SoLid :Search for oscillations with ^{6}Li Detector at BR2

Frederic Yermia
On behalf of the SoLid collaboration

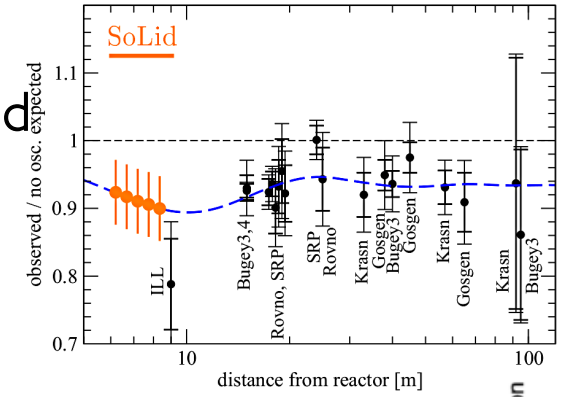
Overview

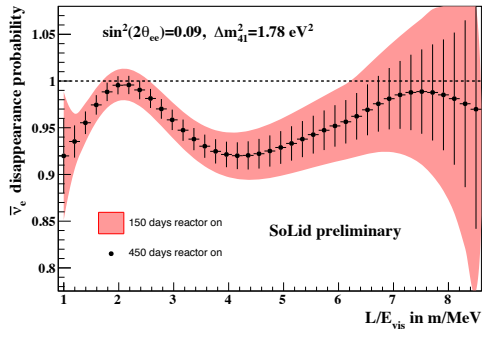
50 collaborators, 12 institutes from Belgium, France, United Kingdom and United States of America

- Physics motivation and the experimental context
- Validation of the technology (full scale prototype Results)
- Phase I: Summer 2017 : construction, commissioning and calibration
- Outlook

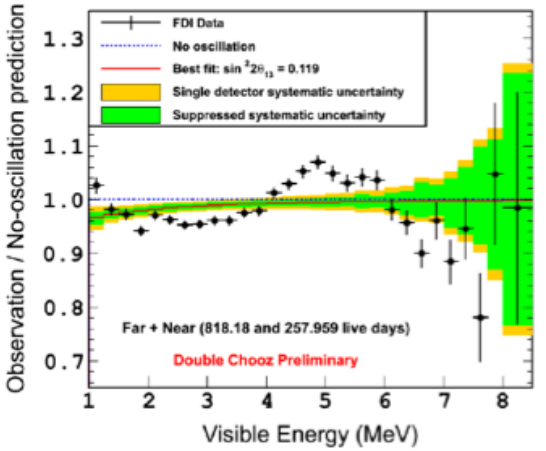
Physics motivation

- ✓ Search for short base-line oscillation and test the sterile neutrino hypothesis ($\Delta m^2 \sim eV^2$)



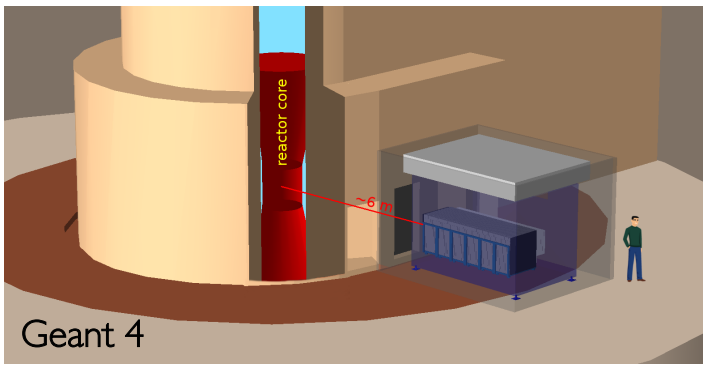


- ✓ Precise measurement of the ^{235}U anti-ν_e spectrum
  - ✓ Novel detection technology at HEU research reactor



- ✓ Full detector for challenging measurement

At Very Short Baseline (VSBL)
(~ 7.3 m from BR2 core @ SCK-CEN)



Challenging Measurement @ VSBL

- Detector
  - High resolutions for oscillation search
    - Spatial & Energy
  - Effective background rejection
    - Cosmics at ground level (corr. bkg)
    - Reactor Radiation (acc. bkg)
- Reactor
  - Compact core
  - Safety implications

(e.g data rates, access rights, reduce flammable liquids)

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SoLid

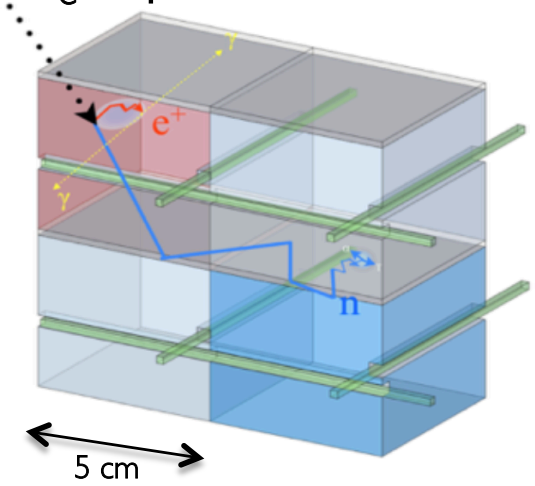
- Highly segmented detector
  - Localisation of events
  - 3D topological information
- Low Z Passive shielding

- Research reactor
  - BR2 at SCK-CEN (Belgium)
  - 95% Enriched ^{235}U
  - Core diameter 0.5m
  - Unique experiment onsite

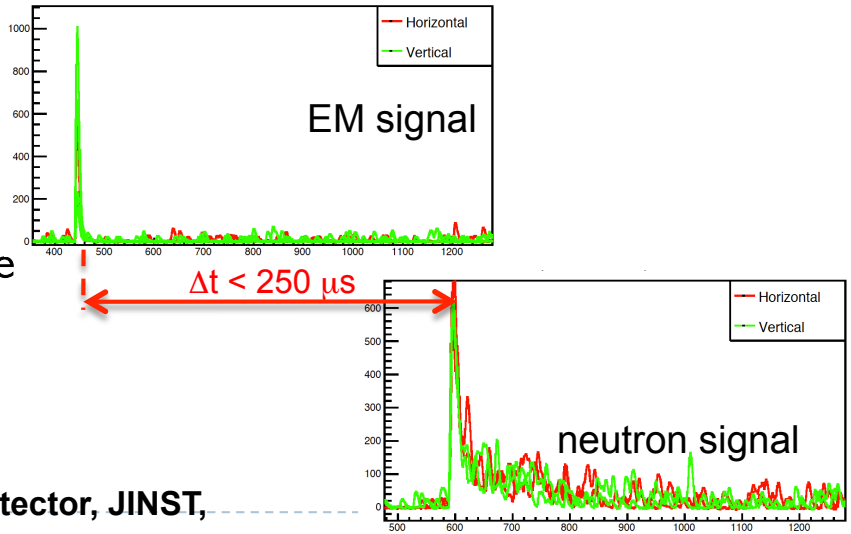
Detection Technology : PVT cubes + ^{6}LiF:ZnS(Ag) scintillators

- Neutrinos via inverse beta decay (IBD) events (coincidence)

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



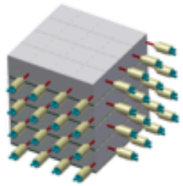
- Prompt e+ scintillation signal:
  - Localised
  - Annihilation γs escaping from the IBD cube provide with their Compton interaction a specific topology for IBD event
- Delayed neutron signal:
  - Two layers ^{6}LiF:ZnS(Ag) per cube
  - Neutron capture on ^{6}Li into ZnS layer:
    - $n + {}^6Li \rightarrow {}^3H + \alpha + 4.78MeV$
- Each cube read by 4 WLS fibres connected to MPPCs
- Distinguished ZNS signal from PVT via Pulse Shape Discrimination
- Neutron Trigger



Y. Abreu et al. , A novel segmented-scintillator antineutrino detector, JINST, Vol. 12, 2017, arXiv:1703.01683

Experiment status

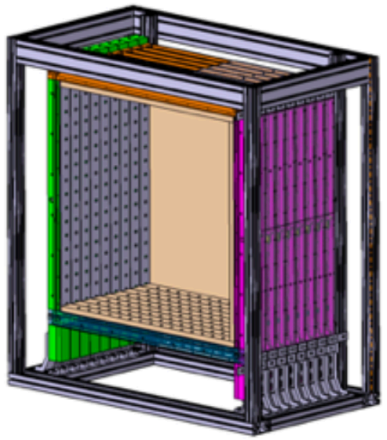
2013



Nemenix (8kg)

- Proof of concept
- Demonstrate PID

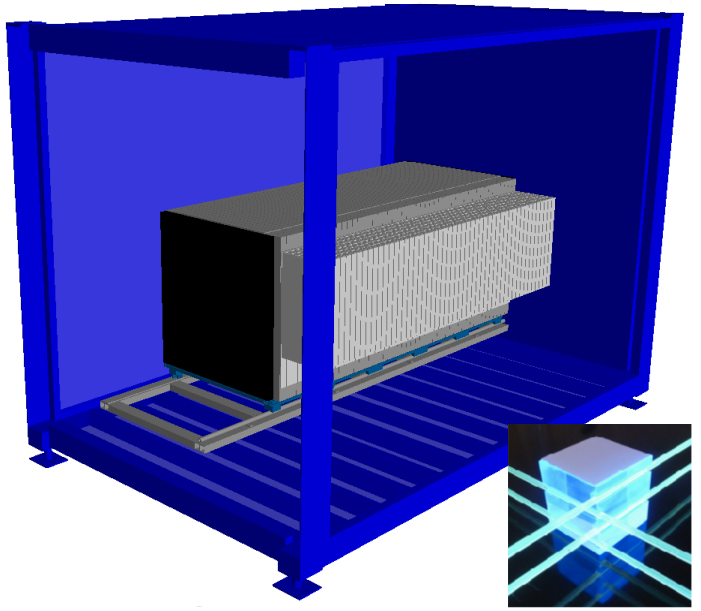
2014-15



SM1 Prototype (288kg)

- Test scalability and production
- Prove power of segmentation

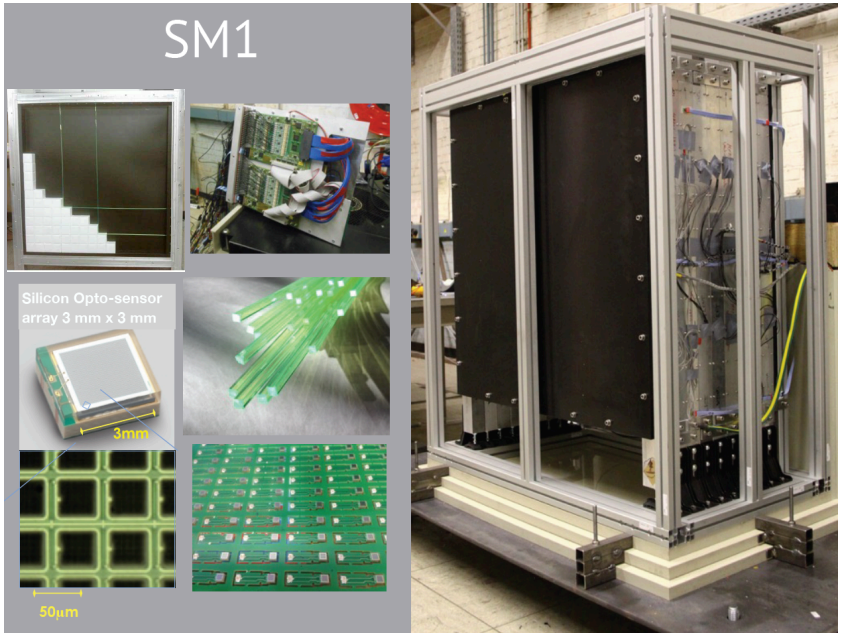
2017

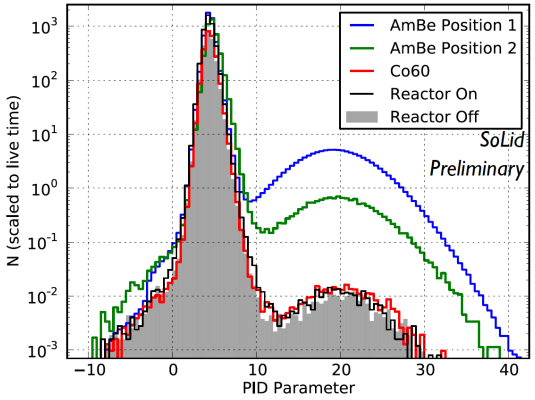


SoLid Phase 1 (1.6 T)

- 12k cubes with 3.2k channels
- Perform initial oscillation search

Validation of the technology: SoLid Module 1 (2015)

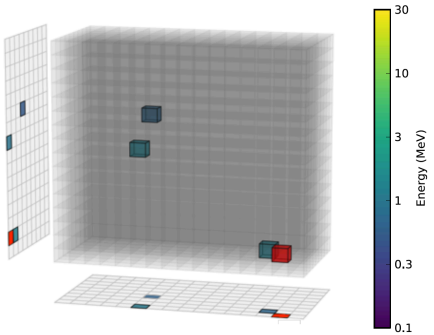




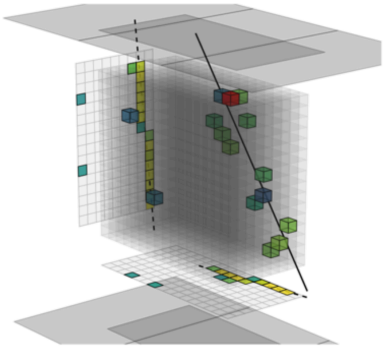
Neutron PID for reactor on/off periods and source calibration runs

➔ Source runs demonstrate population separation

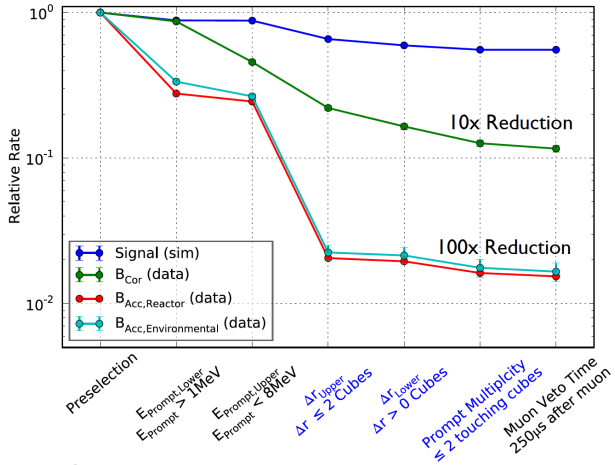
Segmentation & Discrimination



IBD candidates from SM1. Neutrons in red, EM signals use colour scale (Data)

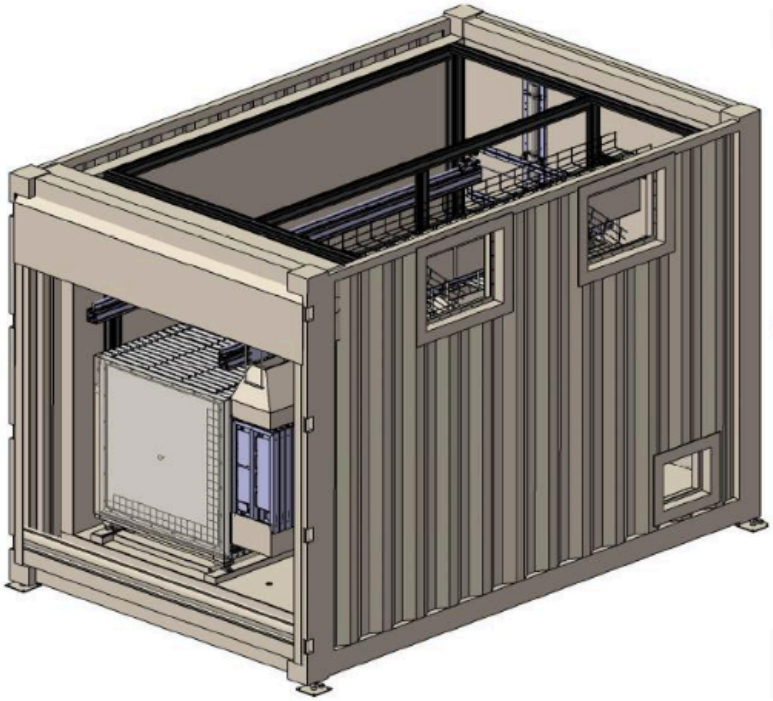


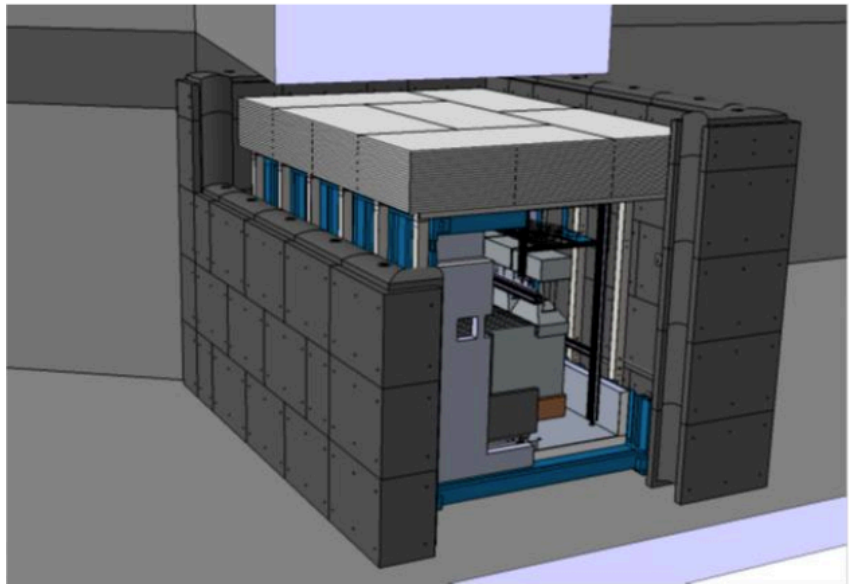
muon spallation event (Data).



Simple cut-based analysis shows significant background reduction

Phase I - 1.6 ton detector





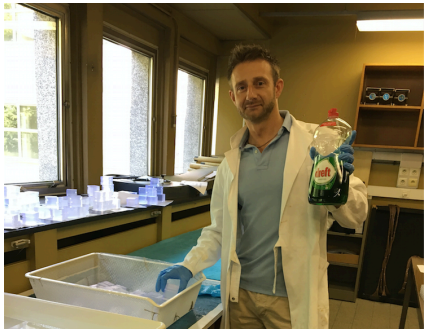
Container, 2.4x2.6x3.8 m^3

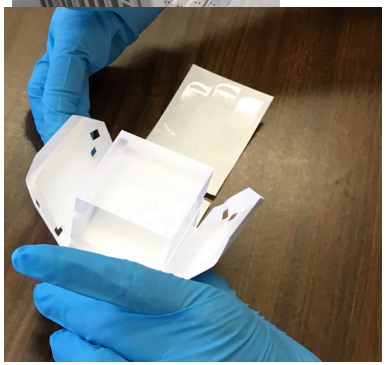
✓ Cooled to 5 °C → noise reduction
✓ Automated calibration system

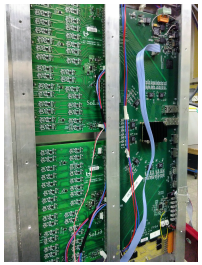
✓ Water wall: 50 cm thick, 3.4 m high, 28 tons
✓ Poly-ethylene ceiling: 50 cm thick, 6 tons

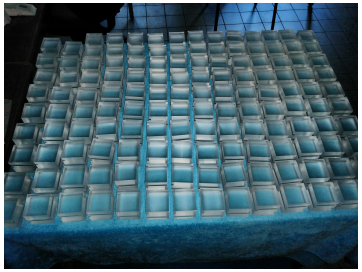
Reduction of background signals (e.g. fast neutrons) in detector (~75% on the Li6 captures)

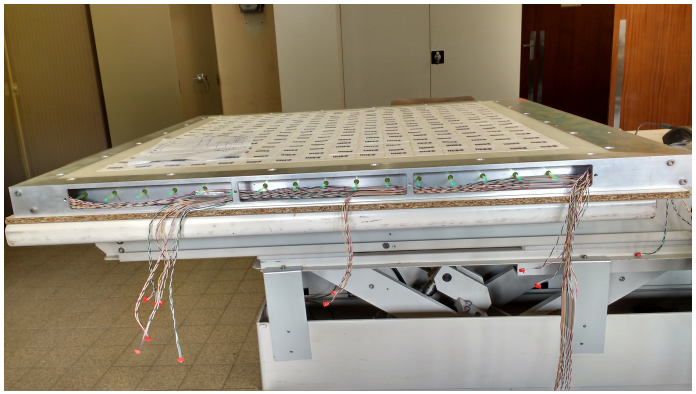
Phase I - 1.6 ton detector: Construction & commissioning









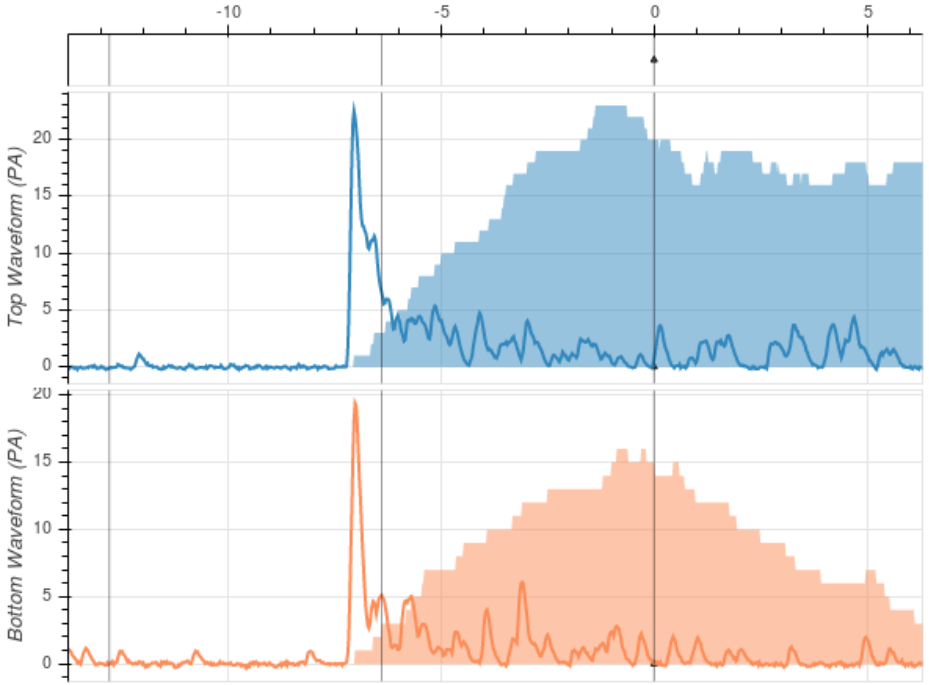


Phase I - 1.6 ton detector: Neutron trigger Commissioning

- Dedicated neutron trigger for neutrino detection.
  - Implemented in FPGAs.
  - Based on peak counting.
  - Combined with large buffer for prompt detection→ high IBD efficiency.

Current status:

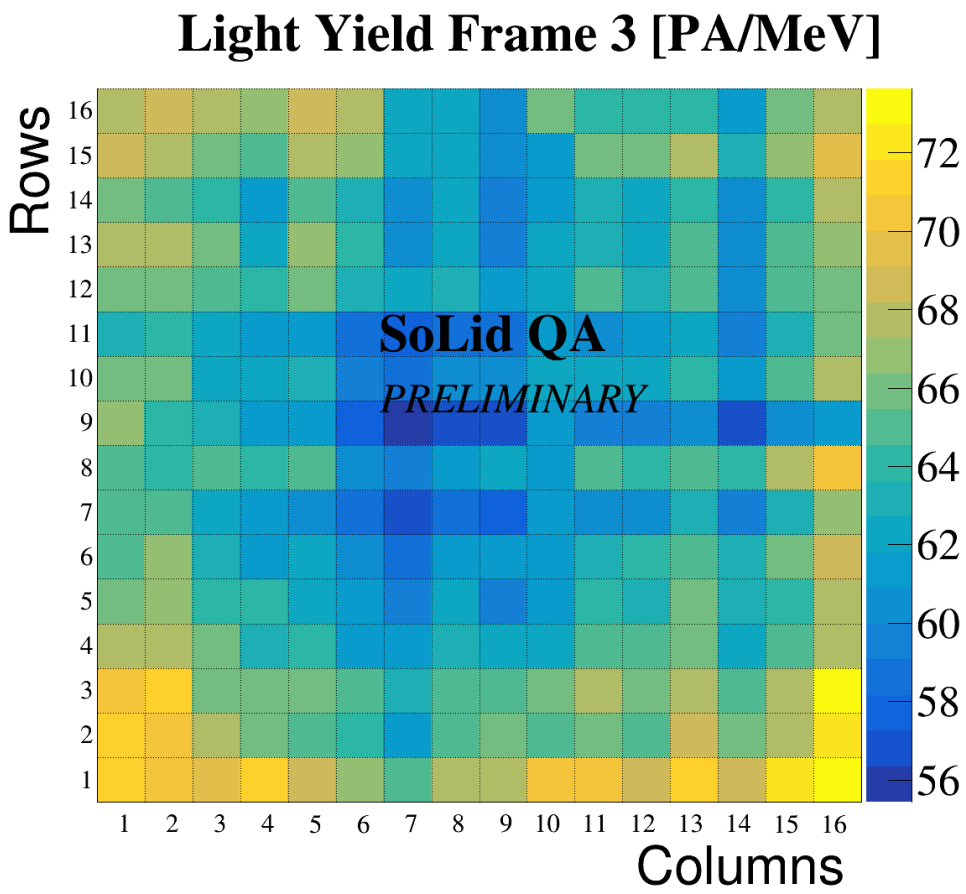
- Recently deployed at Calipso test setup.
- Initial results consistent with design expectations.



Two example neutron waveforms using an AmBe source. Shaded regions show the value of the trigger variable (number of peaks > 1.5 PA).

Phase I - 1.6 ton detector: Quality Assurance - Light Yield

^{22}Na source: Measure the Compton edge of 1.27 MeV gammas to assess the light yield

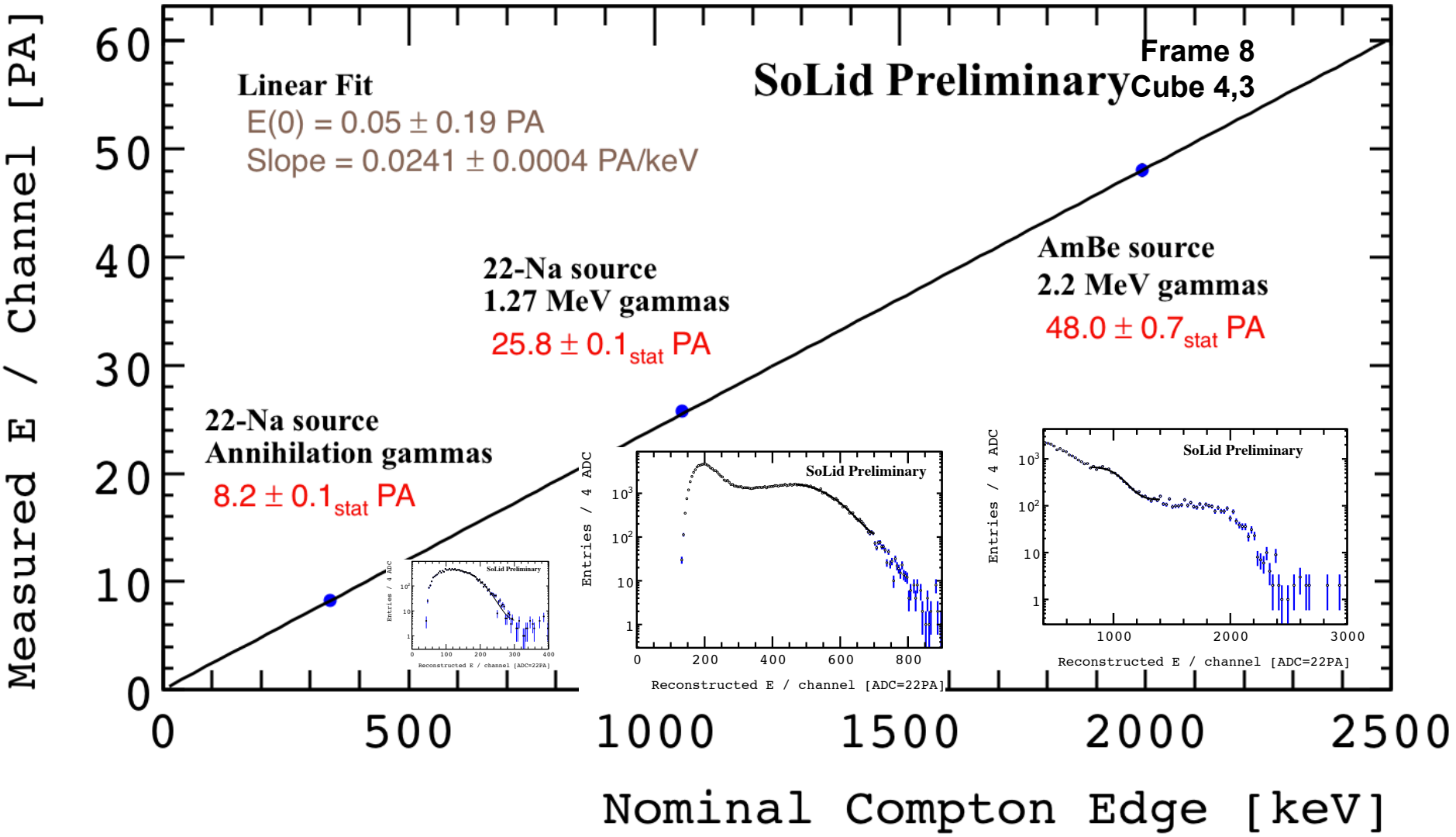


Good sensitivity to the attenuation pattern, corrected by calibration before physics runs

(See during the poster session: neutron calibration strategy by V. Pestel)

Phase I - 1.6 ton detector: Preliminary calibration

Proportionality test between detector response and deposited Energy

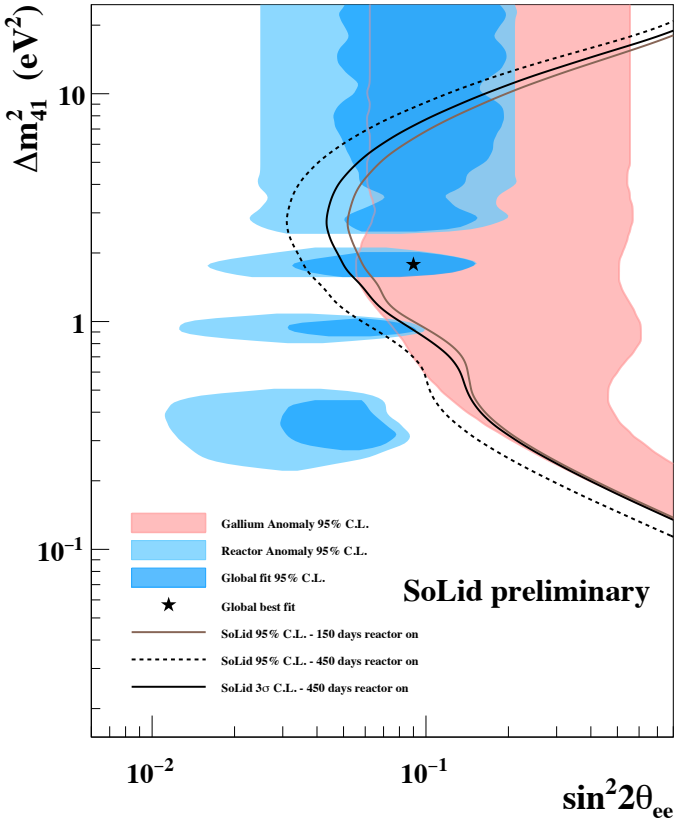


Outlook

- Technology validated with SMI Prototype

(Y. Abreu et al. , A novel segmented-scintillator antineutrino detector, JINST, Vol. 12, 2017, arXiv:1703.01683) + Sm1 results publication in preparation

- Construction of phase 1 SoLid began:
  - 1.6t, to perform initial sterile search
  - Neutron trigger currently commissioning
  - Other upgrades to reduce background, improve energy resolution and trigger efficiency
  - Being deployed during this Summer 2017
  - On track for S:N > 1:1 (target 3:1) with ε_{IBD} ~30%

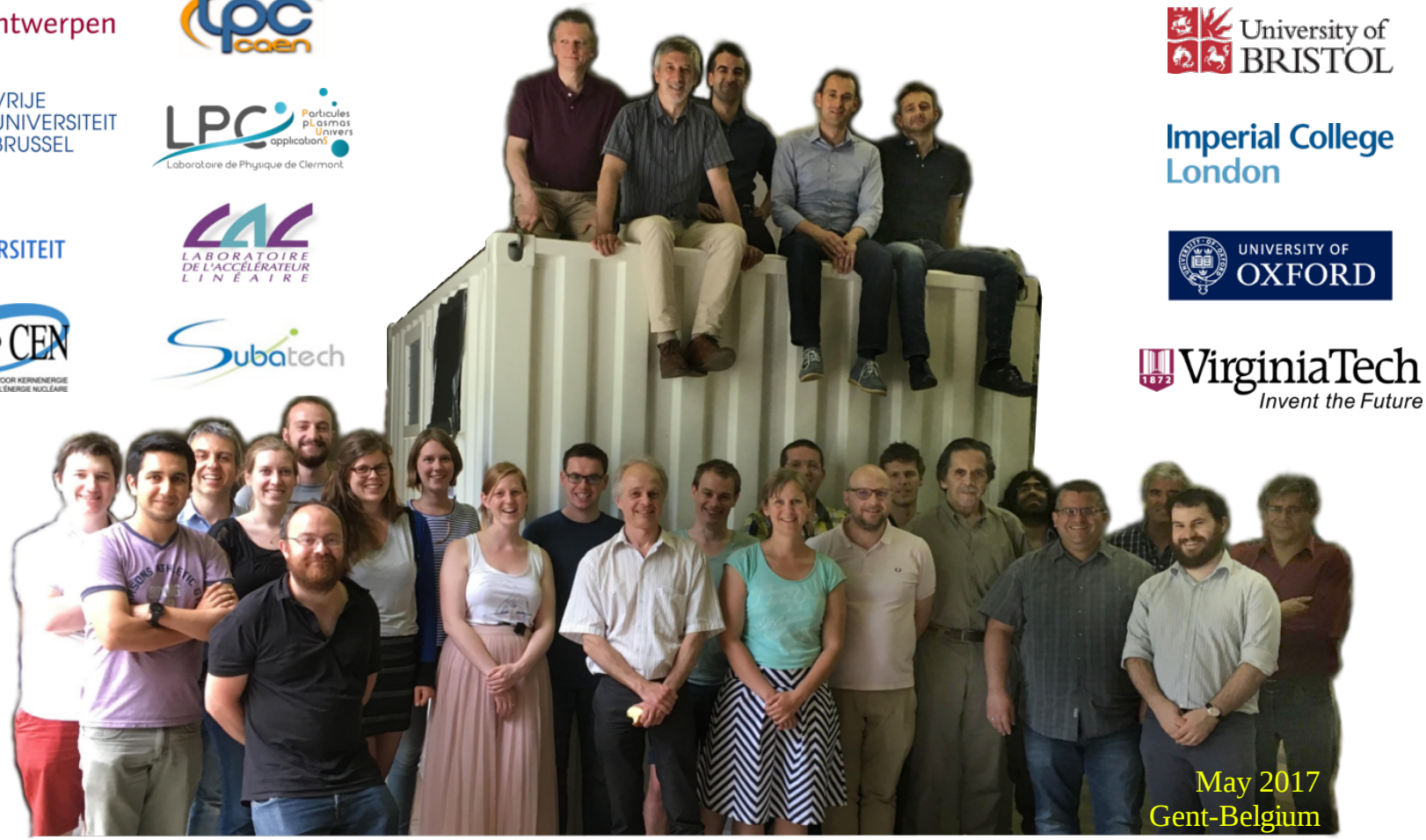


2018: First Antineutrino ^{235}U spectrum measurement and first relative measurement for searching oscillations at very short distance

Thank you for your attention

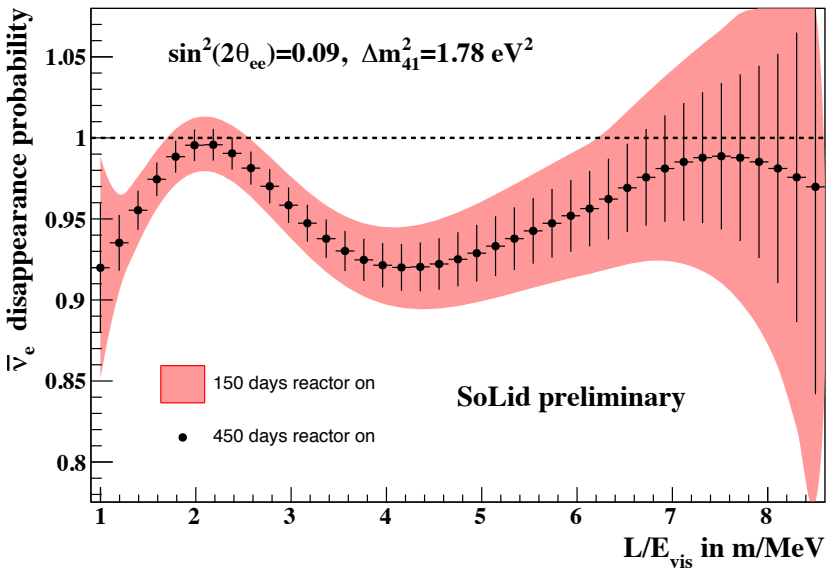
The SoLid Collaboration

4 countries 12 institutes ~50 people

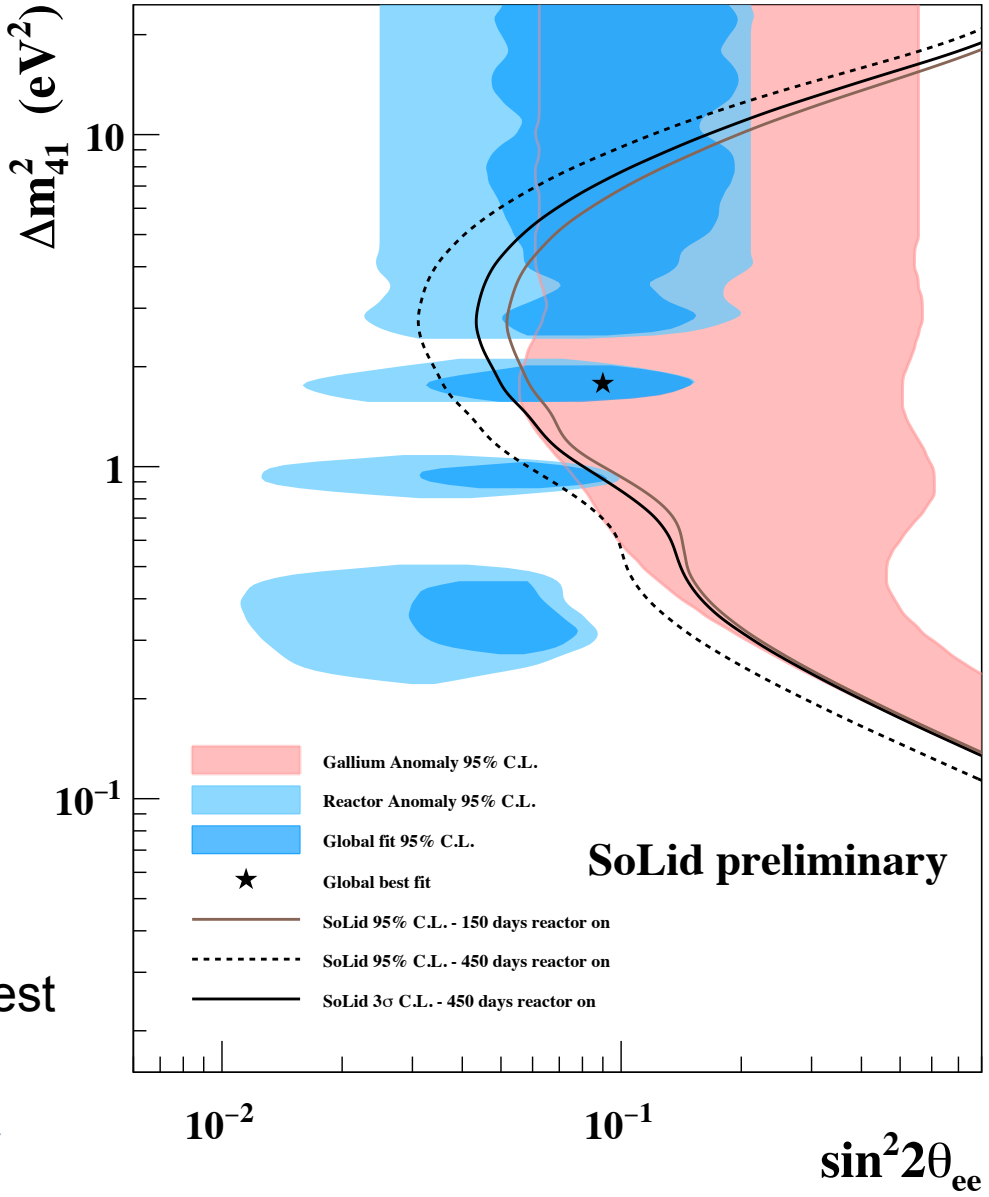


BACKUP

Phase I - 1.6 ton detector: Sensitivity

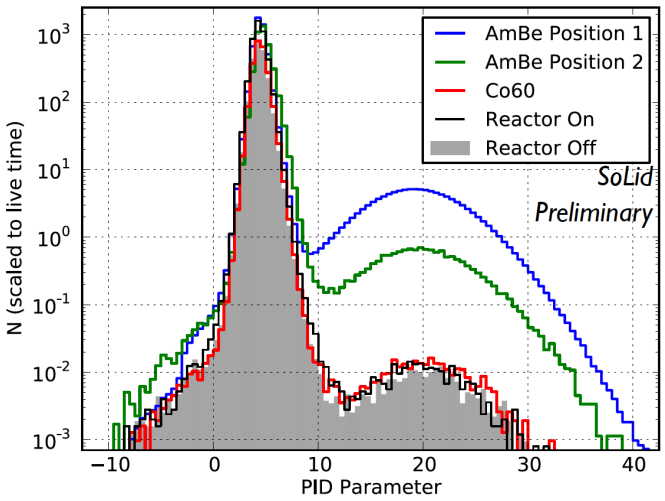


The ratio of oscillated to the unoscillated spectrum in E_{vis} (top) and L/E_{vis} (bottom) for $\sin^2(2\theta_{ee}) = 0.09$ and $\Delta m^2_{41} = 1.78\ eV^2$.



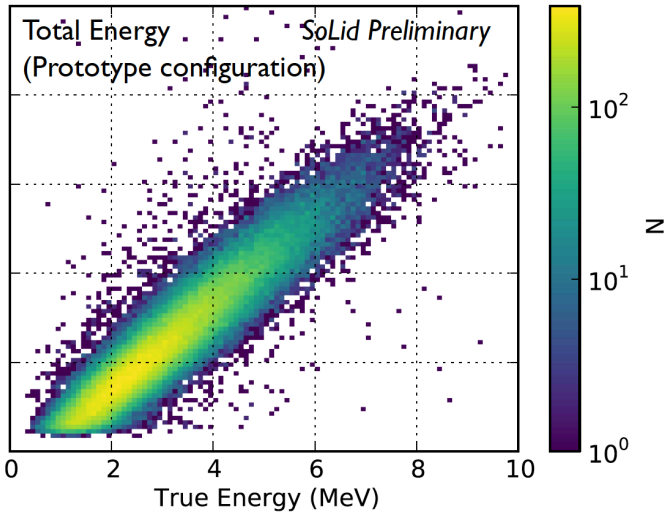
SoLid sensitivity plot using the latest experimental layout

Signal Reconstruction



Neutron PID for reactor on/off periods and source calibration runs

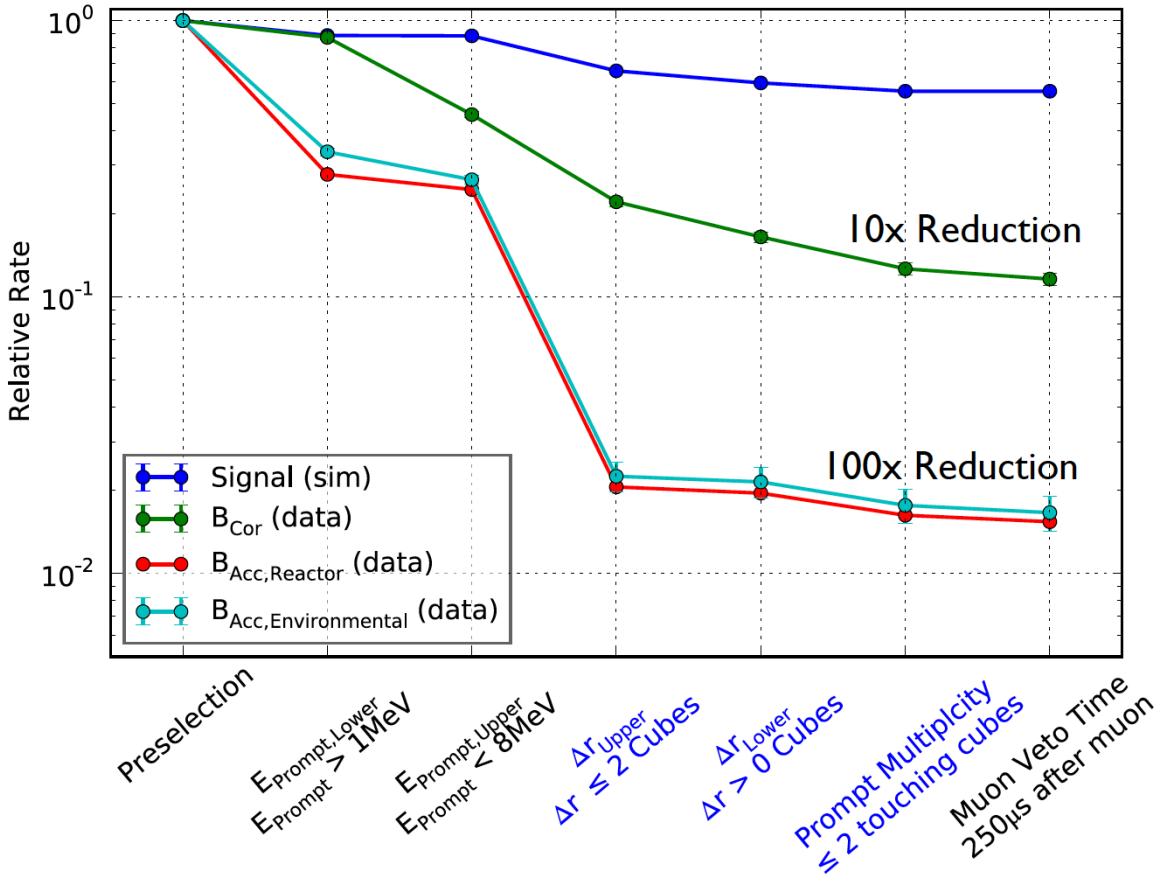
- Source runs demonstrate population separation



Positron reconstruction algorithm comparison for SM1 configuration - Sim. Readout effects included

- Demonstration of positron energy reconstruction algorithms

Validation of the technology: SoLid Module 1 (2015)



Signal Selection

Segmentation provides many handles for tackling backgrounds:

- Spatial separation
- Directionality
- Multiplicity

Simple cut based analysis shows significant reductions in backgrounds