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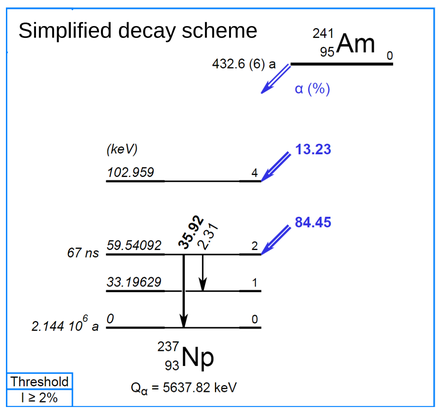
Preparation of drop deposited sources in 4π absorbers for total decay energy spectrometry (*Q* spectrometry)

Introduction

- **α spectrometry** with semiconductor detectors cannot quantify some actinides due to overlapping α peaks (e.g. ^{239}Pu and ^{240}Pu)
  → Measurements must be combined with other techniques
- ***Q* spectrometry**
  - **Advantages**
    - One peak per radionuclide at:
      $E = E_\alpha + E_\gamma + E_X + E_{e^-} + E_{recoil} \sim E_{Q\alpha}$
      → Minimize the overlap between peaks
      → One measurement can quantify all actinides
- **Constraints and conditions:**
  - All radiation must be absorbed
    → Absorber sized to absorb all the radiation **from the decay**
  - All radiations must be converted to heat
    → Self absorption of the nuclear recoil deforms the peak and enlarges the resolution [1-2]
    → **Very thin and homogeneous source deposit required**

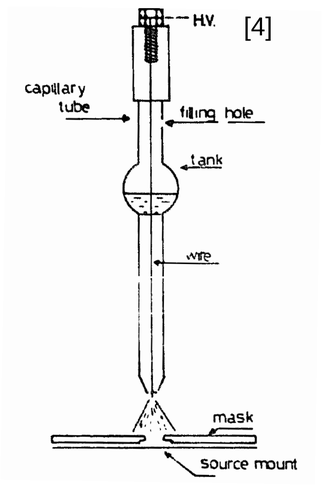


Source deposition techniques

- **Electro-deposition and electro-precipitation**
  - Very thin (nm scale) and homogeneous radioactive deposit
    → *Q* spectrum with energy resolution of 1.25 keV was demonstrated [3]
  - Deposition yield depends on the element → Loss of activity traceability
  - More complex implementation required
- **Drop and dry deposition**
  - Thick, inhomogeneous and unreproducible deposit
    → Deforms and enlarges the *Q* peaks [2]
  - Activity traceability (deposited mass or volume measurement)
  - Very simple procedure
  - To keep the **drop and dry deposition** attractive, we are investigating alternative surfaces to improve the deposit quality.
    → **Drop deposition on gold with latex pad [4]**
    → **Drop deposition on nanoporous gold [5]**

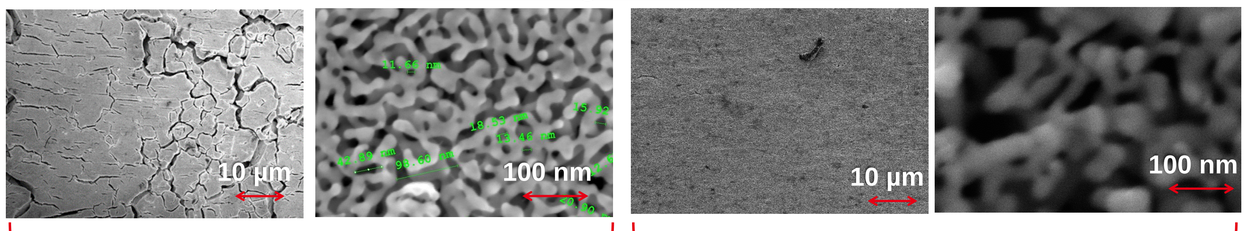
Surface preparations for source deposition

- **Gold surface with latex pad [4]**
  - Latex particles of 70 nm electrosprayed on a Au disk of 12 mm diameter.
  - ^{239}Pu radioactive solution dropped and dried using a micropipette.
  - **The hydrophilic latex pad produces a homogeneous spreading and drying of the drop.**
  - 1 mm² (~1 Bq) cut and enclosed between two 25 µm thick Au foils.

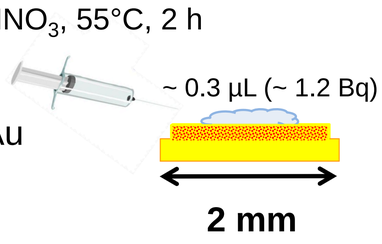


- **Nanoporous gold (NPAu)** prepared by dealloying AuAg [6]
  - $Ag_{70}Au_{30}$ (wt%) foil welded on half of the Au absorber.
  - Ag is dissolved by nitric acid → a NPAu layer remains on the half absorber.

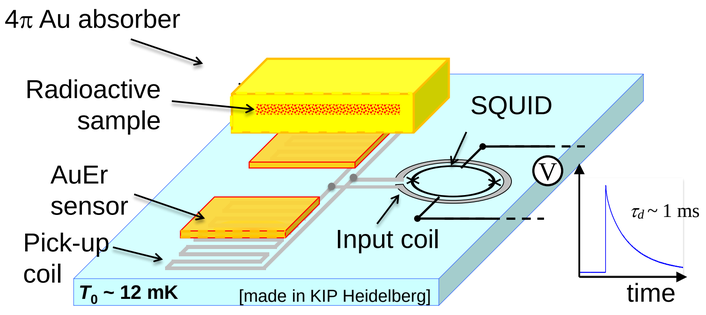
SEM images of NPAu

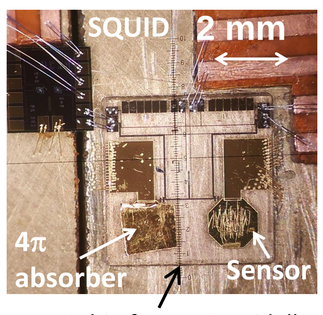


- Radioactive solution (HNO_3 3N, ^{239}Pu 4 kBq/g)
- Easily absorbed and dried (few tens minutes) in NPAu
- Second Au half-absorber diffusion-welded on top



- **MMC prototypes with ^{239}Pu in 4π absorbers**

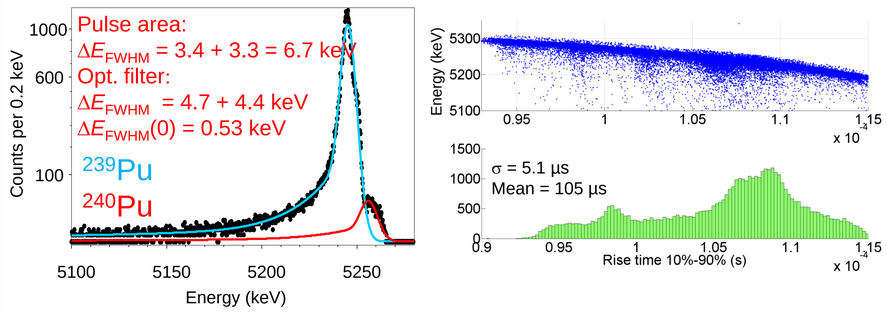




MMC chip from KIP Heidelberg

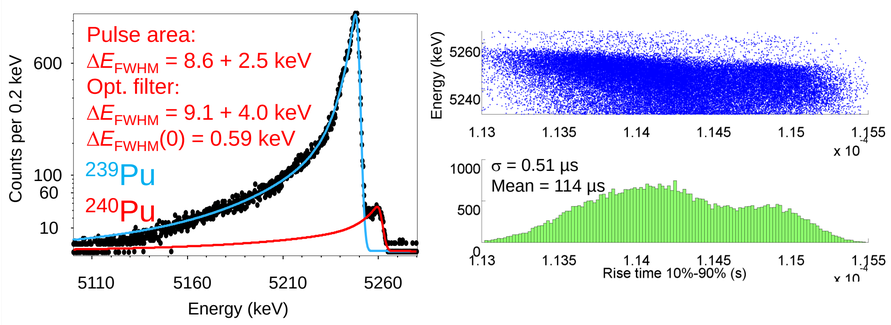
Q spectra and results

- **Absorber with source on latex pad**



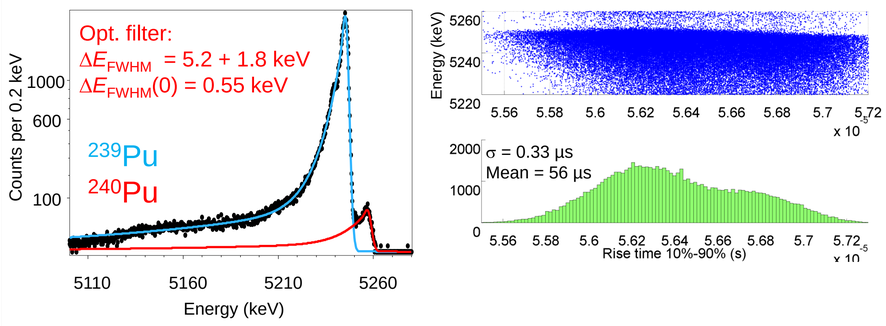
- Dispersion of rise time and dependence of pulse height on rise time
- Peak shape deviates from Bortel function + peak overlap
  → No quantification possible

- **Absorber with source in NPAu (embedded in 2x25 µm)**



- Smaller dependence of pulse height on rise time
- Bortel function peak shape
- Resolution insufficient to separate ^{239}Pu and ^{240}Pu

- **Absorber with source in NPAu (embedded in 2x50 µm)**



- No rise time dependence
- Bortel function peak shape
- Better resolution resolves partially ^{239}Pu ^{240}Pu
  → Isotopic quantification possible

X	Reference values		Measured values with NPAu	
	X/(^{239}Pu+^{240}Pu) (Bq/Bq)	Rel. unc. (%)	X/(^{239}Pu+^{240}Pu) (Bq/Bq)	Rel. unc. (%)
^{239}Pu	0.9683 (40)	0.42	0.9688 (38)	0.39
^{240}Pu	0.03166 (42)	1.3	0.03117 (50)	1.6
^{241}Pu	0.02061 -	-	0.01832 (38)	2.1
^{241}Am	0.00793 (24)	3.1	0.00445 (19)	4.2
^{238}Pu	- -	-	0.00479 (19)	4.0

→ **Good agreement between measured and reference values**

References

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Conclusions and perspectives

- We successfully produced alternative surfaces on gold for source deposition
- A dependence of pulse height on rise time was observed and has been suppressed
- Precise Pu isotopic quantification is possible using drop deposition in NPAu
- Resolution is far from baseline resolution → must be understood and improved