Summary of the SABRE-PoP results and preliminary data analysis with the new PoP-dry setup

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SABRE-PoP

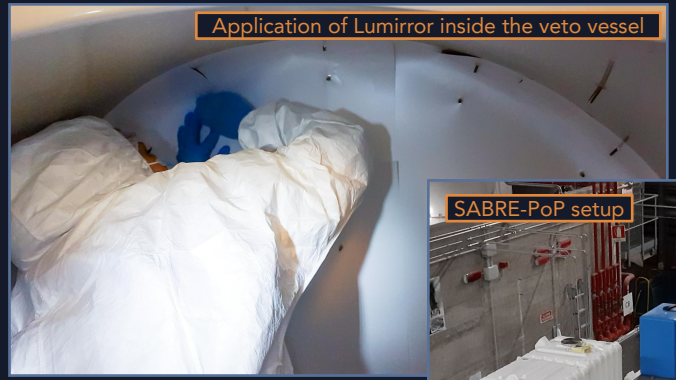
The SABRE Proof-of-Principle (PoP)

Goal: assess the radiopurity of SABRE crystals and test the active veto performance

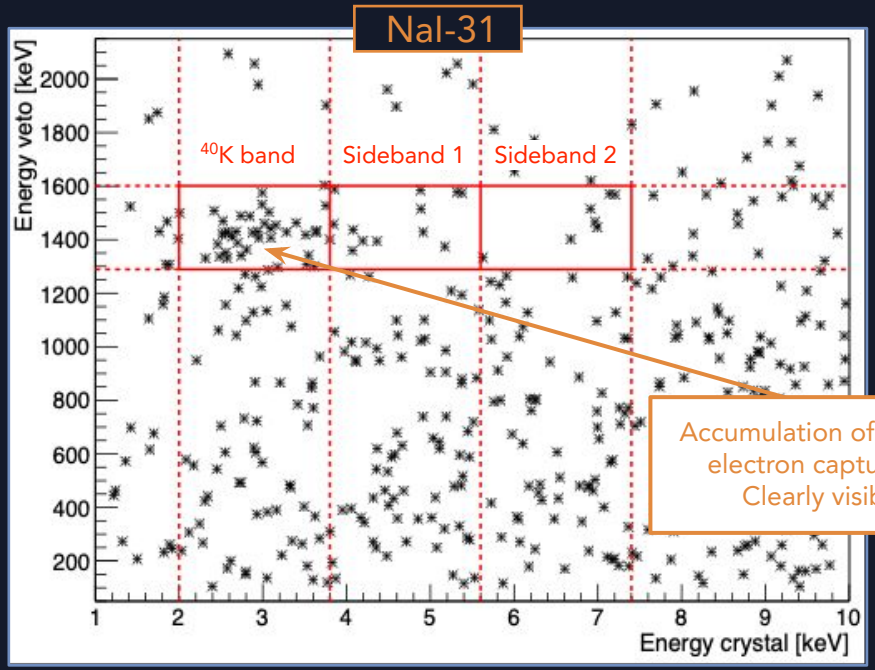
Measurements

- Potassium direct counting;
- Low energy analysis of NaI-33 data;
- Background model of NaI-33.

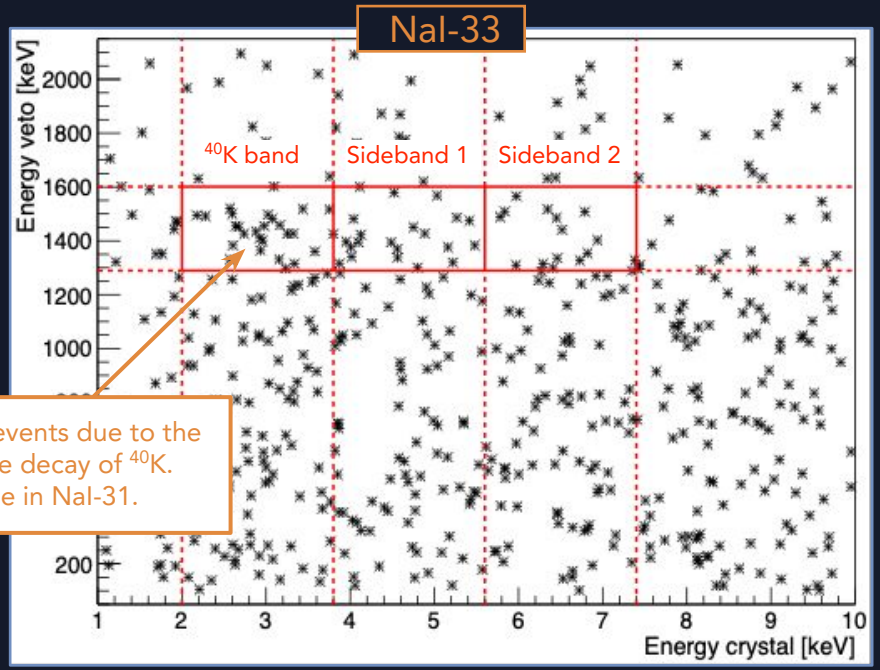
Results submitted for publication to Physical Review Letters



^{40}K analysis - energy crystal vs. energy veto

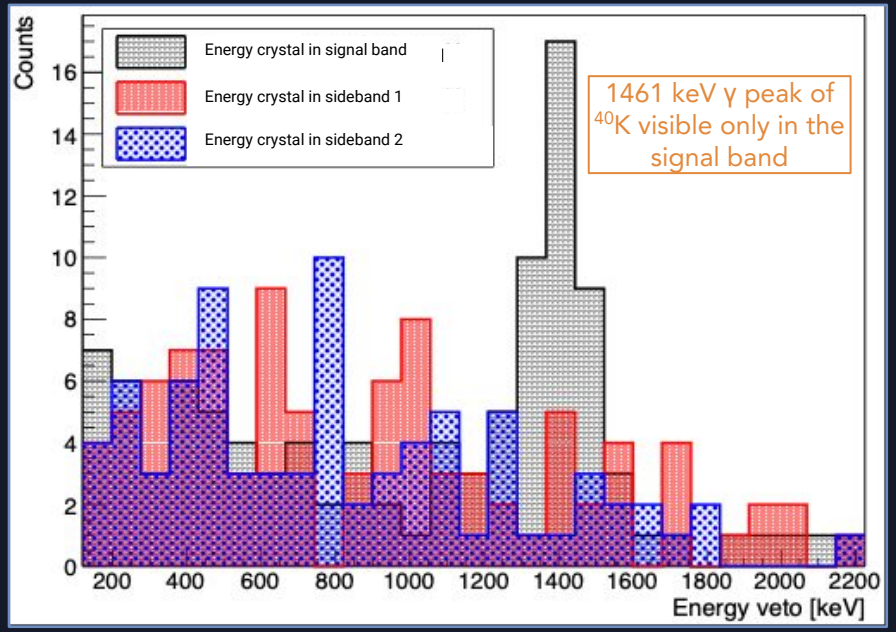


Exposure: ~60 kg · days

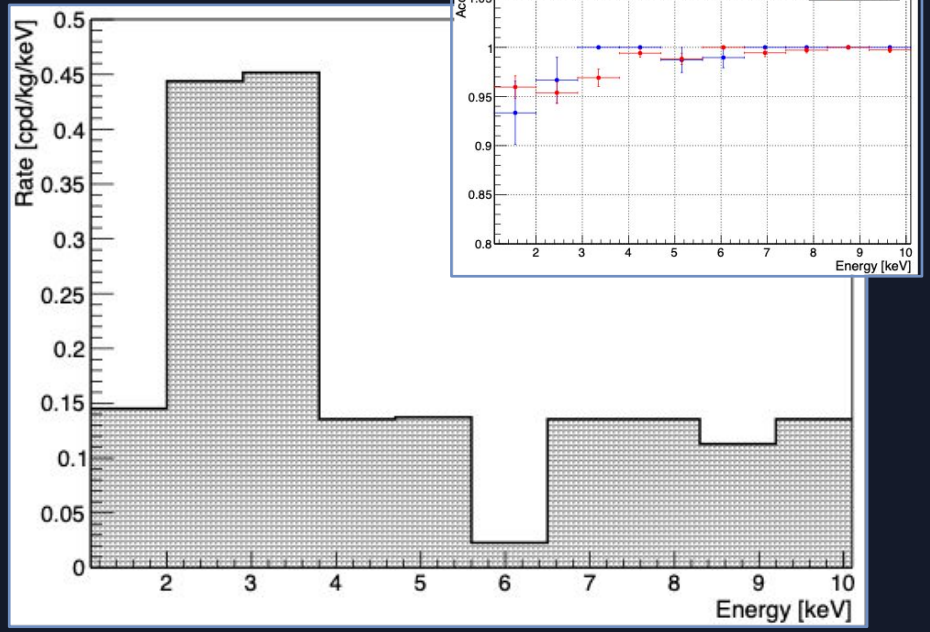


Exposure: ~90 kg · days

^{40}K analysis NaI-31

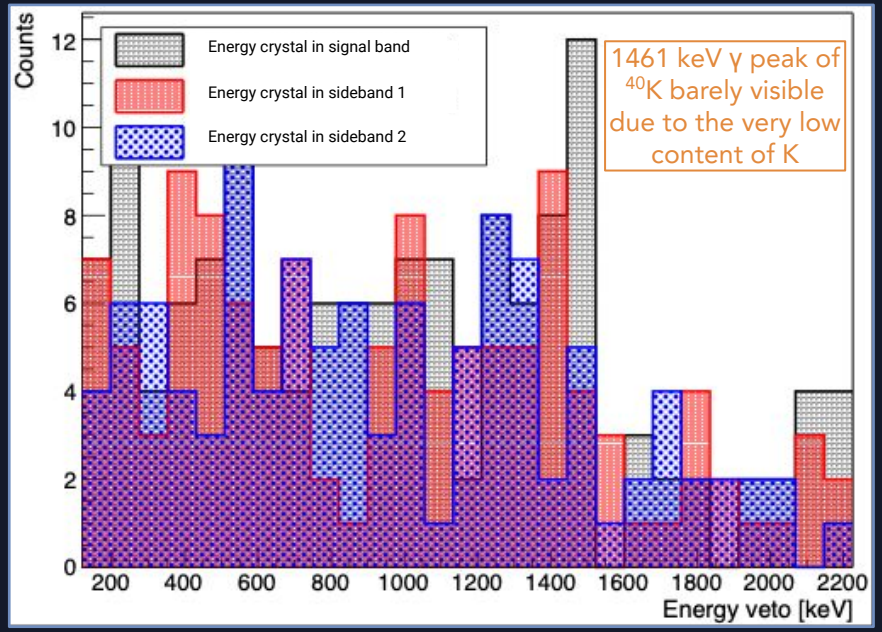


Veto energy spectra

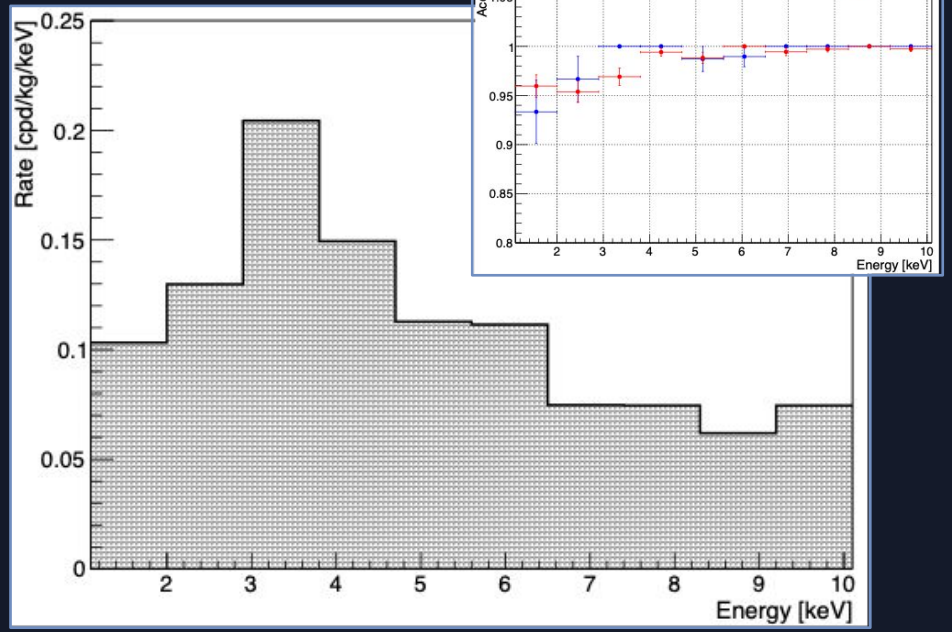


Crystal energy spectrum (efficiency-corrected)

^{40}K analysis NaI-33



Veto energy spectra



Crystal energy spectrum (efficiency-corrected)

^{40}K analysis results

	NaI-31	NaI-33
N_{S+B}	48 ± 7	27 ± 5
N_{B1}	15 ± 4	21 ± 5
N_{B2}	9 ± 3	15 ± 4
N_{40K}	37 ± 7	9 ± 6
^{40}K activity [mBq/kg]	0.49 ± 0.10	0.07 ± 0.05
^{nat}K contamination [ppb]	15.7 ± 3.2	2.2 ± 1.5
^{nat}K contamination by ICP-MS [ppb]	17.7 ± 1.1	4.6 ± 0.2

- N_{S+B}: number of events in signal band;
- N_{B1} (N_{B2}): number of events in sideband 1 (sideband 2);
- $\sigma_{Ni} = \sqrt{N_i}$, with i = S+B, B_1, B_2.

Upper limits for NaI-33 (90% C.L.):

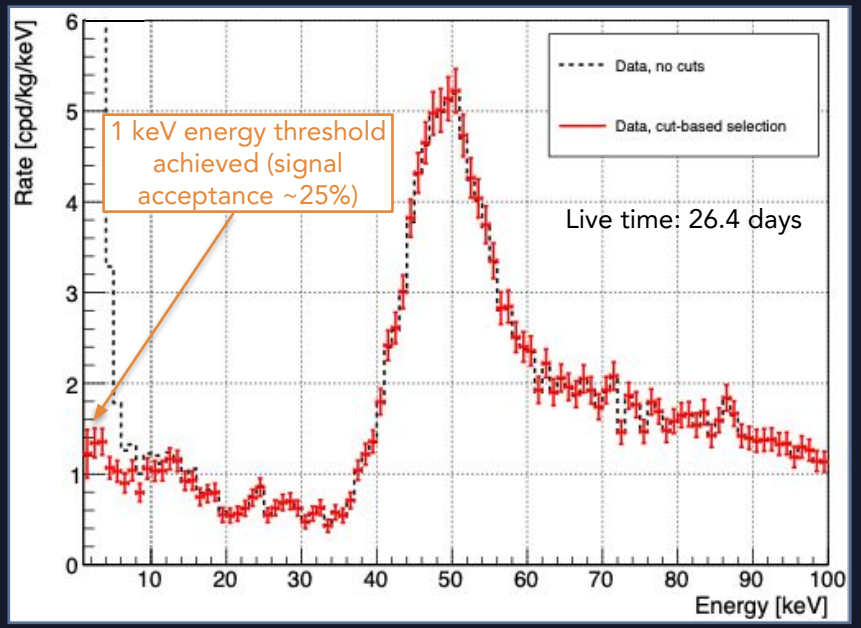
- ^{40}K activity: < 0.15 mBq/kg;
- ^{nat}K contamination: < 4.7 ppb.

PoP setup sensitive to a ppb-level ^{nat}K contamination in the crystal and results from direct counting in agreement with ICP-MS measurements

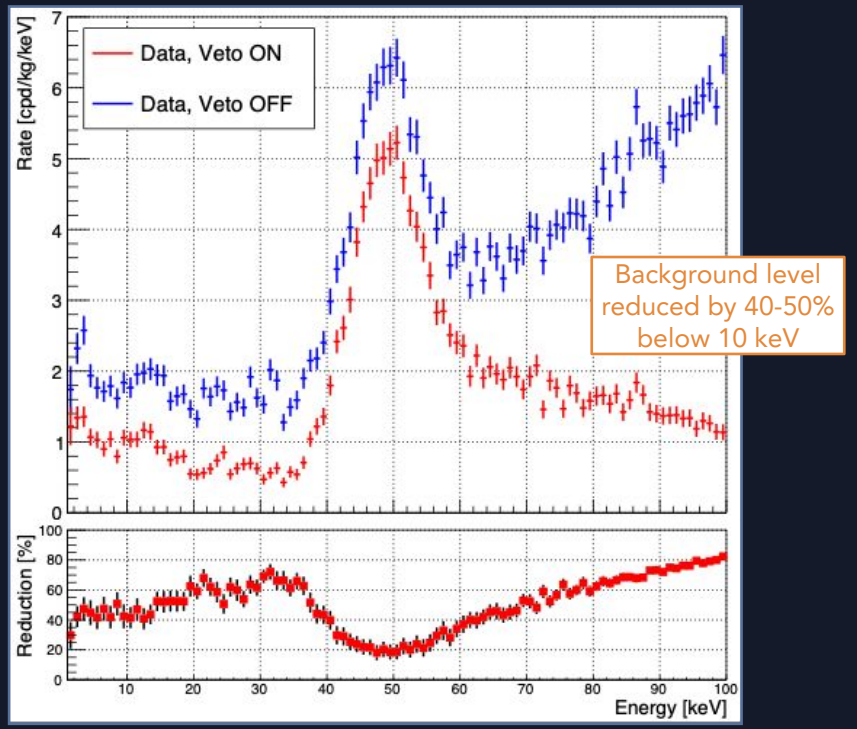
NaI-33 low energy spectrum - [1-100] keV

Anti-coincidence spectrum (efficiency-corrected)

- Events which deposit energy in the crystal, but not in the veto detector (LS threshold = 50 keV).

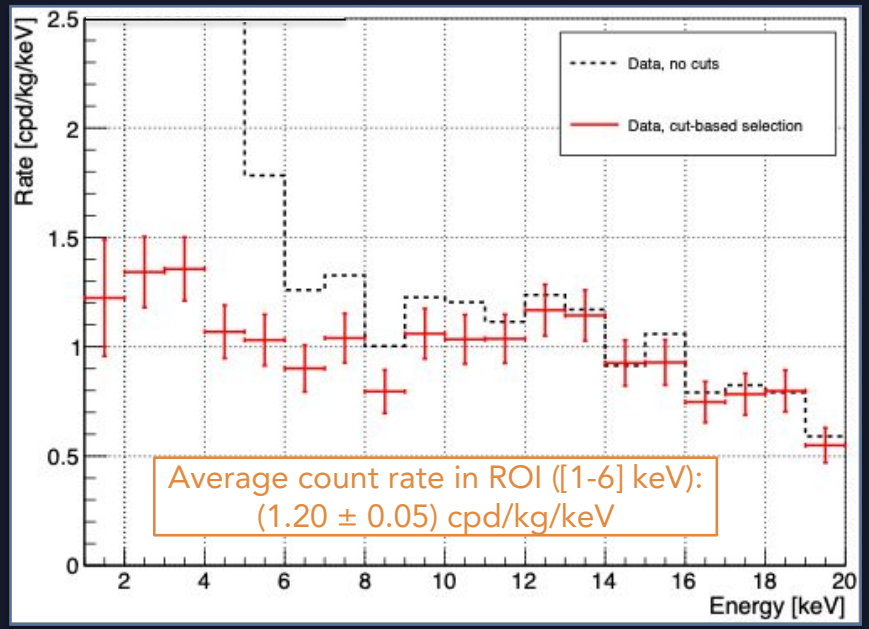


Veto rejection power

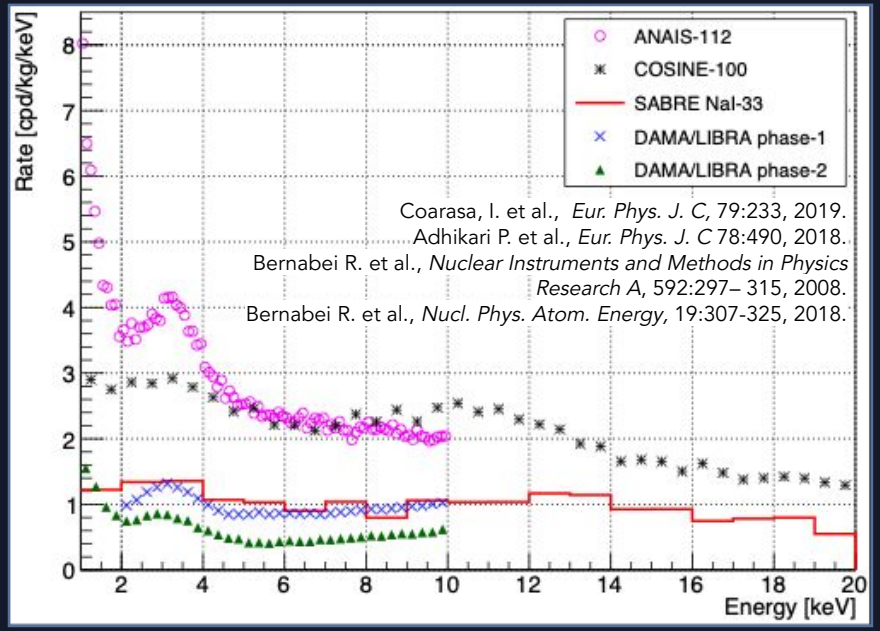


NaI-33 low energy spectrum - [1-20] keV

Anti-coincidence spectrum (efficiency-corrected)

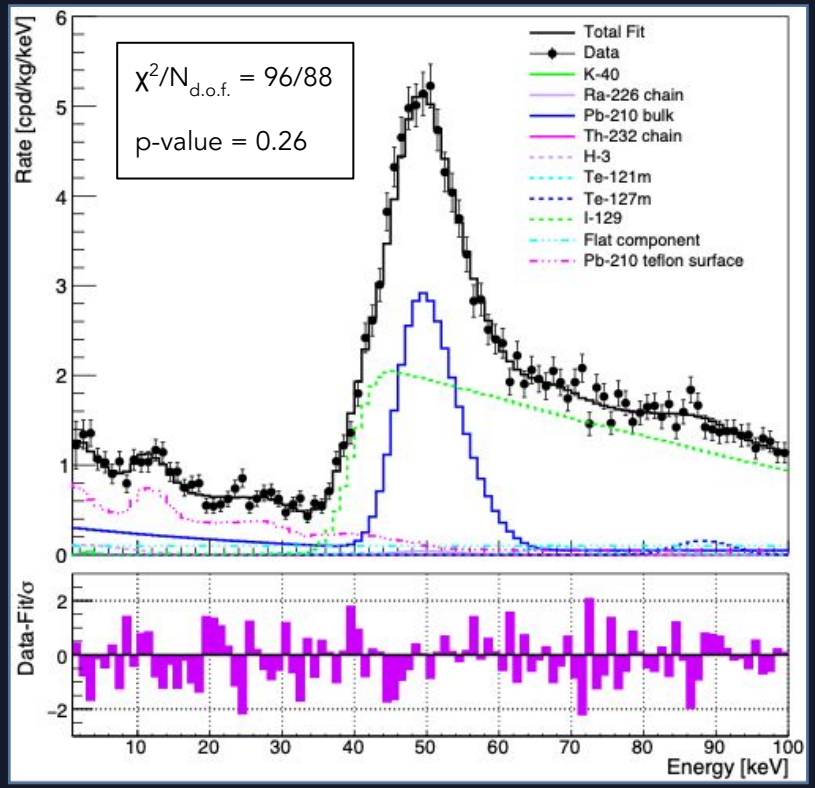


Comparison with other NaI(Tl) experiments



The NaI-33 is the best crystal ever produced after DAMA/LIBRA
(background level comparable with DAMA/LIBRA-phase1)

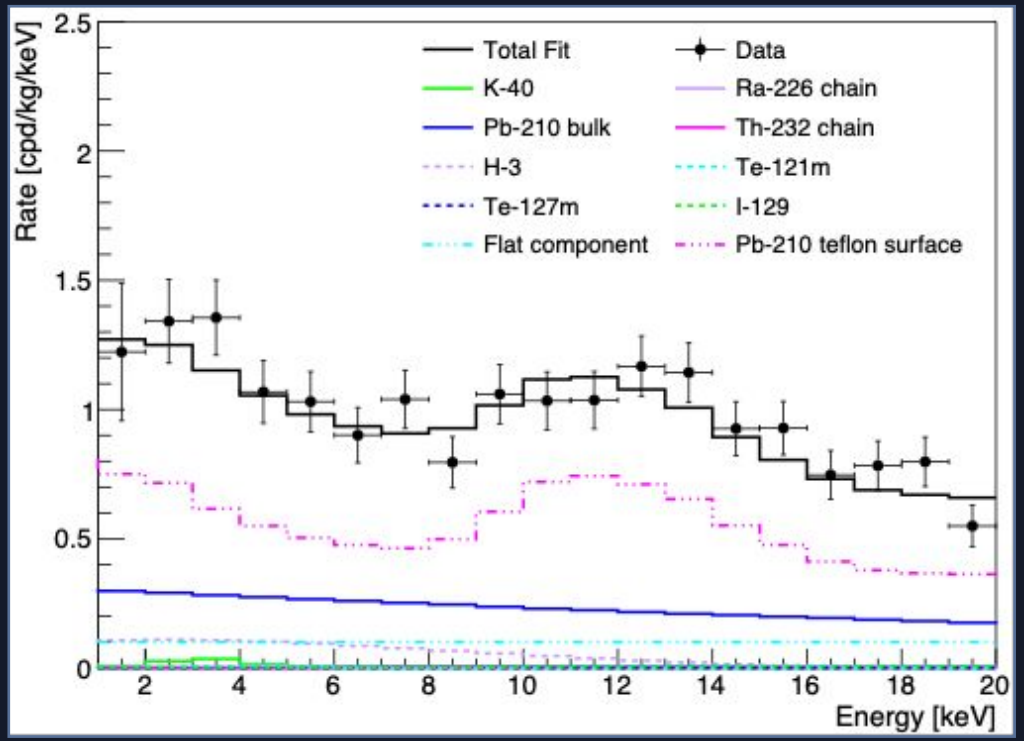
NaI-33 background model



Activities (or rate) of different background components determined from the spectral fit

Source	Activity (or rate)	
^{40}K	(0.14 ± 0.01) mBq/kg	Crystal intrinsic
^{226}Ra	(5.9 ± 0.6) μBq/kg	
^{232}Th	(1.6 ± 0.3) μBq/kg	
^{210}Pb (bulk)	(0.41 ± 0.02) mBq/kg	
^{3}H	(12 ± 7) μBq/kg	Crystal cosmogenics
^{129}I	(1.34 ± 0.04) mBq/kg	
^{121m}Te	≤ 84 μBq/kg	
^{127m}Te	(16 ± 6) μBq/kg	
^{210}Pb (teflon reflector)	(1.1 ± 0.2) mBq	Surface contamination
Flat component	(0.10 ± 0.05) cpd/kg/keV	Internal + External contamination

Background model - [1-20] keV



The dominant background contributions are from internal ^{210}Pb and ^{210}Pb in the teflon reflector wrapped around the crystal

A careful screening and selection of the reflector will be fundamental in view of the SABRE full-scale experiment.

^{3}H activity in NaI-33 seems to be about one order of magnitude lower than measured in ANAIS and COSINE crystals

Coarasa, I. et al., *Eur. Phys. J. C*, 79:233, 2019.
Adhikari P. et al., *Eur. Phys. J. C* 78:490, 2018.

Summary and conclusions SABRE-PoP

	NaI-31	NaI-33	DAMA/LIBRA crystals	ANAIS crystals	COSINE crystals
LY [phe/keV]	9.1 ± 0.1	12.1 ± 0.2	6-10	15	15
FWHM/E @59.5 keV	14.1%	13.5%	15.8%	11.2%	11.8%
^{40}K activity [mBq/kg] (direct counting)	0.49 ± 0.10	< 0.15	< 0.62	0.70-1.33	0.58-2.5
^{238}U content [ppt] (spectral fit, secular eq. assumed)	-	< 0.5	0.7-10	0.2-0.8	< 0.02-0.12
^{232}Th content [ppt] (spectral fit)	-	< 0.5	0.5-7.5	0.1-1	0.3-2.4
^{210}Pb activity [mBq/kg] (spectral fit)	-	0.41 ± 0.02	0.005-0.03	0.7-3.15	-
^{3}H activity [mBq/kg] (spectral fit)	-	0.012 ± 0.007	< 0.09	0.09-0.20	0.05-0.12
Exposure	60 kg·days	90 kg·days	2.17 ton·yr	313.95 kg·yr	97.7 kg·yr
Average count rate in [1-6] keV [cpd/kg/keV]	-	1.20 ± 0.05	< 1	3.605 ± 0.003	2.73 ± 0.14

The NaI-33 crystal has:

- the lowest potassium level ever achieved (measured thanks to the high sensitivity of the SABRE-PoP setup);
- U/Th content fully satisfying the SABRE target;
- average count rate in the [1-6] keV energy region comparable (for the first time) with that of DAMA/LIBRA-phase1, and mostly due to a ^{210}Pb surface contamination in the teflon reflector wrapped around the crystal.

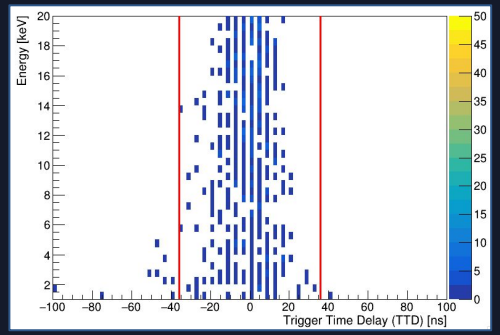
SABRE PoP-dry

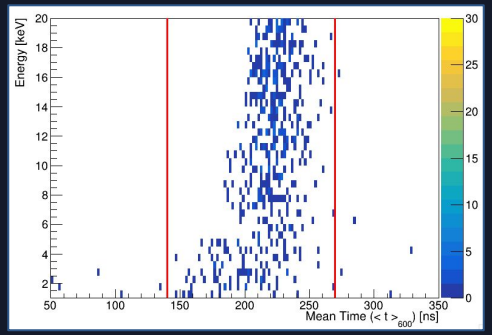
Experimental setup

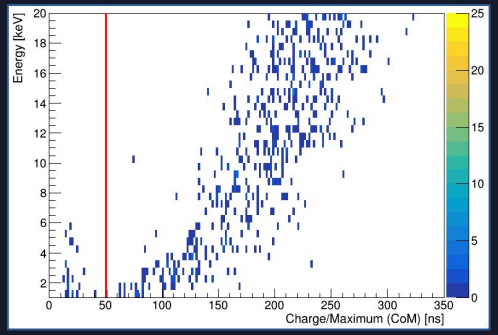
- Passive shielding made of low radioactivity copper (10 cm on all sides and top, 15 cm below) and some polyethylene slabs on sides, located inside the SABRE-PoP polyethylene hut;
- Both SABRE crystals placed inside the Cu shielding one over the other: NaI-31 (bottom) and NaI-33 (top);
- Inner volume of the detector modules flushed with high-purity N_2 gas.

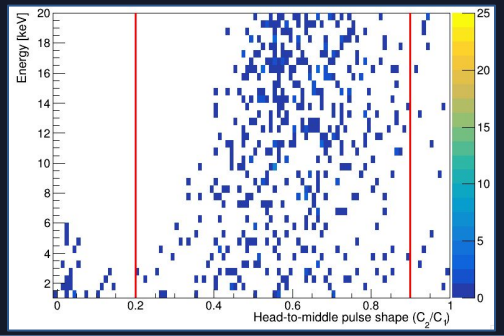
Events selection

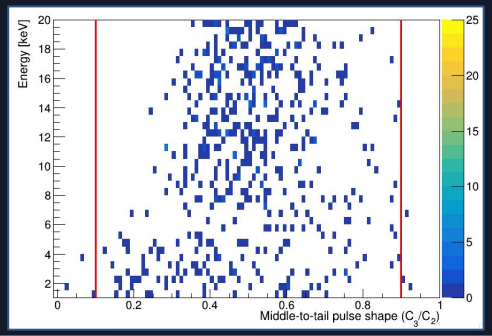
- Selection criteria tuned on data acquired with a ^{226}Ra source
    - Coincidences between the two crystals were used (low statistics, but extremely pure data sample);
- Same cuts parameters and thresholds used for the SABRE-PoP data.



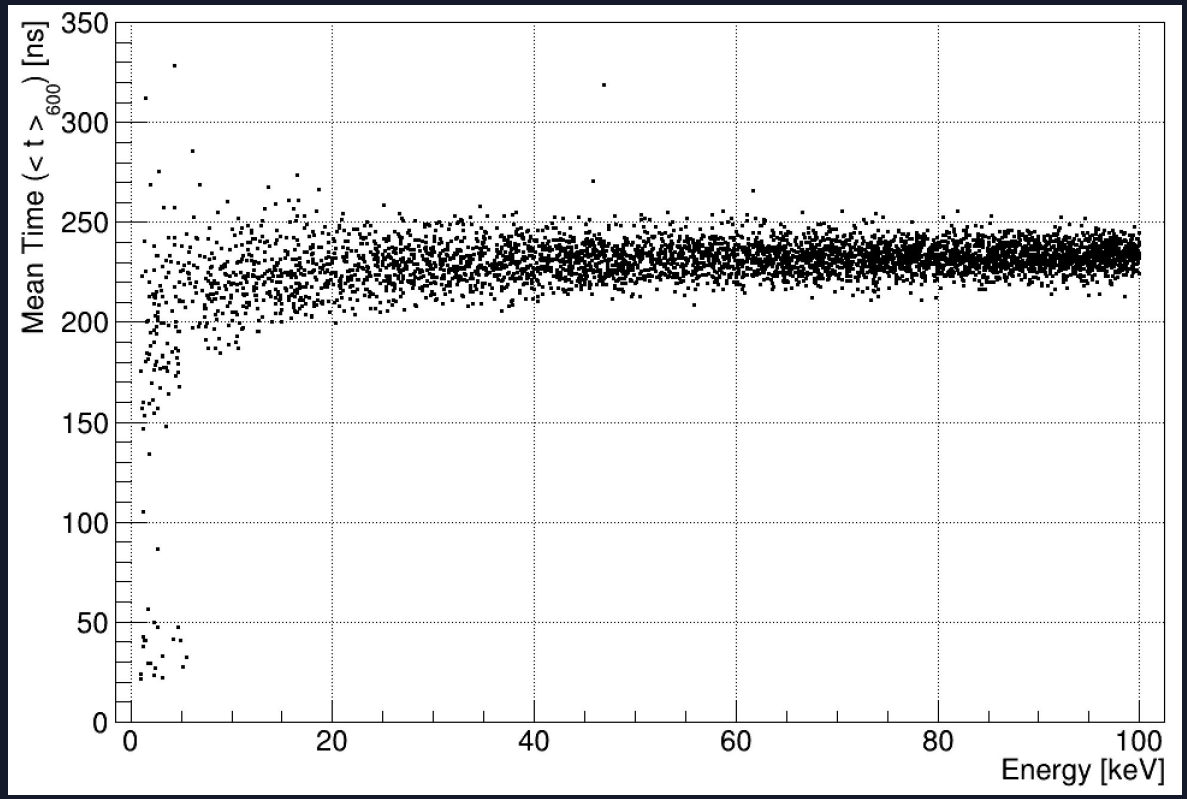




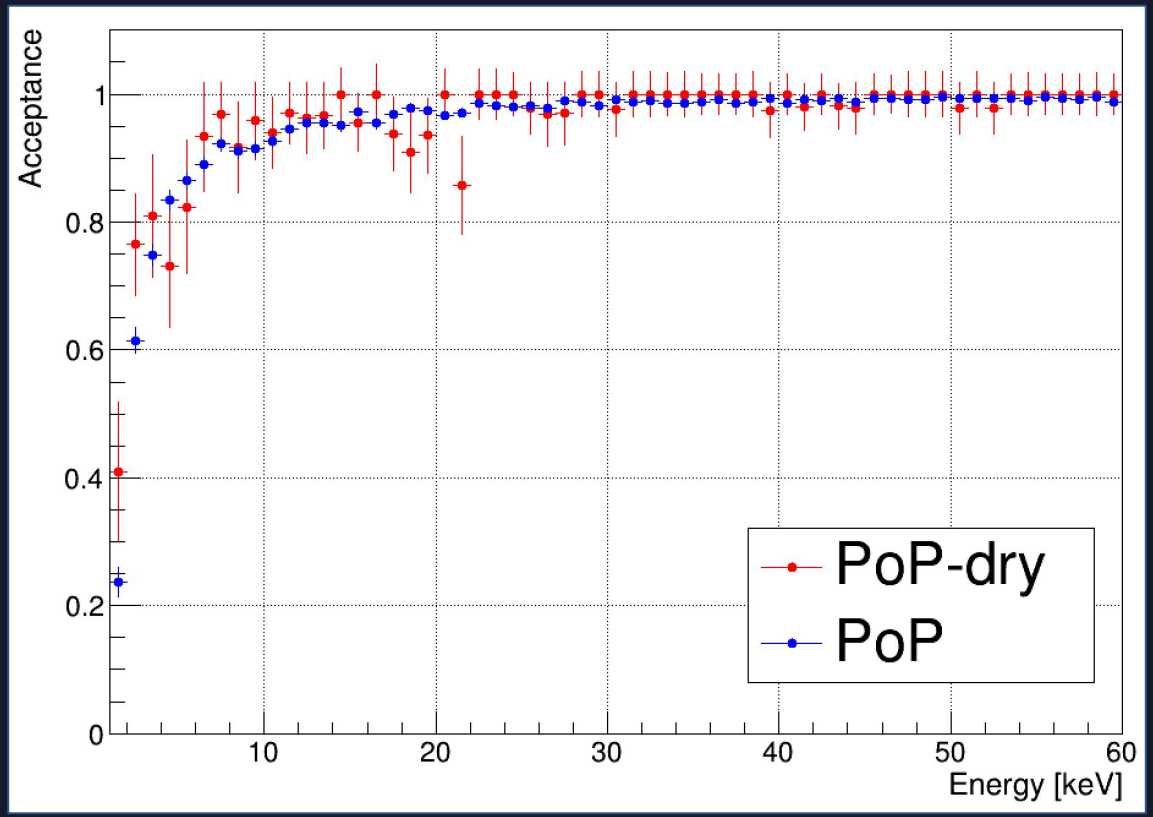




Mean Time vs. Energy - coincidences

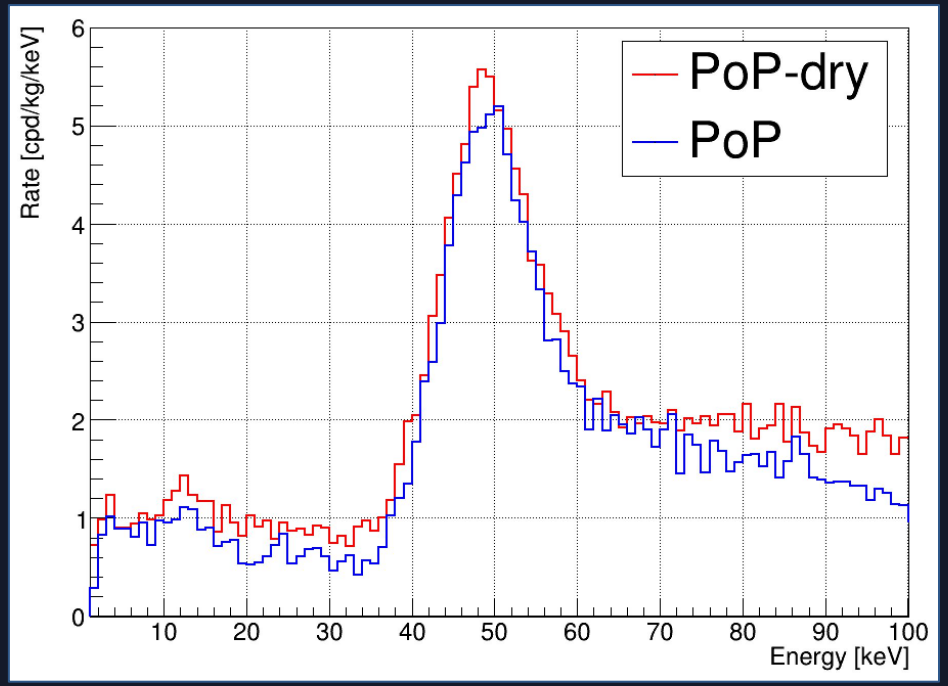


Acceptance

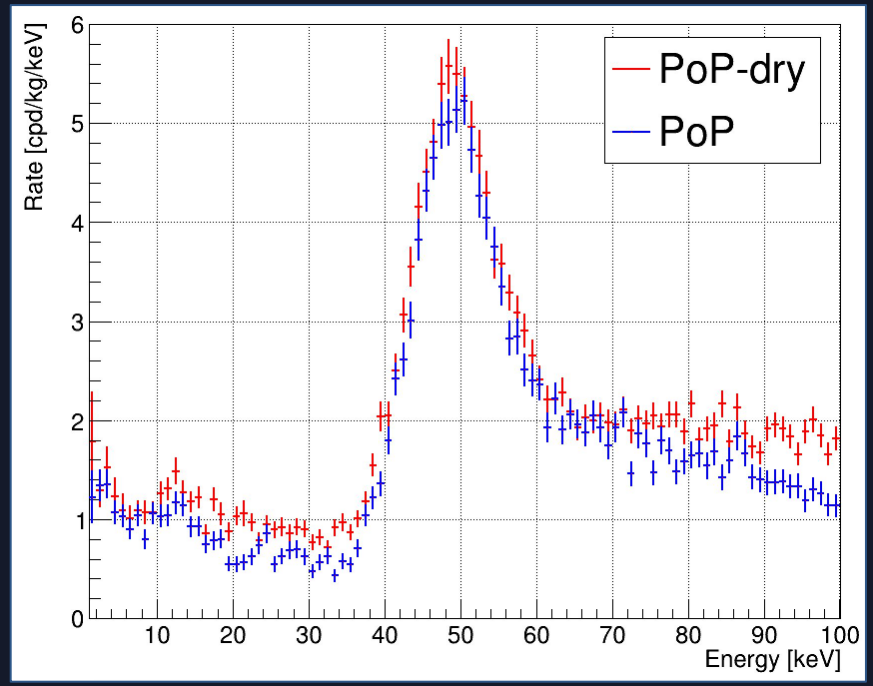

Acceptance
1
0.8
0.6
0.4
0.2
0
10
20
30
40
50
60
Energy [keV]
PoP-dry
PoP

NaI-33 low energy spectrum - [1-100] keV

PoP-dry vs. PoP



PoP-dry vs. PoP (efficiency-corrected)



Summary and conclusions SABRE PoP-dry

With the SABRE PoP-dry setup we can:

- increase statistics and improve the background model of the NaI-33 crystal;
- test the NaI-33 crystal after substitution of teflon reflector;
- test new crystals;
- long-term stability test of the DAQ.

Backup

NaI-33 background model - [1-100] keV