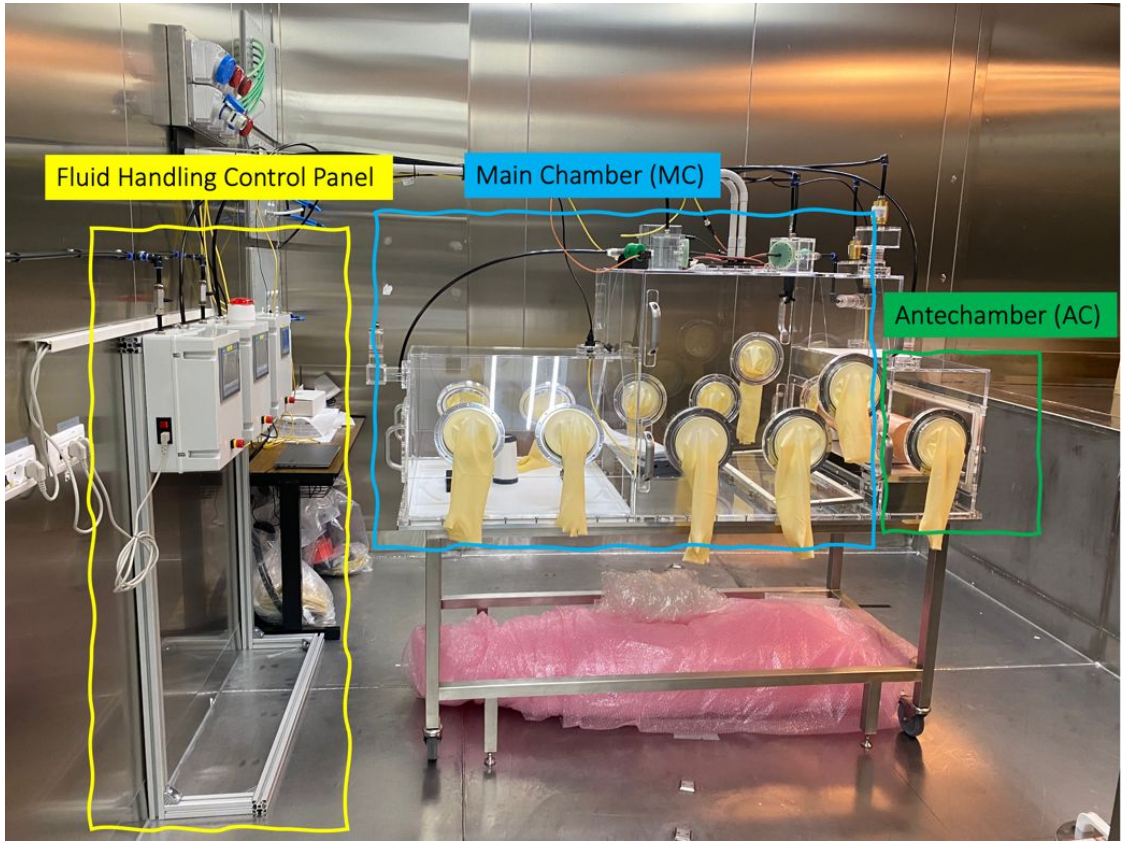
Istituto Nazionale di Fisica Nucleare

SABRE-North activities

Giulia D'Imperio on behalf of SABRE-North collaboration

08/02/2023

SABRE glovebox

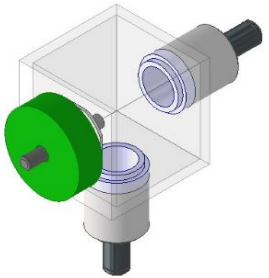


- Located in the Clean Room (CR1) in Hall C
- Two volumes
  - antechamber (AC)
  - main chamber (MC)
- Fluid handling control panel
- Internal tools for handling and shifting objects from one volume to the other

Sensors

The glovebox is equipped with the following sensors:

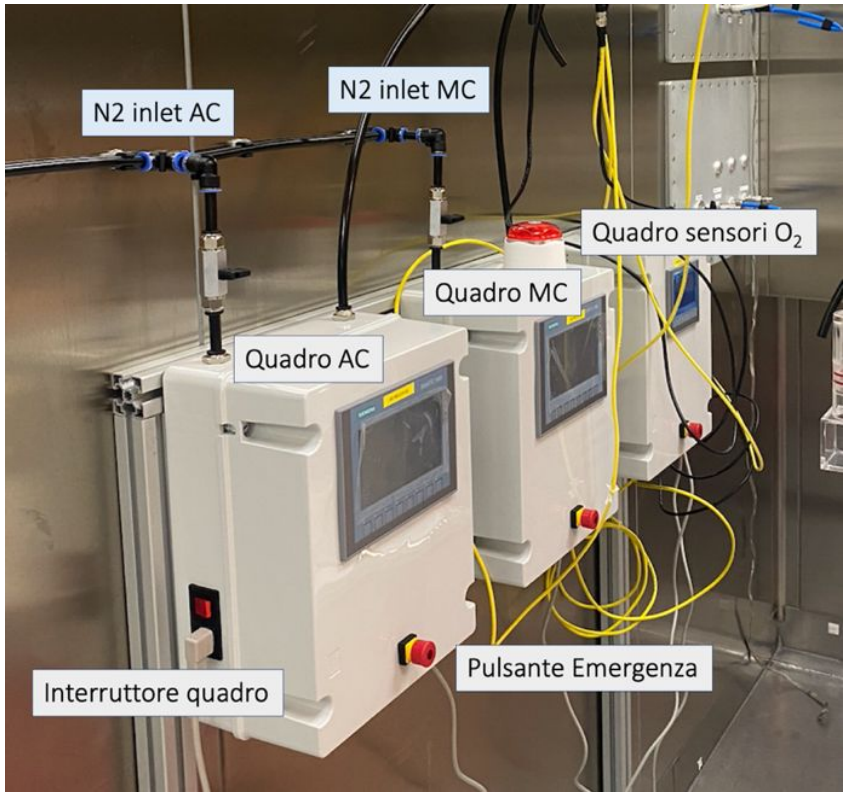
- AC, MC and room are equipped with identical sensors of:
  - Pressure
  - Temperature
  - Humidity (relative)



- Two O_2 sensors operative at high temperature (about 100°C), mounted on dedicated supports, one for AC and one for MC

- Humidity sensors:
  - portable thermo-hygrometer Hygropalm ➔ Dew point and relative humidity
  - Dewpoint Xentaur sensor (up to -100 C) ➔ Dew point, ppm (by volume) and g/m3

Fluid handling control system



- AC and MC panels:
  ➜ monitor pressure, temperature, relative humidity in AC, MC, room
  ➜ set PURGE or FLOW modes
  ➜ emergency buttons

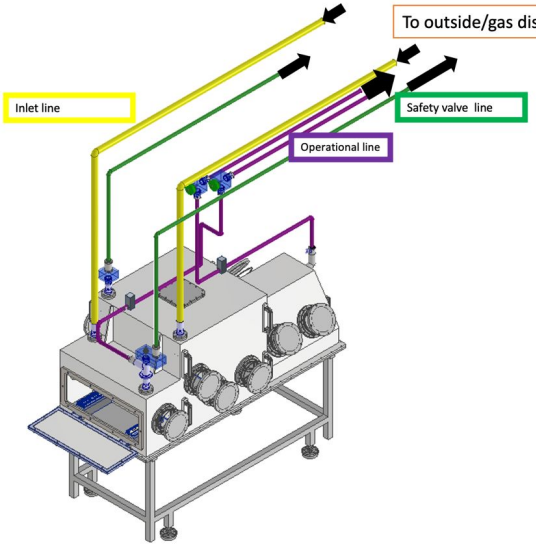
- O_2 panel:
  ➜ measure O_2 level in AC and MC
  ➜ calibrate O_2 sensors

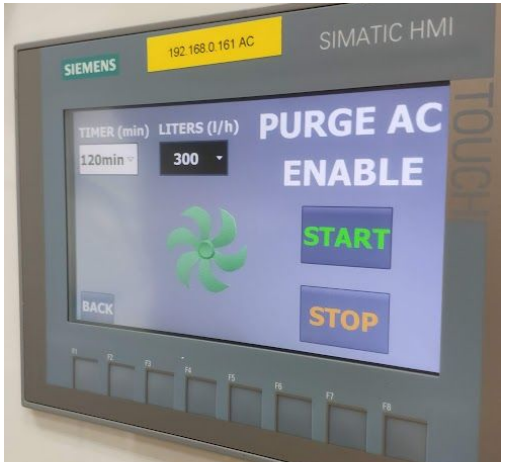
- Emergency button: isolate completely the system

Fluid handling

Two operational modes:

- **PURGE** → continuous flux of nitrogen
- **FLOW** → maintain slight overpressure wrt to room (0.4 mbar and 0.8 mbar in AC and MC), compensate for the insertion of hands, etc..





Commissioning operations

- Test the **FLOW mode** in AC and MC
  - check that the nominal **overpressure** is maintained
  - add/remove hands controlling that the system acts as expected, tune the parameters for opening/closing valves

- Test the **PURGE mode** in AC and MC
  - tune the N2 fluxes in AC and MC
  - check that **humidity** and **O2** level decreases during the flux
  - complete the purging in AC and MC reaching the nominal level of humidity

Requirements

Humidity reference level to operate safety NaI naked crystals:

- COSINE paper [Eur. Phys. J. C 80, 814 (2020)]: “humidity level was maintained to be less than a **few tens of ppmv** (H2O)”
- COSINUS glovebox: **5-20 ppmv**, **up to 85 ppmv**
- Dry room operating at RMD for cut/polish of crystals ➔ **<5% RH**

In our operations we reached **2.5% RH @17 °C** fluxing the MC with 600 lt/h for 72 h(*).
➔ corresponds to **~500 ppmv** and **-30°C dew point**

Humidity slowly rises during operations, but remains <5% RH in 5-6 h

*similar result was achieved after fluxing for 12 h with 600 lt/h.

Crystal operations in glovebox

- **27/09/2022** change of teflon reflector NaI-33
  ➔ removed original teflon from PU, new teflon from italian company

- **29/11/2022** change of teflon reflector NaI-33
  ➔ use new teflon from RMD

- **07/12/2022** first mounting of NaI-37 in the new enclosure

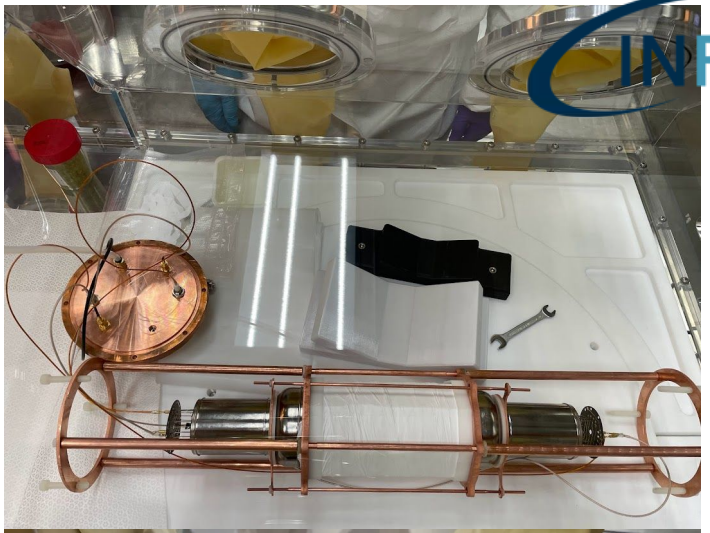
- **24/01/2023** dismount and remount NaI-37 with new delrin internal parts

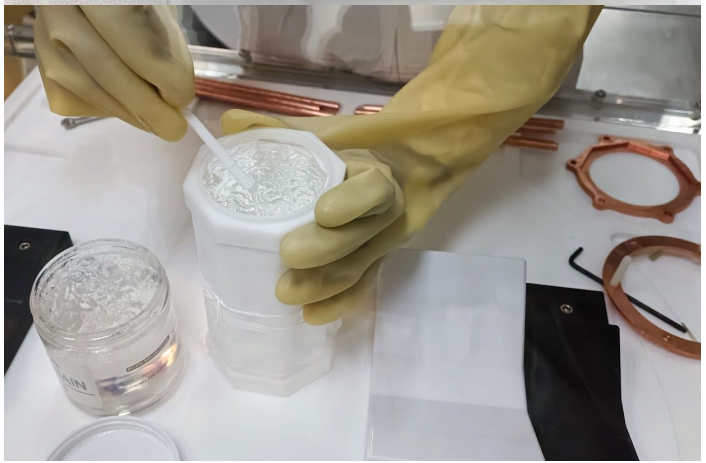
All operations were **successful**: no damage of the crystals, **humidity <5% RH** for the whole duration of the activity (5-6 h)

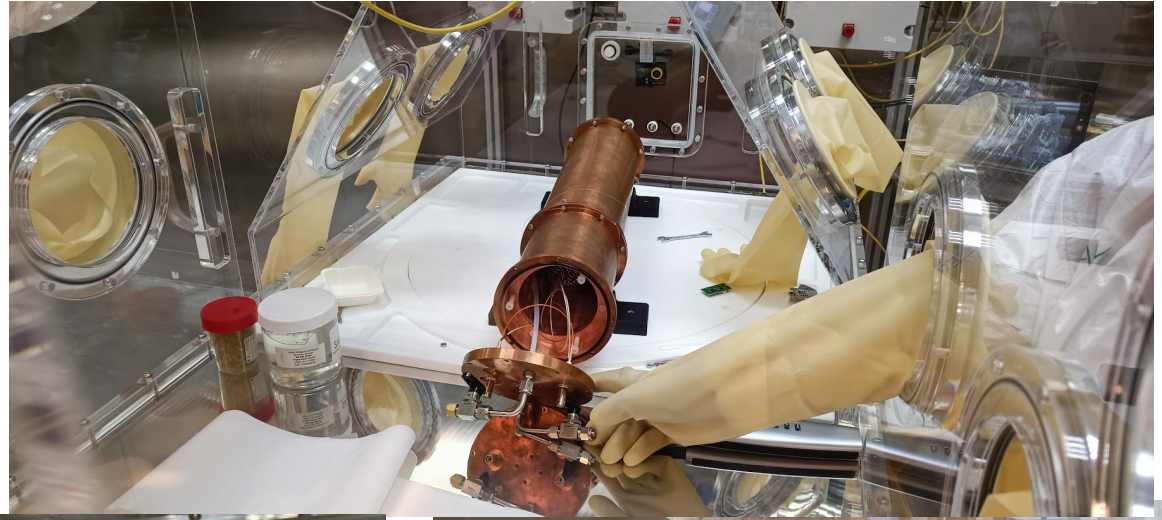
Change teflon reflector

Sequence of operations

1. Insert enclosure from AC & move to MC
2. Open enclosure in the MC & extract crystal+PMTs
3. Unmount crystal & remove reflector
4. Wrap crystal with new reflector
5. Mount again the module: crystal+PMTs
6. Insert module in the enclosure & close
7. Move enclosure from MC to AC
8. Extract enclosure from AC





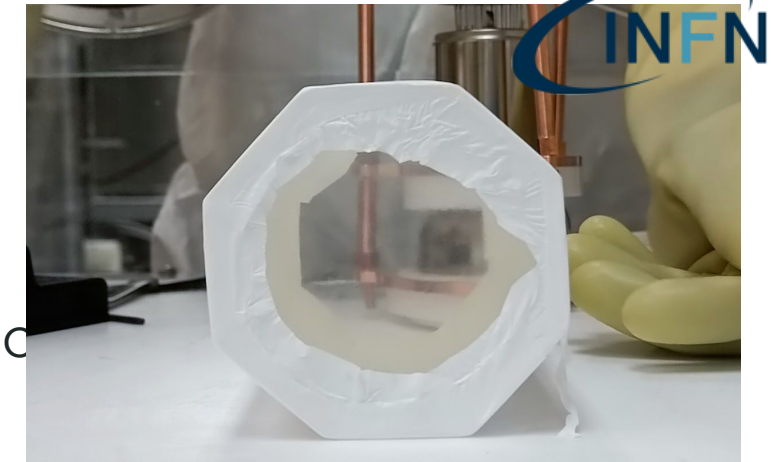


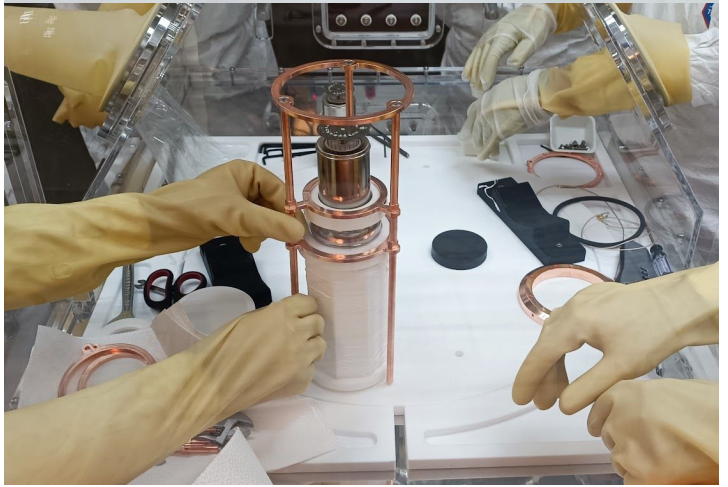
Mount crystal in the enclosure

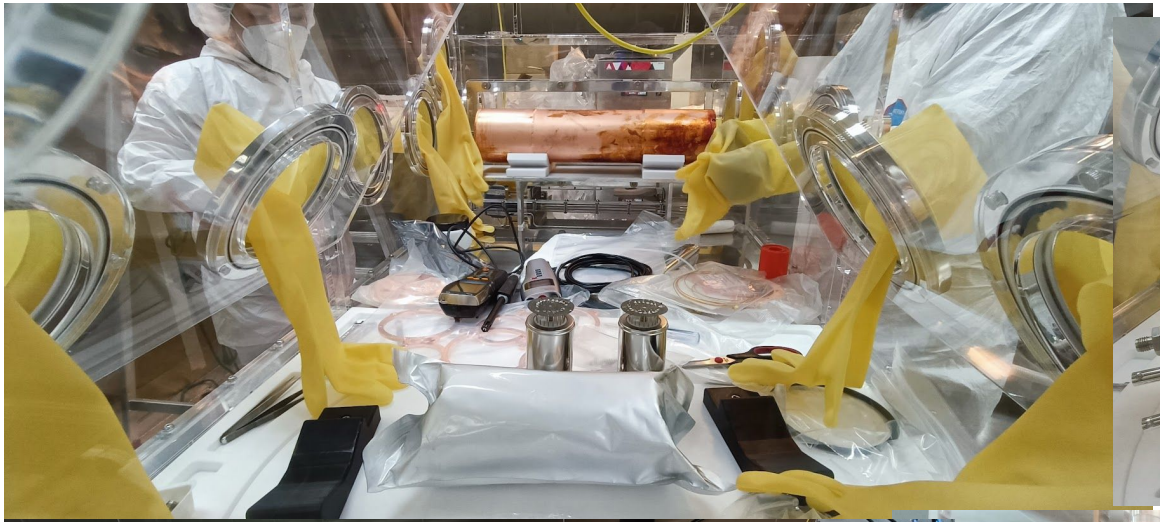
Sequence of operations

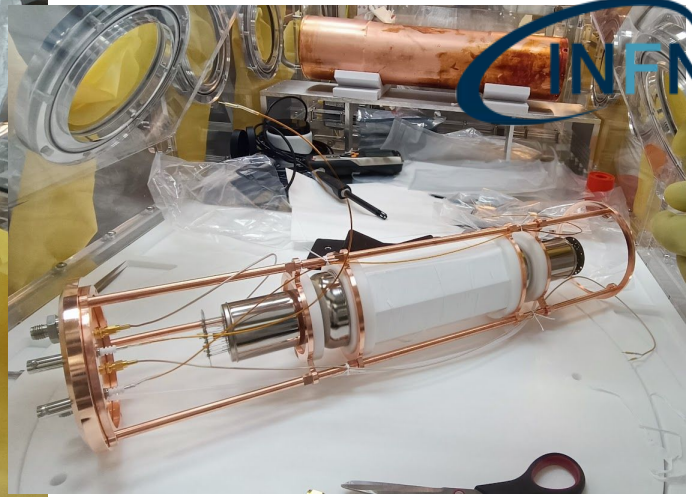
1. Insert enclosure from AC & move to MC
2. Insert crystal and PMTs from AC and move to MC
3. Remove crystal from protective bags
4. Wrap the crystal with reflector
5. Mount the module: crystal+PMTs+ holders
6. Insert module in the enclosure & close
7. Move enclosure from MC to AC
8. Extract enclosure from AC

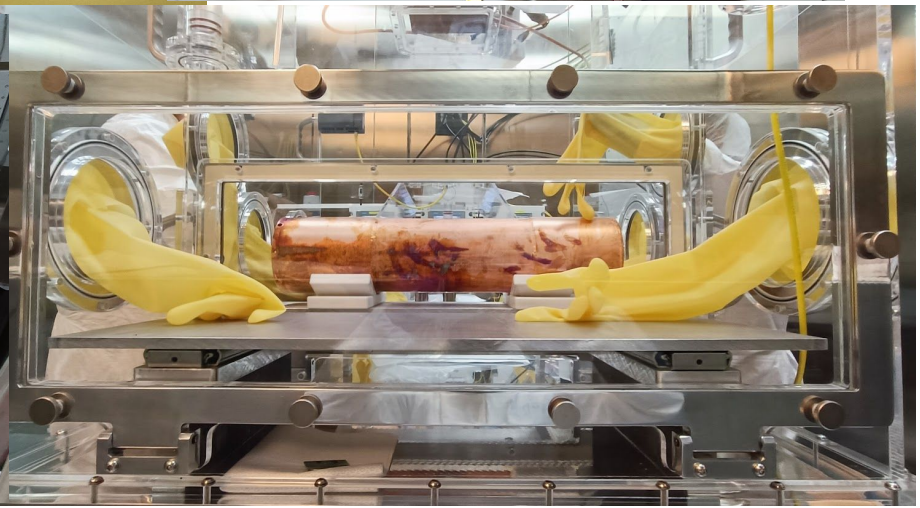
- Some operations in common with the sequence for changing reflector



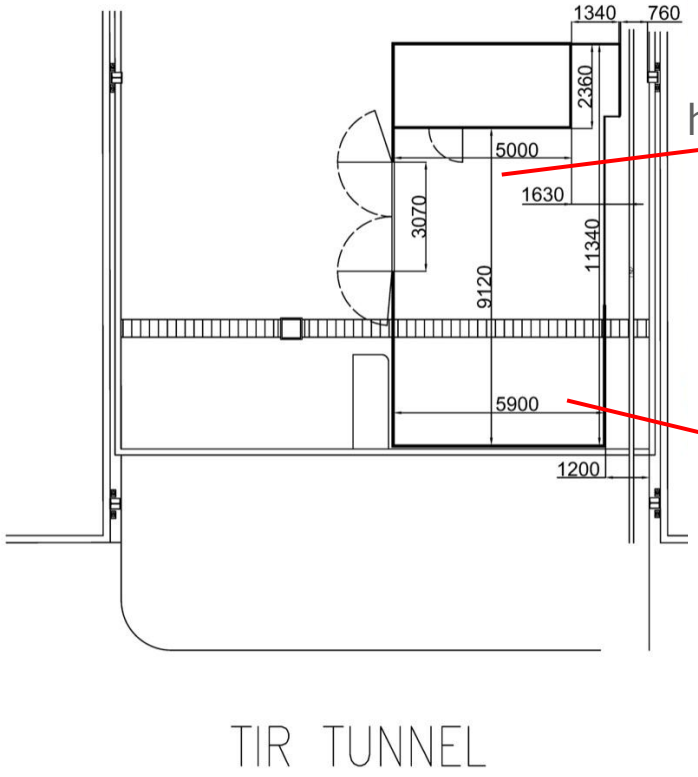








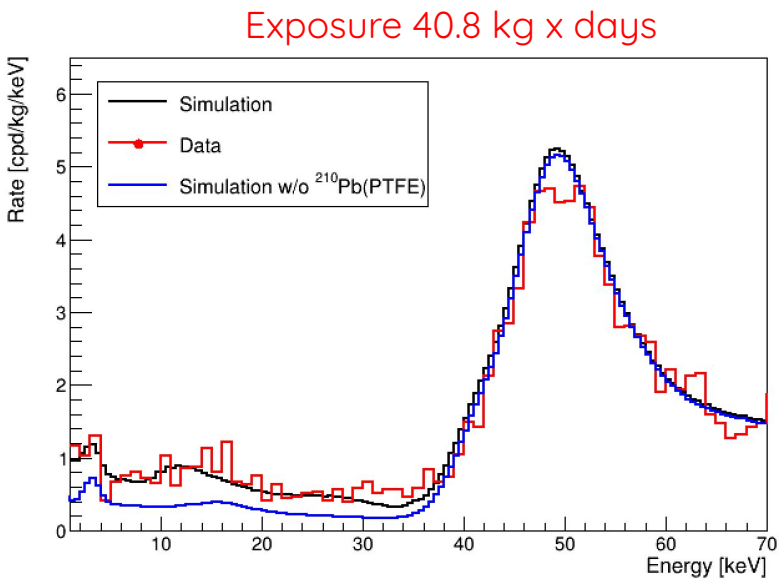
SABRE area in Hall B



New copper shielding

After decommissioning in Hall C (July 2022) we mounted an improved **passive shielding in Hall B**:

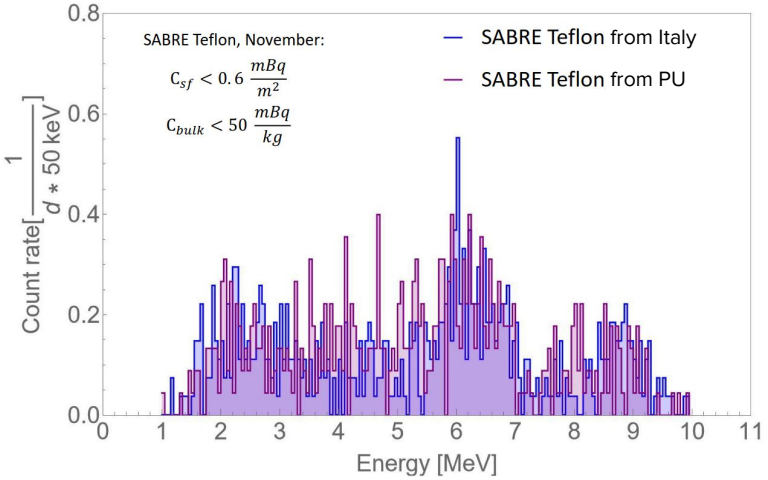
- ~30 cm copper on all sides + PE base
- new setup to test effect of teflon replacement



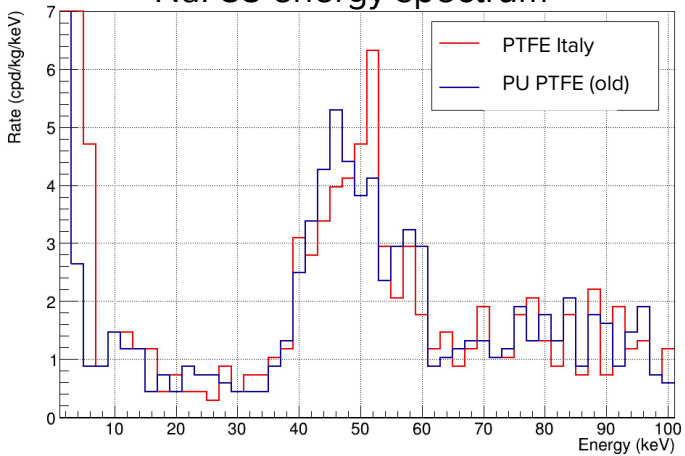
Results on NaI-33

- After 27/09/22 the light yield has dropped from 12 p.e./keV to 6.6 p.e./keV
- After 29/11/22 the light yield went to 7.2 p.e./keV
- Change of the teflon of NaI-33 does not change significantly the background rate in the region around 12 keV

Results from Alpha spectroscopy



NaI-33 energy spectrum

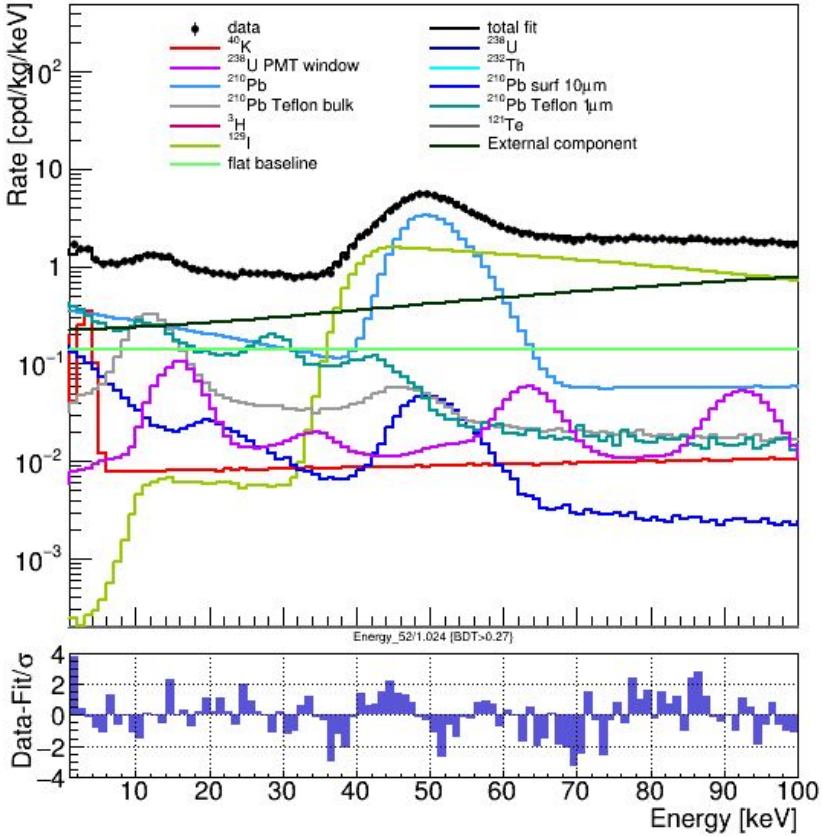


New background model of NaI-33 (preliminary)

Range: [2;100] keV

Parameter	Value	Sigma
Flat baseline	123.56 counts	30.33 counts
40K	0.161 mBq/kg	0.023 mBq/kg
238U	$4.1 \cdot 10^{-6}$ mBq/kg	0.005 mBq/kg
3H	$1.16 \cdot 10^{-8}$ mBq/kg	0.0009mBq/kg
232Th	$4.1 \cdot 10^{-7}$ mBq/kg	0.001 mBq/kg
129I	1.086 mBq/kg	0.017 mBq/kg
210Pb crystal surf 10μm	0.12 mBq	0.053 mBq
210Pb bulk	0.555 mBq/kg	0.007 mBq/kg
210Pb teflon surf 1μm	0.0118 mBq	0.0020 mBq
210Pb teflon bulk	10.43 mBq/kg_{PTFE}	1.10 mBq/kg_{PTFE}
238U PMT windows	0.022 mBq/kg	0.005 mBq/kg
External component	1.082	0.055

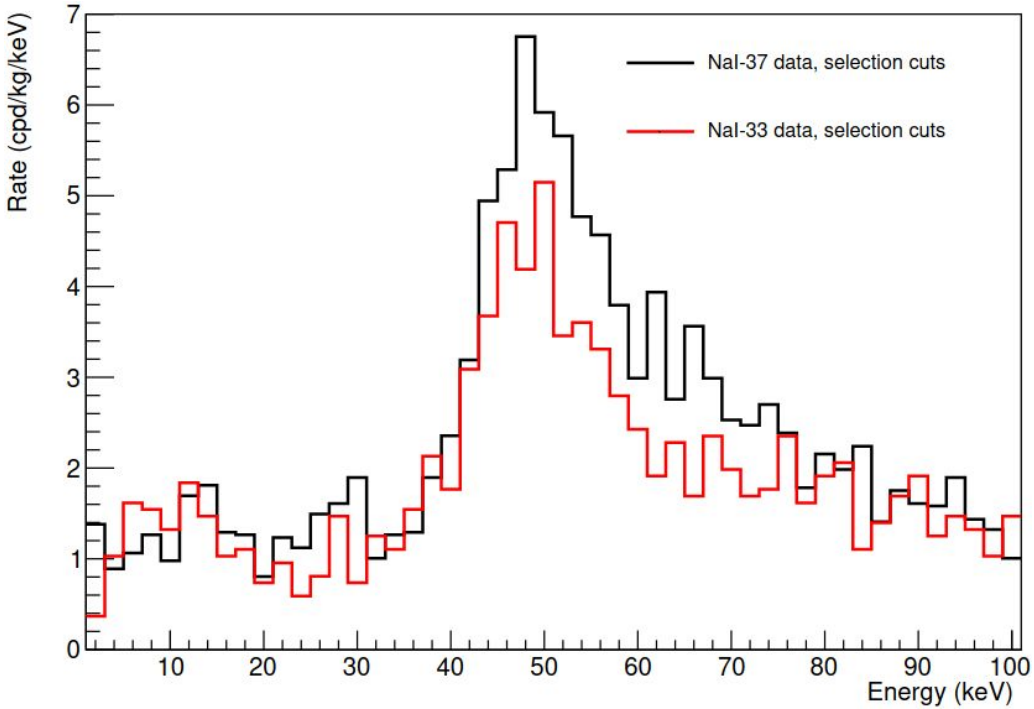
Reduced Chi2 = 1.74398



Preliminary results on NaI-37

- During the mounting of 07/12/2022 we found a problem in delrin holders design
  ➔ air gap of few mm between PMT window and crystal
- Light yield ~5 p.e./keV, very noisy runs
- After 24/01/23 with new holders and better optical contact (with optical grease Saint Gobain 630)
  ➔ light yield improved to **8 p.e./keV**
- Alpha rate **0.76+/-0.02 mBq/kg**
- From ICP-MS NaI-37 has 7.8 ppb of potassium, NaI powder batch different from both NaI-33 and NaI-35

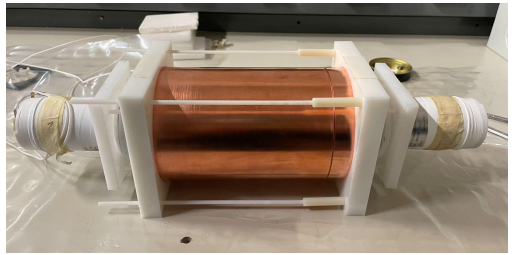
Preliminary results on NaI-37



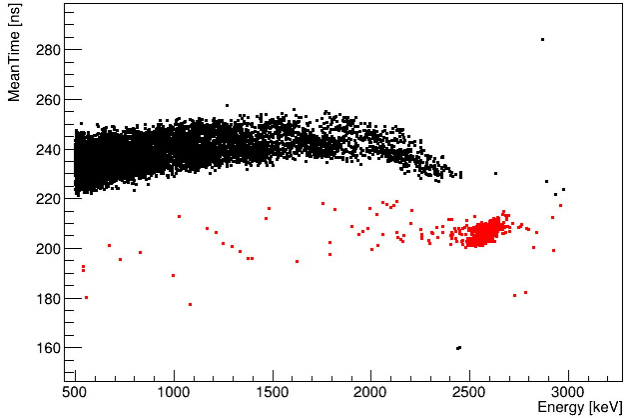
- caveat: no acceptance correction, few days of data taking
- higher ^{210}Pb content of NaI-37 is visible in the 50 keV region
- residual cosmogenics in NaI-37 in the regions around 30 keV and 70 keV

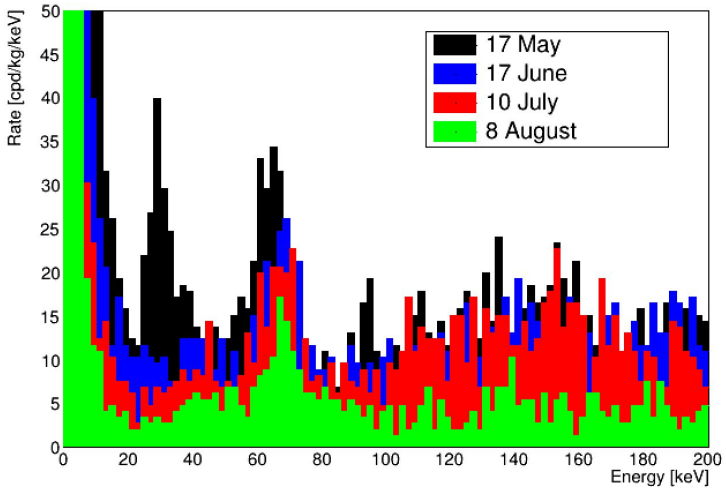
NaI-35 crystal

- **α rate: 0.48 mBq/kg**
  → compatible with NaI-33
- working to put again NaI-35 in measurement with 4 inch PMTs



Data taking in Hall B from Aug 2022
Exposure: 279 kg x days





NaI-35 crystal runs for pyrate development

Pyrate dataset:
`/nfs/sabre2/data/AustralianDAQ_NaI-33/ProcessedFiles/CrystalProcessed_16-21Sept2022.root`

- **Chimera dataset:**
`/nfs/sabre2/data/SABRENorth/flat_output/Flat_HallB_new_6days.root`

- **Raw files for pyrate** (from 16 to 21 September):
`/nfs/sabre2/data/AustralianDAQ_NaI-33`
- **Raw files for Chimera** (from run 30 to 35)**:**
`/nfs/sabre2/data/SABRENorth/HallB_new/NaI-033/daq`

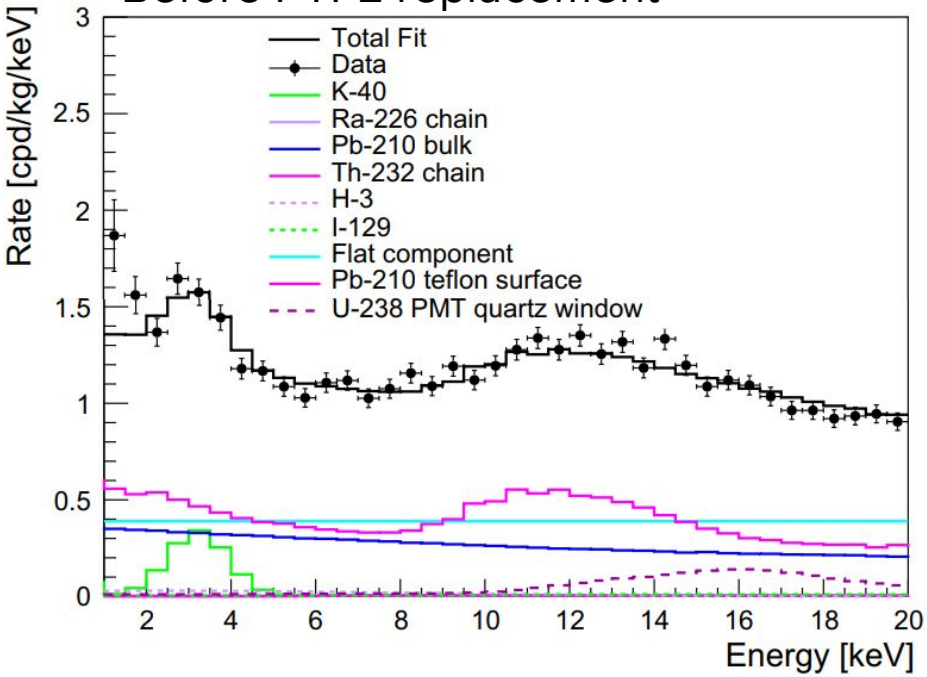
Summary

- The SABRE glovebox allows to operate naked crystals in safe conditions
  ➡ relative humidity down to 2.5%
- PTFE wrapping replacement in NaI-33 didn't have the expected effect
  ➡ different PTFE reflector give similar background
  ➡ new background model including PTFE bulk contamination of ^{210}Pb gives a good fit result
- NaI-37 preliminary analysis show a higher ^{210}Pb content in the crystal bulk with respect to NaI-33 and NaI-35
- Next activities: low energy spectrum and background model of both NaI-35 and NaI-37, pyrate development

Extra slides

Background model of NaI-33 (published)

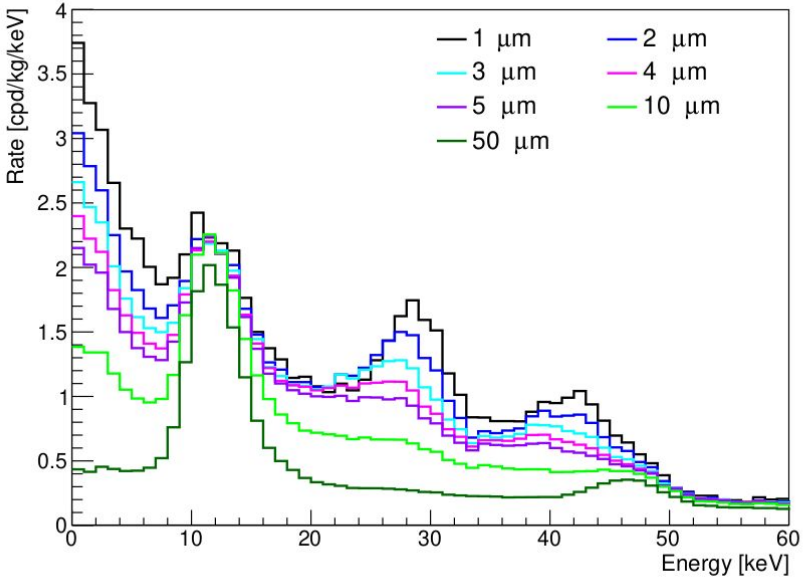
Before PTFE replacement



Source	Activity in NaI-33 [mBq/kg]	Rate in ROI in NaI-33 [cpd/kg/keV]
^{40}K	0.15 ± 0.02	0.12 ± 0.02
^{210}Pb (bulk)	0.461 ± 0.005	0.325 ± 0.004
^{226}Ra	0.0059 ± 0.0006	0.0049 ± 0.0005
^{232}Th	0.0016 ± 0.0003	
^{3}H	≤0.005	≤ 0.05
^{129}I	1.29 ± 0.02	
^{210}Pb (PTFE)	0.83 ± 0.06 mBq	0.46 ± 0.03
^{238}U (PMTs quartz window)	0.31 ± 0.05 mBq	0.011 ± 0.002
Other (flat)		0.39 ± 0.02
Total		1.36 ± 0.04

Eur. Phys. J. C (2022) 82:1158

^{210}Pb teflon spectra



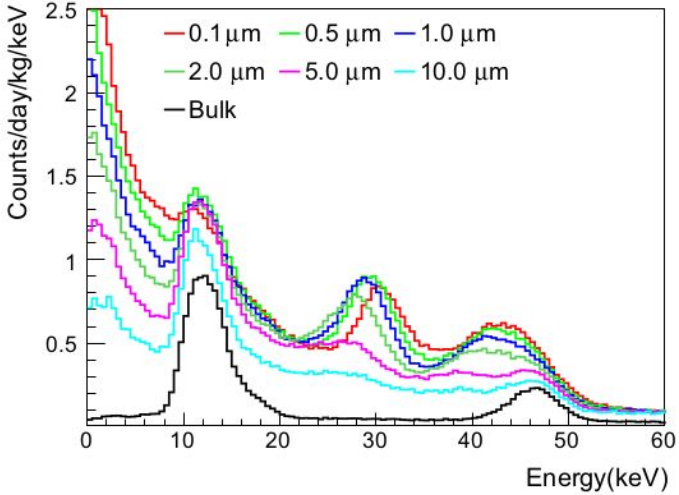


Fig. 5 Comparison of background spectra of ^{210}Pb simulated for various surface thicknesses of PTFE reflector. The activity of 1 mBq/kg is used to normalize the simulation results

https://link.springer.com/content/pdf/10.1140/epjc/s10052-018-5970-2.pdf

ICP-MS measurement of ^{39}K in NaI-37

	Seastar	LNGS
tip 1	6	
tip 2	7	10
tail	14	19

accuracy 20%