The SuperNemo ^{82}Se-source foils radiopurity measurement with the BiPo-3 detector

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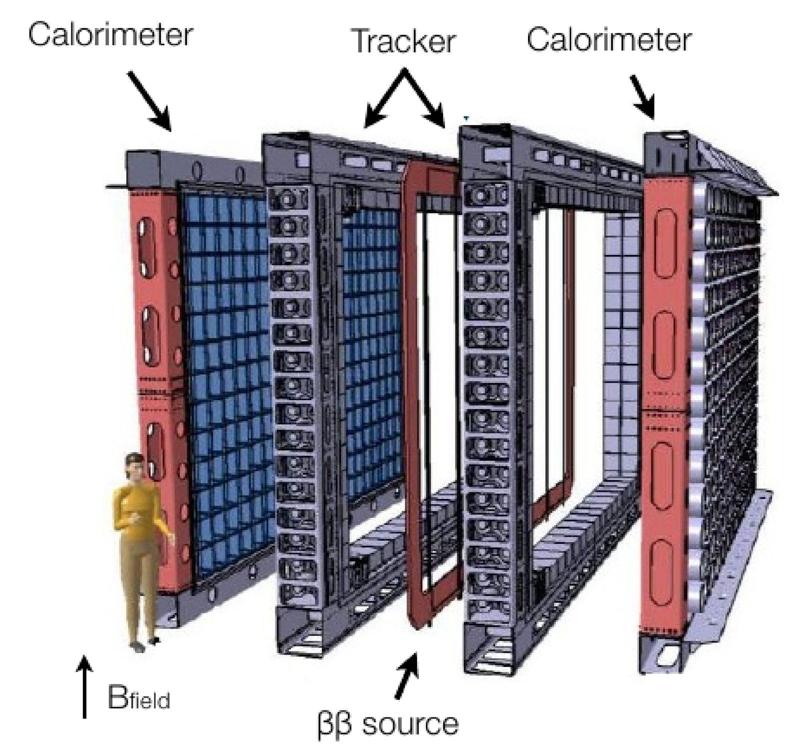
on behalf of the SuperNemo collaboration

1. SuperNemo



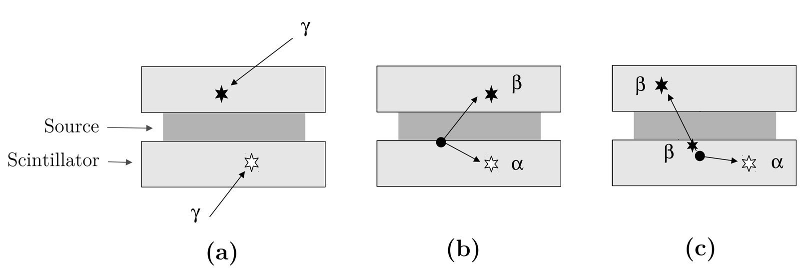
- $2\beta0\nu$ experiment combining tracker and calorimetric measurements
- Baseline isotope: ^{82}Se (Q_β=2998 keV)
- Targetted sensitivity $T_{1/2}(2\beta0\nu) > 10^{26}$ y

2. $2\beta0\nu$ source foils

- The ^{82}Se is in the form of powder between mylar foils
- **Backgrounds from foils are the main background for SuperNemo: ^{208}Tl (Q_β = 4.99 MeV) and ^{214}Bi (Q_β = 3.27 MeV)**
- Required radiopurities : $\mathcal{A}(^{208}\text{Tl}) < 2$ μBq/kg and $\mathcal{A}(^{214}\text{Bi}) < 10$ μBq/kg
  → measured with the BiPo-3 detector

5. The BiPo-3 backgrounds

(a) Random coincidences due to the γ flux
(b) ^{212}Bi or ^{214}Bi contamination on the surface of the scintillators
(c) ^{212}Bi or ^{214}Bi contamination in the volume of the scintillators



Dedicated background measurements

	Mod. 1	Mod. 2	**Comb.**
Duration (d)	36.2	75.7	111.9
Scint. surf. (m^2)	3.06	3.42	3.24
Data events	18	30	48
Surf. Bkg. (fit)	2.5	6.9	9.4
Coinc. (fit)	15.5	23.1	38.5
Coinc. (singles)	14.3	25.0	39.3
$\mathcal{A}(^{214}\text{Bi})$ μBq/m^2	1.0 ± 0.6	1.0 ± 0.4	1.0 ± 0.3

Surface Background

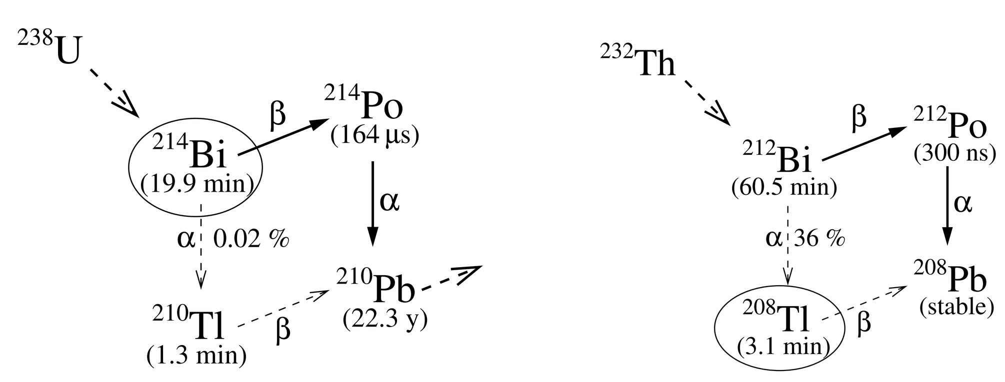
$$\begin{cases} \mathcal{A}(^{208}\text{Tl}) & = & 0.9 \pm 0.2\ \mu\text{Bq/m}^2 \\ \mathcal{A}(^{214}\text{Bi}) & = & 1.0 \pm 0.3\ \mu\text{Bq/m}^2 \end{cases}$$

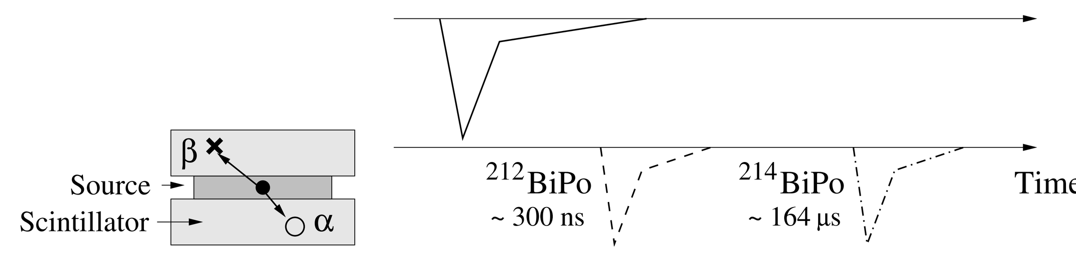
Conclusions

- The BiPo-3 detector reached sensitivities ^{208}Tl $\sim$ 10 μBq/kg and ^{214}Bi $\sim$ 100 μBq/kg in the measurement of thin foils.
- The first four SuperNemo foils have ^{208}Tl levels a factor 5 to 20 higher than the requirements. Other enriched ^{82}Se foils are under development, with a different purification method and production technology.

3. The BiPo-3 detector

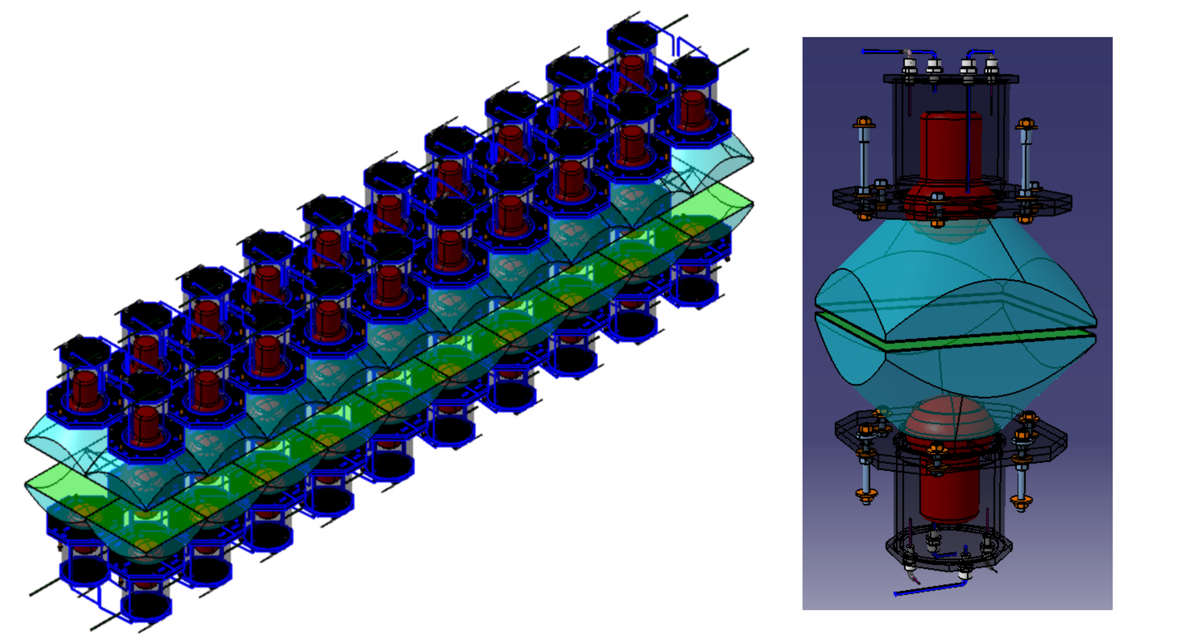
The measurement principle is the detection of an electron followed by a delayed α particle.





The foil of interest is installed between two thin ultra radiopure organic plastic scintillators. The timing of the delayed signal depends on the isotope to be measured.

4. Description of the BiPo-3 detector



- BiPo-3 is composed of 2 modules
- Each module consists of 20 pairs of optical sub-modules
- Each optical sub-module consists of a polystyrene-based scintillator plate coupled with a PMMA optical guide to a 5 inches low radioactive PMT.
- The size of each scintillator is $300 \times 300 \times 2$ mm^3
- The total detector surface is 3.6 m^2.

6. Measurement of the first enriched ^{82}Se foils

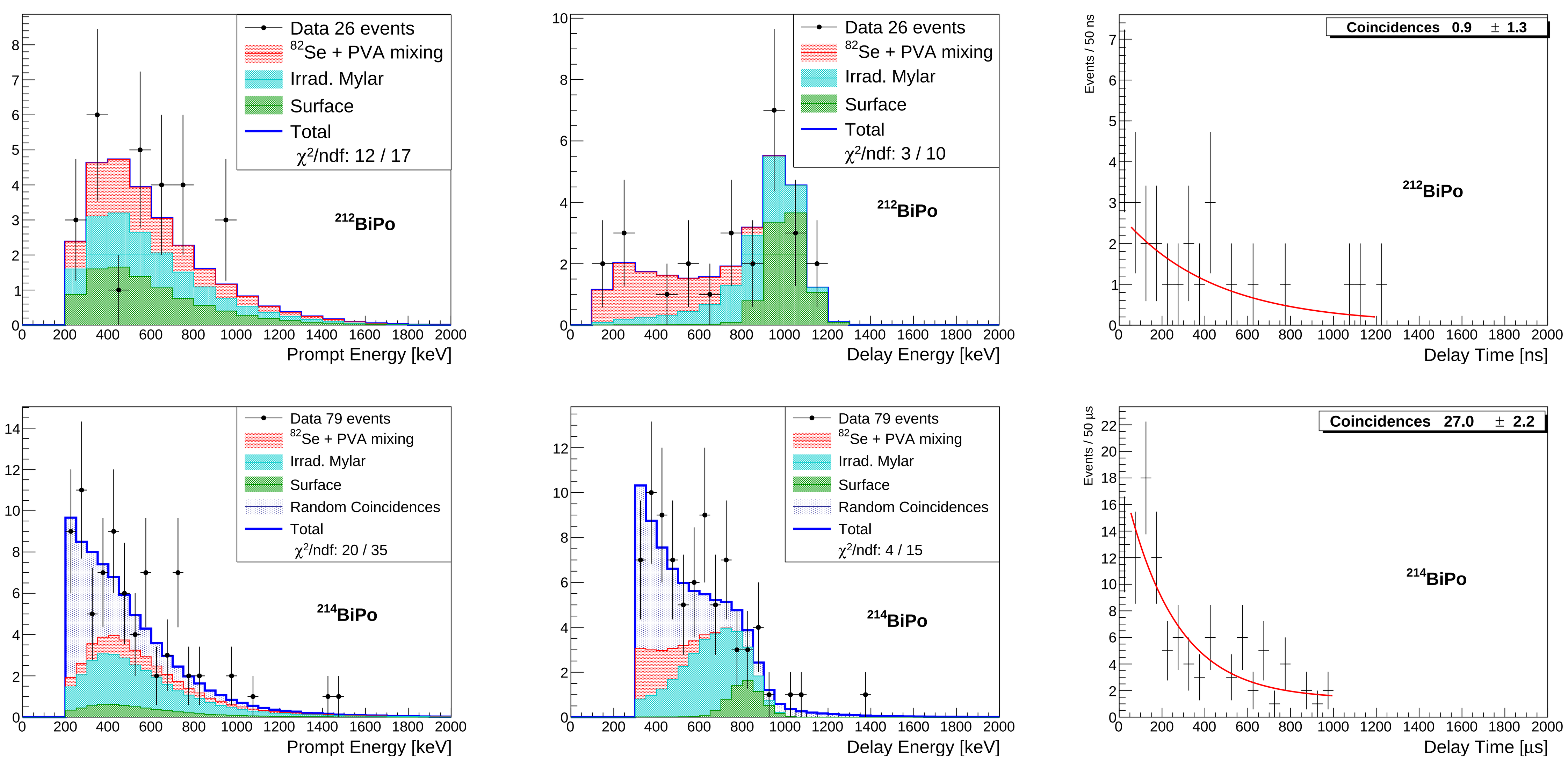
Analysis method

Event selection:

- The energy of the prompt signal is greater than 200 keV.
- The energy of the delayed signal is greater than 150 keV for the ^{212}BiPo events, and greater than 300 keV for the ^{214}BiPo events. The higher energy threshold for the ^{214}BiPo measurement is set in order to suppress the external random coincidence background (larger coincidence window).
- The delay time, Δt between the prompt and the delayed signal is 20 ns$< \Delta t <$ 1500 ns for the ^{212}BiPo events, and 10 $\mu s < \Delta t <$ 1 ms for the ^{214}BiPo events.
- Rejection of PMT noise pulses by pulse shape analysis
- If a signal greater than 3 mV (about 10 keV) is detected in coincidence with the prompt signal in the opposite scintillator, the BiPo event is recognized as a bulk contamination background event and is rejected.

We search for an excess of BiPo events in data above the background expectation in the delayed energy spectrum. The components of background are the random coincidences and the ^{212}Bi or ^{214}Bi contamination on the surface of the scintillators. For the measurement of the ^{82}Se foils, the contamination inside the irradiated Mylar is added as an extra component of background. The delayed energy spectra of the background components are simultaneously fitted to the observed data. The energy spectra of each component are calculated by Monte Carlo, except for the random coincidence background for which the energy spectrum is measured using the single counting events.

Measurement of the first four enriched ^{82}Se foils



$$\mathcal{A}(^{208}\text{Tl}) = (27 \pm 18)\ \mu\text{Bq/kg (90\% C.L.)}$$
$$\mathcal{A}(^{214}\text{Bi}) < 300\ \mu\text{Bq/kg (90\% C.L.)}$$