STATUS OF THE RED EXPERIMENT

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on behalf of COHERENT collaboration
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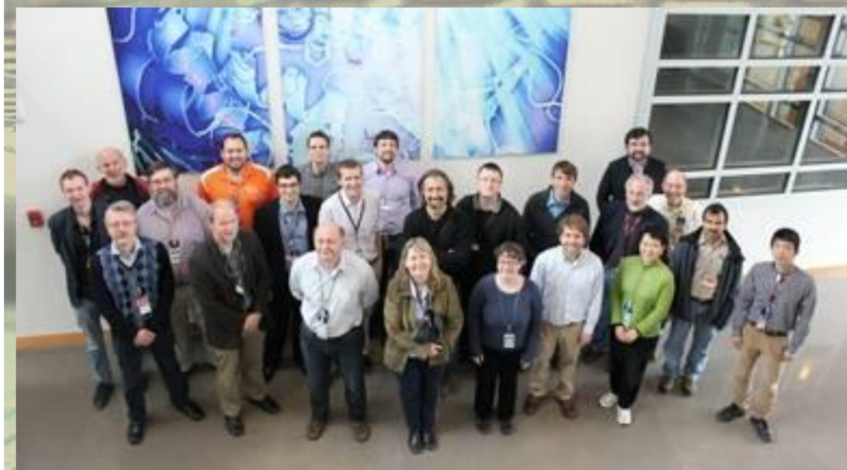
NDM'15, June 1-5, 2015, Jyväskylä, Finland

The COHERENT collaboration

~ 50 collaborators from 16 institutions

Institution	Board Member
University of California, Berkeley	Kai Vetter
University of Chicago	Juan Collar
Duke University	Kate Scholberg
University of Florida	Heather Ray
Indiana University	Rex Tayloe
Institute for Theoretical and Experimental Physics, Moscow	Dmitri Akimov
Lawrence Berkeley National Laboratory	Ren Cooper
Los Alamos National Laboratory	Steve Elliott
National Research Nuclear University MEPhI	Alex Bolozdynya
North Carolina Central University	Diane Markoff
Oak Ridge National Laboratory	Jason Newby
Pacific Northwest National Laboratory	John Orrell
Sandia National Laboratory	David Reyna
University of Tennessee, Knoxville	Yuri Efremenko
Triangle Universities Nuclear Laboratory	Phil Barbeau
University of Washington	Jason Detwiler



The COHERENT collaboration

Team of experts in: CEνNS, broad range of technologies, neutrons, neutrino flux

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U. of Chicago
Juan Collar*
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Todd Hossbach
John Orrell*

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Phil Barbeau*
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U. of Washington
Clara Cuesta
Jason Detwiler*

CB rep, ** spokesperson, # TBC
Students in blue
Note some people listed for >1 institution

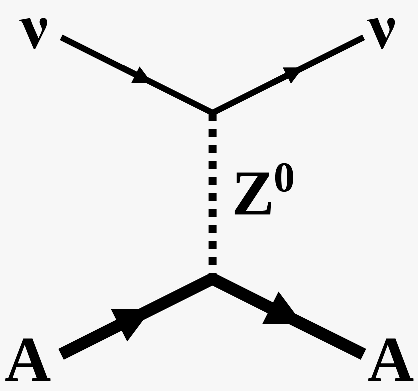
Outline

- History
  - Prediction of the Standard Model
  - Brief review of projects
- RED-100 detector
  - Principle of operation
  - Experiment at SNS (COHERENT Collaboration)
  - Current status of experiment
- Summary

Prediction of the Standard Model

Elastic coherent neutral-current (NC) neutrino-nucleus scattering was 1-st predicted theoretically in 1974: D.Z. Freedman, D.N. Schramm, and D.L. Tubbs. "The weak neutral current and its effects in stellar collapse." Ann. Rev. Nucl. Part. Sci. 27, 167 (1977)
but has never been observed experimentally.

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



A neutrino interacts with a nucleus via exchange of a Z, and the nucleus as a whole,

coherently up to E_ν~ 50 MeV

The low-energy nuclear recoil is the only signature of this process

Differential cross section:

$$\frac{d\sigma}{dE_r} = \frac{G_F^2}{4\pi} Q_w^2 M \left(1 - \frac{ME_r}{2E_\nu^2}\right) F^2(Q^2),$$

G_F – Fermi constant

$F(Q^2)$ – form factor at four-momentum Q

$Q_W = N - (1-4\sin^2(\theta_W))Z$ – weak charge for a nucleus with N and Z

θ_W – weak mixing angle; $\sin^2(\theta_W) \approx 0.22 \Rightarrow Q_W \sim N$; $\sigma \sim N^2$

For heavy nuclei,

the cross sections is by ~ 2 orders of magnitude higher than that for ν-e scattering

and by ~ one order of magnitude higher than that for inverse β-decay

the energy deposition is in keV region for ν produced at spallation neutron sources,

and in sub-keV region for reactor $\tilde{\nu}$

The detector mass must be significant, of an order of several tens of kg or even more.

~30-y anniversary of Drukier&Stodolsky paper

PHYSICAL REVIEW D VOLUME 30, NUMBER 11 1 DECEMBER 1984

Principles and applications of a neutral-current detector for neutrino physics and astronomy

A. Drukier and L. Stodolsky
Max-Planck-Institut für Physik und Astrophysik, Werner-Heisenberg-Institut für Physik, Munich, Federal Republic of Germany
(Received 21 November 1983)

We study detection of MeV-range neutrinos through elastic scattering on nuclei and identification of the recoil energy. The very large value of the neutral-current cross section due to coherence indicates a detector would be relatively light and suggests the possibility of a true "neutrino observatory." The recoil energy which must be detected is very small (10–10^3 eV), however. We examine a realization in terms of the superconducting-grain idea, which appears, in principle, to be feasible through extension and extrapolation of currently known techniques. Such a detector could permit determination of the neutrino energy spectrum and should be insensitive to neutrino oscillations since it detects all neutrino types. Various applications and tests are discussed, including spallation sources, reactors, supernovas, and solar and terrestrial neutrinos. A preliminary estimate of the most difficult backgrounds is attempted.

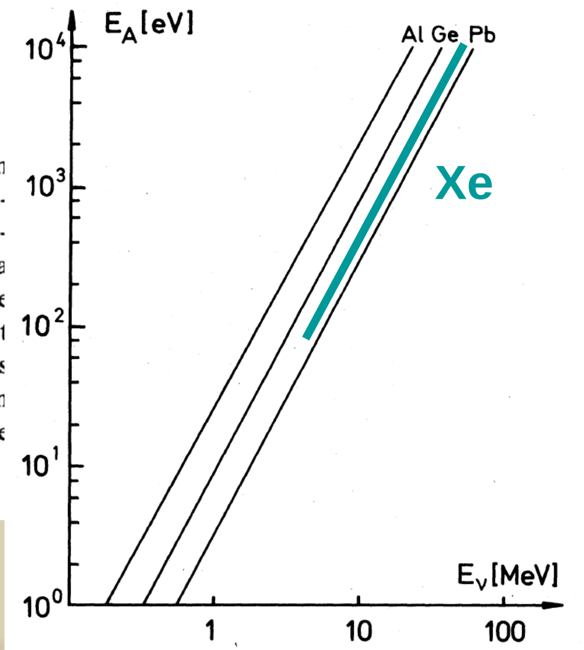
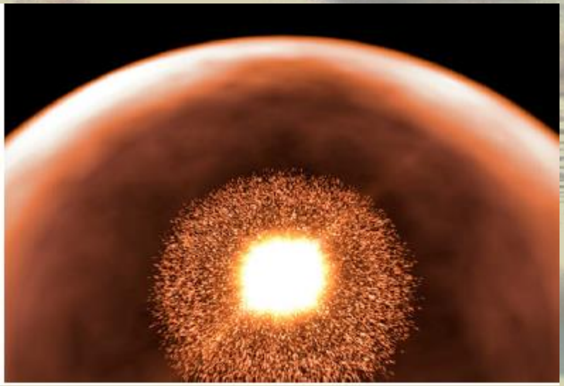


FIG. 2. Average recoil energy for various nuclei as a function of neutrino energy.

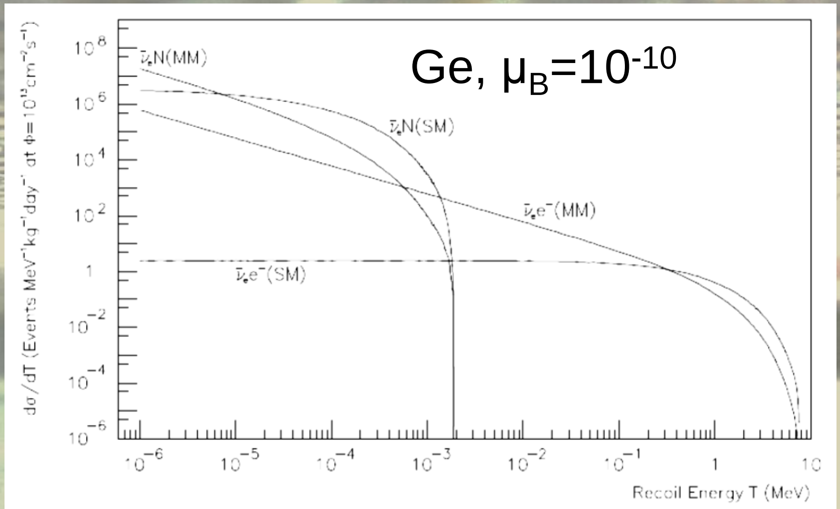
Elastic coherent ν-Nucleus scattering (CEνNS)

Coherent scattering significantly affects supernova dynamics

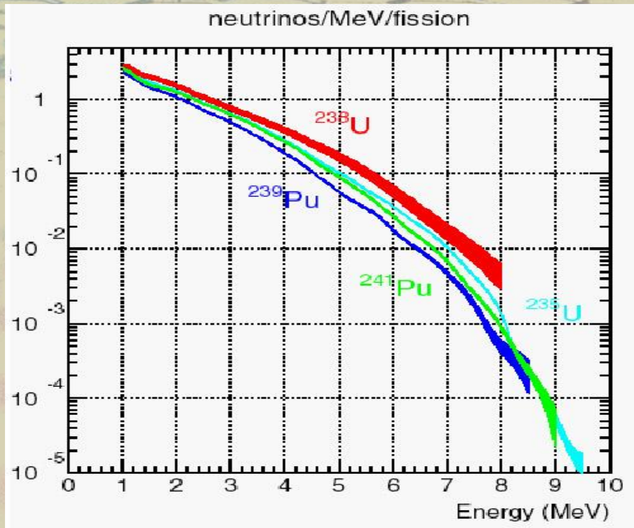


99% of gravitational binding energy goes to ν!

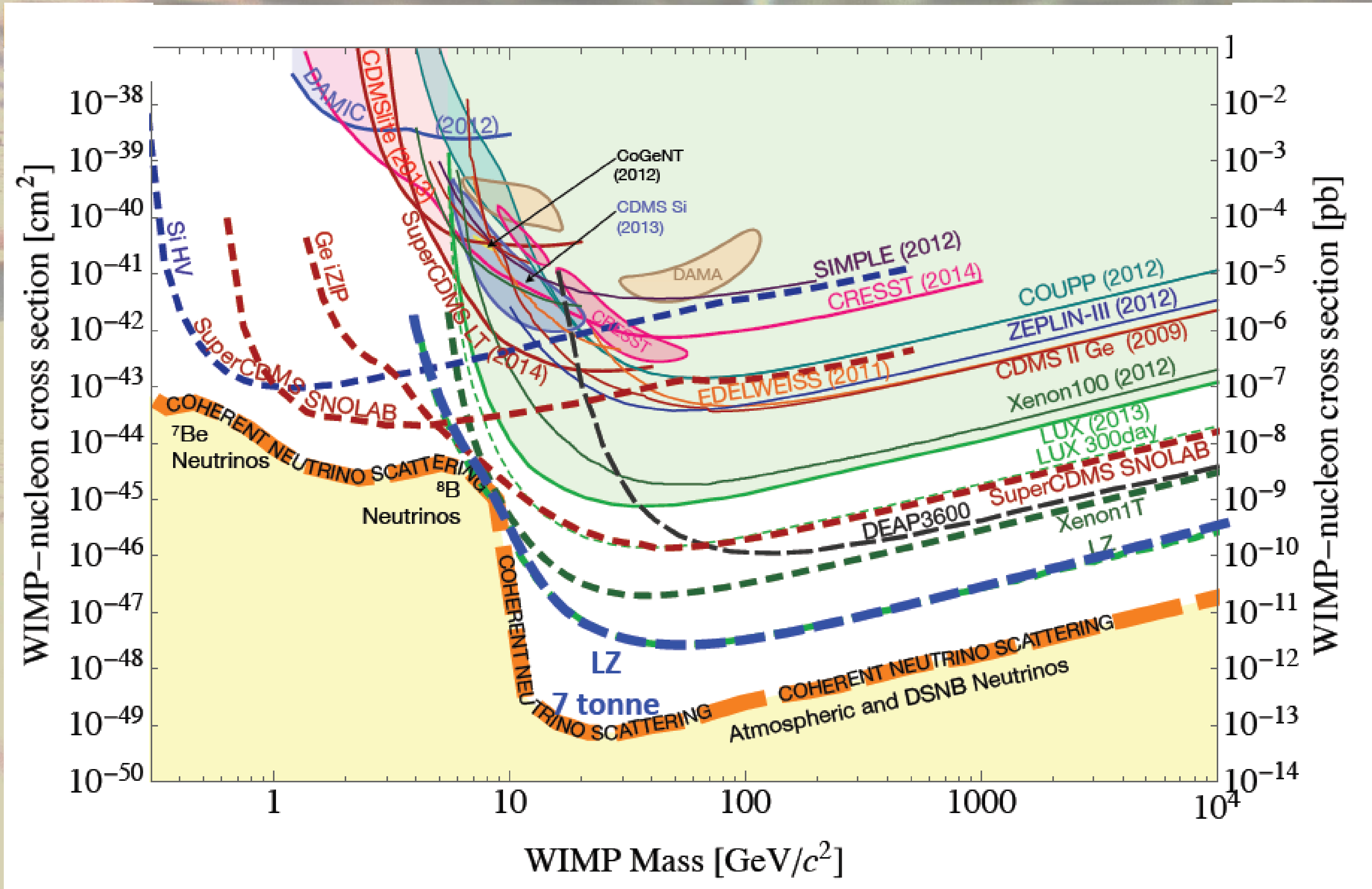
"Non-standard" physics



Monitoring of nuclear reactors



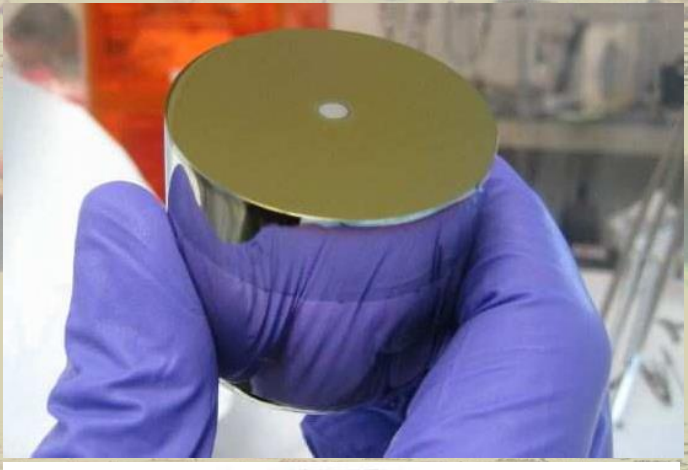
CEvNS is irreducible background in DM experiments



Development detectors for CEvNS

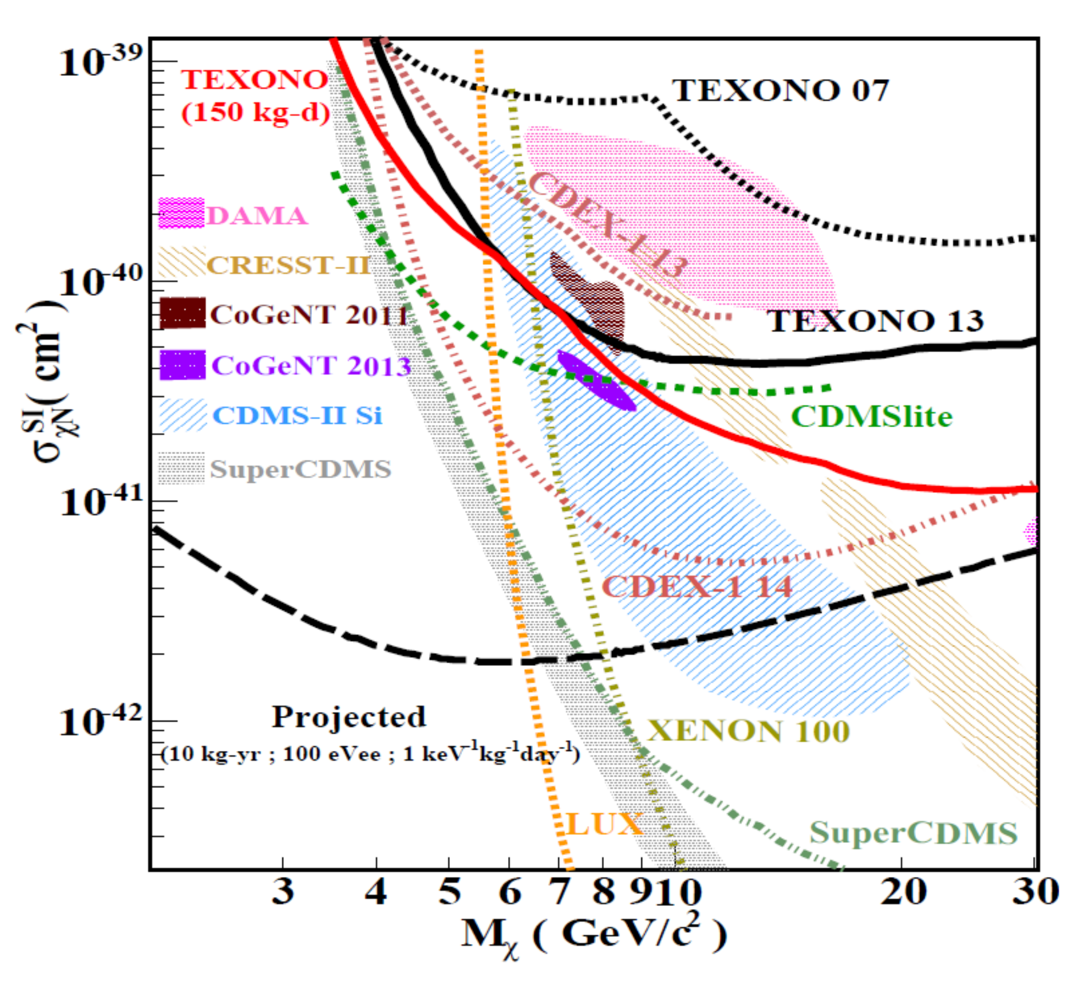
Ge detectors: CoGeNT *(USA)*, TEXONO *(Taiwan)*

p-type point contact (PPC) Ge detector:

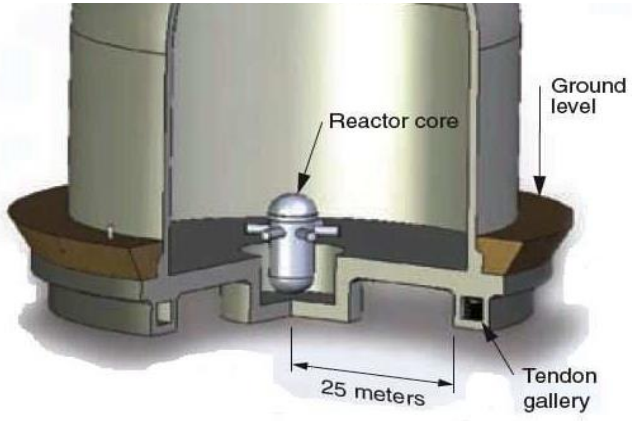


Can operate with a very low threshold (below 1 keV)!

Both detectors were used in DM search experiments:



CoGeNT - San Onofre Nuclear Power Reactor, USA



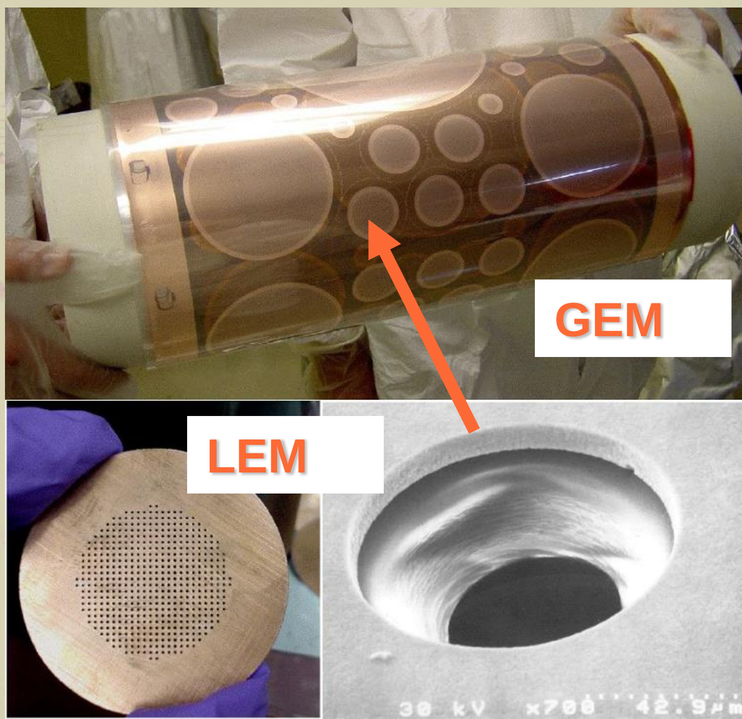
Development detectors for CEvNS

Attempts to build gas detectors

Array of cylindrical gas proportional counters.

A. V. Kopylov et al., Advances in High Energy Physics V. 2014 (2014), Article ID 147046

Gas detectors with micro pattern amplification structures



P. S. Barbeau et al., IEEE Trans. on Nucl. Sci., V. 50 (2003), no. 5, 1285

Such detectors have very low energy thresholds.

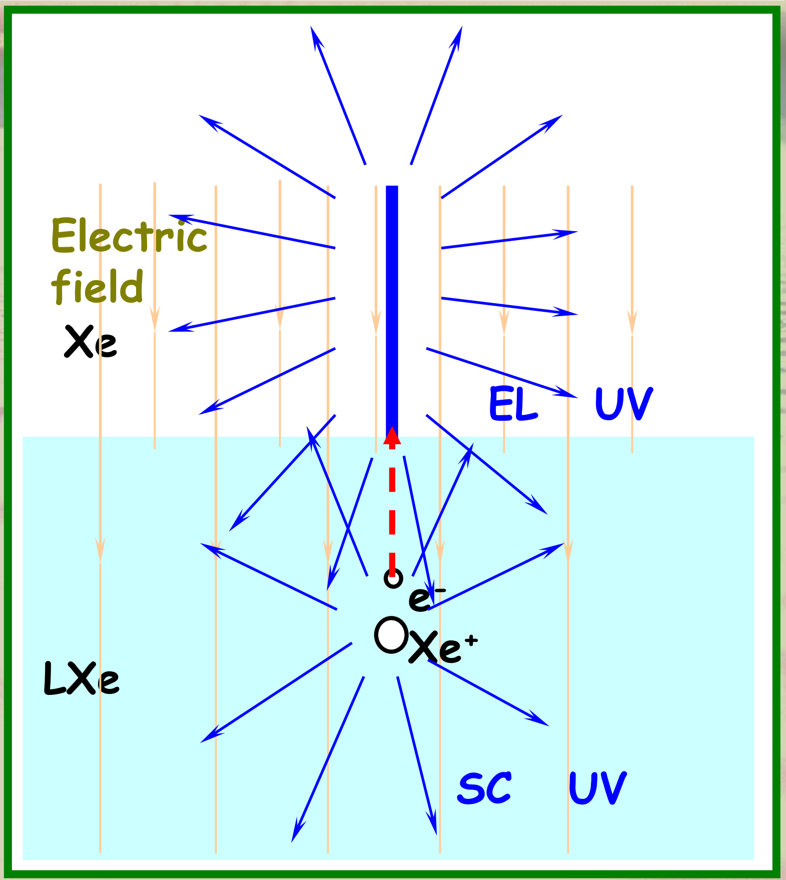
However, it is difficult to obtain the mass higher than several kg

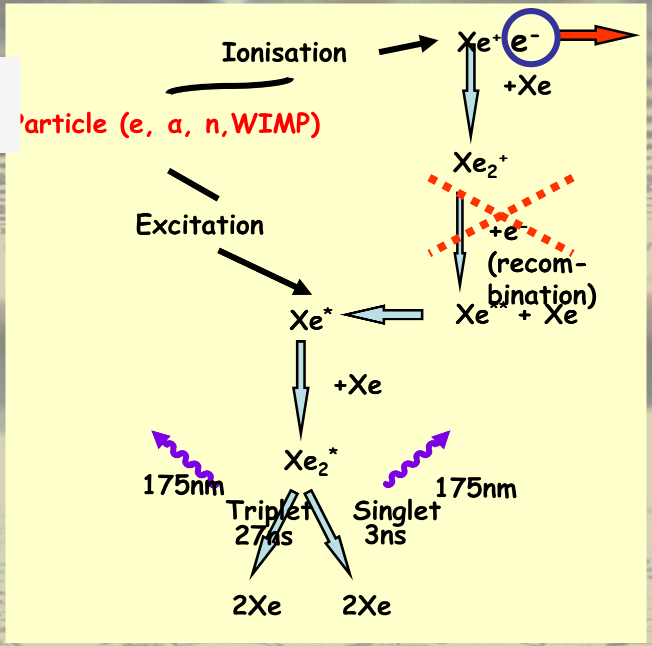
Development detectors for CEvNS

Particle detection of with a two-phase emission detector

B.A. Dolgoshein, V.N. Lebedenko, B.U. Rodionov, JETF Letters (in Russian), 1970, v. 11, p. 513

For the Dark Matter search:
A.S. Barabash and A.I. Bolozdynya, JETF Letters (in Russian), 1989, v.49, p. 359

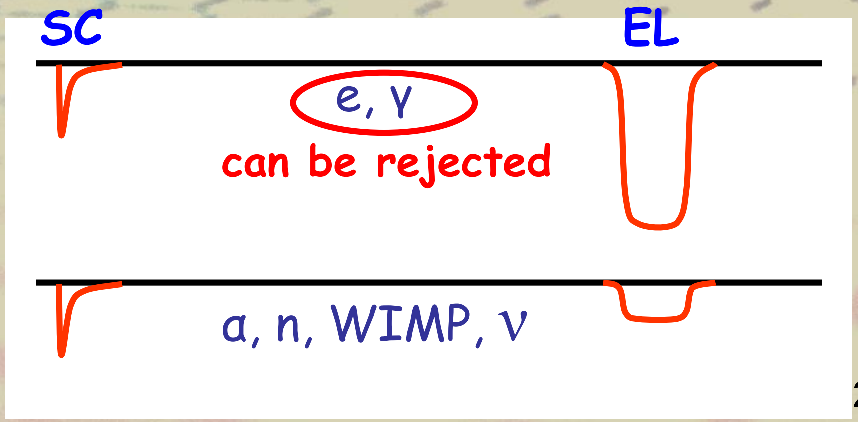




By electric field part of electrons are extracted from the track: recombination is suppressed

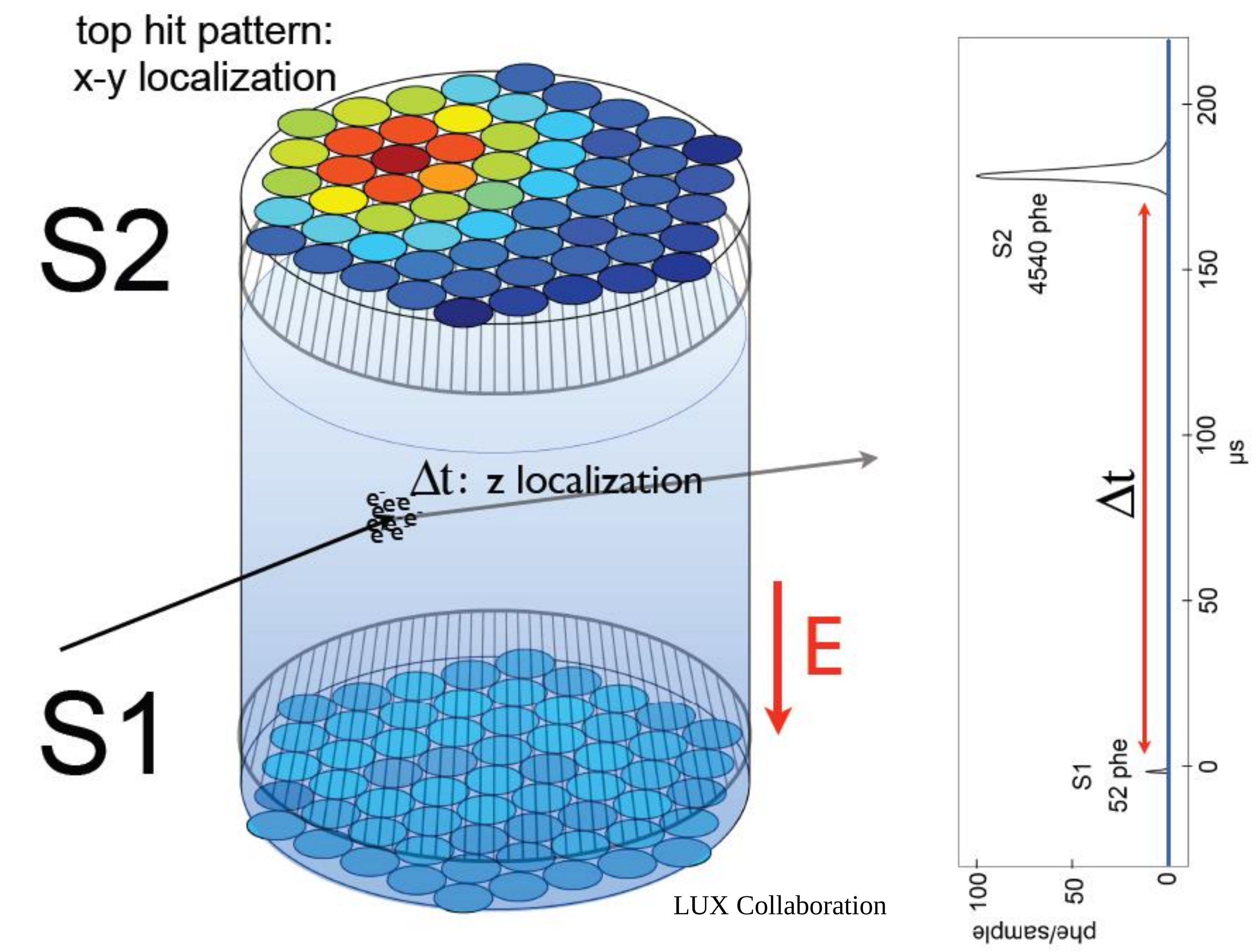
Suppression depends on dE/dX

Ratio of SC/EL is different for different kind of particles



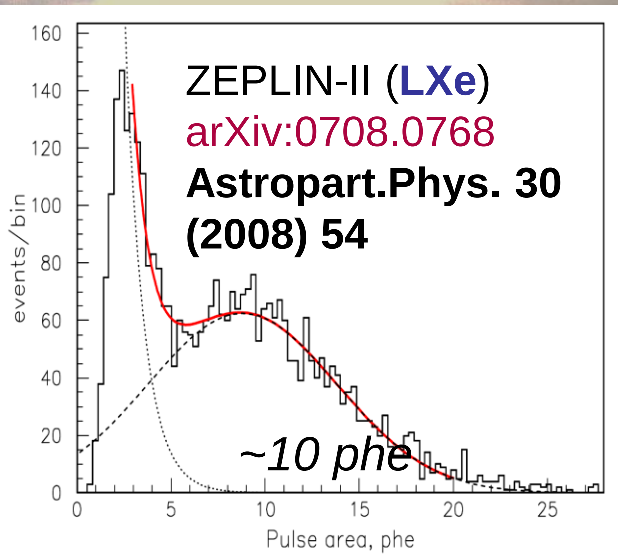
Two-phase detector

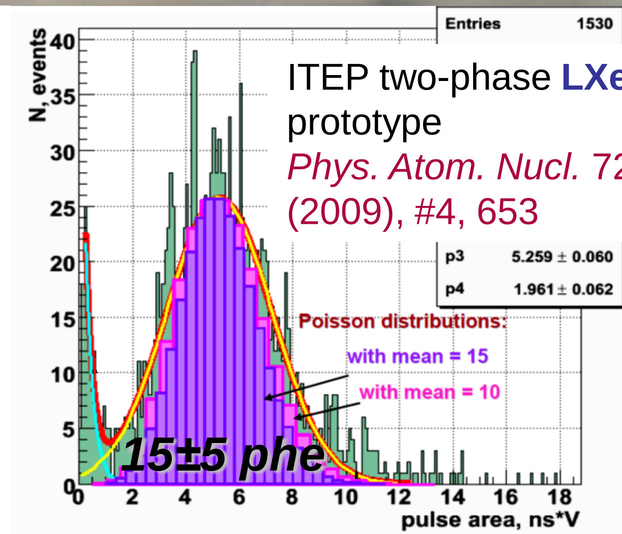
It combines the advantages of gas detectors: the possibility of proportional or EL amplification, XYZ positioning, and the possibility to have the large mass!

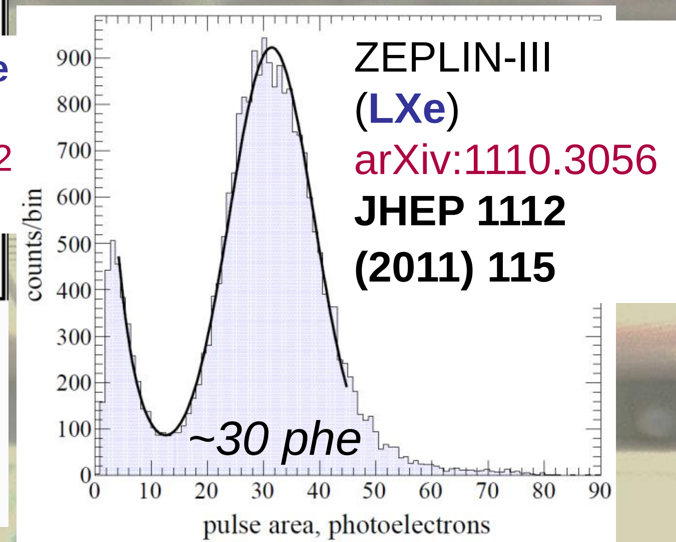


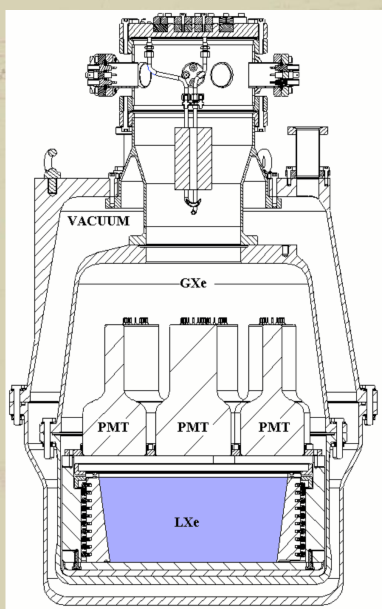
LUX Collaboration

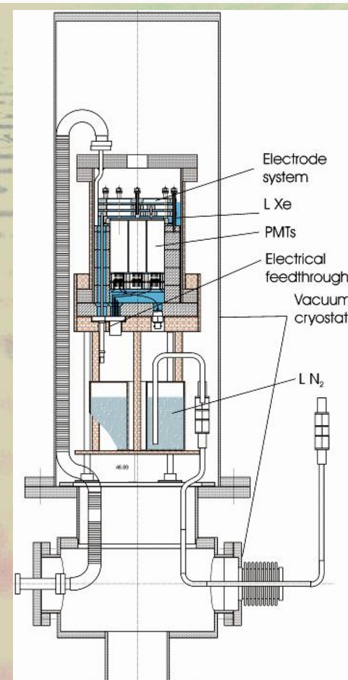
Two-phase noble gas detectors are superior in sensitivity: single ionisation electron can be detected

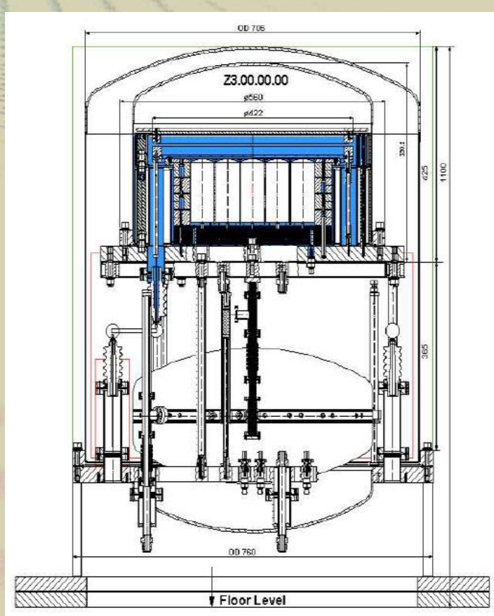








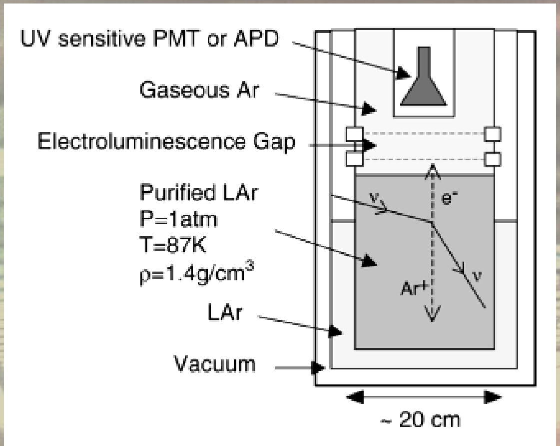




Proposals to use two-phase detector for CEvNS experiments

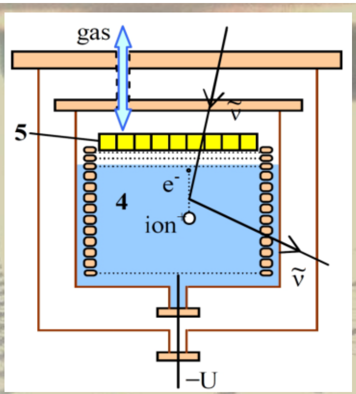
Proposal of Lawrence Livermore National Lab. with a two-phase LAr:

C. Hagmann, A. Bernstein, IEEE Trans. Nucl. Sci. 51 (2004) 2151 [nucl-ex/0411004].



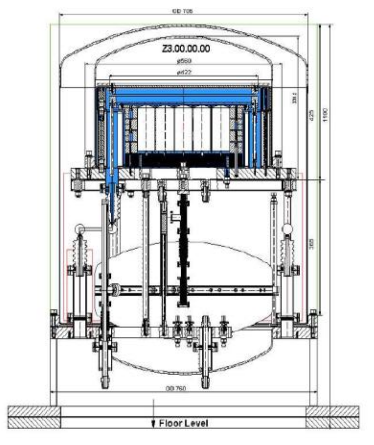
Proposal of ITEP&INR LXe:

D. Akimov, A. Bondar, A. Burenkov, and A. Buzulutskov, JINST 4 (2009) P06010 [arXiv:0903.4821]



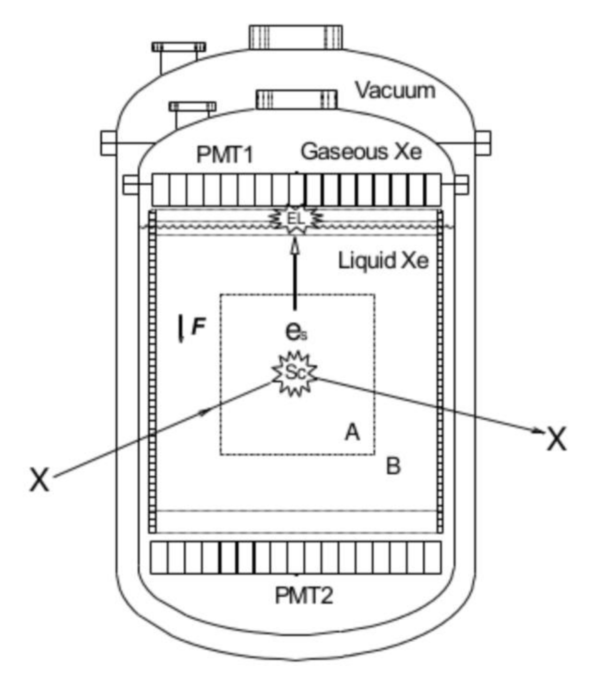
Proposal of ZEPLIN-III Collaboration LXe:

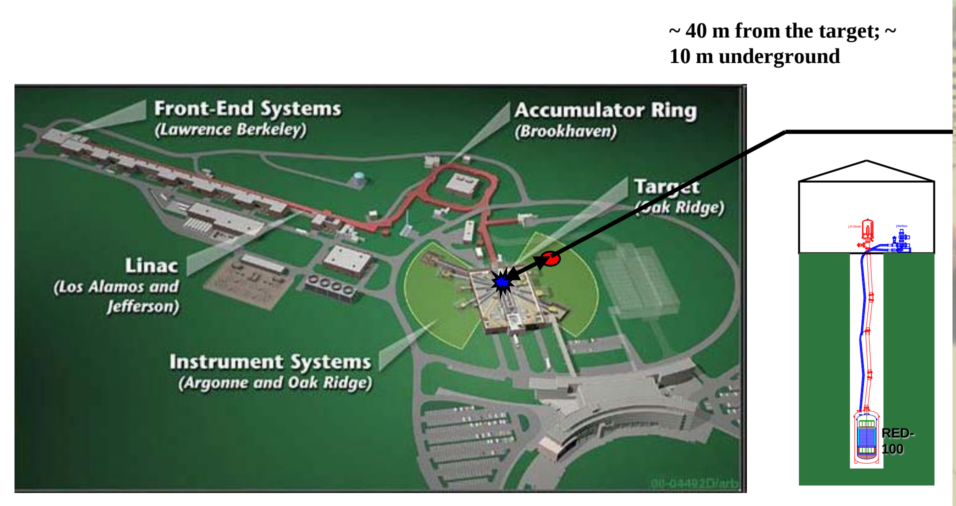
E. Santos, B. Edwards, V. Chepel et al., JHEP 1112 (2011) 115 [arXiv:1110.3056].



RED project

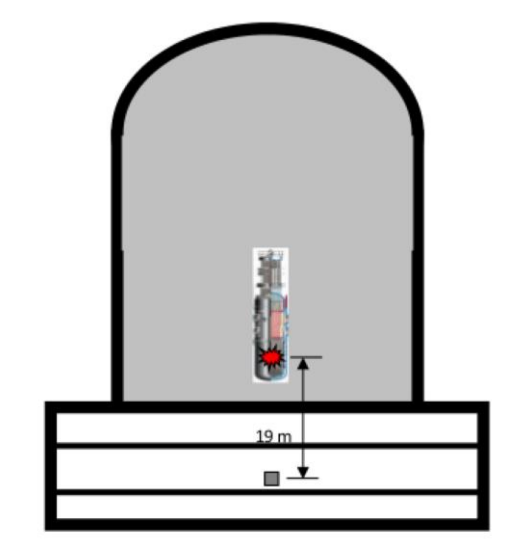
JINST 8 (2013) P10023
e-Print: arXiv:1212.1938





Spallation neutron source (SNS, Oak Ridge National Laboratory, USA)

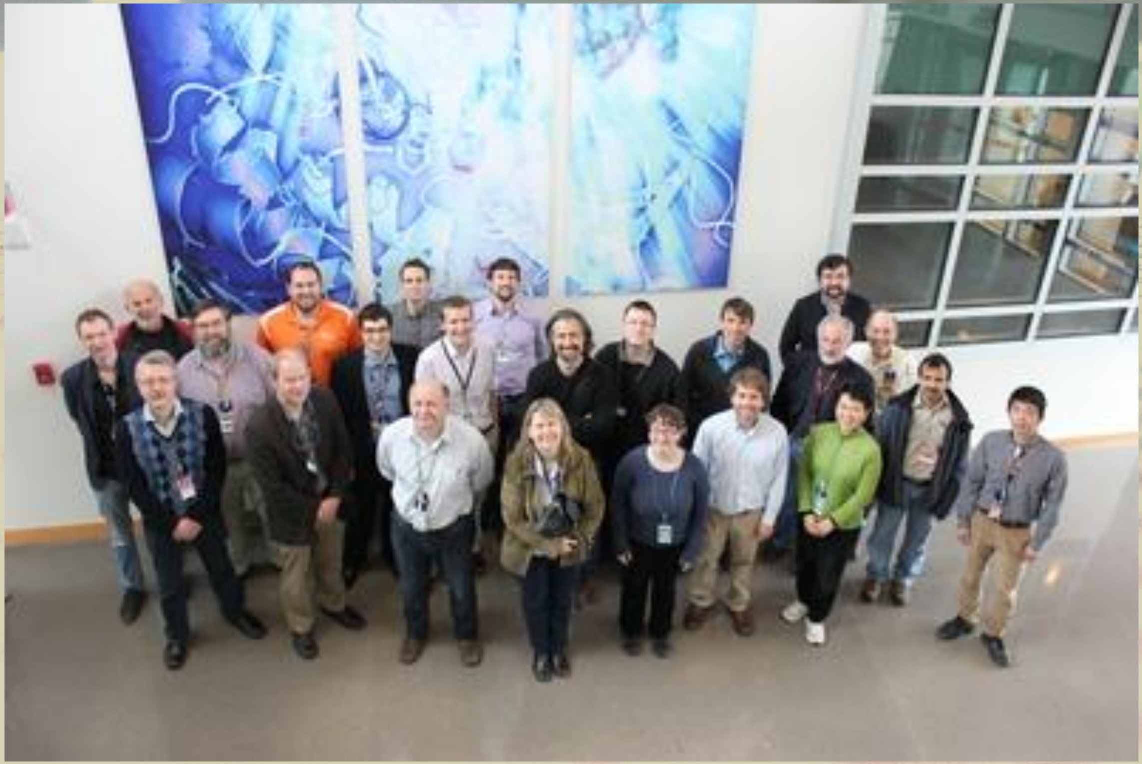
We've got grant 5M$ from RF MES



Kalinin Nuclear Power Plant, Udomlia, RF

In Mar 2014 the COHERENT collaboration established

The goal is the discovery of CEνNS using three different detection techniques at SNS:



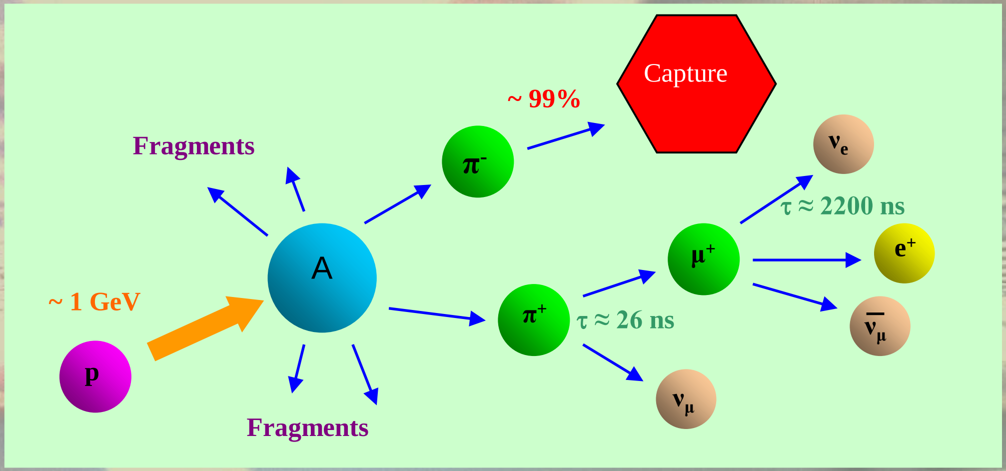
LXe – RED-100

Ge – Majorana detectors

CsI(Na) crystals (CsI and Xe targets has close neutron numbers)

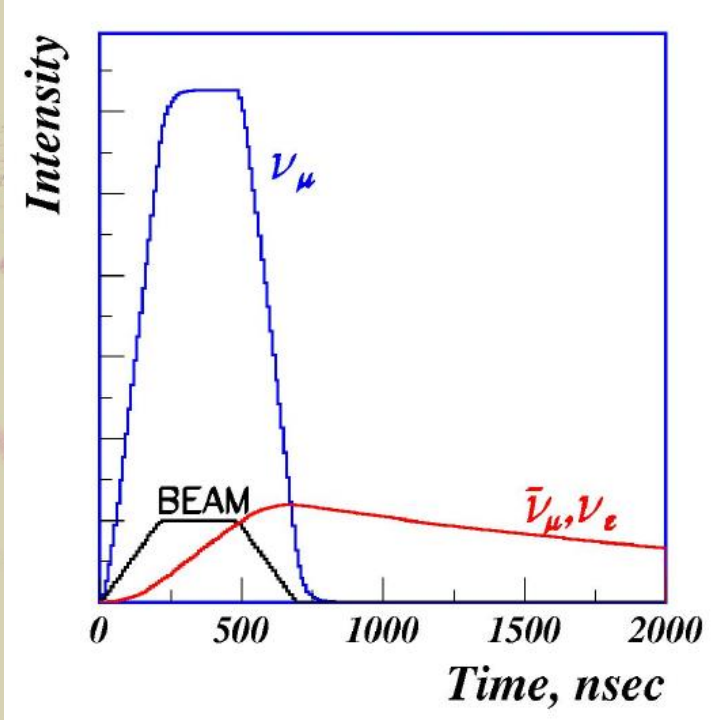
Proposal to DOE is being prepared

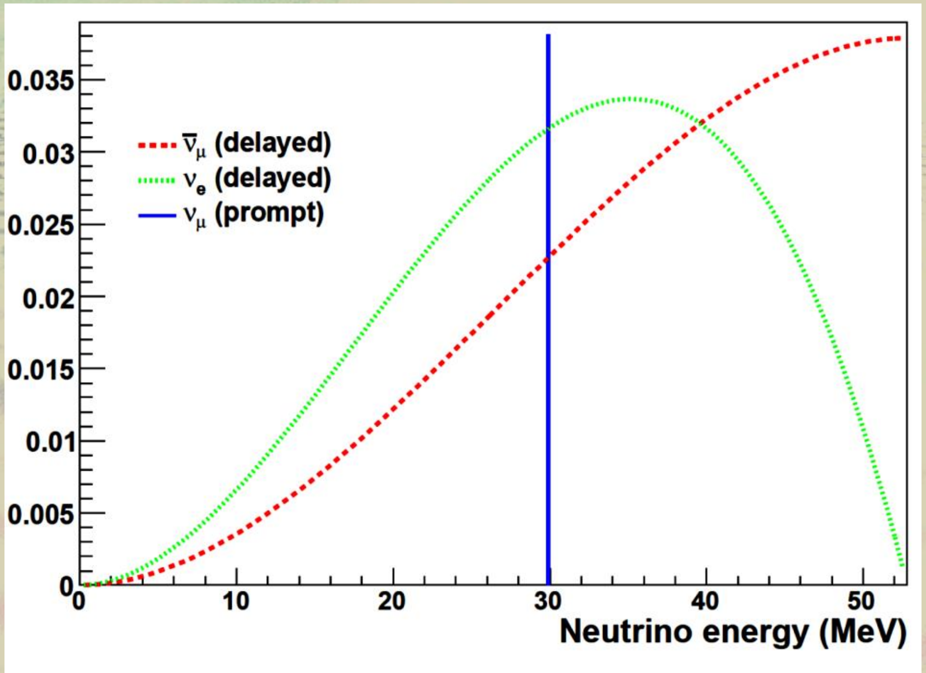
SNS as a neutrino source



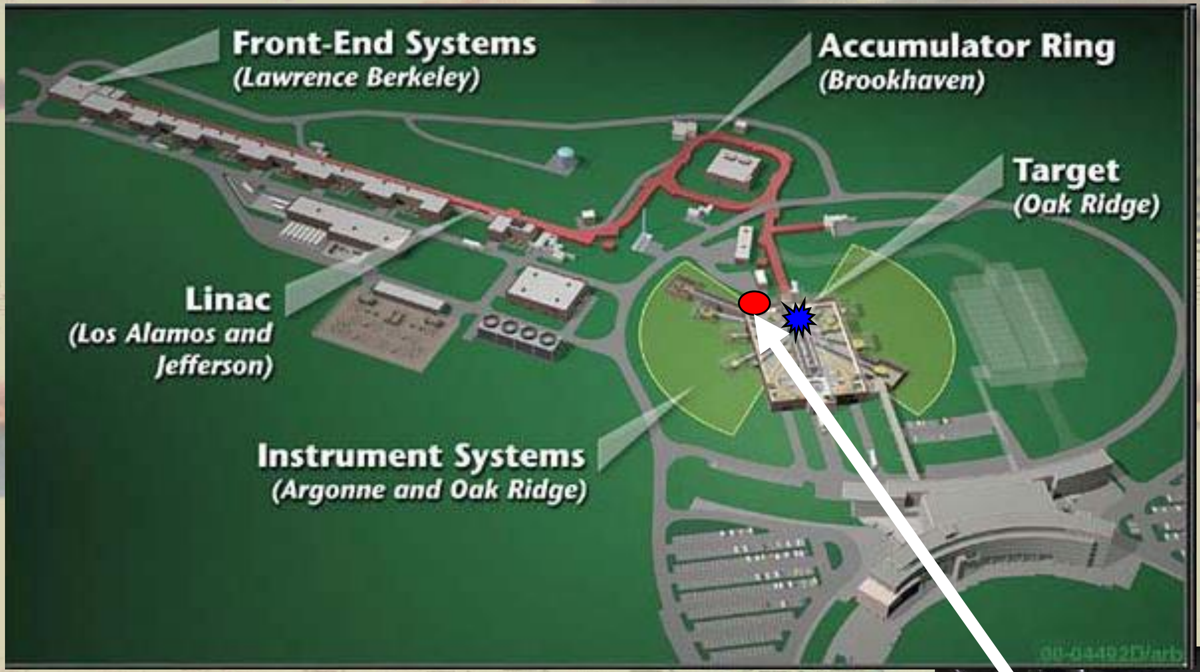
SNS proton energy ~1 GeV
power 1.4 MW

ν flux at 30 m (all 3 types):
~7 x 10^6 ν/cm²/sec



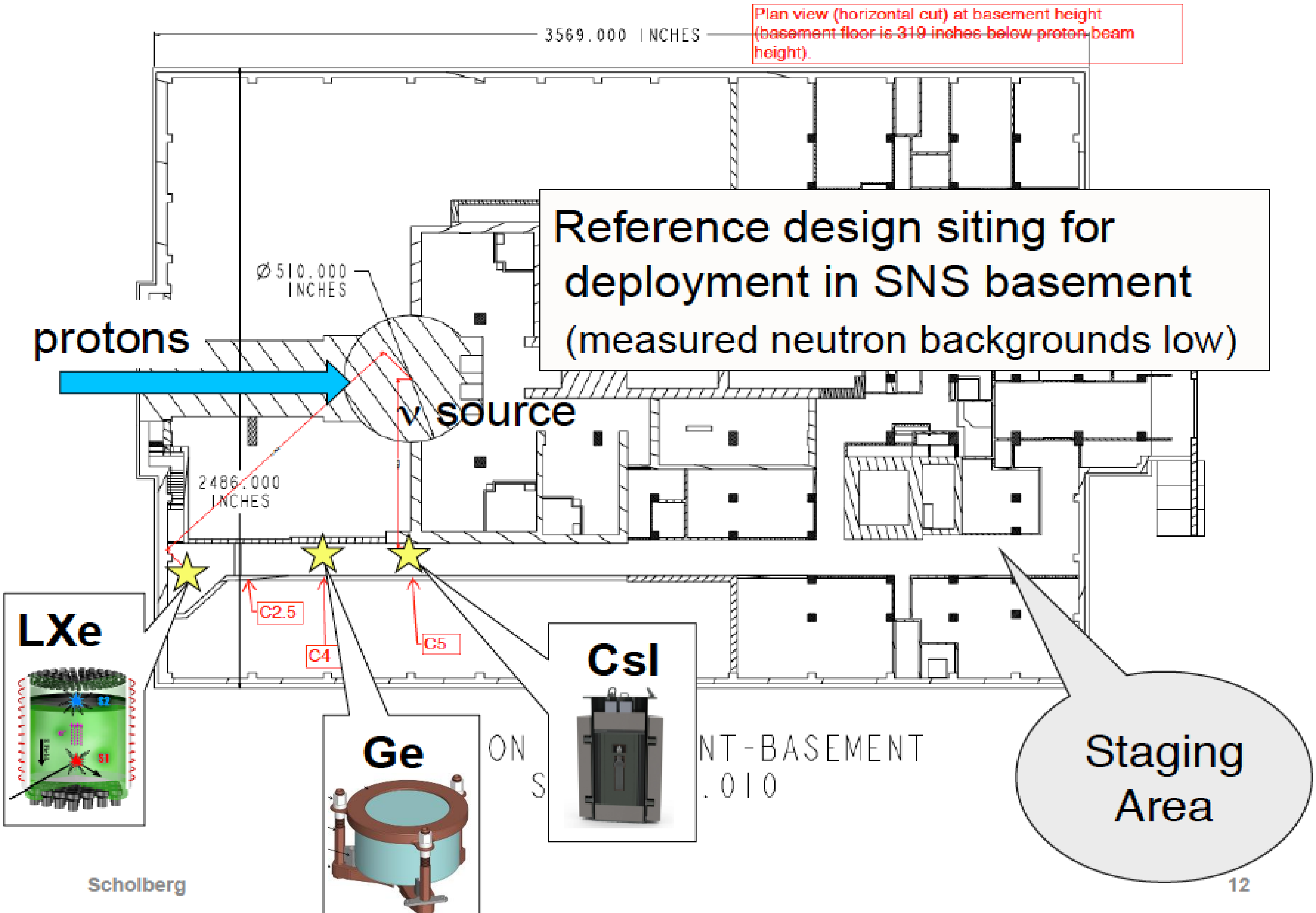


Experimental site



The basement of the experimental hall

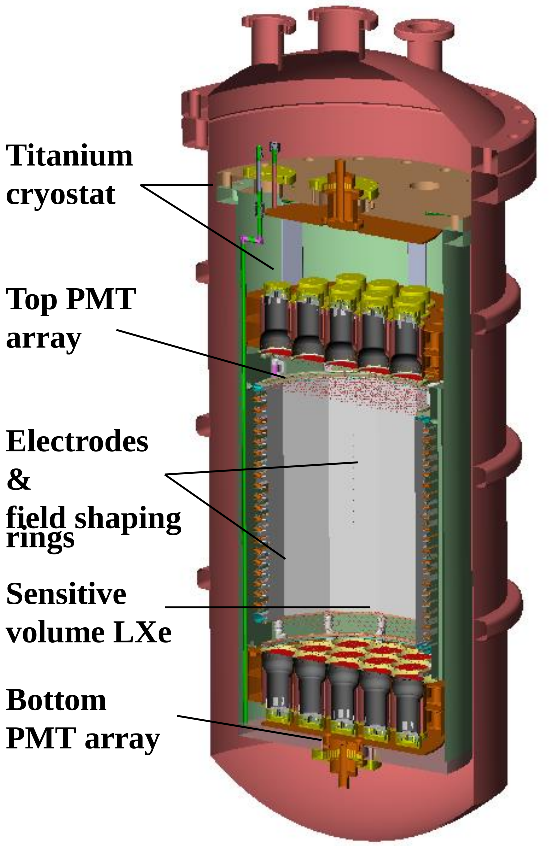
Experimental site



Р Э Д

РОССИЙСКИЙ ЭМИССИОННЫЙ ДЕТЕКТОР

Detector RED-100 (~100 kg of LXe in FV, ~250kg total)
Russian Emission Detector



RED-100 is a two-phase noble gas emission detector. Contains ~250 kg of LXe, ~100 kg in FV.

The sensitive volume ~ 45 cm in diam ~ 45 cm in height, is defined by the top and bottom optically transparent mesh electrodes and field-shaping rings.

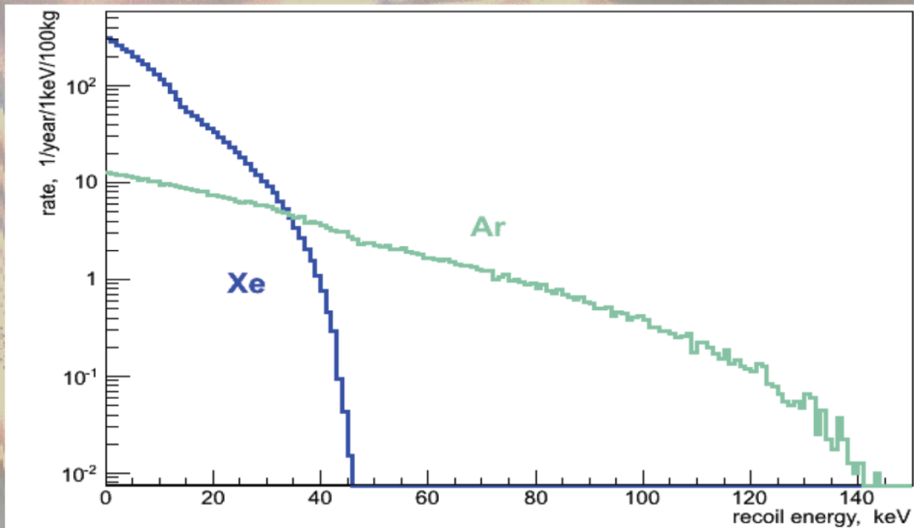
PMTs are Hamamatsu R11410-20 (low-background); 38 in total (2 x 19)

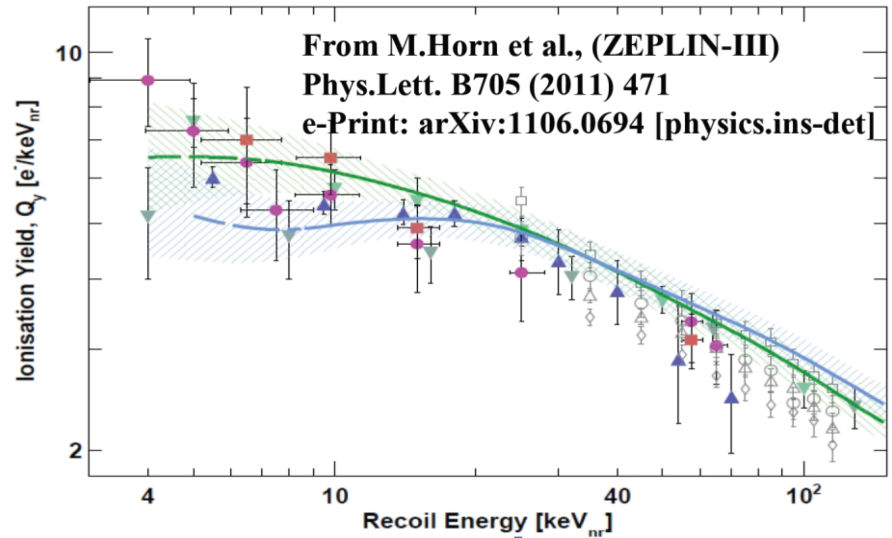
Drift field is ~ 0.5 ÷ 1 kV/cm;

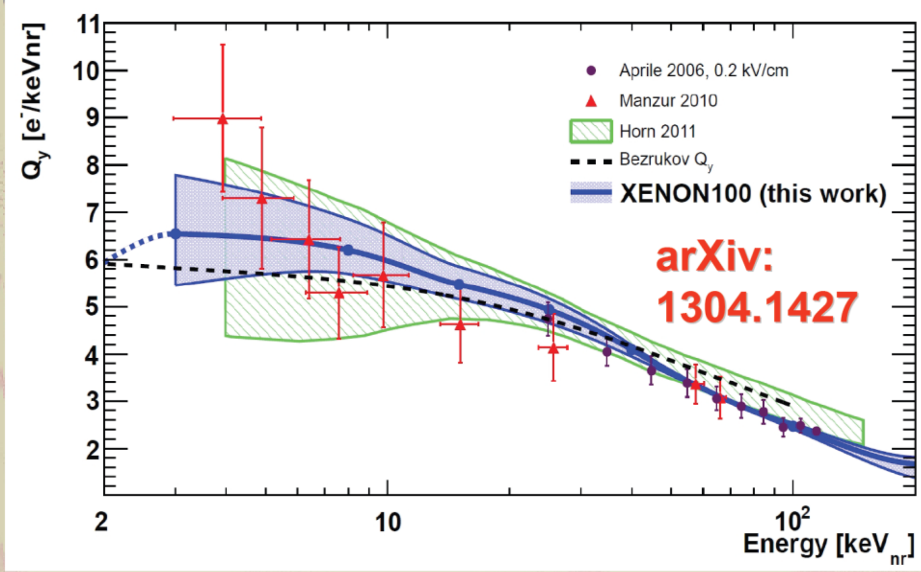
Field in EL region is ~ 7 ÷ 10 kV/cm (in the gas phase).

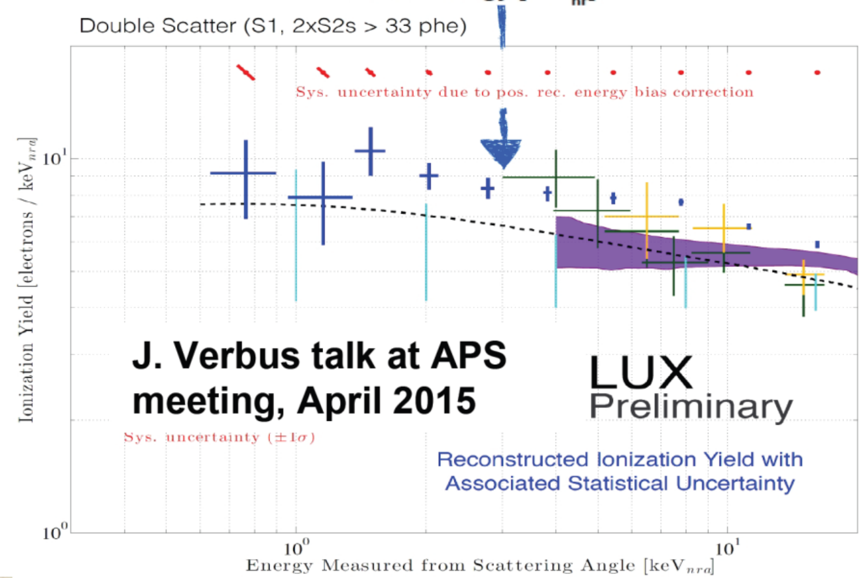
Size of the EL region – 1 cm. The expected *number of photoelectrons per one electron* extracted to the gas phase ~ 80.

NR energy spectrum and ionization yield









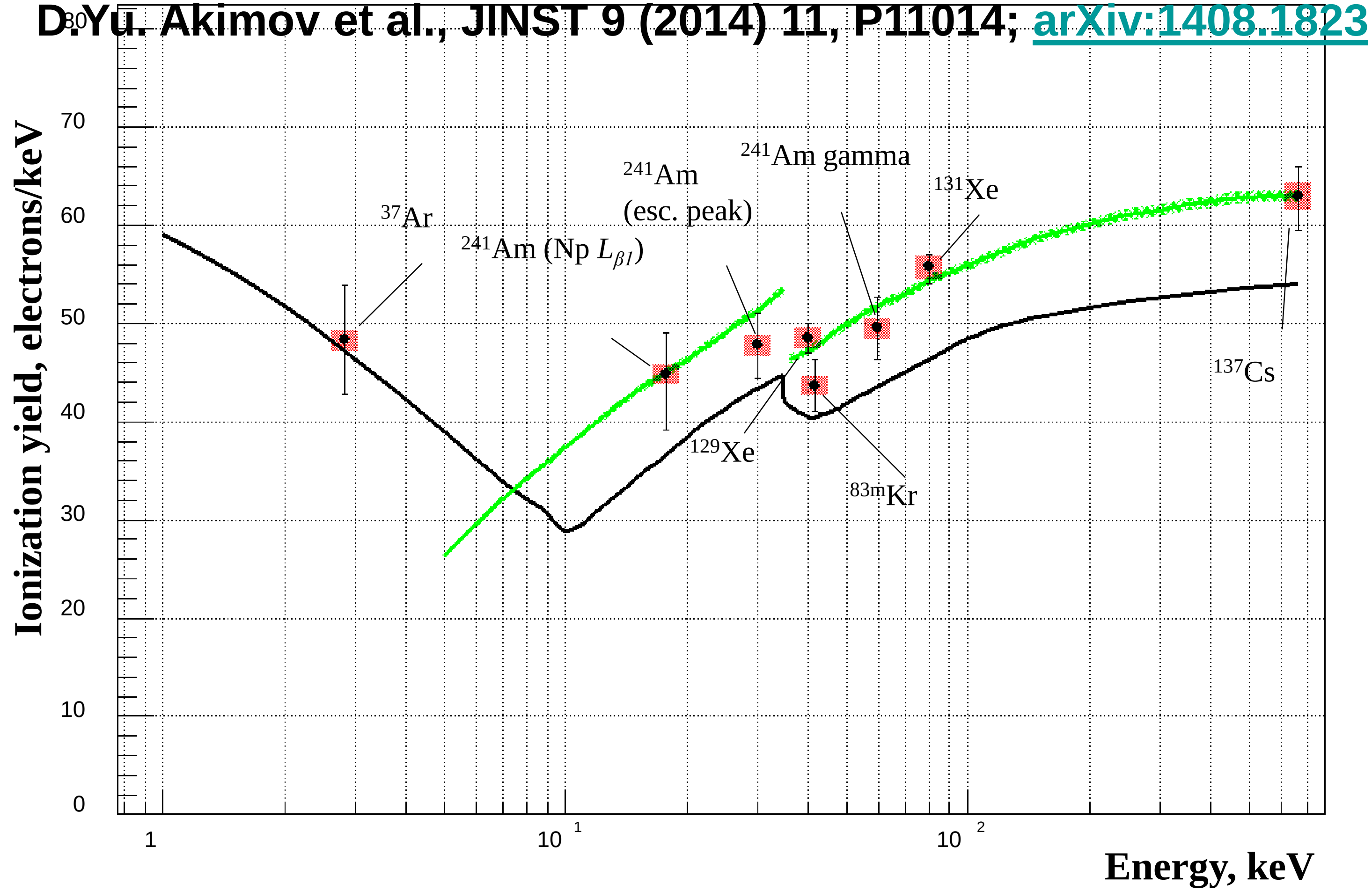
Most of the NR events have energies in the region well studied by the experimental groups carried out the DM search experiments;

LXe response for NR is well known

LXe response for ER is well known too

Experimentally measured ionization yield of LXe for ER:

D.Yu. Akimov et al., JINST 9 (2014) 11, P11014; arXiv:1408.1823



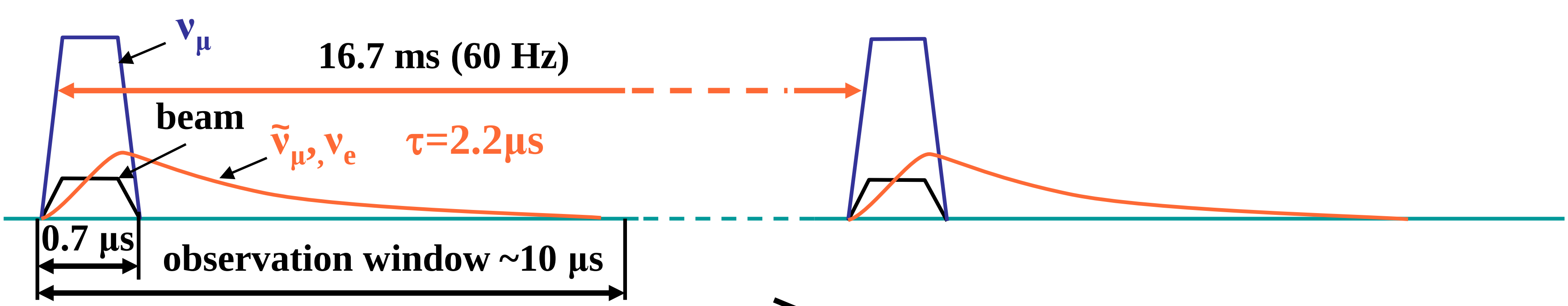
—— T.Ya. Voronova et al., Sov. Phys. Tech. Phys. 34 iss. 7 (1989) 825

—— NEST (Noble Element Simulation Technique) model: http://nest.physics.ucdavis.edu/site

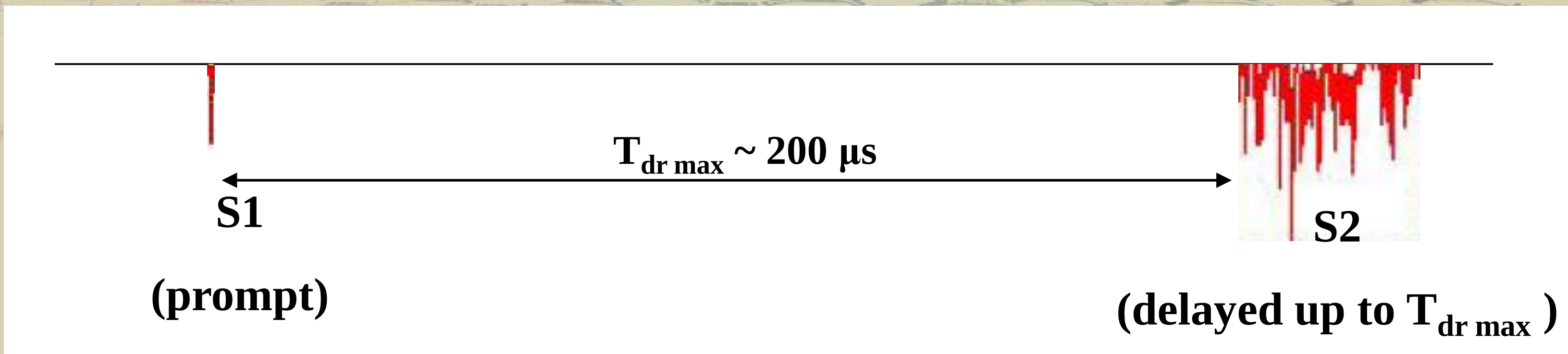
Timing at SNS

SNS pulsed beam is an essential factor in background reduction!

Duty factor = 10 μs/16.7 ms ≈ 1/1600



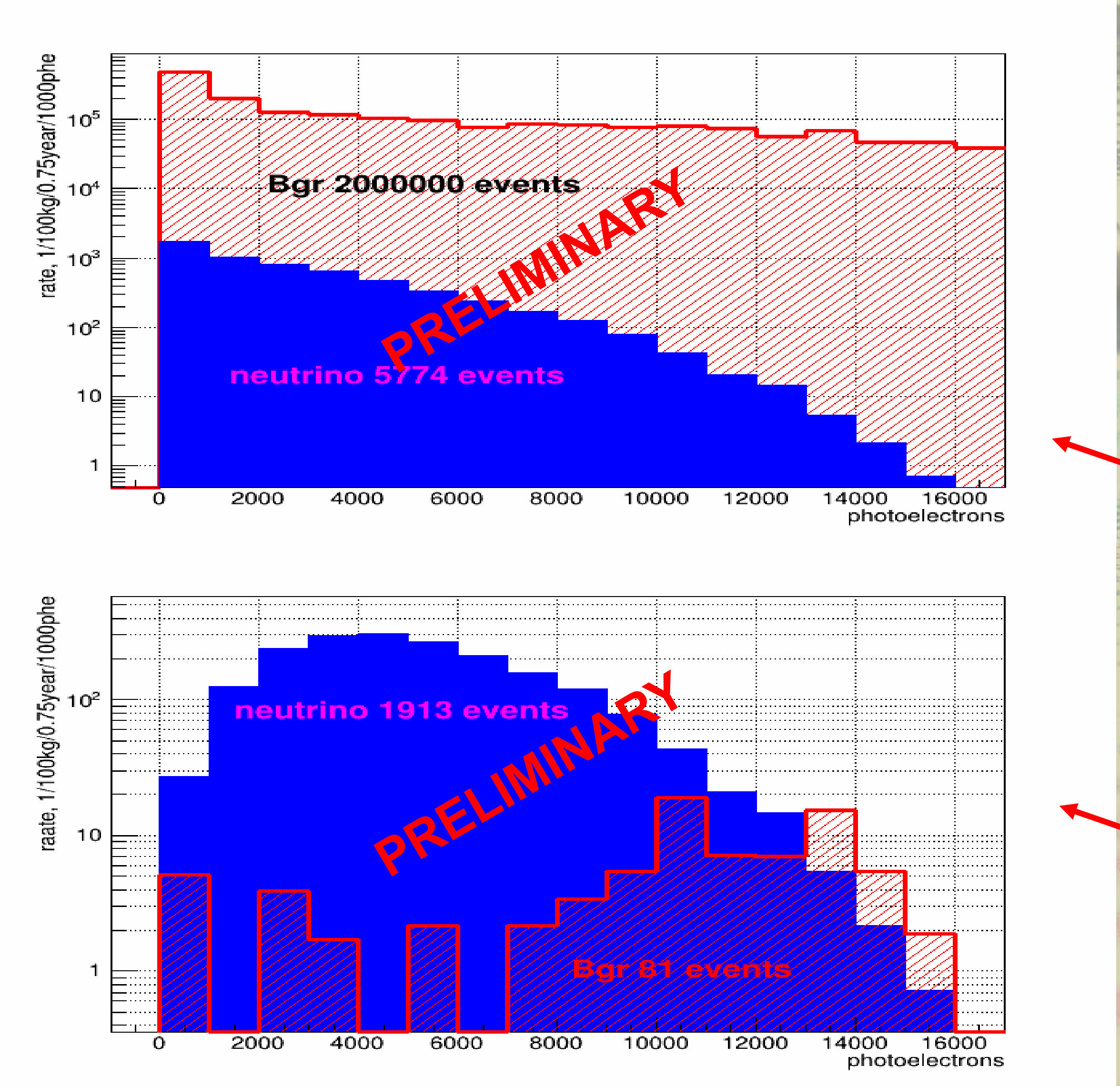
$10\ \mu s < T_{dr\ max} < 16.7\ ms$



Timing is possible only with S1

Expected gamma-background at SNS

We started modeling backgrounds for the experimental site (basement)



Example of the most serious γ- background from the cryostat

External bckg is shielded by 100 mm Pb

Radial cut – 163 mm

Exposition – 9 months

Without duty factor

gamma

ν-N

With duty factor 1/1600 and with selection S1 ≥ 2 phe

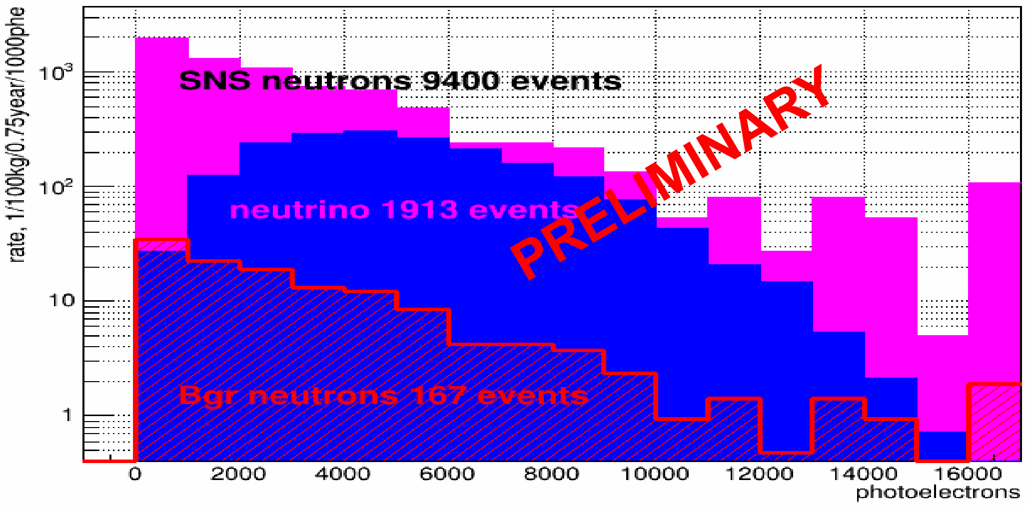
Expected neutron-background at SNS

The neutron bckg simulation is based on the measured neutron flux in the basement

No neutron shield (moderator)!

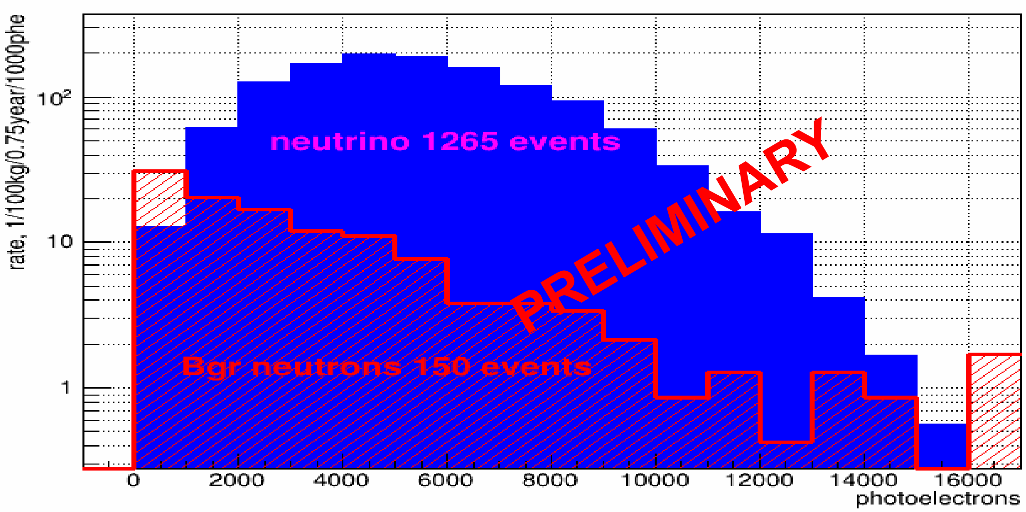
Radial cut – 163 mm

Exposition – 9 months



With duty factor ~1/1600, with selection S1 ≥ 2 phe

n-N	n	associated with beam
n-N	n	not associated with beam
ν-N		

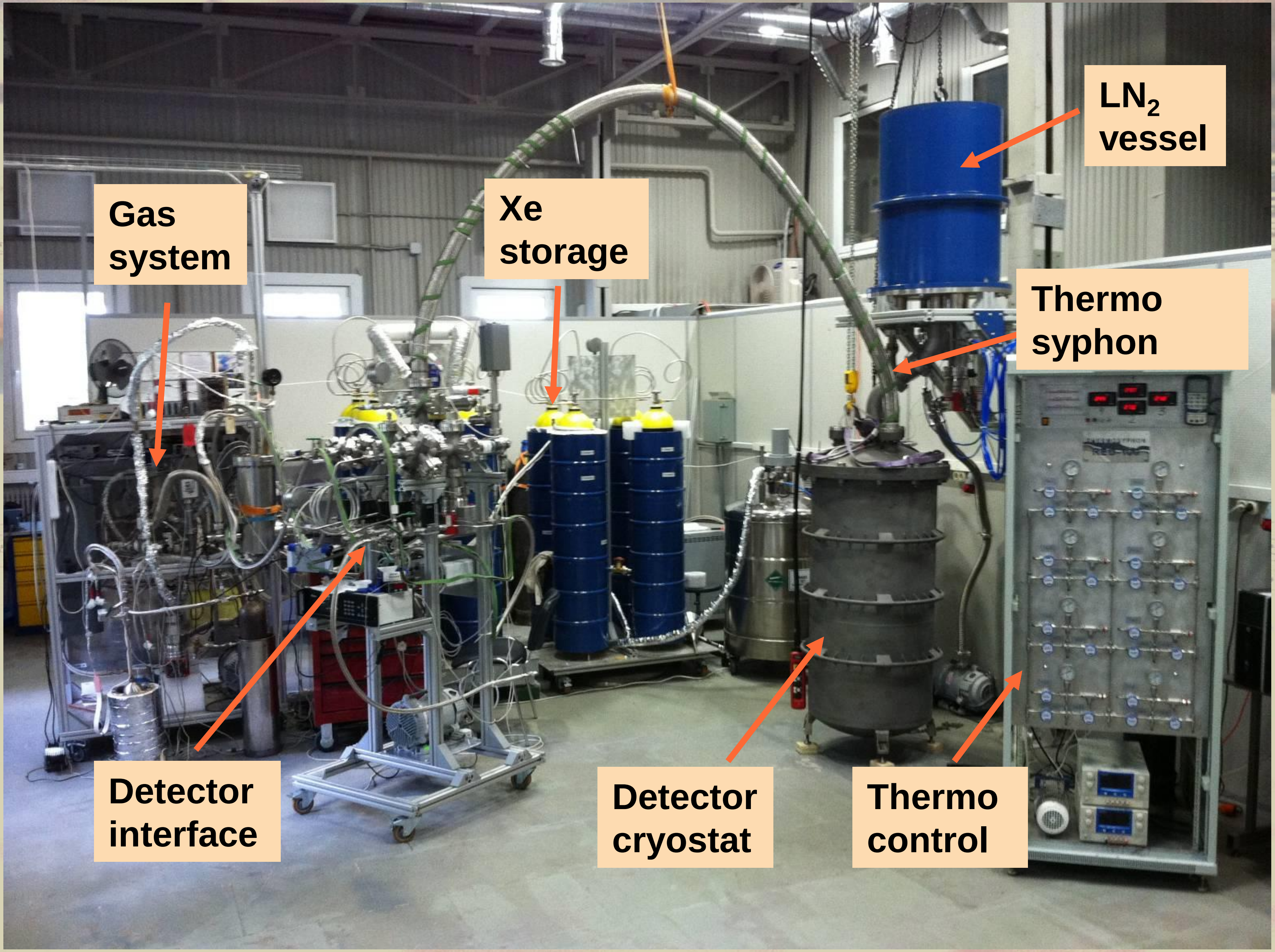


With duty factor ~1/1600, with selection S1 ≥ 2 phe, and with time selection > 1 μs after start of the SNS pulse

Unfortunately, the ν_μ prompt component is lost in this case

RED-100 detector assembling

RED-100 detector infrastructure



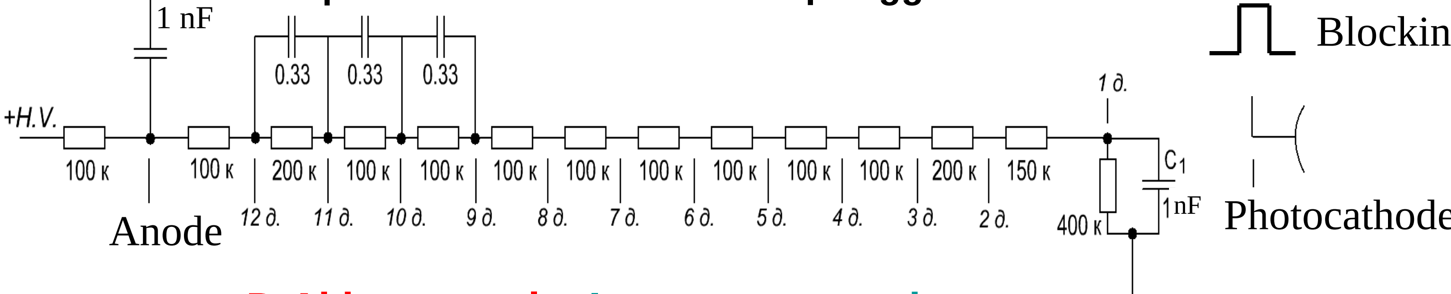
Active divider for R11410-20

The detector will work in much harder muon background (~10 s^{-1}) than that in DM experiments. Muon deposits ~ 250 MeV ➔ 10^9 phe

To prevent rapid degradation of the photocathodes due to the intense illumination a blocking pulse is sent to the PMTs

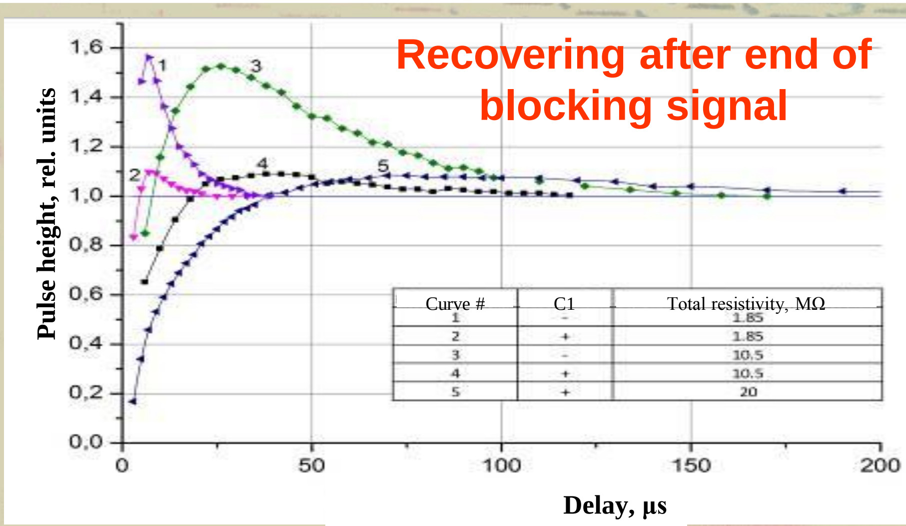
The 1st dynode is at ~ 300 V; the photocathode is at 0 V. A blocking pulse of +300 V is supplied to the photocathode started from μ-trigger.

Full width of the muon signal is ~ 200 μs



D.Akimov et al., Instruments and Experimental Techniques, 57 (2014), 615

Recovering after end of blocking signal



Timeline of experiment

	2015	2016	2017	2018	2019
Assembling RED-100					
Shipping RED-100 to SNS, deployment and commissioning					
Data taking with LXe					

Conclusion

- Discovery of elastic coherent ν-nucleus scattering predicted 40 years ago is very close
- The emission two-phase detection technique well developed for DM search is an excellent tool
- Background conditions are good for the basement of the SNS experimental hall to observe the effect with the LXe detector
- The RED-100 emission detector is being assembled and will be ready for deployment at SNS soon

Short announcement

MEPhI has a PostDoc program on this and other projects

Please enquire: http://mephi.ru/eng/

or

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