# Update on SABRE simulation activity

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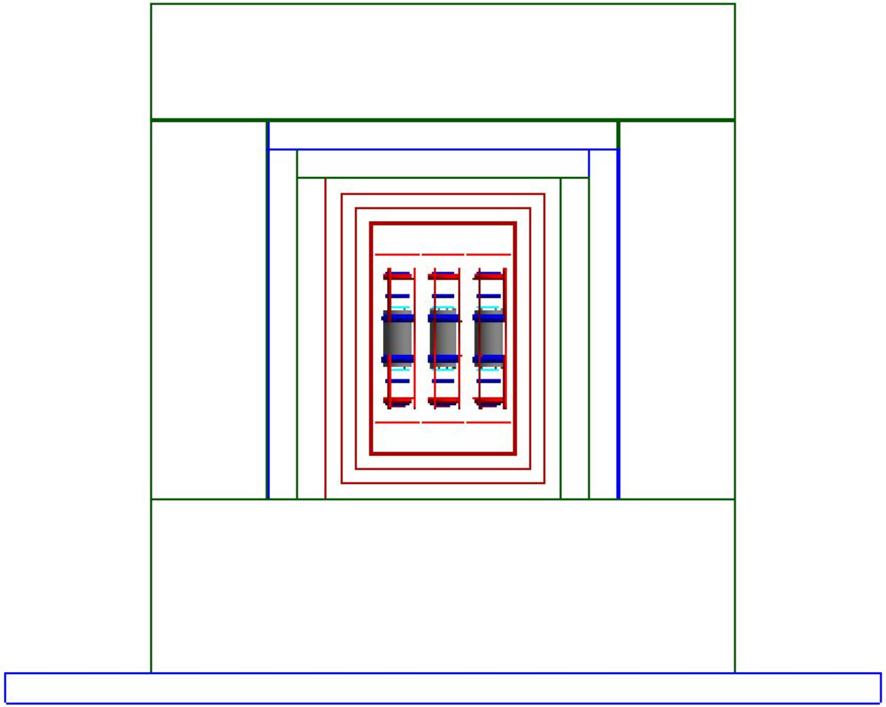
# Simulation repository and access

- Gitlab repository SABRE-MC: https://gitlab.com/SABRE-EXPERIMENT/SABREMC/-/tree/SABRE-North-TDR?ref_type=heads
  - need account on gitlab.com (free)
  - send your username to Giulia D'Imperio or Claudia Tomei for permissions
- Most recent geometry implemented in the branch SABRE-North-TDR
- Setup script on linux.lngs.infn.it: https://gitlab.com/SABRE-EXPERIMENT/SABREMC/-/blob/SABRE-North-TDR/scripts/setup_sabremc.sh?ref_type=heads

# Current SABRE North geometry

The simulation geometry was updated to reflect the design of the SABRE North detector that was described in the TDR.

We did not have time to re-run al of the background simulations, so we just did the ones related to the parts of the geometry that were modified wrt to the PoP and the CDR.



# Internal bkgs: NaI(Tl) crystals, PMTs and PTFE reflector

**Background contributions:**

- $^{40}$K: 1 ppb natK → 0.031 mBq/kg $^{40}$K. We assume an almost complete removal of $^{40}$K content due to ZR purification
- U/Th: we assume a residual contamination at the level of crystal NaI-33.
- $^{3}$H: 4 μBq/kg (ACTIVIA). We assume that the growth process resets the cosmogenic activation of the powder (assumption justified by NaI-33 data) + 1 month exposure at sea level (prepare the crystal for shipment plus travel time from RMD to LNGS).
- $^{210}$Pb: 0.5 mBq/kg. We assume the contamination level of NaI-33.
- $^{210}$Pb in teflon reflector: we assume the contamination from the BM of crystal NaI-33.

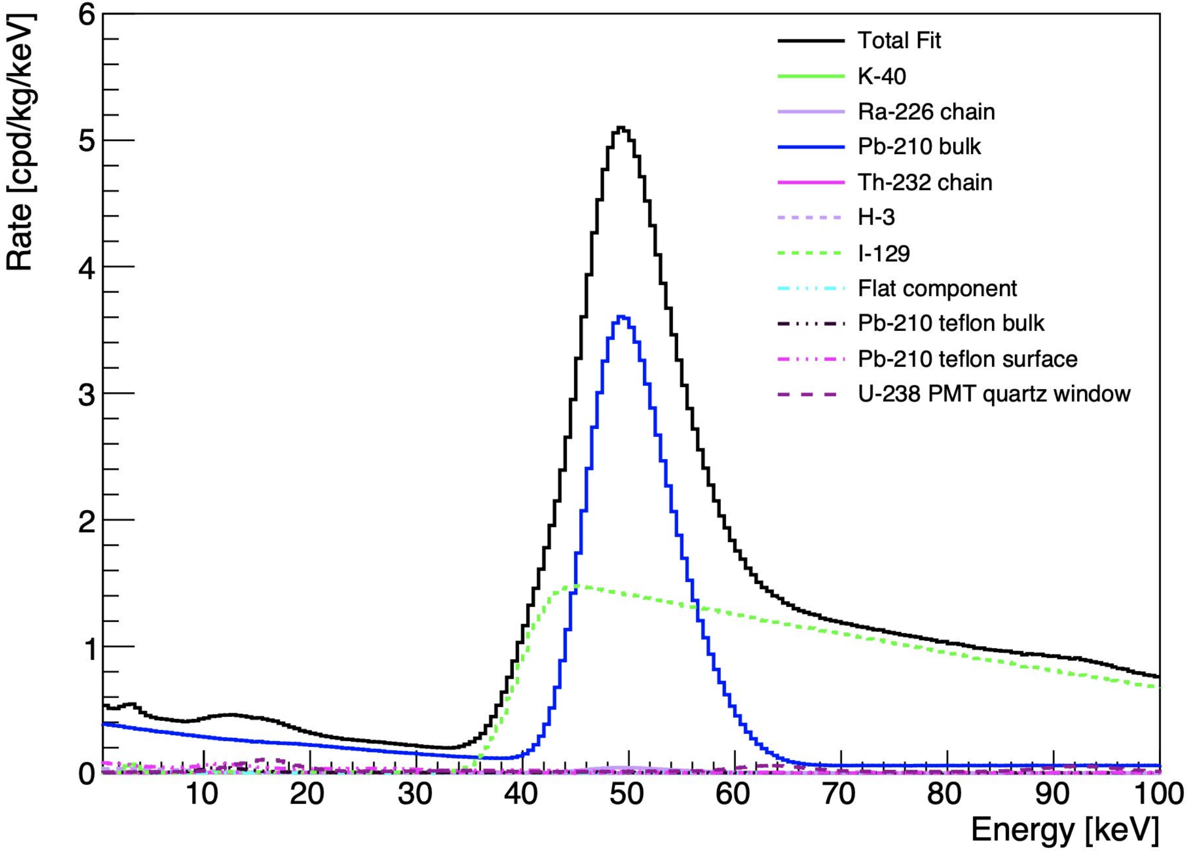
# Internal bkgs

**Background contributions:**

- PMT: we assume the contamination from the BM of crystal NaI-33. $^{238}U$ in the PMT quartz window is the dominant contribution.
- $^{129}I$: we assume the contamination from the BM of crystal NaI-33.
- short-lived cosmogenic isotopes: we assume that short-lived cosmogenic isotopes have decayed out.
- flat component: we conservatively assume a flat background of 10-2 cpd/kg/keV.

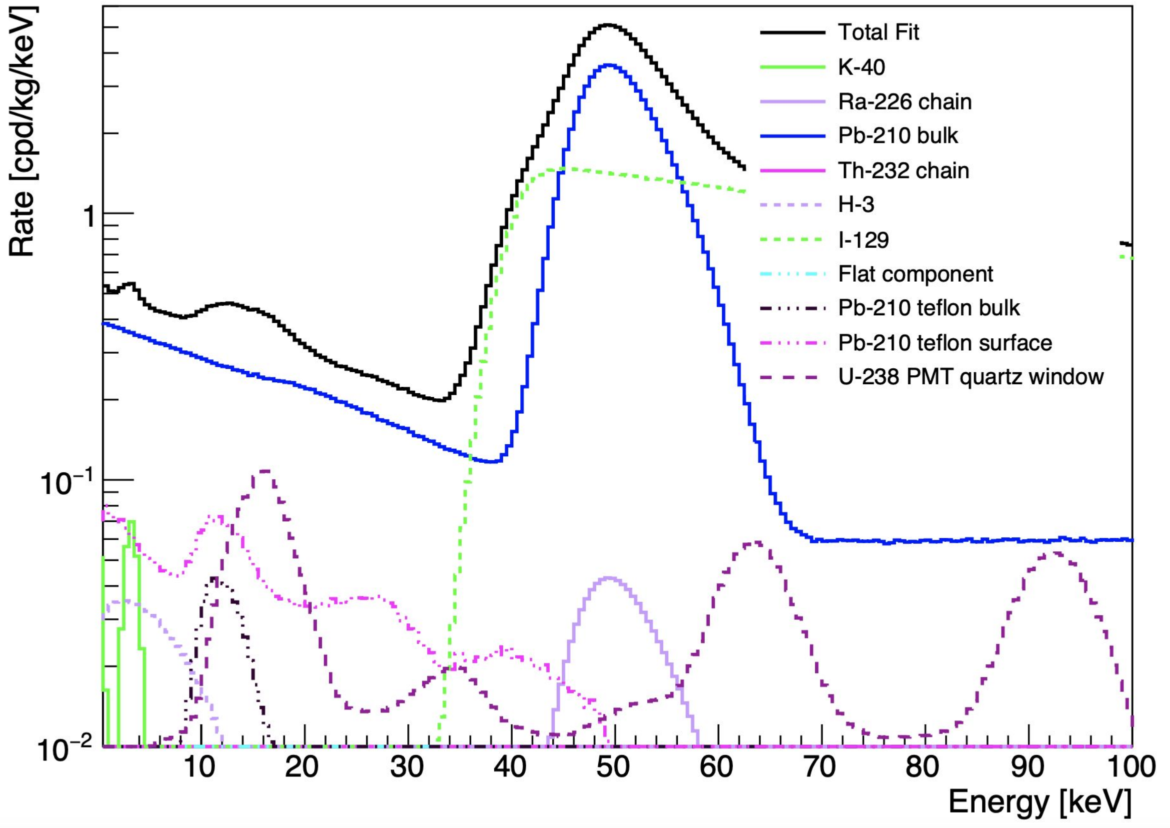
| **Source** | **Rate in ROI [1,6] keV [cpd/kg/keV]** |
|---|---|
| $^{40}K$ | 0.025 |
| $^{210}Pb$ bulk | 0.353 |
| $^{210}Pb$ reflector bulk | 0.005 |
| $^{210}Pb$ reflector surface | 0.060 |
| $^{3}H$ | 0.033 |
| $^{129}I$ | 0.003 |
| $^{238}U$ | 0.005 |
| $^{232}Th$ | 0.0004 |
| PMT | 0.009 |
| Other backgrounds | 0.01 |
| **TOTAL** | **0.50** |

# ROI 0-100 keV



Rate [cpd/kg/keV]
0
1
2
3
4
5
6
10
20
30
40
50
60
70
80
90
100
Energy [keV]
Total Fit
K-40
Ra-226 chain
Pb-210 bulk
Th-232 chain
H-3
I-129
Flat component
Pb-210 teflon bulk
Pb-210 teflon surface
U-238 PMT quartz window

# ROI 0-100 keV



Rate [cpd/kg/keV]
1
$10^{-1}$
$10^{-2}$
10
20
30
40
50
60
70
80
90
100
Energy [keV]
Total Fit
K-40
Ra-226 chain
Pb-210 bulk
Th-232 chain
H-3
I-129
Flat component
Pb-210 teflon bulk
Pb-210 teflon surface
U-238 PMT quartz window

# Crystal enclosures (copper and Delrin parts)

For the PoP setup, the background from the enclosure was estimated at the level of $1 \cdot 10^{-2}$ cpd/kg/keV (rate in [2-6] keV ROI with veto off and cosmogenic backgrounds computed after 180 days underground).

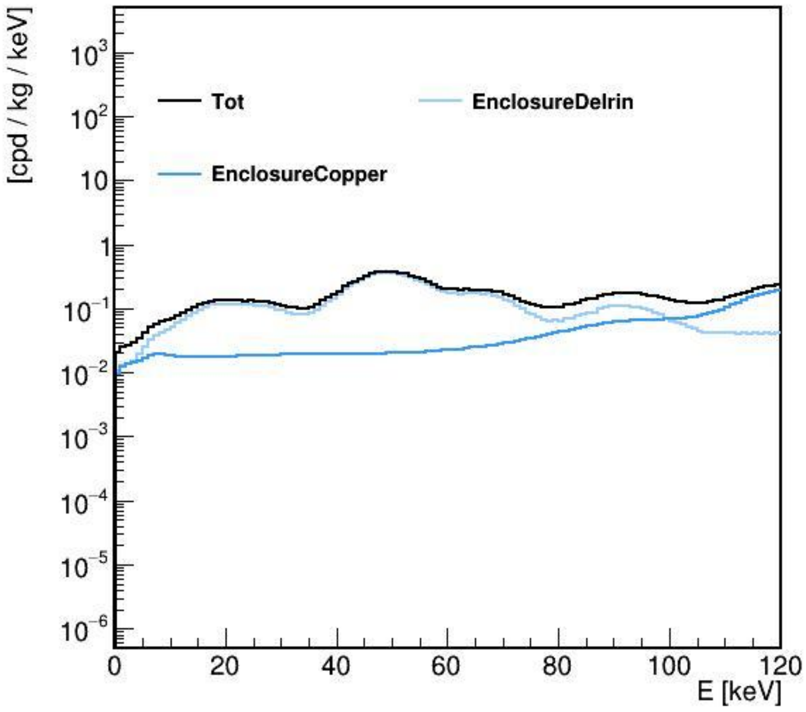
TDR simulations:

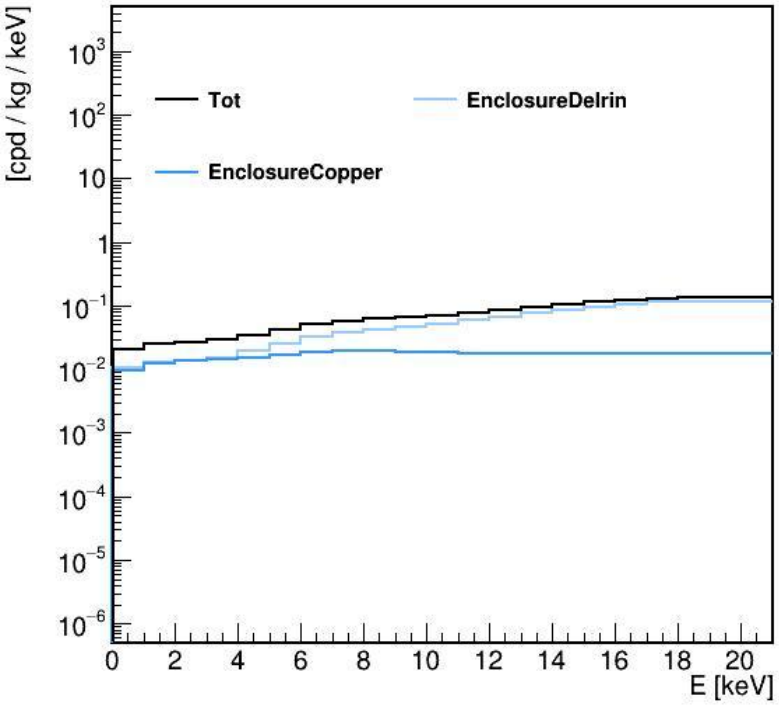
- small changes in the dimensions of the enclosure parts
- Delrin parts

The radioactive contamination levels of copper and Delrin are taken from the TDR.

The total rate in [1-6] keV is $3.2 \cdot 10^{-2}$ cpd/kg/keV. This value does not assume the anticoincidence between the 9 crystals of the array.

# Crystal enclosures (copper and Delrin parts)



# Passive shielding

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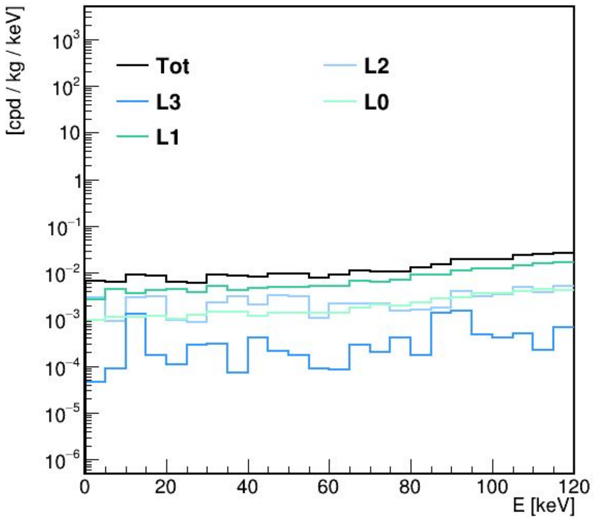
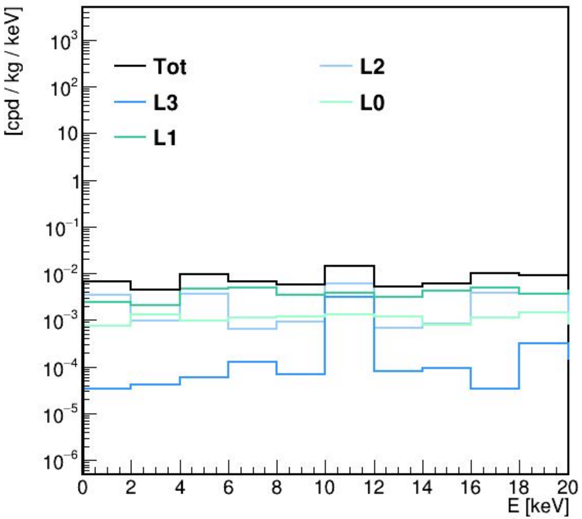
We ran new simulations to evaluate the background contribution from the 15 cm copper shielding taking into account its new design (three 5 cm copper layers with increasing radiopurity towards the detector array) and the radiopurity of each layer (from the TDR).

Each copper is identified with a number from 0 (highest purity, used for the 5 mm copper box containing the detector array) to 4 (lowest purity).

# Passive shielding

The total contribution from the 15 cm copper is $6.3 \cdot 10^{-3}$ cpd/kg/keV, mainly due to the copper box containing the crystal array (L0) and the first two layers (L1 and L2). The contribution from L3 is about 1 order of magnitude lower, even considering the lower radiopurity of this copper.



# Passive shielding

We did not simulate the contribution from the L4 copper layer (downward facing U-shaped, 10 cm thick). Given its positioning, the self shielding and the shielding provided by the inner 15 cm layer and 10 cm PE layer, the resulting background would have been negligible even with a significant computational effort.

The same applies to the PE shielding: a downward facing U-shaped layer, 10 cm thick, between L3 and L4 and an outer layer 40 cm thick on top and on all the sides and 60 cm thick on the bottom. Given the result obtained in the CDR from an 80 cm PE layer, we can safely neglect the PE contribution to the shielding background.

Total (conservative) contribution from passive shielding: $1.0 \cdot 10^{-2}$ cpd/kg/keV in the [1-6] keV ROI. This value does not assume the anticoincidence between the 9 crystals of the array.

# Environmental sources - Gammas

In the SABRE North CDR:

- background contribution in the crystals from external environmental sources such as gammas and neutrons

In the TDR we had no time to redo the simulations so we tried to draw conclusions from the CDR results and the new shielding design:

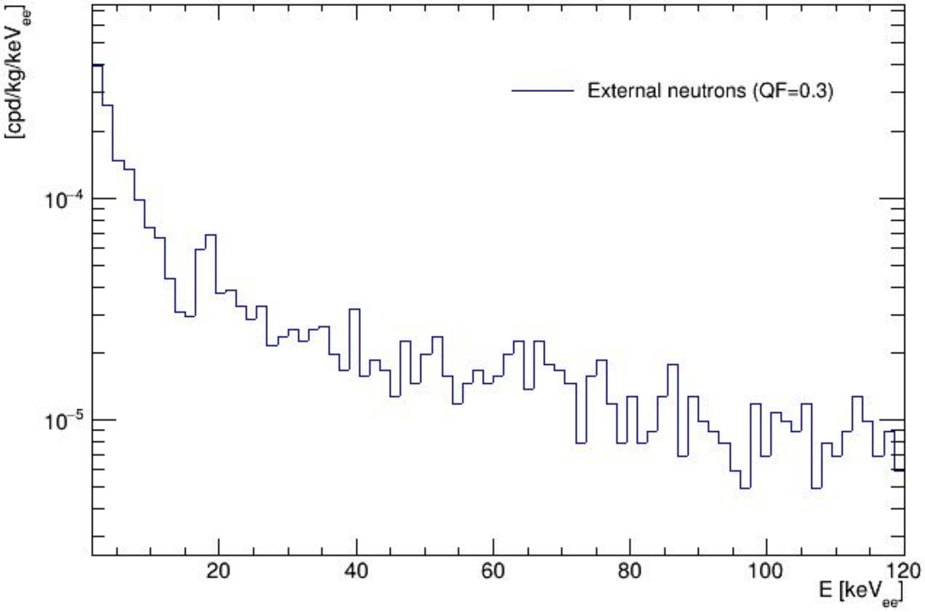
- Concerning gammas, the increase by 10 cm of the copper thickness compensates for the reduction in PE shielding. In the simulation, the input value for the gamma flux is set to 1 gamma/cm2/s, which is a very conservative estimate, when considering several measurements we performed in underground halls at LNGS and published papers
- Under these assumptions, the environmental gamma contribution in the crystal array is below $1.0 \cdot 10^{-3}$ cpd/kg/keV in the [1-6] keV ROI.

# Environmental sources - Neutrons

In the CDR we simulated neutrons at LNGS using measured and simulated fluxes from various authors. The integrated neutron flux corresponds to $2.7 \cdot 10^{-6}$ n/cm²/s.

In the TDR:

- we expect an increased background contribution since the moderator thickness is reduced from 80 cm to 50 cm on top and on all the sides and 60 cm on the bottom.
- However, given that the contribution from neutrons that was simulated for the CDR is at the level of $1.8 \cdot 10^{-4}$ cpd/kg/keV in the [1-6] keV ROI, it is safe to assume that this contribution will remain negligible even with the reduced PE shielding.



# Background budget SABRE North

| Source | **Contribution in the ROI [1,6] keV units dru** |
|---|---|
| Internal: NaI + PMTs + PTFE | 0.5 |
| Enclosure: Copper + Delrin parts | 0.032 |
| Shielding: Inner copper + Outer copper (negligible) + PE (negligible) | 0.01 |
| External gammas + neutrons (negligible) | 0.001 |

# Future activities