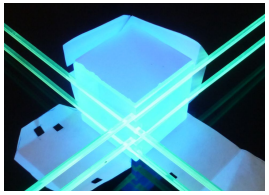
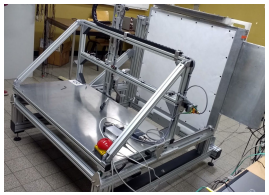



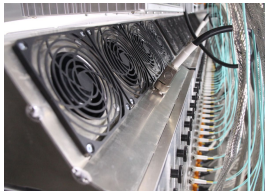


SoLiD

laboratoire de physique corpusculaire

SoLid experiment status

GDR neutrino - Bordeaux
Valentin Pestel
On behalf of SoLid collaboration
30/10/2019

cnrs

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UNIVERSITÉ CAEN NORMANDIE

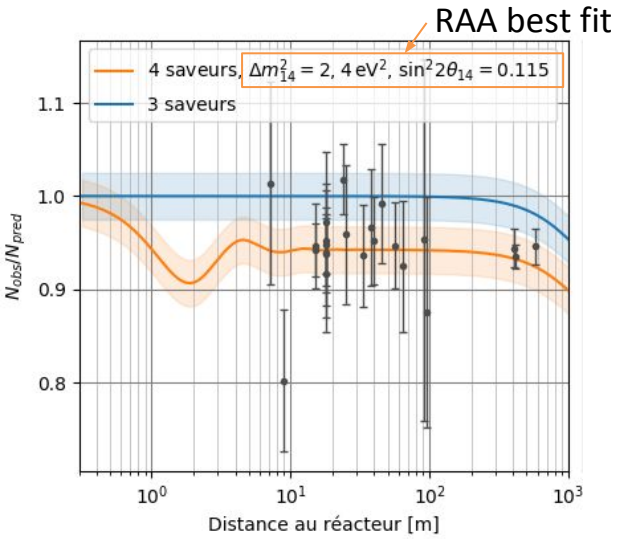
Normandie Université

SoLid goals

Motivations :

- Probe the reactor anomaly deficit and search for oscillation at very short baseline:
  $L \simeq 10\ m \leftrightarrow \Delta m^2 \simeq 1\ eV^2$

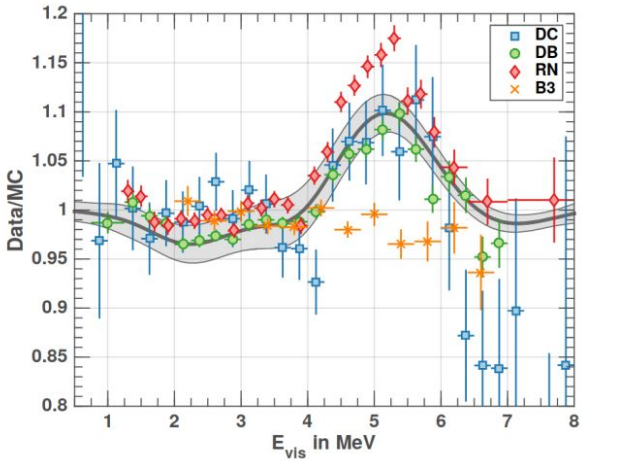
- Resolve discussion on spectral features observed by previous reactor experiments



[G. Mention et al. Phys. Rev. D, 83 :073006, Apr 2011.]

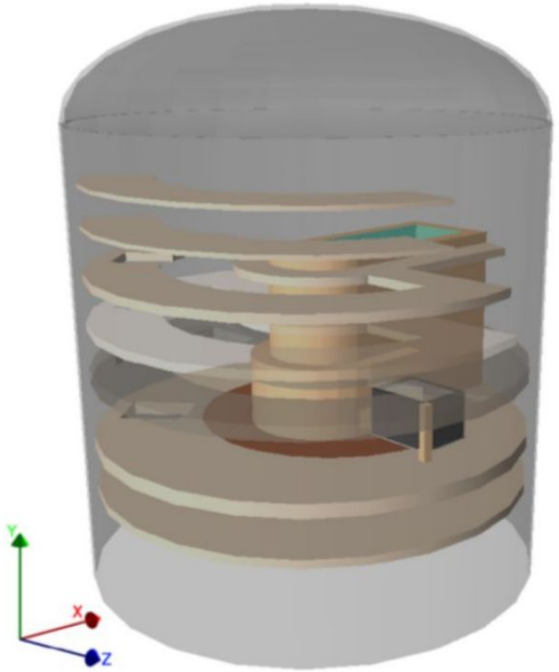
6 different experiments at very short baseline :

- 2 involving french laboratories
  - STEREO (ILL, Grenoble)
  - SoLid (BR2, Mol)



[G. Mention et al. Physics Letters B, 773 :307 – 312, 2017.]

BR2 @ SCKoCEN (Belgium)

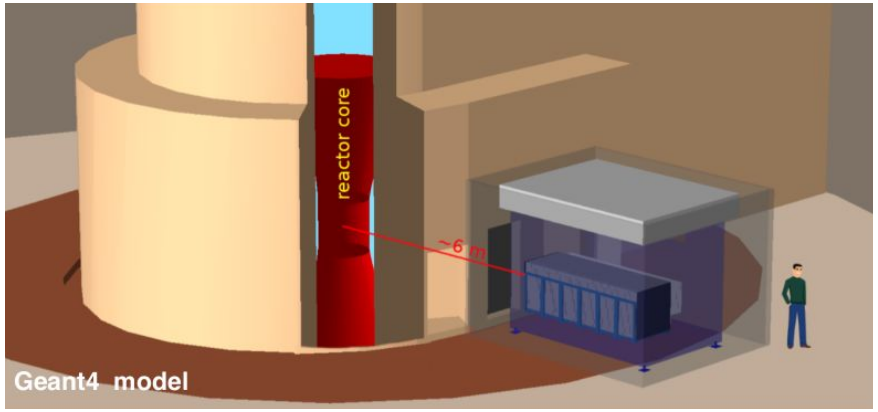


Research reactor :

- Thermal power $P_{th} \simeq 60\ MW_{th}$
- Antineutrino flux $10^{19}\ \overline{\nu}_e/s$
- Fuel 95,3% ^{235}U (99,7% of $\overline{\nu}_e$)
- Compact core ∅ = 50cm, h = 90cm
- Duty cycle 50%

SoLid experiment :

- 1200 $\overline{\nu}_e$ interactions / day
- Energy resolution < 14% à 1 MeV
- 6 to 9 m baseline



SoLid technology

Inverse Beta Decay (IBD) :

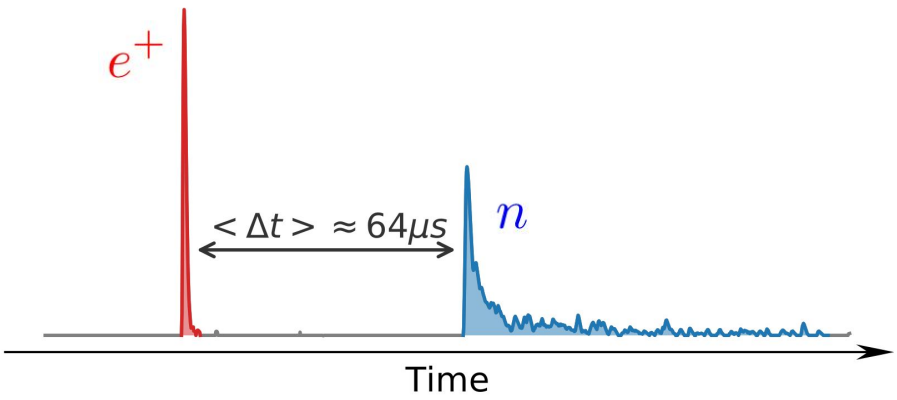
$$\bar{\nu}_e + p \rightarrow e^+ + n \quad (Q = -1,8\,\mathrm{MeV})$$

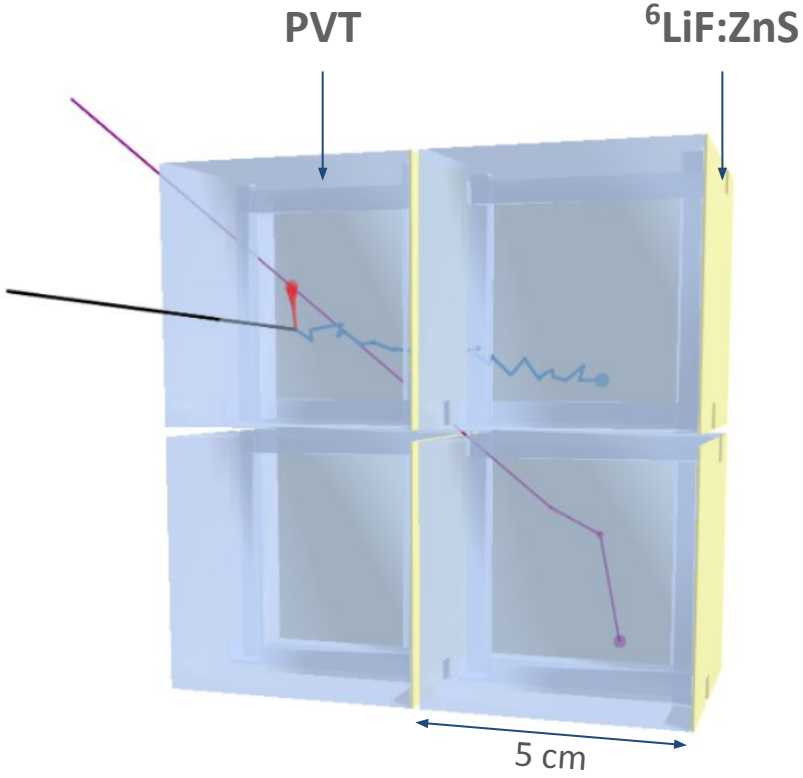
$$E_{\bar{\nu}_e} \approx E_{e^+} + 1,8\mathrm{MeV}$$

$$\vec{p}_{\bar{\nu}_e} \approx \vec{p}_n$$

Neutron absorbed by ^{6}Li :

$$n + {}^6\mathrm{Li} \rightarrow {}^3\mathrm{H} + \alpha \quad (Q = 4,8\,\mathrm{MeV})$$





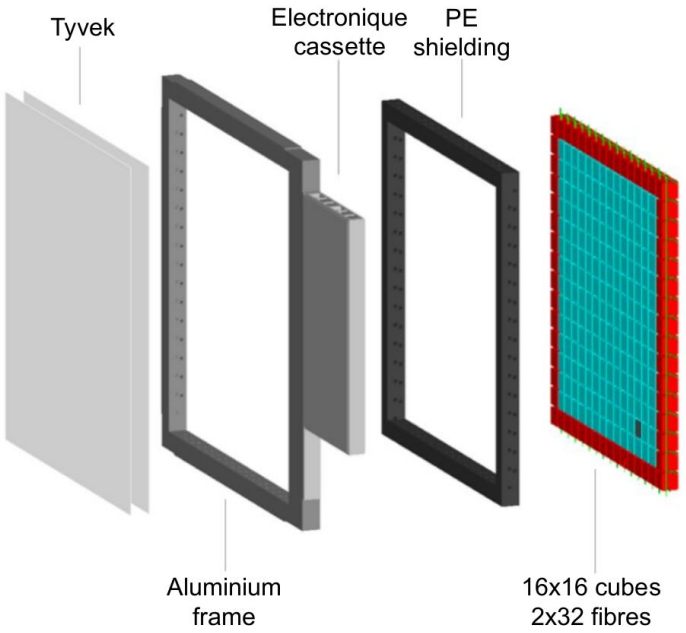
ZnS-PVT pulse shape discrimination :

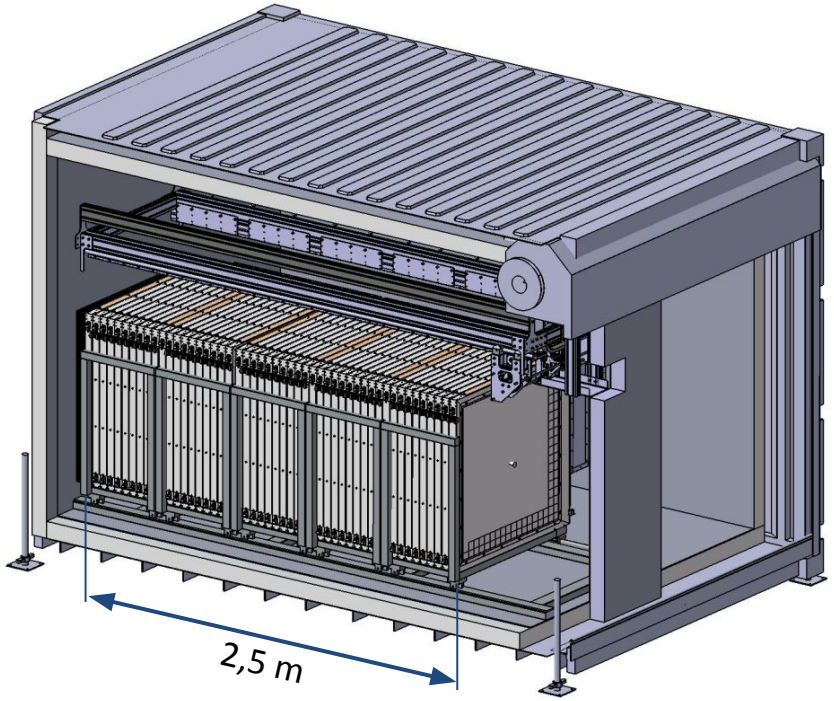
- Positron-neutron identification

Time and space coincidence :

- Background rejection

SoLid Phase 1 detector



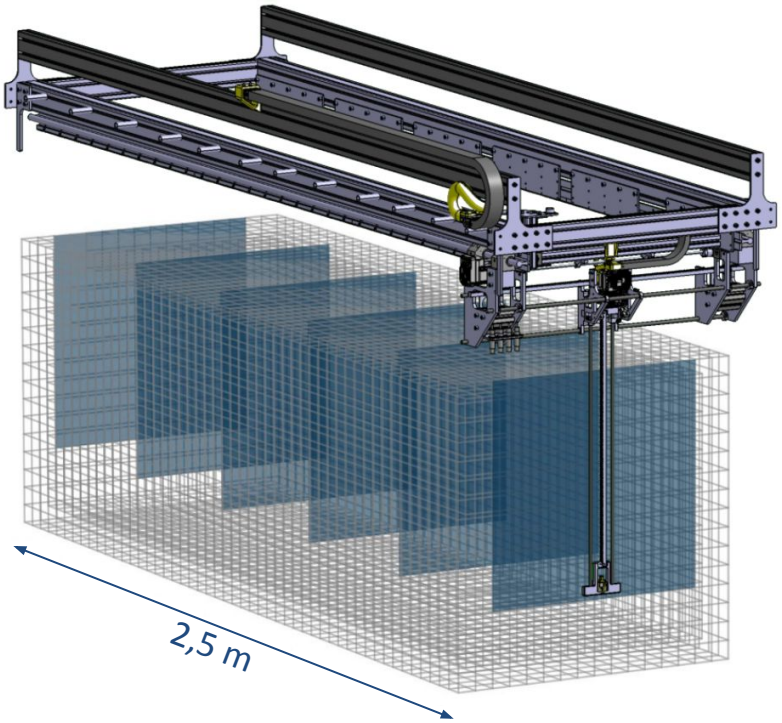


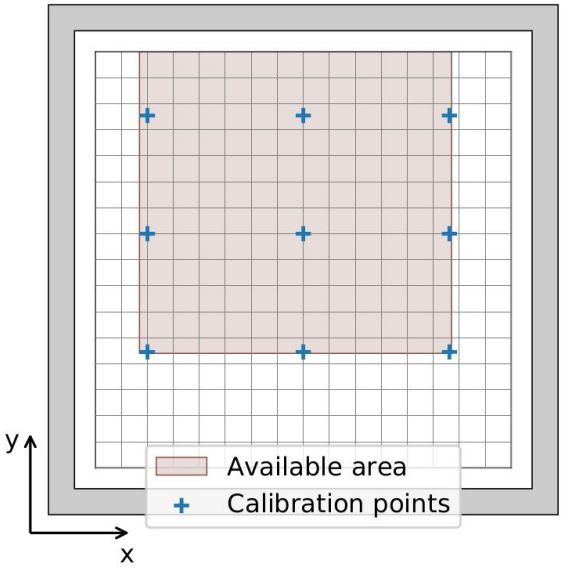
12800 cubes

- 256 cubes / plane
- 64 fibers + MPPC
- 1,6 t in total

- Grouped per modules
- 10°C cooled container

Calibration system : CROSS





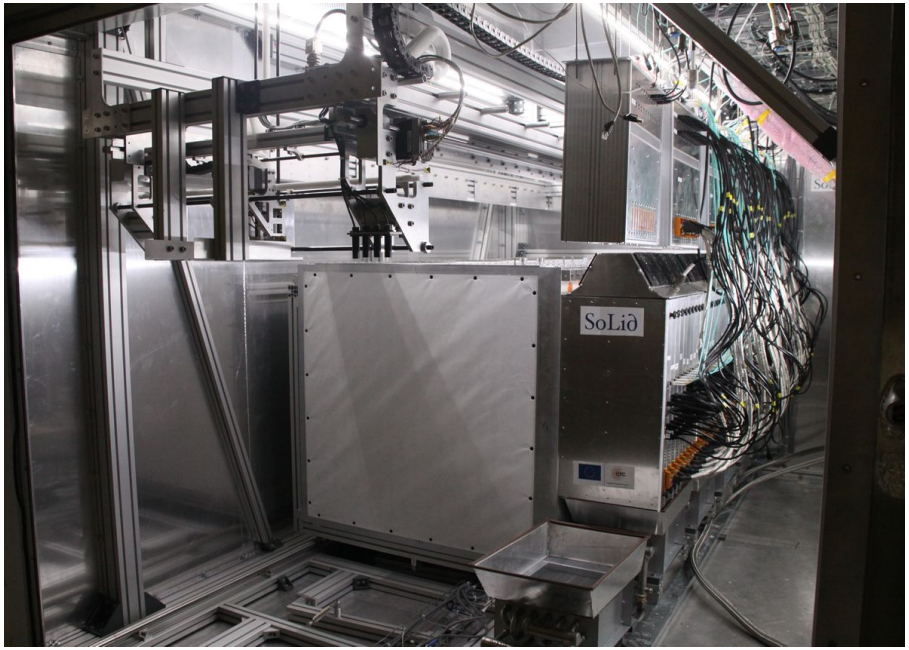
CROSS :

- 3D calibration arm
- 6 calibration gaps (every 50 cm)

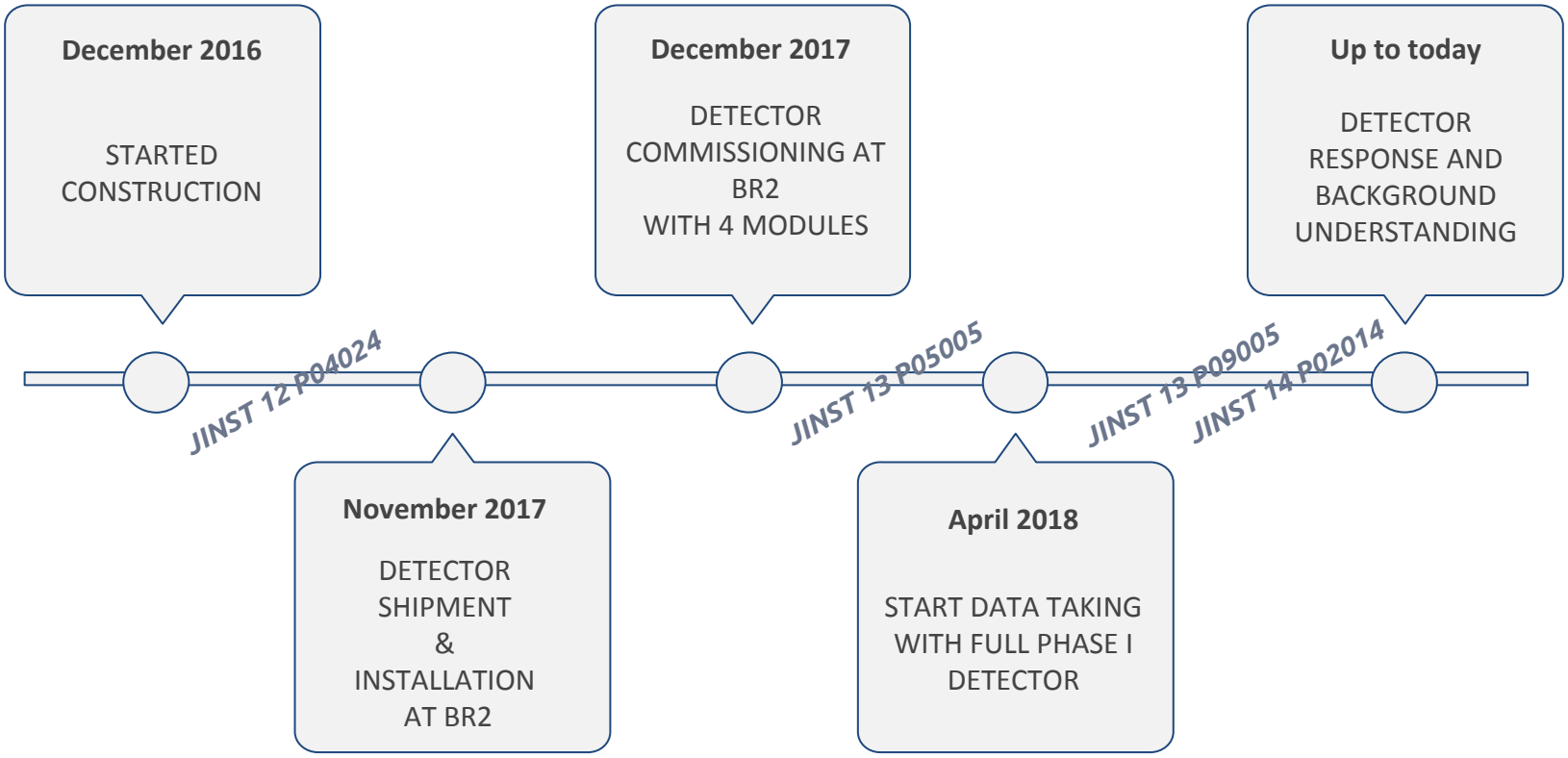
Very good coverage of the detector volume

- 9 measurement points every gaps (x6)

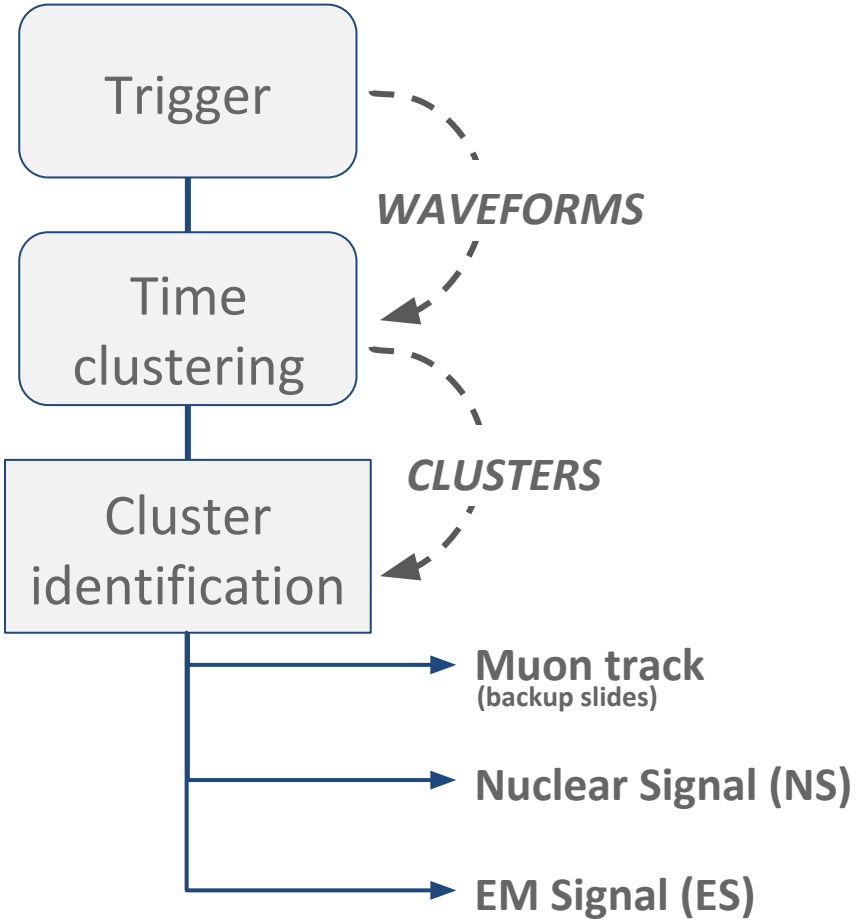
Detector at BR2

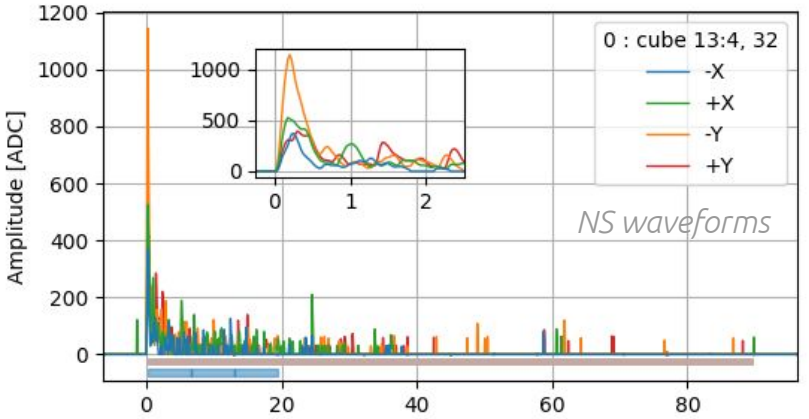


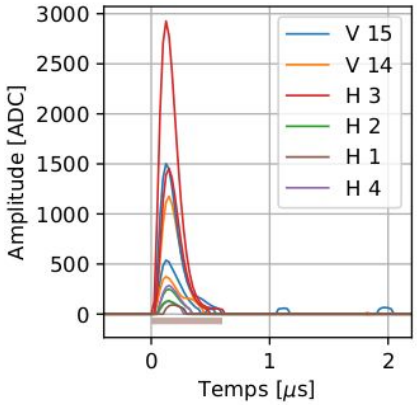
SoLid Timeline

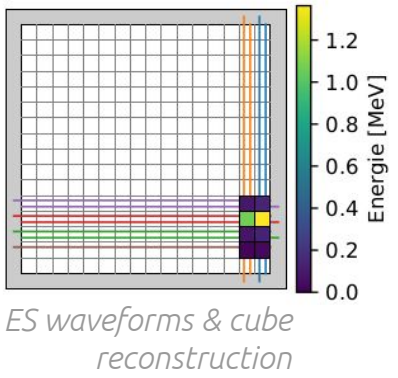


Data reconstruction







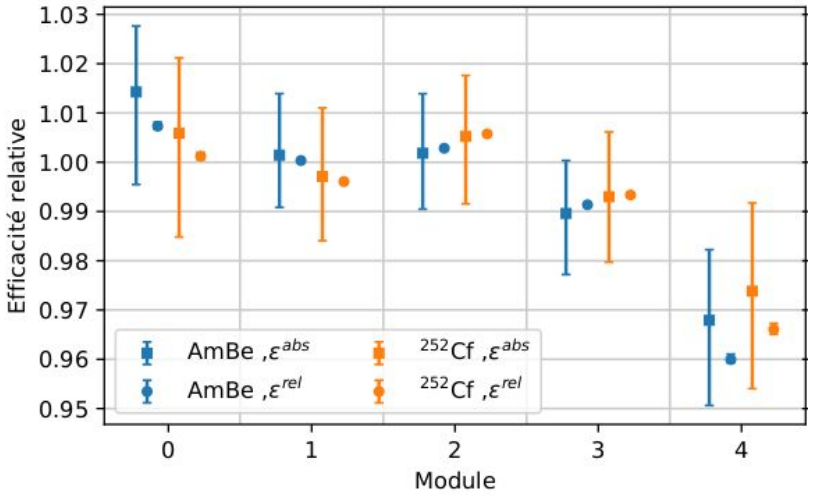


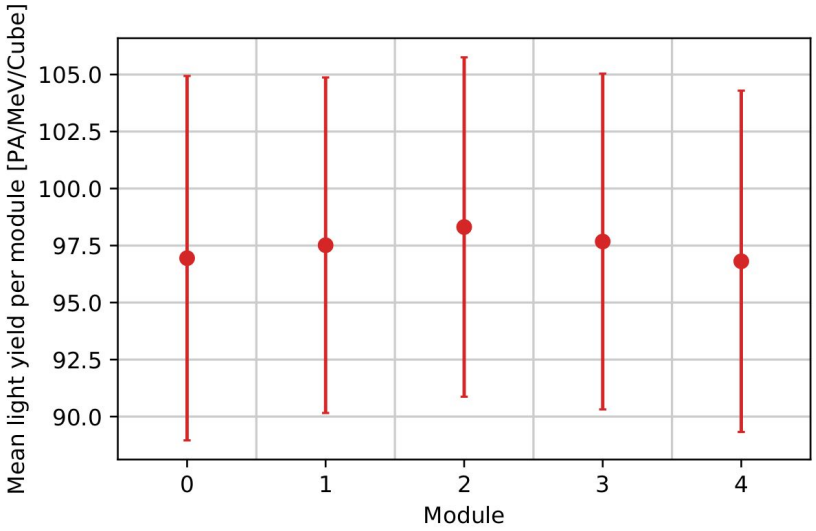
ES waveforms & cube reconstruction

Calibration results

Neutron detection efficiency :

- 2 radioactive sources : AmBe & ^{252}Cf
- Absolute measurement (MC comparison)
  - $\epsilon_{n\,IBD}^{det} \approx 52\,\%$
- Relative measurement
  - 1% agreement per module



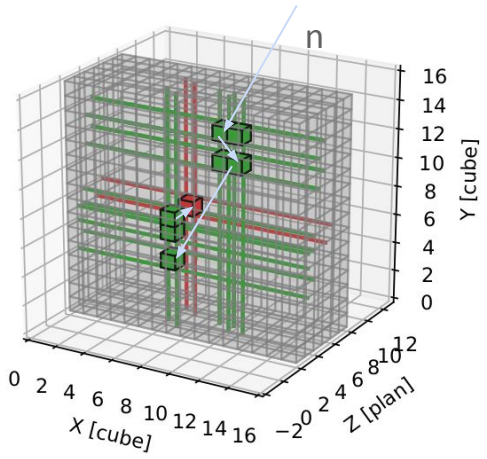


Detector light yield measurement :

- Compton edge fit (data/MC)
- Mean light yield of 97 PA/MeV/Cube
  - Energy resolution > 12% at 1 MeV

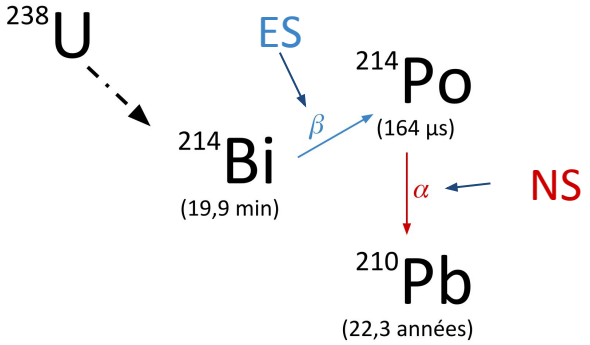
Time correlated backgrounds

Fast neutrons



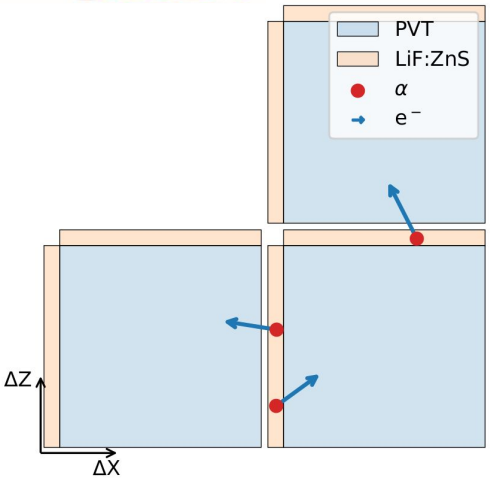
- Fast neutron entering the detector
- $\Delta t_{NS\text{-}ES} \simeq 65\ \mu s$
- Various topologies and energy
- Vary with atmospheric pressure

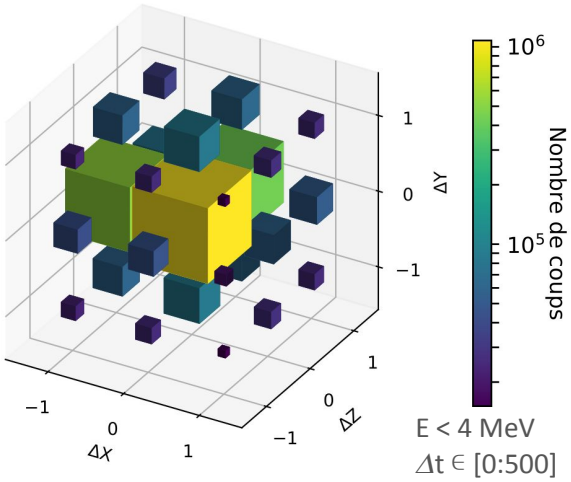
BiPo cascade



- Natural radioactive chain
- $\Delta t_{NS\text{-}ES} = 164\ \mu s$
- $Q_\beta = 3{,}3$ MeV
- α detected as NS (ZnS signal)
  - ➢ ^{214}Po decay in the LiF:ZnS

BiPo rejection

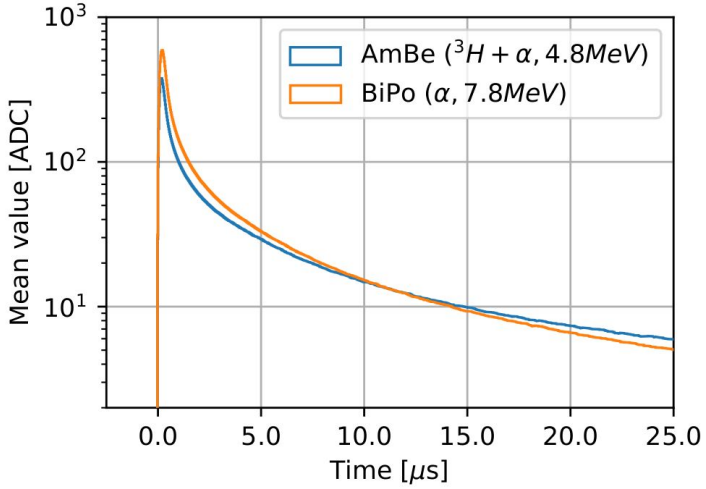


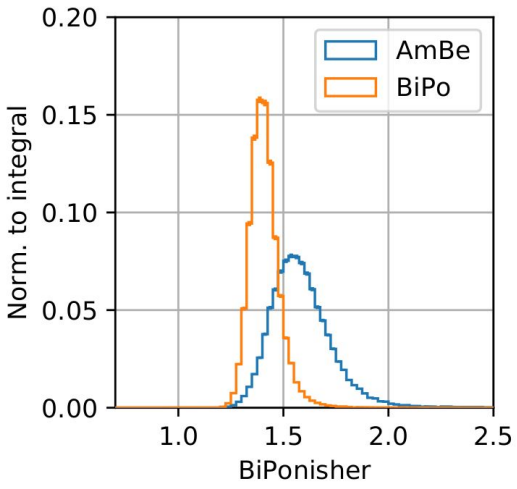


LiF:ZnS contamination :

- 3 main topologies

α-n discrimination using Pulse Shape Discrimination in ZnS : BiPonisher (Q_{long}/Q_{short})





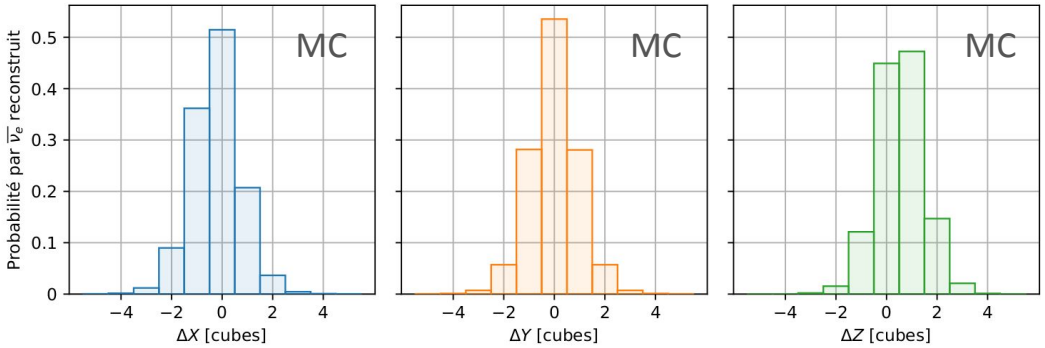
BiPonisher > 1,45 :

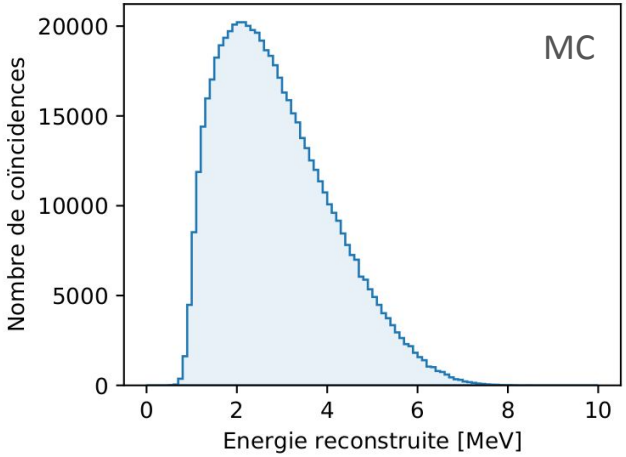
- Reject 75% of α
- Keep 85% of **n**

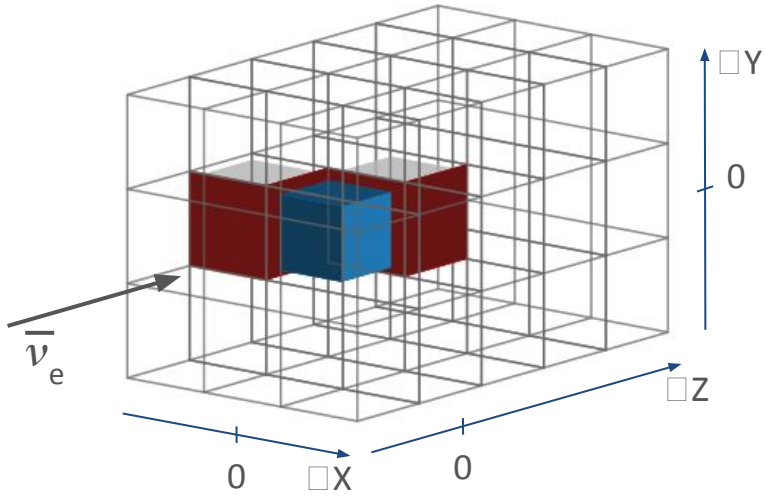
IBD selection

Main cuts

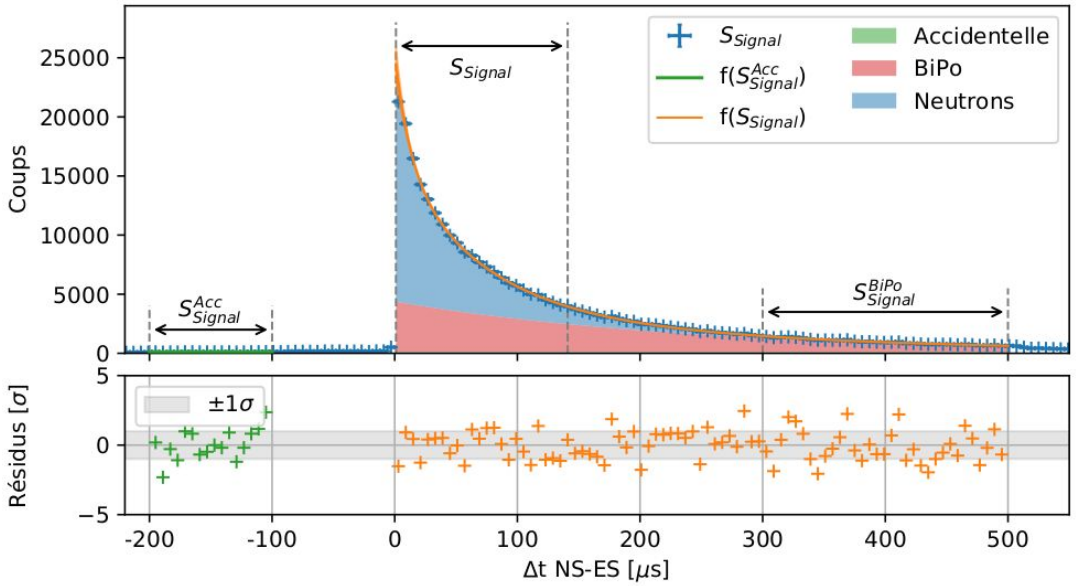
- □X, □Y et □Z optimized with Monte-Carlo
  - Reject topologies dominated by BiPo
- Energy : [2:8] MeV
- BiPonisher > 1.45







IBD selection : Δt_{NS-ES} distribution

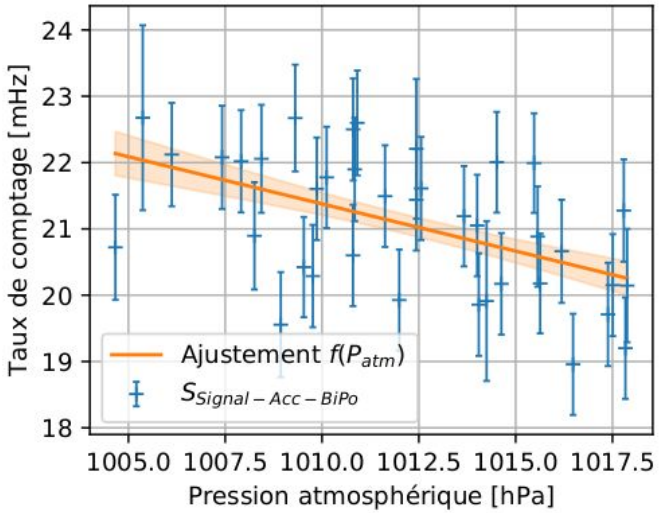


Different Δt_{NS-ES} windows for background monitoring :

- Signal : [1:141]us
- BiPo : [300:500]us
- Accidental : [-200:-100]us

Fast neutron estimator :

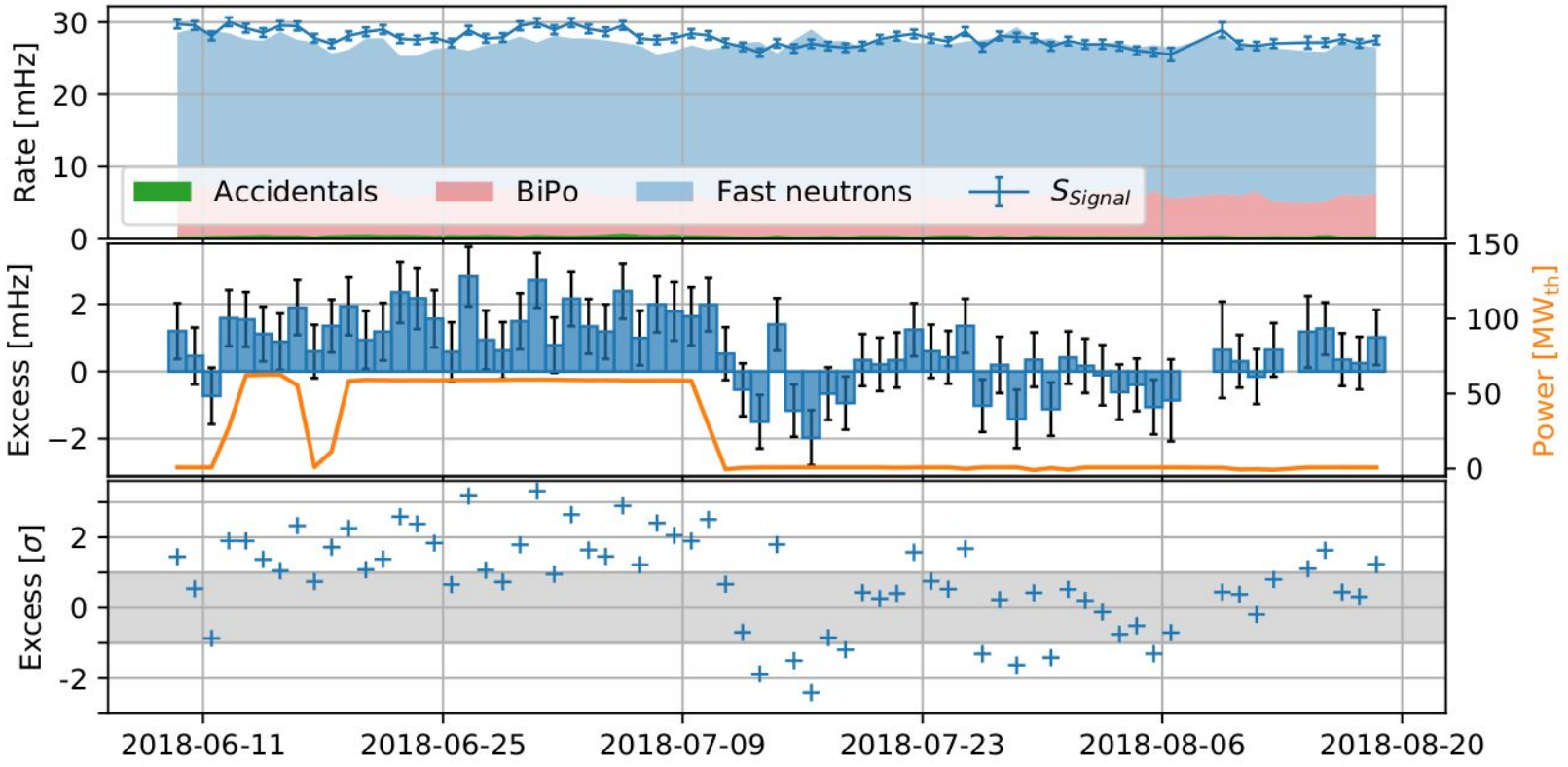
- "Signal - BiPo - Acc" = Fast neutrons in Reactor off
- Fit a linear $f(P_{atm})$ on Reactor Off data



Predictive model for reactor On fast-neutron

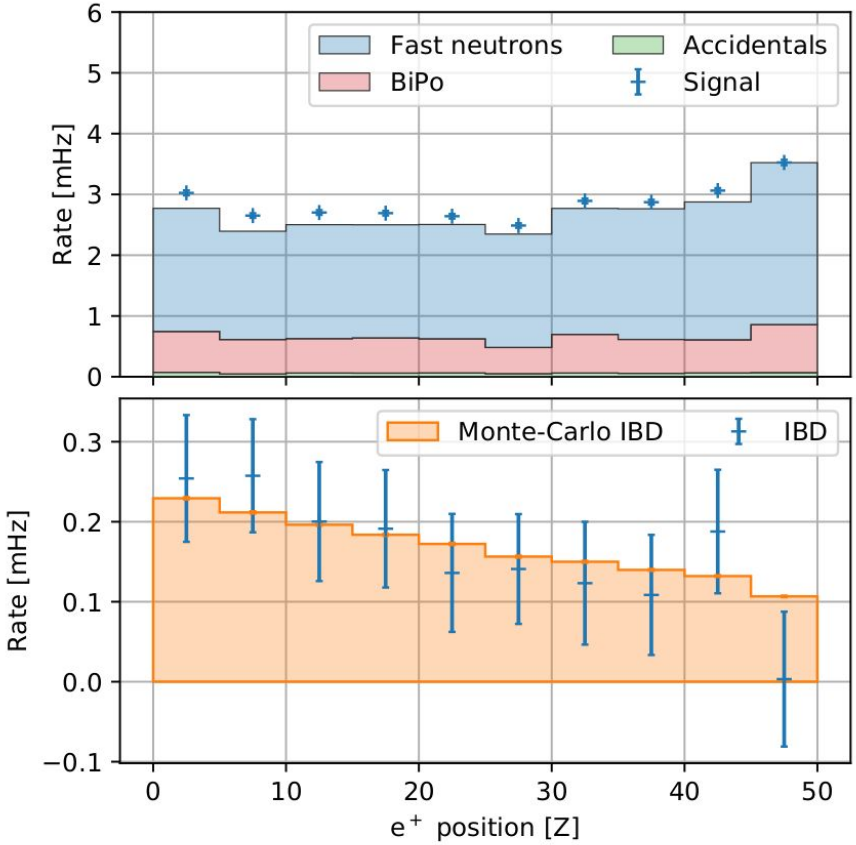
Background model test : June/July 2018 reactor On cycle

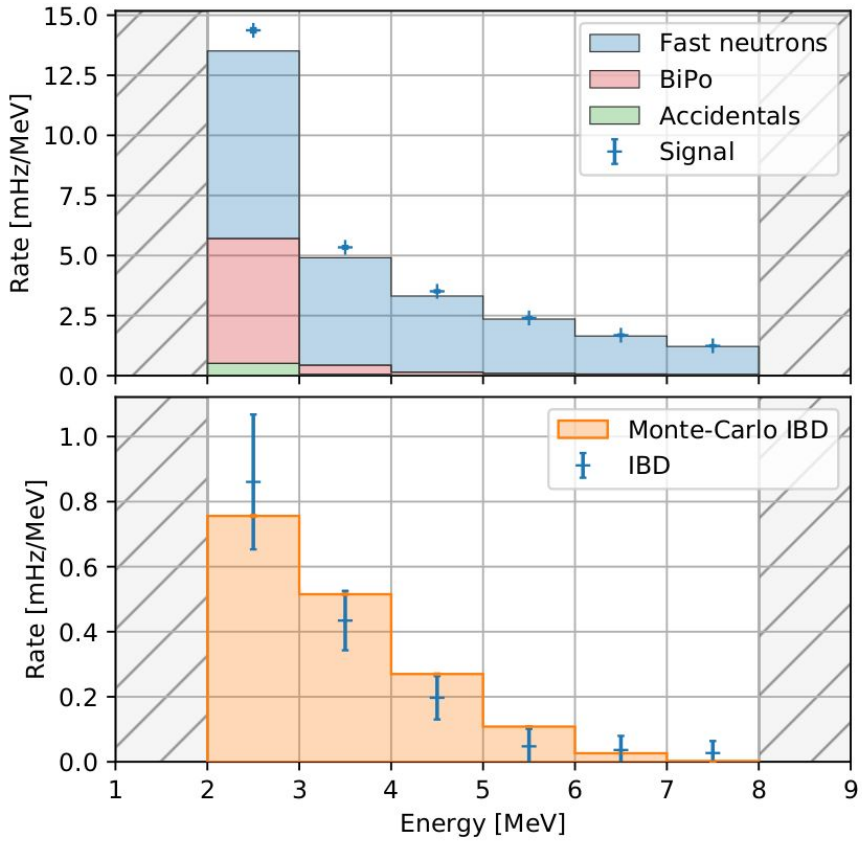
Open dataset : 21,5 days reactor On 34,5 days reactor Off



≈140 events/day excess, 5.4σ significance over the whole period

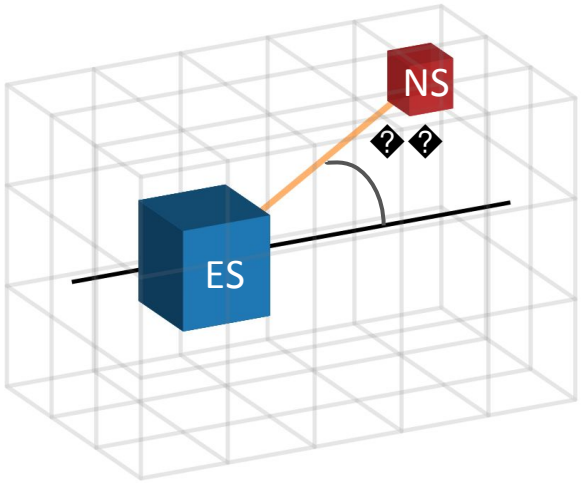
IBD signal : position and energy distribution

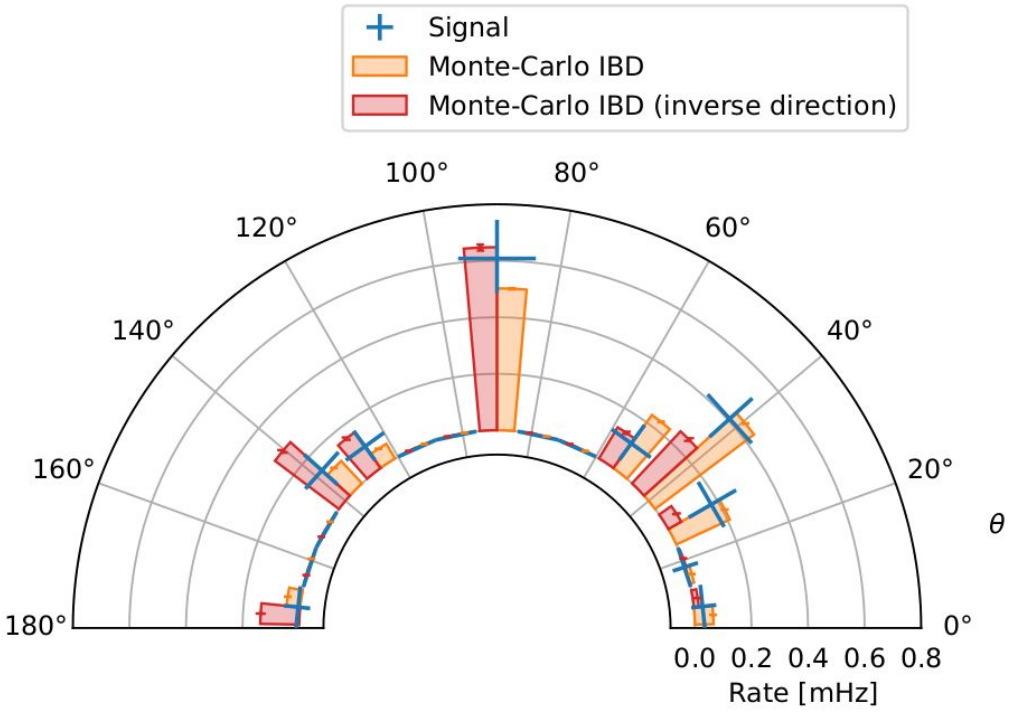




Antineutrinos component in agreement with Monte-Carlo models

IBD signal : directionality





Neutron keep the $\overline{\nu}_e$ momentum

SoLid technology sensitive to $\overline{\nu}_e$ directionality

Outlook

SoLid taking data since April 2018 :

- Very good understanding of detector response and stability
- Calibration under control

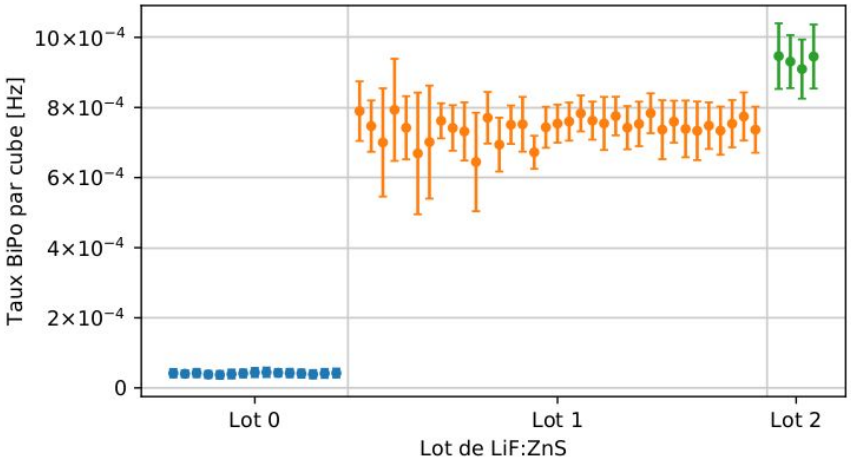
Preliminary analysis with only 1 cycle :

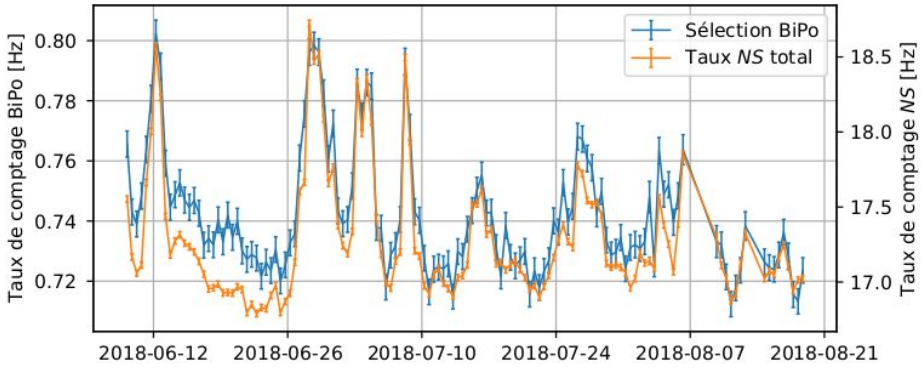
- Enough knowledge about background to develop predictive models
  - Able to extract antineutrino signal
- Good agreement with Monte-Carlo (acceptance, energy, topology)

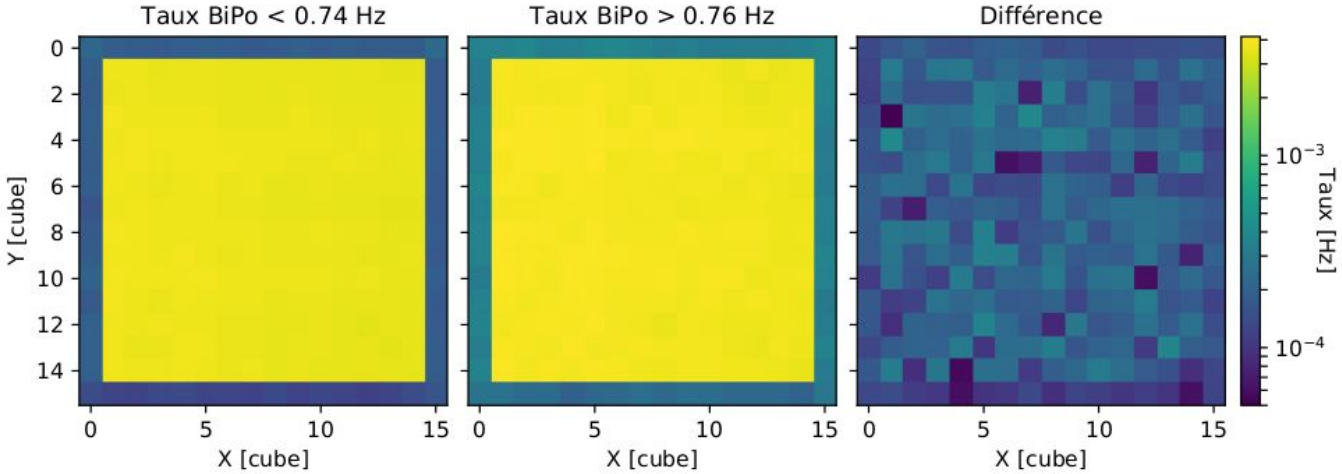
SoLid preparing next steps :

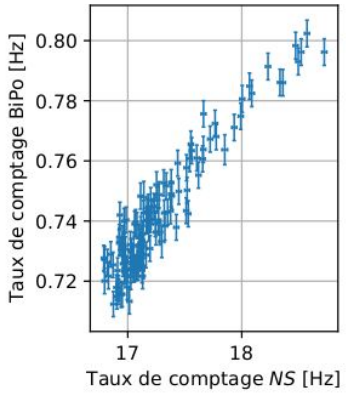
- Optimize selection cuts
- Open larger dataset
- Stay tuned for first oscillation analysis

Contamination BiPo

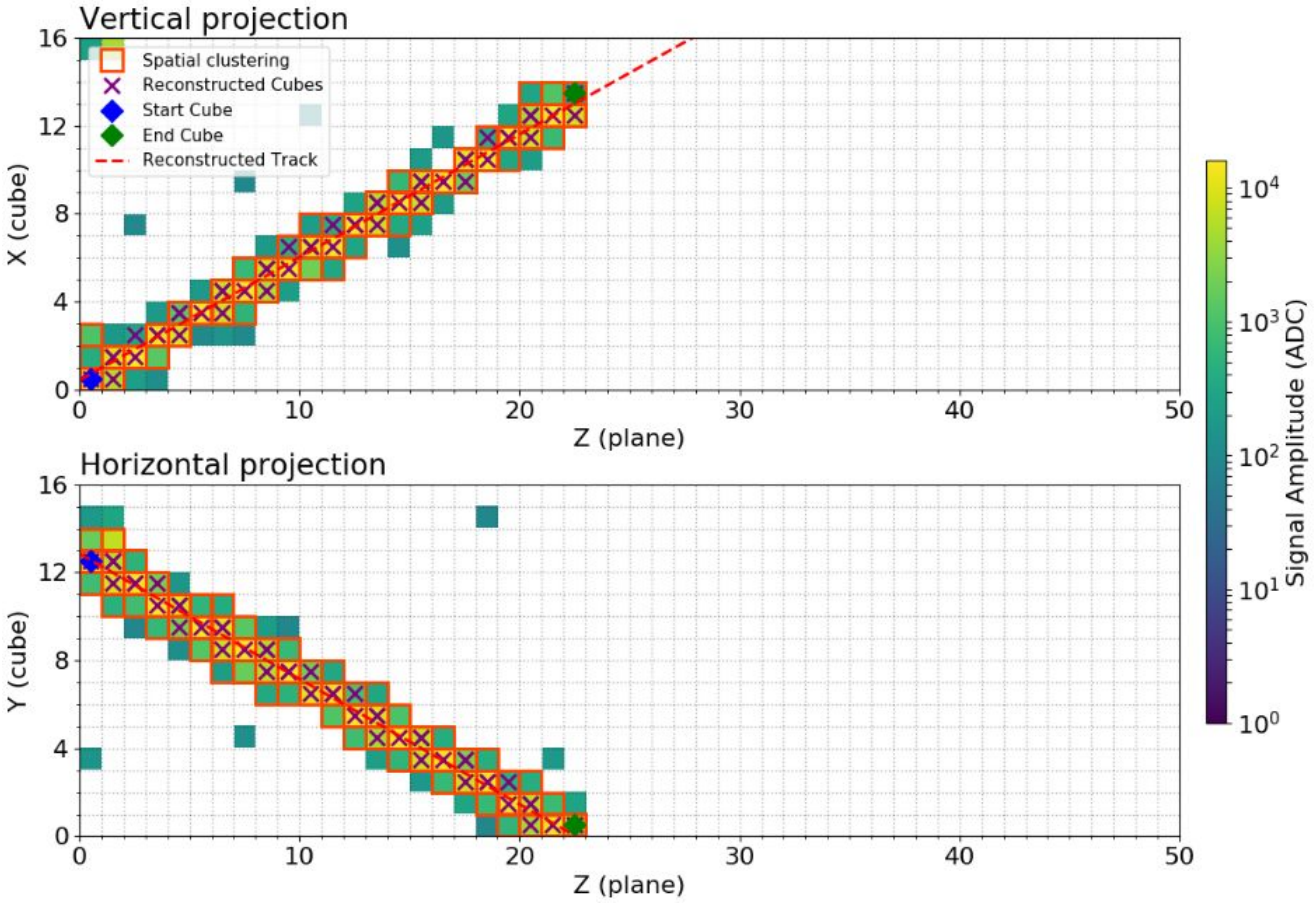




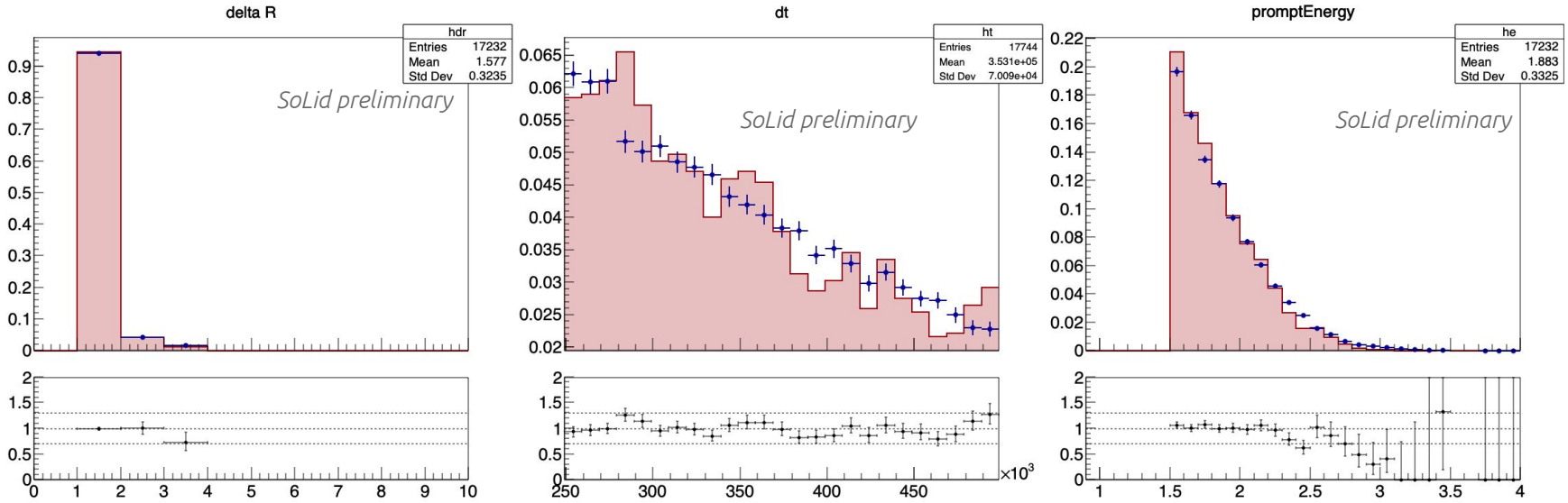




Muon track example



Data/MC comparison : BiPo

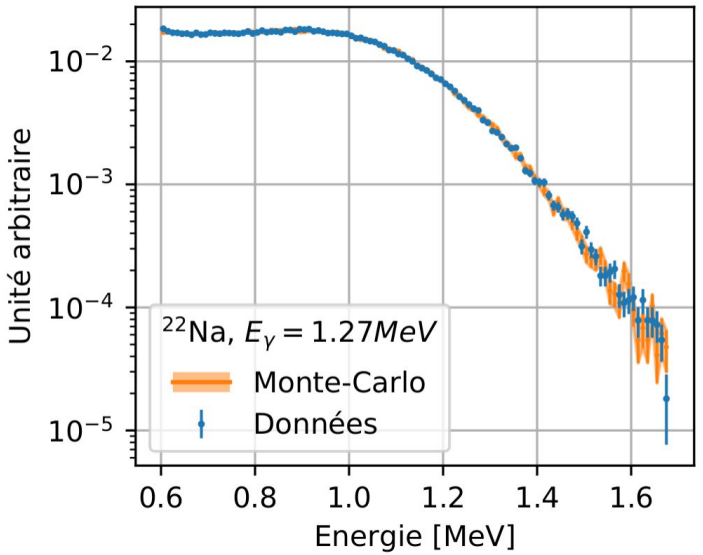


MC/**Data** comparisons of Δt, Δr and prompt E distributions show BiPo background is well understood.

Calibration results : ES signals

Light yield measurement :

- Compton edge fit (data/MC)
- Mean light yield of 97 PA/MeV/Cube
  - Energy resolution > 12% at 1 MeV



dt vs BiPonisher