DESCRIPTION OF THE STRIPPING TEST @ DAYA BAY

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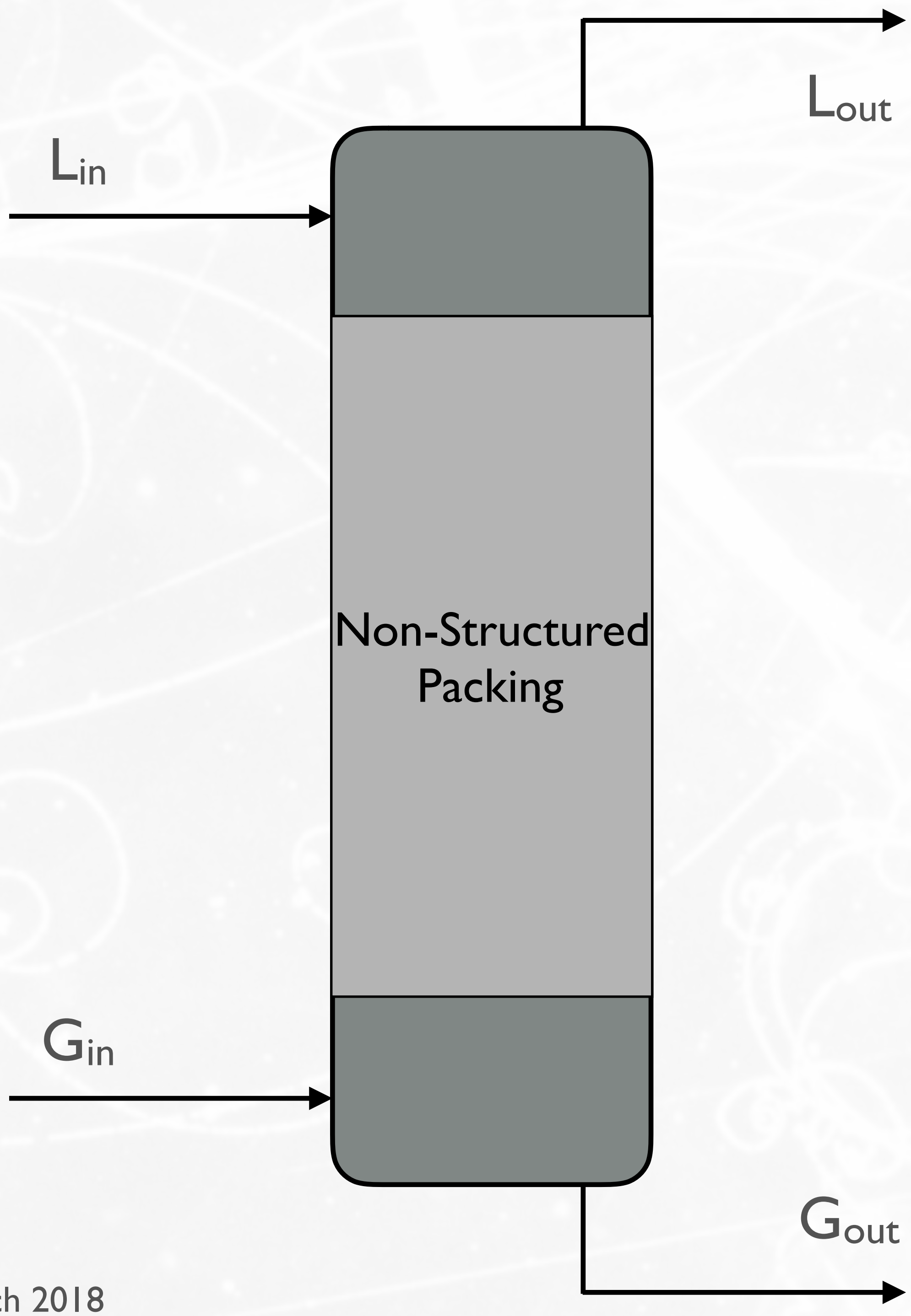
SUMMARY

- **Motivation** of the Test
  - Stripping column **efficiency**
  - **Radon** problem
- **Stripping** Column
  - Nominal and Operational **Conditions**
- **Operations** done at DayaBay
- **Results**
- **Discussion**
- Distillation and stripping pilot plants **paper**
- **Conclusion**

TEST MOTIVATION

STRIPPING COLUMN EFFICIENCY

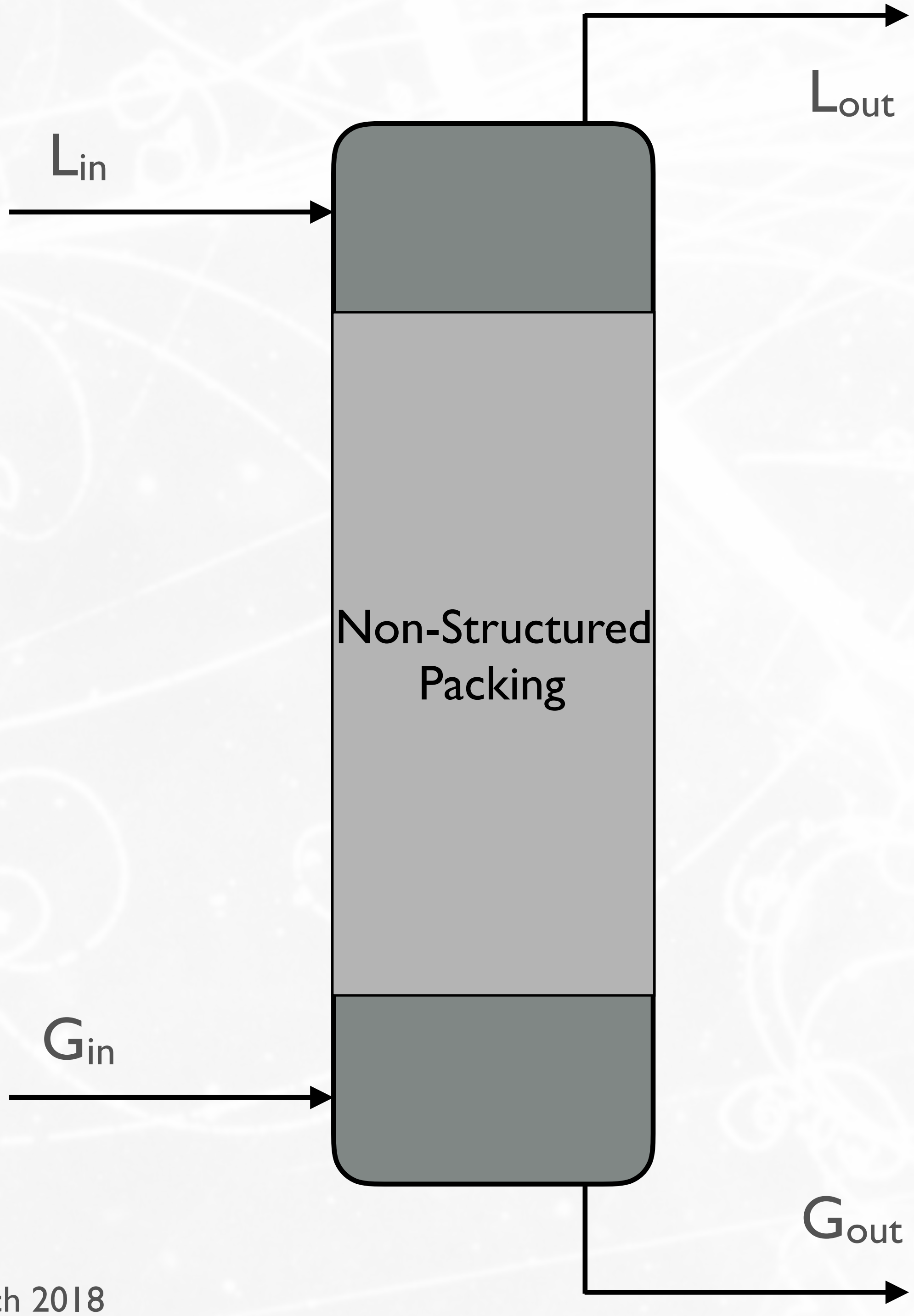
- **Volatile compounds** (as Rn, Ar, Kr) can be removed from a solution by stripping the liquid stream with a gas flow in a stripping tower. The towers serve to breakup the water into droplets and allow contact between the solution and the gas with subsequent transfer of volatile components to air phase.
- The transfer rate of a compound from the gas to the liquid phase depends on the **equilibrium conditions**, basically on T and p



TEST MOTIVATION

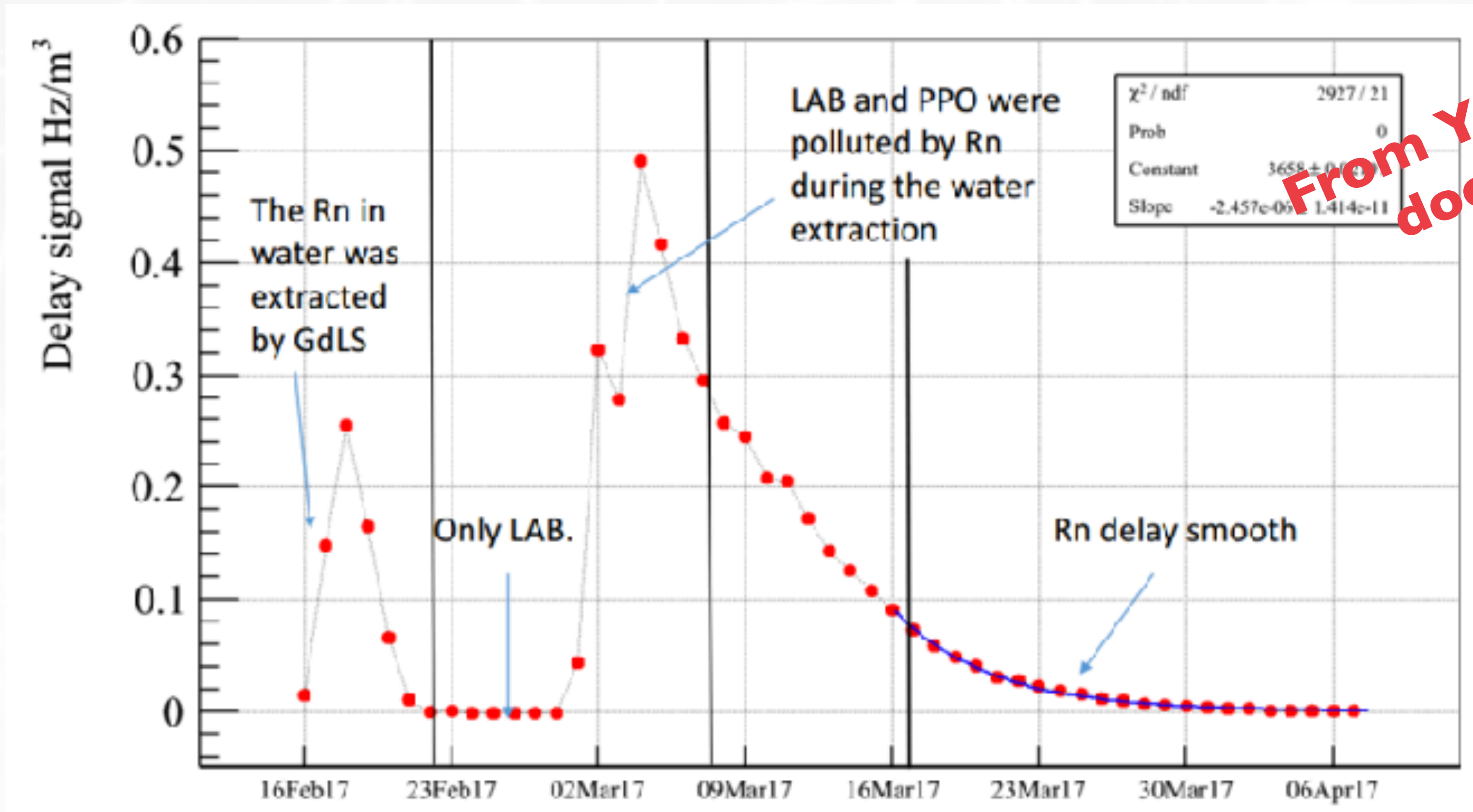
STRIPPING COLUMN EFFICIENCY

- In order to determine the stripping efficiency is necessary to calculate the **column height** imposing the equilibrium in each stage
- The solubility can be extracted from the **Henry Law**
- It is very hard to find the Henry Coefficient for LAB in literature
- Need a specific experiment to prove the capability and the efficiency of the stripping process of the LAB on removing the volatile radioactive impurities



TEST MOTIVATION

RADON PROBLEM

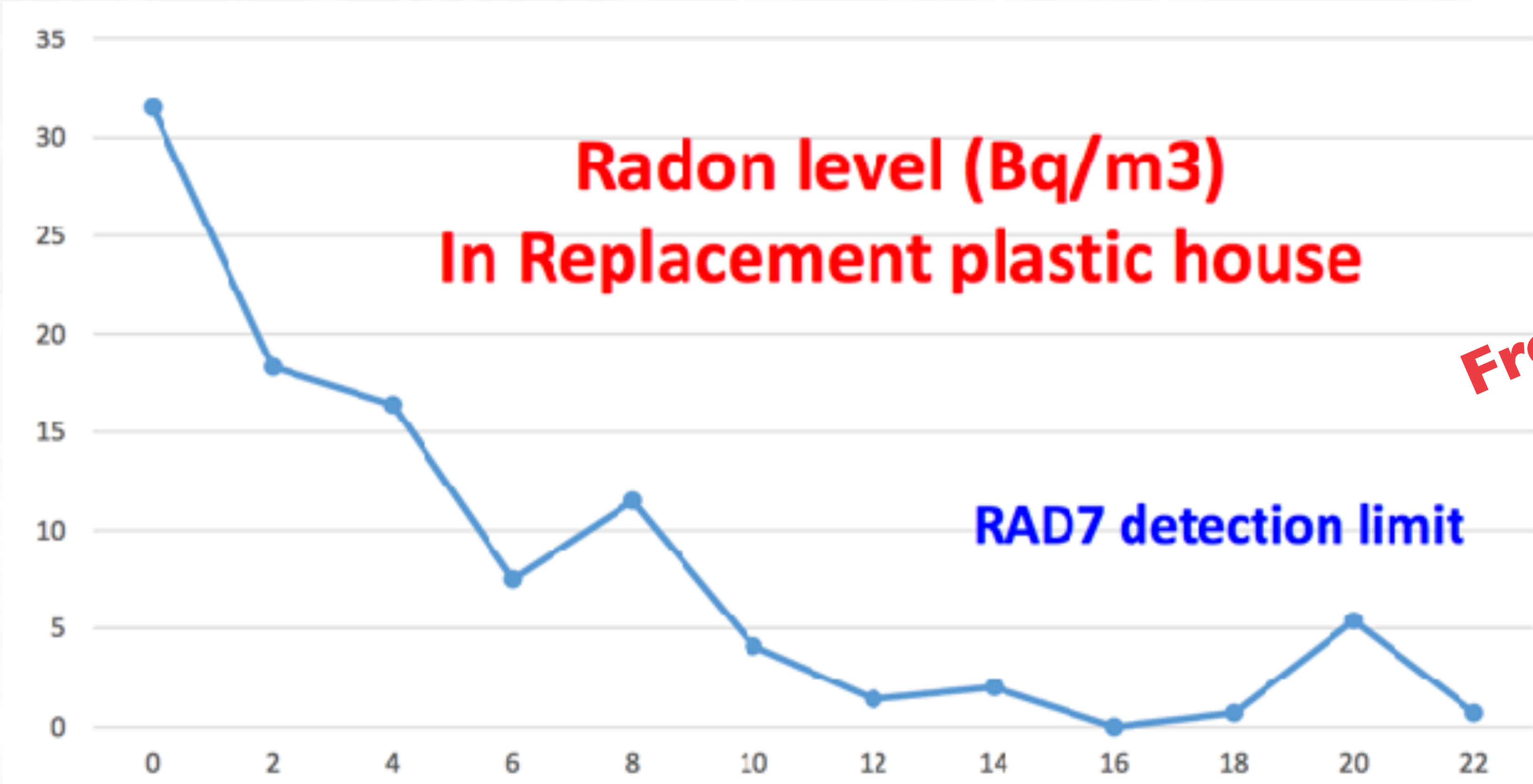


From Yu Boxiang talk docDB 3014-v1

- ^{222}**Rn Pollution** after the insertion of LAB and PPO
- We suspected leakage from
  - Cover-gas pipeline connector and plastic pipe
  - Replacement system

TEST MOTIVATION

RADON PROBLEM

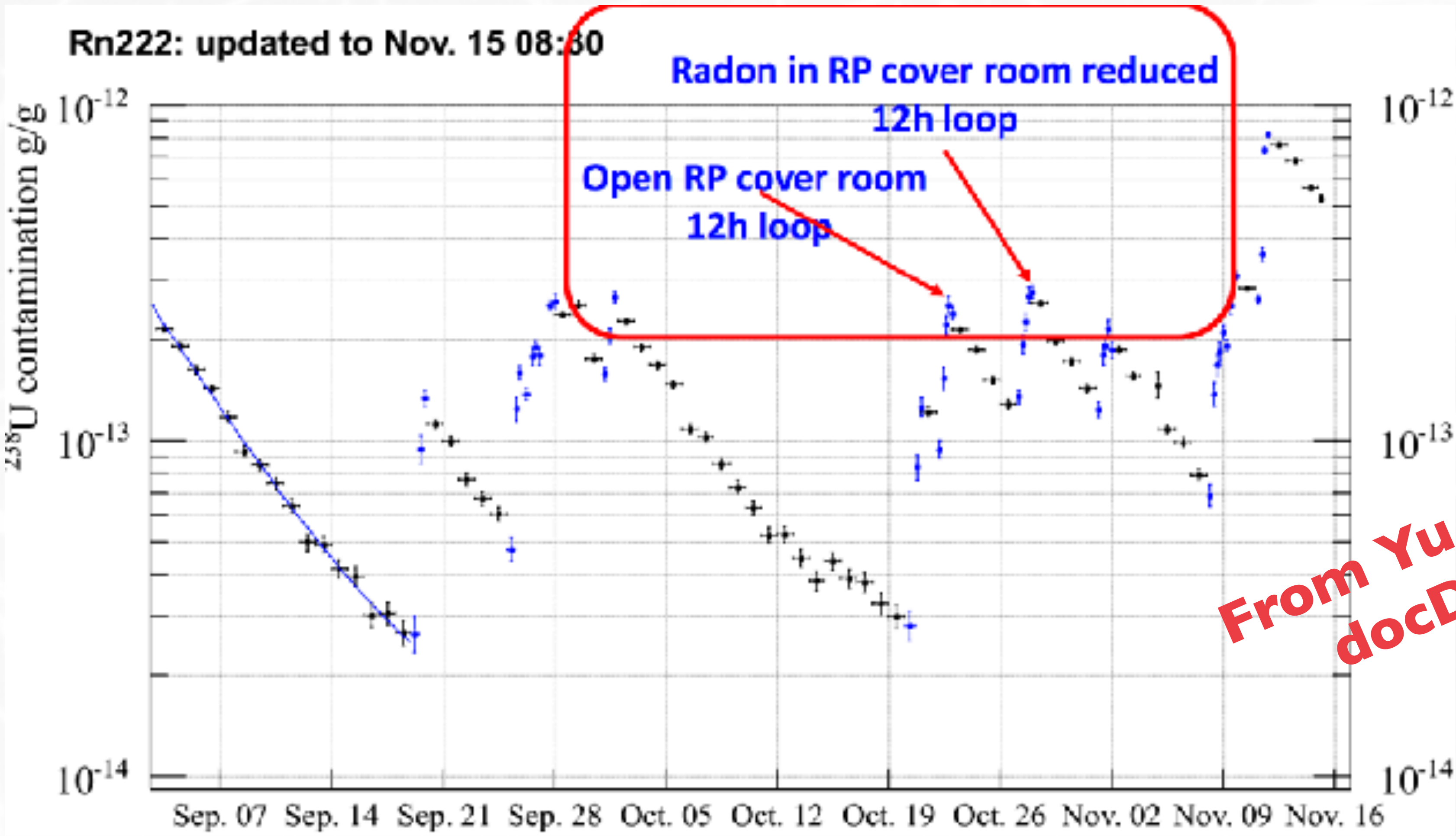


From Yu Boxiang talk docDB 3014-v1

- Upgrade of the Replacement system
  - Replacement system covered with N_2 blanket acrylic house;
  - Pipeline connector encapsulated in boxes purged with N_2;
  - Painted the ground with a radon resistive panting and covered with HDPE foils;

TEST MOTIVATION

RADON PROBLEM

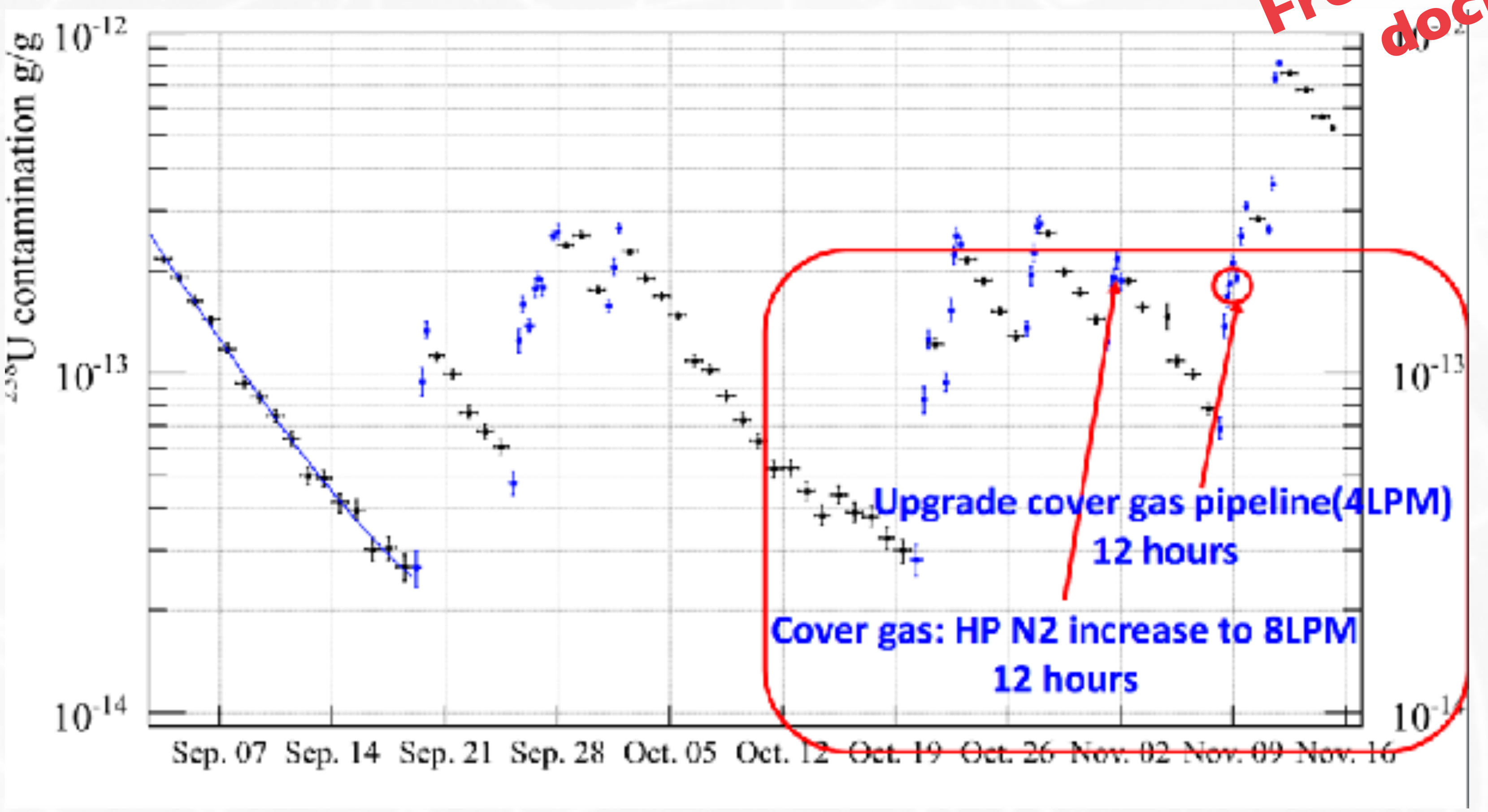


After two 12 hours loop run, one with high Rn content in the acrylic housing, another with very low Rn content, there were no obvious difference in the concentration of the ^{222}Rn inside the AD1-LS. **The Replacement system is not the source of ^{222}Rn**

TEST MOTIVATION

RADON PROBLEM

From Yu Boxiang talk docDB 3014-v1



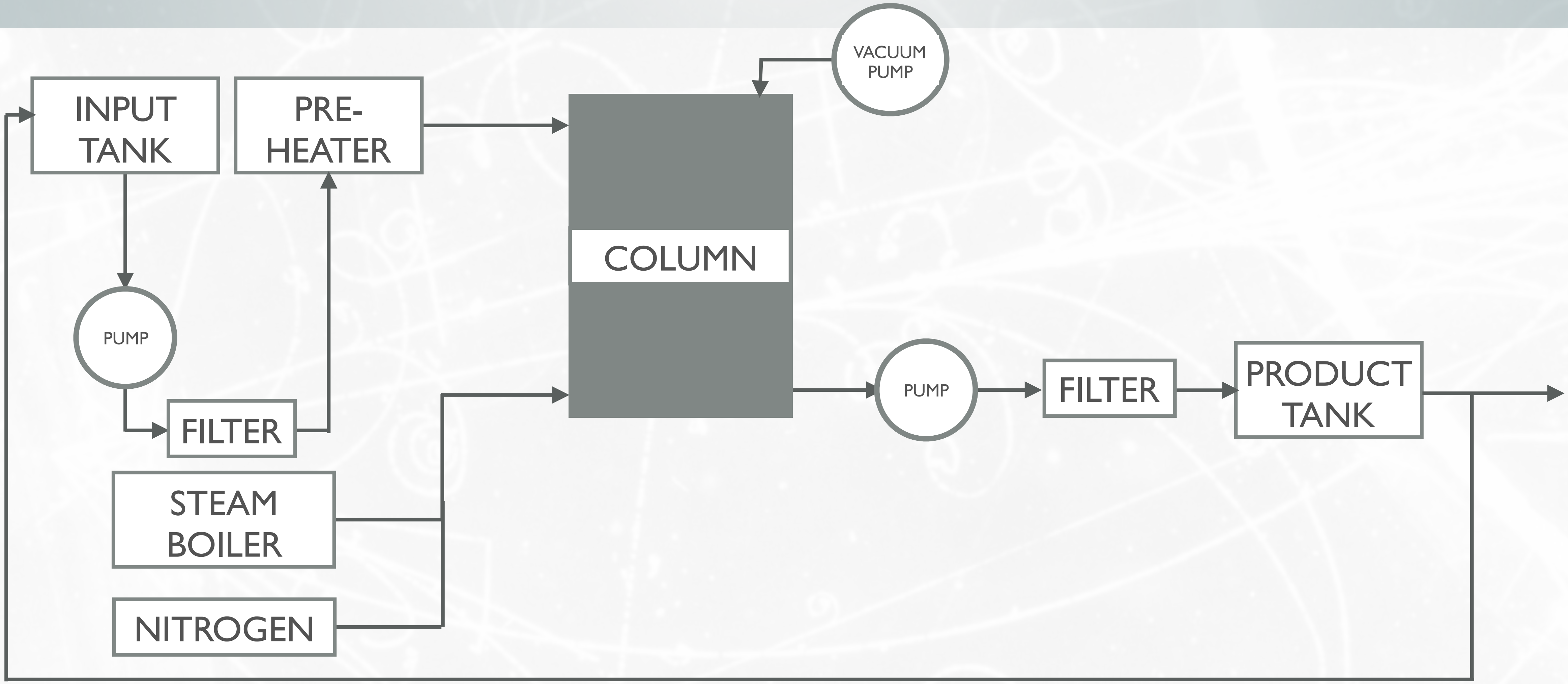
- Upgrade of the AD1 cover-gas
  - Replaced the normal Nitrogen with HP Nitrogen (from 0.19±0.025 Bq/m³ to 0.039±0.009 Bq/m³)
  - Changed the inlet of AD1 cover-gas
  - Pipeline connector encapsulated in boxes with N_2 purging;

STRIPPING PILOT PLANT

- Stripping plant is based is used to remove the impurities that are more volatile than LAB: Ar, Kr and Rn. Water steam in order to avoid to use huge quantity of nitrogen in underground (safety). Stripping is carried out with counter-current flow of the liquid LAB and water super heated steam and/or nitrogen in a column containing non structured packing (Pall Rings 13 x 0.3 mm and 430 m2/m2).
- High temperature (100 °C) for higher column efficiency (low LAB viscosity)
- Partial vacuum (around 300 mbar)
- Both steam and nitrogen stripping could be tested in the plant
- Electrical Power ~ 10 kW
- Cooling Power ~ 5 kW
- Pure water from Daya Bay water plant (approx. 50 l)
- All the plant is kept under continues nitrogen blanket either to avoid oxidation/contamination but also for safety reason (LAB temperature < flash point)
- Vapour condenser before water vapour/nitrogen exhaust for safety
- Rupture disks for pressure safety

Nominal Process Parameter								
Stripping	**Height(m)**	**Diameter (mm)**	**# of Trays**	**Pressure (mbar)**	**Temperature (°C)**	**Scint. flow (l/h)**	**Steam Flux (g/h)**	**Gas Flow (g/h)**
	7	**75**	**Non-Structured Packing**	**300**	**100**	**100**	**250**	**250**

OPERATING CONDITION OF THE STRIPPING PILOT PLANT

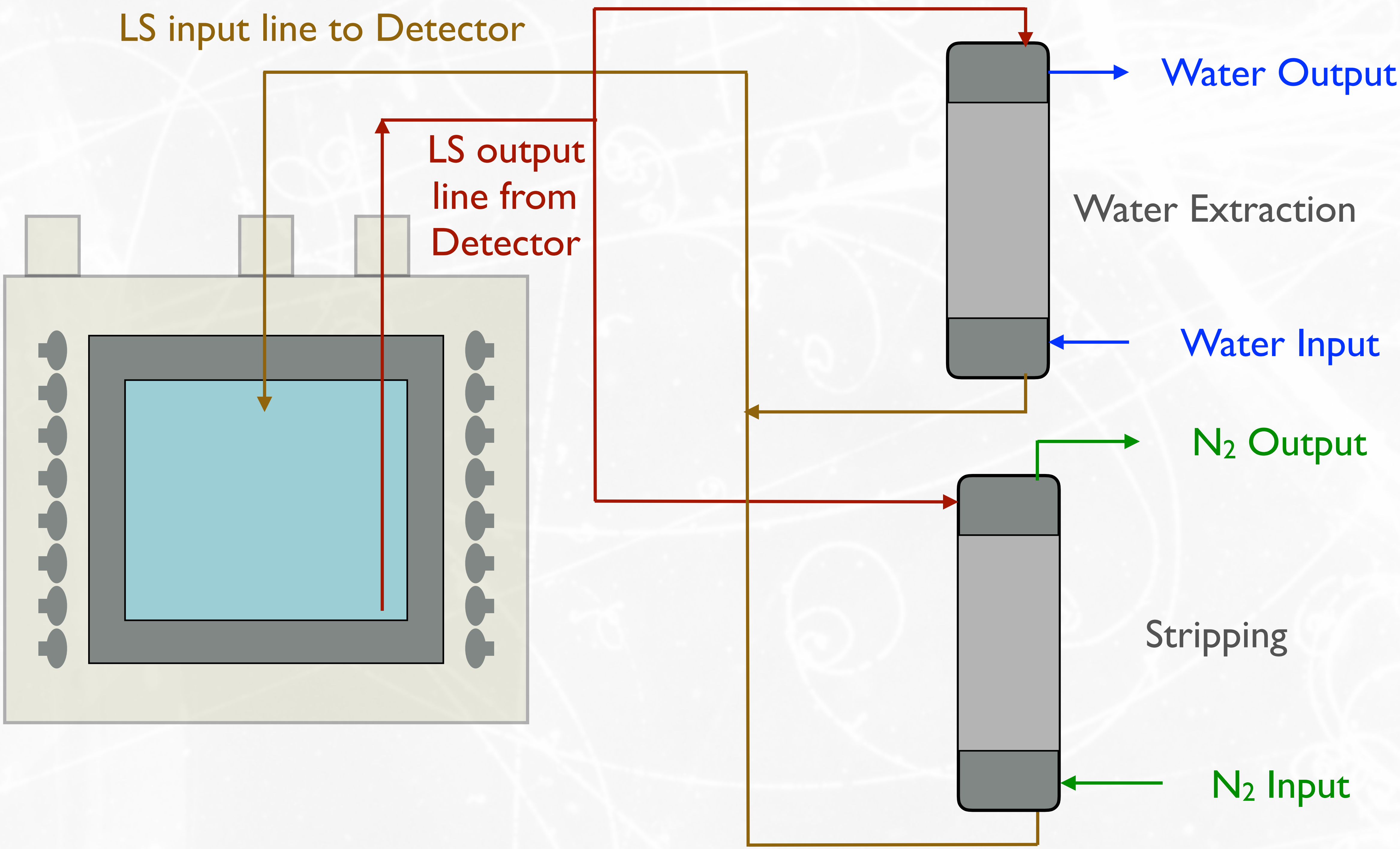


- Column Pressure around 300 mbar regulated with a very small nitrogen flow and partially closing the valve between the vacuum pump and the column
- Output flow between 80 and 140 kg/h
- Temperature of the steam around 80 °C
- Temperature of the LAB flow to the column around 90 °C to avoid condensation of the steam in the LAB
- Filters at 0,05 µm are effective and don't get clogged
- Main issue is to keep constant the steam flow to the column, maybe the orifice is clogged with some LAB

STRIPPING TEST @ DAYA BAY SITE IN NOVEMBER

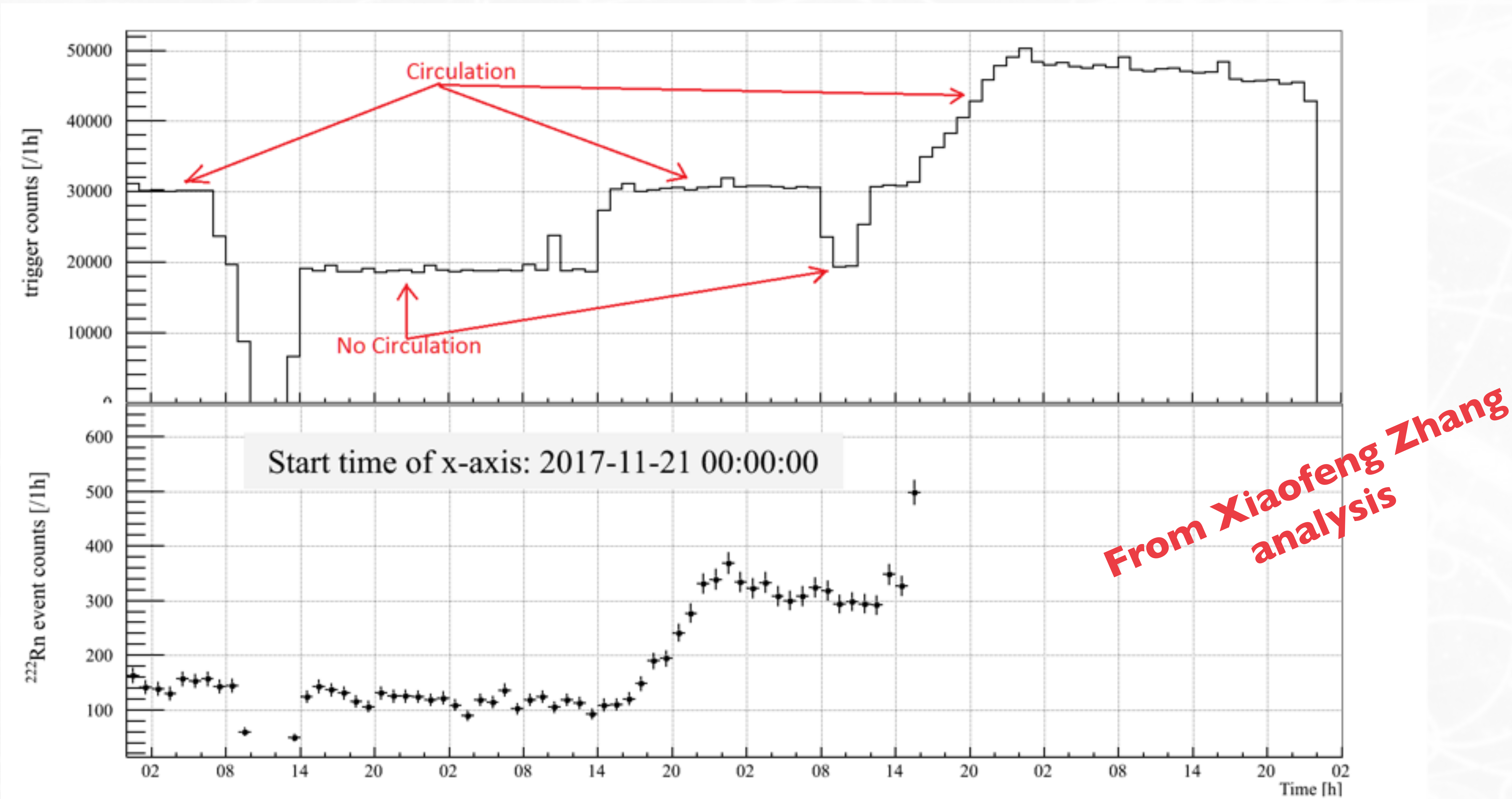
1. **Blank test** (without stripping) to check the amount of ^{222}Rn added during the recirculation
2. **Tested** if the Stripping Pilot Plant **introduce** ^{222}**Rn** in the liquid scintillator during the operations
3. **Added ^{222}Rn in the Liquid Scintillator** using water with an high content of ^{222}Rn in the water extraction plant
4. Processed 10498 l of the Liquid Scintillator at a flow rate of 113 l/h on average with the **Stripping Pilot Plant** using a 1,5 Nm^3/h N_2 flow

STRIPPING TEST @ DAYA BAY SITE IN NOVEMBER



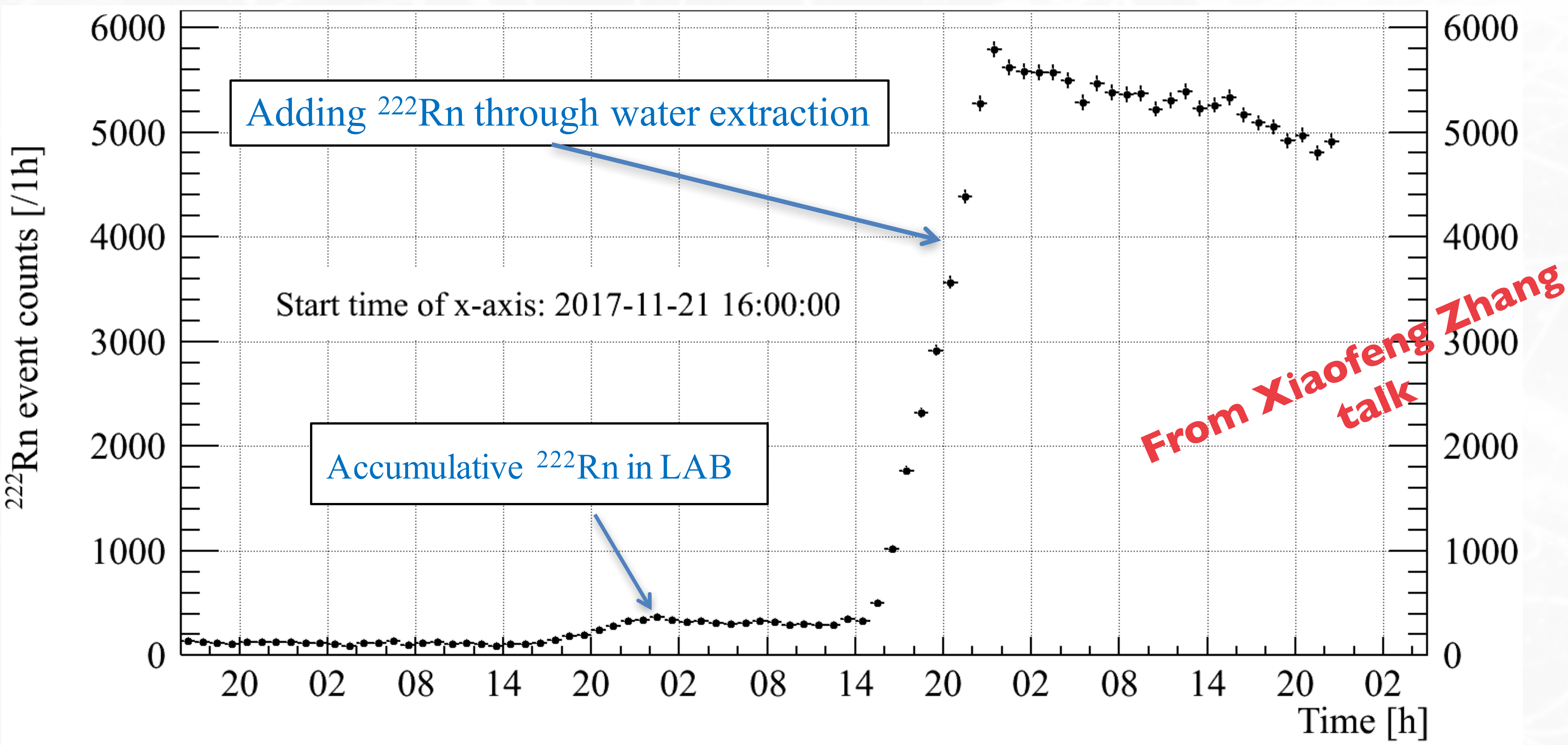
RESULTS

LS AFTER A BLANK RECIRCULATION



RESULTS

LS AFTER WATER EXTRACTION WITH NORMAL WATER



RESULTS

MODEL

- The count of 222Rn decay at each hour could be obtained by the count a hour before:

$$N_t = N_{t-1} \cdot \left[e^{-\lambda \Delta T} - 115 \cdot \eta \cdot \frac{\Delta T}{FV} \right] + leak$$

- N_t: the count of ^{222}Rn decay at the time t
- λ: the decay constant of ^{222}Rn
- η: stripping efficiency
- leak: the contribution of leakage.
- ΔT = 1h
- Both N_t and leak are in the unit of decay/h.

From Xiaofeng Zhang analysis docDB 3048-v1

RESULTS

FIT PARAMETRI

From Xiaofeng Zhang analysis docDB 3048-v1

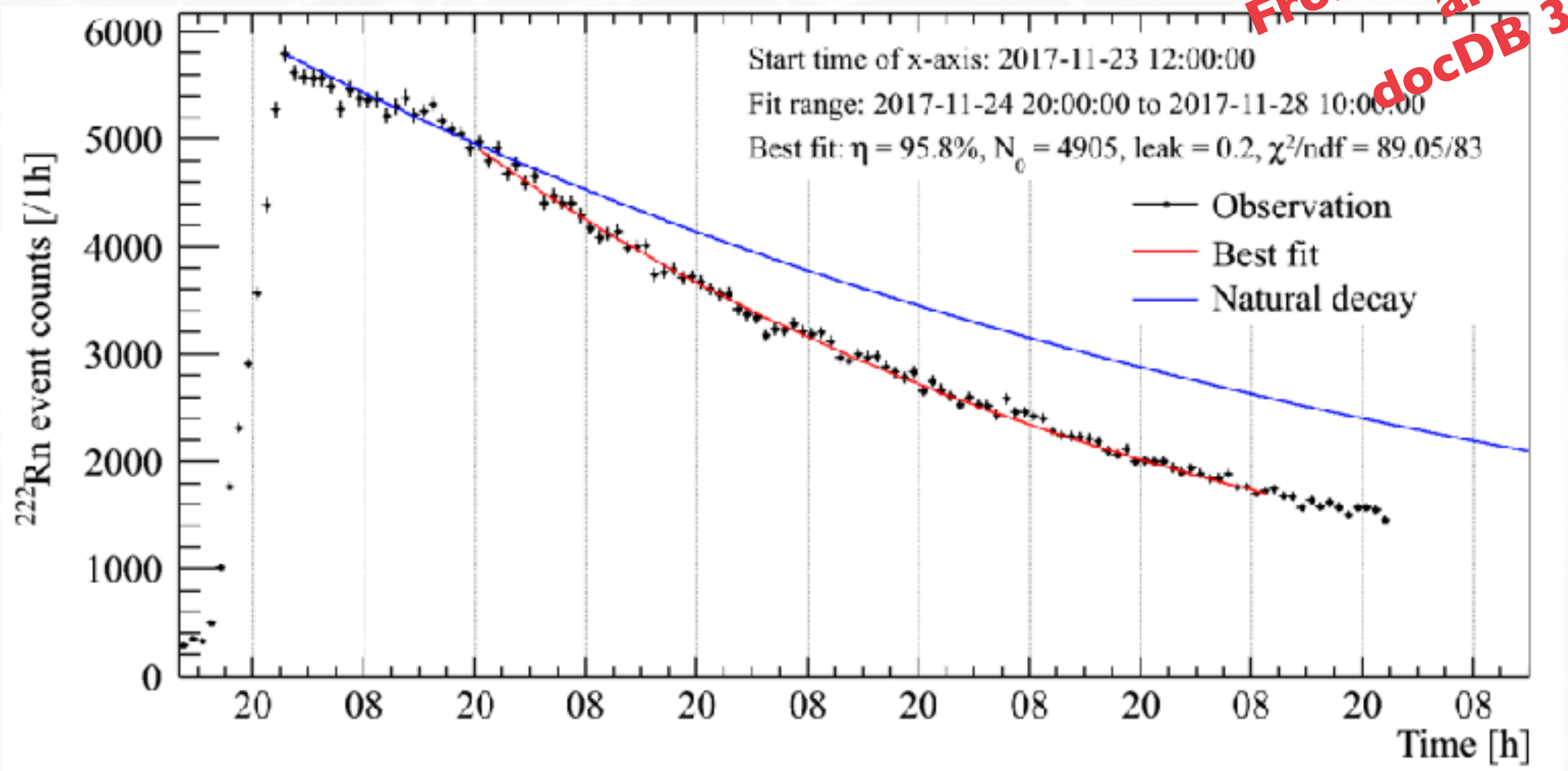
- The has been done minimising the χ^2 defined as follow

$$X^2 = \sum_t \frac{(y_t - N_t)^2}{N_t}$$

- where y_t and N_t are the observed and expected counts of ^{222}Rn decay at time t respectively.
- The free parameters in the equation above are N_0, η, leak.
- The fit range of the three free parameters:
  - N_0: $y_0 - 125 \le N_0 \le y_0 + 124$, step length = 1, total 250 values; y_0 is the observed counts of ^{222}Rn decay at the starting time
  - η: $0.85 \le \eta \le 1.24$, step length = 0.01, total 400 values;
  - leak: $0 \le \text{leak} \le 4.9$, step length = 0.1, total 50 values;

RESULTS

BEST FIT RESULT



From Xiaofeng Zhang analysis docDB 3048-v1

- N_0: 4905±11 decay/h
- η: 95.8% $^{+1.1\%}_{-0.9\%}$
- leak: 0.2 decay/h

DISCUSSIONS

- From the graph shown in the slide 11 the leak can be calculated as 200 Atoms/h

  for a small ΔT

$$\frac{Atoms}{h} \approx \frac{decay}{h} \bullet \lambda \qquad \text{where} \qquad \lambda = \frac{\ln 2}{T^{1/2}} \sim \frac{1}{132}$$

  The 0.2 decay/h was not consistent with the recontamination of 200 Atoms/h ~ 1.5 decay/h.

- if the average flux rate was 113 L/h, then the best fit for efficiency should be 95.8*115/112.9 = **97.6%,** bringing the purification factor from 25 to 41

- From the minimum $\chi 2$ analysis it can be seen that there is a strong correlation between leak and efficiency. One possible reason should be that the influence of variation of efficiency is comparable with leak.

- If there was some radon in the stripping nitrogen, then the actual efficiency should be higher than the best fit. where the parameter c represents the contamination of radon in stripping nitrogen

$$N_t = N_{t-1} \cdot \left[e^{(-\lambda \cdot t)} - 115 \cdot \eta \cdot \frac{t}{FV} \right] + 115 \cdot c + leak$$

- that the precise value of c is unknown.

DISTILLATION AND STRIPPING PILOT PLANTS PAPER

- Scientific **Motivation**
  - Check the effectiveness of removing the radioactive impurities form the LS
  - Check the optical purity of the LS after the purification stages
  - Check the reliability of the equipments
- Distillation and Stopping process **theories**
- **Characterisation** of the distillation and of the stripping plants (focus on P&Id and the peculiar features of the plant)
- **Results**

CONCLUSION

- The Rn main source in the AD1 is from Nitrogen cover-gas maybe due to a leak in the connectors and in the plastic tubes;
- The stripping test has been done from 20/11 to 30/11 processing more than 10000 l of LS.
- Stripping efficiency calculated from the fit is

  η=95.8%

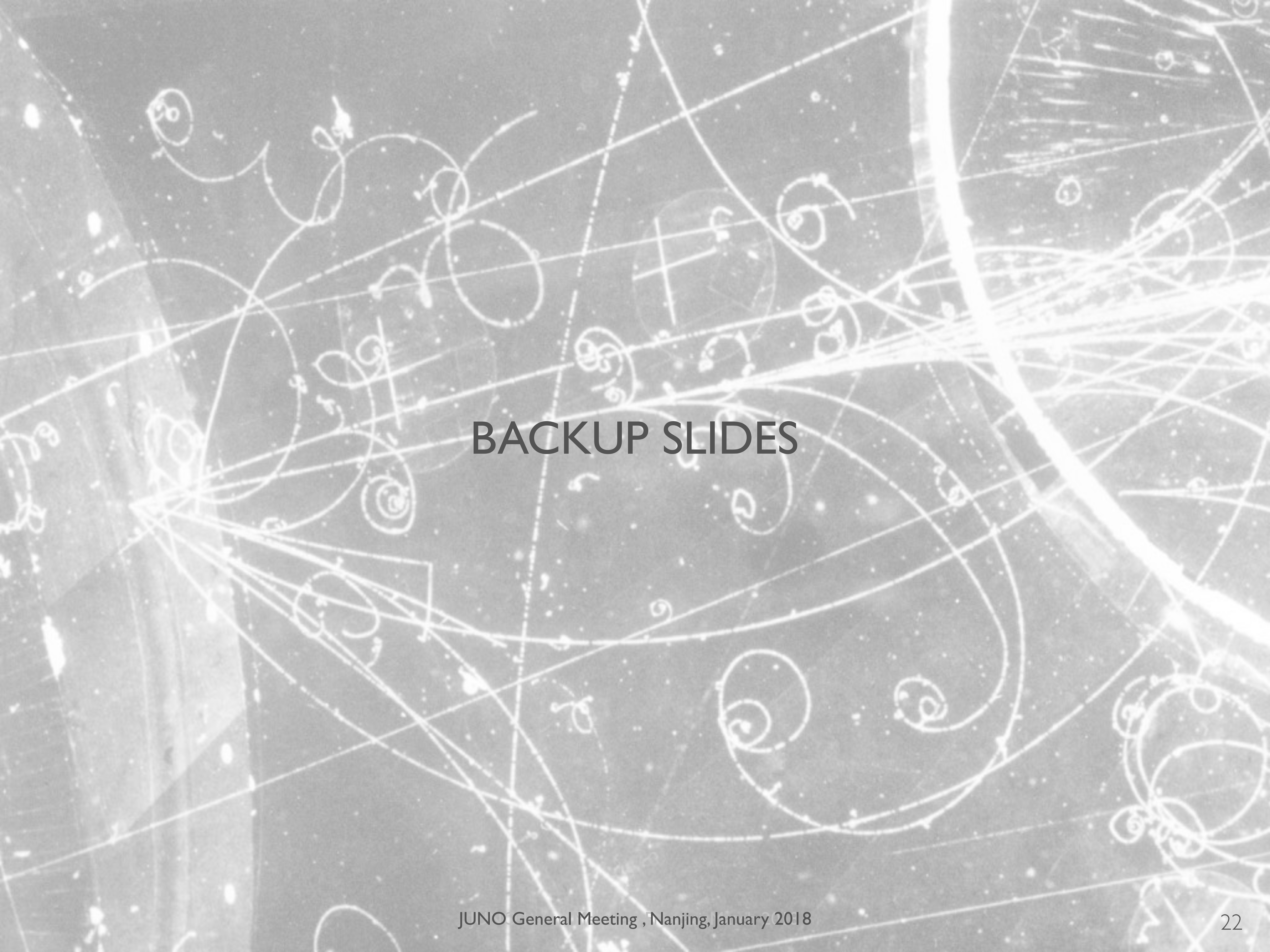
  giving a purification factor of 25.
- Taking into account the value of the Coriolis flow rate the efficiency increase to the value of

  η=97.6%

  with a purification factor of 41, that should be taken into account while estimating the systematic error.
- The leak factor need has to be better understood and probably is underestimated. An higher value of the leak factor could bring to an higher value of the efficiency.
- Also the ^{222}Rn content of the nitrogen can influence the total efficiency of the stripping.

“Thanks!!!”.

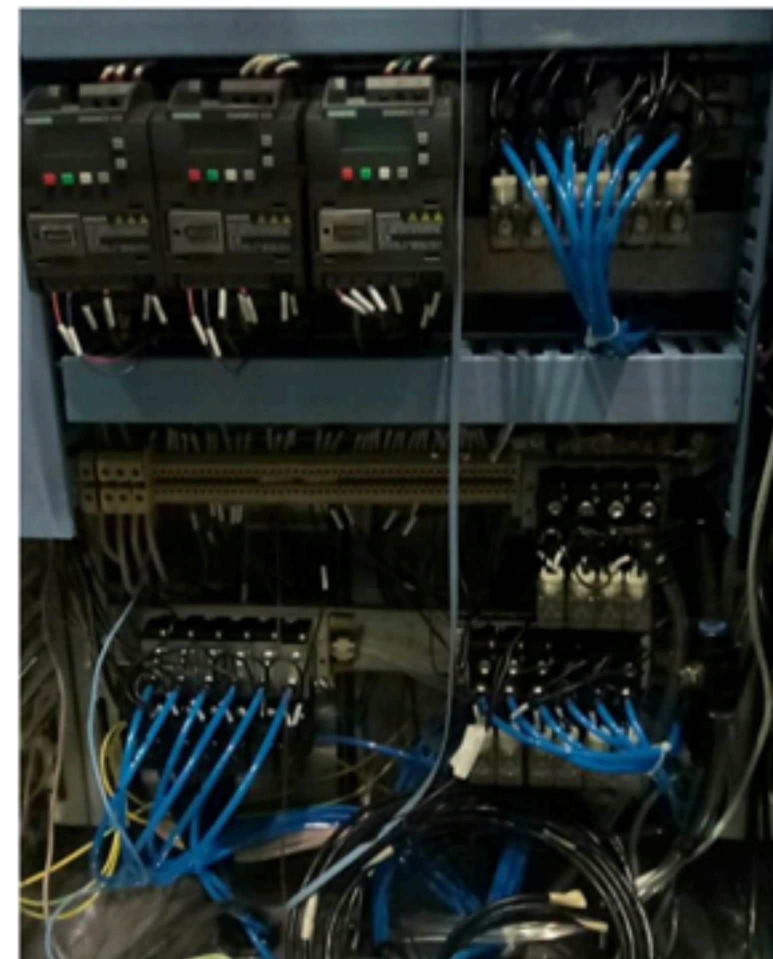
–Michele Montuschi



BACKUP SLIDES

After this process, the Rn count in acrylic house is still high;

LS connector purged by nitrogen



Nitrogen control the valve

- RAD7 Rn detector was sealed in a Acrylic tank on Hall 1 ground (near replacement system), test the Rn level change with the change of time;

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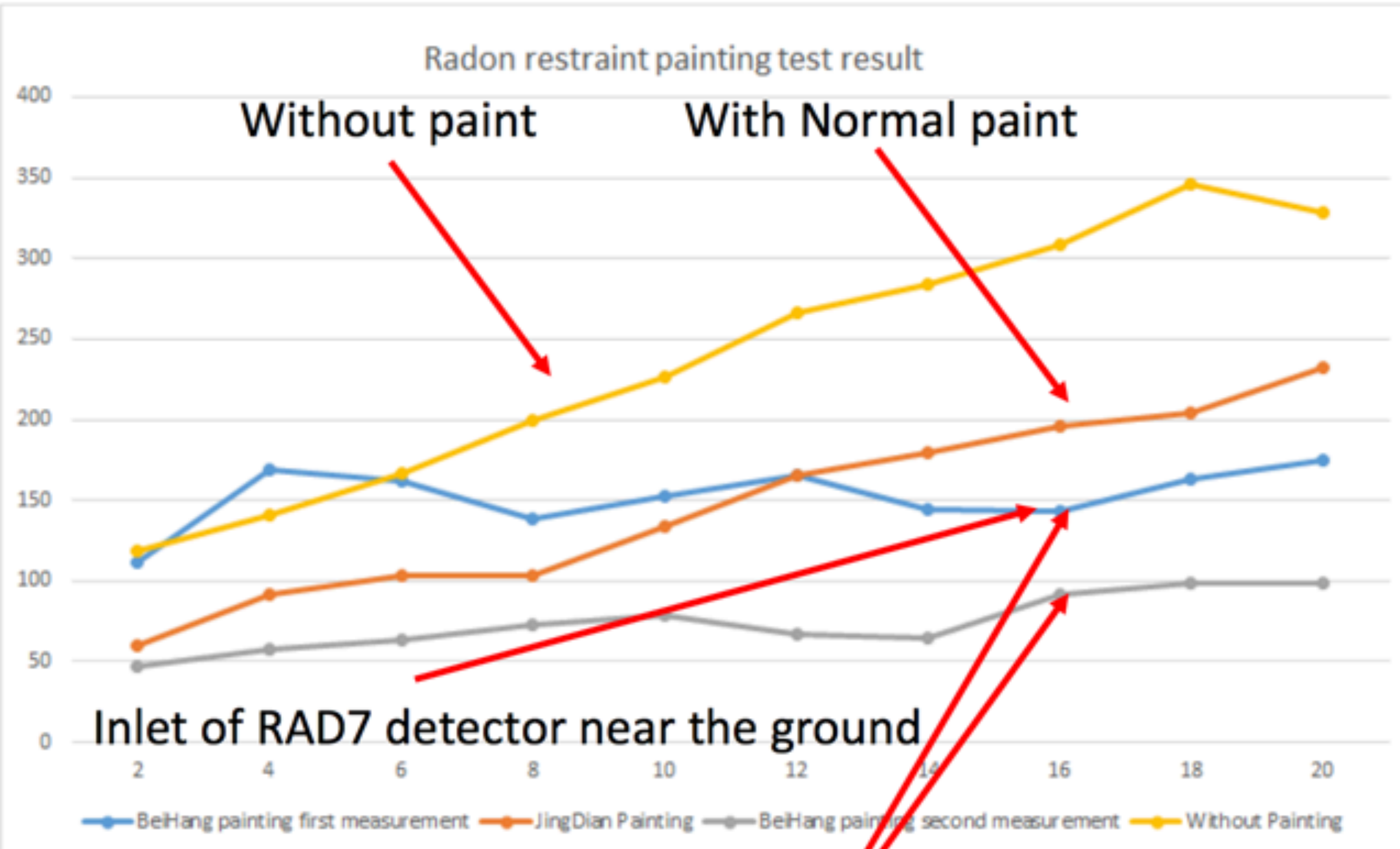
Radon resistive paint experiment



With Beihang paint

Beihang paint

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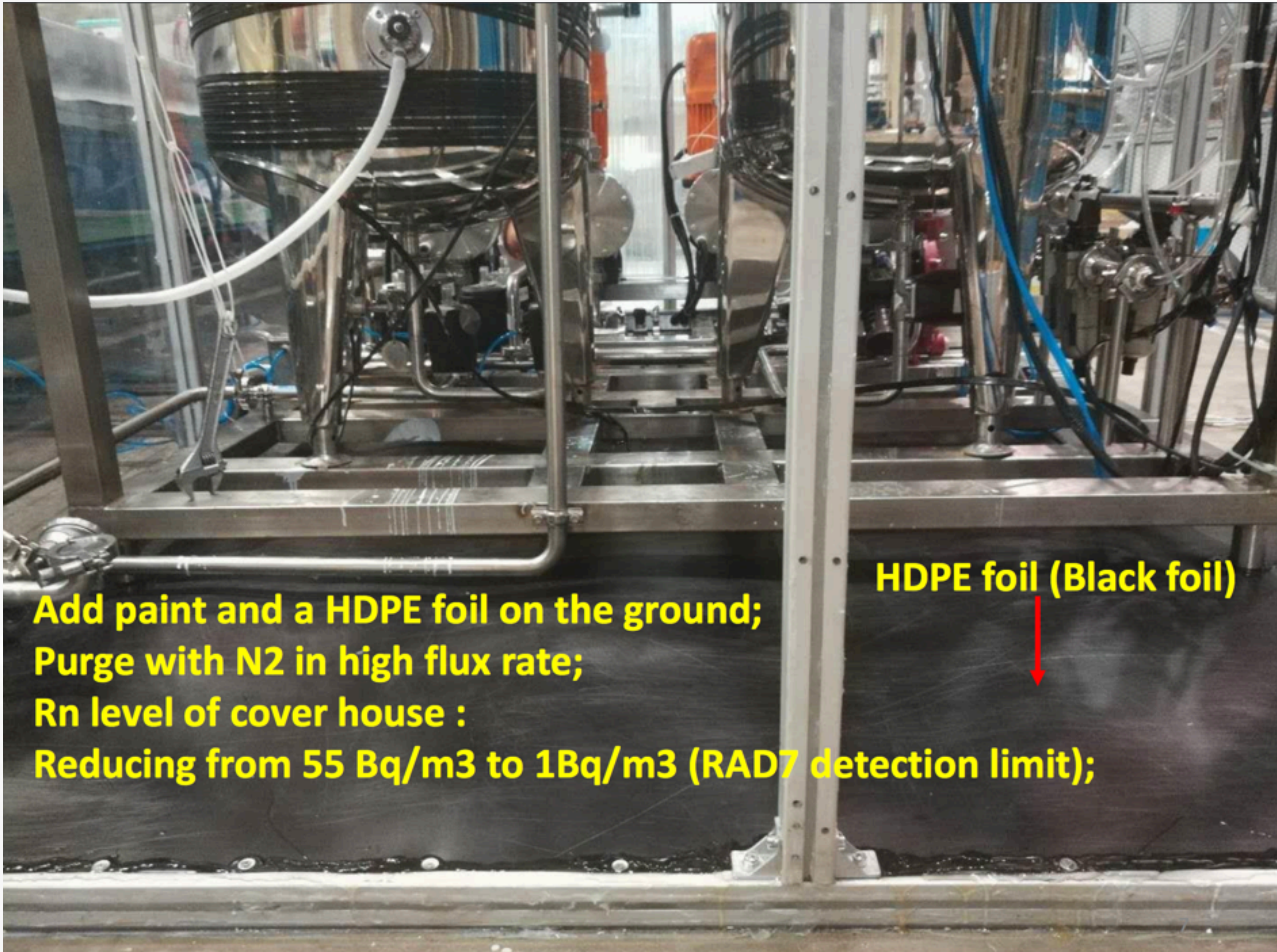
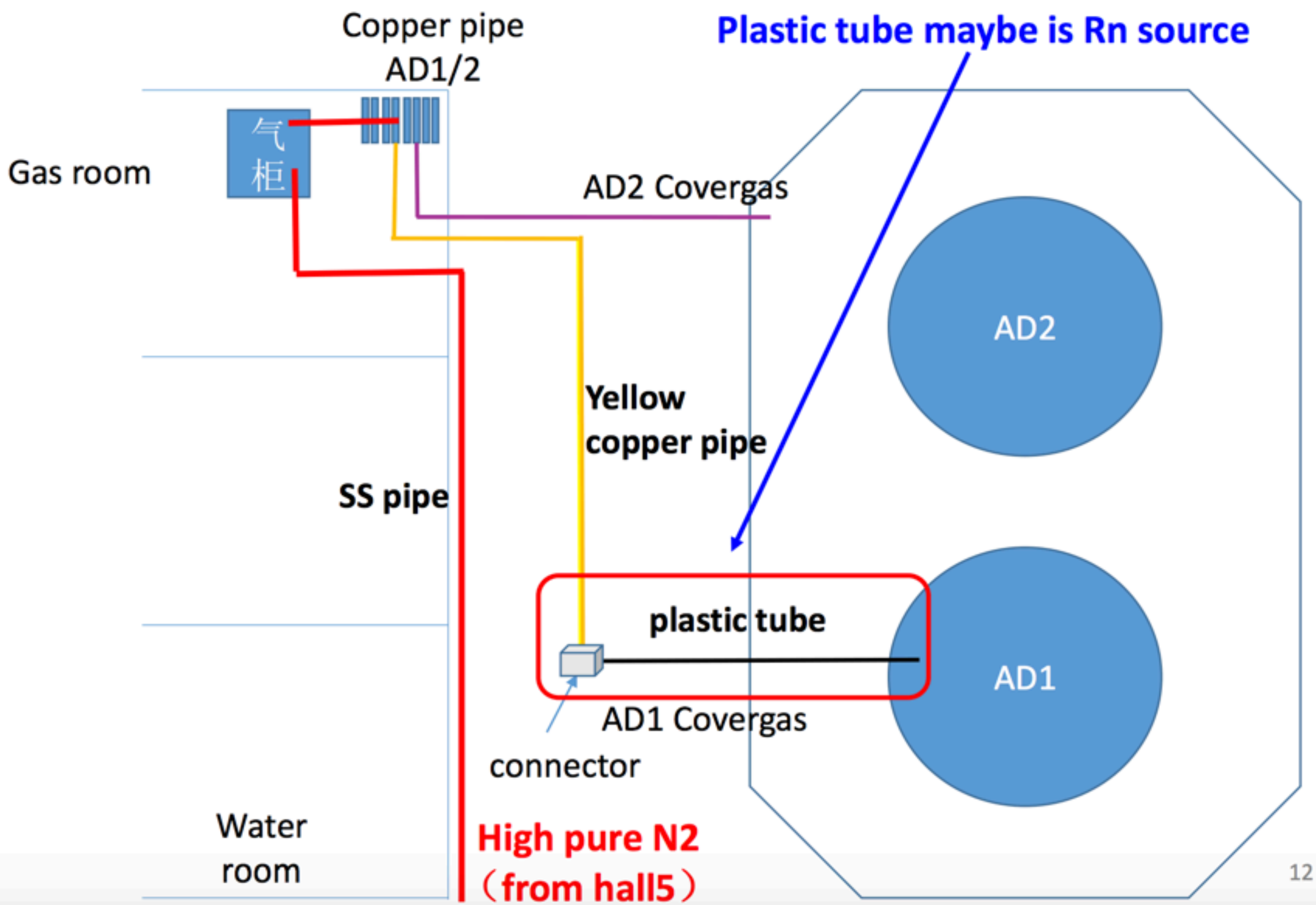
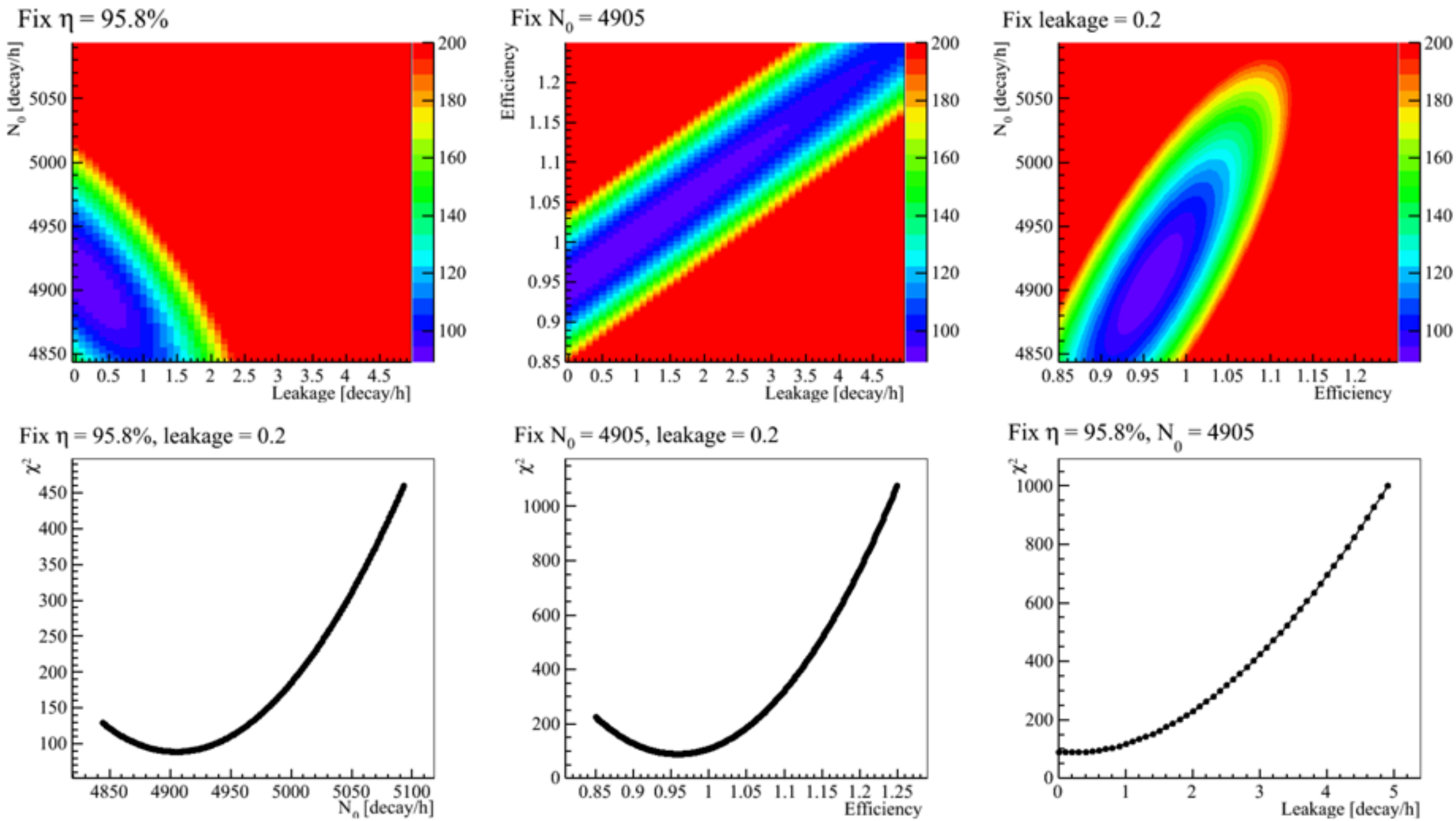

HDPE foil (Black foil)
Add paint and a HDPE foil on the ground;
Purge with N2 in high flux rate;
Rn level of cover house :
Reducing from 55 Bq/m3 to 1Bq/m3 (RAD7 detection limit);

AD1 Cover-gas pipeline @DYB Hall1#



Dependency of χ^2 on η, N_0, leak



- Best fit result given by minimizing χ^2: $\eta = 95.8\%, N_0 = 4905$, leak $= 0.2$.

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