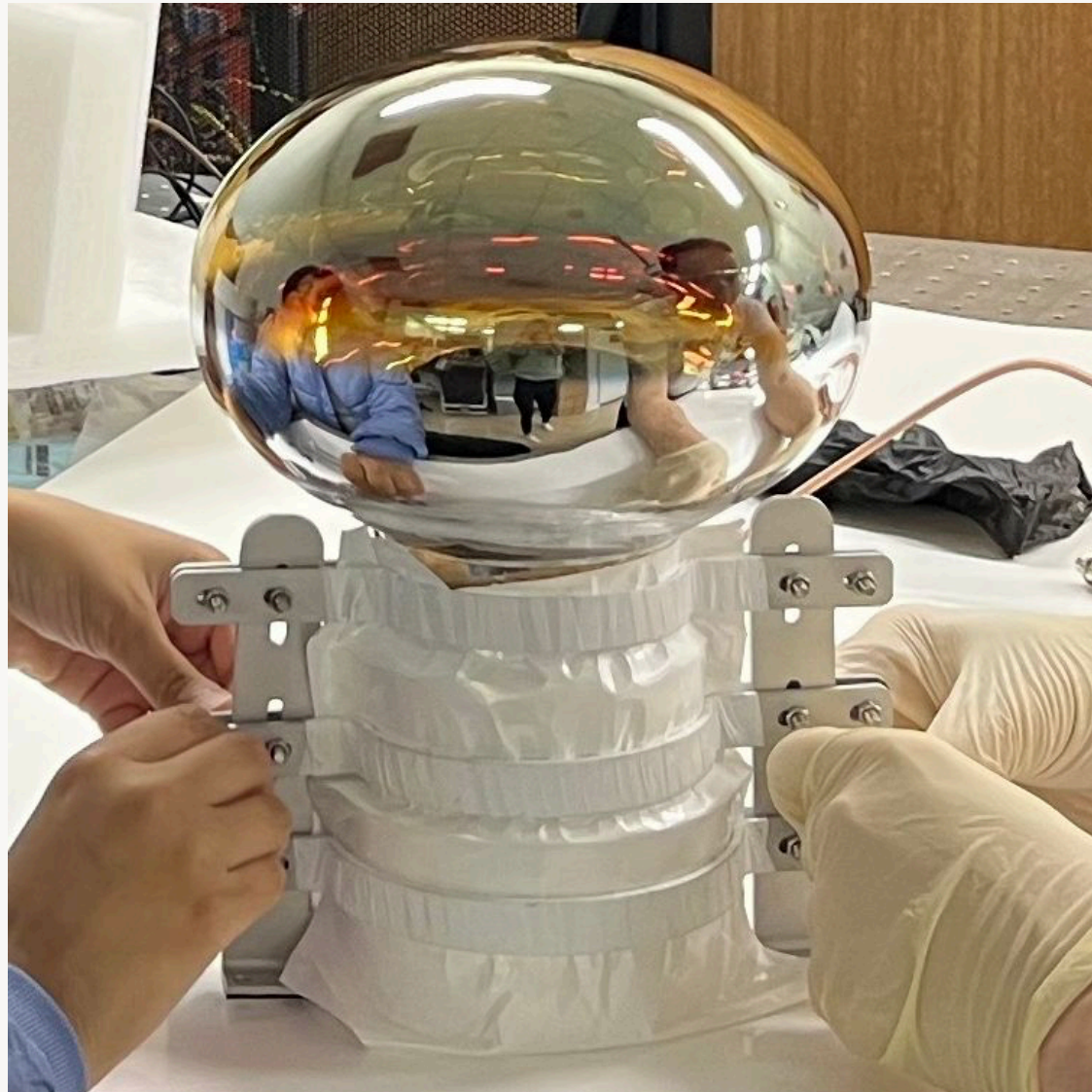
Astrograde crystals
2x 0.5 kg Astrograde NaI(Tl) crystals will undergo **chemical and mechanical polishing** respectively to study impact on ^{210}Pb surface contamination

Astrograde powder for production crystals on the way to SICCAS

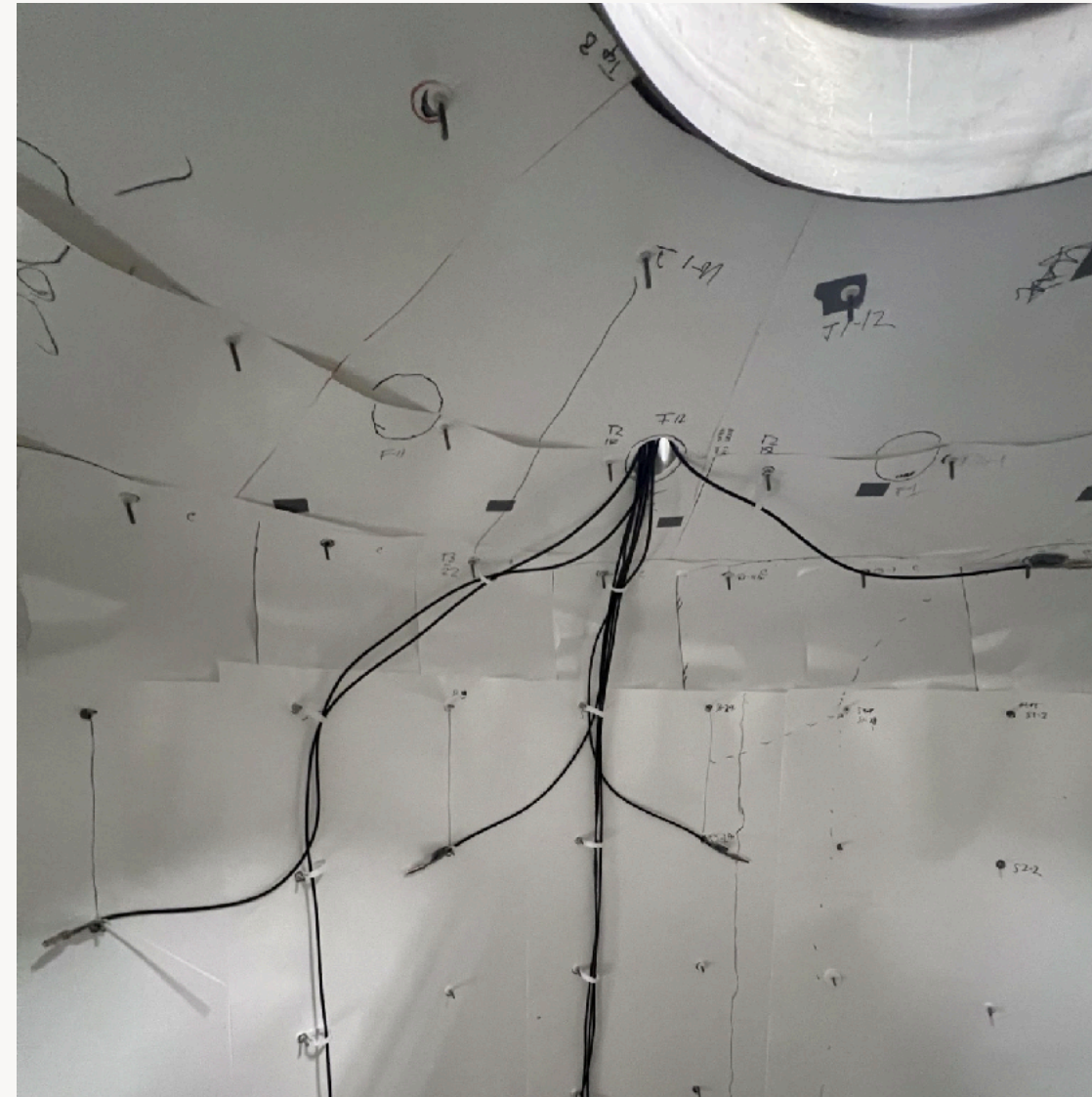
Ongoing work above-ground

VETO VESSEL & SHIELDING

12 / 18



Tests of mounting and assembly of veto PMTs



Tests of Lumirror mounting and cabling inside the vessel

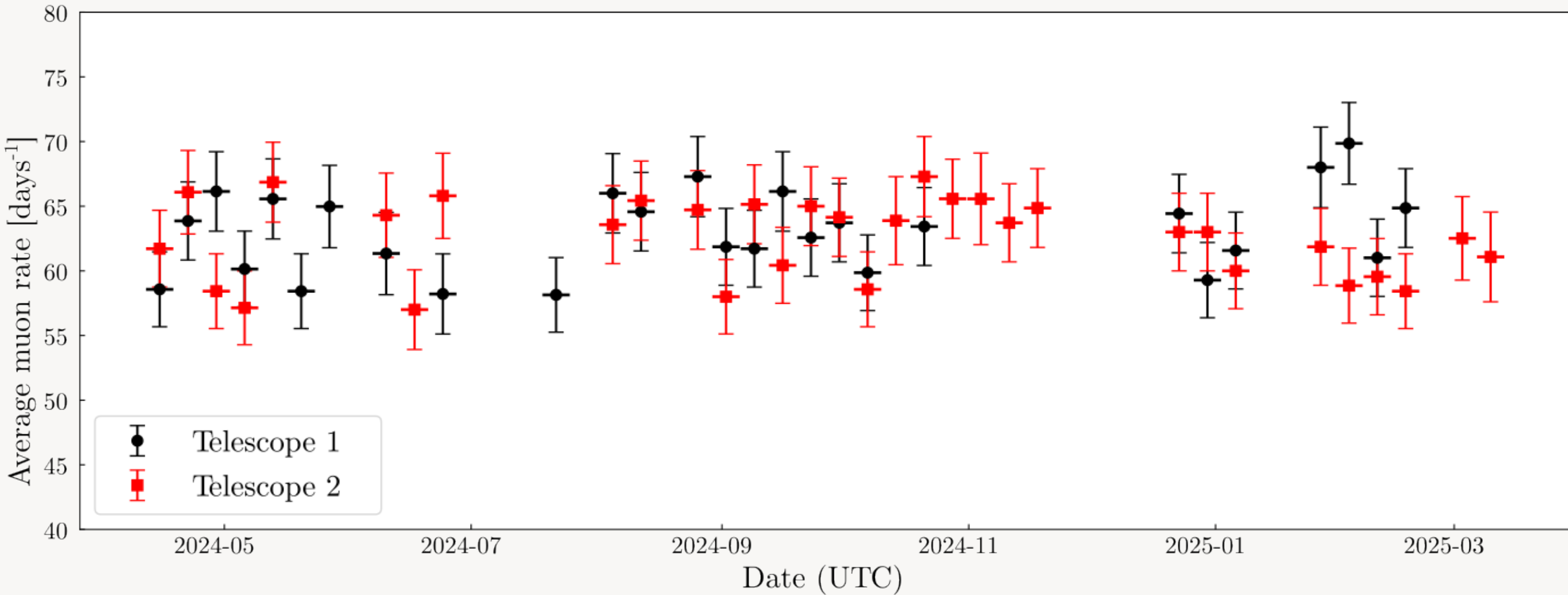
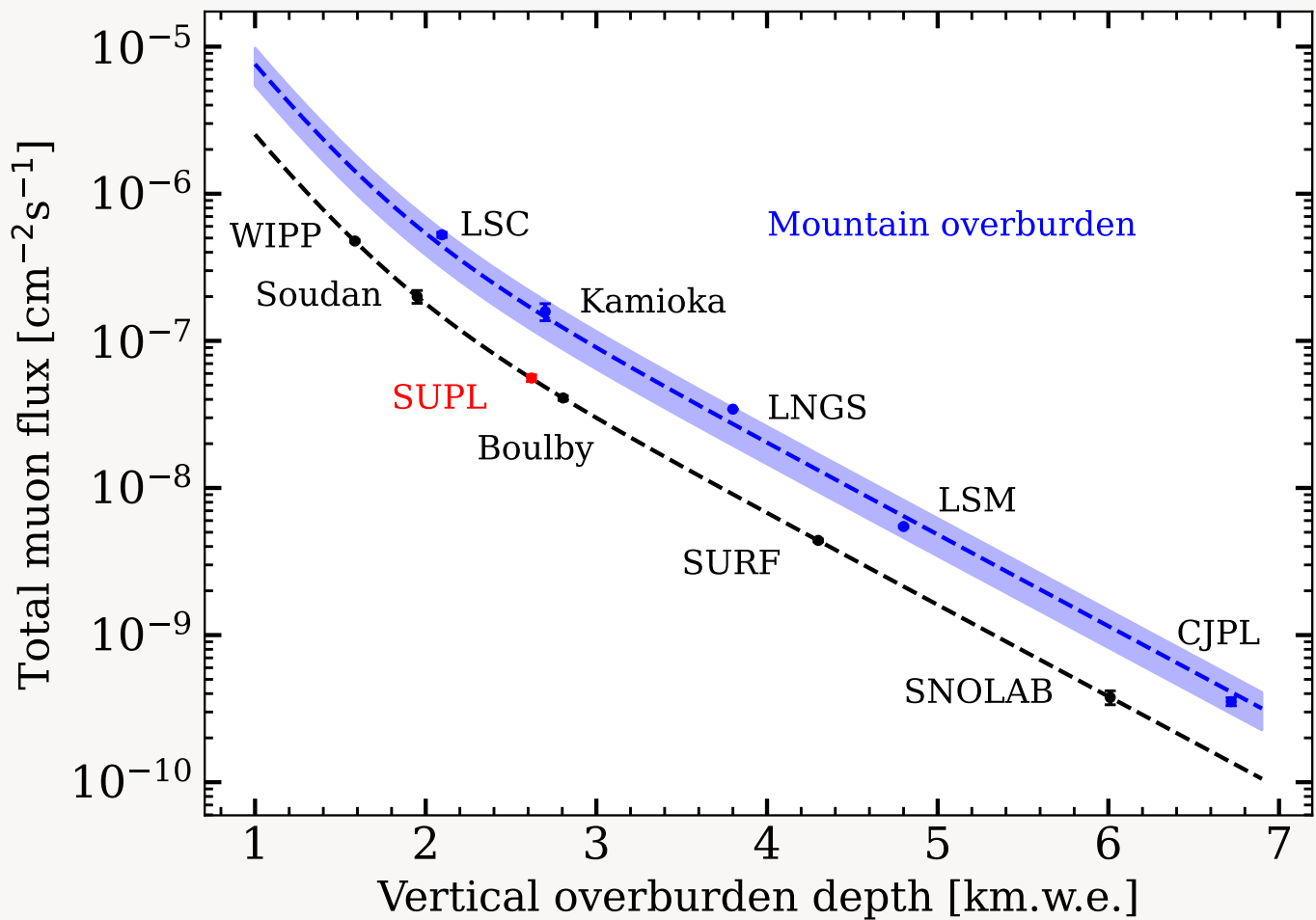


Test assembly of steel shielding and vessel fit-test



MUON FLUX AT SUPL

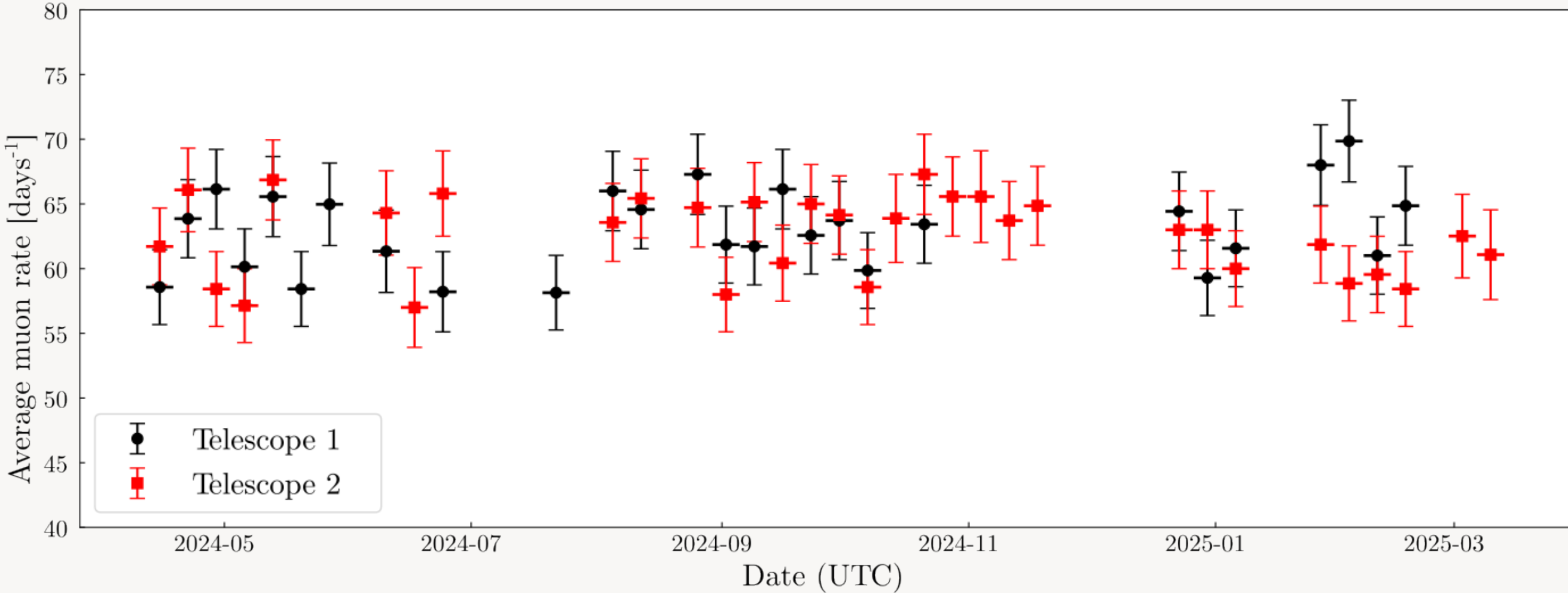
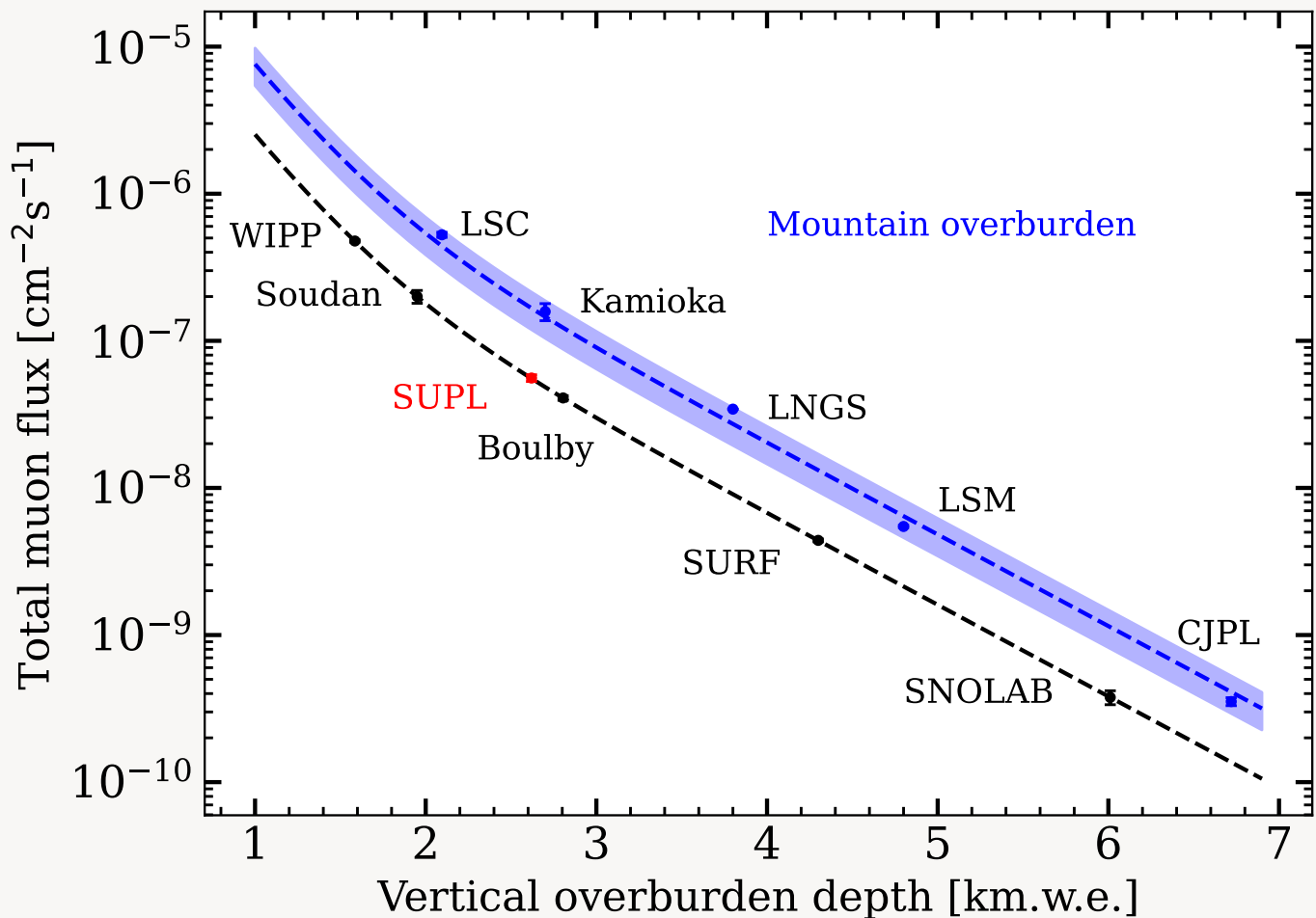
The **first physics result** from SUPL:
Measurement of the cosmic muon flux using
the SABRE South muon veto system, now
published in *Journal of Astroparticle Physics**



MUON FLUX AT SUPL

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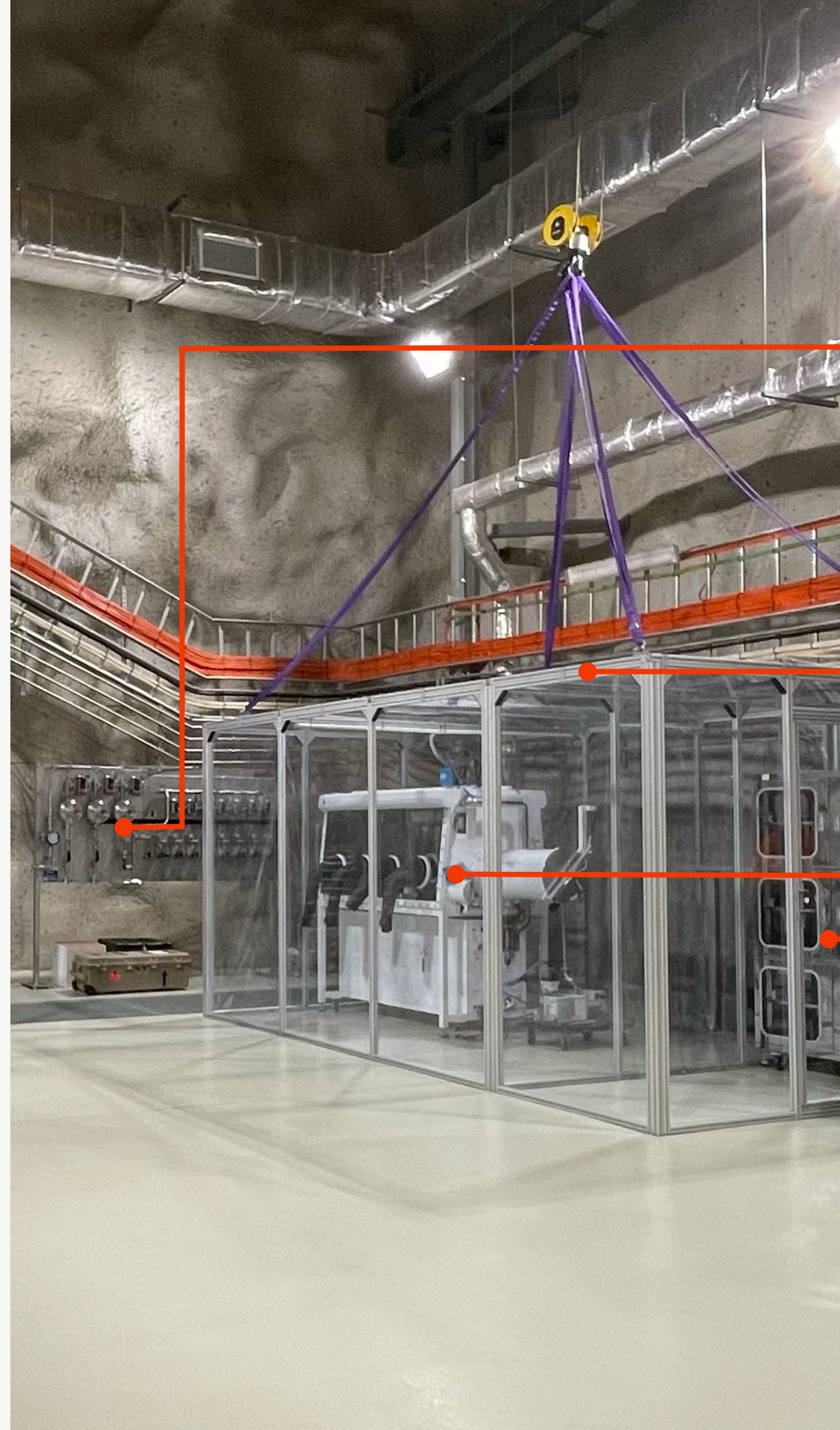
Ongoing analysis of annual fluctuations
and spectral distribution



Ongoing work underground

INFRA- STRUCTURE

Clean infrastructure at SUPL ensures crystal handling and storage meet radiopurity requirements



14 / 18
**2025 JINST 20 T04001*

Fluid handling system

N₂ supply and LAB handling for crystal enclosures, shielding and vessel

Clean tent

Radon-reduced air ($\sim 10\text{-}20\text{ Bq/m}^3$) from above-ground airline

Glove box

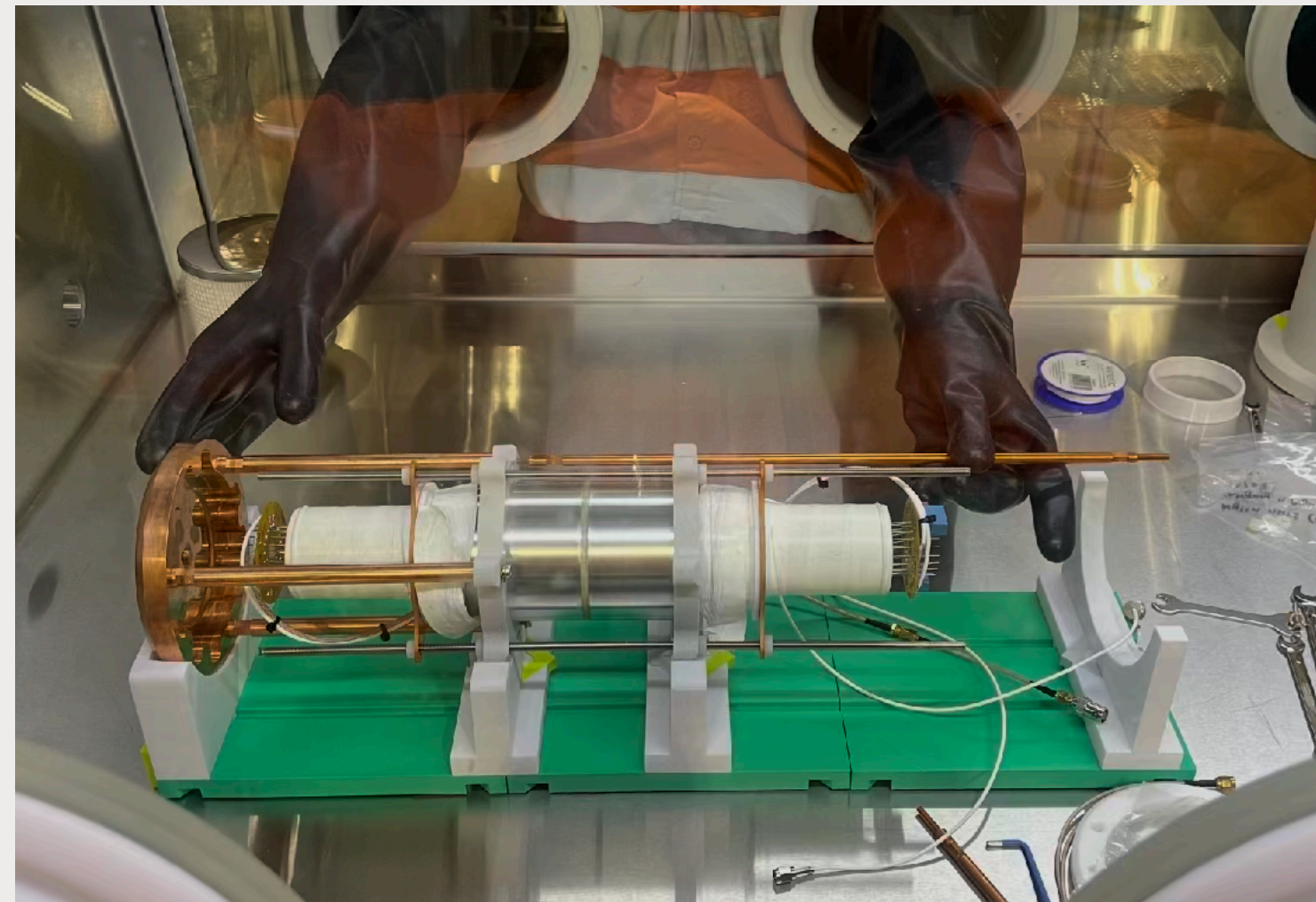
Crystal handling and storage at $\sim 5\text{ppm H}_2\text{O}$ level

Low humidity cabinet

Storage of PMTs, encapsulated crystals, enclosure parts and cabling at $<1\%$ r.h.

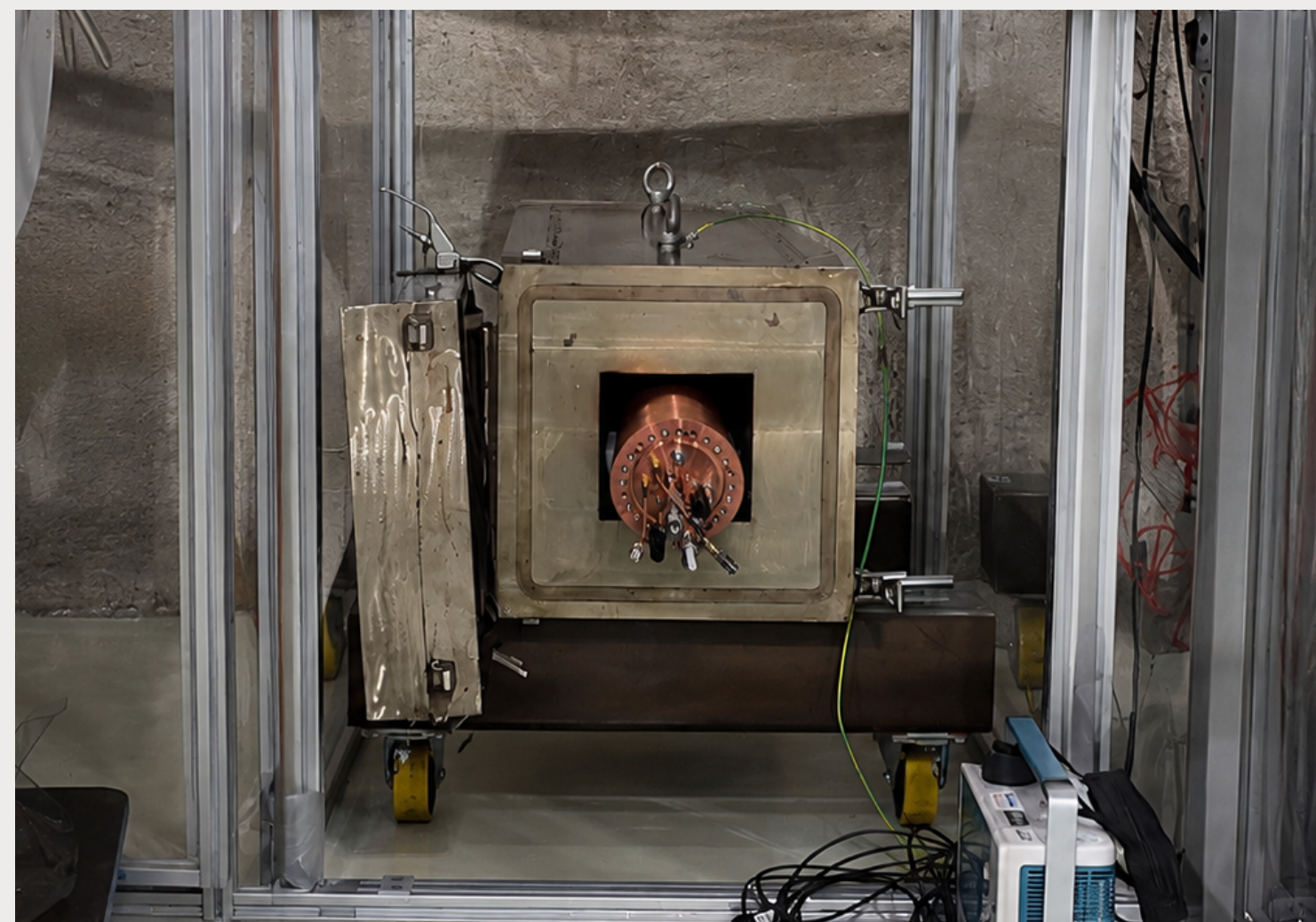
CRYSTAL TESTING

First **underground measurement of a NaI(Tl) crystal** in the SABRE South enclosure and **steel castle** at SUPL



Glove box assembly

Commercial encapsulated NaI(Tl) crystal prepared for measurement using custom-built jigs inside the underground glove box at SUPL

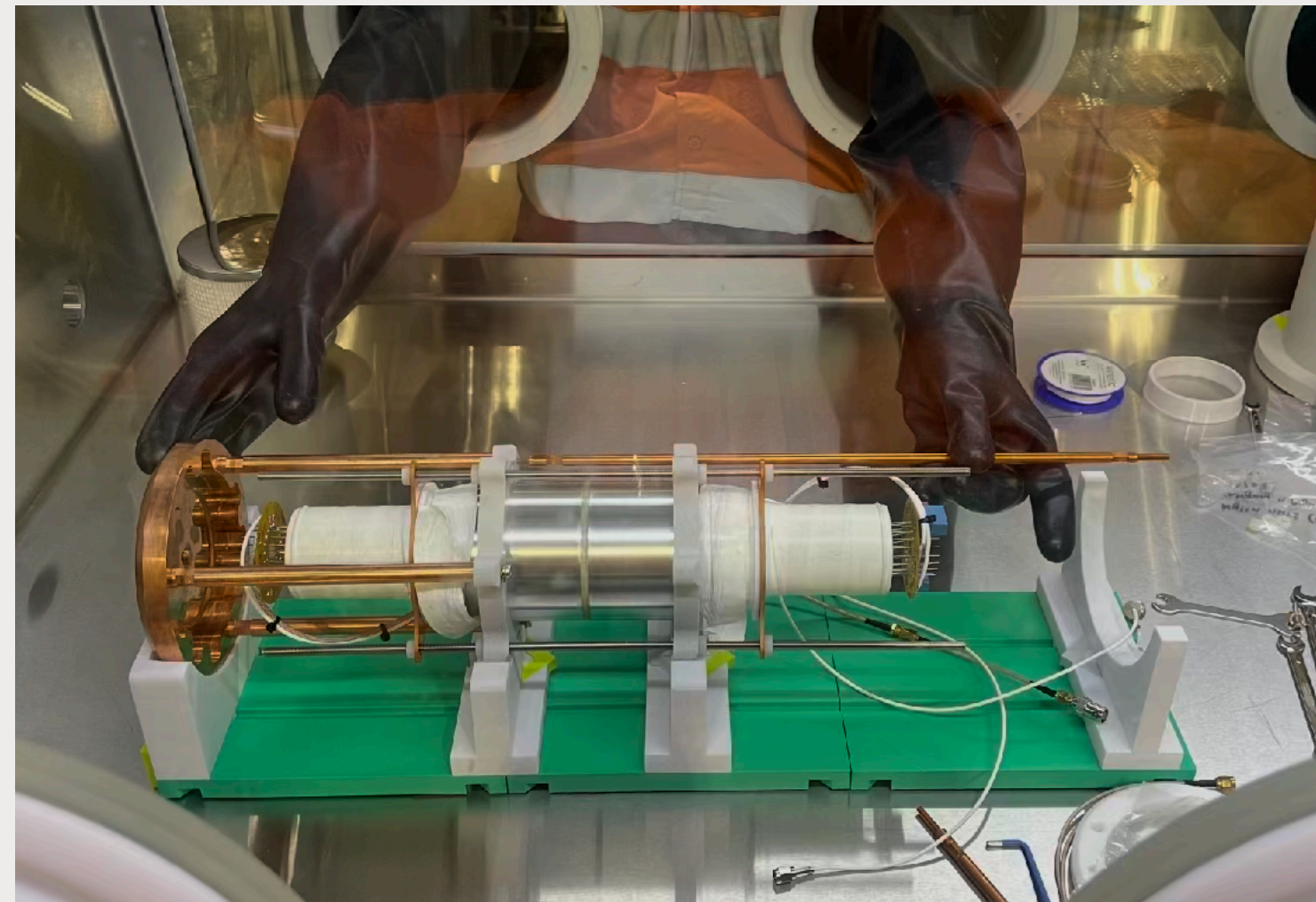


Steel castle measurement

Crystal placed inside the steel castle, located within the clean tent with radon-reduced air supply ($\sim 10\text{--}20\text{ Bq/m}^3$)

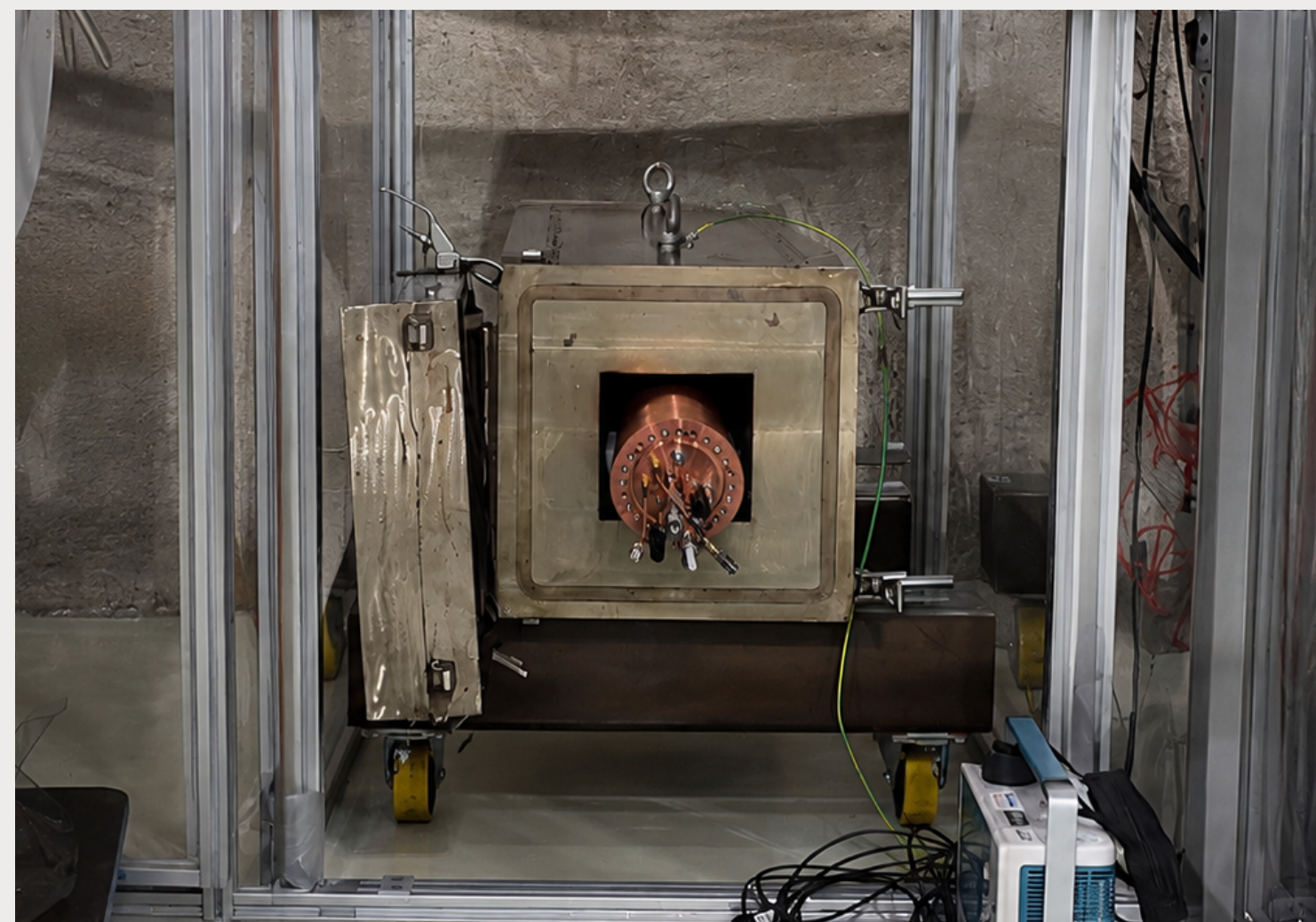
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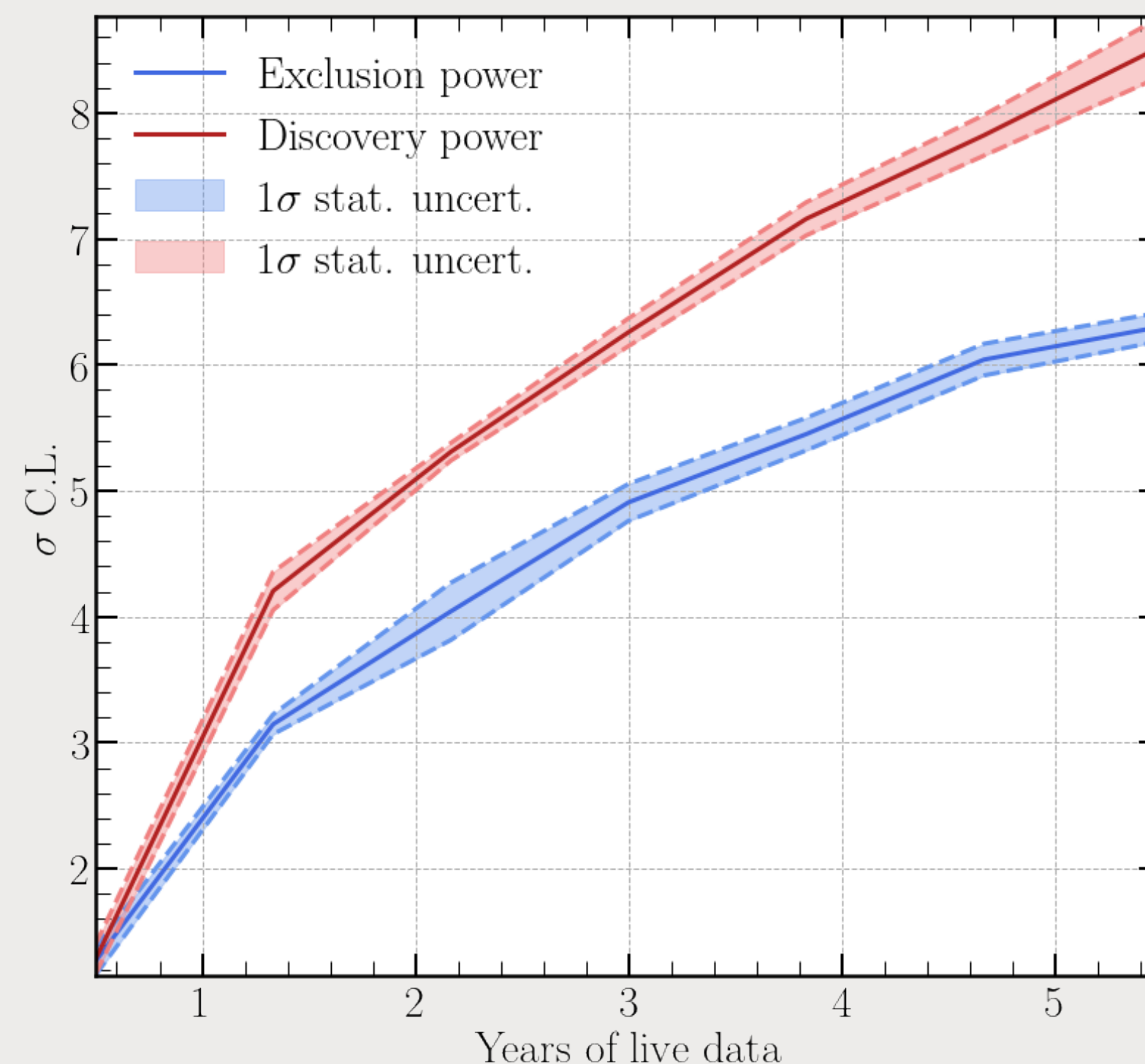
Steel castle measurement

Crystal placed inside the steel castle, located within the clean tent with radon-reduced air supply ($\sim 10\text{--}20\text{ Bq/m}^3$)

Data currently being analysed!

SENSITIVITY OUTLOOK

Sensitivity scales as $\sqrt{M/R_{bkg}}$ —
minimising background is the critical lever



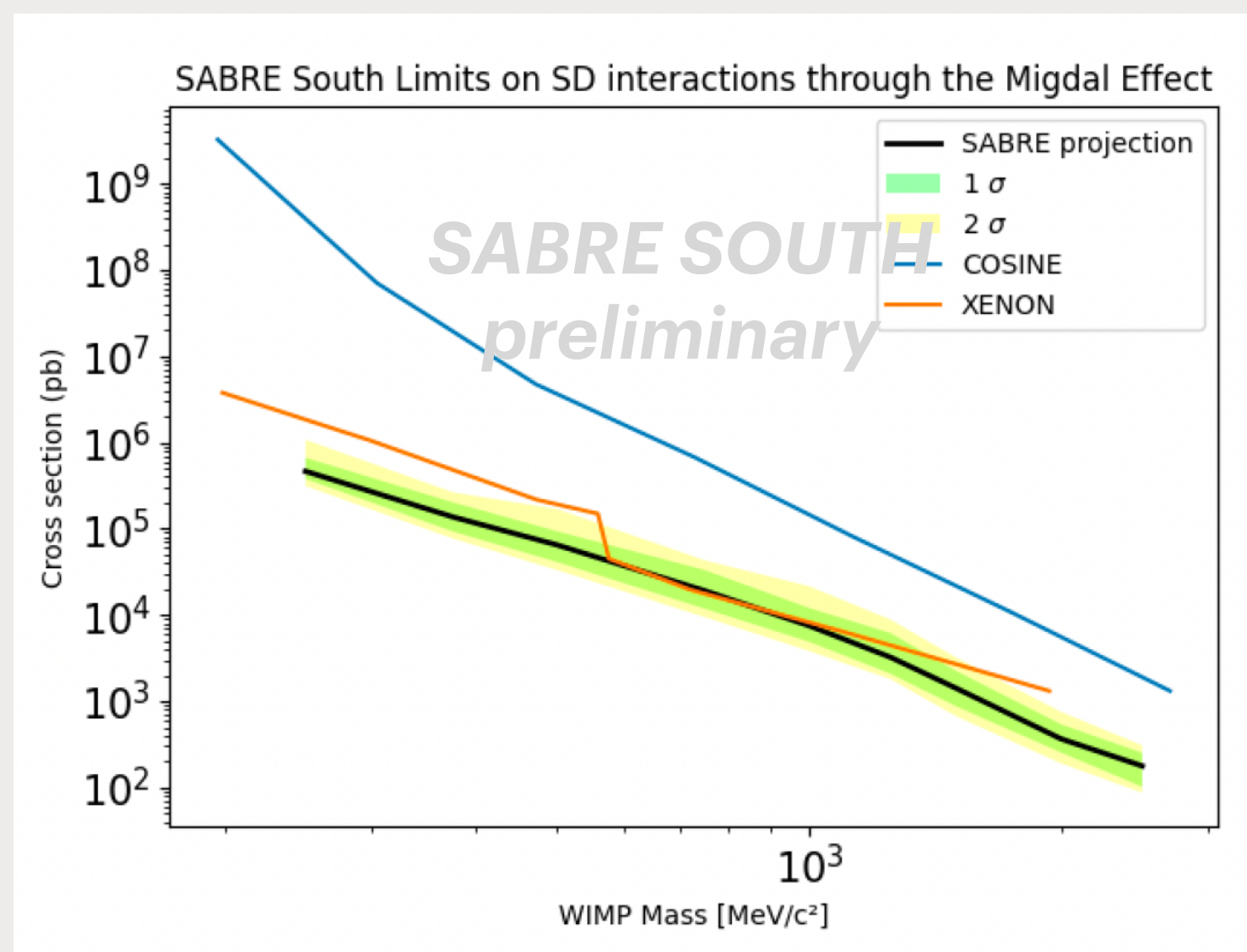
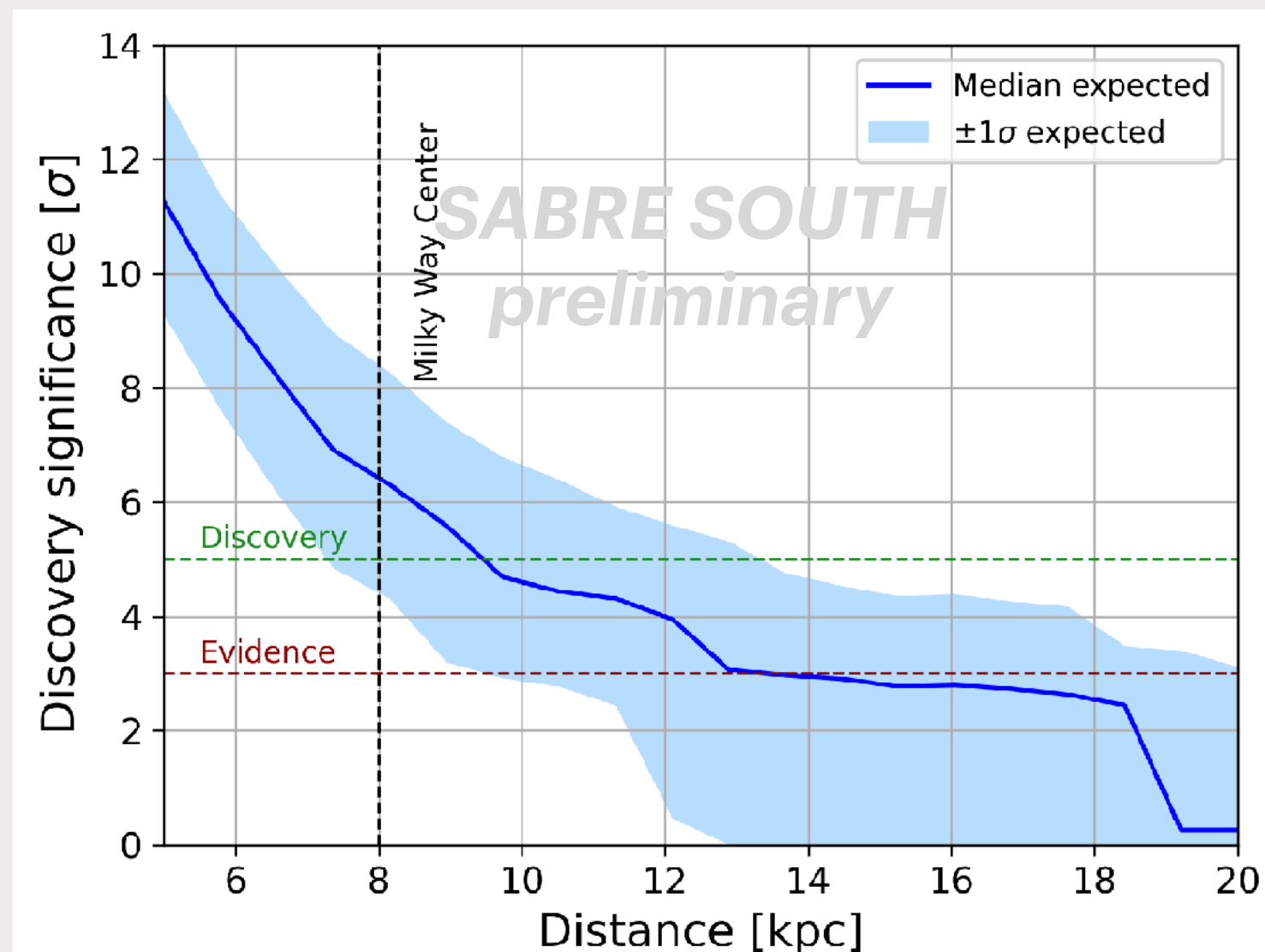
Parameter	Value
Light yield	11.1 ± 0.2 PE/keV [10]
Energy resolution	13.2% (FWHM/E) at 59.5 keV [10]
Crystal energy threshold	1 keV
Veto energy threshold	50 keV
Total active mass	35 - 50 kg
Background rate (PoP)	0.36 cpd/kg/keV [11]

Assuming **0.72 cpd/kg/keV** background (after veto) and 35–50 kg active mass:

- 3σ exclusion reachable within ~ 1 year, 5σ within ~ 3 years
- 5σ discovery of DAMA/LIBRA-like signal achievable within ~ 2 years of live data
- Sensitivity improves significantly after cosmogenic decay (~ 6 months underground cool-down)

PHYSICS REACH

SABRE South has physics reach beyond the dark matter annual modulation signal



Supernova neutrinos

Sensitivity to core-collapse supernovae out to ~8 kpc (Milky Way centre) via the liquid scintillator veto

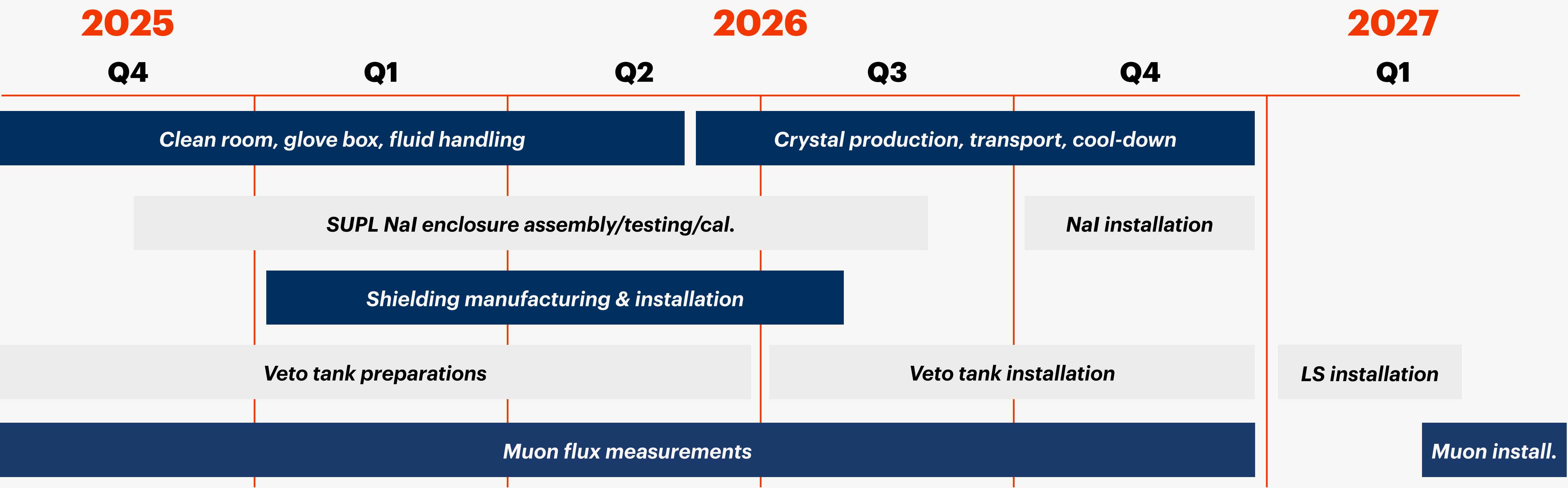
Bosonic super-WIMPs

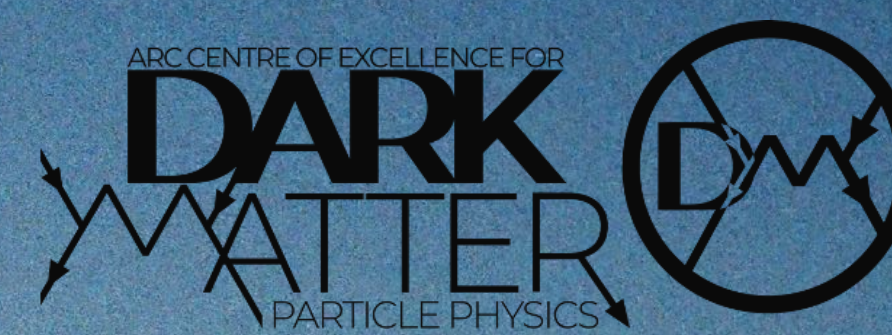
Competitive limits on BSW-electron coupling g_{ae} across 300–1000 keV mass range

Migdal sensitivity studies

Sub-GeV WIMP reach via electron emission (see full TDR)

TIMELINE & OUTLOOK





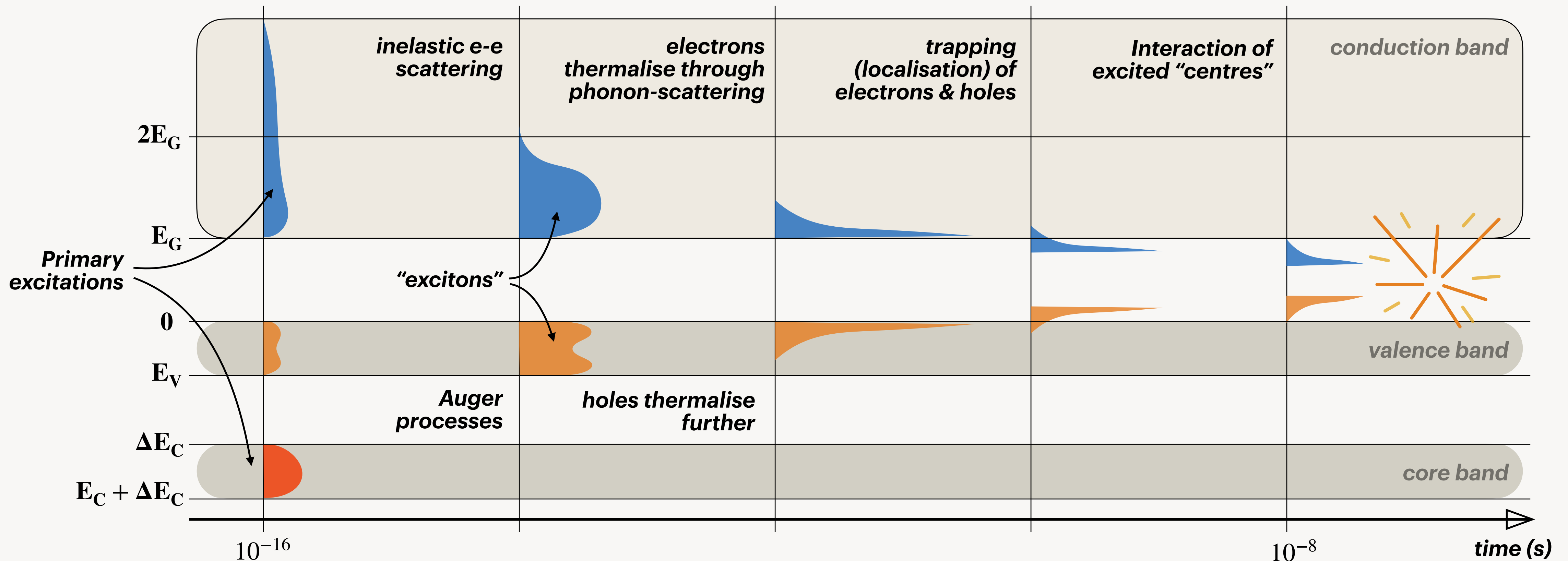
**SABRE
SOUTH**

**lots of
kangaroos**

Grampians

SCINTILLATION PROCESS

scintillation = "luminescence in a crystalline medium caused by ionising radiation"

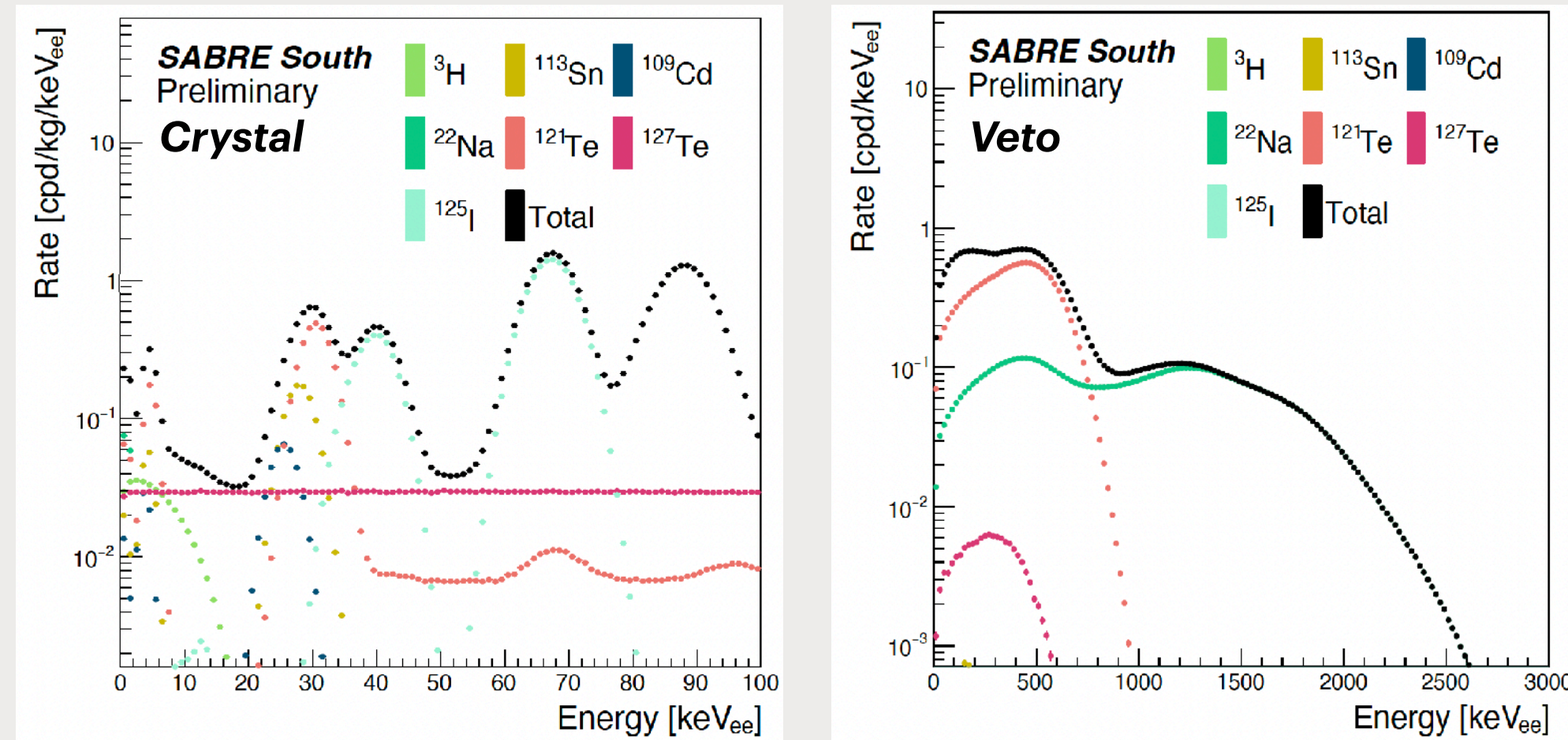


COSMOGENIC ACTIVATION

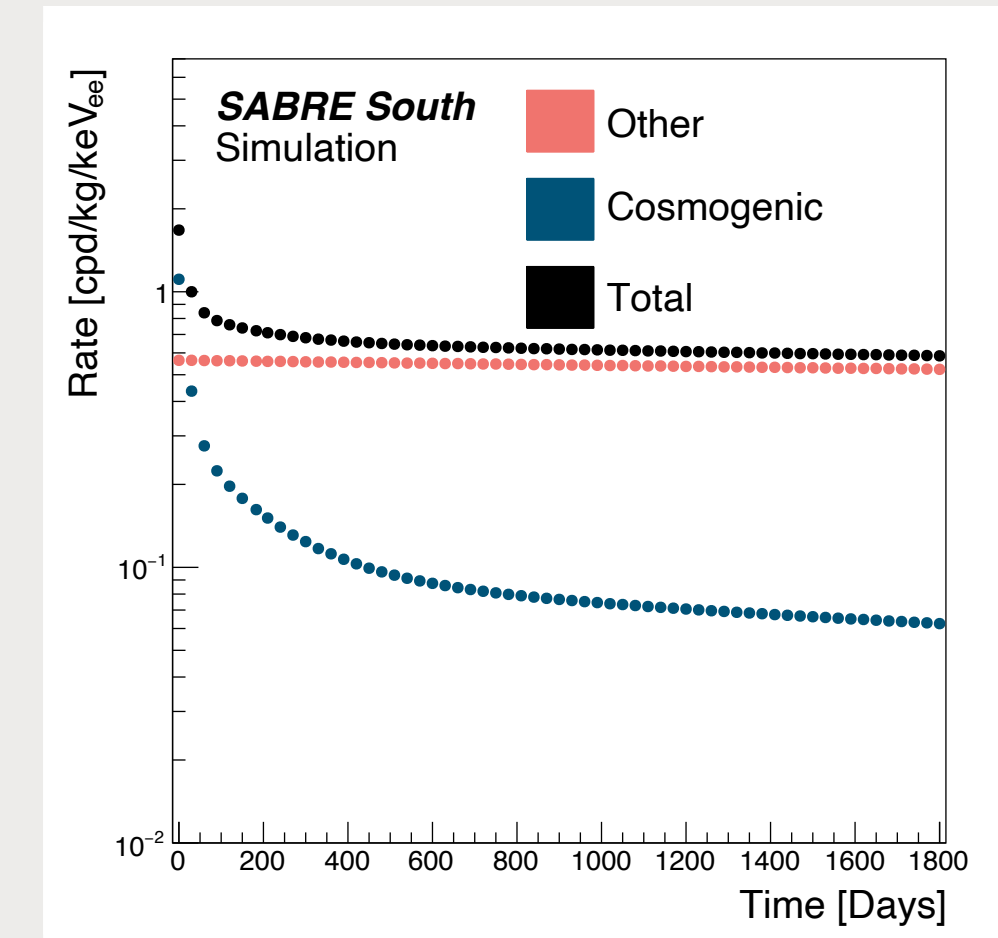
Backup

**Eur. Phys. J. C (2023) 83:878*

NaI(Tl) crystals activated during production and transport; cosmogenic isotopes contribute to the initial background budget



Simulation of backgrounds from cosmogenic activation of the NaI(Tl) crystal and powder, as seen in the crystal detector (left) and the liquid scintillator veto (right).



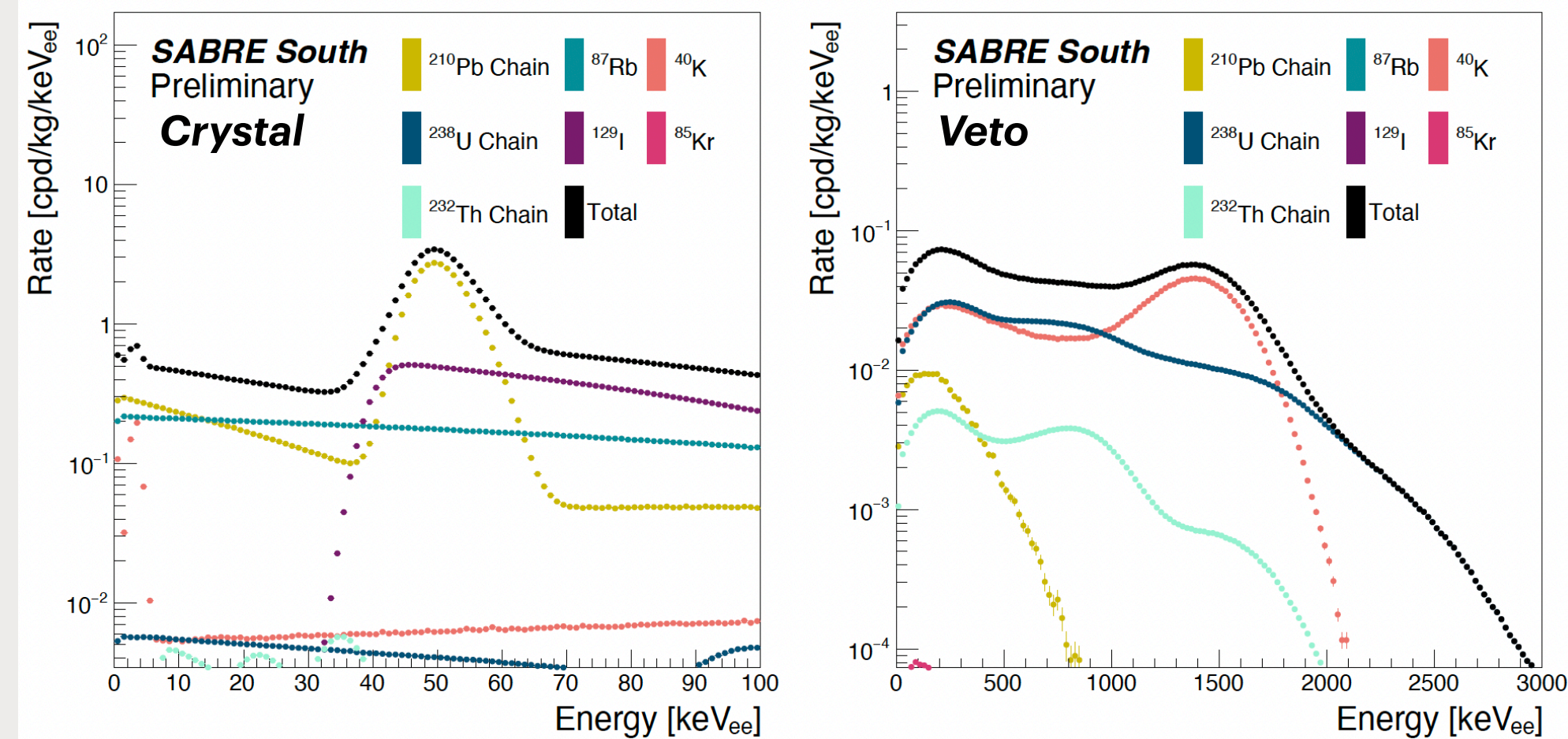
Short-lived isotopes decay to negligible levels within ~6 months underground (³H main long-lived background).

Crystals will be stored underground prior to the physics run to minimise exposure!

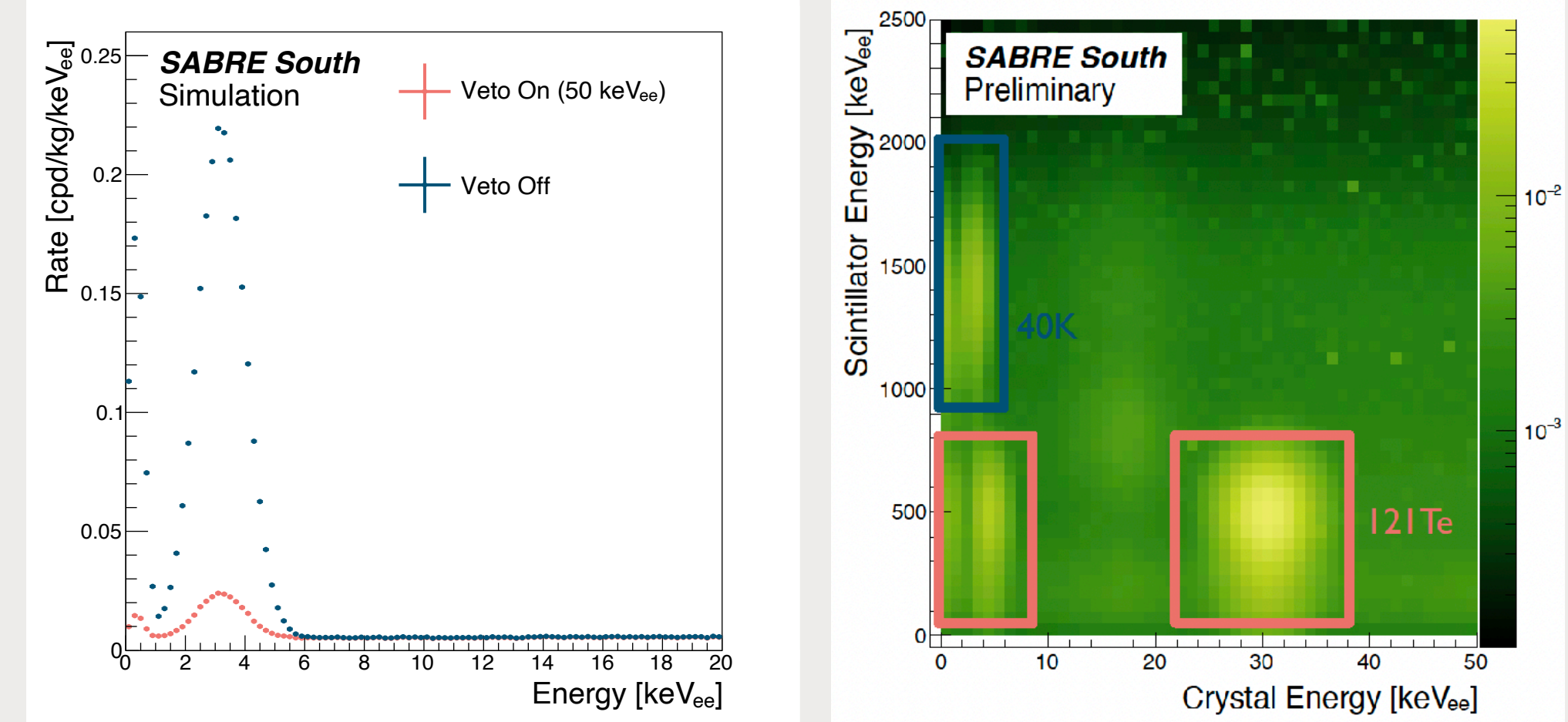
INTRINSIC RADIATION

Backup

**Eur. Phys. J. C* (2023) 83:878



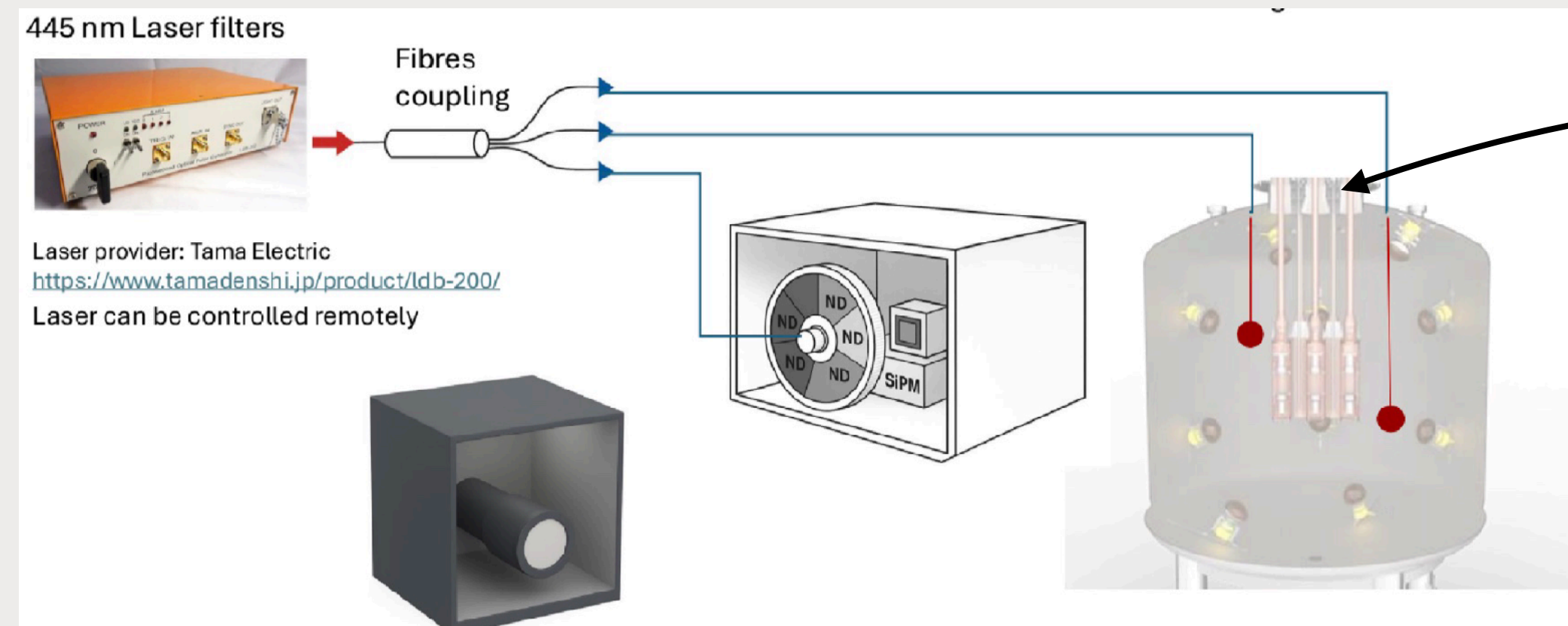
Simulated intrinsic radiogenic background in the NaI(Tl) crystal (left) and liquid scintillator veto (right), dominated by U/Th decay chains and ^{40}K . Crystal intrinsic background <0.52 cpd/kg/keVee in the ROI.



^{40}K peak reduced by $\sim$ factor 10 with the liquid scintillator veto (left). Combining crystal and veto energy depositions enables particle identification; ^{40}K and ^{121}Te clearly separated in the 2D coincidence map (right, sim.).

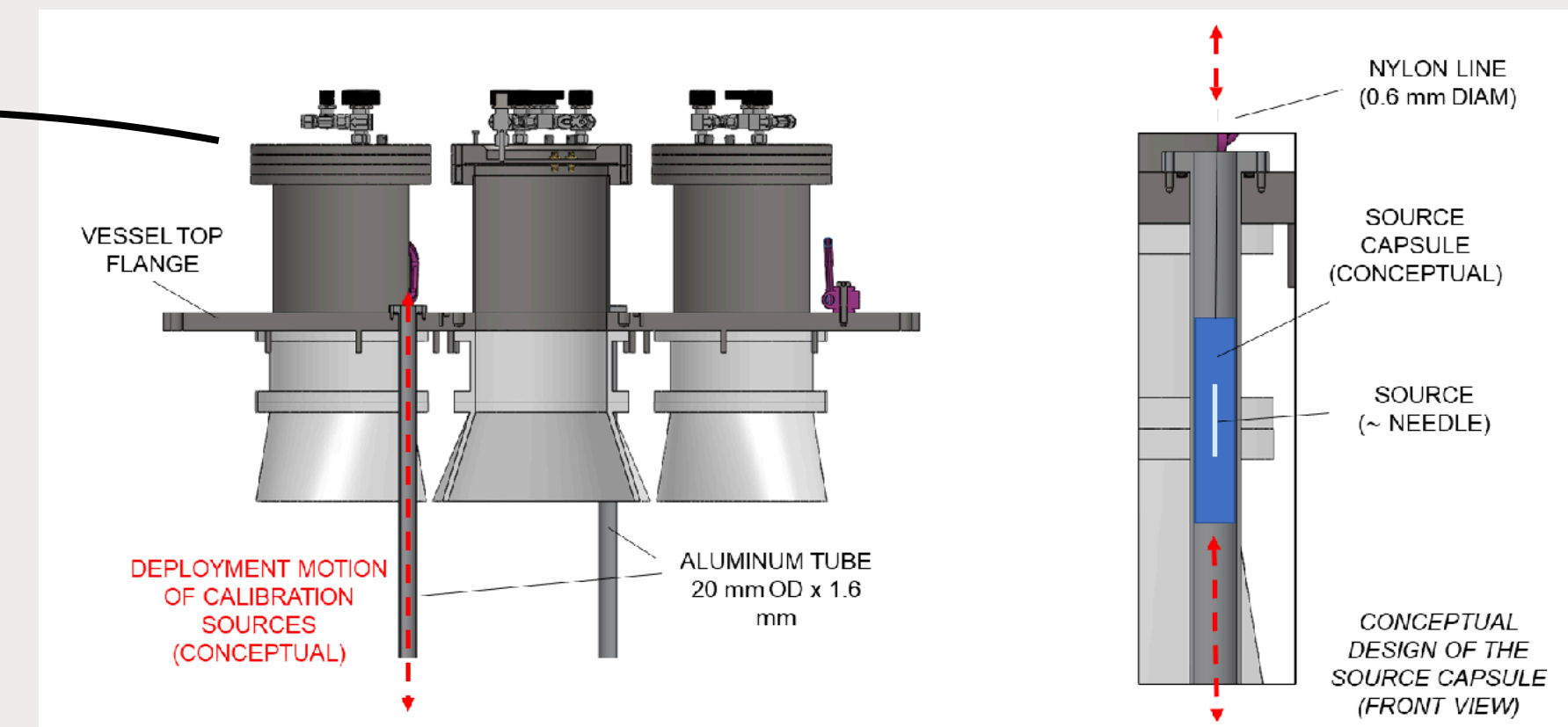
CALIBRATION SYSTEMS

Optical calibration



Full in-situ optical calibration system with laser balls permanently lowered into LAB on optical fibres. Successfully tested and procurement is ongoing.

Radioactive calibration



Automatic deployment of various sources into the vessel for calibration of veto and crystal modules.

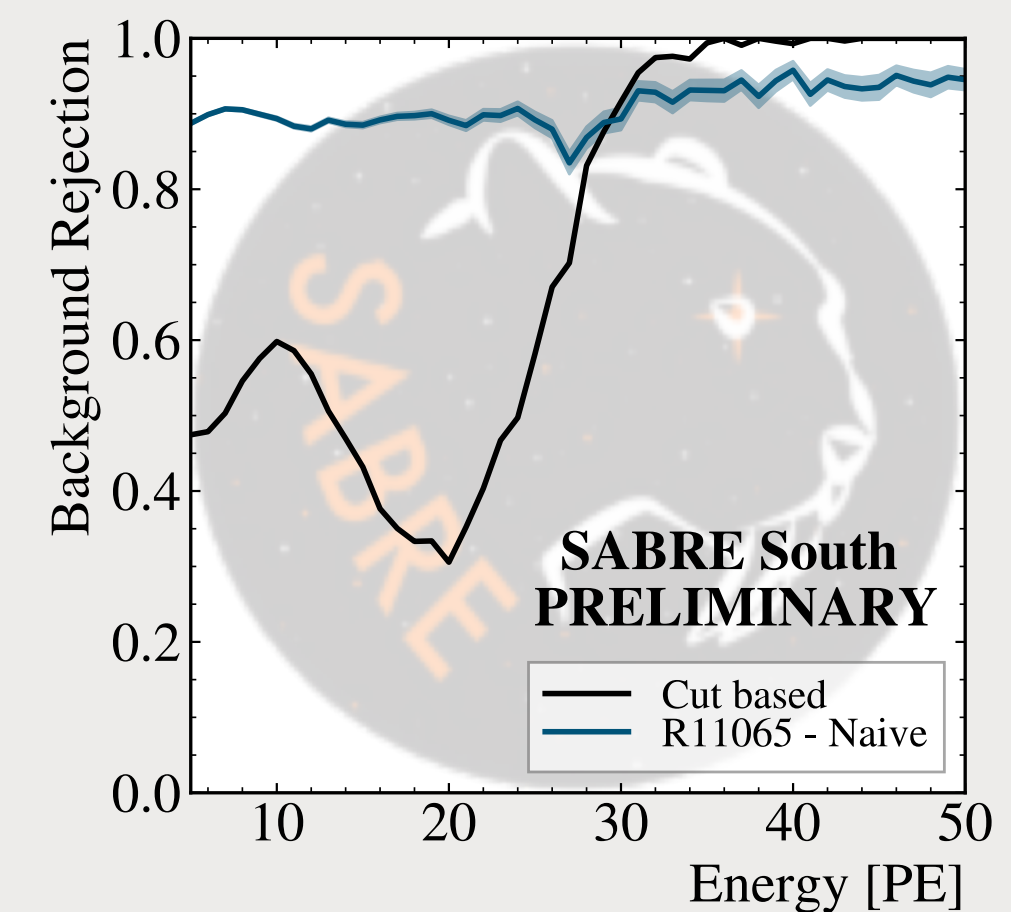
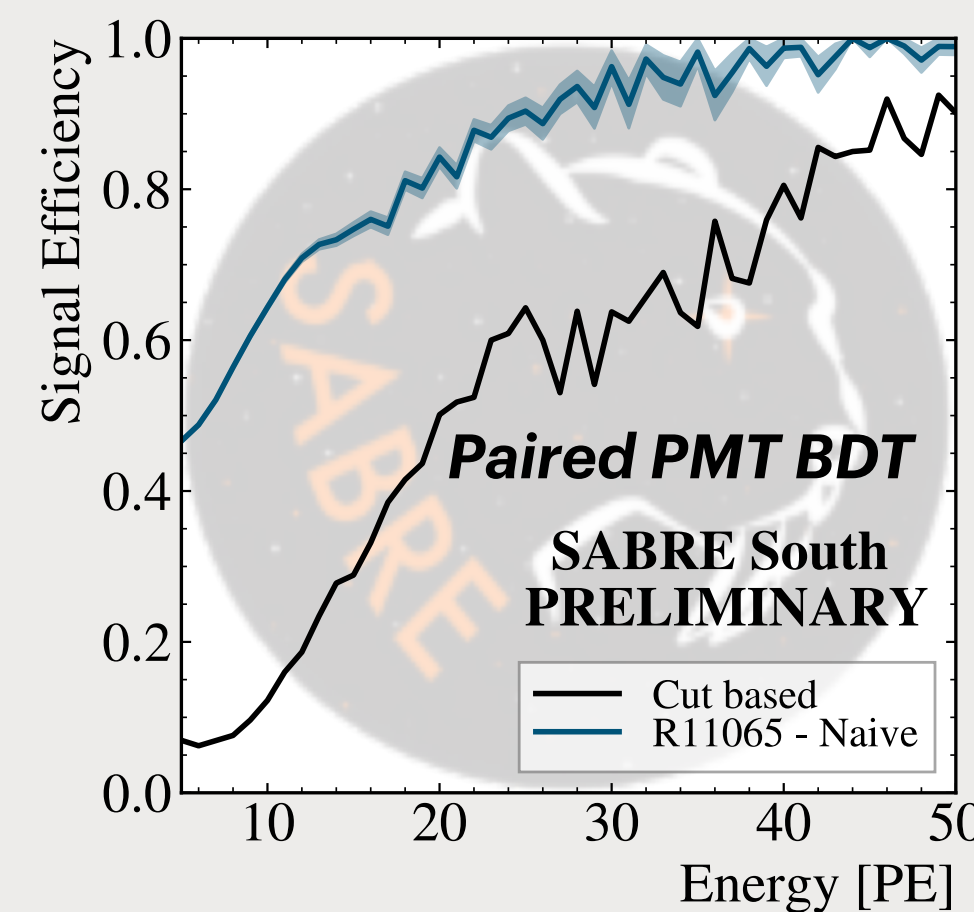
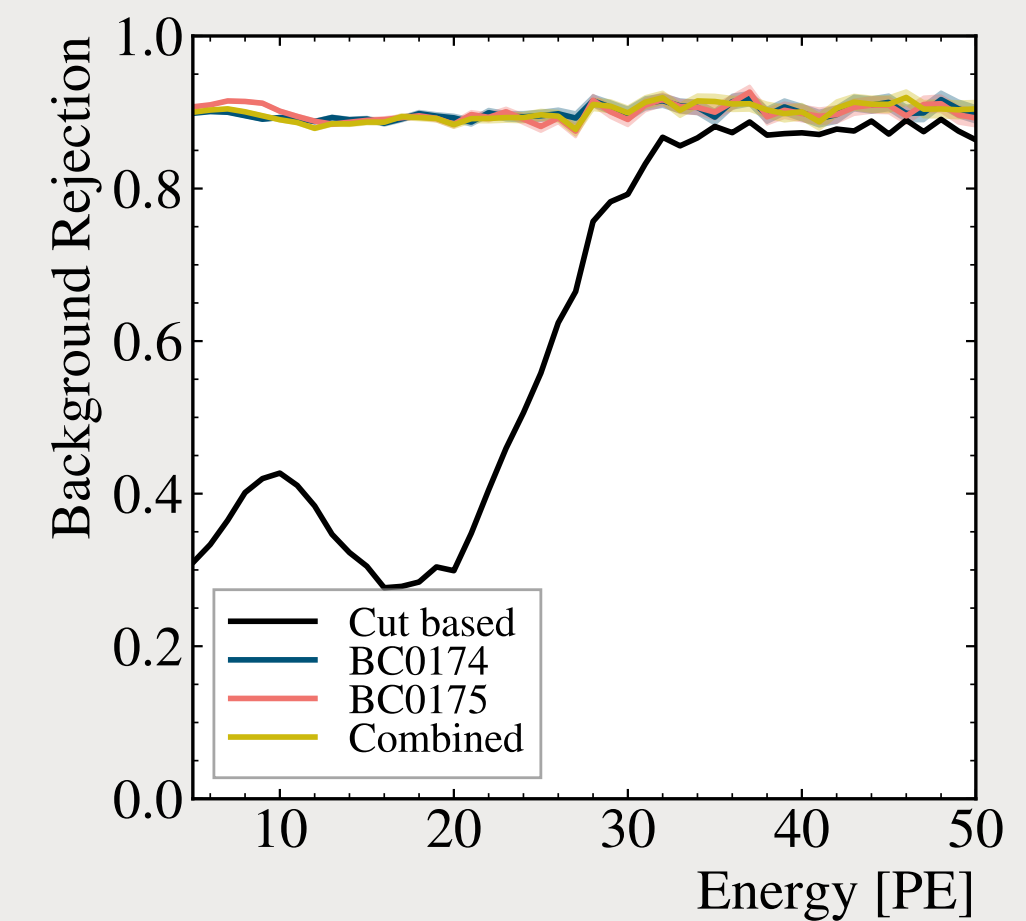
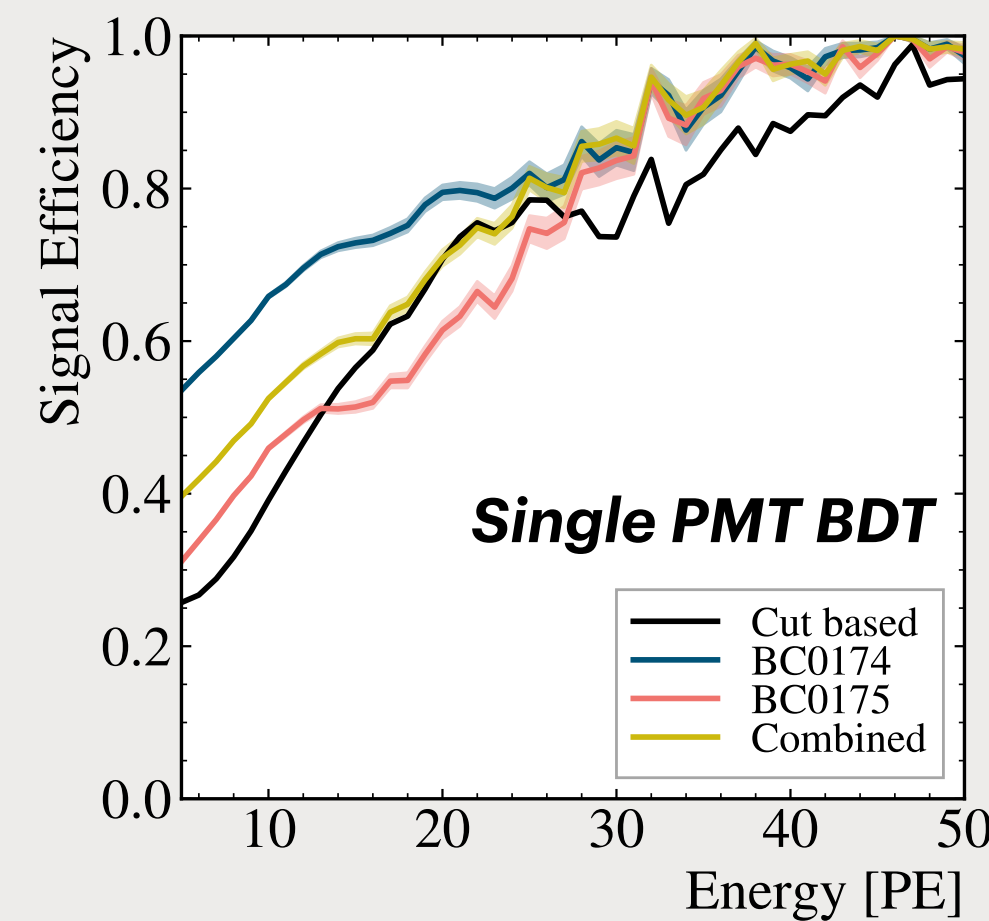
Available sources:

 $^{137}\text{Cs}, ^{207}\text{Bi}, ^{22}\text{Na}, ^{133}\text{Ba}, ^{241}\text{Am} \text{ and } ^{109}\text{Cd}$

PMT ANALYSIS WITH BDTs

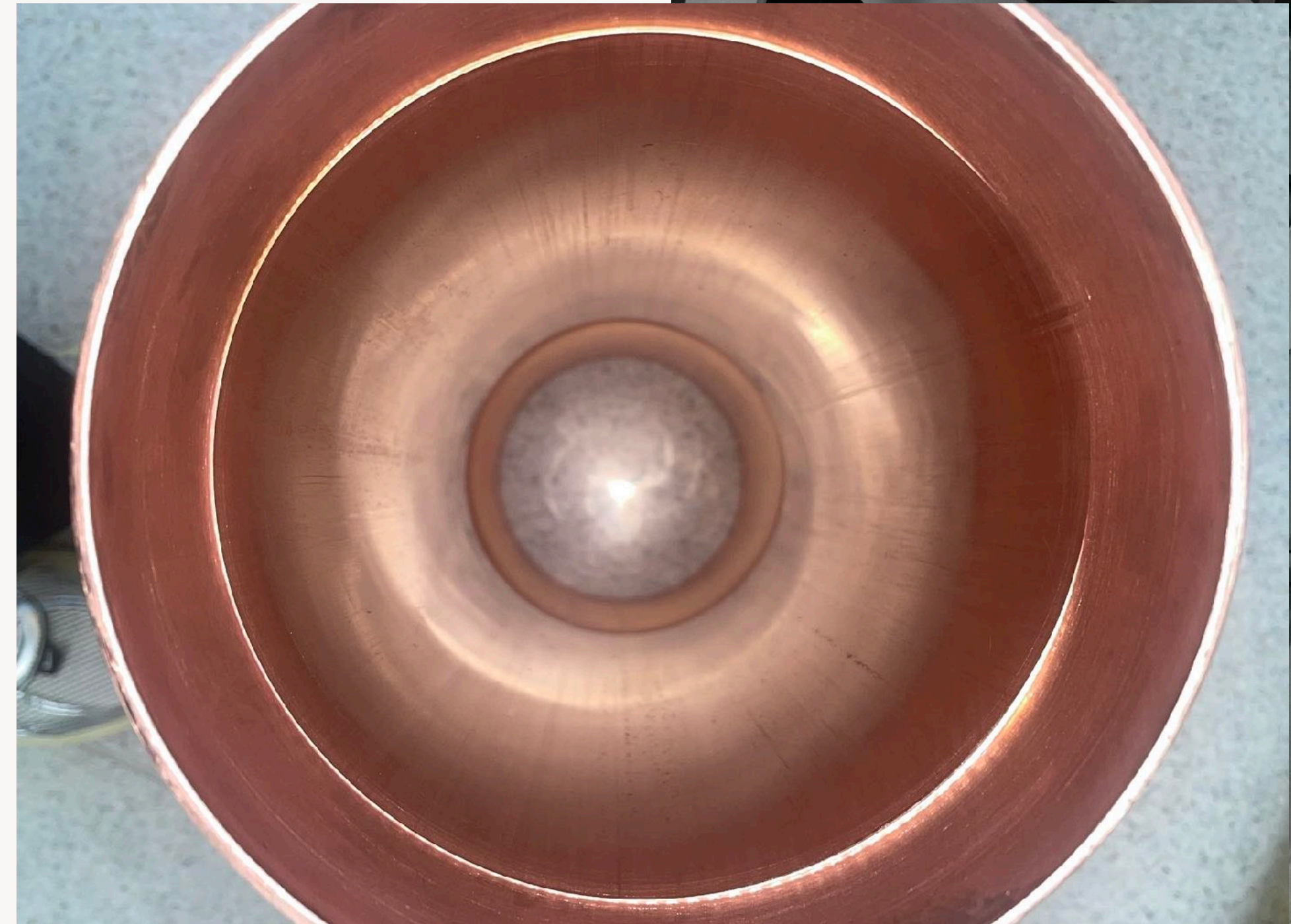
- Low energy region (1-3 keV) affected by PMT noise, which could be time dependent.
- Single PMT and paired PMT background rejection models with BDTs developed - inputs based on pulse shapes, charge asymmetries and timing.
- Reach ~ 1 keV equivalent in test setup (5-10 PE in test set up) in both models
- Suite of other performance and quality checks performed.

Backup
*JINST 20 P07052 (2025)



PRECISION CLEANING

- Precision-cleaning workflow developed for copper enclosures and PTFE components
- Cleaning of veto-PMT brackets ongoing & assessment of procedures for crystal-PMT and base cleaning
- Cleanliness verification programme established with witness plates, SEM scans, and dust-fallout studies
- Engaged with industry for vessel-cleaning options



MASS VS. BACKGROUND

Backup

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