CPAD Workshop 2023

SLAC National Accelerator Laboratory, November 7 - 10, 2023

sPHENIX TPC in the 2023 commissioning run

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on behalf of the sPHENIX collaboration

sPHENIX experiment

Collaboration of 320 members from 80 institutions in 13 countries
First data taking early 2023 3-year run plan

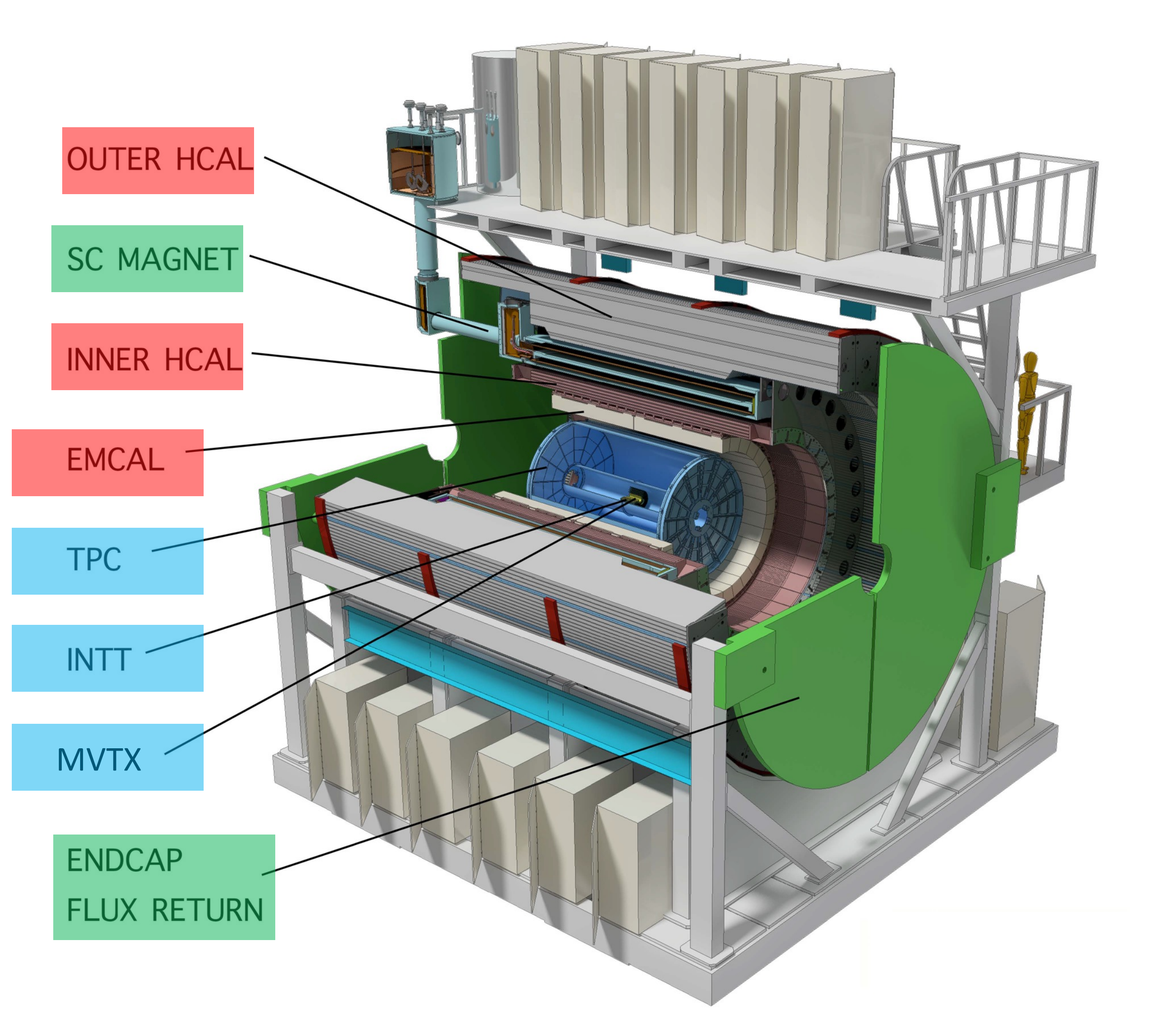
Superconducting Magnet (1.4 T solenoid)
- formerly BaBar

Tracking system:
- MAPS-based Vertex Tracker (MVTX)
- Intermediate Silicon Tracker (INTT)
- Time Projection Chamber (TPC)

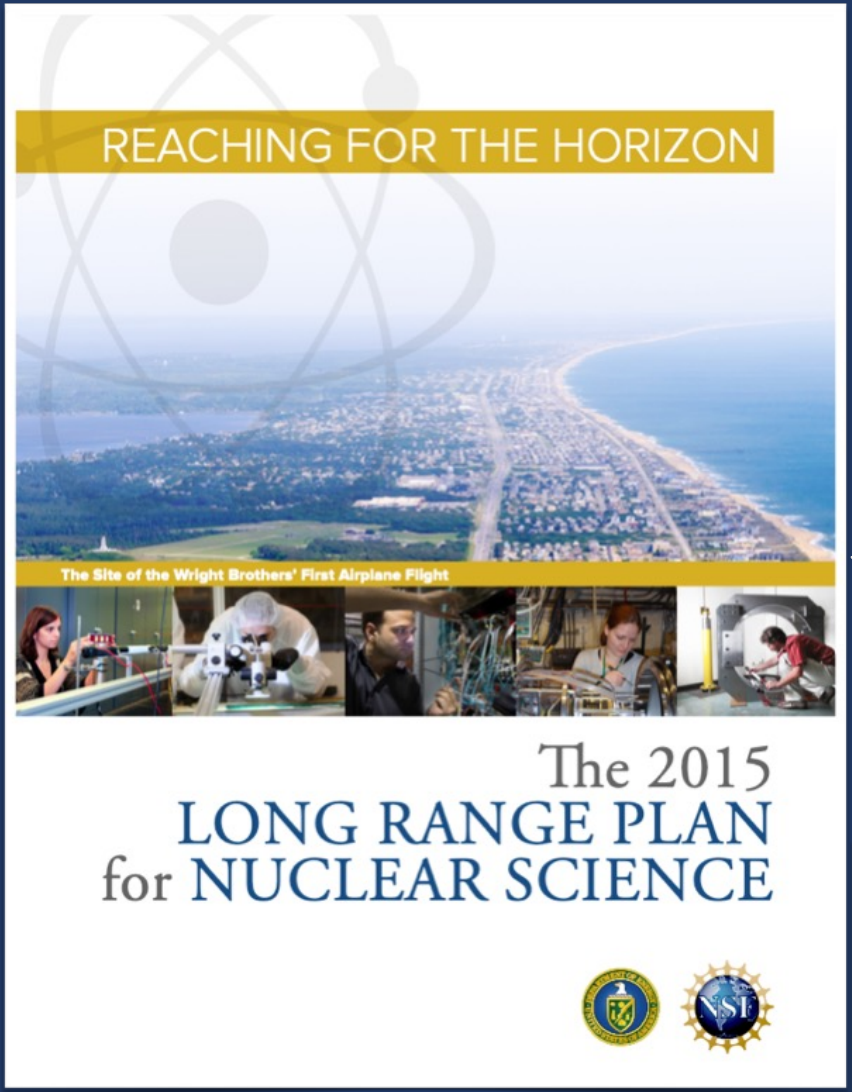
Calorimetry:
- Electromagnetic Calorimeter (EMCal)
- inner Hadronic Calorimeter (iHCal)
- outer Hadronic Calorimeter (oHCal)

High rate:
- 15 kHz Trigger, >10 GB/s DAQ

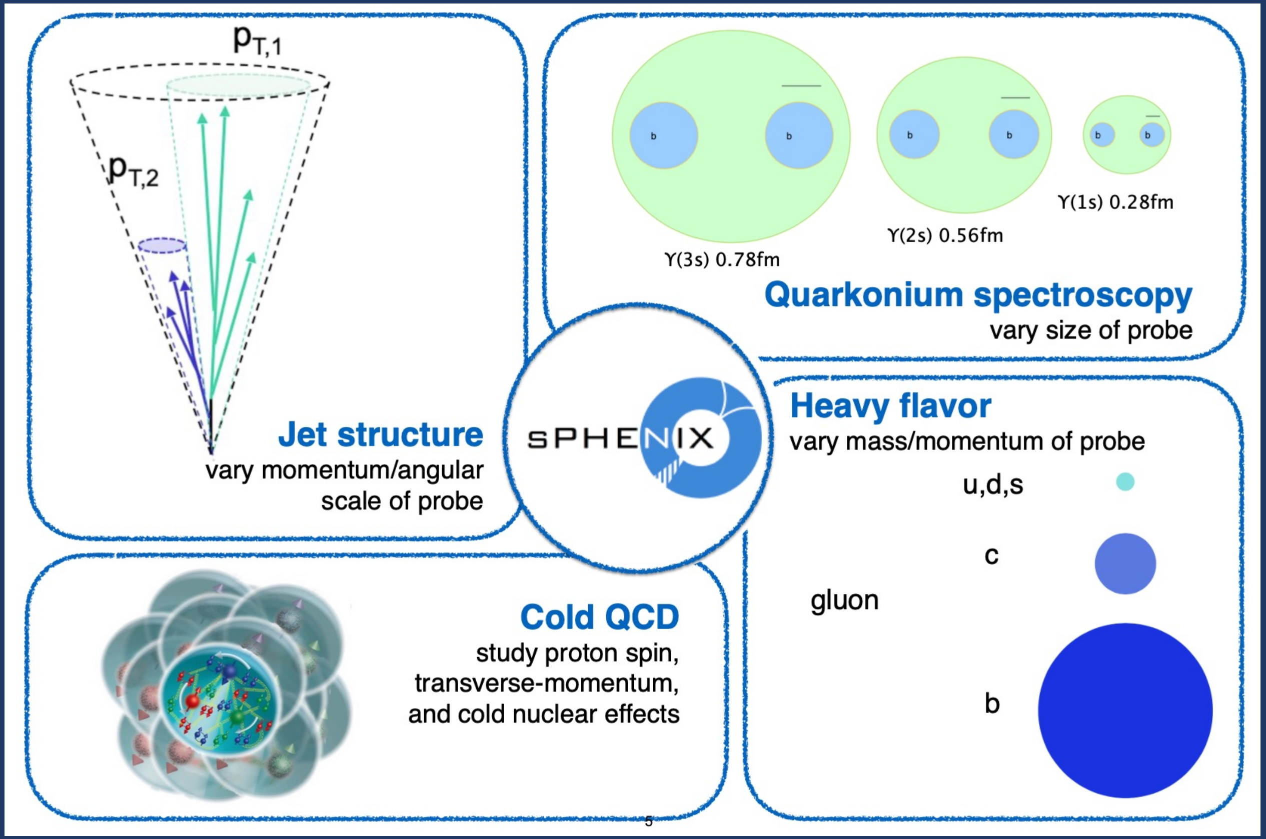
Large acceptance:
- full ϕ coverage; for $|z|<10$ cm: $|\eta|\leq1.1$



sPHENIX physics goal

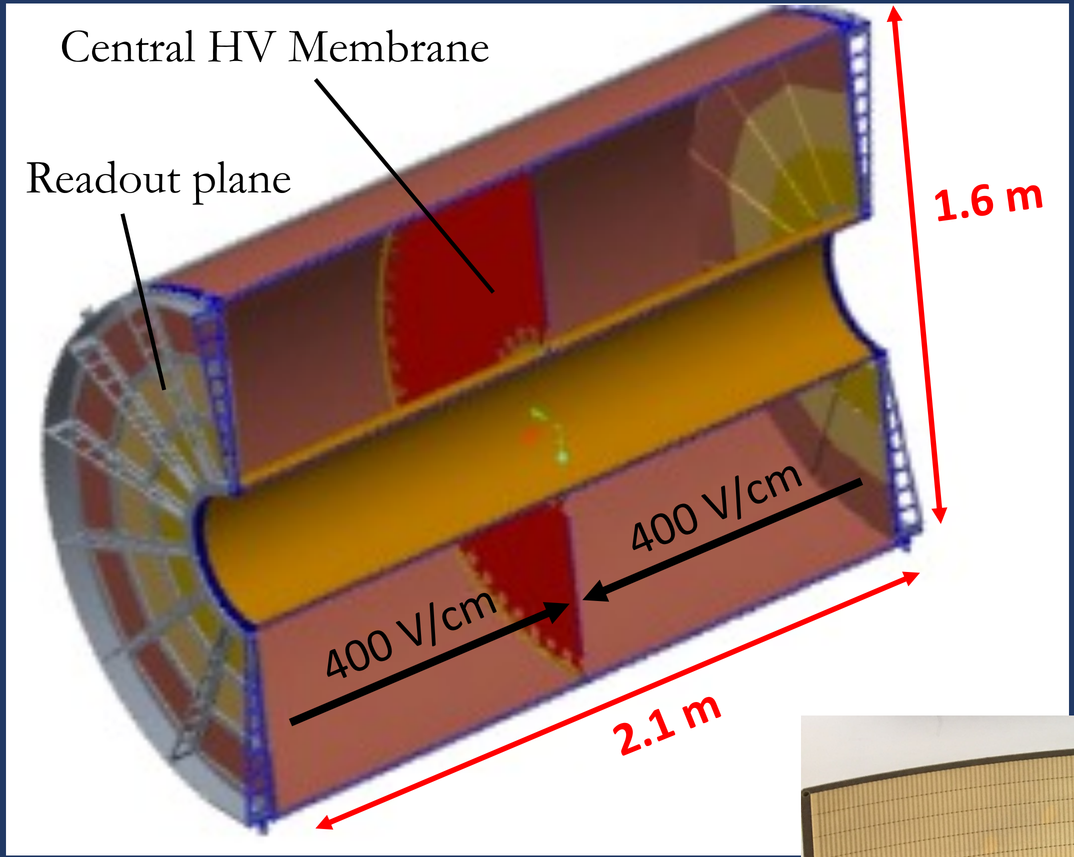


There are two central goals of measurements planned at RHIC, as it completes its scientific mission, and at the LHC: **(1) Probe the inner workings of QGP by resolving its properties at shorter and shorter length scales. The complementarity of the two facilities is essential to this goal, as is a state-of-the-art jet detector at RHIC, called sPHENIX. (2) Map the phase diagram of QCD with experiments planned at RHIC.** [2015 US NP LRP]

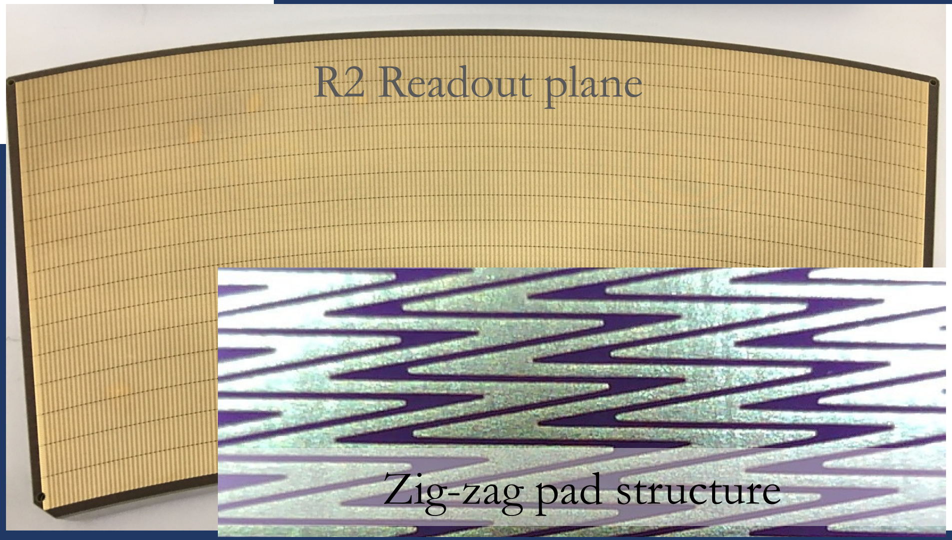


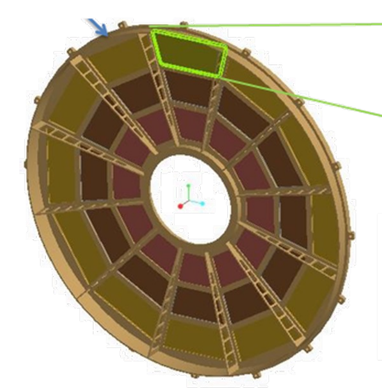
[From DVP @ DNP]

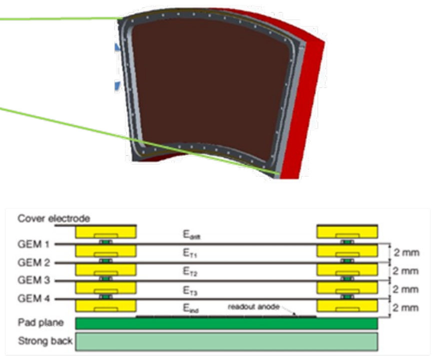
sPHENIX TPC



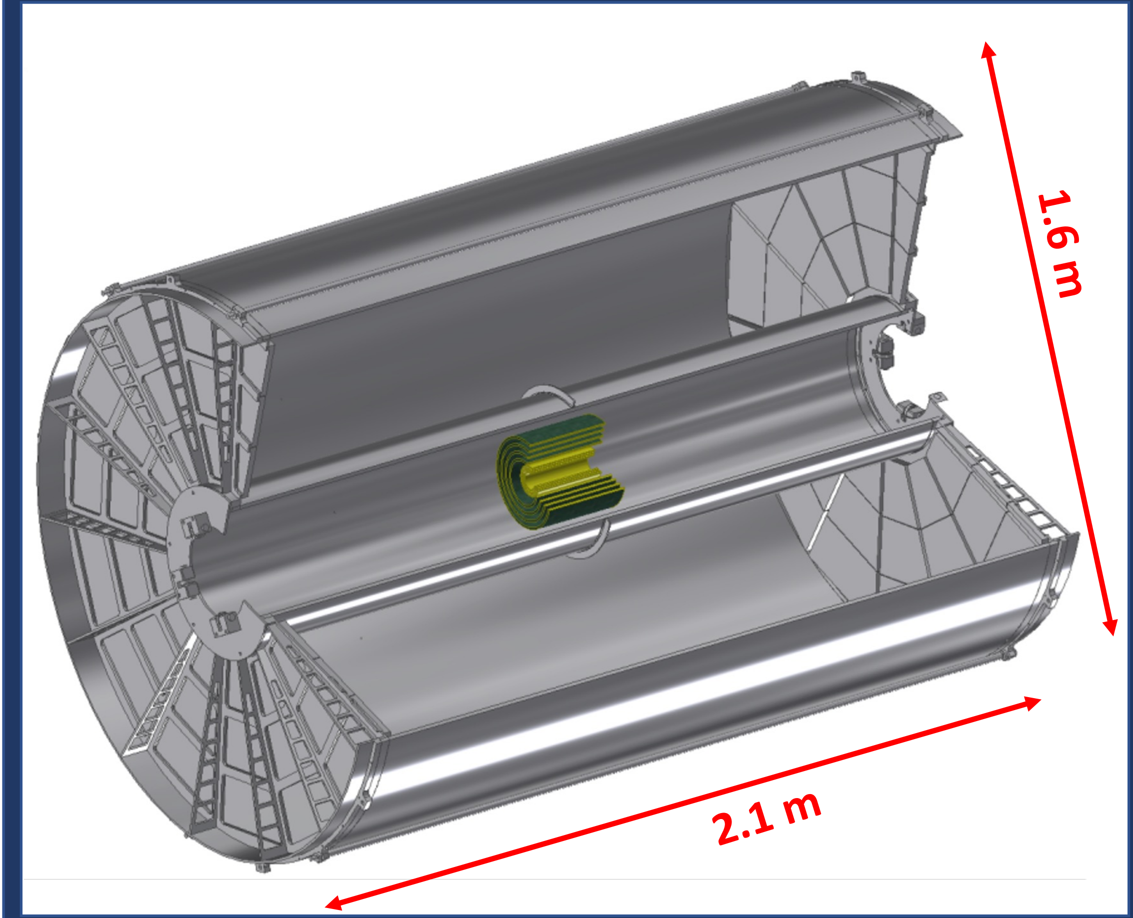
Time Projection Chamber (TPC)
Compact: 20 < r [cm] < 78 (active (>30cm)
Gas: $\cancel{Ne/CF_4} \Longrightarrow Ar/CF_4$
Nominal drift field E = 400 V/cm and magnetic field B = 1.4 T along z
Required spatial resolution: < 150 μm
Charge collection via GEMs → ALICE SAMPA
Gateless and continuous readout (GEMs for IBF suppression)

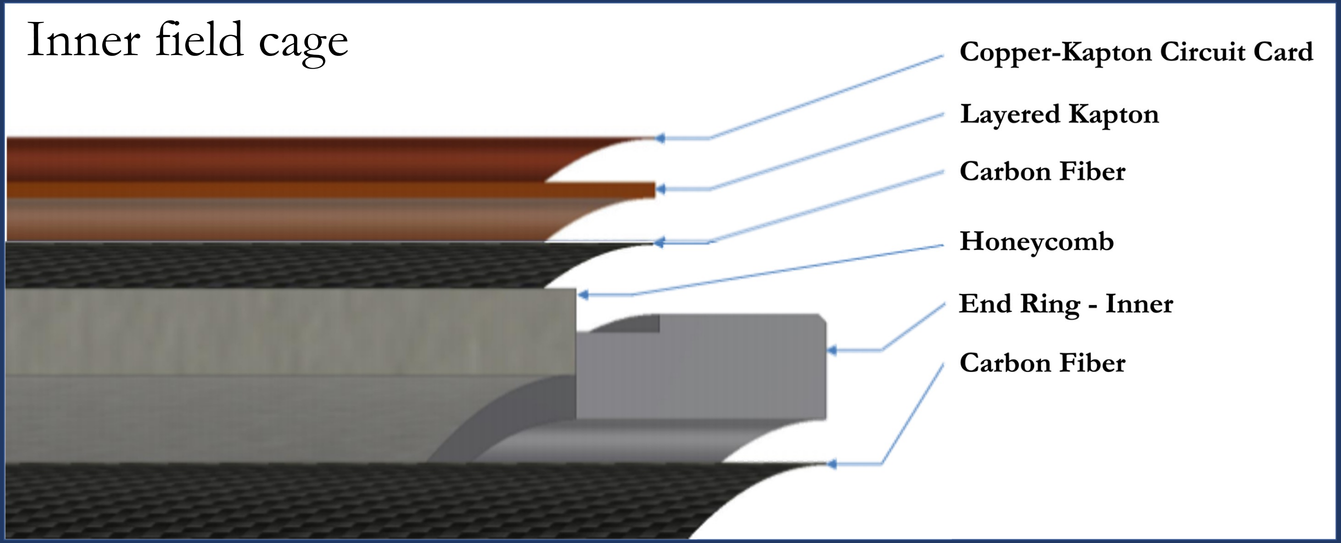






Field cage



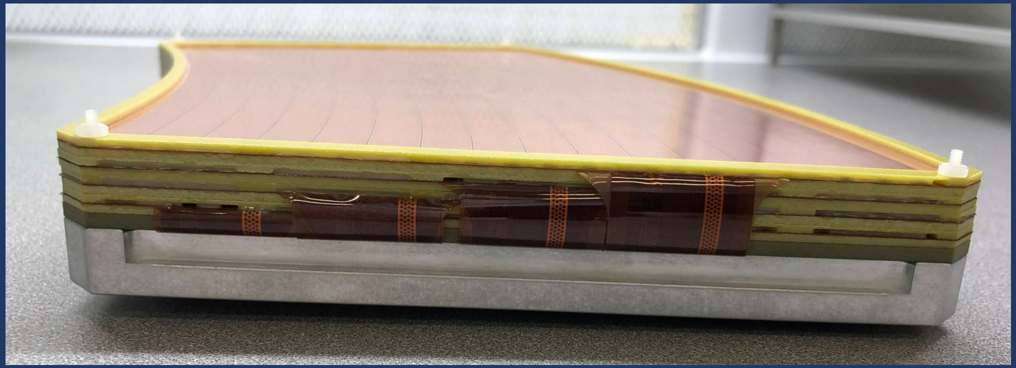


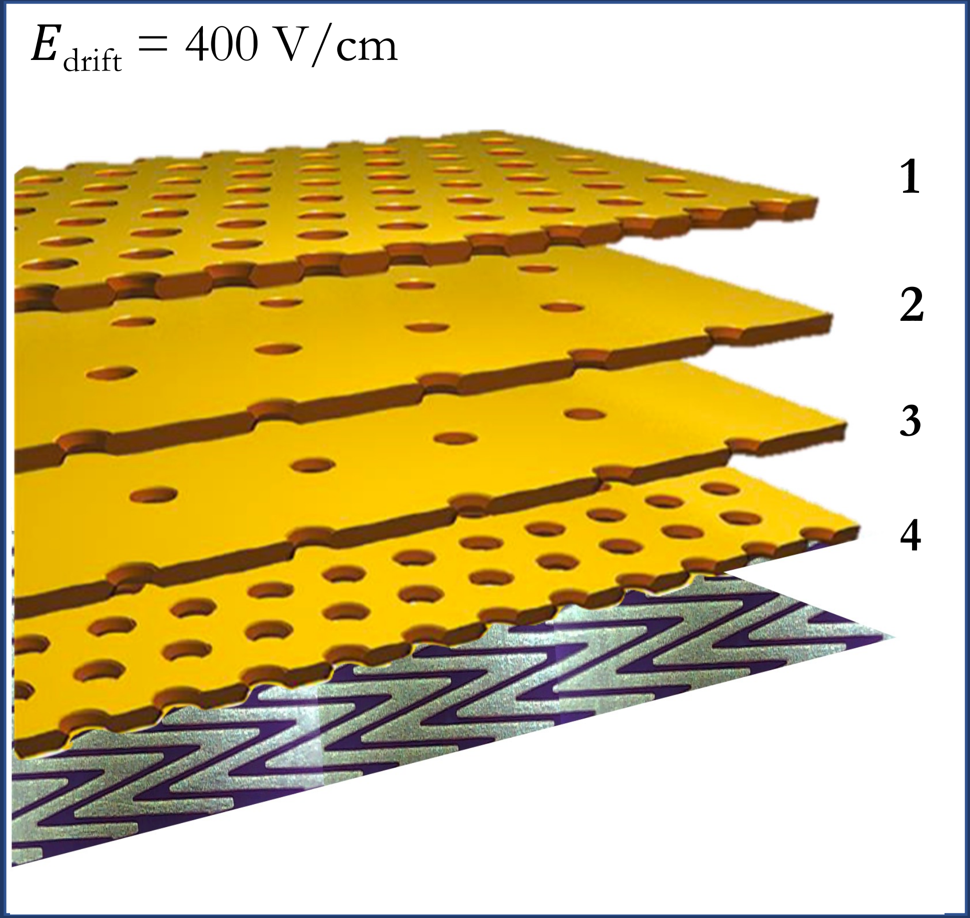
Inner field cage	X_0 [cm]	cm	%X_0
1/2 Oz Copper	1.4	0.0017	0.12
kapton	28.6	0.0051	0.02
1/2 Oz Copper	1.4	0.0017	0.12
Kapton (coverlay)	28.6	0.0076	0.03
Epoxy	35.7	0.0127	0.04
Kapton (insulating)	**28.6**	**0.2286**	**0.80**
Carbon Fiber	23.4	0.0254	0.11
Epoxy	35.7	0.0127	0.04
Honeycomb	845.4	1.2700	0.15
Epoxy	35.7	0.0127	0.04
Carbon Fiber	23.4	0.0254	0.11
TOTAL		**0**	**1.56**

- TPC wall thickness is dominated by an insulating kapton layer
- 45 kV at the "central membrane" & 18 layers of kapton

Quad-GEM

- Planned gas after 2019 test beam: Ne/CF_4 (50:50)
- GEM 3 & 4 are adjusted to achieve a total effective gain of 2000
- GEM 1 & 2 provide effective gain of 1 and used to stop IBF

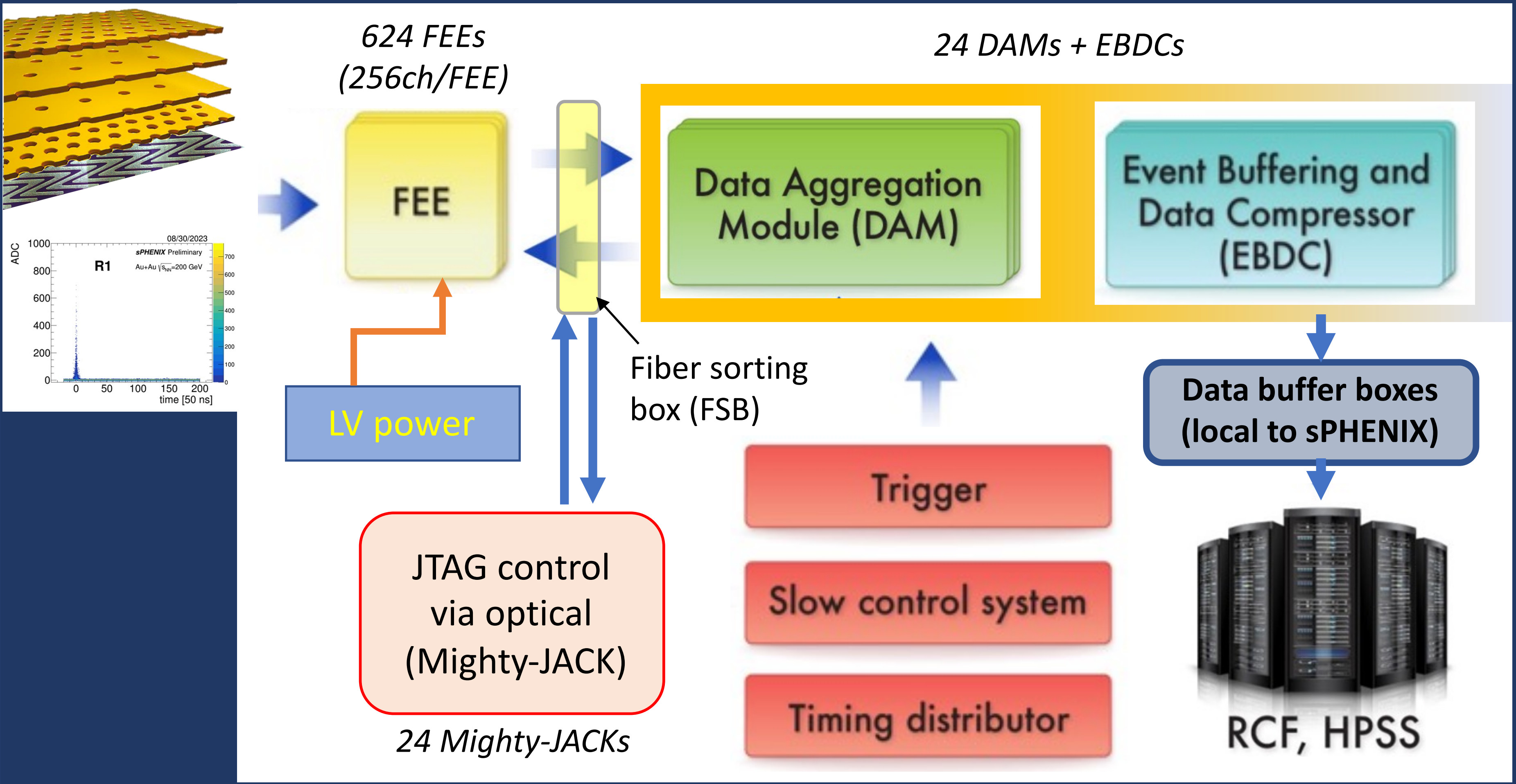




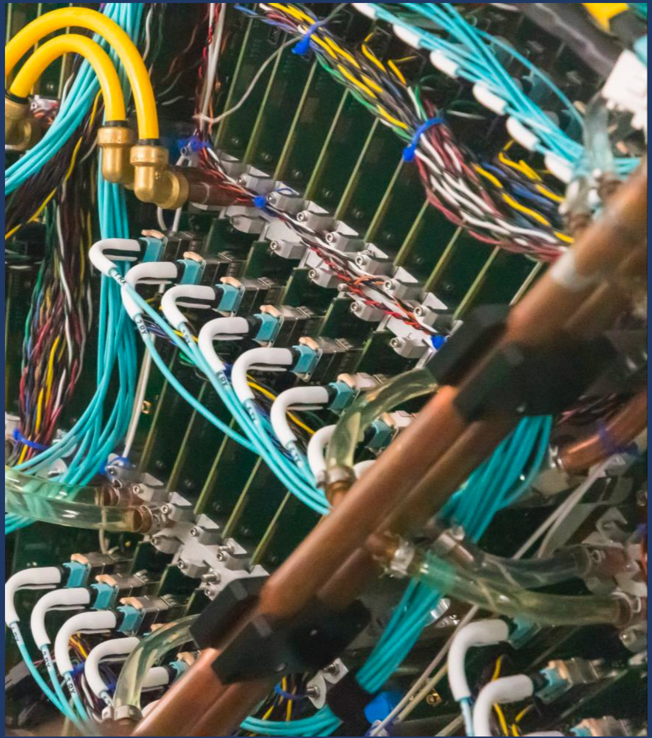
GEM foil	U [V]	ΔV [V]	E^{drift} [V/cm]
G4 b	600	-	-
G4 t	1098	498	-
G3 b	1128	30	95
G3 t	1578	450	-
G2 b	2778	1200	3750
G2 t	3110	332	-
G1 b	4310	1200	3750
G1 t	4578	267	-

Readout structure

- Overall readout scheme: padplane -> FEE -> DAM+EBDC -> Storage
- Data rate: ~10Mbits per Au+Au MB events from whole TPC



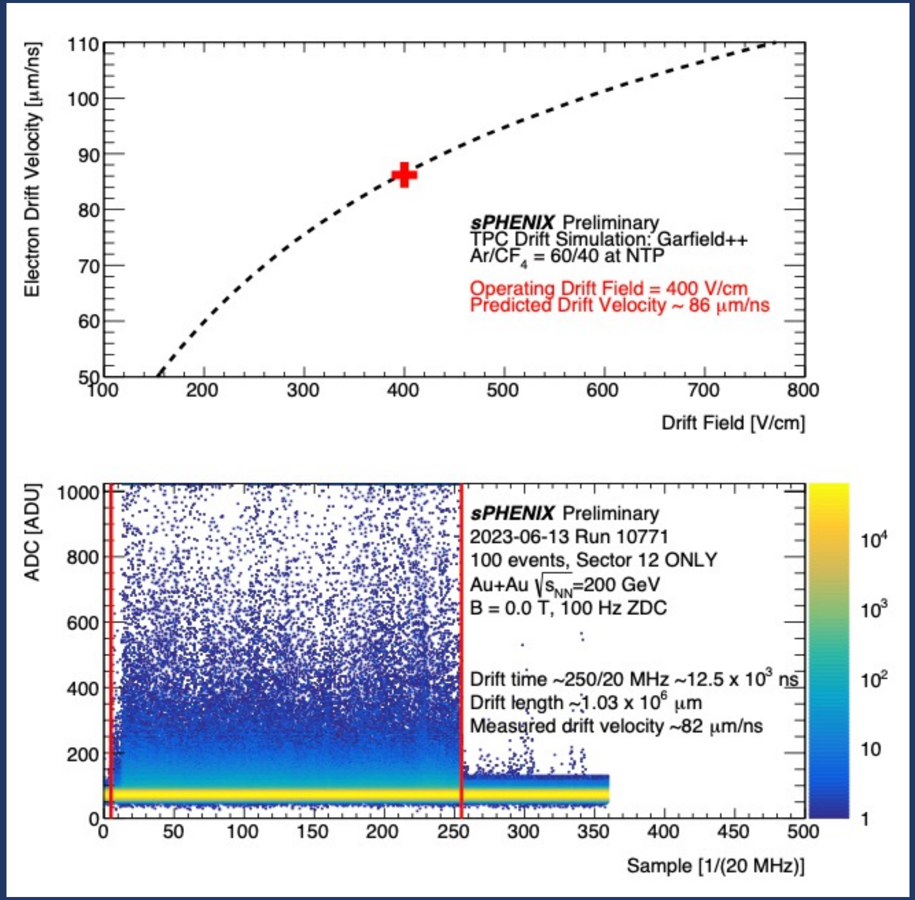
FEEs instrumented

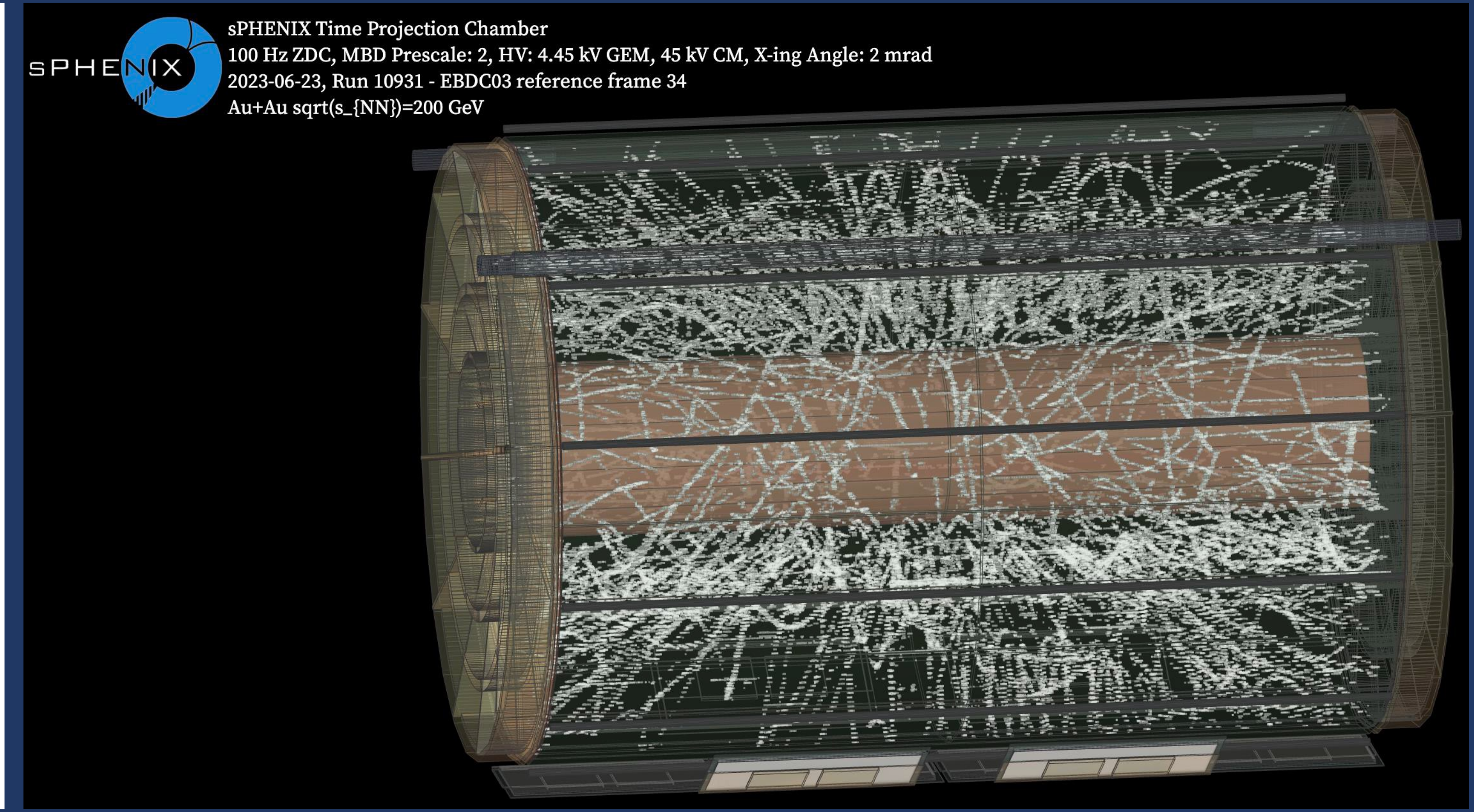


Single FEE

TPC operations in run 2023

First Collisions in TPC June 2023: 12x12 AuAu, 100 Hz ZDC, 20 Hz trigger





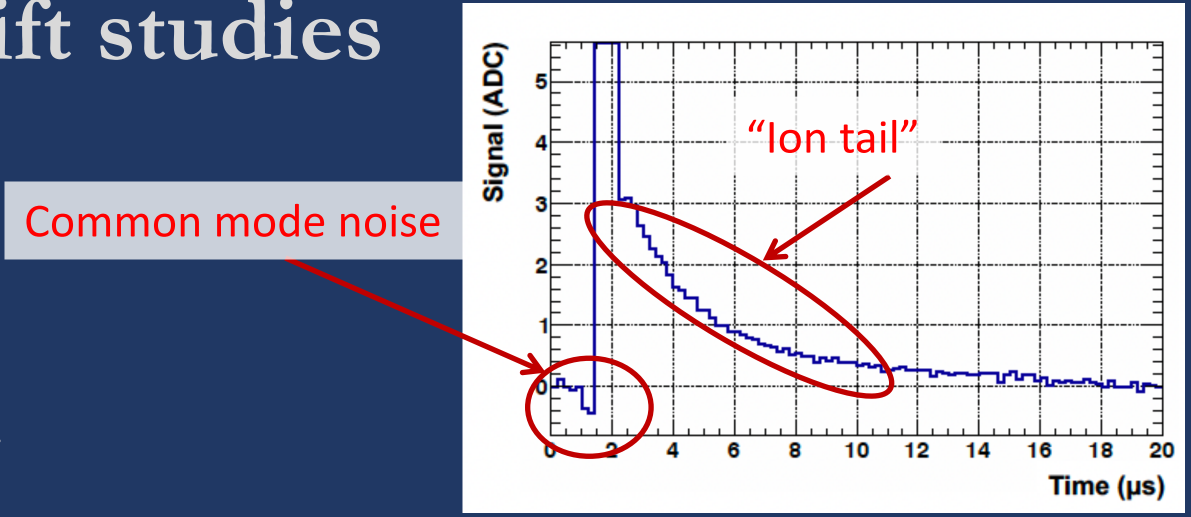
TPC performance is within designed characteristics

Baseline shift studies

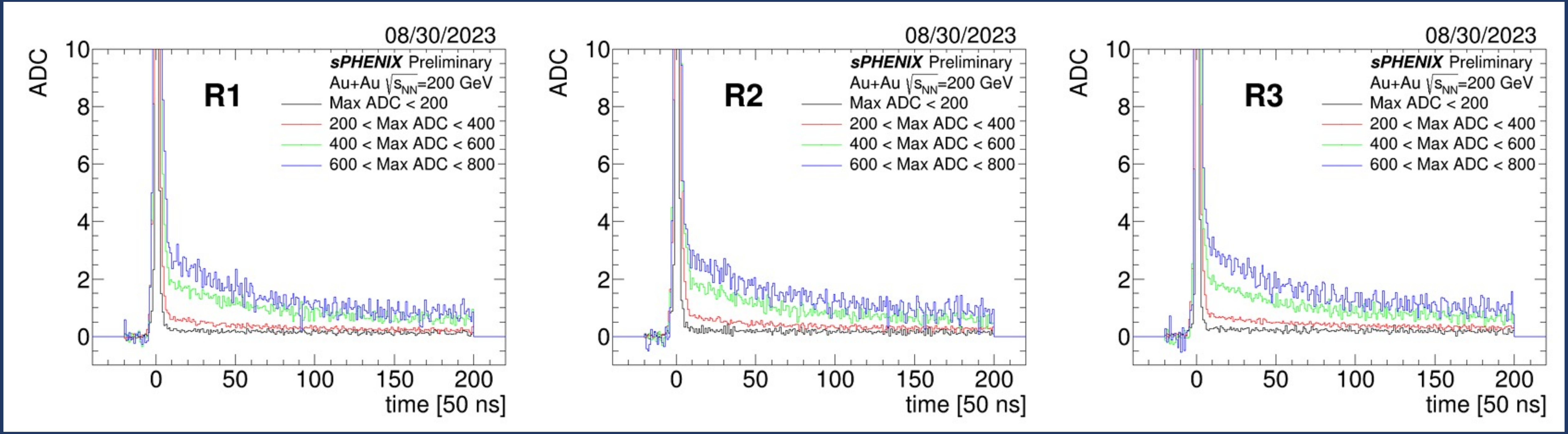
ALICE has reported several features in the readout system

1st addressed with 20 nF capacitor to the bottom of the bottom GEM

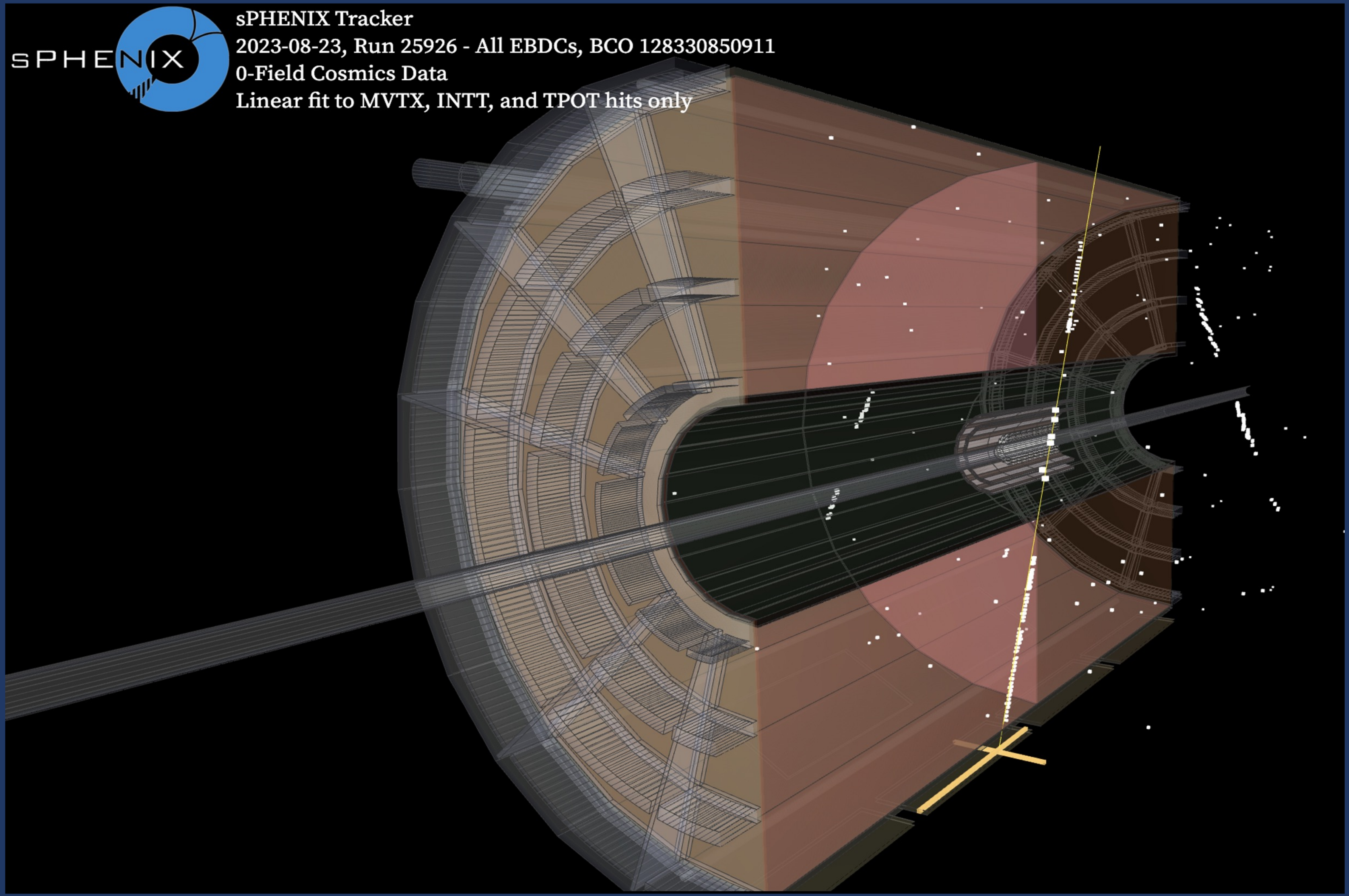
2nd is currently studied & provide baseline shift on the order of few ADCs



https://arxiv.org/pdf/2304.03881.pdf



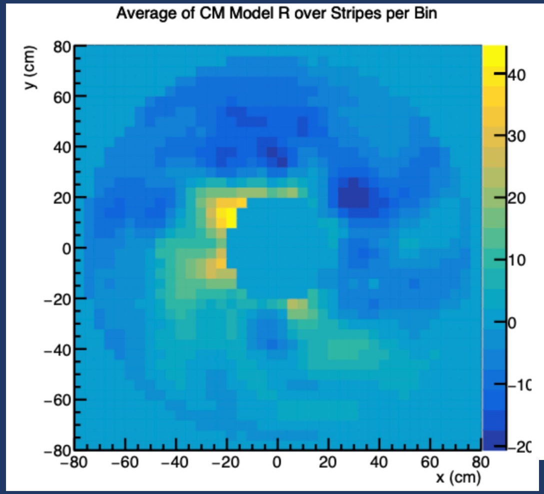
Cosmics

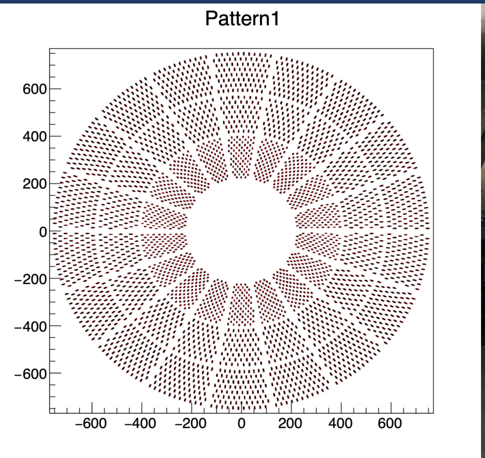


- Collider has unexpectedly stopped operation in August
- Commisioning has been continued with cosmic trigger provided by Hcal
- This data will be used for allignement, distortion and performance caracterizations

Distortion Monitors

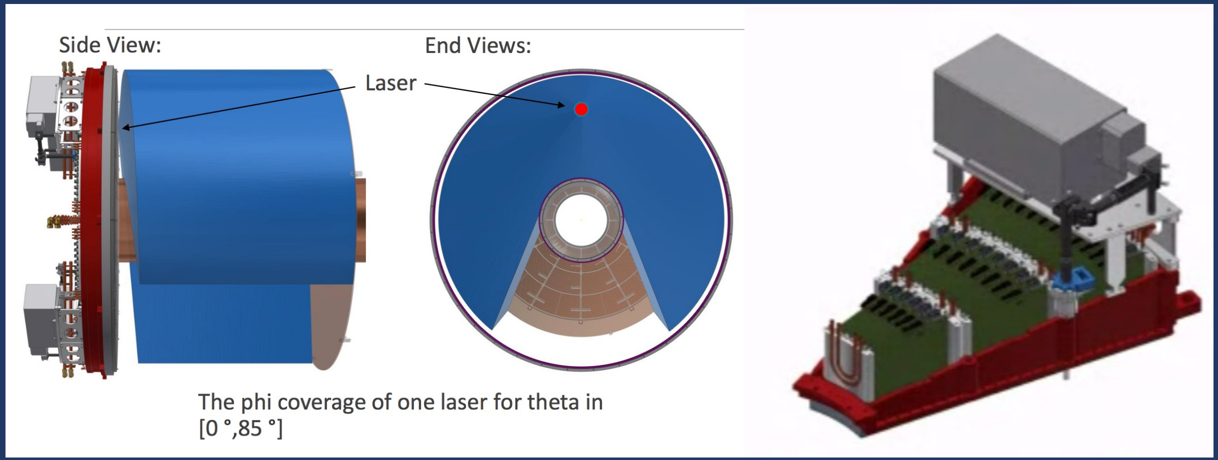
Diffuse Laser



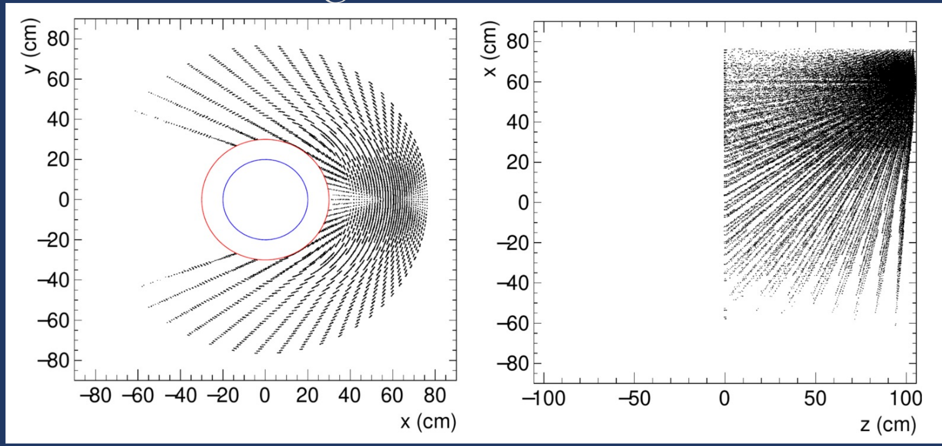


- Al stripes on Central Membrane
-
- kHz diffuse UV laser releases e$^-$
- Reconstructed stripes measure distortion at CM
- fast, interleaved with data $\Longrightarrow$ monitors fluctuations

Direct Laser

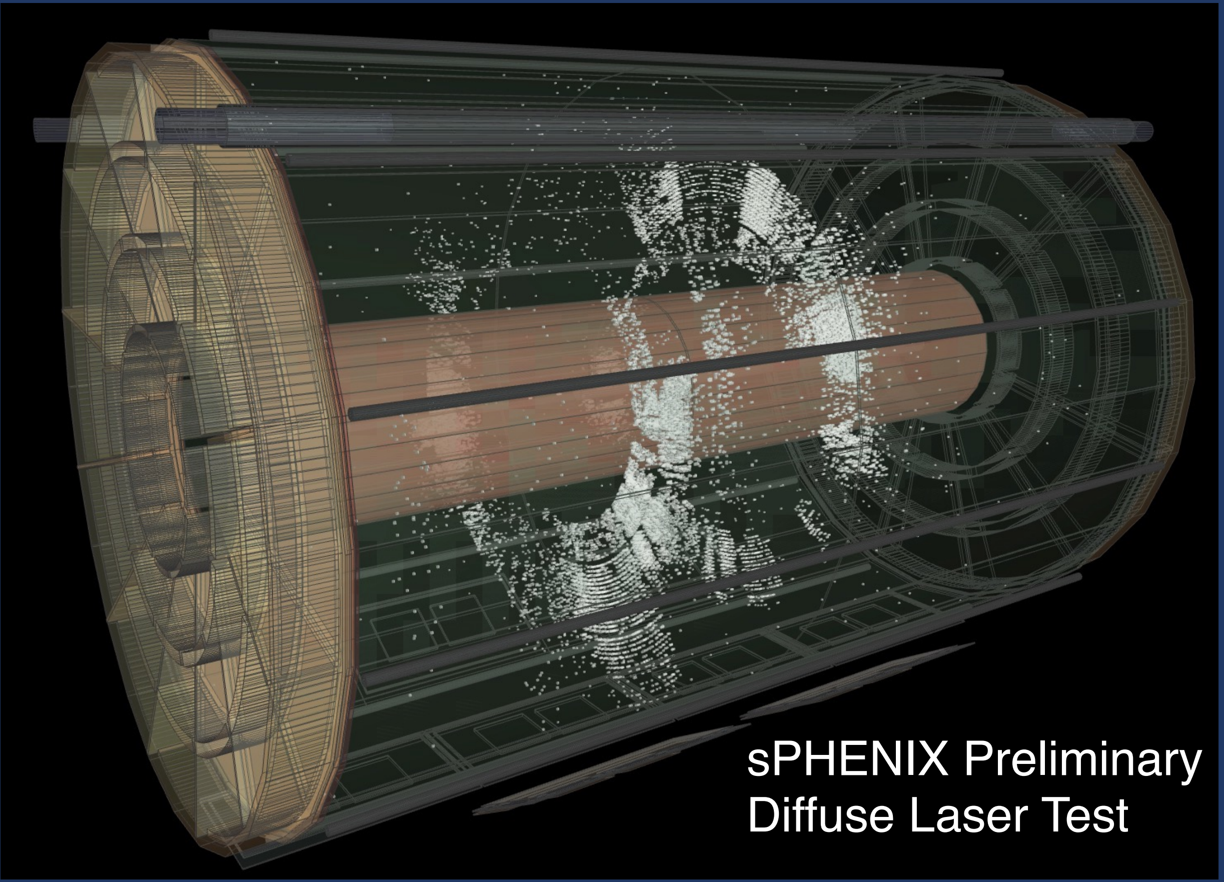


- 3 steerable lasers on each side of TPC
- Almost all points can be reached by 2+ lasers
- Creates straight-line tracks at ~Hz



- Reconstructed laser track measures distortion in volume
- Slow, not used during run $\Longrightarrow$ monitors static distortion

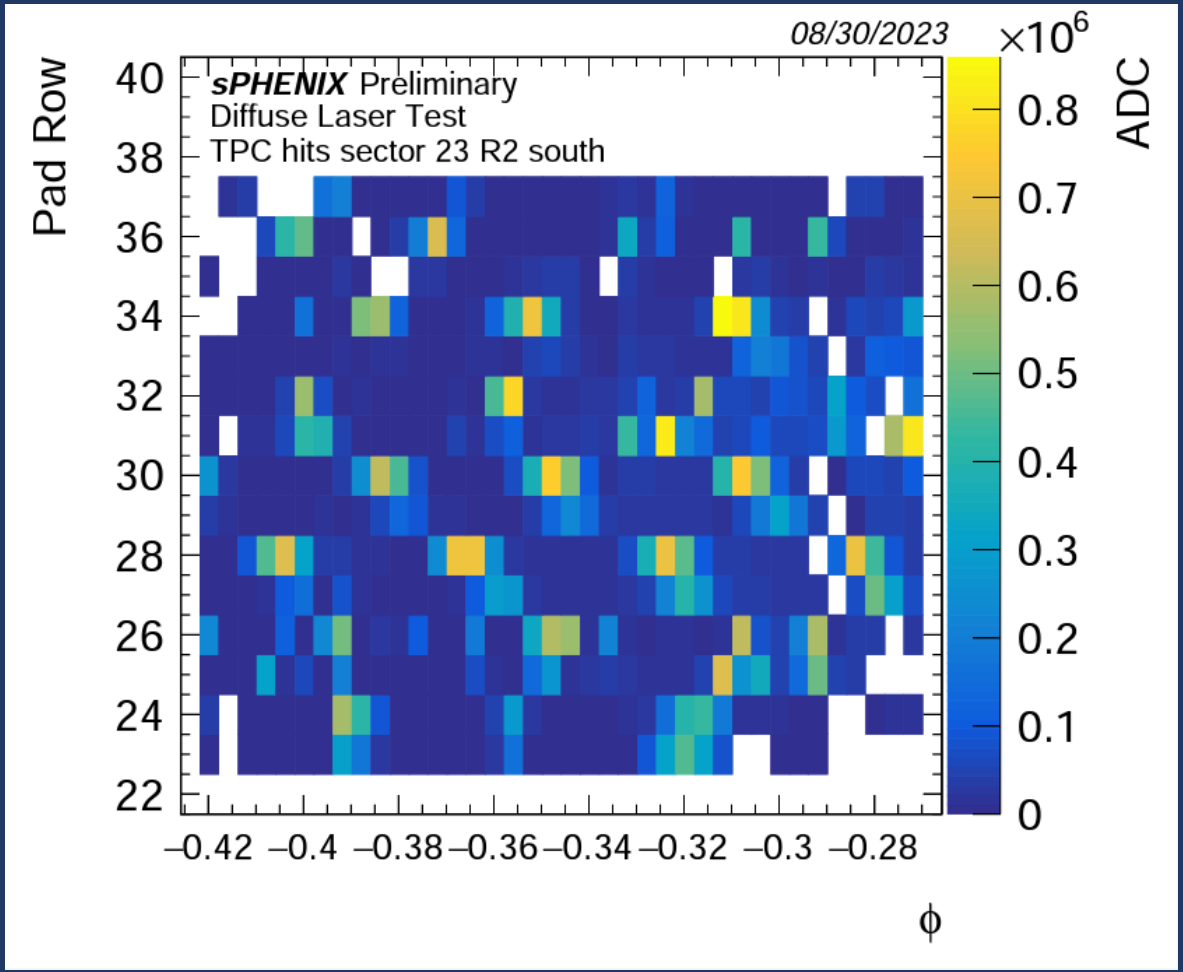
Diffuse laser



- 5 of 6 lasers
- GEM gains below nominal
- Survey data not yet incorporated into pad or truth positions

- Test laser flashes on the TPC Central Membrane reconstructed
- Stripe pattern from the Central Membrane is present in the events
- Work is ongoing to use pattern to reconstruct distortions

Diffuse laser



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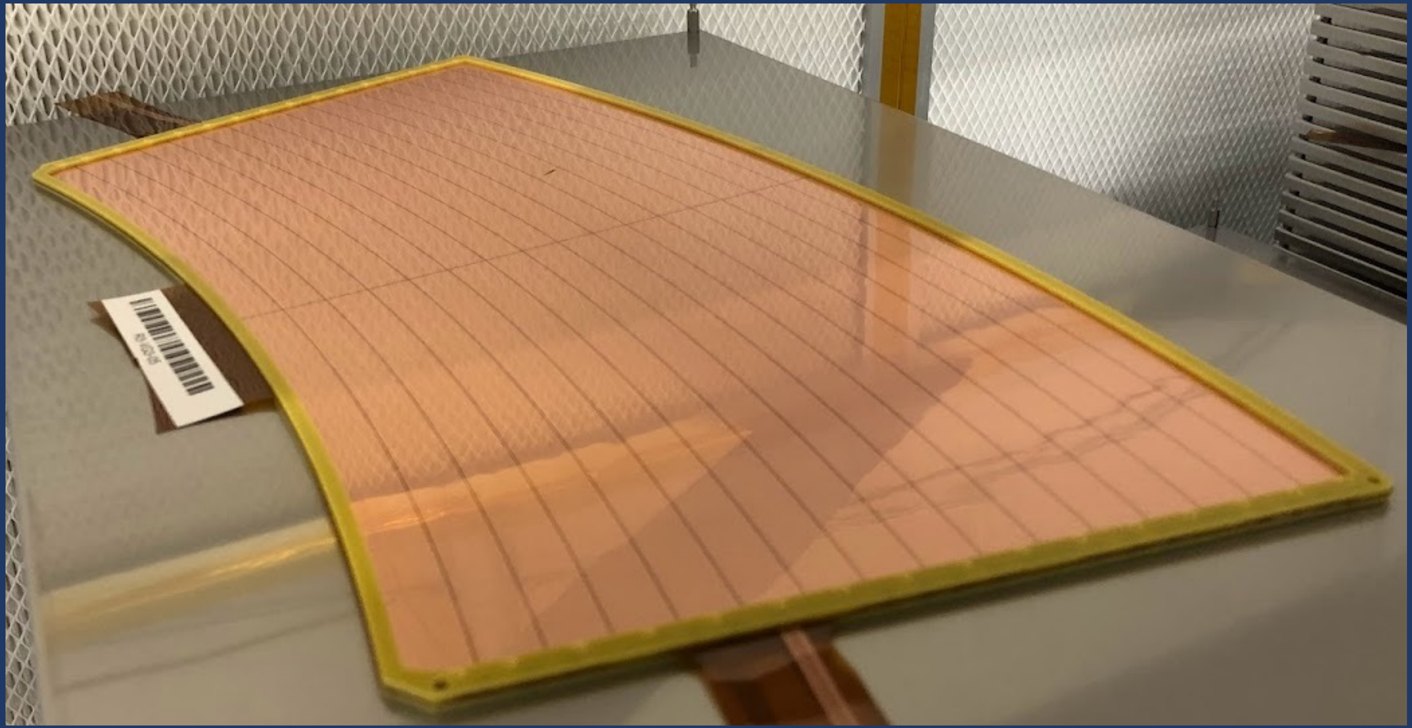
- 5 of 6 lasers
- GEM gains below nominal
- Survey data not yet incorporated into pad or truth positions

Issues during the run

- Pressure and temperature are crucial for all gaseous detectors
- Was not perfect during commissioning ⇒ several GEM stripes are shortened

HV divider × 72 cards

16 stripes, 2 sides



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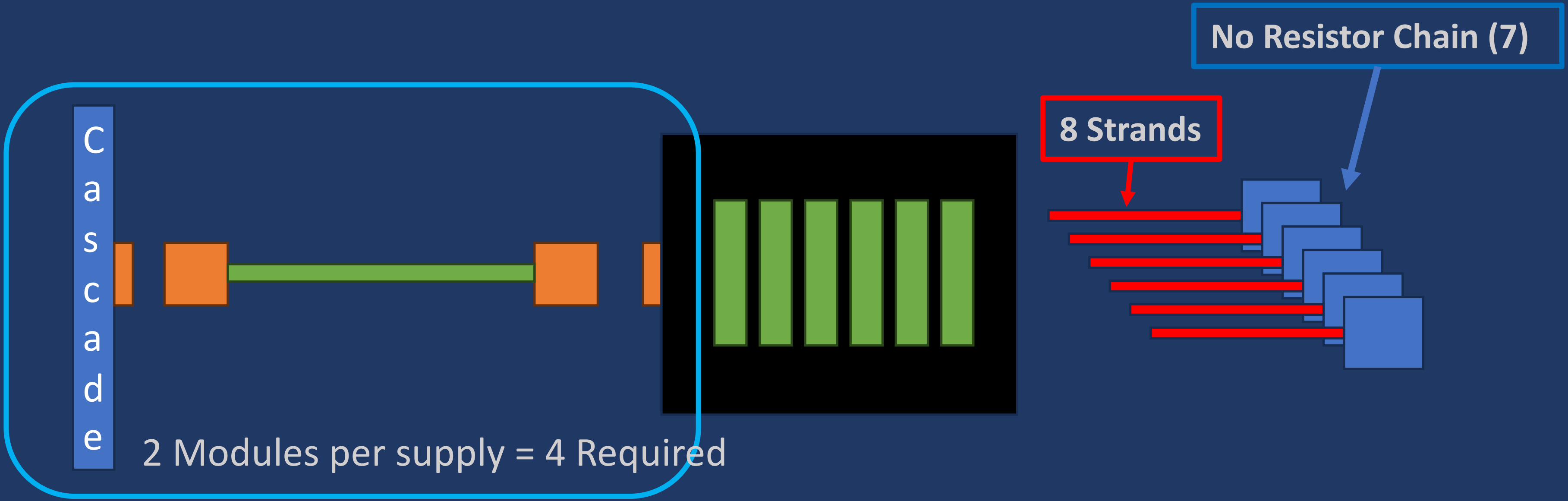


- Solutions:
  - Move resistor chains out of the bore & replace them with individual HV power supplies letter on
  - Improve cooling conditions by introducing additional chiller in the line

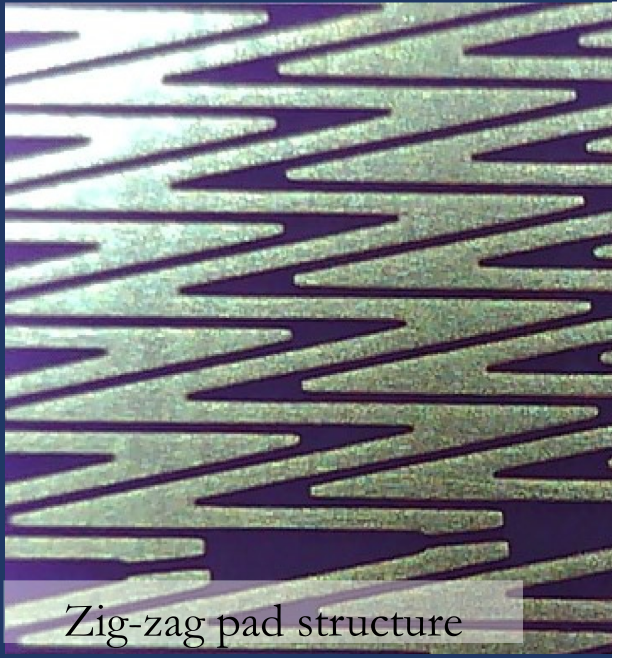
Conclusions

- First sPHENIX commissioning run has started in May 2023
- TPC recorded first 12x12 bunch AuAu collisions in June 2023
- Commissioning results:
  - Significant DAQ development on the way to the streaming readout
  - Diffuse laser has been tested: timed in and several runs have been taken
  - Several improvements are designed and scheduled for the next few months to make TPC operation and maintenance more effective
- Looking forward for the data from the next 2024 run !

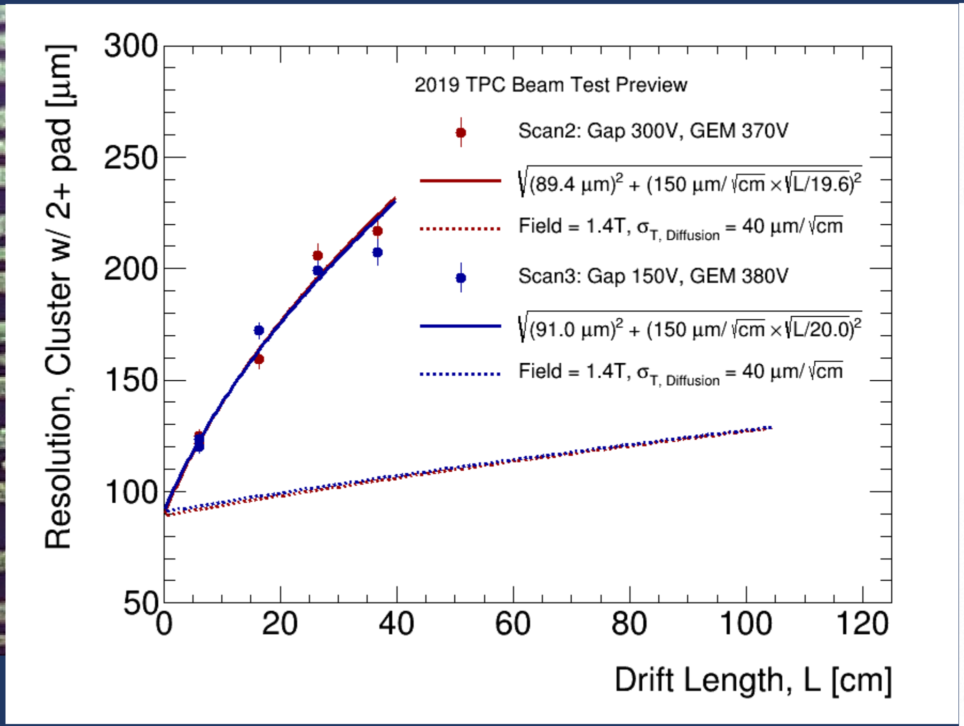
Backup

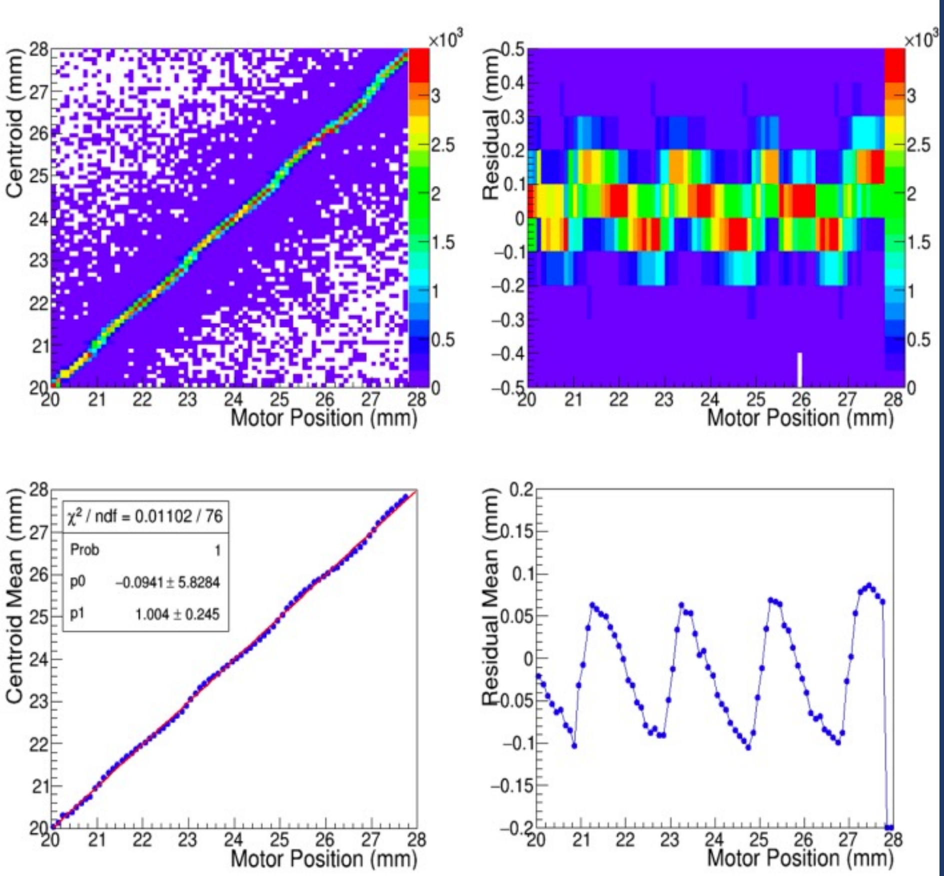
Zig-zag pad structure

[Azmoun, B., et al. *IEEE TNS*, vol. 65, no. 7, 2018](#)



Zig-zag pad structure

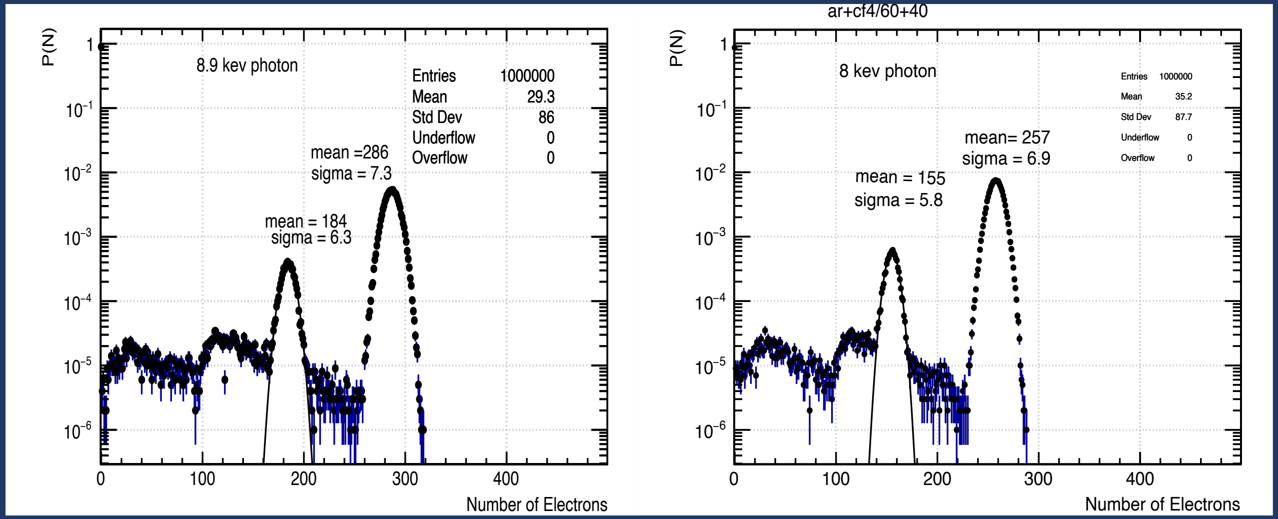




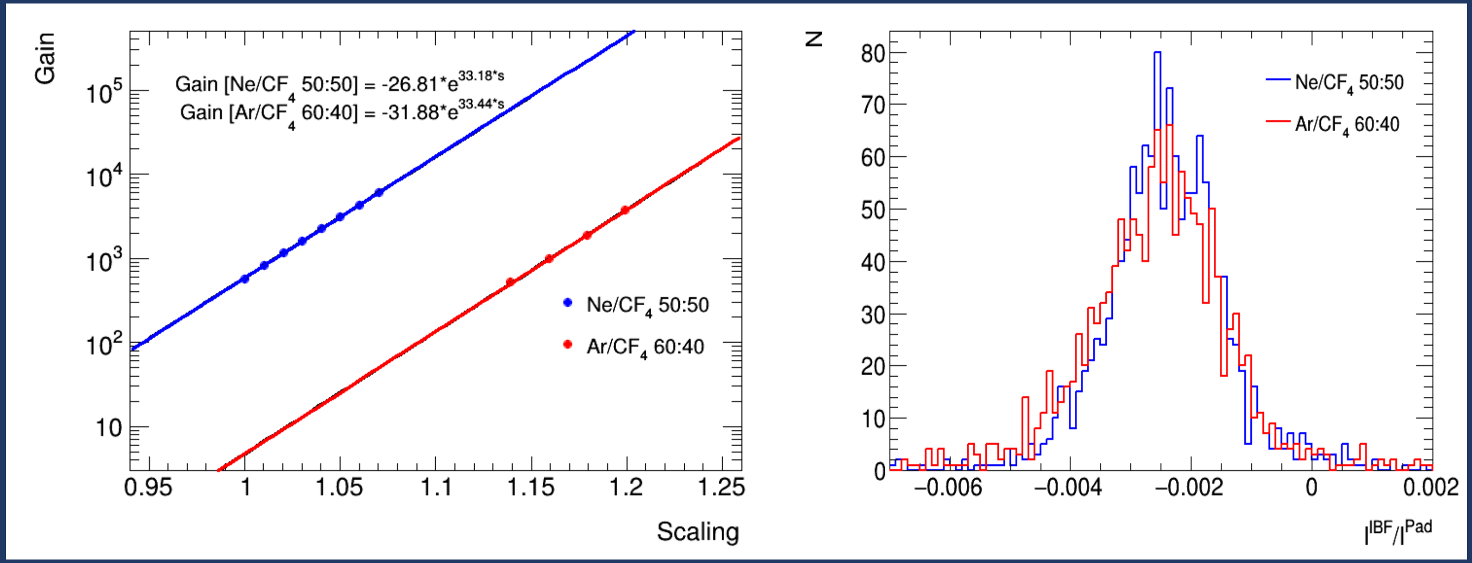
2mm pad pitch and ~0.5mm period

- Simulation expected the resolution of 134 μm
- On bench studies @ BNL have shown resolution of 100 μm in 750 V/cm drift field and Ar-based gas
- Test beam @ Fermi Lab Summer 2019 results provide average resolution of 90-130 μm for Ne/CF_4 50:50

TPC gas: IBF test

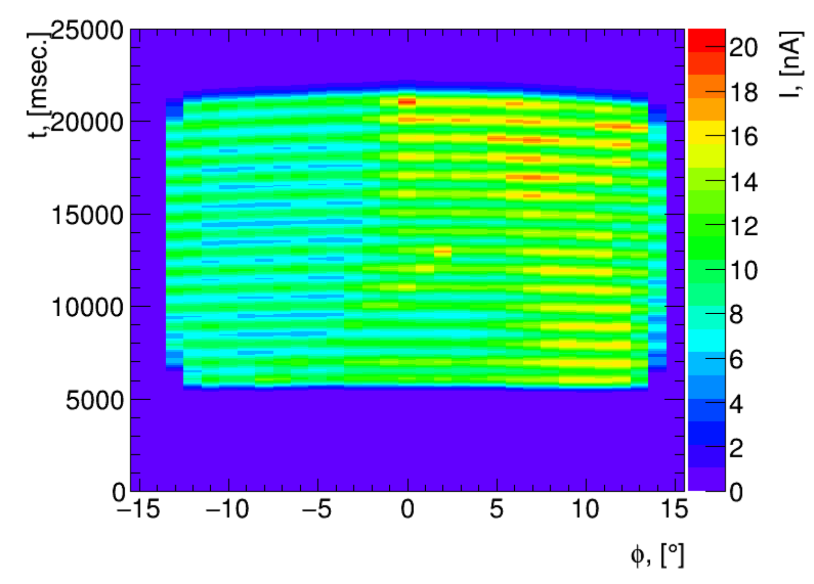


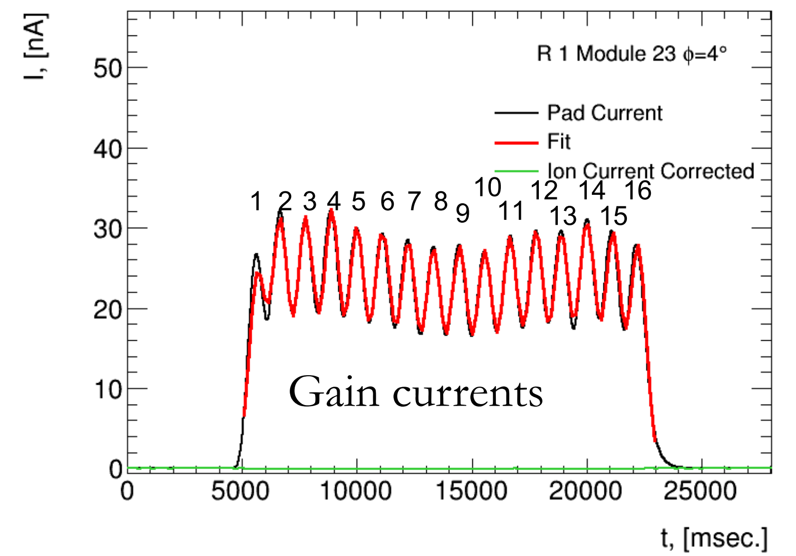
- Cu provides 8 keV and 8.9 keV lines at 15 kV
- Drift fields define GEM stack transparancy to ions
- Thus, only ΔV on GEMs is scaled
- 0.3 % IBF is measured for both gas mixtures

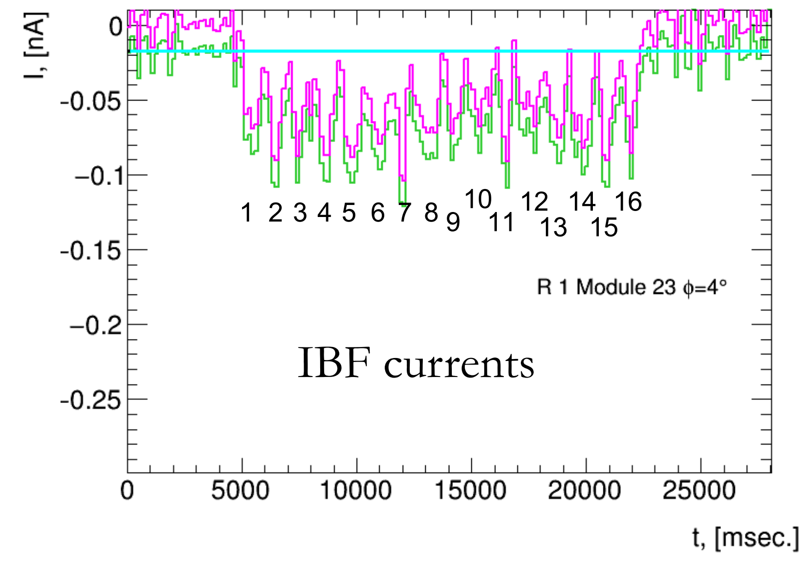


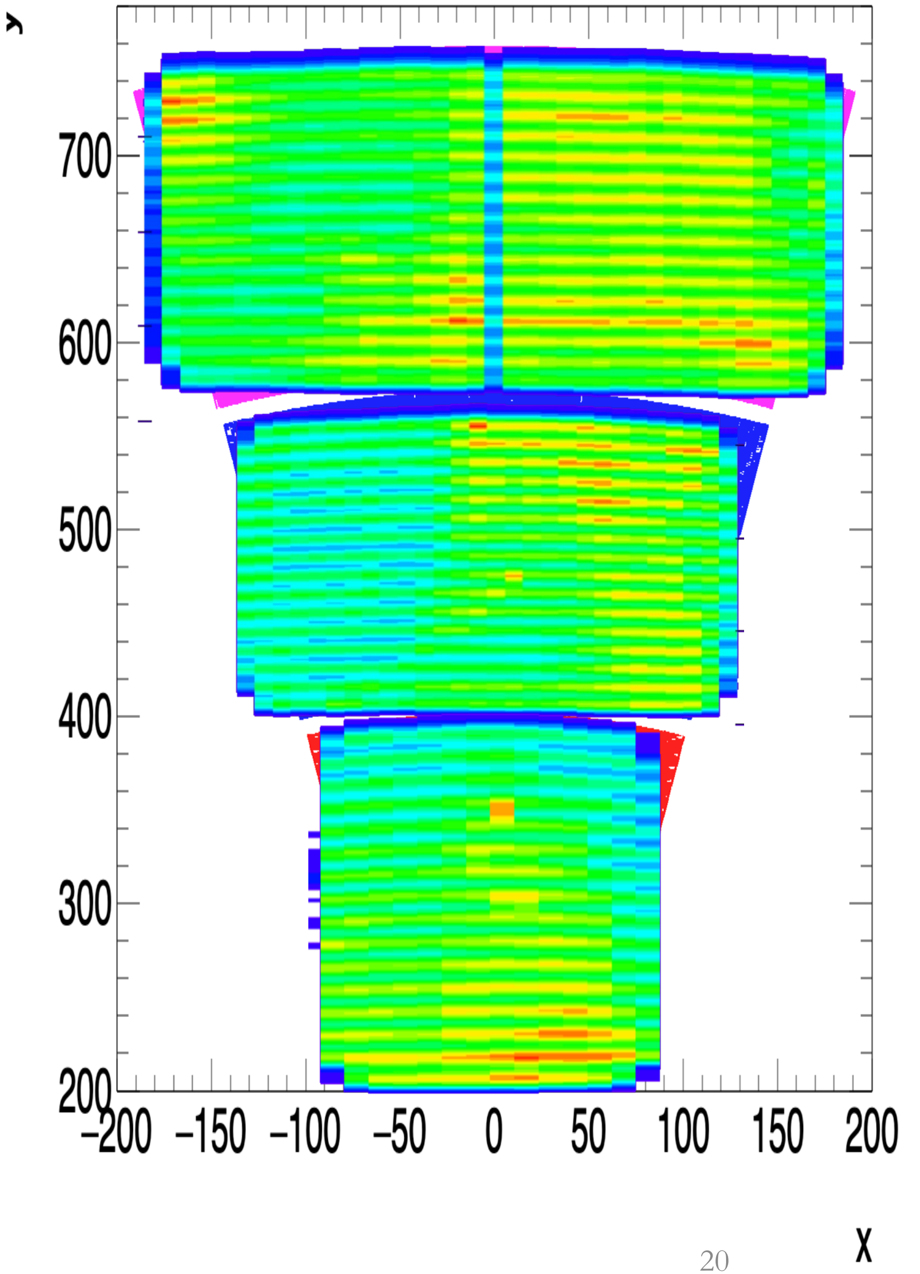
GEM foil	U [V]	ΔV [V]	E^{drift} [V/cm]
G4 b	600	-	-
G4 t	1168	568	-
G3 b	1198	30	95
G3 t	1711	513	-
G2 b	2911	1200	3750
G2 t	3289	378	-
G1 b	4489	1200	3750
G1 t	4793	305	-

Gain & IBF measurements



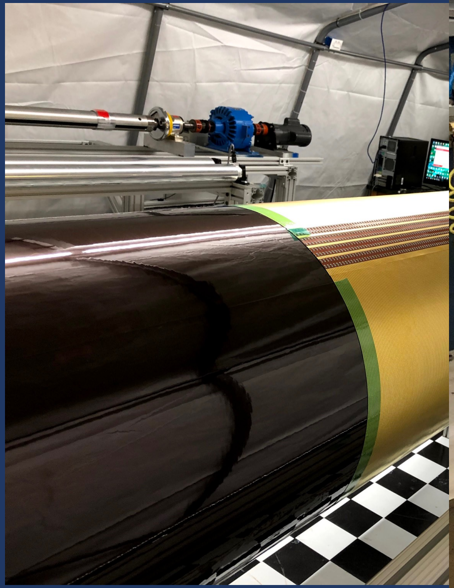






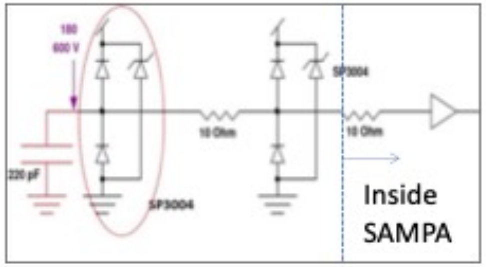
- All modules are scanned for Gain & IBF characterization
- IBF is correlated with gain
- The scans are used for IBF values estimation for the digital currents

TPC assembly

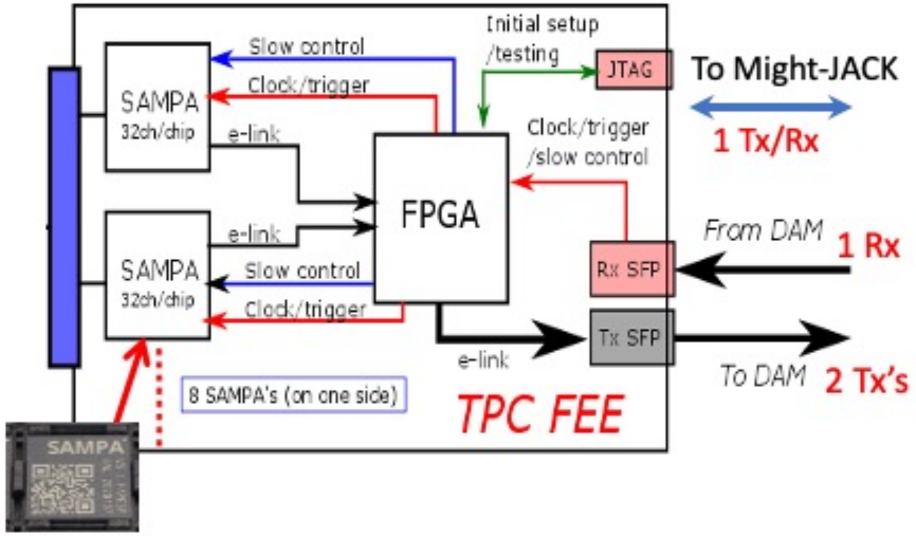


Frontend Electronics (FEE)

- 8 SAMPAv5 + 1 FPGA + 1 QSFP (4 Tx/Rx)
  - FPGA receives data from SAMPA and sends to optical link, and processes clock and slow control data from DAM.
  - JTAG is implemented over optical link.
  - Two data links are available
  - Input protection diodes at input of each channel
  - 6mW/ch for SAMPA
  - **Continuous readout mode**



- Use of newly developed SAMPA v5
  - Two shaping times: 80nsec, 160nsec
  - Two gains: 30mV/fC, 20mV/fC
  - SAR ADC: 5/10/20MHz sampling. At sPHENIX, 4.7/9.4/18.8MHz
- Three powers: 4V dig, 2V dig, and 2V ana
  - Typical rating: ~1A@4V, ~2A@2Vdig, ~2.5A@2V ana
  - Total power consumption: <15W
  - Water cooling system has been developed to take this heat
- It works fine at 1.5T and 100krad.
- Costs: $560 per board (excl SAMPA chips, incl PCBs and assembly)



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