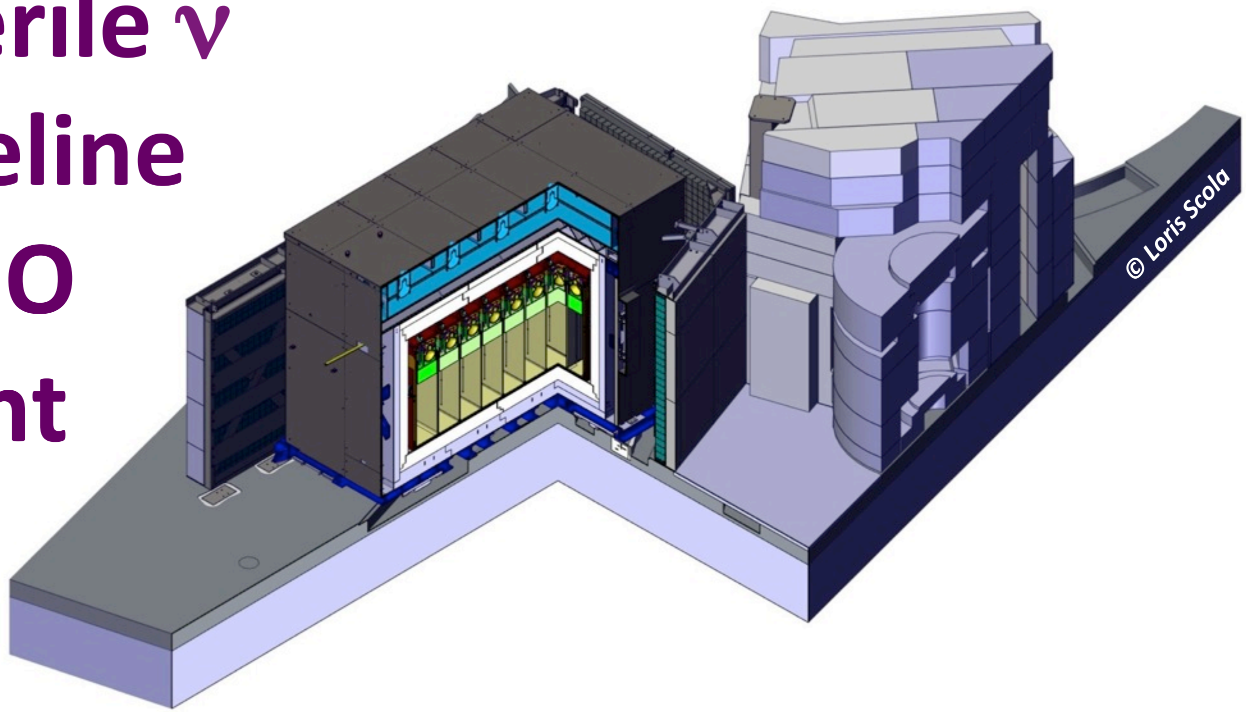
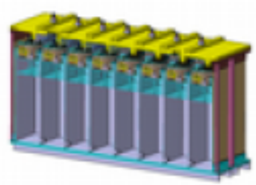
supported by

Search for Sterile ν at Short Baseline The STEREO Experiment



Reactor Anomaly

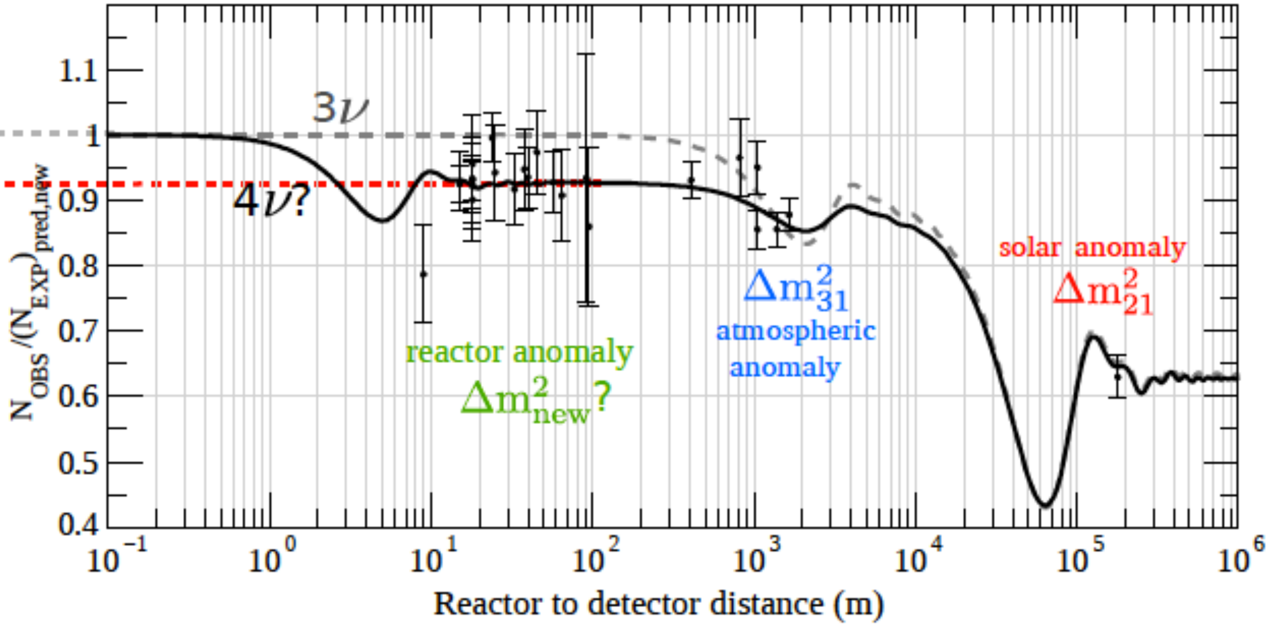
ν_e ⟶ $\nu_{m1}\ \nu_{m2}\ \nu_{m3}$ ⟶ ν_e? ν_μ? ν_τ?



PRODUCTION (flavours) — **PROPAGATION (masses)** — **DETECTION (flavours)**

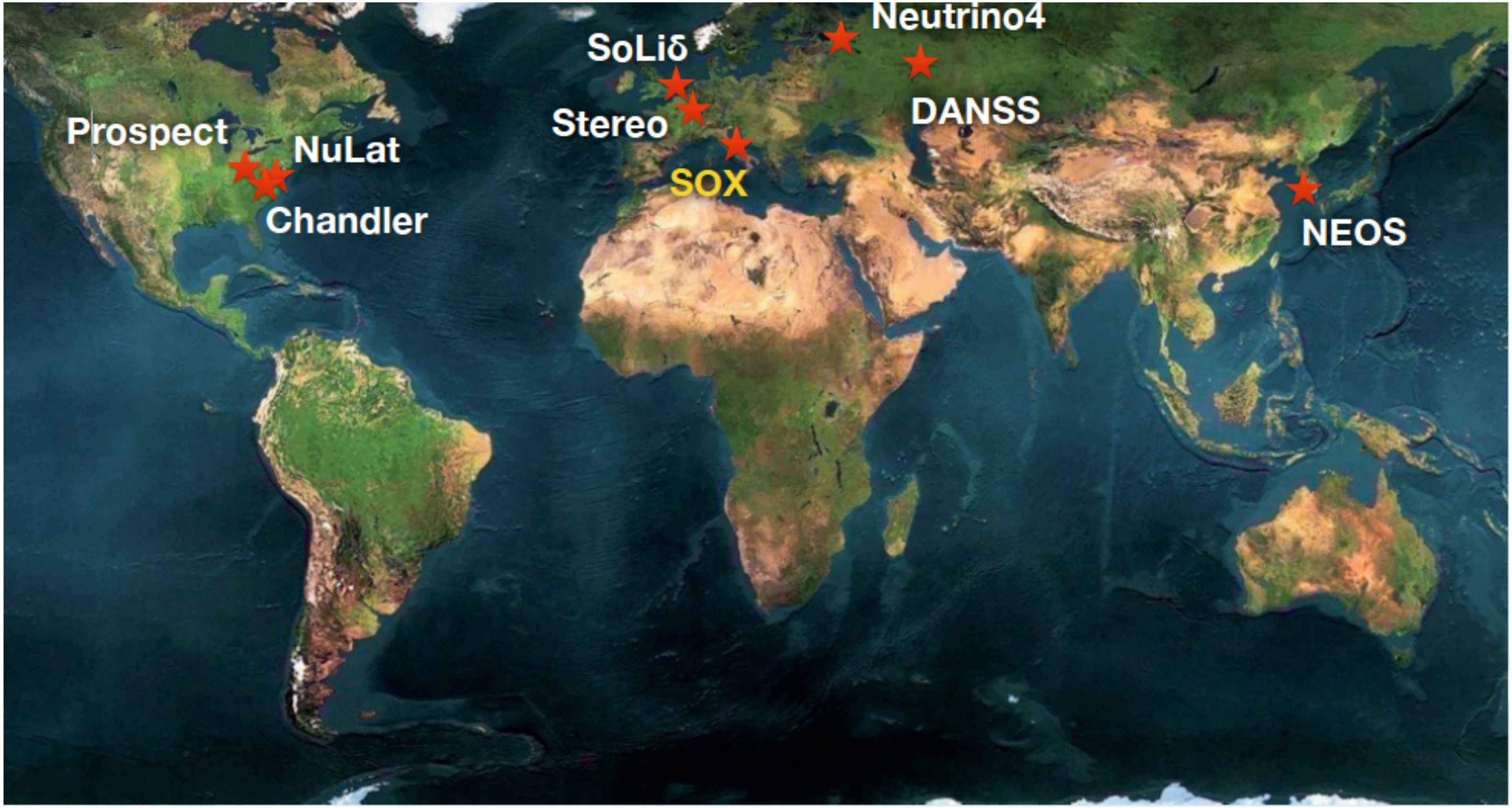
~ 6 % deficit

- **Sterile neutrino ?**
- Wrong prediction ?



$$P_{\overline{\nu}_e\to\overline{\nu}_e}(E_{\overline{\nu}_e},L) = 1 - \sin^2(2\theta_{new})\ \sin^2\left(1.27\frac{\Delta m^2_{new}[eV^2]L[km]}{E_{\overline{\nu}_e}[MeV]}\right)$$

Quest for Sterile ν @ 1eV Mass Scale

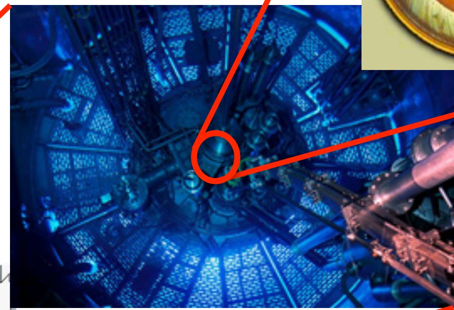


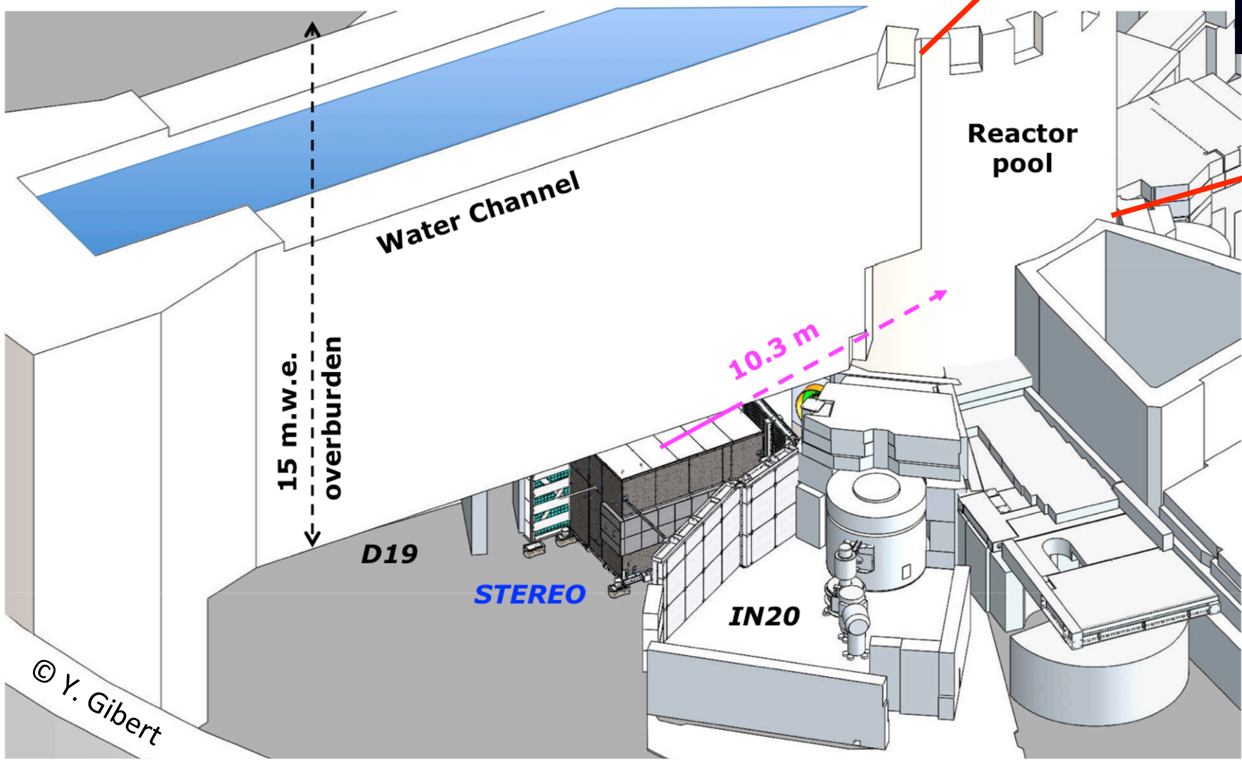
Quest for Sterile ν @ 1eV Mass Scale

ILL Site

Compact core

- 58.3 MW_thermal
- Ø40 cm × 80 cm
- Highly enriched: 93% ^{235}U
- 3-4 cycles/year each of 50 days
- 10^{19} s^{-1} pure $\overline{\nu}_e$ flux

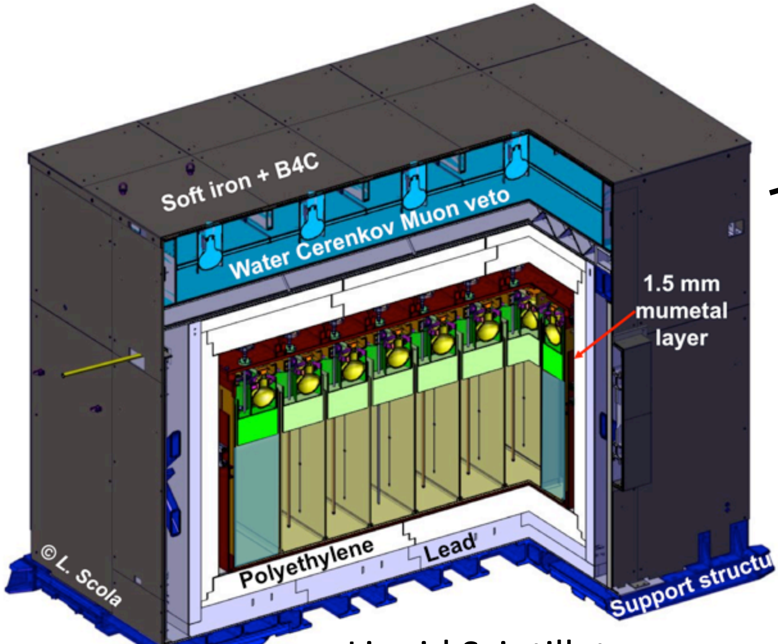




Challenging mitigation of the background generated by:
- Neighboring experiments.
- Cosmic-rays.

STEREO Detector

- Compare 6 target cells to measure oscillation-driven distortions in the $E_{\bar{\nu}_e}$ spectrum.
- Mitigate sensitivity to predicted spectrum.



Reactor

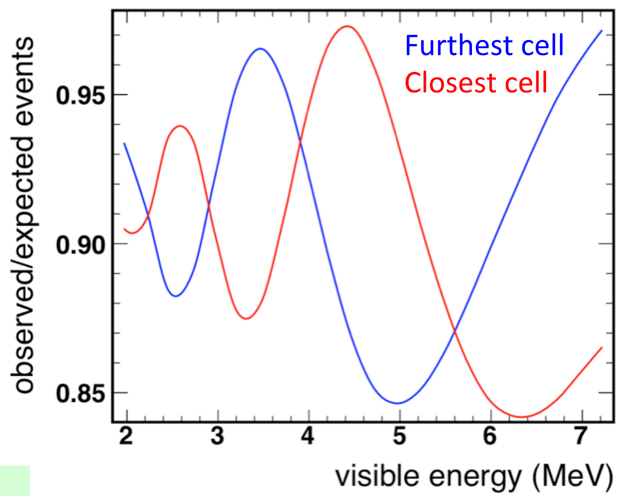
20 cm thick acrylic buffers for homogeneous detector response. PMT coupling via oil bath.

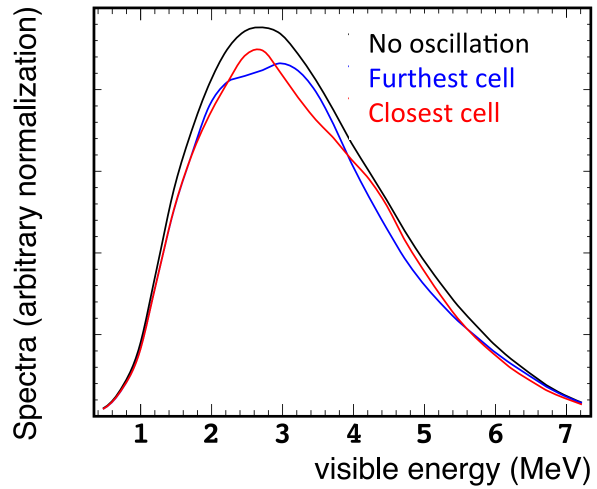
Liquid Scintillator

Target: 6 identical cells
- Gd-loaded (0.2% in mass)
- V_{tot}= 2.2 x 0.9 x 0.9 m^3

Gamma catcher (unloaded):
- Vetos ext. background
- Captures escaping γ's

$\sin^2(2\theta)=0.14$, $\Delta m^2=2.4$ eV^2





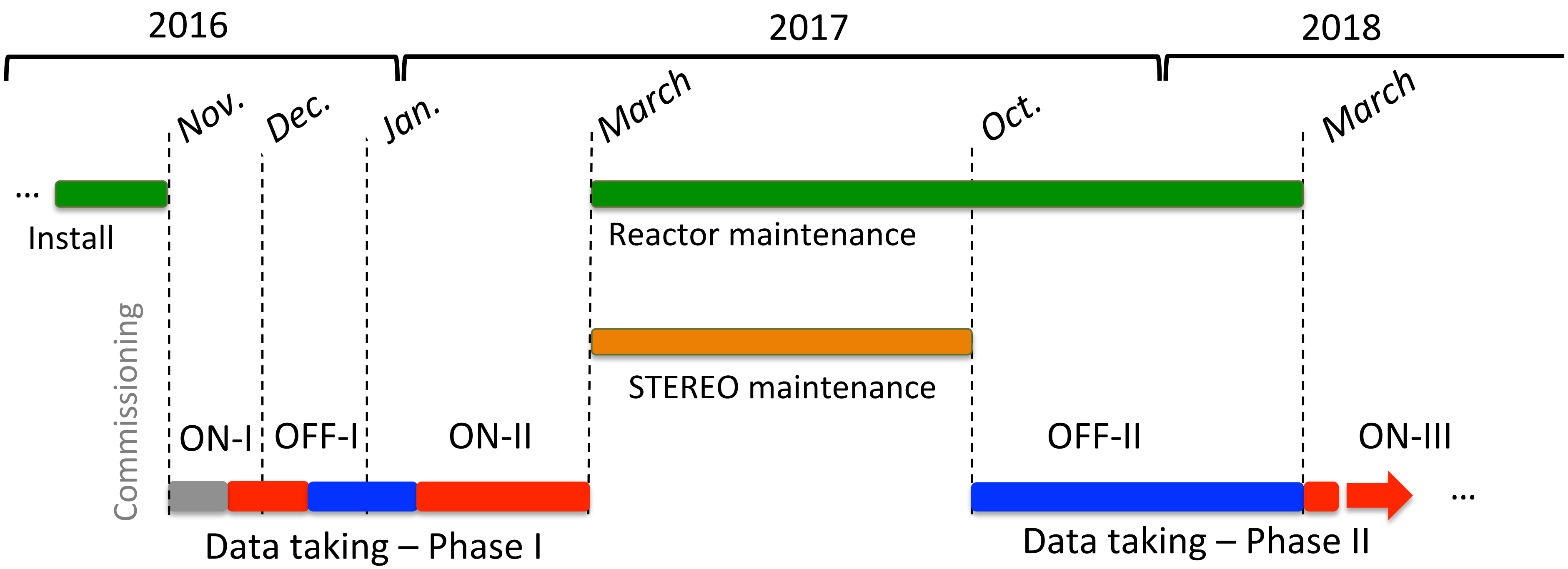
Detector Assemblage Moving on Air Cushions

STEREO Data Taking

- **Reactor ON**: 65.8 effective days - 1.6 cycles)
- **Reactor OFF**: 138.2 days

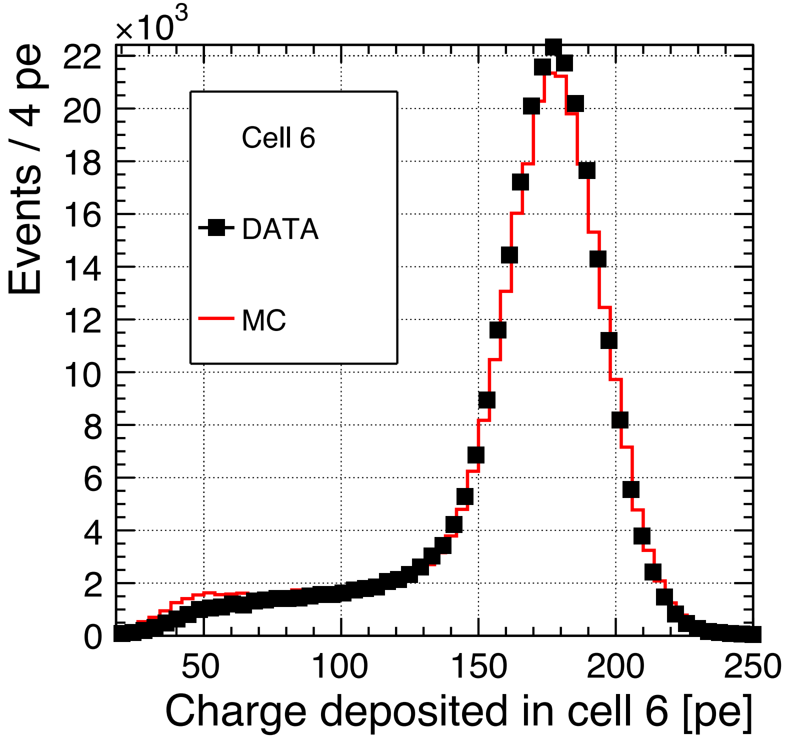
Release of first results at this conference

- Average detected neutrino rate of **396 ν/day**.
- Deficient optical coupling in 4th target cell and front part of the γ-catcher +evolving light cross-talk repaired during the last reactor shutdown.
- Reactor restarted 2 weeks ago; 5 more cycles expected until summer 2019.

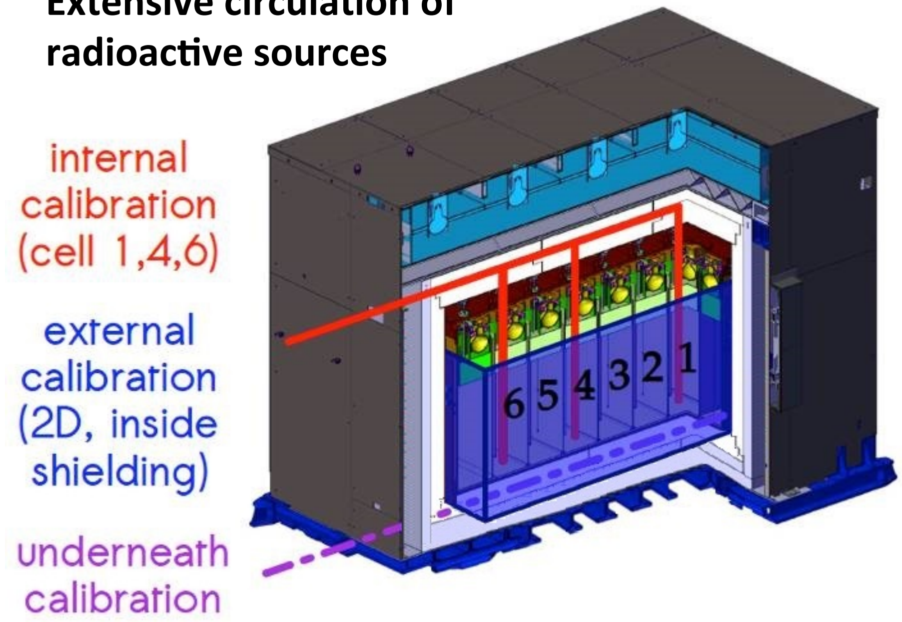


Monitoring of Detector Response

^{54}Mn source – 0.835 MeV



Extensive circulation of radioactive sources



- 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, ^{1}H(n,γ), Am-Be, ^{252}Cf.
- Frequent scans of the detector with the ^{54}Mn source.

Energy Reconstruction

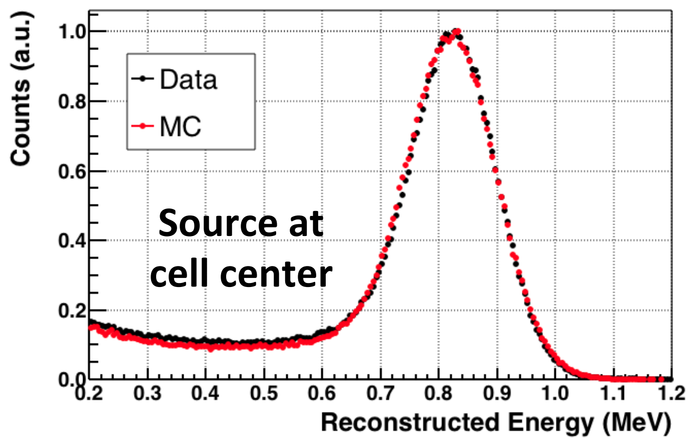
$$Q_i = \sum_{j=cells} E_j\, C_j\, L_{ji} = \sum_{j=cells} E_j\, M_{ji}$$

Collected photons/ MeV from calib runs (target + γ-catcher cells).

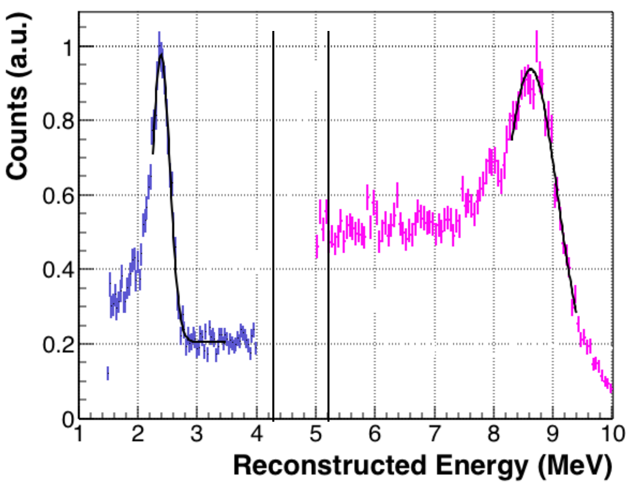
Light cross-talk cells j→i Measured online + calib.

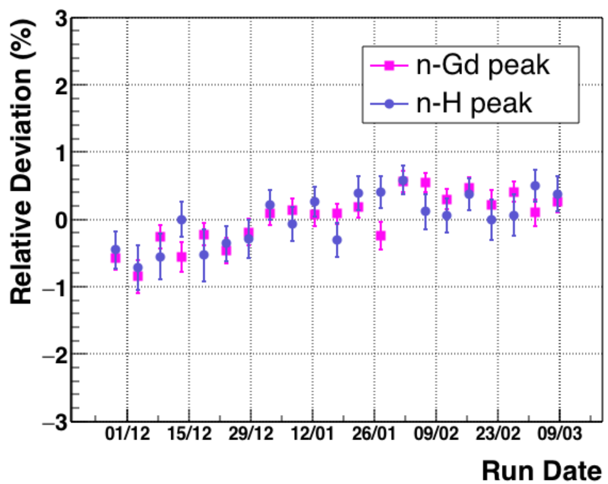
Reconstructed E : $\overrightarrow{E^{rec}} = M^{-1}\vec{Q}$

Anchor point on ^{54}Mn energy



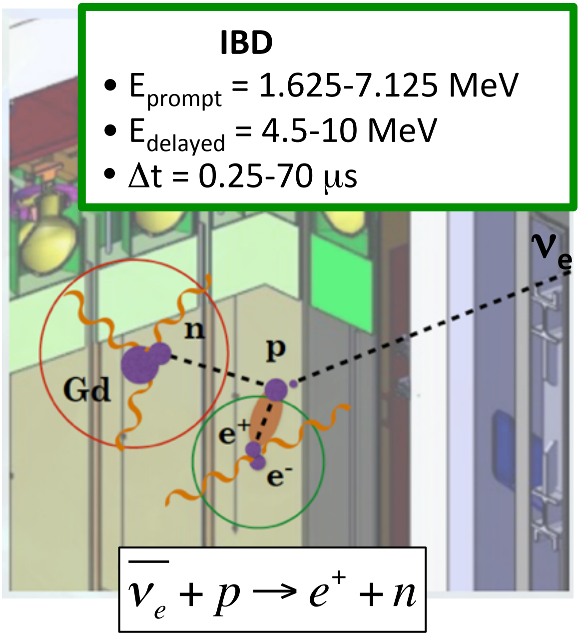
Sub-% stability of the reconstructed n-H & n-Gd peaks – probing whole target volume.





Selection cuts

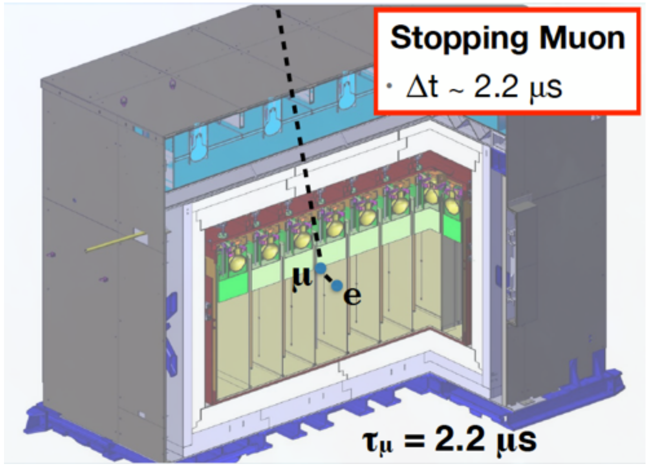
Neutrino selection



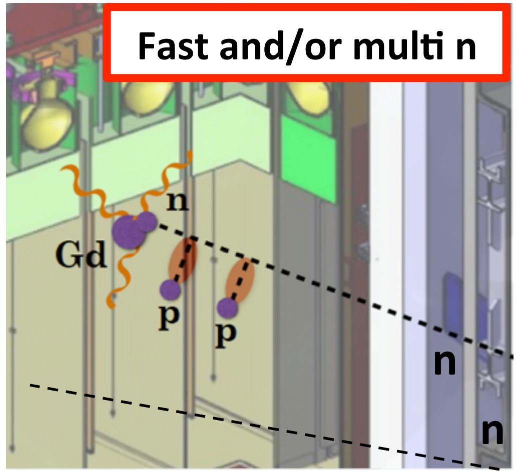
Topology cuts:

- E_{prompt} in γ-catcher < 1.1 MeV
- E_{prompt} in neighboring cell < 0.8 MeV
- $E_{delayed}$ in target > 1 MeV
- $D_{prompt\text{-}delayed}$ < 60 cm

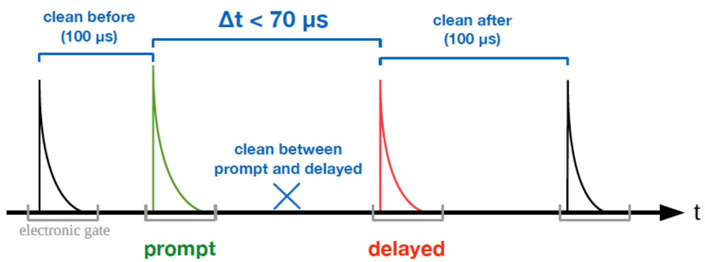
Background rejection (cosmic rays)



- Charge asymmetry per cell: Q_{max}/Q_{tot} < 0.50



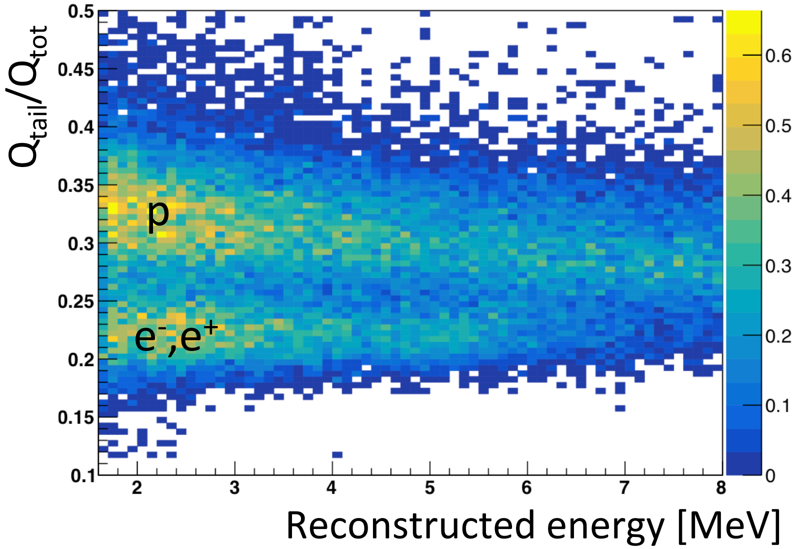
- $\Delta t_{last\text{-}\mu}$ > 100 μs
- Isolated prompt-delayed pair



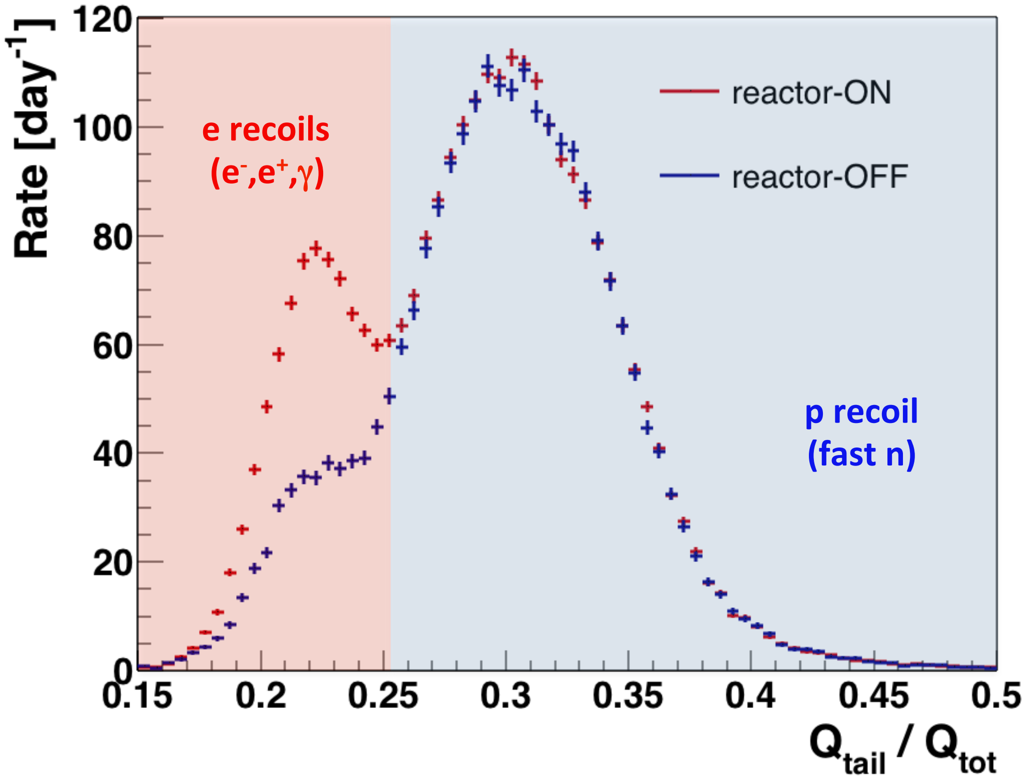
Pulse Shape Discrimination

PSD: Late charge of the light pulse / Total charge = Q_{tail}/Q_{tot}

PSD in cell 1



Projected PSD distribution of all IBD candidates in the Target

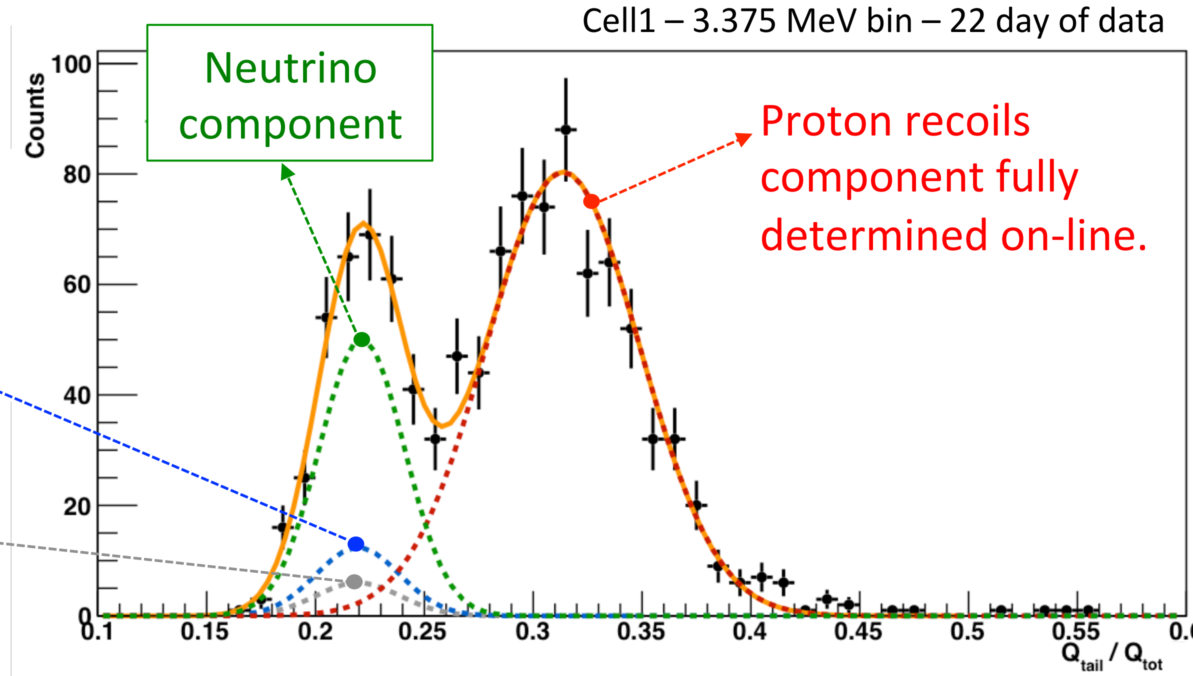


- Superposition of proton recoils for reactor On and Off periods excludes significant fast-n flux from the reactor.

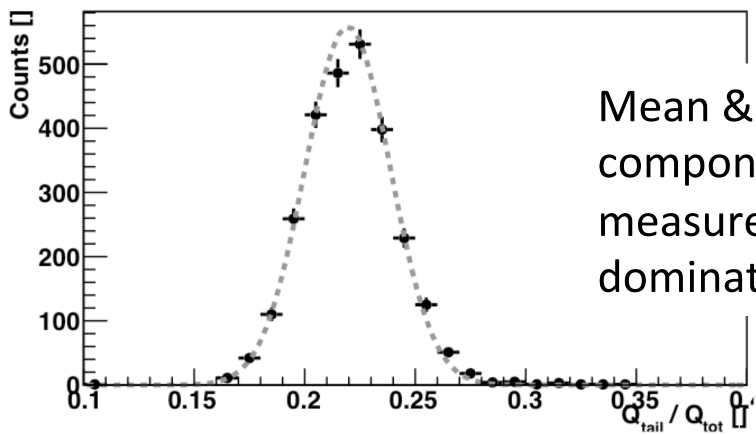
New Extraction of the Neutrino Signal

Amplitude of the electromagn. cosmic background fixed by the A_γ / A_p ratio measured during OFF periods.

Amplitude of the accidental background determined by off-time windows.

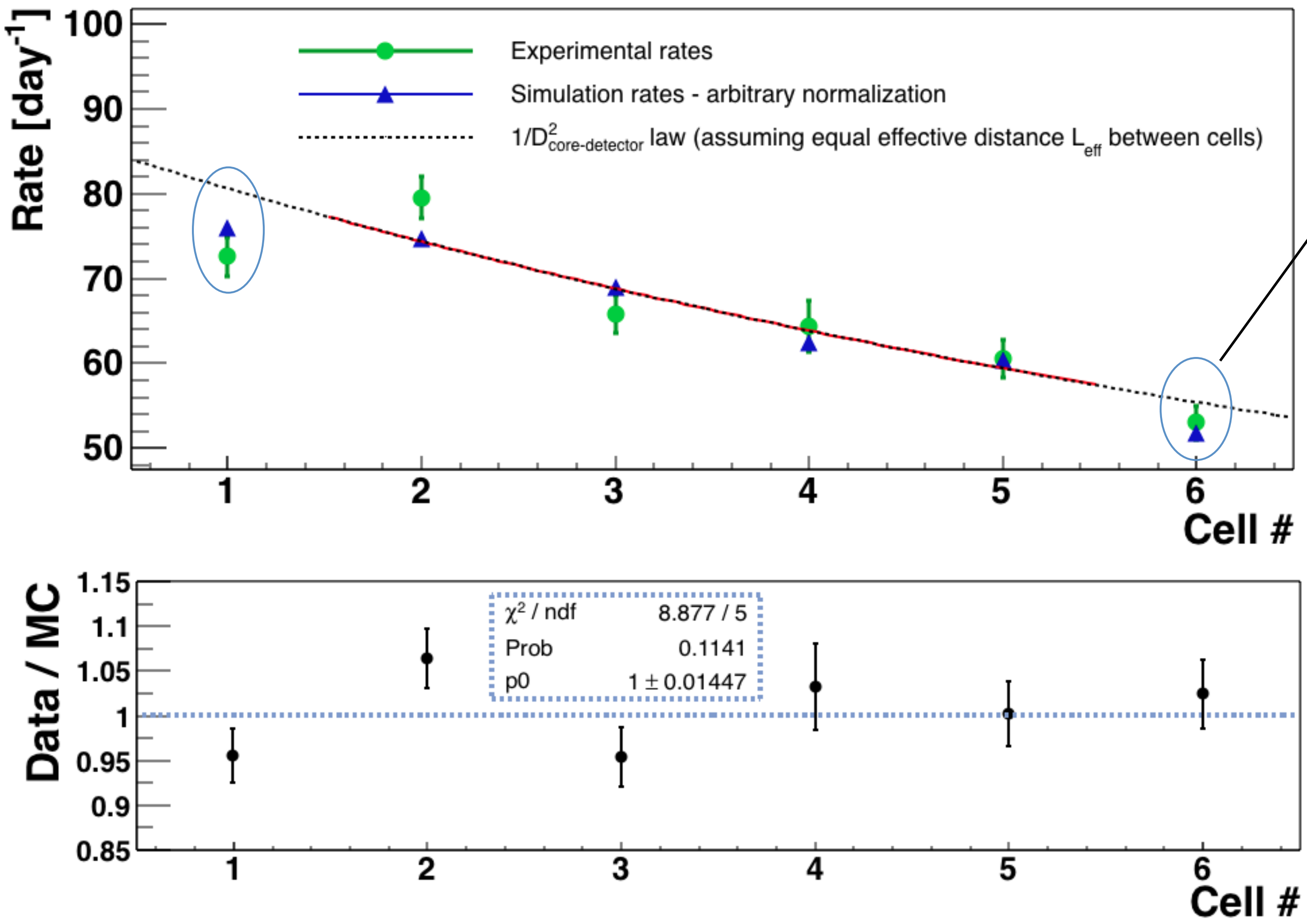


Suppresses most systematics of the usual subtraction procedure: reactor ON - reactor OFF



Mean & σ of the electromagn component accurately measured online using γ-dominated single triggers.

Check of Expected $1/D^2$ Rate Shape



6% reduced efficiency in cell 1 &6 understood as leaks of γ's from n-Gd).

MC predicts well the cell-to-cell relative variation of detected rates.

Ratio Method

One cell taken as reference → compare measured and simulated **ratios** Cell_l / Cell_{lref}

$$\chi^2 = \sum_{i=1}^{NEbins} \sum_{l=1}^{Ncells-1} \sum_{l'}^{Ncells-1} \left(R_{i,l}^{Data} - R_{i,l}^{MC}(\alpha)\right) \left[V^i\right]_{l,l'}^{-1} \left(R_{i,l'}^{Data} - R_{i,l'}^{MC}(\alpha)\right)$$
$$+ \sum_{l=1}^{Ncells} \left(\frac{\alpha_l^{NormUncor}}{\sigma_l^{NormUncor}}\right)^2 + \left(\frac{\alpha^{Escale}}{\sigma^{Escale}}\right)^2 + \sum_{l=1}^{Ncells} \left(\frac{\alpha_l^{Escale}}{\sigma_l^{Escale}}\right)^2$$

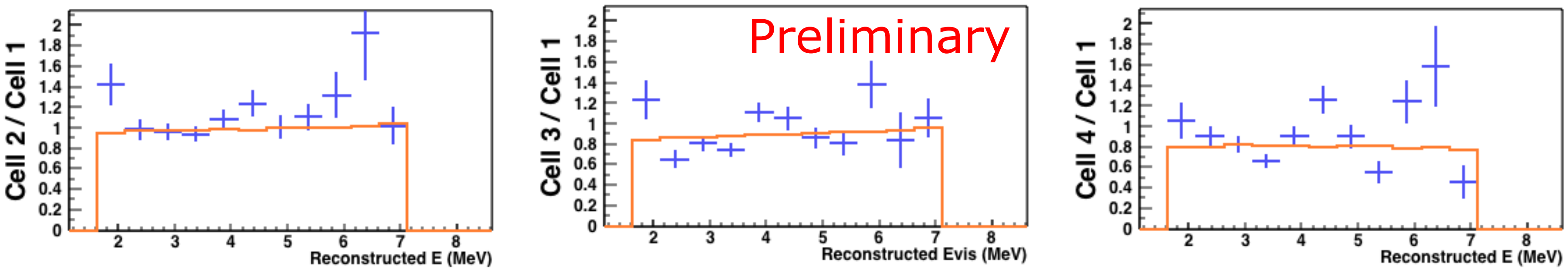
V : covariance matrix accounting for the reference cell common to all ratios.

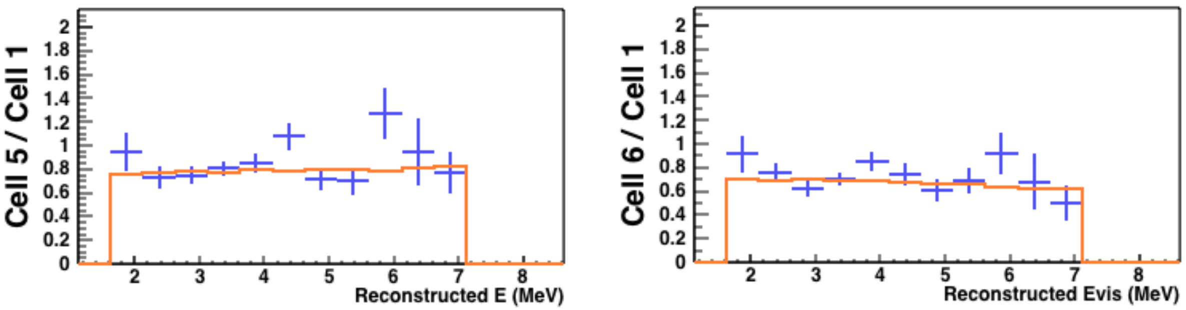
$$R_{i,l}^{Data} = \frac{Data_{i,l}}{Data_{i,lref}}; \quad R_{i,l}^{MC} = \frac{Model_{i,l}(\alpha)}{Model_{i,lref}(\alpha)}$$

Robust method, insensitive to: **- Predicted spectrum shape**
- Absolute normalization

Pull terms	Cell to cell correlated	Uncorrelated
Energy scale	0.35%	1.50%
Normalization	-	1.70% (3.40% cell 4)

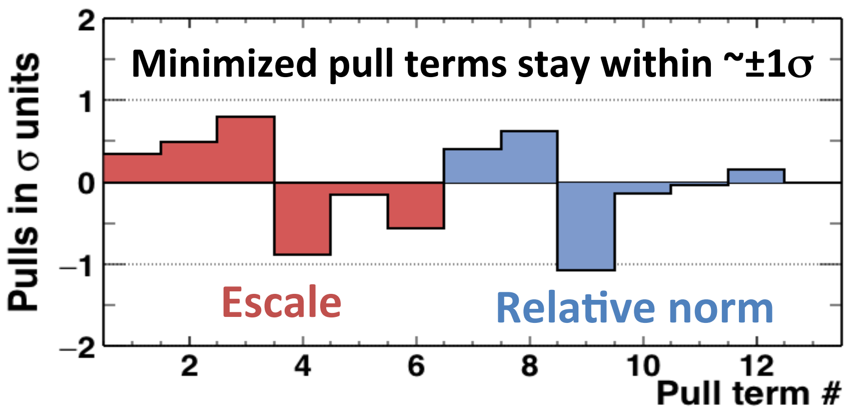
Test of No Oscillation Hypothesis



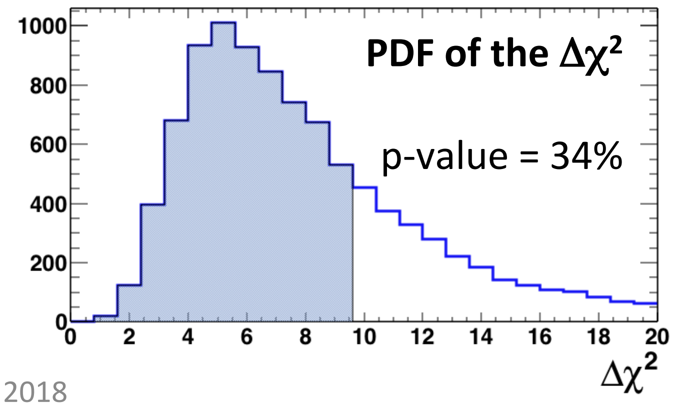


+ Measured ratios

- Non oscillated predictions

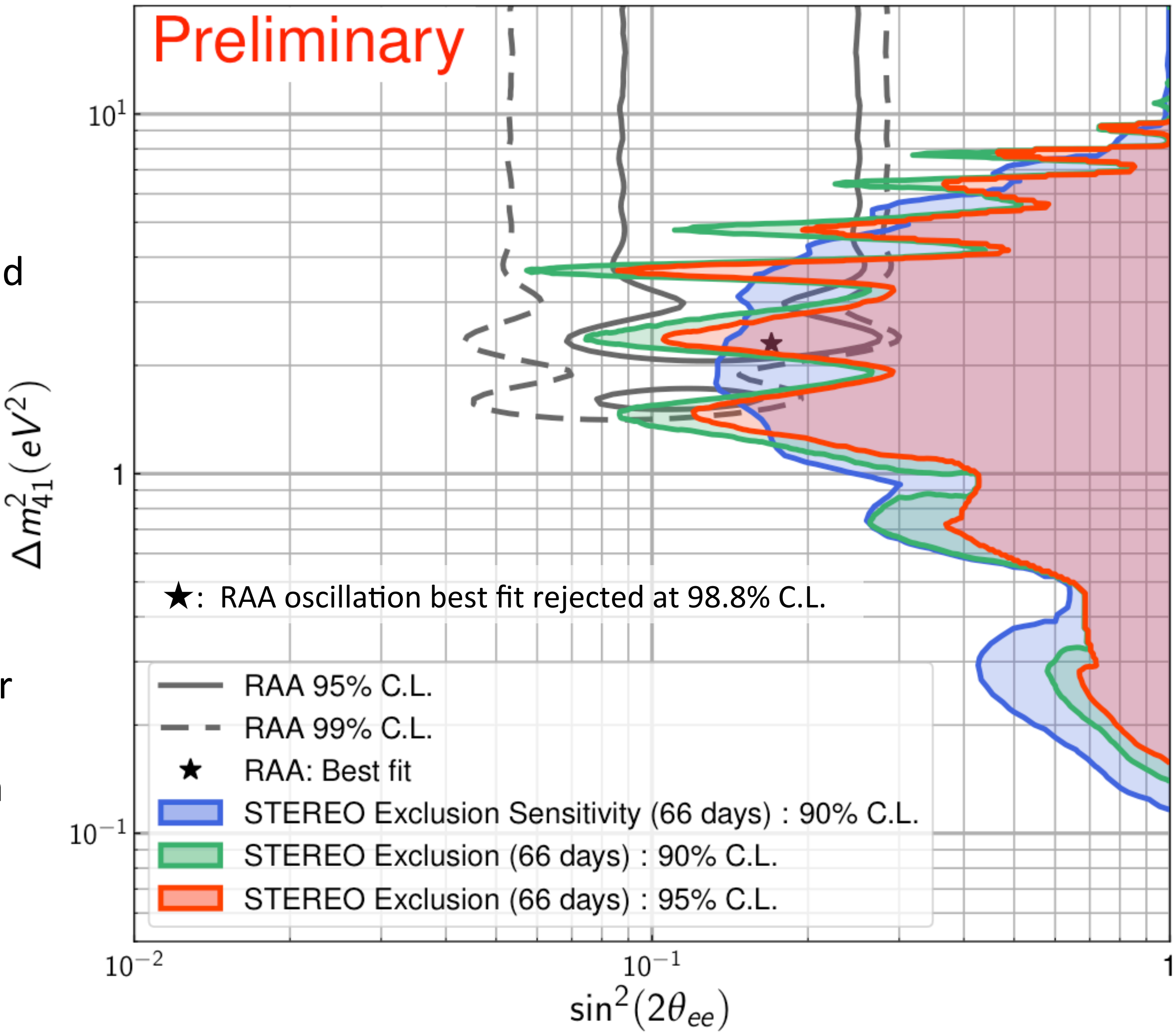


No rejection of the null hypothesis



STEREO Contours

- Raster scan approach.
- $\Delta\chi^2$ law simulated in each Δm^2 bin.
- Reject oscillation amplitudes larger that statistical fluctuations for a given C.L.



More complementary results to come

- ILL reactor has restarted, statistical accuracy of STEREO will improve soon.
- SoLid and Prospect experiments in commissioning phase.

SoLid at BR2

arXiv:1703.01683
arXiv:1802.02884v1

Phase-1 data taking started !

Detector technology: plastic scintillator (PVT) with LiF:ZnS(Ag) phosphor screens

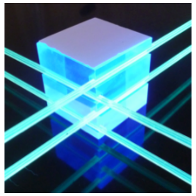
High efficiency neutron ID

PVT has excellent linearity in energy range

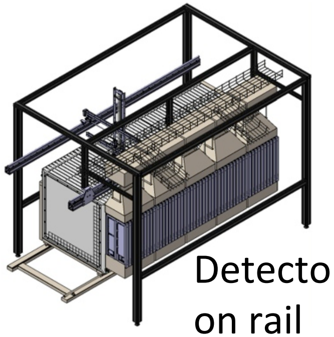
Fine segmentation 12800 cubes to isolate positron energy

50 detector planes, 1.6 tons, 3500 read out channels

Installed 6.2 m from BR2 reactor, SCK•CEN mol, Belgium

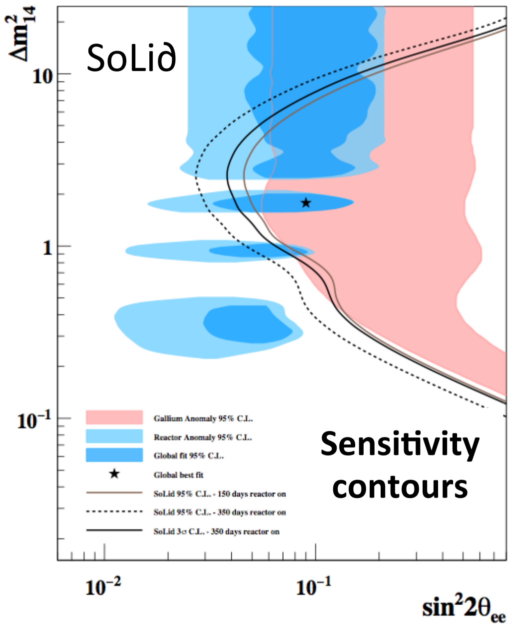


5 x 5 x 5 cm cube

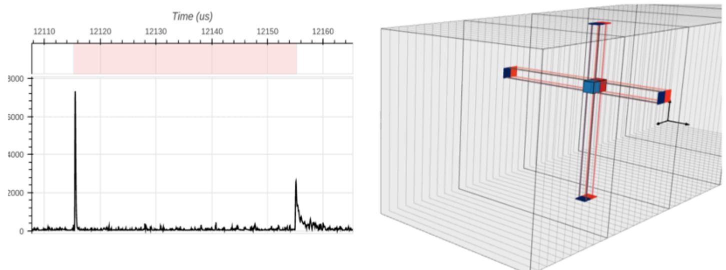


Detector on rail

Parameters	Objectives
Total mass	1.6 t
IBD efficiency	30 %
Threshold	200 - 500 keV
Anti-neutrinos	~1000 d-1
Signal/Background	~3
Energy resolution	14% à 1 MeV
Systematic uncertainty	2.5 - 4.5 %

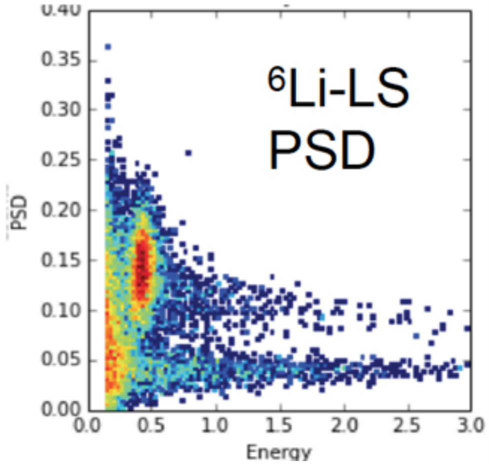


Commissioning completed succesfully in December 2017



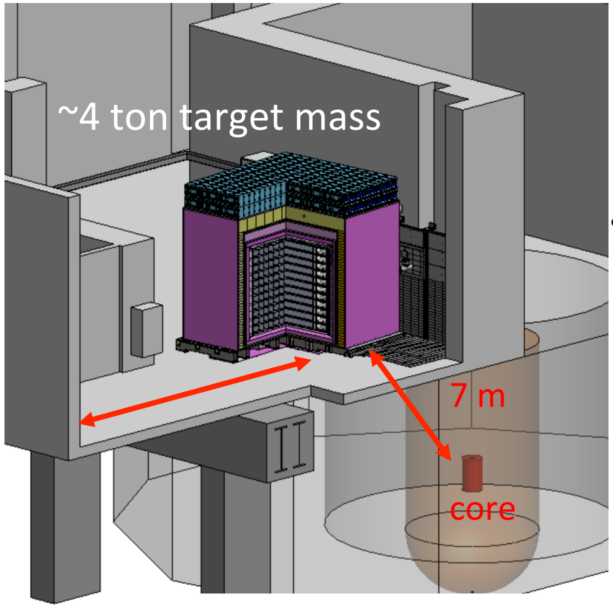
Antineutrino candidate in commissioning data

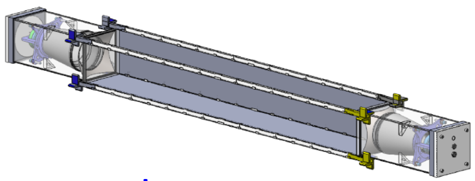
PROSPECT – HFIR@ORNL



Discriminant n-capture on ^{6}Li

Segmented, ^{6}Li-loaded Movable Detector

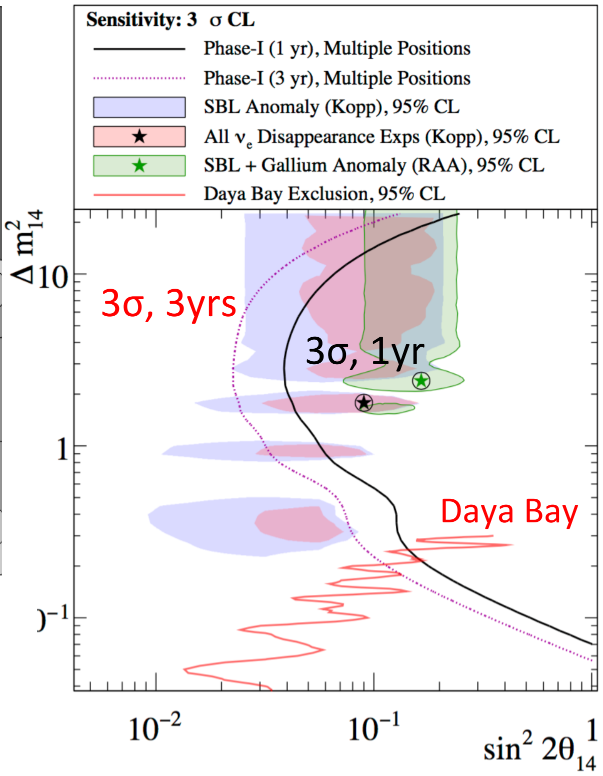




Segmented Detector

14x11 segments

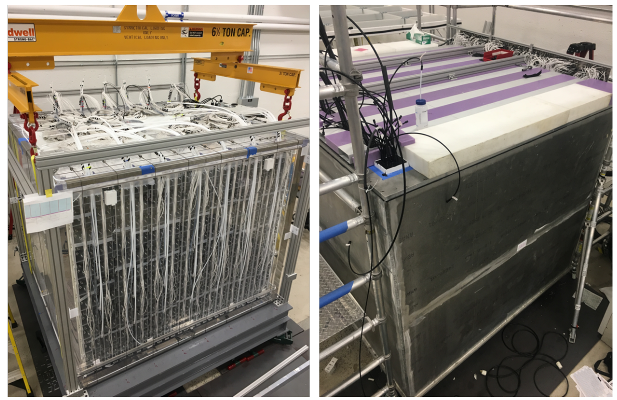
~4.5%/√E resolution



Objectives

4σ test of best fit after 1 year

>3σ test of favored region after 3 years



Detector construction complete

Installation happening now at HFIR

Online soon!

Conclusion

- STEREO demonstrates a good control of the detector response despite the difficult conditions of phase-I.
- Unique analysis features have been developed such as Data-MC comparison at the level of reconstructed energy & direct extraction of the neutrino rates, no more ON-OFF subtraction.
- The **first results using ratios of cells compatible with no oscillation**, rejects the best fit of the Reactor Antineutrino Anomaly at 98.8% C.L.
- Analysis work now focusing on the comparison to a predicted neutrino reactor spectrum for **pure ^{235}U fissions**.
- 27 k neutrinos have been detected so far – to be doubled by end of May 2018.
- **Complementary measurements** with different detection techniques should be soon available from the SoLid and PROSPECT experiments.