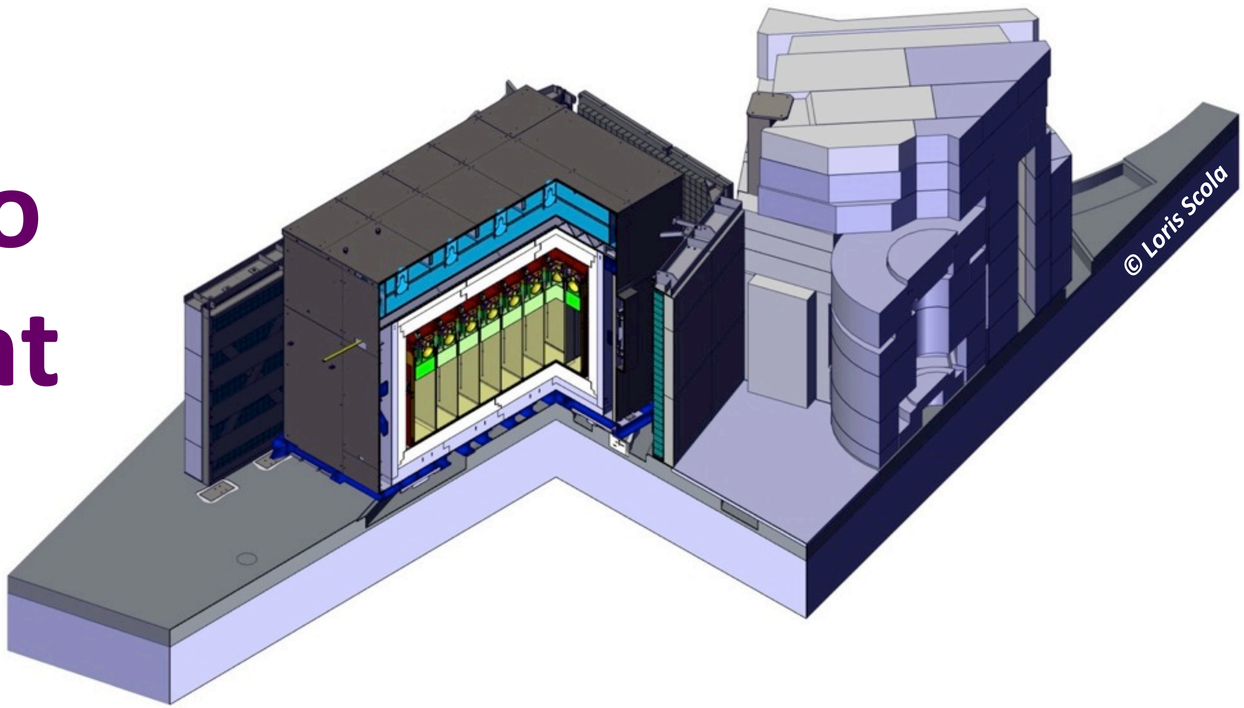
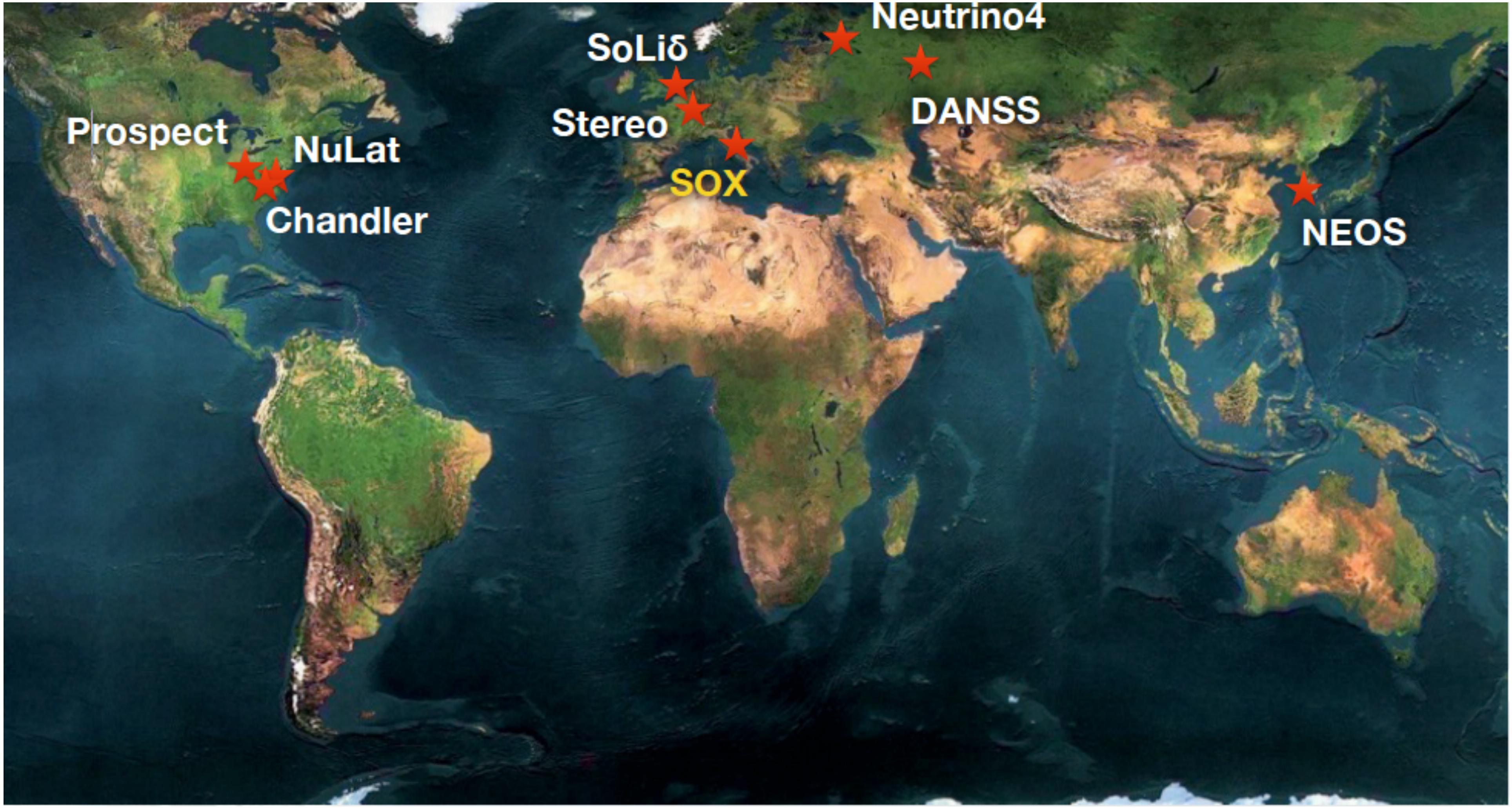
supported by

The Stereo Experiment

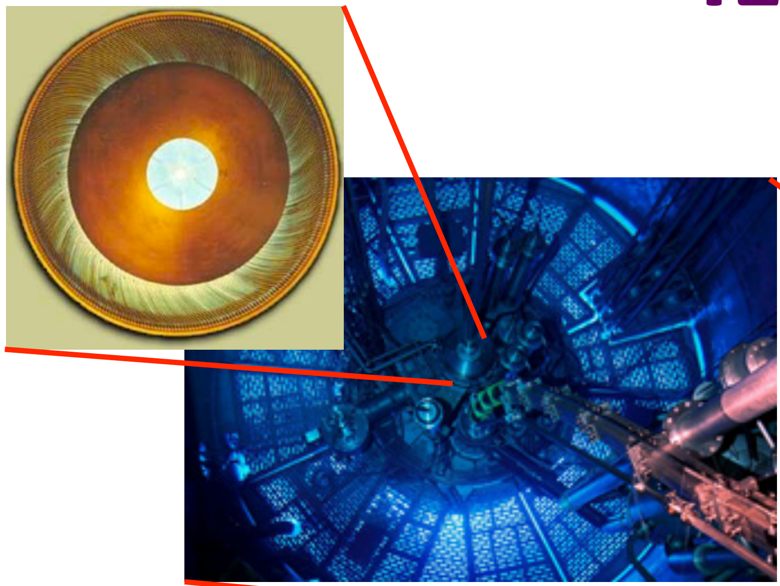


Quest for Sterile ν @ 1eV Mass Scale

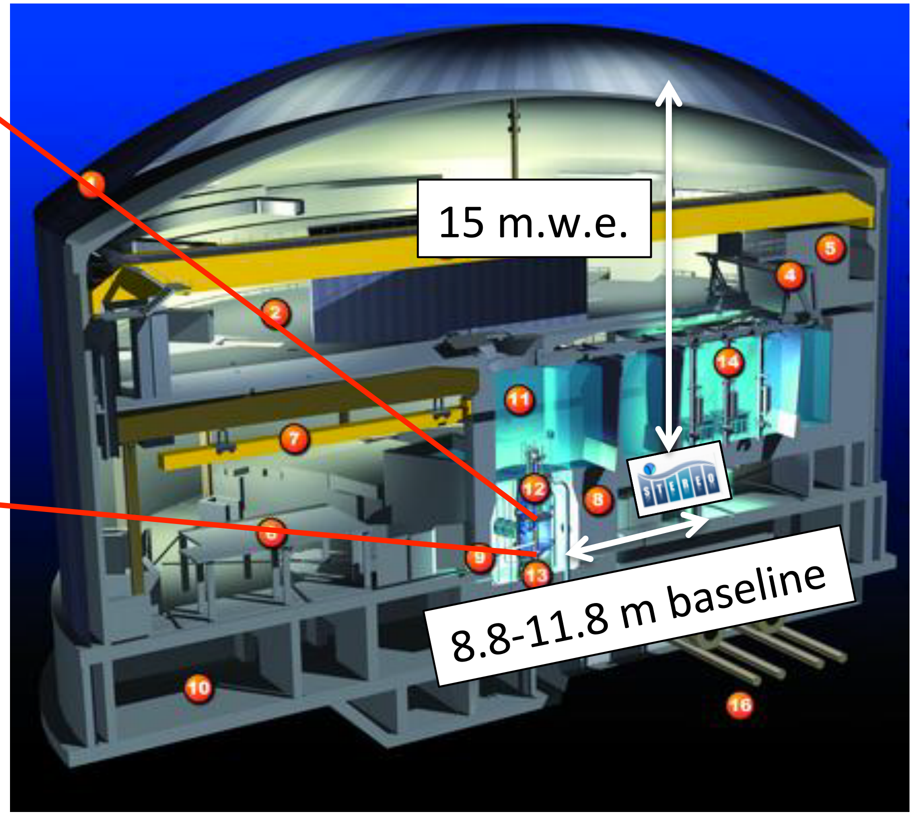


Quest for Sterile ν @ 1eV Mass Scale

ILL Site



High flux reactor of the ILL



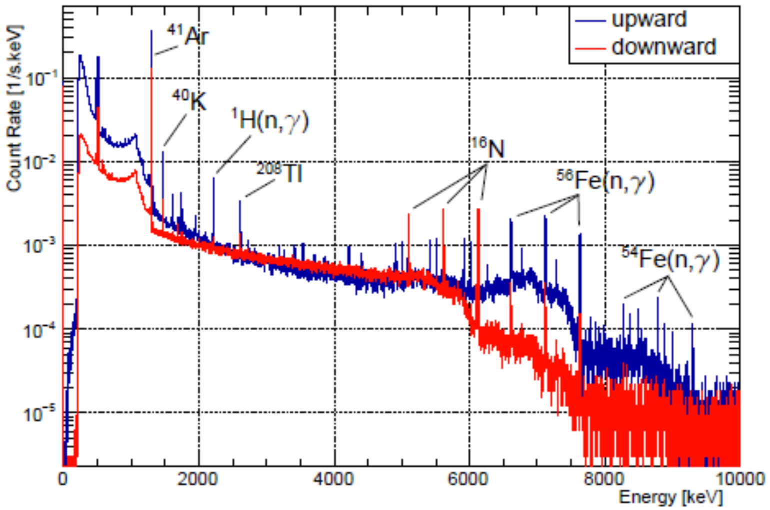
Compact fuel element:

- 58.3 MW
- Ø40 cm × 80 cm
- Highly enriched fuel: ^{235}U (93%)
- 3-4 cycles of 50 days/year
- Heavy water coolent

Challenging mitigation of the background generated by the reactor and cosmic-rays.

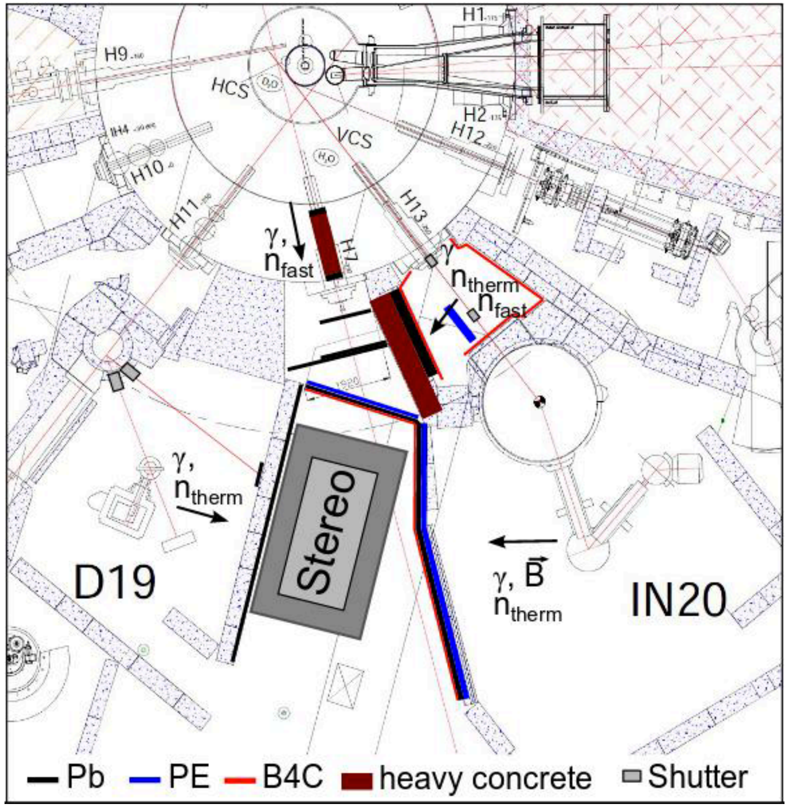
Reactor Sources of Background

- Extraction of neutron beams for neighboring experiments.
- Extensive campaigns of characterization of n and γ sources before shielding design.



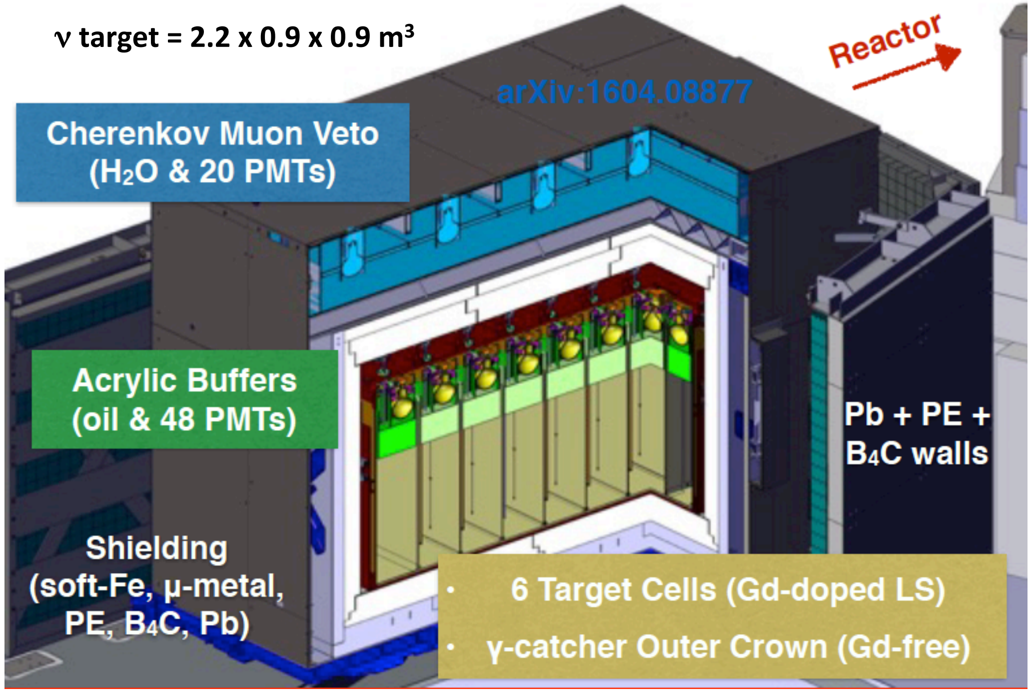
- Background of fast and thermal neutrons from side experiments →High E γ's from n-capture on metals: ^{56}Fe(n, γ) 7.6 MeV, …
- Activation: ^{41}Ar in air ($T_{1/2}$~2h, 1.3 MeV), primary water circuit (^{16}O(n,p)^{16}N, $T_{1/2}$~7s, 6.1 MeV).
- Stray magnetic fields.

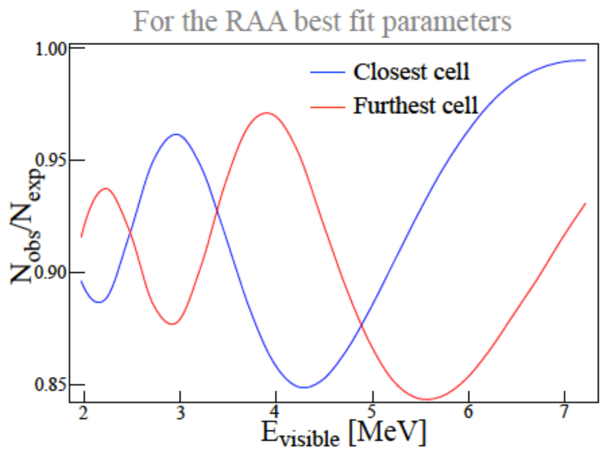
Heavy passive shielding added on front and side walls

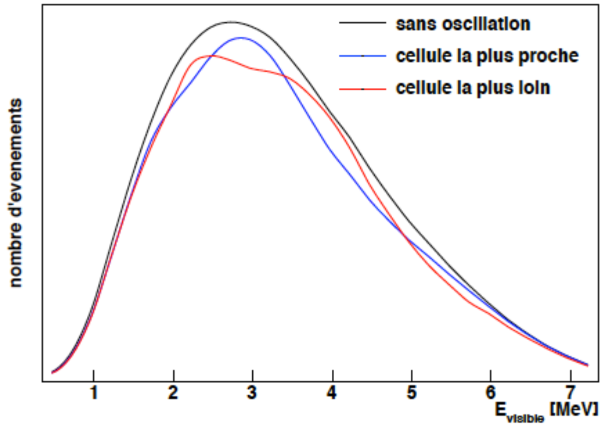


Stereo Detector

- Compare 6 target cells to measure oscillation-driven distortions in the $E_{\bar{\nu}_e}$ spectrum. Mitigate/suppress sensitivity to predicted spectrum depending on analysis scenario.
- Gd-loaded liquid scintillator

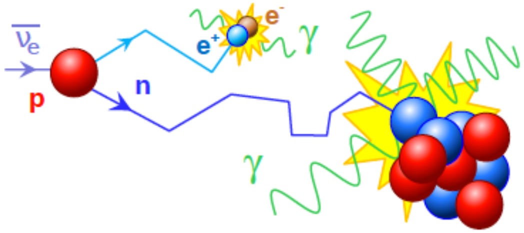


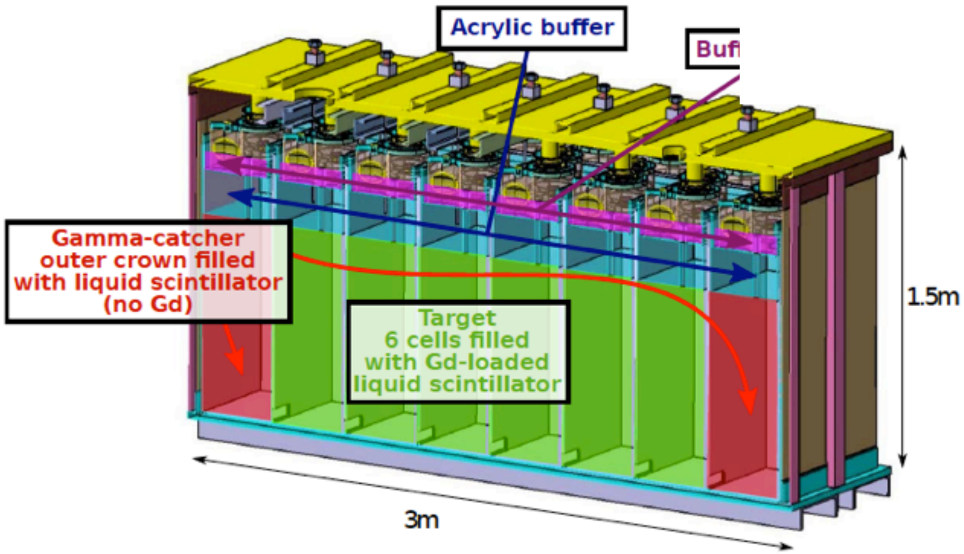


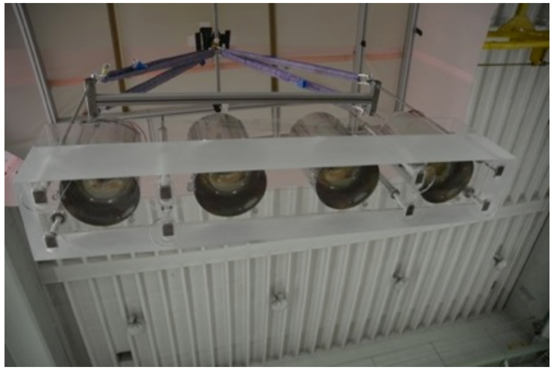


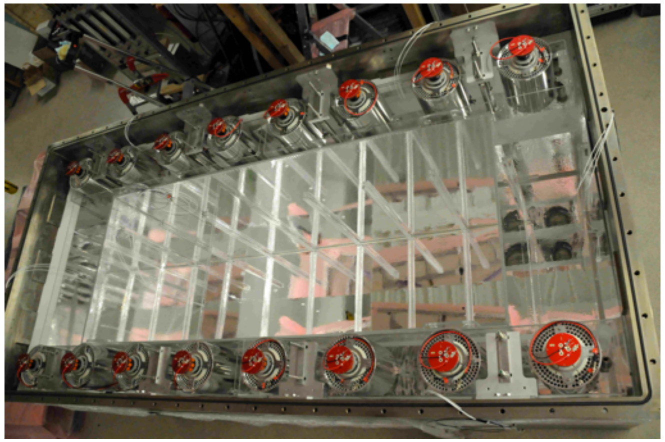
Stereo Detector

IBD process:



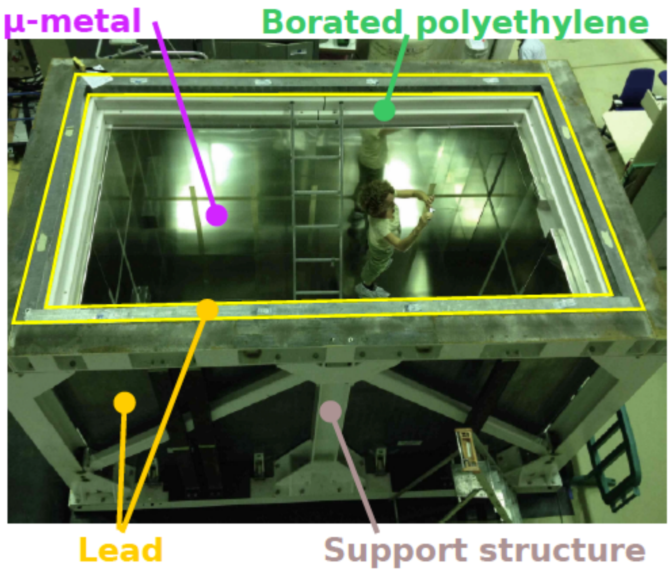


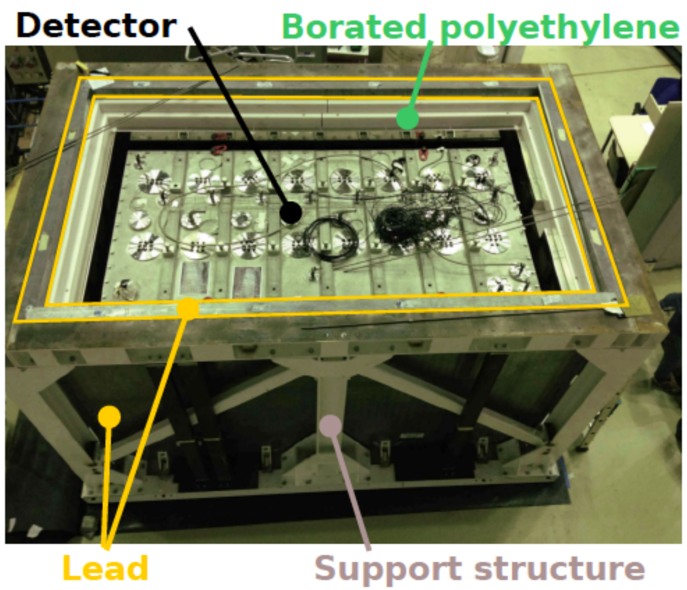


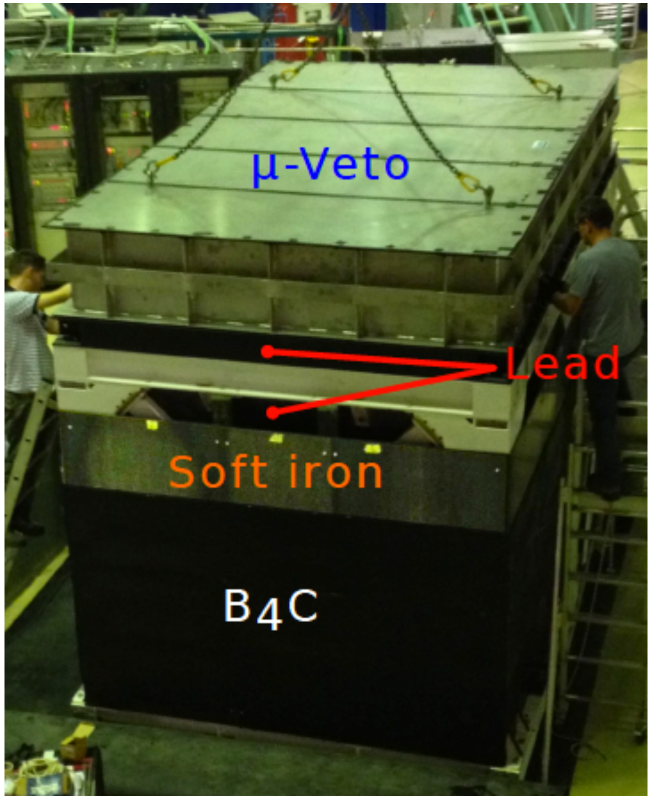


- 6 identical target cells, Gd-loaded
- Gamma-Catcher outer crow (unloaded) acts as veto against external background and recovery of γ-escapes.
- PMT coupling through 20 cm thick acrylic buffers for homogeneity of det response

Mounting @ ILL – Level C



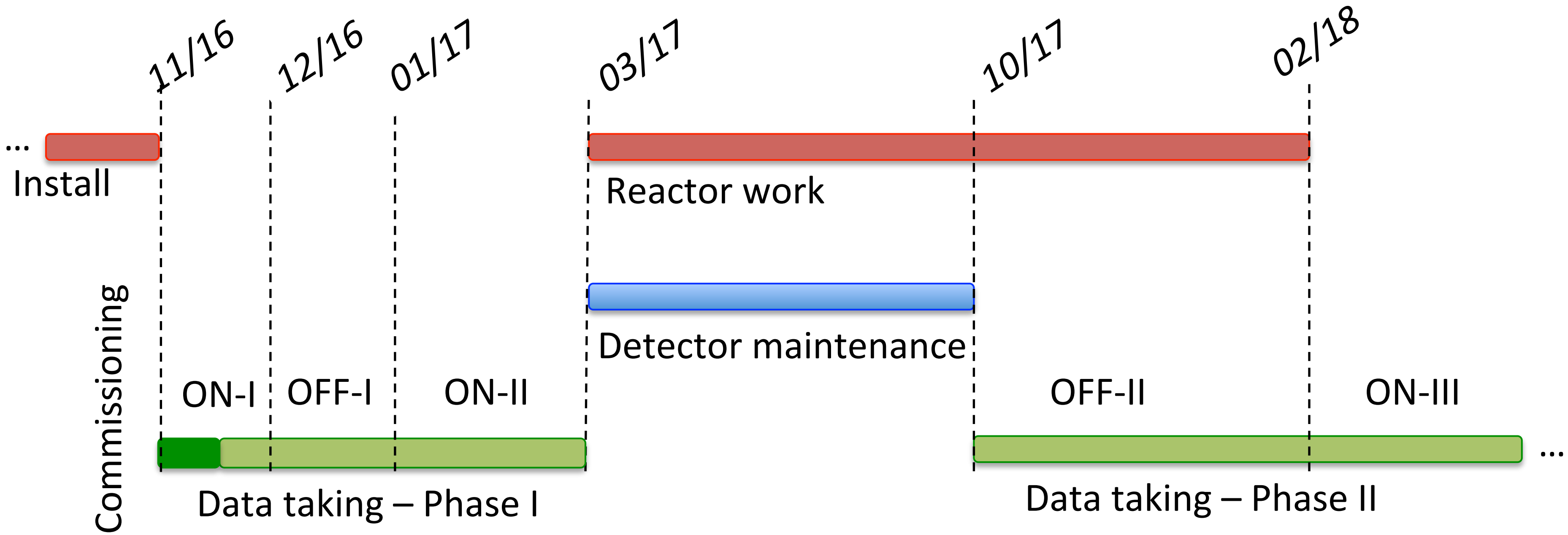




Flying Neutrino Detector

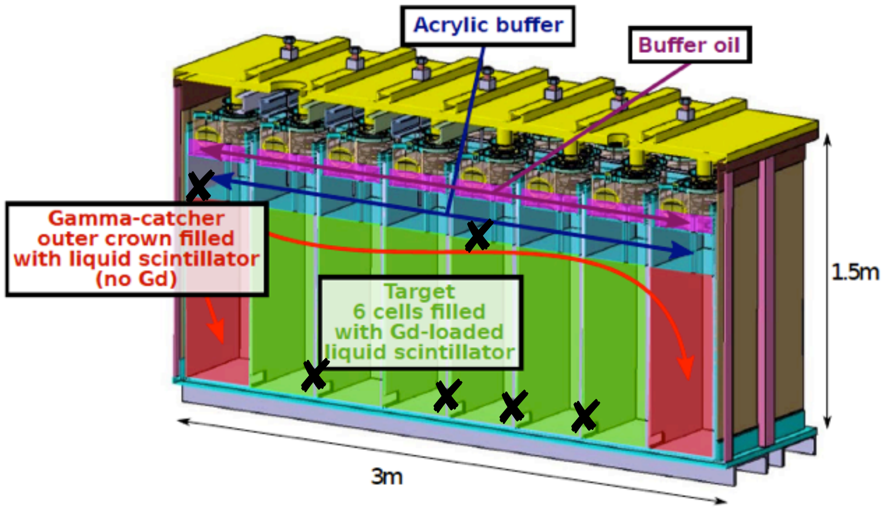
Planning

- Phase I (from Nov 2016): 70 days reactor ON (~1.5 cycles), 25 days OFF
- Detector maintenance during major reactor shutdown this year
- Phase II: taking reactor OFF data since Oct 4, 2017 + 5 more cycles expected by summer 2019.



Cross-Talks Between Cells

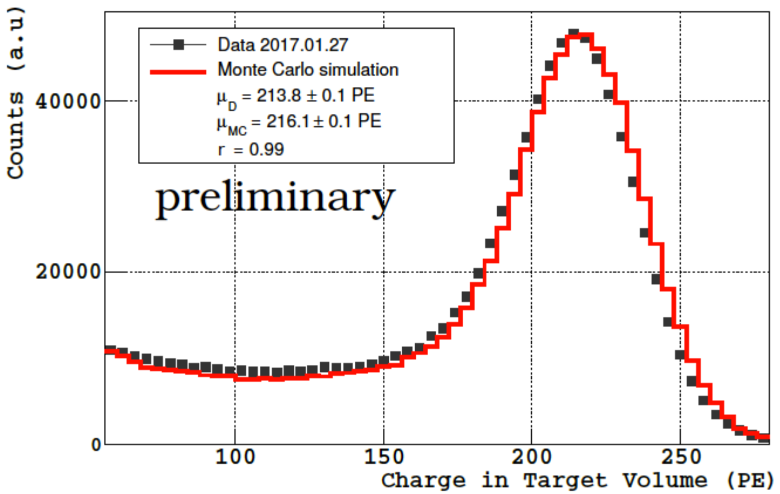
- 1TG + 1GC leaking buffers→ reduced light collection
- Defective glue joints of the separation plates between the target cells → lost of air gaps and increase of cross-talk from few to 10-15%.
- Issues fixed for phase-II. Currently running with symmetric and stable detector.
- Development of an energy reconstruction procedure for phase-I analysis.



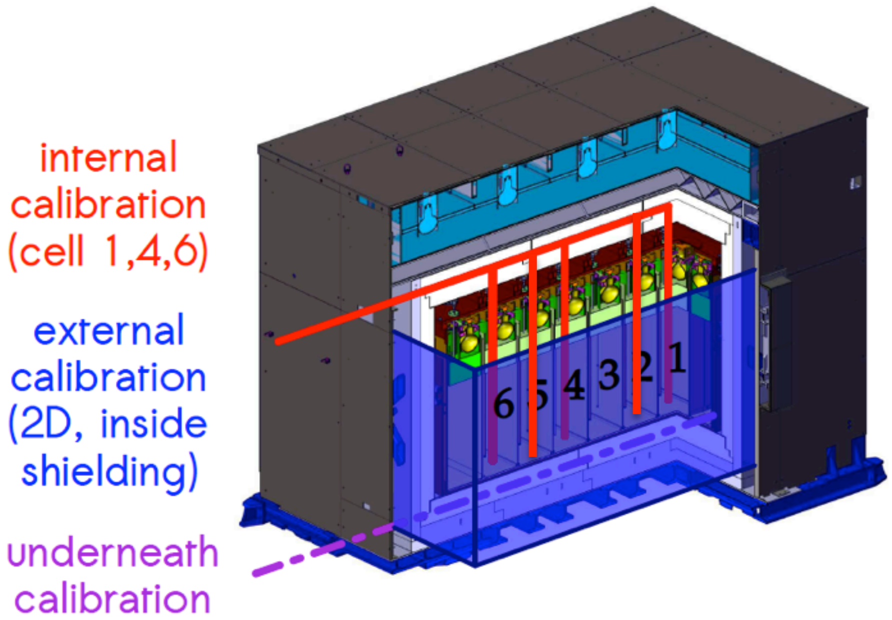
New protection of defective glue joints + baking

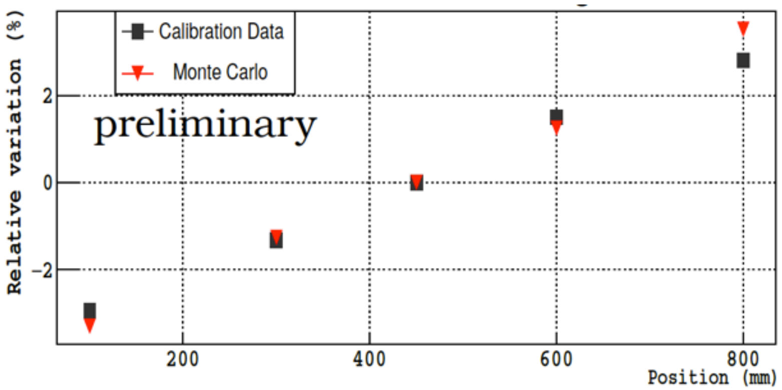
VM2000 reflective foil + air gap

Calibration



~270 p.e./MeV in target





- Monitoring of det response with LEDs: p.e. fits, PMT-DAQ linearity in E_ν range at sub% level.
- Set of γ and n sources: ^{68}Ge, ^{124}Sb, ^{137}Cs, ^{54}Mn, ^{65}Zn, ^{24}Na, 1H(n,γ), Am-Be, ^{252}Cf.
- Scan of the detector with ^{54}Mn source, twice a week→ Reference calibration point.

Energy Reconstruction

$$Q_i = \sum_{j=cells} E_j\, C_j\, L_{ji} = \sum_{j=cells} E_j\, M_{ji}$$

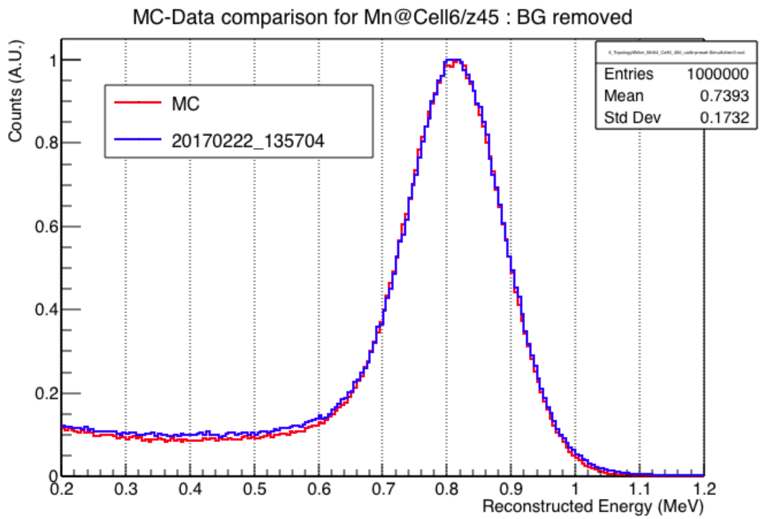
Collected photons/MeV
from calib runs

Cross-talk cells j→I
Measured online + calib

The vector of deposited E in each cell is
reconstructed by inverting the M matrix:

$$\overrightarrow{E^{rec}} = M^{-1}\vec{Q}$$

Anchor point on ^{54}Mn energy

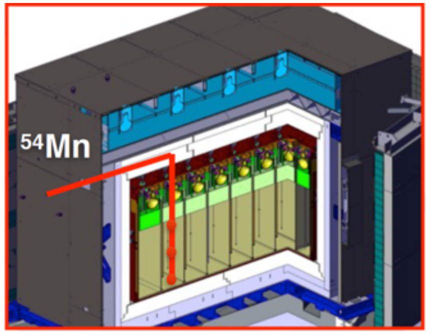


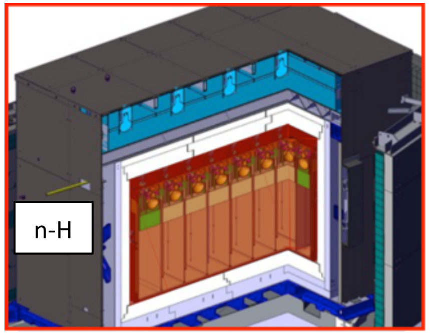
- ❑ Compare Data and MC at the level of E^{rec}, corrected to first order for light collection effects.
- ❑ Iterative fine-tune of C and LL coefficient for an accurate matching of experimental and simulated E^{rec} distributions from a ^{54}Mn source circulated in the calibration tubes.

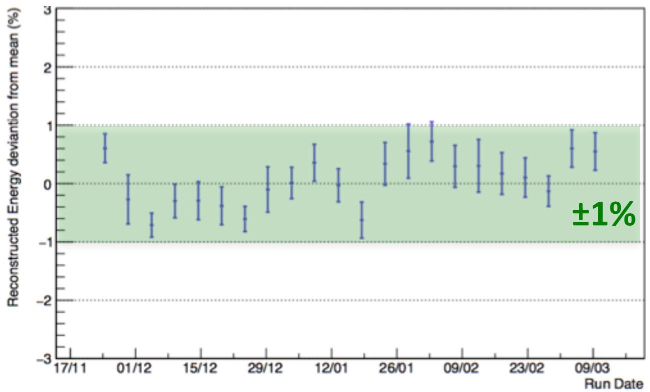
Energy Reconstruction

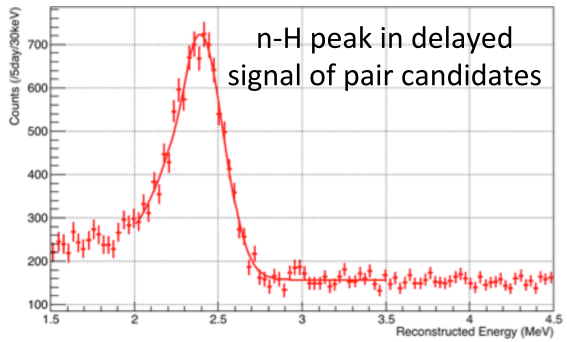
- n-captures are homogeneously distributed in the target volume and associated γ-rays often share energy deposit between two cells.
  → stringent cross-check of the energy reconstruction testing volume effects beyond the reference points of the ^{54}Mn source.

n-H capture peak

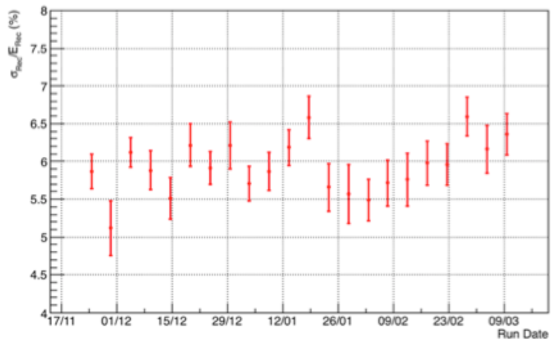








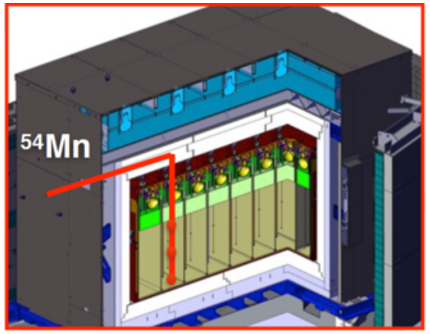
- Subpercent stability of n-H peak position
- 6.5% resolution.

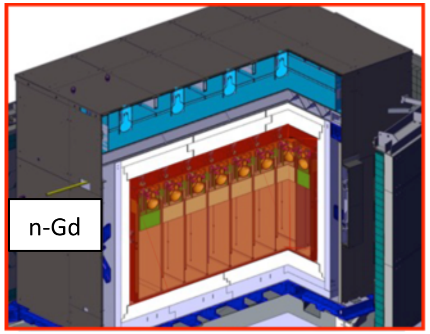


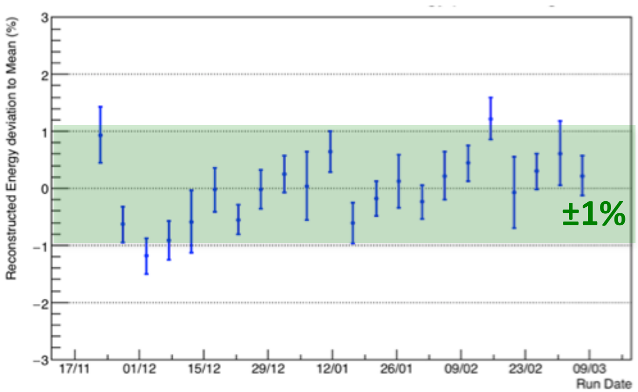
Energy Reconstruction

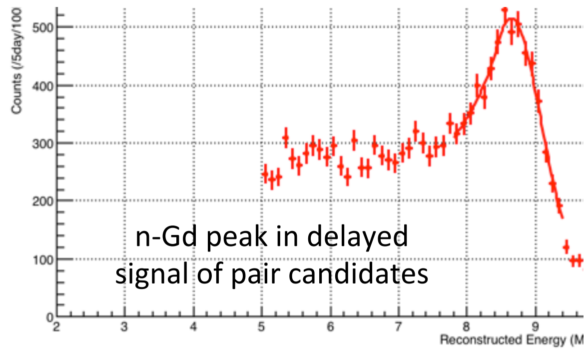
- n-captures are homogeneously distributed in the target volume and associated γ-rays often share energy deposit between two cells.
  → stringent cross-check of the energy reconstruction testing volume effects beyond the reference points of the ^{54}Mn source.

n-Gd capture peak

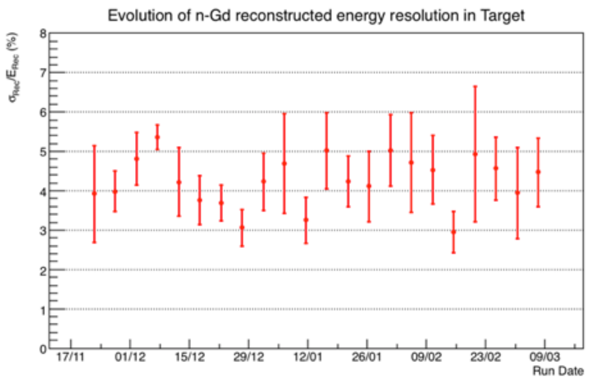








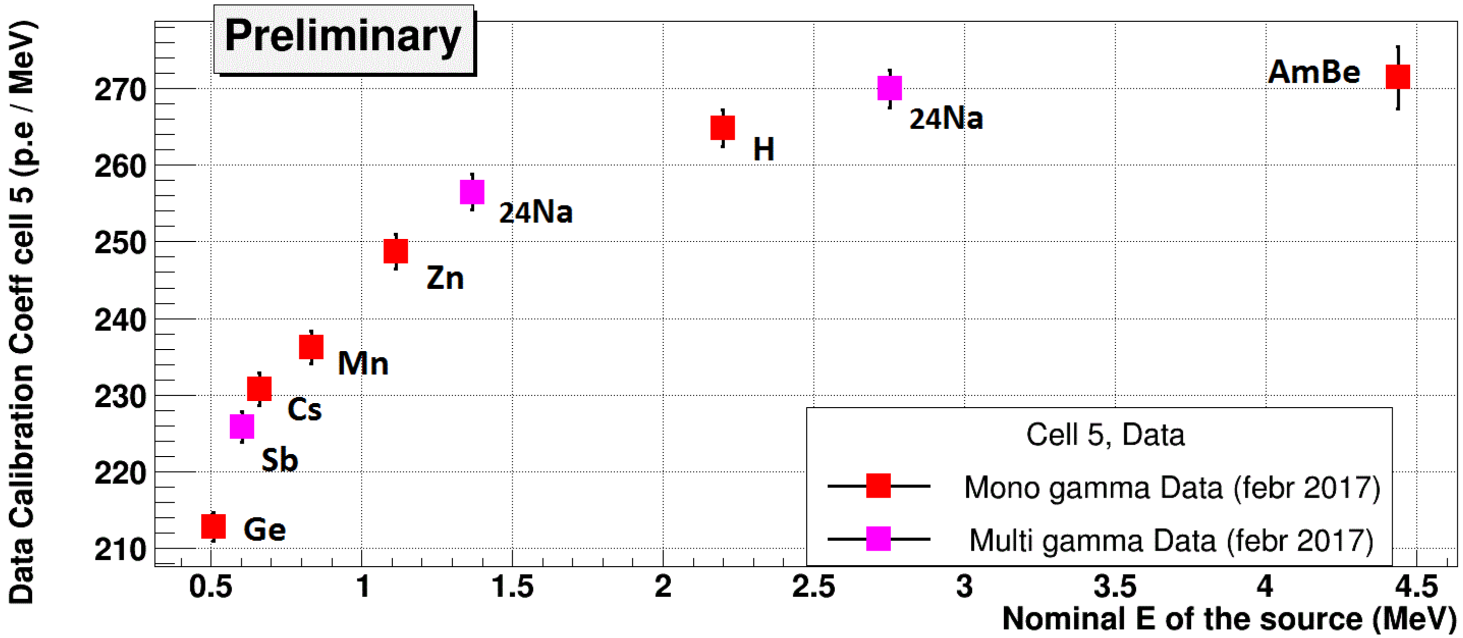
- Percent stability of n-Gd peak position
- ~4.5 % resolution.



Quenching Curve

$$\frac{dL}{dx} \propto \frac{dE}{dx} \Bigg/ \left(1 + k_B \frac{dE}{dx}\right)$$

Non-linear light production in the large dE/dx regime (low E – Bragg peak)



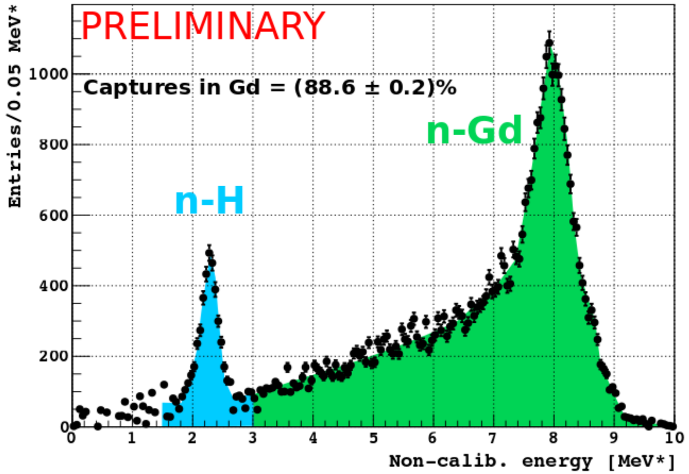
- Fine-tuning of the k_B value in MC in progress to quantify associated systematics.

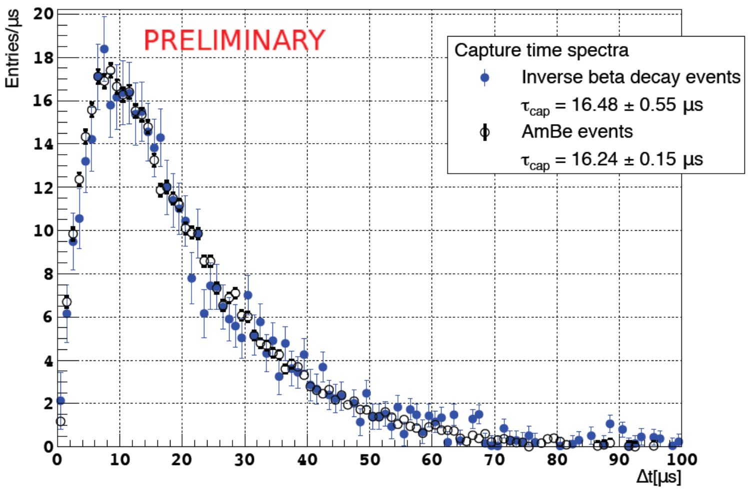
Neutron Detection Efficiency

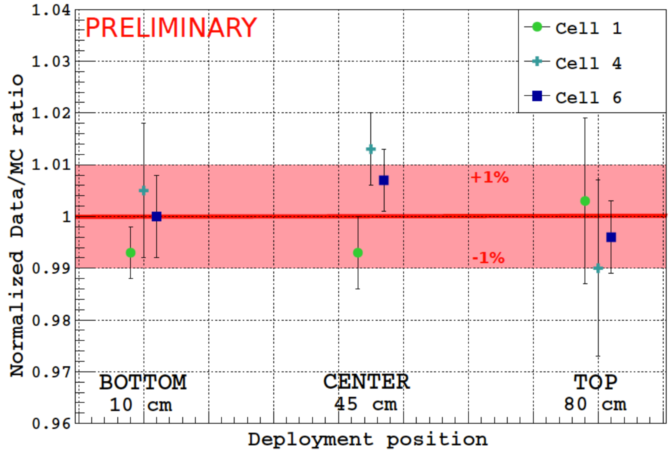
Am-Be neutron source in the target cells:

- n-capture time from Am-Be in agreement with IBD candidates
- Relative variations of n efficiency in agreement between MC and data.
- Absolute fraction of Gd-capture fine-tuned in MC → determination of the global n-capture efficiency

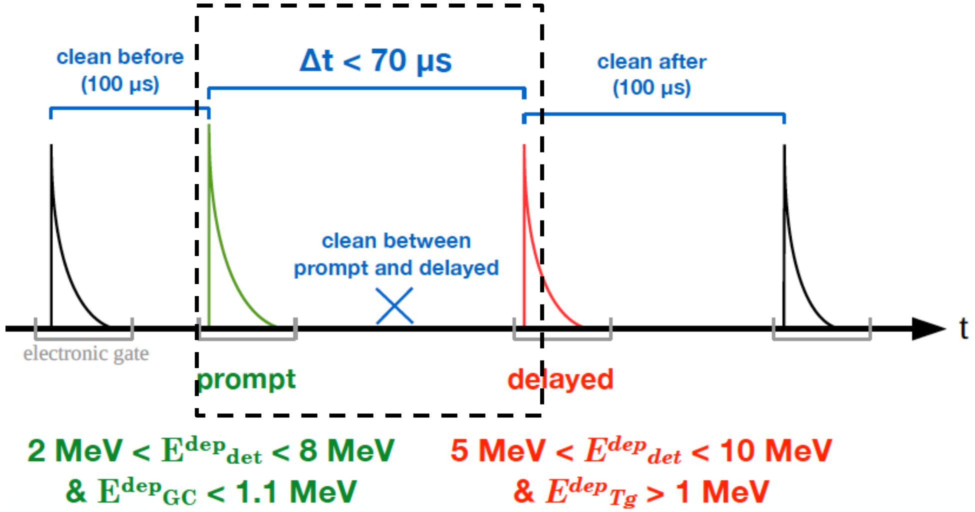
Energy reconstruction of neutron capture peaks







Selection of ν Candidates

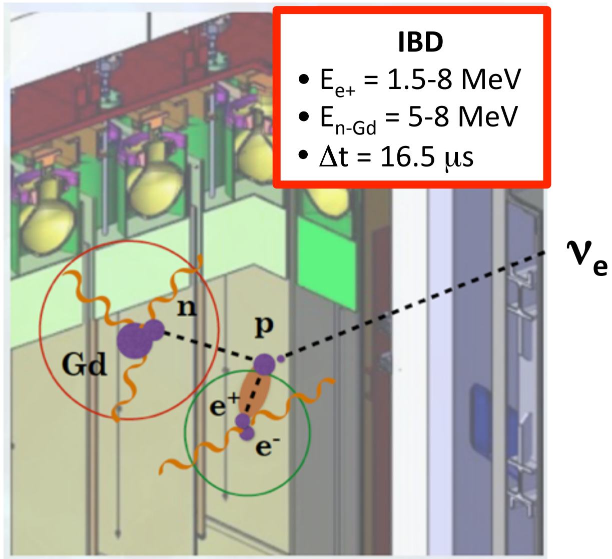


Prompt-Delayed standard cuts

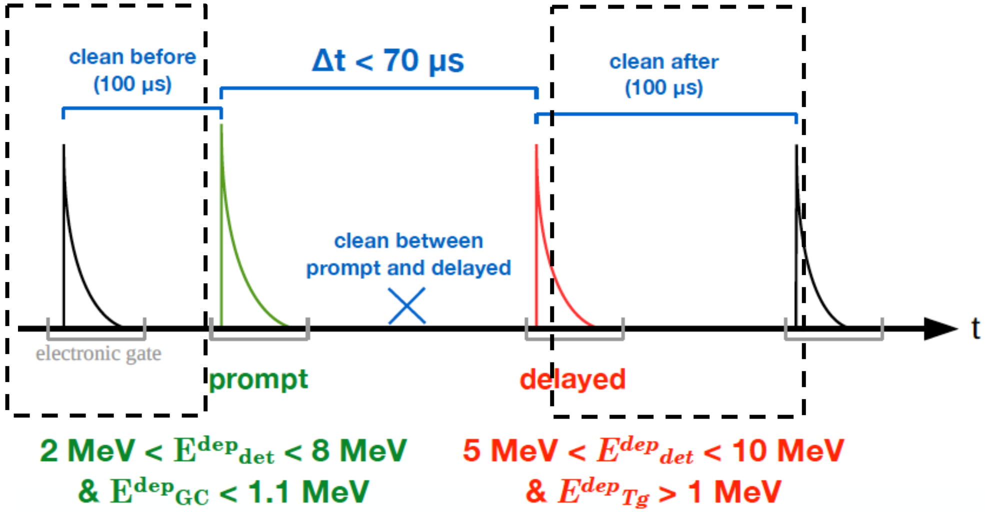
- Optimal thresholds for E_{prompt} and $E_{delayed}$ in the [1.5 – 2] and [4-5] MeV range respectively.
- ΔT=70μs ≃4*n-capture time

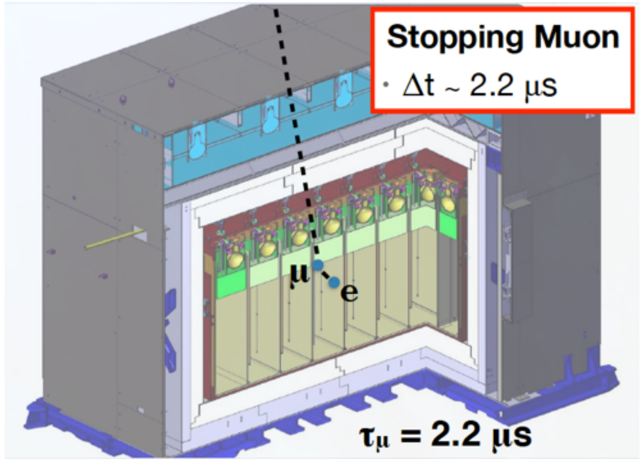
Topology

- E_{prompt} in GC < 1.1 MeV
- E_{prompt} in cell≠vertex_cell< 0.7 MeV
- $E_{delayed}$ in TG > 1 MeV
- $D_{prompt-delayed}$ < 1.5 cell size.



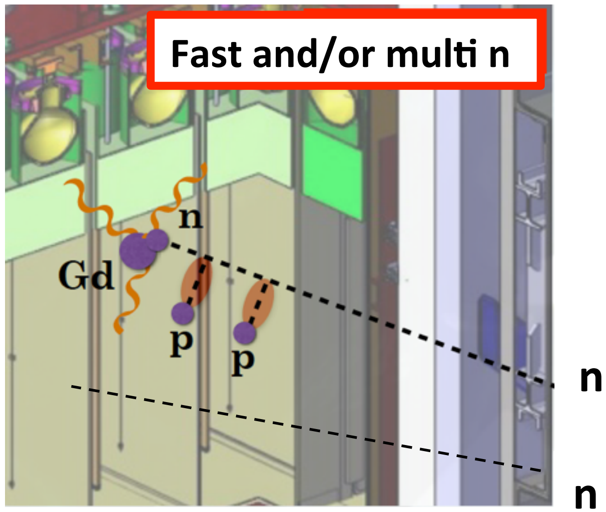
Selection of ν Candidates





Online rejection of μ-induced background

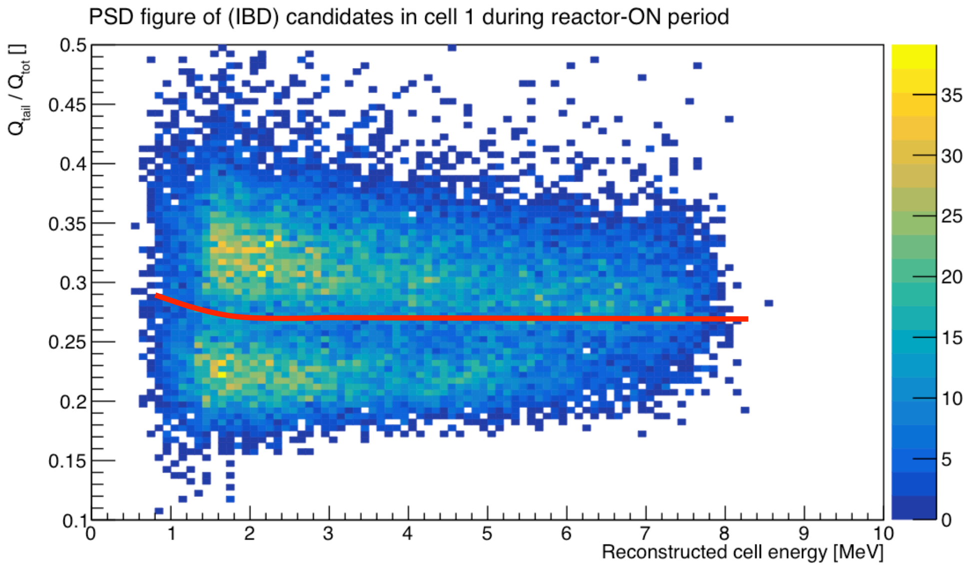
- 100 μs μ veto (6.5% dead time)
- Charge asymmetry: $Q_{PMT\_max}/Q_{cell}<0.5$
- Isolation gates
- PSD against p-recoils and stopping μ.

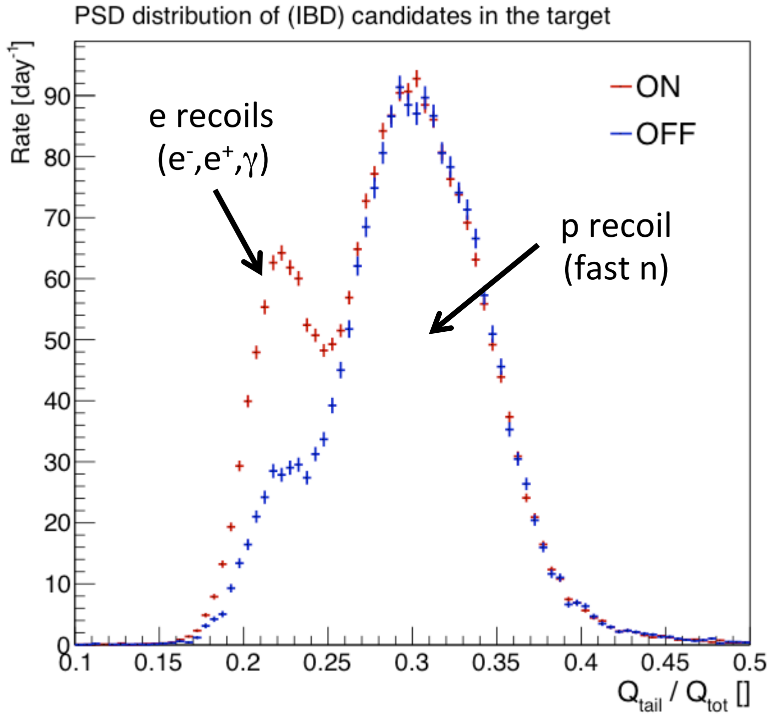


Pulse Shape Discrimination

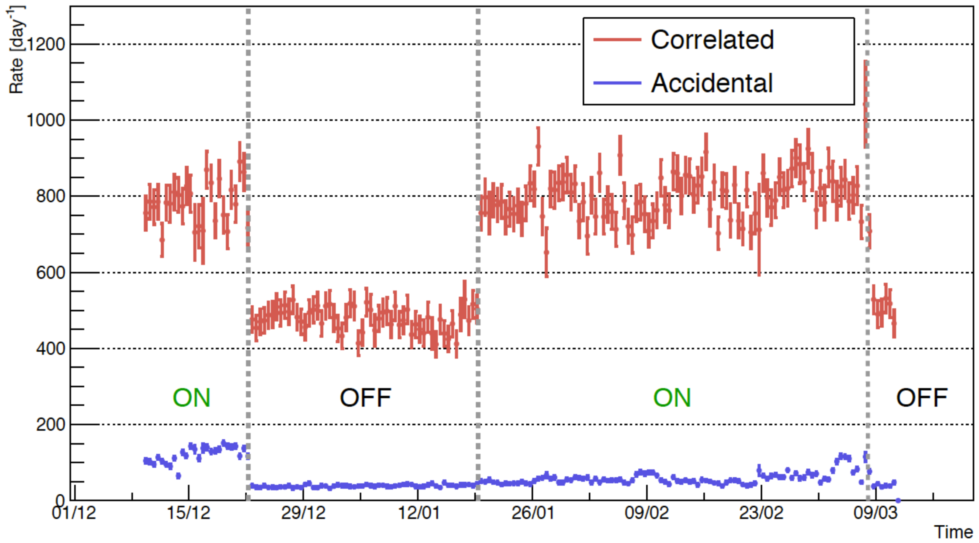
- Superposition of proton recoils for reactor On and Off periods excludes significant fast-n flux from the reactor.
- Figure of merit ~0.65 for phase-I, improved to 0.70 for phase-II.

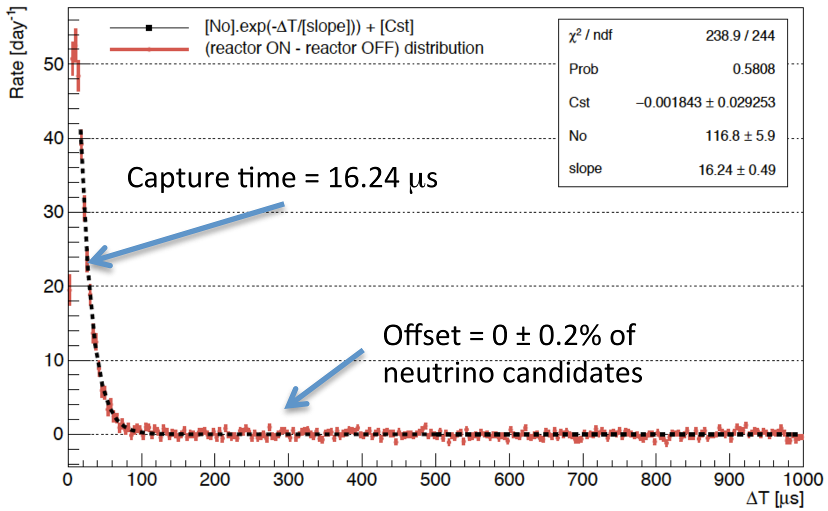
$$F.O.M. = \frac{\langle protons \rangle - \langle electrons \rangle}{2.35 \times (\sigma_{protons} + \sigma_{electrons})}$$





Prompt-Delayed Candidates

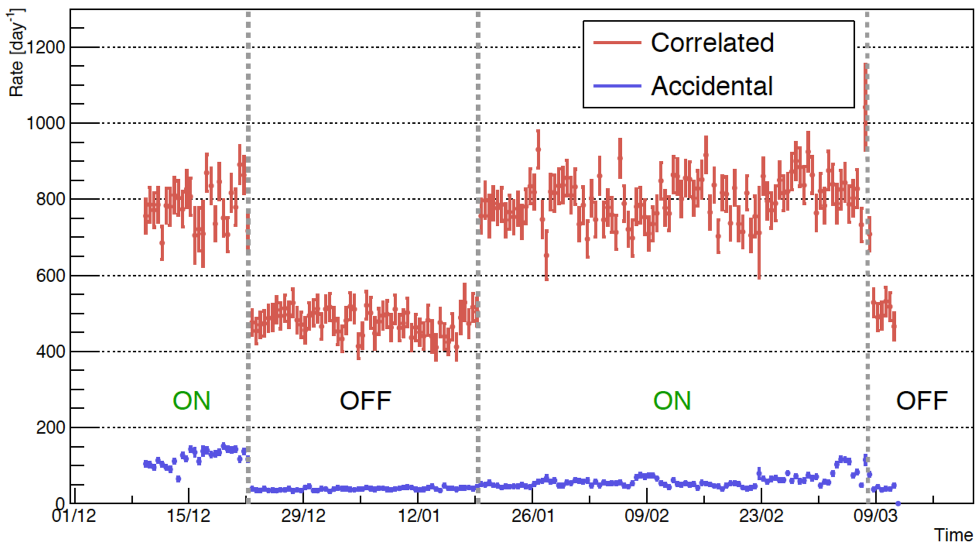


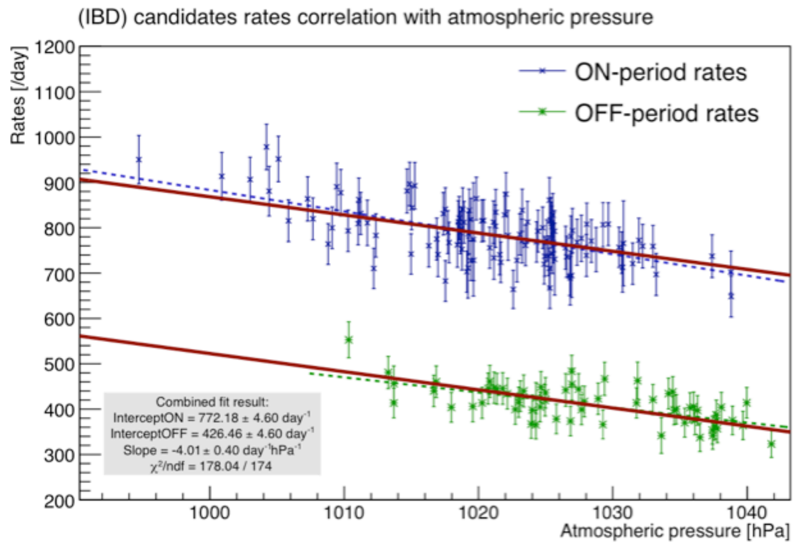


Accidental background:

- On specifications thanks to the heavy passive shielding and topological cuts.
- Residual contribution measured online with virtually infinite stat precision using many off-time prompt-delayed coincidences.
- Residual offset in the distribution of n-capture time of neutrino candidates is compatible with zero with uncertainty of 0.2% of candidate neutrinos rate.

Prompt-Delayed Candidates

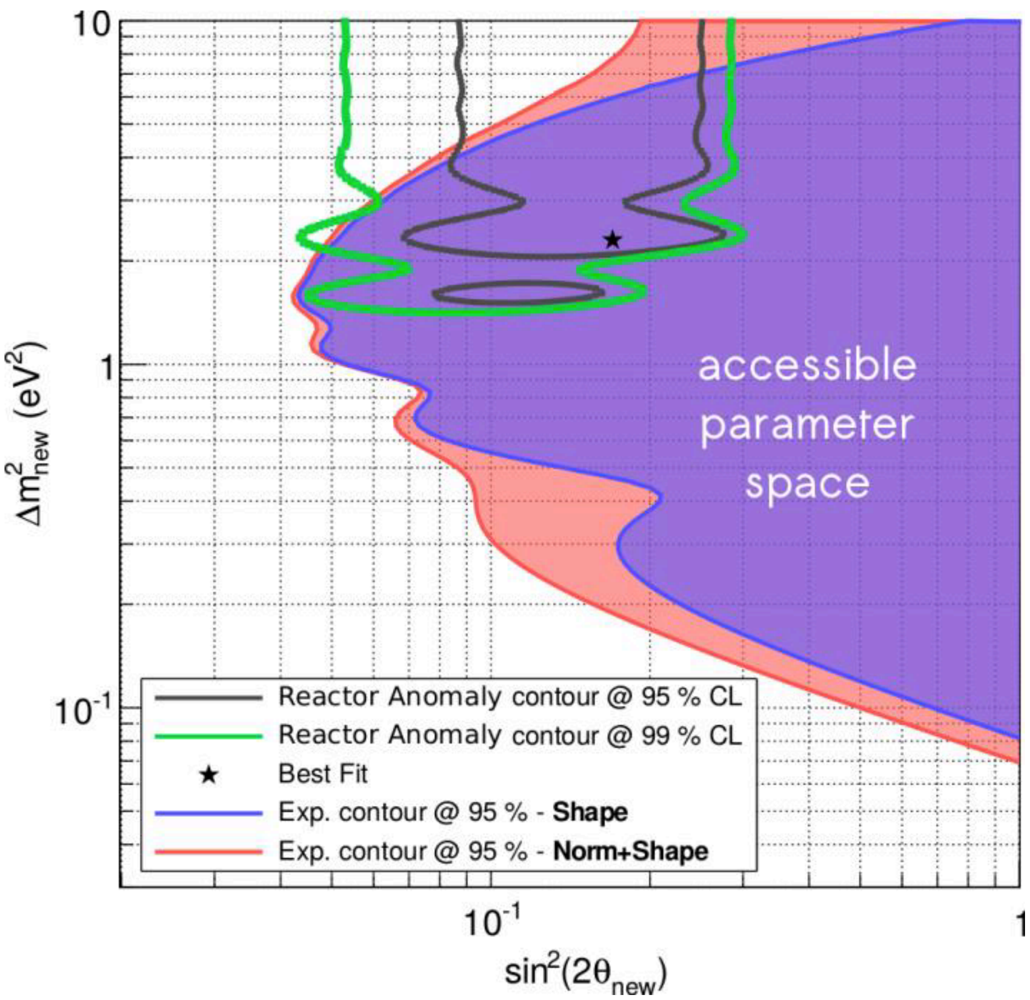




Correlated, cosmic-rays induced background:

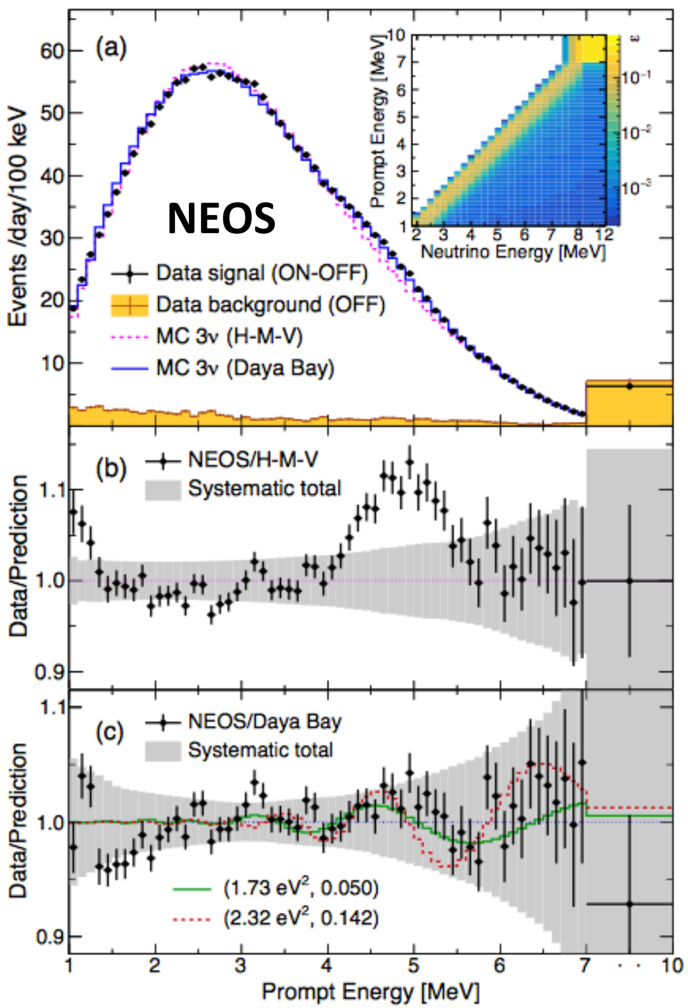
- The shallow depth of the experiment induces a dependence of background on atmospheric pressure. Measured online to correct the rates back to a reference pressure of 1024 hPa.
- Larger amount of reactor off data is being acquired to optimize cuts and determine systematics on background stability.

Expected sensitivity

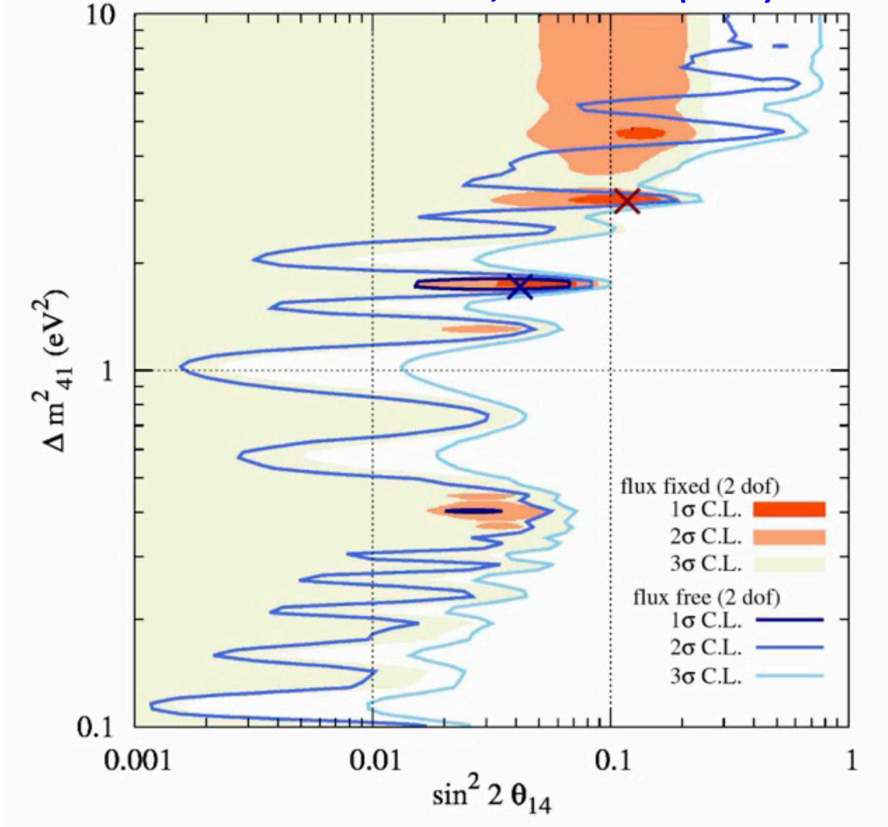


Phys.Rev.Lett. 118 (2017) no.12, 121802

Global Fit



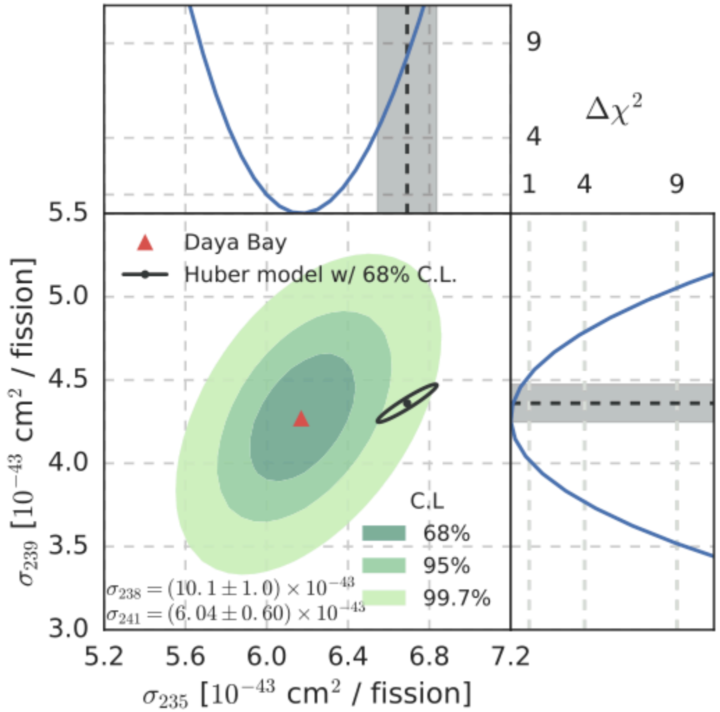
M. Dentler et al., JHEP 1711 (2017) 099



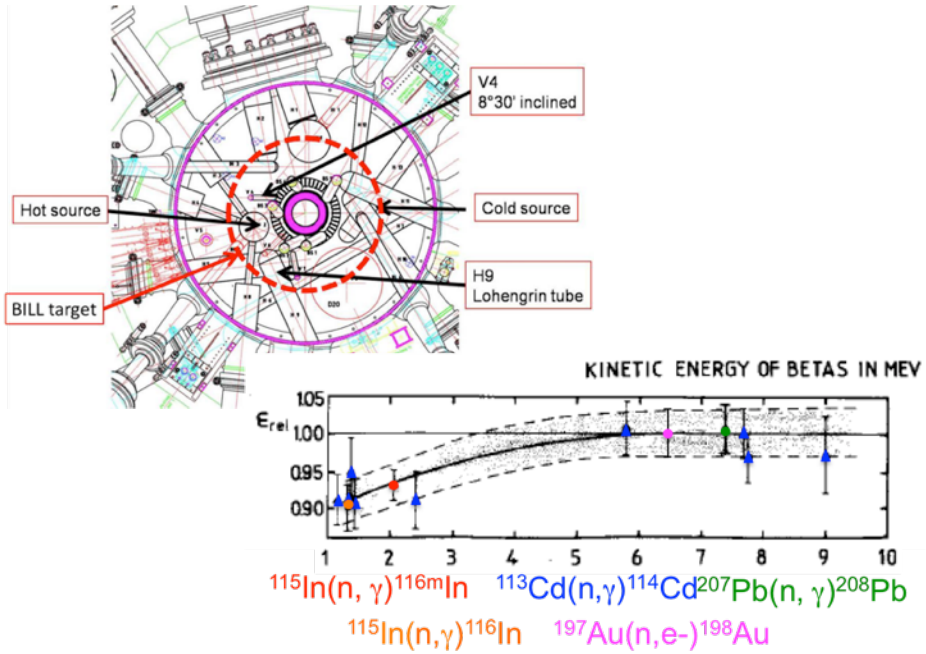
- Remaining oscillation contour is driven by the Neos (+Danss) data.
- Stereo brings complementary measurements based on relative distortions between cell.

Predictions vs Data

- Daya Bay separate measurement of neutrino rates induced by ^{235}U and ^{239}Pu fissions → most of the deficit on ^{235}U only.



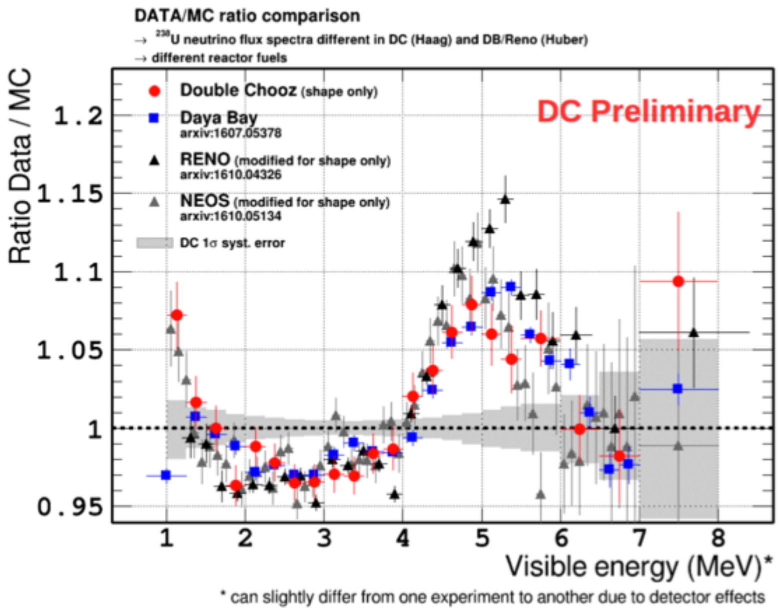
- Normalization of ILL reference fission spectra

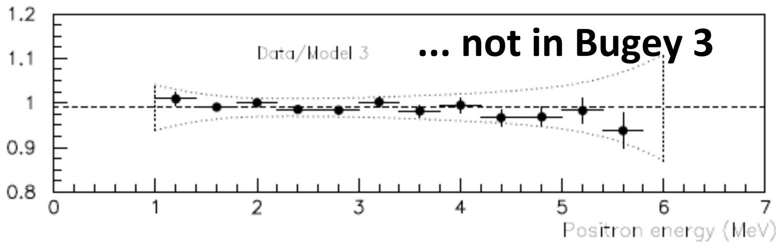


- Ongoing review of the calibration procedure of the reference β spectra,
- Update of e-conversion and fission cross sections → increase of ^{239}Pu prediction?
- Stereo (+ Solid + Prospect) will check pure ^{235}U norm.

Predictions vs Data

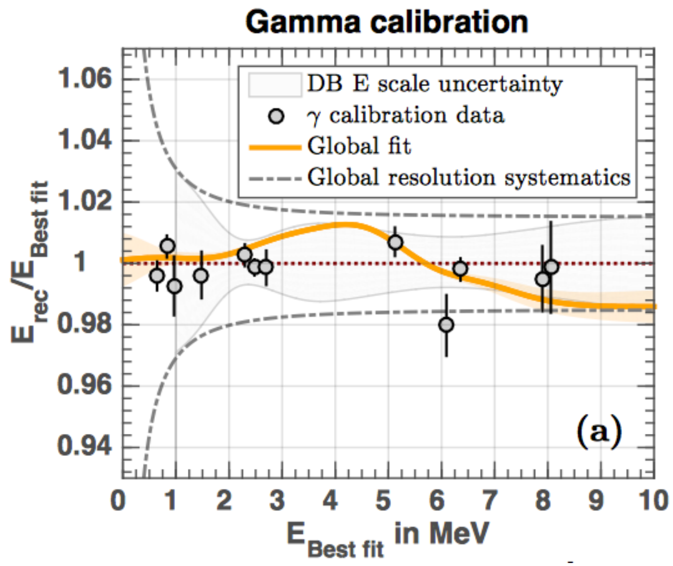
- Similar shape distortions observed by several experiments.





- Sensitivity to energy scale distortions

G. Mention et al., Phys.Lett. B773 (2017) 307-312



- Stereo: all E_{scale} systematics to be included in a final uncertainty on the calibration coefficient, “à la Bugey”.

Conclusions

- Important features of the experiments shown to meet the specifications. Working on cut optimization and systematics of cosmic background subtraction.
- Publication of results from phase-I by spring 2018. Phase-II expected to be completed by mid-2019 (5 more cycles, expendable to 7)
- Stereo addresses the hot issues about fission neutrino spectra:
  - Search for sterile neutrino with relative distortion among identical cells. Little sensitivity to the predicted ^{235}U spectrum.
  - Check the neutrino deficit from ^{235}U only.
  - Full E range exploited, complementarity to rate dominated info from other experiments.
- Combined measurements about to answer the question of sterile neutrinos at the eV scale in the next few years. Constraints U_{e4}, connects to LSND anomaly as well.

Thank you