Final cleaning of the acrylic sphere

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Simple history of cleaning (11.18-12.2)

- 11.18-11.20: veto system run without cooling and radon removal system, which lead to temperature of cleaning water 27°C, radon in water is 3 Bq/m3. Total cleaning time is about 10 hours.

- 11.21: cleaning time is about 10 hours, while changing nozzle height and remove paper from bottom takes about 2 hours, water system debugging takes about 3 hours. Radon in water decreased to 0.2 Bq/m3 and temperature at 20°C

- 11.22-11.23: 14 hours per day, working from 7:00 to 2:00 next day

- 11.25: 12 hours, change DN50 SS pipe to DN80 SS bellow, water flow from 64 m3/h to 73 m2/h

- 11.26-27: 18 hours per day, working for 24 hours, decrease the rotation speed of the nozzle, most of the paper film were removed

- 11.28: 8 hours, try to change SS bellow to PPR pipe, failed and changed back to SS bellow and continue flushing

- 11.29: 10 hours, calibration expert Yue go into the bottom chimney and repair their CLS line for 2.5 hours. The particle counting became stable after 8 hours flushing, that means the particle introduced from the people going inside is removed.

- 11.30: 18 hours

- 12.1: 13 hours, change nozzle height to flush the top and bottom layers, try fixed point injection

- 12.2: 14 hours, there are still three large pieces of paper film on the acrylic surface, and four persons go inside the acrylic and removed them by a 15m long pole. After that operation, flush the acrylic for 9 hours, and the particle counting is stable and near JUNO 50 requirement, so we finished the flushing at 23:30 on 12.2

Information from cleaning

Cleaning exposure: totally 15 days, effective flushing of 6.6 days

Radon in air inside the acrylic sphere: ~50 Bq/m3
- Radon in top EH ~130 Bq/m3, radon in bottom EH ~170 Bq/m3
- Radon inside the acrylic sphere: equilibrium of decay and radon leaking during top and bottom flange opening for paper removal and nozzle adjustment

Possible contamination sources:
- Cleaning water absorbed in acrylic: radon and daughters
- If no water flushing on the acrylic surface, the acrylic surface is exposed to radon, which will lead to radon diffusion and daughters fallout on surface
- Residual paper film

Cleaning water absorbed in acrylic

Experimental data:

- Since the radon in air inside the acrylic is 50 Bq/m3, the radon in water can reach ~10 Bq/m3 (for calculation)

- 2mm acrylic panel soaking in water for two months

- Based on the curve, water absorbed in acrylic for 6.6 days soaking is 19 g/m2, totally 77 kg

Background estimation

- 10 Bq/m3 radon in water, acrylic absorbed 77 kg

- Assume all the radon daughters go into LS, will lead to 6e-27 g/g ^{210}Pb in LS

- Negligible
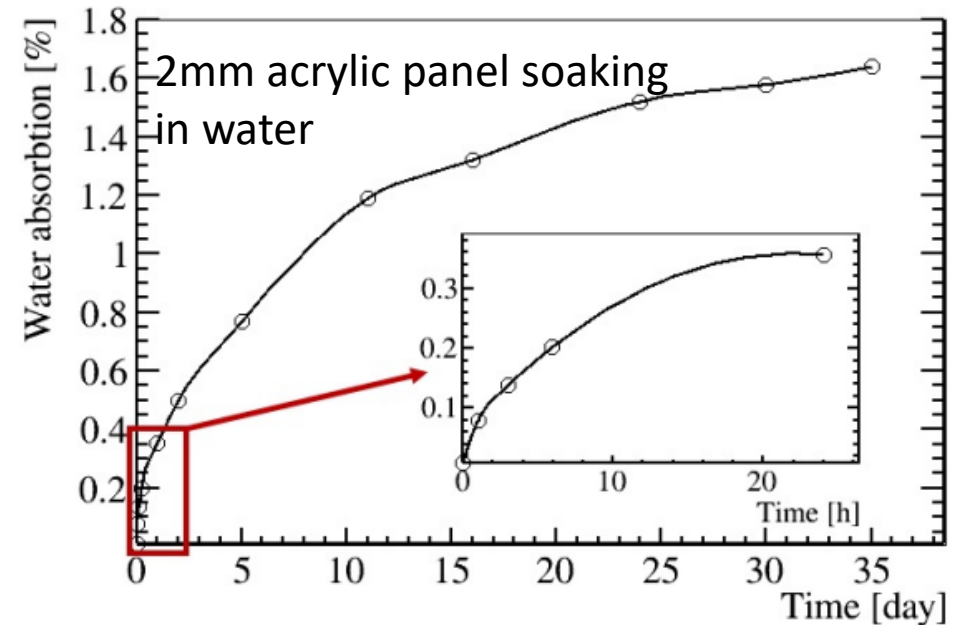
*Ref: Yuanxia Li et al 2023 JINST **18** P05023*

Exposed to radon in air without water film

Experiment data

- 0.17 m2 acrylic panel exposed in top EH (180 Bq/m3 radon in air) for 194 days, measure the alpha rate from acrylic surface
- Different sampling direction (up, bottom, sideway), different surface treatment before measurement (paper wipe, alcohol wipe, water flushing)

	Downwards (untreated)	Sideways (untreated)	Upwards (Paper wipe)	Upwards (Water wash)	Downwards (Water wash)	Upwards (alcohol wipe)	Downwards (alcohol wipe)	Blank (Cu bkg)	No exposure
Contamination of sample + gas [uBq/cm^2]	0.91 ± 0.03	0.82 ± 0.03	0.45 ±0.03	0.36 ±0.02	0.36 ±0.02	0.18 ±0.02	0.18 ±0.02	None	0.20 ±0.02
Background of cathode Cu + gas [uBq/cm^2]	0.24 ± 0.02	0.24 ± 0.02	0.24 ± 0.02	0.24 ± 0.02	0.24 ± 0.02	0.24 ± 0.02	0.24 ± 0.02	0.24 ± 0.02	0.17 ± 0.02
Estimated contamination of sample [uBq/cm^2]	0.73	0.64	0.27	0.18	0.18			none	0.03± 0.01
Fall out rate @100Bq/m^3 (bkg substracted) [mBq/day/m^2]	0.021	0.018	0.008	0.005	0.005				
Fall out rate @100Bq/m^3 (with bkg) [mBq/day/m^2]	0.026	0.023	0.013	0.010	0.010	0.005	0.005		

Doc12134

Exposed to radon in air without water film

Experimental conclusion

◦ Samples of upwards and downwards with water flushing, the results are similar, and we take the average value to be 0.01 mBq/d/m2 @ 100 Bq/m3 radon environment (upper limit without background subtraction)

◦ While the DYB model (Doc11160), the fallout rate is 0.5 mBq/d/m2 @ 100 Bq/m3, which is 50 times larger than the experimental results, since the DYB model includes many uncertainties, such as contamination from production, surface treatment, exposure environment etc.

Background estimation

◦ We assume the water film can avoid radon daughters fallout on acrylic surface. Radon in air is 50 Bq/m3

◦ From 11.18-11.28, effective water flushing is 4.3 days, that means the exposure without water film is 6.7 days. Assume paper film residual 50%, → 1.2e-24 g/g ^{210}Pb, 300 cpd/kt ^{210}Po in LS

◦ From 11.29-12.2, effective water flushing is 2.3 days, that means the exposure without water film is 1.7 days. Assume paper film residual ~100% → 0.6e-24 g/g ^{210}Pb, 150 cpd/kt ^{210}Po in LS

◦ Conservative assumption: assume all deposited Pb/Po leaching into LS → 1.8e-24 g/g ^{210}Pb, 450 cpd/kt ^{210}Po
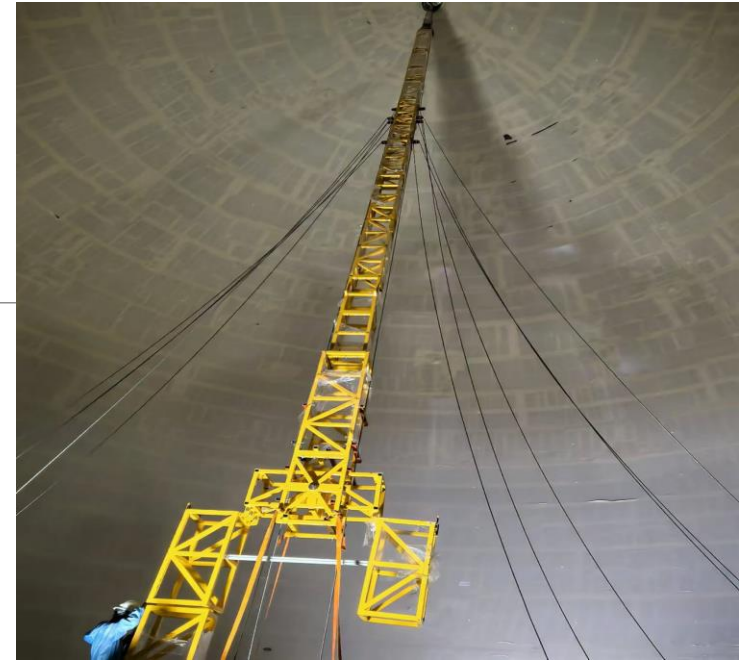
Residual paper film

Most of the residual is on the bonding line with epoxy on the top hemisphere.

◦ All the paper film on the lower hemisphere bonding line are removed during the repairmen by the yellow structure

◦ However, the yellow structure can not go to top hemisphere, thus the paper film on the bonding line are not removed on the top hemisphere

Careful check by workers from Donchamp and firemen (above -2 layer)

◦ About 5-7 m2 (0.15% of acrylic surface) by eye check, some pictures in next slide. The shape is not regular.

4-5赤道0

2cm

4-5赤道
3cmX2cm

4-5第五层
4cmX3cm

4-5第五层
三处平均15cmX2cm

5-6第六层
1.5mX5cm
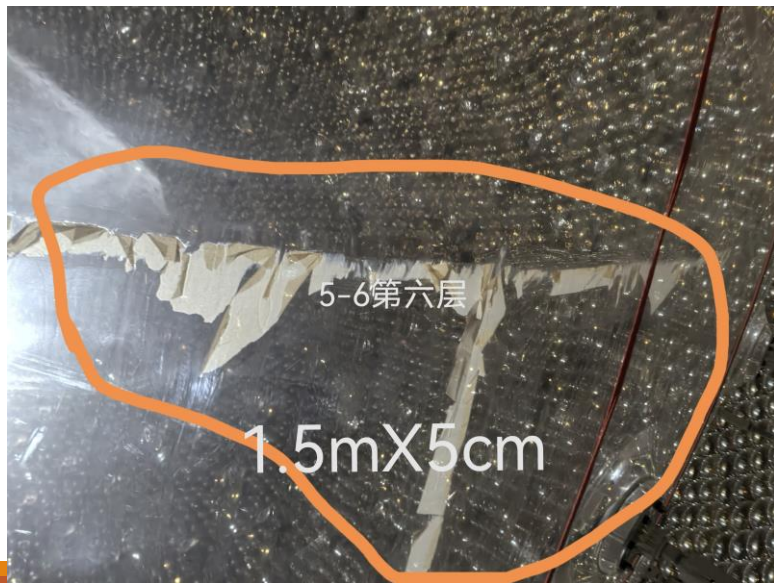
Effect of residual paper film

For ICP-MS

Background test
- Paper film soaked in LS at 80°C for 24 hours, which equals to 244 days soaking at room 21°C
- U/Th leaching from paper film: 2.3×10^{-20} g/g per m2 per year → negligible
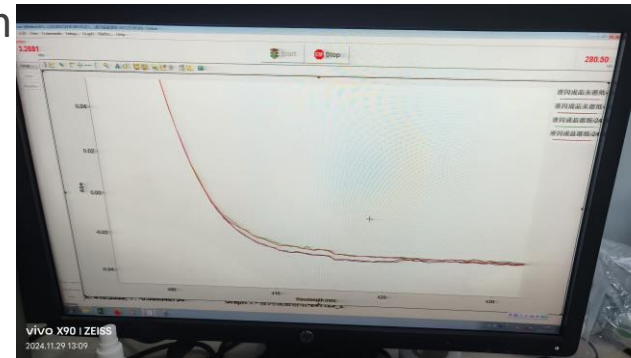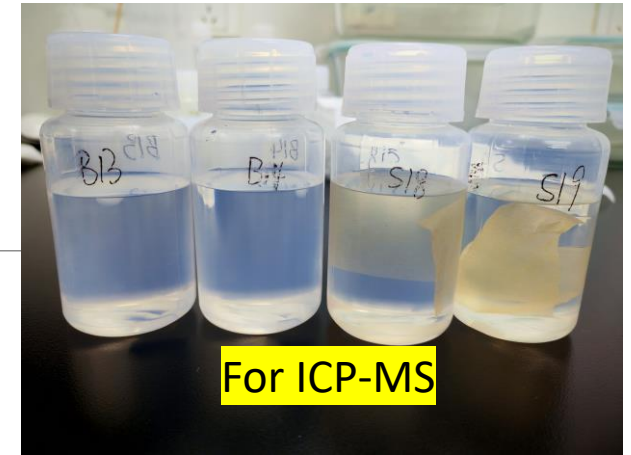
Compatibility test
- Paper film soaked in LS at 90°C for one week, which equals to 10 years
- No obvious change, the paper film will sink to bottom

Absorption spectrum test
- Paper film soaked in LS for 24 hours, no change on the absorption spectrum

Conclusion
- Residual paper film blocking 0.15%, no obvious effect on background, compatibility and absorption spectrum

Summary

Cleaning exposure: totally 15 days, effective flushing of 6.6 days

- Radon inside acrylic sphere: ~50 Bq/m3 from 11.18-12.2
- Both the top and bottom flanges are blocked on 12.4, and radon started to decay to below 10 Bq/m3 since 12.5

Background estimation during cleaning

- Water absorption: assume all the radon daughters go into LS, will lead to 6e-27 g/g ^{210}Pb in LS
- Radon daughters fallout: assume all deposited Pb/Po leaching into LS → 1.8e-24 g/g ^{210}Pb, 450 cpd/kt ^{210}Po
- Paper residual: U/Th leaching from paper film: 2.3×10^{-20} g/g per m2 per year, no obvious change on compatibility (10 years) and absorption spectrum (24 hours)