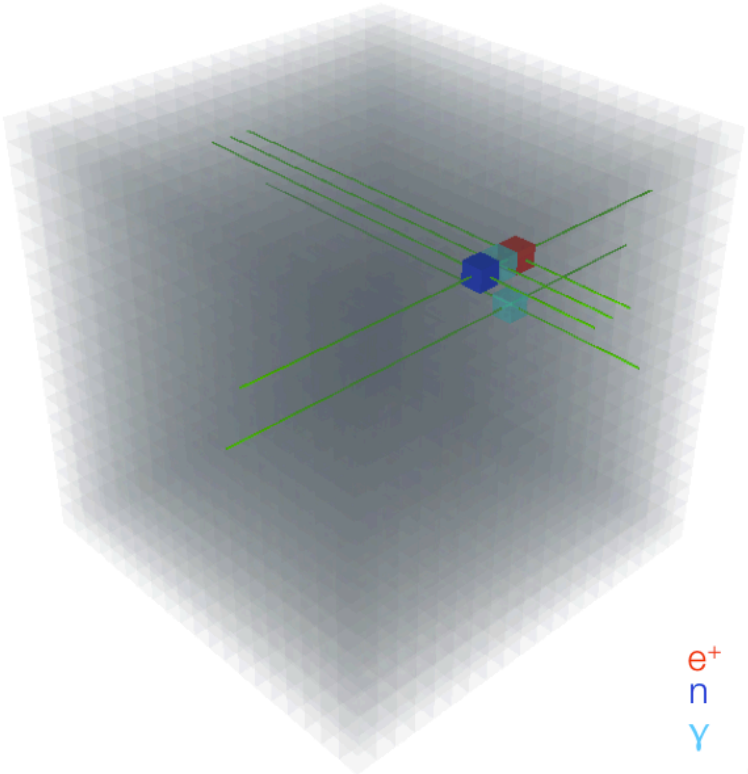
SoLiδ: Search for Oscillation with Lithium-6 Detector at BR2

Status of the SoLid experiment



Frederic Yermia (SUBATECH)
On behalf of the SoLid collaboration

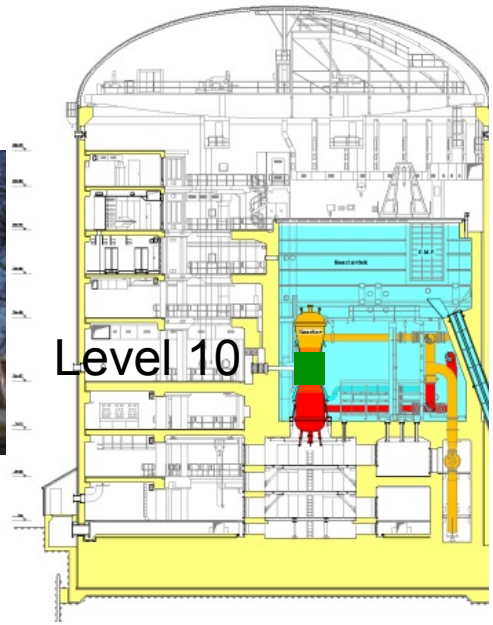
SoLiϑ - Reminder I

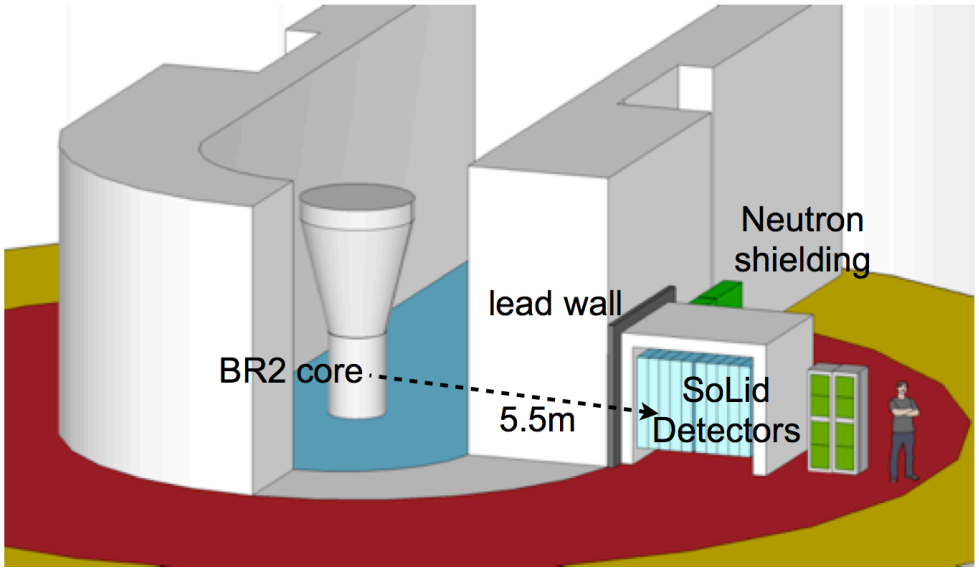
PHYSICS MOTIVATION

- Search for short distance oscillation & Non proliferation

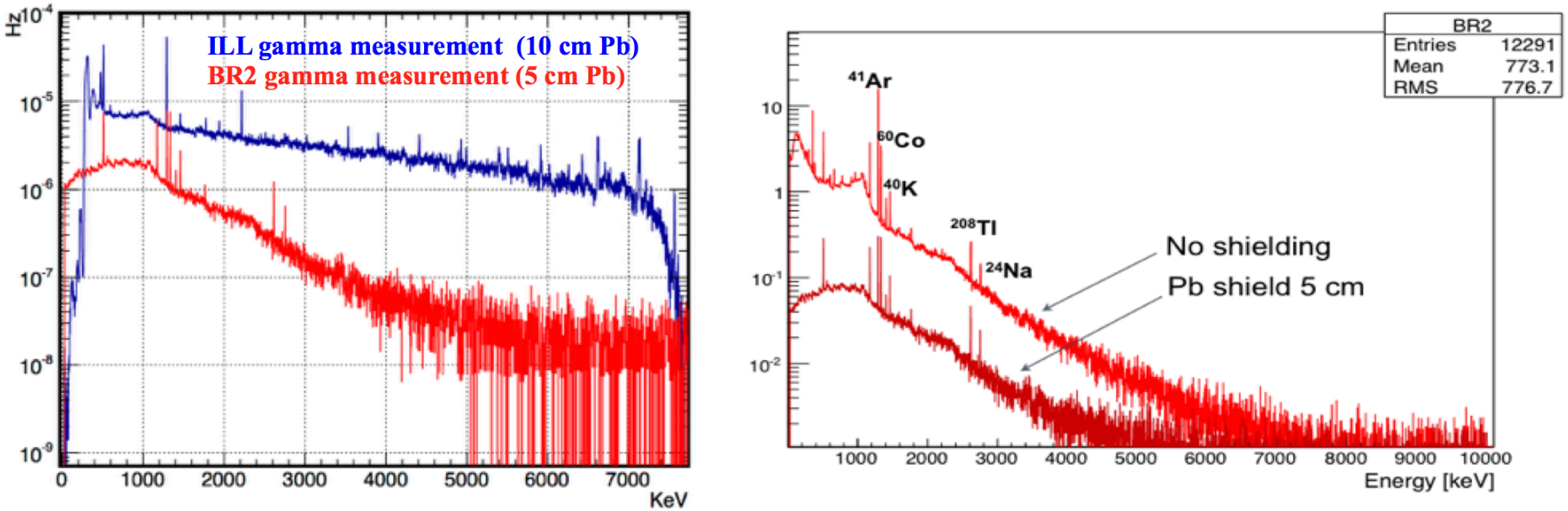
SCK-CEN BR2 (Belgium) MTR research reactor

- tank-in-pool research reactor, HEU fuel
- 45-70 MWth, cycles of 20-25 days
- VERTICAL PORTS
- Closest approach 5.5 m
- Large surface area available at level
- 150 days /year, no time limit for measurement
  - Not statistically limited
- Antineutrino project started at SCK•CEN
  - Scientific and non-proliferation collaboration
  - Committed resources for prototype shielding





Gamma background at BR2



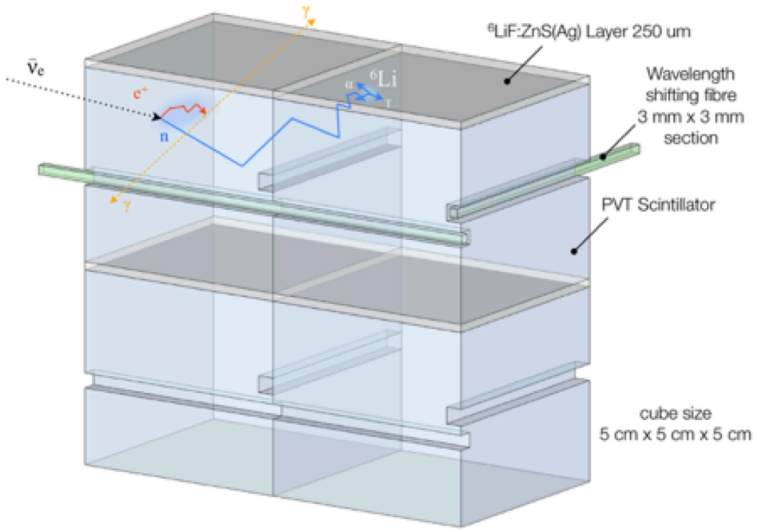
Gamma-ray spectra measured with HPGe detectors at ILL (blue) and BR2 (red) (right). Gamma-ray spectrum measured with same HPGe detectors at level 1 on BR2 close the primary water circuit where nitrogen isotope decays (left).

- Soft Gamma-rays
- No reactor neutrons

SoLiδ - Reminder II

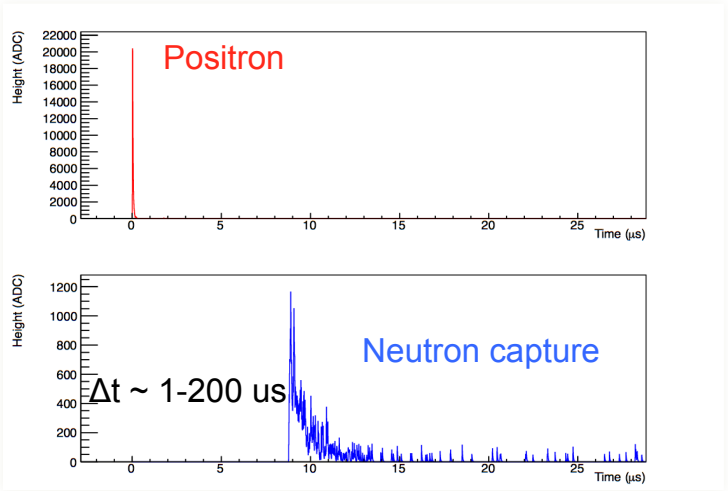
DETECTOR

- 2.88t fiducial volume
- Novel type of composite solid scintillator detector (PVT + 6LiF:ZnS)
- detection element: 5cm x 5cm x 5cm
- read out by WLS fibres and Geiger-mode APDs (MPPC)
- Physics Trigger : neutron events to limit data rate



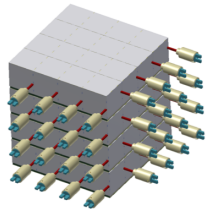
Detection Principle

- Detection: Inverse Beta decay (IBD)
- Neutron detection: $n + {}^6Li \rightarrow {}^3H + \alpha \ + 4.78\ MeV$
  - High capture efficiency on Lithium-6 (>70%)
  - **160 000 photons/neutron** in ZnS, no quenching !
  - Tritium and alpha excite higher ZnS energy levels : slower decay time constants (200ns and 10-20us)
  - Powerful discrimination between neutron and fast signals (EM) : 10^{-4} down to 10^{-8} achievable !



- 3D reconstruction close to interaction point:
High background rejection capability using topological information of IBD.

Prototype aims



- ✓ Better understand the detection technology
- ✓ Check the expected response of the system
- ✓ Validation of the technology

- ✓ Characterize the level 10 BR2 environment (reactor on/off data)

- ✓ Demonstrate background suppression method

- ✓ Demonstrate practicality and safety of the technology of SoLid for non proliferation purpose

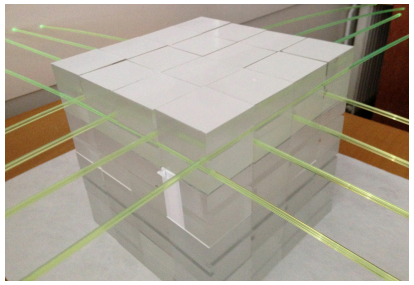
NEMENIX : 8 kg prototype

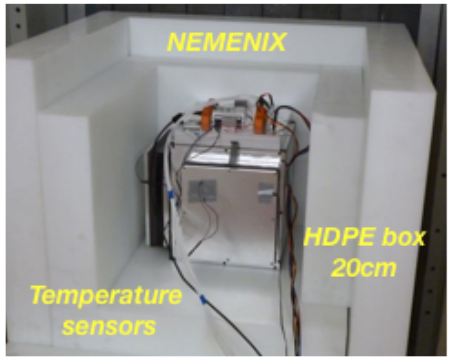
20cm x 20 cm x 20cm

- 4x4x4 cubes detector system
  (without specific funding)
- Electronics and DaQ (32 read out channels, PHOBOS amplifier cards, Caen DT5740 desktop digitiser 62.5MS/s , custom Labview front-end)

➔ Physics trigger: pulse amplitude ≠ SOLiD

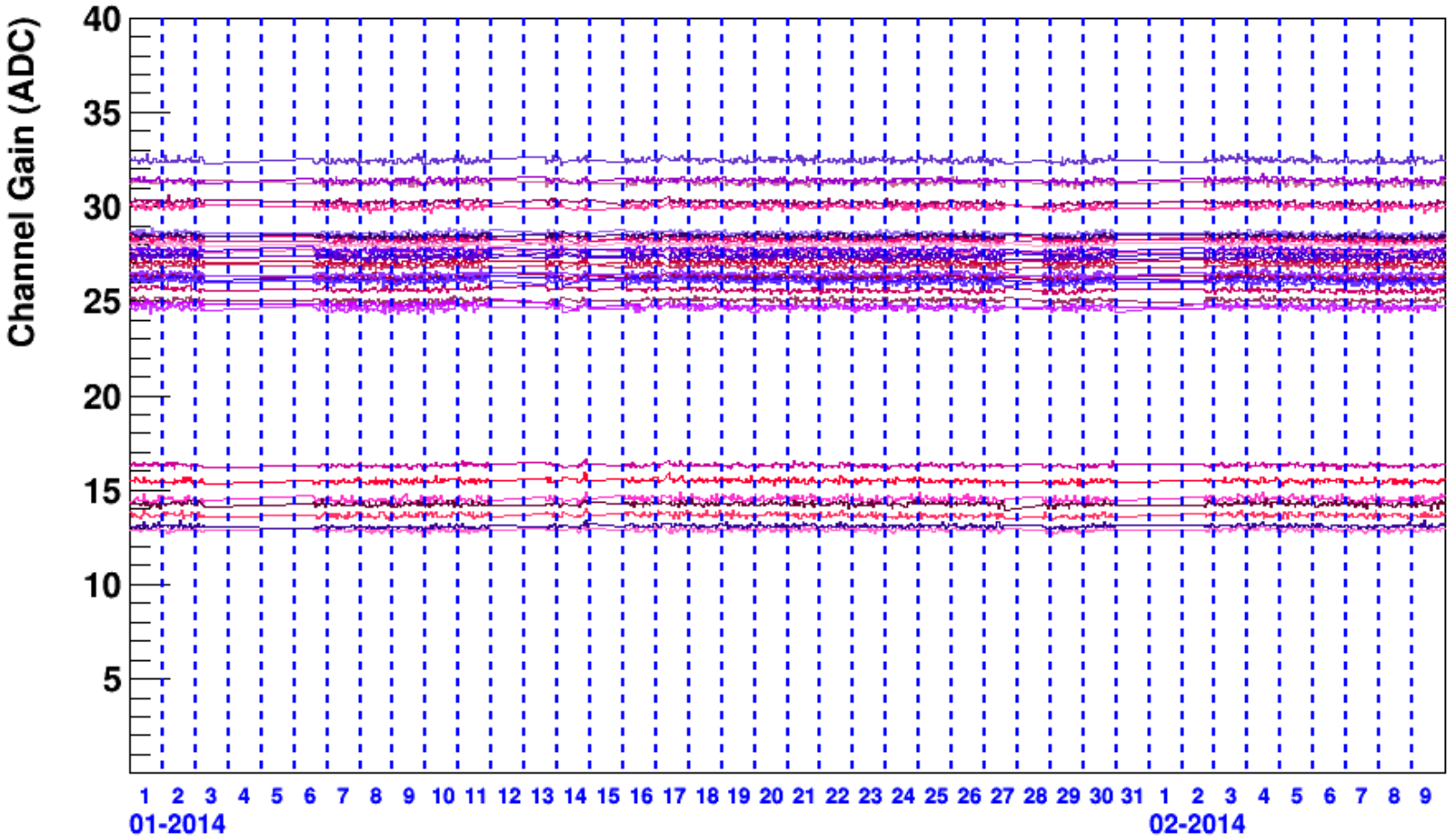
- had to compromise efficiency/sensitivity with DAQ rate and data storage
- Expected target efficiency ~ 15% (no threshold)





- NEMENIX prototype moved to BR2 at 5.0m from core (level 10 at R1 position) By end of July 2013
- Detector shielding provided and installed by BR2 staff, Used similar shielding envisioned for SoLid (lead wall, HDPE box)
- **April 2014: prototype upgrade**
- DaQ upgrade to avoid saturation (limited data rate)
- Muon Veto added (very small volume target, 1/3 of the target on the edges: clipping muons)

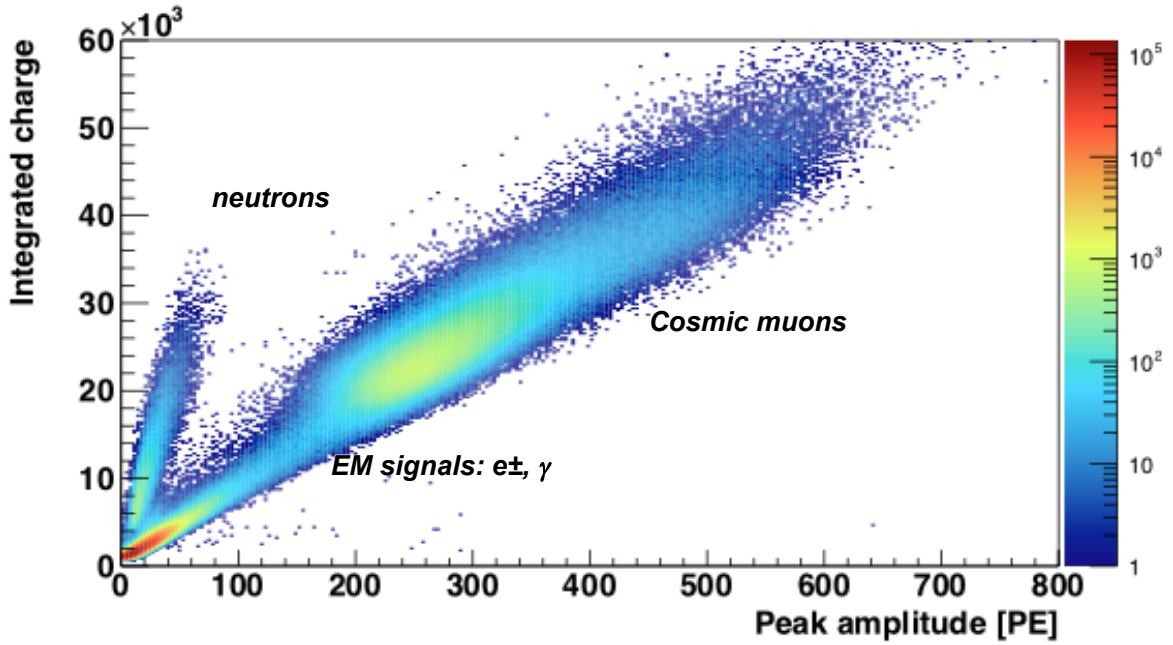
Gain



- Automatic temperature feedback loop on sensor bias voltage to maintain stable gain
- Gain stabilized (1% fluctuations) for data taking

Detector response

Reconstructed waveform amplitude
vs integral charge

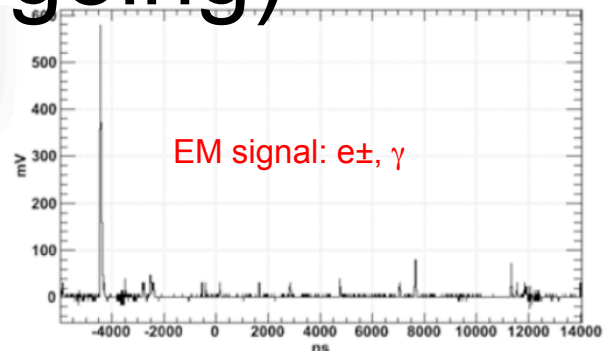


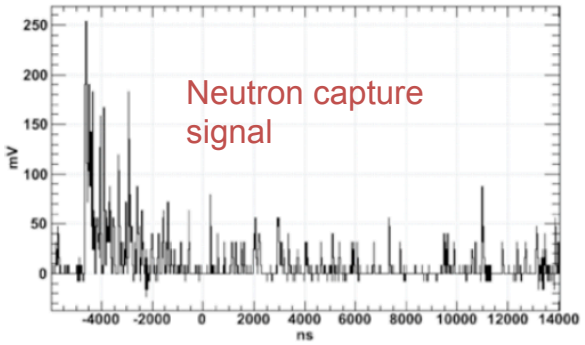
1PE= 80 keV

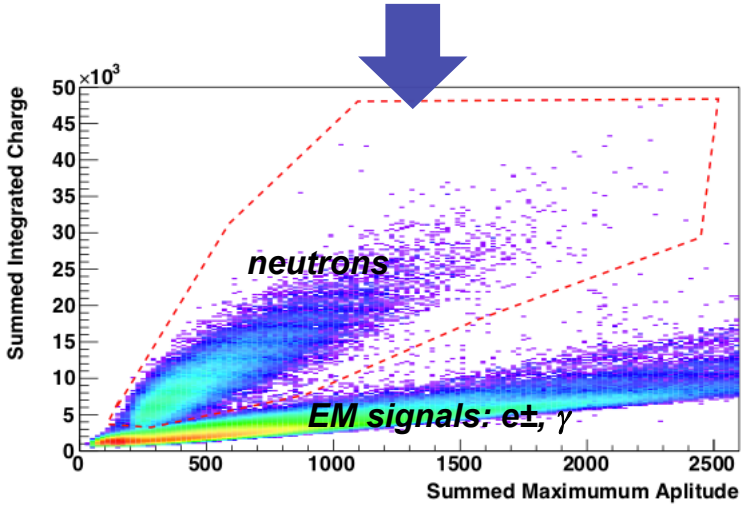
- Prototype response as expected
- Energy calibration with cosmic muons
- Energy resolution: 20 % @ 1 MeV (with one MMPC/fiber)

IBD candidates identification with new runs since the upgrade (on-going)

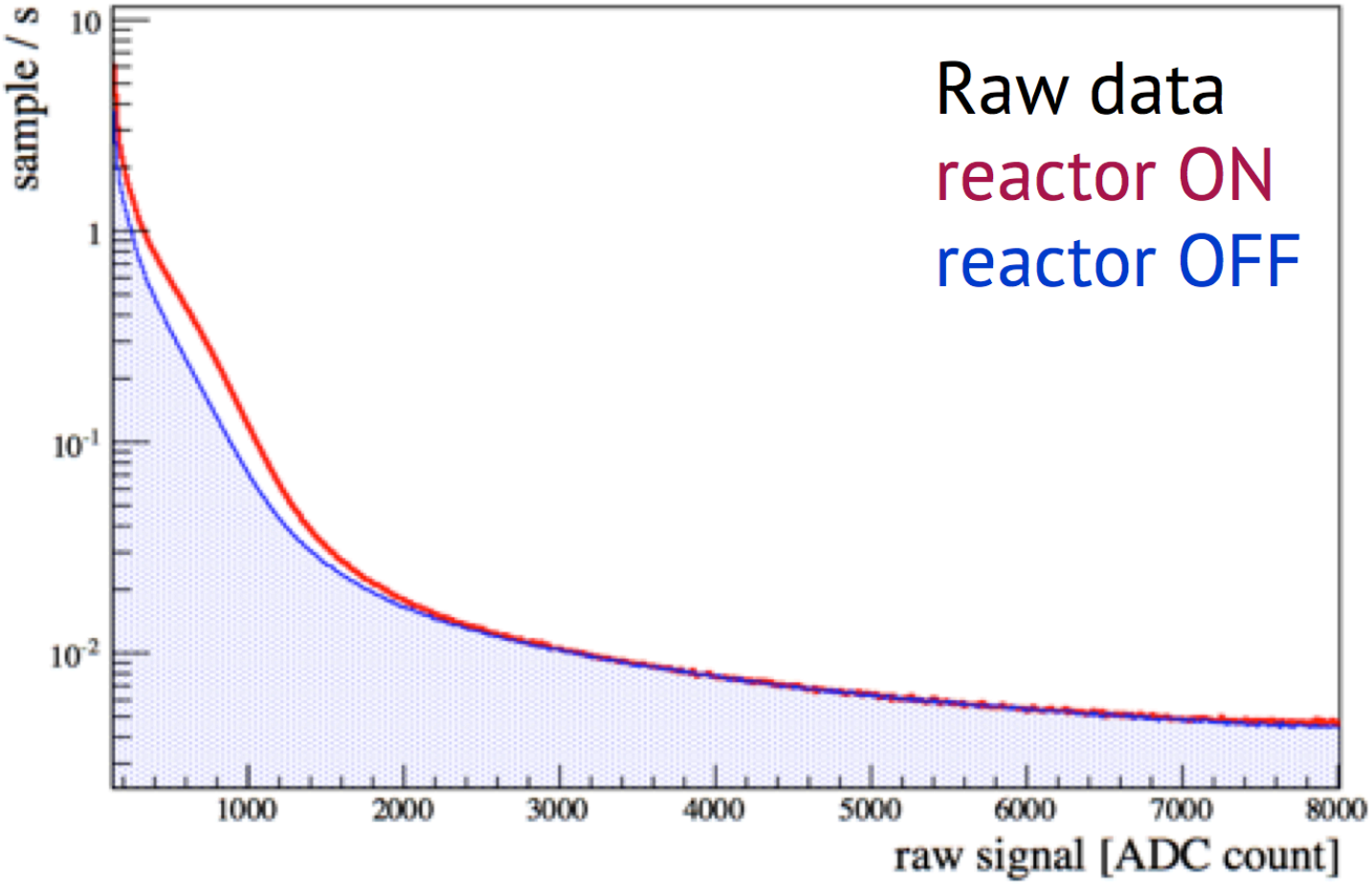
- Selection:
  - positron : X & Y cube highest prompt signal
  - neutron selection using 2D cuts
  - IBD = 200 μs Δt coincidence between EM signal and n capture + no crossing μ (no μ cut)
- Rate analysis:
  - Comparison Reactor ON / OFF
  - Off time window analysis for accidentals rejection





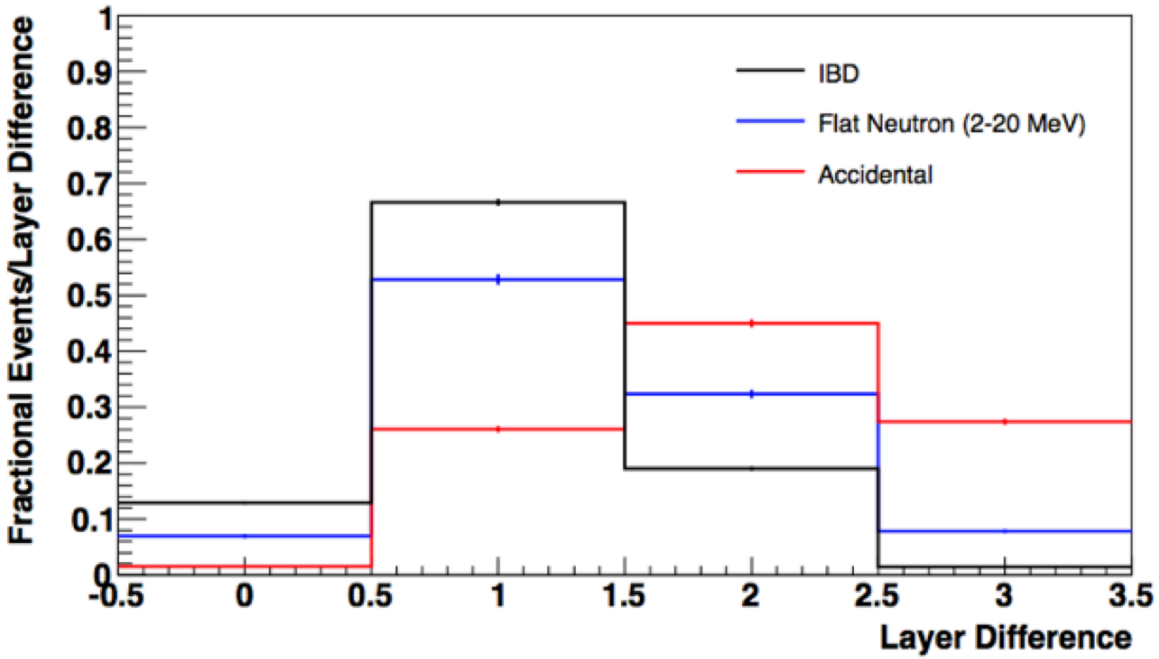


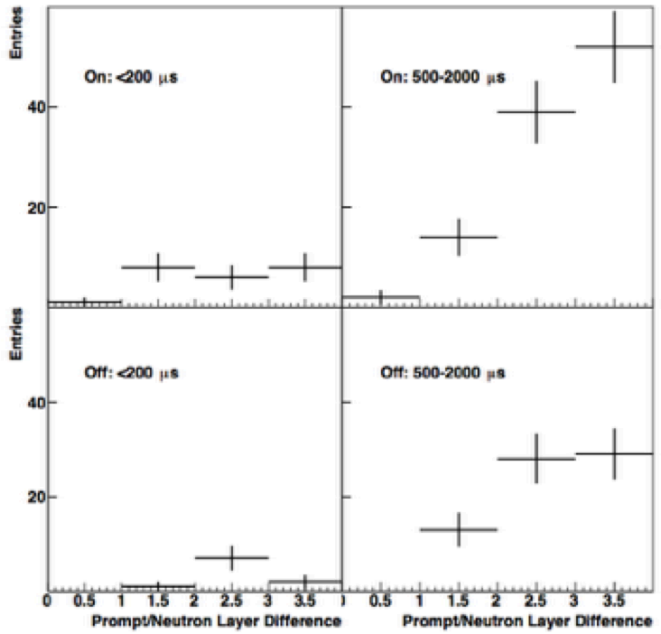
ADC count ON/OFF



- Small difference between ON and OFF period
- Confirmation of a low reactor background
- Dominated by muons induced correlated background

Topological information: rejection capability for accidentals





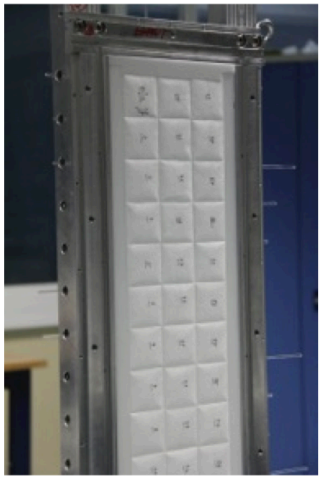
(left) Distance in number of cubes separating a neutron from a positron signal, for different events and obtained by Monte-Carlo simulations. (right) Distance reactor ON and OFF.

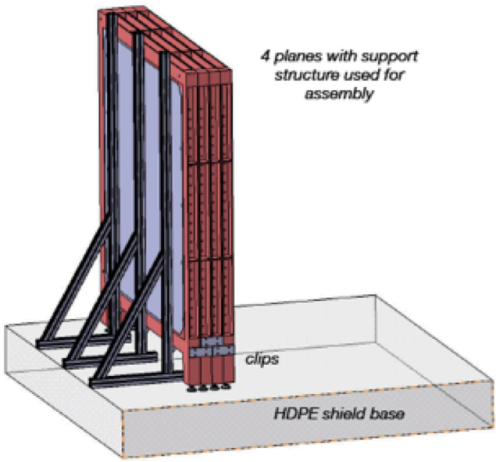
- Topological cuts for reducing accidental background

Status

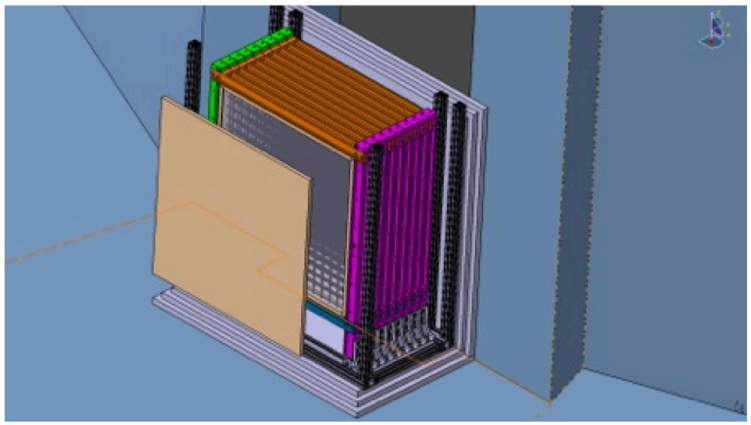
- ✓ Prototype analysis of mars-may 2014 cycles (on-going)
- ✓ Mock-up built and fulfilled the requirements
- ✓ Construction of a large scale prototype
  - 288 kg module (2304 cubes) deployment planned before end of year 2014 at BR2 before the 2015 BR2 stop.

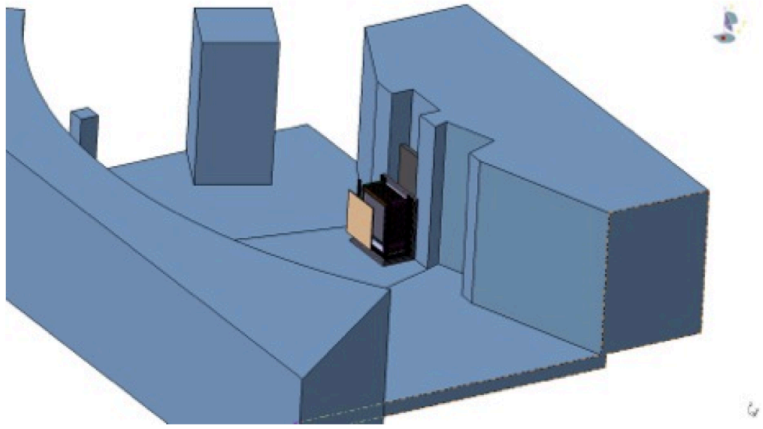
Mock-up and large scale prototype





Pictures of the Solid mock-up (March 2014) and one sub-module design (right).





Schematic view of the first SoLid sub-module detector installed at position R1 in the BR2 hall on level 3. The detector are shielded from gamma-rays by a lead wall in front of the reactor concrete wall.

Short Perspectives

- Prototype: very encouraging results to understand the technology
- increase statistics and efficiency:
- upgrade DaQ Nemenix and installation of a Muon Veto
  - Analysis ongoing

- Carnot Mines Funding for one sub module @ SUBATECH (288 kg)
- Mechanical Design and Mock up 3 x 24 cubes
- Commissioning at the end of the year (before the 2015 BR2 stop)

- Reactor Flux Calculations, Working Group created between SCK-CEN, Subatech and LPC-Caen

- 4 Sub modules funded by Belgian partners
- UK: ERC 2014 + R&D STFC 2014

- SUBATECH-LPC CAEN: ANR “Projet international” for 2 sub-modules funding

SoLid Installation early 2016 at BR2