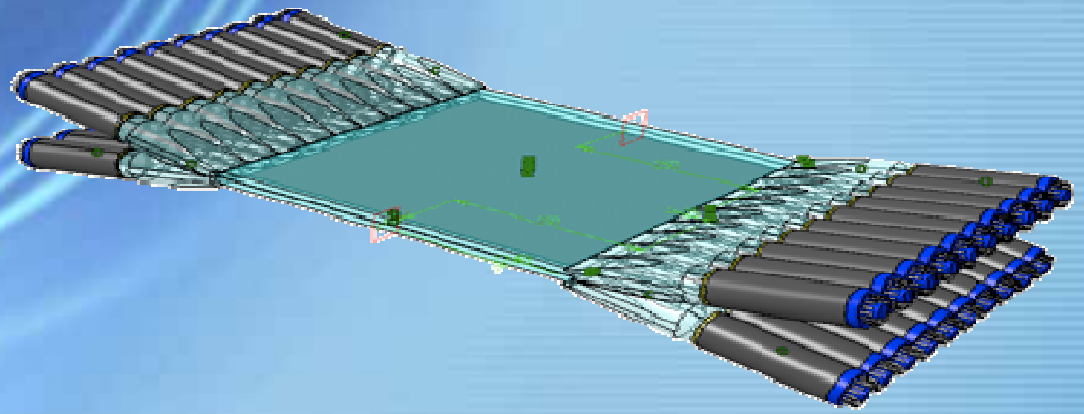
A BiPo detector for extremely low level radioactivity diagnostic



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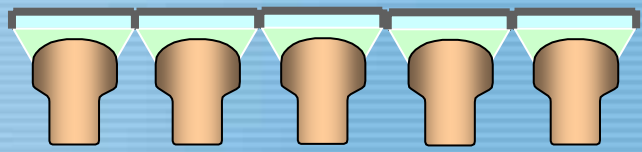
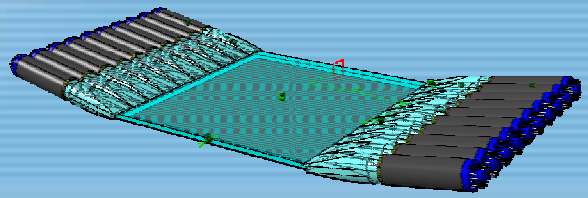
CENTRE NATIONAL DE LA RECHERCHE SCIENTIFIQUE

Outline

1. What is the BiPo radio-impurity? Detection technique
2. R&D program description
3. Prototype BiPo I : scintillator cubes



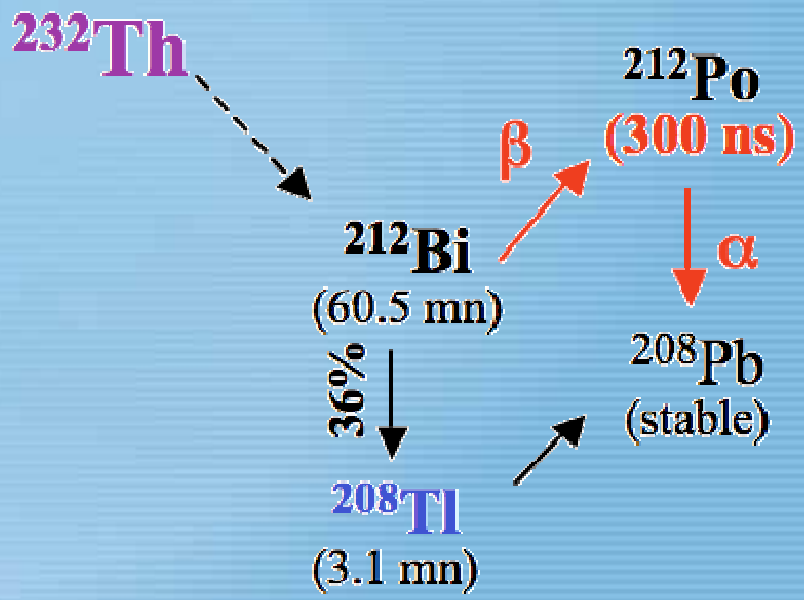
4. Prototype BiPo II : scintillator plates



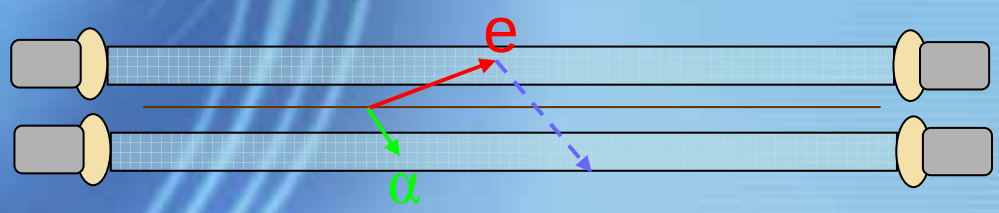
BiPo decay process

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

BiPo detector measures the e^- from ^{212}Bi --> ^{212}Po, and after ~300ns, the α from ^{212}Po --> ^{208}Pb



Detection technique



$E_{threshold}$ (e^-) = 100 keV

+ $E_{threshold}$ (α) = 1 MeV

+ back-scattering rejection > 40 keV

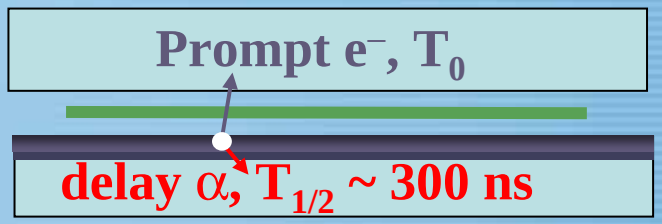
➔ Detection efficiency of 7.5% (G4 MC)

Background sources :

- Random coincidence
- **Surface contamination (until a depth of 100µm)**

Additional cut for surface contamination

Important background : surface contamination



e^- from ^{212}Bi: ~ ***50 keV in 100 µm of scintillator***

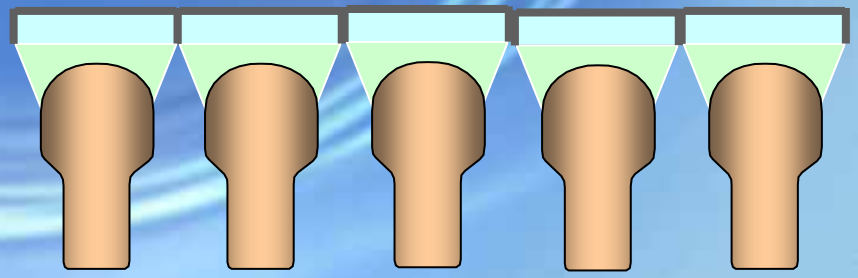
Cut : no e^- with energy > 50 keV in the scintillator of the α

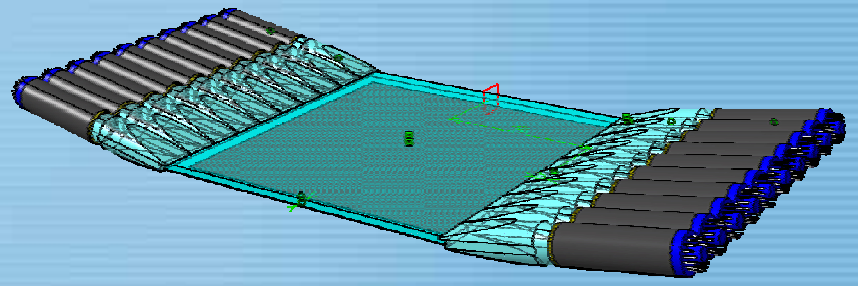
- efficiency ↘ to 6%
- BUT background ÷ 15 !

Merit factor : Signal/√(Background) ↗ by 300 % ! ☑

R&D program

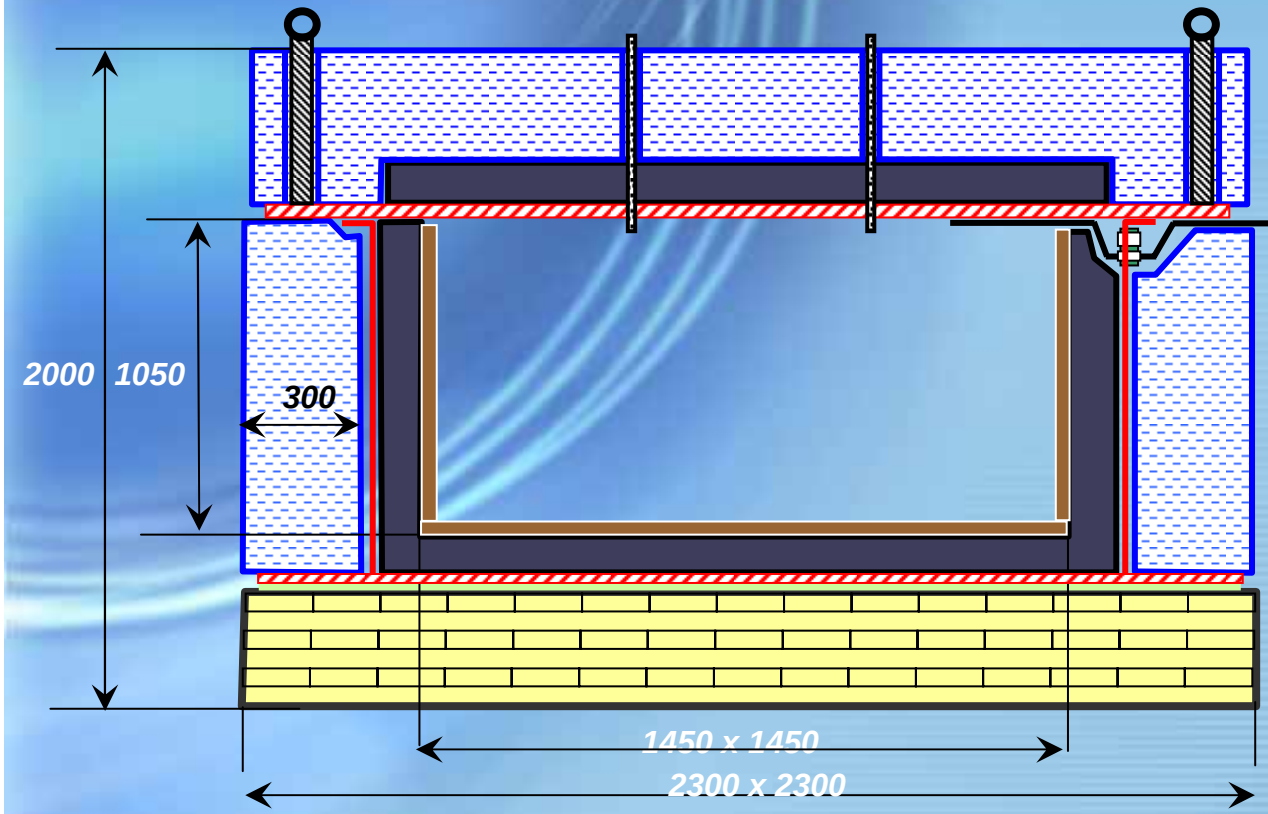
- *2 different prototypes studied :*
  - 25 blocks of scintillator/m², 1 PMT/block
  - 1 plate of scintillator/m², ~30 PMTs/plate





- Additional R&D : ultra-thin scintillating fiber for e^-/α 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.)

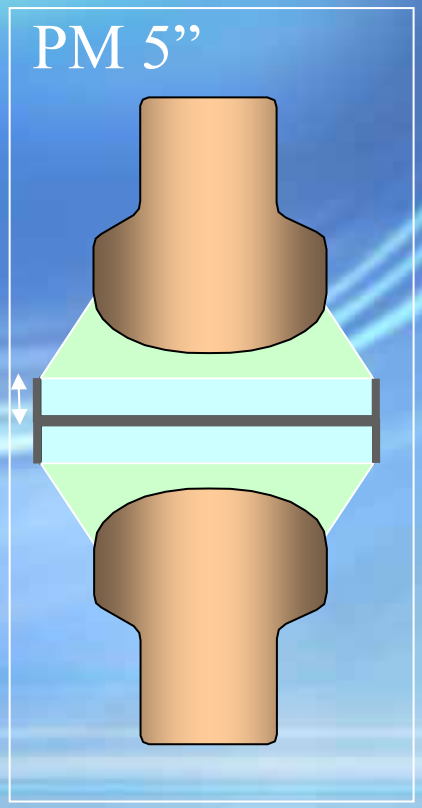
Canfranc Shielding



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

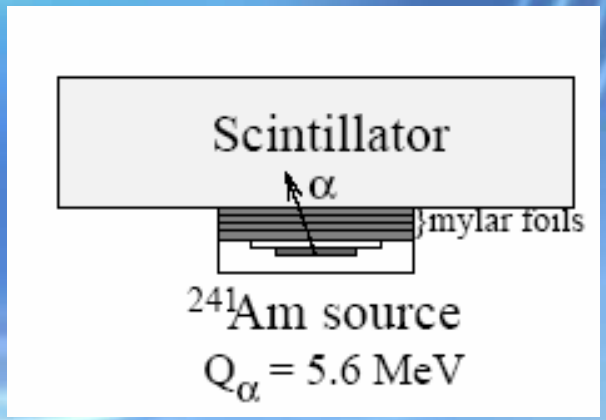
Description of the BiPo I prototype



BiPo I CAPSULE

- 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 ➔

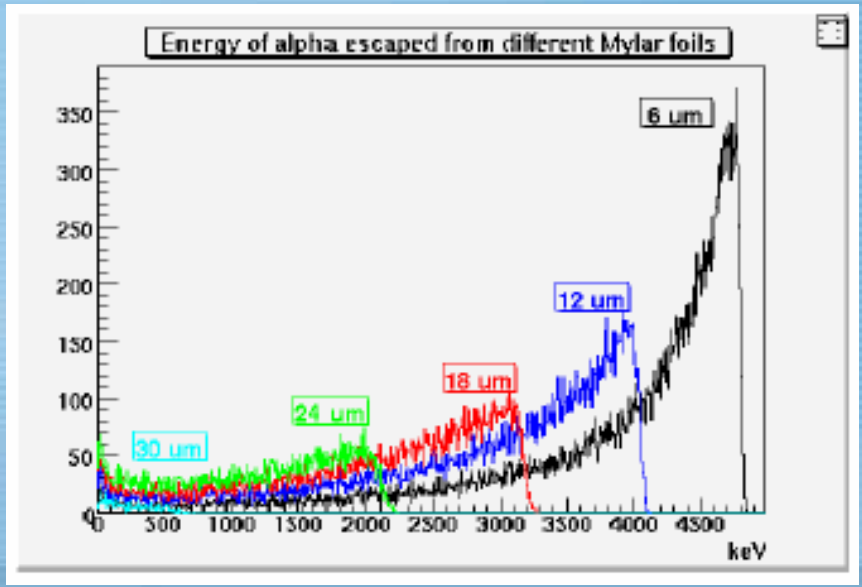
Measurement of the quenching factor



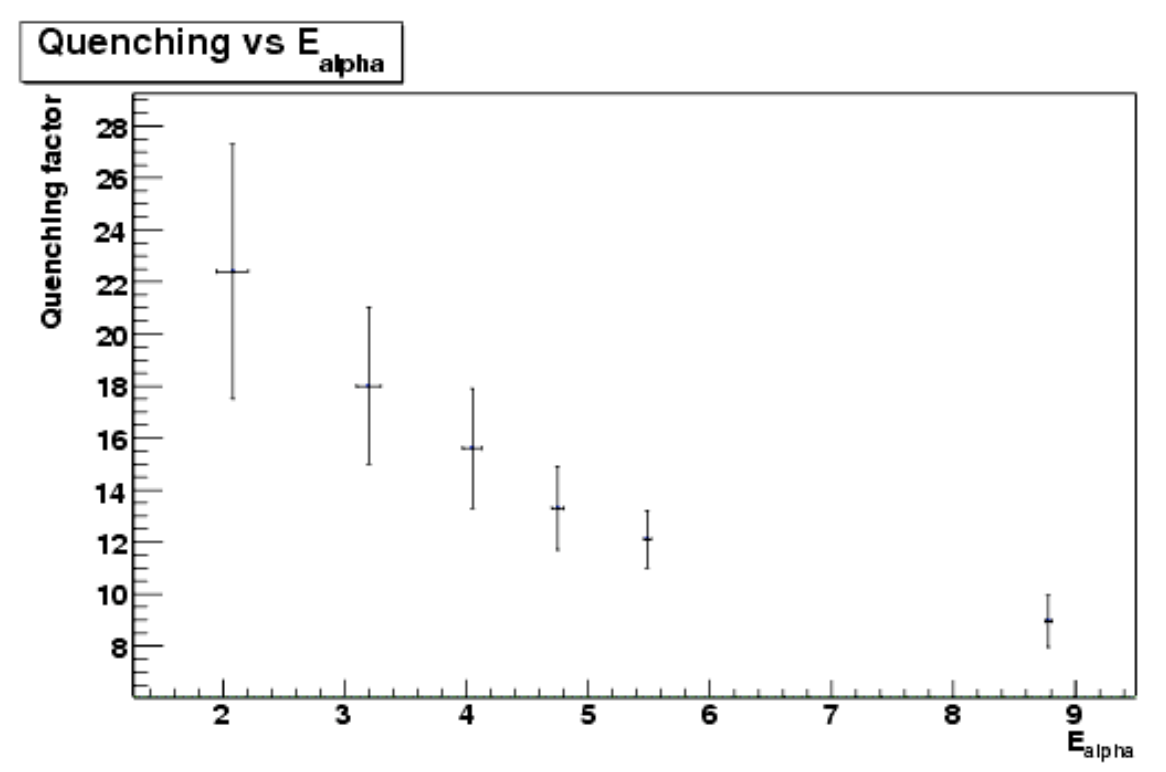
^{241}Am α source, peak at 5.6 MeV

Light in a scintillator detected by a PMT

Successive mylar foils to decrease the α energy



Measurement of the quenching factor



@ 1 MeV

QF = ~25

40 keV threshold for e^- = ~1MeV threshold for α

Calculation principle of the BiPo sensitivity

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

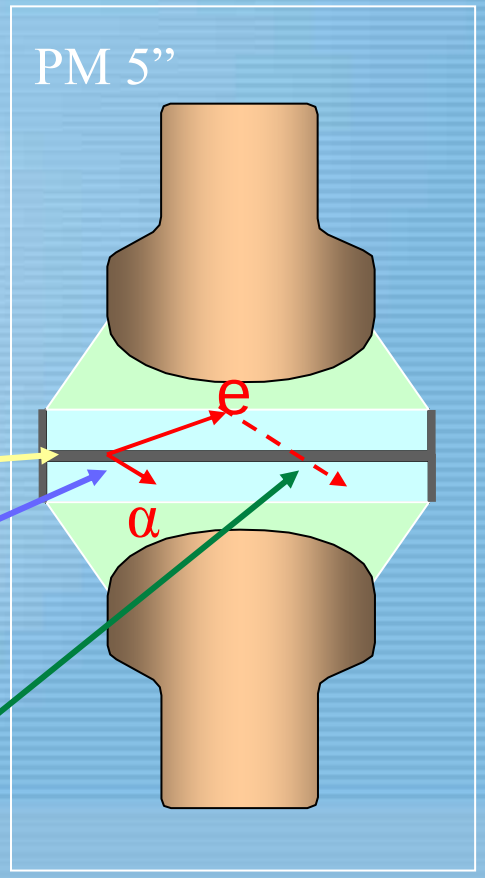
Surface of 1 Capsule : S = 400 cm^2

Efficiency: ε = 36% because :

50% : e^- and α are back-to-back

$\times$ 90% : delay time up to 1 µs (= 3.3 $T_{1/2}(^{212}Po)$)

$\times$ 80% : event is rejected if back-scattered e^-



➔ **Sensitivity : $A(^{212}Bi \rightarrow {}^{212}Po) < N_{excluded} / (\varepsilon \times S \times T_{obs})$**

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

➔ **limit $A(^{212}Bi \rightarrow {}^{212}Po) < 65$ µBq/m²**

($A(^{208}Tl) < 32.5$ µBq/m²)

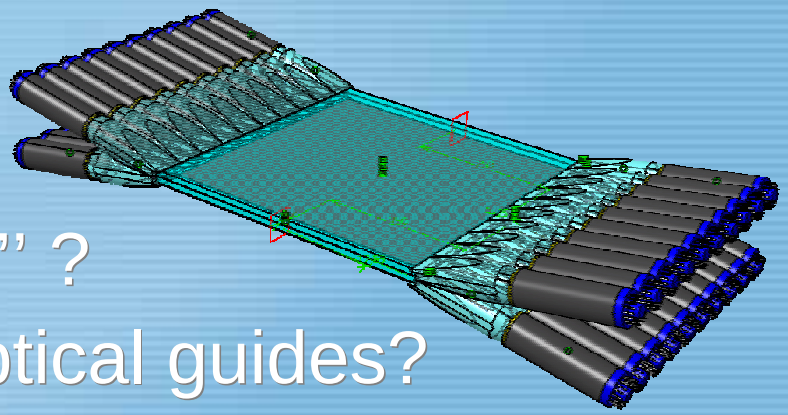
- 2 capsules : 11.3 days
  - 0 BiPo “in time” events
  - 0 BiPo “random” events for 1 expected coincidence

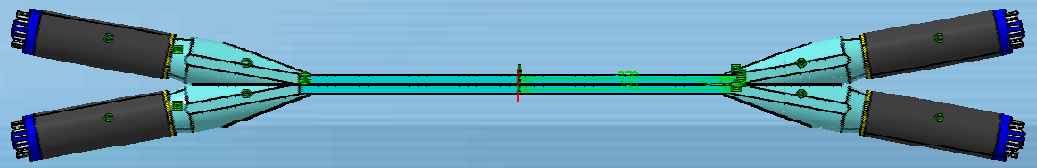
➔ **$A(^{212}Bi \rightarrow {}^{212}Po) < 29$ µBq/m²**

($A(^{208}Tl) < 14.5$ µBq/m²)

Description of BiPo II prototype

- Scintillating plate 75×75 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 α in the middle?

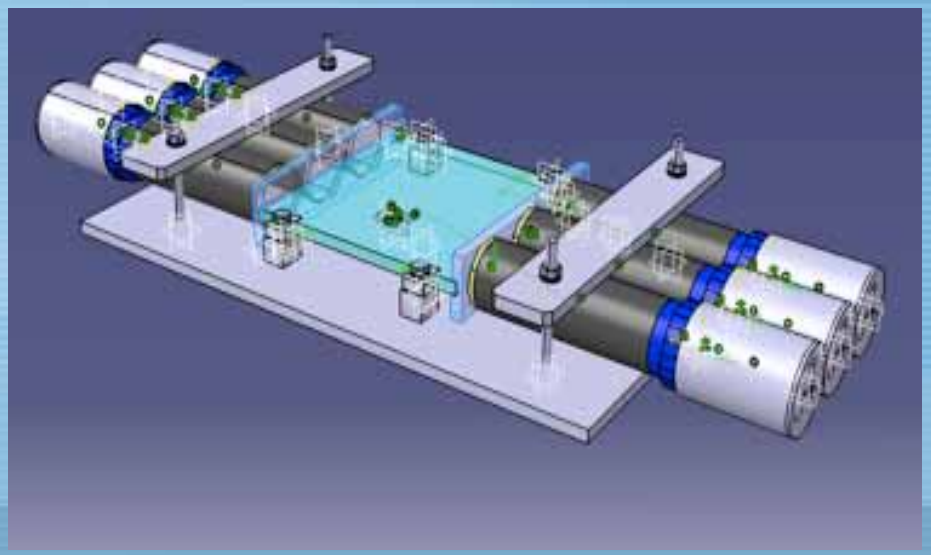




Experimental set-up in Orsay

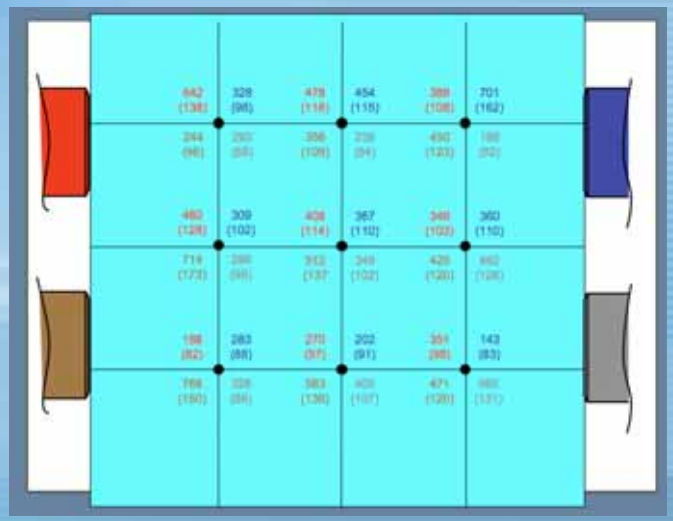
A well-designed mechanical support has been conceived :

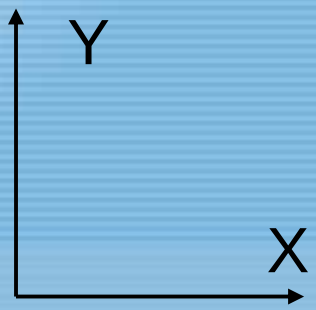
- Plots for the 20x20 cm^2 scintillator plate
- Fixation for the PMTs



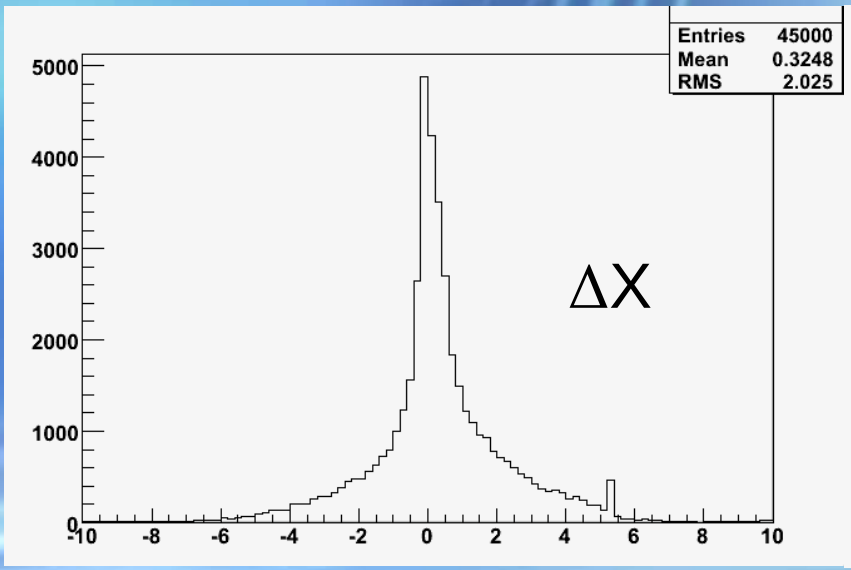
Position reconstrution

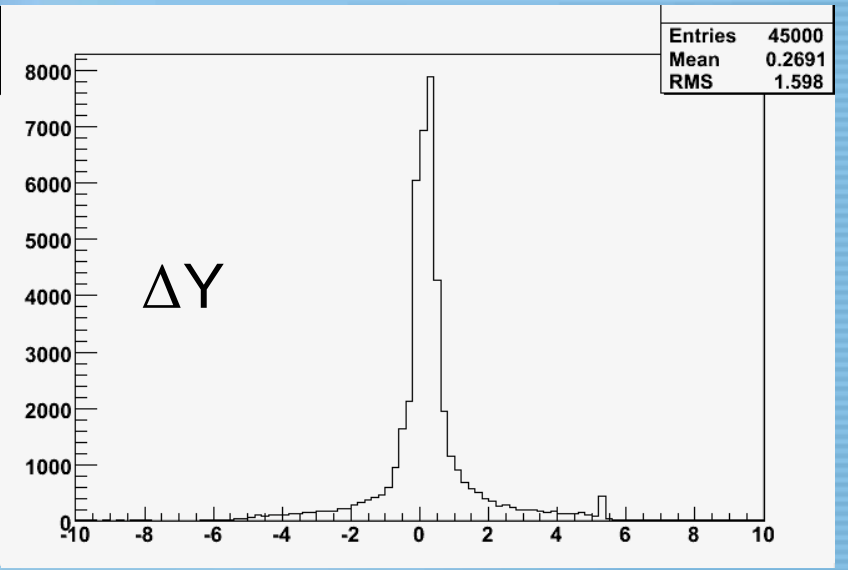
- 4 PMTs reading a 20×20 cm^2 plate
- ^{241}Am α source placed every 5cm on the plate
- We need to reconstruct the source position with charge information





Neural Network Software



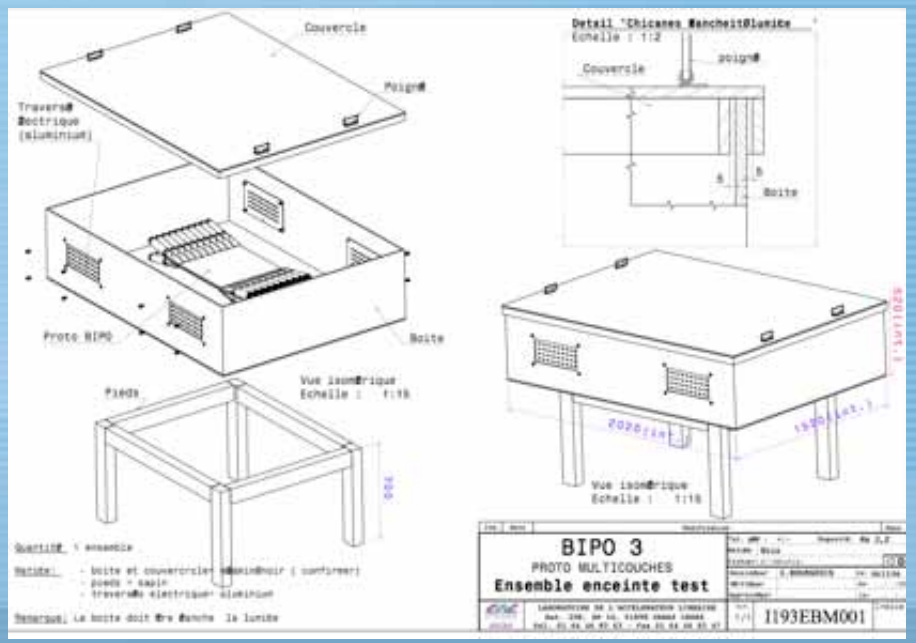


- Testing sample (different from learning one) is reconstructed. Estimation of the position resolution by $\Delta X = X_{reconstructed} - X_{true}$ and ΔY

Position resolution better than 2 cm

Technical solutions

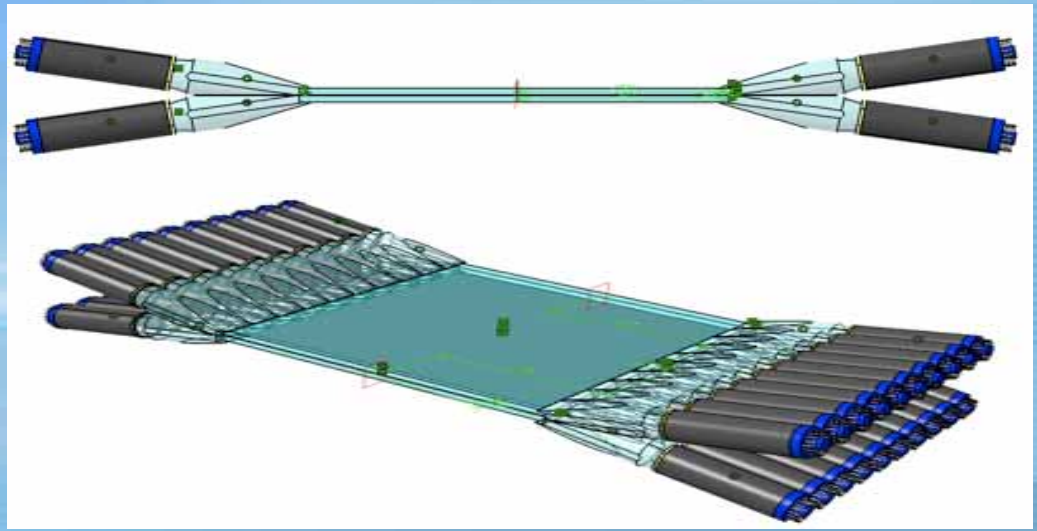
- December 2006 :
  source support for its “magnetic” displacement
  5mm precision
- January 2007 :
  larger black box ⇒ 50cm x 50 cm plate available



Planning

- 20 BiPo I capsules tested in Canfranc in 2007

- Summer 2007 : 50×50 cm^2 and 75×75 cm^2 scintillator plates tested
- End of year 2007 : 1st 2-layers BiPo2 prototype installed in Canfranc for low radioactivity measurement



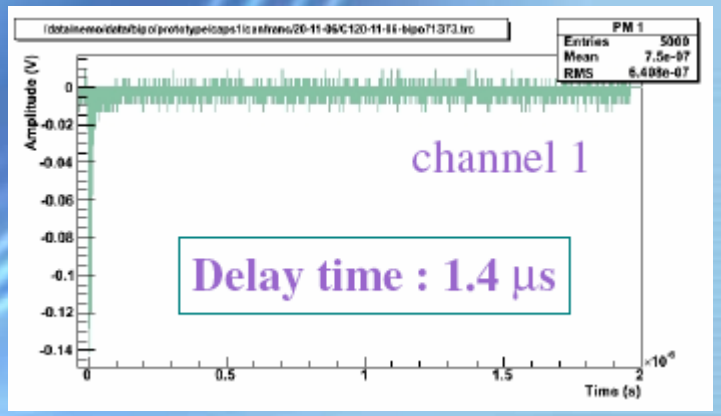
Conclusion

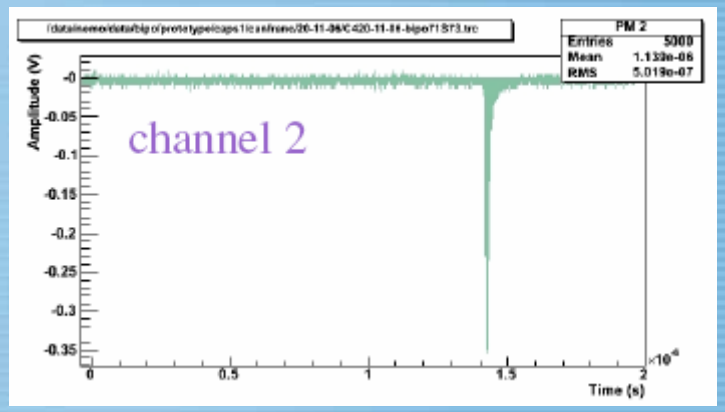
- Intense R&D program for the BiPo detector.
- 1st important questions will be answered this year (BiPo I or II ? PMTs size ? Expected sensitivity of 0.2 µBq/m^2 is reachable ?)
- Collaboration with Osaka University for BiPo II : 53x53cm^2 scintillator plate with 32 PMTs.
- In the middle term, we need to build an operative prototype in the year 2008. Test of ββ source foils (ILIAS JRA2).
- Transnational access for test in Canfranc, around 100 days.

Thanks, merci, gracias, Ευχαριστώ, □□□□□, Спасибо, grazie, متشكرم, благодаря, děkuji

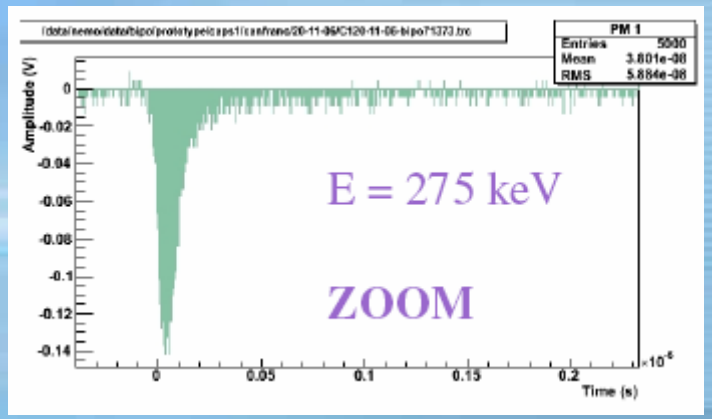
Backup

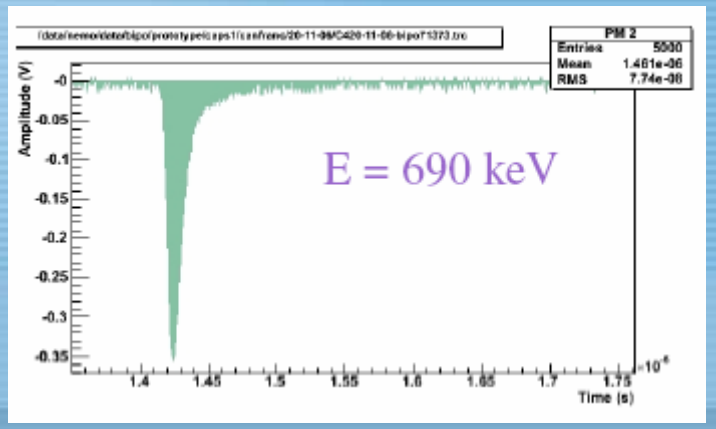
Candidate





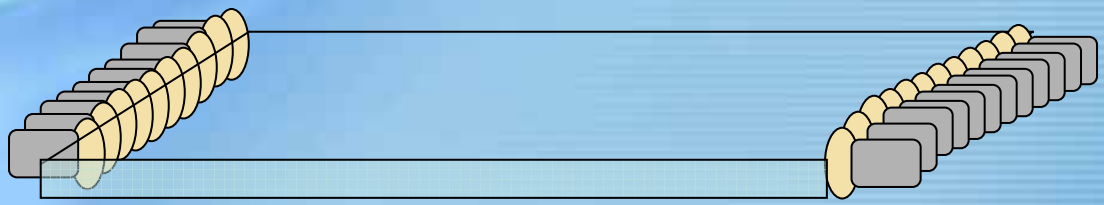
ZOOM

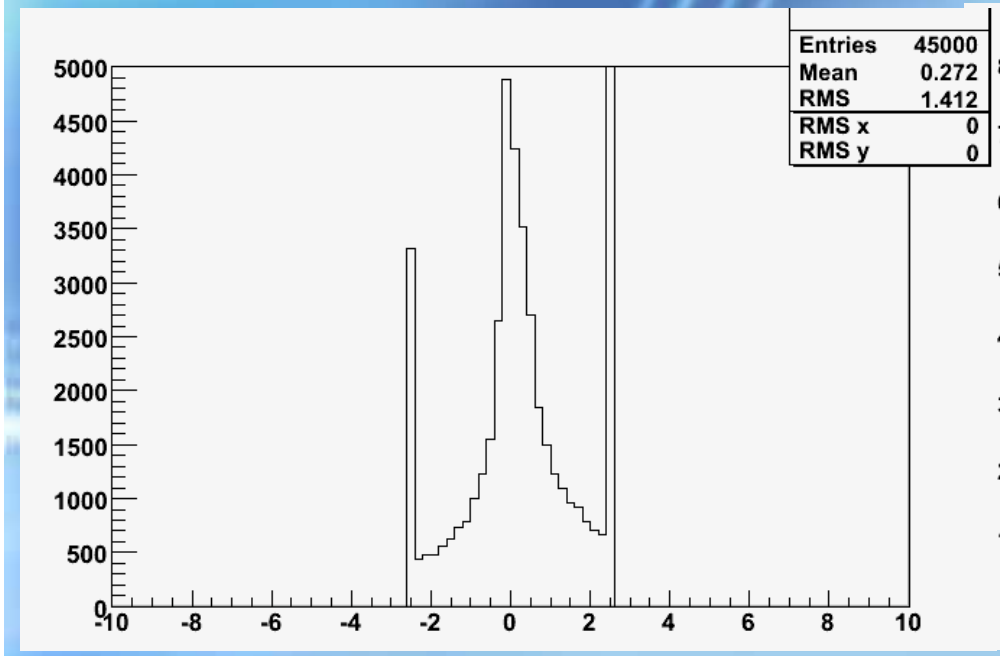




Why SuperNEMO needs a radiopurity ultra-sensitive detector ?

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

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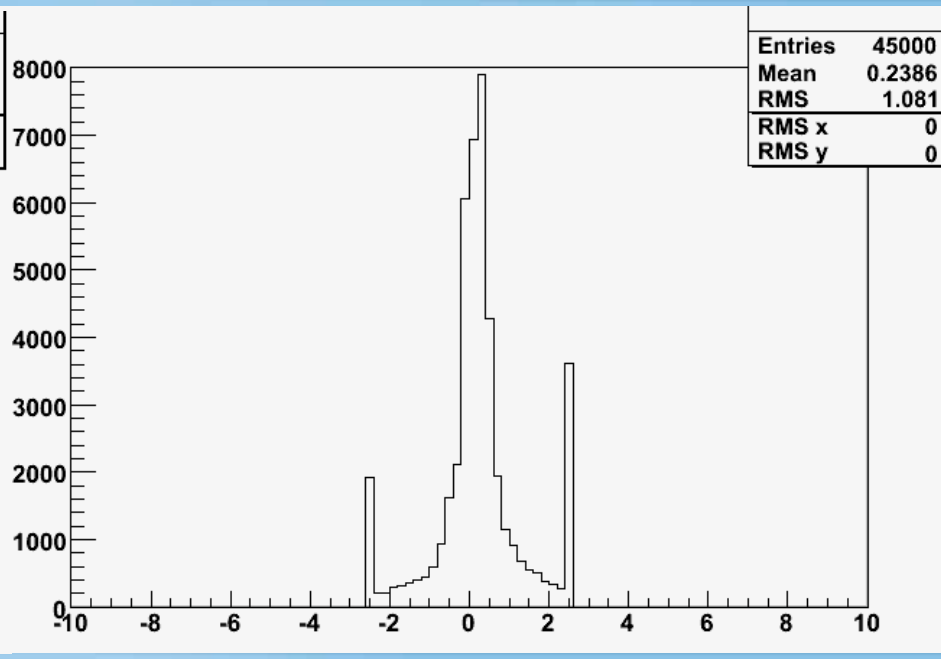
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RMS 1.081
RMS x 0
RMS y 0
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6000
5000
4000
3000
2000
1000
0
-10 -8 -6 -4 -2 0 2 4 6 8 10

Super NEMO - MOON collaboration

- I'm working since February 10th in Osaka University with Nomachi san group.
- Installation of a 53×53 cm^2 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.