Processing liquid xenon working medium of the RED-100 detector for setting up an experiment to observe the elastic coherent scattering of nuclear reactor neutrinos off xenon nuclei

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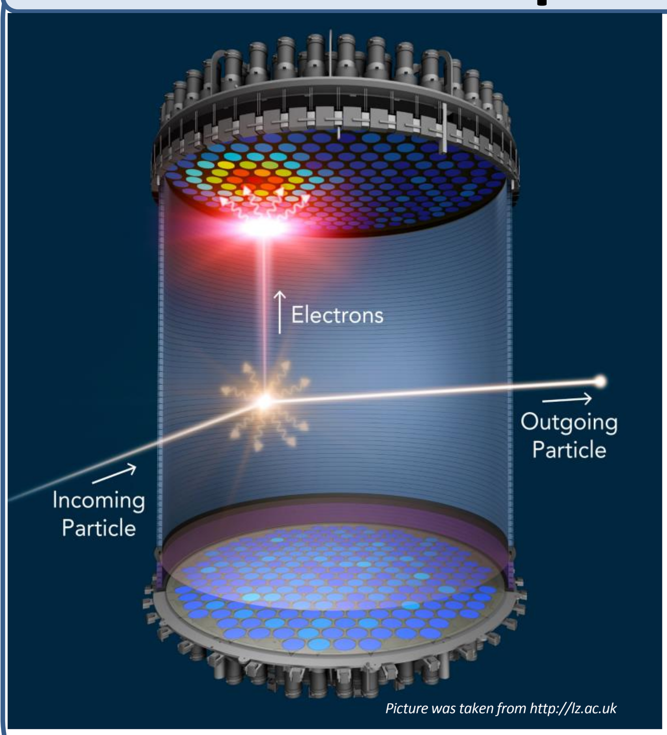
RUSSIAN EMISSION DETECTOR

Two-phase emission detectors



The most sensitive experiments searching for direct WIMPs

- *Provide excellent yield and low detection threshold*
- *Scalable*
- *High LXe density, large Z*
- *Good scintillation characteristics*
- *Low intrinsic radioactivity*

The multi-ton detectors of this type are proposed:

- DARWIN (~50t)
- XENONnT (~8t)
- PandaX-4T (~6t)

etc…

Basic operating principle:

Neutral particle interaction in LXe can reveal itself by nuclear recoil. The recoil nucleus ionizes Xe atoms and produces a prompt scintillation signal S1. The electrons are pulled upwards by an electric field and extracted into the gas to produce electroluminescence signal S2. Both light signals are detected by PMTs at bottom and top of TPC.

Xenon purity

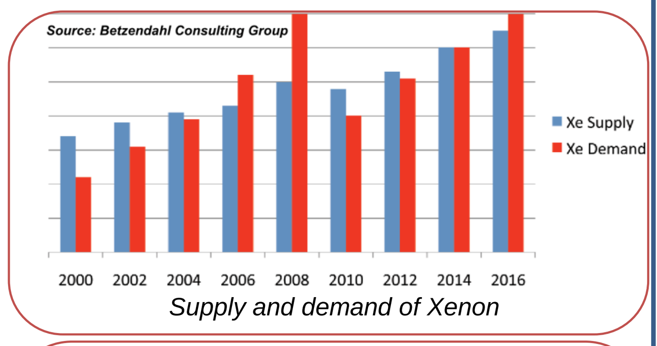
The main issue is to get high purity (<1ppm of impurities) for effective electrons collection

0ν2β Xe experiments use isotopically enriched in gas centrifuges xenon

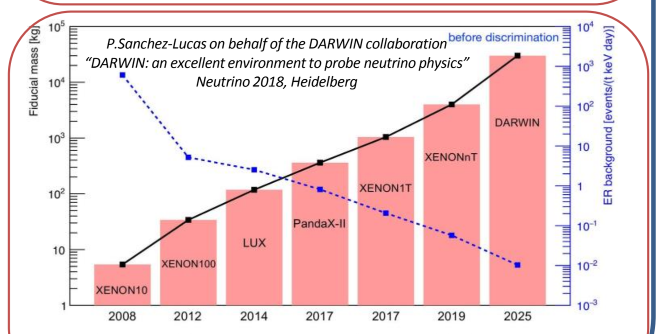
The rapid growth of xenon detectors leads to situation when significant part of Xe distributed between experiments will be subjected to the isotope separation

Xenon after isotopic modification with centrifuges becomes contaminated with high molecular weight lubricants and difficult to purify by hot metal getters, the most popular purification method [1, 2]

An effective technology of Xenon purification is required

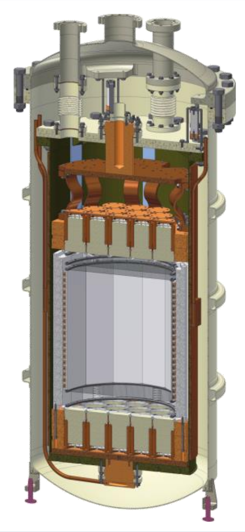


Supply and demand of Xenon



Size and background evolution of dark matter detectors based on dual-phase LXe TPCs.

Purification of ~200kg of xenon for the RED-100 detector

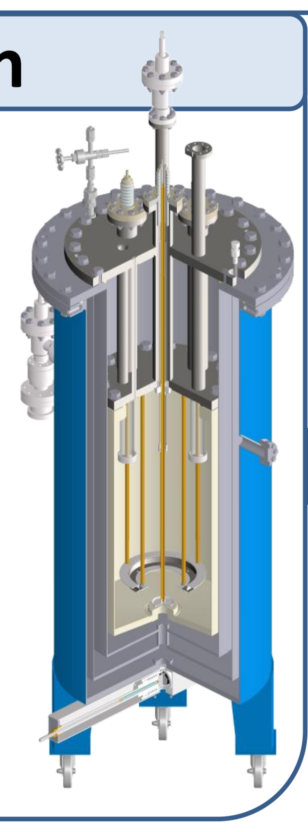


We have successfully applied the described method for purification of ~200 kg xenon used in the RED-100 two-phase emission detector

- RED-100 (Russian Emission Detector, 100 kg of LXe in a fiducial volume) is a two-phase emission detector contains ~ 250 kg of xenon.
- The detector has been built in NRNU MEPhI and proposed to study coherent elastic neutrino-nucleus scattering (CEvNS) at the KNPP (Kalinin Nuclear Power Plant, Russia).
- 38 (2 arrays x 19) Hamamatsu R11410-20 low-background PMTs allow to detect both S1 and S2 signals and reconstruct the track. The special active divider for PMTs allows to work on the Earth surface, suppressing muon flares.

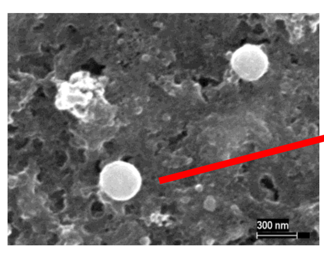
Spark purification

- The spark discharge method for purifying liquid noble gases was invented in 1980 by I. Obodovsky et al. [3].
- The high-voltage discharge between metal electrodes in LXe produces hard UV and generates metal powder from the electrodes. UV disintegrate high molecular weight impurities. The powder surface acts as chemical getter..
- These two processes operating simultaneously competing with each other. UV can decompose impurities bound on the powder surface and contaminate Xe again.

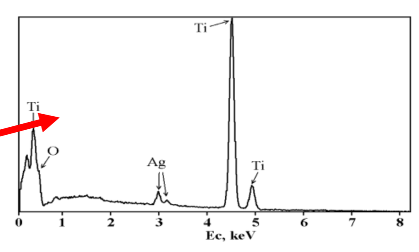


Absorbing impurities by Ti powder

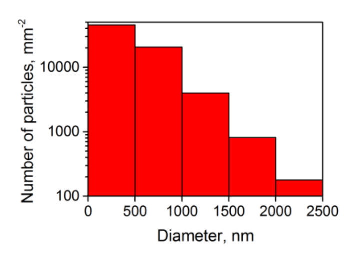
The produced titanium powder continue to absorb impurities after turning off spark discharge. Even more, the purification process become more intensive due to stop of UV radiation.
The powder was analyzed using scanning electron microscope and it was found to have spherical shape with an average diameter less than 0.5 μm



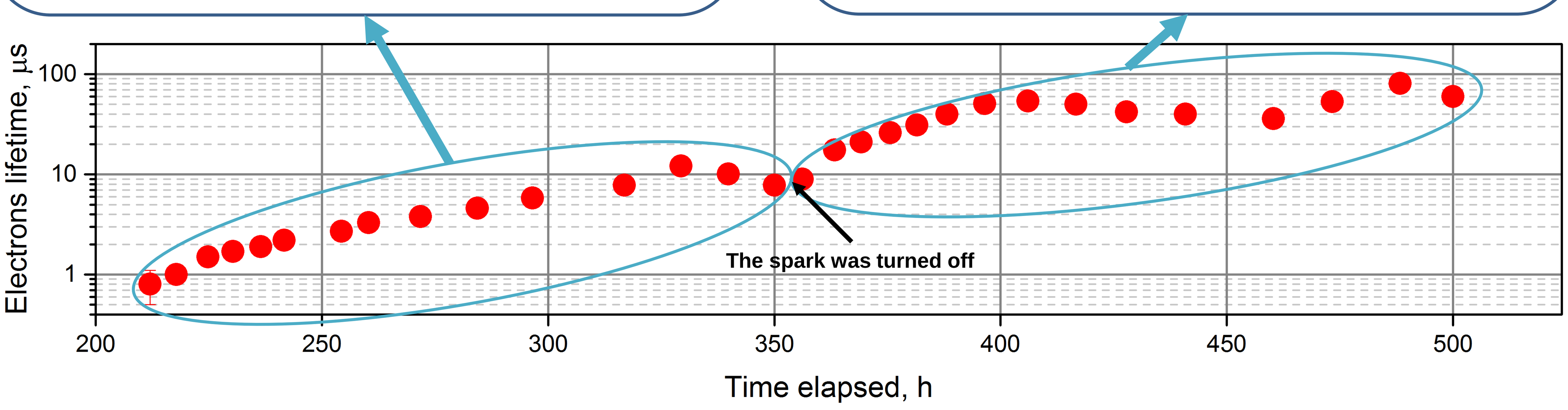
Typical powder particles



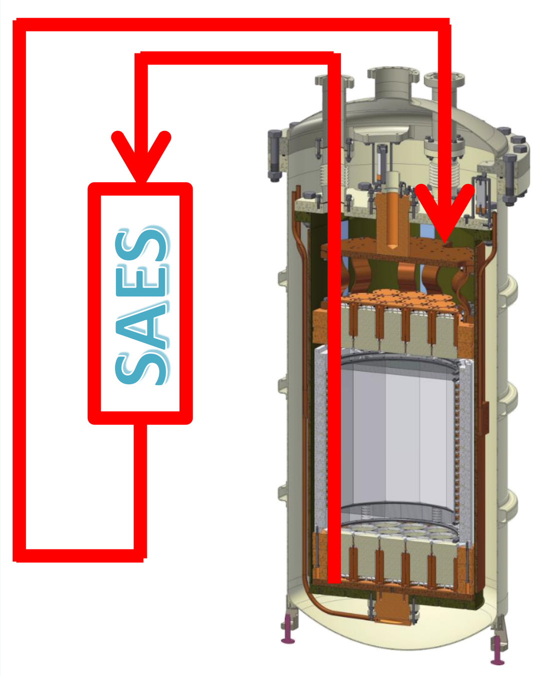
Chemical composition of powder



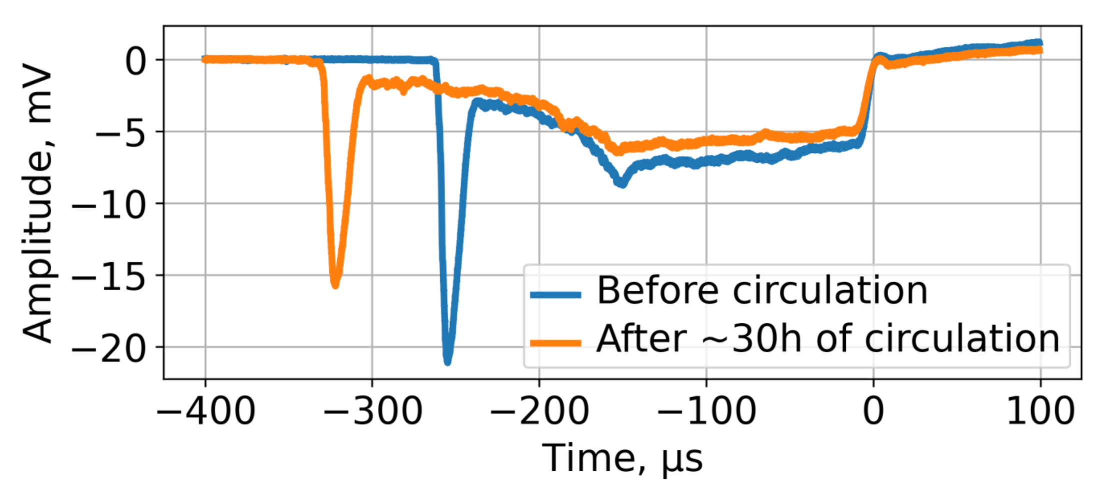
Diameter distribution



Preliminary circulation of Xe

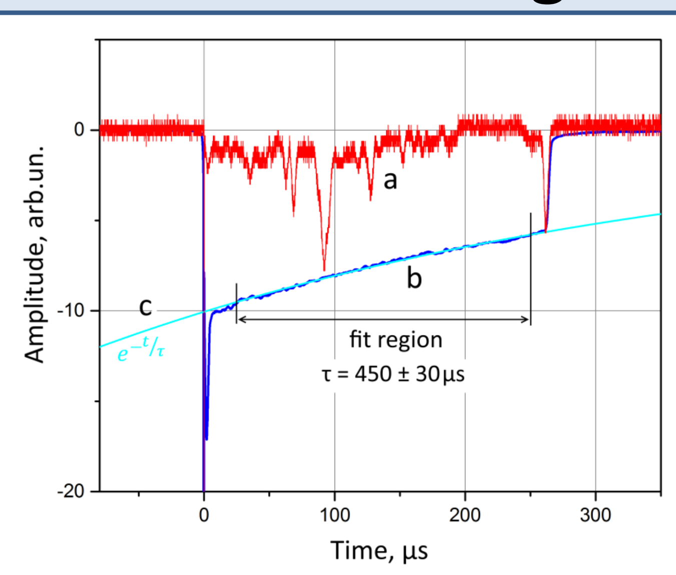


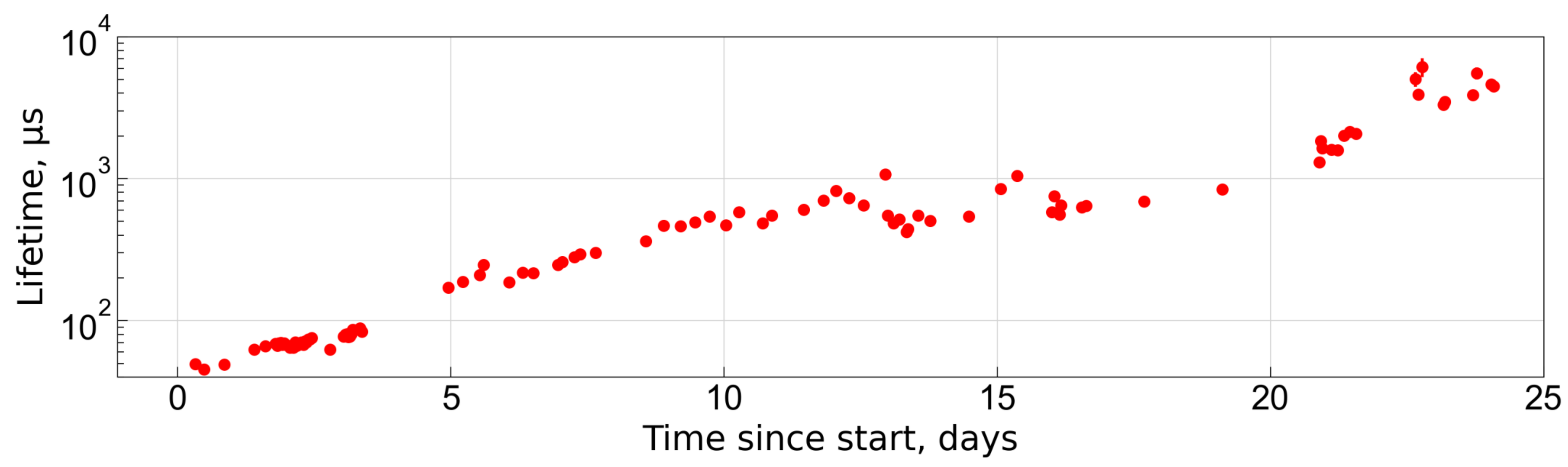
While most of the xenon mass is undergoing to purification by spark discharges, a relatively small amount of gaseous xenon is being circulated continuously through the detector volume and hot metal getter.
This procedure is necessary to remove impurities absorbed on the internal surfaces of the detector and its infrastructure.
The purification process is easiest to control by measuring the drift time of electrons through the drift gap.



Circulation during detector's working mode

The last stage is the circulation of xenon during the operation of the detector.
In the RED-100 detector the circulation was performed during the test run. A special heat exchanger between flows of xenon condensed into the detector (warm and purified xenon) and xenon evaporated from it (cold and "dirty" xenon) has been developed.
The electrons lifetime have been measured by cosmic muons





Conclusion

It was demonstrated that a combined four-stage method could be used to purify Xe from specific impurities appeared due to isotopic separation in gas centrifuges. ~200 kg of xenon for the RED-100 detector has been purified by this method from <1 μs to ~10 ms, so the purity of xenon was improved ~10 thousand times in about 2 months.

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References

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