Ultra low radioactivity

Technical review

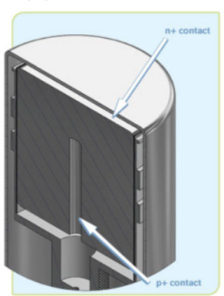
Introduction

- Main measurements are made with HPGe for the majority of the experiments due to versatility of the tool
- Rising interest for ICP-MS allowing to measure long half life nuclei (end of germanium?)
- Specific background are monitored using specific detectors
- New background are rising with sensitivity of experiments 14C 42K

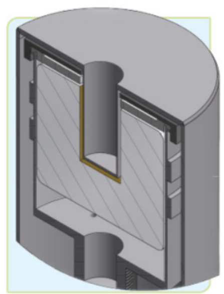
Germanium basics

- Semi conductor crystal cooled down to 77 K
- Z=32 and density = 5,32
- Sample at room temperature
- Sensitive to gammas from 20keV up to 3MeV
- Non destructive measurement
- Sensitive to muons and cosmic activation

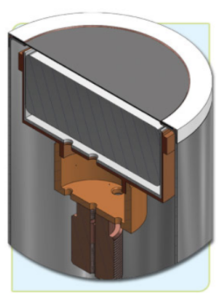
Coax

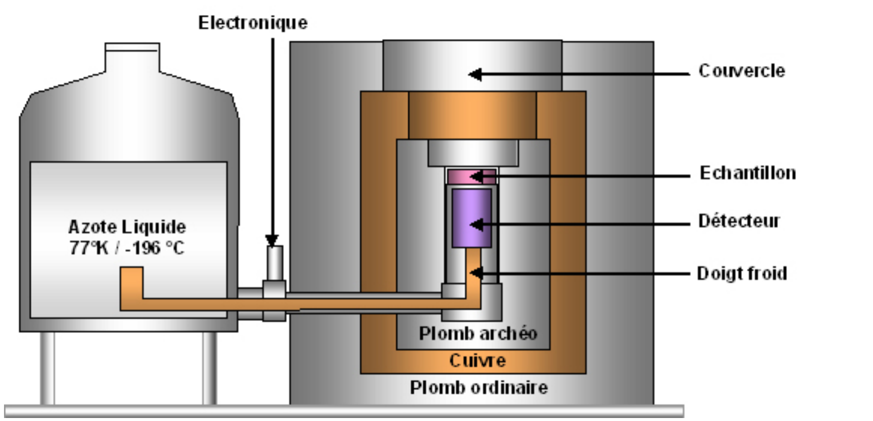


Well

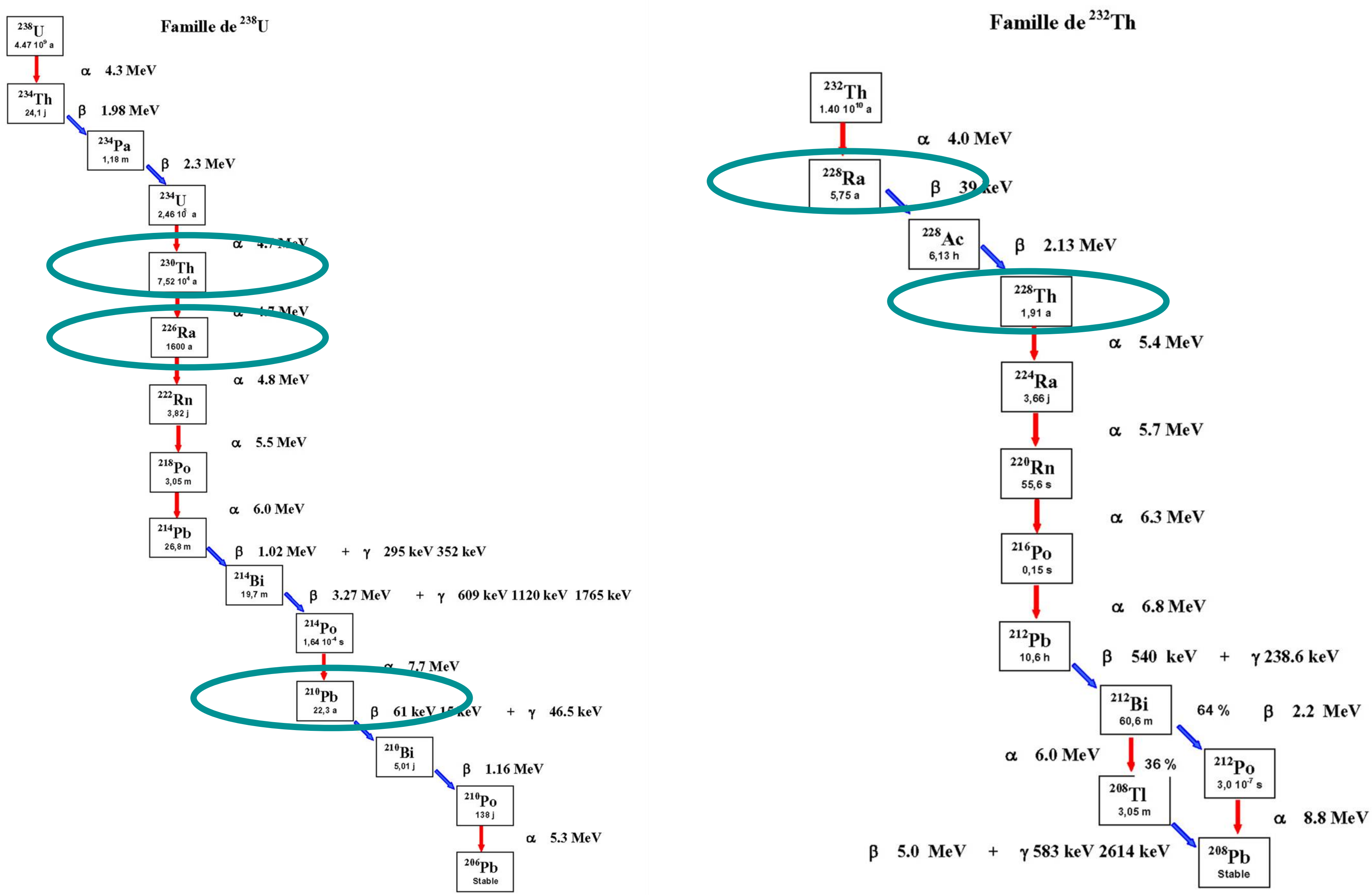


Planar





Main contaminants



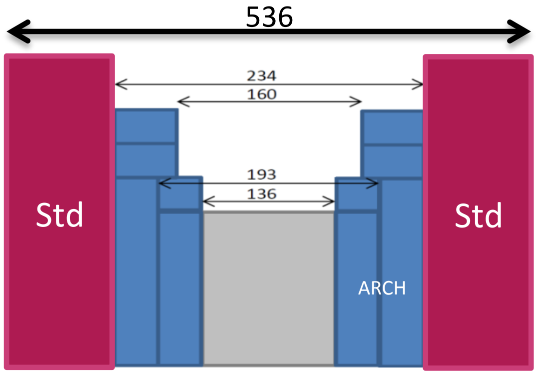
Germanium detector

- Example of detection limits

Mafalda : (our swiss army knife)

- Size 150 cc – 43,1%
    - Φ 80mm h 31,7mm
- Resolution
    - 122 keV 920 eV
    - 1,33MeV 1,97keV
- Background
    - Integral 115±3,5 count/day
    - 133 c/kg
    - Peaks
    - 46,5 keV 1,49 ± 0,37 c/d [210Pb]
    - 75 keV 3,6 ± 0,62c/d [Pb]

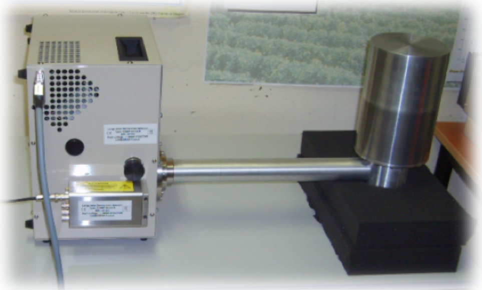
Shielding



limit (Bq)=

$$1{,}43+2{,}36\sqrt{1{,}36+bdf\times t} \,/\, \varepsilon(m)\, m\, t$$

$$\varepsilon = detected/emitted$$



Silicon wafer measurement
700 000s 650g

Nucleide		Bq/kg
210Pb	<	1,58E-02
^{226}Ra	<	1,27E-03
238U	<	6,27E-03
228Ra	<	3,82E-03
228Th	<	8,66E-04

Guillaume Warot

Germanium detector

- Improving detection limit :
  - Imply choices :

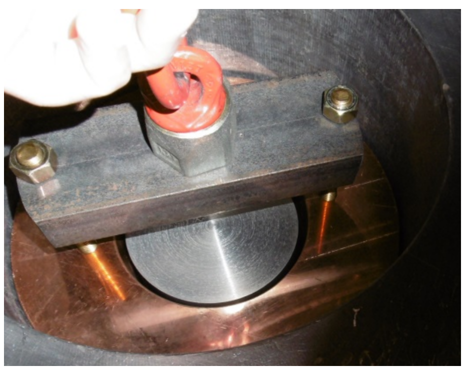
This detector can welcome much bigger sample but the low energy gamma are stopped by the dead layer around the detector.

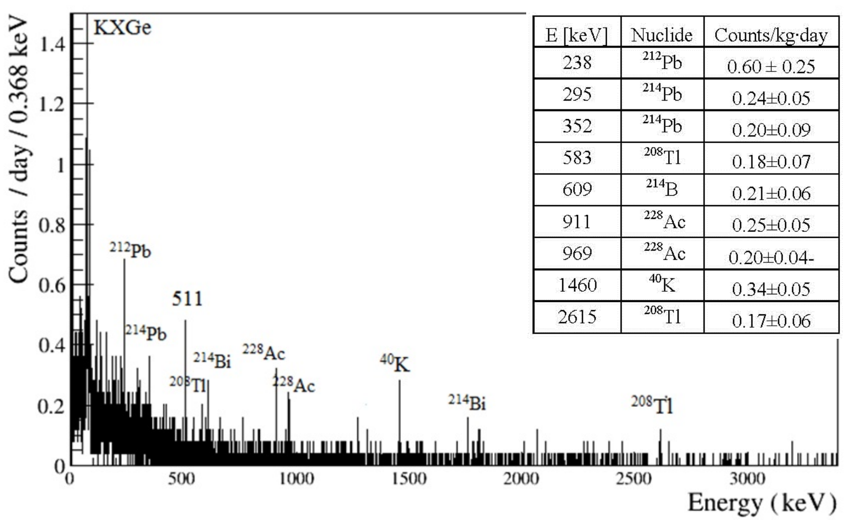
Theoretical sample of 1kg for 500000s

Nucleide		Bq/kg
210Pb		NA
^{226}Ra	<	4,96^{E}-4
238U		NA
228Ra	<	1,78E-03
228Th	<	4,37E-04

Obélix :

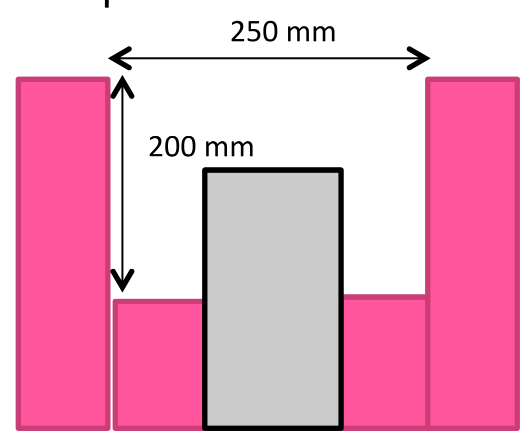
- Size
  - 600cc-160%
- Background
  - 95 counts/kg.d
- Resolution
  - 122 keV 1,1 keV
  - 1,33MeV 2keV





E [keV]	Nuclide	Counts/kg·day
238	^{212}Pb	0.60 ± 0.25
295	^{214}Pb	0.24±0.05
352	^{214}Pb	0.20±0.09
583	^{208}Tl	0.18±0.07
609	^{214}B	0.21±0.06
911	^{228}Ac	0.25±0.05
969	^{228}Ac	0.20±0.04-
1460	^{40}K	0.34±0.05
2615	^{208}Tl	0.17±0.06

Sample Chamber



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Germanium facility

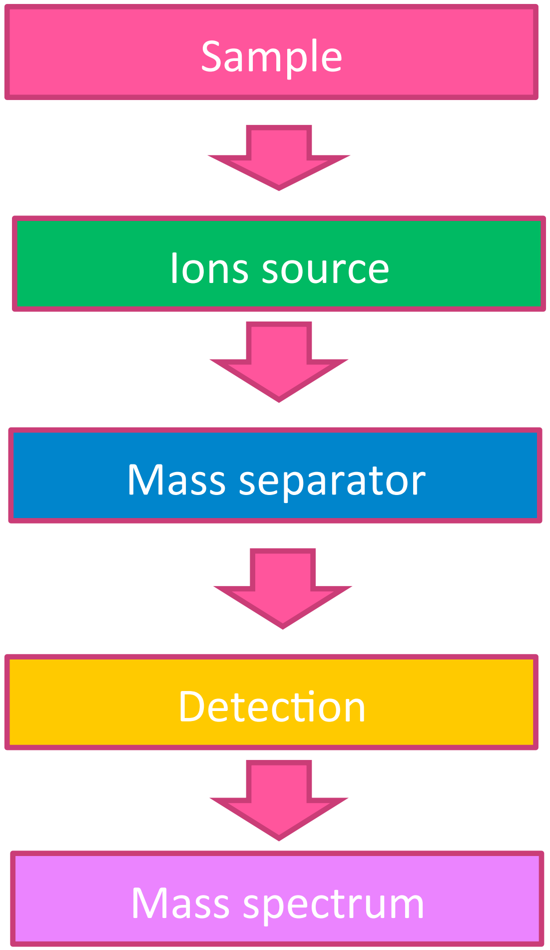
- Germanium hosted deep underground

- Additional facility in shallow deep lab
- Jinping
- Sno
- Dusel
- Kamioka

Germanium facility access

- Time of measurement long and multiplied by the number of samples
- Necessity of specialist of the detector to interprete the result
- My opinion , has to be done inside collaboration
- 100-10µBq/kg reachable but not enough for modern experiments
- Germaniums outdated ? Mass spectrometry is solution?

Elemental mass spectrometry



Preparation (chemical) of raw material to be usable for the detector

Gives an electric charge to nuclei and inject them under vacuum mainly as ion (1+)

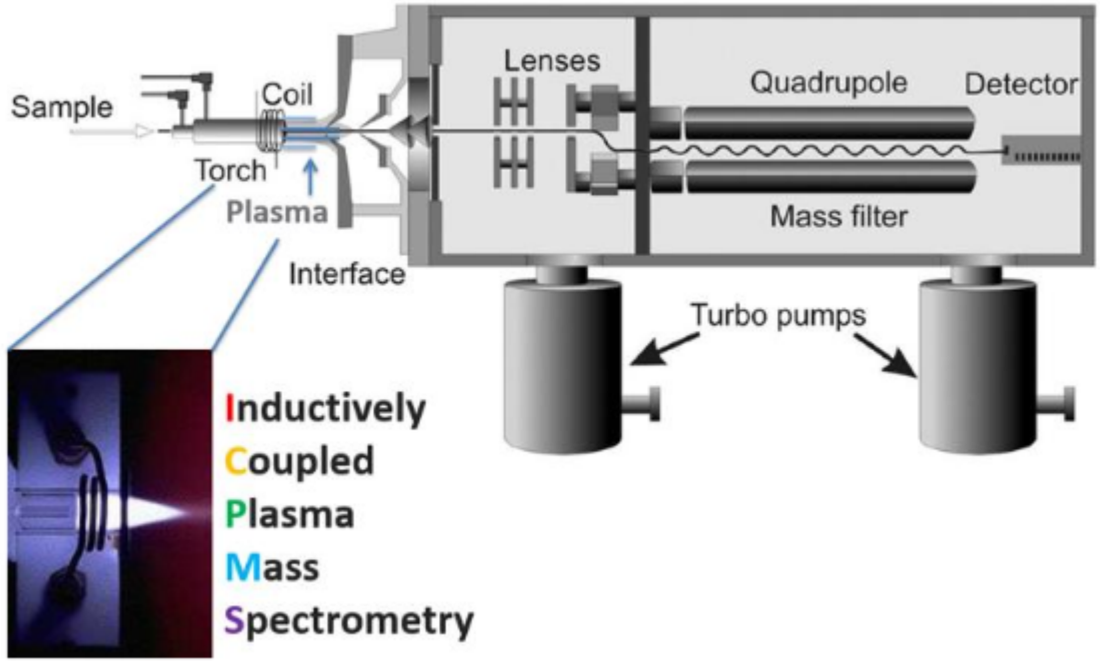
Separate the ions in function of m/Z

Gives electric signal in function the atom passing through

Interpreted result usually in ppt

ICP-MS

- New challenger
- Impressive limits
- Liquid sample
- Mass spectrometry
- Based on A=ʎN



ICP-MS

- Need to dissolve few grams of the sample
- Track the dissolution, ionisation and collection yield
- Measurement time 15 min
- Sample preparation 1-3 days (PNNL)
- Need to have a radiochemist in collaboration
- PNNL may be able to sell the measurement and preparation
- ENS Lyon has service for analyse contact philippe.telouk@ens-lyon.fr

Detection limits

- Conversion mass to activity
- 1 ppt Th= 4.1 µBq 232Th/kg
- 1 ppt U = 12.4 µBq 238U/kg
- Dedicated ICP-MS at PNNL can reach 0,1ppt
- 1 ppt 226Ra => 30 Bq/kg can be lowered by dissolving more sample and concentration
- Imply assuming secular equilibrium

Examples

- ENS needs better chemistry to improve results
- 2.10^6 cts/ppb and 50cts blank
- Reach $7{,}5.10^{-2}$ ppt with chemical purification
- Useful tool in case of (α,n) ^{230}Th
- Different backgrounds as isobar and dimer
- Pb analysis in ICP-MS
- <1ppt U-Th
- Doesn't give any information about 210Pb

Improvements

Improve ionisation yield

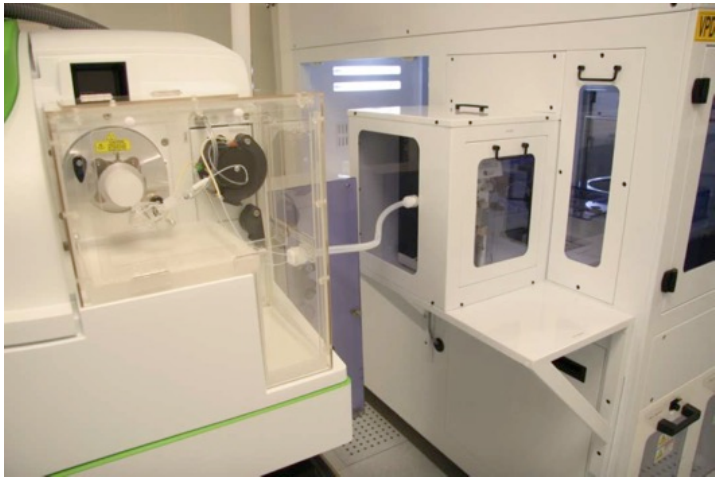
Application from semiconductor industrie
Destroy silicon surface with hydrofluoric gas

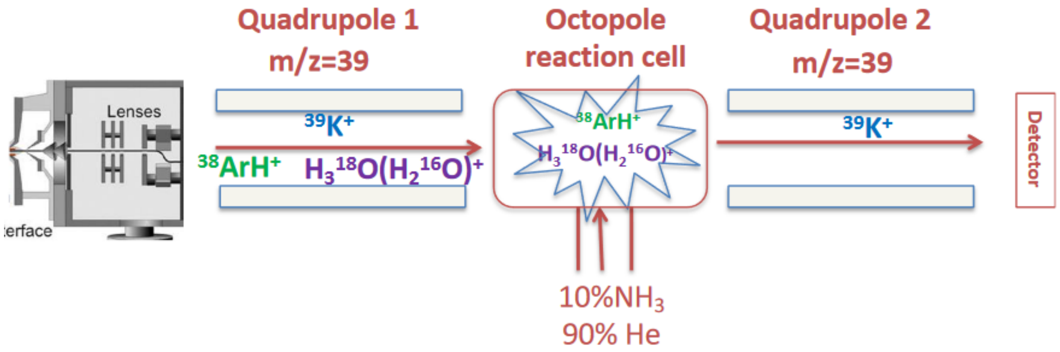
VPD-ICPMS

Resolve the isobar of K

Potassium has the same mass of argon dimer. Reaction cells are used to resolve this interference by destroyer the dimer

REACTION CELLS





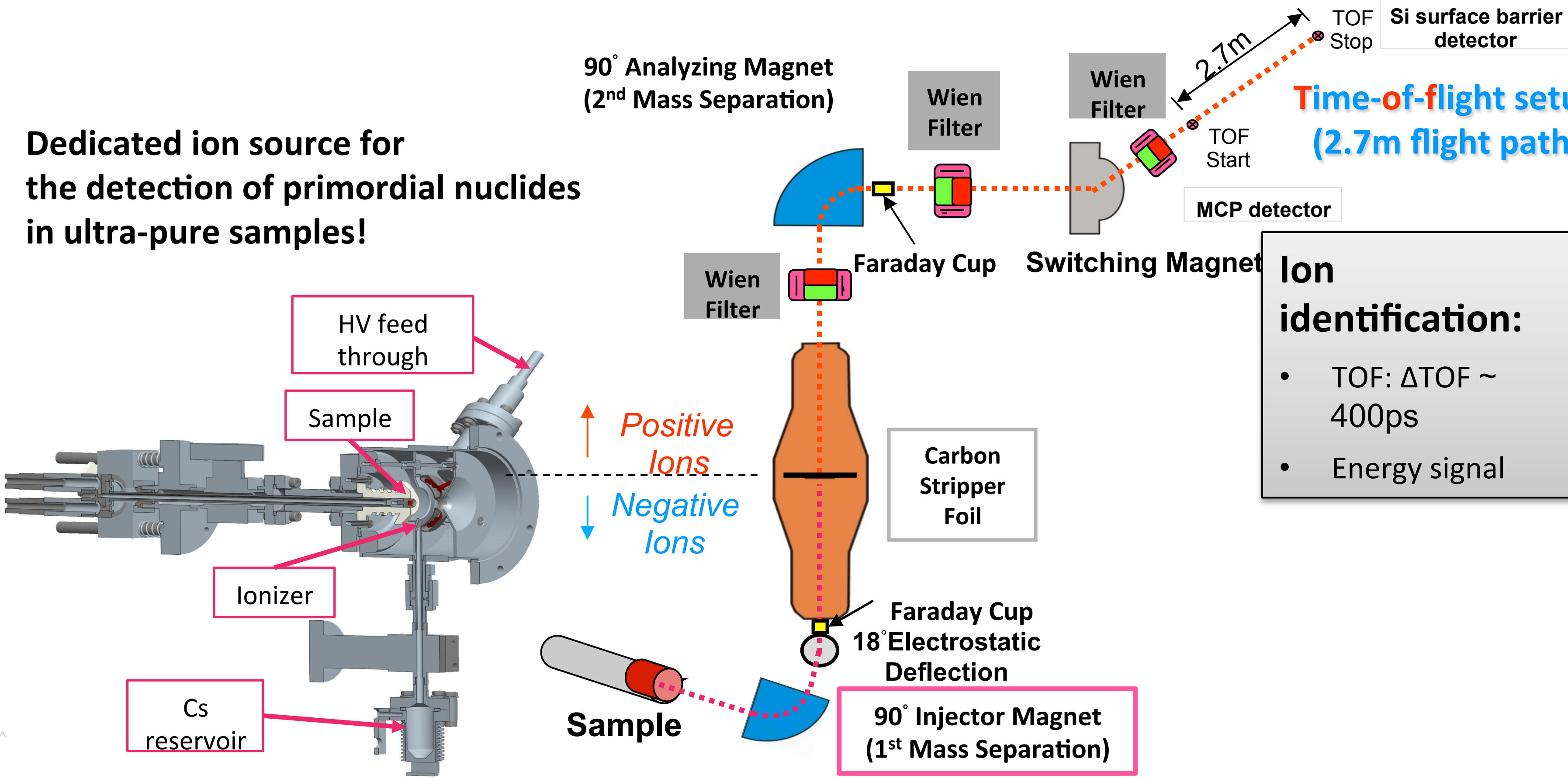
AMS

AMS setup at the MLL

TECHNISCHE UNIVERSITÄT MÜNCHEN

MLL

Dedicated ion source for the detection of primordial nuclides in ultra-pure samples!



Ion identification:

- TOF: ΔTOF ~ 400ps
- Energy signal

Other nuclear techniques

- Alpha spectrometry can also be helpful for some nucleides
- Can be used to check small pieces surfaces
- Sample dimension in LSM 5cm diameter
- Sensitivity 3α/day but detection limits highly dependant of the shape and so chemistry is needed
- Xia counter allow to test 1800 cm^2 60*30cm
- Radon emanation
- Beta counting require a very precise chemistry to disentangle spectrums

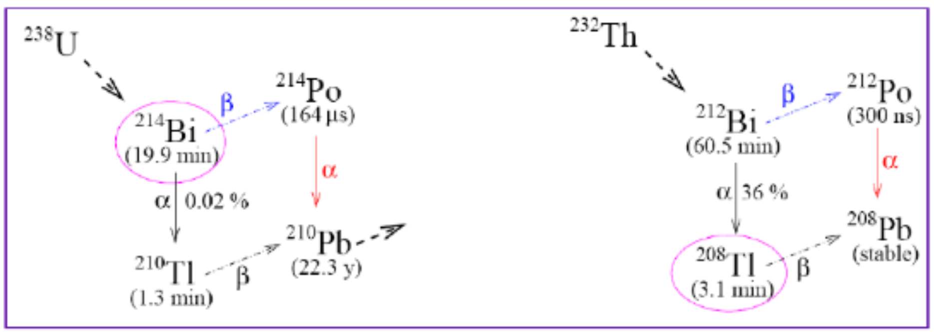
Nuclear Activation Analysis

- No preparation, described as non destructive but not for low background. Many restriction about samples
- Activation by neutron flux , analyse by gamma spectrometer
- 3 step analysis 1 hour, 1 day, 1month
- Limited by compton and internal germanium background , almost impossible to take out of the facility these sample
- Facility are closing all over the world
- Detection levels µBq/kg in U/Th

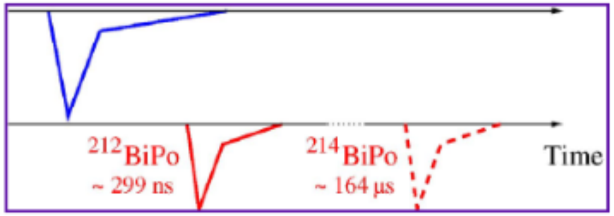
Experiment dependant background

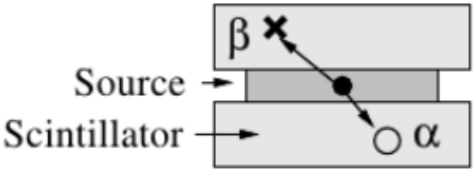
BiPo-3

- Developped by the SuperNEMO collaboration to measure $\beta\beta$ source foils at the level of 2 μBq/kg for Tl-208



^{212}Bi and ^{214}Bi are measured by electron-alpha coincidence in the BiPo desintegration





The sample is placed between two plastic scintillators coupled to low radioactive PMTs

Emergent background

- 42Ar/K for Gerda, unexpected , remeasured
- Carbon 14 is now a problem for the low mass dark matter detection (NewsG)
- Measurement using specific AMS
- Avoid contamination from CO2 (air)
- Avoid the use of carbonated material : not easy.

Conclusion

- Gamma spectrometry pushed to the limit of capability
- Possibility of lower limit using mass spectrometry
- Necessity to define the nucleides of interest especially 210Pb and the deviation to secular equilibrium
- Influence of (α,n) on the background and contamination level associated especially the 230 Th
- Develop specific technic for low level measurement of target nuclei

BaDGe Sample

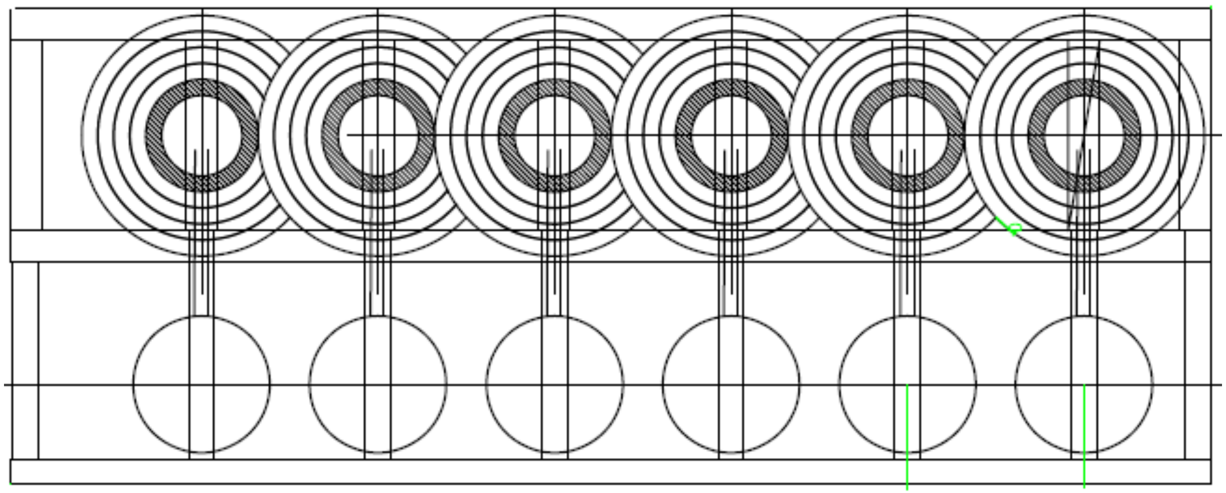
Ech : NW_BAK

Date de reception : 07/06/2018
Proprietaire : LSM
Detecteur : ObÃ©lix
Poids : 88.79
Dimensions : phi 100
Observations : stockÃ©s dans le pla
card du bureau

- Php standard
- Can be adapted to the Damic needs by adding more information

Future of measurement at LSM

- PARTAGe project
  - Combining shields in common walls



- Robotisation
- Optimisation of measurement time based on the radiopurity objectives

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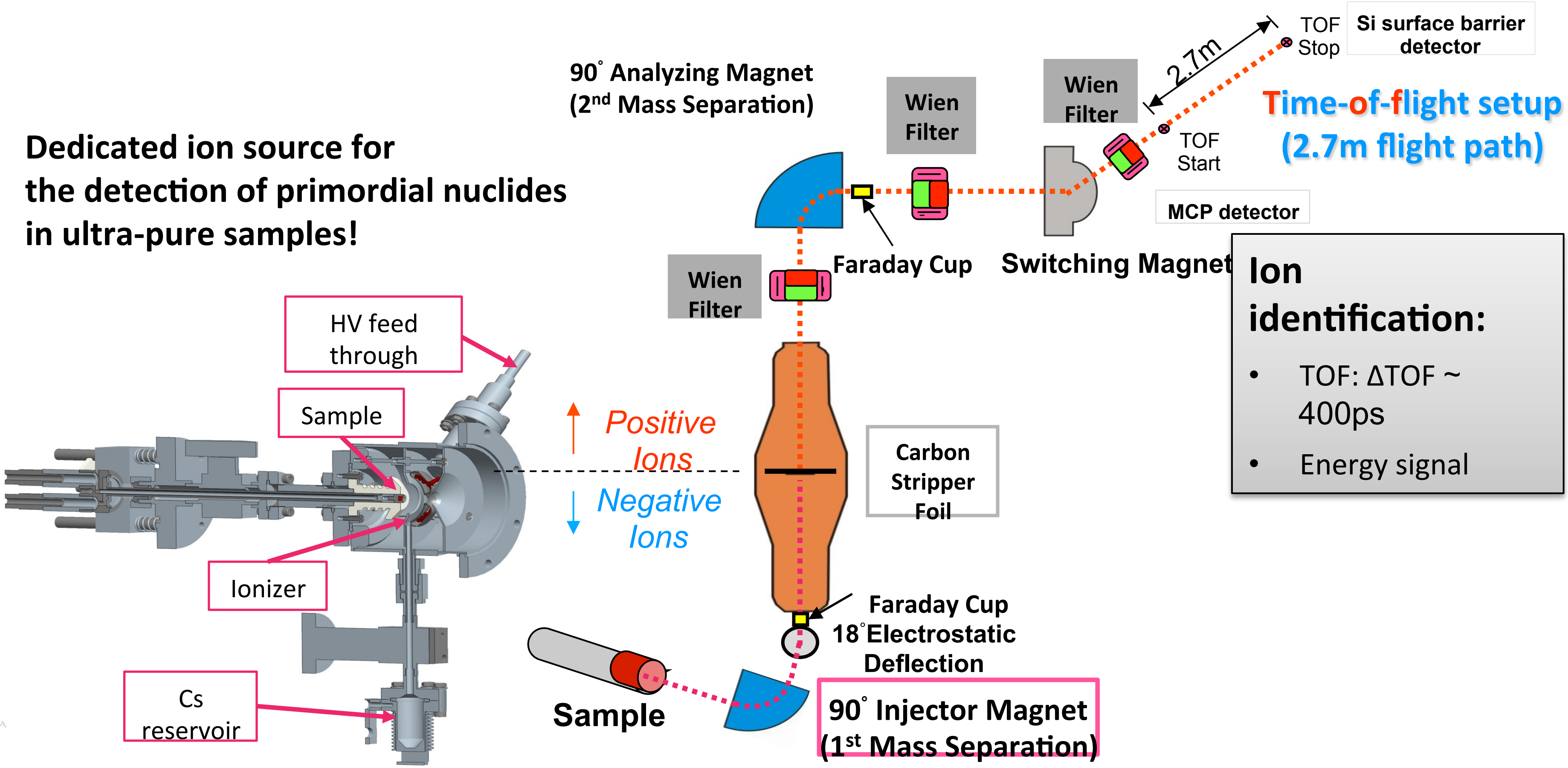

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From LRT 2017 Dr KORISHNIEK