End Cap Tracking with small-Strip Thin Gap Chambers (sTGC)

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Outline

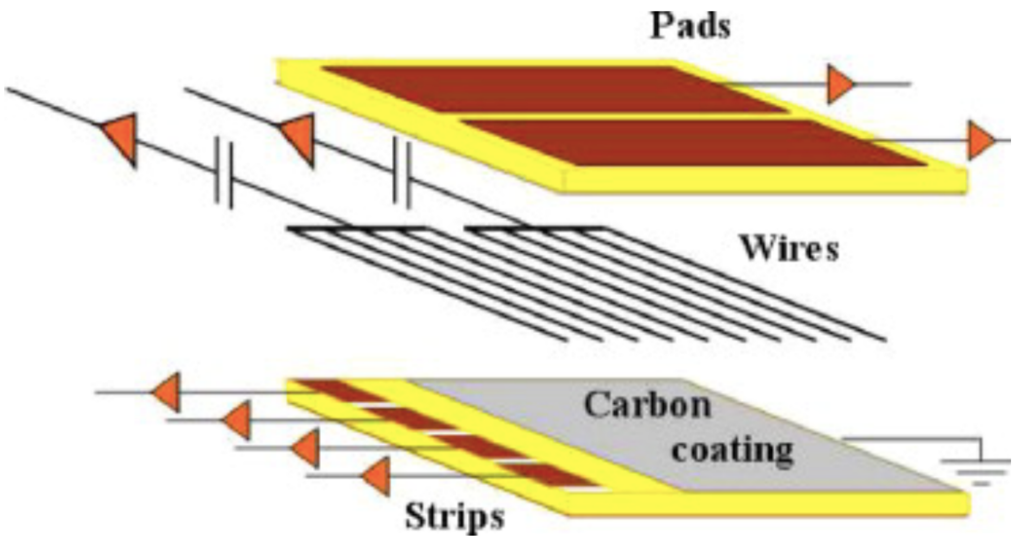
- Overview: Small-Strip Thin Gap Chambers (sTGC)
- Forward Tracking System in STAR with sTGCs
- Prototype Testing @ BNL
- Module production at Shandong University
- Performance tests of full sTGC
- Integration in STAR & Gas system

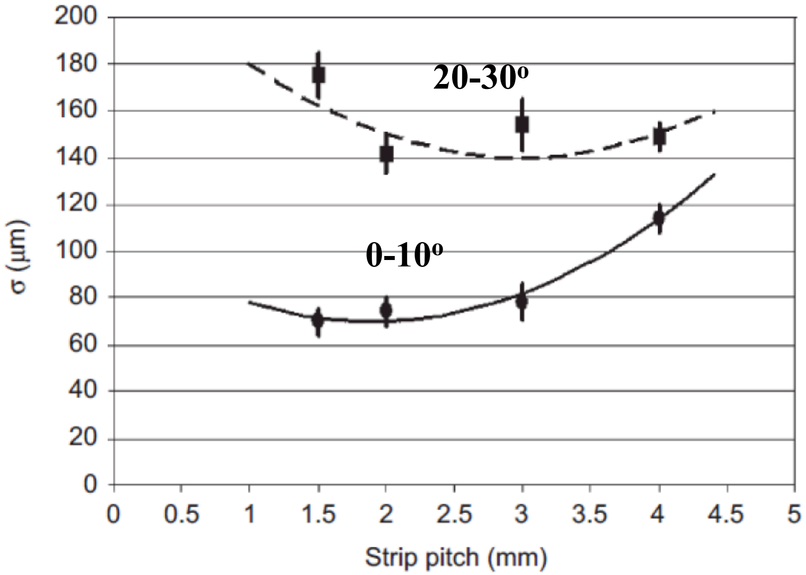
- Summary & Conclusions

Overview: Small-Strip Thin Gap Chambers

sTGC Detector Specification

- Double-sided:
  - X & Y strips provided by one layer
  - Diagonal strips on other layer
- Pentagonal shape:
  - Rotational symmetry
  - One “disk” = 4 identical modules
- 22,000 readout channels in total
- STAR sTGCs are much smaller than ATLAS sTGCs
- **Expected Position Resolution: < 100 μm**
  - Resolution depends on perpendicular angle of incidence





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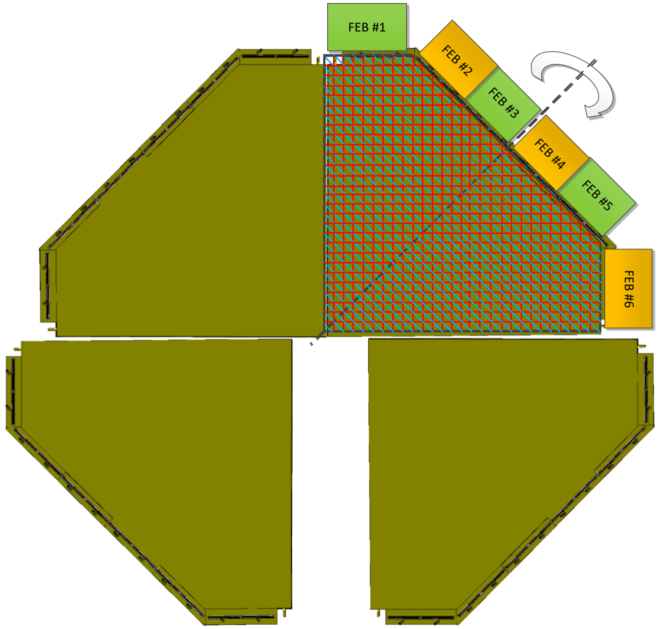
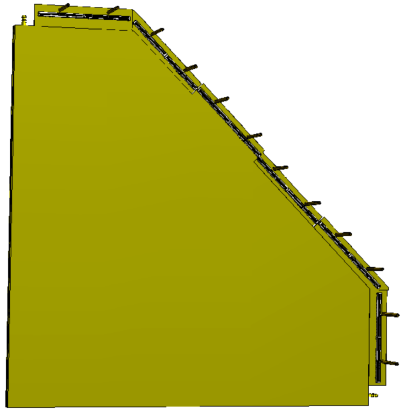
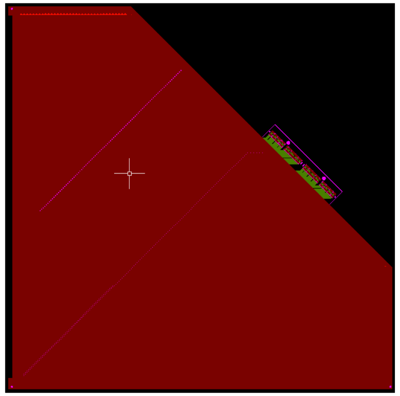


One complete sTGC “disk” :
Pentagonal design for integration into STAR endcap region



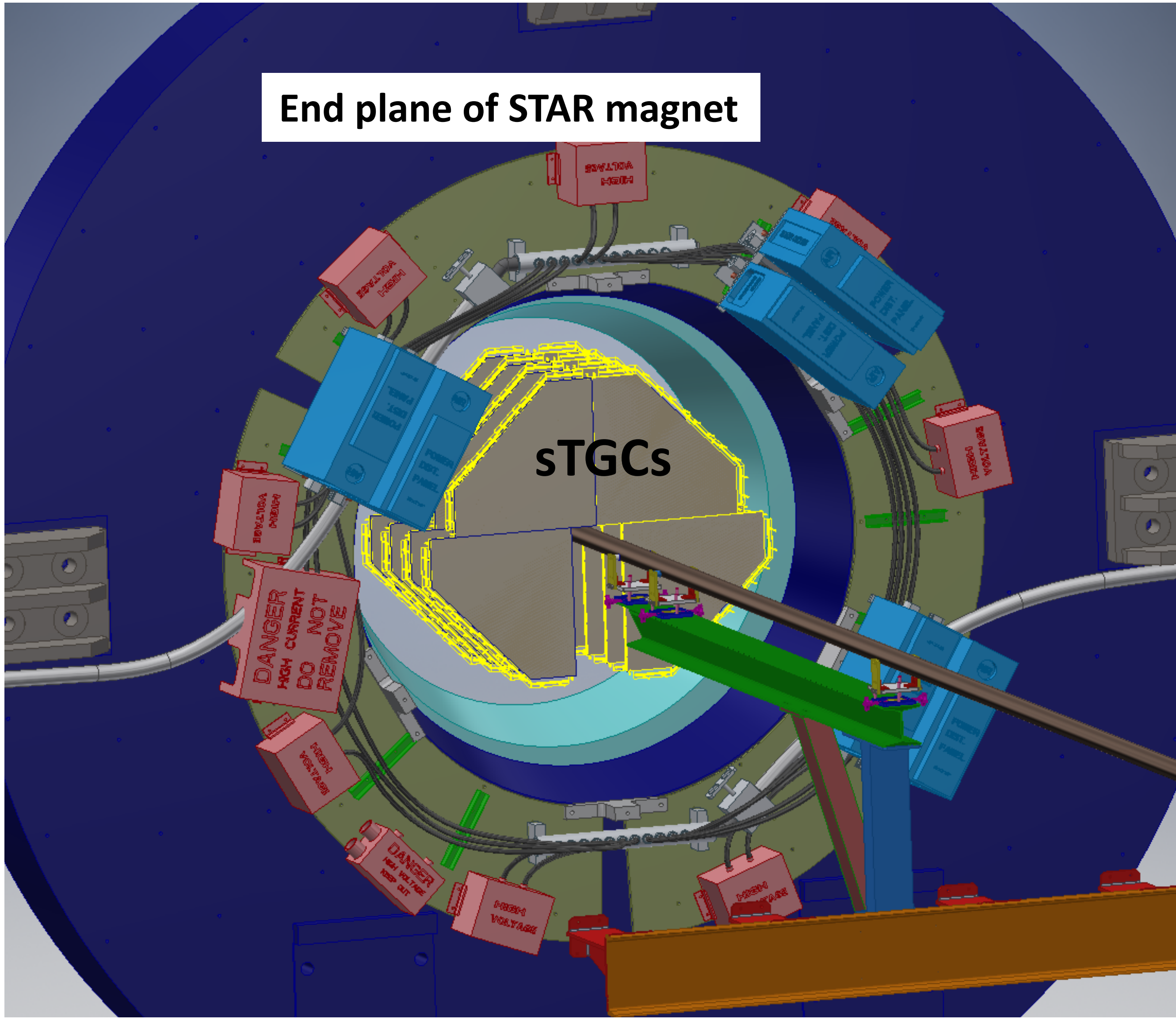
XY layer

Diagonal layer



Pentagonal sTGC disks in STAR

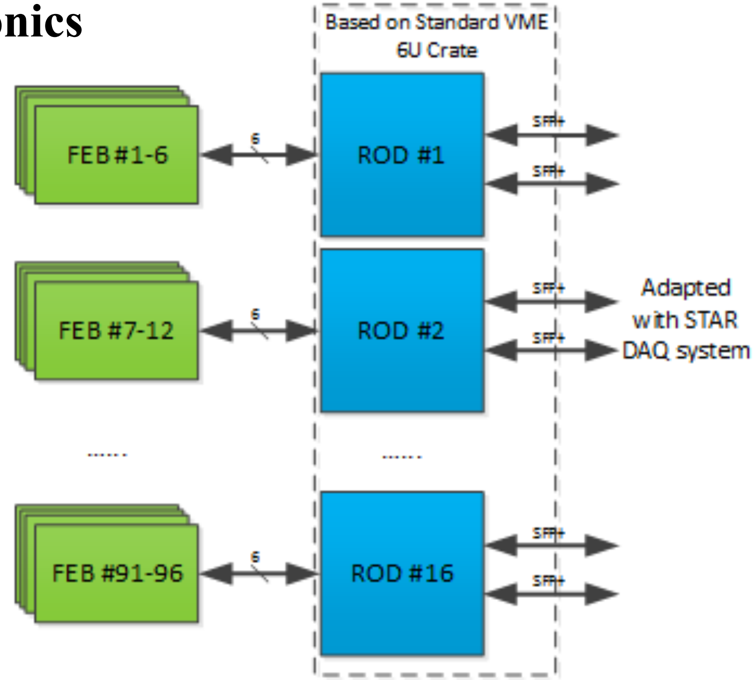
- View of final sTGCs in STAR endcap region
- Shown with final pentagonal design
- Detectors provide large coverage in a compact space

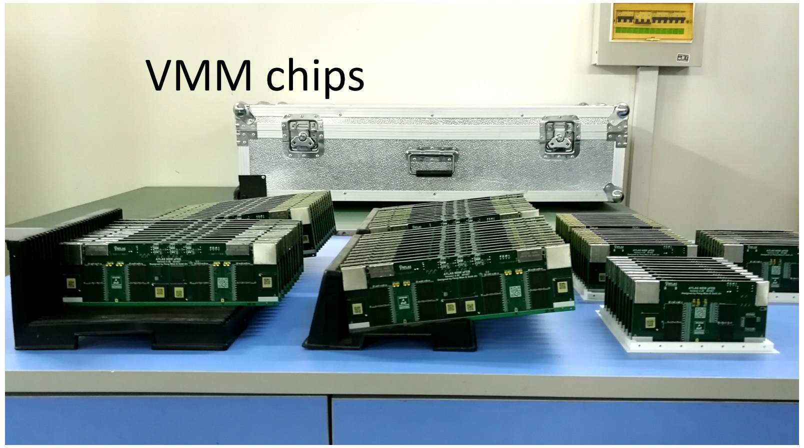


Electronics for sTGC

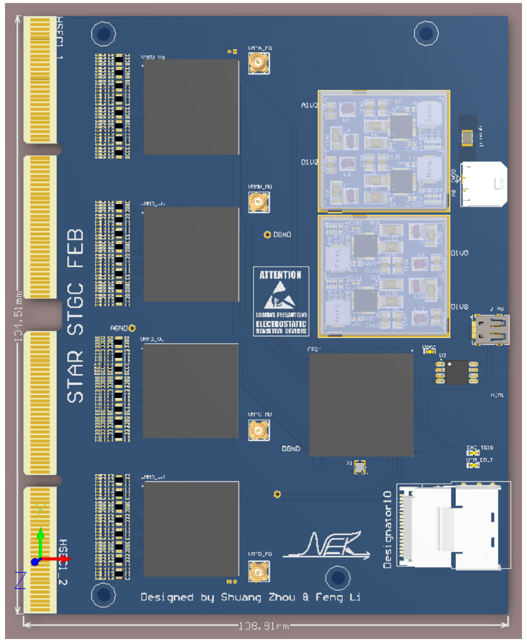
- Based on ATLAS VMM chips
- 4 chips per board, 96 FEE boards in total, 16 ROD boards

Readout Electronics Architecture





Front-End Board Layout



- FEB schematics finalized
- Design of ROD schematics and layout are ongoing
- Designed to work with STAR data acquisition system
- Good timing (~15 ns)
- High rate (>100 kHz/cm^2)

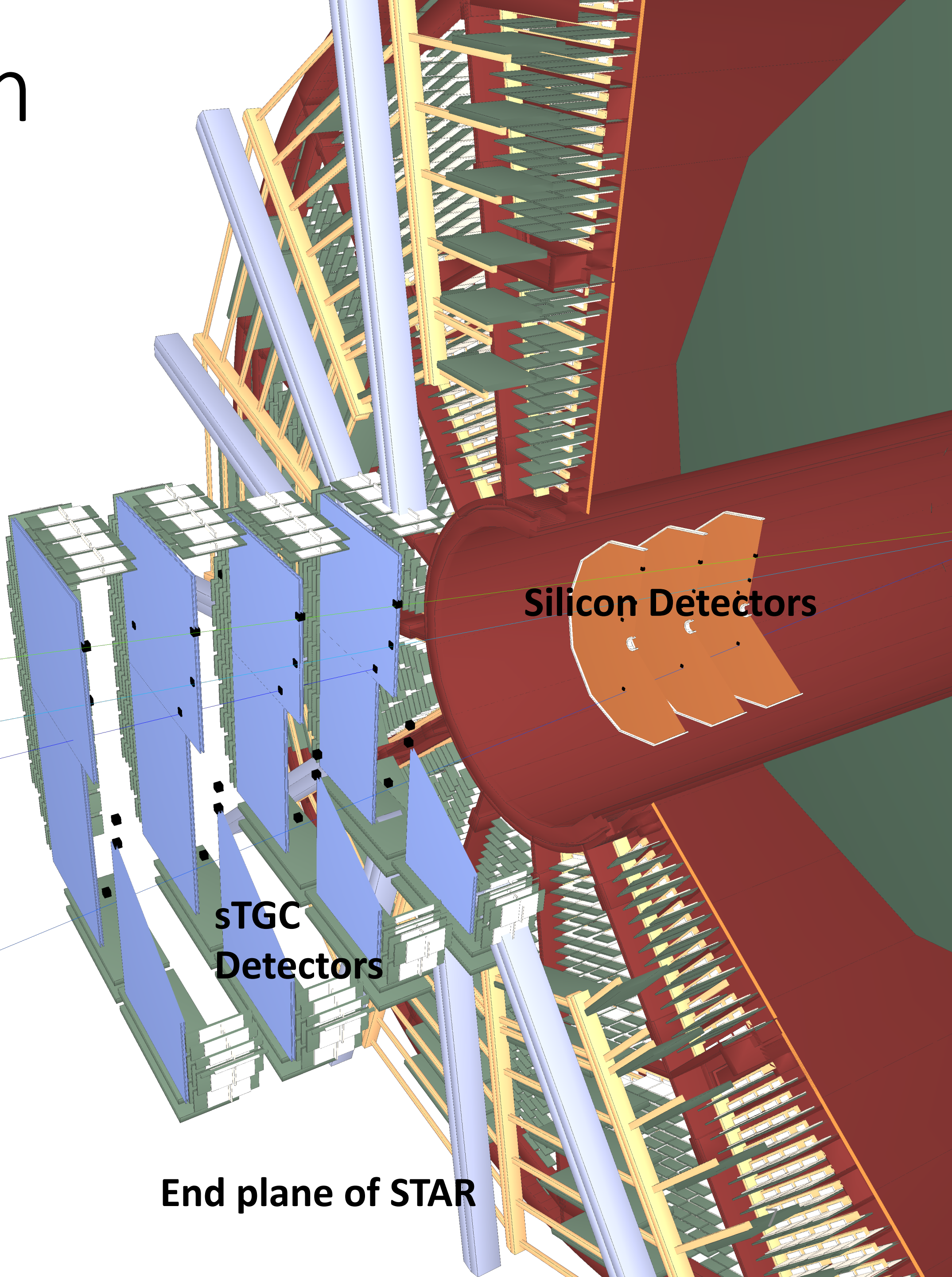
STAR Forward Tracking System

https://drupal.star.bnl.gov/STAR/system/files/ForwardUpgrade.Nov_.2018.Review_0.docx

- Covers the forward region ($2.5 < \eta < 4$)
- Combination of two detector technologies:
  - Three Silicon detectors closest to interaction point
  - Four sTGC modules 200 – 400 cm from interaction point
- Significantly reduced cost compared to all silicon

Performance requirements for physics goals

	Requirement	Motivation
Momentum Resolution	< 30%	A+A goals
Tracking Efficiency	$> 80\%$ @ 100 tracks / event	A+A goals
Charge Separation	–	p+p / p+A goals



Forward Rapidity Physics at STAR

- ➢ **Unique program addressing several fundamental questions in QCD**
- ➢ Essential to RHIC cold & hot QCD physics mission + fully realize scientific promise of future Electron Ion Collider

Mid-rapidity $-1.5<\eta<1.5$ | Forward-rapidity $2.5<\eta<4$

Au+Au

Beam:
Full Energy (200 GeV) Au+Au

Physics Topics:
- Temperature dependence of viscosity through flow harmonics up to $\eta\sim4$
- Longitudinal decorrelation up to $\eta\sim4$
- Global Lambda Polarization
  → Test for strong rapidity dependence

p+A, p+p

Beam:
500 GeV: p+p
200 GeV: p+p and p+A

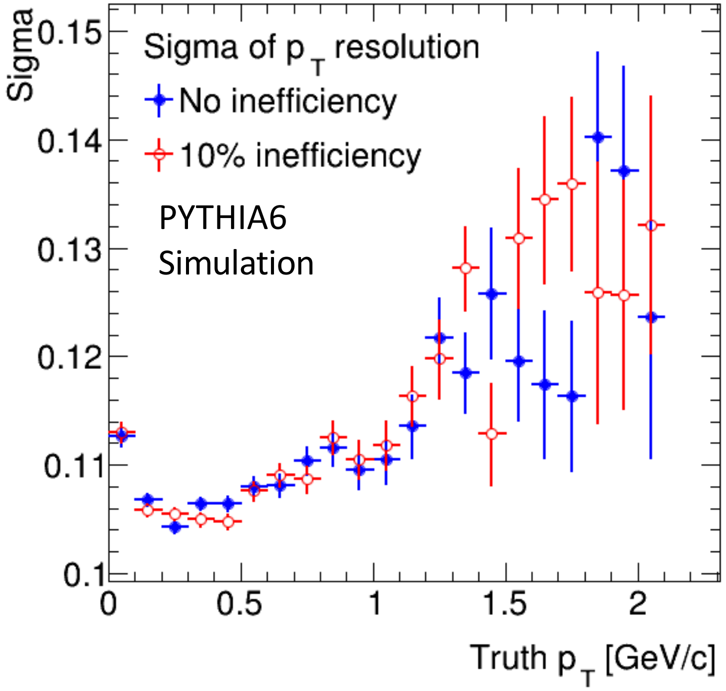
Physics Topics:
- TMD measurements at high x transversity → tensor charge
- Improve statistical precision for Sivers through Drell-Yan
- $\Delta g(x,Q2)$ at low x through Di-jets
- Gluon PDFs for nuclei
- ➢ R_{pA} for direct photons & DY
- Test of Saturation predictions through di-hadrons, γ-Jets

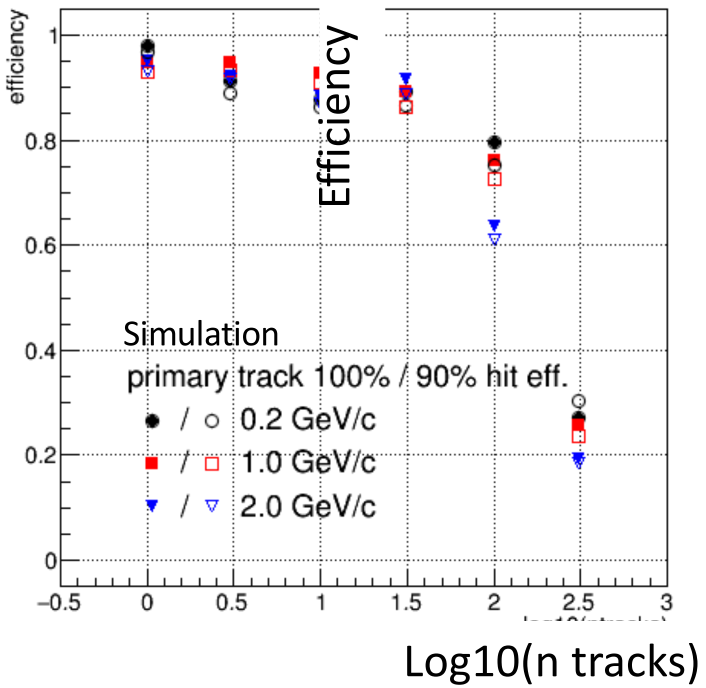
STAR Forward Tracking System

	Requirement	Motivation
Momentum Resolution	< 30%	A+A goals
Tracking Efficiency	> 80% @ 100 tracks / event	A+A goals
Charge Separation	–	p+p / p+A goals

https://drupal.star.bnl.gov/STAR/starnotes/public/sn0648

Tracking Software:
- Track finding uses Cellular Automata
- Track fitting using GENFIT2
- Dedicated tracking framework for forward rapidity in region of changing magnetic field





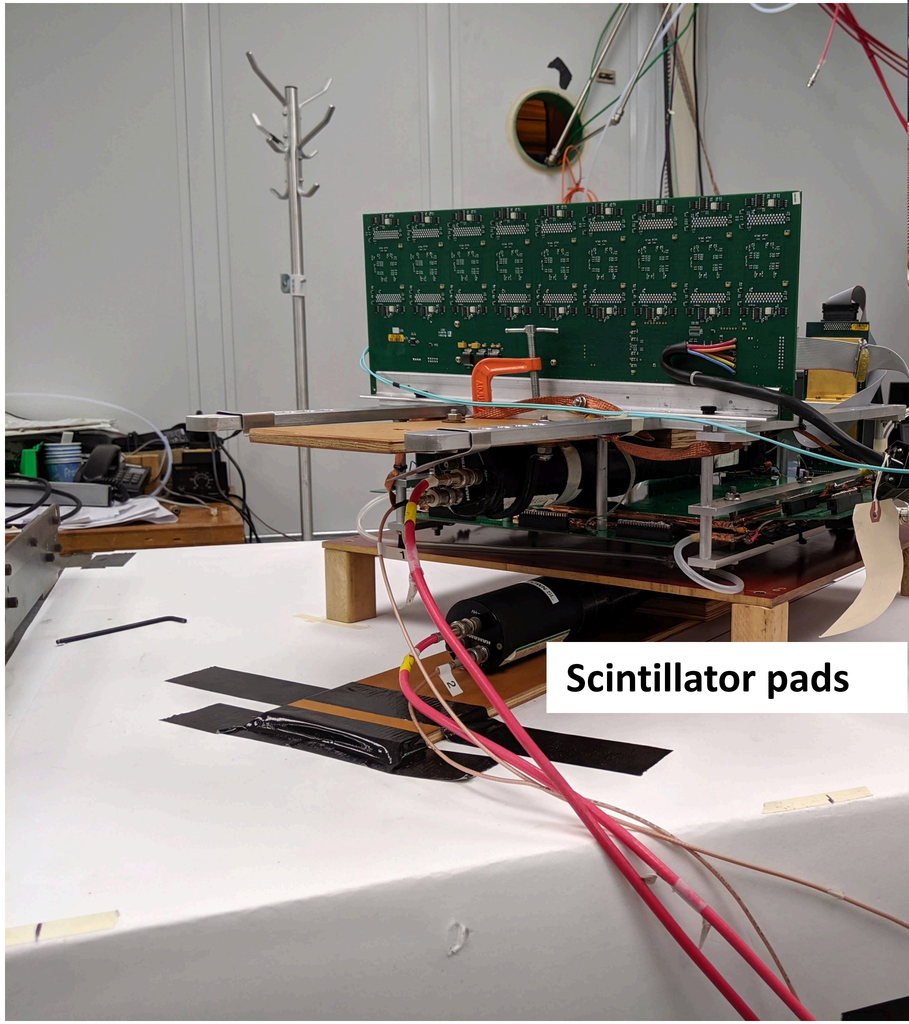
Tracking performance from simulation for full system:
3 Silicon disks +
4 sTGC disks in STAR

Prototype Tests I : BNL Clean Room Tests

sTGC Detector

- 30x30 cm prototype delivered to BNL in January 2019
- Module tested in test-stand using cosmic rays + scintillator pads for trigger
- Tested gas flow systems with C10 (90% argon + 10% CO_2)

30x30 cm sTGC prototype

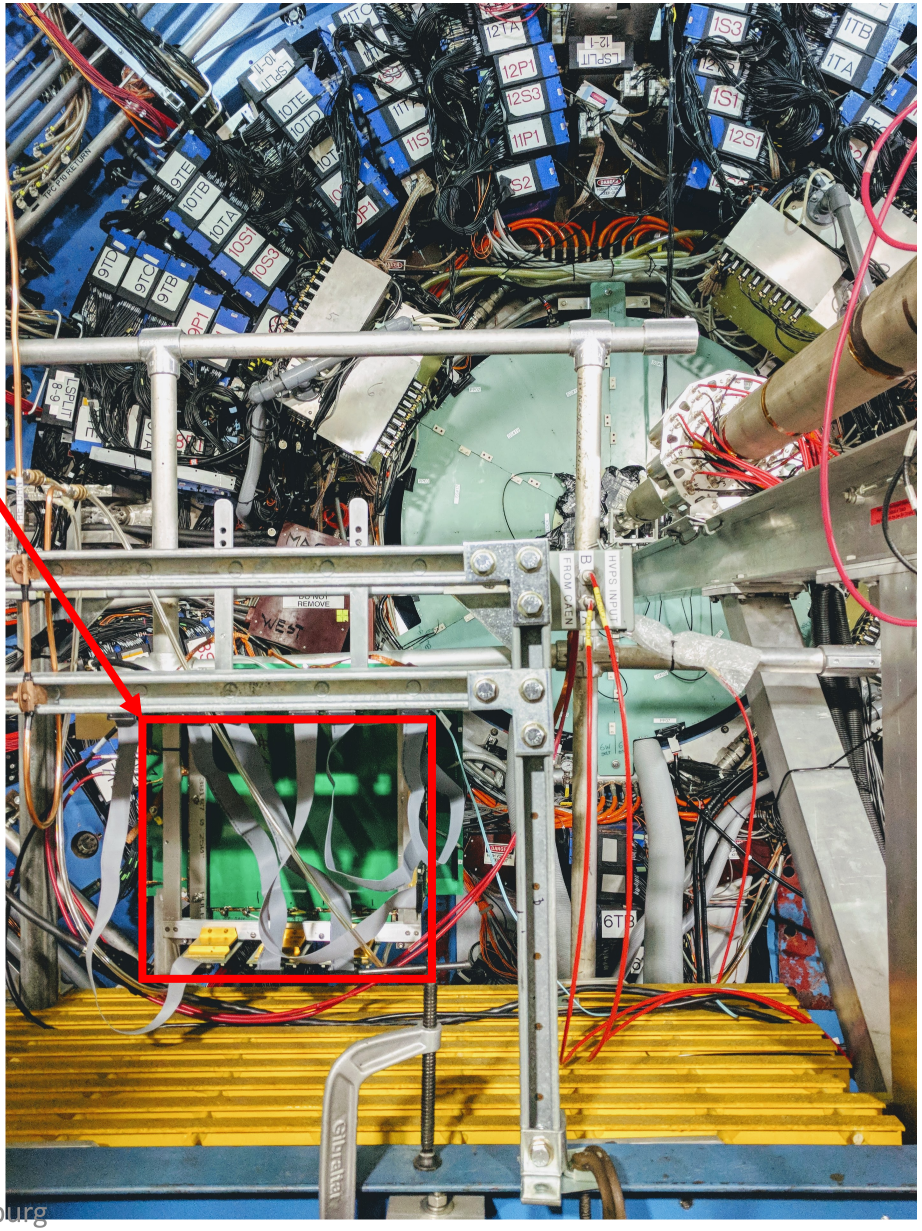


Prototype Tests II : In-beam @ STAR

Prototype sTGC Detector installed @ STAR

- Installed in STAR on June 5th, 2019
- 30x30 cm prototype module
- Test in STAR data acquisition system.
- Tested with C10 (90% argon + 10% CO_2)

- Collected data from Au+Au collisions at $\sqrt{s_{NN}}$ = 7.7, 9.2 and 200 GeV
- Performed voltage scans to test efficiency and gas response
- Performance with C10 gas was not optimal -> need n-Pentane gas mix

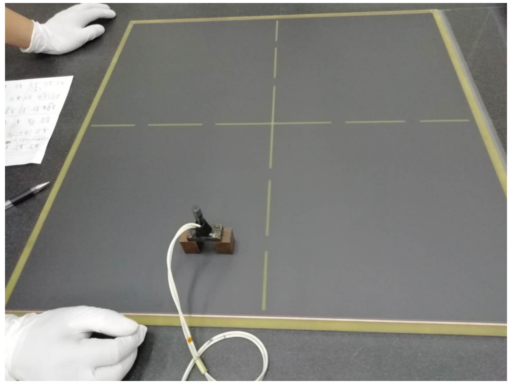


sTGC Production Procedure

- Shandong University has developed significant expertise
  - Production of ATLAS and STAR sTGC detectors

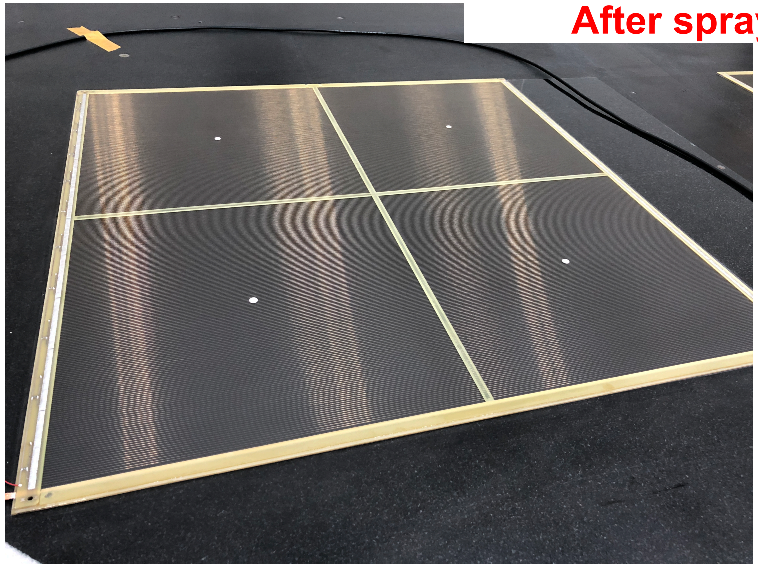
Carbon Coating
↓
Wire Winding
↓
Two Halfs Combination
↓
X-ray Scan
↓
Two Chambers Combination
↓
Performance Test

Polishing



Measuring

After spraying

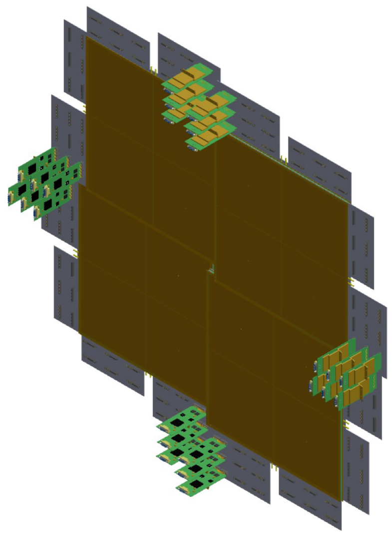


Ready to be bonded to the PPPCB half to build a chamber

  - sTGC Production and QA Procedures in place

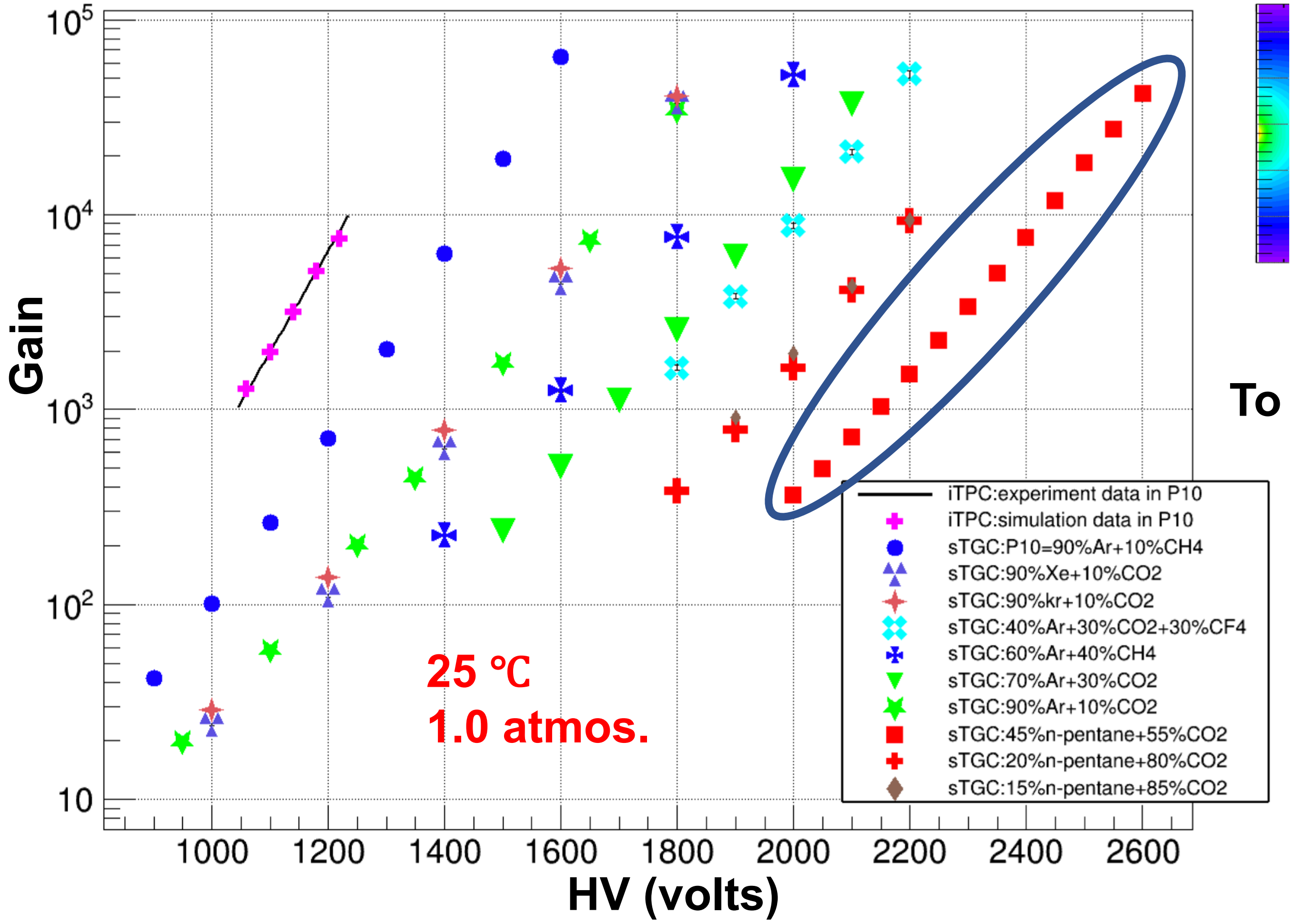
Prototype Tests III : @ SDU

Full size (60x60 cm) prototype built at Shandong University using 30x30cm square module design



Performance Test @ SDU

- Gas : 45% n-Pentane + 55% CO2
- HV: 2700V



Optimal gas for sTGC: n-Pentane + CO2

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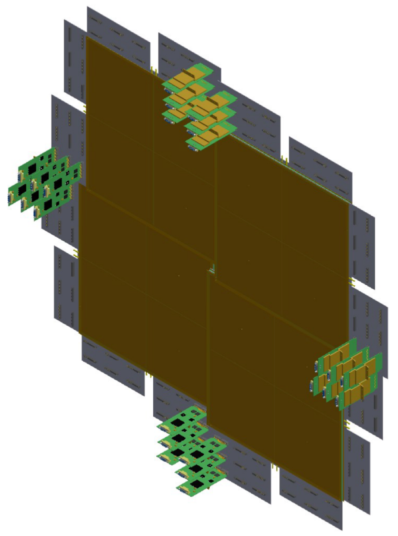
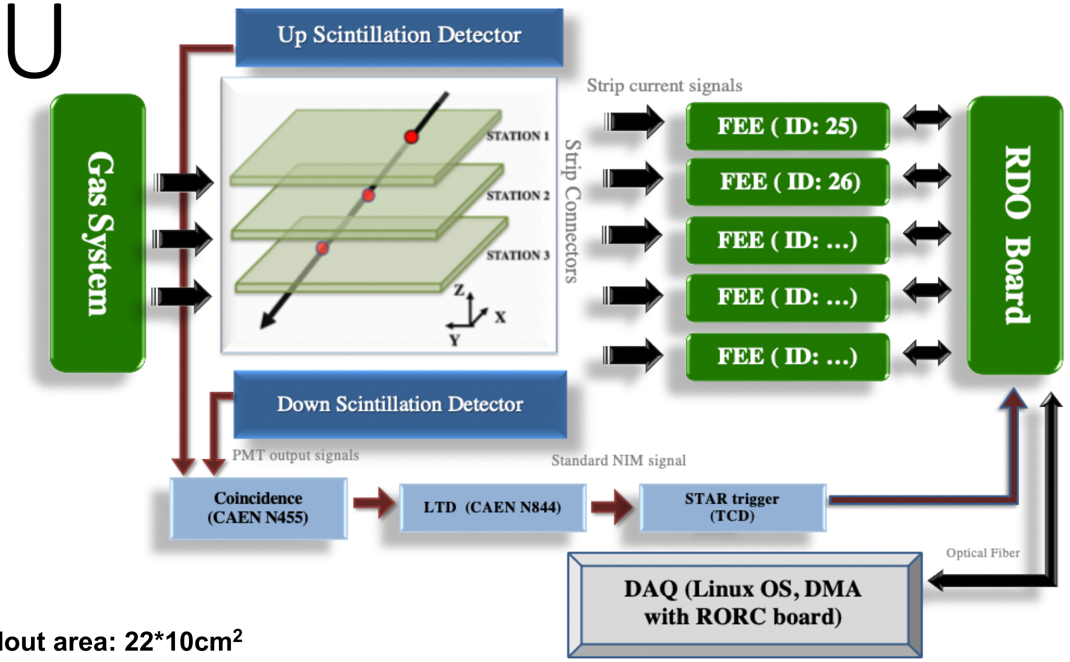
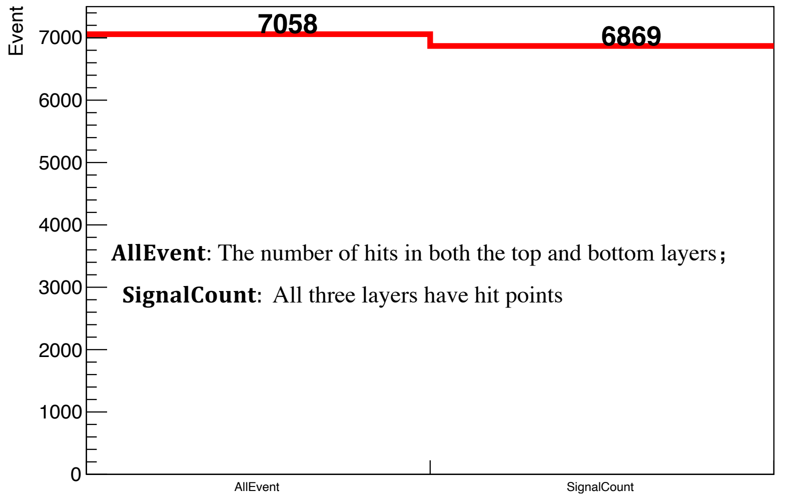




Readout area: 22*10cm^2
Gas: 45%n-Pentane + 55%CO_2
HV: 2700V

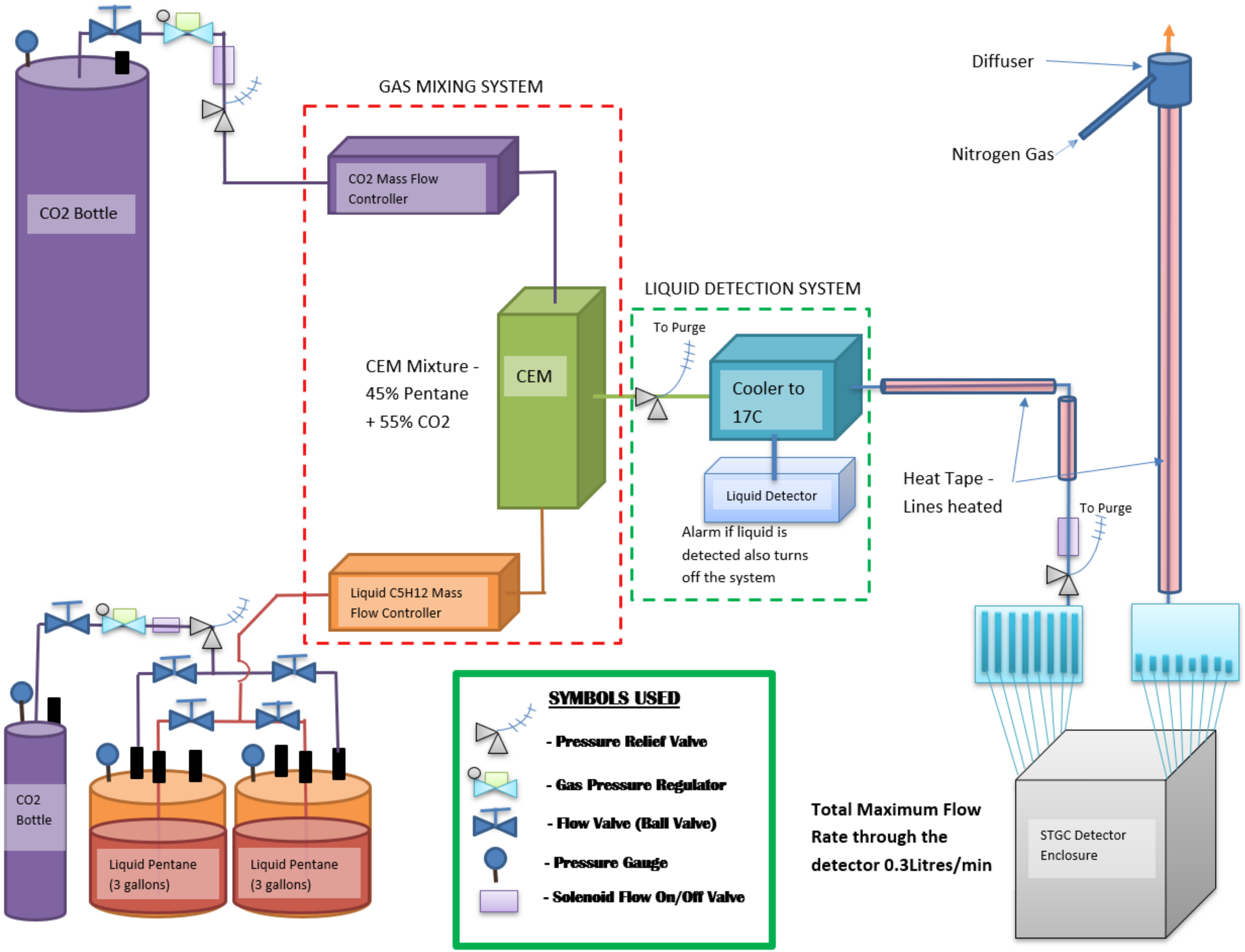


Performance Test @ SDU

- Gas : 45% n-Pentane + 55% CO2
- HV: 2700V
- **Efficiency > 98%**

Gas System for n-Pentane

- Optimal performance requires 45% n-Pentane + 55% CO_2
- Gas System will comprise of the following:
    - Gas and liquid Storage - CO_2 and n-C_5H_{12} bottles and containers.
    - Gas Mixing System
    - Liquid Detection System
    - Gas Delivery to the detector
    - Purging System
- Safety and interlock requirements are fully established
- Plan for testing and commissioning in STAR Run 2020
- Significant work developing gas system – can be reused for EIC detector



Summary and Conclusions

- Small-Strip Thin Gap Chambers detector technology:
  - Cost effective technology for large area tracking detector
  - Provide good space point resolution of $\sim 100\mu$m
  - High rate (100 kHz/cm^2)

- The STAR Forward tracking system (including silicon and sTGCs)
  - Meet or surpass requirements for physics goals in p+p, p+A, A+A
  - Momentum resolution better than 30% (for p_T < ~5 GeV/c)
  - Will be commissioned and run in STAR Fall 2021+

- Use of sTGC technology for EIC endcap detectors
  - Potential to benefit from significant developments from ATLAS & STAR
  - Design & Production expertise at Shandong University
  - Reuse of integration expertise & gas system design for n-Pentane