The SoLid experiment … a personal story

Nick van Remortel
University of Antwerp, Belgium

NIKHEF Colloquium

Jan 10, 2020

The SoLid Collaboration

4 countries | 12 institutes | ~50 people

Universiteit Antwerpen

lpc caen

Vrije Universiteit Brussel

LPC Particules plasmas Univers applications — Laboratoire de Physique de Clermont

Universiteit Gent

LAL Laboratoire de l'Accélérateur Linéaire

SCK•CEN Studiecentrum voor Kernenergie Centre d'Étude de l'Énergie Nucléaire

Subatech

University of Bristol

Imperial College London

University of Oxford

VirginiaTech Invent the Future

EOS The Excellence of Science

Belgian Science Policy Office belspo

foundation of public utility HERCULES STICHTING

Agence Nationale de la Recherche ANR

erc

PI A. Vacheret
CoG 682474 SOLID

How things started (2014)

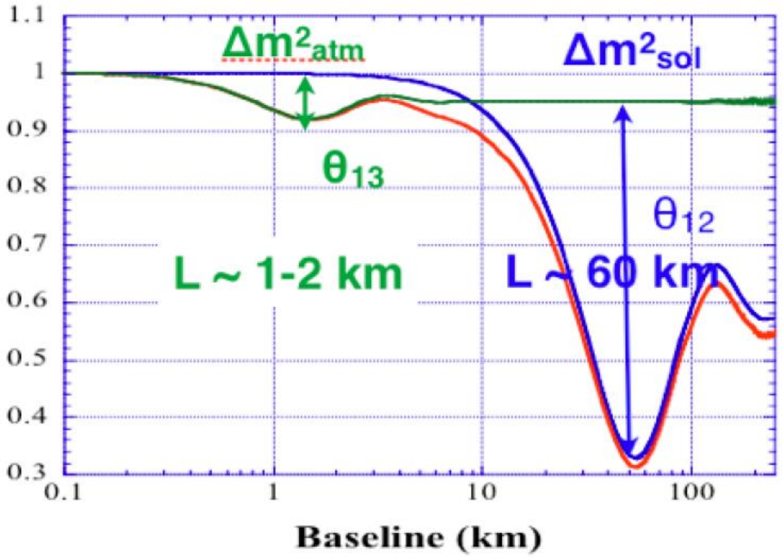
- Possible to make cheap, modular, plastic neutrino detector?
- Starting from T2K near detector & neutron homeland security detector technology
- With small spatial resolution?
- Suitable for short baseline oscillation physics ?
- In Belgium??
- Exotic physics: sterile neutrinos
- Reactor neutrino production: reference spectra and nuclear safeguards

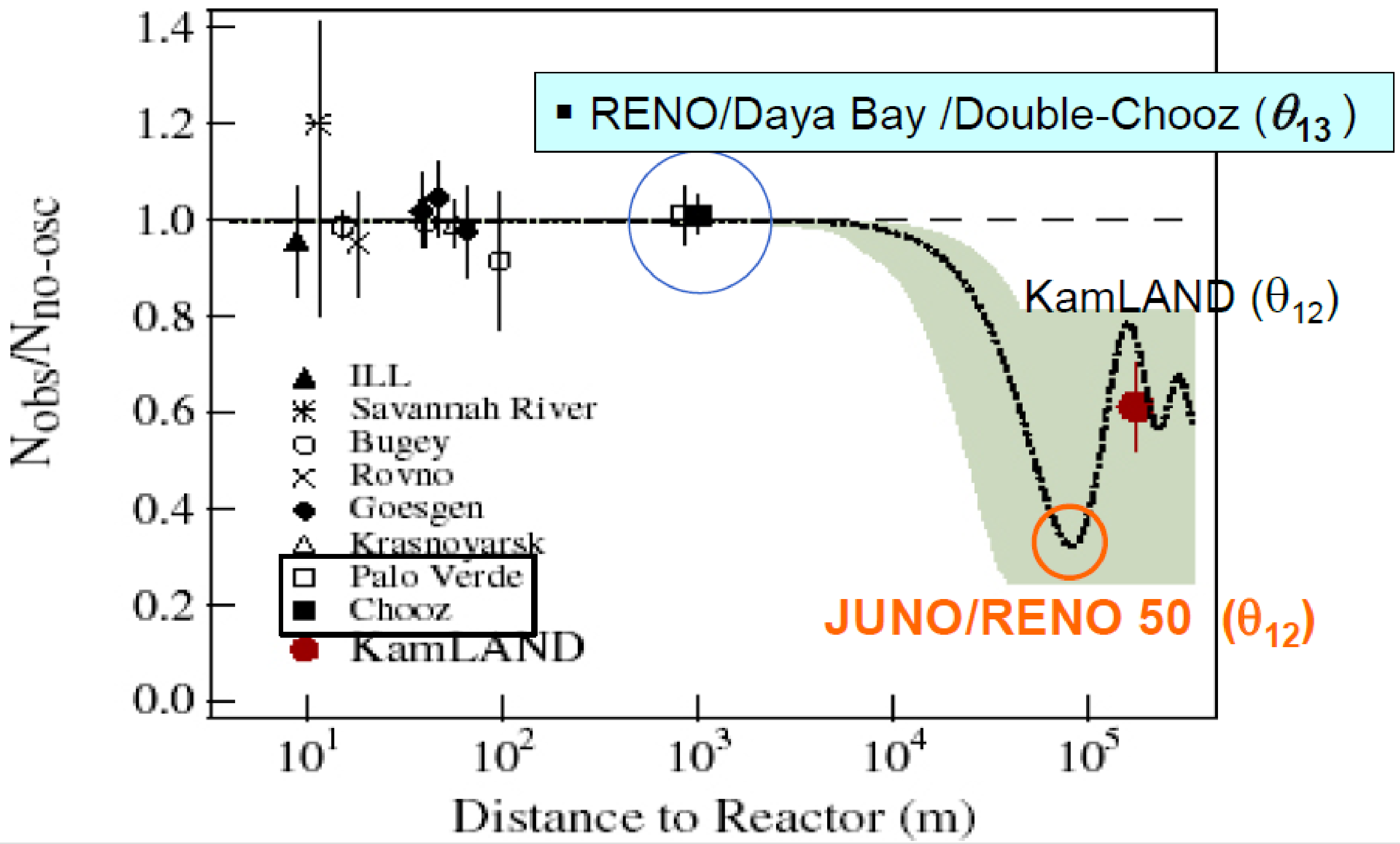
Baselines in reactor $\overline{\nu_e}$ oscillation physics ?

$$P(\bar{\nu}_e \to \bar{\nu}_e) \approx 1 - \boxed{\cos^4\theta_{13}\sin^2 2\theta_{12}\sin^2\left(\frac{1.27\Delta m^2_{12}L}{E_\nu}\right)} - \boxed{\sin^2 2\theta_{13}\sin^2\left(\frac{1.27\Delta m^2_{13}L}{E_\nu}\right)}$$

$\Delta m^2_{sol} = \Delta m^2_{21}$ $\Delta m^2_{atm} = \Delta m^2_{31} \approx \Delta m^2_{32}$

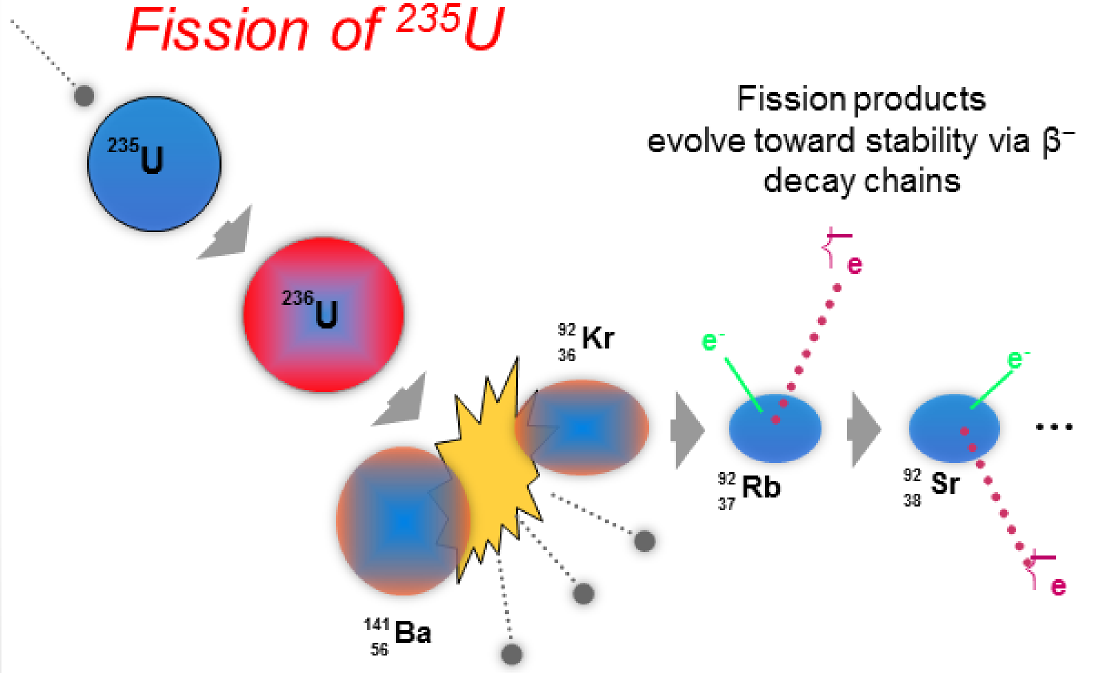
Medium baseline: O(10~100km) Short baseline: O(~1km)





Energies and fluxes ?

Fission of ^{235}U

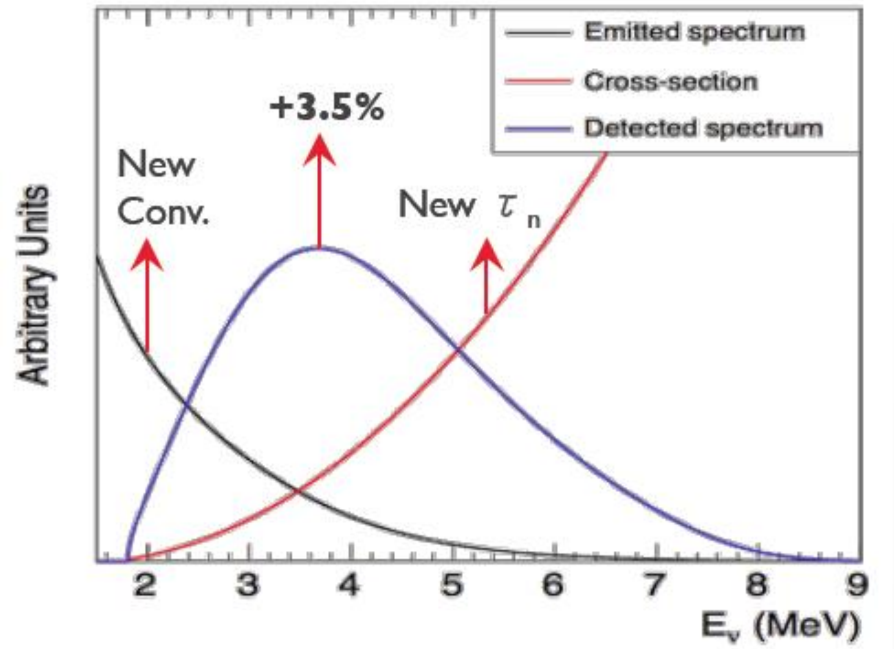


$$\langle E_{PF} \rangle / fission = 201.7\,MeV$$

$$\langle E_{\bar{\nu}} \rangle / fission = 1.49\,MeV$$

$$\langle N_{\bar{\nu}} \rangle / fission = 5.98 \quad \text{(no threshold)}$$

$$1GW_{th} \Rightarrow \approx 2.10^{20}\, \nu / s$$



In 2011, new computation of ν_e spectra

T. Mueller at al., Phys Rev C 054615 (2011)

+

Improved knowledge of IBD cross section

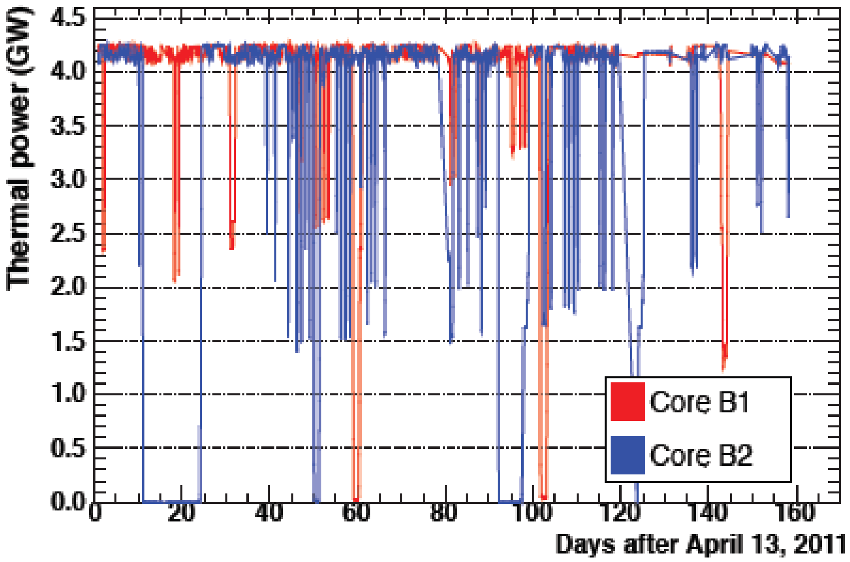
Reactor anomaly

G. Mention et al. Phys. Rev. D 83, 073006 (2011)

Expected number of neutrinos

$$N_{\nu}^{\exp}(E,t) = \frac{N_p \, \varepsilon}{4\pi L^2} \times \frac{P_{th}(t)}{\langle E_f \rangle} \times \langle \sigma_f \rangle$$

Thermal power

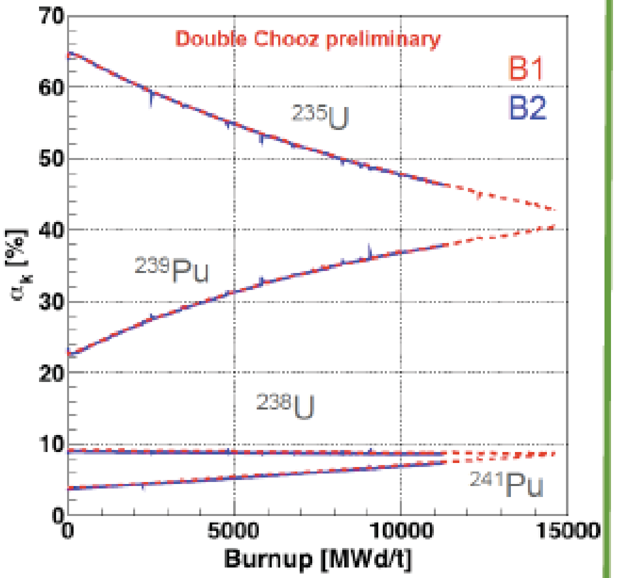


Mean energy per fission

(k = ^{235}U, ^{238}U, ^{239}Pu, ^{241}Pu)

$$\langle E_f \rangle = \sum_k \alpha_k(t) \langle E_k \rangle$$

Fuel evolution in reactor core



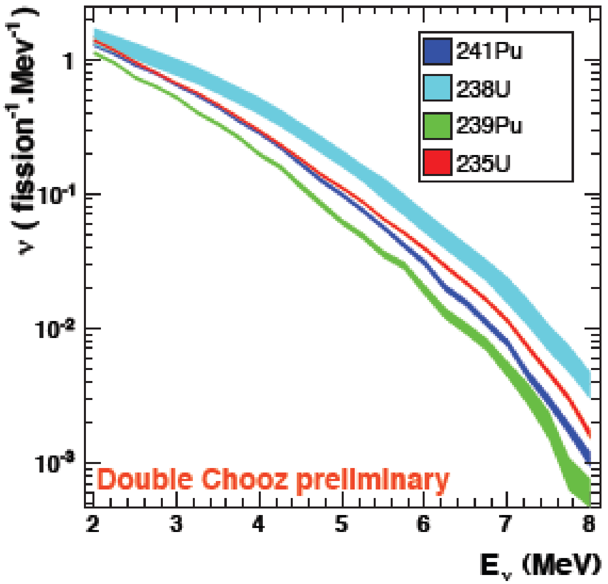
Mean cross-section per fission

(k = ^{235}U, ^{238}U, ^{239}Pu, ^{241}Pu)

$$\langle \sigma_f \rangle = \langle \sigma_f \rangle^{Bugey} + \sum_k \left(\alpha_k^{DC}(t) - \alpha_k^{Bugey}(t) \right) \langle \sigma_f \rangle_k$$

$$\langle \sigma_f \rangle_k = \int_0^{\infty} dE \cdot S_k(E) \cdot \sigma_{IBD}(E)$$

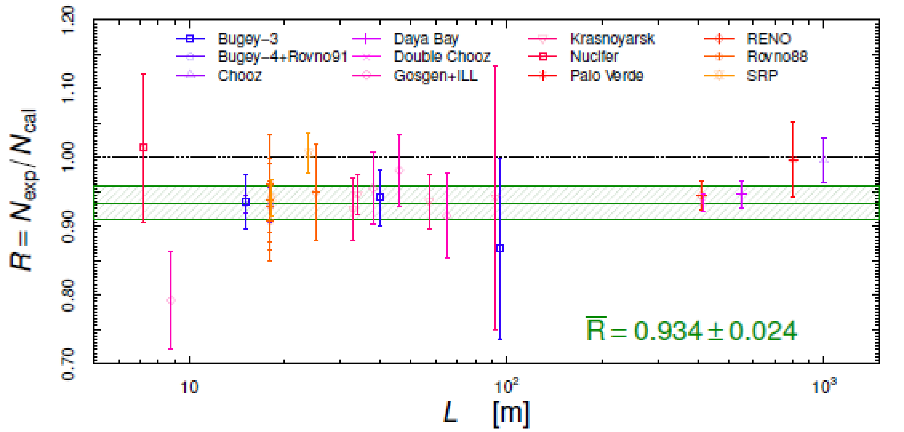
Reference spectra

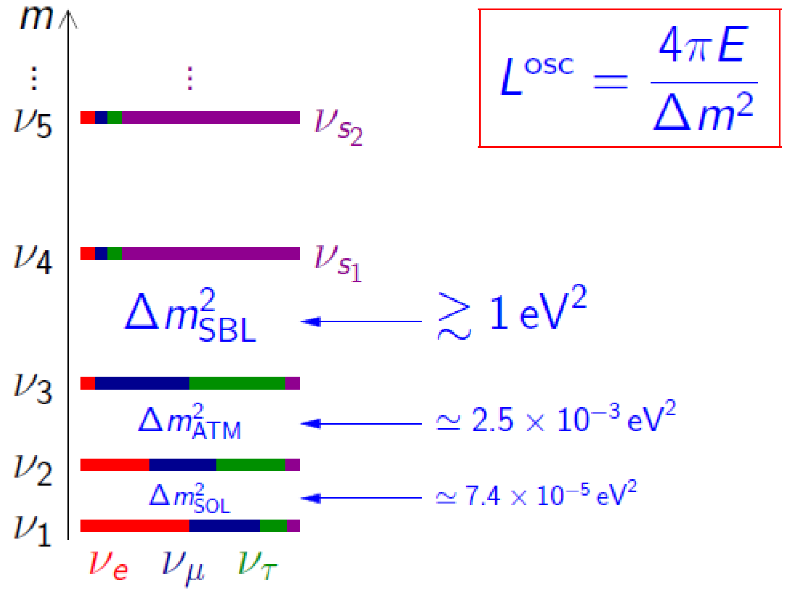


- Th. A. Mueller et al, Phys.Rev.C83(2011)054615
- P. Huber, Phys.Rev.C84(2011)024617

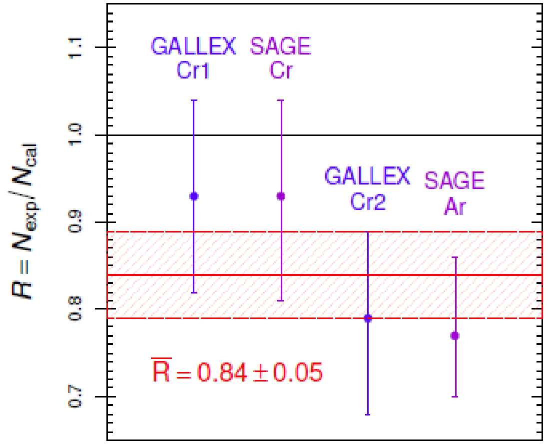
Short baseline oscillation anomalies

Reactor Anomaly: $\bar{\nu}_e \to \bar{\nu}_x$ $(\sim 3\sigma)$

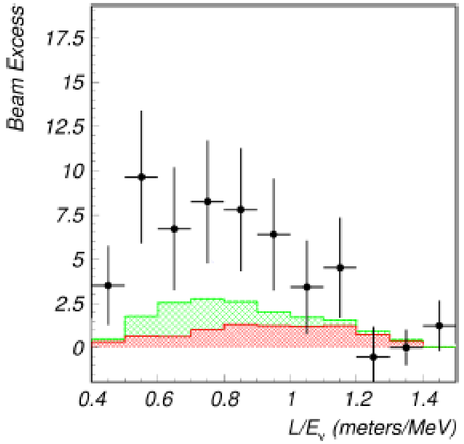




Gallium Anomaly: $\nu_e \to \nu_x$ $(\sim 3\sigma)$



LSND Anomaly: $\bar{\nu}_\mu \to \bar{\nu}_e$ $(\sim 4\sigma)$

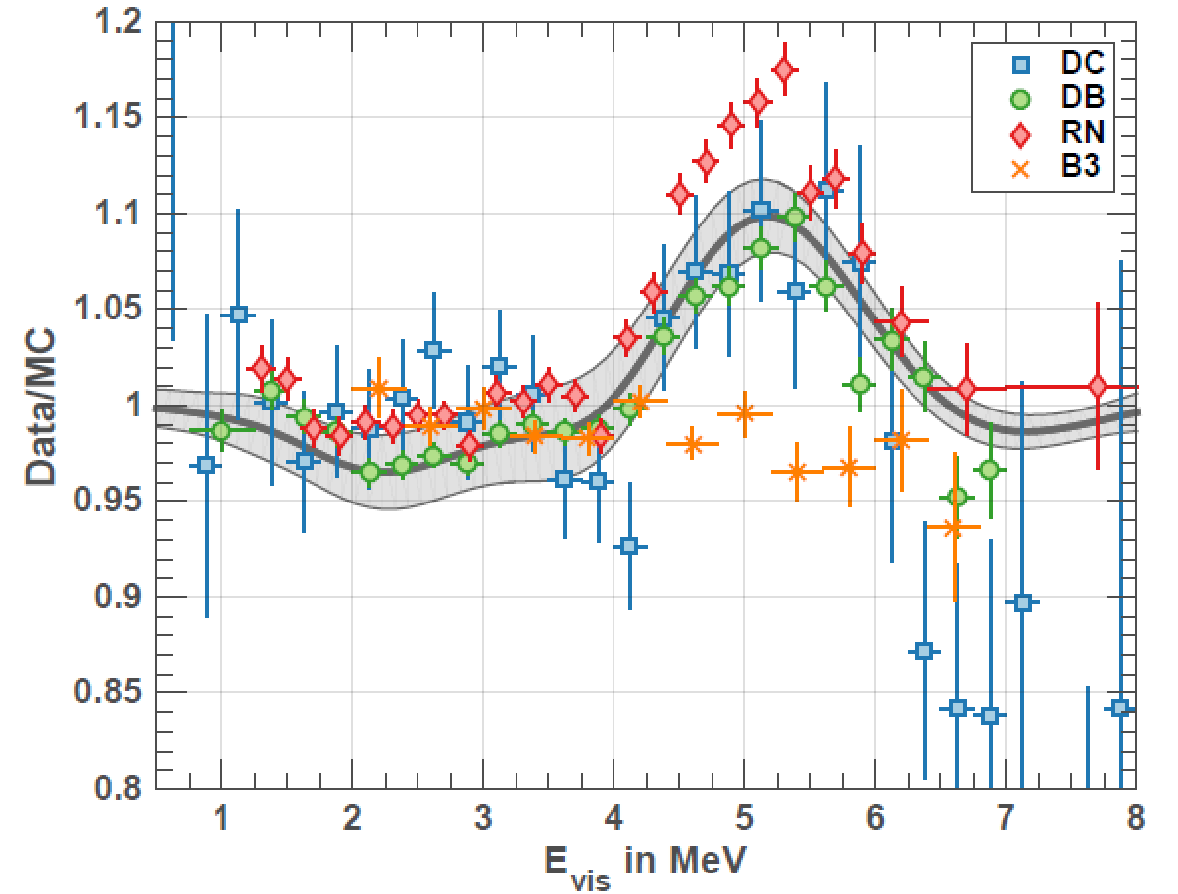


- Various 3σ deviations hinting compatible with $\Delta m^2 \simeq 1 eV^2$
- BUT: also mutual tension
- Tension with cosmological predictions
- Resolvable by adding more than 1 extra neutrino species
- New deviations from predictions appearing: Daya Bay/RENO spectral distortion
- Discussion on flux calculations
- Enough to warrant further investigation
- Keep option for new physics open

Motivation

- Establish or disprove new neutrino eigenstates at $\Delta m^2 \sim O(1\ eV^2)$, see also reactor- and gallium anomaly
- Resolve discussion on spectral features observed by long baseline reactor expts using common fuels (^{235}U, ^{238}U, ^{239}Pu, ^{241}Pu)

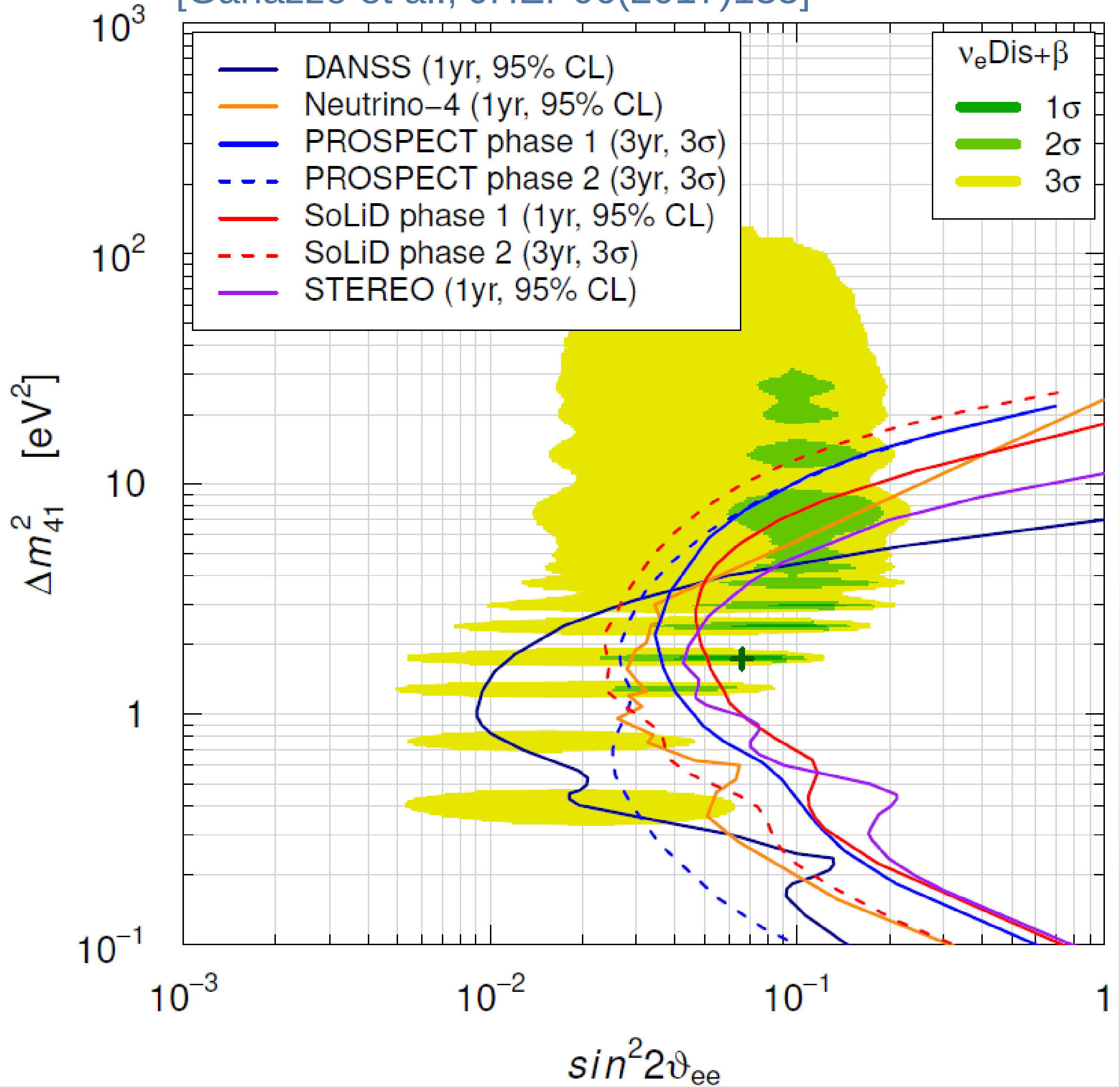
[G. Mention et al., Phys. Lett. B773(2017)307]



Motivation

- Establish or disprove new neutrino eigenstates at $\Delta m^2 \sim O(1\ eV^2)$, see also reactor- and gallium anomaly
- Resolve discussion on spectral features observed by long baseline reactor expts using common fuels (^{235}U, ^{238}U, ^{239}Pu, ^{241}Pu)
- Several experiments taking data since 2018!
- SoLid approach:
  - $\bar{\nu}_e$ energy measurement with plastic scintillator: Linear energy response (see eg. ESCAPE 2018)
  - Very small segmentation:
    - Topological event information & Bg reduction
    - 2D Oscillometry in E and L
  - Using highy enriched ^{235}U reactor fuel

[Gariazzo et al., JHEP06(2017)135]

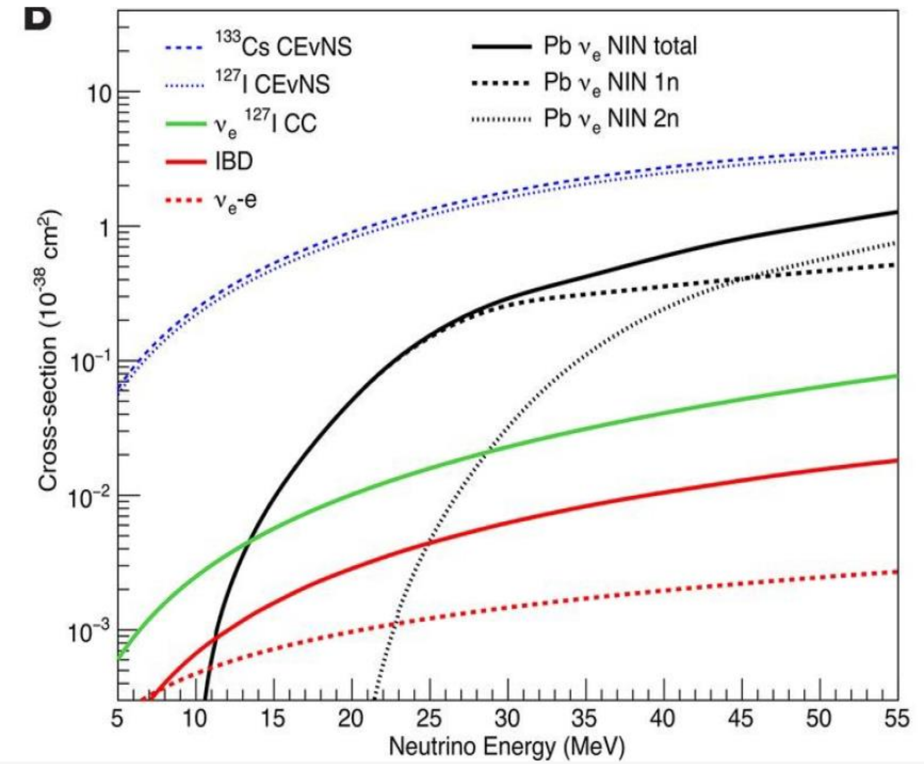


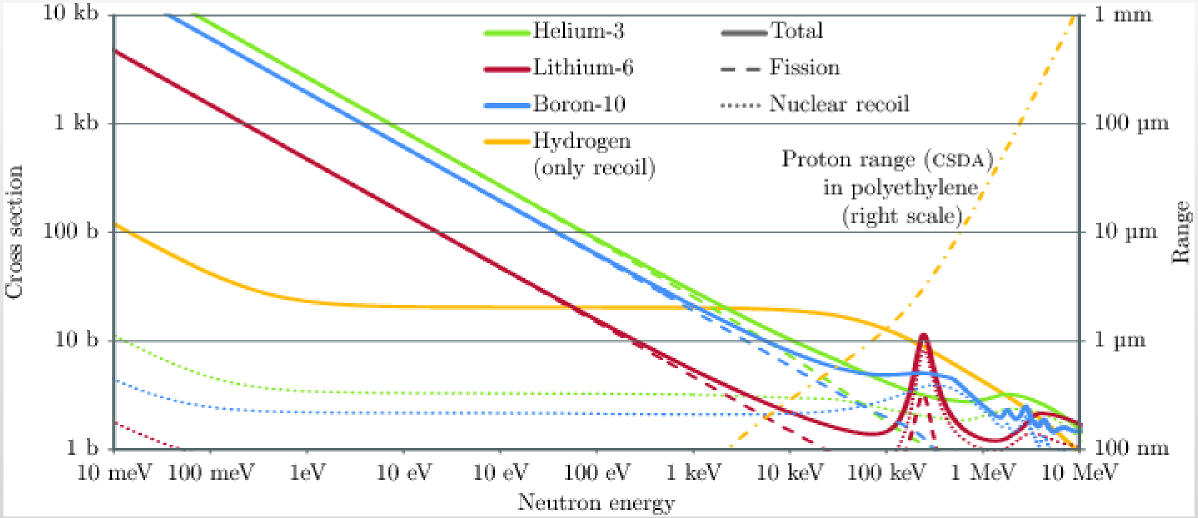
BR2 nuclear site

- Compact research reactor
  - ∅ 50 cm and height 90 cm
  - Fuel 93.5% ^{235}U
  - Thermal power 50-80 MW
  - Duty cycle 150 days/year (~ 1 month cycles)
  - SoLid at baseline 6-9 m
- At ground level
  - Overburden 10 mwe
  - Muon rate: O(250 Hz)
  - Cosmogenic neutrons
  - Natural radioactivity

From security portals to ν detector

- Anti-electron-neutrinos detected through inverse beta decay (IBD) in the composite (PVT + ^{6}LiF:ZnS) scintillator element
  $\bar{\nu}_e + p \rightarrow n + e^+$ $\quad$ $(E_{\overline{\nu_e}} > 1.8$ MeV)
- Prompt positron signal
- Delayed neutron signal
  - Neutron captured in ^{6}LiF:ZnS close by
    $n + {}^6Li \rightarrow {}^3H + \alpha$ $\quad$ + 4.78 MeV
  - Capture time O(60 μs)
- R&D program with
  - Materials, geometries, wrappings
  - Reactor measurements: backgrounds, shielding
  - Off-shelf vs custom electronics

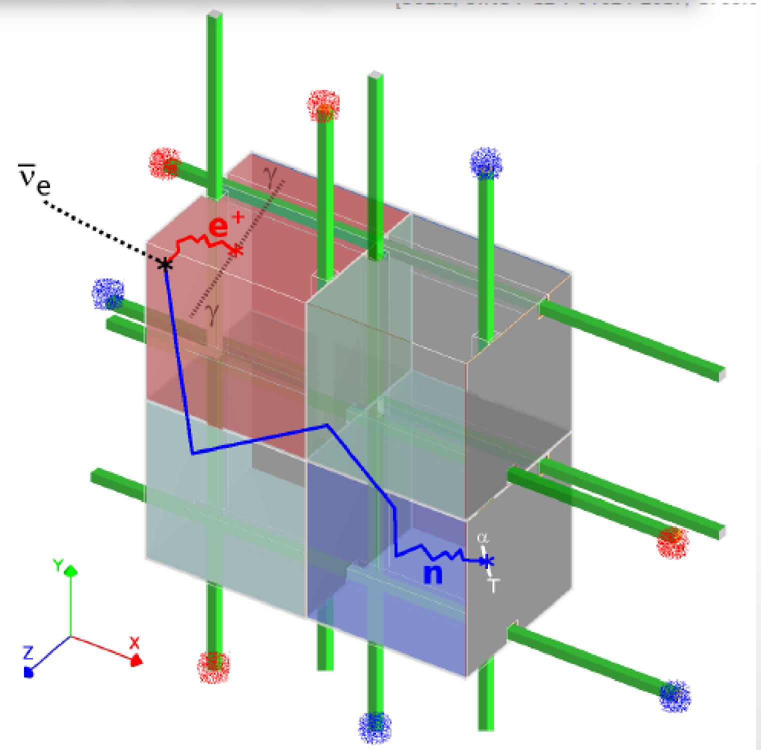


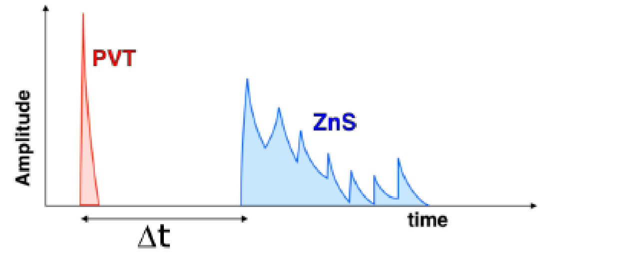


SoLid detection principle

JINST 12 (2017) no.04, P04024
JINST 13 (2018) no.05, P05005

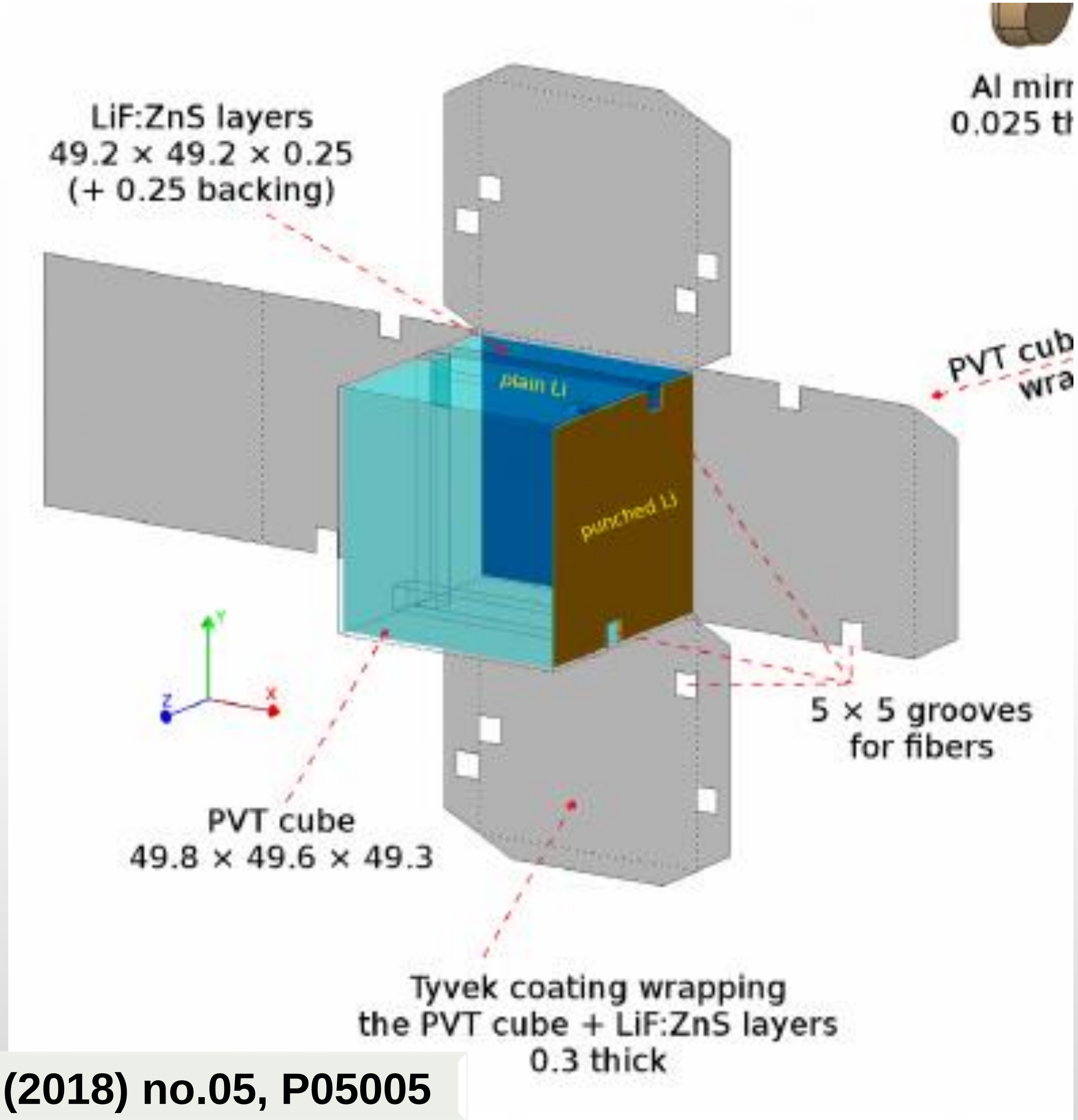
- Anti-electron-neutrinos detected through inverse beta decay (IBD) in the composite (PVT + ^{6}LiF:ZnS) scintillator element
  $\bar{\nu_e} + p \rightarrow n + e^{+}$ $(E_{\overline{\nu_e}} > 1.8 \text{ MeV})$
- Prompt positron signal
  - Positron energy contained in one/two PVT cubes
  - Allows precise localisation of IBD interaction
  - Provides seed for anti-neutrino energy
- Delayed neutron signal
  - Neutron captured in ^{6}LiF:ZnS close by
    $n + {}^{6}Li \rightarrow {}^{3}H + \alpha$ + 4.78 MeV
  - Capture time O(60 μs)
- Both signals
  - Collected by WLS fibers in X and Y directions and transported to MPPC for readout
  - Discrimination (ES – NS) based on pulse shape





SoLid phase 1

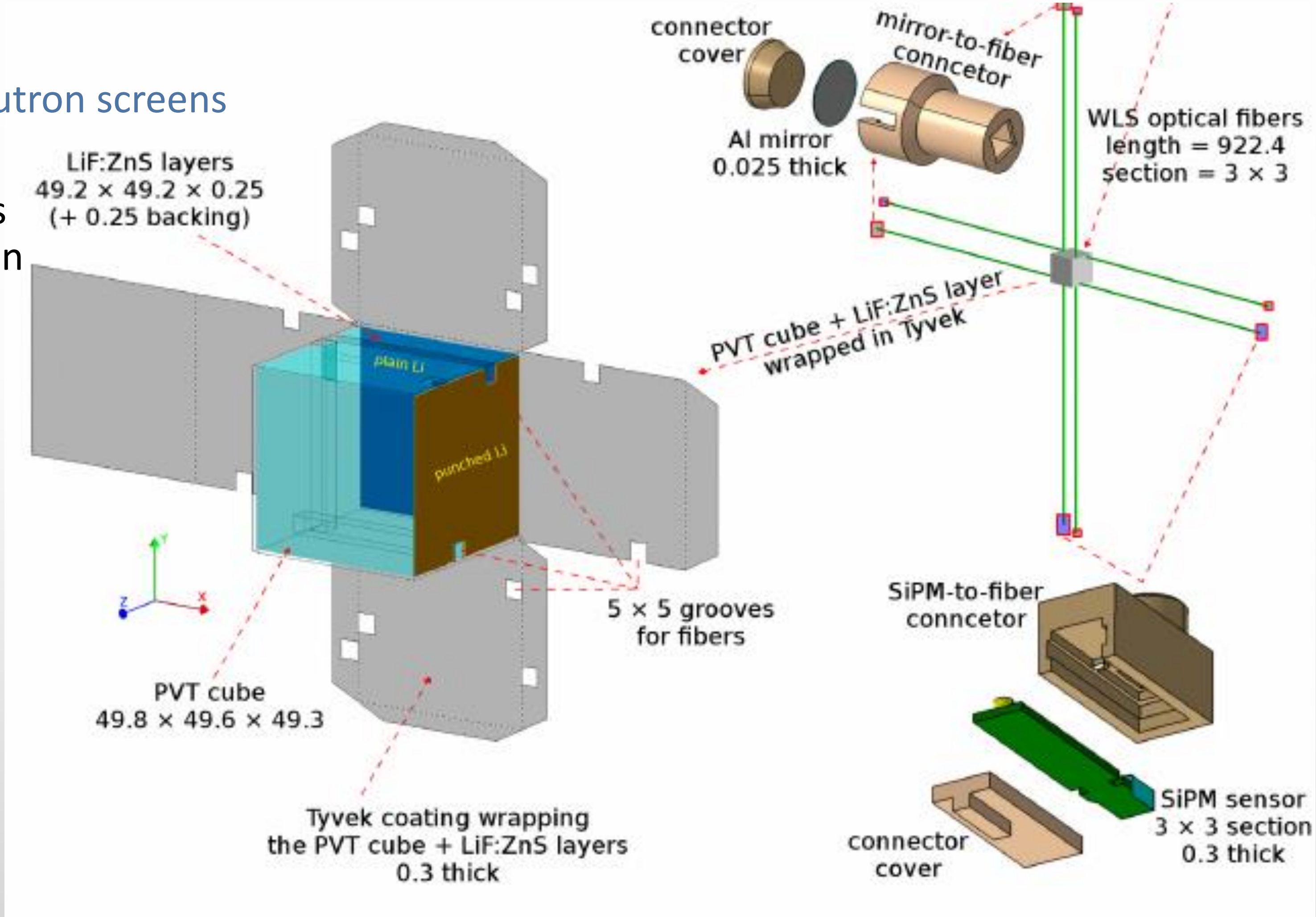
- SoLid detector cells: Cubes
  - PVT cubes of 5x5x5 cm^3 with 2 ^{6}LiF:ZnS neutron screens
  - Optically isolated with Tyvek wrapping



JINST 13 (2018) no.05, P05005

SoLid phase 1

- SoLid detector cells: Cubes
  - PVT cubes of 5x5x5 cm^3 with 2 ^{6}LiF:ZnS neutron screens
  - Optically isolated with Tyvek wrapping
  - Scintillation light extracted via 4 WLS fibers towards 2MPPC's (SiPMs) in either direction

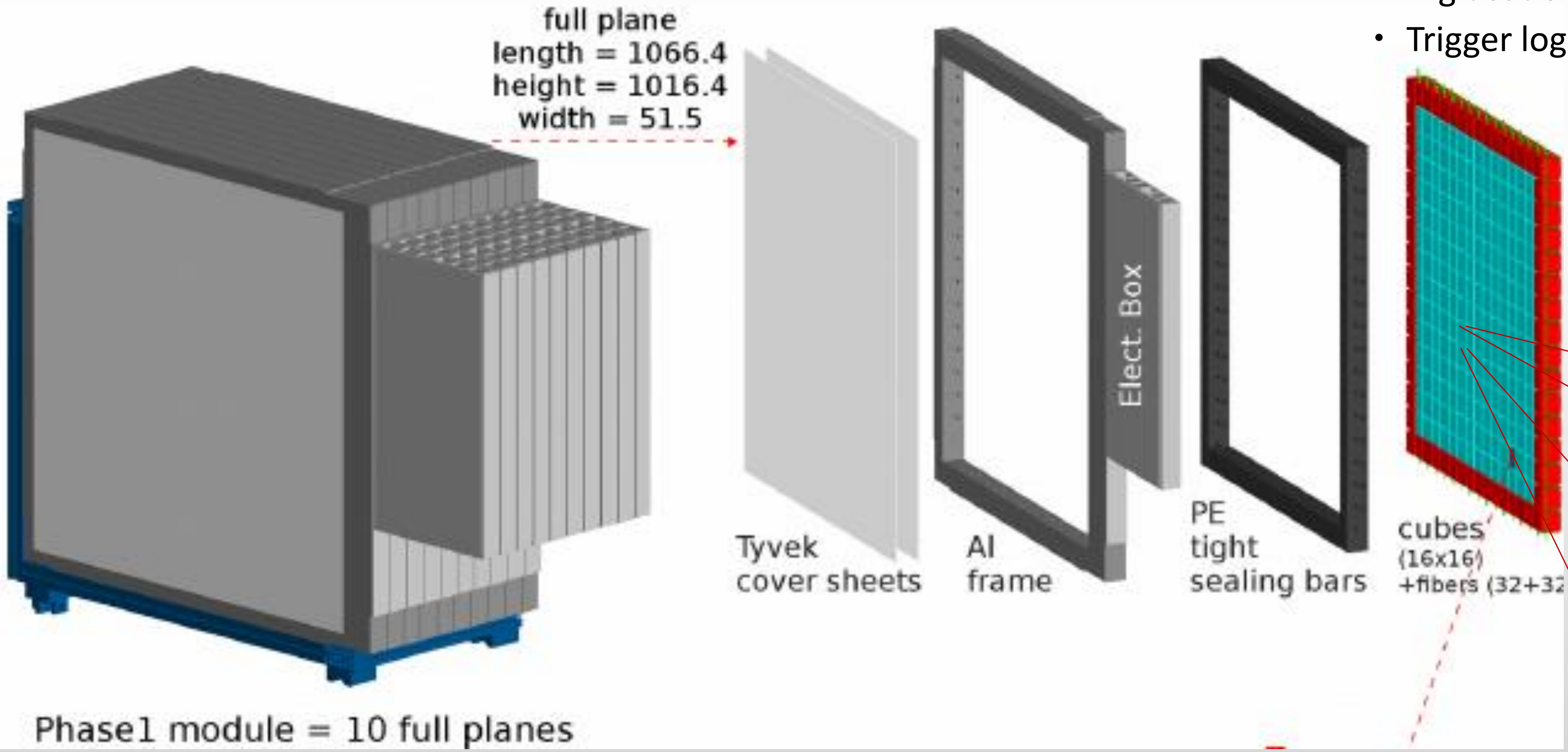


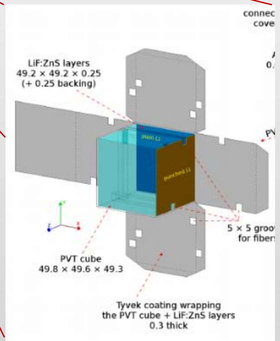
SoLid phase 1

- SoLid detector cells: Cubes
  - PVT cubes of 5x5x5 cm^3 with 2 ^{6}LiF:ZnS neutron screens
  - Optically isolated with Tyvek wrapping
  - Scintillation light extracted via 4 WLS fibers towards 2MPPC's (SiPMs) in either direction

- SoLid detection planes
  - Planes of 16x16 cubes = 64 RO channels give 3D topological information
  - Plane readout & trigger:
    - amplification& shaping
    - Digitisation at 40 MHz - 2 Tb/s output for full detector
    - Trigger logic in FPGA

- SoLid detection Modules
  - 5 modules of 10 planes each
  - 1.6 ton sensitive mass

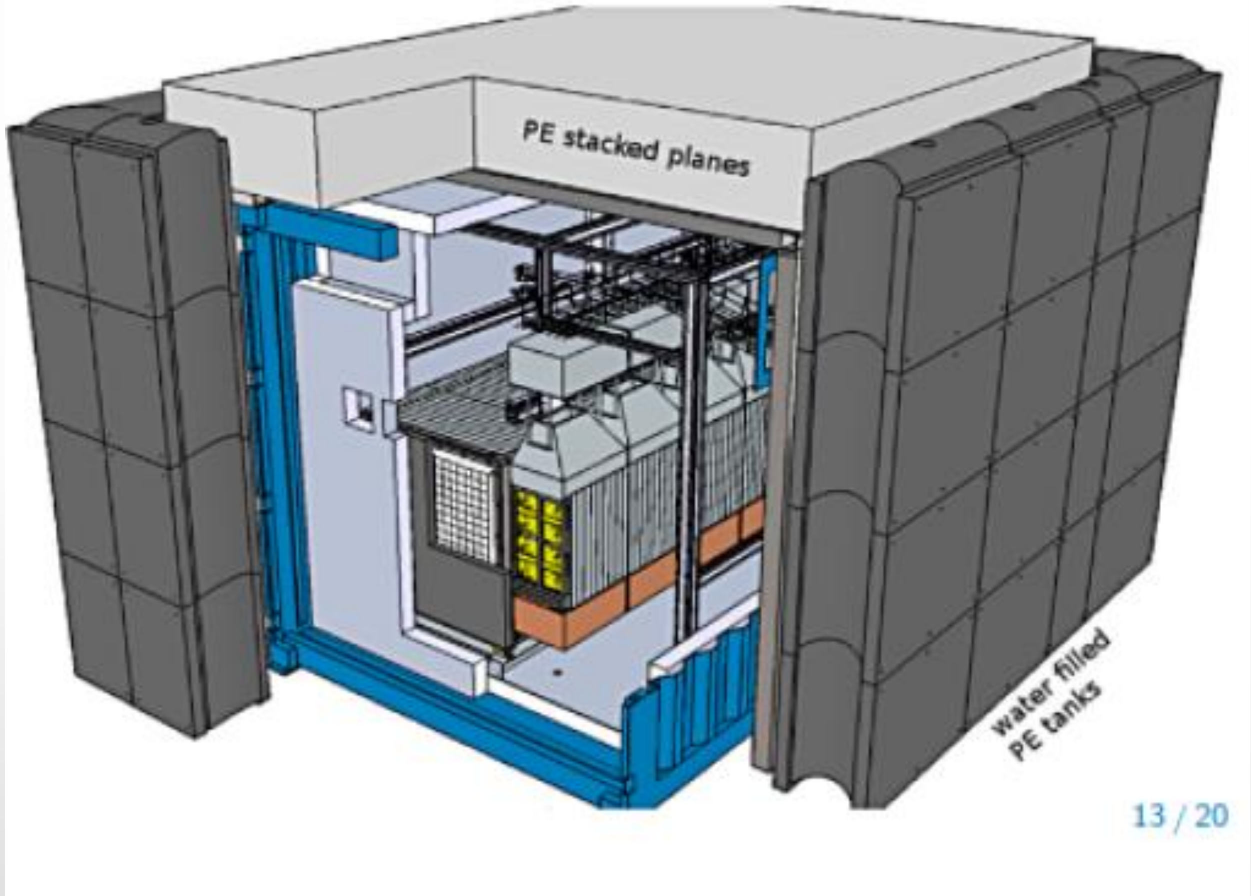




SoLid Phase 1

- Container 2.4x2.6x3.8 m^3
  - Cooled to 10°C to reduce MPPC dark count rate (1/3)
- Shielding
  - Water enclosure 50cm thick, 3.4 m high, 28ton
  - Polyethylene ceiling 50cm thick, 6ton
  - Cadmium lining
- Automated calibration system for absolute efficiency and energy scale calibration at % level (^{207}Bi, ^{60}Co, ^{137}Cs, ^{22}Na, AmBe, ^{252}Cf)

  → Full G4 simulation



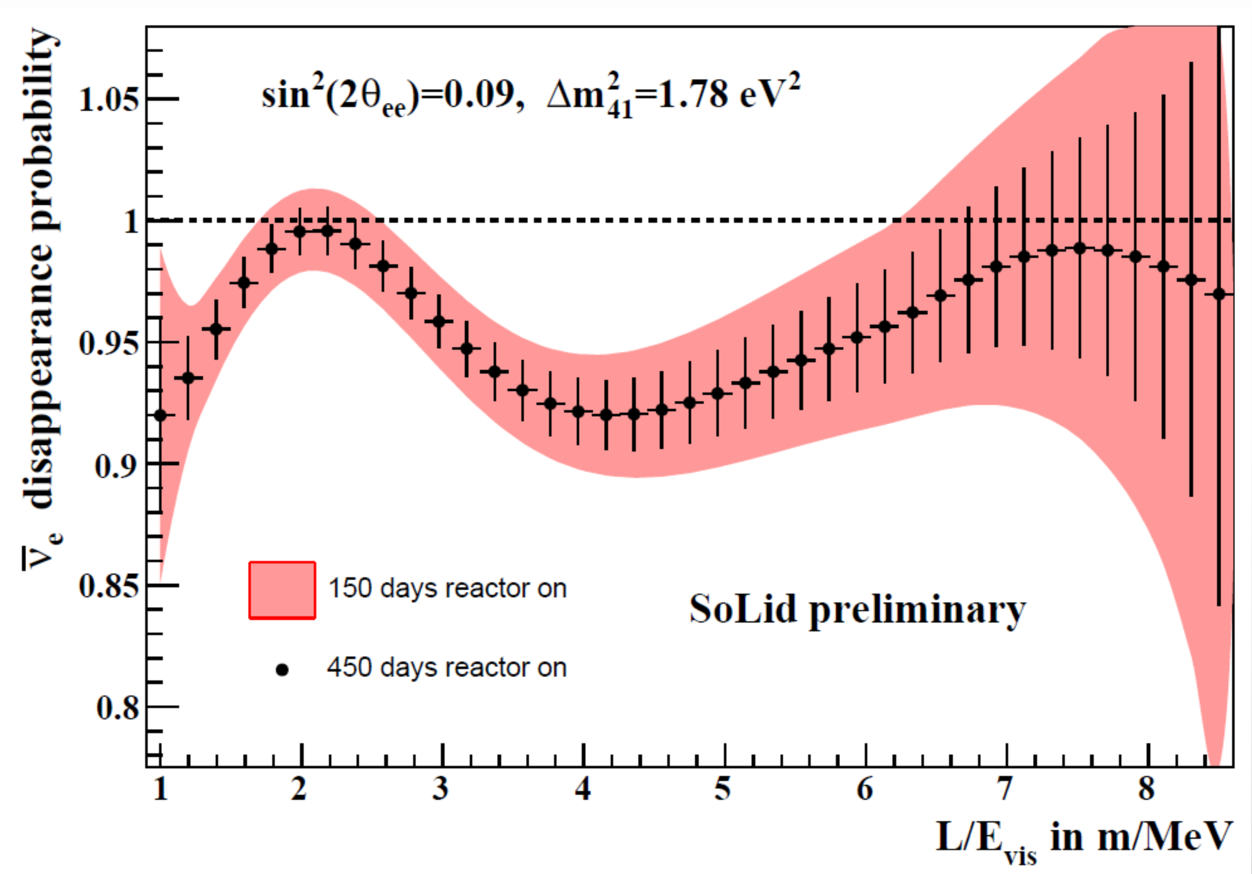
SoLid Phase 1

- Container 2.4x2.6x3.8 m^3
  - Cooled to 10°C to reduce MPPC dark count rate (1/3)
- Shielding
  - Water enclosure 50cm thick, 3.4 m high, 28ton
  - Polyethylene ceiling 50cm thick, 6ton
  - Cadmium lining
- Automated calibration system for absolute efficiency and energy scale calibration at % level (^{207}Bi, ^{60}Co, ^{137}Cs, ^{22}Na, AmBe, ^{252}Cf)

  → Full G4 simulation

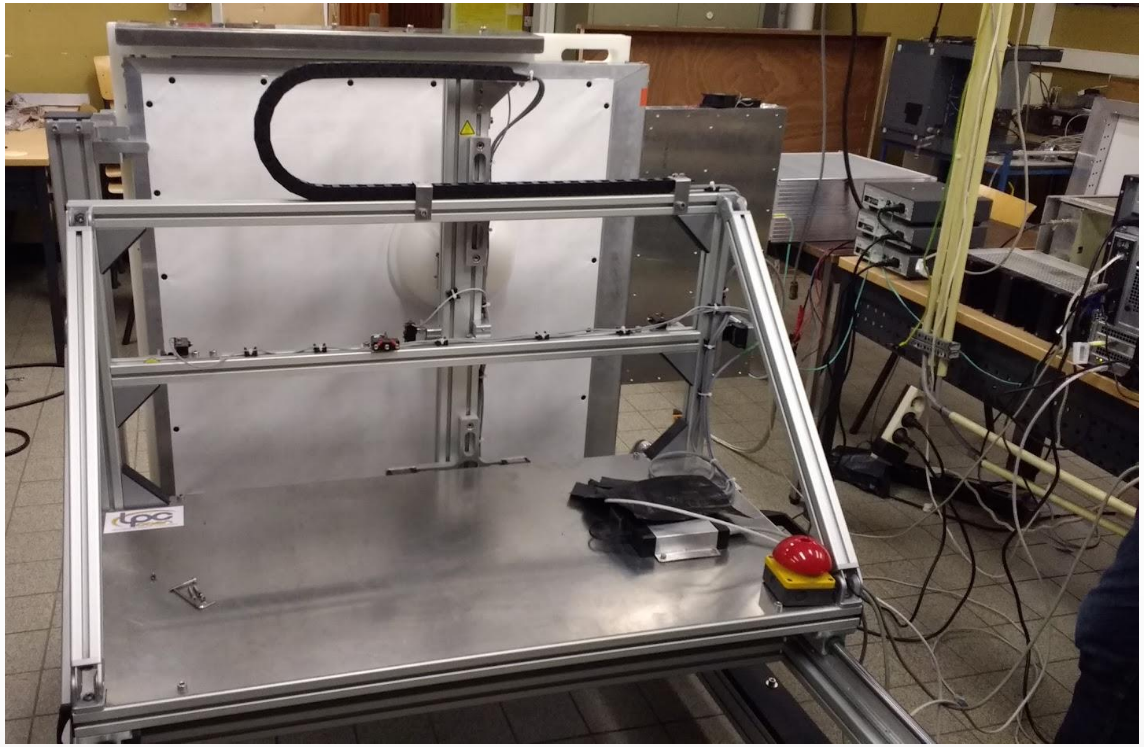
- Target sensitivity
  - Energy resolution $\frac{\sigma_E}{\sqrt{E\ (MeV)}} = 14\%$
  - IBD efficiency 30%
  - Signal-to-Background 3:1

$P_{ee} \sim 1 - \sin^2(2\theta_{14})\sin\ (1.267\Delta m_{14}^2\ L[m]/E[MeV]\ )$



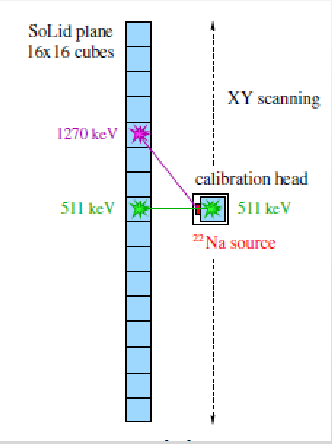
Quality control: CALIPSO

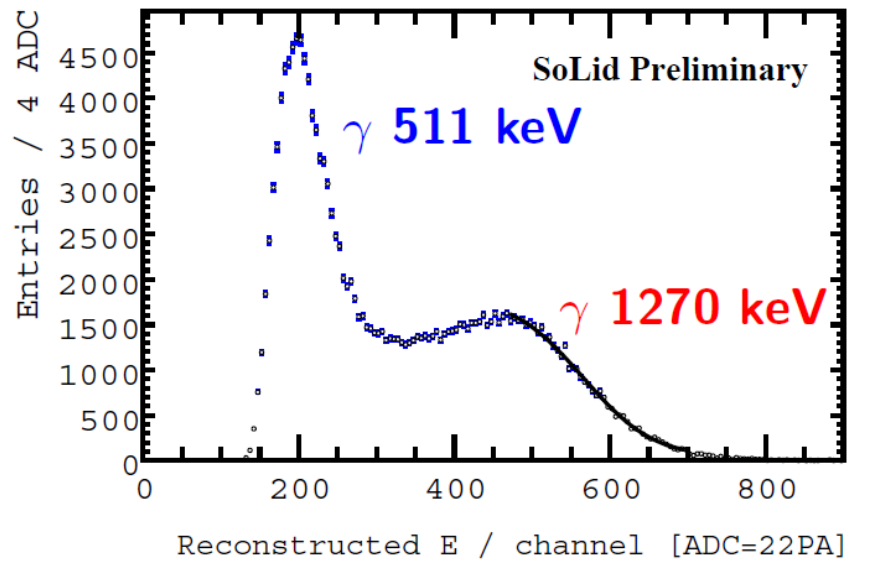
- Automated scanner with active calibration head accommodating various neutron, electron/gamma sources:
  - ^{207}Bi, ^{22}Na, ^{137}Cs, ^{60}Co, …
  - ^{235}Cf, AmBe
  - 16x16 cell plane in 4 hours
- Employs same readout&DAQ as full detector



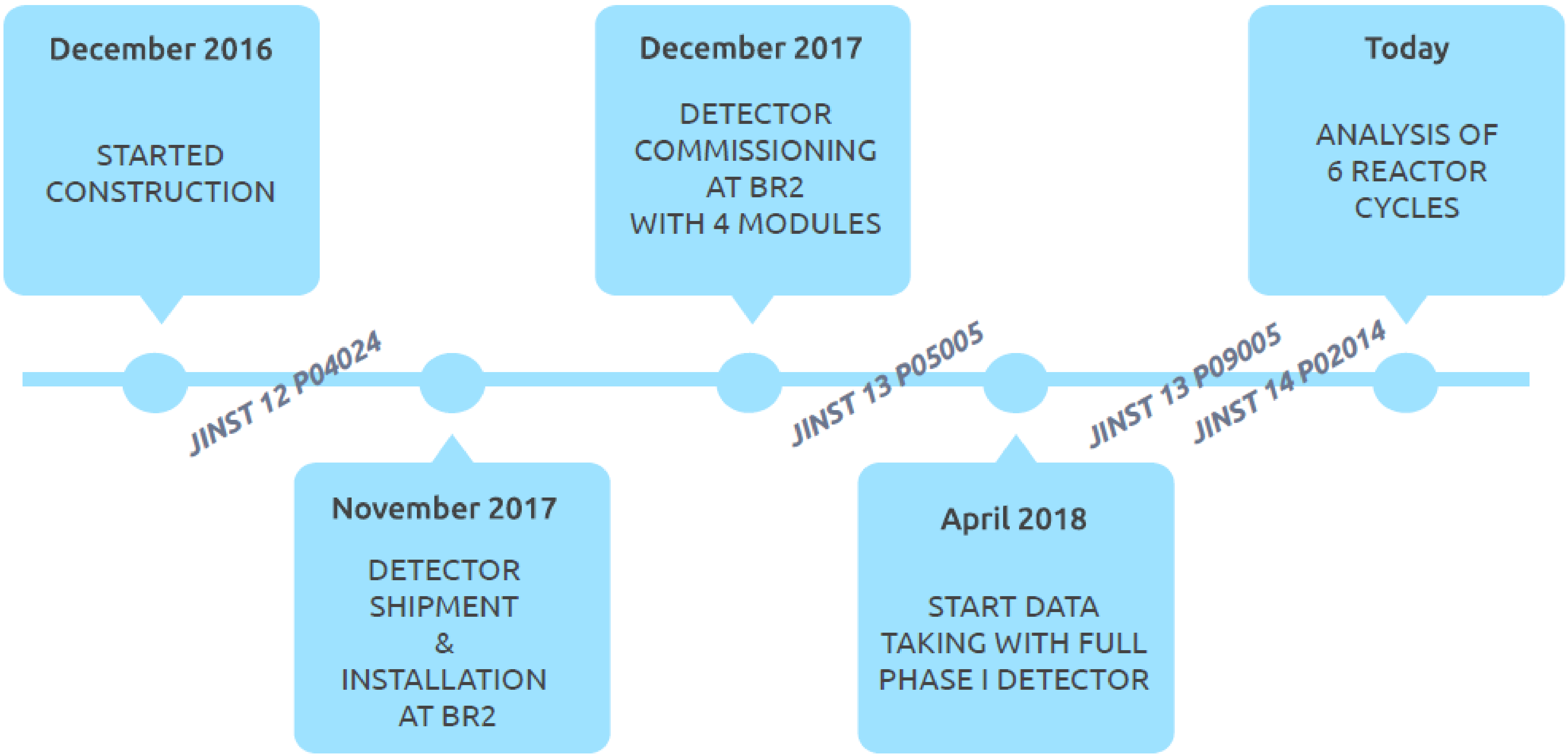
JINST 14 (2019) no.02, P02014

^{22}Na Compton edge of 1270 keV gamma used for LY measurement





SoLid Phase I Timeline



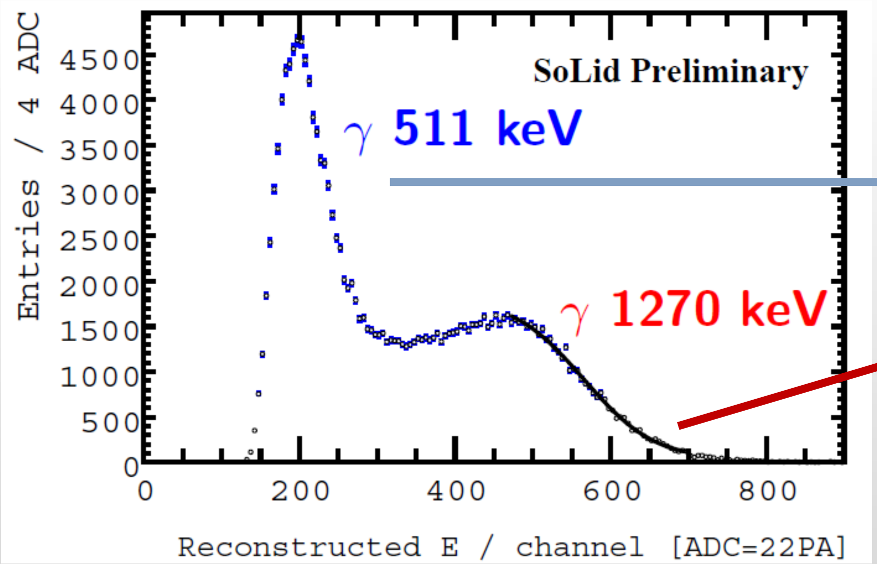
Construction & Integration:

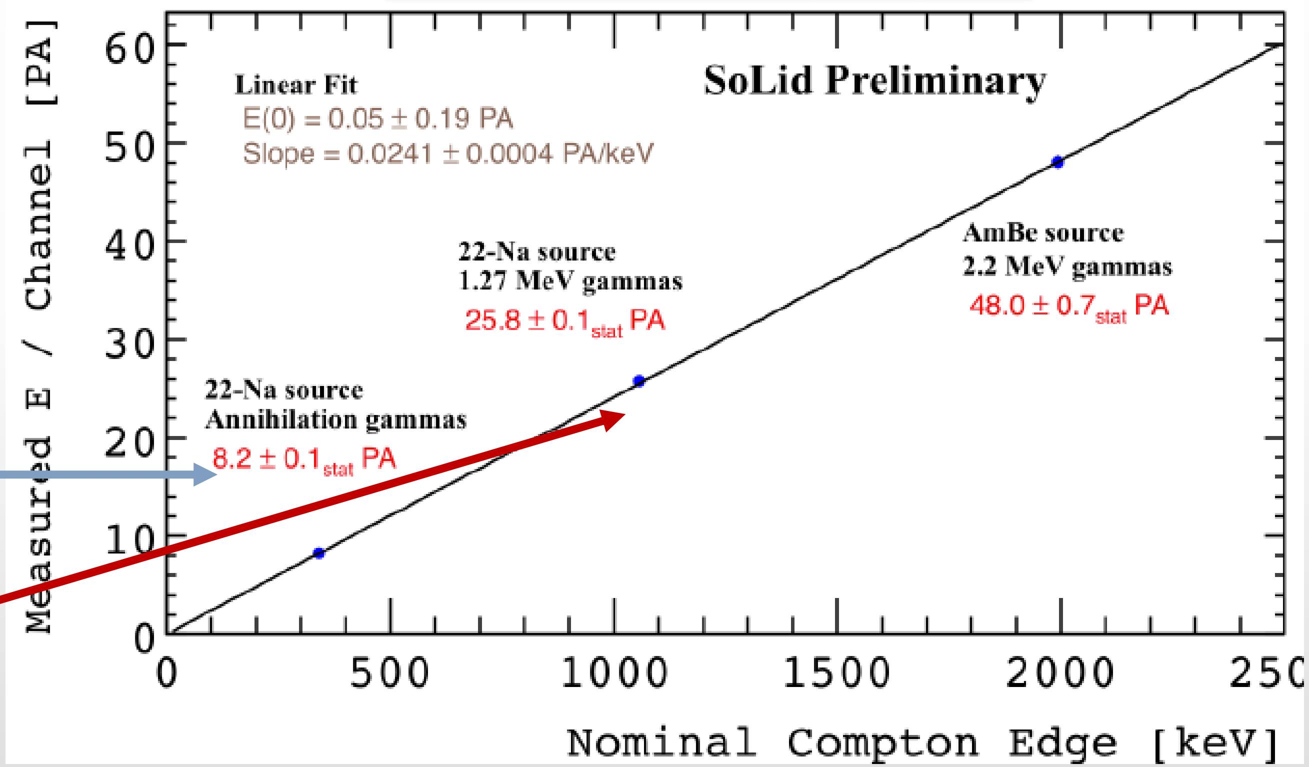
Nov 2017

Optical performance

- 99% of channel gains equalized to 1.4% spread
- Linear energy response over wide range
- Will add more sources/energies: Including conversion γ's from ^{207}Bi
- Exploit muons for real-time monitoring

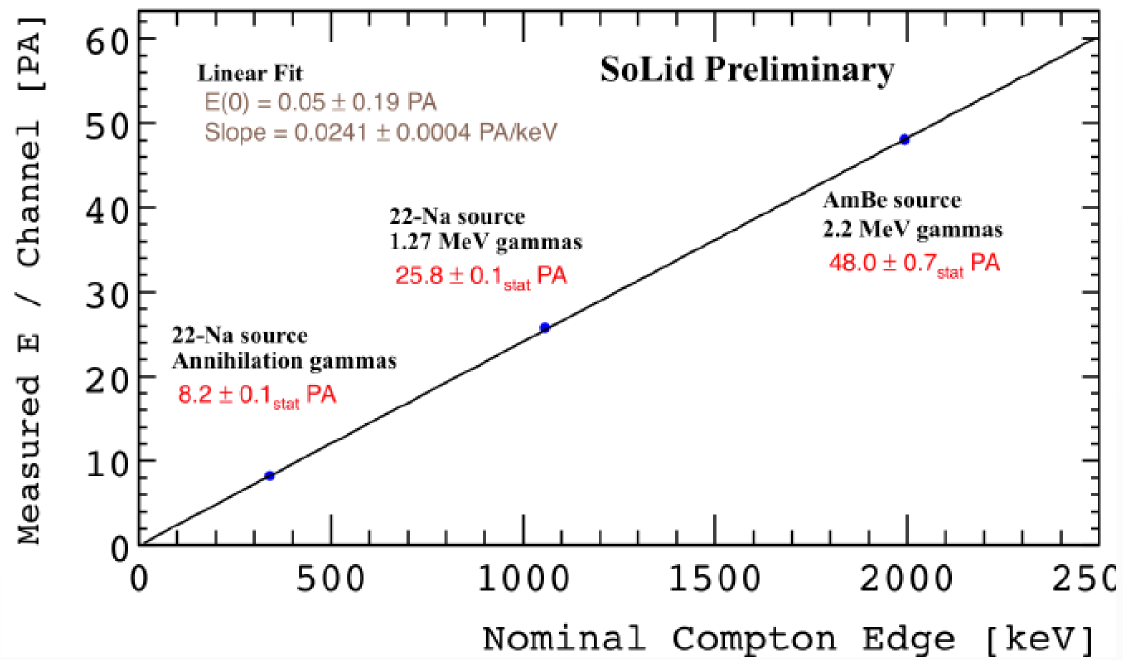
JINST 2018_JINST_13_P09005

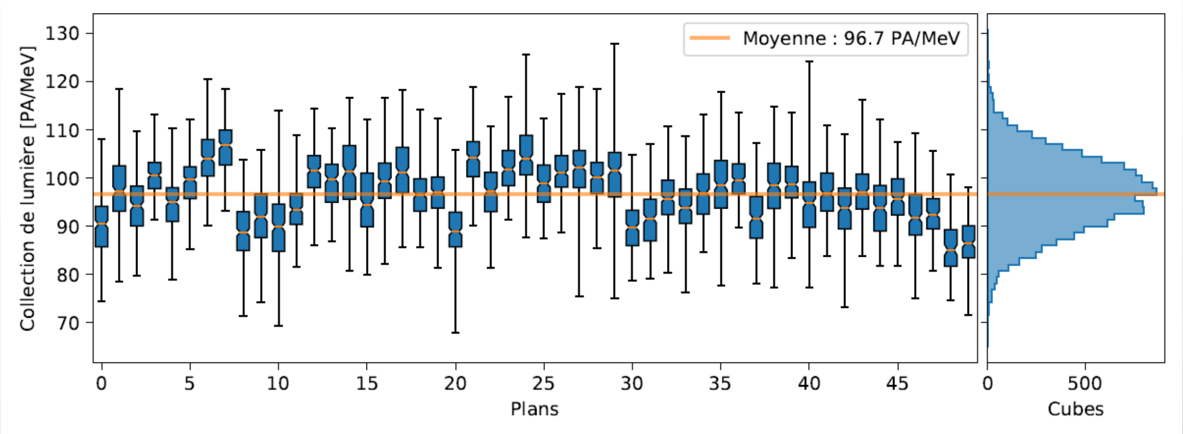




Optical performance

- Channel gains equalized to 1.4% spread
- Linear energy response over wide range
- Will add more sources/energies and exploit muons for real-time monitoring
- Pre-integration calibration crosschecked & complemented by in-situ calibration
- Light yield: 96.7 PA/MeV/cube with 20% X-talk 81 PA/MeV→$\sigma(E)/\sqrt{E}$ = 11% at 1 MeV
- Very good consistency between ^{22}Na and AmBe





Trigger and DAQ

Nov 2017 | Dec 2017 | Feb 2018 | Mar 2018

Construction & Quality Control

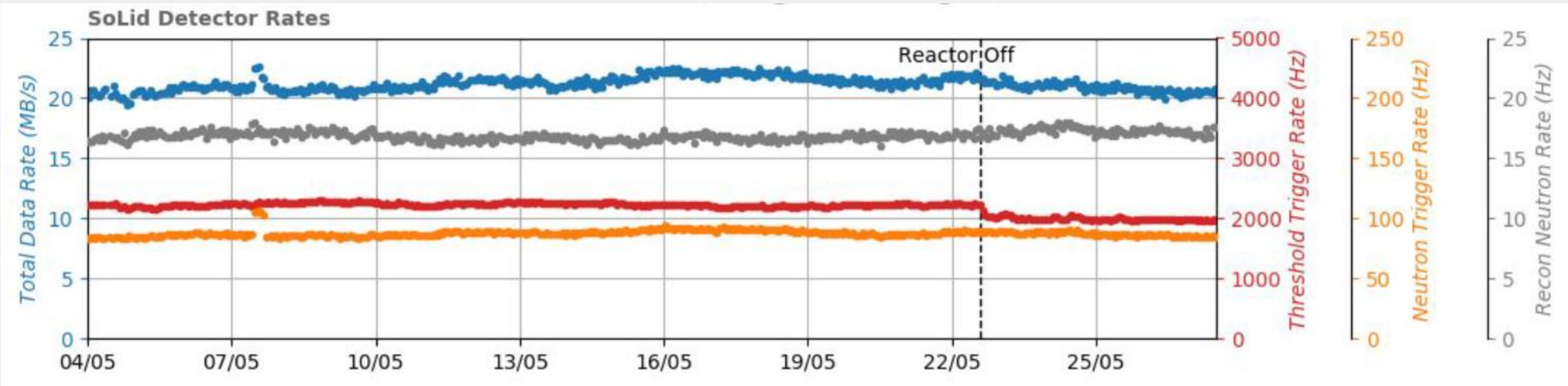
Installation

Commissioning at BR2

In-situ calibration

Physics

Random	Threshold	Neutrino
Full detector readout at 1 Hz. Non zero-suppressed waveforms for SiPMs monitoring.	Require XY coincidence > 2 MeV. Muon and high electromagnetic event tagger.	PSD algorithm for neutrons. Past time buffer & *multiplane* readout →**Unbiased prompt detection.**



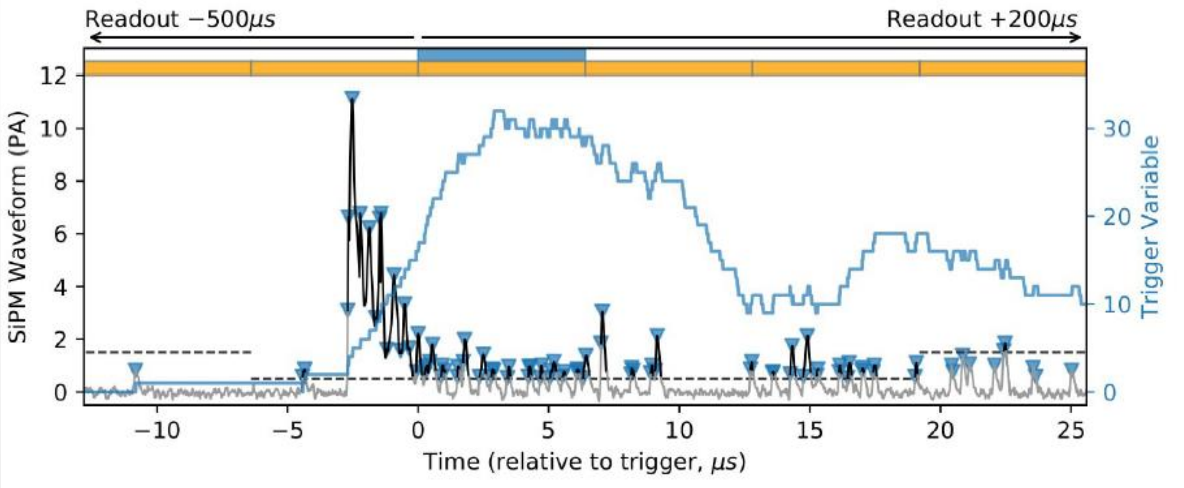
Trigger and DAQ

Random	Threshold	Neutrino
Full detector readout at 1 Hz. Non zero-suppressed waveforms for SiPMs monitoring.	Require XY coincidence > 2 MeV. Muon and high electromagnetic event tagger.	PSD algorithm for neutrons. Past time buffer & *multiplane* readout →**Unbiased prompt detection.**

- Neutron trigger implemented in FPGA
  - Based on scintillation signal induced in 6LiZnS: lots of secondary peaks

    → Count number of peaks over treshold in sliding time window
  - Read out long time buffer around NS: [-500 µs, +200µs]

Type	Signal	Taux	Amplitude
ES	Bruit thermique	100 MBq	< 10 PA
	γ Réacteur	100 kBq	10-100 PA
	Muons	100 Bq	> 150 PA
NS	Alpha	10 Bq	< 50 PA
	Neutron	1 Bq	< 40 PA
ES+*NS*	IBD	0.01 Bq	50-200 PA (*ES*)



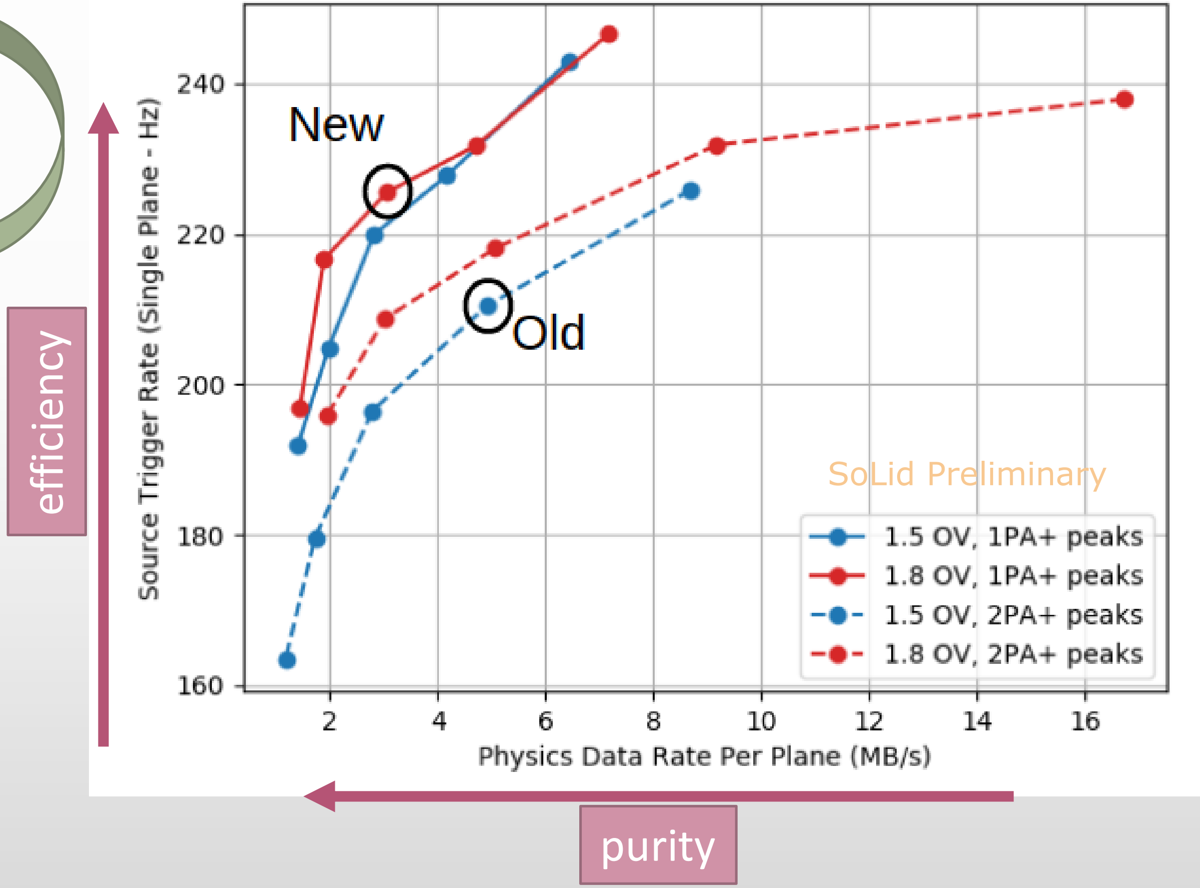
Trigger and DAQ

Random	Threshold	Neutrino
Full detector readout at 1 Hz. Non zero-suppressed waveforms for SiPMs monitoring.	Require XY coincidence > 2 MeV. Muon and high electromagnetic event tagger.	PSD algorithm for neutrons. Past time buffer & *multiplane* readout →**Unbiased prompt detection.**

- Neutron trigger implemented in FPGA
  - Based on scintillation signal induced in 6LiZnS: lots of secondary peaks

    → Count number of peaks over treshold in sliding time window
  - Read out long time buffer around NS: [-500 µs, +200µs]
- Performance
  - Trigger&PID efficiency 79 ± 3 % (trig dominated)
  - Trigger purity ~20%
  - DAQ efficiency > 90%

Neutron trigger performance



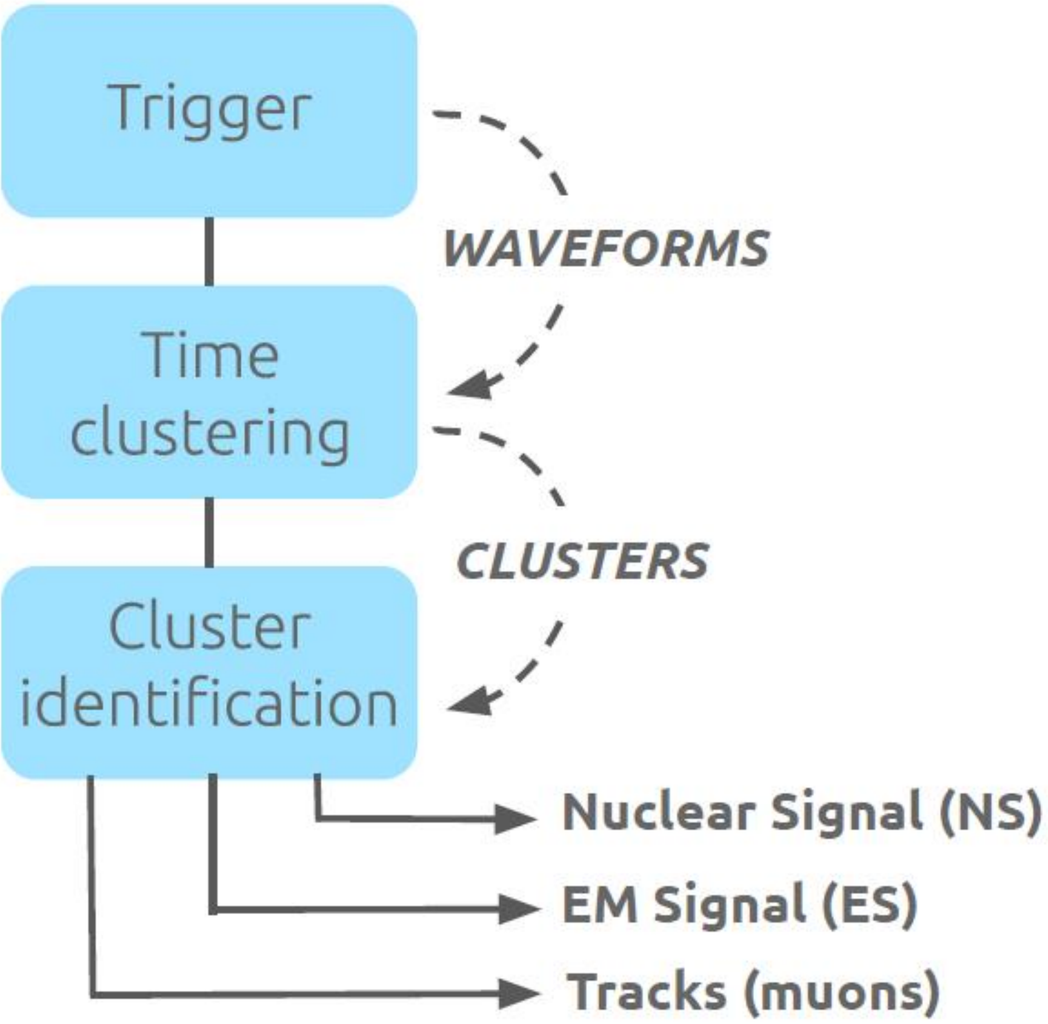
Trigger and DAQ

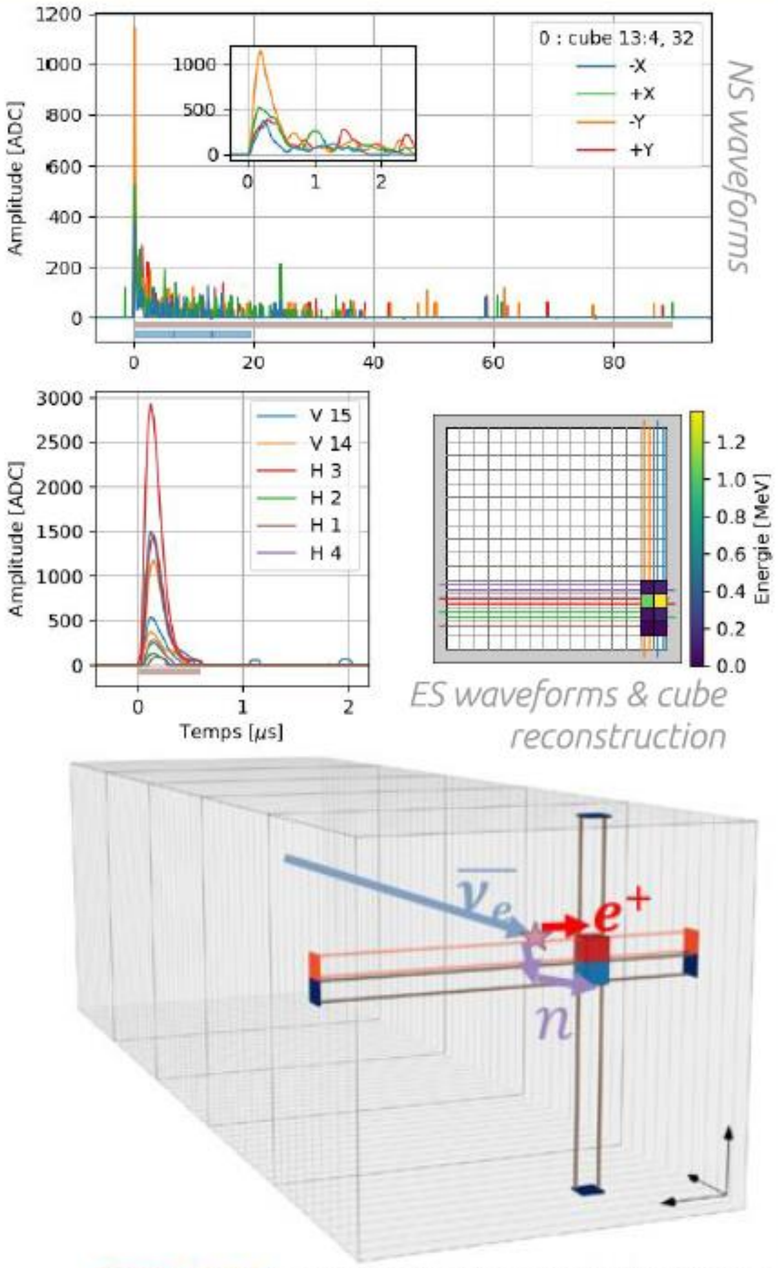
Random	Threshold	Neutrino
Full detector readout at 1 Hz. Non zero-suppressed waveforms for SiPMs monitoring.	Require XY coincidence > 2 MeV. Muon and high electromagnetic event tagger.	PSD algorithm for neutrons. Past time buffer & *multiplane* readout →**Unbiased prompt detection.**

- Performance
  - Trigger&PID efficiency 79 ± 3 % (trig dominated)
  - Trigger purity ~20%
  - DAQ efficiency > 90%
- Physics 'run' = 480 s
- Data rate after trigger (1000x reduction of raw output): 20 MB/s
- Up to 2 TB/day of data, locally stored and distributed to Belgian Tier2 and IN2P3 LYON and Grid-UK
- On Tier2 centres processed by Reconstruction Software (SAFFRON)

Trigger	ZS	Région de lecture		Taux [Hz]	Débit [MB/s]
		Espace	Temps [μs]		
Périodique	Aucune	50 plans	12.8	1.2	3.9 (19 %)
Seuil	1.5 PA	1 plans	6.4 μs	2.1 k	2 (10 %)
NS	0.5-1.5 PA	7 plans	-500, +200	40	15 (71 %)

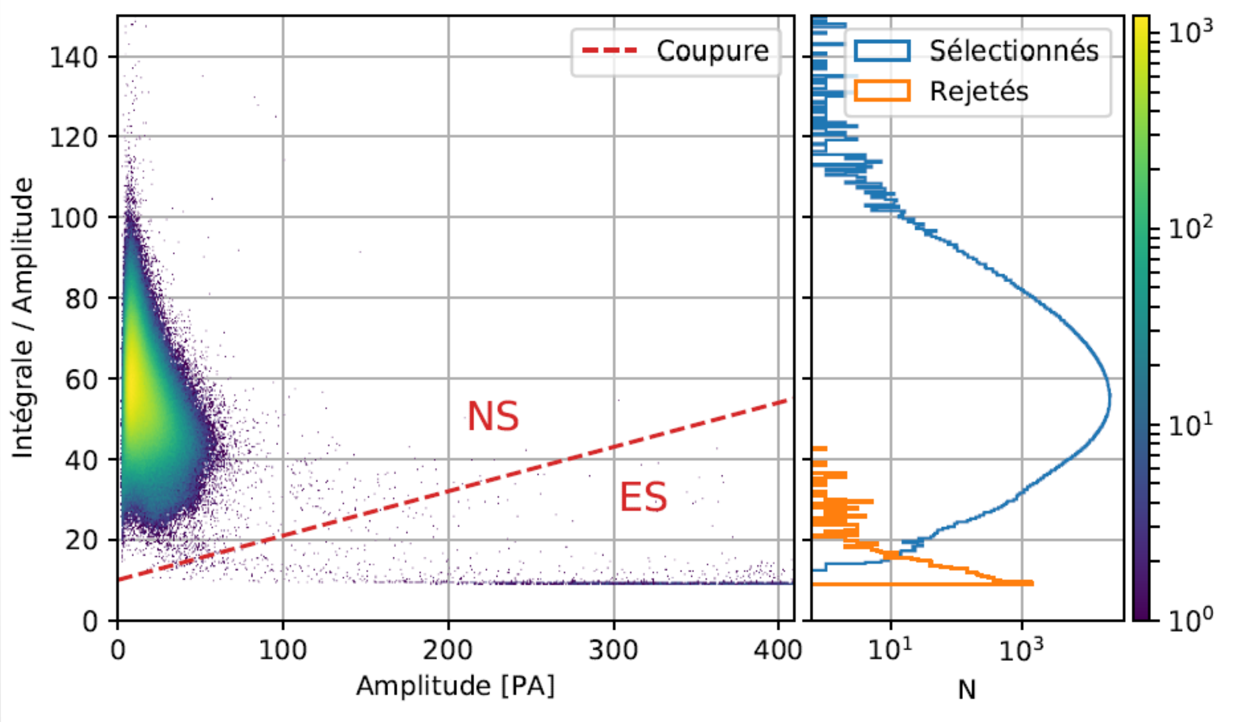
Data reconstruction



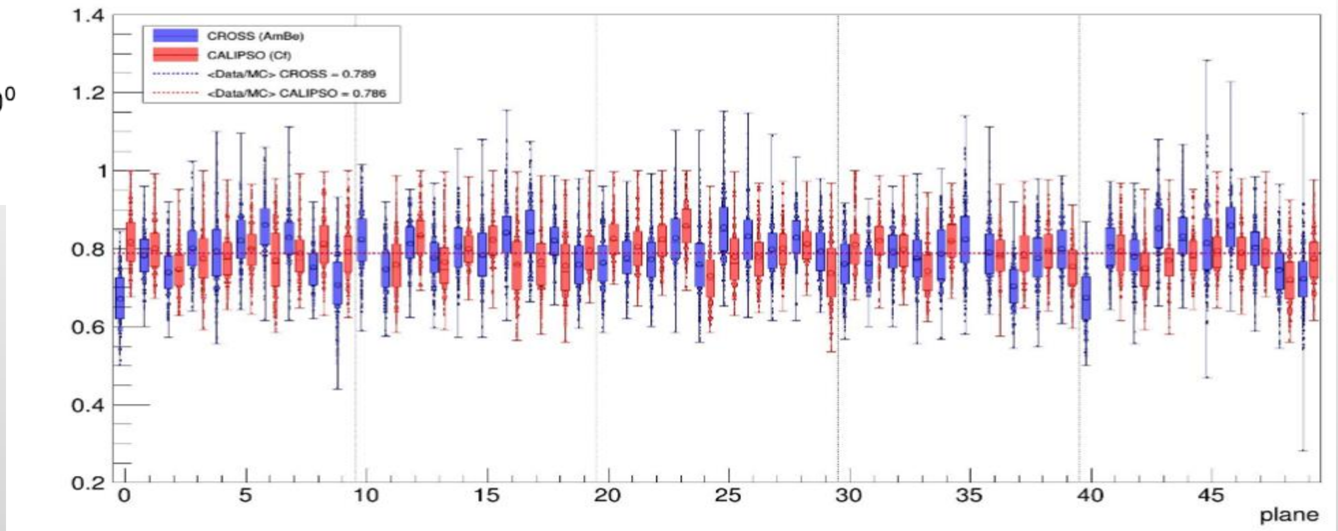


Prompt-Delayed Coincidence Candidate - 2017/12/05, 00:07:26

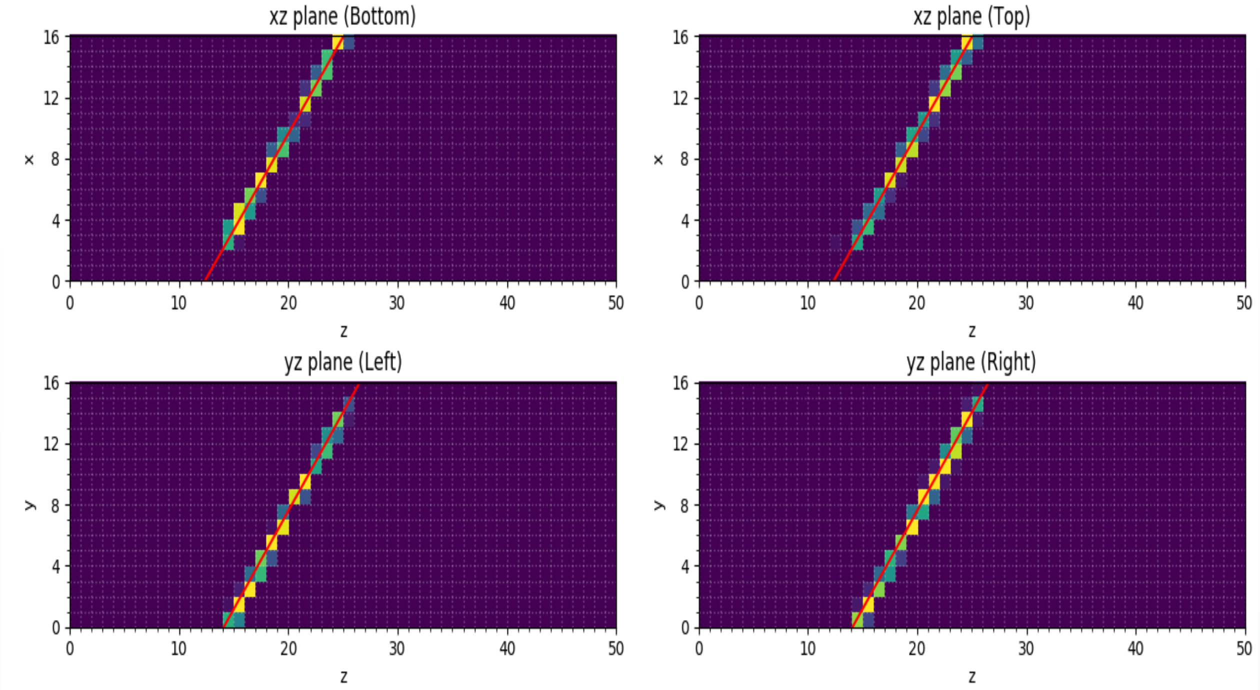
Neutron reconstruction



- Validated in-situ with AmBe and ^{252}Cf sources: $\rightarrow$ neutron detection efficiency per cube!
- Average trigger $\otimes$ reconstruction efficiency= $73.9^{+4}_{-3.3}\%$
- Capture efficiency = 71 $\pm$ 2%
- Total neutron detection eff= 52 $\pm$ 5%

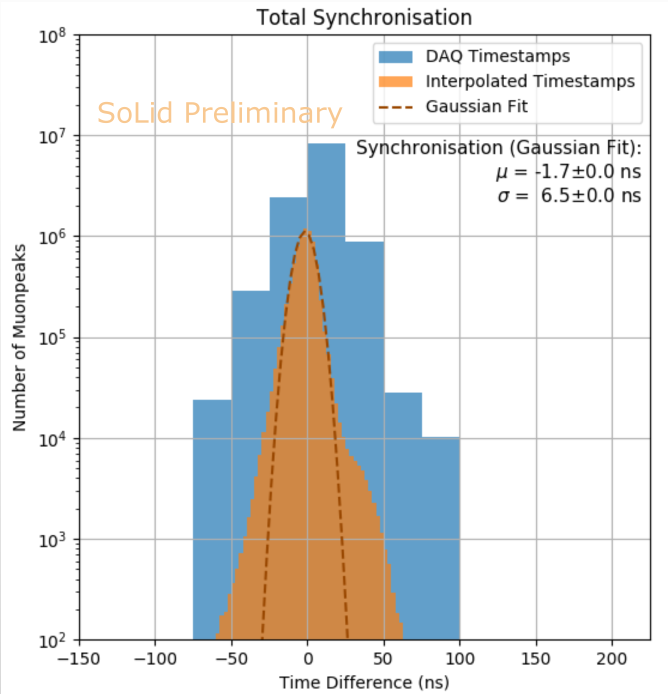


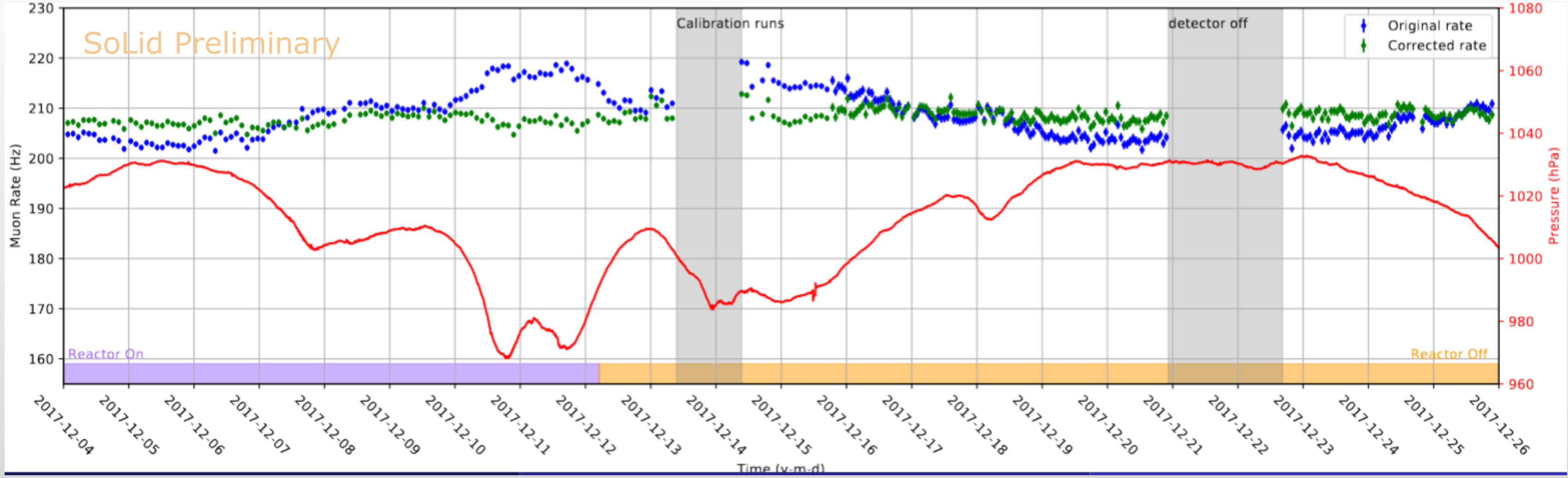
Event Topologies: Muons



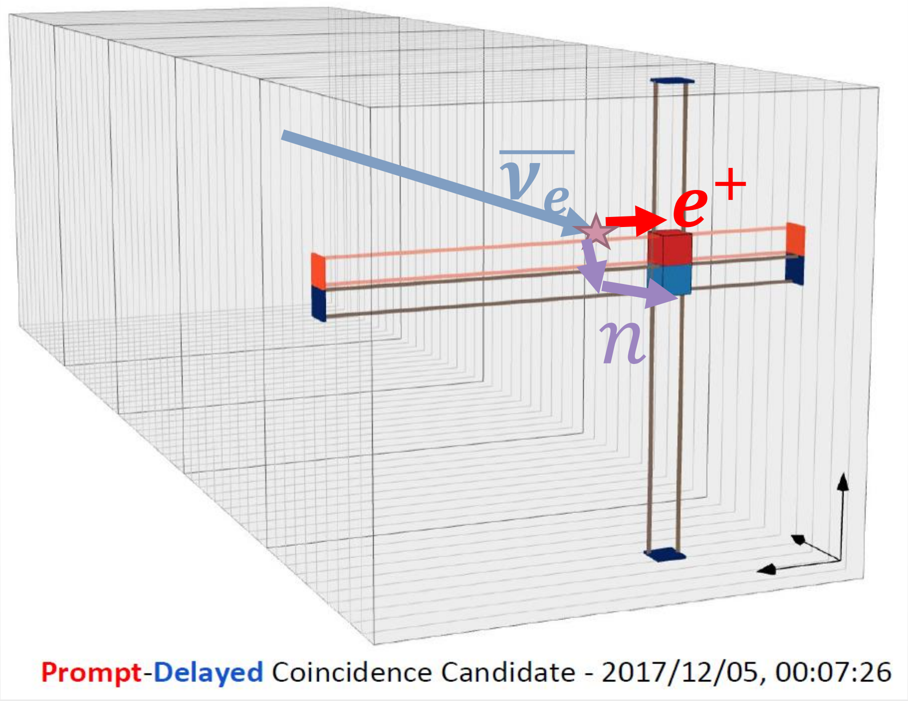
Exploit temporal AND spatial event information:

- Muons: Tracking and dE/dx
- Time Synchronisation Validation
- Monitoring and pressure correction

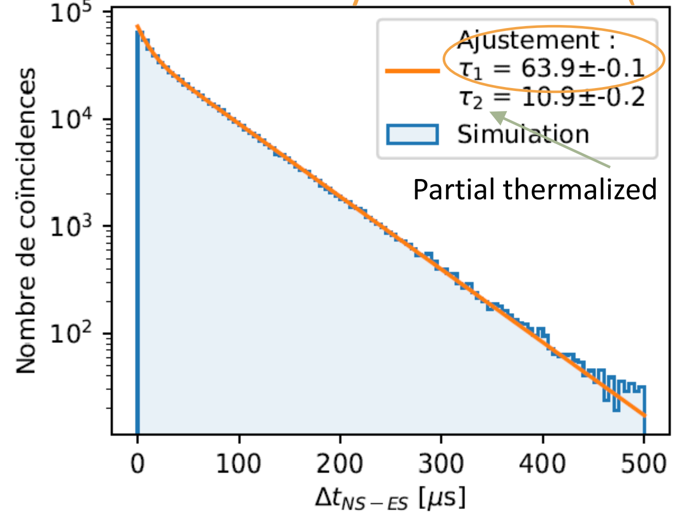




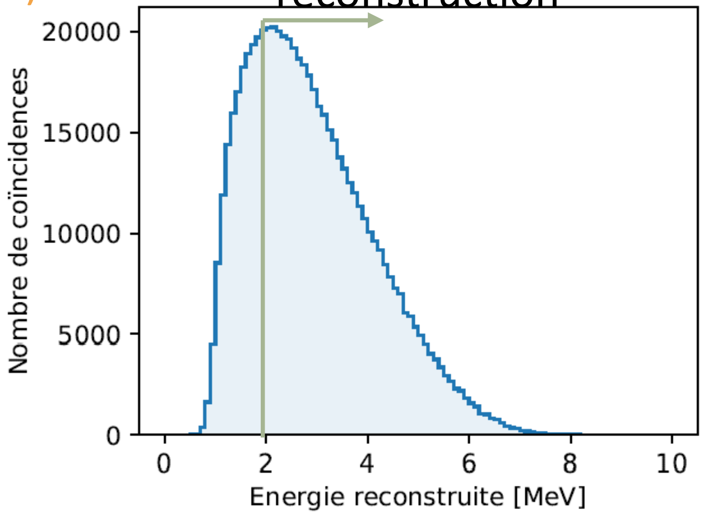
Event Selection: IBD

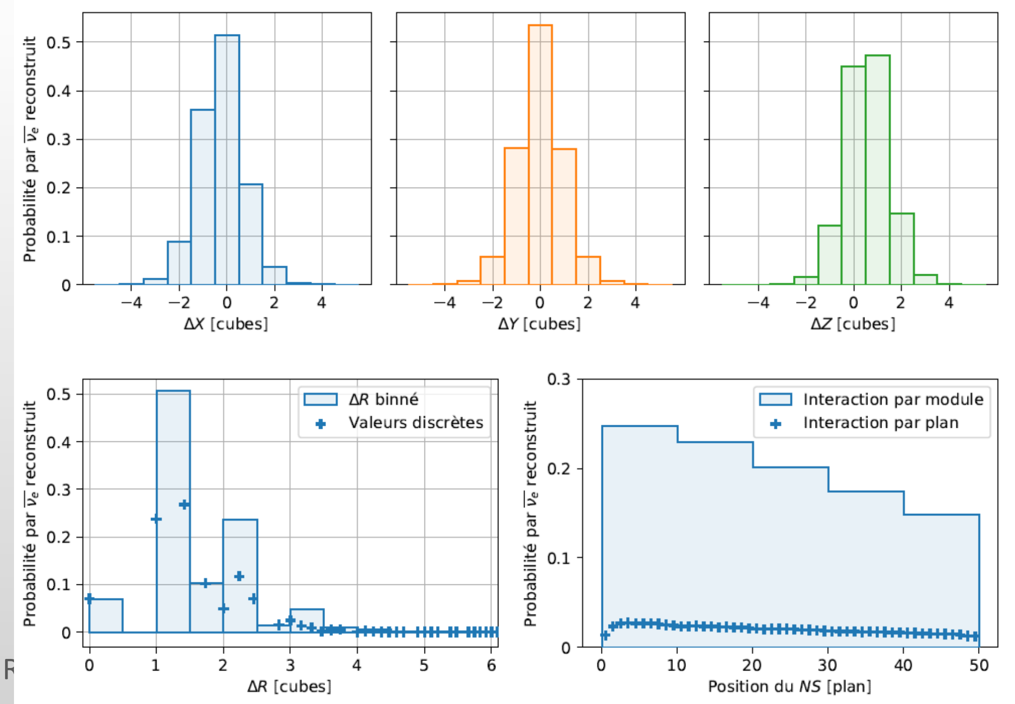


Fuly thermalized (90%)



1 MeV treshold, from reconstruction





Maximum detectable rate (flux x IBD x acceptance x n captured in Li: 7mHz

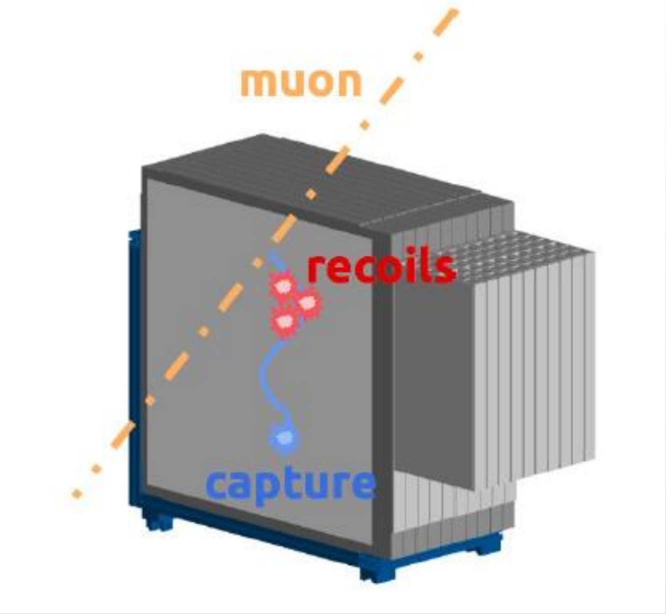
$$\Delta X = X_{NS} - X_{ES}^{\max(E)}$$

$$\Delta R = \sqrt{\Delta X^2 + \Delta Y^2 + \Delta Z^2}$$

+ muon and 2nd neutron veto
+ fiducialisation

Main Backgrounds

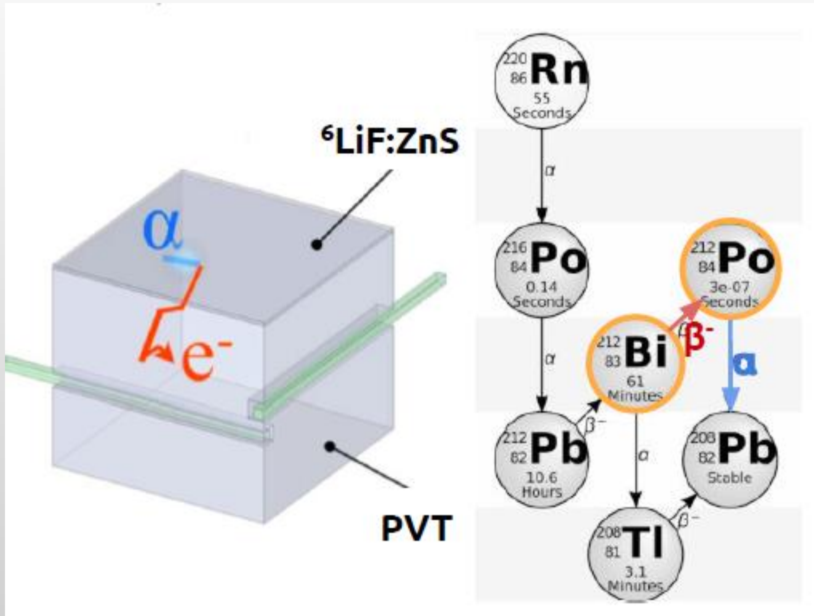
- Fast neutrons:
  - Cosmic muon spallation
  - Direct from cosmic shower
- n-recoils mimic prompt ES: very difficut to distinguish, need to tag annihilation gamma's from true prompt ES
- Delayed n-detection identical to IBD



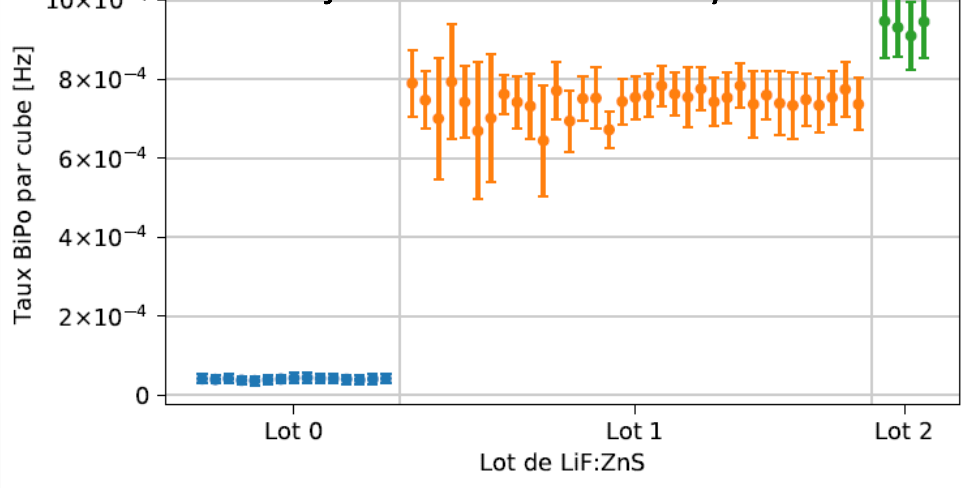
- BiPo:
- Contamination from $^{238}U/^{232}Th$ series in n-detection screen
- $^{214}Bi \underset{\beta}{\rightarrow} {}^{214}Po \underset{\alpha}{\rightarrow} {}^{210}Pb$

Results in $\beta^-$and α with

$$T_{\frac{1}{2}}(Po) = 164\mu s$$
$$Q_\beta = 3.27\ MeV$$



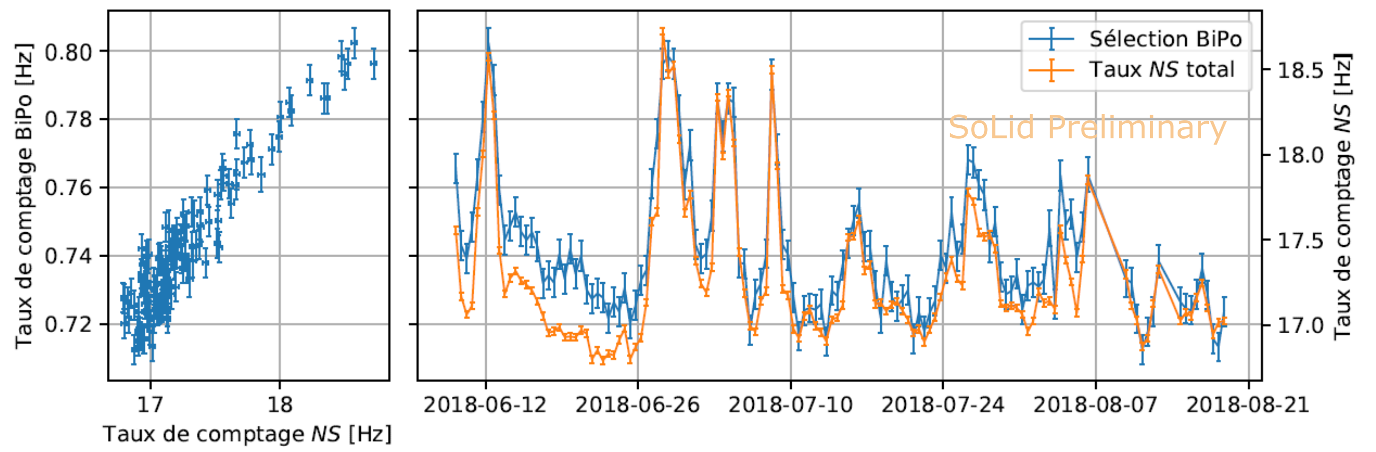
Major concern for analysis!

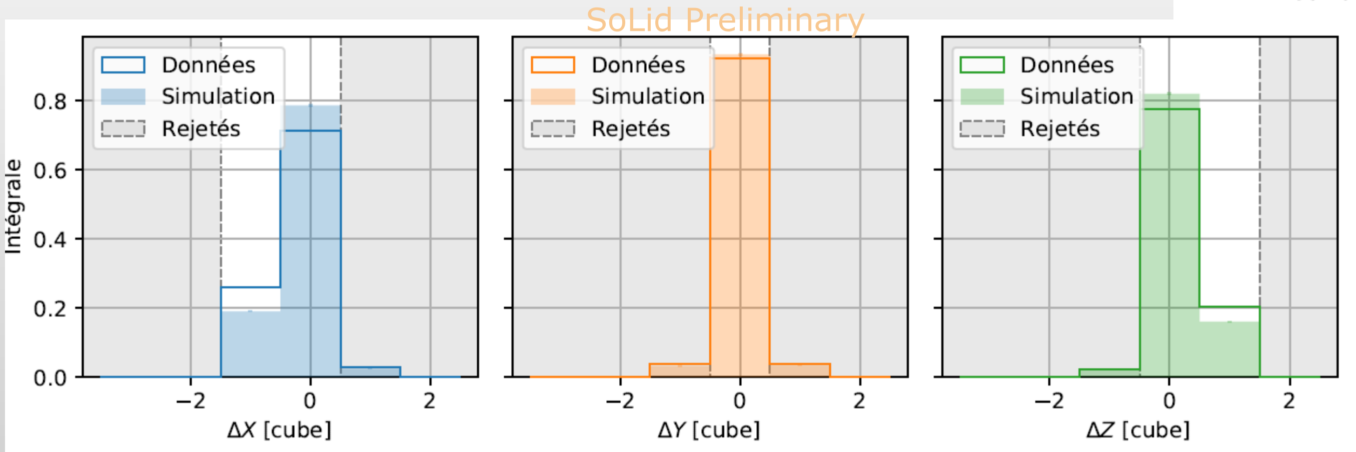


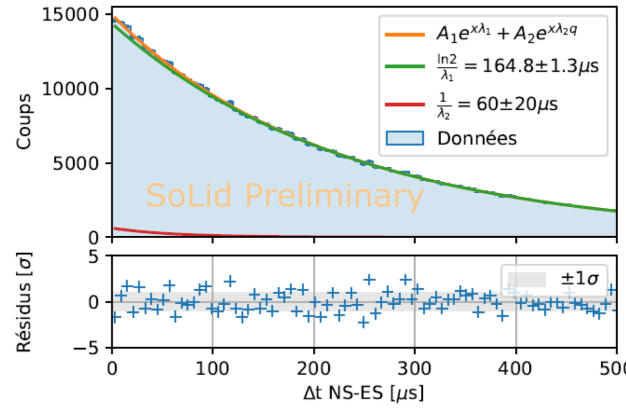
- Mitigation:
  - Energy
  - Timing
  - Topology
  - Localisation inside hybrid cell

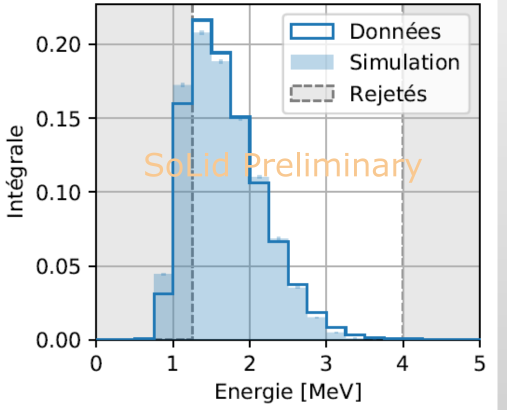
Attacking the natural radioactivity

- Neutron signals are very correlated with dedicated and pure BiPo control region
- BiPo contaminates our main event sample at energies < 2 MeV
- 10% time variation in measured BiPo indictes airborne Rn , built up in Reactor building: Started flushing container in controlled way as of April 2019.
- How does it behave?
  - Spatially confined ✓
  - Low energy✓
  - Longer capture time✓
- Event rate: using efficiency derived from sim: 2,2-2.8 Hz vs 0.007 Hz for IBD!



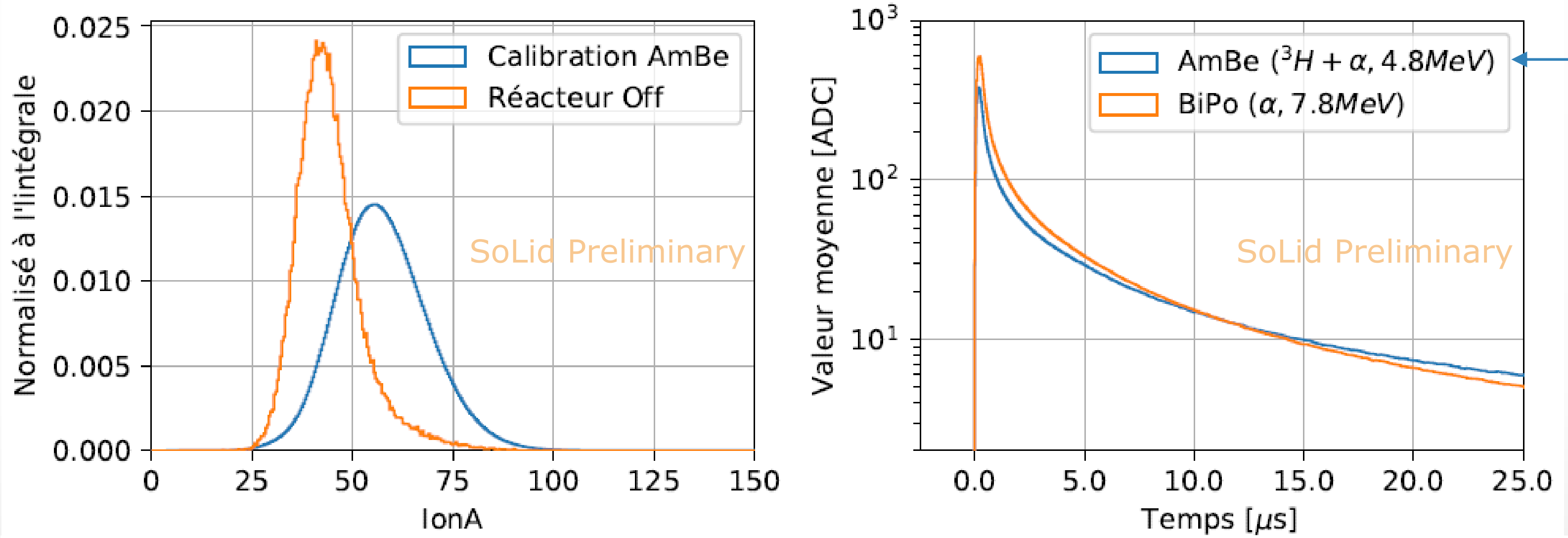






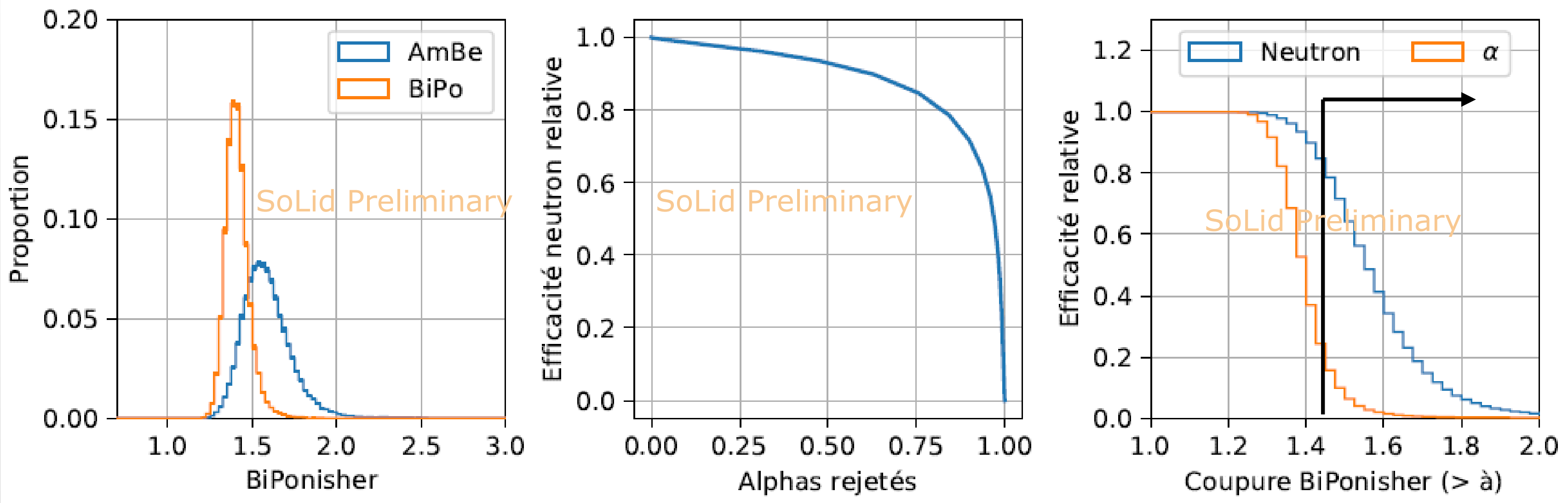
Killing the BiPo

- Waveforms from N-captures on ^{6}Li are different than alphas exciting the LiF:ZnS screens



Pure n-samples from high-activity calibration sources

Discriminant :Ratio of long time {0-87,5} μs integral over short time {0-7} μs integral



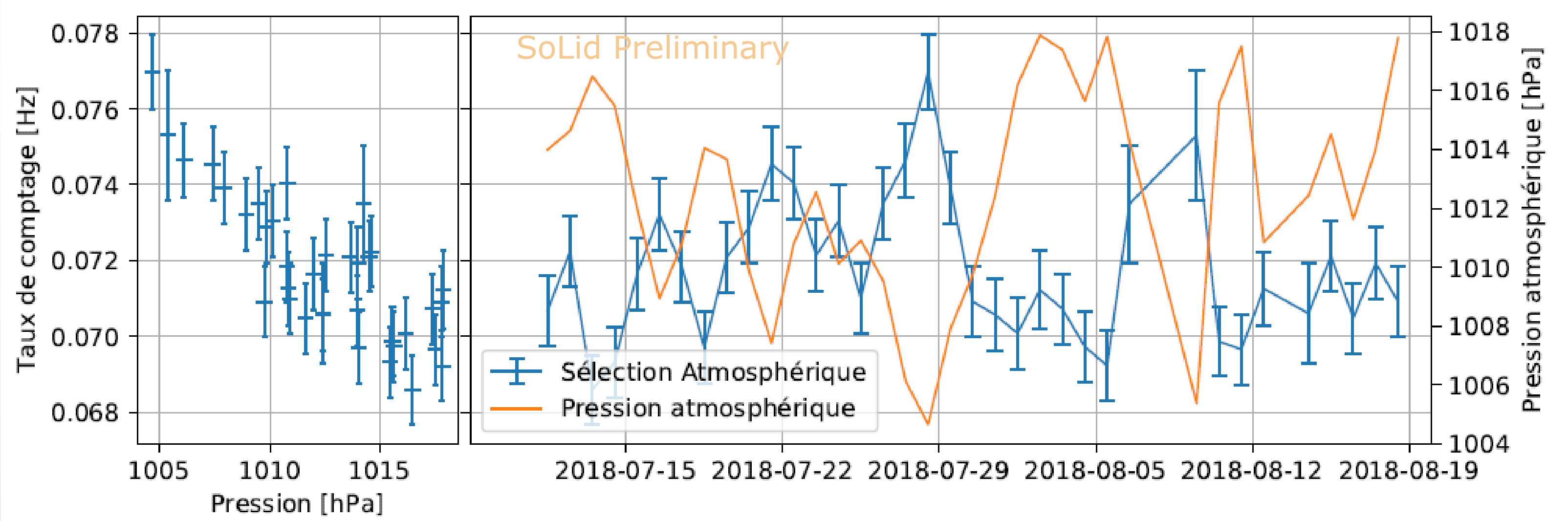
Killing alpha contamination by 75% while retaining 85% good neutrons

Nice! But still not good enough
⇒Additional topological and

energy cuts, or smarter methods

Fast (atmospheric) neutrons

- Disadvantage of neutrino detector with no overburden!
- Passive water shielding removes some fraction (epithermals)
- >2MeV neutrons can induce proton recoils that mimic prompt ES
- Possible to onstruct pure control sample from data
- Flux strongly correlates with atmospheric desnsity (pressure)

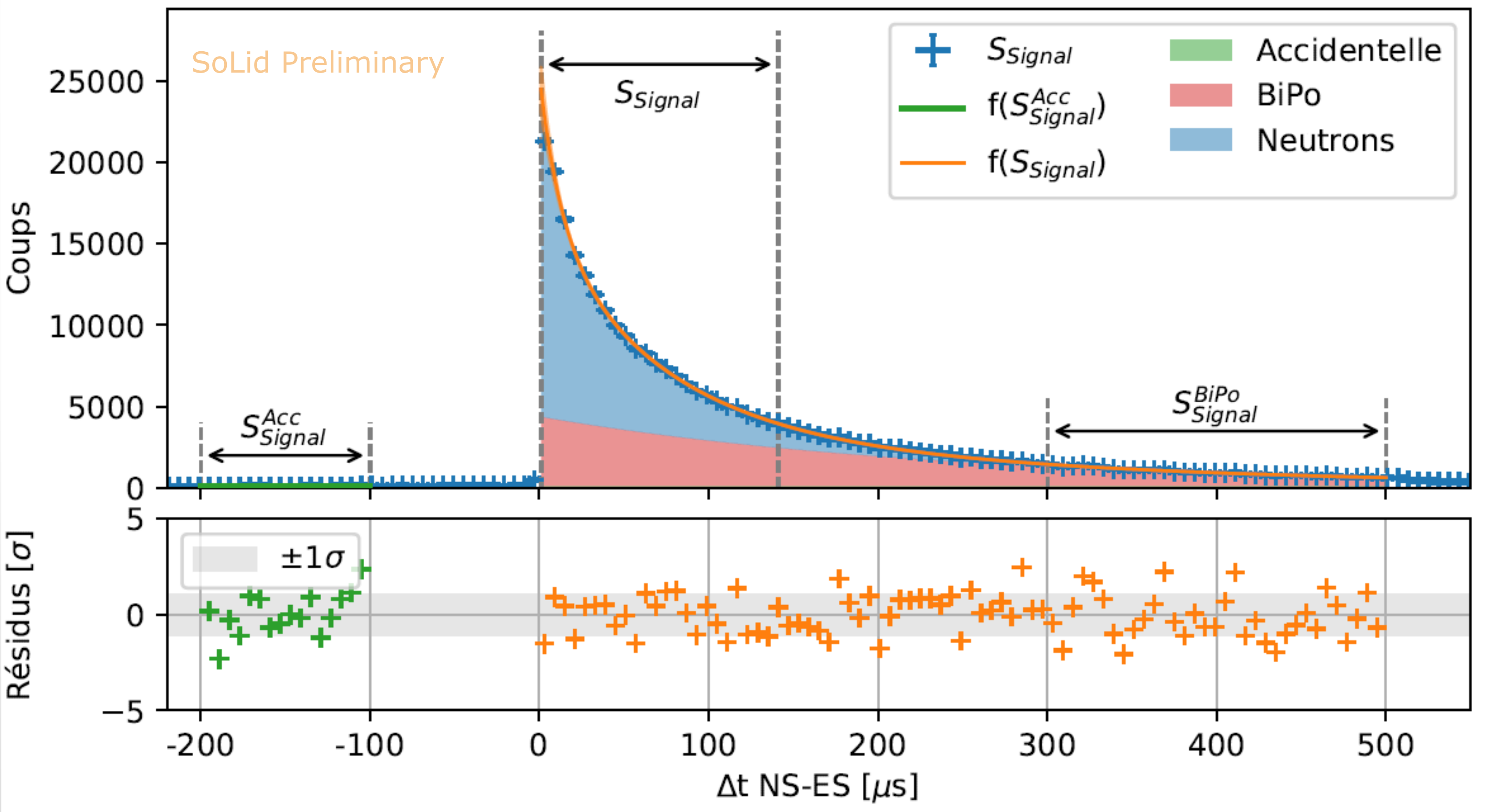


Allows to model this bg rate during reactor ON periods

Can one discriminate waveforms induced by p-recoils from prompt ES? Hardly!

Rely on presence of Muon signals in relevant time window
Rely on multiplicity: multiple recoils

Defining signal and background regions



- BiPo: extracted from tails: real time monitoring sample in data
- Accidentals:
  From negative time window
- Atmospheric n: extracted from different control region (not shown) and modeled wrt atm. press.
- Optimize time window for signal extraction
- Complementary approach via BiPonisher discriminant

Sélection	Neutrons	BiPo	Accidentels
S_{Signal}	63 % (64 %)	36 % (36 %)	1 %
S^{BiPo}_{Signal}	5 % (5 %)	83 % (95 %)	12 %

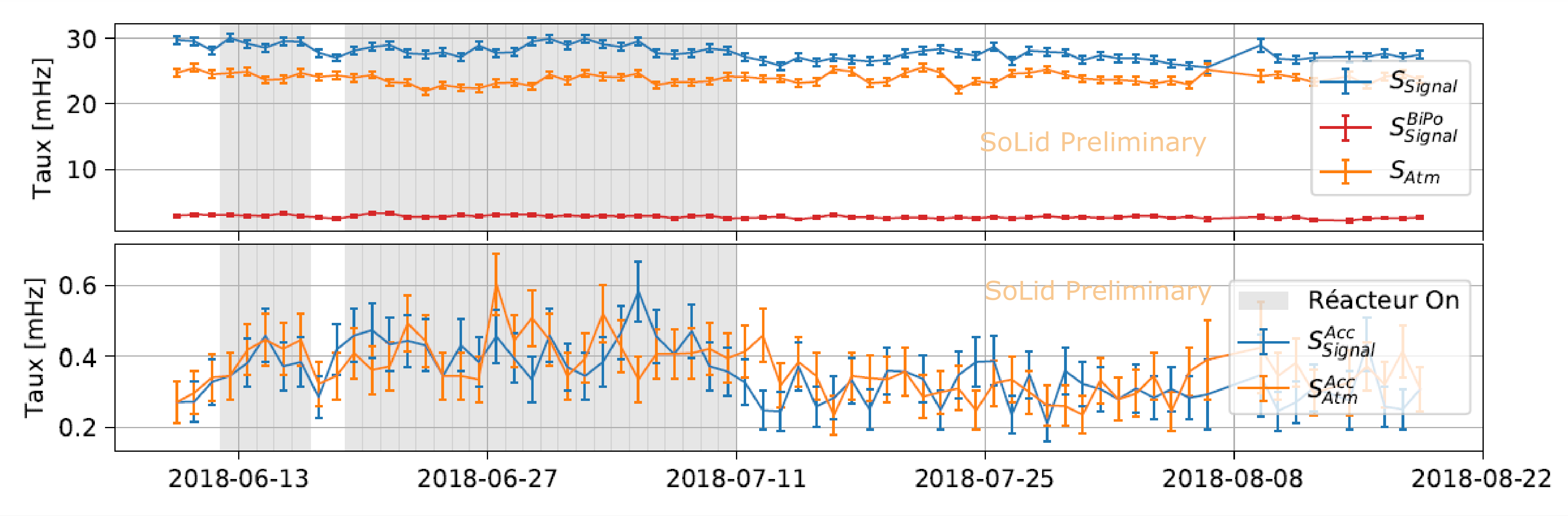
Extracting the IBD signal

- Commissioning data: June 2018- Feb 2019
- Physics data: > April 2019
  - 227 Days Reactor off (reference)
  - 281 Days Reactor ON, average Thermal power 54 MW_{th}
    - Initial exposure to O(600) $\overline{\nu_e}$ IBD interactions/day
    - Blinded until Nov 2019 to perform unbiased analysis
  - Unblinded dataset for analysis setup:
    - June 9 – Aug 18 2018:
      22 days reactor ON at 60 MW_{th}
      34 days reactor OFF

Results shown today will be based on the small setup sample

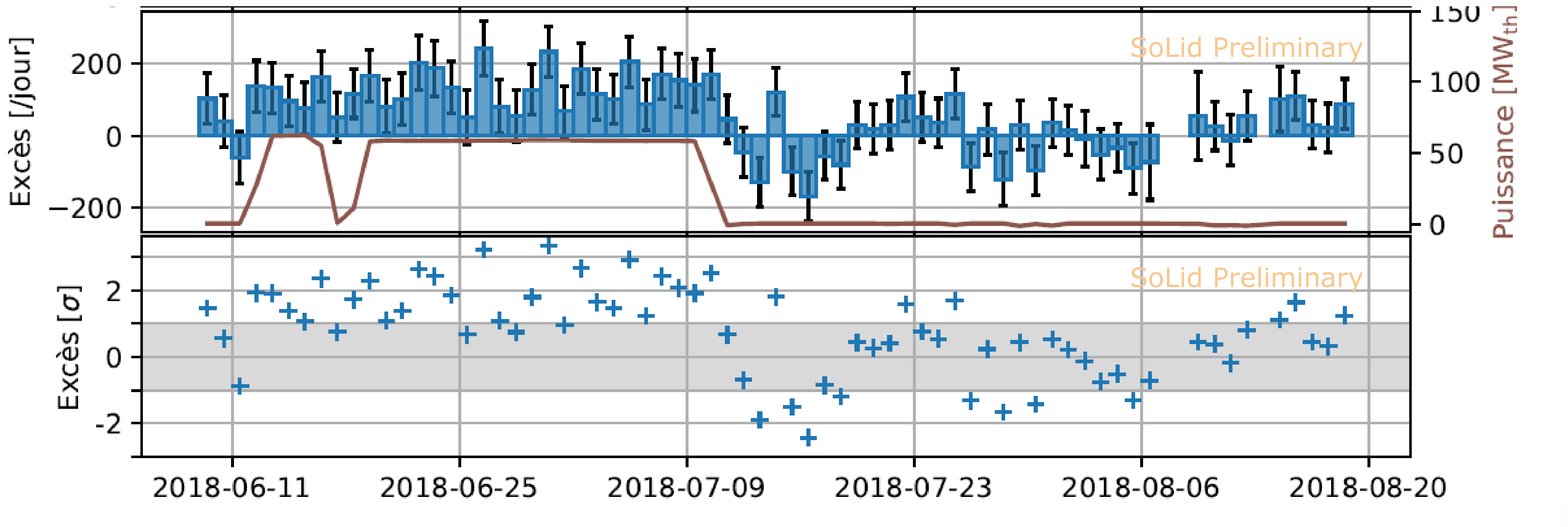
Large data set is currently being analyzed: expect public results by Moriond 2020

Time evolution (before subtraction)



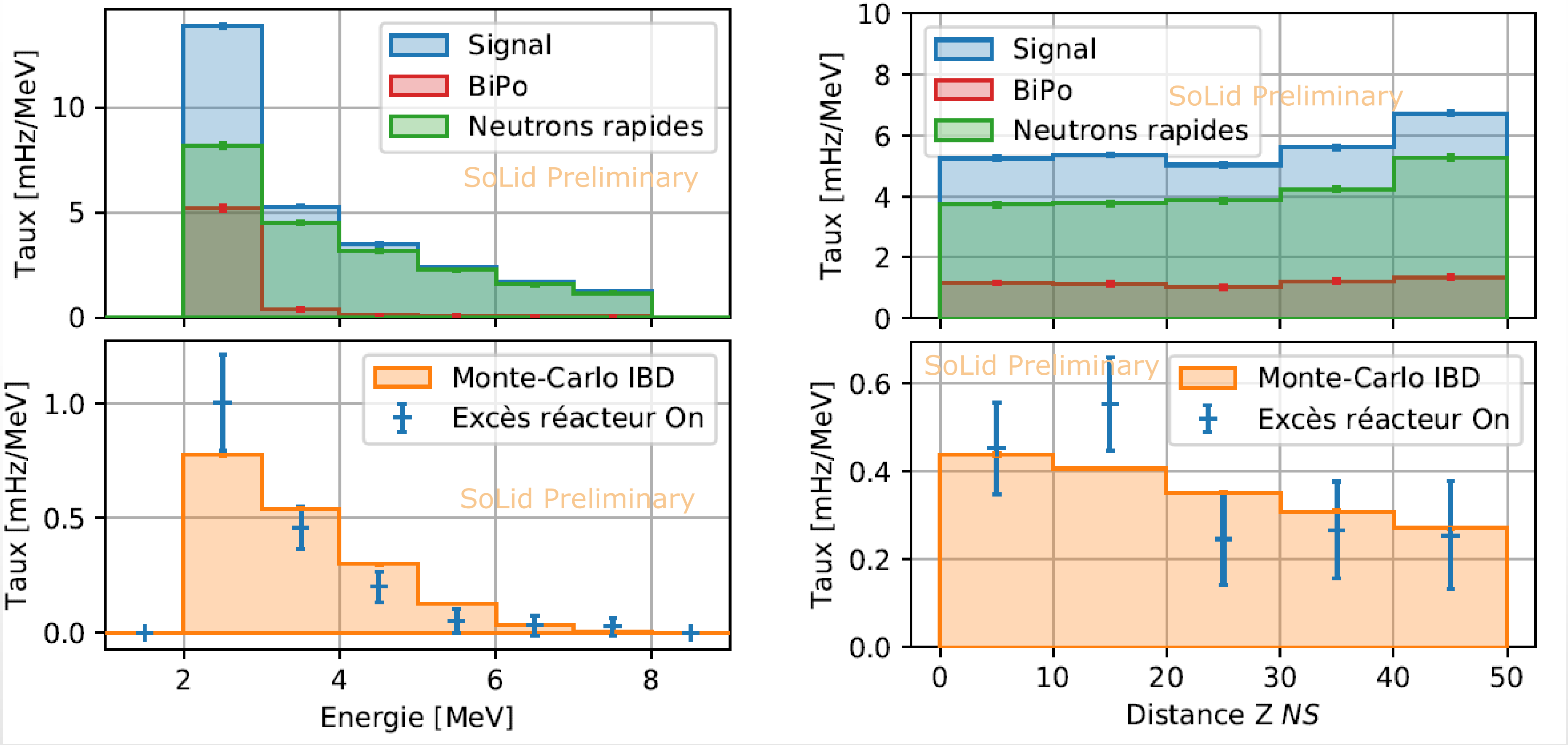
- Day to day fluctuations in rate are significant
- Scaling of BiPo control signal and Accidental rates according to time integration windows
- Atmospheric signal rate is complementary/independent data region and used for modeling
- Reactor On data is corrected for pressure dependence, computed from reactor off data
- IBD signal is extracted from Corrected reactor ON – reactor OFF difference

Time evolution (after subtraction)



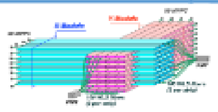
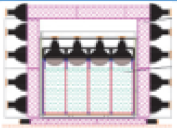
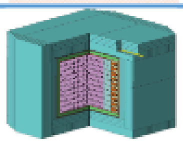
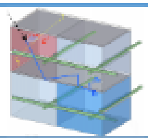
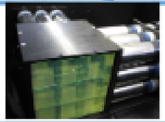
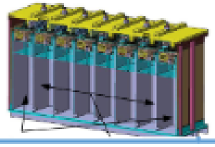
- Systematic excess of 2s/day observed during rector operations, coresponding to a rate of 1.7 mHz
- With IBD selection efficiency of 24% and a neutron detection efficiency of 52% one expects 145 IBDs/day at a S/N of 1/15
- Total integrated excess amounts to 3313 $\pm$ 558 (stat) events (5.9 σ stat)

Excess characteristics



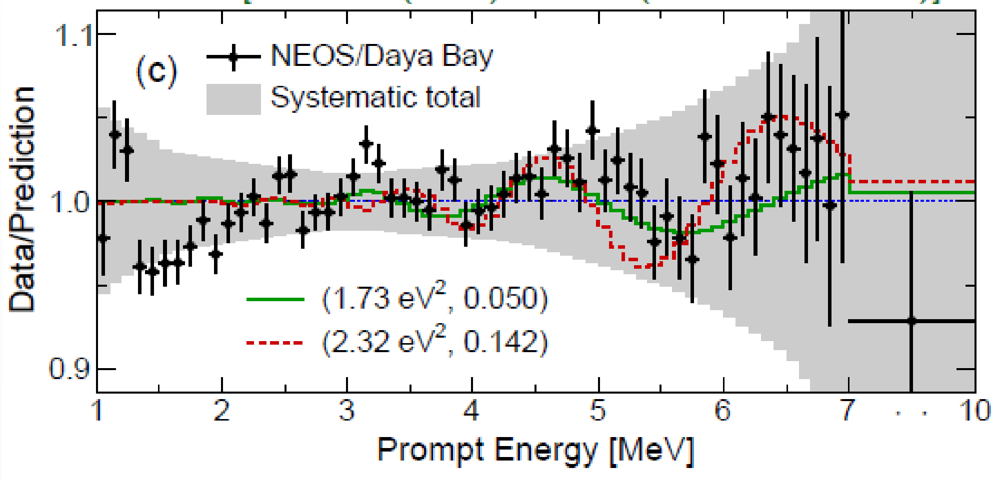
- Energy spectrum and vertex position behave as expected
- Also other topological distributions look OK
- Gives extra confidence that IBD exces is real

Short Baseline Reactor Experiments*

Experiment	Reactor Power/Fuel	Overburden (mwe)	Detection Material	Segmentation	Optical Readout	Particle ID Capability
DANSS (Russia) 	3000 MW LEU fuel	~50	Inhomogeneous PS & Gd sheets	2D, ~5mm	WLS fibers.	Topology only
NEOS (South Korea) 	2800 MW LEU fuel	~20	Homogeneous Gd-doped LS	none	Direct double ended PMT	recoil PSD only
nuLat (USA) 	40 MW ^{235}U fuel	few	Homogeneous ^{6}Li doped PS	Quasi-3D, 5cm, 3-axis Opt. Latt	Direct PMT	Topology, recoil & capture PSD
Neutrino4 (Russia) 	100 MW ^{235}U fuel	~10	Homogeneous Gd-doped LS	2D, ~10cm	Direct single ended PMT	Topology only
PROSPECT (USA) 	85 MW ^{235}U fuel	few	Homogeneous ^{6}Li-doped LS	2D, 15cm	Direct double ended PMT	Topology, recoil & capture PSD
SoLid (UK Fr Bel US) 	72 MW ^{235}U fuel	~10	Inhomogeneous ^{6}LiZnS & PS	Quasi-3D, 5cm multiplex	WLS fibers	topology, capture PSD
Chandler (USA) 	72 MW ^{235}U fuel	~10	Inhomogeneous ^{6}LiZnS & PS	Quasi-3D, 5cm, 2-axis Opt. Latt	Direct PMT/ WLS Scint.	topology, capture PSD
Stereo (France) 	57 MW ^{235}U fuel	~15	Homogeneous Gd-doped LS	1D, 25cm	Direct single ended PMT	recoil PSD

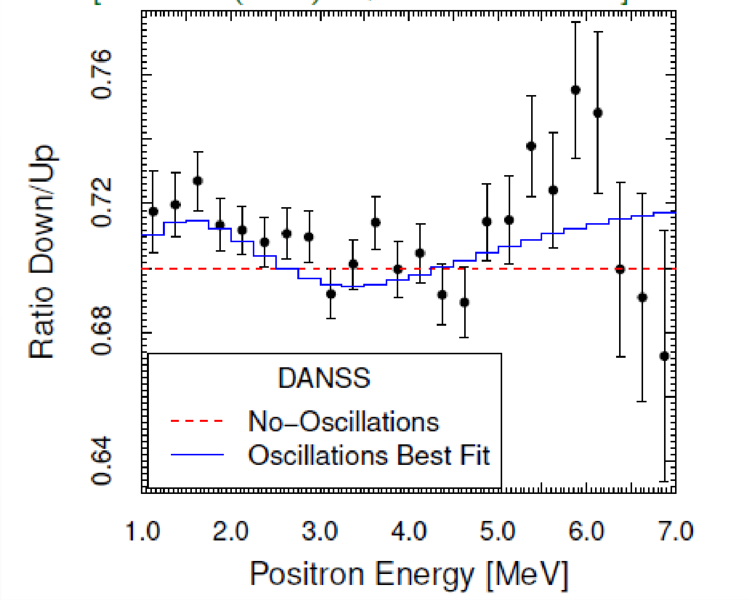
Hints of oscillations?

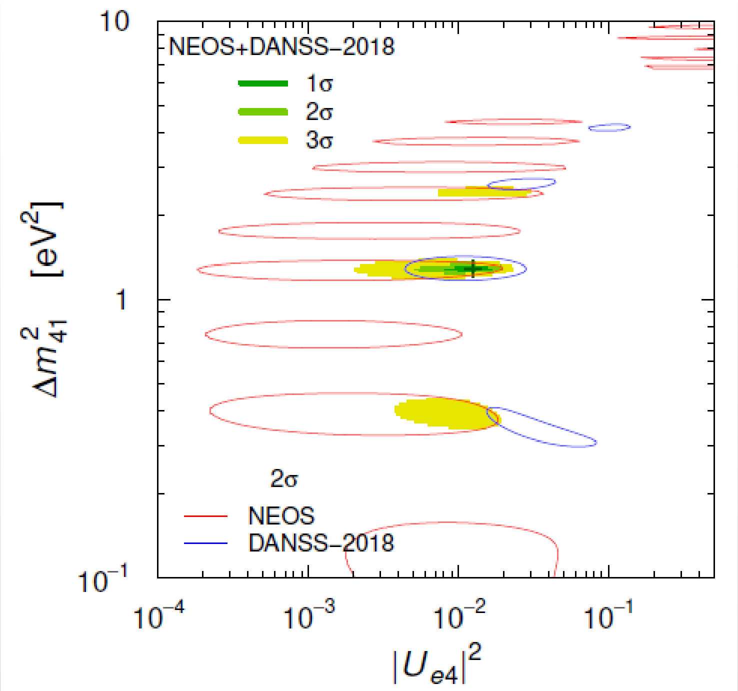
NEOS [PRL 118 (2017) 121802 (arXiv:1610.05134)]



DANSS-2018

[PLB 787 (2018) 56, arXiv:1804.04046]





2018 model independent indication in favor of SBL oscillations

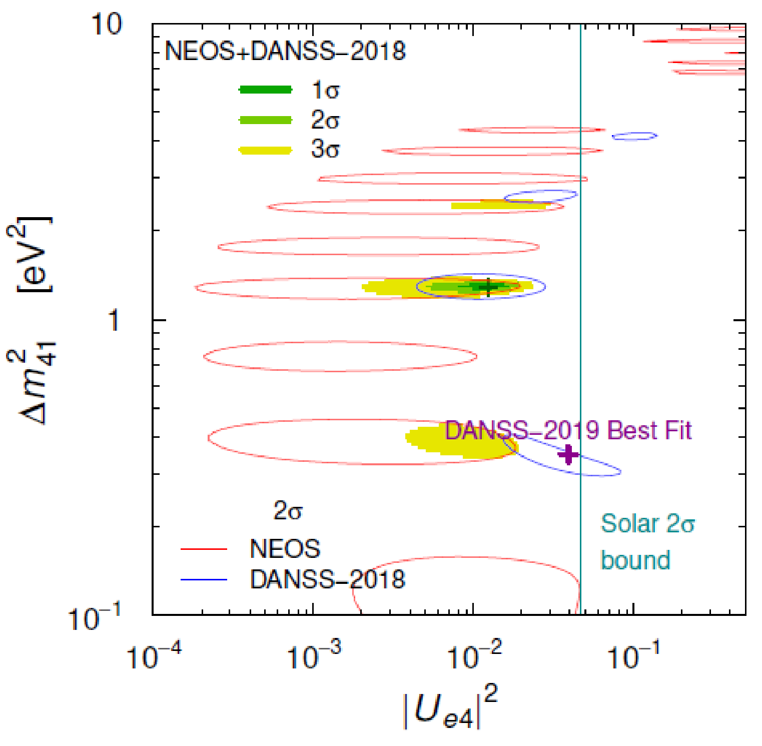
NEOS: $\sim 1.7\sigma$

DANSS-2018: $\sim 2.7\sigma$

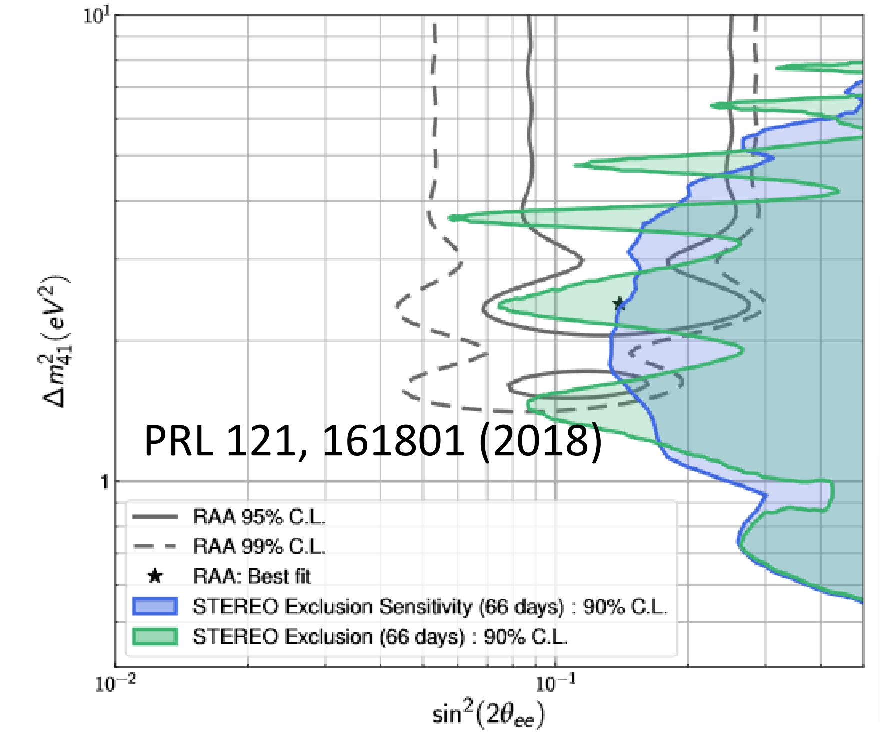
Combined: $\sim 3.5\sigma$

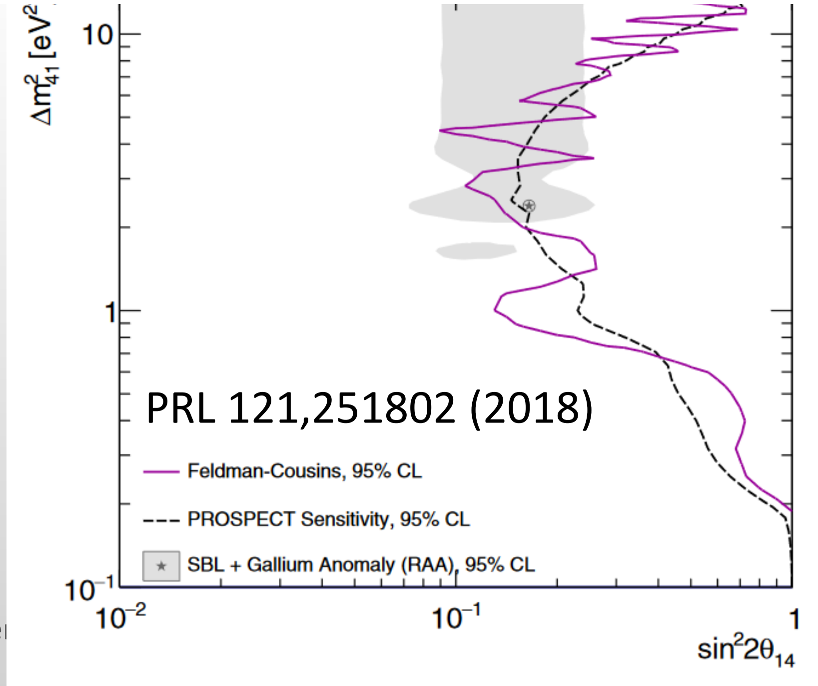
[Gariazzo, Giunti, Laveder, Li, arXiv:1801.06467]
[Dentler, Hernandez-Cabezudo, Kopp, Machado, Maltoni, Martinez-Soler, Schwetz, arXiv:1803.10661]

Hints of oscillations?



??





Conclusion & outlook

- Solid improved design after evaluating performance of full scale prototype module in 2015-2016
- Constructed a 1.6 ton detector (Phase1) in 2017 and commissioned it in 2018
- Validated performance with calibration & commissioning data
- SoLid is now taking good quality physics data and observes IBD-like events with 28% IBD efficiency and S/B = 1/15
- Additional efforts ongoing to increase the eff and improve the S/B
- More detailed results from a large unblinded dataset prepared for Moriond 2020
- Small upgrade is planned for summer 2020 (phase1.5): Replacing all MPPC's with newer generation (higher Photo efficiency and lower cross talk), will allow to tag annihilation gamma's of prompt signal

SoLid papers

[1] SoLid collaboration, Y. Abreu et al., A novel segmented-scintillator antineutrino detector, JINST 12 (2017) P04024, [1703.01683].

[2] SoLid collaboration, Y. Abreu et al., Performance of a full scale prototype detector at the BR2 reactor for the SoLid experiment, JINST 13 (2018) P05005, [1802.02884].

[3] SoLid collaboration, Y. Abreu et al., Optimisation of the scintillation light collection and uniformity for the SoLid experiment, JINST 13 (2018) P09005, [1806.02461].

[4] S. Kalcheva, G. Van den Branden, V. Kuzminov, E. Koonen, L. Giot and M. Fallot, Reactor Core Simulations for Determination of the Antineutrino Spectrum for the SoLid Experiment at BR2 Reactor, Proceedings M&C 2017 (Jeju, South Korea) April 16–20, 2017.

[5] L. Arnold et al., The SoLid anti-neutrino detector’s readout system, JINST 12 (2017), [1701.02278].

[6] SoLid collaboration, Y. Abreu et al., Development of a Quality Assurance Process for the SoLid Experiment, JINST 14 (2019) P02014, [1811.05244]