Brookhaven National Laboratory

STAR

small-Strip Thin Gap Chamber as a STAR Forward tracker

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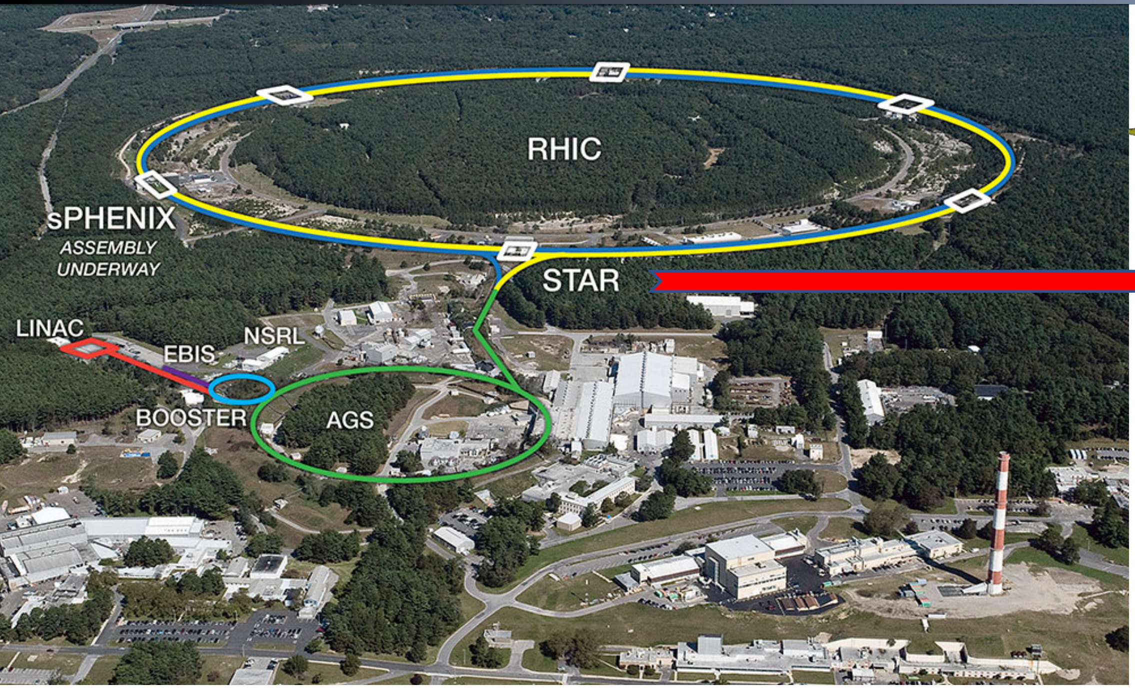
(for the STAR Collaboration)

U.S. DEPARTMENT OF ENERGY

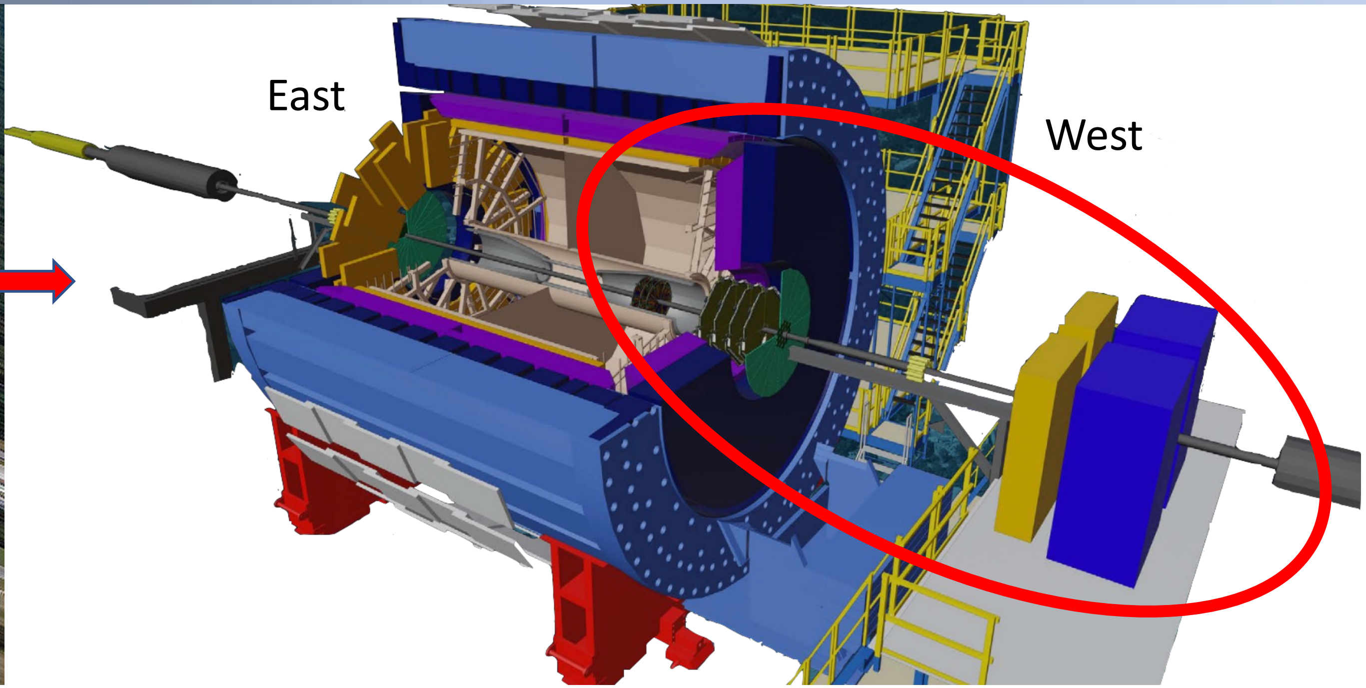
Office of Science

DNP2022

STAR Forward Upgrade



Relativistic Heavy Ion Collider (RHIC)
Long Island, NY

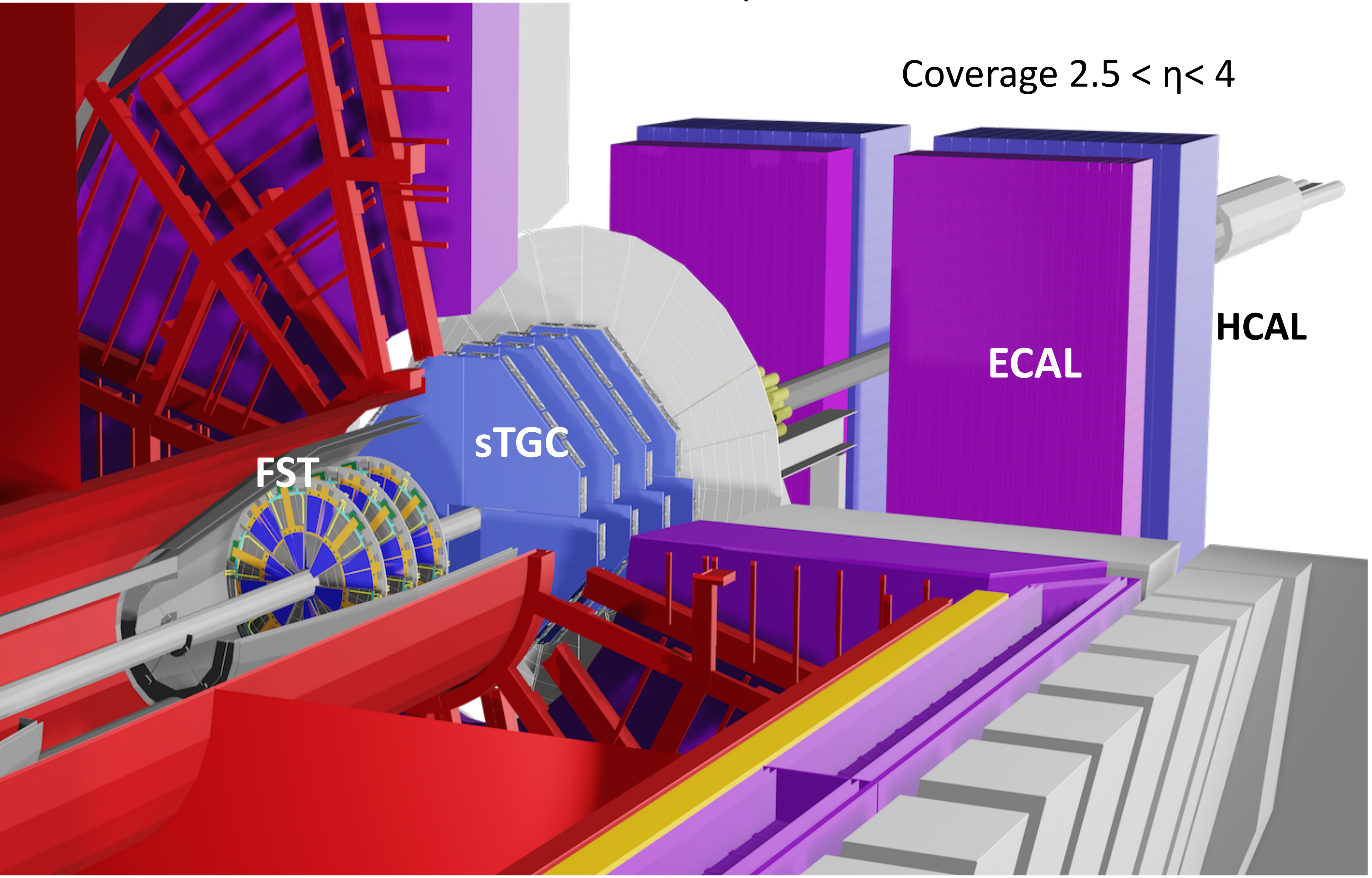


STAR Experiment
(The Solenoidal Tracker At RHIC)

- STAR Forward Upgrade (2021+)
  - p+p: Proton transverse spin structure
  - p+A: gluon saturation at small-*x*
  - A+A: initial state conditions
- Measures
  - h+/-, e+/-(with good e/h discrimination)
  - Photons, π^0, jets

STAR Forward Upgrade

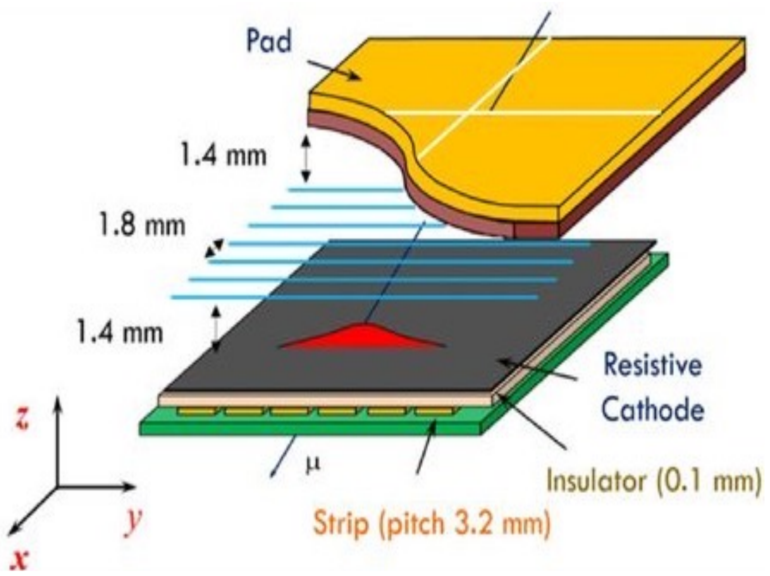
West side of STAR experiment

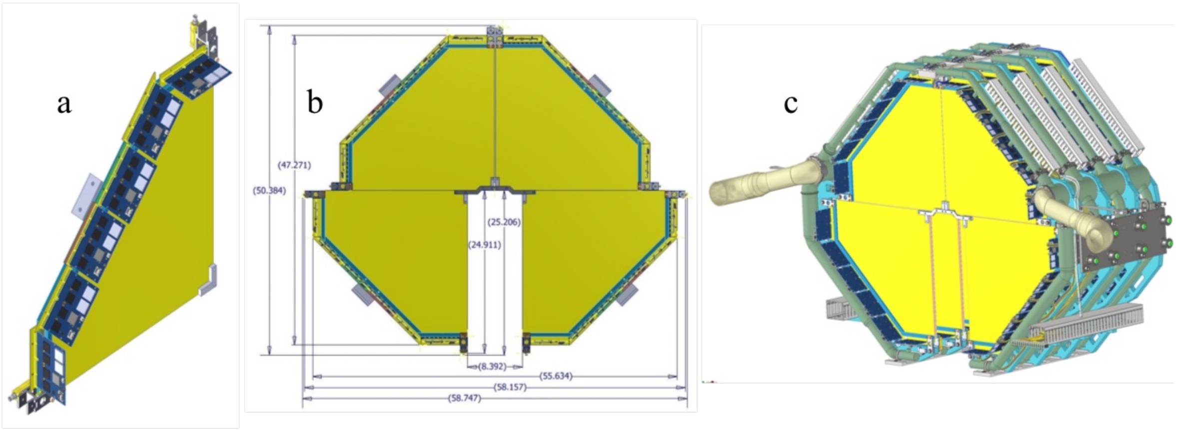


- Four new sub-systems:
  - Charged particle tracking
    - Forward Silicon Tracker
    - small-Strip Thin Gap Chambers (sTGC)
  - Electromagnetic calorimeter
  - Hadronic calorimeter
- Covers the pseudorapidity region 2.5 < η< 4
- Rapidity coverage is the same as the Electron Ion Collider hadron arm

- Calorimeter:LC.00002: Improving Energy Resolution for the STAR Forward Calorimeter System
- LC.00003: Calibrating the Electromagnetic Calorimeter of the STAR Forward Calorimeter System using p + p collision data at √s = 510 GeV data
- Forward upgrade proposal
- Beam use request

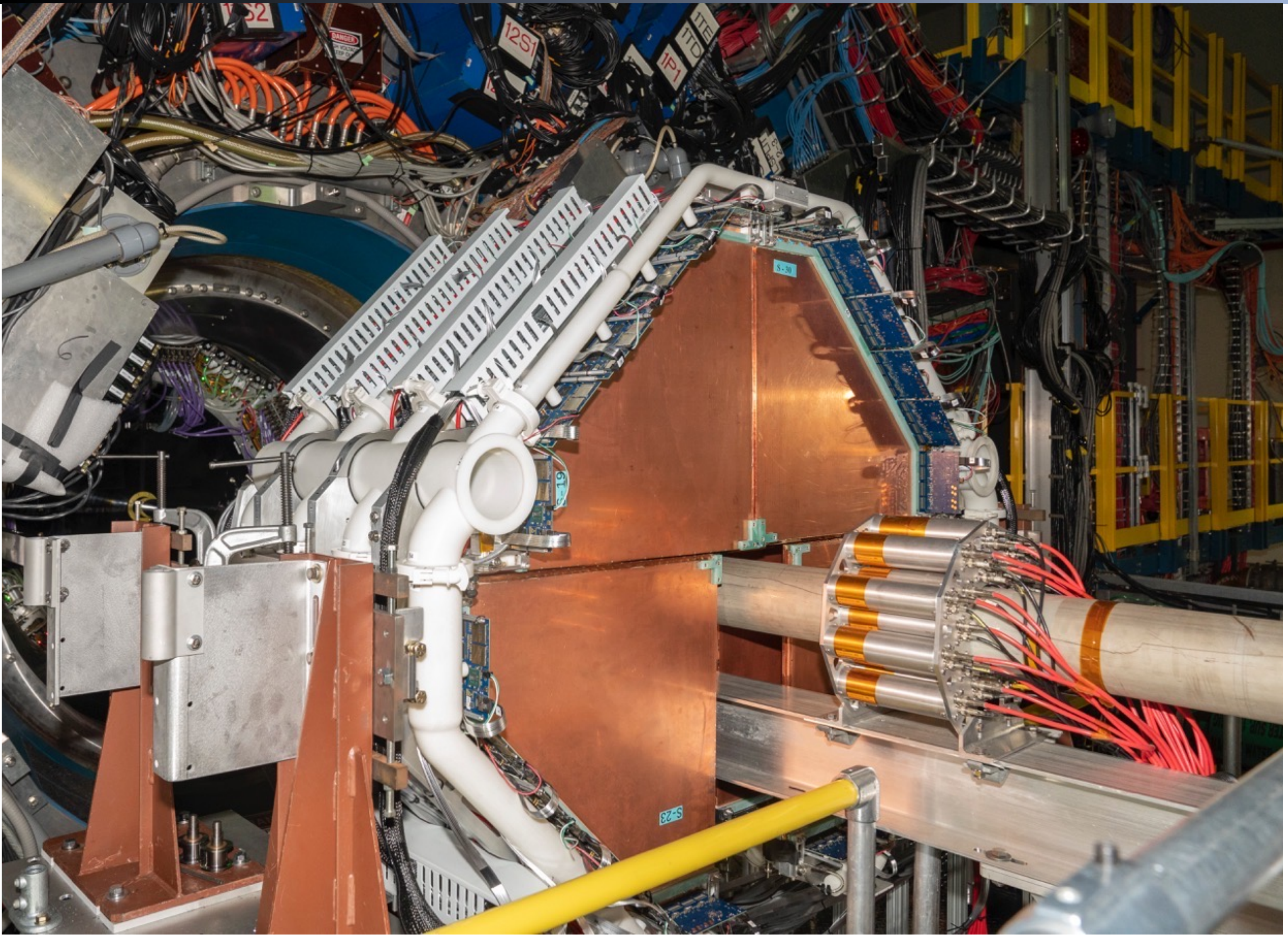
Small-Strip Thin Gap Chamber



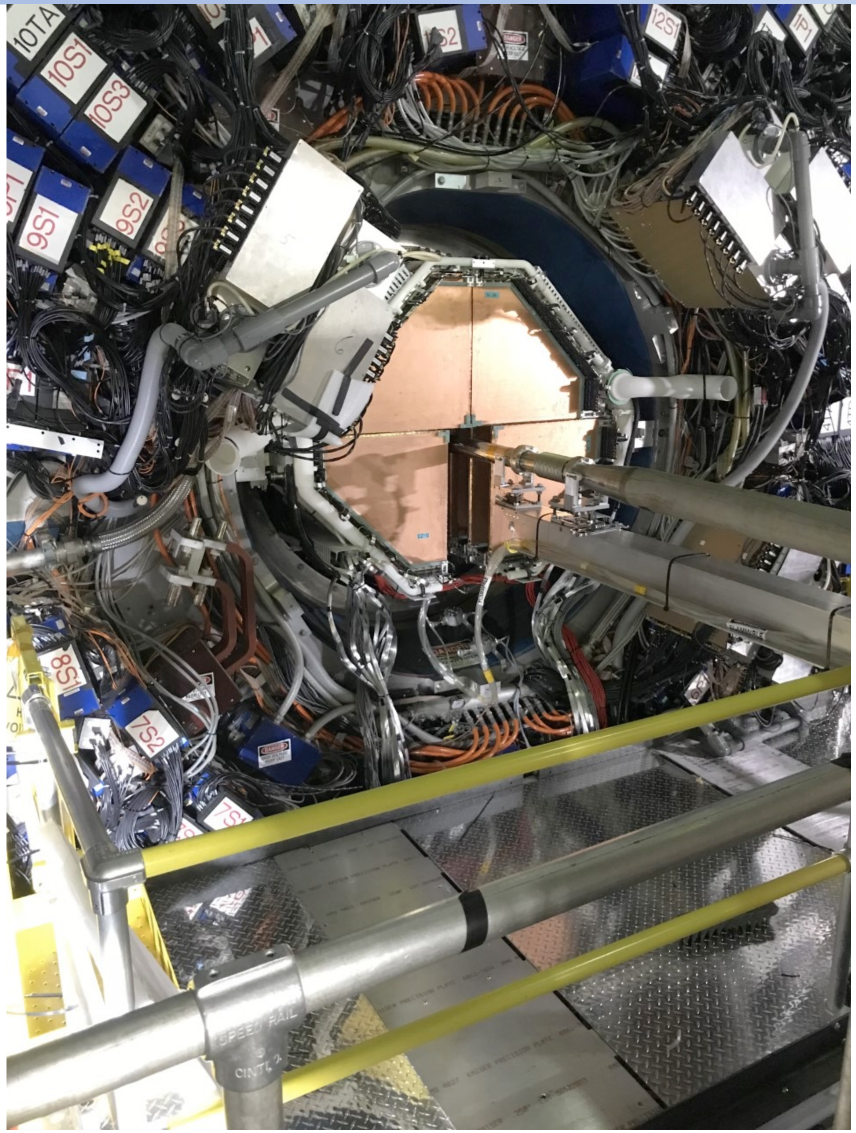


- sTGCs are multiwire ionization chambers operated in the saturation mode
  - Used as hit finding detector or tracking detector
- Provides position and tracking resolution less than 200 μm, at high multiplicity and background
- Anode (HV): 50 μm gold-plated tungsten wires held at a potential of ~2900 V
- Cathode(Ground): graphite-epoxy mixture with a typical surface resistivity of 100 to 200 kΩ/□ sprayed on G-10 material
- Working gas: n-Pentane+CO2= 45:55% by volume
  - This gas mixture is needed to get more than 98% hit efficiency
- n-Pentane (C_5H_{12}) is flammable and liquid in normal atm
- Readout: Small copper strips, perpendicular to anode wires, behind the cathode
- Built double-sided chambers with diagonal strips
  - give *x*, *y*, *u* in each plane

Detector Assembly



sTGC detector (before pushed inside the STAR magnet, the final location)



sTGC detector in the final location

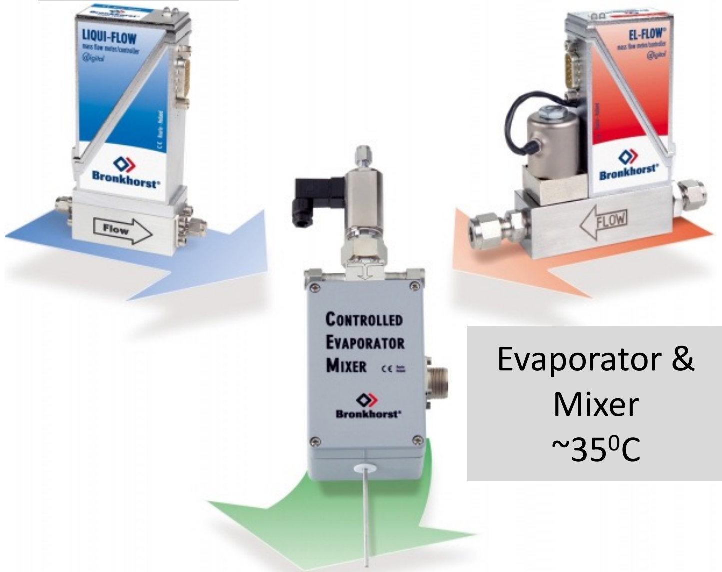
Gas System

Heated gas lines

Gas mixing cabinet

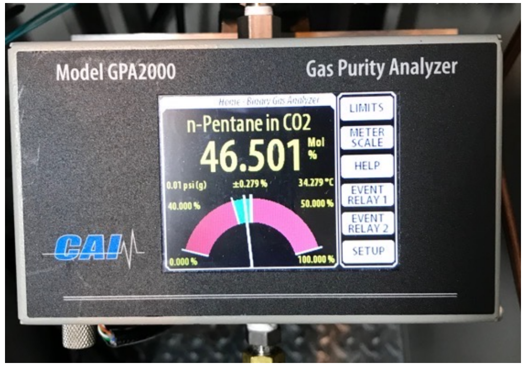
n-Pentane liquid 21.5 g/hr

CO_2 130 cc/min



Evaporator & Mixer ~35^{0}C

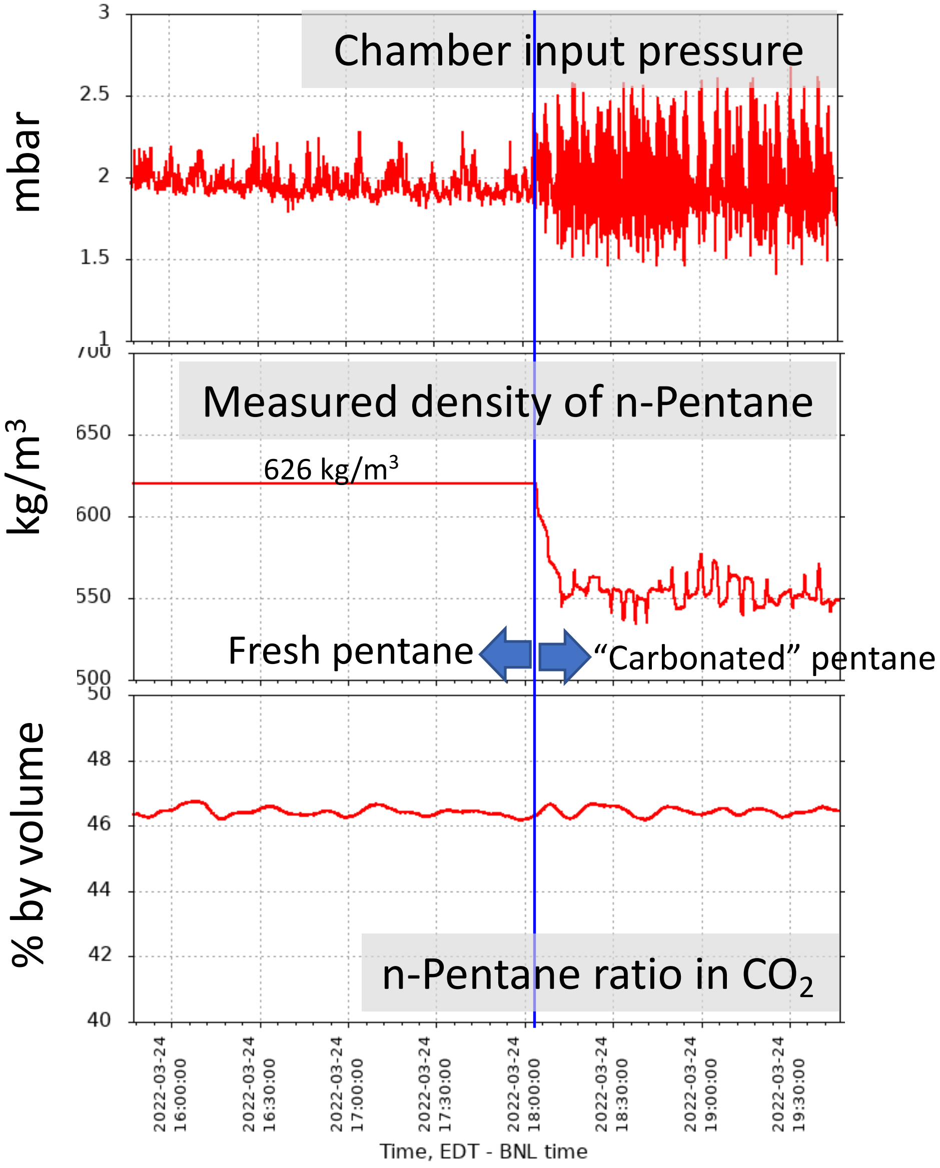
Mixed gas ~240 cc/min



Tank blanketing pressure regulator (0-2 mbar)

Gas distribution cabinet

Gas System - Performance



- Gas system was able to provide gas mixture to chambers at
  - 2 ± 0.5 mbar -> Acceptable range
  - ~50 cc/min per plane (8 chambers)
  - n-Pentane ratio 46 ± 1%
- Mixing of CO_2 in liquid pentane when pumping pentane out, caused about 0.5 mbar of pressure oscillation
  - But, it is damped out traveling through long gas lines
- Gas system was able to provide constant pressure even with the atmospheric pressure changing more than 50 mbar
- No liquification was found in the gas lines

Safety System

- n-Pentane is Highly flammable & Liquid
  - Very difficult to handle
- sTGC chambers are vulnerable to high pressure
  - Acceptable tolerance is 4 mbar above atm
- Dedicated safety system was built to protect the detector & the experiment from safety incidents
- All the gas lines & the sTGC chambers are pressure tested for leaks at least 1 ½ times the operating pressure to ensures no leak
- Pentane leak detection system detects pentane leaks
- Pressure relief valves and pressure monitoring to avoid over pressurizing the system
- Pentane liquid detection
- Heated gas lines for transporting pentane gas mixture
- Programmable Logic Controller (PLC) monitors warning signal from safety sensors & take actions to put the system in safe state
  - PLC orient the safety valves in the gas system such that the system is flushed with pure CO_2 in a safety event
  - Turn off HV & LV

Pentane leak detector

Liquid pentane detector

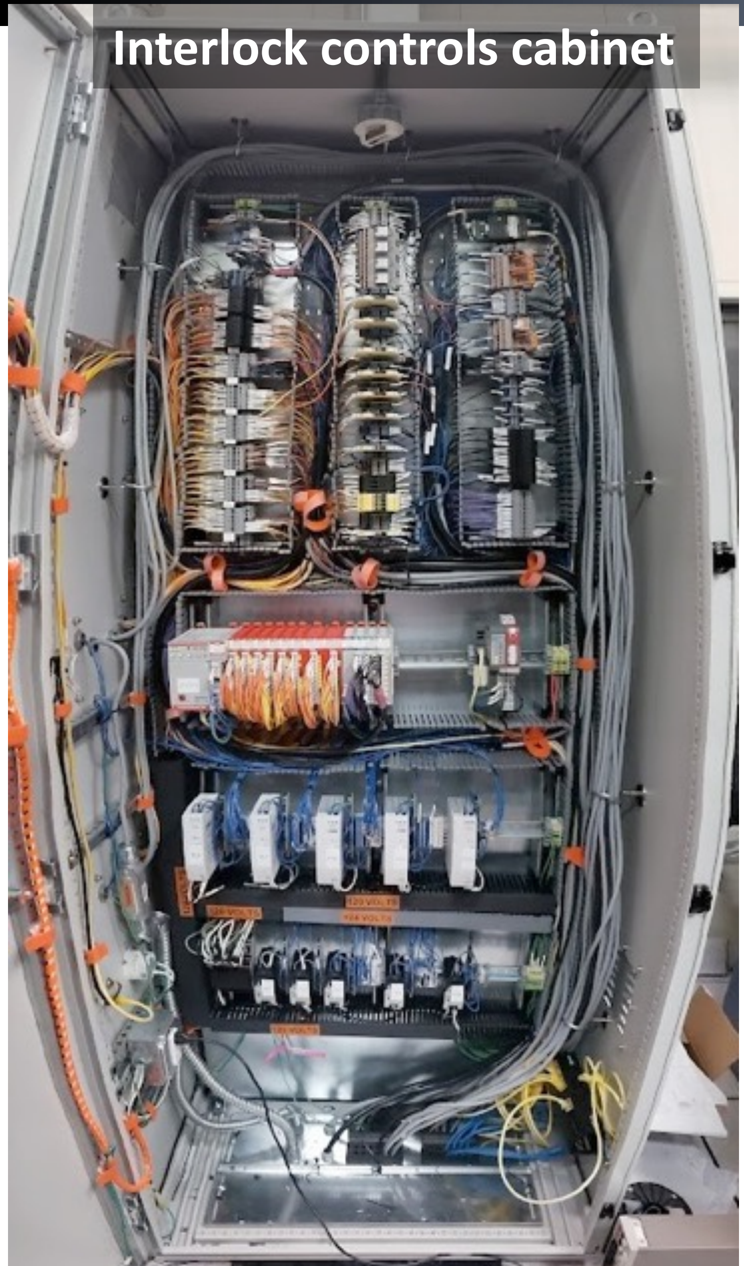
Heat tape

Fail safe solenoid valves

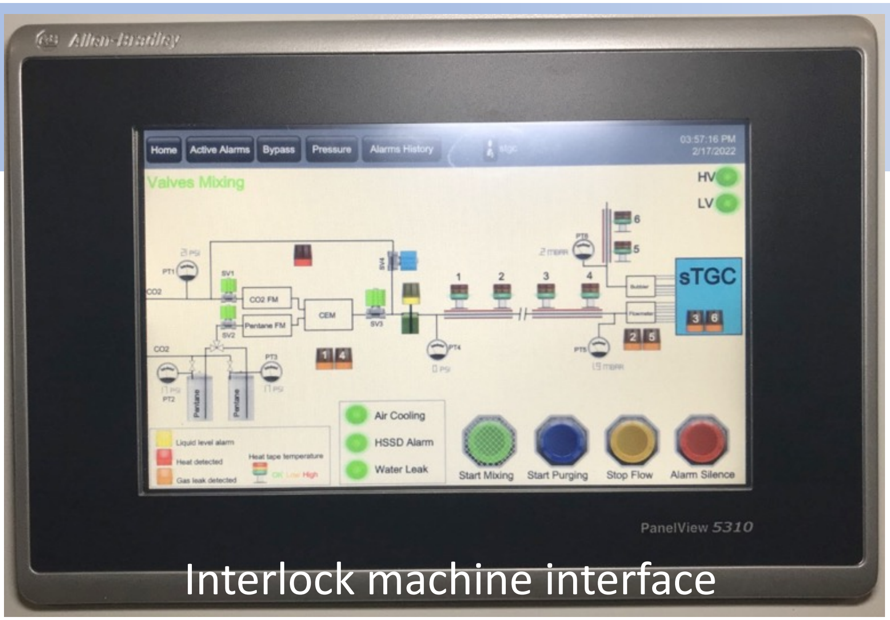
Intrinsically safe pressure transmitters

Safety System

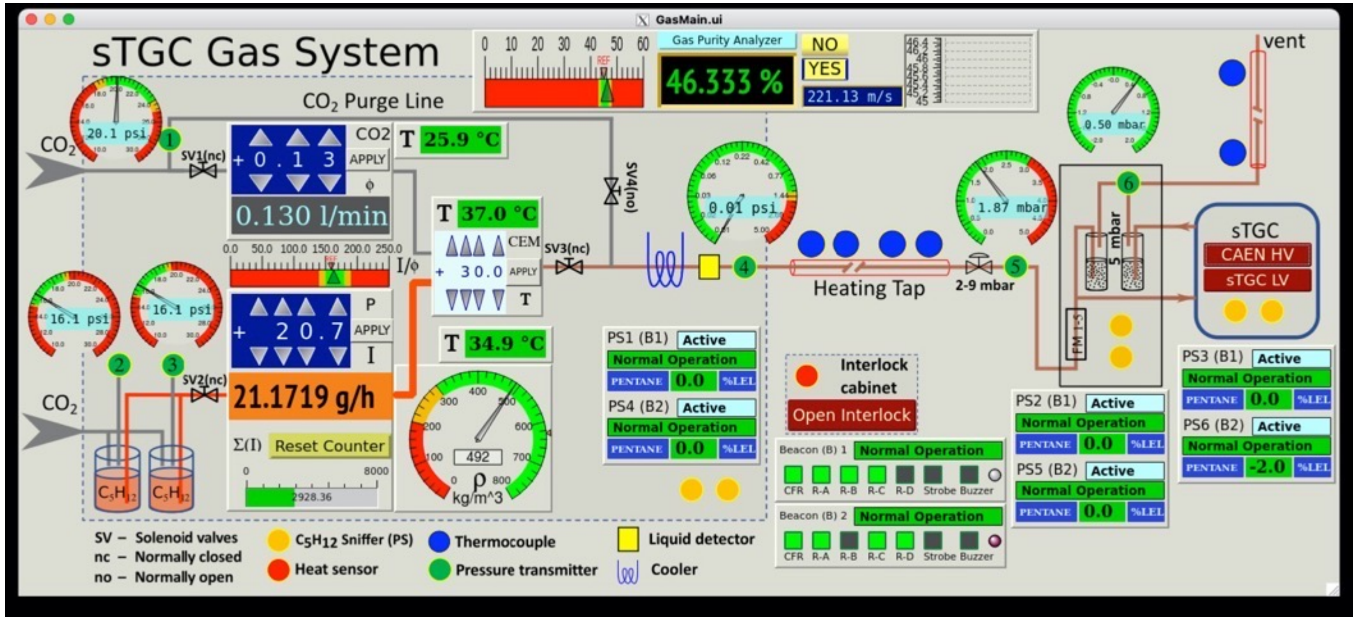
Interlock controls cabinet



Safety PLC, redundant monitoring of inputs & outputs

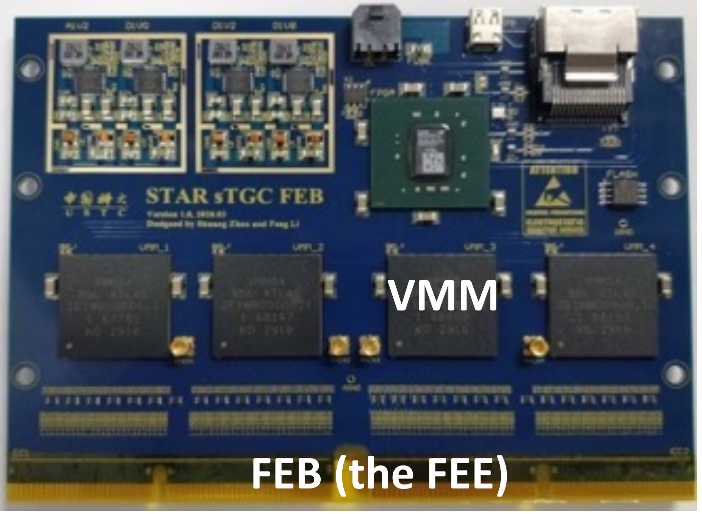


Interlock machine interface



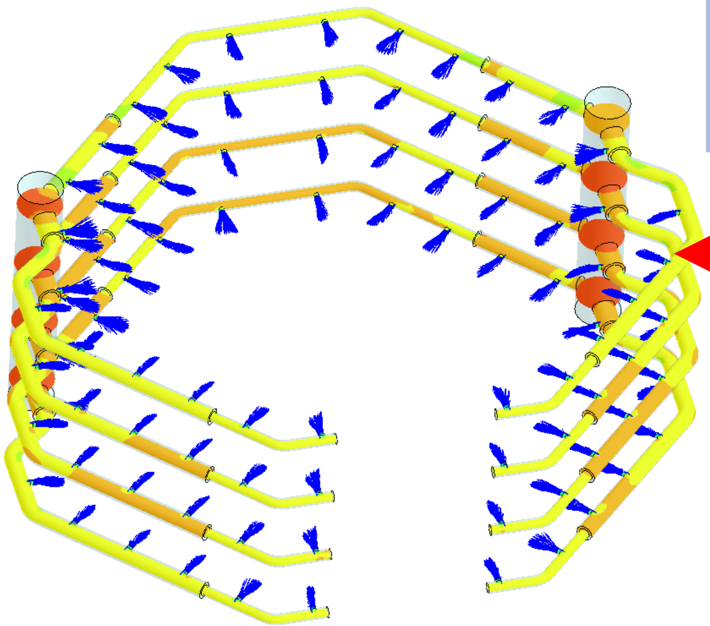
System monitoring GUI & Archiver

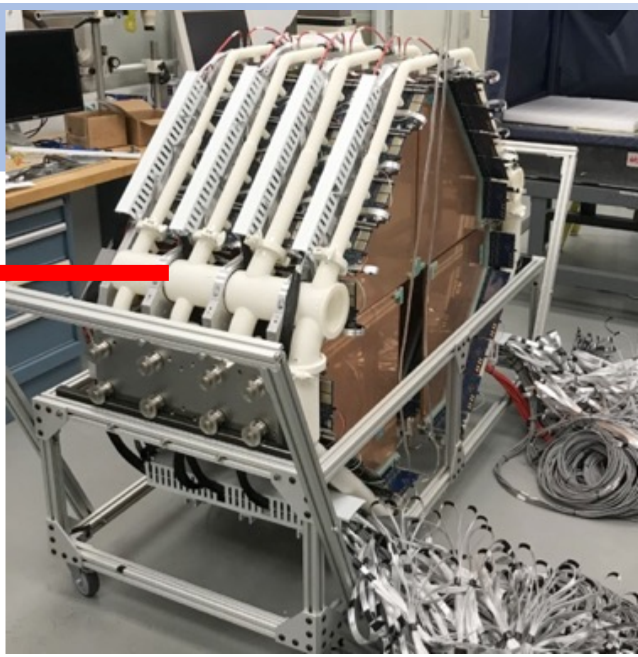
Readout and Electronics



ROB (the RDO)

LV power supply

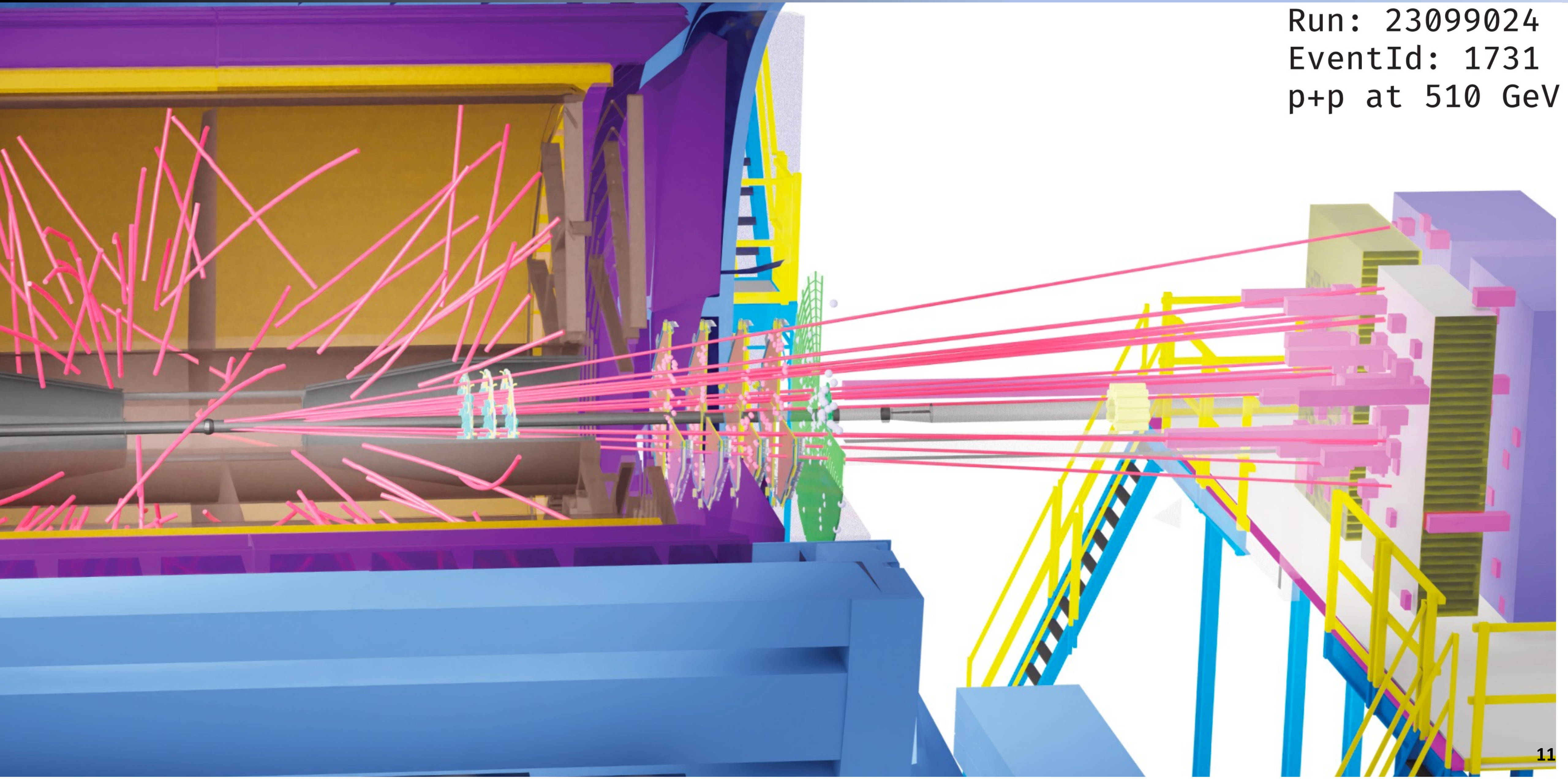




Cooling tubes for the FEEs

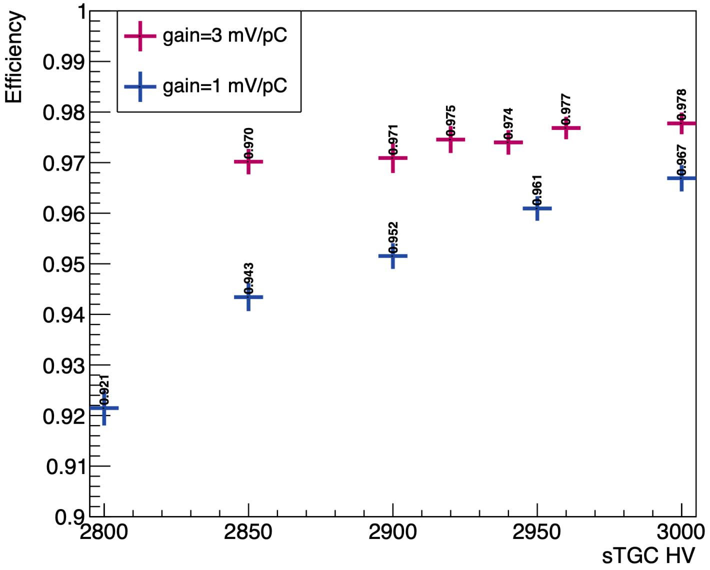
- sTGC read out is based on ATLAS VMM chips
- FEEs, aggregators (RDOs) and power supply are in house built
- 3D printed cooling ducts with the dedicated air cooling unit regulate the FEE temperature to 35 ^{0}C

Performance during the data taking

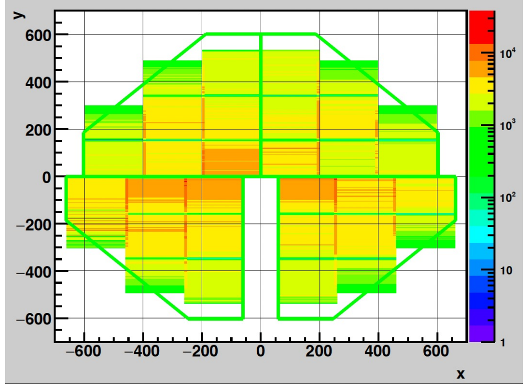


Performance during the data taking

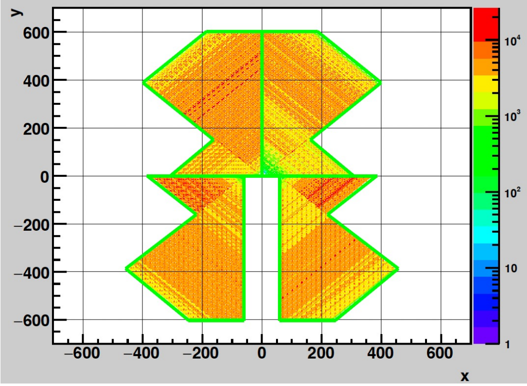
- Despite of COVID and lot of obstacles/complications, all the forward upgrade subsystems including the sTGC detector were fully installed on time and commissioned
- *p+p* 508 GeV data were collected during the RHIC Run 22 and will take data in next three years
- sTGC chambers were operated around the nominal 2900 V
    - Leakage current was about 50-60 uA during *p+p* 508 GeV collisions
- Achieved 97% hit efficiency
- Gas mixing system and the associated safety system performed very well
- Readout electronics performed exceptionally well during the data taking, given the high luminosity data taking



Hit patterns



Horizontal strips



Diagonal strips