Development of the neutrino control method for nuclear reactors within the iDREAM project.

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Industrial Detector for Reactor Antineutrino Monitoring

iDREAM project is aiming to develop an industrial detector, which can provide information about a reactor power and an isotope content of the active core independently from the reactor services. Unlike a research detector an industrial detector must meet strict requirements such as long-term stability and full independence.

Experimental site and detector design.

Kalinin NPP is located within 400 km from Moscow in a picturesque area near the city Udumba. The detector site is located under the 3rd nuclear unit. Overall overburden is ≈20-25 m.w.e.

3rd nuclear unit began operating in 2004. It is TWR-1000.

Monitoring method

For the TWR-1000 with a thermal power $P_m = 3000$ MWe the total flux $\Phi = 10^{12}$ $1/s$

$>$98% from 4 main isotopes $^{235}$U, $^{238}$U, $^{239}$Pu, $^{241}$Pu.

$\sim$ 6 $\tau_0$ per one fission, thus number of fissions $N \sim \Phi$.

Inverse Beta Decay

IBD reaction has special signature which helps to distinguish it from background events.

There are two signals: the prompt and the delayed.

**Prompt:** The positron simultaneously loses its energy and annihilates with electron giving two gammas with energy $\sim$0.511 keV each.

**Delayed:** Due to the presence of the Gd in the Target the neutron live time in the Gd-LOS is reduced to $\sim$30 ns. Firstly the neutron loses its energy on thermalisation. Afterwards it captures on Gd, which irradiates several gammas with total energy of $\sim$4 MeV.

**Background:** Unfortunately, some BG events can mimic IBD, such as BG induced by cosmic muons, fast neutrons and also neutron and gamma irradiation from reactor. To conquer these BG iDREAM will be equipped with passive and active shielding systems.

Modeling detector response for the reactor spectra

\[ N = N_0 \times \mathcal{P} [\alpha(E) \times \phi(E) \times dE] \]

Number of events

$N_0$ - Proton number

$\alpha(E)$ - IBD cross-section

$\phi(E)$ - antineutrino spectrum

The fission rate evolution during Kalinin NPP reactor campaign

Model inputs:

- antineutrino spectrum based on the Huber-Muller model,
- detector baseline $19$ m.

A toy model:

\[ N(t) = N(t=0) - dN/daq(t) - dN/daq(t=0) \]

$\alpha_{239}$Pu fission rate