MRPC and RPC production capabilities in USTC

Yongjie Sun

State Key Laboratory of Particle Detection and Electronics
Department of Modern Physics
University of Science and Technology of China

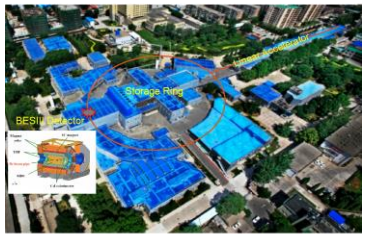
Outline

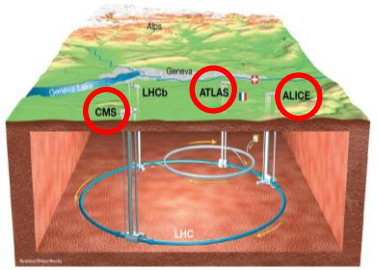
- Introduction
- Completed mass production
  - MRPC for STAR TOF
  - MRPC for STAR MTD
  - MRPC for BES-III e-TOF
- Ongoing & foreseeing projects
  - MRPC for CBM TOF (pre-production for STAR e-TOF)
  - RPC for ATLAS Phase-II Upgrade
  - RPC for STCF Muon system
- Summary and outlook

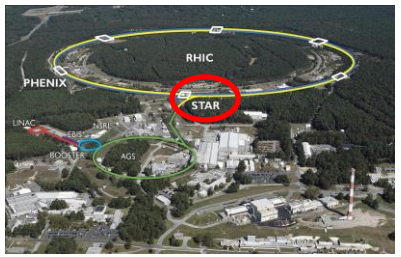
Introduction

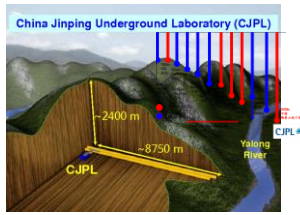
Particle and Nuclear Physics and Electronics in the Modern Physics Department at USTC.
State Key Laboratory of Particle Detection and Electronics, USTC

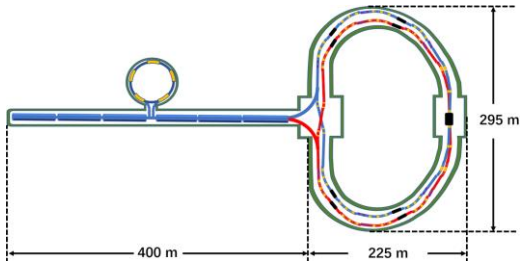
- Collider physics
  - ee: BES3, Belle2
  - pp: ATLAS, CMS
  - AA: STAR, ALICE
- Non-accelerator physics
  - Dark matter: DAMPE, PandaX-4T
  - $0\nu2\beta$: CUPID-Mo/CUPID
  - Axion/Monopole: R&D
- Particle detector
  - Micro-pattern gaseous detector
  - Silicon detector (MAPS, LGAD)
  - Timing/trigger detector (MRPC, RPC)
  - Calorimeter (EMCal, HCal, Bolometer)
- Super Tau-Charm Facility
  - Next generation ee collider in China
  - Leading the R&D

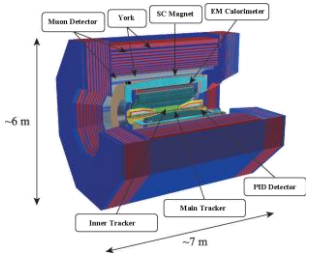








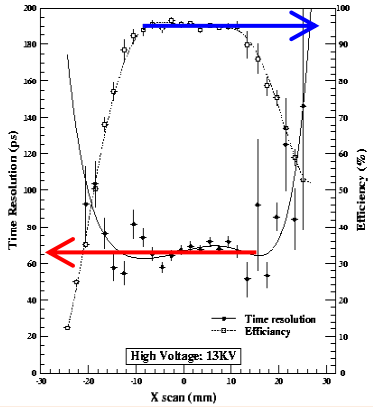




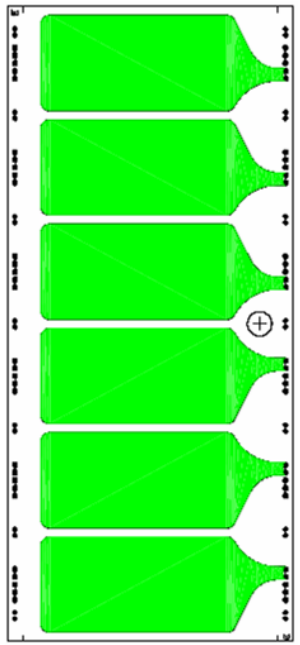
MRPC for STAR TOF

- R&D Started in 2000.
- Prototypes tested in 2001
- MRPC final design in 2002
- First TOFr tray installed (2002-2004)

First single-cell MRPC with 5×0.22mm gaps

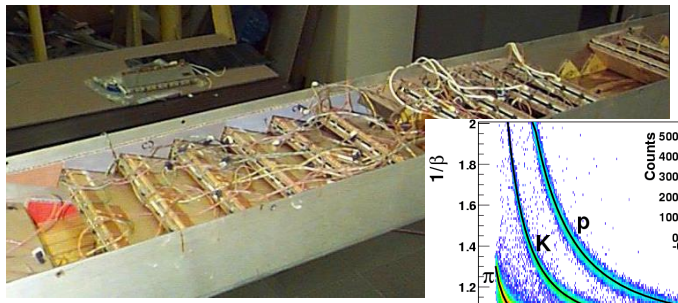


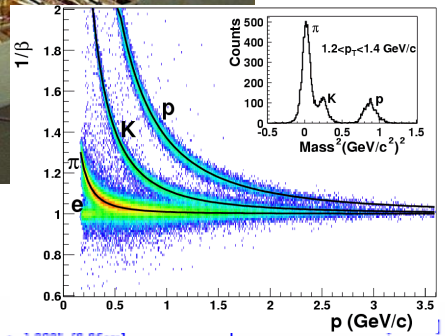
- Efficiency >~ 95%
- Timing resolution ~70 ps
- Good uniformity



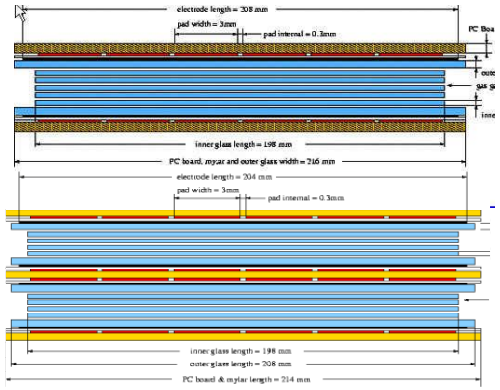
Final design
Module: 20×6 cm
Gap: 6×0.22 mm
Pad: 3.15cm×6.1cm
Gas: 95% C2H2F4
+5% Iso-C4H10

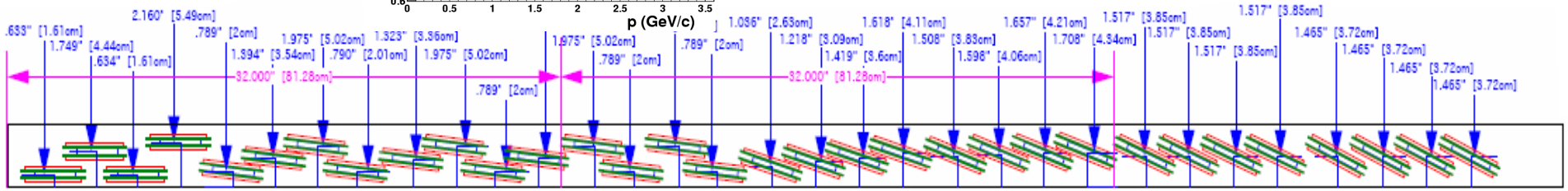
TOFr tray at STAR





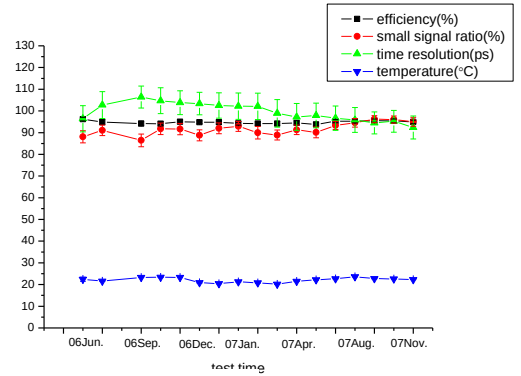
Prototypes with single- and double-stack

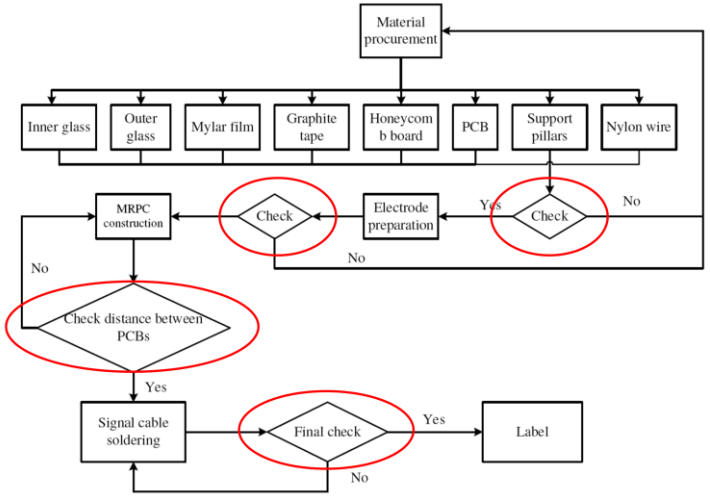


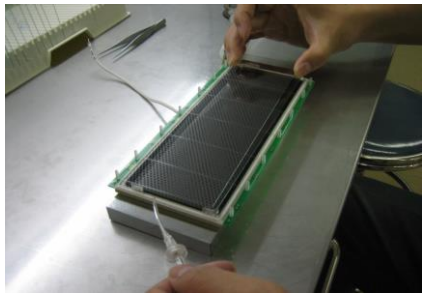


Mass production for STAR TOF

- Mass production started in April 2006 and finished in Nov. 2007.
- 1283 MRPCs produced and qualified in USTC (30% of total STAR-TOF MRPCs).
- Over 95% of MRPCs tested with good quality.
- Operating in STAR smoothly from 2008 till now.
  - Clean room (100K) with temperature and humidity control
  - Detailed documents of assembly and test for tracking
  - Database for the mass production
  - Cosmic ray test system





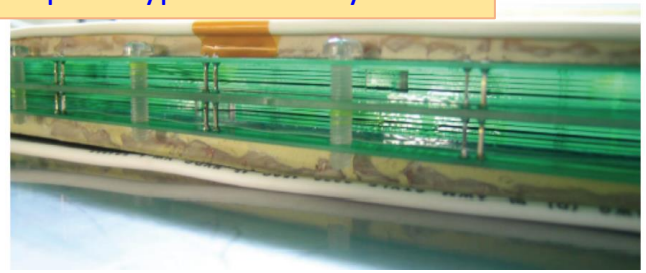


2006	Month	Output	2007	Month	Output	Month	Output
	Jun.	12		**Jan.**	58	**Jul.**	120
	Jul.	64		**Feb.**	24	**Aug.**	120
	Sep.	55		**Mar.**	83	**Sep.**	119
	Oct.	35		**Apr.**	80	**Oct.**	121
	Nov.	42		**May.**	126	**Nov.**	120
	Dec.	22		**Jun.**	82		
Total	230			1053			

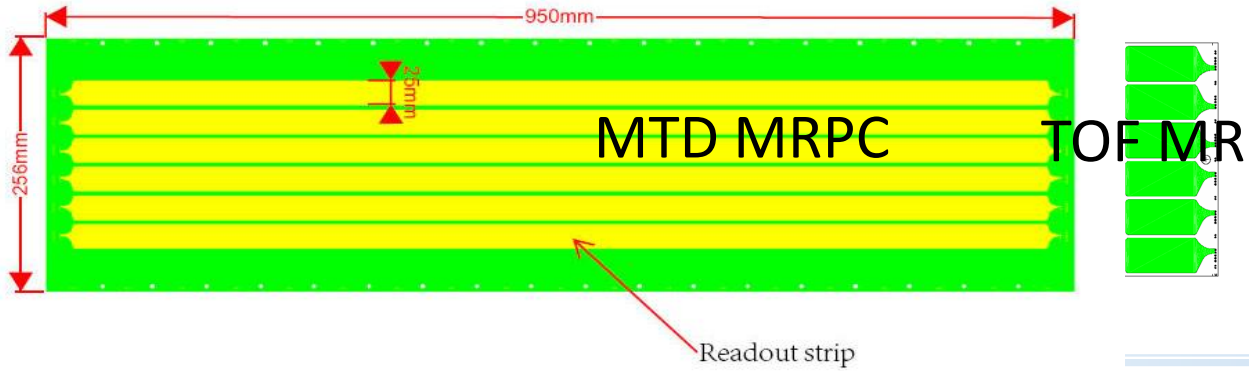
Long strip MRPC for STAR Muon Telescope Detector

- Motivated by the muon trigger requirement of STAR
- High time resolution and good spatial resolution for muon trigger and identification
- Finally Realized by a single layer of LMRPC
  - Suitable for large area coverage
  - Mean time independent of incident position
  - Time difference for positioning

First prototype in 2006 by USTC

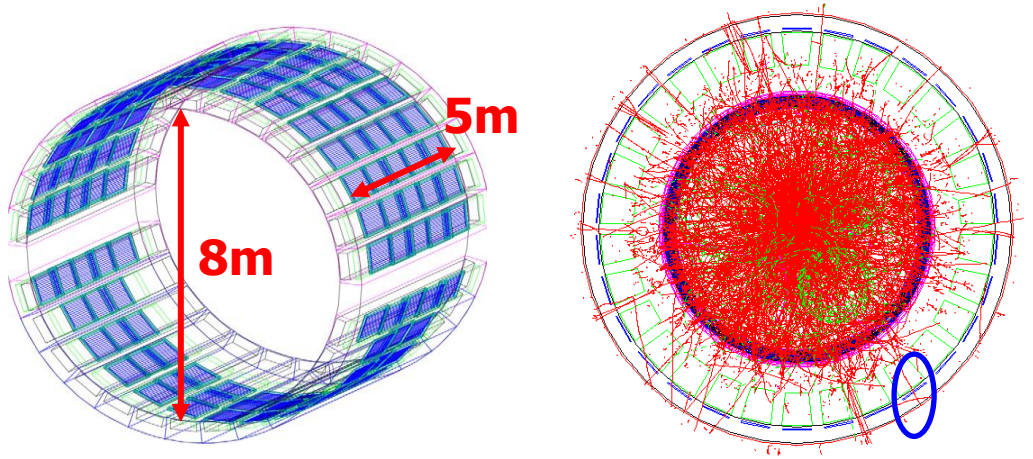


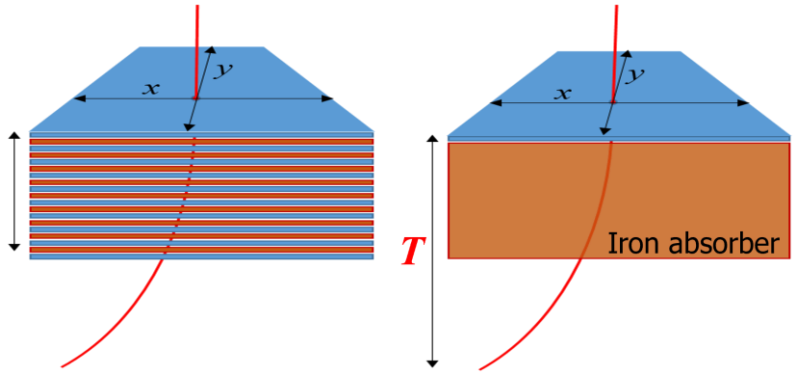
Performance of prototype:
Time resolution: ~70 ps
Efficiency: >97%
Spatial resolution: ~ 1 cm



MTD MRPC

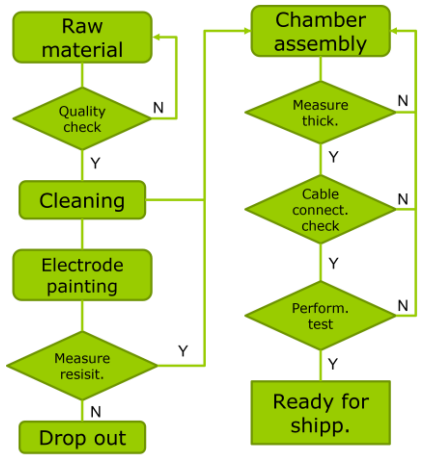
TOF MRPC

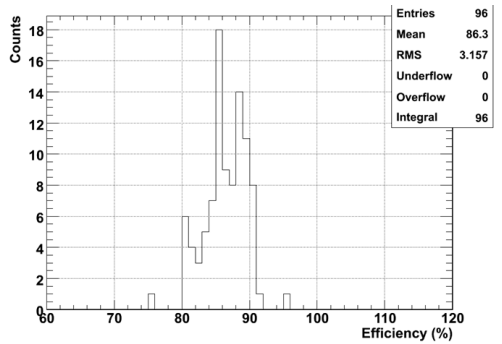


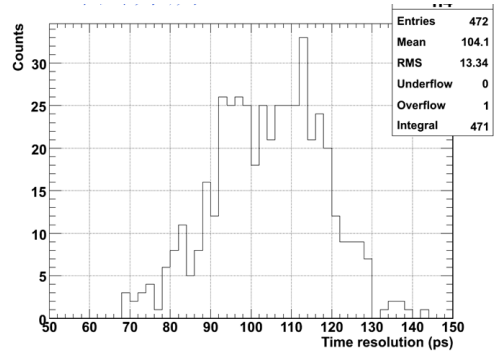


Mass production of LMRPC for STAR MTD

- Final design in 2009:
  - Size: 58×91.5 cm, strip: 3.8×87 cm
  - Gap: 5×0.25 mm
  - Readout: double-end
- LMRPC mass production: May. 2011 - Jan. 2013
- 57 LMRPC produced and qualified in USTC (50% of total)

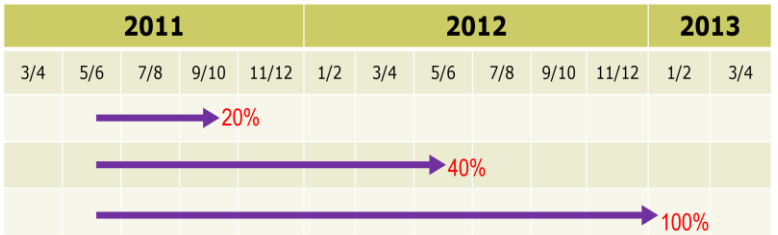






	Timeline of STAR MTD
2005	R&D started
2006	Beam test at Fermi-Lab T963 beam
2007	2 modules with trigger elec. installed
2008	3 modules with TOF elec. installed
2009	Design finalized
2010	1 module of final design installed
2011	Mass production started
2012	10% installed
2013	63% installed
2014	100% installed

Progress of mass production



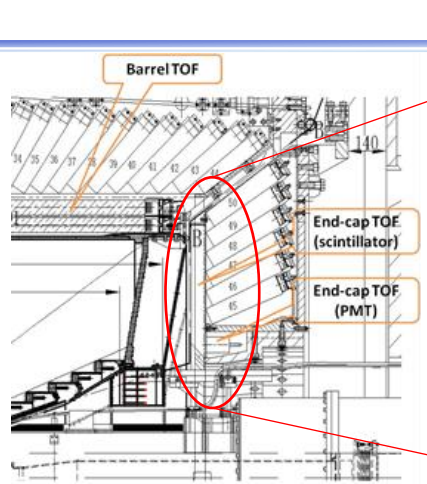
BES-III@BEPC e-TOF upgrade

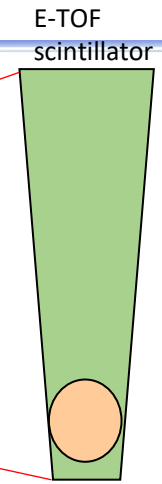
- Upgrade BES-III e-TOF from scintillator to MRPC:
  - Better time resolution of <50 ps
  - Smaller cell size to reduce the scattering effect
- Prototypes tested in 2011 and 2013@BEPC E3 line
  - Same gap structure: 2×6×0.22 mm
  - Different readout pattern: single- vs. double-end

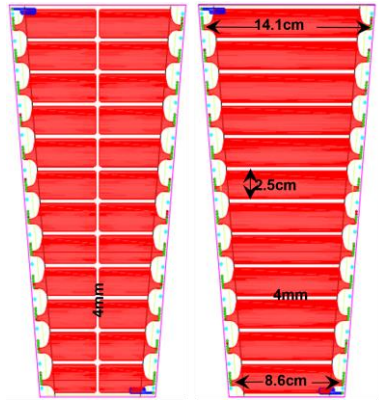
✓Double-end shows better time resolution without position correction

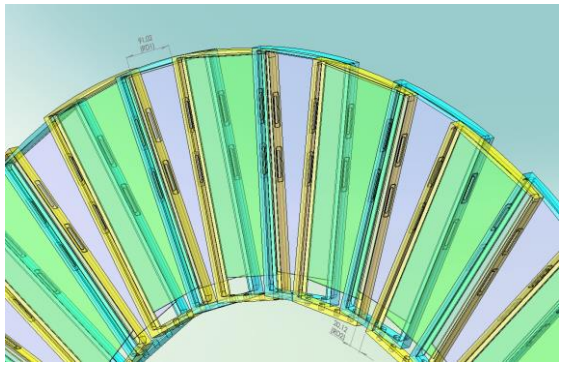
✓Double-end time resolution independent of strip length

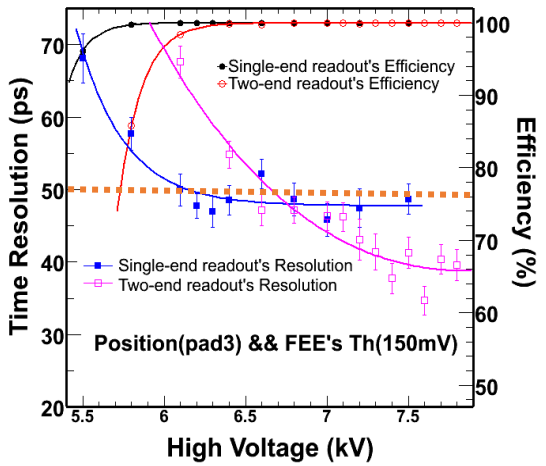
✓Single-end time resolution varies between strips

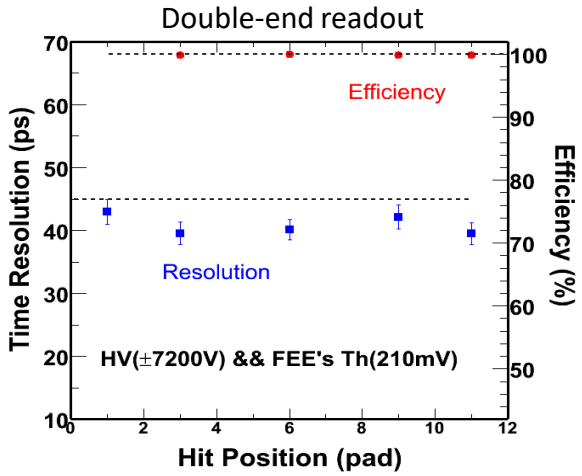


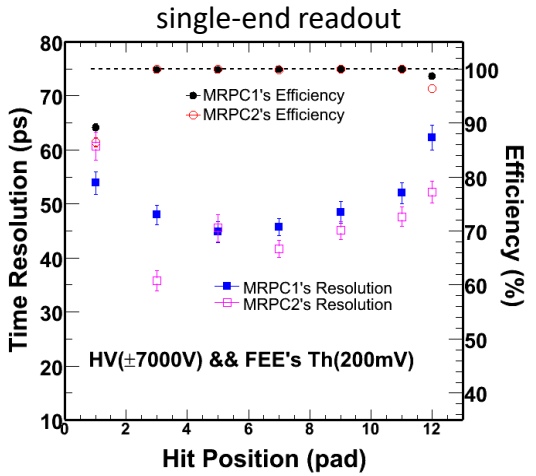


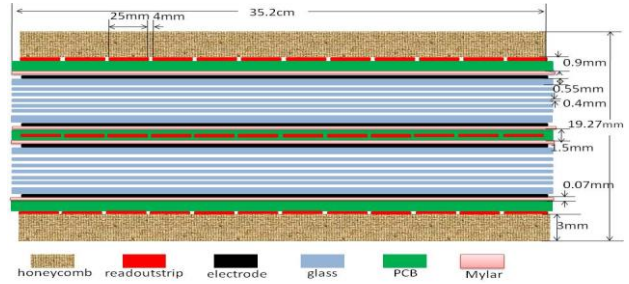






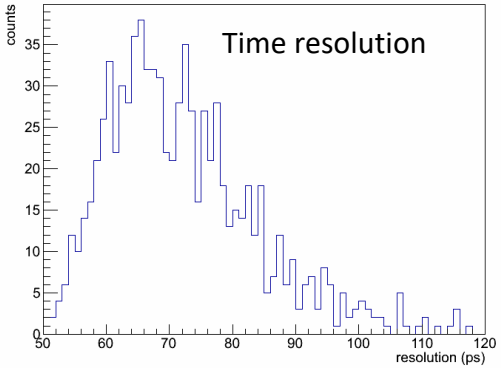


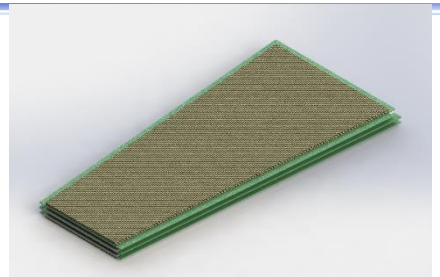


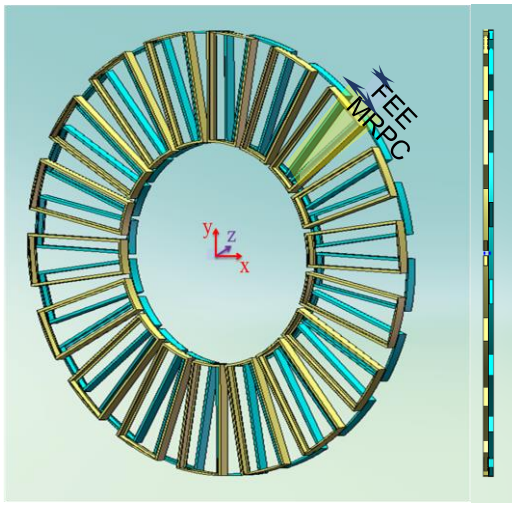


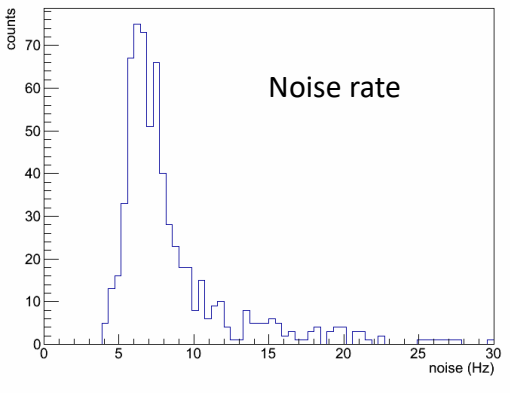
Mass production of BES-III e-TOF MRPC

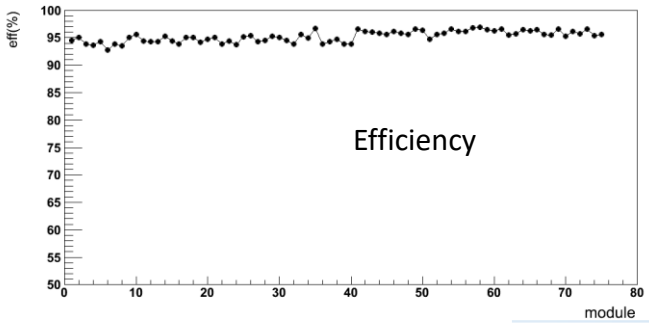
- Final design in 2014
- Production: 2014-2016
- Totally, 80 MRPC were produced and qualified

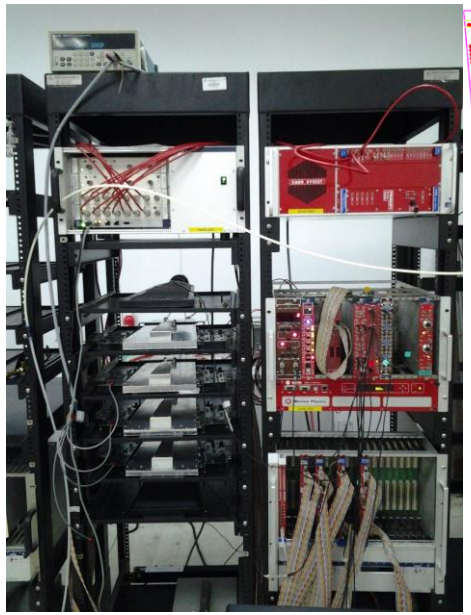


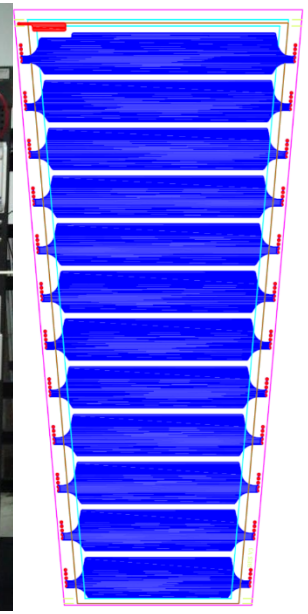


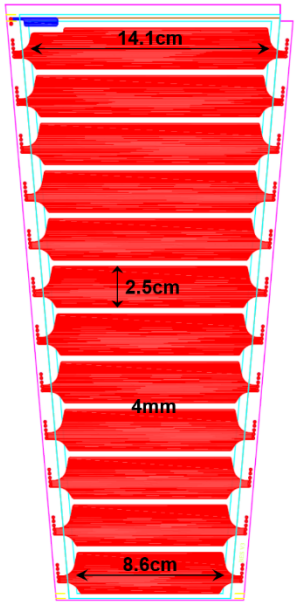






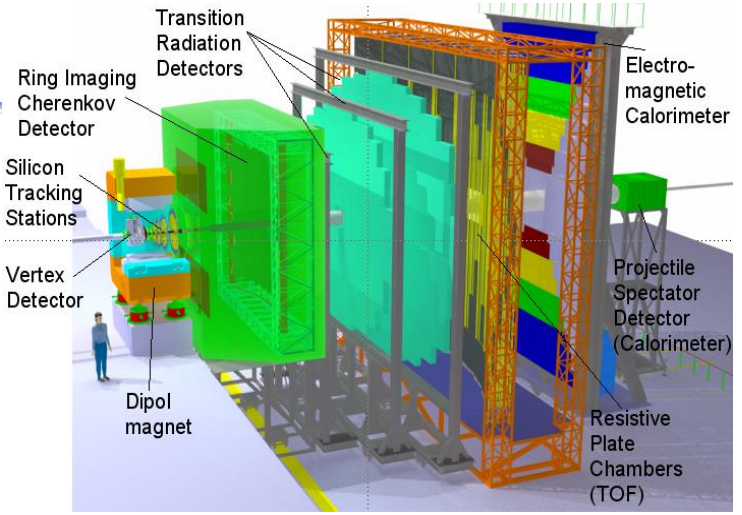




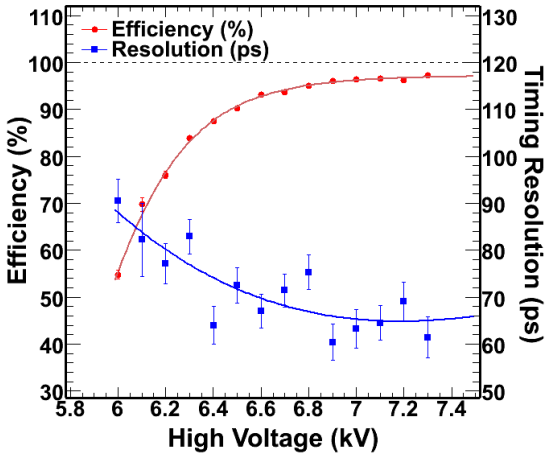


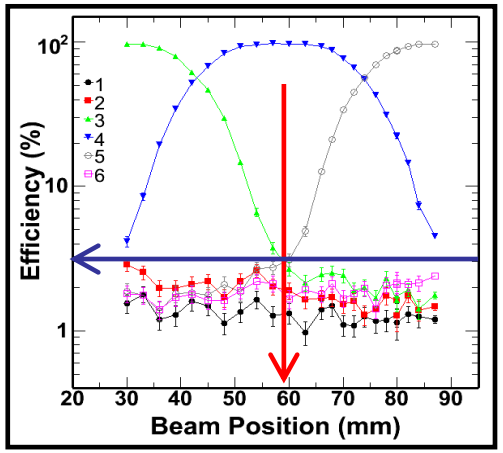
MRPC for CBM TOF

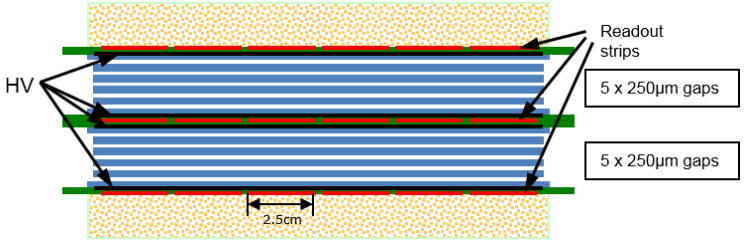
- High rate @CBM TOF as a fixed target heavy iron experiment
  - Coverage: ~ 120 m^2
  - Rate: 1-25 kHz/cm^2
- Thin float glass MRPC is a cost-effective solution for the TOF wall outer region (rate ~ 1 kHz/cm^2)
- R&D started as early as 2009
- The first prototype to check the cross-talk effect with a long-strip structure

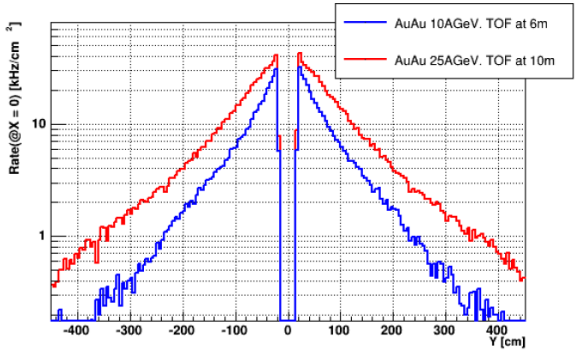


Beam test Aug. 2009 @ GSI

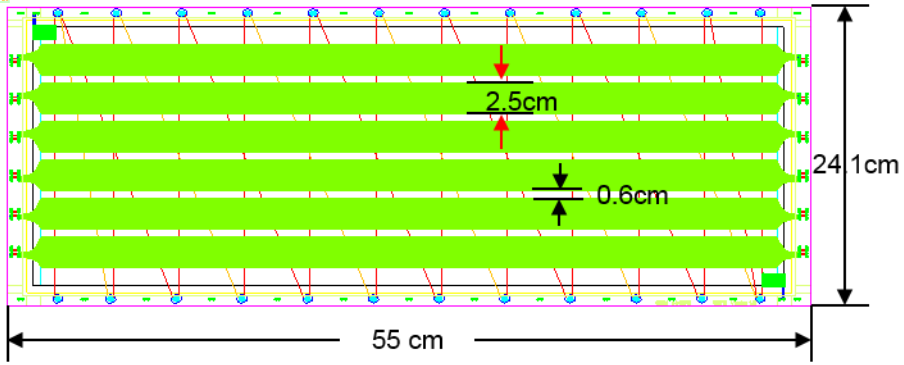






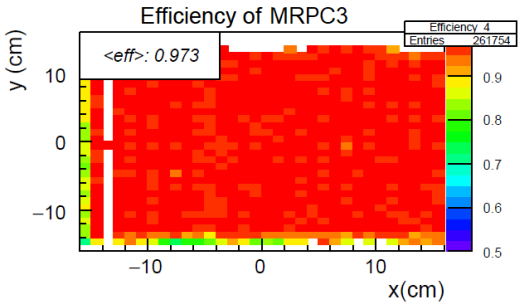


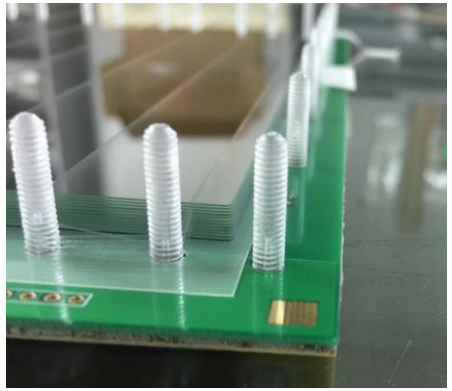
- Effective size: 50 x 18 cm^2
- Strip: 50 cm x 2.5 cm
- Gaps: 2×5×0.25 mm

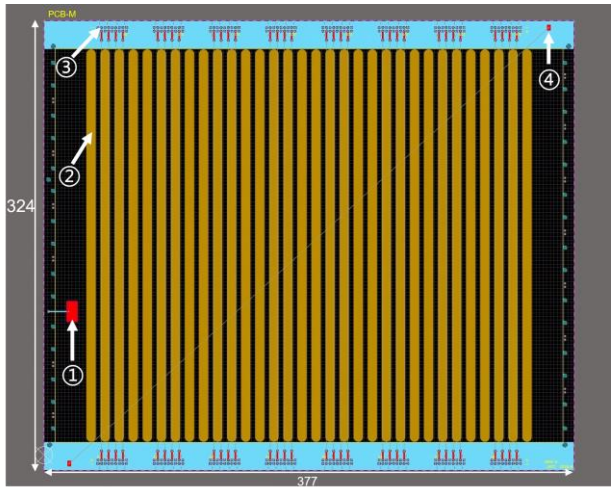


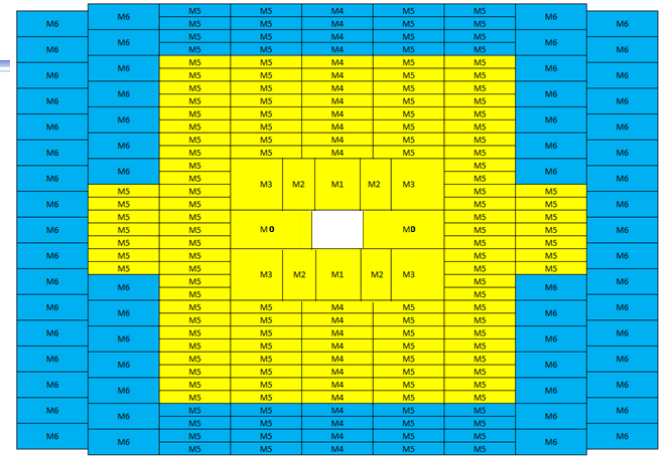
Thin float glass MRPC3/4 for CBM TOF

- Final design
  - Glass: 0.23 mm
  - Rate capability: 2 kHz/cm^2
  - Strip: 1 cm pitch, 50 Ω differential impedance
- 80 MRPC3 produced and installed for STAR e-TOF as pre-production

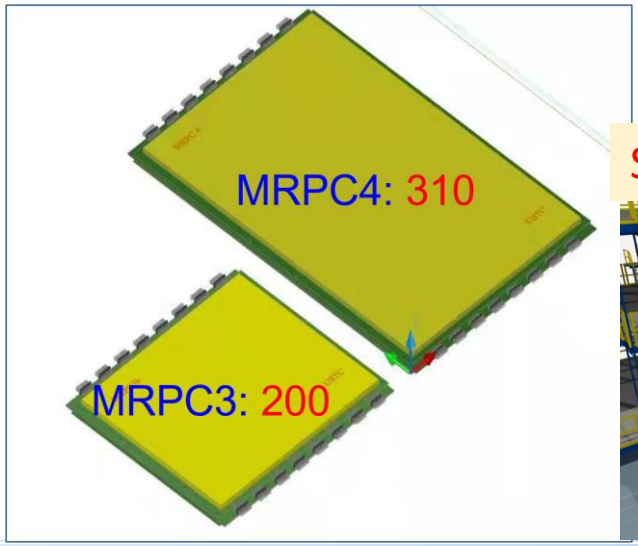


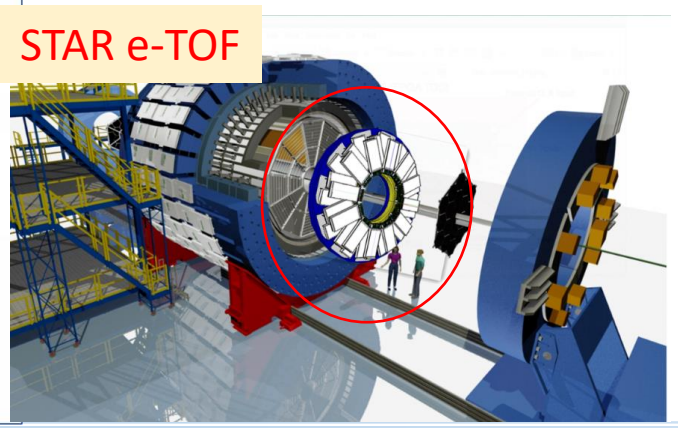


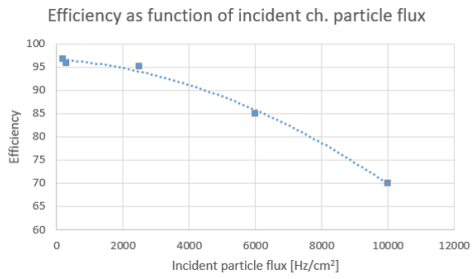


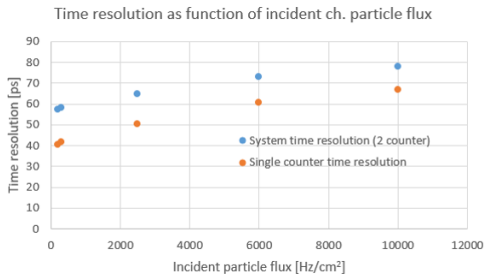


		MRPC 3	MRPC 4
Glass	Type	ultra-thin float	
	Size	353 x 276 x 0.23 mm	353 x 540 x 0.23 mm
Gaps	Size	0.230 mm	
	Number	5 x 2	
Readout strips		(0.7 cm + 0.3 cm) x 32, double-end strip	
Impedance		50 Ω differential signal to PADI	
Active area		320 mm × 270 mm	320 mm × 540 mm
Detector size		377 ×324 mm	377 × 588 mm
Total Amount		200	310



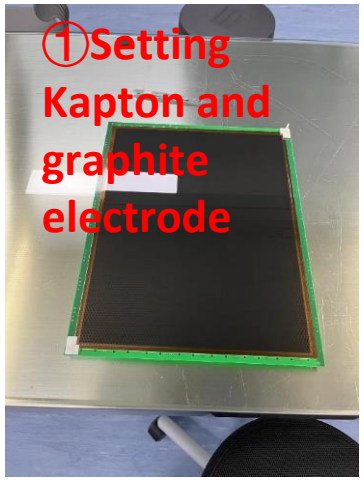


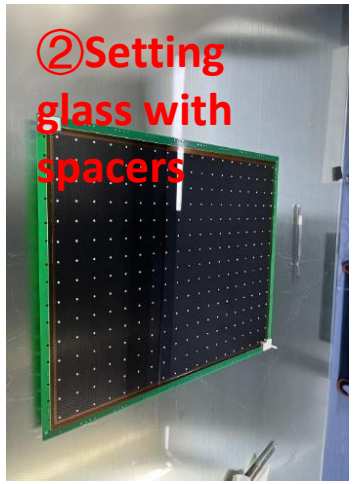


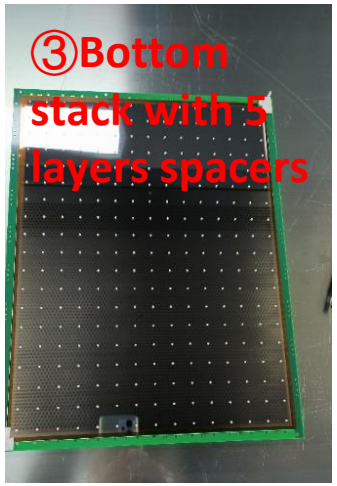


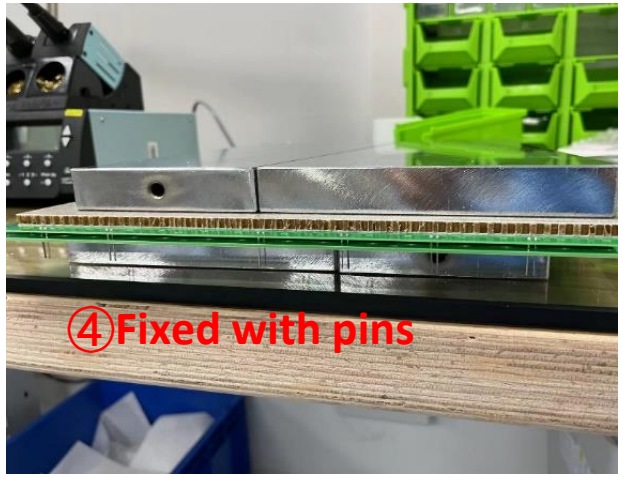
MRPC with pad spacers

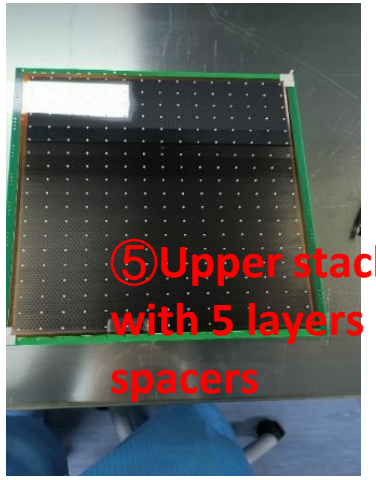
- Good candidate for CBM TOF MRPC3
- Have a better anti-aging effect under high flux.

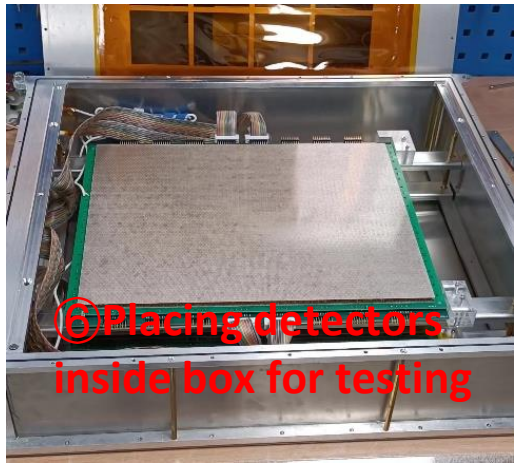


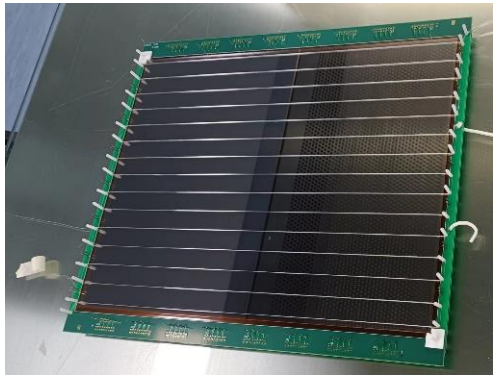




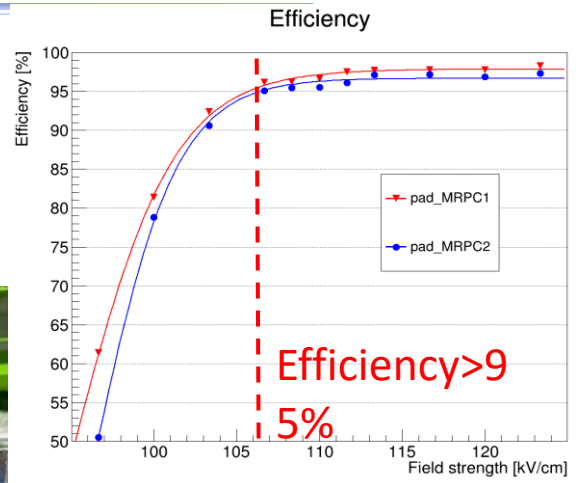


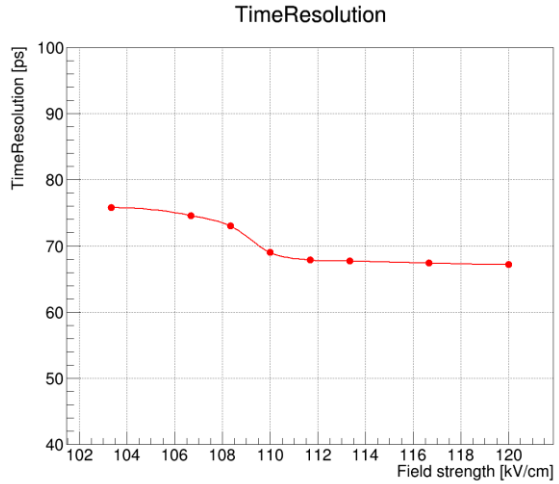






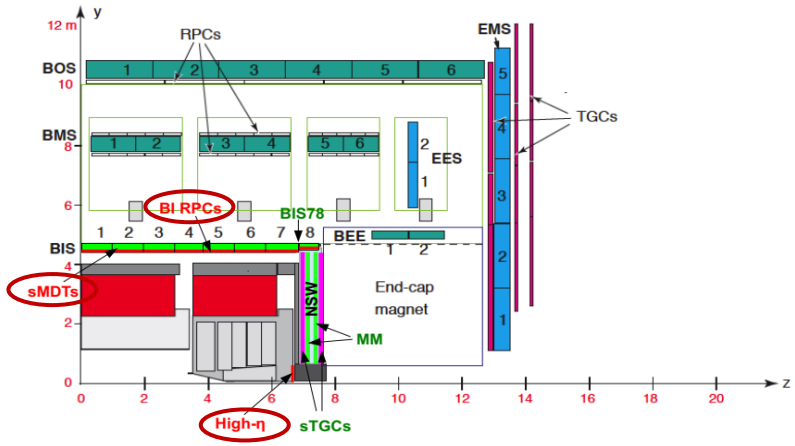
Fishline spacer MRPC

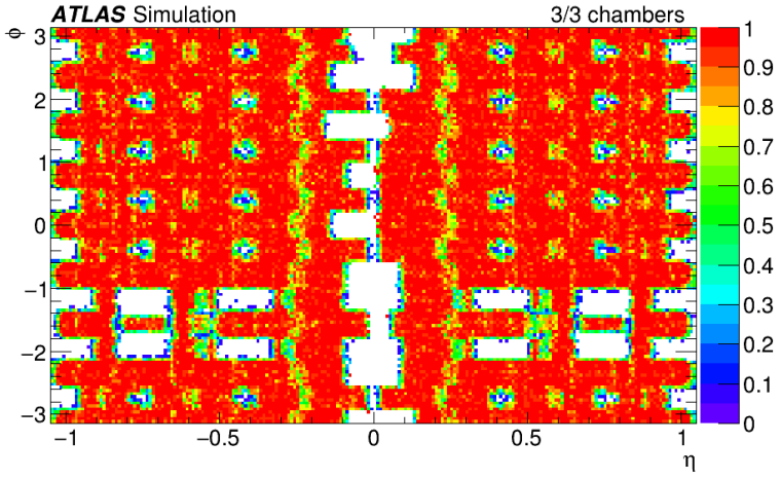


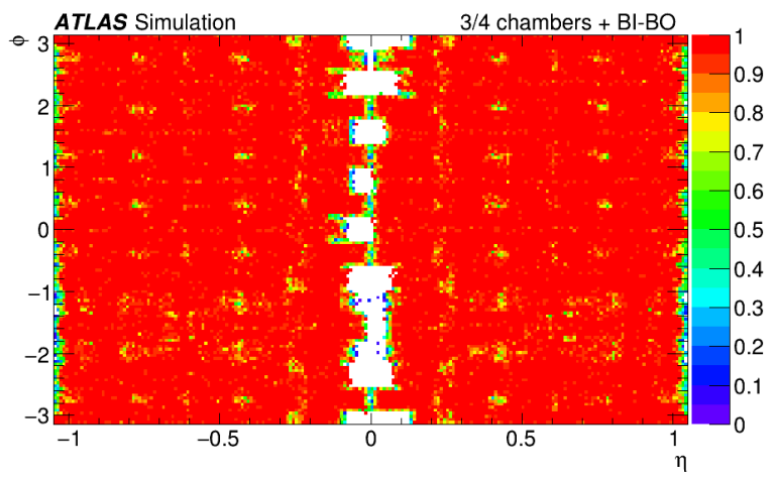


Thin-gap RPC for ATLAS Phase-II upgrade

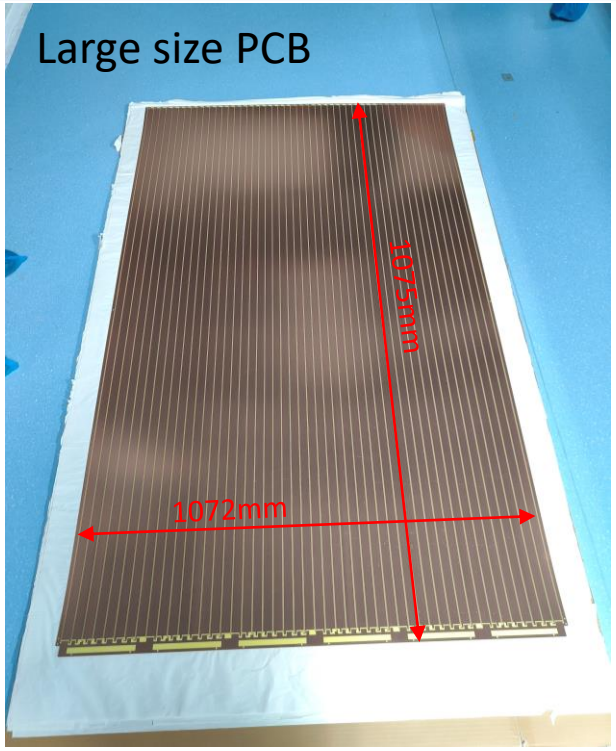
- 3 layers of thin-gap RPC to be installed in ATLAS Barrel Inner region during LS3 with rate capability up to 1 kHz/cm^2
  - Recover most of the current geometrical acceptance holes
  - The redundancy of the system will be greatly enhanced
  - Full trigger efficiency can be maintained even if the old RPCs have to be operated at reduced efficiency (mix gas or reduced HV)
- Tasks undertaken by ATLAS Chinese cluster (USTC-SDU-SJTU)
  - ~ 900 BIS/BIL/BOM/BOR read-out panels will be produced and qualified
  - ~70 gas gap will be produced and qualified
  - ~360 singlets assembly carried out in China

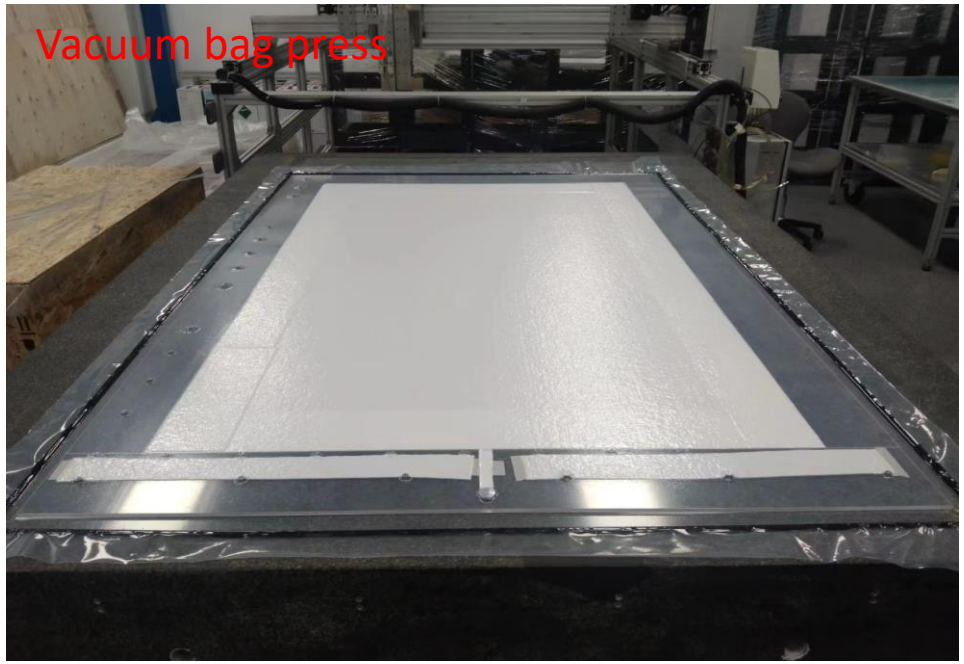


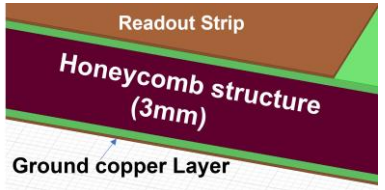


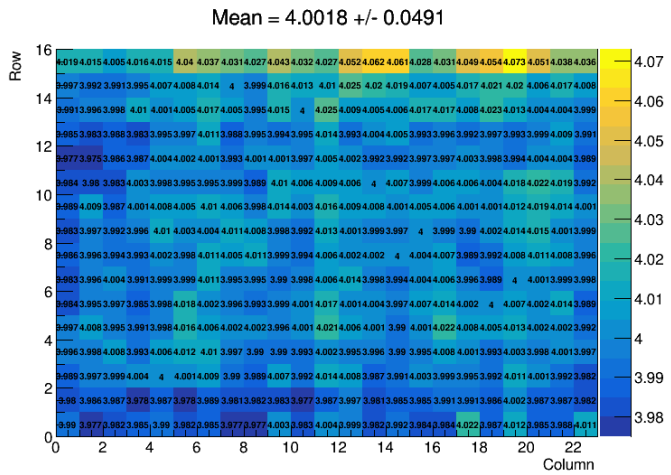


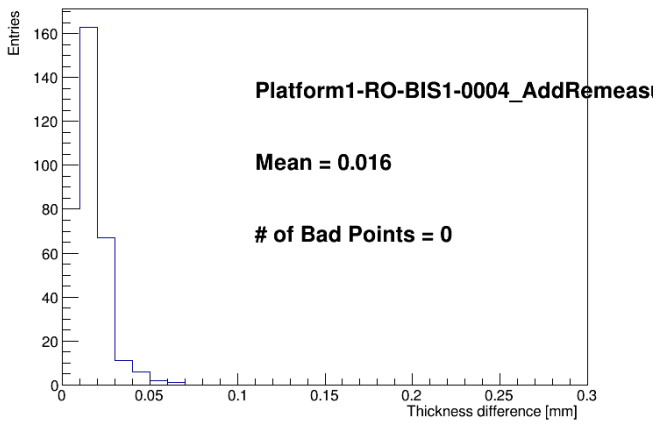
Large size honeycomb readout panels

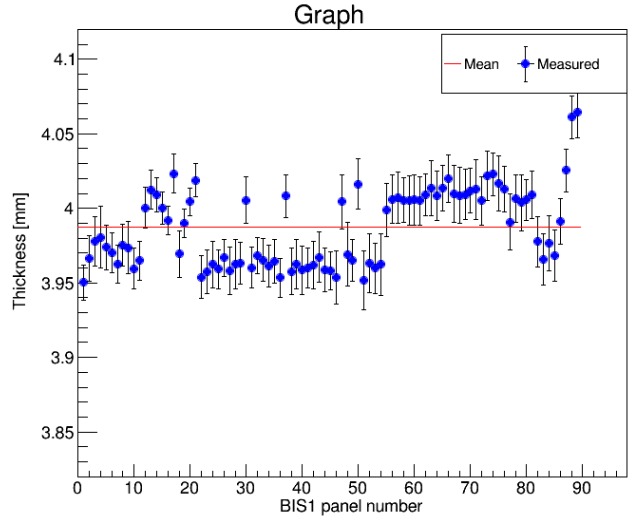






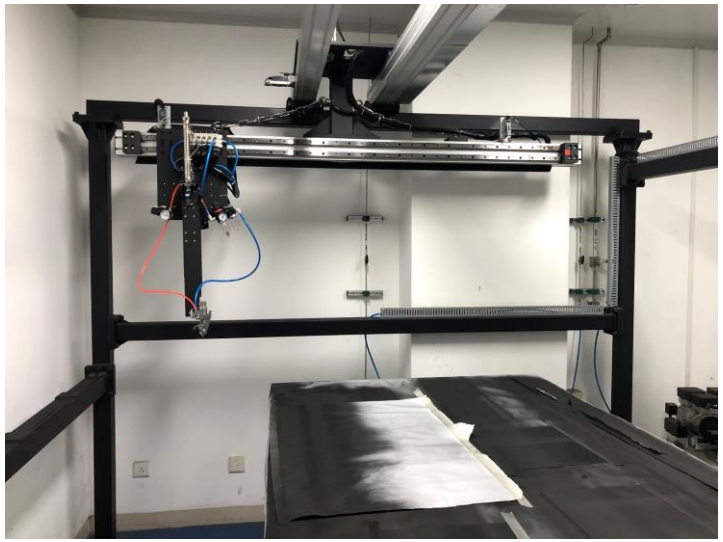


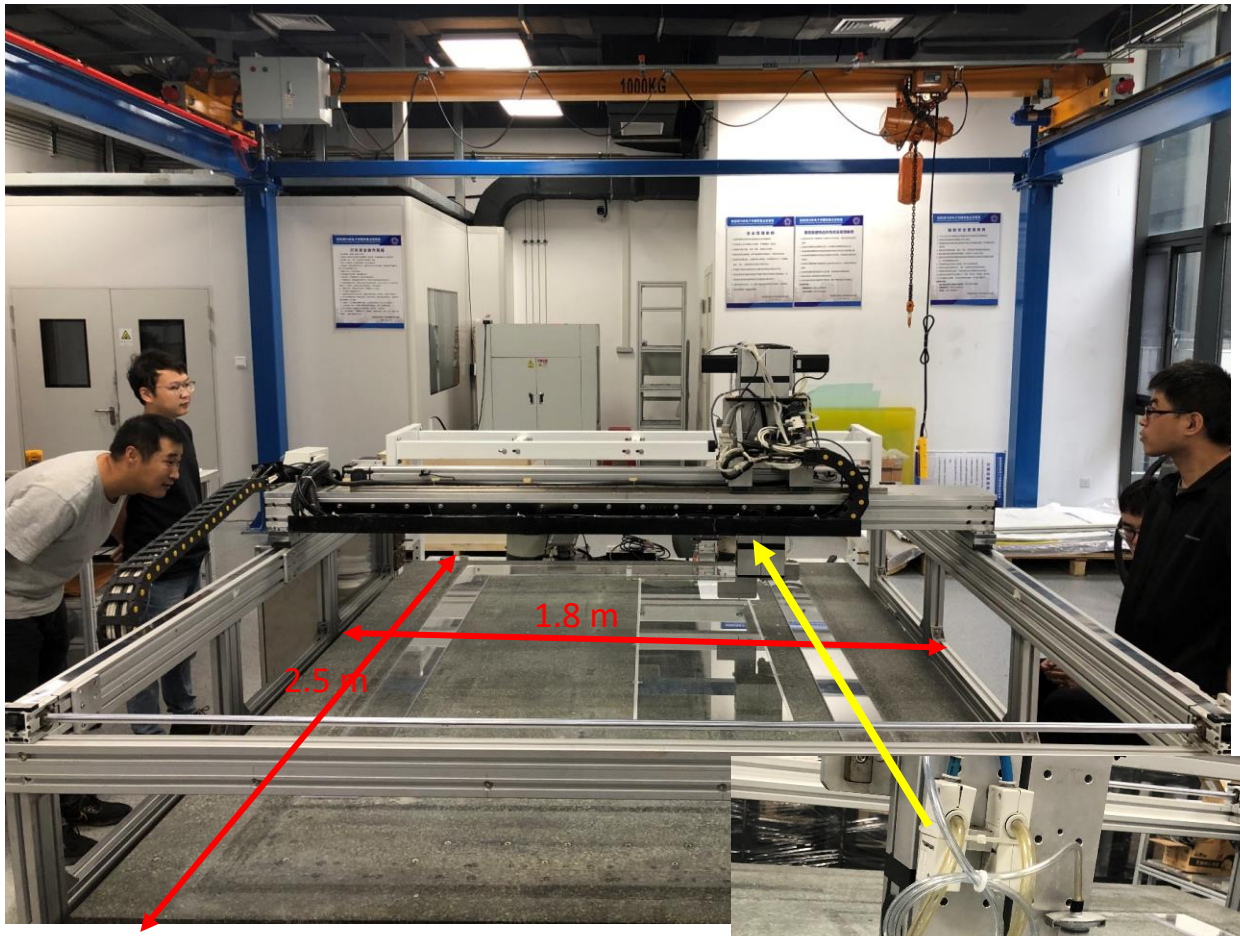


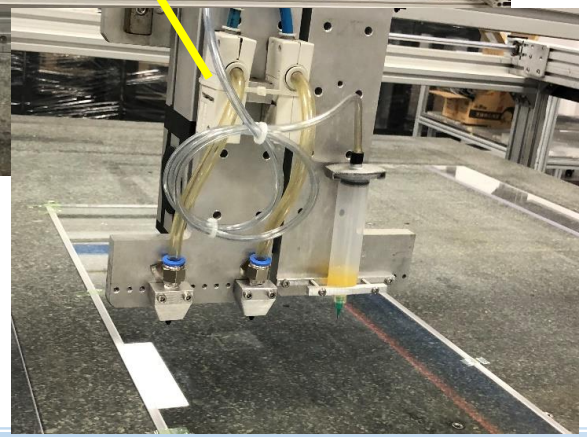


RPC gas gap production

- A marble table base: 2.5m×1.8m
- A headstock supported by a gantry
- The headstock holds two spacer pickers and a glue syringe.
- The origin, moving range, and steps of the head part are programmable.
- A graphite electrode painting room







- ✓ Potentially to be used for ATLAS gas gap production (candidate site to be qualified)
- ✓ Preparation for the future STCF Muon RPC

Summary

- USTC has a long-term experience in MRPC production.
- Several projects completed successfully.
- All built MRPC systems operated smoothly.
- For each project, we started from the R&D according to the requirements.
- Proposals submitted successfully with abundant R&D efforts.
- Beyond that, our group also continues till physics analysis.

R&D → Proposal → Mass production → Commission ←
Physics analysis ← Calibration / Software ←