STAR forward upgrade overview

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BNL

Introduction

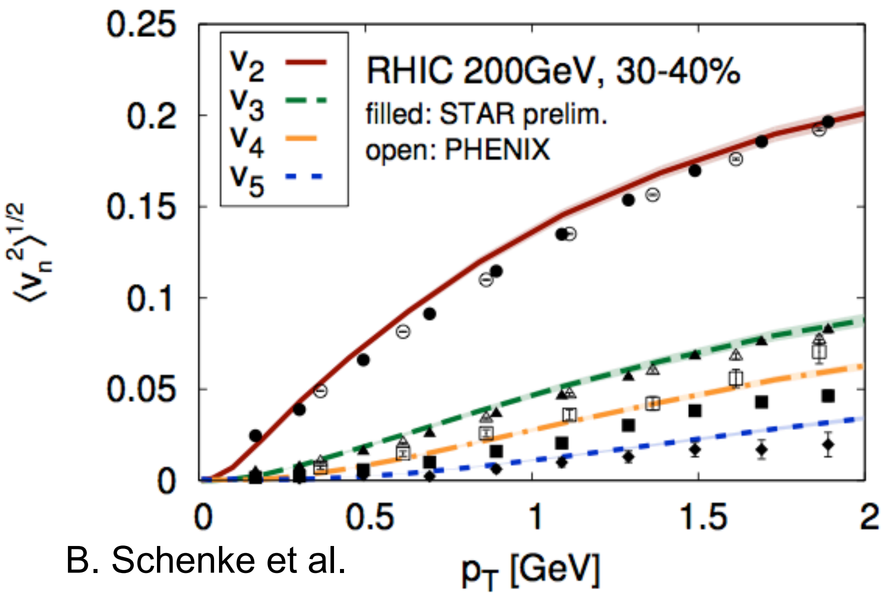
The project

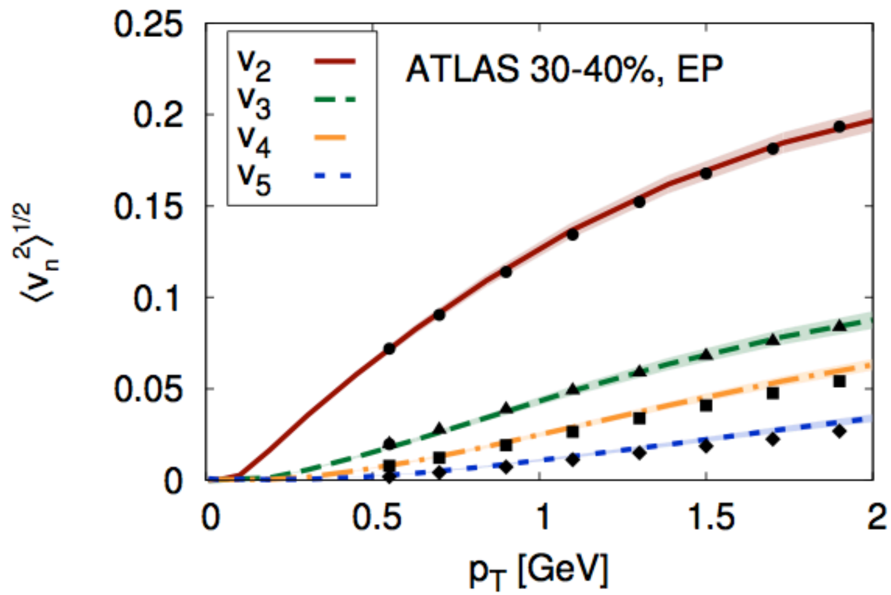
The prototype performance at STAR

Summary

A workshop on QCD Physics & Study of the QCD Phase Diagram and New-type Topologic Effect, July 19 - 25, 2019, SDU, Weihai

η/s constrained from flow observables



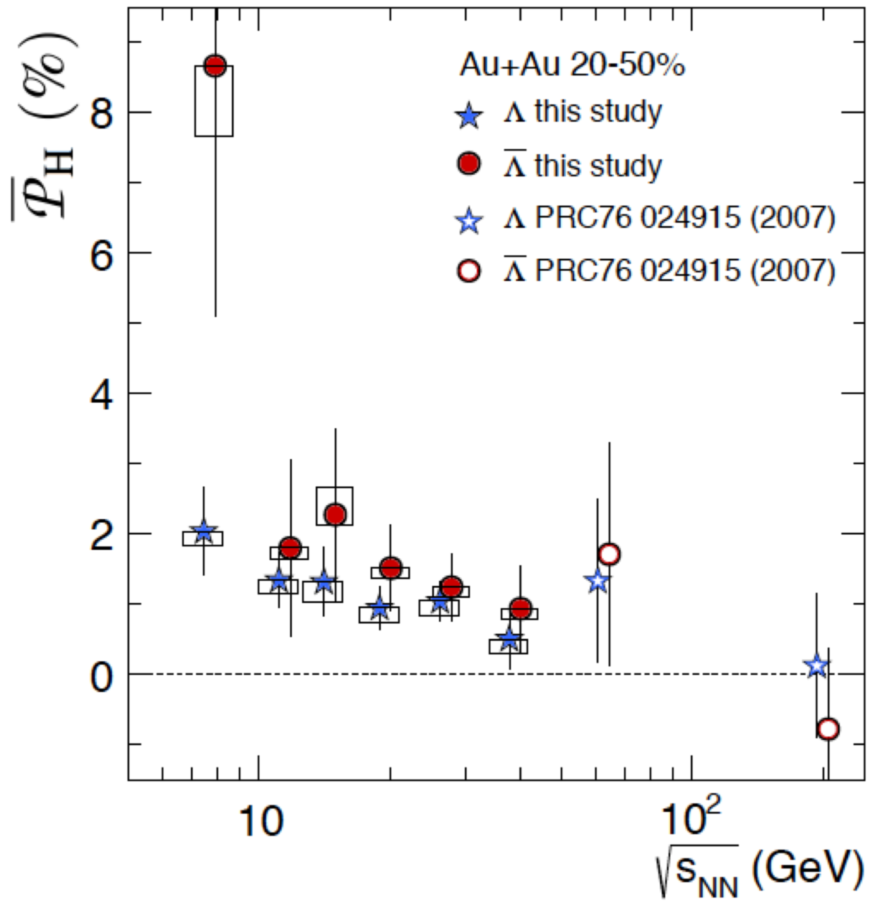


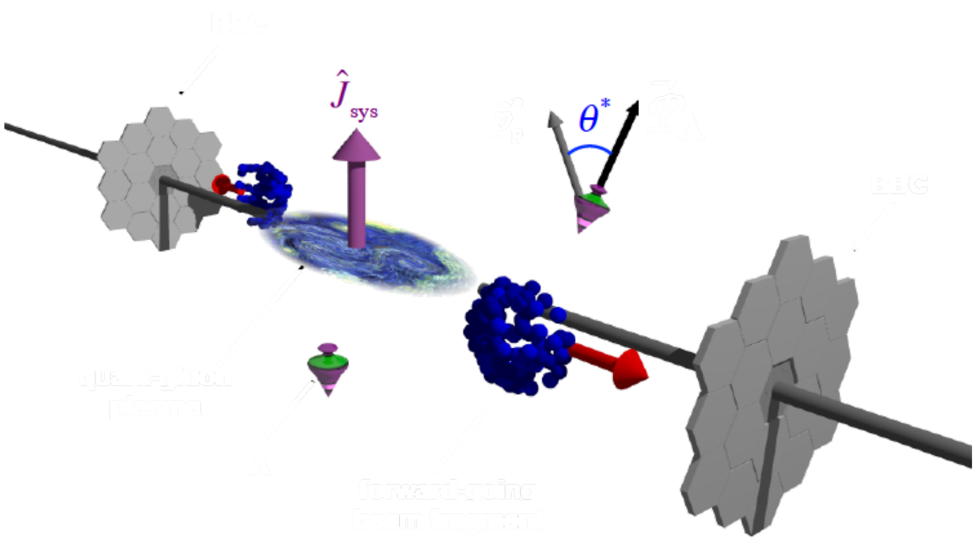
IP Glasma initial condition, subnucleonic color charge fluctuations, 3+1D hydro evolution: η/s=0.12 (0.2) at 0.2 (2.76) TeV

1. **Transverse fluctuation essential to reproduce data**

2. **How about longitudinal dynamics? How much do we understand it?**

Lambda global polarization



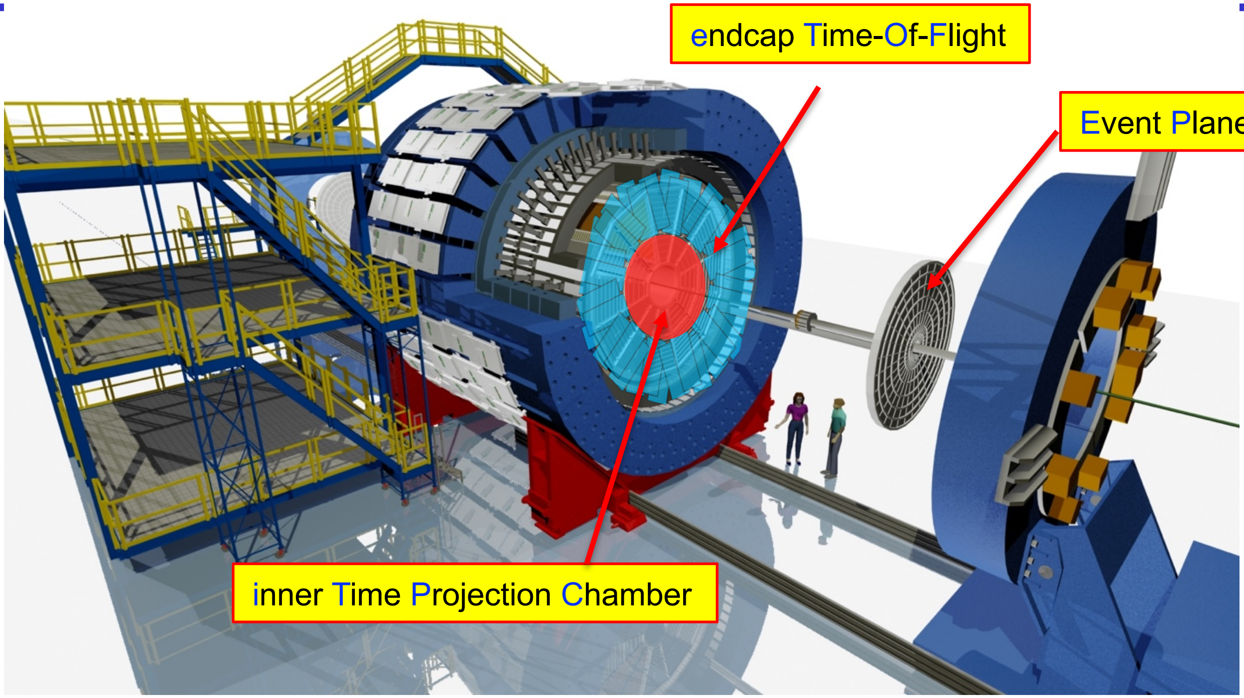


Nature **548** (2017) 62

Lambda and anti-Lambda polarized.

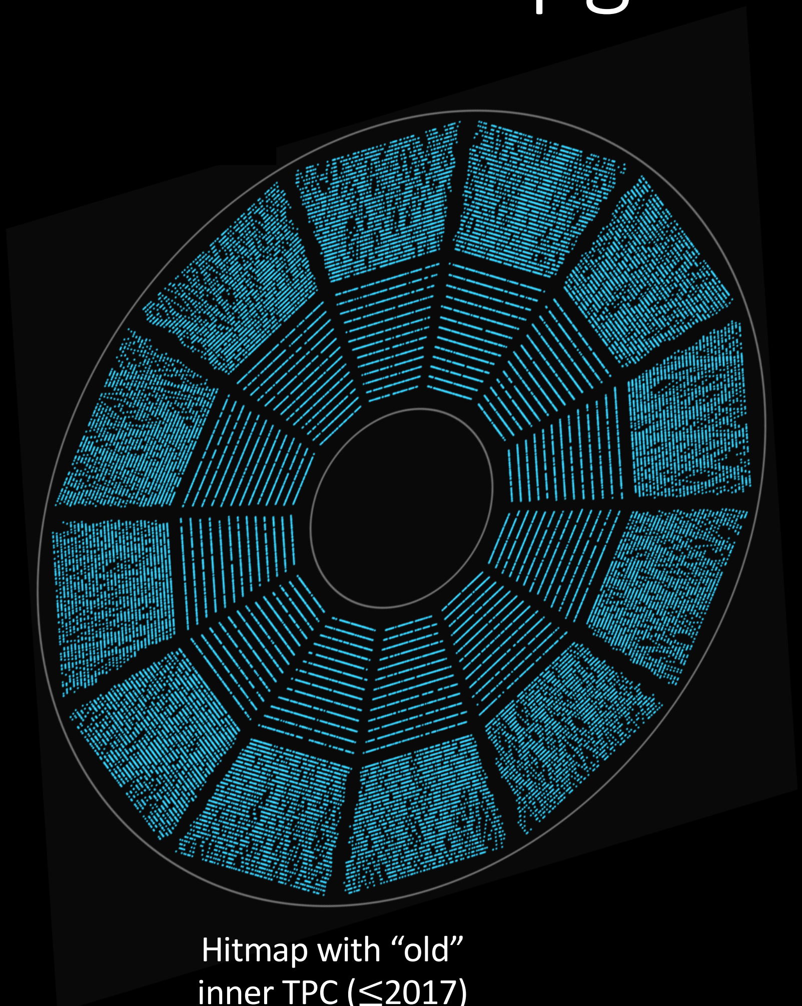
Most vortical system! What is the rapidity dependence?

STAR Detector



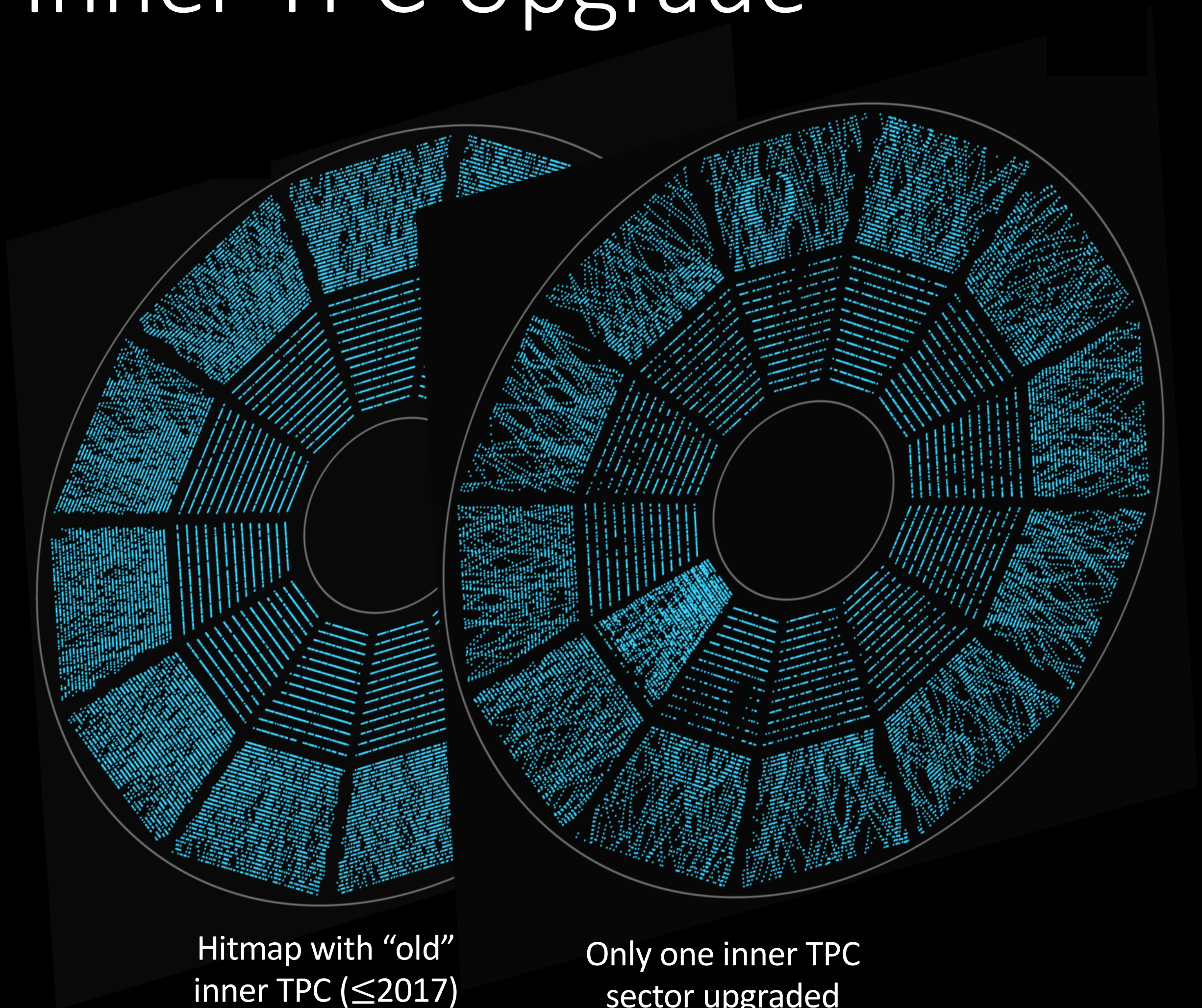
iTPC upgrade	EPD upgrade	eTOF upgrade
Continuous pad rows Replace all inner TPC sectors	**Replace Beam Beam Counter**	**Add CBM TOF modules and electronics (FAIR Phase 0)**
$\lvert\eta\rvert<1.5$	**$2.1<\lvert\eta\rvert<5.1$**	**$-1.6<\eta<-1.1$**
p_T >60 MeV/c	Better trigger & b/g reduction	Extend forward PID capability
Better dE/dx resolution Better momentum resolution	Greatly improved Event Plane info (esp. 1st-order EP)	Allows higher energy range of Fixed Target program
Fully operational in 2019	**Fully operational in 2018**	**Operational in 2019**

Inner TPC Upgrade



Hitmap with “old” inner TPC (≤2017)

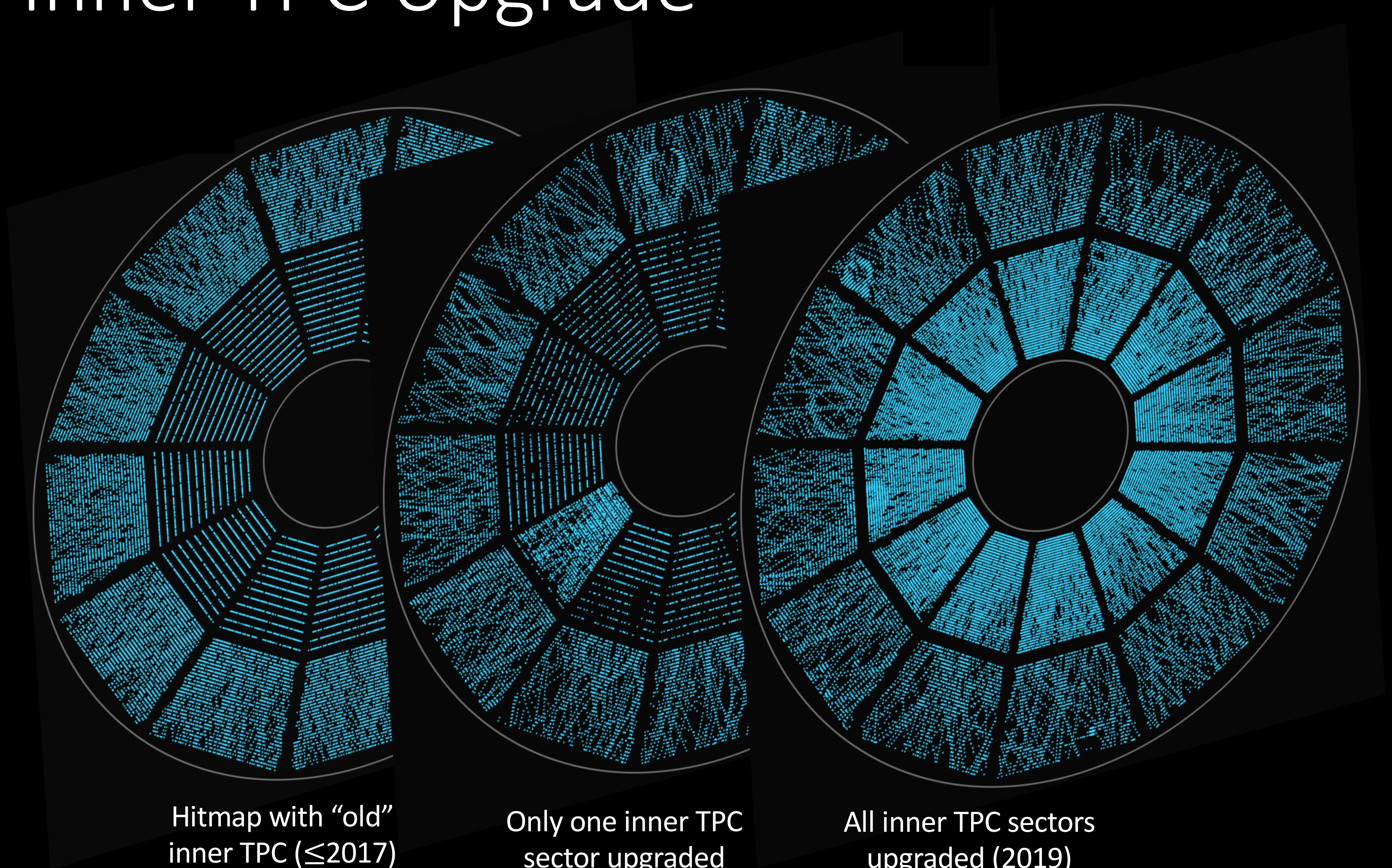
Inner TPC Upgrade



Hitmap with “old” inner TPC (≤2017)

Only one inner TPC sector upgraded (2018)

Inner TPC Upgrade

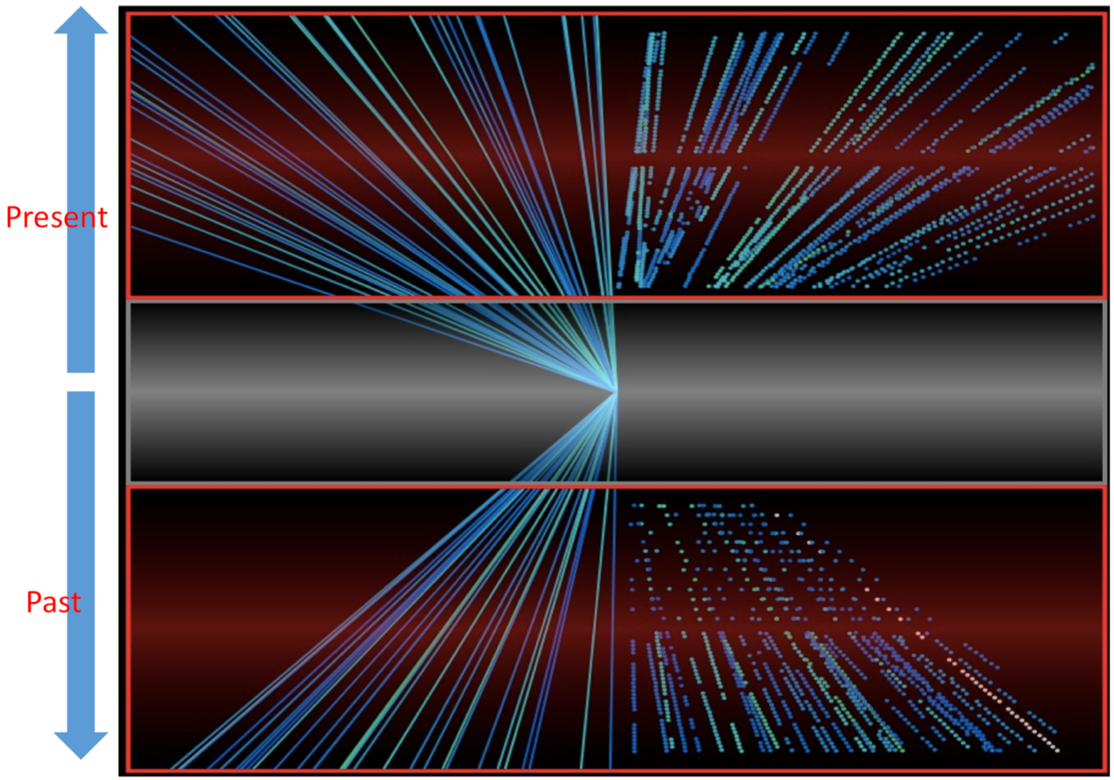


Hitmap with “old” inner TPC (≤2017)

Only one inner TPC sector upgraded (2018)

All inner TPC sectors upgraded (2019)

iTPC upgrade

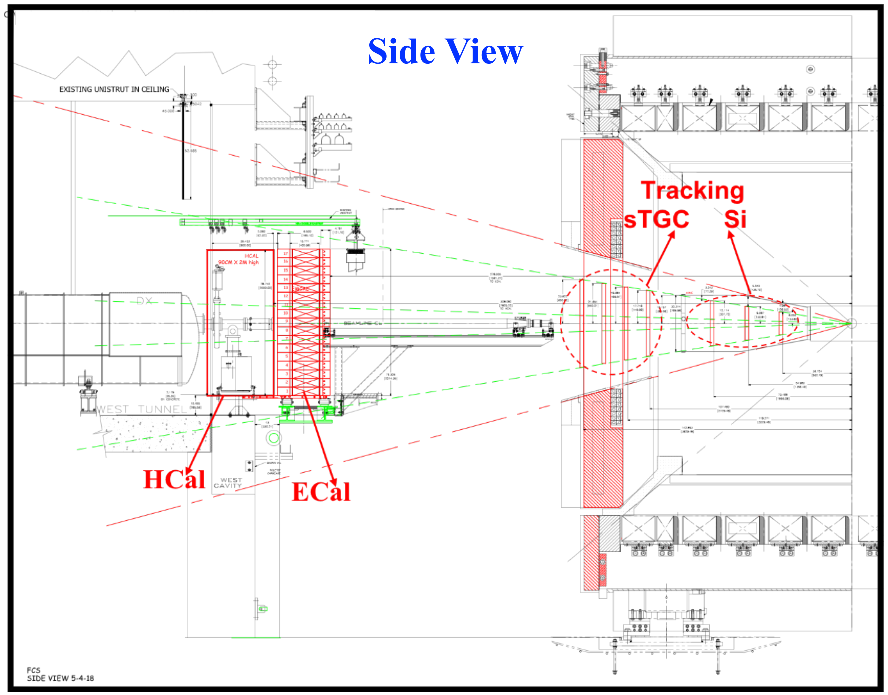


DOE close-out review:
"A success story!"

"Shandong University should be recognized for this technical achievement as well as for the team's willingness and ability to recover schedule delays caused by upstream technical and performance issues."

Congratulations to Qinghua Xu and Chi Yang!

STAR forward upgrade for 2.5 < η < 4



Calorimetry:
Electromagnetic and Hadronic

Tracking:
Silicon detectors and
small-strip Thin Gap Chambers (sTGC)

pp, pA and AA data taking in FY2021/22 and parallel with sPHENIX data taking period

AA physics at 200 GeV for 2023-2025:
Constrain 3D hydro evolution
Temperature dependent η/s
Rapidity dependent vorticity

Successful cost and schedule review on Nov 19, 2018, BNL

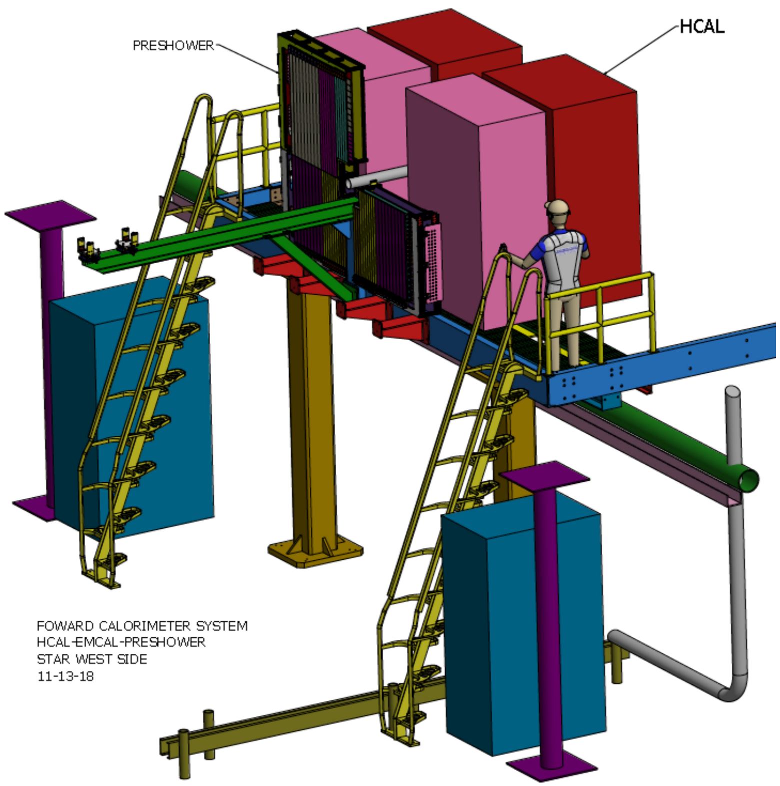
Key Performance Requirements

Charged sign separation for cold QCD physics

Momentum resolution 20-30% for peripheral heavy ion physics

Detector	pp and pA	AA
ECal	~10%/√E	~20%/√E
HCal	~50%/√E+10%	---
Tracking	charge separation photon suppression	$0.2<p_T<2$ GeV/c with 20-30% $1/p_T$

ECal & HCal



Location: 7 m from the IP on the "FMS platform"
Readout: SiPMs

- Used in Trigger
- Split in 2 movable halves inside and outside of ring
- Slightly projective

ECal:
reuse PHENIX PbSC calorimeter with new readout on front phase → 1496 channels

- Secured one Sector (2592 towers) PbSc towers: 5.52 x 5.52 x 33 cm3 (18 X_0)
  66 sampling cells with 1.5 mm Pb,
  4 mm SC & Wavelength shifting fibers

HCal:

- Fe/Sc (20mm/3 mm) sandwich.
- 520 readout channels
- Lateral tower size 10 x 10 cm2, ~ 4.5 l
  - in close collaboration with EIC R&D

Preshower

- Reuse 2 of the existing planes from the FMS-pre-shower operated in 2015 & 2017
- SC-slats with SiPM readout

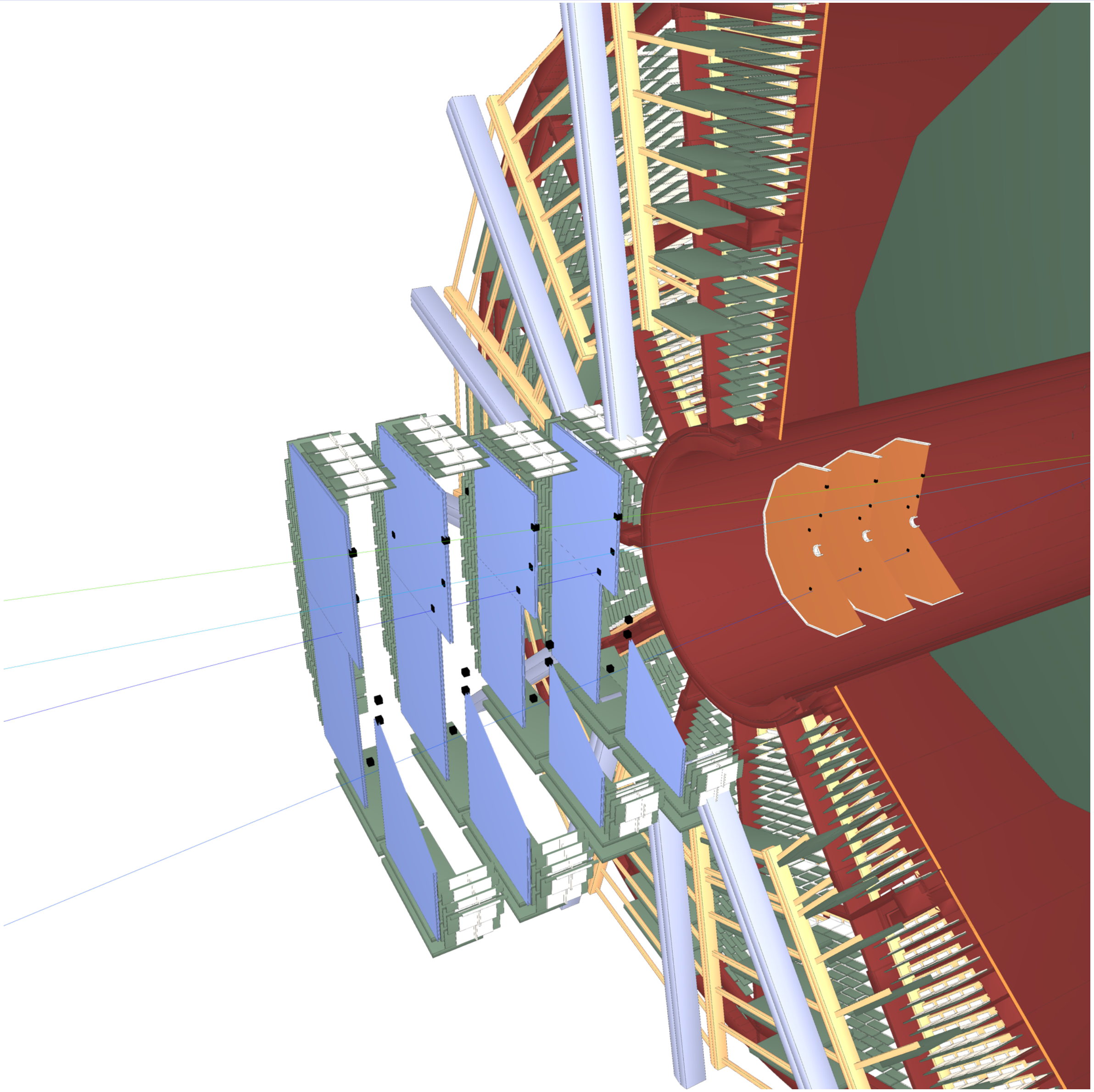
ECal & HCal

NSF proposal submitted Jan 2019

- Funding for Forward Calorimeter systems

Received very positive feedback
Awaiting final response from NSF Division of Grants and Agreements - expect to be funded

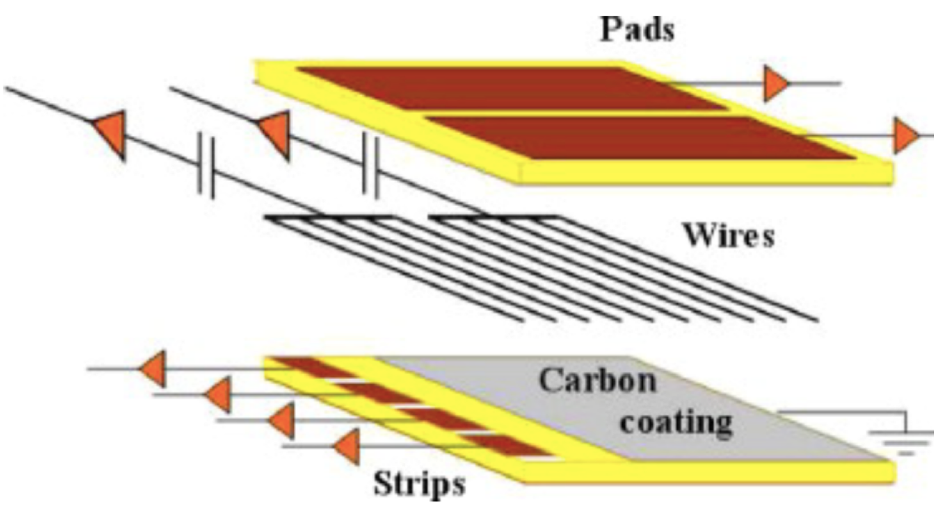
The tracking

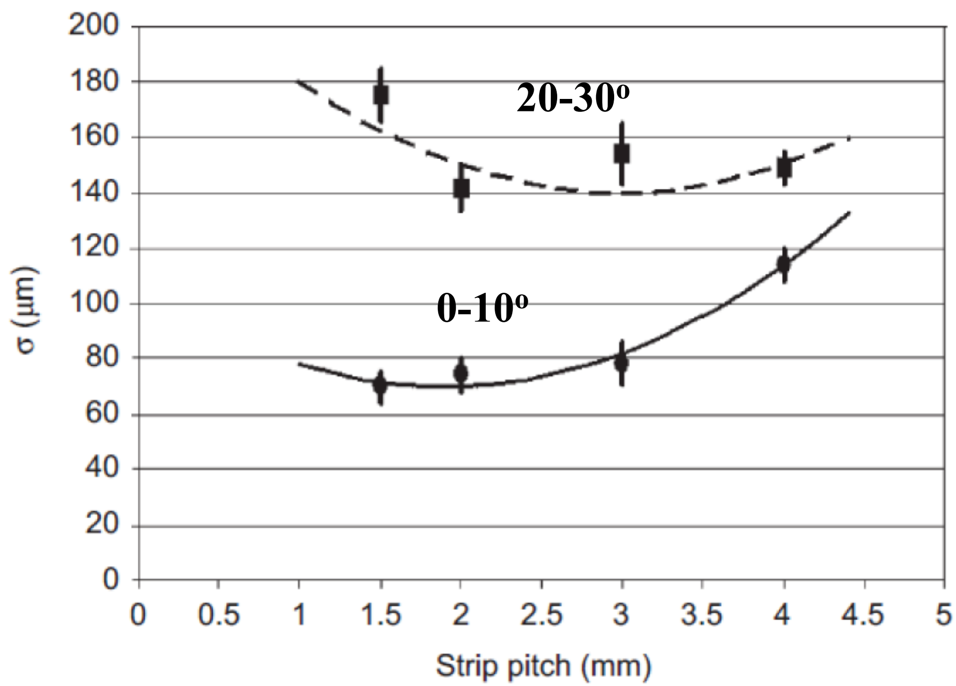


The sTGC

The size will be around 60 cm ✖ 60 cm. Four double-sided sTGC with x, y, and diagonal-direction readouts will form a disk. We will have 22000 readout channels in total.

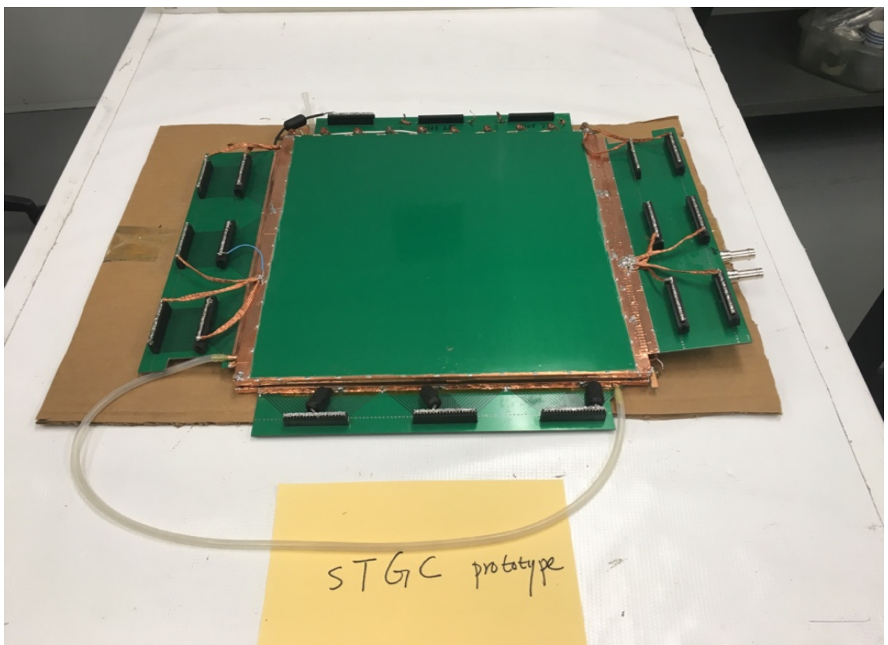
The sTGC module is much smaller than ATLAS sTGC.
All the PCB boards can be fabricated in China.

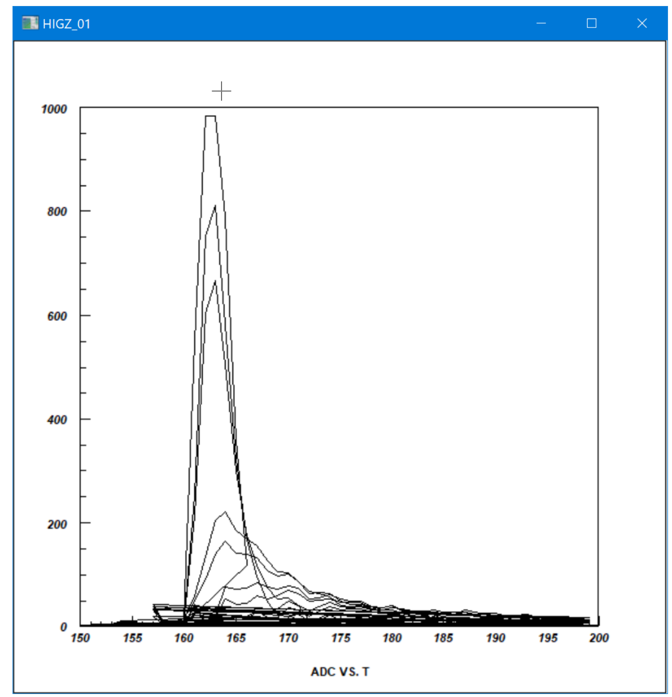




sTGC module production

Shandong University (SDU) will produce all the modules. Funds are available now.
SDU has established a procedure to build and test an sTGC module for STAR.
The same group has completed the iTPC module production timely.
A prototype of 30 cm ✖ 30 cm was built and tested with TPX electronics at SDU last year, and shipped to BNL in Jan. 2019. A large signal was seen. The prototype was installed to STAR on June 5, 2019.

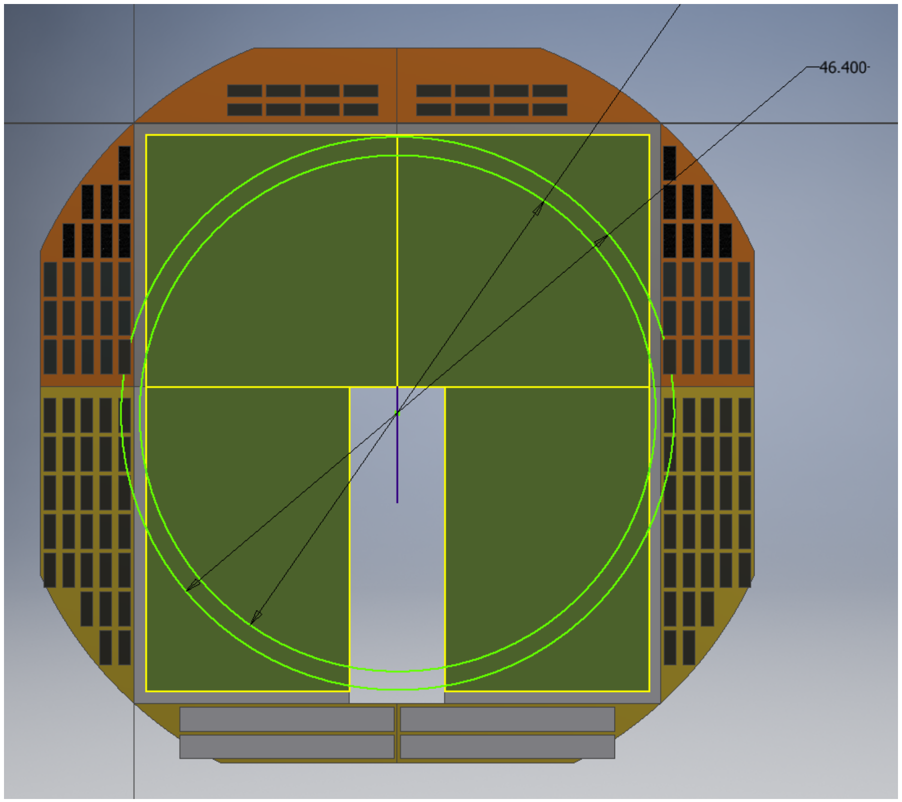


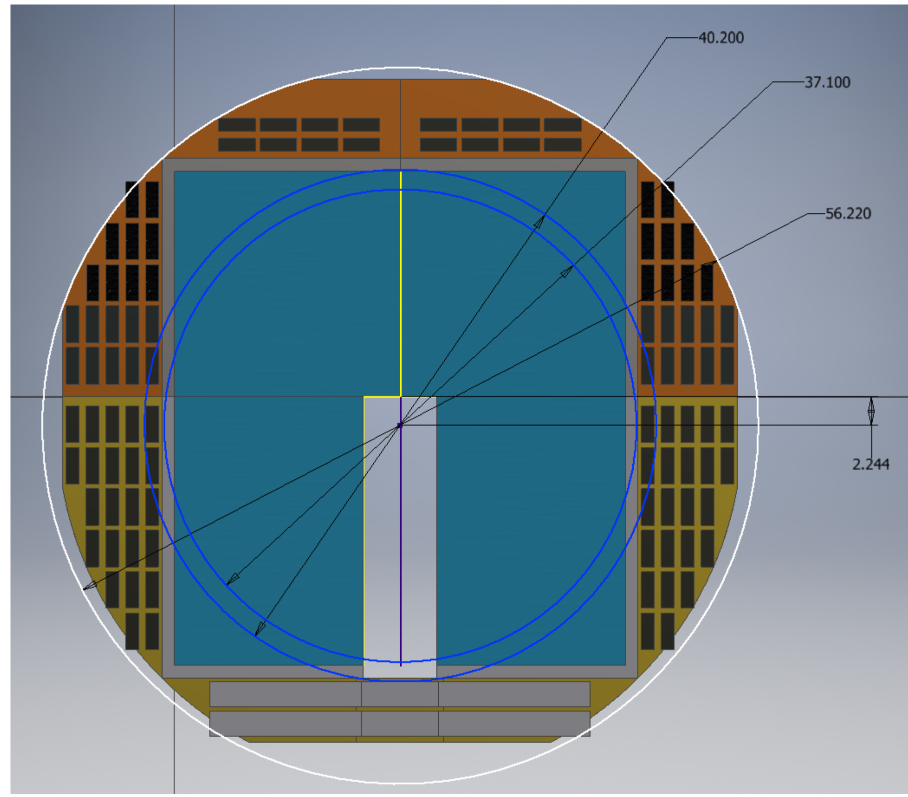


SDU started to build another 3 prototypes of 60 cm ✖ 60 cm. Expect to have performance results such as position resolution, efficiency with different gas mixtures this summer.

sTGC electronics readout

- Each double module with x-y readout need 30 TPX FEEs and 1 RDO. The length of ribbon cable from FEE to RDO need to be less than 75 cm. No enough space for FEEs and RDOs if using old TPX electronics!!!

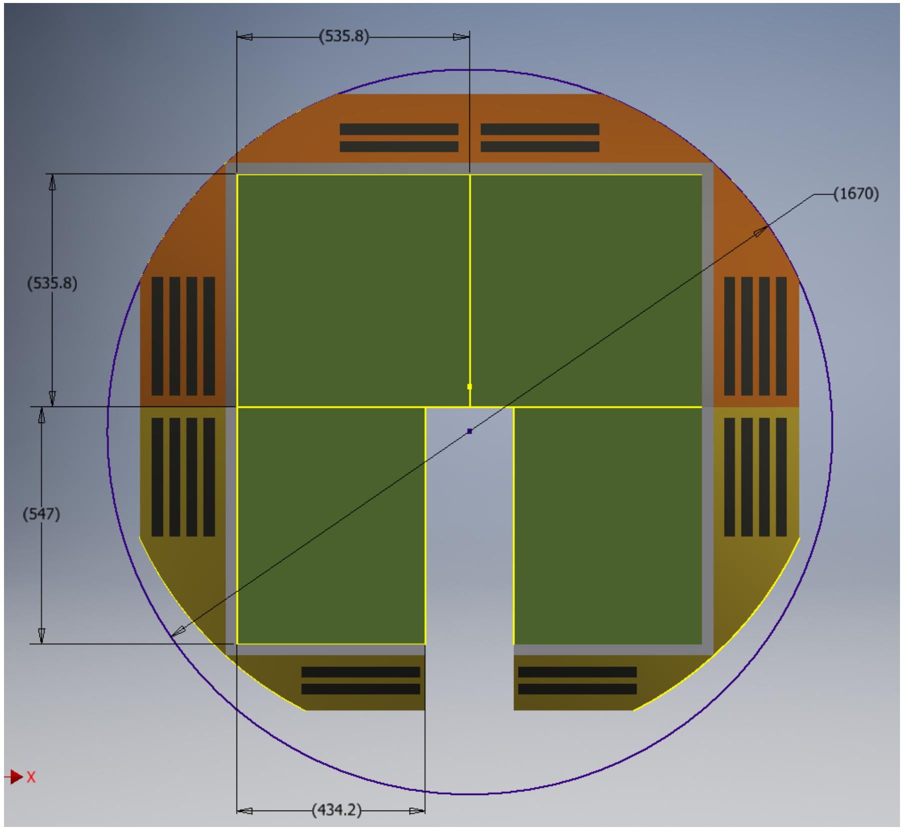


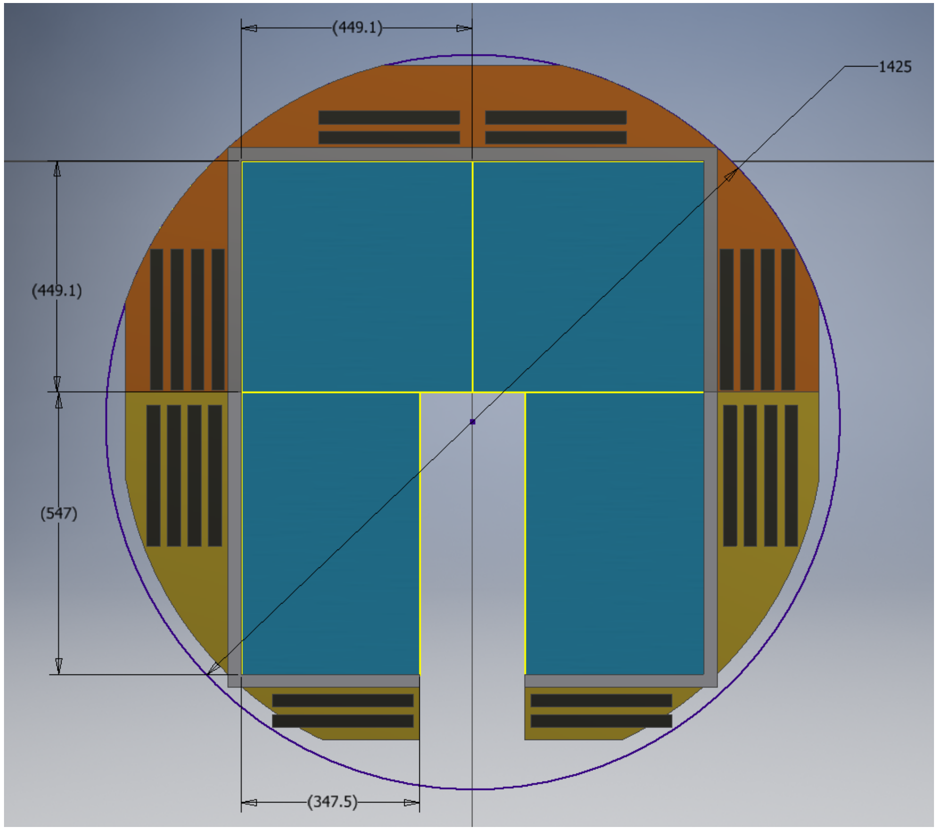


Solution: use ALTAS electronics based on VMM trips or use electronics boards based on SAMPA chips designed for sPHENIX. Cost: 150 k USD in total. USTC will apply MOST funds in China for VMM option while BNL has to pay for SAMPA option. Finalize the option this summer.

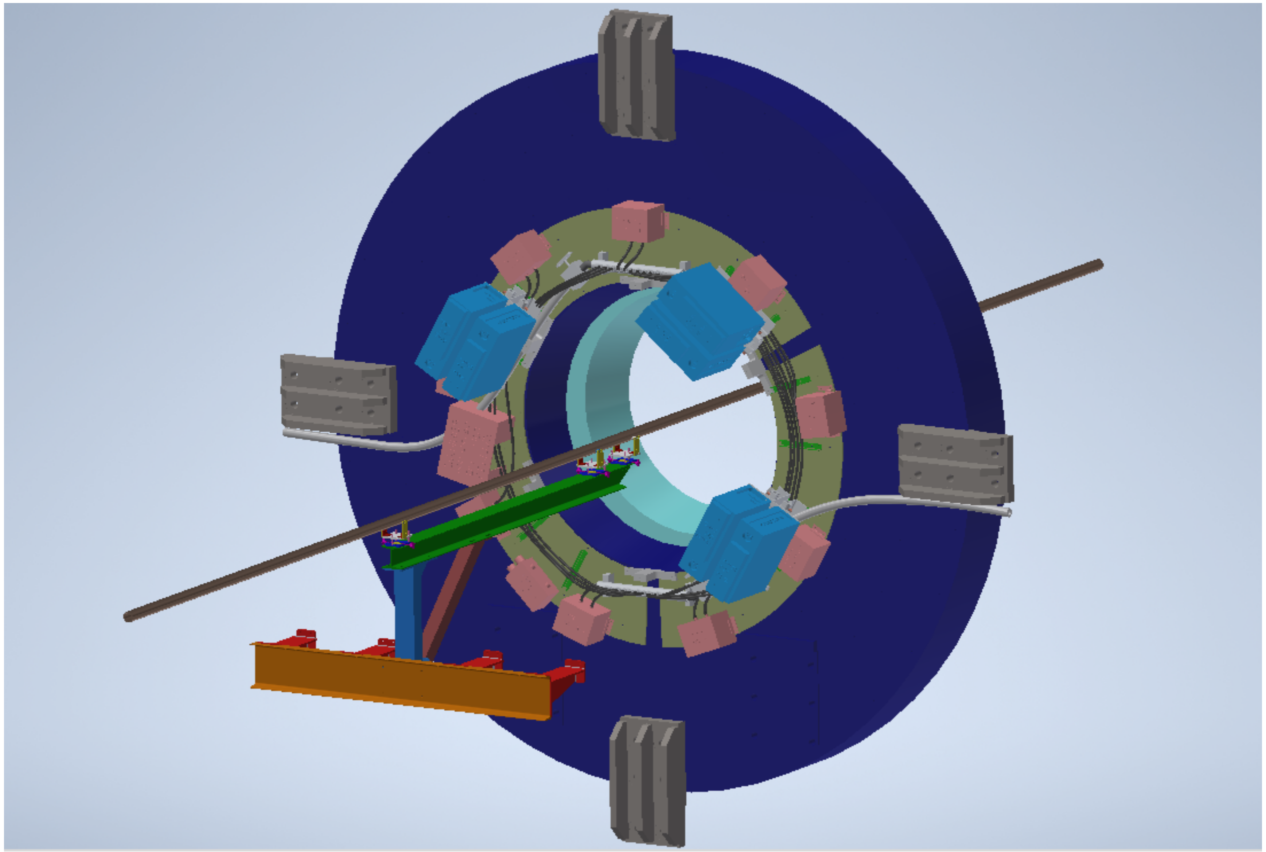
sTGC integration

- With SAMPA option

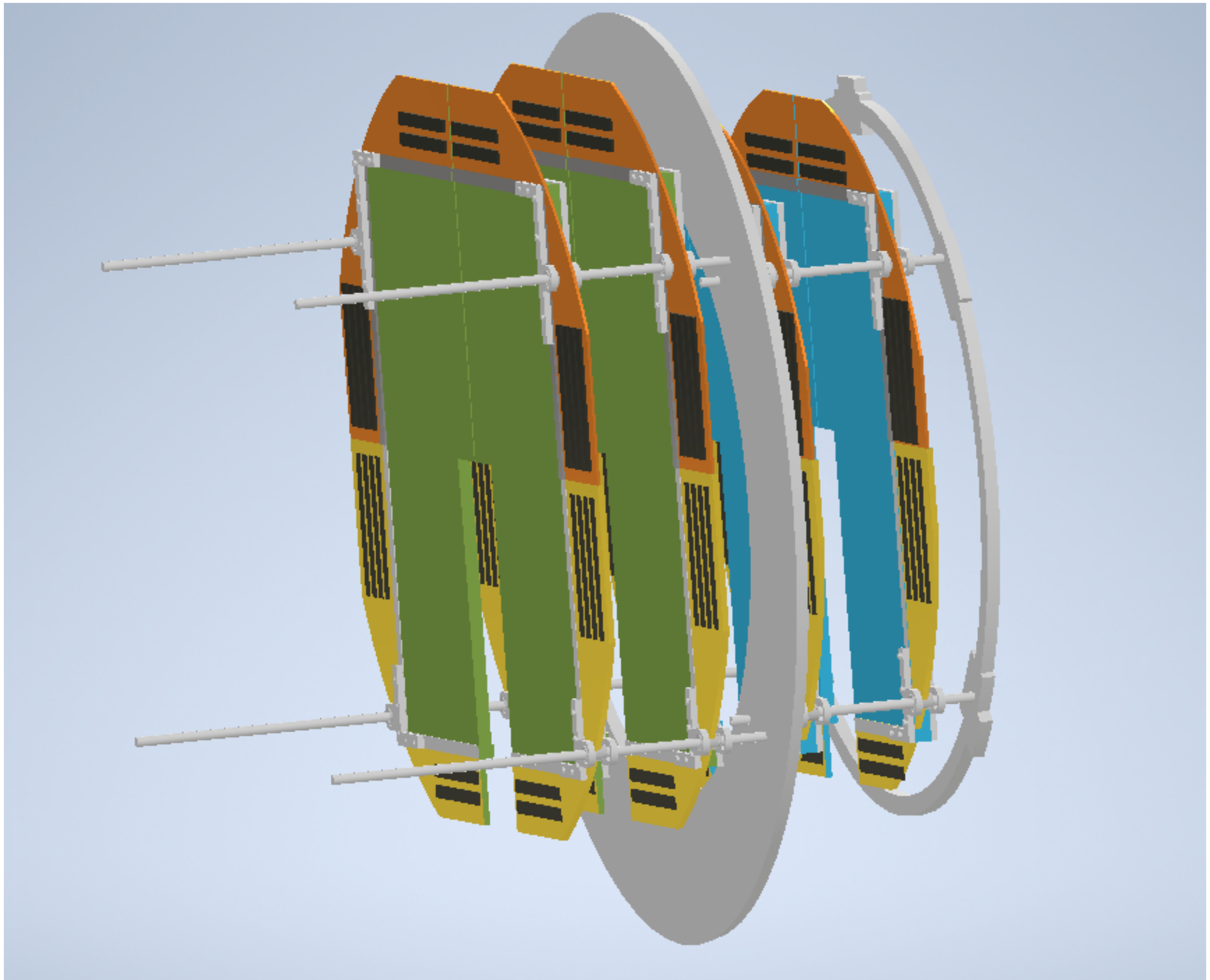




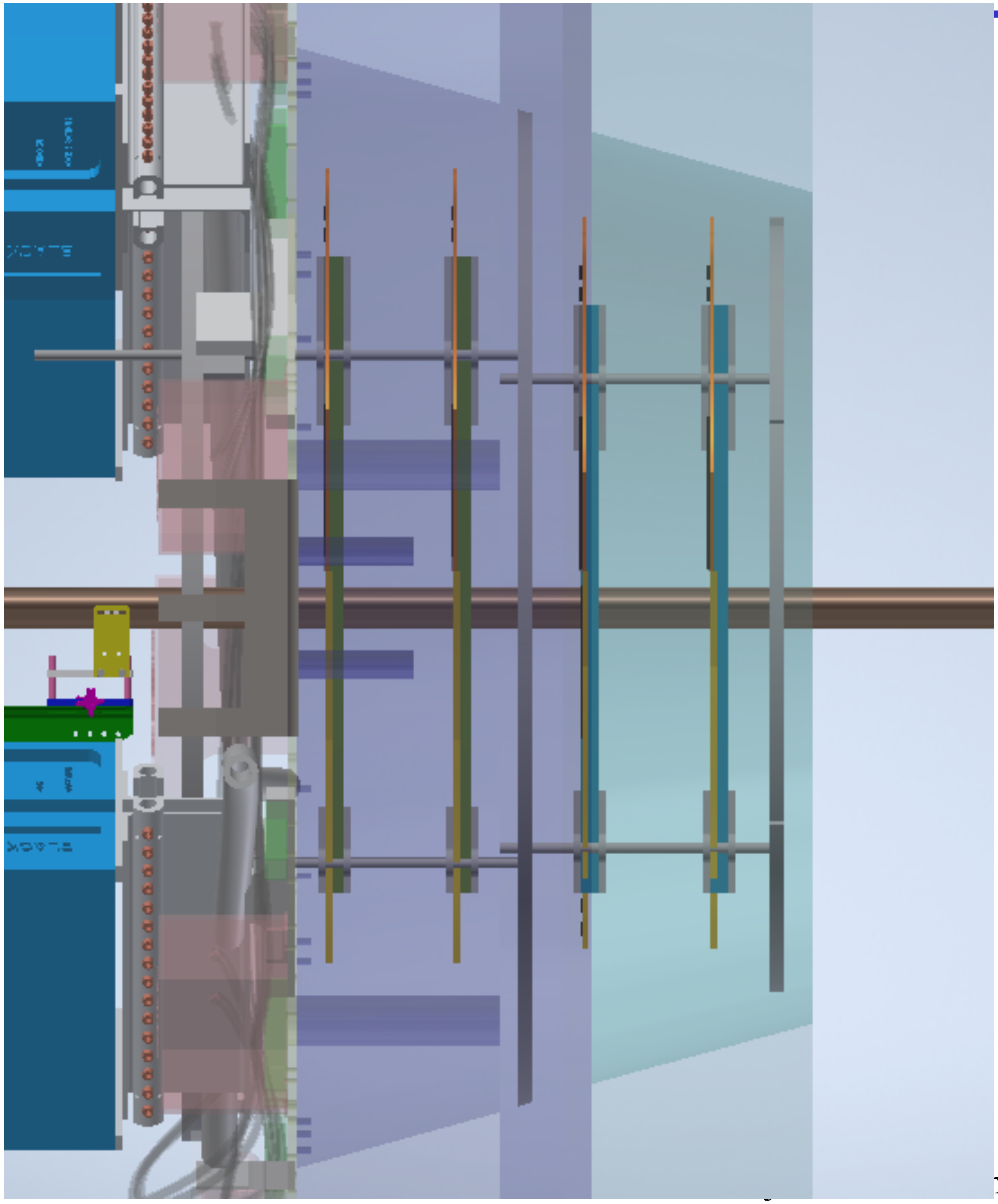
sTGC integration

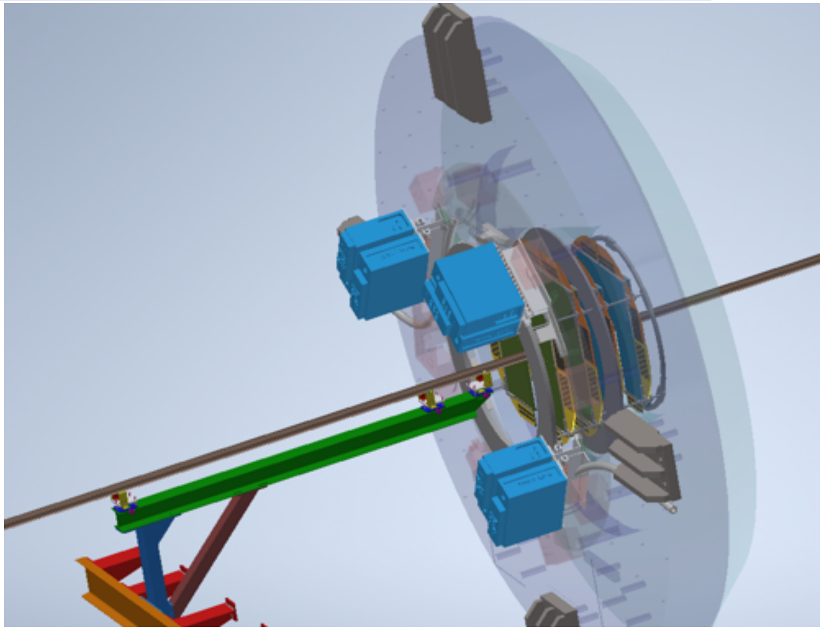


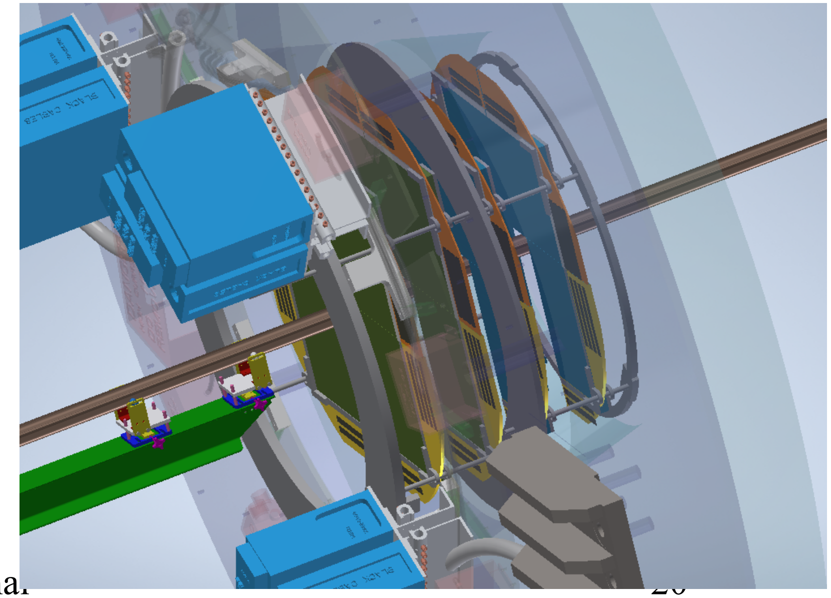
sTGC integration



sTGC integration



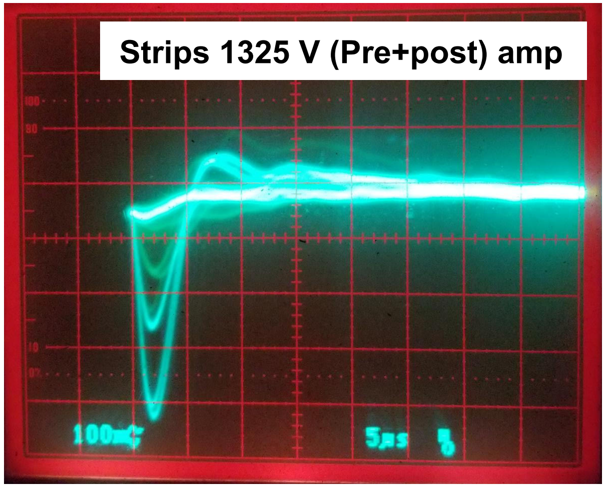




sTGC gas

For sTGC, we plan to use gas mixture: 45% n-pentane and 55% CO_2
n-pentane is flammable.
Gas flow rate: less than 400 ccm.

The review committee in Nov. 2018 recommended us to look for alternative options. At BNL, we tried different gas mixtures and eventually chose C10 (90% argon + 10% CO_2) for our run19 test. We saw a good signal however the efficiency is as low as 10%-30%.



SDU will test 3 new prototypes with different gas mixtures this summer. At the same time, we contacted ATLAS experts and are working on solutions for running n-pentane gas. We plan to finalize the gas option this summer.

Schedule

Milestones:
Aug 2019, sTGC R&D completed (build another two 60 cm✖60 cm modules)
Sep 2019, sTGC mass production readiness review
Oct 2019 to Oct 2020, mass production of 32+8 (spare) sTGCs
May 2021, Last batch of sTGCs installed at STAR
Schedule float: 6 months

SDU made a detail assessment for the production time:

#	Step	Duration(hour)
1	Material inspection/cleaning	14
2	PPPCB masking tape pasting	2
3	Graphite mixing/spraying/polishing	8
4	Half-chamber production, HV burn-in	48
5	wire winding, soldering, washing	24
6	Two half combination	24
7	Air tap installation and sealing	48
8	Gas leak inspection and repairing	4
9	Flow in CO2 HV burn-in	12
10	Flow in CO2+N.P X-ray test	24
11	CO2 washing residual N.P.	12

About 9 days per chamber, including preparation and testing.

In addition, the ALTAS sTGC production project will end in Aug-Sep, 2019.
If using their technicians, SDU can finish the project in 4-6 months after mass production is started

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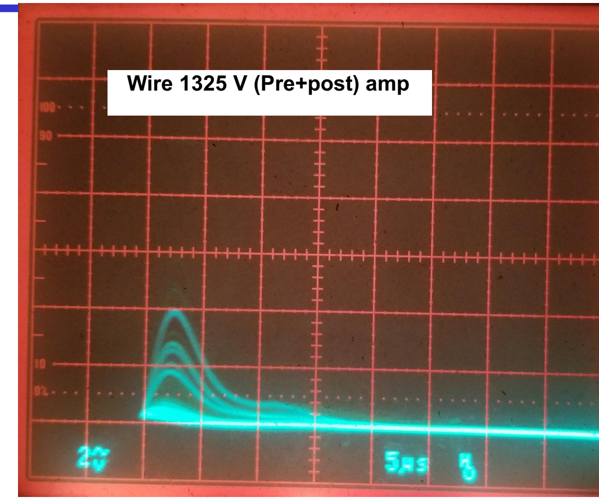
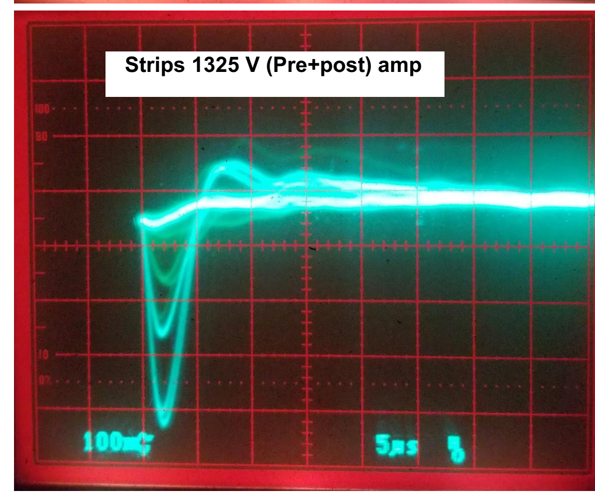
C-10 Test in the clean room

- Ar 90 % and CO_2 10%
- C-10 flown overnight
- Wire readout with Sr90:
  - 1250 V -> ~ 70 mV
  - 1300 V -> ~100 mV
  - 1350 V -> ~ 200 mV
  - 1400 V -> ~250 mV
  - 1450 V -> ~500 mV
  - 1500 V -> ~800 mV
  - 1550 V -> pre-amp saturates
  - 1600 V -> tripped
- Noise level is about 20 mV
- Pre-amp gain ~10, pre+post amp gain ~140
- Kept overnight at 1450 V -> Stable





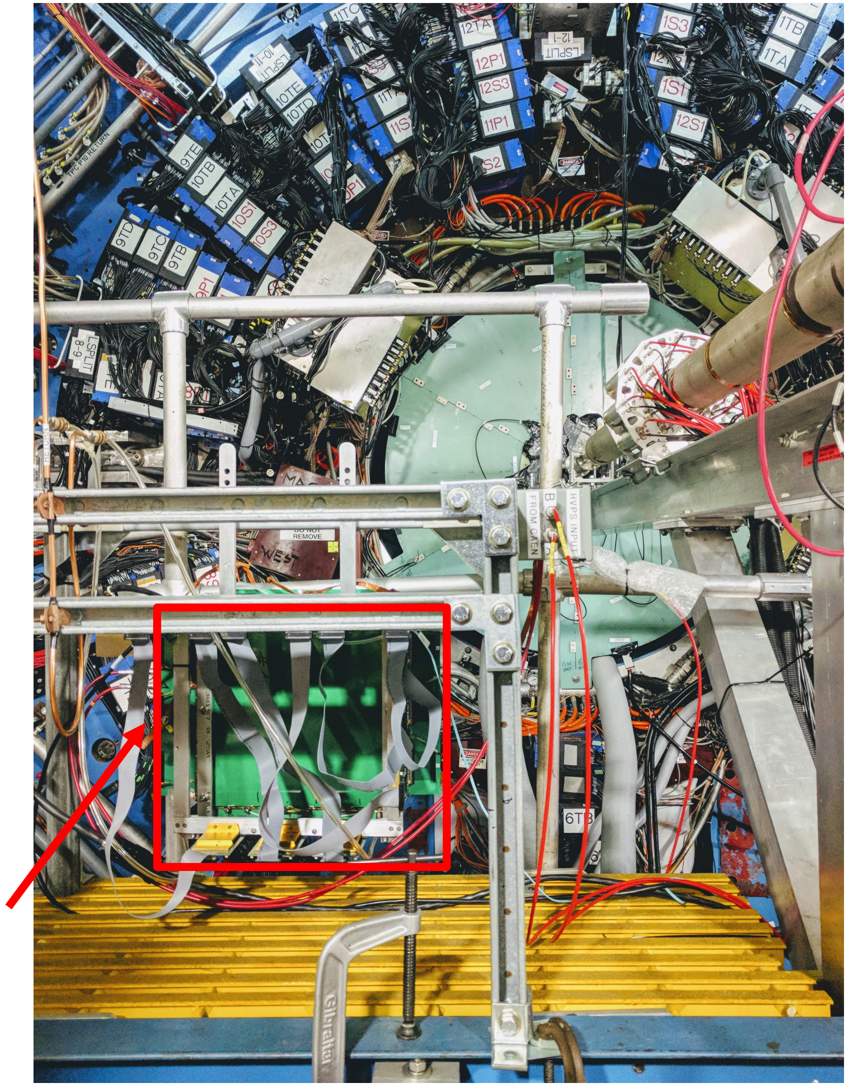
Note: pre-amp inverts the signal

sTGC prototype at STAR

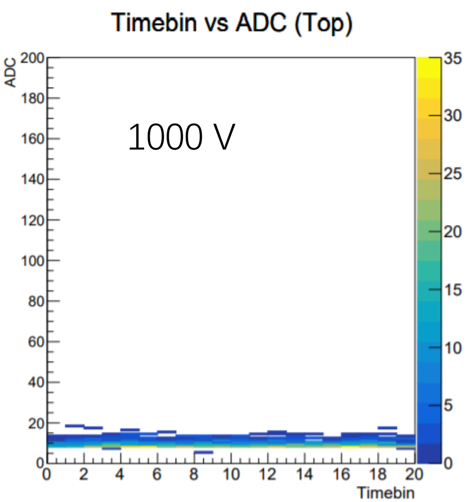
Prototype installed on June 5, 2019 at STAR

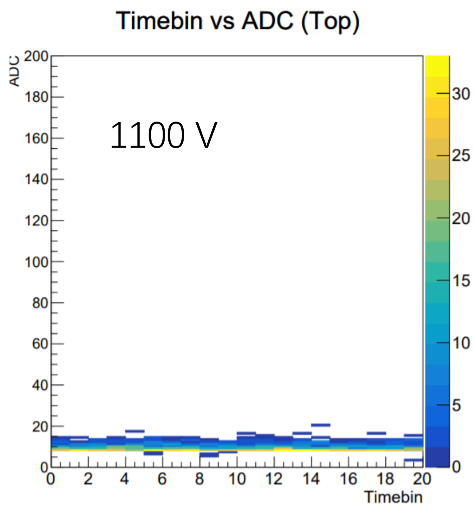
Gas: C10

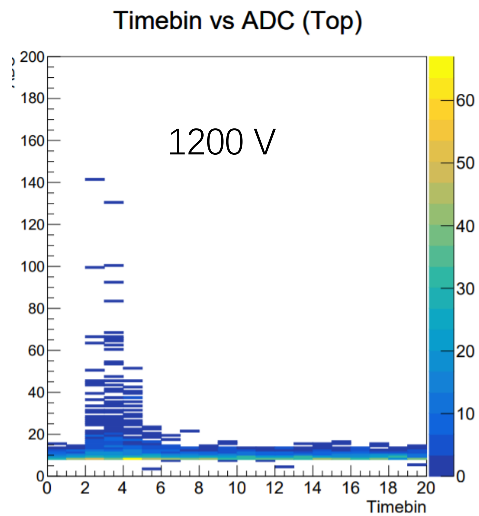
Performed a voltage scan at 7.7 GeV and 9.2 GeV Au+Au run

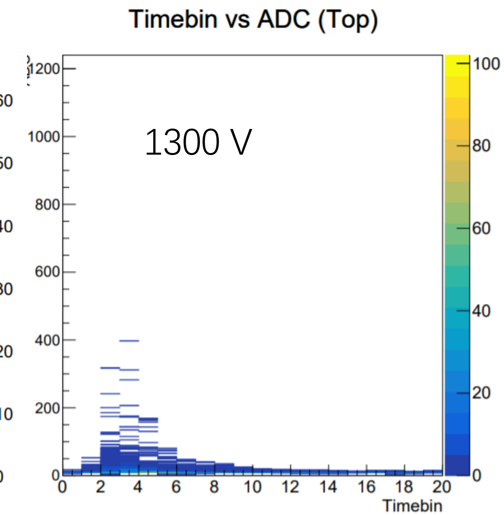


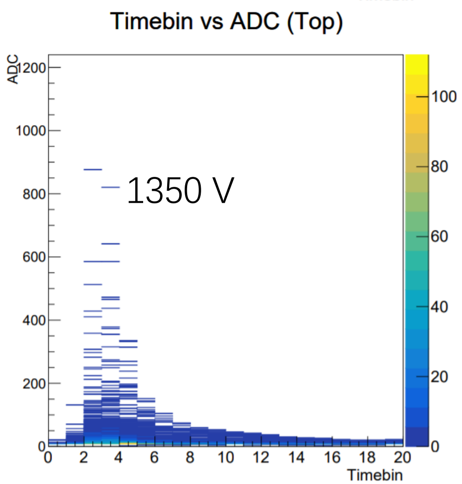
Time bin vs ADC with different high voltages

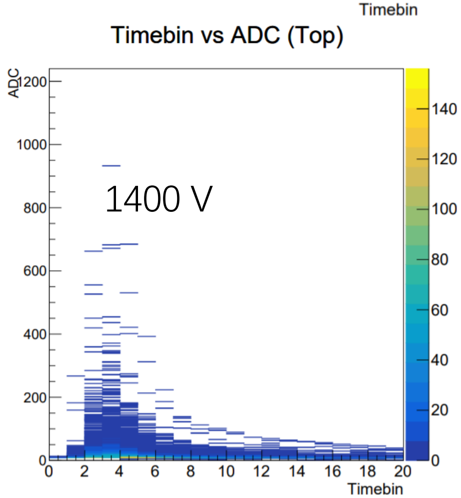


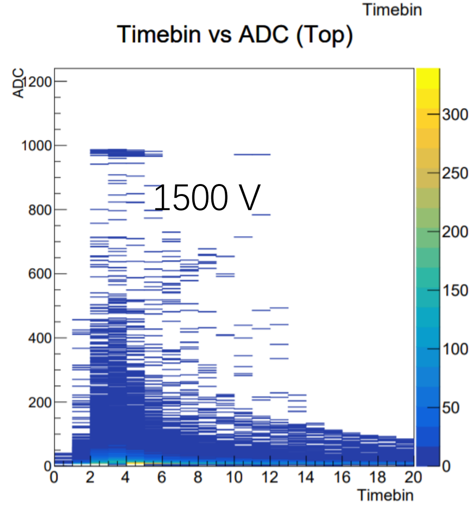








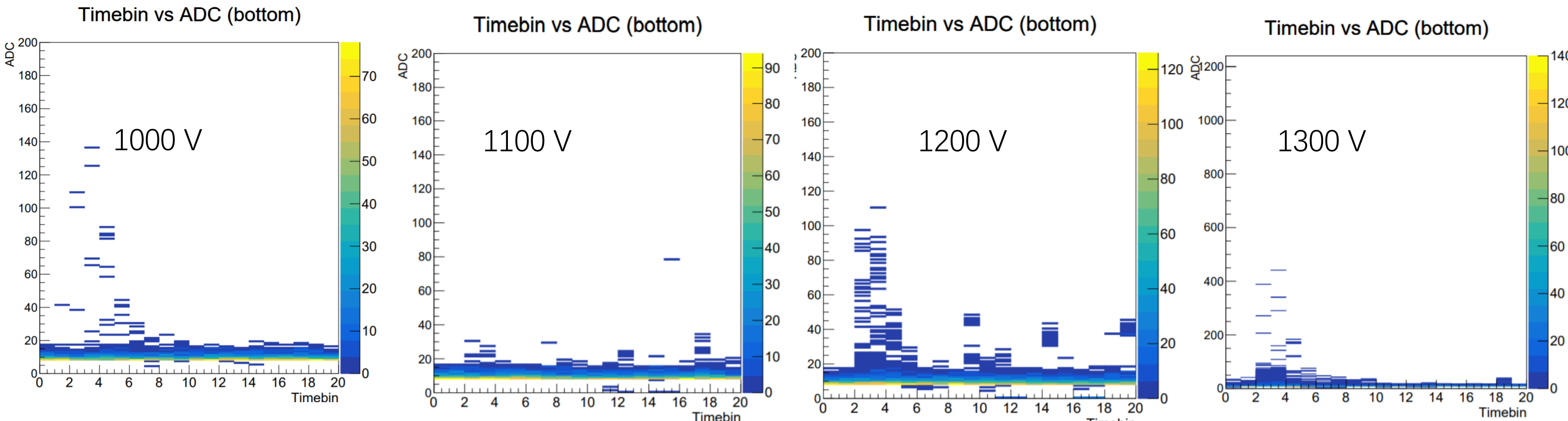


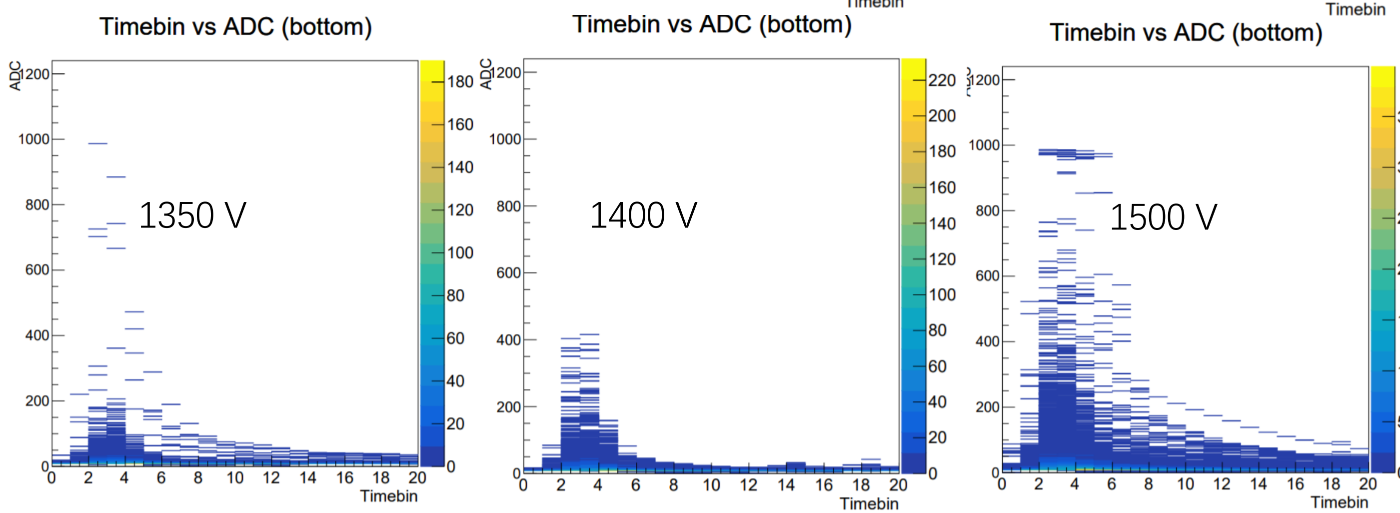


Maximums of y axis in 1300V , 1400V, 1350V, 1500V are 1200

Maximums of y axis in 1000V , 1100V, 1200V, are 200

Time bin vs ADC with different high voltages (Bottom layer)



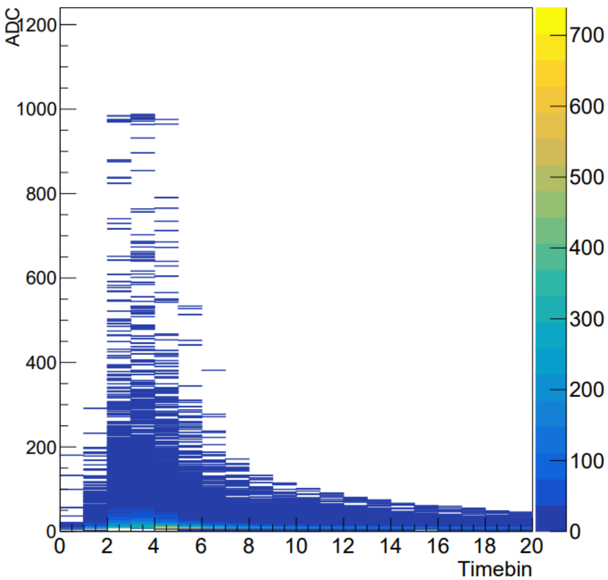


Maximums of y axis in 1300V , 1400V, 1350V, 1500V are 1200
Maximums of y axis in 1000V , 1100V, 1200V, are 200

ADC vs time bin with different HV (Top)

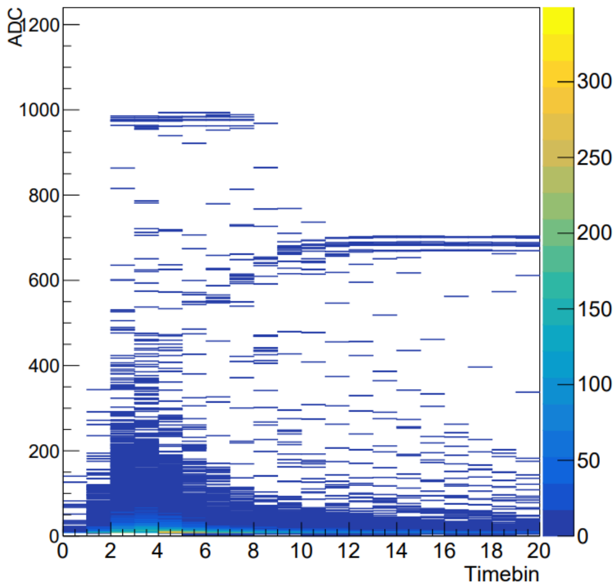
1425V

Timebin vs ADC (Top)



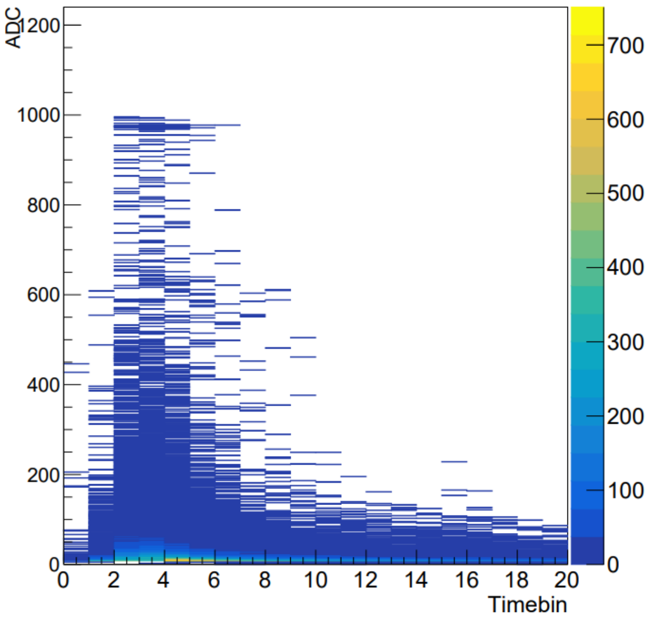
1450V

Timebin vs ADC (Top)



1475V

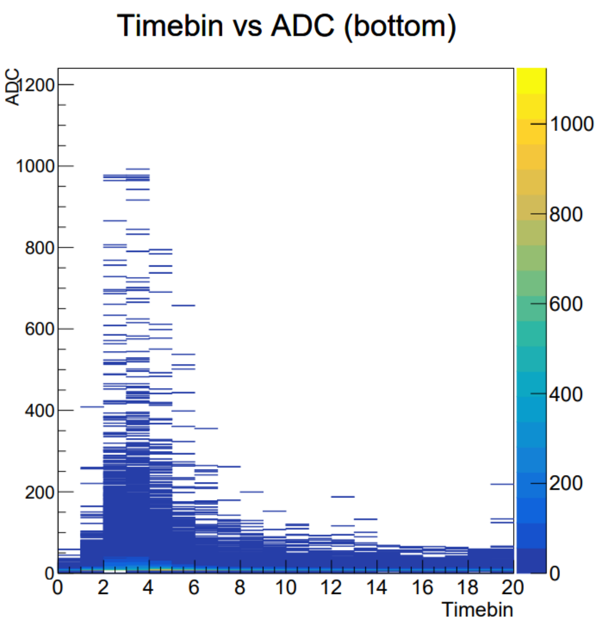
Timebin vs ADC (Top)



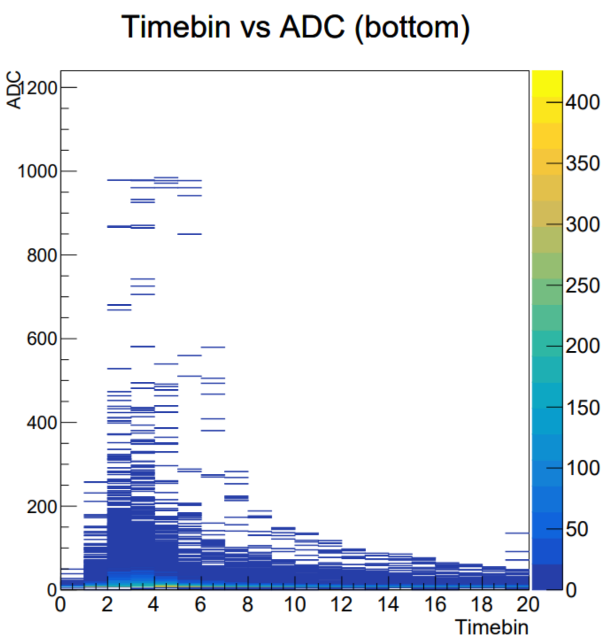
We can find a “plain” at time bin 10-20 in run with 1450V

ADC vs time bin with different HV (Bottom)

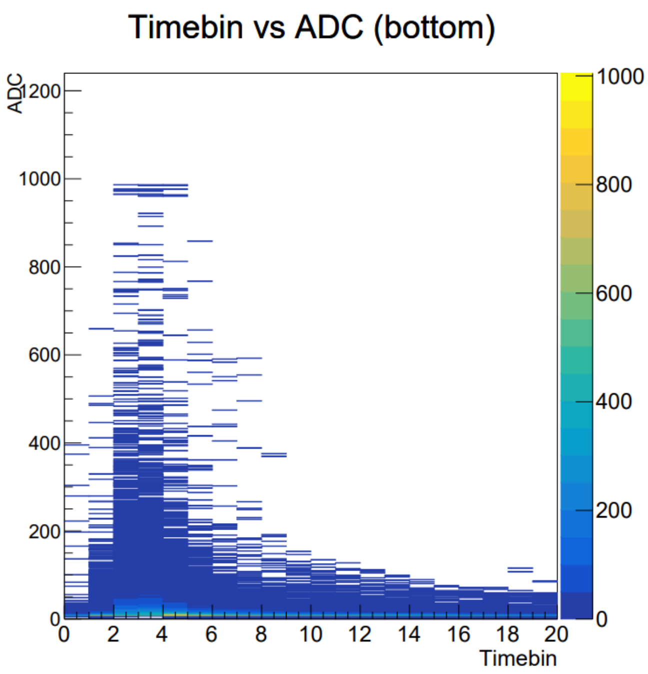
1425V



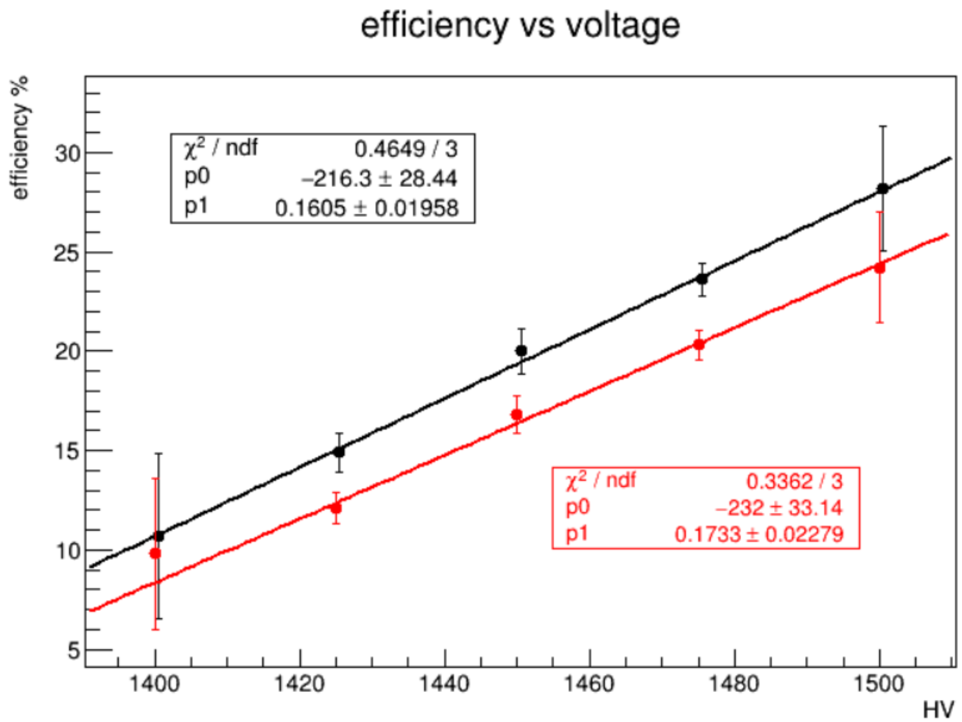
1450V



1475V



Efficiency with different HV



Efficiency increases linearly with increasing voltage

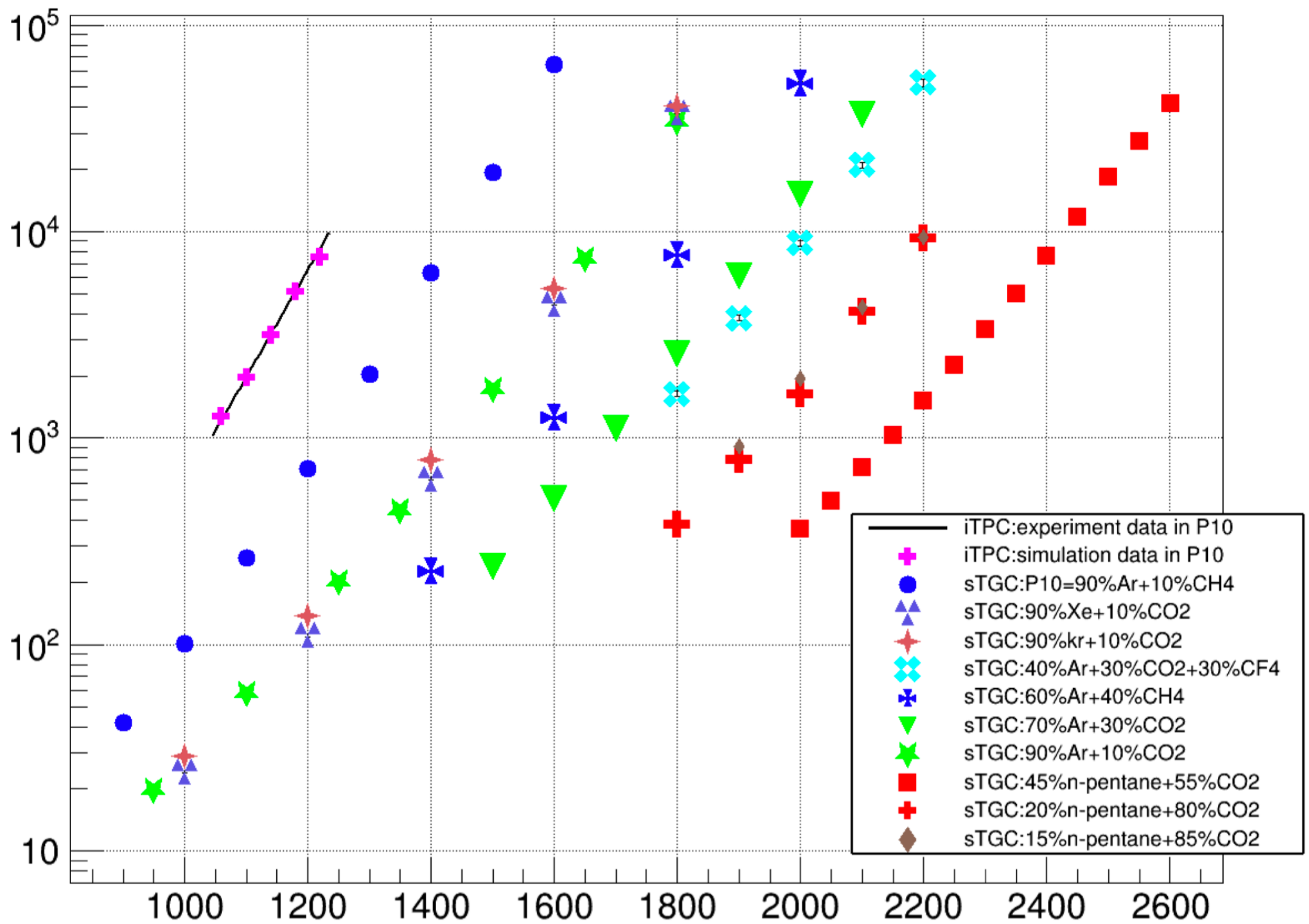
Isaac (sTGC operation)
Prashanth (co run-coordinator)
Zhen Wang (analyze data)
Daniel Brandenburg (forward upgrade software coordinator)
Zhenyu Chen (sTGC software point of contact)

sTGC gas gain simulation

Simulation done by Yingying Shi

BNL will order Xe and Kr gas this summer and will test the efficiency with different gas mixtures

If using 30 um wire, we might not need n-pentane



Conclusion

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There is a team on board for the sTGC detector. The team has been successful to deliver the STAR upgrade projects timely: TOF (2008-2010), MTD (2011-2014), and iTPC (2016-2018).

The 3 silicon disks + 4 sTGC disks will provide the forward tracking, and meet the requirement of the cold QCD and heavy ion physics.

The sTGC prototype is fully integrated to STAR.

Path forward:

1. Decide VMM versus SAMPA this summer
2. Work with safety committee to get the n-pentane/CO_2 gas system approved in the clean room for the summer shut down test
3. Test efficiency with different gas mixtures for the prototype

For SDU

1. For the sTGCs of 60*60 cm2, test them with TPX/ATLAS electronics and with different gas mixtures so that we know whether absolutely we need n-pentane or we have an alternative

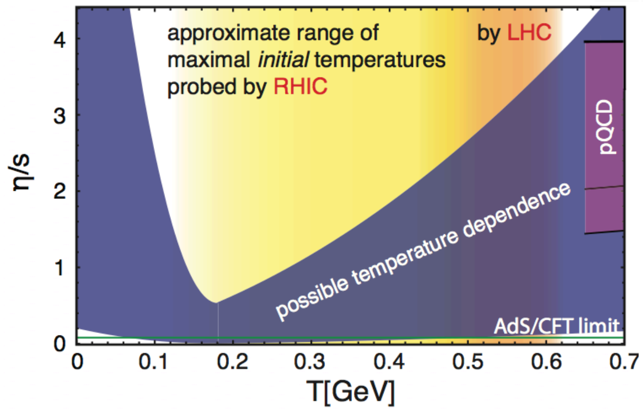
STAR forward upgrade has an important impact on EIC detector technology choices.

The physics program enabled by STAR forward upgrade is very important for us to sharpen the EIC physics cases!

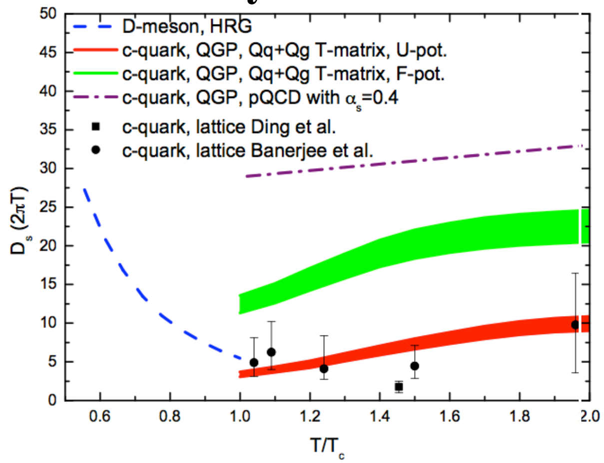
Backup

Transport coefficients

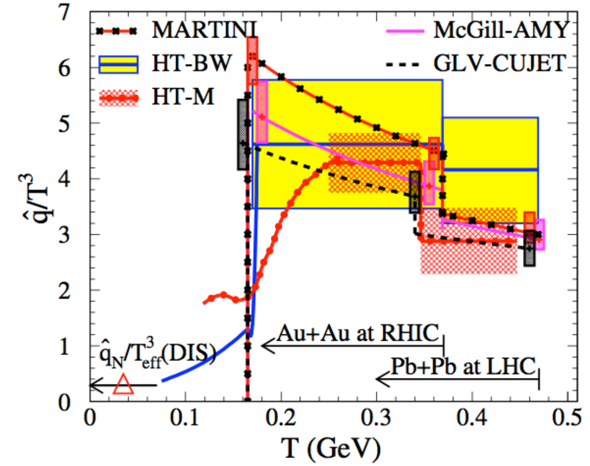
Flow and particle correlation



Heavy flavor



Jets



Currently η/s and 3+1D hydro are essentially constrained by bulk measurements.

Utilizing 3+1D viscous hydro evolution and the heavy flavor measurements, one can constrain heavy flavor diffusion coefficient.

Utilizing 3+1D viscous hydro evolution and the jet related measurements, one can obtain jet transport coefficients (the average squared transverse momentum broadening per unit length and longitudinal energy loss coefficient with the latter constrained by heavy flavor).

Direct constraints on the temperature dependence of η/s from bulk observables are essential to understand heavy flavor and jet physics.

i-Butane Test

- Ar 70% + C_4H_{10} 30%
- Flown for about 40 min
- Strip readout:
  - Noise 20 mV
  - 1500 V -> ~ 40-60 mV
  - 1600 V -> ~100-150 mV
  - 1700 V -> ~200-300 mV and trip
  - 1800 V -> ~400 -600 mV and trip fast