Status of the PandaX Experiment at China Jinping Underground Lab

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Shanghai Jiao Tong U. and UMD
On Behalf of the PANDA X Collaboration

PandaX collaboration

~40 people

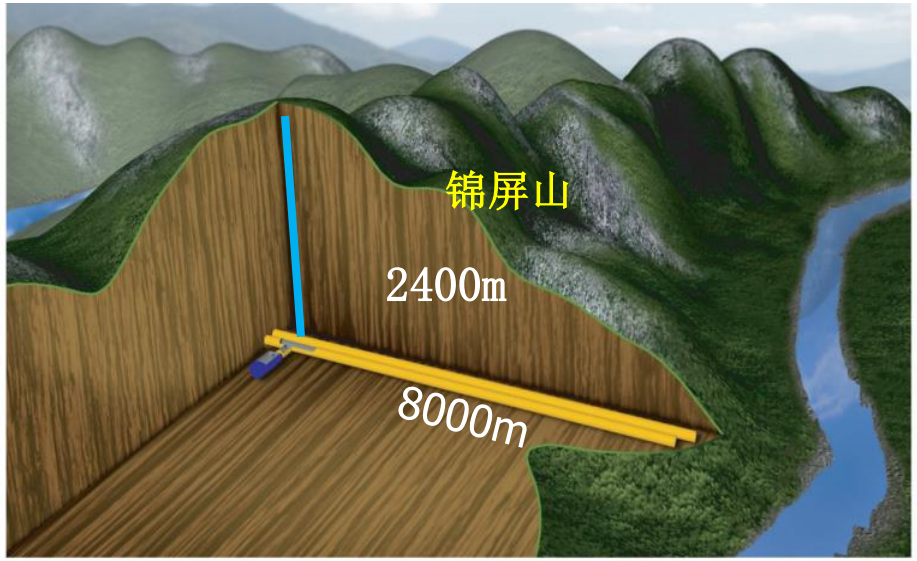
Started in 2009

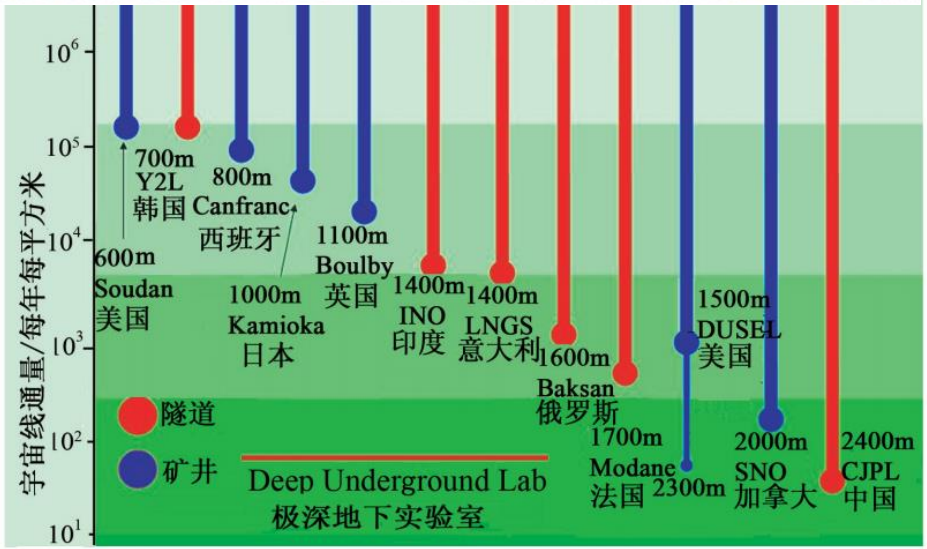
- Shanghai Jiao Tong University (2009-)
- Peking University (2009-)
- Shandong University (2009-)
- Shanghai Institute of Applied Physics, CAS (2009-)
- University of Science & Technology (2015-)
- China Institute of Atomic Energy (2015-)
- Sun Yat-Sen University (2015-）
- Yalong Hydropower (2009-)
- University of Maryland (2009-)
- University of Michigan (2011-2015)

China Jinping Underground Laboratory

Deepest in the world (1μ/week/m²) and Horizontal access!

See Qian Yue's talk



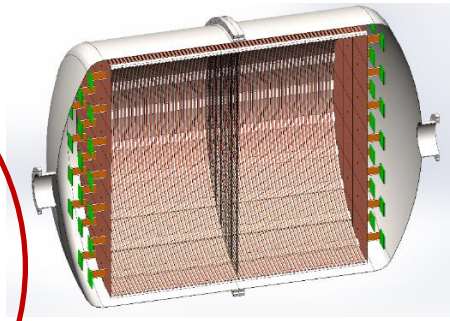


PandaX experiment

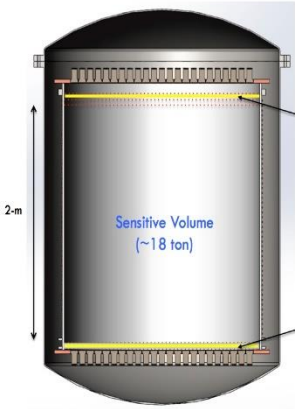
PandaX = Particle and Astrophysical Xenon Experiments

Phase I: 120 kg DM
2009-2014

Phase II: 500 kg DM
2014-2017



Phase III: 200 kg to 1 ton ^{136}Xe 0vDBD
2016-

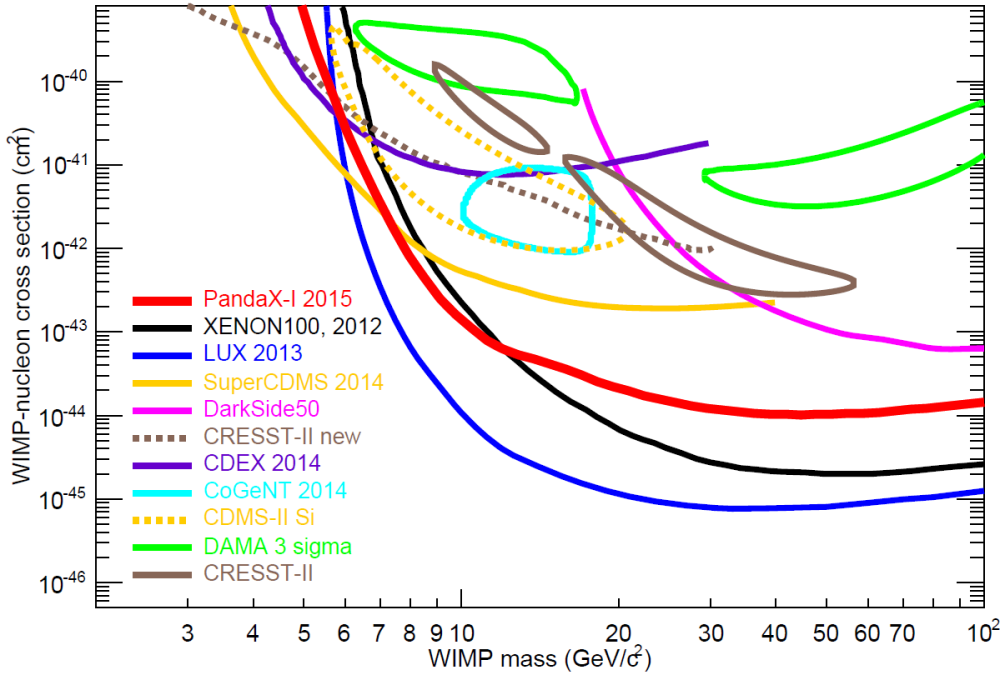


Phase IV: 20 ton DM
2019-

First batch of PandaX equipment were moved to Jinping lab on Aug. 16, 2012

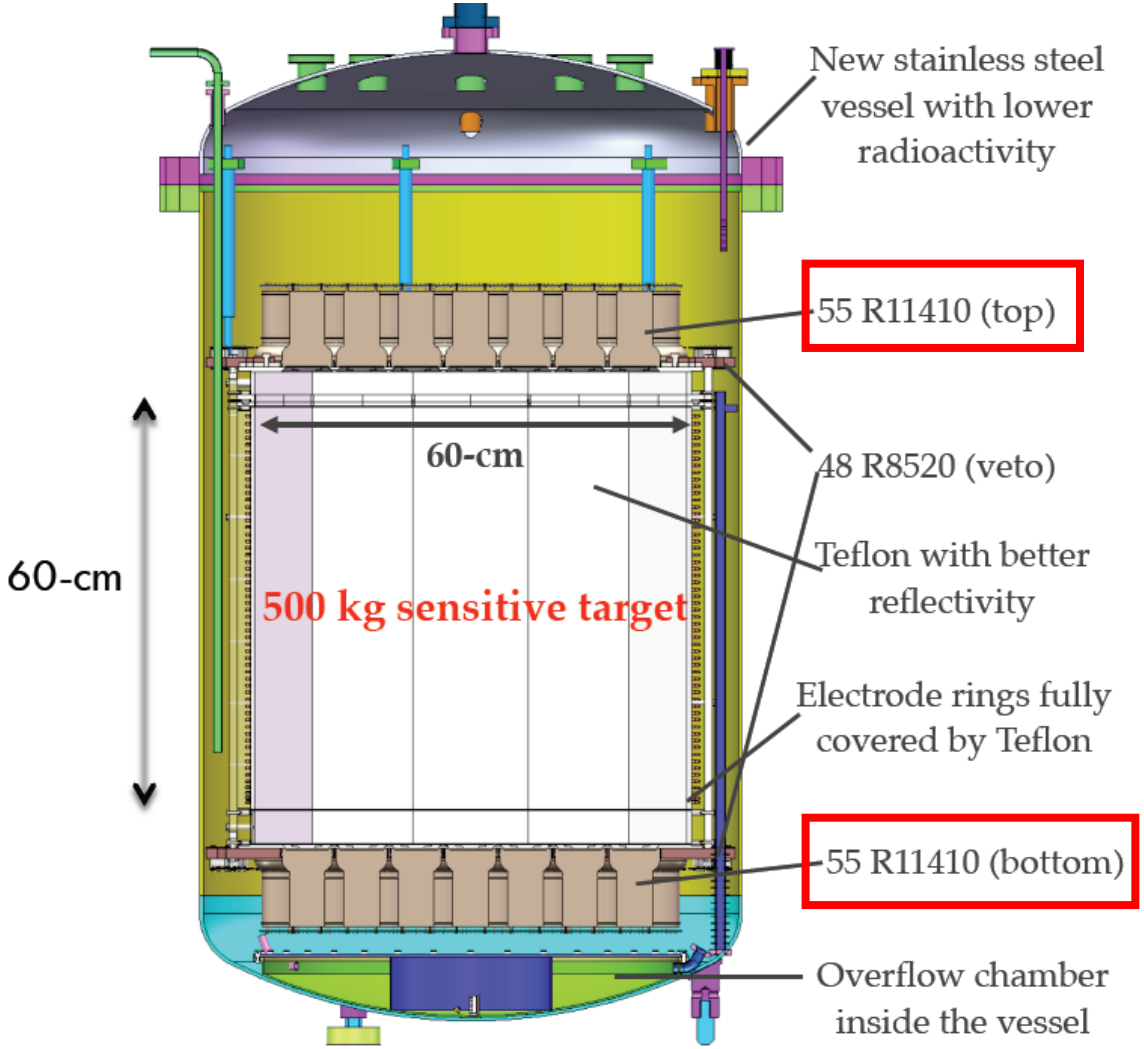
Final Results from PandaX-I

Phys. Rev. D **92**, 052004(2015)



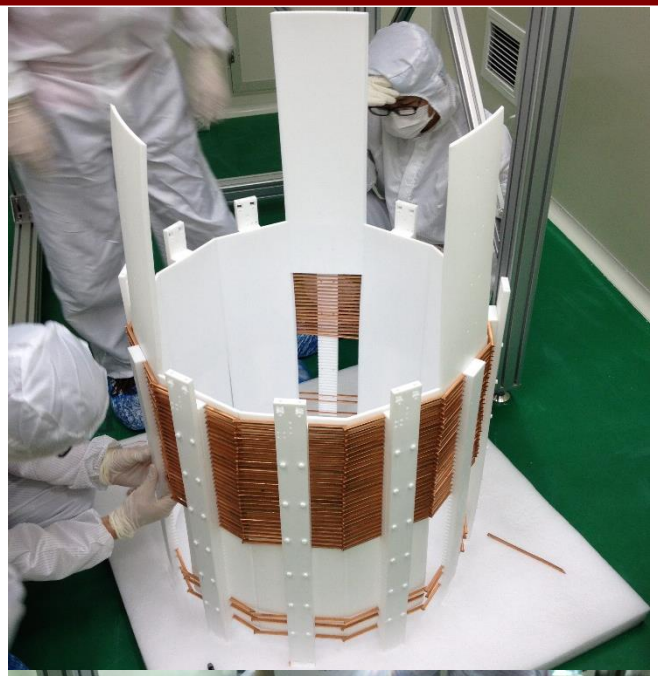
- **Completed Oct. 2014, with 54.0 x 80.1 kg-day full exposure**
- **Data strongly disfavors all previously reported claims from other experiments**
- **Competitive upper limits for low mass WIMP**

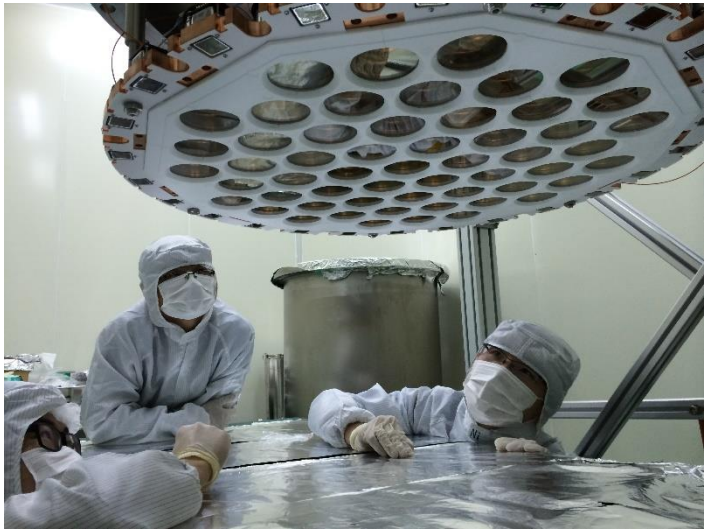
PandaX-II

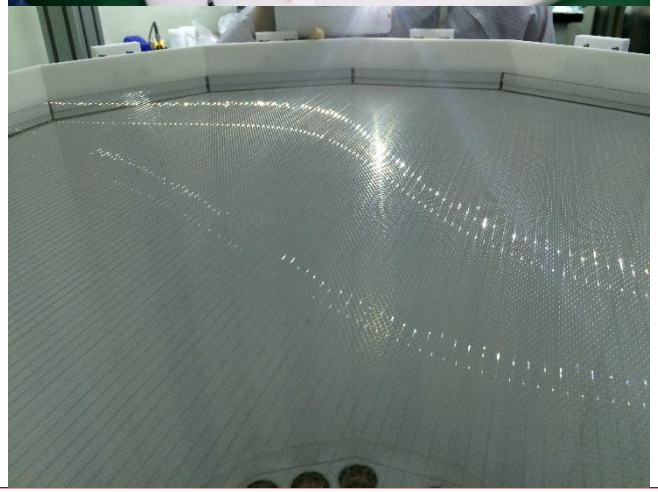


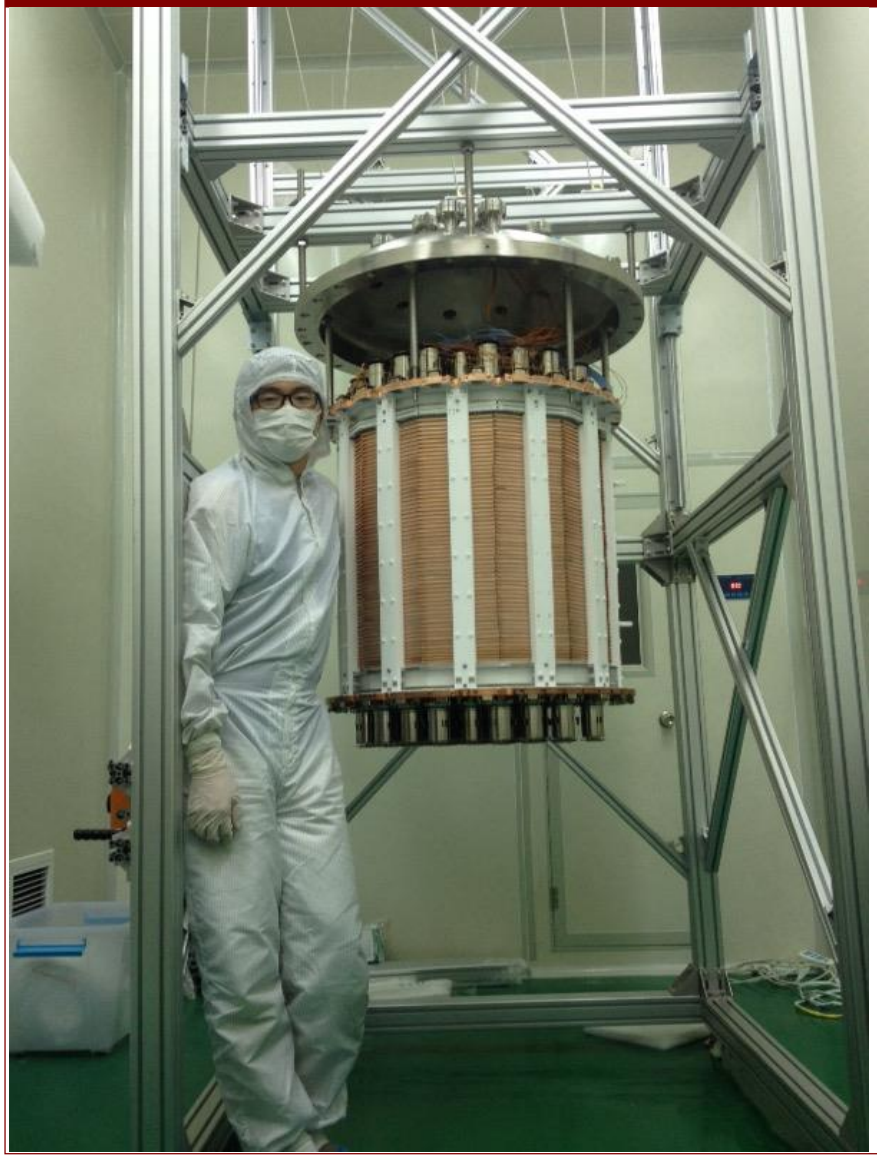
- New inner vessel with clean SS
- New and taller TPC with brand-new electrodes
- More 3” PMTs and improved base design
- New separate skin veto region
- New overflow chamber

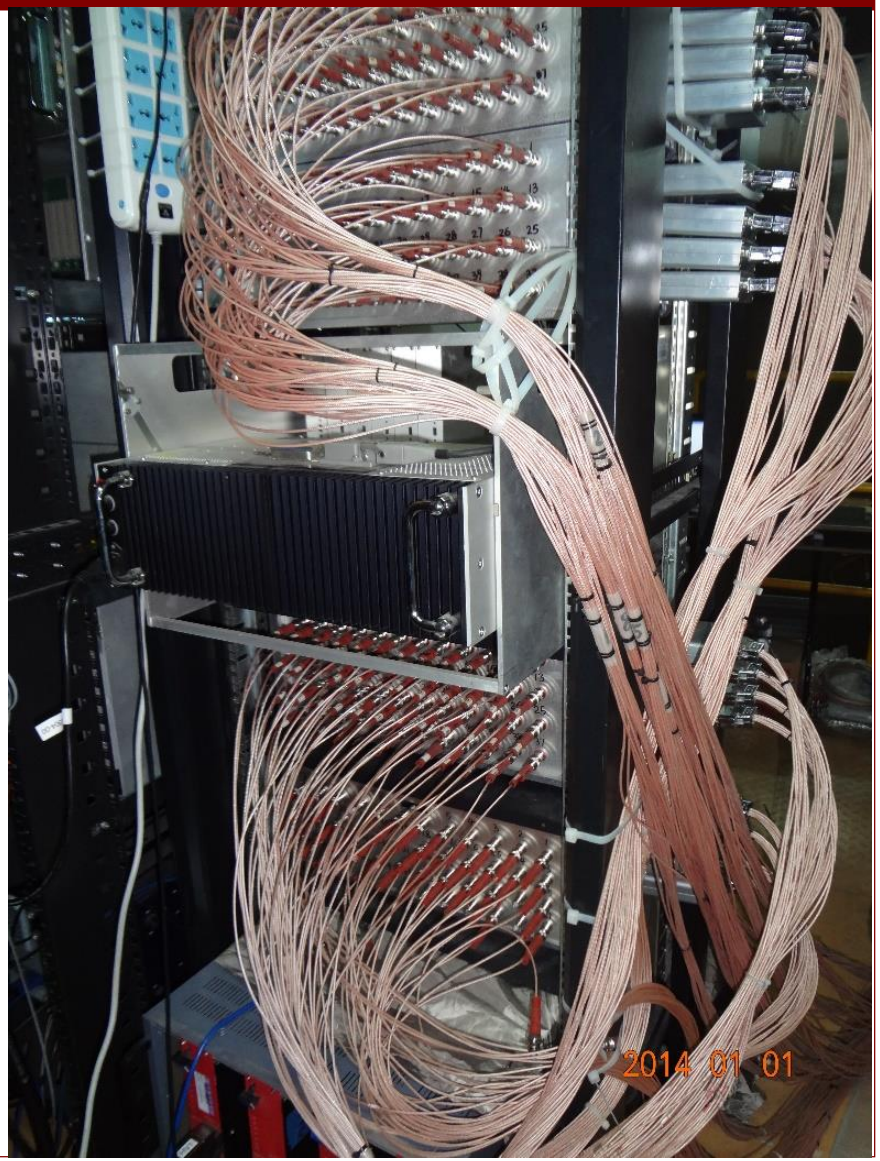
Assembling the detector



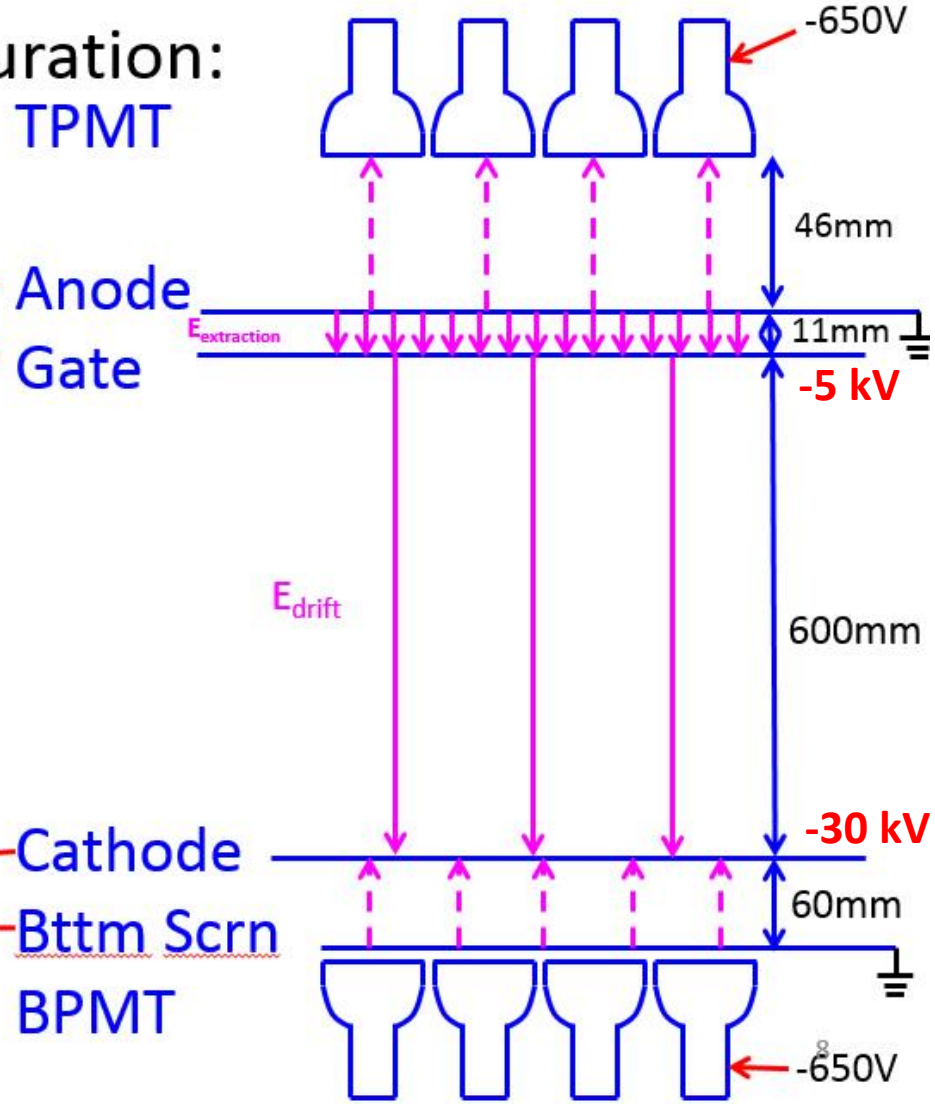







2014 01 01

Configuration of fields



Run history

- We had a series of engineering runs in 2015, fixing various problems as we were testing all the components of the setup.

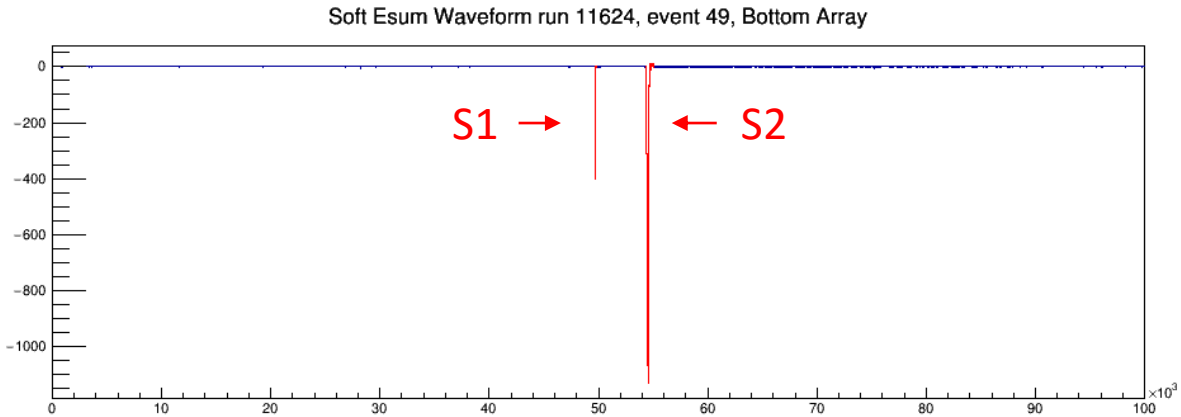
- A physics commissioning run: Nov. 22 – Dec. 14 (19.1 live-day x 306 kg FV)

  not everything in perfect conditions:

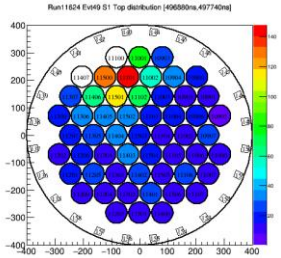
  no gamma calibration (-) * large Kr contamination (-)

  = some physics result (+)

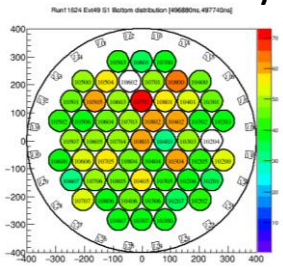
Typical single-scatter waveform

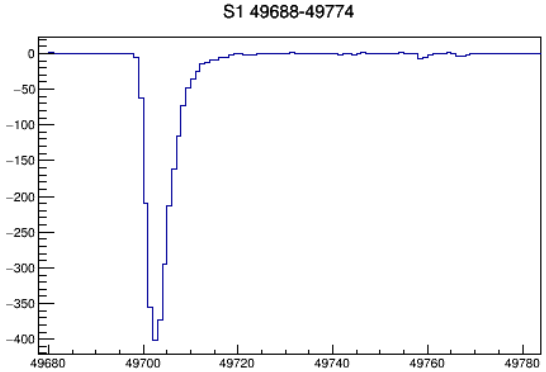


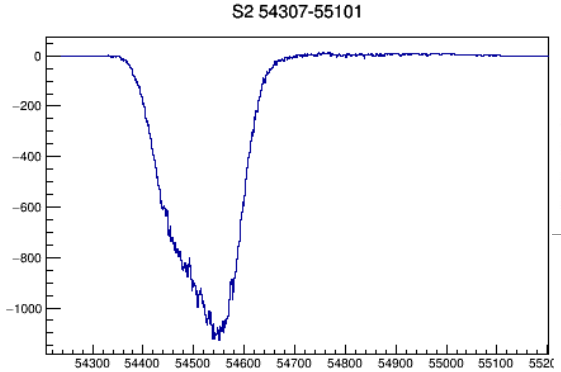
Top Array



Bottom Array







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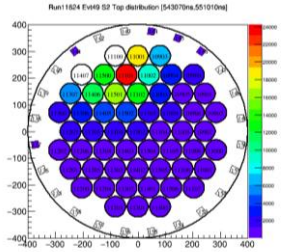

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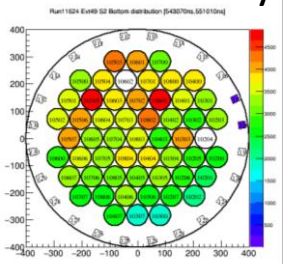
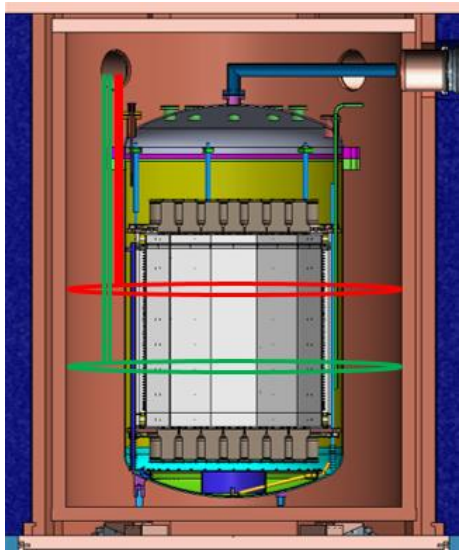


Calibrating the detector responses

- **Detector uniformity correction**
- **Light/charge collection parameters in energy reconstruction**

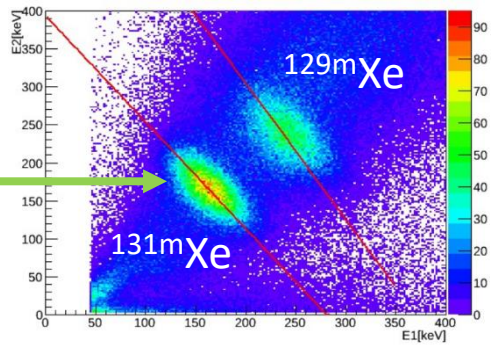


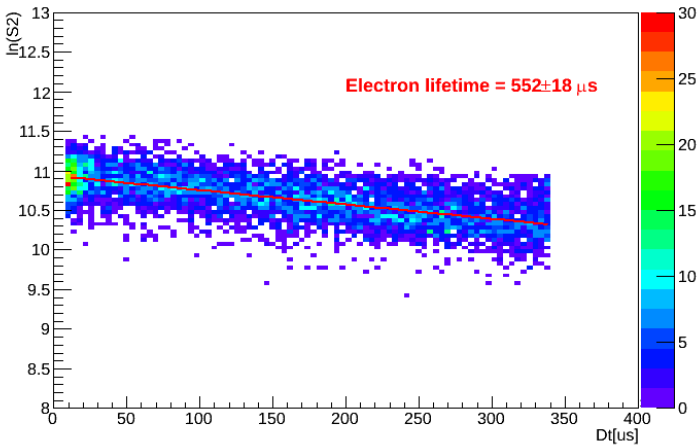
$$E_{ee} = W \times \left(\frac{\mathrm{S1}}{\boxed{\mathrm{PDE}}} + \frac{\mathrm{S2}}{\boxed{\mathrm{EEE}} \times \boxed{\mathrm{SEG}}}\right)$$

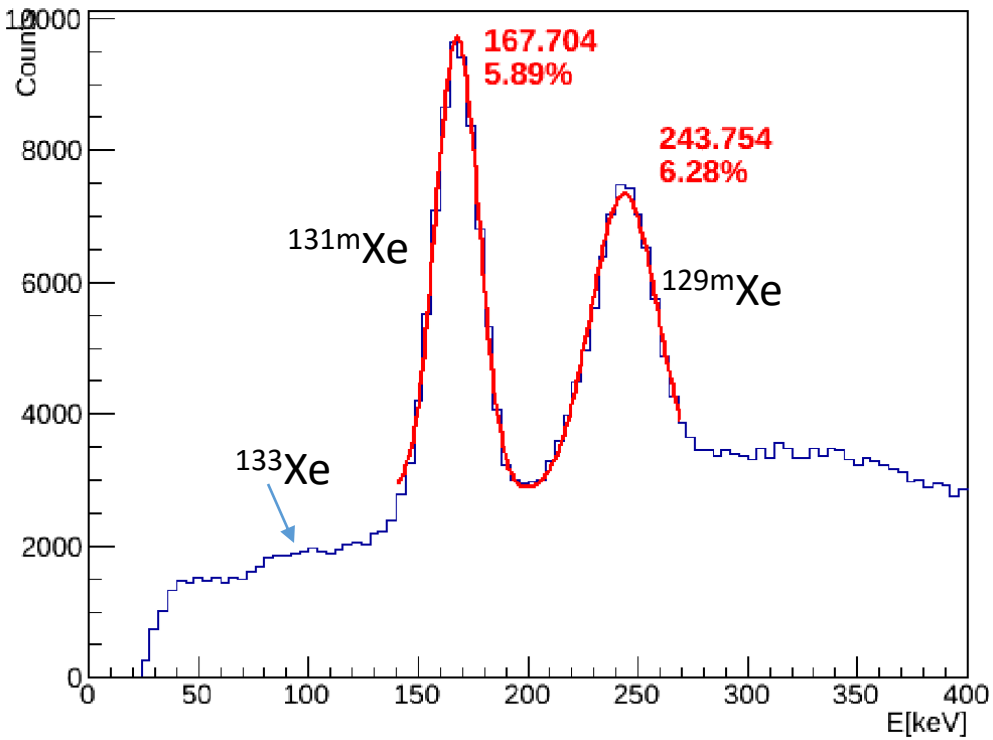
- **Compare the low energy NR response between neutron calibration data and MC (NEST-based + measured parameters)**

Activated xenon peaks

"Workhorse" in uniformity correction

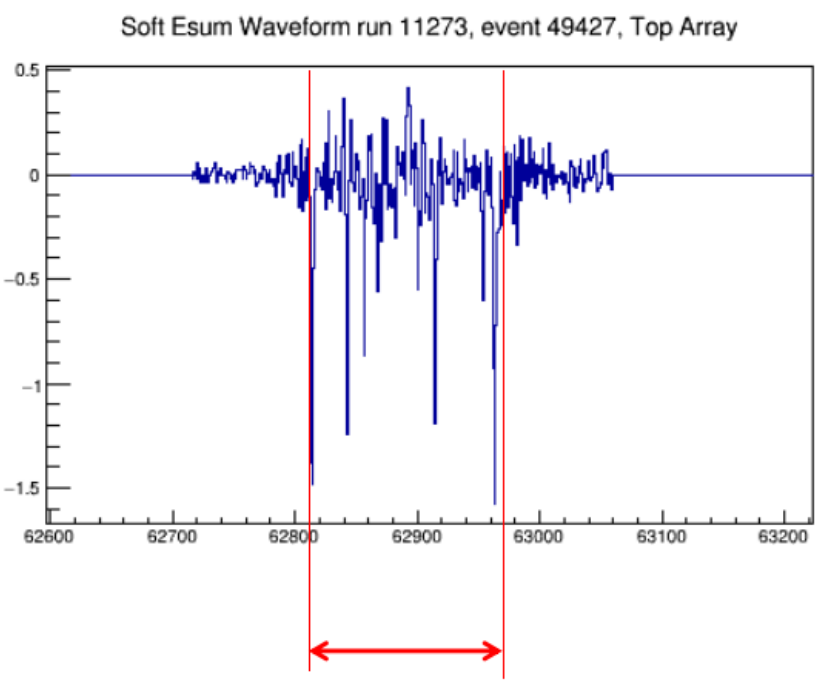


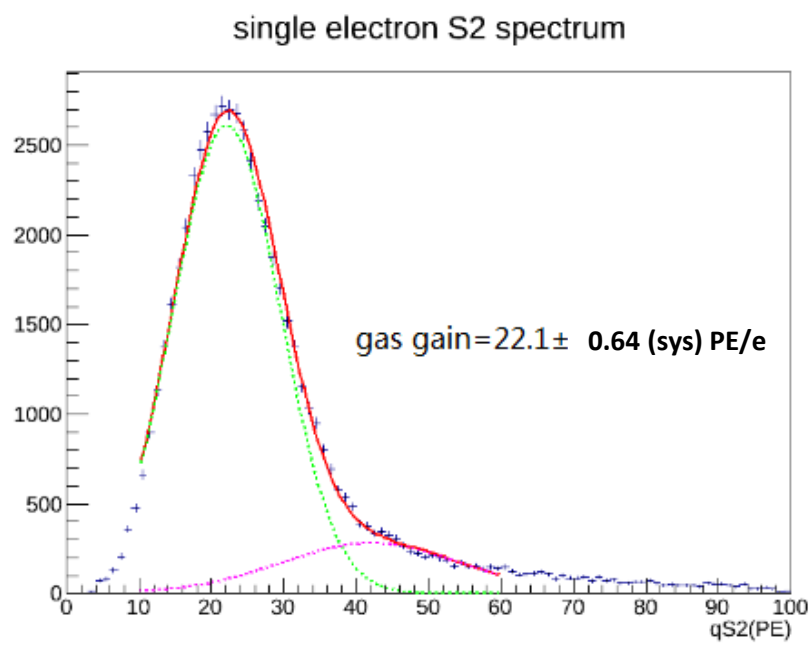




- **Electron lifetime kept improving during the data taking (average 324 μs)**
- **Energy resolution <6% (1σ) achieved for 164 keV γ rays**
- **Energy bias <3%**

Single electron gain

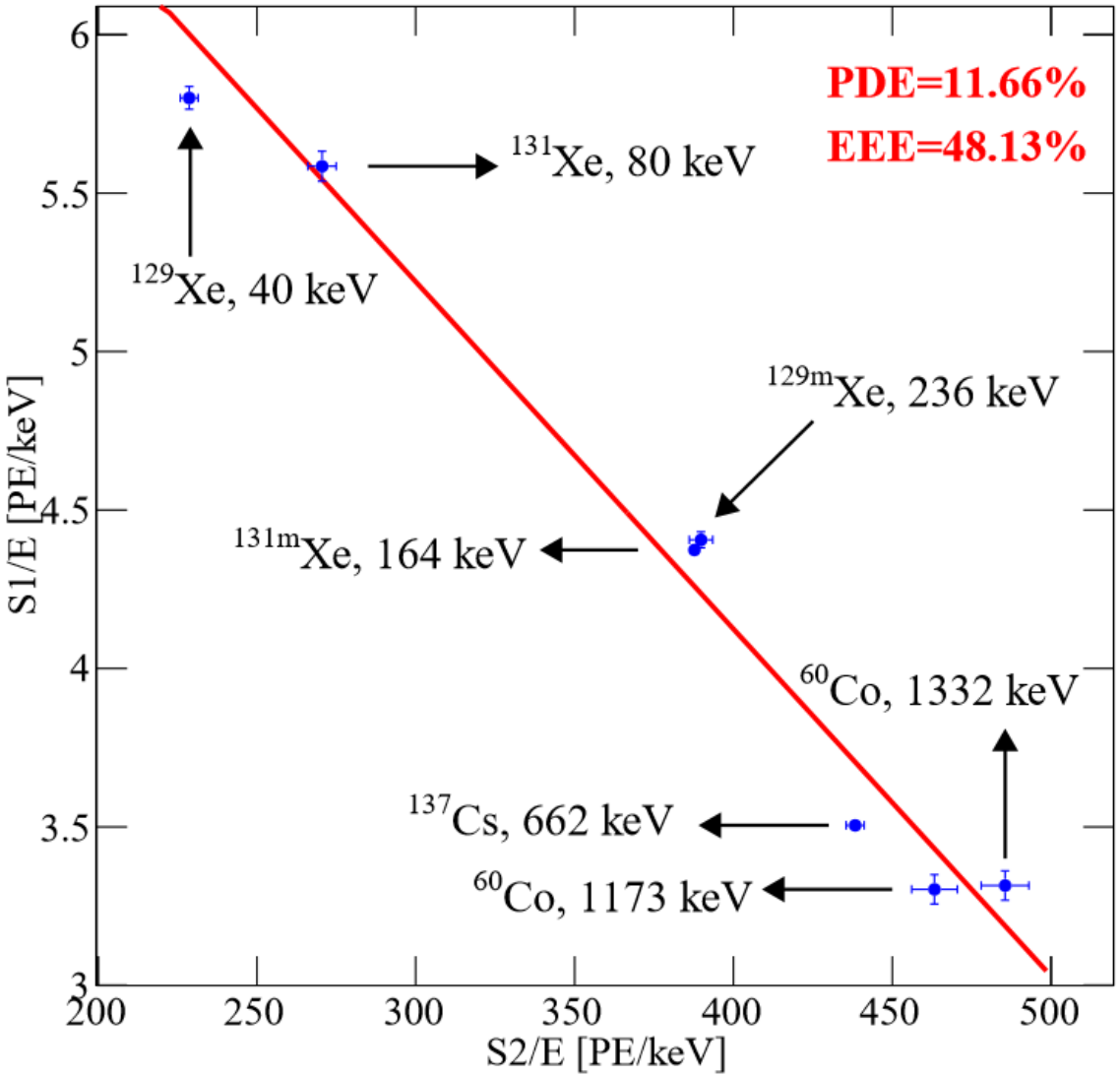




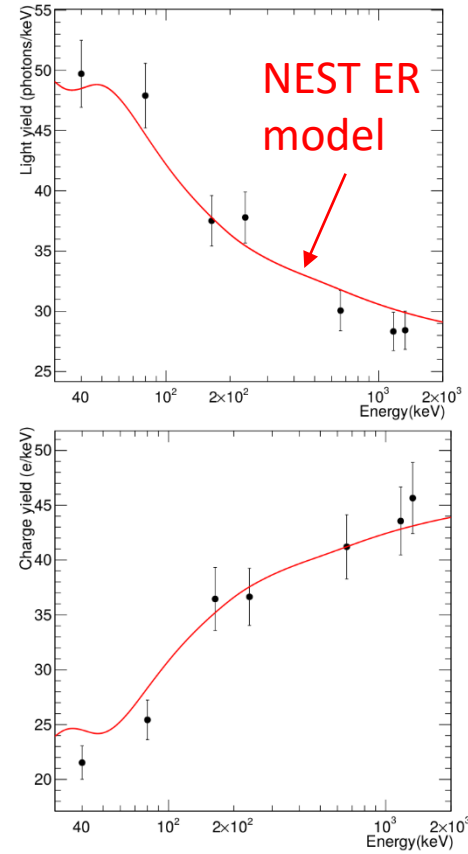
- **Identifying smallest S2 in the data**
- **Varying selection method and fits to study systematics**

$\Rightarrow$ **22.1 ± 0.7 PE/e,**

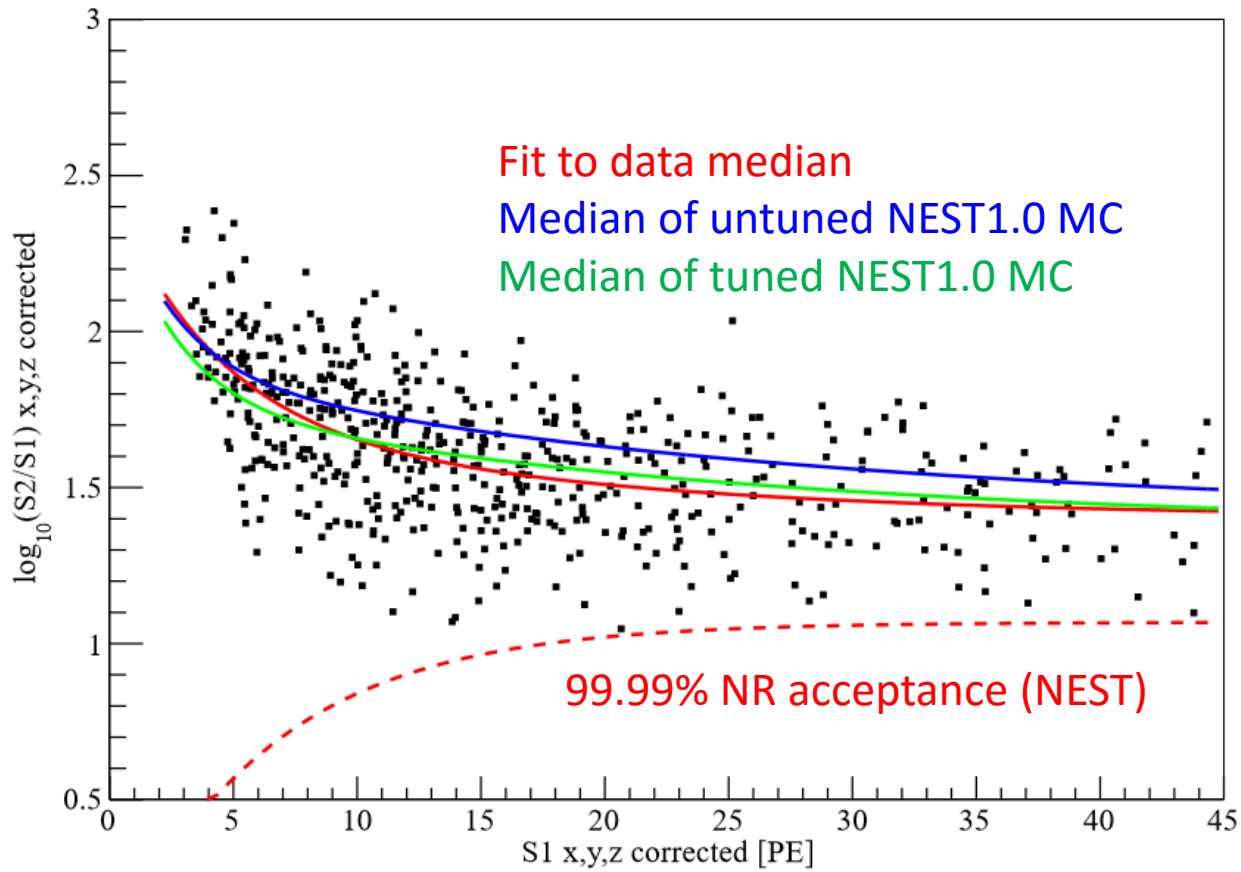
PDE and EEE



Fractional sys. uncert. estimated by comparison with NEST ER model: 5.6% (PDE), 7.1% (EEE)



NR calibration

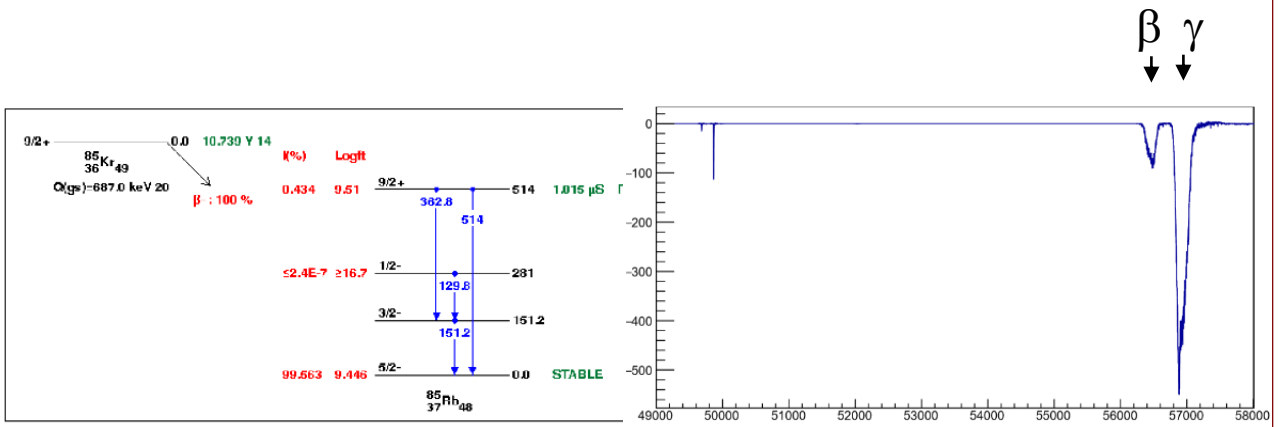


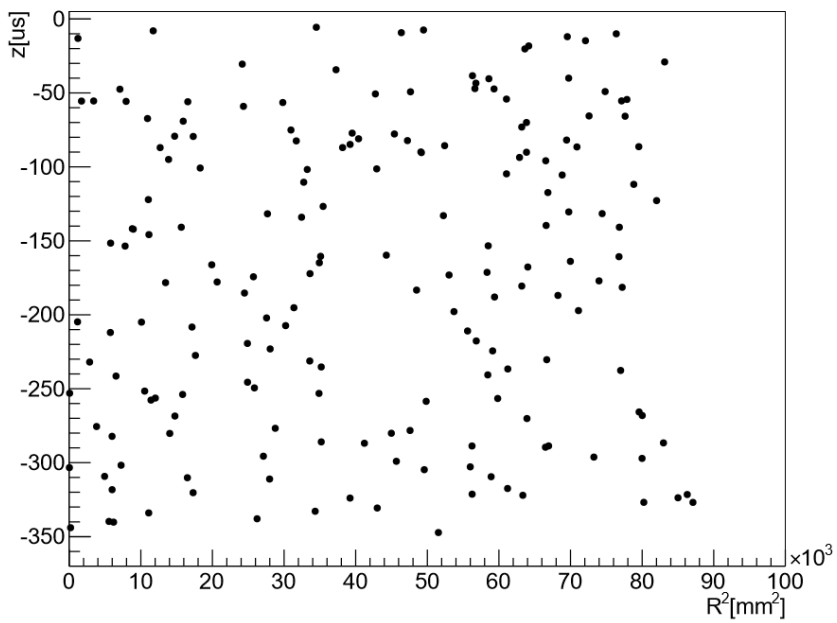
- Geant4 energy spectrum
- NEST 1.0 photons/electrons
- PDE/EEE/SEG from calibration
- Double PE emission from R11410 from Faham et al. (JINST 10, P09010)
- Electron lifetime correction

Tuned NEST 1.0:
N_{ex}/N_i ratio scaled up by **1.5**

Kryton background

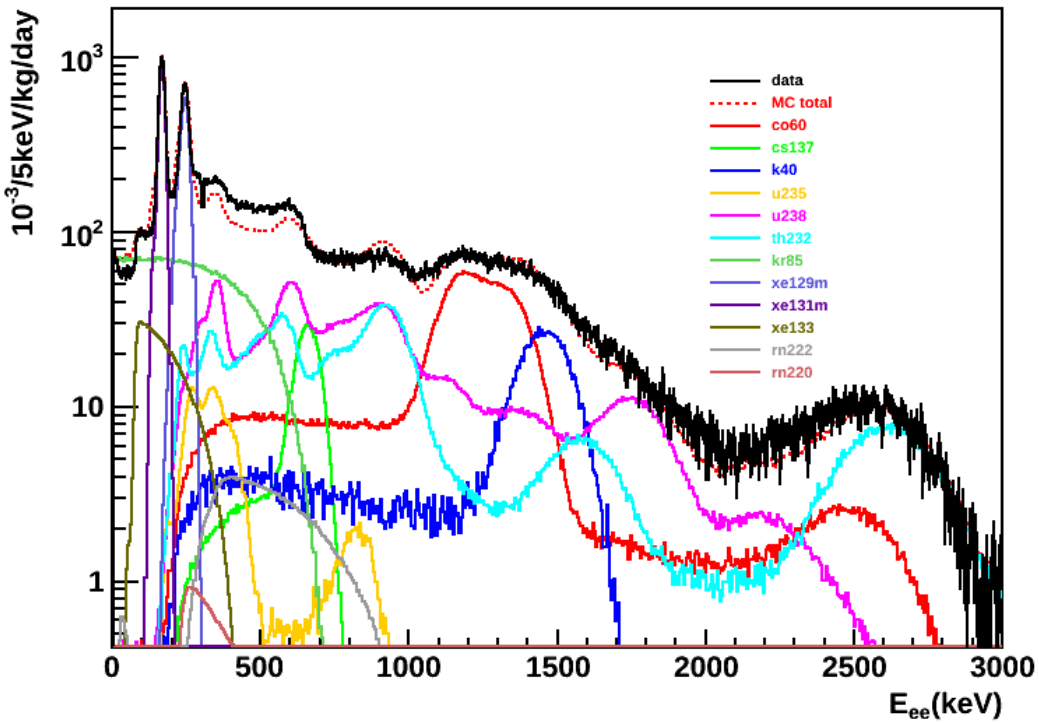
- Significant uniformly distributed ER background observed in the data
- (β,γ) analysis confirmed that it is due to ^{85}Kr, Kr/Xe = (437±70) ppt
- Due to an accidental air leak in the previous recuperation





Distribution of β vertices

ER background summary

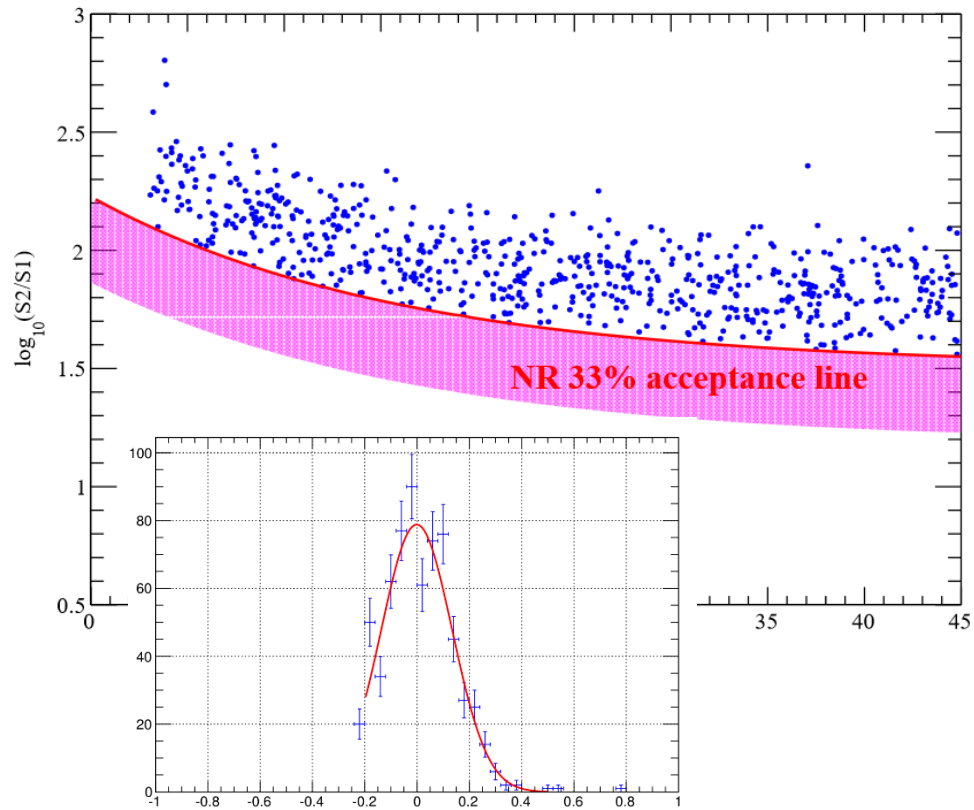


Item	Background (mDRU)
Total	15.33
^{85}Kr	15.04
^{222}Rn	0.075
^{220}Rn	0.021
^{129m}Xe, ^{131m}Xe, ^{133}Xe	~0
PMT arrays & bases	0.097
PTFE wall	0.021
Inner vessel	0.045
Others IV components	0.026
Cu outer vessel	0.016

- Shape in reasonable agreement with MC
- Low energy agreement also within 17%

ER background leakage

- Simple DM acceptance cut: below NR median
- Insufficient statistics of low energy ER calibration data in the FV
- Assume ER nature in DM search data above the 33% NR acceptance
- Use Gaussian fit to predict the tail below NR median
- Consistent leakage obtained using full data distribution



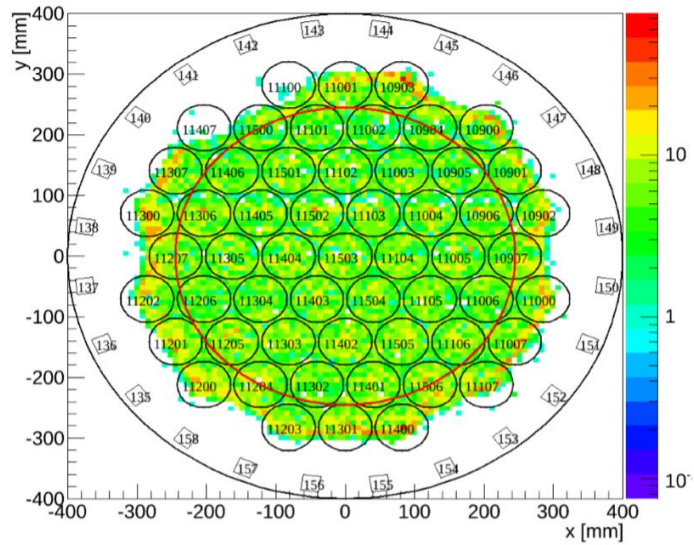
Gaussian ER leakage
0.4%±0.2%

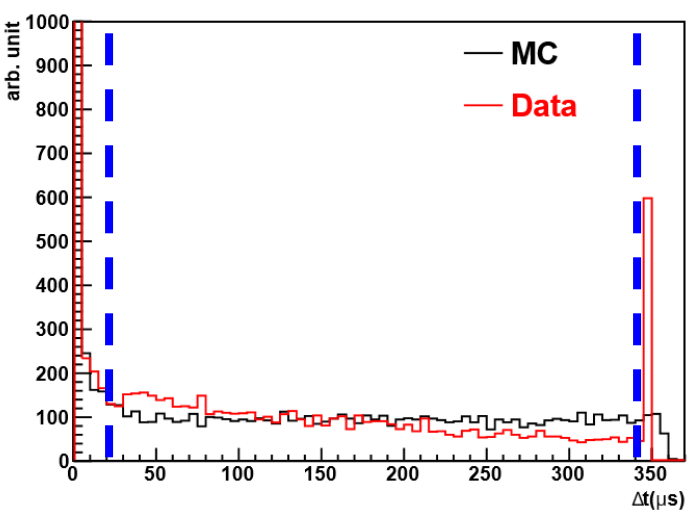
Total expected background

	ER	Accidental	Neutron	Total Expected	Total observed
All	611	5.9	0.13	617±104	728
Below NR median	2.5	0.7	0.06	3.2±0.71	2

- Accidental background statistically determined from data using isolated S2 and S1 from the data
- Neutron background dominated by the (α, n) from PTFE reflector
- Background systematics dominated by the ER leakage fraction (0.4%±0.2%) and Kr rate (17%) uncertainty

Final selection cuts

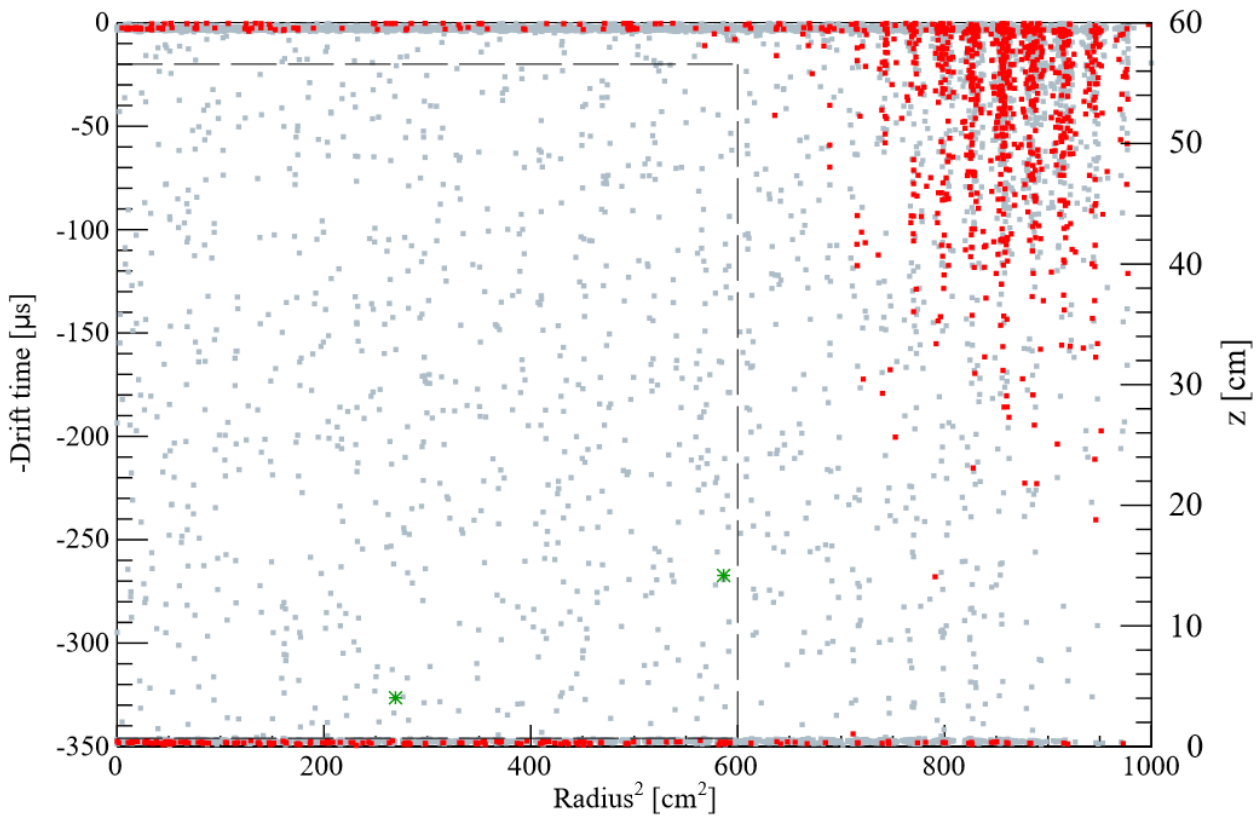




- Horizontal cut determined by reconstruction quality (removing the last ring of PMT)
- Vertical cut determined by choosing the flat region in non-DM-window for both data and MC (excess at cathode likely due to Rn daughters accumulation)
- S1 cut: [3, 45] PE by optimizing the median sensitivity using **expected background only**

Final candidates

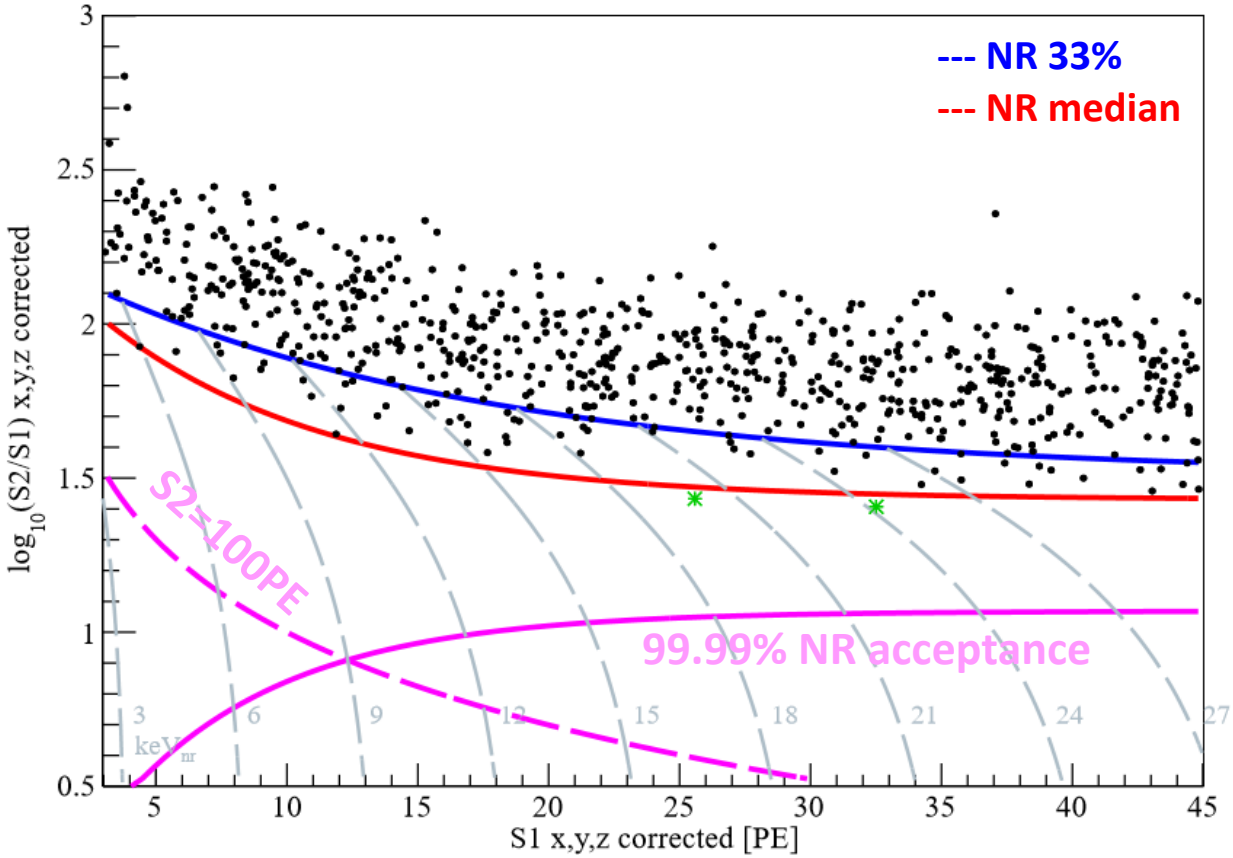
Gray: all
Red: below NR median
Green: below NR median and in FV

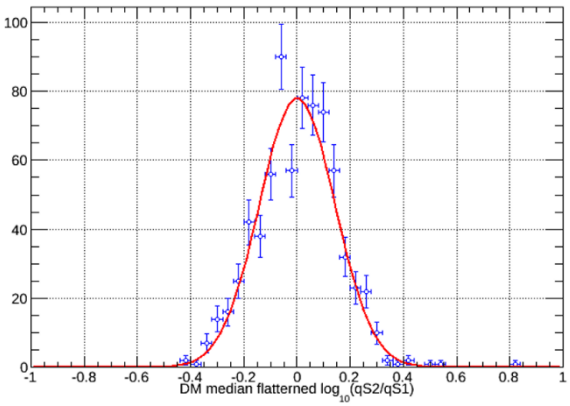


Cut	#Events	Rate (Hz)
All triggers	4779083	2.89
Single S2 cut	1833756	1.11
Quality cut	1262906	0.76
Skin veto cut	1081044	0.65
S1 range	45883	2.77×10^{-2}
S2 range	29755	1.80×10^{-2}
Fiducial volume	728	4.40×10^{-4}

- 728 total candidates found in the FV
- **2** below NR median
- Outside FV, edge events more likely to lose electrons, leading to S2 suppression

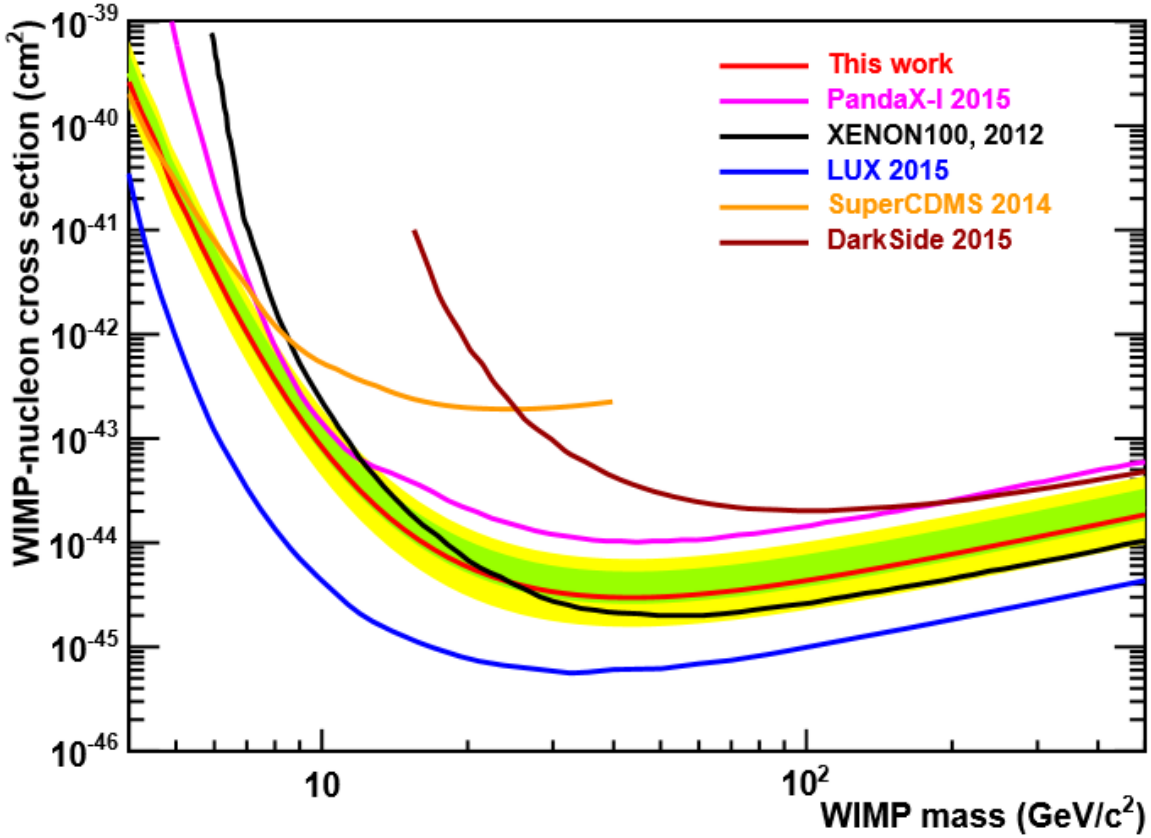
Final candidates





Two events below NR median appear consistent with Gaussian background leakage

Exclusion limits

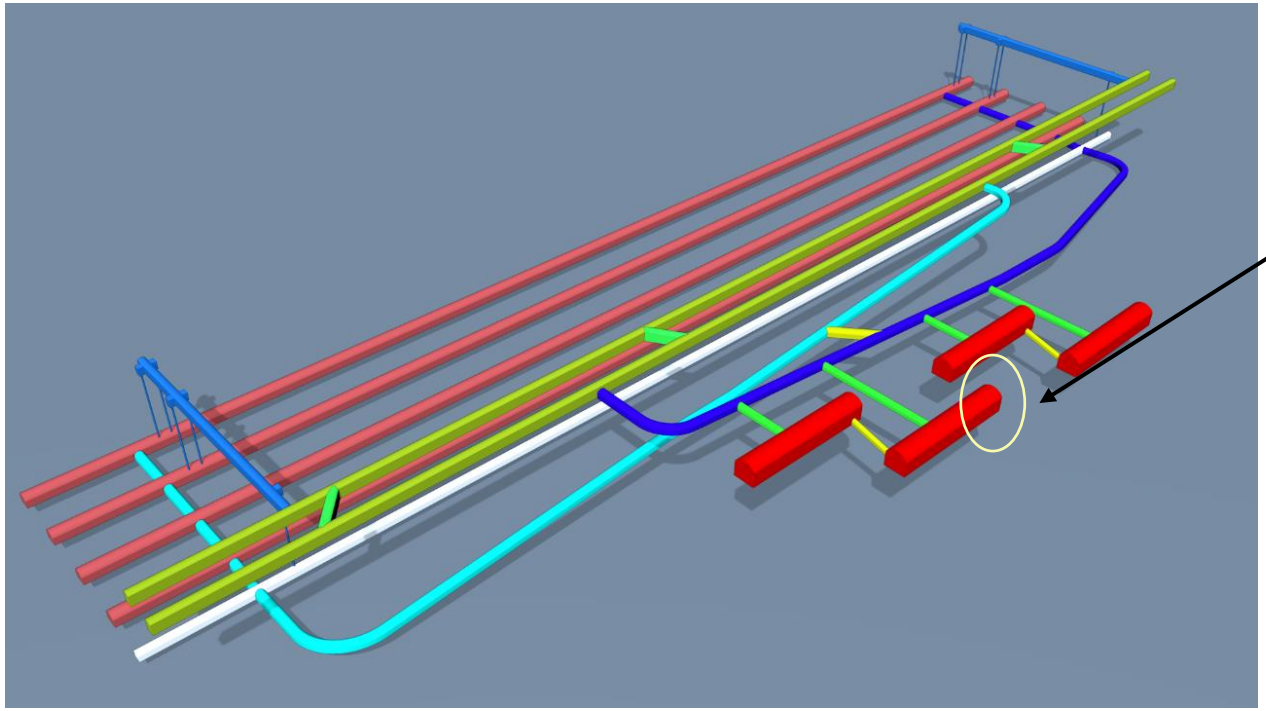


- Simple counting analysis based on an expected background of 3.2(0.7) evts and 2 observed evts
- Sizable (x2) difference of using original NEST or tuned NEST to predict DM distribution due to DM acceptance, but within 1σ band
- Low mass: competitive with SuperCDMS; high mass: similar exclusion limit as XENON100 225-day

A preprint will be submitted to arXiv this weekend and it will appear on Tuesday.

PandaX new home: CJPL-II

8 experimental Halls, 65m long each.



B4, PandaX site!

PandaX experiment

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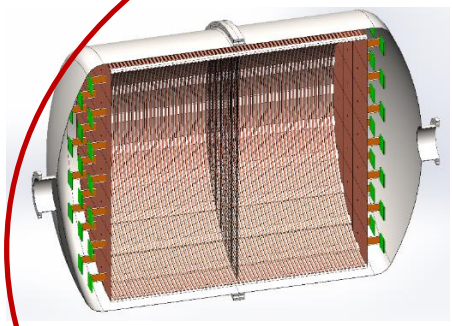

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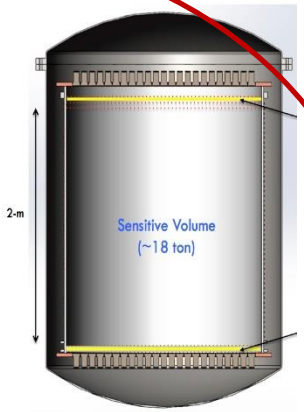

Phase IV: 20 ton DM
2019-

Summary & outlook

- Half-ton scale PandaX-II has tuned up all key components of the experiments
- Commissioning run with 19.1 live-day x 306 kg exposure observed no DM candidate with an exclusion limit similar to 225 day XENON100 results
- After a maintenance to distill Kr, PandaX-II will resume physics data taking in the spring
- Stay tuned!