SoLid: why and how we search for sterile neutrinos

Céline Moortgat for the SoLid collaboration

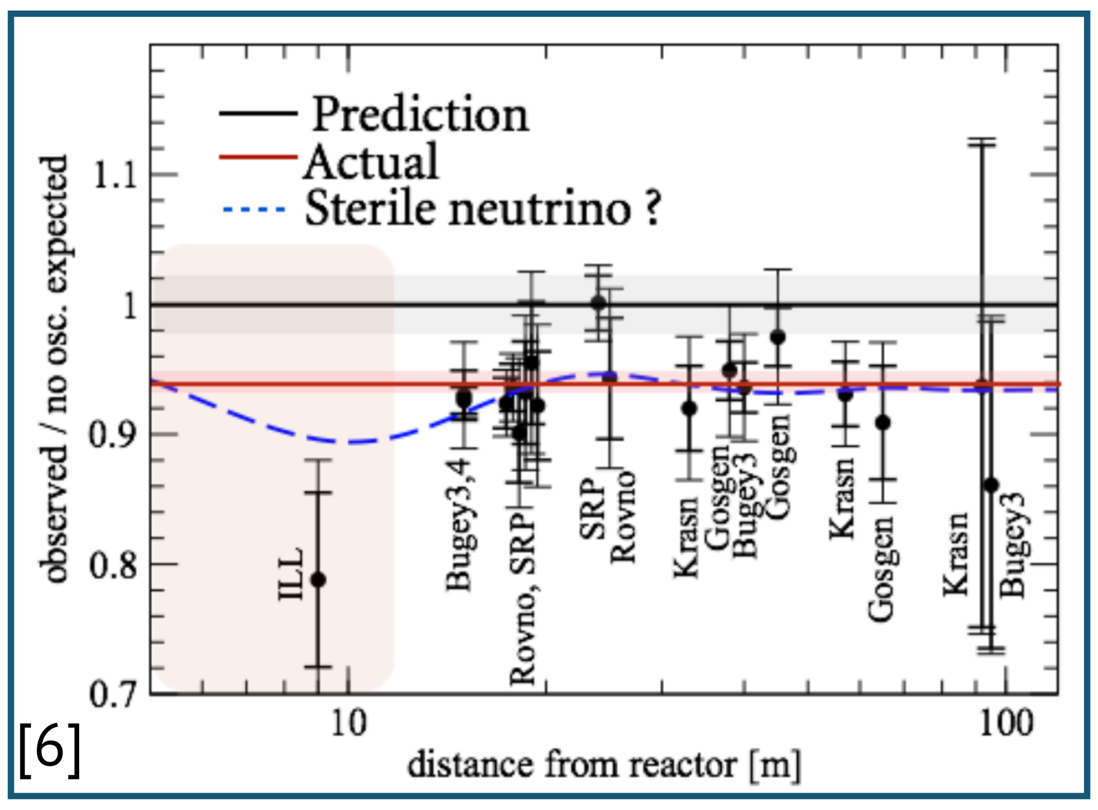
Neutrino oscillations

- Exactly 3 weakly interacting neutrino flavors (from Z boson decay)
- Neutrino flavors can oscillate into each other
  - Nobel Prize for Physics in 2015 [1]

- Well understood theory except for some anomalies:
  - LSND and MiniBooNE appearance results [2]
  - Reactor antineutrino anomaly [3] after a recent re-evaluation of antineutrino spectra [4]
  - Gallium anomaly from re-analysis of SAGE and Gallex calibration runs [5]

Reactor antineutrino anomaly

- $\overline{\nu}_e$ from reactors are not expected to oscillate at distances < 100 m
- Expect to detect the same $\overline{\nu}_e$ flux as created; but a deficit of $\overline{\nu}_e$ is observed
- "Reactor antineutrino anomaly"



[6]

Possible explanations

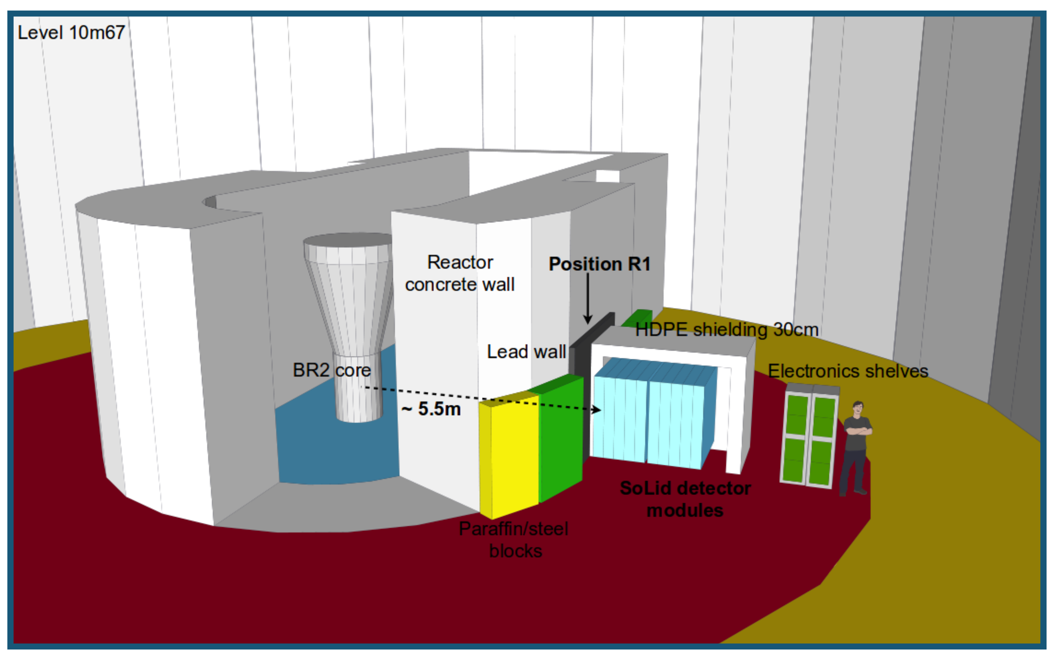
- Uncertainties on reactor $\overline{\nu}_e$ flux calculation
- Problem on the detector side
- New Physics: oscillation into new type of neutrino
  - Can not be weakly interacting: "Sterile Neutrino"
  - Only explanation to predict distance-dependent signal

SoLid at the SCK•CEN in Mol, Belgium will

- Investigate the reactor anomaly by performing oscillometric distance and energy measurements
- Measure the ^{235}U spectrum precisely to help understand the 5 MeV distortion (Daya-Bay, Double Chooz [7], Reno)

SoLid @ BR2

Search for Oscillation with a ^{6}Li Detector at the BR2 research reactor



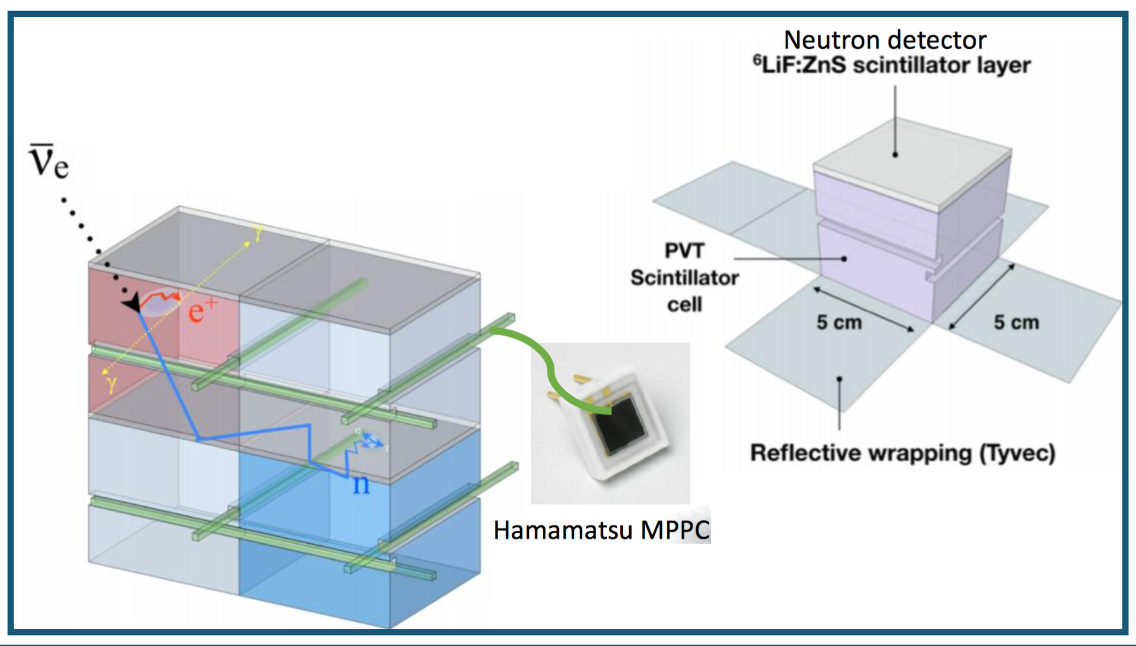
- Distance from core is 5.5 m - 10 m
- Excellent background conditions
- Small core diameter → point source behavior
- ~ 450 $\overline{\nu}_e$ interactions/tonne/day

Detector technology

Detection via inverse beta-decay (IBD)

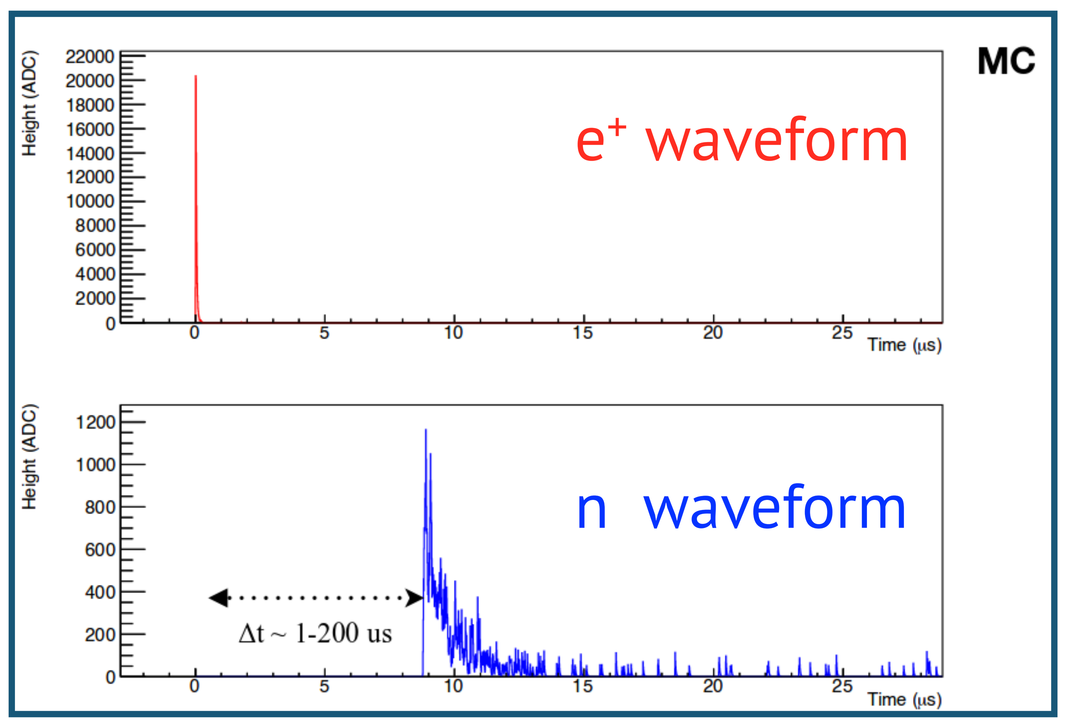
$\overline{\nu}_e + p \rightarrow n + e^+$

- e^+ interacts in PVT scintillator cube
- n captured by ^{6}LiF:ZnS(Ag) sheets:
  - $n + {}^{6}Li \rightarrow {}^{3}H + \alpha + 4.78$ MeV
  - ^{3}H and α excite ZnS followed by slow de-excitation



IBD identification

- Pulse shape discrimination to identify the particles



- Time and spatial (thanks to highly segmented detector) correlation of e^+ and n absorption signals from an IBD event

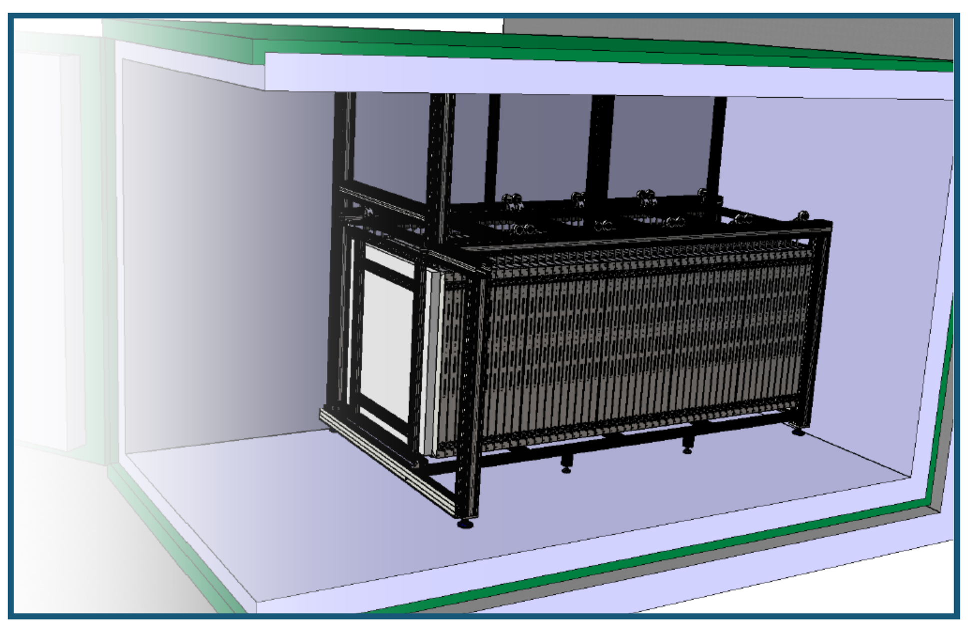
SubModule 1 prototype

Demonstrate large scale use of the detector technology

- 2304 PVT cubes in 9 planes
- ~ 288 kg prototype calibrated and commissioned at BR2 and data taking under realistic conditions
- Analyses and simulations finishing up
  - ☞ *See poster of Ianthe Michiels*

Full SoLid detector

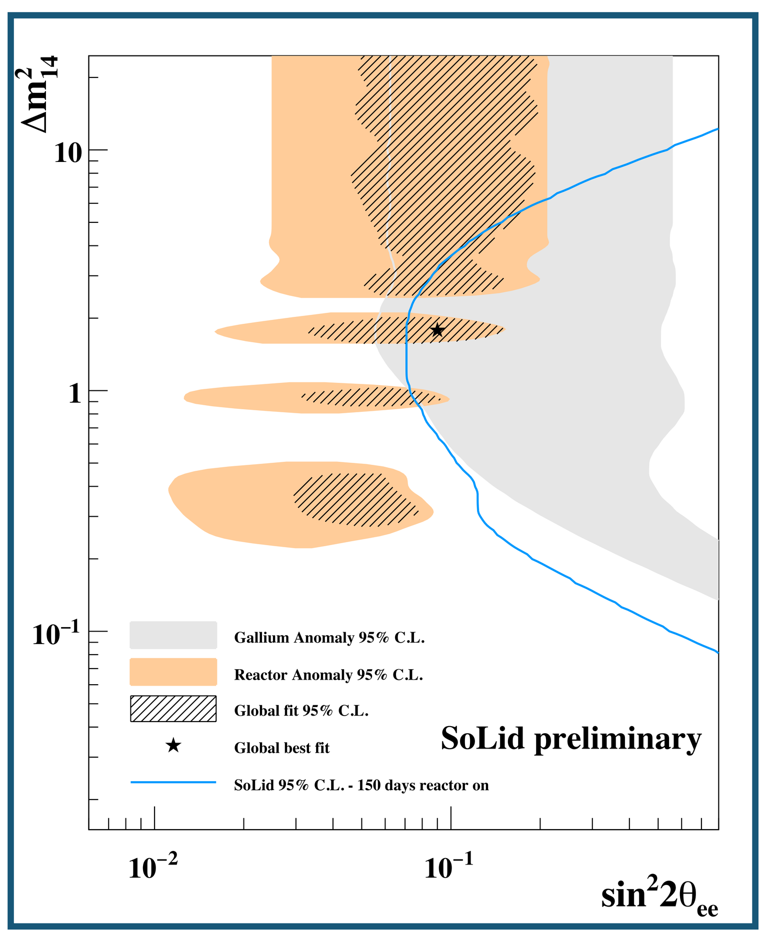
- 5 modules of 10 planes each
- 1.6 tonnes detector mass
- Doubled amount of fibers and ^{6}Li screens per plane
- Cooled container for thermal noise reduction
- Water shielding to reduce neutron background



Data taking from beginning of 2017

Outlook

- Target mass: 1.6 tonnes
- Reactor power: 60 MW
- IBD efficiency: 30 %
- S/B: 3/1
- Energy resolution: 14%/$\sqrt{E_\nu}$



[1] The Royal Swedish Academy Of Sciences, Nobel Prize in Physics 2015, nobelprize.org [2] A. Aguilar-Arevalo et al. (MiniBooNE Collaboration), Phys. Rev. Lett.102, 101802 (2009). A. Aguilar-Arevalo et al. (MiniBooNE Collaboration) Phys. Rev. Lett. 105, 181801 (2010) [3] G. Mention et al., The Reactor Antineutrino Anomaly, Phys. Rev. D 83 (2011) & K. N. Abazajian et al ., "Light Sterile neutrino: a white paper", arXiv:1204.5379 [4] T. A. Mueller et al., Improved Prediction of Reactor Antineutrino Spectra, Phys. Rev. C 83 (2011) & P. Huber,On the determination of reactor Antineutrino Spectra from nuclear reactors, Phys. Rev. C 84 [5] C. Giunti and M. Laveder, Statistical Significance of the Gallium Anomaly, Phys.Rev. C 83, 065504 (2011), arXiv:1006.3244 [6] J. Kopp et al., Sterile Neutrino Oscillations: The Global Picture, JHEP 1305:050 (2013) [7] Y. Abe et al., Improved measurements of the neutrino mixing angle θ13 with the Double Chooz detector, JHep 1410 (2014) 086

celine.moortgat@ugent.be