Measurement of Radon concentration in Super-Kamiokande tank

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Contents

- Super Kamiokande detector
- High sensitivity Rn detector
- Rn concentration in the air layer of SK tank
- Rn concentration in SK water
- Conclusion and Future

Super Kamiokande detector

◆Feature of SK detector

◎Structure of SK

(1)Inner detector 20-inch PMT

Fiducial volume 22.5 kton (2m from wall)

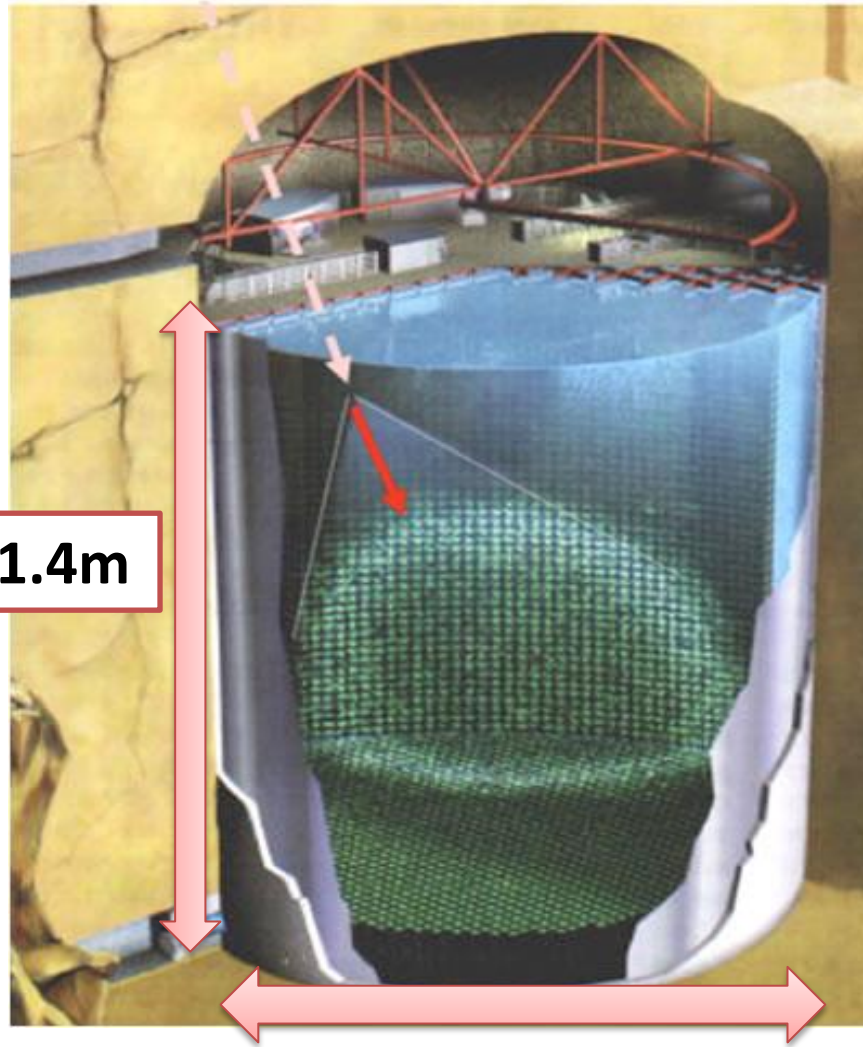
(2)Outer detector 8-inch PMT

◎Water Cherencov type detector

-Energy

-Vertex

-Direction



◆Research for neutrino

-Long baseline neutrino oscillation(T2K)

-Atmospheric neutrino

-Proton decay

-Supernova neutrino (< 100MeV)

-Solar neutrino (< 20MeV, Yokozawa-san's talk)

Background in Low-Energy region

◆Purpose of Background study

(1)Understand the origin of BG
(2)Reduce BG events
(3)Achieve lower energy threshold → Current 4.5MeV (Total Energy)
→Get lower energy (Solar) neutrino!!

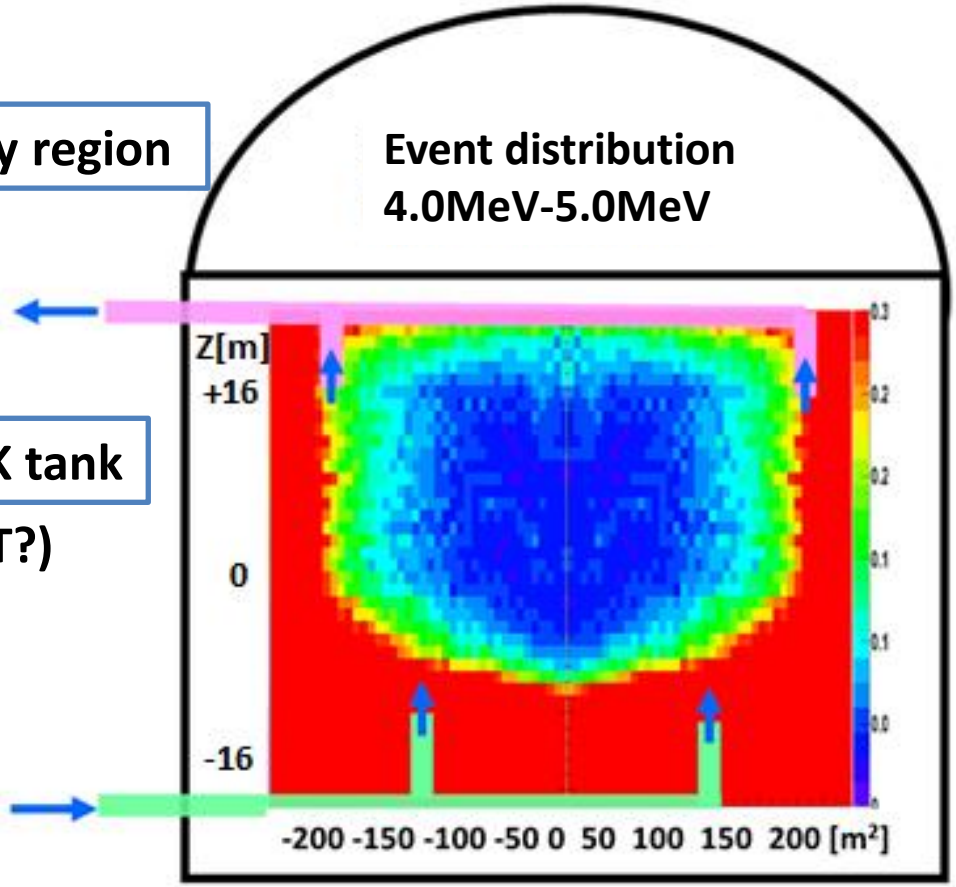
◆Candidate of Background in Low-Energy region

β decay of ^{214}Bi(Q=3.27MeV)
^{222}Rn daughters remaining in SK water
→Main background of Solar neutrino.

◆Measurement of Rn concentration in SK tank

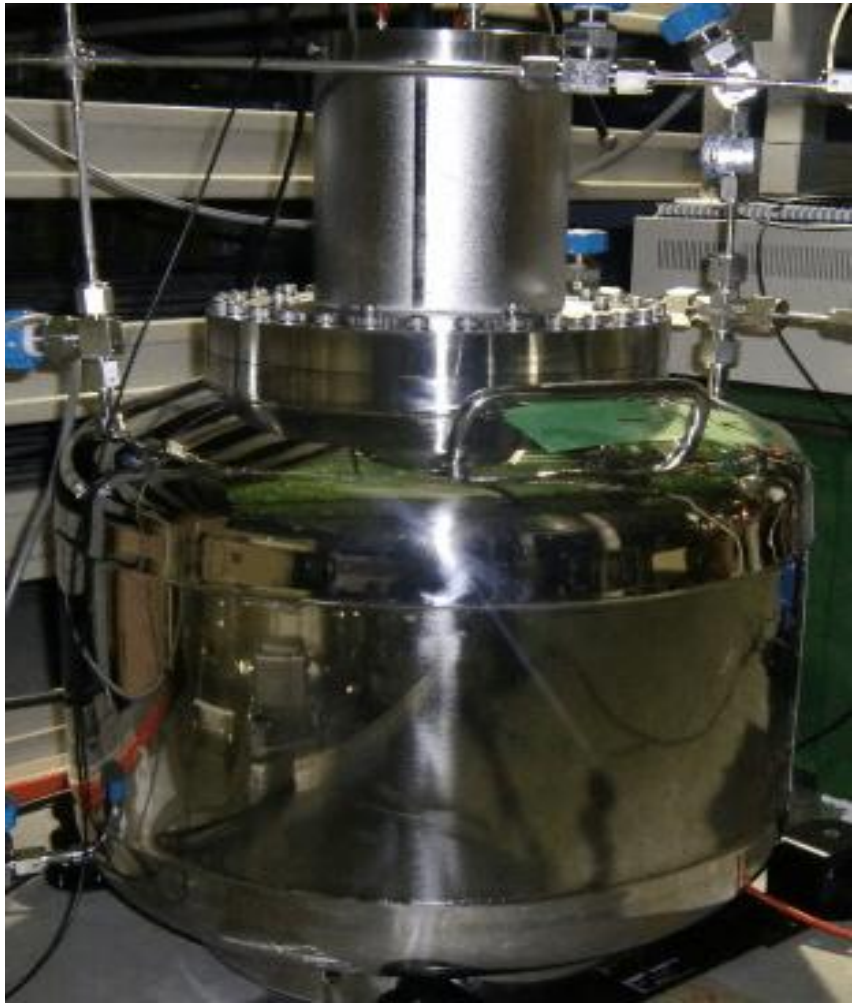
Excess of event rate in SK tank (Rn or NOT?)

Measurement positions
(1)Input water
(2)Near wall (bottom region)
(3)Position dependence(Z direction)



(Color)event/kton/day
Blue Low → High Red

High sensitivity Rn detector



High sensitivity Rn detector

◆Detection method — Electrostatic collection

-90% of ^{218}Po is positive charged

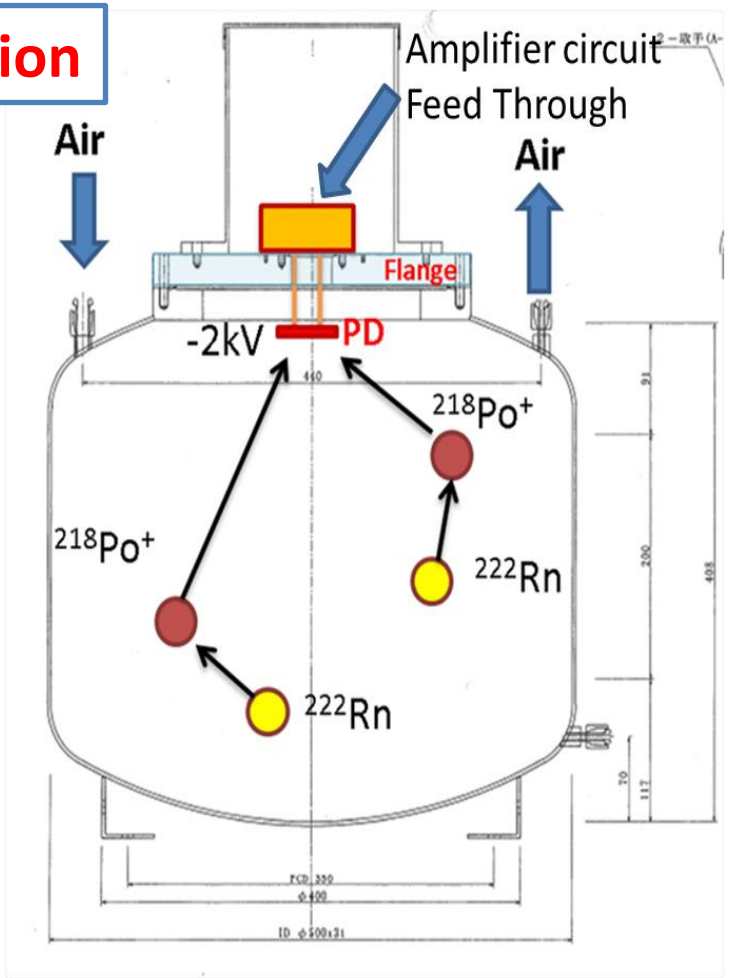
^{222}Rn→^{218}Po^{+}→^{214}Pb^{+}→^{214}Bi^{+}→^{214}Po^{+}

-Supply HV to PIN Photo Diode(PD)

→Collect positive charged particles.

Detect α ray(7.68MeV) from decay of ^{214}Po

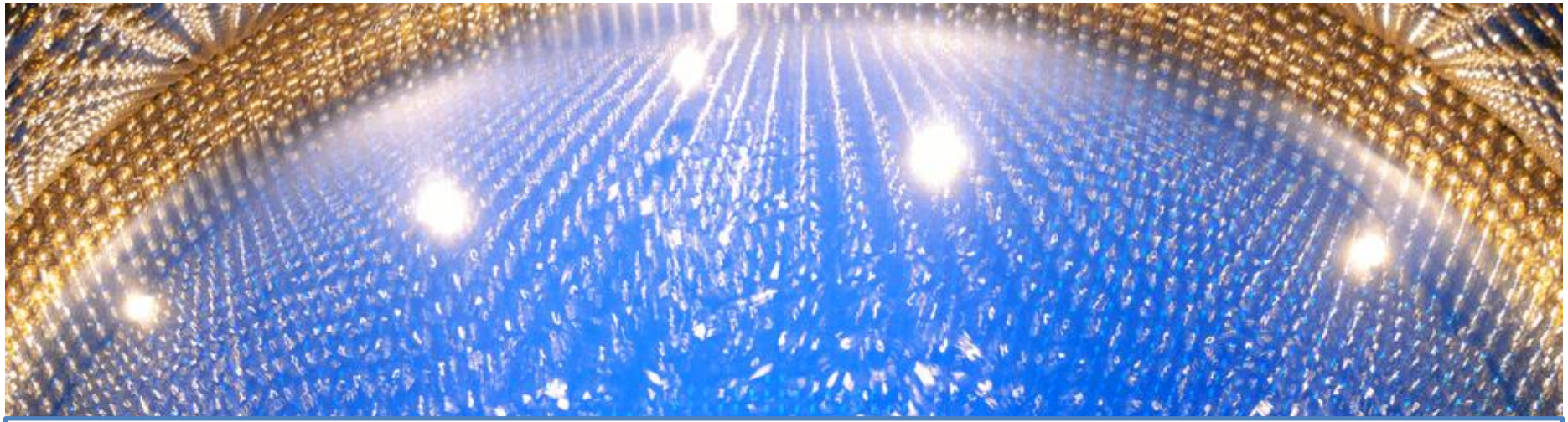
Count it and convert to Rn concentration



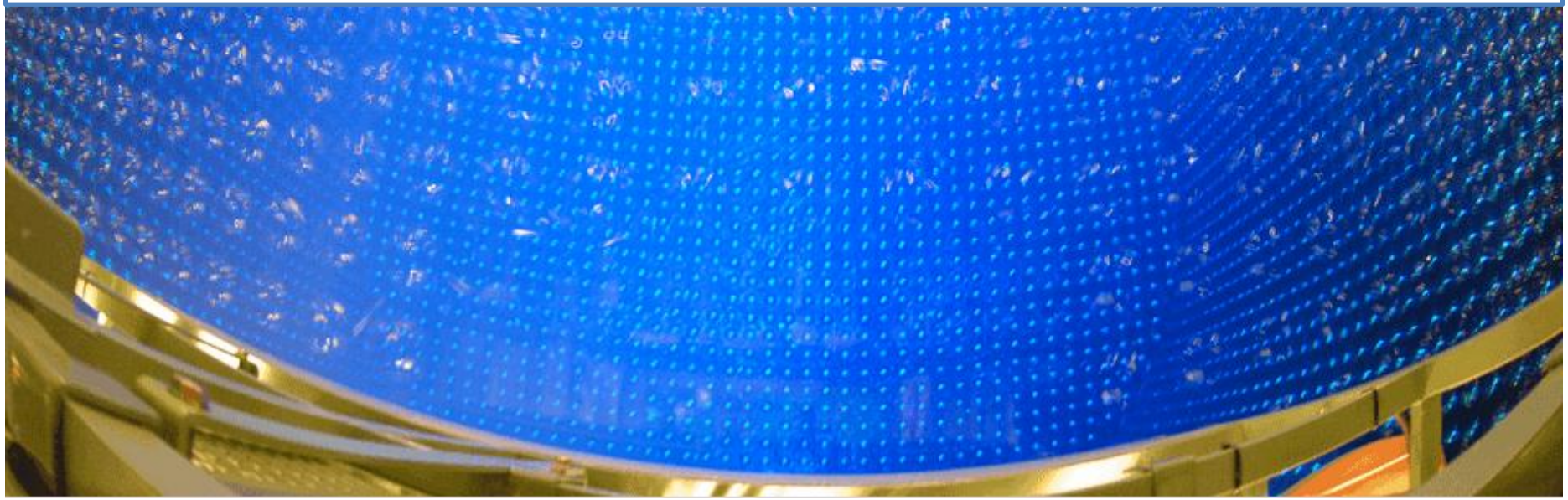
◆Calibration Factor

$$CF[\mathrm{CPD}/(\mathrm{mBq/m^3})] = \frac{\text{Count of α decay of 214Po per day[CPD]}}{\text{Rn concentration [mBq/m}^3\text{]}}$$

→Detection limit of this detector -> ~2 mBq/m^3



Rn concentration in the air layer of SK tank

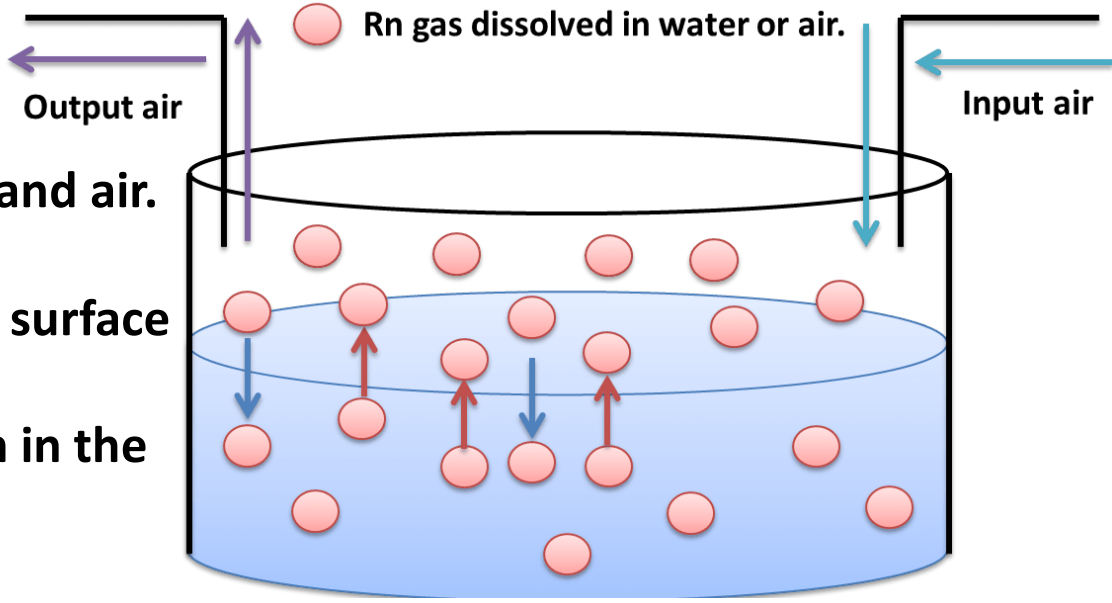


Equilibrium between air and water

◆Equilibrium

◎Exchange Rn gas between water and air.

◎Estimate Rn concentration of the surface of SK water,
using the result of Rn concentration in the air layer of SK tank.

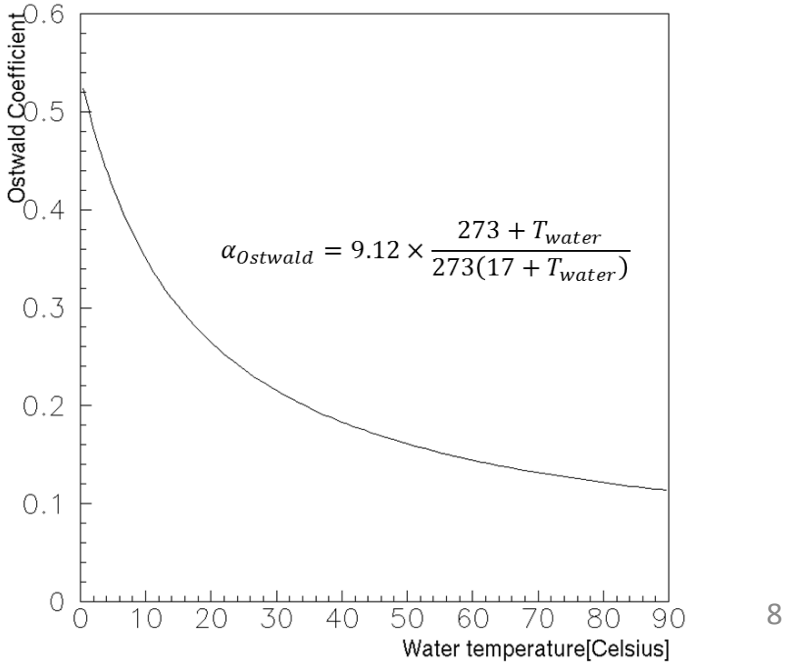


◆Ostwald coefficient

The ratio of Rn concentration in water to Rn concentration in air depend on a temperature of water.

$$\alpha_{Ostwald} = \frac{\text{Rn concentration in water}}{\text{Rn concentration in air}}$$

$$= 9.12 \times \frac{273 + T_{\text{water}}}{273(17 + T_{\text{water}})}$$



Measurement of Rn concentration in the air layer of SK tank

◆The air layer of SK tank

-60cm air layer between the surface of SK water and the top of SK.

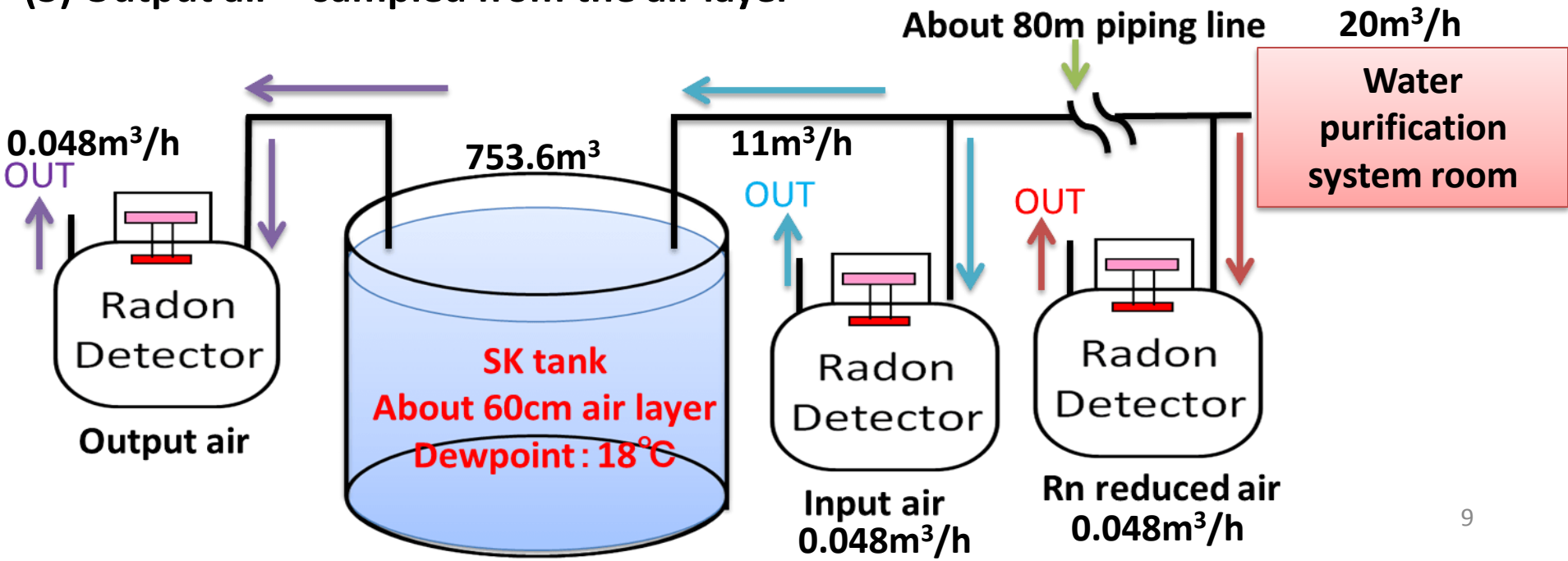
-Rn reduced air is always flowing to SK tank

◆Measurement position

(1) Rn reduced air – made in Water purification system room

(2) Input air – flowing into the SK tank

(3) Output air – sampled from the air layer



Result

◆Period

From November 17, 2012
To February 5 , 2013 (81days)

◆Result

(1)Rn reduced air

$C_{reduced}$ = 3.7 ± 0.2 mBq/m³

(2)Input air

C_{In} = 3.5 ± 0.2 mBq/m³

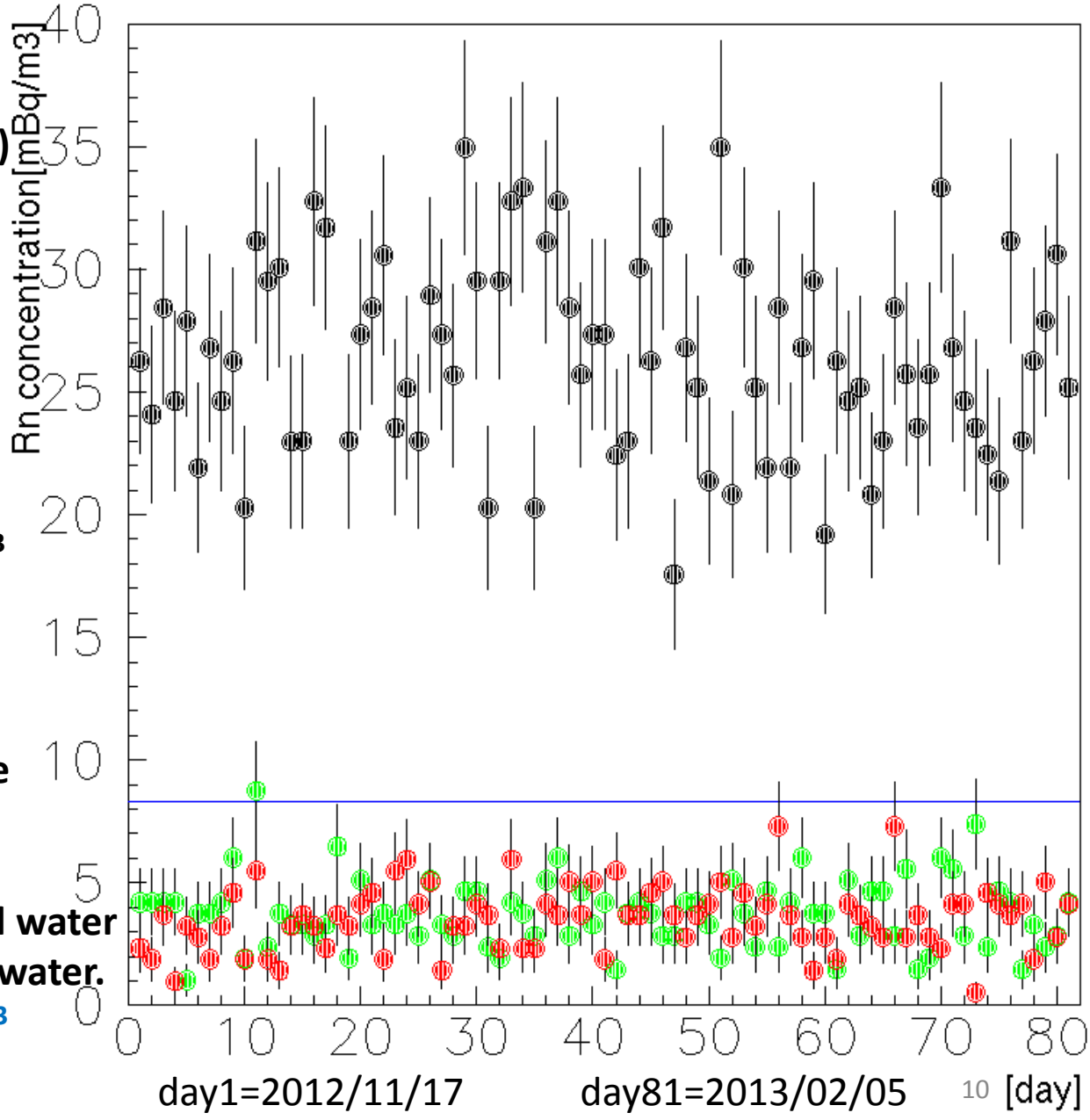
(3)Output air

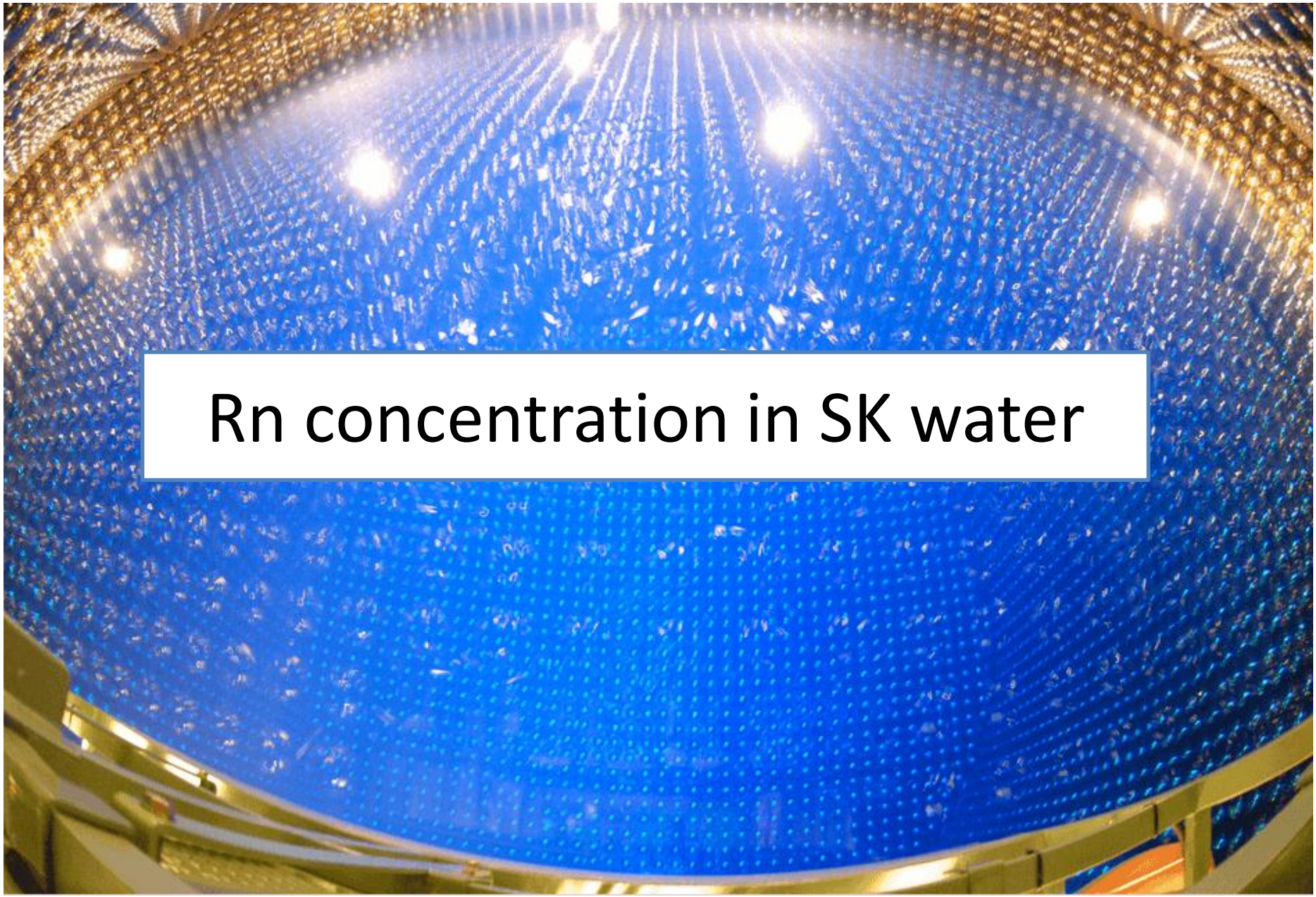
C_{Out} = 26.7 ± 0.5 mBq/m³

-Emission of Rn in the tank
-No emanation of Rn from
the piping line thorough the mine

Assuming equilibrium of
Rn concentration between air and water
We estimate Rn concentration of water.

C_{water} = 8.3 ± 0.1 mBq/m³





Rn concentration in SK water

Measurement of Rn concentration

◆Measurement method

(1)Extracting Rn in SK water

→Mixed SK water and G1 pure air with Mixer

(2)Absorption Rn with activated charcoal.

→Cooled ethanol as -90℃ with a cooler

Desorption Rn from activated charcoal.

→250℃ with a heater

(3)Measure Rn concentration with Rn detector

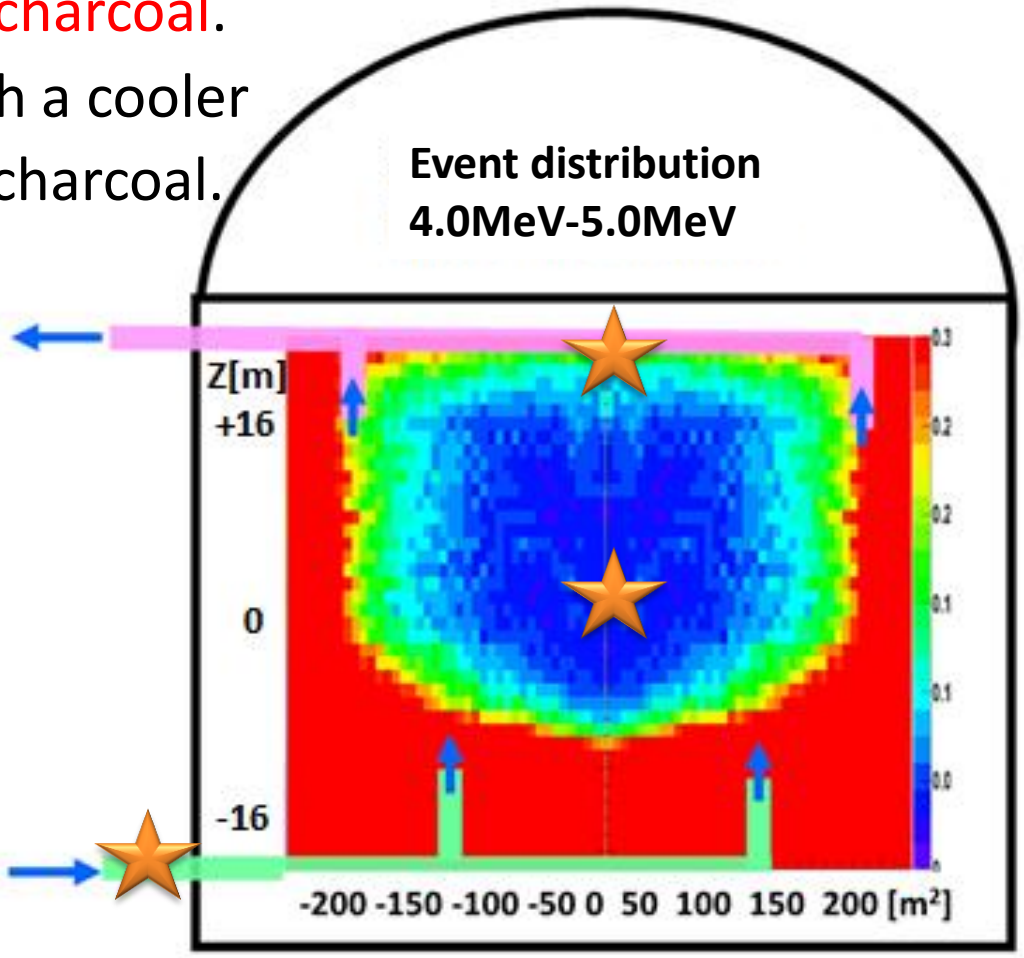
◆Measurement positions

(1)Center (Z = +0.4m)

(2)Surface(Z = +20.4m)

(3)Input water(2 times)

(4)Background



Mixer

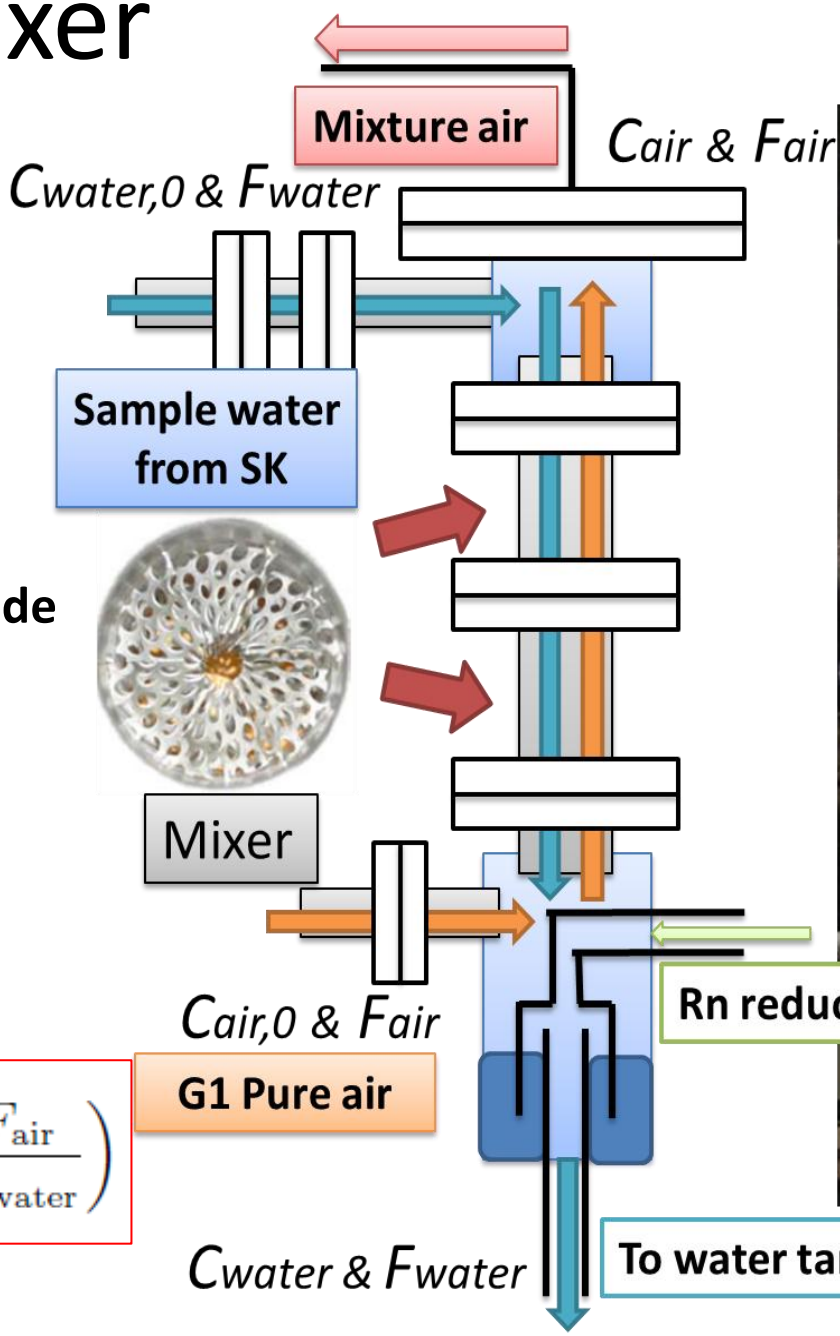
◆Mixing process

Mixed pure air and SK water sampled from SK tank.
Rn (water → air)

◆Mixer

Water sampled SK tank is made into mist state with Mixer.

Mist mixed with pure air, Rn dissolved SK water are extracted by pure air.



$$C_{\mathrm{water},0} = C_{\mathrm{air}} \left(\alpha_{\mathrm{Ostwald}} + \frac{F_{\mathrm{air}}}{F_{\mathrm{water}}} \right)$$

Absorption/Desorption with activated charcoal

◆Efficiency of absorption

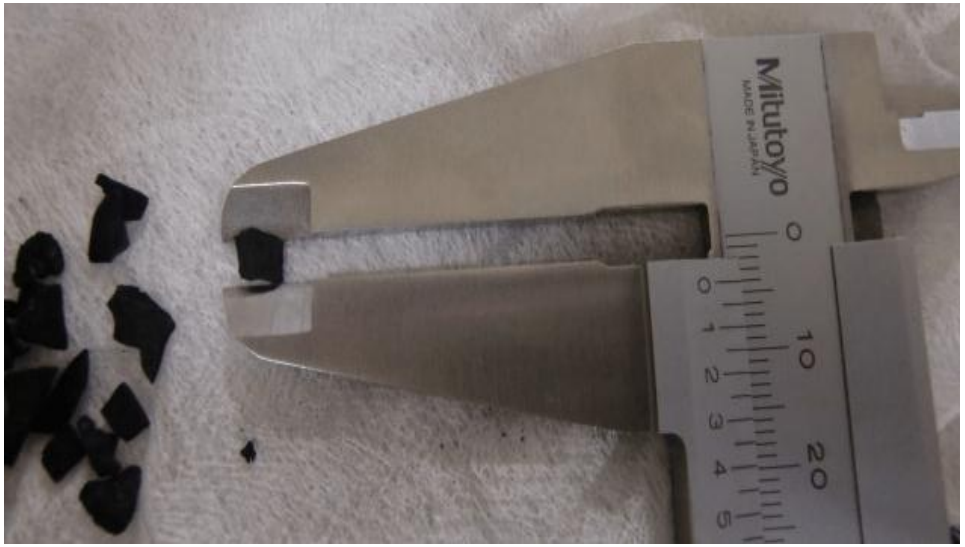
Efficiency of absorption Rn is ~100% under -60℃

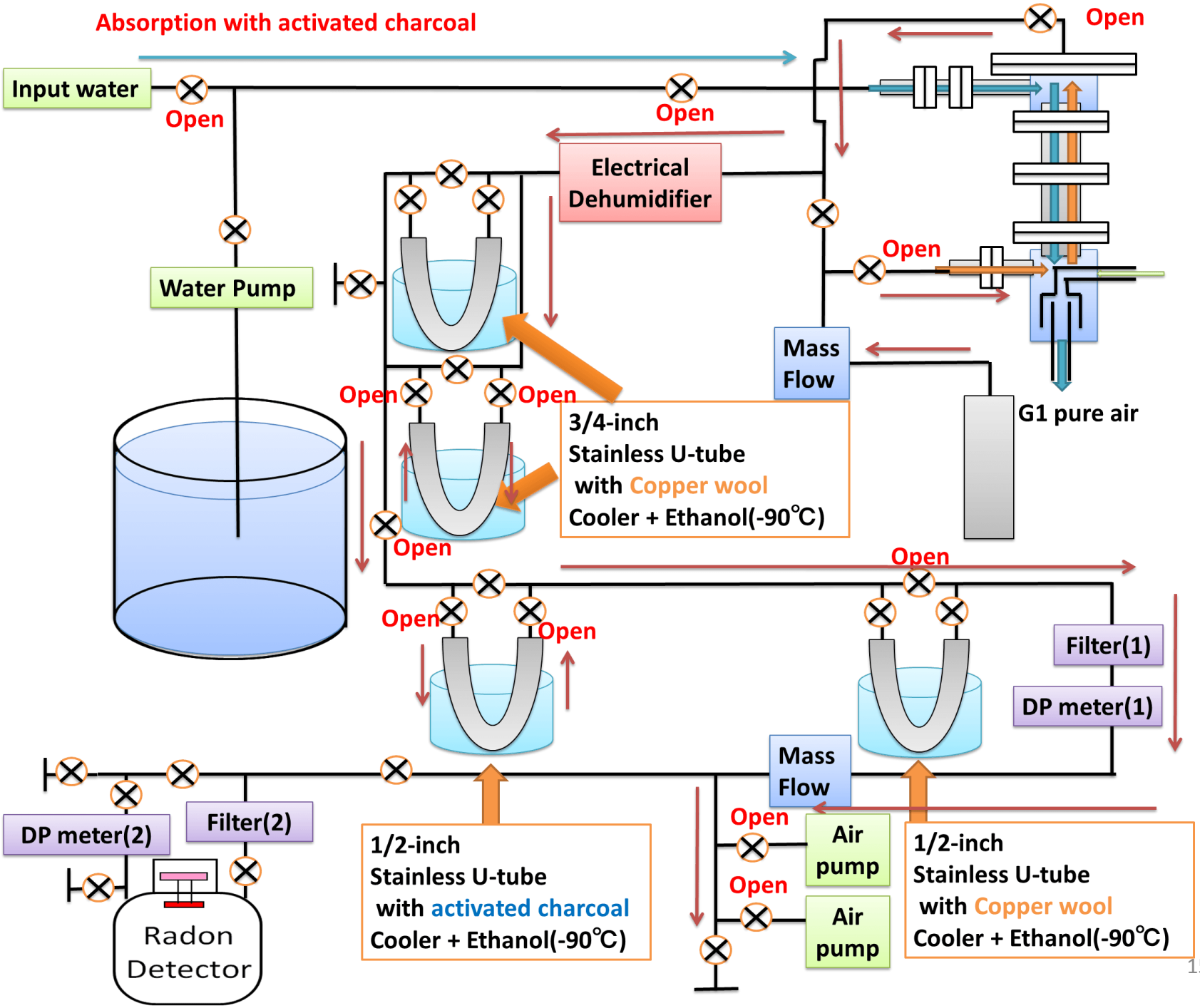
◆Efficiency of desorption

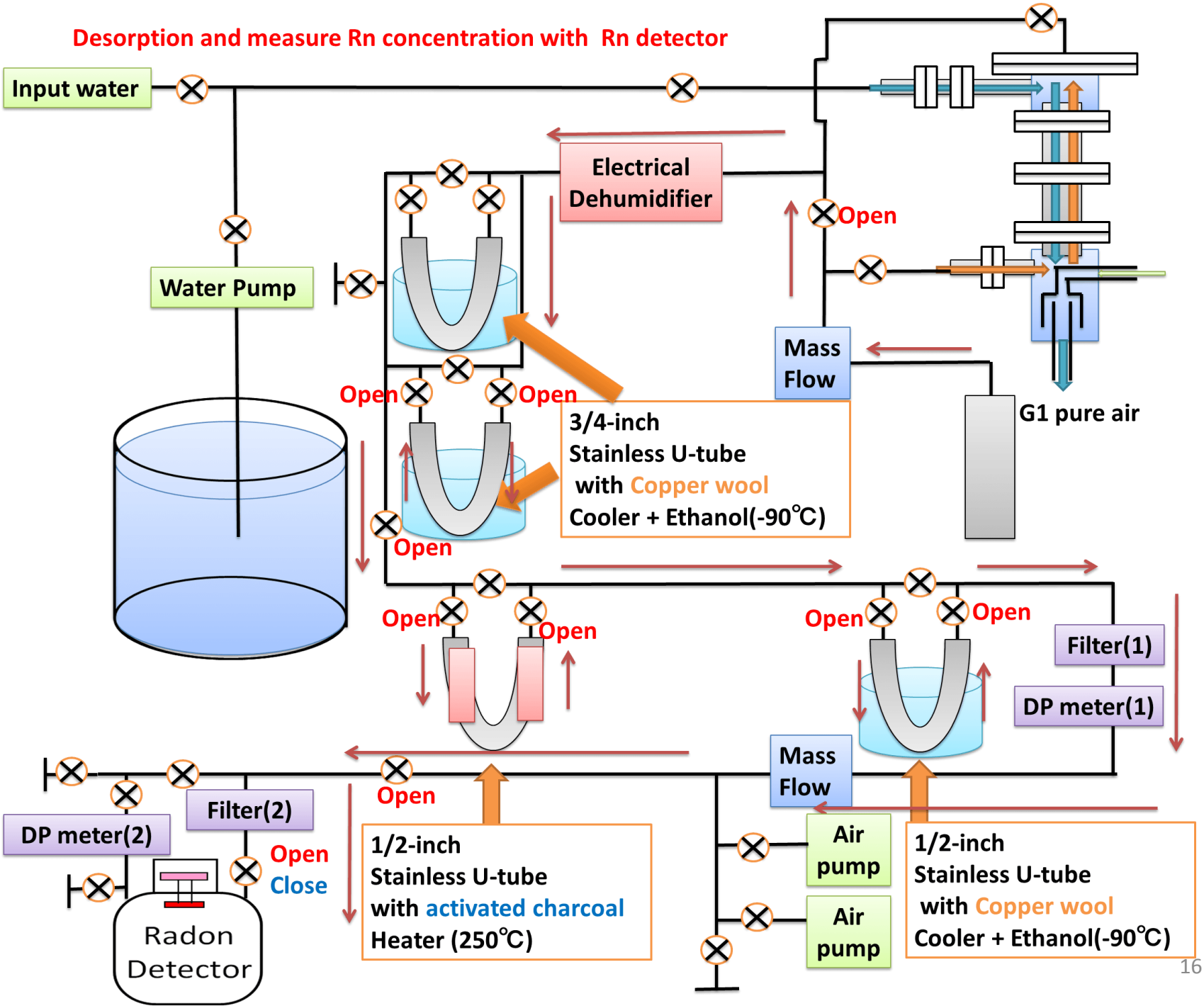
Efficiency of desorption Rn is ~100% over +200℃

◆How to cool/heat

Put charcoal into
½ -inch stainless U piping
(Cool) Ethanol＋cooler(-90℃)
(Heat) Hater(+250℃)




Absorption with activated charcoal
Input water
Open
Open
Open
Electrical Dehumidifier
Water Pump
Open
Mass Flow
G1 pure air
Open
Open
3/4-inch
Stainless U-tube
with Copper wool
Cooler + Ethanol(-90℃)
Open
Open
Open
Open
Filter(1)
DP meter(1)
Mass Flow
DP meter(2)
Filter(2)
1/2-inch
Stainless U-tube
with activated charcoal
Cooler + Ethanol(-90℃)
Open
Air pump
Open
Air pump
1/2-inch
Stainless U-tube
with Copper wool
Cooler + Ethanol(-90℃)
Radon Detector


Desorption and measure Rn concentration with Rn detector
Input water
Water Pump
Electrical Dehumidifier
Open
Mass Flow
G1 pure air
Open
Open
3/4-inch
Stainless U-tube
with Copper wool
Cooler + Ethanol(-90℃)
Open
Open
Open
Open
Open
Filter(1)
DP meter(1)
Mass Flow
Open
DP meter(2)
Filter(2)
Open
Close
Radon Detector
1/2-inch
Stainless U-tube
with activated charcoal
Heater (250℃)
Air pump
Air pump
1/2-inch
Stainless U-tube
with Copper wool
Cooler + Ethanol(-90℃)

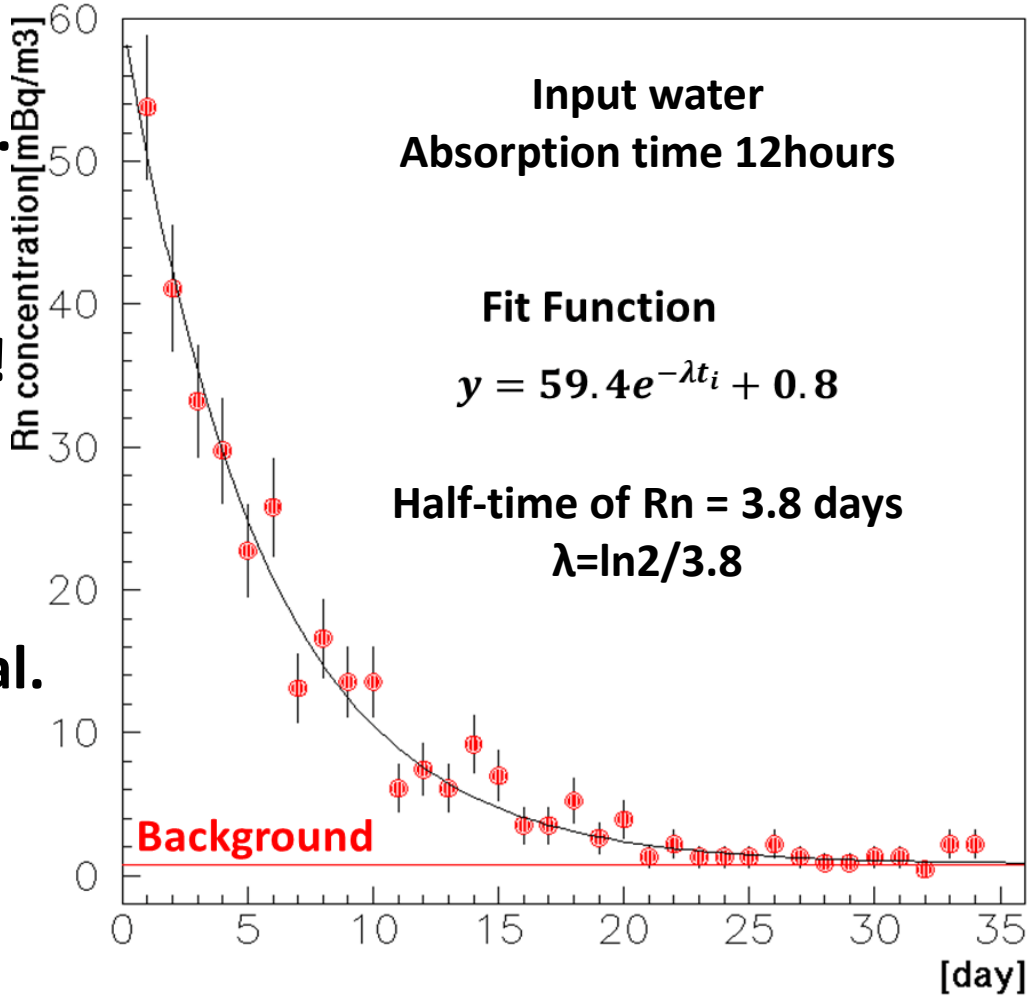
Measurement of Rn concentration with Rn detector

◆Method

Close Rn detector.
And Measure Rn concentration.
(Over 20 days)

We can see decay curve clearly!

By fitting,
calculate Rn concentration
after a desorption from charcoal.

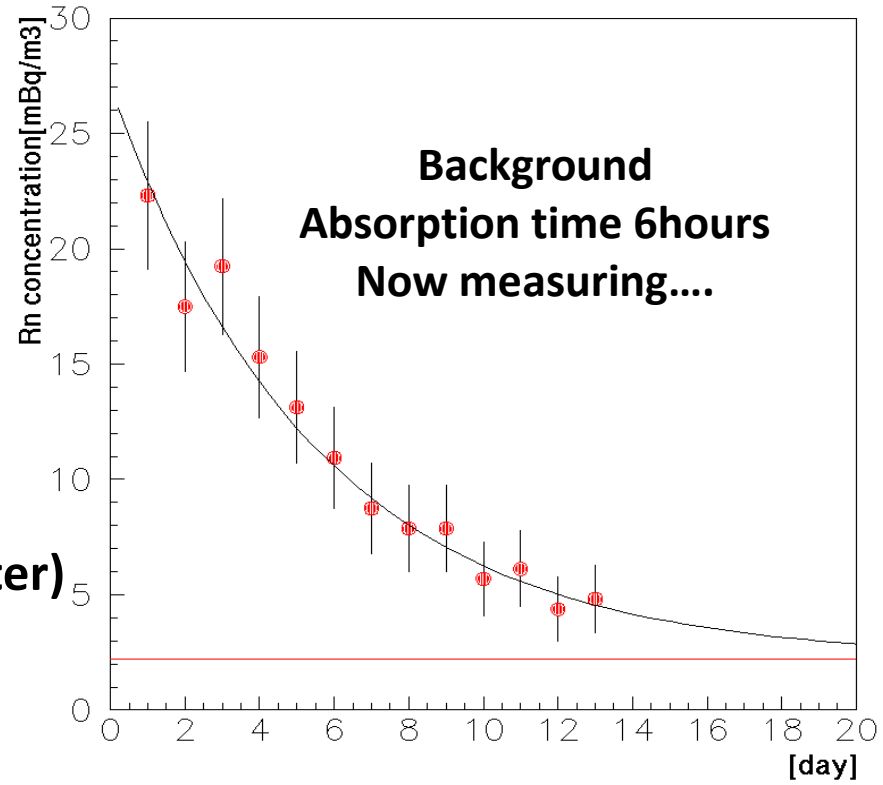


Result

◆Background of this measurement system

Emanation of Rn from
(1)piping line
(2)activated charcoal itself

Same process without sampling water.
(pure air through Mixer / DID NOT mixed water)
BG = 2.8 ± 0.4 mBq/m³



◆Result

Sample water	Air flow [L/min]	Water flow [L/min]	Temperature [℃]	Absorption [h]	Result [mBq/m³]
Center	1.8	1.9	16.0	12	1.0±0.6
Surface	2.0	1.8	16.1	6	5.2±0.9
Input water(1)	1.7	1.6	15.3	12	2.4±0.6
Input water(2)	1.7	1.6	14.9	6	3.7±0.8
Background	1.7	-	-	6	2.8±0.4

Background subtracted

Discussion

◆Input vs Center

Rn concentration in input water is **higher** than that of center.
Rn dissolved in SK water **decay** along with the flow of SK water.

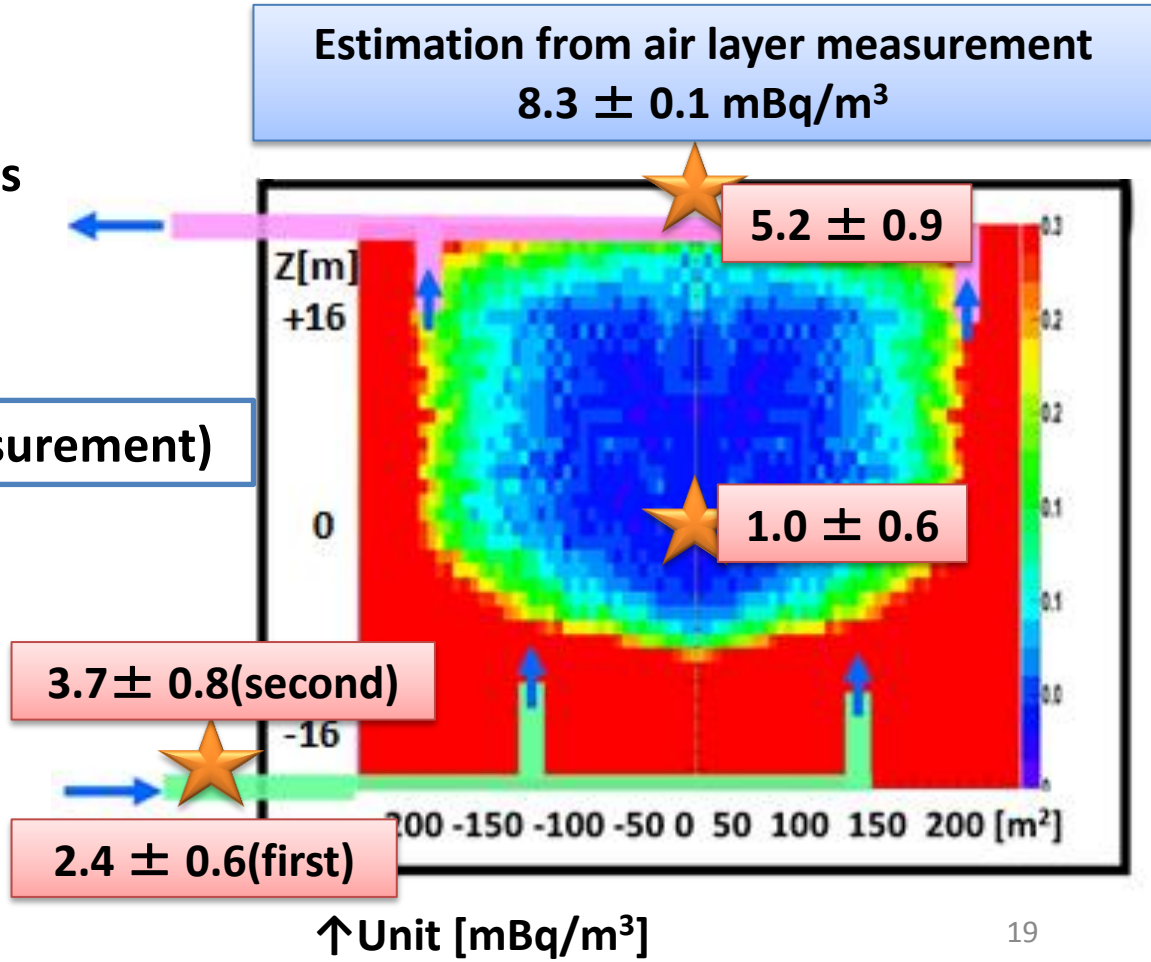
◆Input vs Surface

Rn concentration in input water is **lower** than that of surface water.
→Emanation of Rn in SK tank.

◆Surface(Estimated vs this measurement)

Rn concentration(Surface) obtained by this measurement is **lower** than estimated value.

Emanation of Rn from structure of SK.



Summary and Future

◆Background in Low-Energy region

β decay of ^{214}Bi(Q=3.27MeV)

^{222}Rn daughters remaining in SK water

→Main background of Solar neutrino.

◆Measurement of Rn concentration in the air layer of SK tank

Measured Rn concentration in Input air and Output air

C_{In} = 3.5 ± 0.2 mBq/m^3, C_{Out} = 26.7 ± 0.5 mBq/m^3

Emanation of Rn in SK tank

Estimated Rn concentration of the surface of SK water → 8.3 ± 0.1 mBq/m^3

◆Measurement of Rn concentration in SK water

Measured Rn concentration in SK water with Mixer and activated charcoal.

Rn concentration in SK water is ~mBq/m^3 level.

Continue this measurement, and understand the origin of Rn in SK tank.

Moreover, reduce Rn and achieve lower energy threshold!

BACK UP