Status and Recent Results from the PandaX Experiment

Mengjiao Xiao

Shanghai Jiao Tong University/University of Maryland

On Behalf of the PANDA X Collaboration

2016-06-20

PandaX Collaboration

PandaX = Particle and Astrophysical Xenon Experiments

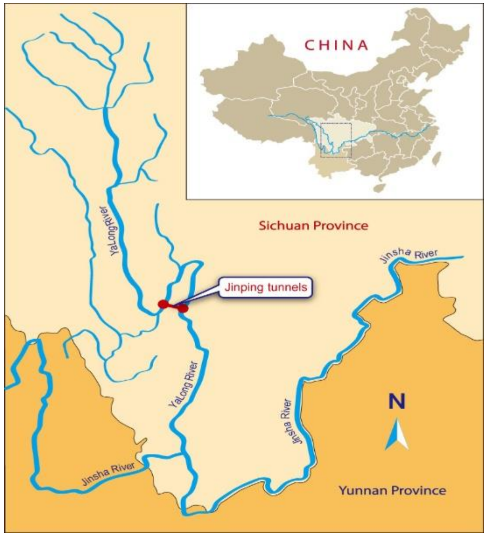
~ 40 people

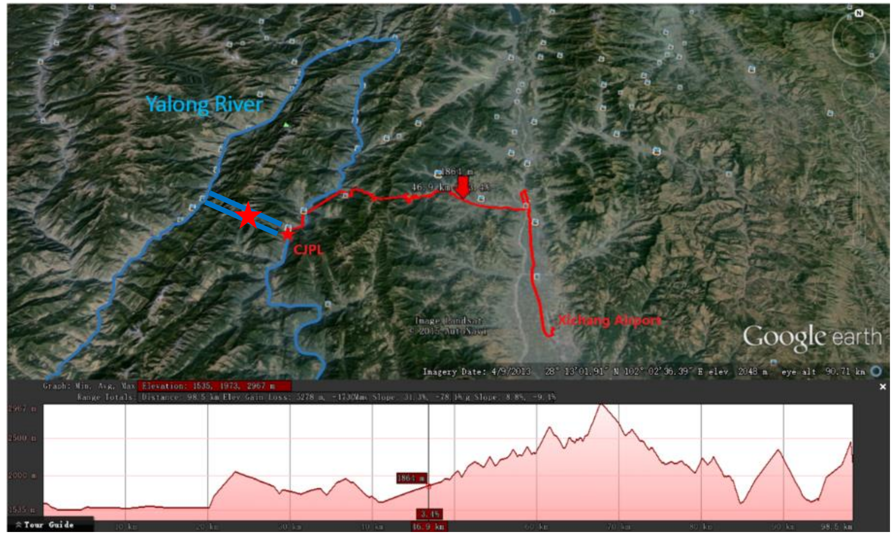
Started in 2009:

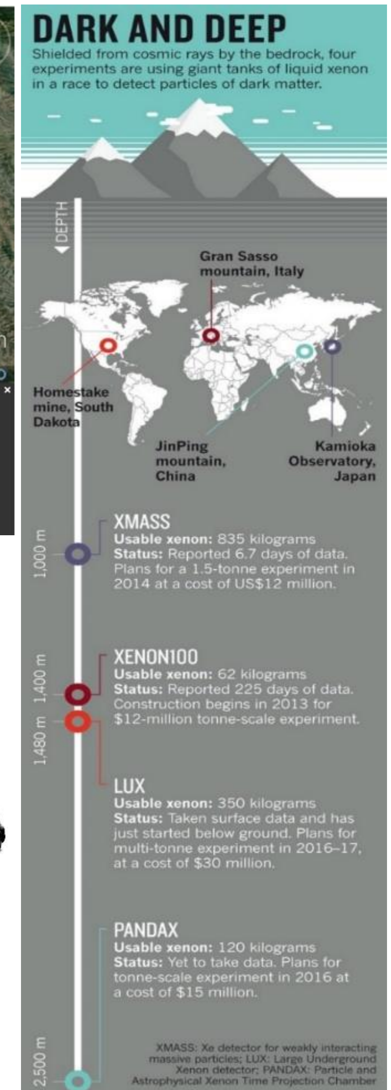
- Shanghai Jiao Tong University (2009~)
- Shanghai Institute of Applied Physics, CAS (2009~)
- Shandong University (2009~)
- Peking University (2009~)
- Yalong River Hydropower Company (2009~)
- University of Science & Technology of China (2015~)
- China Institute of Atomic Energy (2015~)
- University of Maryland (2009~)
- University of Michigan (2009~2015)

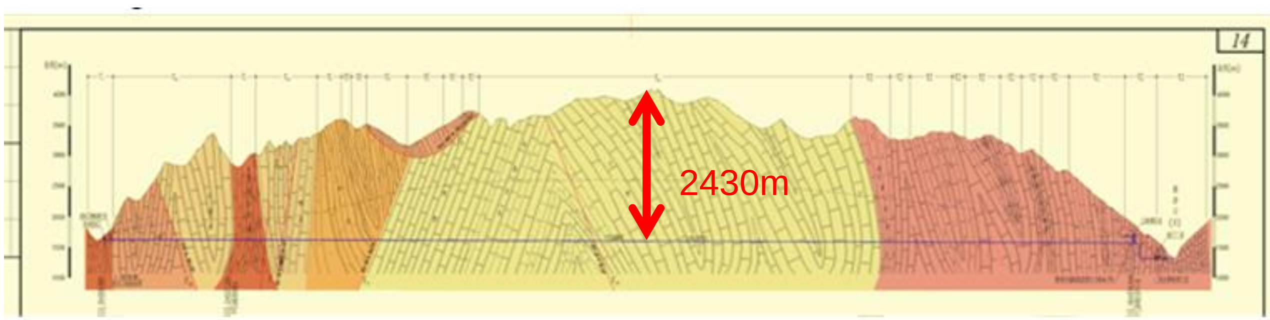
PANDA X http://pandax.org

China Jin-Ping Underground Laboratory





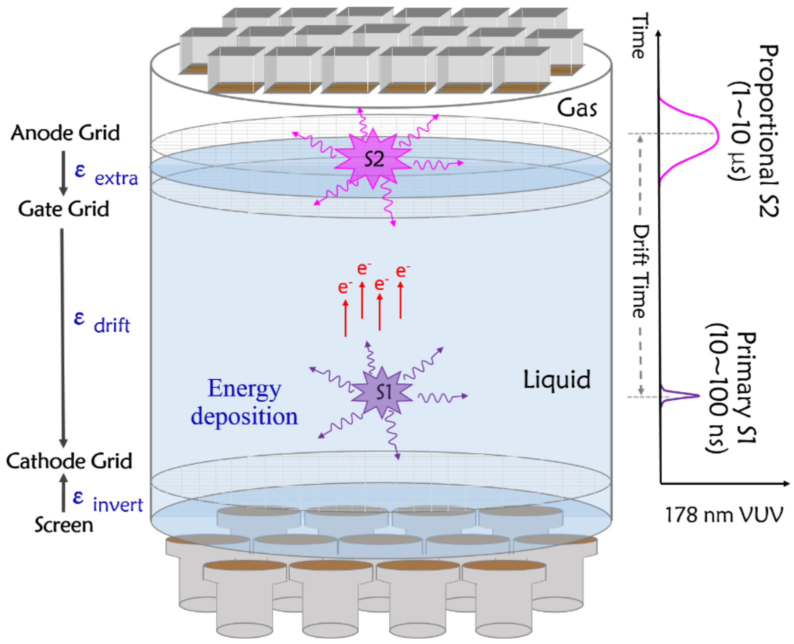


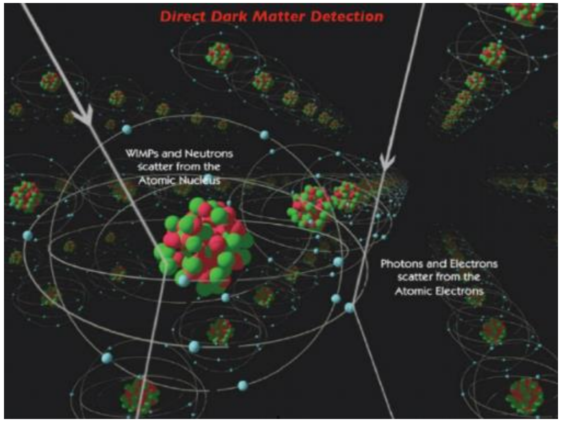


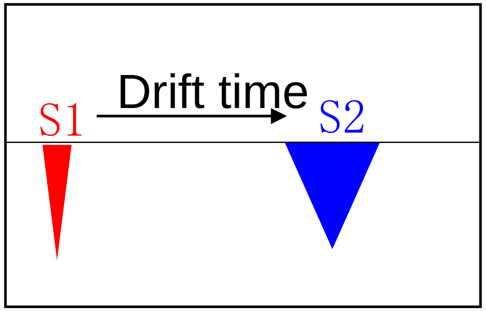
17 km tunnel

- Deepest in the world, muon flux ~1 μ/week/m^2;
- Horizontally access, Drive in!

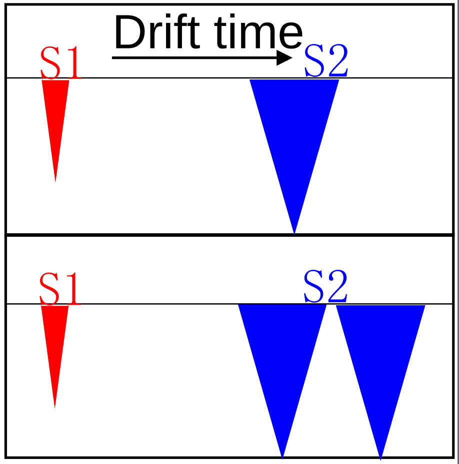
Dark matter search with dual-phase Xe TPC







Dark matter:
nuclear recoil (NR)

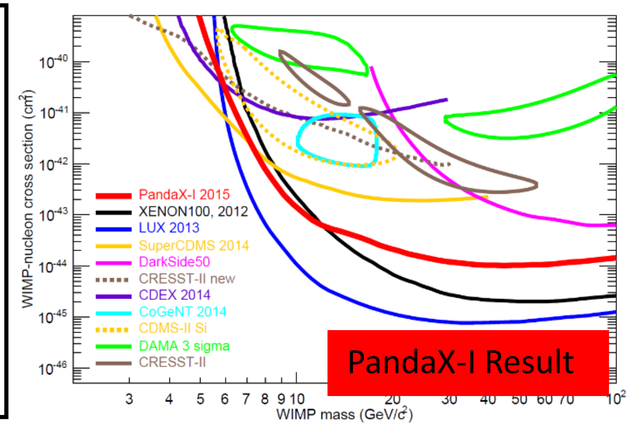


Gamma background:
electron recoil (ER)

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

PandaX-I ➔ PandaX-II

- 54 kg × 80.1 day exposure;
- No DM signal was found;
- Lowest excluded: 10^{-44} cm^2 at 44.7 GeV/c^2;
- Strongly disfavored the all positive WIMP claims.



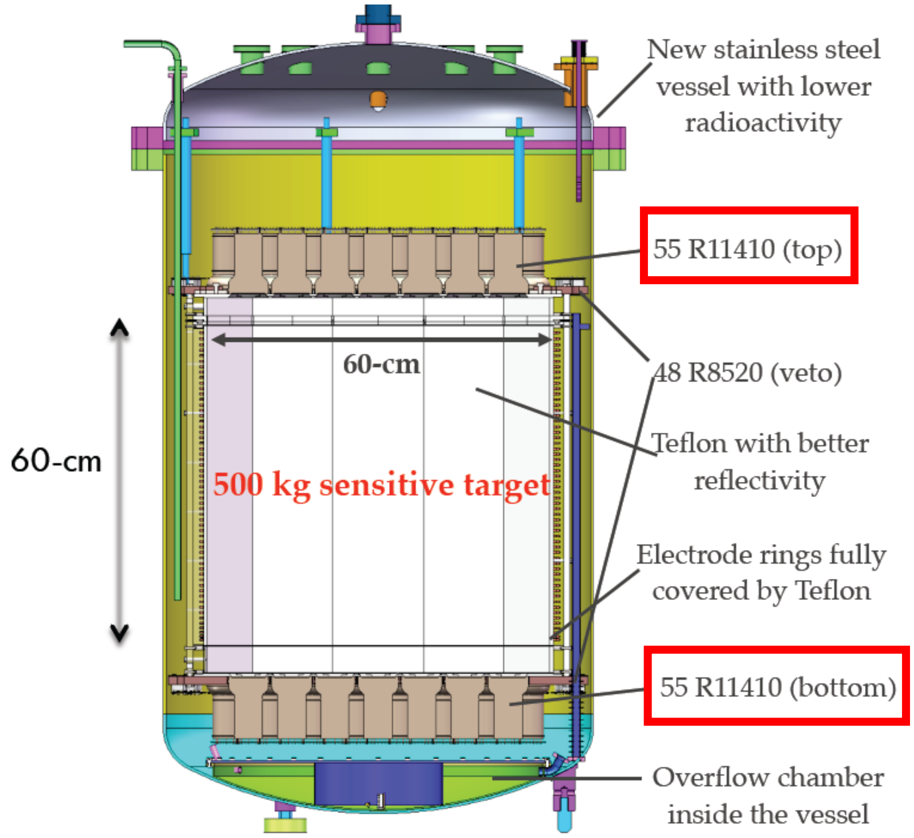
2009---Aug. 2012---Oct. 2014

2014---Nov. 2015---Now

Reused:

- Same experimental hall at CJPL;
- Passive shielding + outer vessel;
- Cryogenic system;

PandaX-II new TPC



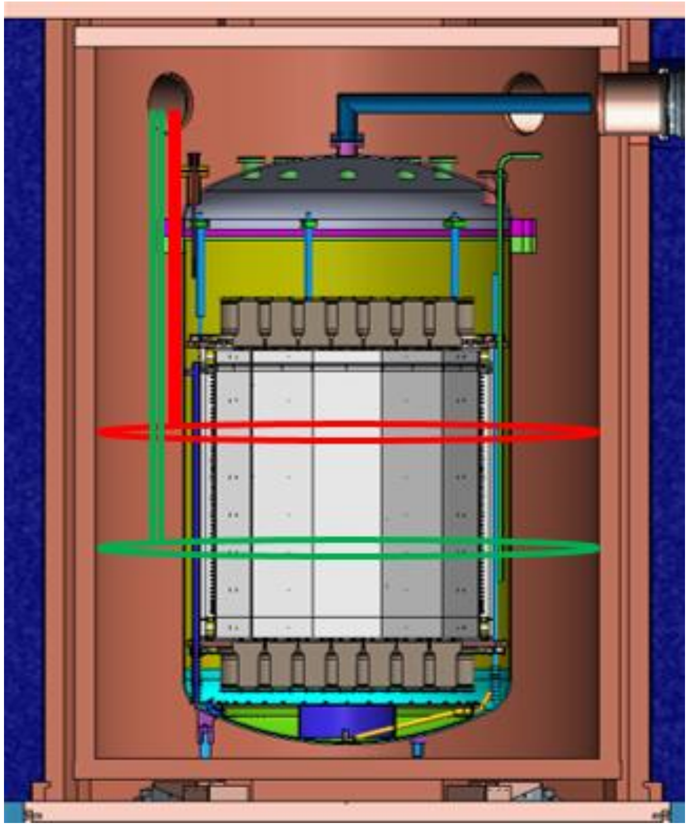
More than Larger Volume:

- New IV: inner vessel with clean low radioactive Stainless steel
- New PMTs: 55+55, 3-inch High QE (R11410), improved base design (±650 V).
- New Veto: PMTs in skin region
- New OC: overflow chamber at Bottom, save expensive Xe
- Better Reflector: improved reflectivity of PTFE, etc.

PandaX-II running history

- Oct. 2014: Start the on-site installation of detector;
- 2015, series of Engineering Runs in 2015: fixing various problems as we were testing all the components of the setup;
- Nov. 22 – Dec. 14 2015, a physics Commissioning Run: 19.1 live-day x 306 kg FV, not everything in perfect conditions
  - ✓ Large Kr contamination
  - ✓ No low energy ER calibration
- 2016, the re-distillation of Kr completed and data taking is resumed.

Detector calibration



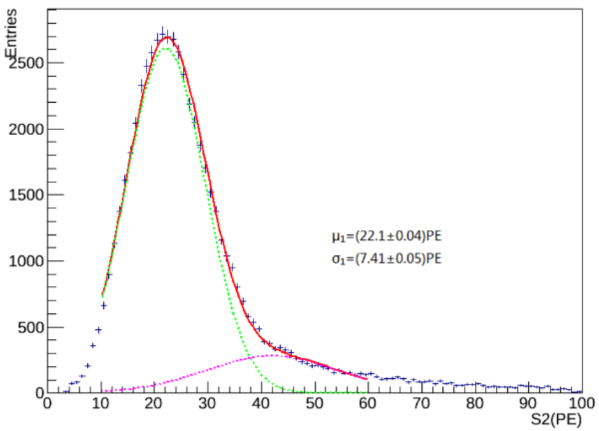
- Calibration setup for PandaX-II

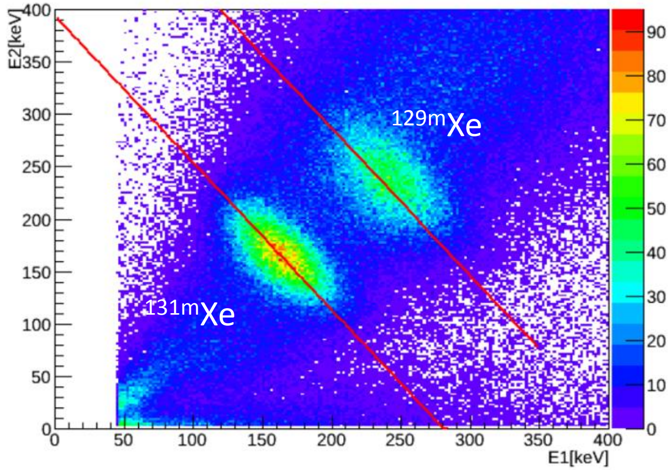
- Radioactive Sources, through Two tracks:
  - NR: Cf252
- Position Reconstruction
  - PMTs + MC + Field Map
- Detector parameters:
  - anti-correlation between S1 (photons) and S2 (electrons):

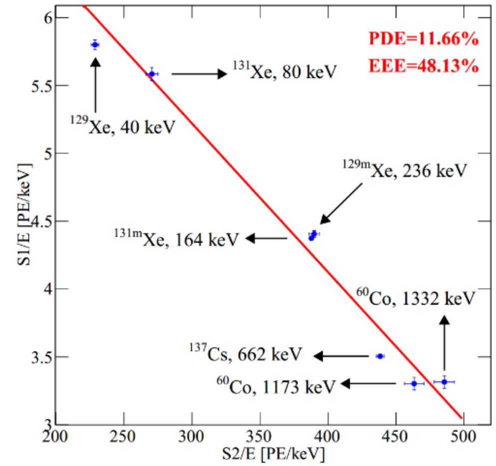
$$E_{ee} = W \times \left(\frac{S1}{PDE} + \frac{S2}{EEE \times SEG}\right)$$

- W: mean energy to produce a quanta (photon/e^-)
- PDE: Photon Detection Eff.
- EEE: Electron Extraction Eff.
- SEG: Single Electron Gain

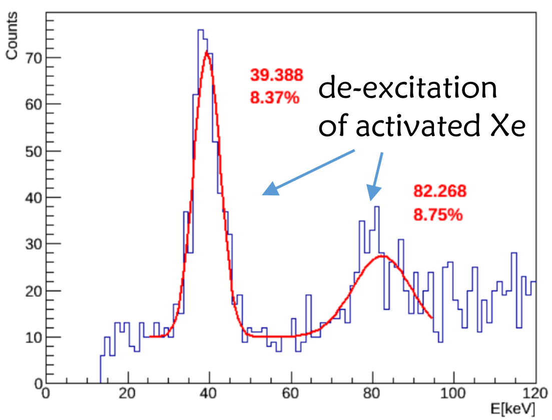
Detector parameters and energy reconstruction



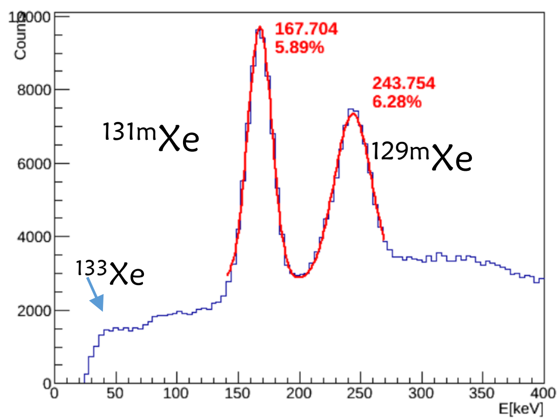




$$E_{ee} = W \times \left(\frac{S1}{\boxed{PDE}} + \frac{S2}{\boxed{EEE} \times \boxed{SEG}}\right)$$



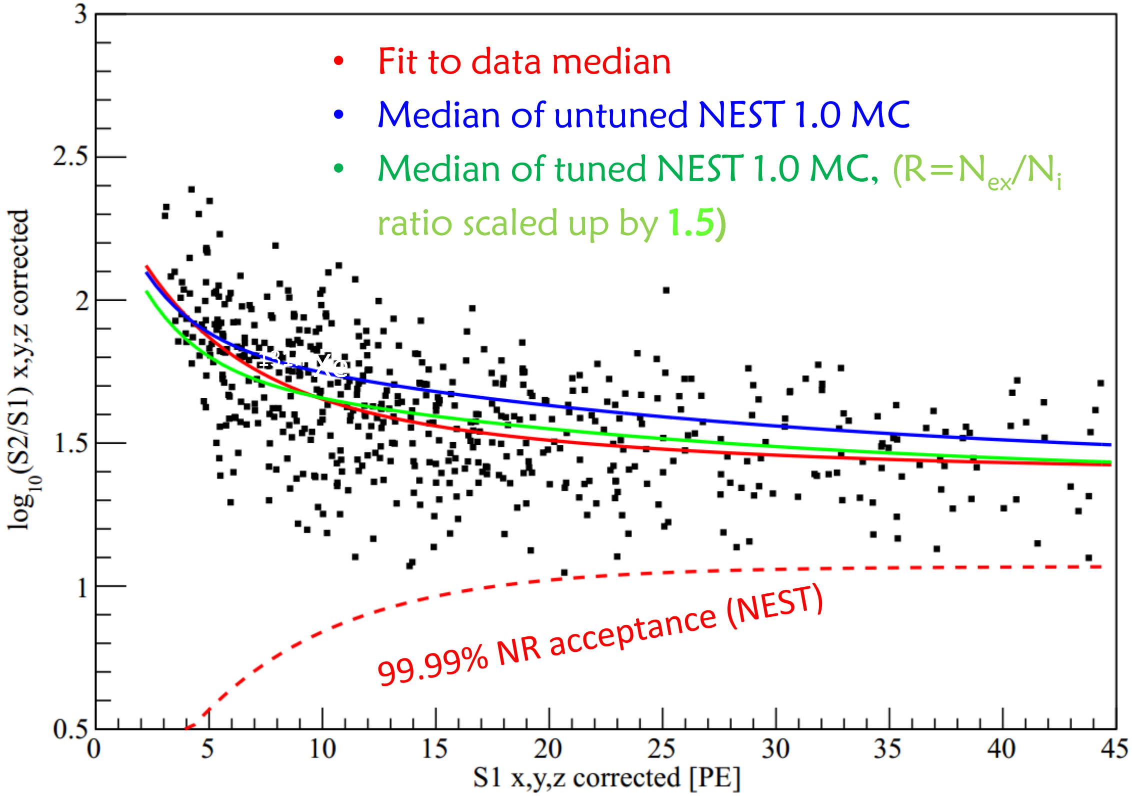
(a)40 keV



(b)164 and 236 keV

- W=13.7 eV
- PDE=11.66(0.5)%
- EEE=48.13(3.4)%
- SEG=(22.1±0.04) PE/e^-

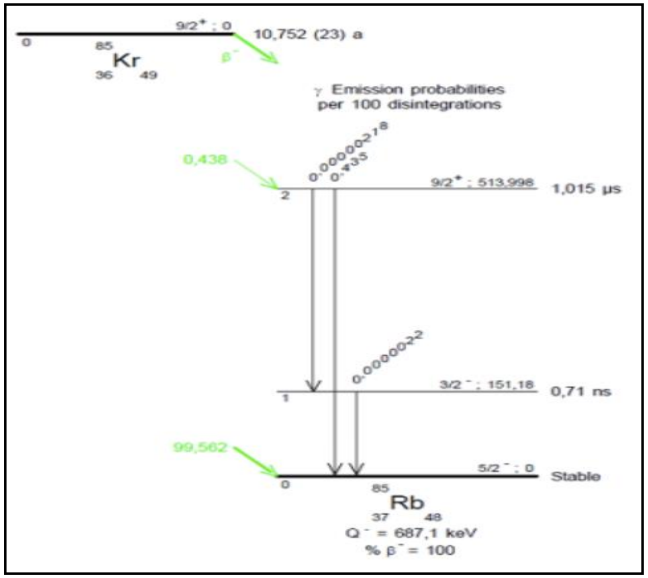
Nuclear recoil calibration: neutron source, ^{252}Cf

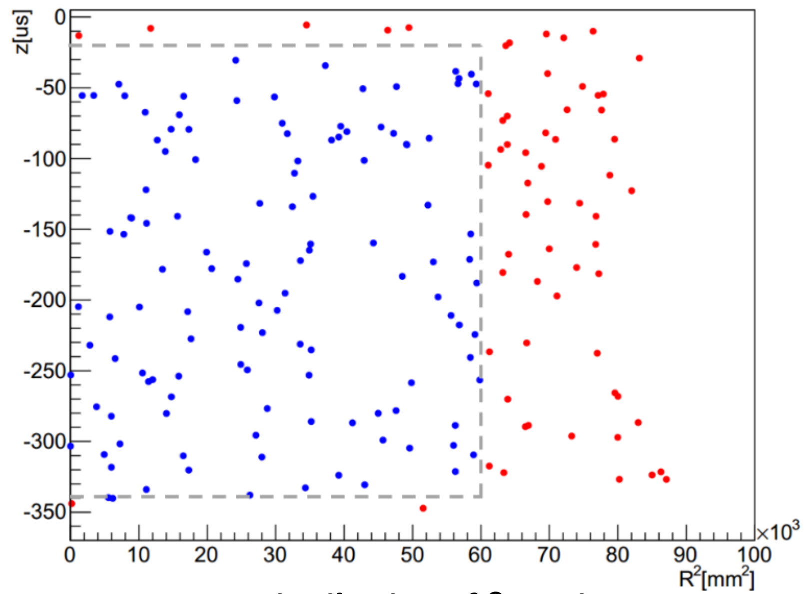


- Better agreement was achieved between data and tuned MC (median and width)
- NR detection efficiency was calculated by the comparison between data and MC
- Tuned MC was adopted to predict the WIMP NR distributions

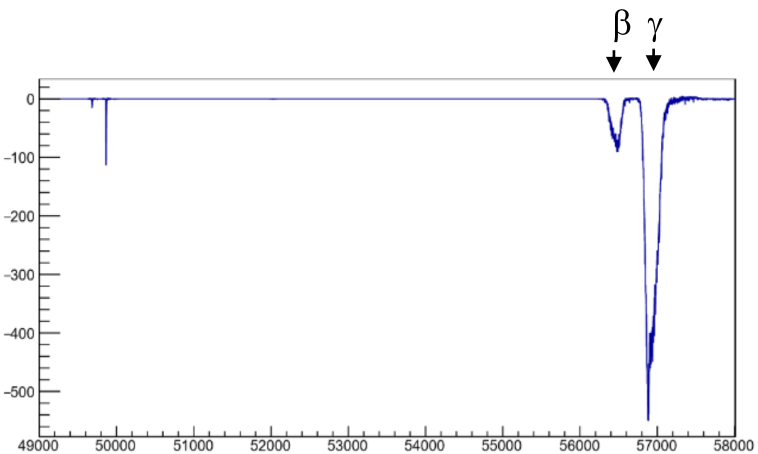
NR detection efficiency $$\epsilon = 0.94\left[e^{-\frac{S1-6.21}{1.66}}+1\right]^{-1}\left[e^{-\frac{S2_{raw}-79.3}{20.8}}+1\right]^{-1}$$

Internal background from ^{85}Kr



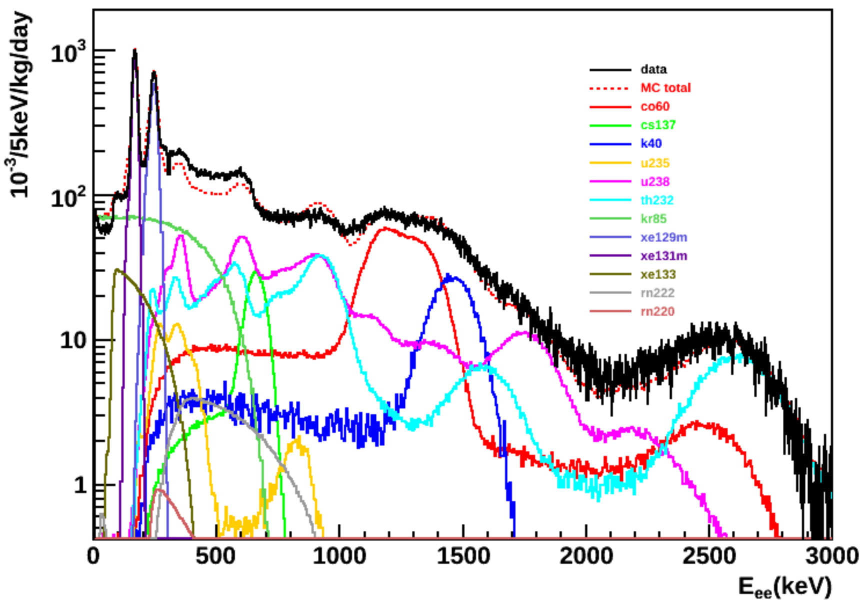


Distribution of β vertices



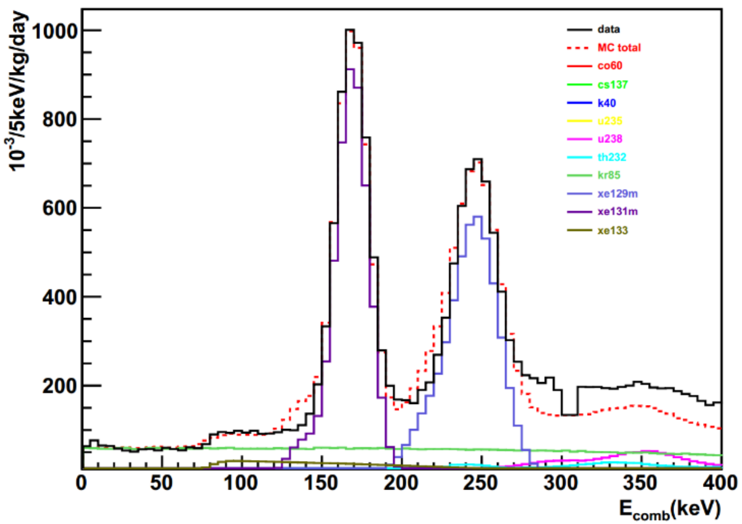
- (β, γ) analysis confirmed that it is due to ^{85}Kr, Kr/Xe = (437±70) ppt
  - Accidental air leak in engineering runs.
  - Consistent with the offline measurement.

ER backgrounds: data & MC



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

- Data and MC were consistent in shape with each other;
- Low energy agreement also within 17%;
- The dominating background came from ^{85}Kr.



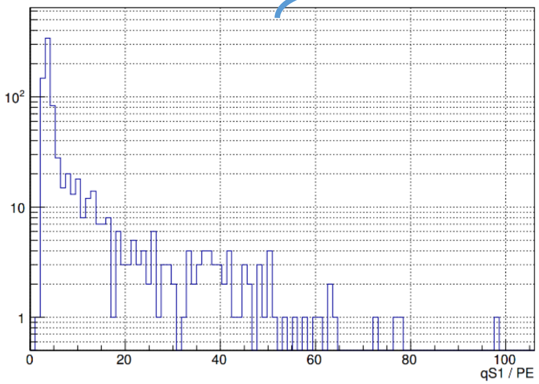
Background budget in DM data

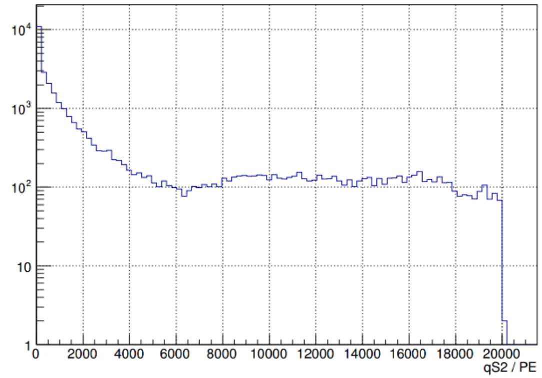
	ER	Accidental	Neutron	Total Expected
All	611	5.9	0.13	617±104
Below NR median	2.5	0.7	0.06	3.2±0.71

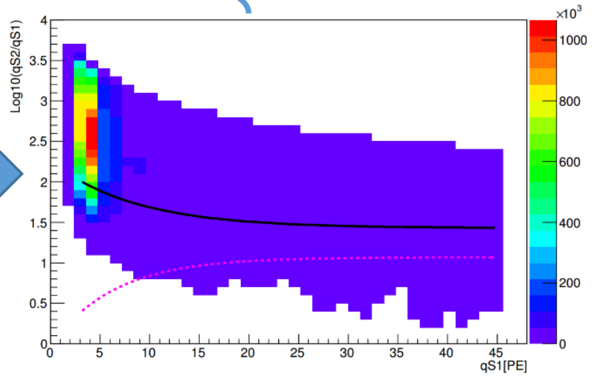
Based on Kr event distribution

Data driven

Based on MC



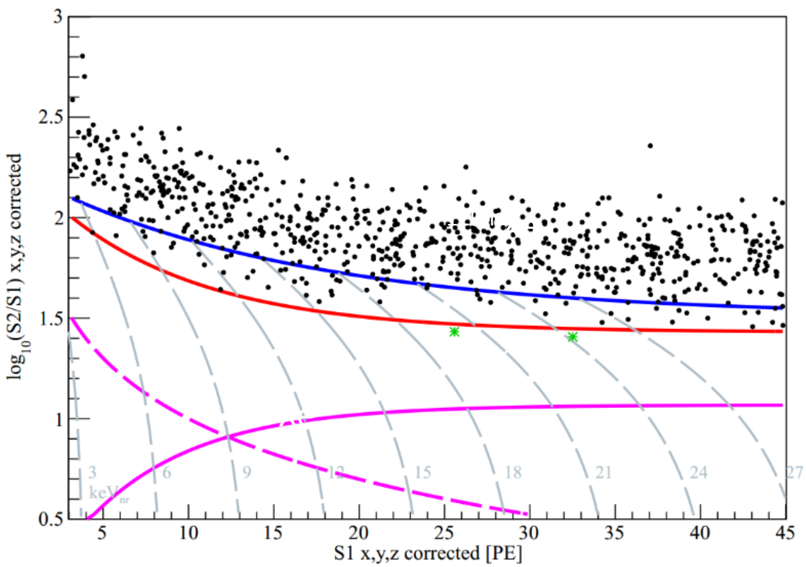


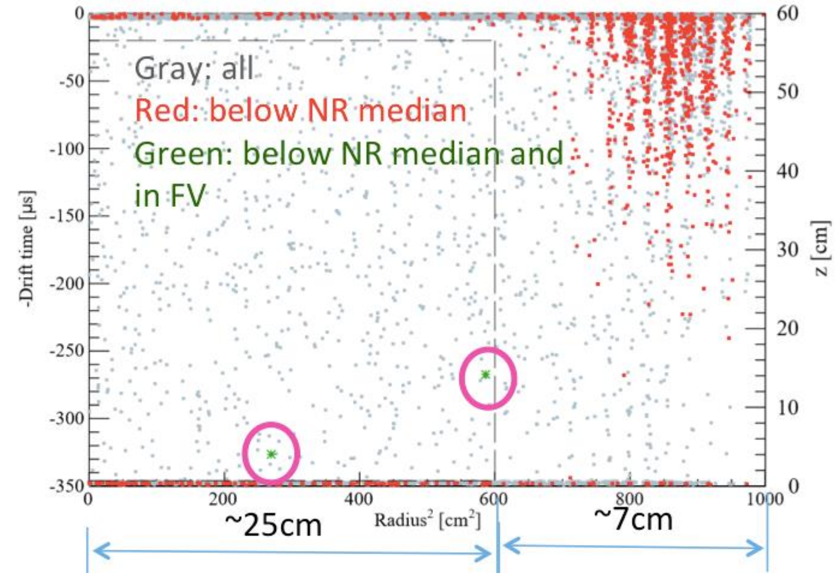


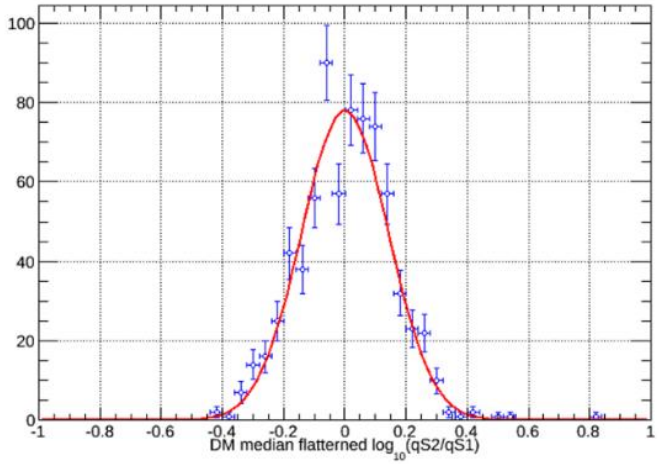
- Single S1
- Single S2

Random coincidence

Final DM candidates: 19.1 live-day·306 kg





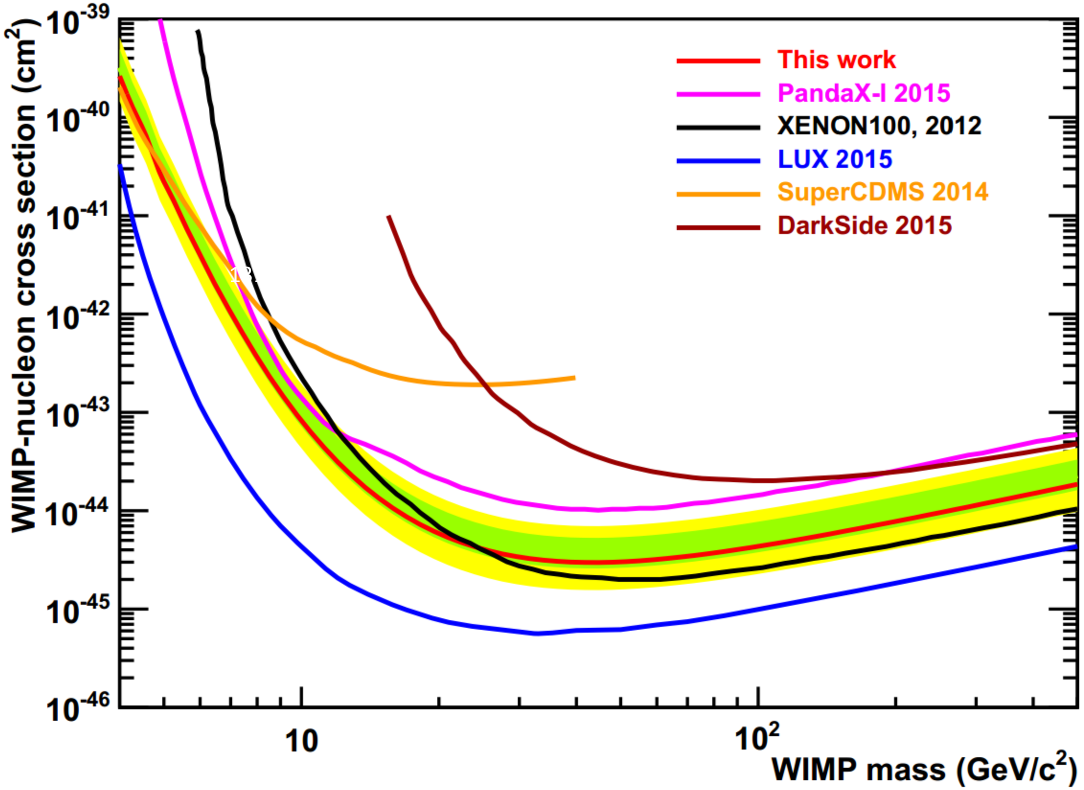


Budget of backgrounds in DM runs

	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

No excess signal !

Exclusion limits on DM



- Simple counting analysis based on an expected background of 3.2(0.7) evts and 2 observed evts
- Low mass: competitive with SuperCDMS;
- high mass: similar exclusion limit as XENON100 225-day

Summary & Outlook

- Half-ton scale PandaX-II has been tuned, most of the key components were working well;
- Commissioning run with 19.1 live-day x 306 kg exposure observed no DM candidate;
- After a maintenance of Re-distilling Kr, the ER backgrounds were suppressed significantly and the data taking was just resumed.
- PandaX DM experiments have carved into the “mainstream” WIMP predication region. Stay tuned for the future excitement!

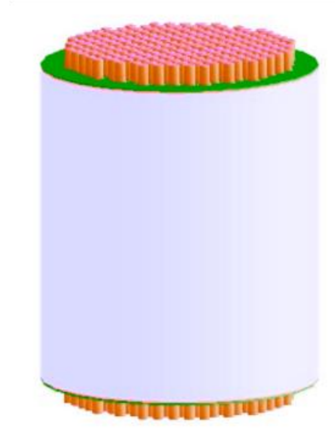
Thank you !

PandaX Experiment

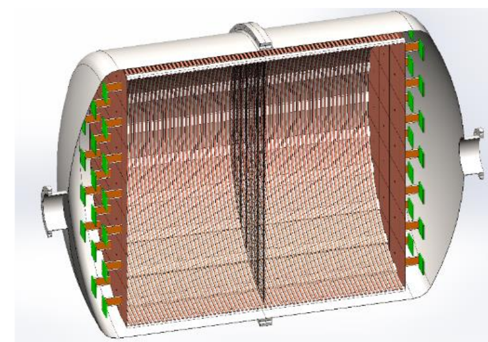
PandaX = Particle and Astrophysical Xenon Experiments

Phase I:
120 kg DM
2009-2014

Phase II:
500 kg DM
2014-2017

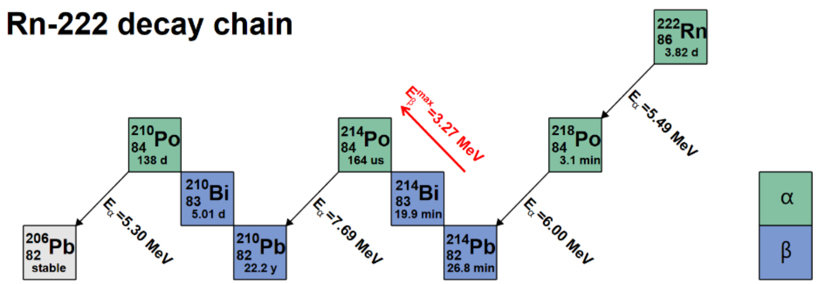


PandaX-xT:
multi-ton DM
future

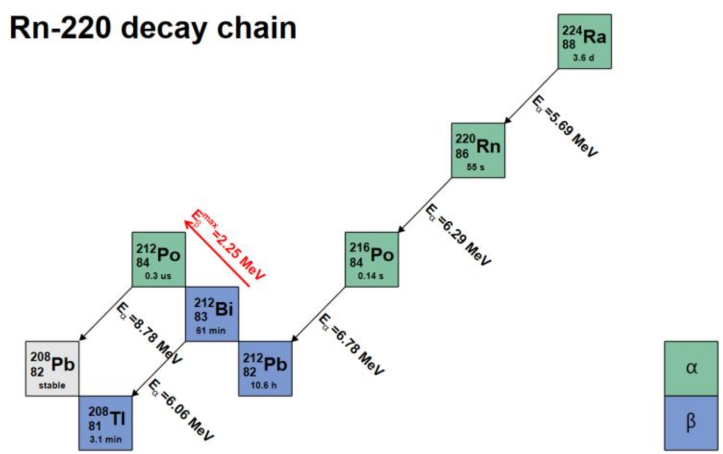


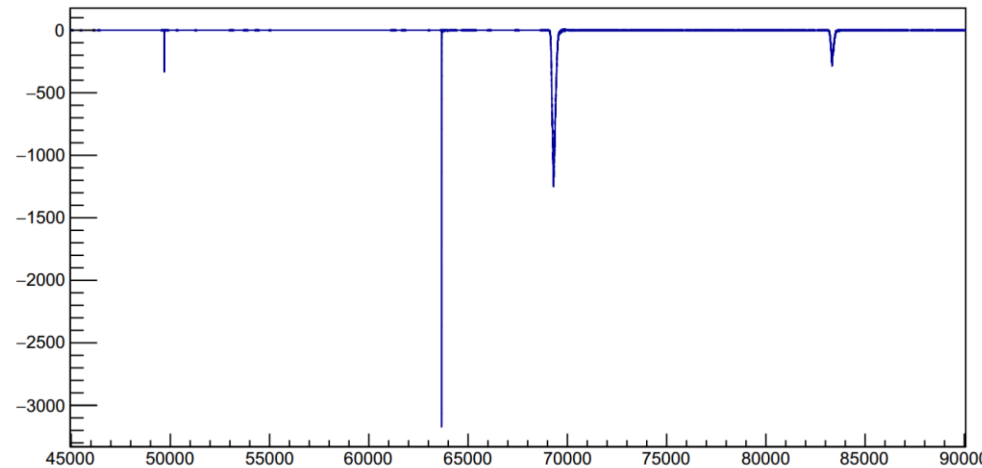
PandaX-III:
200 kg to 1 ton
^{136}Xe 0νDBD
future

Internal Background from $^{220/222}$Rn



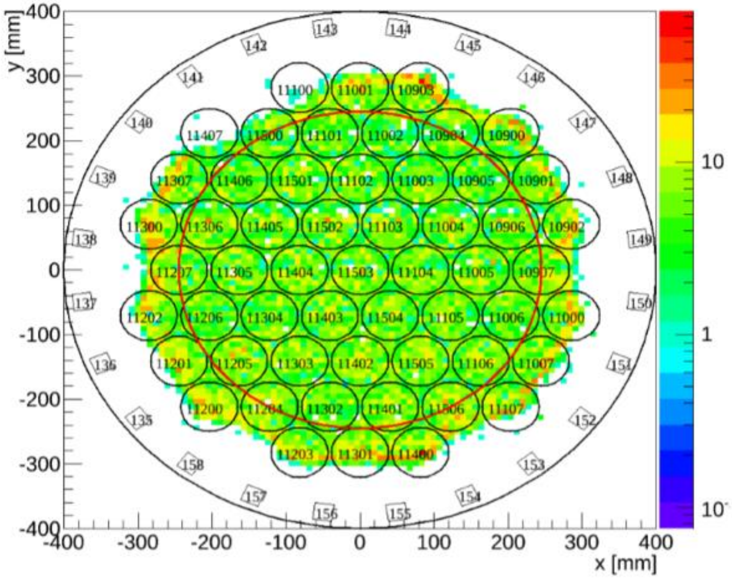
- ➢ ^{220}Rn, ^{222}Rn were identified by (β , α) and (α , α) coincidence events:
  - ^{222}Rn: ^{214}Bi-^{214}Po, 6.57 μBq/kg in FV
  - ^{220}Rn: ^{212}Bi-^{212}Po (0.54 μBq/kg), ^{220}Rn-^{216}Po (0.41 μBq/kg) in FV,

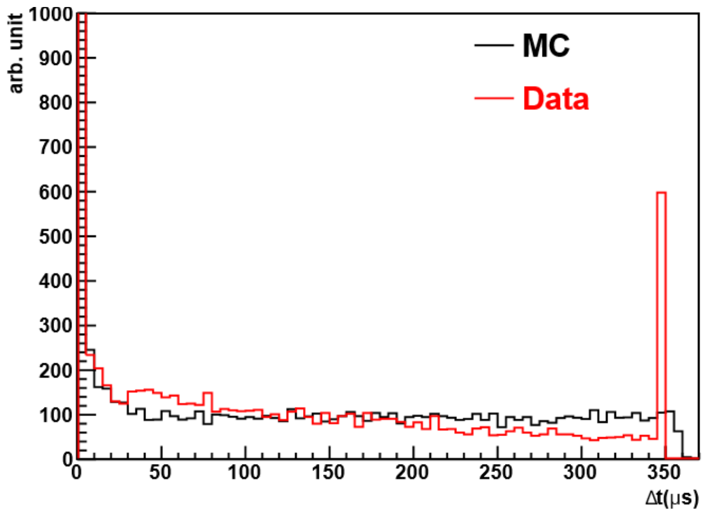




A typical ^{214}Bi-^{214}Po β - α event

Event selection





- **Horizontal cuts:**

  determined by the quality of event position reconstruction (removing the last ring of PMT)

- **Vertical cuts:**

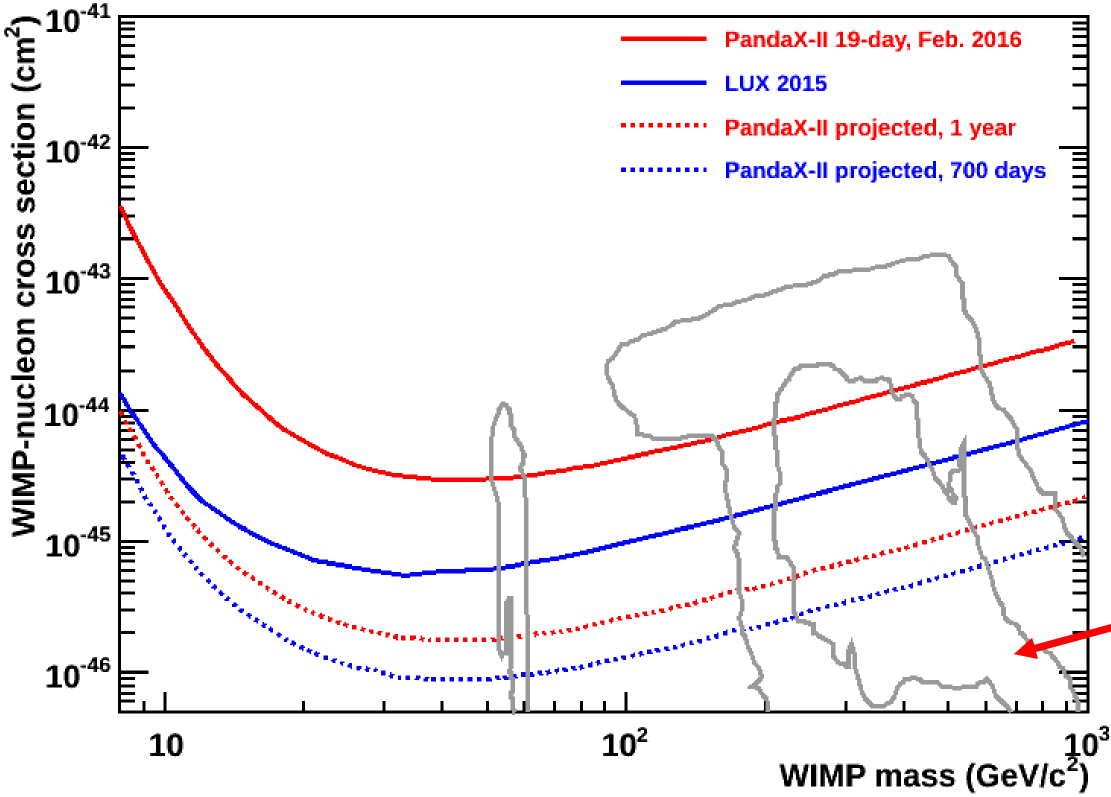
  determined by choosing the flat region in non-DM-window for both data and MC (excess at cathode likely due to Rn daughters accumulation)

- **S1 cuts: [3, 45] PE**

  Optimized for the DM Searching sensitivity by using **expected background only**

- **S2 cuts:** Event Trig. (100_{raw}---$10k_{correct}$)PE

Back up



PandaX-II sensitivity assumes:

- 300 kg x 365 day
- 4.4 PE/keV @ 122 keV
- S1 range [3, 47] PE
- ER rejection 99.75%
- NR acceptance 35%
- <3.7 background events

WIMP parameter space, CMSSM region

- C. Strege et al., JCAP 1203,030 (2012);
- A. Fowlie et al. (2012), arXiv:1206.0264;
- O. Buchmueller et al. (2011), arXiv:1112.3564.