RPC gap & detector production facilities @KODEL

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Current status of KODEL lab and facilities in 2024

The current KODEL lab and facilities have been operated for

- Construction of CMS endcap RPCs (2002 -)
- PHENIX RPCs (2008-2009)
- Future SHiP/BDF (2018 and ?)

Facilities and human resources for RPC production at KODEL

1. Human resources

Minho Kang and Youngmin Jo are working for gas gap production, QC tests, and detector assembly

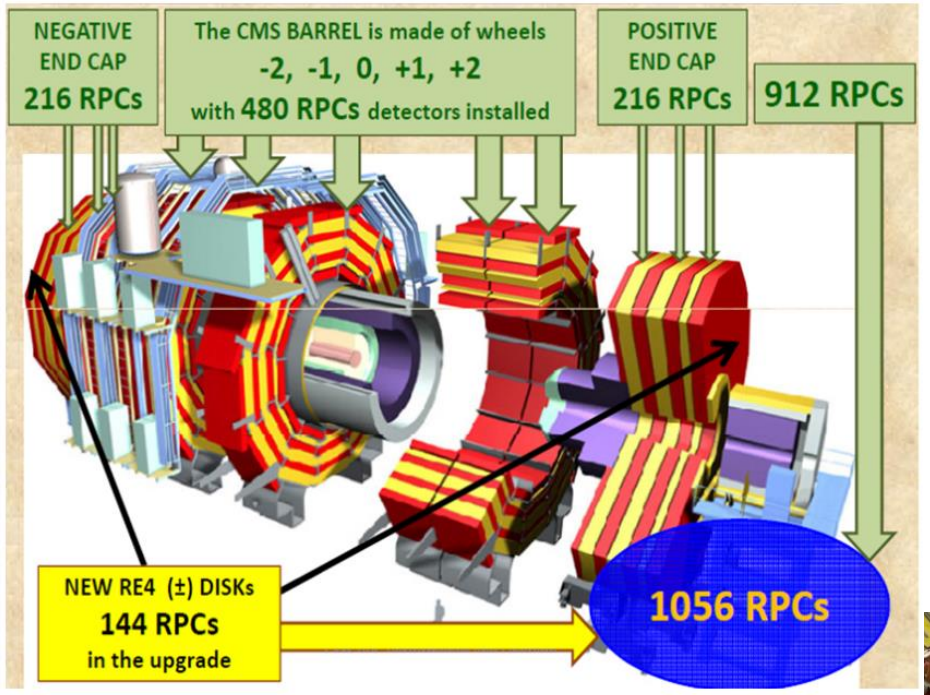
2. Facilities of phenolic electrode gas gaps (also for glass RPCs) operated since 1999

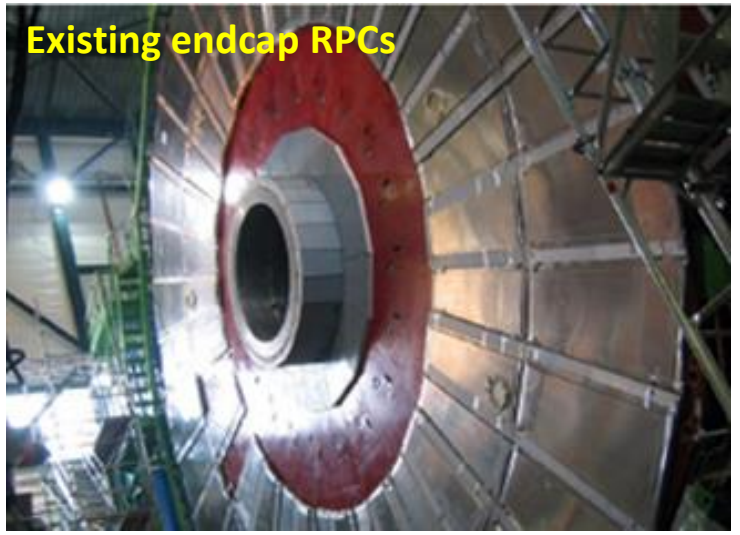
- Gluing and curing for gas gaps
- Linseed-oil varnishing tool
- QC test for Leak and spacer bonding
- QC test for stability of detector currents

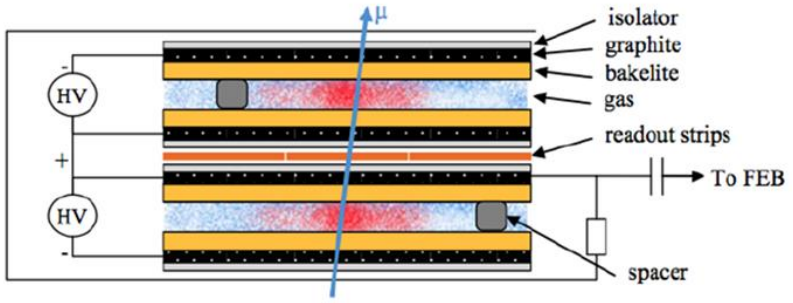
3. Utilizing dedicated facilities of company nearby Seoul for some processes (since 2020)

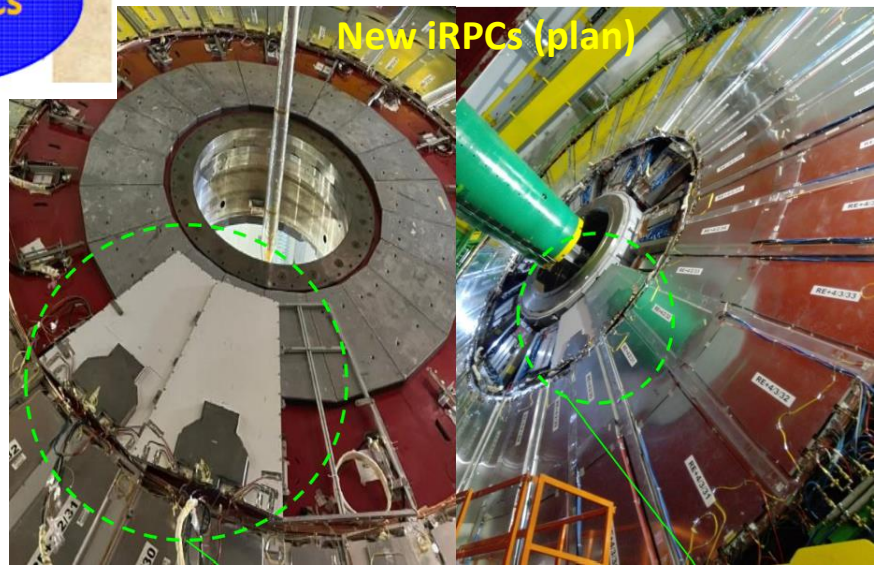
- Washing electrode: Damia @Goyang city
- Graphite coating: Damia @Goyang city
- Insulator coating (PET): Yurim @Goyang city

CMS endcap double-gap RPCs



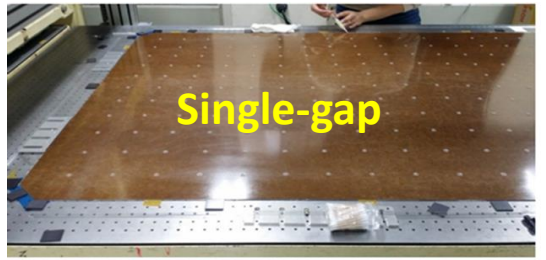


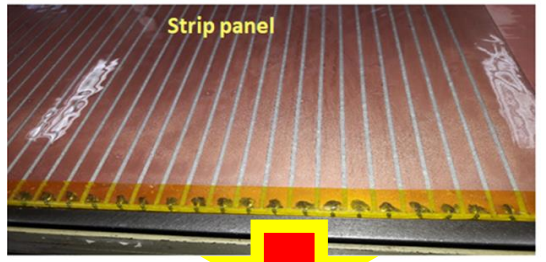




RPCs for SHiP/BDF-SND (muon tagger/filter)

Prototype 2-mm gaps and strips were used for measurements of muon flux and charm cross sections @H4 (2018)

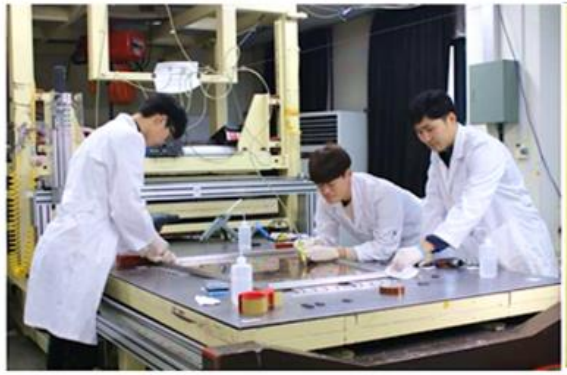




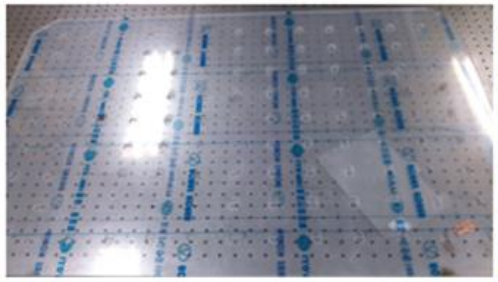
Gap production facilities

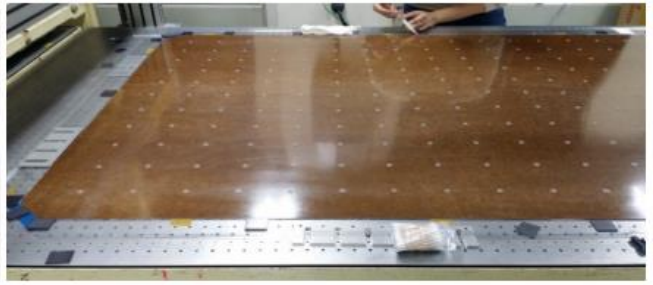
Gluing RPC electrodes (gas gaps)

Gluing tables and pressure devices



Spacer jig



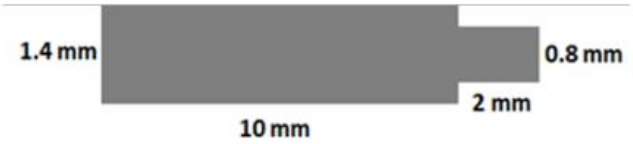


Metric tables and multi-layer air pouches for gluing and glue hardening for gaps

Air pouches uniformly press the whole surface of the gap with a pressure of 30 hPa (equivalent to 300 kg m^{-2}).

Gap supporting materials (molding)

peripheral strip spacers



gas-inlet profiles

circular spacers

Epoxy glue (3M DM460):
hardening time ~ 24 h
Requiring epoxy out gassing for additional 48 hours before oil varnishing

Gap production facilities

Linseed-oil vanishing and drying

Procedure of the linseed-oil varnishing using a facility composed of compressors, an oil tank, and a lifting device.

Oil mixture: 50% linseed oil + 50% heptane

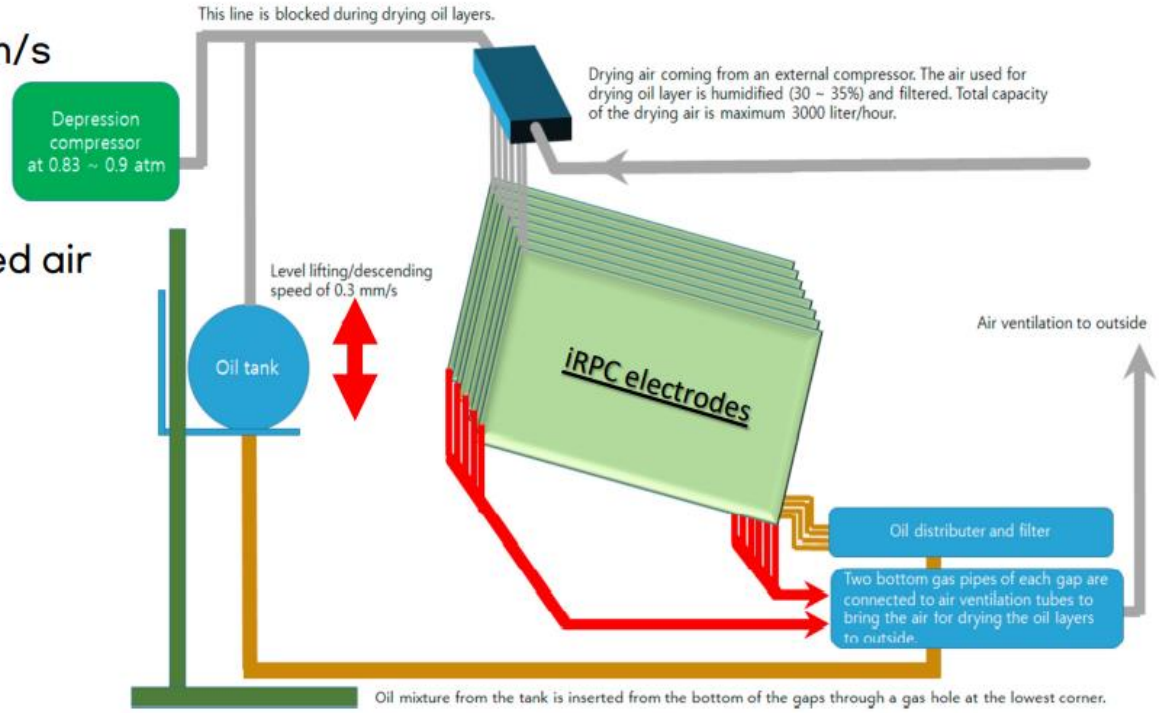
Speed of the lifting device = 0.3 mm/s

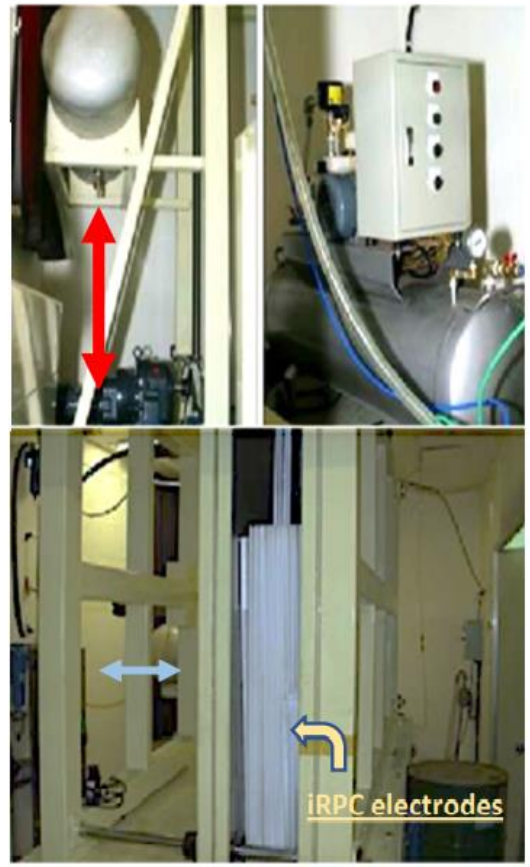
Quick double oiling @T=28 °C

Apply drying gaps with compressed air

@T=30 °C for 120 h and

@ room temperature for 24 h



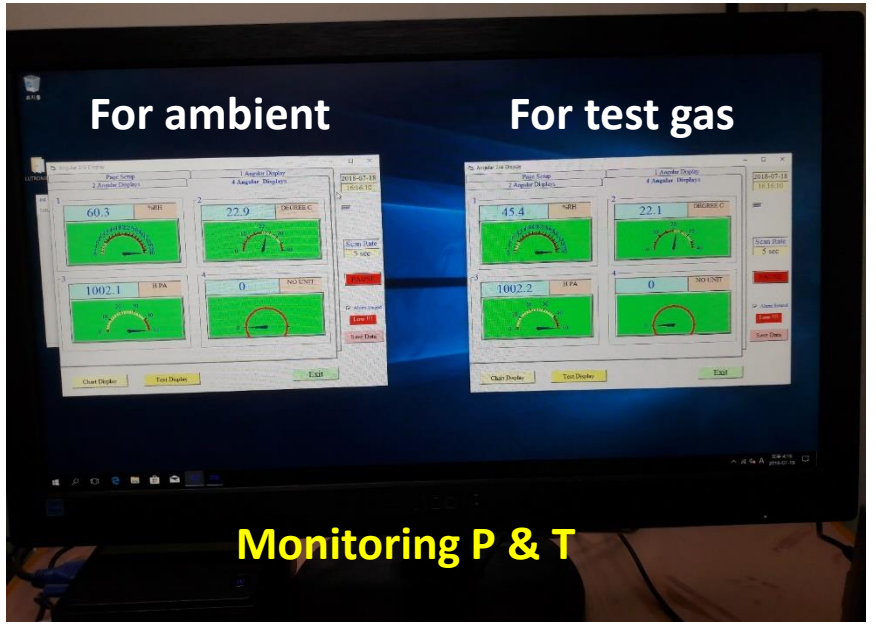


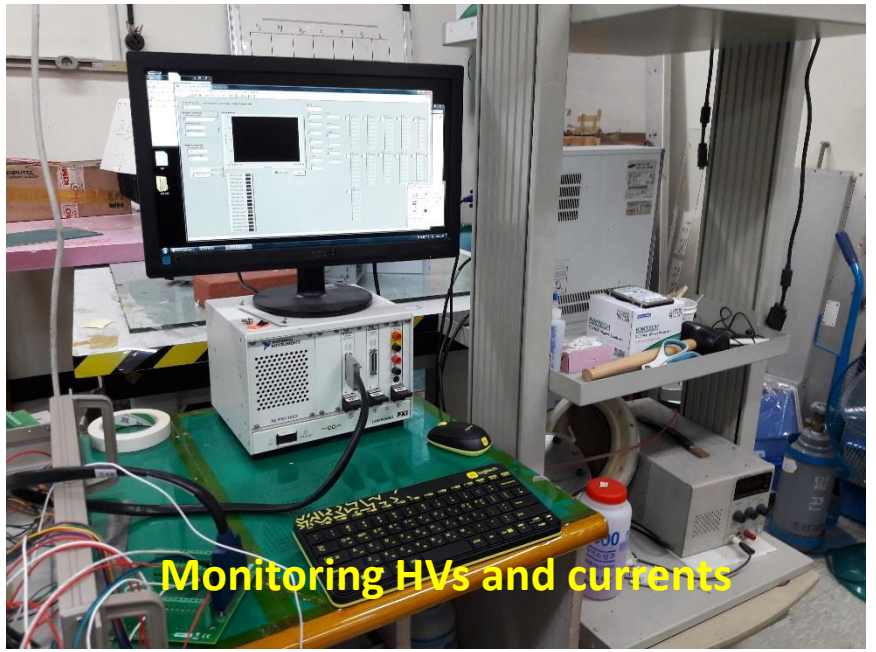
Test facilities for gaps

of gaps in a single test batch: 24

✓ Six gas channels

Gas rate: max 25 l/h

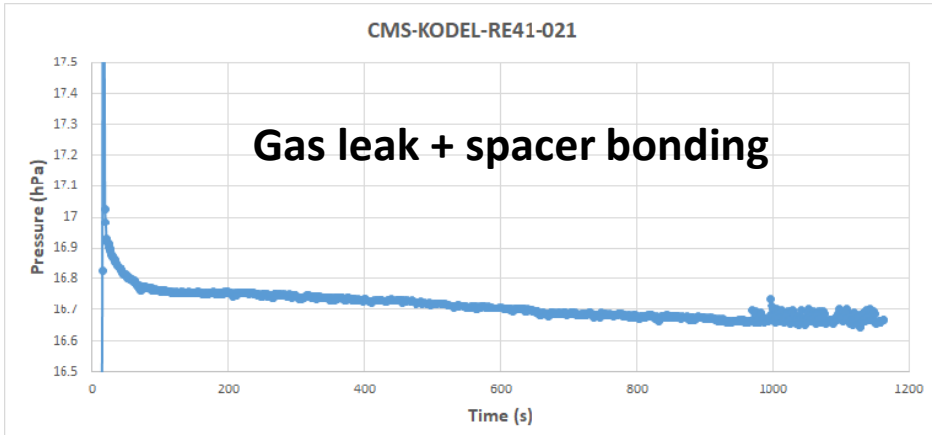


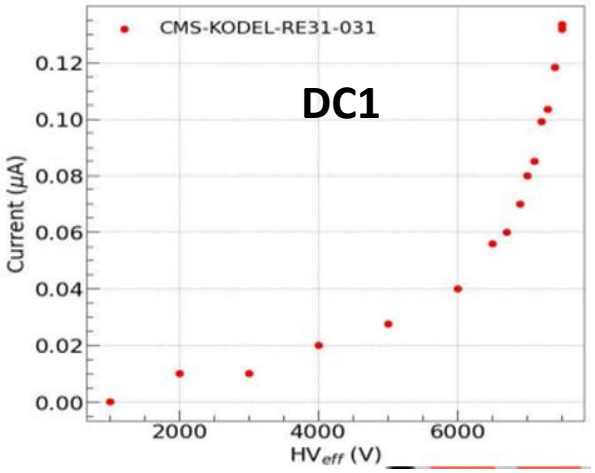


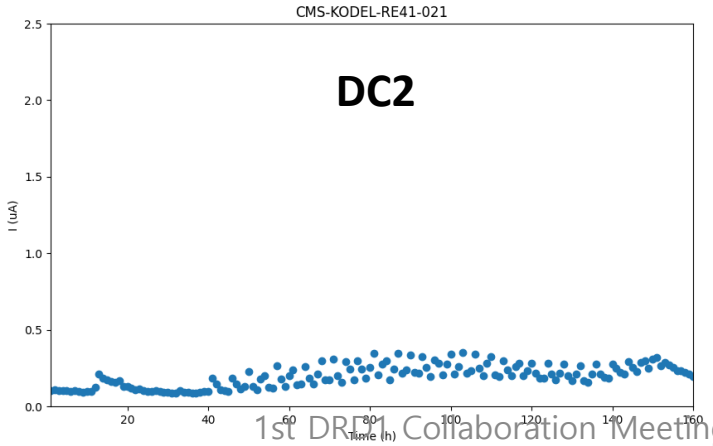
Two 16 ch ADCs to read HVs and currents of gaps (National Instrument PXI-6229)

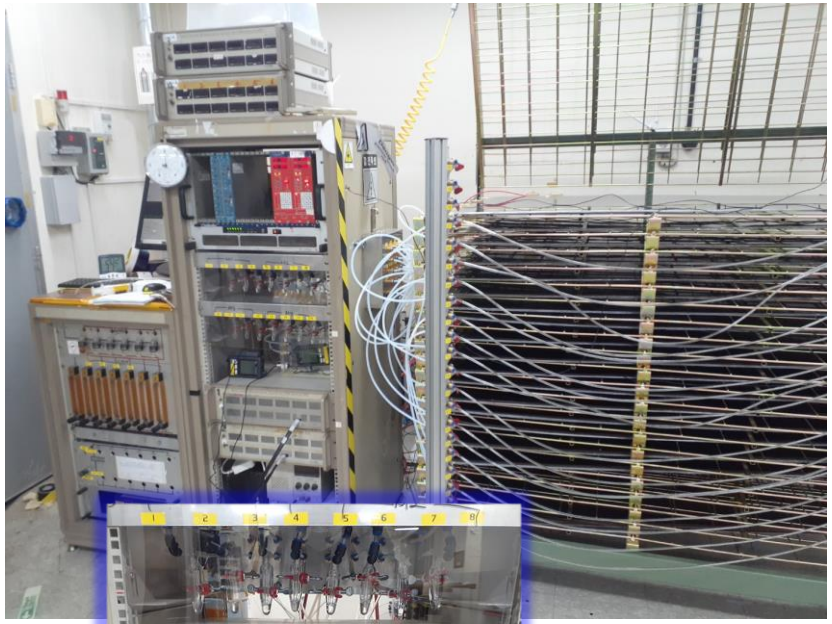
QC2 for gas gaps (QC2 database) at KU & assembly sites

- Inspection for gas leak (< 0.4 hPa loss for 10 mins @+17 hPa) and spacer bonding
- Dark current tests:
  - ✓ 1st HV scan test (DC1): Acceptance limits: 0.75 µA @ 5 kV and 2.5 µA @ 7.6 kV
  - ✓ 7-days HV test at WP HV (DC2): Acceptance limits: 2.5 µA @ 7.25 kV
  - ✓ 2nd HV scan test (DC1): Acceptance limits: 0.75 µA @ 5 kV and 2.5 µA @ 7.6 kV









Outsourcing

Damia Company at Goyang city for washing and graphite coating on HPL electrodes (resistive plates)

1. Washing HPL surface with MEP to improve oil attachment (@Damia)
2. Graphite coating & inspection and measurement of resistivity (@Damia): 100 kOhm/□ (RPCs) → **450 kOhm/□ (iRPCs)**
3. Final visual inspection for HPL panels (@Damia)

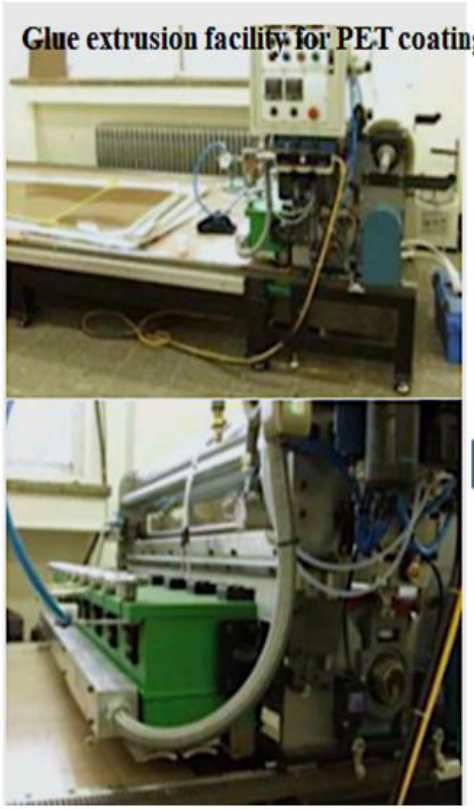
Graphite coating

Washing

Outsourcing

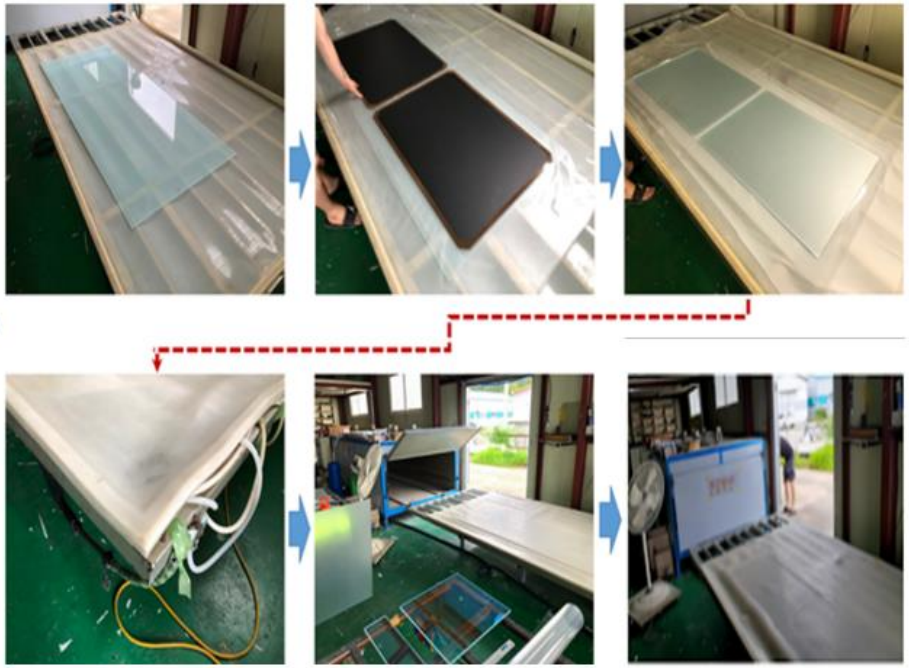
Yurim Company at Goyang city for insulator coating on HPL electrodes

PET-film coating procedure (new)



NEW

Vacuum gluing facility @Yurim



Steps

1) Place 250-μm thick EVA glue film on HPL

2) Place 190-μm thick PET film on the EVA-film covered HPL

3) Insert ~ 5 layers in a vacuum chamber

4) Increase the temperature to 90°C for 60 mins.

5) Cure adhesiveness of the glue on PET @90 °C for 60 mins

6) Gradual decrease of vacuum temperature for 60 mins

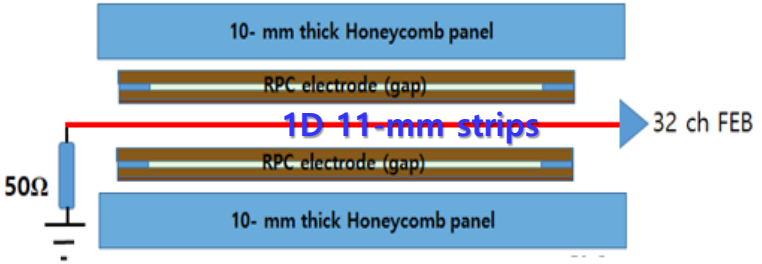
R&D: Aging Study

Gap/chamber size = 50 cm x 40 cm
32 strips with a 32-ch KODEL FEBs
Strip pitch = 11 mm
Digitization Th = 0.4 mV ~ 60 fC

During 5~6 year operation in the Phase-2, the expected charge per unit area of a RE4.1 iRPC detector ~ 2.2 C cm^{-2}/iRPC (with no safety factor)

Main activity is **@GIF++ (13 TBq Cs-137)**, but wish parallel test @KU (production site)

At KU, we plan to test **250 mC cm^{-2}/gap** for 1 year.



Installed a small iRPC **@45 cm from a 4.7 GBq** Cs-137 source

Gamma particle rate ~ 1.0 kHz cm^{-2}

Effective irradiation area on the detector ~ 1000 cm^2

→ Induced gamma current/gap ~ 12 μA (with streamer-mode operation)

Monitored Ohmic current for cases

✓ 54% TFE + 40% CO2 + 5% iC4H10 + 1% SF6 (in the beginning)

✓ 94.7% TFE + 5% iC4H10 + 0.3% SF6

By the end of the last year

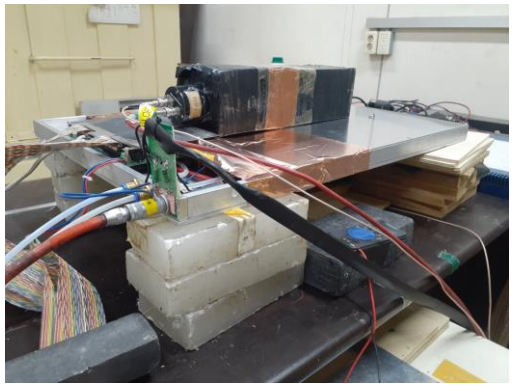
120 mC cm^{-2} on top gap and 180 cm^{-2} on bottom gap

→ ~ So far, 150 mC cm^{-2}/gap (In phase-2, ~ 1.1 C cm^{-2}/gap expected)

R&D: Study of Echo Friendly Gas for iRPCs

Overall results for iRPC gas mixtures

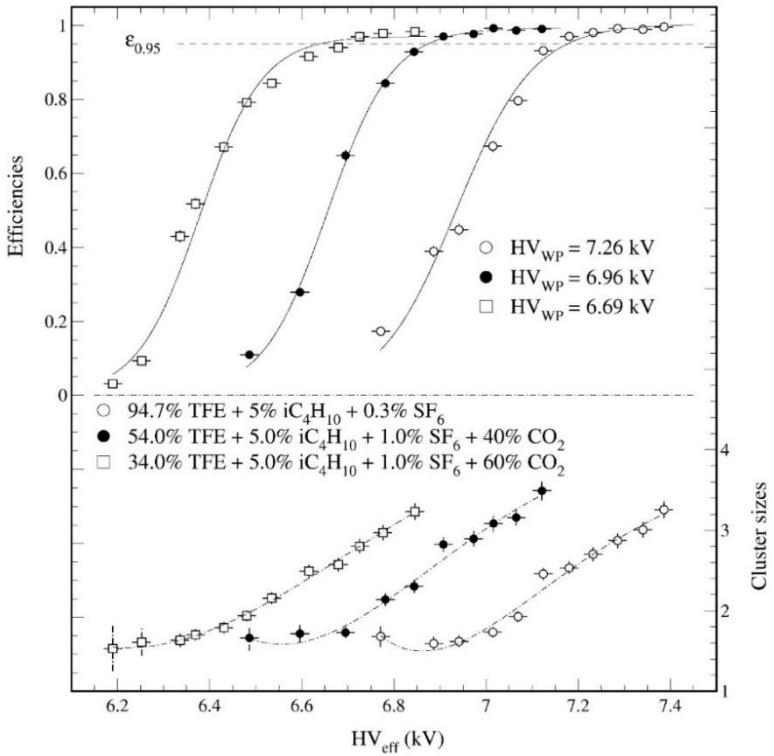
	CO2	TFE	iC4H10	SF6	WP HV (kV)	<Cs>	Efficiency	P(Cs>6)	N. R. (Hz/cm^2)	T (°C)
TFE R&D	0.00	94.7	5.0	0.3	7.26	2.73(0.08)	0.985	0.0143	0.24	15.7
	30.0	64.7	5.0	0.3	6.80	2.91(0.07)	0.973	0.0191	0.41	17.2
	30.0	64.4	5.0	0.5	6.89	2.79(0.07)	0.976	0.0118	0.33	17.7
	30.0	64.1	5.0	0.9	7.02	2.85(0.07)	0.972	0.0175	0.36	17.0
	40.0	54.7	5.0	0.3	6.63	2.94(0.07)	0.976	0.0179	0.39	16.4
	40.0	54.4	5.0	0.5	6.72	2.93(0.07)	0.974	0.0219	0.44	17.5
	40.0	54.0	5.0	1.0	6.96	2.89(0.09)	0.977	0.0154	0.32	17.1
	40.0	57.0	2.0	1.0	7.07	3.18(0.11)	0.978	0.0229	1.38	19.1
	60.0	34.0	5.0	1.0	6.69	2.88(0.09)	0.974	0.0198	0.36	17.4
HFO R&D	CO2	HFO	iC4H10	SF6	WP HV (kV)	<Cs>	Efficiency	P(Cs>6)	N. R. (Hz/cm^2)	T (°C)
	60.0	34.0	5.0	1.0	8.28	3.99(0.13)	0.987	0.0502	4.06	17.4



Gap size = 50 cm x 40 cm
32-ch KODEL FEBs, Strip pitch = 11 mm
Th = 0.4 mV ~ 60 fC, Digitized pulse width = 30 ns

std. TFE gas vs. TFE + 40, 60% CO_2

Adding 40% CO_2:
~ - 300 V shift
Adding 60% CO_2:
~ - 600 V shift
when compared to the std. TFE gas

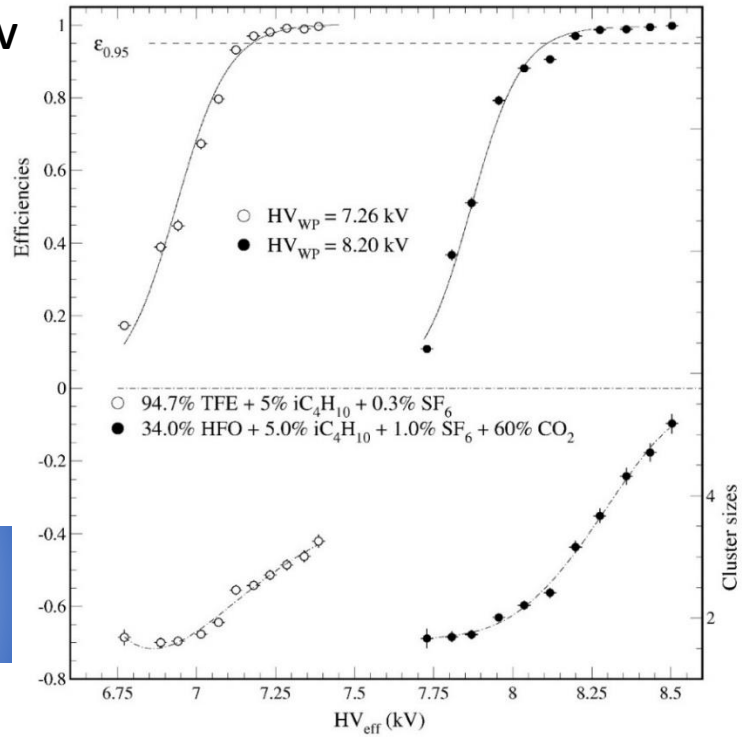


std. TFE vs.HFO+60% CO_2

Adding 60% CO_2 to HFO: HV_{WP} ~ 940 V higher compared to the std. TFE
<C_s> with std. TFE gas = 2.75
<C_s> with 60% CO_2 + 34% HFO = 3.67

Increasing factor of Ohmic current ~ 3
Increasing factor of noises ~ 15

The test results are fairly well agree with EP-DT group!



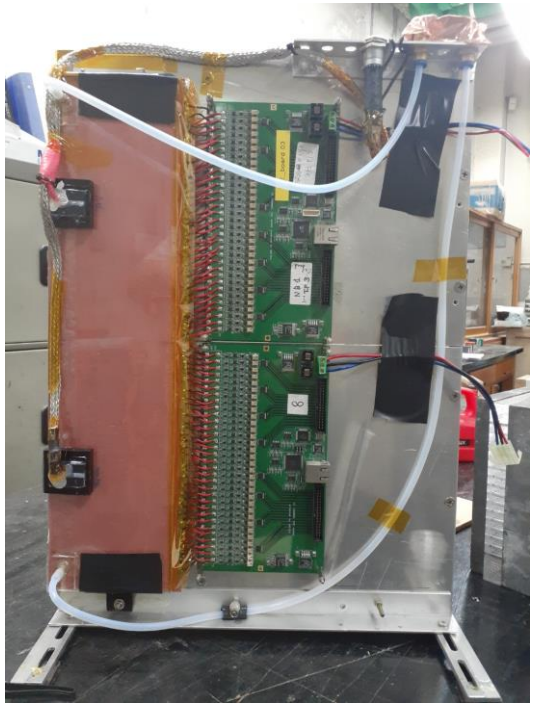
R&D: Applications: Gamma-ray scan with line-scan MRPC detectors (in RPC2022)

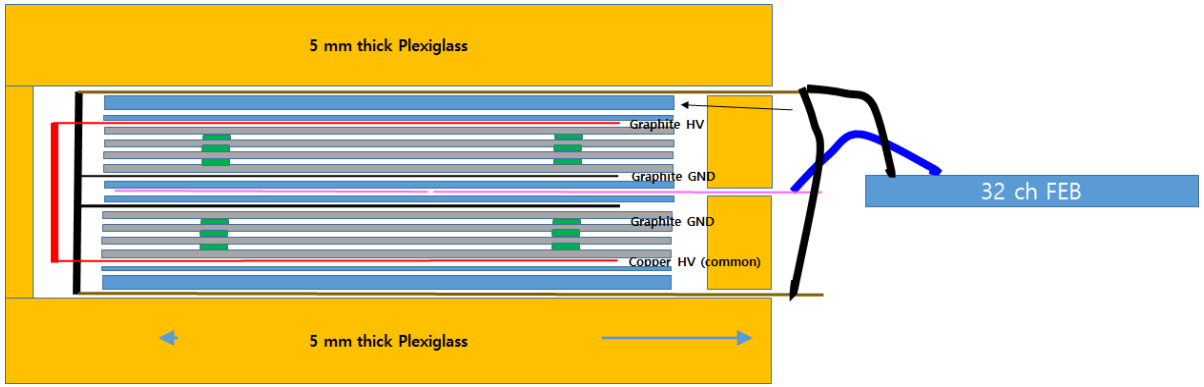
Detector dimension (active):
38.4 cm (length) x 7.0 cm (depth)
Thick of the sensitive volume: 9 mm

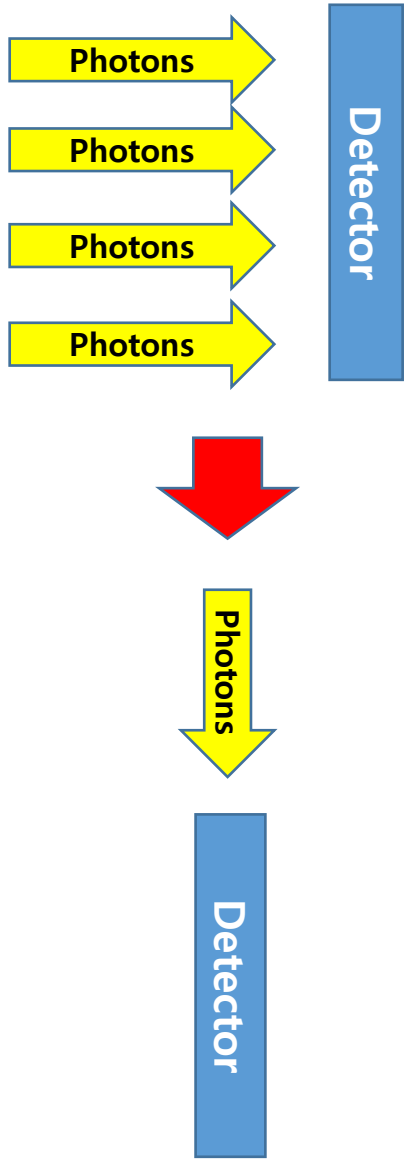
Number of spacers per gap: 24
Diameter of spacers: 8 mm

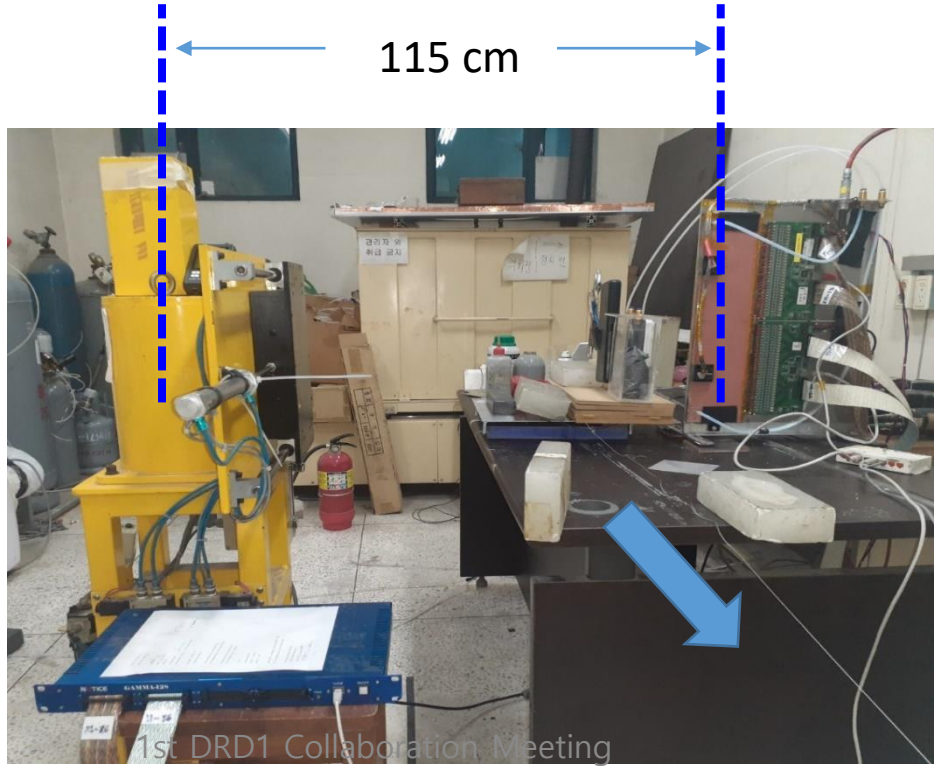
# of 1D strips: 64
Strip pitch: 6 mm

Expected position resolutions
1.5 mm along the scan direction
~ 2 mm in the vertical direction

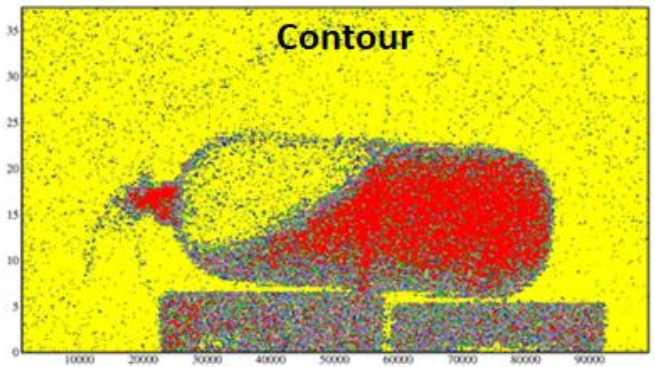


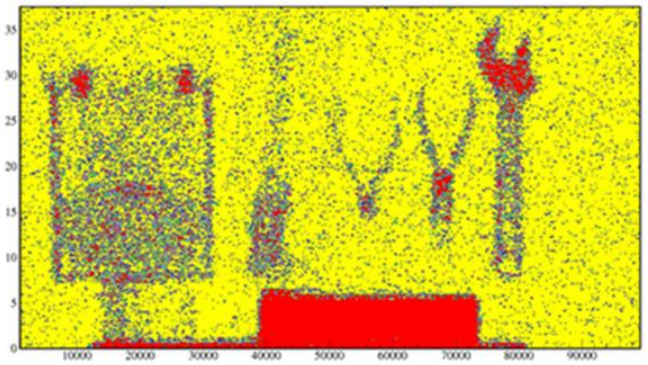


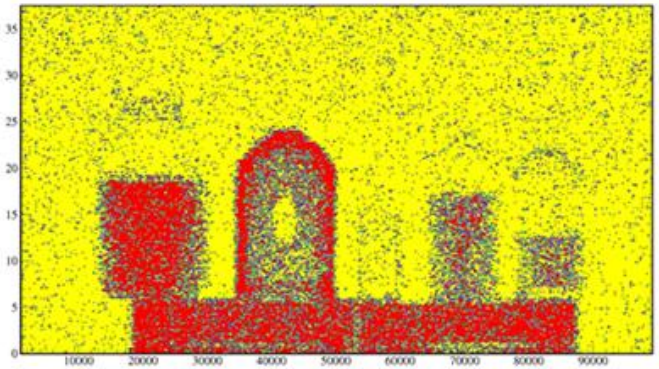




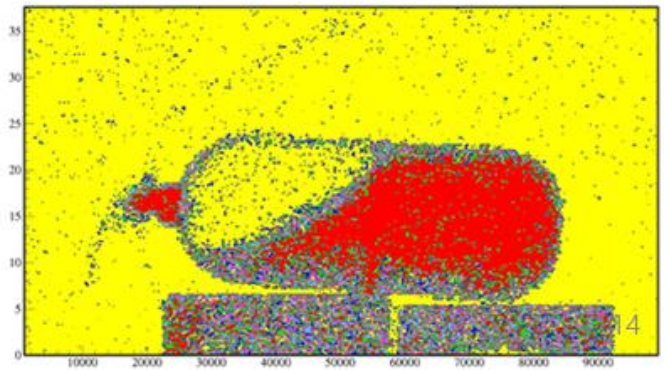
1.5mm pixel resolution, color depth ~ 60

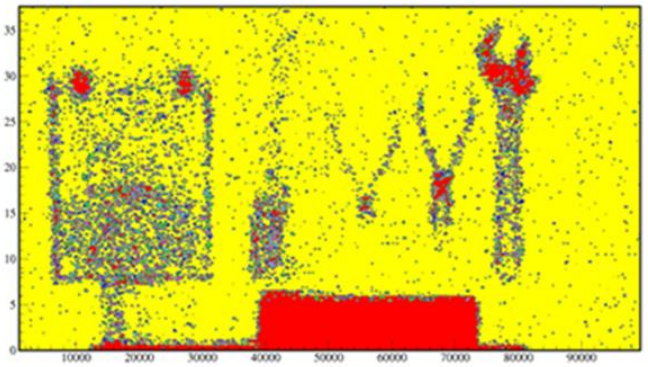


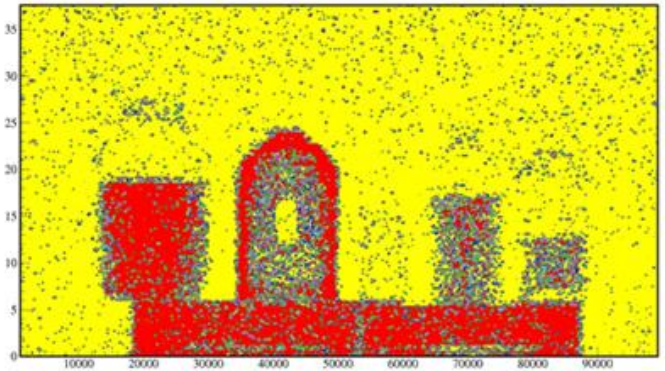




2.0mm pixel resolution, color depth ~ 100







Plan for near future in 2024

Gas gap production CMS upgrade (iRPCs)

- Totally ~ 260 iRPC gaps will be produced for CMS iRPCs by the end of June 2024.
- Completion of detector assembly for all 40 RE3.1 and 40 RE4.1 chambers at 904, Ghent, and Ibero Americana by August 2024.

What to do for KODEL lab from June 2024?

- Repairing of broken iRPC gaps (~ 20) and further spares
- Temporary transition of the current KODEL detector facilities to Korea Basic Science Institute (KBSI) in Korea University.
- In future, we have a plan to move them to Institute of Basic Science (IBS) in Daejeon (?).

KODEL lab and facilities will be available for

- Future high-energy physics experiments like SHiP, Mathusla, and Future Collider (both for phenolic and glass RPCs)
- Applications to nuclear sciences like Muon radiography and Radiation nondestructive imaging