New results from the PandaX Dark Matter Experiment

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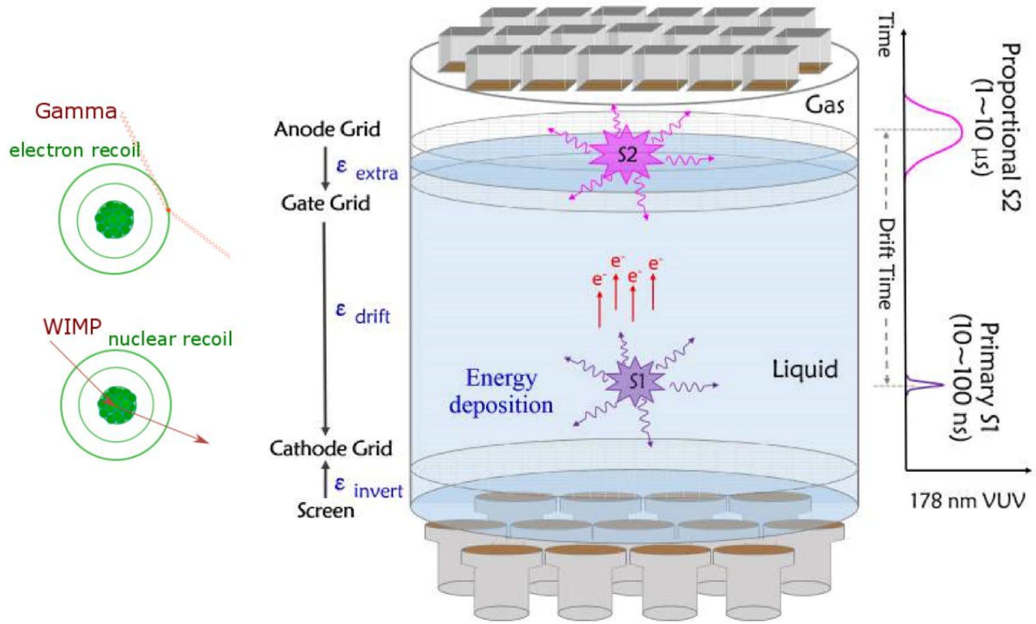
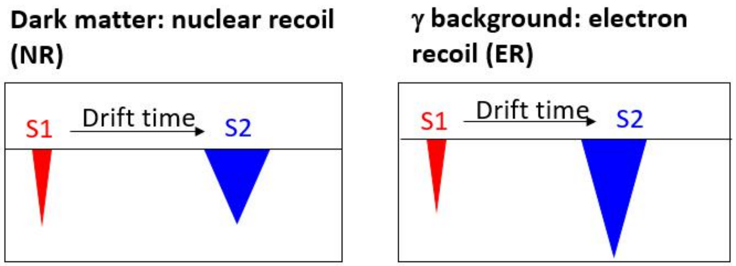
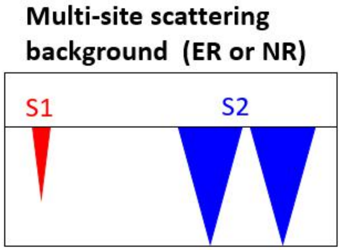
Dual phase xenon experiments

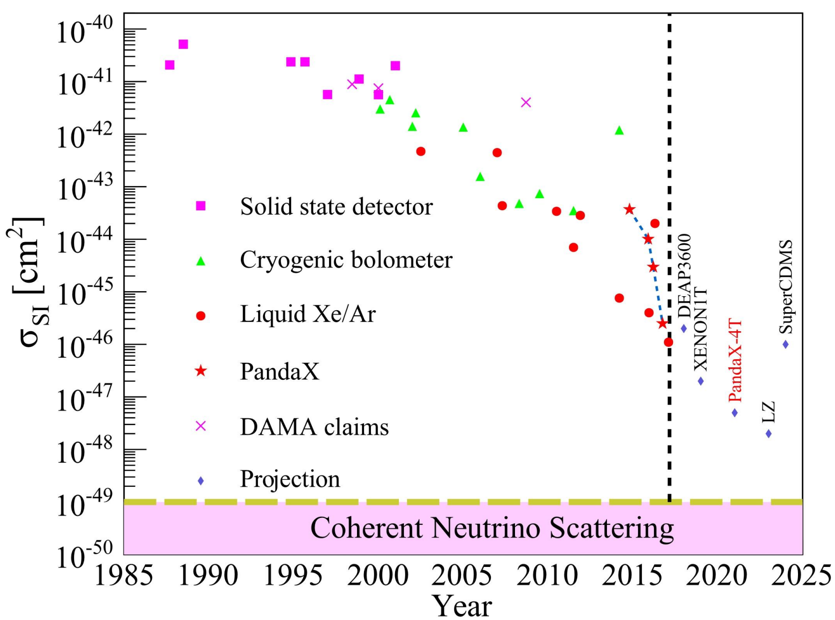


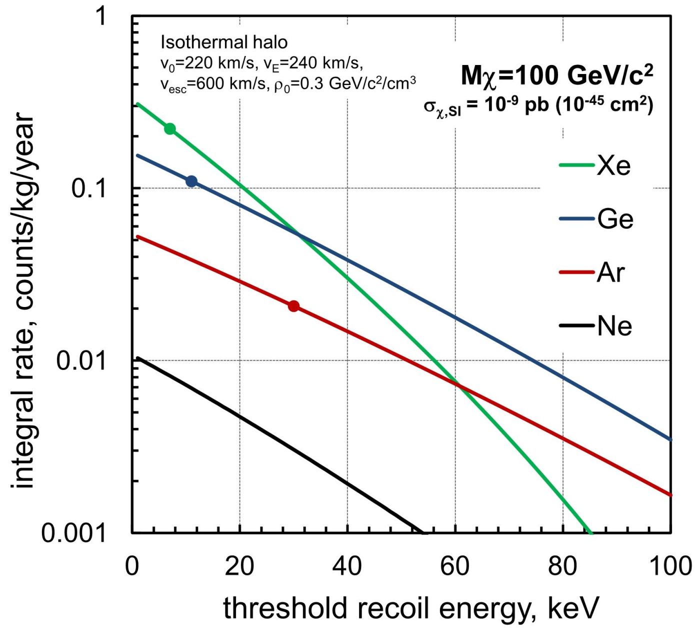


$(S2/S1)_{NR} << (S2/S1)_{ER}$



Direct detection with Xenon

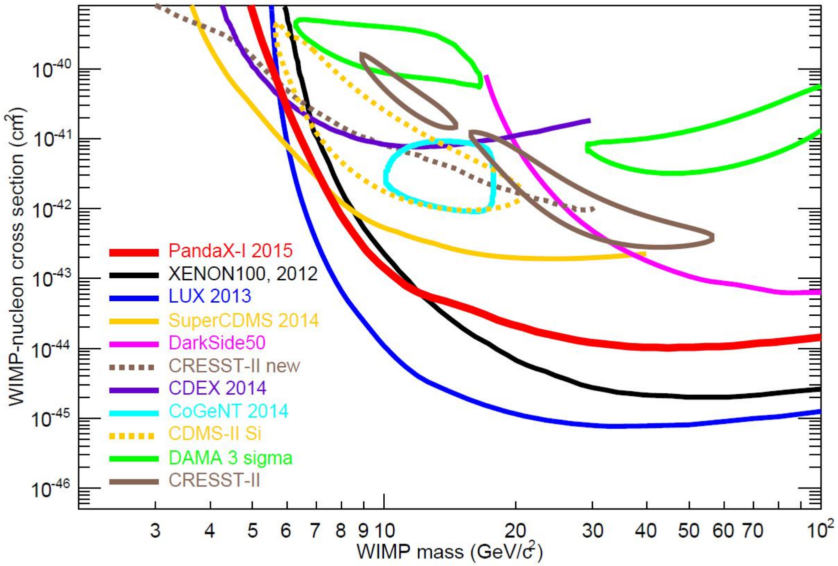




- Accessible cryogenic temperature (178.5K, 1.8Bar)
- No long-lived radioisotopes (Except Xe^{136} with $T_{1/2}=2.2\cdot10^{21}$year)
- High stopping power (high mass number A~131 and density 3.1kg/L)
- High rate for Spin Independent Interactions

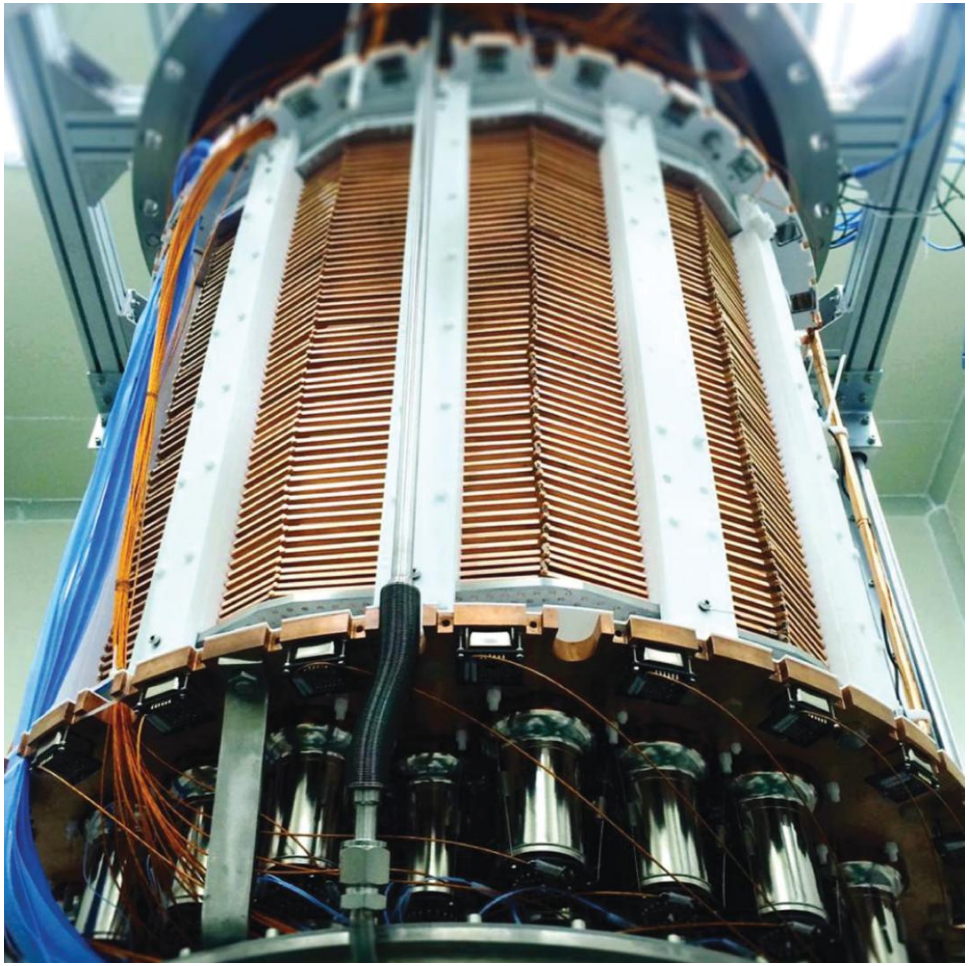
Results from PandaX-I

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



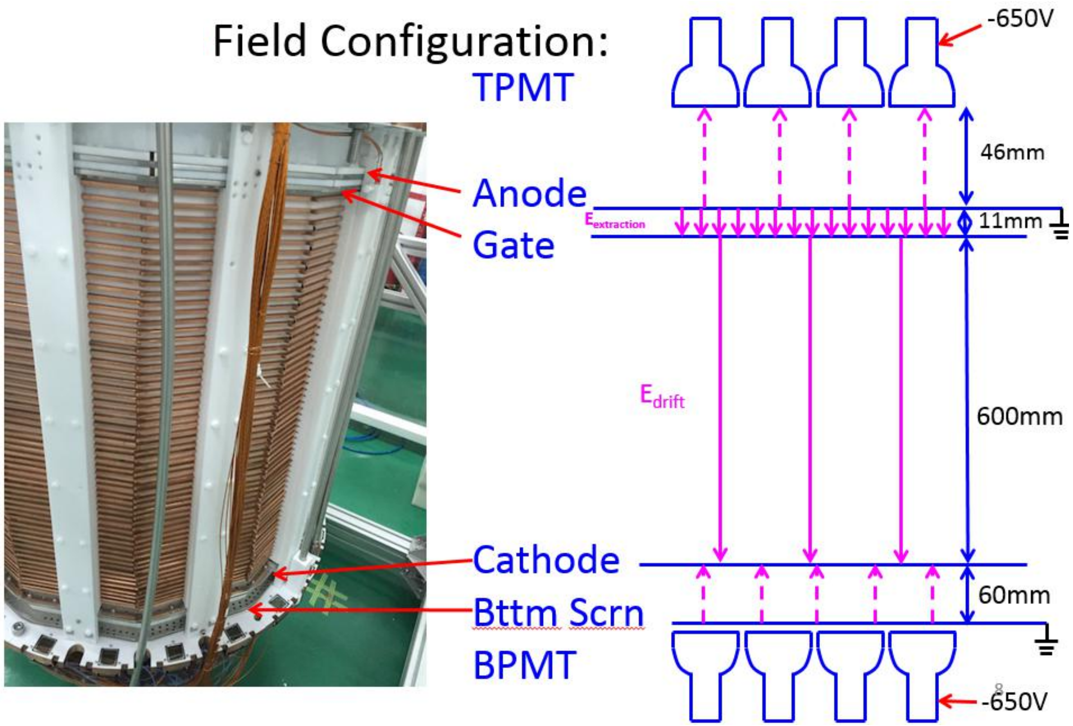
- Completed in Oct. 2014, with 54.0 x 80.1 kg-day exposure
- Data strongly disfavor all previously reported claims
- Competitive upper limits for low mass WIMP in xenon experiments

PandaX-II Detector



- 60 cm x 60 cm cylindrical TPC
- 580-kg of LXe in sensitive region, 1.2-ton LXe in total
- 55 top + 55 bottom R11410 3” target PMTs (split –ve and +ve HV)
- 24 top + 24 bottom R8520 1” VETO PMTs

PandaX-II field conditions



	Cathode (-kV)	Gate (-kV)	Drift field (V/cm)
Run9	-29.3	-4.95	400
Run10	-24.0	-4.95	320

Ref: LUX: 180 V/cm, XENON1T: 120 V/cm

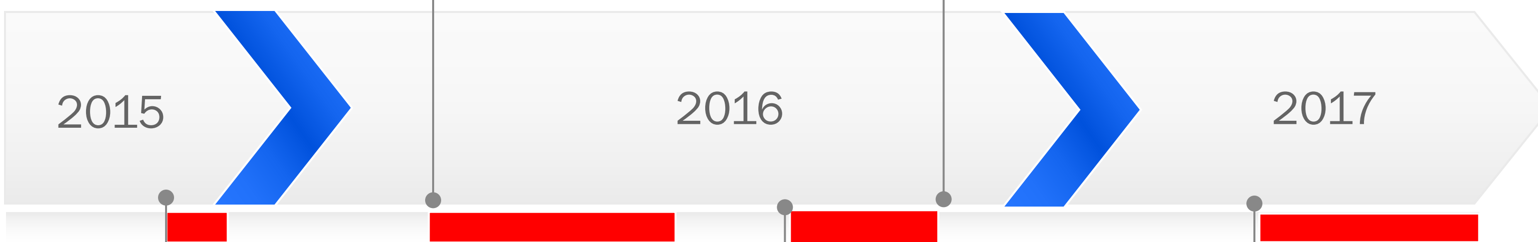
Drift field in Run10 was lowered to avoid spurious discharge from the cathode

PandaX-II run history

PandaX

Mar. 9 – June 30, low background with 10-fold reduction of Kr (Run9, 79.6 days)

Nov. 2016 – Apr 2017, 2nd distillation campaign and recommissioning



Nov. 22 – Dec. 14, Physics commission (Run8, 19.1 days, stopped due to high Krypton background)

Jul – Oct, ER calibration & tritium removal

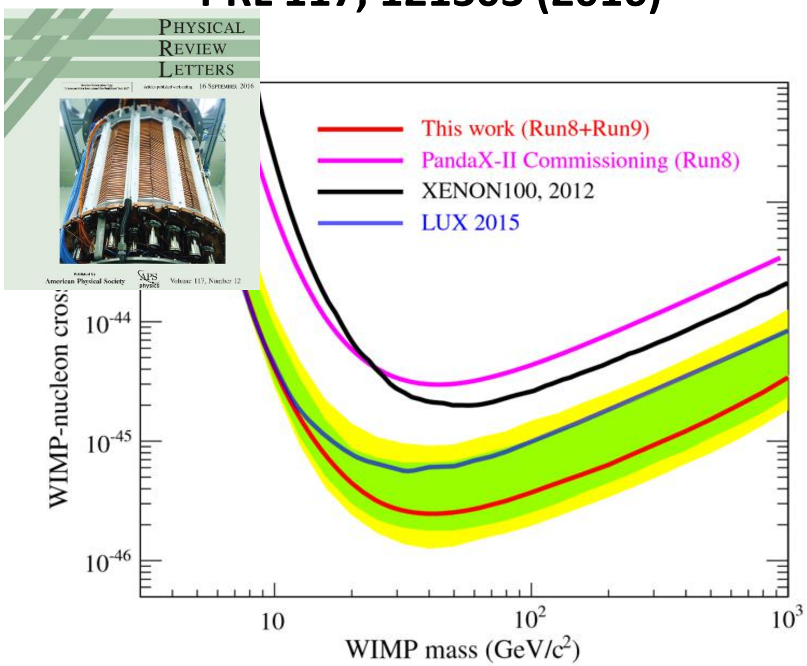
Apr.22 – July15, dark matter data taking (Run10, 77.1 days)

- Run9 =79.6 days, exposure: 26.2 ton-day
- Run10 =77.1 days, exposure: 27.9 ton-day
- Largest reported DM exposure to date

Run8+Run9 SI and SD results

33,000 kg-day exposure

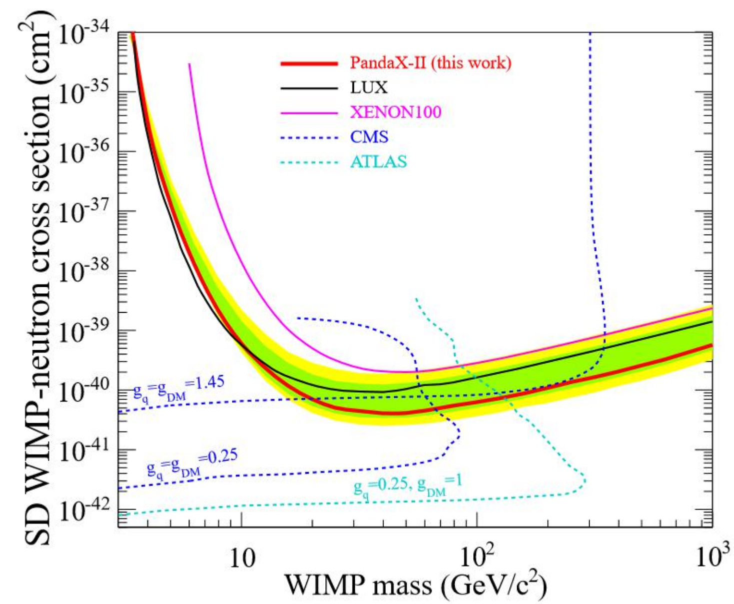
PRL 117, 121303 (2016)



Minimum elastic SI exclusion:

2.5×10^{-46} cm^2 @ 40 GeV/c^2

PRL 118, 071301 (2017)



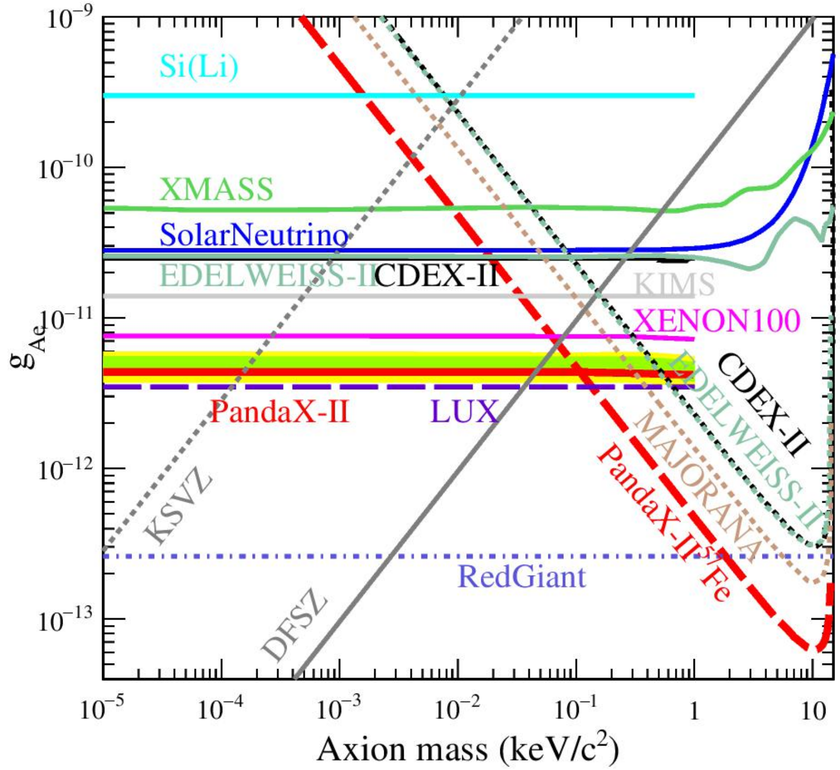
Minimum χ-n SD cross section limit:

4.1×10^{-41} cm^2 at 40 GeV/c^2

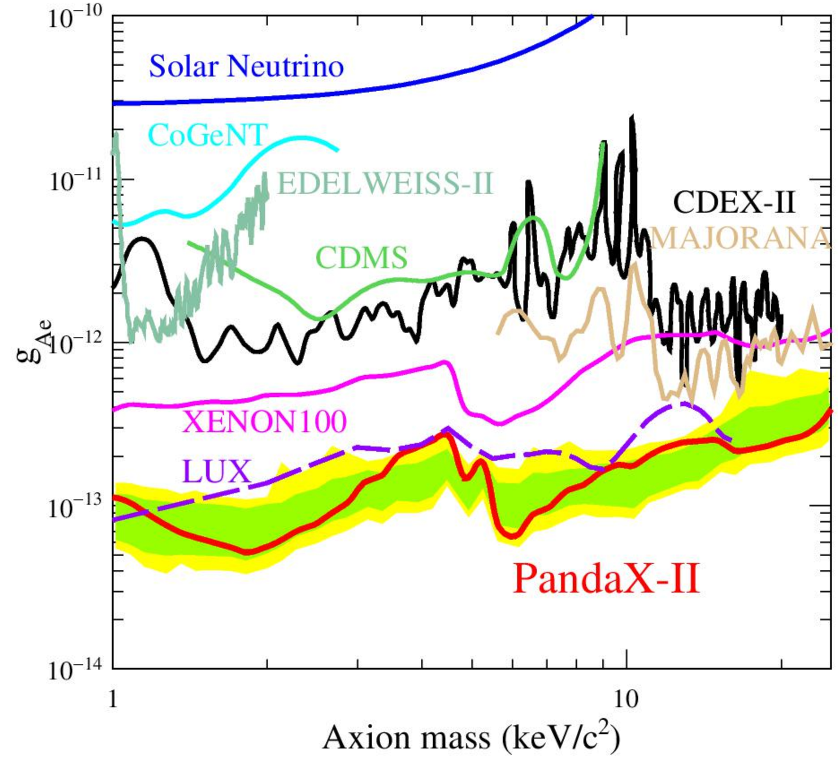
Run9 axion search results

arXiv:1707.07921

Solar axions



Galactic axion-like DM particles

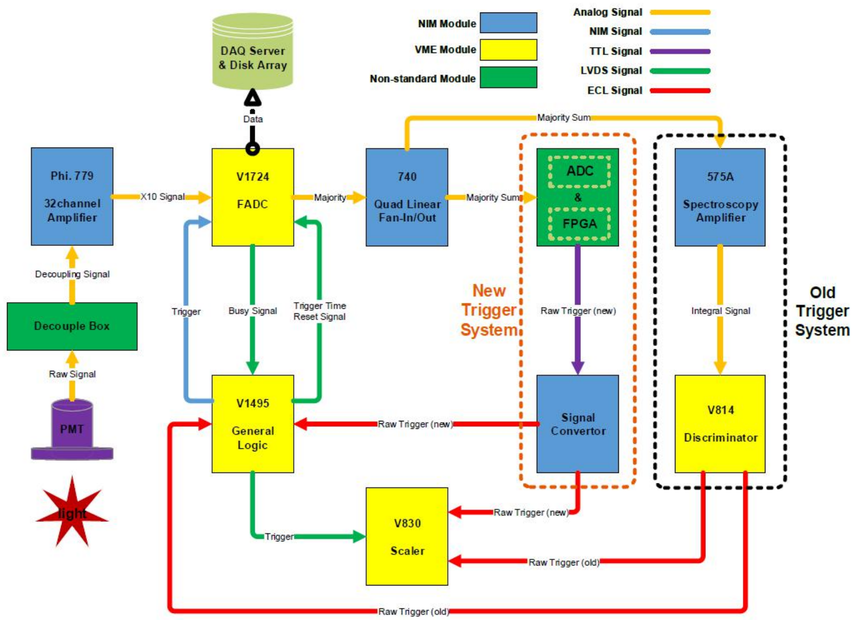


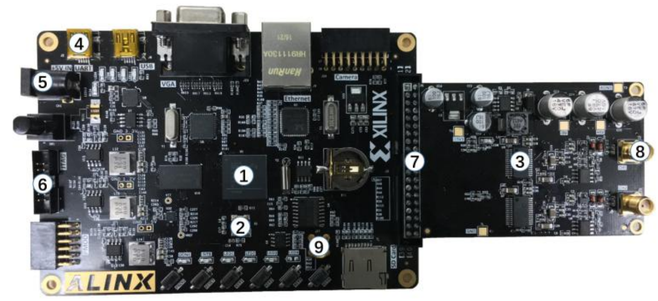
Among the leading axion search on axion-electron coupling using DD experiments

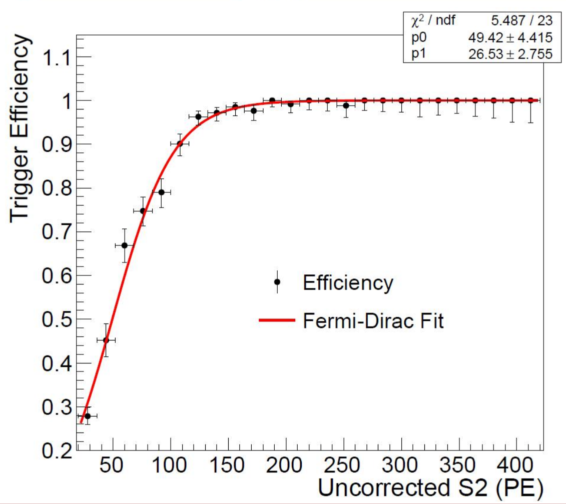
New search results from Run10

- Improved trigger threshold
- Channel-by-channel SPE efficiency (ε_{ZLE})
- Improved detector ER/NR response model
- 2.5 times reduction in total background
  - Kr85 ↓ 6 times
  - Accidental ↓ 3 times
  - Xe127 ↓13 times

Trigger improvement







- FPGA-based trigger allows realtime programmable noise rejection algorithm, lowering the trigger threshold
- Real data-driven determination of trigger threshold using off-trigger-window S2s ⇒ threshold 50 PE (before ~80 PE)

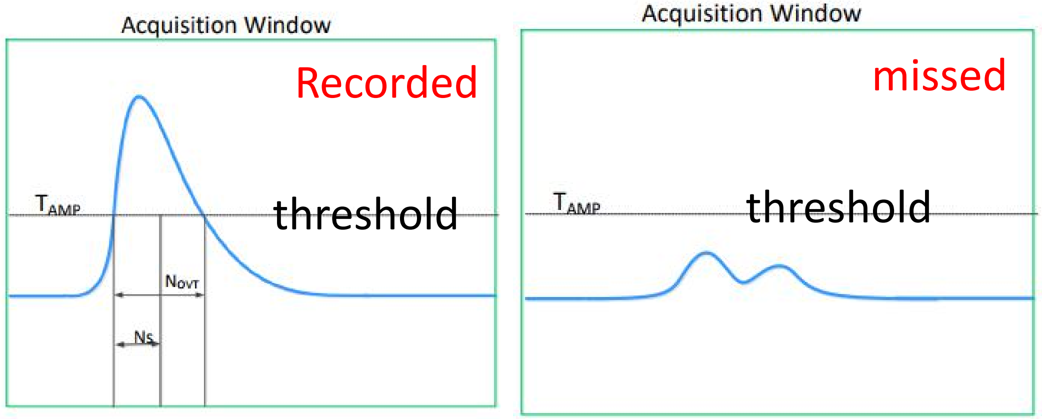
SPE efficiency calibration

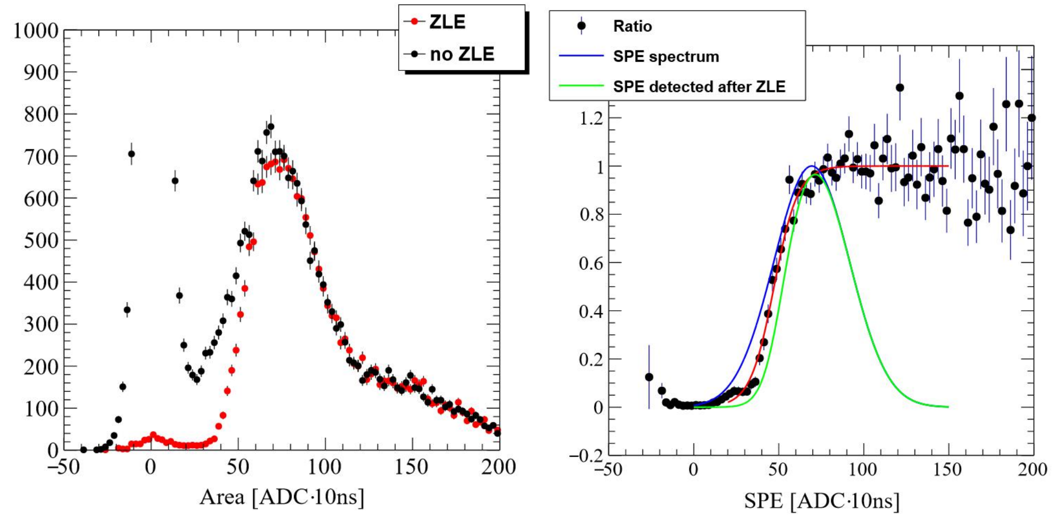
- Baseline suppression firmware (ZLE) in the digitizer affected SPE detection

⇒a source of nonlinearity for low photons

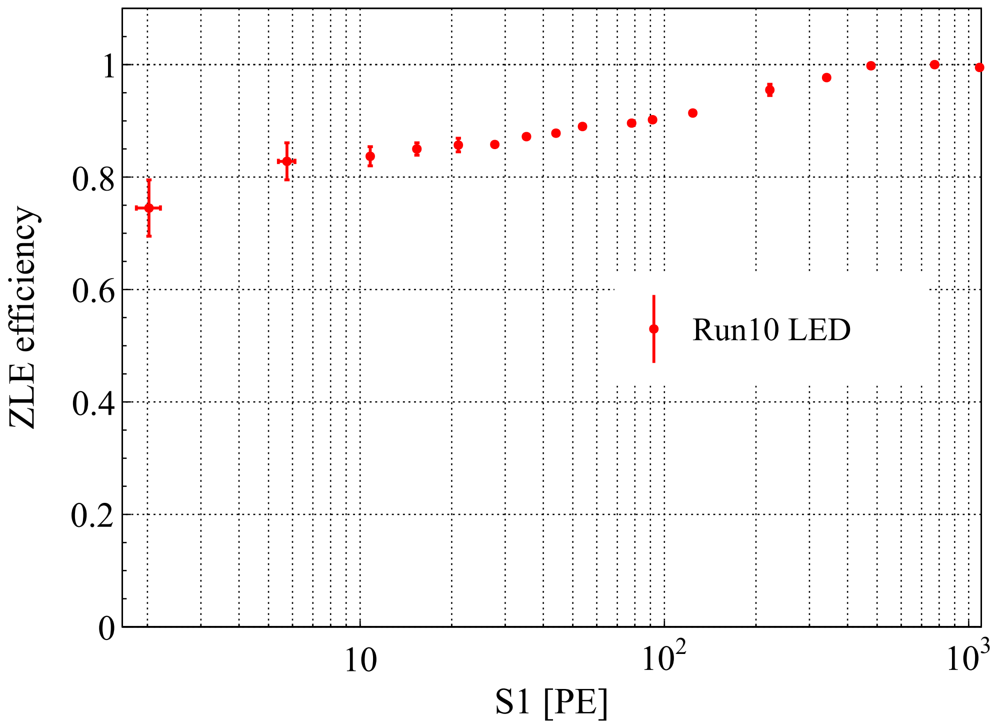
- Run10 PMT HV down with low dark rate also affect SPE efficiency

- Use LED runs with/wo ZLE to measure efficiency channel-by-channel



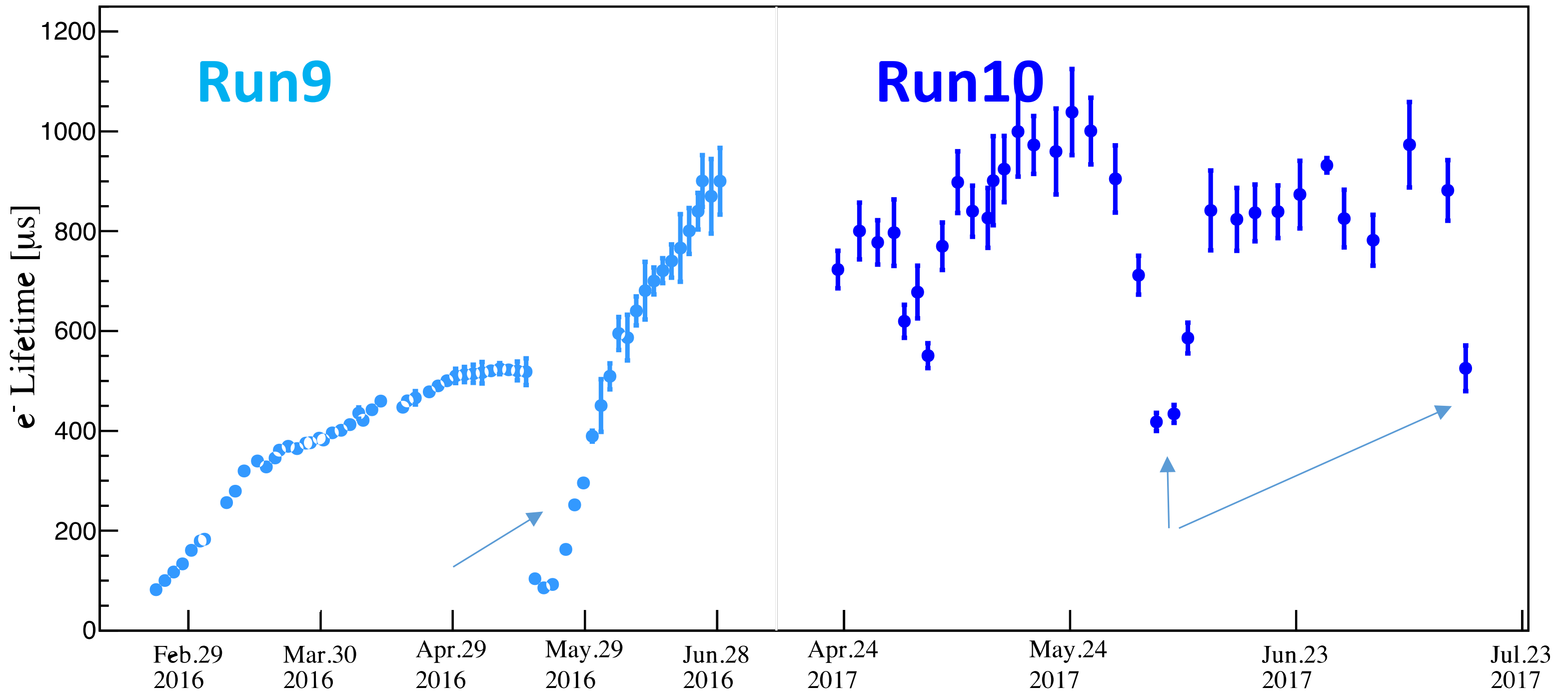


Overall ZLE efficiency by LED (≅ S1)



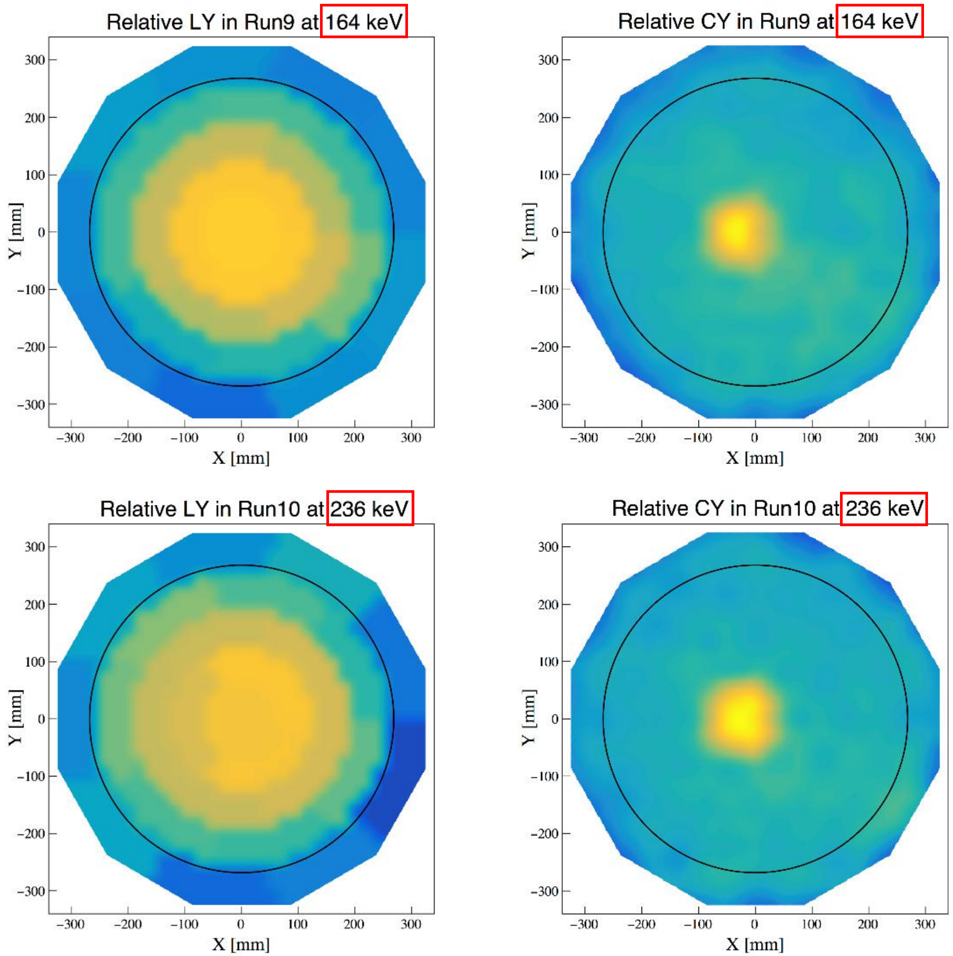
- Average efficiency measured at 3 PE (S1 threshold) was about 80% using blue LED
- PMT Double-PE emission would further improve the efficiency
- Little impact to S2, little impact to position reconstruction

Electron lifetime



- Electron lifetime on average 800 μs (1.4 m drift distance) in Run 10, and generally stable
- Significantly improved from Run 9

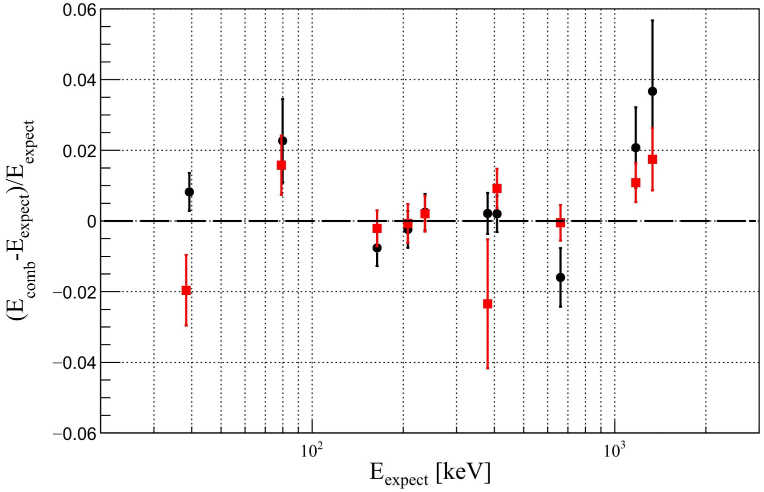
S1/S2 uniformity correction



- Using uniform gammas from xenon metastable states: RMS for S2 18.2%; for S1 10.0%
- Negligible dependence on gamma energy

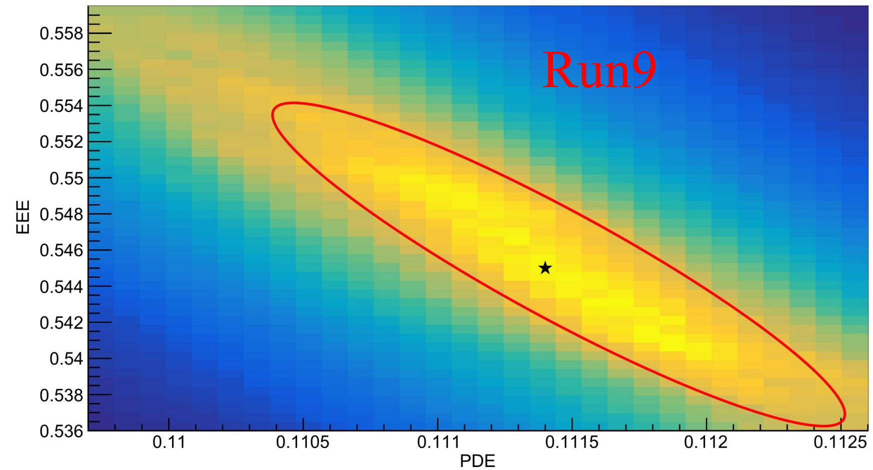
Extracting detector parameters

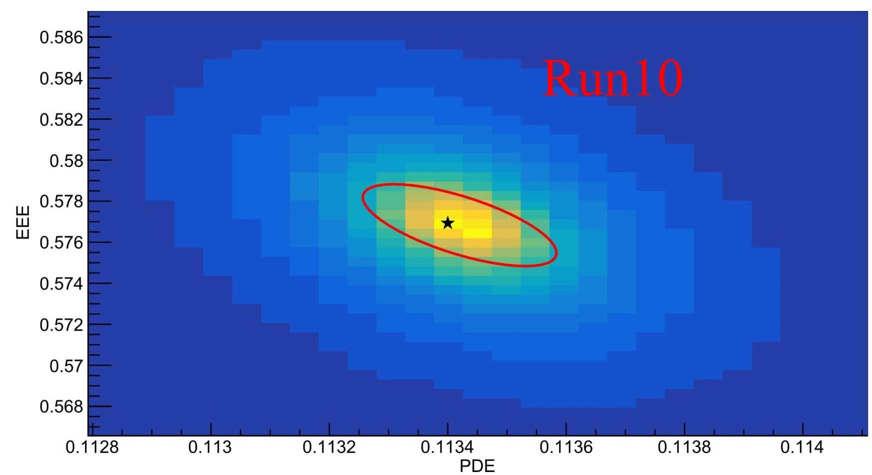
$$E_{ee} = W \times \left(\frac{S1}{PDE} + \frac{S2}{EEE \times SEG} \right)$$



For this analysis

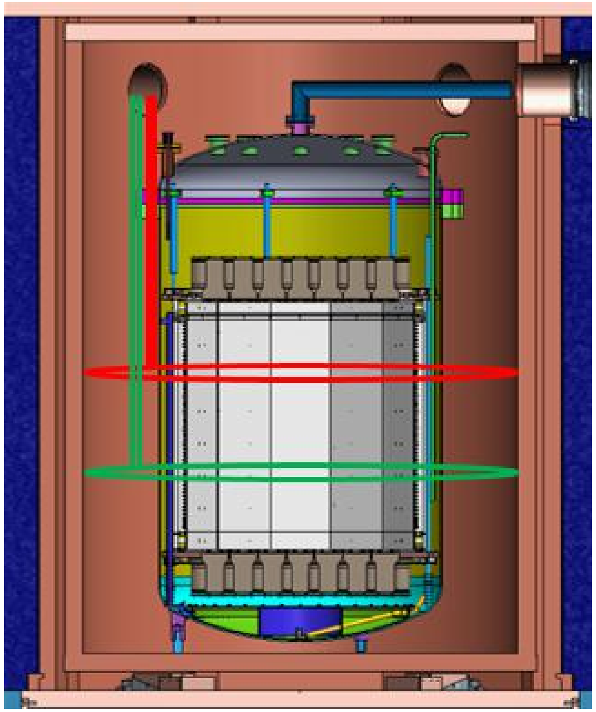
- SEG determined with ZLE efficiency taken into account
- Utilized a more careful treatment for the S2 saturation
- Resulting best fit <2% with expected energies

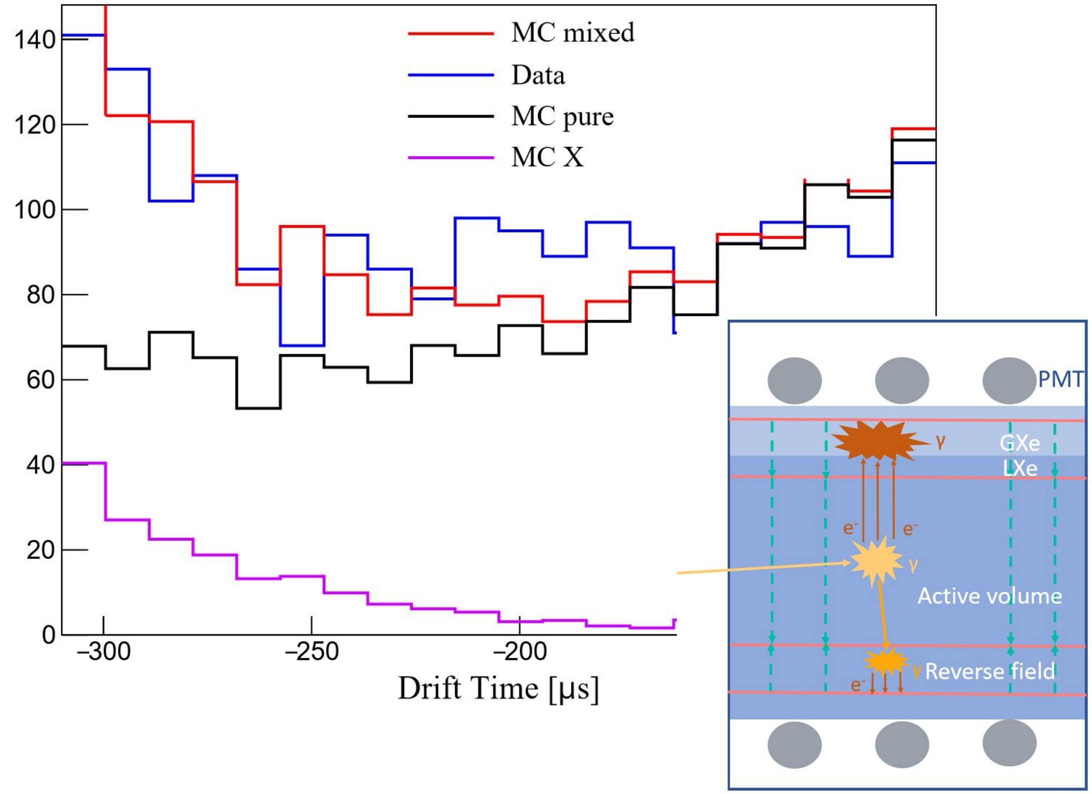




PDE/EEE combined scan with $1/\chi^2$ as the weight

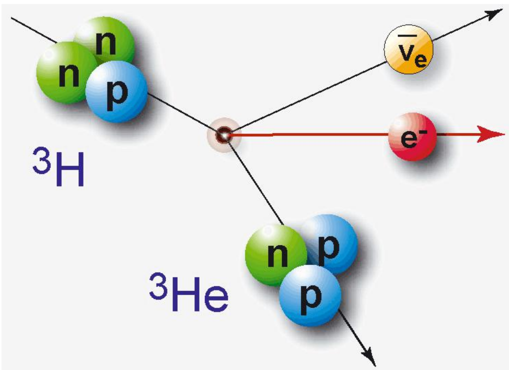
AmBe neutron calibration



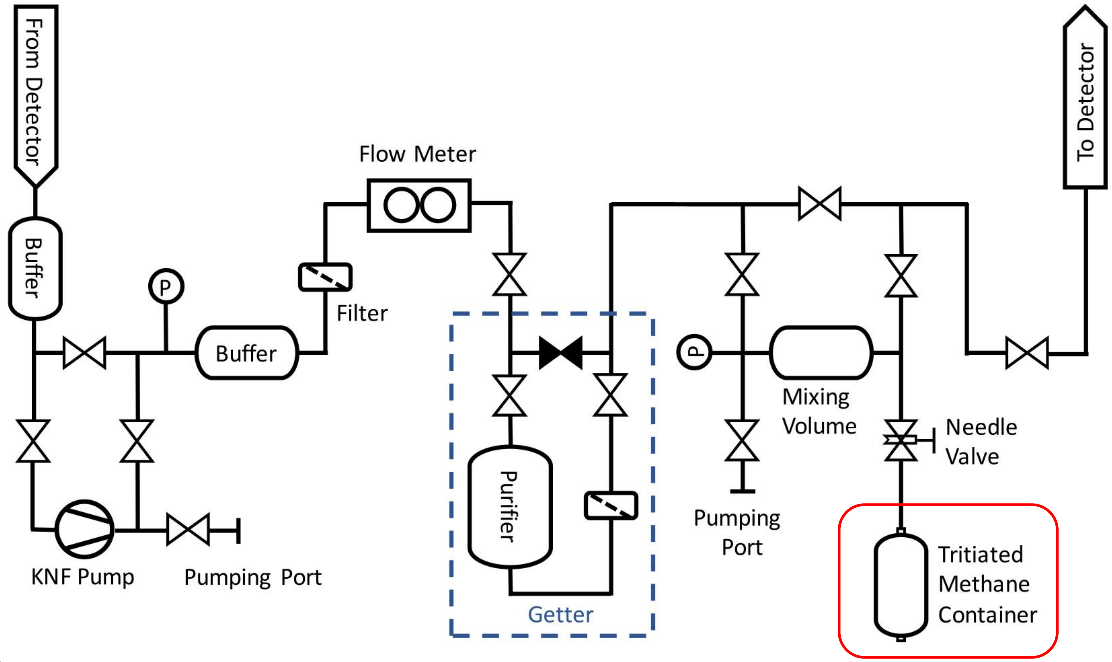


- 162.4 hours of AmBe data taken, with ~3200 low energy single scatter NR events collected
- By using position distribution of single-scatter NR events, we get good experimental handle on the X-events

ER calibration

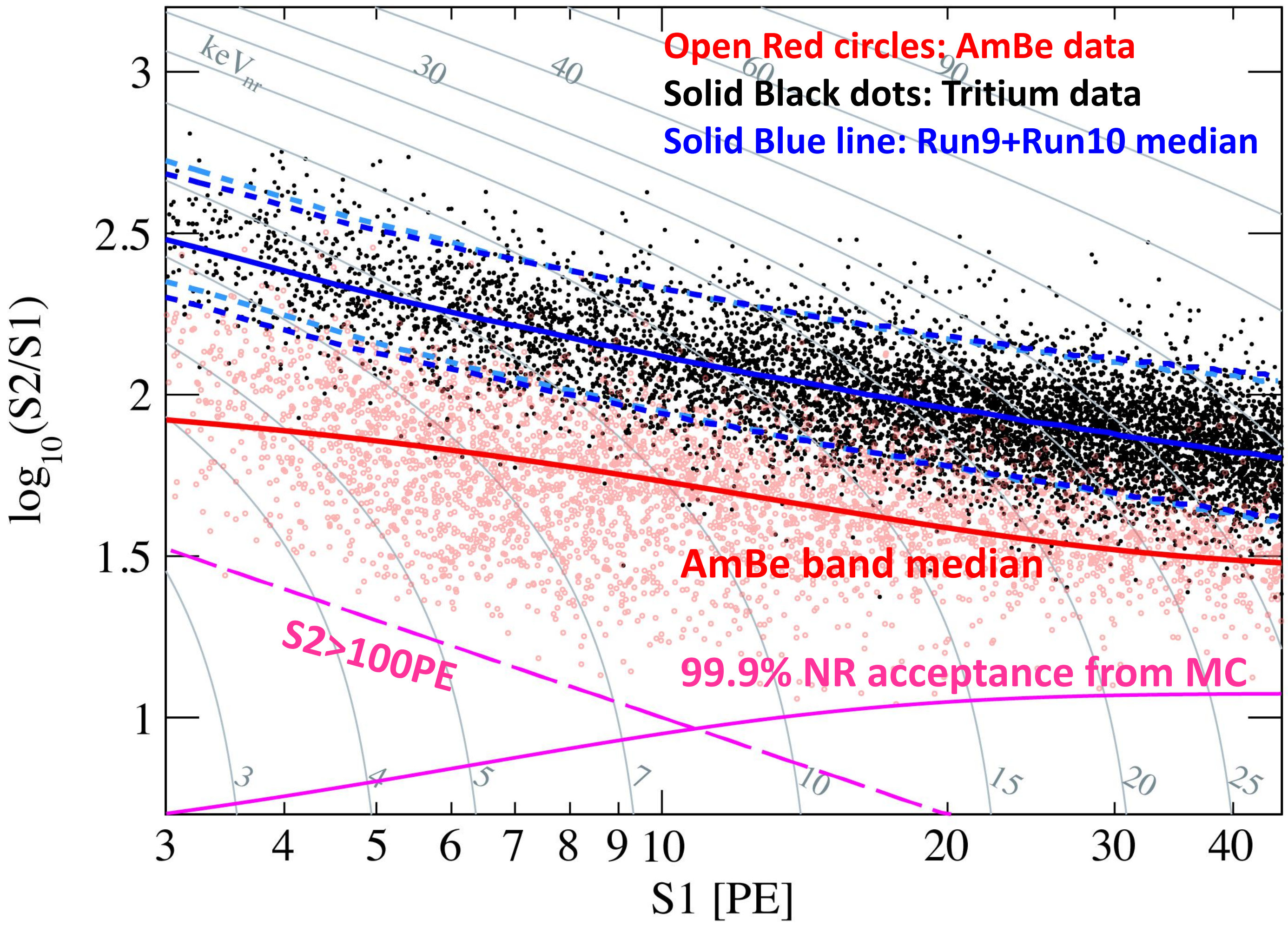


July – Oct, performed ER calibration using tritiated methane (a technique pioneered by LUX collaboration)



- Selected data with electron lifetime ~700 μs, ~8000 low energy ER events
- Events leaked below the NR median: 0.53(8)%
- Consistent with Gaussian estimate

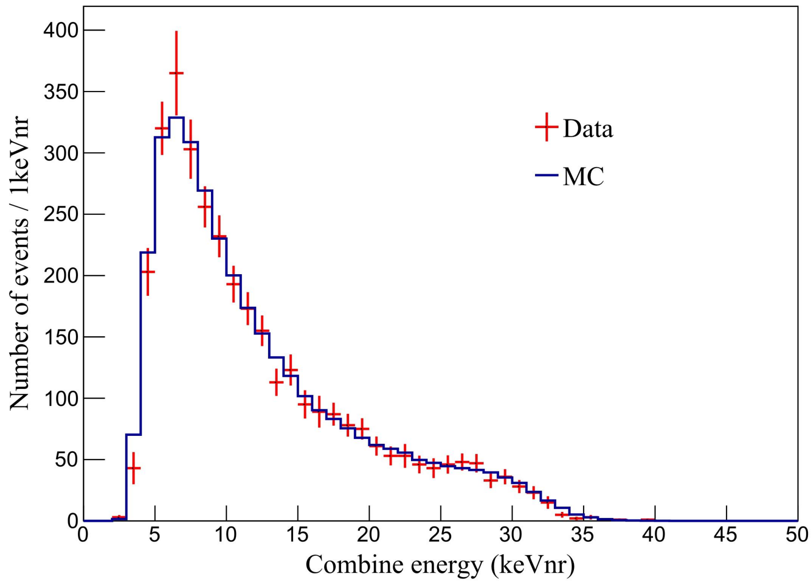
NR&ER data



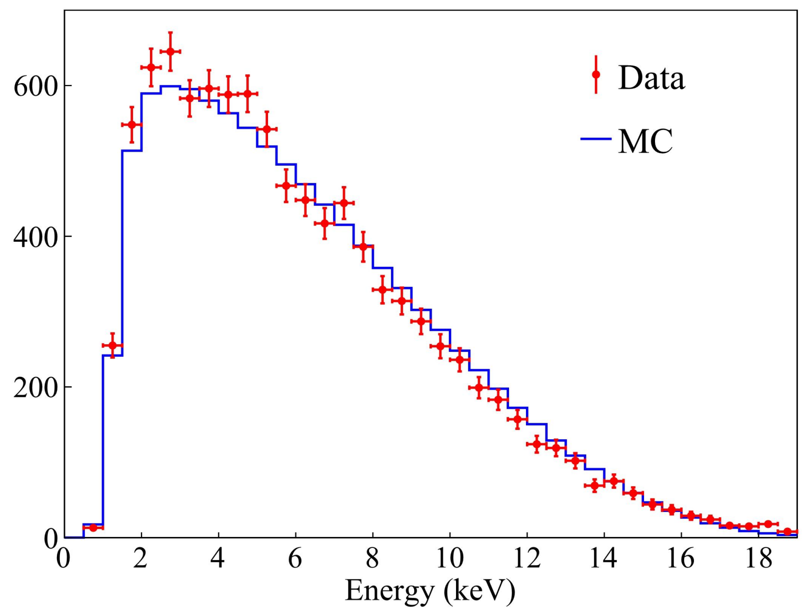
Open Red circles: AmBe data
Solid Black dots: Tritium data
Solid Blue line: Run9+Run10 median
AmBe band median
S2>100PE
99.9% NR acceptance from MC
keV$_{nr}$
$\log_{10}(S2/S1)$
S1 [PE]

Data comparison with MC

NR data with MC

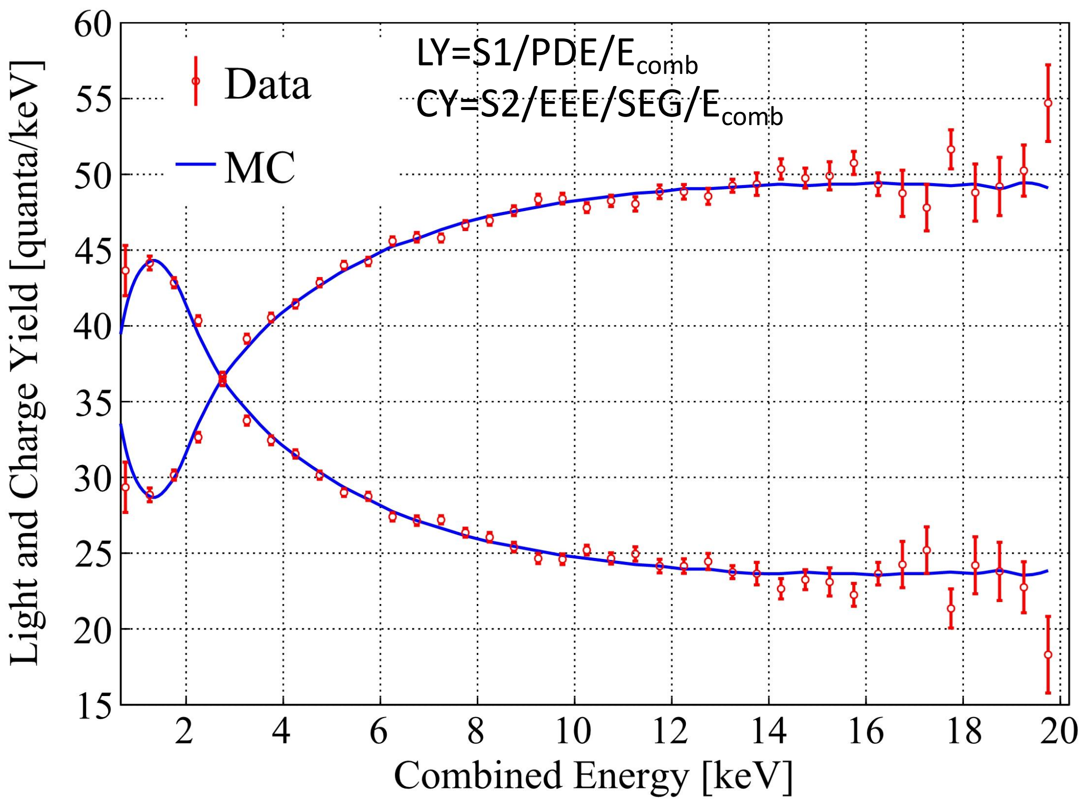


Tritium data with MC



- A tuning of the N_{ex}/N_i (excitation/ionization) parameter was made on the NEST model, after which data and MC yield good agreement
- Good consistency between data and MC over the entire tritium energy range.

ER calibration LY/CY from



- LY/CY reconstructed using detected photon/electron from data
- MC is NEST-based, but tuning the "recombination parameter", together with PDE/EEE/SEG and channel-channel ε_{ZLE}

2nd Distillation Campaign

- After ER calibration, realized that the getter could not remove tritium background effectively

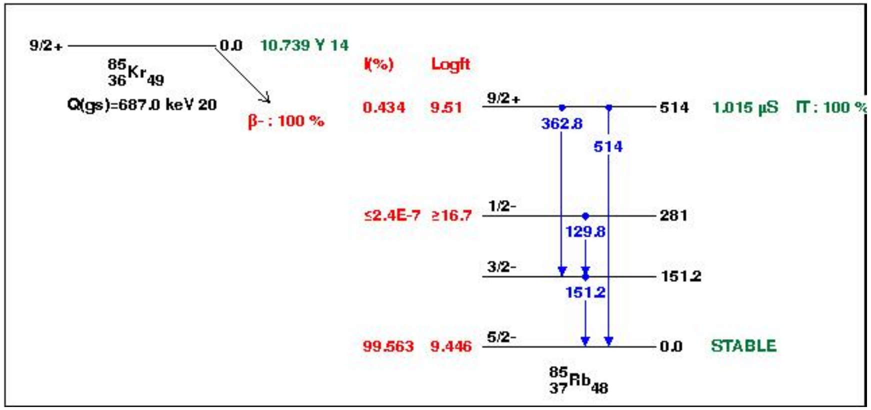
- Suspected tritium attached to wall, emanation rate balance with removal rate

⇒ 2nd distillation campaign (for Kr and tritium)

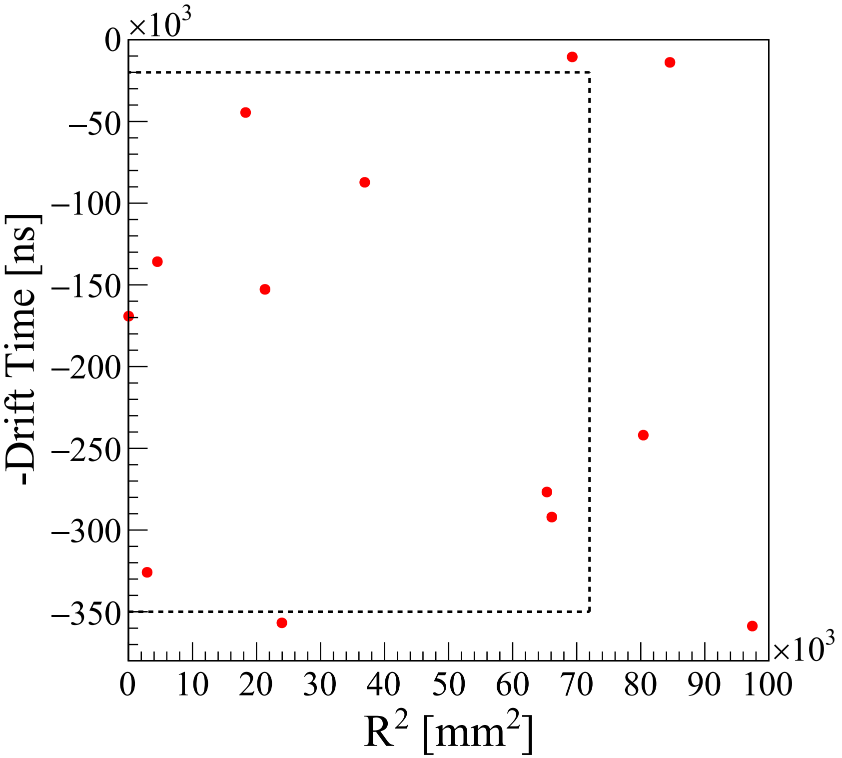
- Nov. – Mar 2017: **recuperate → distillation → refill,** flush (closed) detector with warm xenon

First beneficial occupancy of CJPL-II!

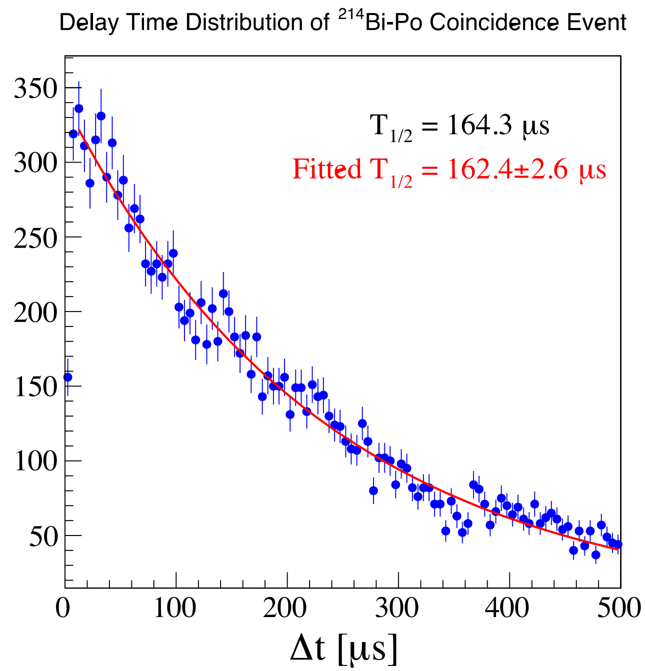
Krypton background

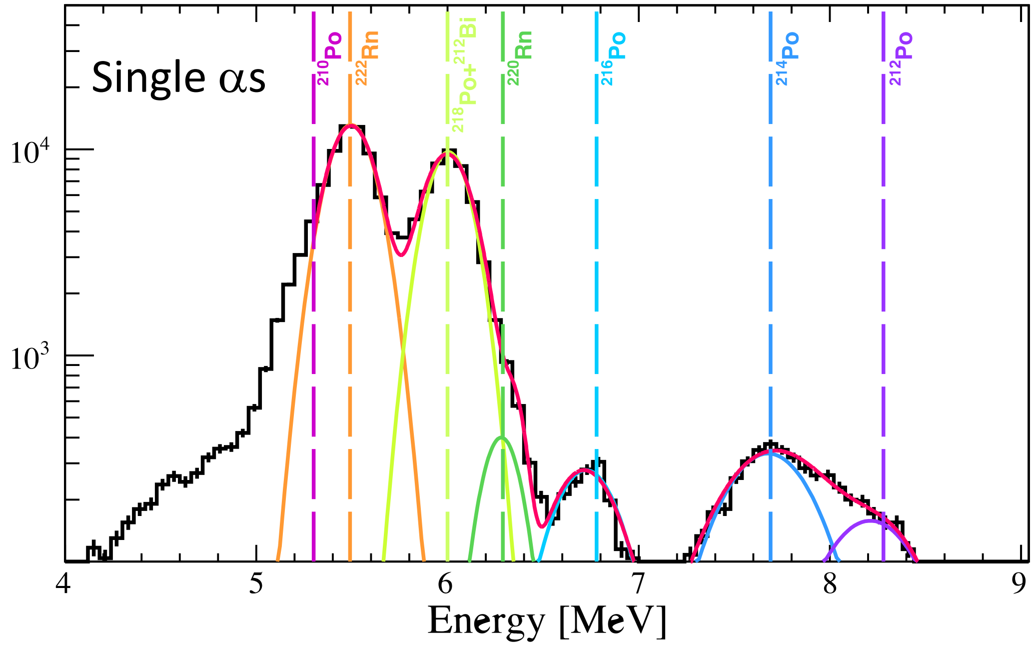


- 0.43% β decay with delayed ^{85m}Rb γ de-excitation
- Use (β,γ) delayed coincidence tag
- 13 events found in target ⇒ 6.6(1.8) ppt of Kr in Xe
- Reduced by 6 times from Run 9



Radon background

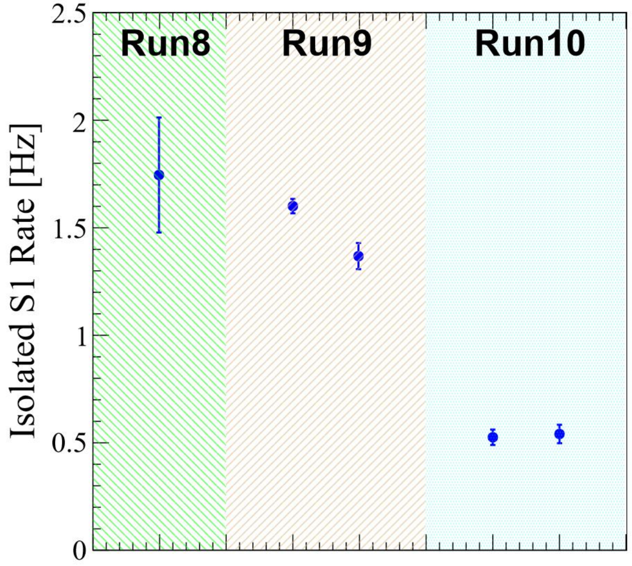


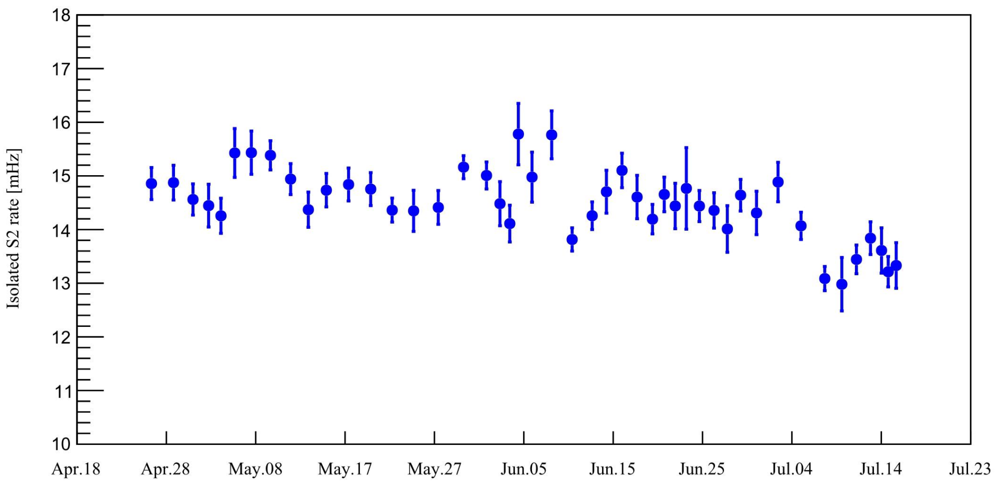


	Rn222	Rn220
μBq/kg	7.73	0.63
mDRU	0.10	0.02

Accidental background

Randomly select isolated S1 and S2





- The isolated S1 rate reduced by ~3times in run10, possibly a direct consequence of the reduced PMT gain and dark rate
- Single S2 rate remain consistent with Run 9
- Same BDT cuts from Run9 was applied to Run10 data, suppressing accidental background below-NR-median by another 50%

Background budget table

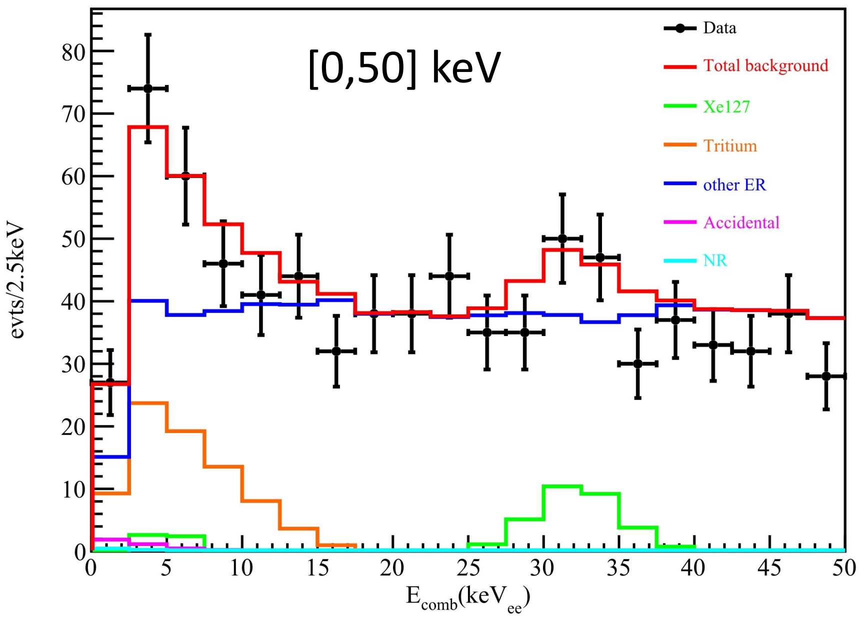
PandaX

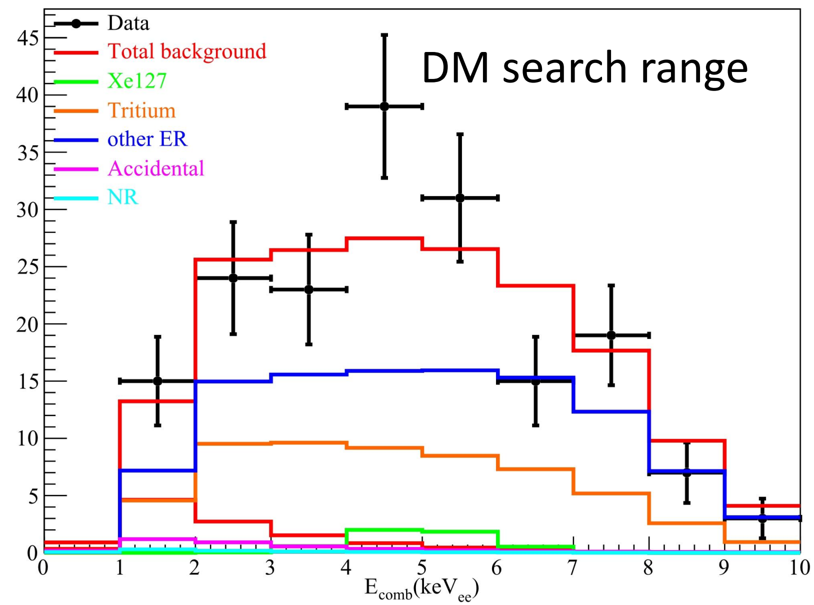
1 mDRU = 10^{-3} evts/keV/kg/day

	Run9	Run10
Xe127	0.42	0.021
Tritium	0	0.27
Kr85	1.19	0.20
Rn222	0.13	0.12
Rn220	0.01	0.02
Detector ER	0.20	0.20
Solar neutrino	0.01	0.01
Xe136	0.0022	0.0022
Total	1.96	0.79

- ^{127}Xe gone by time (Xe127)
- Based on best fit to data (Tritium)
- Reduced 6 times (Kr85)
- Rest are consistent between Run 9 and Run 10 (Rn222 to Xe136)
- Reduced 2.5 times (Total)

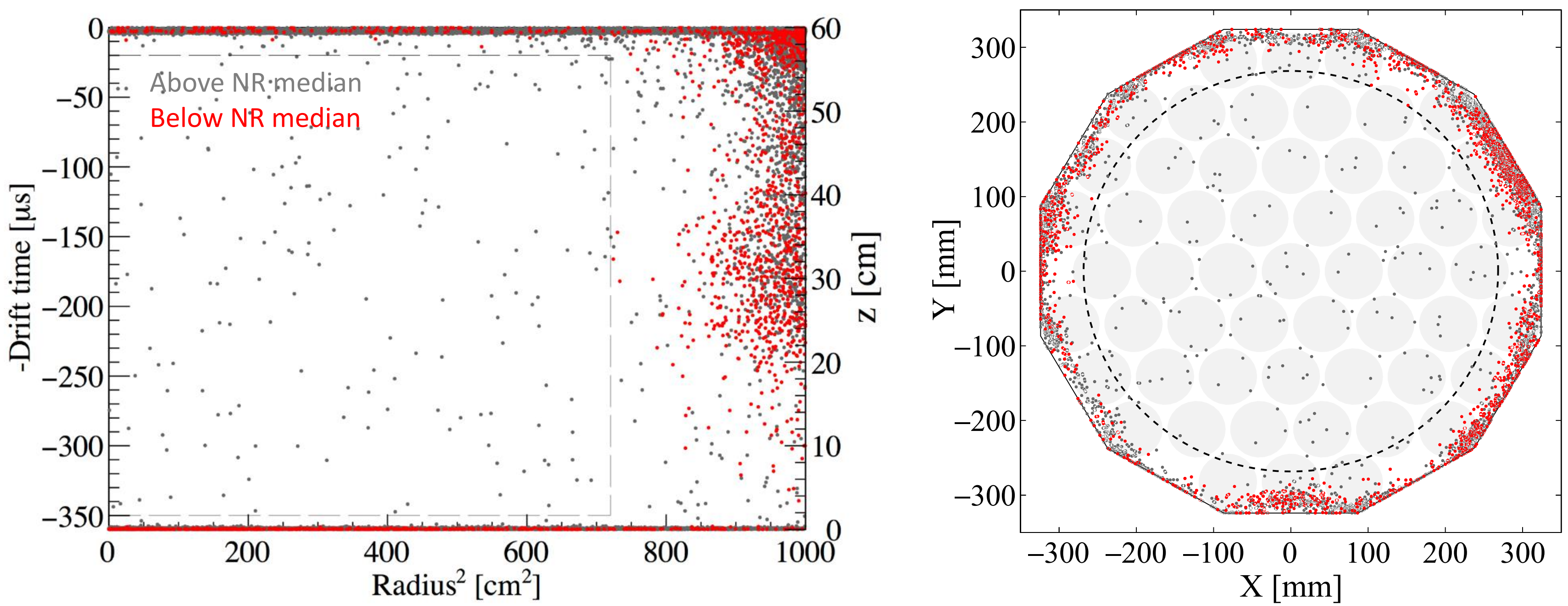
E_{comb} spectrum





Data and expected background in good agreement

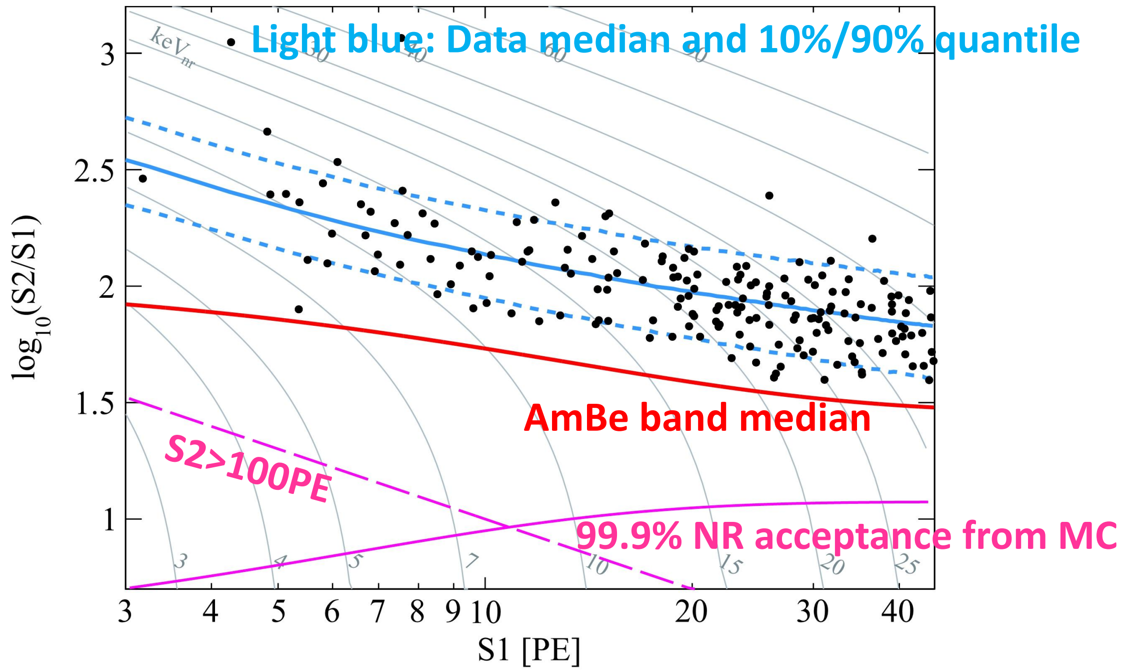
Vertex distribution



- Vertical cut adjusted from [18, 310] μs (Run 9) to [20, 350] μs (Run10)
- Radius cut remained at r<268 mm
- FV = 361.5±23.5 kg

- Residual events are uniformly distributed in the detector

Distribution of events (run10)



Total events: 177

- Expected background below NR median: 1.8±0.5 evts
- Observed: 0

Appears to have a downward fluctuation of background

Combined analysis with Run9

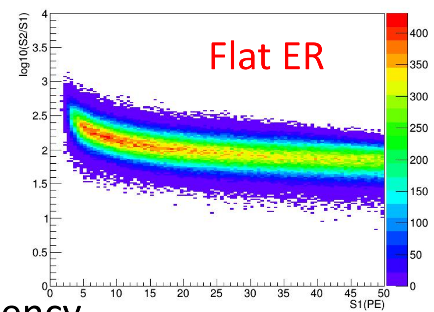
PandaX

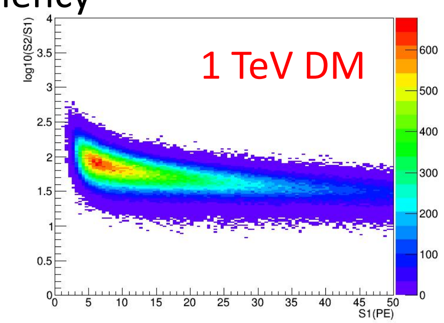
- Total exposure = 54 ton-day (world largest set)
- Background separated estimated in two runs but with common systematics
- Combined likelihood function with signal and background: flat ER (^{85}Kr, Rn and others), ^{127}Xe, tritium, accidental, neutron)

$$\mathcal{L}_{\rm pandax} = \left[\prod_{n=1}^{\rm nset} \mathcal{L}_n\right] \times \left[G(\delta_{\rm DM},\sigma_{\rm DM}) \prod_b G(\delta_b,\sigma_b)\right],$$

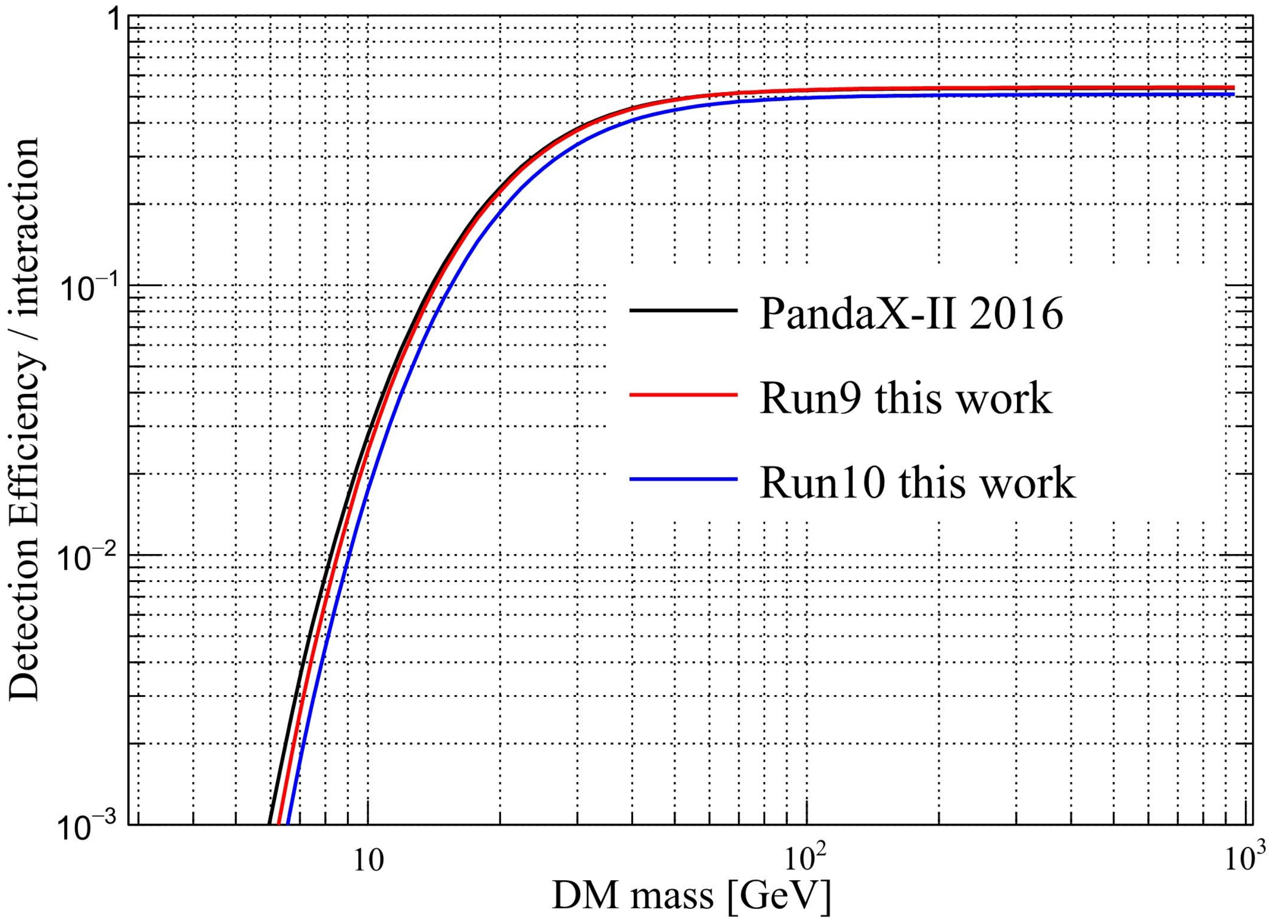
$$\mathcal{L}_n = {\rm Poiss}(N^n_{\rm meas}|N^n_{\rm exp}) \times \left[\prod_{i=1}^{N^n_{\rm meas}} \left(\frac{N^n_{\rm DM}(1+\delta_{\rm DM})P^n_{\rm DM}(S_1^i,S_2^i)}{N^n_{\rm exp}} + \sum_b \frac{N^n_b(1+\delta_b)P^n_b(S_1^i,S_2^i)}{N^n_{\rm exp}}\right)\right]$$

PDFs with efficiency

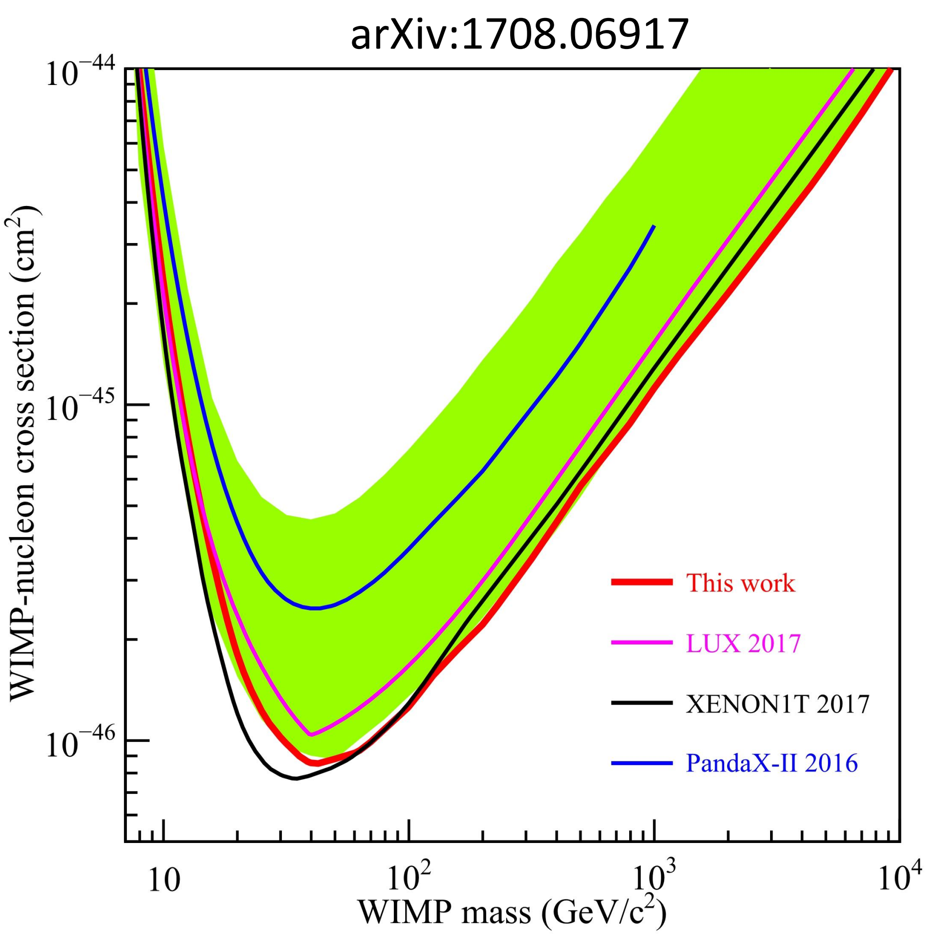


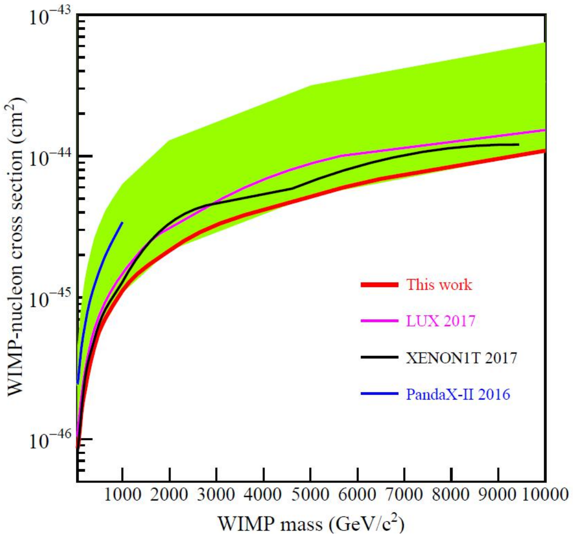


Detection efficiency



Results on elastic SI DM-nucleon scattering





- Profile likelihood fits made to the data
- Yield a most stringent limit for WIMP-nucleon cross section for mass >100GeV
- Improved from PandaX-II 2016 limit about 2.5 time for mass>30 GeV
- Lowest exclusion at 8.6×10^{-47}cm² at 40GeV/c²

Summary and outlook

- PandaX-II remains at the forefront of the DM search
- Will continue PandaX-II data taking until a multi-ton scale experiment at CJPL
- The collaboration is going forward in preparation for PandaX-xT and PandaX-III

Thank you