Search for coherent elastic neutrino-nucleus scattering with RED-100 detector

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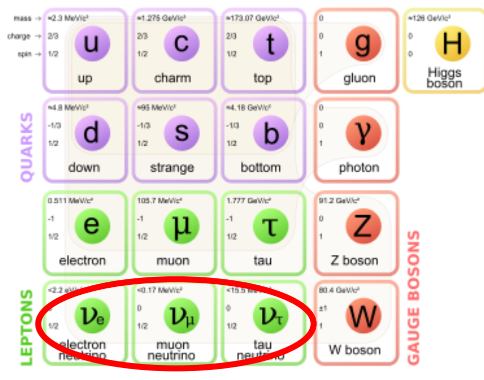
Introduction to neutrinos

Neutrino was postulated by W. Pauli in 1930
First experimental observation in 1956 by F. Reines and C. Cowan

Facts about neutrinos:
Three neutrino flavours in Standard Model
Have a very small mass
Have no electric charge
Interacts extremely weakly with matter
Neutrino oscillations

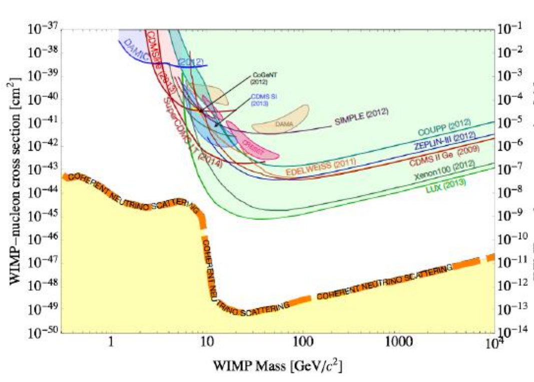
But there are a lot of open questions:
Value of mass, Dirac or Majorana particle, sterile neutrinos, role of neutrinos in the evolution of the Universe

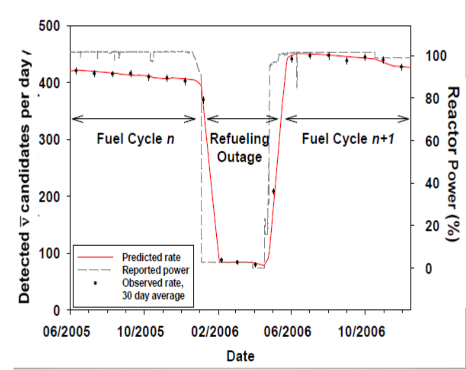


We are looking for the most high cross-section neutrino interaction process **Coherent Elastic Neutrino-Nucleus Scattering (CEvNS)**. The effect was predicted in 1974 by D. Z. Freedman but still has not been experimentally observed due to experimental challenges.

Physics motivation for CEvNS

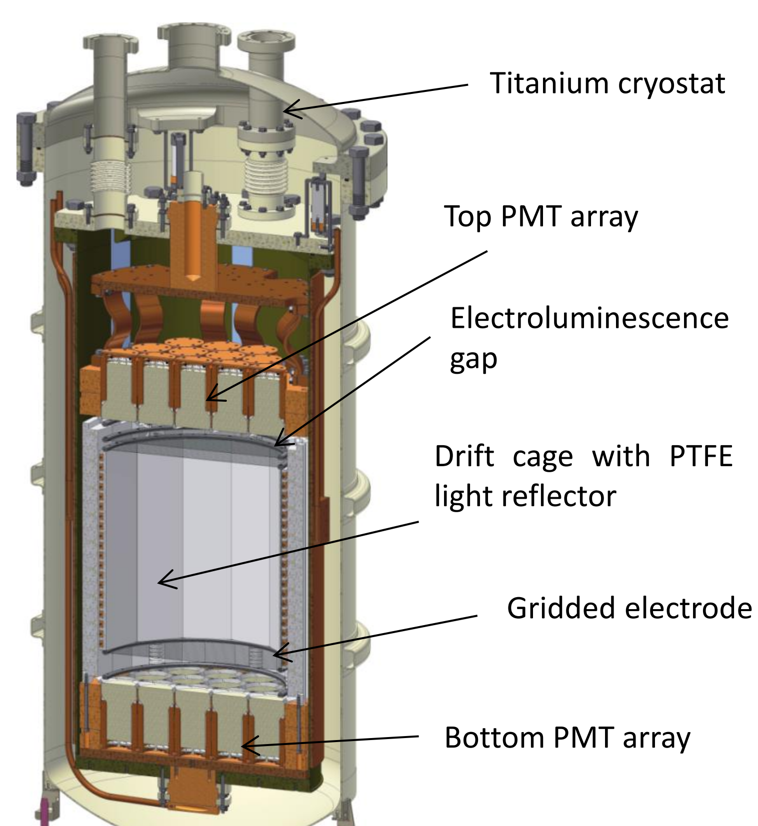
Test of the Standard Model and probe of neutrino non-standard interactions. Any measured deviation from prediction can indicate New Physics.
Understanding processes in supernovae core-collapse. 99 % of SN gravitational binding energy goes to neutrinos in first 10 seconds.
Direct dark matter experiments. CEvNS of solar and atmospheric neutrinos can be irreducible background for the next direct dark matter experiments.
Practical application for nuclear non-proliferation purposes. Monitoring of antineutrino flux one can independently verify declared versus real isotope content of a nuclear reactor core.





RED-100 overview

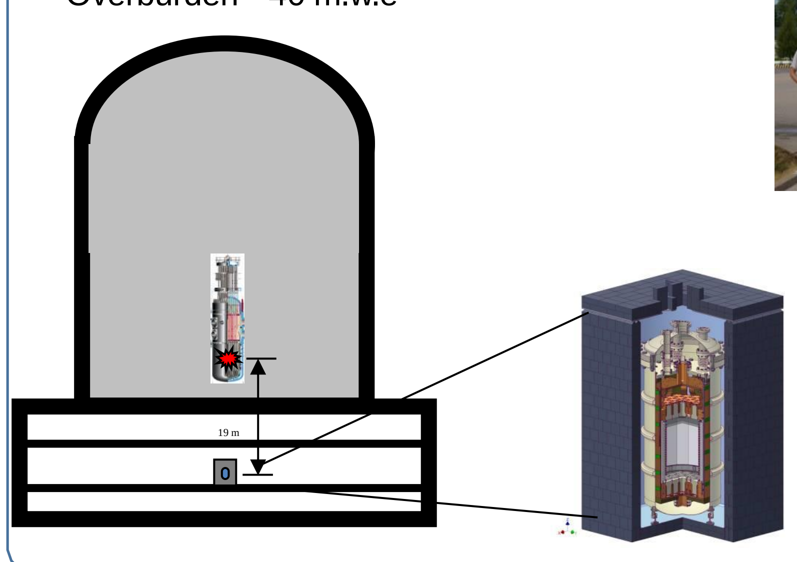
RED (Russian Emission Detector) – 100 is a two-phase emission liquid xenon detector and contains ~ 250 kg of LXe (~ 100 kg in a fiducial volume).
Sensitive volume ~ 40 cm in diameter and ~ 45 cm in height
-38 (2 arrays x 19) Hamamatsu R11410-20 low-background PMTs
Drift field ~ 0.5 ÷ 1 kV/cm
Electroluminescence gap length ~ 1 cm with field 7 ÷ 10 kV/cm
Expected number of *photoelectrons per one electron* extracted to the gas phase ~ 100



Experimental site for RED-100

The RED-100 is supposed to be deployed at the 3rd Unit of the Kalinin Nuclear Power Plant (Udomlya, Tver' region, Russia) in 2017

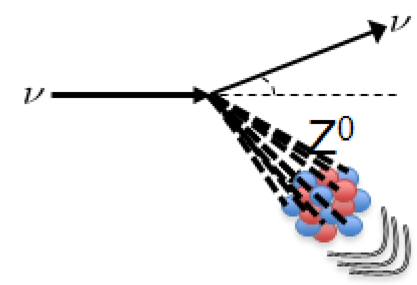
Experimental hall is under a nuclear reactor
19 m from a nuclear reactor core
Neutrino flux at this place is $\mathbf{1.35 \cdot 10^{13}}$ $\mathbf{cm^{-2}s^{-1}}$
Overburden ~40 m.w.e



Gamma and neutron passive shielding:
10 ÷ 15 cm Pb + ~15 H_2O
Expected number of events: 3500 events/day

Coherent Elastic Neutrino-Nucleus Scattering

CEvNS is a neutral current process where an incoming neutrino elastically scatters on a nucleus



$$\nu + A \rightarrow \nu' + A'$$

- large cross section
- flavor-blind
- Predicted by the Standard Model but never experimentally observed

$$\sigma_{cs} \simeq \frac{G^2 N^2}{4\pi} E_\nu^2 \simeq 0.42 \times 10^{-44} N^2 \left(\frac{E_\nu}{\text{MeV}}\right)^2 \text{cm}^2$$

Neutrinos with energies up to 50 MeV satisfy coherence condition

But low recoil energy:

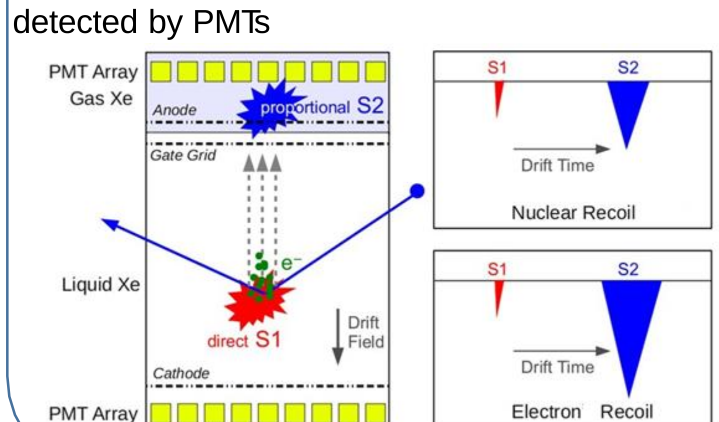
$$\langle E_r \rangle = 716\,\text{eV}\,\frac{(E_\nu/\text{MeV})^2}{A}$$

Sources:
- •Reactors
- •spallation sources
- •supernovae
- •the Sun

Two-phase emission detector technology

- Noble-gas, two-phase (liquid/gas) emission detector
  - large detector mass
  - low detection threshold
  - scalability
- Similar to those currently developed for direct dark matter experiments searching for WIMPs
- This method of particle detection was invented in MEPhI about 40 years ago

Basic operating principle:
The recoiling nucleus produces ionization and scintillation in the liquid. The electrons are drifted toward the phase boundary and cross into the gas. The electric field in the gas is high enough so that the accelerated electrons excite atoms which then produce scintillation light detected by PMTs



S1 - scintillation
S2 – electroluminescence
3D position reconstruction
S2/S1 ratio depends on a recoil type (excellent background rejection)

RED-100 details

RED-100 experimental setup consists of several subsystems:
Detector itself with an internal structure placed in titanium cryostat
Passive/active shielding
Cryogenics based on thermosyphon technology
Xenon purification system with continuous gas passage through a getter or/and spark discharge technique
Photon detection system using Hamamatsu R11410-20 PMTs with active dividers to block cosmic muon signals
Electronics and Data Acquisition System
Slow control system

Summary

Coherent Elastic Neutrino-Nucleus Scattering can be observed with RED-100 detector

The RED-100 detector has been constructed in the Laboratory for Experimental Nuclear Physics of NRNU MEPhI due to support of Ministry of Education and Science of RF (contract №11.G34.31.0049 from October 19, 2011)

We applied for a grant in the framework of Russian Academic Excellence Project **5-100** by Ministry of Education and Science of the Russian Federation. If it is approved, RED-100 will be transferred to Kalinin Nuclear Power Plant in 2017 to discover CEvNS