Super NEMO : R&D Status

BiPo detector

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Outline

1. What is the BiPo? Why Super NEMO needs it?
2. Detection technique
3. R&D program description
4. Prototype BiPo I: scintillator cubes
5. Prototype BiPo II: scintillator plates
Why SuperNEMO needs a radiopurity ultra-sensitive detector?

- **Goal of BiPo**: precise measurement of the $^{202\text{Tl}}$ (via $^{214\text{Bi}}$) on source foils before their installation in Super NEMO
- **Required sensitivity**: $2$ µBq/kg in 1 month $\Rightarrow 0.2$ µBq/m²
- **Technique**: plastic scintillator to search for Bi $\rightarrow$ Po decay
BiPo decay process

$^{212}$Bi from Thorium decays 1/3 into $^{208}$Tl, 2/3 into $^{212}$Po

BiPo detector measures the $\text{e}^-$ from $^{212}$Bi $\rightarrow$ $^{212}$Po, and after $\sim$300ns, the $\alpha$ from $^{212}$Po $\rightarrow$ $^{208}$Pb
Detection technique

\[ E_{\text{threshold}}(\text{e}^-) = 100 \text{ keV} \]
\[ + \ E_{\text{threshold}}(\alpha) = 1 \text{ MeV} \]
\[ + \text{ back-scattering rejection} > 40 \text{ keV} \]

\[ \Rightarrow \text{ Detection efficiency of 7.5\% (G4 MC)} \]

Background sources :

- Random coincidence
- Surface contamination (until a depth of 100\text{\mu}m)
**Additional cut for surface contamination**

**Important background:** surface contamination

- Prompt $e^-$, $T_0$
- Delay $\alpha$, $T_{1/2} \sim 300$ ns

- $e^-$ from $^{212}$Bi: $\sim 50$ keV in 100 $\mu$m of scintillator

**Cut:** no $e^-$ with energy $> 50$ keV in the scintillator of the $\alpha$

- Efficiency $\downarrow$ to 6%
- BUT background $\div 15$

**Merit factor:** $\frac{Signal}{\sqrt{Background}} \uparrow$ by 300 % !
R&D program

• 2 different prototypes studied:
  - 25 blocks of scintillator/m², 1 PMT/block
  - 1 plate of scintillator/m², ~30 PMTs/plate

• Additional R&D: ultra-fine scintillating fiber for $e^-/\alpha$ separation

• Common electronic: acquisition by card MATACQ
  (12 bits, 0-1V, 2.5µs, 2GHz/s)

• Low background test in LSC, Canfranc, Spain (2500 m.w.e.)
Canfranc Shielding

Shield Test:
- external: 2.3 m x 2.3 m x 2 m
- internal: 1.45 m x 1.45 m x 1.05 m
- 25 capsules BiPo I can be installed in Phase I
- Multilayer BiPo II fit inside the shielding
Description of the BiPo I prototype

- Scintillator blocs: 20 x 20 x 1 cm
- NEMO-3 equipments (radiopure 5” PMTs, radiopure scintillator, etc…)
- First capsule installed in Canfranc end of the year 2006 with ultra-pure Al
- For the moment, DAQ with Lecroy oscilloscope
- PMMA optical guide
Measurement of the quenching factor

$^{241}\text{Am } \alpha$ source, peak at 5.6 MeV

Light in a scintillator detected by a PMT

Successive mylar foils to decrease the $\alpha$ energy

Scintillator

$^{241}\text{Am source } \quad Q_\alpha = 5.6 \text{ MeV}$
Measurement of the quenching factor

@ 1 MeV
QF = ~25

40 keV threshold for e⁻ = ~1 MeV
threshold for α
Calculation principle of the BiPo sensitivity

If we see during $T_{\text{obs}}$ N events, we can calculate the sensitivity as follows:

Surface of 1 Capsule: $S = 400 \text{ cm}^2$

Efficiency: $\varepsilon = 36\%$ because:
- 50\%: $e^-$ and $\alpha$ are back-to-back
- $\times 90\%$: delay time up to 1 $\mu$s (= 3.3 $T_{1/2}(^{212}\text{Po})$)
- $\times 80\%$: event is rejected if back-scattered $e^-$

$\Rightarrow$ Sensitivity: $A(^{212}\text{Bi} \rightarrow ^{212}\text{Po}) < N_{\text{excluded}} / (\varepsilon \times S \times T_{\text{obs}})$
1st sensibility result of BiPo I capsules

• 1 capsule alone : 10.1 days of measurement
  – 0 BiPo “in time” events (<1µs)
  – 1 BiPo “random” event (>1µs) compatible with 0.32 expected coincidences
  \[ \text{limit } A(^{212}\text{Bi} \rightarrow ^{212}\text{Po}) < 65 \text{ µBq/m}^2 \]
  \[ (A(^{208}\text{Tl}) < 32.5 \text{ µBq/m}^2) \]

• 2 capsules : 11.3 days
  – 0 BiPo “in time” events
  – 0 BiPo “random” events for 1 expected coincidence
  \[ \text{limit } A(^{212}\text{Bi} \rightarrow ^{212}\text{Po}) < 29 \text{ µBq/m}^2 \]
  \[ (A(^{208}\text{Tl}) < 14.5 \text{ µBq/m}^2) \]
Description of BiPo II prototype

- Scintillating plate $75 \times 75 \text{ cm}^2$ or wider
- ~20 PMTs’ lecture on 2 sides
- Optical guides to transfer the light from scintillator to PMTs

R&D Issues:
- How many PMTs? 2” or 3”?
- Optimized shape of the optical guides?
- Energy threshold for an $\alpha$ in the middle?
Experimental set-up in Orsay

A well-designed mechanical support has been conceived:
- Plots for the 20x20 cm² scintillator plate
- Fixation for the PMTs
Position reconstruction

- 4 PMTs reading a 20×20 cm² plate
- $^{241}\text{Am} \alpha$ source placed every 5cm on the plate
- We need to reconstruct the source position with charge information
Neural Network Software

- Learning sample of ~100 events for each position
- MLP neural network \( \Rightarrow \) MultiLayer Perceptron = the network weighting process starts from expected outputs (X and Y position) and regress until the inputs (4 PMTs’ charges)
- Testing sample (different from learning one) is reconstructed. Estimation of the position resolution by \( \Delta X = X_{\text{reconstructed}} - X_{\text{true}} \) and \( \Delta Y \)
Neural Network Software

• Testing sample (different from learning one) is reconstructed. Estimation of the position resolution by $\Delta X = X_{\text{reconstructed}} - X_{\text{true}}$ and $\Delta Y$

Position resolution better than 2 cm
Technical solutions

• December 2006: source support for its “magnetic” displacement 5mm precision
• January 2007: larger black box ⇒ 50cm x 50 cm plate available
Super NEMO - MOON collaboration

- I’m working since February 10th in Osaka University with Nomachi san group.
- Installation of a 53×53 cm² plastic source and 32 K free square PMTs (4 sides).
- Trigger and DAQ electronic, HV cabling, mechanical support and light shielding.
- 1mm precision positioning.
- Special thanks for Kanamaru and Sakihuchi for their efficiency.
- Preliminary result: LED in the middle of the plate. Software correction of the gain.

10% gain non uniformity

⁻ 2% with LED calibration
Planning

- 20 BiPo I capsules tested in Canfranc in 2007
- Summer 2007: 50×50 cm² and 75×75 cm² scintillator plates tested
- End of year 2007: 1st 2-layers BiPo2 prototype installed in Canfranc for low radioactivity measurement
Conclusion

• Intense R&D program for the BiPo detector.
• 1st important questions will be answered this year (BiPo I or II? PMTs size? Expected sensitivity of 0.2 µBq/m² is reachable?)
• Collaboration with MOON people will continue and increase
Thanks, merci, gracias,
Ευχαριστώ, ありがとう,
Спасибо, grazie,
متشكرم, благодаря,
děkuji
Backup
Candidate

- Channel 1: Delay time: 1.4 μs
- Channel 2

E = 275 keV
ZOOM

E = 690 keV
ZOOM