Direct Dark Matter Search in China Jinping Underground Laboratory

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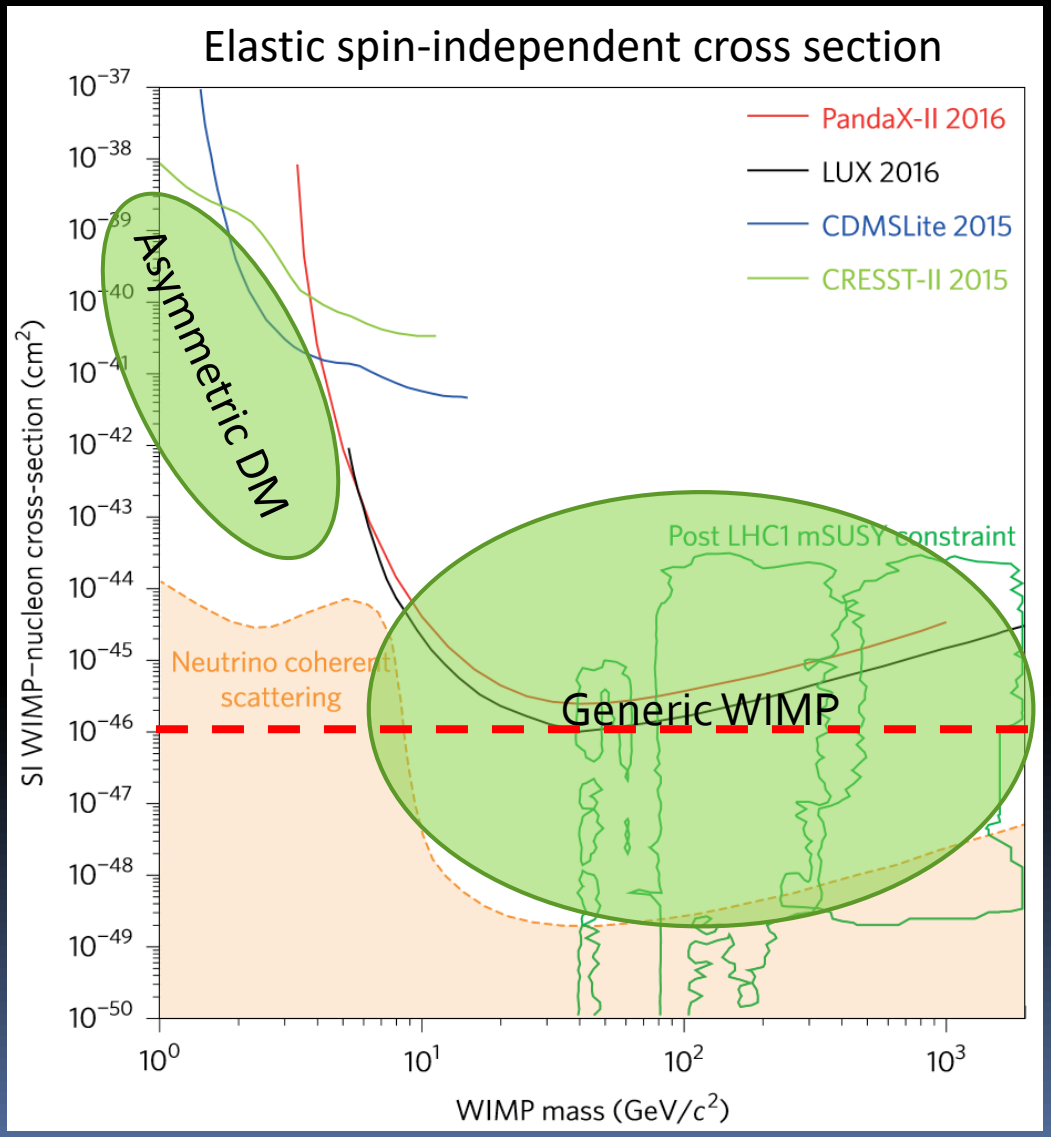
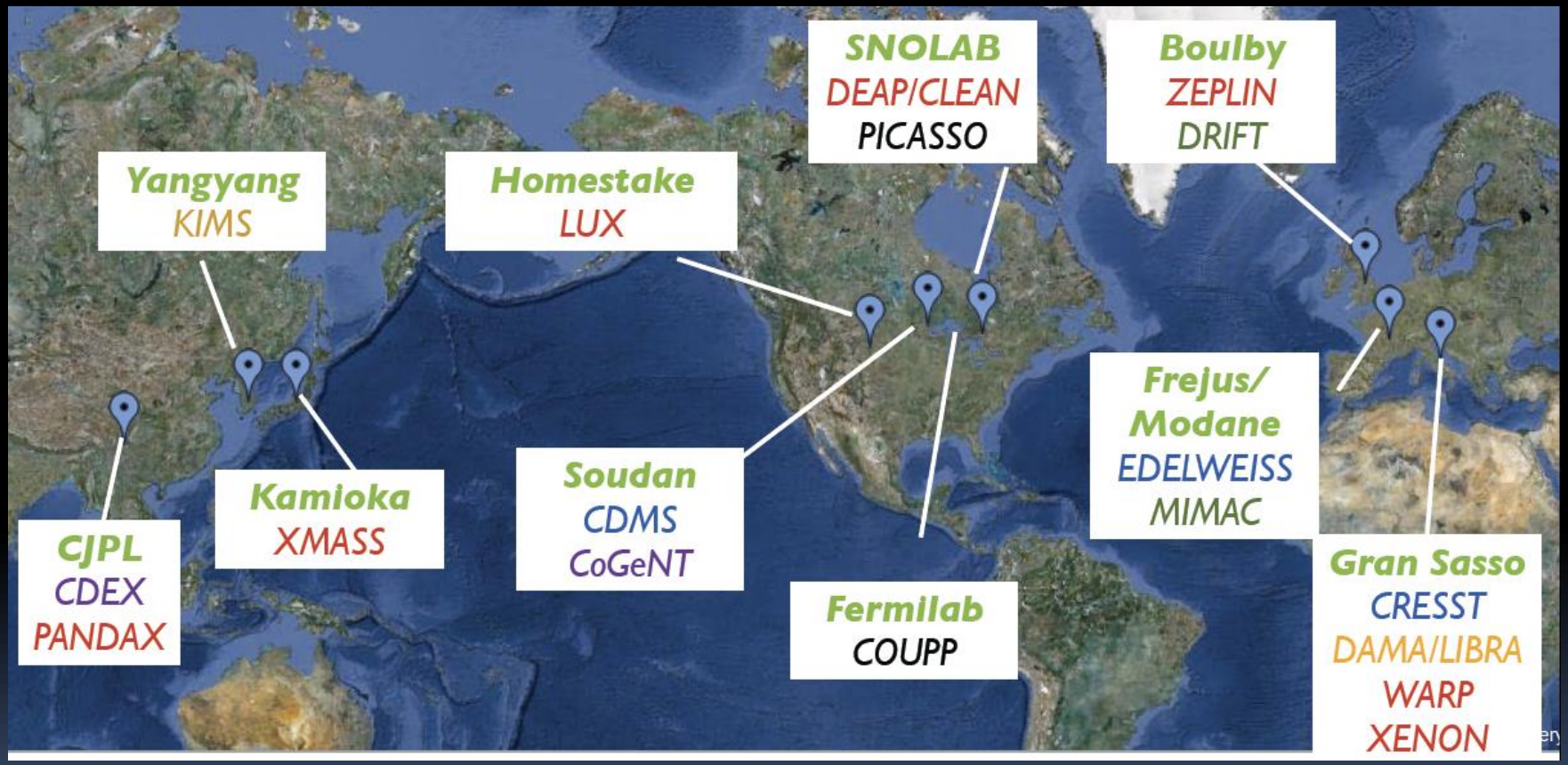
Available hiding space for DM



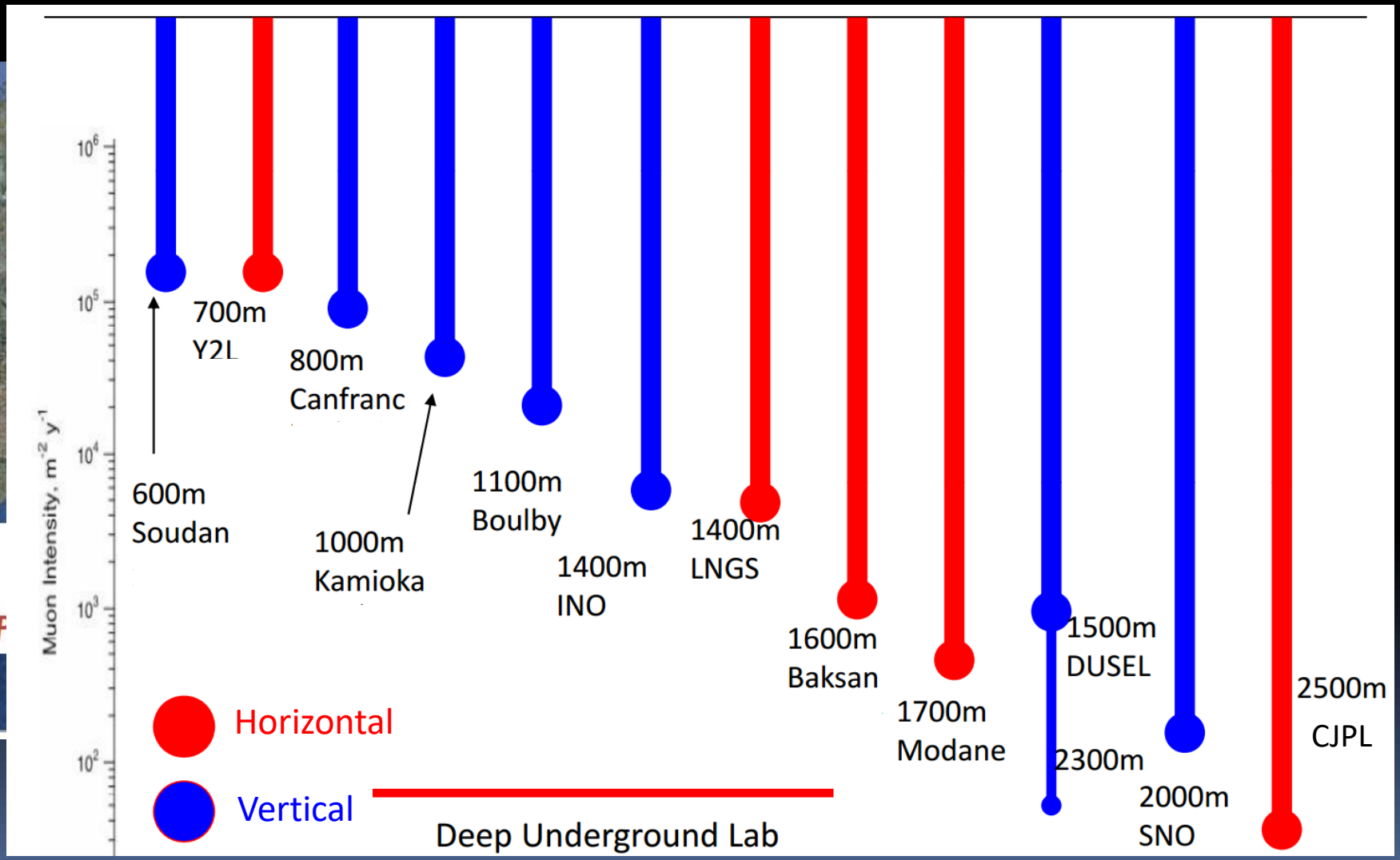
a few events/100kg/year

Nature Physics 13, 212–216 (2017)

A “dark matter rush”



A “dark matter rush”



China Jin-Ping Underground Lab (CJPL)

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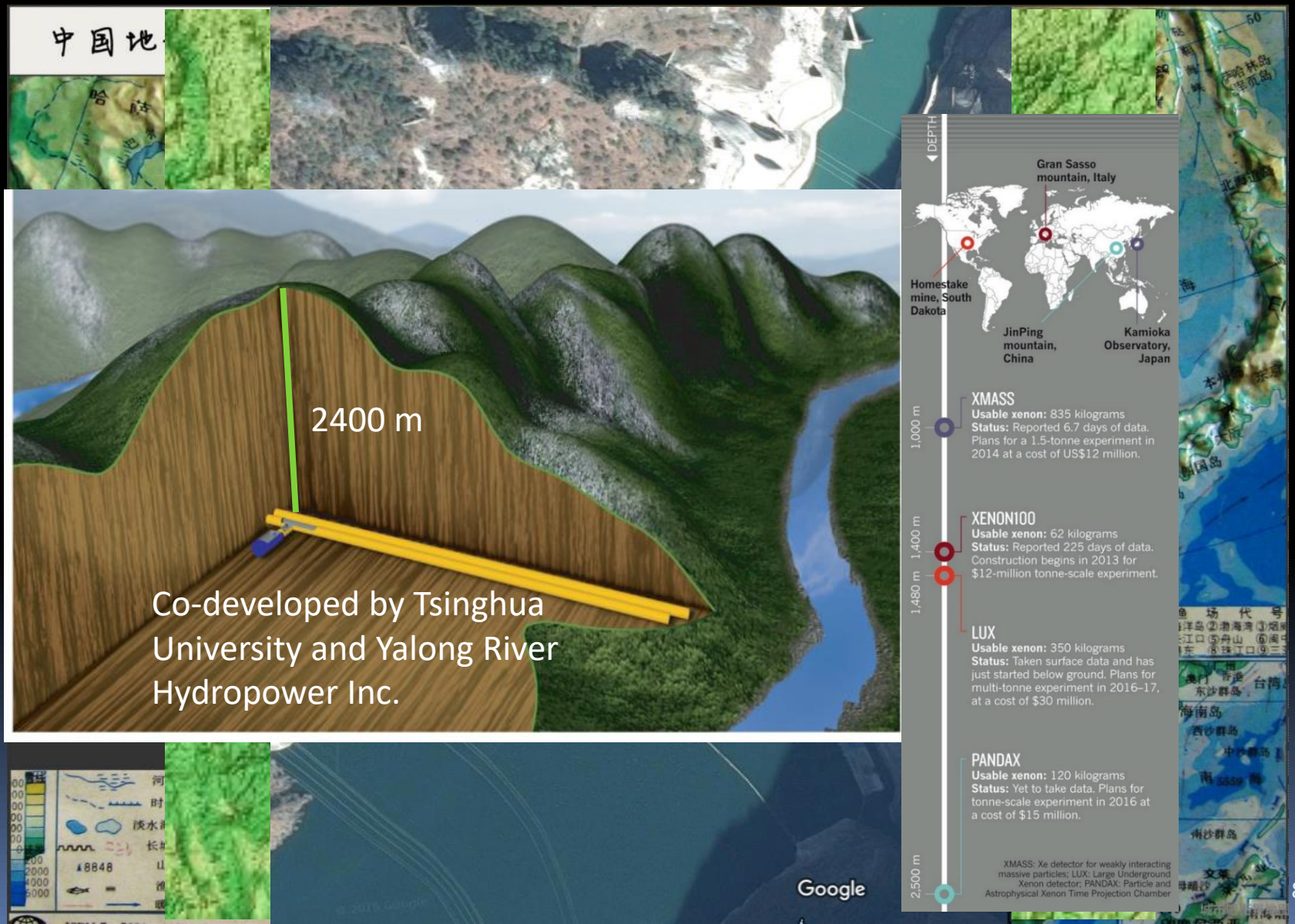
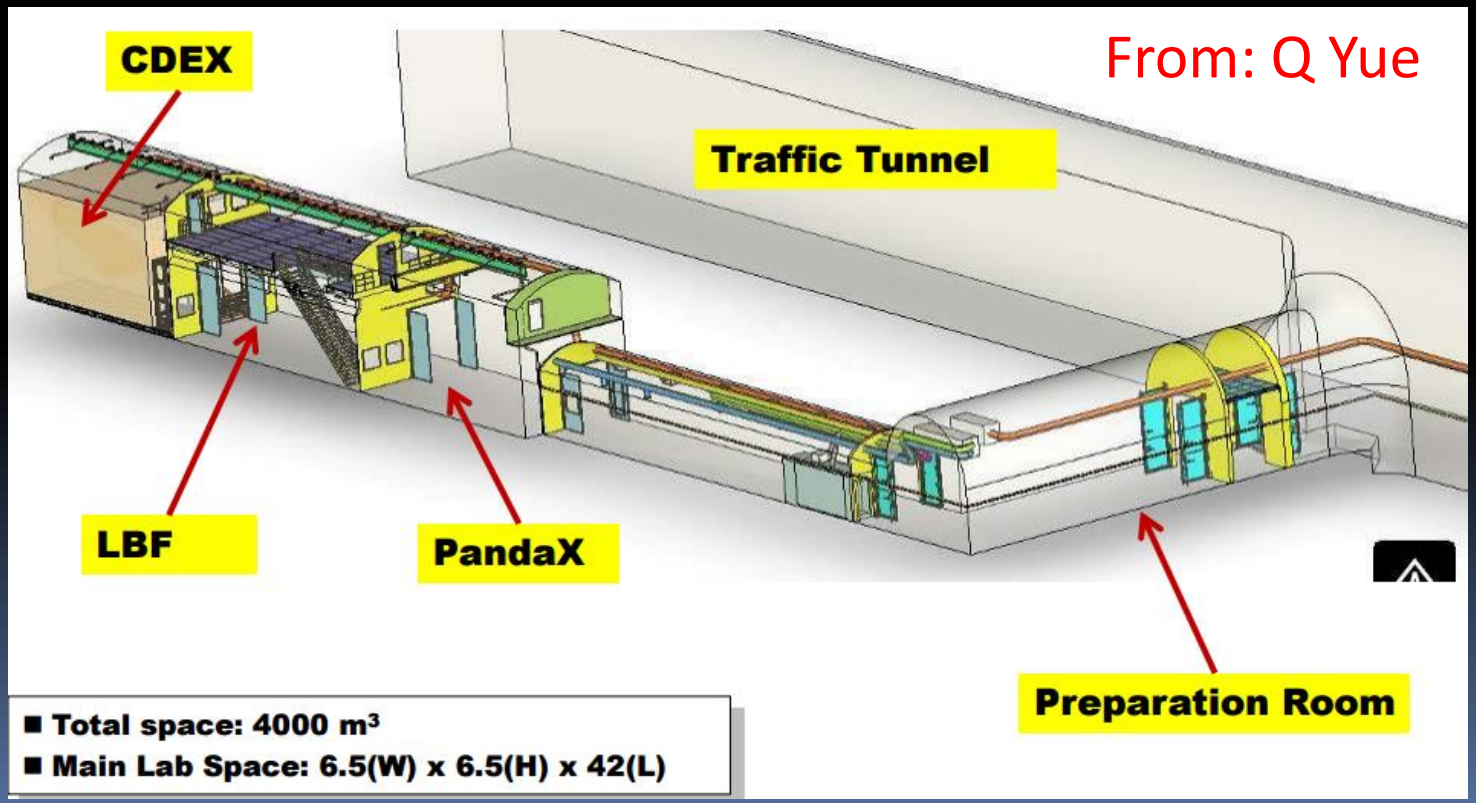


1st generation of DM experiments in China

- CDEX Project (Point-contact Ge)
- PandaX Project (LXe)



From: Q Yue

CDEX: China Dark matter EXperiment

Established in 2009.

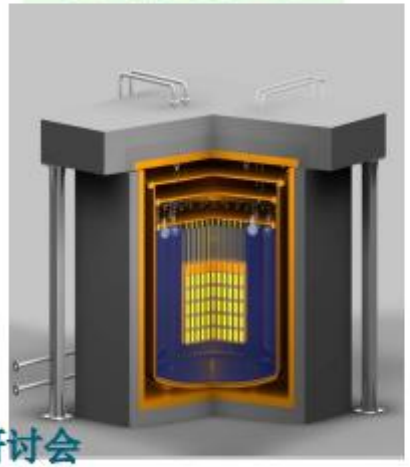
- Tsinghua University, THU
- Sichuan University, SCU
- Nankai University, NKU
- China Institute of Atomic Energy, CIAE
- Yalong River Hydropower Company, EHDC
- Collaborate with TEXONO and KIMS group.

part members of the CDEX collaboration

From: Q Yue

CDEX development stages

- CDEX-1: Development of HPGe detector, its background understanding and the studies of its performances based on 1kg-scale-mass HPGe detector.
- CDEX-10: Performances of HPGe array detector system and its passive/active shielding systems.
- CDEX-10X: Fabrication of HPGe detector and Germanium crystal growth by CDEX.
- CDEX-1T: Multi-purpose experiment for dark matter and double beta decay.
- CDEX@CJPL



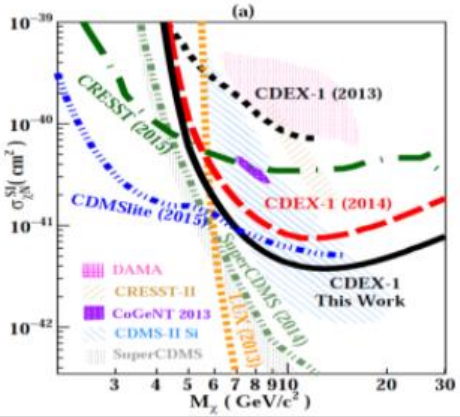
CDEX-1A 2016 results

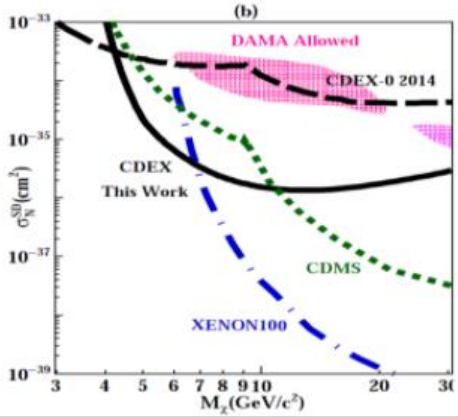
From: Q Yue

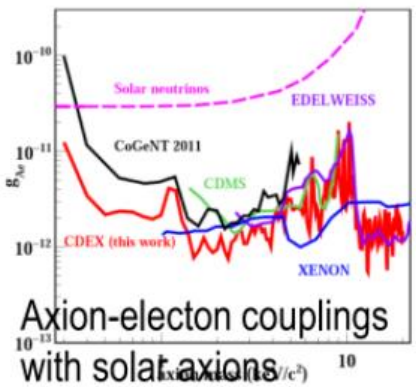
- CDEX-1A run > 500 day, totally ~336 d·kg dataset;
- Flat background level decay from ~10 to ~3 cpkkd;
- ~2 times more sensitive than 2014 SI result and best sensitivity at 4-7 GeV region for SD;
- Axion detection new results: 2-3 times better than CoGeNT results below 1keV;
- AM analysis with >1 year data going on.

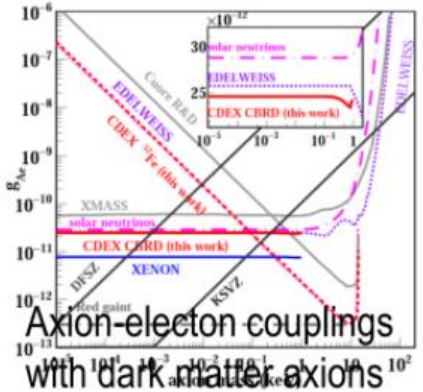
CDEX Collaboration. PRD93, 092003, 2016

CDEX： PRD95, 052006, 2017





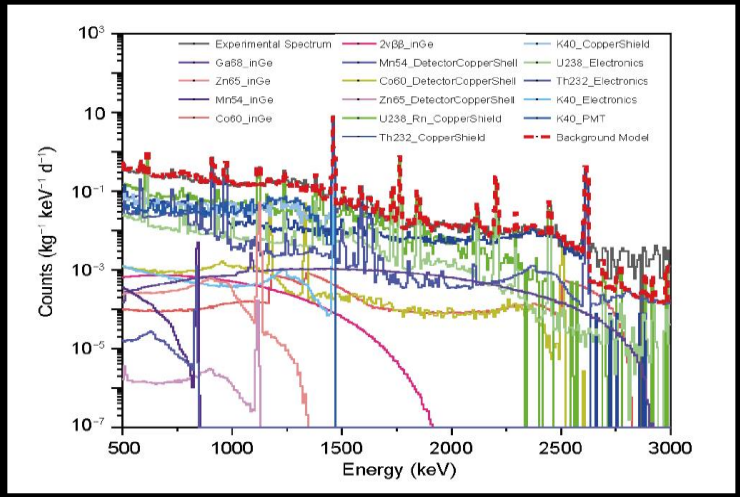


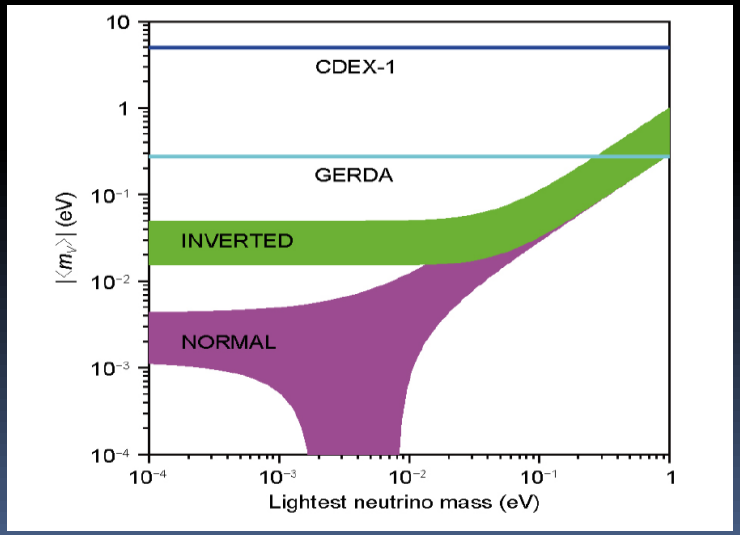


From: Q Yue

CDEX on 0vDBD

- Published the first Ge-76 0vbb result of CDEX based on the high energy spectra
- Special method developed to estimate the cosmogenic background of Ge based on ultra-low energy spectrum with energy lower than 10keV





L. Wang, **Q. Yue*,** et al. Sci. China Phys. Mech. Astron. (2017) 60: 071011

CDEX-10 Array detectors

From: Q Yue

CJPL

From: Q Yue

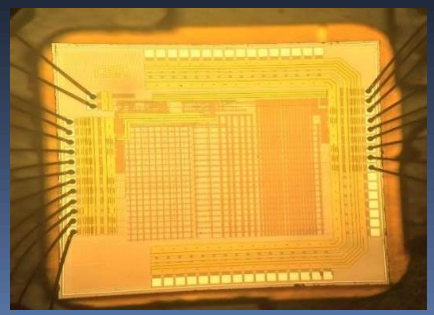
CDEX-10 to CDEX-1T

Key HPGe technologies development

- HPGe crystal growth;
- HPGe detector fabrication;
- ULB-VFE including substrate and cables;
- ULB-Copper production in underground







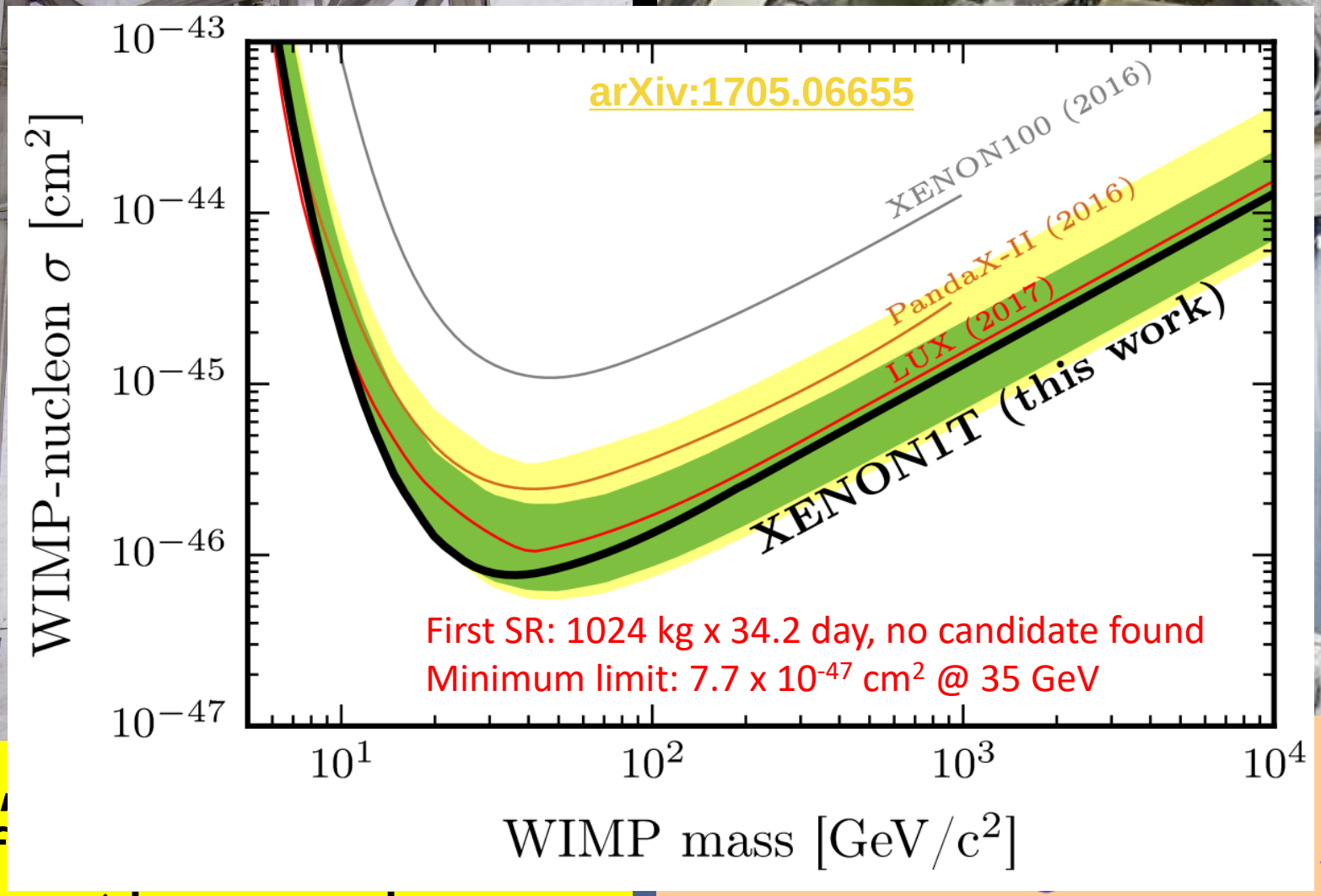
Dual phase xenon experiments

LUX, 250 kg, concluded 2016,
Sanford Lab
LZ(7-ton) in preparation

XENON1T

largest LXe TPC ever built
cylinder: 96 × 97 cm
active LXe target: 2.0t (3.2t total)
248 PMTs (Hamamatsu R11410-21)

Dual phase xenon experiments



LUX,
Sanf
LZ(7-ton) in preparation

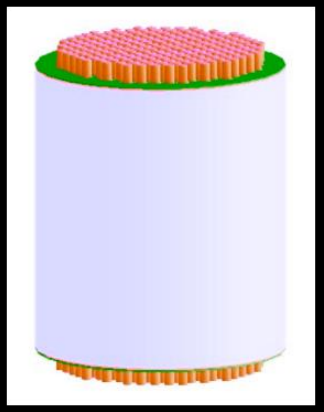
total)

248 PMTs (Hamamatsu R11410-21)

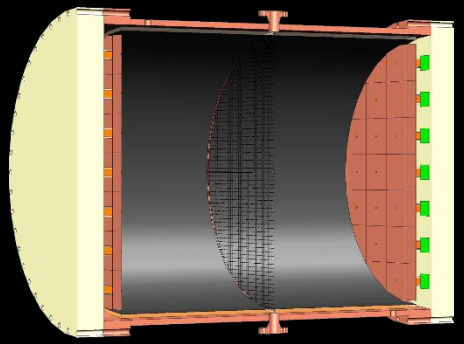
PandaX Experiments

PandaX-I: 120 kg DM experiment 2009-2014

PandaX-II: 580 kg DM experiment 2014-2018



PandaX-xT: multi-ton (~4-T) DM experiment Future



PandaX-III: 200 kg to 1 ton HP gas ^{136}Xe 0vDBD experiment Future

PANDA X = Particle and Astrophysical Xenon Experiments

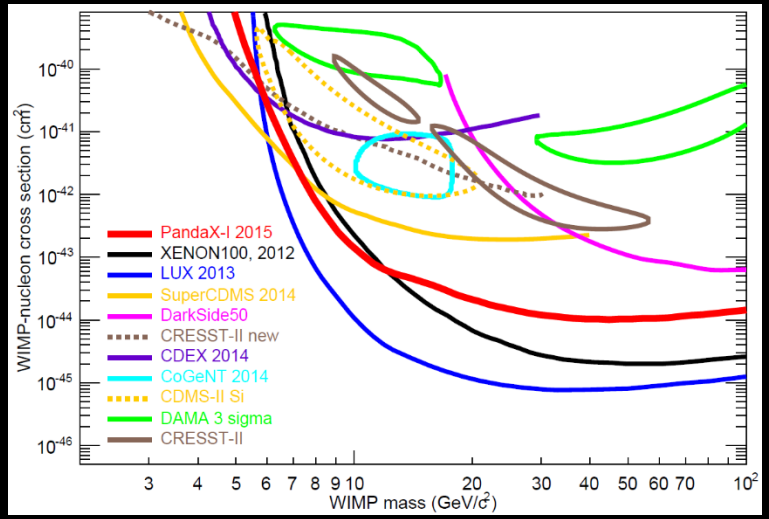
PandaX collaboration

Started in 2009, ~50 people

- Shanghai Jiao Tong University (2009-)
- Peking University (2009-)
- Shandong University (2009-)
- Shanghai Institute of Applied Physics, CAS (2009-)
- University of Science & Technology of China (2015-)
- China Institute of Atomic Energy (2015-)
- Sun Yat-Sen University (2015-)
- Yalong Hydropower Company (2009-)
- University of Maryland (2009-)
- Alternative Energies & Atomic Energy Commission (2015-)
- University of Zaragoza (2015-)
- Suranaree University of Technology(2016-)

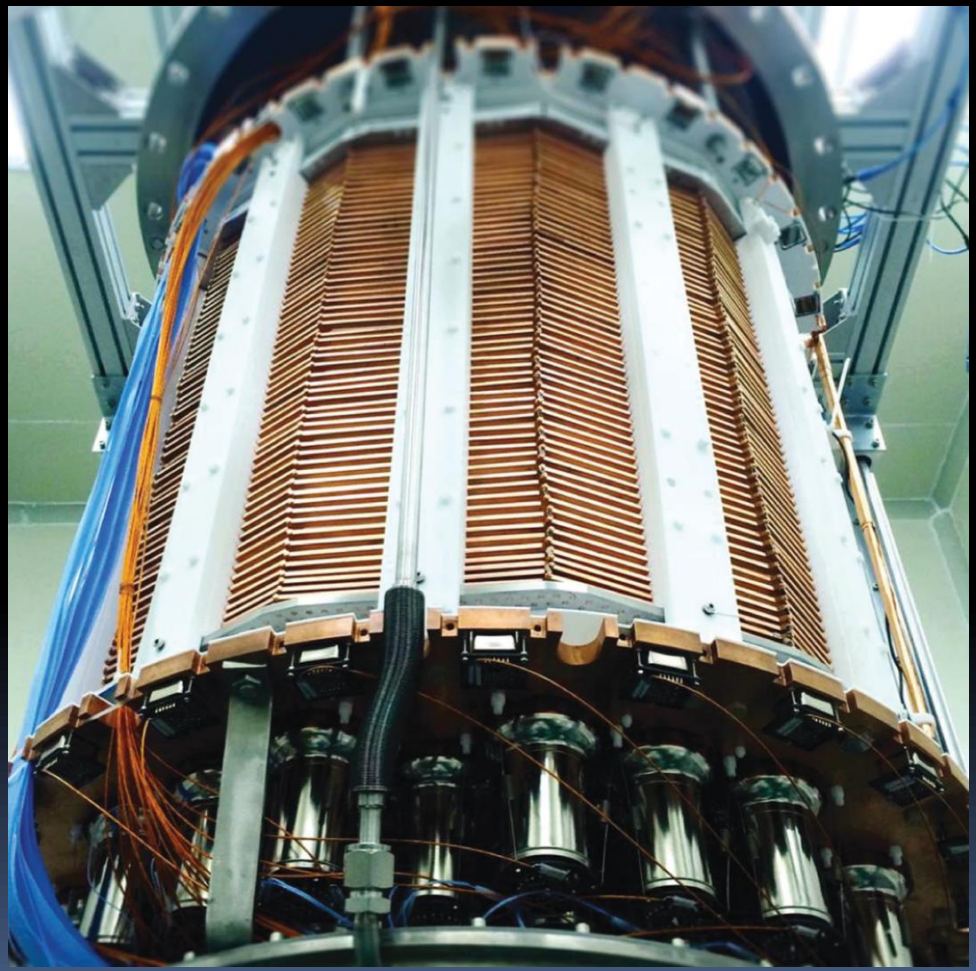
Results from PandaX-I

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



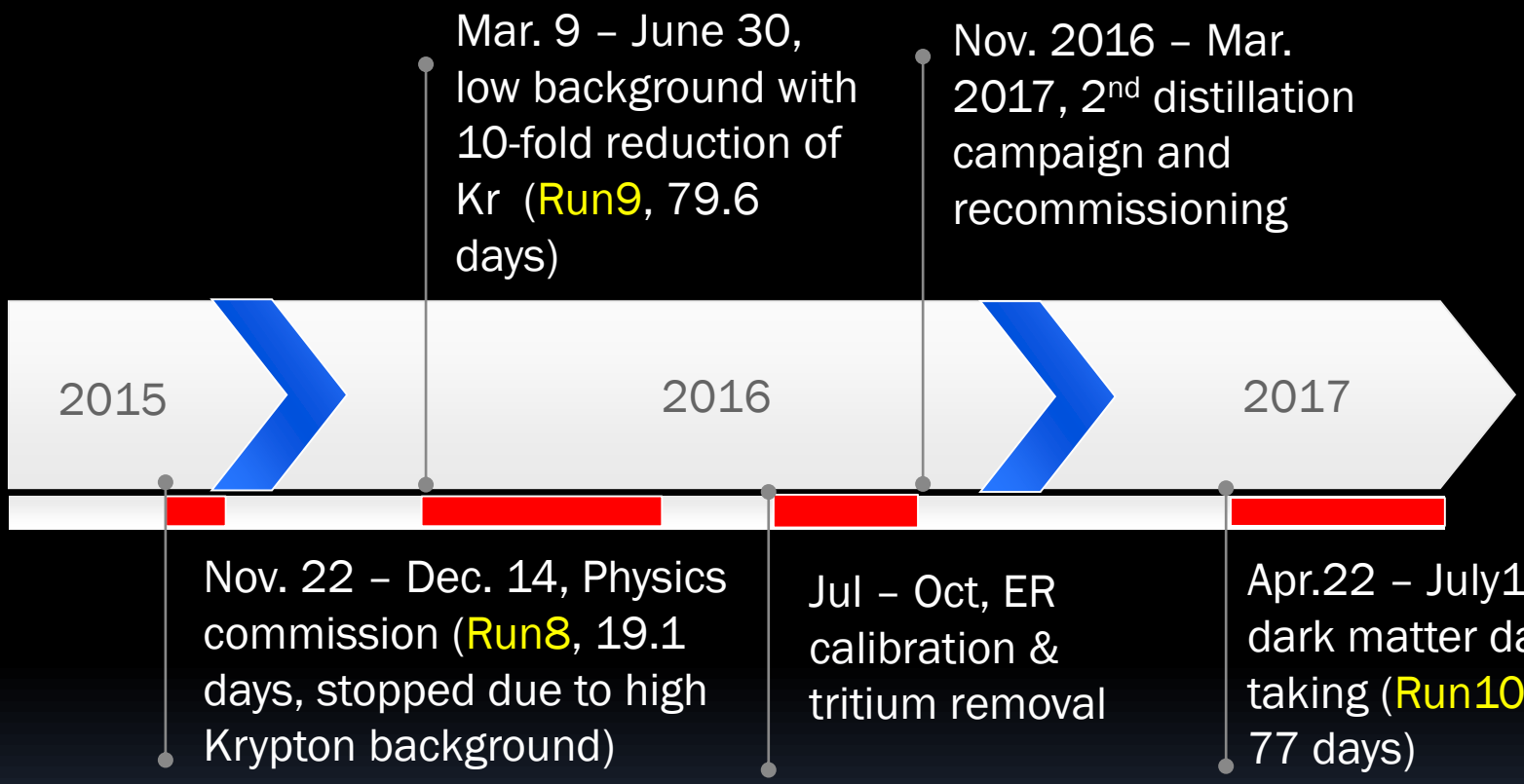
- Completed in Oct. 2014, with 54.0 x 80.1 kg-day exposure
- Data strongly disfavor all previously reported claims
- Competitive upper limits for low mass WIMP in xenon experiments

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 run history

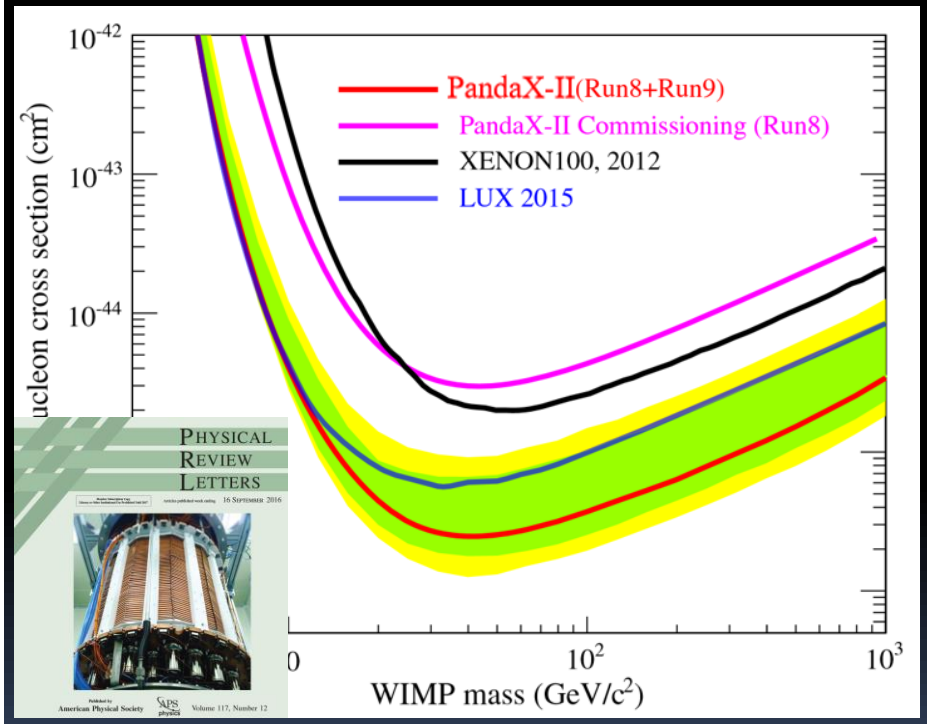


- Run9 =79.8 days, exposure: 26.2 ton-day
- Run10 =77.1 days, exposure: 27.9 ton-day
- Largest reported DM exposure to date

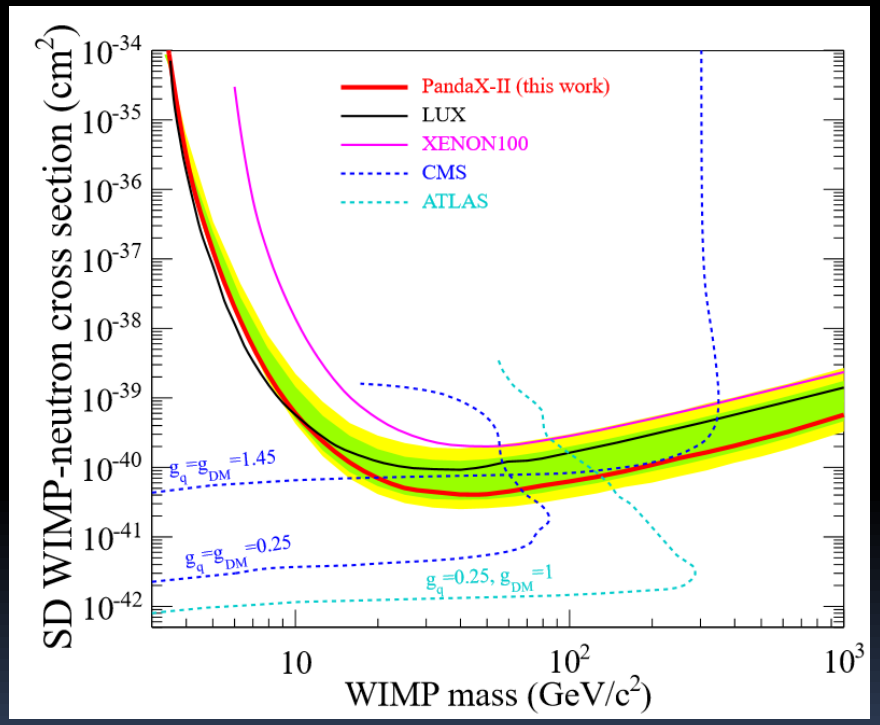
Run8+9 SI and SD results

33,000 kg-day exposure

PRL 117, 121303 (2016)



PRL 118, 071301 (2017)

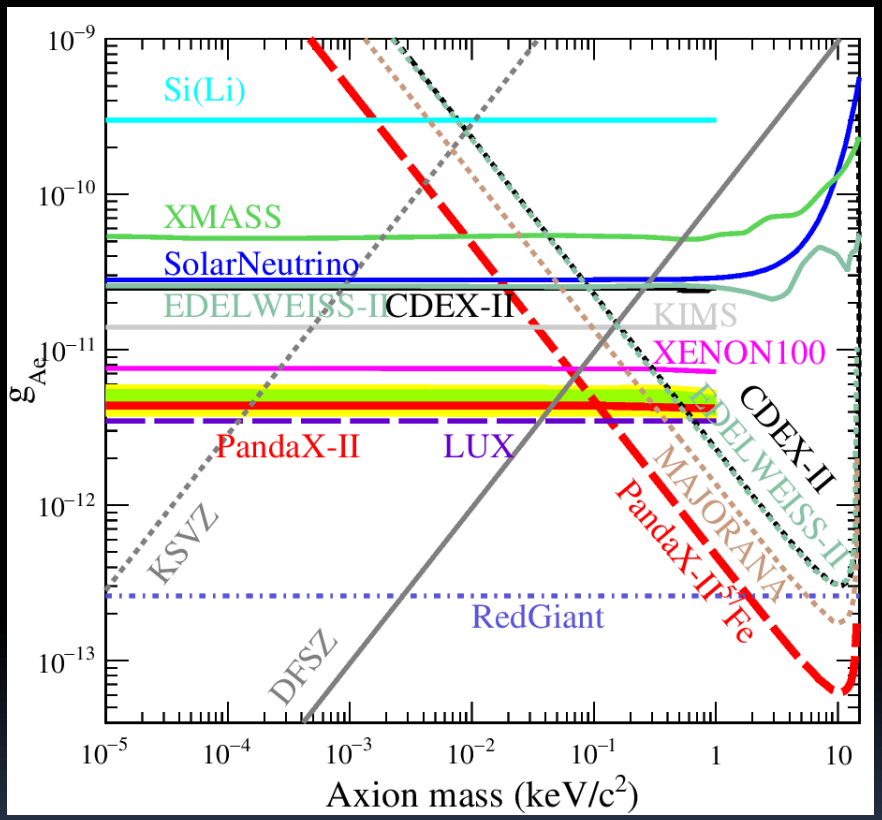


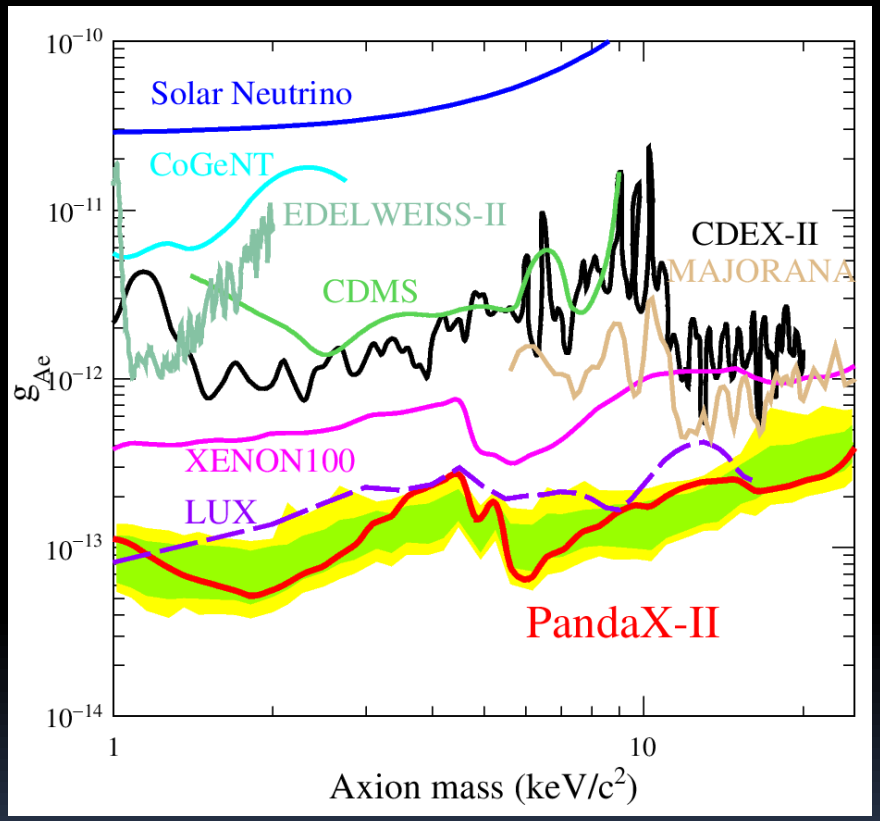
Minimum elastic SI exclusion:
2.5×10^{-46} cm² @ 40 GeV/c²

Minimum χ-n SD cross section limit:
4.1×10^{-41} cm² at 40 GeV/c²

Run9 axion search results

arXiv:1707.07921

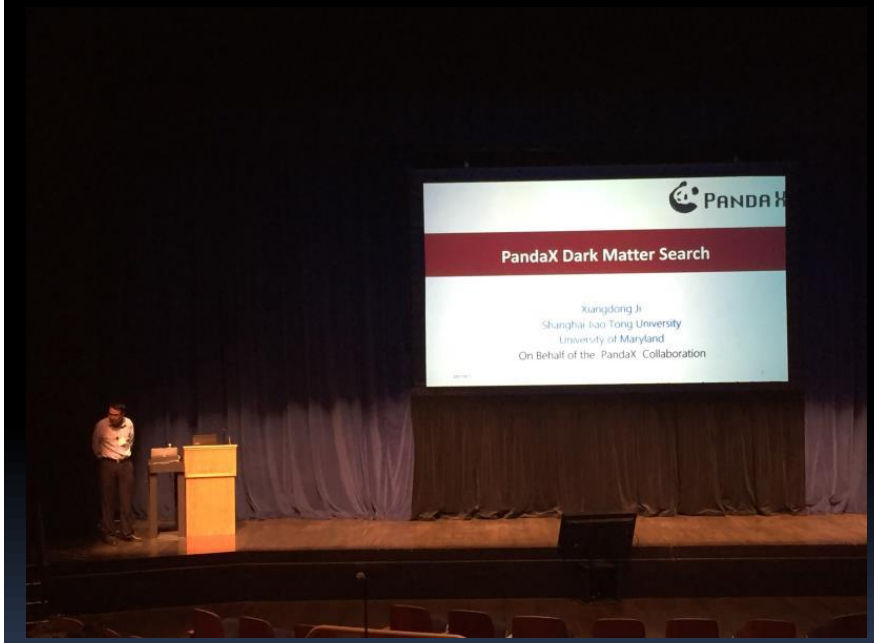




Among the leading axion search on axion-electron coupling using DD experiments

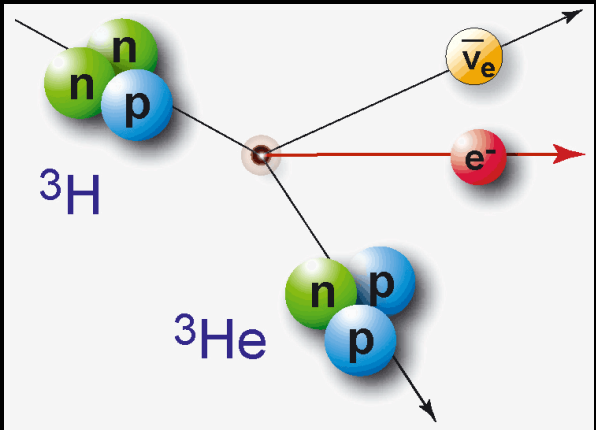
New preliminary results

SI DM search results from Run10 released at TeVPA, Aug. 7 2017

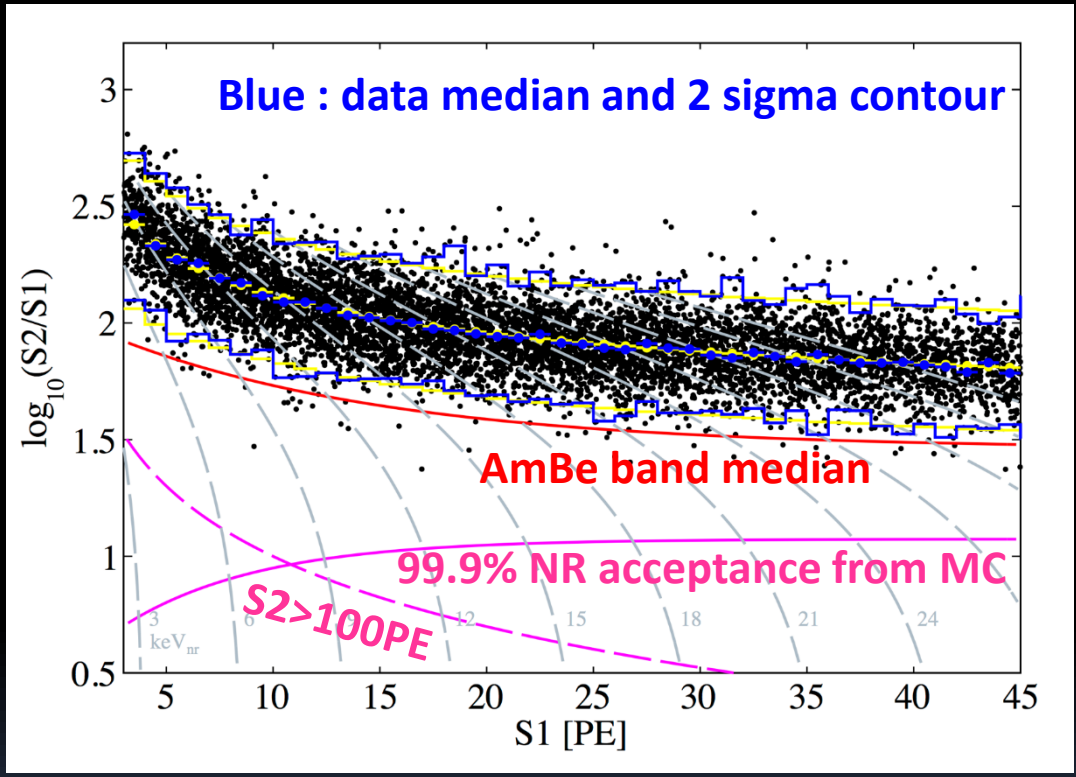


- Improved trigger threshold
- Channel-by-channel SPE efficiency (ε_{ZLE})
- Improved detector ER/NR response model
- 2.5 times reduction in total background
  - Kr85 ↓ 6 times
  - Accidental ↓ 3 times
  - Xe127 ↓13 times

Electron-recoil (ER) calibration

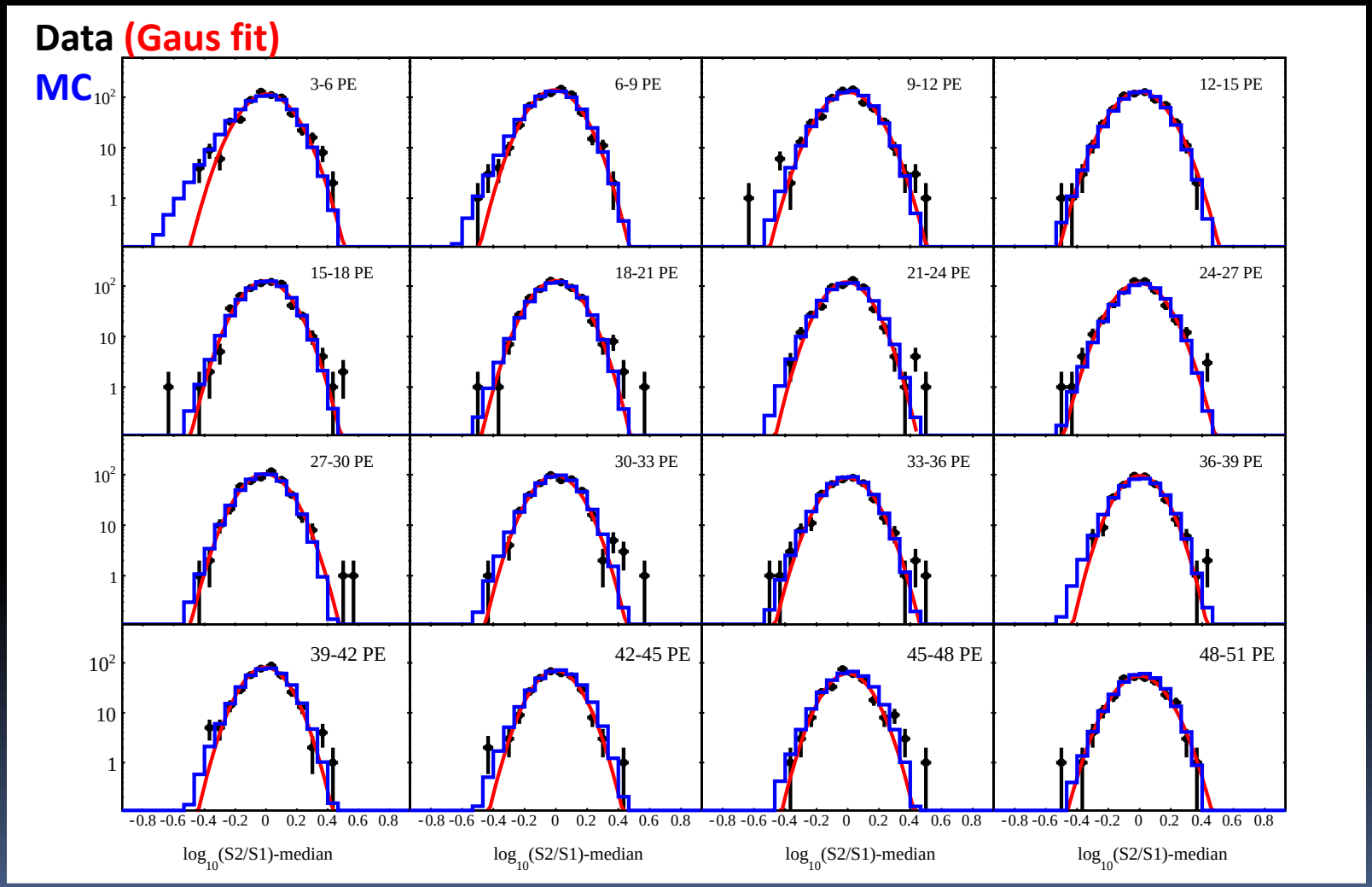


July – Oct, performed ER calibration using tritiated methane (a technique pioneered by LUX collaboration)



- 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

Comparison in different S1 slices



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!

Background budget table

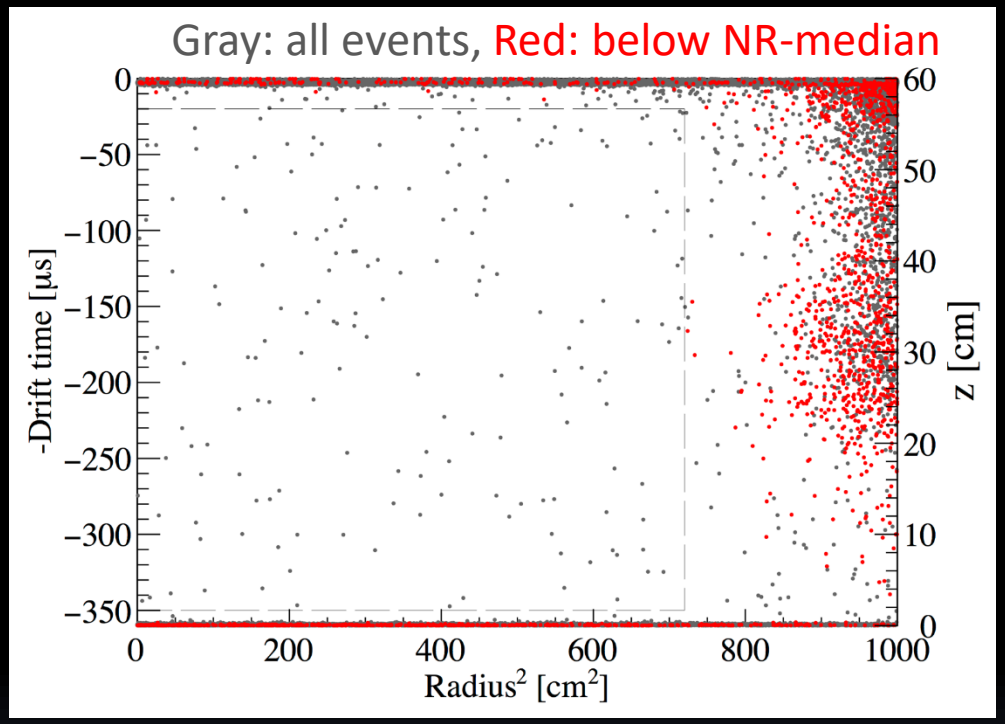
	Run9	Run10
Xe127	0.42	0.033
Tritium	0	0.22
Kr85	1.19	0.20
Rn222	0.13	0.10
Rn220	0.01	0.02
Detector ER	0.20	0.21
Solar neutrino	0.01	0.01
Xe136	0.0022	0.0023
Total	1.95	0.79

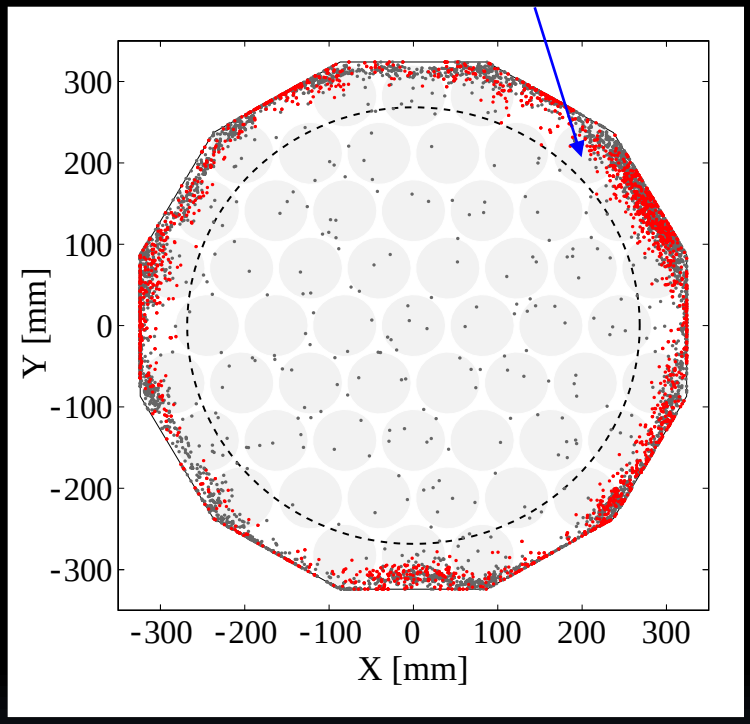
Original ^{127}Xe gone, additional introduced by a bottle of surface xenon during distillation

Based on best fit to data (later)

Rest are consistent between Run 9 and Run 10

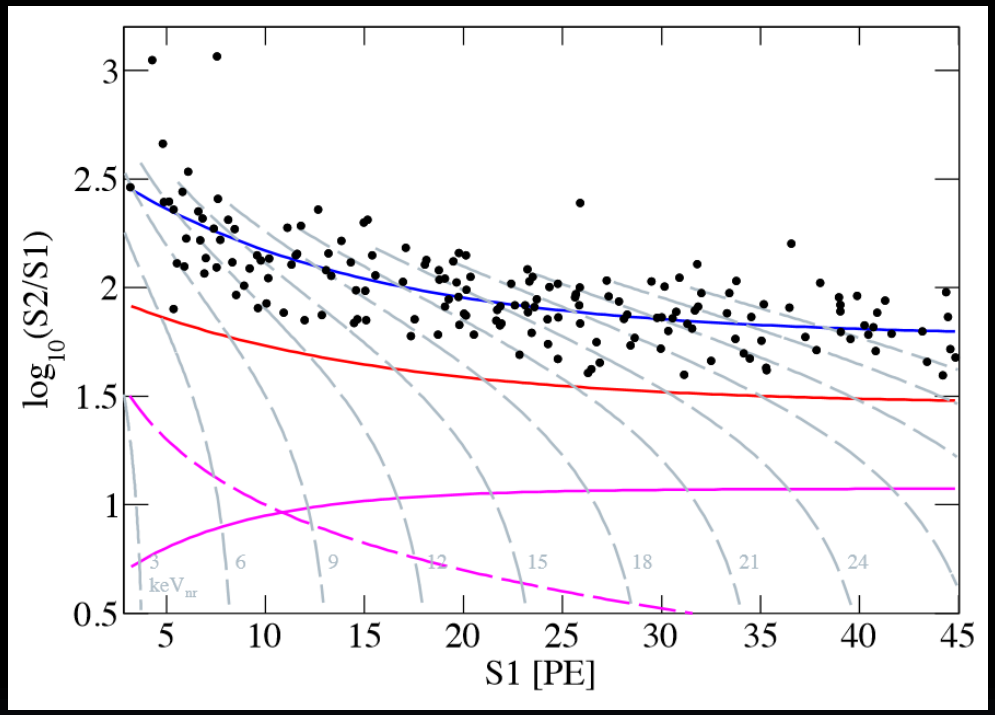
Vertex distribution





- Events @ large radius with suppressed S2: electron loss on the wall due to field irregularity.
- One noisy outer PMT caused biased reconstructed position, particularly for suppressed S2 (deeper in the TPC).
- Residual events are uniformly distributed in the detector

Distribution of events (run10)



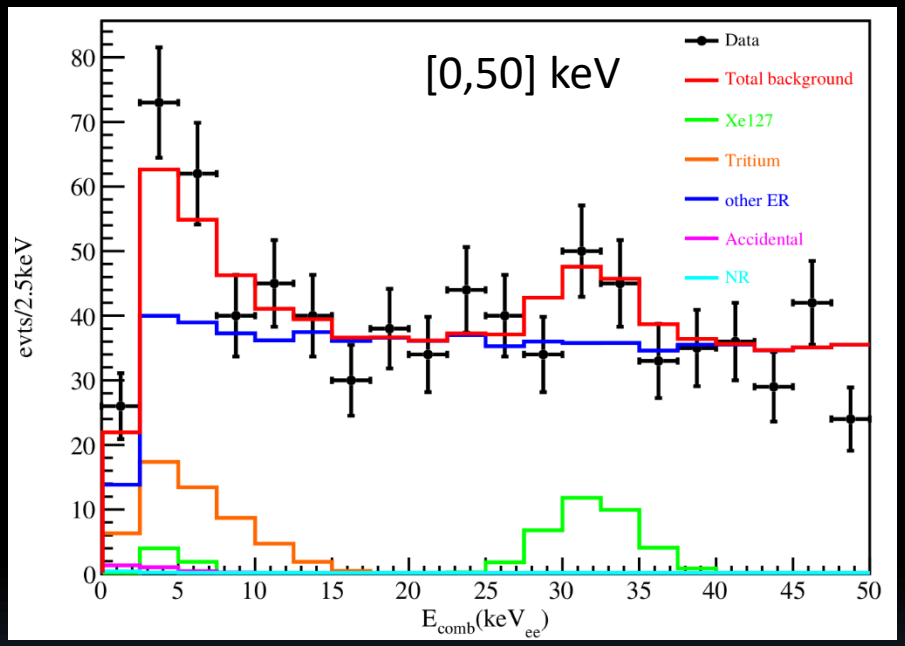
All high level cuts remained identical in Run9 and Run10 except the vertical drift time cut (400 V/cm to 310 V/cm)
FV = 361.5 kg of LXe

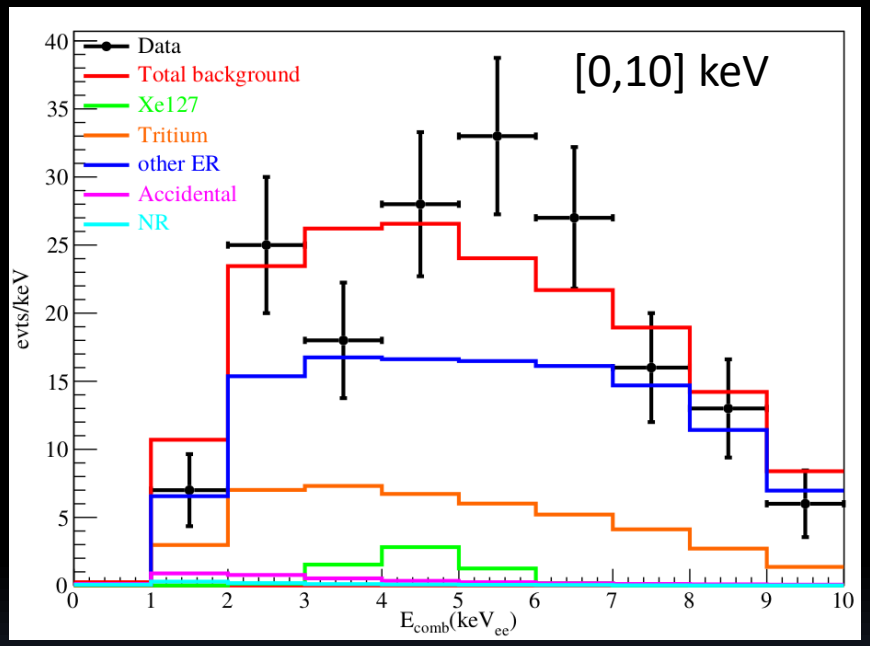
Total events: 177

- Expected background below NR median: 2.05 evts with ~20% uncertainty
- Observed: 0

Appears to have a downward fluctuation of background

E_{comb} spectrum

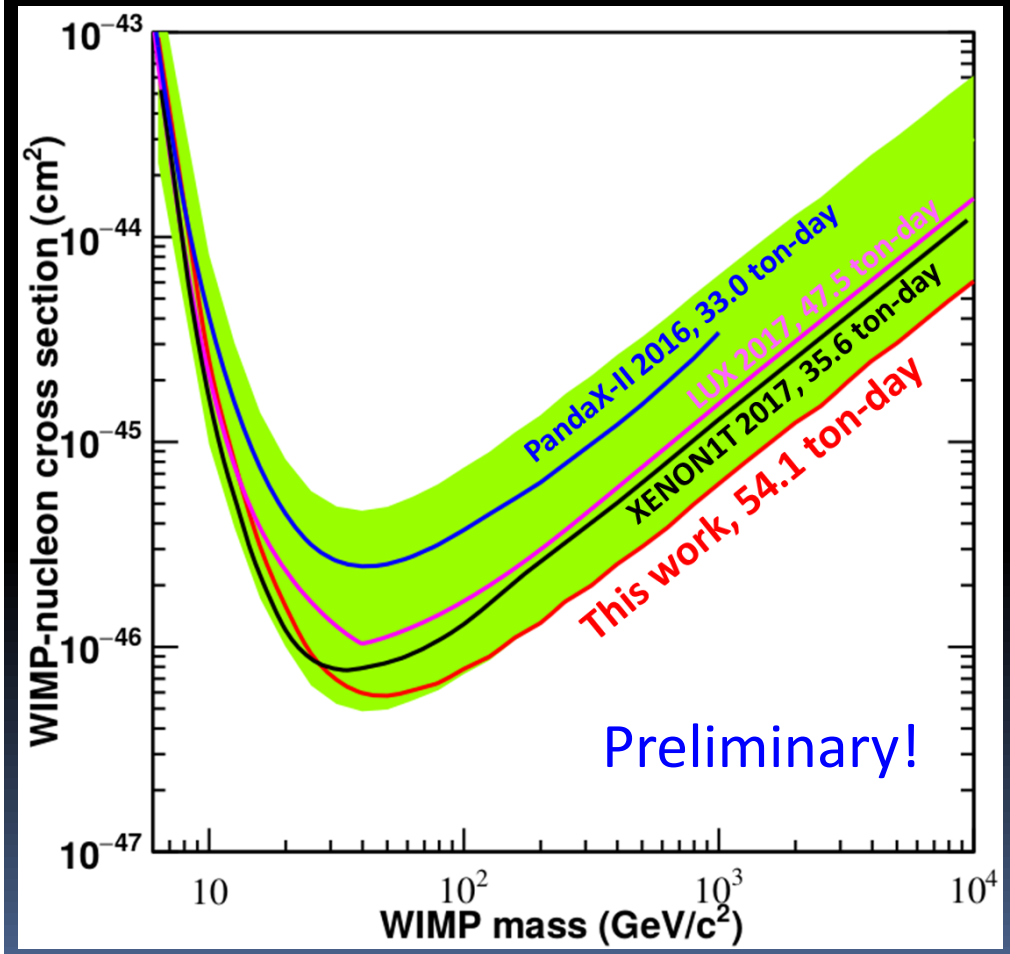




- MC: expected background spectra fixed to low energy best fit
- Data and expected background in good agreement

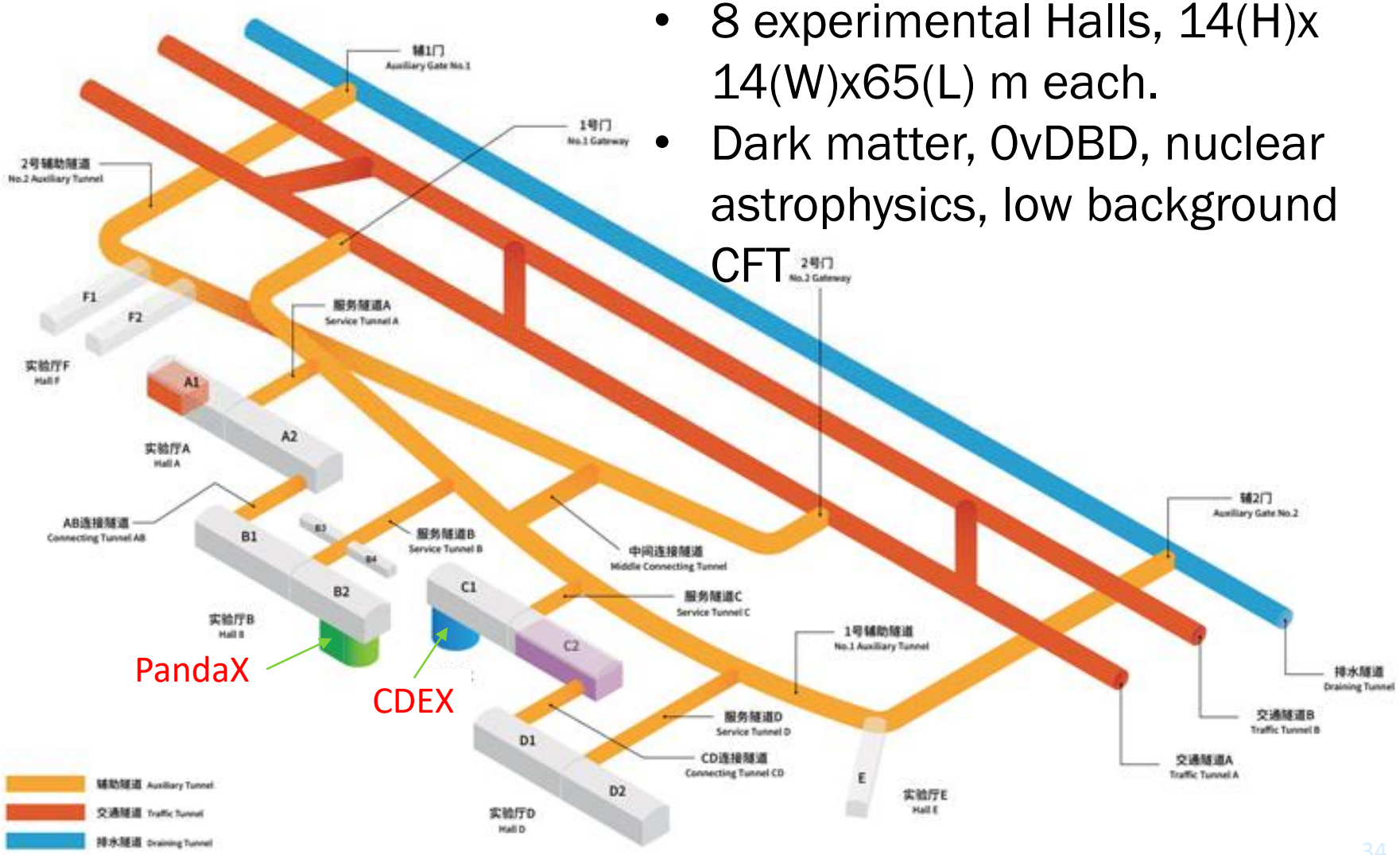
Results on elastic SI DM-nucleon scattering

Combination of Run 9 and Run 10, 54.1 ton-day



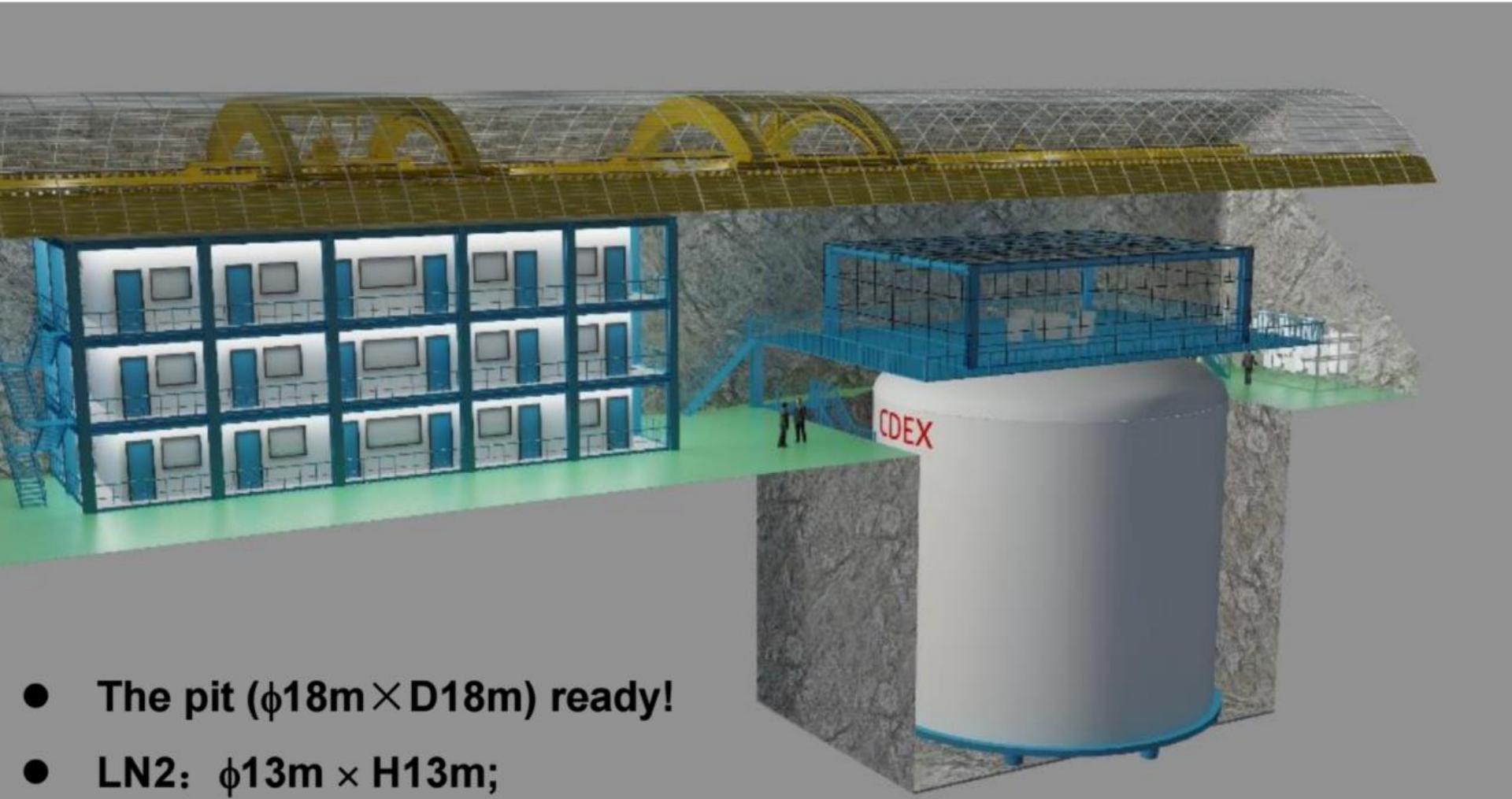
- Profile likelihood fits made to the data in grids of (m_χ, σ_χ).
- 90% upper limits produced by comparison of test statistic to toy MC, and power-constrained to -1σ, but conservatively power-constrained to -1σ
- Improved from PandaX-II 2016 limit about 4 time for mass>30 GeV.
- More constraining than LUX and XENON1T 2017

CJPL-II



- 8 experimental Halls, 14(H)x 14(W)x65(L) m each.
- Dark matter, 0vDBD, nuclear astrophysics, low background CFT

CDEX Space at CJPL-II



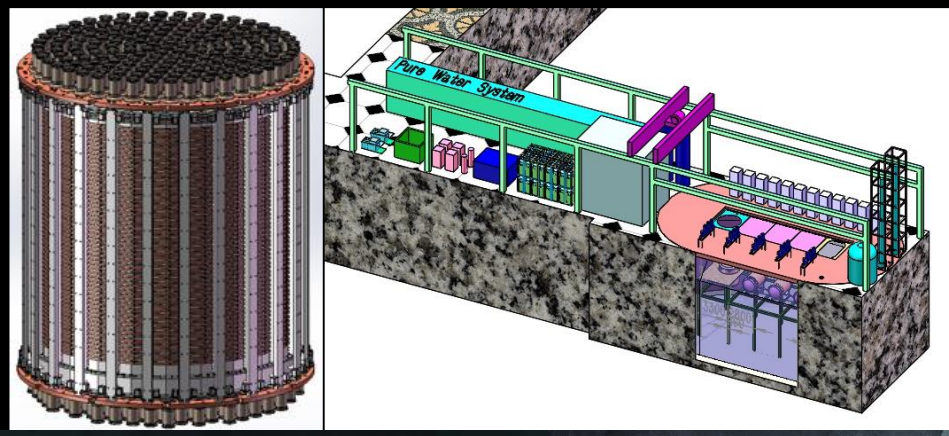
- The pit (ϕ18m×D18m) ready!
- LN2：ϕ13m × H13m;
- LN2 tank design finished and plan to install in 2017.

CJPL

CDEX Space at CJPL-II

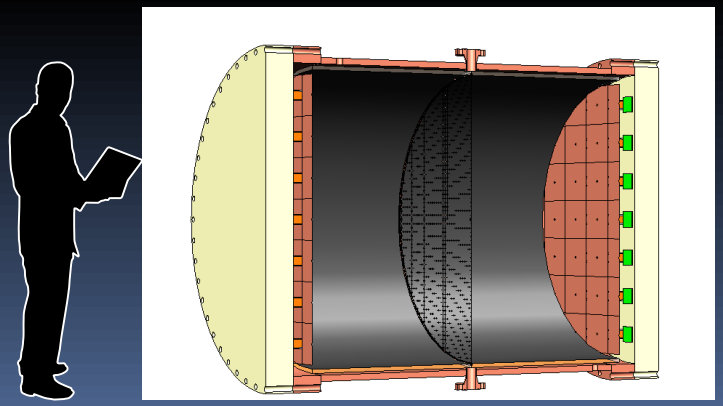
PandaX-xT

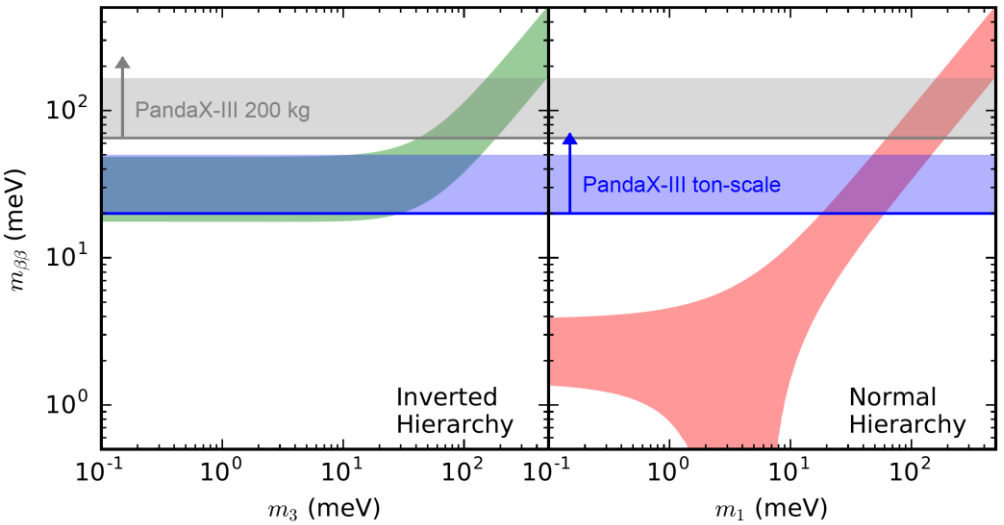
- Preparing new experiments in CJPL-II, hall #B2
- Intermediate stage:
  - PandaX-4T (4-ton target) with SI sensitivity ~10^{-47} cm^2
  - On-site assembly and commissioning: 2019-2020
- Eventual goal: G3 xenon dark matter detector (~30T) in CJPL to “neutrino floor” sensitivity



PandaX-III: High pressure ^{136}Xe TPC

- 0νDBD signal: two electrons emitting from the same vertex with a summed energy at the Q value (tracking essential)
- TPC: 200 kg, 10 atm, symmetric, double-ended charge readout plane with micromegas module with cathode in the middle
- Four more upgraded modules for a ton scale experiment
- Published CDR recently: ArXiv:1610.08883





Summary and outlook

- CJPL-I has produced excellent science on DM direct search (CDEX, PandaX)
  - PandaX-II reached and remains at the forefront of the DM search
- Exciting upgrade plans and future opportunities at CJPL-II
- A bright future ahead!