Search for eV Sterile Neutrinos: the STEREO experiment

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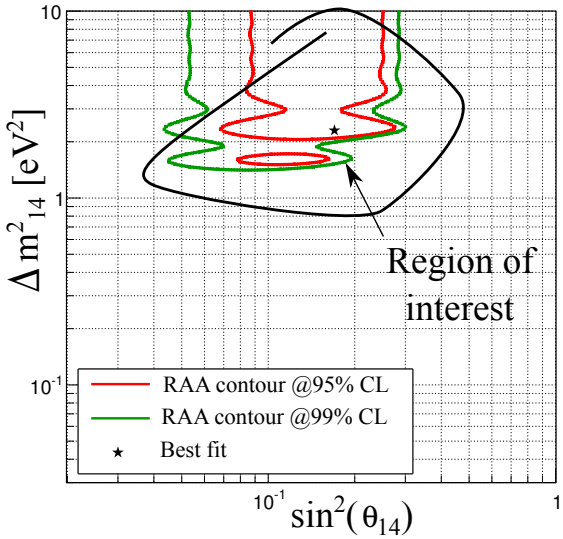
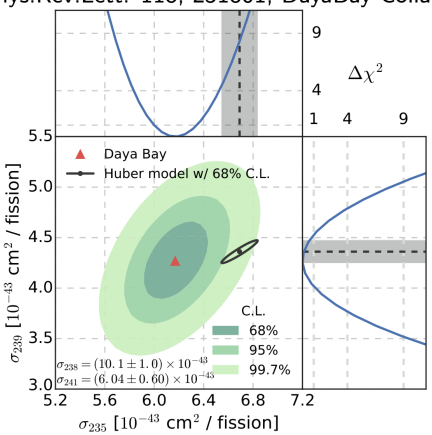
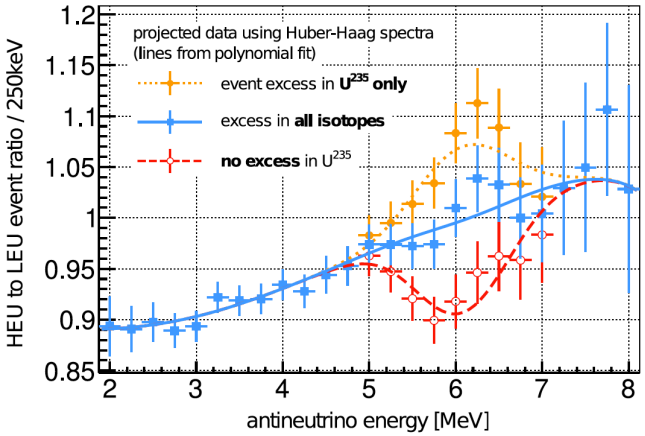
Targets

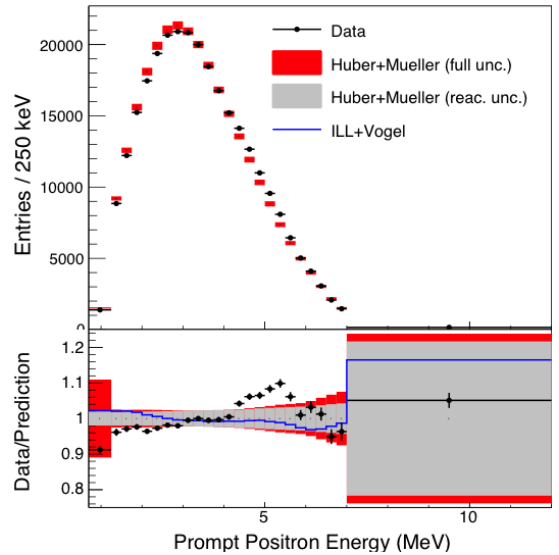
- Reactor Anti-ν Anomaly (RAA)
  - Wrong predictions of reactor spectra ?
  - Light sterile neutrino ?
- Measurement of pure ^{235}U spectrum
  - ^{235}U contribution to 5 MeV excess in experimental data
  - test σ_{235} determined by DayaBay



Phys.Rev.Lett. 118, 251801, DayaBay Collab.



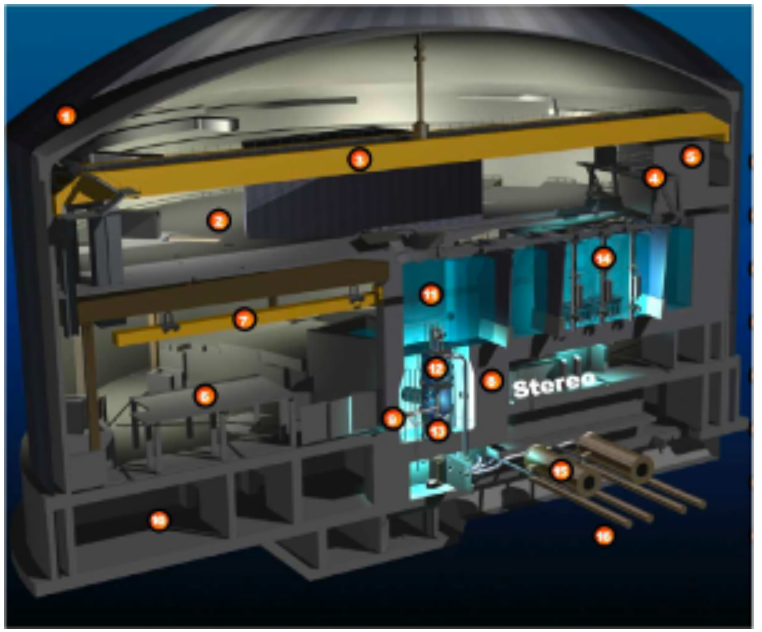


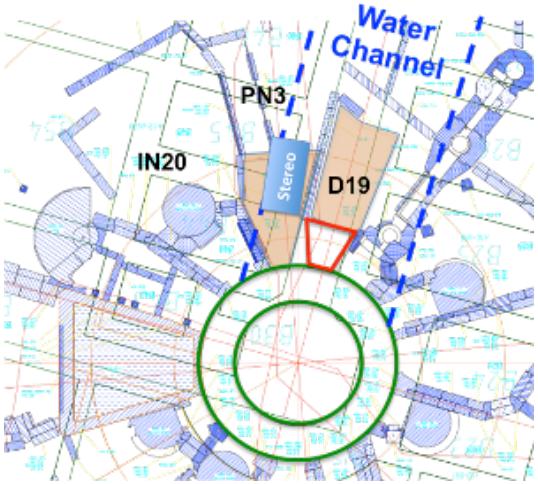


The ν_s tracking place

ILL experimental site

- Very short baseline : 9-11 m.
  - $\bar{\nu}_e$ energy : 2→8 MeV.
- Compact core : h=80 cm, d=40 cm.
  - Oscillation pattern not smeared out.
- High ^{235}U enrichment (93%).
  - Simplify $\bar{\nu}_e$ flux predictions.
- Significant overburden : 15 mwe.
- 58.3 MW thermal power.



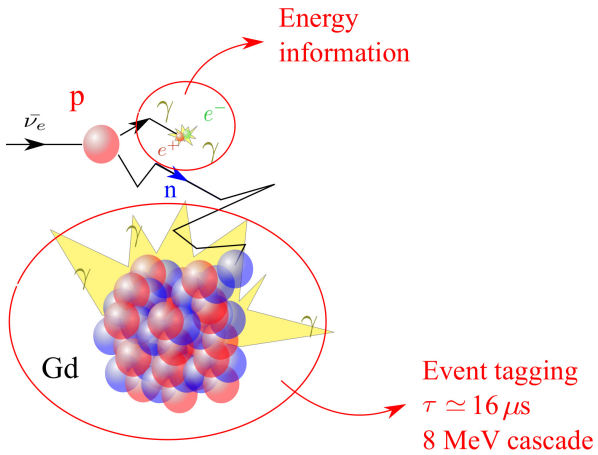


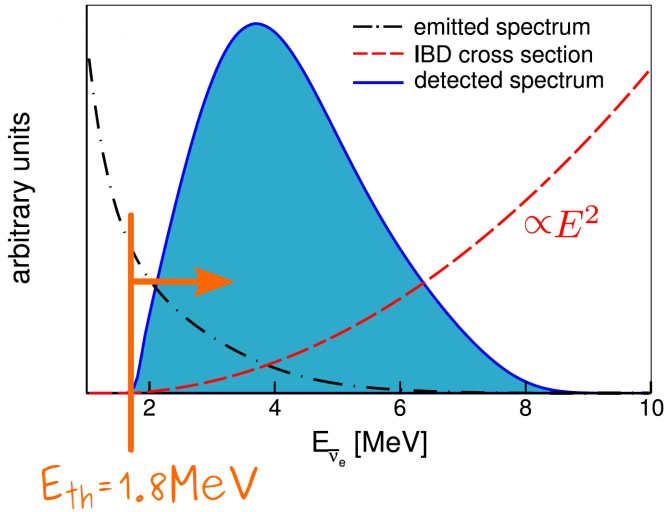
- Drawbacks :
  - Safety requirements.
  - Limited space.
  - High background level due to neutron experimental lines.

Detection principle

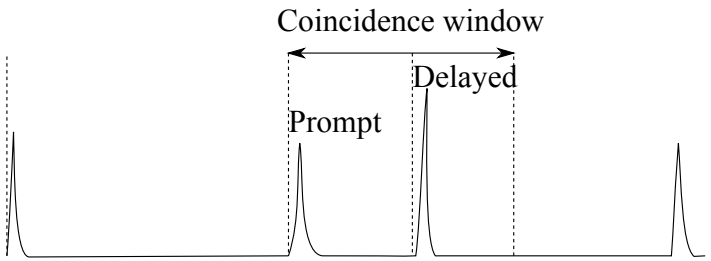
- Inverse β decay in Gd doped scintillator.

$$\bar{\nu}_e + p \rightarrow e^+ + n$$



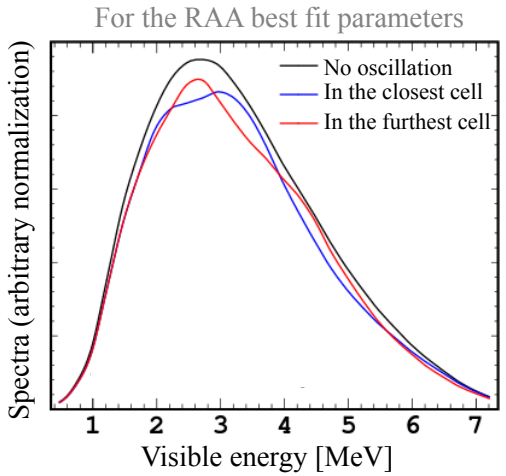


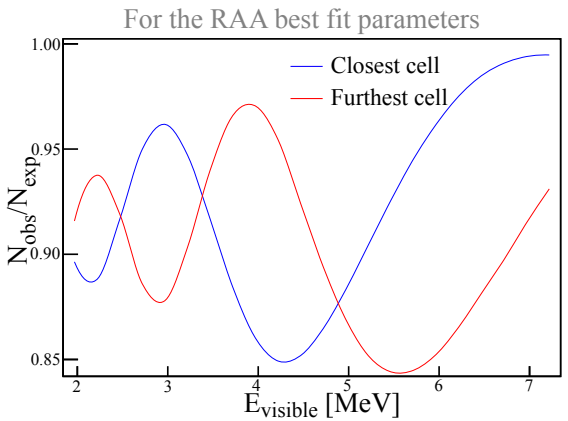
- Time coincidence and energy signature
  - e^+ prompt signal : ionisation + annihilation.
  - n delayed signal : capture by Gd.
    - 8 MeV γ cascade.
    - $\gg$ natural radioactivity ^{208}Tl @ 2.6 MeV.
    - $\tau \simeq 16$ µs.

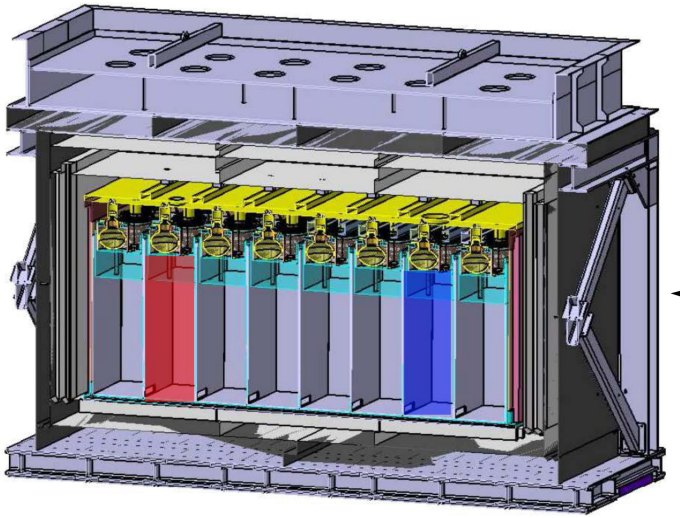


ν_s evidence

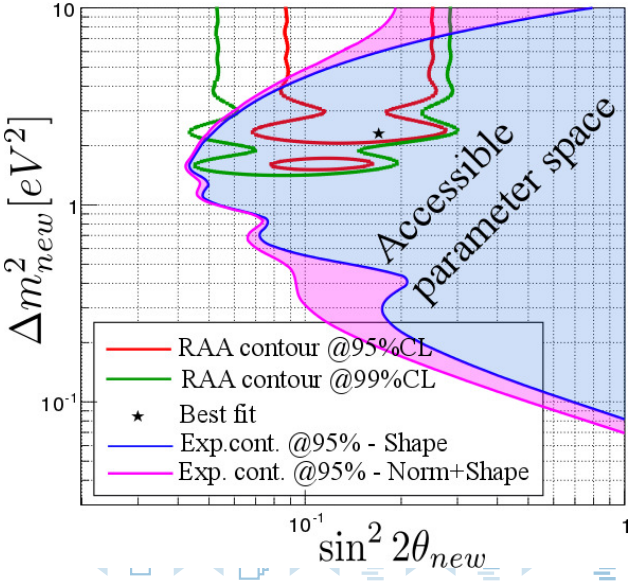
- Robust analysis of oscillation pattern :
  - Distortion of the energy spectrum with distance.





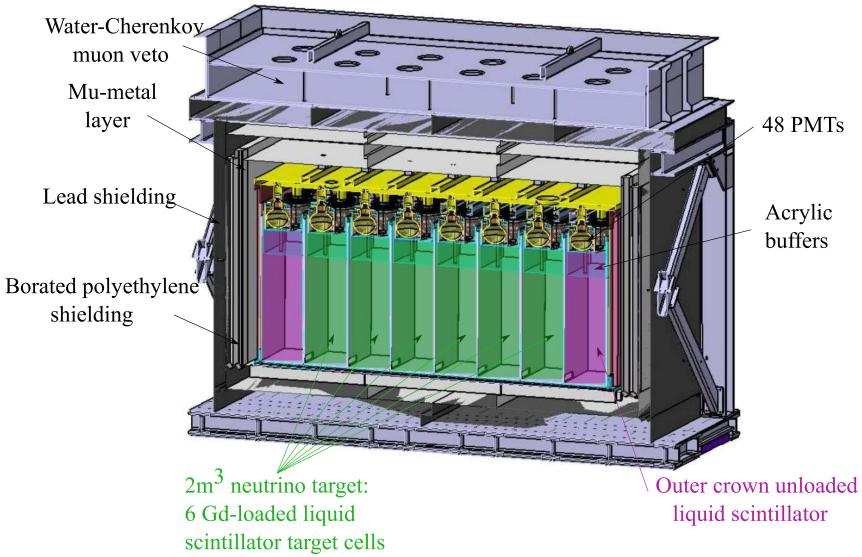


Expected contours for 300 days

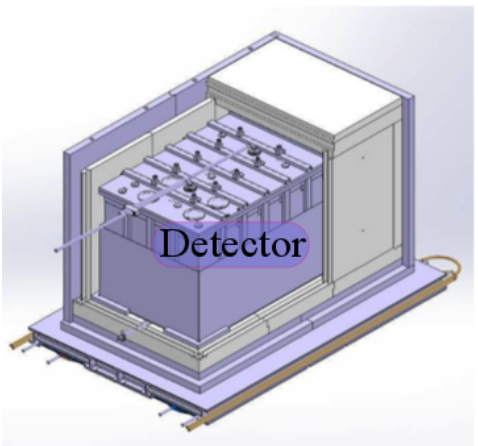


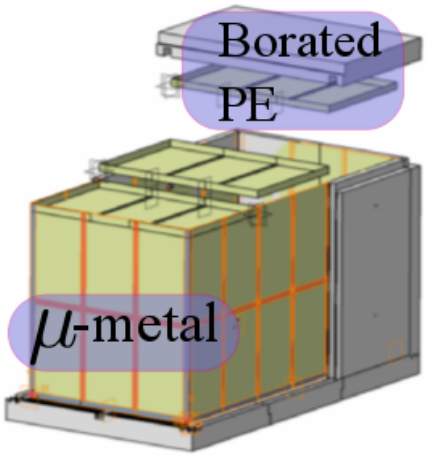
The detector

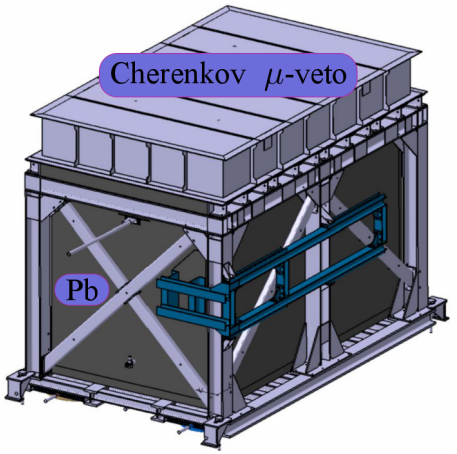
- Neutrino target :
  - $37 \times 90 \times 90\,\mathrm{cm}^3$ cells.
  - Response ~ 300 PE/MeV
- γ-catcher :
  - 37/27 cm thick outer crown.
  - Containment of energy leaks.
    - ★ Better energy resolution.
    - ★ Better neutron efficiency.
  - Active veto.
- Shielding :
  - About 90 tons around detector
- Water-Cherenkov μ-veto

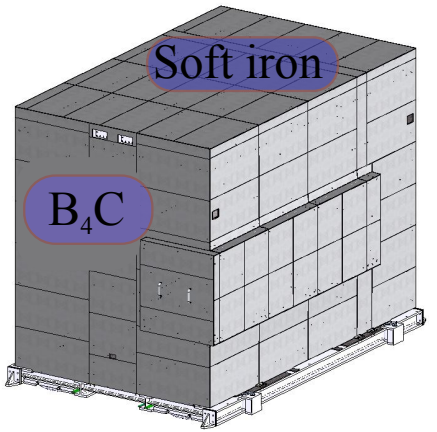


- Acquisition :
  - Trigger threshold $\sim$300 keV
  - No dead time up to a few kHz

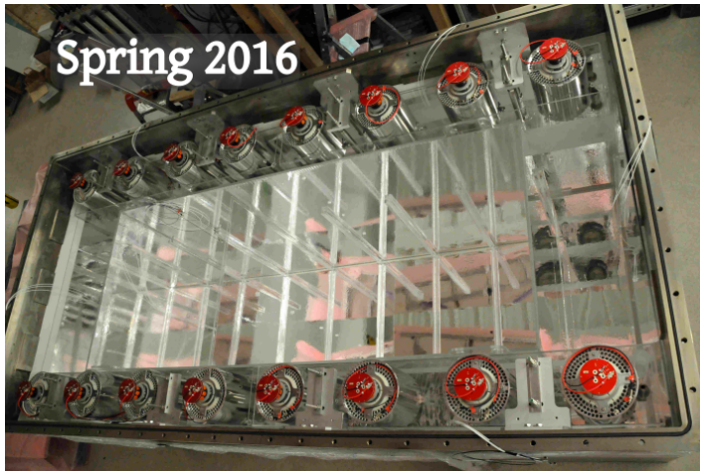


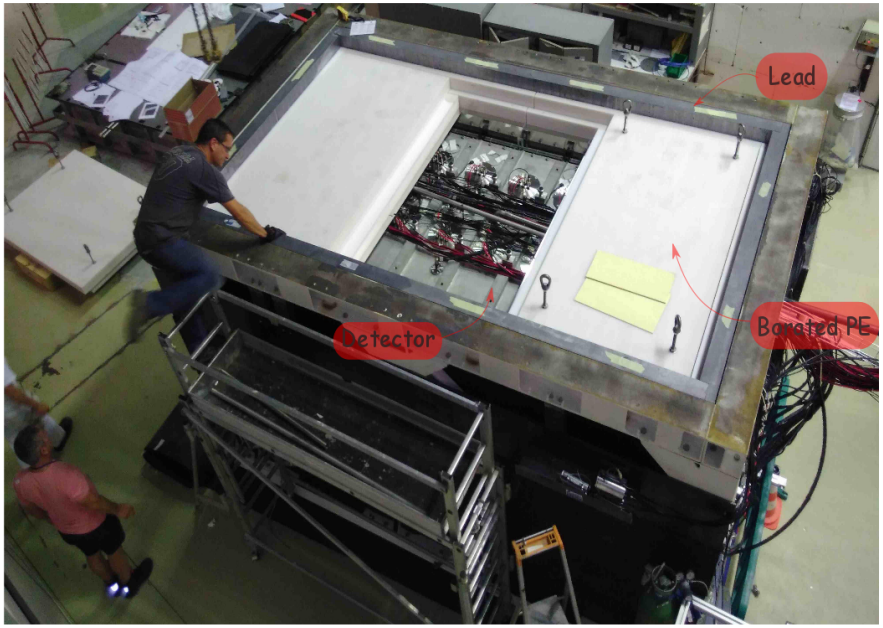


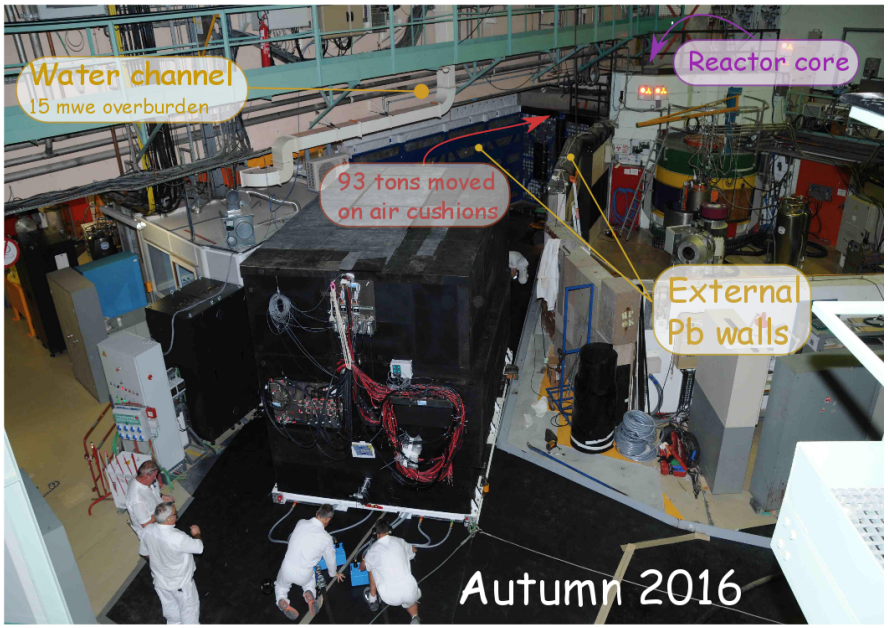


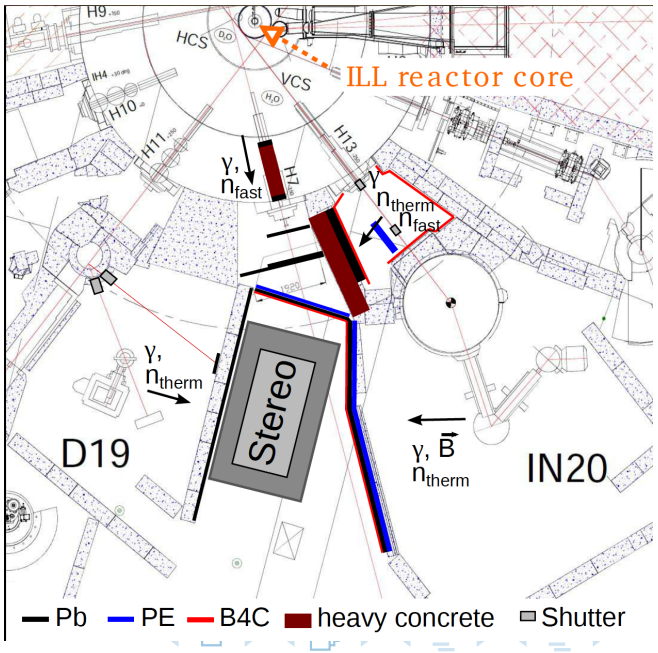


Building and installation









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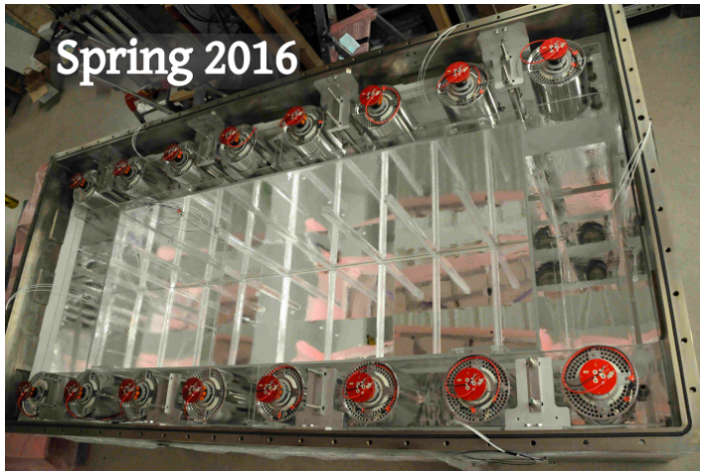
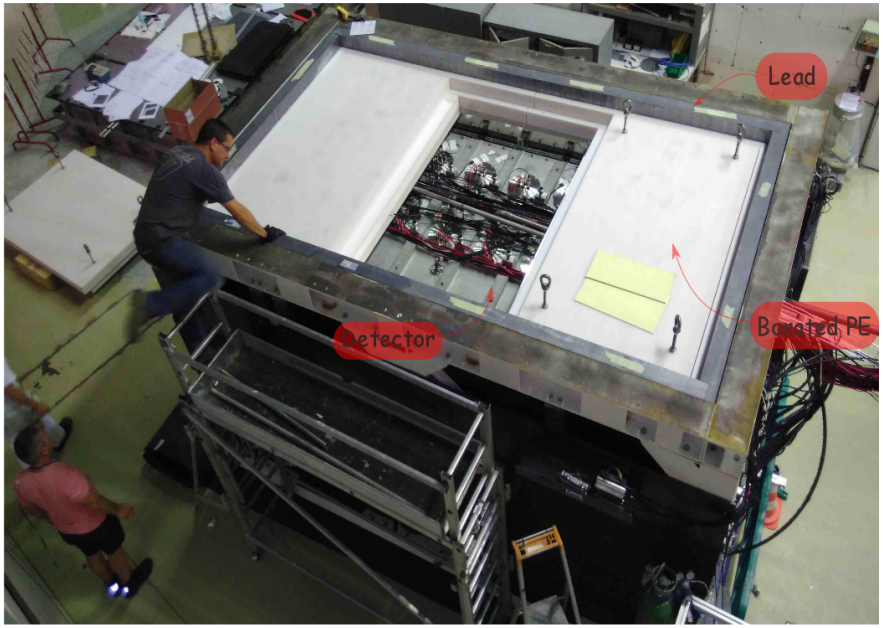
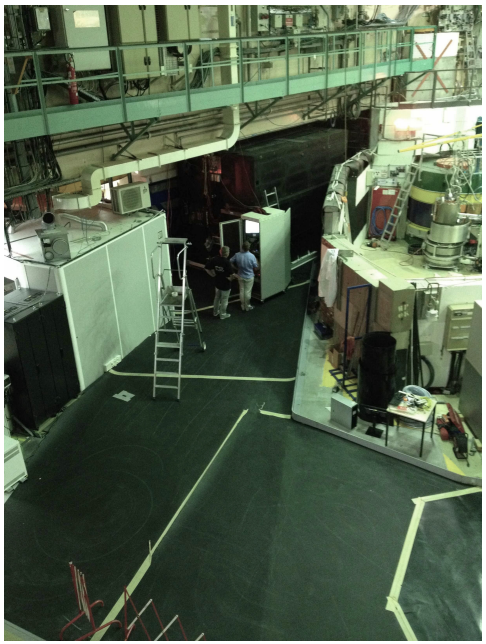






Data taking since November 2016 :

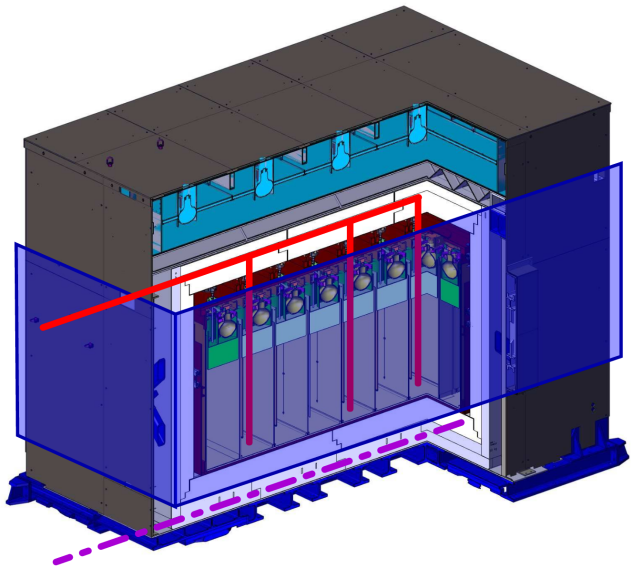
- 2 weeks of commissioning
- 75 days reactor ON
- 28 days reactor OFF

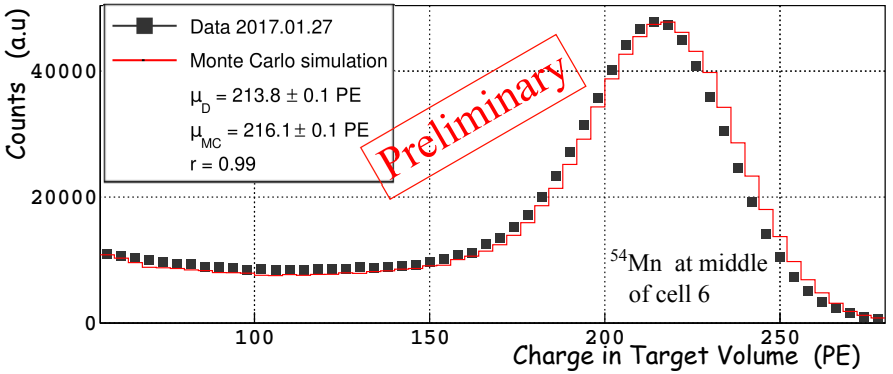
Calibration

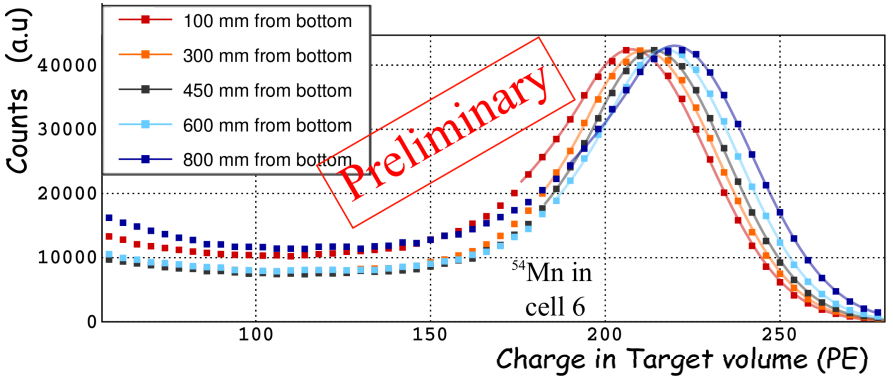
internal calibration (cell 1,4,6)

external calibration (2D, inside shielding)

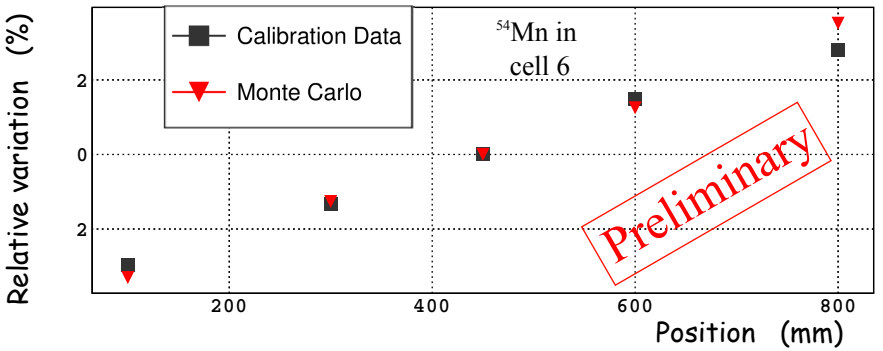
underneath calibration







- From experiment and MC data :
  - Low z-dependence
  - Excellent agreement

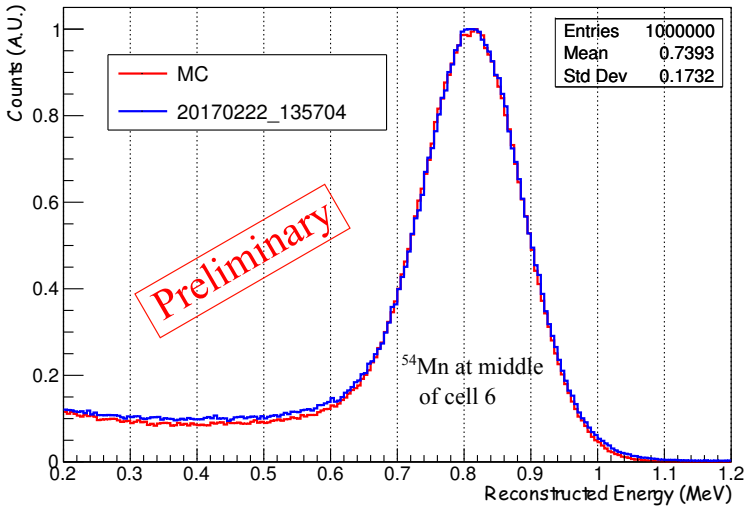


Energy reconstruction

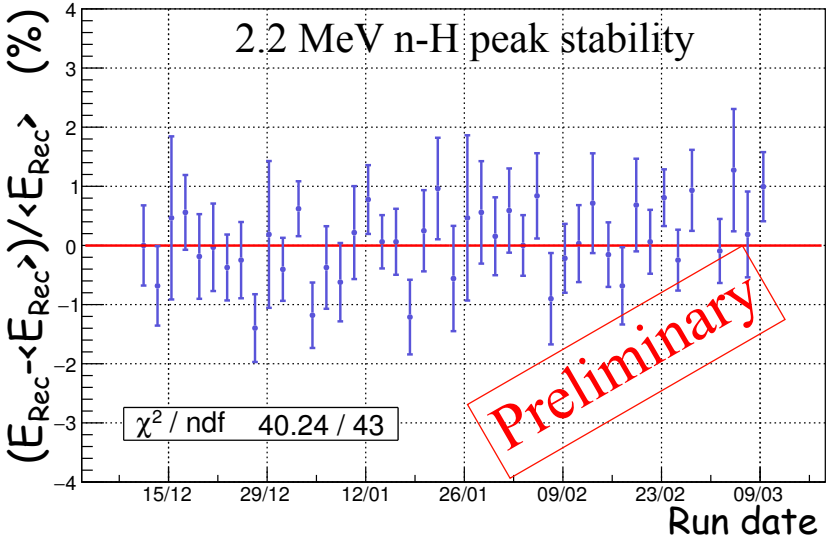
- Charge collected in one cell :
  - Light produced in cell j : C_j
  - Light cross-talk from/to other cells $l_{i\to j}$

$$Q_i = \sum_j E_j^{\mathrm{dep}} \times C_j \times l_{i\to j}$$

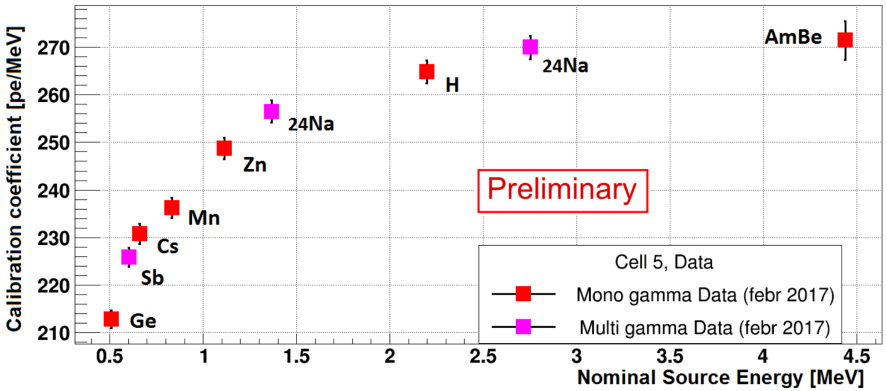
  - C_j and $l_{i\to j}$ determined using ^{54}Mn



- Validated by H (n,γ) peak

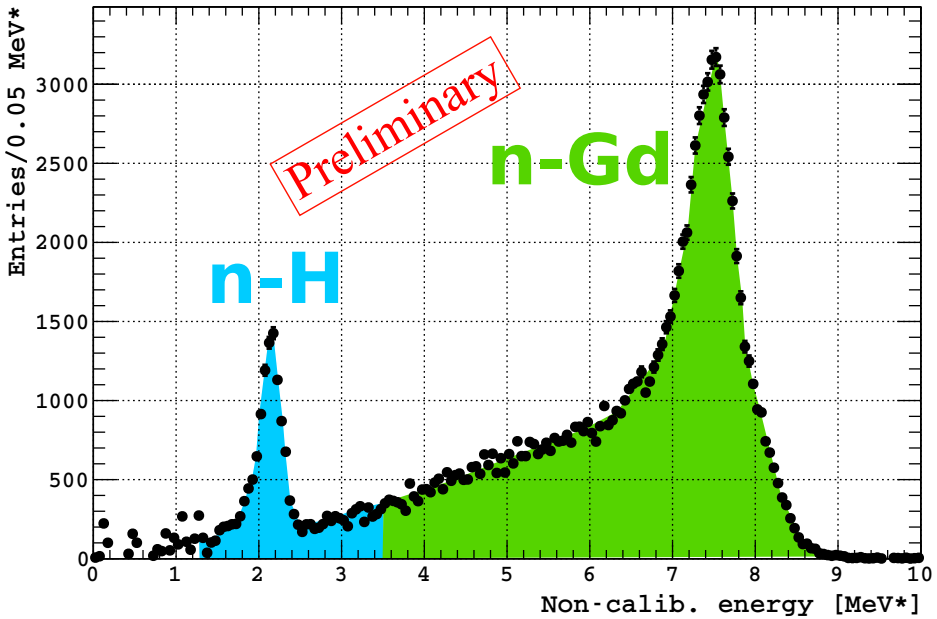


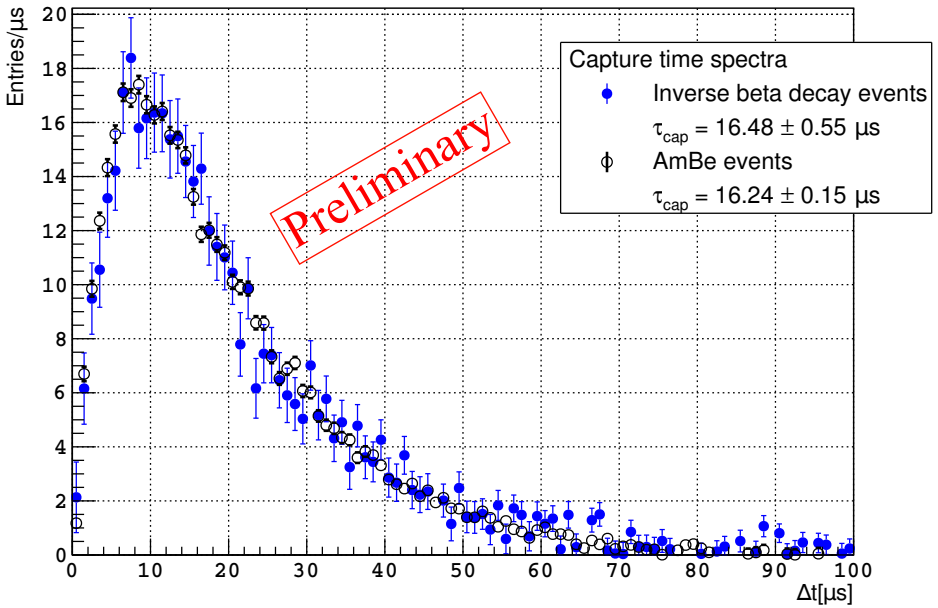
- Scintillator energy response



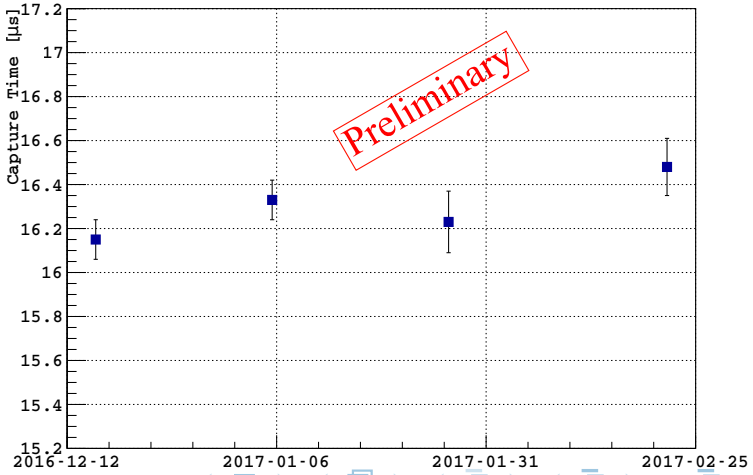
Gd-neutron capture fraction

- AmBe source inside detector
  - 4.4 MeV γ as prompt
  - Fast neutron in coinc.
- Relative cell intercalibration
- n-Gd capture fraction $\sim$ 85%
- n-capture time consistent between AmBe and IBD





- n-capture time stable



Background assessment

<table>
<tr><th>Accidentals</th><th colspan="2">Correlated</th></tr>
<tr><td rowspan="2">γ and fast n from reactor
Radioactive decay
Cosmics</td><td>Cosmics</td><td>Reactor</td></tr>
<tr><td>$\mu \rightarrow$ fast neutron
$\mu \rightarrow$ multi-neutrons
$\mu \rightarrow$ stop + Michel e^-</td><td>Fast neutrons</td></tr>
<tr><td>Shielding
μ-veto+γ-catcher
Topology
Statistical subtraction</td><td colspan="2">Shielding
μ-veto+γ-catcher
Topology / Coinc. multiplicity
Pulse Shape Discrimination
ON-OFF measurement</td></tr>
</table>

Background assessment

Accidentals

- γ and fast n from reactor
- Radioactive decay
- Cosmics

$\Downarrow$

- Not dominant
- Increase dead time introduced by selections

Correlated

Cosmics

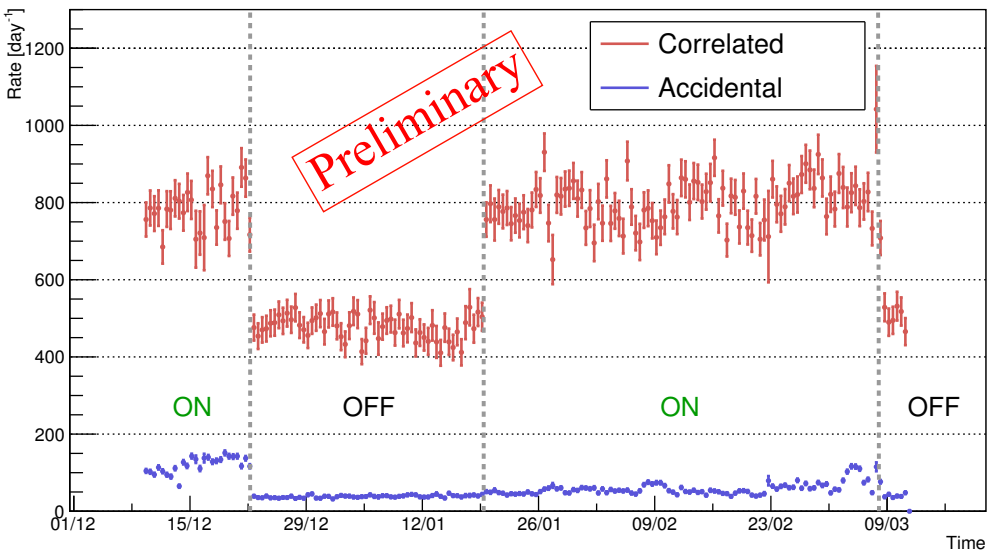
- $\mu \rightarrow$ fast neutron
- $\mu \rightarrow$ multi-neutrons
- $\mu \rightarrow$ stop + Michel e^-

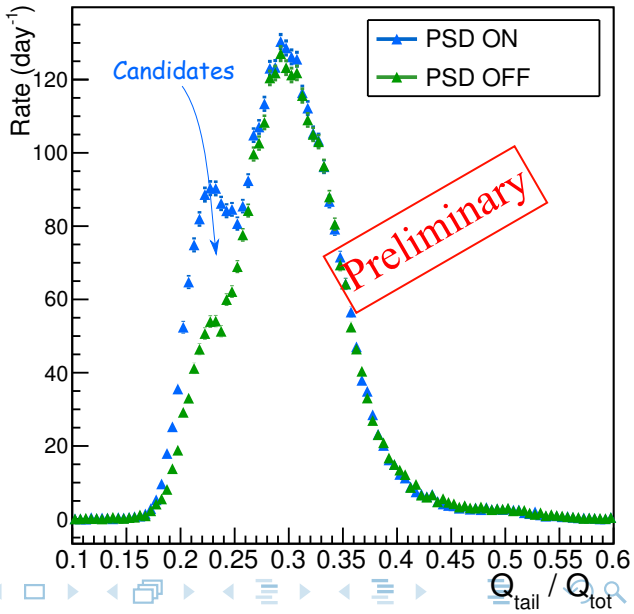
Reactor

- Fast neutrons

$\Downarrow$

- No significant contribution of reactor neutrons
  - Shielding sufficient





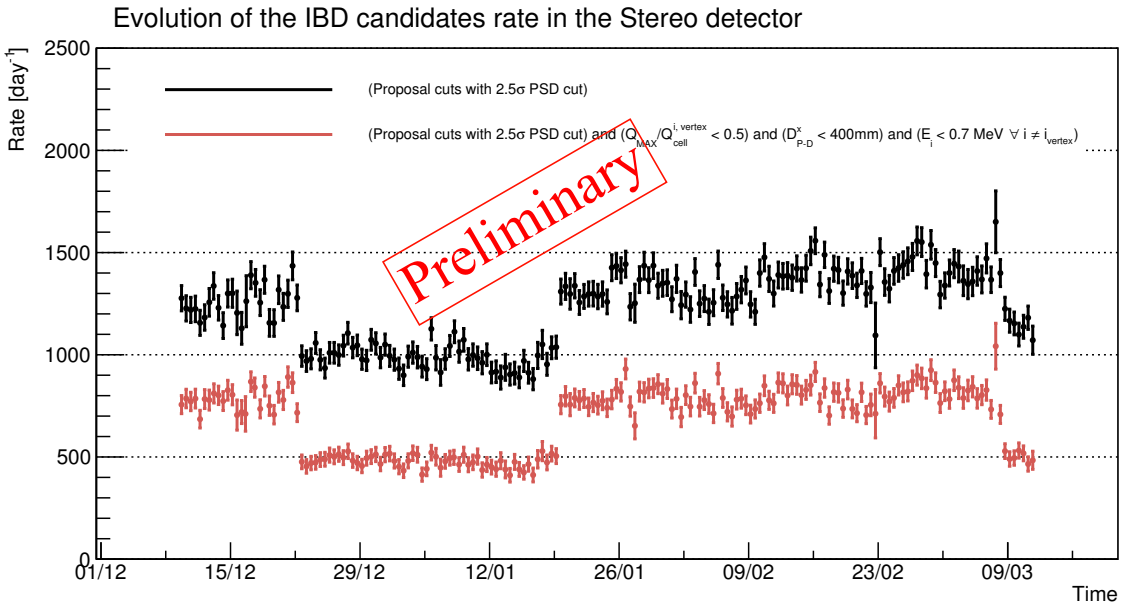
Candidates rates

- Proposal cuts :
  - Veto 100 μs after muon

	IBD signature	Rough topology	Nuclear recoils
Prompt	$1.5\,\text{MeV} < E_{\text{Tot}} < 8\,\text{MeV}$	$E_{\text{GC}} < 1.1\,\text{MeV}$	$2.5\,\sigma$ PSD cut
Delayed	$5\,\text{MeV} < E_{\text{Tot}} < 10\,\text{MeV}$	$E_{\text{Target}} > 1\,\text{MeV}$	
ΔT_{coinc}	$< 70\ \mu\text{s}$		

- + cleaning cuts

- Neutrino rate : $\sim$ 300/day

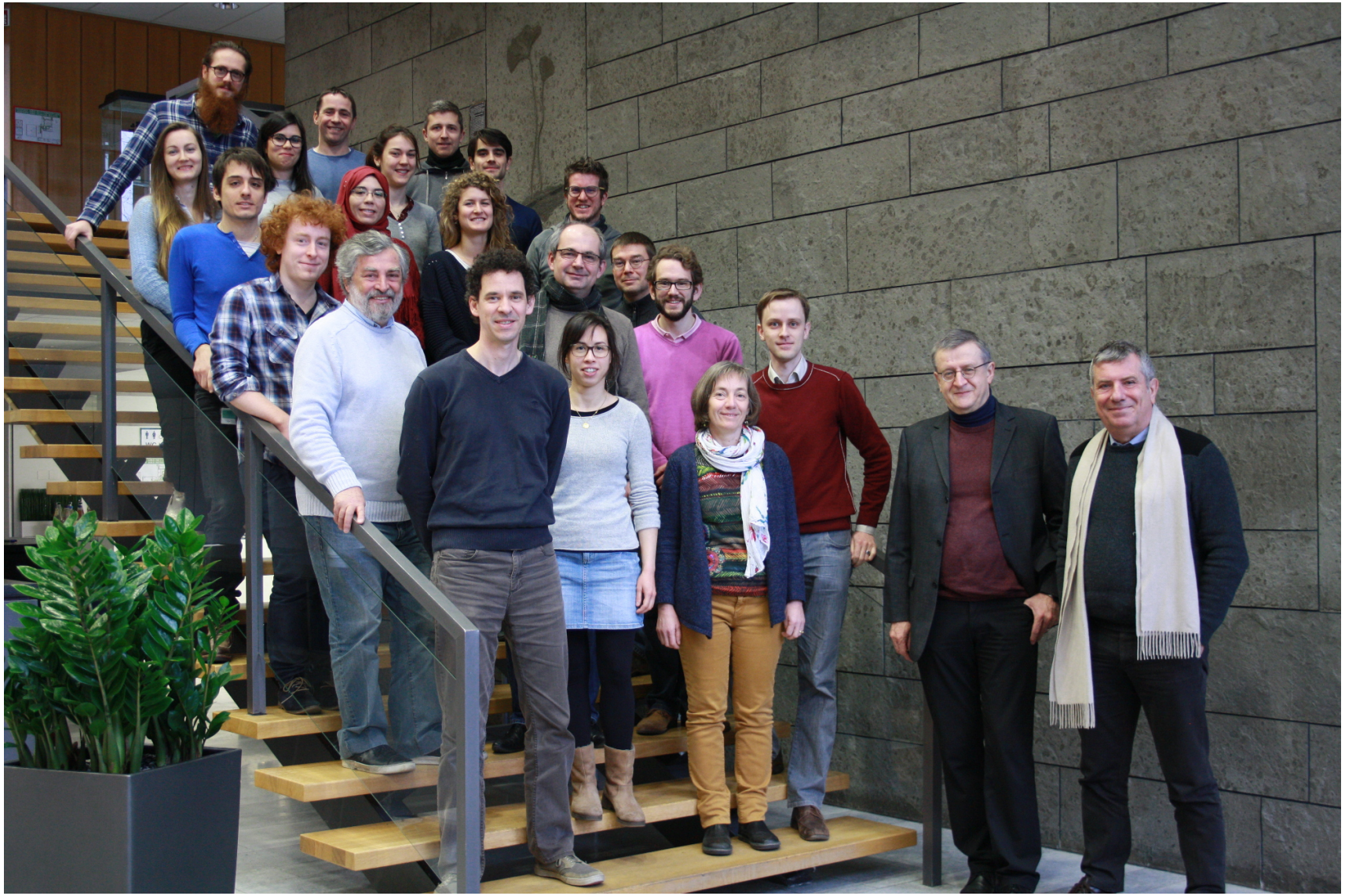


Next

- Cut optimisation studies (*e.g.* event topology, multivariate analysis)
- Background studies (mainly cosmic muon induced background)
- Finalisation of energy reconstruction
- Spectral analysis

- Data taking
  - 2018 : +150 days reactor ON

Thank you for your attention

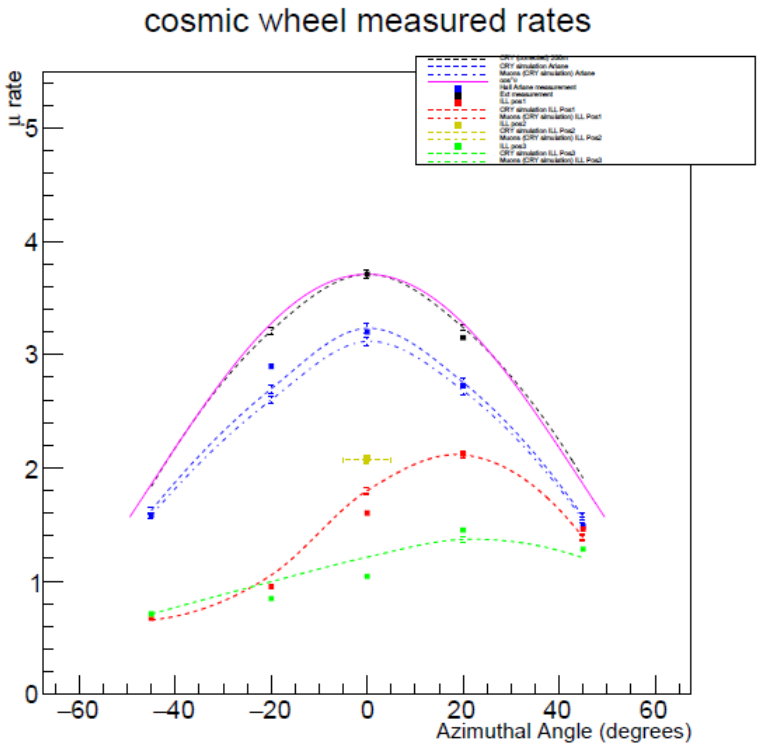


Reactor very short baseline competition :

Name	P_{th} (MW)	L (m)	Depth (m.w.e)	M_{target} (Tons)	Tech	Seg	Mov	Start
Nucifer	70	7	13	0.8	Gd	x	x	2014
NEOS far	2700	25	16-23	1	Gd	x	x	2015
NEOS near	15	5	23	1	Gd	x	x	2016
STEREO	57	9-11	18	1.75	Gd	✓	✓	2016
SoLiδ	70	5.5-10	10	2.9	^{6}Li	✓	x	2016
DANSS	3000	9.7-12.2	50	0.9	Gd	✓	✓	2016
Neutrino-4	100	6-12	10	1.5	Gd	x	✓	2016
Prospect	85	7-18	few	1-10	Gd+^{6}Li	✓	✓	2017
NuLat	85	3-8	few	1	^{6}Li+^{10}B	✓	✓	2017

μ veto

- Fast neutrons produced in heavy materials.
  - Limit thickness in the detector neighbourhood.
- Protection from water channel.
  - 2 m concrete+6 m water.
  - Suppress the hadronic component.
- In situ flux measurement using cosmic wheel.
  - Factor 4 reduction compared to at the surface.
- Active veto 100 μs→ 5 % dead-time.



Atmospheric pressure correction