NATIONAL RESEARCH NUCLEAR UNIVERSITY MEPhI
(Moscow Engineering Physics Institute)

Laboratory for Experimental Nuclear Physics
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РОССИЙСКИЙ ЭМИССИОННЫЙ ДЕТЕКТОР

Alexander Bolozdynya

Emission two-phase xenon detector RED-100 to search for coherent neutrino elastic scattering off xenon nuclei

БНО50
June 6, 2017

Р Э Д

РОССИЙСКИЙ ЭМИССИОННЫЙ ДЕТЕКТОР

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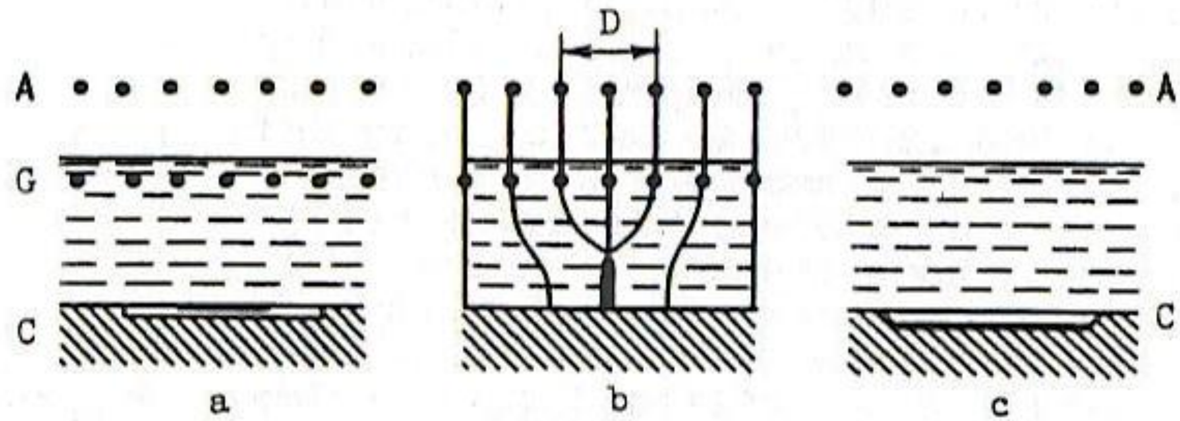
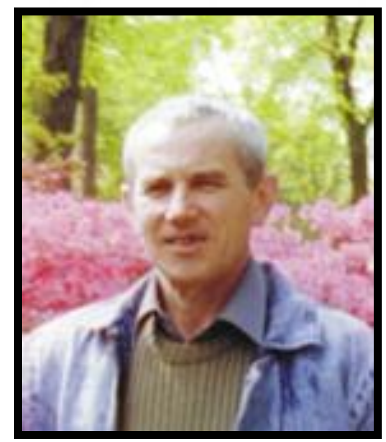
1969-70 Emission detection principle



Boris Dolgoshein

Boris Rodionov

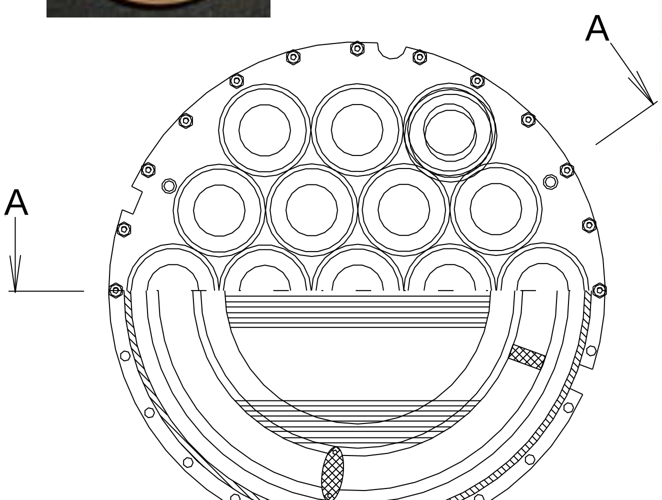


Vadim Lebedenko

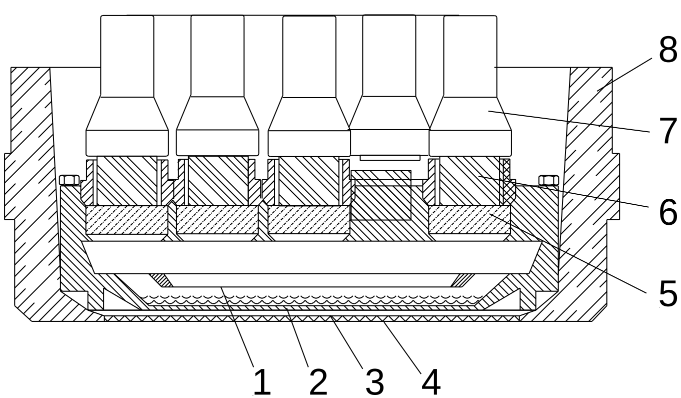
Долгошеин Б.А., Лебеденко В.Н. и Родионов Б.У. Новый метод регистрации треков ионизирующих частиц в конденсированном веществе, Письма в ЖЭТФ 11 (1970) 351-353.

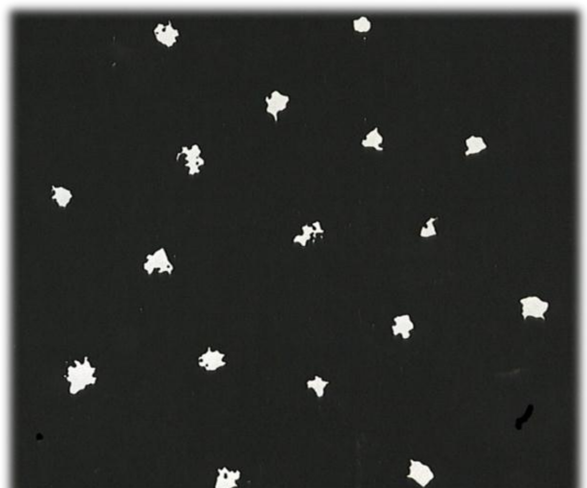
Hutchinson G. W. (1948). Ionization in liquid and solid argon, Nature 162 (1948) 610-611.

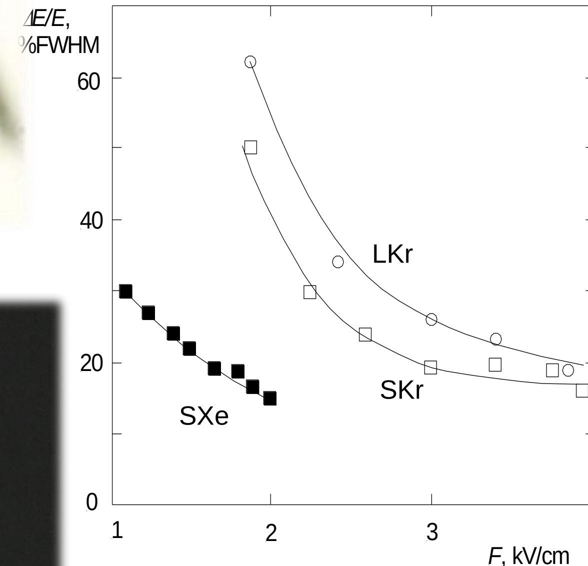
1982-1985 SolidXe 2D emission gamma camera



AA view

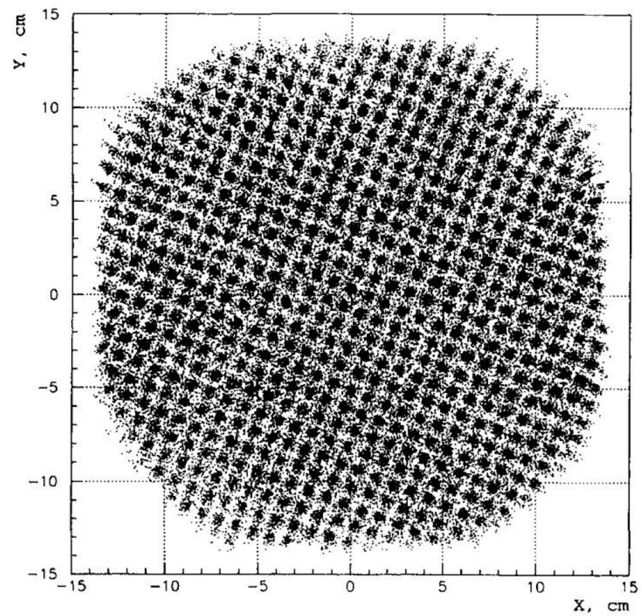


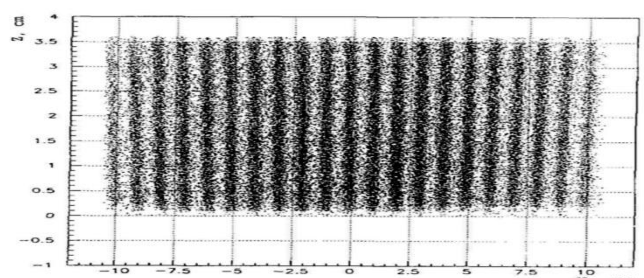


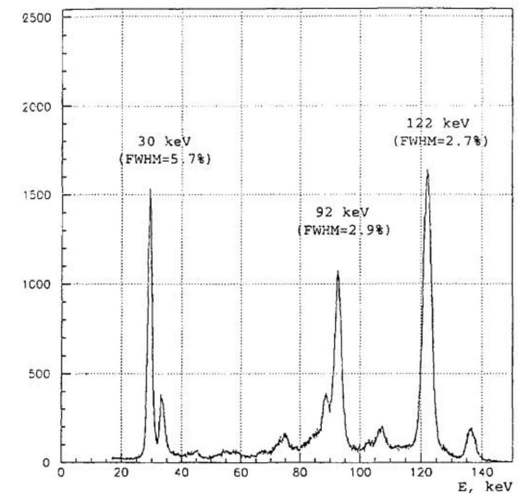


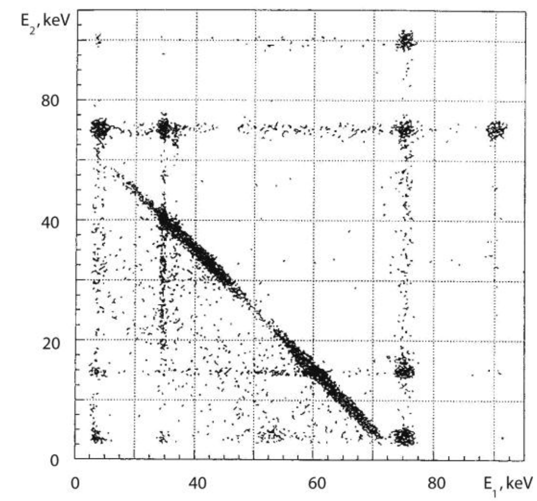
V.Egorov, V. Miroshnichenko, B. Rodionov, A. Bolozdynya, S. Kalashnikov, V. Krivoshein. Electroluminescence emission gamma-camera, Nucl. Instrum. Meth. 205 (1983) 373-374.

1990-95 3D High-Pressure Xe gamma camera



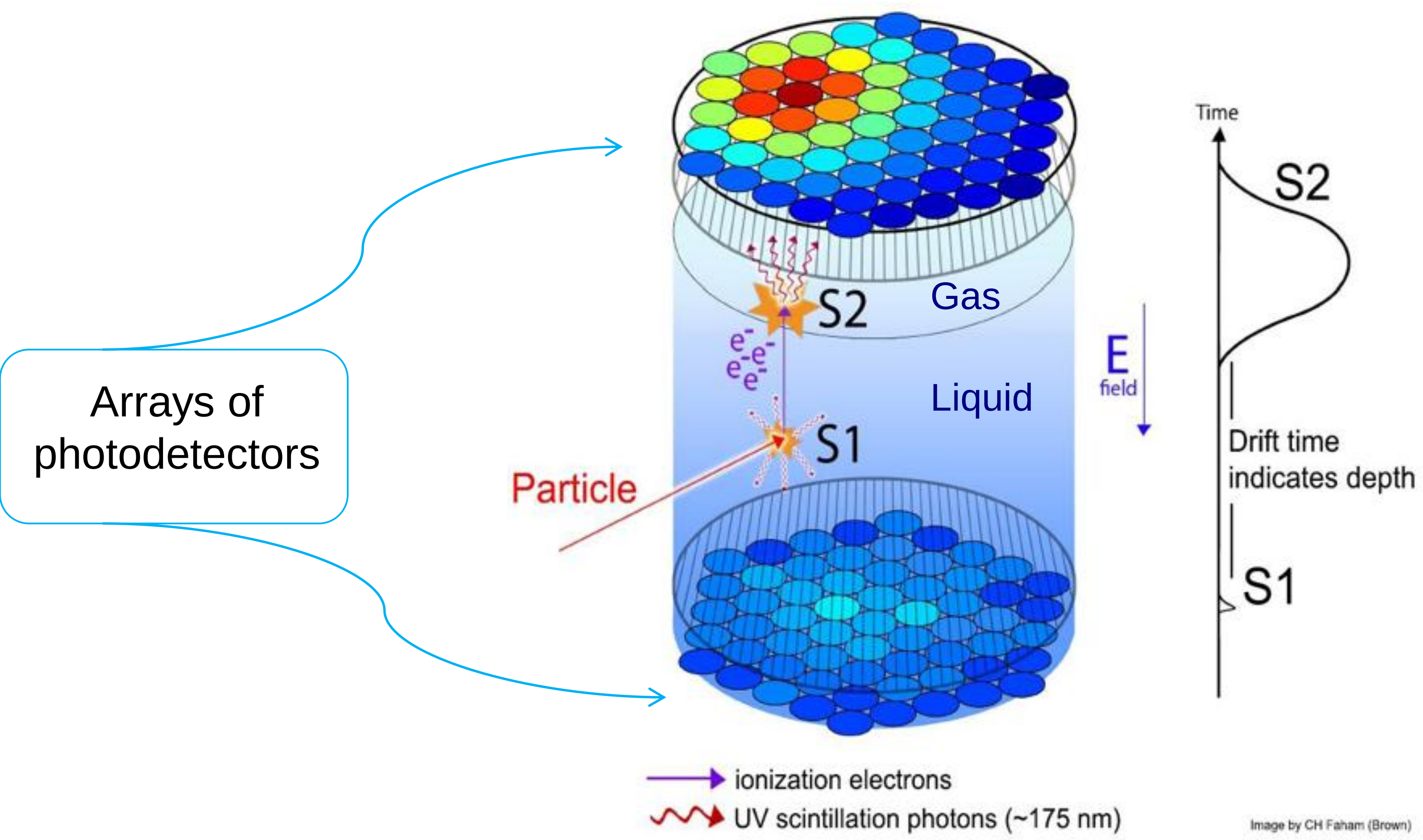






Bolozdynya A., Egorov V., Koutchenokov A., Safronov G., Smirnov G., Medved S. and Morgunov V. A high pressure xenon self-triggered scintillation drift chamber with 3D sensitivity in the range of 20–140 keV deposited energy, Nucl. Instrum. Meth. A 385 (1997) 225-238.

1995 Idea of "wall-less" emission detector formulated

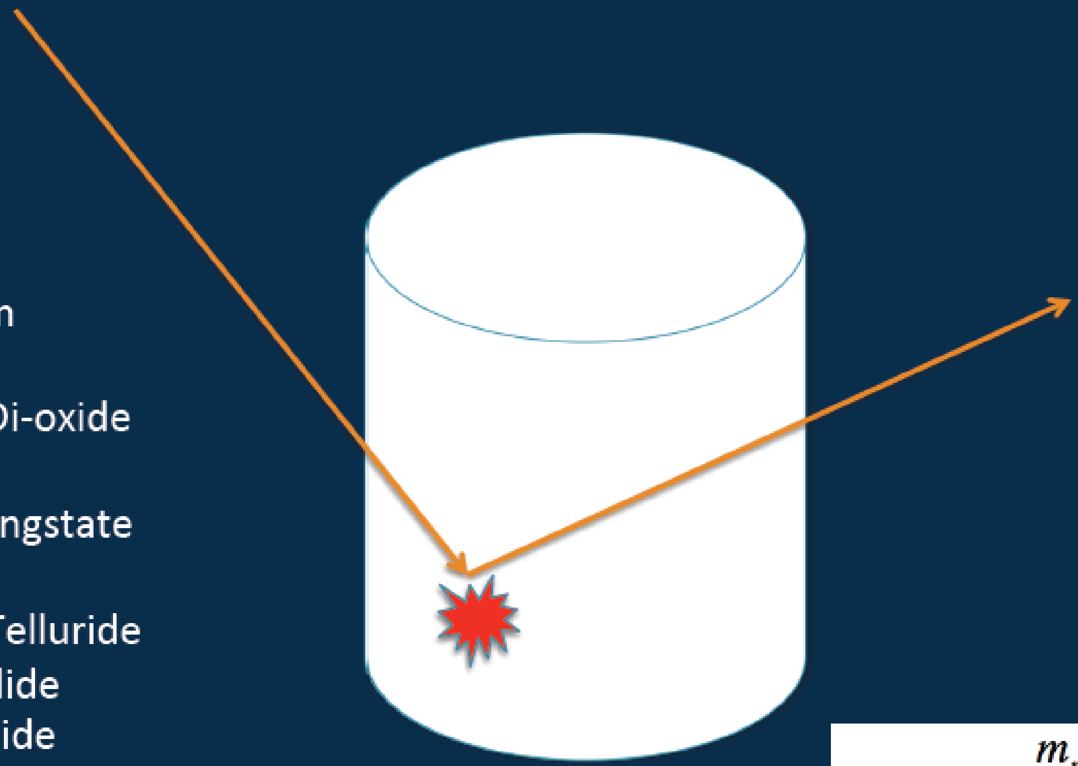


1) two signals: Sc & EL (S1 & S2); 2) 3D position; 3) massive; 4) single electron sensitive

can be used to search for rare and low-ionization signals

A. Bolozdynya, V. Egorov, V. Miroshnichenko, B. Rodionov. Emission detectors, IEEE Trans. Nucl. Sci. 42 (1995) 565-569

Direct detection of WIMPs

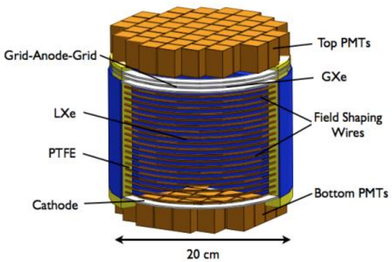


Germanium
Saphire
Tellurium Di-oxide
Xenon
Calcium Tungstate
Argon
Cadmium Telluride
Sodium Iodide
Cesium Iodide
And more

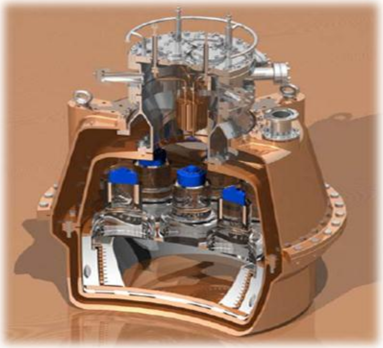
$$\sigma_{nucleus} = \frac{m_n + M_w}{m_n^2 (A + m_n)^2} A^4 \sigma_{nucleon}$$

The interaction produces ionization and/or phonons or and/or Scintillation light, even noise pulses.

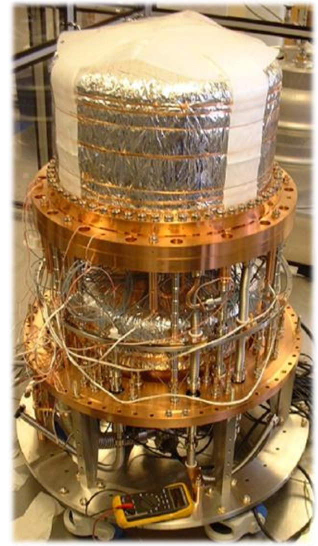
2003-2016 LXe emission WIMP detectors



XENON10



ZEPLIN II

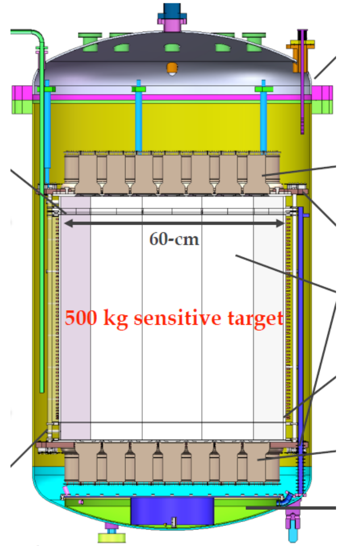


ZEPLIN III

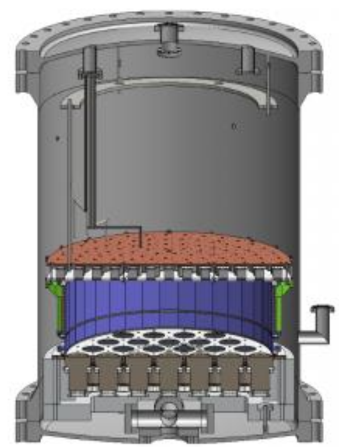
LUX

XENON100

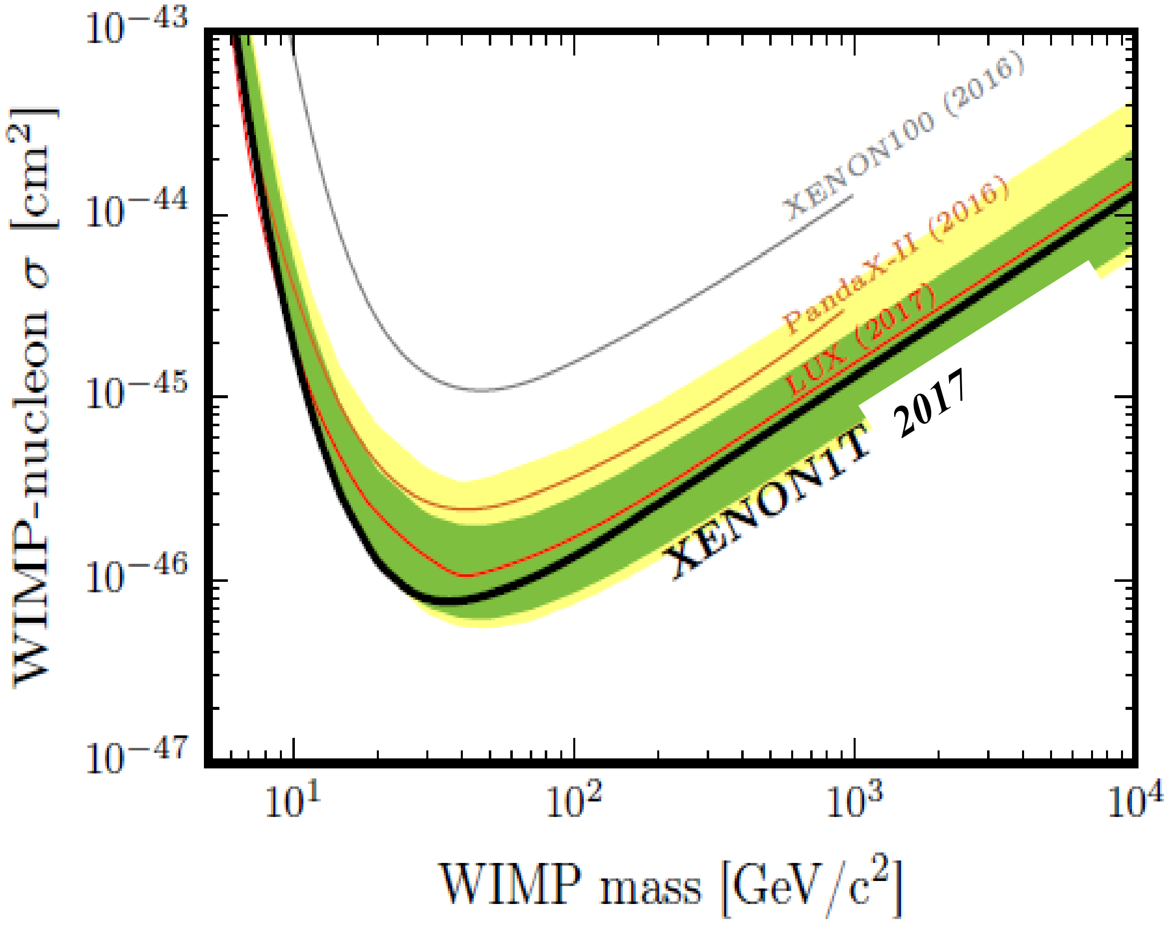
XENON1T



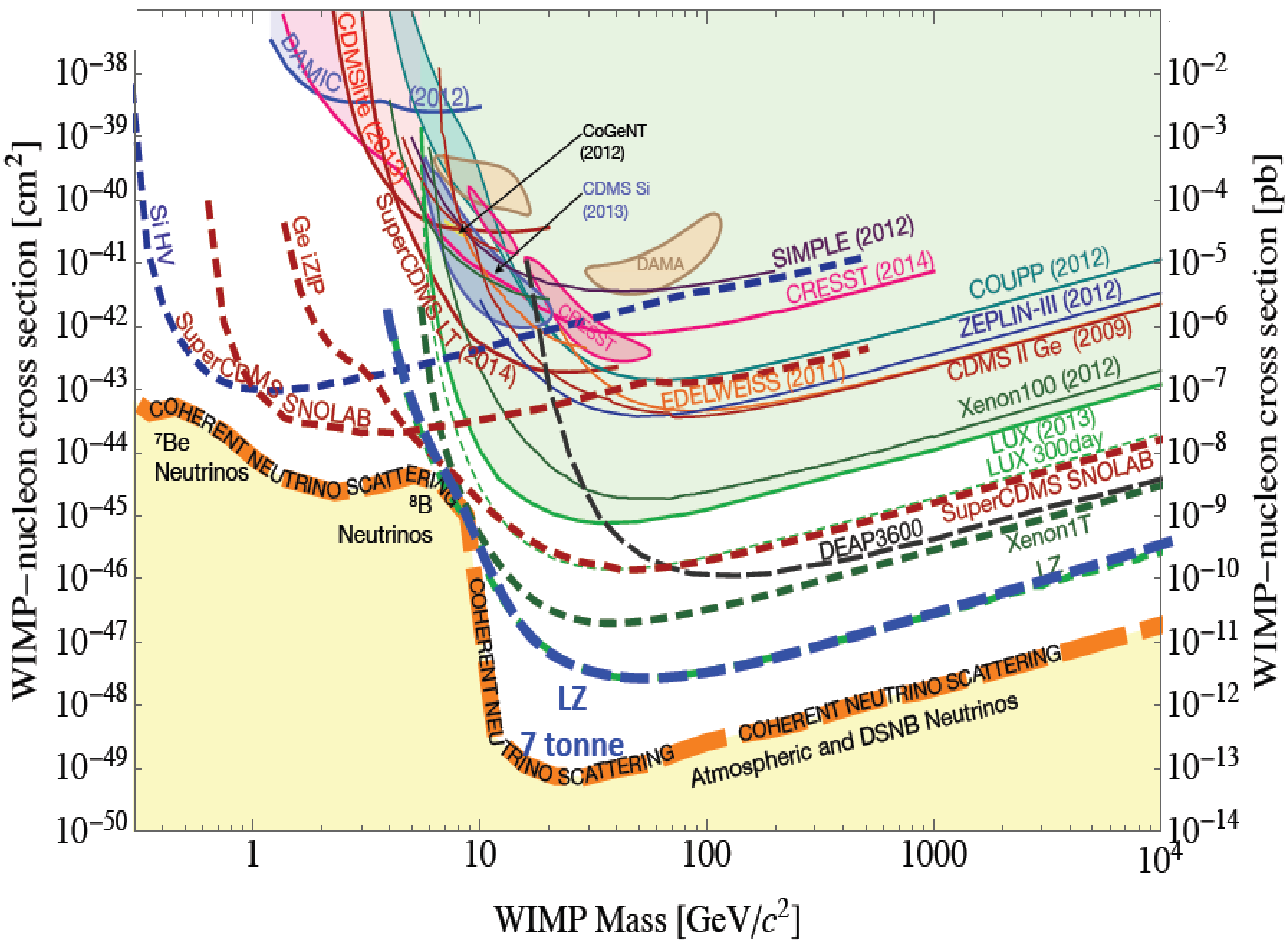
PandaX-II



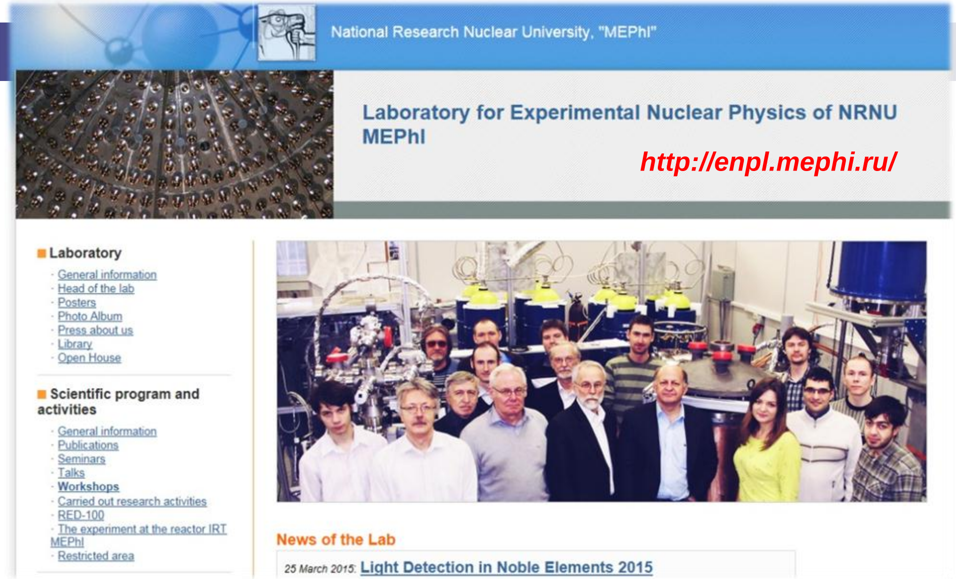
PandaX-I



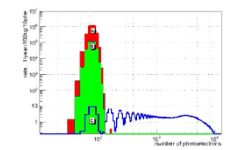
arXiv:1705.06655v2 [astro-ph.CO] 23 May 2017



WIMP−nucleon cross section [cm²]
WIMP−nucleon cross section [pb]
WIMP Mass [GeV/c²]
DAMIC
(2012)
CDMSlite (2013)
CoGeNT
(2012)
CDMS Si
(2013)
DAMA
SIMPLE (2012)
CRESST (2014)
CRESST
COUPP (2012)
ZEPLIN-III (2012)
CDMS II Ge (2009)
Xenon100 (2012)
EDELWEISS (2011)
LUX (2013)
LUX 300day
SuperCDMS SNOLAB
DEAP3600
Xenon1T
LZ
Si HV
Ge iZIP
SuperCDMS LT (2014)
SuperCDMS SNOLAB
COHERENT NEUTRINO SCATTERING
⁷Be
Neutrinos
⁸B
Neutrinos
LZ
7 tonne
Atmospheric and DSNB Neutrinos

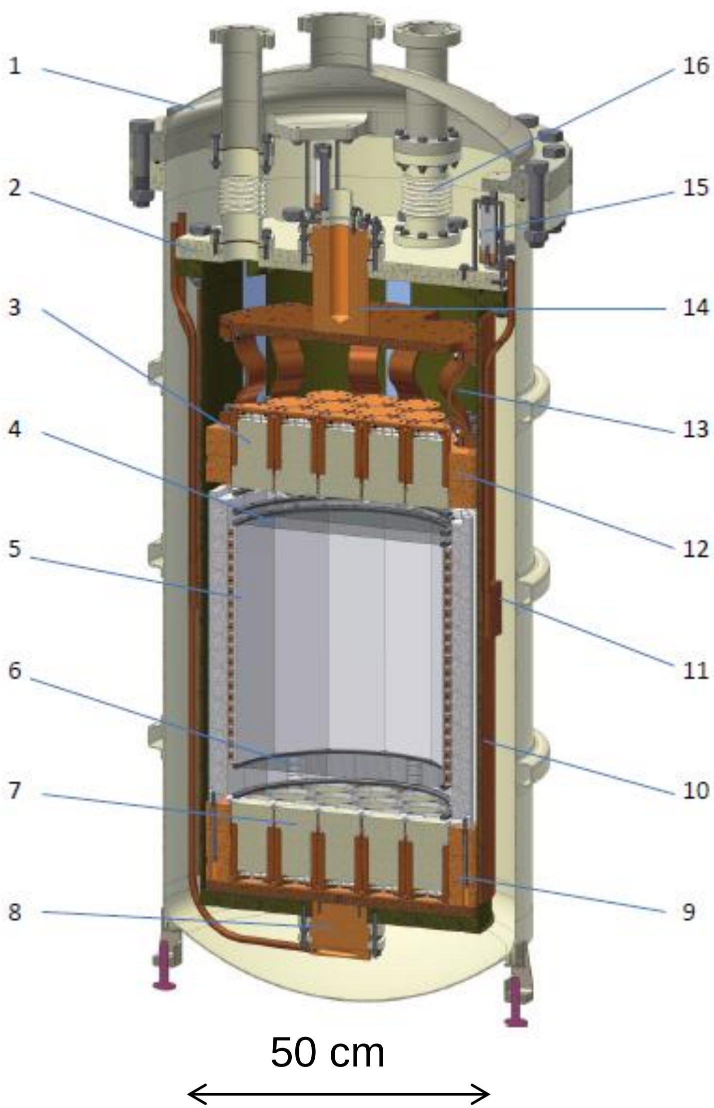


Laboratory for Experimental Nuclear Physics of NRNU MEPhI

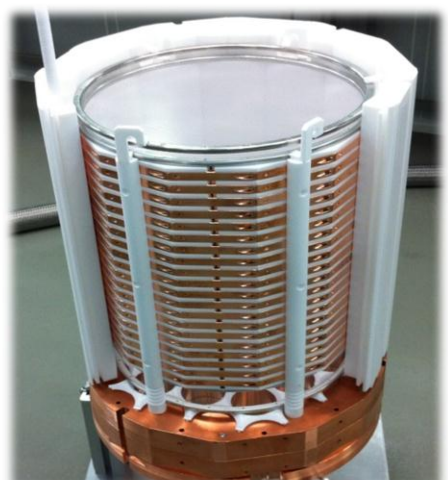


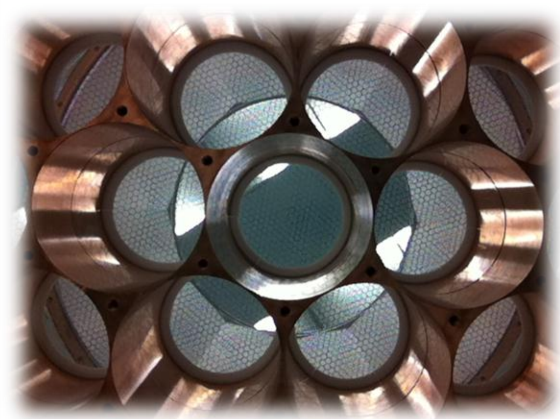
- **Neutrino Physics and Astroparticle Physics (dark matter search)**
- **R&D of detectors for fundamental physics research and applications**
- **Novel radiation detector technologies based on high density xenon, room temperature semiconductor detectors, silicone solid state photomultipliers, advanced scintillators**
- **Innovative technologies for radioisotope diagnostics in Nuclear Medicine**
- **Detection systems for nuclear material identification, nonproliferation and monitoring nuclear reactors**

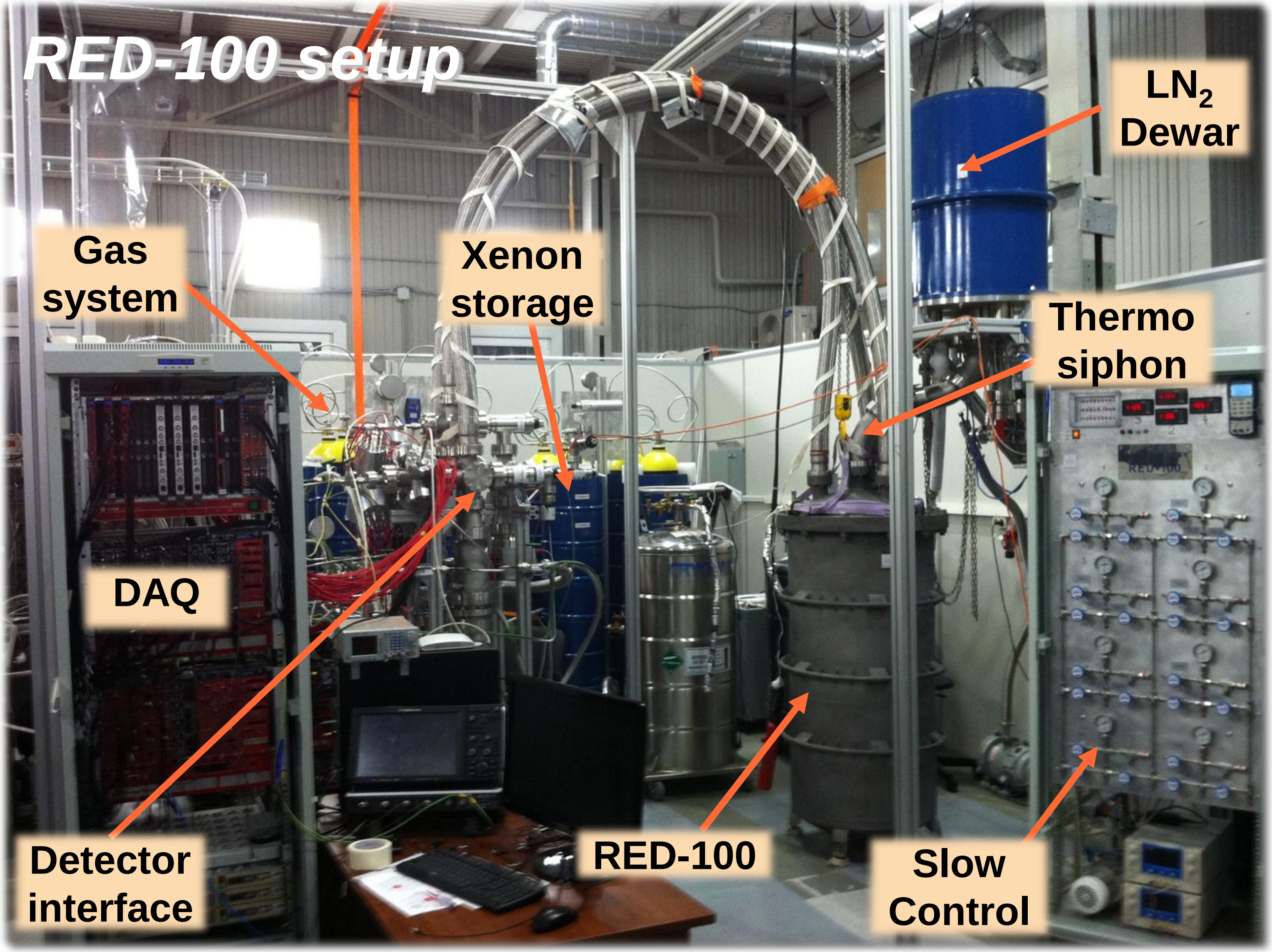
RED-100 detector



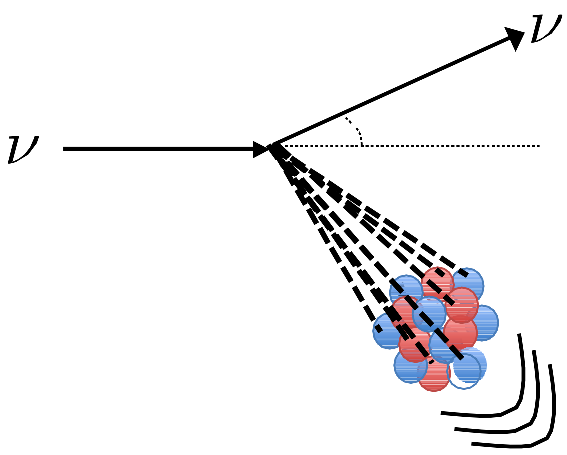
1 - warm Titanium made vessel
2 - cold Titanium made vessel
3 - array of 19 *Hamamatsu R11410-20* PMTs
4 - mesh anode and electron extraction electrodes
5 - drift electrodes
6 - cathode
7 - bottom array of 19 PMTs
8 - bottom thermo siphon cold head
9 - copper housing for the bottom PMT array
13 - thermo-screen of the cold vessel
14 - top thermo siphon cold head
15 - heat-isolating suspension
19 – bellow thermal decoupling of pipelines






RED-100 setup
LN$_2$ Dewar
Gas system
Xenon storage
Thermo siphon
DAQ
Detector interface
RED-100
Slow Control

Coherent neutrino scattering off Xenon nuclei

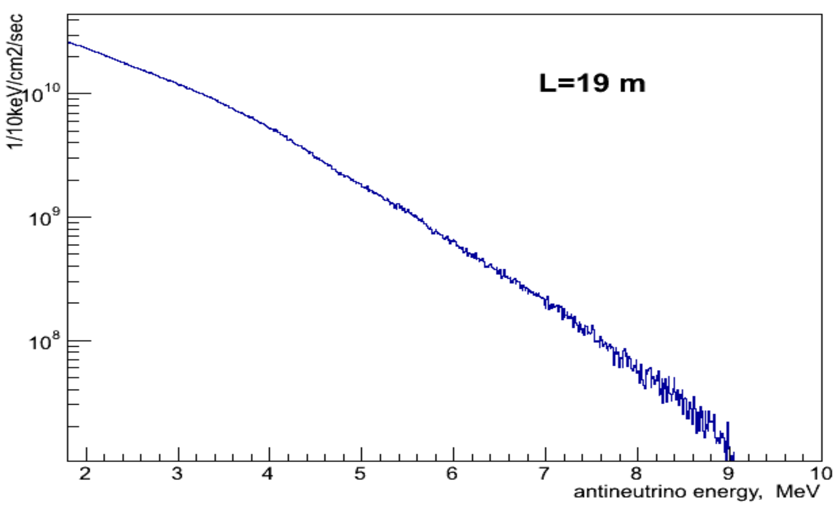


Large cross-section

$$\sigma_{\text{elastic}} = \frac{G_F^2}{4\pi} N^2 E_\nu^2$$

$$\approx 0.4\times10^{-44}\text{cm}^2 A^2 E_\nu(\text{MeV})^2$$

for Xe ***<σ> ≈ 7·10^{-41} cm^2*** averaged over energy spectrum of reactor antineutrinos



~700 times more than

<σ> ≈ 1·10^{-43} cm^2

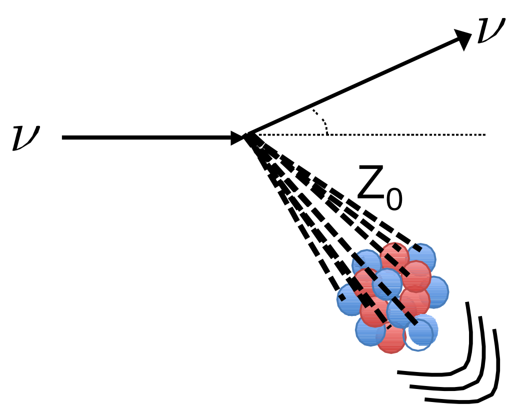
for inverse beta decay of proton

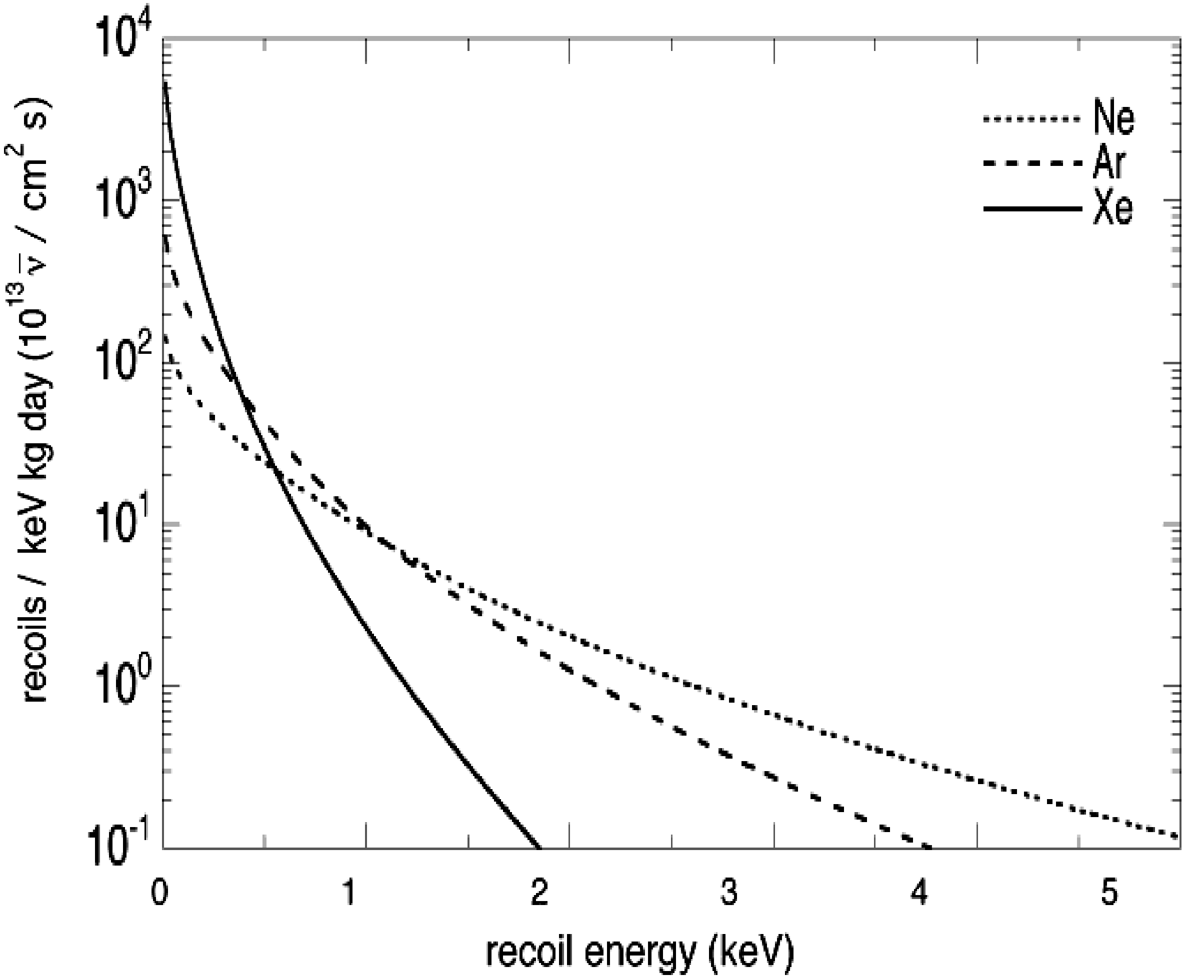
$$p + \overline{\nu}_e \rightarrow e^+ + n$$

D.Z. Freedman, D.N. Schramm, and D.L. Tubbs. Ann. Rev. Nucl. Part. Sci. 27 (1977) 167

But Small recoil energies

$$< E_{\text{recoil}} > \; = \; 716\,\text{eV}\,\frac{E_\nu^2(\text{MeV})}{A}$$

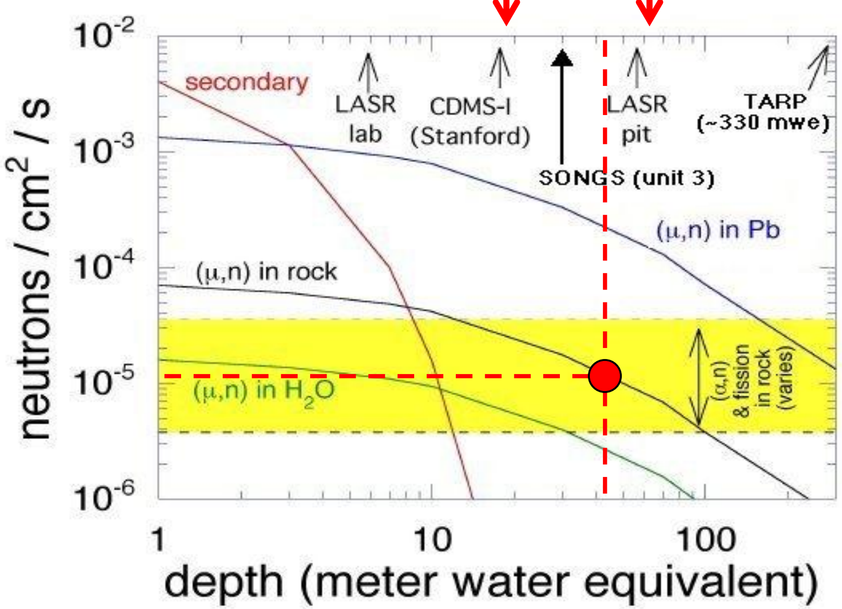


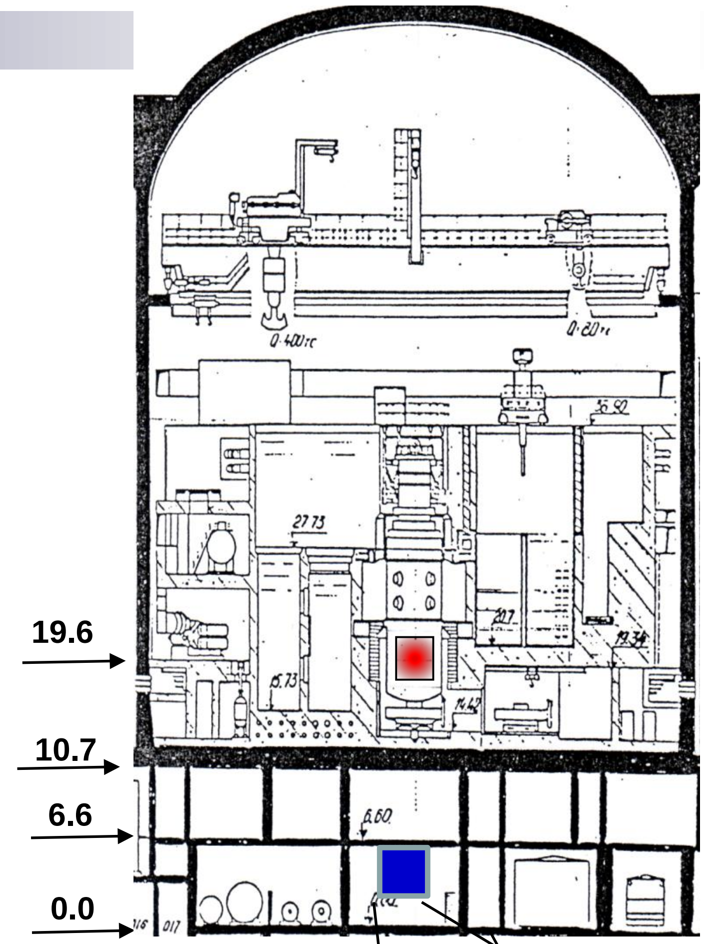


P. S. Barbeau, J. I. Collar, J. Miyamoto, and I. Shipsey Toward coherent neutrino detection using low-background micropattern gas detectors, IEEE TNS 50 (2003) 1285 - 1289

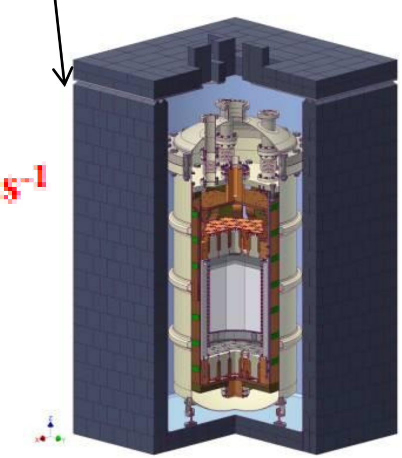
Kalinin Nuclear Power Plant

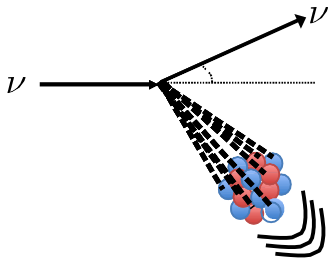
Cosmogenic neutron flux

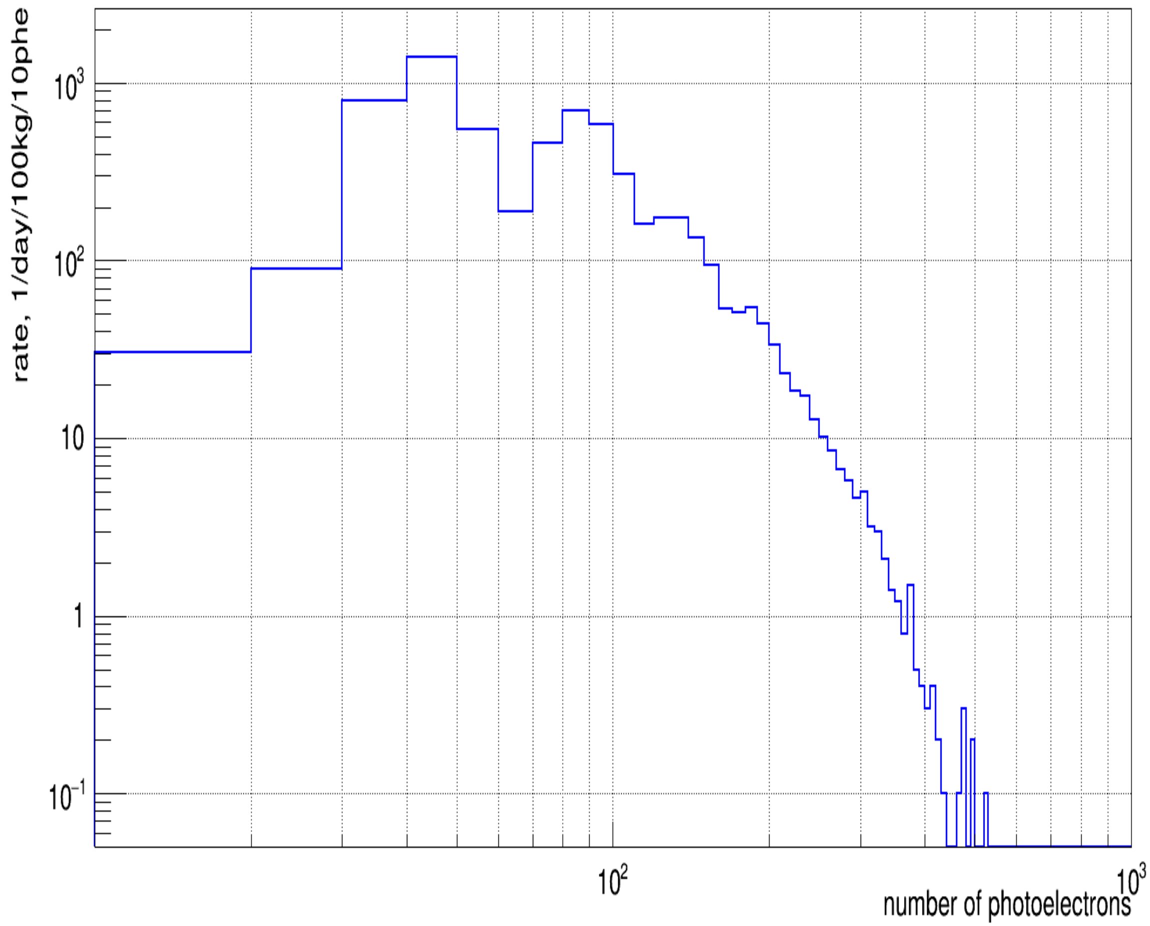




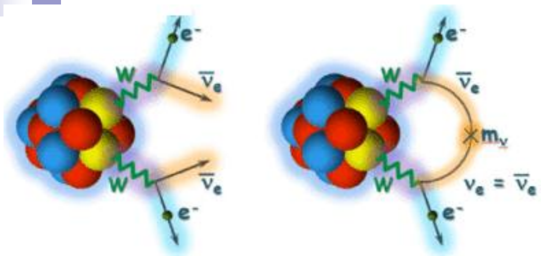
$\bar{\nu}_e$: $1.35 \cdot 10^{13}$ $cm^{-2}s^{-1}$



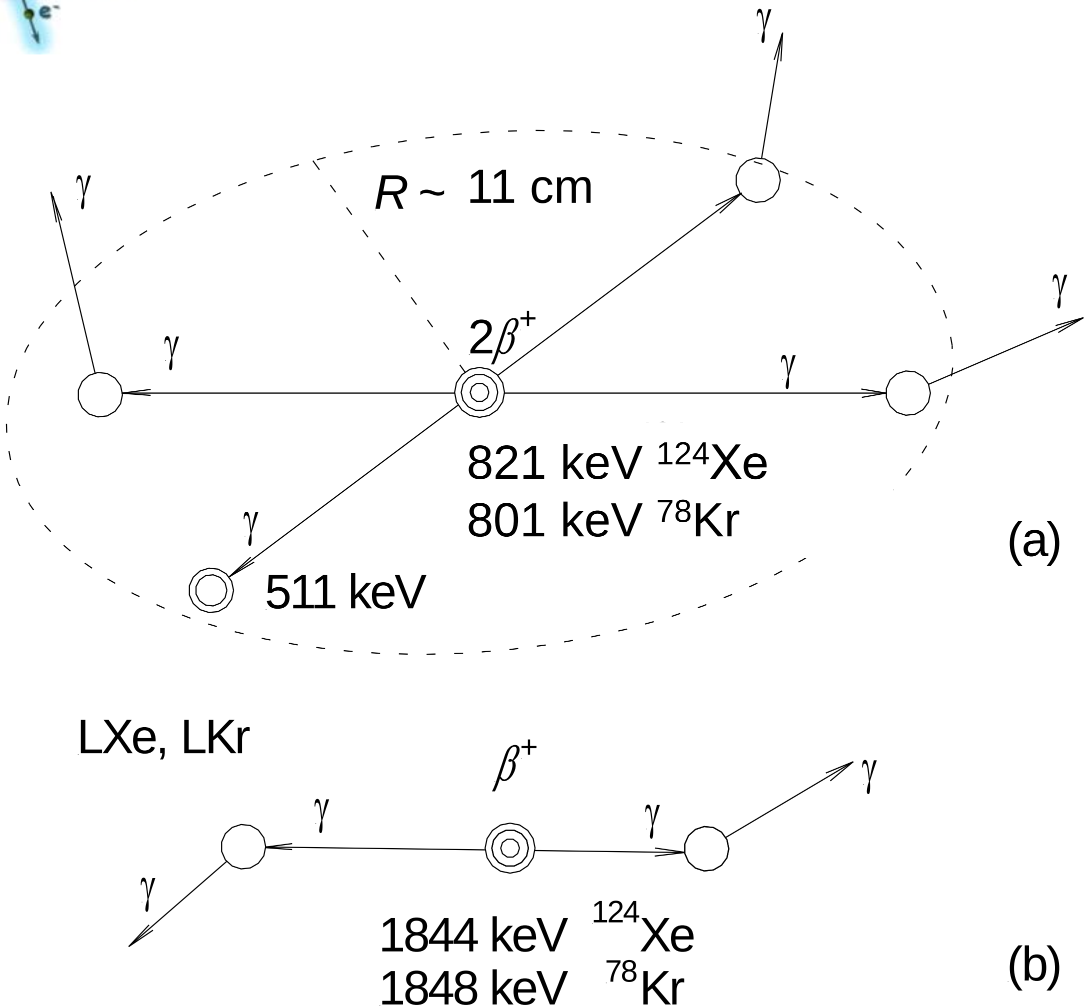




Monte Carlo simulated signal in the RED-100 detector expected for the flux of the reactor antineutrino of $1.35 \cdot 10^{13}$ cm^{-2}s^{-1}



There is a new possibility to search for double positron decay of ^{124}*Xe* & ^{78}*Kr*



A. Bolozdynya V. Egorov, A. Koutchenkov, G. Safronov, G. Smirnov, S. Medved, V. Morgunov An electroluminescence emission detector to search for double-beta positron decays of ^{124}Xe and ^{78}Kr, IEEE Trans. Nucl. Sci., 44 (1997) 1046-1051

Conclusion

1. Two-phase emission detectors proposed at MEPhI 45 years ago is very promising technology to search for low-ionization, rare and topologically complicated events

2. Underground located emission detectors of *G2* generation shall either unambiguously detect WIMPs or rule out current theoretical predictions for WIMP existence. Detectors of the *G3* generation will be used for multiple purposes including detection of double beta neutrinoless decay and Solar neutrinos.

3. Recently constructed RED-100 detector can be used to observe coherent neutrino scattering in 2018-2019 and to search for neutrinoless double positron decay of ^{124}Xe & ^{78}Kr in up ground lab conditions