UNIVERSITA' DEGLI STUDI DI MILANO BICOCCA

INFN Istituto Nazionale di Fisica Nucleare

Sez. Milano-Bicocca

Development of detector for high sensitivity measurements on activated samples

Juno-Italia Meeting - Ferrara
May 9-10, 2019

Speaker: Nastasi Massimiliano

Challenge: radiopurity measurements

Acrylic material

^{238}U $< 10^{-12}$ g/g

$^{232}Th < 10^{-12}$ g/g

^{40}K $< 10^{-13}$ g/g

Liquid Scintillator

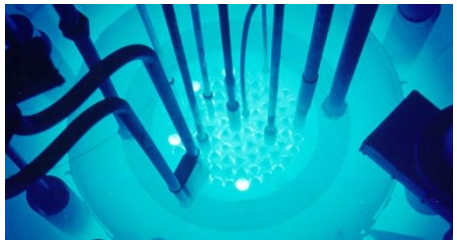
^{238}U $< 10^{-15}$ g/g

$^{232}Th < 10^{-15}$ g/g

^{40}K $< 10^{-15}$ g/g

Extremely demanding requirements for radiopurity

Neutron Activation Analisys



→ **~ppt level** of contamination (^{238}U,^{232}Th, ^{40}K)

NAA it's a good tool, but in order increase sensitivity, we need to combine **Neutron Activation** and **high sensitivity measurement systems**

Ge-Ge detector

GeSparK β-ϒ coincidence detector

Neutron Activation Analysis (NAA)

The neutron activation process consists in the production of unstable isotopes through neutrons absorption by the nuclei present in the sample

$$ {}^{A}_{Z}X + \mathrm{n} \xrightarrow[\beta^-]{} {}^{A+1}_{Z+1}Y + \gamma_{\text{cascade}} $$

The NAA technique consists of several steps:

Sample **exposure** to a neutron flux → **Extraction** of the irradiated sample and **measurement** of induced ϒ radioactivity (HPGe- detector) → **Calculation** of the **quantity of precursor** element ($^{A}_{Z}X$)

Sensitivity depends on:

Interferences in the matrix → Care in the sample preparation is **extremely important!**

Background detector in the region of the gamma emission → Development of **background reduction** techniques

Efficiency HPGe-detector → Development **high efficiency** measurements system

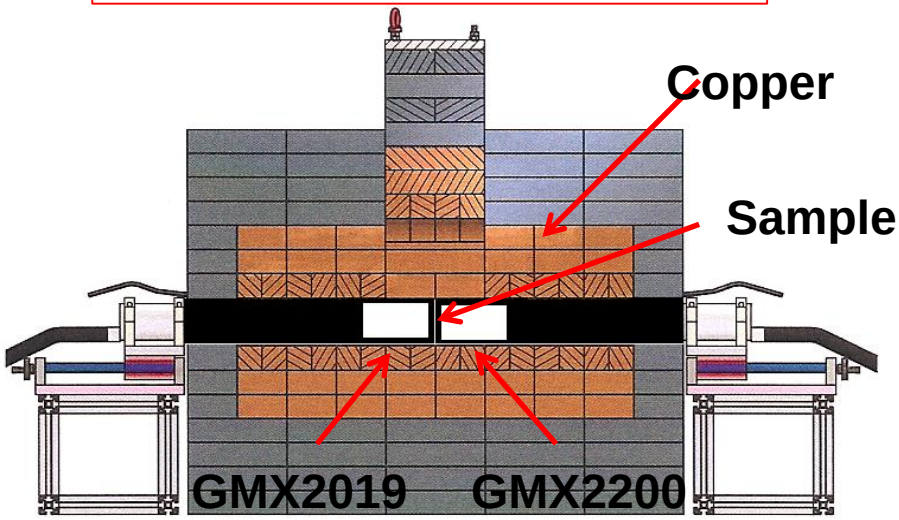
Ge-Ge HPGe: γ-γ detector

2x GMX detector

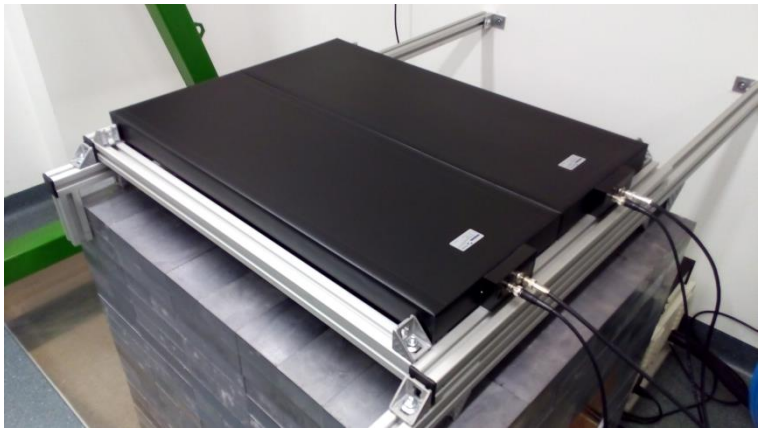
- Coaxial detector (n-type)
- Relative efficiency: 100%
- Ultra Low Background configuration
- Low Threshold (20keV)

Shielding:
15cm copper
20cm lead

High efficiency of measurement



Ge-Ge HPGe: Veto System

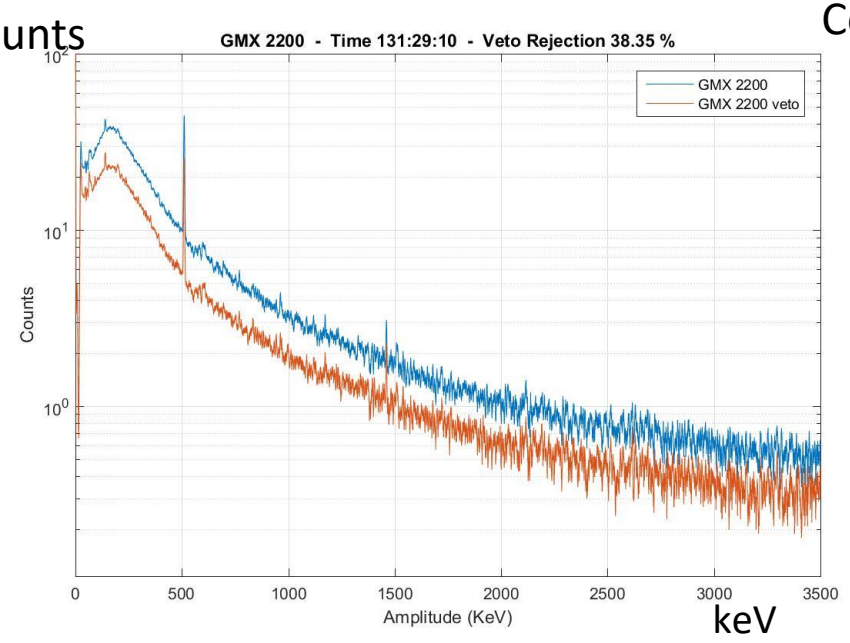


Anticoincidence technique

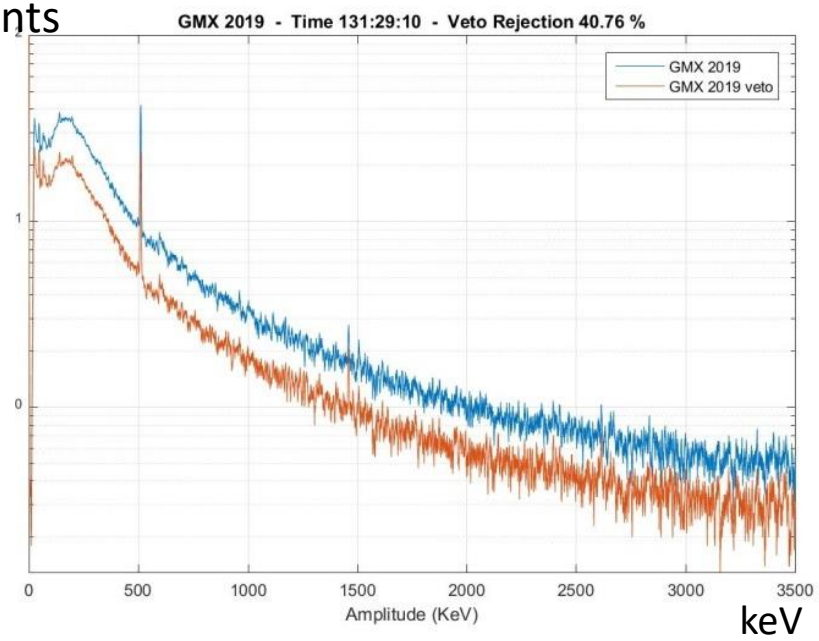
Plastic scintillator detector

Background suppression **~40%**

Counts



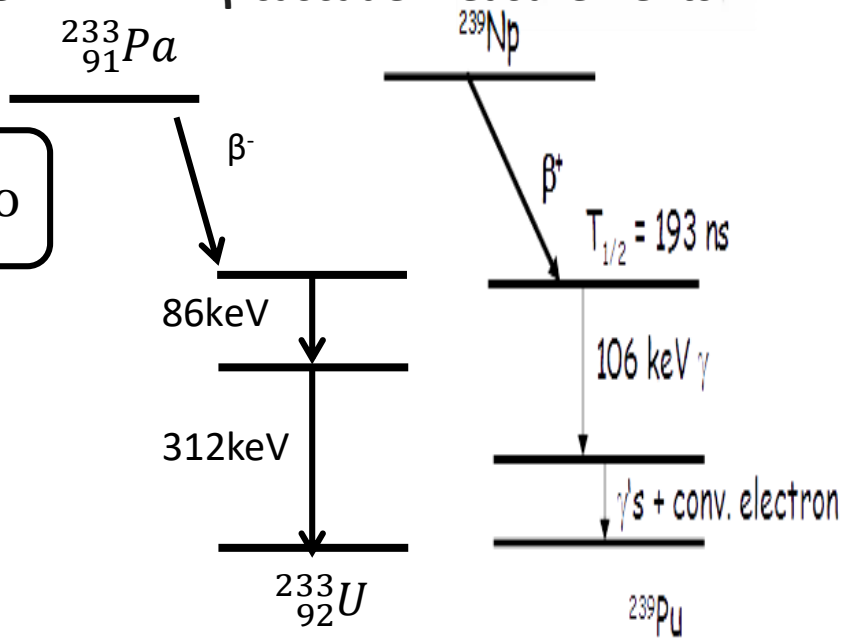
Counts



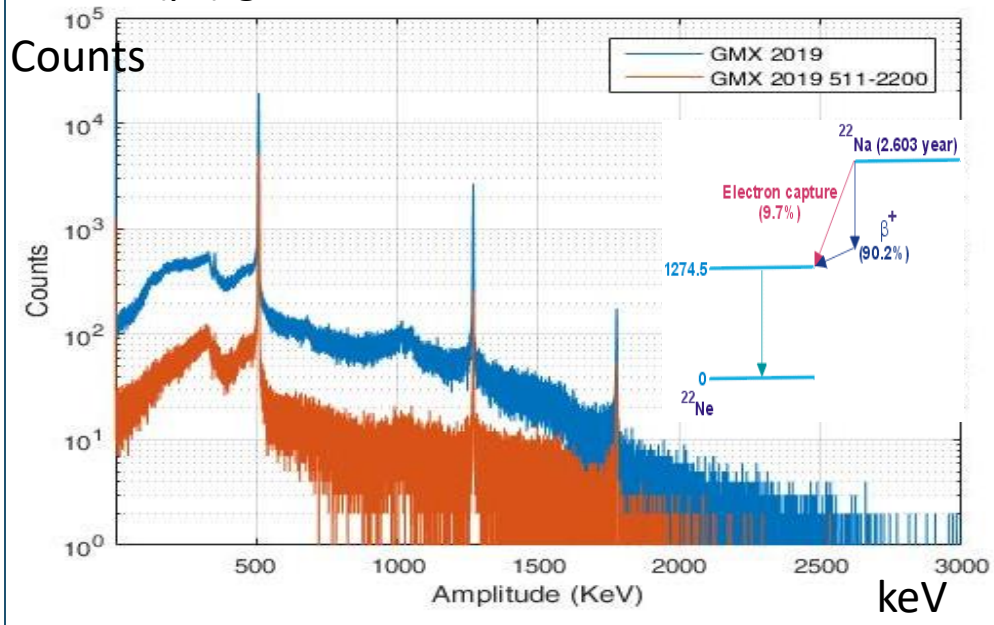
Ge-Ge HPGe: γ-γ coincidence

Dedicated acquisition system
allow to detect signals registered in coincidence
considering a very sharp time windows

The system is suitable for study
γ cascade measurements



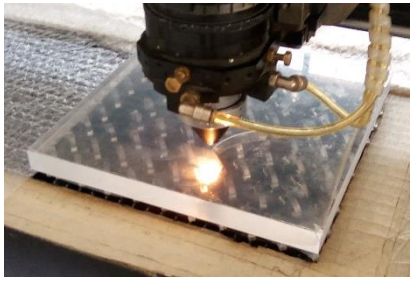
Coincidence analysis: Source measurements
$^{22}Na(\beta^+)$ gamma 511keV back to back



Background Reduction

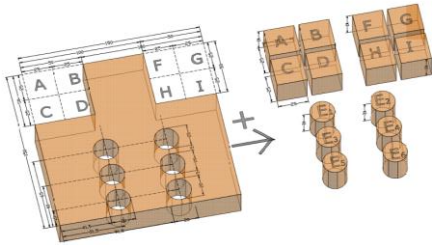
GeGe sensitivity: 0,5mBq/kg on ^{232}Th

NAA Acrylic – December 2018

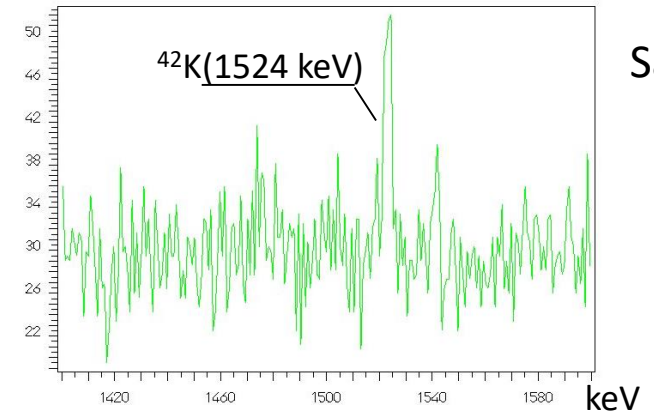


Sample	E1 – L1
Irradiation	**Dec2018**
Channel	Lazy Susan
T irradiation	6 hours
Detector	**Ge-Ge**
T measurement	27d
Sample mass	**8,22g**
Waiting Time	3h

Sample E1 of Panel n.1
(production step #2)



(See M. Sisti's talk for @mib results and Acrylic Panel references)



Potassium contamination seems to be in the **Acrylic bulk**

Samples have been prepared in clean room and container cleaned whit nitric acid

Limit @ 90% C.L.

Detector	^{40}K [ppt] Pre	^{40}K [ppt] Post	^{238}U [ppt]	^{232}Th[ppt]
GMX	**0,21±0,04**	<0,016	**<0,31**	**<0,49**

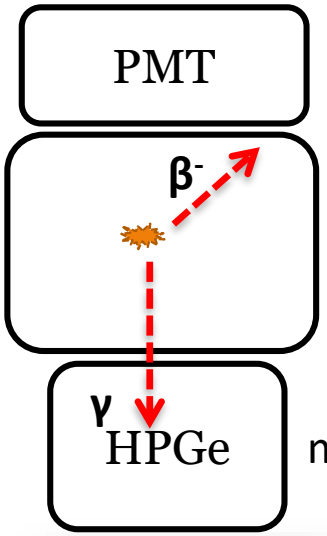
We have achieved sensitivity <1ppt for acrylic material

β-ϒ coincidence measurements on LAB activated samples

GeSparK: β-γ detector

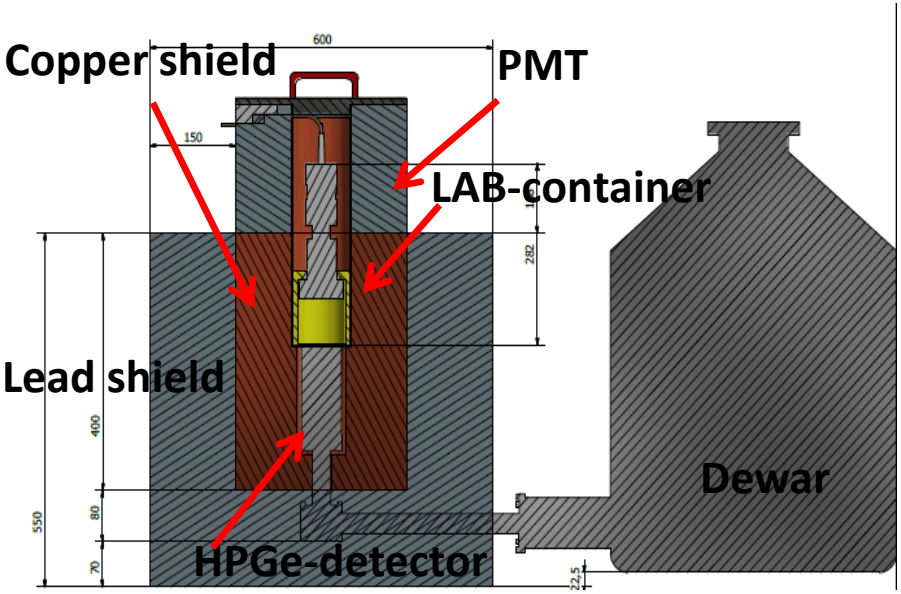
We are developing a new detector suitable for low background measurementes

Allow to perform **α/β – γ coincidence** measurements

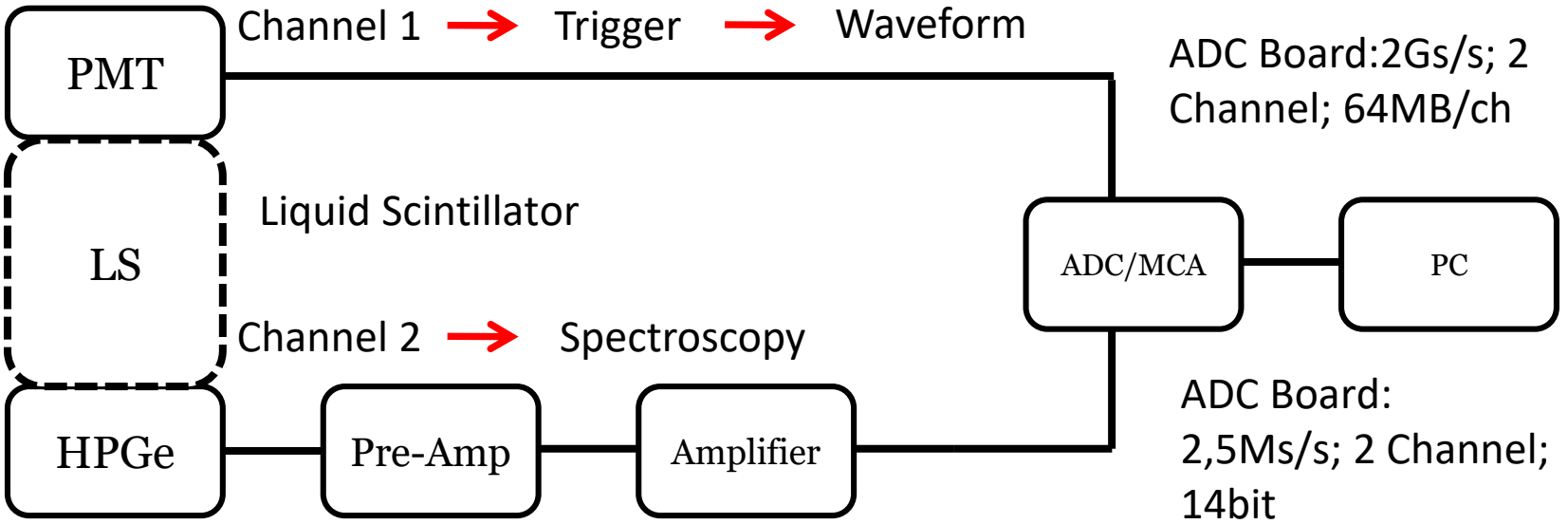


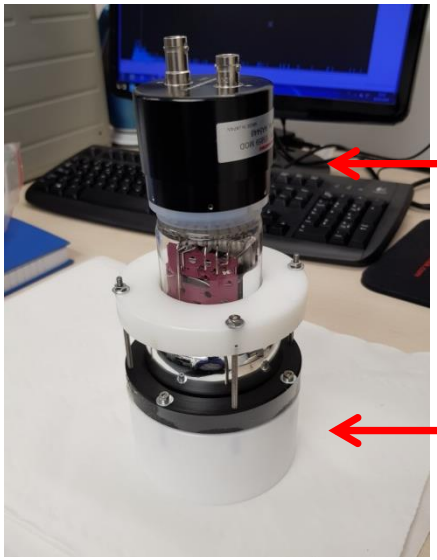
Liquid Scintillator

Irradiated sample is mixed with not irradiated liquid scintillator



Ge-SparK: electronic chain





PMT Hamamatsu

LAB-Container

HPGe Detector

HPGe P-Type

Relative Efficiency: 30%

Cryostat: L configuration

Carbon Window Input

Low Background configuration

GeSparK: pulse shape discriminator

Ultima Golden AB
Perkin Elmer

STD U
2ml- 25Bq

→ Liquid scintillator →

^{238}U – 4.46E9y
α (4.12MeV - 23%)
^{234}Th – 24d
β
γ (92keV - 5.6%)
γ (63keV - 3.8%)
^{234m}Pa – 1.17m
β
γ (1001keV - 0.83%)
^{234}U – 2.4E5

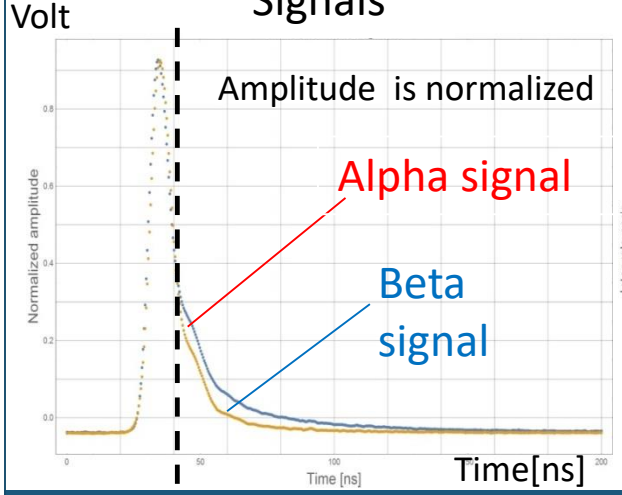
^{235}U – 7.04E8y
α (4.4 MeV - 57%)
α (4.37MeV - 18%)
α (4.32MeV - 3%)
α (4.58MeV - 8%)
α (4.21MeV - 5.7%)
γ (143keV - 10%)
γ (163keV - 4.7%)
γ (185keV - 53%)
γ (205keV - 4.7%)

→ Test of Pulse Shape Discriminator (PSD)

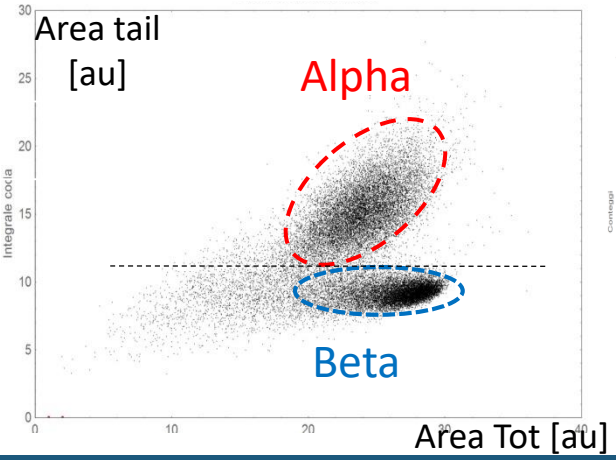
Alpha particles

Beta particles

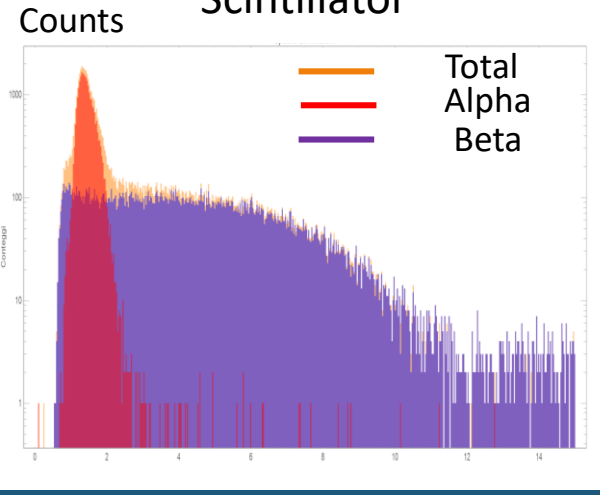
Signals



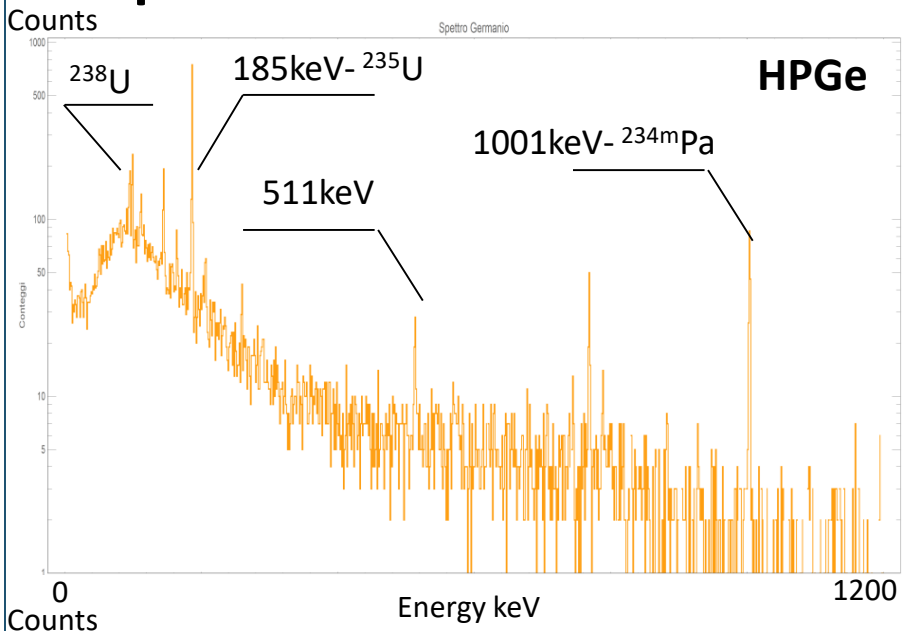
Alfa/Beta discrimination

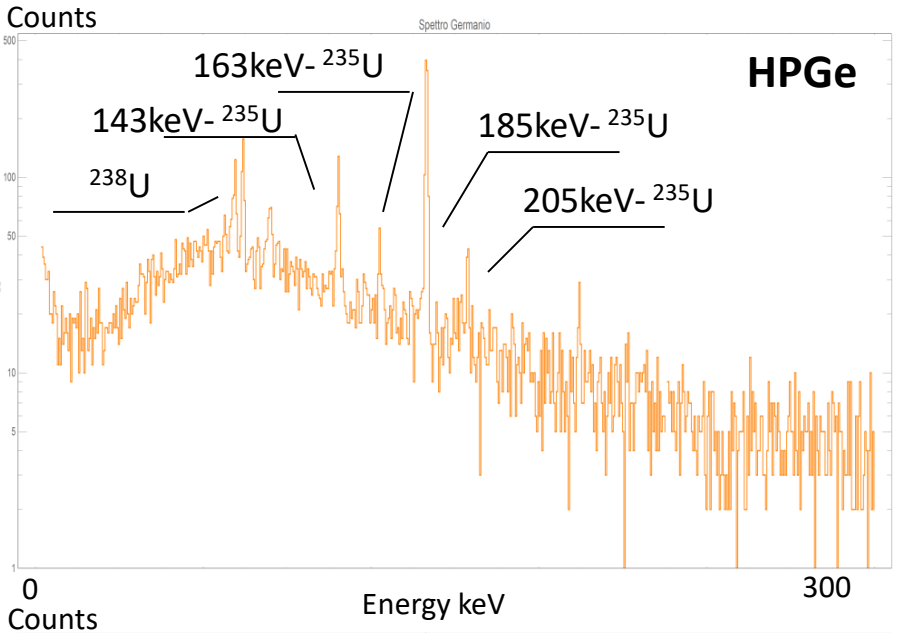


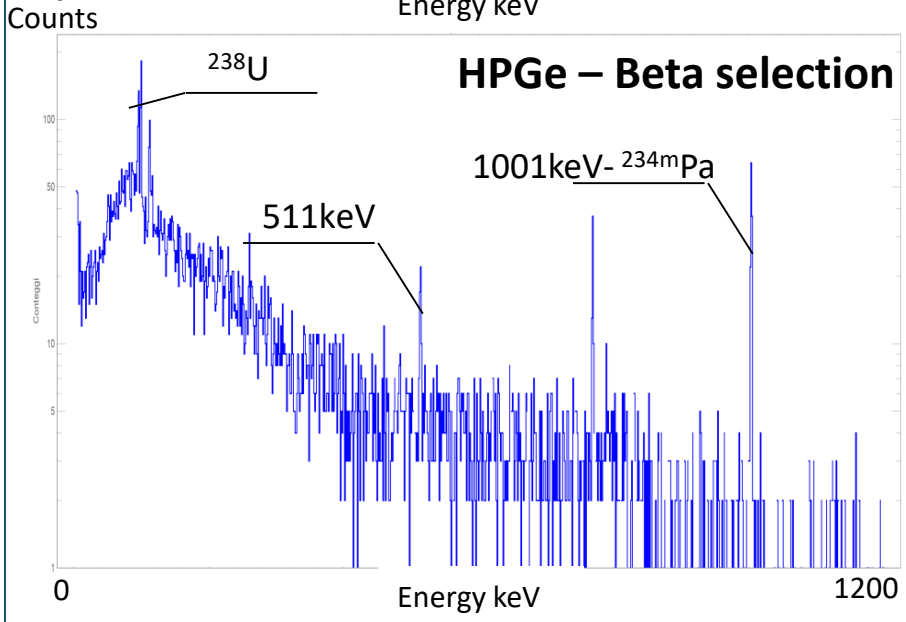
Scintillator

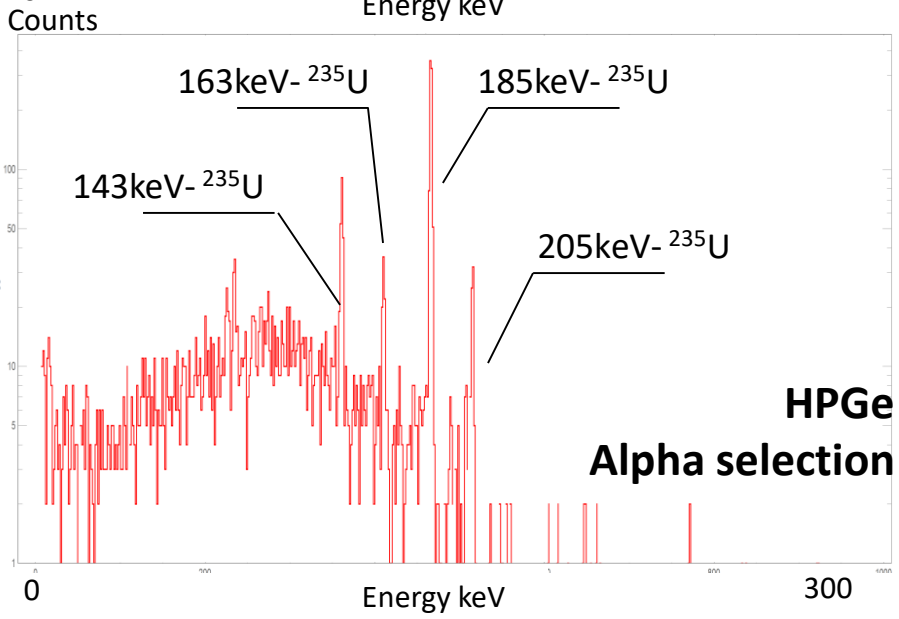


GeSparK: STD uranium









Irradiations – Distilled LAB after Al_2O_3 column

Three neutron irradiation campaigns of 6 hours on Distilled LAB sample

Sample	LAB Distilled	LAB Distilled	LAB Distilled
Irradiation	**1**	**2**	**3**
Channel	Lazy Susan	Lazy Susan	Lazy Susan
T irradiation	6 hours	6 hours	6 hours
Detector	**GeSparK**	**GeSparK**	**GeSparK**
T meas	736h	552h	26d
Sample mass	**6g**	**13g**	**28g**
Container	PE	PE	Aluminum

$$ {}^{A}_{Z}X + n \longrightarrow {}^{A+1}_{Z+1}Y + \gamma_{cascade} \quad (\beta^-) $$

GeSparK
β-ϒ coincidence

Irradiation **#1**

Polyethylene

Irradiation **#2**

Polyethylene

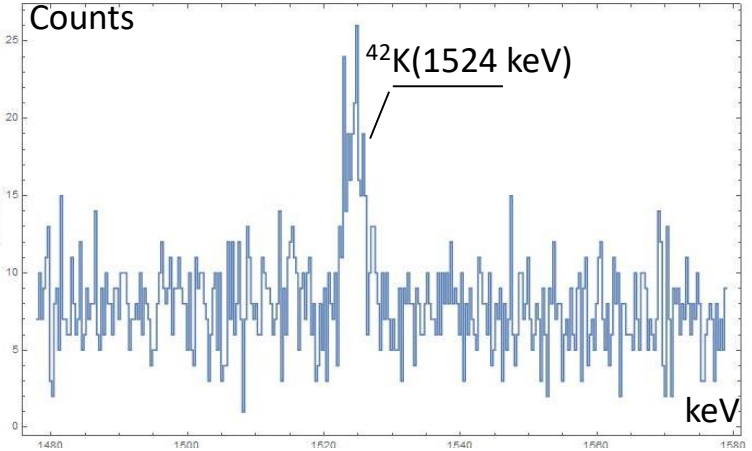
Irradiation **#3**

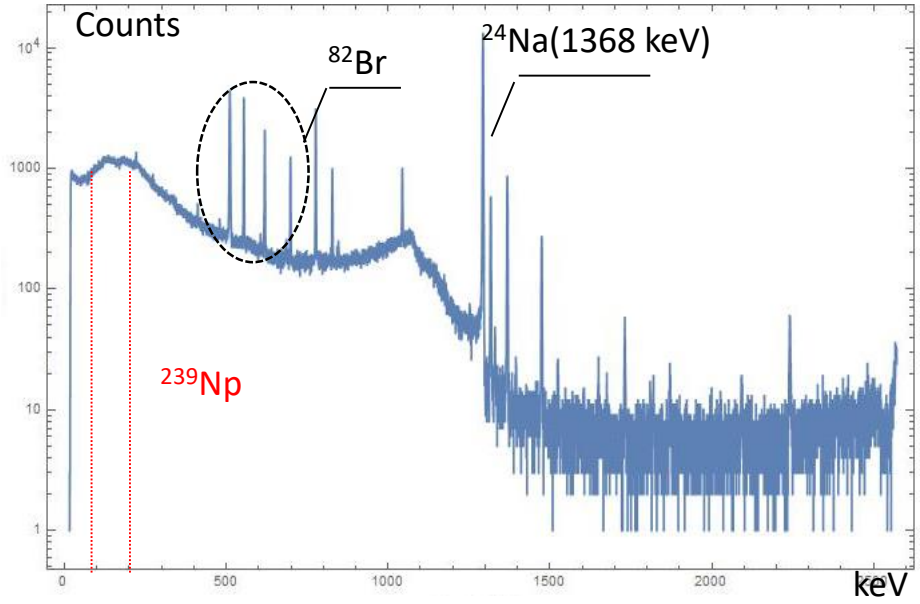
Aluminum

Distilled LAB

^{40}K [ppt]	^{238}U [ppt]	^{232}Th [ppt]
0,12±0,02	<0,7	<0,8

Limit @ 90% C.L.





A slight **^{40}K contamination** is presente Distilled LAB

Presence of interferences are a limit for the sentivity on ^{238}U

For ^{232}Th sensitivity is limited by cosmic muons

Screening of measurements on activated Raw and Al_2O_3 purified LAB samples

NAA on Raw and Al_2O_3 purified LAB

Three neutron irradiation campaigns of 6 hours

In each irradiation we have exposured at the flux of neutron a Raw and Al2O3 purified LAB sample

Irradiation **#1** Irradiation **#2** Irradiation **#3**

Polyethylene Polyethylene Aluminum

HPGe detectors in low background configuration

GeGEM ε_{rel}30%

BeGE detectorε_{rel}50%

Summary

LAB Sample	^{40}K[ppt]	^{238}U[ppt]	^{232}Th[ppt]
Raw	<0,05	<4,8	<4,1
Al_2O_3	0,19±0,03	<3,2	<4,0
Distilled	0,12±0,03	<0,7	<0,8

- A slight **^{40}K contamination** is presente in Al_2O_3 and Distilled LAB
- Between step Al_2O_2 and Distilled the contamination of ^{40}K decrease

Next steps for β-ϒ detector:

- Implement cosmic rays veto
- Optimize data analysis
- Increase sample mass in the next irradiation