Measurement of the ^{115}In β-decay with ACCESS

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ACCESS Homepage

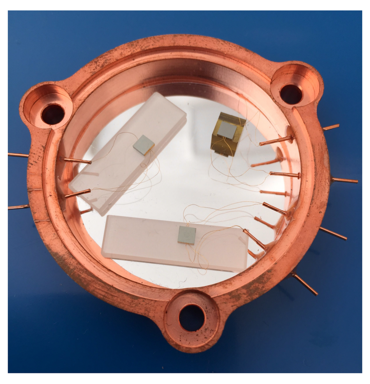
ACCESS (Array of Cryogenic Calorimeters to Evaluate Spectral Shapes)

The ACCESS project aims to establish a novel technique to perform **precision measurements of forbidden β-decays**, which can serve as an important benchmark for **nuclear physics calculations** and represent a significant **background in astroparticle physics experiments**. ACCESS will operate a pilot array of cryogenic calorimeters based on natural and doped crystals containing β-emitting radionuclides. In this way, **natural (^{113}Cd and ^{115}In) and synthetic isotopes (^{99}Tc)** will be simultaneously measured with a common experimental technique. The array will also include further crystals optimised to **disentangle the different background sources**, thus reducing the systematic uncertainty. Here we present an overview of the ACCESS research program, and the first results on ^{115}In β-decay.

Overview

Array of cryogenic calorimeters:

- Natural Crystals
  - In_2O_3 and InI ⇒ ^{115}In
  - $CdWO_4$ ⇒ ^{113}Cd
  - $PbWO_4$ ⇒ ^{210}Pb/^{210}Bi
- Doped Crystals
  - TeO_2:^{99}Tc
  - TeO_2:^{151}Sm
  - TeO_2:^{210}Pb
- Un-doped Crystals
  - Background assessment



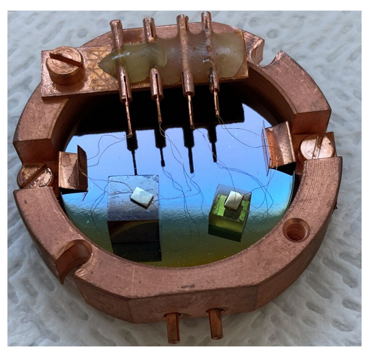


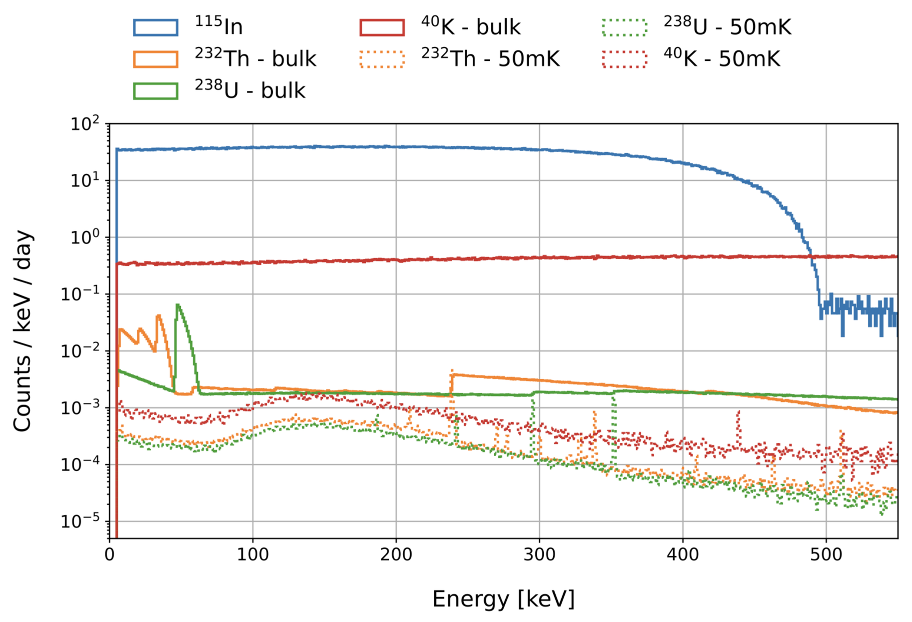
Table 1 List of the isotopes whose β-decay could be measured using the carrier crystal approach proposed by ACCESS (in bold) or natural crystals

Physics case	Isotope	Q_β (keV)	Half-life (year)	Natural abundance or target doping
Nuclear physics	**^{99}Tc**	293.8	2.11×10^5	0.25 ppb
	^{113}Cd	316	7.70×10^{15}	13.47%
	^{115}In	496	4.41×10^{14}	95.7%
	^{90}Sr	545.9	28.8	30 ppq
Background in ν-physics and dark matter search	**^{39}Ar**	565	269	0.15 ppt
	^{42}Ar	599	32.9	20 ppq
	^{210}Bi	1161.2	0.014	^{238}U decay chain
Cosmic neutrino background detection	**^{151}Sm**	76.4	94.7	0.20 ppt
	^{210}Pb	63.5	22.2	^{238}U decay chain

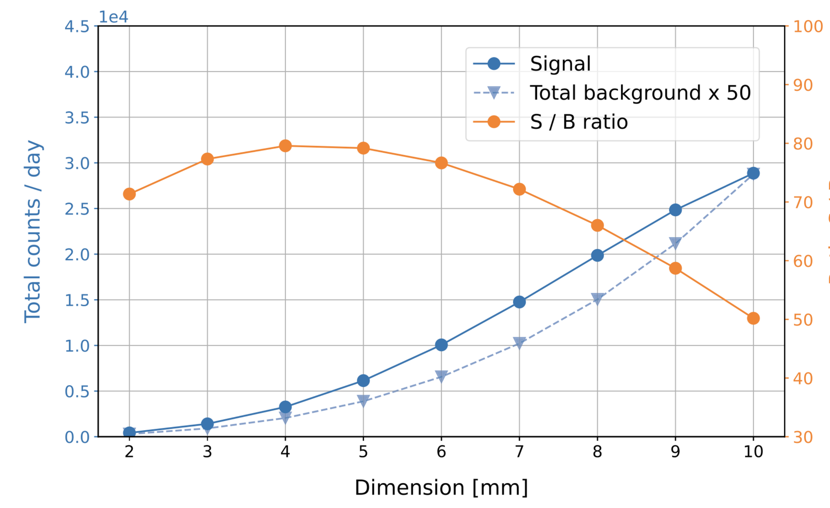
In the rightmost column, we report the isotopic abundance of naturally occurring isotopes, and the target activity of artificial isotopes in doped crystals. ^{210}Pb and ^{210}Bi belong to ^{238}U natural radioactive chain, so that their spectra can be measured with natural $PbWO_4$ exploiting the residual ^{210}Pb contamination

Design study of an InI-based cryogenic calorimeter

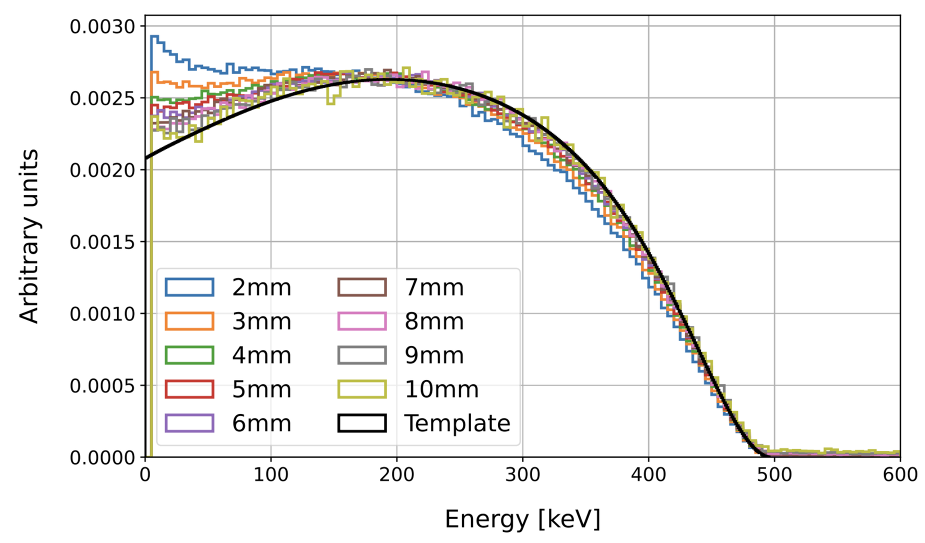
Paper



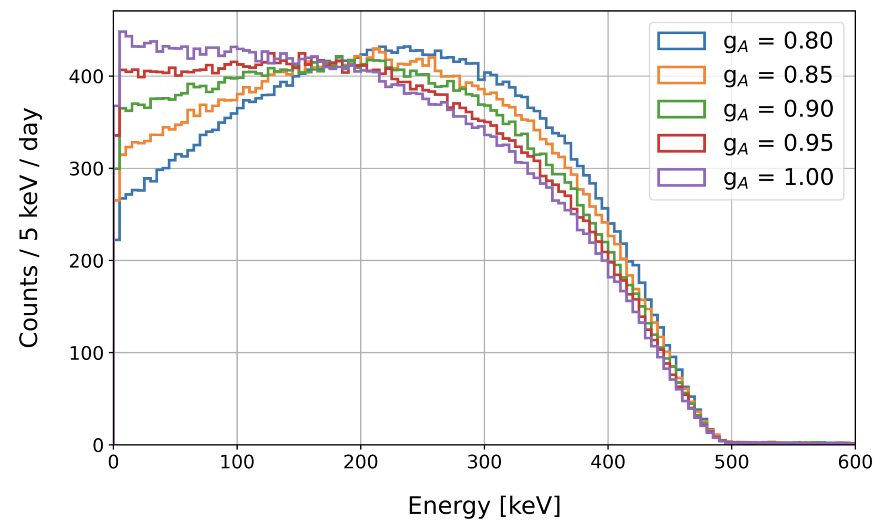
Simulated energy spectra of the ^{115}In β-decay (blue), and the different background components for a 7 mm-side InI crystal with NTD readout. As expected, the ^{115}In β-decay is two orders of magnitude higher with respect to the limit on the ^{40}K background (solid red)



Signal rate (blue solid line), limit on background rate (blue-dashed line), and signal-to-background ratio (orange solid line) as a function of the absorber side.



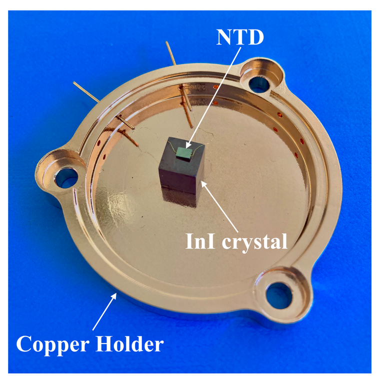
Simulated energy spectra of the ^{115}In β-decay for different dimensions of the absorber (assuming s-NME = 2.0 and g_A = 0.9, left). The larger is the crystal the lower is the difference between the template spectrum (black) and the simulated one.



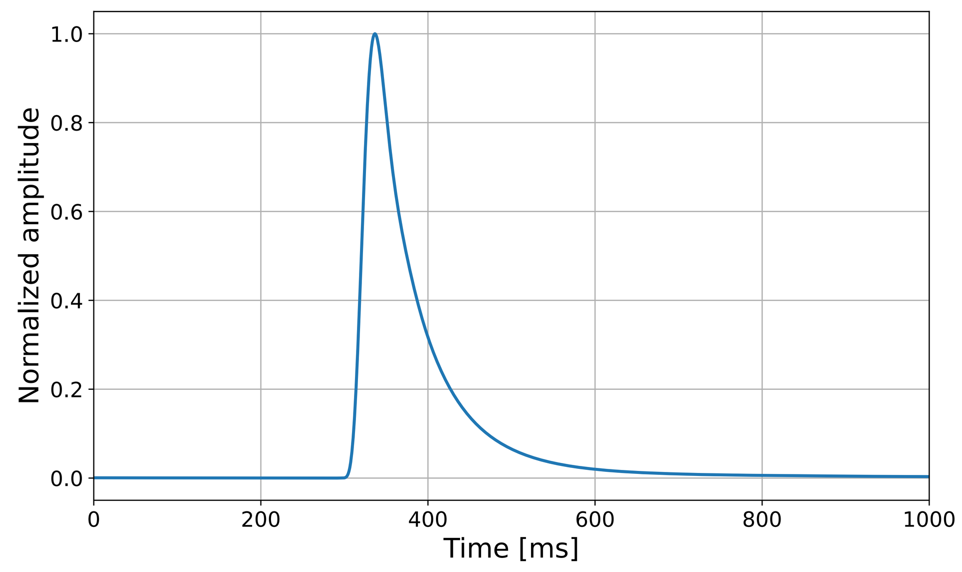
The simulation for the 7 mm side crystal is repeated for five different values of g_A around the chosen reference value).

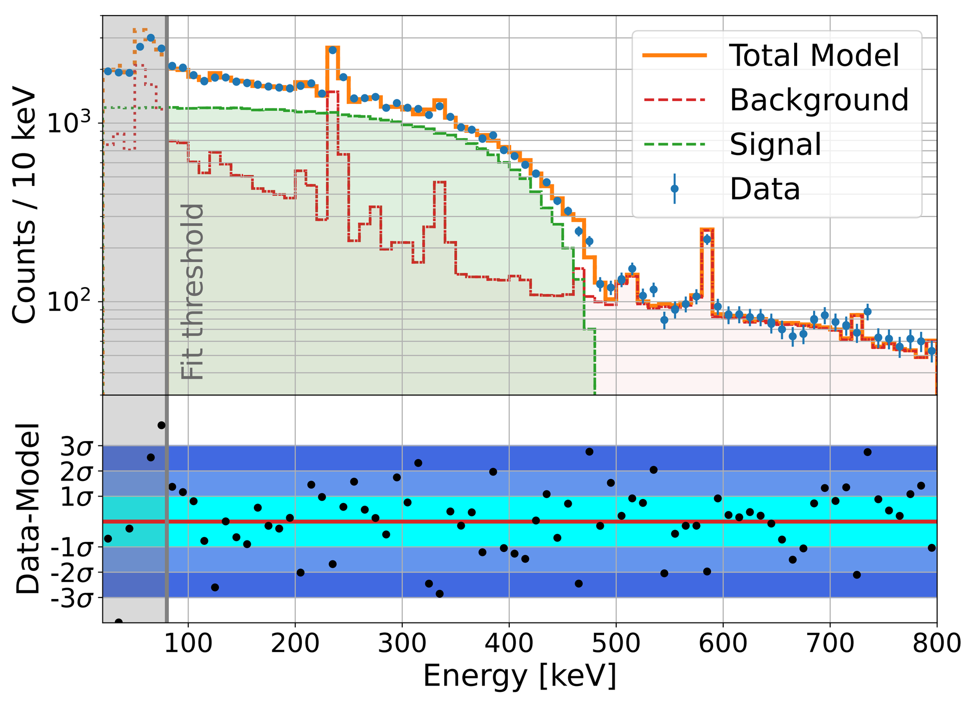
Experimental Measurement

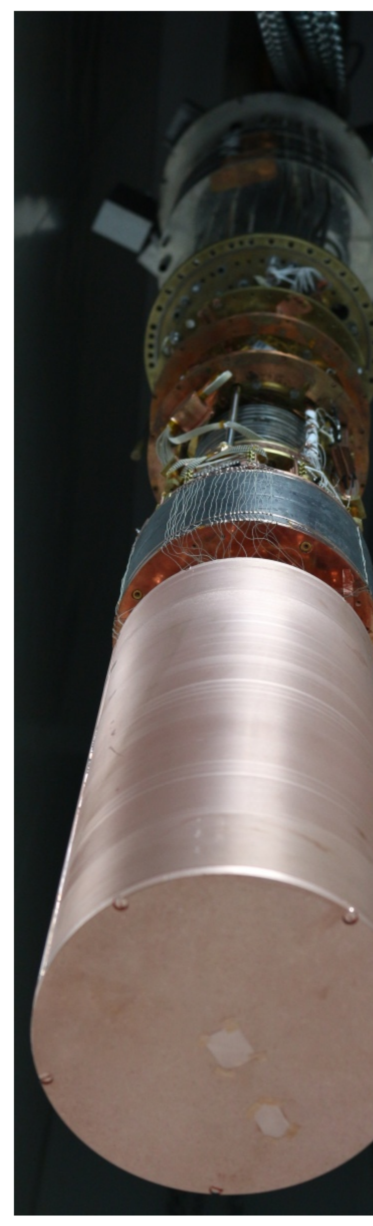
Paper



- 7×7×7 mm³ (1.9 g) indium iodine crystal
- Equipped with a 3×3×1 mm³ NTD
- Live-time of 140 h
- Permanent ^{232}Th calibration source
- Energy threshold of 17 keV
- Energy resolution of 3.1 keV FWHM at 60 keV





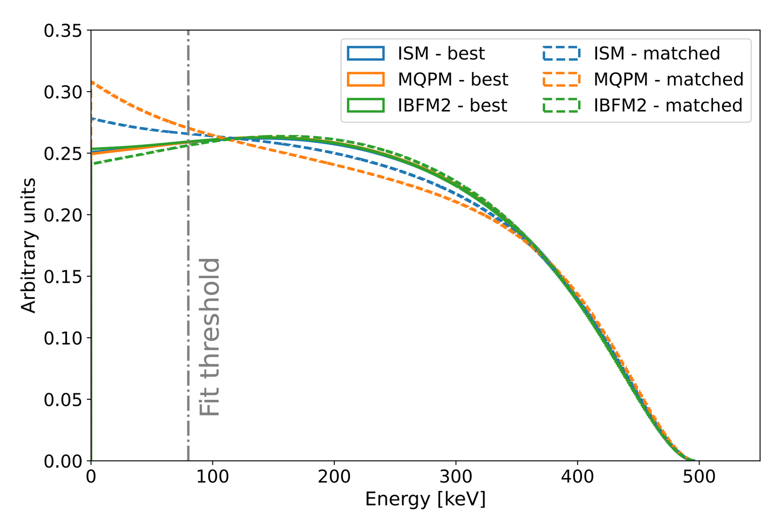


Measurement of the ^{115}In β-decay with a InI-based cryogenic calorimeter

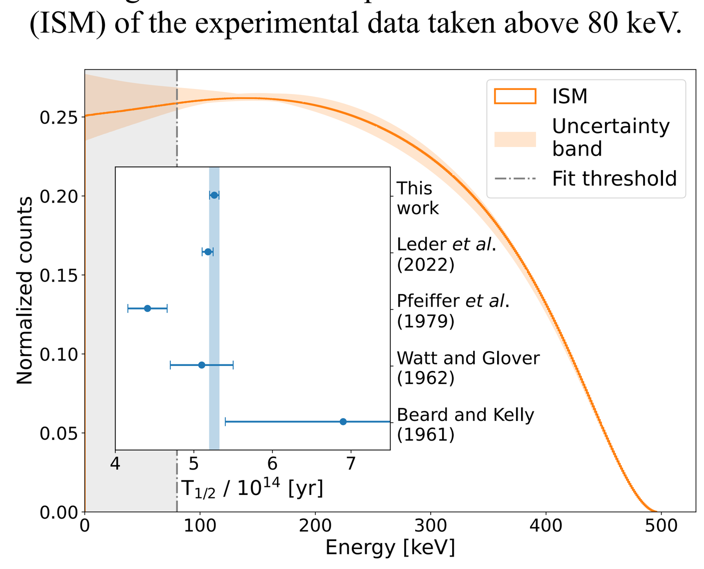
Results for the two fit methods and the three considered nuclear models on the parameters of interest g_A, sNME and $T_{1/2}$.

Model	g_A	sNME [fm^3]	$T_{1/2}/10^{14}$ [yr]	χ^2_{red}
Best fit				
ISM	$0.964^{+0.010}_{-0.006}$	$1.75^{+0.13}_{-0.08}$	5.26 ± 0.06	1.55
MQPM	$1.104^{+0.019}_{-0.017}$	$2.88^{+0.49}_{-0.71}$	5.26 ± 0.07	1.65
IBFM-2	$1.172^{+0.022}_{-0.017}$	$0.81^{+0.52}_{-0.24}$	5.25 ± 0.07	1.66
Matched				
ISM	$0.965^{+0.013}_{-0.010}$	1.10 ± 0.03	5.20 ± 0.07	1.78
MQPM	$1.093^{+0.009}_{-0.007}$	0.90 ± 0.03	5.05 ± 0.06	2.32
IBFM-2	$1.163^{+0.036}_{-0.010}$	1.10 ± 0.03	5.28 ± 0.06	1.67

Theoretical templates correspondent to the best fit and the matched fit approaches.



Theoretical energy spectrum of ^{115}In β-decay. The orange solid line corresponds to the best model fit (ISM) of the experimental data taken above 80 keV.



Accepted by PRL!

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GSSI OPENINGS

Lorenzo Pagnanini
on behalf of the ACCESS collaboration

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