The Stereo Experiment

Search for Sterile Neutrino at ILL reactor

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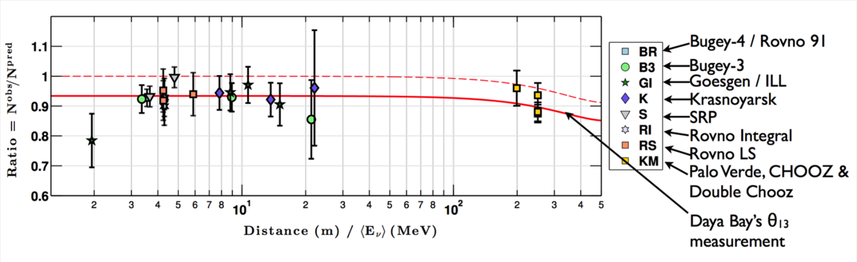
Reactor antineutrino anomaly

- Reevaluation of reactor $\bar{\nu}_e$ spectra, Th. A. Mueller et al., Phys. Rev.C 83, 054615.
- Reanalysis of short baseline experiments, G. Mention et al., Phys. Rev. D 83, 073006

$\Rightarrow$ **neutrino deficit of 6.5%**



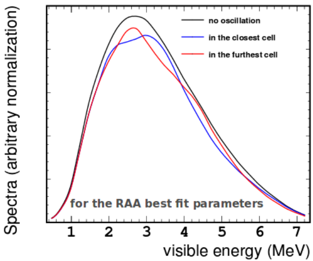
New oscillations toward a sterile neutrino ($\Delta m^2 \gtrsim 0.5$ eV^2, $\sin^2(2\theta) \sim 0.1$).

Motivation and specifications of the Stereo experiment

MOTIVATION :

- Observe an **unambiguous** new oscillation pattern **in energy and distance**.

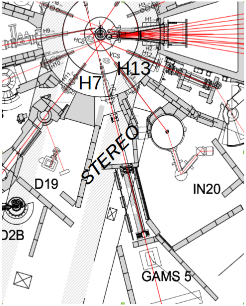
Oscillation phase shift between 2m apart cells



SPECIFICATIONS :

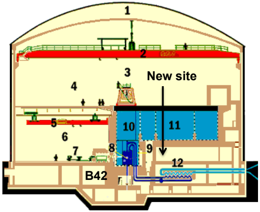
- Close to a compact and high flux nuclear reactor core : 10 m from the **ILL reactor**.
- Relative distortions among identical detector cells : **independent from reactor normalization** and history (pure ^{235}U spectrum).
- Accurate detector response : **mature technology of Gd-Loaded liquid scintillators**.

ILL site



ADVANTAGES :

- 58 MW research reactor.
- High ^{235}U enrichment and compact core.
- Overburden with the transfer water channel.
- Strong structure of floor (500 t /slab).



DRAWBACK :

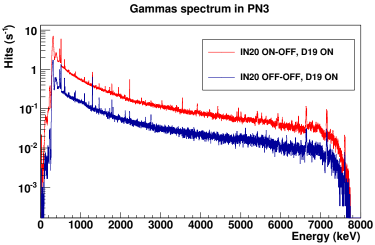
- High neutron and gamma flux because of experimental beam lines.

  → **Requires heavy shielding**.

Gamma and neutron measurements

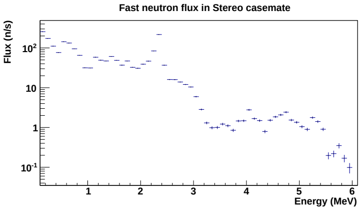
Several campaigns with gamma and neutron detectors → directional measurements.

- Main gamma sources : H13 and H7.



- 80% of gammas coming from H13.
- High energy n-captures on metals and Compton background.

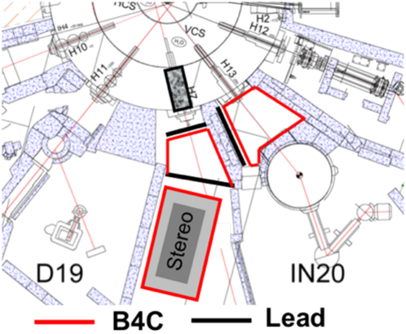
- High thermal neutron flux because of H13 beam line.
- Fast neutrons from reactor :
  - Lithium in H7 → removed.
  - Scattering on H13 collimator → CH_2 shielding.

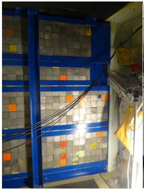


- MCNPX + G4 simulations in agreement with measurements.

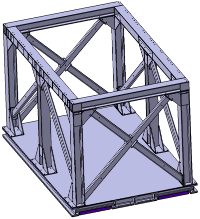
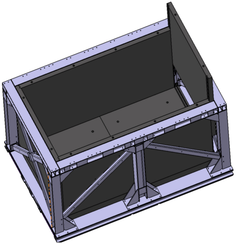
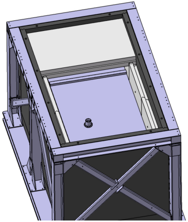
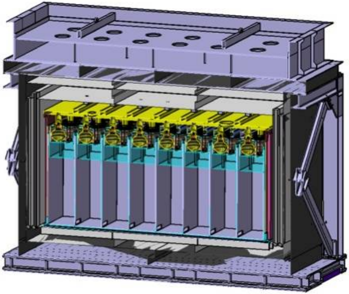
Shieldings against muons, gammas and neutrons

- Front wall shielding and H13 reinforcement :
  - Dedicated beam plug.
  - Additional lead wall.
  - Additional neutron shielding : B_4C.
- Shielding surrounding the target :
  - 10 cm thick lead.
  - 15 cm thick polyethylene.
  - 30 cm thick surrounding crown.
- "On-site" protection :
  - Water channel.





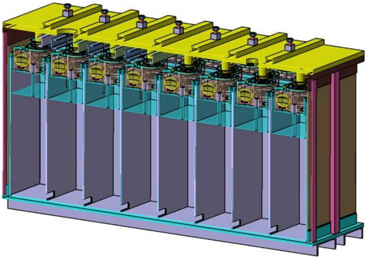
Detector shielding - LAPP

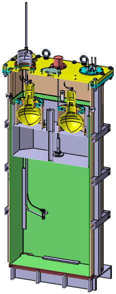





- Strong external struture to hold shielding.
- Installation with reactor crane and move using air pads.
- On-going studies for safety.

Detector design - Saclay

- Six cells (40x90x90) cm^3 filled with Gd-loaded liquid scintillator.
- Surrounding crown filled with unloaded liquid scintillator.
  - Containment of energy leakage
  - Active veto of external background
- Light collection :
  - Four PMTs per cell and acrylic buffer.
  - Acrylic walls and optical segmentations with VM200.
- Validation with prototype in July 2014.



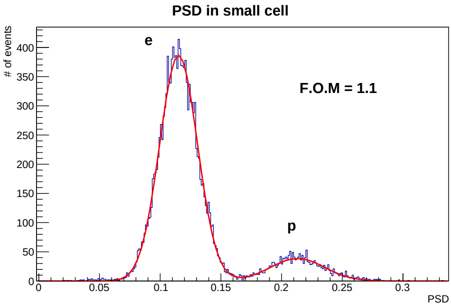


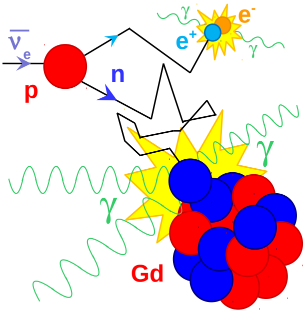
Liquid scintillator - MPIK

- $\overline{\nu}_e$ are detected through **inverse β decay** in Gd-loaded liquid scintillator :

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

- Liquid studies to maximize light yield and PSD.
- Attenuation length at 430 nm > 4 m.
- Good pulse shape discrimination :





Detection by **time coincidence** :

- Prompt event = positron ionisation and annihilation
- Delayed event = neutron capture on Gd nucleus

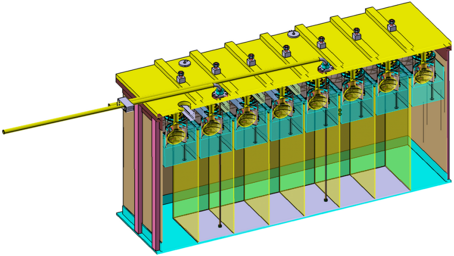
Calibration system - LAPP

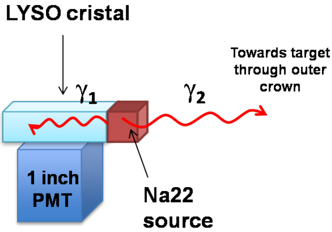
OBJECTIVES :

- Energy scale and neutron efficiency.
- Fine-tuned simulation.

TOOLS :

- Gamma and neutron sources :
  - Inside cells along vertical axis.
  - Underneath the detector vessel.
  - Around the detector vessel.
- Tagged source :
  - Circulated around the detector vessel at different Z.
  - Absolute calibration at 511 keV.





Electronics - LPSC

- Signal digitization (14 bits FADC 250 MHz) with signal analysis functions : Qtot, Qtail, full trace readout, timming ...
- Trigger on selected configuration of deposit charges + external trigger.
- LED calibration driver.

Current prototypes :

- New PMT base design.
- Front end and trigger boards based on μTCA technology$\rightarrow$ validated.
- Currently routing the prototype of the 8 channel FE board using μTCA technology.

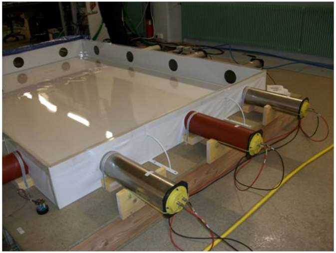
Muon veto - LPSC

Requirements

- Fully efficient to cosmic muons.
- Quasi-insensitive to gamma rays.
- Made of non-flammable material $\rightarrow$ water Cerenkov (4.0 x 2.6) m^2.

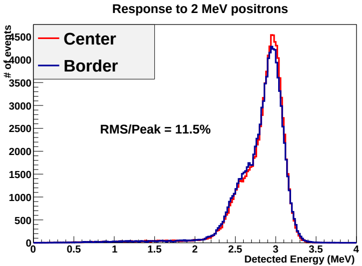
Current prototype :

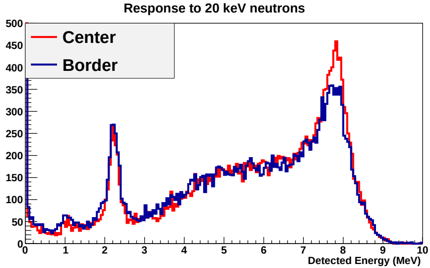
- Almost full size tank (3 x 2 x 0.25) m^3.
- Optimization of geometry and light collection :
  - Purified water.
  - Wave Lenght Shifter.
  - Tyvek diffuser.
  - 14 PMTs on sides or 12 on top.



Positron and neutron response

- Complete GEANT4 model to simulate the detector response.

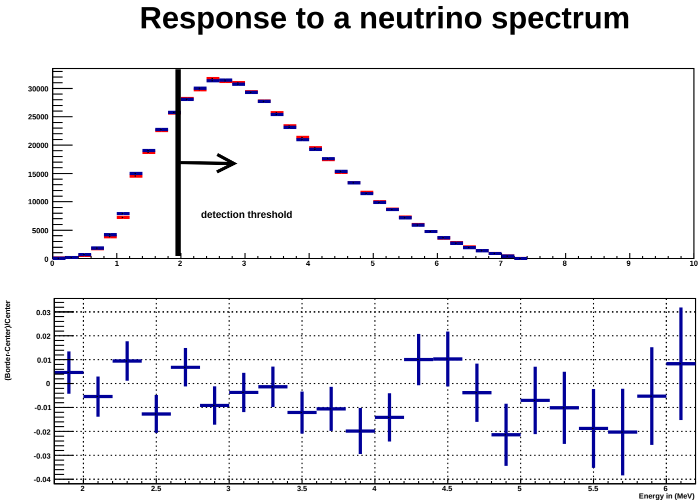




- Similar response between center and border cell :
  - RMS/Peak(center cell) = 11.5%
  - RMS/Peak(border cell) = 11.7%.

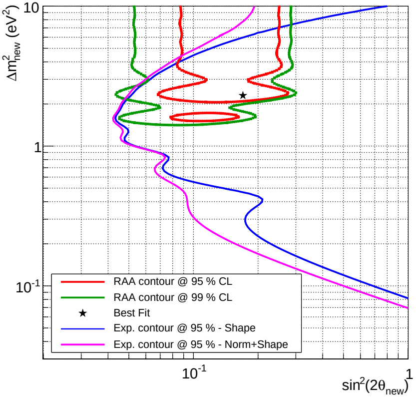
- Neutron efficiency above 5 MeV :
  - 64.5% $\pm$ 0.5% for center cell
  - 60.1% $\pm$ 0.5% for border cell.

Neutrino response



- % level agreement of detector cells for detected neutrino spectrum.

Stereo contours



- 300 days data taking (6 reactor cycles)
- Energy reconstruction systematics : $\delta E_{scale} = 2\%$
- Systematics of the emitted neutrino spectra included
- Normalisation : 4%
- Signal / background = 1.5
- Prompt signal energy > 2 MeV
- Delayed signal energy > 5 MeV
- Expected detection rate = 410 $\overline{\nu}_e$ / day

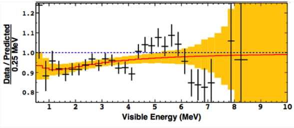
Prospects

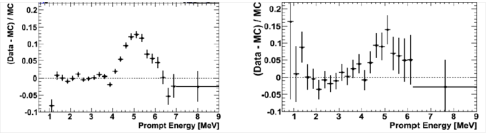
- The sensitivity covers the contour of the reactor anomaly.
- Several prototypes are under test to validate the detector response.
- Shielding installation and background reduction check this summer when the reactor restarts.
- Beginning of data taking in Spring 2015.

Back-up

Bump at 5 MeV

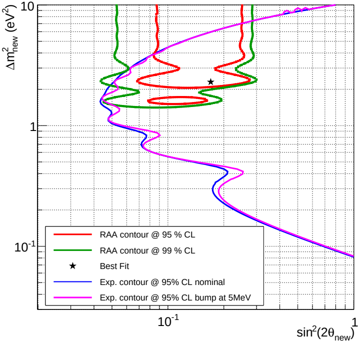
- Neutrino excess at 5 MeV in several experiments : DC, RENO, Chooz, Rovno ...

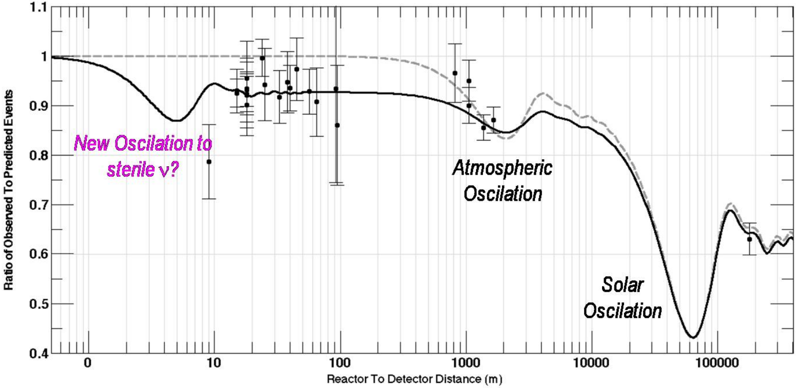




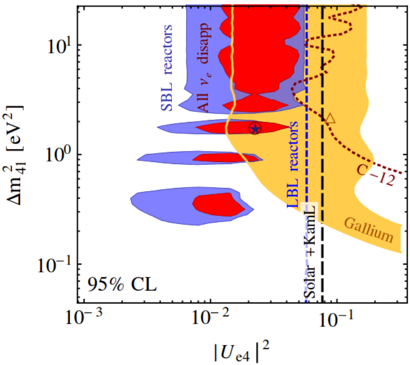
- Scale with reactor power so
  - bias in the conversion procedure ?
  - bias in the reference electron spectrum ?
  - another neutrino interaction ?

- Which impact on Stereo sensibility ?
- Bump amplitude = 10% of neutrino signal.
- Incertainty = 50% of bump amplitude. $\rightarrow$ No significative impact on the contour.





1.1
1
0.9
0.8
0.7
0.6
0.5
0.4
Ratio of Observed To Predicted Events
0
10
100
1000
10000
100000
Reactor To Detector Distance (m)
New Oscillation to sterile ν?
Atmospheric Oscillation
Solar Oscillation



Kopp, Joachim et al. JHEP 1305 (2013) 050 arXiv:1303.3011