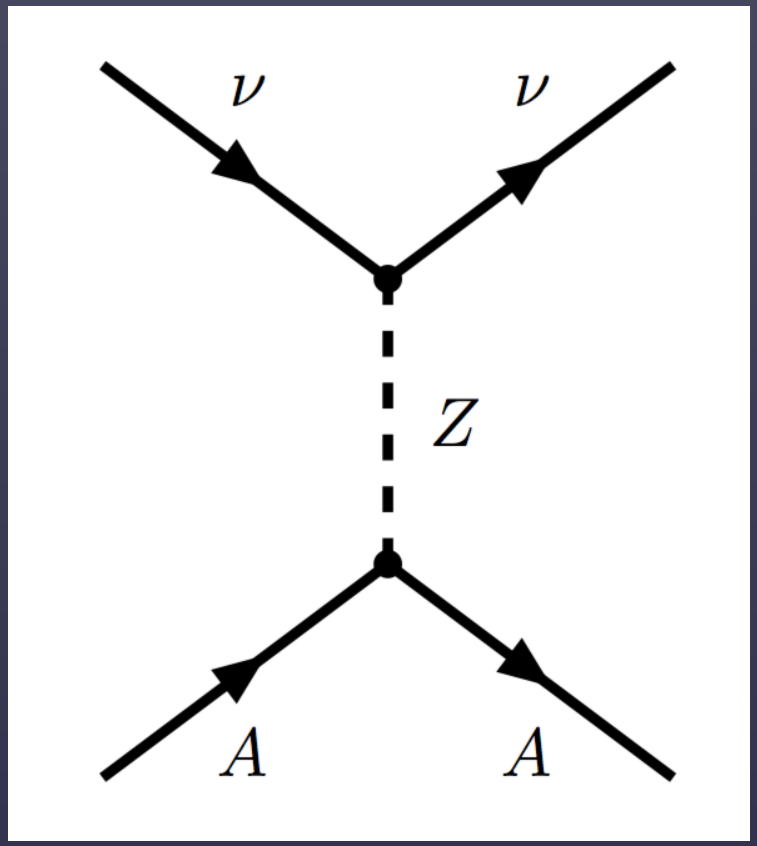
RED-100 experiment for CEvNS study

Ekaterina Kozlova
on behalf of RED collaboration

Coherent elastic neutrino-nucleus scattering (CEvNS)



The differential cross section is described by formula:

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

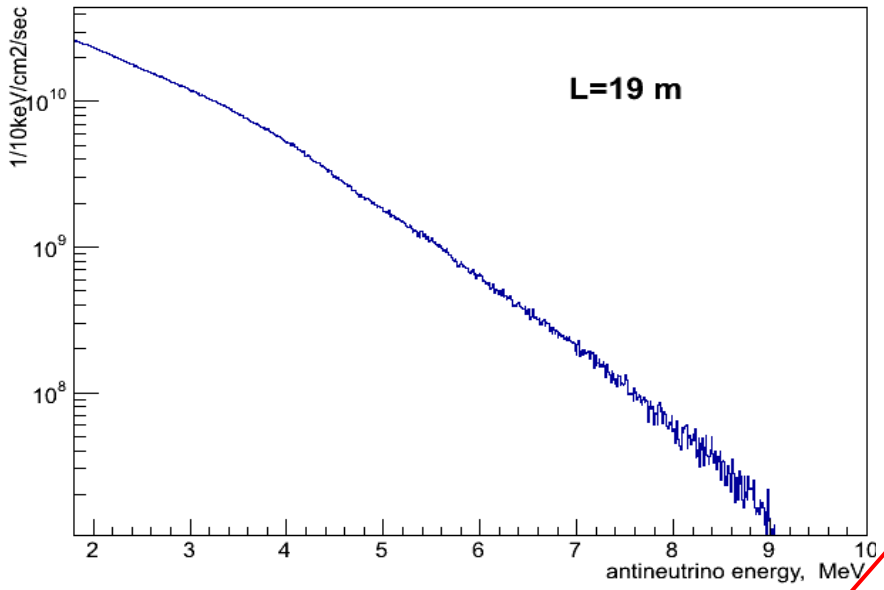
where G_F is Fermi constant
$F(Q^2)$ is nuclear formfactor
Q is four-momentum
$Q_W = N - (1 - 4\sin^2(\vartheta_W))*Z$ is a weak charge of nucleus with N neutrons and Z protons
ϑ_W is Weinberg angle.

$\sin^2(\vartheta_W) \approx 0.25$, $\sigma \sim N^2$ => for heavy nuclei (Xe, Cs, I) $\langle\sigma\rangle \approx 7 \cdot 10^{-41}$ cm^2 averaged over the energy spectrum of reactor antineutrinos.

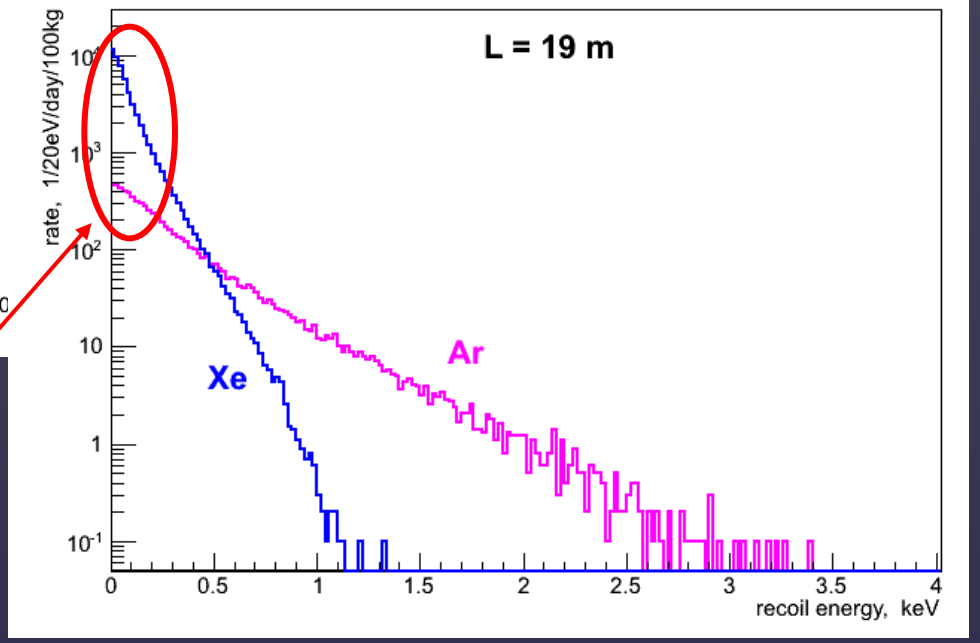
Effect was discovered by COHERENT collaboration in 2017 (DOI: 10.1126/science.aao0990)

CEvNS and nuclear reactor

$\widetilde{\upsilon_e}$spectrum from nuclear reactor

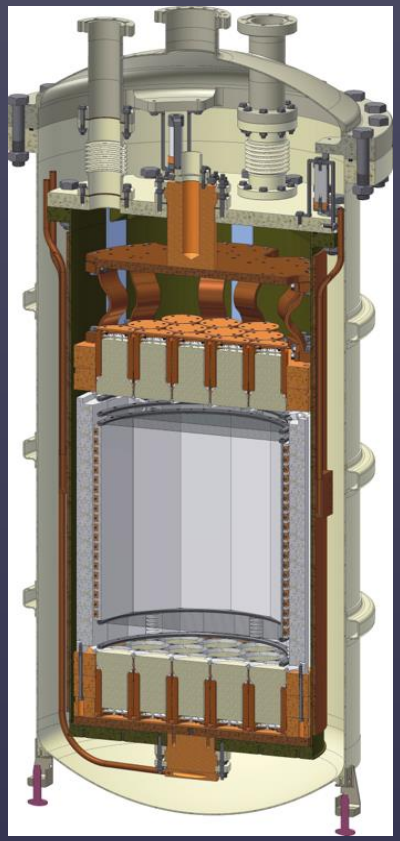


Xe and Ar nuclear recoil spectrum

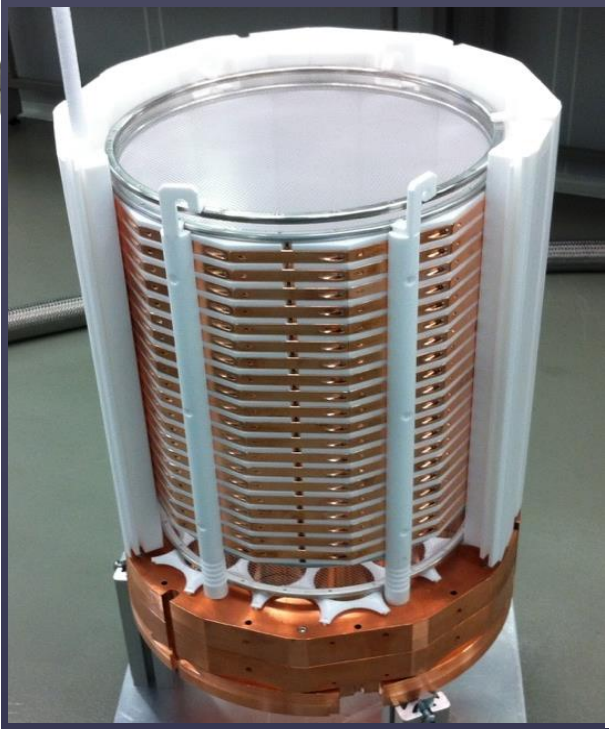


Few ionization electrons

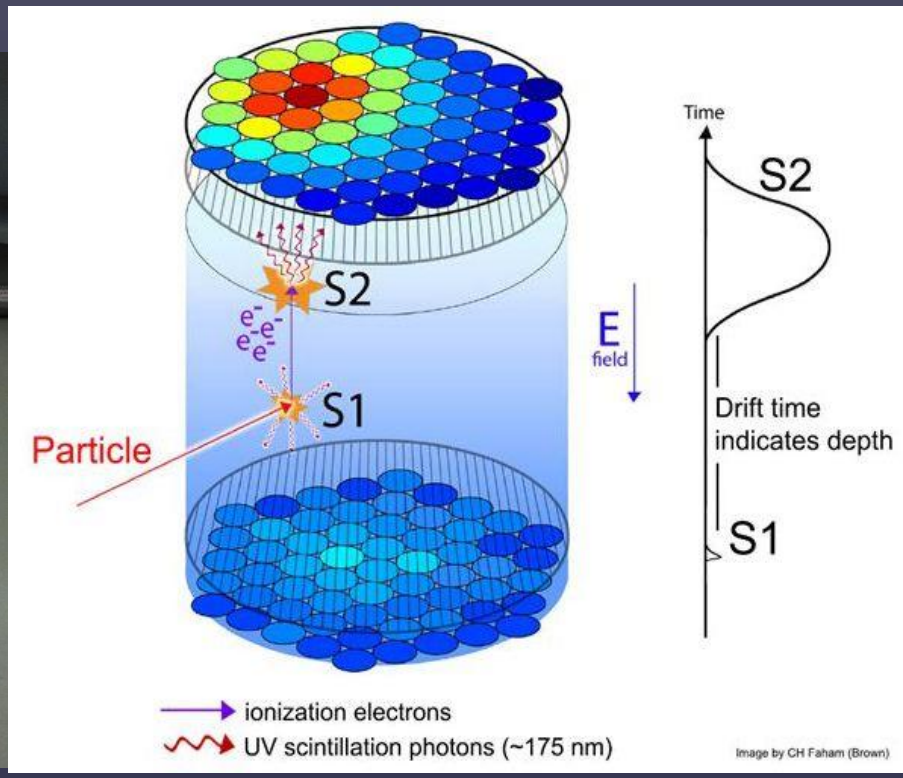
RED-100 detector @ ENPL MEPhI



a



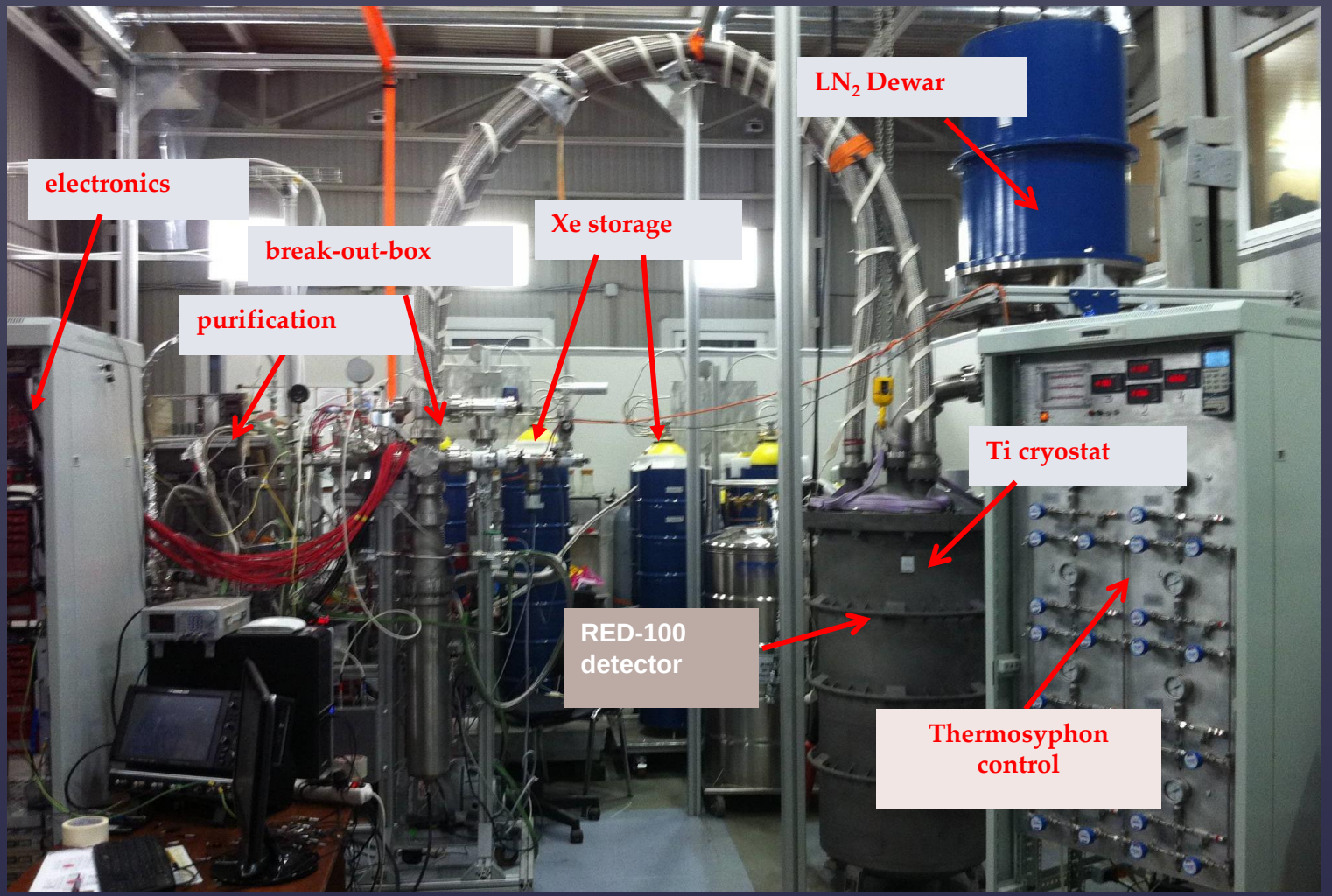
b



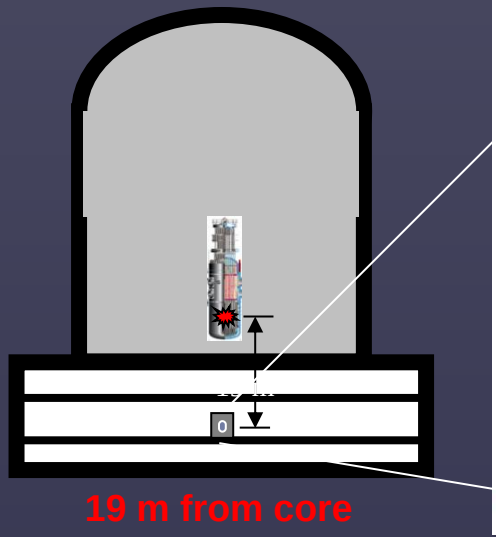
c

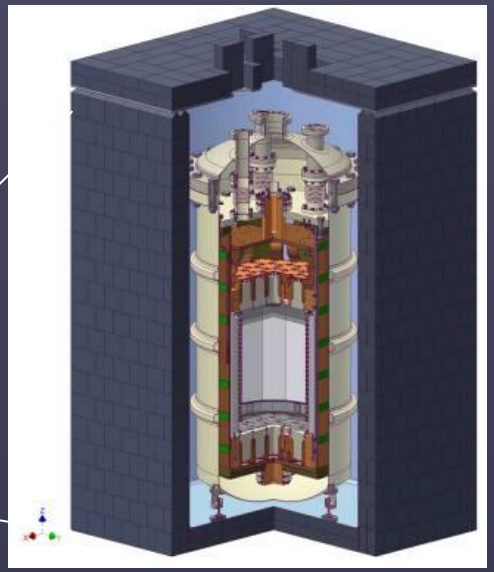
(a)Schematic view of RED-100,(b)photo of internal design, (c)working principle of two-phase detectors

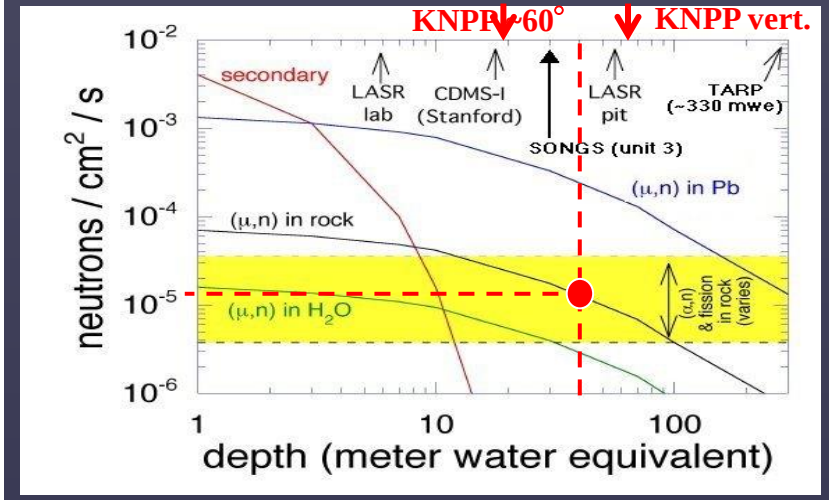
RED-100 detector @ ENPL MEPhI



RED-100 at Kalinin Nuclear Power Plant

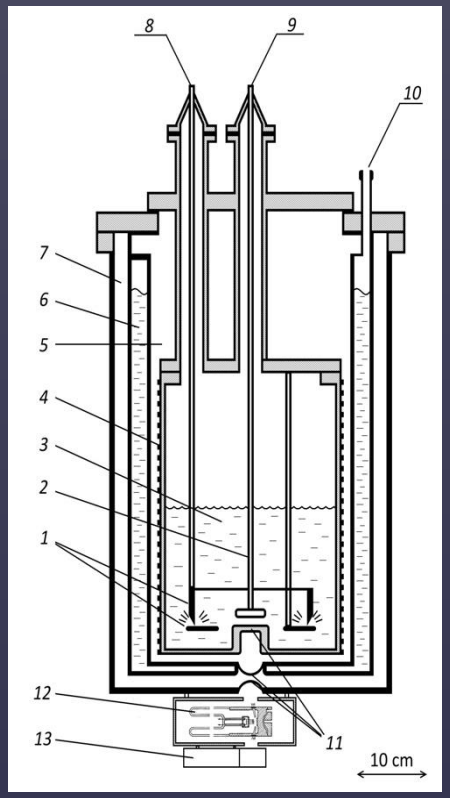


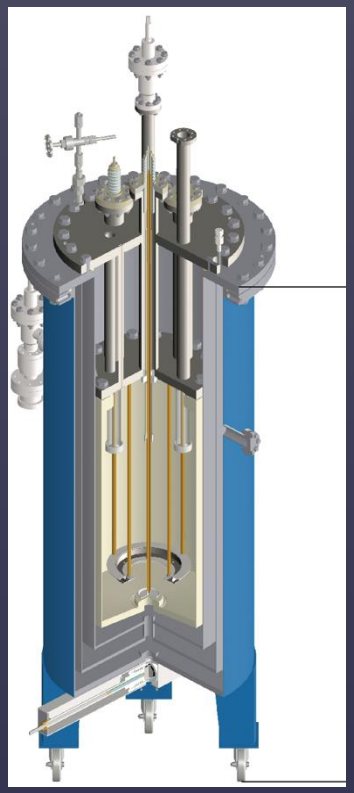


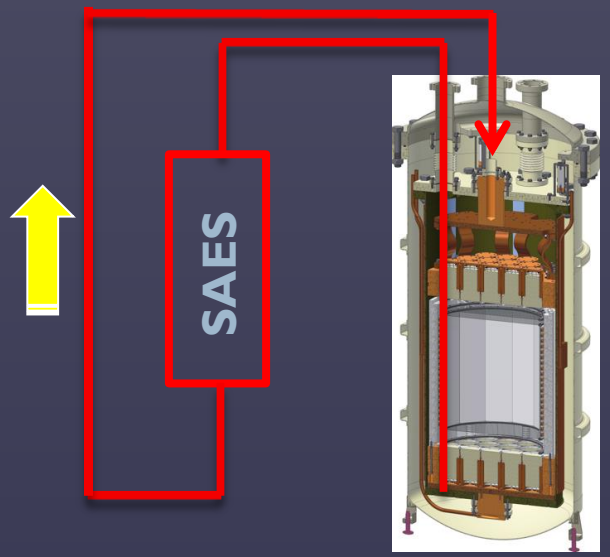


- Building and reactor itself would be a good shield from cosmic rays
- Aprx. shield is 50 m.w.e.
- Thousands of events per day depending on threshold
- Detector will have additional Pb and water shield
- JINST 12 (2017) no.06, C06018

Xenon purification



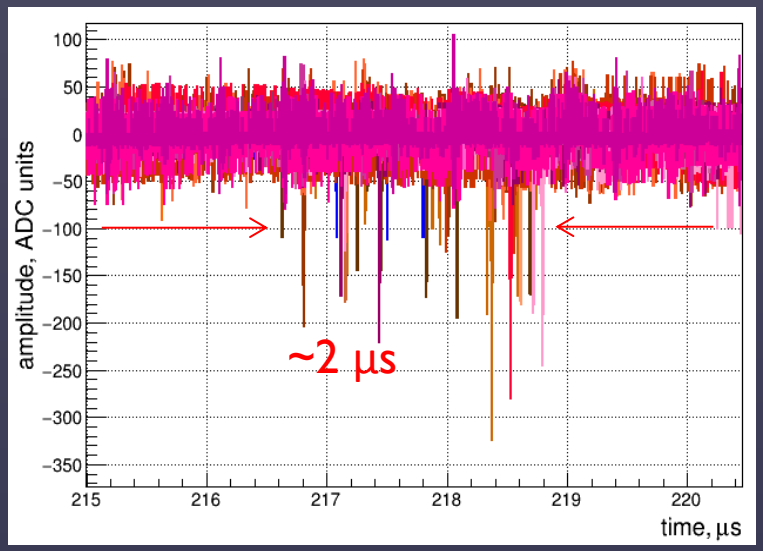




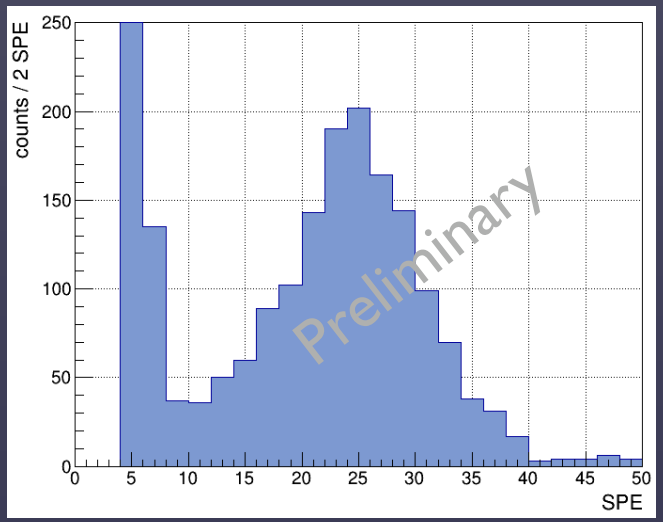
- Mojdodyr is based the spark discharge technology
- During the first engineering run electron lifetime ~450 μs was obtained (2018)
- Instrum Exp Tech (2017) 60: 782.

First engineering run (March – April 2018)

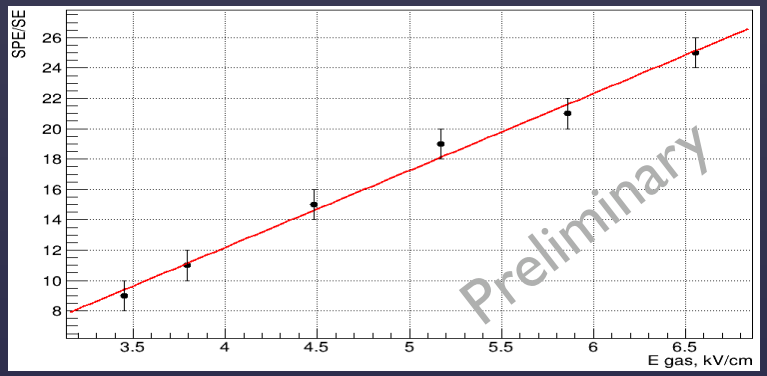
Example waveform of SE :



SE spectrum:



SPE/SE vs electric field in EL region:

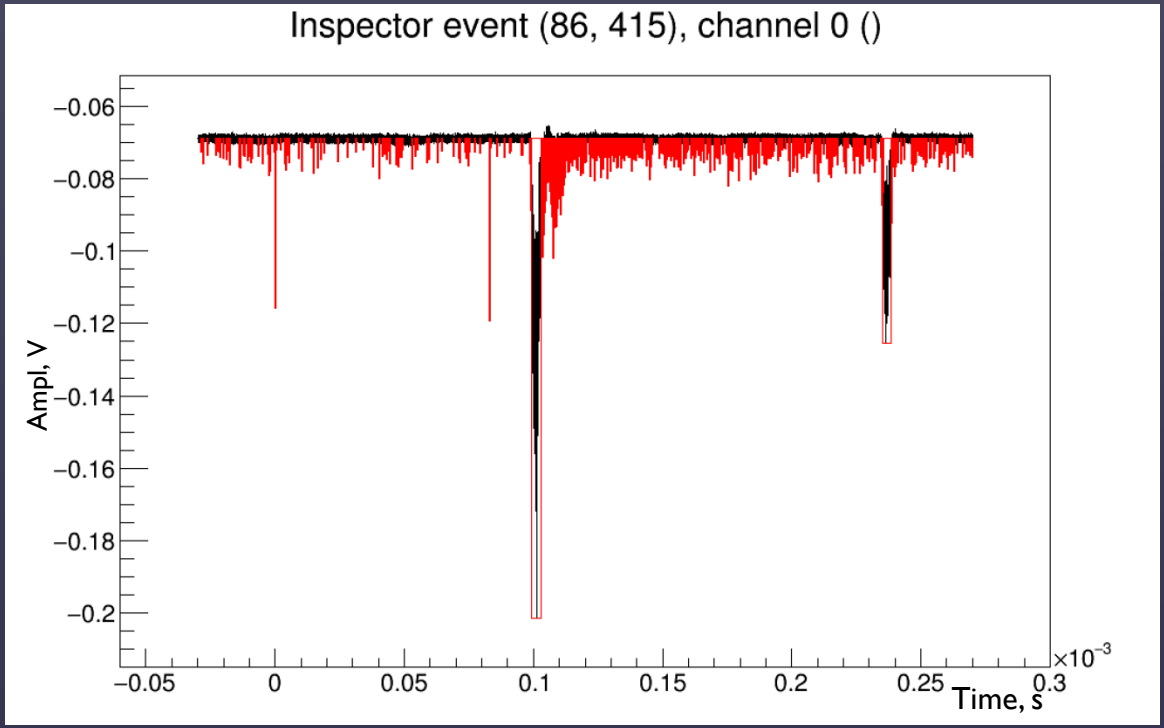


Two-phase detector has the possibility to measure such low-energy signals as 1 SE

More info about SE nature:

- arXiv:1904.02885
- Instrum.Exp.Tech. 55 (2012) 423-428

SE background



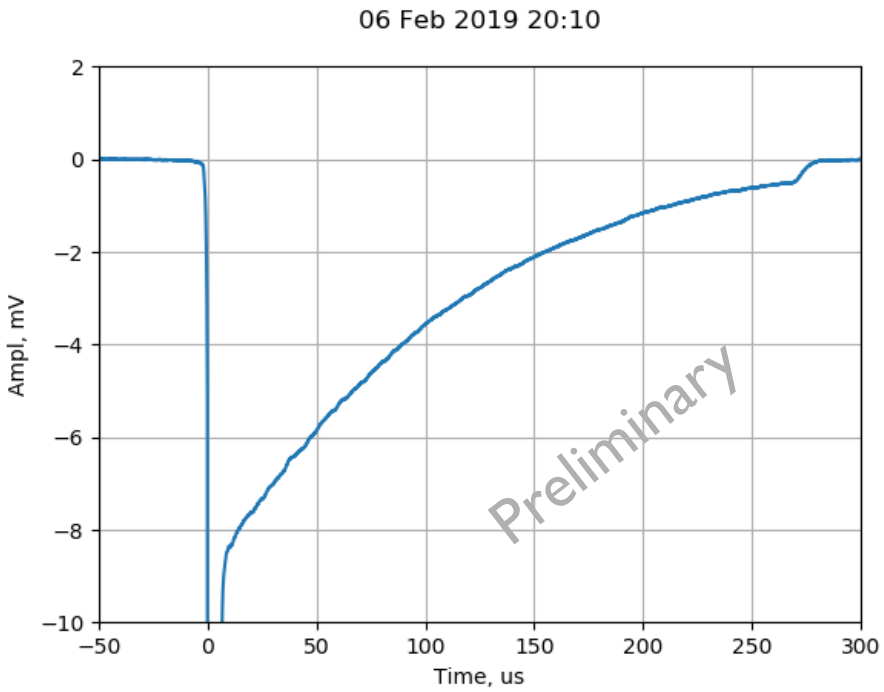
- SE signals - background for our purposes
- Main reason – emission of delayed under-surface electrons
- Solution – «electron shutter»
- **JINST 11 (2016) no.03, C03007**

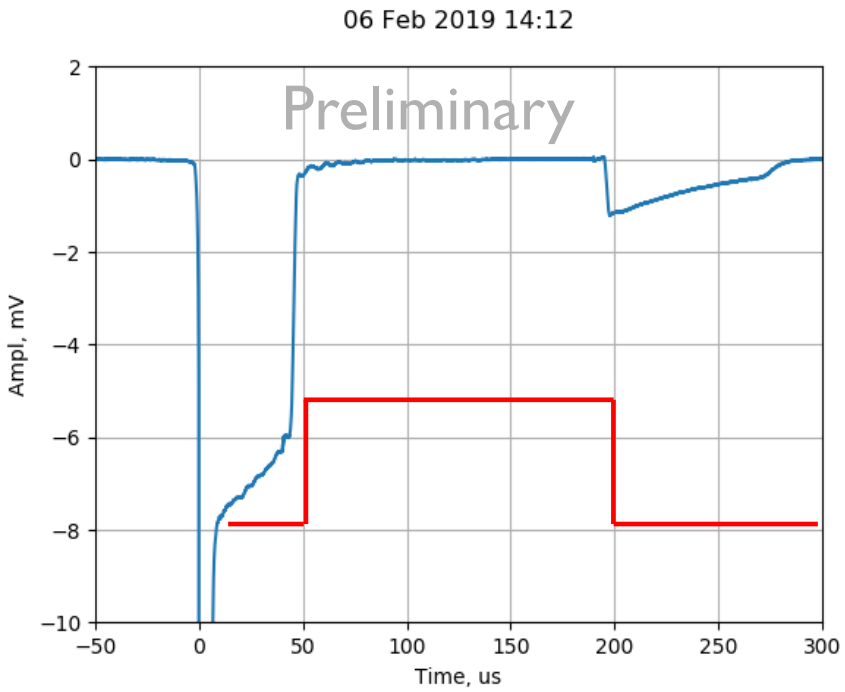
Second engineering run

- Second engineering run was performed during February 2019 in ENPL MEPhI
- Main goals of run:
  - Test the new «electron shutter»
  - Calibrate the detector with gamma-sources (Co-60, Na-22)

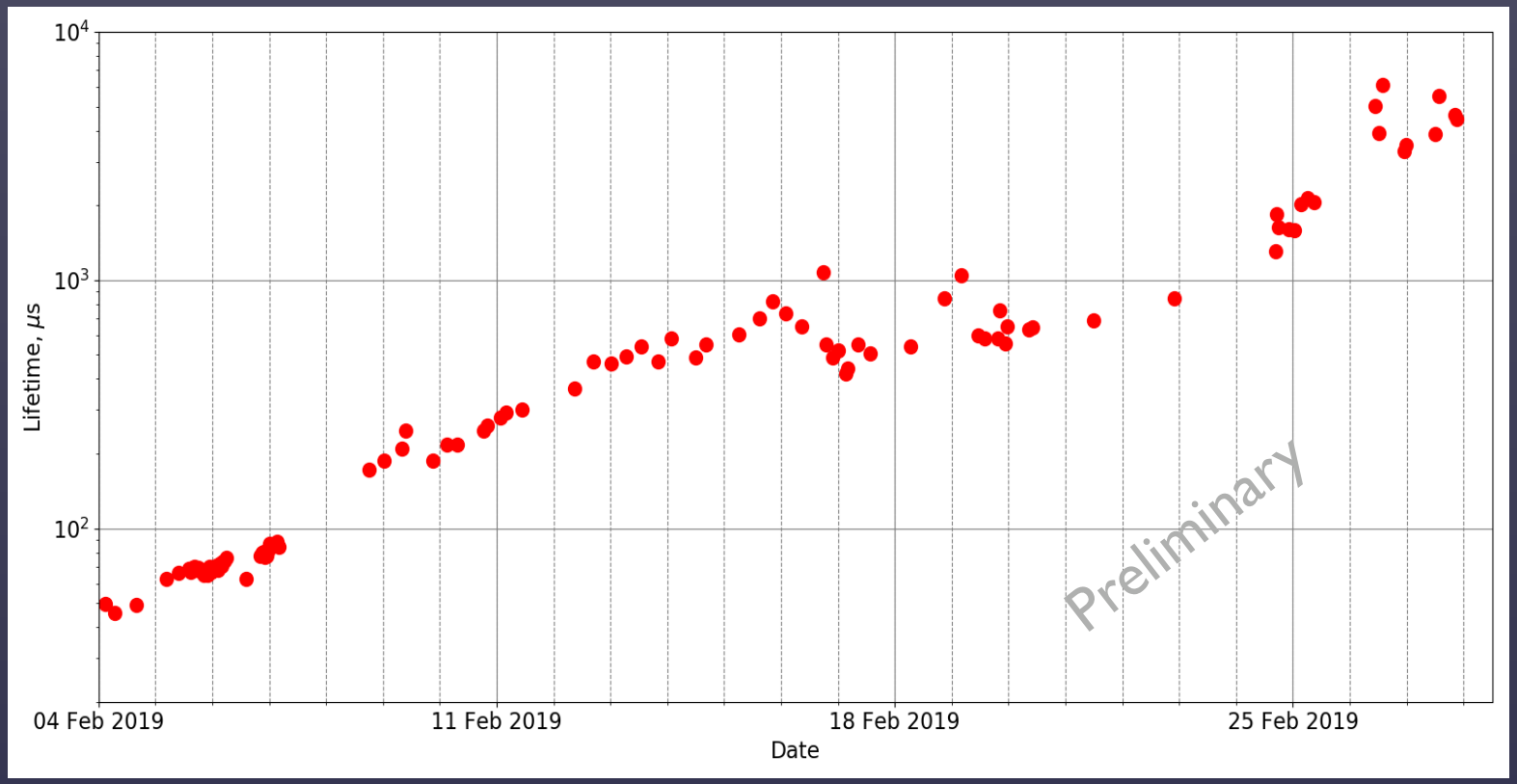
Electron shutter

- Electron shutter was developed for minimizing SE noise
- Collecting ionization electrons after high-energy signals
- Patent RU184222U1 was obtained



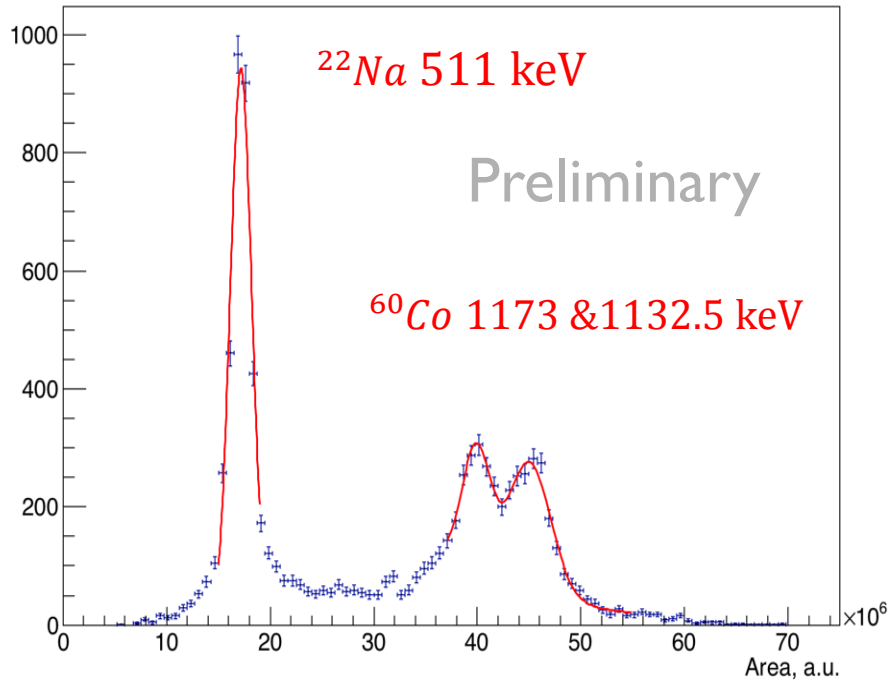


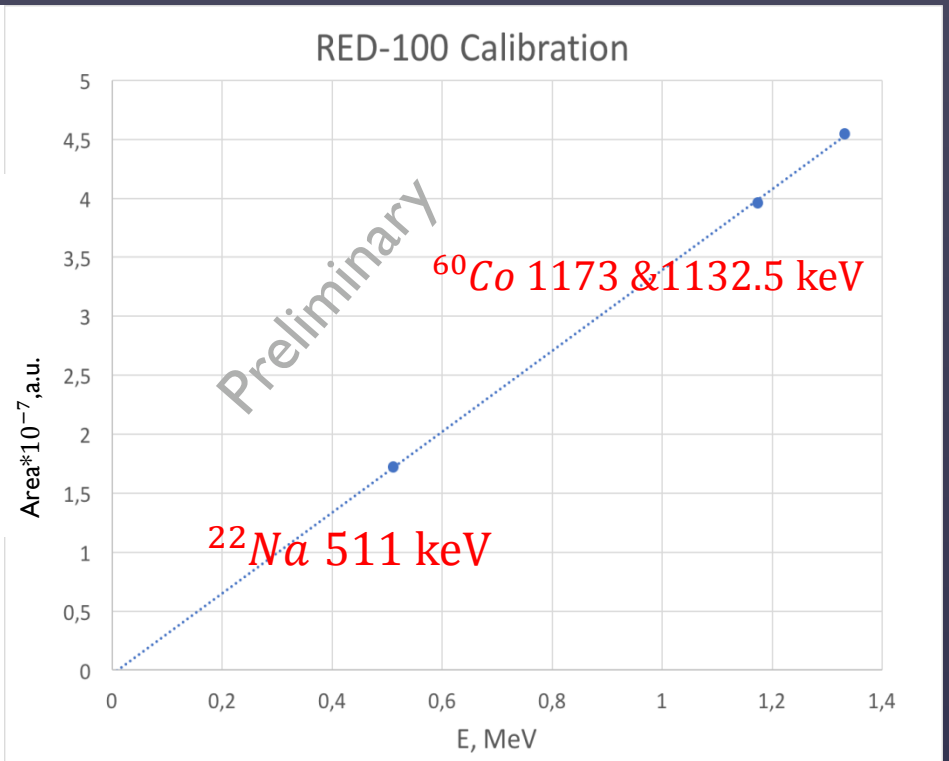
Electron lifetime during run



- Lifetime at the end of the run: > few ms
- And it was achieved after month of work
- For two-phase detectors lifetime is near ~1000 μs

Gamma preliminary calibration





- Calibration sources (Na-22, Co-60) were placed outside cryostat

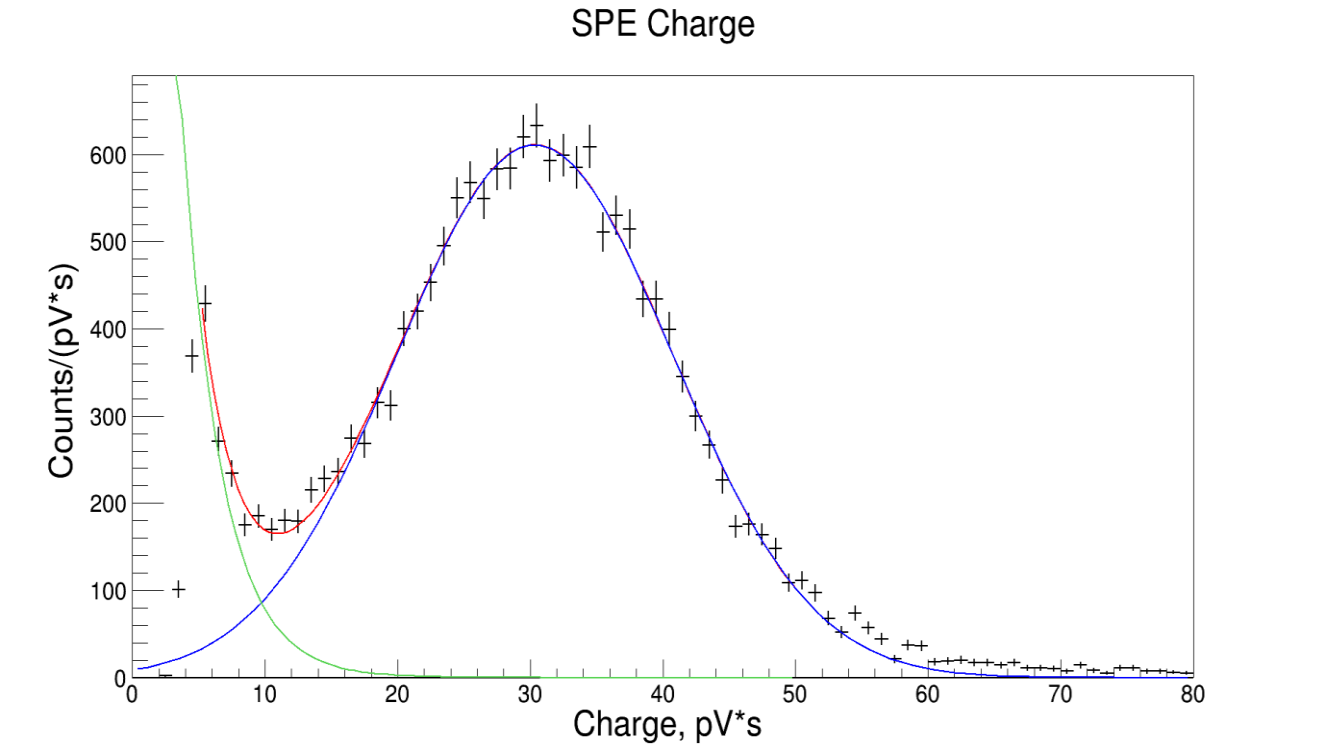
Conclusion

- Two-phase liquid xenon detector RED-100 was assembled and tested
- Record electron lifetime > few ms
- RED-100 is sensitive to single electron signals
- Gamma calibration was performed
- RED-100 is ready for shipment and installation @ KNPP for CEvNS observation

Thank you for your attention!

Backup slides

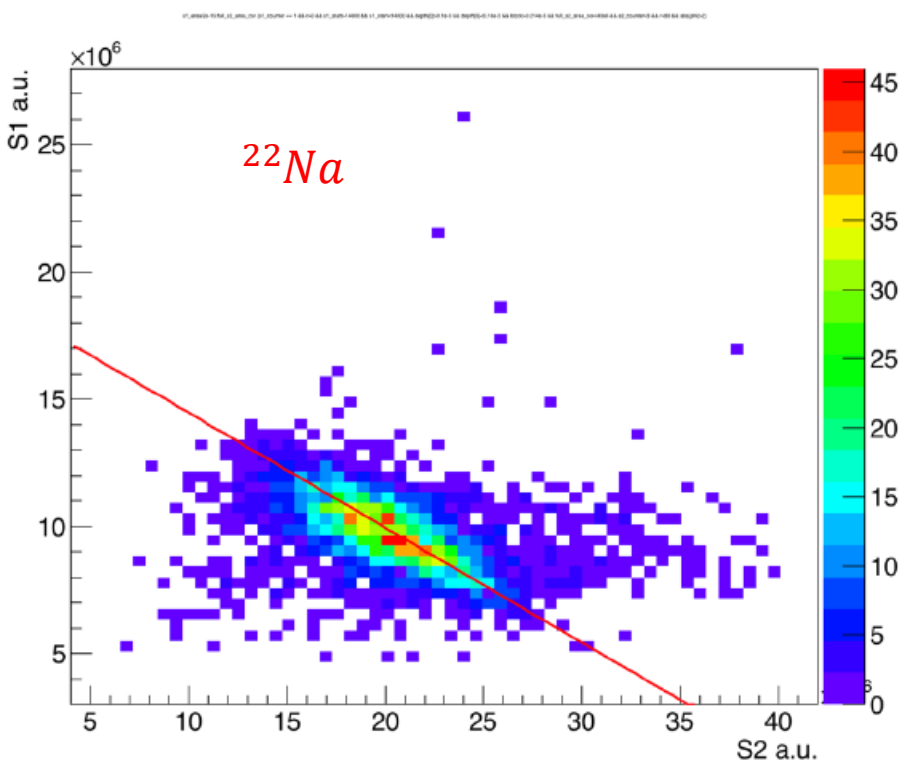
PMT calibration

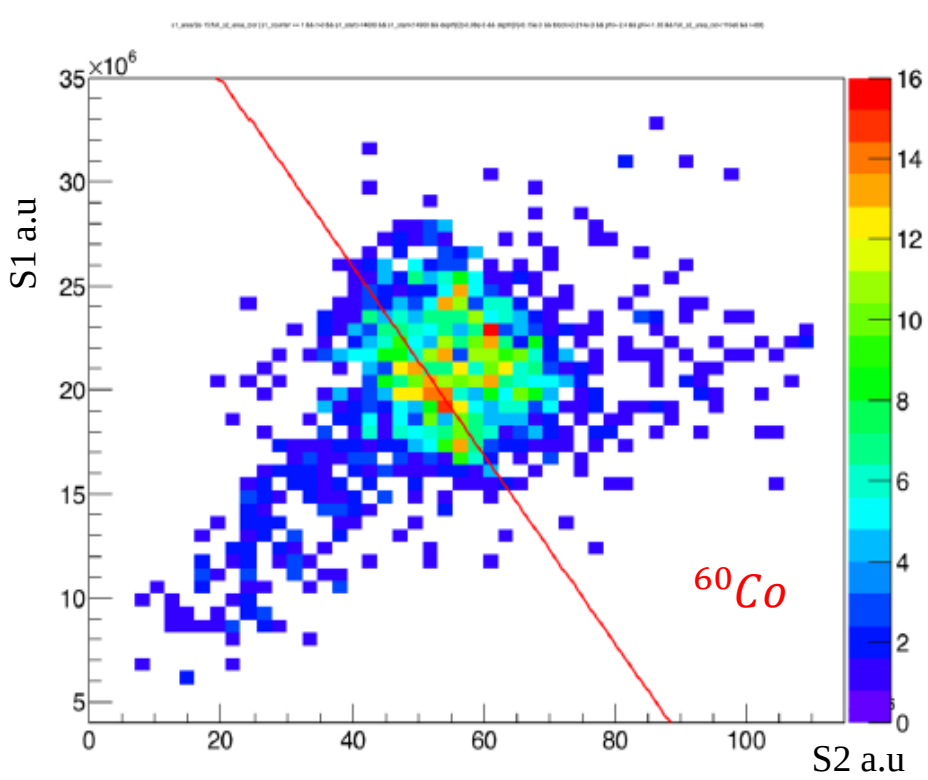


SPE calibration for each PMT was performed

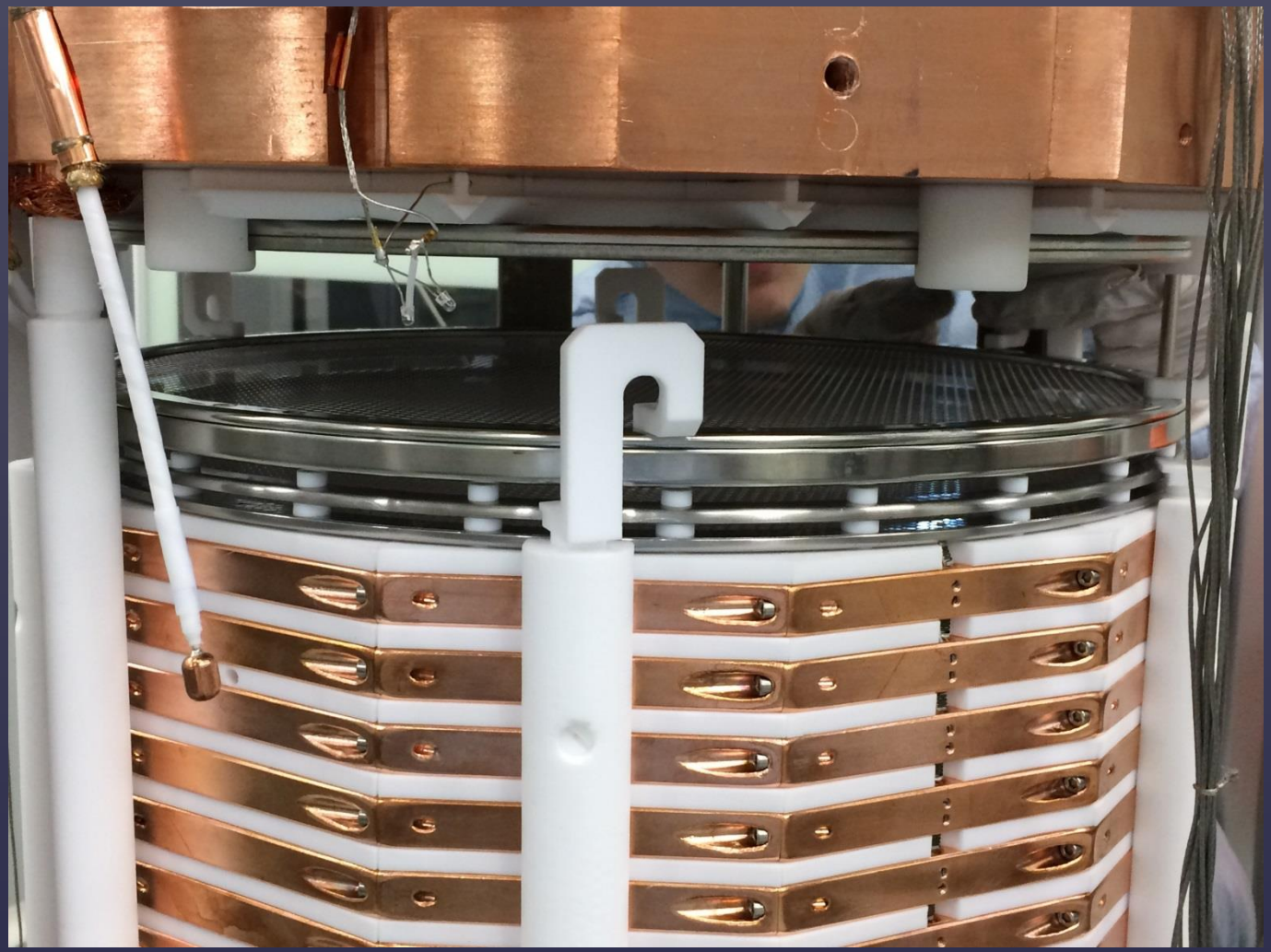
Charge spectrum for PMT

Gamma calibration - anticorrelation





Electron shutter



Electron shutter

Electron noise