Radiation Background of PandaX Experiment at China Jinping Underground Lab

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On Behalf of PandaX Collaboration

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Outline

- Intr. of PandaX @ CJPL
- Several Rad. Background Related Issues
  - Cosmic Muon, Rocks, Rn
  - Counting Station
  - Rad. Shielding
  - Xe Purity
  - Customized Stainless Steel
- Future Plan
  - PandaX Phase II
  - CJPL II

PandaX Collaboration

Mission: Search DM with Xe 2phase TPC Det.
Started from 2009;
PandaX-I Data taking, finished!
PandaX-II Under construction…


Shanghai Jiao Tong University, China(上海交通大学)


Shanghai Inst. of App. Phys., China(中科院上海应物所)


Shandong University, China(山东大学)

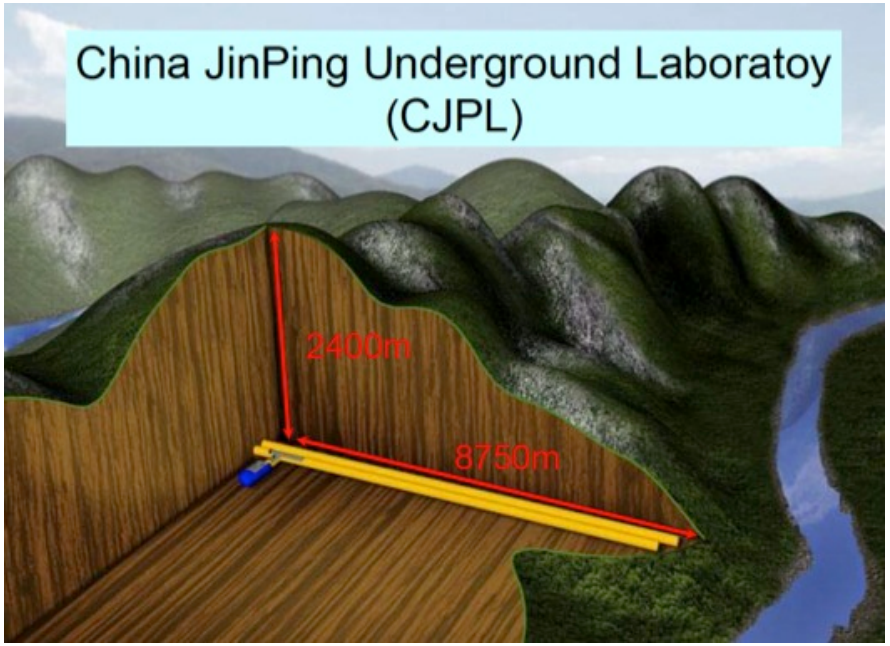

Peking University, China(北京大学)

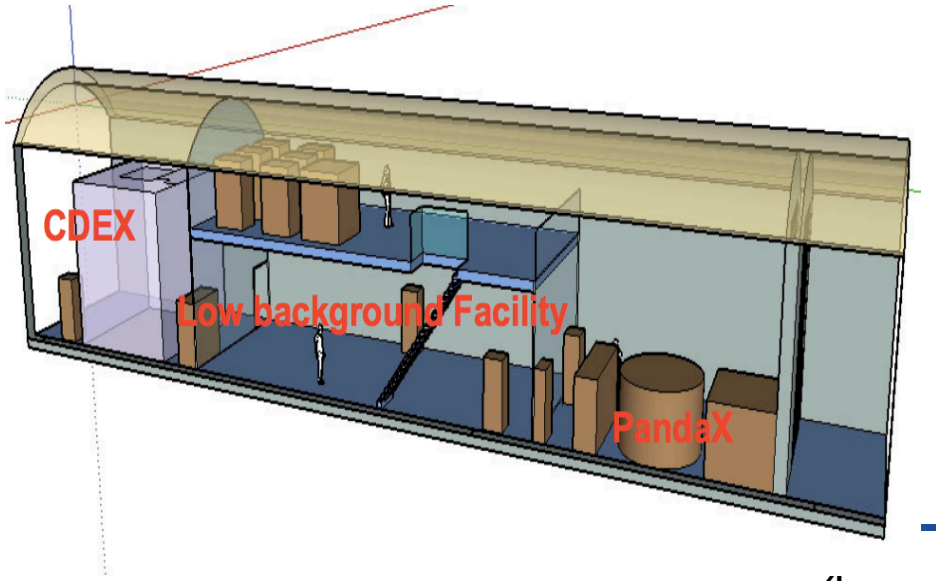

University of Michigan, USA


University of Maryland, USA

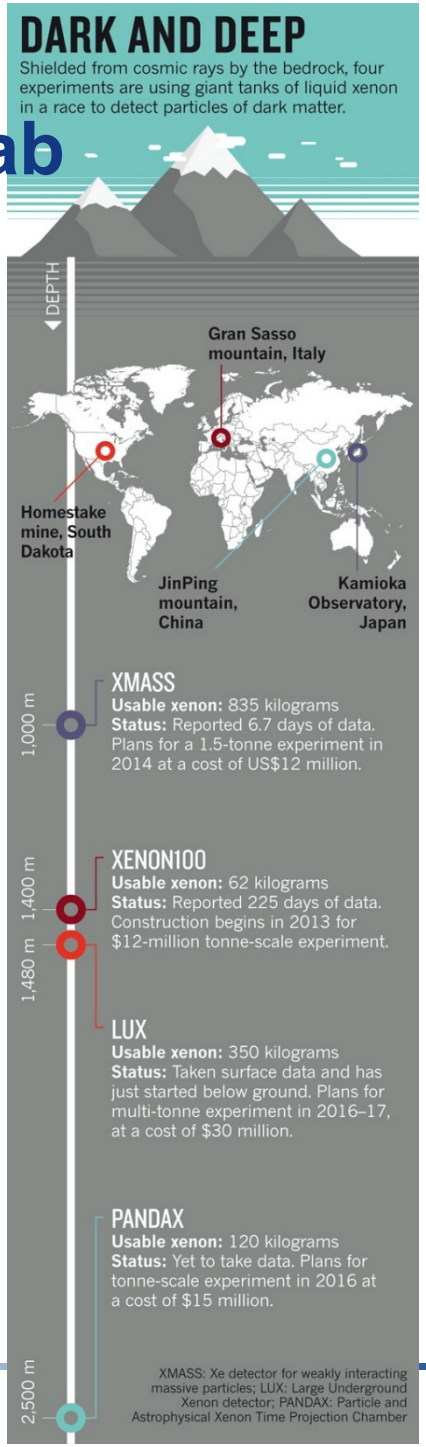

Yalong Hydro Power Co., China(雅砻江水电开发公司)

JinPing Underground Lab (CJPL)

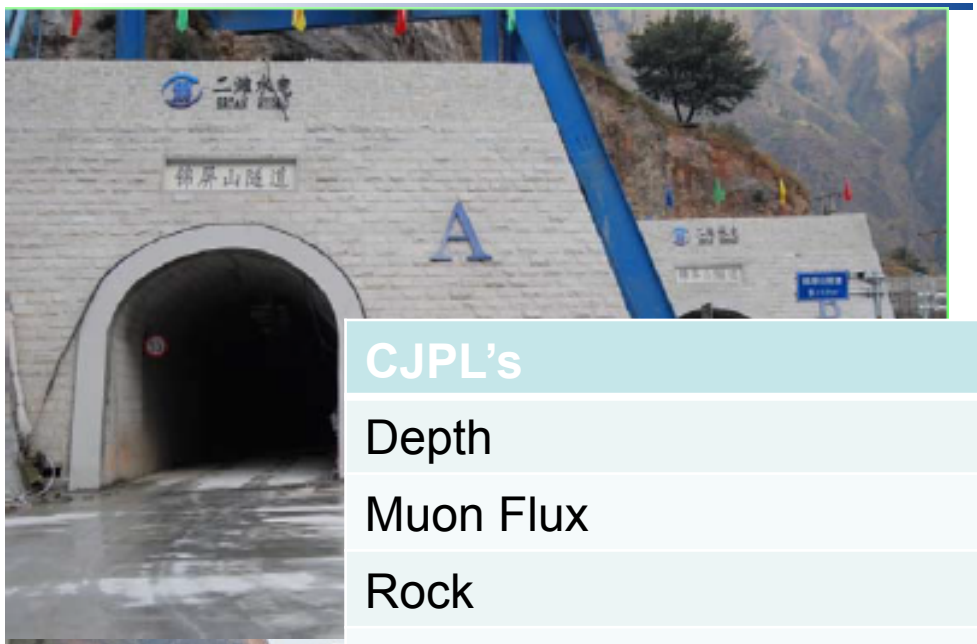


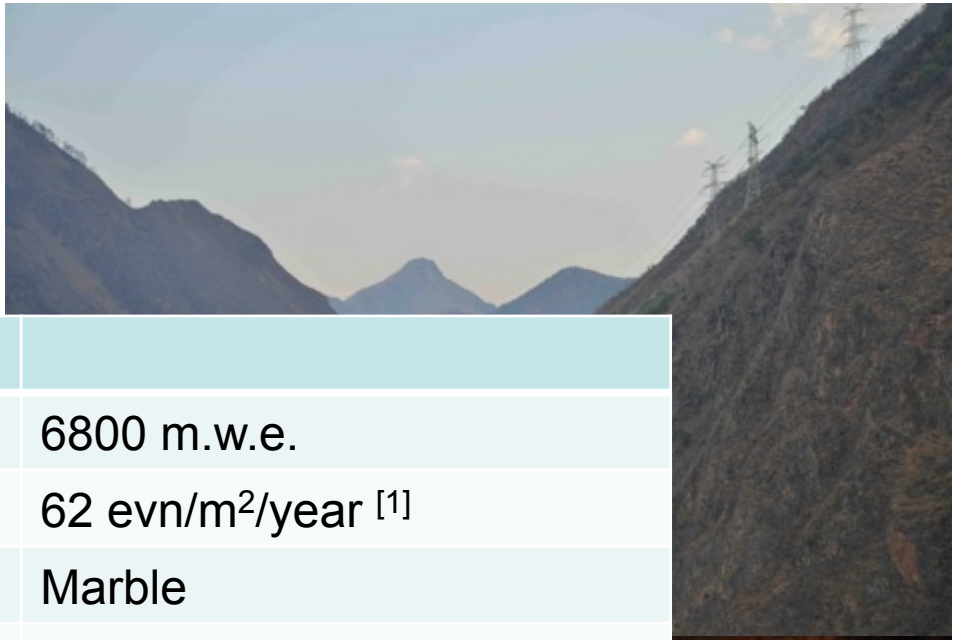


China Jinping Underground Lab

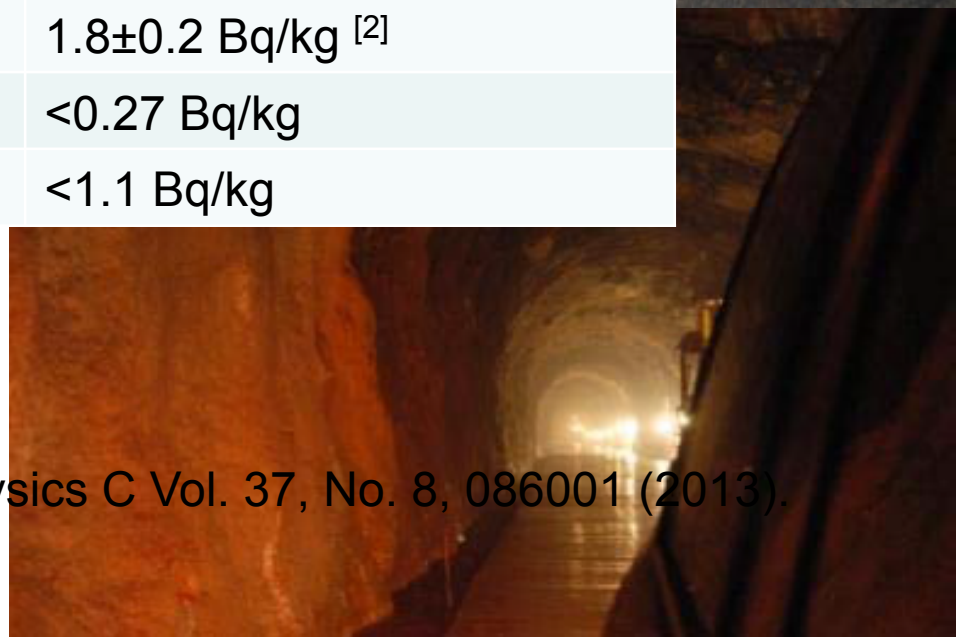


CJPL's Natural Background



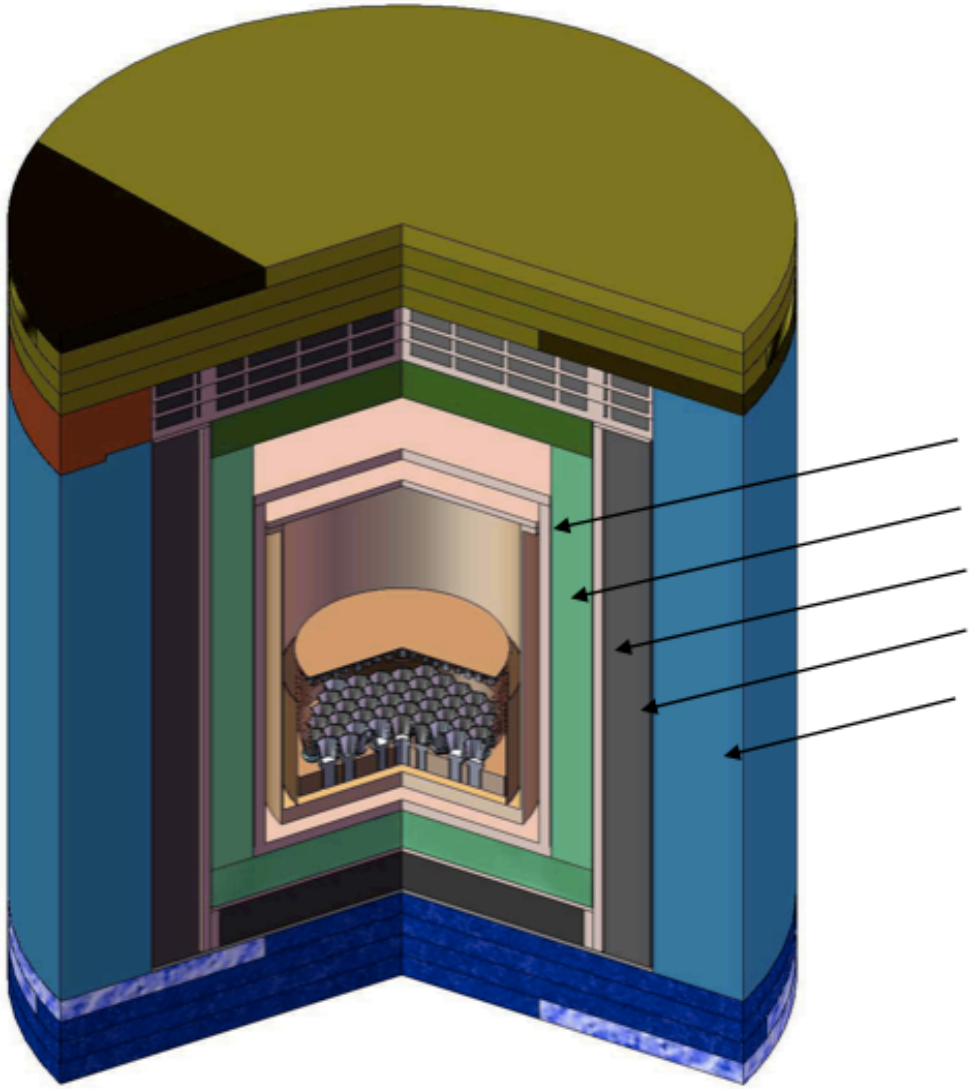


CJPL's	
Depth	6800 m.w.e.
Muon Flux	62 evn/m^2/year [1]
Rock	Marble
^{238}U	1.8±0.2 Bq/kg [2]
^{232}Th	<0.27 Bq/kg
^{40}K	<1.1 Bq/kg



1. Y. C. Wu, et al., Chinese Physics C Vol. 37, No. 8, 086001 (2013).
2. From CDEX

PandaX Passive Shielding



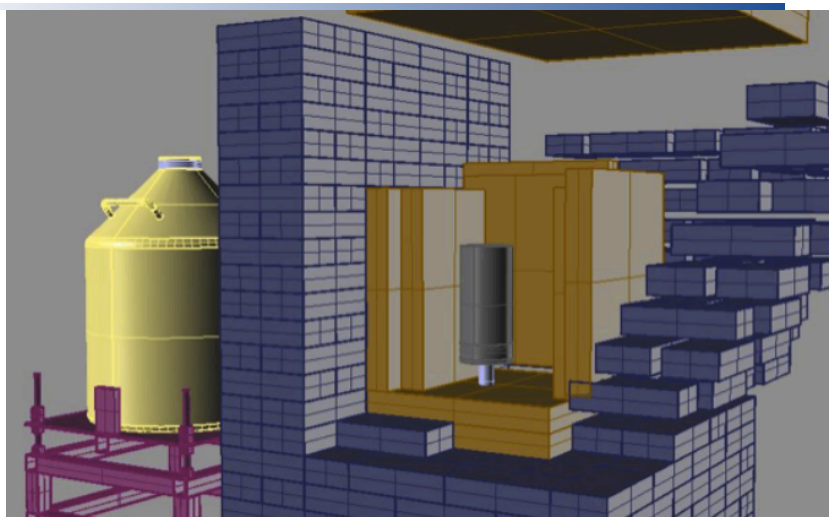
Diameter 3m, Height 3.6m

5cm Cu (outer vessel)
20cm PE
5cm Cu
20cm Pb
40cm PE

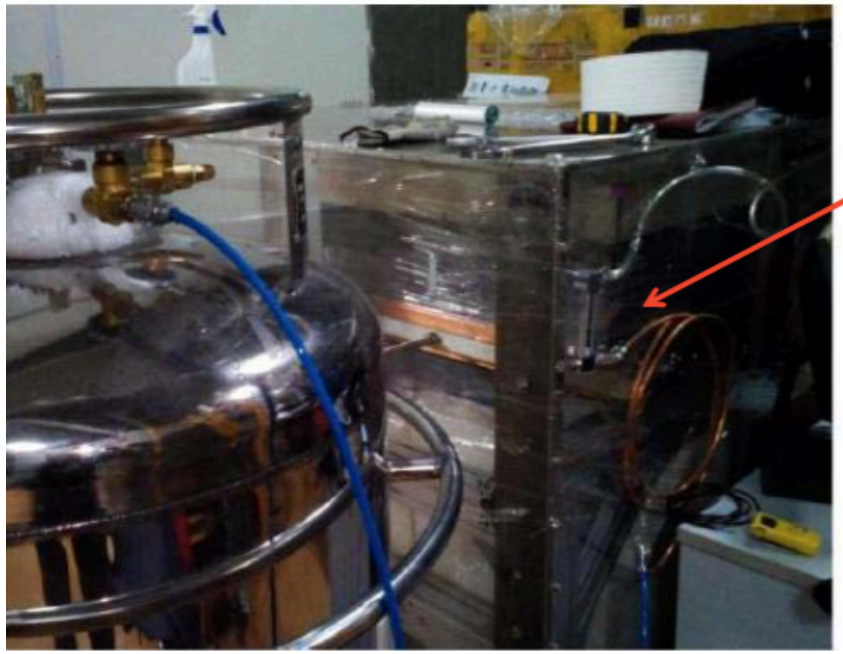
Inner Vaccum
Height 160cm
Diameter 120cm

Goal: <1 external bg event in 5-15keV per year

Counting Station

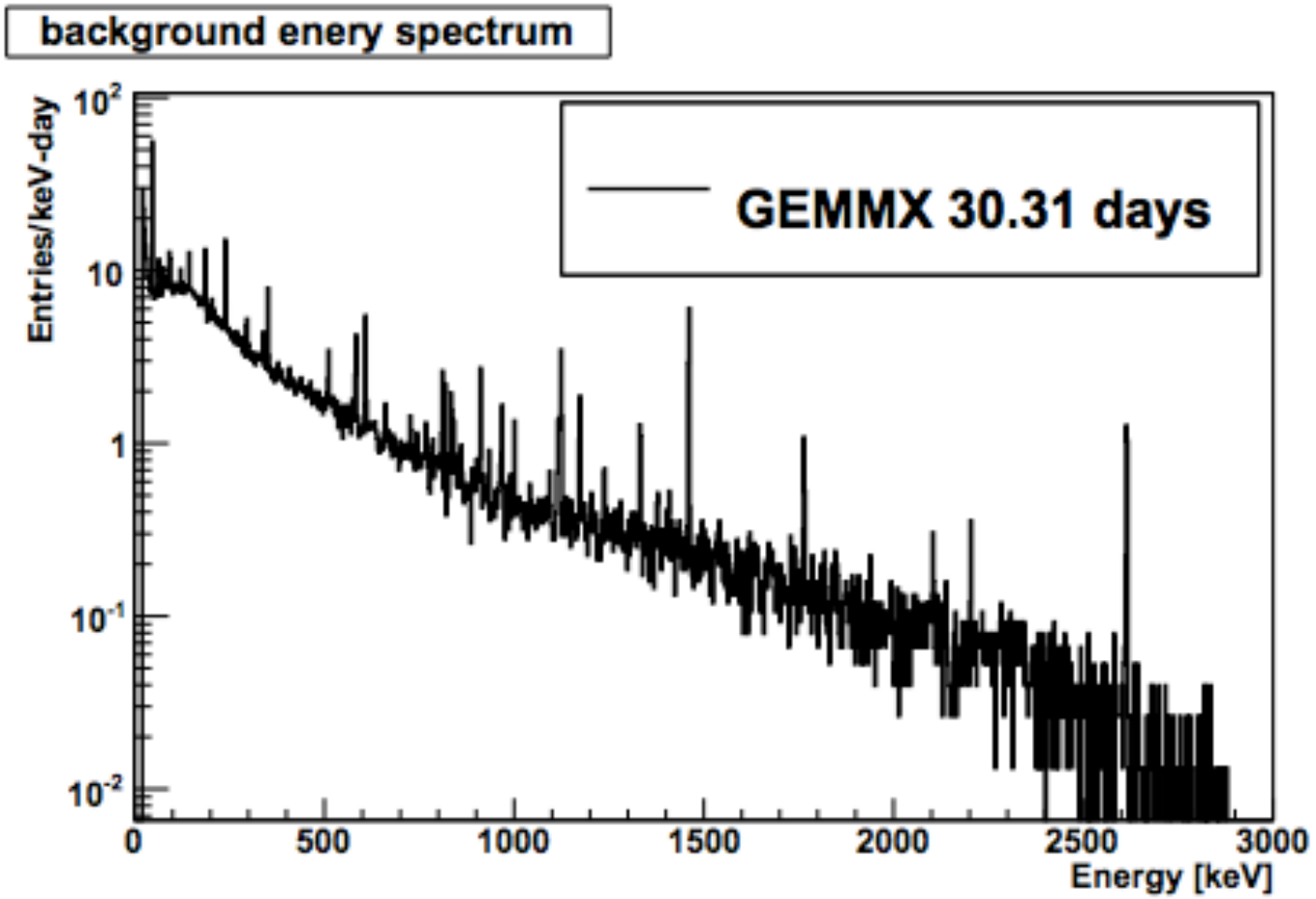


1. 10cm OFHC Cu
2. 20 cm Pb
3. 10 cm PE
4. Bkgd counting rate: ~1.5-2Hz
5. Sensitivity Limit: order mBq
6. Rel. Eff. 175%
7. Resolution:
   - 1.3keV@200Kev
   - 3.2keV@2.46MeV



Ortec GEMMX-941000 low bkgd, HPGe Detector used to screen radioactivity of detector components

Typical Spectrum of the Counting Station



Example: Cu used in PhandaX-I

Radioactive elements:

isotope	PANDAX [mBq/kg]	Xenon100 [mBq/kg] [2]
Ra228 (Th232)	<0.36	0.021
Th228 (Th232)	<0.51	
Ra226 (U238)	<0.38	0.070
Pa234m (U238)	<9.0	
U235	<0.86	0.0034
K40	4 ± 1	0.023
Cs137	<0.16	

Rad. Assays for PandaX-I

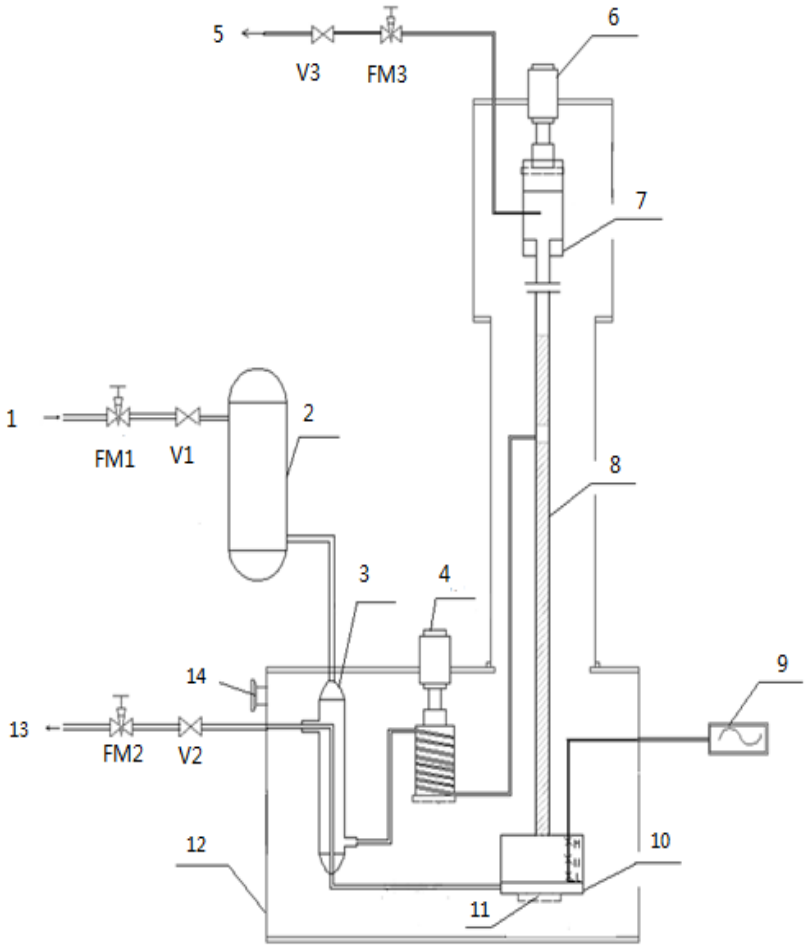
samples	unit	^{226}Ra	^{228}Th	^{40}K	^{137}Cs	^{60}Co	^{235}U
PMT8520	mBq/PMT	<0.11	<0.08	9.8±1.0	0.20±0.05	0.50±0.05	<0.12
Base 8520	mBq/base	.07±0.2	<0.32	<2.4	0.4±0.1	<0.07	<0.18
PMT11410	mBq/PMT	<0.72	<0.83	15±8	<0.31	3.4±0.4	1.4±1.2
Base 11410	mBq/base	1.1±0.1	0.16±0.15	<1.3	0.33±0.08	<0.06	0.4±0.2
PTFE samples	mBq/kg	2.3-33	<1-<14	<6 - 89	6 - 68	<0.3 - <6	<3 - <8
SS sample	mBq/kg	118±3	17±4	53±14	<0.9	6.0±0.8	<8

TABLE II: Radioactivity of the PMTs and some other detector components. The PTFE samples are used for the TPC construction. The stainless steel (SS) sample is from the stage-I inner vessel.

Sci. China, V57(2014)1476-1494,
also http://arxiv.org/pdf/1405.2882.pdf

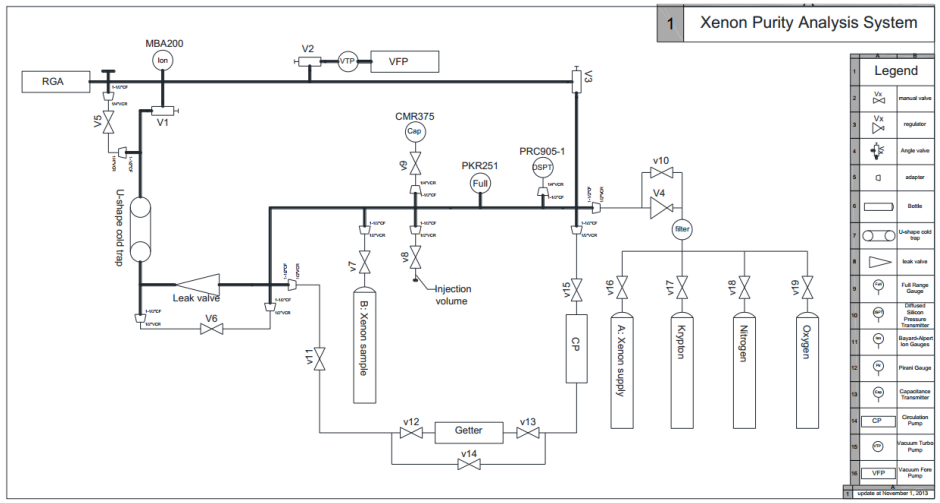
Radioactive background: Kr in Xe

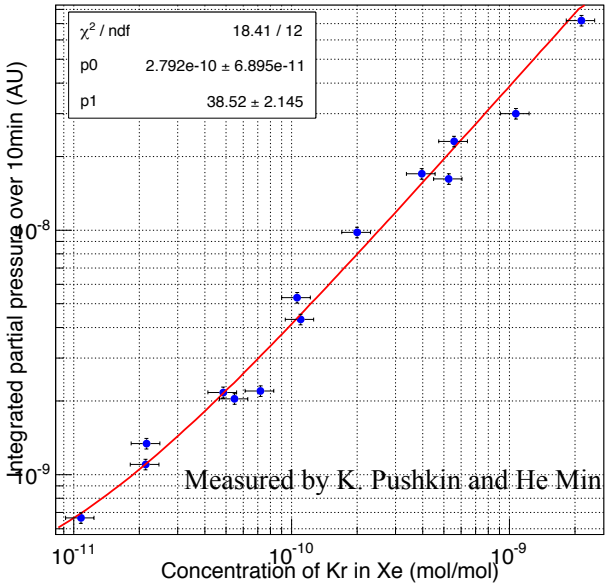
Kr-85, $T_{1/2}$=10.756 y, Beta Emax=687 keV



Journal of Instrumentation 11/2014; 9:11024

Xe Purity Analysis System





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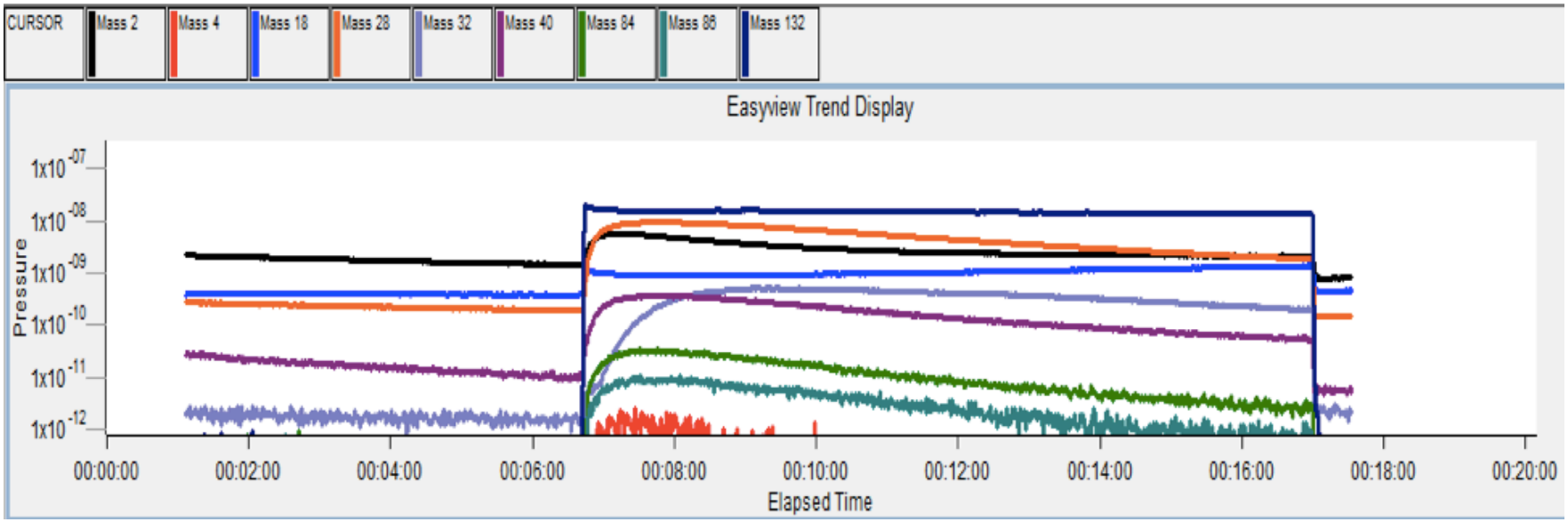
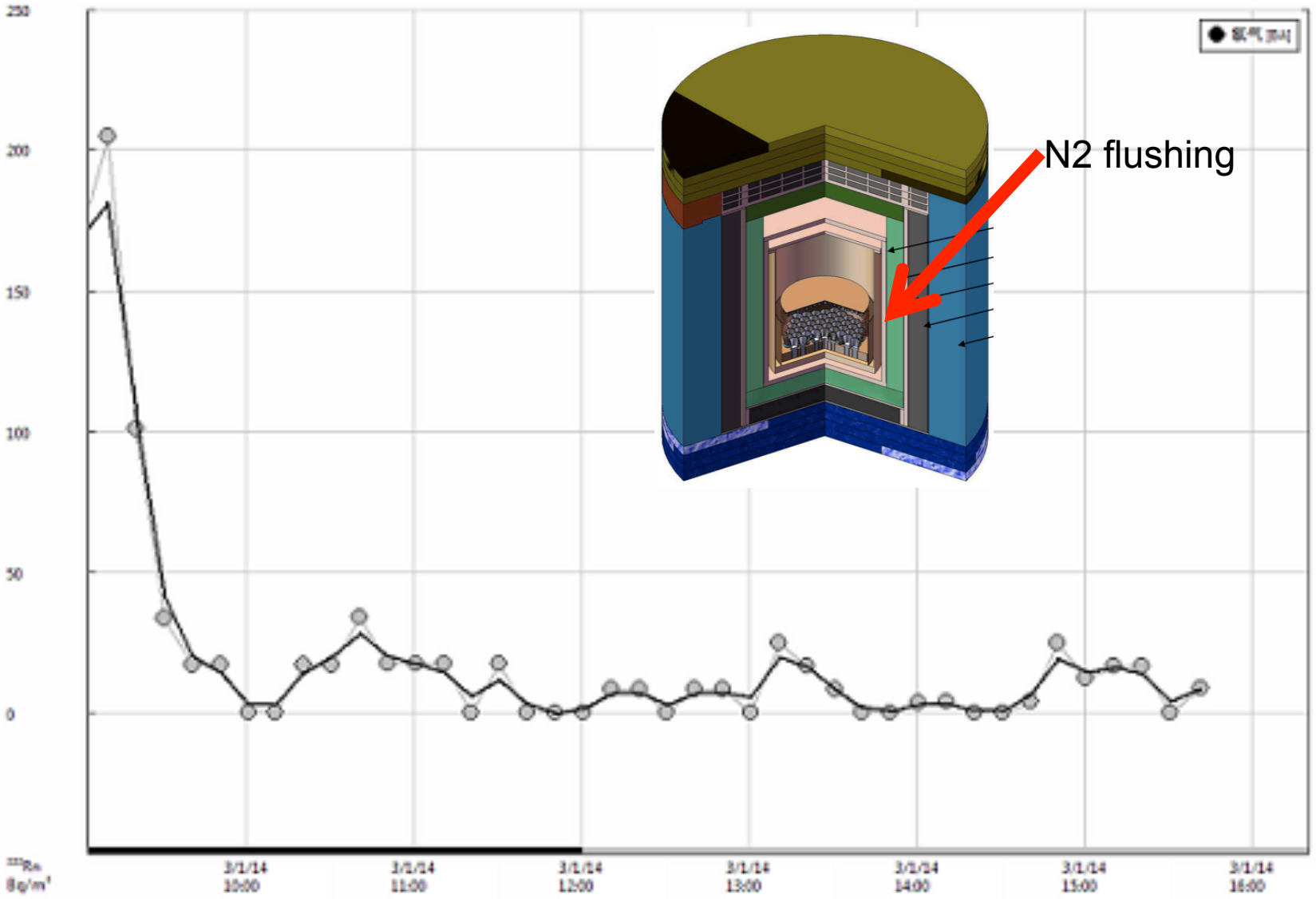
Xe Purity Results



Rn Level Control

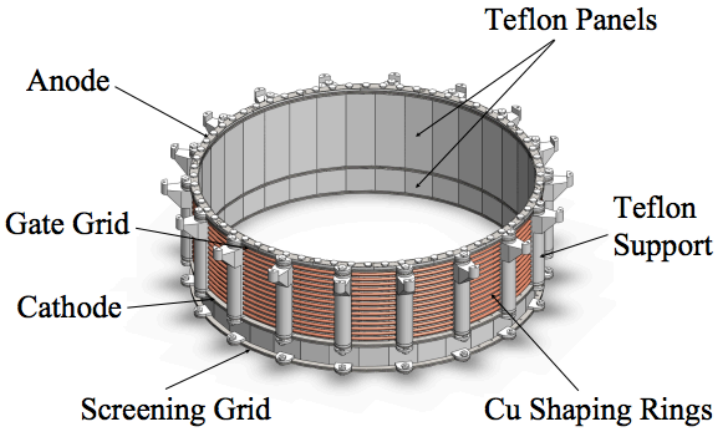


Neutron Background

^{13}C (n.a.=1.1%)
^{13}C (a,n)

component	event per year
Top PTFE Reflector	0.646
Side PTFE	2.70
Side PTFE holder	0.11
Bottom PTFE reflector	0.118
Bottom side PTFE	0.440
Inner Vessel	0.112
Inner Vessel bottom flange	0.87
Inner Vessel top flange	0.661
One Inch PMT	1.59×10^{-3}
One Inch PMT Base	3.06×10^{-3}
Three Inch PMT	7.55×10^{-3}
Three Inch PMT base	4.65×10^{-3}
total	6.68

Table 11: The neutron background contribution.



Gamma Background

part	component	bkg (mDRU)	leakage (events/year)
Top PMT Array	R1PmtBase	1.66	1.36
	R1PmtCasing	2.85	0
Bottom PMT Array	R3Pmt	2.03	0.42
	R3PmtBase	3.12e-01	0.13
TPC	SidePTFEHSD	5.26e-02	0
	SidePTFESD	1.99e-01	0
	PTFEholder	6.73e-02	0
	TopCuPlate	3.01e-01	0.069
	TopPTFERef	2.53e-01	0.028
	BottomCuPlate	1.00e-01	0.014
	BottomPTFERef	3.71e-02	0.016
	ShapingRing	8.58e-01	0
Inner vessel	Filler	1.73e-01	0
	InnerVessel	2.48	0.10
	IVTopFlange	9.52e-01	0.30
	IVBottomFlange	4.46e-02	0
Outer Vessel	outer vessel	8.62e-01	0
Kr85	KryptonSD	2.54	0
Total		15.77	2.44

Table 10: The gamma background from different components.

PandaX-I Background Budget

Source	background level (mDRU)
Top PMT array	10.9±1.8
Bottom PMT array	4.0±0.6
Inner vessel components	18.5±10.1
TPC components	2.3±0.8
^{85}Kr	<3.3
^{222}Rn and ^{220}Rn	2.7±2.0
Outer vessel	1.3±0.9
Total expected	43±11
Total observed	32±5

Here only part of data obtained in Phase-I; more data under analyzing

TABLE II: The expected and observed background rates in the fiducial volume. Uncertainties in the MC prediction originate from uncertainties in the material radioactivity screening, except those for Rn and Kr that are due to the uncertainty in the PandaX data.

Sci. China, V57(2014)1476-1494, also http://arxiv.org/pdf/1405.2882.pdf,

Customized Stainless Steel

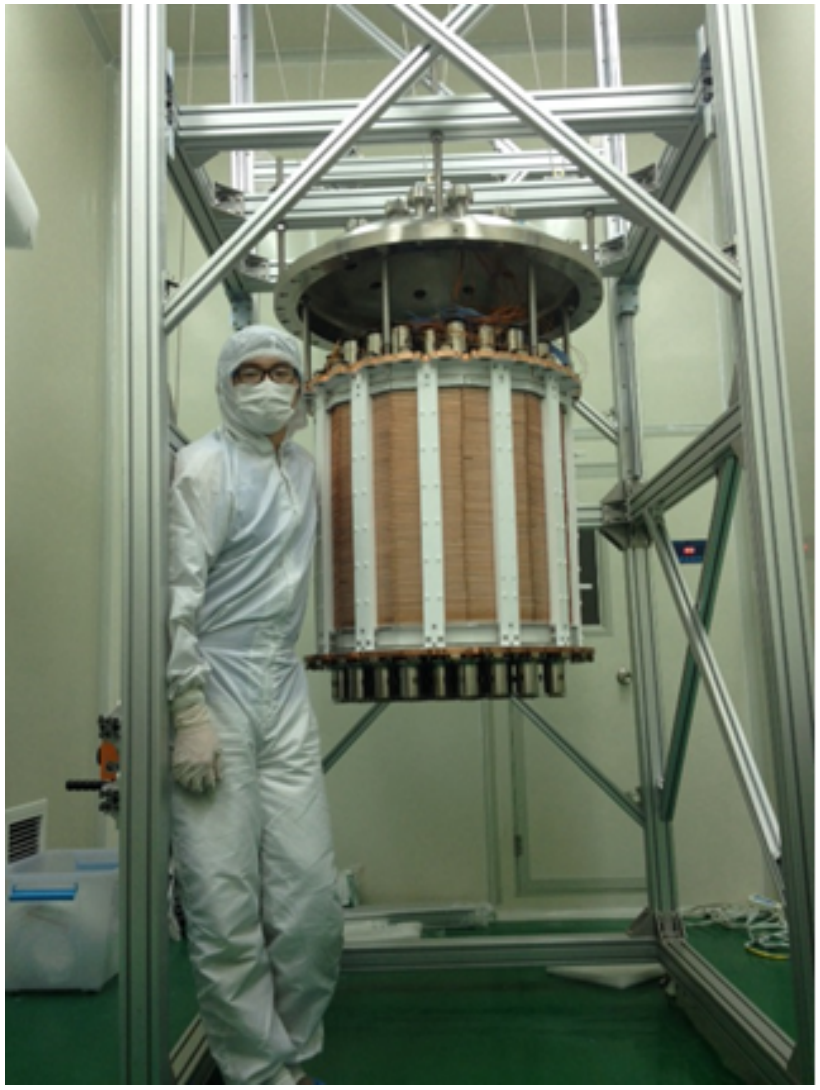
Fabricated by Central Iron & Steel Research Institute (CISRI), Beijing

Comparison of Diff. SS Samples

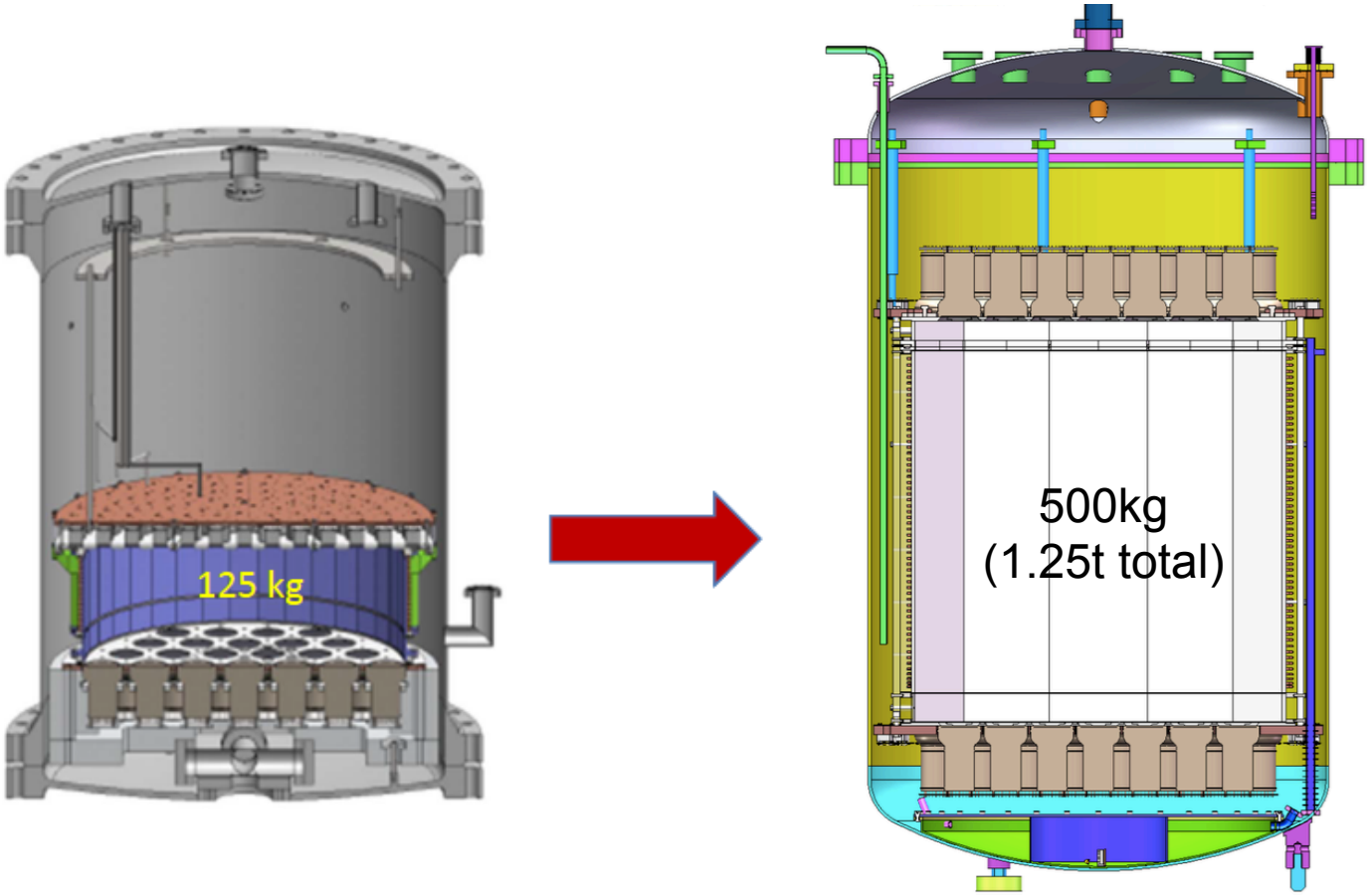
Item#*	Ac228 (Th232)	Th228 (Th232)	Th234 (U238)	Ra226 (U238)	K40	Cs137	Co60	Pb210 (U238)	U235
SS316L_1	2.59 (1.62)	6.79 (1.62)	<26.74	35.86(1.40)	<6.74	<0.42	19.04 (0.81)	526.72(224.96)	<2.37
SS316L_2	6.34 (2.95)	20.11 (2.44)	183.20 (62.27)	61.86 (2.55)	<15.98	1.10(0.90)	75.32 (1.95)	<577.64	<5.30
SS316L_3	7.98 (2.81)	15.05 (2.10)	157.04 (80.95)	63.39 (2.46)	30.73(8.83)	1.84 (0.81)	74.17 (1.75)	<620.46	<3.82
SS_HP1	<2.53	<2.16	<43.04	<1.55	<11.22	<0.96	<0.56	<435.78	3.16(2.53)
SS_HP2	2.75 (2.25)	10.35(2.61)	99.34 (42.81)	<1.51	<10.55	2.68(0.76)	<0.52	<615.50	<4.82
SS304LA	<1.93	<1.53	53.03 (29.90)	<1.28	<13.43	0.60 (0.58)	<0.53	381.88 (293.83)	<2.35
SS304LB	<1.64	<1.27	53.35(23.09)	<1.45	9.24 (8.76)	0.49 (0.45)	<0.40	<274.16	<1.67

Last 4 samples: Customized

Inner Vessel for PandaX-II



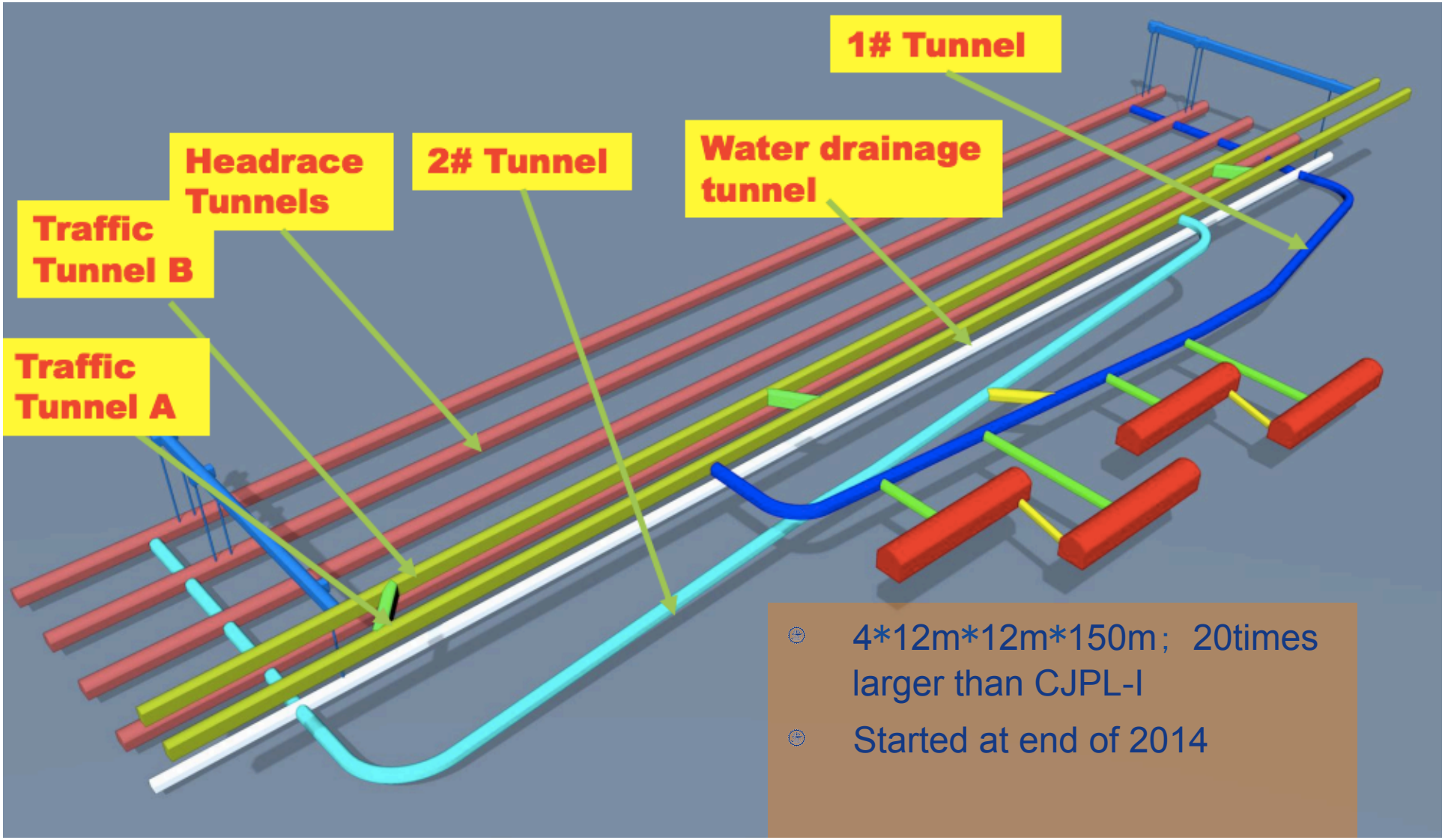
PandaX Phase-II (On going…)



Major Improvement (from background point of view):

- TPC materials (PTFE, Cu)
- Xe purity (<1 ppt)
- Inner Vessel Steel

CJPL Next Step: CJPL-II



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PANDAX: Particle and Astrophysical Xenon

Thanks!