R&D Status of Thin Double- and Multi-gap RPCs

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Facilities and human resources for RPC production at KODEL will be preserved after the upgrade of CMS RPCs

1. Human resources for gas gap production, QC tests, and detector assembly

2. Facilities of phenolic and glass RPCs

- ✓ **Currently, @441 lab in Asan science in Korea University**
- ✓ Will be transferred to a lab in Korea Basic Science Institute (KBSI) **IBS in Korea University**
- ✓ **IBS in future(?)**

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

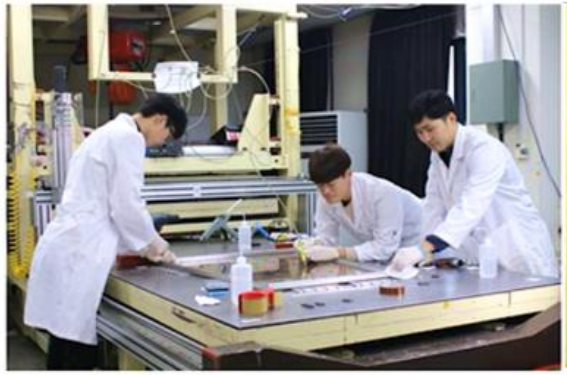
- ➢ Washing electrode: Damia @Goyang city
- ➢ Graphite coating: Damia @Goyang city
- ➢ Insulator coating (PET): Yurim @Goyang city

So, the human resources and facilities are available for R&Ds and detector productions for future experiments

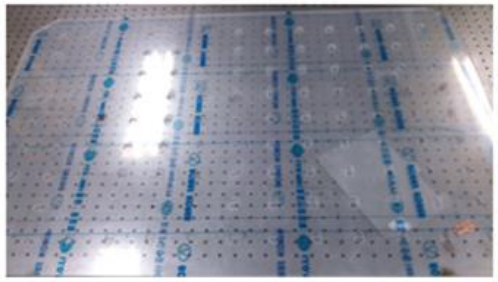
Gap production facilities

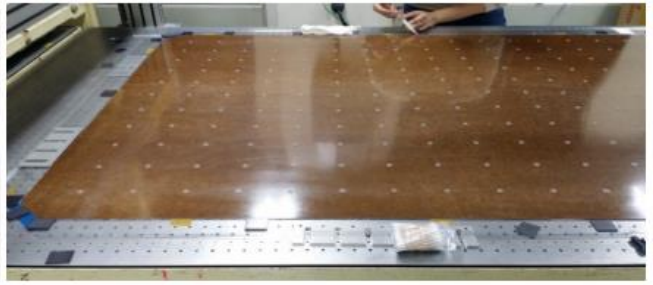
Gluing RPC electrodes (gas gaps)

Gluing tables and pressure devices



Spacer jig



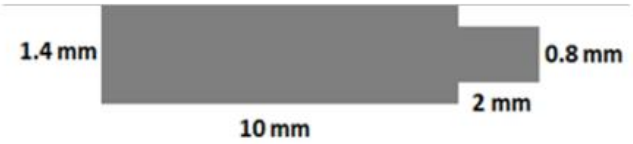


Metric tables and multi-layer air pouches for gluing and glue hardening for gaps

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

Outsourcing

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

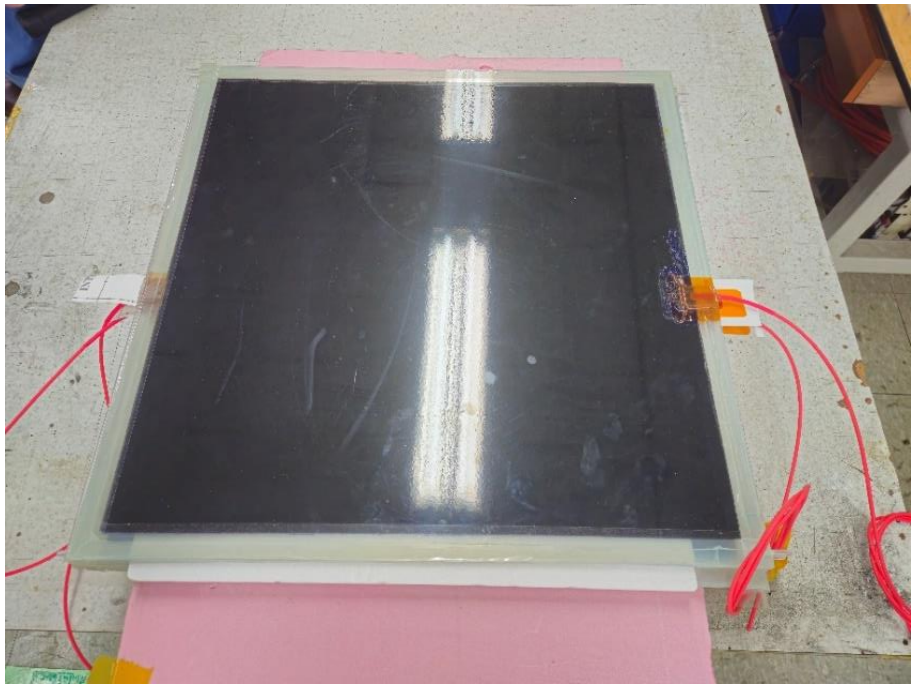
1. Washing HPL surface with MEP to improve oil attachment (@Damia)
2. Graphite coating & inspection and measurement of resistivity (@Damia): 100 kOhm/□ (RPCs) → **450 kOhm/□ (iRPCs)**
3. Final visual inspection for HPL panels (@Damia)

Graphite coating

Washing

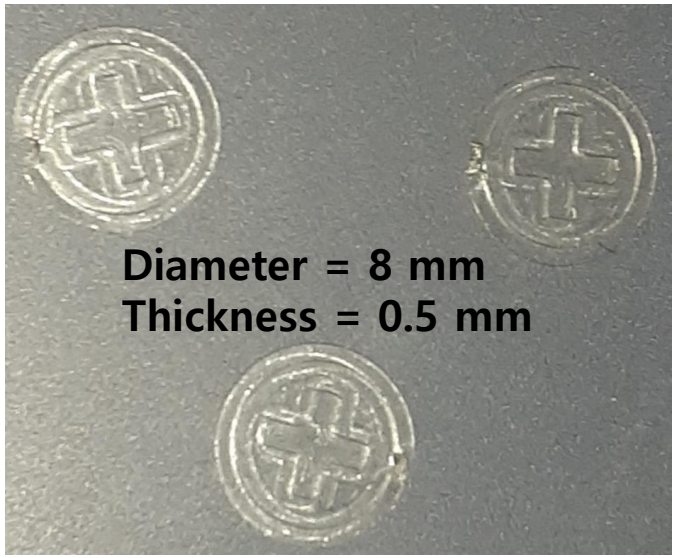
1st R&D items: 0.5 mm double-gap RPCs

Small 50 cm x 50 cm prototype gas gaps has been produced at Korea University

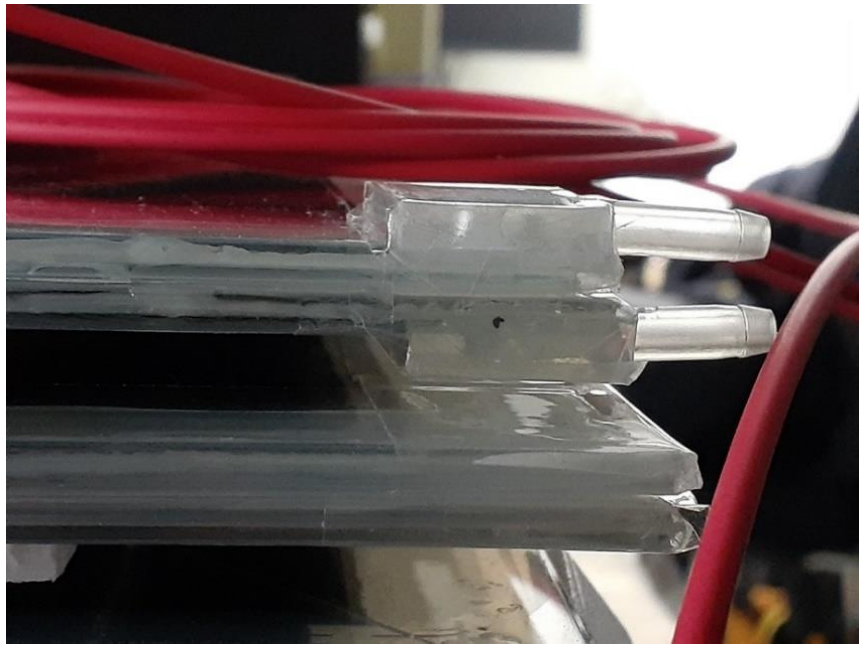


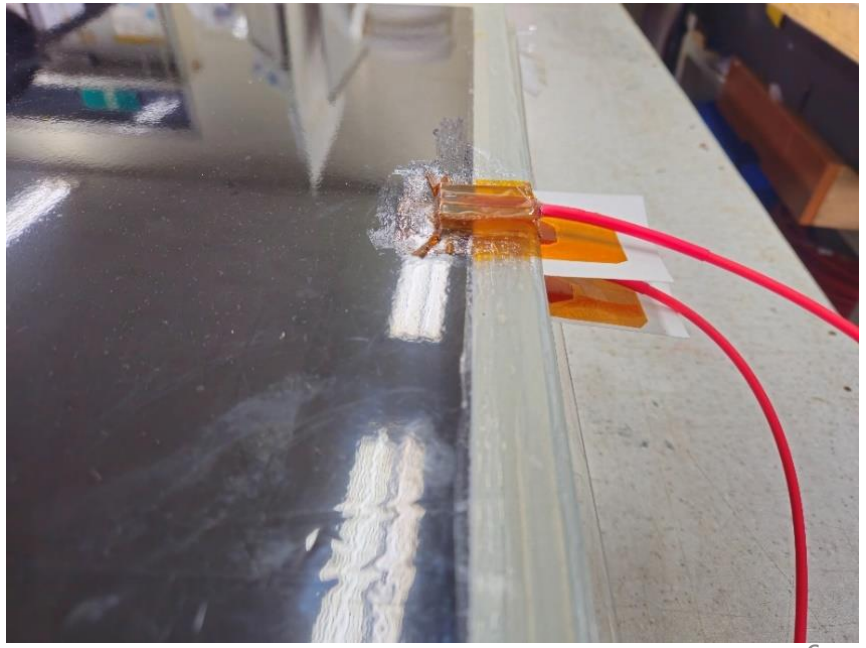
- Gap thickness: 0.50 mm (intrinsic time resolution ~ 150 ps)
- Glass thickness: 1.1 mm (resistivity ~ 7×10^{11} Ωcm)
- Surf resistivity of graphite ~ 200 kΩ/sq
- So far, 4 gaps were constructed with ordinary soda-lime glass RPCs
  - ✓ Korea University: Thin-gap detectors
  - ✓ Bari University: Electronics and tests at Bari and CERN
- High rate capability (~1 kHz cm^{-2}) depends on the sensitivity of **front-end electronics**
  - ✓ Digitization threshold @FEE as low as ~ 10 fC
  - ✓ Time resolution for FEEs for digitization should be < 50 ps

Polycarbonate spacers can be produced with a molding method
Cost < 10 cents/spacer
Accuracy ~ 10 μm

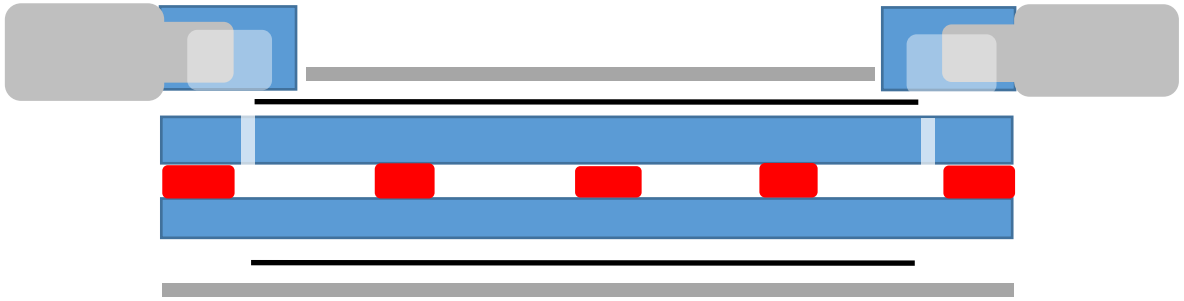


Thickness of a single gap = 3.0 mm

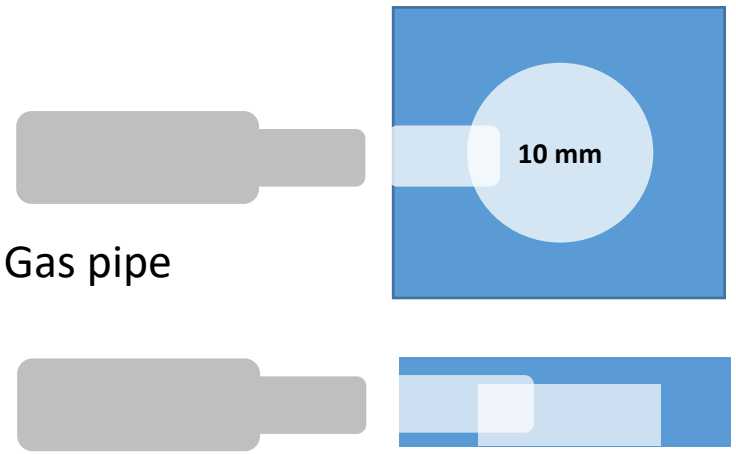


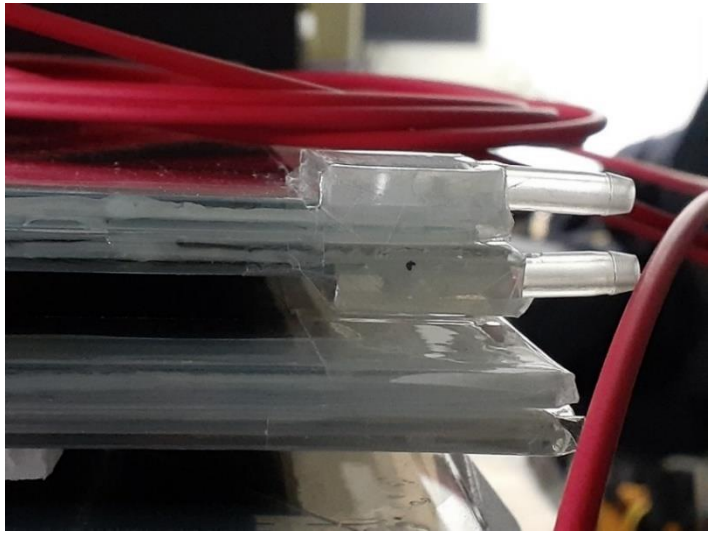


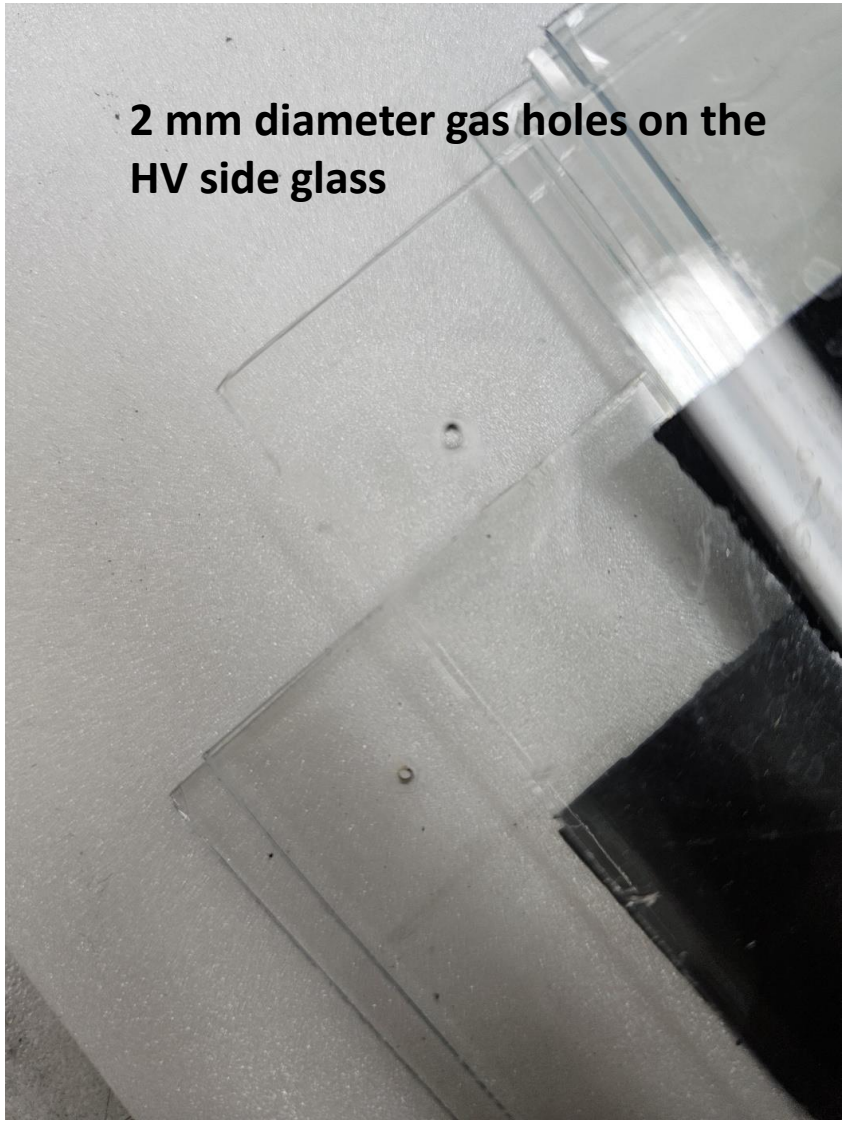
Thickness of gas gap = 3.0 mm. So, gas piping should be done on the top side of the gap.



Gas inlet profile made of 5 mm thick 2 cm x 2 cm area PC

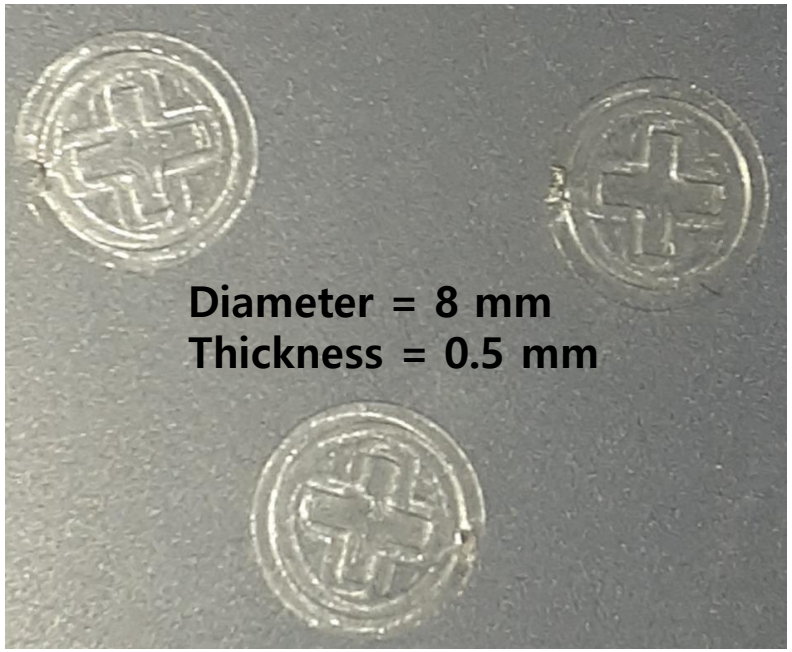






- **Spacing of spacers = 7.5 cm x 7.5 cm (56.25 cm^2)**
- **Inactive area due to a 8 mm spacer = 0.50 cm^2**
- **Ratio of inactive area in a single gap = 0.009**

But, applied a 11 mm offset for the positions of the spacer in the top and bottom gaps in one direction to get rid of all physically dead regions in the double-gap chamber due to spacers.



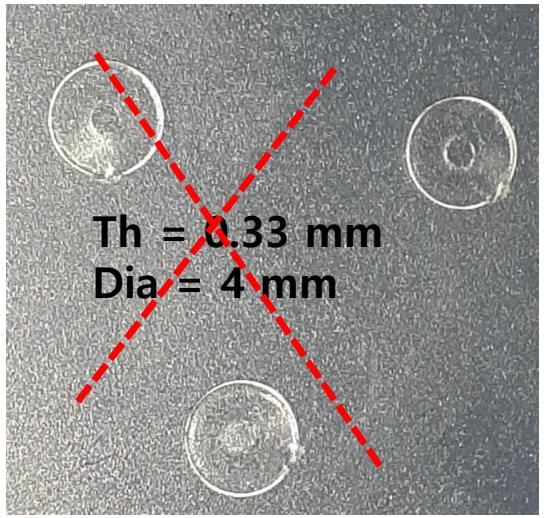
Spacers positioned using a spacer jig

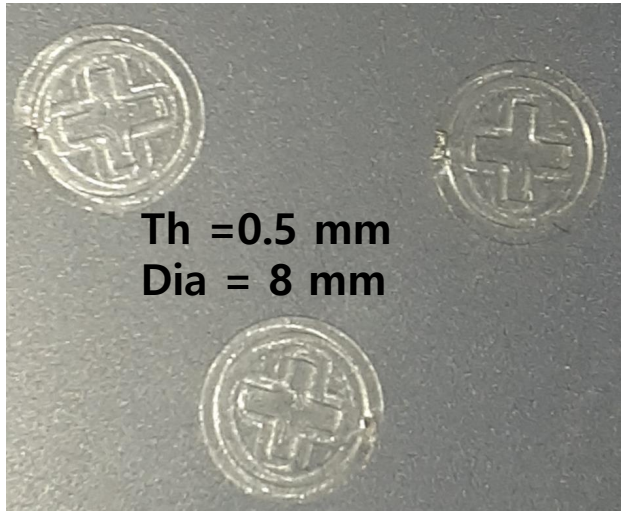
2nd item of R&D: Multi-gap GRPCs (planning)

Proposed by Korean group

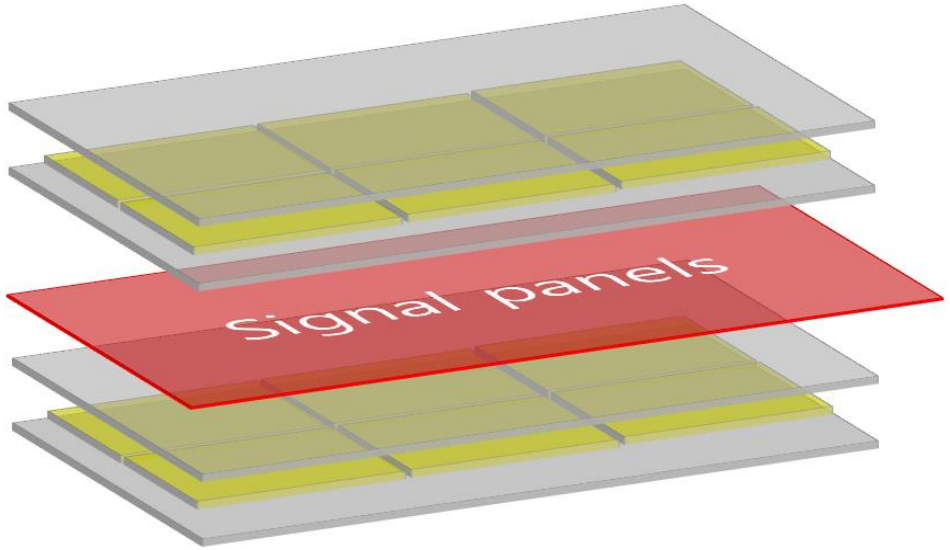
Time resolution ~ 100 ps and rate capability ~ 1 kHz cm^{-2} are relevant for triggers for future high-energy experiments.

- Aiming for experiments that high rate capability is not required (like SHiP UBT)
- Higher sensitivity of electronics is NOT essential.
- Gap thickness 0.33 or 0.5 mm
- Rate capability ~ ***at best 1 kHz cm^2*** with ordinary soda-lime glass RPCs (~ 7×10^{11} Ωcm)
- Spatial resolution depends on strip pitches: *depend on the physics performance*
- ***efficiency ~ 99%*** is required to be adequate for ***charged-particle VETO.***
- Time resolution for FEEs for digitization should be ***much better than 50 ps***





Triple (or bi)-gap RPCs



Basic idea: a detector composed of two layers of for triple or bi gap gas envelopes

- For proper gas circulation We use thin spacers instead of fishing rod.

→ 0.33 (~ 60 ps) or 0.5 mm (~ 100 ps) thick spacers

  - ✓ Use of spacers instead of fishing rod for relevant gas circulation
  - ✓ **Productivity of all gluing gas-gap envelopes with spacers is high and fast but no way to repair inside**
  - ✓ Strip panels are free from gas volumes

- Number of thin gaps in a single gas envelope: 3 or 2
- Surf resistivity of graphite: minimum 500 kΩ/sq and maximum 2 MΩ/sq
- A spacer-position offset bet. top and bottom gas envelopes to get rid of physical dead regions due to spacers.
- Maximum ~ 1 m long strips to allow dispersion of signals < 50 ps.

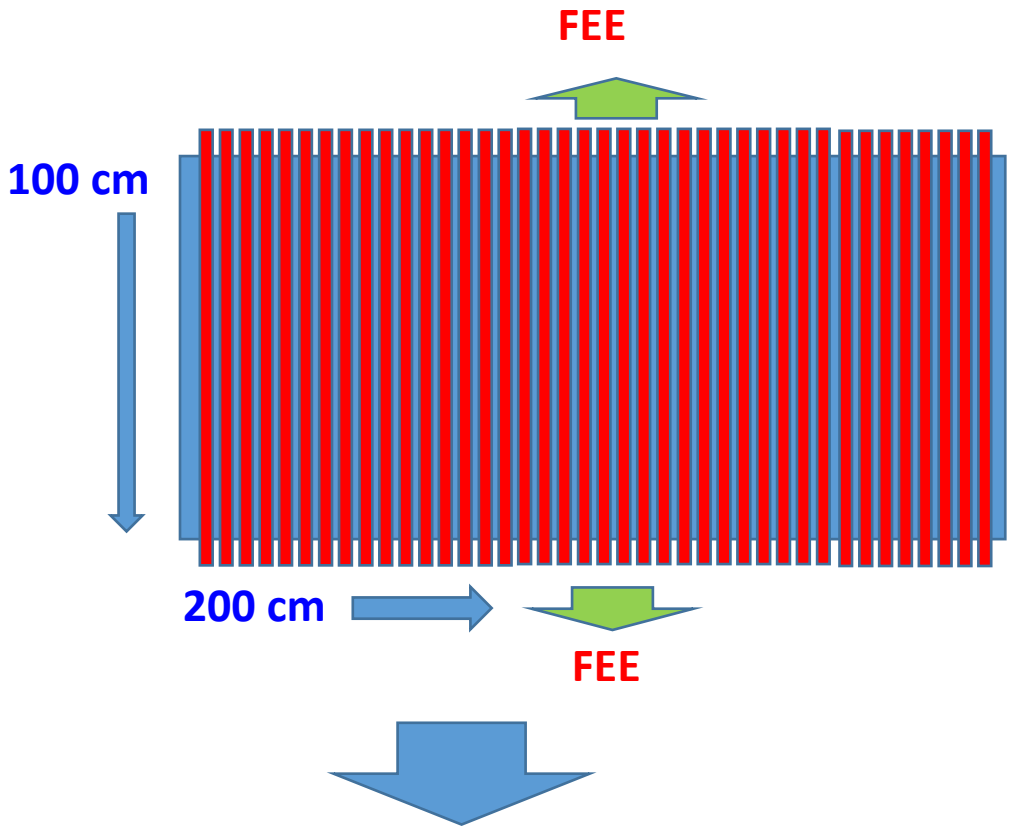
→ 1-m detector width will be maximum to get σ_t = 100 ~ 150 ps
and so adequate for these type MRPCs.

- Thickness of a single trip-gap gas envelope = 7.0 mm with 0.33 mm spacers

- The vertical position of a particle can be determined by the time difference of the pulse ($t_u - t_d$) measured from two ends of the strips.
- Thickness of a single-detector with double-layer gas volume ~ 28 mm
- A detector composed of four gas envelopes of triple gaps (two on top and on bottom layer each to minimize the inactive regions in the detector

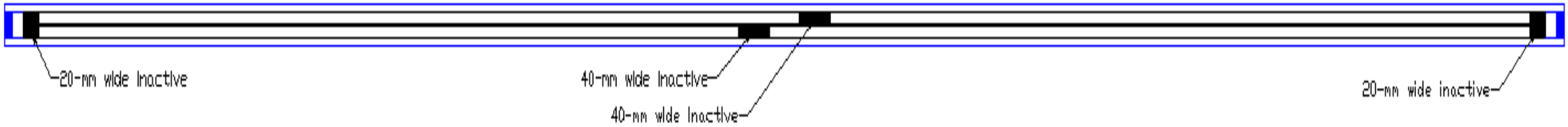
- The maximum size of thin glass (0.7, or 1.1 mm) for inner electrodes is a real bottleneck to make large size MRPCs.

→ In case, we should use a Mosaic method for the inner electrodes to make ~ 1 m^2 sized gas envelopes.



A single detector composed of 4 triple-gap gas envelopes

Strips placed between top & bottom gas envelopes



Planning minimal size six-gap RPC prototypes for the R&D

- Size of a triple gas volume = 100 cm x 50 cm
- Strip pitch = 2.5 cm
- Strip length = 102 cm
- Single-gap thickness = 0.33/0.50 mm
- 16-strip readout in both directions