

# Applying astroparticle physics techniques to the detection of Pb contamination in water

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On behalf of TRACE collaboration,  
Dr. Jaime Octavio Guerra-Pulido (ICN-UNAM)

Seminario Virtual de Física de Altas Energías ICN-IF-UNAM nov/18/2020

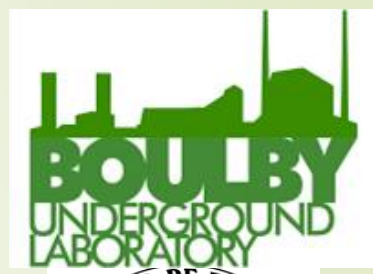
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- ▶ LABChico: An underground laboratory in México.
- ▶ Characterization of HPGe detectors for LABChico's.
- ▶ HistoGe: a software for isotope identification in gamma spectroscopy.
- ▶ Plombox: a device to detect Pb contamination in water



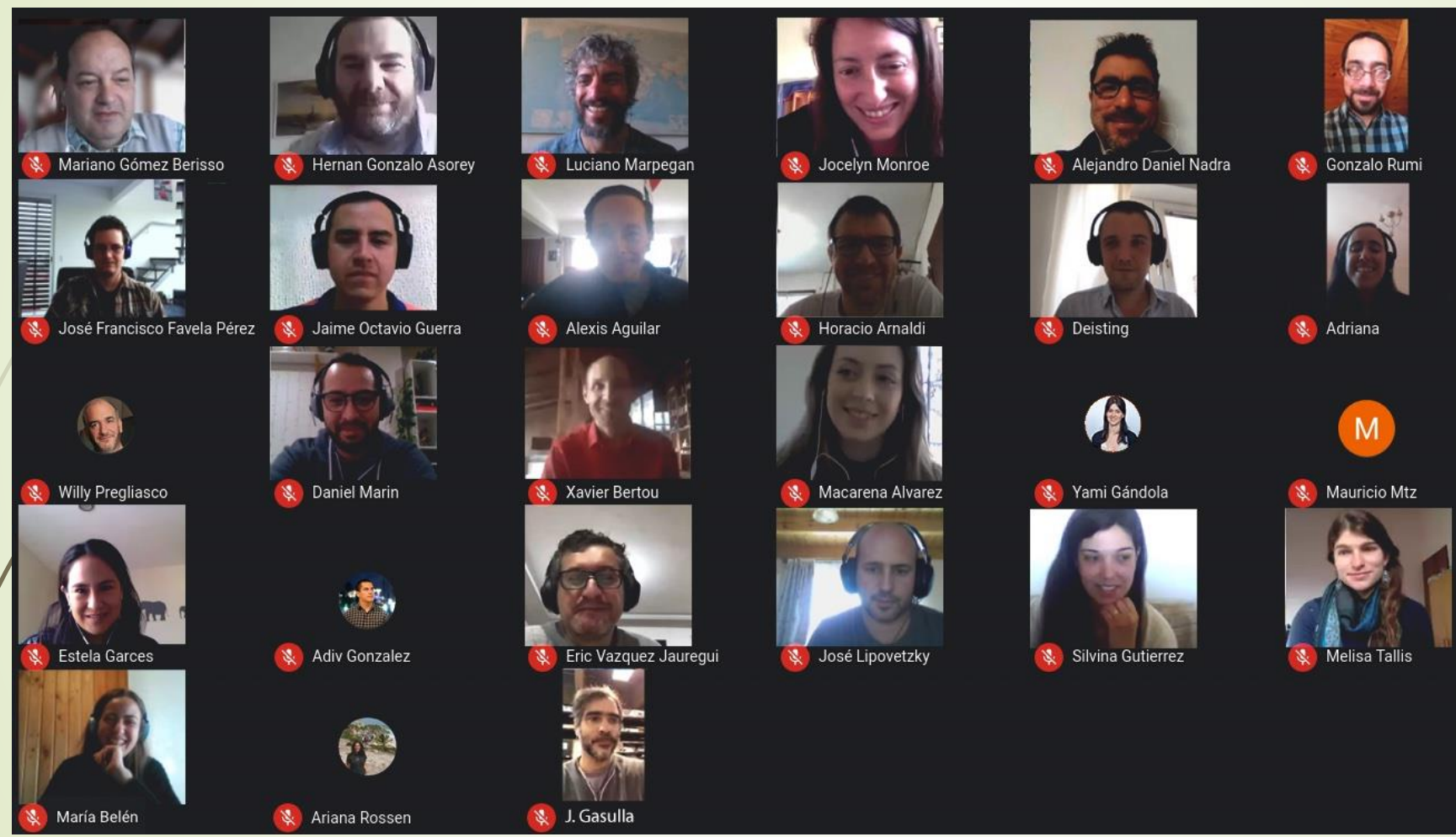


Comisión Nacional de Energía Atómica



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# TRACE collaboration



➤ TRACE means “Tools and Research to Assay Contamination in the Environment”

## Origin of TRACE

- ▶ International collaboration of physicists, biologists and engineers developing technologies for the detection of Pb contaminants in water.
- ▶ Started as a group of physicists interested in applying expertise in High Energy/Astroparticle physics experiments, e.g., direct dark matter (DM) searches to the detection of Pb in water:
  - ▶ CCD/CMOS detector expertise from DAMIC experiment.
  - ▶ Ultralow background techniques from PICO and DEAP experiments.
  - ▶ Experience with Monte Carlo simulations and data analysis
  - ▶ Use of underground facilities to reduce cosmogenic backgrounds.

## Origin of TRACE

- ▶ Later, physicists teamed up with biologists and engineers to develop a device for the detection of Pb in water via biochemical markers and colorimetry in CMOS detectors (Plombox).
- ▶ An important task of the Mexican group is to develop a (shallow) underground laboratory (LABChico) where measurements can be performed, and which will be a site for technological development and innovation in Mexico.

# Why is Pb contamination a real health threat?

- "No safe blood level has been identified for young children, all sources of lead exposure for children should be controlled or eliminated" (CDC).
- "Lead is a toxic metal that is persistent in the environment and can accumulate in the body over time". (CDC)

#BanLeadPaint

## FACT: LEAD IS TOXIC

It is harmful to everyone and

**DAMAGES:**



BRAIN



KIDNEYS



LIVER



BLOOD



REPRODUCTIVE SYSTEM

### Young children

are most vulnerable. Their nervous systems are still developing and they absorb **4-5 times more than adults**, which can cause:

- intellectual disability
- underperforming at school
- behavioural issues



### In adults

lead exposure increases the risk of:

- ischaemic heart disease
- stroke



### In pregnant women

lead exposure damages many organs but also affects:

- the developing foetus



# Sources of lead exposure



CONCERNED ABOUT LEAD IN YOUR DRINKING WATER?

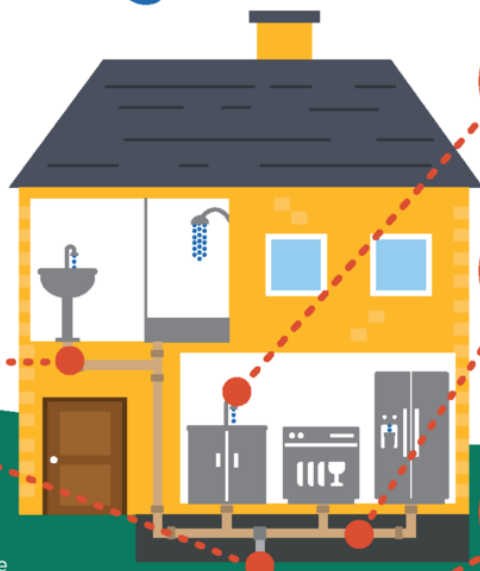
## Sources of LEAD in Drinking Water



**Copper Pipe with Lead Solder:** Solder made or installed before 1986 contained high lead levels.



**Lead Service Line:** The service line is the pipe that runs from the water main to the home's internal plumbing. Lead service lines can be a major source of lead contamination in water.



**Faucets:** Fixtures inside your home may contain lead.



**Galvanized Pipe:** Lead particles can attach to the surface of galvanized pipes. Over time, the particles can enter your drinking water, causing elevated lead levels.



**Lead Goose Necks:** Goose necks and pigtails are shorter pipes that connect the lead service line to the main.

## LEAD EXPOSURE CAN OCCUR THROUGH...

#BanLeadPaint



**Inhalation**  
of particles released by industry or recycling



**Ingestion**  
of contaminated soil or dust from decaying lead paint – particularly when children play on the ground and put toys or fingers in their mouths



### Lead-containing products

such as lead-glazed ceramics and some traditional medicines or cosmetics



**Food or water**  
contaminated with lead



There is no safe level of lead exposure

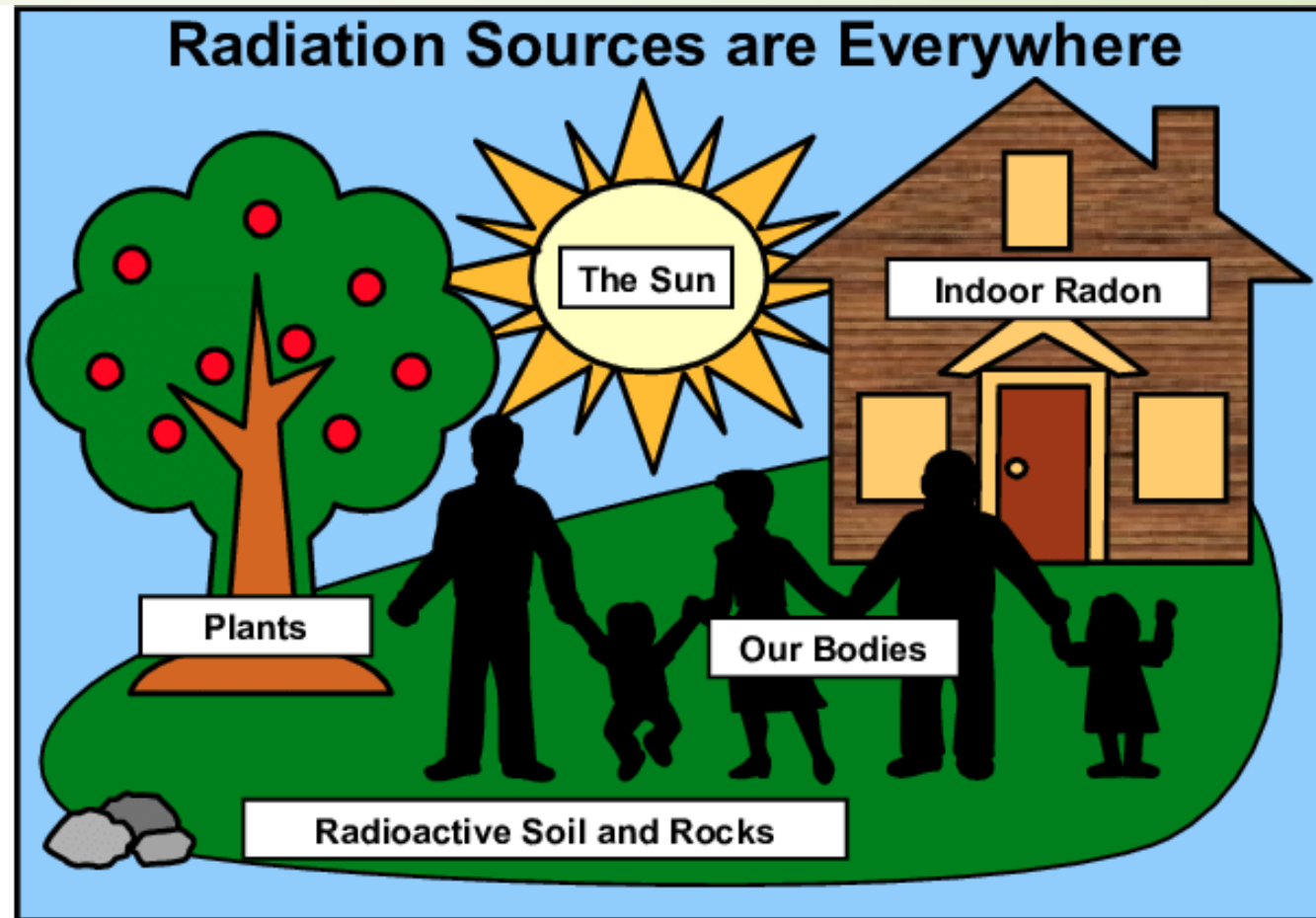
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# LABChico

An underground laboratory in the heart of Mexico



Radiation is everywhere

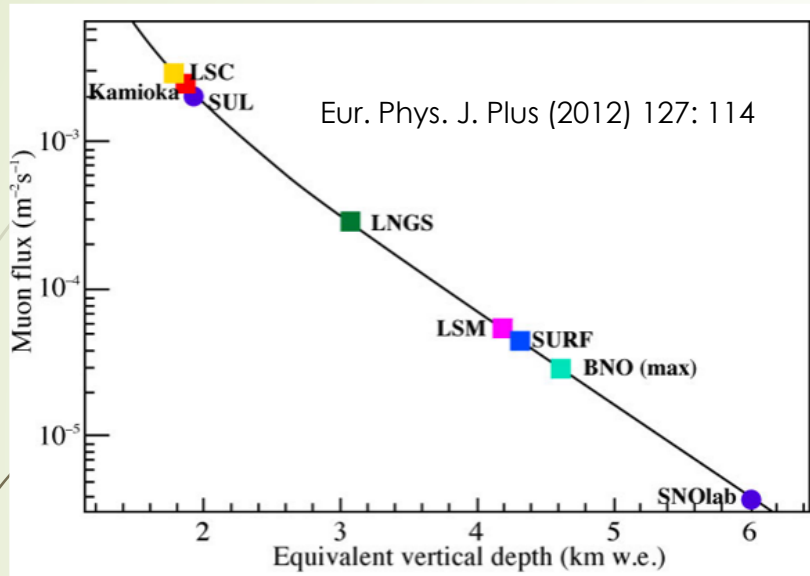


Everything around us is composed of radioactive isotopes and their radioactive decays produce gamma rays, alpha particles, beta particles, neutrons or neutrinos.

**A clean and well characterized environment helps mitigate those effects. Knowing the radiation pattern of the environment allows to know the composition of samples more accurately.**

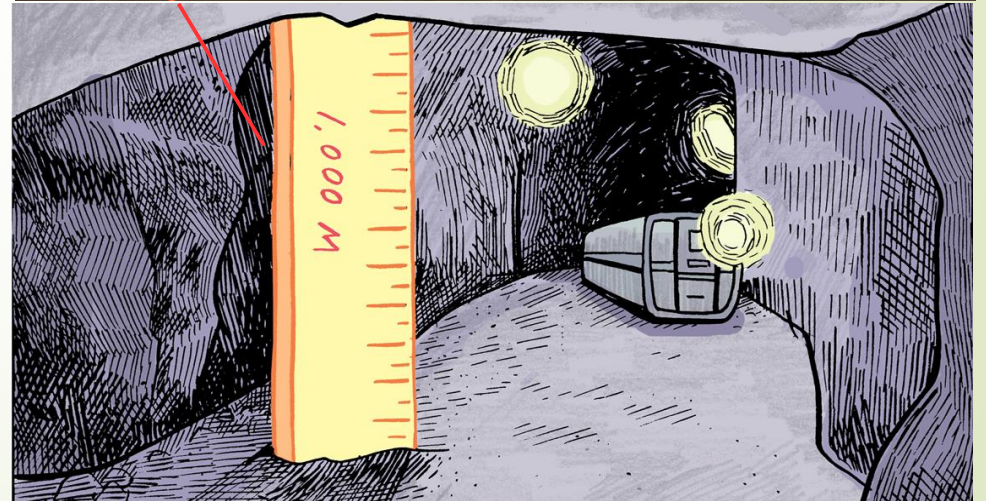
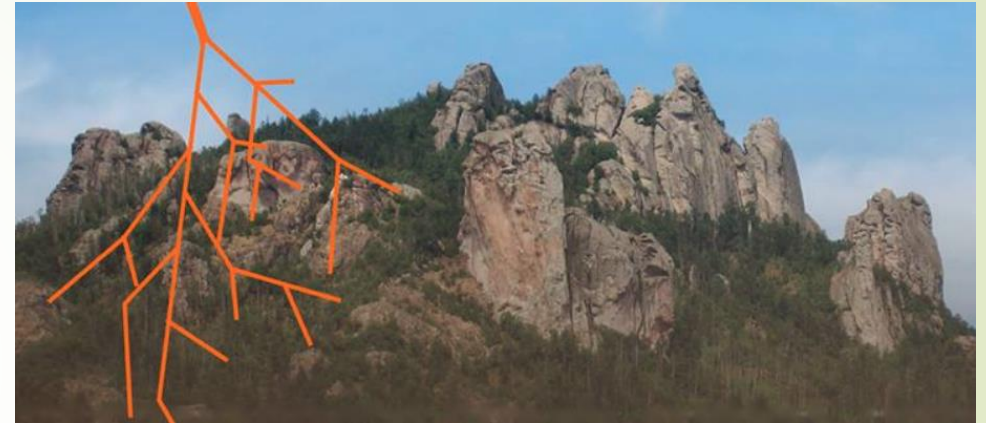
# Underground laboratories

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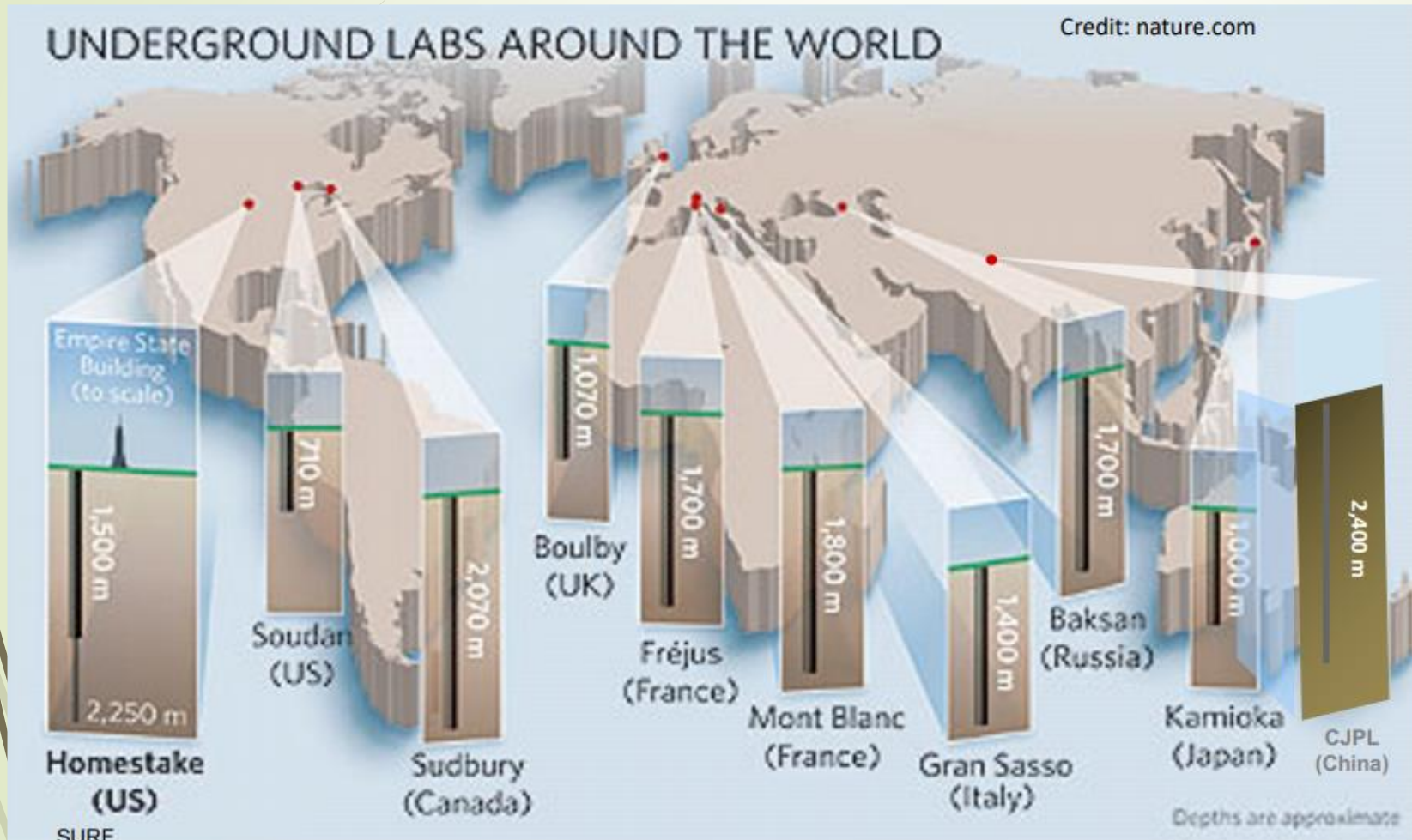


Cosmic rays produce a particle cascade in the atmosphere. Those particles (mostly muons) interfere with the detectors. Beneath earth the flux of those particles is much lower.

**A particle detector in the surface is like trying to hear the tic-tac of a watch in a rock concert.**



# Underground laboratories around the world



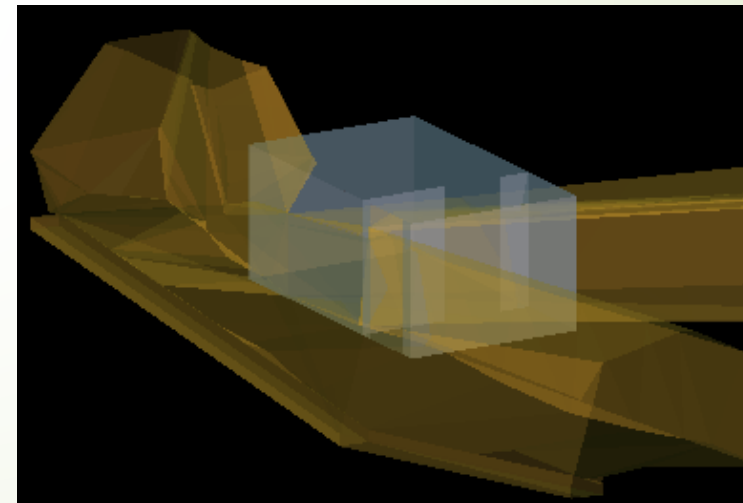
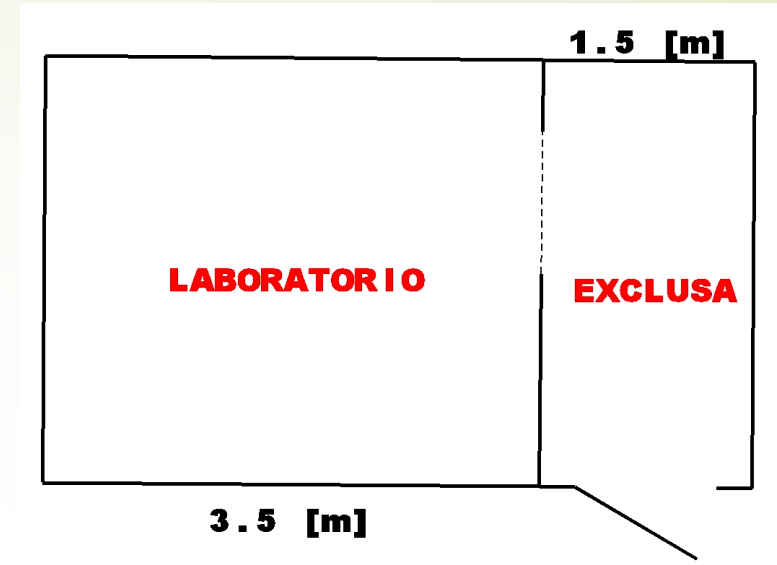
- There are many underground laboratories around the world in countries such as: USA, Canada, Italy, France, UK, Russia, China, Japan.
- Many more are in construction in India, Argentina and Australia



What will LABChico be?

# LABChico will be:

- A shallow (~100m overburden) underground laboratory inside a decommissioned silver mine that was in service for three centuries in central Mexico.
- A research laboratory of pure and applied sciences that will host experiments from Mexican and the world scientific community.
- A teaching space to highly qualified personnel in the field of low background and low radioactivity techniques.
- A place for outreach activities in Hidalgo.



# Where would it be located?

- In the Geopark “Comarca Minera”, Hidalgo, México.
- Inside the Guadalupe mine.
- 30 km away from the mexican city of Pachuca, Hidalgo.
- 135 km away from UNAM’s main campus (Ciudad Universitaria).
- Its location in the Geopark would give LABChico a long-term security and acceptance by local community.



# Geopark "Comarca Minera"



Organización  
de las Naciones Unidas  
para la Educación,  
la Ciencia y la Cultura



Comarca Minera  
Geoparque  
mundial de  
la UNESCO

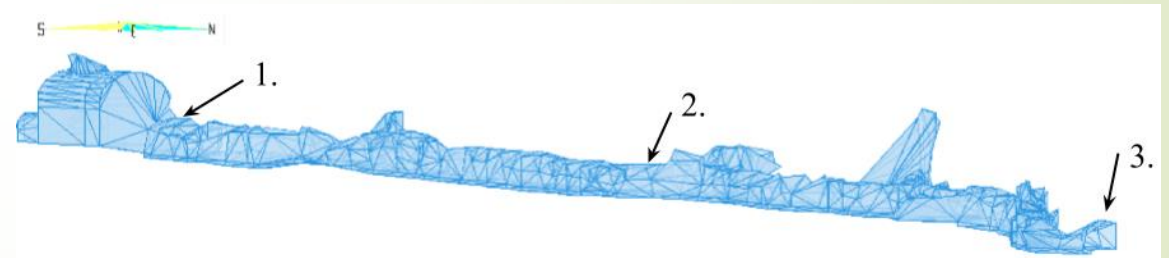
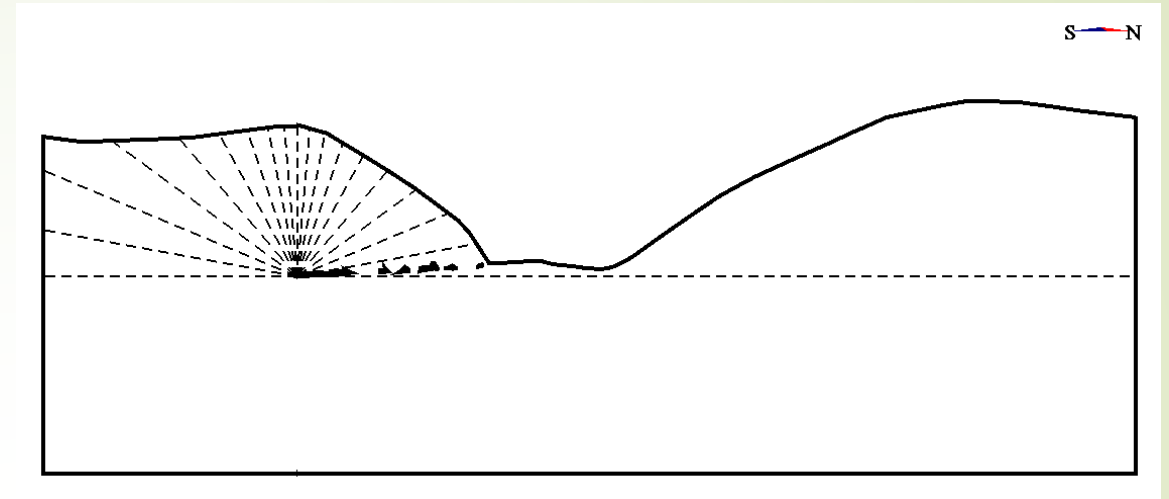


COMARCA MINERA  
GEOPARQUE HIDALGO



# Topographical survey for LABChico

- Figure at the top shows the side view, **at least 100 m of rock in all directions.**
- Figure at the bottom shows the current shape of the main tunnel of the mine.
- The room will be located almost at the end of the tunnel (~150 m).
- It is probable the tunnel will need some expansions, although it is undesirable to modify the shape of the tunnel substantially.
- The current state of the tunnel is evidence of the mining period in central Mexico.



1. Entrance to laboratory
2. Location where gamma flux was measured last march.
3. Entrance to mine





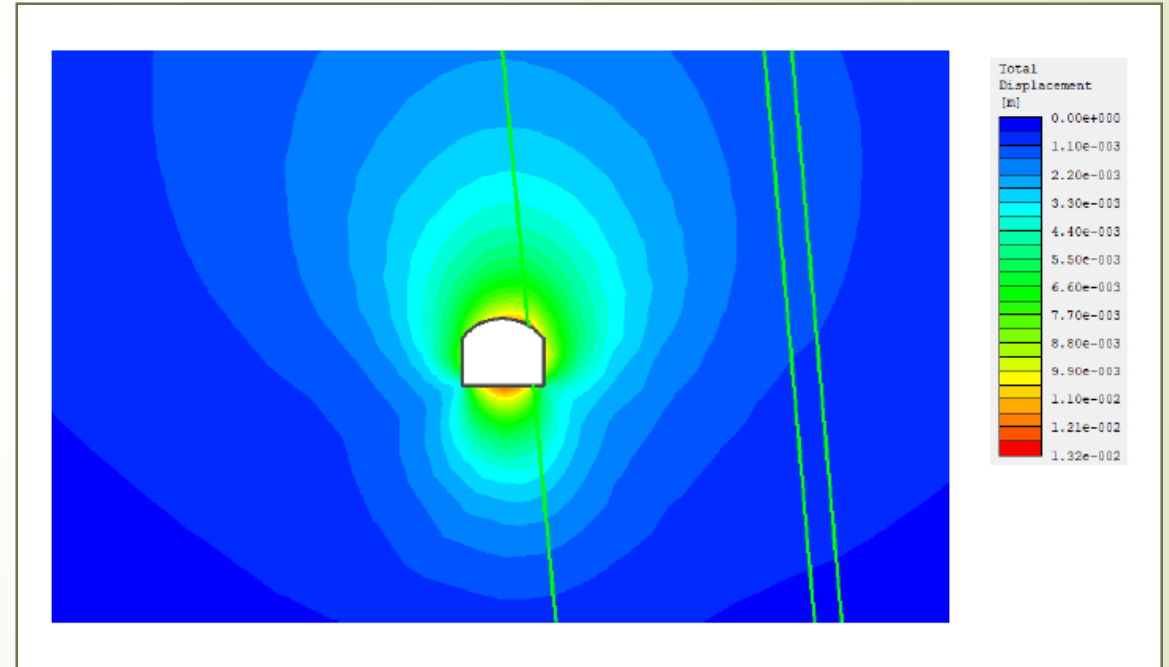
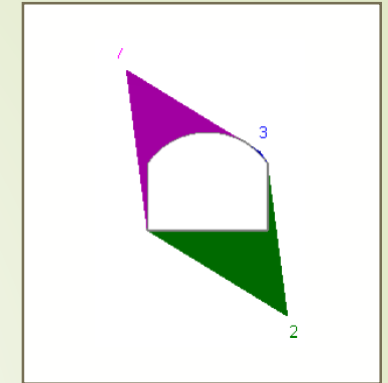
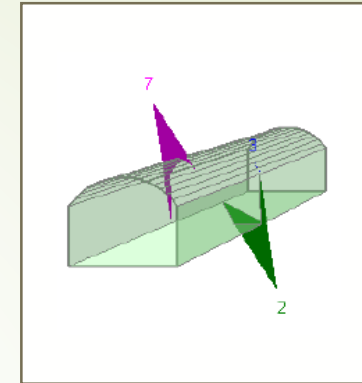
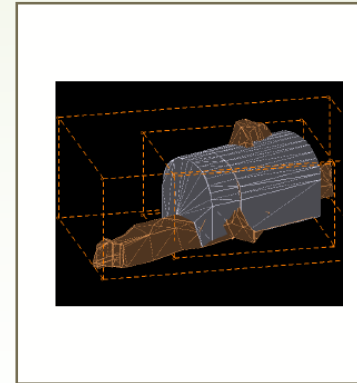
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## What about the tunnel security? Will LABChico be safe?

- **In its current state**, the site where the construction of LABChico is planned **is safe**.
- Around a century has passed since the mine was closed and **no accidents or rock collapses have been observed**.
- The rock in the surroundings is of good quality due to their excellent mechanical properties in general, however, more **studies have to be performed to ensure security during construction and operation** of the Laboratory.
- A team of engineers of the UNAM's School of Engineering performed **geomechanical studies** to precisely know the properties of the rock and know exactly the **maximum size of the room without compromising the security**.

## Geomechanical studies

- The studies identified a secure volume of rock that could be removed but inhomogeneities were found too.
- A section of rock represented as purple would be the main safety risk.
- Then, an anchoring with concrete was proposed in order to fix it.
- FEM simulations were performed to know the displacement and strain of the rock.
- **The maximum dimensions are: 6m x 5m x 4.5m.**



# Test deployment of detectors

- Until now, there have been three test deployments: two of the HPGe and one NaI (TI) detector.



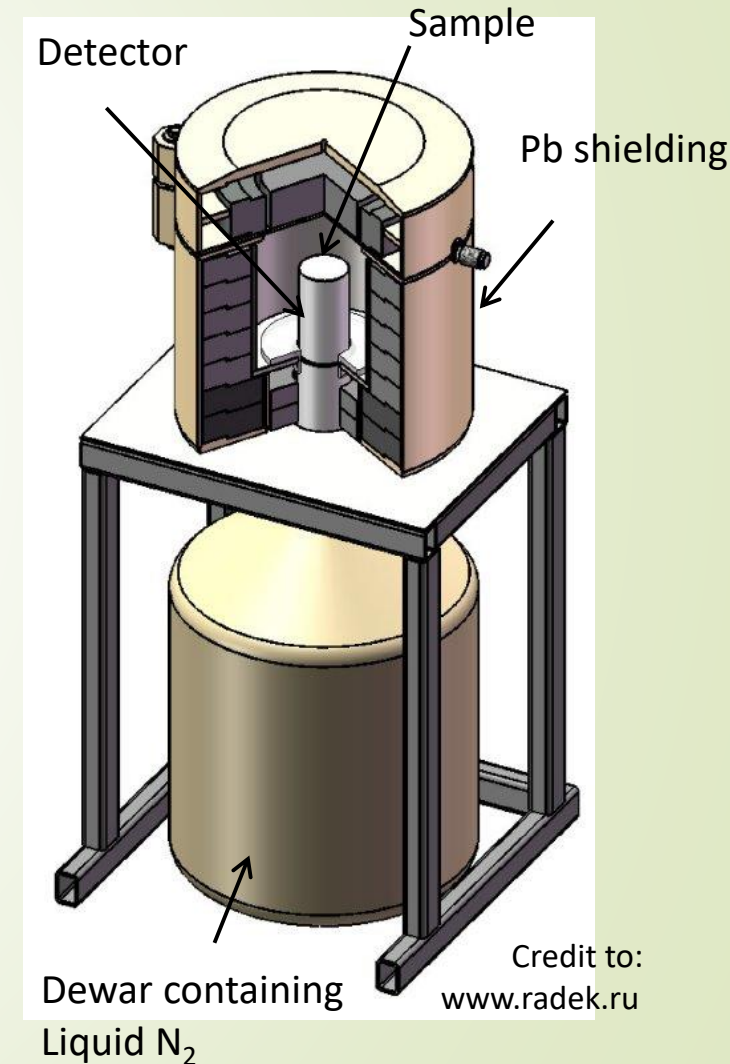
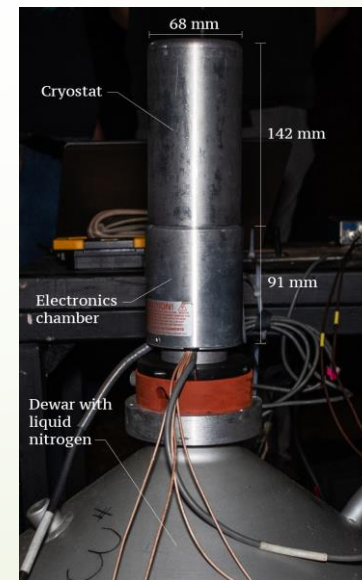
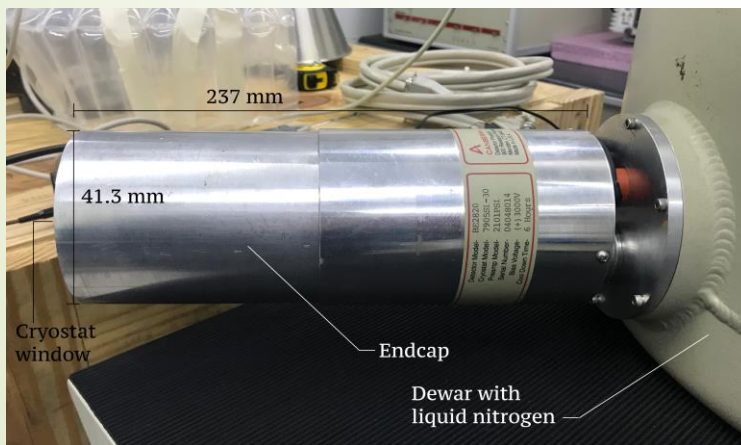
Second deployment May 6 and 7,  
2020  
La Guadalupe mine

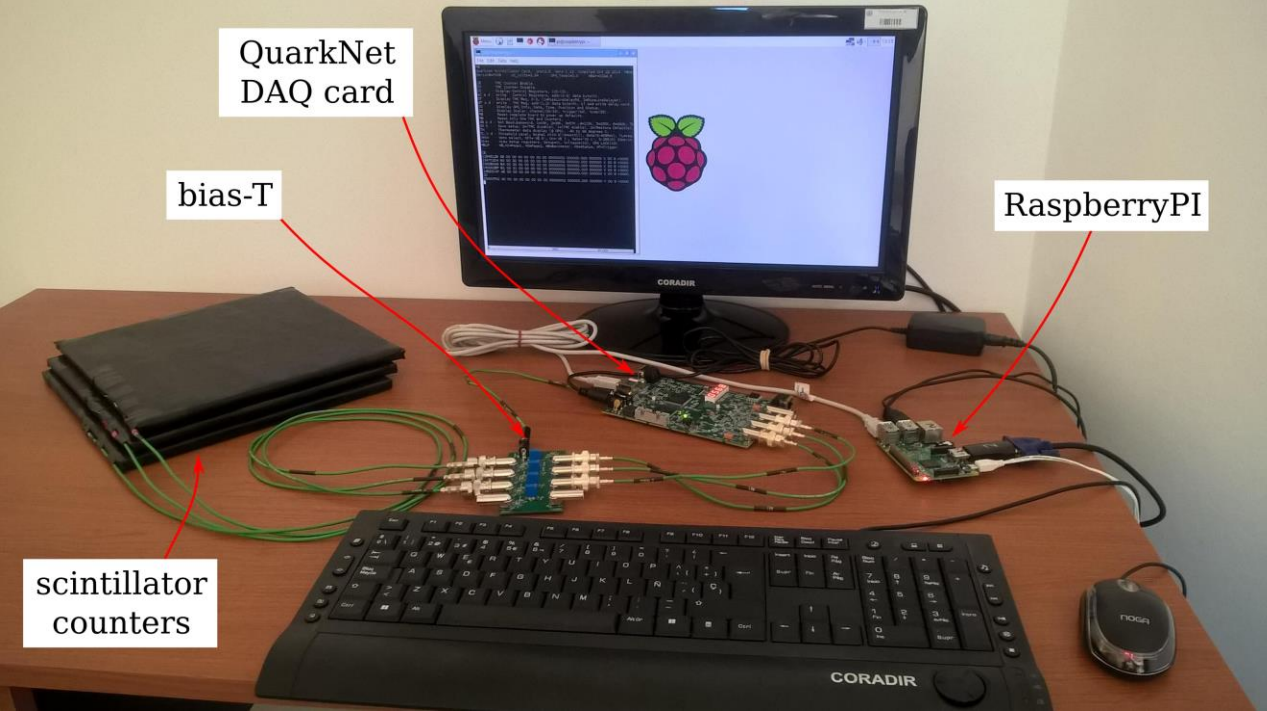
First deployment  
Nov 20 and 21, 2018  
San Antonio mine

Third deployment  
Mar 12 and 13, 2020  
La Guadalupe mine

# Instrumentation for LABChico: HPGe

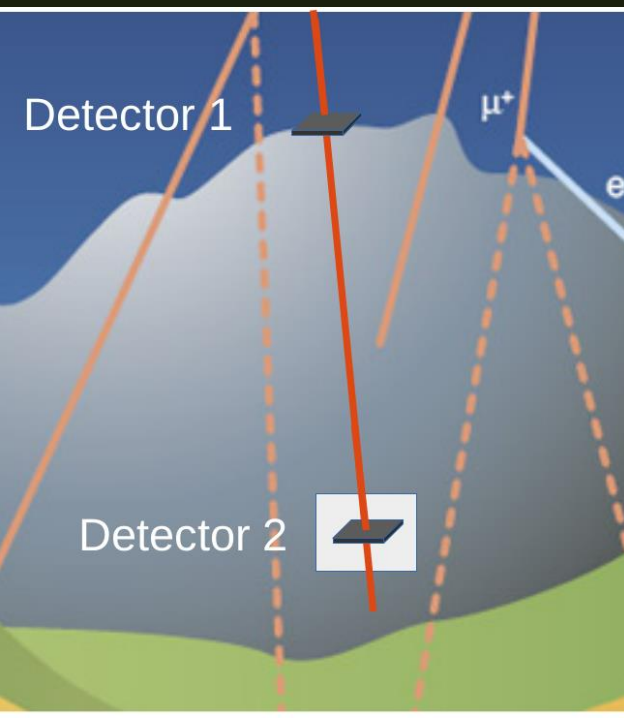
- There are two HPGe detectors: ICN-HPGe (to be installed at LABChico) and IF-HPGe.
- HPGe detectors are cooled down using LN<sub>2</sub>.
- Detectors are shielded surrounded by Pb, copper and iron.
- Both detectors were manufactured by Ortec.





## Instrumentation of LABChico: a muon detector

- The muon detector was designed by Federico Israelevich (Escaramujo project, Universidad Nacional San Martín, Arg.).
- The escaramujo detects muons so it is possible to measure muon flux.
- Two detectors will be placed: one inside of the mine and one outside (visitors center).
- They will serve to measure the muon flux attenuation due to rock.



# LABChico on the news

- National or local media showed interest for the Laboratory.



# Follow LABChico on social networks

You will find more information about the laboratory and its activities.



**/LABChico**



**@LAB\_Chico**

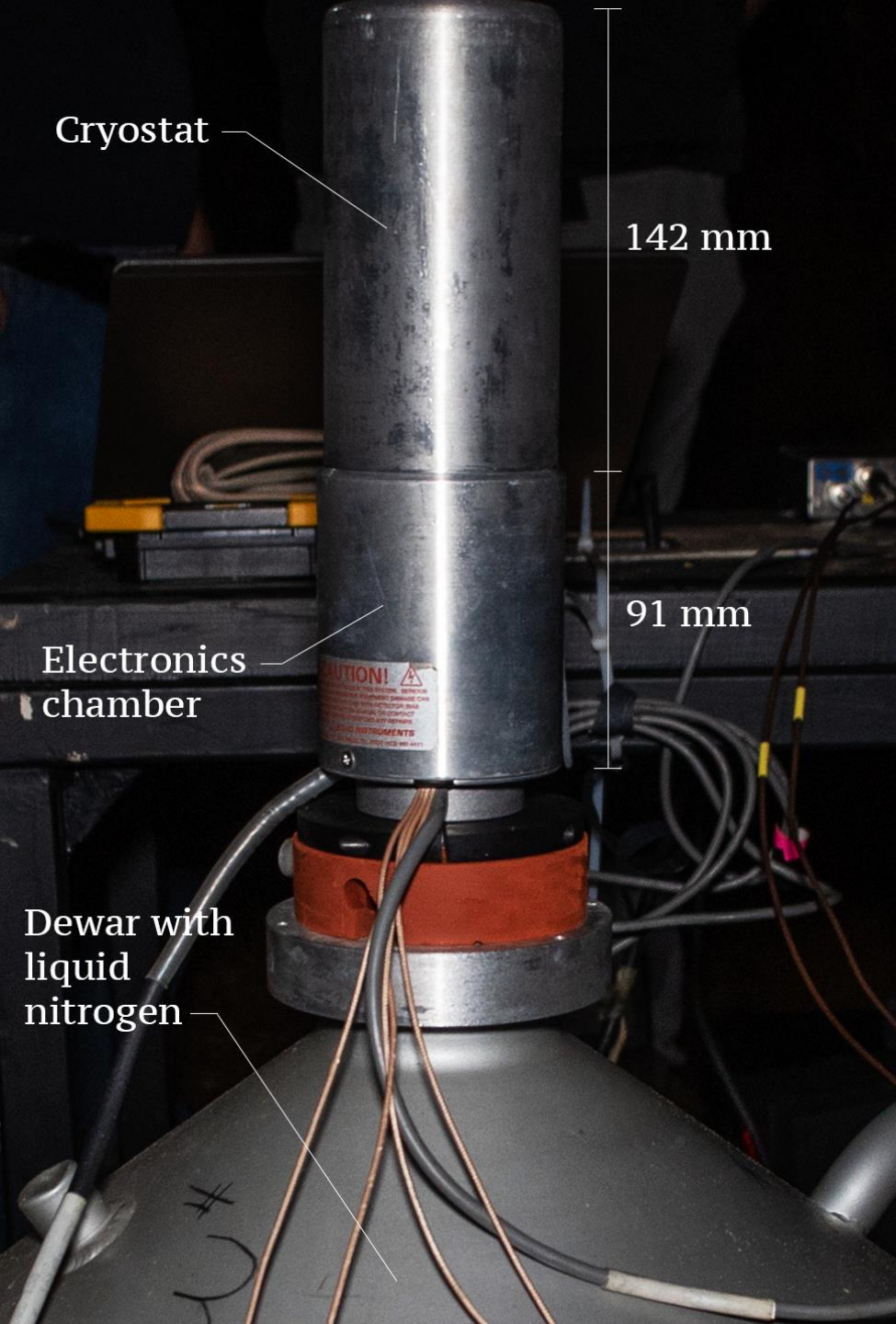


**@labchico**

# Characterization of LABChico HPGe detectors

Published in JINST 15 (2020) 11, P11014, [arXiv:2009.11757]





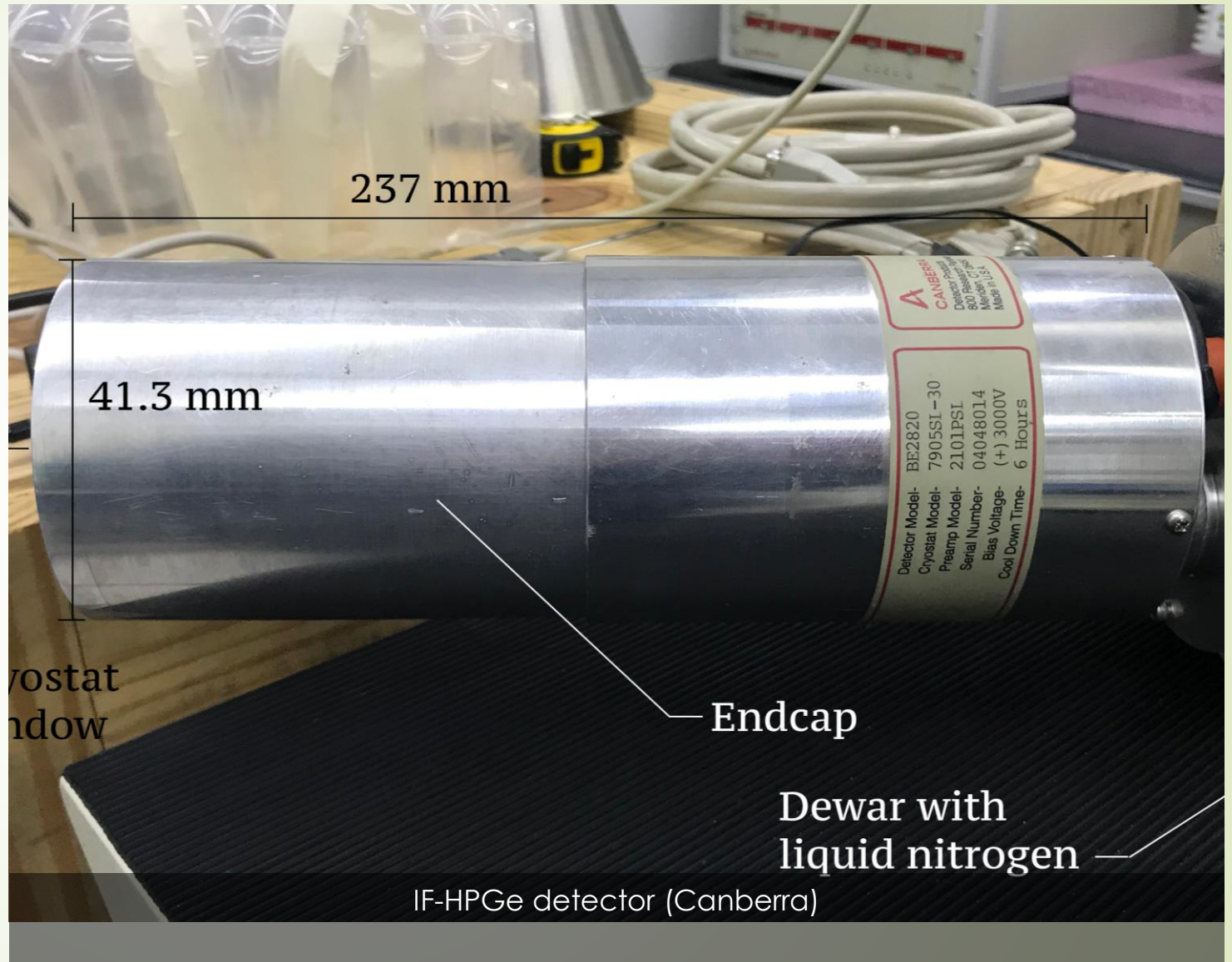
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## Specifications of LABChico's ICN-HPGe detector

- ICN-HPGe detector (Ortec) is a p-type with a coaxial closed vertical geometry.
- It operates with a -3,200 V voltage bias.
- A PX5-HPGe multichannel analyzer (MCA) and a digital pulse processor and software analyzer provided by Amptek.
- Internal dimensions were estimated using X-rays images.

# Specifications of LABChico's IF-BeGe detector

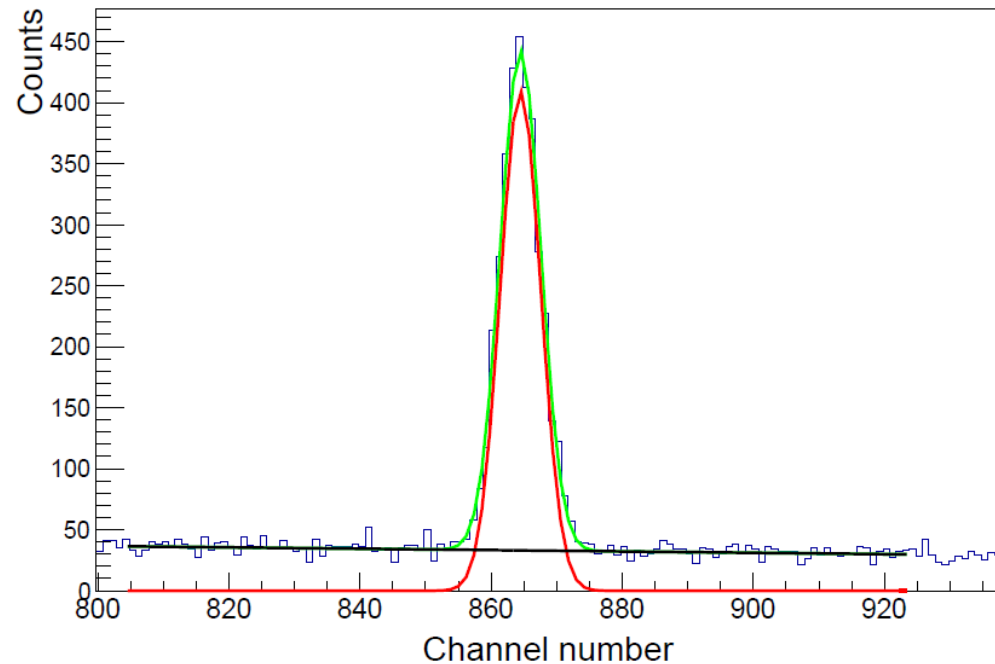
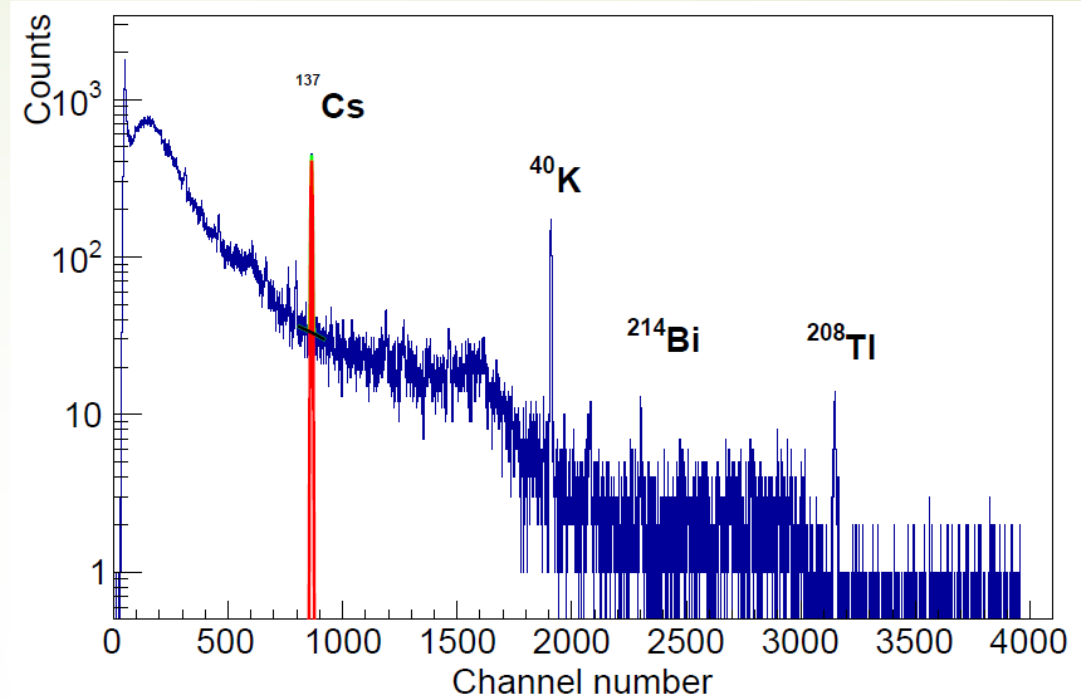
- IF-BEGe detector (Canberra) model BE2820.
- Horizontal planar configuration with 30 mm radius and 20 mm height.
- Operational bias of +3000V.
- Pocket MCA 8000 A (DAQ).
- ADMCA software of Amptek.
- To be used for cross-check measurements at UNAM.



# Energy response of LABChico's Ge detectors

- Used a set of radioactive sources with 20% of uncertainty in activity.
- Those sources were placed at 25 cm from the detector endcap.

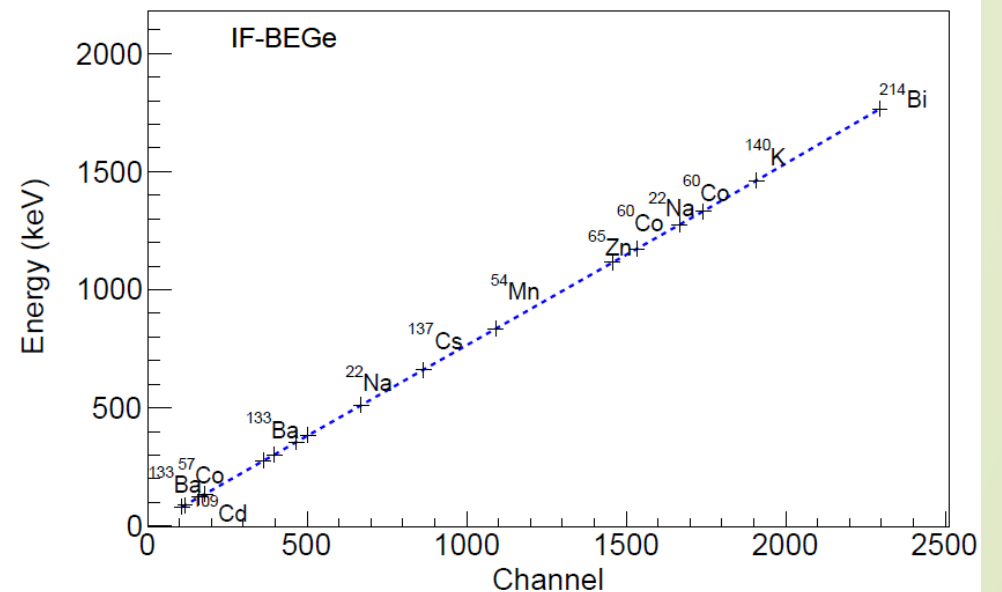
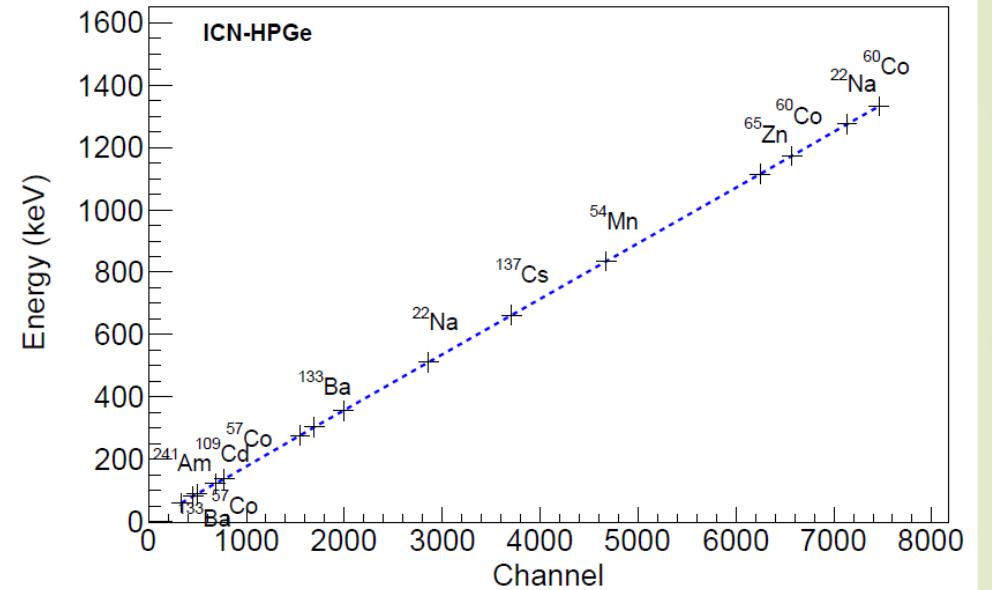
Source	$\gamma$ peaks [keV]	Half-life [yr]
$^{241}\text{Am}$	59.54	432.2
$^{133}\text{Ba}$	81.0, 276.0, 303.0, 356.0	10.5
$^{109}\text{Cd}$	88	1.27
$^{57}\text{Co}$	122.0, 136.0	0.745
$^{22}\text{Na}$	511.0, 1275.0	2.6
$^{137}\text{Cs}$	662.0	30.1
$^{54}\text{Mn}$	835.0	0.855
$^{65}\text{Zn}$	1115.0	0.668
$^{60}\text{Co}$	1173.2, 1332.5	5.27



# Linearity of LABChico's Ge detectors

- A radioactive source set with 20% of uncertainty was used.
- Those sources were placed at 25 cm from the detector endcap.
- After setting the configuration of the MCA, spectra were captured for each radioactive source of the set.
- A linear correlation between channels and the well-known energies of the gamma rays was obtained.

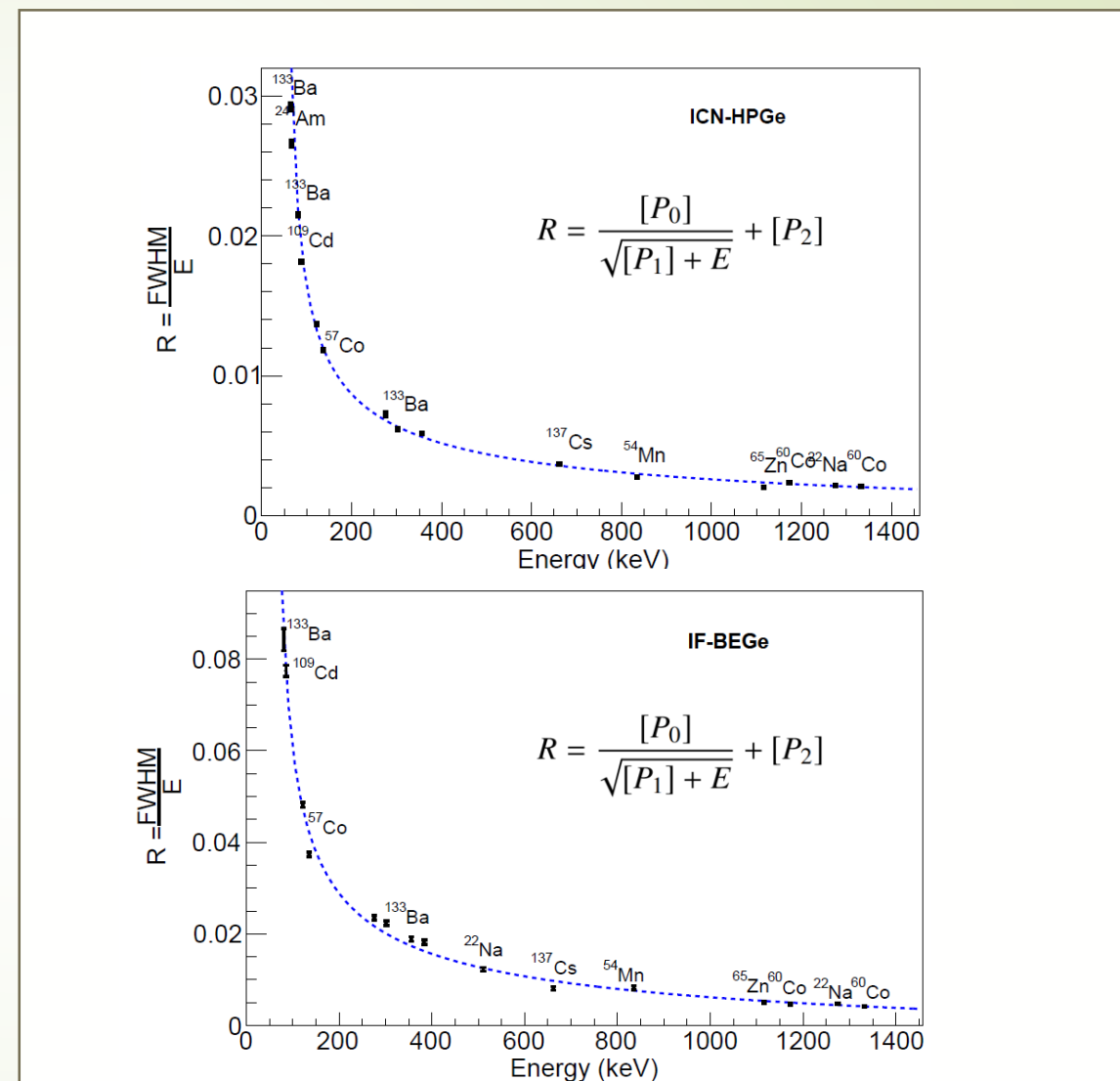
Parameter	ICN-HPGe	IF-BEGe
m	$0.1800 \pm 0.0001$	$0.7662 \pm 0.0002$
b	$-0.19 \pm 0.32$	$-1.62 \pm 0.19$



# Resolution of LABChico's detectors

- Spectra were fitted to a Gaussian plus one order polynomial with negative slope.
- Then, the full width at half maximum (FWHM) is given as approximately  $2.355\sigma$ .
- The resolution is given as:
 
$$R = \text{FWHM}/E$$
- The more energetic the gamma ray, the wider the photopeak is.

Parameter	ICN-HPGe	IF-BEGe
$P_0$ (keV)	$1.38 \times 10^{-1} \pm 1.14 \times 10^{-2}$	$4.49 \times 10^{-1} \pm 1.0 \times 10^{-3}$
$P_1$ (keV)	$-36.73 \pm 5.21$	$-57.68 \pm 0.11$
$P_2$	$-1.63 \times 10^{-3} \pm 3.54 \times 10^{-4}$	$-8.45 \times 10^{-3} \pm 2.70 \times 10^{-5}$

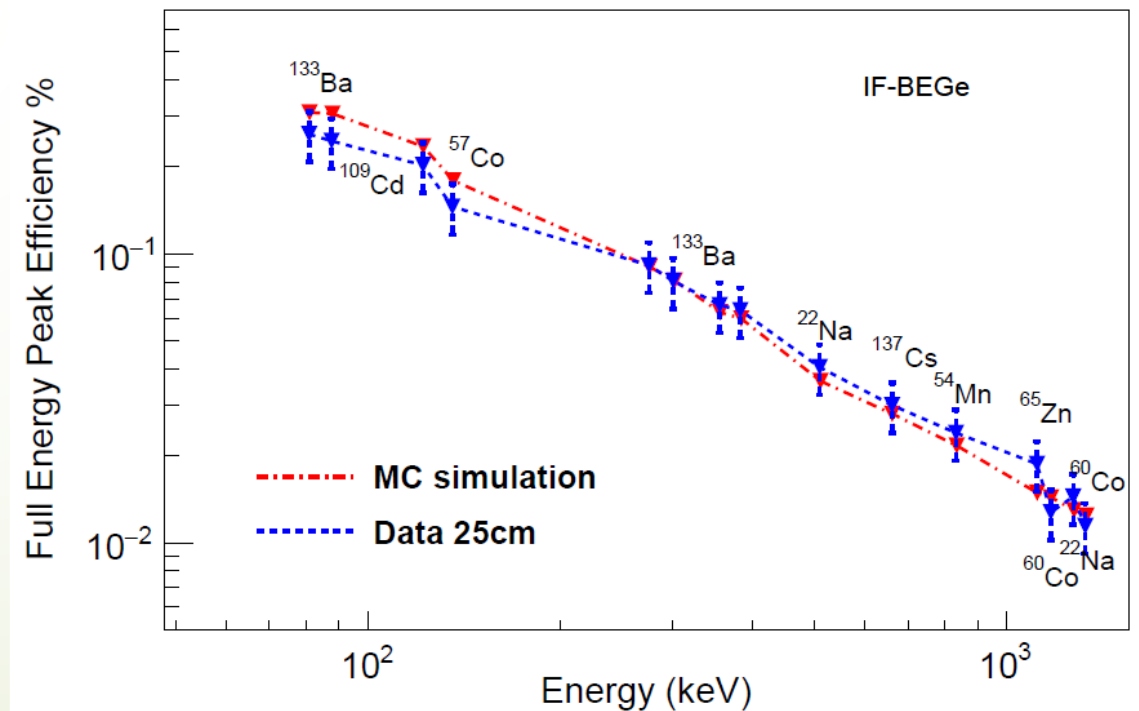
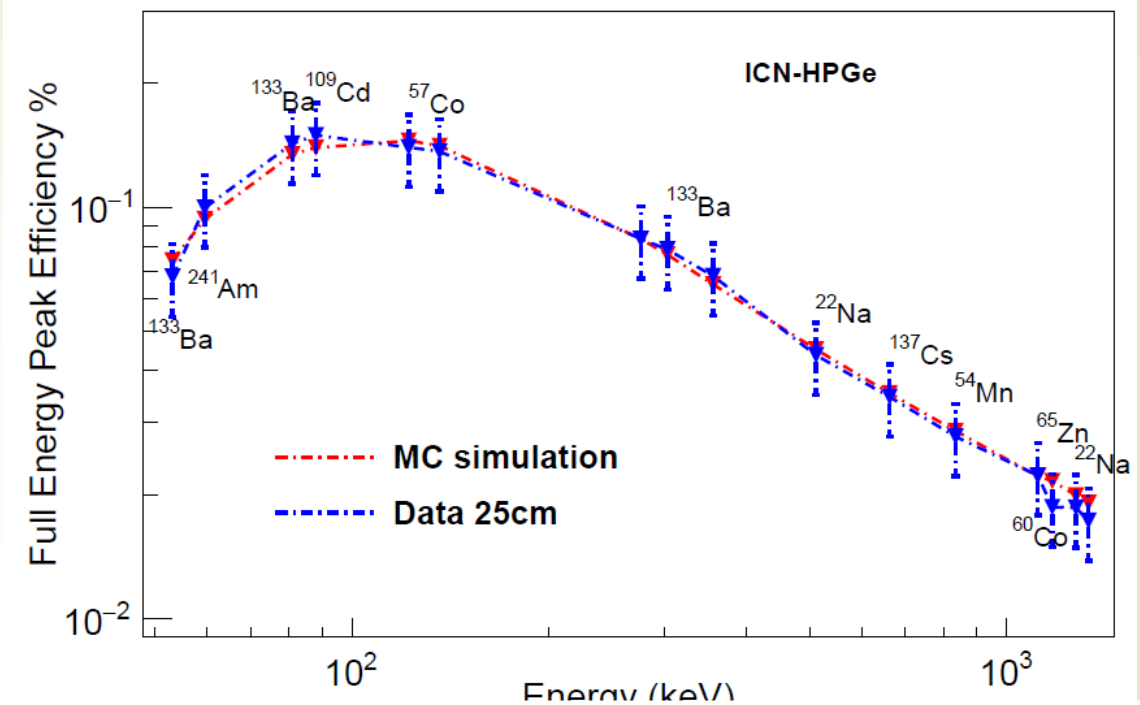


# Photopeak efficiency of LABChico's detectors

- The absolute efficiency is defined as:

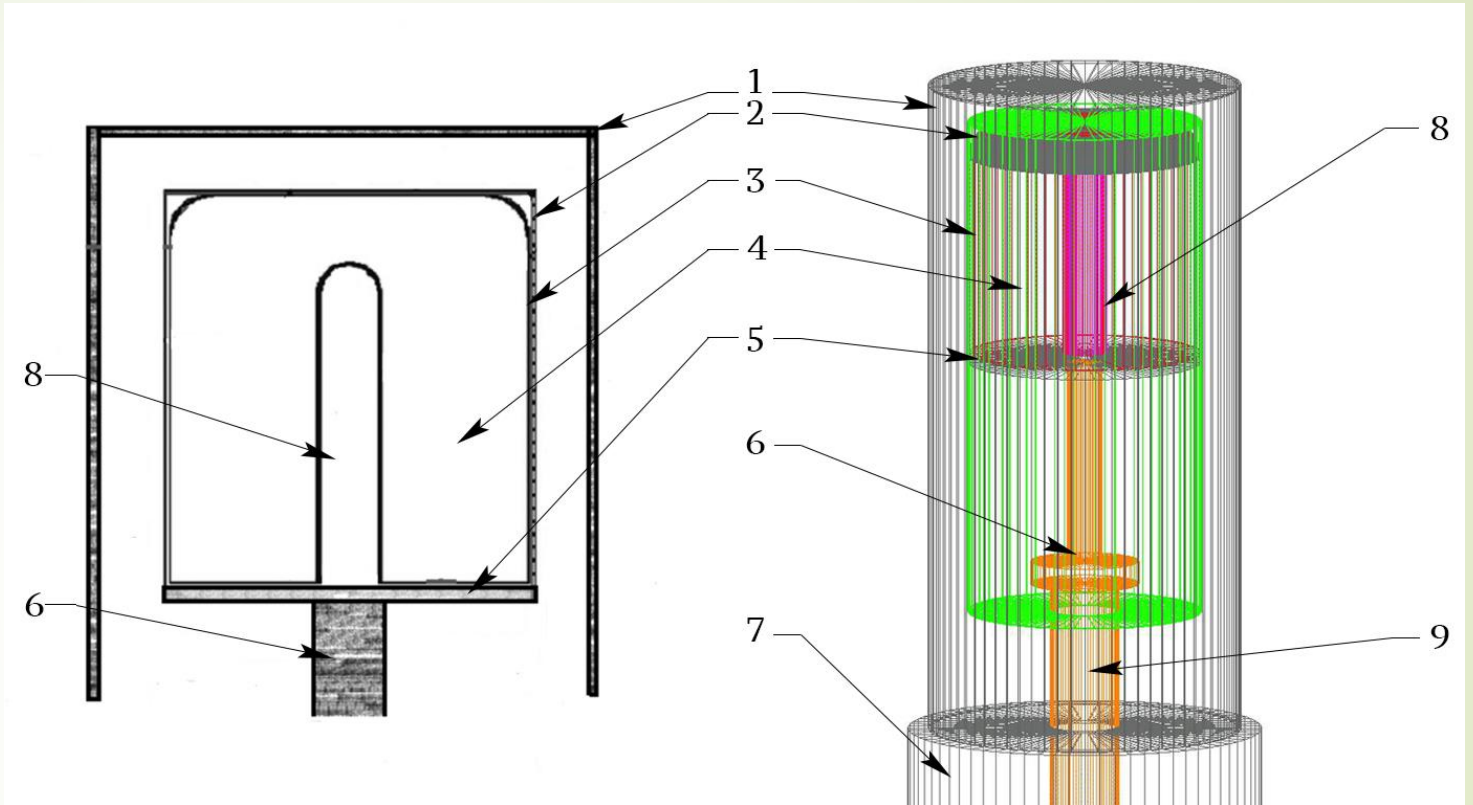
$$\epsilon = \frac{N_{FEP}}{P_{\gamma} N_{TOT}}$$

- $N_{FEP}$  is the full energy peak count rate,  $P_{\gamma}$  is the emission probability of the gamma ray being measured and  $N_{TOT}$  is the total number of gamma rays emitted at the specific energy.
- $N_{TOT}$  should consider the reduced activity since the source was manufactured.



## Monte Carlo simulations of LABChico's detectors: ICN-HPGe

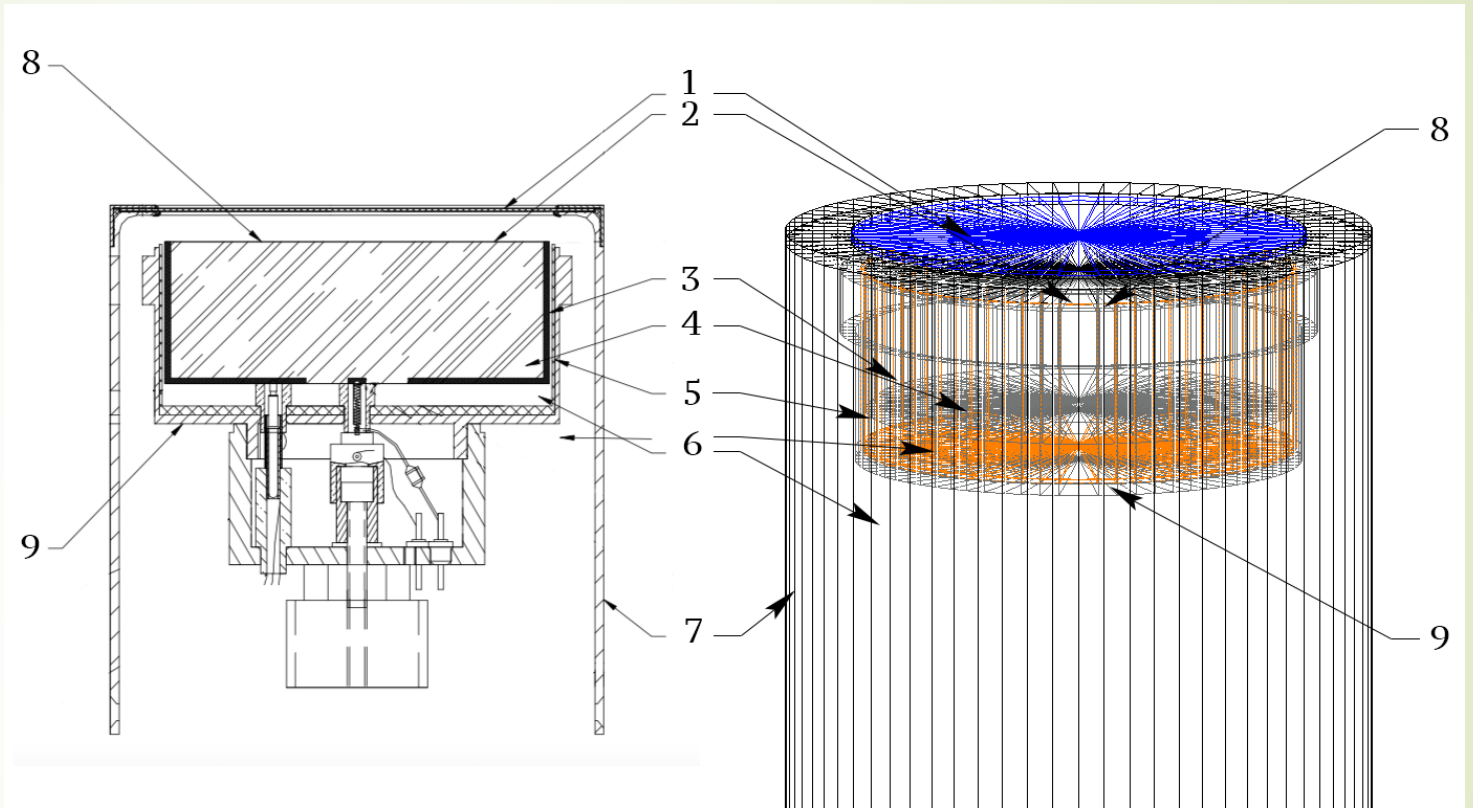
1. Cryostat
2. Outer contact
3. Dead layer
4. Germanium crystal
5. Carbon fiber endcap
6. Thermal strap
7. Electronics chamber
8. Inner contact
9. Cold finger



Monte Carlo simulations were performed in GEANT4. All components that could interfere with gamma ray detection are simulated. Best match for dead layer is 0.65 mm.

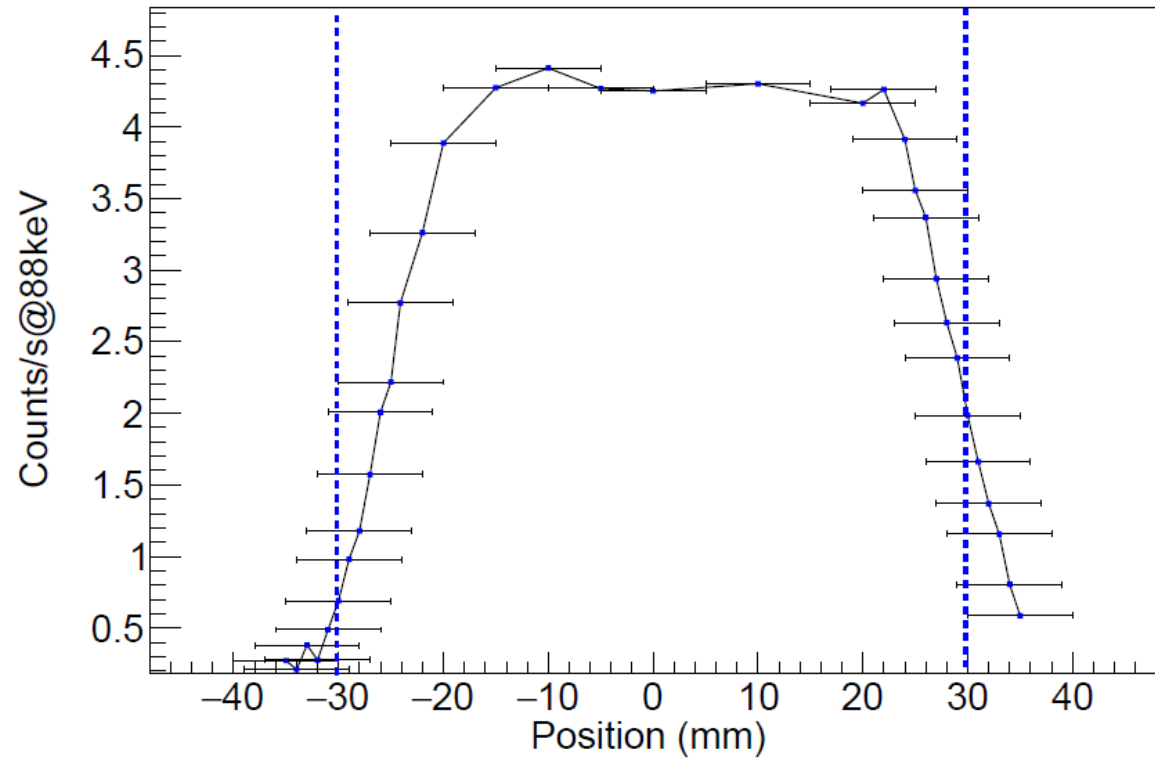
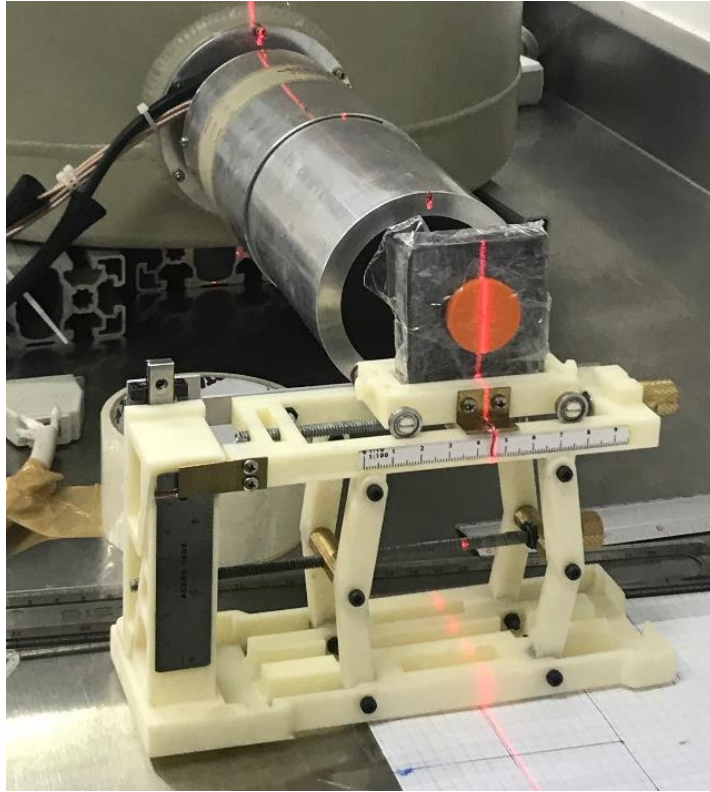
# Monte Carlo simulations of LABChico's detectors: IF-BEGe

- 1. Cryostat
- 2. IR window
- 3. Side electrode dead layer
- 4. Germanium crystal
- 5. Teflon cup
- 6. Vacuum space
- 7. Endcap
- 8. Front electrode dead layer
- 9. Detector holder



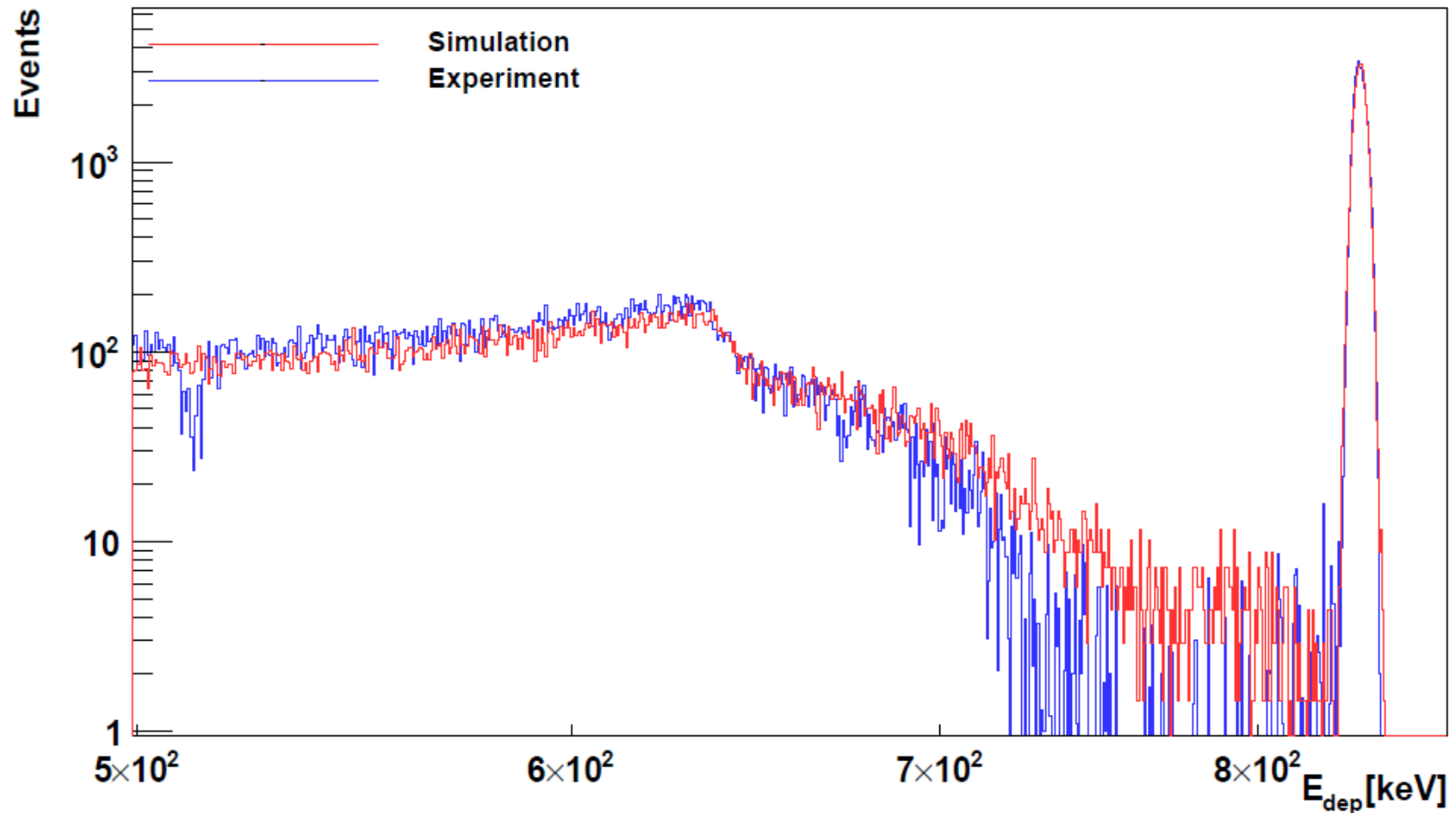
The dead layer was modeled as 0.05 mm on the front, 1.45 mm on the sides and 2.8 mm on the back, which contrast with what was specified by the manufacturer (500  $\mu\text{m}$  at the sides and 0.3  $\mu\text{m}$  on the front). 30% disagreement between both simulated results. The manufacture's specification is not accurate.





## Active volume of IF-BEGe detector

- ▶ A lead collimator was used to focus the gamma beam on a narrower point.
- ▶ Spectra were taken for 1 hour.
- ▶ A clear asymmetry between the response of the right/left sides was observed, this was not reported in the datasheet.



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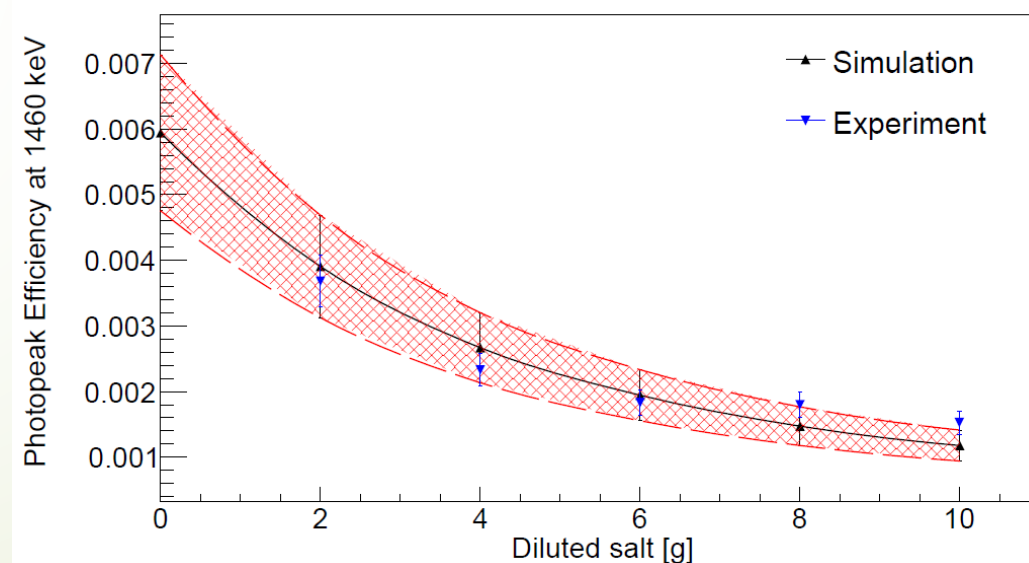
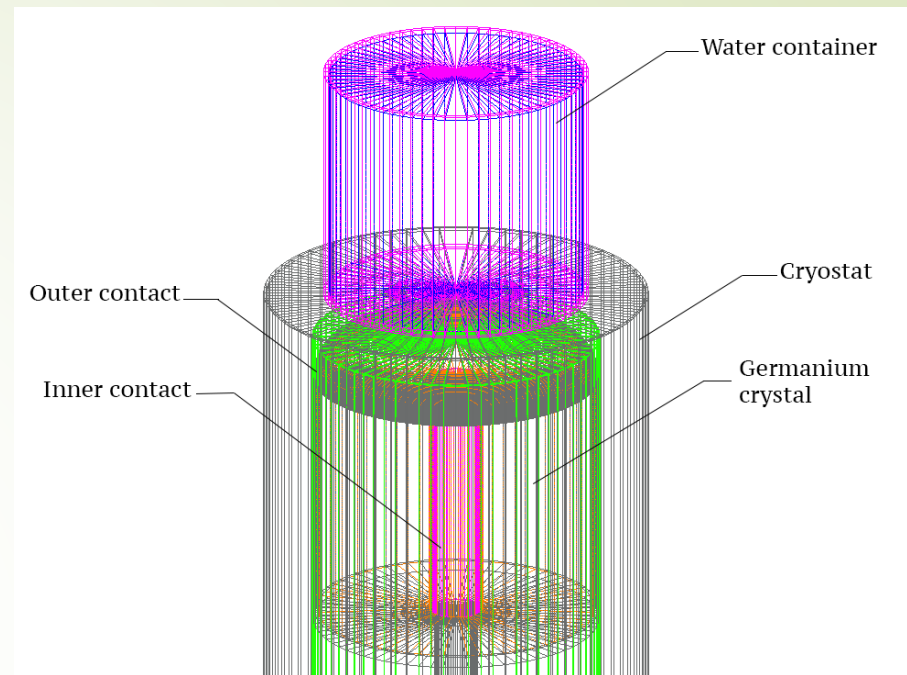
## Comparison between experimental data and Monte Carlo

- ▶ Experimental (background subtracted) and simulated spectra of  $^{54}\text{Mn}$ .
- ▶ Agreement is observed for the photopeak at 835keV, the Compton shoulder and the Compton continuum.

# Validation with extended sources: KCl dissolutions

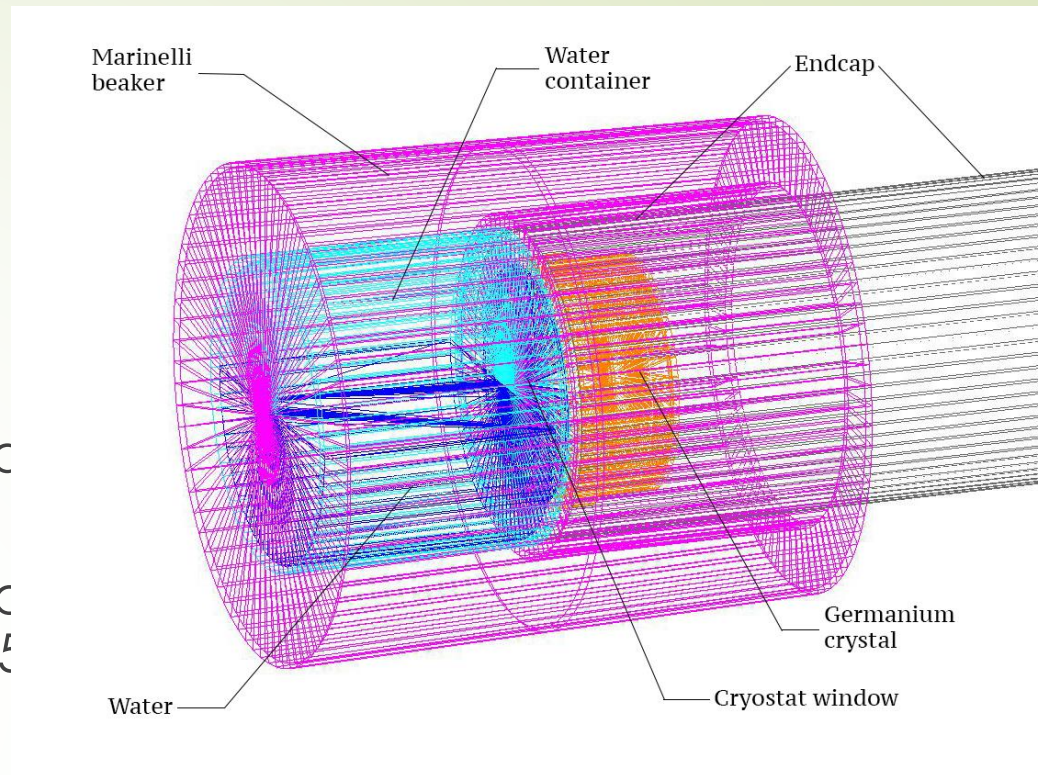
- ICN-HPGe detector was used to measure the  $^{40}\text{K}$  concentration in commercial potassium salt and 5 dissolutions were prepared using injectable water.
- Spectra were taken for different concentrations and the background (measured using a container with pure injectable water) were subtracted.
- Monte Carlo simulation allows to obtain the efficiency of the detector considering the specific geometry.
- Self-absorption effect of gammas was observed at higher concentrations.
- The concentration of  $^{40}\text{K}$  is:

$$\eta_s = 0.0324 \pm 0.0028 \text{ mg}[^{40}\text{K}]/\text{g}[\text{PS}]$$



# Validation with extended sources: $^{210}\text{Pb}$ samples

- Water samples containing  $^{210}\text{Pb}$  were prepared in Boulby.
- Monte Carlo simulations were performed to calculate IF-BEGe detector's efficiency at 46.5 keV.
- Extended sources were prepared at Royal Holloway, next, they were measured at the Boulby underground laboratory. Their radioactive activities were determined.
- Agreement was found among the results of Boulby, IF-BEGe detector and the expected value.



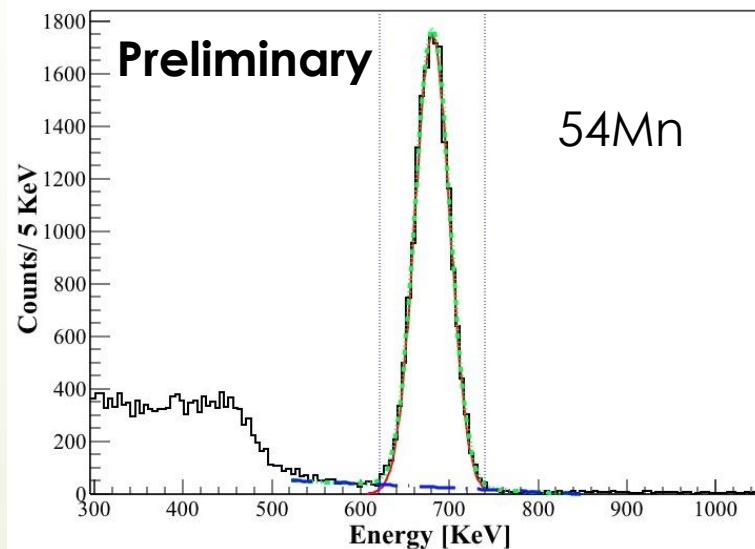
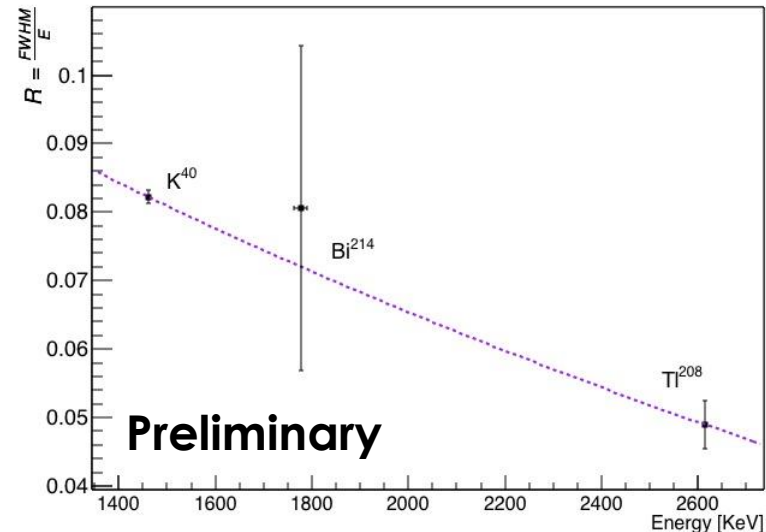
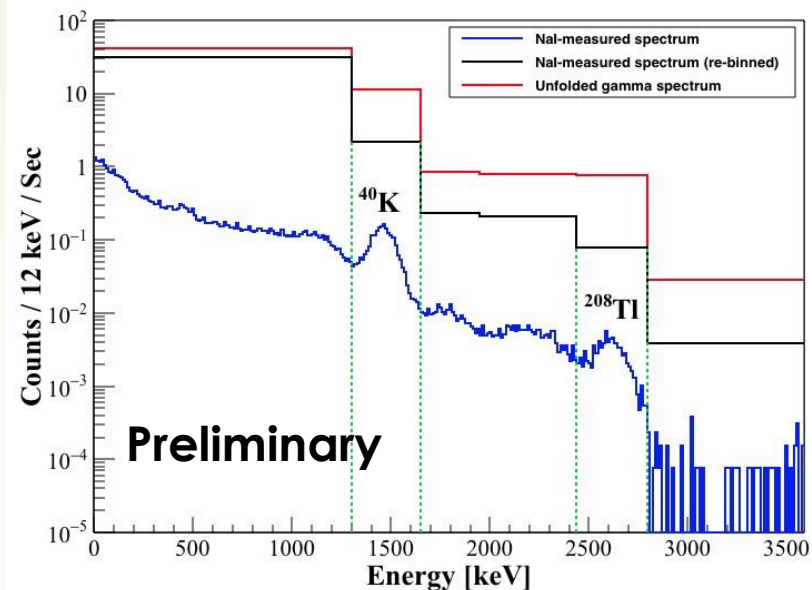
	Mass (g)	Expected (Bq/kg)	Boulby (Bq/kg)(stat)	IF-BEGe (Bq/kg)(stat+sys)
I	170.8	blank	N/A	N/A
II	165.6	40	26.9(6)	26(4)
III	177.9	22	23.3(3)	17(2)
IV	163.6	N/A	0.029(7)	2.5(4)
V	124.6	70	77(1)	71(10)
VI	120.45	744	754(3)	837(124)

# Gamma flux measurement in La Guadalupe mine (LABChico)

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# Gamma flux measurement

- Gamma flux was measured inside the mine where LABChico will be located.
- The measurements were performed using a Thallium Activated NaI(Tl) detector.
- Flux from  $^{40}\text{K}$ ,  $^{214}\text{Bi}$  and  $^{208}\text{Tl}$  extracted from a rebinned Unfolded Spectrum.
- Work in preparation.



“histoGe”: a software to identify radioactive isotopes in gamma spectroscopy

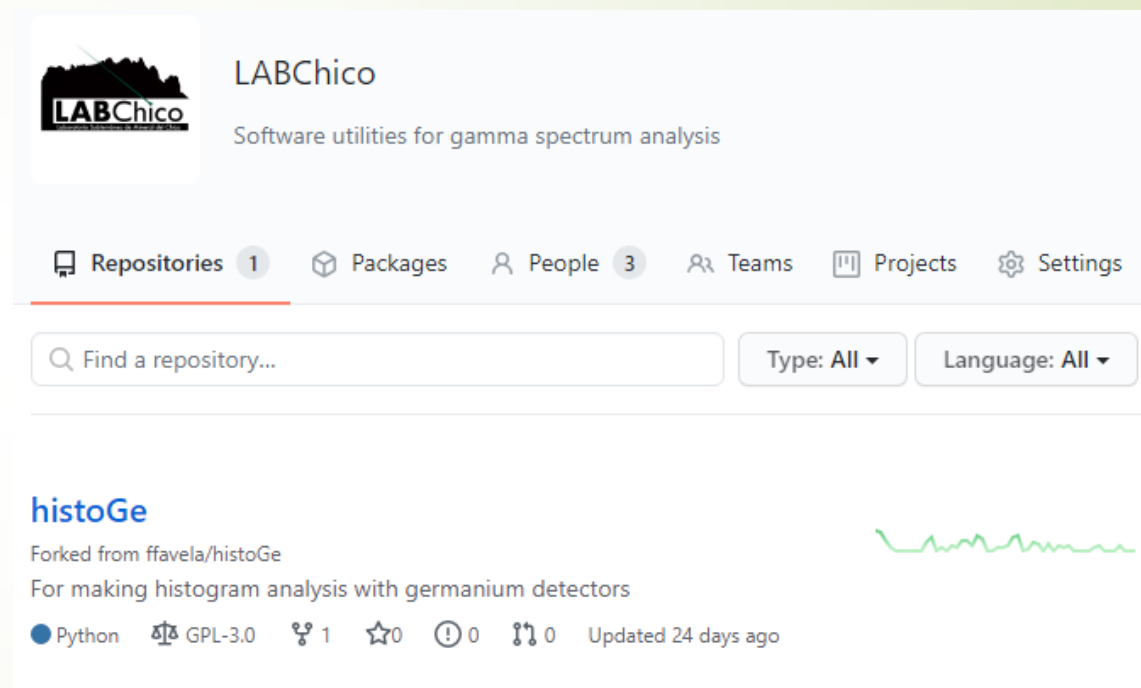
## Which solutions have been proposed previously?

- ▶ Until now, many solutions exist to identify isotopes in spectra. Some of them are: SPECTREW, Hyperlab, Gammalab (NUCDATA – database of only 408 isotopes), ASPRO-NUC (database with 45,000 gamma lines).
- ▶ Some of the techniques that have been used for isotope identification include: swarm optimization, Fisher linear discriminant analysis, Bayesian statistics approach, neural networks and hybrid fuzzy-genetic algorithm.



# What is histoGe software?

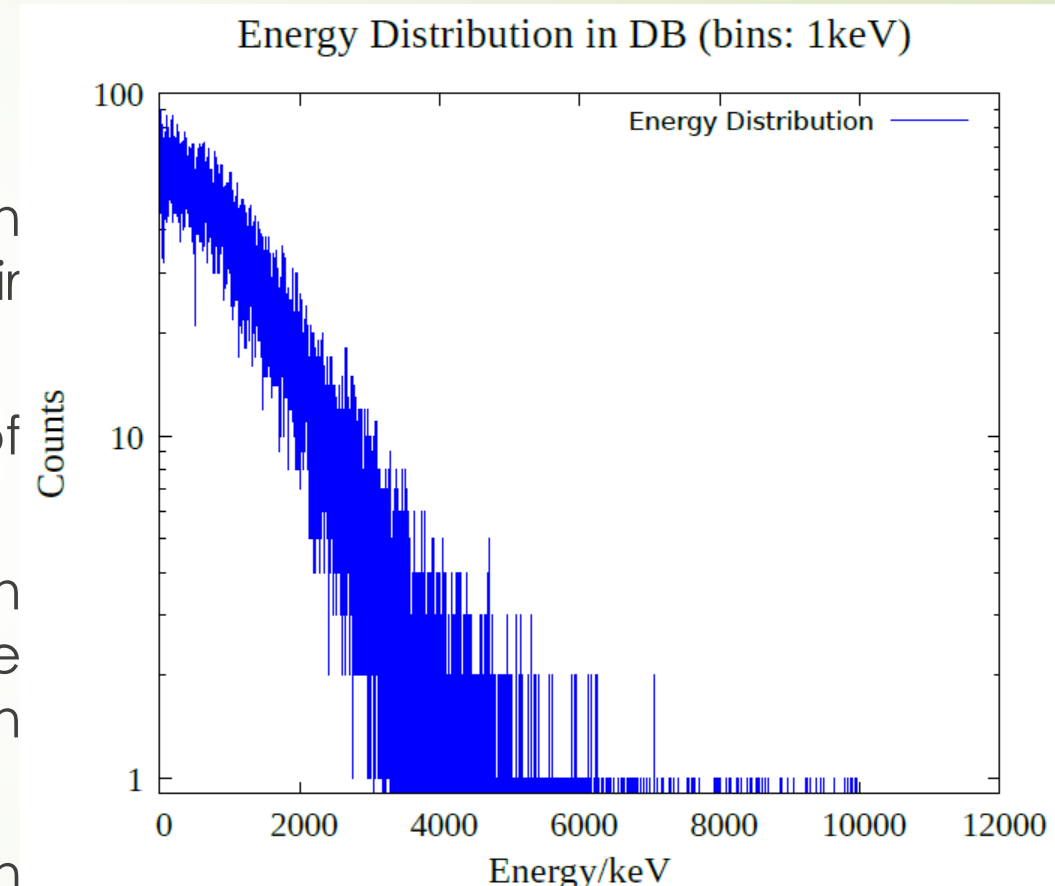
- histoGe is a free computational software programmed in python3.
- It was designed to plot spectra, calculate Gilmore statistics of peaks in a spectrum, automatic peak detection, consultation of database and identification of isotopes through the photopeaks found in a spectrum.
- <https://github.com/LABChico/histoGe>

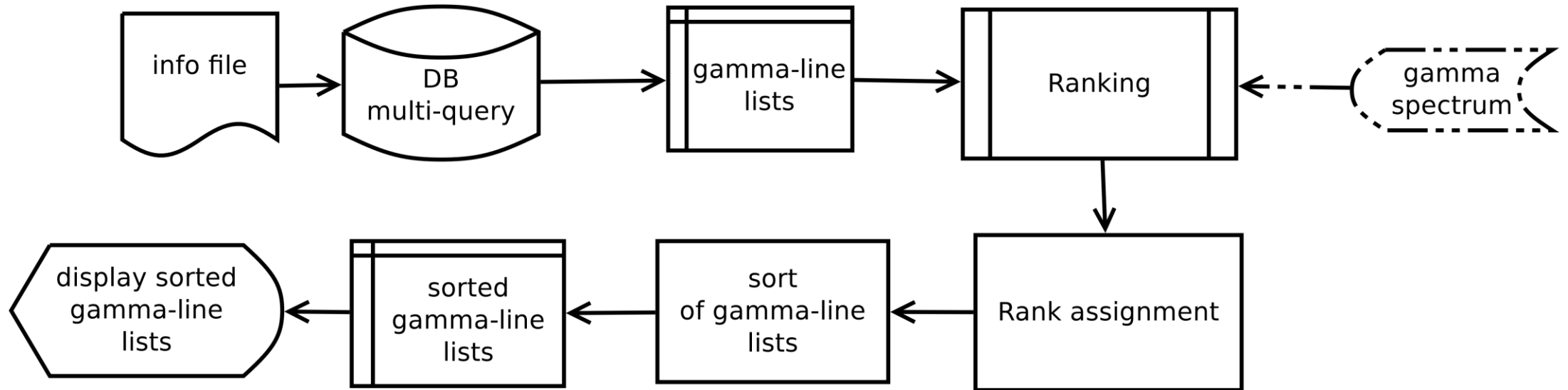


The screenshot shows the GitHub profile for LABChico. The profile name is LABChico, and the bio is "Software utilities for gamma spectrum analysis". The profile has 1 repository, 0 packages, 3 people, 0 teams, 0 projects, and 0 settings. A search bar is present with the text "Find a repository...". Below the search bar, the repository "histoGe" is listed. It is a forked repository from "ffavela/histoGe" and is described as "For making histogram analysis with germanium detectors". The repository is written in Python, uses the GPL-3.0 license, has 1 fork, 0 stars, 0 issues, and 0 pull requests. It was updated 24 days ago. A small green waveform icon is visible to the right of the repository name.

# Why is identification of isotopes through gamma spectroscopy important and complicated?

- Gamma spectroscopy is a technique which allows identification of isotopes through their gamma radiation.
- It can be used to detect even small amounts of contaminations.
- The number of gamma lines produced through radioactive decay is too large. In our case, we have a database which contains more than 93,000 entries.
- Thousands of gamma lines could be identified in small energy ranges.





## histoGe's methodological approach

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- The block diagram represents a general procedure to identify peaks.
- The procedure includes queries to data base, calculating a ranking according to a specific method and sorting the list of possible candidates.

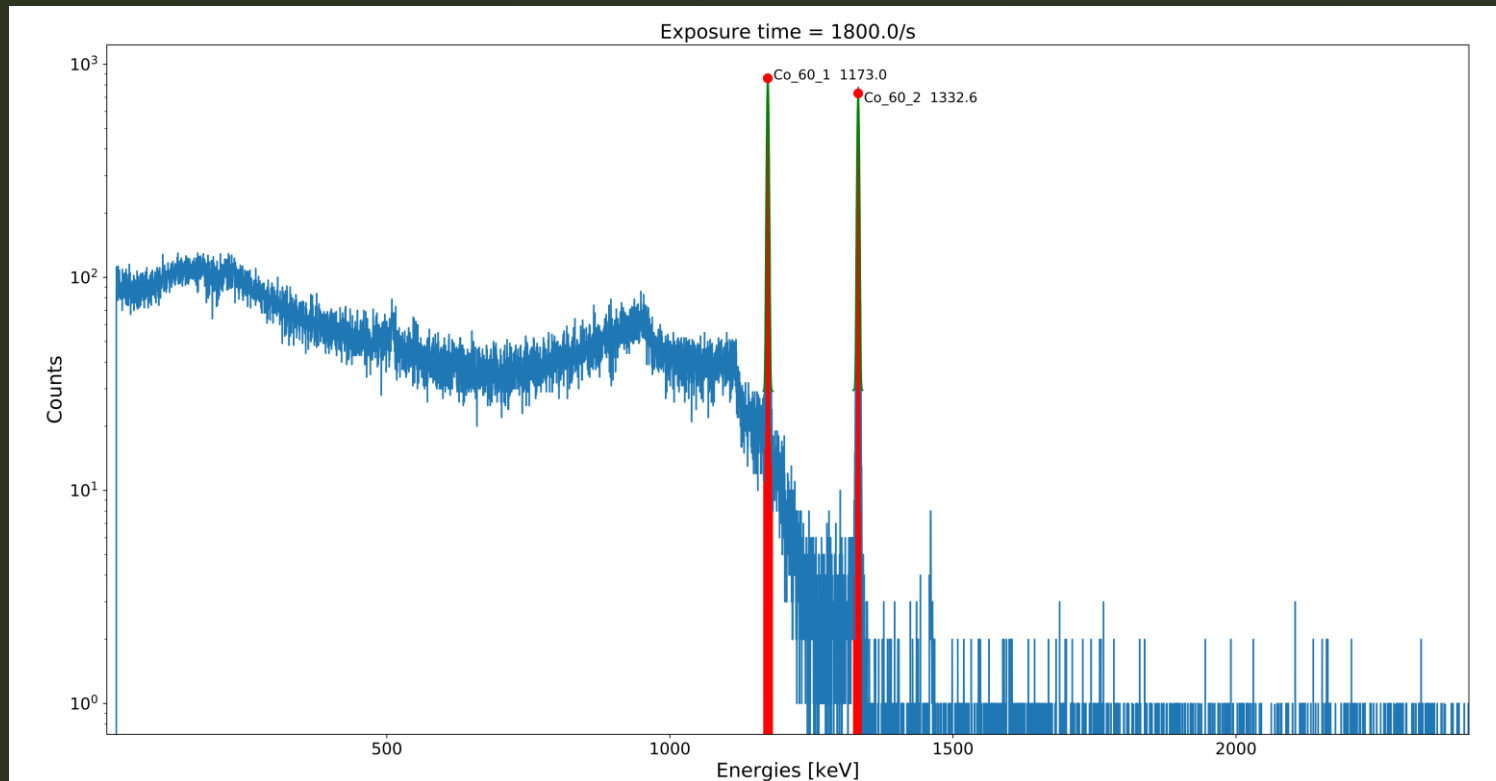
# Which methods are being used in histoGe?

- 1.  $\gamma$ -line distance from peak mean:** A ranking value is assigned for each  $\gamma$ -line calculating the distance between the energy of the  $\gamma$ -line and the mean value of the Gaussian fit.
- 2.  $\gamma$ -line coincidence probability:** The distance as calculated previously is used to estimate a probability using a cumulative distribution function for the Gaussian distribution.
- 3. Half-life sorting:** The half life is assigned as ranking value. Then, those isotopes with larger half life are considered more suitable candidates of explaining peaks.
- 4. Peak Explanation Power:** It is known that an isotope has a specific number of  $\gamma$ -line, this method counts the number of  $\gamma$ -lines found for an isotope.
- 5. Improved Peak Explanation Power:** The number of peaks found for an isotope is divided between the total number of  $\gamma$ -lines in the range of the spectrum.

# Which methods are being used in histoGe?

6. **Relative Emission Probability:** The emission probability of isotopes is normalized, then, the sum of all  $\gamma$ -lines of a certain isotopes is calculated. The one with the highest is ranked as the most suitable candidate.
7. **Relative Emission Probability with Gilmore's statistics:** It calculates a mean square deviation between each  $\gamma$ -line counts divided by total counts of  $\gamma$ -lines and relative emission probability divided by the total emission probability for a certain isotope in the range of the spectrum.
8. **Fuzzy logic:** A fuzzy inference system is used. It is based in approximate reasoning through fuzzy sets to find the most suitable candidate
9. **Decay chain peak members:** It counts the number of  $\gamma$ -lines found for isotopes that belongs to a certain chain.
10. **Decay chain improved:** It counts the number of  $\gamma$ -lines found for isotopes that belongs to a certain chain and then, it is divided between the total number of  $\gamma$ -lines for a certain decay chains.

# histoGe test ( $^{60}\text{Co}$ )

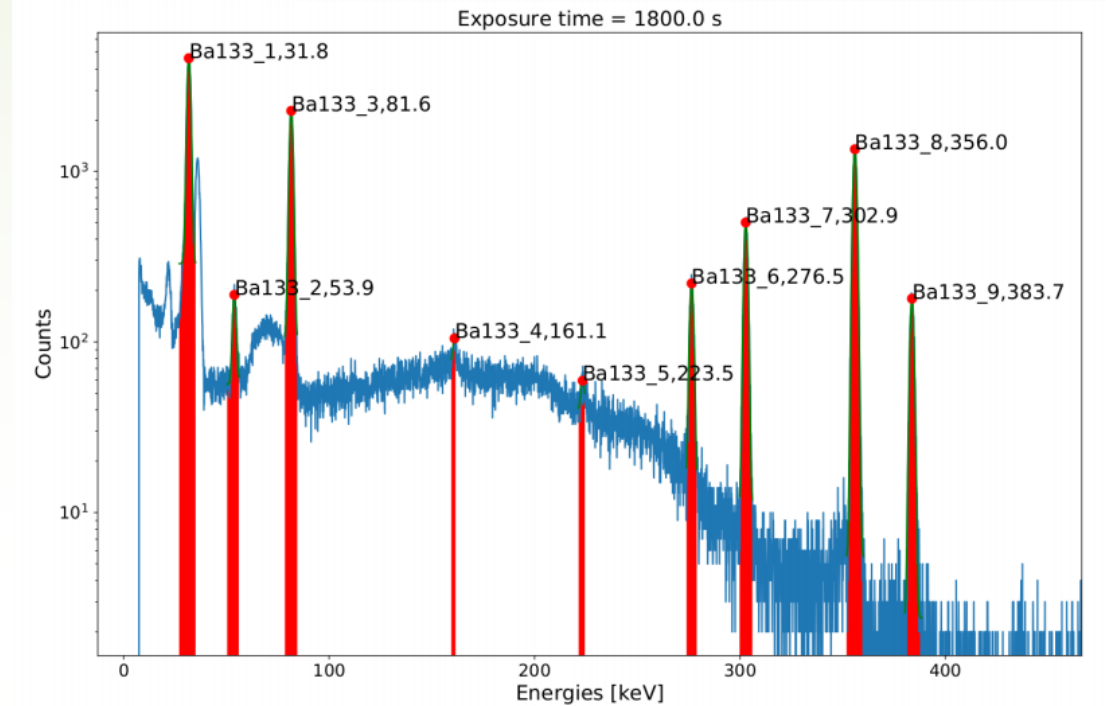


Eg [keV]	Ig (%)	Parent	Rank Value	Position
1173.237 (4)	99.97	$^{60}\text{Co}$	1.000	0
1171.3 (2)	1.70	$^{120}\text{Sb}$	0.889	1
1172.9 (1)	98.00	$^{62m}\text{Co}$	0.806	2
1172.9 (1)	98.00	$^{62m}\text{Co}$	0.806	3
1171.3 (2)	19.00	$^{120}\text{In}$	0.731	4
1172.9 (1)	84.00	$^{62}\text{Co}$	0.722	5
1172.9 (1)	0.34	$^{62}\text{Cu}$	0.579	6
1168.8 (5)	100.00	$^{128m}\text{Sn}$	0.491	7
1173.237 (4)	0.26	$^{60}\text{Cu}$	0.442	8
1178.5 ( )	64.00	$^{34}\text{Si}$	0.400	9

Eg [keV]	Ig (%)	Parent	Rank Value	Position
1328.2 (3)	5.60	$^{53}\text{Co}$	1.000	0
1332.501 (5)	99.99	$^{60}\text{Co}$	1.000	1
1335.04 (10)	71.00	$^{125}\text{In}$	0.693	2
1332.501 (5)	88.00	$^{60}\text{Cu}$	0.442	3
1324.1 (2)	0.47	$^{210}\text{At}$	0.347	4
1328.2 (3)	86.00	$^{53m}\text{Co}$	0.305	5
1328.2 (3)	87.00	$^{53m}\text{Fe}$	0.304	6
1333.4 (3)	0.52	$^{142}\text{Cs}$	0.221	7
1333.4 (3)	0.52	$^{142}\text{Cs}$	0.221	8
1324.51 (6)	17.50	$^{150}\text{Pm}$	0.192	9

# $^{133}\text{Ba}$ ranking?

- A spectrum of  $^{133}\text{Ba}$  was obtained and the identification of the observed peaks in the spectrum are ranked.
- Positions are shown in the table. 0 is the first position.



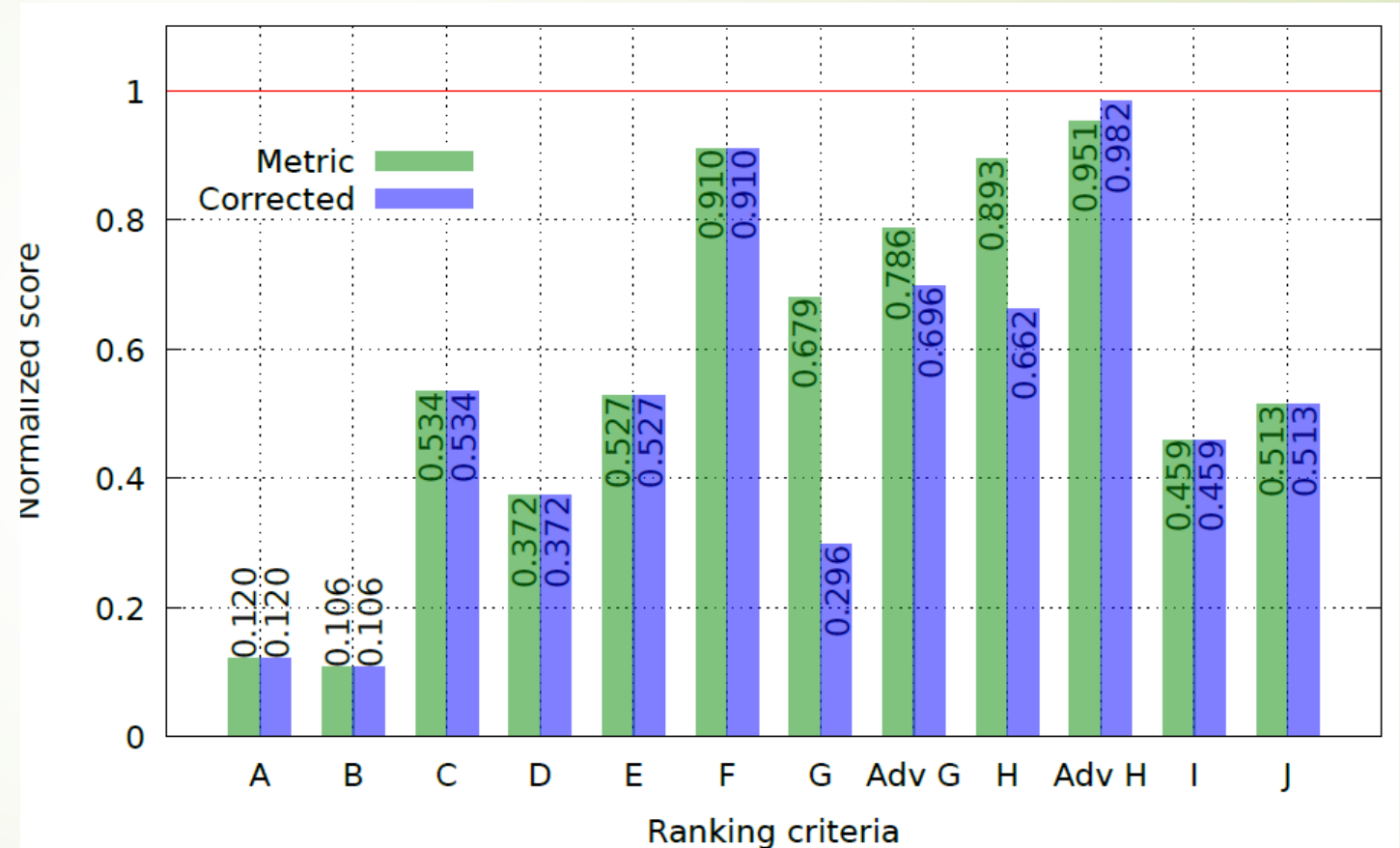
$\gamma$ ray properties		Query Range			$^{133}\text{Ba}$ Position											
Eg [keV]	Ig (%)	Emin	Emax	Size	A	B	C	D	E	F	G	Adv. G	H	Adv. H	I	J
53.161 (1)	2.20	52.35	54.03	101	10	10	8	3	2	0	6	1	0	0	2	1
79.6139 (26)	2.62	78.32	79.8	79	1	3	8	2	2	1	1	0	0	0	2	2
80.9971 (14)	34.06	80.53	81.5	51	10	10	2	1	1	2	1	0	0	0	1	1
160.613 (8)	0.65	159	161	146	21	18	8	1	5	2	4	2	0	0	2	2
223.234 (12)	0.45	222	224	120	22	20	2	4	3	1	3	0	0	0	1	1
276.398 (2)	7.16	275.77	277.10	74	8	38	1	1	1	1	0	1	0	0	2	4
302.853 (1)	18.33	301.86	303.07	78	10	10	4	1	4	1	2	0	0	0	2	1
356.017 (2)	62.05	354.92	358.14	170	14	14	3	2	0	0	4	2	0	0	2	5
383.851 (3)	8.94	381.34	384.55	211	19	19	5	4	3	1	4	1	0	0	2	2
Rank Value					0.15718	0.8608	3.31e+08s	9	1.0	1.0	0.12	0.12	0.81	0.84	0.29123	0.291

# Global analysis of a set of radioactive sources

A metric was defined to evaluate performance. Each spectrum was tested in with all methods and a global value was calculated.

The method that performed best is the fuzzy logic method followed by the Improved Peak Explanation Power.

Source	$\gamma$ -lines [keV]	Half-Life [yr]
<sup>241</sup> Am	13.81, 27.03, 33.19, 43.42, 59.54, 69.76 98.97, 102.98, 120.36, 125.33	432.5
<sup>133</sup> Ba	53.1, 79.6, 81.0, 160.6, 223.3, 276.3 302.8, 356.0, 383.8	10.5
<sup>109</sup> Cd	88.07	1.27
<sup>57</sup> Co	122.0, 136.0	0.745
<sup>60</sup> Co	1173.2, 1332.5	5.27
<sup>137</sup> Cs	662.0	30.1
<sup>54</sup> Mn	835.0	0.855
<sup>22</sup> Na	1275.0	2.6
<sup>210</sup> Pb	46.539	22.3
<sup>65</sup> Zn	1115.0	0.668





isotope	Level properties		Query Range [keV]		Size	Position				Rank			
	Eg [keV]	Ig (%)	Emin	Emax		C	D	F	I	C [s]	D	F	I
<sup>210</sup> Pb	46.539	4.25	45.42	49.98	227	8	209	2	4	7.03e+08	1	1	0.28877
<sup>234</sup> Th	63.29	4.8	62.34	64.20	127	16	64	9	4	2.08e+05	3	0.446	0.28877
<sup>226</sup> Ra	187.1	-	184.2	188.20	278	6	180	3	4	5.05e+10	3	1	0.28877
<sup>212</sup> Pb	238.632	43.3	236.64	241.97	306	52	164	1	7	3.83e+04	4	0.981	0.21831
<sup>214</sup> Pb	351.932	37.6	349.9	353.9	265	91	156	5	6	1.61e+03	10	0.827	0.28877
<sup>208</sup> Tl	583.2	84.5	581.20	585.27	219	130	154	1	8	1.83e+02	5	0.831	0.21831
<sup>214</sup> Bi	581.9	-	607.30	611.35	225	90	34	3	3	1.19e+03	22	0.585	0.28877
<sup>137</sup> Cs	661.657	85.1	659.7	663.7	198	3	180	1	3	9.48e+08	2	1	0.25568
<sup>228</sup> Ac	911.204	25.8	909.21	913.26	182	36	33	2	9	2.21e+04	21	0.555	0.18268
<sup>228</sup> Ac	968.971	15.8	967.27	971.03	155	36	36	0	7	2.21e+04	21	0.555	0.18268
<sup>234m</sup> Pa	1001.03	0.84	999.02	1003.08	188	131	61	0	151	7.02e+01	13	0.557	0
<sup>214</sup> Bi	1120.2	15.1	1118.3	1122.35	151	20	20	2	0	1.19e+03	22	0.585	0.28877
<sup>60</sup> Co	1173.23	99.0	1171.2	1175.2	176	1	127	0	0	1.66e+08	3	1	0.49998
<sup>60</sup> Co	1332.5	99.0	1330.5	1334.5	360	2	85	0	0	1.66e+08	3	1	0.49998
<sup>40</sup> K	1460.83	11.0	1458.8	1462.5	268	0	91	0	90	4.03e+16	1	1	0
<sup>214</sup> Bi	1764.49	15.4	1762.5	1766.5	85	36	11	0	1	1.19e+03	22	0.585	0.28877
<sup>208</sup> Tl	2614.5	99.0	2612.5	2616.5	39	23	23	2	1	1.83e+02	5	0.831	0.21831

## Is histoGe effective?

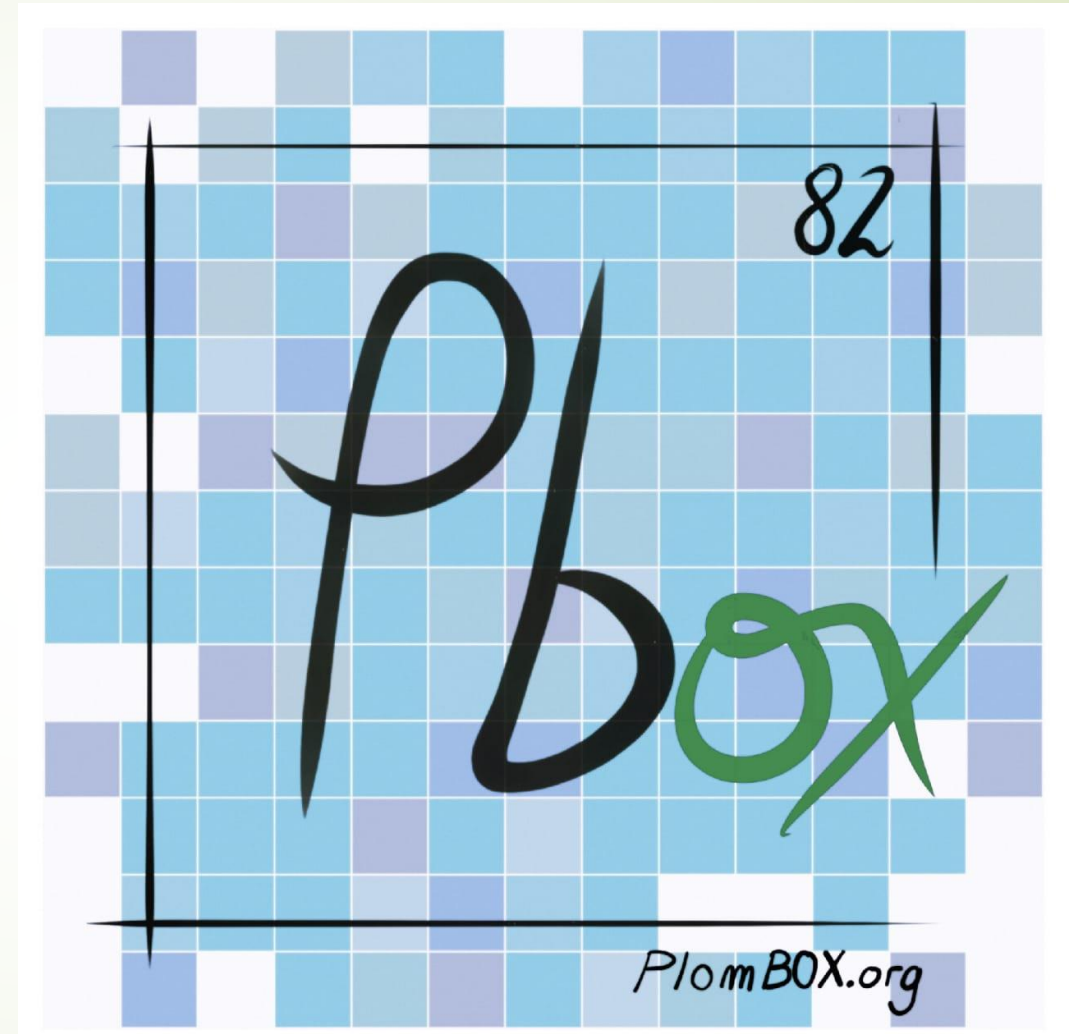
- Relative emission probability can be applied without knowing the spectrum but only the ranges where peaks had been observed.
- Grand Sasso Laboratory's spectrum reported previously was analyzed and it shows to be effective.

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# Plombbox: $^{210}\text{Pb}$ water pollution

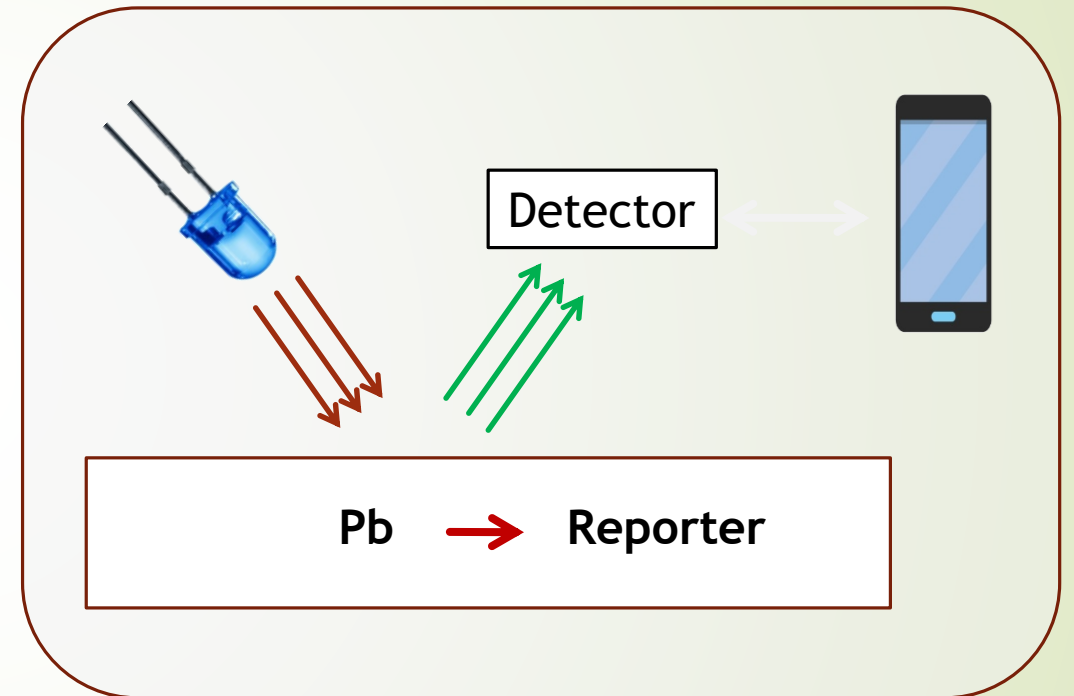
# What is Plombox?

Plombox is...



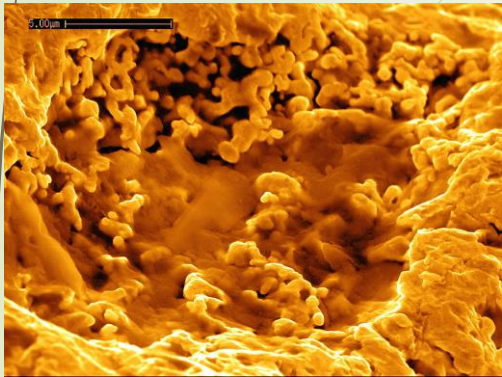
# Plombox is...

- ▶ a R+D+I project of free open-source hardware and open software devices to sense lead and other contaminants in water.
- ▶ The main idea of Plombox is having a sensible media that change color in the presence of lead.
- ▶ Then, measuring that change in color of the sample would allow to know the concentration of lead in the water sample.

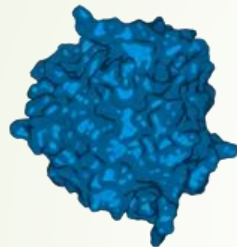


# How Plombbox works?

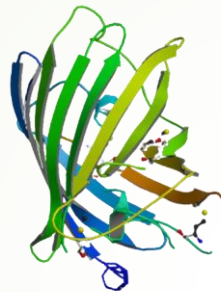
Sample with lead



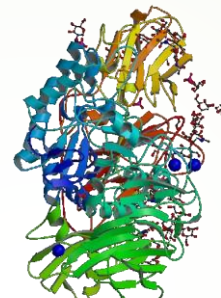
Luciferase



GFP



B-Gal



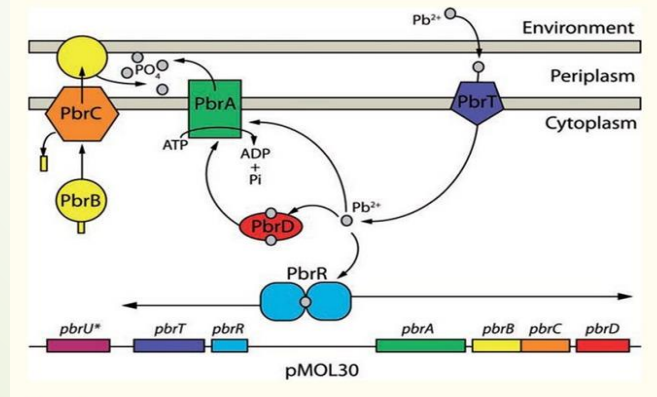
Electronic circuitry and camera



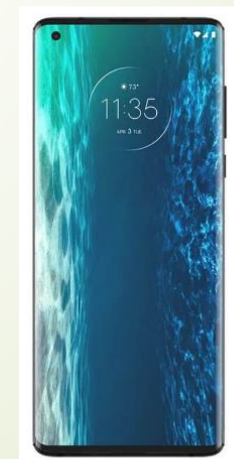
Remote server



DNA modified bacteria



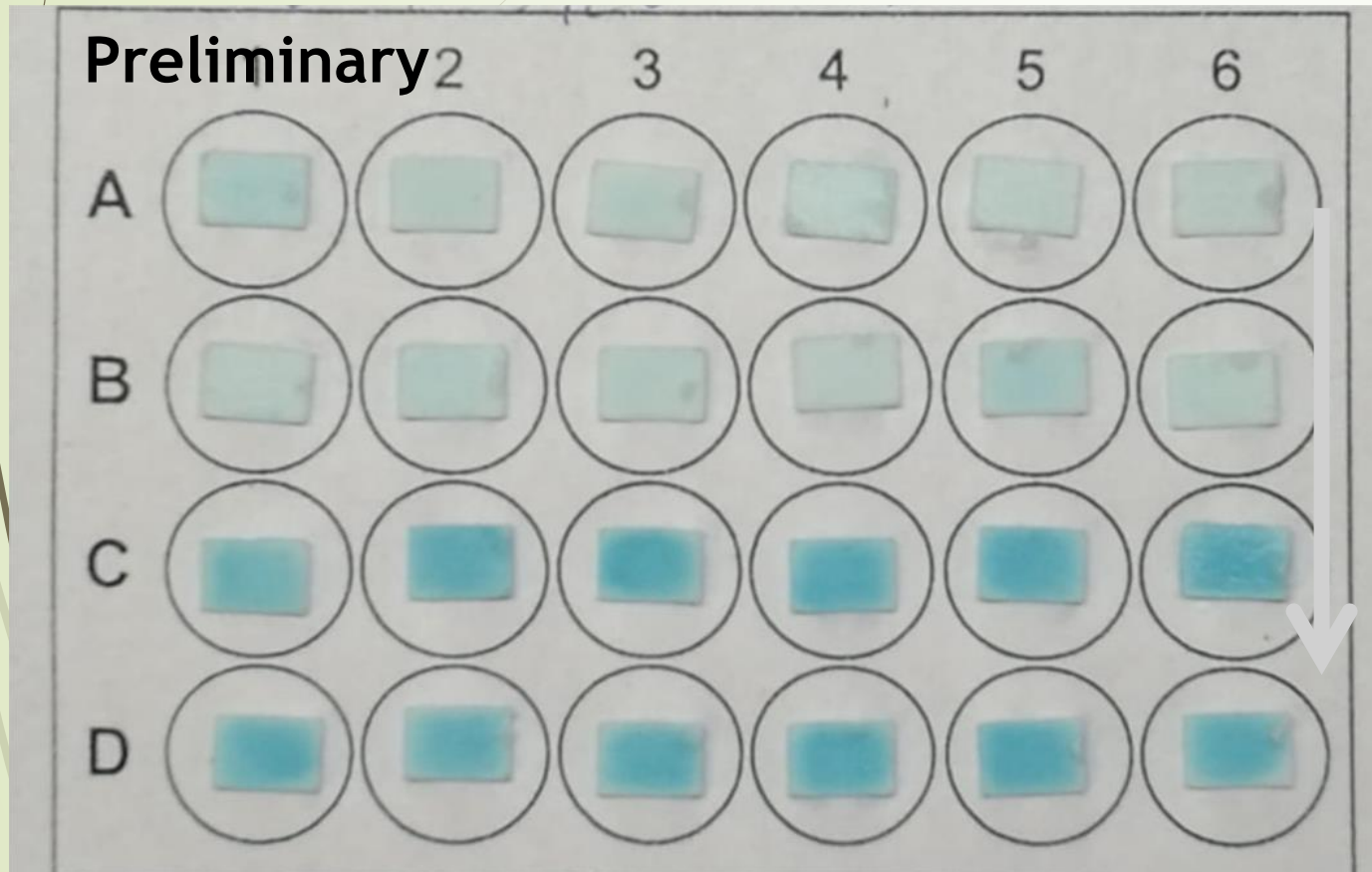
Metabolic mechanism



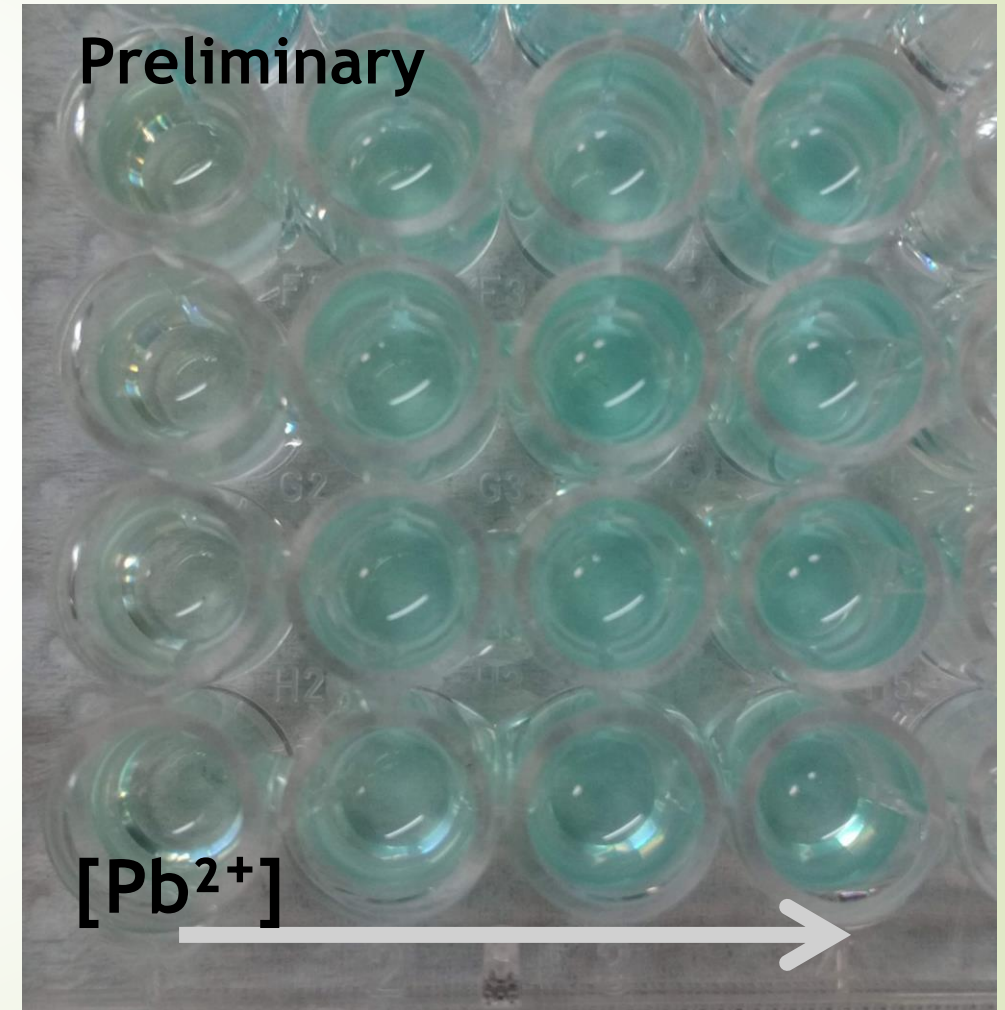
Cell-phone



# Colorimetry measurements



paper



$[Pb^{2+}]$

dissolutions

# How colorimetry is used to measure lead?

```

piPlom          color units in ADU
shutter speed: 33243 us
iso: 100

d-m-y: 27-03-20
time: 11:07:27
  
```



```

color average sigma
blue: 132.9 +- 38.4
green: 225.0 +- 31.0
red: 243.6 +- 20.4
  
```

```

color Min-Max
blue: 3-231
green: 92-255
red: 137-255
  
```

Plombbox.org

time: 126.1 ms

fps: 7.9 1/s

```

piPlom          color units in ADU
shutter speed: 33243 us
iso: 100

d-m-y: 07-08-20
time: 20:22:46
  
```

```

HSV color base
ave  min  max
h: 204.4 203.5 205.5
s: 99.3 98.2 100.0
v: 92.5 90.0 95.1
  
```



```

color average sigma
blue: 236.9 +- 6.5
green: 141.2 +- 8.8
red: 1.6 +- 2.8
  
```

```

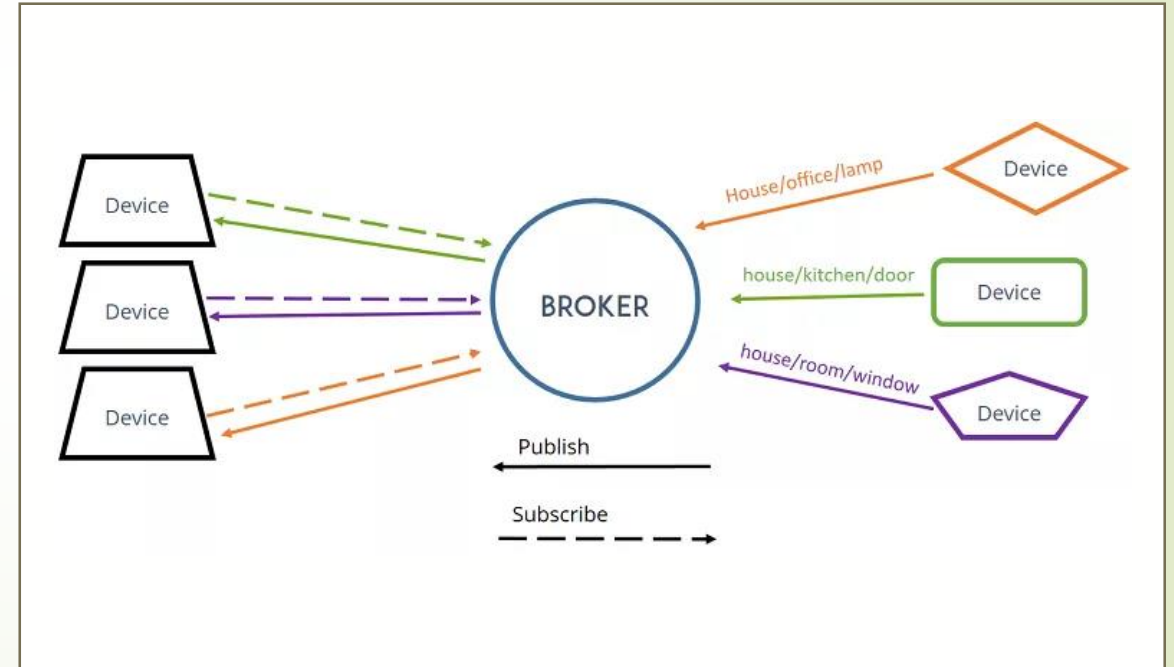
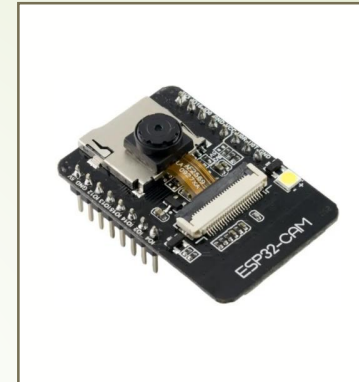
color Min-Max
blue: 205-255
green: 94-163
red: 0-14
  
```

time: 5915061.9 ms

fps: 0.0 1/s

## How is information collected and processed remotely?

- The images are captured with an OV6770 camera and an ESP32 board.
- The ESP32 transmits the images to cellphone via Bluetooth.
- The cellphone receives the information and retransmits to a server through the internet.
- The protocol used to transmit the data is Mosquitto protocol (MQTT).
- The data is stored using influxDB.





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# Conclusions

# Conclusions

- ▶ LABChico will be an underground laboratory for research and education that will be located in Hidalgo, Mexico.
- ▶ Germanium detectors will measure small amounts of radioactivity in water, food, soils, etc.
- ▶ The characterization of those detectors has been performed and the results have been published in JINST (IOP).
- ▶ HistoGe is an open-source free software for identification of radioactive isotopes through gamma ray spectroscopy. It was capable to identify most of the isotopes using relatively simple methods.
- ▶ Plombox is a project to develop a sensor to detect lead contaminants in water. Once it is completed, it will be tested in Argentina.

# UNAM's group...

- is responsible for leading the management of the construction of LABChico.
- leads the idea, programming and testing of histoGe software.
- leads the characterization of ICN-HPGe and IF-HPGe detectors.
- collaborates with the programming of the ESP32 board.
- collaborates with the colorimetry measurements.
- collaborates with the phone's app development to establish the communication between the ESP32 board and the remote server.
- collaborates in programming the server and manage the database.
- organizes scientific talks in Hidalgo to promote LABChico.

**LABChico**  
Laboratorio Subterráneo de Mineral del Chico

## Cuarta Jornada La Ciencia de LABChico

**DESDE  
CASA**

Pláticas de divulgación de la ciencia  
por [facebook.com/LABChico](https://facebook.com/LABChico)

Jueves 3 de diciembre a las 10:00 a.m.

**Lucía Capra Pedol**  
Centro de Geociencias, UNAM

**Felipe de Oliviera Alves**  
Max-Planck-Institut für extraterrestrische Physik

Viernes 4 de diciembre a las 10:00 a.m.

**Adiv González Muñoz**  
Instituto de Ciencias Nucleares, UNAM

**Libertad Barrón Palos**  
Instituto de Física, UNAM

f LABChico    t LAB\_Chico    i labchico

GCRF    iF Instituto de Física    CITNOVA

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- ▶ Global Challenges Research Fund – UKRI for financial support of the project (Grant ST/R002908/1).
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- ▶ Fermilab for the donation of germanium detectors and instrumentation.

Questions?

Thank you!!



# The TRACE Collaboration

**A. Aguilar-Arevalo<sup>g</sup>, E. Alba Posse<sup>a</sup>, M. Alvarez<sup>a</sup>, H. Arnaldi<sup>b</sup>, H. Asorey<sup>b,h</sup>, X. Bertou<sup>b</sup>, A. Colque<sup>a</sup>, A. Deisting<sup>f</sup>, A. Dias<sup>f</sup>, J.C. D'Olivo<sup>g</sup>, F. Favela-Pérez<sup>g</sup>, Y. Gándola<sup>a</sup>, E. A. Garcés<sup>d</sup>, J. Gasulla<sup>a</sup>, M. Gómez Berisso<sup>b</sup>, A. González Muñoz<sup>d</sup>, J. O. Guerra-Pulido<sup>g</sup>, S. Gutierrez<sup>b</sup>, S. Jois<sup>f</sup>, J. Lipovetzky<sup>b</sup>, M.B. Lovino<sup>b</sup>, D.J. Marín-Lámbarri<sup>d</sup>, L. Marpegan<sup>b</sup>, D. Martín<sup>a</sup>, M. Martínez Montero<sup>g</sup>, S. Mejía Muñoz<sup>a</sup>, J. Monroe<sup>f</sup>, A. Nadra<sup>a</sup>, S. Paling<sup>c</sup>, R. Pregliasco<sup>b</sup>, G. Rumi<sup>b</sup>, A. Rossen<sup>c</sup>, J. Santos<sup>a</sup>, P. R. Scovell<sup>c</sup>, M. Sofo Haro<sup>b</sup>, M. Tallis<sup>b</sup>, A. Teijeiro<sup>a</sup>, M. Triana<sup>a</sup>, E. Vázquez-Jáuregui<sup>d</sup>**

<sup>a</sup>Universidad de Buenos Aires, Buenos Aires, Argentina.

<sup>b</sup>Centro Atómico Bariloche and Instituto Balseiro, Comisión Nacional de Energía Atómica (CNEA), Consejo Nacional de Investigaciones Científicas y Técnicas (CONICET), Universidad Nacional de Cuyo (UNCUYO), San Carlos de Bariloche, Argentina

<sup>c</sup>Laboratorio de Experimental de Tecnologías Sustentables. Centro de Tecnología del Uso del Agua. Instituto Nacional del Agua. Au Ezeiza-Cañuelas km 1.6 CP (1804) Pcia de Buenos Aires.

<sup>d</sup>Instituto de Física, Universidad Nacional Autónoma de México, A. P. 20-364, México D. F. 01000, Mexico

<sup>e</sup>Boulby Underground Laboratory. Science and Technology Facilities Council, England, United Kingdom.

<sup>f</sup>Royal Holloway. University of London, United Kingdom.

<sup>g</sup>Instituto de Ciencias Nucleares, Universidad Nacional Autónoma de México, CDMX, México

<sup>h</sup>Instituto de Tecnologías en Detección y Astropartículas, Comisión Nacional de Energía Atómica (CNEA), Consejo Nacional de Investigaciones Científicas y Técnicas (CONICET), Universidad Nacional de San Martín (UNSAM), Buenos Aires, Argentina.