



LIDINE2025, Hong Kong



Noble gas impurities removal in PandaX-4T by Distillation

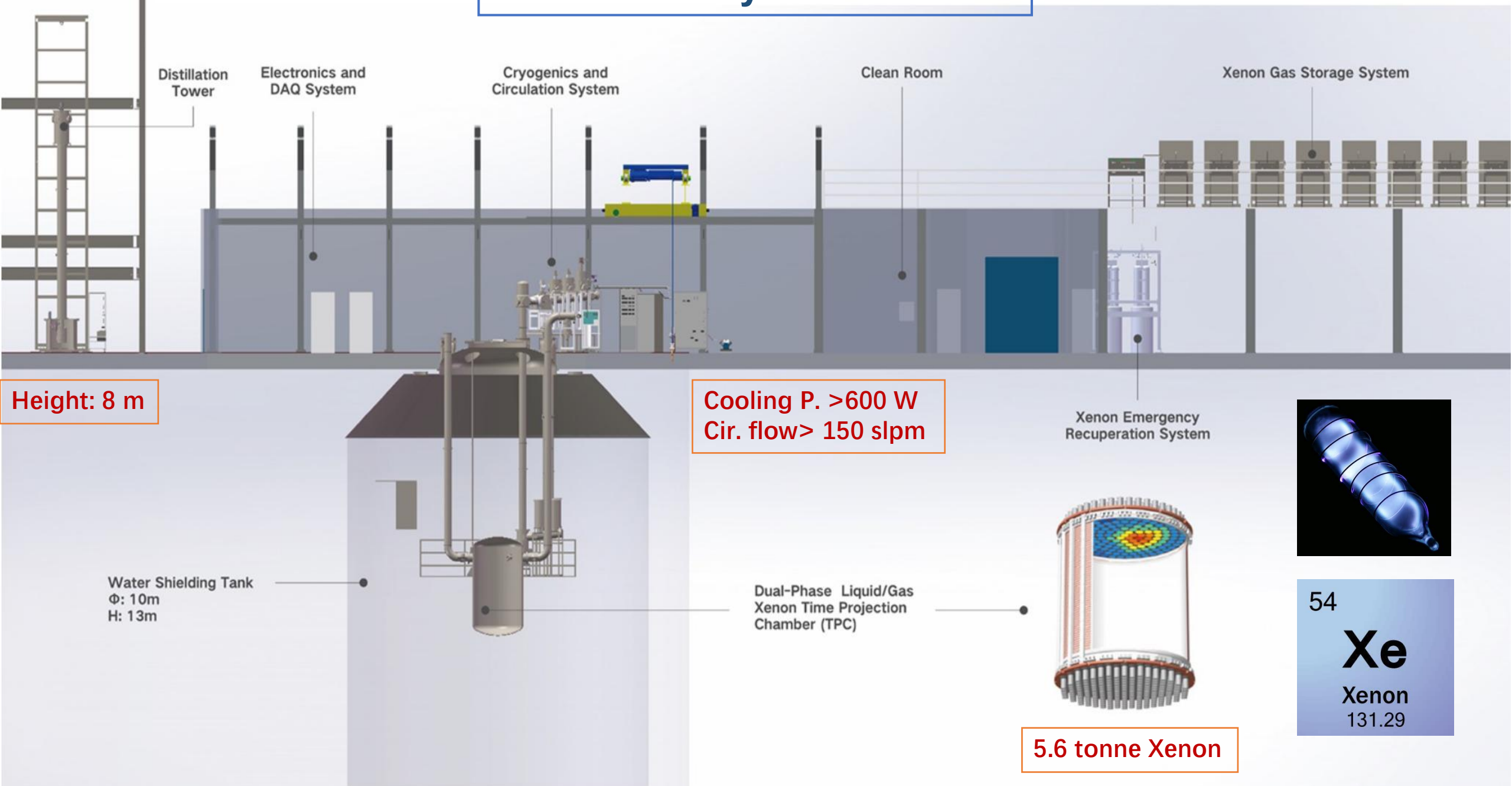
Xiangyi Cui *by PandaX Collaboration*

2025.10.22



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PandaX-4T Layout at CJPL-II



PandaX-4T Run history



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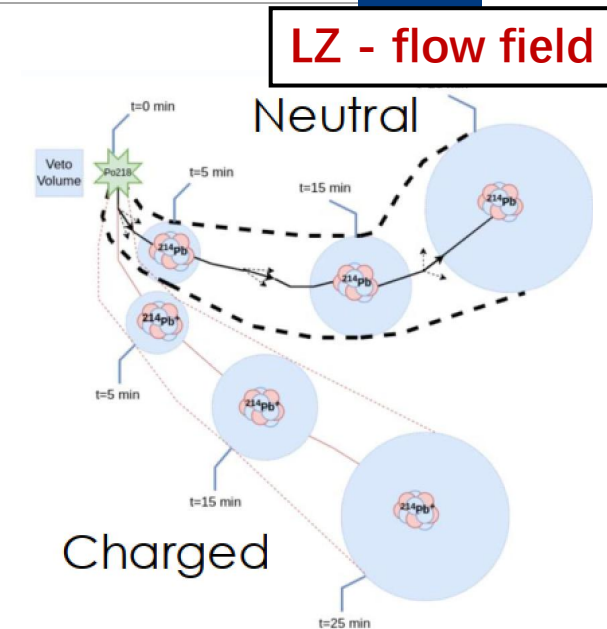
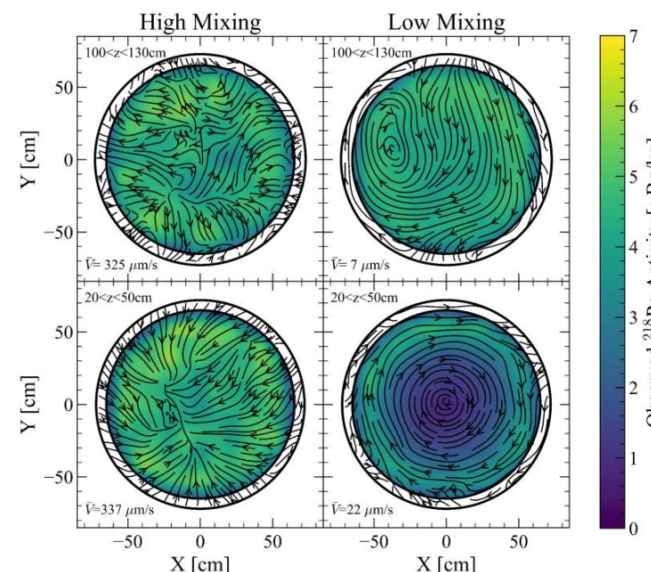
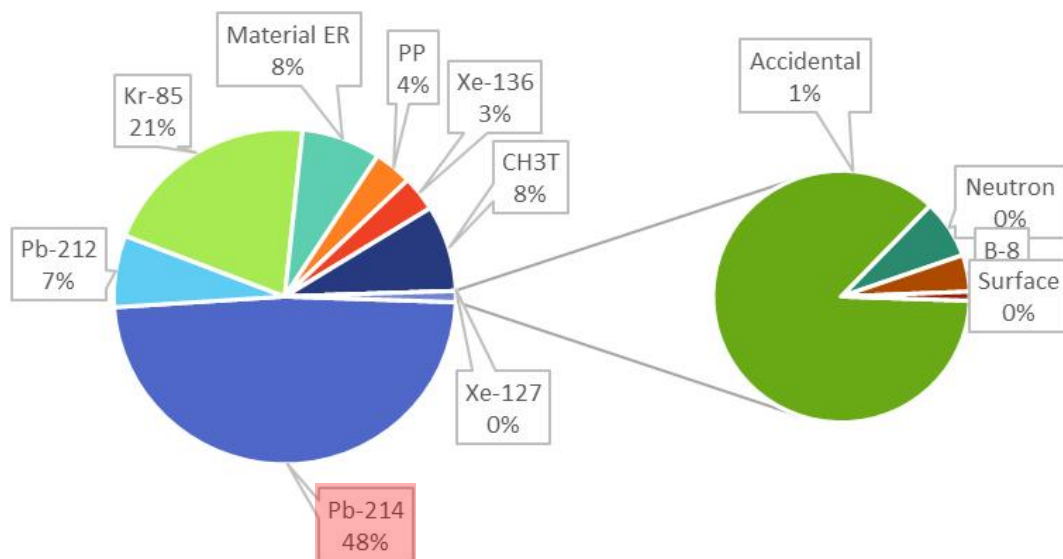
2020/11 – 2021/04	Commissioning (Run 0) 95 days
2021/07 – 2021/10	Tritium removal xenon distillation, gas flushing, etc
2021/11 – 2022/05	Physics run (Run 1) 164 days
2022/09 – 2023/12	CJPL B2 hall renovation xenon recuperation, detector upgrade
Current Status	Resuming physics data-taking



Background from noble gas impurities



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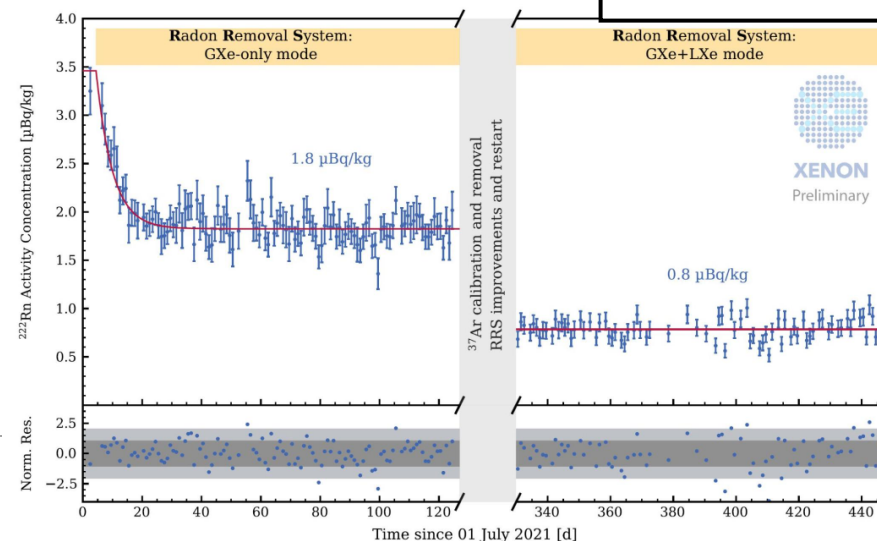


❑ Almost a half of BKG from Rn222 in Run1, 8.7 uBq/kg;

❑ Kr-85 not only affect the low energy region, but also important for the solar neutrino analysis;

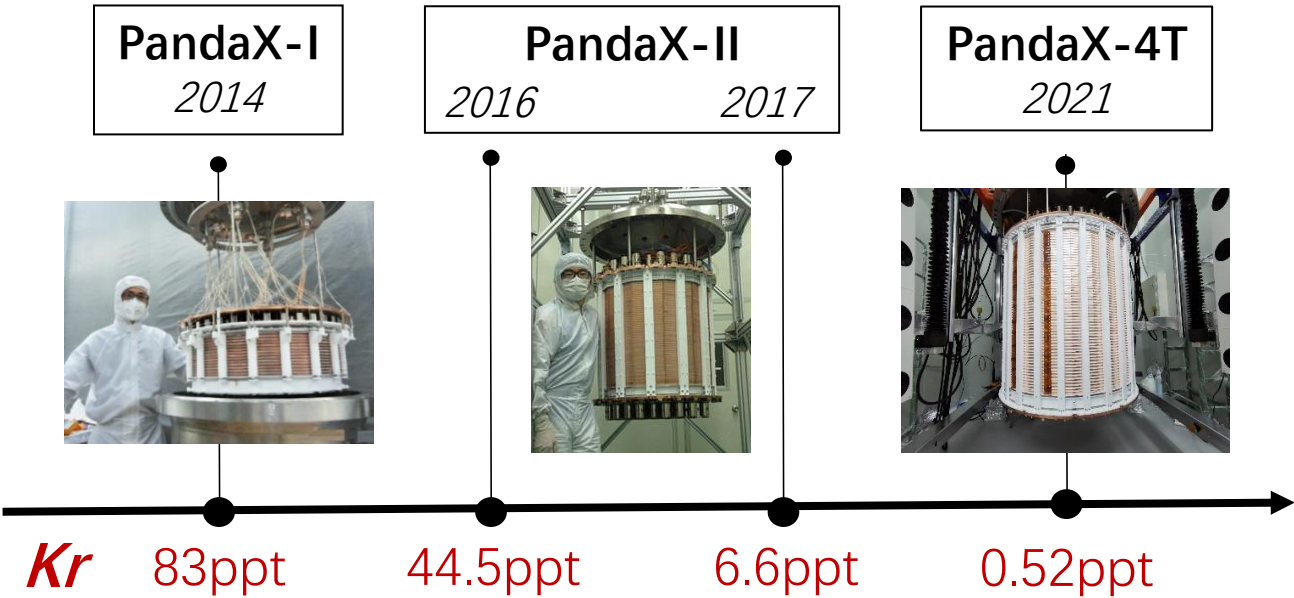
❑ LZ and XENON collaboration apply different method to suppress the radon contribution;

XENON - distillation



PandaX Distillation system

Phase-I Distillation



		Phase-I	Phase-II
Flow rate [kg/h]	Kr	5	10
	Rn	/	>50
Reduction by design	Kr	10^3	10^6
	Rn	/	10^3



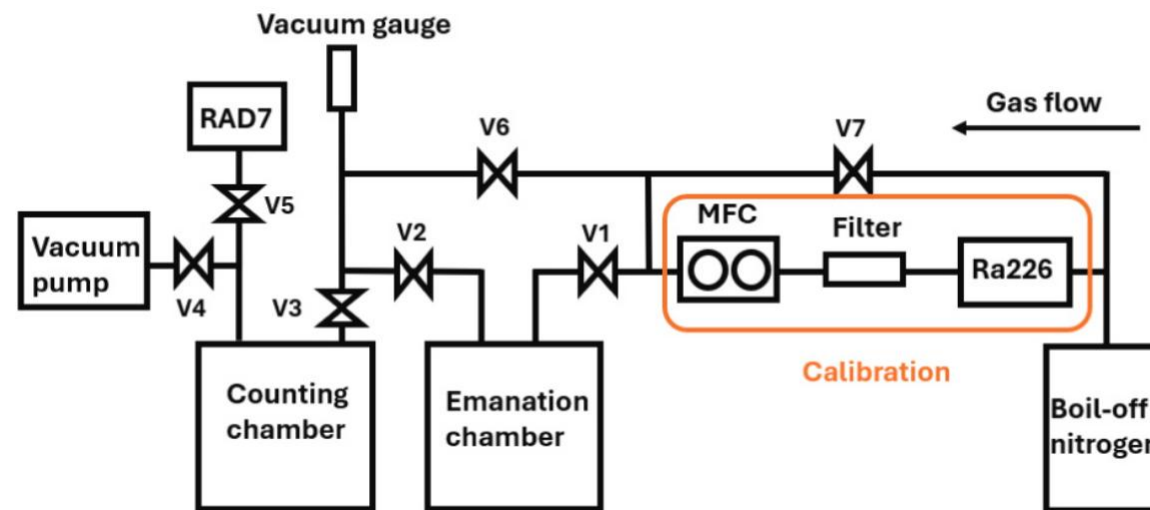
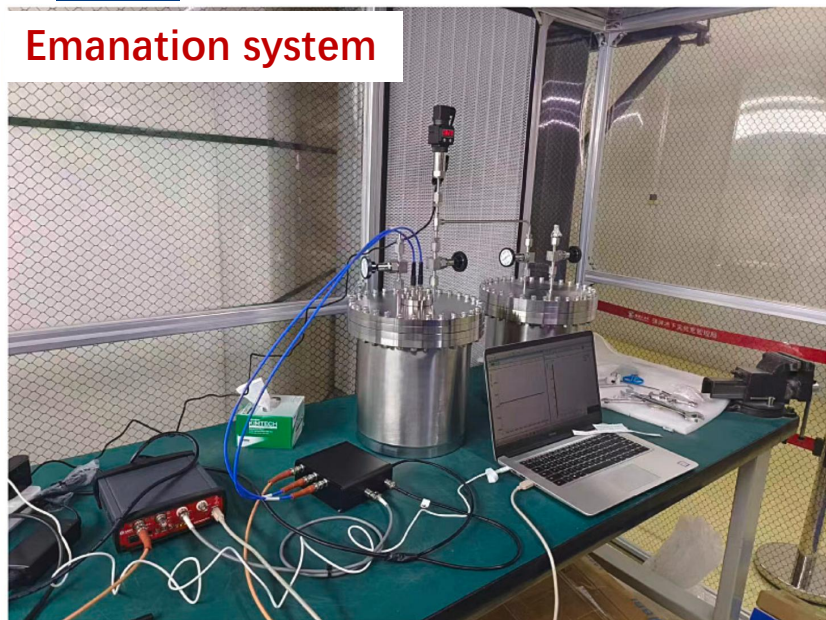
Phase-II Distillation

Radon measurement system



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Emanation system

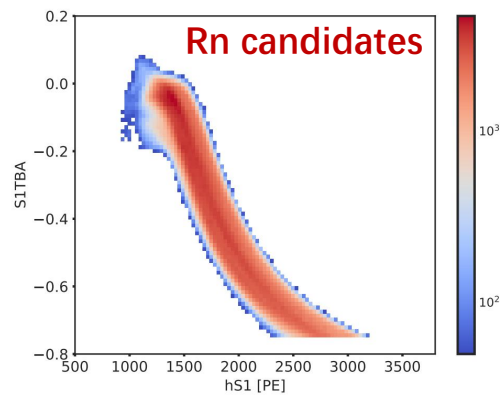
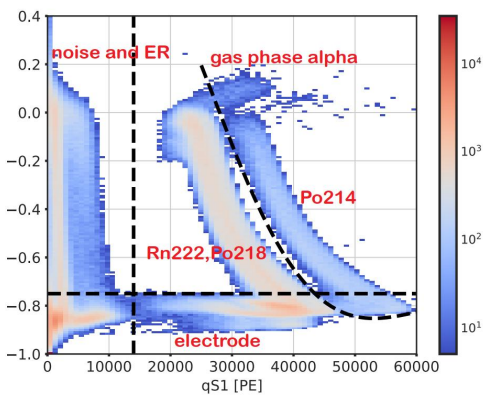
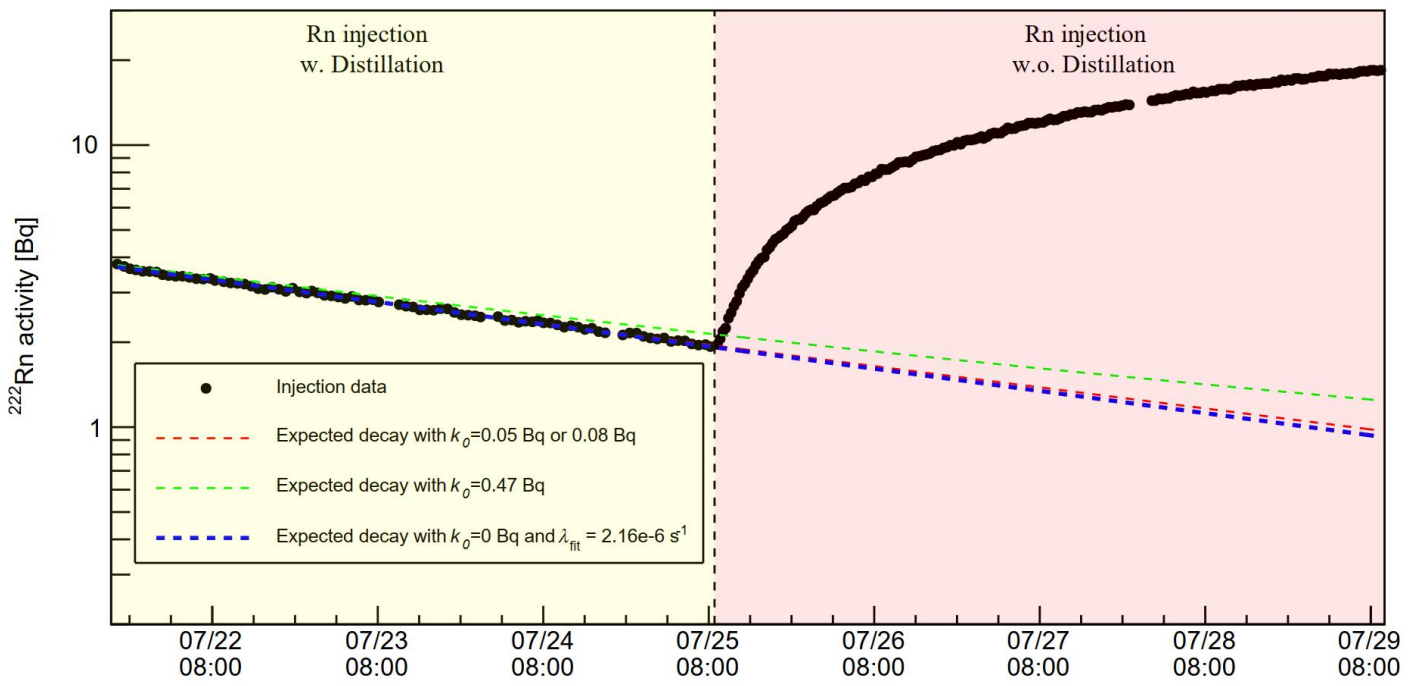


Radon trap system

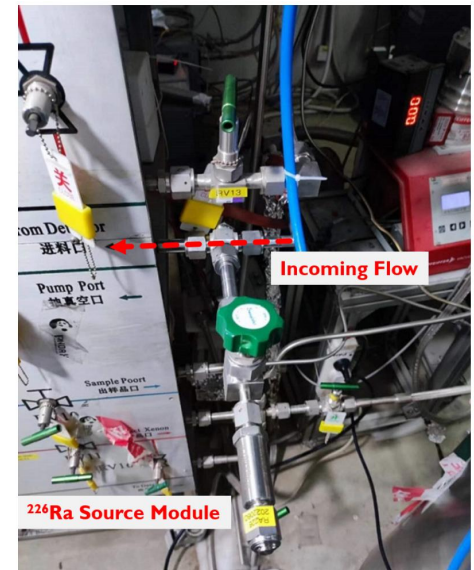
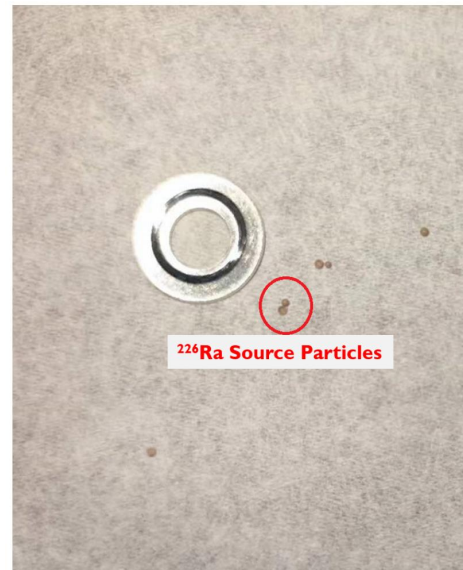


- ❑ Based on the electrostatic method, the radon measurement system is build with 0.03 mBq blank rate;
- ❑ For small samples or large chamber, the emanation system or a radon trap system used for the counting;

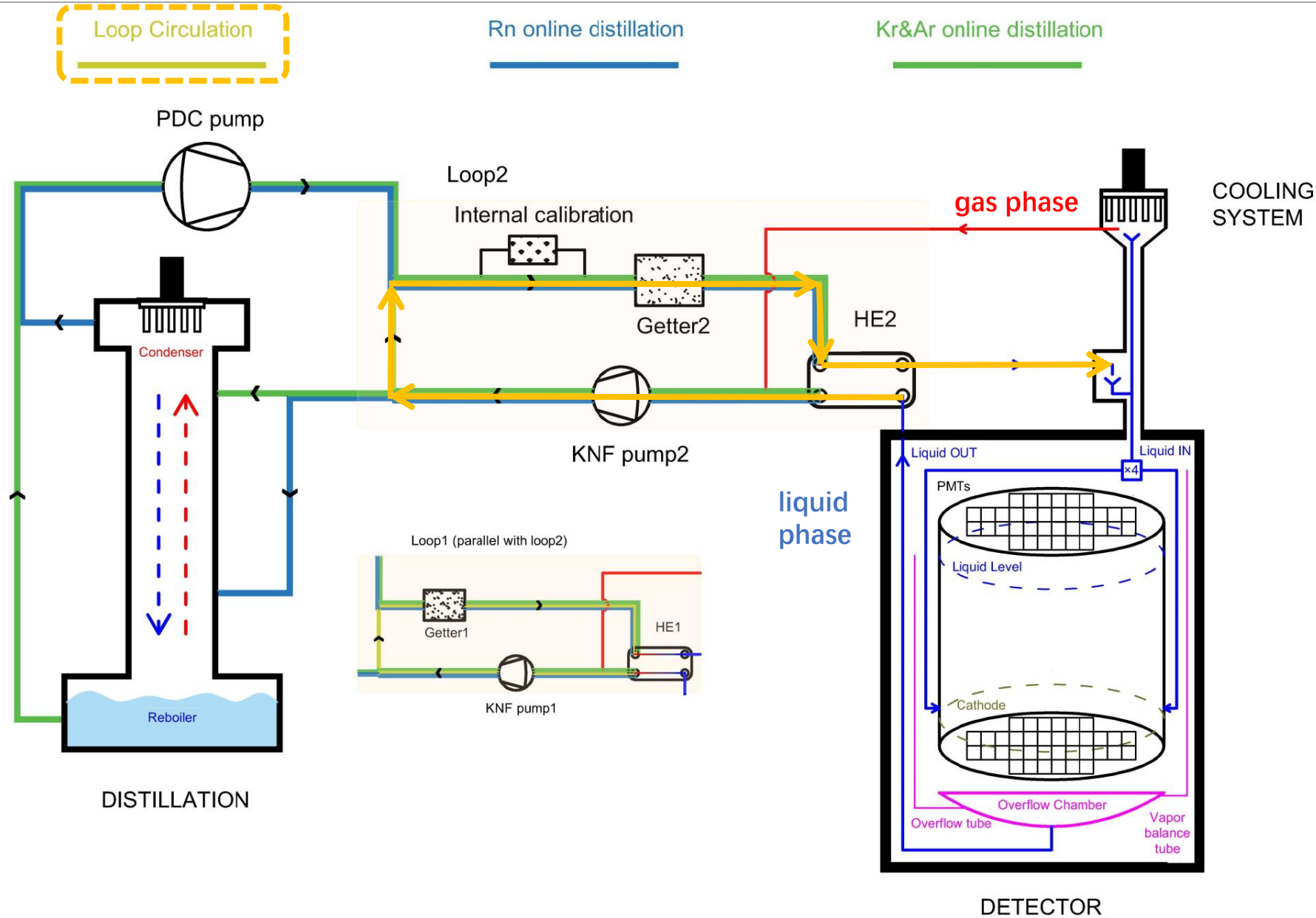
Suppression ability for Rn



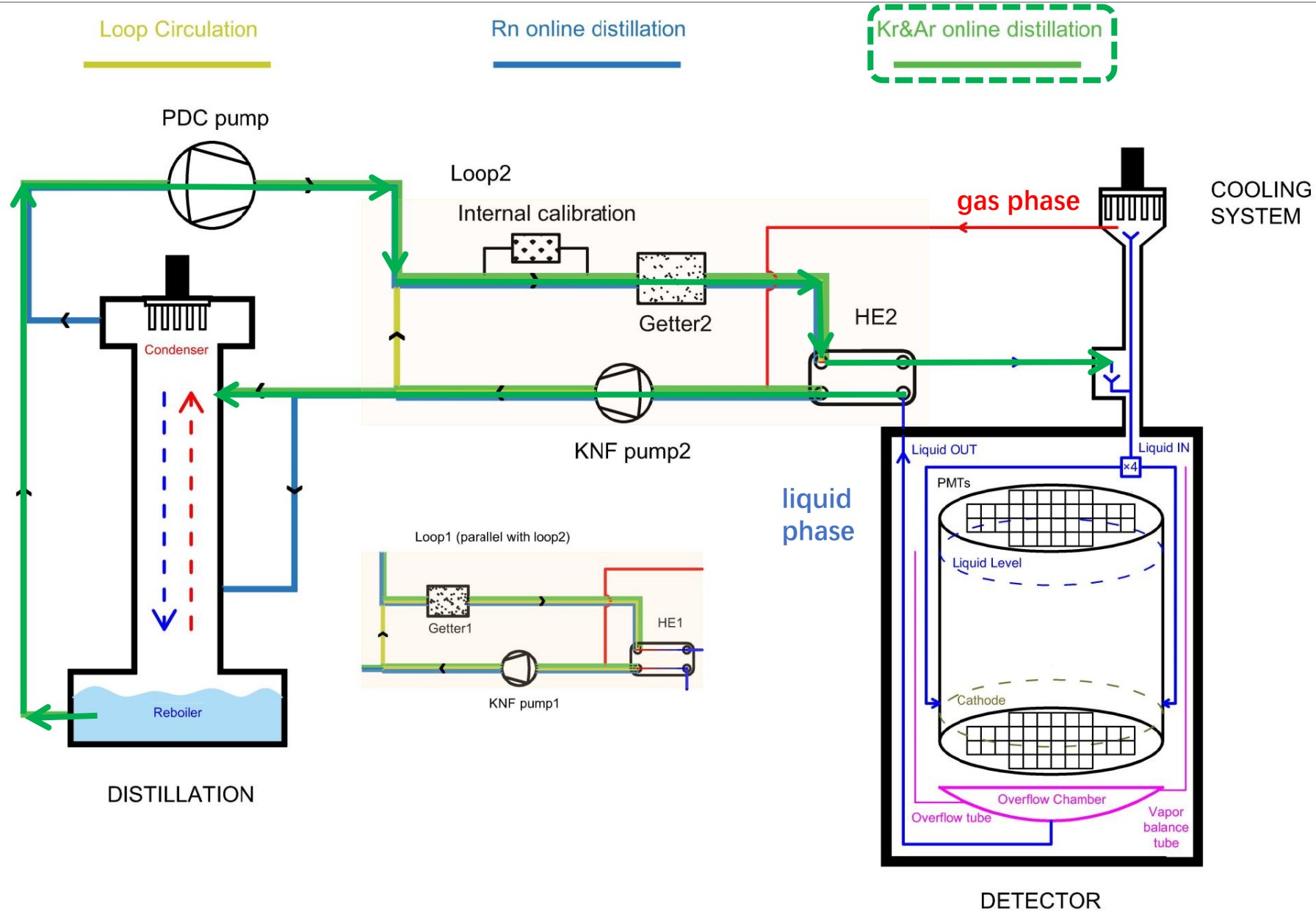
- With Ra-226 source, the radon reduction factor >190 by comparing the source flow pass or not the distillation system.



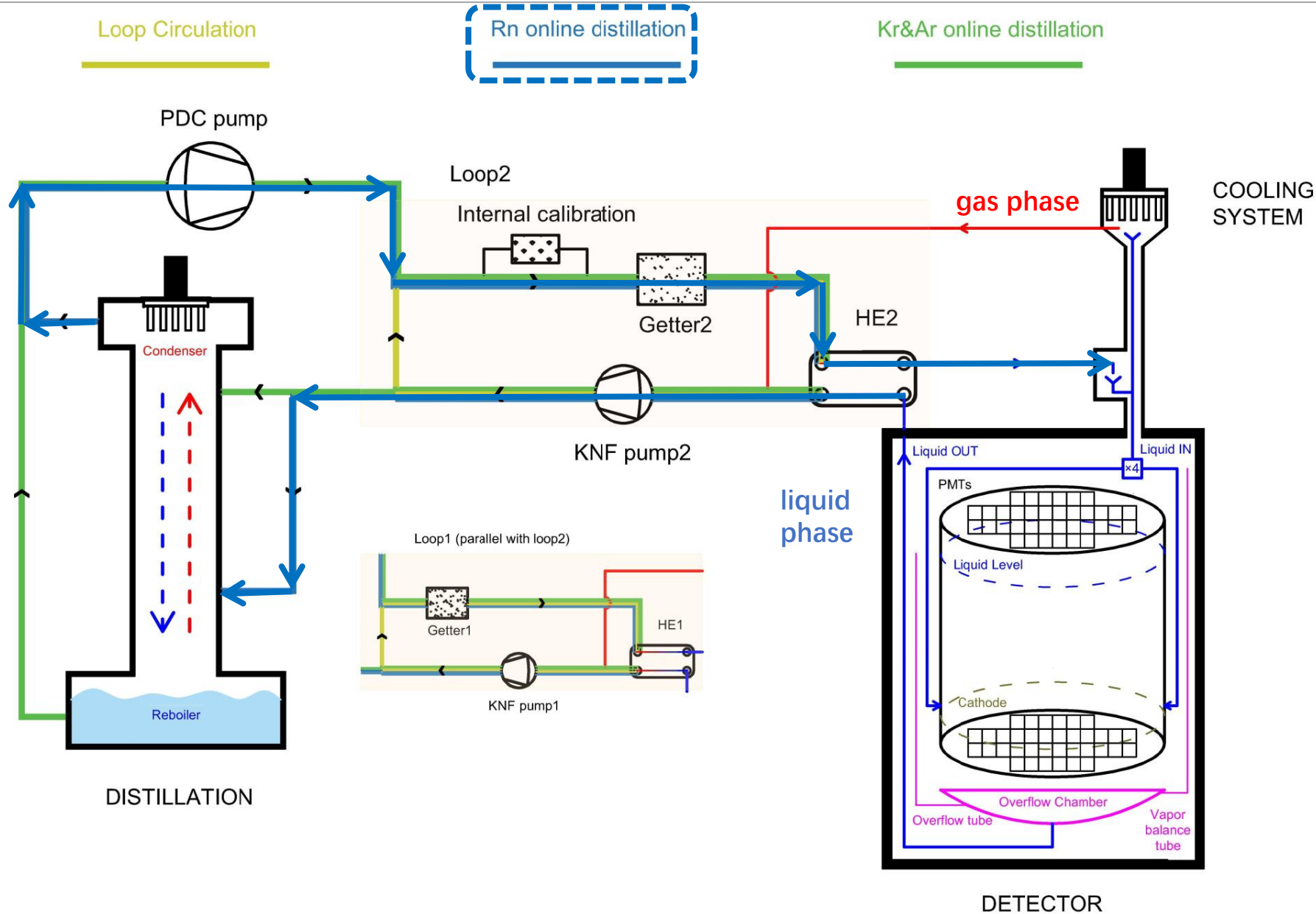
PandaX-4T online diagram



PandaX-4T online diagram



PandaX-4T online diagram



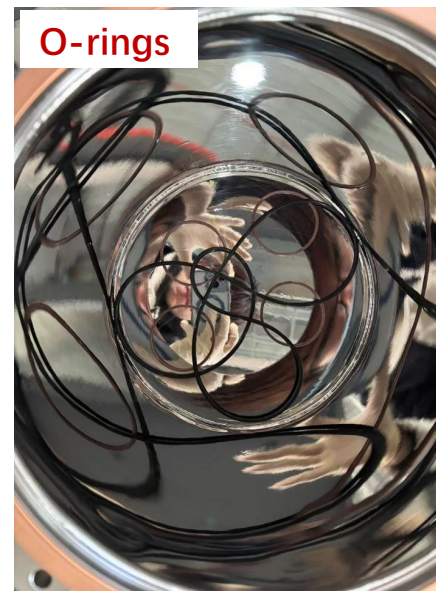
PDC pump



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PDC pump



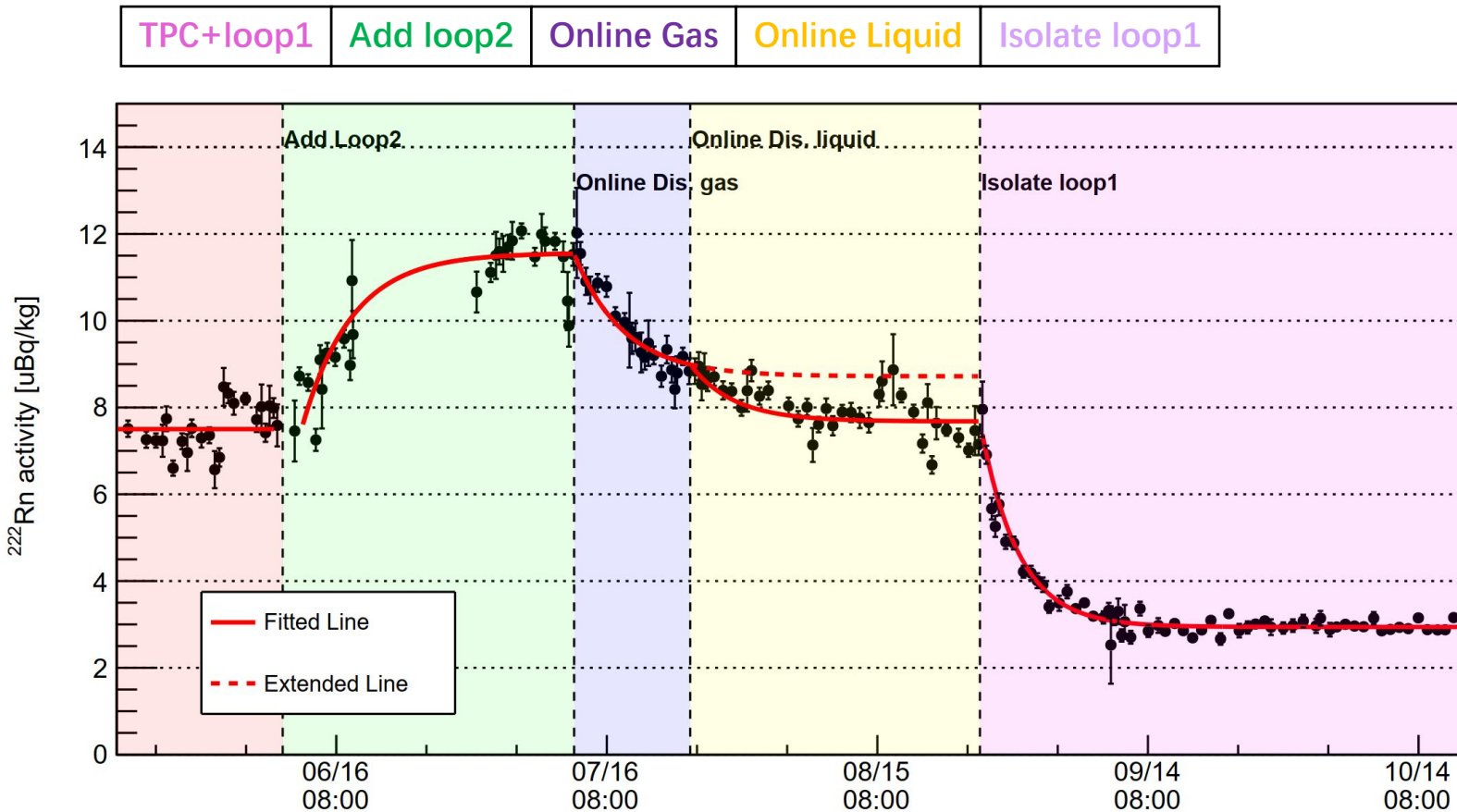
O-rings



check valves

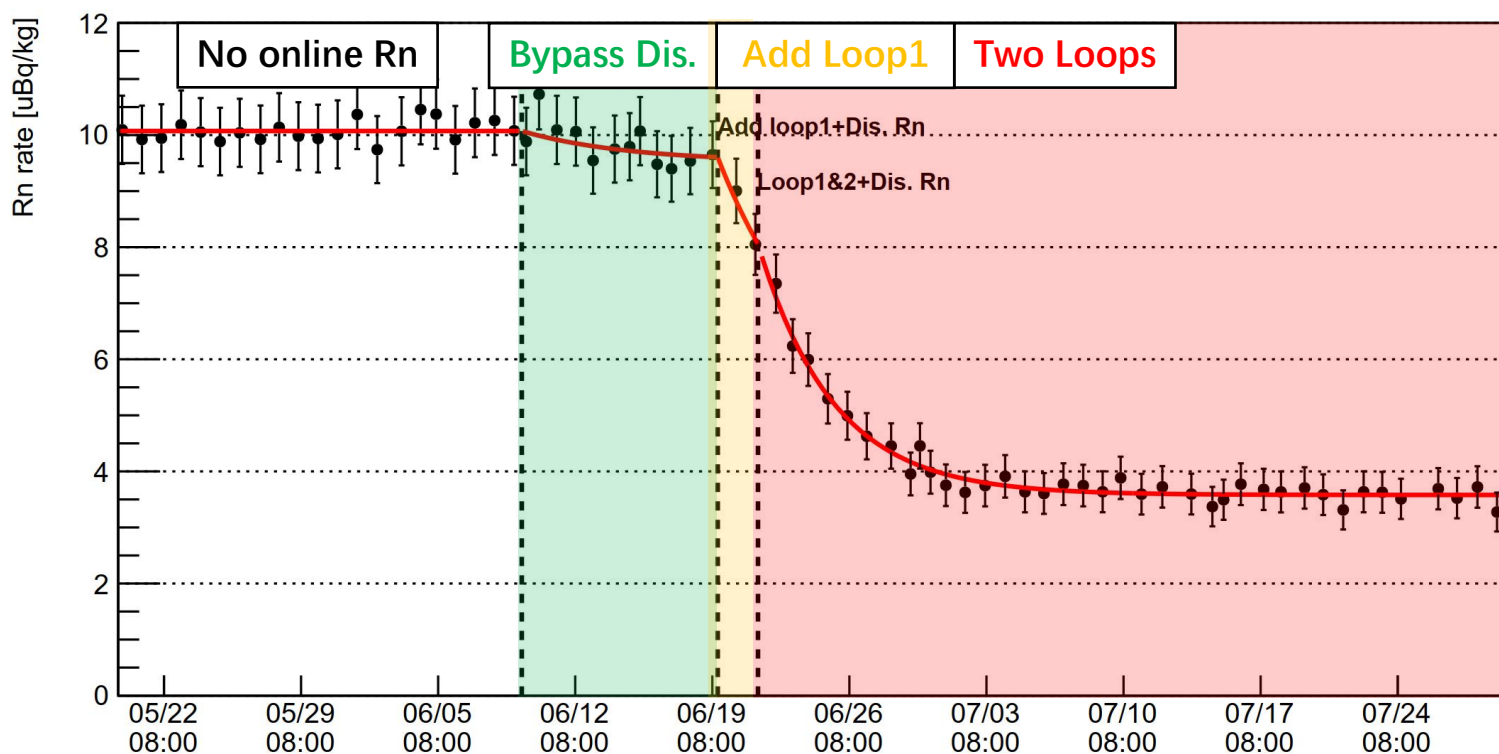
- ❑ By the Rn measurement system, PDC pump and each PDC un-metal parts are tested that 1.1 mBq in total;
- ❑ PDC pump coupled with the circulation system at 2025/04;

Rn online distillation with loop2-only



- With online Rn distillation **40 slpm** and loop1 isolated, the Rn level decrease to **3 uBq/kg**;
- Loop parts contribute a large Rn contamination to the detector;

Rn online distillation with two loops



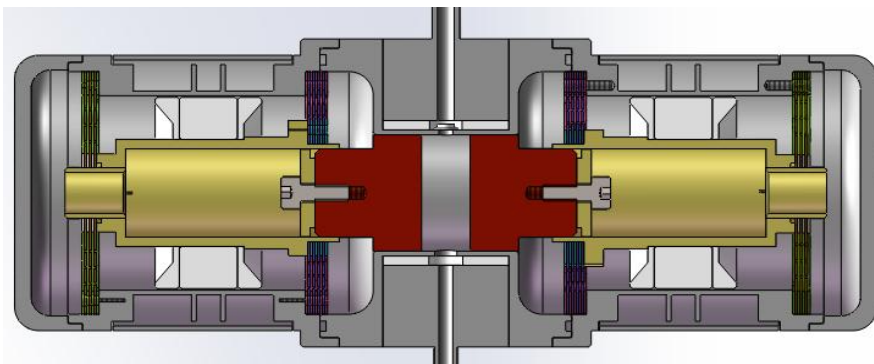
Rn contribution [uBq/kg]	
Loop1	4.7 ± 0.6
Loop2	3.1 ± 0.3
TPC	2.13
Distillation+PDC	0.56

- ❑ With two loops, the radon level stable at **3.6 uBq/kg at 60 slpm**, higher than loop2-only mode;
- ❑ Loop1 parts downstream the distillation system beat the higher Rn online flow rate;

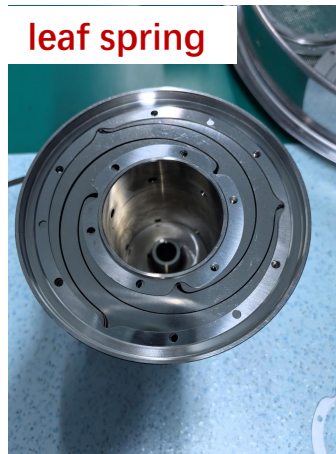
Magnetic-driven pump - custom-designed



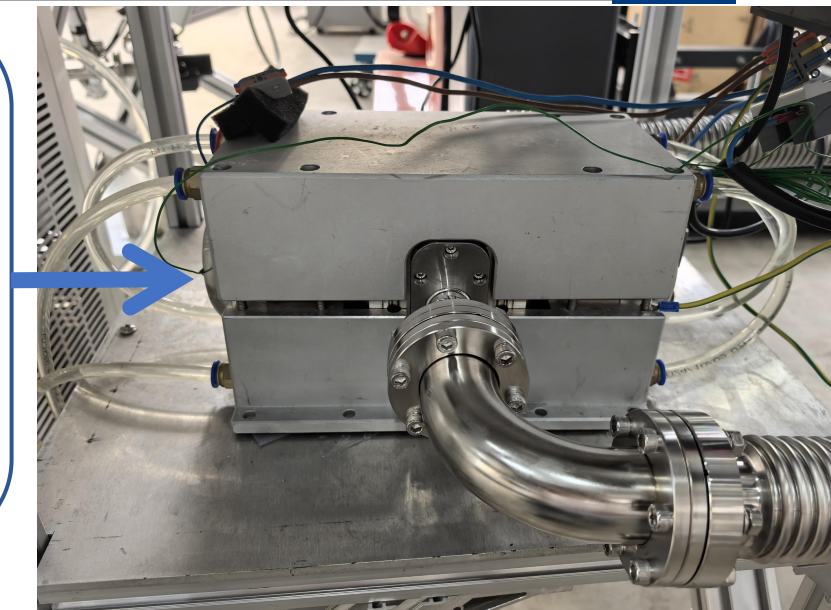
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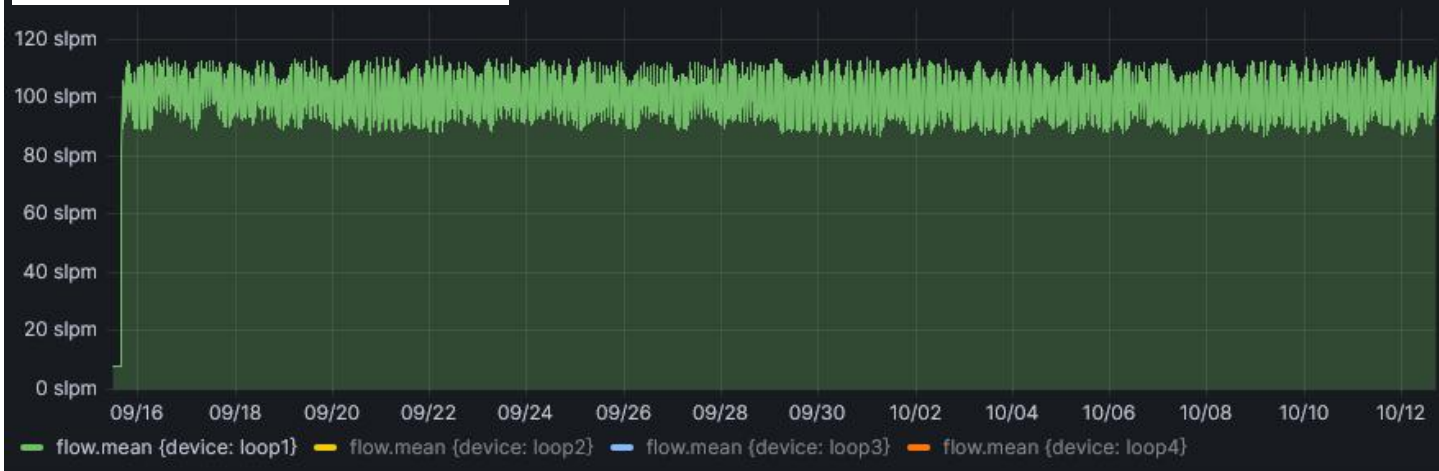
leaf spring



piston



Flow of self-circulation



- ❑ Permanent magnetic-driven gas pump is made and did self-circulation for 3 months with 100 slpm Argon;
- ❑ 0.55 mBq radon emanation rate with the pump ON;

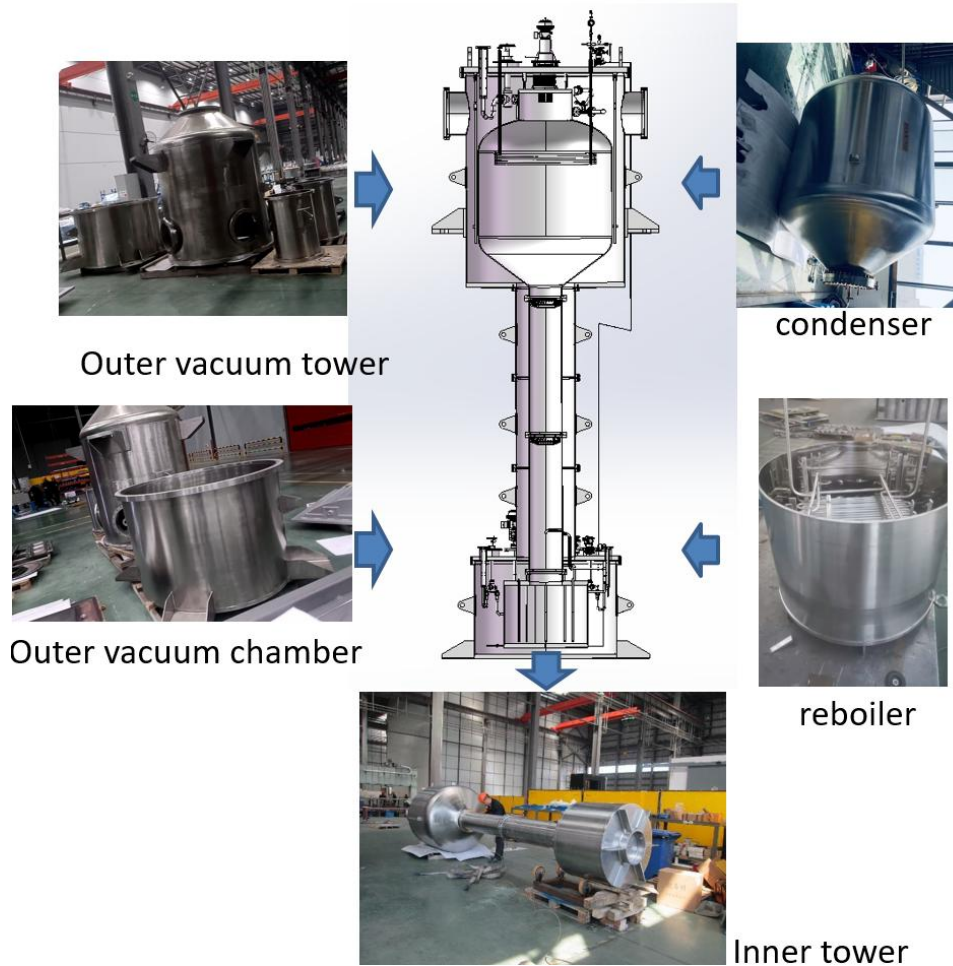
Further improvement - PandaX-xT distillation



Kr tower



Rn tower



New Kr tower:

▣ Handling flow rate increase to 30 kg/h;

▣ Target Kr in LXe: <0.1 ppt;

New Rn tower:

▣ Handling flow rate increase to 860 kg/h;

▣ Target Rn in LXe: <1 uBq/kg;

- ❑ Rn removal ability of the PandaX-4T distillation system has been studied by injected Rn source;
- ❑ Rn measurement system with $3\text{E-}2$ mBq background helps to identify the Rn contamination from circulation pumps and other parts;
- ❑ The online Rn distillation process has been applied and the radon level decrease to 3 uBq/kg;
- ❑ Radon emanation rate from different parts are studied based on the on-site Rn analysis;
- ❑ More studies are ongoing, like gas-circulation mode, online flow efficiency;



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