SoLid Detector Technology

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on behalf of the SoLid Collaboration

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SoLid Experiment at SCK•CEN

SoLid is a **short baseline reactor anti-neutrino experiment** using a novel detector technology deployed at close distances between **5.5 and 10 m** from the BR2 nuclear reactor compact core at SCK•CEN in Belgium.

Main purposes of the experiment
- search for neutrino oscillations at VSBL,
- measure the pure ^{235}U ν energy spectrum,
- demonstrate the feasibility of ν detectors for reactor monitoring.

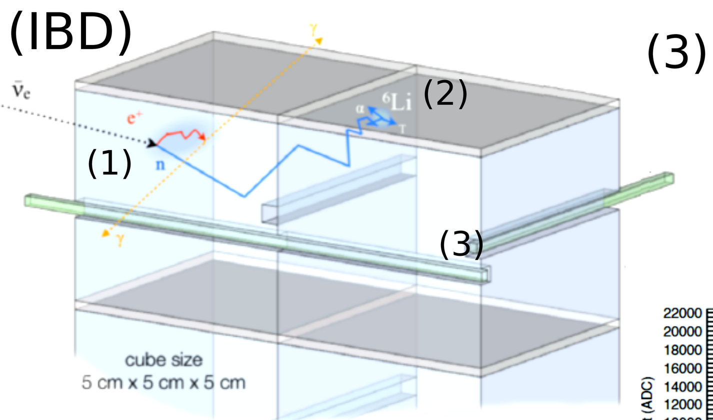
Reactor characteristics
- high ν flux (~10^{19} ν/s) from 70MWth reactor,
- compact (~50cm) and well-shielded core,
- 150 days per year of "reactor-on" data → "reactor-off" data for background studies.

Environmental backgrounds @ BR2
- cosmics muons → id-ed, vetoed and used for cal,
- neutrons from reactor and cosmic muon spallation,
- gamma-rays from activation in walls,
- negligible BiPo contamination in scintillator.

Detection Principle & Material

Highly Segmented Detector for the detection of reactor anti-neutrinos via Inverse Beta Decay (IBD)

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



(1) EJ-200 **PVT Scintillator Cube** 5 cm
- p target for ν interaction known at precision of 1%
- e^+ yields **prompt** scintillation light

(2) **Neutron screen** ^{6}LiF:ZnS(Ag) 250 μm
- thermalized n captured by ^{6}Li within ~15 cm from interaction point

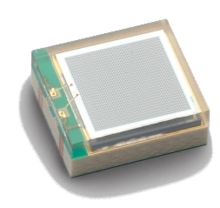
$$\mathrm{n} + {}^6\mathrm{Li} \longrightarrow {}^3\mathrm{H} + \alpha + 4.78\ \mathrm{MeV}$$

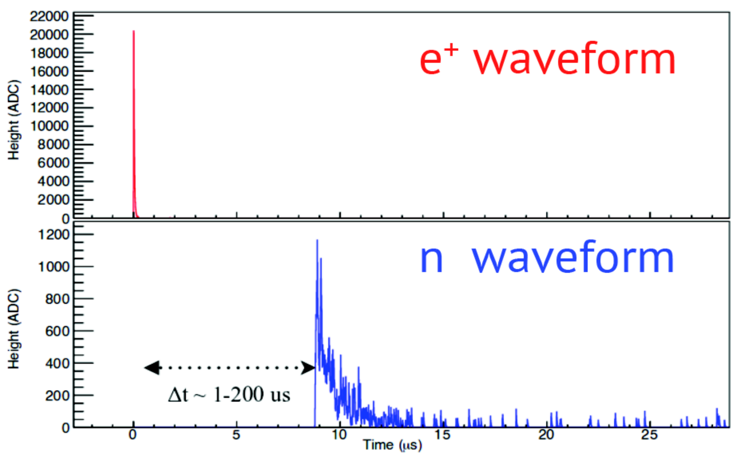
- H and α produce **slow** scintillation upon interaction with ZnS(Ag)

⇒ **Two different light pulses signatures**

Each cube is **optically isolated** by reflective Tyvek wrapping

(3) Light is collected by **WLS Fibres** 0.3 x 0.3 cm section
equipped with **Multi-Pixel Photon Counters (MPPC)**
and reflected by a mirror at opposite end of the fibre

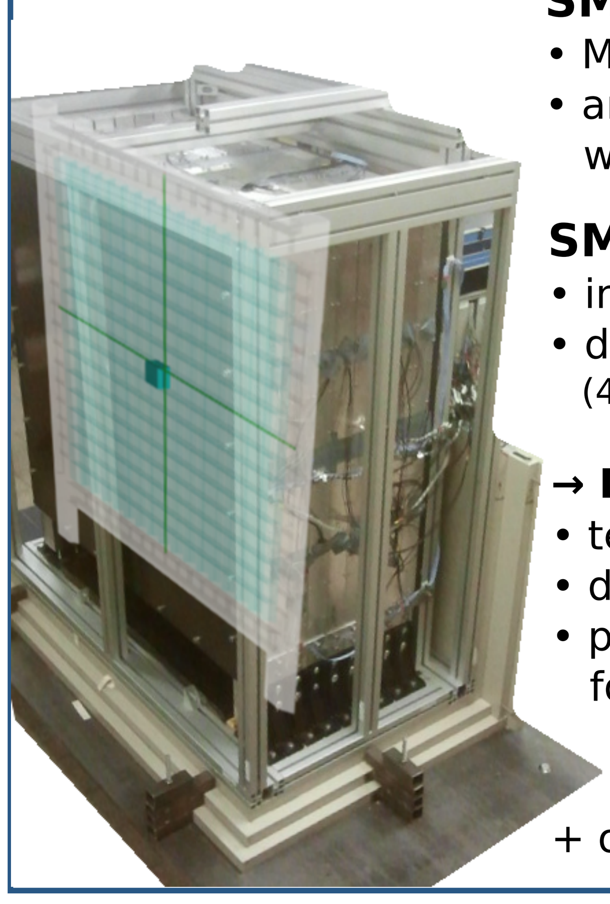




Advantages of the design :
- e^+ : prompt isolated signal
  → Good energy resolution
  → Better IBD localisation precision
- spatially separated n delayed signal
  → Unambiguous indentification
  → Excellent background reduction
  → Potential for direction reconstruction

2014/15: SM1 prototype

Detector characteristics
- 9 frames of 16x16 cubes for a fiducial mass of 288 kg (2304 cubes)
- hor. & vert. network of WLS fibres with 288 read-out channels
- HDPE neutron shield (9cm thick) and muon veto planes (4 above & 4 below)

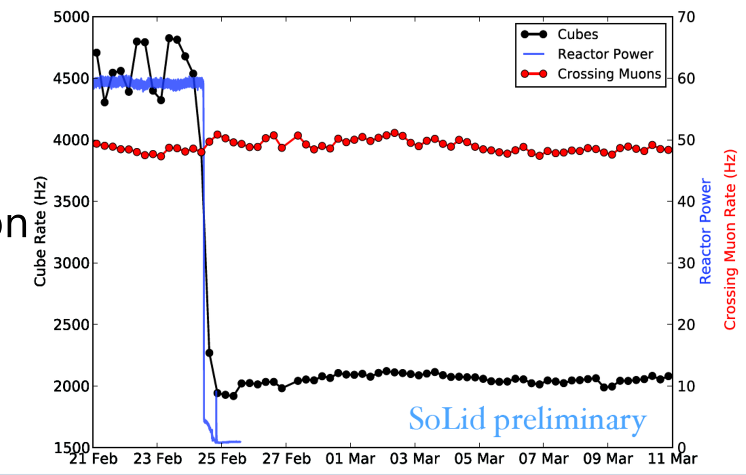


SM1 DAQ & Trigger
- MPPC signal digitised @ 65 MS/s rate (sample 16ns)
- amplitude trigger with hor-ver coincidence in plane within a 50 ns time window.

SM1 Timeline @ BR2
- installed on-site in November 2014
- data taking between February and March 2015 (4 days of Reactor ON before scheduled BR2 stop for ~1 year)

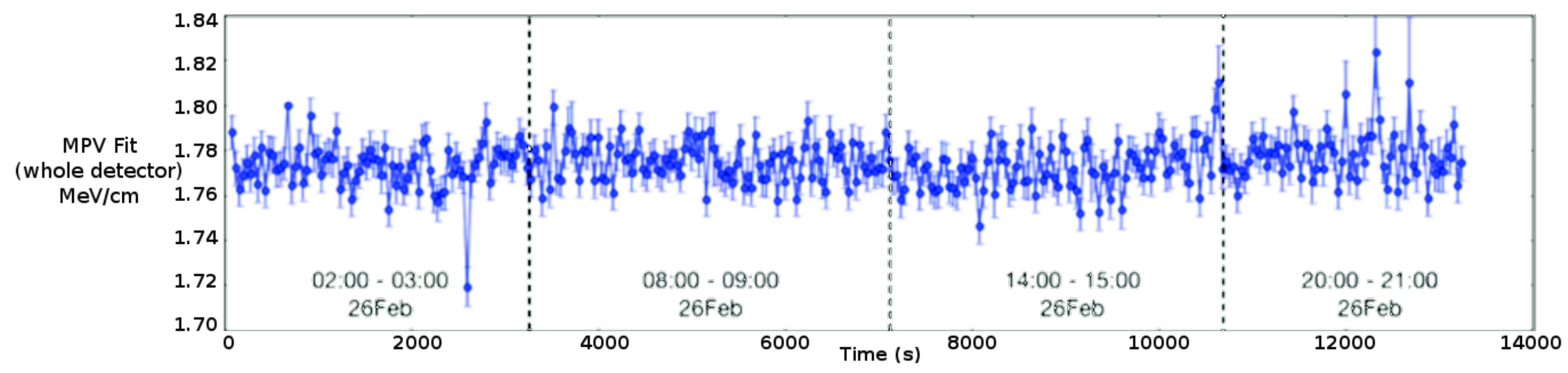
→ Demonstration of:
- technology viability
- detector **stability**
- power of segmentation for an IBD analysis

+ on-site calibration

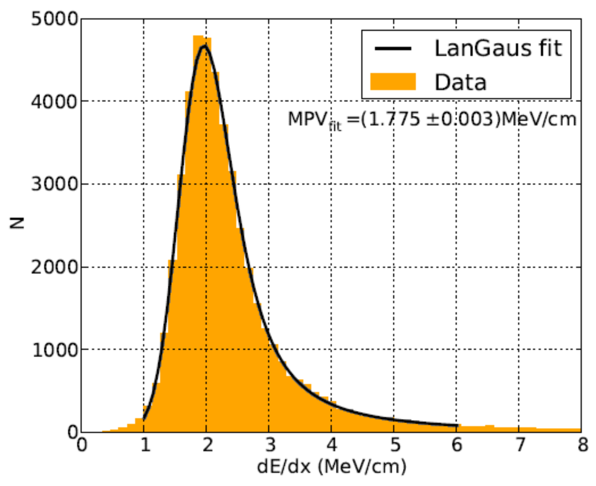


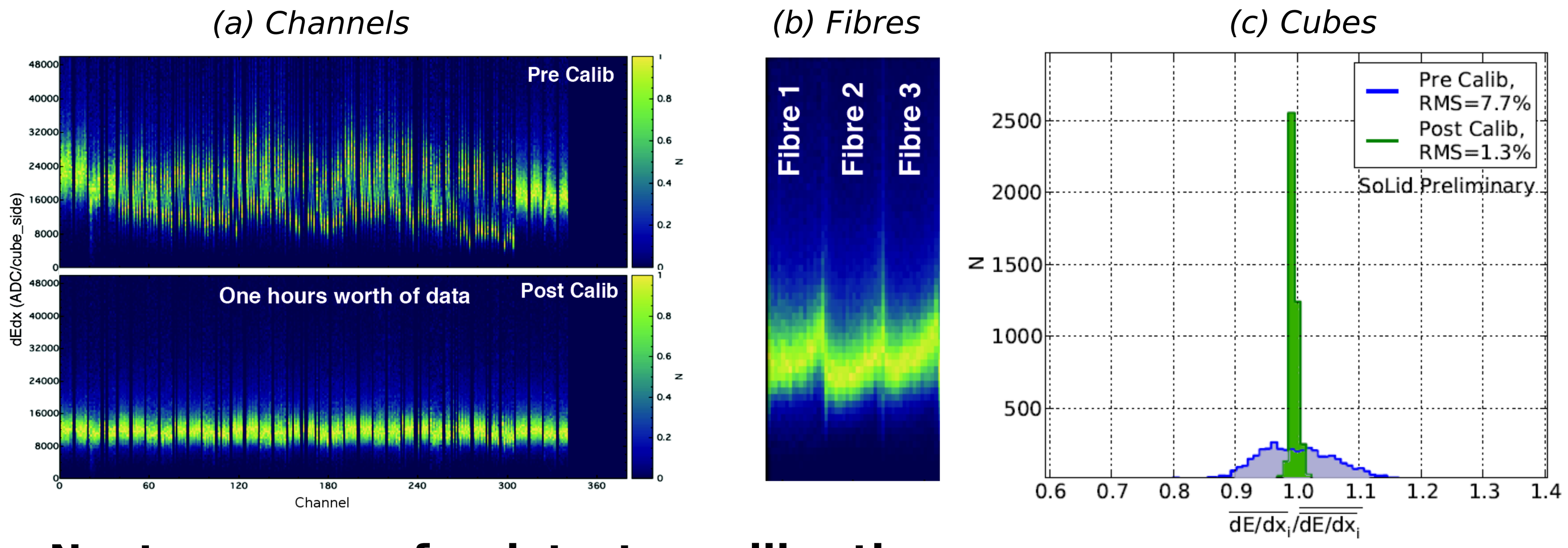
Calibration, Data & Simulations

Using muons dE/dx for energy calibration

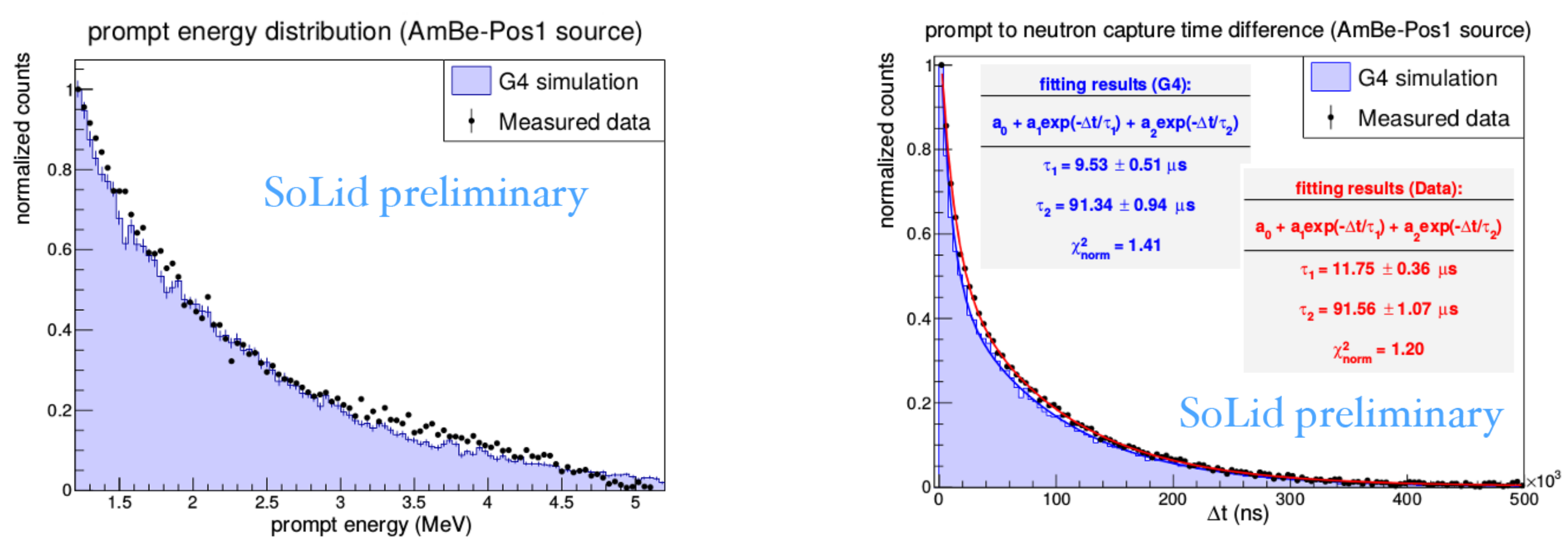


Measurement of energy deposit is affected by:
- Poisson statistical uncertainties
- (a) gain differences in electronic read-out
  Channel equalization: 22.5% (Pre-cal) → **3.8%** (Post-cal)
- (b) light attenuation loss in fibre with 24% relative efficiency loss between opposite edges.
- (c) difference in cube-to-fibre coupling
  Cube equalization: 7.7% (Pre-cal) → **1.3%** (Post-cal)



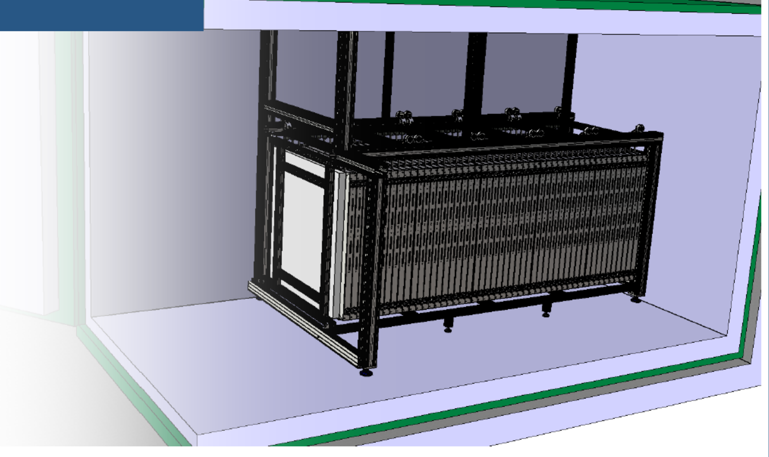


Neutron source for detector calibration
- April 2015 : ^{60}Co, **AmBe** → validation of neutron transport and Li^6 capture
- August 2015: ^{252}Cf efficiency with MCNP/Geant4 (G4) simulation



2016-2018 : SoLid Phase-1

Experiment upgrades
- 5 modules of 10 frames
  → fiducial mass of **1.6 tons** (12800 cubes)
- **two neutron screens** per cube
- two double-clad WLS fibres in both directions
  → 3200 read-out channels
- housed in an insulated cooled container
- internal calibration system between modules
- passive shielding of 50cm borated water around the detector
- extended **triggering** and **identification** methods on neutron @ FPGA level
- **construction: Summer/Fall 2016 - Run: Feb 2017**



Summary of expected performances

	SM1 dev. 2014 - data 2015	**SoLid Phase-I** dev. 2016 - data 2017
Fiducial mass	288 kg	1.6 t
Proton Content Resolution	< 1%	< 1% (exp)
Detector Performances		
DAQ Clock Rate	62.5 MHz	40 MHz
Neutron capture time	102 μs	65 μs
Light Yield (photons/cube/MeV) [2]	22	37 - 50
→ Energy Res @ 1MeV	20%	14% (exp)
IBD efficiency [3],[4]	~1%	~30% (exp)
Reactor ν detected (/day)	~ 4	~ 400
Signal over Background ratio	1:20	3:1

SoLid Experiment @ Neutrino2016

[1] **The Solid Experiment** L.Kalousis
[2] **Light yield & Energie resolution studies for Phase-1** D.Boursette
[3] **Analysis of IBD Signature** D.Saunders
[4] **Novel compact ν detector dev.** A.Vacheret

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