Radon monitoring in the Kamioka Mine

Guillaume Pronost

on behalf of SK radon group

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Personal introduction

Guillaume Pronost
ギョム プロノスト
(Guillaume is my first name)

I come from Nantes, in France, the home city of Jules Verne (ジュール・ヴェルヌ) one of the first SF novelist.
Now in Toyama, post-doc at the Kamioka Observatory.

Current activities:

- Radon studies in Kamioka Mine
- EGADS (Radium reduction, DAQ & data analysis)

Past activities:

- Double Chooz (Reactor $\overline{\nu}_e$ oscillation)
- SoLiD (Short baseline sterile reactor $\overline{\nu}$)

Personal introduction

Japan & Nantes common love: giant robots!

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Why monitor the radon concentration in Kamioka Mine?

Radon is a radioactive gas which tend to accumulate indoors
$\rightarrow$ Accumulation in the Kamioka Mine

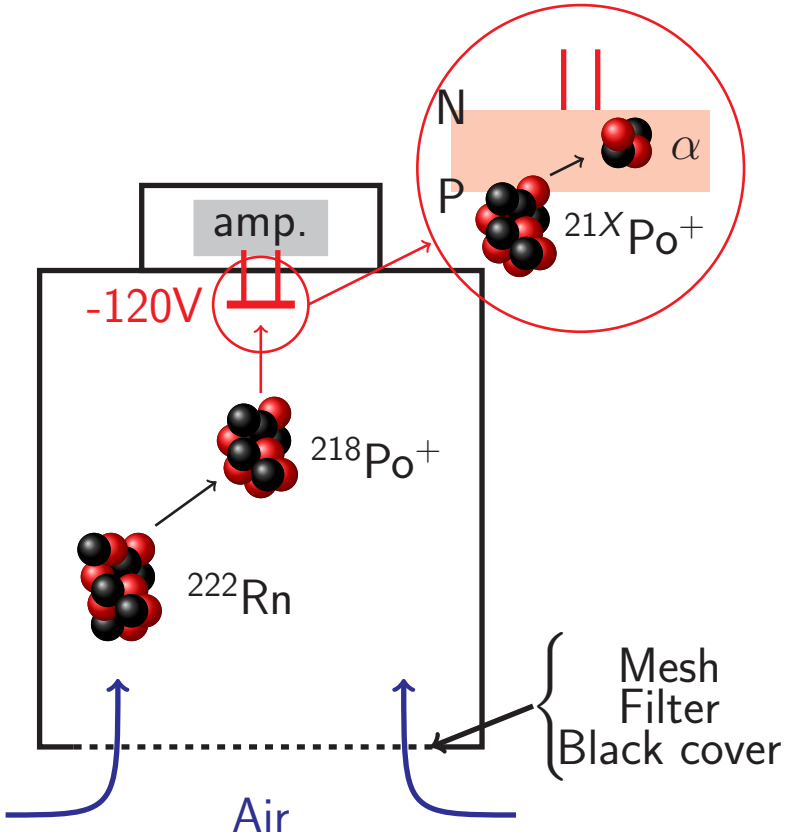
- Radioactivity from Radon can lead to health issue in case of high exposure.
- Radioactivity from Radon is a background for high precision experiments looking for low energy physics, like the ones present in the Kamioka mine.

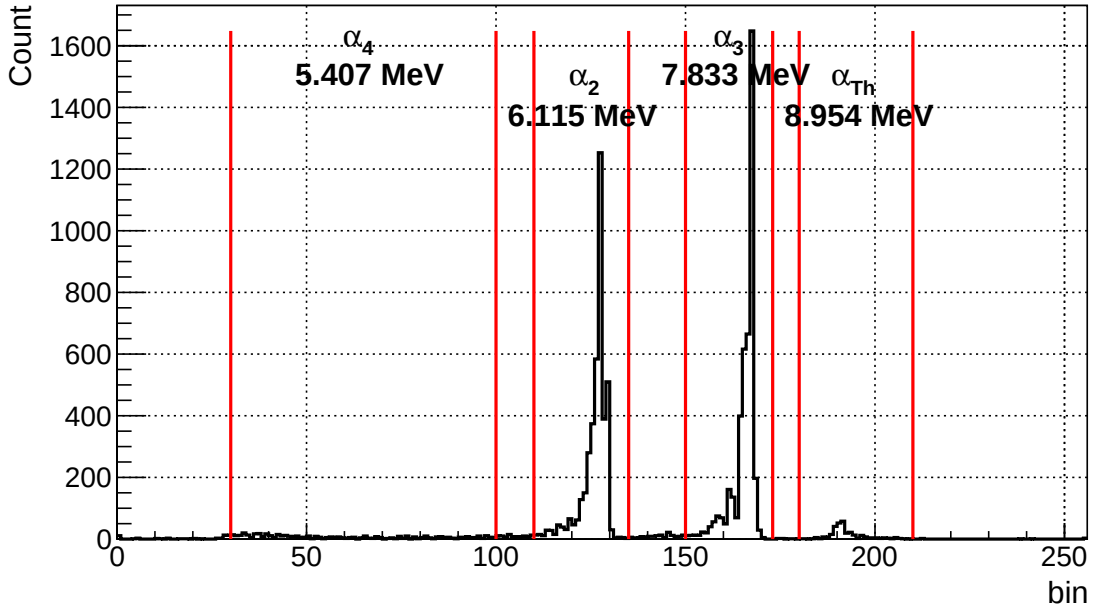
$\rightarrow$ Monitoring the Radon concentration allows to protect the health of the researchers and technicians working in the mine, as well as, to control the background coming from Radon.

We use the US recommendation for indoor radon concentration:

$$4 \text{ pCi/L} \rightarrow 148 \text{ Bq/m}^3$$

Radon detection method: electrostatic collection



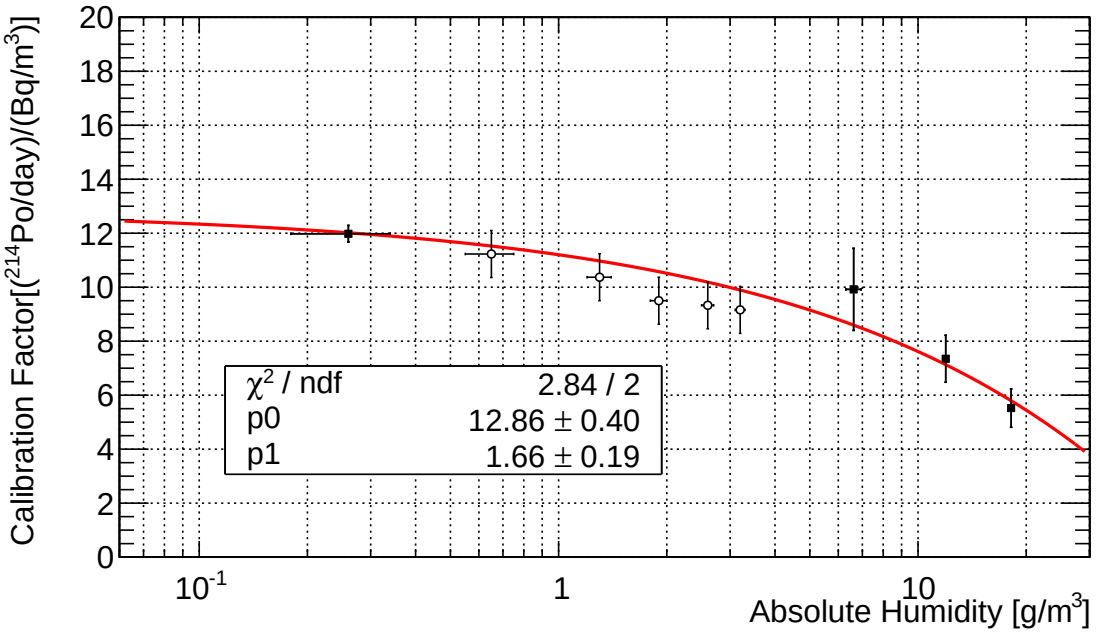


- Collection of positive ions from ^{222}Rn decay chain on the PN photo-diode:

$$^{222}\text{Rn} \xrightarrow{\alpha_1} {}^{218}\text{Po}^{+} \xrightarrow{\alpha_2} {}^{214}\text{Pb}^{+} \xrightarrow{\beta} {}^{214}\text{Bi}^{+} \xrightarrow{\beta} {}^{214}\text{Po}^{+}$$
$$^{214}\text{Po}^{+} \xrightarrow{\alpha_3} {}^{210}\text{Pb}^{+} \xrightarrow{\beta} {}^{210}\text{Bi}^{+} \xrightarrow{\beta} {}^{210}\text{Po}^{+} \xrightarrow{\alpha_4} {}^{206}\text{Pb}^{+}$$

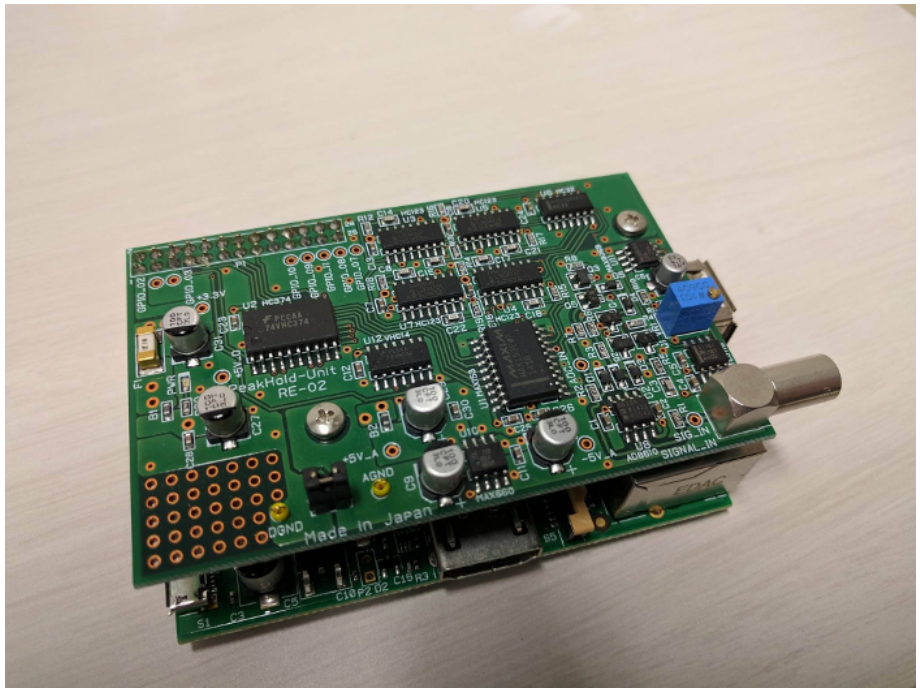
- Concentration $= \alpha_3$ counts $\times$ Calibration Factor(Humidity, $\Delta t_{\textit{data taking}}$)

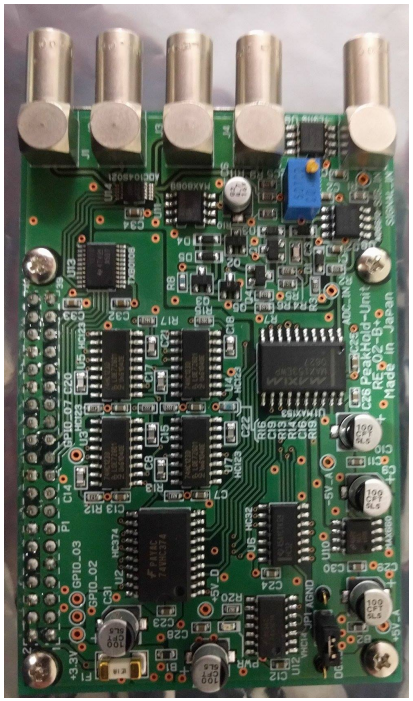
Calibration



- Radon measurement has a humidity dependence (ion neutralization)
  $\longrightarrow$ humidity dependence calibration taken into account

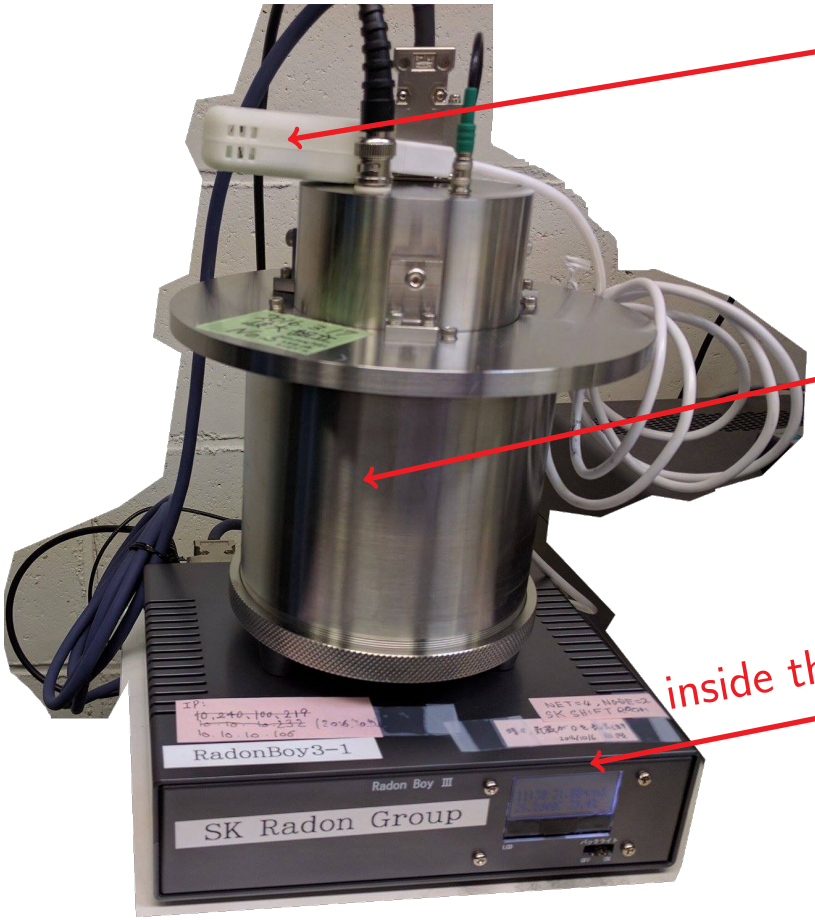
Data taking





- We are using RaspberryPi electronics as DAQ
- The RaspberryPi ADC board is a custom electronics board designed by S. Tasaka-san (Gifu university)
- For the Rn monitoring, these ADC board integrates all hits from the detector over 10 minutes.

1L radon detectors in the mine

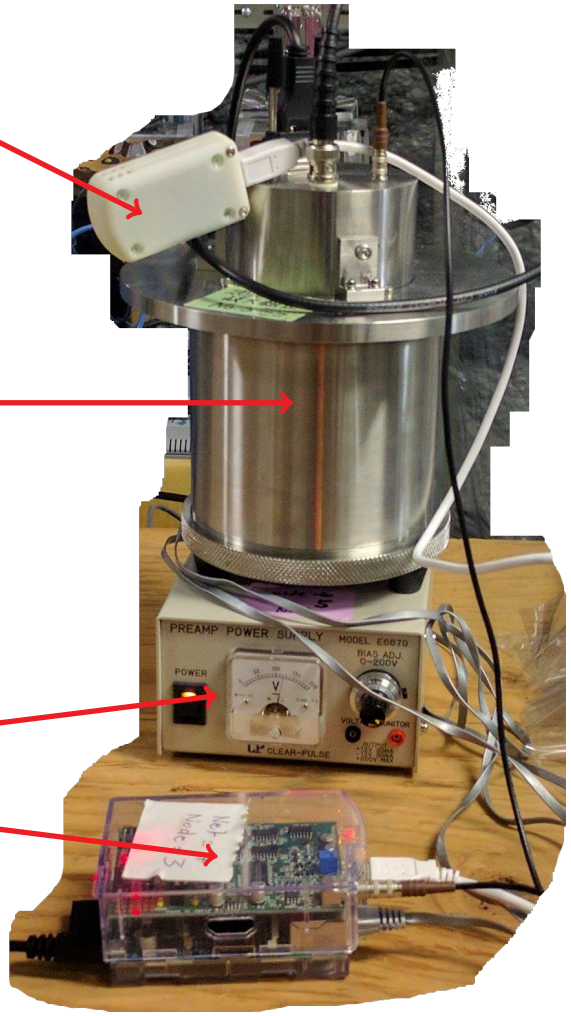


USB Humidity sensor

1L detector

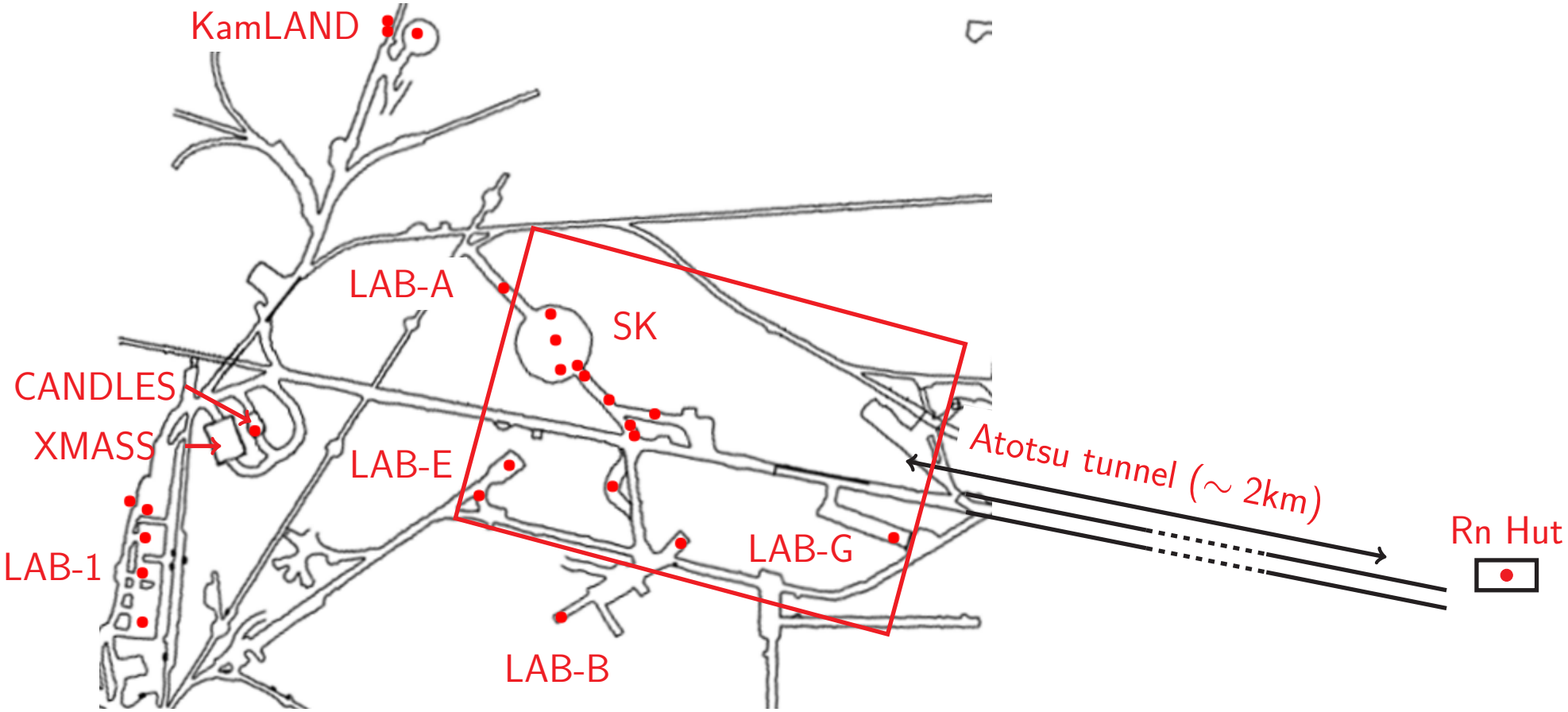
inside the box

-120V H.V.
±12V signal input
Raspberry Pi ADC



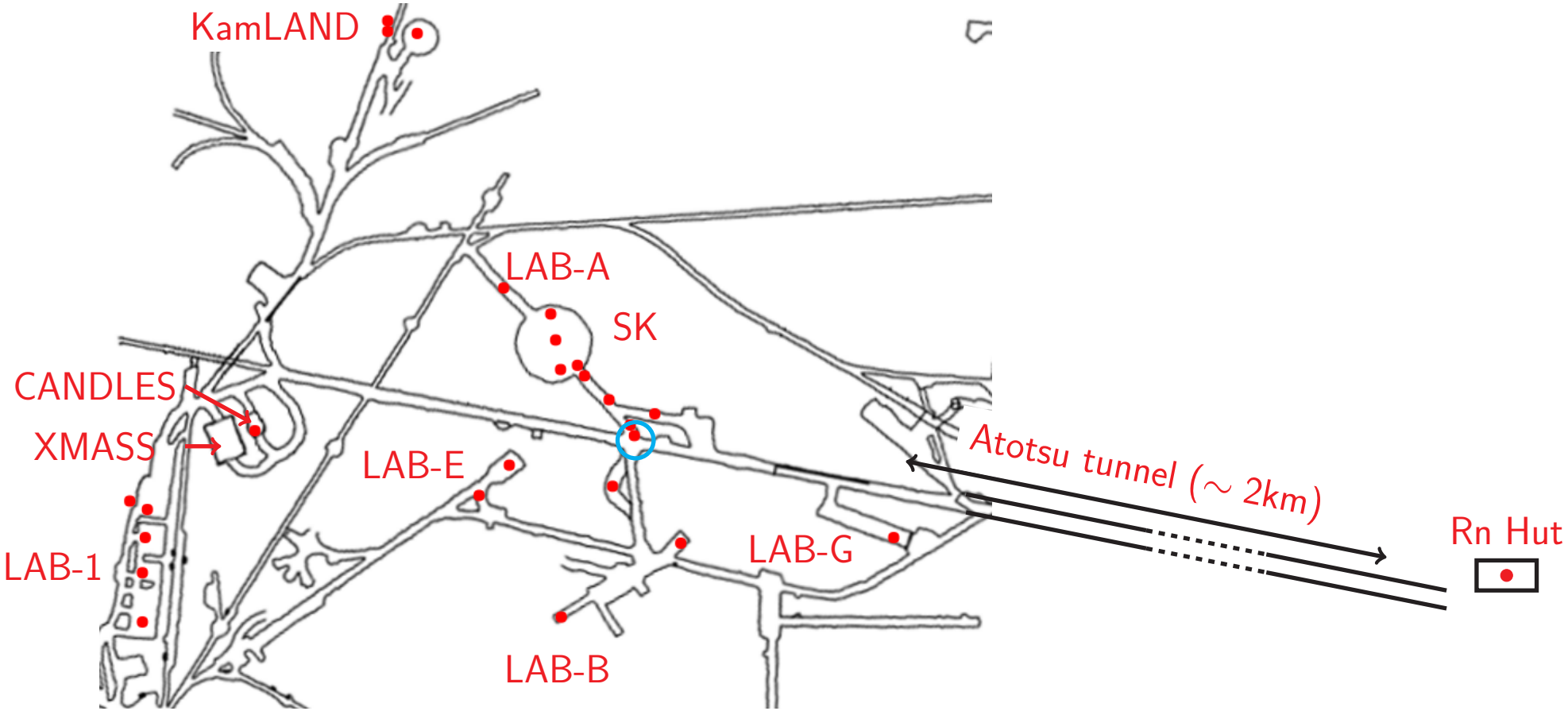
- Same 1L detector, but two different electronics “packages” in the mine

Radon detectors map in Kamioka mine

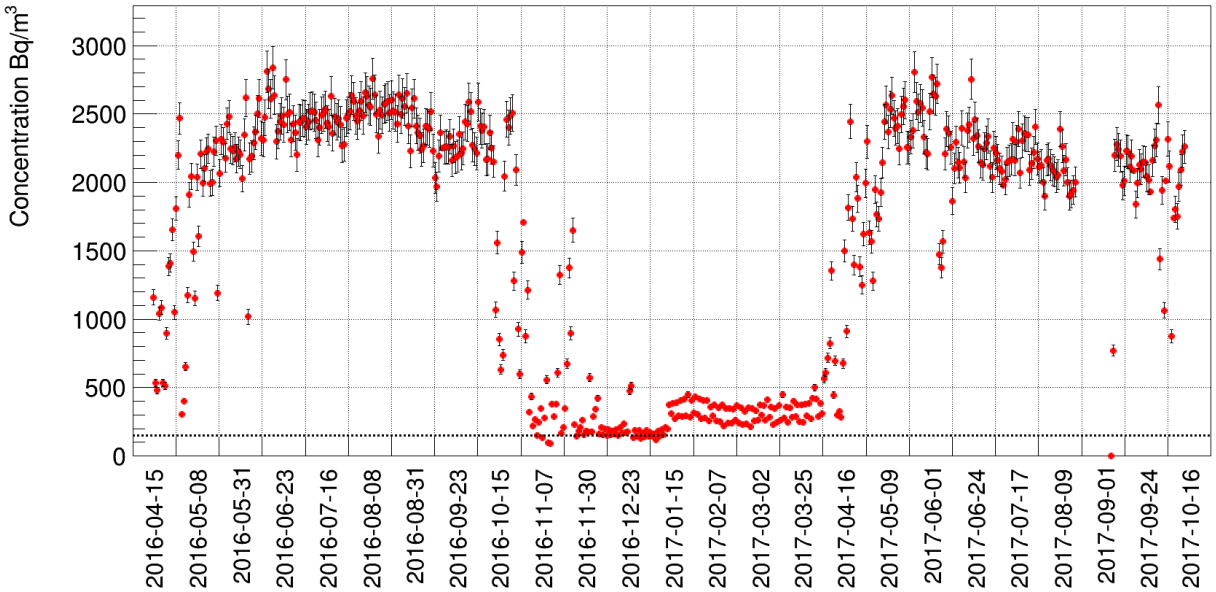


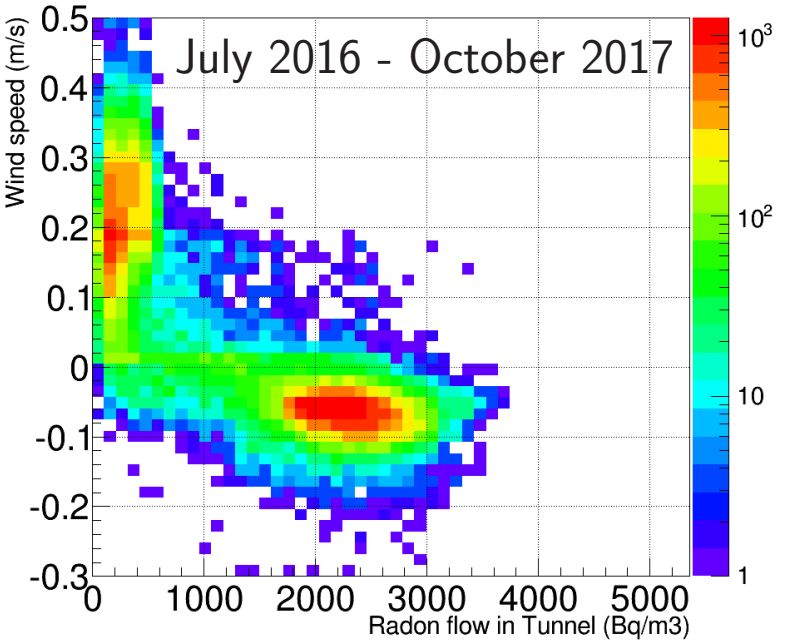
- 27 Rn detectors used to monitor the radon in the mine (14 in SK areas)
- with 22 using the Raspberry Pi electronics

Radon monitoring in the tunnel



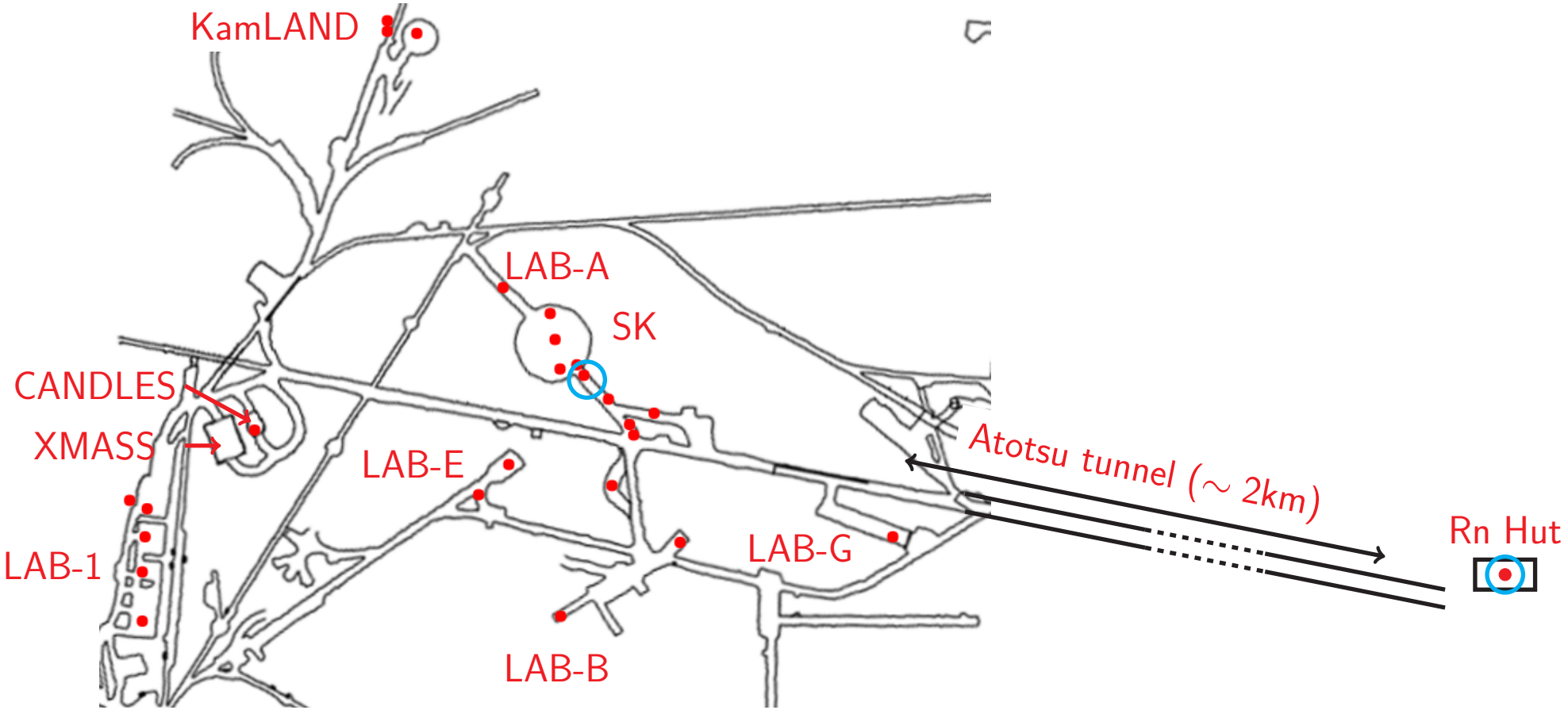
Radon monitoring in the tunnel: Seasonal fluctuation



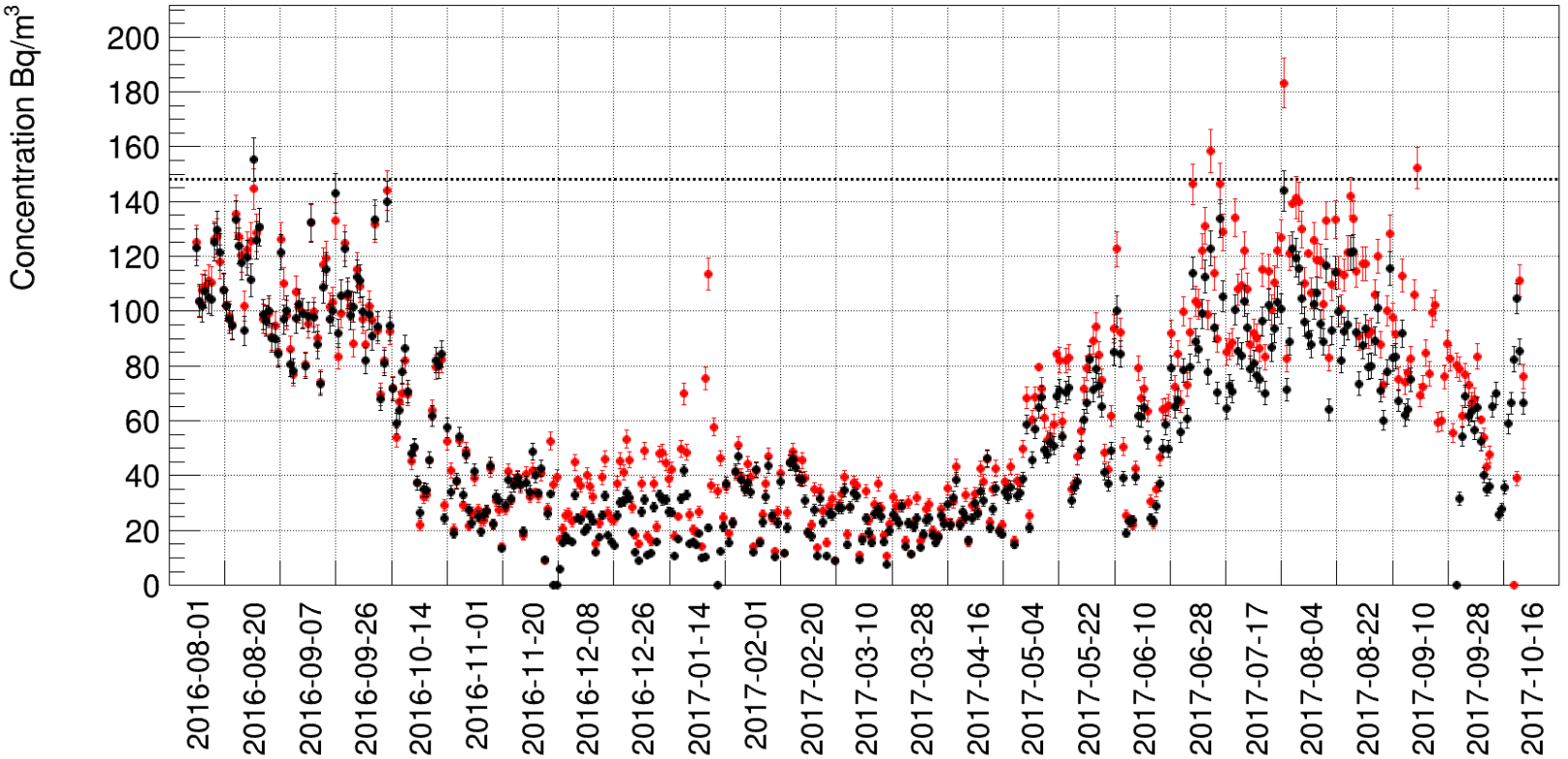


- Very high concentration, visible seasonal fluctuation
- Observation of correlations between wind direction and Rn concentration:
- In summer, the wind is coming from inside the mine $\rightarrow$ dirty air
- In winter, the wind is coming from outside the mine $\rightarrow$ fresh and clean air

Radon monitoring of the fresh air

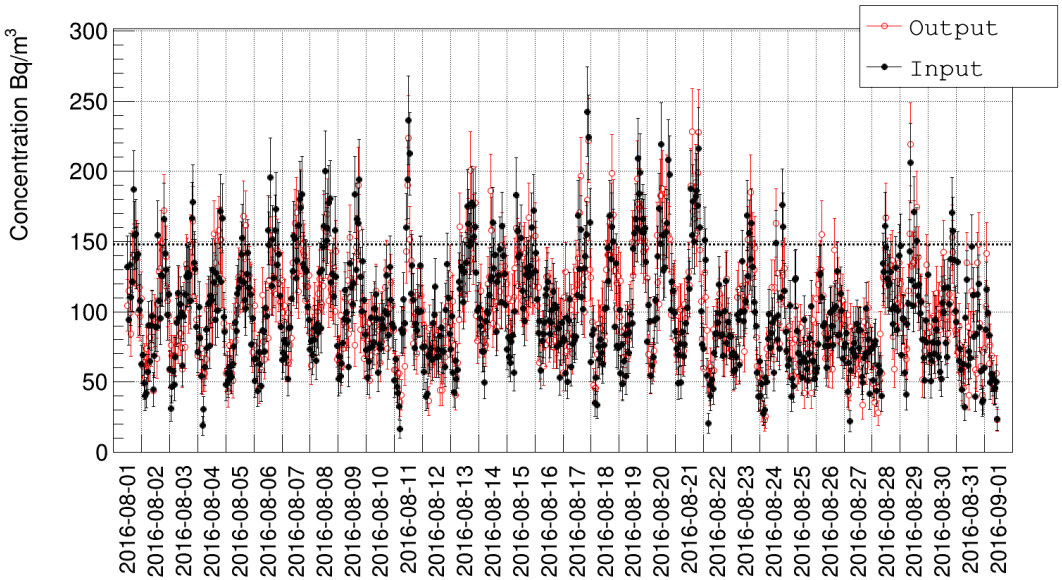


Radon monitoring of the fresh air



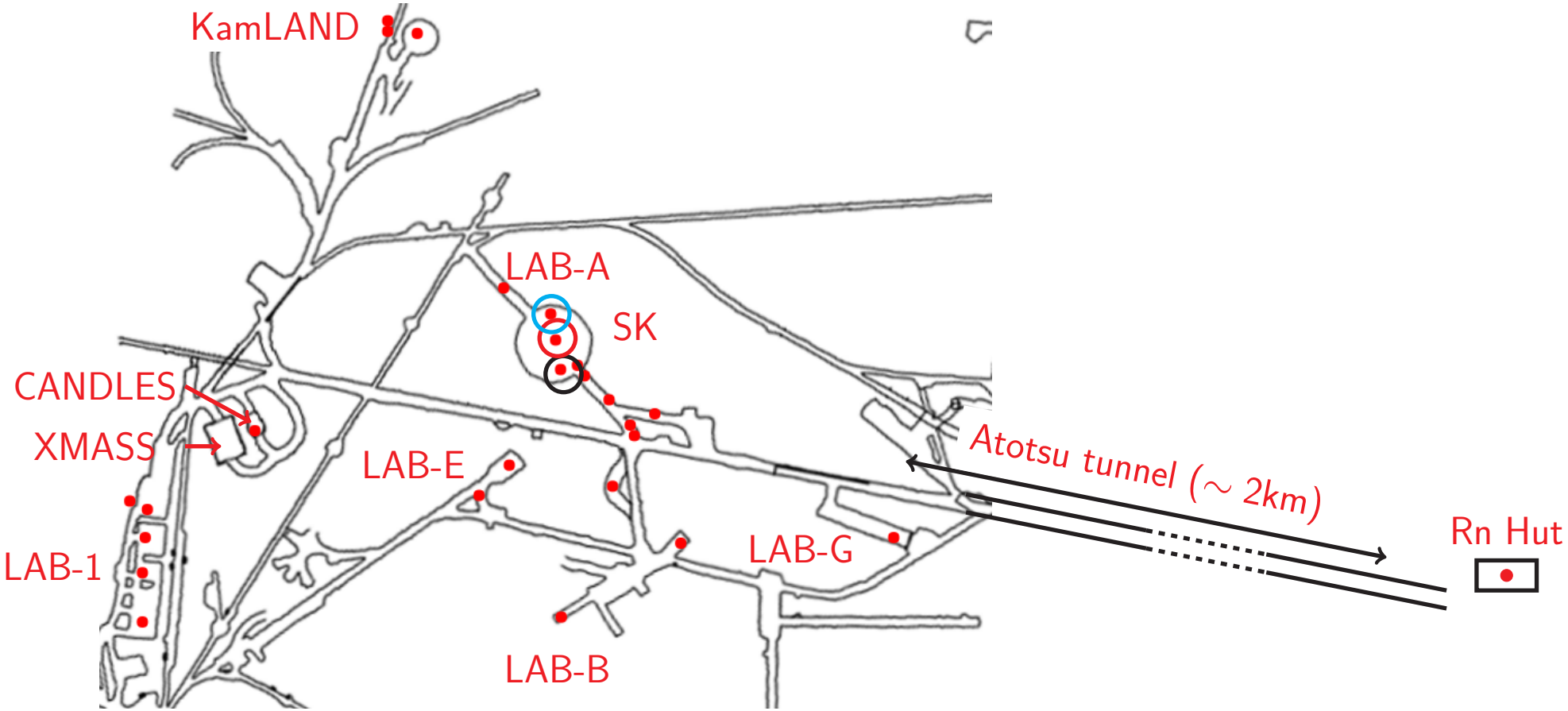
- Need to bring fresh air in the mine to reduce the Rn concentration
- Rn concentration mostly below 148 Bq/m^3, but time to time higher during summer

Radon monitoring of the fresh air: Day / Night fluctuation



- Second Radon detector, settled at the input of the air pipe
- Clear correlation between the concentration in the input and in the output $\longrightarrow$ no leak
- Day/Night fluctuations, phenomenom expected from the stratification of the air during nighttime, and from the intermixing caused by the heat from the sun radiations during daytime.

Radon monitoring in Super-K areas: Dome



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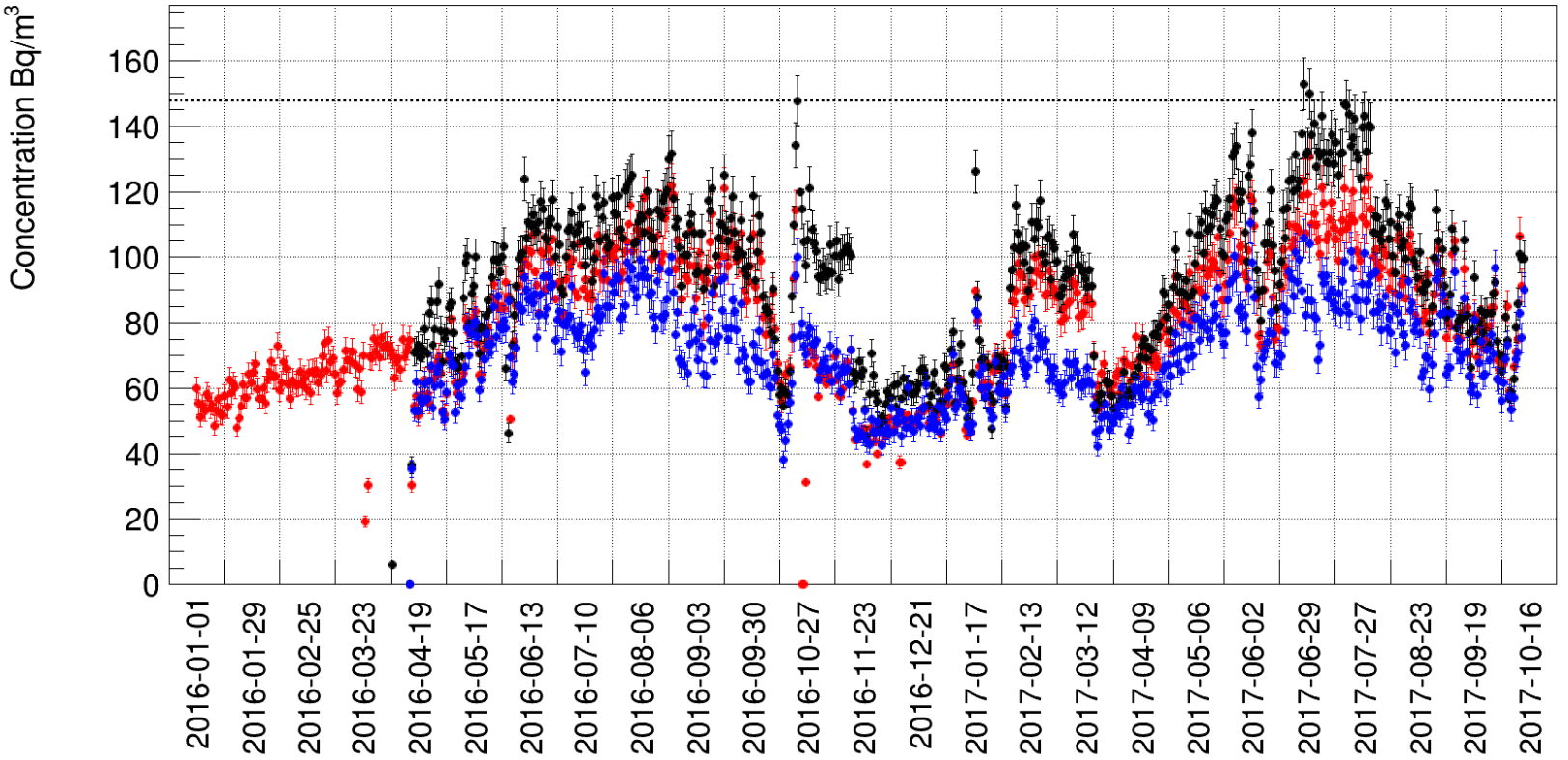


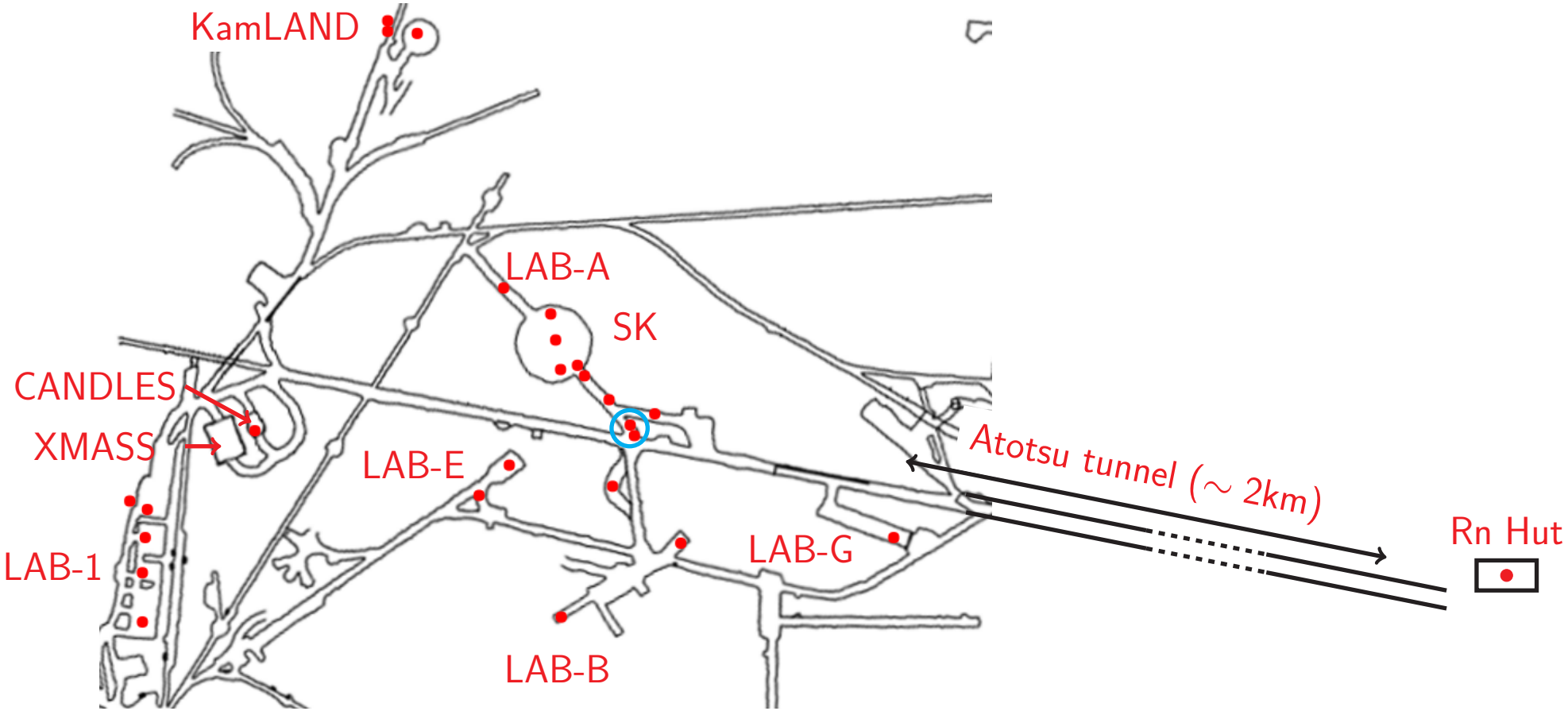
Dome Tunnel side

Dome Center

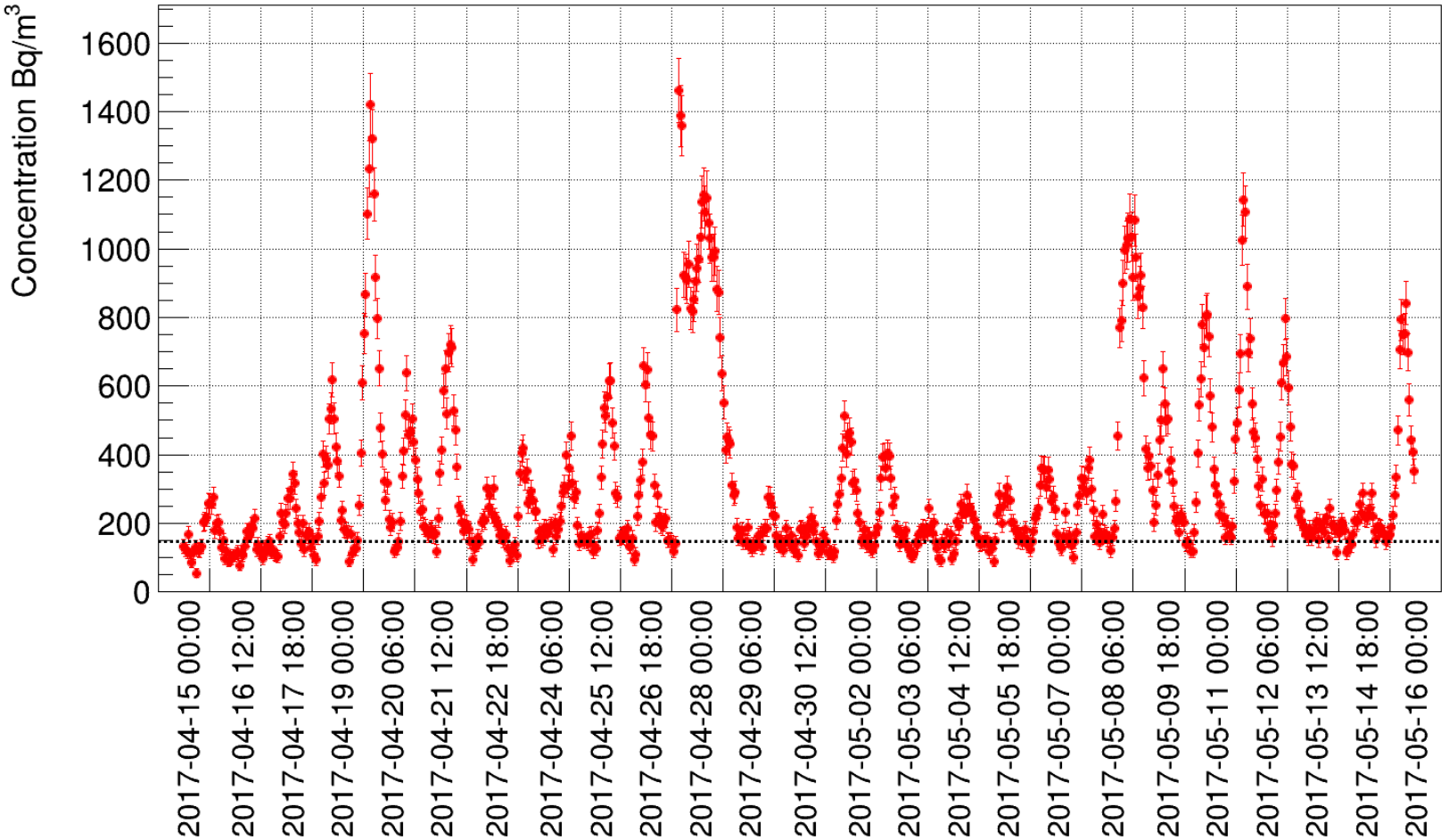
Dome LAB-A side

- Rn concentration mostly below 148 Bq/m^3
- 2 large increases during last winter (1st/ entrance room opened overnight, 2nd/ work on aeration system)

Radon monitoring in Super-K areas: Entrance

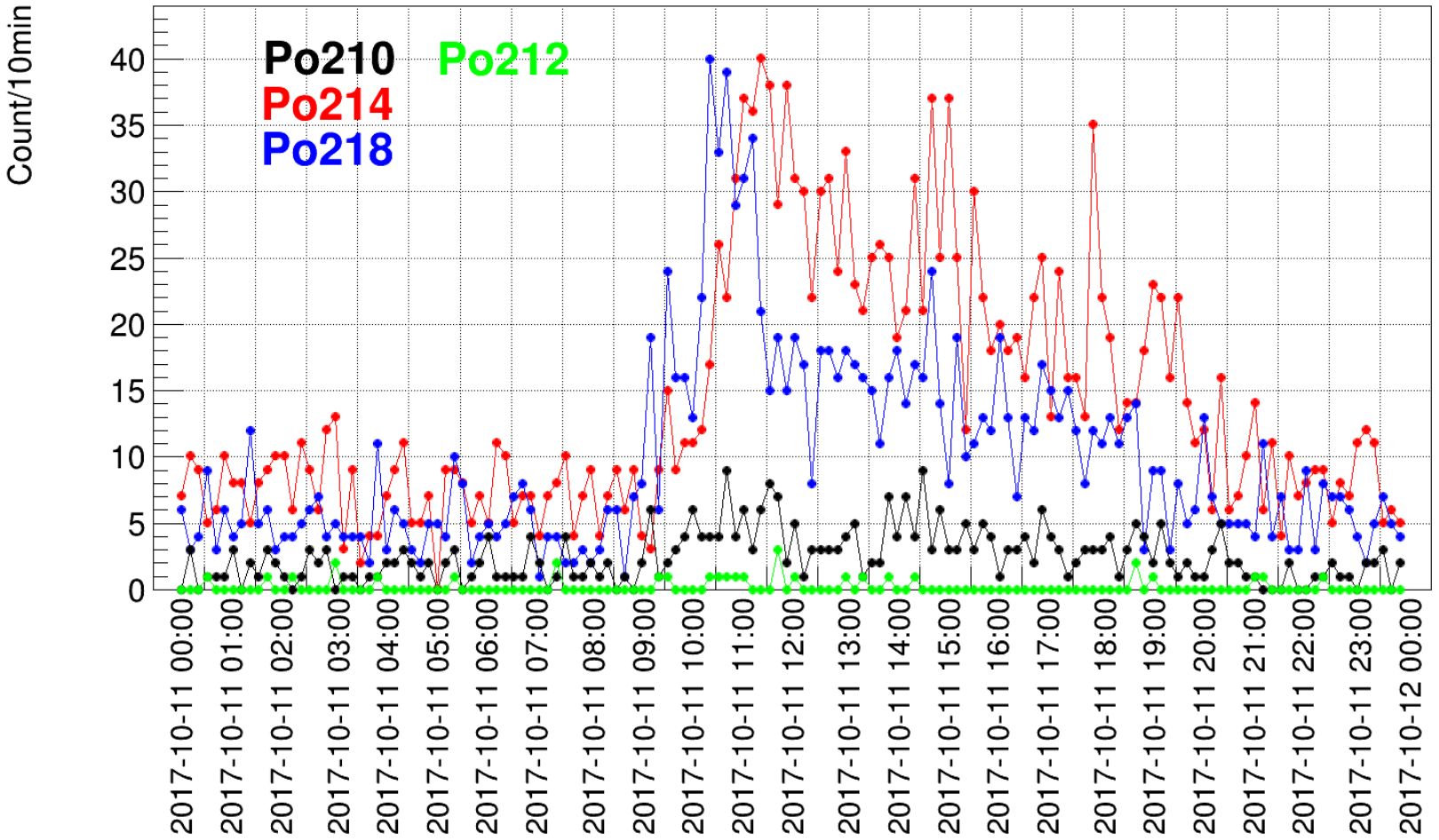


Radon monitoring in Super-K areas: SK entrance zoom



- The entrance room acts as a airlocked door between the tunnel (with high radon concentration) and the SK dome (where we need low radon concentration)
- Each time someone open the door, the radon increase in the entrance room

Radon monitoring in Super-K areas: SK entrance zoom



- We can even determine at which time the door was openned!

Summary table

	Detectors	Averaged radon concentration ± fluctuation (Bq/m^3)				
		Year	Winter	Spring	Summer	Fall
Tunnel	1	1324 ± 986	281 ± 94	1440 ± 765	2418 ± 139	1031 ± 915
Fresh air	2	53 ± 36	27 ± 15	36 ± 20	98 ± 23	46 ± 29
Super-K (Dome)	3 (+1)	87 ± 24	76 ± 20	84 ± 21	104 ± 21	75 ± 22
Super-K (Entrance)	1	172 ± 135	96 ± 35	141 ± 58	274 ± 112	233 ± 211
Super-K (Shift room)	1	54 ± 14	48 ± 10	56 ± 12	68 ± 10	43 ± 9

Fluctuation are the RMS of the distributions

- More than 20 1L detectors deployed to monitor the radon concentration in the Kamioka mine, taking data since more than 2 years.
- Similar seasonal variations observed in the whole mine, due to the air flow.
- The experimental areas are relatively safe for workers, with the radon concentration mostly below 148 Bq/m^3