The PandaX Dark Matter Experiment

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(On behalf of the PANDA X Collaboration)

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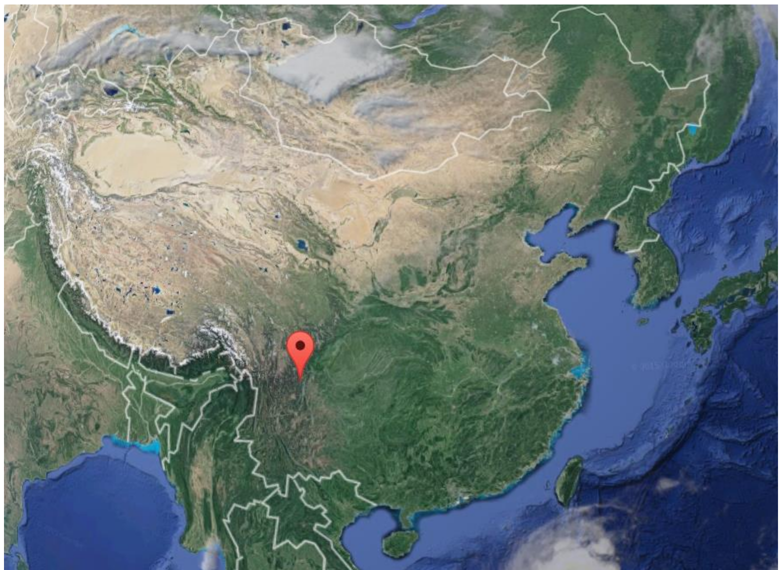
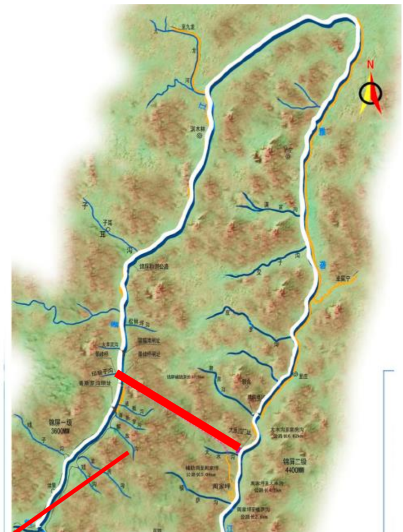
Outline

- Introduction
- The PandaX-I Detector
- Data Analysis and Results of PandaX-I
- Future programs of PandaX
- Summary

China JinPing Laboratory (CJPL)

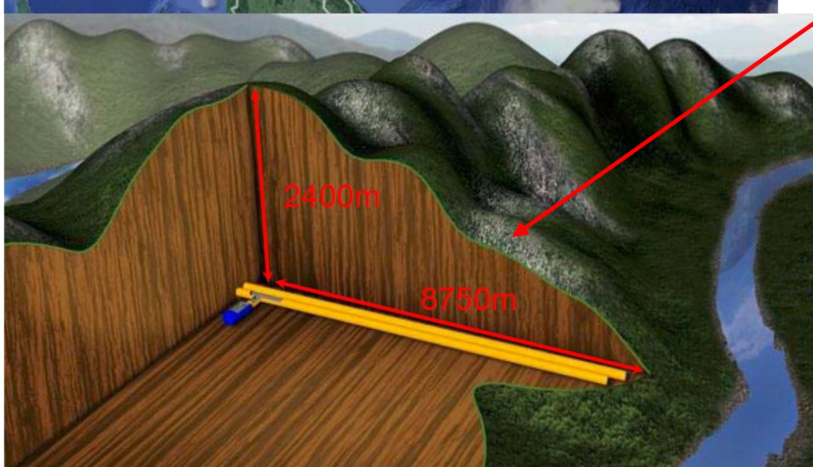


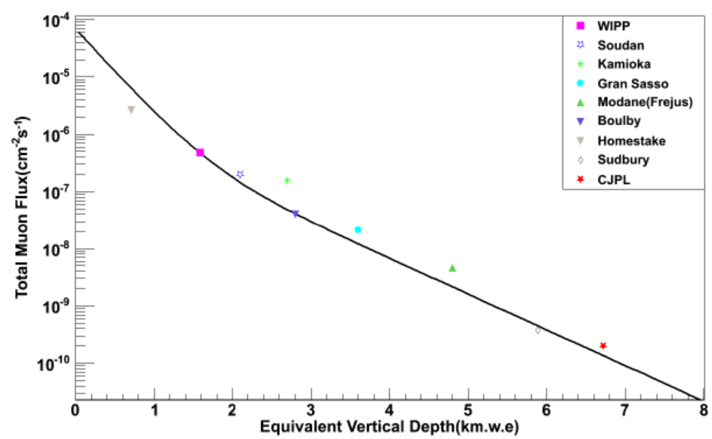


Sichuan
Southwest China

2400m of rock overburden

Muon flux ~ 63cts/m^2/year





Roadmap of PandaX

- PandaX = Particle and Astrophysical Xenon Experiments

PandaX-I

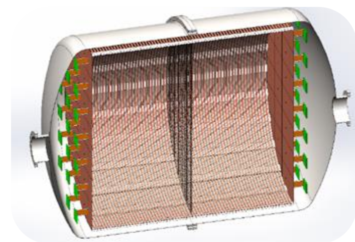
120 kg DM

2009 – 2014

PandaX-II

500 kg DM

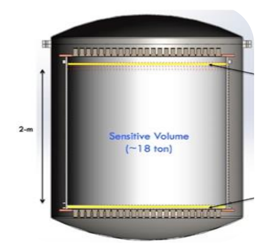
2014 – 2017



PandaX-III

200 kg – 1 ton NLDBD

2016 – 2022



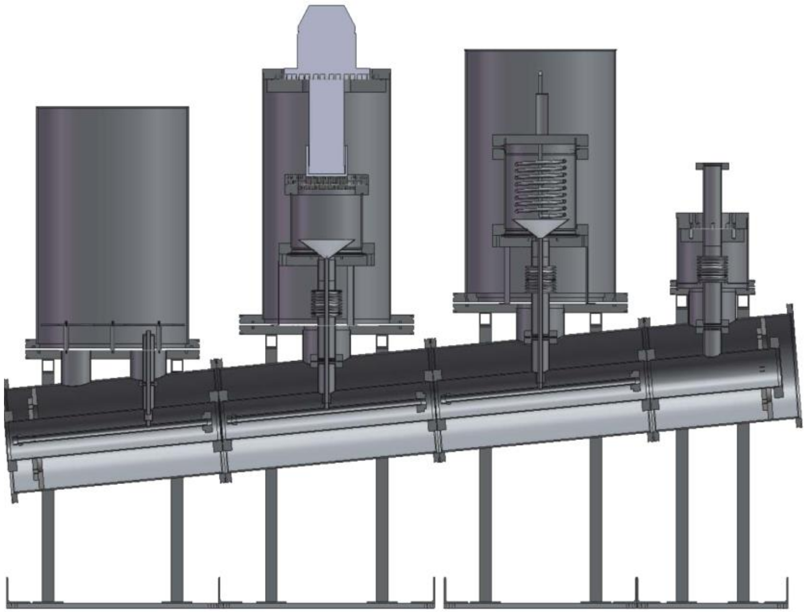
PandaX-IV

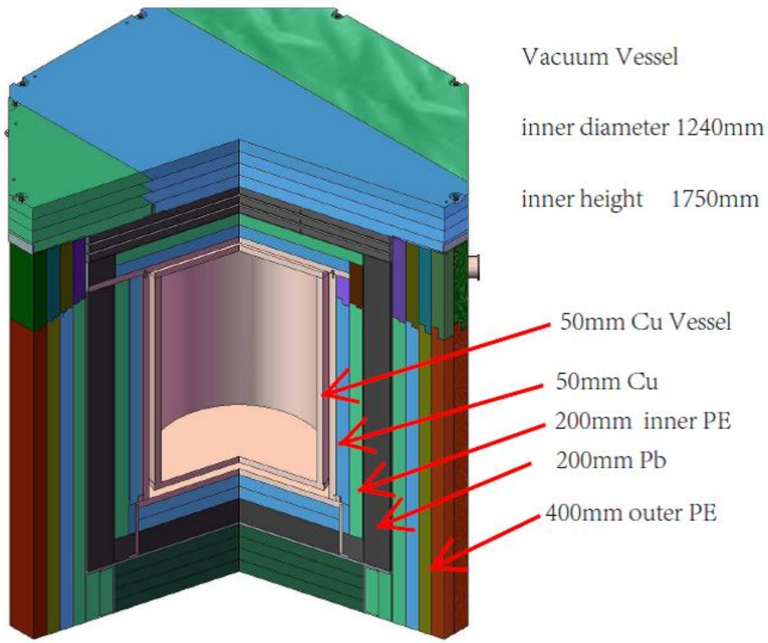
20 – 30 t DM

2020 – 2025

Infrastructure

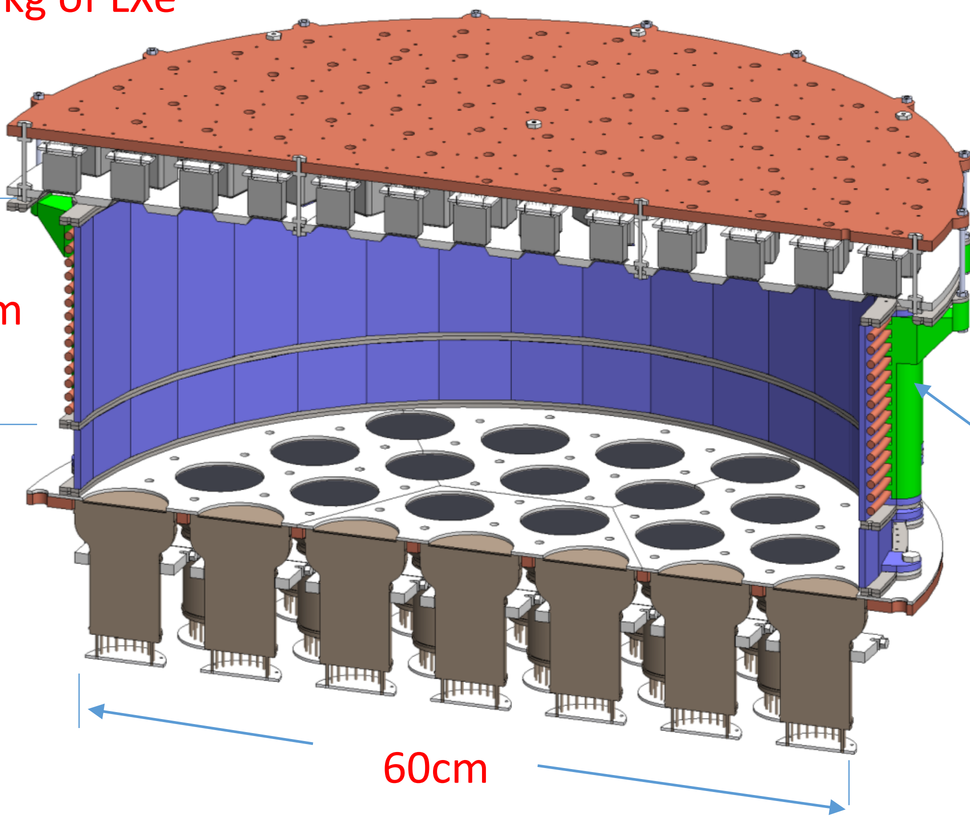
- Cryogenics and Gas Handling: “Cooling Bus”
- Shield with Polyethylene, copper and lead
- Used in both PandaX-I & II





TPC of PandaX-I

120 kg of LXe



15cm

Cathode

143
R8520 PMTs
1”

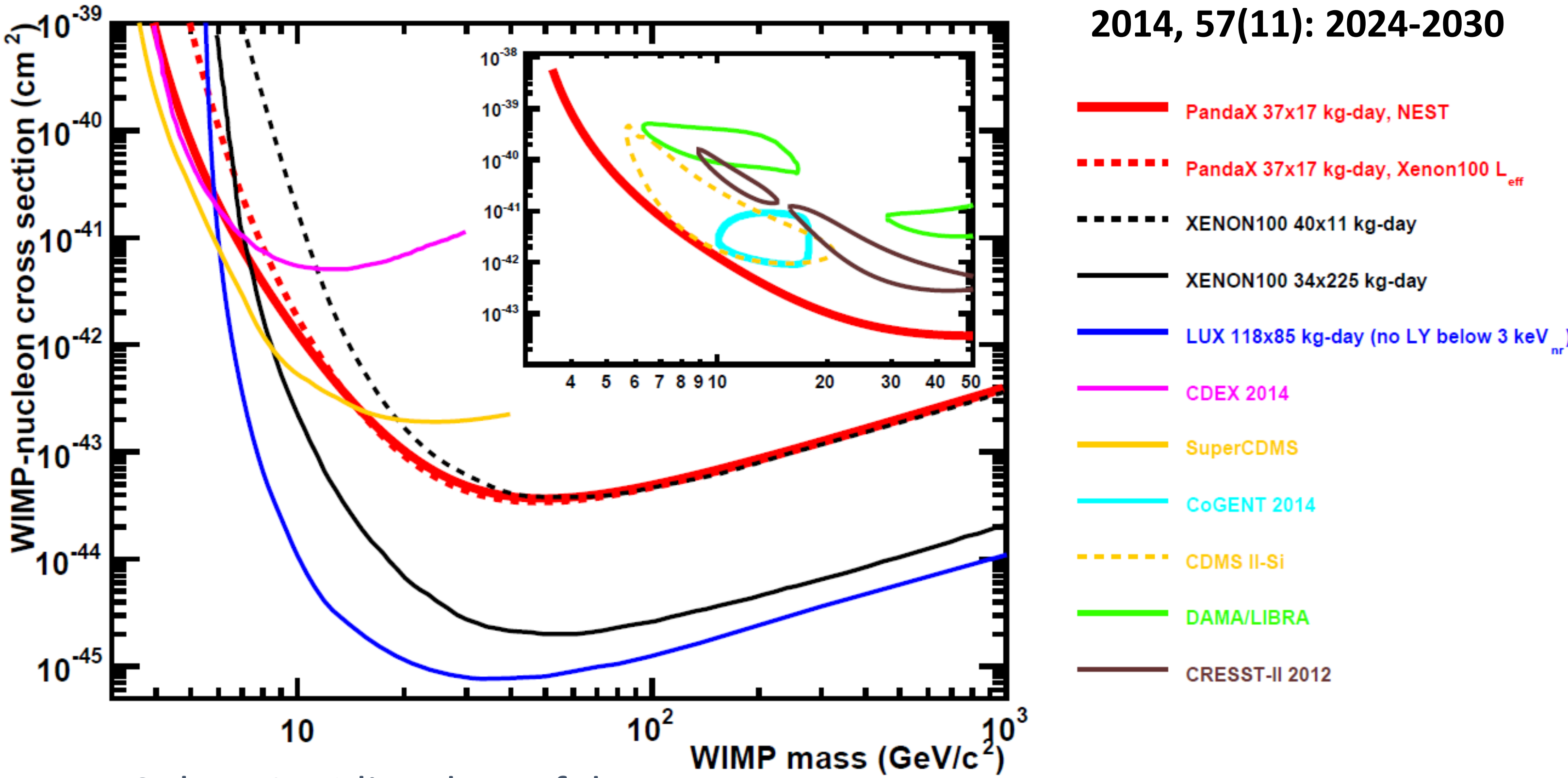
“Skin”

37
R11410 PMTs
3”

60cm

Key design goal: high light collection efficiency

PandaX-I First Results



Sci China Phys Mech Astron 2014, 57(11): 2024-2030

- 37kg x 17.4 live days of data
- Disfavor all previously positive signals
- At low mass region, our results more constraining than XENON100 first results with similar exposure

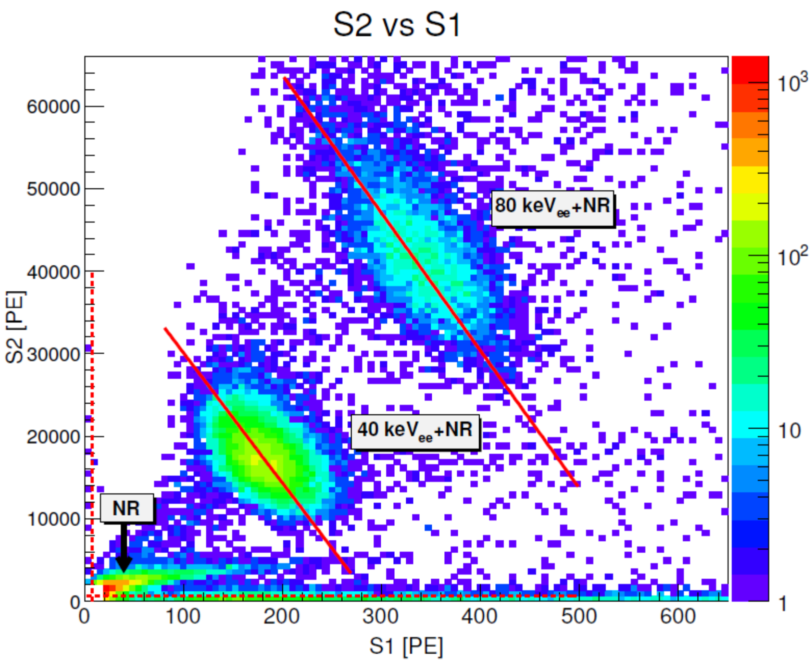
PandaX-I Full Exposure Run

Phys.Rev. D92 (2015) 5, 052004

- 80.1 live-day × fiducial mass 54 kg (× 7 exposure)
- Calibrations with much larger statistics (ER/NR)
- Updated energy modeling at low recoil energy and improved treatment to low mass WIMPs
- Better understanding/modeling of background
- Blinded analysis: FV and energy acceptance defined blindly using FoM based on background expectation and exposure
- Likelihood approach to final results

Detector Parameters

^{129}Xe: 40 keV
^{131}Xe: 80 keV

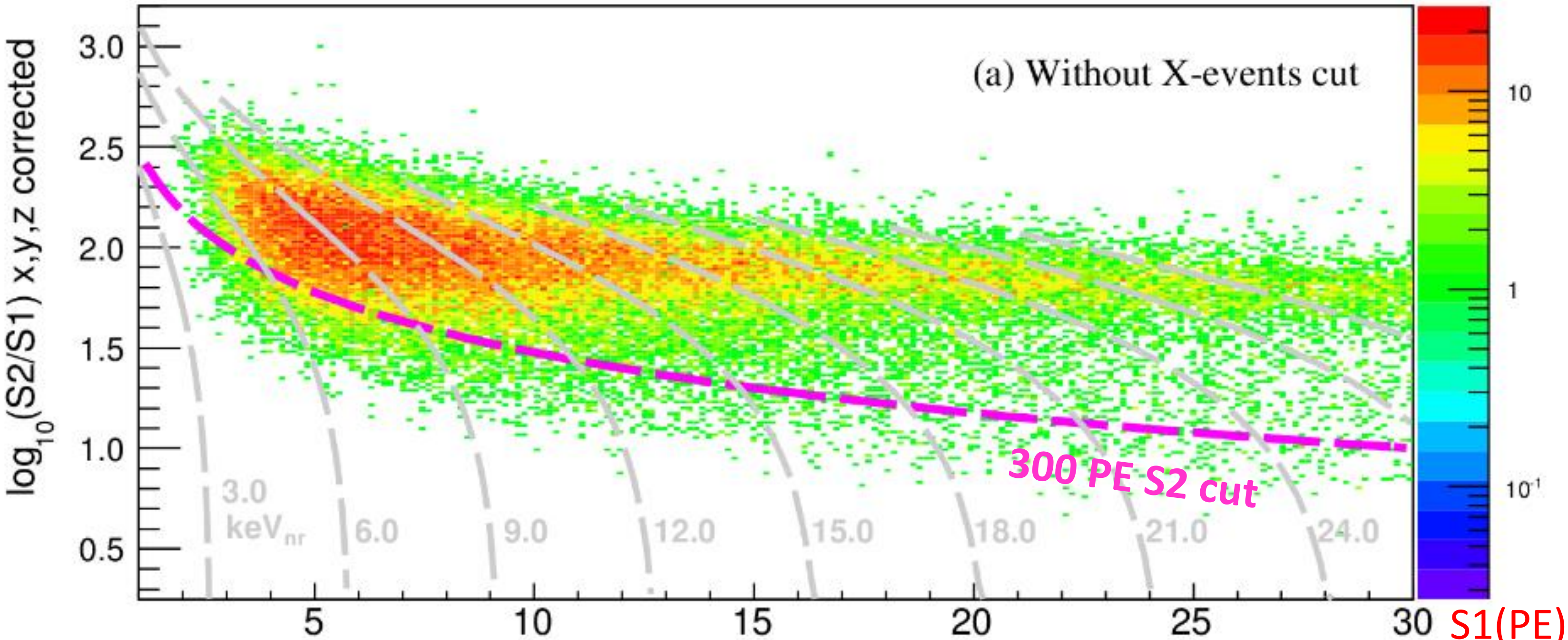


$$E_{ee}^{ce} = w\left(\frac{S1}{PDE} + \frac{S2}{\text{gas gain} \times EEE}\right)$$

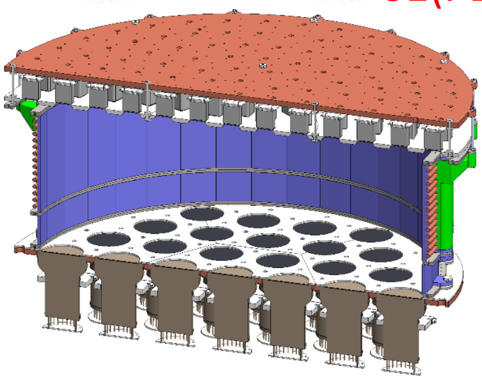
- ***w* = 13.7 eV (NEST)**
- **Photon detection efficiency (PDE): 9.55(1.0)%**
- **Electron extraction efficiency (EEE): 82.1(7.4)%**

neutron calibration with ^{252}Cf

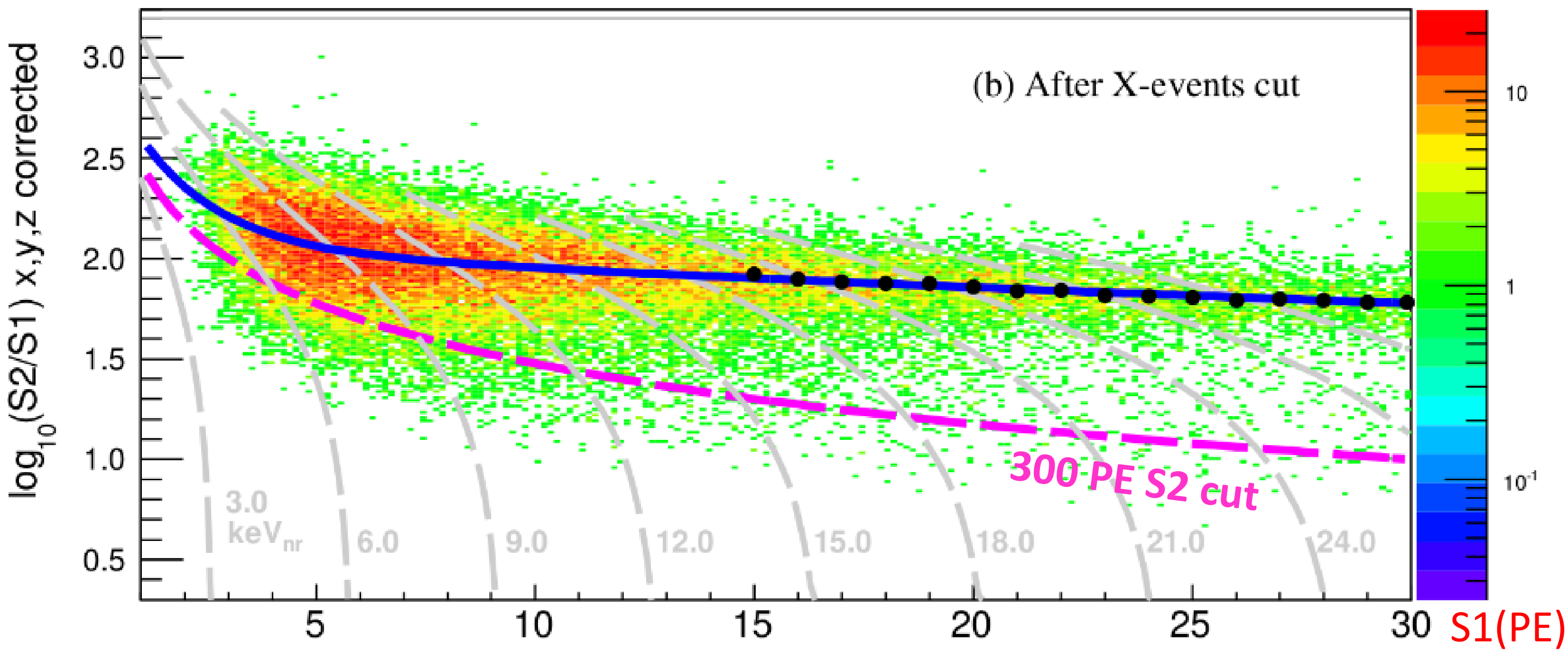
Nuclear Recoil Band



- Observe significant "single scatter" events with suppressed S2
- "X"-events in chargeless region
  - Below cathode (5cm)
  - "Skin"

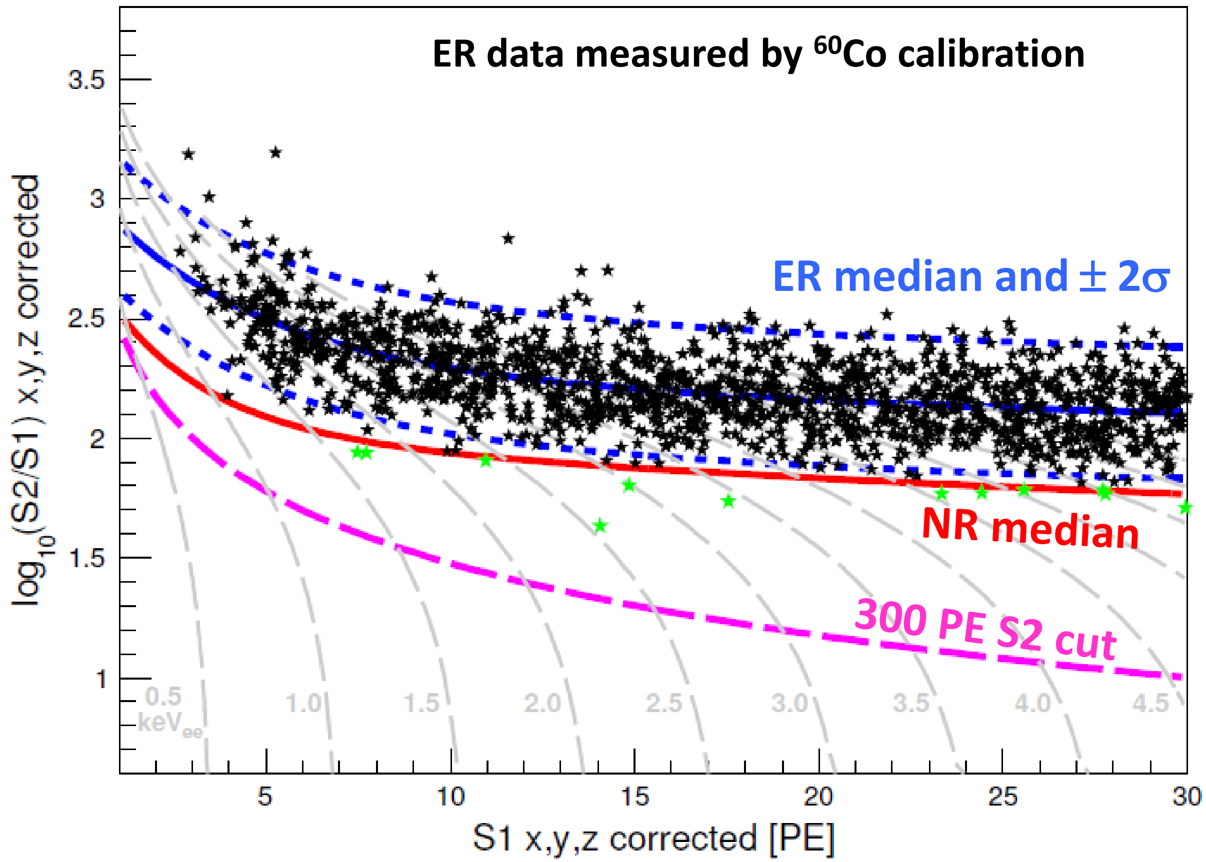


Nuclear Recoil Band after cut



- Charge pattern cut developed to remove the “X”-events effectively.
- MC with NEST model agrees well with the data

ER/NR discrimination

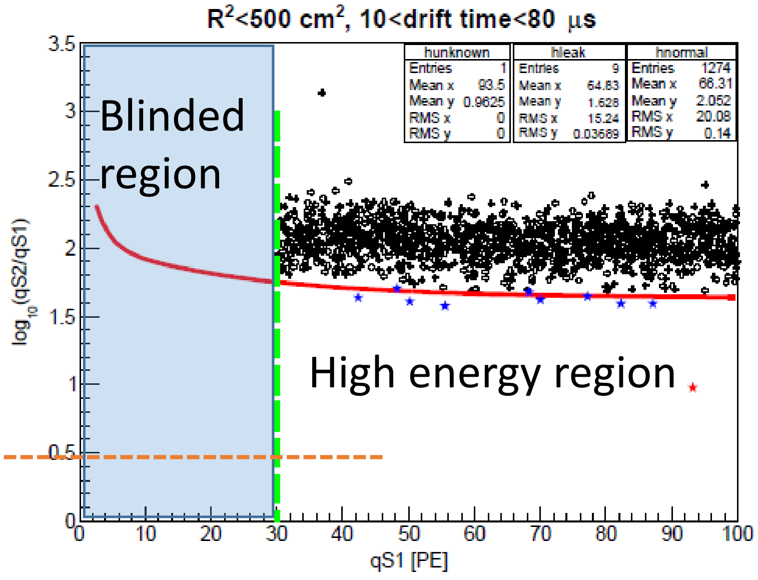


Event Type	# events
total	1520
Below NR median	12
Accidental	1.6

- "Leakage" = 10.4/1520=0.68(23)%
- Expected Gaussian: 0.5%

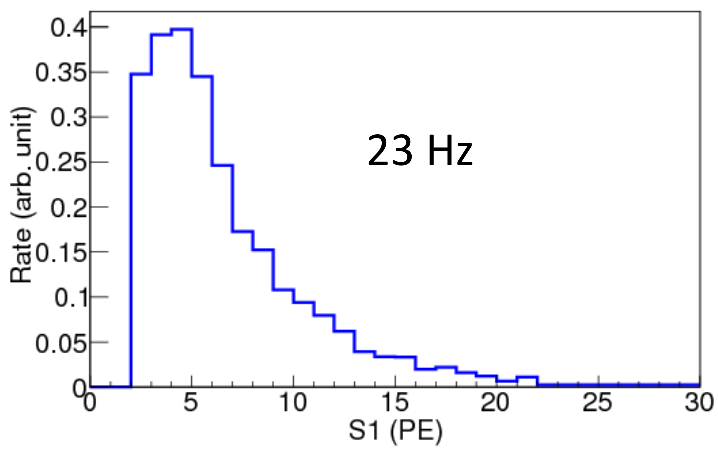
ER background

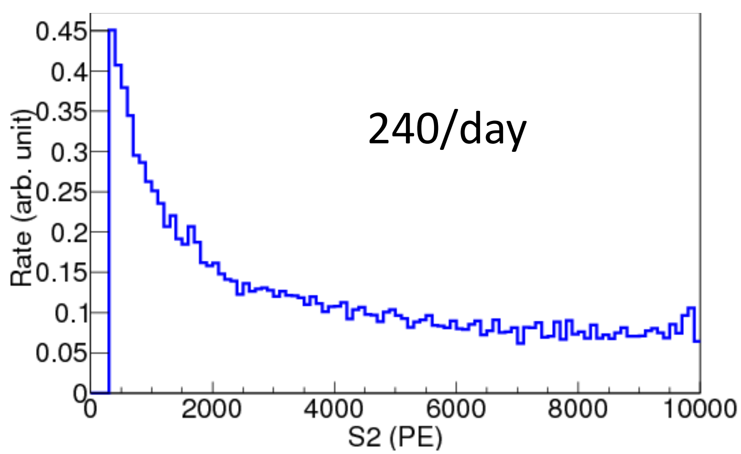
Source	background level (mDRU)
Top PMT array	4.7±2.3
Bottom PMT array	2.3 ±1.5
Inner vessel components	3.8 ±2.2
TPC components	1.9 ±0.9
^{85}Kr	2.6 ± 1.2
^{222}Rn & ^{220}Rn	0.5 ± 0.2
Outer vessel	0.9±0.6
Total expected	16.7±3.9
Total observed	23.6±3.5

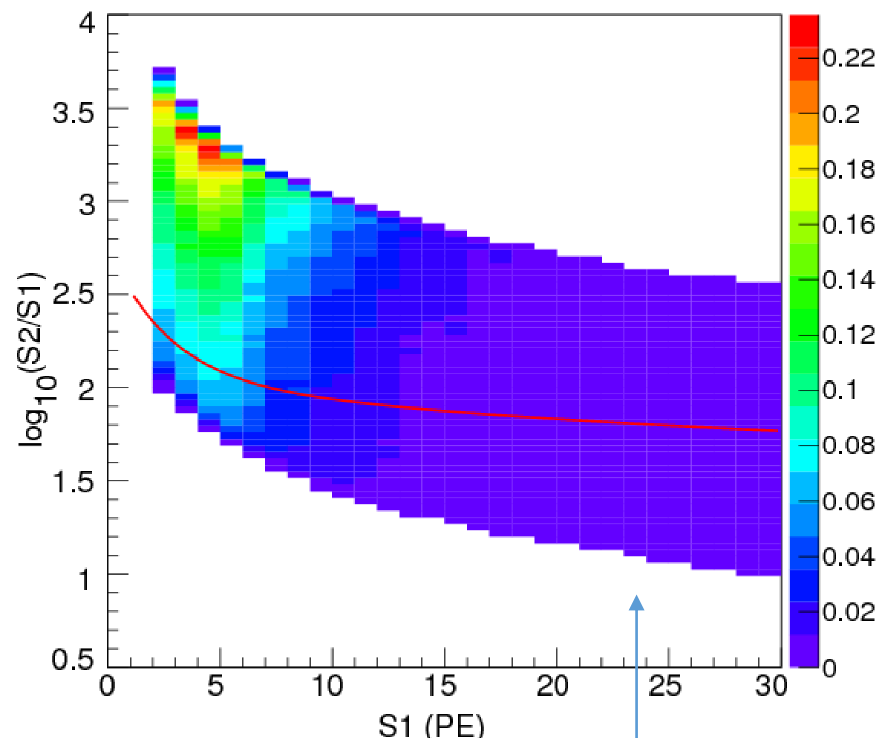


Accidental Background

- Coincidence combination of isolated S1 and S2







Accidental distribution

300 PE S2 cut to suppress the accidental backgrounds

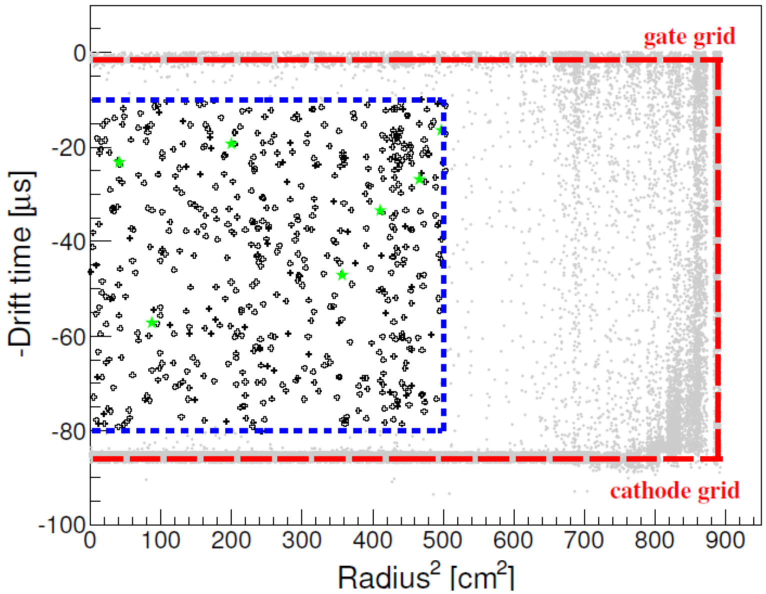
Blinded Analysis

- Fiducial volume and S1 cut determined blindly by maximizing the counting sensitivity based on the background expectation below the NR median

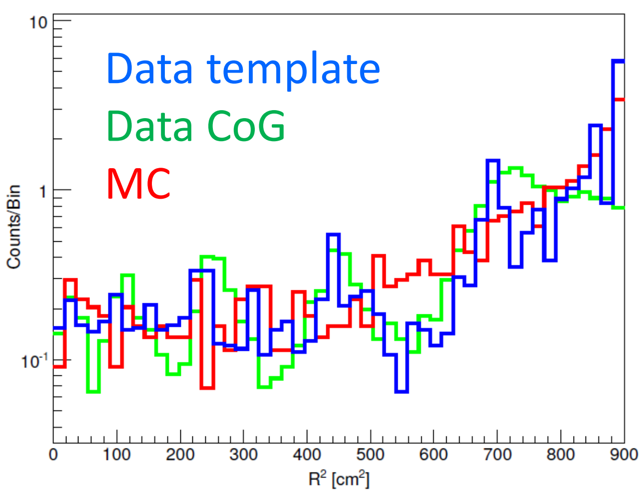
	ER	Accidental	Neutron	Total expected
All	503.7	35.1	0.35	539.1
Below NR med	2.5	4.2	0.18	6.9

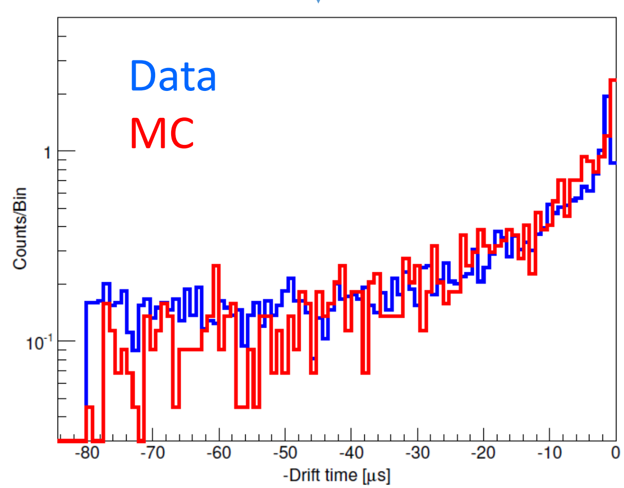
All the values are expectations!

Unblinded Vertex Distribution



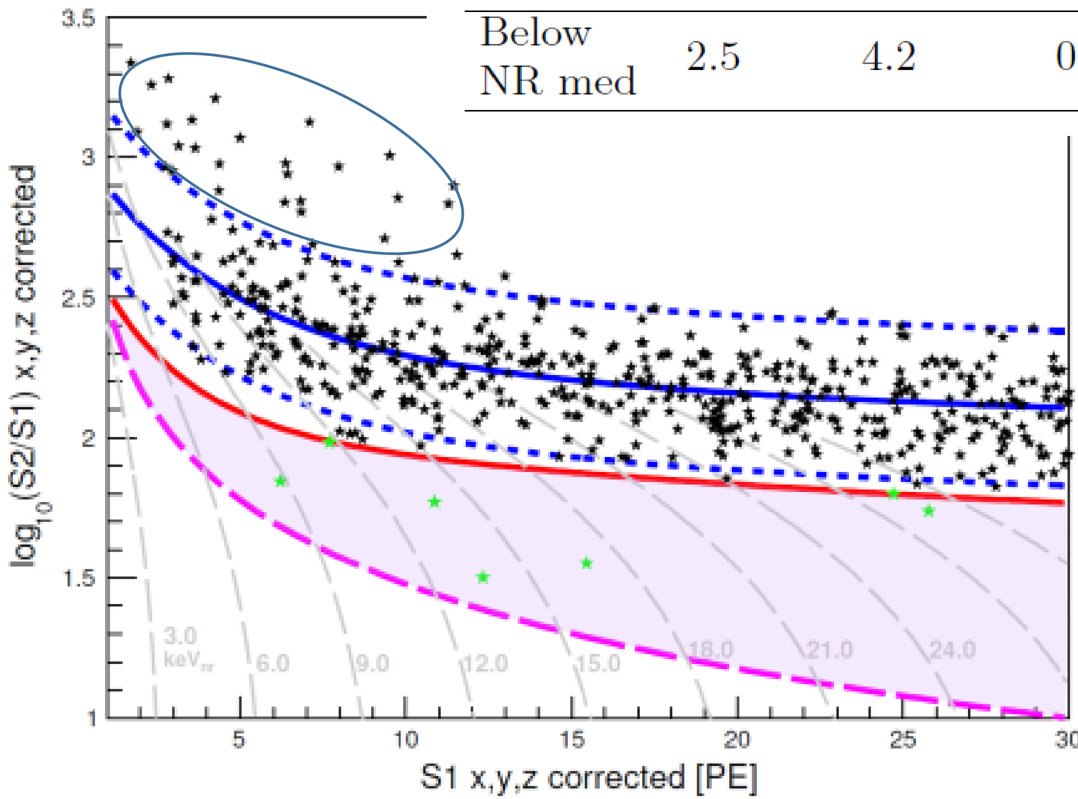
Data/MC agree well!





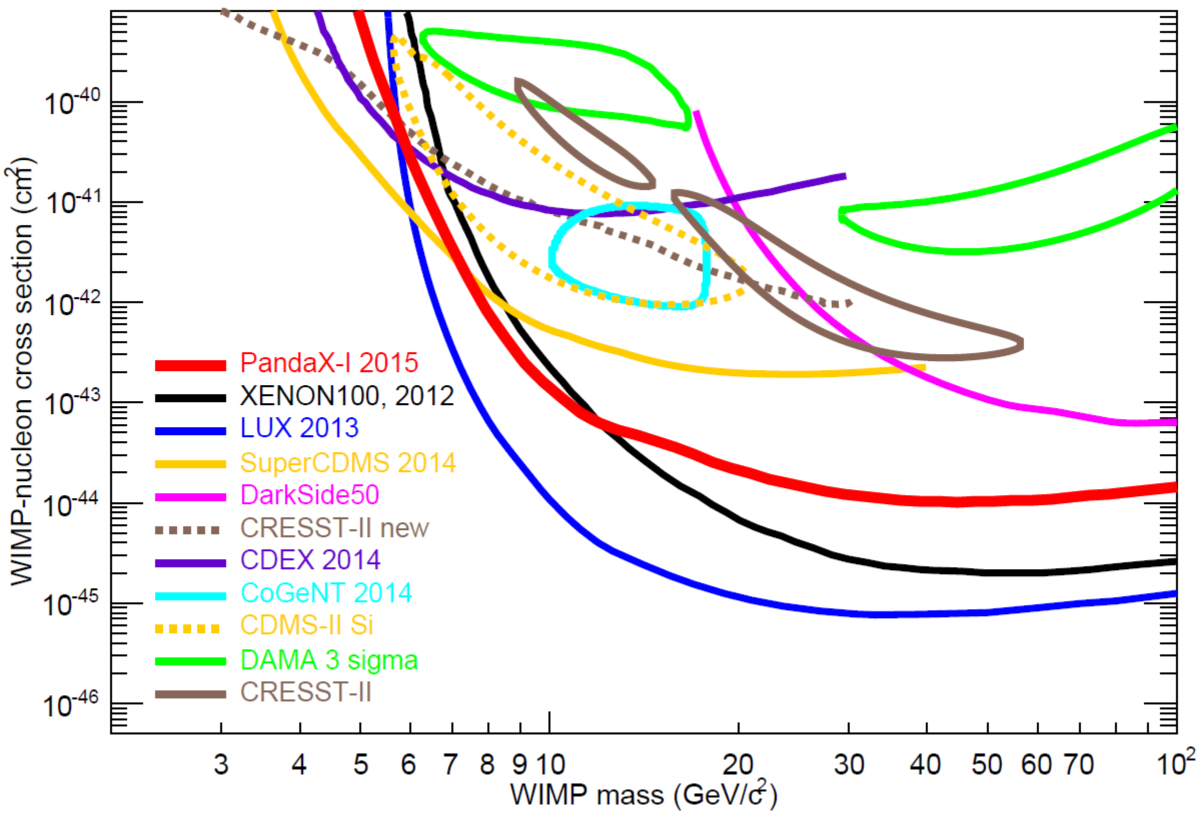
Search For DM

	ER	Accidental	Neutron	Total expected	Total observed
All	503.7	35.1	0.35	539.1	542
Below NR med	2.5	4.2	0.18	6.9	7



- 7 events found in the DM search region, still consistence with the background expectation.

Limits on DM



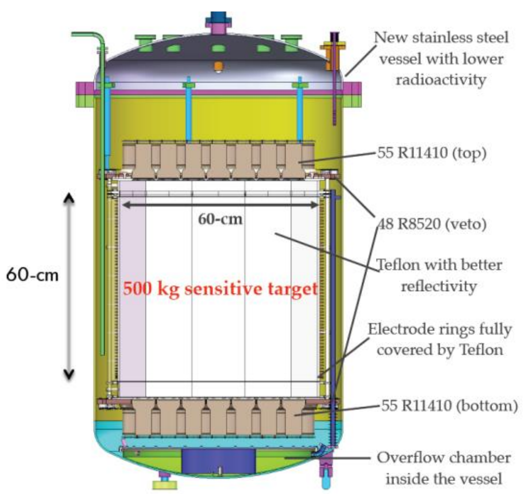
- Full exposure results with an improved analysis confirmed the finding from the first results, disfavoring all positive WIMP claims
- Tighter bound than superCDMS above WIMP mass of 7 GeV/c^2
- Best reported* WIMP limits below 5.5 GeV/c^2 in xenon community

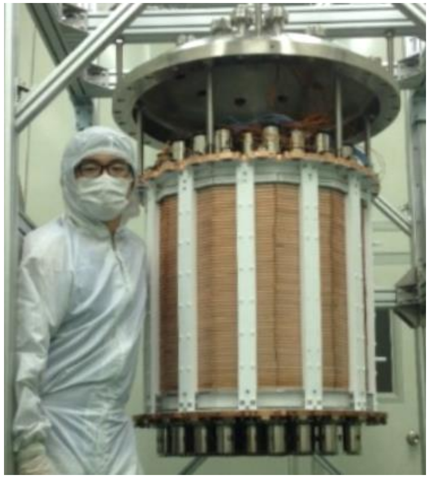
Profile likelihood fit using DM and background distribution.

*LUX chose a cutoff below 3 keVnr, whereas we used the NEST model all the way.

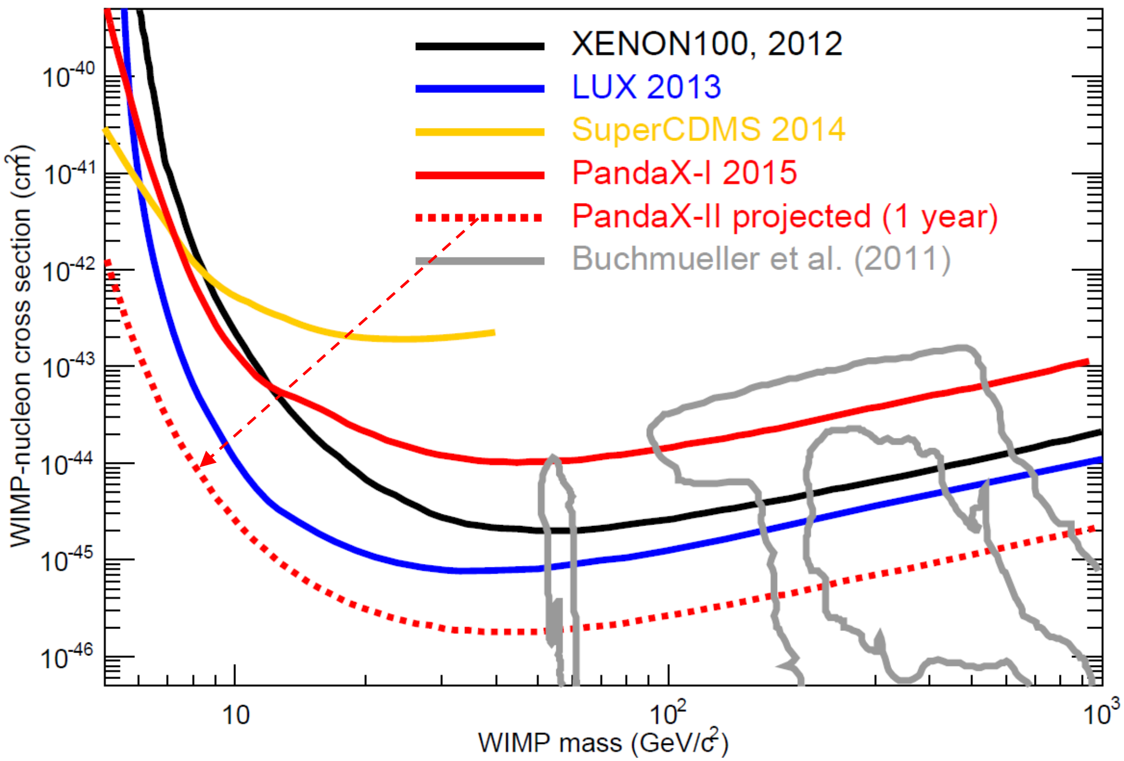
PandaX-II: 500 kg LXe

- Started construction June 2014
- Presently under commissioning
- Expect to start dark matter data taking in 2015
- Expected running time for physics: 2 years





PandaX-II Expected Sensitivity



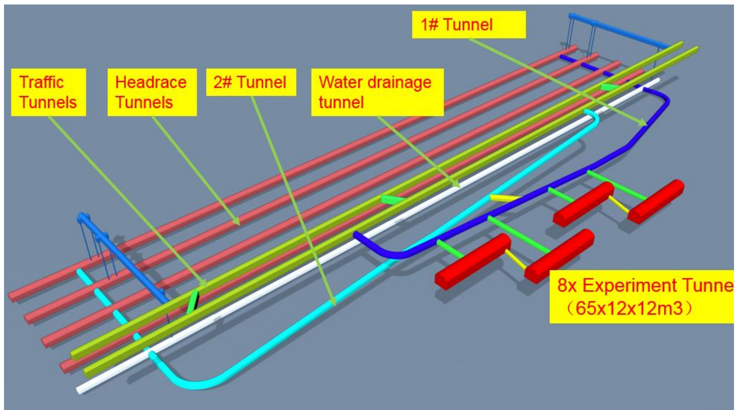
PandaX-II sensitivity assumes:

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

PandaX-II covers significant region in the SUSY WIMP parameter space.

PandaX future Programs

- CJPL-II (ready in 2016)
- Double beta decay (PandaX-III) and ultimate DM (PandaX-IV)

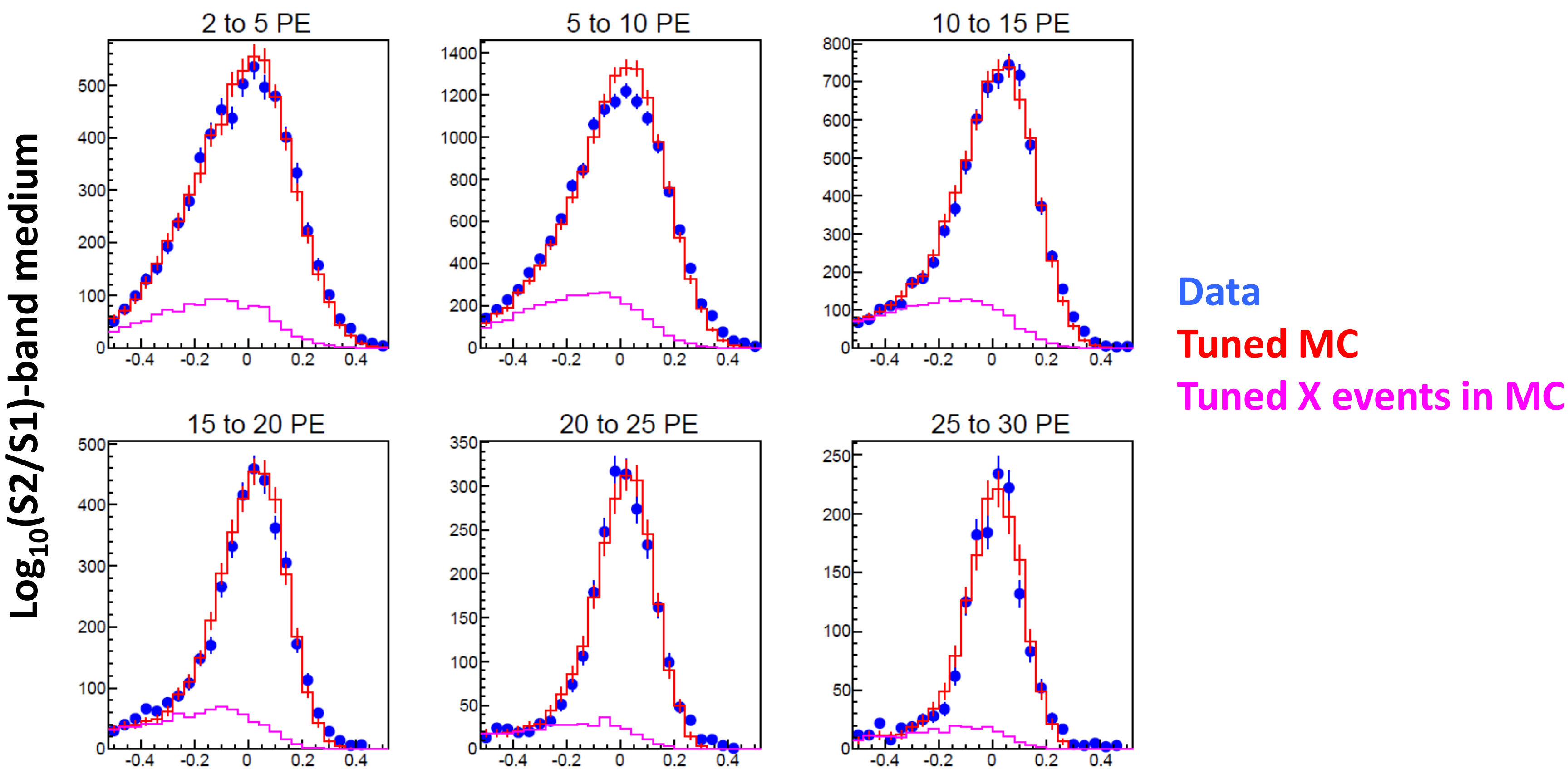


Summary

- PandaX-I finished DM search with 80.1 day ×54 kg exposure
  - Data disfavor previously reported signals from other experiments
  - Tighter bound than superCDMS above WIMP mass of 7 GeV/c2
  - Best reported WIMP limits below 5.5 GeV/c2 in xenon community
- Learn A LOT from PandaX-I experience
- PandaX-II being commissioned.
- More PandaX programs planned in CJPL-II.

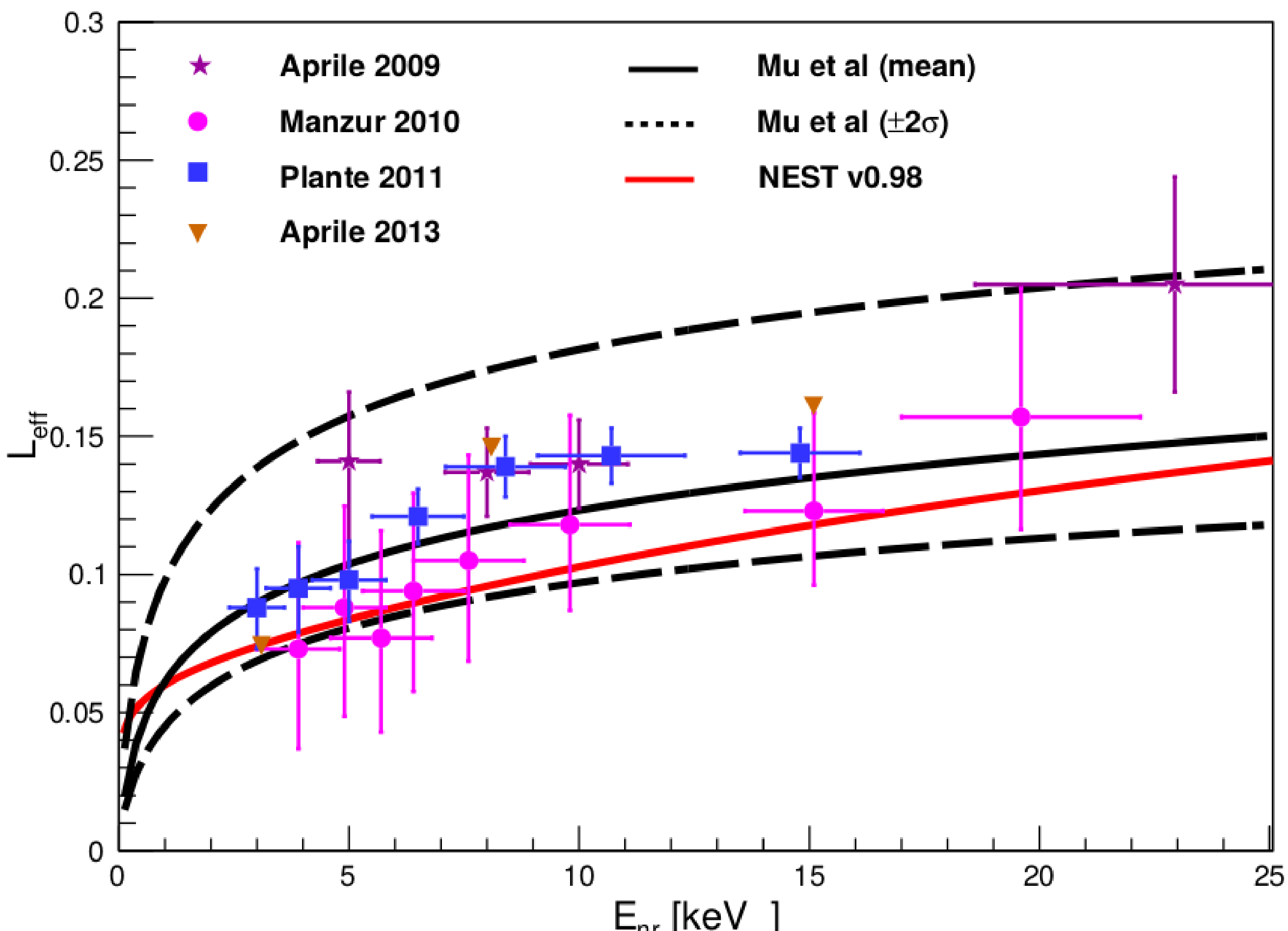
Backup Slides

Nuclear recoil band: data vs MC

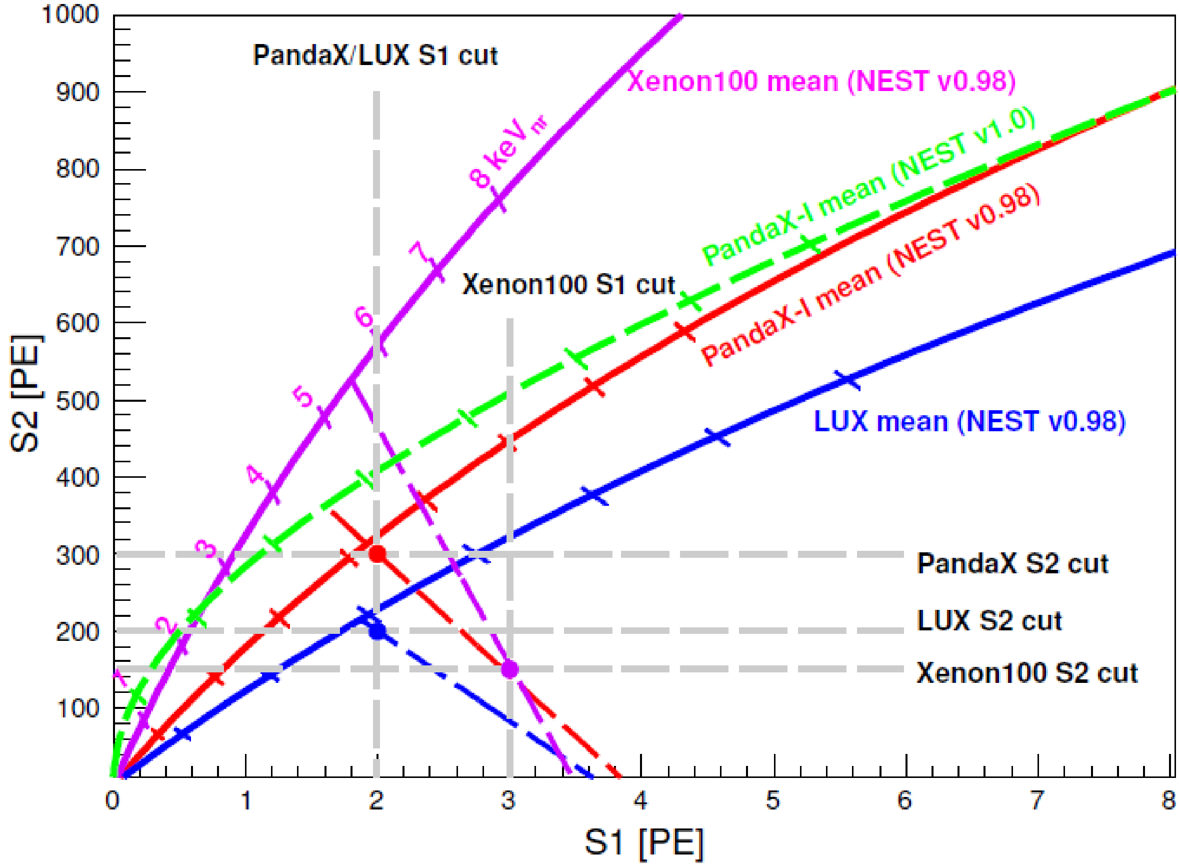


- Established quantitative understanding of the “X” event by Monte Carlo
- Tuned MC (efficiency applied) is able to reproduce the full NR distribution observed in the data

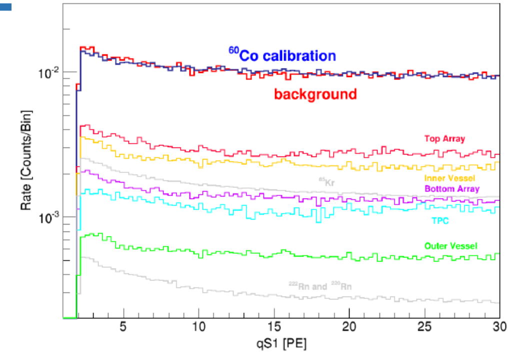
Low NR energy model



Comparison of analysis thresholds



Unbinned likelihood function

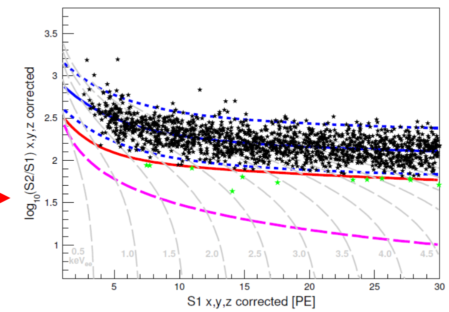


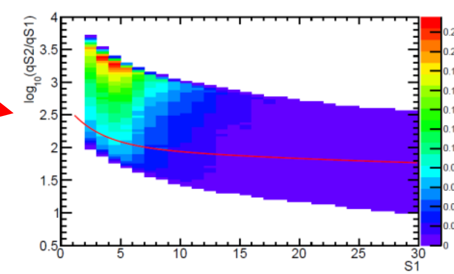
Expected shape of ER background same as that in ^{60}Co calibration!

$$
\mathcal{L} = Poiss(N_m | N_{exp}) \times
$$

$$
\Pi_{i=1}^{i=N_m} \Big[\frac{N_{DM}(1+\delta_{DM}) P_{DM}(s_1^i, s_2^i) \epsilon_{NR}(s_1^i, s_2^i)}{N_{exp}}
+ \frac{N_{ER}(1+\delta_{ER}) \boxed{P_{ER}(s_1^i, s_2^i)}}{N_{exp}}
+ \frac{N_{Acc}(1+\delta_{Acc}) \boxed{P_{Acc}(s_1^i, s_2^i)}}{N_{exp}}
+ \frac{N_{nbkg}(1+\delta_{nbkg}) P_{nbkg}(s_1^i, s_2^i) \epsilon_{NR}(s_1^i, s_2^i)}{N_{exp}} \Big]
$$

$$
\times G(\delta_{DM}, 0.2) G(\delta_{ER}, 0.15) G(\delta_{Acc}, 0.1) G(\delta_{nbkg}, 0.5)
$$

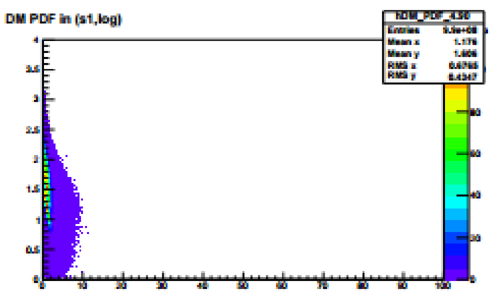




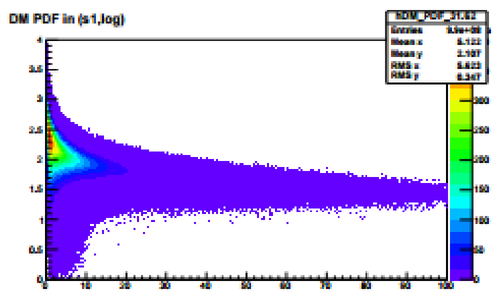
DM PDF

$$\Pi_{i=1}^{i=N_m}\left[\frac{N_{DM}(1+\delta_{DM})P_{DM}(\mathrm{S1}^i,\mathrm{S2}^i)\epsilon_{NR}(\mathrm{S1}^i,\mathrm{S2}^i)}{N_{exp}}\right.$$

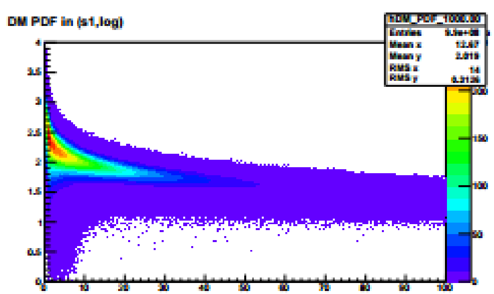
Average DM efficiency (WIMP mass dep) : $\langle \varepsilon_{\mathrm{DM}} \rangle = \int P_{\mathrm{DM}}(S1,S2)\varepsilon_{\mathrm{NR}}(S1,S2)dS1dS2$



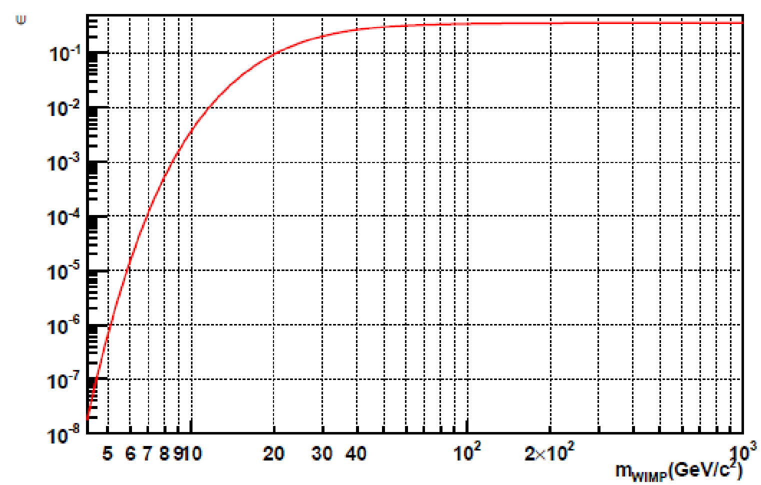
(a)4.9 GeV/c²



(b)31.62 GeV/c²



(c)1000 GeV/c²



PandaX-I sensitivity