SoLid short baseline neutrino experiment

LPNHE seminar

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for the SoLid Collaboration

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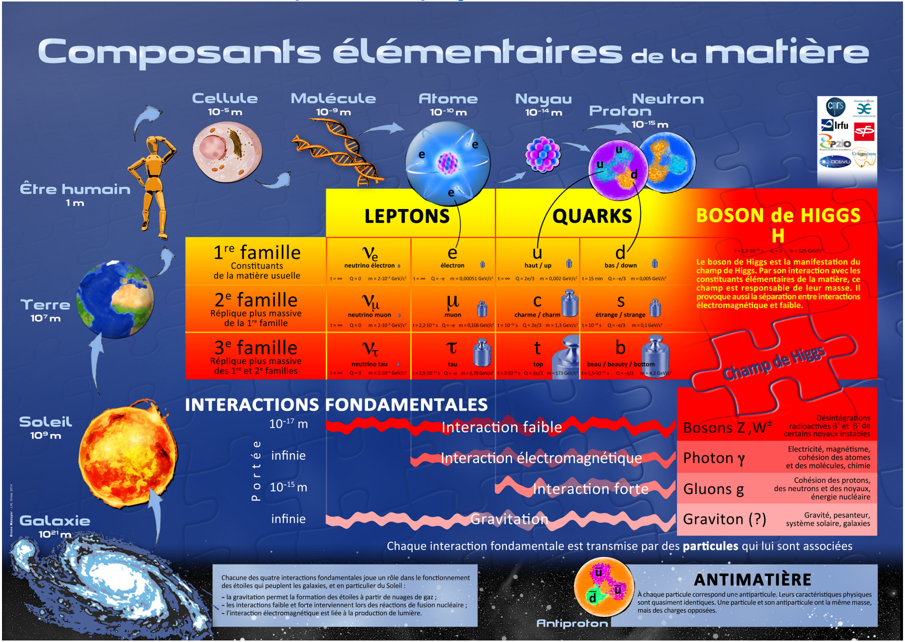
2020/01/20

Standard model of particle physics



Neutrino mixing and oscillations

B. Pontecorvo first considered neutrino oscillations $\nu \leftrightarrow \overline{\nu}$ in 1957.
(Mesonium and antimesonium, JETP 33, 549-551 - like $K^0 - \overline{K}^0$)

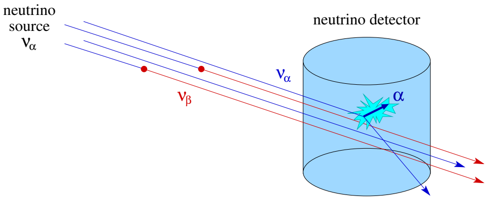
Quantum-mechanical interference since flavor eigenstates ν_α ($\alpha = e, \mu, \tau$) are superpositions of mass eigenstates ν_i $(i = 1, 2, 3)$.

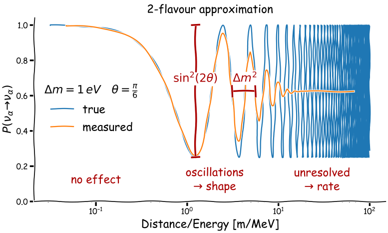
Given L and E the oscillation is dominated by one Δm^2 ($\Delta m^2_{12} \ll \Delta m^2_{32}$):

$$\begin{pmatrix} \nu_\alpha \\ \nu_\beta \end{pmatrix} = \begin{pmatrix} \cos\ \theta & \sin\ \theta \\ -\sin\ \theta & \cos\ \theta \end{pmatrix} \begin{pmatrix} \nu_i \\ \nu_j \end{pmatrix}$$

The oscillation probability can be written as:

$$P_{\nu_\alpha \to \nu_\beta}(L, E) = \delta_{\alpha\beta} - \sin^2 2\theta \sin^2 \left(1.27\ \frac{\Delta m^2\,[eV^2]\ L\,[m]}{E\,[MeV]} \right)$$

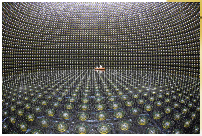


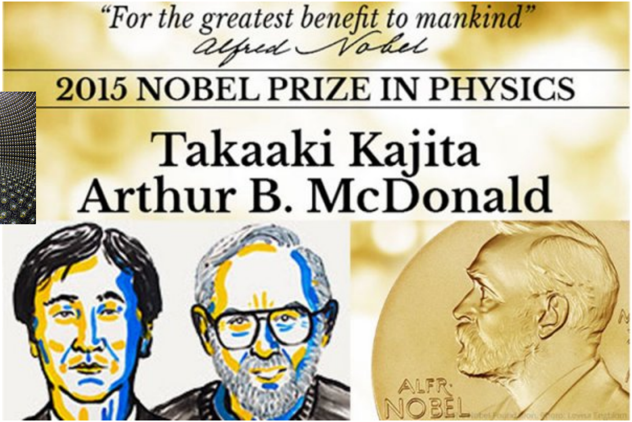


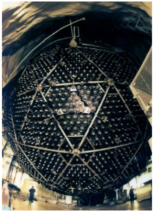
S. Böser et al., arXiv:1906.01739

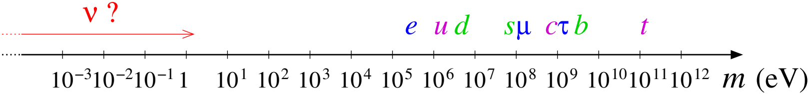
Discovered by SuperKamiokande and SNO

The Nobel Prize in Physics 2015 was awarded jointly to Takaaki Kajita and Arthur B. McDonald *"for the discovery of neutrino oscillations, which shows that neutrinos have mass"*.









Three Flavors Neutrino Mixing

3×3 neutrino mixing matrix PMNS*
(similar to CKM mixing matrix for quarks):

$$\begin{pmatrix} \nu_e \\ \nu_\mu \\ \nu_\tau \end{pmatrix} = \begin{pmatrix} c_{13}c_{12} & c_{13}s_{12} & s_{13}\ e^{-i\delta} \\ -c_{23}s_{12} - s_{13}c_{12}s_{23}\ e^{+i\delta} & c_{23}c_{12} - s_{13}s_{12}s_{23}\ e^{+i\delta} & c_{13}s_{23} \\ s_{23}s_{12} - s_{13}c_{12}c_{23}\ e^{+i\delta} & -s_{23}c_{12} - s_{13}s_{12}c_{23}\ e^{+i\delta} & c_{13}c_{23} \end{pmatrix} \begin{pmatrix} \nu_1 \\ \nu_2 \\ \nu_3 \end{pmatrix}$$

$s_{ij} = \sin\theta_{ij}$ and $c_{ij} = \cos\theta_{ij}$

*Pontecorvo, Maki, Nakagawa & Sakata

3×3 neutrino mixing parametrized by:

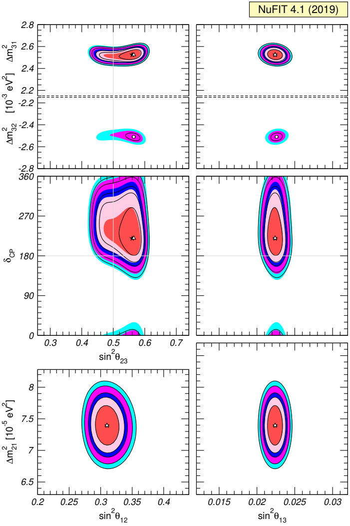
- 2 squared-mass difference: $\Delta m^2_{32},\ \Delta m^2_{21}$
- 3 mixing angles: $\theta_{12},\ \theta_{23},\ \theta_{13}$
- 1 $\mathcal{CP}$ violation phase: $\delta_{\mathcal{CP}}$
- 2 Majorana phases: $\eta_1,\ \eta_2$?

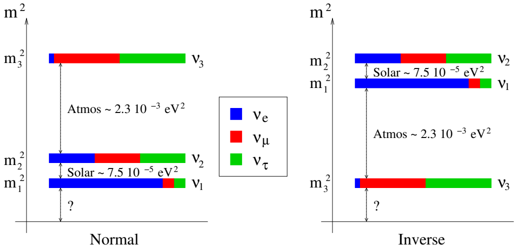
$$\begin{pmatrix} \nu_e \\ \nu_\mu \\ \nu_\tau \end{pmatrix} = \begin{pmatrix} 1 & & \\ & c_{23} & s_{23} \\ & -s_{23} & c_{23} \end{pmatrix} \begin{pmatrix} c_{13} & & s_{13}\ e^{-i\delta} \\ & 1 & \\ -s_{13}\ e^{i\delta} & & c_{13} \end{pmatrix} \begin{pmatrix} c_{12} & s_{12} & \\ -s_{12} & c_{12} & \\ & & 1 \end{pmatrix} \begin{pmatrix} \nu_1 \\ \nu_2 \\ \nu_3 \end{pmatrix}$$

atmospheric — reactor — solar

Summary of Neutrino Oscillation measurements

JHEP 01 (2019) 106 and NuFIT 4.1 (2019)





Missing: the mass ordering and θ_{23} octant, the $\mathcal{CP}$ violation phase $\delta_{\mathcal{CP}}$ and the absolute neutrino mass scale + anomalies in experimental results

Neutrino oscillations introduction

Motivations for the SoLid experiment

Short baseline reactor experiments

SoLid experiment

SoLid SM1 prototype

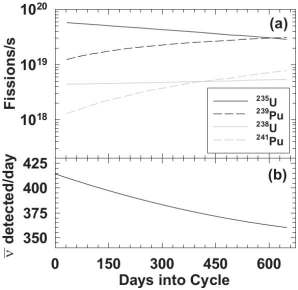
SoLid Phase 1

Anti-neutrino energy spectrum reevalutation for θ_{13}

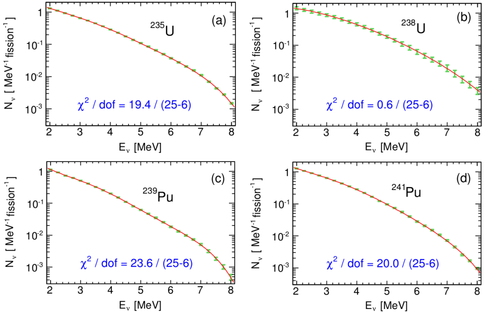
Nuclear reactors are huge isotropic sources of electron anti-neutrinos

- $\sim$200 MeV and 6 $\overline{\nu}_e$ per fission of 4 isotopes ^{235}U, ^{239}Pu, ^{238}U and ^{241}Pu
- short lived β-emitters $\rightarrow \overline{\nu}_e$ rate follows the thermal power
- $1 - 2 \times 10^{20}\ \overline{\nu}_e\ \text{s}^{-1}\text{GW}_{\text{th}}^{-1}$

N. S. Bowden et al., arXiv:0808.0698 [nucl-ex]



T. Mueller et al., Phys. Rev. C 83, 054615, 2011

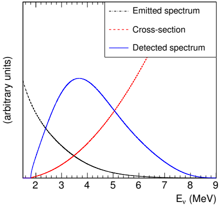


+3.5% new conversion of ILL β spectra: $\nearrow \phi_{\overline{\nu}_e}$

+1.5% off-equilibrium (long-lived isotopes): $\nearrow \phi_{\overline{\nu}_e}$

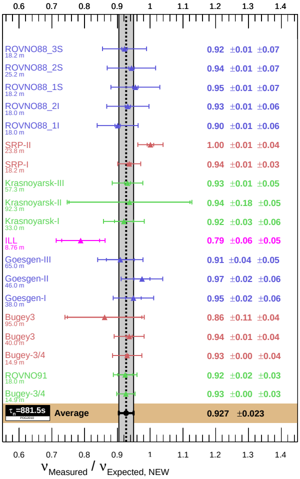
+1.5% neutron live-time τ_n (880$\pm$1 s): $\nearrow \sigma_{\text{IBD}}$

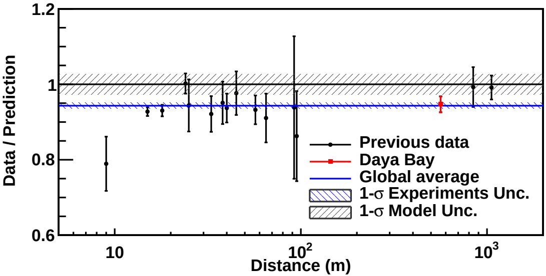
$$\text{IBD: } \overline{\nu}_e + p \rightarrow e^+ + n$$



Reactor anti-neutrino anomaly (RAA)

This reevalutation of the anti-neutrinos reactor spectrum for reactor experiments → ∼ 6.5 % deficit in short baseline experiments





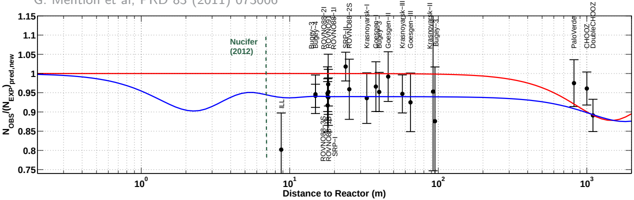
G. Mention et al, PRD 83 (2011) 073006
K. N. Abazajian et al., arXiv:1204.5379
F. P. An et al., Phys. Rev. Lett. 116, 061801 (2016)

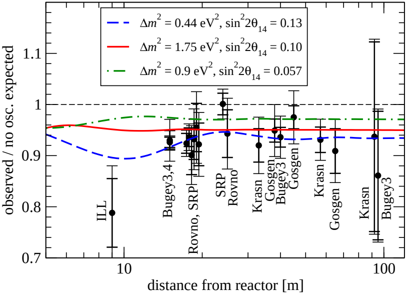
Research reactors have the thermal power by fission of $^{235}U > 90$ %

Possible explanation: oscillation to sterile neutrino ν_s

The sterile neutrino is a neutral lepton not sensitive to weak interaction:
SM right-handed singlet which can have in principle any mass
Can couple to active neutrinos through Lagrangian mass term

G. Mention et al, PRD 83 (2011) 073006



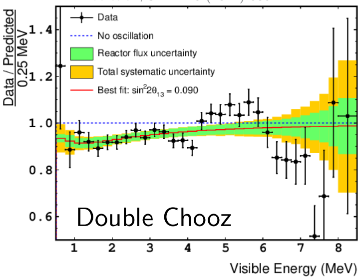


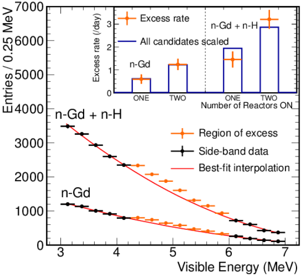
J. Kopp et al., JHEP 1305:050, 2013

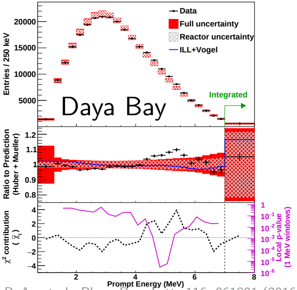
Distortion of anti-neutrino spectrum (RSA)

All 3 θ_{13} reactor experiments observes an excess between 4 and 6 MeV

Y. Abe et al., JHEP 10 (2014) 086

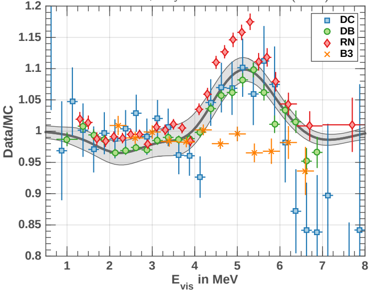






F. P. An et al., Phys. Rev. Lett. 116, 061801 (2016)

G. Mention et al., Physics Letters B 773 (2017)



Radioactive calibration sources anomaly

Calibration of the gallium Solar neutrino experiments: SAGE et GALLEX

Sources ν_e (EC) :

$$e^- + {}^{51}\text{Cr} \rightarrow \nu_e + {}^{51}\text{V}$$

$E_\nu \sim 0.75$ MeV

$$e^- + {}^{37}\text{Ar} \rightarrow \nu_e + {}^{37}\text{Cl}$$

$E_\nu \sim 0.81$ MeV

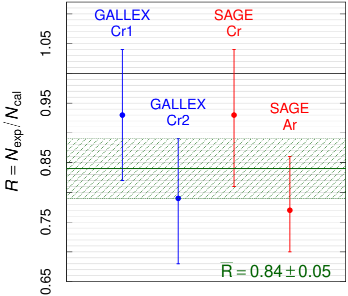
Detection :

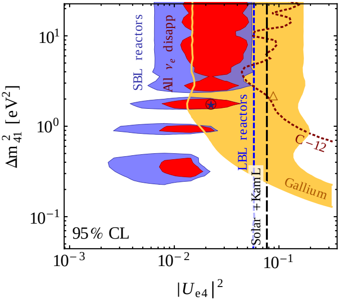
$$\nu_e + {}^{71}\text{Ga} \rightarrow e^- + {}^{71}\text{Ge}$$

Active to sterile neutrino oscillation hypothesis: compatible with the parameters of the reactor anomaly

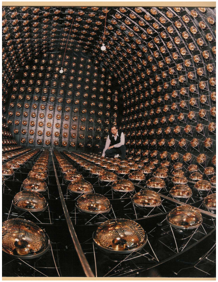
J. Kopp et al., JHEP 1305:050, 2013

C. Giunti et al., Phys. Rev. D 88, 073008 (2013)





Accelerator neutrinos anomaly



LSND 167 t LS

(DAR) $\overline{\nu}_\mu \rightarrow \overline{\nu}_e$

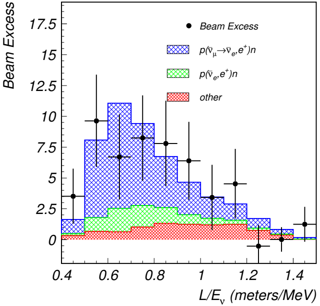
$\overline{\nu}_e\ p \rightarrow e^+\ n$

L $=$ 30 m

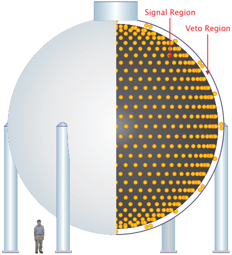
$E_\nu \in [20 - 200]$ MeV

$3.8\sigma\ \overline{\nu}_e$ excess

A. Aguilar et al.,
Phys. Rev. D64 (2001) 112007



MiniBooNE Detector



MiniBooNE 806 t LS

$\nu_\mu \rightarrow \nu_e$ et $\overline{\nu}_\mu \rightarrow \overline{\nu}_e$

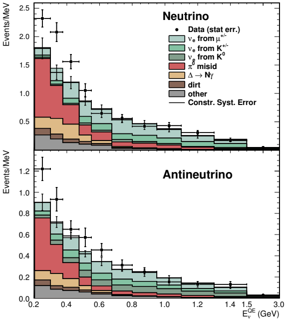
L $=$ 540 m

$E_\nu \in [0.2 - 3]$ GeV

$E_{LSND} > 475$ MeV

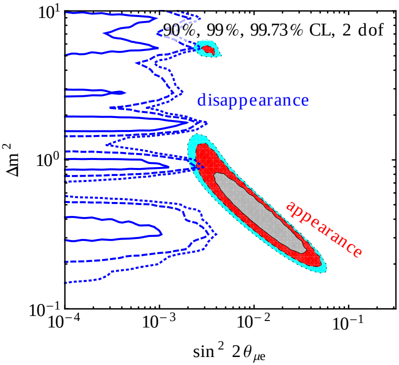
$3.4\sigma\ \nu_e$ et $2.8\sigma\ \overline{\nu}_e$ excess

A. A. Aguilar-Arevalo et al., Phys. Rev. Lett. 102 (2009) 101802
Phys. Rev. Lett. 103 (2009) 111801

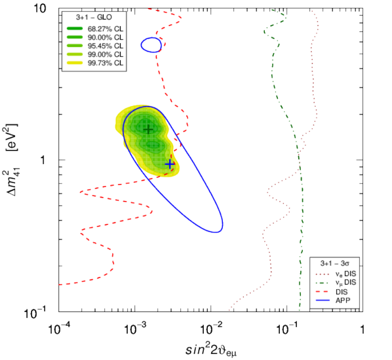


Global fit of anomalies

3+1 model of active and light sterile neutrinos $\sim$ 1 eV



J. Kopp et al., JHEP 1305:050, 2013



C. Giunti et al., Phys. Rev. D 88, 073008 (2013)

Tension between apparition experiments (LSND and MiniBooNE) & disappearance (reactor and Gallium)

Low energy excess of MiniBooNE can't be explained by sterile neutrinos even with 1+3+1 ou 3+2

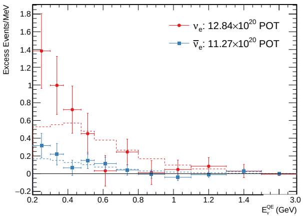
Update on MiniBooNE results (2018)

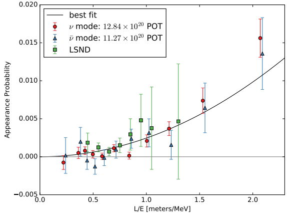
Almost doubled the neutrino mode statistics since first publication

Total ν_e CCQE event excess of 460.5 ± 99.0 events (4.7σ)

Combined with LSND the significance reaches 6.0σ excess

Phys. Rev. Lett. 121, 221801 (2018)

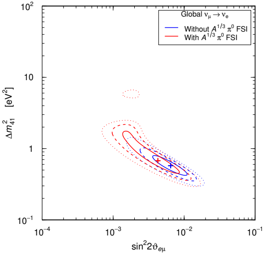




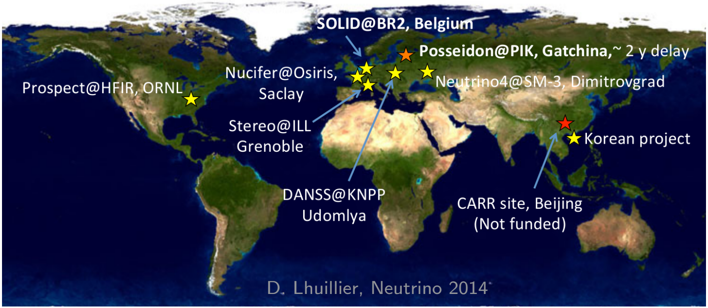
New analysis of the low-energy excess by C. Giunti et al. taking into account the additional background of photons from $\Delta^{+/0} \to N\gamma$ decay

Reduces the significance to 3.3σ and may lead towards a solution of the appearance-disappearance tension (smaller active-sterile neutrino mixing)

C. Giunti et al, arXiv:1912.01524



Reactor anti-neutrino projects

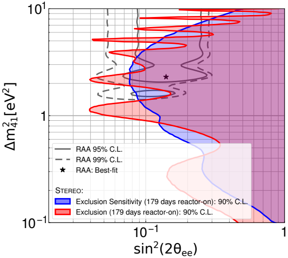


Experiments	**Techno**	**P** [MW_{th}]	$\mathbf{M_{target}}$ [t]	**L** [m]	**Depth** [m.w.e.]
Nucifer (Fr)	LS-Gd	70	0.8	7	13
Poseidon (Ru)	LS-Gd	100	$\sim$3	5 - 8	$\sim$15
Stereo (Fr)	LS-Gd	57	1.75	8.8 - 11.2	18
Neutrino-4 (Ru)	LS-Gd	100	1.5	6 - 12	$\sim$10
Prospect (US)	LS-^{6}Li	85	4	7 - 9	1
DANSS (Ru)	PS-Gd	3000	0.9	9.7 - 12.2	50
Hanaro (Ko)	PS-Gd/^{6}Li	30 - 2800	$\sim$ 1	6	qqs
SoLid (UK/B/Fr/US)	PVT-^{6}LiF:ZnS	45 - 80	2.88	5.5 - 12	10

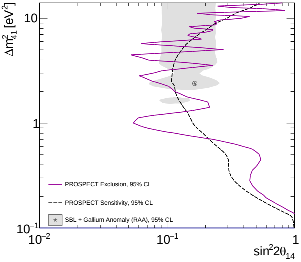
Recent reactor results

Three experiments have produced oscillation contours and energy spectra: STEREO (179 ON + 235 OFF), PROSPECT (33 d ON) and Neutrino-4

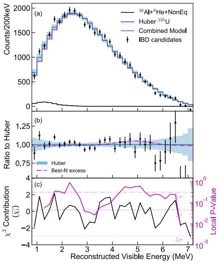
STEREO arXiv:1912.06582



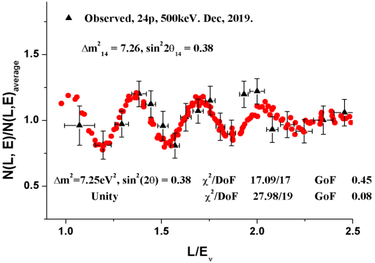
PROSPECT arXiv:1806.02784



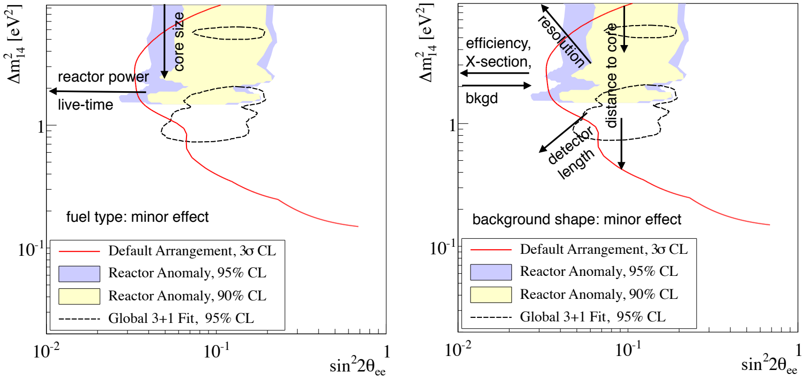
PROSPECT arXiv:1812.10877



Neutrino-4 arXiv:1809.10561



Experimental parameters for reactor experiments



K. M. Heege et al., Phys Rev D.87.073008, arXiv:1212.2182

Anti-neutrino detection through inverse beta decay (IBD):

$$\overline{\nu}_e + p \rightarrow e^+ + n \qquad (E_{\overline{\nu}_e} > 1.805 \text{ MeV})$$

Two techniques to sign the IBD events by the neutron detection:

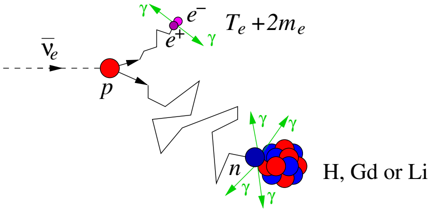
$$n + Gd \rightarrow Gd + N\gamma \qquad n + {}^6Li \rightarrow {}^3H + \alpha$$

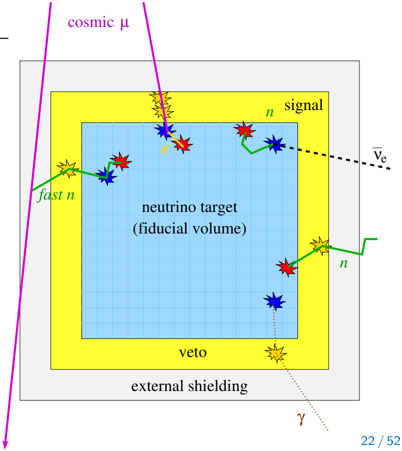
$$E_{N\gamma} = 8 \text{ MeV} \qquad E_{{}^3H+\alpha} = 4.78 \text{ MeV}$$

Backgrounds for short baseline reactor experiments

Reactor induced and shallow depth cosmic rays backgrounds

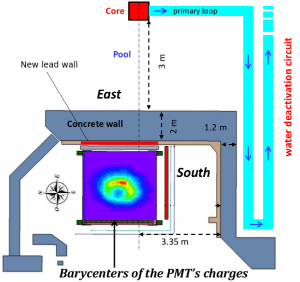
	Accidental	Correlated
e^+-like	reactor γ or radioactivity	fast n (μ-cosmic)
n-like	n reactor or radioactivity (α,n) spallation n (μ-cosmic)	same n thermalised





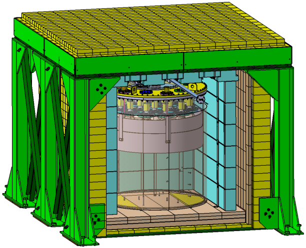
Difficulty of reactor backgrounds

Example of Nucifer at Osiris Saclay (2012-2015)

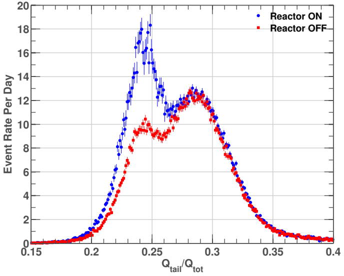


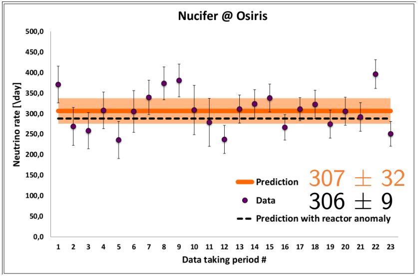
$$L = 7\ \text{m}$$
$$P = 70\ \text{MW}_{\text{th}}$$
$$V = 850\ \text{L}$$

arXiv:1509.05610



	Accidentals (d^{-1})	Correlated (d^{-1})
Reactor OFF	68.5 ± 0.1	1133.9 ± 3.4
Reactor ON	3332.8 ± 0.5	1400.3 ± 5.9





The SoLid Collaboration

Spokesperson: A. Vacheret (ICL)
Analysis coordinator: F. Yermia (Subatech)
Technical coordinator: N. van Remortel (Antwerpen Univ.)

BR2 reactor at Mol Belgium

Compact research reactor

ϕ 50 cm - h 90 cm

93 % de ^{235}U

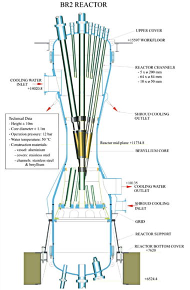
P = 60-70 MW_{th}

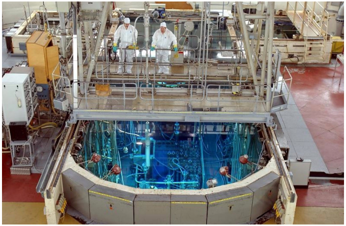
$\sim 1 \times 10^{19}\ \overline{\nu}_e/s$

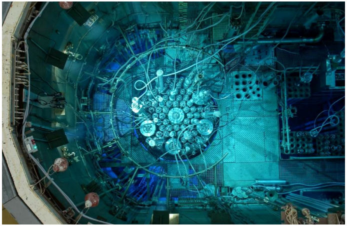
150 days/y

$\sim$ 1 month cycles

isotopes production, test of materials...







SoLid at BR2

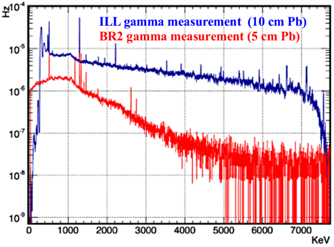
SoLid at the reactor core level

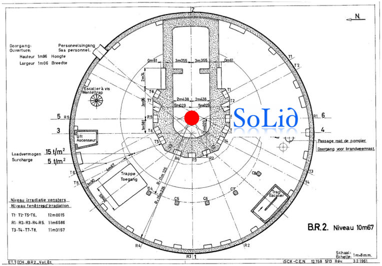
Detector from 5.5 to 10 m

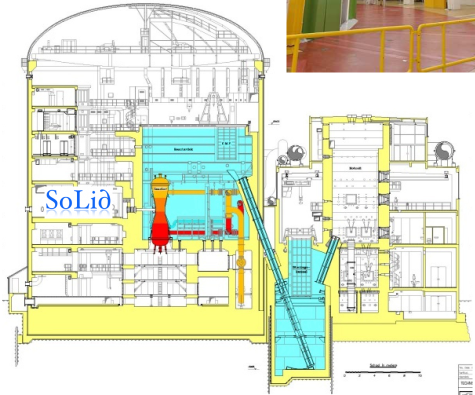
No surrounding experiments

Low neutron and gamma fluxes

Overburden 10 m.w.e.







SoLid principle

JINST 12 (2017) no.04, P04024
arXiv:1703.01683

IBD in PVT scintillator

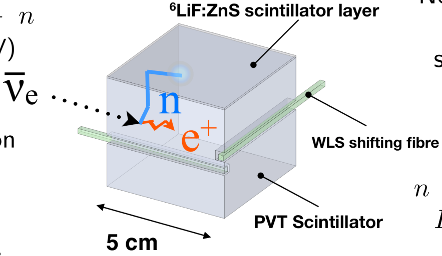
$\overline{\nu}_e + p \rightarrow e^+ + n$

$(E_{\overline{\nu}_e} > 1.805$ MeV$)$

High segmentation
5×5×5 cm^3

IBD localization

Background rejection

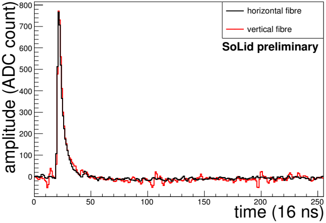


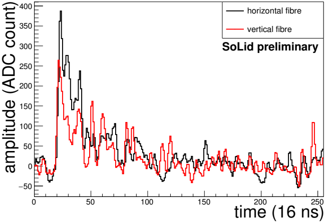
Neutron capture on ^{6}Li of the ^{6}LiF:ZnS scintillator (250 µm)

$n + {}^6Li \rightarrow {}^3H + \alpha$

$E_{^3H+\alpha} = 4.78$ MeV

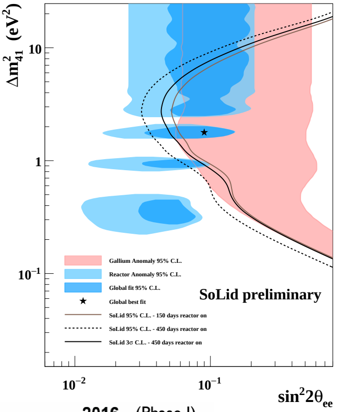
Pulse shape analysis to distinguish PVT and ZnS signals (AmBe run)



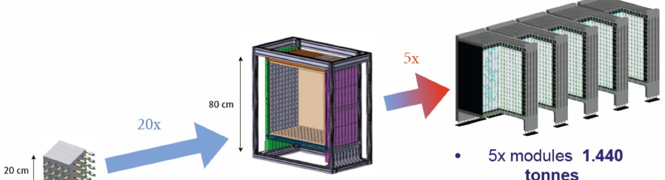


SoLid experimental parameters

parameters	objectives
total mass	1.6 t
$\overline{\nu}_e$ interactions	$\sim$ 1200 d^{-1}
IBD efficiency	$\sim$30 %
closest approach	6.2 m
signal/background	$\sim$1
energy resolution	14 % @ 1 MeV
spatial resolution	5 cm
systematic uncertainty	2.5 - 4.5 %



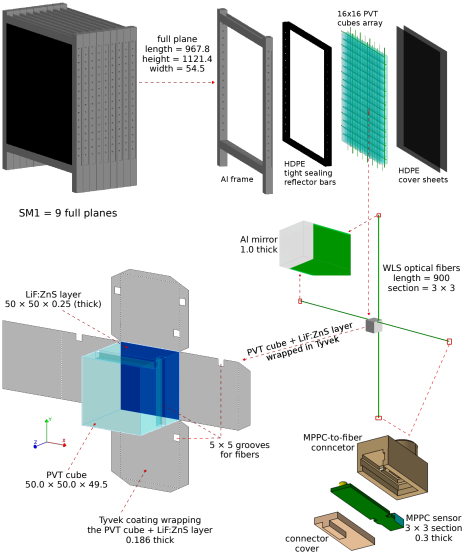
2013 **2014-2015** **2016** (Phase I)

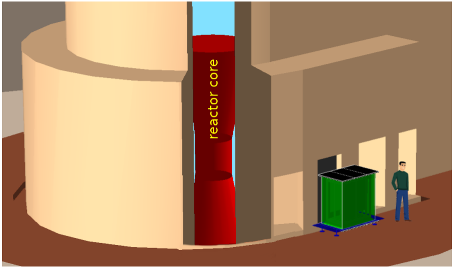


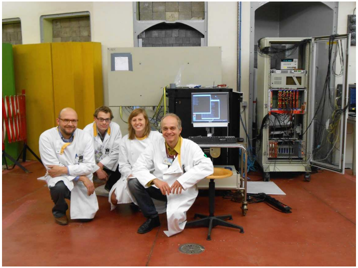
- NEMENIX **8kg**
  64 voxels, 32 chan.
- SoLid Module 1 (SM1)
  288kg
  9 Detector planes
  2304 voxels, 288 chan.
- 5x modules **1.440 tonnes**
  11520 voxels, 1920 chan.
  needs 2-3 tonnes for SoLid

SM1 prototype detector

JINST 13 (2018) no.05, P05005
arXiv:1802.02884





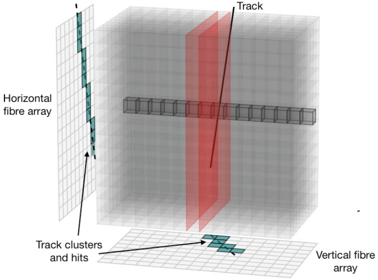


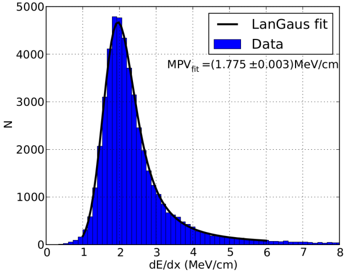
SM1 prototype calibrations

JINST 13 (2018) no.05, P05005
arXiv:1802.02884

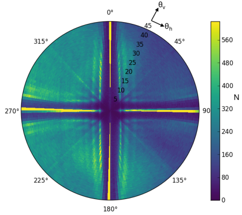
Muons are used to calibrate the SM1 module by fitting the tracks and adjusting dE/dx distributions

13 PA/MeV/fiber - $\sigma_E \approx 20$ % @ 1 MeV

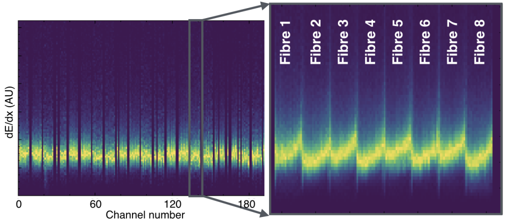




angular distribution



attenuation along fiber



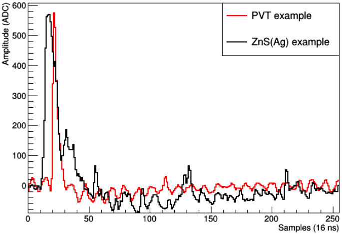
SM1 neutron identification

JINST 13 (2018) no.05, P05005
arXiv:1802.02884

Pulse shape discrimination of neutrons signals and EM signals

Electronics issues:
periodic noise, glitches, undershoot...

Increased threshold 6.5 PA
$\rightarrow$ strongly reduced neutron efficiency

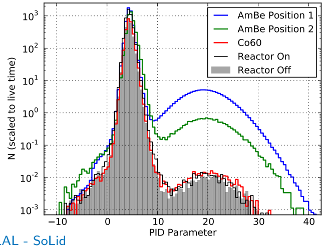


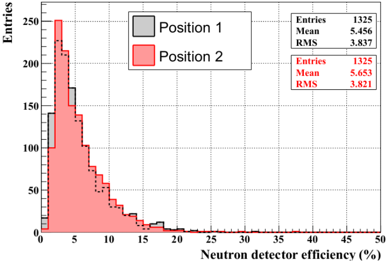
Neutron detection efficiency: $\boldsymbol{\epsilon_n = \epsilon_{Li} \times \epsilon_{det}}$

$\epsilon_{Li} = 52.01 \pm 0.53 \text{ (stat)} \pm 3.06 \text{ (syst) } \%$ (MC)

$\epsilon_{det} = 5.51 \pm 0.02 \text{ (stat)} \pm 1.21 \text{ (syst) } \%$ (calib)

$\boldsymbol{\epsilon_n = 2.87 \pm 0.65 \ \%}$



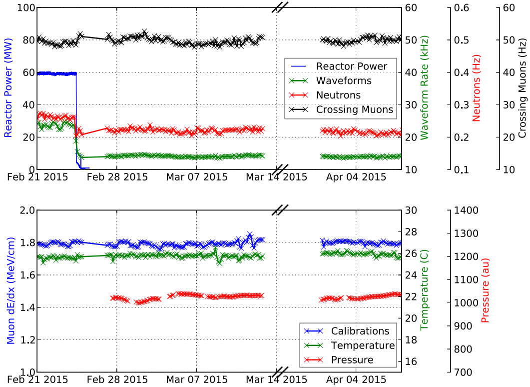


JINST 13 (2018) no.05, P05005
arXiv:1802.02884

SM1 data taking 2015

At the end of February 2015 the reactor was shut down for a 1.5 year-long overhaul of its Beryllium fuel core matrix

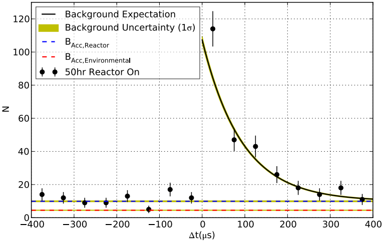
Period	Dates	Exposure Time (h)
Reactor ON	00:00 21st Feb to 08:00 24th Feb	50.91
Reactor OFF	00:00 27th Feb to 00:00 13th Mar, and 00:00 27th Mar to 00:00 11th Apr	525.51
	Exposure time ratio (ON/OFF)	0.0969

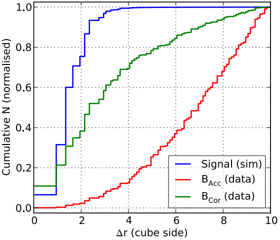


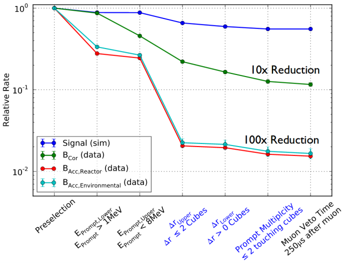
SM1 backgrounds and IBD analysis

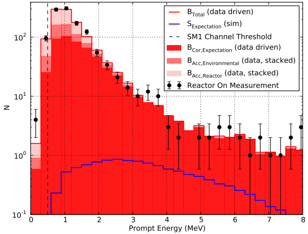
JINST 13 (2018) no.05, P05005
arXiv:1802.02884

The spatial segmentation (unique feature of the SoLid) is a powerful tool in reducing both accidental and time-correlated backgrounds









Neutrino oscillations introduction

Motivations for the SoLid experiment

Short baseline reactor experiments

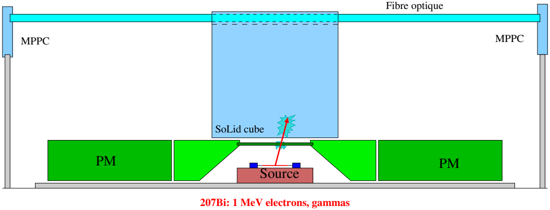
SoLid experiment

- SoLid SM1 prototype
- SoLid Phase 1

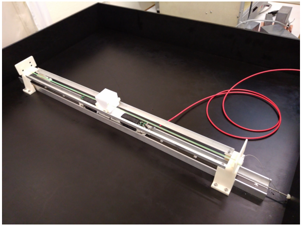
LAL calorimeter test bench

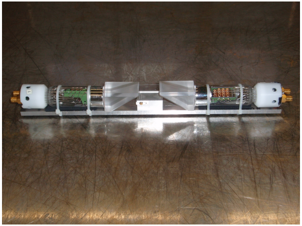
JINST 13 (2018) no.09, P09005
arXiv:1806.02461

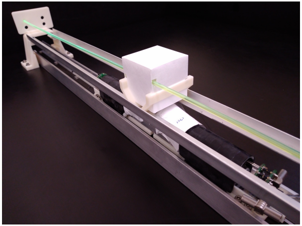
We developed a test bench for PVT scintillator (neutrino target) to investigate improvements on light collection for the next SoLid phase



- PVT production
- number of fibers and configuration
- fiber type
- light collection and interfaces
- ZnS absorption
- calibrations e^-, γ
- ...





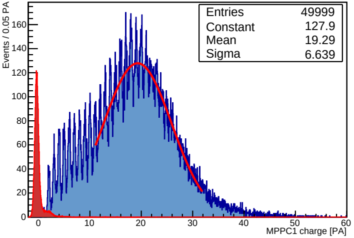


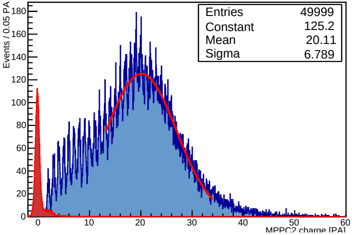
Unique test bench with peaked signal & systematic uncertainty < 5 %

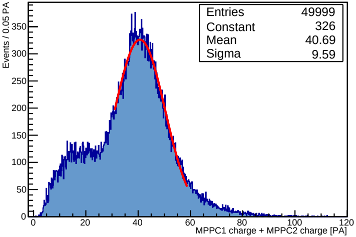
JINST 13 (2018) no.09, P09005
arXiv:1806.02461

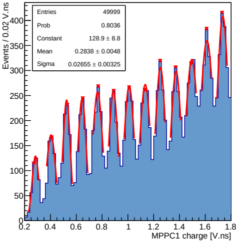
Scintillator test bench analysis

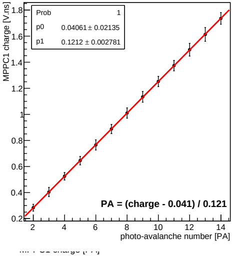
Analysis and calibration of the 2 MPPCs signals











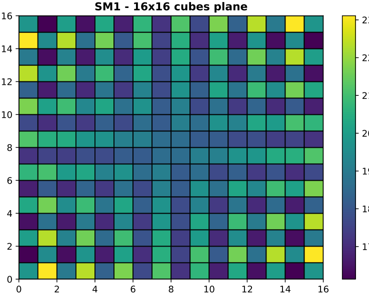
Scintillator test bench results

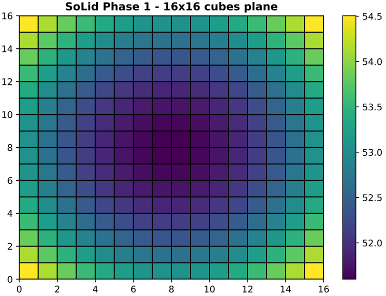
JINST 13 (2018) no.09, P09005
arXiv:1806.02461

SM1 prototype: 24 PA/MeV - $\sigma_E/E \sim 20\%/\sqrt{E}$ with 2 single-clad fibers, 2 MPPCs, aluminium mirrors and 1 ZnS screen per cube

We obtained a factor 2.8 improvement in the light yield and the plane uniformity is expected to be 6 % between the most extreme cubes

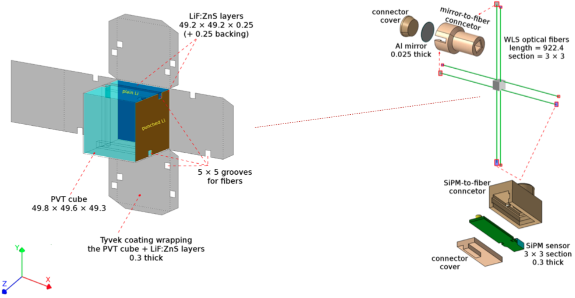
SoLid phase 1: light yield of 52 $\pm$ 2 PA/MeV - $\sigma_E/E < 14\%/\sqrt{E}$ with 4 multi-clad fibers, 4 MPPCs, thicker Tyvek, aluminised mylar mirrors and 2 ZnS screens

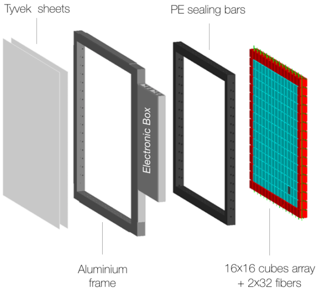


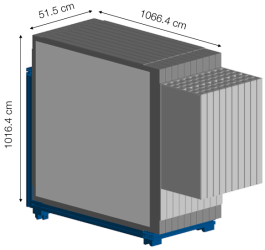


SoLid detector design

Paper soon released







10 planes module

SoLid detector construction

Paper soon released

December 2016
STARTED CONSTRUCTION

JINST 12 P04024

November 2017
DETECTOR SHIPMENT & INSTALLATION AT BR2

December 2017
DETECTOR COMMISSIONING AT BR2 WITH 4 MODULES

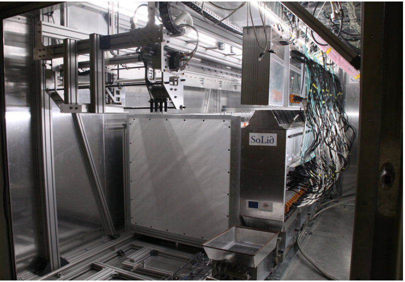
JINST 13 P05005

April 2018
START DATA TAKING WITH FULL PHASE I DETECTOR

JINST 13 P09005

JINST 14 P02014

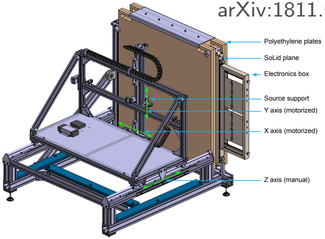
Today
ANALYSIS OF 6 REACTOR CYCLES

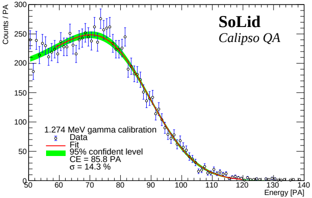


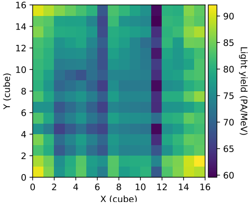
JINST 14 (2019) P02014
arXiv:1811.05244

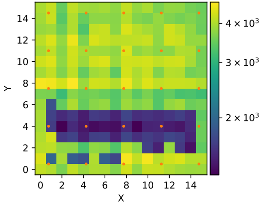
Construction quality assurance

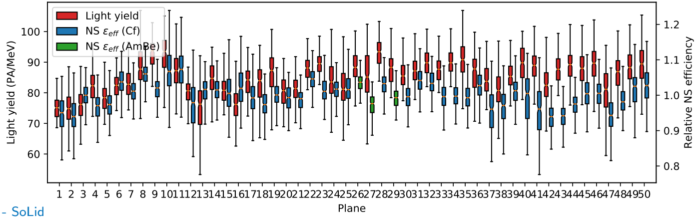
After construction each plane was tested on Calipso robot with ^{22}Na gamma source and AmBe neutron source





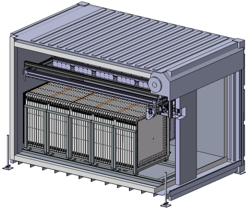




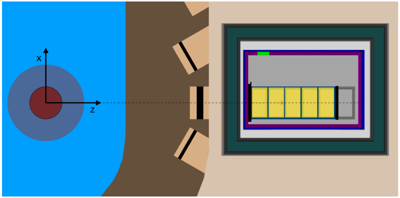


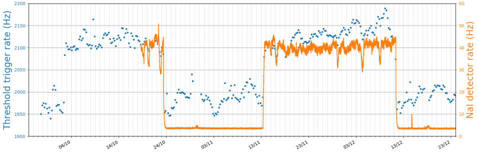
SoLid detector environment

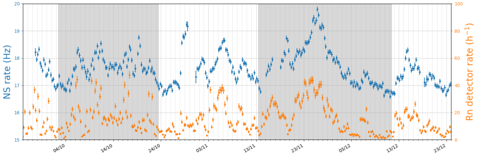
Paper soon released

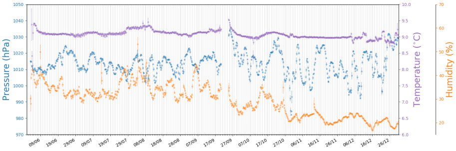


- The detector is at the level of the core
- Oscillation baseline is 6.2-8.7 m
- All the beam port have been shielded
- Detector inside a container at 10 °C
- CROSS robot to calibrate the modules
- Low overburden 10 m.w.e.
- Environmental sensors:
  P, T, H, Radon, Gamma



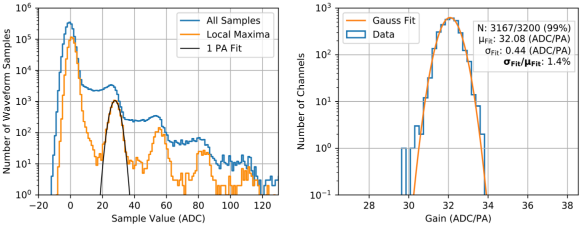






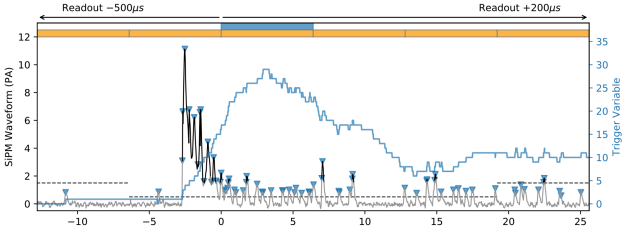
SoLid detector equalisation and trigger

The 3200 MPPCs gains have been equalised at 1 % level



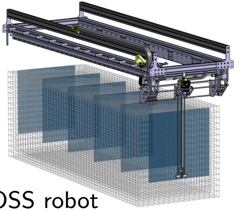
Three trigger running in parallel:

- periodic trigger: gains, noise and detector monitoring
- threshold trigger: high amplitude ES signals (muons)
- NS trigger: NS signals identification and ES buffer

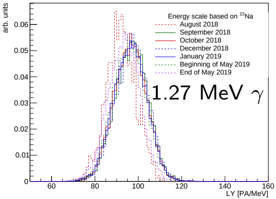


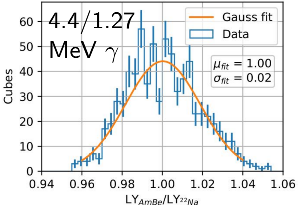
SoLid detector calibration

Paper soon released

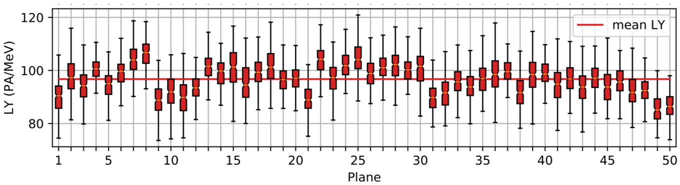


CROSS robot



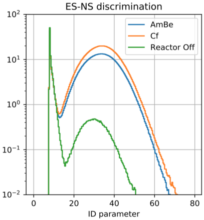


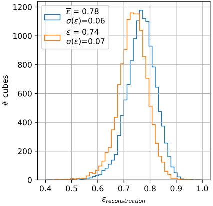
LY $\sim$ 75 PA/MeV

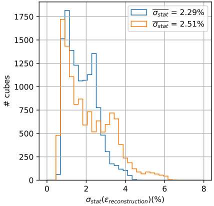


$\sigma_E/E < 12$ %

Improved n ID







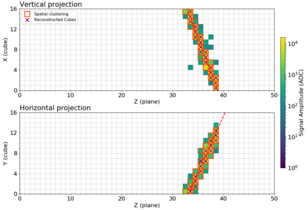
$\epsilon_{reco}^{nsce} \sim 74\%$

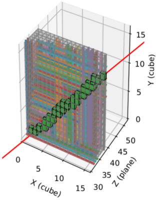
$\epsilon_{det}^{nIBD} \sim 52\%$

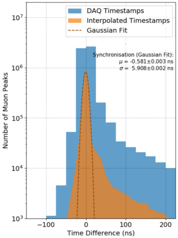
SoLid muons

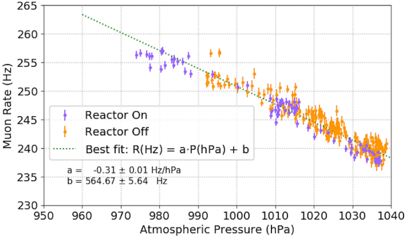
Muons tracks can be easily be reconstructed

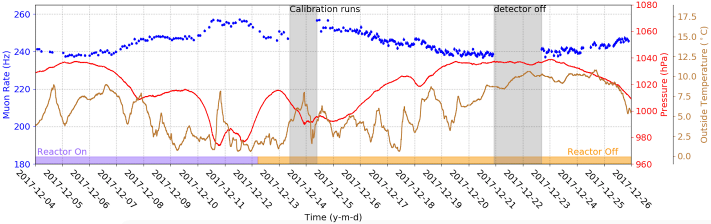
Tools for calibration and detector monitoring





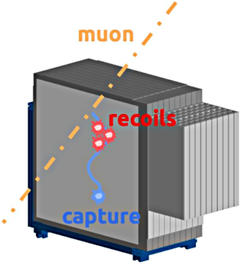


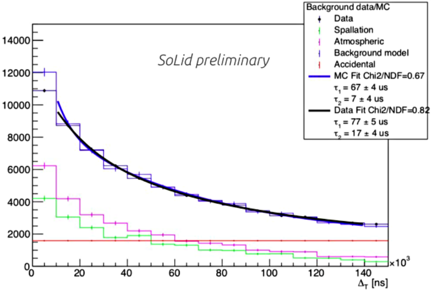


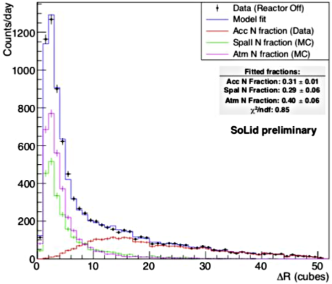


SoLid atmospheric background

Due to the low overburden
the cosmic background is important



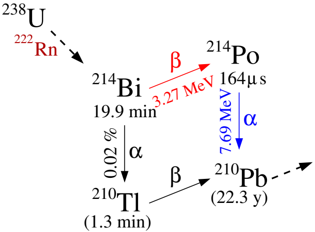


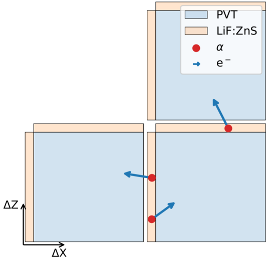


A combination of 42 % spallation and 58 % atmospheric neutrons describes very well the data

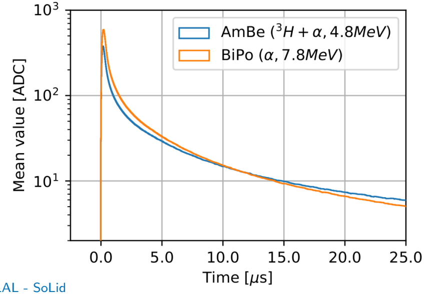
SoLid radioactivity background

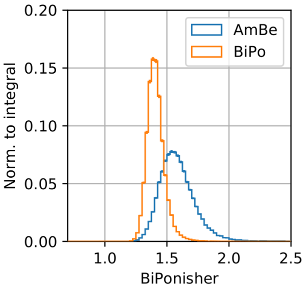
^{6}LiF:ZnS(Ag) neutron screens are contaminated by natural radioactivity





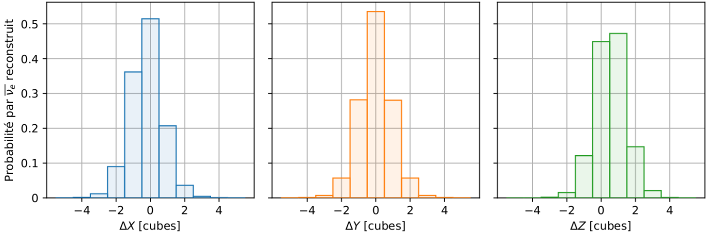
The topologies of coincidences and the NS signal shape helps rejection



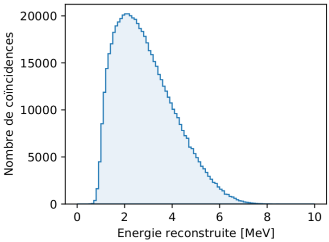


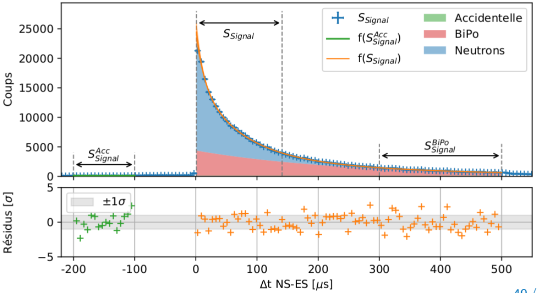
SoLid IBD analysis

IBD events have spatial distribution of ES-NS different from backgrounds



Prompt ES energy and time distribution also helps to reject backgrounds

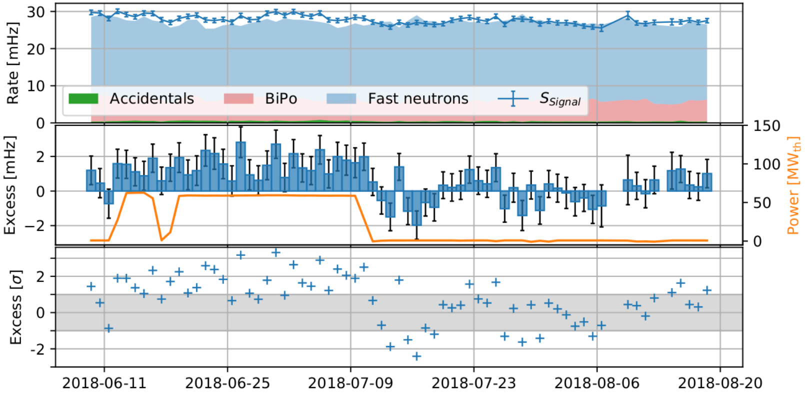




SoLid reactor ON/OFF transition

Opened dataset June/July 2018 reactor cycle:

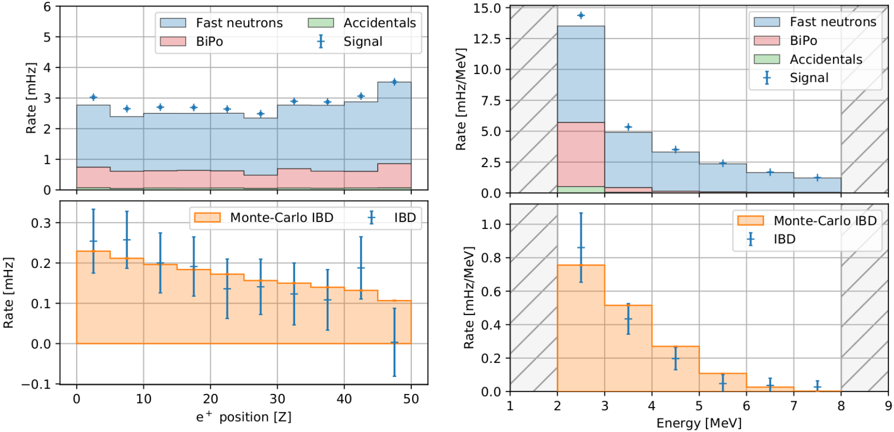
- 21,5 days reactor On
- 34,5 days reactor Off



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

SoLid IBD signal

The distributions of the excess are in agreement with the IBD simulations



Work needed on cubes reconstruction to try to reduce the threshold and identify the annihilation γ to tag the e^+ and reduce the backgrounds

MPPCs upgrade from S12 to S14 next summer: better light-yield, less pixel cross-talk, higher dark count rate (require cooling down to 5 °C)

Summary

- Active to sterile oscillations could explain experimental anomalies
- SoLid innovative experiment at BR2 using hybrid PVT - ^{6}LiF:ZnS(Ag) scintillators to search for the sterile neutrino and measure a pure ^{235}U $\overline{\nu}_e$ energy spectrum at the shortest distance from a reactor core
- The SM1 prototype of 280 kg validated the technology
- Light-yield improvements permitted to reach $\sigma_E/E < 14\%/\sqrt{E}$
- SoLid Phase 1 detector of 1600 kg is taking data
- Detector well behaving and first results encouraging
- The processing of all the collected data since 1.5 years done
  $\rightarrow$ new results coming soon