Novel High Sensitivity Analysis for Determination of Ultra-Trace Elements in Liquid Samples

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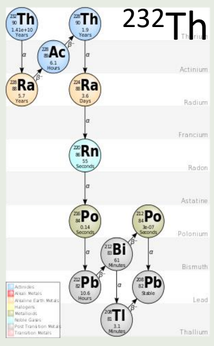
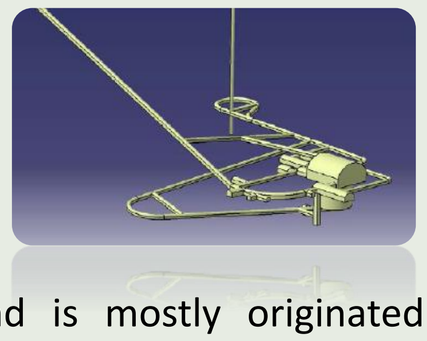
Introduction

In **rare event experiments** sensitivity is conditioned by the **radioactive background**





Background is mostly originated from **natural radioactive elements** present in the materials of the experimental apparatus

The greatest risk: radioactive background overlaps in the energy regions of interest

Material selection

Essential condition to reduce radioactive background in last generation rare event searches with increasing sensitivity

High **radiopurity** materials:

acceptable levels for ^{238}U and ^{232}Th: **$1 \cdot 10^{-13}$ - $1 \cdot 10^{-15}$ g/g**

Development of a methodological approach for trace element measurements in organic liquids (**liquid scintillators (LS)**)

High sensitivity analysis for the determination of ^{238}U and ^{232}Th in organic liquids

Our **methodological approach** combines neutron activation analysis (NAA), radiochemical treatments and high sensitivity measurements by a novel β-γ low background detector

Chemical treatments → **Sample irradiation** → **Radiochemical separation** → **β-γ measurements**

Chemical treatments	Sample irradiation	Radiochemical separation	β-γ measurements
Remove interferences **Concentrate** sample	**Activates** elements of interest	**Separation** of activated elements	**High sensitive** measurements

Neutron activation analysis

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

Sample and STD reference are **exposed** to a neutron flux

$$^{232}_{90}Th + n \rightarrow {}^{233}_{91}Pa$$

$$^{238}_{92}U + n \rightarrow {}^{239}_{93}Np$$

TRIGA Mark II

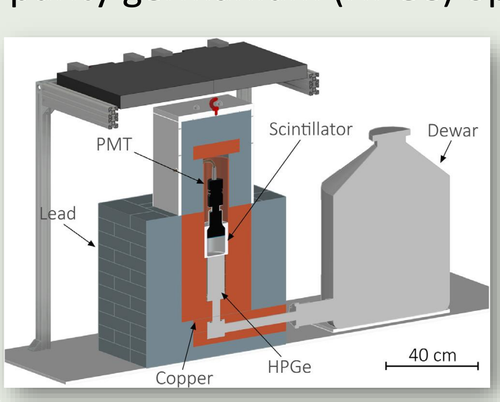
Research reactor (250 kW) - Pavia, Italy

Extraction of the irradiated sample and **measurement** of induced ϒ radioactivity

Calculation of the **quantity of precursor** element ($^{A}_{Z}X$)

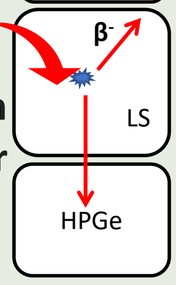
β-γ measurements

Detector is made of a liquid scintillator and a high purity germanium (HPGe) operating in time coincidence



Activated sample is mixed with not irradiated liquid scintillator

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



This measurement system is suitable to detect well-defined time correlated events allowing a **strong reduction of background**

Radiochemical treatments

The following operations are carried out in sequence in **clean room** (class 1000)

1. Cleaning of tools prior to sample handling with a specific protocol

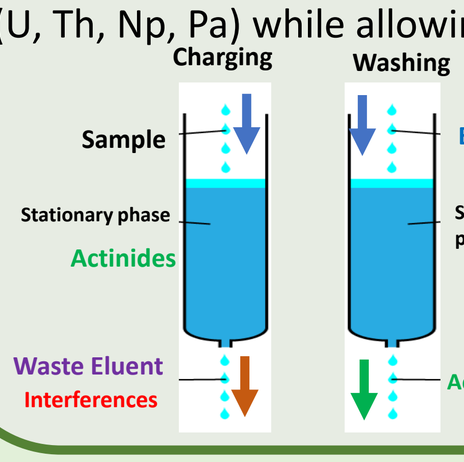
2. Liquid-Liquid Extraction

Allows the **transfer of U and Th contaminations** from the **LS sample** into an acid liquid solution (ACL)

$$\frac{Volume_{ACL}}{Volume_{LS}} = \frac{1}{5}$$

3. Extraction Chromatography

Ideally, column chromatography **selectively absorbs actinide** (U, Th, Np, Pa) while allowing interferences to pass through



Pre-Irradiation: *U-TEVA Resin*

Absorbs: Uranium and Thorium

Post-Irradiation: *TEVA Resin*

Absorbs: Neptunium and Protoactinium

Overall efficiency of the process:

80% for Uranium - 20% for Thorium

Test on blank sample

The blank is a sample which went through all processing steps **just without LS.** Blank = nitric acid solution (mass: 228 g)

Measurements on blank sample

^{238}U [g/g]	^{232}Th [g/g]
$(9,5 \pm 2,4) \cdot 10^{-15}$	**$< 7,7 \cdot 10^{-14}$**

limits @ 90% C.L.

Considering a LS sample of 1 kg without contaminations it is possible to achieve a **sensitivity of:**

$2 \cdot 10^{-15}$ g/g for **^{238}U - $1,5 \cdot 10^{-14}$ g/g** for **^{232}Th**

Future plan…

In order to increase sensitivity:

- β-γ mesurements with an higher efficiency system
- Increase sample mass

Apply the methodological approach to perform measurements on liquid scintillator samples used in rare events experiments

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