Solid Scintillator Detector of the Reactor Antineutrino

DANSS

status report
KNPP

Udomlya
Russia

**GEMMA-1**
Unit #2 (25 y. old)
dist. = 14 m
$2.7 \times 10^{13} \text{ v} / \text{cm}^2 / \text{s}$

**GEMMA-2**
Unit #3 (new)
dist. = 10 m
$5 \times 10^{13} \text{ v} / \text{cm}^2 / \text{s}$

Unit #4:
Under construction (to be started in 09/2011)
The standard $3GW_{th}$ ББЭР-1000 Water-moderated Water-cooled Power Reactor

- Life-time $\sim 320$ days

- 1500 kg of $^{235}\text{U}$ is burned out

- and 311 kg of $^{239}\text{Pu}$ is produced

- which changes the flux and energy spectrum of the neutrino emitted

$\Rightarrow$ Would be nice to monitor it!...
In addition, detection of the reactor neutrino would allow to solve some fundamental, applied and even political problems:

• Precise Weak ($\nu$-e) cross-section
• Measure the actual reactor power ($N_\nu$)
• Deduce the actual fuel composition ($E_\nu$)
• On-line reactor monitoring (tomography?)
  - especially important in view of the future FBR (with longer life-time and less studied)

• Non-proliferation (prevent unauthorized extraction of $^{239}$Pu)
Detection idea: Inversed Beta-Decay in plastic with Gd/Cd interlayers

Inversed $\beta$-decay: $\bar{\nu} + p \rightarrow n + e^+$

- E - up to 7 MeV
- range - up to 3 cm

$^{157}$Gd ($n,\gamma$) 255 000 barn  $E(\sum\gamma) = 8$ MeV

Moderation time: 10 - 50 $\mu$s

Interlayers containing $^{157}$Gd

Plastic scintillator layers

1-2 cm
Signature of the IBD registration

\[ e^+ (n, \gamma) \]

Local burst

30-50 µs

The burst spread in space

(from 2.6) to 8 MeV
Polystyrene-based scintillator

Gd-containing light-reflecting coating

3 wave-length shifting (WLS) fibers Ø1.2 mm

Basic element - scintillator cell ("strip")
Conception of the detector: Modular structure

A number of strips are combined into intercrossing X- and Y-modules (20\times20\times100 \text{ cm})
Segmental solid plastic scintillator (2500 cells)

Sensitive volume = 1 m³

DANSS
Ceiling = Bottom of the reactor shielding

Lifting gear:
• Easy mounting
• Partial operation

4.1 m
Jan. 2010. Mounting of the trial section #0
Important features
(resp. to conventional liquid scint.)

• **Handling is much safer** (not caustic, spontaneously igniting, volatile or solvent) → no restrictions to move the detector very close to the reactor core → higher neutrino flux → **better sensitivity**.

• **High segmentation** (2500 cells) → space information → better IBD-signature → stronger **BCKG suppression**.

• **PS** is not doped with Gd, but **interlaid** with it → better **quality** and **stability** of the scintillator.

• **WLS-fibers** improve homogeneity of light-collection → better **energy resolution**.

• Each cell in a module is looked through with both **individual MPPC** (high QE, but bad noise and range) and **common PMT** (lower QE, but better range and stability) → coincidence mode and combination of **PMT and MPPC advantages**.

• **Sectional structure** → possibility of “**partial**” operation, renewal and upgrade.

• Use of **lifting gear** → measurements at **different distance** → more reliable data interpretation.
**Expected parameters:**

- Sensitive volume: $1 \text{ m}^3$
- Composition: 5 sections (1m 1m 0.2m) of $(5X + 5Y)$ modules = 2500 scint. strips
  
  \[
  \begin{align*}
  1 \text{ module} & = 5 \times 10 = 50 \text{ strips}
  \end{align*}
  \]
- IBD detection efficiency: $\sim74\%$
- Count rate: **9200 IBD-events per day**
- Background: 40-50 events per day
- Due date:
  - section №0 – **Feb 2010**
  - sections №1-3 – **2011**
  - №4-5 – **2012**
The work was going on, but then priority changed
Sterile Neutrinos and Short-Baseline Oscillations

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Workshop on Sterile Neutrinos and the Reactor Antineutrino Anomaly

T.U.M, Garching, 8 February 2011

Collaboration with Marco Laveder (Padova University)
The Reactor Antineutrino Anomaly

M. Fechner, G. Mention, T. Lasserre,
M. Cribier, Th. Mueller D. Lhuillier, A. Letourneau,
CEA / Irfu


V. THE FOURTH NEUTRINO HYPOTHESIS

\[ P_{ee} = 1 - \cos^4 \theta_{\text{new}} \sin^2(2\theta_{13}) \sin^2 \left( \frac{\Delta m_{31}^2 L}{4E_{\bar{\nu}_e}} \right) - \]
\[ \sin^2(2\theta_{\text{new}}) \sin^2 \left( \frac{\Delta m_{\text{new}}^2 L}{4E_{\bar{\nu}_e}} \right). \] (13)
The conclusion of the Workshop was:

the 4\textsuperscript{th} (sterile) neutrinos probably exist and cause short-range oscillations

but

new experiments are needed
Of-course, we trust our colleagues who claim they observe neutrino oscillations.

But how much stronger evidence of the neutrino oscillations would be direct observation of the oscillations with distance instead of just some deficit of events with respect to the expected number.
From this point-of-view, one needs to change the distance in the range of ~10 meters.

If made movable, our DANSS of all detectors is probably the best suited for the job.
• In principle it is possible to move DANSS by ~2.5 m (from 9.7 to 12.2) doing it **on-line**.

• Or by longer distance (up to 18.8 m), but with **partial dismounting 😞** and moving to the ground floor.
GEMMA-2 experiment

Lifting gear “PS-16”
Bottom part of the GEMMA-2 shield mounted on the movable platform
Use similar lifting gear with DANSS to move it as a whole
(not only internal part as was planned initially)
MC-simulation with realistic parameters

Reactor dimensions  \((h=3.50, \ d=3.12, \ \cos)\)
Typical neutrino spectrum  \((arXiv:1101.2663)\)
Detector finite resolution  \((\sigma\sim30\% \ @ \ E_v=4 \ MeV)\)
Neutrino Energy Spectrum expected with DANS S
Different energy parts behave in a different way with distance.
\[ \Delta m^2 = 1.0 \text{ eV}^2 \]
\[ \sin^2 2\theta = 0.17 \]
90\% CL limitations on oscillation parameters estimated for 1-year measurements with DANSS at L=11 and 16 m
95% CL limitations on oscillation parameters estimated for 1-year measurements with DANSS at L=9.7, 11.0 and 12.2 m

![Graph showing oscillation parameter limitations](image)

- **MiniBOONE**
- **Bugey**
- **Gavrin et al.**

**Axes:**
- $\Delta m^2, \text{eV}^2$ (vertical)
- $\sin^2 2\theta$ (horizontal)

**Limitations:**
- 90% CL limitation
Both estimations are very preliminary and do not include systematics caused by the gain and background instability, etc.