



Dark Matter Search with Liquid Xenon at Jinping

from PandaX-I to PandaX-II

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2015.4.9 Sino-French PPL, Hefei

PandaX dark matter search program

- ❖ **2009.3 SJTU group visited Jinping for the first time**
- ❖ **2009.4 Proposals submitted for dark matter search with liquid xenon at Jinping**
- ❖ **2010.1 PandaX collaboration formed, funding supported by SJTU/MOST/NSFC, started to develop the PandaX-I detector at SJTU**
- ❖ **2012.8 PandaX-I detector moved to CJPL**
- ❖ **2012.9-2013.9 Two engineering runs carried out for system integration**
- ❖ **2014.3 Detector fully functional for data taking**
- ❖ **2014.8 PandaX-I first results (17 days) published**
- ❖ **2014.11 Another 63 days dark matter data were collected**
- ❖ **2015 Upgrading from PandaX-I (125-kg) to PandaX-II (500-kg)**

PandaX Collaboration for Dark Matter Search



Shanghai Jiao Tong University
Shanghai Institute of Applied Physics, CAS
Shandong University
University of Maryland
University of Michigan
Peking University
Yalong River Hydropower Development Co.
China Institute of Atomic Energy (new group joined 2015)

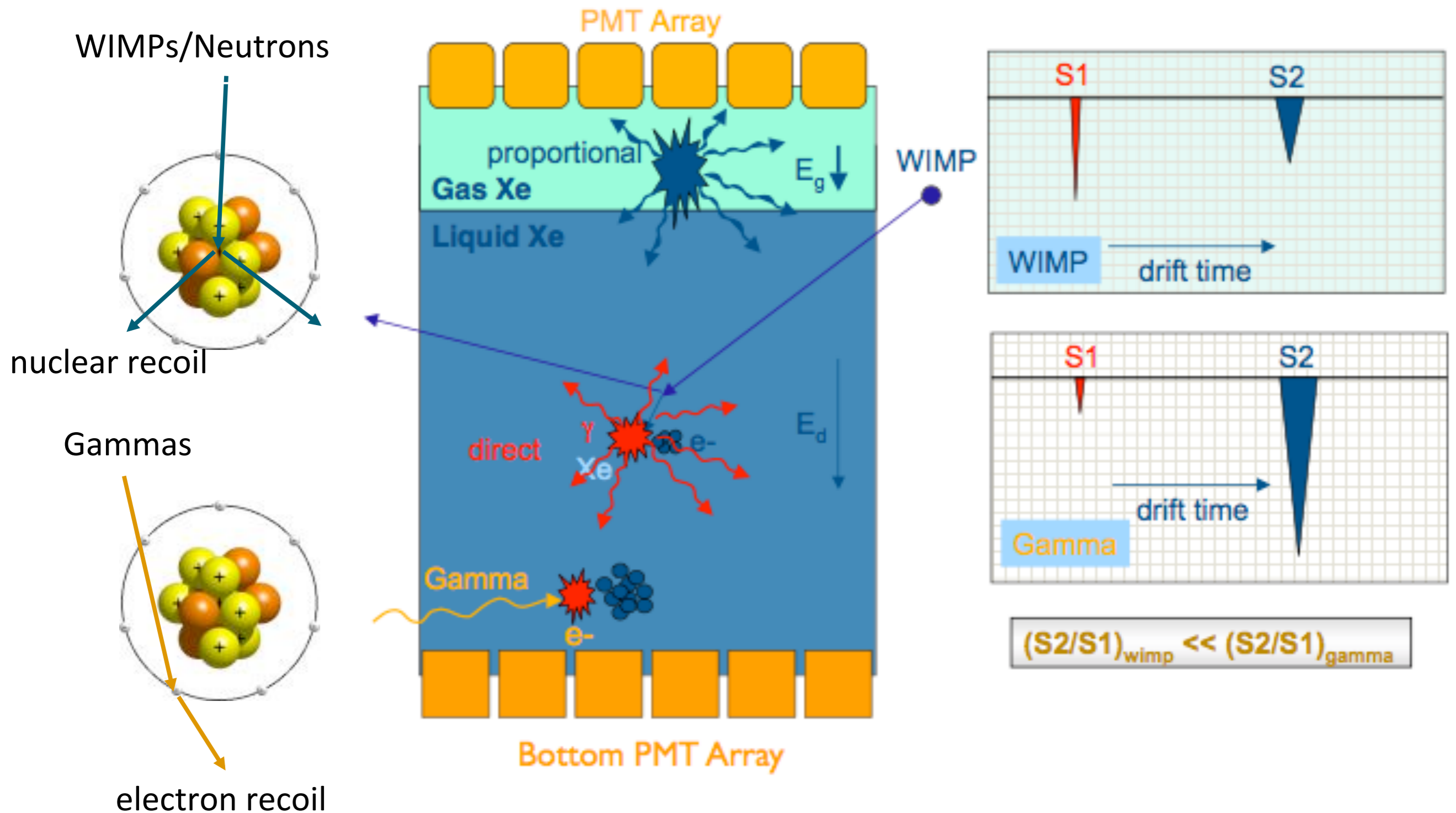


<http://pandax.org/>

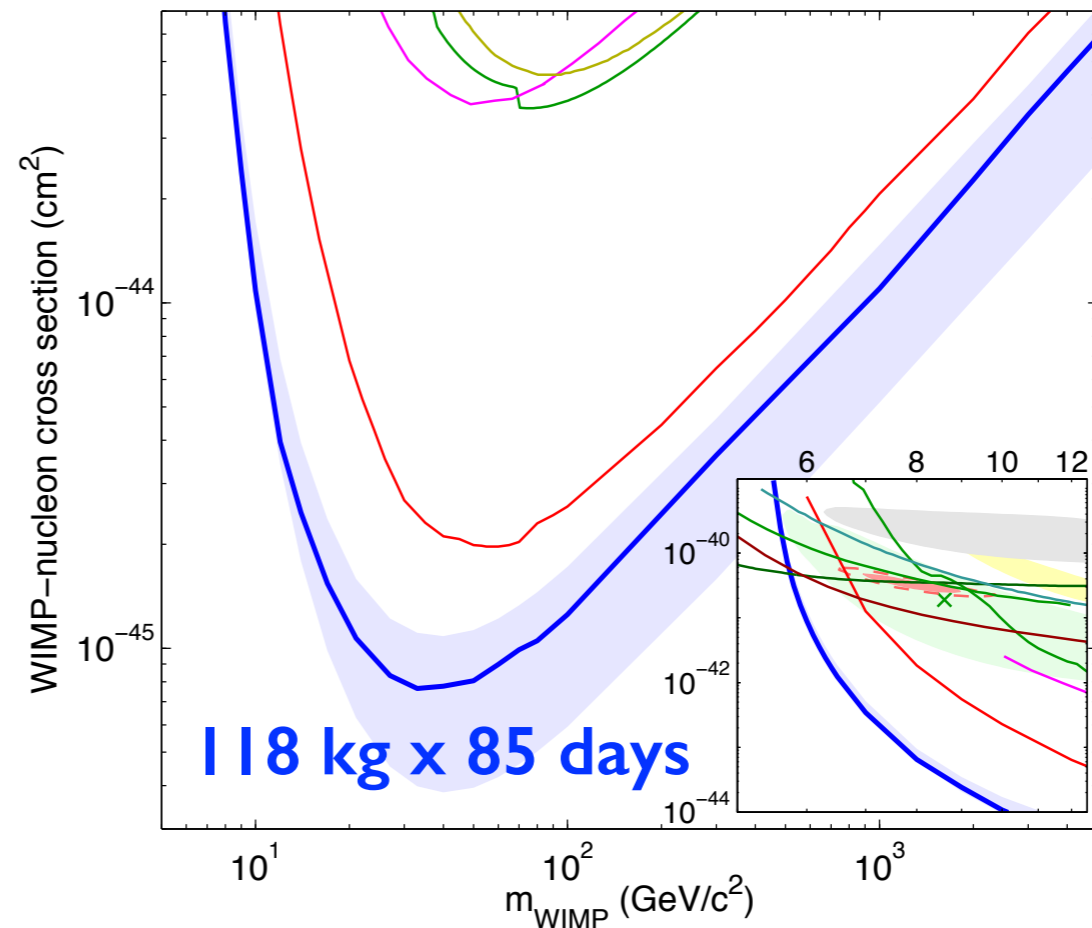
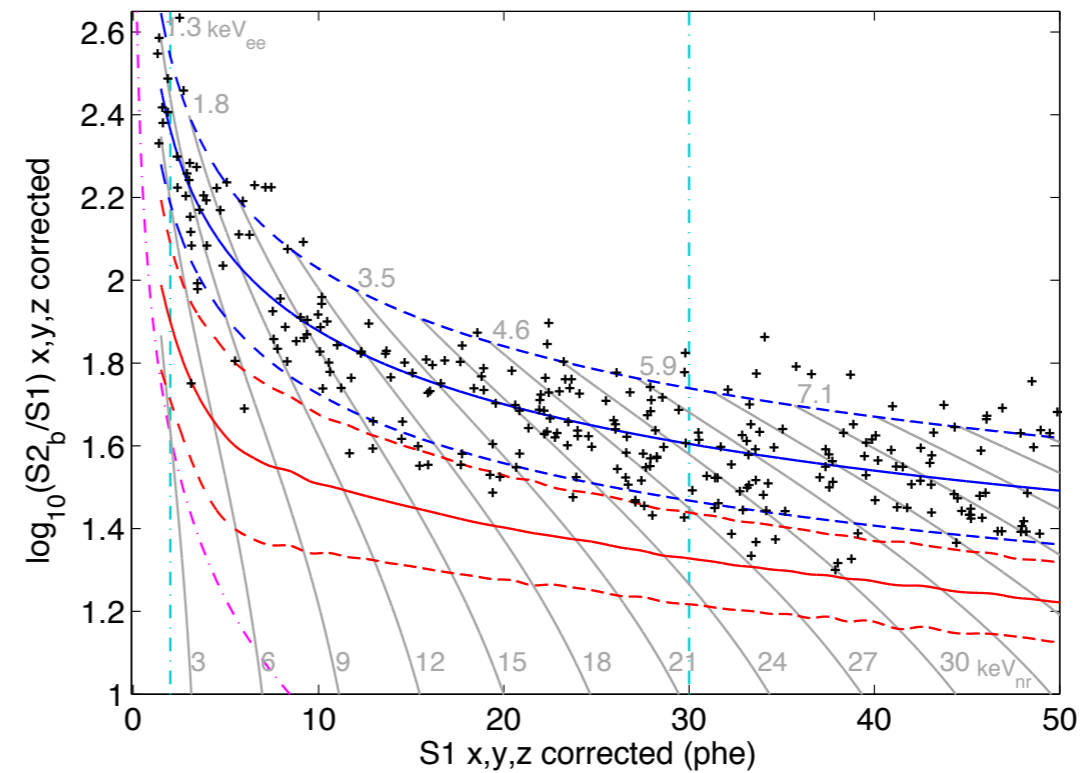
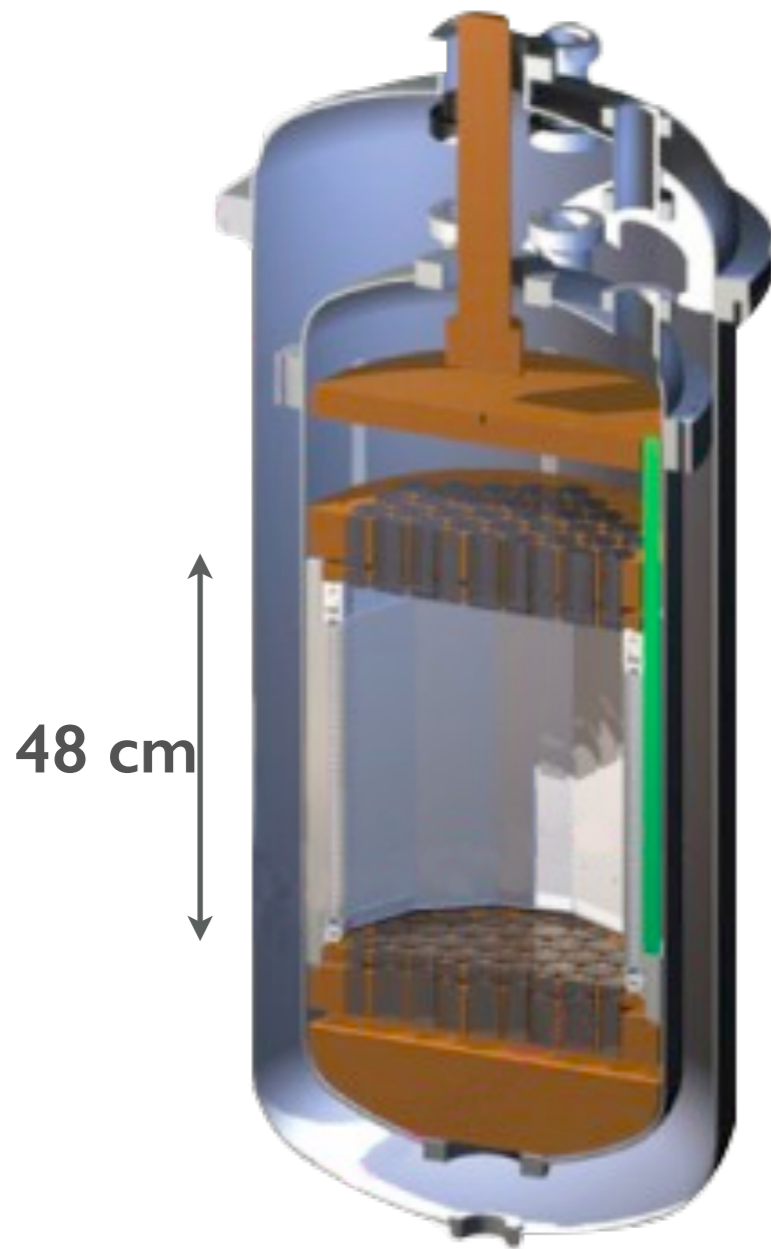
Why Liquid Xenon?

- **Ultra-low background:** using self-shielding with 3D fiducialization and ER/NR discrimination
- Sensitive to both **heavy** and **light** dark matter
- Sensitive to both **Spin-independent** and **Spin-dependent** (^{129}Xe , ^{131}Xe)
- **Ultra-pure Xe target:** xenon gas can be purified with sub-ppb (O_2 etc.) and sub-ppt (Kr) impurities
- **Multi-ton target achievable:** with reasonable cost (\$1.5M/ton) and relative simple cryogenics (165K)

Two-phase xenon for dark matter searches



So far **the most sensitive** dark matter direct detection is from LUX with **the two-phase xenon** technology.



The evolution of **two-phase xenon** detectors for dark matter

2001-2007

2008-2014

2015-2022

2001 2002 2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015 2016 2017 2018 2019 2020 2021 2022

ZEPLIN-II, 31-kg, finished, $6.6e-43$ cm²

ZEPLIN-III, finished, $3.9e-44$ cm²

XENON10, 15-kg, finished, $4.5e-44$ cm²

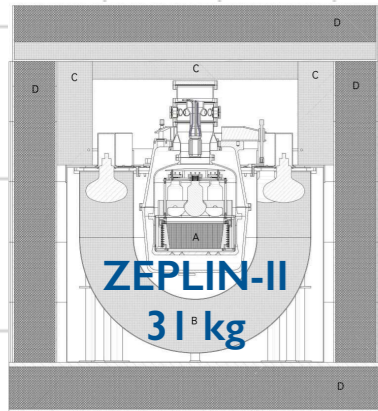
XENON100
62 kg

PandaX-II
500-kg

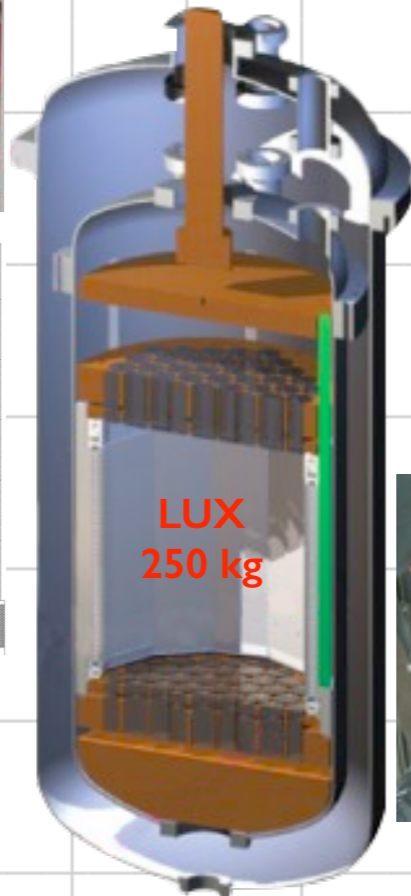
XENONIT/nT
3 Ton/7 Ton



XENON10
15 kg



ZEPLIN-II
31^B kg



LUX
250 kg

XENON100, 62-kg, operation, $2e-45$ cm²

LUX, 250-kg, operation, $7.6e-46$ cm²

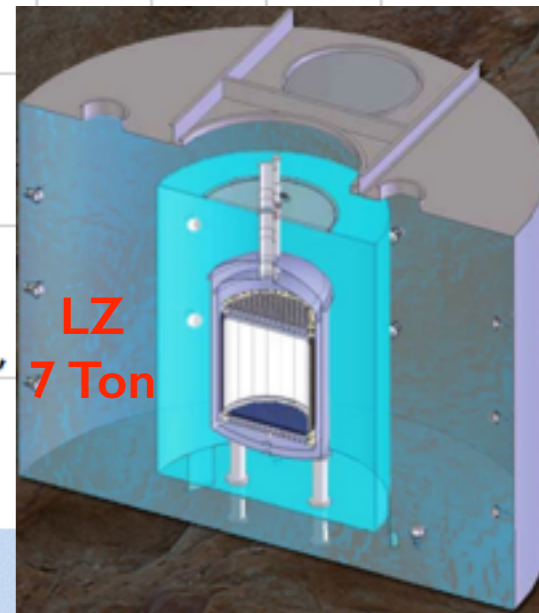
PandaX-I, 125-kg, operation, $3.7e-44$ cm²



PandaX-I
125 kg

PandaX-II, 500-kg, construction,

XENONIT, 3 ton, construction, $1e-47$ cm²



LZ
7 Ton

XENONnT, 7 ton, proposed, $1e-48$ cm²



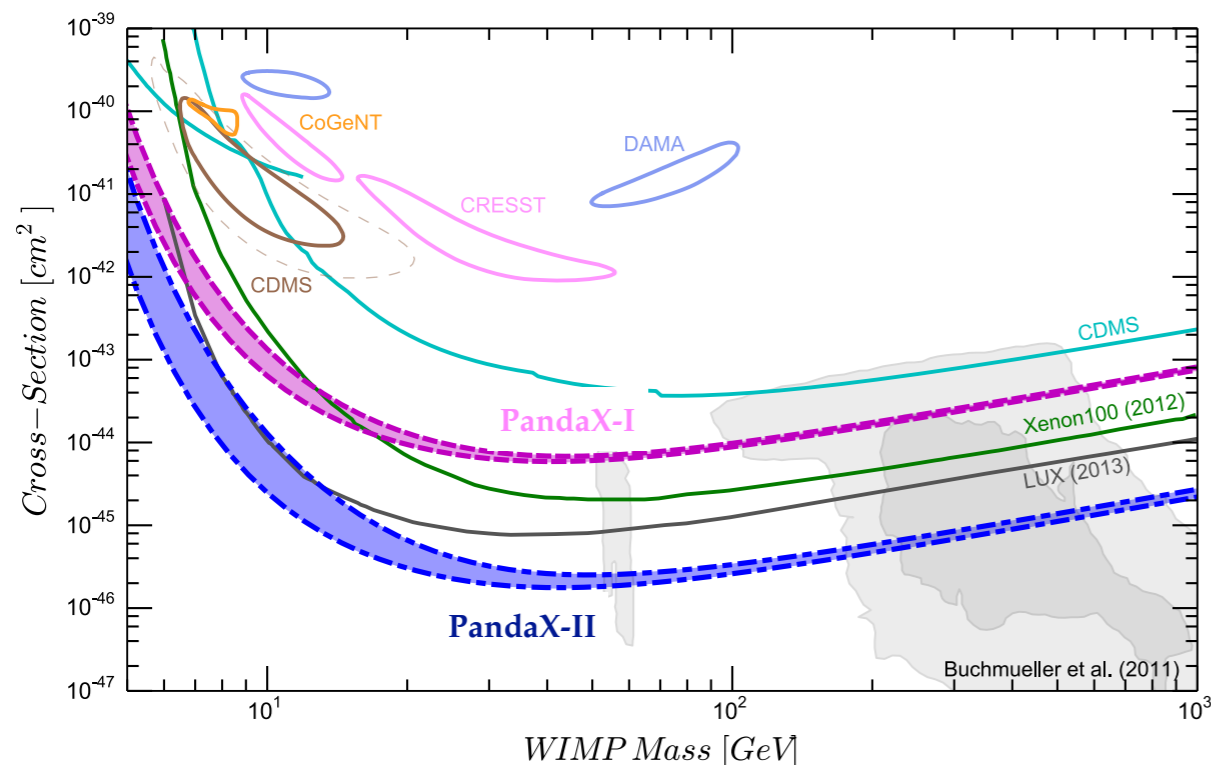
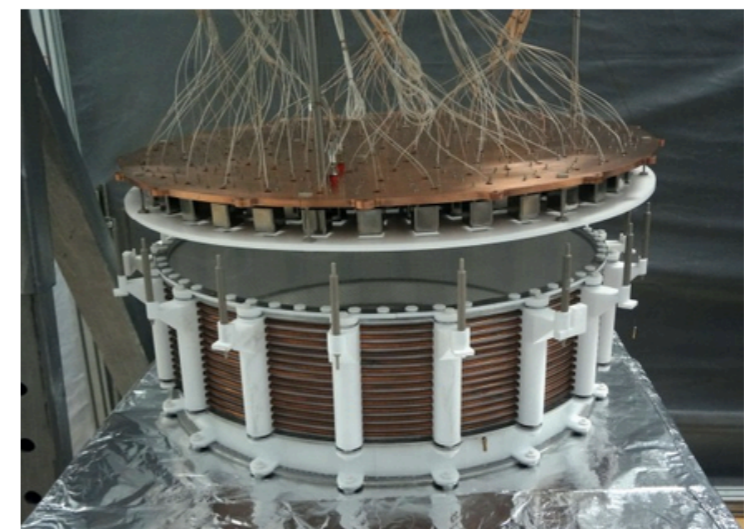
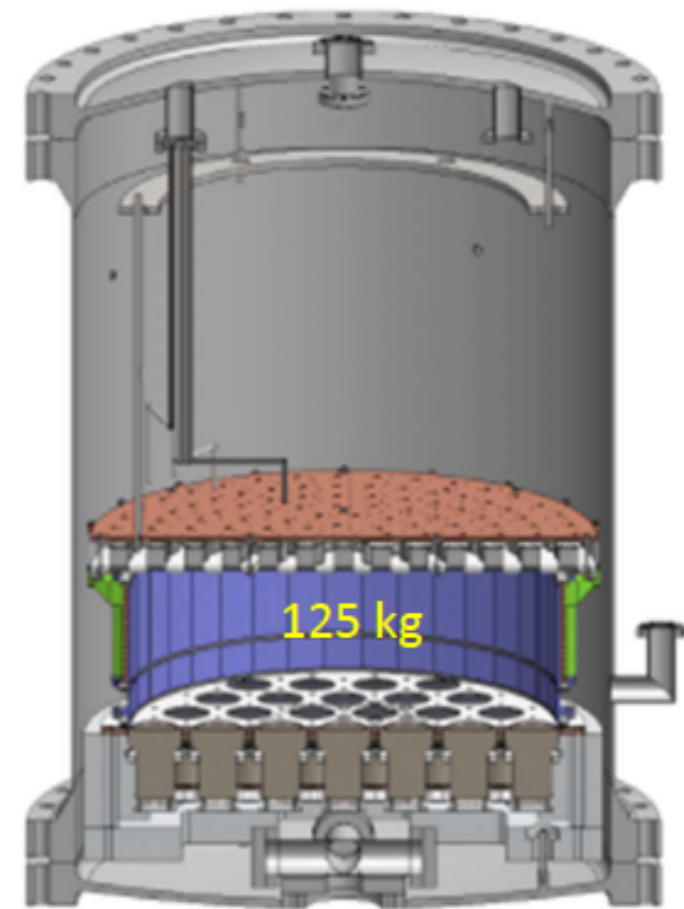
ZEPLIN-III

LZ, 7-ton, approved, $1e-48$ cm²

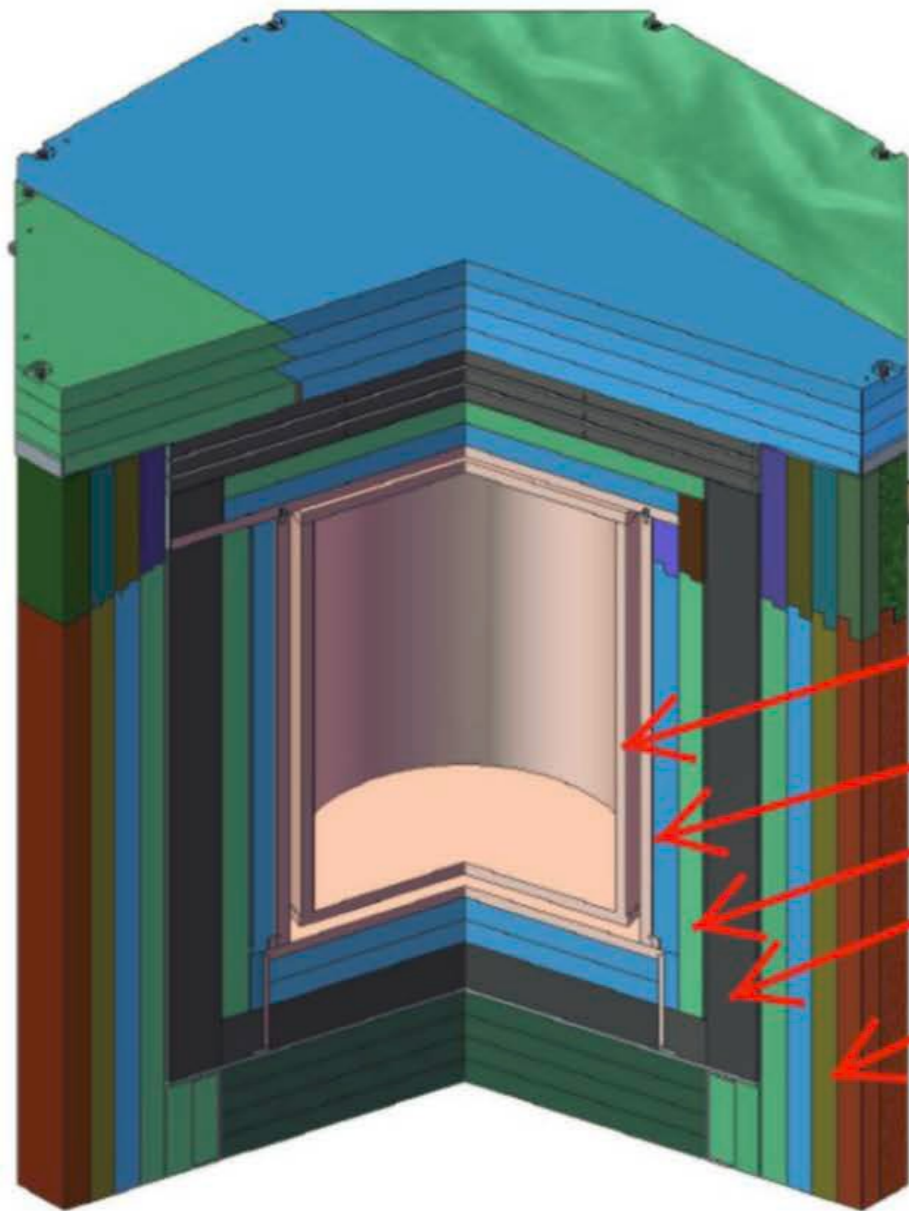
detector sizes not to scale

PandaX-I (2010-2014) Goals

- ☑ Search for (or exclude) **Light Dark Matter** as reported by DAMA, CoGeNT etc.
- ☑ Build the infrastructures (shielding, cryogenics, DAQ, analysis etc.) at CJPL-I for **ton-scale Liquid Xe** dark matter experiment to be competitive at all WIMP masses
- ☑ Develop **low background** techniques for the next generation experiments (DM & DBD)



PandaX Shielding: developed to accommodate **up to a 3 ton** liquid xenon dark matter detector



Vacuum Vessel

inner diameter 1240mm

inner height 1750mm

50mm Cu Vessel

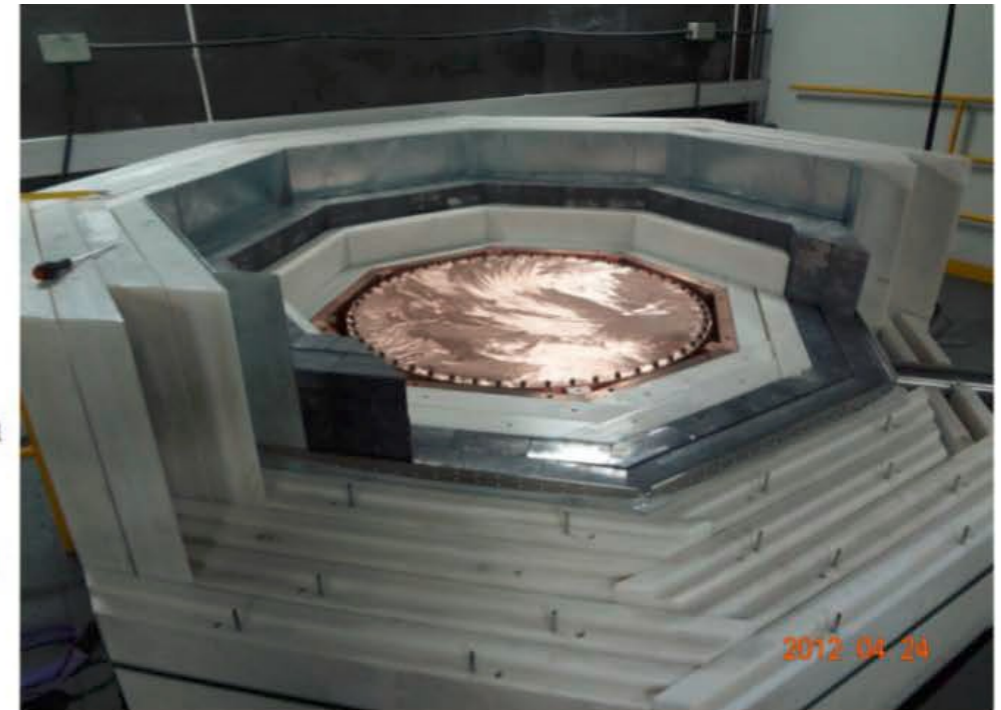
50mm Cu

200mm inner PE

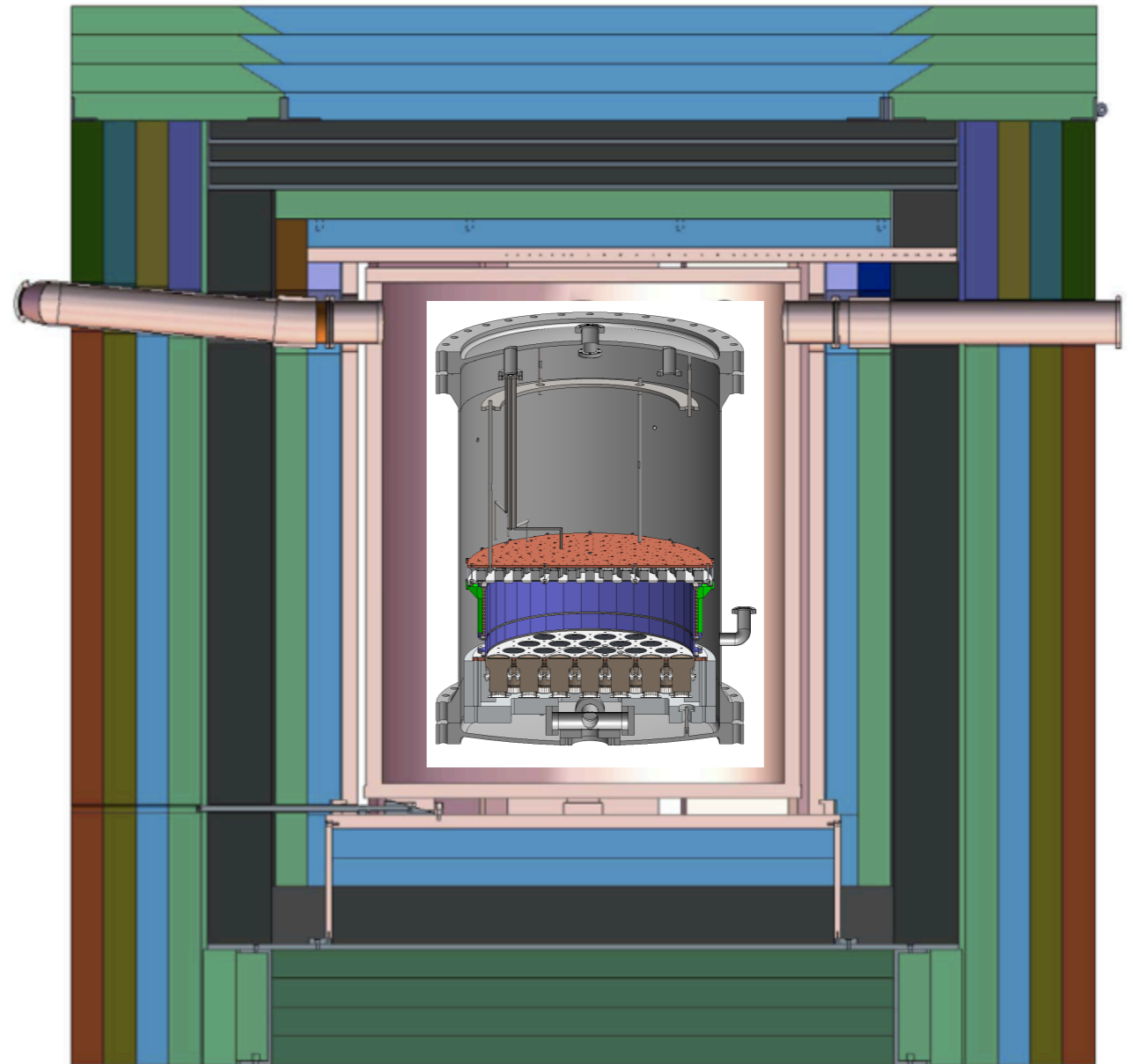
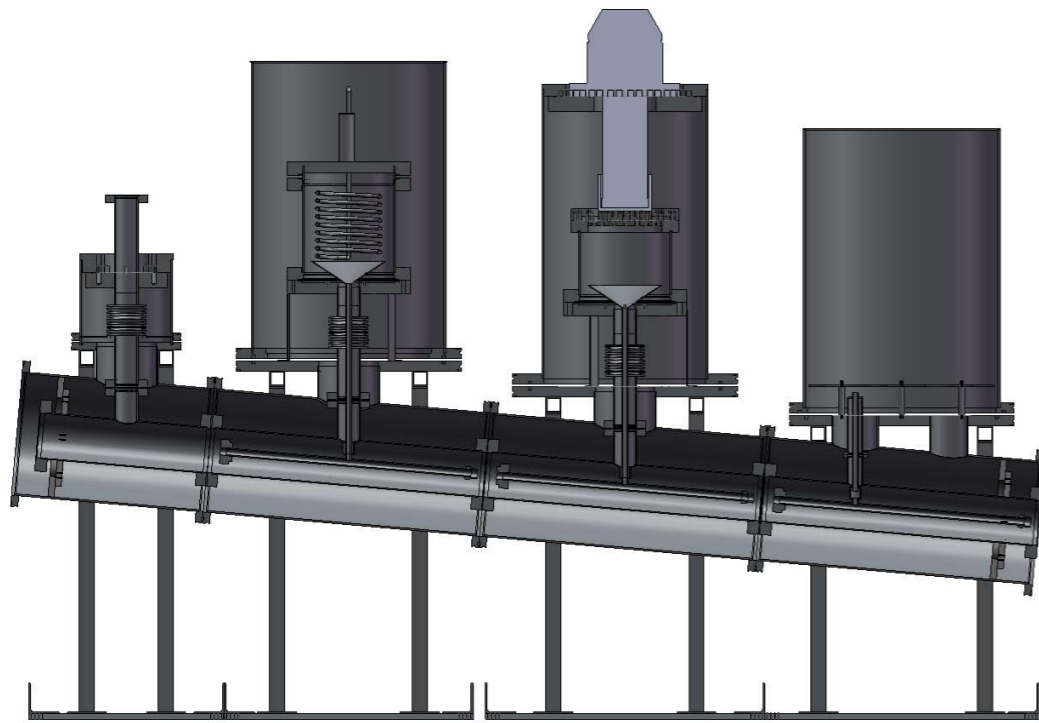
200mm Pb

400mm outer PE

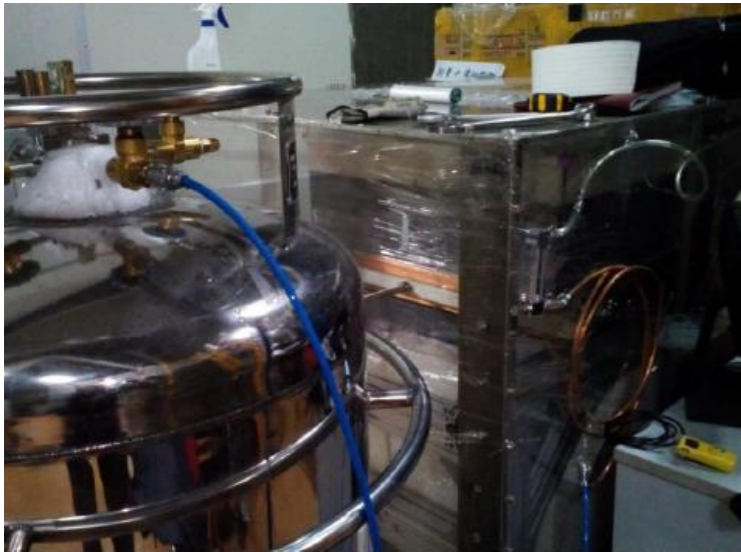
~3 m



PandaX Cryogenics and Gas Purification system: developed for ton-scale and tested with **one ton LXe and 30 L/min** circulation speed



PandaX Low Background techniques: developed with sensitivity down to mBq/kg (material) and ppt (Kr/Xe)



PandaX Germanium counting station at CJPL



Customized low background stainless steel production

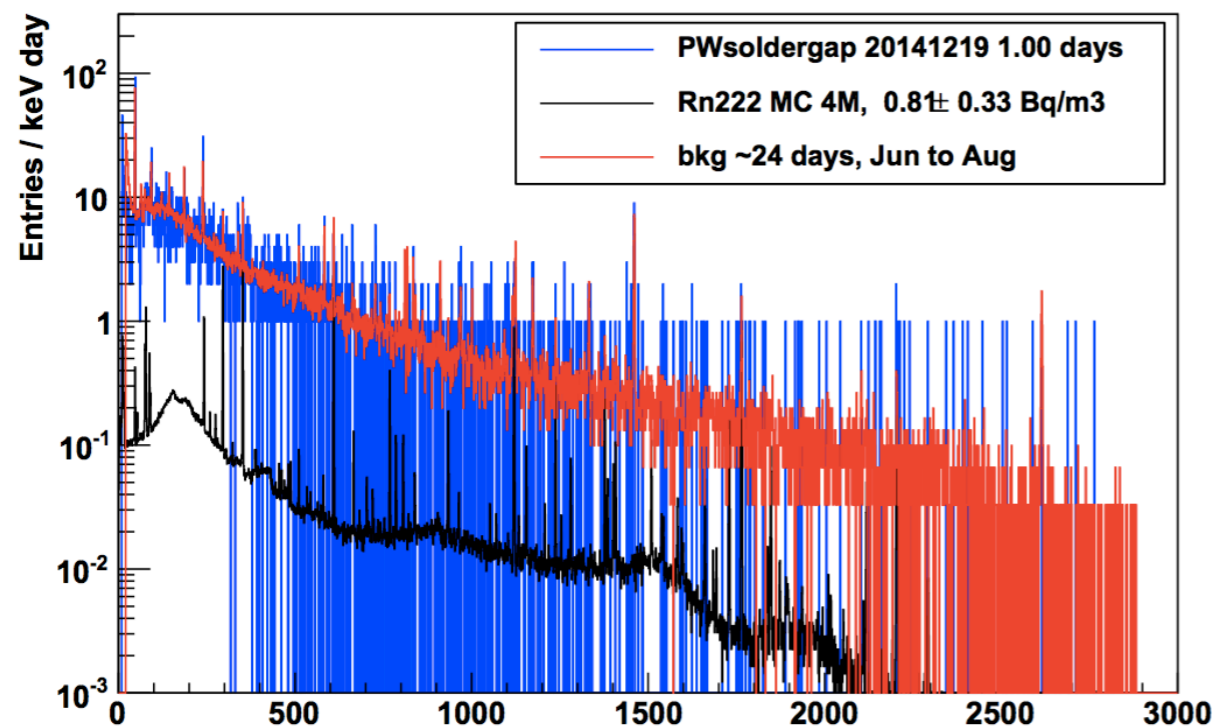


Krypton removal system (from ppb to ppt Kr/Xe)

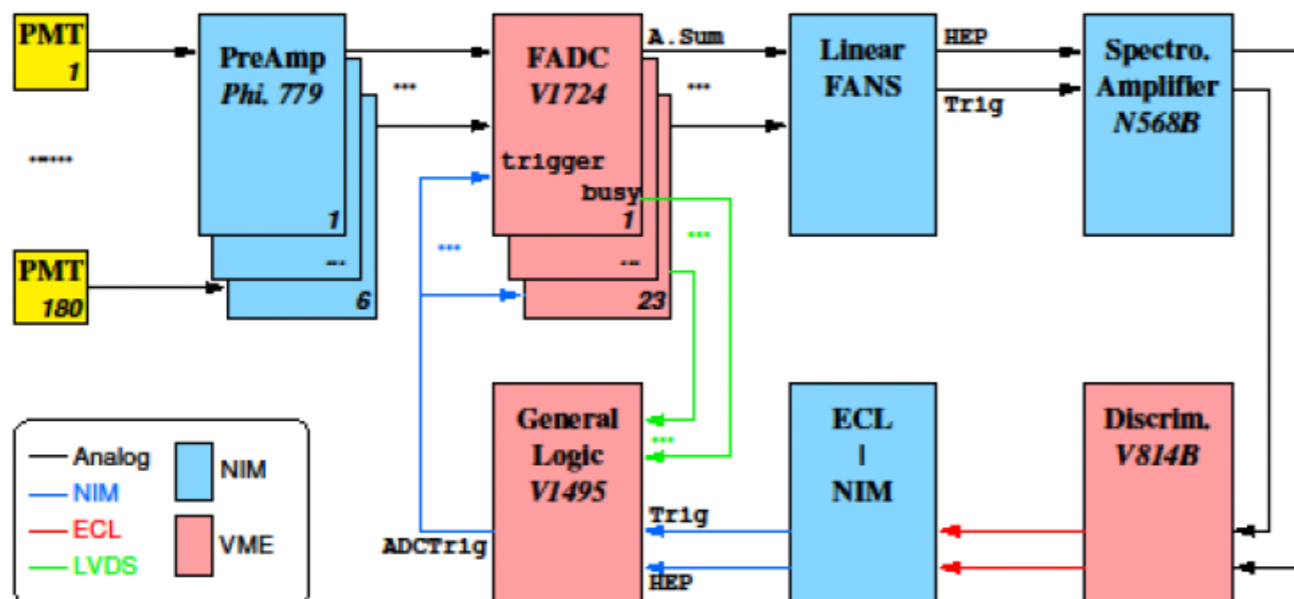
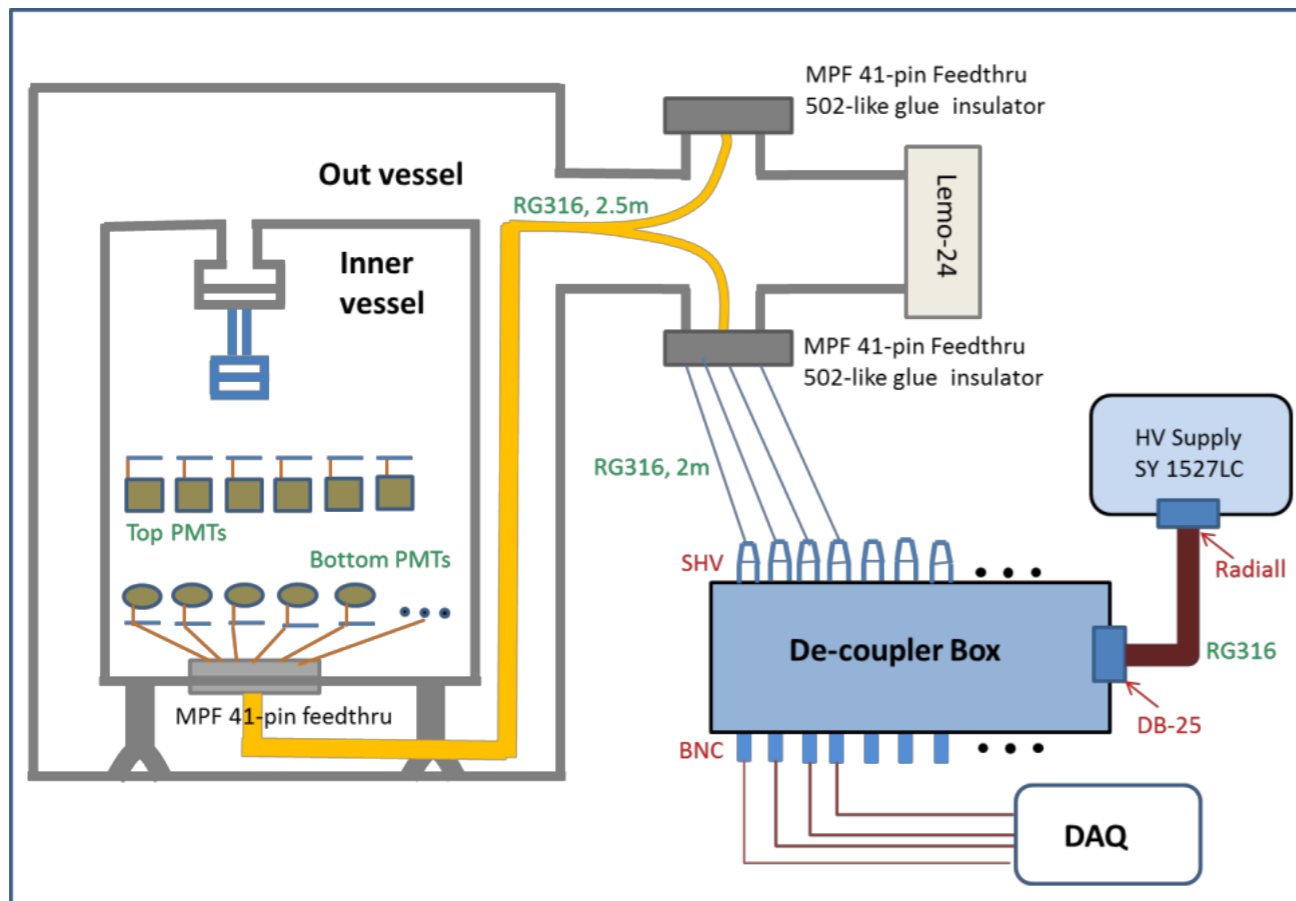


a cold-trap system to measure Kr/Xe down to ppt level

20141219

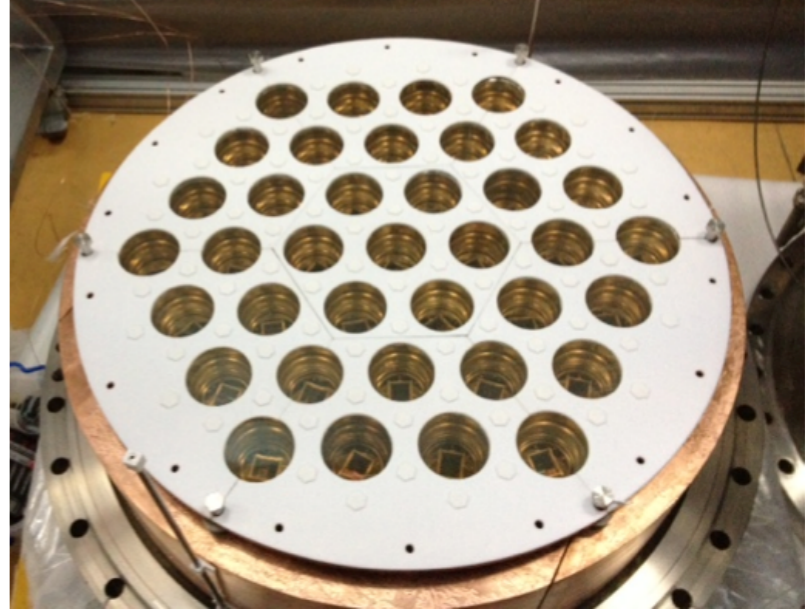
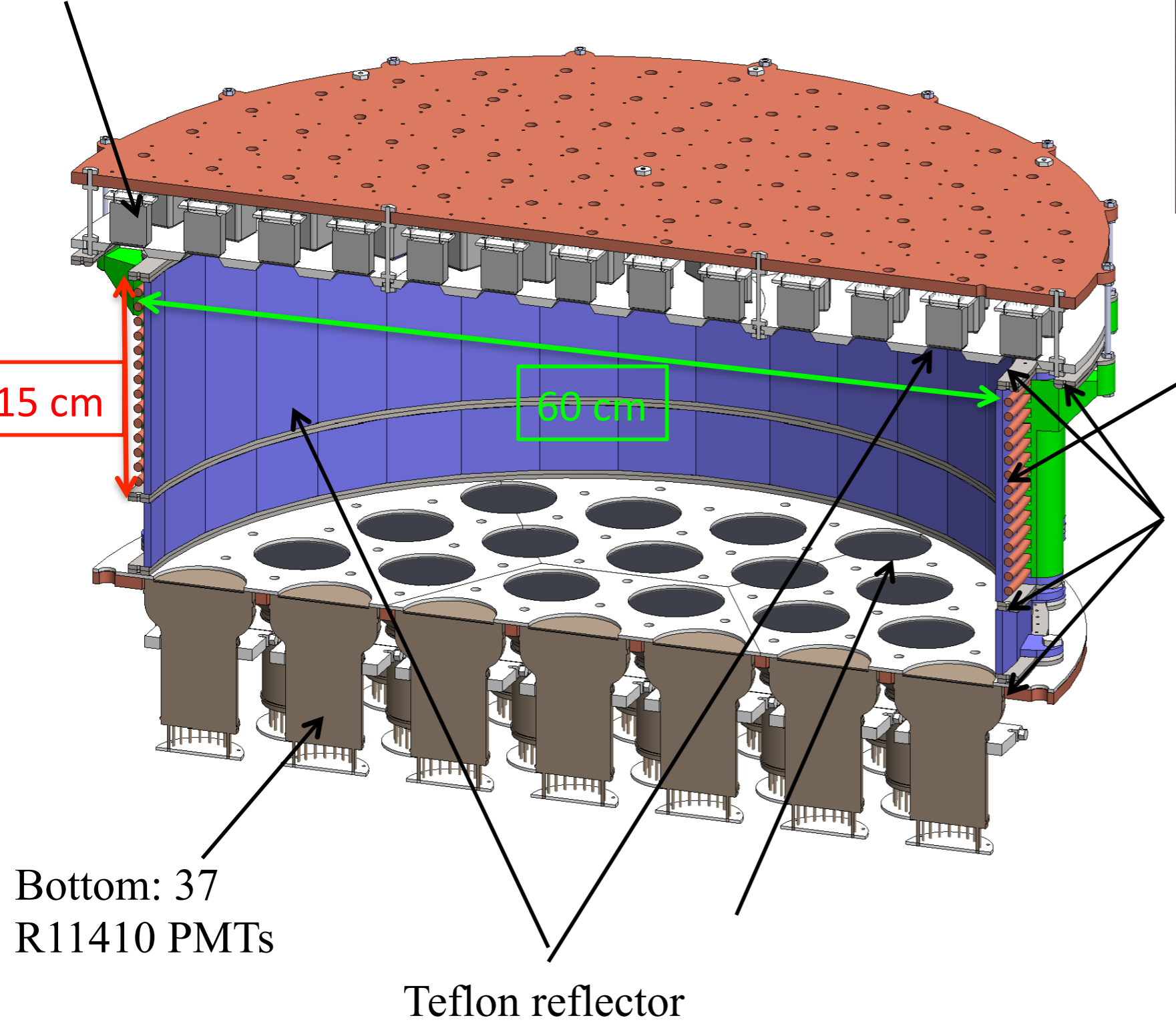


PandaX DAQ and Electronics: techniques developed for ~180 channels of full PMT waveforms and low-threshold trigger

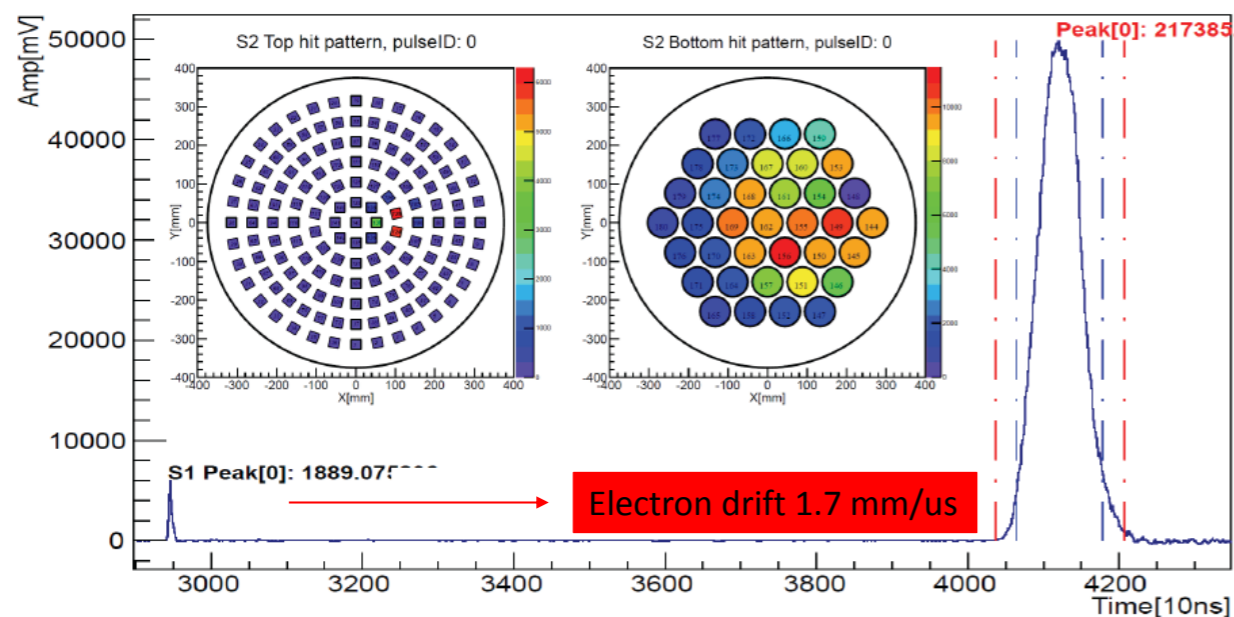


PandaX-I TPC: first time to operate large number of R11410 in LXe, demonstrated high light yield

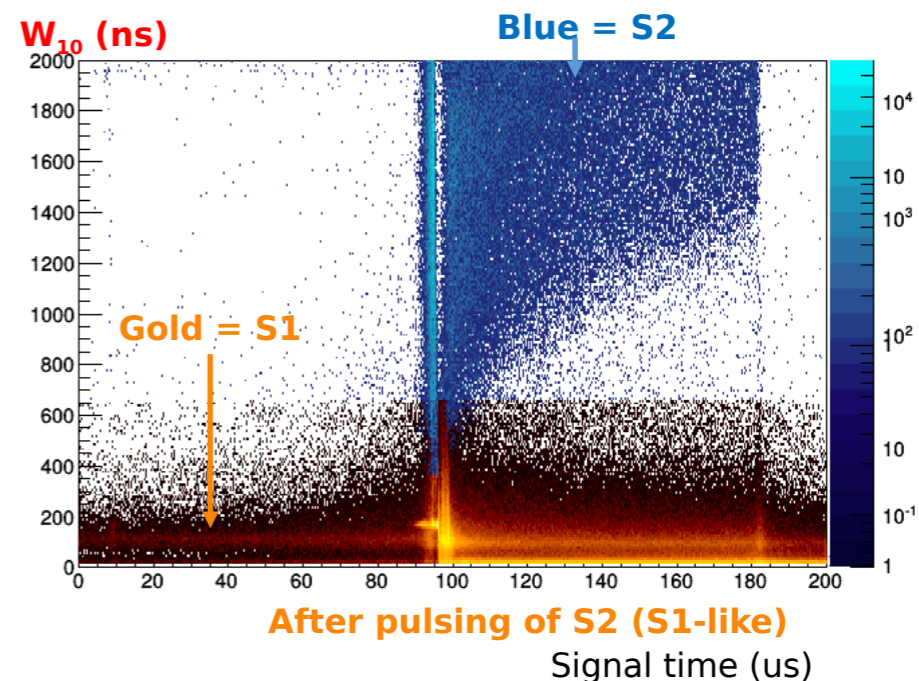
Top: 143
R8520 PMTs



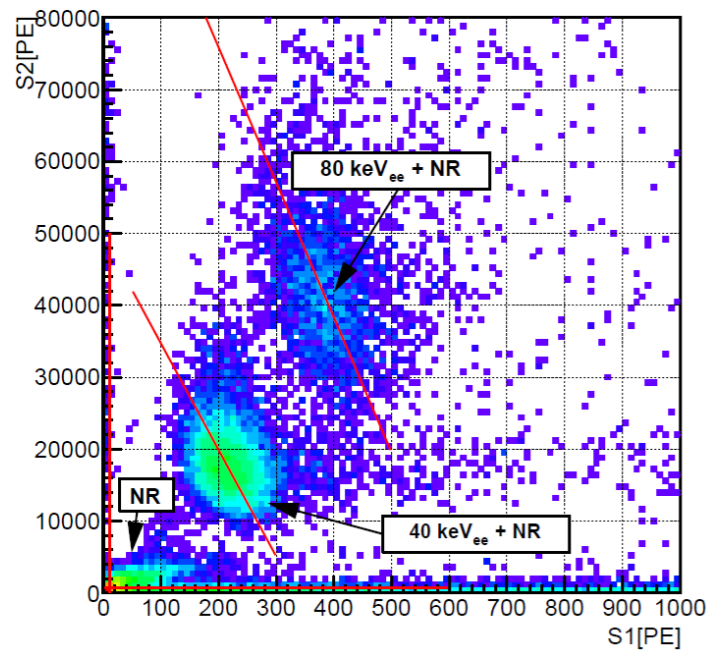
PandaX-I analysis: two full analysis chains developed independently for cross-checking, ready for PandaX-II



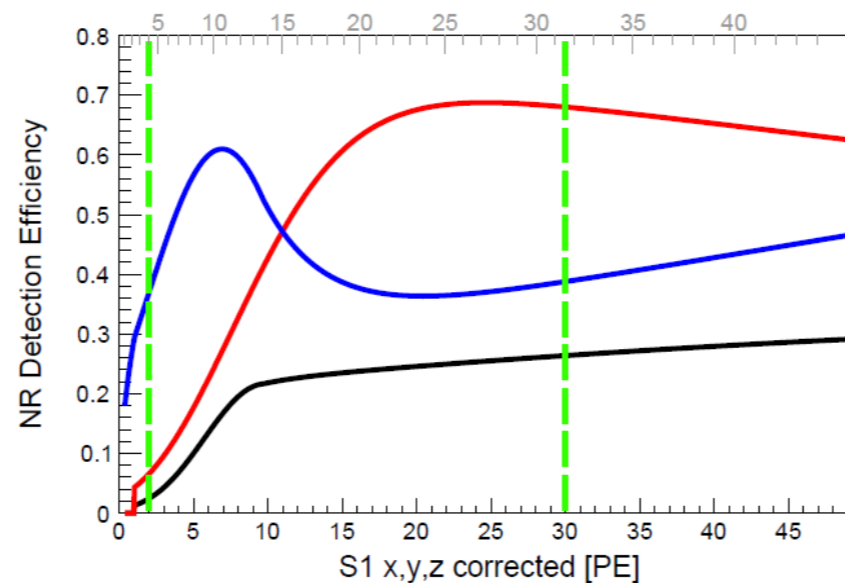
pulse-peak finding
3D position reconstruction



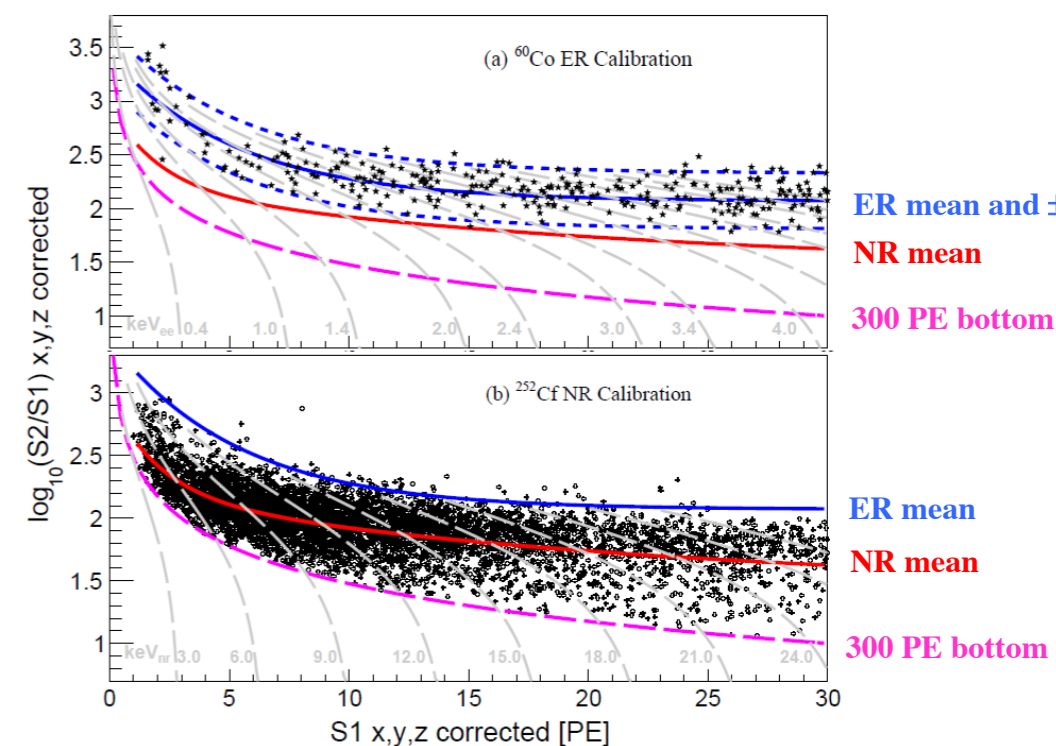
After pulsing of S2 (S1-like)
signal identification



energy calibration

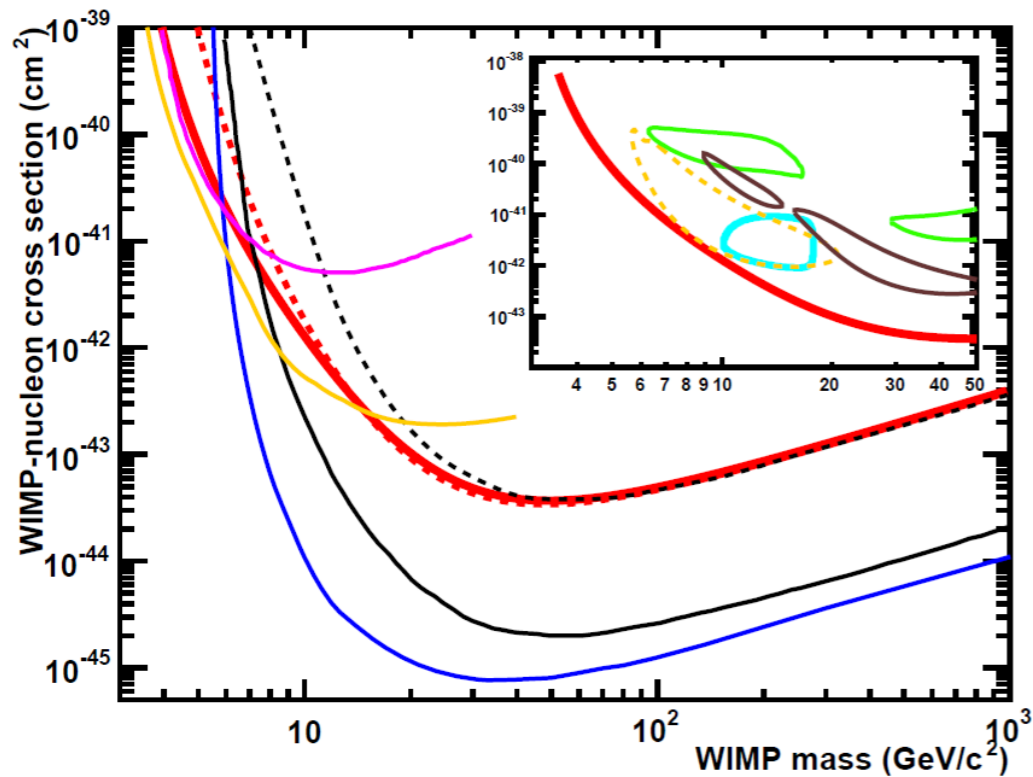
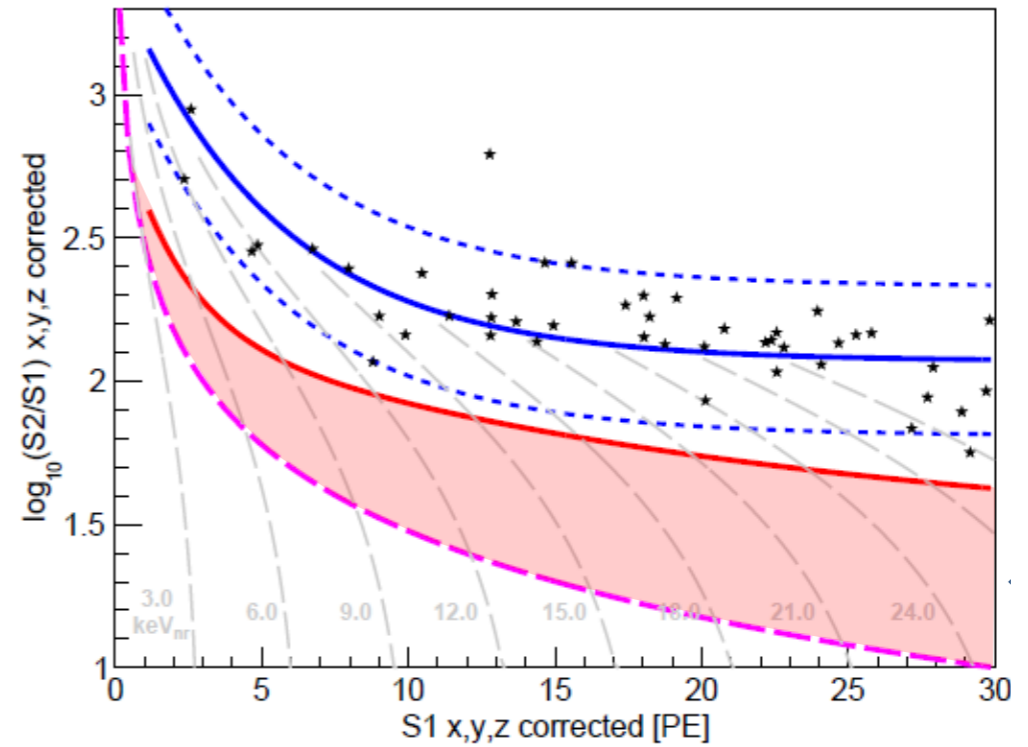
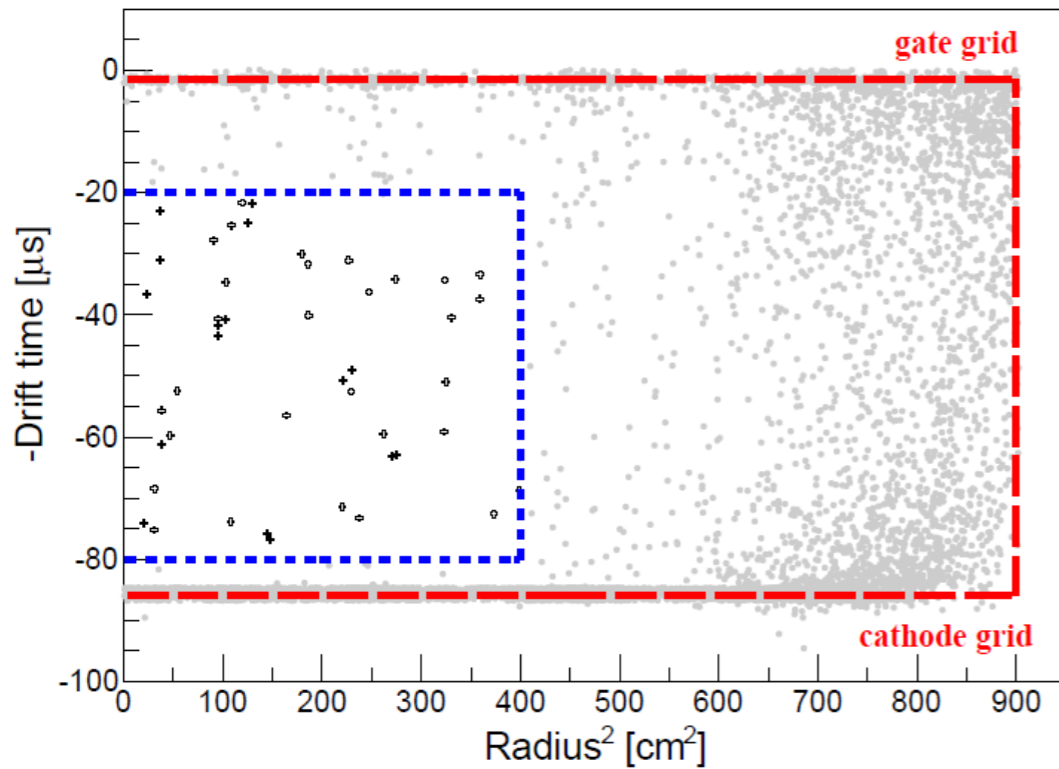


NR efficiency calculation



ER/NR discrimination

PandaX-I first results: 37 kg x 17.4 days data excluded all previously reported light dark matter signals

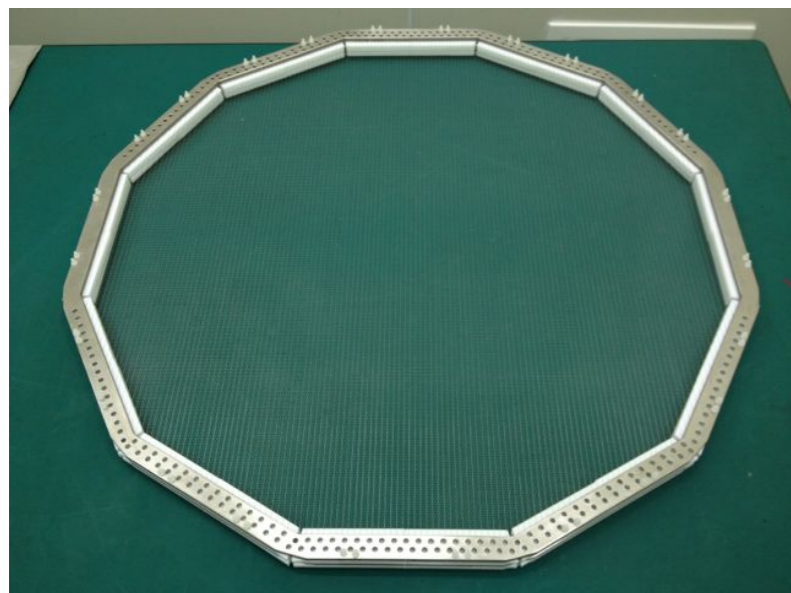


Sci China-Phys Mech Astron, 2014, 57(11):
2024-2030

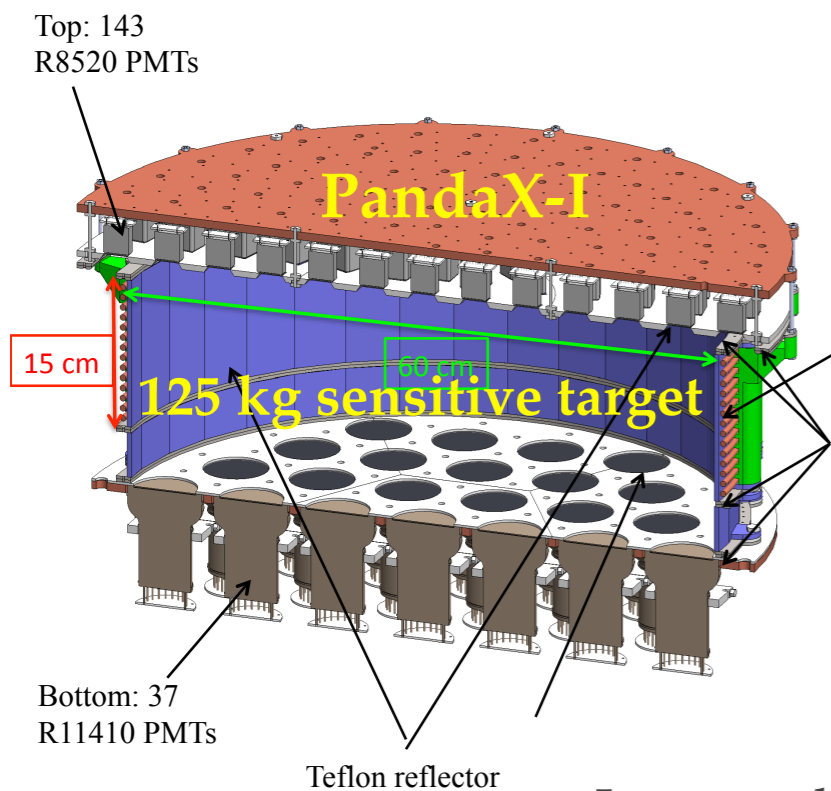
- PandaX 37x17 kg-day, NEST
- - - PandaX 37x17 kg-day, Xenon100 L_{eff}
- - - XENON100 40x11 kg-day
- XENON100 34x225 kg-day
- LUX 118x85 kg-day (no LY below 3 keV_{nr})
- CDEX 2014
- SuperCDMS
- CoGENT 2014
- - - CDMS II-Si
- DAMA/LIBRA
- CRESST-II 2012

**Second dark matter results
with another 63 days of dark
matter search data to be
released soon!**

From PandaX-I to PandaX-II



improved electrodes with higher transparency



Top: 143 R8520 PMTs

PandaX-I

125 kg sensitive target

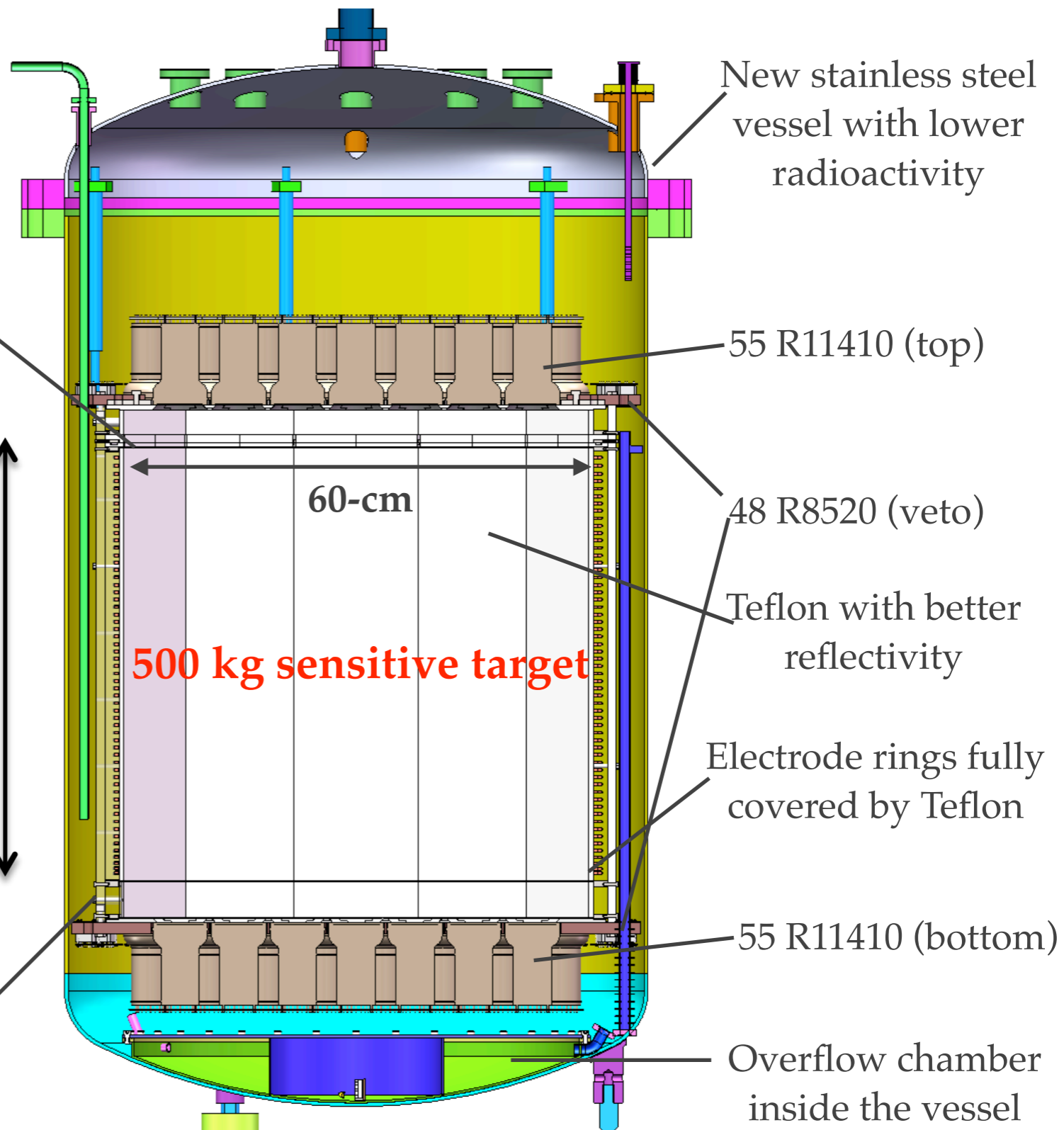
Bottom: 37 R11410 PMTs

Teflon reflector

Improved circulation path

60-cm

PandaX-II



New stainless steel vessel with lower radioactivity

55 R11410 (top)

60-cm

500 kg sensitive target

48 R8520 (veto)

Teflon with better reflectivity

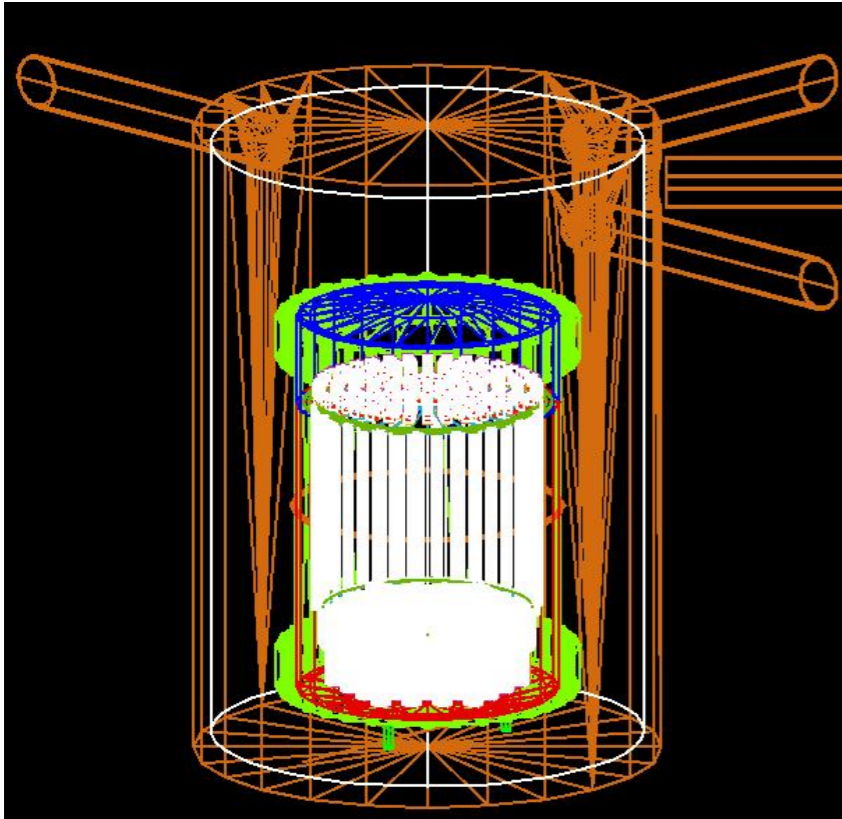
Electrode rings fully covered by Teflon

55 R11410 (bottom)

Overflow chamber inside the vessel

PandaX-II background goal: less than one event in 300 kg-year exposure

PandaX-II Geant4
Background Simulation

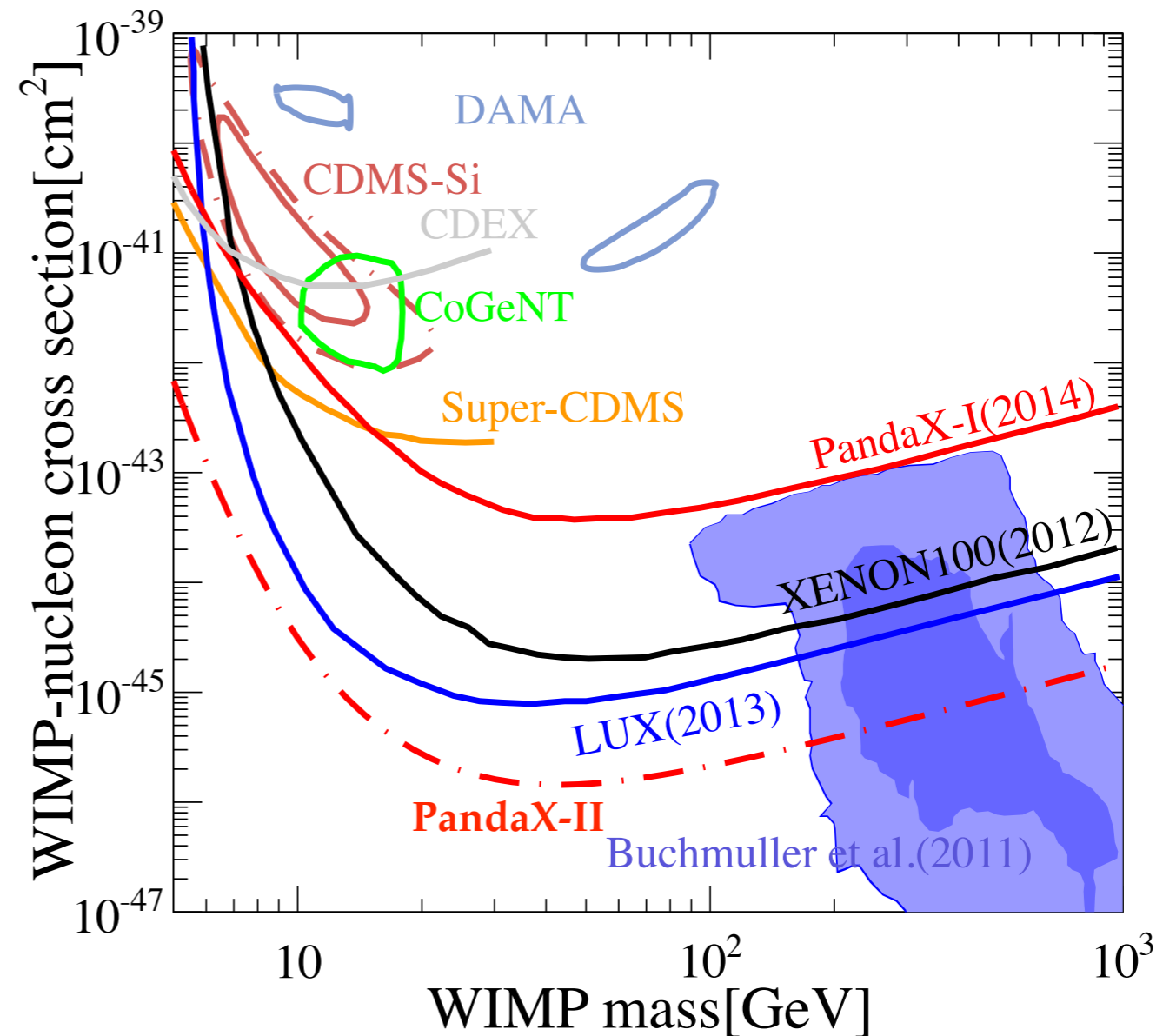


Radioactivity for stainless steel in PandaX-I/II (unit: mBq/kg)

Isotopes	PandaX-I SS	PandaX-II SS
U238(Ra226)	6.7	<1.5
Th232(Th228)	9.0	<2.2
K40	54	<11
Co60	8.0	<0.6

PandaX-II Bkg Source	Bkg rate before ER rejection (10)	Bkg event in 300 kg-year and 10 keVee (with 99.75% ER rejection)
SS vessel	0.07	0.38
PMTs	<0.38	<0.95
Kr85 (1 ppt Kr/Xe)	0.05	0.24
Solar neutrinos	0.01	0.04

PandaX-II sensitivity projection



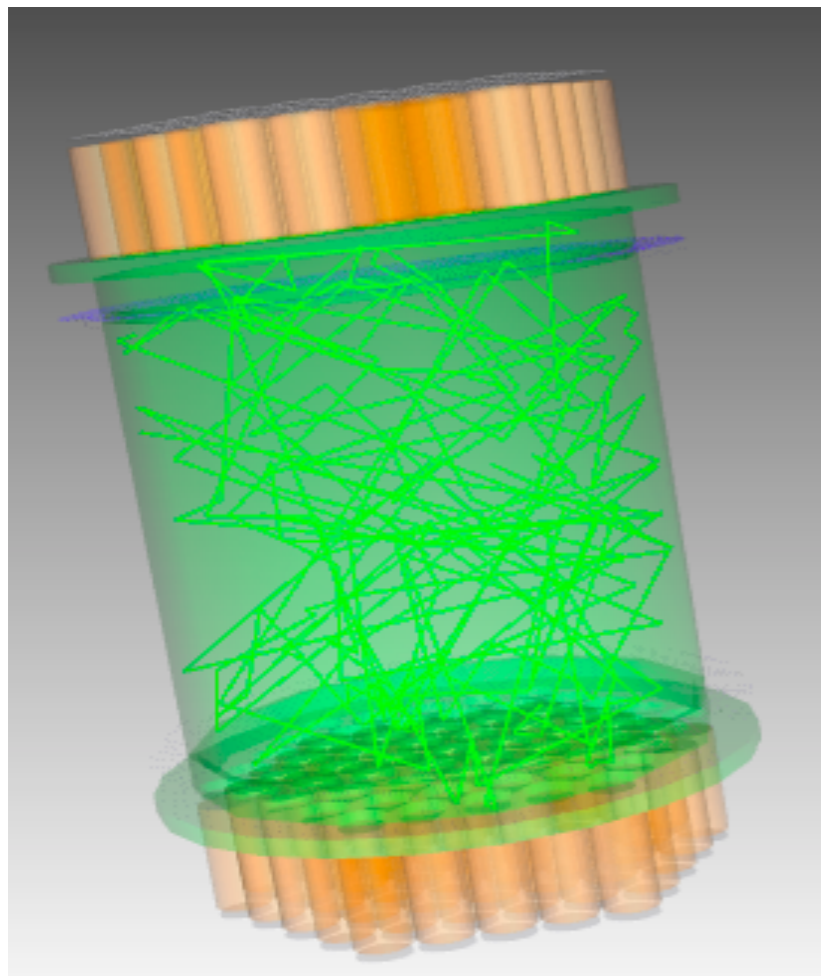
PandaX-II Sensitivity Projection:

- **Exposure: 300 kg x 1 year**
- **Background: < 1 event**
- **Photon detection efficiency: 10%**
- **S1 energy window: 3 - 30 PE**
- **Nuclear recoil acceptance: 35%**
- **Leff: NEST v1.0**

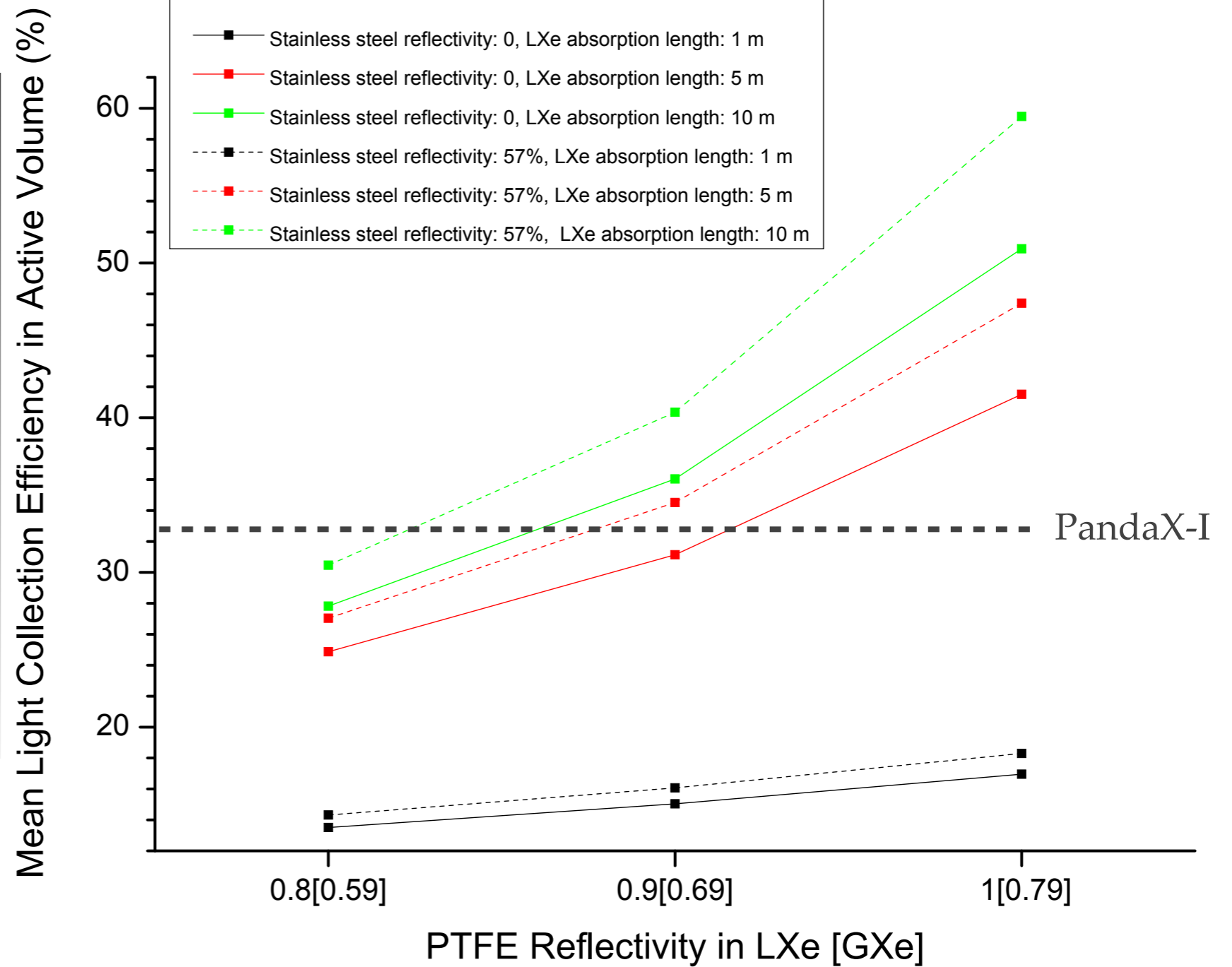
Summary

- ❖ PandaX is a staged dark matter search program using liquid xenon at CJPL
- ❖ PandaX-I's first 17 days of data **excluded previously reported light dark matter signals**; new results with another 63 days of dark matter data will be released soon
- ❖ PandaX-I has **paved way for ton-scale liquid xenon experiment**
- ❖ PandaX-II is in good progress and expected to take data in 2015
- ❖ **A 20-ton LXe dark matter experiment (PandaX-20T) is proposed for CJPL-II**

PandaX-II: expected light collection efficiency (same or higher than PandaX-I)



PandaX-II Light Simulation



Liquid Xenon towards the Detection of Dark Matter

arXiv:1310.8327

