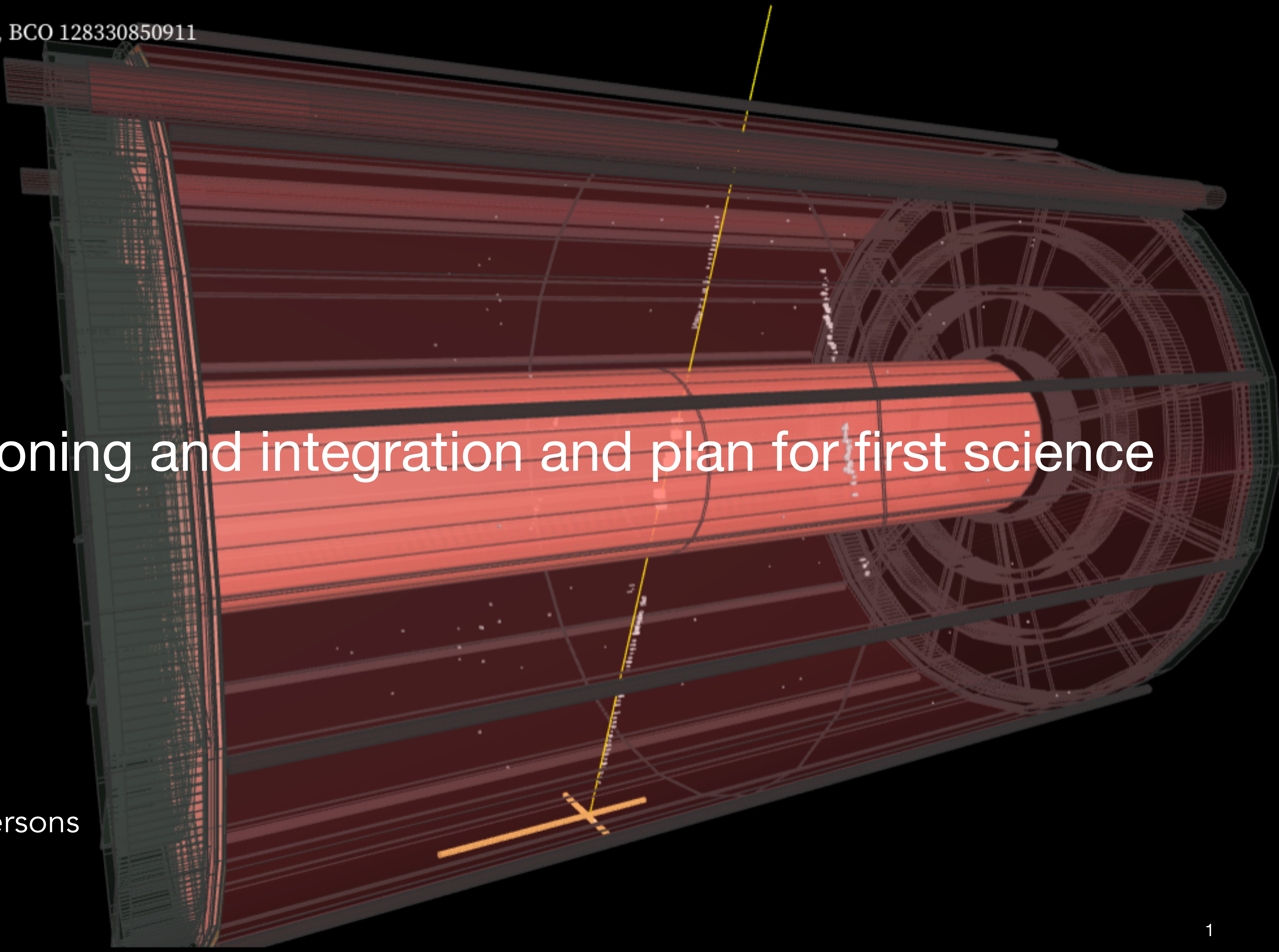
sPHENIX Tracker
2023-08-23, Run 25926 - All EBDCs, BCO 128330850911
0-Field Cosmics Data



# sPHENIX commissioning and integration and plan for first science

David Morrison (BNL)
Gunther Roland (MIT)

co-spokespersons


June 2022


Las Vegas
Since
1967

# April 2023

Some of the many students and postdocs working on sPHENIX …


… and some of the many technicians, engineers, trades, and others too.


sPHENIX ribbon cutting January 2023
Asmeret Berhe
DOE Director
Office of Science
Vanessa Chan
DOE Director
Office of
Technology
Transitions

# Smooth sailing? Successful sailing.

- PD-2/3 schedule included 14 months of float, early finish in October 2021
- Direct effects of COVID — workforce availability, construction logistics
- Indirect effects of COVID — electronics lead time
- Conflict in Ukraine — necessitated switch from neon to argon for TPC
- Logistics around Run 22
- Beryllium beam pipe
- Complex process readying for DOE's Approval to Operate decision

# Beryllium beam pipe

Plan A

Plan B

# From installation to commissioning with beam

Received approval to operate on **May 18** (operating gas, HV, LN2/LHe)
SC solenoid cool-down **May 19–25**; ramped to operating current **May 31**

Plan presented in 2022 BUR

| Weeks | Designation |
|---|---|
| 0.5 | Cool Down from 50 K to 4 K |
| 2.0 | Set-up mode 1 (Au+Au at 200 GeV) |
| 0.5 | Ramp-up mode 1 (8 h/night for experiments) |
| 11.5 | sPHENIX Initial Commission Time |
| 9.0 (13.0) | Au+Au Data taking (Physics) |
| 0.5 | Controlled refrigeration turn-off |
| 24.0 (28.0) | Total cryo-weeks |

Implicit assumption: all infrastructure is ready

| Weeks | Details |
|---|---|
| 2.0 | low rate, 6-28 bunches |
| 2.0 | low rate, 111 bunches, MBD L1 timing |
| 1.0 | low rate, crossing angle checks |
| 1.0 | low rate, calorimeter timing |
| 4.0 | medium rate, TPC timing, optimization |
| 2.0 | full rate, system test, DAQ throughput |
| 12.0 | **total** |

**May 18** + 12 weeks: **August 10**
End of RHIC beam: **August 1**

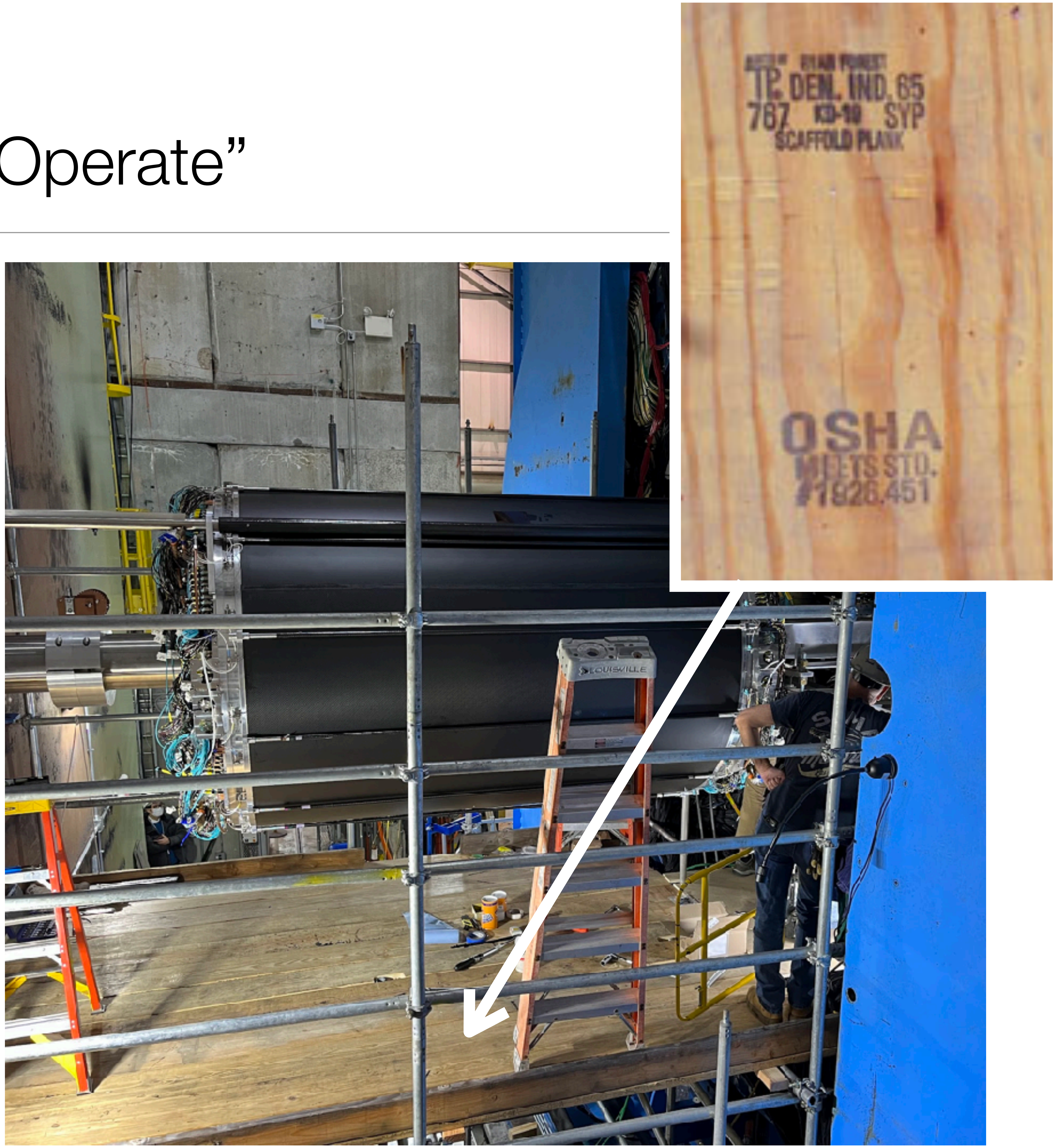
The success of our commissioning period would not have been possible without the dedicated support by C-AD and their flexibility in accommodating our requests

# Into the home stretch: “Approval to Operate”

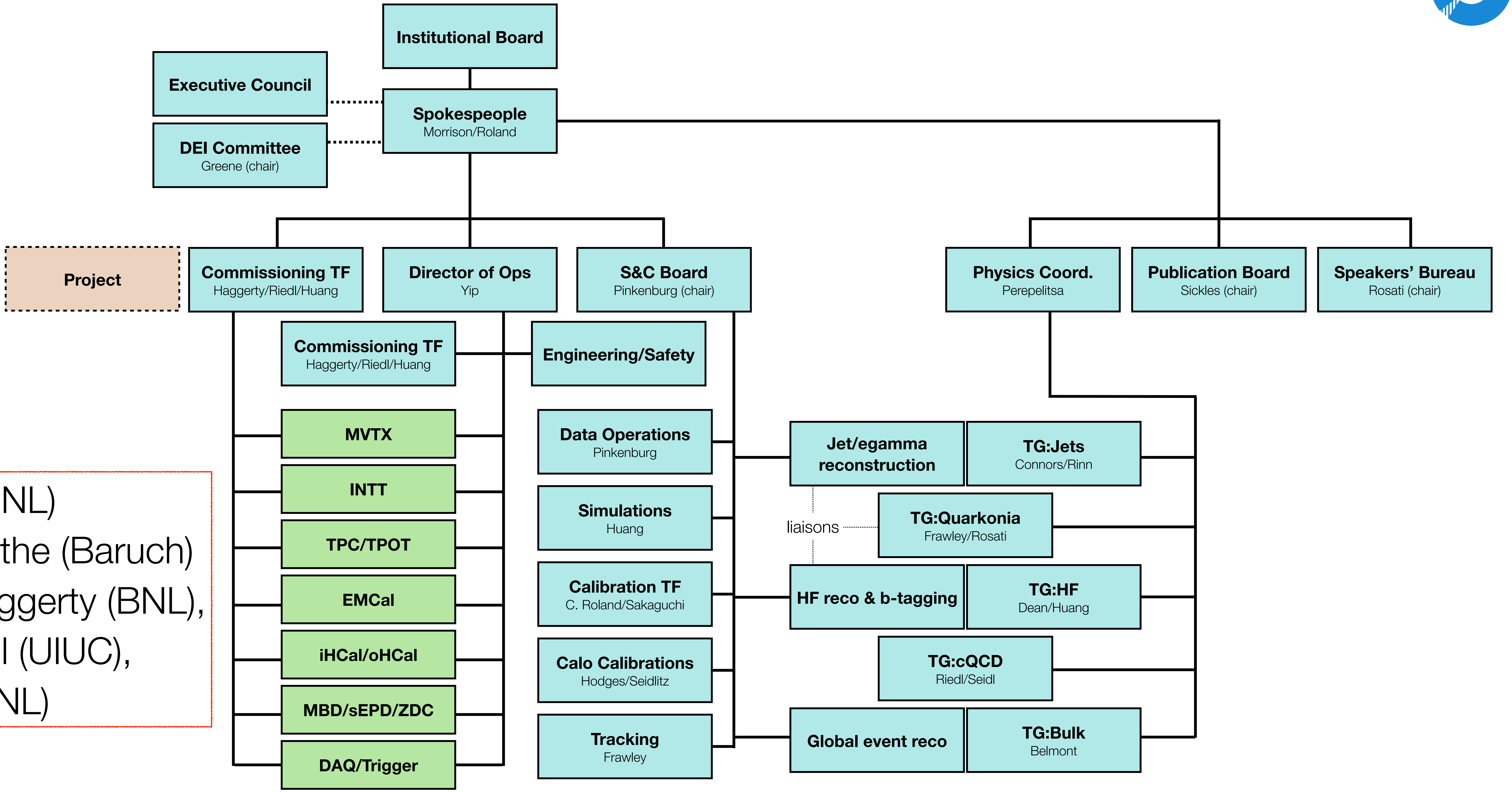
- Major focus was safety: documentation, procedures, interviewing shift crew, electrical code inspections, signage & labeling, hand rails, walking surfaces, and many other things

- For some of us, unfamiliar review territory — about nine weeks to complete

- Received approval from Brookhaven DOE site office on May 18 — fantastic!



# Transition from project to operations




**DO**: Kin Yip (BNL)
**RC**: Stefan Bathe (Baruch)
**CTF**: John Haggerty (BNL), Caroline Riedl (UIUC), Jin Huang (BNL)


sPHENIX control room

# Commissioning report

- Infrastructure — e.g., the SC solenoid
- Ten detectors: MVTX, INTT, TPC, TPOT, EMCal, iHCal, oHCal, MBD, sEPD, ZDC/SMD
- DAQ/Trigger
- Operations
- Online monitoring
- Offline computing — archiving, event assembly, reconstruction, analysis

**90 page document on commissioning**

sPHENIX Report

**tag:**
**version:** 0.1
**DOI:** unspecified
**date:** August 16, 2023

Commissioning Status: August 2023

sPHENIX Collaboration

Abstract

sPHENIX began commissioning with beam on May 18, 2023 with the receipt of approval to operate. This document details the progress made to date bringing the sPHENIX detectors and its associated infrastructure to a state in which physics running can begin.

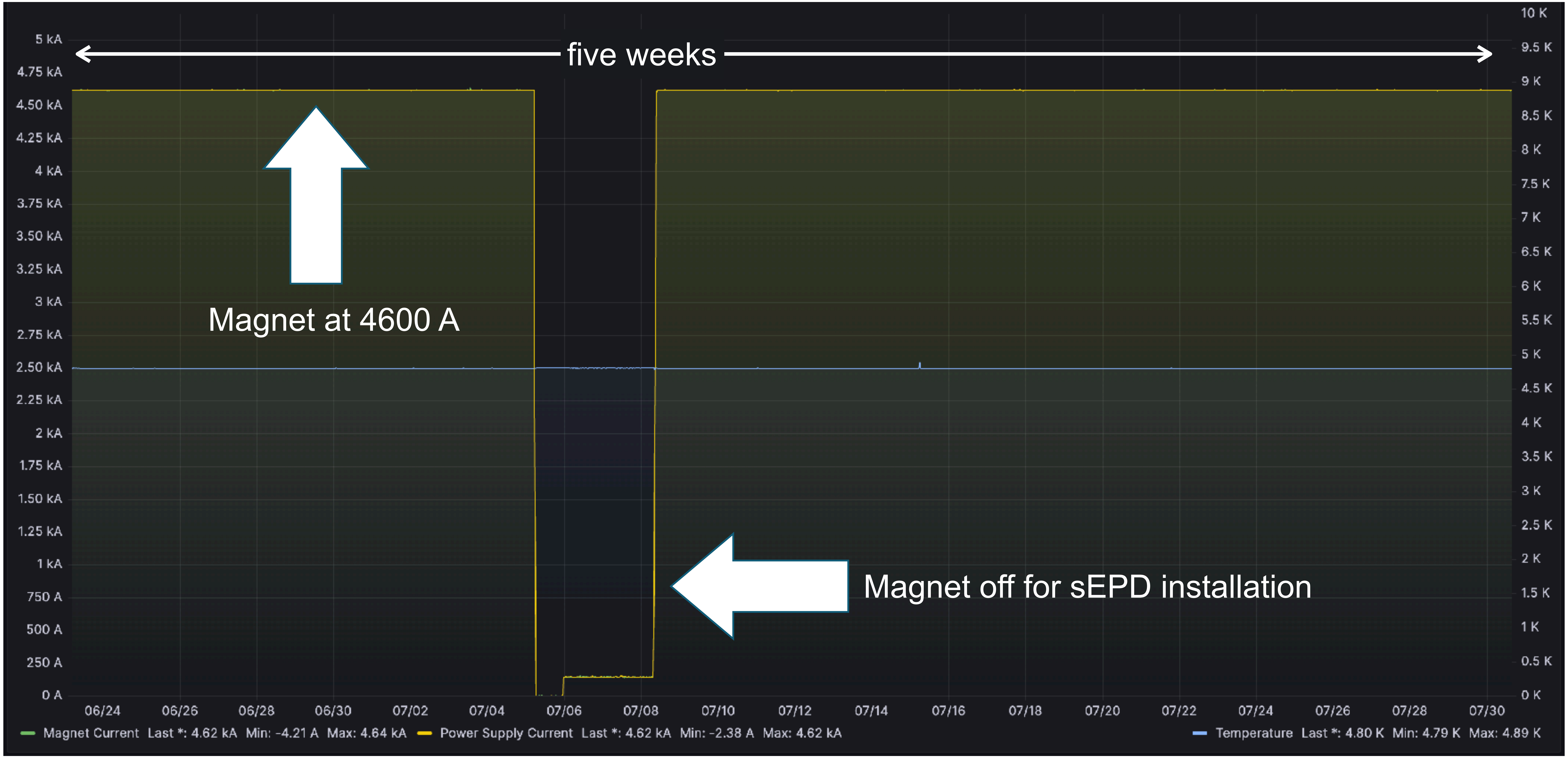
# Commissioning report synopsis

- SC magnet: **complete**
- Min Bias Detector: **complete**
- Outer HCal: **complete**
- Inner HCal: **complete**
- EMCal: **complete**
- TPC outer tracker: **complete**
- ZDC: **complete**
- INTT: triggered mode **complete**, testing streaming mode

- MVTX: successful operation; response to backgrounds underway
- TPC: operating HV achieved, tracks observed; work on stability of operations
- DAQ: all detectors have been read out; work continues on stability and rate
- SMD: some channels still to read out
- sEPD: successful readout; detector and electronics installation completed after August 1 end of run

Commissioning continues — ‘round the clock shifts scheduled through October 3

# Superconducting magnet — works perfectly




Very stable operation after faulty QLI ribbon cable replaced

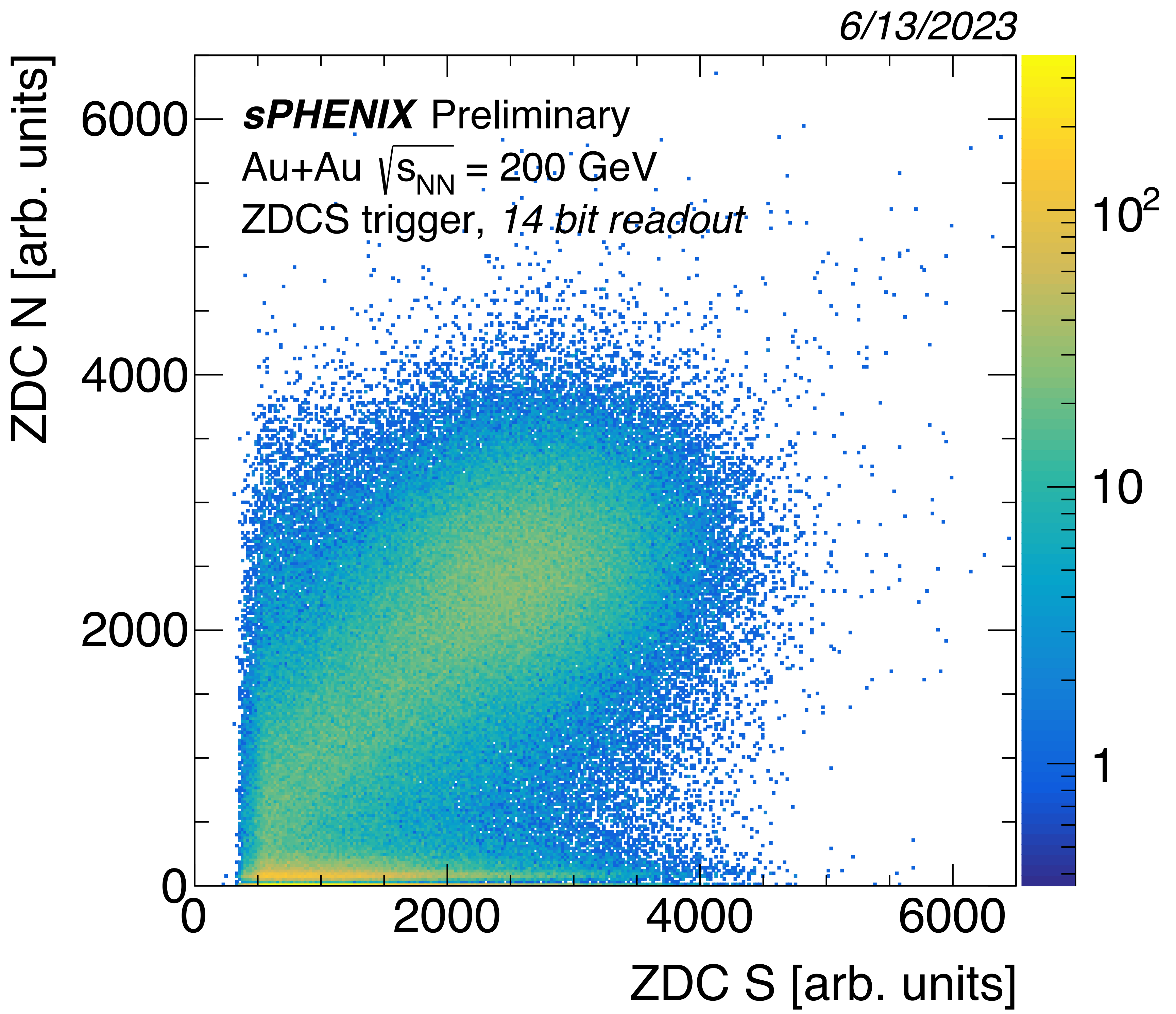
# Crossing angle studies: MBD determines $\sigma_{z\text{-vertex}}$


Effect on z-vertex distribution as expected
More severe effect on luminosity than predicted

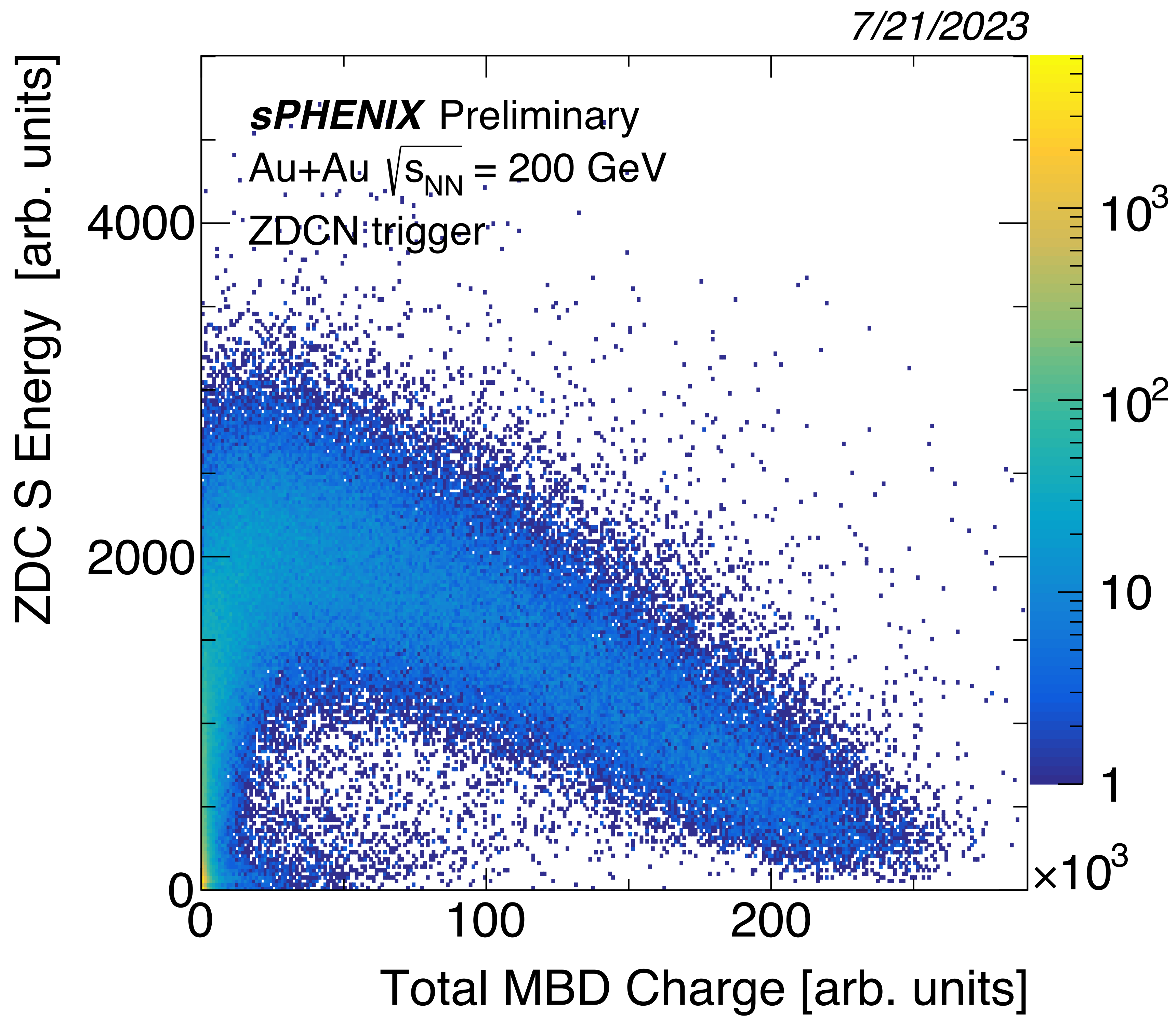
n.b. fewer collisions outside of useful $z_{vertex}$ range reduces TPC charge dependent calibrations

# Global detectors: ZDC, MBD, sEPD

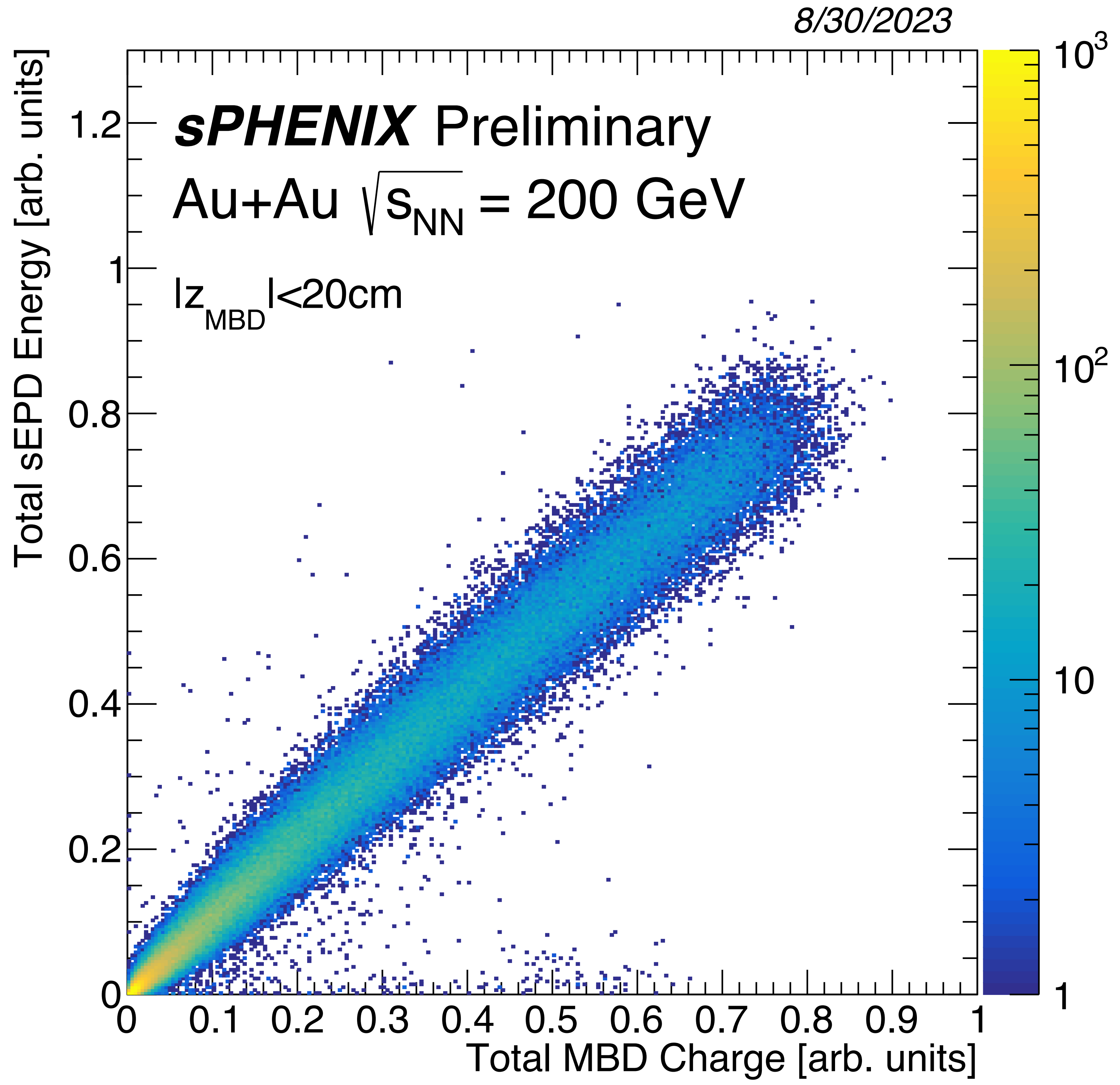
## ZDC North-South Correlation



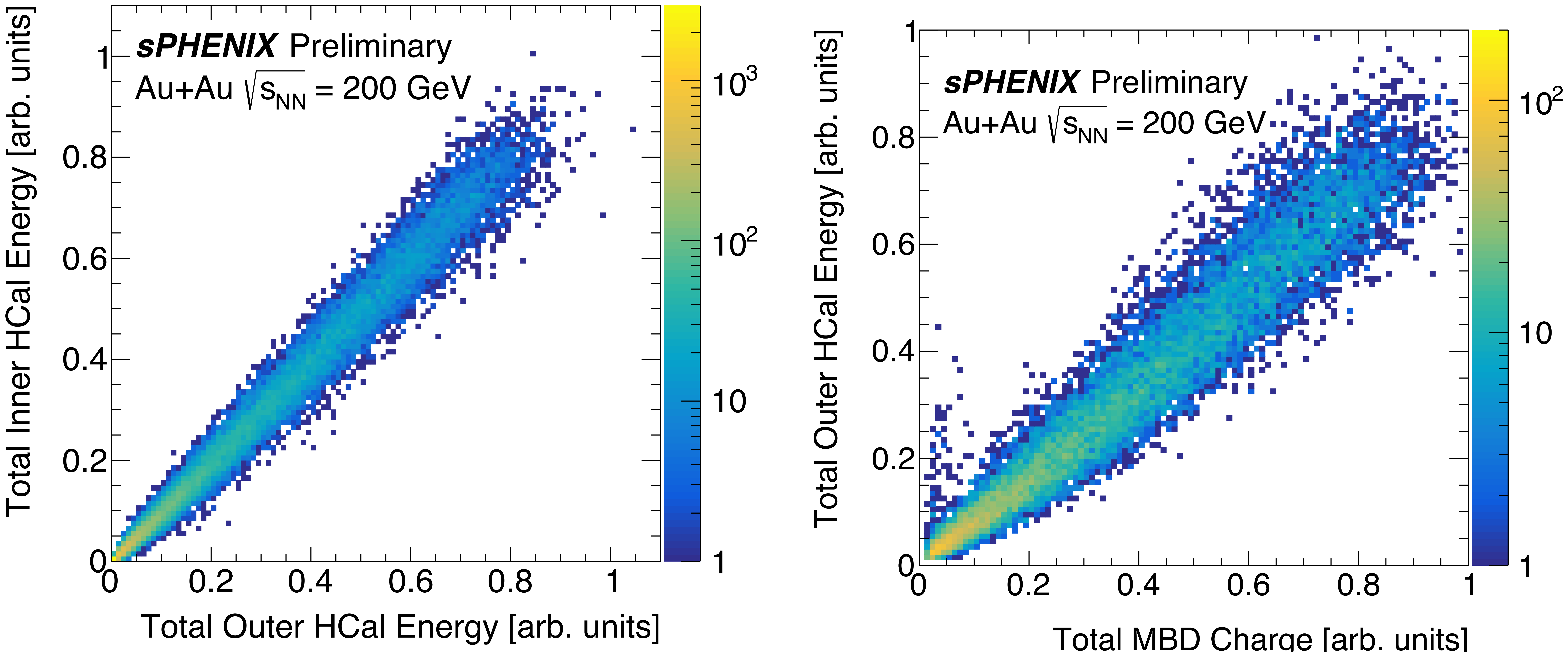

## ZDC-MBD correlation



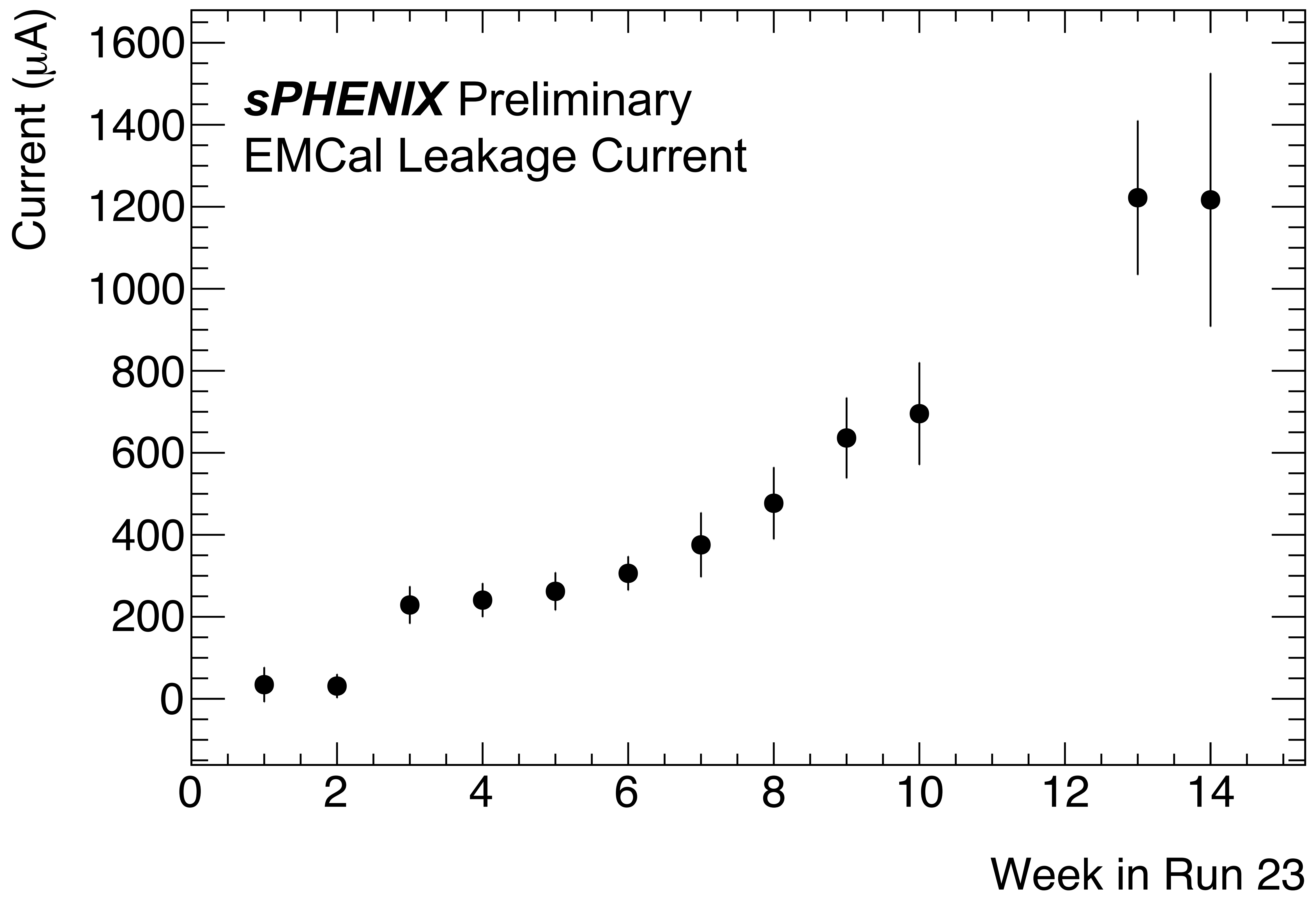

## sEPD-MBD correlation



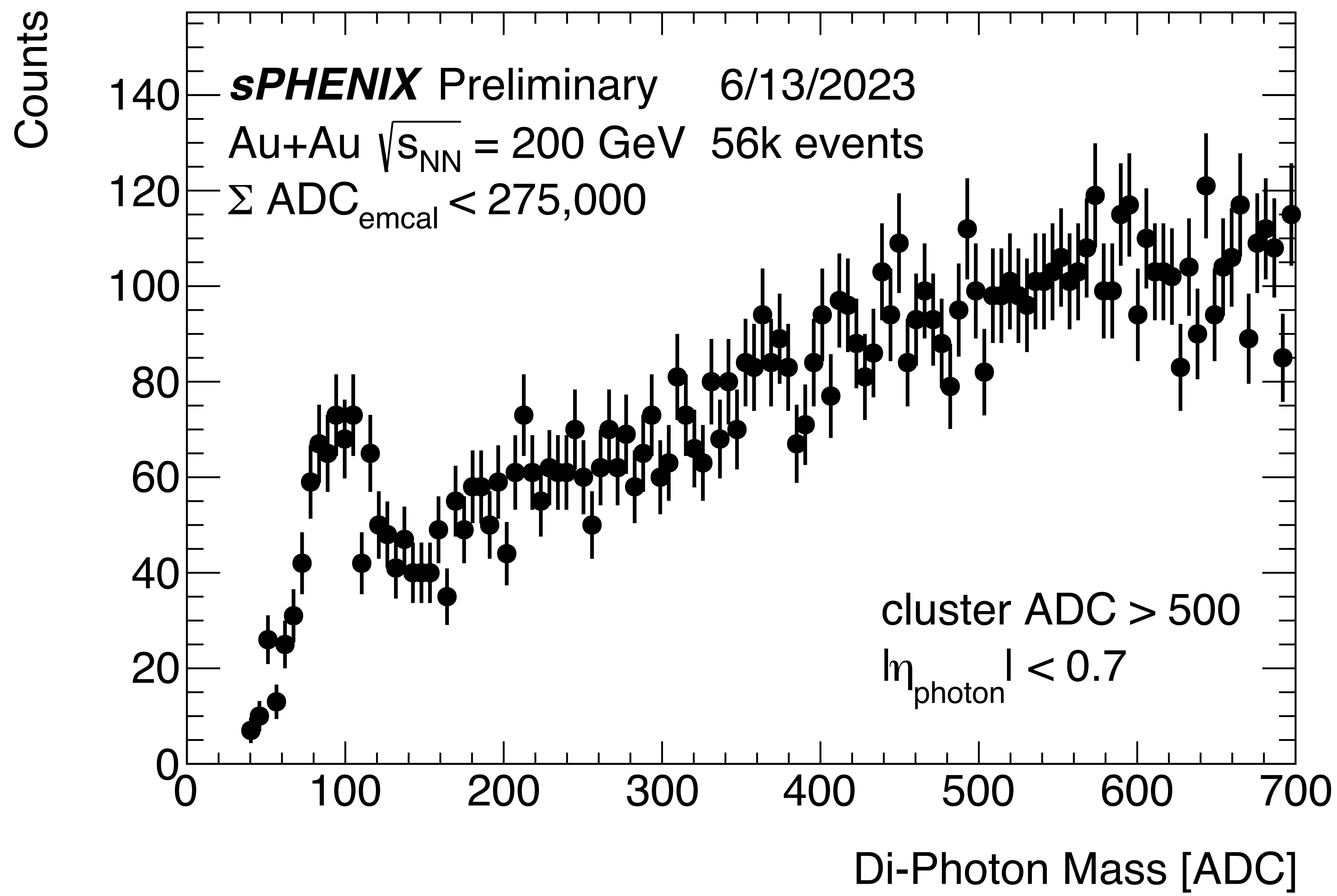
# Hadronic Calorimeter



# Electromagnetic calorimeter

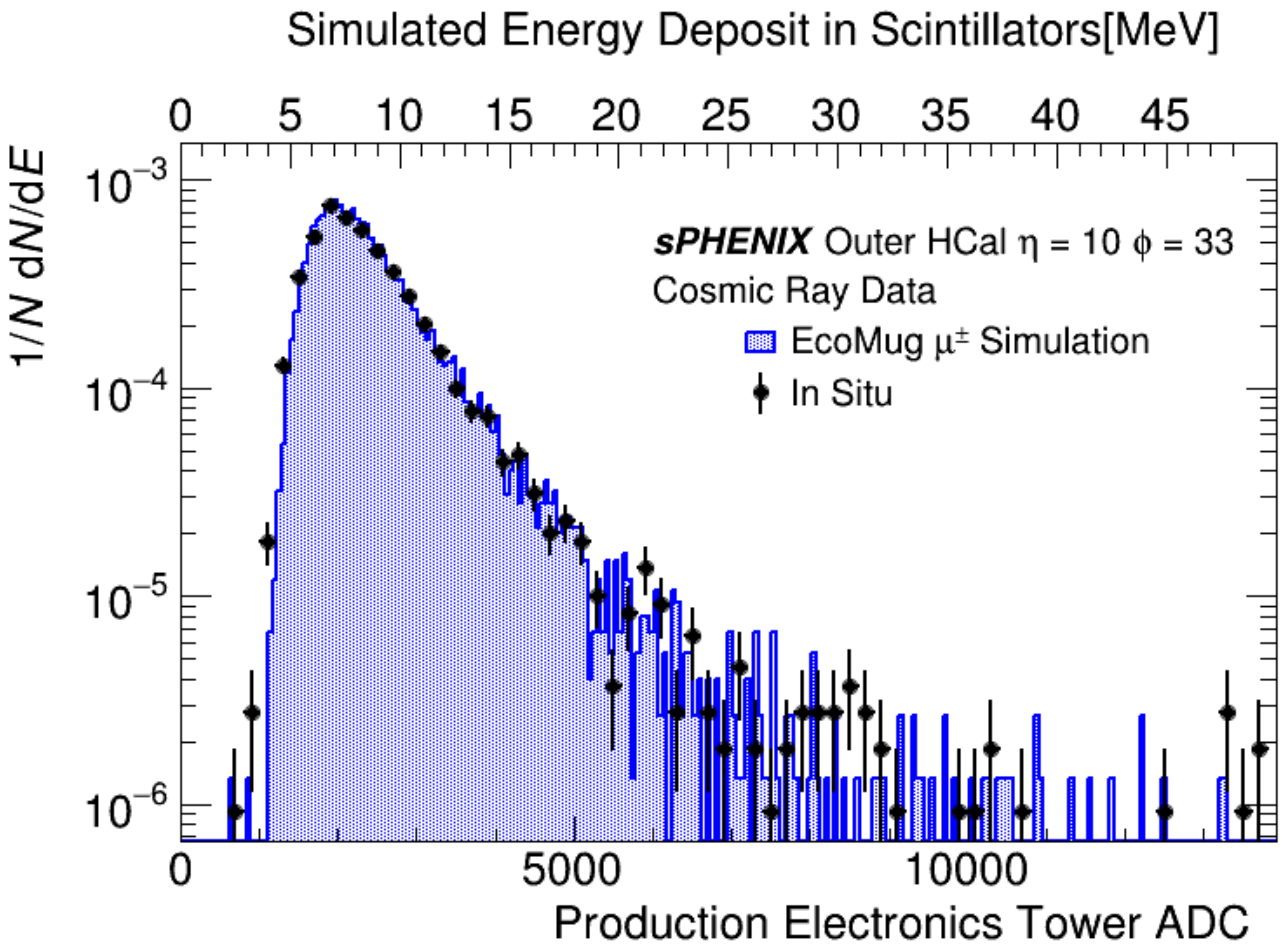


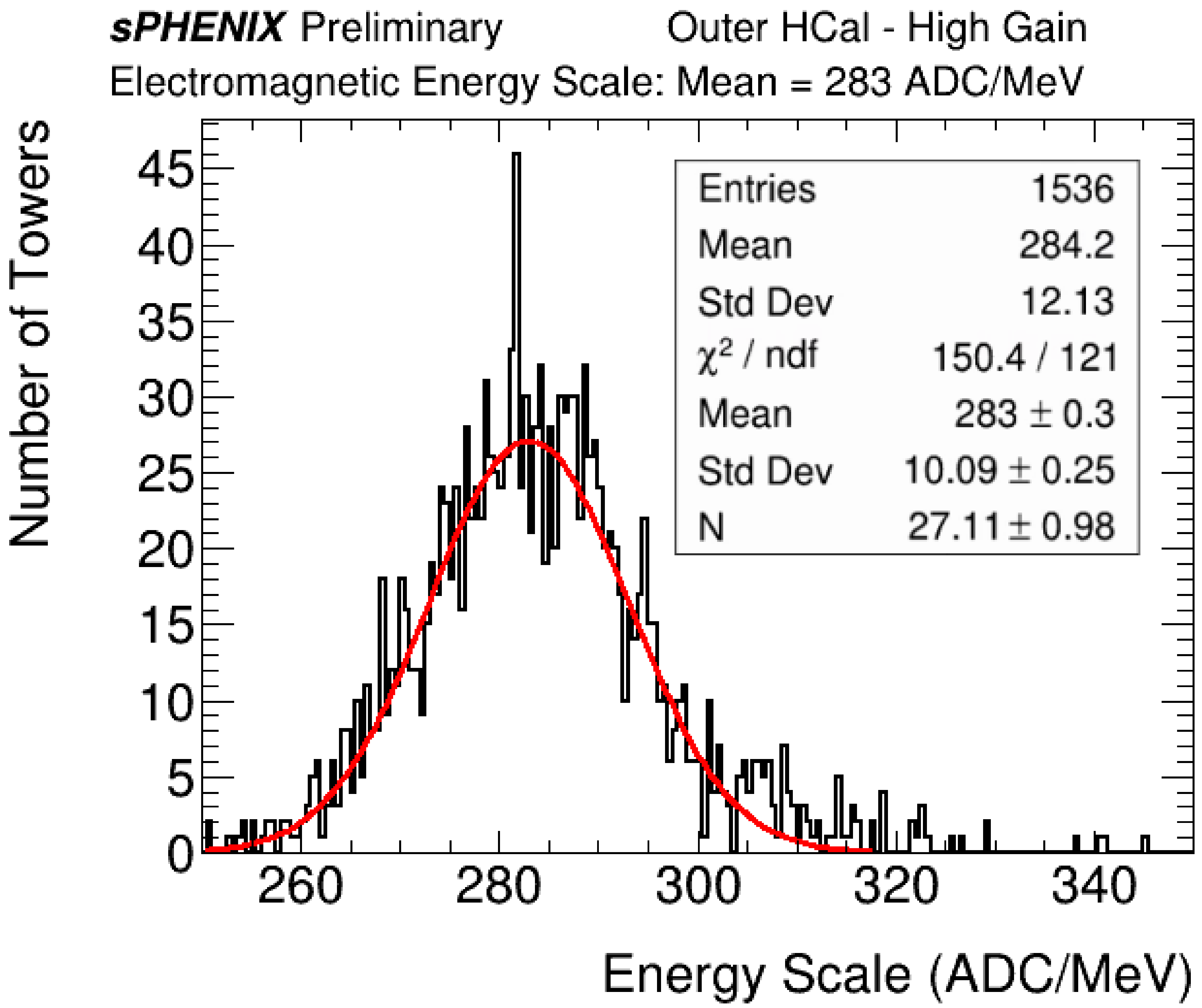

>99% live channels; growth of SiPM leakage current consistent with expectation



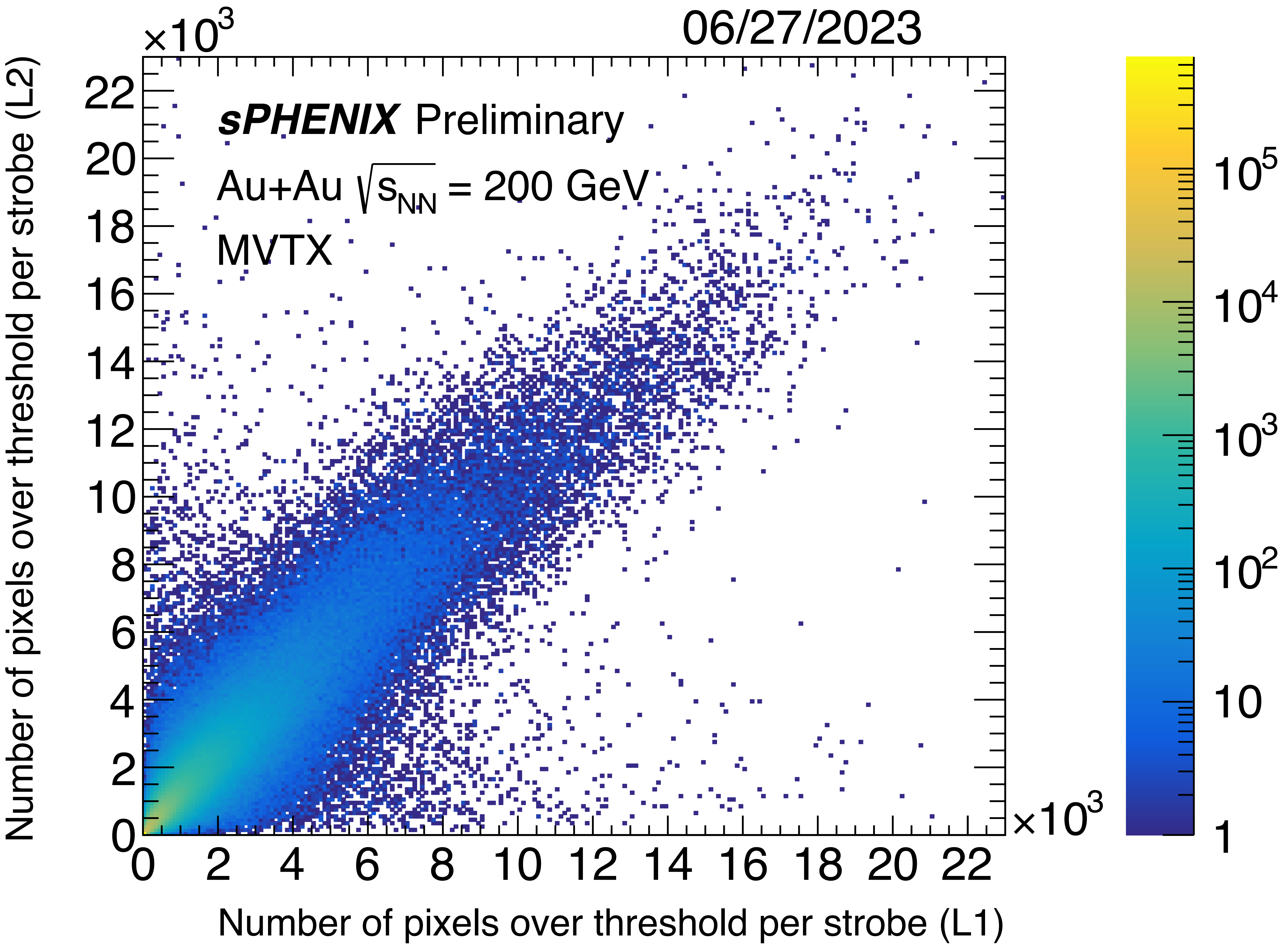

reconstructed di-photon mass — in ADC counts — peak corresponds to $\pi^0$

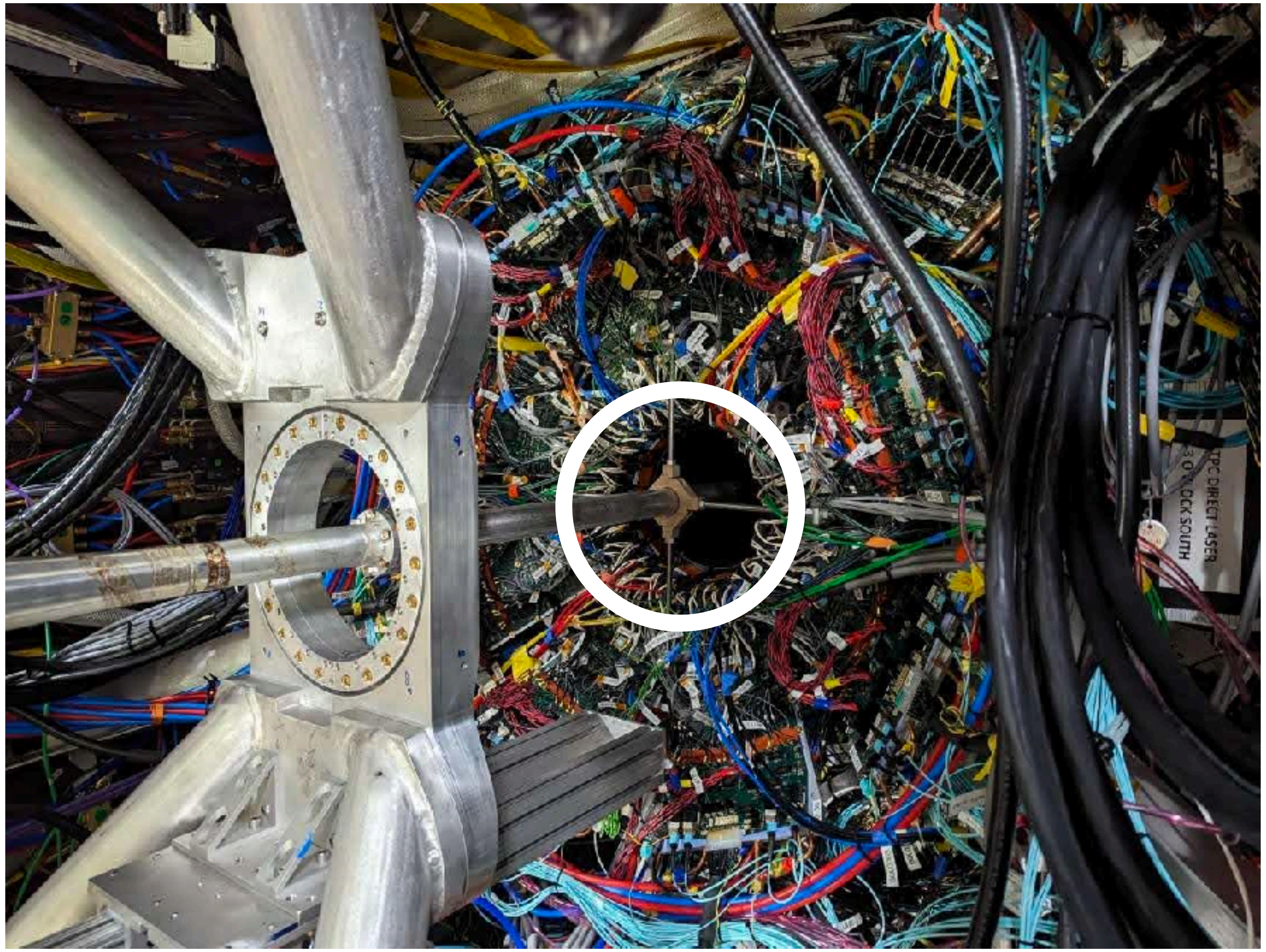
# Calibrating the calorimeter energy scale



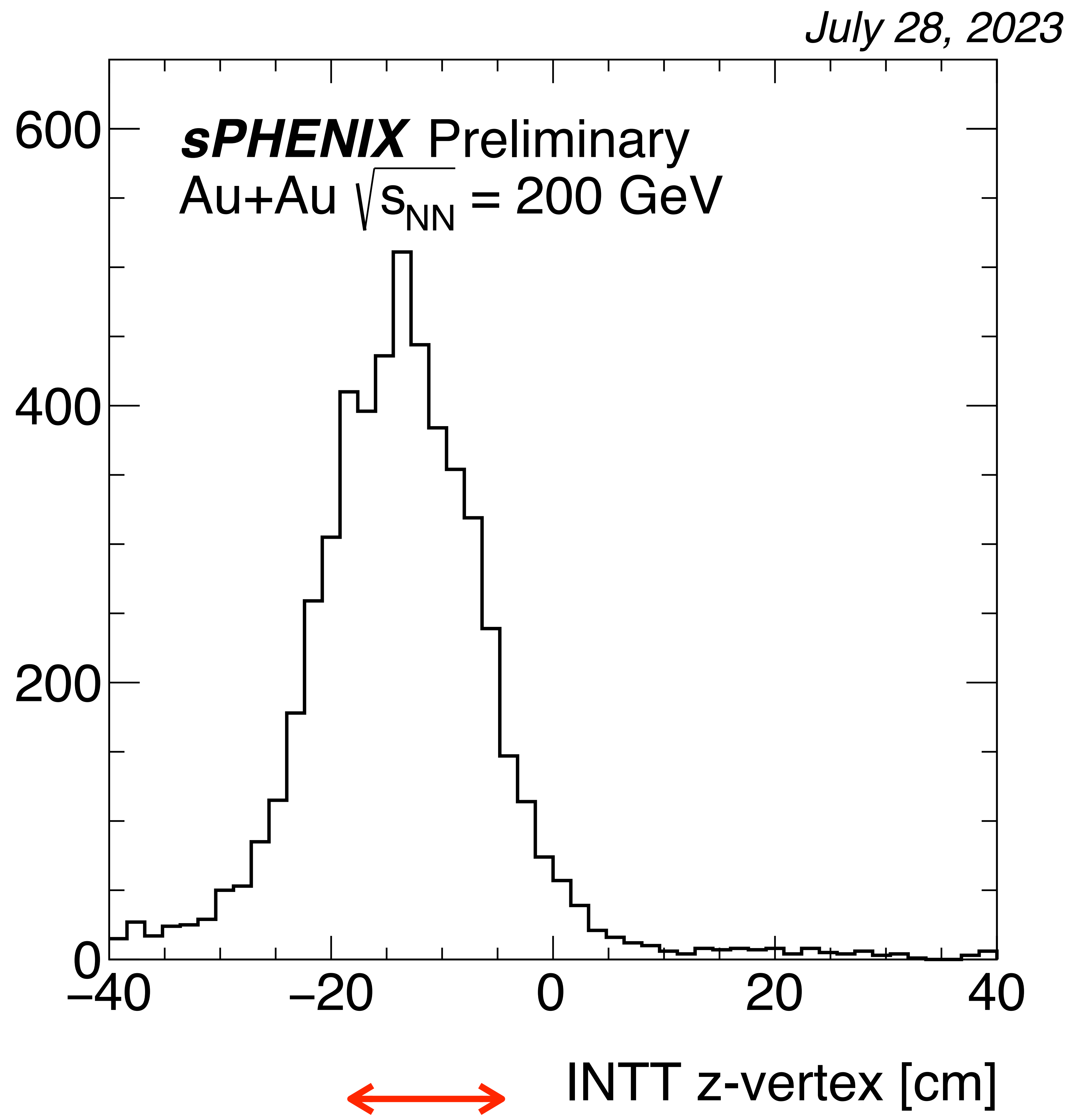
# MAPS vertex detector (MVTX)



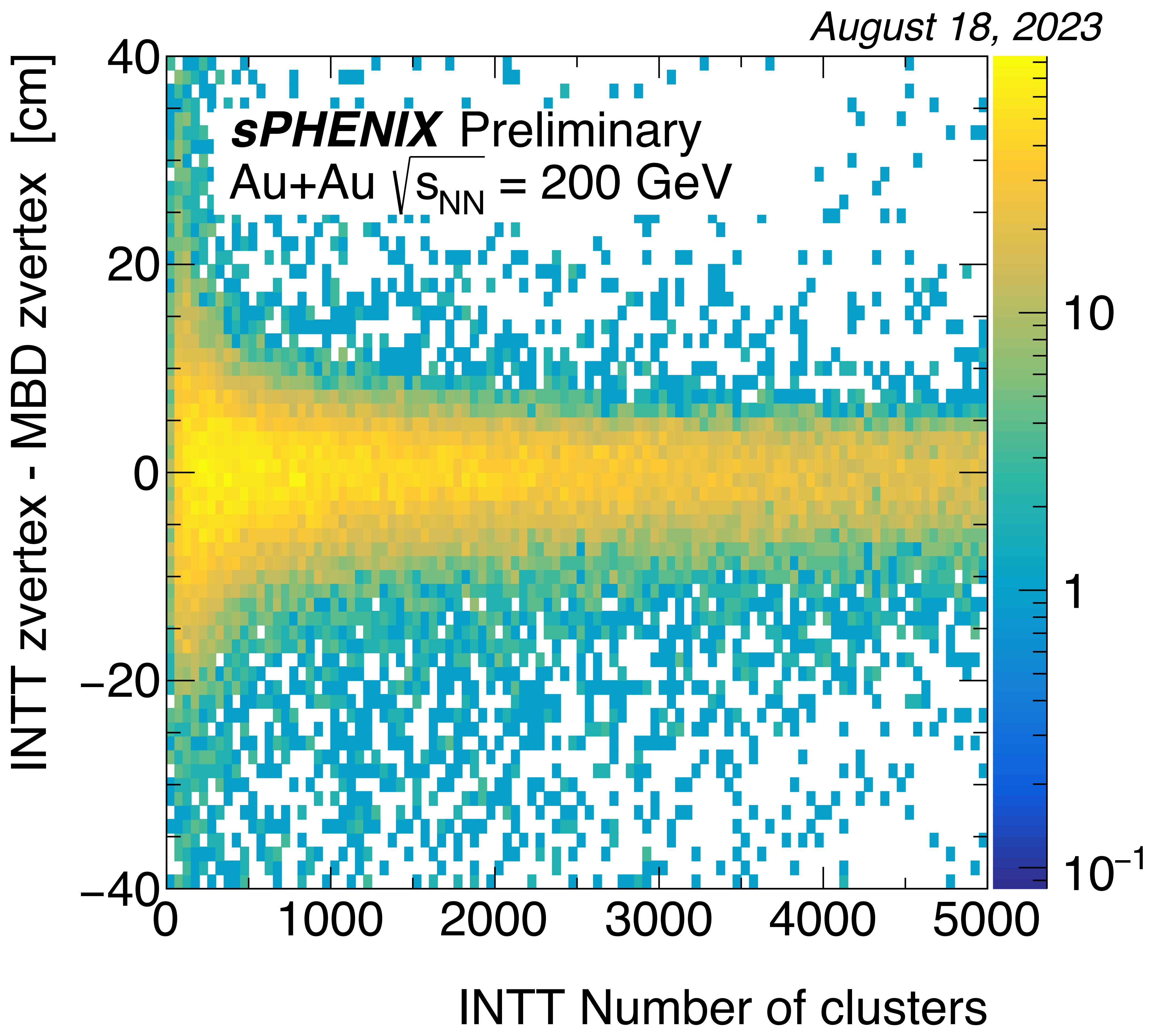



Correlation multiplicities in two outermost MVTX layers, across multiple FELIX cards

# Primary vertex location: INTT and MBD

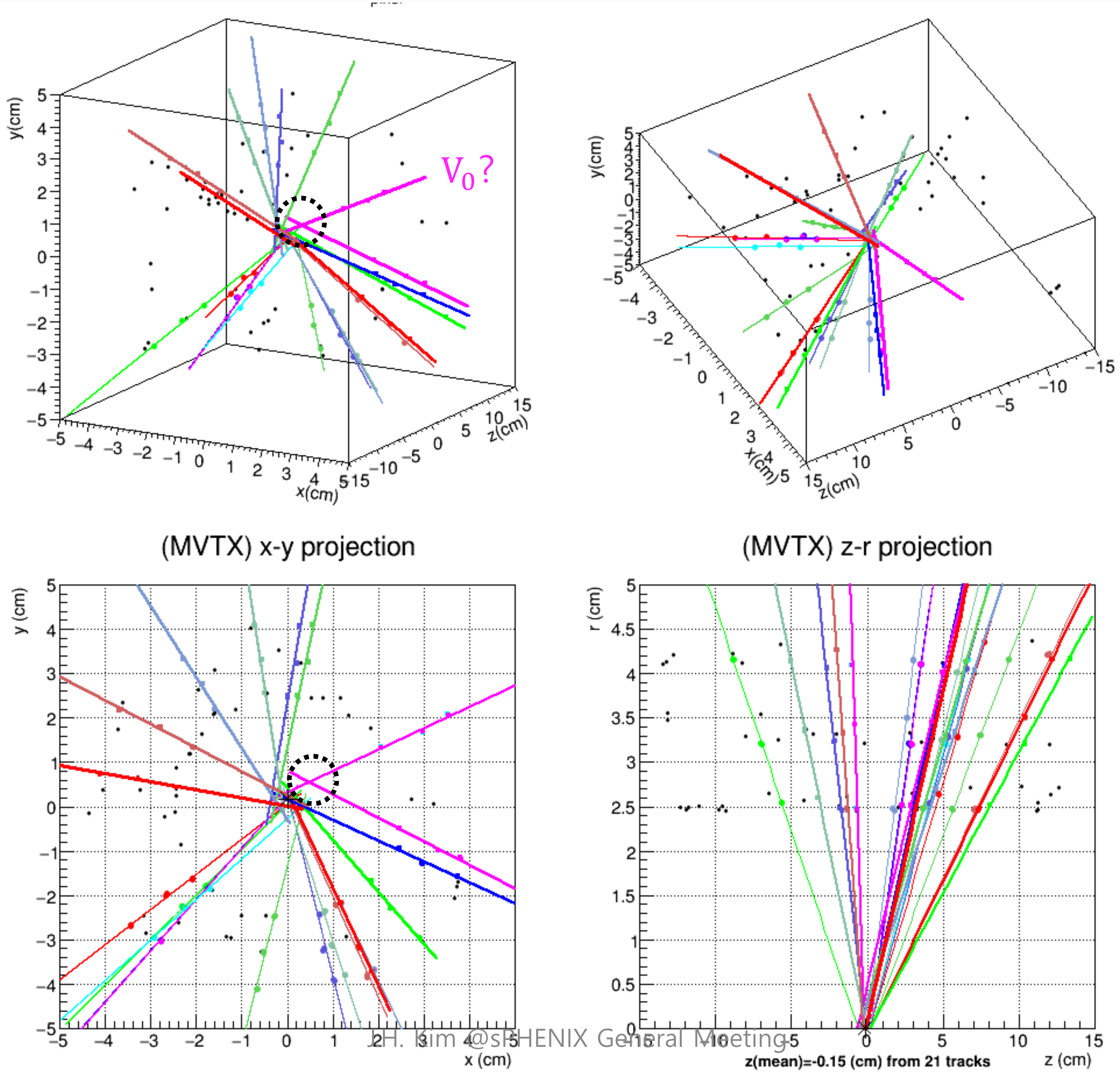



offset from $z = 0$ was expected

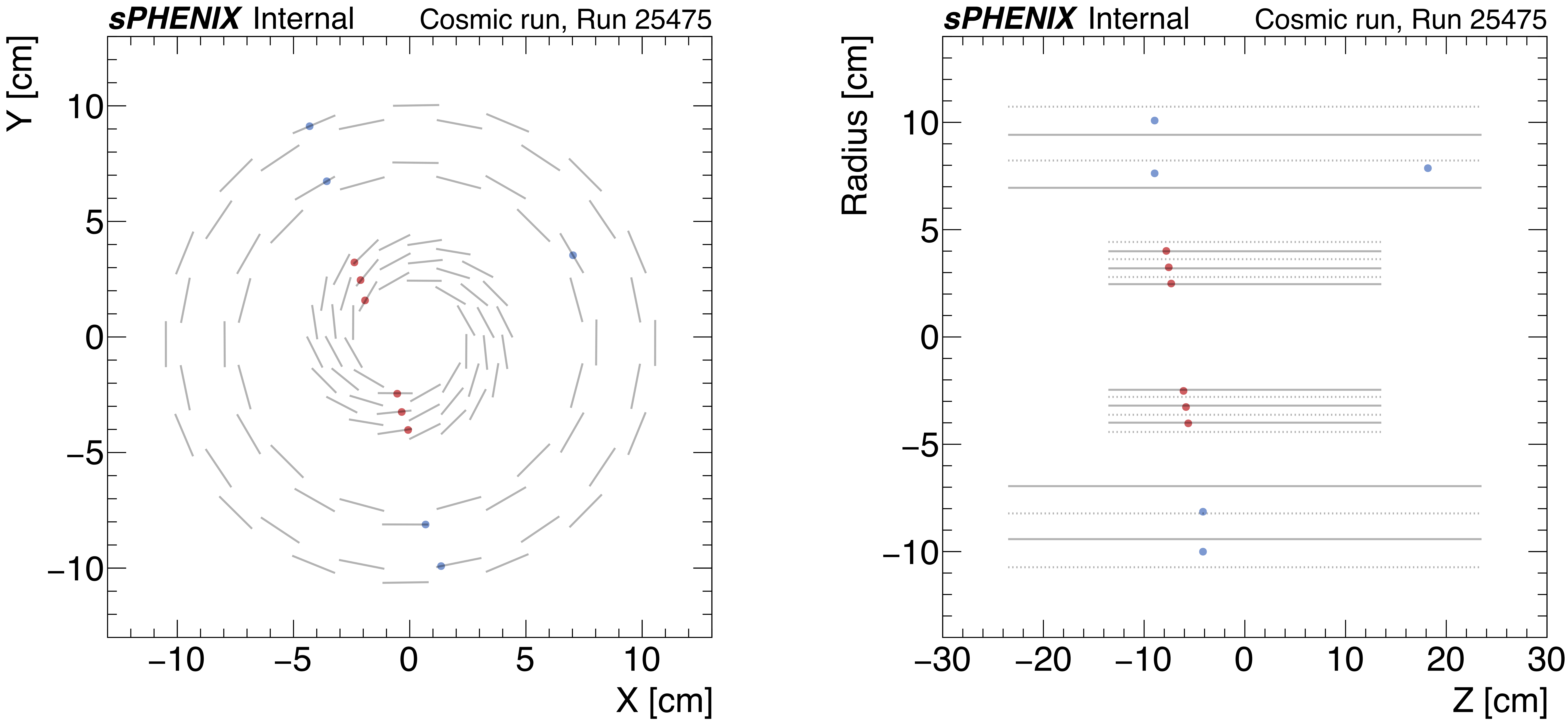


# Standalone MVTX vertex reconstruction

Three layers of MVTX used to reconstruct primary and secondary vertex



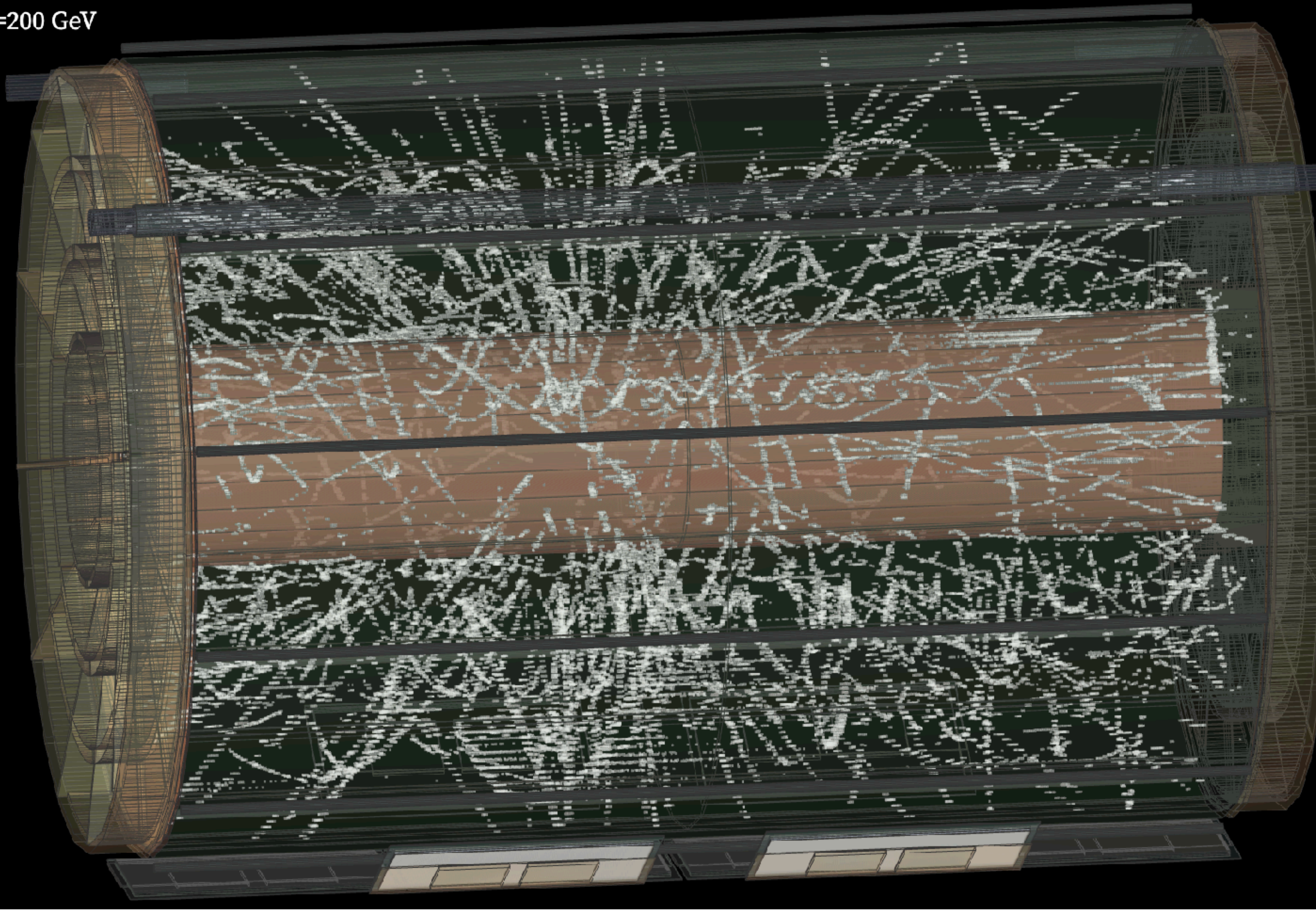
# Cosmic data in MVTX and INTT



# MVTX, INTT, and TPOT

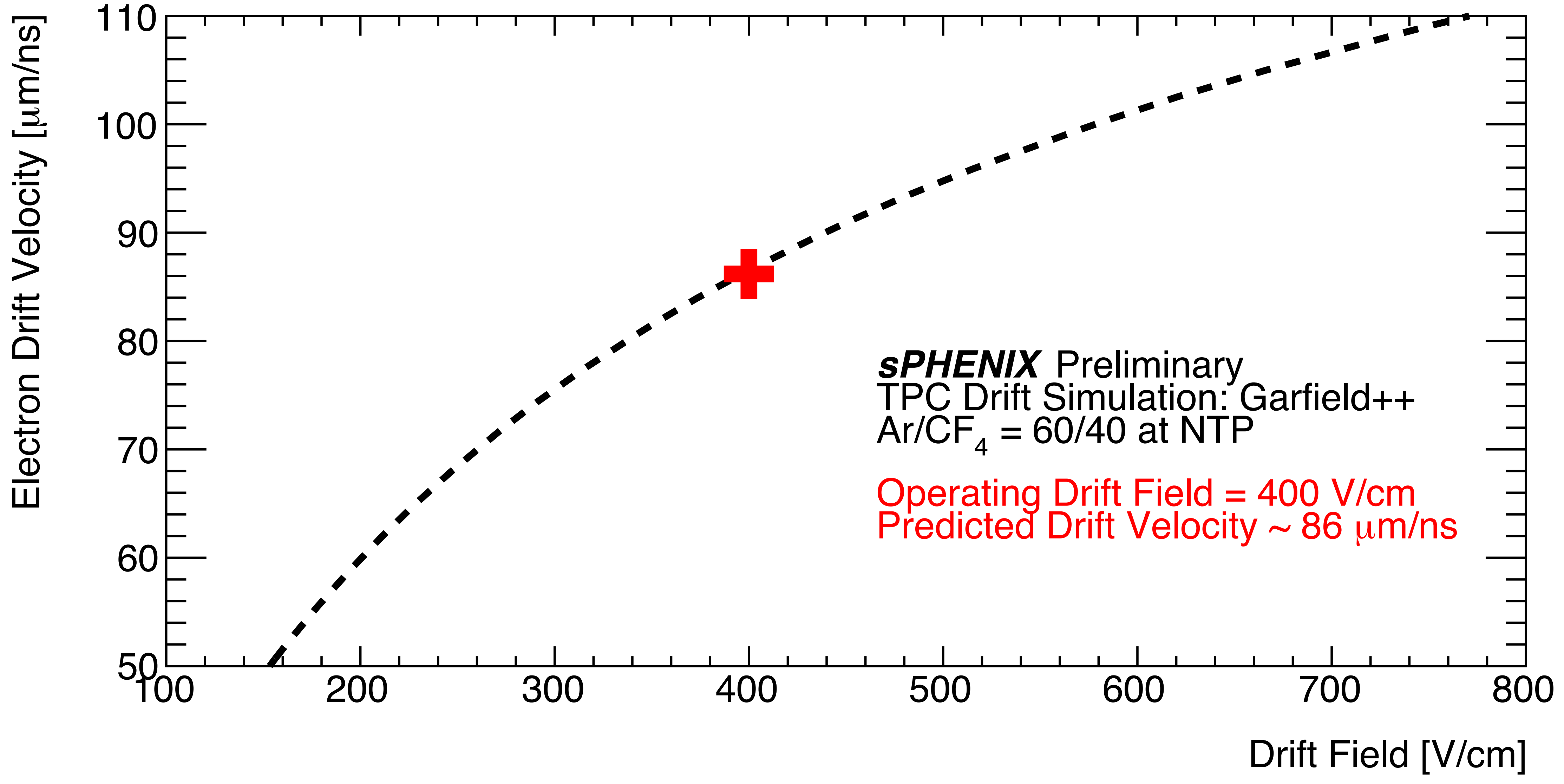

Helical fit to cosmic tracks in 1.4 T solenoidal magnetic field

sPHENIX Time Projection Chamber
100 Hz ZDC, MBD Prescale: 2, HV: 4.45 kV GEM, 45 kV CM, X-ing Angle: 2 mrad
2023-06-23, Run 10931 - EBDC03 reference frame 85
Au+Au sqrt(s_{NN})=200 GeV

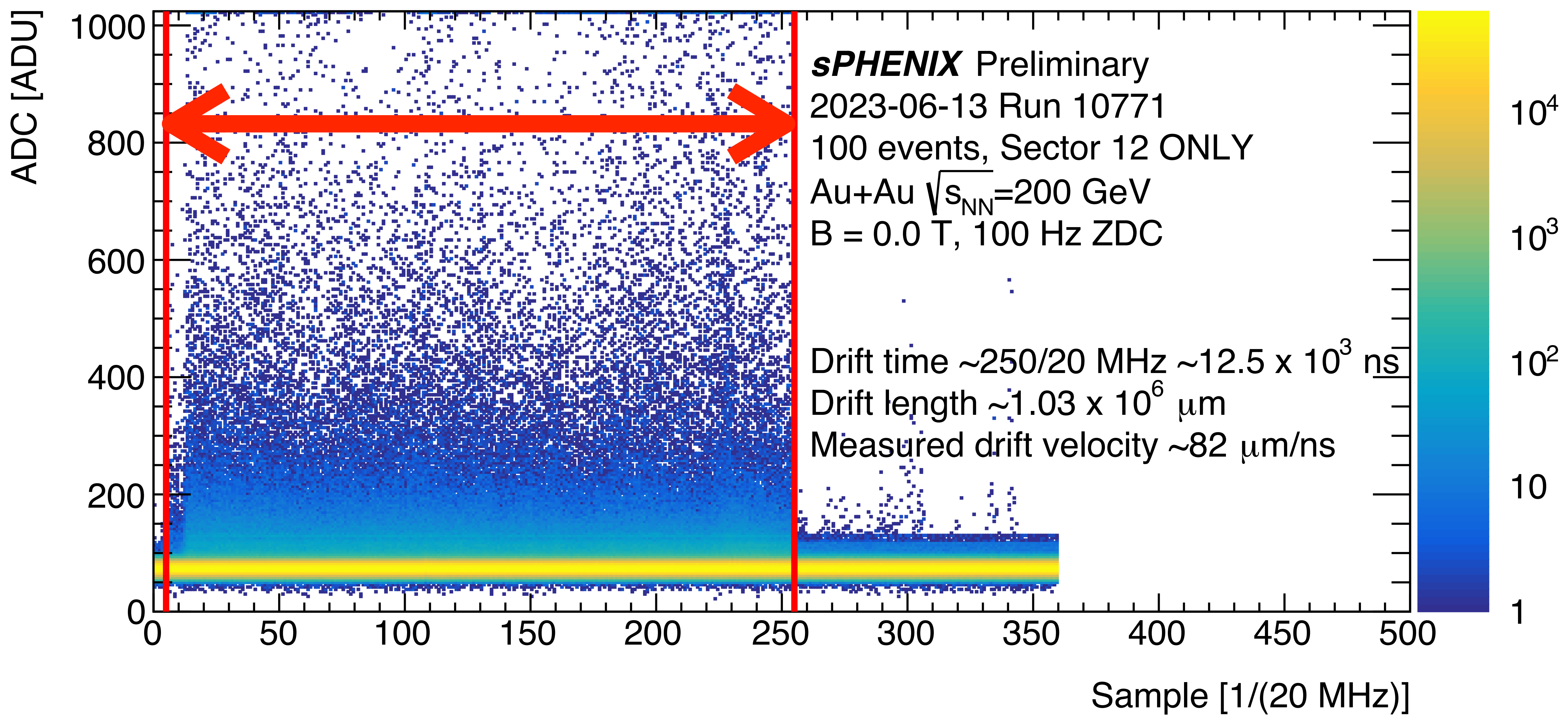


# Initial validation of TPC drift velocity

First TPC data with collisions were used to validate the calculation of the gas drift speed to within 10%

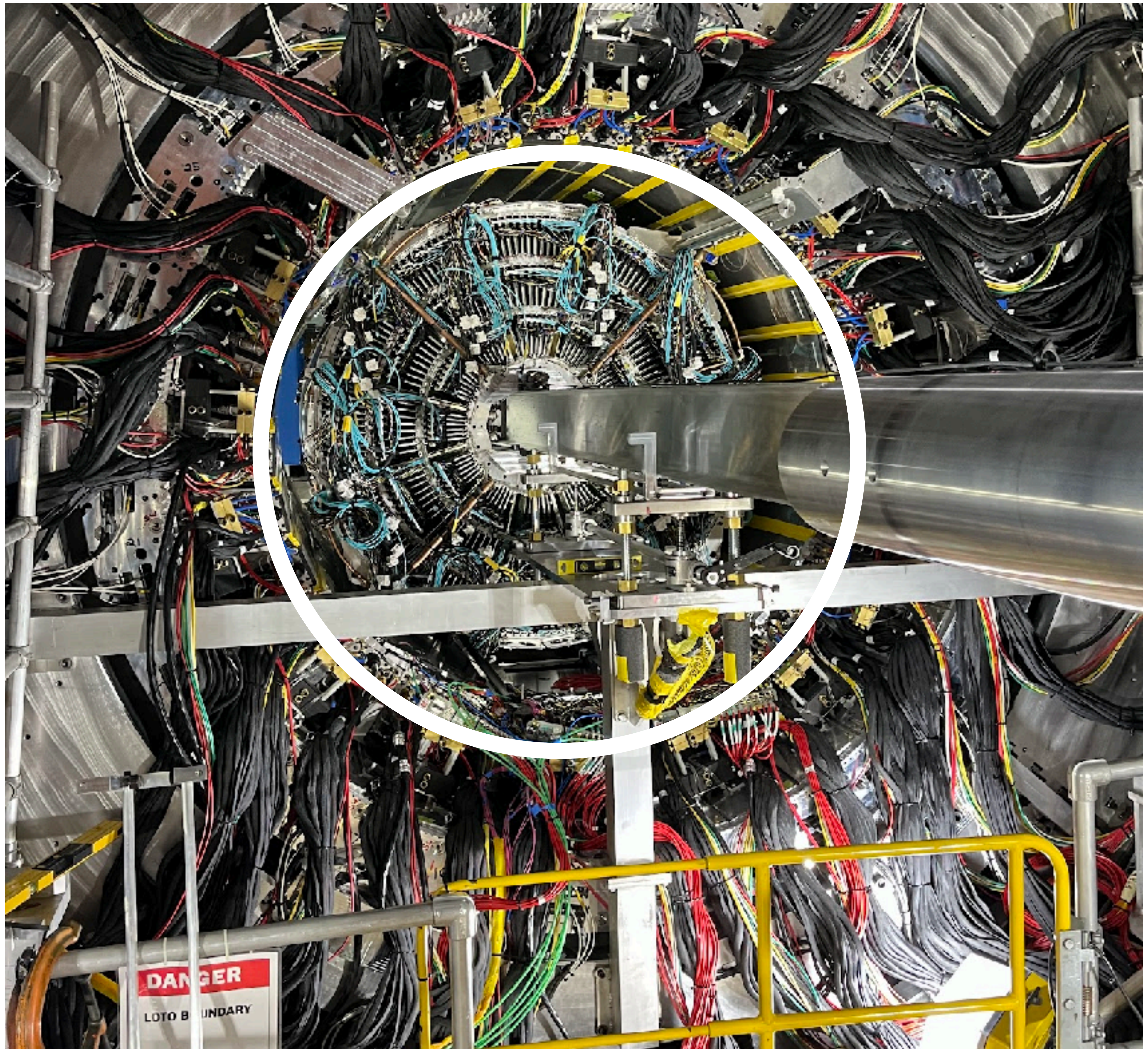



ionization arrives over this time window



# Operational challenges with TPC

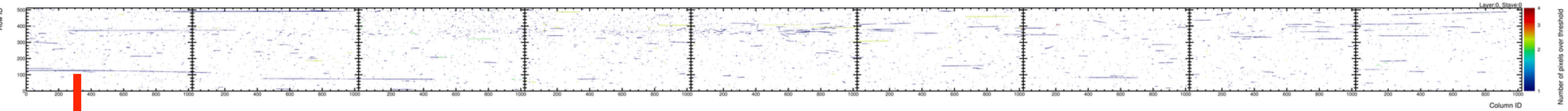
- Post-installation TPC exhibiting challenges with HV stability not present in extensive pre-installation system tests
- Met with ALICE TPC experts to discuss experience — both TPCs share similar design
- Continuing to step through specific plan of investigation and possible remediation



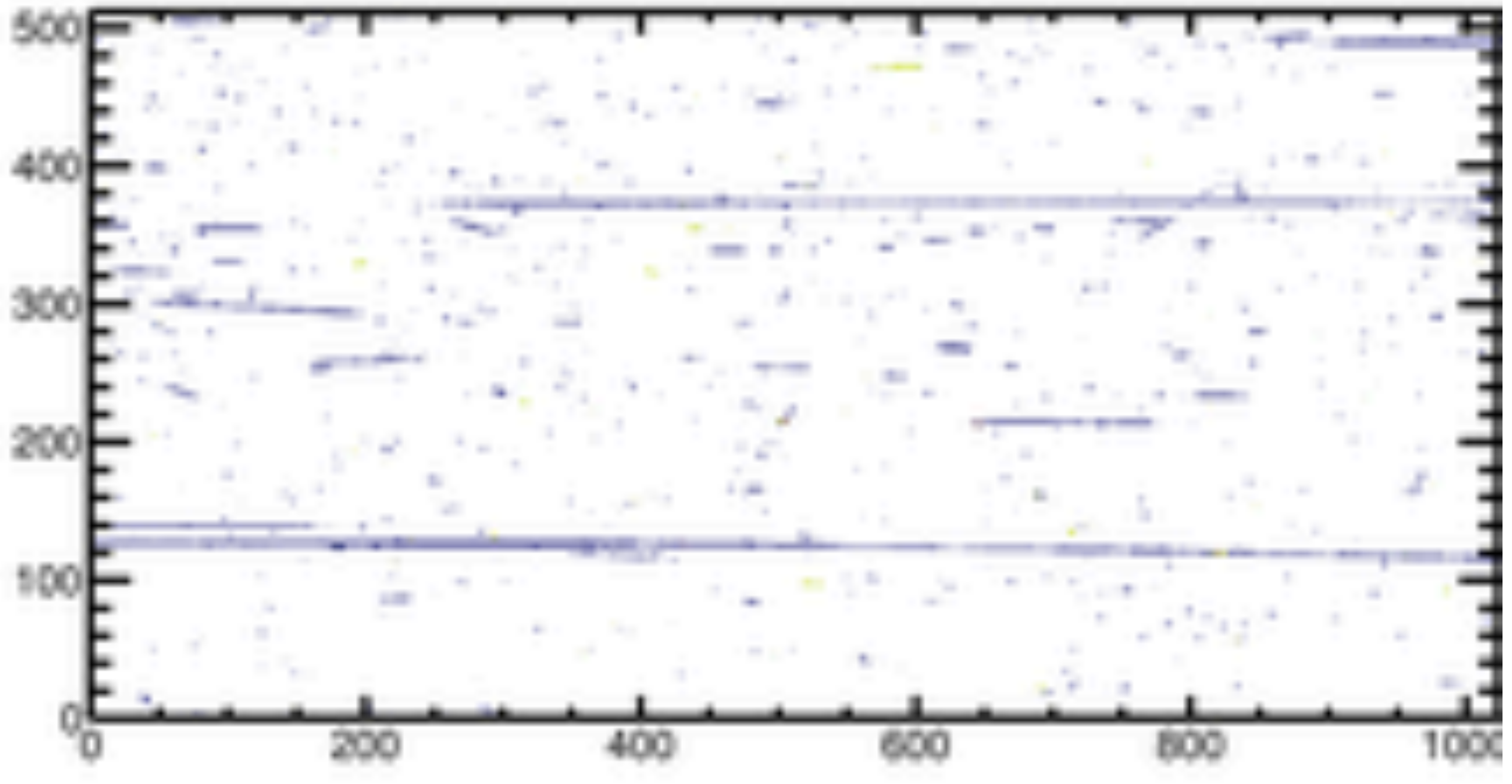
# Operational challenges with MVTX

Beam halo at r > 2 cm enough to overwhelm the readout and turn off chips after a few seconds of running

Nine ALPIDE chips of one MVTX stave



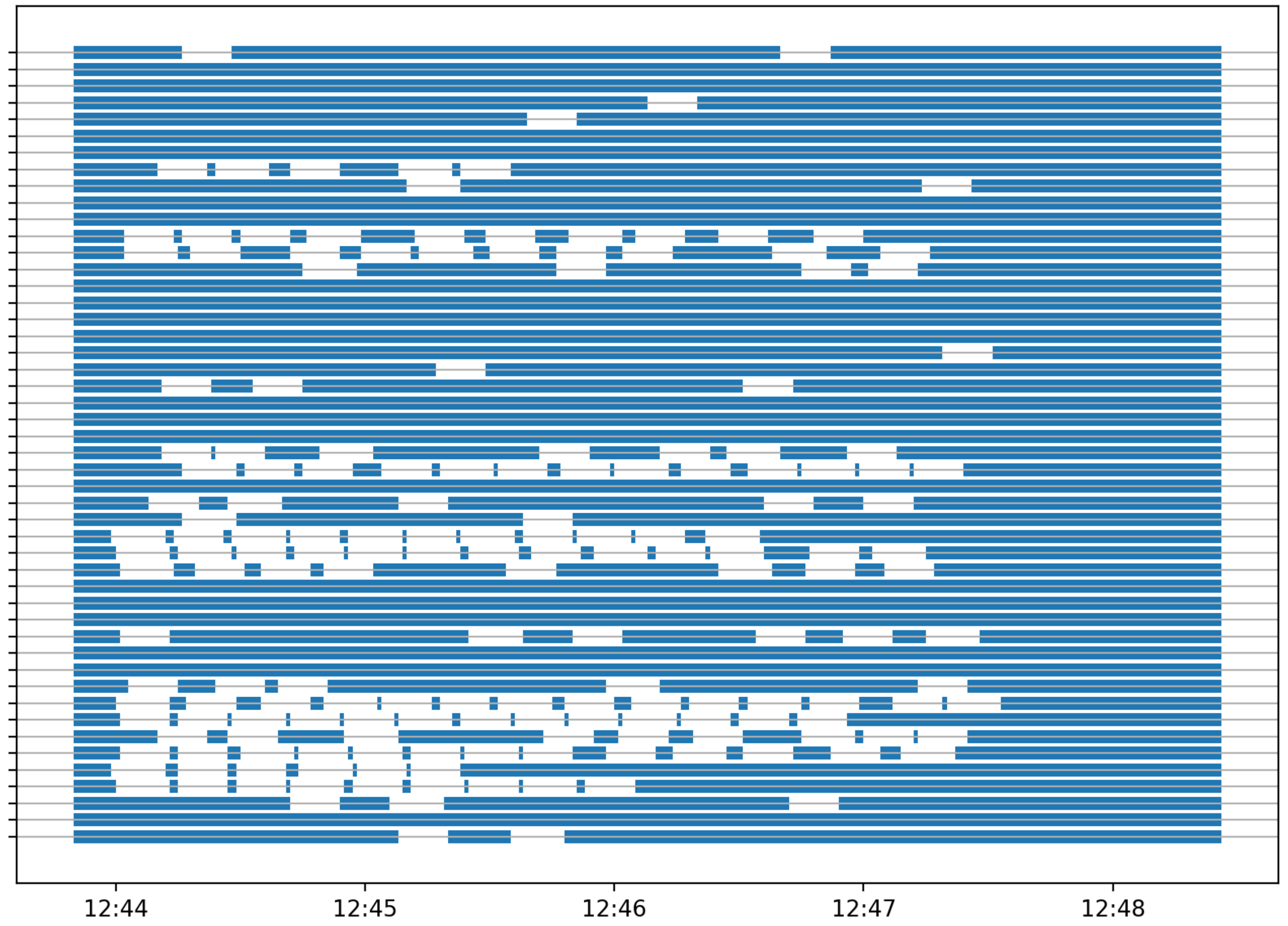
One ALPIDE sensor




Acquired few minutes of β* = 5m data just before RHIC valve box incident

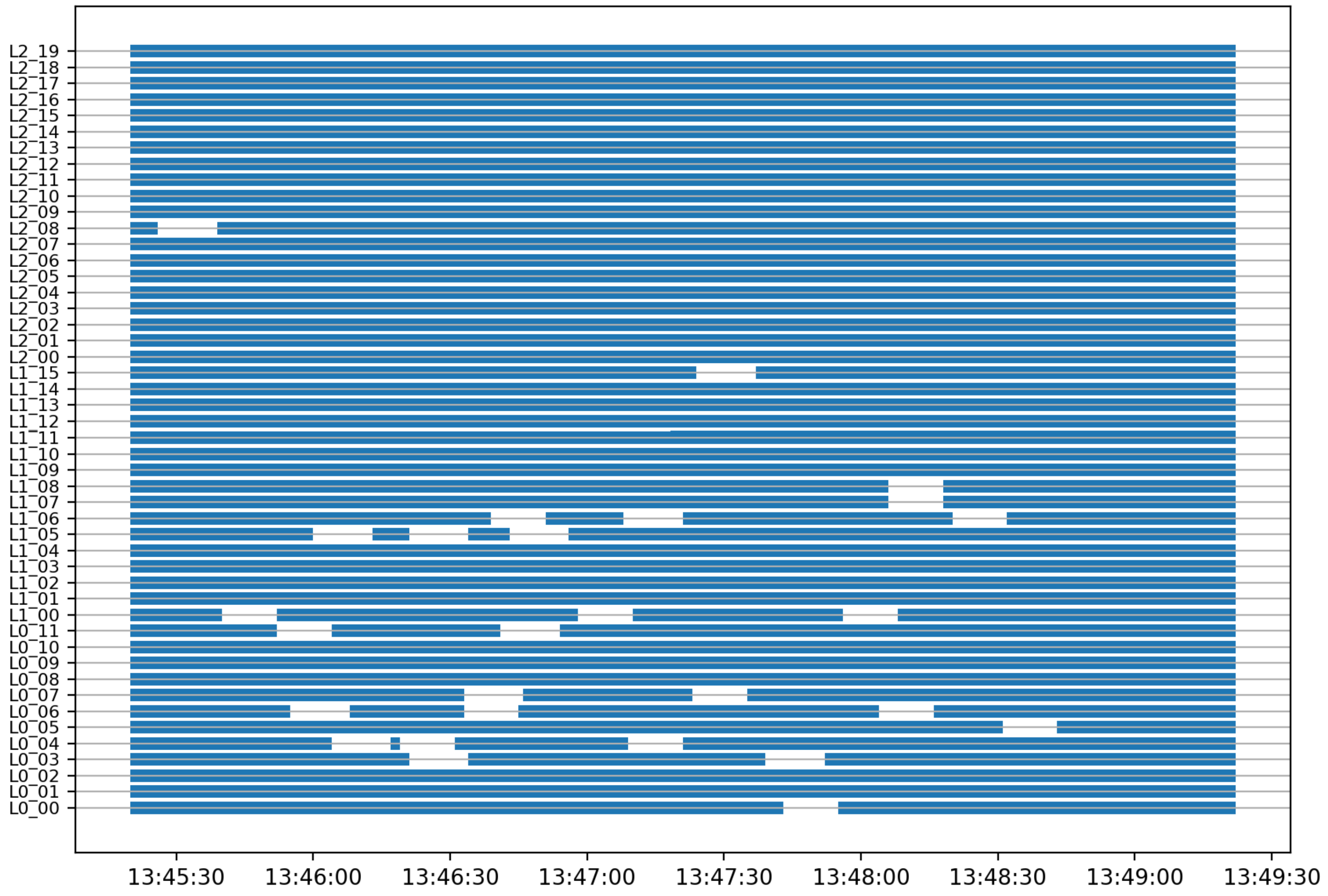
before collimation

all MVTX staves




time →

after collimation

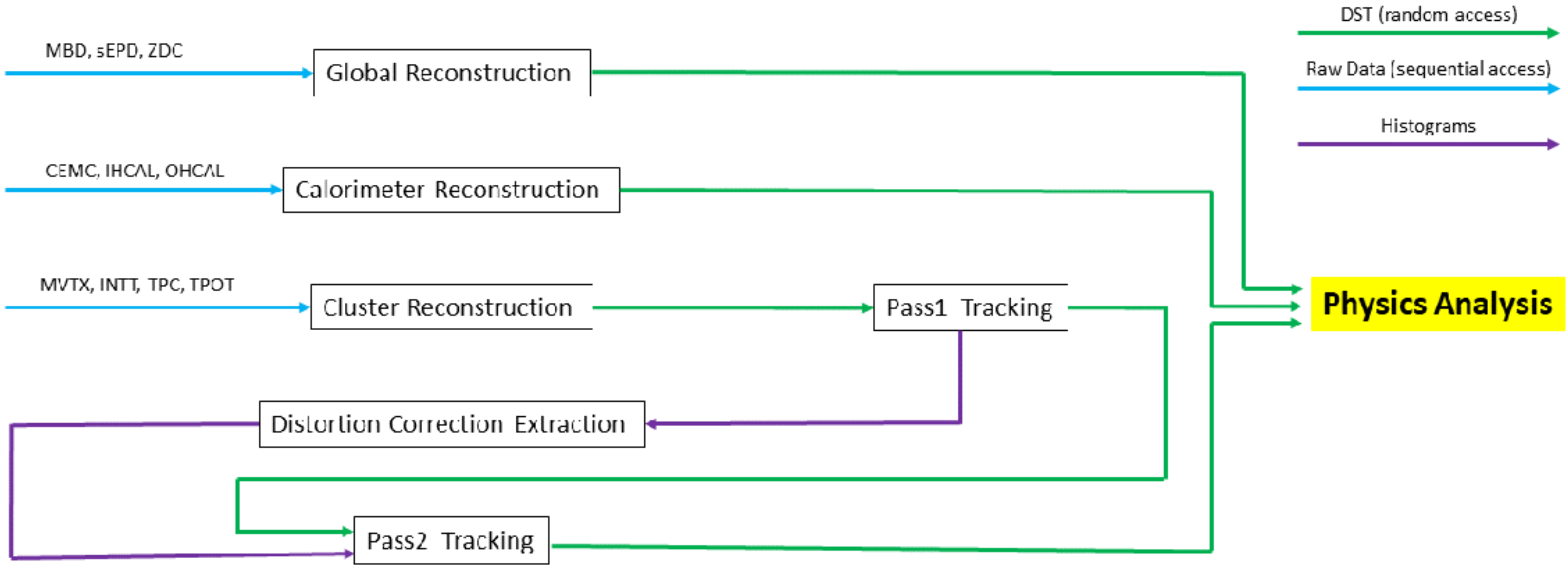



blue: normal operation

white: in recovery

# Offline event assembly and reconstruction

- Worked with SDCC to address infrastructure-level stability issues with large disk array (Lustre)
- Have used ATLAS-developed PanDA to successfully run our complex workflow to assemble and reconstruct events for analysis
- Still require collision and corresponding laser data to validate TPC distortion correction



# Remaining tasks

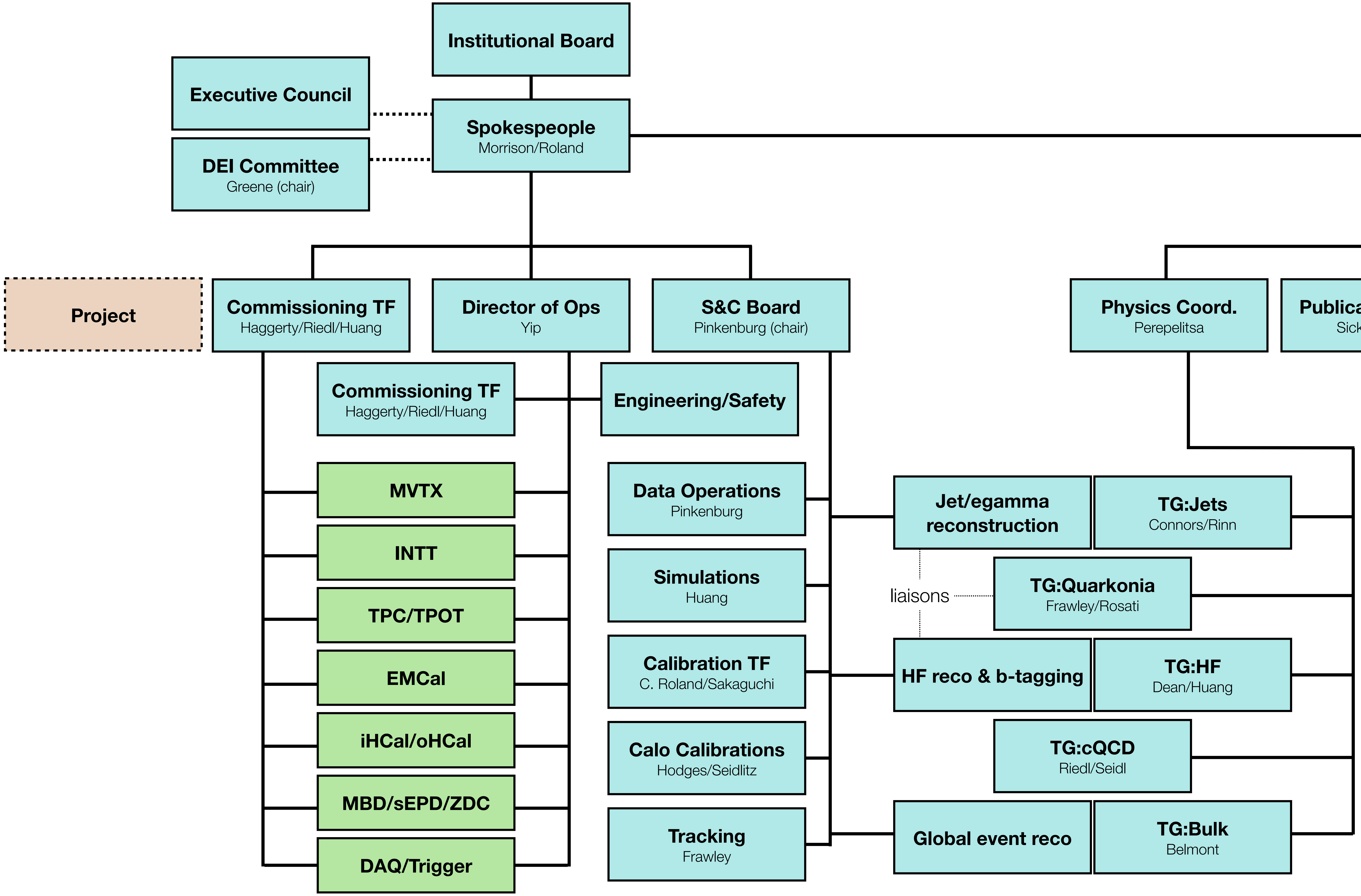
- Tremendous progress before/during Run 23 — at the same time, quite a bit still needs attention
- TPC investigations and remediations
- MVTX firmware mods to decrease reset time — possible tungsten beam pipe collar?
- Exercise computing facility with archived data and simulations to further validate and automate processing infrastructure
- Significant cosmic running prior to Run-24 for alignment and to validate tracking

Table 6 in commissioning document

| System | Before Run 2024 | During Run 2024 |
|---|---|---|
| Trigger | Firmware and software development of calorimeter triggers | First operation of calorimeter triggers with beam |
| TPC | • FEE firmware completion<br>• tests of zero suppression<br>• completion of MJACK to mitigate SEU<br>• development of digital current<br>• cosmic ray data with and without zero suppression | • Stable operation with HV<br>• collision data with and without zero suppression<br>• testing of digital current and SEU mitigation |
| DAQ | • Tests with zero suppression in calorimeters and TPC<br>• Throughput and livetime tests with multievent buffering<br>• Development of offline event building<br>• Any additional development needed to achieve routine 15 kHz<br>• Improvements in reliability, data integrity, and error handling | • Tuning of zero supression<br>• Timing of detectors to new triggers<br>• Spin: integrate ZDC, SMD and MBD digital scaler information into GL1 |
| MVTX | • Field off cosmic data for tracking development and alignment<br>• Development of mitigation strategies for background and lock-up | • Field off and field on collision data for tracking development and alignment<br>• Tests of mitigation strategies for background and lock-up |
| INTT | Field off cosmic data for tracking development and alignment | Field off and field on collision data for tracking development and alignment |
| EMCal HCal | (HCal) tower-by-tower cosmics analysis | Demonstration of design energy resolution and response uniformity |

# Plan for first sPHENIX science

# Pushing toward first science




**PC**: Perepelitsa (UC)
**Pub**: Sickles (UIUC)
**SB**: Rosati (ISU)
**S&C:** Pinkenburg (BNL)
**TG conveners**
**Calibration:** Sakaguchi, C. Roland
**Calo Calibration:** Hodges, Seidlitz
**Tracking:** Frawley (FSU)

# Coordinating the effort toward first science

- Physics coordination meetings — cuts across topical groups
  - Identifying topics that can be pursued with available Run 23 data
  - Identifying workforce to tackle specific analyses
  - Coordinates with simulation and computing effort — sufficient computing power is available to support needed activities
- Topical group conveners are organizing post-QM “kick-off” meetings for a jet performance paper, $dN/d\eta$, $dE_T/d\eta$, and $\pi^0$ $v_2$ and other topics

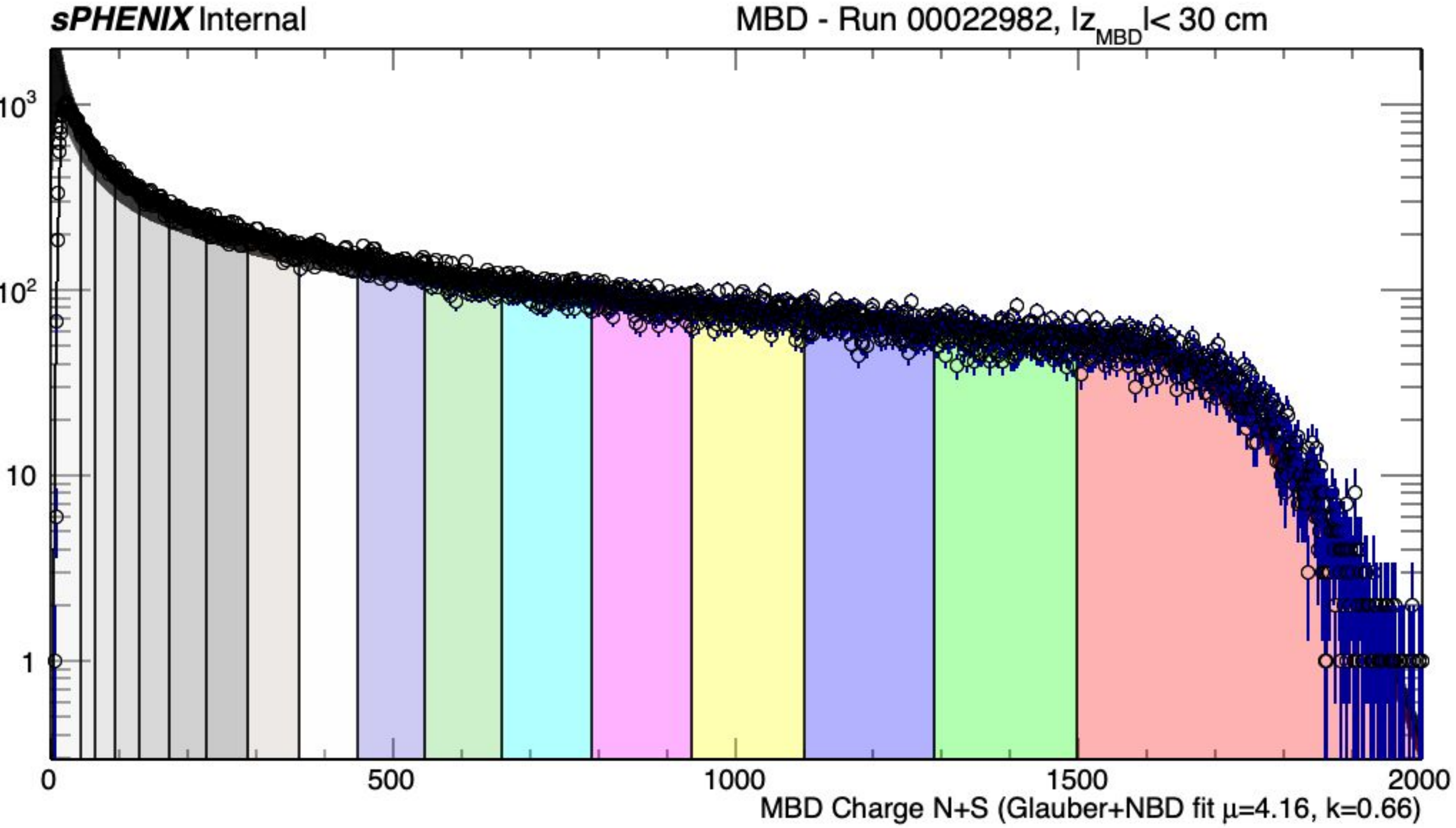
# Timeline for first sPHENIX science

- Complicated by premature end to Run-23
  - Lack planned six weeks of physics data  (n.b. fewer than the 9 weeks in 2022 BUR)
  - Reduced data available for systematic checks, calibration development
- Recall previous experience ~ six months from first RHIC run to QM'01
- Many performance plots shown at QM'23
- First "standard candle" soft physics ($dN/d\eta$, $v_n$) — end of CY'23
- Unique RHIC capabilities (e.g., unbiased jets) longer timescale
  - detailed jet performance studies — end of CY'23
  - taking cosmic ray data for alignment and validation of data processing

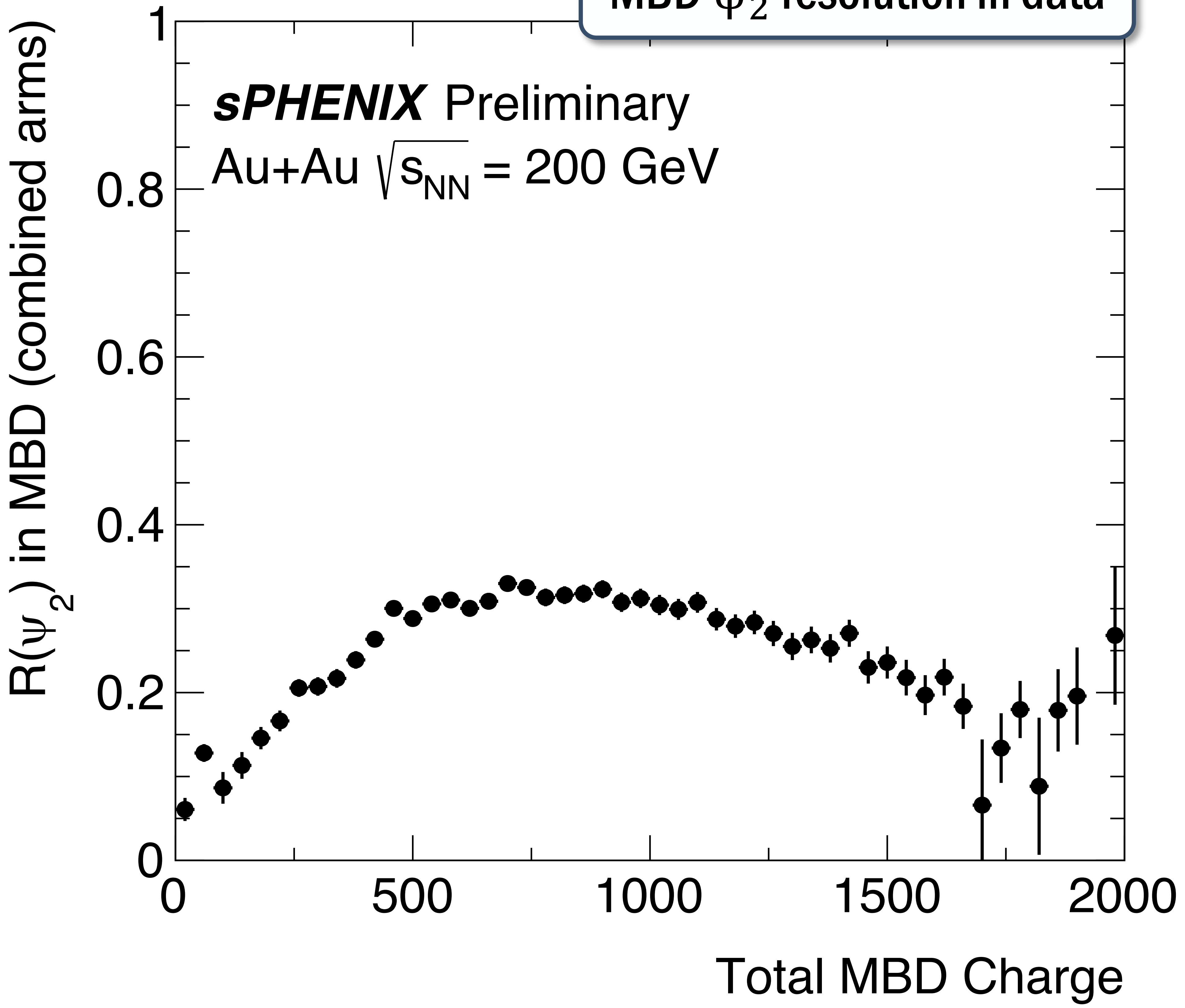
# Ingredients for first sPHENIX science

- event selection and centrality determination
- event plane determination: MBD event plane resolution
- primary and secondary vertex location: INTT and MVTX reconstruction
- $\pi^0$, $\eta$: EMCal clustering, energy calibration
- jets: energy calibration, background subtraction, jet finding, data based UE subtraction
- systematically performing calibrations and reconstruction steps needed for first physics
- even with the limited data set: wide range of standard candle measurements that can be performed, and in-roads to be made towards full calorimeter jet physics at RHIC
- this effort needs to be balanced with preparations for Run-24

# Au+Au centrality and event plane based on MBD

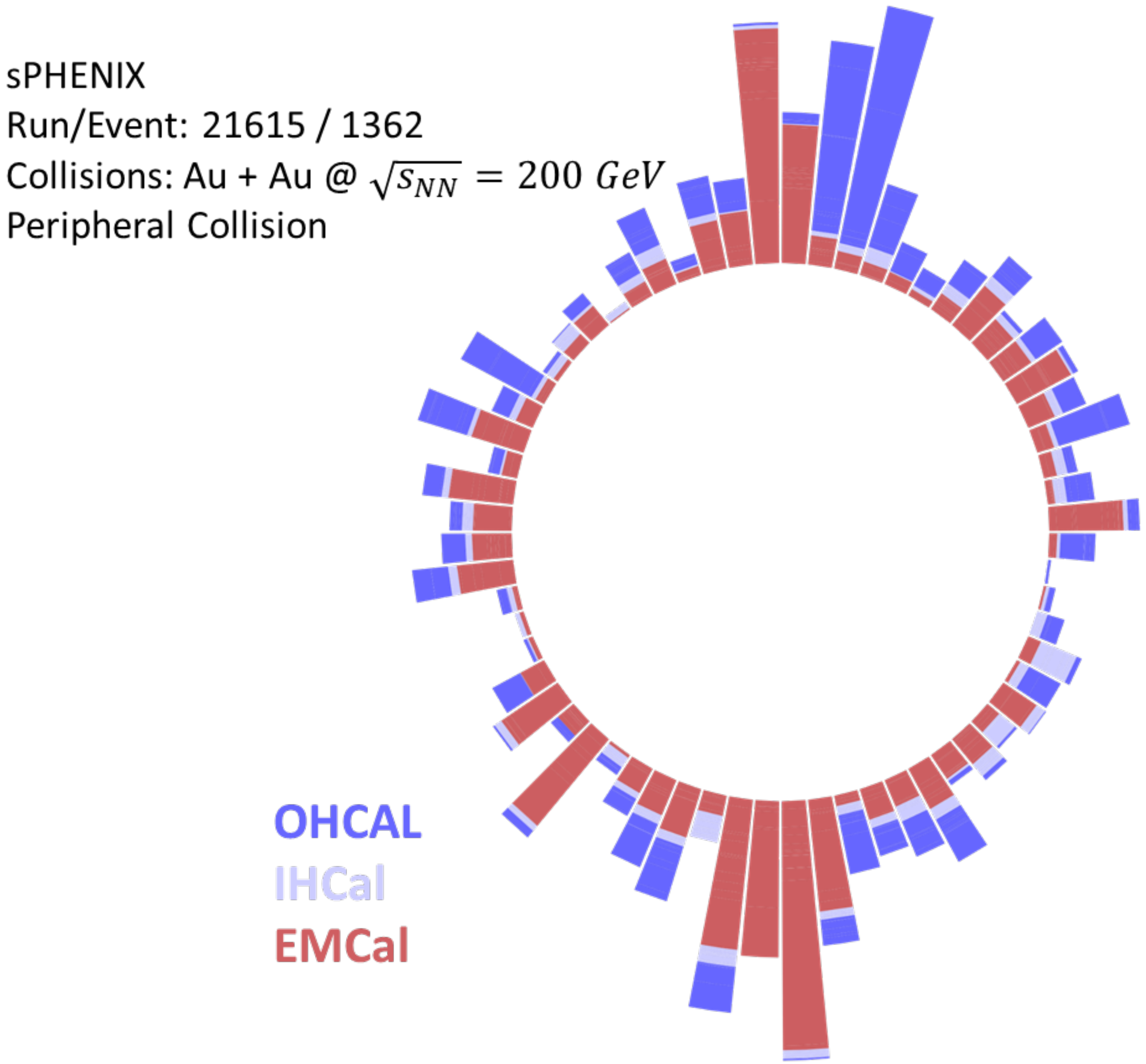


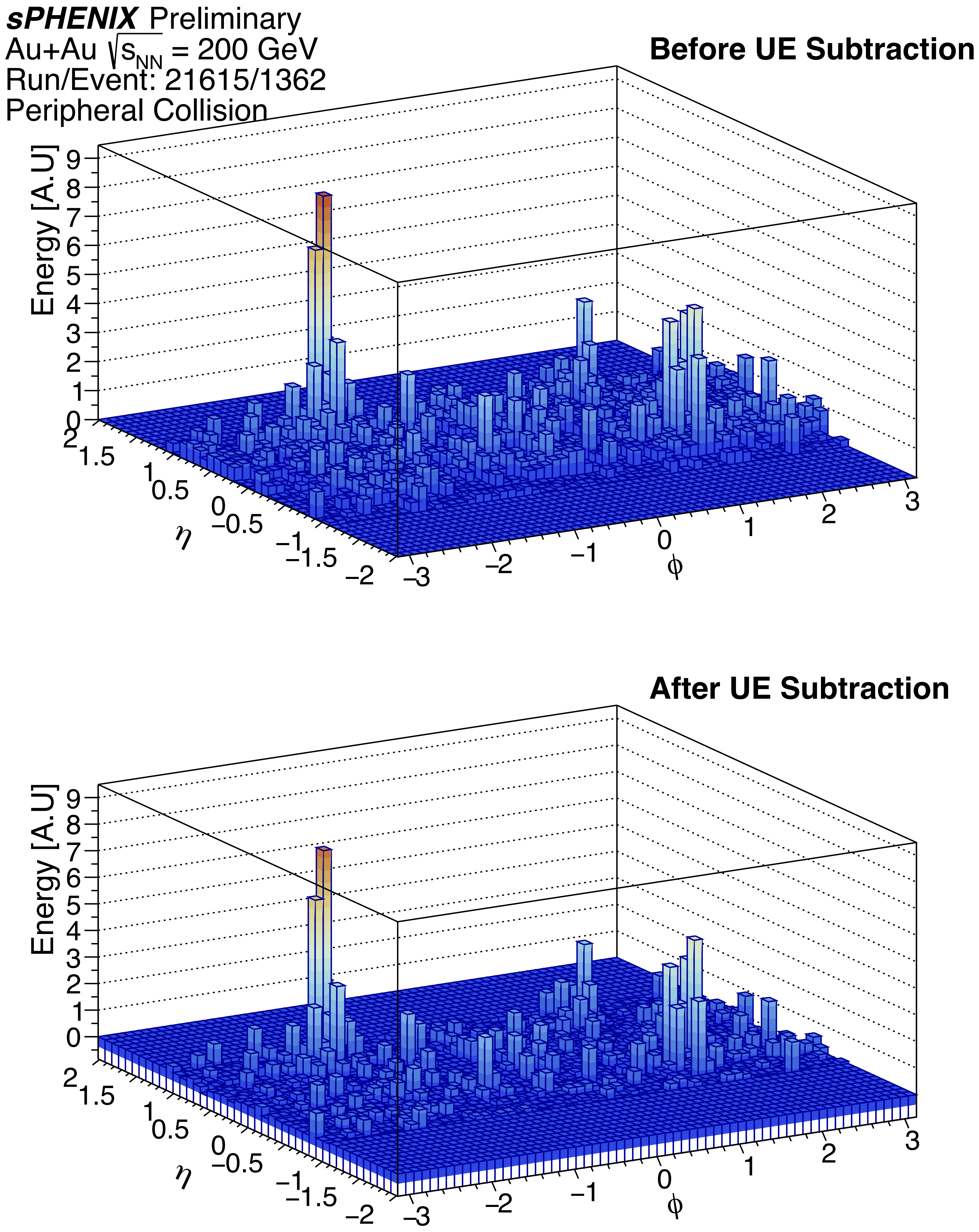

MBD $\psi_2$ resolution in data




n.b. STAR beryllium beam pipe isn't upstream/downstream symmetric; removes a useful systematic check on MBD response

# Calorimetric jets — EMCal, iHCal, and oHCal combined



# Initial tracking performance


Cluster residuals before static and time-dependent corrections in the expected sub-cm (**z**) and mm (**rϕ**) ranges — TPC only

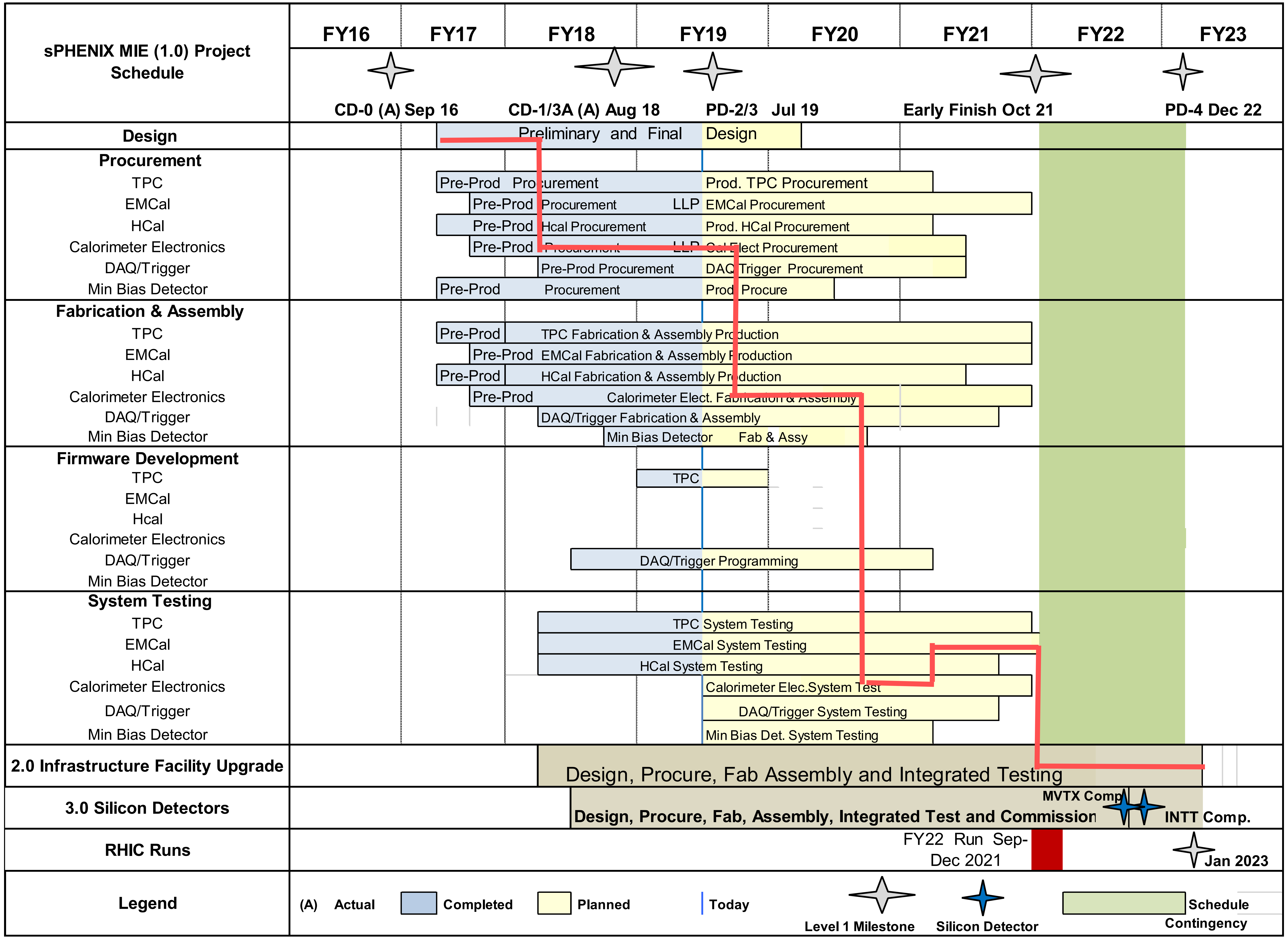
# What do we need to progress to Run 24 successfully?

- Continued priority in technical support and trade work — e.g. for detector access that is currently planned
- Electrical engineering support from ATRO — critical for completing firmware mods for TPC and INTT
- Engineering support for MVTX background mitigation plans we may decide to implement (e.g., tungsten beam pipe collar)
- Support for Invenio development (e.g., search on document content) and other tools for collaboration information management

# Summary, concerns, prospects

- Tremendous progress readying sPHENIX for physics — lots of excitement throughout collaboration with students/postdocs taking major roles
- Concerned about near-term morale, job prospects of students/postdocs — potential collaboration workforce implications
  - Will have open forum on Friday within collaboration to discuss this; ALD has welcomed a subsequent discussion to be able to share her perspectives and field questions
- There are unfinished commissioning activities — activities that can done w/o beam are continuing now
- Plan of work leading to Run-24 described in commissioning document
- Standard candle physics soon; detailed studies with data to prepare for

# sPHENIX Project Summary Schedule




Critical Path runs through:

- Cal Elect. Preprod. Procure
- Cal. Elect. Fab/Assy
- Cal Elect. Sys. Testing
- EMCal Fab/System Testing
- Early Completion
- Installation, Integrated Test and Commissioning


21
19
17
15
13
11
9


Since 1967