R&D of Commercially Produced Large GEM Foils

College of Science and Technology
TEMPLE UNIVERSITY®

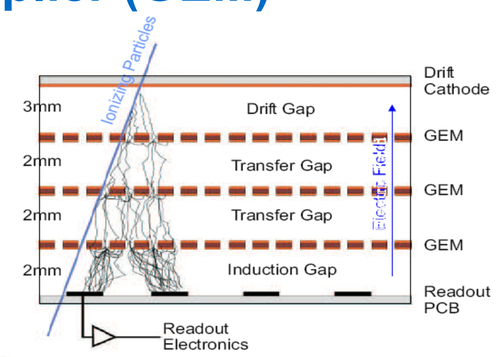
Matt Posik, Xuan Li and Bernd Surrow
for the STAR Collaboration
Temple University, College of Science and Technology, Philadelphia, PA

Motivation

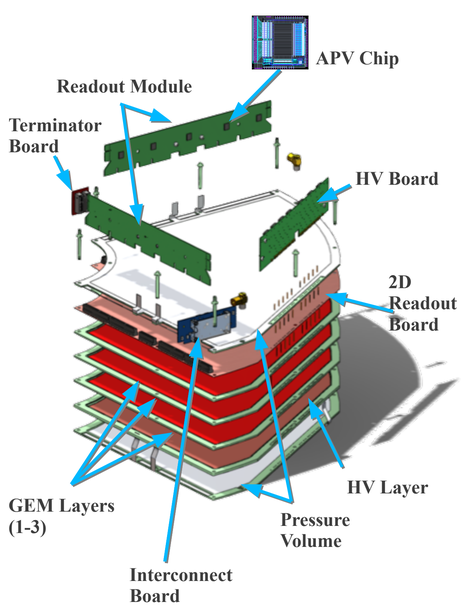
- Currently CERN is the only main distributor of GEM foils. Many future detectors are being designed with GEM foil technology in mind. This escalates the need for commercially available GEM foils.
- GEM foils are well suited for high energy particle detectors.
- Recent tracking upgrade of STAR experiment took advantage of large double-mask GEM foils (~ 30 cm x 30 cm) to achieve electron/positron charge separation.
- EIC will require even larger GEM foils (≥ 50 cm x 50 cm).
- It is not practical to produce larger GEM foils via the double-mask process. Therefore, a single-mask process has been established.

Gas Electron Multiplier (GEM)

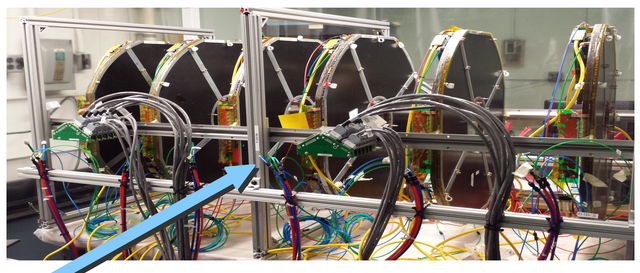
- A GEM foil is a perforated copper sheet with a thin polymer sheet in the center.
- Electrons from ionizing radiation are directed through the holes by an electric field, which causes an avalanche effect.



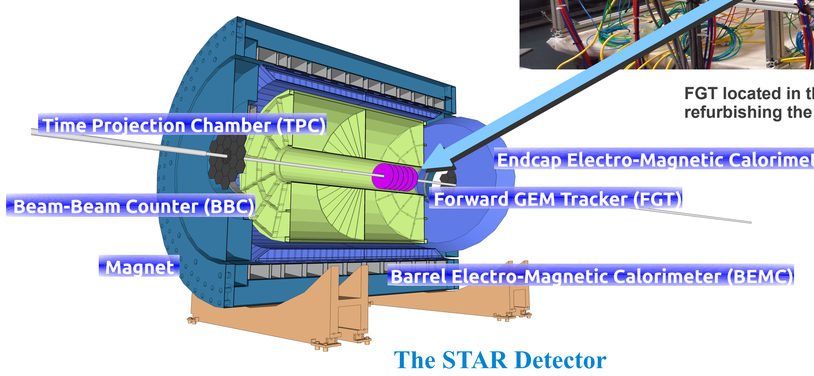
Double-Mask GEM Foil Performance



- The GEM foil holes were etched using a double-mask photolithographic technique performed by Tech-Etch. In this process the holes were chemically etched on both sides of the foil, and each mask was aligned so the holes matched up.
- Double-mask GEM foil technology has already been successfully used in the STAR Run 13 experiment via the forward GEM tracker (FGT).
- Three GEM foils went into making up a quarter section of the FGT.
- There were four quarter sections per FGT disk, with a total of six disks.

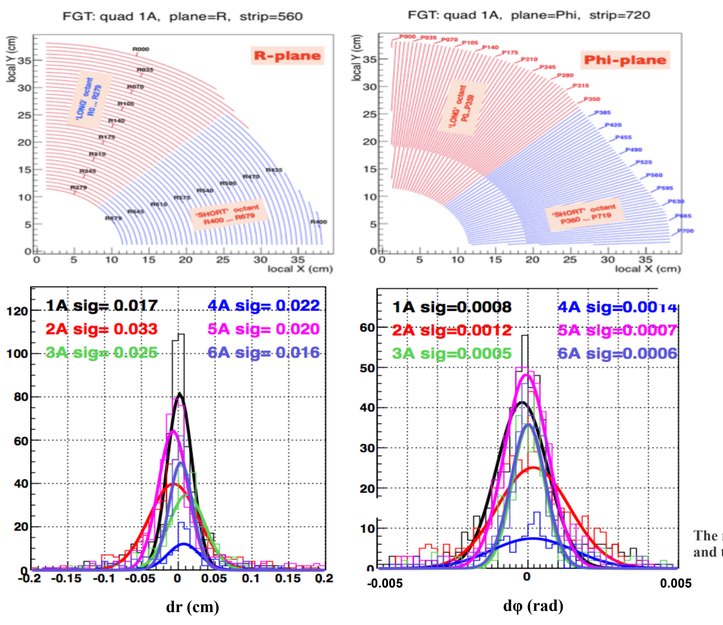


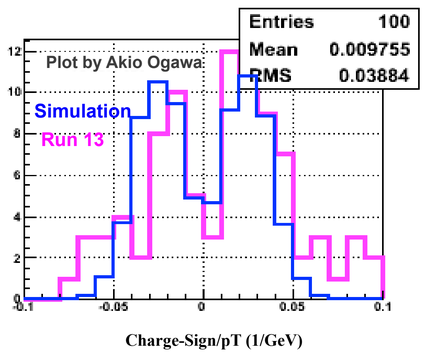
FGT located in the Temple University GEM lab for refurbishing the front-end electronics.



The STAR Detector

- Tracking residuals of ~ 200 μm in the R plane and ~ 1 mrad in the φ plane lead to a detector resolution of ~150 μm.
- A charge separation (without the use of TCP tracking) of ~ 2.5 σ was achieved.

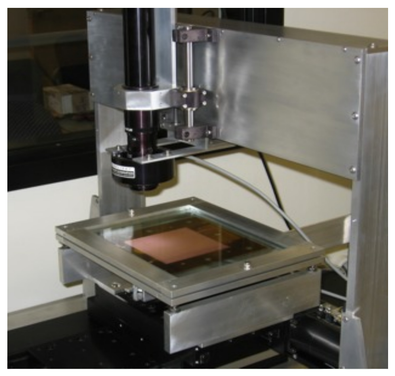


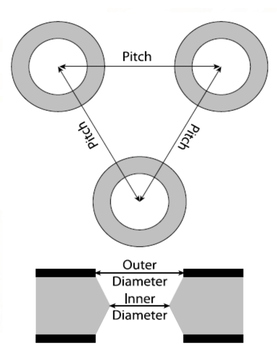


The numbers in the residual plots represent the FGT disk, and the letters represent the FGT quadrant.

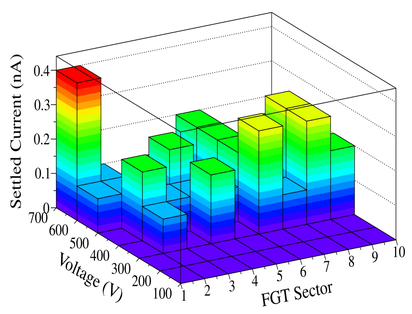
Single-Mask GEM Foil Production

- The single-mask GEM fabrication employs a glass mask for the photolithographic process. The chemical etching is based on a single-sided etching process.
- The advantage of using the single-mask process is that it removes the need to align two masks, as is done in the double-mask process, which allows for much larger foils.
- Tech-Etch has now established a single-mask process, and has produced 10 cm x 10 cm and 30 cm x 30 cm GEM foils.

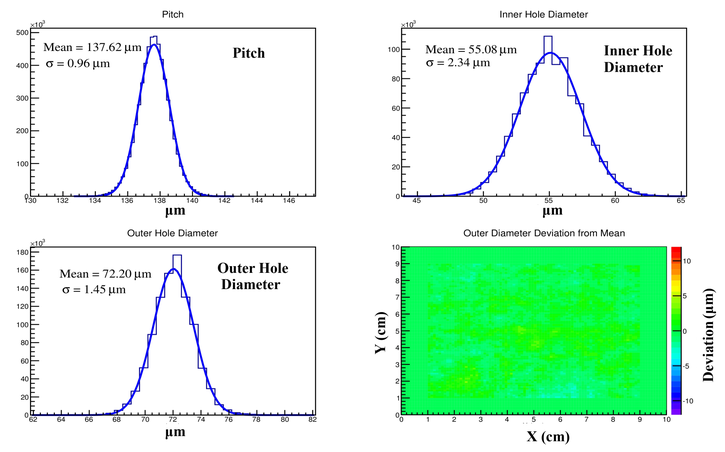




- The gain achieved from a GEM foil and its uniformity depends on the foil's geometric properties and its hole uniformity.
- The pitch, inner and outer hole diameters, and hole uniformity of the 10 cm x 10 cm Tech-Etch single-mask GEM foils were measured using an optical scanning setup at Temple University.
- The mean optical properties reflect the desired parameters and are consistent with those found in double-mask GEM foils.
- FGT sized single-mask GEM foils are currently under optical analysis.
- The electrical properties of both the single-mask 10 cm x 10 cm and FGT sized foils performed very well. Current leakages, performed in a nitrogen environment, were typically measured to be < 1 nA for voltages < 600 V. These results are superior to that of the double-mask GEM foils due to the replacement of Kapton base material with Apical.

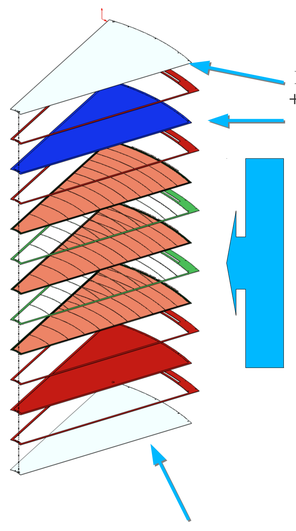


Single-mask FGT sized GEM foil

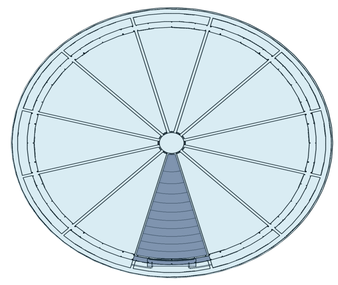


Single-mask 10 cm x 10 cm GEM foils

EIC GEM Foil Development

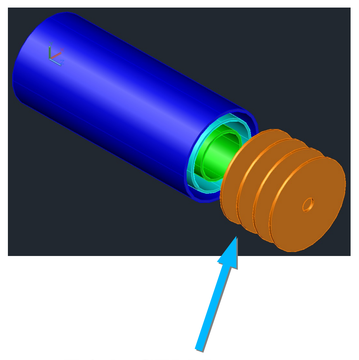


- Work has begun on designing triple GEM detectors for the EIC using large GEM foils.
- GEM foils would be about 50 cm x 50 cm.
- 12 segments would make up one disk.



Disk setup used to hold 12 triple GEM segments

Illustration of a barrel and forward tracking system for an EIC detector.



Triple GEM Detectors

Summary

- The FGT performed well in Run 13, providing good tracking residuals, allowing for a clear charge separation at forward rapidity without using the TPC inner/outer pad planes.
- Electrical and geometrical quality assurance (QA) analysis has been completed for the Tech-Etch produced 10 cm x 10 cm single-masked GEM foils.
- Electrical QA has been completed for the Tech-Etch produced FGT sized single-masked GEM foils. Geometrical QA analysis is currently underway.
- Discussions have begun with Tech-Etch to manufacture GEM foils up to about 1 m x 0.5 m.
- Initial design work towards an EIC GEM detector is progressing.