Center for Frontiers in Nuclear Science

EIC R&D: sTGC

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Working with Lijuan Ruan

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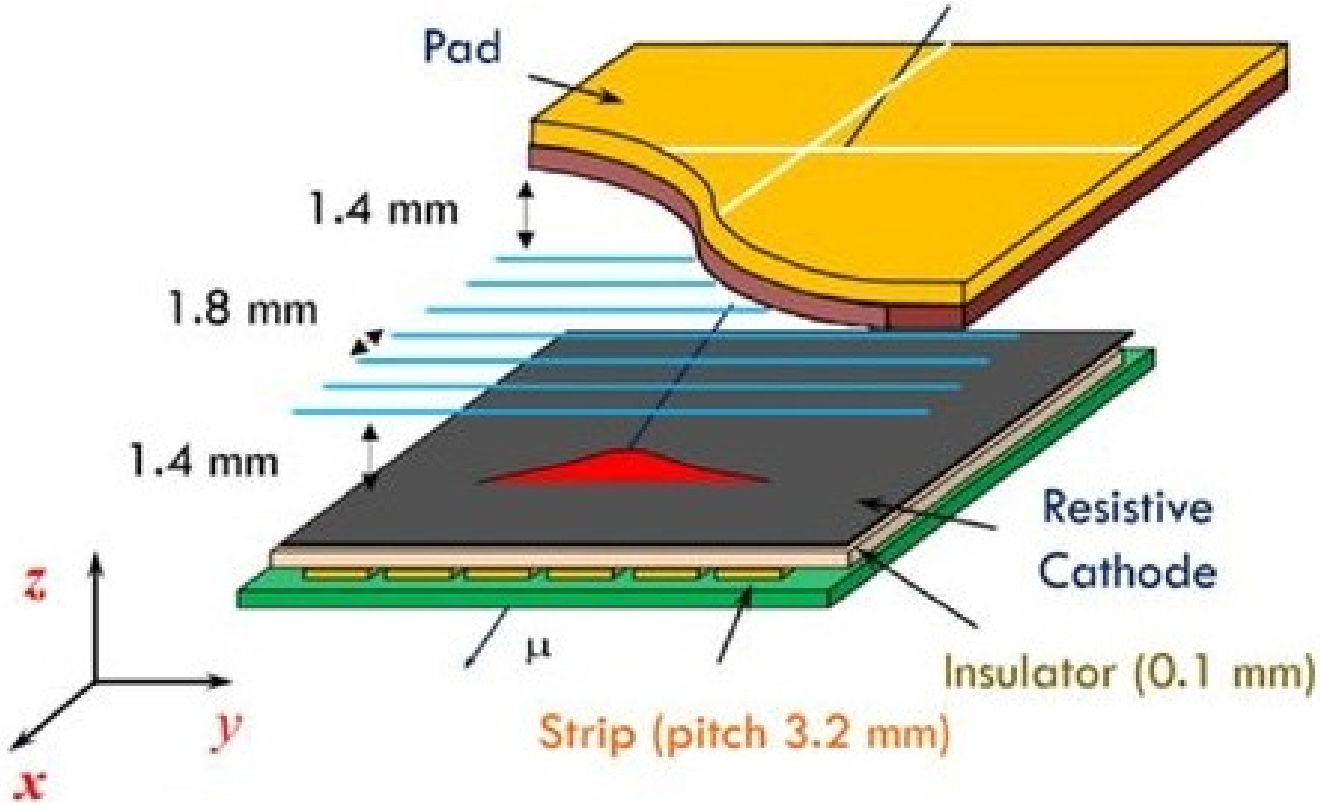
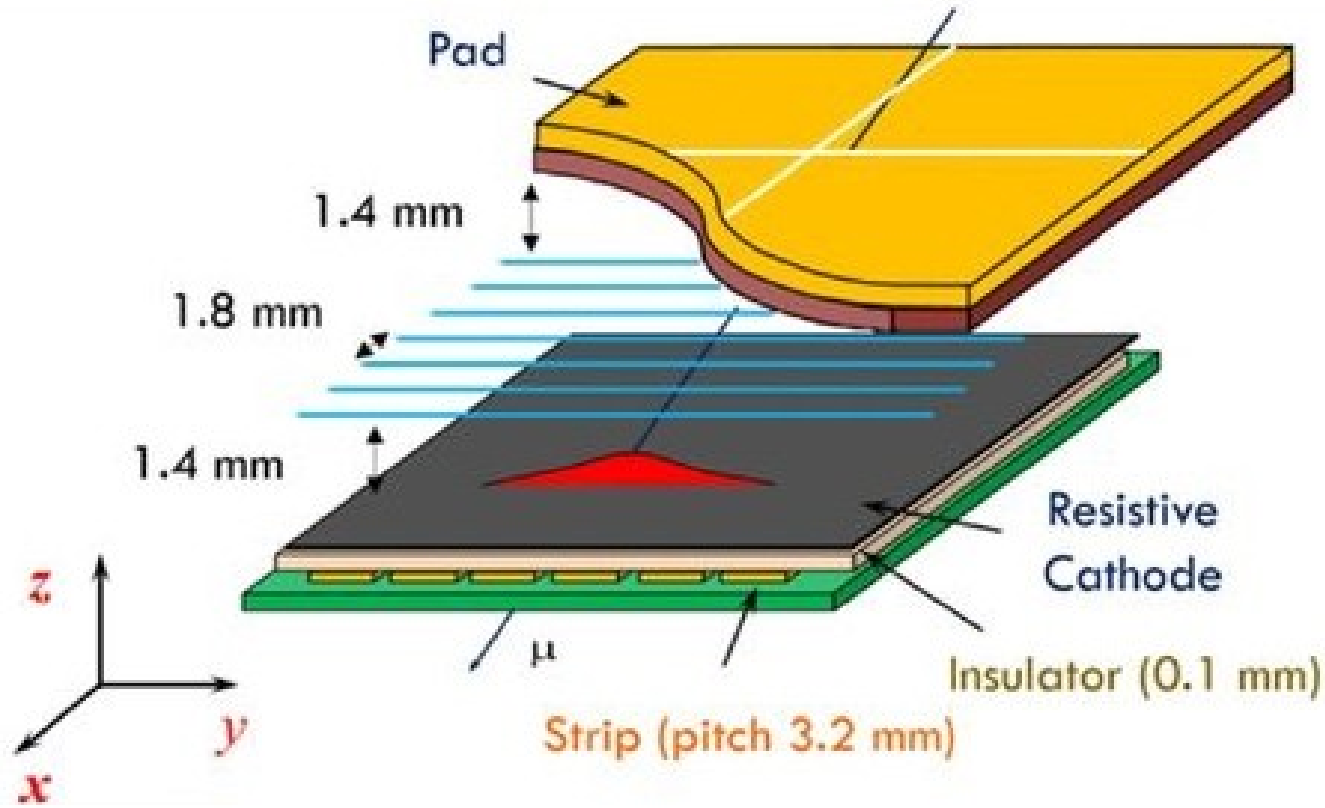
What is a sTGC?

- small-strip Thin-Gap Chamber is a MWPC (like a TPC)
  - Charged particles ionize gas-filled volume
  - Signal is avalanche of electrons on strips
- Developed for ATLAS forward region (a smaller-strip TGC)
  - Large: 1.2m x 1m
  - Low mass
  - Robust at high luminosity



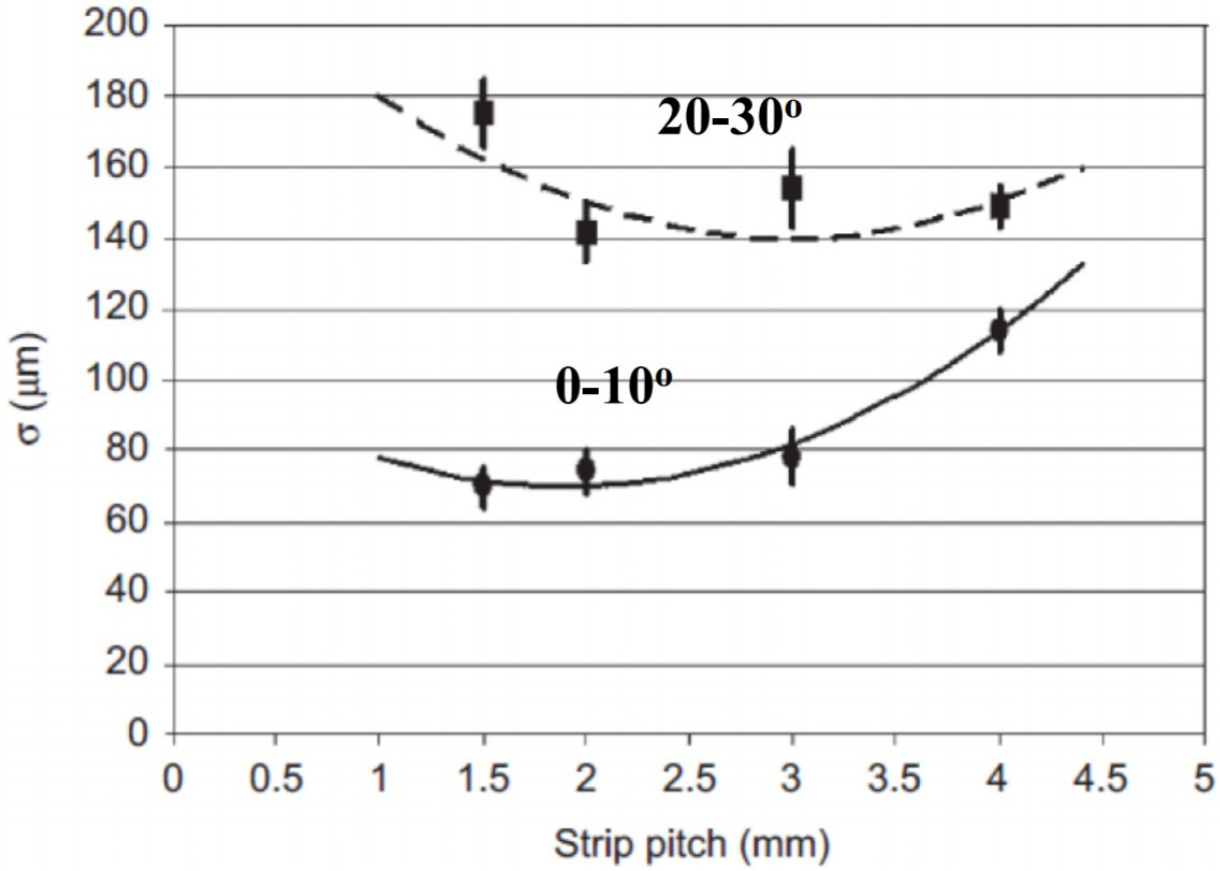
Basic specs

- 50 μm-diameter gold-plated tungsten wire at 1.8 mm pitch
- 3.2 mm pitch copper strip
- One-layer height of 5.8 mm
- HV ~2900 V



Qualities

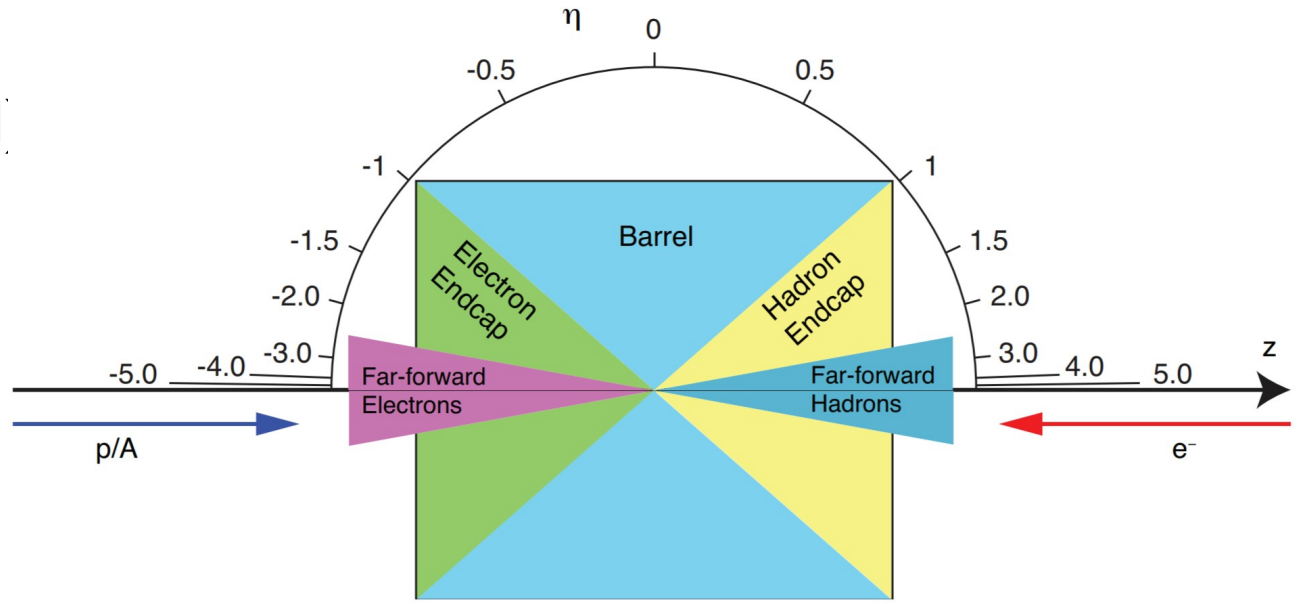
- Spatial resolution ≲100 μm
- Arrival time of 95% of signals can be contained in 25 ns window
- Low mass: 0.5% radiation lengths/layer
- No space-charge accumulation up to 100 kHz/cm^2 single hit rate
- Counting rate of 20 kHz/cm^2
- Low cost (considerably less expensive than all-Si option in STAR)



*Simualtion of Au+Au collisions in STAR

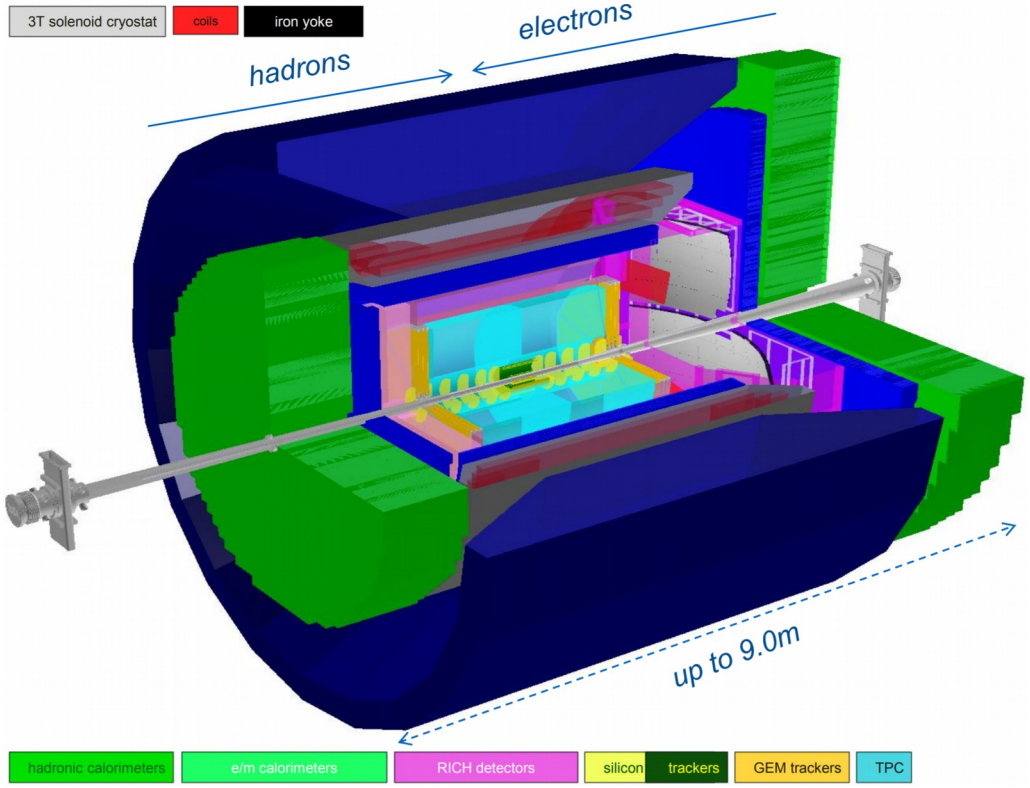
Role in EIC: Forward Tracking Detector

- Far-forward tracking and PID essential for an EIC detector
- Good to have trackers before PID (RICH) and between PID and calorimeters
- For reasonable momentum resolution at p = 30-50 GeV/c, 50 μm spatial resolution is desirable (EIC handbook)
- Because the magnetic field drops at large |z|, detector should be thin to precisely constrain hit in z
- Detector should be low mass
- sTGC may be more cost effective alternative to MAPS and GEMs

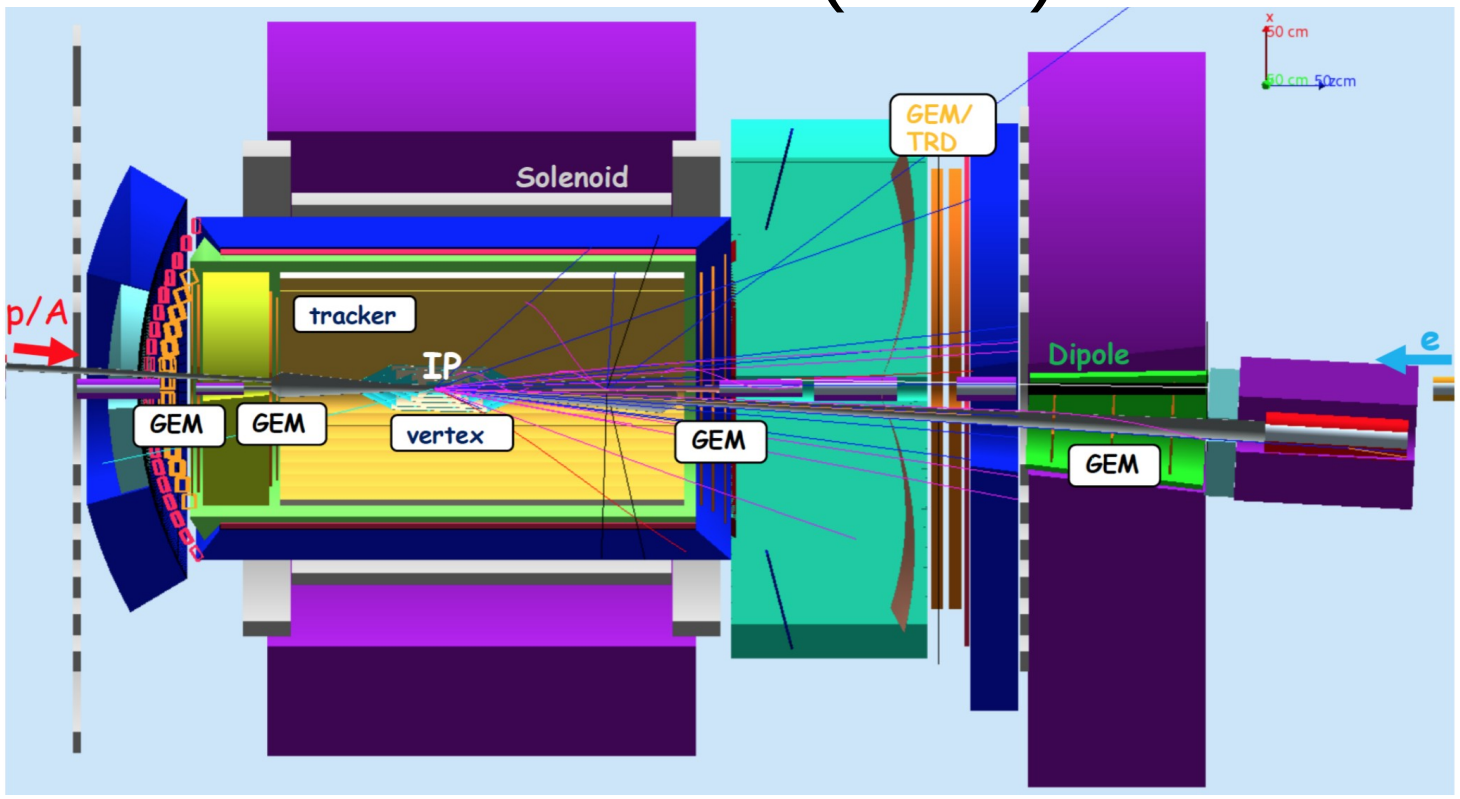


EIC Concept Detectors (I)

BeAST (BNL)

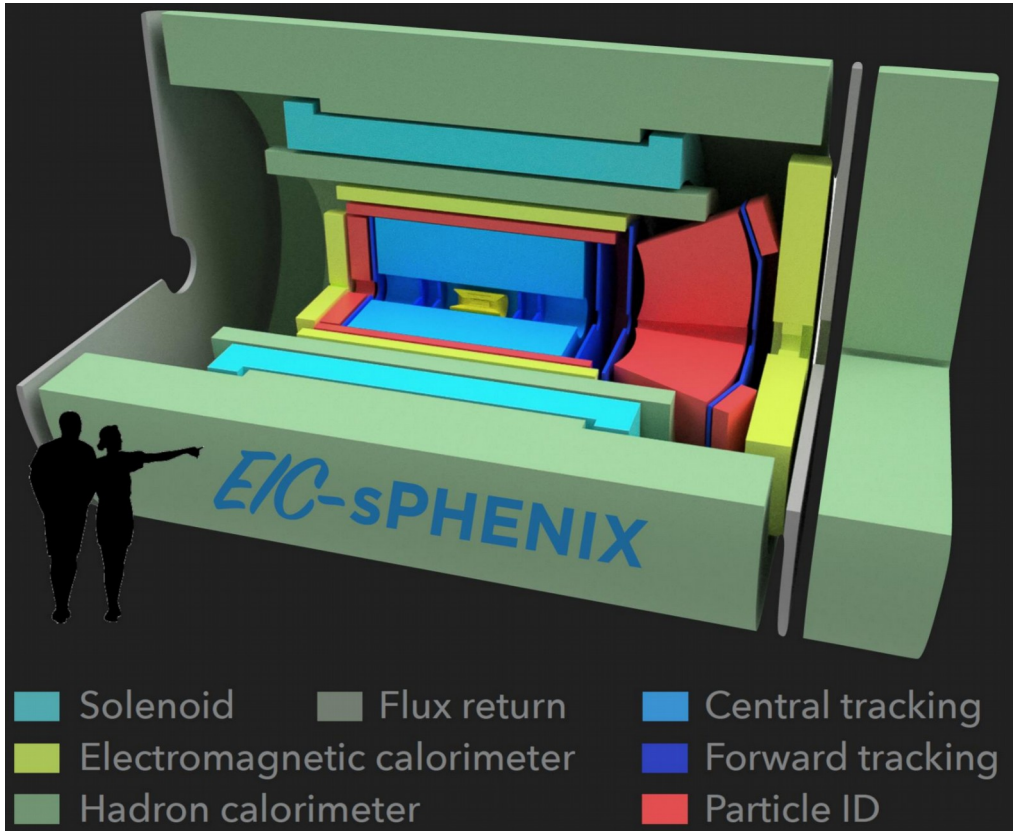


JLEIC (JLab)

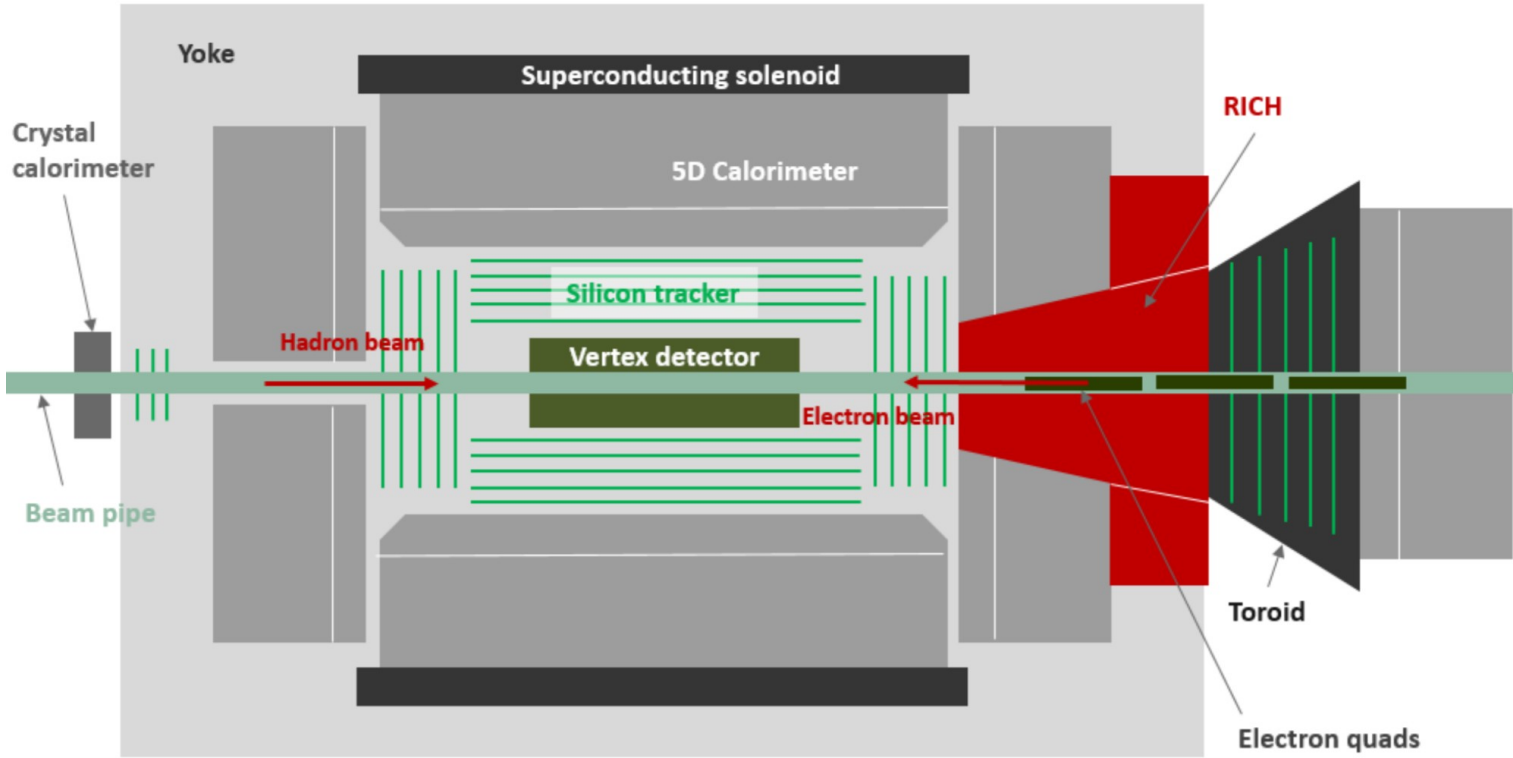


EIC Concept Detectors (II)

ePHENIX (BNL)

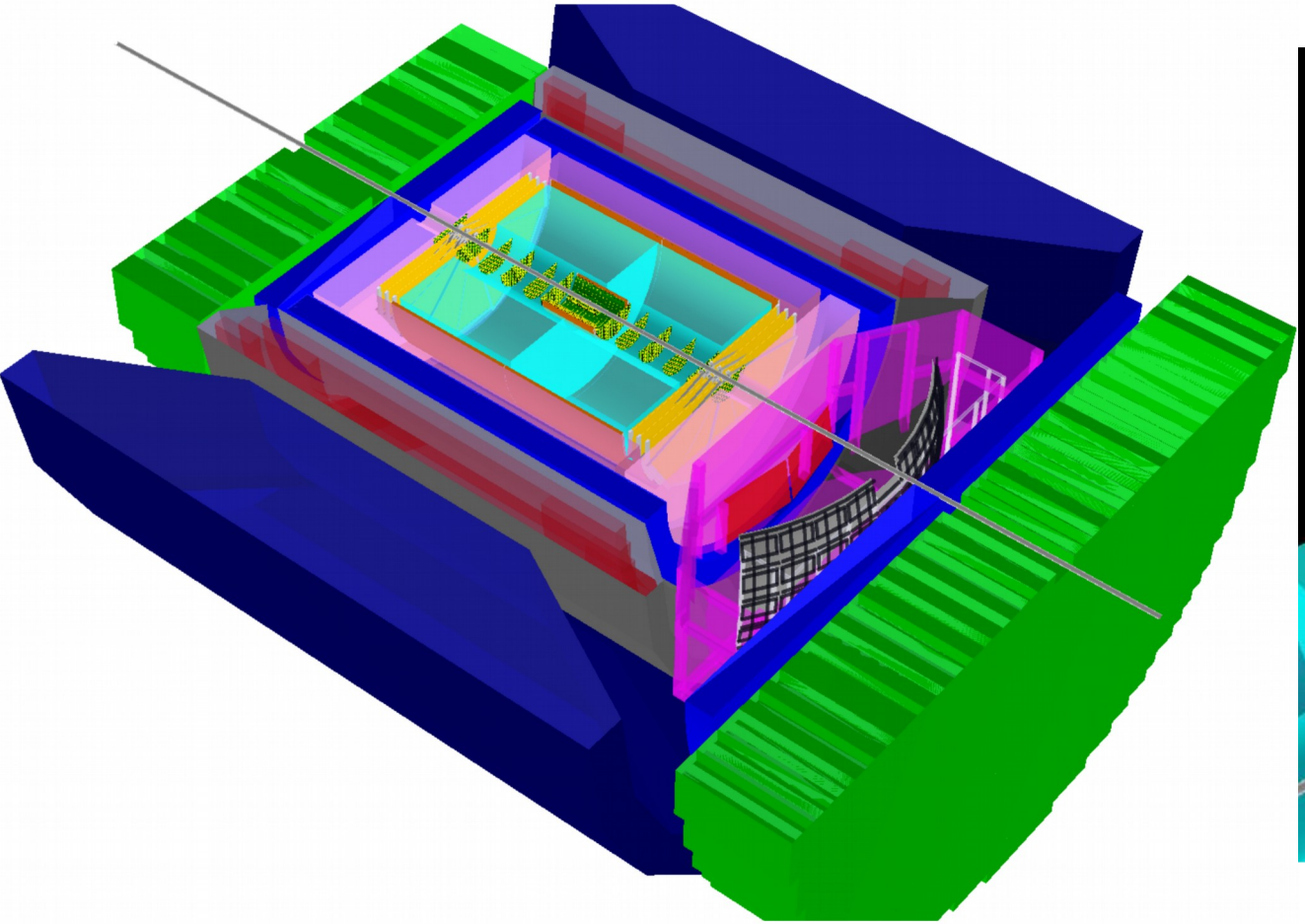


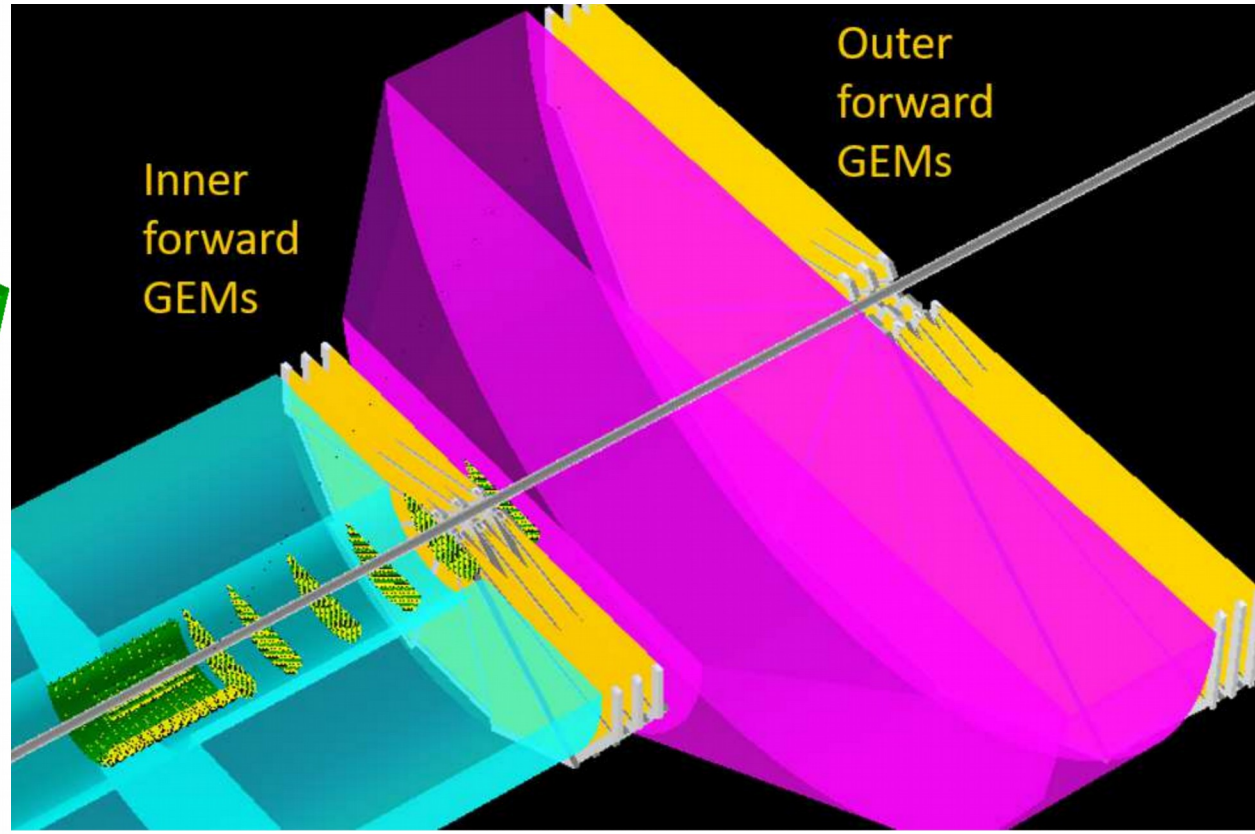
TOPSiDE (ANL)

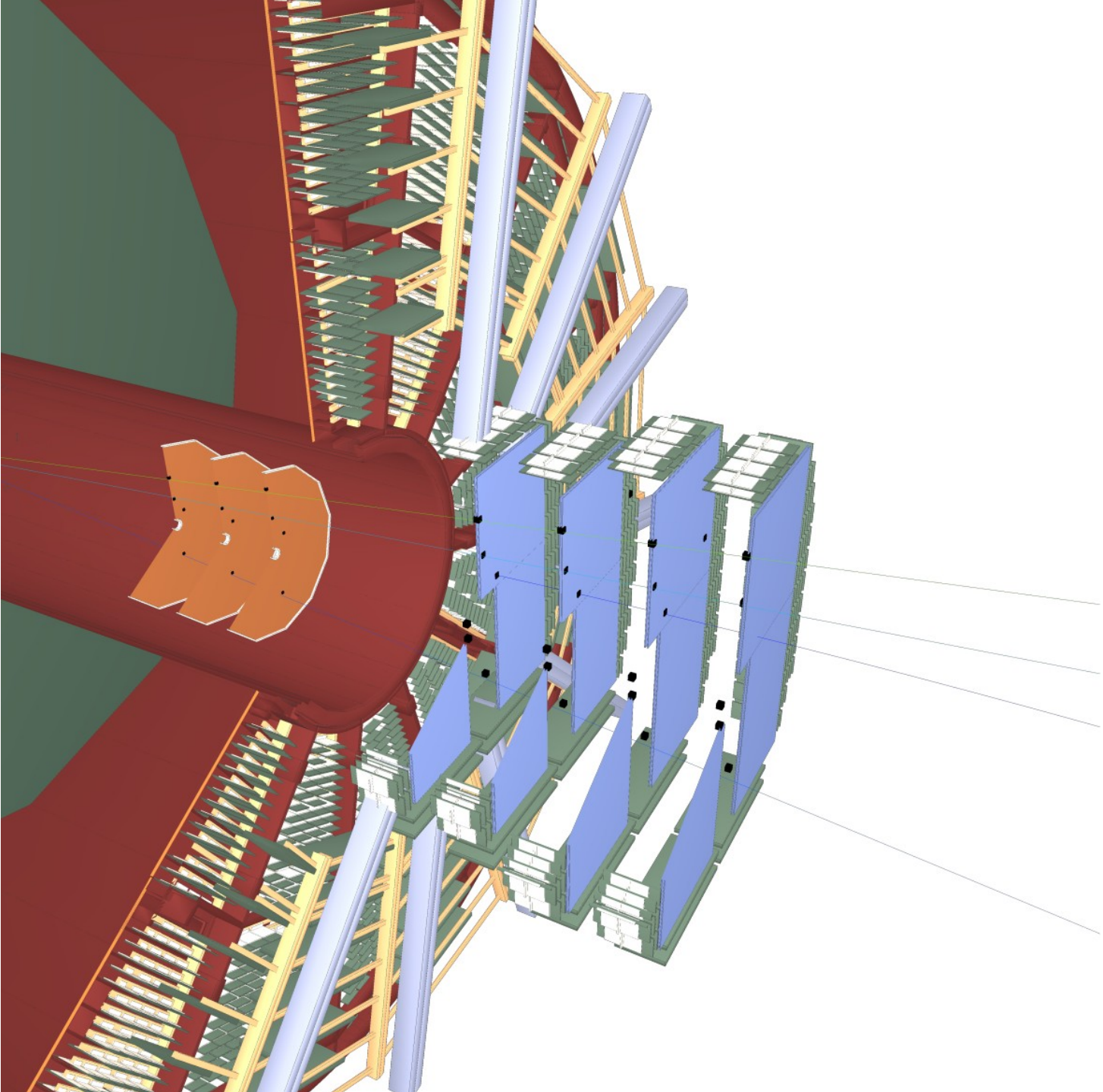


Using sTGCs in BeAST (e.g.)

- STGCs could replace GEMs, especially the larger outer forward GEMs, which have looser resolution requirements



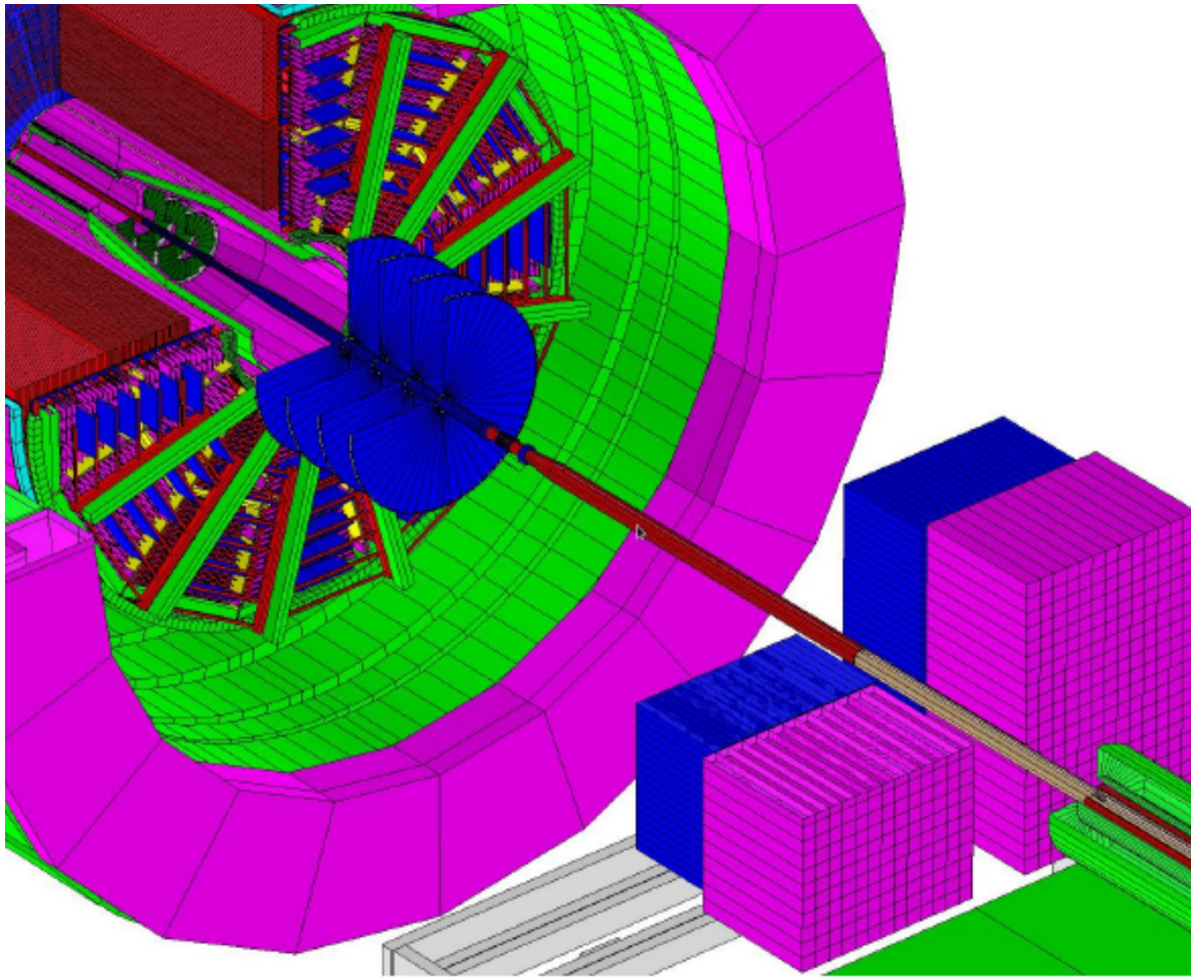




EIC R&D, preparing sTGC for use at STAR

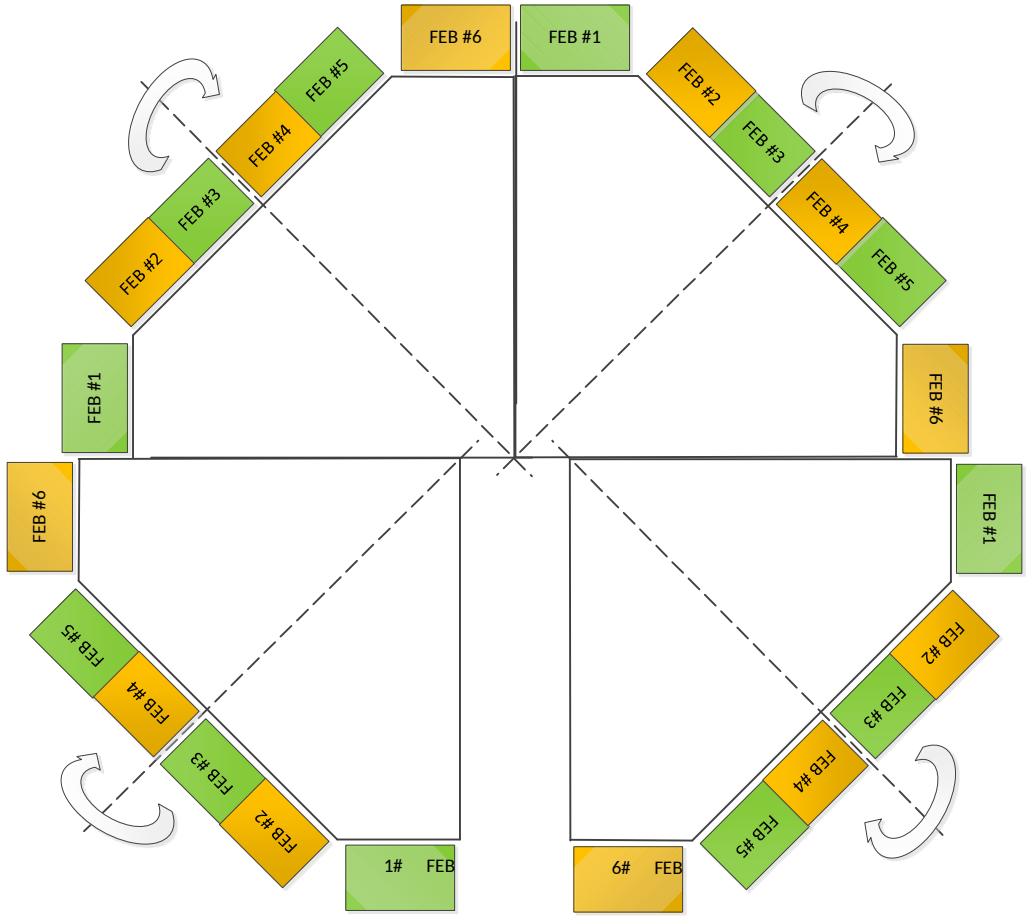
STAR Forward Upgrade

- Coverage ~ 2.5-4 in pseudorapidity
- Silicon disks and sTGC (tracking)
  - Note similarity to BeAST
- ECal and HCal (calorimetry)
- ~ Autumn 2021-2025



STAR sTGC

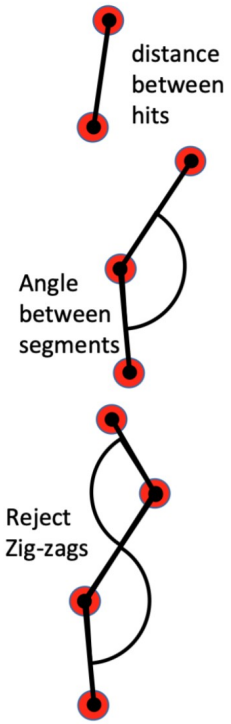
- 4 60x60 cm dual-layer sTGCs
- 22k total channels
- ATLAS sTGCs were built by ATLAS group at Shandong University, ours are built by the SDU STAR group (sharing lab)
- Significant design and R&D already done by ATLAS
- Project undertaken by SDU, USTC, and BNL

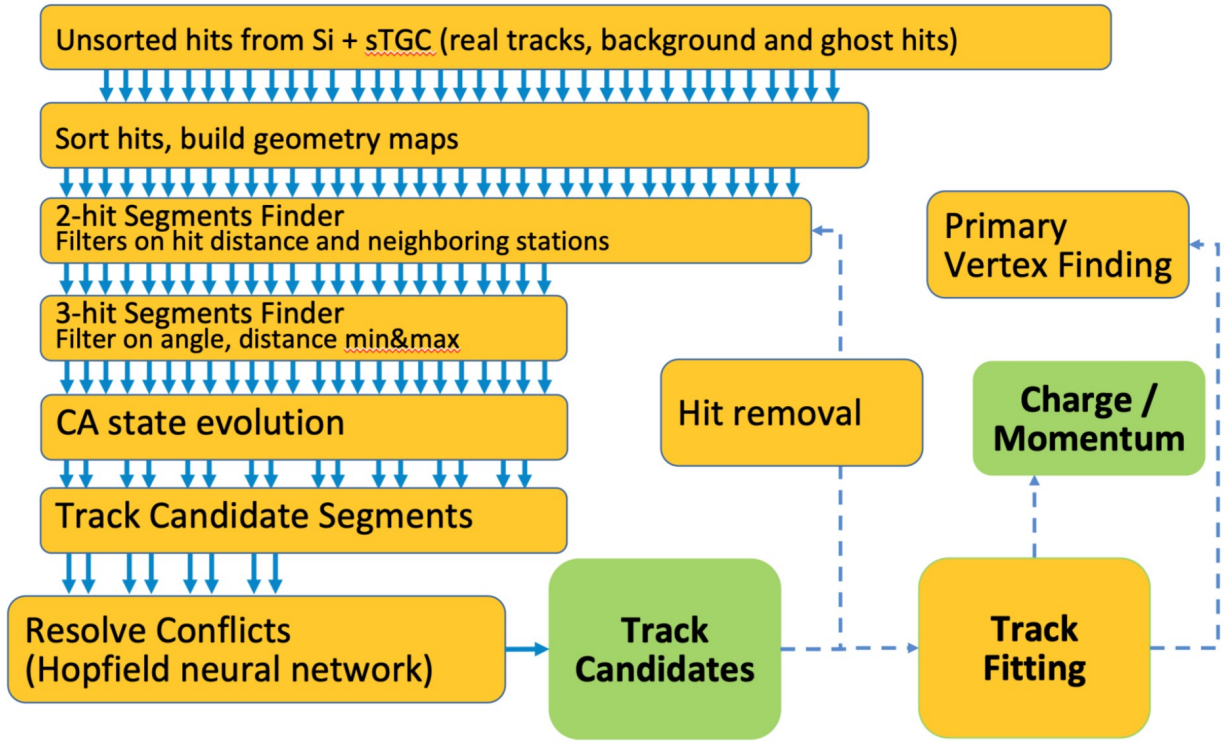


(Gap is space for crane to remove STAR poletip)

Forward tracking simulation

- Current STAR tracker utilizes a helix model, which is not totally correct in the changing magnetic field
  - Simulation results use constant field
- Daniel is writing a new tracker for the forward region



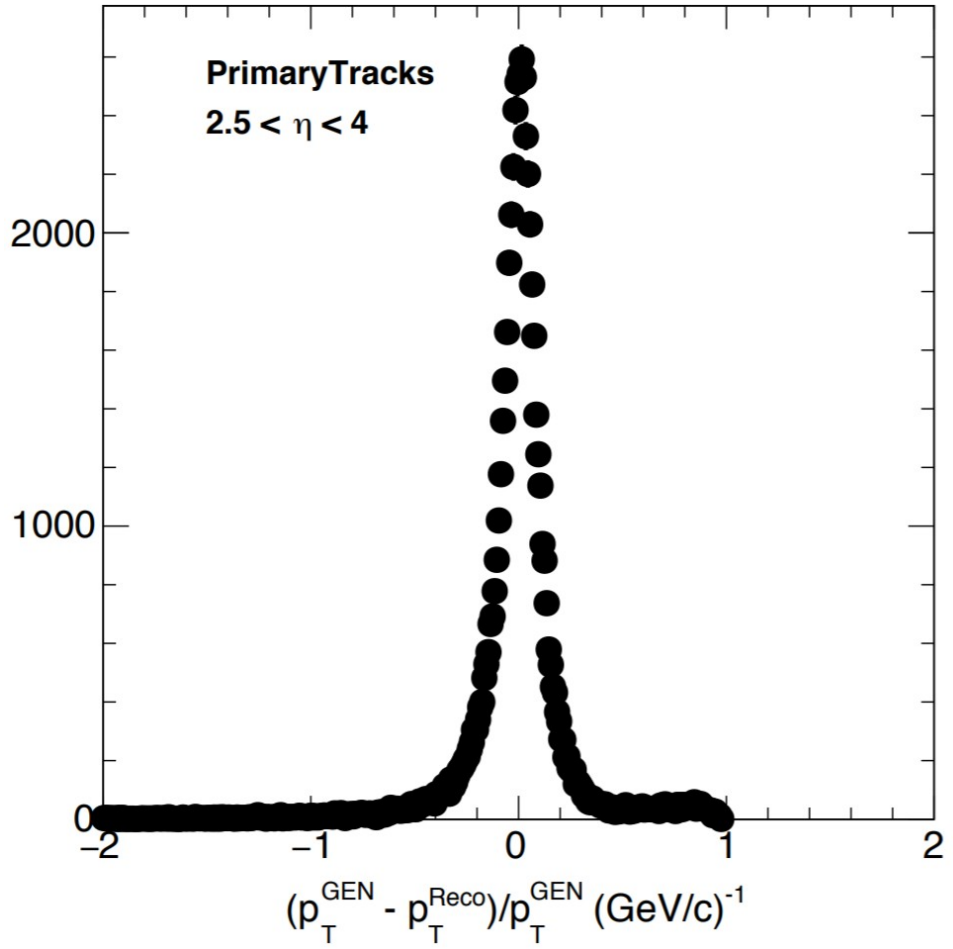


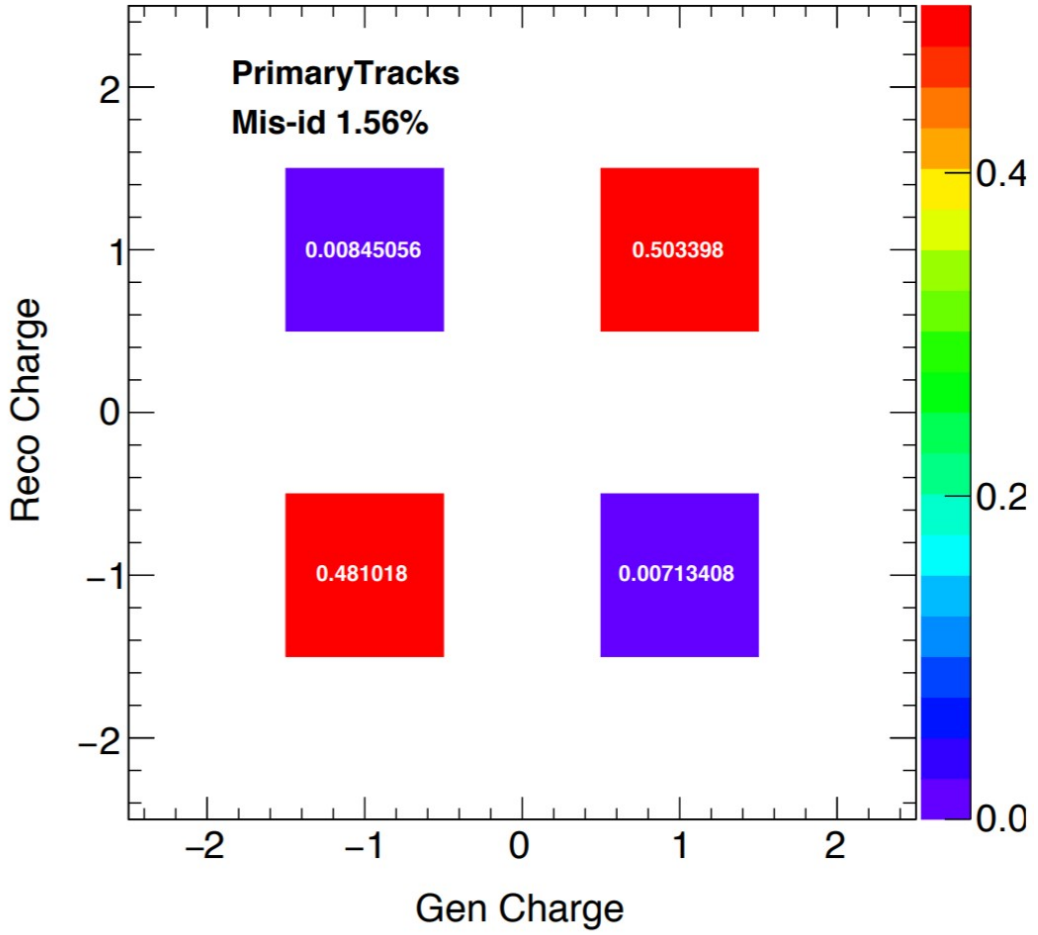
Based on iterative tracking and Cellular Automaton (CA)

Only sTGC hits used and no track fitting at this momemt

sTGC simulation

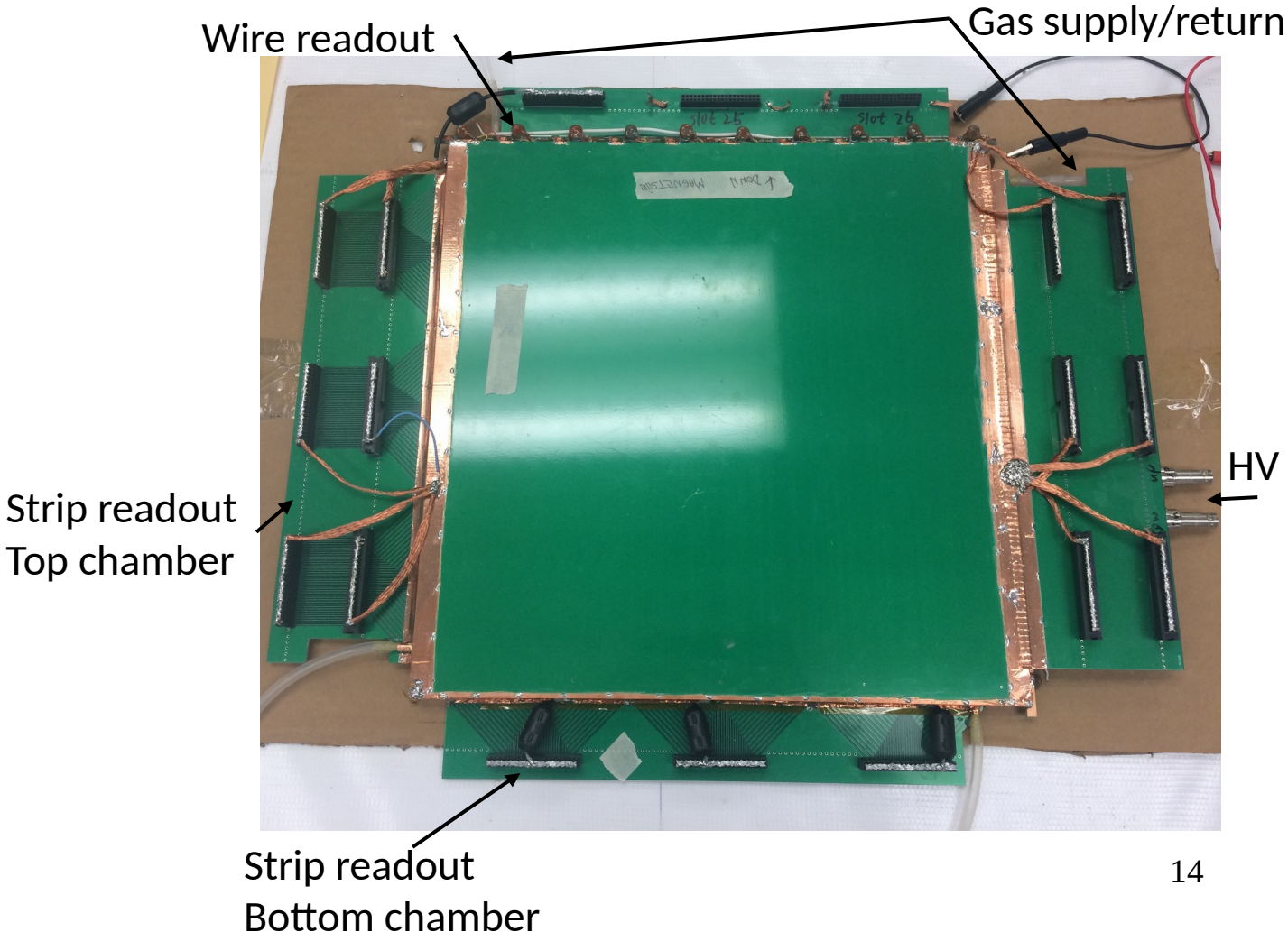
- sTGC has good momentum resolution and charge separation





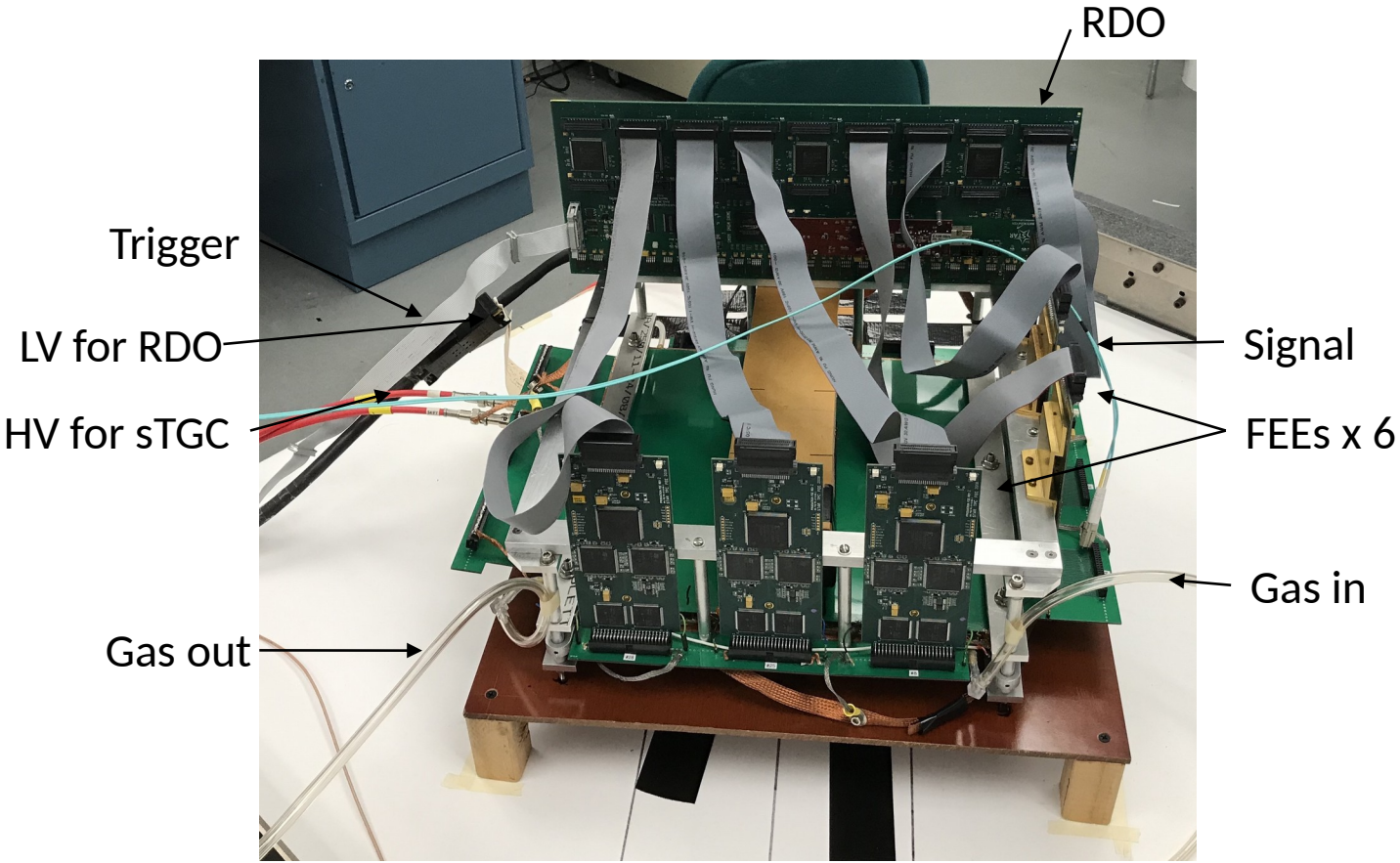
sTGC Prototype

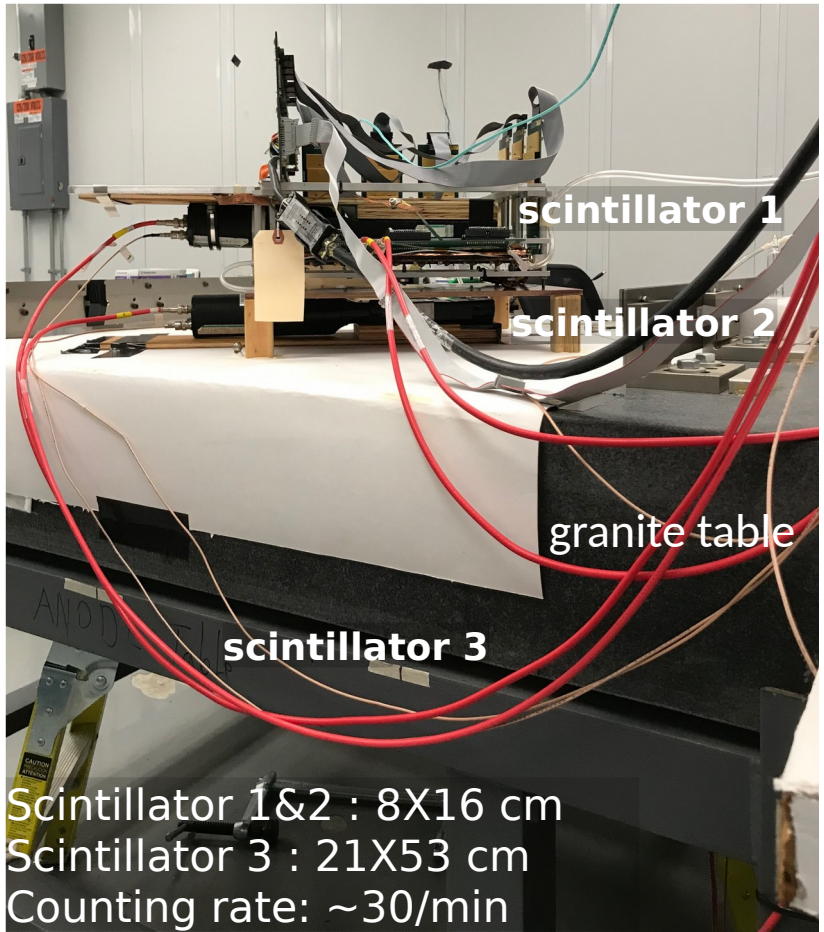
- SDU STAR group made a prototype sTGC last year
- 30 x 30 x 0.28 cm
- Strip read out with old TPC electronics
- 94 channels/chamber
- Tested at BNL with cosmic ray telescope setup and in 2019 beam



Cosmic Ray Telescope

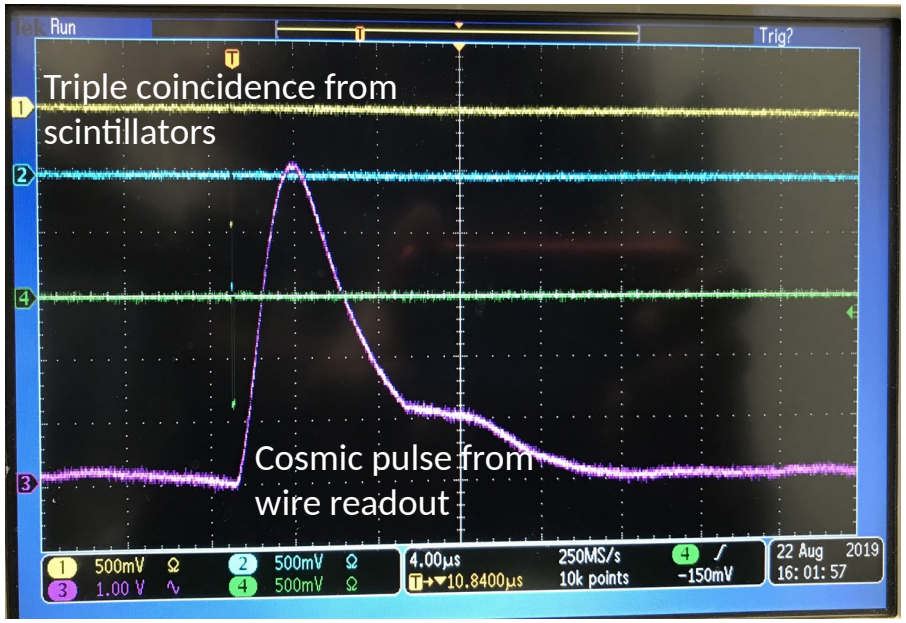
- Collected data requiring triple scintillator-paddle coincidence
- Tested readout and data acquisition
- Tested response with several gases

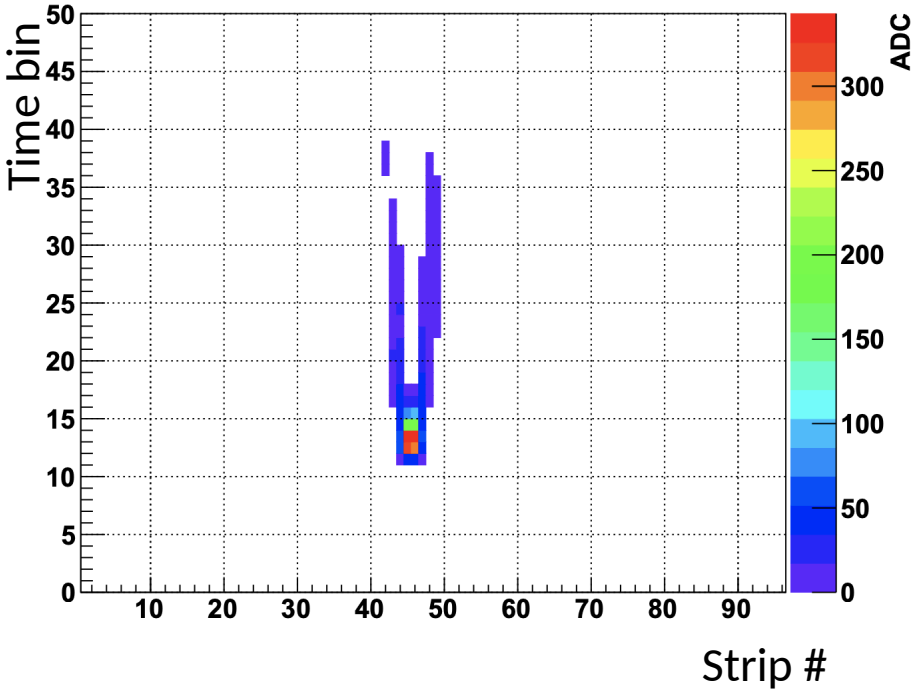




Cosmic Ray Results

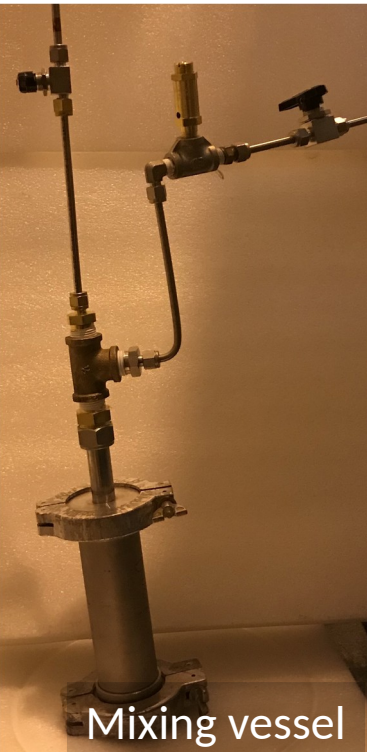
- Initially tested with safe (but inefficient) C10 gas
- Clear signals seen in the wire and strips
- 45% n-pentane + 55% CO_2 is by far the best performing gas (efficiency = 98-99%)
- Other gasses (C10, Ar+CO_2+CH_4, Ar+CO_2+Isobutane) have efficiency $\lesssim$ 10%

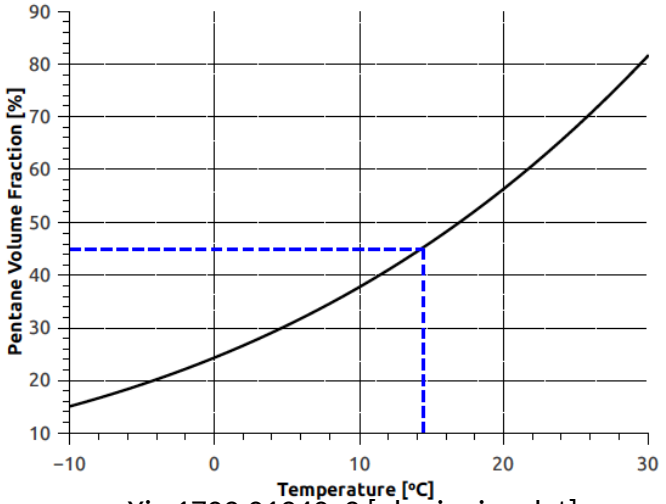




Gas considerations

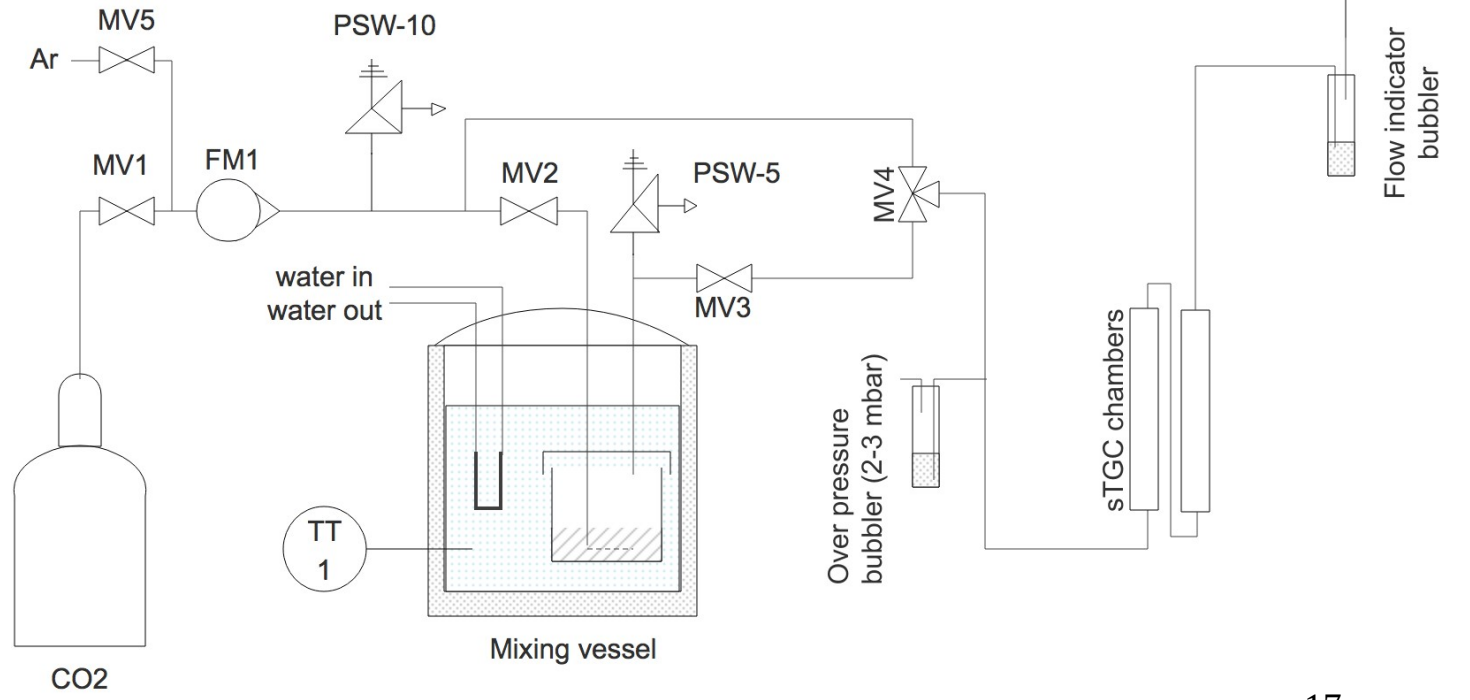
- n-pentane is flammable, so there are safety considerations
- Still, it's superior efficiency makes it unavoidable
- Gas system being designed and vetted at BNL


Mixing vessel

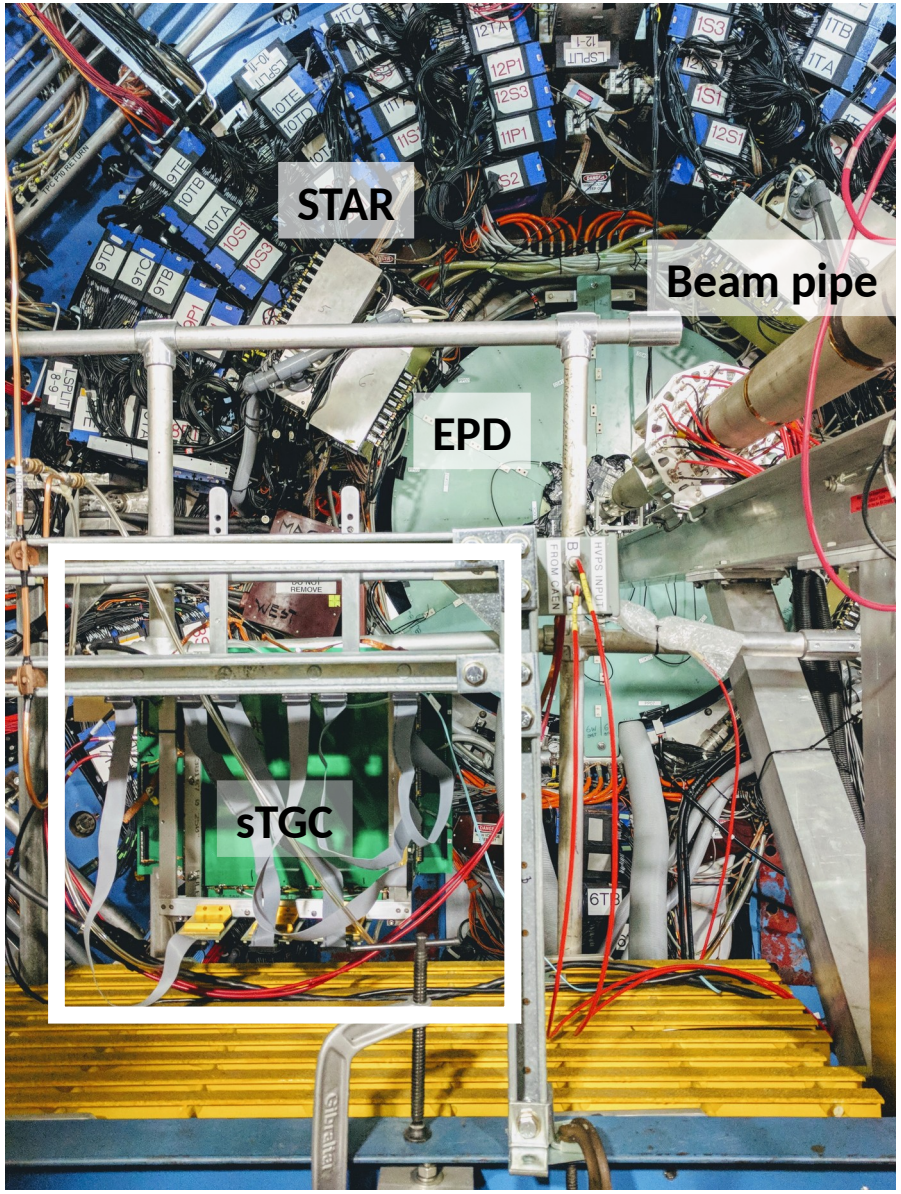


arXiv:1702.01240v3 [physics.ins-det]

Mixing vessel is in insulated water bath, which is cooled by water chiller to maintain at the required temperature 17^0 C



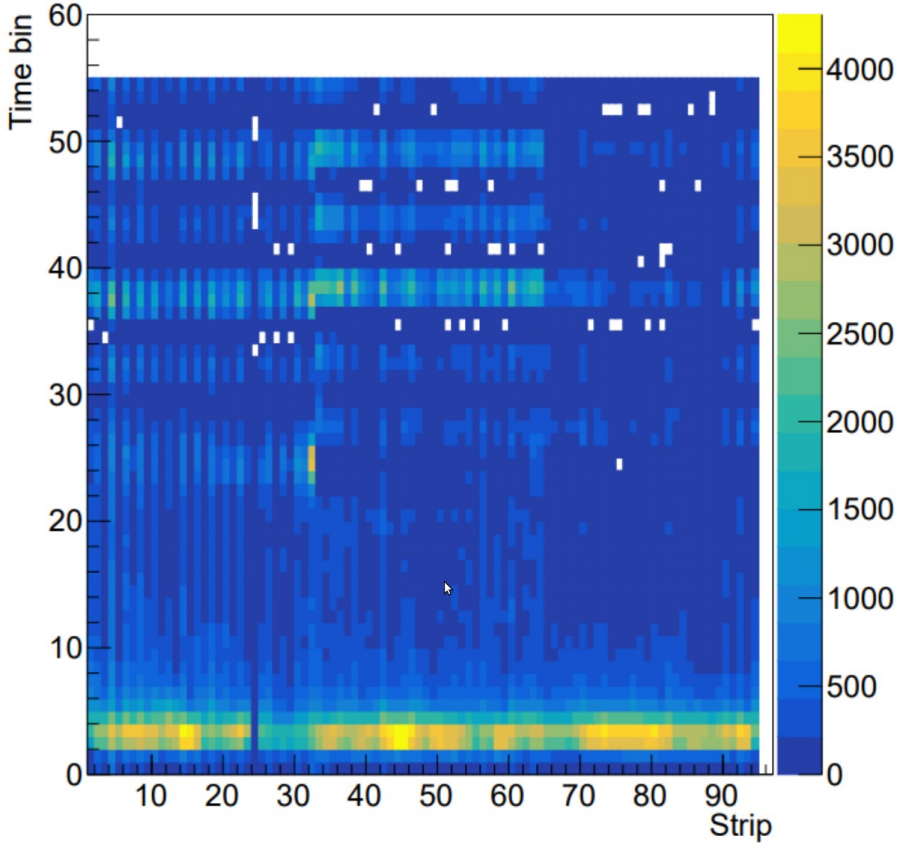
2019 Prototype

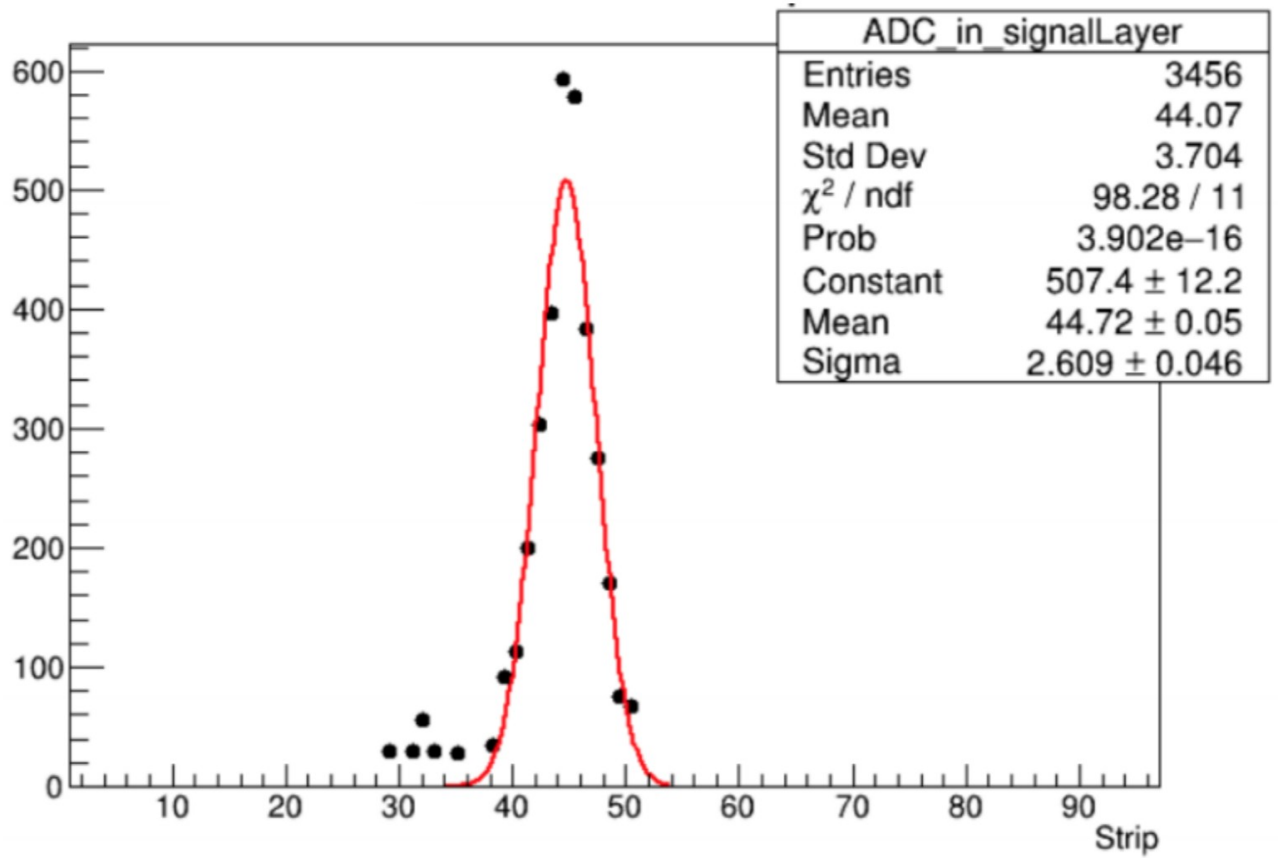


- Detector placed out of the way, on the West side (FMS) platform
- Collected data during 14.5 GeV and 200 GeV collisions
- Sub-optimal C10 gas (safety)
- Large data volume (compared to cosmics) allows us to test uniformity of response (ongoing)

2019 Prototype Results

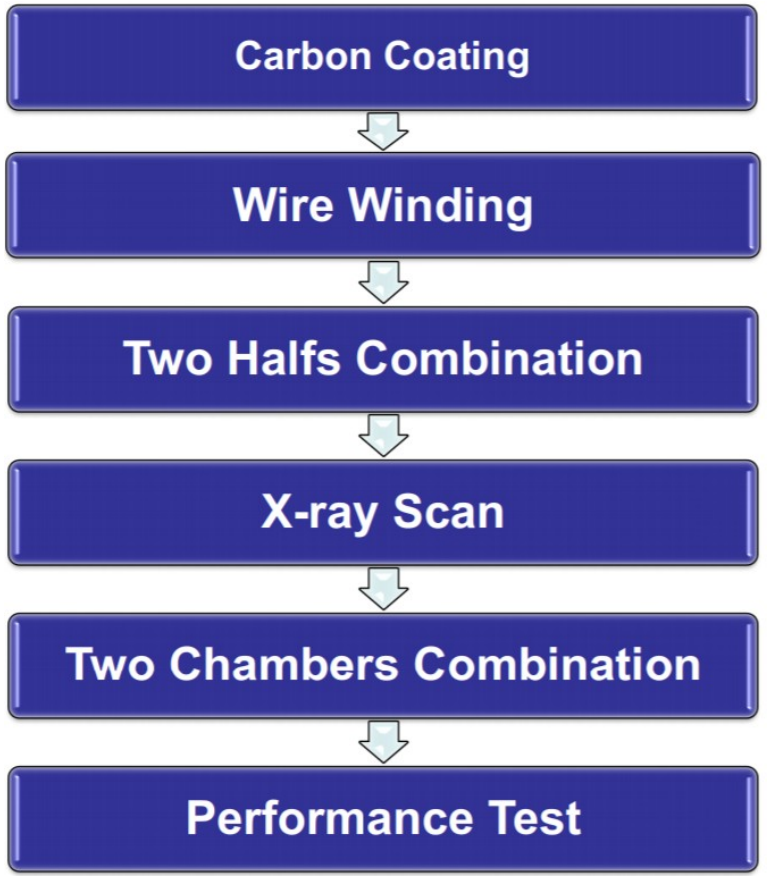
- Clear signal seen in AuAu collisions with good uniformity
- Analysis of shower size is ongoing





Construction

- Construction underway for a 60 x 60 cm sTGC prototype for the RHIC 2020 run
- 4 sTGCs are being produced at SDU
- To do: comprehensive program of performance testing
- Develop construction and testing methodology for future EIC use

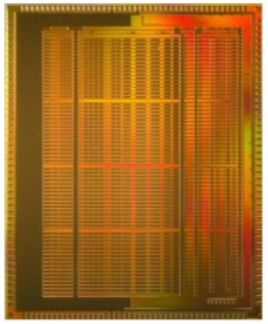


Same clean room as iTPC production

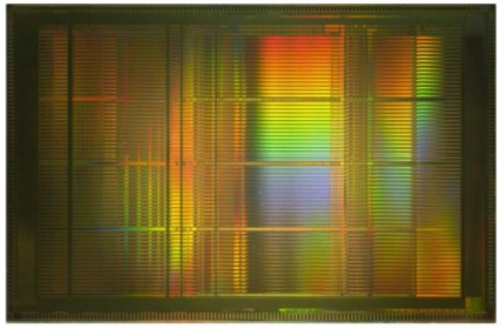
Now shared with ATLAS sTGC group

Electronics

- Currently we're using STAR TPC electronics, but will transition to ATLAS VMM chips
  - ATLAS electronics group at BNL is useful resource
- VMM can be used at EIC and FEE boards come from USTC
- USTC has a long hardware commitment in STAR and is interested in joining EIC effort

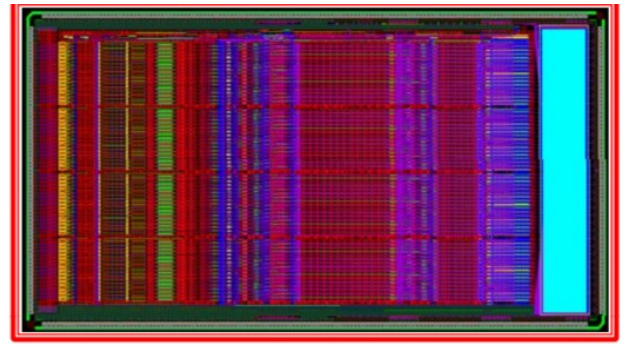


VMM1 (2012)
50 mm²
500k MOSFETs (8k/ch.)
- mixed-signal
- 2-phase readout
- no ADCs



VMM2 (2014)
115 mm²
> 5M MOSFETs (>80k/ch.)
- planned deep re-design of VMM1
- much higher functionality and complexity than VMM1
- continuous fully-digital readout
- ADCs

sTGC specifications finalized →



VMM3 (2016, in fabrication)
130 mm²
> 10M MOSFETs (>160k/ch.)
- **deeply revised front-end for sTGC**
- **L0 processor**
- SEU-tolerant
- SLVS interface
- additional functions
- aims at pre-production

(G. De Geronimo)

What does this mean for EIC?

- Ultimately all of this is leading to analysis-level integration checks of the detector
- sTGC in STAR is building institutional knowledge for
  - Design
  - Construction techniques
  - Independent electronics

  for a cost effective forward detector
- All of which means the project can be quickly be integrated into an EIC detector configuration with little additional expense

Conclusion

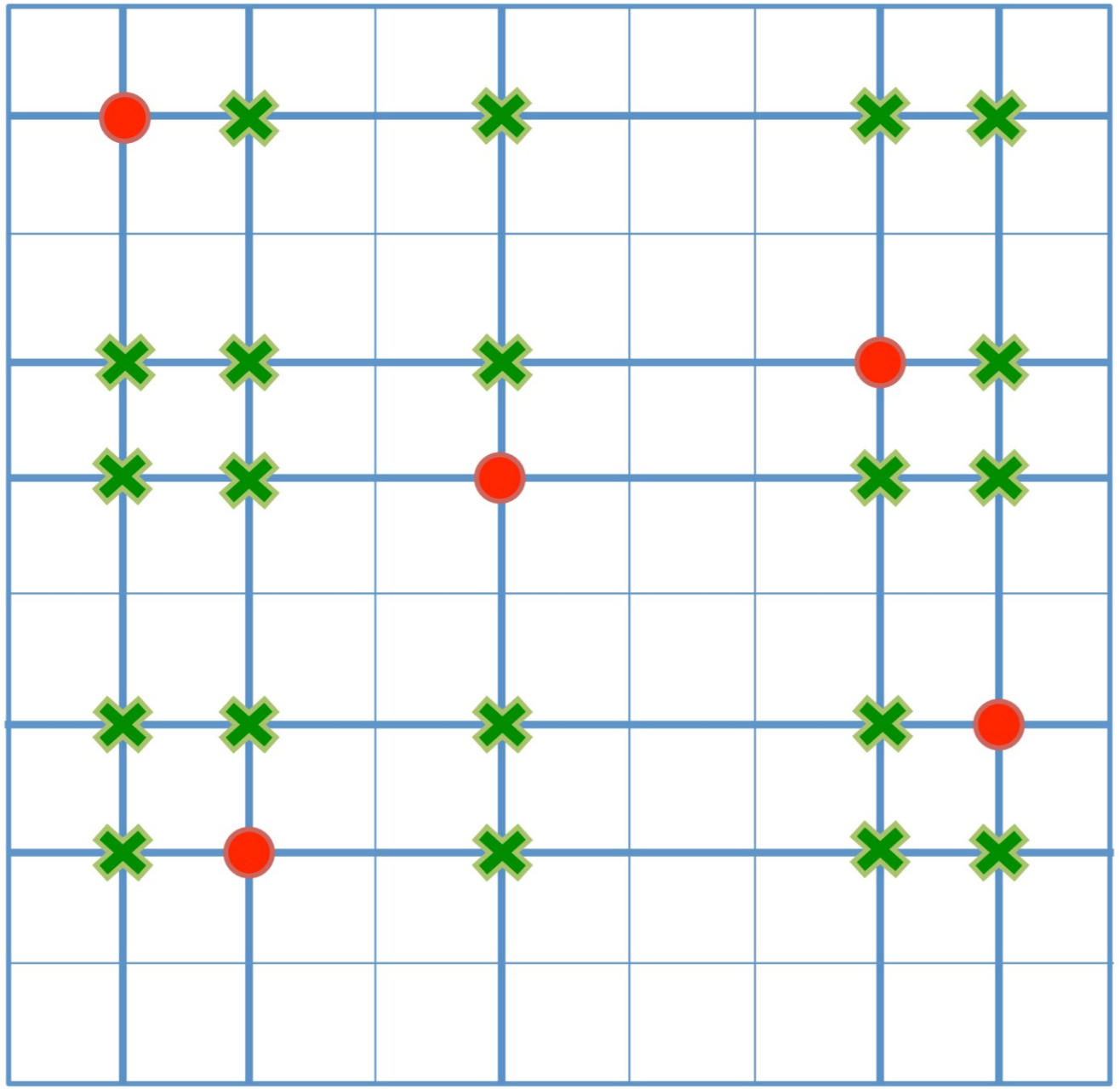
- Design concept is well tested by ATLAS
- Good, inexpensive alternative forward tracking element
  - sTGC has a few issues at high track density (ghosting/fake rate), which are not concerns in the low-multiplicity environment of the EIC
- Construction of STAR sTGCs are underway at SDU and electronics acquisition is underway at USTC
- Use in forward tracking at STAR to be demonstrated in 2021-2025 era

Presentations and awards

- Talks:
  - SQM (summary talk 06/19)
  - Weihai meeting (07/19)
  - DNP award talk (10/19)
- Awards:
  - DNP dissertation award (2019)

Ghost hits

- At strip intersections with high multiplicity it isn't obvious which hits are real



Real Hit

Ghost Hit