# Updates from the PandaX-II experiment

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**On Behalf of the PANDA X Collaboration**

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# PandaX Collaboration

PandaX = Particle and Astrophysical Xenon Experiments

**~ 40 people**

PANDA X http://pandax.org

**Started in 2009:**

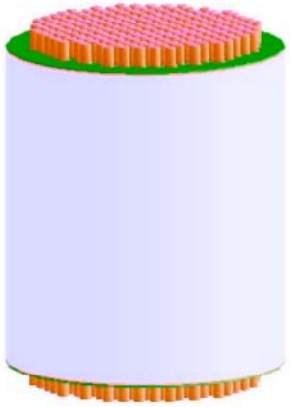
- Shanghai Jiao Tong University (2009~ )
- Shanghai Institute of Applied Physics, CAS (2009~ )
- Shandong University (2009~ )
- Peking University (2009~ )
- Yalong River Hydropower Company (2009~ )
- University of Science & Technology of China (2015~ )
- China Institute of Atomic Energy (2015~ )
- Zhongshan University(2015~)
- University of Maryland (2009~ )
- University of Michigan (2009~2015)
- Lawrence Berkeley National Laboratory（2015~）
- Commission of Alternative Energies & Atomic Energy (2015~)
- University of Zaragoza(2015~)
- Suranaree University of Technology(2015~)

# PandaX Experiment

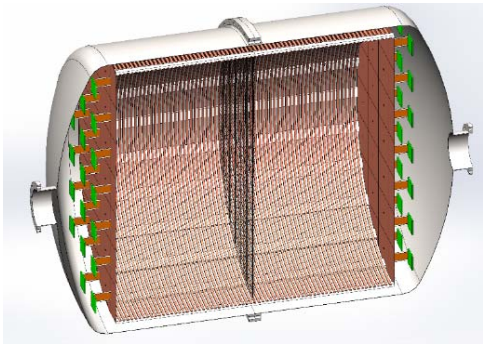
**PandaX＝Particle and Astrophysical Xenon Experiments**

**Phase I:**
**120 kg DM**
**2009-2014**

**Phase II:**
**500 kg DM**
**2014-2017**

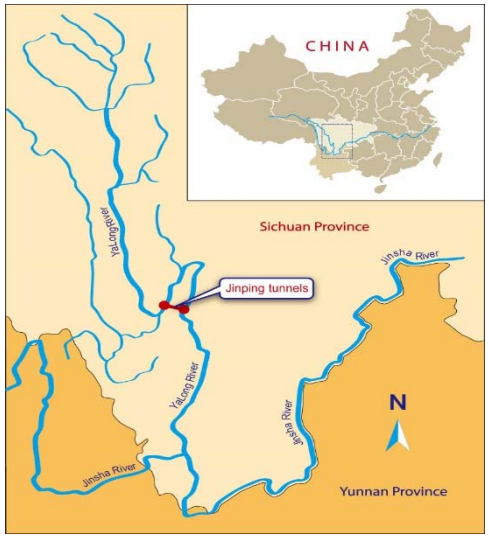


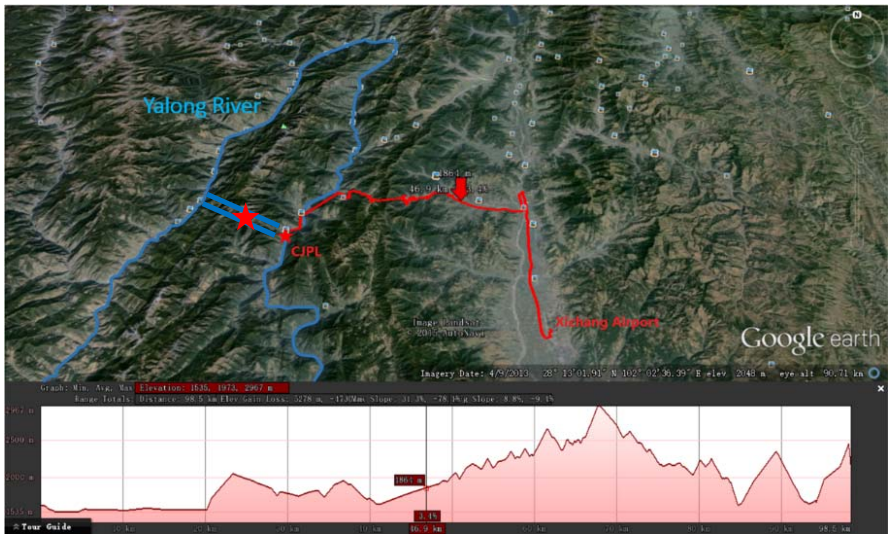
**PandaX-xT:**
**multi-ton DM**
**future**

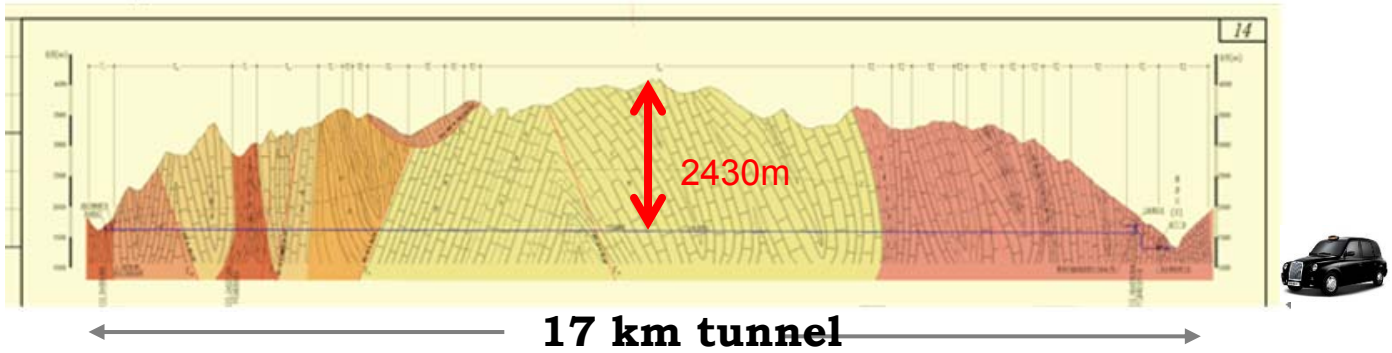


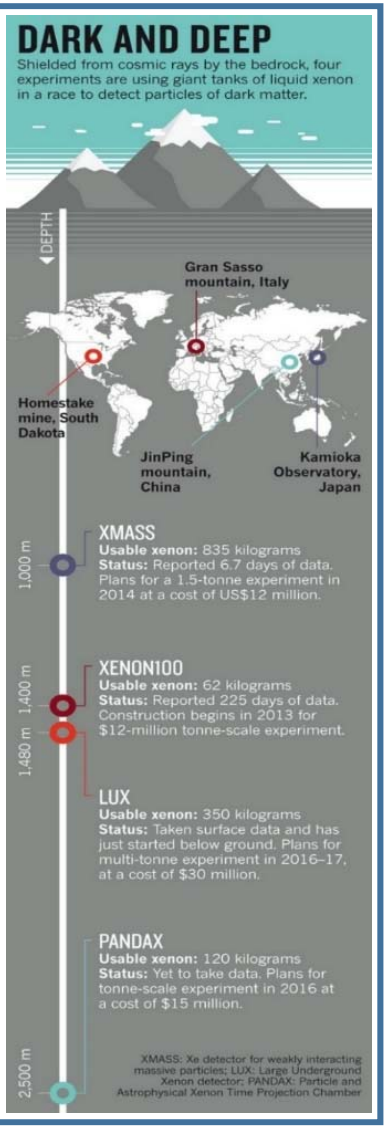
**PandaX-III:**
**200 kg to 1 ton**
**$^{136}$Xe 0vDBD**
**future**

# China Jin-Ping Underground Laboratory



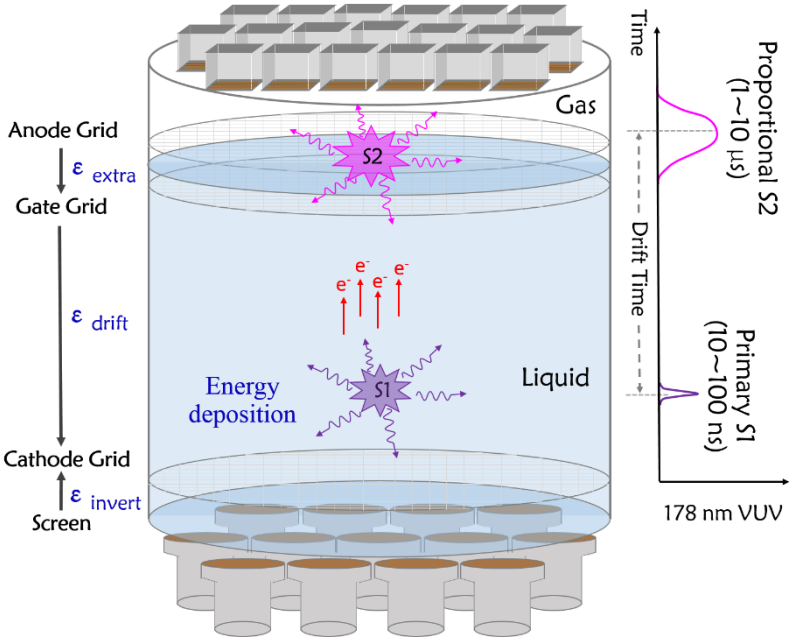



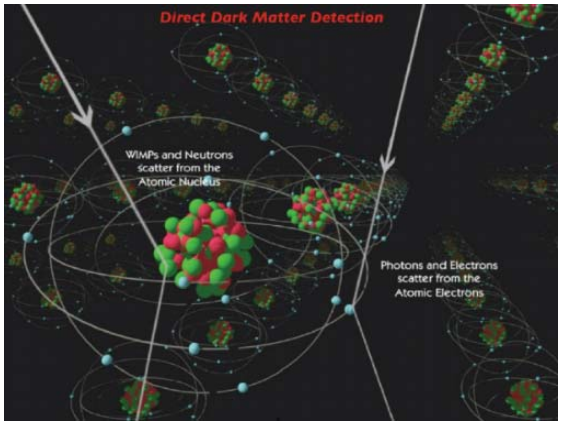



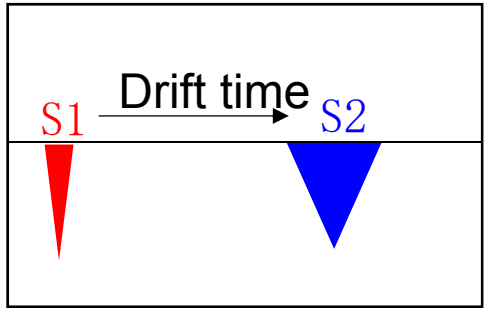

- Deepest in the world, muon flux ~1 μ/week/m$^2$;
- Horizontally access, Drive in!

**Chinese Physics C. Vol 37, No. 8 (2013) 086001**

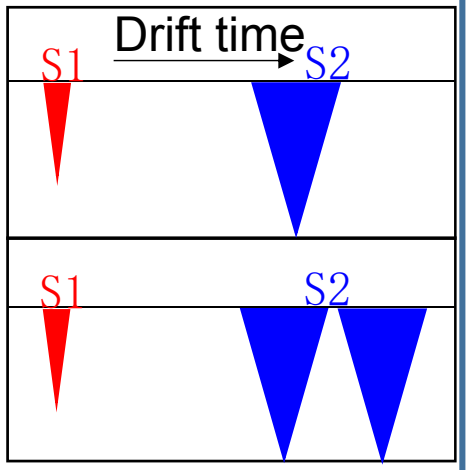
# Dark matter search with dual-phase Xe TPC




Dark matter:
nuclear recoil (NR)

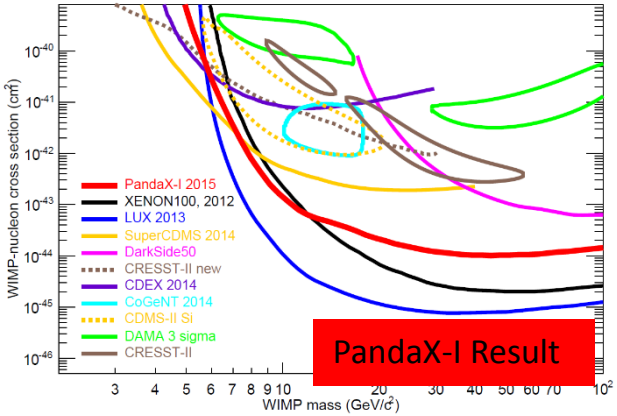



Gamma background:
electron recoil (ER)

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

# 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**

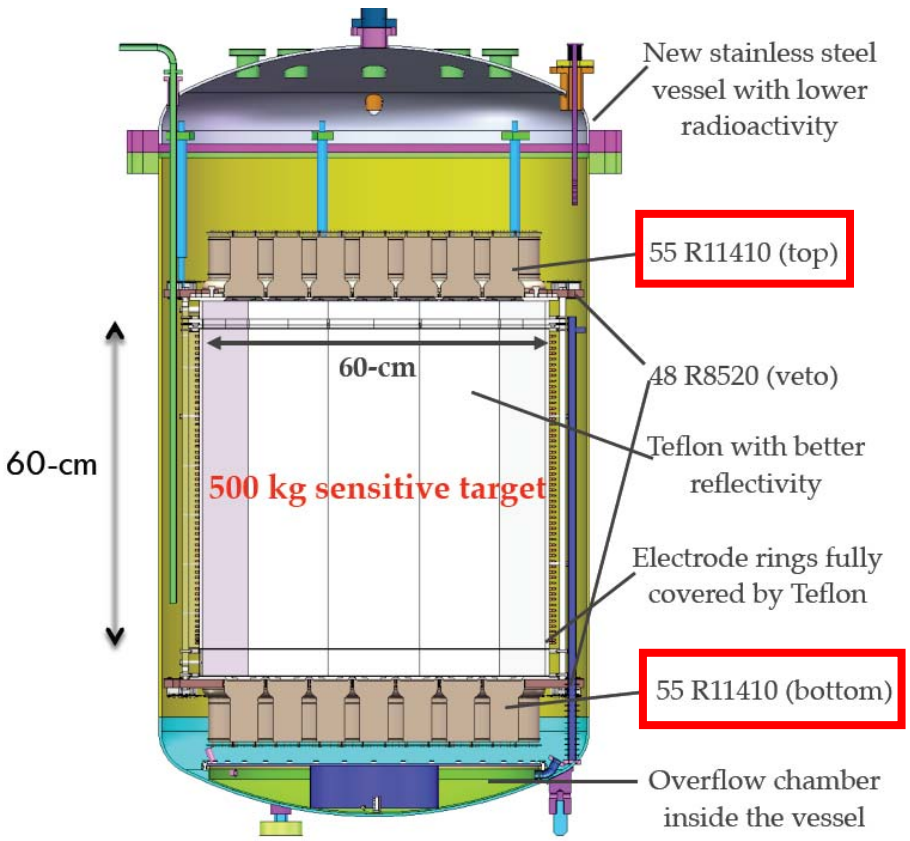
**Phys. Rev. D 92, 052004 (2015)**

**2014---Oct. 2015---Now**

**Reused:**

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

# PandaX-II new TPC



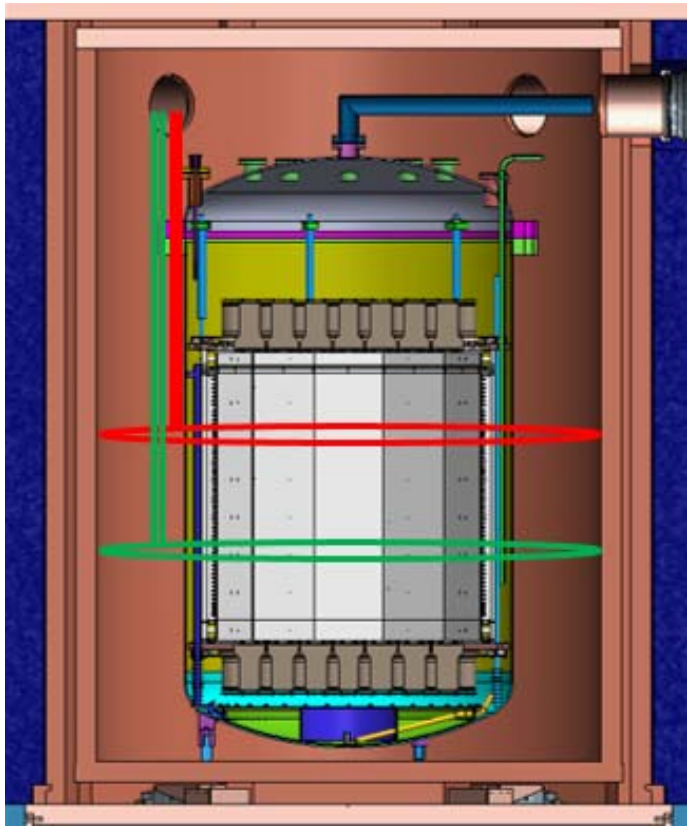

**More than Larger Volume:**

- **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: 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



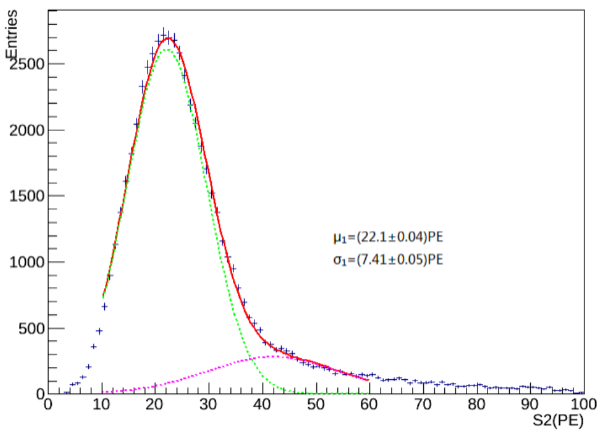
- **Calibration setup for PandaX-II**

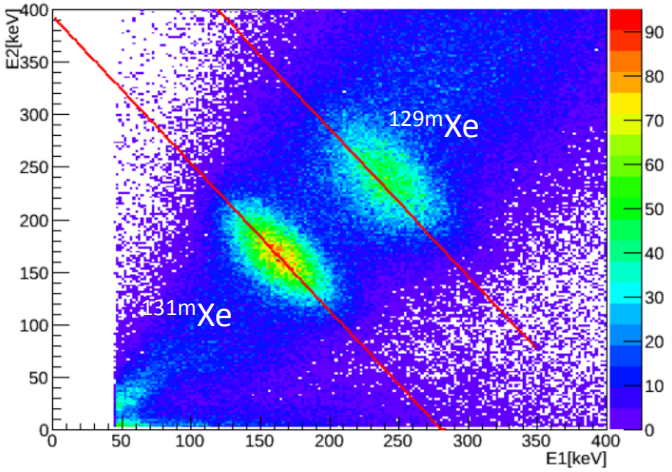
- **Radioactive Sources, through Two tracks:**
  - **NR: Cf252， AmBe**
- **Position Reconstruction**
  - **PMTs + MC**
- **Detector parameters:**
  - **anti-correlation between S1 (photons) and S2 (electrons):**

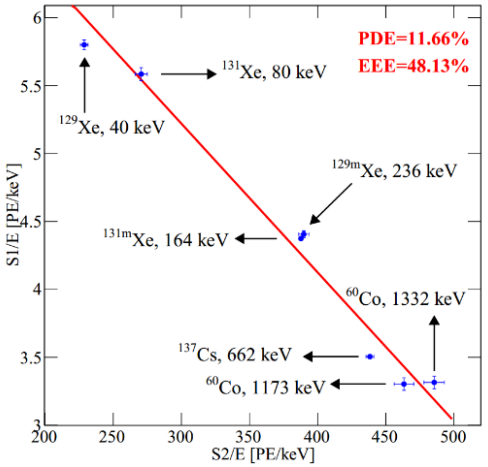
$$E_{ee} = W \times \left(\frac{\mathrm{S1}}{\mathrm{PDE}} + \frac{\mathrm{S2}}{\mathrm{EEE} \times \mathrm{SEG}}\right)$$

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

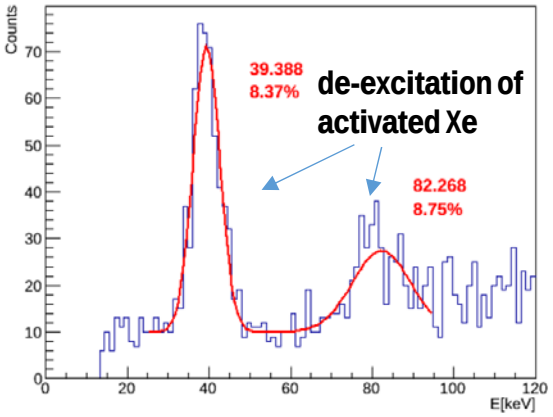
# Detector parameters and energy reconstruction



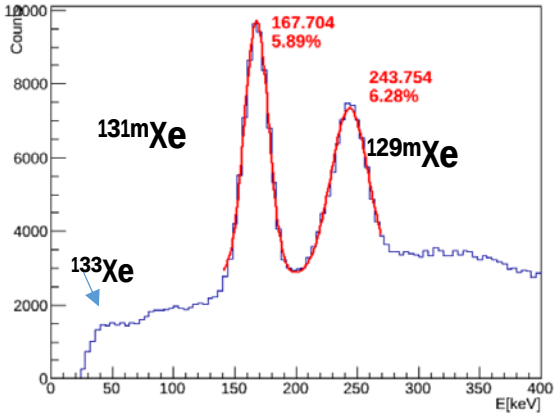




$$E_{ee} = W \times \left(\frac{S1}{PDE} + \frac{S2}{EEE \times SEG}\right)$$



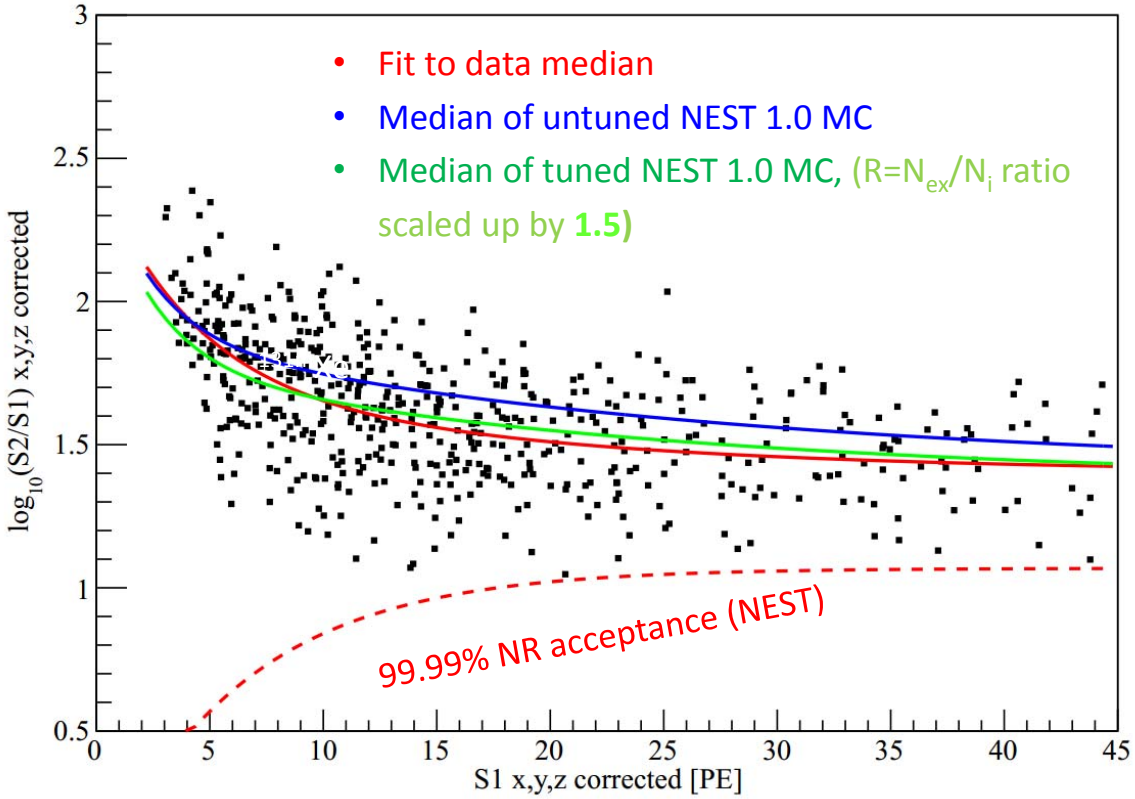

(a)40 keV




(b)164 and 236 keV

- W=13.7 eV
- PDE=11.7(0.5)%
- EEE=48.1(3.4)%
- SEG=(22.1±0.04) PE/e⁻

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

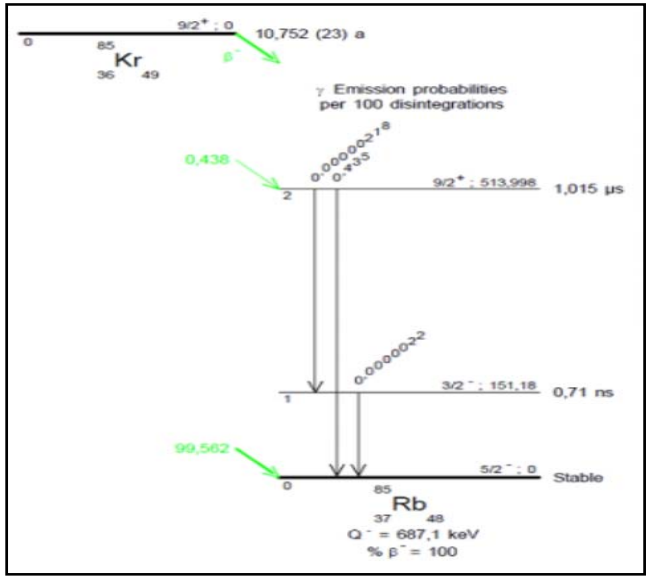


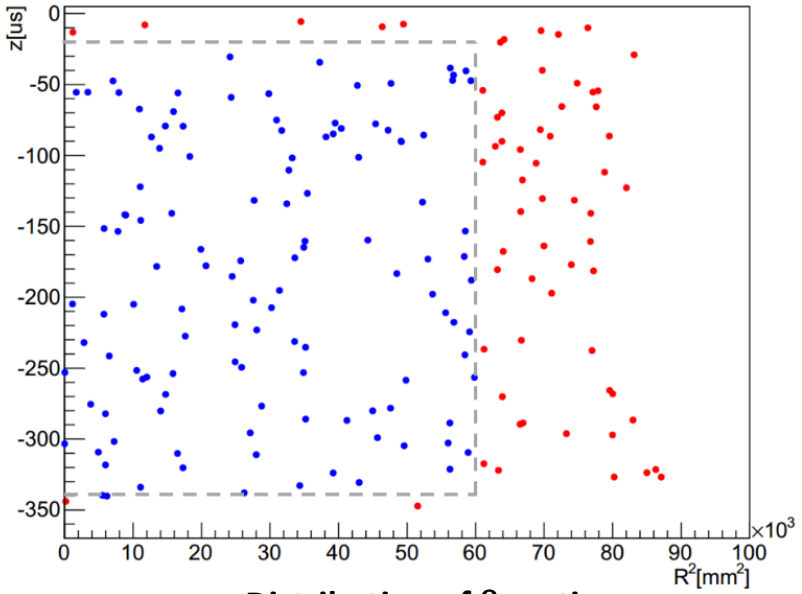

- **Better agreement was achieved between data and tuned MC （median and width）**
- **NR detection efficiency was calculated by the comparison between data and MC**
- **Tuned MC was adopted to predict the WIMP NR distributions**

**NR detection efficiency**

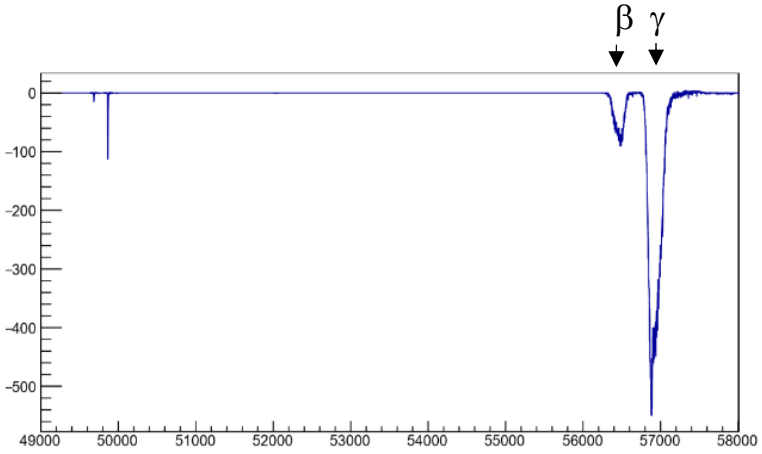
$$\epsilon = 0.94\left[e^{-\frac{\mathrm{S1}-6.21}{1.66}}+1\right]^{-1}\left[e^{-\frac{\mathrm{S2_{raw}}-79.3}{20.8}}+1\right]^{-1}$$

# Internal background from $^{85}$Kr



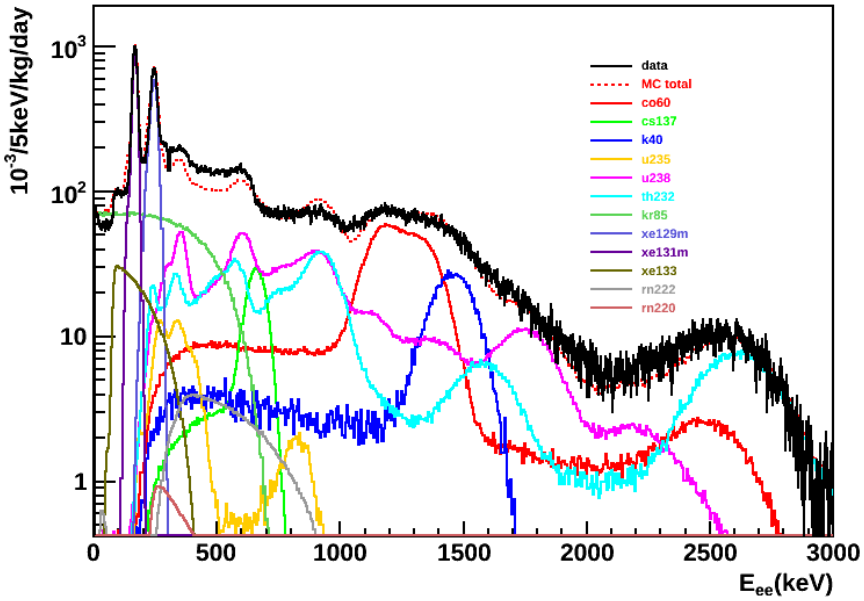




**Distribution of β vertices**



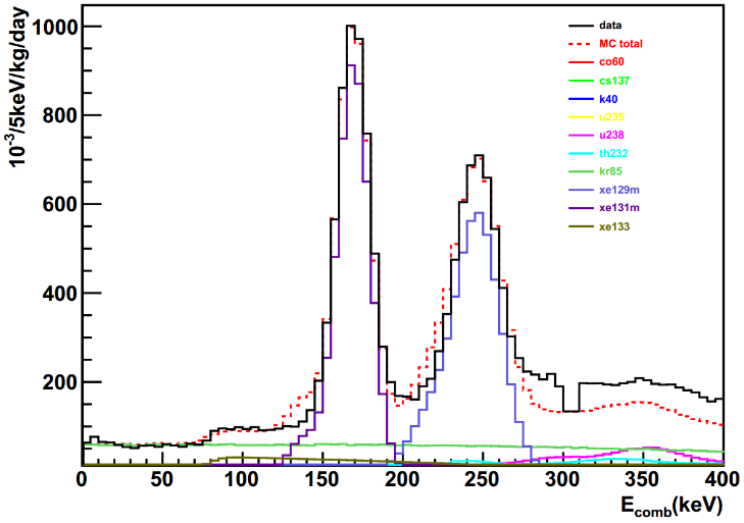

- (β, γ) analysis confirmed that it is due to $^{85}$Kr, Kr/Xe = (437±70) ppt
  - Accidental air leak in engineering runs.
  - Consistent with the offline measurement.

# 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.



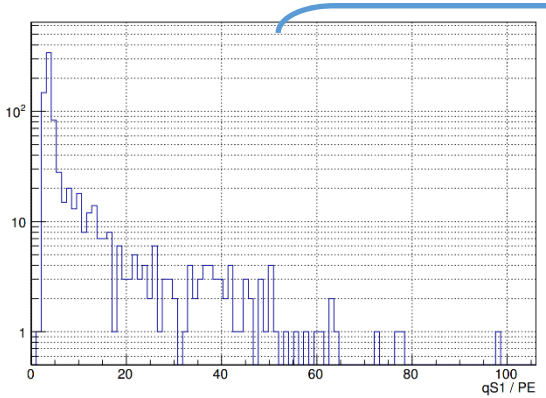
# Background budget in DM data

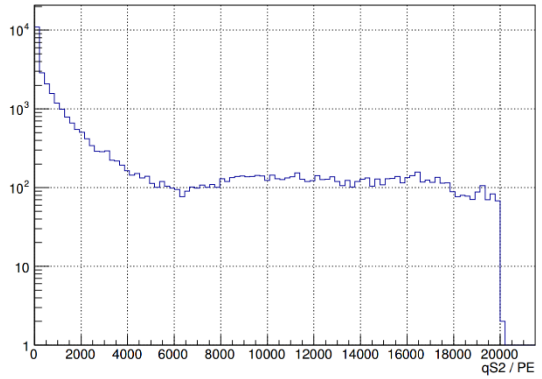
| | ER | Accidental | Neutron | Total Expected |
|---|---|---|---|---|
| All | 611 | 5.9 | 0.13 | 617±104 |
| Below NR median | 2.5 | 0.7 | 0.06 | 3.2±0.71 |

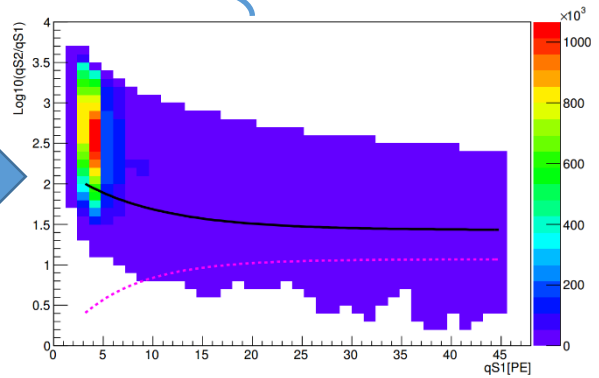
Based on Kr event distribution

Data driven

Based on MC



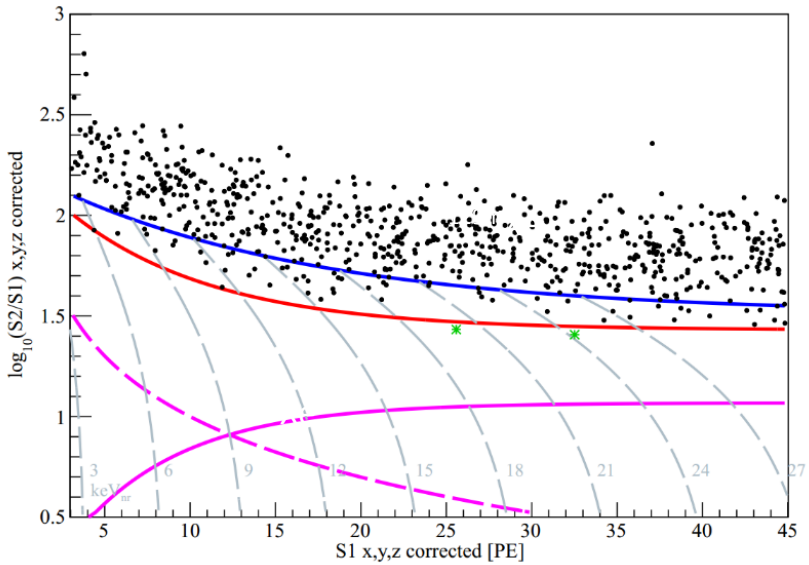



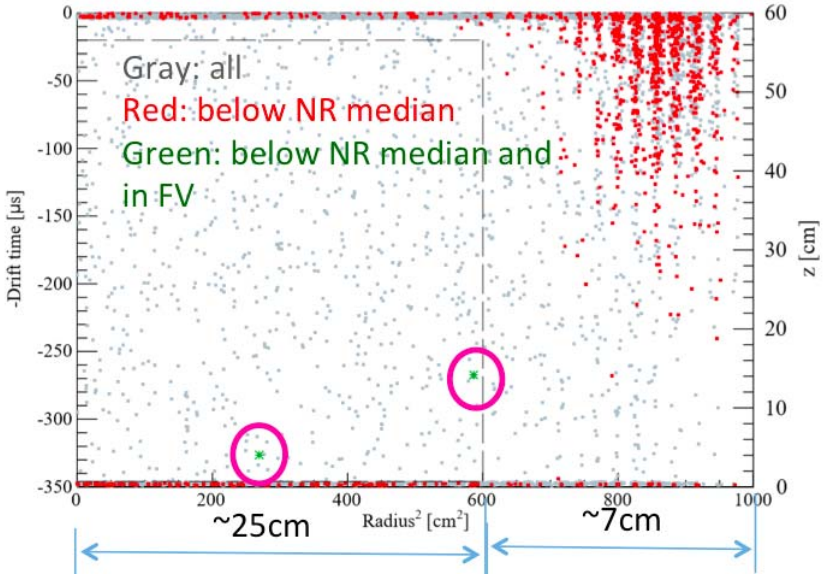



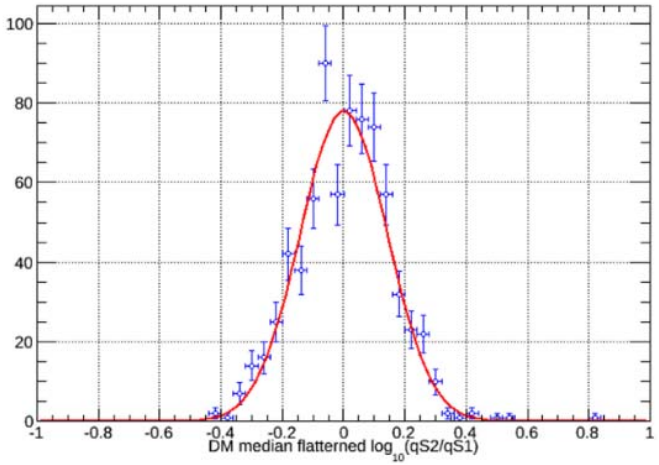

- Single S1
- Single S2

Random coincidence

# Final DM candidates: 19.1 live-day·306 kg



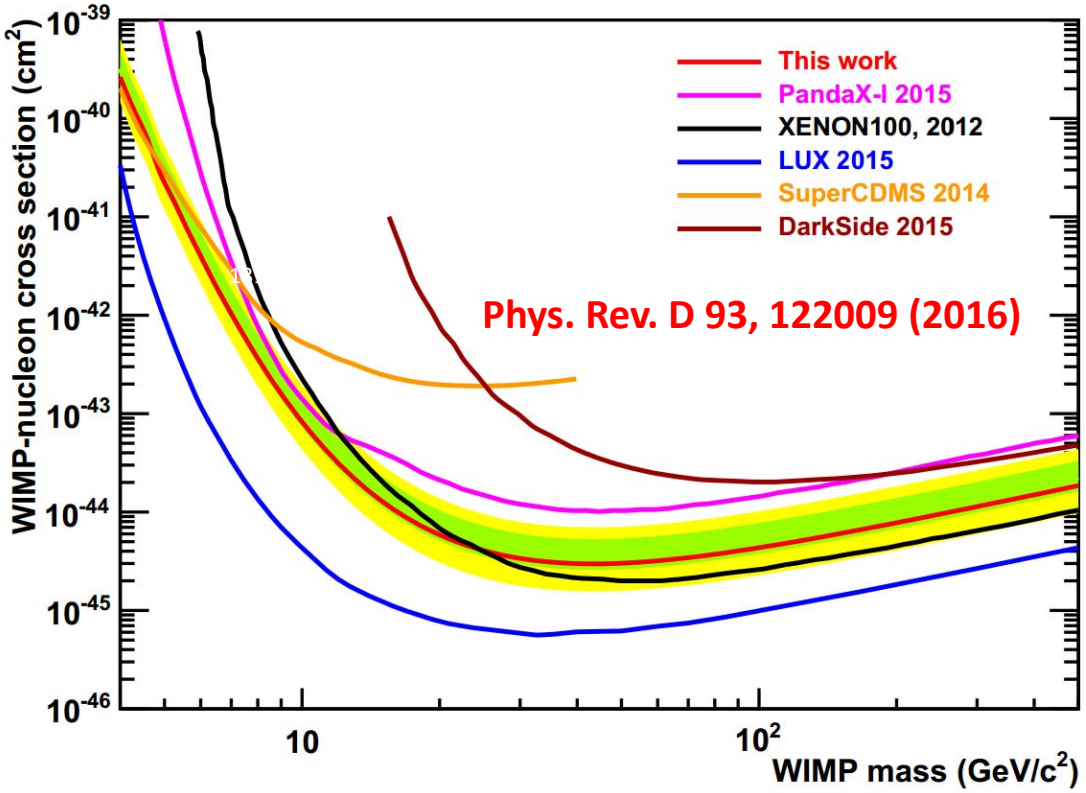




**Budget of backgrounds in DM runs**

| | 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 of signals !

# Exclusion limits on DM



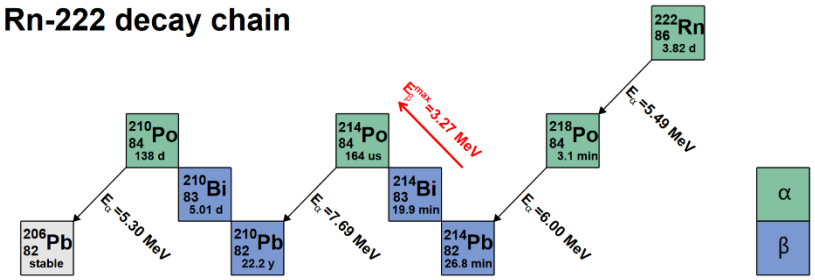

- Simple counting analysis based on an expected background of 3.2(0.7) evts and 2 observed evts
- Low mass: competitive with SuperCDMS;
- high mass: similar exclusion limit as XENON100 225-day

# Summary & Outlook

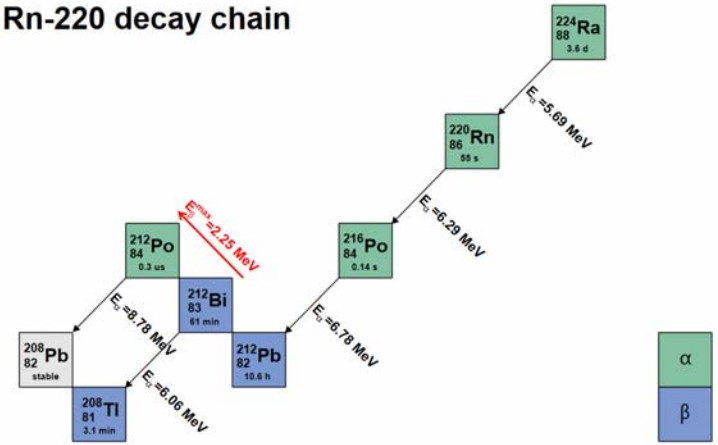
- Half-ton scale PandaX-II has been tuned, most of the key components were working well;
- Commissioning run with 19.1 live-day x 306 kg exposure observed no DM candidate;
- After a maintenance period to re-distill Kr, the ER background were suppressed significantly and the data taking was just resumed.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

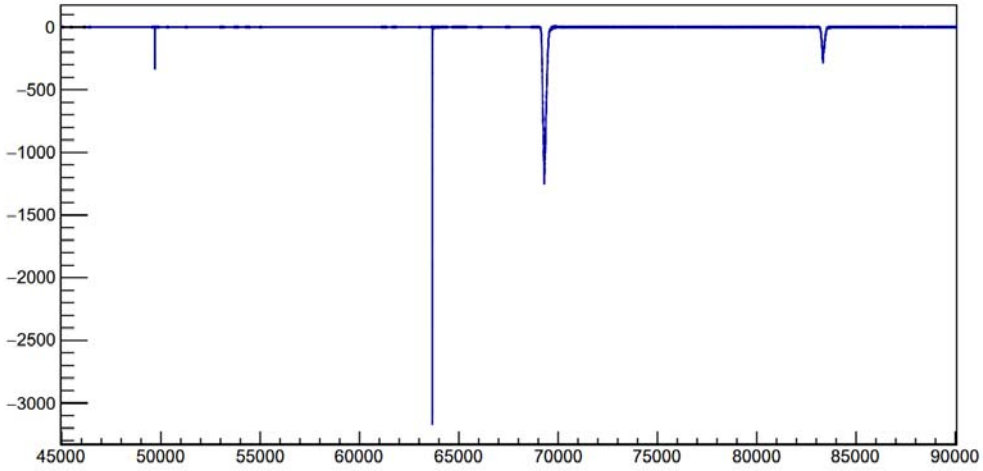
# Thank you !

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



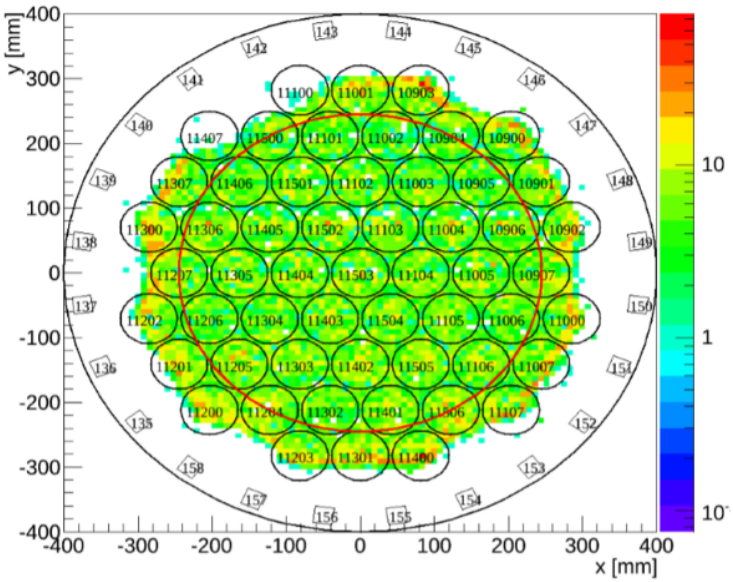

- $^{220}$Rn,$^{222}$Rn were identified by (β,α) and (α,α) coincidence events:
  - $^{222}$Rn: $^{214}$Bi-$^{214}$Po, 6.57 $\mu$Bq/kg in FV
  - $^{220}$Rn: $^{212}$Bi-$^{212}$Po (0.54 $\mu$Bq/kg), $^{220}$Rn-$^{216}$Po (0.41 $\mu$Bq/kg) in FV,

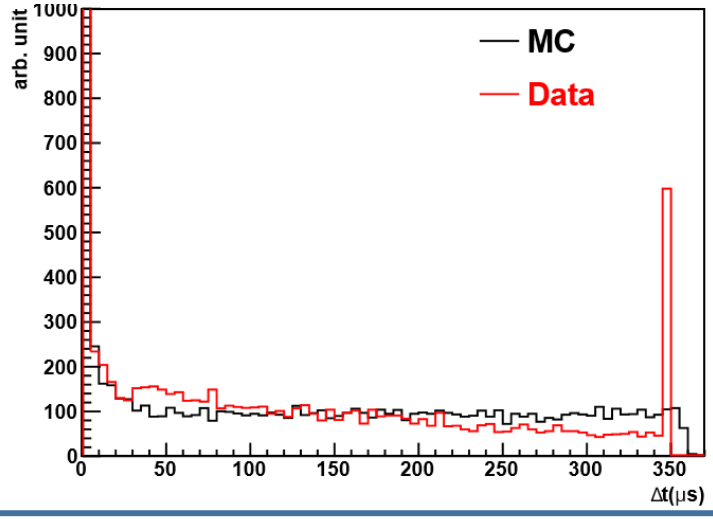



A typical $^{214}$Bi-$^{214}$Po β- α event

# Event selection




- **Horizontal cuts:**

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

- **Vertical cuts:**

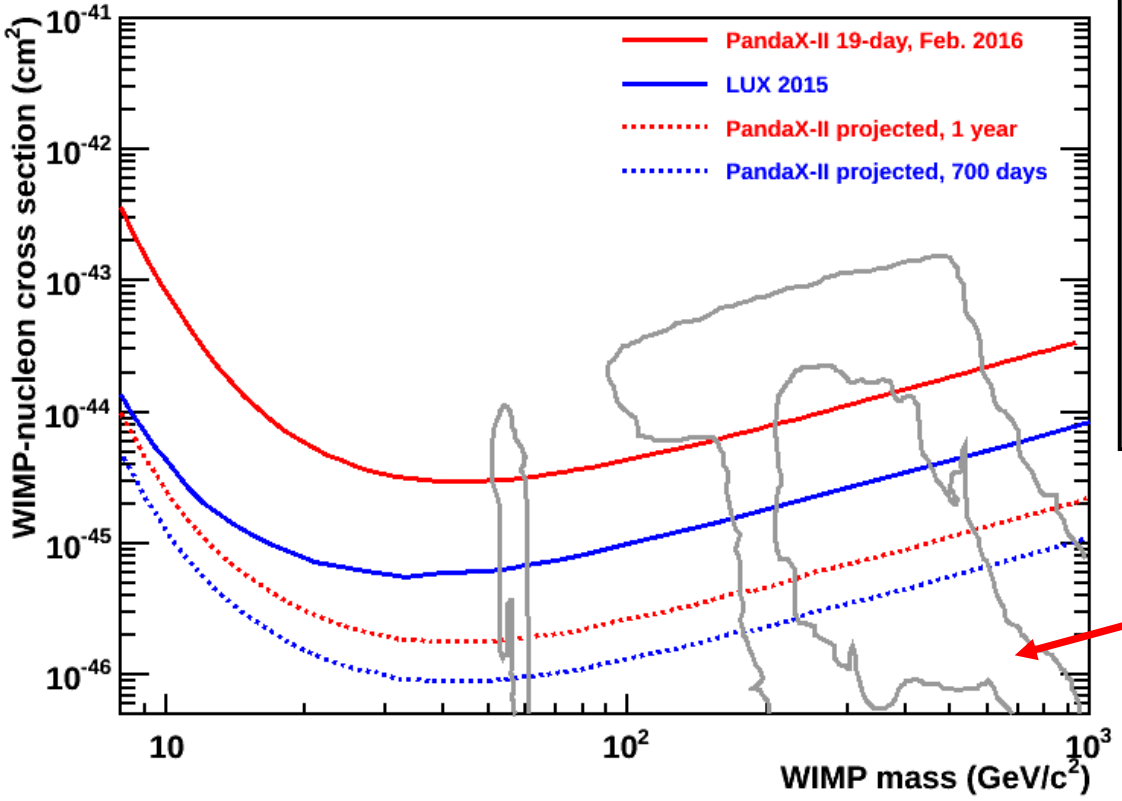
  determined by choosing the flat region in non-DM-window for both data and MC (excess at cathode likely due to Rn daughters accumulation)

- **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. arXiv:1206.0264;
- O. Buchmueller et al. (2011),