The BiPo detector

Measure the purity in ^{208}Tl and ^{214}Bi

of thin foils and materials

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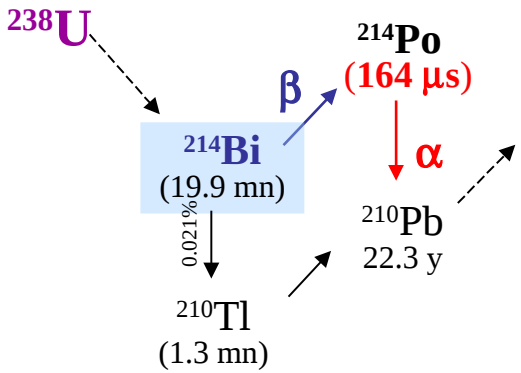
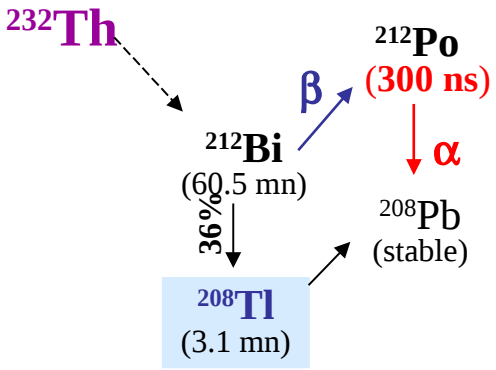
ISOTTA Meeting, 18 December 2013

Principle of BiPo detection

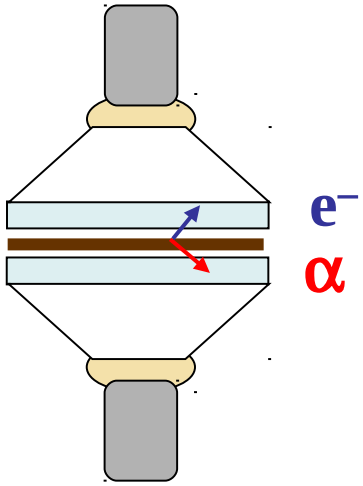
Detect the BiPo decay cascade: beta + delay alpha

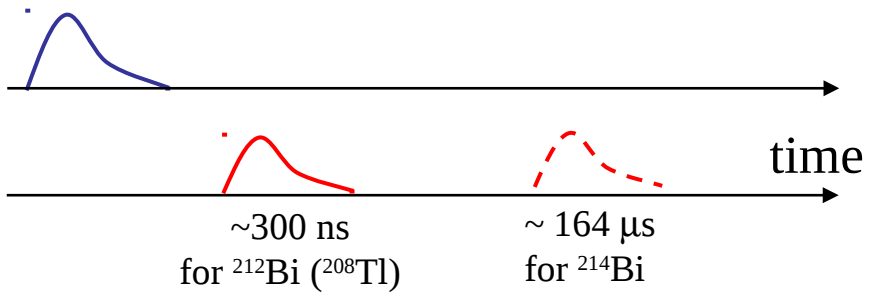




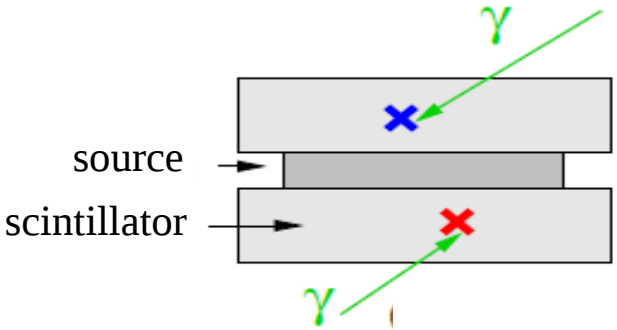
Sandwich of two low radioactive thin polystyrene plastic scintillators

Time topology signature: 1 hit + 1 delay hit (and no coincidence)



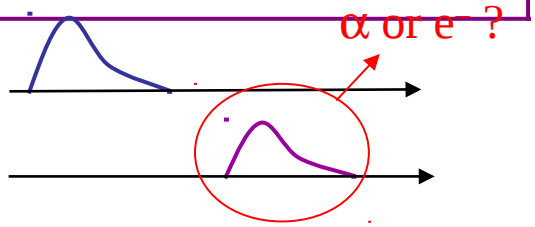


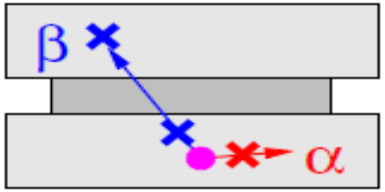
Sources of background



Random coincidence
(e^- Compton from ext. γ)

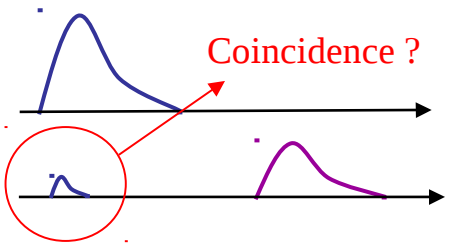
- Low counting rate
  $\tau \times S \lesssim 1$ mHz.m^2
- Low background detector and shield in Canfranc Underground Lab (Spain)
- Discrimination e^-/α

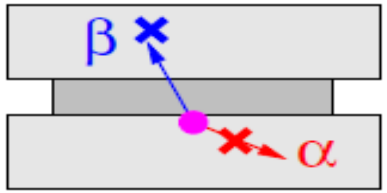




Bulk contamination
Scintillator

- Low energy threshold to reject coincidence
  10 keV ≈ 100 µm
- Radiopure scintillator
  A(^{232}Th) $\lesssim$ 1 µBq/kg



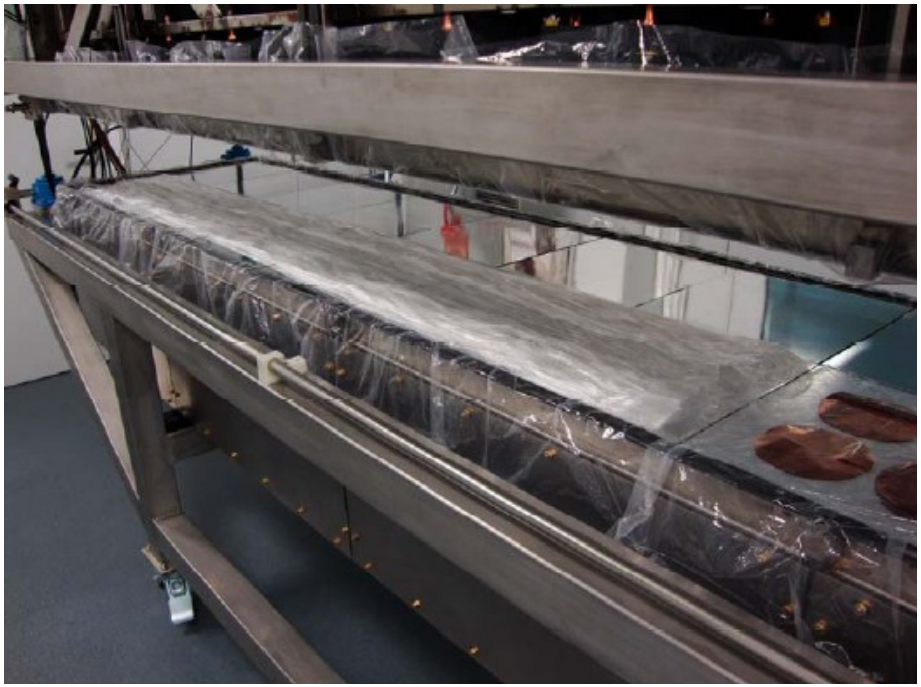


Surface contamination
^{238}U and ^{232}Th

- Ultra high surf. radiopurity
  (~100 µm deep)
  A(^{232}Th) $\lesssim$ 1µBq/m^2
- No Radon and Thoron
  A(Radon) $\lesssim$ 10 mBq/m^3
  (if gap = 200µm)

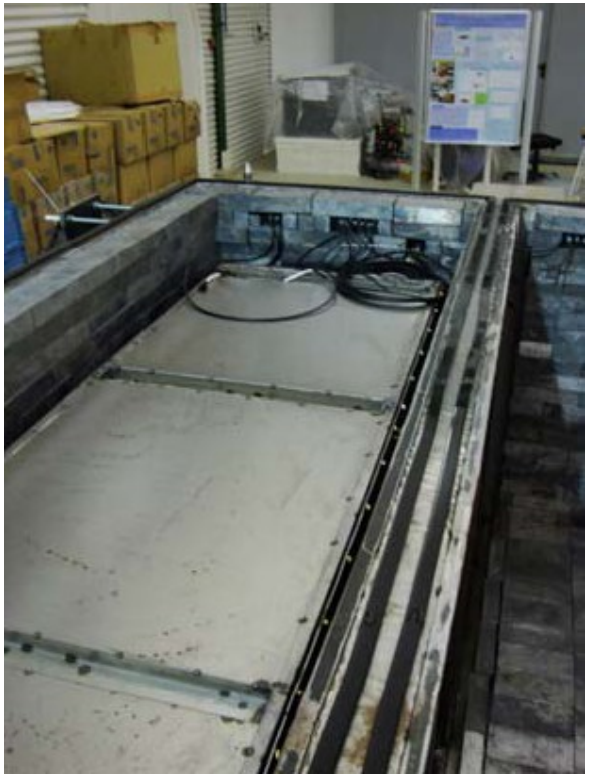
The BiPo-3 detector

- Two distinct modules
- Each module = 20 pairs of scintillators
- Scintillator 300×300×2 mm^3, aluminized with 200 nm ultra radiopure Al
- Total surface of the BiPo-3 detector = 3.6 m^2
- BiPo-3 installed in Canfranc Underground Laboratory (Spain)



View of a BiPo-3 module in the clean room in LSC

The BiPo-3 detector

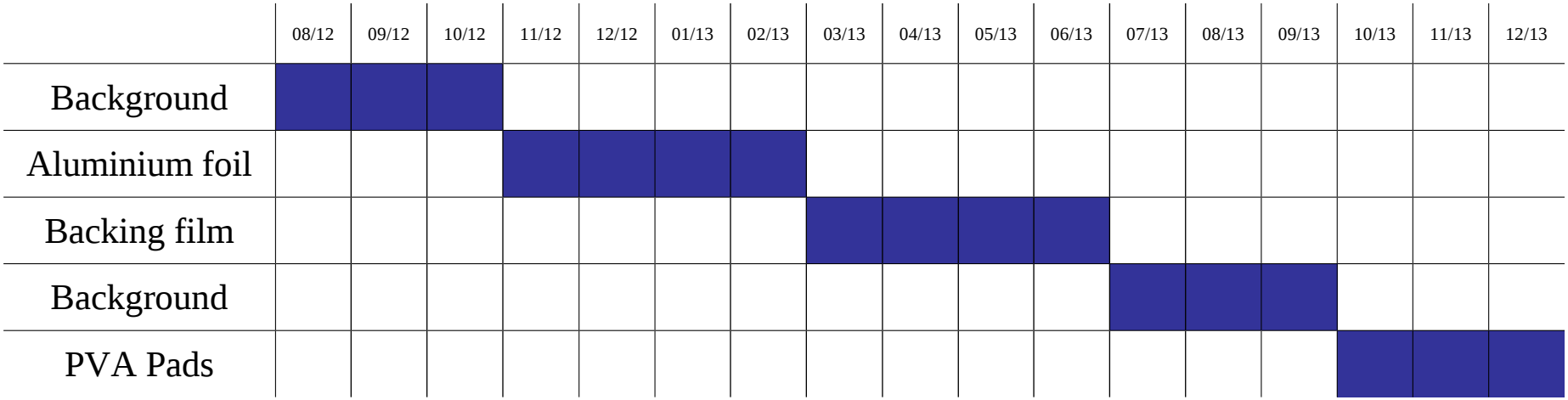


A BiPo-3 module inside the low radioactive shield

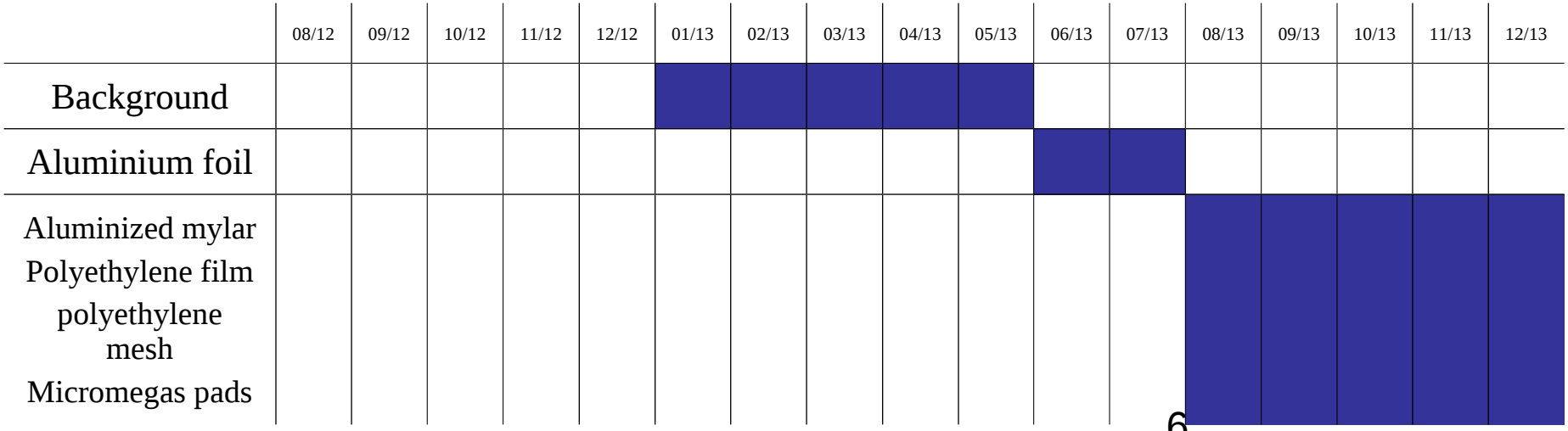
Full BiPo-3 detector inside the shield with separate acquisition for each module

Results of the BiPo-3 Measurements

Module 1



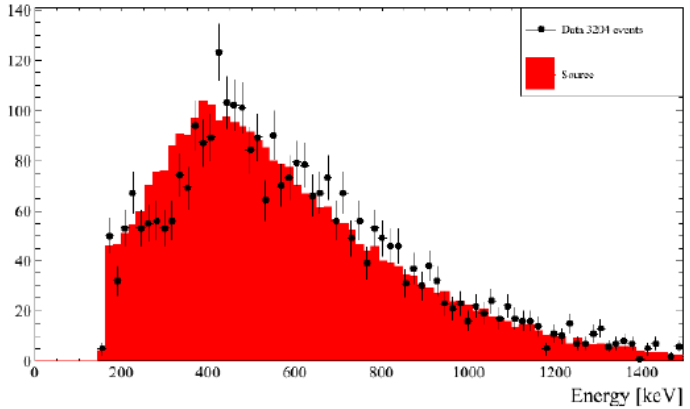
Module 2



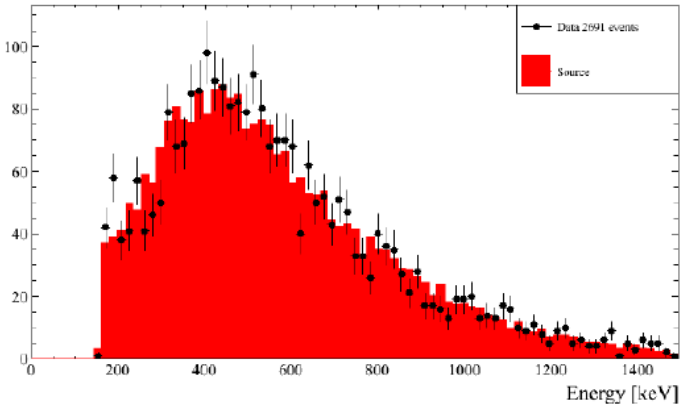
Validation of the BiPo-3 detection with a calibrated aluminium foil

Analysis performed with new reconstruction software
(previous release showed 50% lost of efficiency)

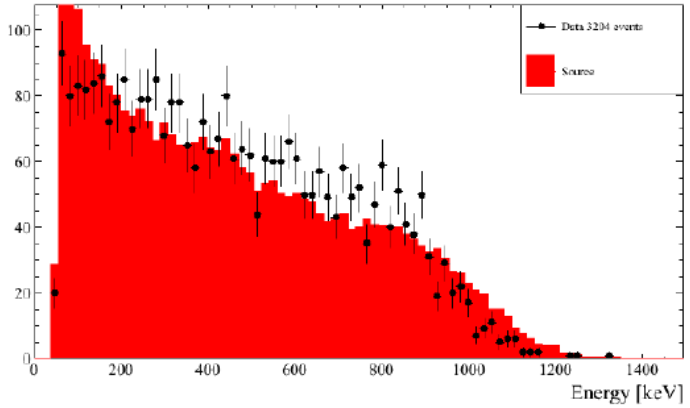
Channel ^{212}Bi – ^{212}Po



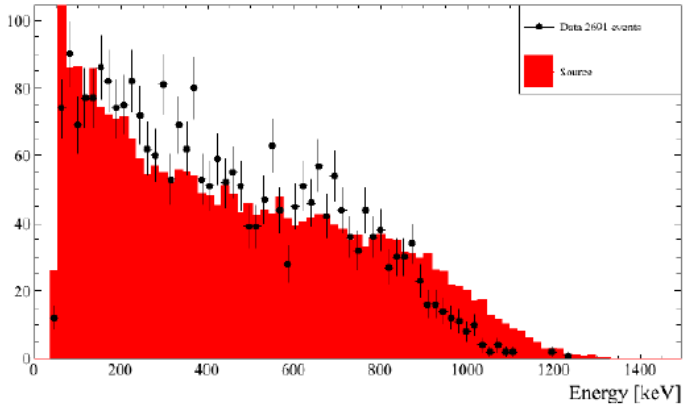
Prompt (e^-) spectrum, 85 μm sample



Prompt (e^-) spectrum, 170 μm sample



Delay (α) spectrum, 85 μm sample



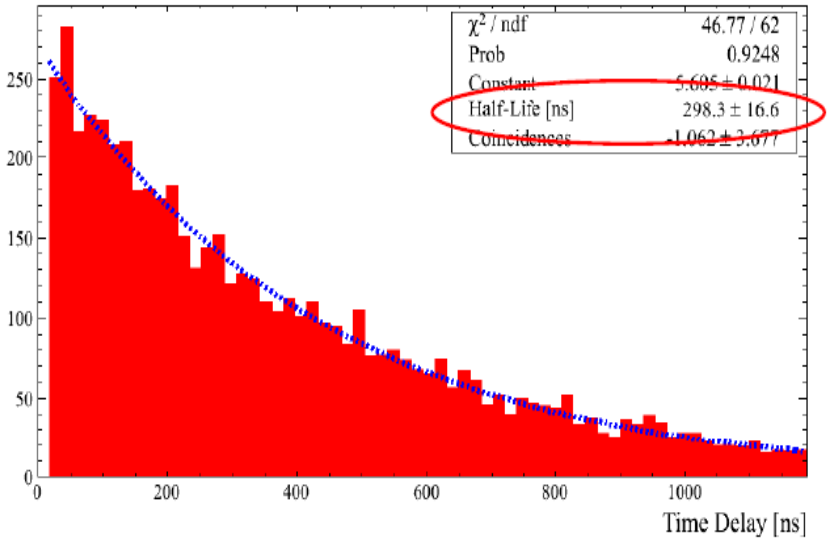
Delay (α) spectrum, 170 μm sample

Validation of the BiPo-3 detection with a calibrated aluminium foil

Channel ^{212}Bi – ^{212}Po

Delay Time dirtibution in agreement with the expected value:

$T_{1/2}(^{212}Po) = 300$ ns



Al foil A(208Tl) results [mBq/kg]	
BiPo (85 μm)	75 ± 24
BiPo (170 μm)	73 ± 23
HPGe (2007)*	107 ± 23

- BiPo measurements for both thicknesses in agreement
- BiPo measurements compatible with available HPGe data
- *More accurate HPGe measurements (LSC & Modane) available

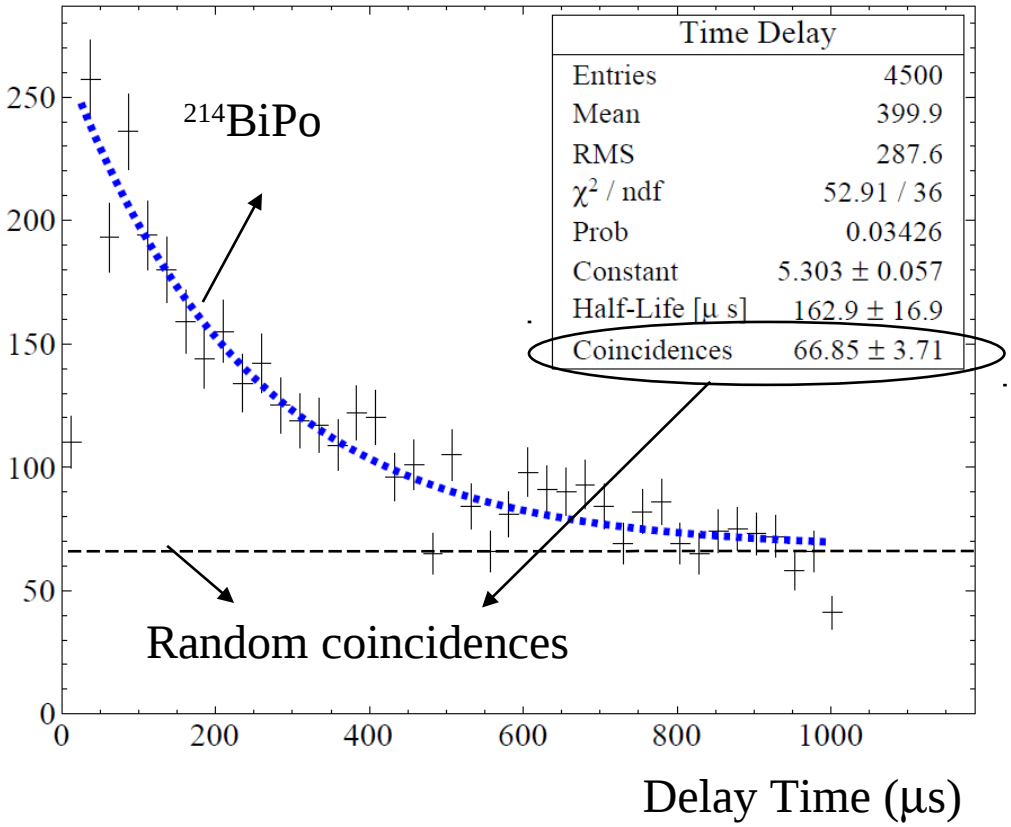
Wait to finish BiPo analysis to compare all the results (blind analysis)

Validation of the BiPo-3 detection with a calibrated aluminium foil

Channel ^{214}Bi – ^{214}Po

$T_{1/2}(^{214}Po) = 164\ \mu s$

$\Rightarrow$ Random coincidence background becomes the dominant background

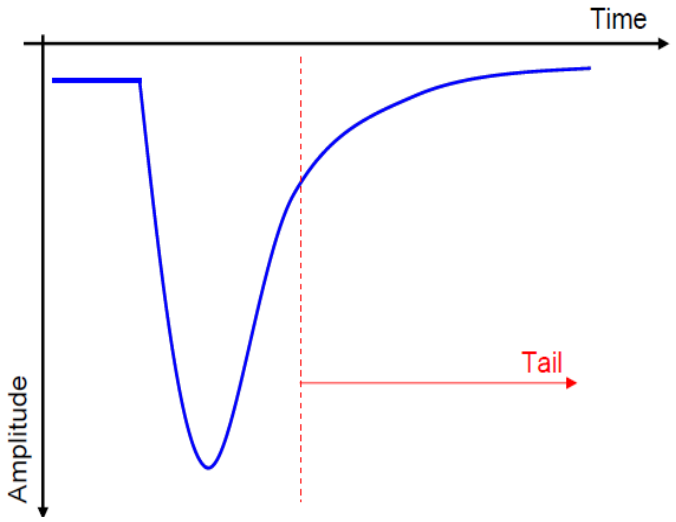


Random coincidences are mostly Compton electron

$\Rightarrow$ They are rejected by electron alpha discrimination

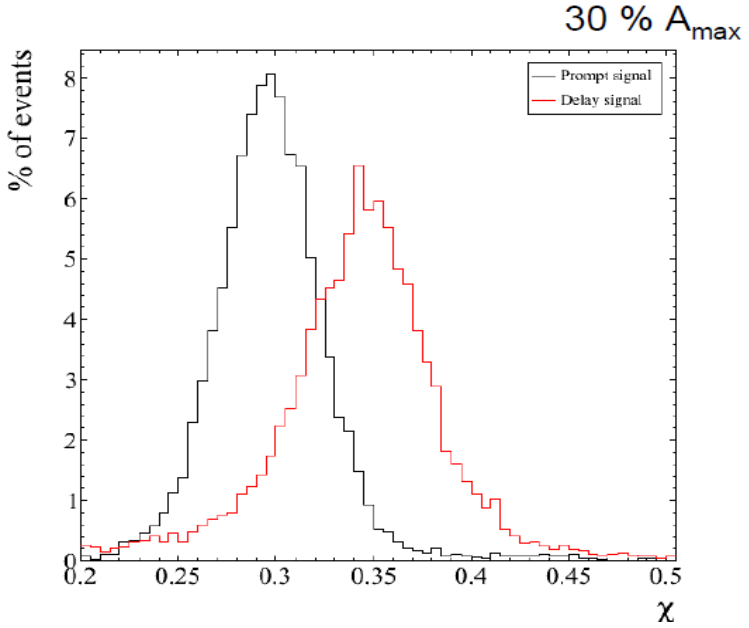
Electron / alpha discrimination

Based on the differences of the pulse tail of α's and e^-'s due to the slow scintillation component for α's (higher stopping power)



$$\chi = \frac{Q_{Tail}}{Q_{Total}}; \chi_\alpha > \chi_\beta$$

Discrimination obtained with ^{212}Bi – ^{212}Po events



Rejected bkg	Signal efficiency
80%	80%
95%	50%

Validation of the BiPo-3 detection with a calibrated aluminium foil

Channel ^{214}Bi – ^{214}Po

Preliminary results for background and samples measurements

“Preliminary” because:

- **“old” software reconstruction version has been used**

  ~ 50% less sensitive than new version

  (new version has been used for aluminium foil analysis)

  ⇒ ^{208}Tl activities presented here have been corrected by a factor 1.5

- **e^-/α discrimination not yet applied**

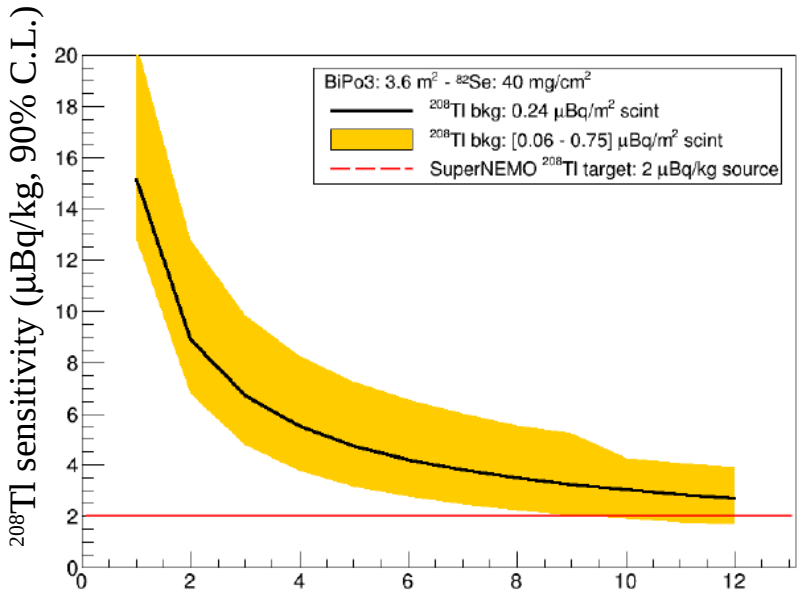
  ⇒ only results for ^{212}Bi – ^{212}Po (^{208}Tl)

Background measurement

	Duration (days)	Exposure (days×m^2)	^{212}BiPo events	ε(%)	**Bkg level (90% C.L.) μBq/m^2 scintillator**
Module 1	85	230	2	30	**[0.06 – 0.75]**
Module 1 *(after samples measurement)*	40	129	2		**[0.14 – 1.44]**
Module 2	99	338	2		**[0.05 – 0.53]**

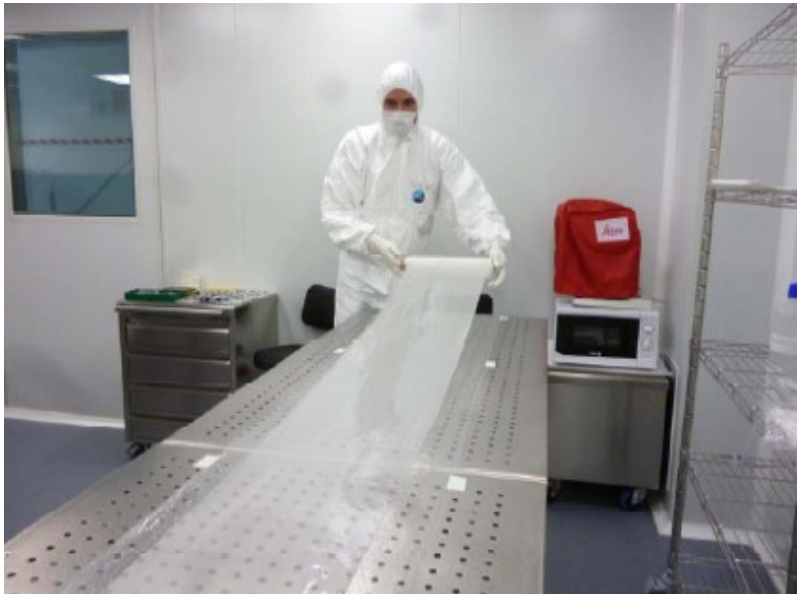
Compatible results of the three background measurement
Background looks stable after sample measurement

Expected sensitivity
Two modules (3.6 m^2)
SuperNEMO ^{82}Se foils (40 mg/cm^2)



Measurements of SuperNEMO samples

Backing film = mylar irradiated to beam (JINR) in order to get micro holes



Measurements of SuperNEMO samples

Backing film = mylar irradiated to beam (JINR) in order to get micro holes

	Duration (days)	ε(%)	^{212}BiPo events	Expected Bkg events	^{208}Tl activity (90%CL) *(1.5 correction factor)*
With polyethylene protection	48.5	6.8	15	$0.5\ ^{+1.0}_{-0.4}$	A(^{208}Tl) = [114 – 320] µBq/kg = $213\ ^{+107}_{-99}$ µBq/kg
Without polyethylene	36.7	7.6	11	$0.4\ ^{+0.8}_{-0.3}$	A(^{208}Tl) = [82 – 296] µBq/kg = $183\ ^{+113}_{-101}$ µBq/kg

- SuperNEMO requirement: A(^{208}Tl) < 20 µBq/kg
- BiPo-3 detector observed ^{208}Tl contaminations in few days at a level of ~100 µBq/kg !
- Old measurements performed by HPGe: old irradiation A(^{208}Tl) ~ 670 ± 150 µBq/kg
  new irradiation A(^{208}Tl) < 170 µBq/kg

Current and next measurements in BiPo-3

Current measurements:

- Polyethylene film 4 mm
  - Used to screen samples to BiPo scintillator surface
  - Looks very clean in Tl, so far…
- PVA pads
  - PVA used to mix Se powder
- Aluminized mylar
- Micromegas pads

} Results in January 2014

Next measurements (samples should be installed end January 2014)

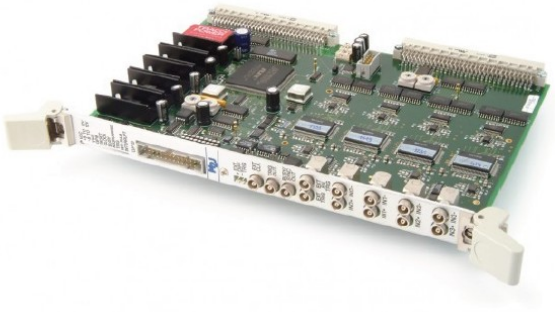
- Membrane film (used for blood filtering) for SuperNEMO foils:
  - ~ 3 m^2
- Reflective film for scintillating bolometers

Backup

PMT's readout and acquisition

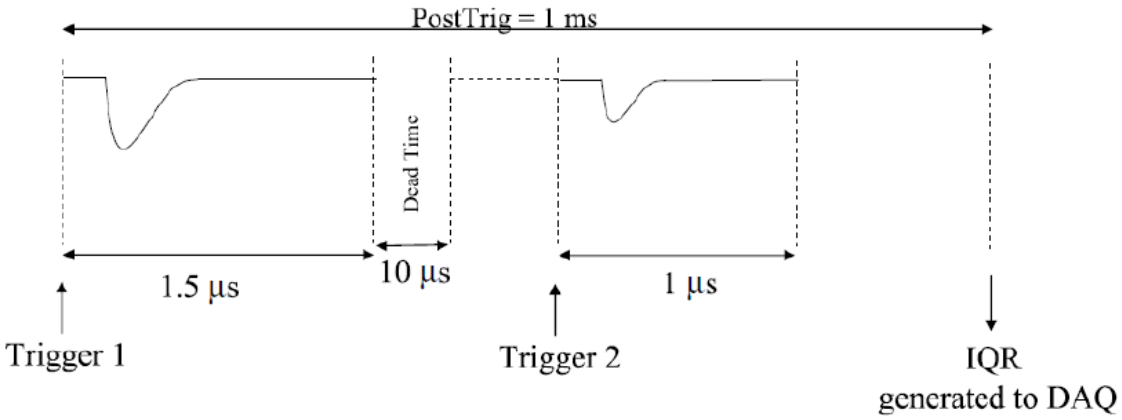
➢ PMT signals sampled with MATACQ VME digitizer boards (LAL & IRFU)

- 4 channels, 2.5ms time window
- 1 GS/s high sampling rate
- 12-bit amplitude resolution
- 1 Volt amplitude dynamic range
- Electronic noise ~ 250 µV (r.m.s.)



➢ Trigger (LAL)

- MATACQ sampling of the PMT signal during 1.5 µs
- Dead time during 10 µs ⇒ avoid false trigger on PMT delay noise
- Start watch dog
- MATACQ sampling of the PMT signal during 1 ms in case of a 2nd trigger
- IQR generated after 1 ms



➢ Acquisition developed by LPC Caen

Validation of the BiPo-3 detection with a calibrated aluminium foil

Channel ^{214}Bi – ^{214}Po