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The Cryogenics and online purifying of PandaX-4T and future PandaX-30T

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- 2022-08-08



C O N T E N T S

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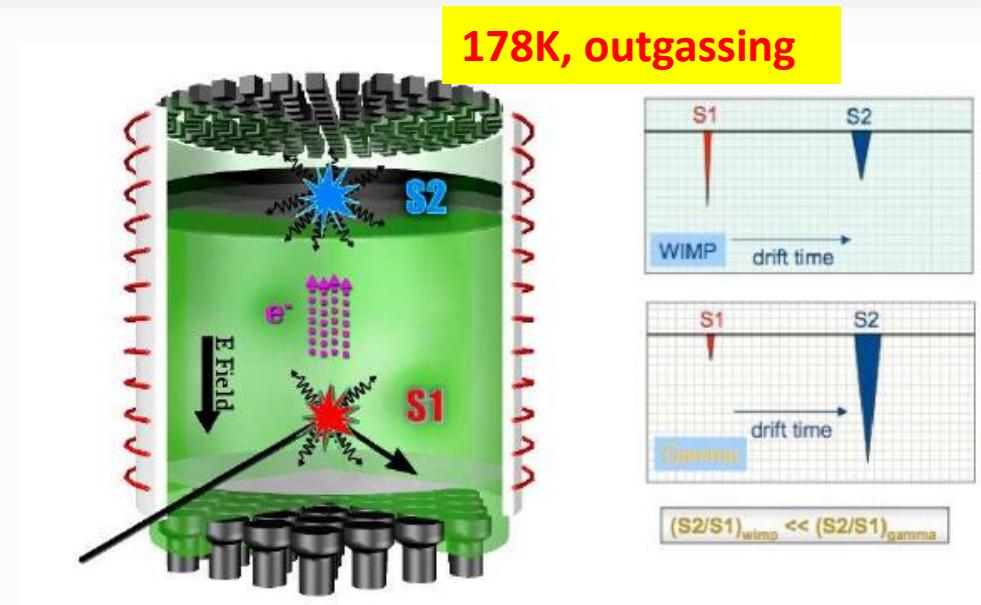
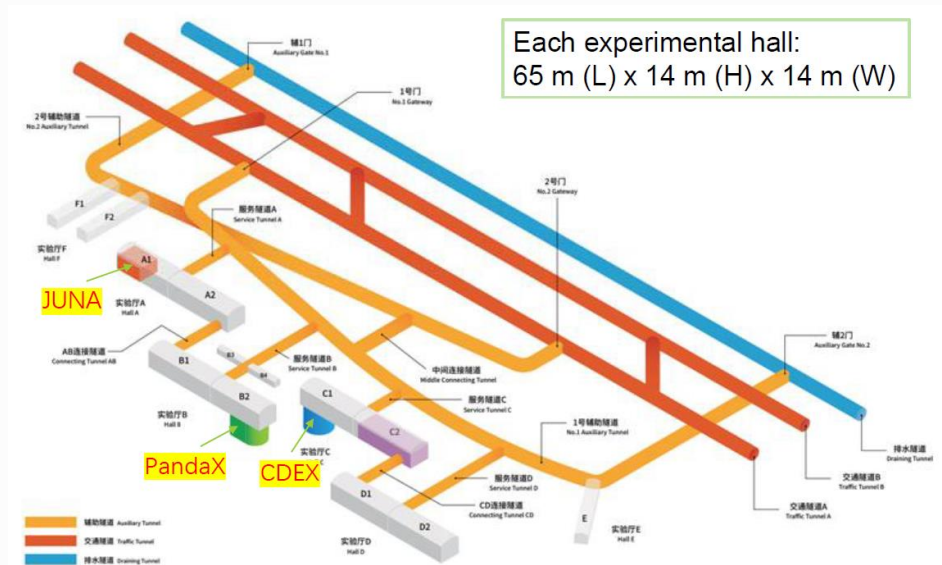
Design of Cryogenics and
purification for future 30T

04

Summary

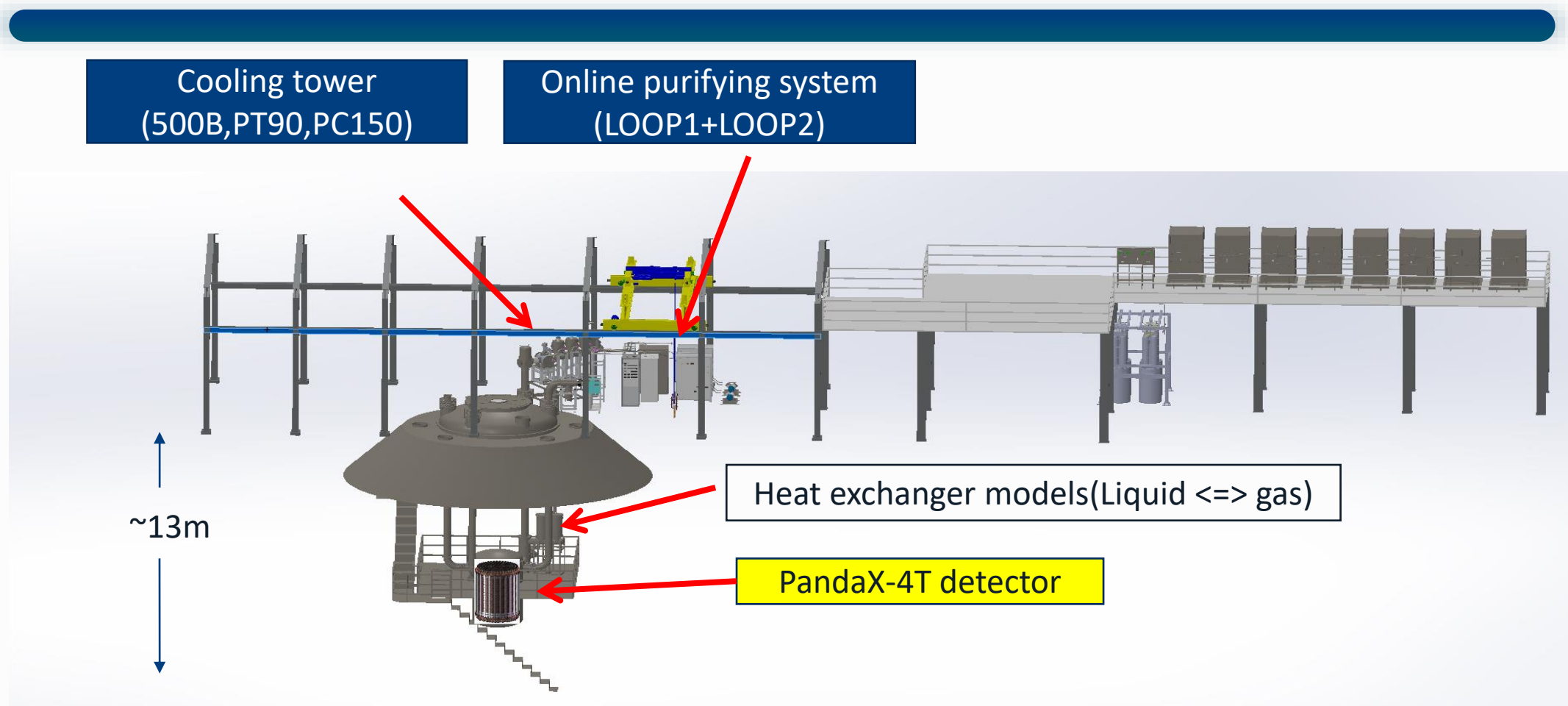
1 Motivation

- 1) Target of dark matter experiment PandaX-4T: **liquid Xenon**;
- 2) Liquid Xenon of **PandaX-4T: ~6 tons**; Liquid Xenon of **future PandaX-30T: ~50 tons**;
- 3) Aims: a) the detector in liquid Xenon will be kept **stable at 178K**; b) **outgassing** from all material insides has to be **suppressed** for good signal collection(S2 from drifted electrons, **lower Electronegative gas**);
- 4) Stable and reliable **cryogenics and online purifying** is **necessary**.



2.1 Cryogenics and online purifying for PandaX-4T

- 1) Dark matter detector is in the water tank at B2 hall of CJPL-II, around 7 m below the floor;
- 2) **Main devices of cryogenics and online purification are on the floor.**



2.2 Timeline of Cryogenics and purifying for PandaX-4T

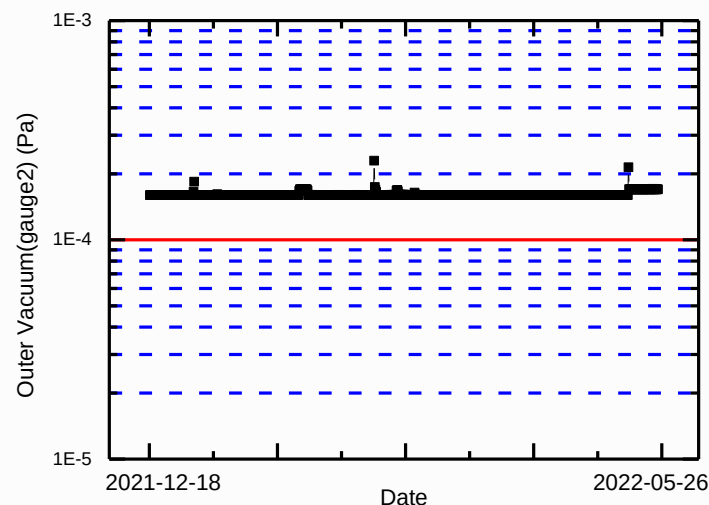


2.3 Performance of Cryogenics for PandaX-4T

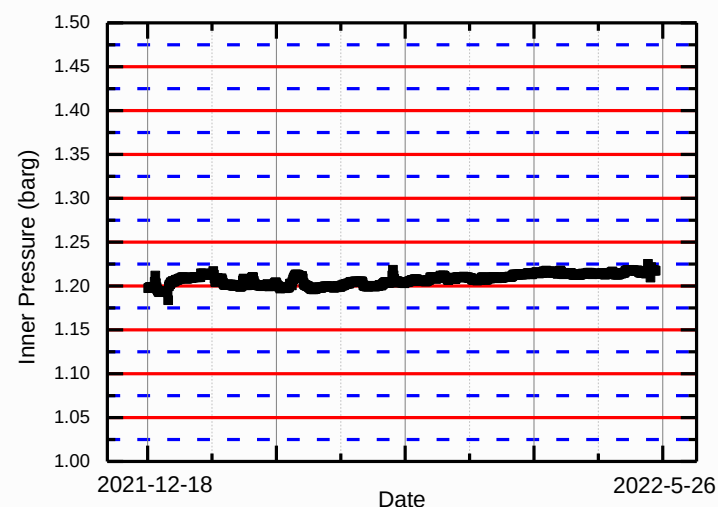
1) Maximum cooling Power of PandaX-4T: **~580W**; **2 Crycoolers are enough.**

Parameters	Static Heat	Outer vacuum	Fluctuation of P_Xe	Fluctuation of T_Xe
Value	~90 W	<3.0E-4 Pa	< 0.05 bar	< 0.1 K

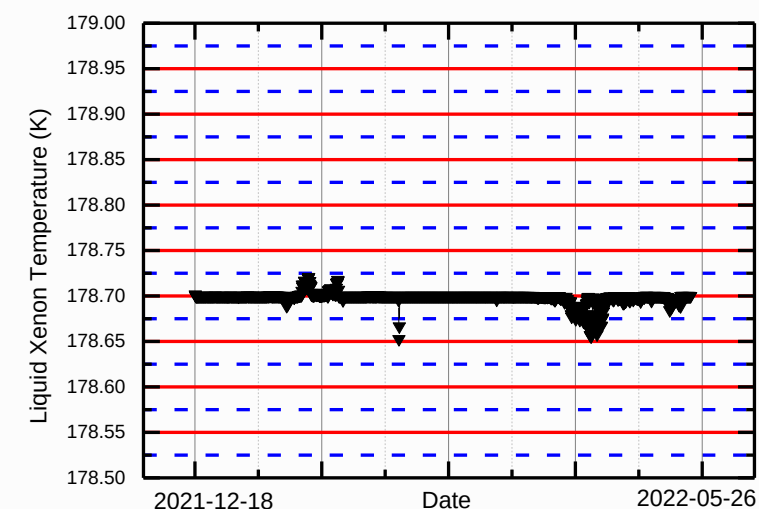
Outer vacuum of PandaX-4T



Inner pressure of PandaX-4T



Temperature of liquid Xenon



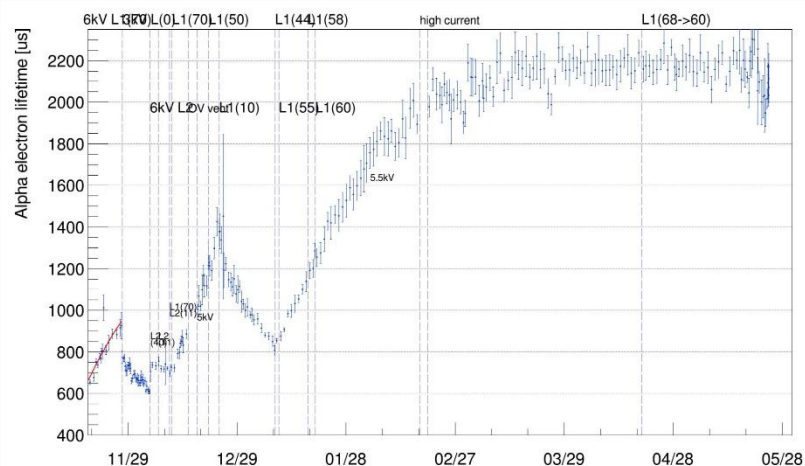
2.4 Performance of online purifying for PandaX-4T

- 1) Maximum purifying speed:
~130 slpm; only
LOOP1(~100slpm) are enough.
- 2) Pumps with lower radon are
needed, have to be produced by
ourselves. (the next plan)

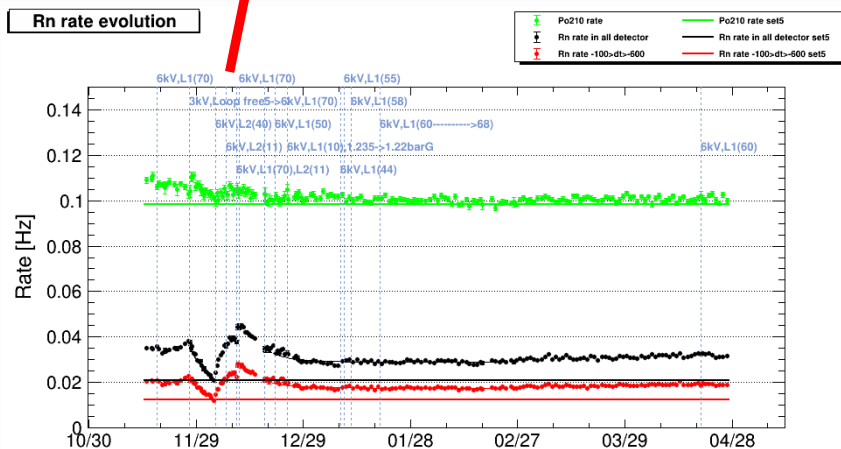
Radon222 level	PandaX-4T(uBq/Kg)	XENON1T(uBq/Kg)	XENONnT(uBq/Kg)	LZ (uBq/Kg)
TPC+Cryosta+cables	~2.3	~6.5	-	-
LOOP (Hot Getter+Pumps)	~1.9 (45%)	~3.5	-	-
Sum	~4.2	~10	~1.87	~4.37

Maximum e_lifetime: 2200 us (requirement=>800 us) .

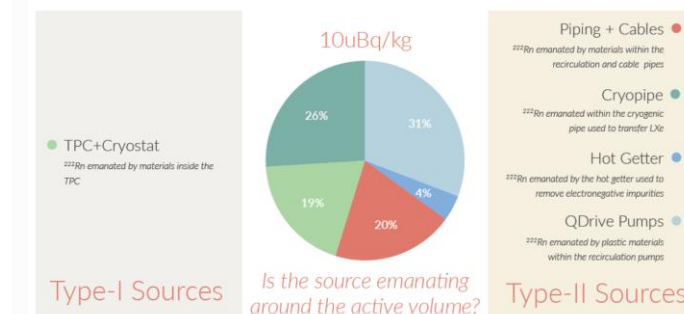
Radon level with different LOOPS, circulation pumps are key. “air cooling pump”-> “water cooling pump”



2021.11~2022.05



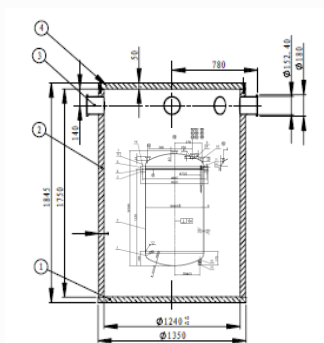
Rn-budget breakdown: emanations measured in XENON1T



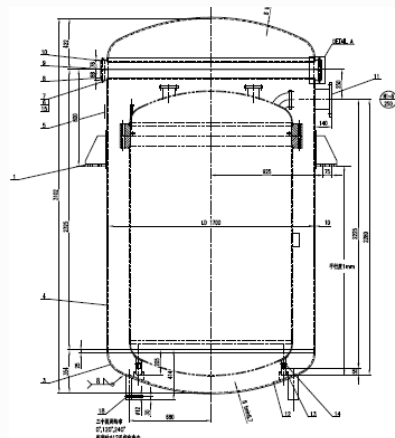
3.1 Design of Cryogenics and purifying for future 30T

Experiment	Inner vessel D (m)	Inner vessel H (m)	Surface of IV(m ²)	Volume of IV (m ³)	Outer vessel (m ³)	Static heat (W)	Outer vacuum (Pa)	Purifying speed (slpm)	Cooling power (W)	Emergency cooling (W)
PandaX-II	0.8	1.47	~5.5	~1.9	~2.1	~74	~1.E-3Pa	50~70	~180 (1*)	~300
PandaX-4T	1.33	2.34	~13	~2.9	~6.8	~96	~2.0E-4Pa	100~200	~560 (3*)	~700
PandaX-30T	3.0	3.5	~47	~25	~43	350~610	<1.0E-3Pa	>=500	>=1500	>1400

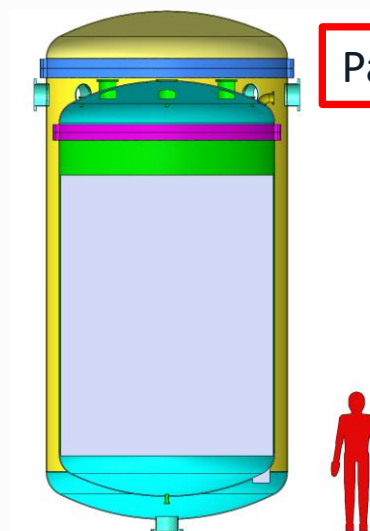
PandaX-II



PandaX-4T



PandaX-30T



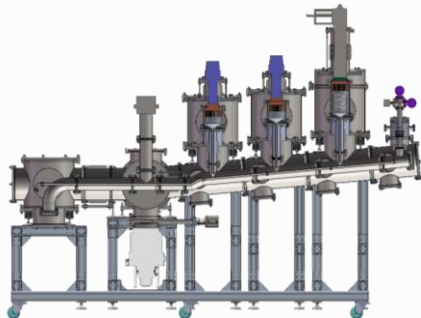
3.1 Estimation heat load for future 30T

NO	Item	Heat (W)	Note
1	Static heat of IV	~610	Worse case, from PandaX-II (13W/m ²)
2	Heat from Circulation	~500	Purifying speed ~ 500slpm, 90% efficiency(1W/slpm)
3	Heat from PMT	~50	2000*25mW
4	Feedthrough of PMT cable	~200	Cable feedthrough
		~1360	Total heat load (> current cooling tower)

Cooling tower: cryogenic coolers (**commercial product**)

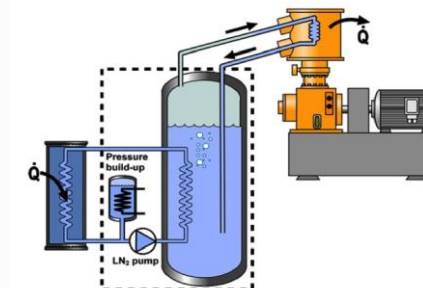
PandaX-4T (~580W), 6T Xe

XENON1T and XENONnT ~(400W), 3~9T Xe



Nitrogen-filled thermosyphons+LN₂ bath (**free-boiling**)

LUX and LZ (~1000W), 0.4~10T Xe

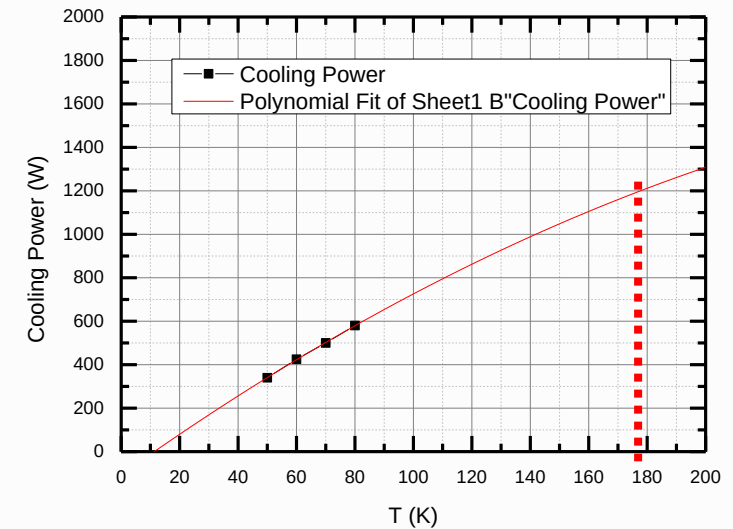
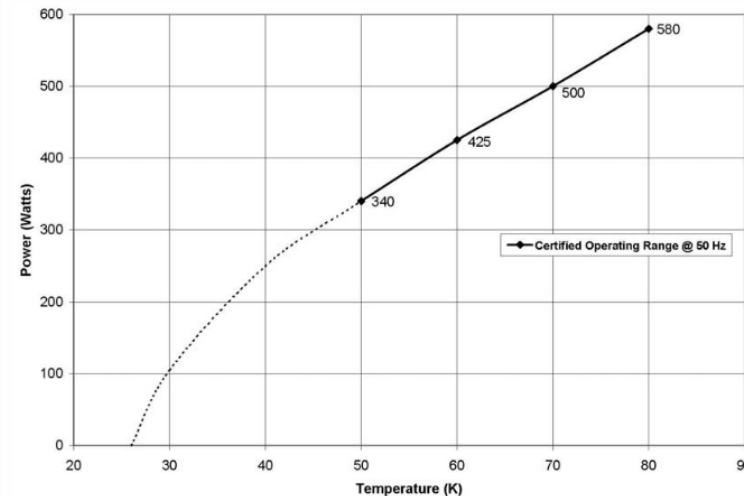
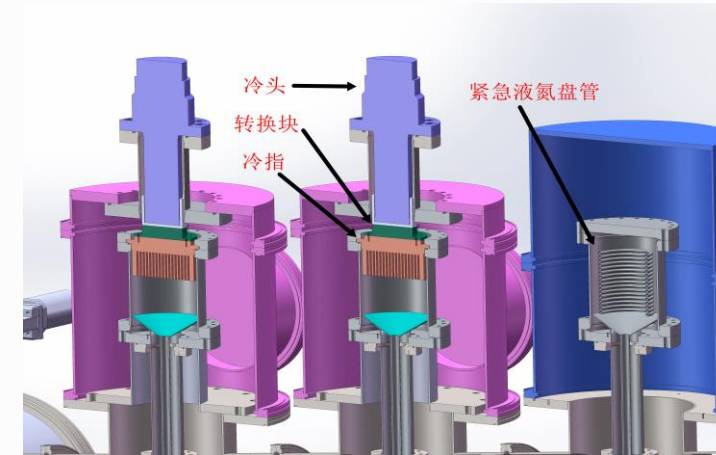


3.2 Cooling tower with Standard products

Normal operation (aim: >1500 W):

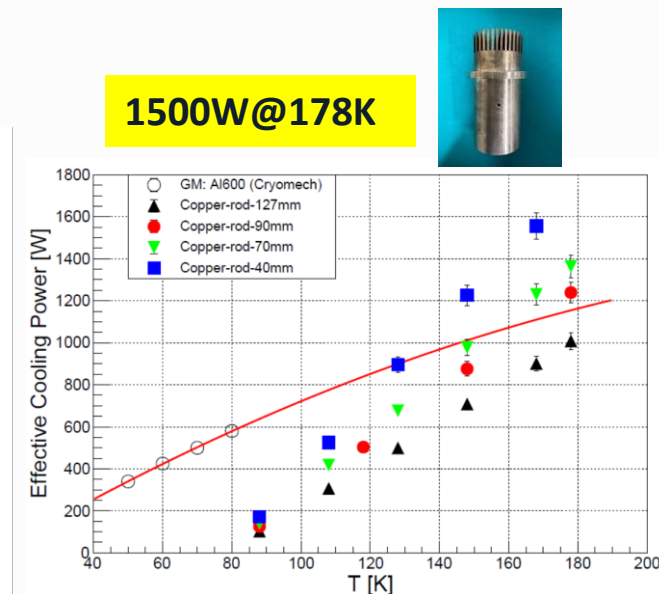
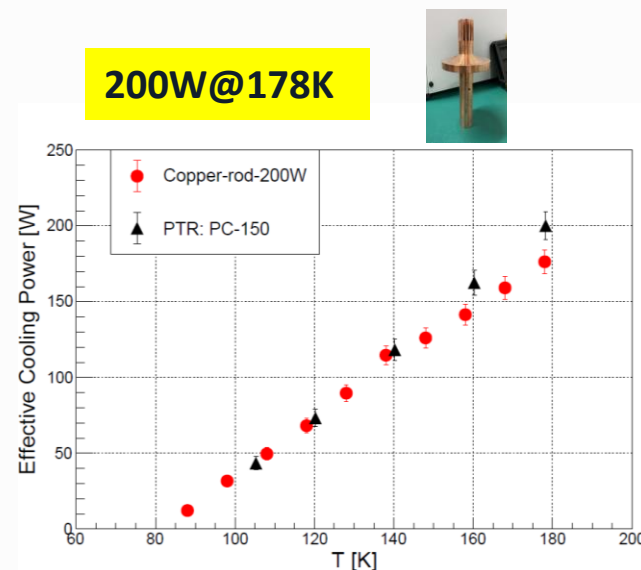
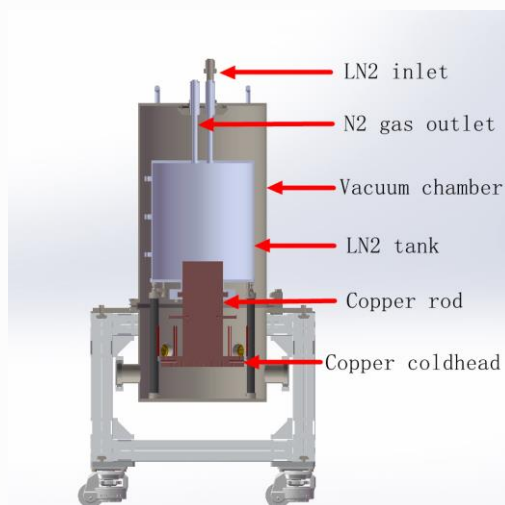
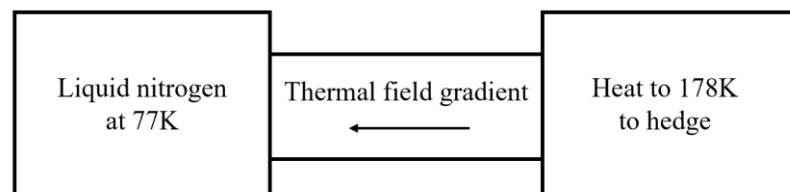
1. GM Cryogenic cooler AL600 (from USA Cryomech company);
2. Estimated maximum cooling power: **~1200W@178K;**
3. Number: **>= 2;**
4. Maintenance period: **1 time /10000h.**

Emergency LN2 cooling: >=1400W.

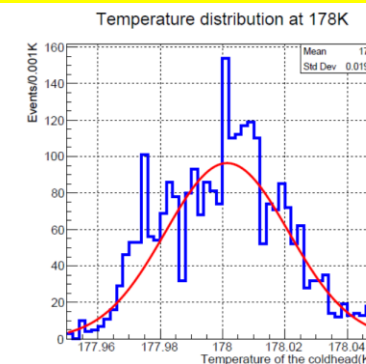
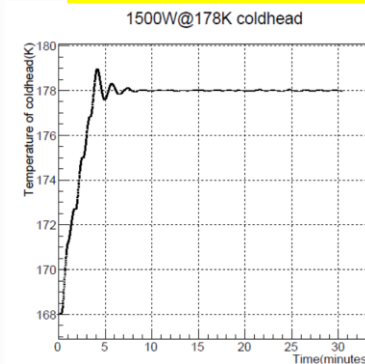


3.3 LN2-based cooling system prototype (self-designed)

- 1) Heat conductor: **HPOF copper**.
- 2) PID: temperature fluctuation **<0.1K**.
- 3) Advantage : **simple**, maintenance free.



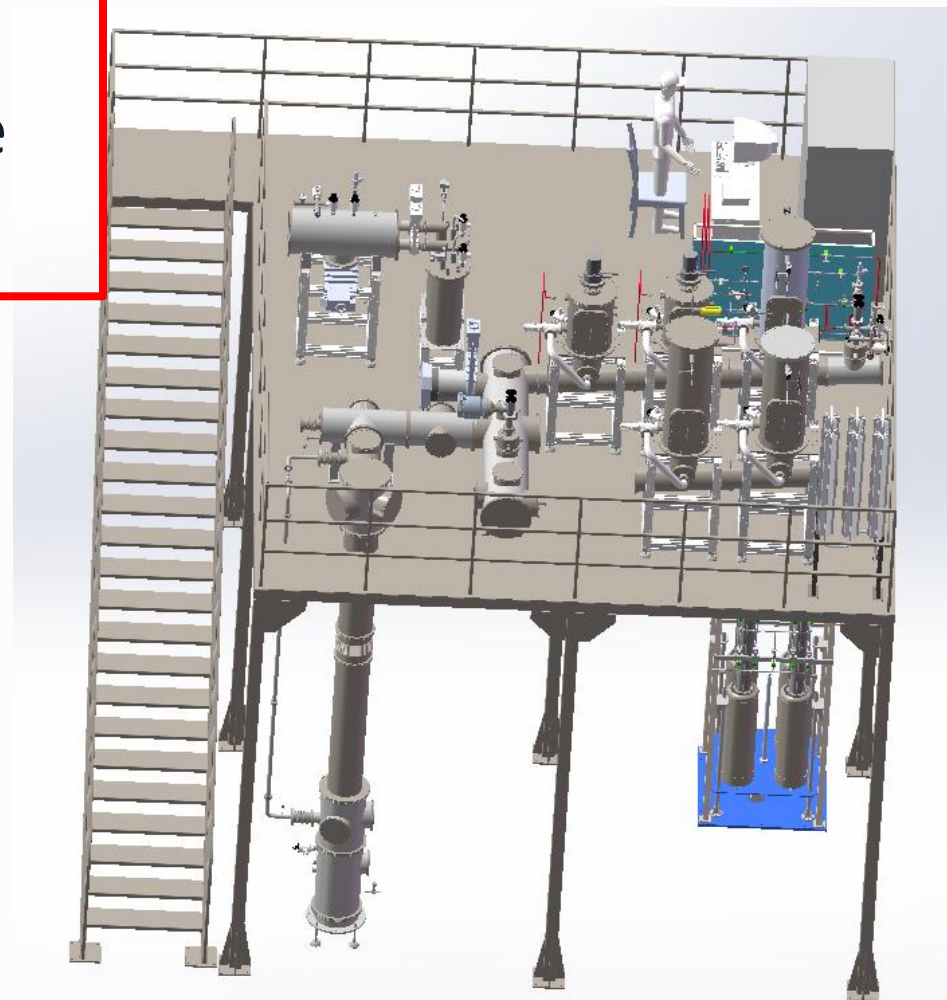
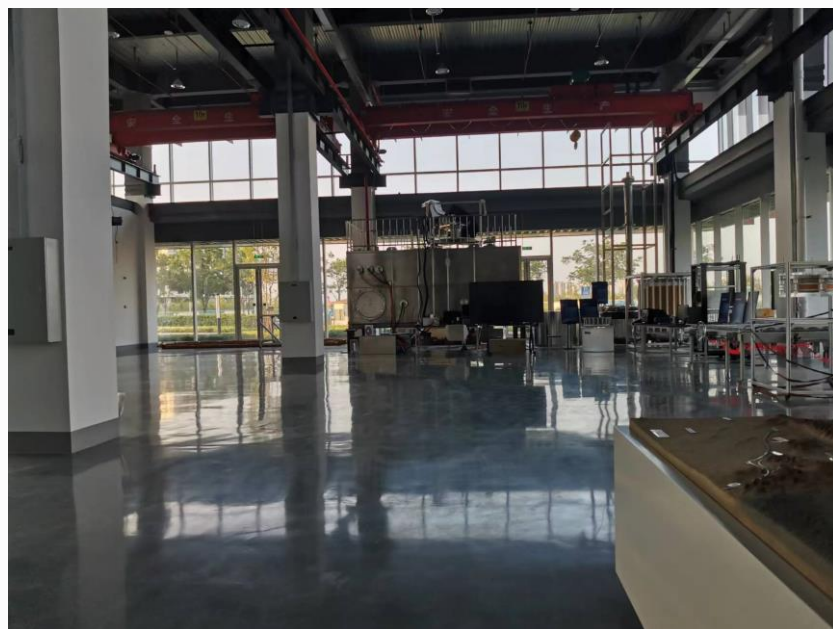
T fluctuation (1500W@178K)



Xinbei Jiang *et al* 2022 JINST
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3.4 Cooling tower for future 30T

Cooling tower prototype for 30T is being designed and produced, will be installed and tested at TDLI.



3.5 Online purifying for future 30T

Purification using hot Zirconium getter: to remove non-noble impurities and improve the collection efficiency of drifting electrons in liquid Xenon.

Xenon: ~500Kg
Purifying speed: ~30slpm
Requirement: $\geq 100\mu\text{s}$
Maximum e_lifetime: $\geq 328\mu\text{s}$

Xenon: ~1.1T
Purifying speed: ~50slpm
Requirement: $\geq 350\mu\text{s}$
Maximum e_lifetime: $\geq 800\mu\text{s}$

Xenon: ~5.8T
Purifying speed: 100slpm
Requirement: $\geq 800\mu\text{s}$
Maximum e_lifetime: $\geq 2000\mu\text{s}$

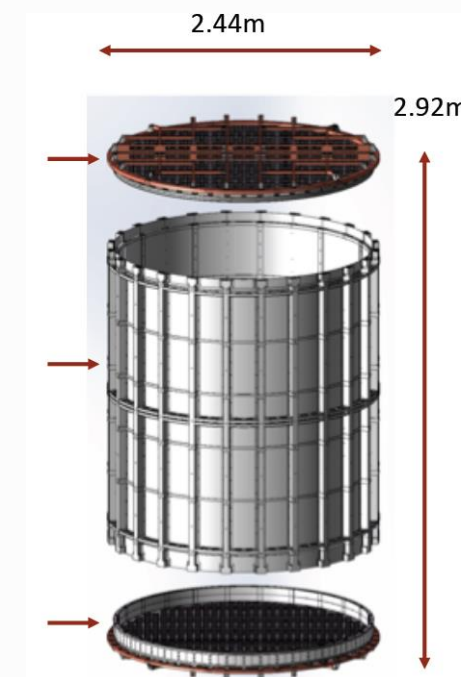
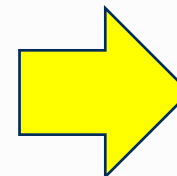
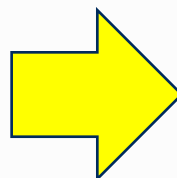
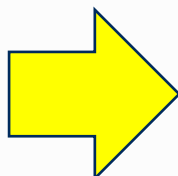
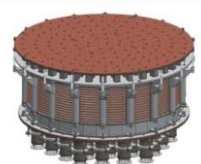
Xenon: ~50T
Purifying speed: $\geq 500\text{ slpm}$
Requirement: $\geq 2000\mu\text{s}$
Maximum e_lifetime: ?

TPC of PandaX-30T:
D: 244cm, H: 292cm

TPC of PandaX-4T:
D: 118.5cm, H: 118.5cm

TPC of PandaX-II
D: 60cm, H: 60cm

TPC of PandaX-I
D: 60cm, H: 15cm



3.6 Online purifying of other experiments

XENONnT:

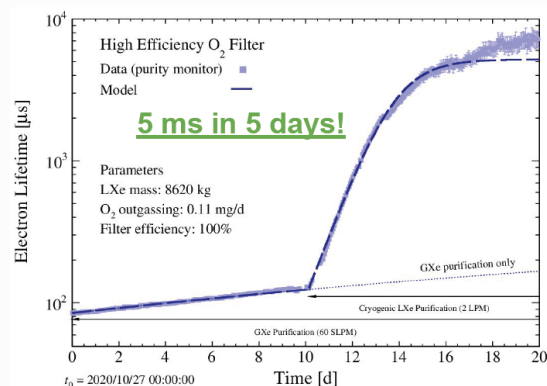
TPC: 1.4m diameter*1.4m height

Xenon: ~8.6T

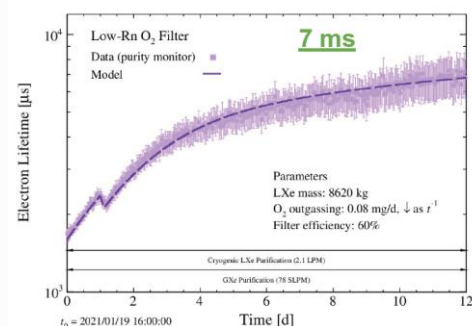
Purifying: **liquid Xe purification** (~2LPM, O₂ filter) + Gas Xe purification (~80 slpm).

Requirement: >0.933 ms

Maximum Electron lifetime: > 7ms.



- Switch to O₂ filter with ultra-low Rn emanation
- Reached electron lifetime of >7 ms



LZ:

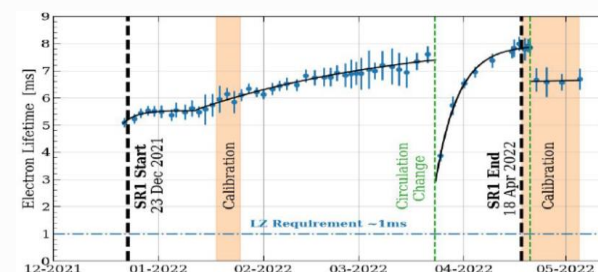
TPC: 1.5m diameter*1.5m height

Xenon: ~10T

Gas Xe purification: ~600 slpm.

Requirement: >1ms

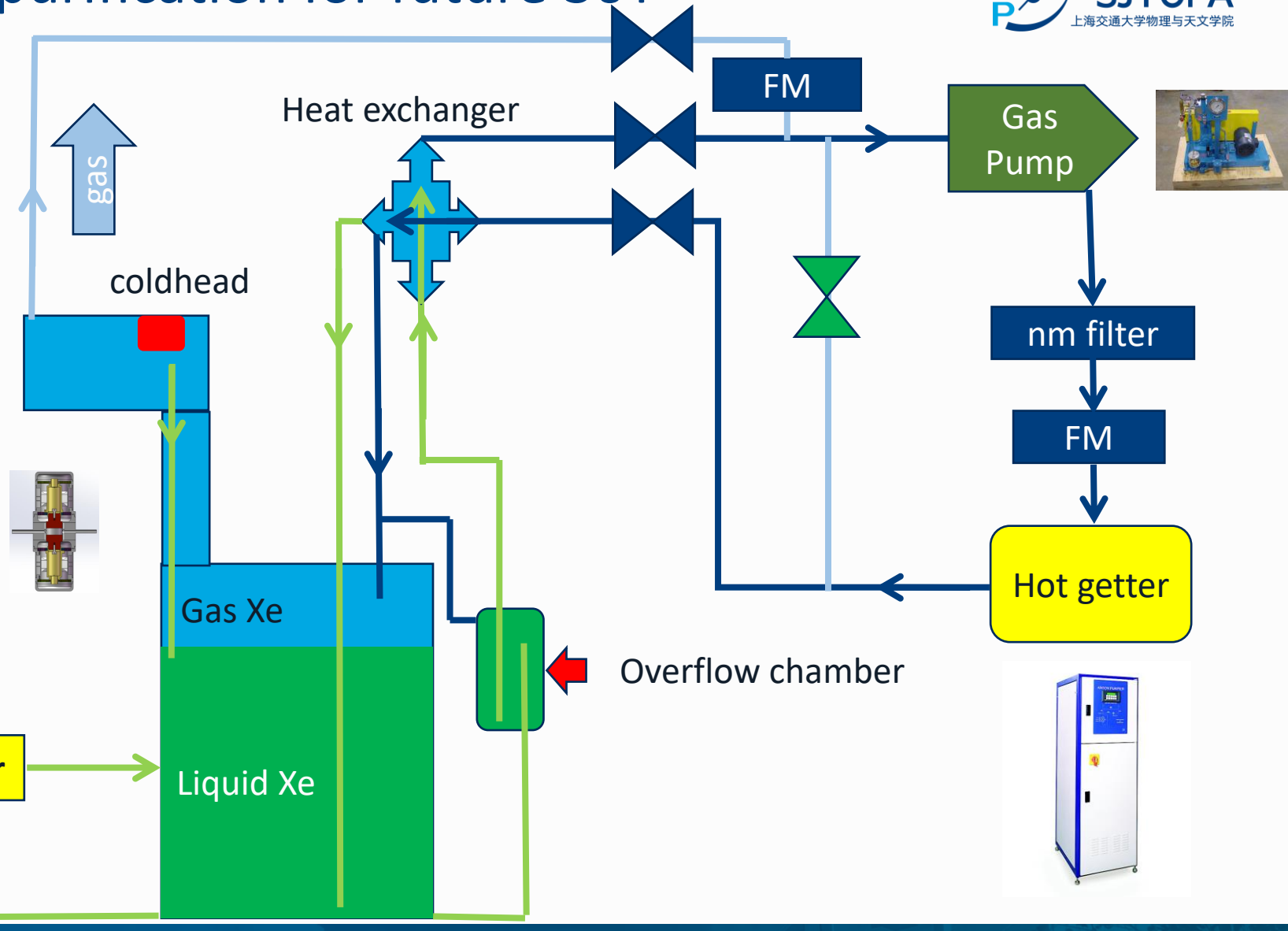
Maximum Electron lifetime: > 7ms.



3.7 Design of online purification for future 30T

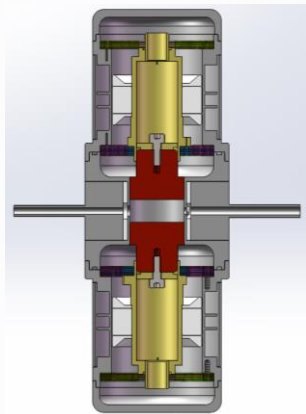
Both methods will be tested at TDLI :

- 1) **Conventional Method:** Gas Xenon purifying (liquid Xe $\rightarrow$ HE $\rightarrow$ gas pump+Hot getter $\rightarrow$ liquid Xe); **~ 500 slpm.**
- 2) **New cryogenic O2 Filter:** Liquid Xenon purifying (liquid Xe $\rightarrow$ Cryogenic pump $\rightarrow$ O2 filter $\rightarrow$ liquid Xe); ~ 1 lpm.
- 3) **Gas Magnetic drive pumps with lower radon:** self-designed.



4 Summary

1. The cooling tower ($\sim 580\text{W}$) of PandaX-4T works well;
2. Online purifying of PandaX-4T runs well, however, radon contribution need to be suppressed;
3. **Prototype Design** of cooling tower and online purifying **for PandaX-30T** is being designed, and will be tested in 2 years at TDLI.
4. **Gas Magnetic drive pumps** with lower radon are being self-designed and produced.



The light is ahead, and
we still need to work
harder.

T H A N K Y O U

