SoLi∂

Search for Oscillation with Lithium-6 Detector at SCK•CEN BR2 research reactor

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Conseil Scientifique IN2P3

Outline

- SoLid Collaboration
- Reactor Anomaly
- BR2 Research Reactor and the SoLid Experiment
- SoLid Detector Technology
- Schedule and Cost

SoLid Collaboration

- Collaboration highly complementary (Oxford -SUBATECH collab on non-proliferation)
- Very good record of delivery in previous projects

• Collaboration UK

❑ Oxford, Imperial College

✓ Expertise MINOS/T2K
✓ Calibration conveners
✓ Detector construction
✓ Electronics
✓ MARS technology

• Collaboration France

❑ SUBATECH

✓ Reactor experiments Double Chooz, Nucifer
✓ Reactor Simu. Resp. and Reactor and Flux convener (2 PhDs)
✓ Experience with background analysis (2 PhDs)
✓ Expert in flux calculation
✓ Nucifer veto detector

❑ LPC Caen

✓ IN2P3 neutron expertise

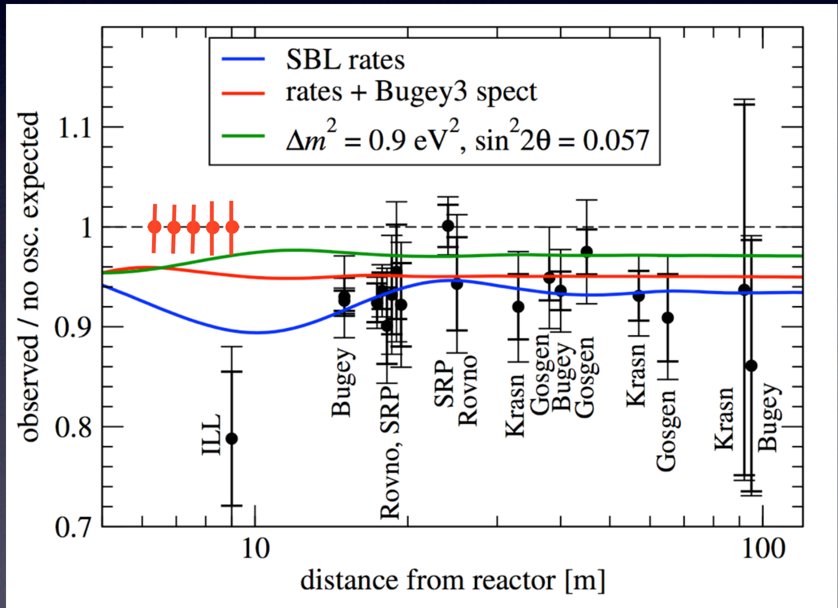
• Collaboration SCK-CEN BR2

✓ Research reactor environment
✓ Resource for Shielding and Background measurements

Motivation

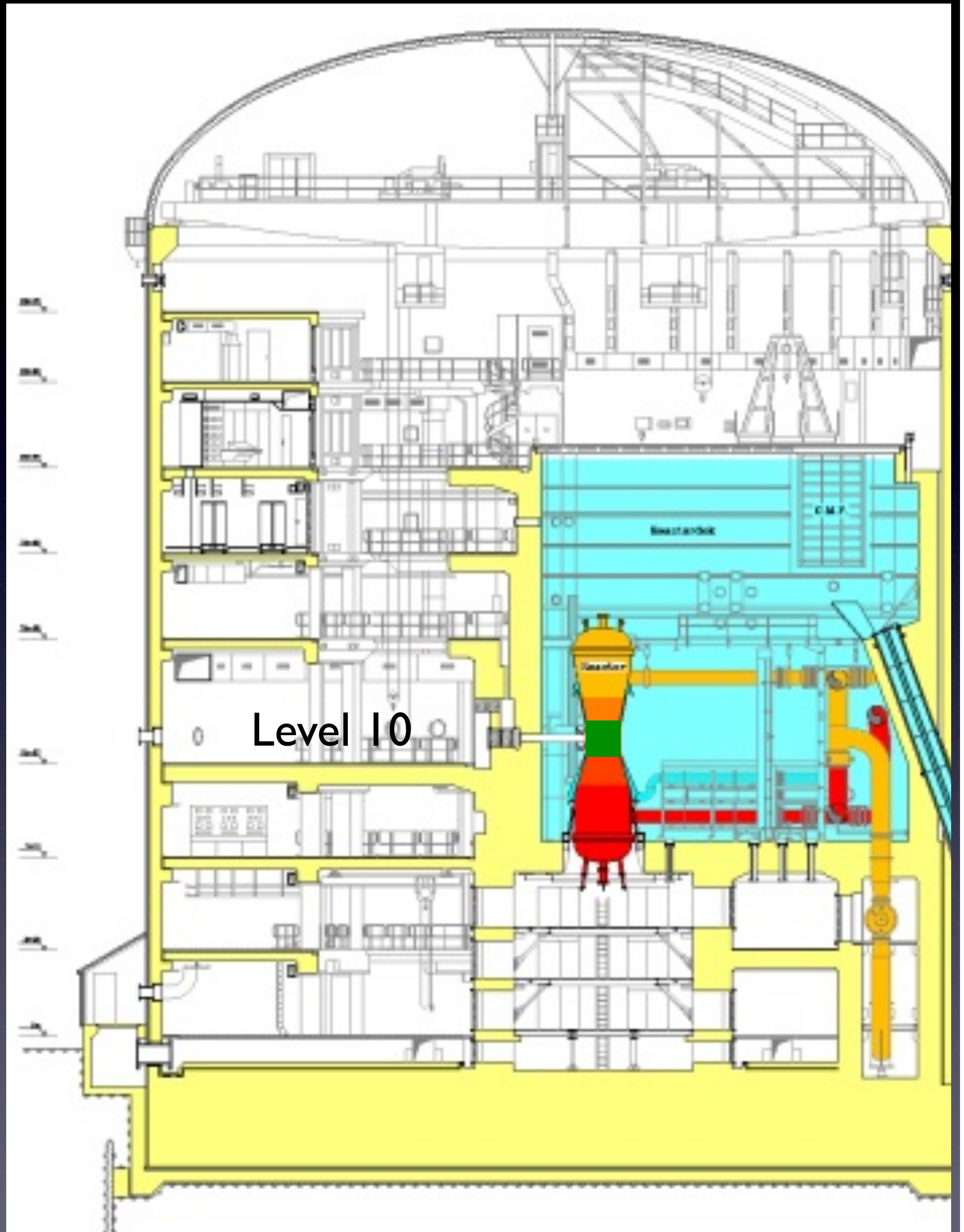
- Search for short distance oscillation
  - Assess rate anomaly accurately
    - Only few % effect !
  - Improved experimental set up : improve technology
  - Need for definitive experiment : high sensitivity both in position and energy
  - Careful measurement : minimise impact of backgrounds

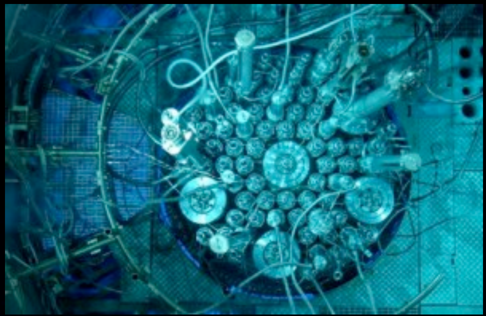
T. Schwetz et al. talk @ APC



BR2

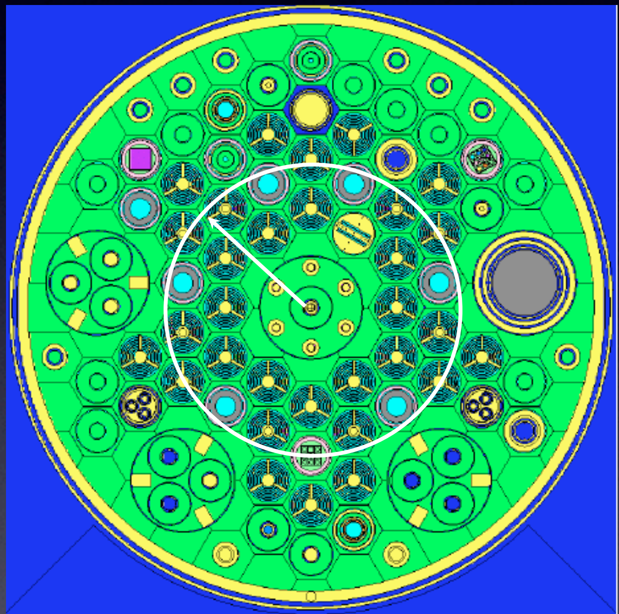
- Compact source with high power (60-80 MW)
- VERTICAL PORTS
- Closest approach 5.5 m
- Large surface area available at level
- 140 days /year, no time limit for measurement
  - Not statistically limited
- Antineutrino project started at SCK•CEN (BR2-NEMENIX)
  - Scientific and non-proliferation collaboration
  - Committed resources for prototype shielding

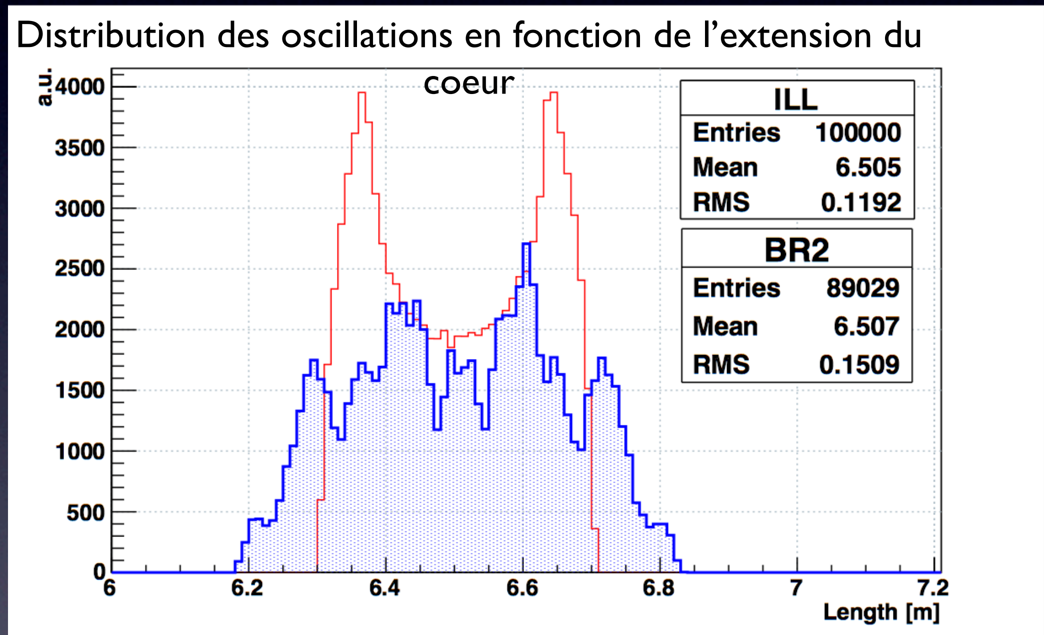




Size of core

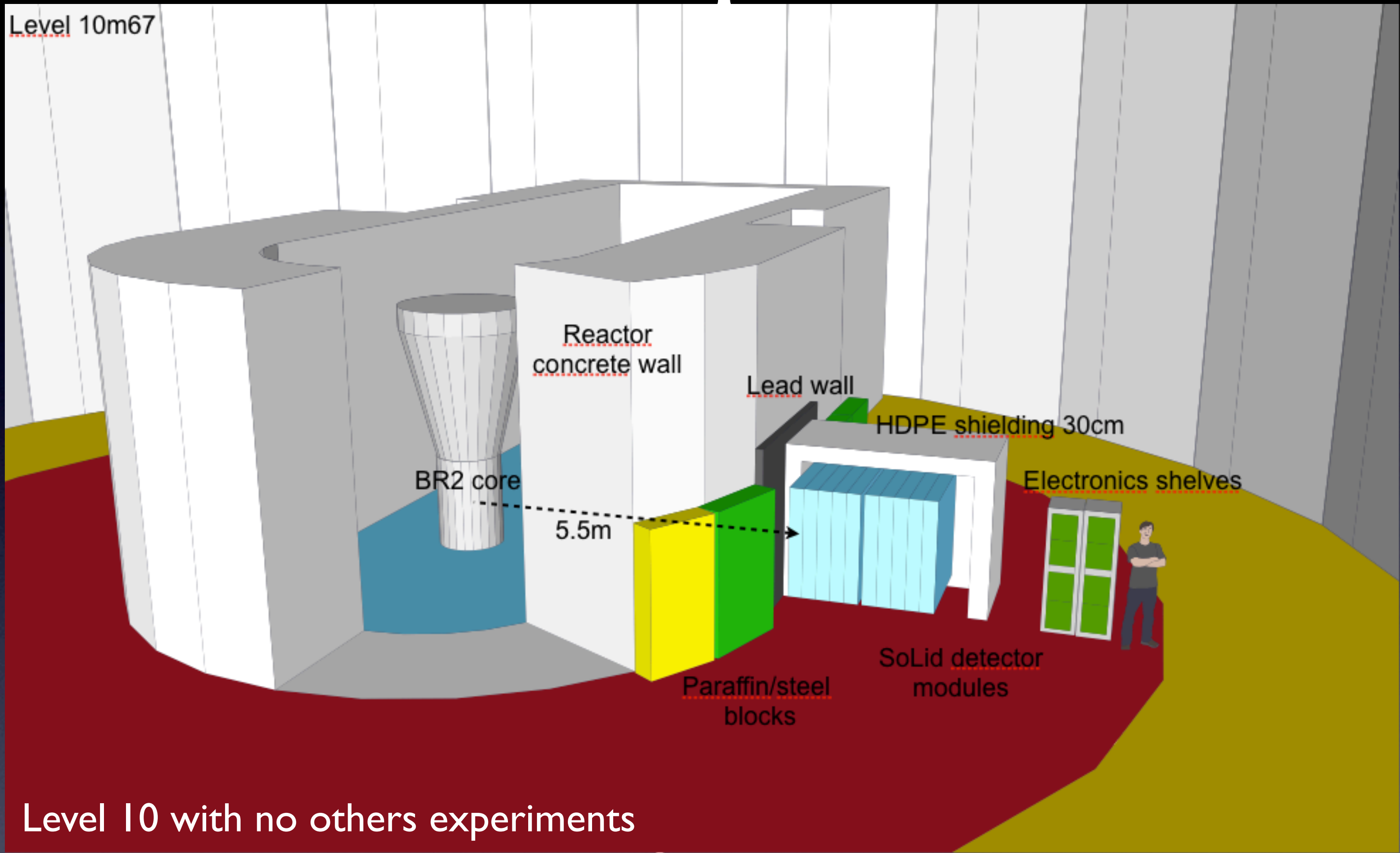
50 cm effective Ø x 90 cm





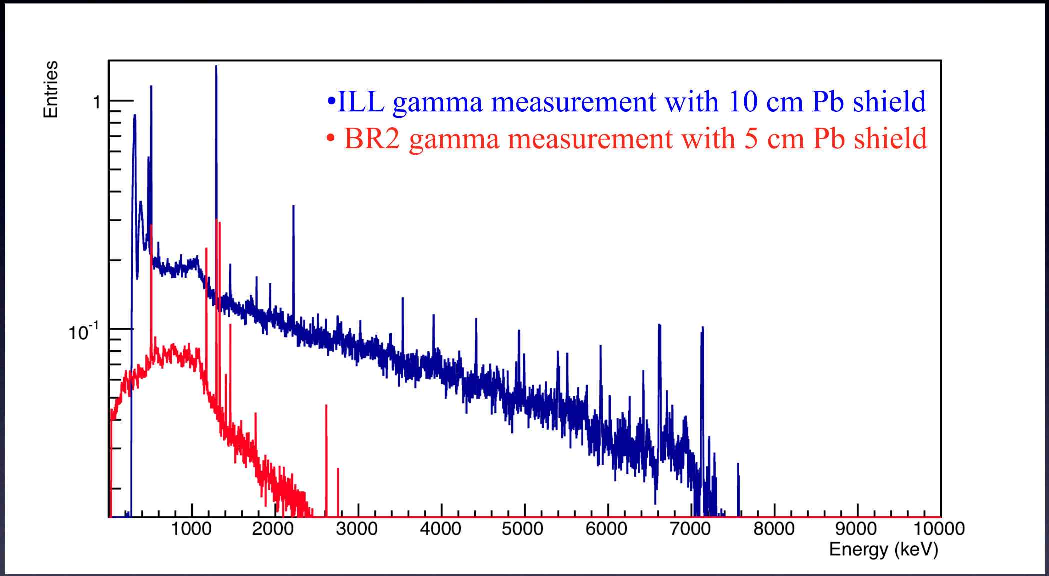
- Compact antineutrino source (effective radius is ~ 25 cm)
  - No significant difference with ILL core
- Low duty cycle but various power level of operation

SoLid Experiment



- If signal seen move planes to optimize measurement
  - Diminish detector systematics

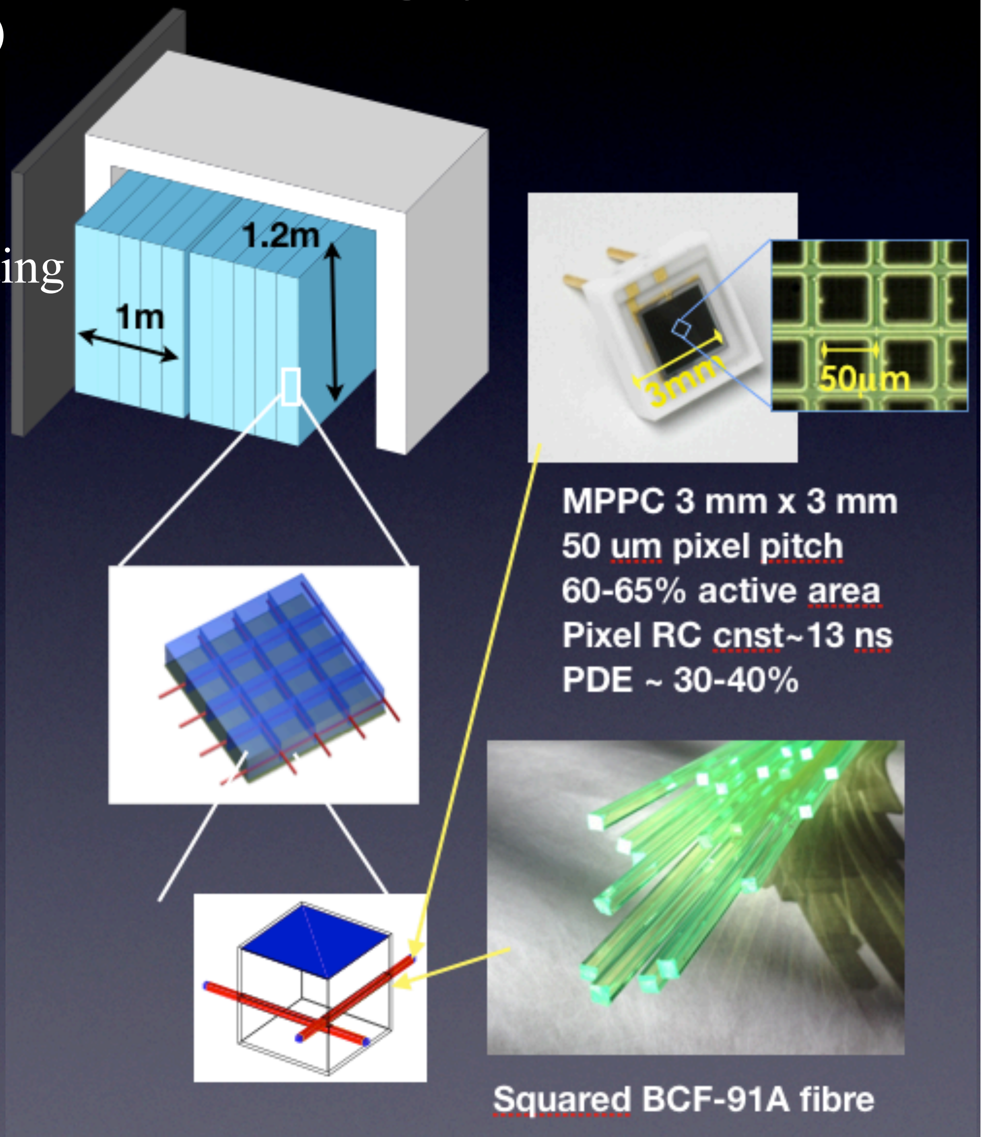
Backgrounds conditions at BR2 10m67



- BR2 has a relatively low background environment
- Gamma-rays with softer spectrum than ILL (different core structure)
- Very low risk of change of conditions
- Ports are shut and no other experiments !

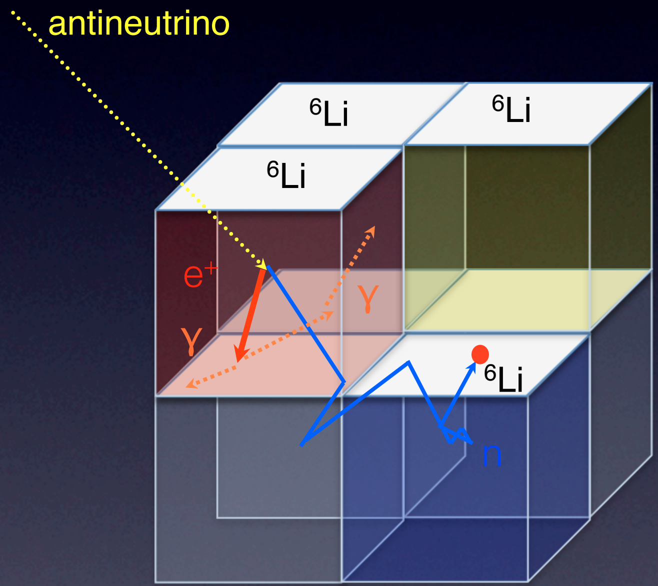
SoLid technology

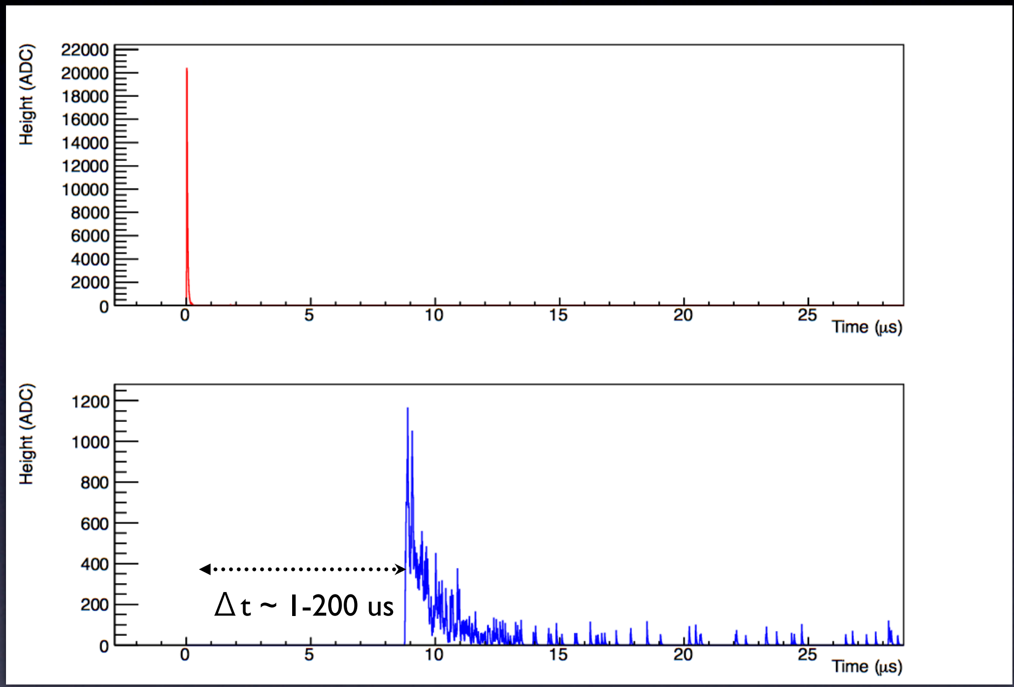
- Based on MARS detector technology (patent)
  (development for novel types of neutron and anti-neutrino detectors
  for science and applications in security)
  - ➢ Robust to background,
  mitigate better background than passive shielding
- Segmented detector (2.88 t)
divided in 10 sub-modules (1.2x1.2x0.2 m^3)
- Detector element :
  - EJ-200 PVT cubes 5 cm x 5 cm x 5 cm
  - 6LiF:ZnS(Ag) screens 5 cm x 5cm x 250um
  - Covered with Tyvec sheets
  - Carbon fibre tray to hold cubes in layer
  - Scintillator light collected by fibre
  - MPPC read out at one end of fibre
  - Detector read on X et Y
  (10 sub-modules = 23040 cubes, 1920 read out channels)
  - Electronics developed by Oxford (based on MARS tech.)



Detector principle

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





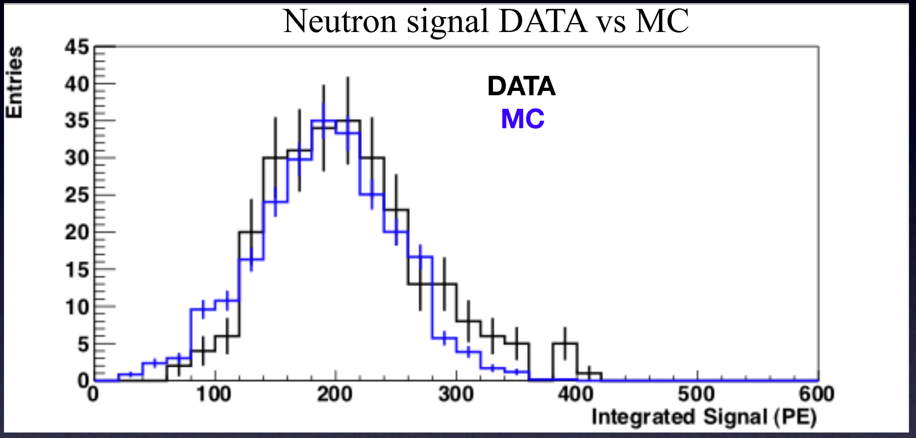
- Isolate positron energy in one cube : reconstruct energy not affected by gamma energy leakage

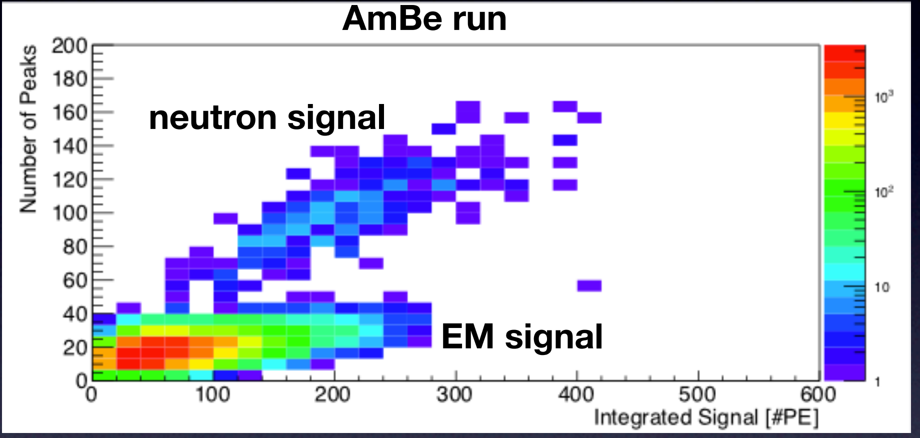
  (Evis = Ee^+)

- Neutron is captured in neighboring cube increasing localisation of IBD event

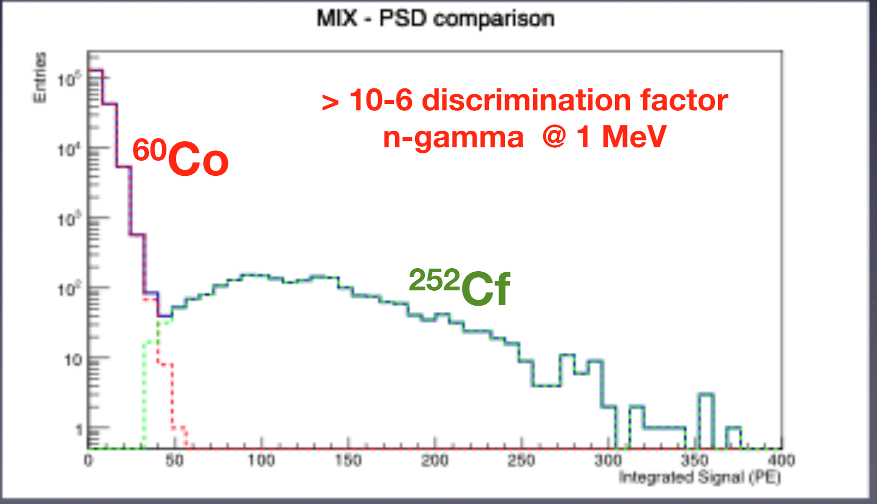
Neutron detection

$$^{6}_{3}\mathrm{Li} + \mathrm{n} \rightarrow^{2}_{4} \mathrm{He}\ (2.05\ \mathrm{MeV}) +^{1}_{3} \mathrm{T}\ (2.75\ \mathrm{MeV})$$





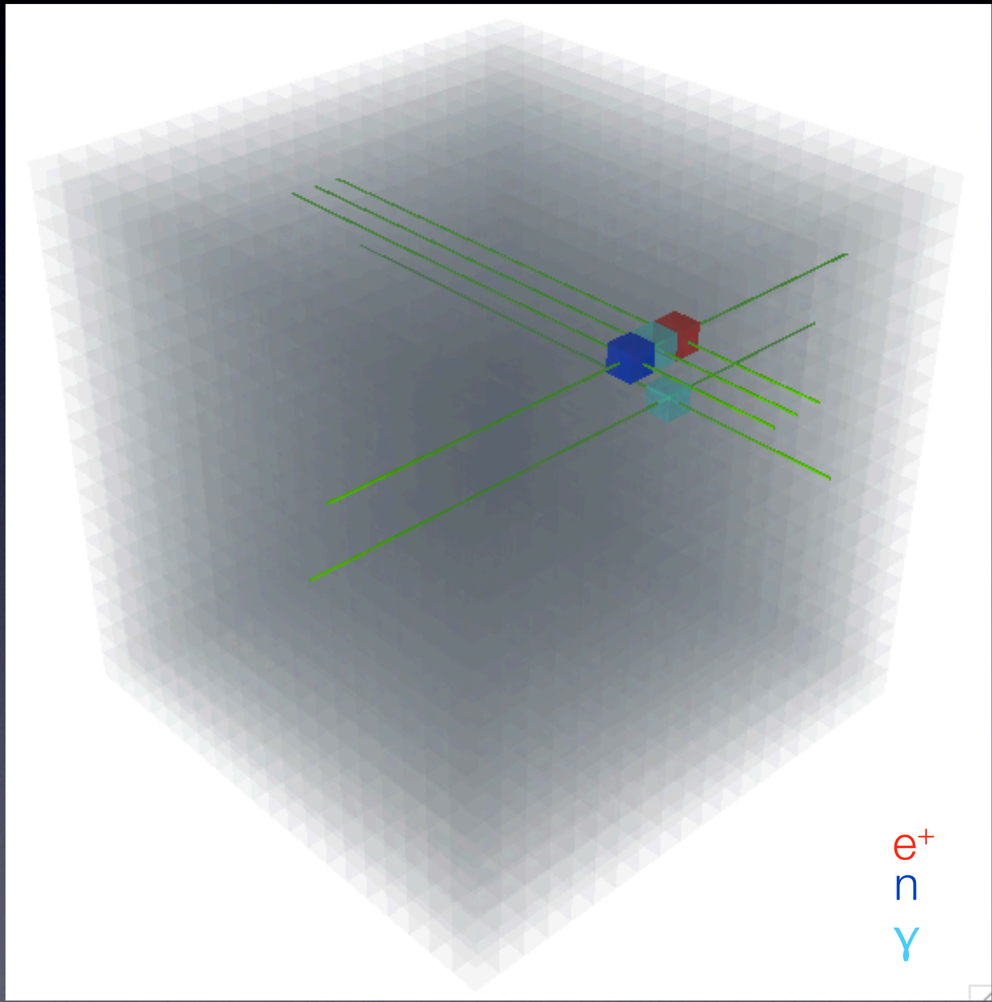
- High capture efficiency on Lithium-6 (>70%)
- **160 000 photons/neutron** in ZnS, no quenching !
- Tritium and alpha excite higher ZnS energy levels : slower decay time constants (200ns and 10-20us)
- Powerful discrimination between neutron and fast signals (EM) : 10^{-4} down to 10^{-8} achievable !
- NEUTRON DETECTION VALIDATED WITH REAL SYSTEM
- **Physics Trigger : neutron events to limit data rate**



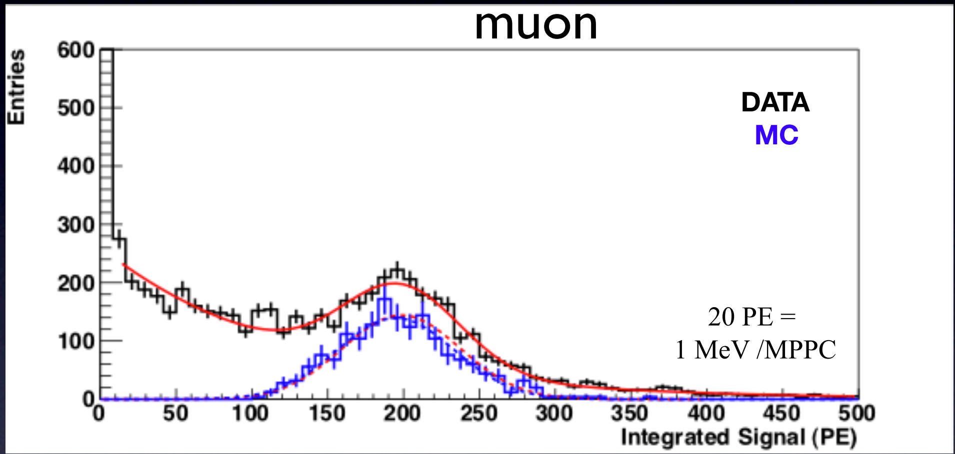
IBD imaging

- Topology well defined in space
  - Tight spatial cut possible
- Additional handle on background rejection

➢ Multiplicity cut to distinguish IBD from backgrounds



Light yield and IBD reconstruction

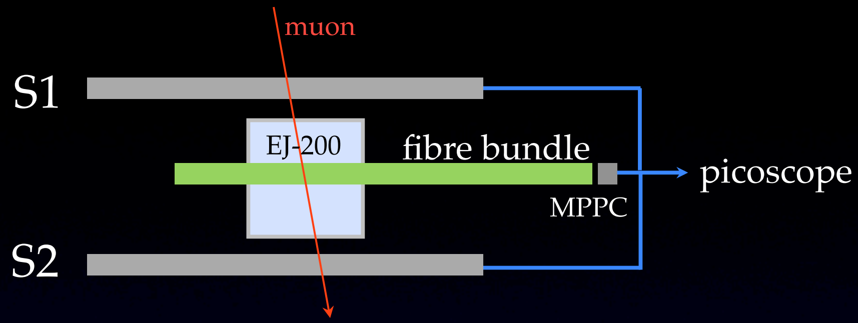


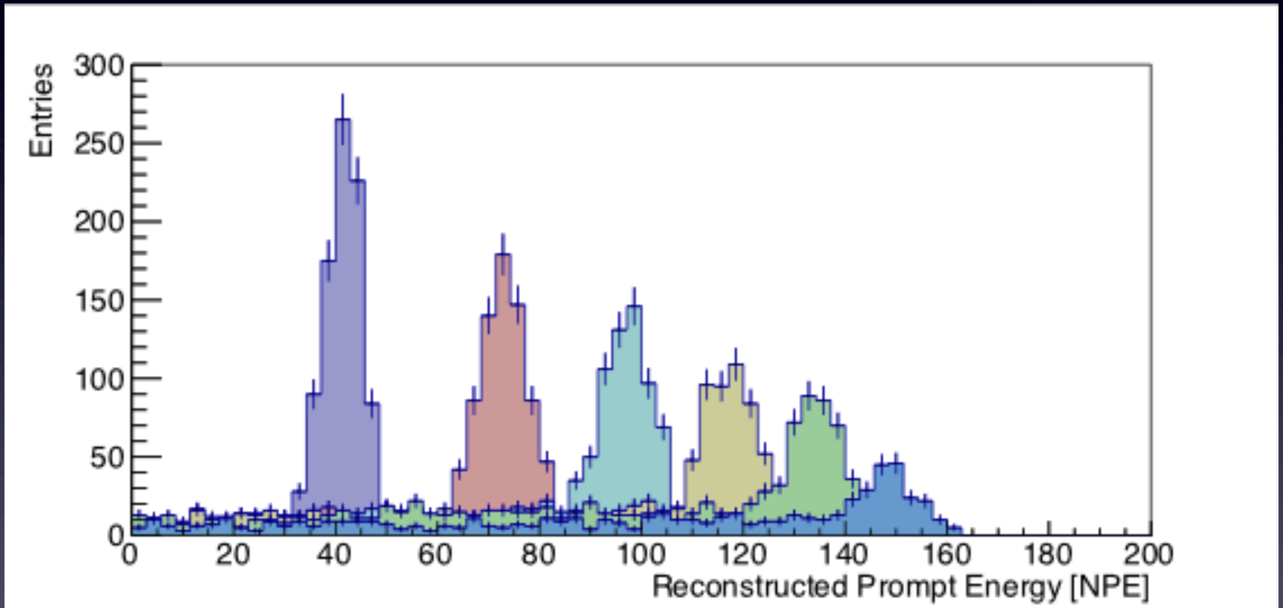
Cut	Efficiency
n trigger	0,71
Coincidence 100us	0,58
Energy cut (20PE/ 600keV)	0,48
Spatial cut	0,47
Multiplicity cut (5 cubes)	0,45

- Large light yield based on real dimension PVT cubes with BCF-91A fibre and MPPC read out
  - Optical model tuned on data
- High IBD reconstruction efficiency
  - Flat in energy both for e^+ and neutron

Energy resolution

Test bench at Oxford





- Good energy resolution
  - Very low e^+ energy leakage and lower energy threshold

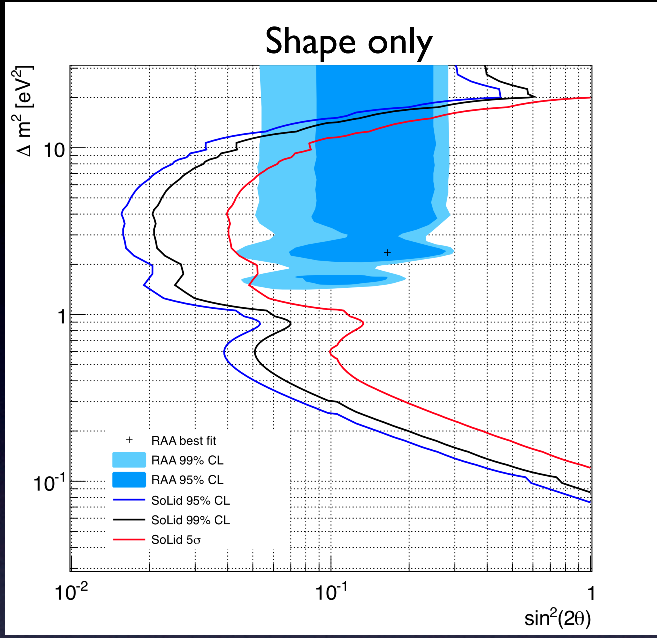
Background rejection

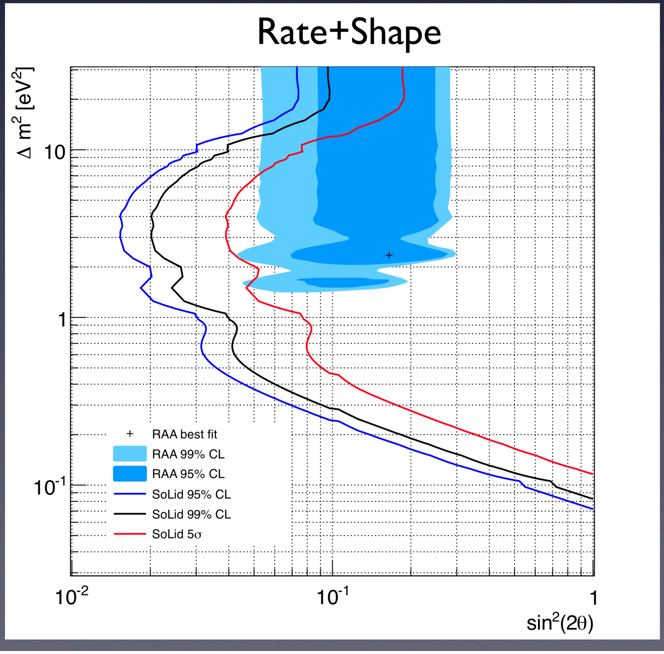
- High flux of γ from reactor (MHz rate on detector surface)
  - High discrimination with $^{6}LiF:ZnS$
  - Timing and spatial cut efficient at reducing accidentals
  - Compton scatter cut
- unprecedented background rejection capability !

Type of signal	Rate/2.88t/day w/ shielding
Antineutrinos @ 6.8m	1198
neutron Reactor ON [50 keV - 5.5MeV]	**< 1**
Fast neutrons	**126**
Cosmogenics	**42**
Accidentals	**29**
S/B	**6**

Sensitivity to oscillations

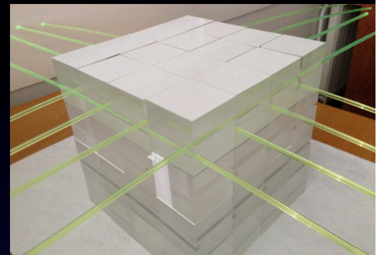
- BR2 reactor characteristics
  - 58 MW, 50 x 90 cm BR2 core
- baseline : 6.8 m (416 nu/day/ton)
- 2.88 ton detector mass
- division in 10 sub-modules of 20cm
  - ~45% detection efficiency
  - energy resolution : 0.17 at 1 MeV
  - 300 days running (140 days/year)
  - signal to backgrounds ratio 6:1
  - Spectrum norm.: 1.8%
  - Spectrum shape: 0.7-4%
  - Thermal power: 3%
  - Detection efficiency 2%





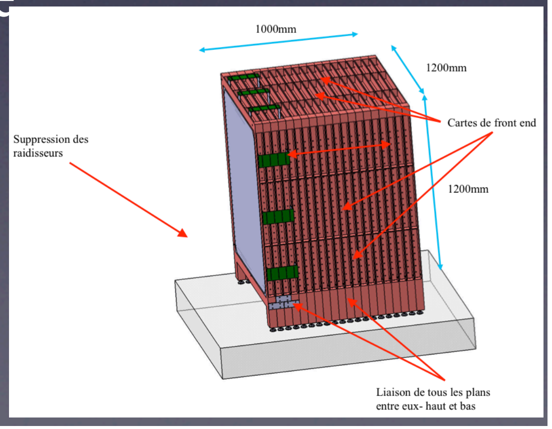
Schedule

BR2-
NEMENIX
(prototype)



- 2013
  - 20cm footprint prototype under construction
  - Validation of system during summer 2013 at BR2
  - Full design of detector and development of electronics ongoing
- 2014-2015
  - Full scale detector construction complition mid - 2015
  - Assembly of detector modules and test with calibrated source
- September 2015
  - Installation and commissioning of systems
  - Start data taking January 2016

5 sub-modules
installation



IN2P3 contribution

- Subatech responsibilities:
  - Module Design, 3 modules assembly/mounting
  - Reactor simulations and antineutrino spectra
- Caen responsibilities :
  - Neutron calibration

+ commissioning, installation, analysis

Physics case and Synergies

- Search for short baseline oscillations
- New technology for neutron detector with an exceptional noise rejection of gamma background

(LoI from F. De Oliveira, S. Harrisopoulos, P. Ujic - Spokespersons of the E563 collaboration at GANIL)

- Antineutrino-based reactor monitoring for Safeguards

(LoS from H. Toivonen – Chair of ESARDA WG for Novel technology)

- Study of backgrounds induced by cosmic rays
- Antineutrino detector for future experiments

Conclusion

- Look for disappearance measurement at 3-5% level
  - Need clean measurement to maximise chance to identify new phenomenon
- If background large impact on subtraction
- SoLid experiment is a low risk experiment
  - Exceptional conditions at BR2
  - SoLid technology has unprecedented background rejection capability
  - Even if background change the detector can handle it with no extra shielding
- Cost to IN2P3 is €(270k hardware +72k electronics) for 3 submodules construction
  - Long term prospect of using technology for other projects
  - A careful and robust measurement the community can believe