

A new HPGe spectrometer with $\mu\text{Bq/kg}$ sensitivity for sample analysis

G. Zuzel¹, A. Biondi¹, C.P. Garay²

¹⁾ Jagiellonian University, Cracow, Poland

²⁾ Canfranc Underground Laboratory, Spain



JAGIELLONIAN UNIVERSITY
IN KRAKÓW



Outline



JAGIELLONIAN UNIVERSITY
IN KRAKÓW

Introduction

Installation

Performance

Plans

Summary

- Introduction
- Installation of the spectrometer
- Performance of the spectrometer
- Plans
- Summary



Rysy



JAGIELLONIAN UNIVERSITY
IN KRAKÓW

Introduction

Installation

Performance

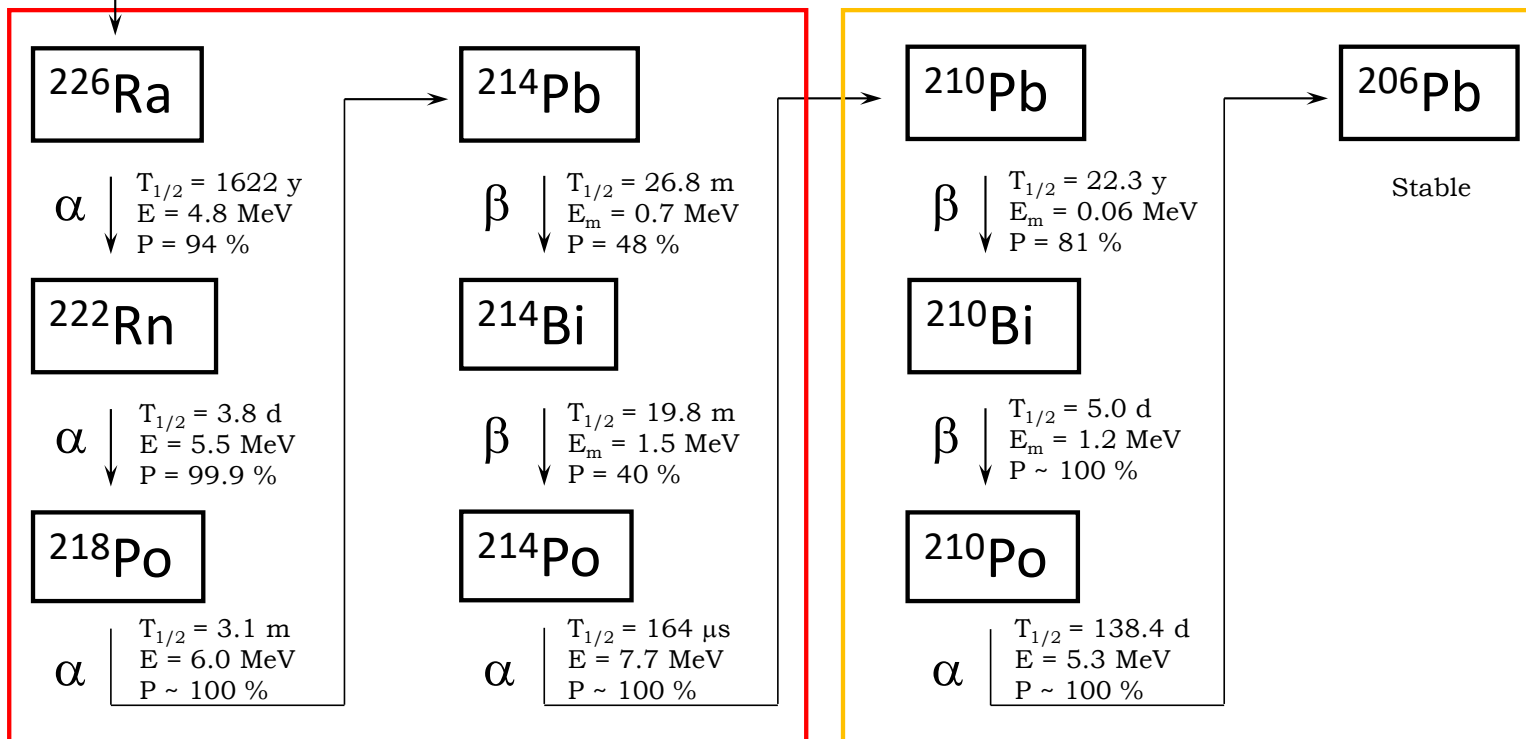
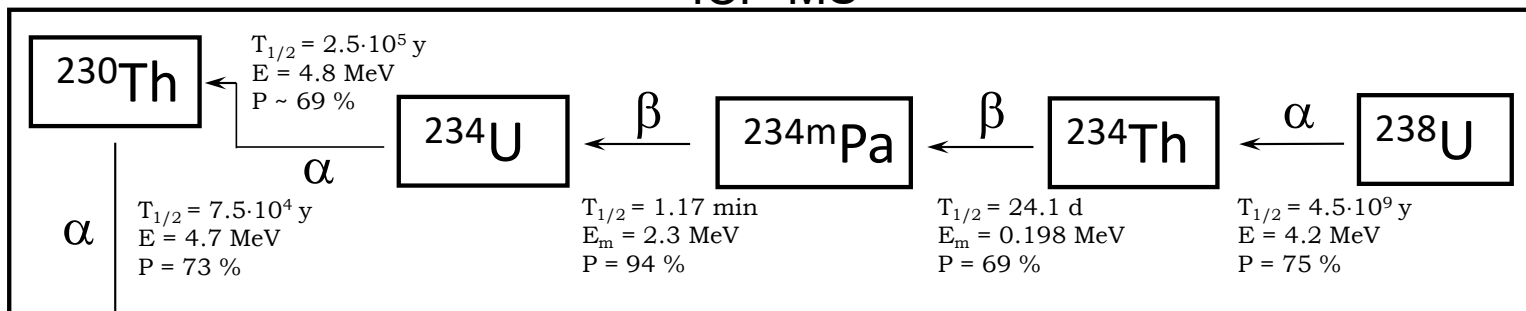
Plans

Summary



Motivation

ICP-MS



γ -spectrometry / ^{222}Rn emanation

α / β -spectrometry



JAGIELLONIAN UNIVERSITY
IN KRAKÓW

Introduction

Installation

Performance

Plans

Summary



Motivation

- Secular equilibrium in the ^{238}U (^{232}Th) can be broken (rather rule than an exception).
- Each sub-chain needs to be assayed separately.
- Ultra-sensitive spectrometers needed to assay ^{226}Ra , which with ^{222}Rn daughters poses in many cases the most important background source.
- Very limited screening capacities (world-wide) at the level of 1 ppt U-equivalent ($\sim 10 \mu\text{Bq/kg}$) \rightarrow new ultra-sensitive instrument(s) needed.
- To be used for screening of the construction materials for experiments like DARKSIDE, LEGEND, NEXT, ...



JAGIELLONIAN UNIVERSITY
IN KRAKÓW

Introduction

Installation

Performance

Plans

Summary



GeRysy

Project financed by the Polish Ministry for Science and Higher Education

Detector delivered to LSC on 09.06.2020



JAGIELLONIAN UNIVERSITY
IN KRAKÓW

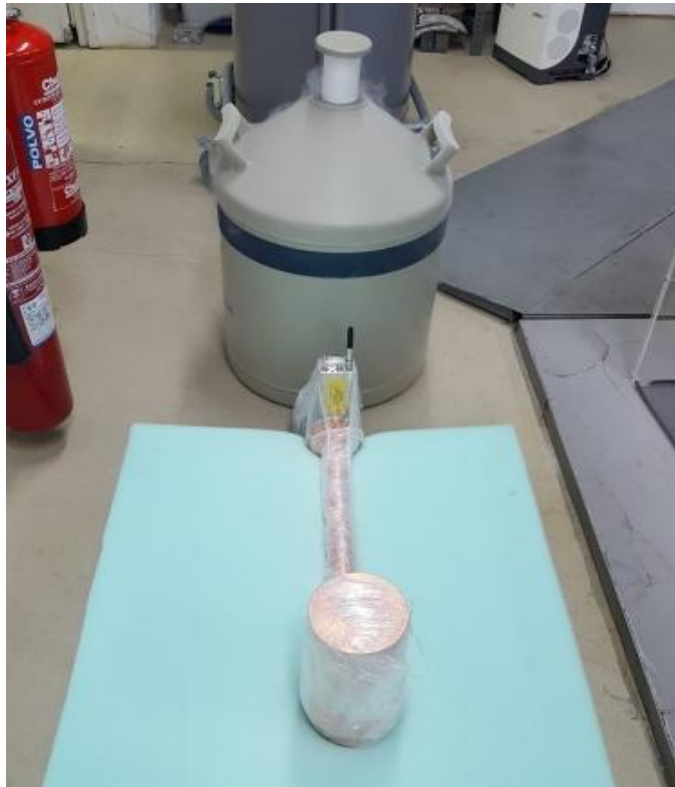
Introduction

Installation

Performance

Plans

Summary



- Freshly pulled 450-cm³ HPGe crystal (~2.3 kg, ~100 % rel. efficiency).
- SAGe-well geometry (well capacity is 19.7 cm³).
- Special copper used for fabrication of the cryostat.
- Selected VFE components.
- Cosmic exposure of all materials reduced to minimum during fabrication.
- Selected gas adsorber.
- Special solder material (mix of selected tin and roman led).

Project of the Spectrometer



JAGIELLONIAN UNIVERSITY
IN KRAKÓW

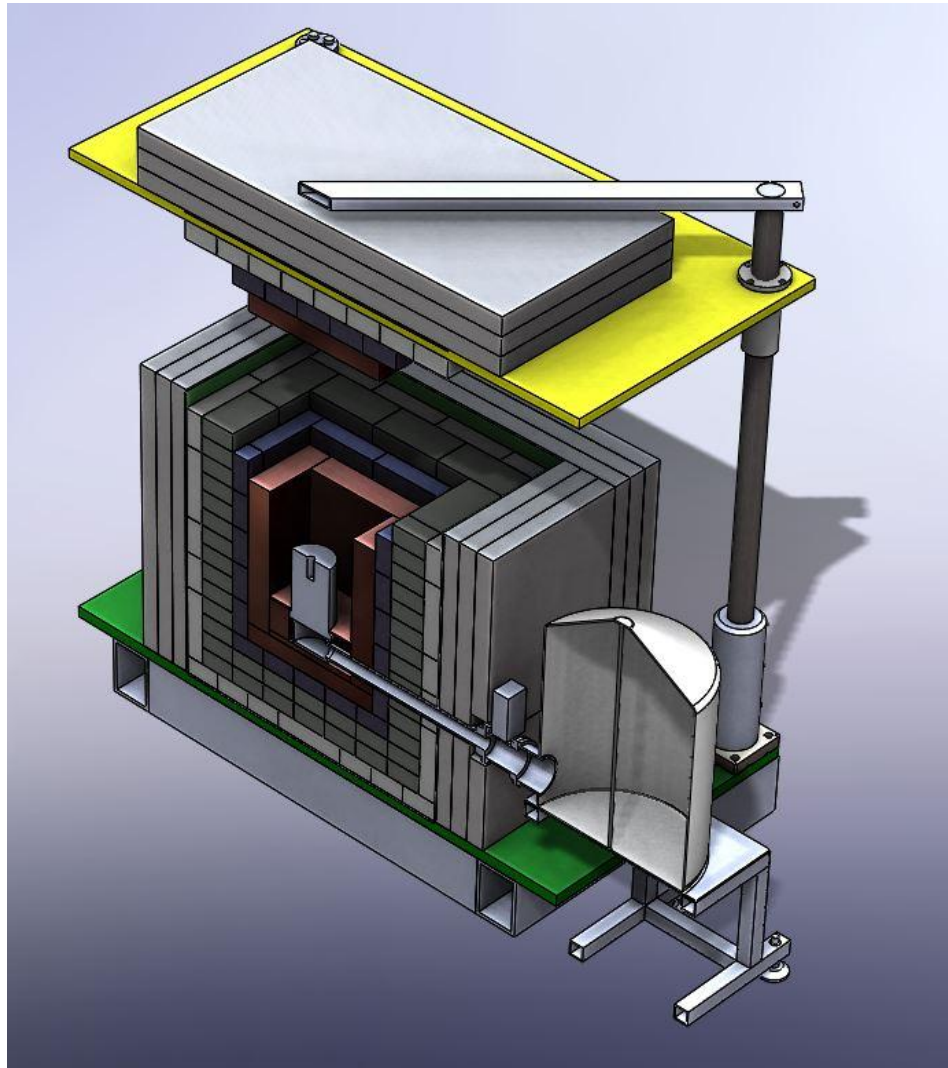
Introduction

Installation

Performance

Plans

Summary



Fabrication of the final shield in Kraków

- Ultra-High Purity copper (7 cm, the same material as that used for fabrication of the detector cryostat) .
- UHP lead ($^{210}\text{Pb} \sim 2 \text{ Bq/kg}$, 5 cm).
- High purity lead ($^{210}\text{Pb} \sim 5 \text{ Bq/kg}$, 10 cm) .
- Normal lead (5 cm).
- PE with 5% B (15 cm, 3 layers, 5 cm each).
- Volume of the detector chamber is 15 L.
- Volume of the well is $\sim 20 \text{ cm}^3$.

Ultra-High Purity Copper Shield



JAGIELLONIAN UNIVERSITY
IN KRAKÓW

Introduction

Installation

Performance

Plans

Summary



Cu for the cryostat
and the most internal
shield layer



Isotope	Specific activity [mBq/kg]	Comments
^{238}U	< 0.012	< 1 ppt U, 90 % C.L.
^{232}Th	< 0.004	< 1 ppt Th, 90 % C.L.
^{235}U	< 0.069	90 % C.L.
^{40}K	< 0.14	90 % C.L.
^{60}Co	$(14 \pm 4) \cdot 10^{-3}$	
^{234}Th	< 4.2	Upper ^{238}U sub-chain, 90 % C.L.
$^{234\text{m}}\text{Pa}$	< 0.45	Upper ^{238}U sub-chain, 90 % C.L.
^{228}Th	< 0.041	90 % C.L.
^{228}Ra	< 0.027	90 % C.L.
^{226}Ra	$(29 \pm 8) \cdot 10^{-3}$	Clear disequilibrium between the middle and the bottom ^{238}U sub-chain
^{210}Pb	14 ± 2	

ICP-MS
HPGe
Po

Shipping Materials to LSC



JAGIELLONIAN UNIVERSITY
IN KRAKÓW

Introduction

Installation

Performance

Plans

Summary



Installation at LSC (Dec. 2022)



JAGIELLONIAN UNIVERSITY
IN KRAKÓW

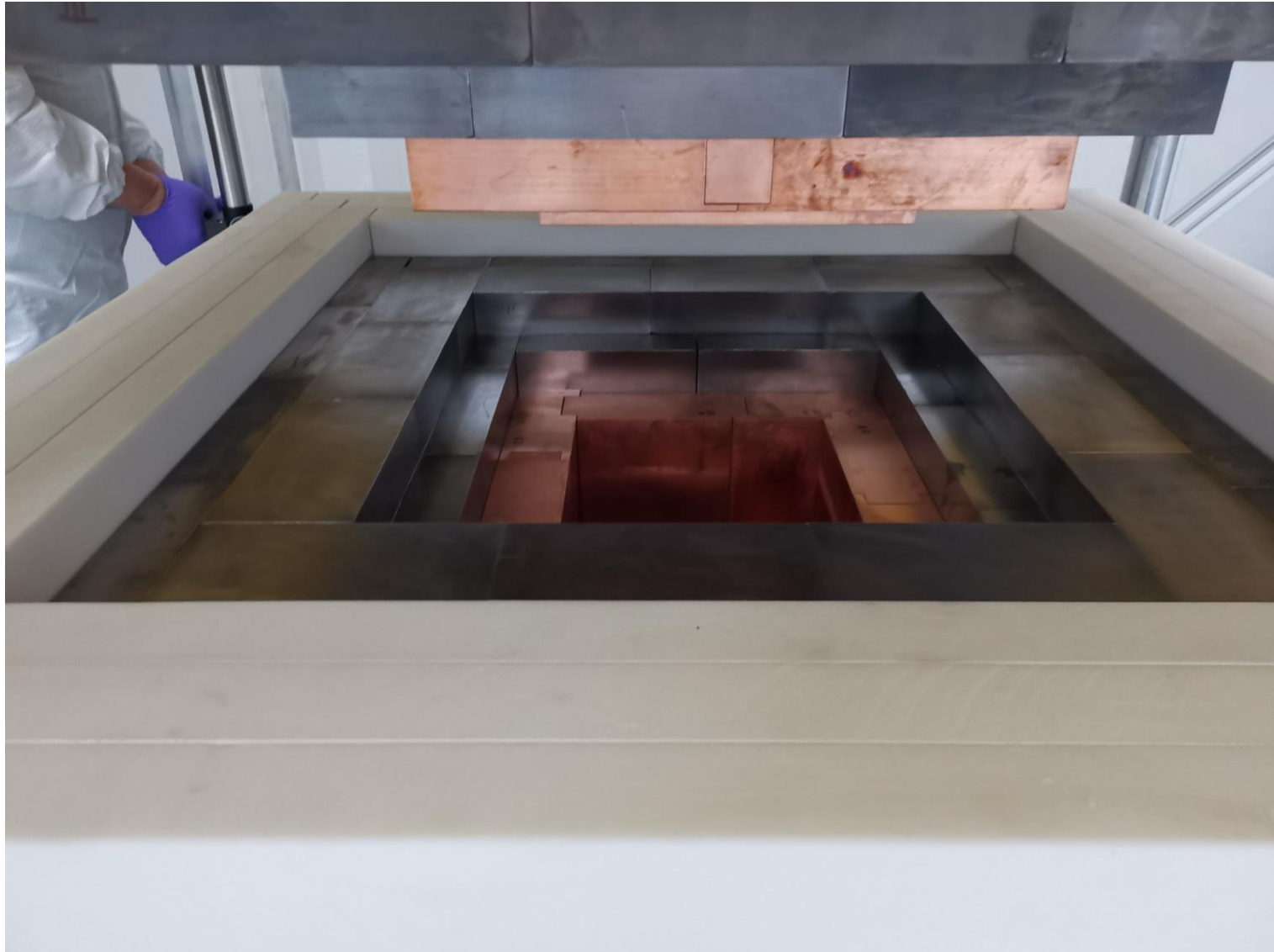
Introduction

Installation

Performance

Plans

Summary



GeRysy at LSC



JAGIELLONIAN UNIVERSITY
IN KRAKÓW

Introduction

Installation

Performance

Plans

Summary



The XIX International Conference on Topics in Astroparticle and Underground Physics (TAUP2025), Xichang, China, 25-29.08.2025

Calibration with ^{60}Co



JAGIELLONIAN UNIVERSITY
IN KRAKÓW

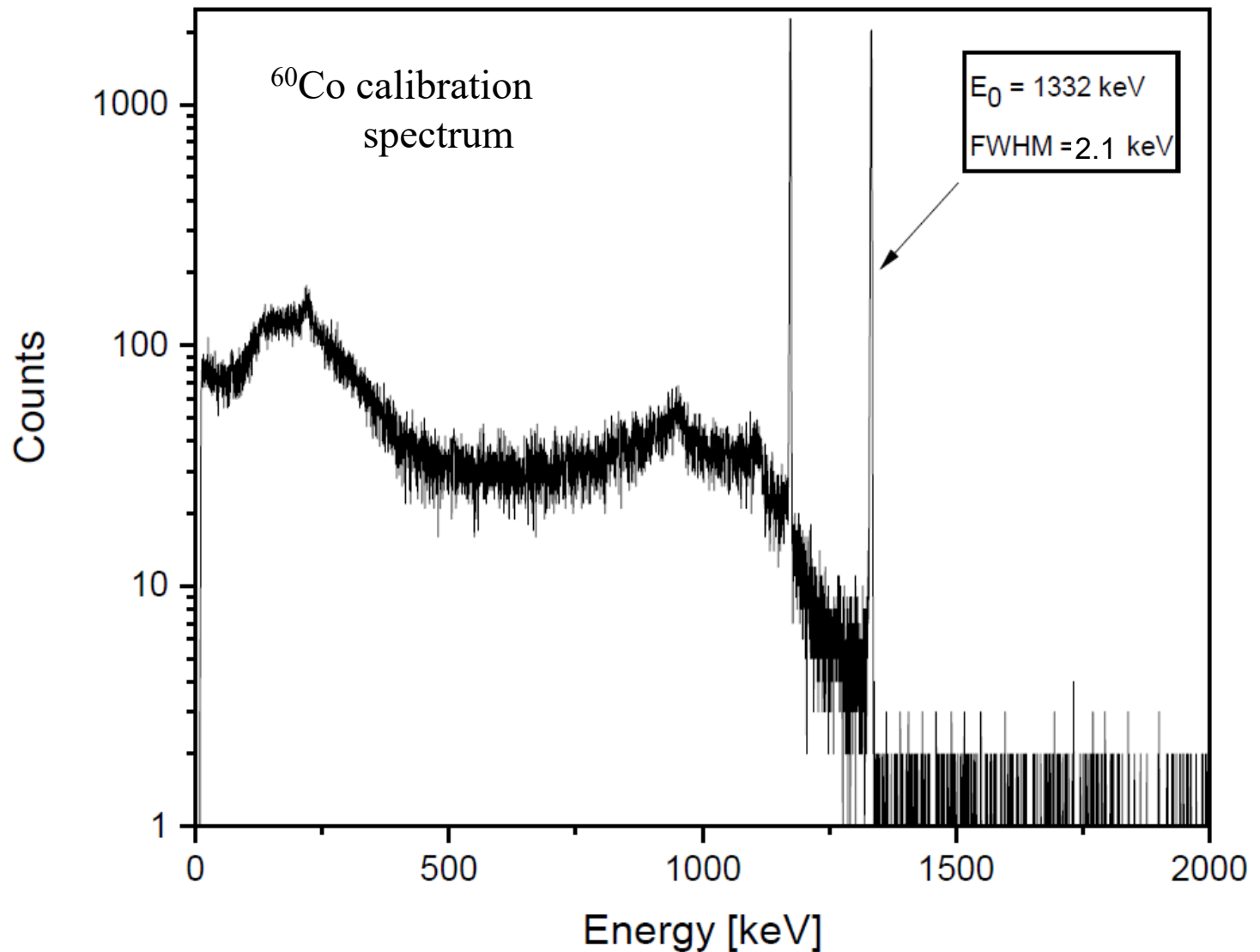
Introduction

Installation

Performance

Plans

Summary



Background Measurement



JAGIELLONIAN UNIVERSITY
IN KRAKÓW

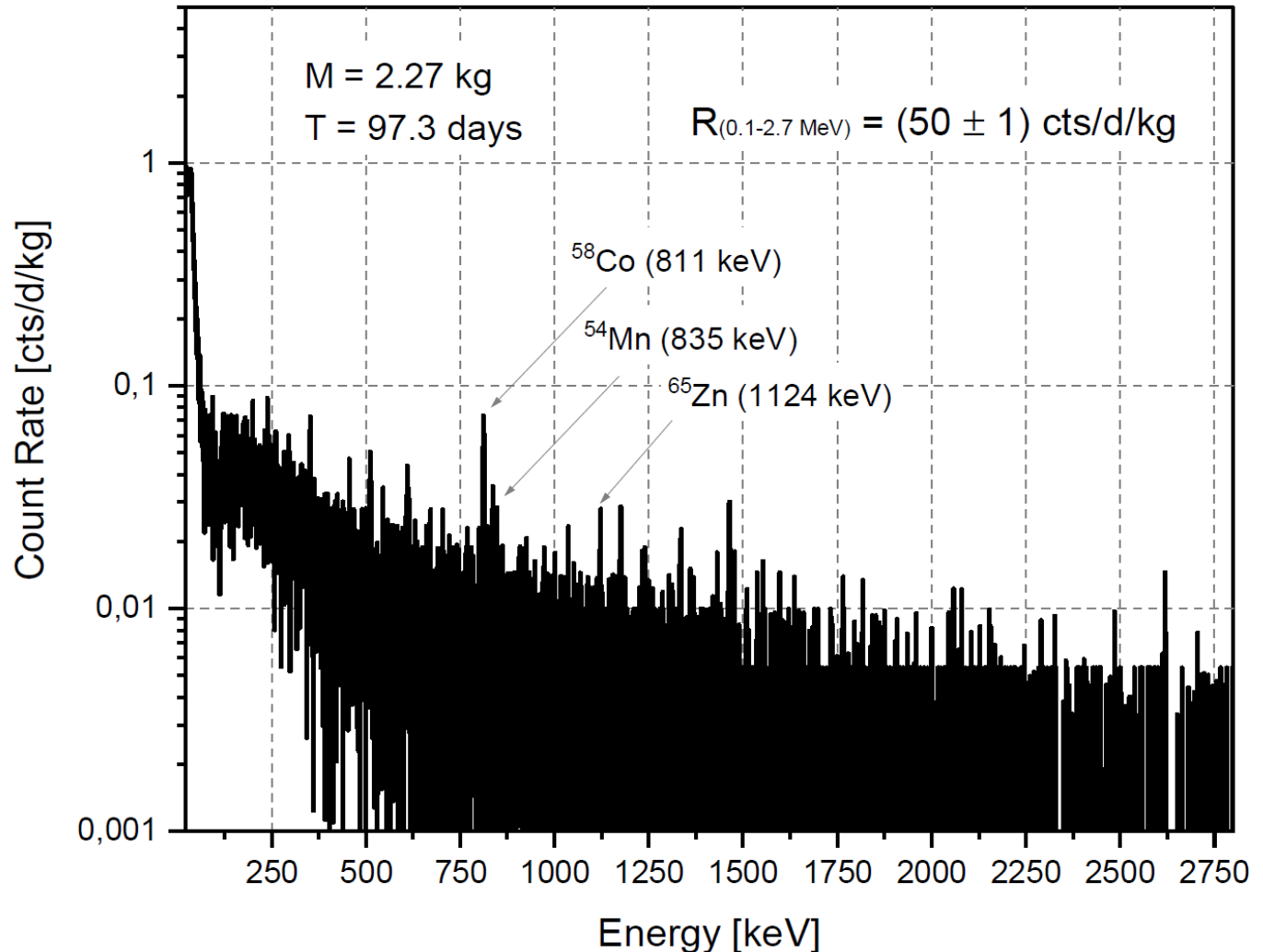
Introduction

Installation

Performance

Plans

Summary



Performance of the Spectrometer



JAGIELLONIAN UNIVERSITY
IN KRAKÓW

Introduction

Installation

Performance

Plans

Summary



Comparison with other high sensitivity HPGe spectrometers

Detector	M_{act} [kg]	V_{cham} [L]	Lab	Counting rates in the full energy range [cts/d/kg] and for various peaks [cts/yr/kg]						
				40 - 2700 keV	609 keV [²²⁶ Ra]	662 keV [¹³⁷ Cs]	583 keV [²²⁸ Th]	1332 keV [⁶⁰ Co]	1461 keV [⁴⁰ K]	2614 keV [²²⁸ Th]
GeRysy	2.27	15	LSC	64 ± 1	74 ± 19	< 27	27 ± 17	< 37	60 ± 16	25 ± 9
GeMPI	2.21	15	LNGS	66 ± 1	< 30	57 ± 27	< 21	35 ± 8	86 ± 12	18 ± 5
GATOR	2.20	15	LNGS	$103 \pm 1^*$	99 ± 33	50 ± 17	--	83 ± 17	83 ± 17	33 ± 16
GeOroel	2.31	40	LSC	142	190	--	182	91	66	--

* (100 – 2700) keV

Performance of the Spectrometer



JAGIELLONIAN UNIVERSITY
IN KRAKÓW

Introduction

Installation

Performance

Plans

Summary



Estimated detection limits

Assumed measurement time = 60 d

		Detection limits: [mBq] / [mBq/kg]				
		^{226}Ra	^{228}Th	^{137}Cs	^{60}Co	^{40}K
Well	Low density	0.02	0.03	0.005	0.005	0.15
		1.0	1.7	0.2	0.2	7.3
	High density	0.03	0.04	0.005	0.006	0.18
		0.14	0.23	0.03	0.03	1.0
Detector chamber	Low density	0.3	0.5	0.08	0.08	2.4
		0.02	0.03	0.005	0.005	0.16
	High density	1.4	2.4	0.3	0.2	5.1
		0.01	0.02	0.002	0.002	0.04

Selected Measured Samples



JAGIELLONIAN UNIVERSITY
IN KRAKÓW

Introduction

Installation

Performance

Plans

Summary



- Optical Geel (NEXT)
- PEEK (NEXT)
- Teflon Screws (NEXT)
- Stainless steel (LEGEND)
- ULTEM insulator (LEGEND)
- WLS Fibers (LEGEND)
- 3D Printed Dental Resin Sample (LEGEND)
- Ph-Br (LEGEND)
- ESR Film (DarkSide)
- SMD Resistors (DarkSide)

Plans for GeRysy 2 and GeRysy 3



JAGIELLONIAN UNIVERSITY
IN KRAKÓW

Introduction

Installation

Performance

Plans

Summary



- Received funds for GeRysy 2 (Polish Ministry of Science and Higher Education).

GeRysy 3 funded by LSC and constructed in parallel to GeRysy 2.

- Spectrometers under construction (Mirion) – customized design.
- Shielding materials, HP lead and copper, procured (high purity copper produced by the Polish KGHM company).
- Support structures of the shield delivered to LSC.
- Assembly of the spectrometers expected in 2026.
- GeRysy spectrometers installed in a clean room built by LSC in Hall C (Hall C will be dedicated to high sensitivity gamma screening).

Copper for GeRysy 2/3

Copper blocks produced by the KGHM Polska Miedź Company (from fresh and selected cathodes). Hot forging and cutting scheduled for this week.



JAGIELLONIAN UNIVERSITY
IN KRAKÓW

Introduction

Installation

Performance

Plans

Summary



HPGe Clean Room at LSC

GeRysy spectrometer and the shielding support frames of GeRysy 2 and GeRysy 3 in a dedicated clean room in Hall C of LSC.



JAGIELLONIAN UNIVERSITY
IN KRAKÓW

Introduction

Installation

Performance

Plans

Summary



Conclusions

- Need for ultra-high sensitivity γ -ray spectrometers (MDA $< 10 \mu\text{Bq/kg}$, 1 ppt U equivalent)
- GeRysy mounted in the final shield in Dec. 2022
- Sensitivity goals reached \rightarrow GeRysy one of the most sensitive gamma spectrometers
- GeRysy used for regular screening of highly radiopure samples
- GeRysy 3 financed by LSC, construction in parallel to GeRysy 2
- Expected assembly of GeRysy 2 and GeRysy 3 in 2026
- All spectrometers to be operated in a clean room supplied with the Rn-free air

The Polish Ministry of Science and Higher Education is acknowledged for the support of the Construction of the GeRysy spectrometers (grants 6811/IA/SP/2018 and 2022/WK/10).



JAGIELLONIAN UNIVERSITY
IN KRAKÓW

Introduction

Installation

Performance

Plans

Summary



THANK YOU!



JAGIELLONIAN UNIVERSITY
IN KRAKÓW

