

Data analysis of the first physical run and calibration of the RED-100 detector

Olga Razuvaeva on behalf of the RED-100 collaboration

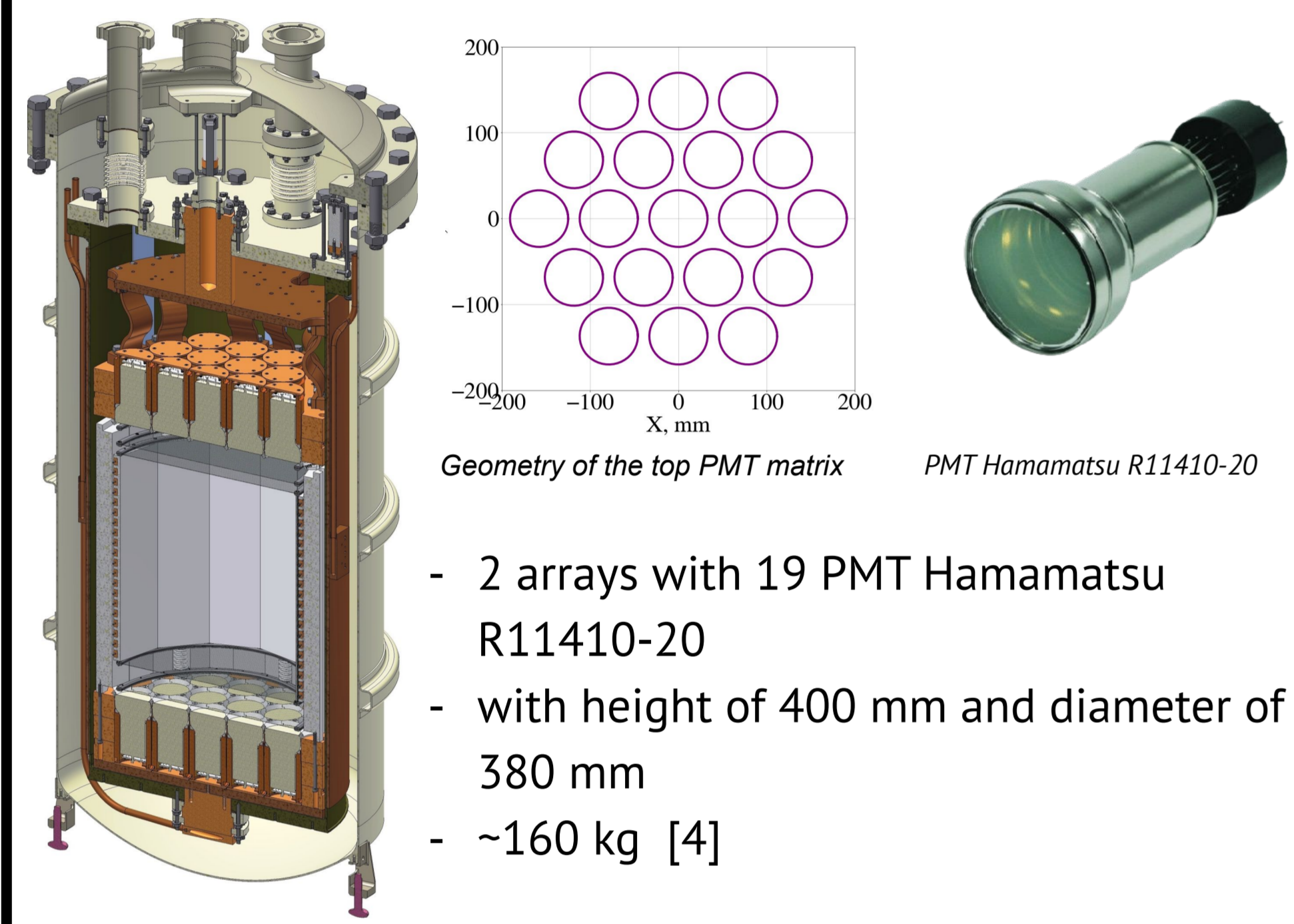
This poster is dedicated to methods used in the analysis. For preliminary results see poster by Dmitry Rudik "First results of the RED-100 experiment for the CEvNS search in close vicinity of the reactor core"

Coherent elastic neutrino-nucleus scattering

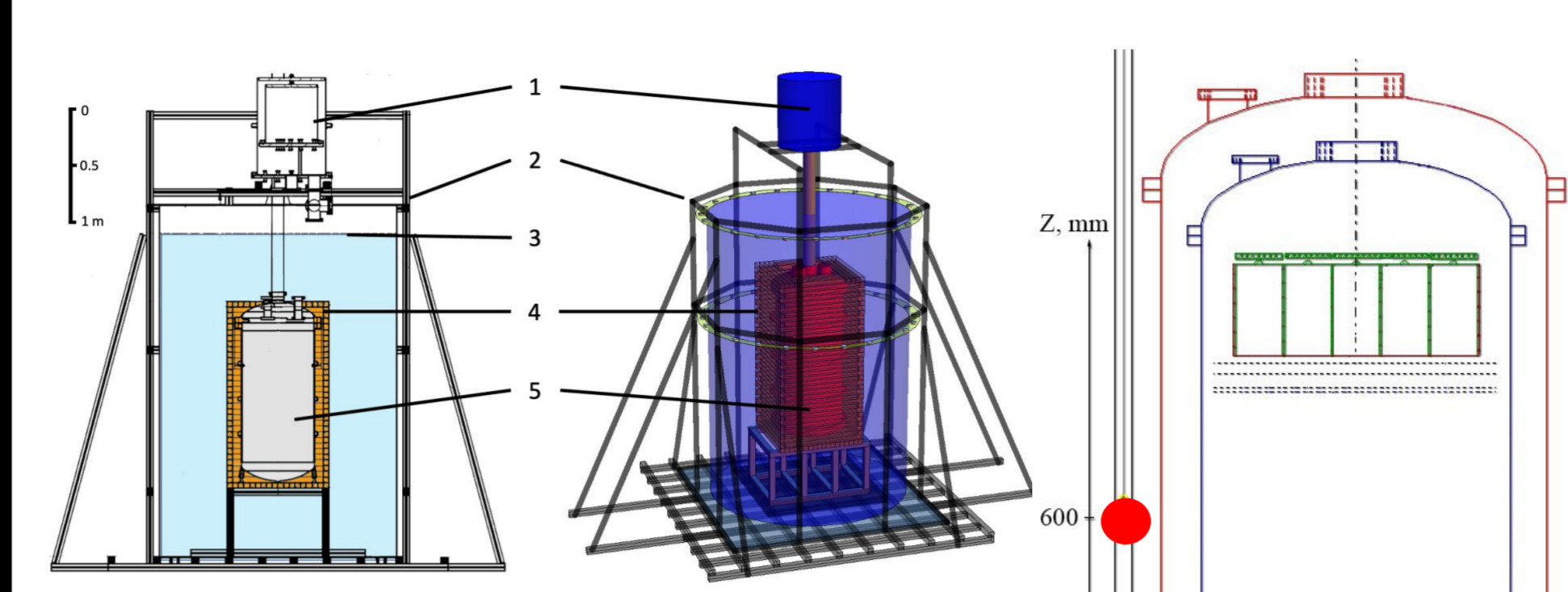
- predicted by Standard Model [1,2]
- very low energy (in keV range) of recoil nucleus
- first observed in 2017 by COHERENT [3]

RED-100 detector construction

- designed in order to study coherent elastic scattering of reactor electron antineutrinos off xenon atomic nuclei
- two-phase Xe emission detector
- sensitive to single ionization electron (SE)



RED-100 experiment at KNPP



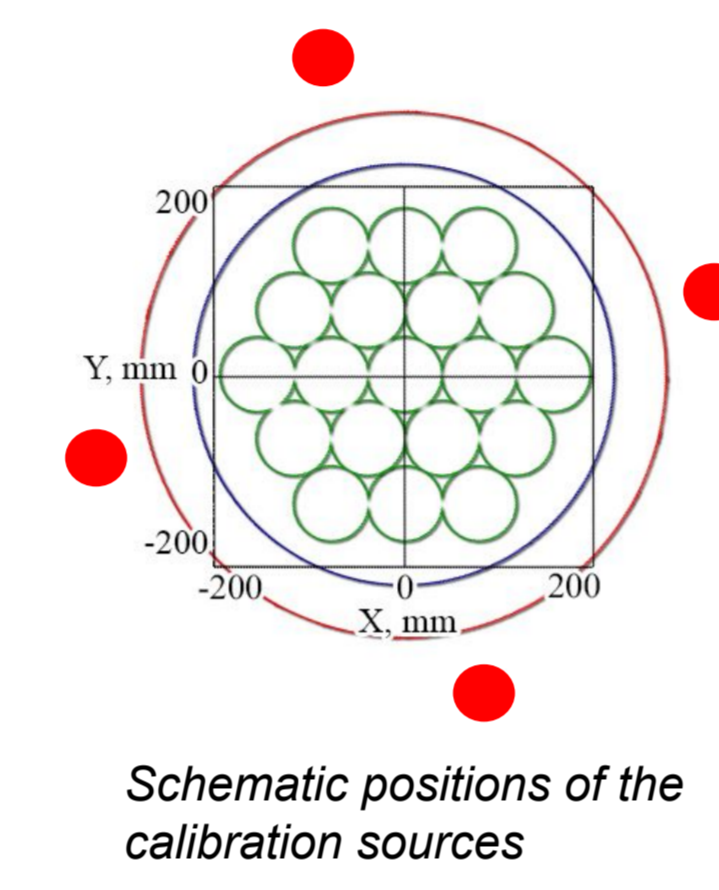
Design of the RED 100 passive shielding, 1—thermosphon, 2— support frame, 3— water tank, 4— Cu shielding, 5— Ti cryostat of the RED-100

KNPP WWER-1000 reactor:

- thermal power ~3000MW
- reactor off and reactor on periods

RED-100 experiment construction

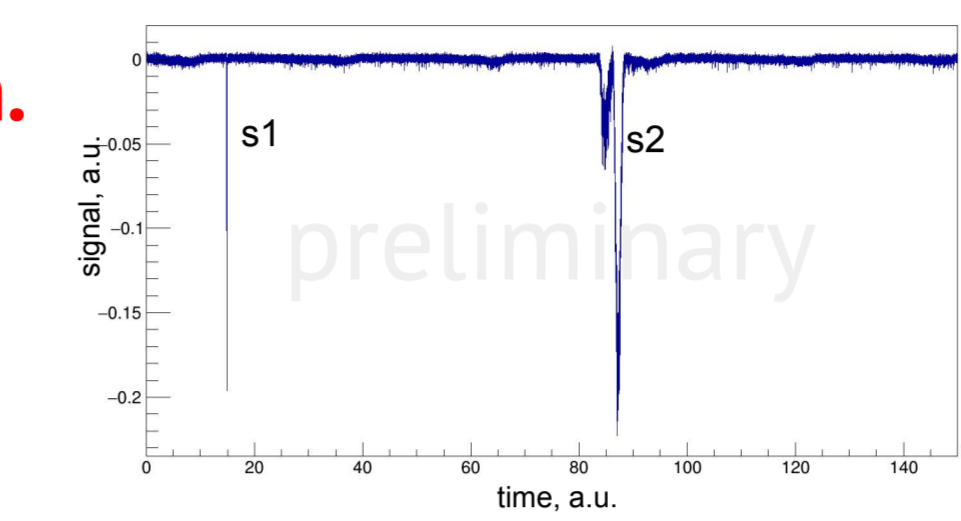
- 19 meters from the reactor core
- reactor and reactor building&infrastructure as a passive shielding from muons
- water tank as a passive shielding from neutrons
- Cu as a passive shielding from gamma sources (thickness 5 cm)
- calibration with ^{60}Co and ^{137}Cs gamma sources



Calibration analysis. Data processing. Event selection.

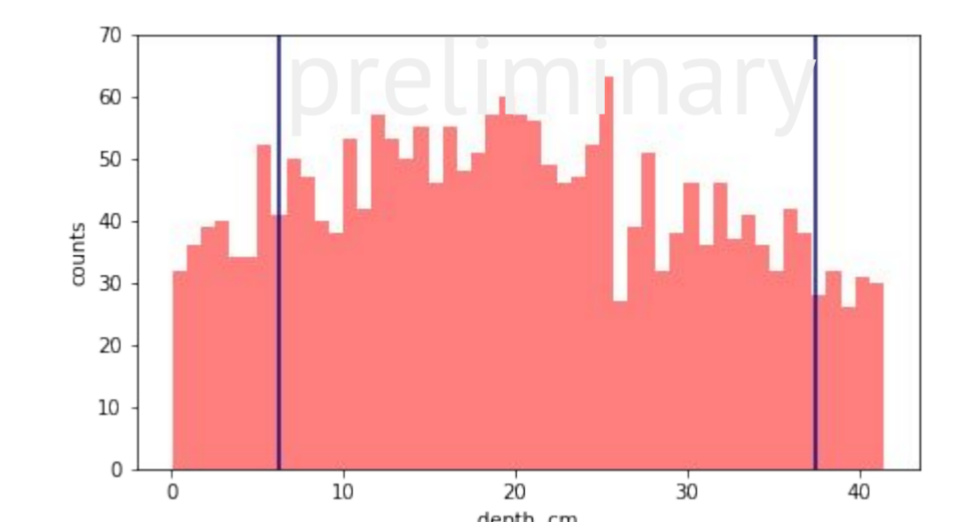
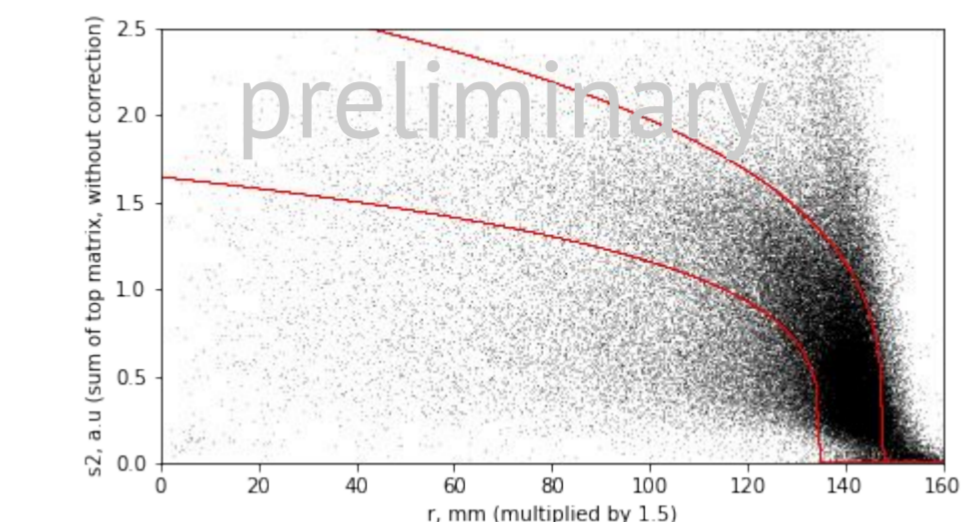
First stage

- waveform to pulses
- s1 and s2 signals were defined as sum of pulses with specific parameters
- electron lifetime correction



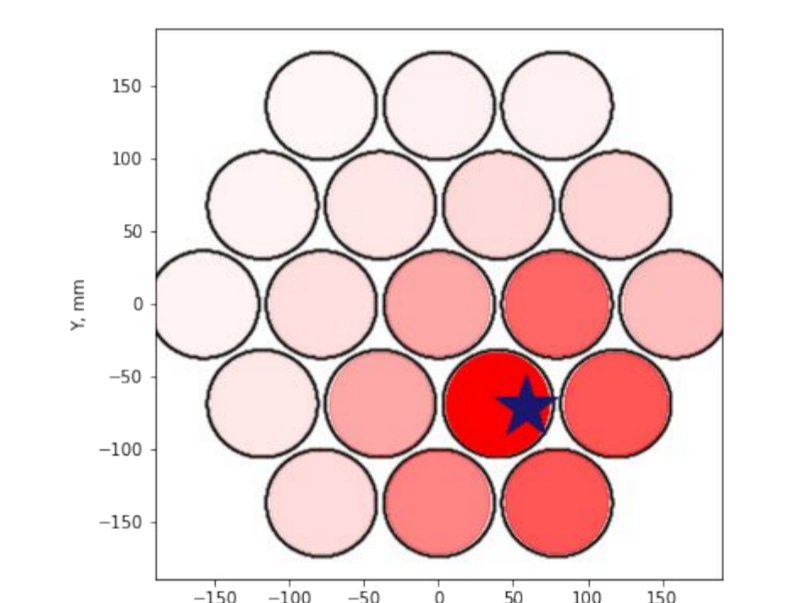
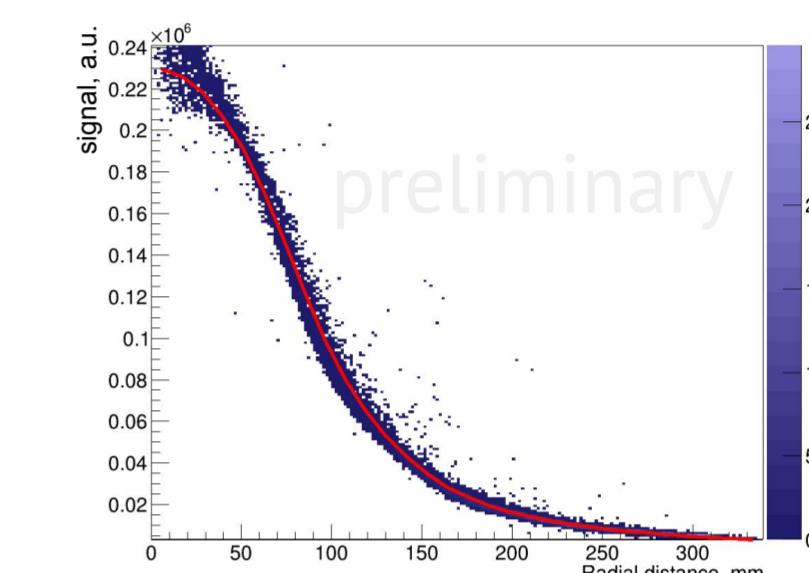
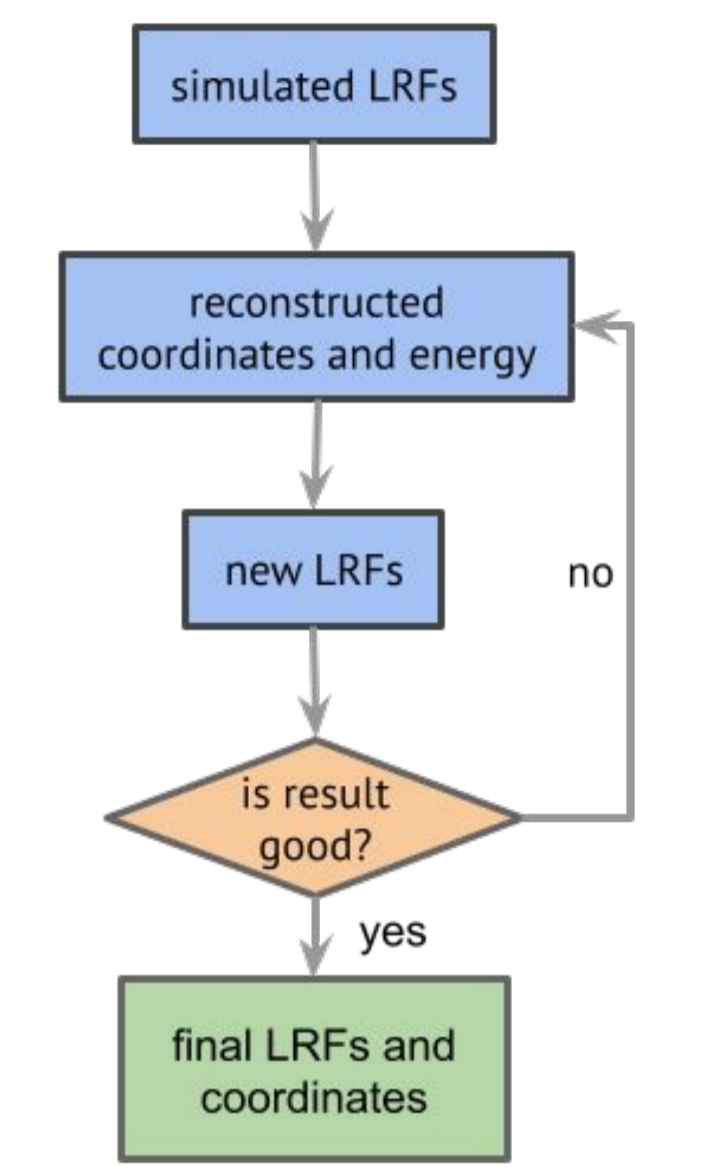
Cuts before reconstruction

- single scintillation and single electroluminescence
- on the event depth (reconstructed using drift time)
- cut on the distribution s2 vs radius, where radius was reconstructed using centroid method



Calibration analysis. Position and energy reconstruction.

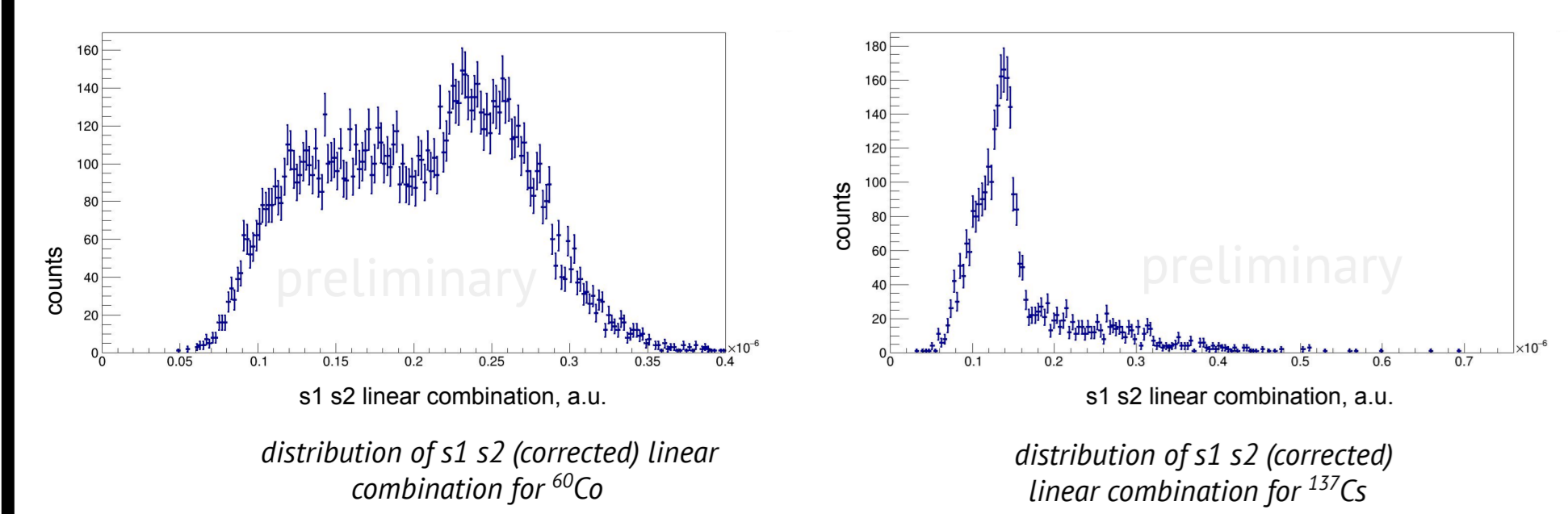
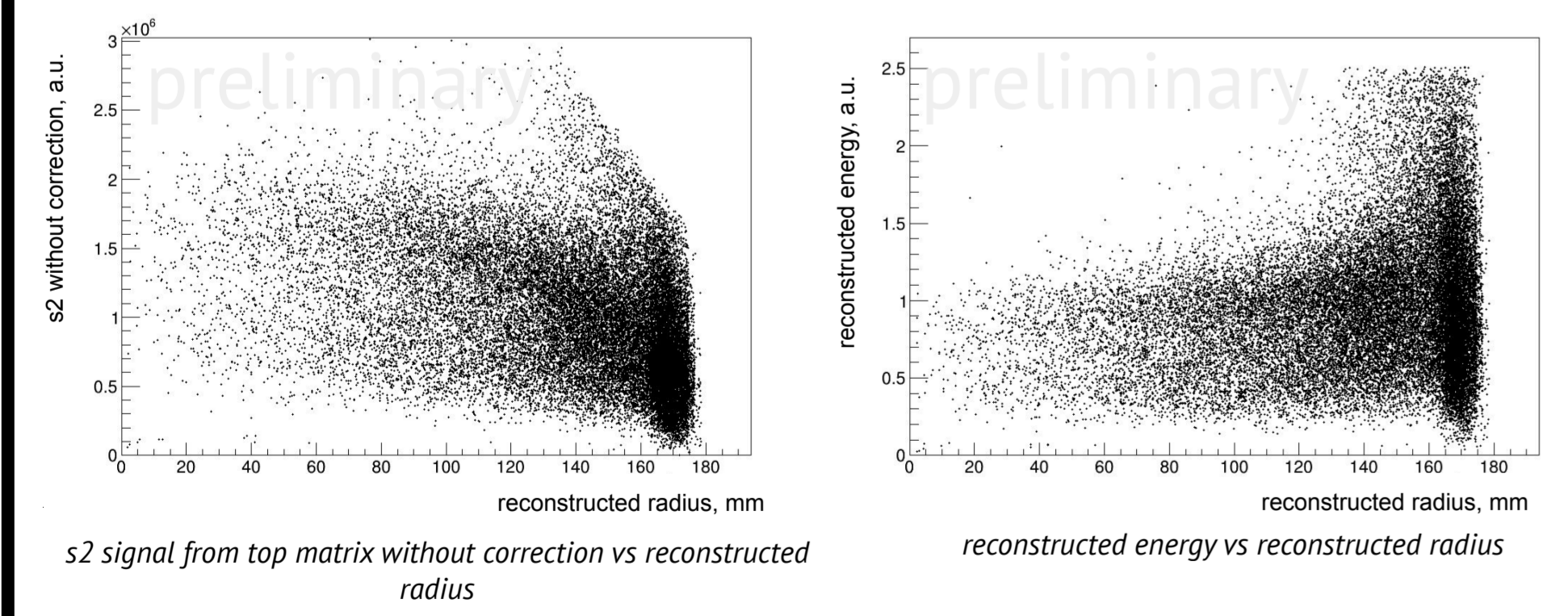
- in order to reconstruct energy and coordinates of events we use light response functions (LRFs)
- reconstruction algorithm is based on minimization of error between observed signal distribution and expected one calculated using LRFs
- both s2 energy and coordinates were reconstructed
- we use ANTS2[5] package for modelling and reconstruction



Example of the PMT (top matrix) signals from the calibration event. Blue star shows the reconstructed position.

Calibration analysis. Results.

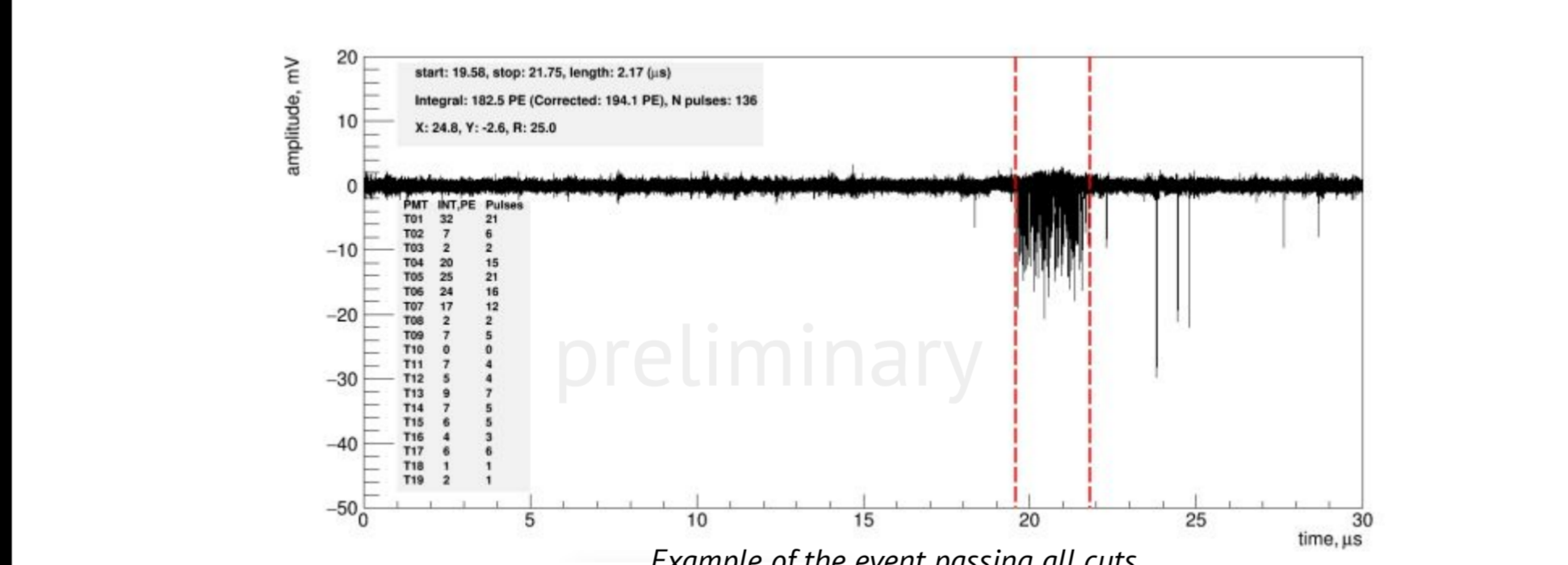
- reconstruction algorithm corrects energy for XY position dependence
- energy is a linear combination of s1 and reconstructed s2
- cut on reconstructed radius <140 mm
- energy resolution (sigma/mean): ~6% (^{60}Co)
- pictures below obtained without cut on the distribution s2 vs radius



SE and ME analysis*. Data processing.

CEvNS events in our case are of a size of several ionization electrons (our region of interest is 3-6) generated at one point.

- SE – single electron
- ME – multiple electrons (includes SE)

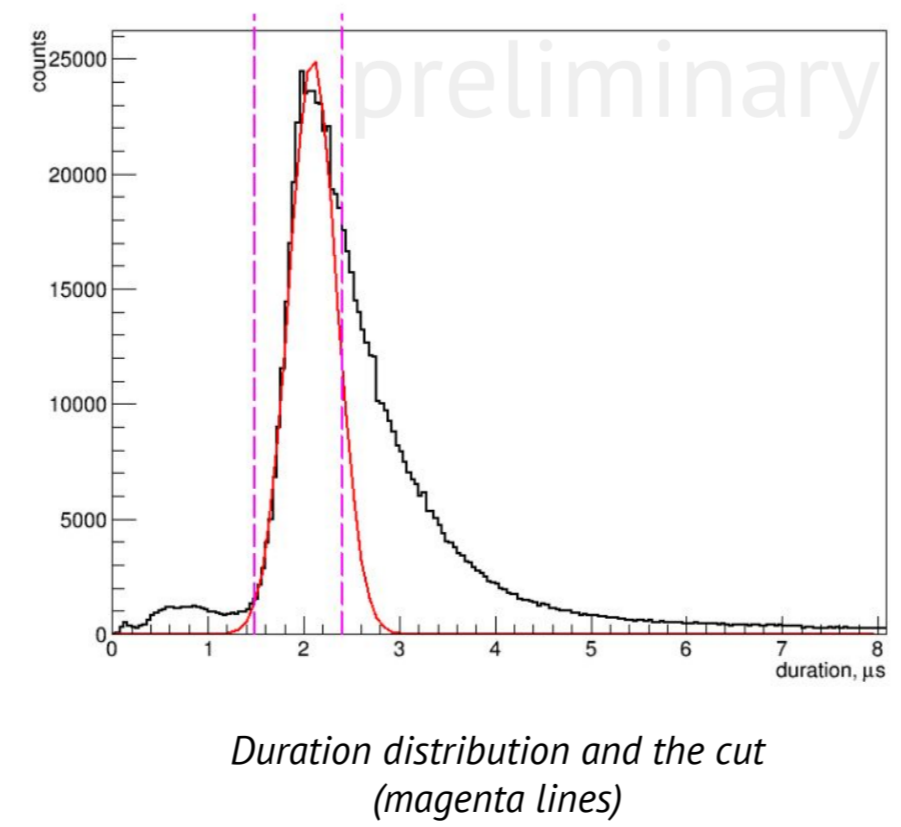


Trigger:

- counts SPEs in individual channels in 2μs time window
- vetos after muons and gammas
- has livetime ~60%

Data analysis:

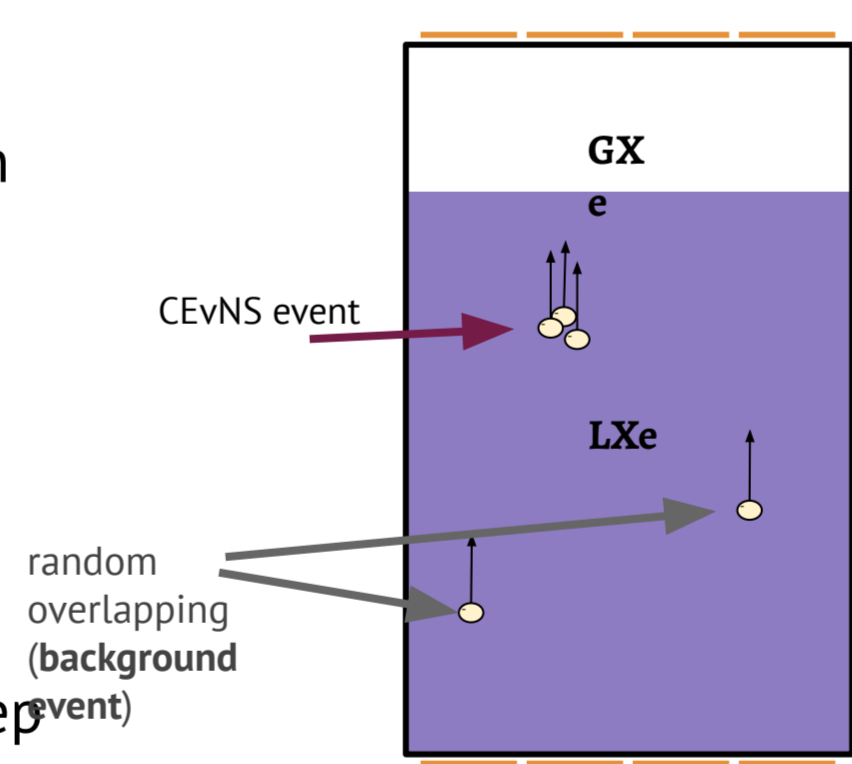
- electric pickup correction
- SPE detection
- clusterization
- data filtering (event selection): duration ~2μs
- energy ~3-6 ionization electrons
- "good" signal shape



*All analysis for now was made using data collected only during reactor-off period

SE analysis. Coincidence background events.

The very important background source in our energy range comes from random overlapping of several independent ME events because of spontaneous emission of electrons.



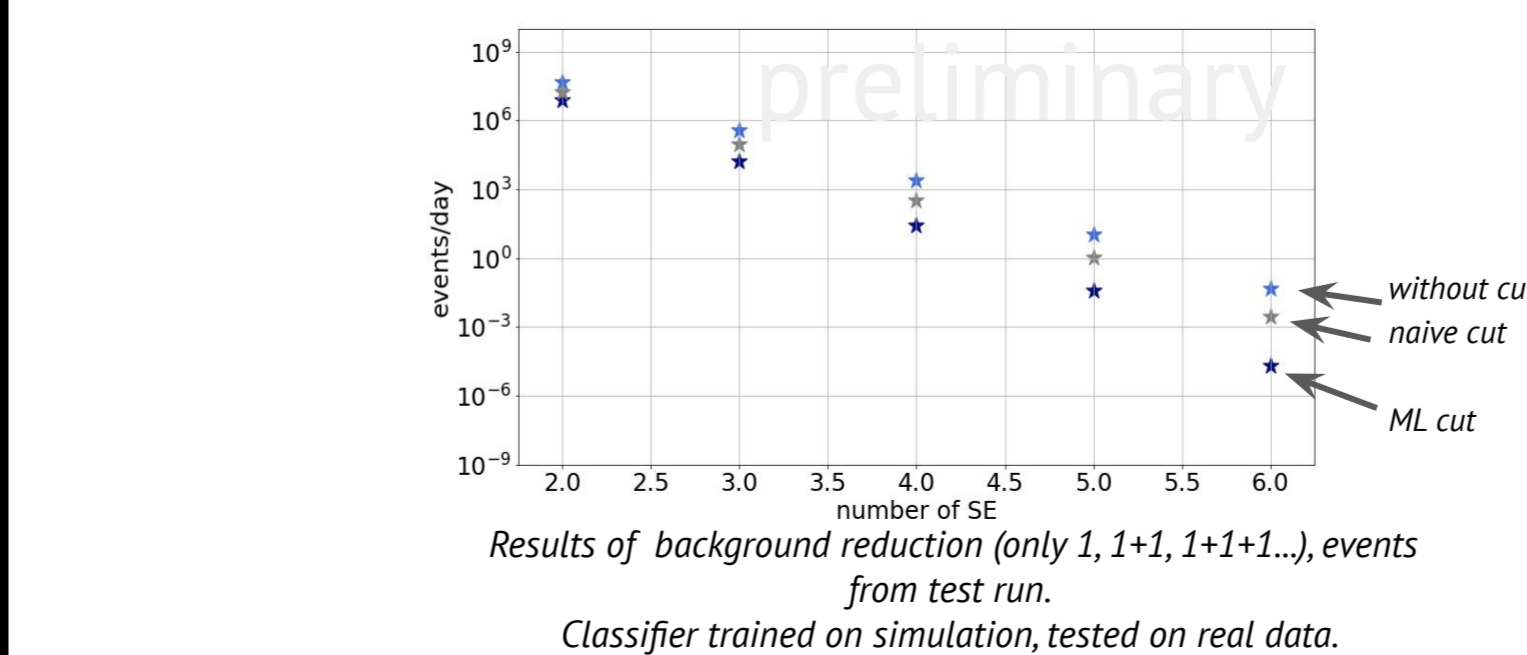
Possible ways of solving this problem:

- simple naive geometry cut [4]
- Machine learning (ML) cut based on classical ML (trees, adaboost)
- ML cut based on neural networks (Deep learning – DL cut)

ML cuts were trained on simulated data obtained using NEST [6] and optical RED-100 model in ANTS2.

Number of SE	No cut	naive cut	ML cut	DL cut
2	465	283	290.3	317
3	129	78	79.4	100
4	35.5	21.7	22	29.3
5	10.6	6.4	6.9	9.1
6	1.9	1.2	1.6	1.7

CEvNS signal reduction (based on prediction from [4])



Conclusion

- first physical run of the RED-100 experiment just finished
- data analysis is in progress
- calibration of the detector using sources ^{137}Cs and ^{60}Co was made
- general methods of ME analysis were developed



[1] D.Z. Freedman, Phys. Rev. D 9 (1974) 1389
 [2] Kopeliovich V B, Frankfurt L L JETP Lett. 19 145 (1974); Pis'ma Zh. Eksp. Teor. Fiz. 19 236 (1974)
 [3] D.Akimov, J.Albert, P.An et al., Science. – 2017.
 [4] First ground-level laboratory test of the two-phase xenon emission detector RED-100, Akimov D. et al., JINST 2020
 [5] ANTS2 package: Simulation and experimental data processing for Anger camera type detectors / A. Morozov [et al.] // JINST. – 2016.
 [6] Szydagis et al., Noble Element Simulation Technique (v2.3.6) // Zenodo. – 2022.