Forward sTGC Tracker Prototyping and Performance Test for the STAR Upgrade

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Outline

1. Motivation
2. small-strip Thin Gap Chambers (sTGC)
3. Forward sTGC Tracker (FTT) prototype design and production procedure
4. Quality assurance
5. Performance test
6. Summary

Motivation

Forward Tracking System (FTS) upgrade at forward rapidity ($2.5 < \eta < 4$) is ongoing at STAR to address fundamental questions about cold QCD physics program. arXiv:1602.03922

- Forward Tracking System (FTS):

  Forward Silicon Tracker (FST) (3 silicon disks).

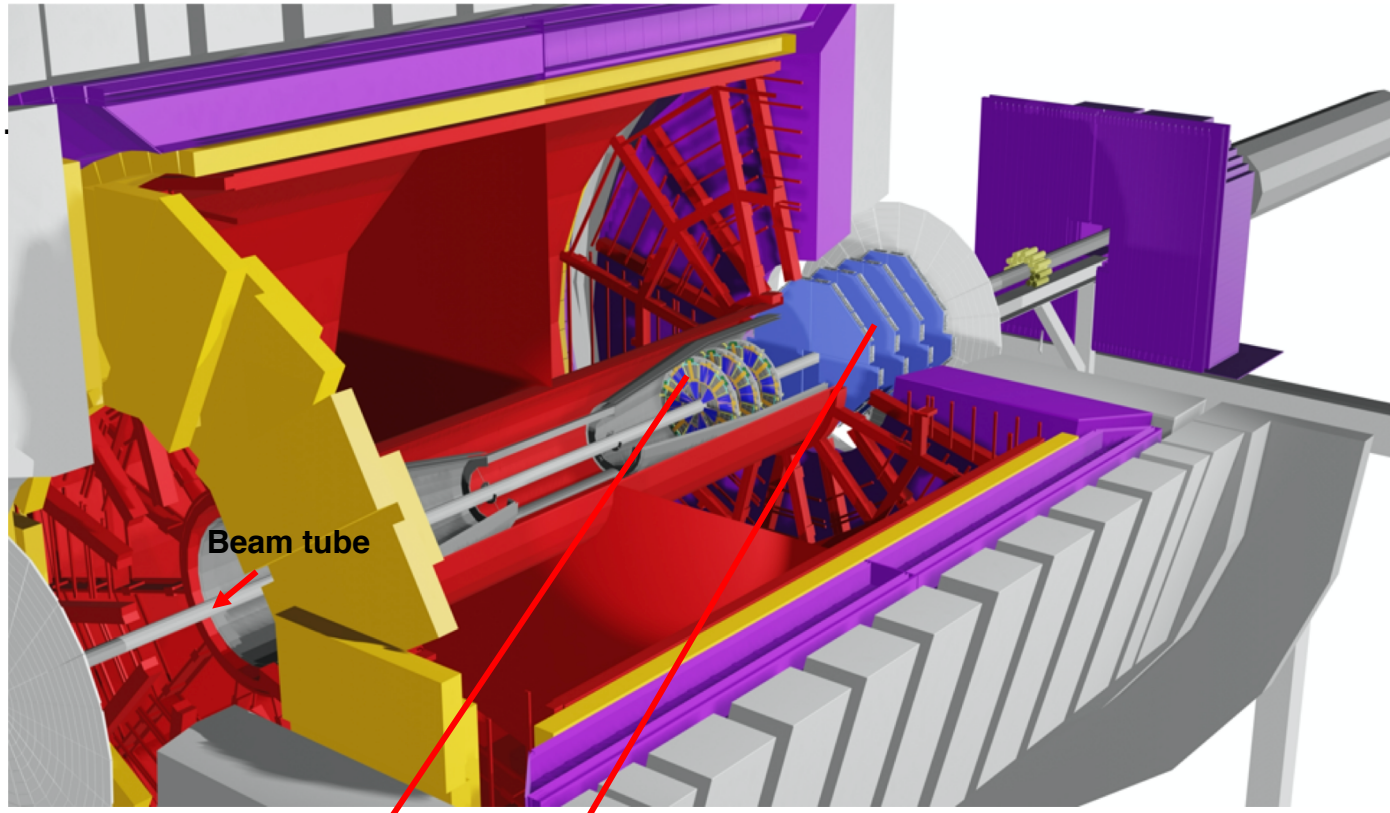
  Forward sTGC Tracker (FTT) (4 sTGC disks).

- Forward sTGC tracking requirements:
  - 4 Tracking points
  - Position resolution (<200um)

small-strip Thin Gap Chamber (sTGC)

–original designed by the ATLAS experiment

V. Smakhtin et al., NIM.A, 598 (2009) 196–200
A. Abusleme et al., NIM.A, 817(2016) 85–92

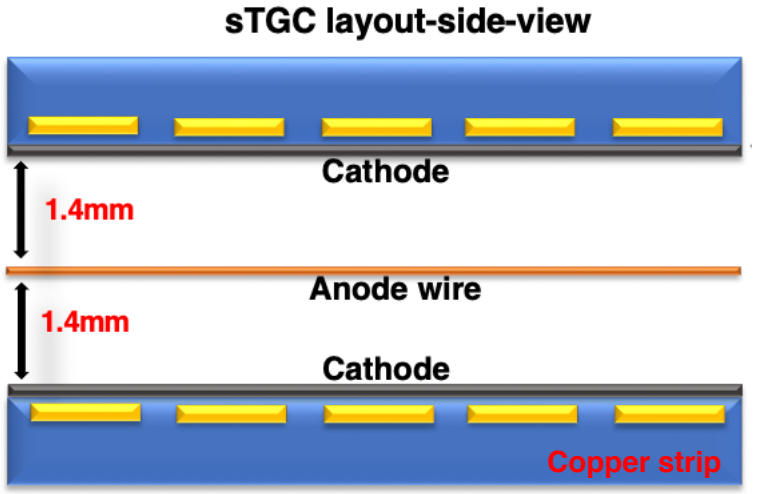


RK.00004: Tracking for the STAR Forward Upgrade
James Brandenburg

FST's talks

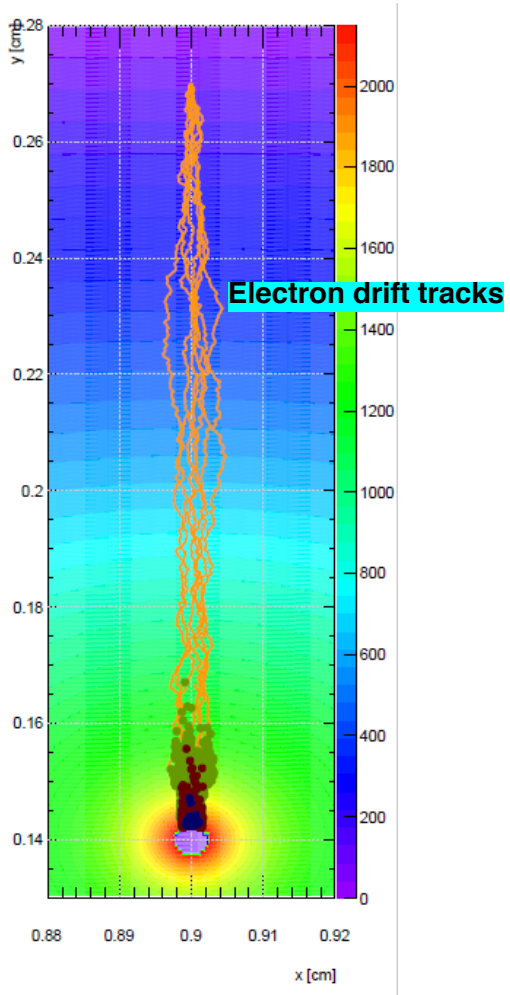
- FN.00004: Laser Test Stand for Silicon Detectors , Xu Sum and Zhenyu Ye
- RK.00005: STAR Forward Silicon Tracker Upgrade Status, Xu Sun
- RK.00007: STAR Forward Silicon Tracker: Characterizing Prototype Module Performance with Cosmic Rays and Simulation Studies , Gavin Wilks

sTGC

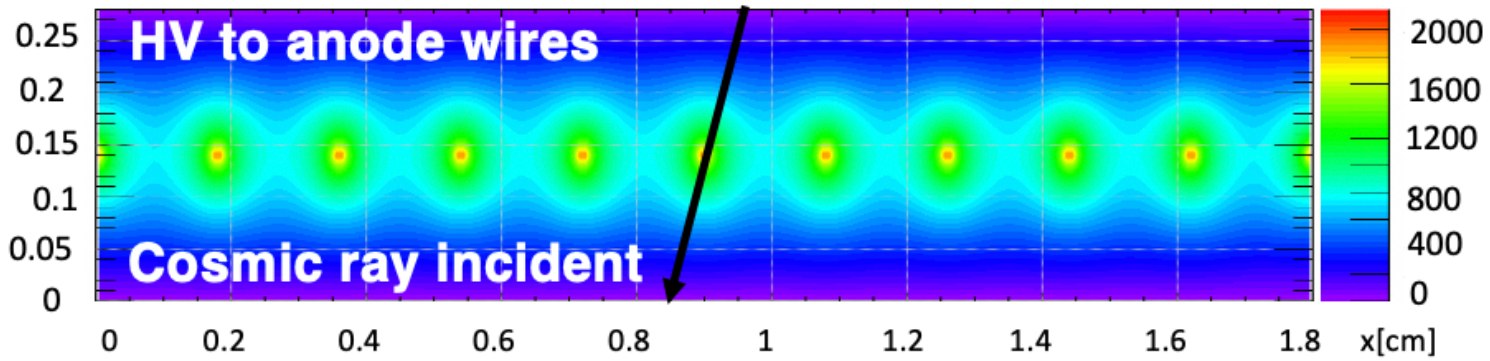


- **Anode:** 50μm gold-plated tungsten wire, wire pitch 1.8mm, the wire tension 350g;
- **Cathode:** graphite epoxy mixture
- **Readout:** copper strips, perpendicular to anode wires, outside of cathode

Ionization avalanche



Garfield++ simulation sTGC structure and electric field

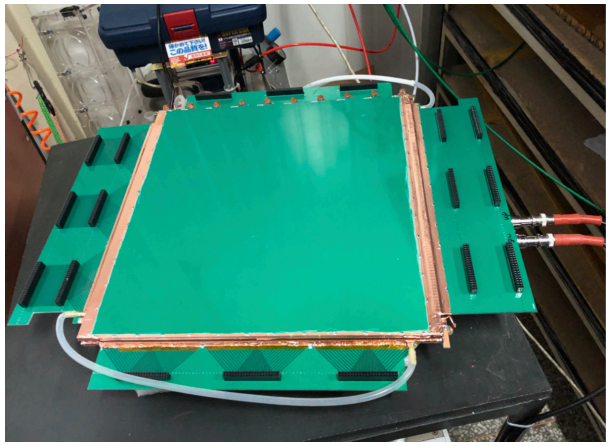


The charged particles pass through sTGC and ionize gas and generate electron ion pairs, which will generate avalanche and output signals when drifting to the anode wire.

sTGC prototype design and status

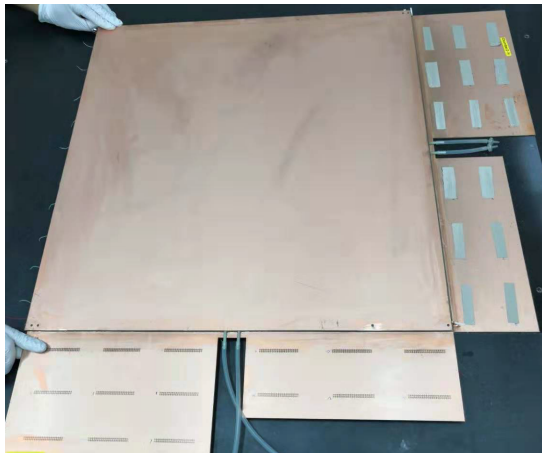
Three versions of sTGC prototype have been built in Shandong University.

30cm*30cm square



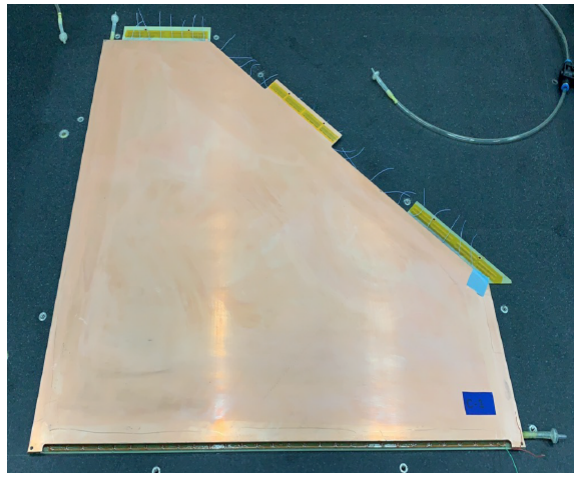
Readout electronics used for STAR TPX

60cm*60cm square



Readout electronics used for STAR TPX

~ 55cm*55cm pentagon



Readout based on VMM chips

- **30cm*30cm square prototype finished in Oct. 2018, delivered to BNL in Jan. 2019, installed in STAR on Jun. 2019**
- **60cm*60cm square prototype finished in Jan. 2019, delivered to BNL in Jul. 2020, installed in STAR**
- **55cm*55cm pentagon prototype finished in Oct. 2020, ongoing cosmic ray testing (close to final design)**

sTGC prototype production procedure

Prototype production procedure

PCB board

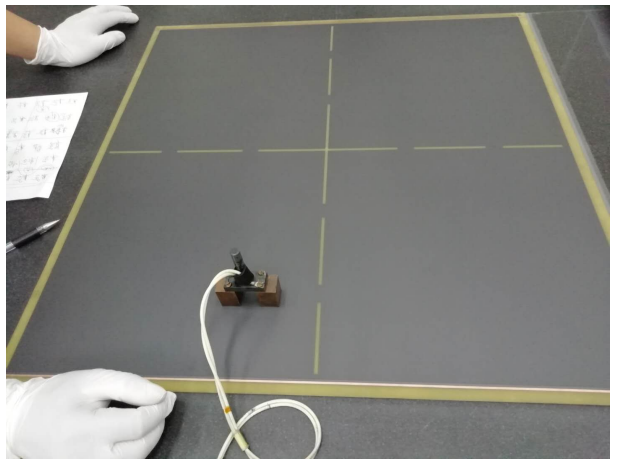
- Flatness inspection
- Connectivity check of PCB copper strip
- Spraying graphite
- Graphite polishing

Half-chamber

Chamber

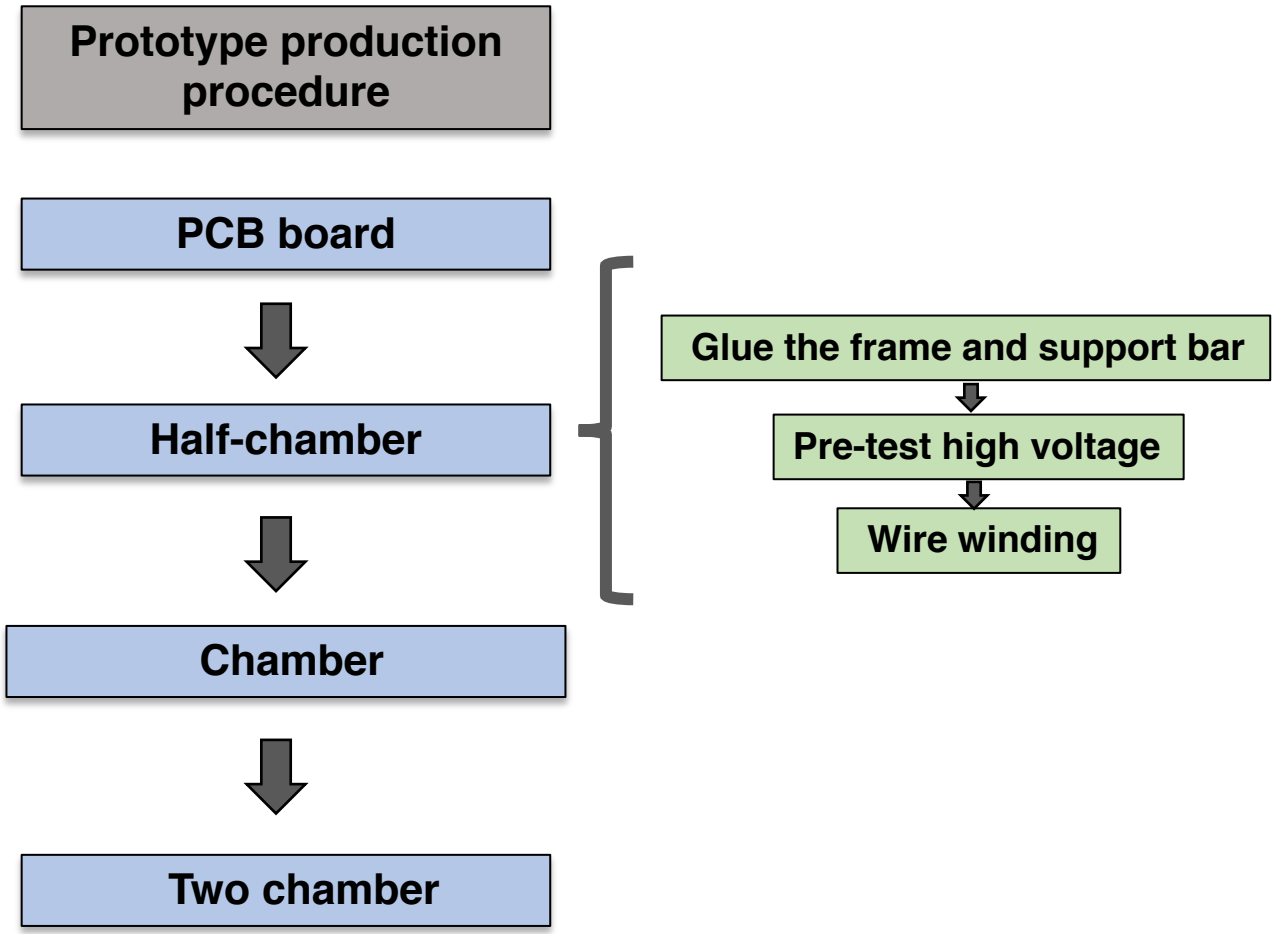
Two chamber

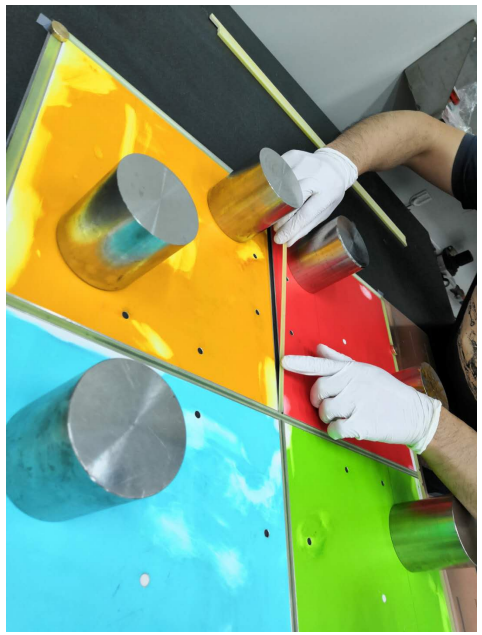
Spraying graphite



Polished graphite surface resistance to 160-240 kΩ/2.5cm^2

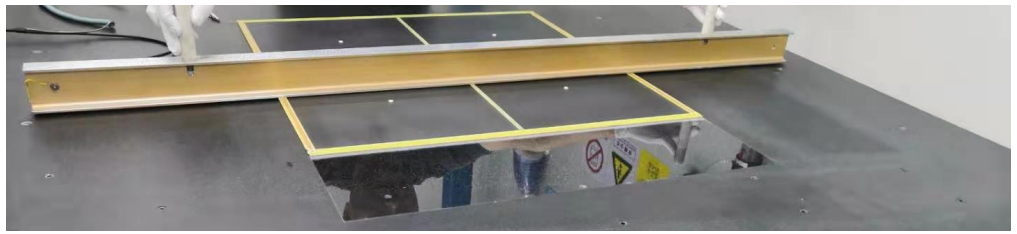
sTGC prototype production procedure





Glue the frame and support bar

Wire winding



Pre-test high voltage

sTGC prototype production procedure

Prototype production procedure

PCB board

↓

Half-chamber

↓

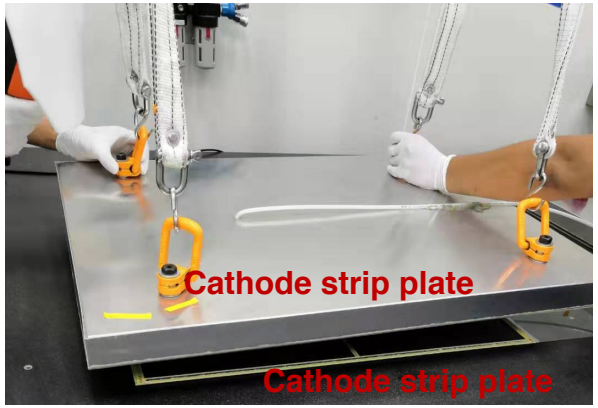
Chamber

↓

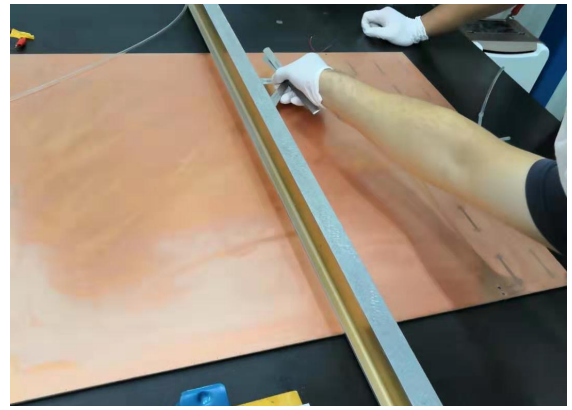
Two chamber

- **Pre-combination with two half chamber**
- **Pre-test high voltage**
- **Combination with two half chamber**
- **High voltage burning && X-ray scan**
- **Flatness inspection of chamber**

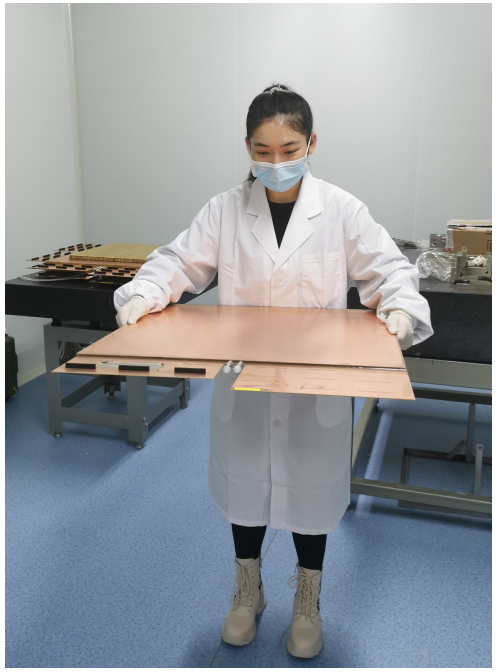
Combination with two half chamber



Flatness inspection of chamber



60cm*60cm sTGC chamber



sTGC prototype production procedure

Prototype production procedure

PCB board

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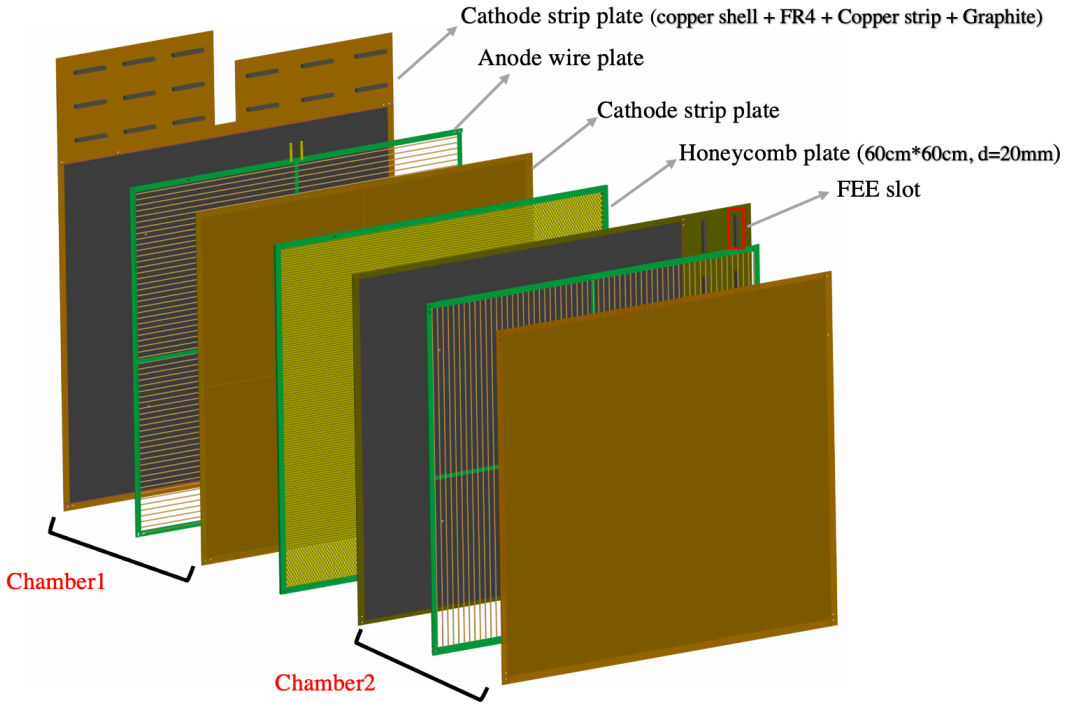
Half-chamber

↓

Chamber

↓

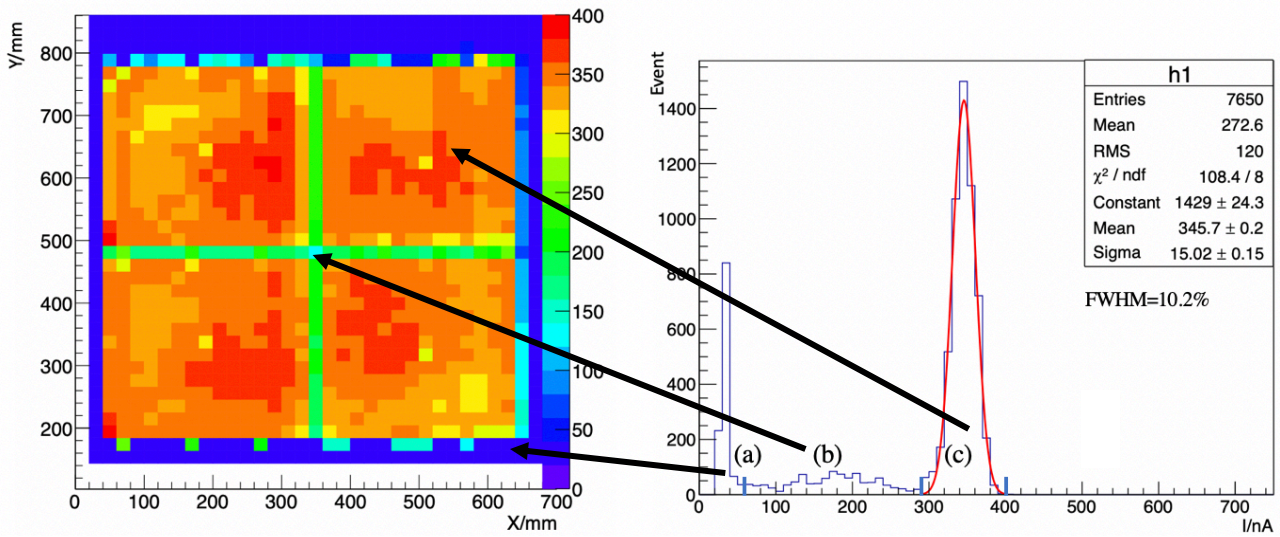
Two chamber { **Combination with two chamber**



60cm*60cm prototype

Quality assurance: X-ray scan and high voltage burning

X-ray scan require FWHM < 20%



60cm*60cm prototype

Working gas: 45%n-Pentane + 55%CO_2

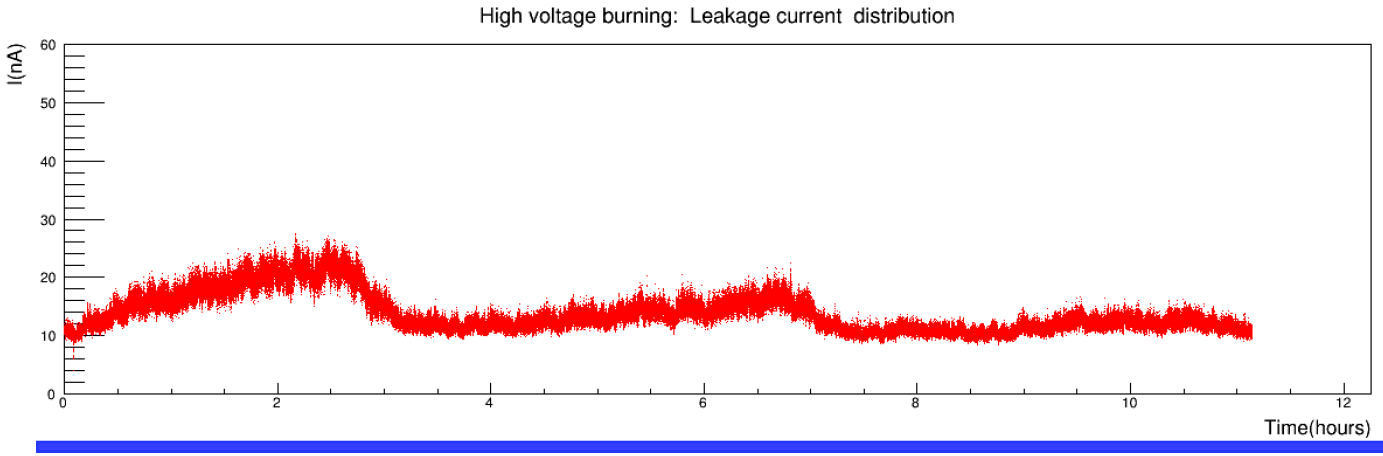
a) Outside the active area

b) The support part

c) Active area

X-ray scan meets the requirements.

High voltage burning with stable current < 500nA

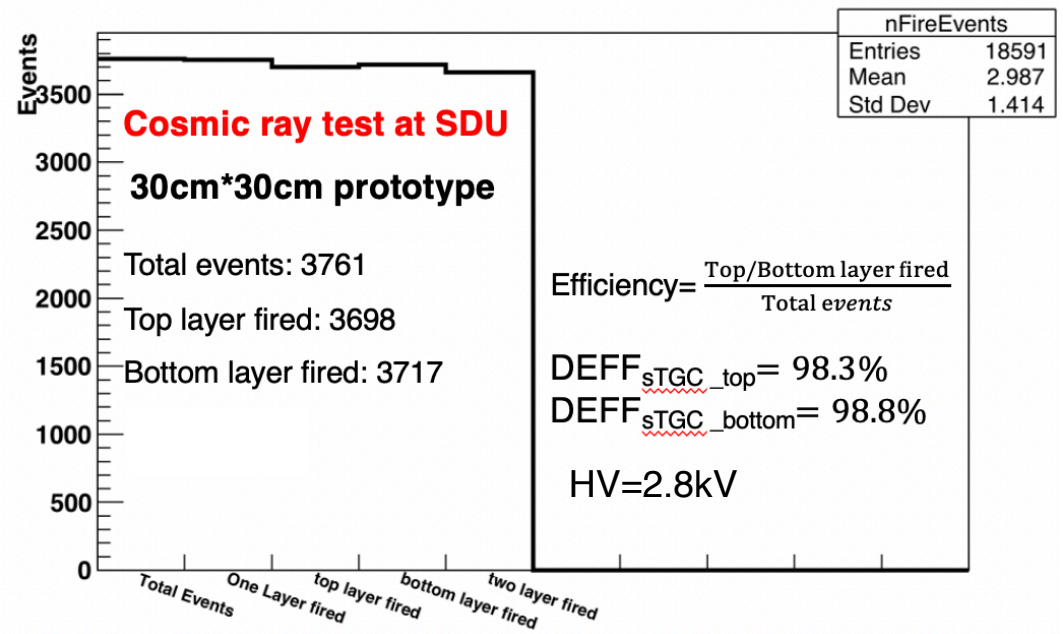


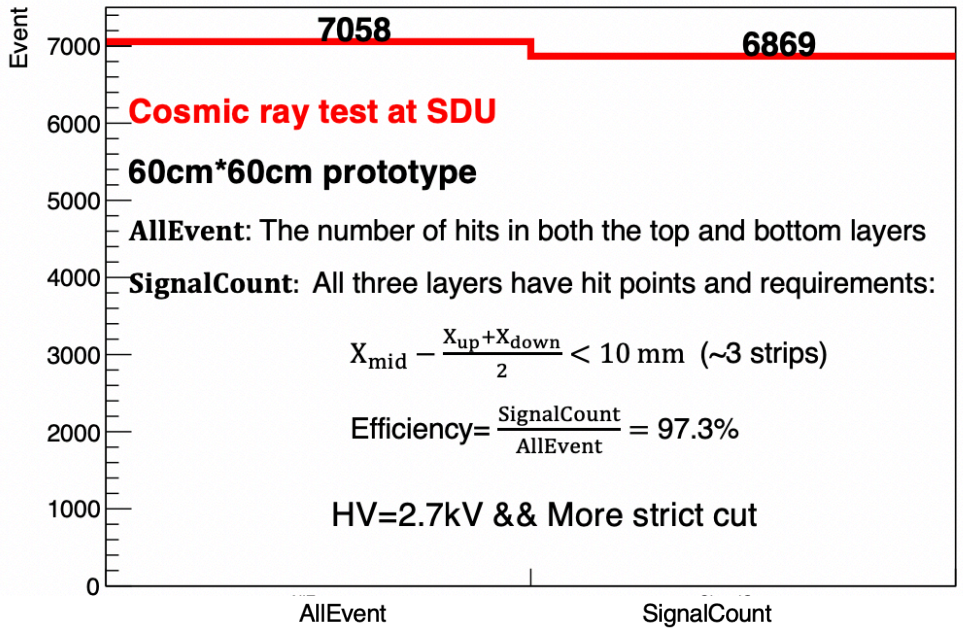
a) 11 hours leakage current tracking

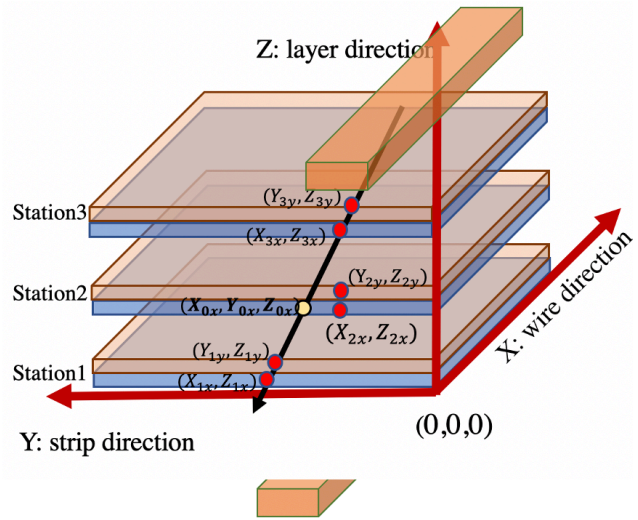
b) HV=3200V

Leakage current meets the requirements.

Detection efficiency





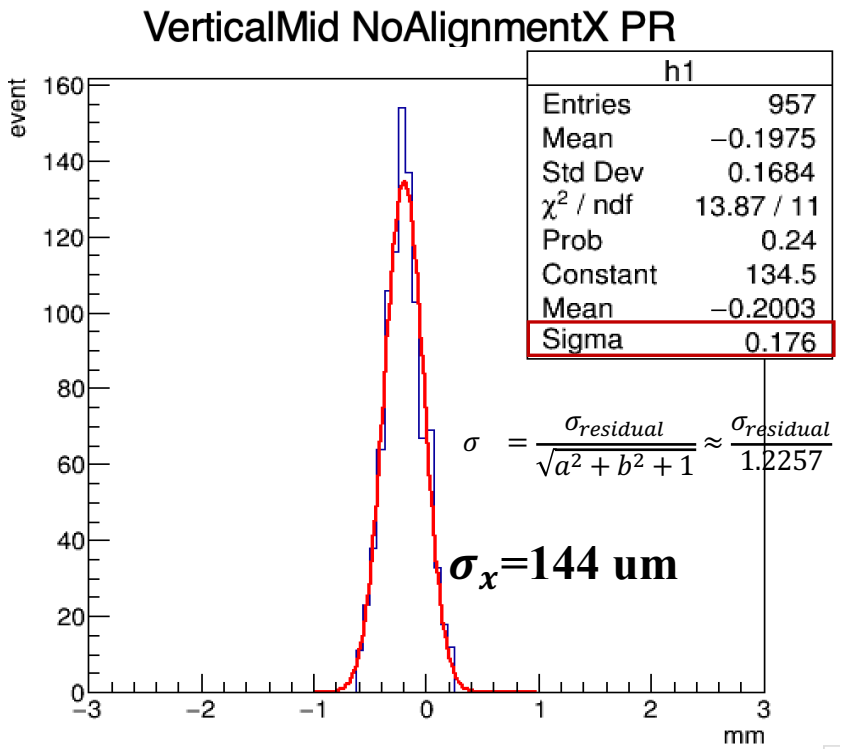


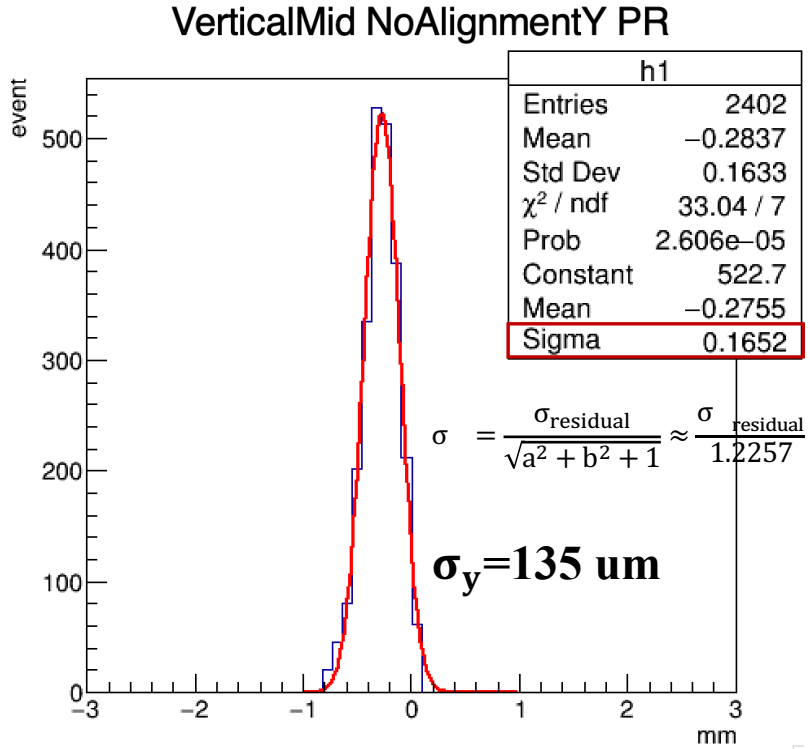
Due to the impact of COVID-19, STAR will test the 60cm*60cm prototype in the near future.

Cosmic-ray tests in both SDU local and STAR show consistent efficiencies at the level of 98%.

Position resolution

Position resolution requirement < 200um.





1. Select the event where the vertical angle is $[-1°, 1°]$.
2. **Vertical X**: Angle_x is $[-1°, 1°]$ & angle_y is not select.
3. **Vertical Y**: Angle_y is $[-1°, 1°]$ & angle_x is not select.
4. No rotation and shift alignment.

Position resolution of 60cm*60cm prototype is about 140um at 2.7kV.

Summary

1. Forward Tracking System (FTS) upgrade at RHIC STAR is ongoing.
2. Three versions of the sTGC module have been designed and produced at Shandong University.
3. 98% detection efficiency has been achieved by 30cm*30cm and 60cm*60cm prototype.
4. 60cm*60cm prototype tested 140um position resolution under 2700V.
5. Pentagon prototype is ready for cosmic ray testing at Shandong University.

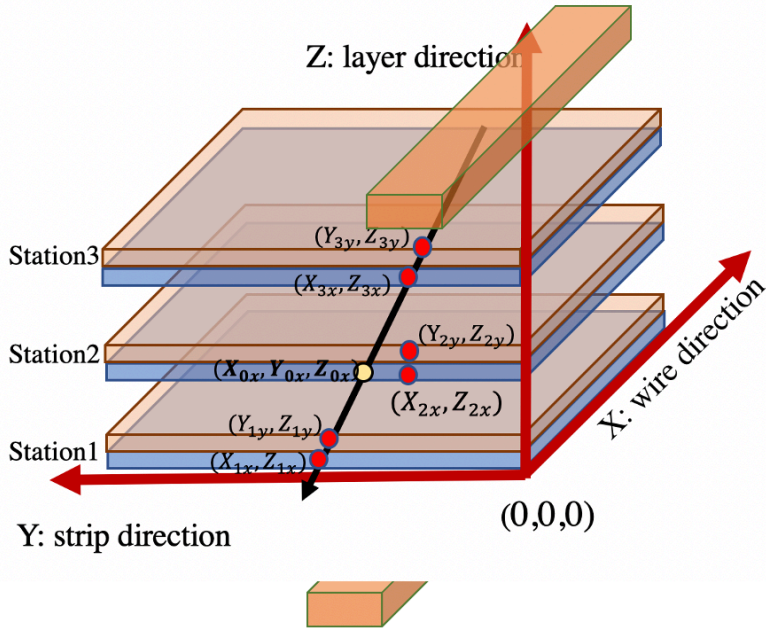
Future plan:

Mass production of sTGC will start from Nov. 2020

and will completed at Apr. 2021.

Thanks for your attention!

Formula calculate:



In the same production environment, it is assumed that the position resolution of each layer of sTGC is the same σ .

- **Position resolution in X direction**

Expect point： Mid_X layer (X_{0x}, Y_{0x}, Z_{0x})

Measurement point： (X_{3x}, Z_{3x}), (X_{1x}, Z_{1x}) and (X_{2x}, Z_{2x})

Intrinsic position resolution： σ

Because the spacing of the three-layer sTGC in the test is not uniform, the weight a≠b.

	X-plane	mm	Y-plane	mm
station3	Z_{3x}	66	Z_{3y}	77.0
station2	Z_{2x}	30.7	Z_{2y}	41.7
station1	Z_{1x}	0	Z_{1y}	11

$$X_{ox}=\frac{35.3}{66}X_{1x}+\frac{30.7}{66}X_{3x}$$

$$X_{residual}=\frac{35.3}{66}X_{1x}+\frac{30.7}{66}X_{3x}-X_{2x}$$ (Same y direction)

Error propagation calculate:

$$\sigma = \frac{\sigma_{residual}}{\sqrt{a^2+b^2+1}} = \frac{\sigma_{residual}}{1.2257}$$