R&D on thin-gap RPC towards production for ATLAS Phase-2 upgrade

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(USTC-SDU-SJTU)

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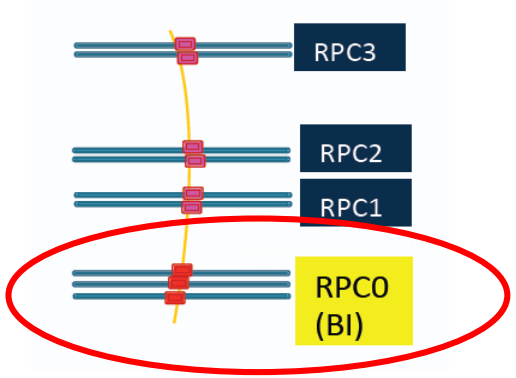
Introduction: ATLAS RPC Phase II Upgrade

➢Problem of current RPC in ATLAS

- Exceed their service time (10 years @ LHC)
- Rate capability limited: 20 Hz/cm^2
- Work under lower voltage ➔ 15-35% eff. Lost

➢ The solution

- Add BI RPC layers (3 layers of RPC)
- Improvement of rate, longevity, time & spatial resolution.



- 9 layers instead of 6

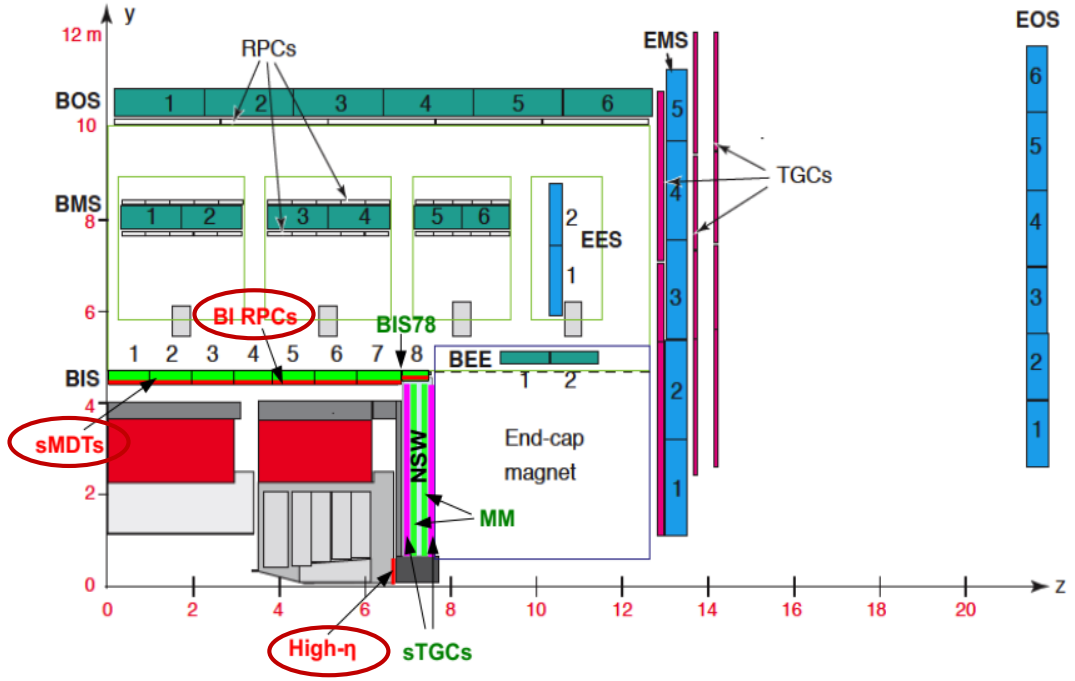
Status: Nearly finish the FDR. Prepare for the mass production.

Mass production:

- Preparation of readout panel production
- Test system (DAQ) preparation

RPC R&D:

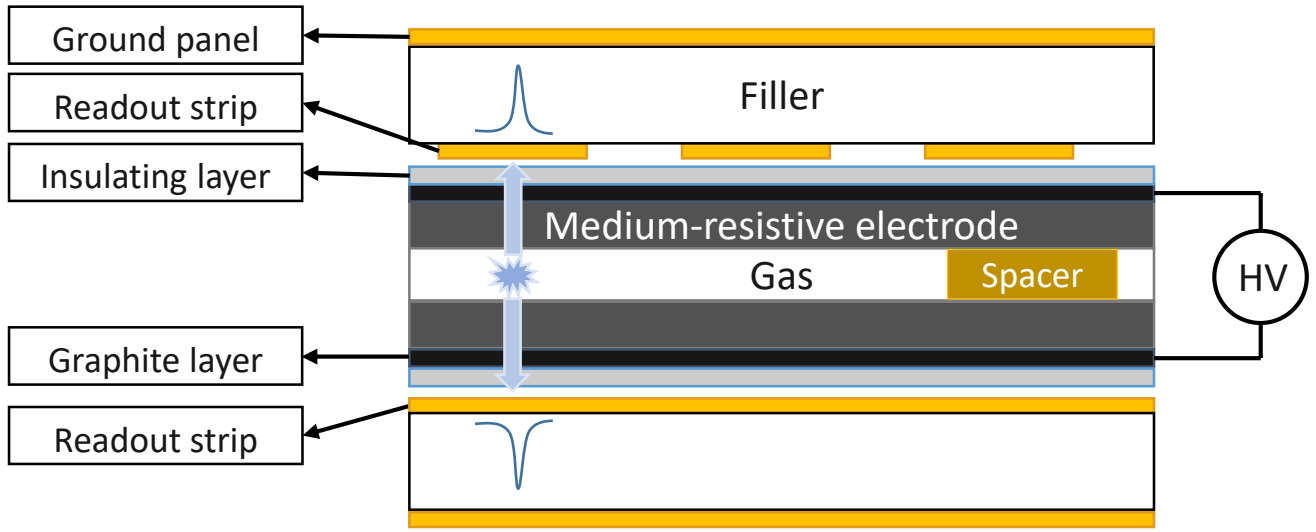
- Double-end readout method
- Simulation of signal transmission
- New design of RPC

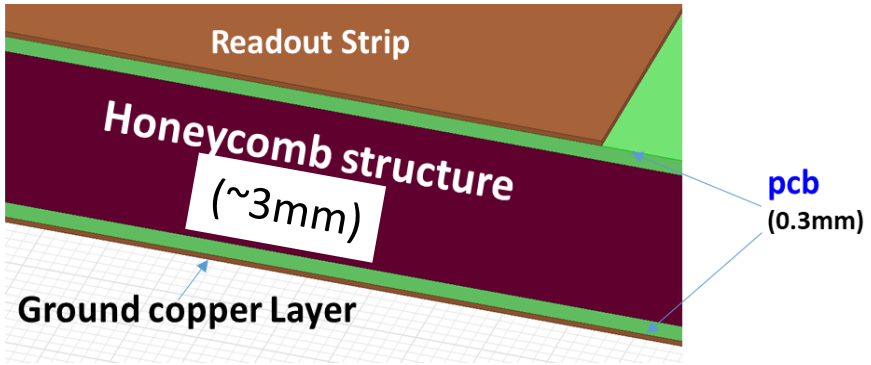


Mass production

Readout panel production in upgrade

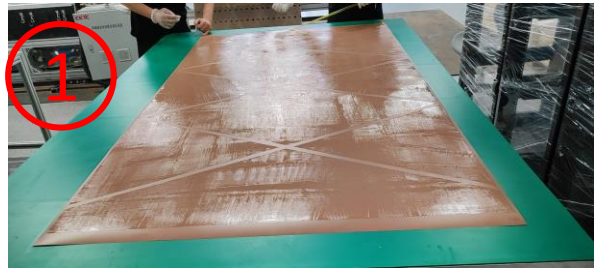
- Production of RPC components:
  - Gas gap: General Technic (GT) etc.
  - Readout panel: USTC-SJTU-SDU etc.
  - Electronics: Roma II etc.
  - Mechanism: MPI etc.
- In the ATLAS RPC Phase II upgrade, ~1/2 of all the readout panels will be produced in China.
- Honeycomb paper will be used as medium instead of foam.
- Based on a marble platform and vacuum system.

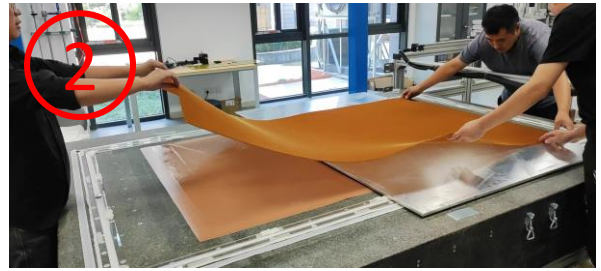


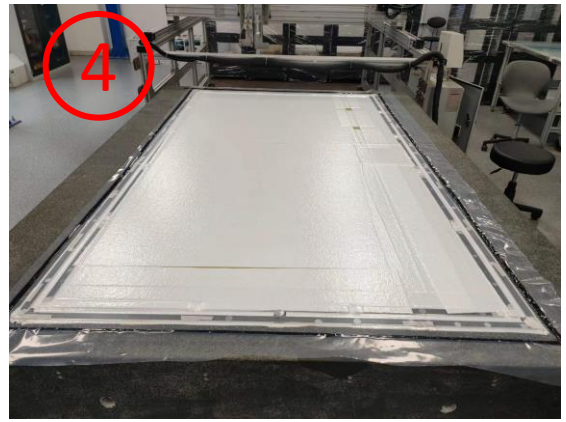


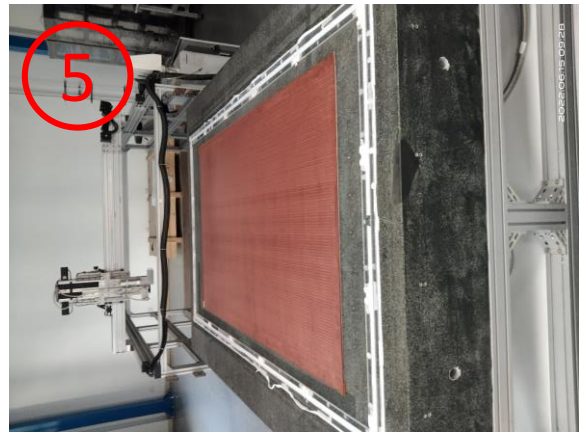
Production process of readout panel

1. Put the glue on the surface of PCB strip board or copper layer board.
2. Put the board on the marble platform and place the honeycomb paper core on the it.
3. Coat the system with vacuum bag.
4. Open the vacuum system for uniform pressure.
5. At least 6 hours for the solidification of glue.
6. Re-do 1-5 for the other side of the panel.
7. One panel completed.







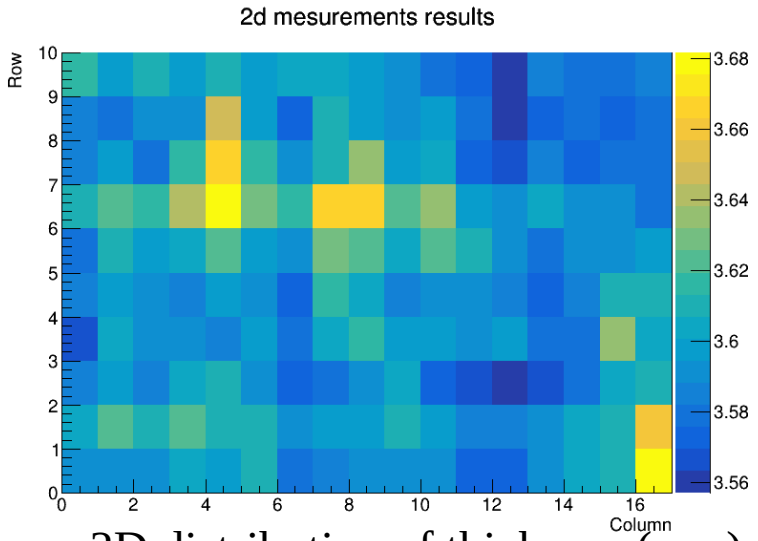


QA&QC of readout panel

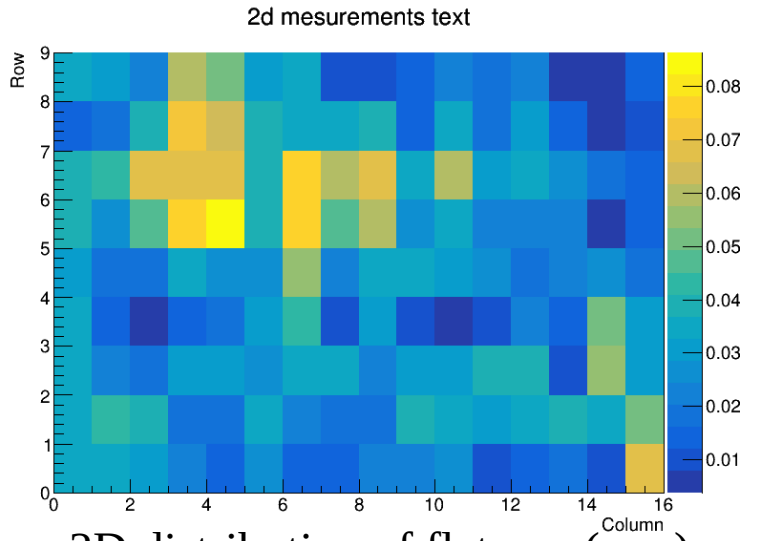
Requirement of flatness:

Max-min<100 um(in 10cm*10cm)

Gantry on the optical table with laser measurement system.



2D distribution of thickness (mm)

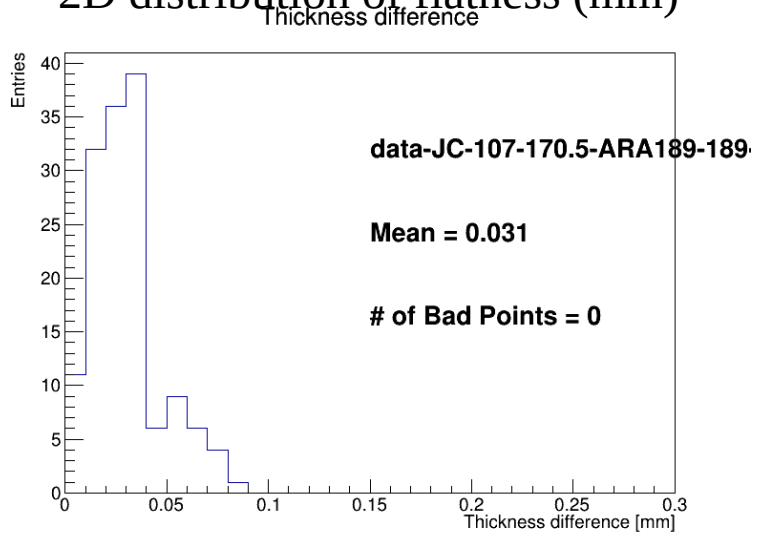


2D distribution of flatness (mm)

Measurement system:

- 1.2 m * 2.6 m at most.
- Flatness of table: +-20 μm
- Auto trigger: every 100 μs

Match the requirement of Phase II upgrade.

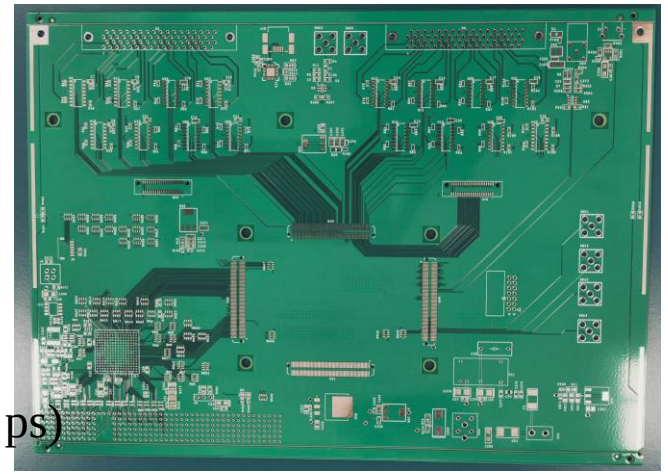


Histogram of flatness

DAQ for mass production

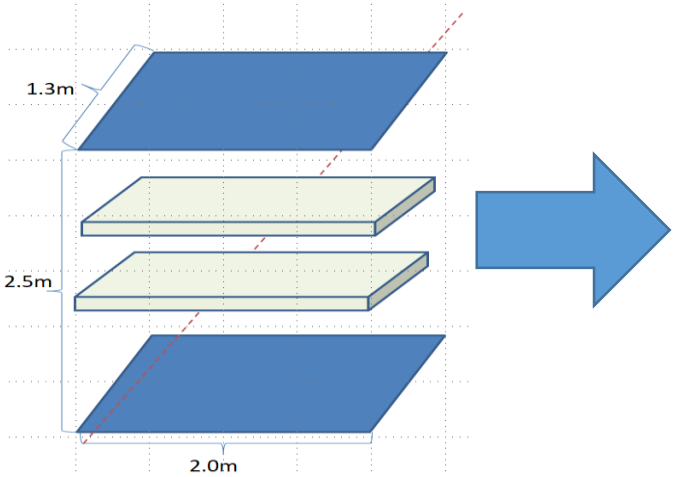
DAQ for the mass production QA&QC.

- TDC
- Designed by USTC.
- Comparison with CAEN v1190:
  1. Better time resolution ~70 ps (1190: ~100 ps)
  2. More channels 128 chs*boards (1190: 128 chs)
  3. Small dead time: ~3 ns (1190: 5 ns)
- Trigger system:
- Large area scintillators trigger system design by SDU
- Trigger region: 2000mm * 1300 mm



TDC board

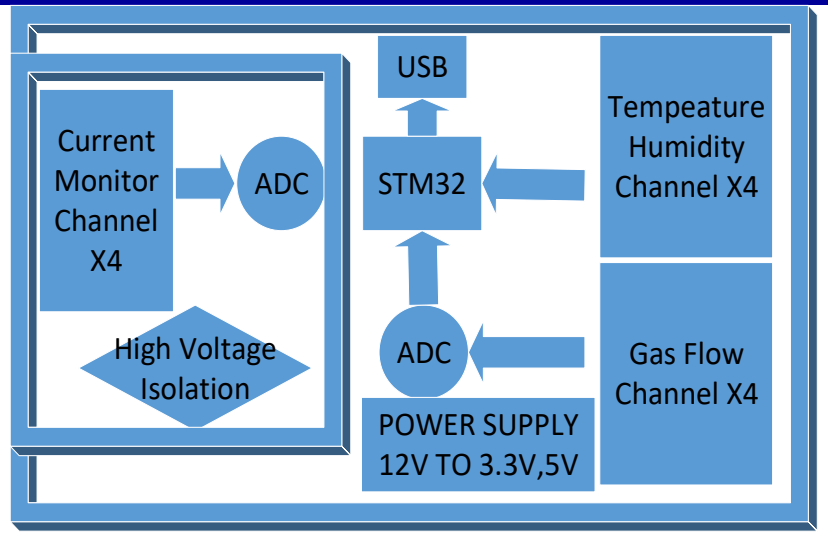
PXI crate

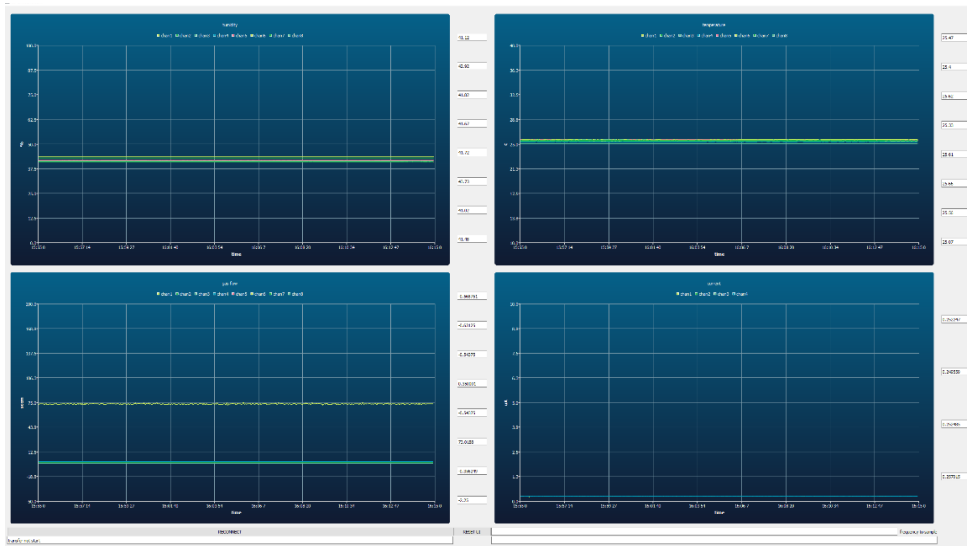


Large area trigger system

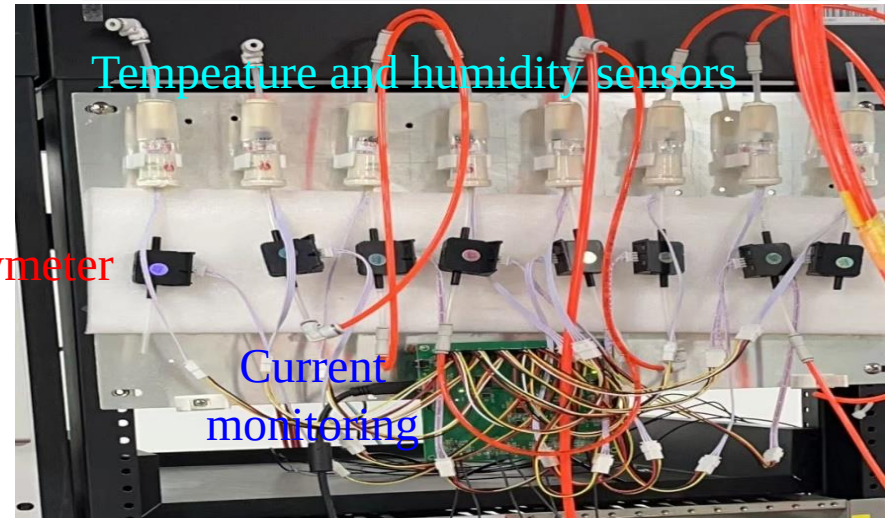
Monitoring system for mass production

- Motivation: monitor the gas flow, temperature, humidity, current of a multi-RPC system
- Four gas gaps at most.
- Inlet and outlet for each channel.
- Real-time monitor and recorder.





Software

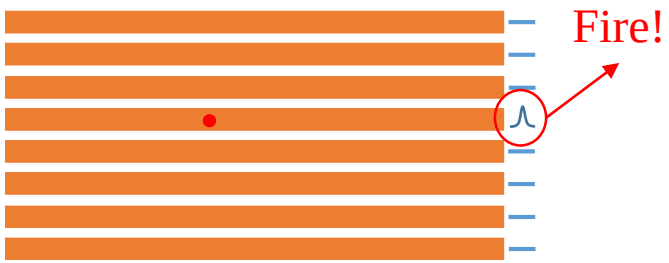


Hardware

RPC R&D

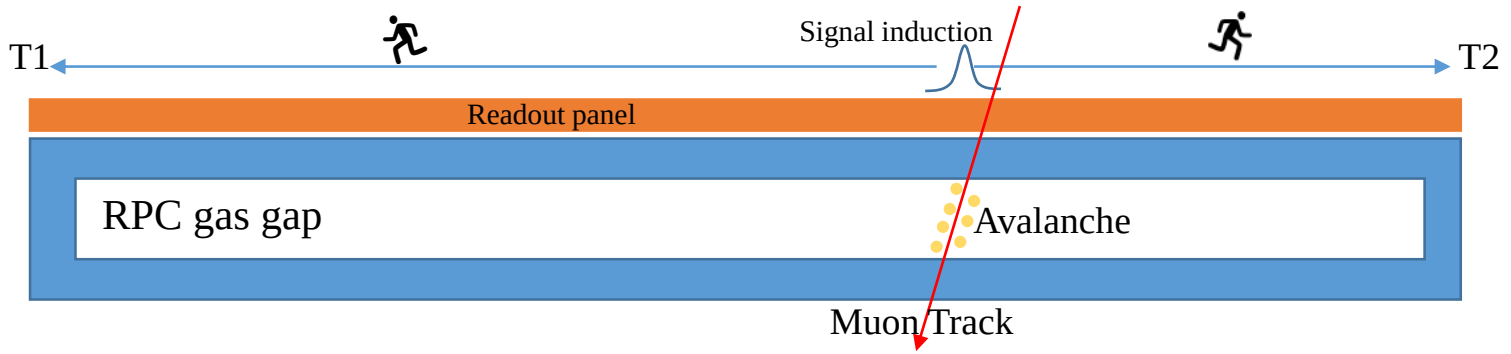
Double-end readout method

- Traditional method:

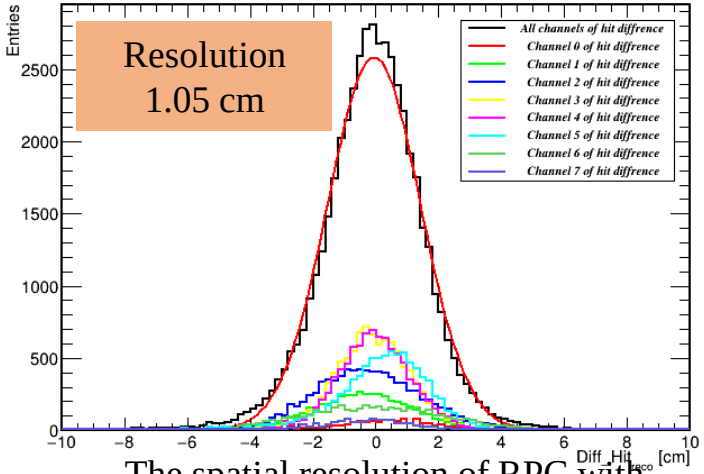


Spatial resolution: $\frac{Width\ of\ strip}{\sqrt{12}}$

- Double-Ends method:



Reconstructed hit position: (T2-T1)*v/2



The spatial resolution of RPC with double-end readout method (analog signal)

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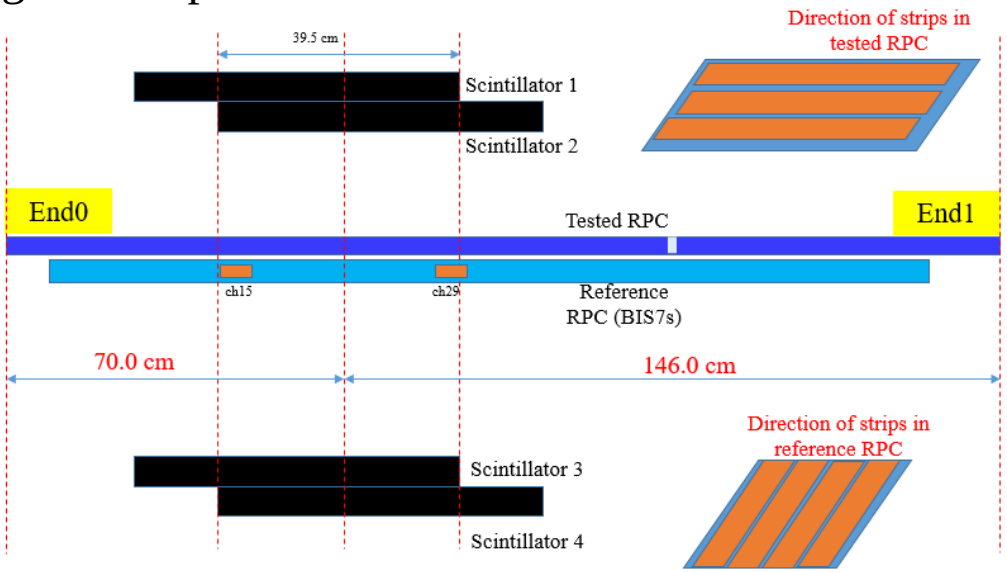
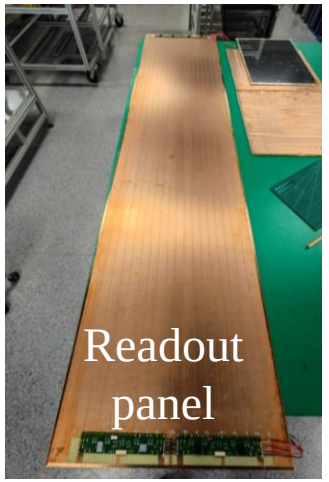
- Advantages of double-ends method:
  - Save electronic channels (1/3 of all channels could be saved.)
  - Save readout panels.
  - Increase the effective region.
- Status:
  - Double-end readout method with analog signal has been validated.
  - Validation of this method with the real phase II RPC electronics need to be done.

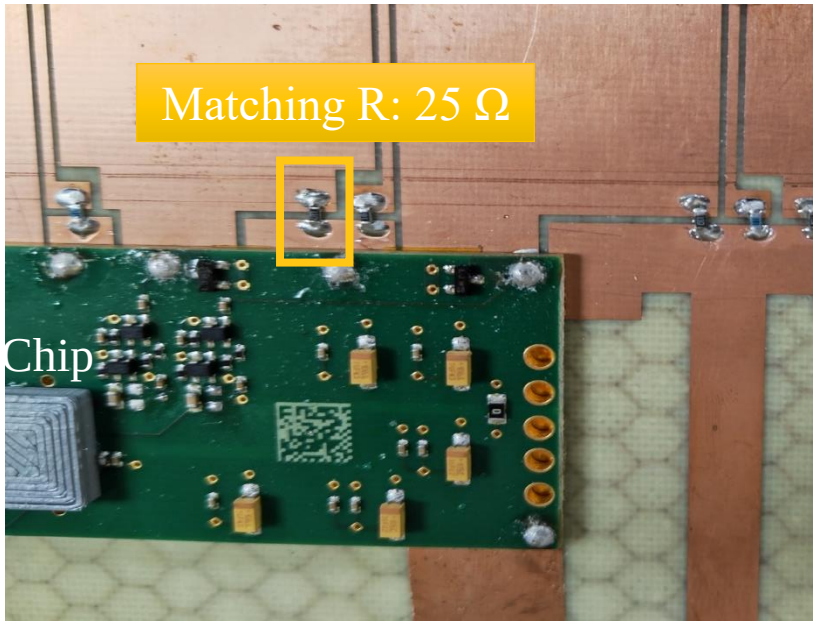
Validation of double-end readout method with real phase II electronics

- Electronics:
  - The real electronics with pre-amplifier, discriminator and signal convertor in a chip which will be used in RPC Phase II upgrade
- Differences with previous results:
  - Digital signal only with time of leading edge and trailing edge.
  - Length of strips: 2 meters



Experiment setup



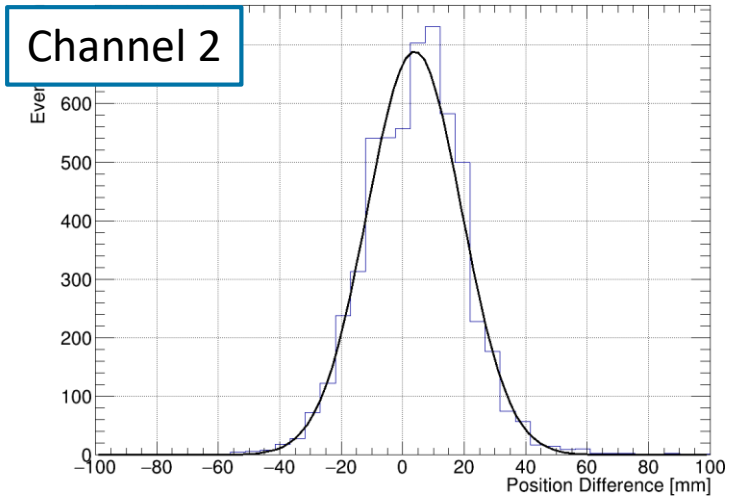


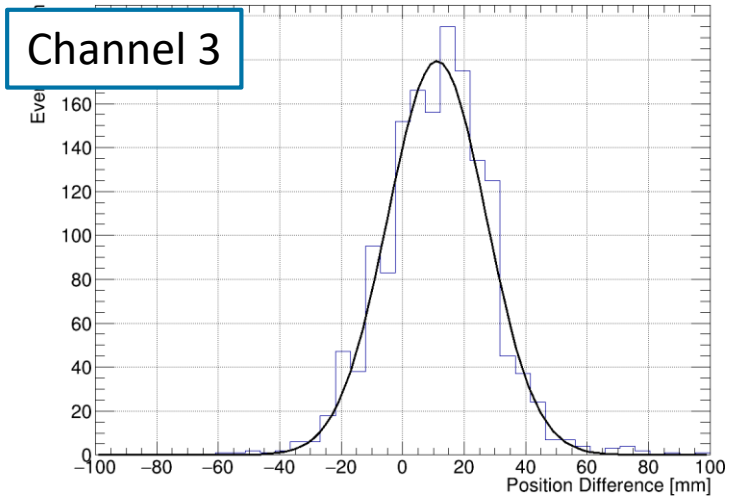
Results

- Reconstructed position $x' = \frac{\Delta T - bias}{2/v}$, $(\Delta T = T_{End0}^{Leading} - T_{End1}^{Leading})$
- Reference position x given as the center of the reference strip
- Position difference $x - x'$

$$\sigma(x - x') = \sqrt{\sigma(x)^2 + \sigma(x')^2} \qquad \sigma(x - x') = \sqrt{\sigma(x')^2 + \frac{2.7^2}{12}}$$

- The $\sigma(x')$ for the four center strips:
  - $1.24, 1.32, 1.26, 1.39\ cm$
- Requirement of Phase II upgrade: < 2 cm
- The result match the requirement of RPC Phase II upgrade.

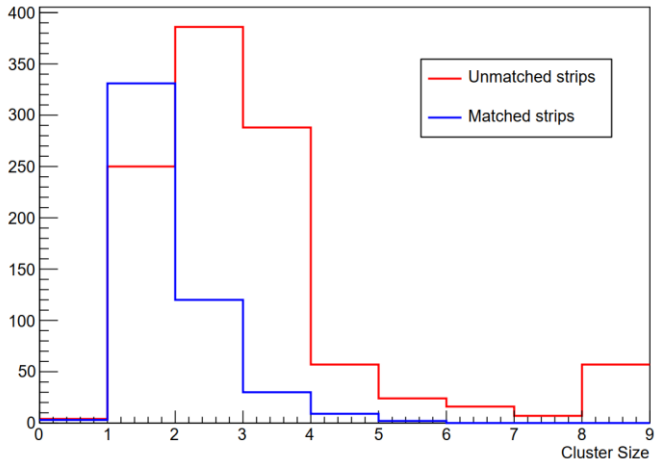




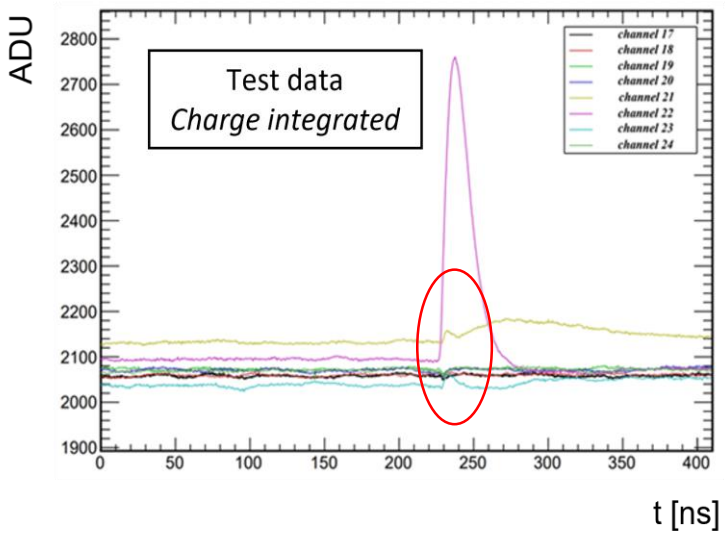
Simulation of signal transmission

Motivation:

- Large cluster size and crosstalk signal were observed in the RPC beam test (dominated by graphite layer)
- One solution: Add ground wires between two strips
- Study the various phenomena during the signal transmission with software simulation



Large cluster size of RPC in beam test.



Crosstalk signal observed in RPC beam test

- **Fundamental formulae:**

$$\frac{d^2}{dz^2}\vec{V}(z,t) = \hat{L}\hat{C}\frac{d^2}{dt^2}\vec{V}(z,t) \qquad \frac{d^2}{dz^2}\vec{I}(z,t) = \hat{C}\hat{L}\frac{d^2}{dt^2}\vec{I}(z,t)$$

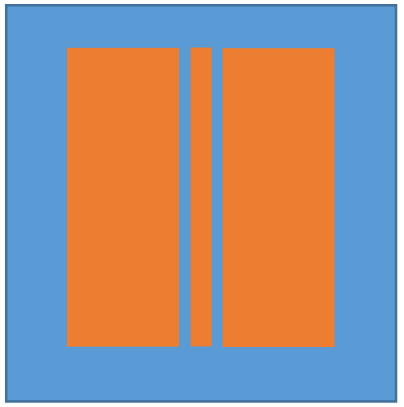
  - $\hat{C}, \hat{L}$: matrices of capacitance and inductance
    - Given by **Maxwell**
  - $\vec{V}(z,t), \vec{I}(z,t)$: vectors of signal
    - $\vec{V} = \hat{Z}\vec{I}$, $\hat{Z}$ impedance matrix
    - Solved using **Mathematica**

Simulation Results

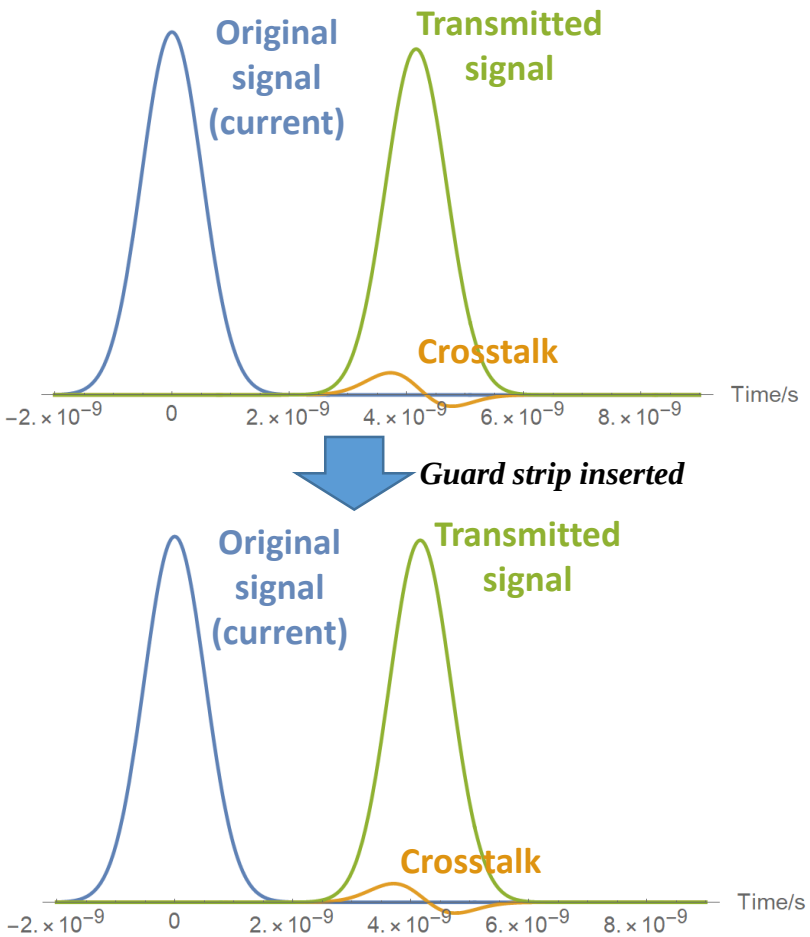
Comparison between strip-strip model and strip-ground wire-strip model:

- Setup:
  - 27 mm pitch (25 mm strip + 2 mm spacing)
  - 0.8 mm guard strip
  - 1 m transmission distance
  - Guard strip matching resistor 100 Ω
- Analysis:
  - Inter-strip capacitance drop: 13.3 pF/m → 7.1 pF/m
  - Crosstalk amplitude: 6.1% → 4.9%
- The effect is small, but this simulation will provide guidance for the optimization of strips in the future.

Strip-strip Model: 2 mm space between strips



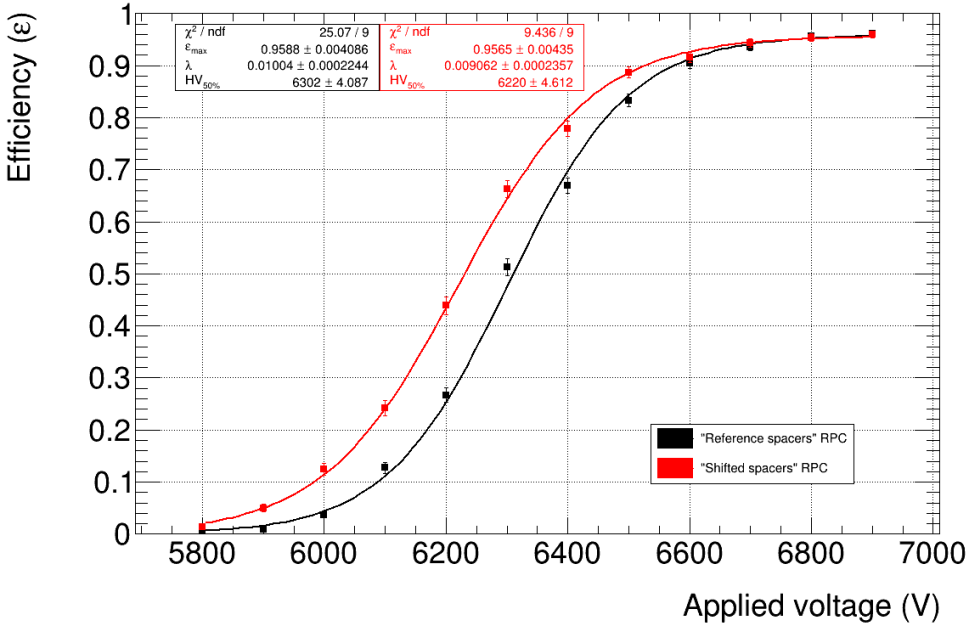
Strip-ground wire-strip Model: 0.8 mm ground wire between strips



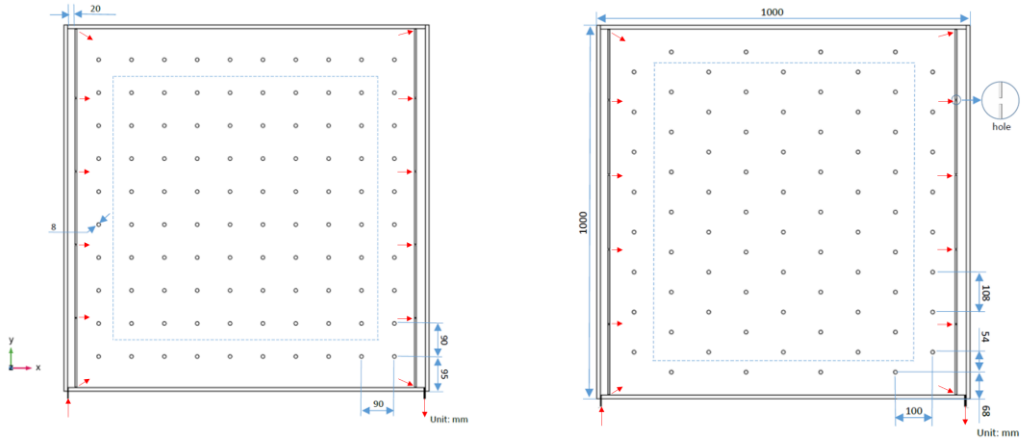
（结论）

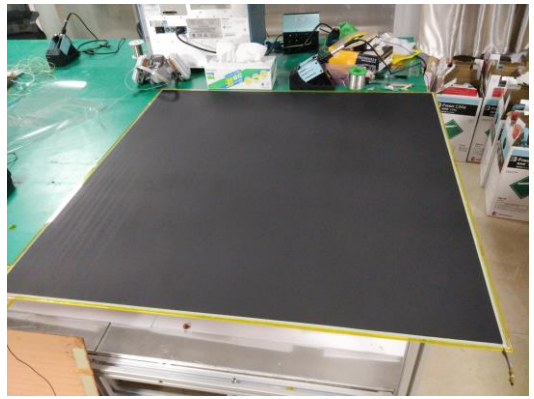
Optimize Gas Chamber Design

- Gas flow simulation with difference design of spacers (linear and shifted.)
- Decrease the number of spacers by 24%.
- Improve the uniformity of gas flow and electric field.

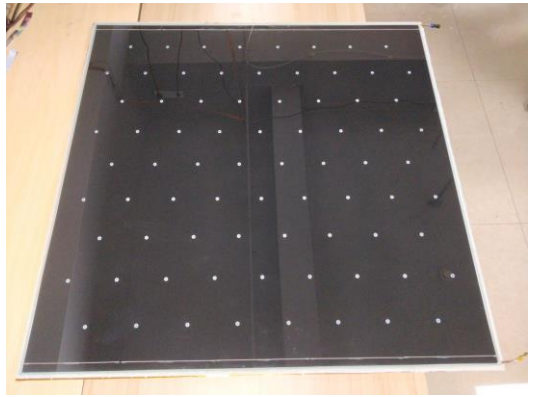


Difference in behaviour is mainly due to P, T difference between runs





Gas gap with standard design



Gas gap with shifted design

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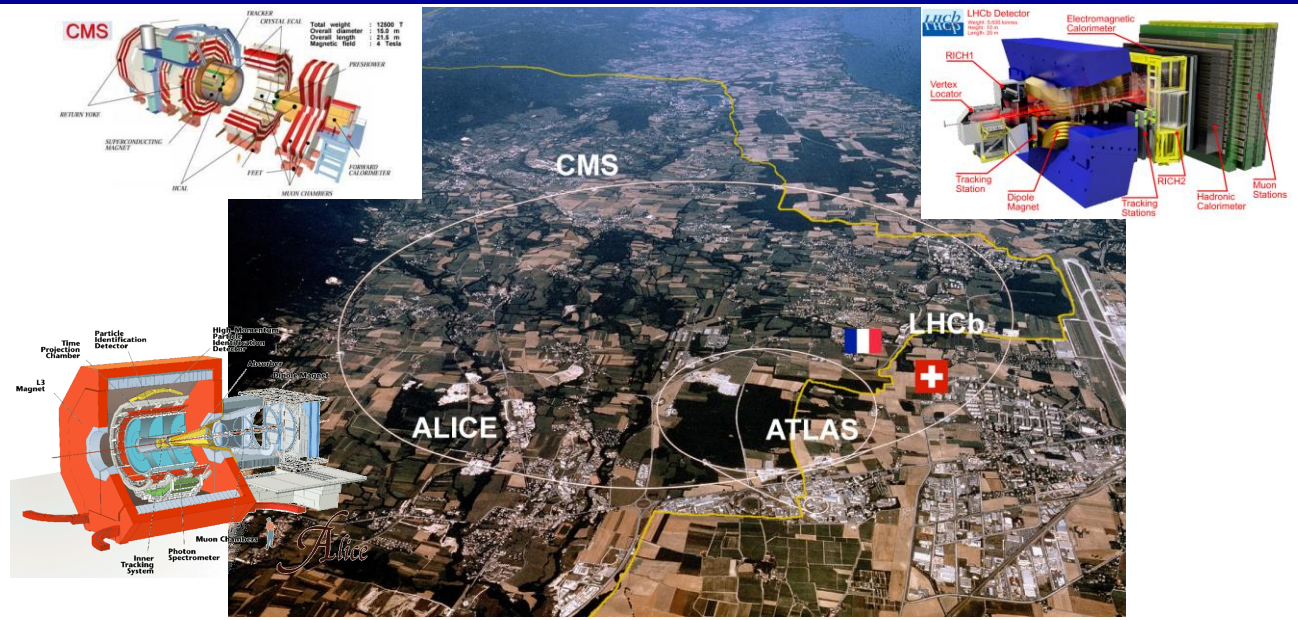
Summary

- Systems of readout panel production and flatness measurement have been built.
- Readout panel with very good quality could be produced locally.
- Test system (DAQ, monitoring) for mass production has been built.
- Double-end readout method has been preliminarily validated.
- Simulation of signal transmission has been performed.
- New design of RPC has been studied.

LHC, ATLAS and RPC



The Large Hadron Collider（LHC）

- The most power full accelerator and collider
- Proton-proton collision, center-of-mass energy 13 TeV
- Four large detectors: ATLAS, CMS, LHCb和ALICE.

ATLAS detector:

- One od the two general used detectors in the LHC。
- Collect the data of proton-proton collision.
- Searching target: Higgs, extra dimension, SUSY, dark matter and so on

Position of ATLAS RPC. Trigger of ATLAS barrel region.