# BiPo: A dedicated radiopurity detector for the SuperNEMO experiment

**Héctor Gómez Maluenda** on behalf of SuperNEMO Collaboration

Laboratoire de l'Accélérateur Linéaire

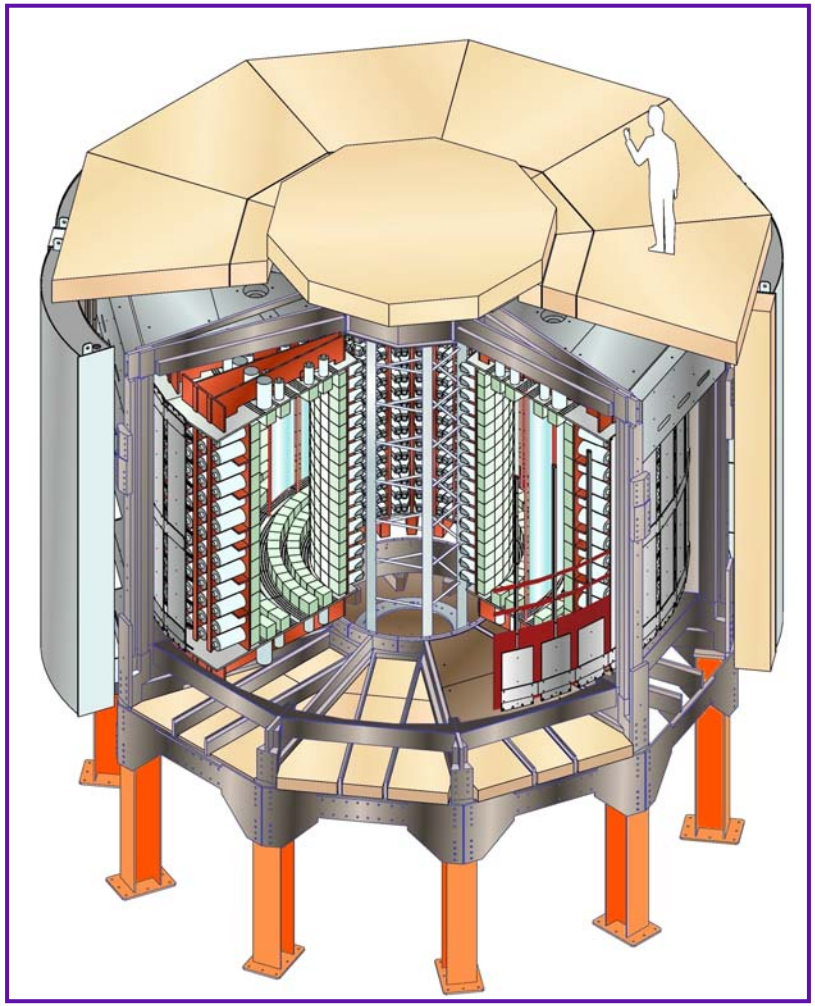
gomez@lal.in2p3.fr

- NEMO 3 and SuperNEMO experiments.
    - Motivation: SuperNEMO $\beta\beta$ source foils radiopurity.
- The BiPo detector:
- BiPo 3 present status.
- Outlook and Prospects.
- Summary and Conclusions.

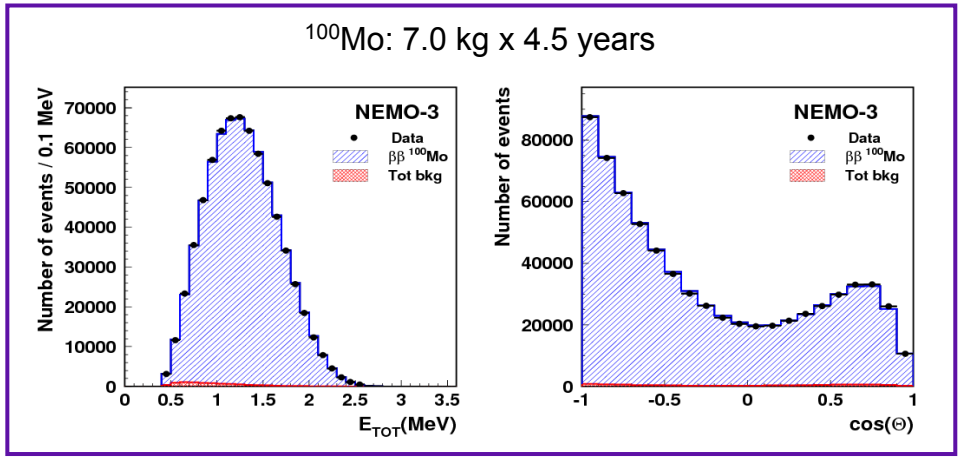
# NEMO 3 and SuperNEMO

## *NEMO 3*

- ***10 kg*** of $\beta\beta$ isotopes:
  - 6.9 kg of $^{100}$Mo, 0.9 kg of $^{82}$Se
  - Also $^{130}$Te, $^{116}$Cd, $^{150}$Nd, $^{96}$Zr and $^{48}$Ca
- "Tracko – calo" detection:
  - Tracking → Geiger cells
  - Calorimetry → Polystyren + 3" & 5" PMTs
- Located at Modane Underground Laboratory
  - Depth ~4800 mwe
- Running from February 2003 until January 2011.
- Results on $T_{1/2}^{2\nu\beta\beta}$ and $T_{1/2}^{0\nu\beta\beta}$ for different isotopes.
- Complete background characterization.



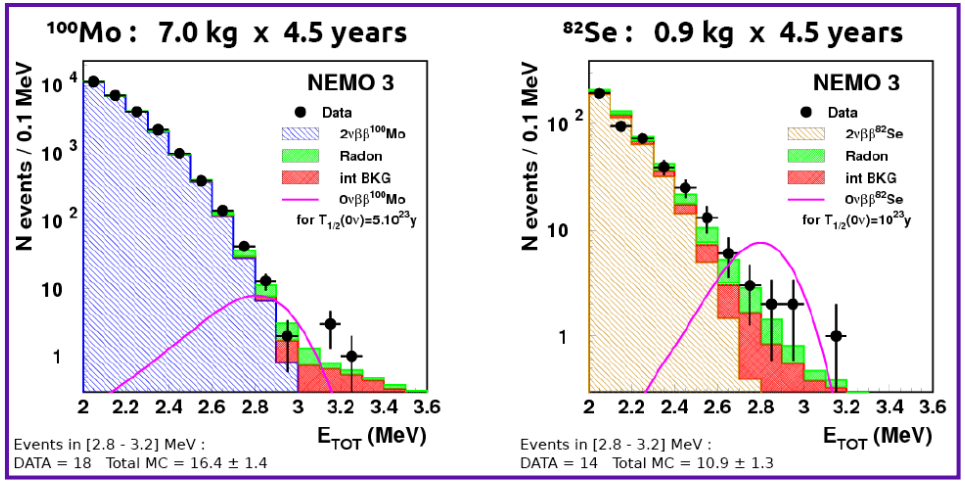
## NEMO 3 - Results




### $2\nu\beta\beta$ [Preliminary]

$T_{1/2}^{2\nu\beta\beta}(^{100}Mo) = (7.16 \pm 0.01\ (stat.) \pm 0.54\ (sys.))\ 10^{18}$ y.

$T_{1/2}^{2\nu\beta\beta}(^{82}Se) = (9.6 \pm 0.1\ (stat.) \pm 1.0\ (sys.))\ 10^{19}$ y.




### $0\nu\beta\beta$

$T_{1/2}^{0\nu\beta\beta}(^{100}Mo, \langle m_\nu \rangle) > 1.0\ 10^{24}$ y (90% C.L.).

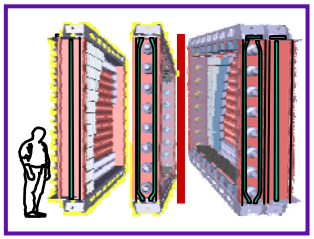
$\langle m_\nu \rangle < 310 - 960$ meV

$T_{1/2}^{0\nu\beta\beta}(^{82}Se, \langle m_\nu \rangle) > 3.2\ 10^{23}$ y (90% C.L.).

$\langle m_\nu \rangle < 940 - 2600$ meV

# NEMO 3 and SuperNEMO

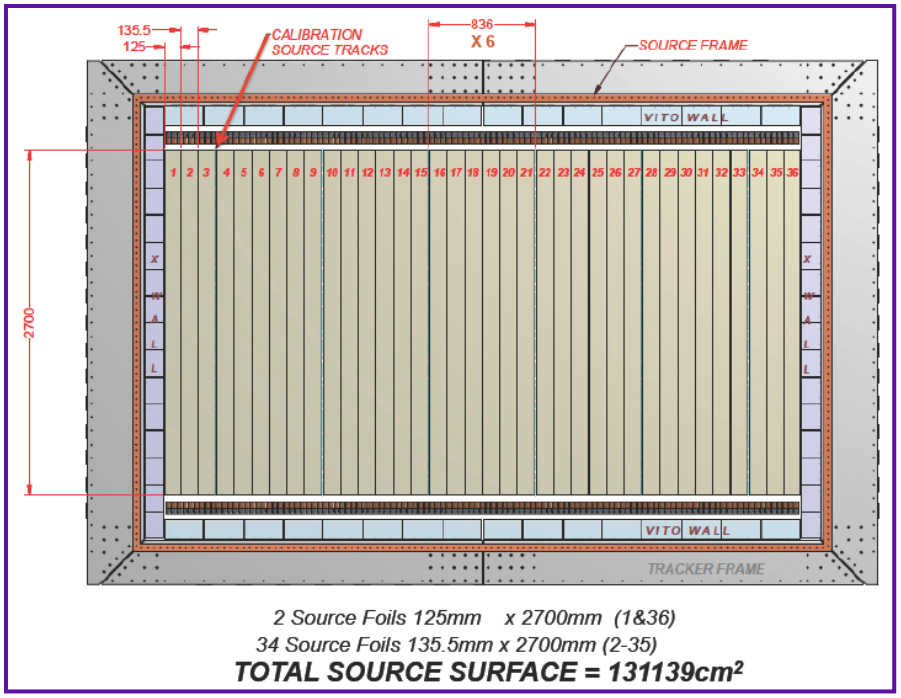
From NEMO 3 to SuperNEMO



| ***NEMO 3*** | | ***SuperNEMO*** |
|---|---|---|
| $^{100}$Mo, $^{82}$Se and others | *Isotope* | $^{82}$Se ($^{150}$Nd or $^{48}$Ca?) |
| **7 kg** | *Mass* | **~100 kg** |
| 18 % | *Efficiency* | 30 % |
| 15 % FWHM @ 1 MeV | *Energy Resolution* | 7 % FWHM @ 1 MeV |
| ***~ 100 μBq/kg*** | ***$^{208}$Tl source radiopurity*** | ***< 2 μBq/kg*** |
| ***< 300 μBq/kg*** | ***$^{214}$Bi source radiopurity*** | ***< 10 μBq/kg*** |
| ~ 5 mBq/m$^3$ | *Rn level* | < 0.1 mBq/m$^3$ |
| 1-2 $10^{24}$ y | *Sensitivity* | 1 $10^{26}$ y |
| **$\langle m_\nu \rangle$ < 0.3 – 0.9 eV** | | **$\langle m_\nu \rangle$ < 0.04 – 0.1 eV** |

# SuperNEMO ββ source foils radiopurity

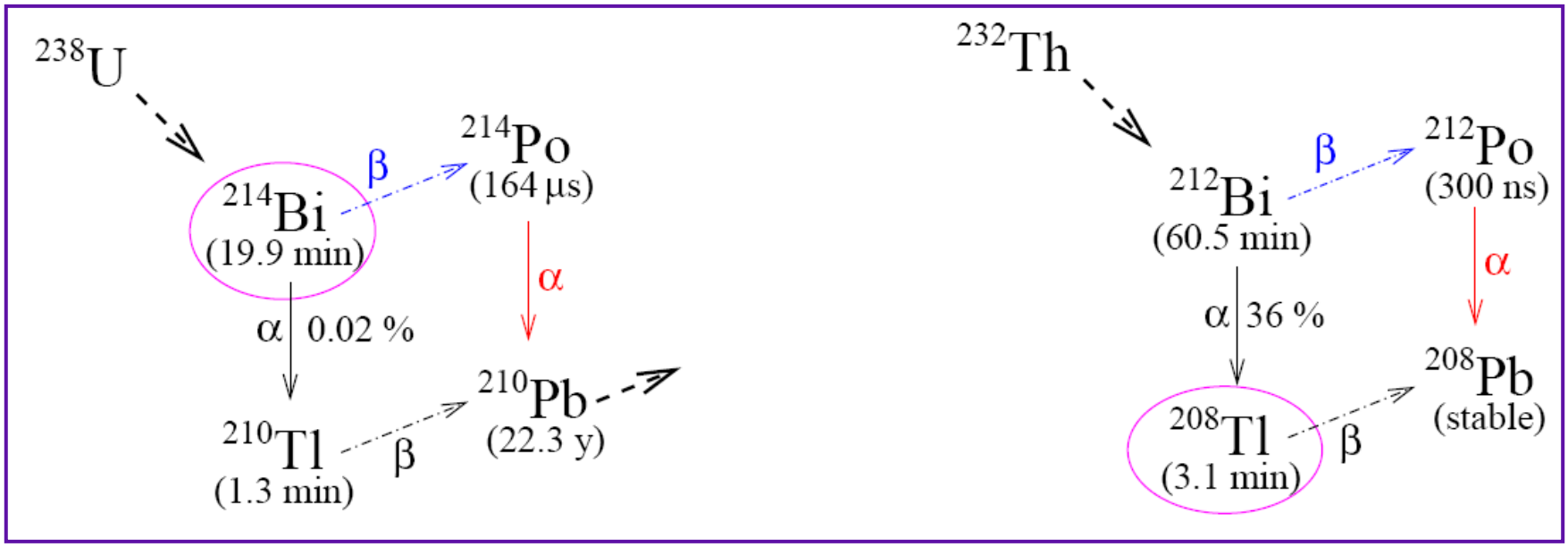
- SuperNEMO experiment will have ~100 kg of ββ emitter distributed in the so-called source foils.
- Sensitivity requirements limits the source foil contamination to:
  - ***< 2 μBq/kg in $^{208}$Tl***
  - ***< 10 μBq/kg in $^{214}$Bi***
- Most sensitive HPGe detectors ~50 μBq/kg for $^{208}$Tl.
- In addition:
  - Better to measure the source itself (particular geometry)
  - Non destructive measurement procedure




***NECESSITY OF A DEDICATED DETECTOR***

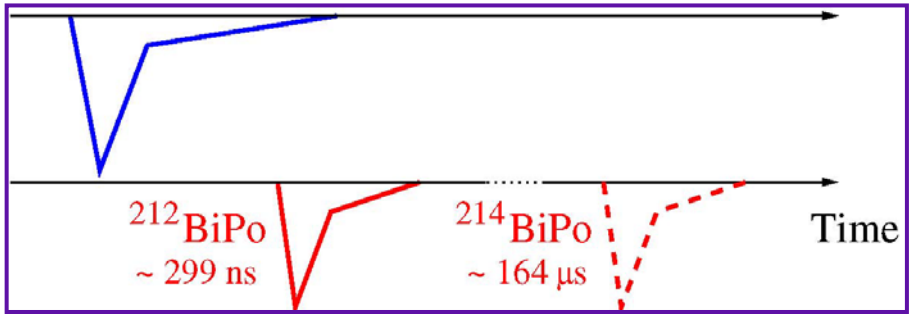
# The BiPo detector: Detection Principle

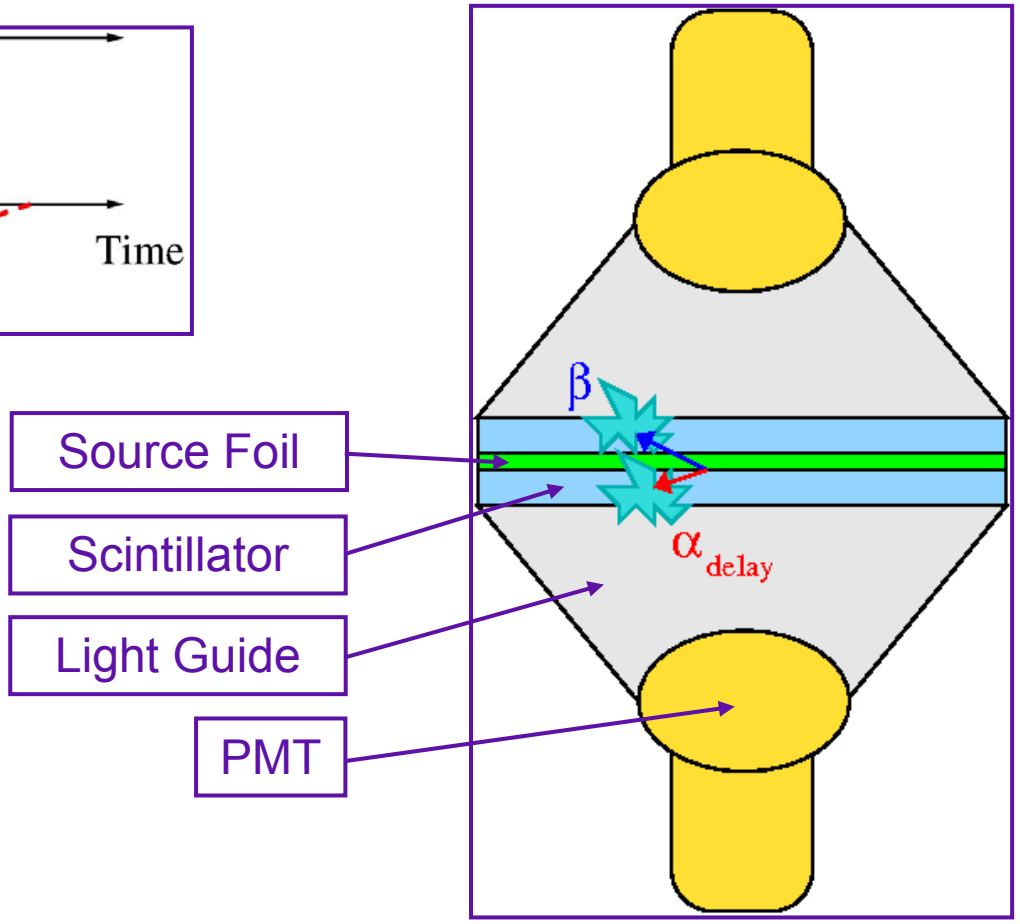
- BiPo is a dedicated detector for the measurements of ultra-low levels of contamination in $^{208}$Tl and $^{214}$Bi present in the SuperNEMO source foils.
  - Detection principle → BiPo $\beta - \alpha$ delayed coincidence detection.



# The BiPo detector: Signal and Backgrounds

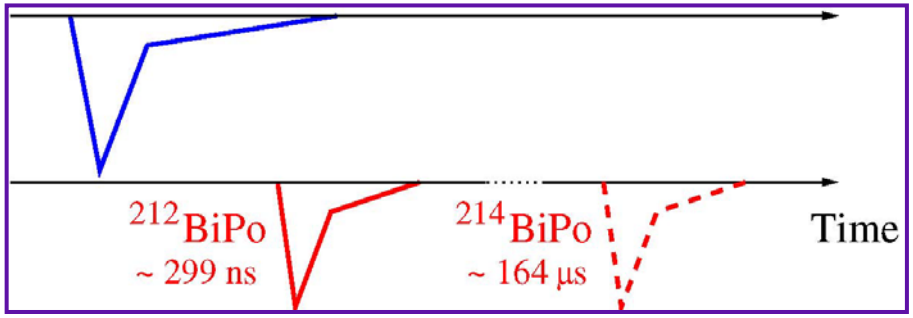
- BiPo is a dedicated detector for the measurements of ultra-low levels of contamination in $^{208}$Tl and $^{214}$Bi present in the SuperNEMO source foils.
  - Detection principle → BiPo $\beta - \alpha$ delayed coincidence detection.

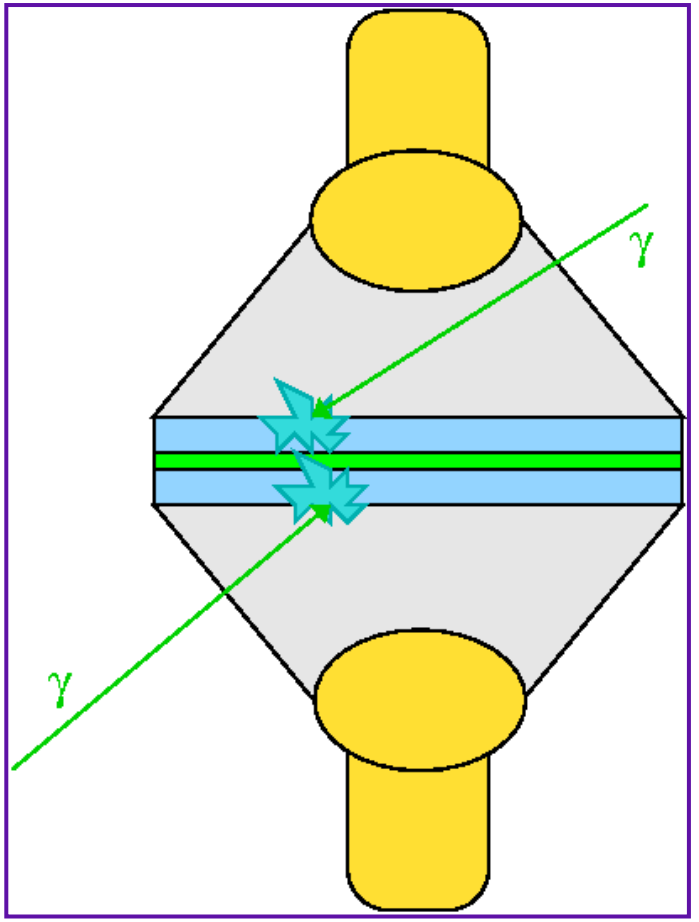


# The BiPo detector: Signal and Backgrounds

- BiPo is a dedicated detector for the measurements of ultra-low levels of contamination in $^{208}$Tl and $^{214}$Bi present in the SuperNEMO source foils.
  - Detection principle → BiPo $\beta - \alpha$ delayed coincidence detection.

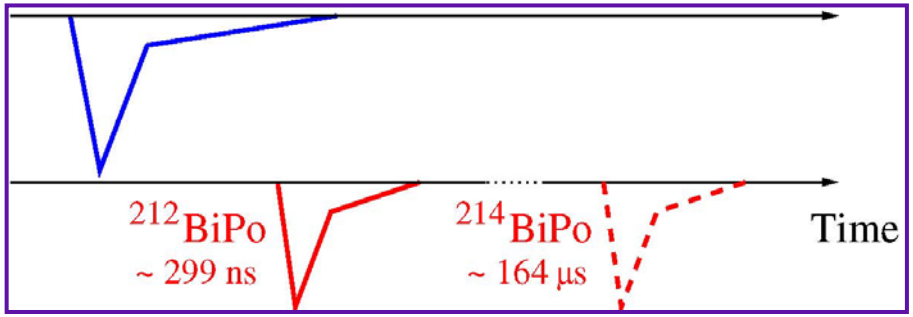


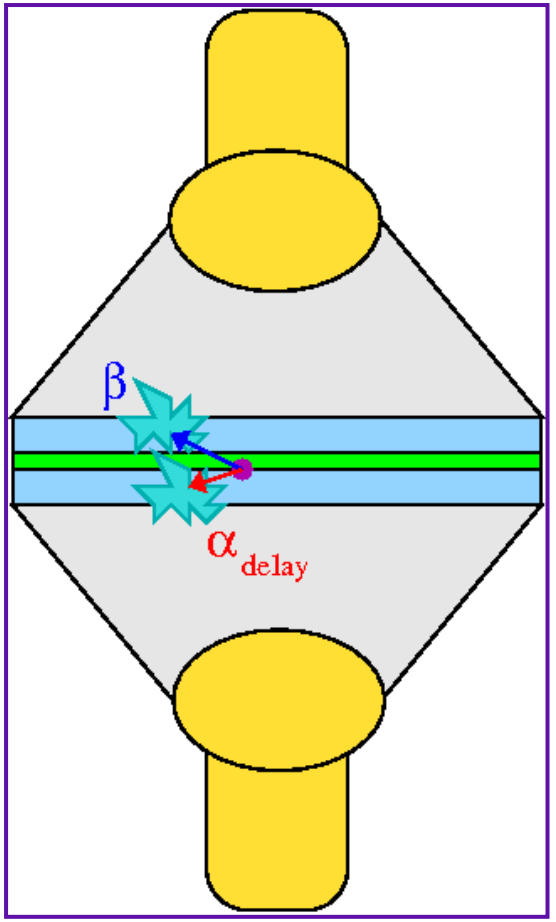




  - ***Background sources:***
    - γ-induced random coincidences

# The BiPo detector: Signal and Backgrounds

- BiPo is a dedicated detector for the measurements of ultra-low levels of contamination in $^{208}$Tl and $^{214}$Bi present in the SuperNEMO source foils.
  - Detection principle → BiPo $\beta - \alpha$ delayed coincidence detection.

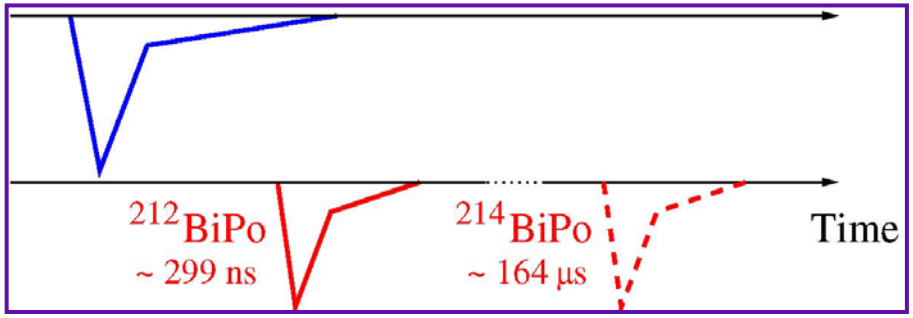


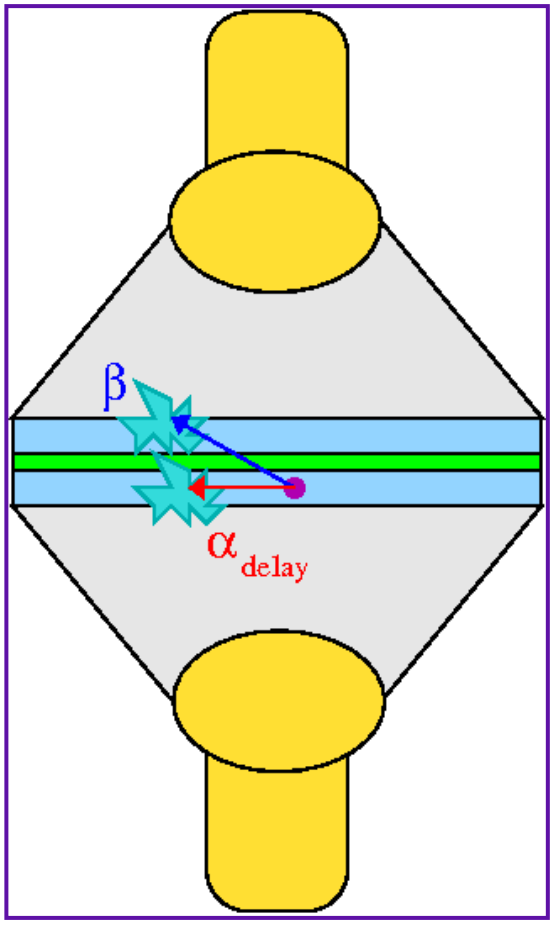




  - ***Background sources:***
    - γ-induced random coincidences
    - Scintillator surface contamination
    - Radon contamination in the sensitive volume

# The BiPo detector: Signal and Backgrounds

- BiPo is a dedicated detector for the measurements of ultra-low levels of contamination in $^{208}$Tl and $^{214}$Bi present in the SuperNEMO source foils.
  - Detection principle → BiPo $\beta - \alpha$ delayed coincidence detection.

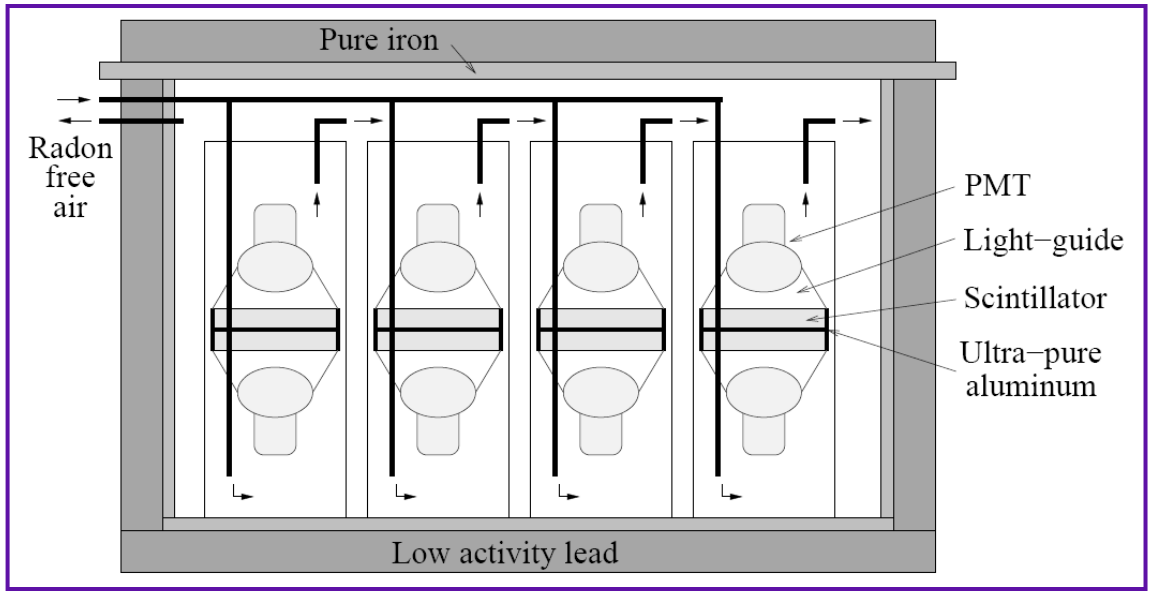



  - ***Background sources:***
    - γ-induced random coincidences
    - Scintillator surface contamination
    - Radon contamination in the sensitive volume
    - Scintillator bulk contamination

# The BiPo detector: Previous prototypes

- BiPo prototypes have been really useful to fix different open questions and to validate the technology.
  - ***BiPo 1***:
    - 20 modules
    - Face to face scintillators
    - Installed at LSM
  - DAQ tests
    - MatAcq digitizer board
    - Trigger modules
  - Analysis methods tests
  - Radiopurity of the scintillators




Detection principle tested with a calibrated ***Al*** foil between the scintillators

$^{208}$***Tl*** contamination level of ***1.5 $\mu$Bq/m$^2$ of scintillator*** measured

***NIM A 622 (2010) 120-128***

# The BiPo detector: Previous prototypes

- BiPo prototypes have been really useful to fix different open questions and to validate the technology.
  - ***BiPo 1***:
    - 20 modules
    - Face to face scintillators
    - Installed at LSM
  - DAQ tests
    - MatAcq digitizer board
    - Trigger modules
  - Analysis methods tests
  - Radiopurity of the scintillators

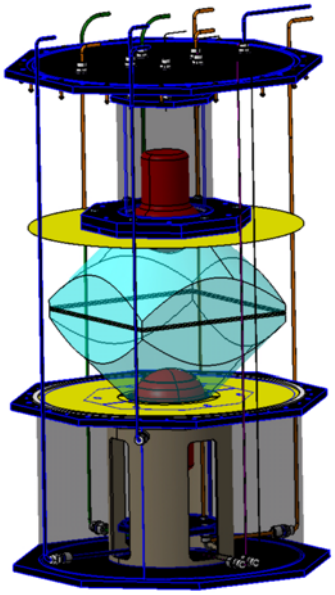
Detection principle tested with a calibrated ***Al*** foil between the scintillators

$^{208}$***Tl*** contamination level of ***1.5 $\mu$Bq/m$^2$ of scintillator*** measured

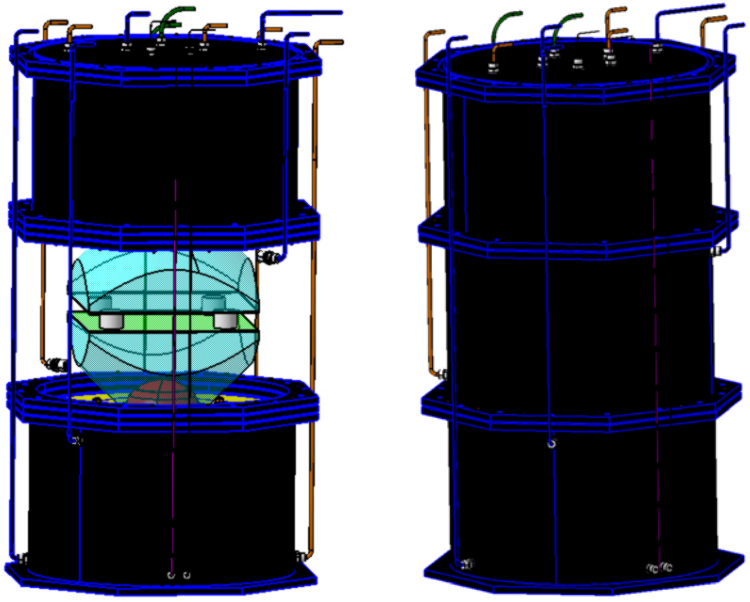
***NIM A 622 (2010) 120-128***

# The BiPo detector: Previous prototypes

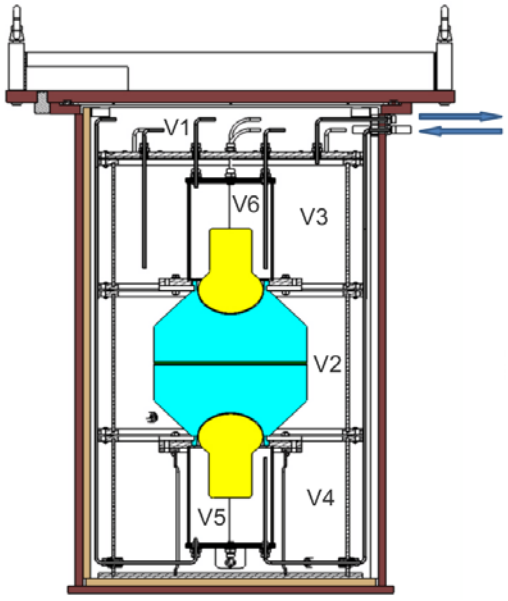
- BiPo prototypes have been really useful to fix different open questions and to validate the technology.
  - ***BiPo 3 prototype***:
    - 1 module previous to the final setup.
    - Installed @ Canfranc Underground Laboratory (Depth ~ 2500 mwe).



Optical Module Scheme



Opaque and Rn tight enclosure of the optical module




Independent Volumes Scheme

# The BiPo detector: Previous prototypes

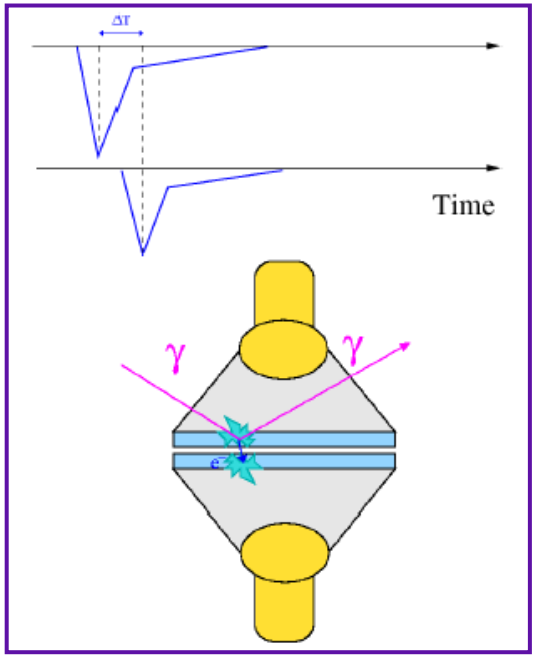
- BiPo prototypes have been really useful to fix different open questions and to validate the technology.
  - ***BiPo 3 prototype***:
    - 1 module previous to the final setup.
    - Installed @ Canfranc Underground Laboratory (Depth ~ 2500 mwe).

# The BiPo detector: Previous prototypes

- ***BiPo 3 prototype***:
  - 1 module previous to the final setup.
  - Installed @ Canfranc Underground Laboratory (Depth ~ 2500 mwe).

  ***→ How low can we go in terms of Rn level and Counting Rate?***

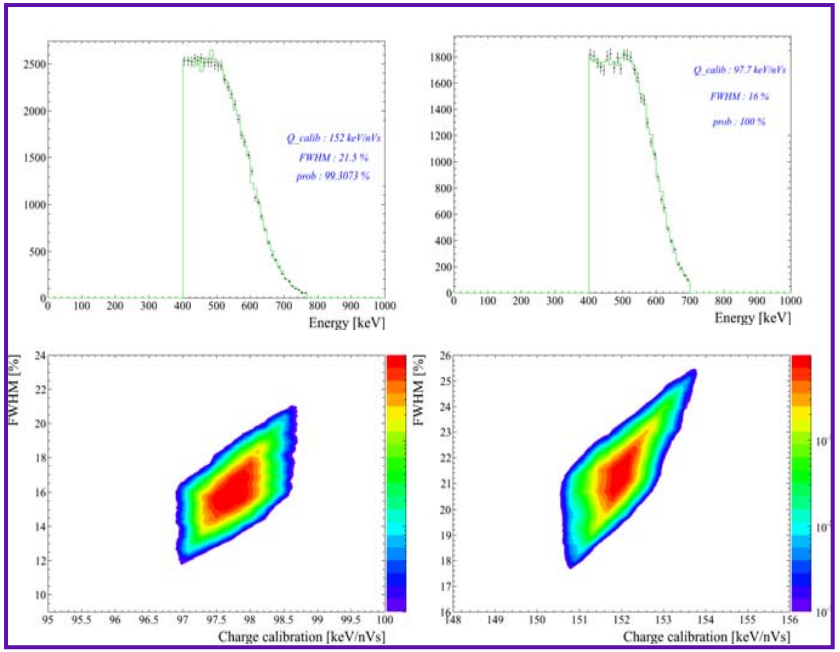
  - **Calibrations ($^{54}$Mn and $^{22}$Na) for energy, resolution and timing**
  - Counting Rate monitoring
  - BiPo events analysis




Energy Spectrum (Compton Edge)

Calibration Kolmogorov Test

(Best Gain & FWHM Fit)



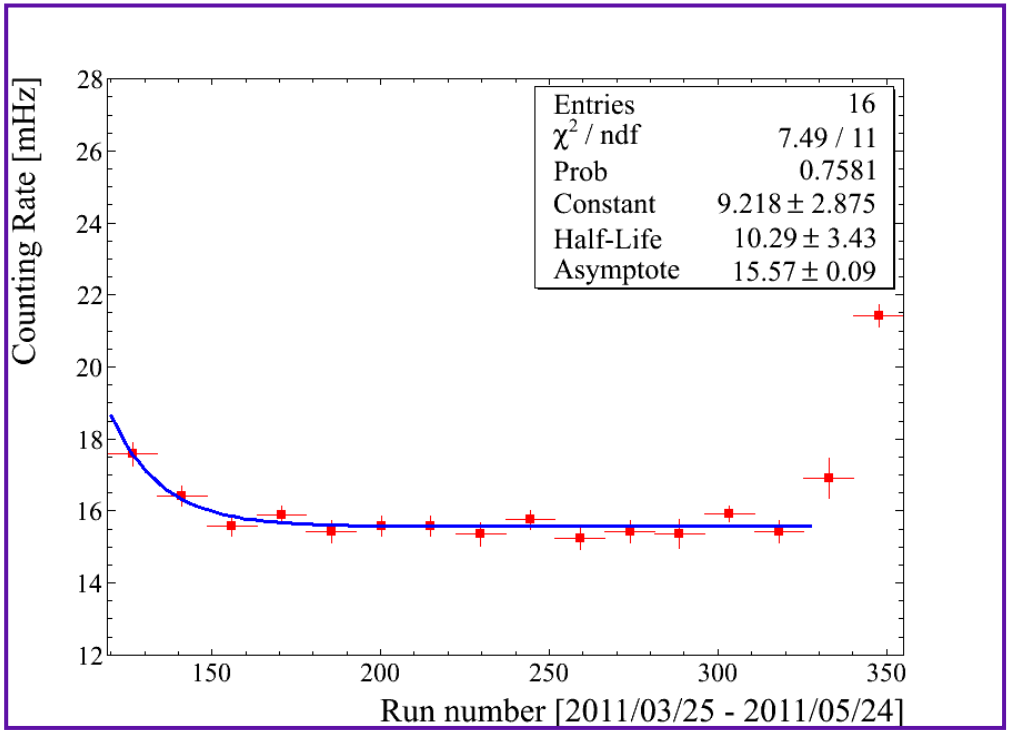
# The BiPo detector: Previous prototypes

- ***BiPo 3 prototype***:
  - 1 module previous to the final setup.
  - Installed @ Canfranc Underground Laboratory (Depth ~ 2500 mwe).

  ***→ How low can we go in terms of Rn level and Counting Rate?***

  - Calibrations ($^{54}$Mn and $^{22}$Na) for energy, resolution and timing
  - **Counting Rate monitoring**
  - BiPo events analysis

***With Nitrogen flush:***




- ***15-20 mHz*** integral rate
- Quite stable
- Dependance with Rn concentration

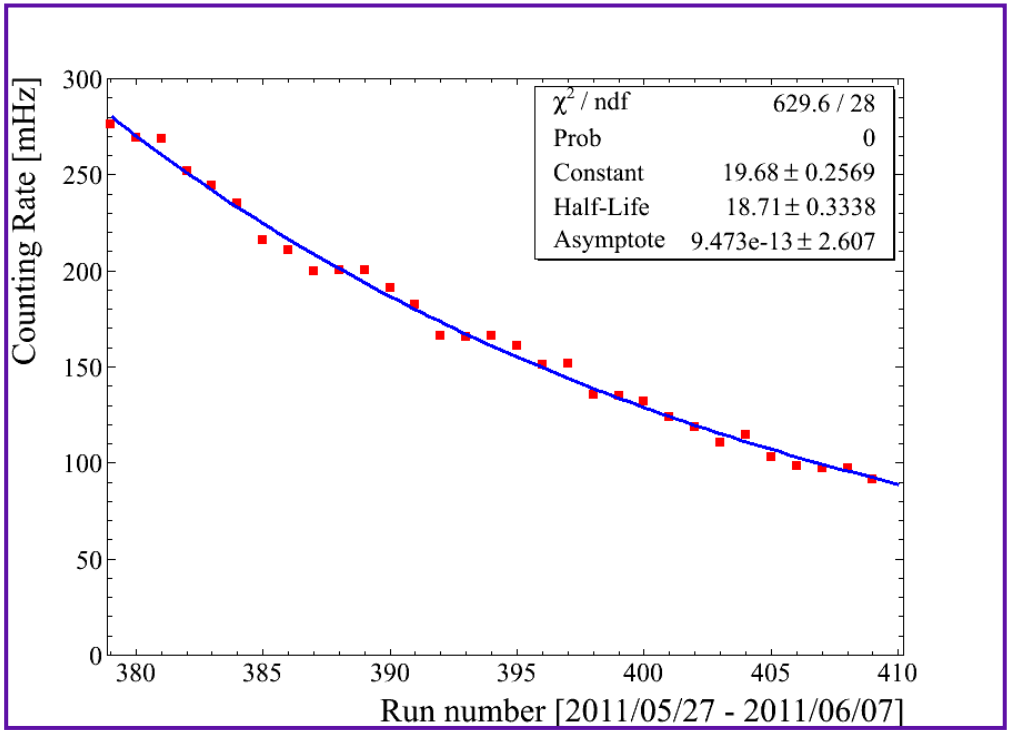
# The BiPo detector: Previous prototypes

- ***BiPo 3 prototype***:
  - 1 module previous to the final setup.
  - Installed @ Canfranc Underground Laboratory (Depth ~ 2500 mwe).

***→ How low can we go in terms of Rn level and Counting Rate?***

  - Calibrations ($^{54}$Mn and $^{22}$Na) for energy, resolution and timing
  - **Counting Rate monitoring**
  - BiPo events analysis

***Without Nitrogen flush:***




- Decay rate
- ***$T_{1/2}$ ~ 4.7 ± 0.1 days***
- Rn detection

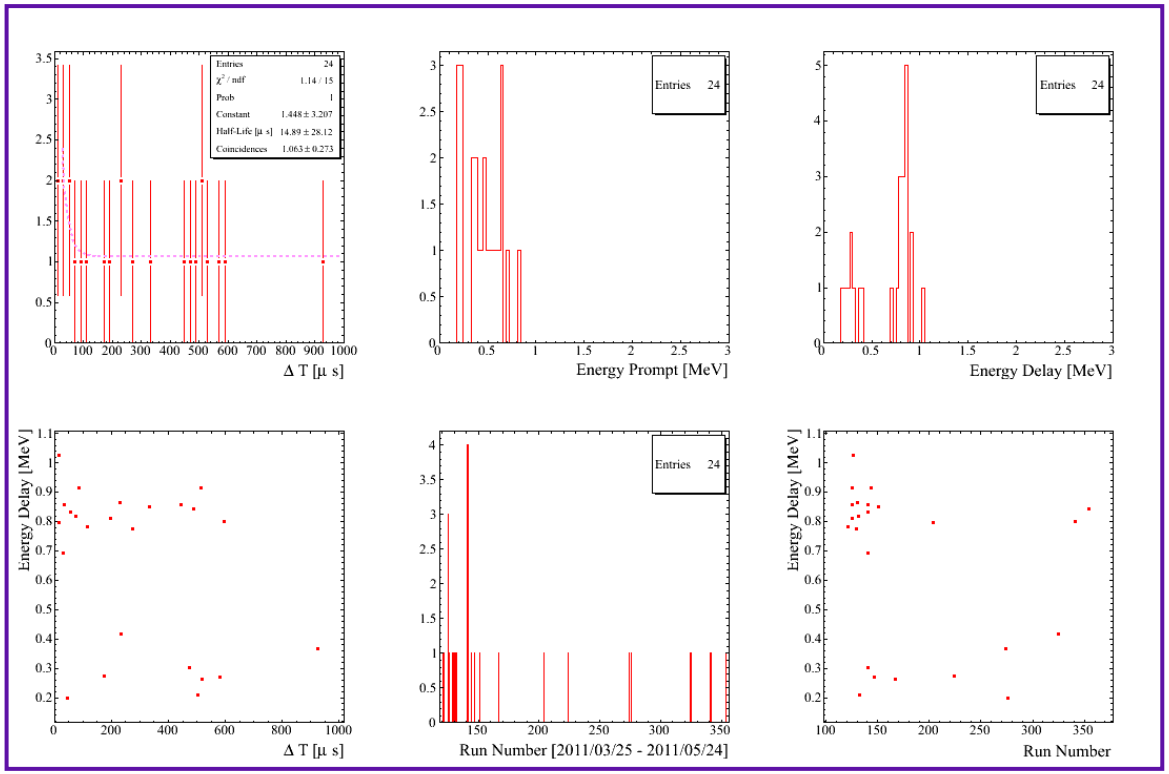
# The BiPo detector: Previous prototypes

- ***BiPo 3 prototype***:
  - 1 module previous to the final setup.
  - Installed @ Canfranc Underground Laboratory (Depth ~ 2500 mwe).

  ***→ How low can we go in terms of Rn level and Counting Rate?***

  - Calibrations ($^{54}$Mn and $^{22}$Na) for energy, resolution and timing
  - Counting Rate monitoring
  - **BiPo events analysis**

- Data from one candidate:
  - Prompt energy ($e^-$)
  - Delay energy ($\alpha$)
  - $\Delta t$
- Rate evolution
  - Assure is constant



# The BiPo detector: Previous prototypes

- ***BiPo 3 prototype***:
  - 1 module previous to the final setup.
  - Installed @ Canfranc Underground Laboratory (Depth ~ 2500 mwe).

  ***→ How low can we go in terms of Rn level and Counting Rate?***

  - Calibrations ($^{54}$Mn and $^{22}$Na) for energy, resolution and timing
  - Counting Rate monitoring
  - **BiPo events analysis**

• ***Results*** after ~***60 days*** data taking:

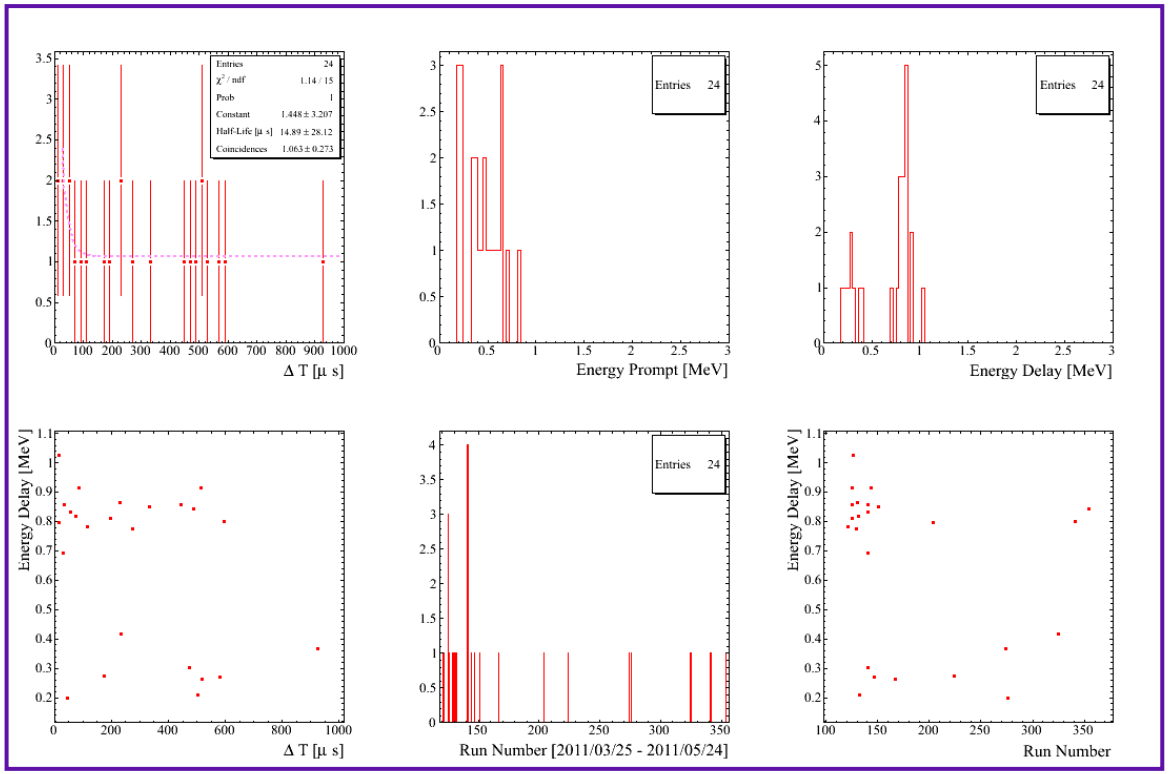
***$^{208}$Tl:***

A ($^{208}$Tl) < 5.45 μBq/m$^2$ scint @ 90% C.L.

***$^{214}$Bi:***

0.6 < A ($^{214}$Bi) = 5.3 < 23 μBq/m$^2$ scint

***PROMISING RESULTS***

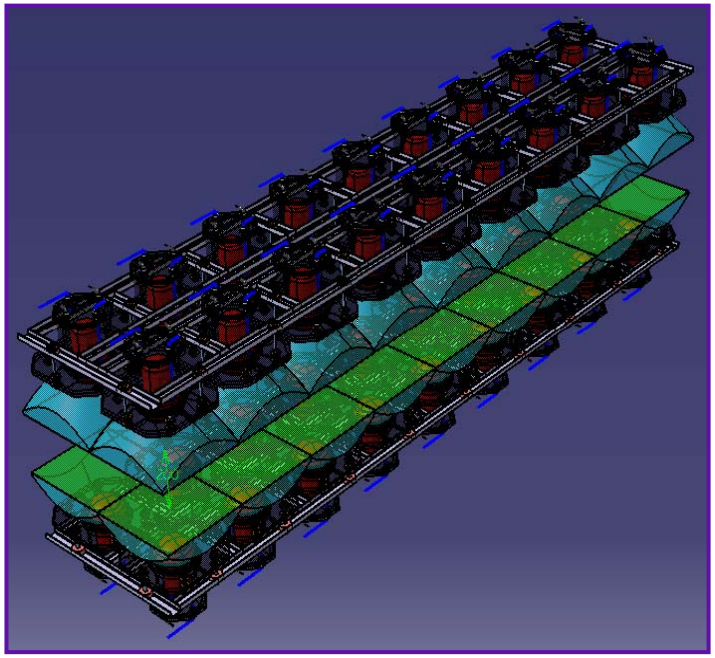


# Final setup: BiPo 3 detector

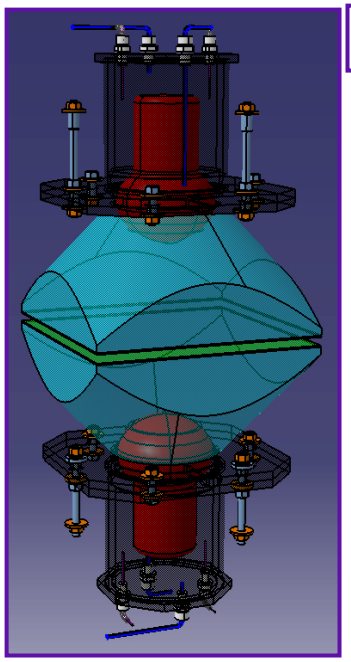
- Prototypes have shown that required sensitivity levels could be reachable with the face to face detector approximation.

- Main features:

  - 2 modules detector → Possibility to measure 8 SuperNEMO source foils simultaneously
  - 20 30x30 $cm^2$ optical sub-modules in each module
    - 3.6 $m^2$ of sensitive surface
  - 2 mm thick scintillator plates
  - Light guide geometry optimized
  - Volume separation and nitrogen flushing for Rn suppression and external shielding



Assembling of 20 optical submodules → 1 BiPo 3 module



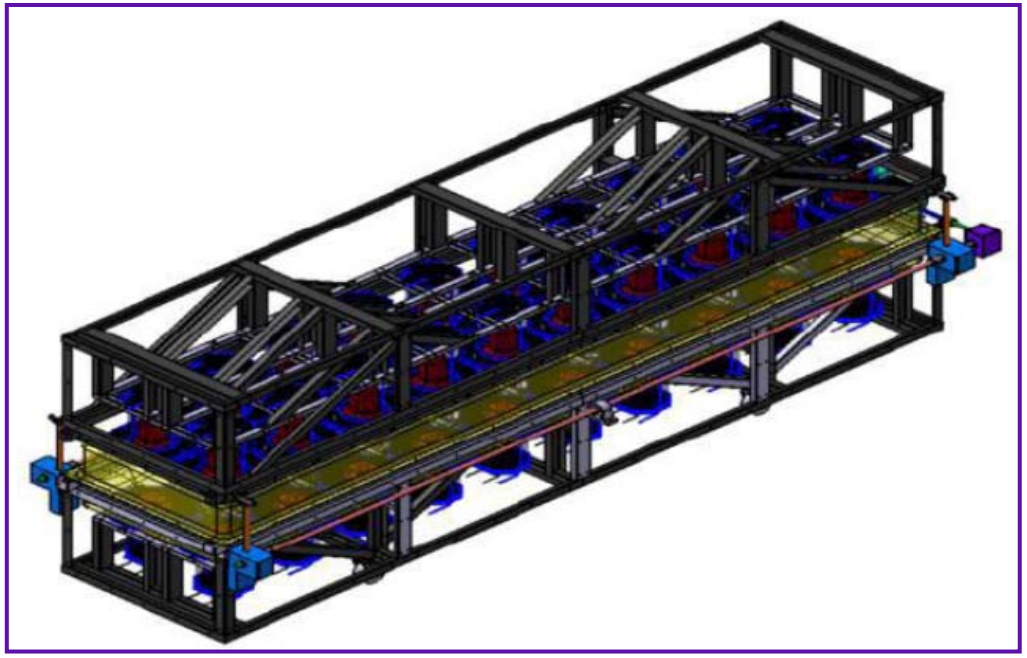
BiPo 3 Optical Submodule

# Final setup: BiPo 3 detector

- Prototypes have shown that required sensitivity levels could be reachable with the face to face detector approximation.

- Main features:

  - 2 modules detector → Possibility to measure 8 SuperNEMO source foils simultaneously
  - 20 30x30 $cm^2$ optical sub-modules in each module
    - 3.6 $m^2$ of sensitive surface
  - 2 mm thick scintillator plates
  - Light guide geometry optimized
  - Volume separation and nitrogen flushing for Rn suppression and external shielding



BiPo 3 detectors installed in the internal structure

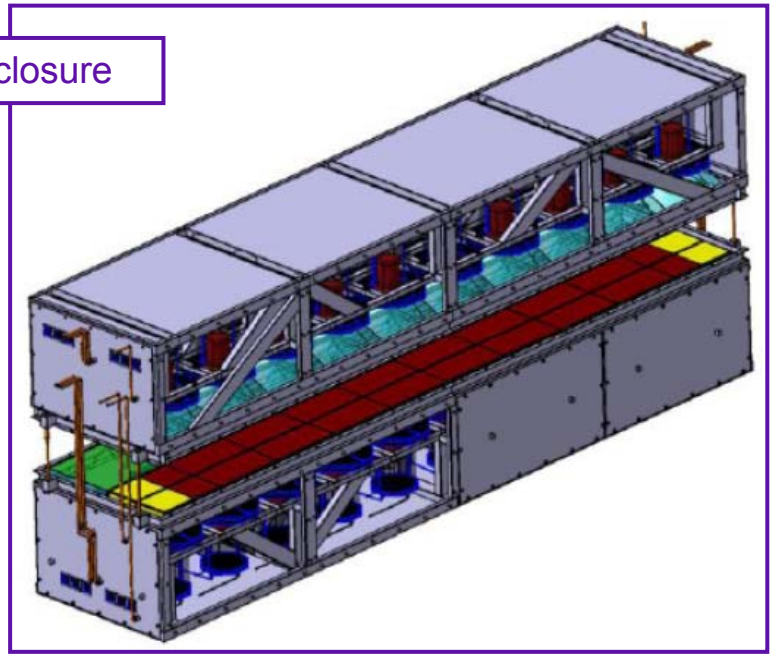
# Final setup: BiPo 3 detector

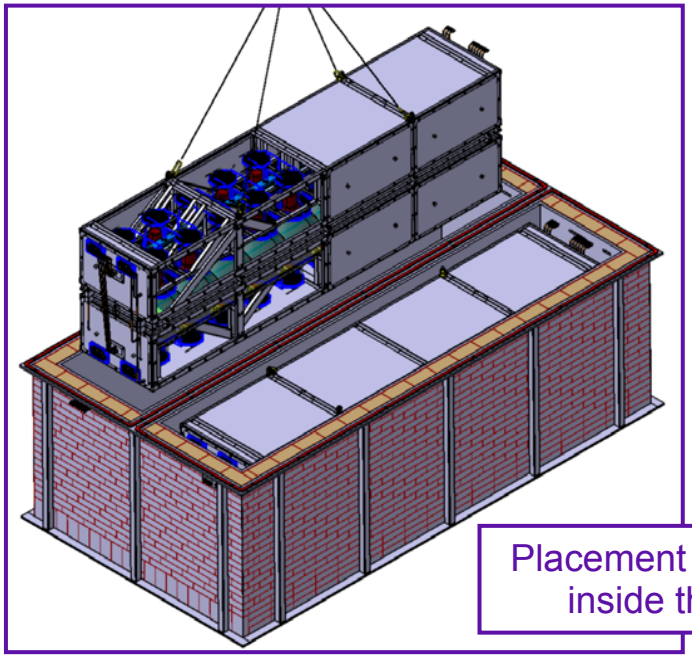
- Prototypes have shown that required sensitivity levels could be reachable with the face to face detector approximation.

- Main features:

  - 2 modules detector → Possibility to measure 8 SuperNEMO source foils simultaneously
  - 20 30x30 $cm^2$ optical sub-modules in each module
    - 3.6 $m^2$ of sensitive surface
  - 2 mm thick scintillator plates
  - Light guide geometry optimized
  - Volume separation and nitrogen flushing for Rn suppression and external shielding

BiPo 3 enclosure





Placement of the modules inside the shielding

# BiPo 3 present status

- Almost the 80 optical submodules assembled and characterized in a test bench @ LAL.

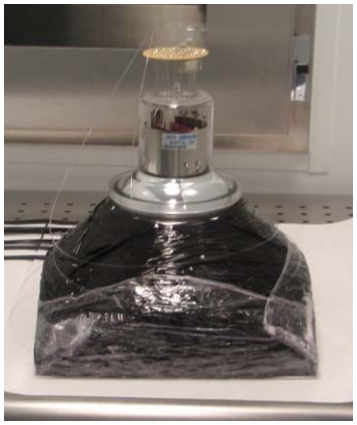
Light guide annealing

Gluing of the scintillator

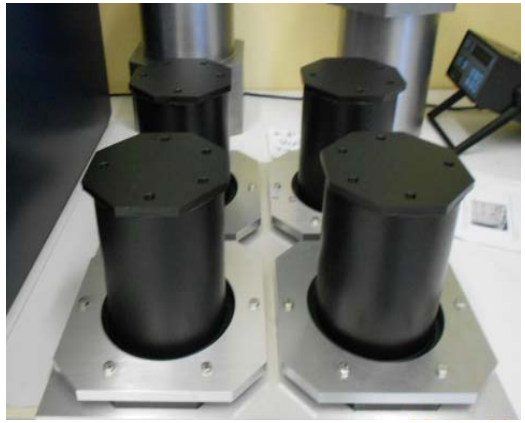
Aluminization

PMT gluing

Tyvek wrapping



Black film



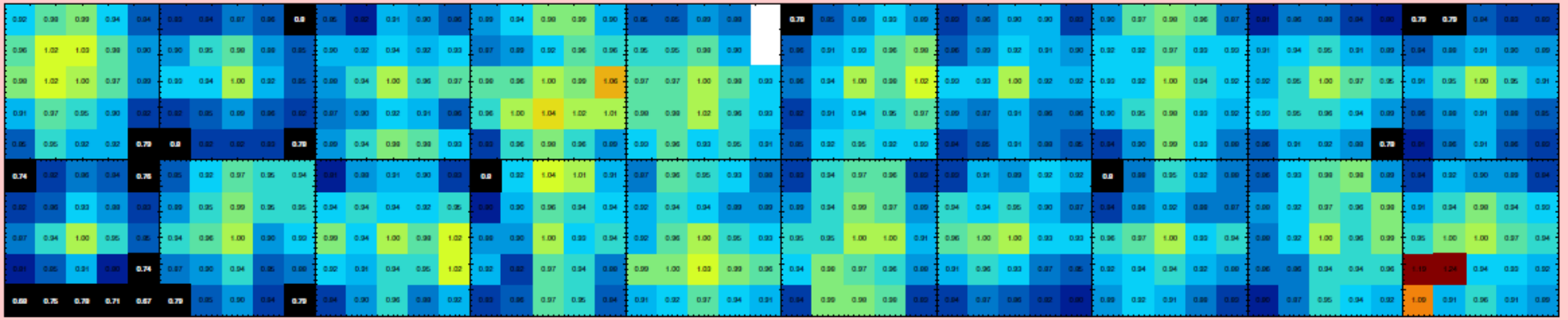
Light black box

Characterized sub-modules storage

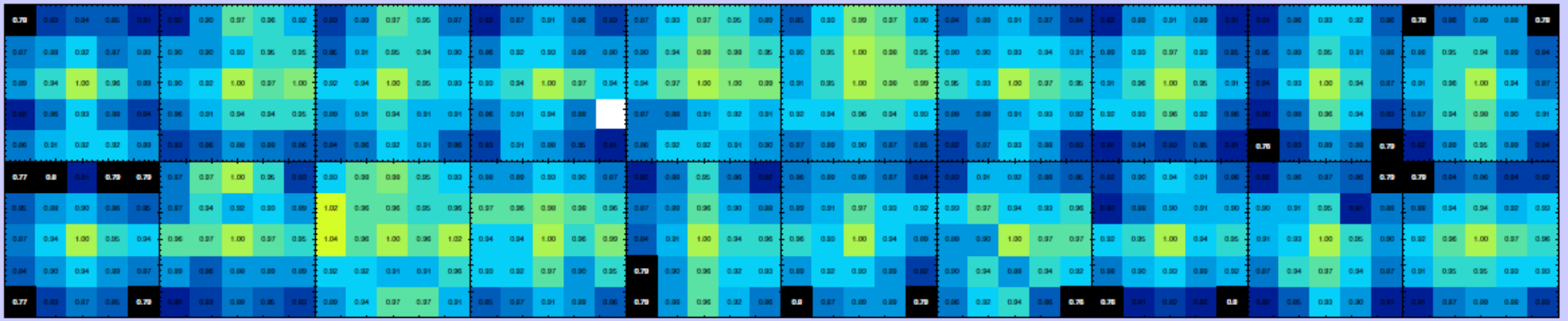
# BiPo 3 present status

- Almost the 80 optical submodules assembled and characterized in a test bench @ LAL.

Top Part of BiPo3 Module



Bottom Part of BiPo3 Module



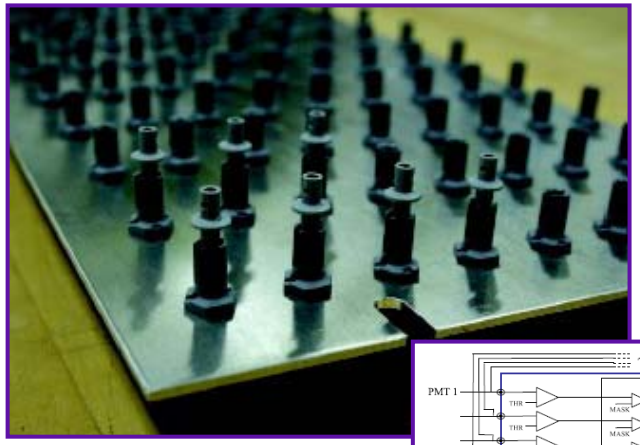
# BiPo 3 present status

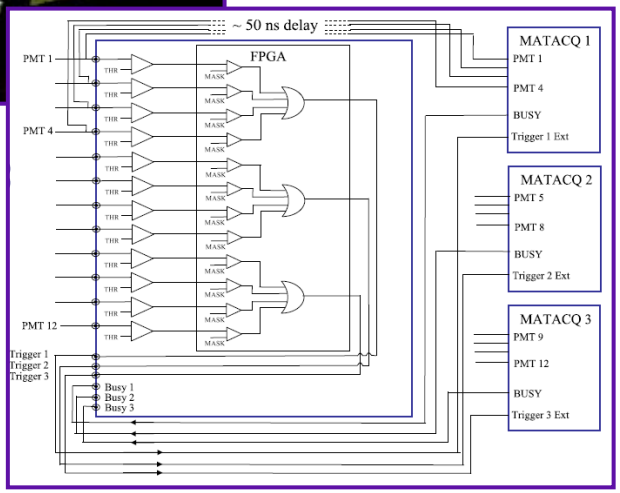
- Almost the 80 optical submodules assembled and characterized in a test bench @ LAL.
- Mechanical frame ready for the first module, and almost ready for the second

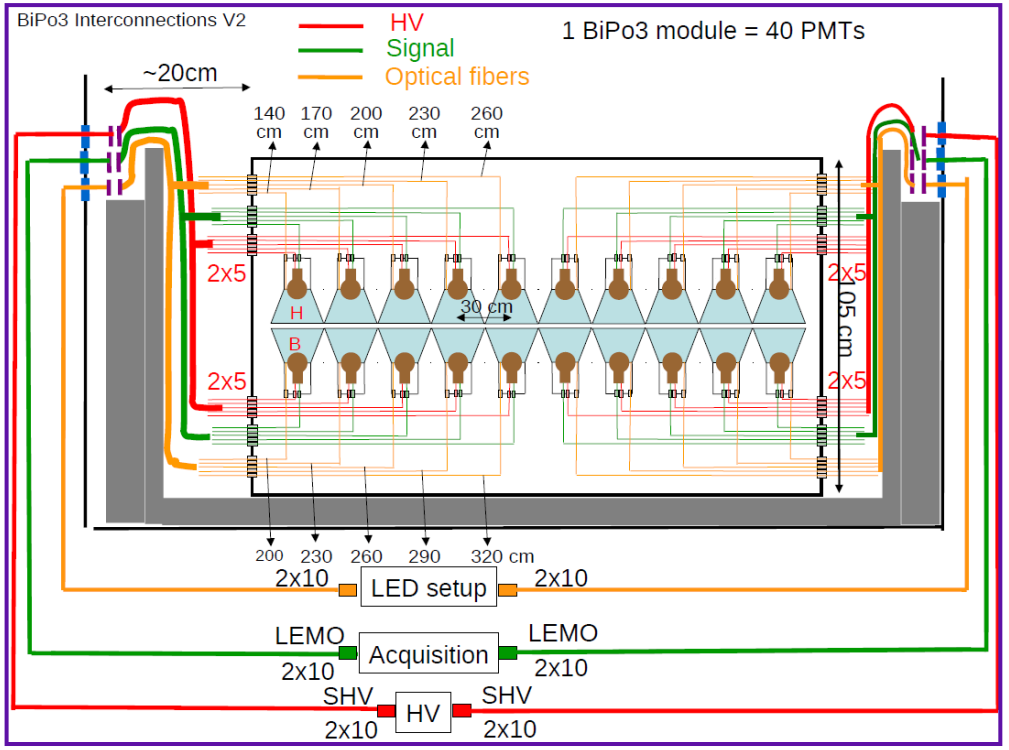


# BiPo 3 present status

- Almost the 80 optical submodules assembled and characterized in a test bench @ LAL.
- Mechanical frame ready for the first module, and almost ready for the second
- Preliminary test and commissioning for DAQ system, Nitrogen flushing feedthroughs, calibrations…





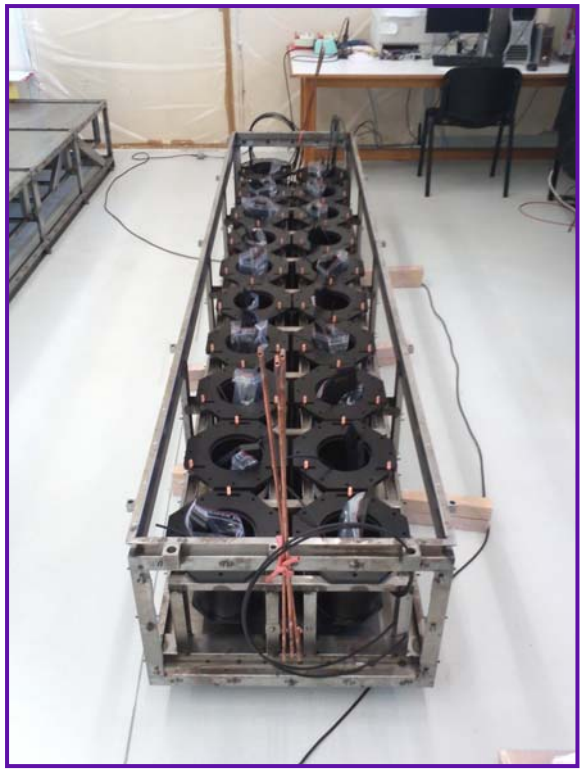




***ALMOST READY FOR THE COMMISSIONING OF THE FIRST MODULE.***

# BiPo 3 present status

- Almost the 80 optical submodules assembled and characterized in a test bench @ LAL.
- Mechanical frame ready for the first module, and almost ready for the second
- Preliminary test and commissioning for DAQ system, Nitrogen flushing feedthroughs, calibrations…

***FIRST ASSEMBLING TESTS @ LAL CLEAN ROOM***



# Outlook and Prospects

- Approximate timeline:
  - ***Module 1:***
  - All the required material for the first BiPo 3 module will be tested at LAL before mid – June
  - The material will be delivered to Canfranc Underground Laboratory last week of June
  - ***Installation*** of the first BiPo 3 module between ***2 and 13 of July***
  - ***Commissioning*** of the detector during ***summer***
  - ***Calibrations*** and background measurement: Until ***end 2012***
  - ***Source*** measurement: ***Beginning 2013***
  - ***Module 2:***
  - ***Same*** schedule that for ***module 1*** with ***~3 months of delay***

***In March 2013 the whole detector will be completely ready, being possible to make source measurements since beginning 2013***

# Summary and Conclusions

- ***NEMO 3*** experiment has obtained really good results in the measurement of $T_{1/2}^{2\nu\beta\beta}$ and also upper limits of $T_{1/2}^{0\nu\beta\beta}$ for $^{82}Se$ and $^{100}Mo$.
- ***SuperNEMO*** experiment will use the same technique with ***100 kg*** of ββ emitter trying to reach the $\langle m_\nu \rangle \sim 50$ meV level.
- One requirement for SuperNEMO is to have really good ***radiopurity*** levels for the ***source foils***: ***< 2 μBq/kg*** in $^{208}Tl$ and ***< 10 μBq/kg*** in $^{214}Bi$.
- ***BiPo*** is a ***dedicated*** detector designed to measure these foils with the required sensitivity.
- A set of ***prototypes*** have showed the ***viability*** to construct the detector proving the ***detection principle***.
- ***Results*** of these prototypes lead to think that required ***sensitivity*** will be ***reached***.
- ***Final setup*** is almost ***completed*** and source foil measurements are expected to ***start beginning 2013***.

# BiPo: A dedicated radiopurity detector for the SuperNEMO experiment

**Héctor Gómez Maluenda** on behalf of SuperNEMO Collaboration

Laboratoire de l'Accélérateur Linéaire

gomez@lal.in2p3.fr

- NEMO 3 and SuperNEMO experiments.
    - Motivation: SuperNEMO $\beta\beta$ source foils radiopurity.
- The BiPo detector:
- BiPo 3 present status.
- Outlook and Prospects.
- Summary and Conclusions.