The measurement of backgrounds at Spallation Neutron Source for RED-100 experiment.

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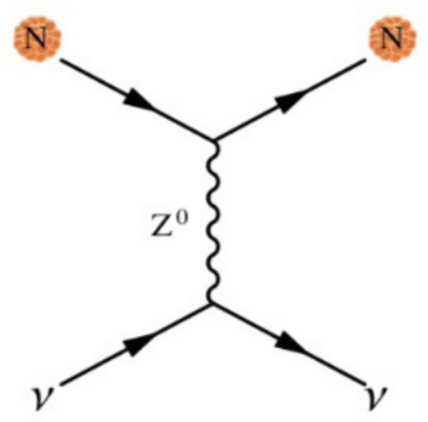
Coherent Neutrino Scattering

Coherent Neutrino Scattering is a fundamental process predicted within the Standard Model by D.Z. Freedman in 1974:

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



Differential and total cross sections of the process are described by the formulas:

$$\frac{d\sigma}{dT_A} = \frac{G_F^2}{4\pi} m_A [Z(1-4\sin^2\theta_w)-N]^2 [1-\frac{m_A T_A}{2E_\nu^2}] F^2(Q^2)$$

$$\sigma_{tot} = \frac{G_F^2 E_\nu^2}{4\pi} [Z(1-4\sin^2\theta_w)-N]^2 F^2(Q^2)$$

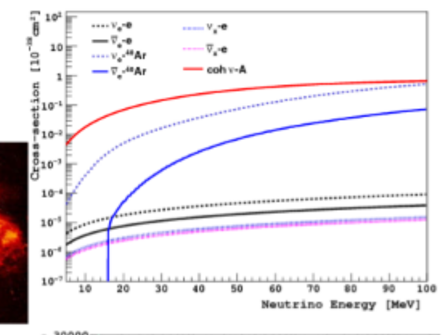
m_A - nucleous mass
T_A - kinetic energy of recoil nucleous
E_ν - neutrino energy
Z - nucleous charge
N - number of neutrons in nucleous
F - nucleous form factor

D.Z. Freedman PRD 9 (1974)
A. Drukier & L. Stodolsky, PRD 30, 2295 (1984)
Horowitz et al. astro-ph/0302071

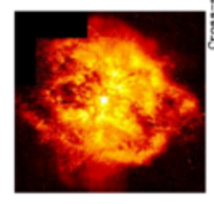
Coherent Neutrino scattering has not been observed yet due to experimental difficulties: the energy deposition less then 1 keV and detection mass must be significant. Since $\sin^2\theta_w \approx 0.22$, the value $(1-4\sin^2\theta_w)$ is small and the total cross section is then proportional N^2.

Advantages of Coherent Neutrino Scattering

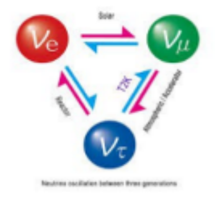
CNS cross section is proportional to the N^2 of number of neutrons in the detector target material. For heavy elements it is order of magnitudes lager then usial processes that used to detect neutrinos (inverse β-decay or ν-e scattering) .

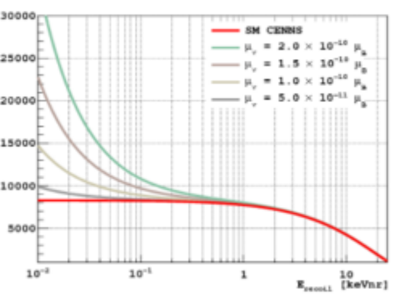


Coherent Neutrino Scattering plays a very important role in physics and it can improve our understanding of :



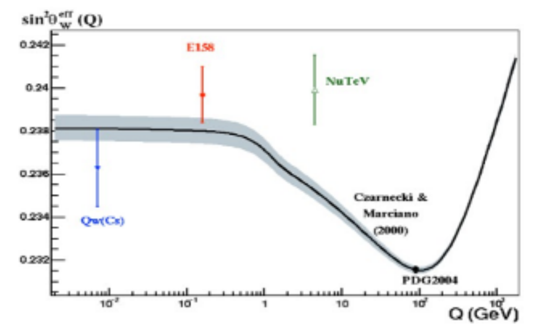
Dark Matter. CNS background is a robust lower bound for the next generation Dark Matter search experiments which can't be reduced without CNS studies.





Sterile Neutrino. The CNS interaction is insensitive to the differences of active flavors of neutrinos, so we can measure total fluxes of active flavor neutrinos. If the experiment will show the disappearance of the CNS, then sterile neutrinos are exist.

Supernova Physics. CNS plays a major role in an explosion of a core-collapse supernova: neutrinos carry 99% of total energy out of the star before anything else. Moreover, this process is important for detection of supernova neutrino. It also can help to explain how neutrinos are thermalized with matter in a supernova.



The weak mixing angle. It can be found by measuring the absolute cross section. A cross section measurement with ~ 10% uncertainty gives a $\sin^2\theta_w$ uncertainty of ~ 5% at a typical Q value of 0.04 GeV/c.

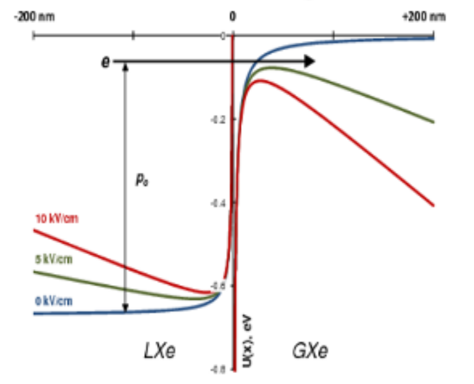
Practical application. The process can be used for monitoring of the nuclear reactor active zone: start/stop, fuel burnup and nuclear fuel consistance.

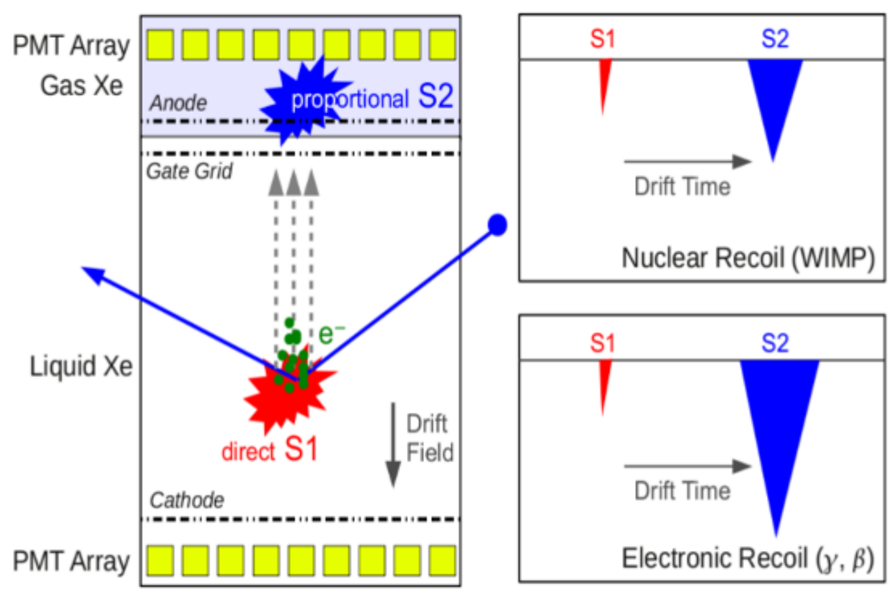
Two Phase liquid noble gas Emission detector technology

The two phase emission detectors were invented in MEPhI 40 years ago. Presently it is one of the most promising technology for the massive dark matter experiments.

A two phase emission detector is a time projection chamber. It works as follows:

- Radiation interacts with the condensed target medium, exciting and ionizing atoms. This process leads to production of the primary scintillation signal signal marked as S1.
- The resulting charge emitted from under the surface due to application of a strong electric field generates the electroluminescence signal marked as S2.





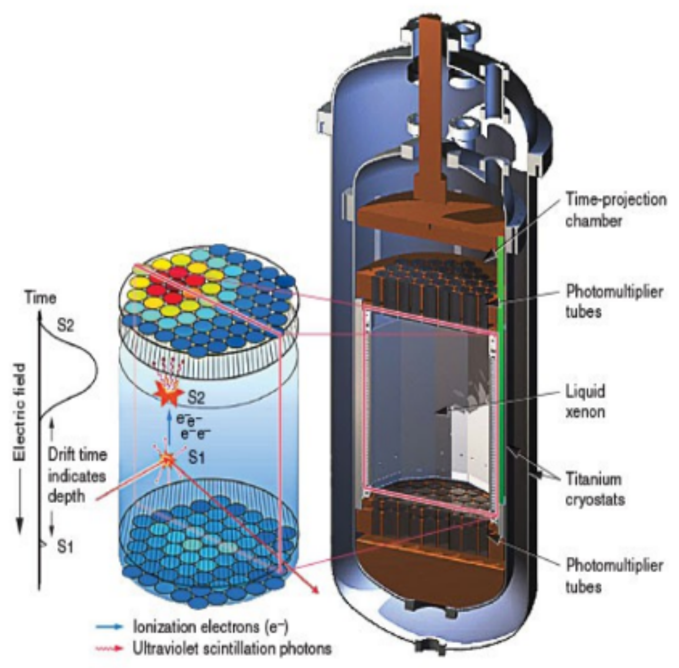
Bolozdynya, Egorov, Miroshnichenko, Rodionov. IEEE Trans. Nucl. Sci. v.42, n.4 (1995) 565-569

This method is used to search for dark matter in the form of WIMPs by LUX and it can be used to observe the Neutrino Coherent Scattering.

Two phase liquid xenon emission detector RED-100

RED-100 is two phase noble gas emission detector which is developed by the RED Collaboration (Russian Emission Detector). Now it is under construction in Laboratory for Experimental Nuclear Physics (LENPh) of NRNU MEPhI.

LENPh was established in 2011 due to a grant given to Yuri Efremenko, a Full Professor of the University of Tennessee, by the Government of Russian Federation (Resolution number 220).



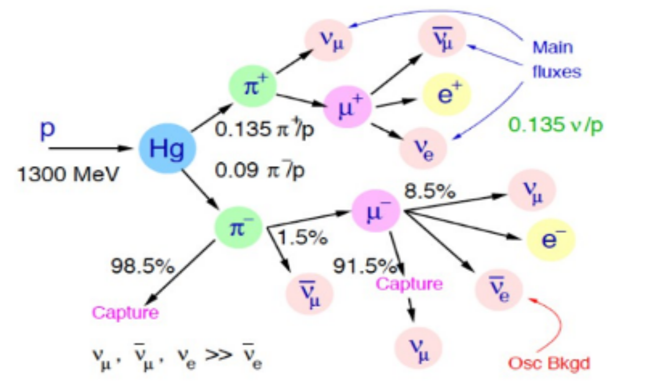
RED-100 features

- RED-100 will filled with 250 kg of liquid Xenon, thus detector's fiducial volume will be about 100 kg
- The sensitive volume will have ~ 45 cm in diam. and ~ 45 cm in height, will be defined by the top and bottom optically transparent mesh electrodes and thin field-shaping rings
- Drift field is 0.5 ÷ 1 kV/cm. Extraction field, and the field in EL region is ~ 7 ÷ 10 kV/cm (in the gas phase)
- Detector will have 38 low-background PMTs Hamamatsu R11410-20
- Width of the S2 region – 1 cm
- The detector will be placed in a passive borated polyethylene and lead shield and will have an active muon veto
- Detector will work on the Earth's surface

Spallation Neutron Source (SNS)
Oak Ridge National Laboratory, USA

≈ 40 m from the target, ~ 10 m underground

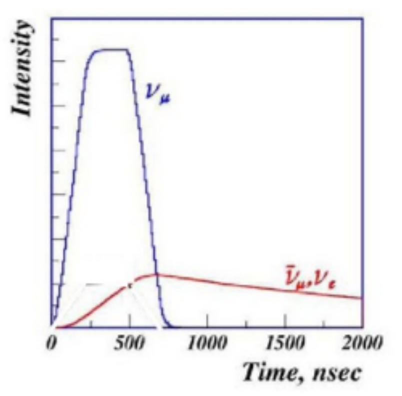
$$\pi^+ \rightarrow \mu^+ \nu_\mu$$
$$\mu^+ \rightarrow e^+ \bar{\nu}_\mu \nu_e$$

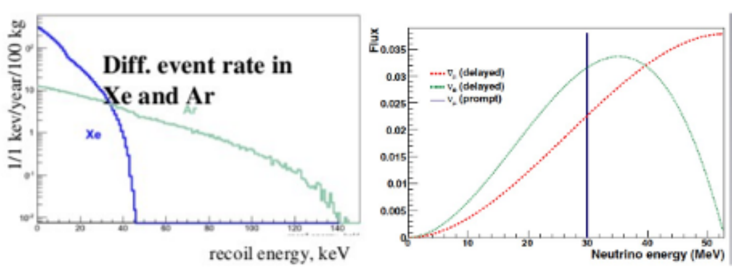


For 1300 MeV protons on Hg (nucl-ex/0309014)

Proton beam energy – 0.9 – 1.3 GeV
Intensity – 9.6 * 10^{15} protons/sec
Pulse duration – 700 ns
Repetition rate – 60 Hz
Liquid Mercury Target

$1.9 \cdot 10^{22}$ $year^{-1}$ neutrinos each of three flavor (ν_e, ν_μ, ν_μ):
$5 \cdot 10^6$ $cm^{-2}s^{-1}$ at 40 m from the target



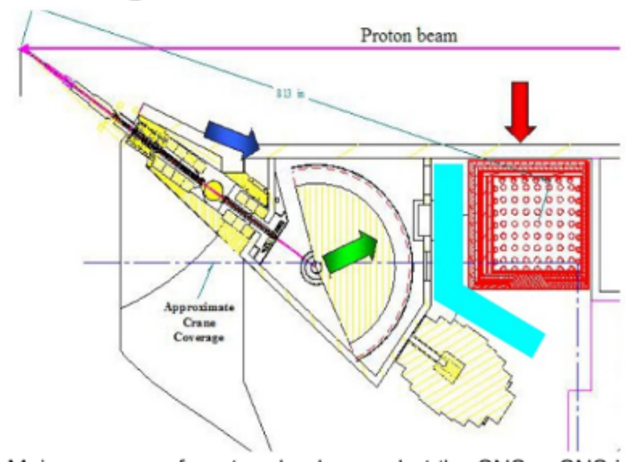


K. Scholberg, Phys. Rev. D 73, 033005 (2006)

Background Challenges

Possible SNS background sources

- Neutrons originating from the spallation target (blue arrow)
- Neutrons originating from the proton beam tunnel, either resulting from proton beam losses in the RTBT (Ring to Target Beam Transport) or from the interaction of albedo hadrons from the spallation target (red arrow):
  - Loss of the primary proton beam in various beamline elements.
  - Hadrons backscattering from the target followed by interactions in the tunnel walls.
- Neutrons originating from beamlines 17 and 18 (green arrow).
- Cosmic ray muons and neutrons.

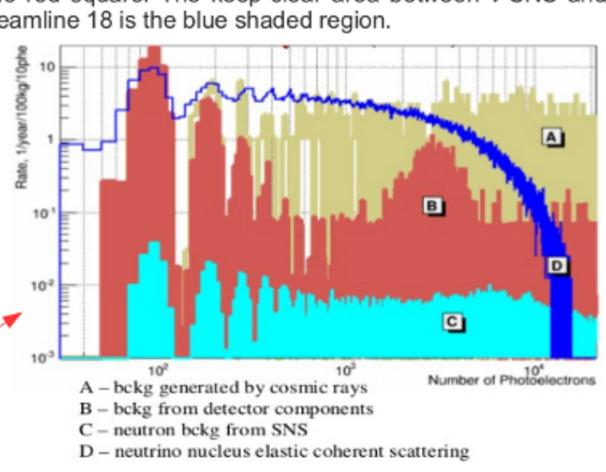


Major sources of neutron background at the SNS. ν-SNS is the red square. The keep-clear area between ν-SNS and beamline 18 is the blue shaded region.

These background sources are very dangerous for Coherent Neutrino Scattering search:

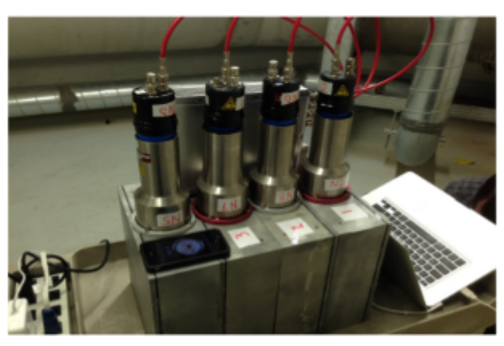
- Detector responses of CNS and interaction of low energy neutrons with the detector volume are the same
- Cosmic muon passing through detector makes it blind for a long period of time

RED-100 background simulations

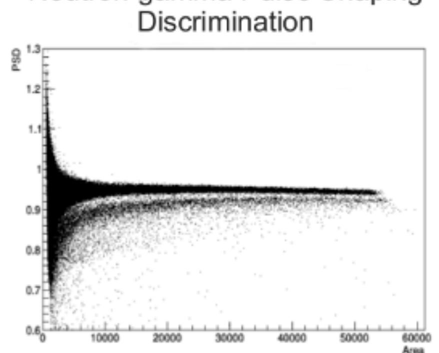


The first result of background measurements

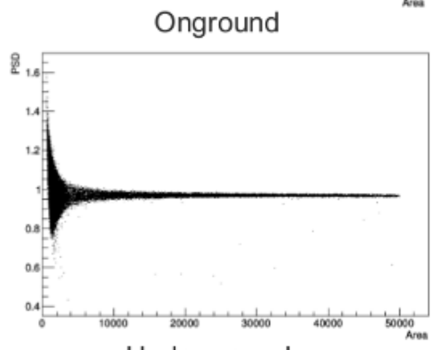
SNS background measured by the telescope, composed of four identical sections. Each section is a volume filled with liquid scintillator EJ-301 which looked through by PMT XP4312



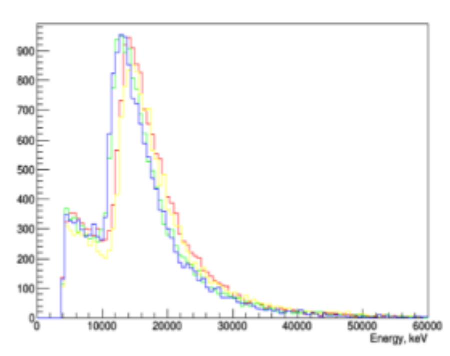
Neutron-gamma Pulse Shaping Discrimination



Onground



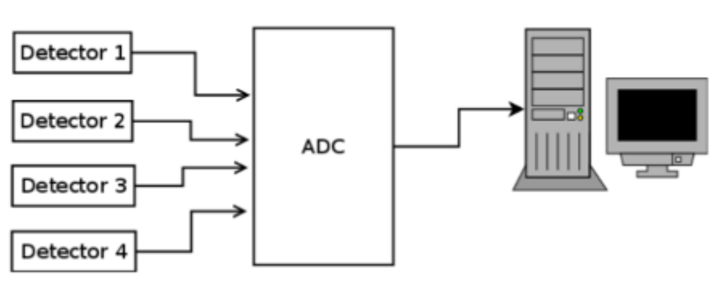
Underground



Muon experimental spectrum

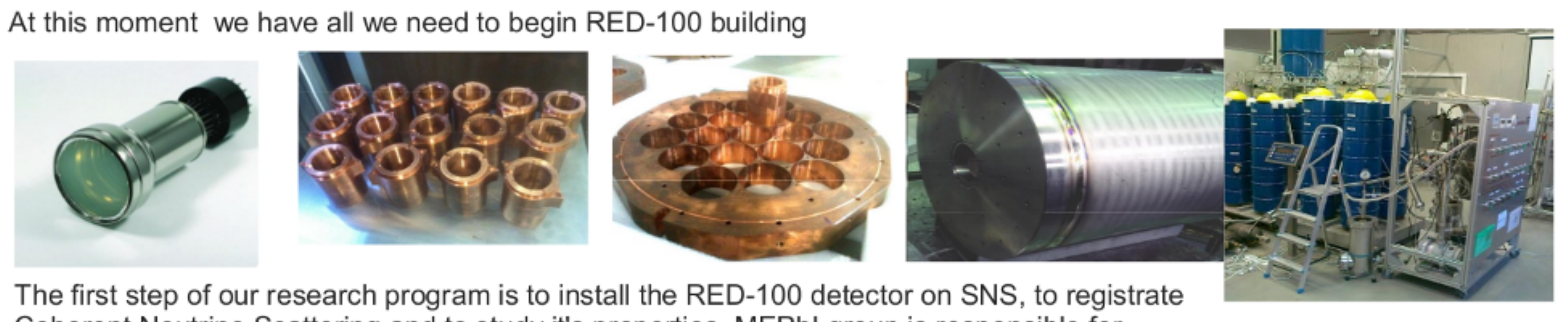
The first result of measurement muon fluxes on ground and underground are:

Onground flux ~ $4.68 \cdot 10^{-3}$ [$cm^{-2}c^{-2}$]
Underground flux ~ $2.35 \cdot 10^{-3}$ [$cm^{-2}c^{-2}$]
Suppression factor ~ 2



Current Status and Future Plans

At this moment we have all we need to begin RED-100 building



The first step of our research program is to install the RED-100 detector on SNS, to registrate Coherent Neutrino Scattering and to study it's properties. MEPhI group is responsible for detector, gas purification system, thermosyphon, Xe and electronics.

The second, but not last step is installation of the RED-100 to a commercial nuclear power plant – KNPP and development of methods for real time monitoring of reactor active zone. We hope that results of our work will be widely used in nuclear energy sector.