



sPHENIX FORWARD DETECTORS AND PHYSICS PROGRAM

Ejiro Umaka on behalf of sPHENIX
Brookhaven National Laboratory



The 39th Winter Workshop on Nuclear Dynamics

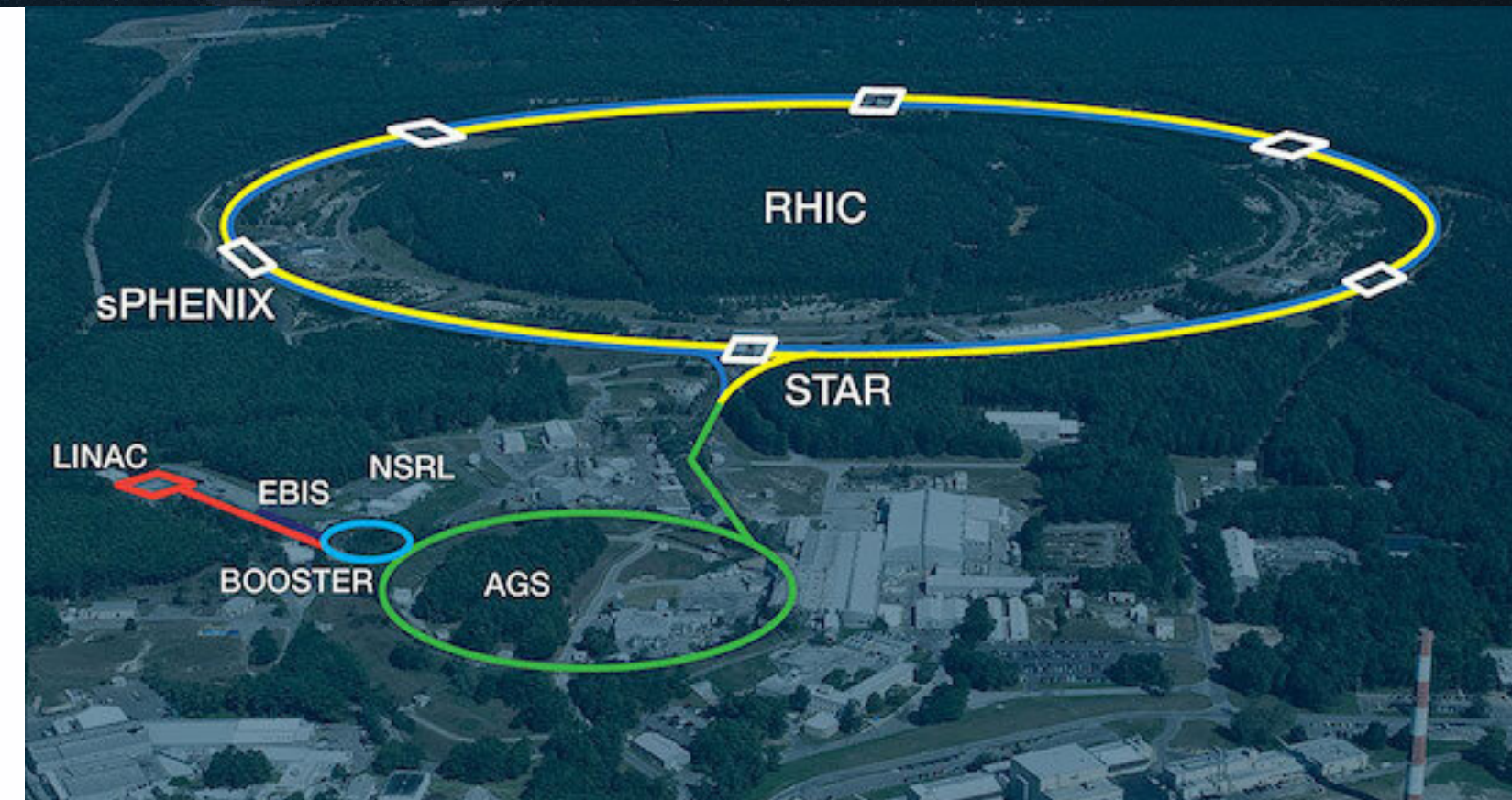


A NEW ERA OF DISCOVERY

THE 2023 LONG RANGE PLAN FOR NUCLEAR SCIENCE

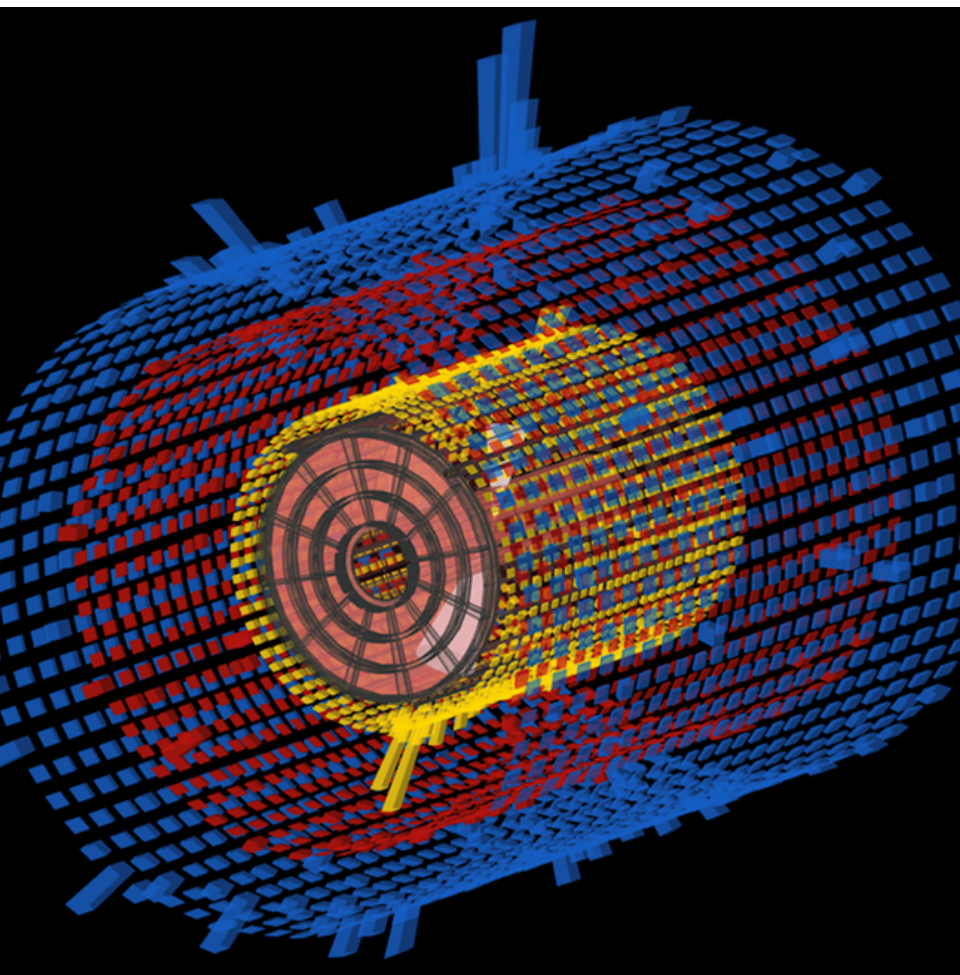


- **The sPHENIX detector was designed and built as a powerful microscope to probe the inner workings of the quark-gluon plasma**
- **Required to complete RHIC's science mission**
 - "To successfully conclude the RHIC science mission, it is essential to (1) complete the sPHENIX science program as highlighted in the 2015 Long Range Plan...(3) analyze the data from all RHIC experiments. Crucially, sPHENIX, with its large acceptance, is beginning its physics program."

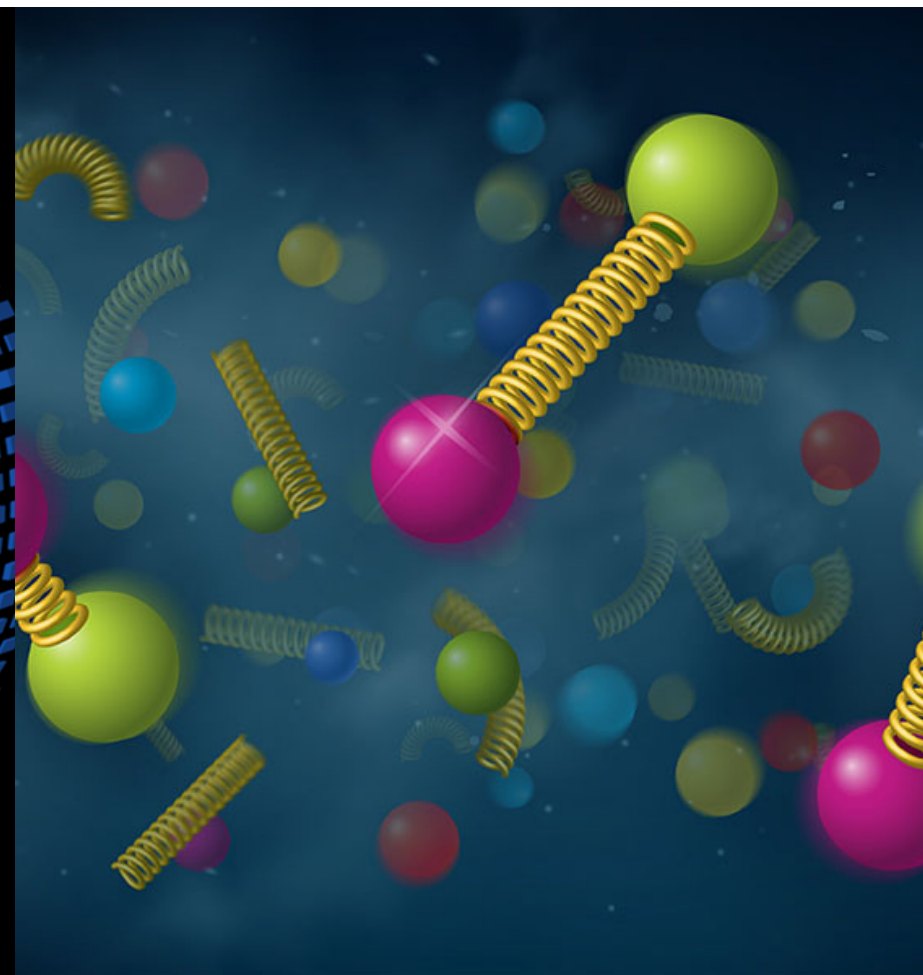




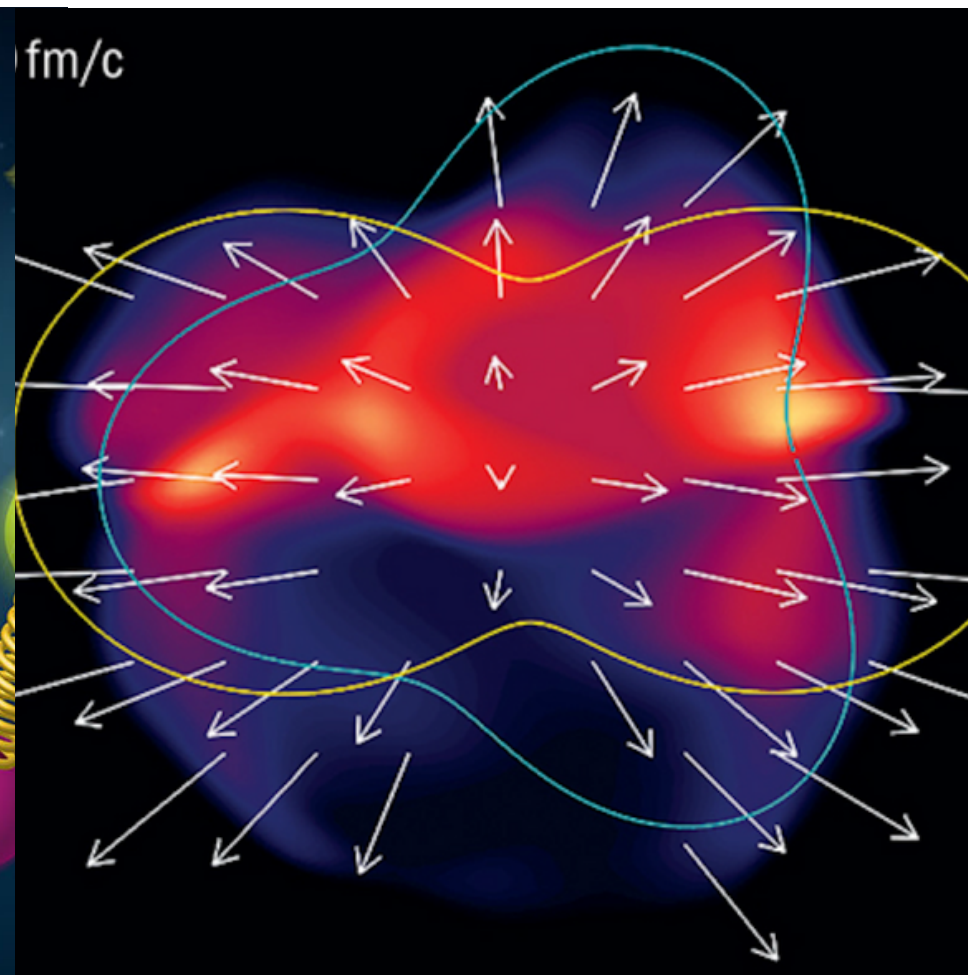
Wide range of physics topics from hard probes (jets and heavy flavor) to bulk and cold QCD physics



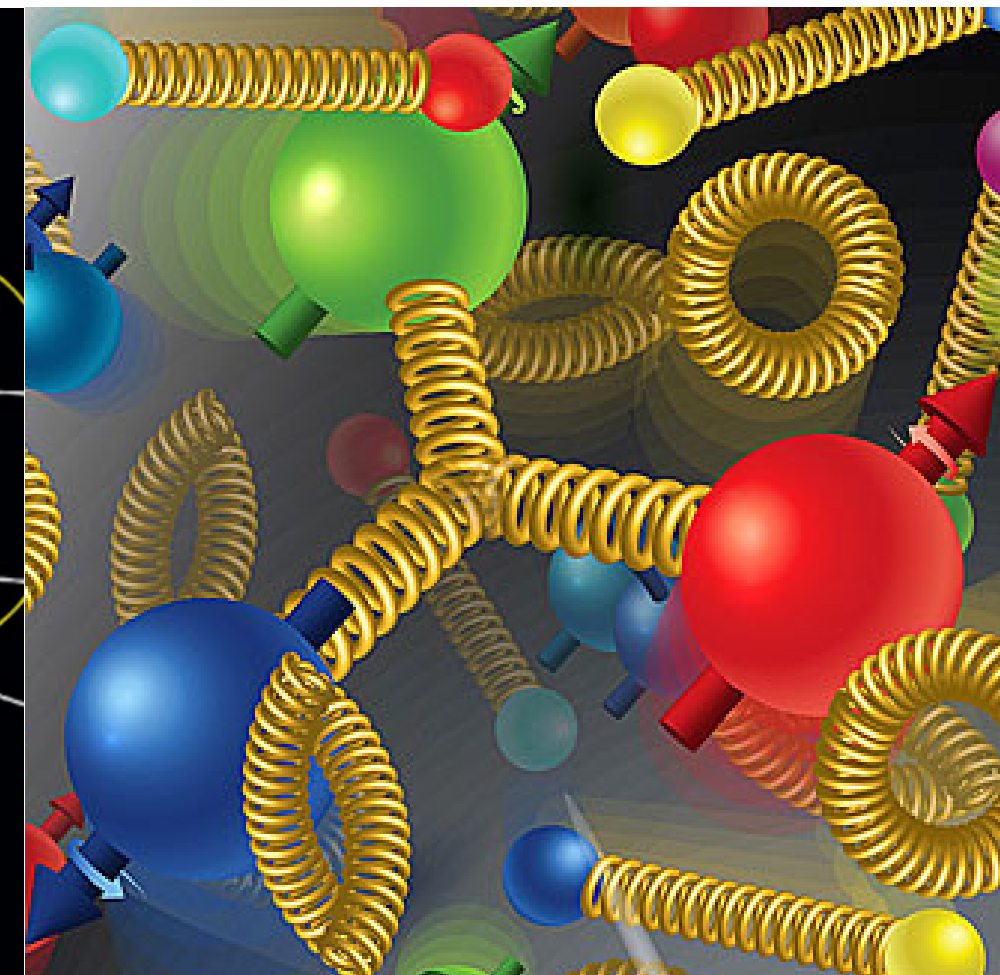
Jet Correlations
vary the momentum &
angular size



Upsilon Spectroscopy
vary size of the
probe

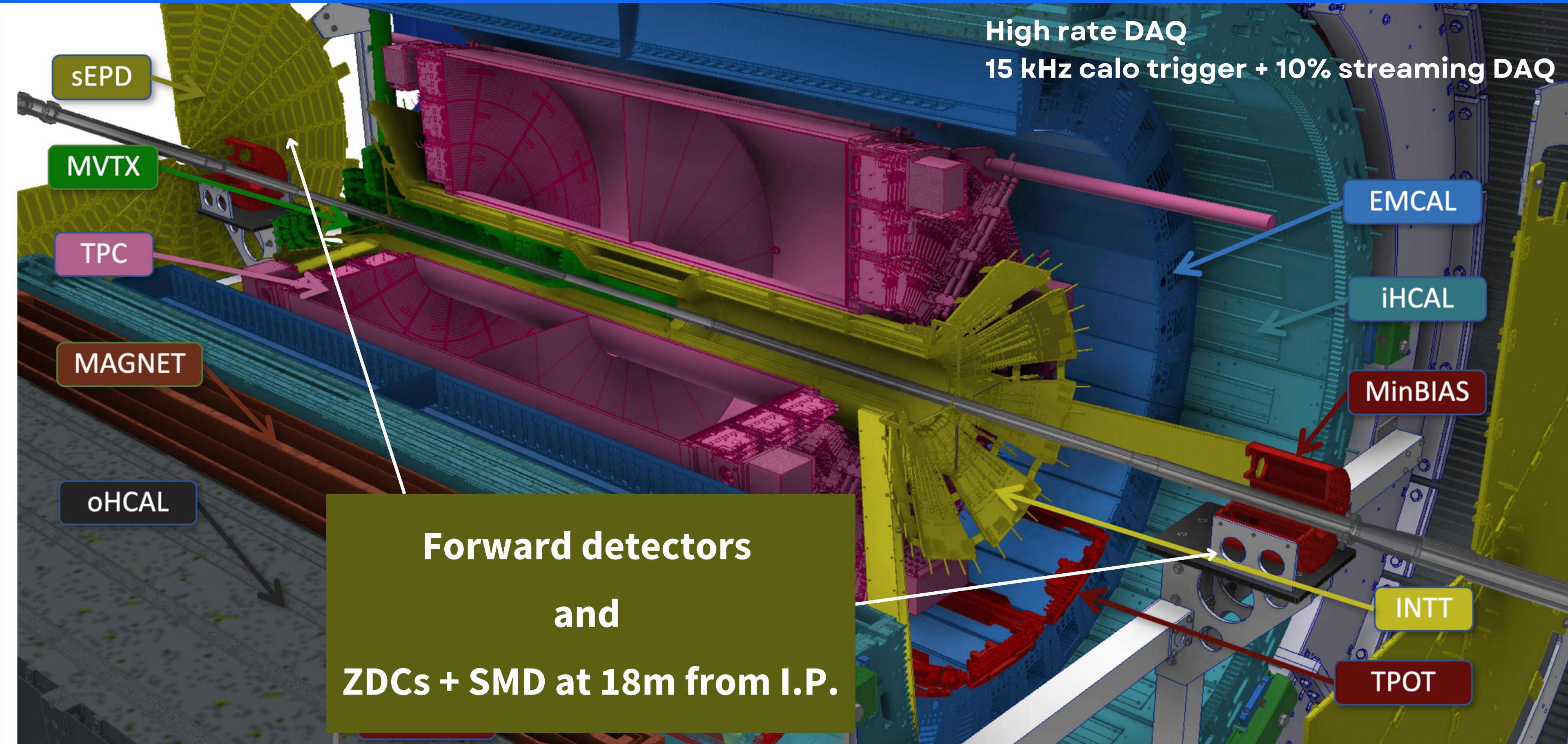


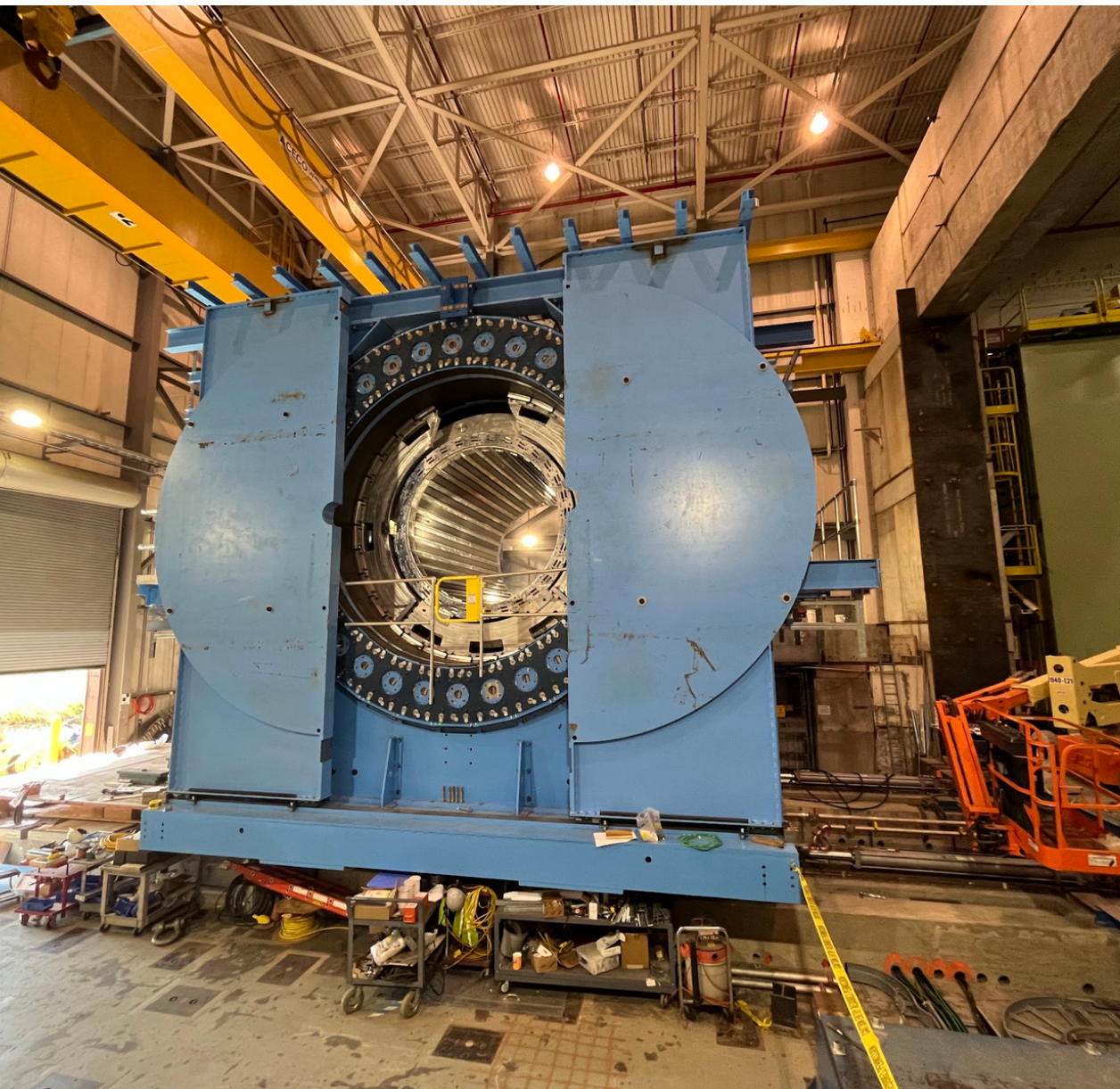
Collectivity
bulk properties of
the QCD matter



Cold QCD
nucleon partonic
structure

sPHENIX Detector



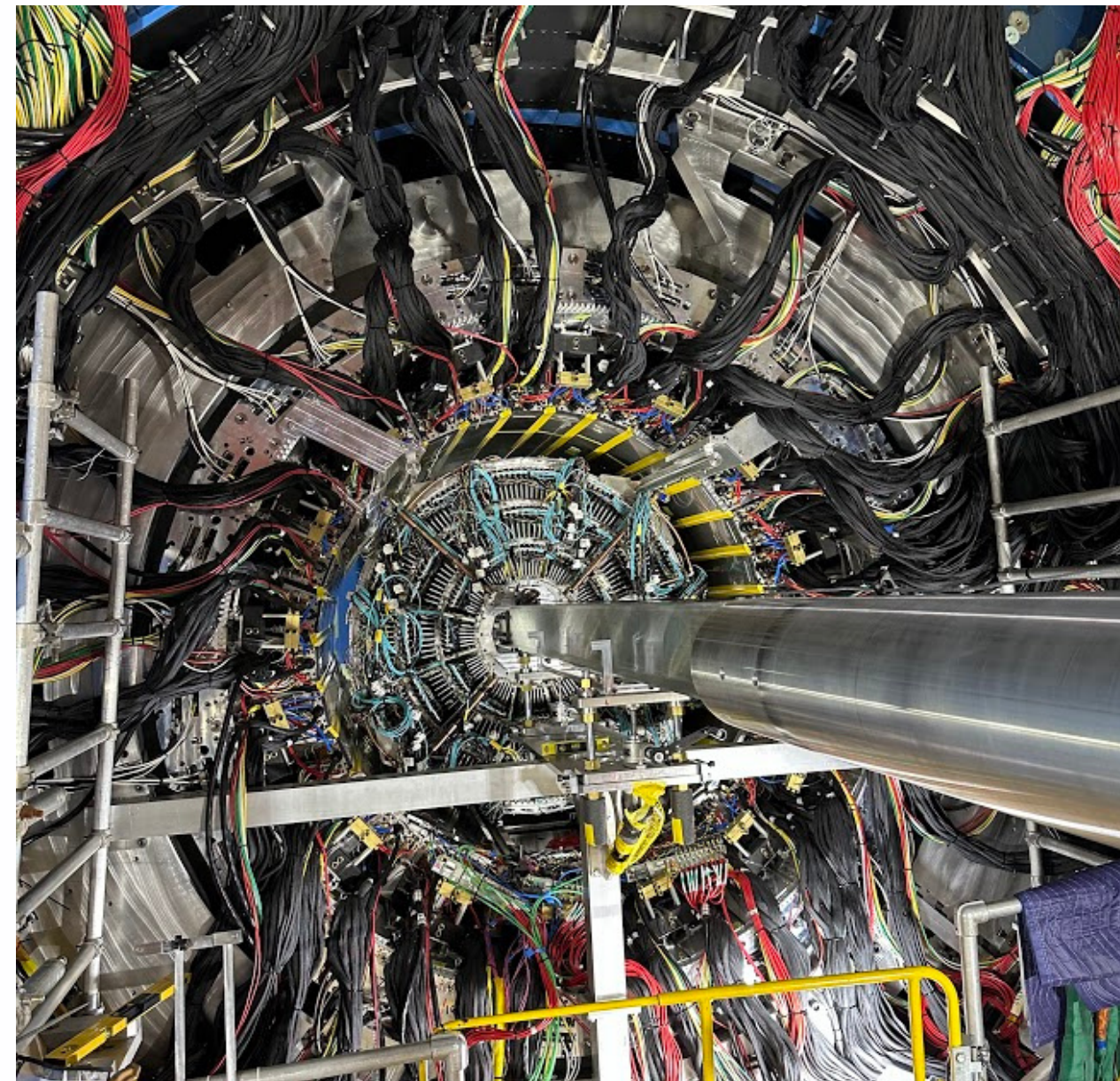


June 2022

Mid-rapidity calorimeters and 1.4T

magnet installed

EMCAL+HCAL cover full azimuth & $|\eta| \leq 1$

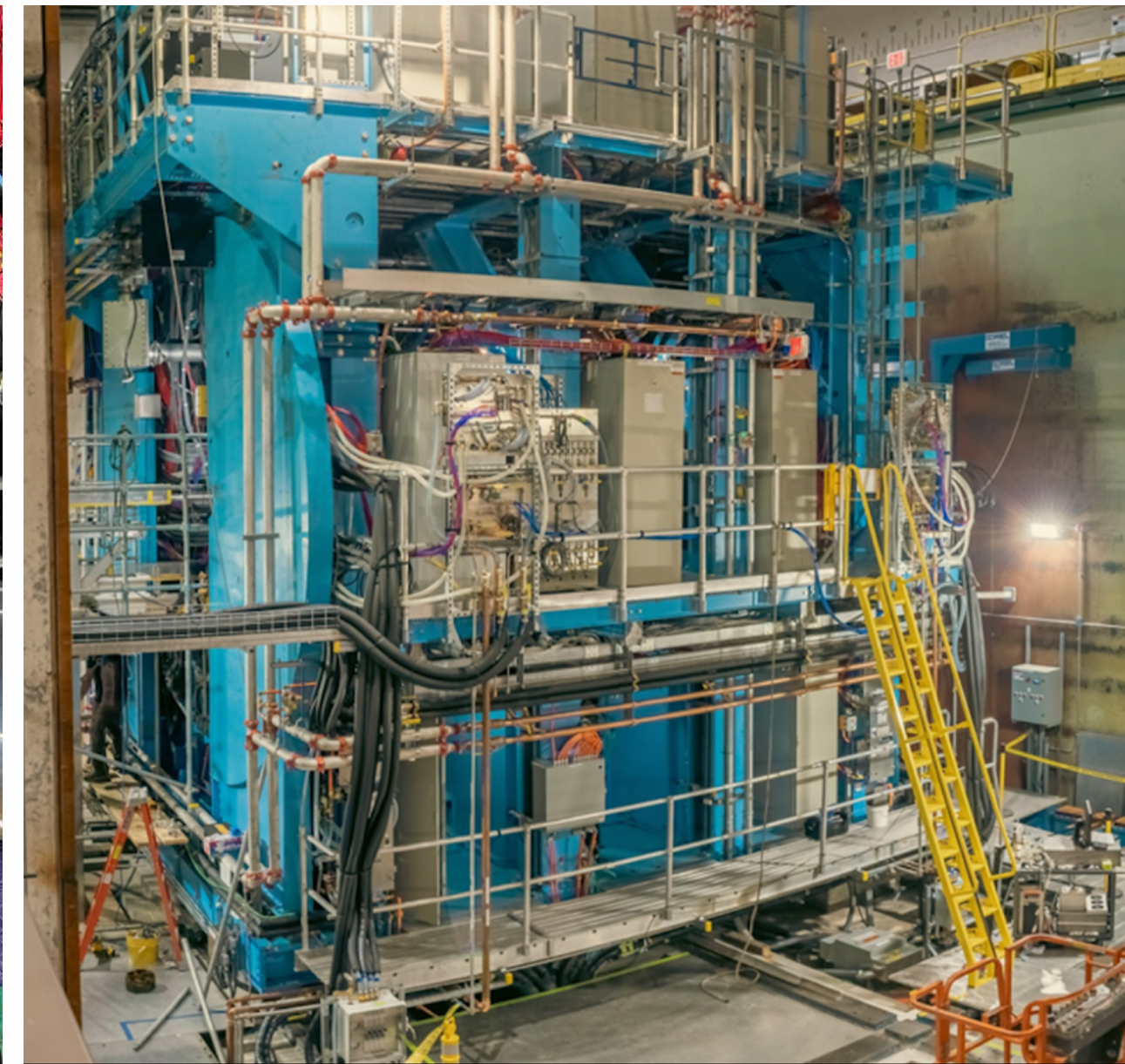


January 2023

TPC installed

Precision tracking and vertexing

with the silicon trackers

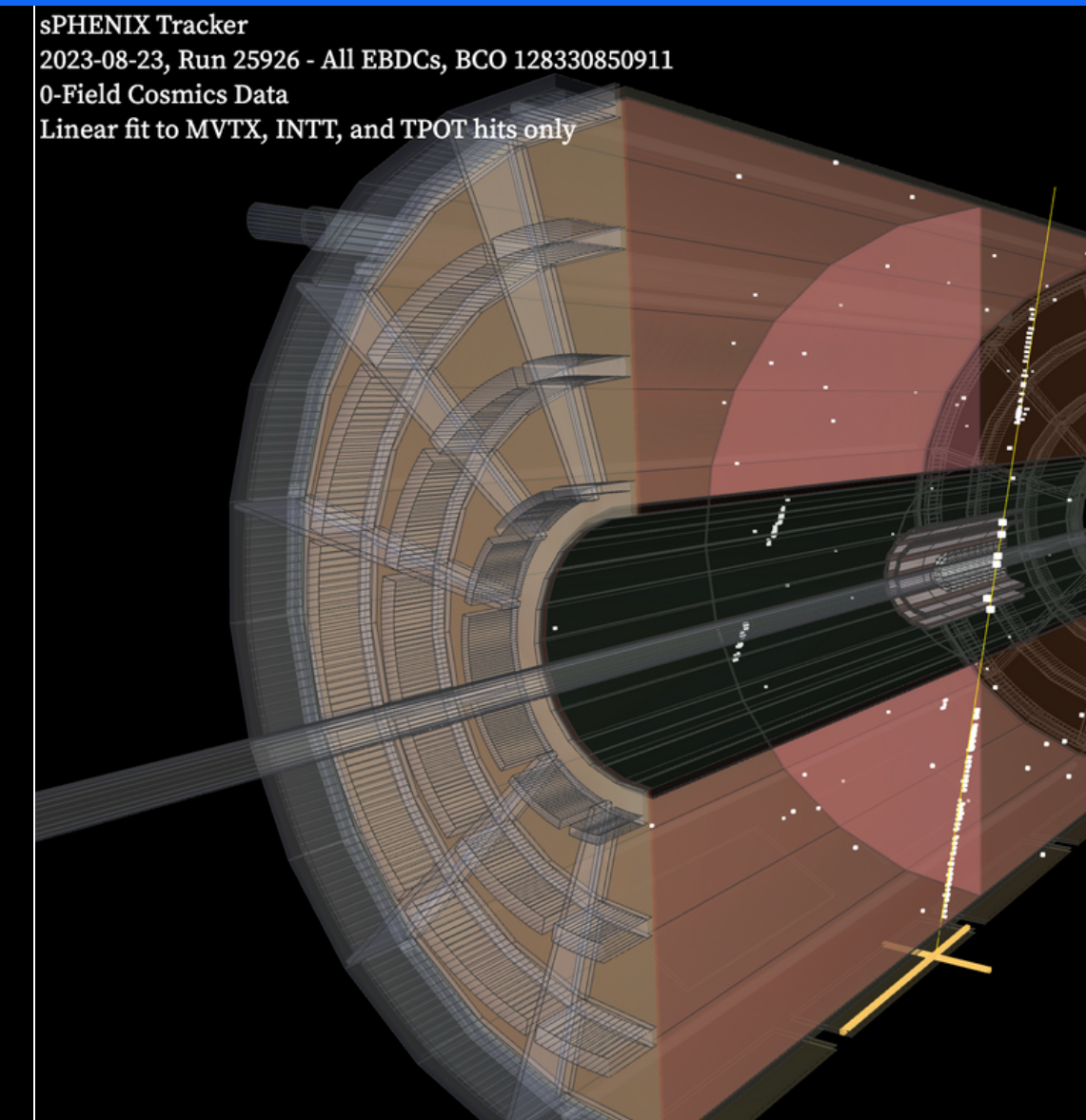
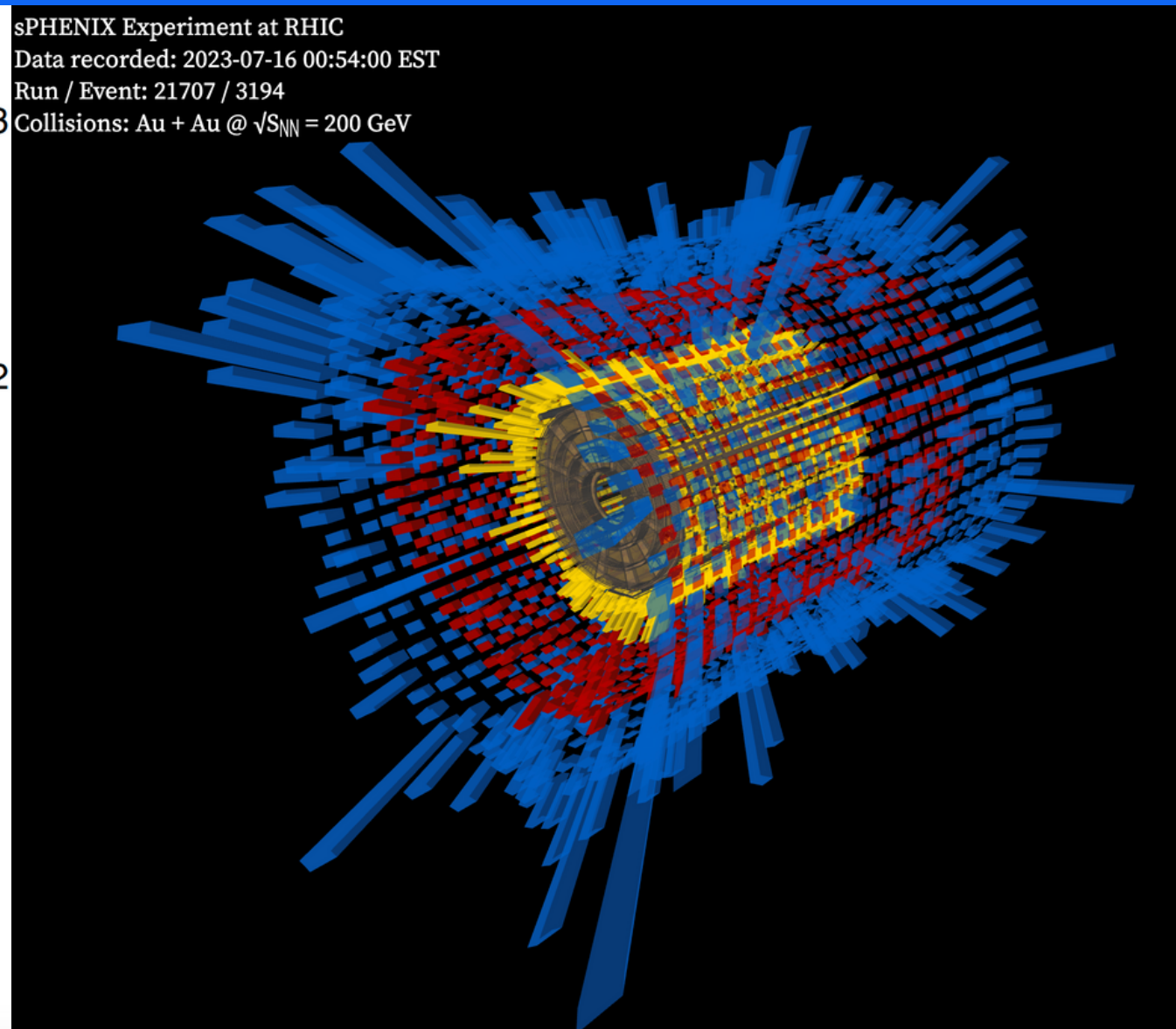
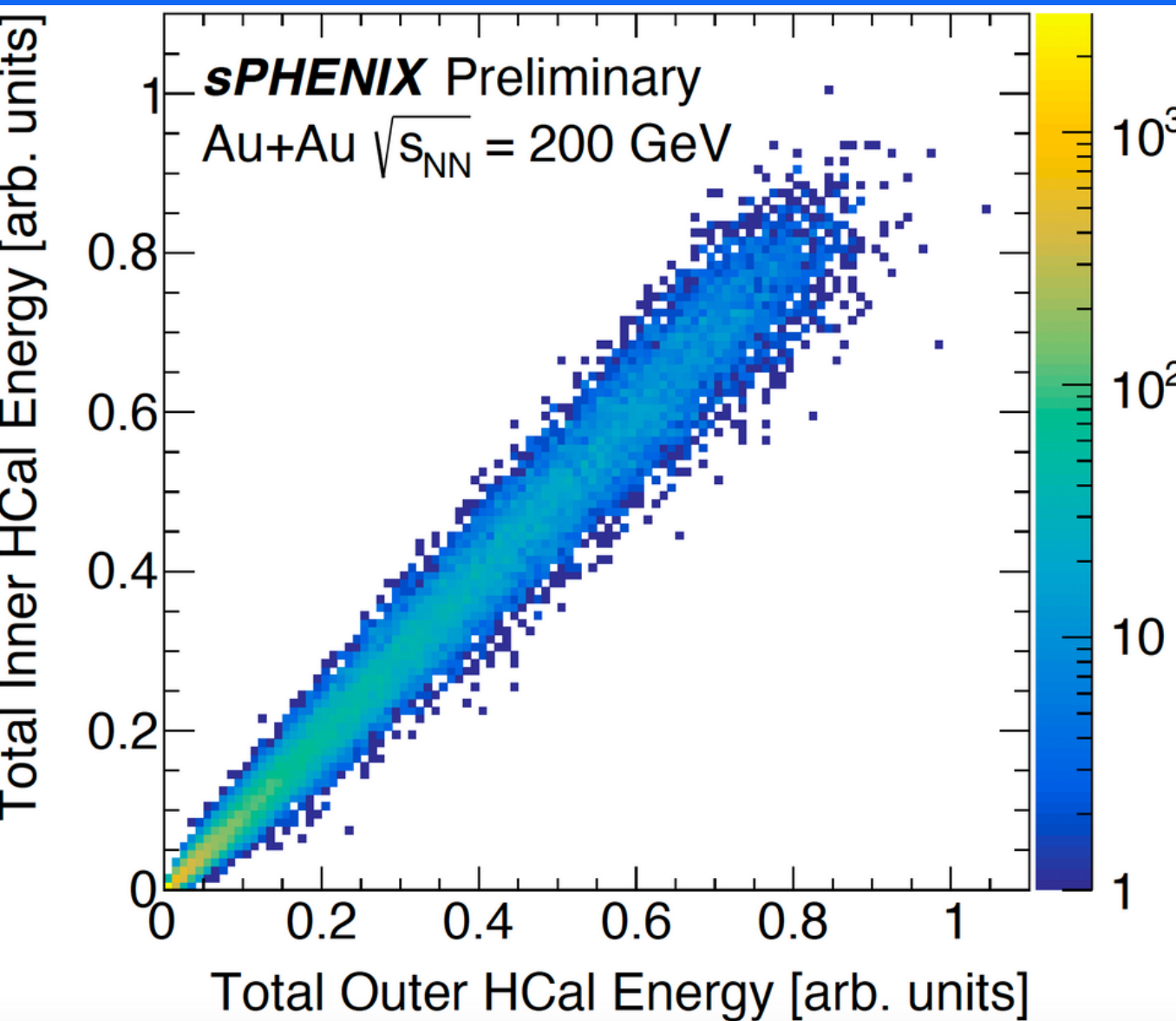


May 2023

Installation Complete

Commissioning with Au+Au at

200 GeV began immediately after



May 2023

Inner and outer hadronic calorimeter total energy correlation

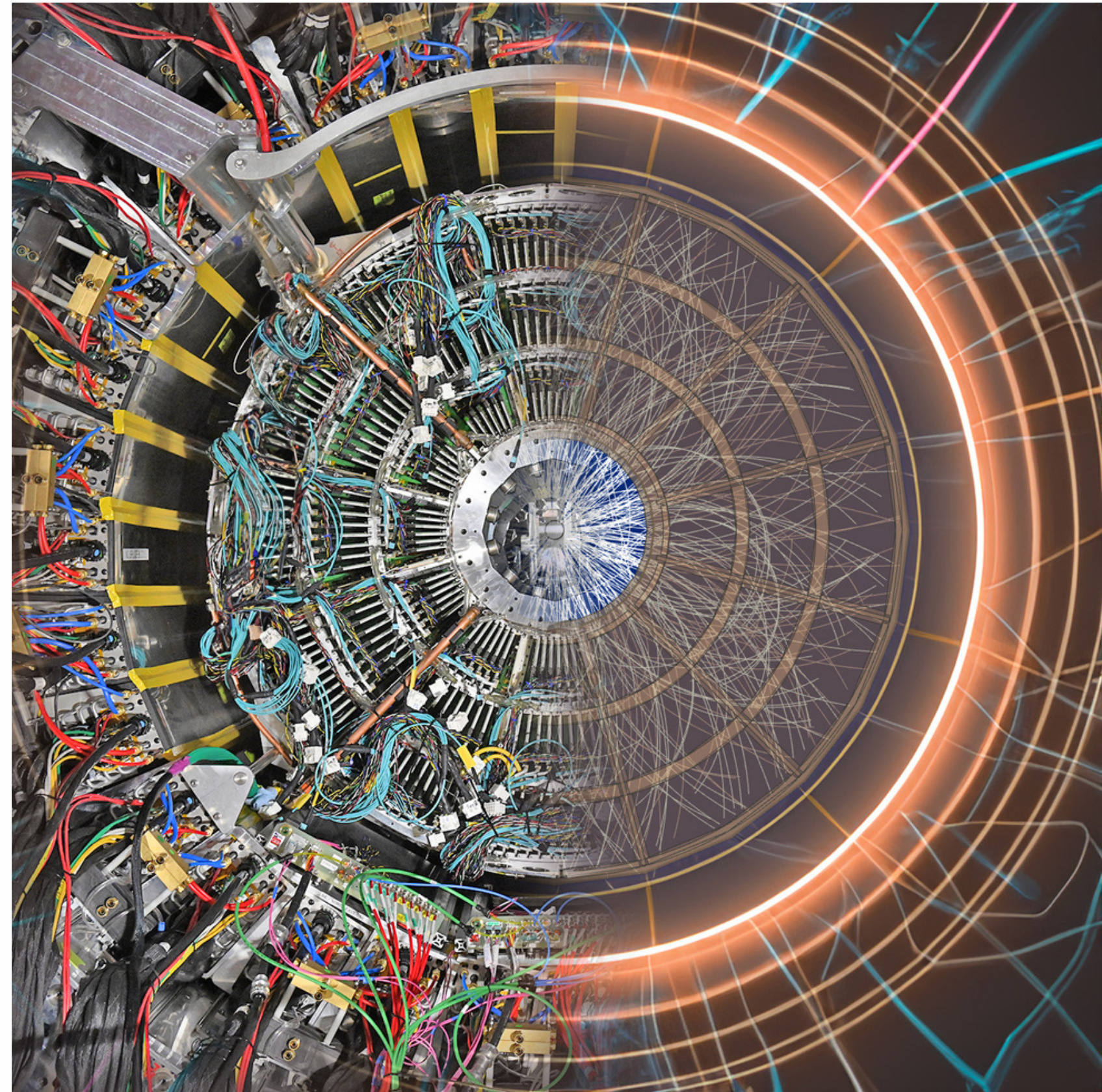
July 2023

Central Au+Au data event recorded in the sPHENIX calorimeter system

September 2023

Cosmic track through all tracking subsystems. Linear fit to only MVTX, INTT and TPOT

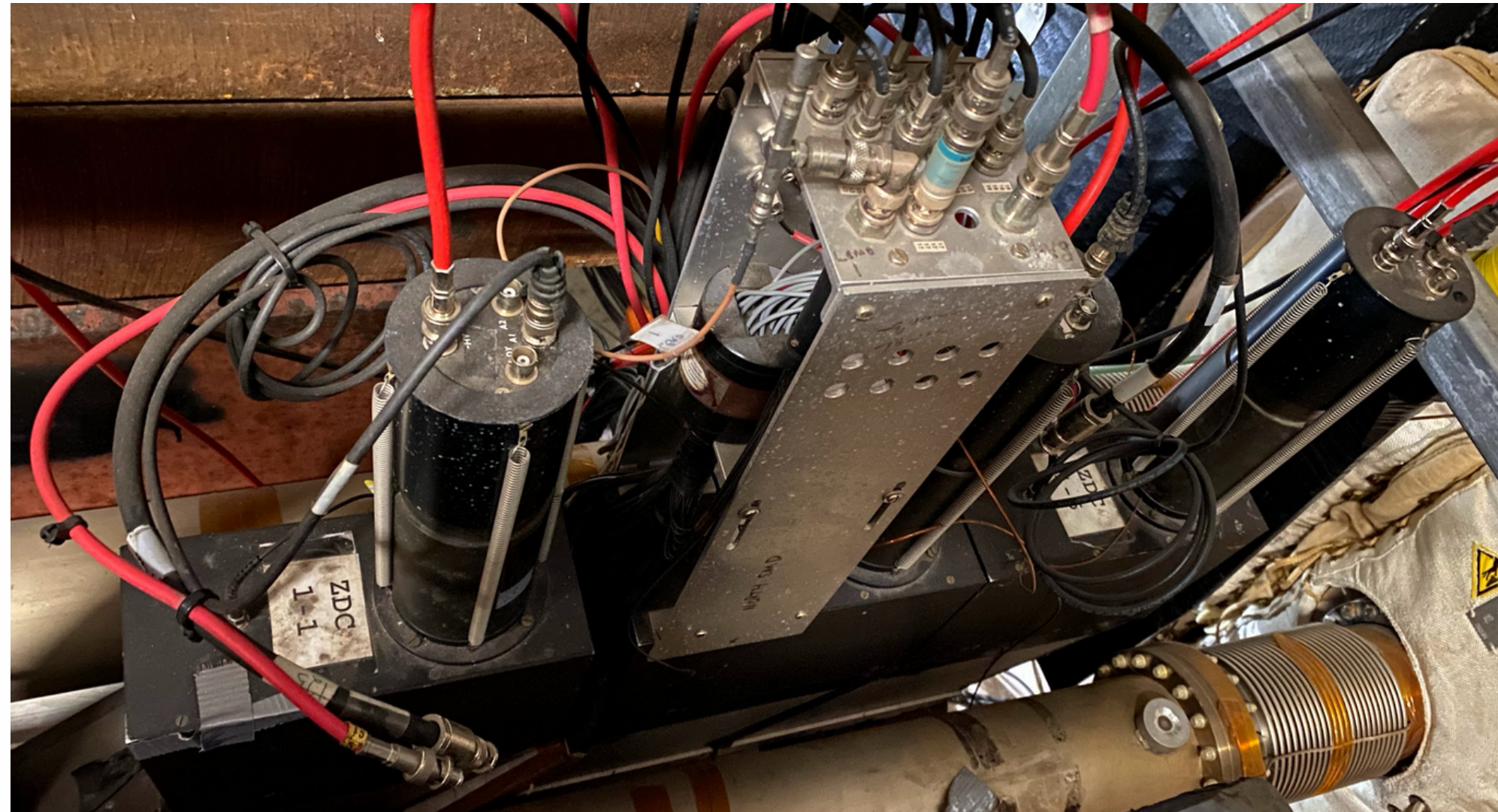
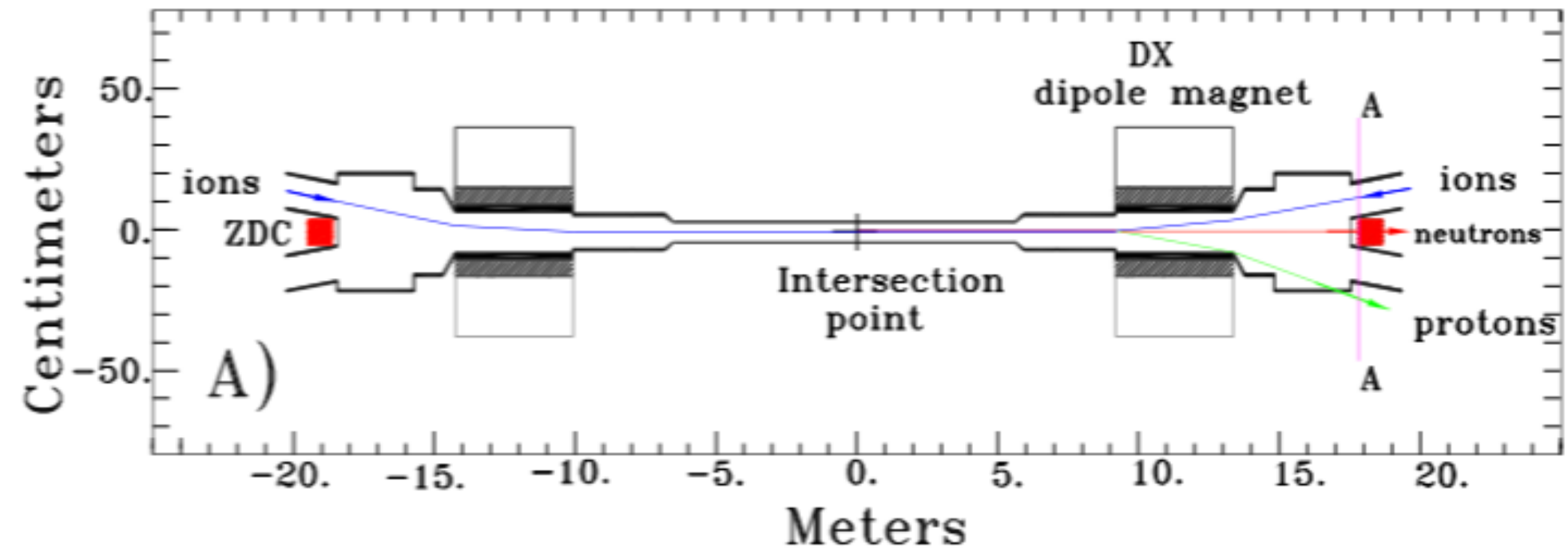
- **sPHENIX Zero Degree Calorimeter (ZDC) commissioning, the Shower Max Detector (SMD) and physics capabilities**
- **Commissioning of the Minimum Bias Detector (MBD) and event plane determination with the MBD in run 2023 data**
- **sPHENIX Event Plane Detector (sEPD) and projections for physics measurements with the sEPD**

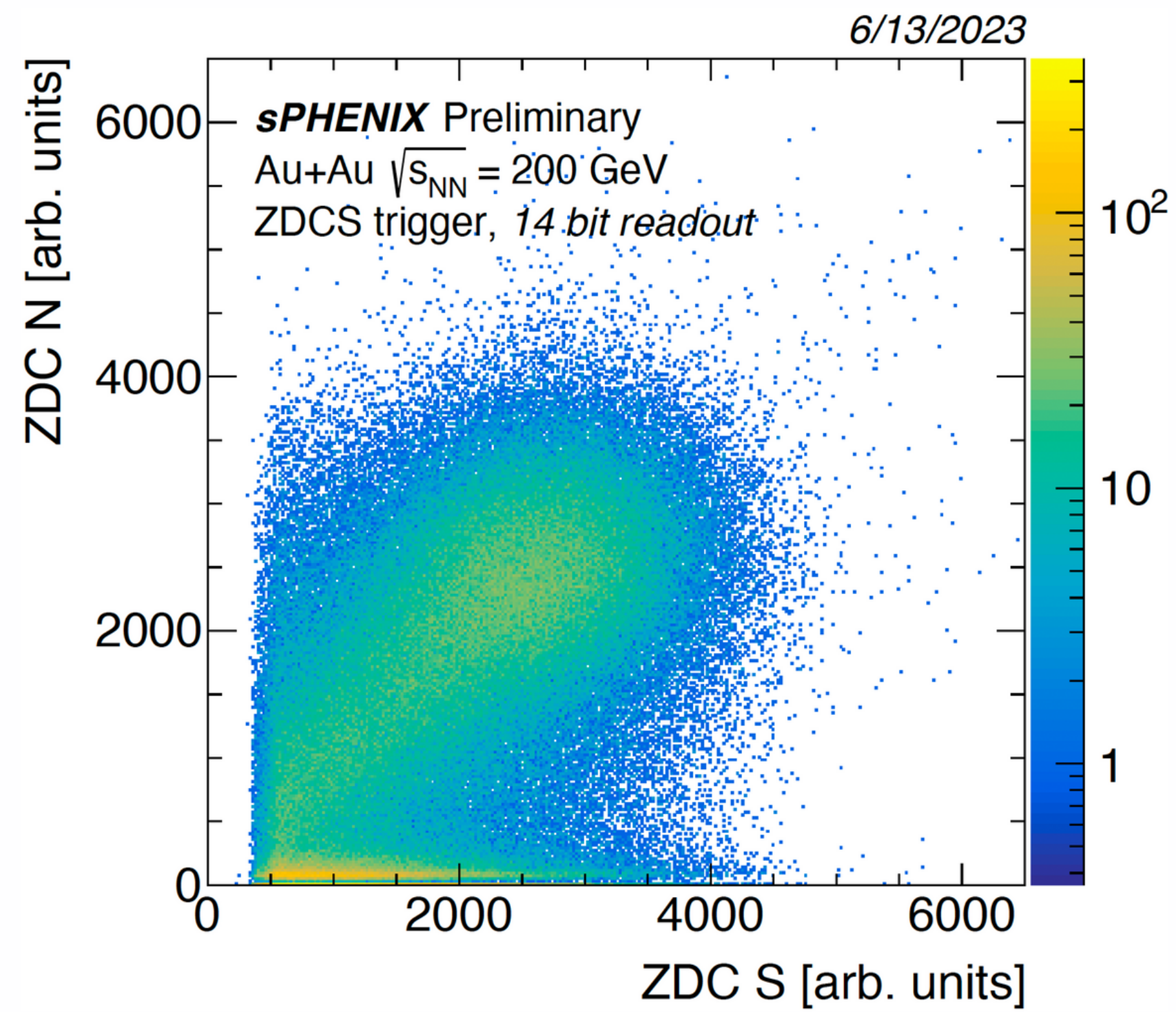
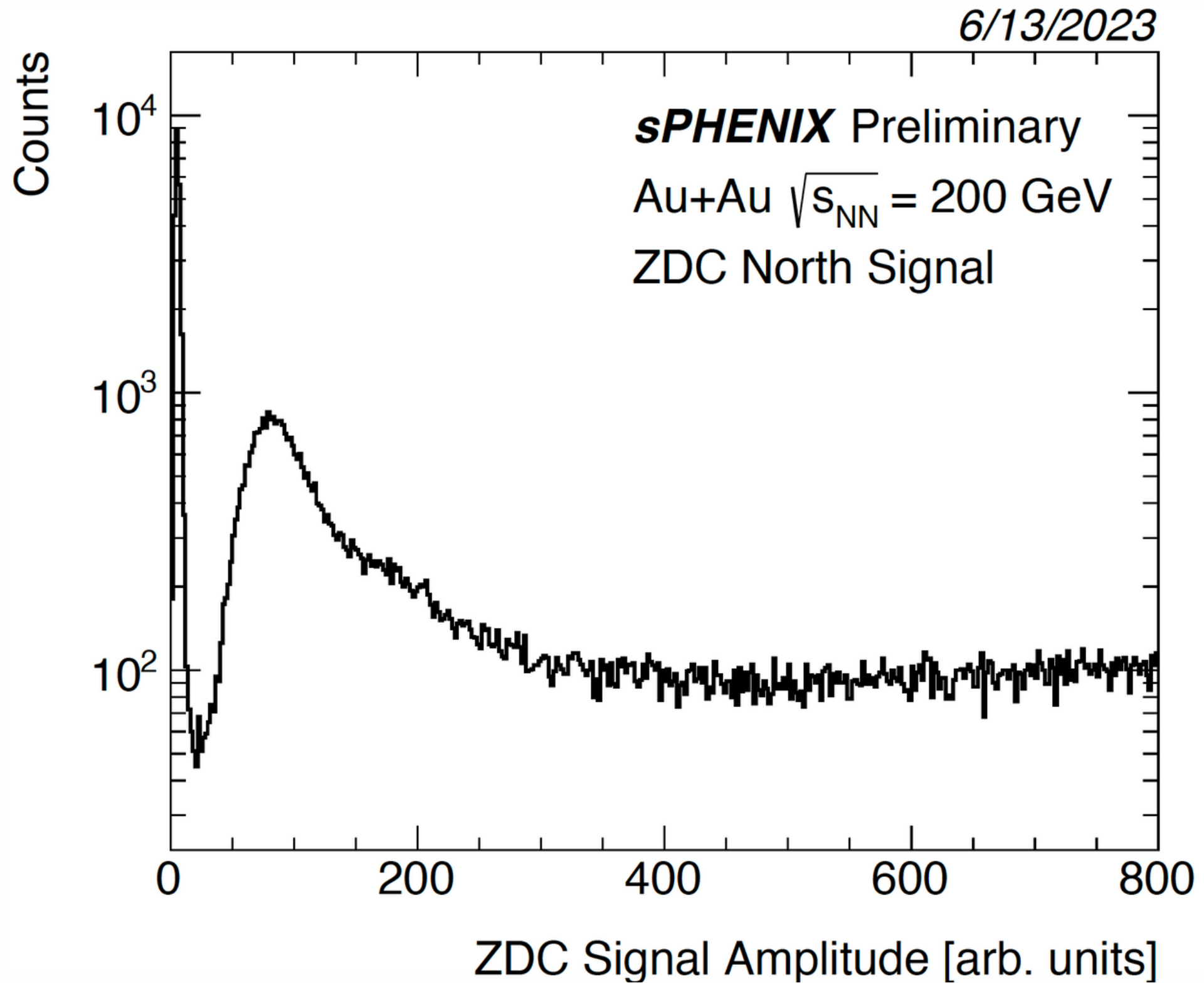


sPHENIX Zero Degree Calorimeter

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- The ZDC hardware is the same as the PHENIX ZDC used during 2001-2016
- Two arms in south and north made out of 3 tungsten-fiber modules
- Located symmetrically at $z = \pm 18\text{m}$
- Measures spectator neutrons
- Serves as accelerator tool; main measure of luminosity at RHIC
- Important for UPC and spin physics program, and measure of centrality for heavy ion collisions



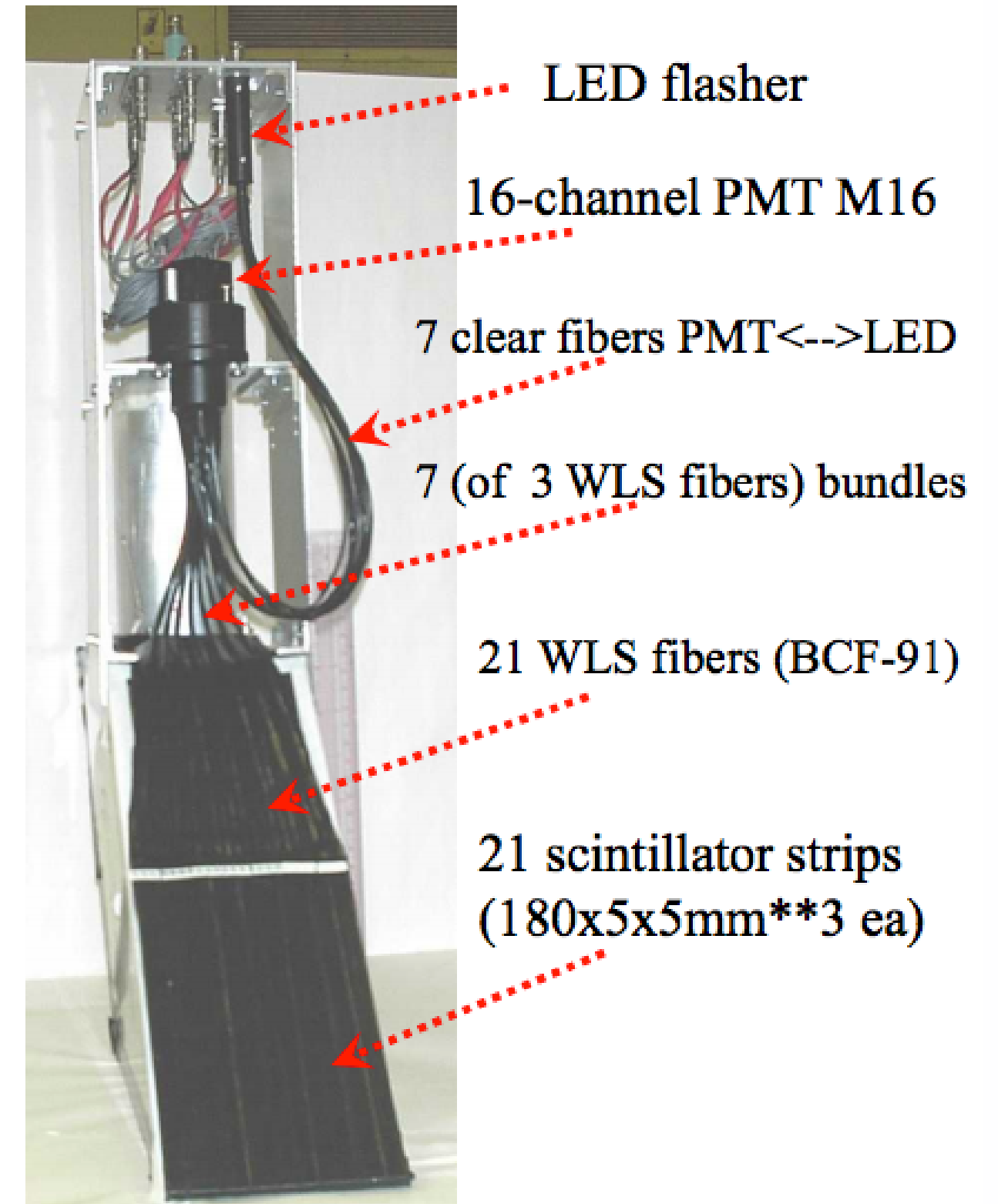


Raw ADC signal in the north ZDC with single neutron peak

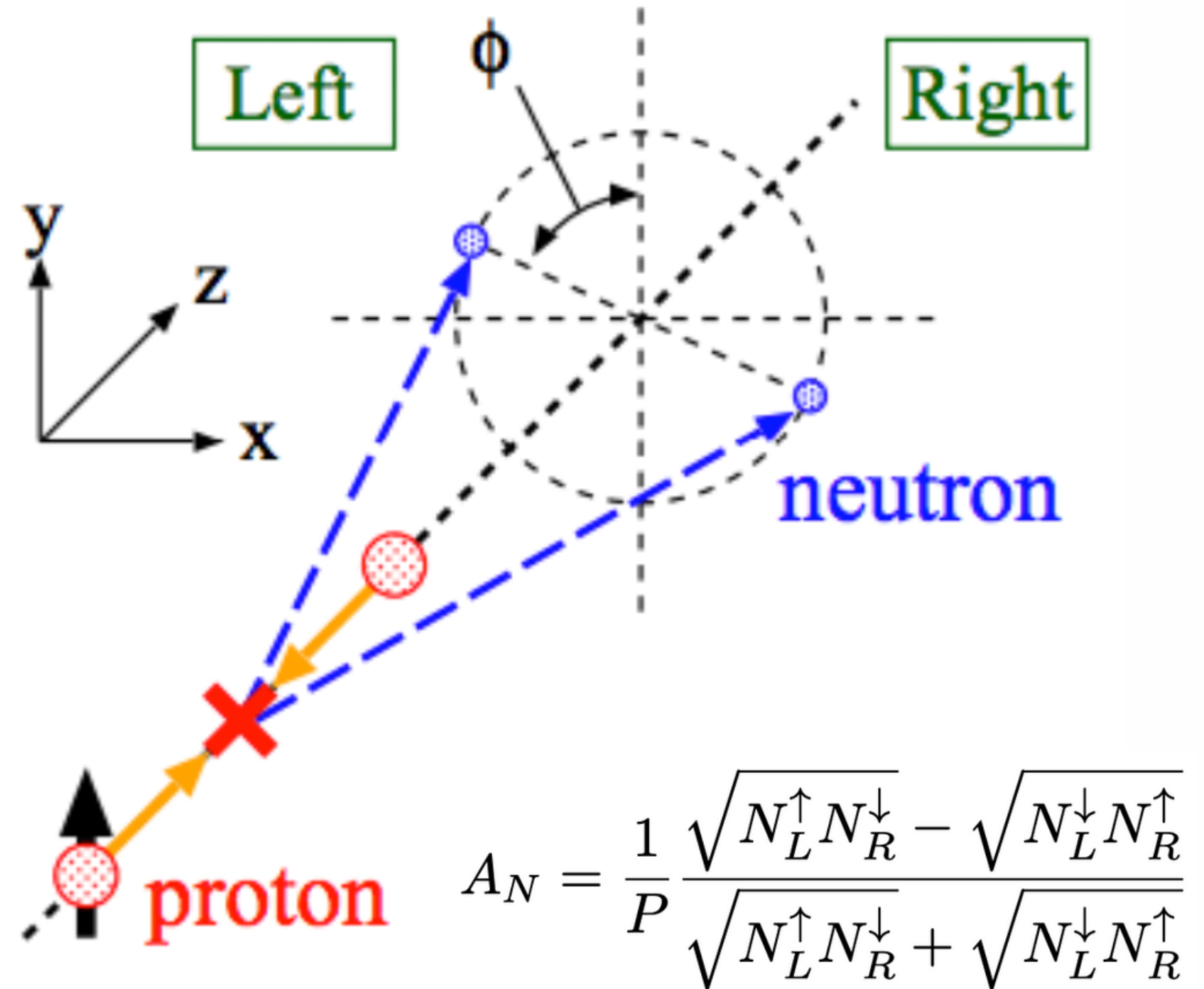
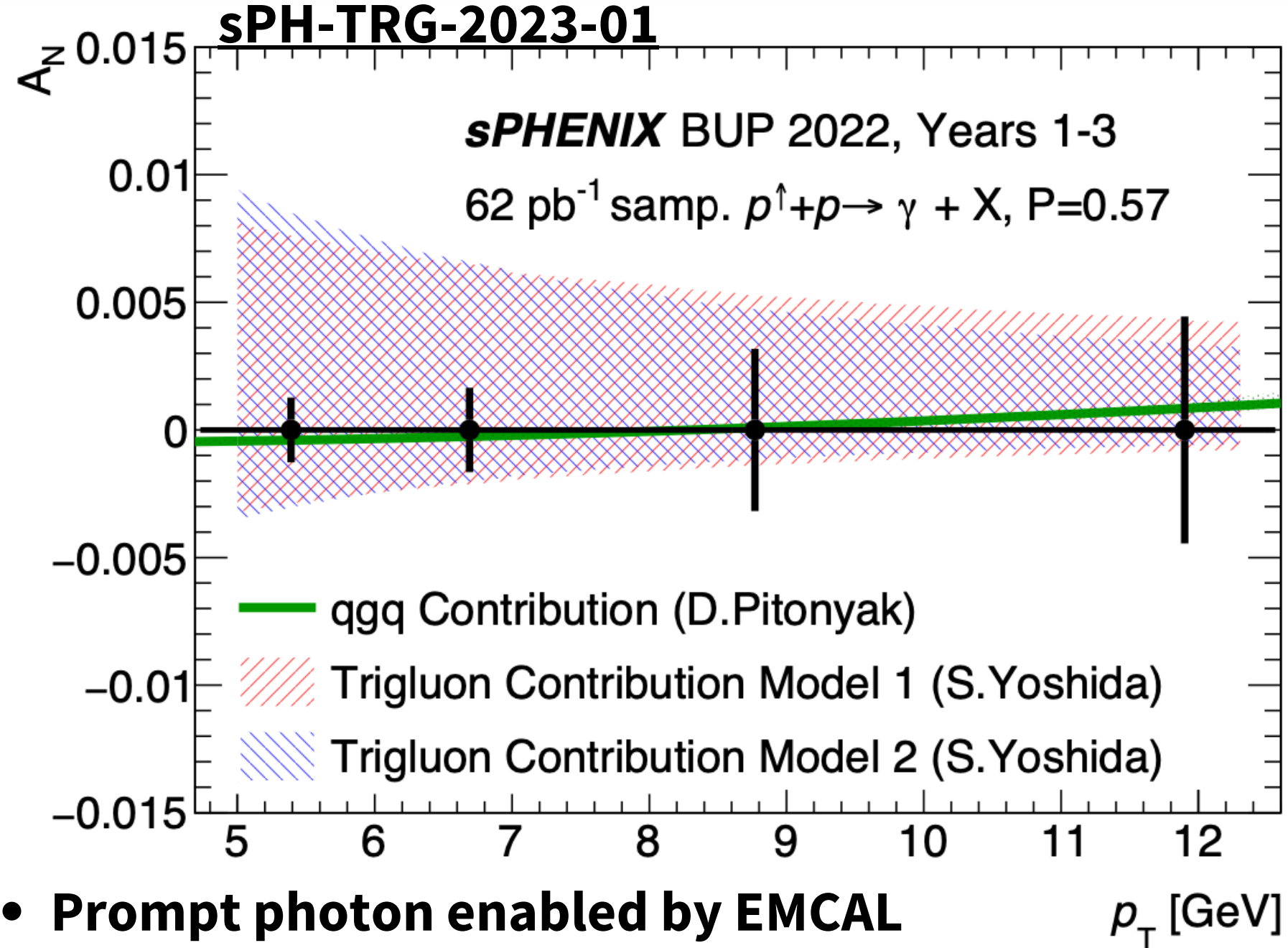
North-South raw signal correlation

- The raw signal has since been calibrated to the expected one neutron energy of 100 GeV

- The SMD is between the 1st and 2nd modules of the ZDC
- It has 2 layers of scintillator strips, which provides (x , y) positions for where the neutrons hit
- The ZDC-SMD provides event plane measurement for the first harmonic flow
- Allows for study of UPCs (tag photon polarization), Spin Physics (e.g. neutron asymmetry)

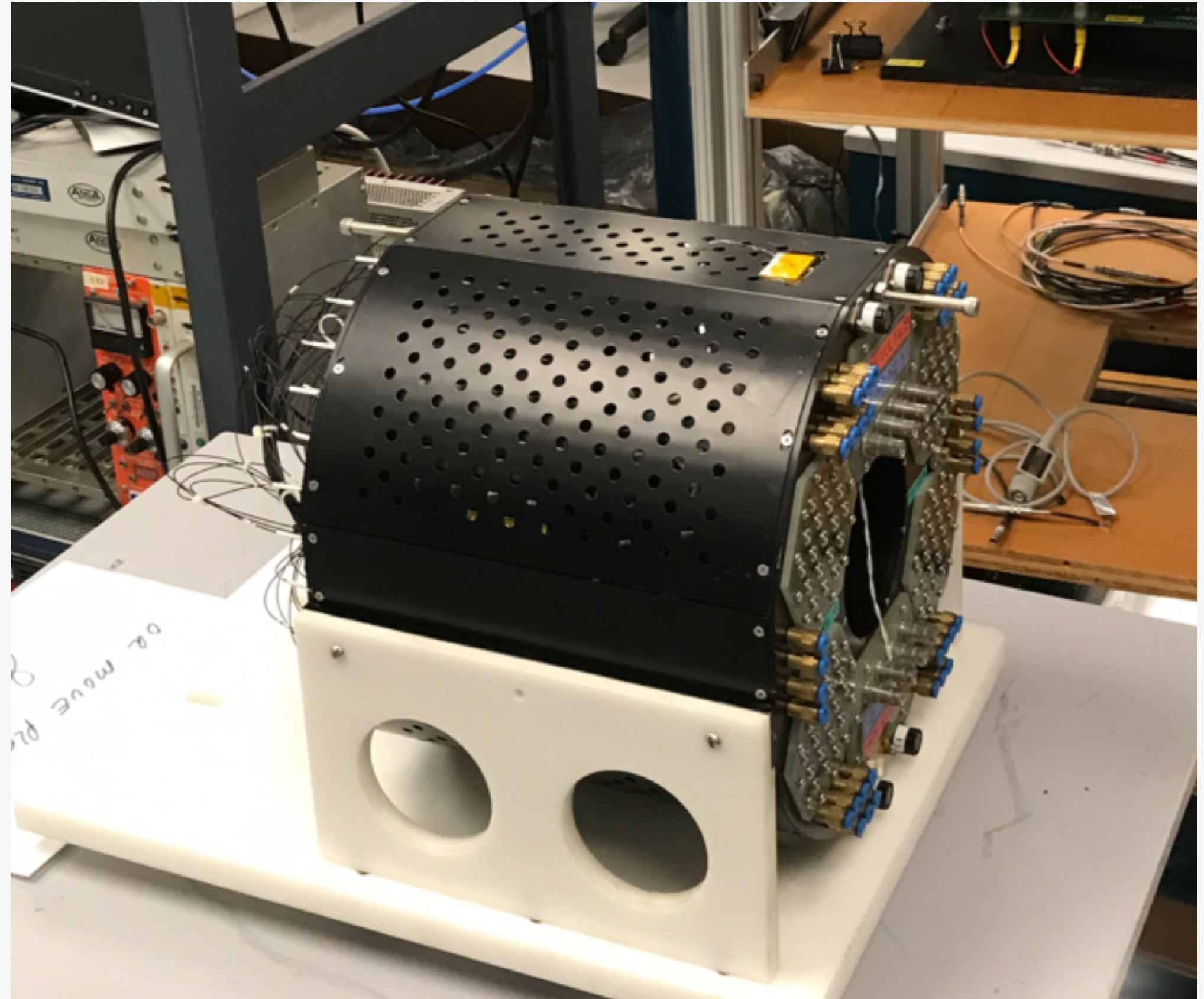


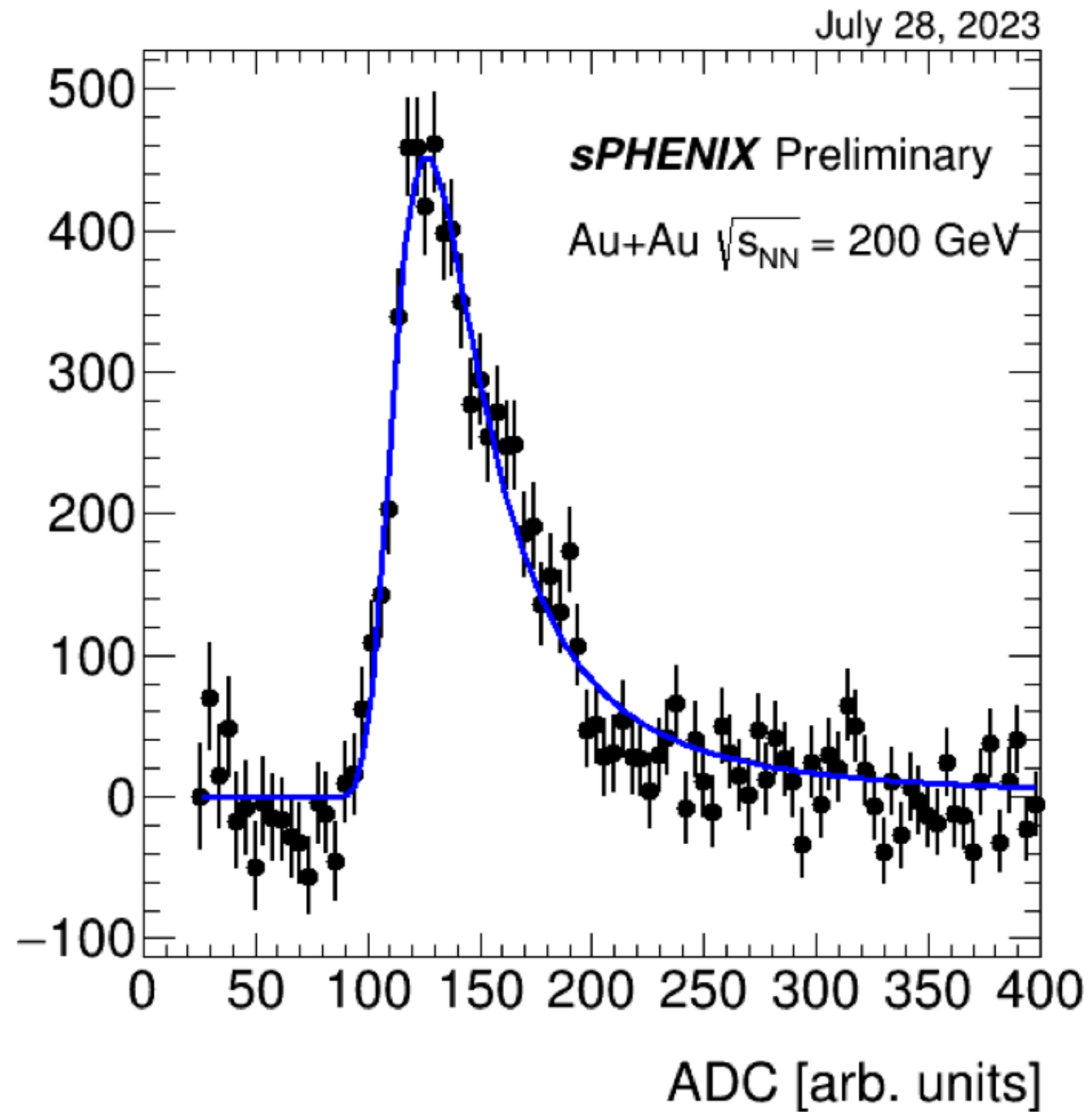
Statistical projections for prompt photon TSSA



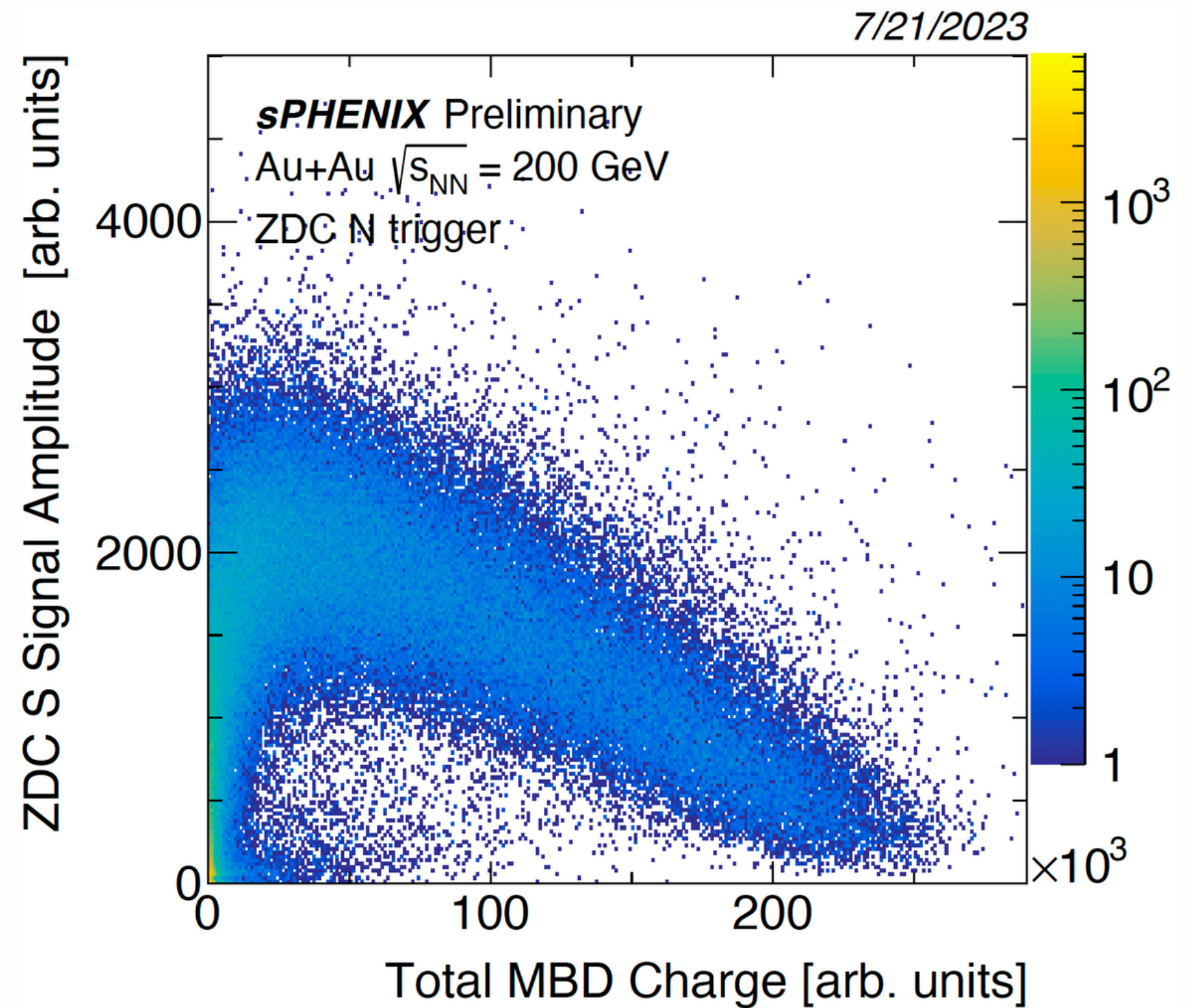
- Prompt photon enabled by EMCAL
- TSSAs probe gluon correlations in the nucleon
- Square root method uses geometric mean of the yields from 2 azimuthal regions on opposite sides of the SMD and 2 polarization directions (up and down)

- Reuse of PHENIX BBC. Consists of two arms with 64 channels each
- 3 cm thick quartz radiator on mesh dynode PMT
- Pseudorapidity : $3.51 \leq |\eta| \leq 4.61$
- Used as trigger and for z-vertex determination
- One of three event characterization detectors used for centrality determination
- Also used for event plane determination in run 2023





MBD single channel MIP peak

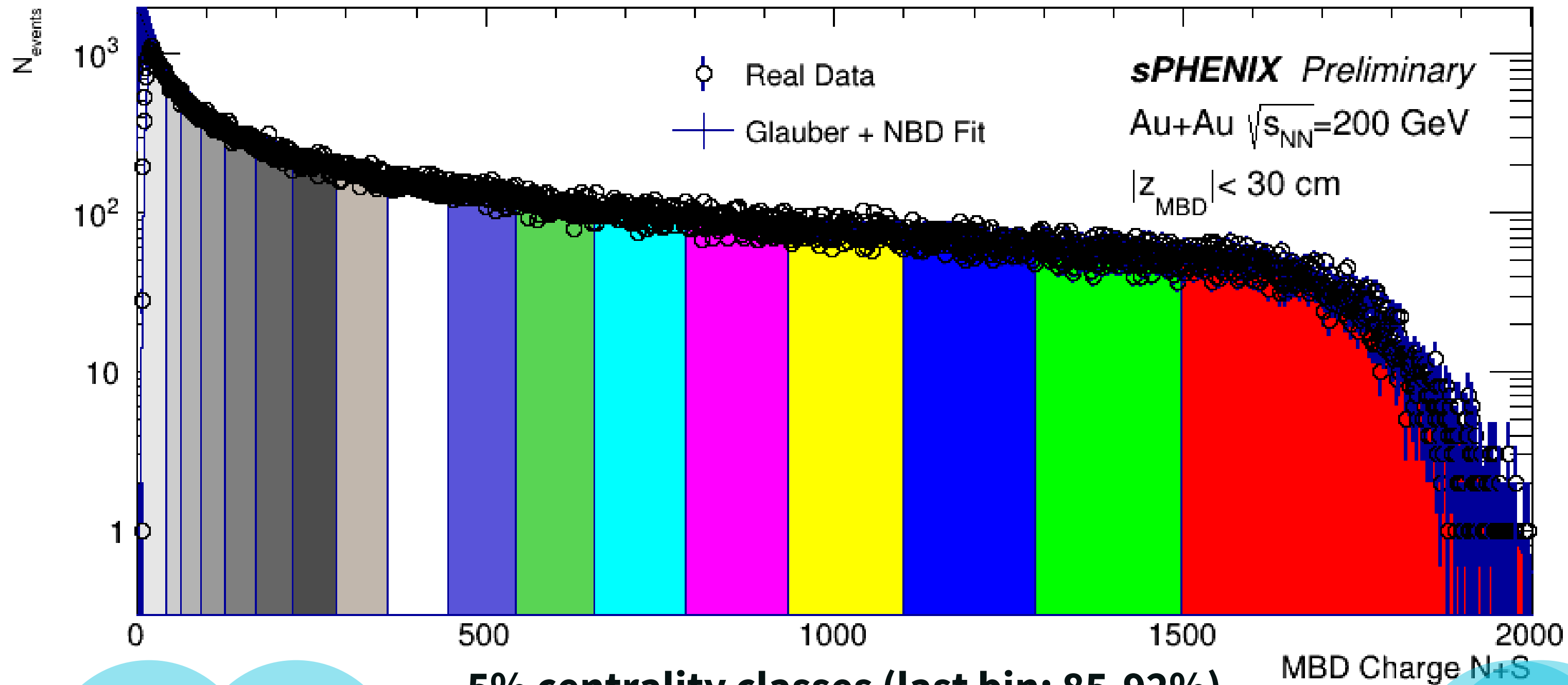


ZDC signal correlated with MBD total charge

Centrality Measurement

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08/30/2023

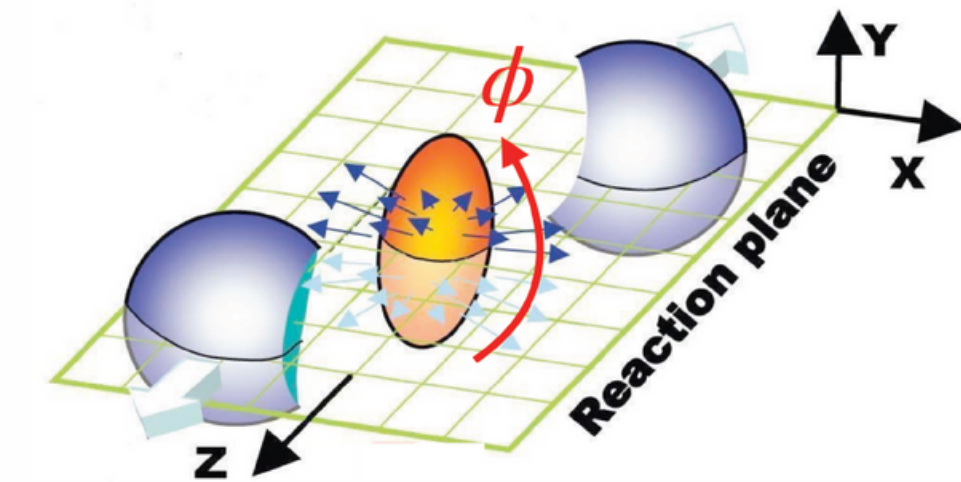
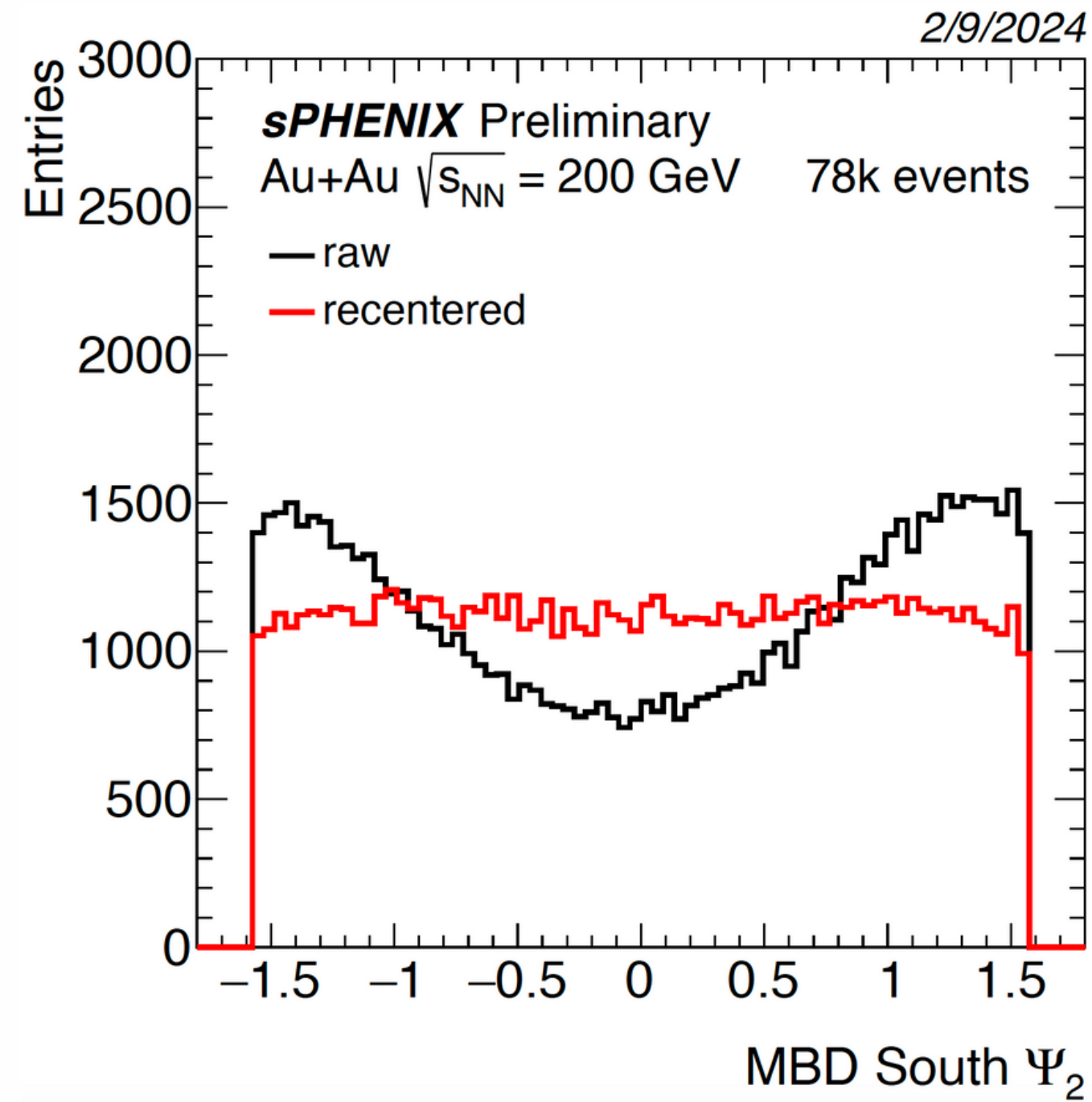
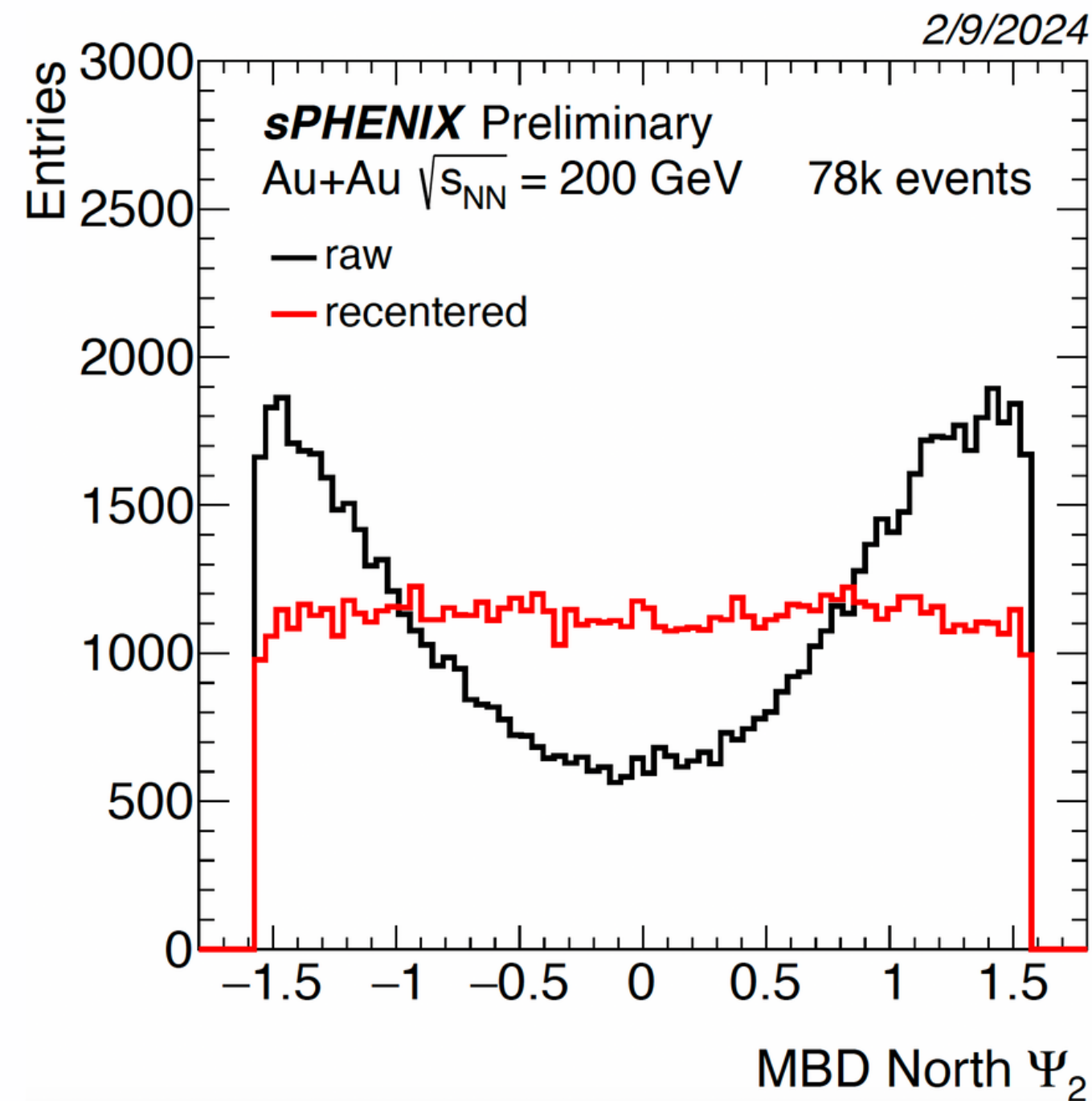


peripheral collisions

5% centrality classes (last bin: 85-92%)

**determined from the measured MBD total
charge distribution and Glauber + NBD fit**

central collisions



MBD second order event plane angle measurement

Raw

Recentered

A.M. Poskanzer, S.A. Voloshin

$$Q_n \cos(n\Psi_n) = X_n = \sum_i w_i \cos(n\phi_i),$$

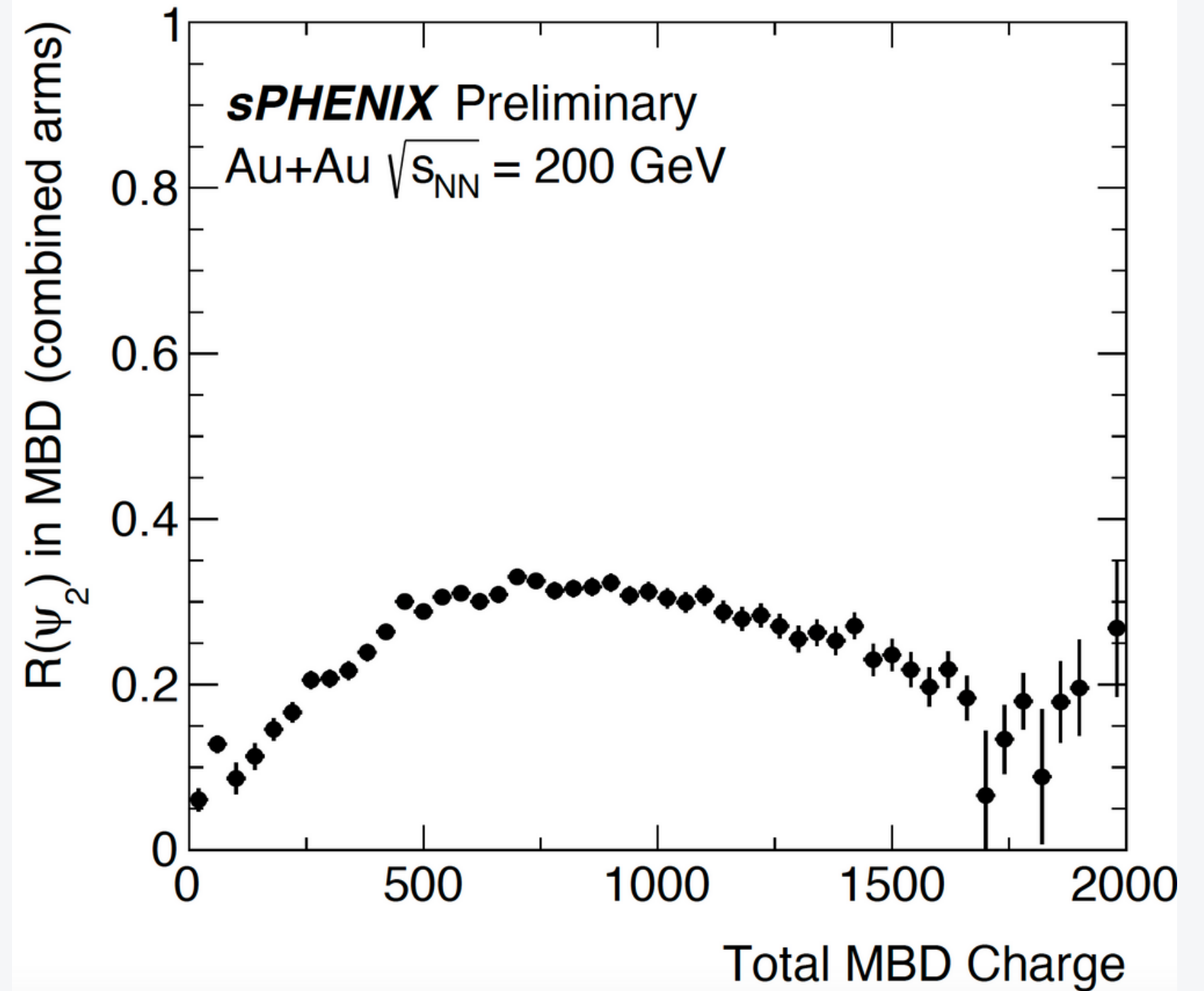
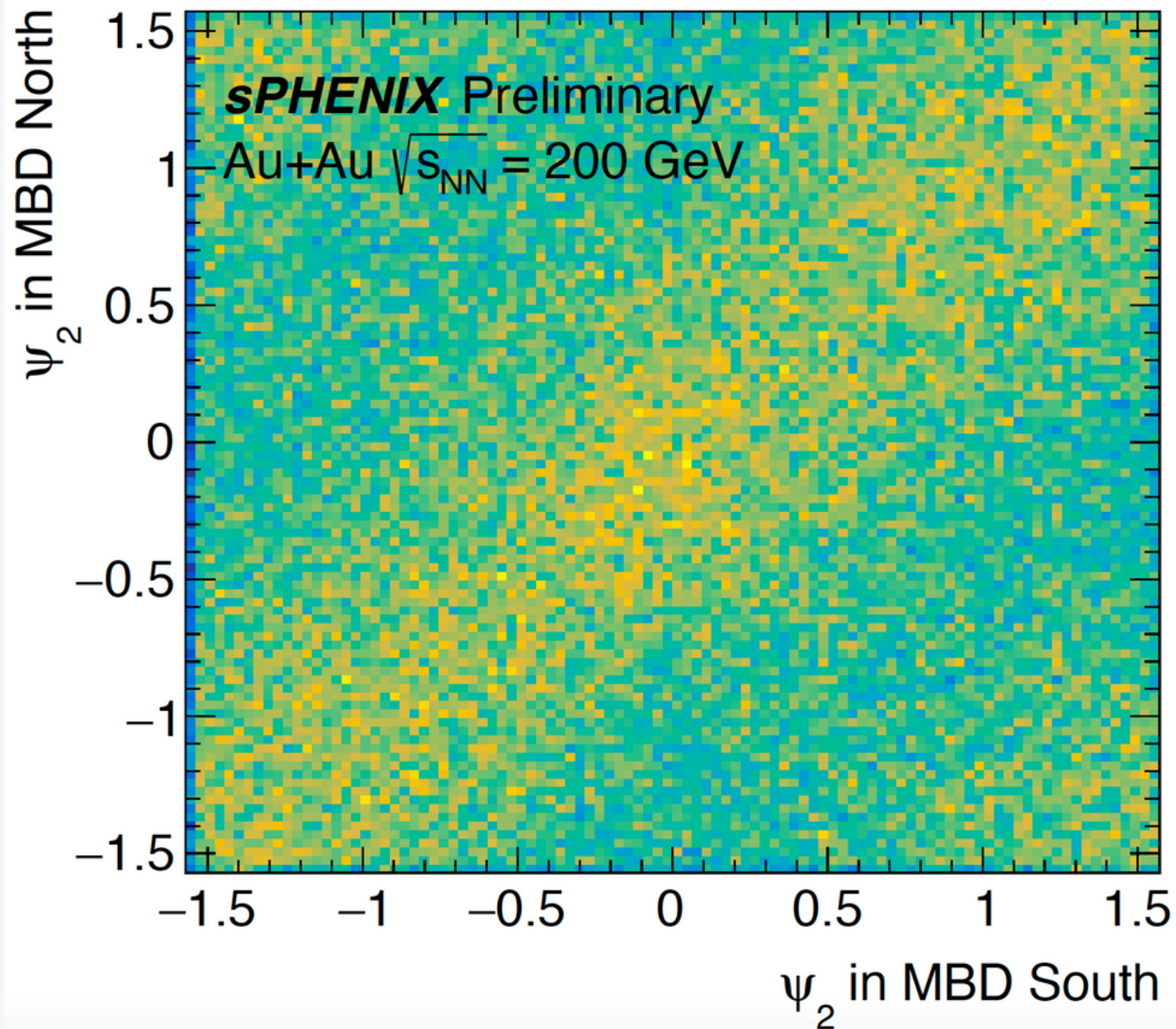
$$Q_n \sin(n\Psi_n) = Y_n = \sum_i w_i \sin(n\phi_i),$$

$$\Psi_n = \left(\tan^{-1} \frac{\sum_i w_i \sin(n\phi_i)}{\sum_i w_i \cos(n\phi_i)} \right) / n.$$

$$Q_n^{\text{corrected}} = Q_n^{\text{raw}} - Q_n^{\text{average}},$$

$$Q_n^{\text{average}} = M \langle \cos n\phi \rangle + iM \langle \sin n\phi \rangle$$

$$M = \sum_k w_k.$$

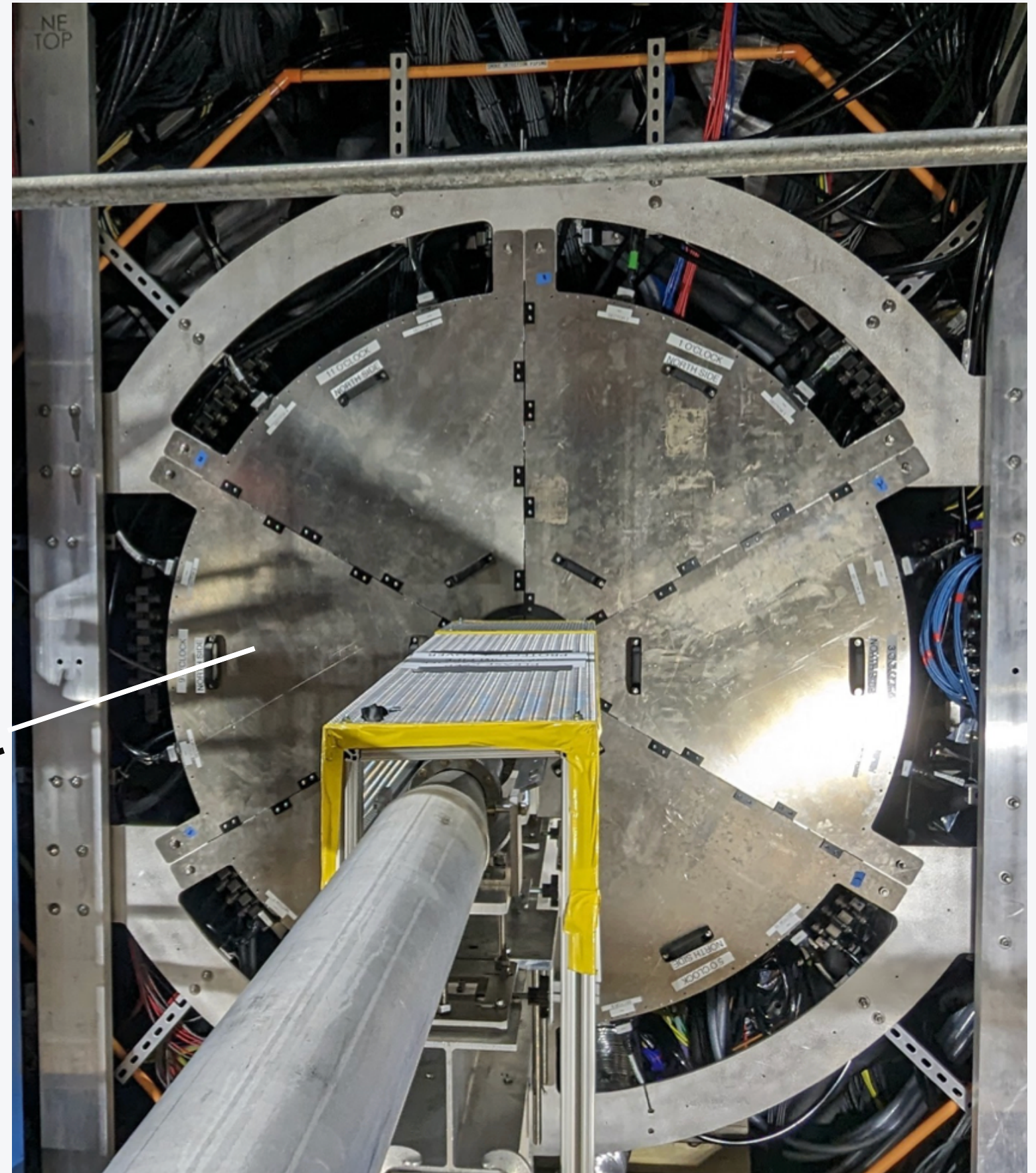
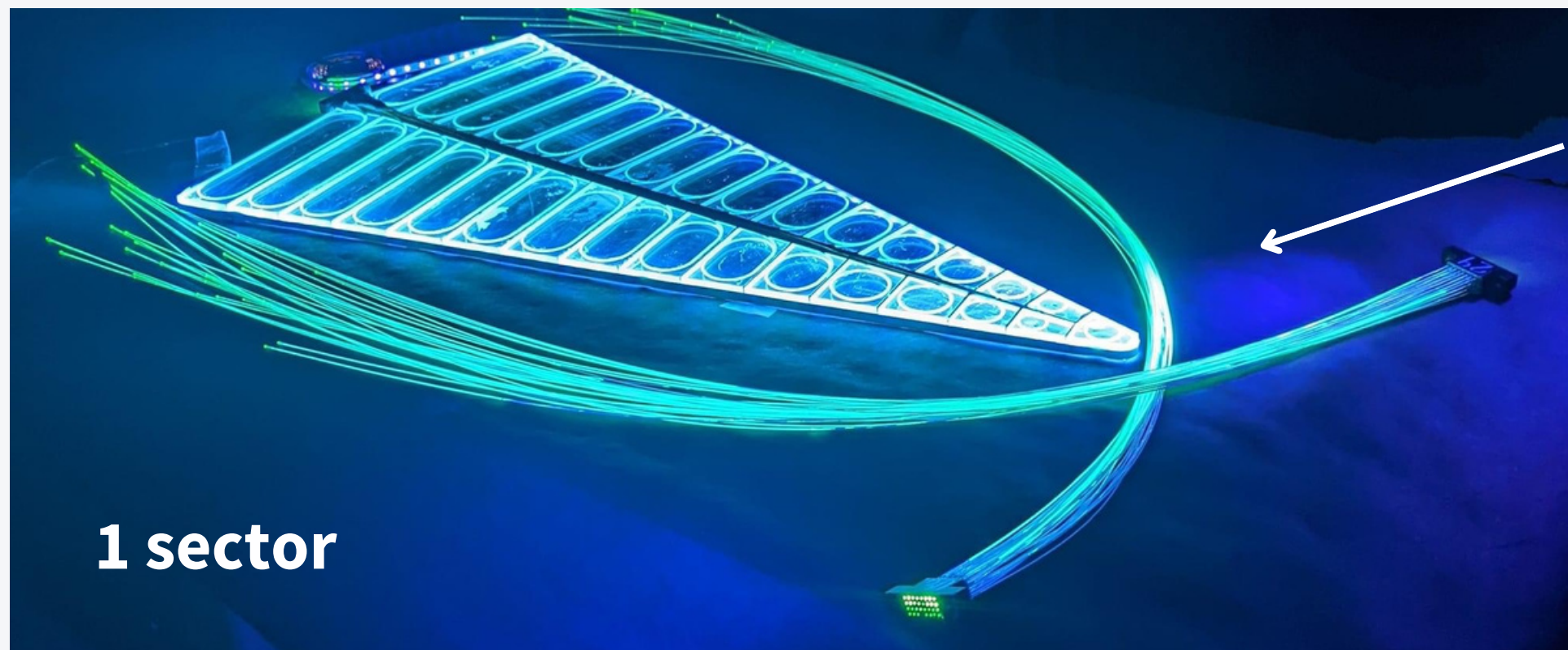


Correlation of the second order event plane angle determined with the MBD north and south

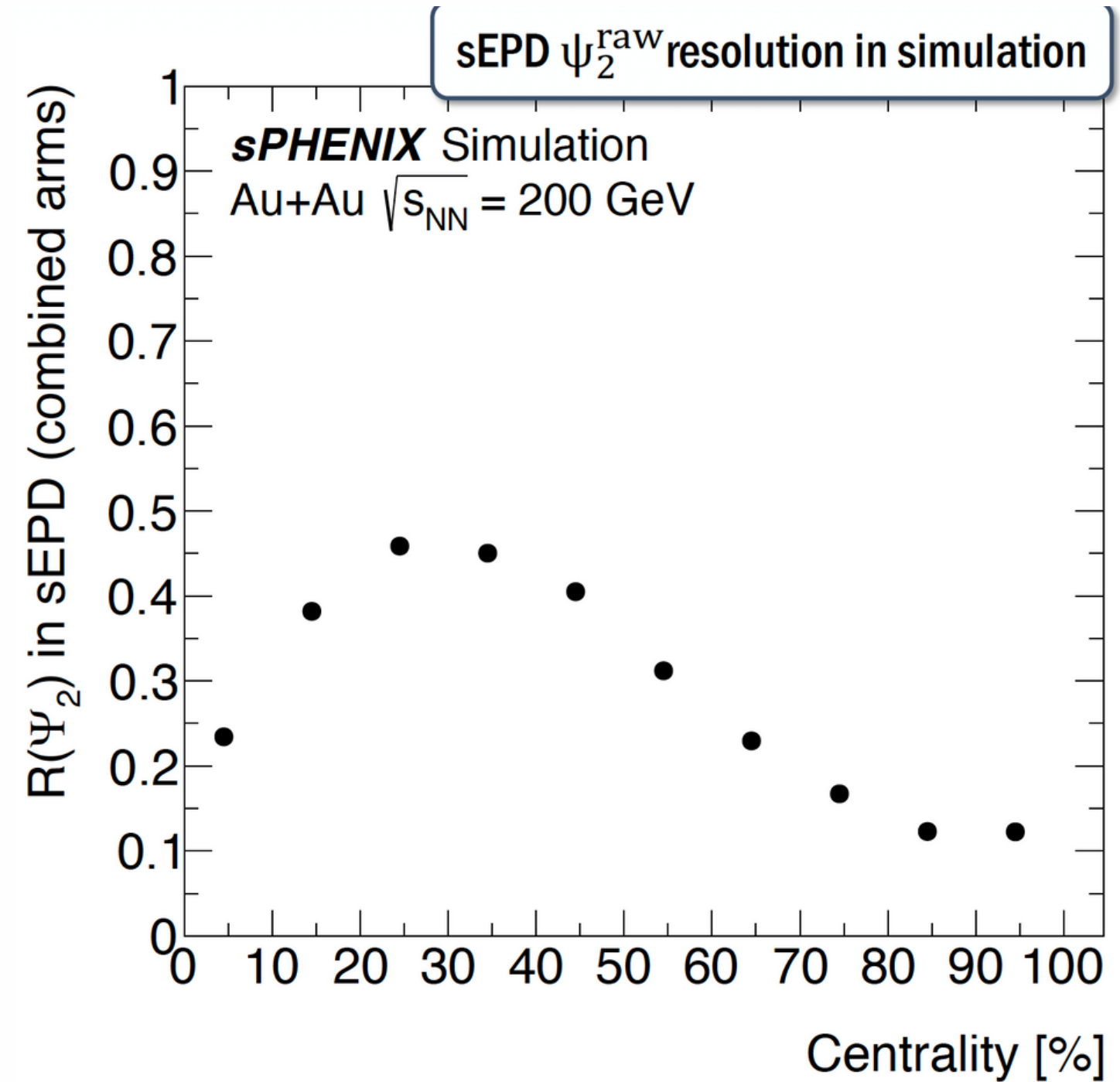
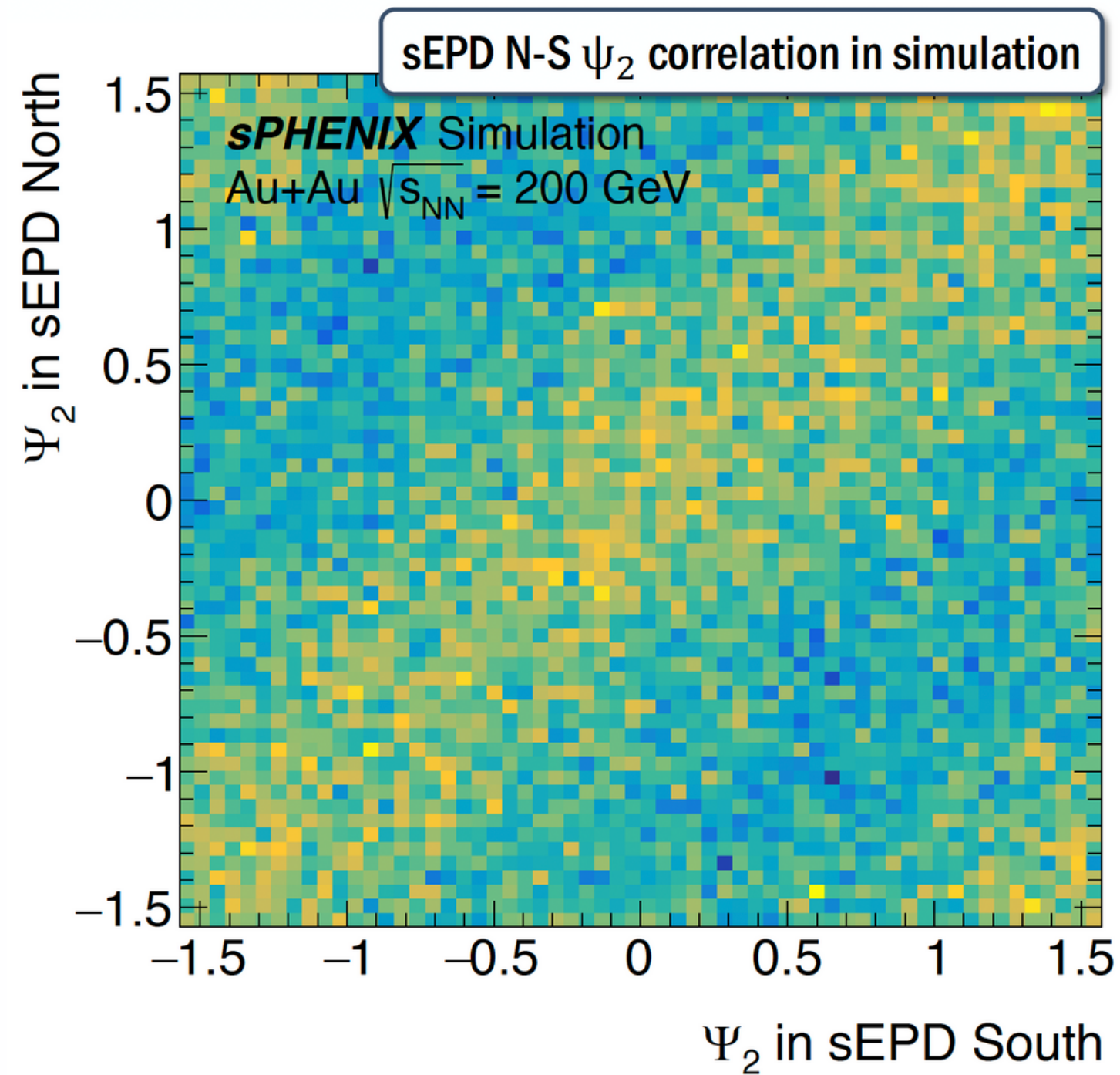
Second order event plane resolution determined with the combined MBD arms

See talk by Tristan Protzman

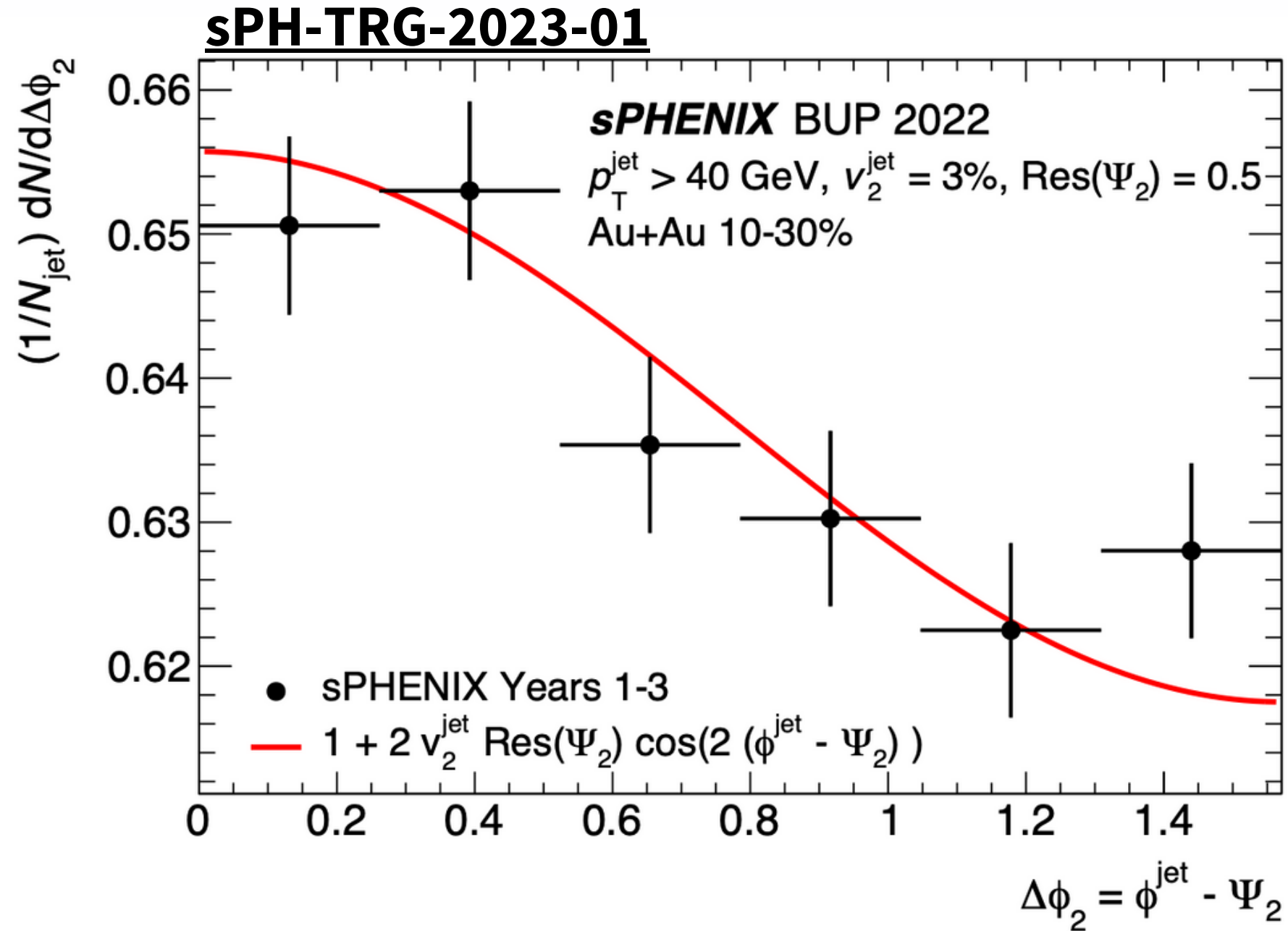
- Consists of two wheels with 12 sectors. 744 total channels
- 1.2 cm thick plastic scintillators with embedded WLS fibers
- Pseudorapidity interval: $2.0 \leq |\eta| \leq 4.9$
- Used primarily for event plane determination



Event Plane Determination with the sEPD in simulation 17



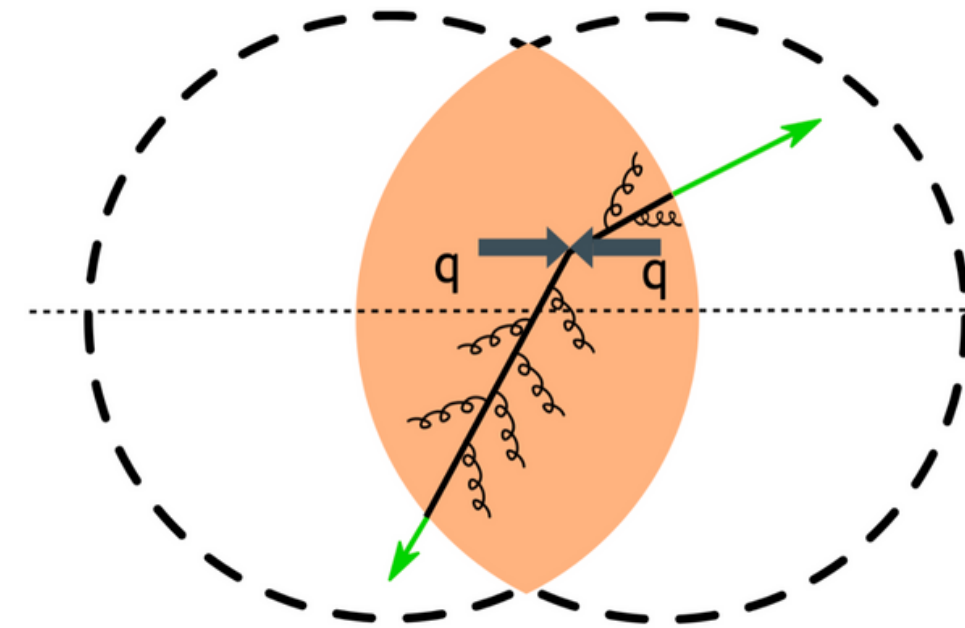
- sEPD second order event plane as determined in simulation
- Higher resolution than the MBD of at least 50% expected with the sEPD
- This will enable many of the azimuthal anisotropy measurements planned for in sPHENIX



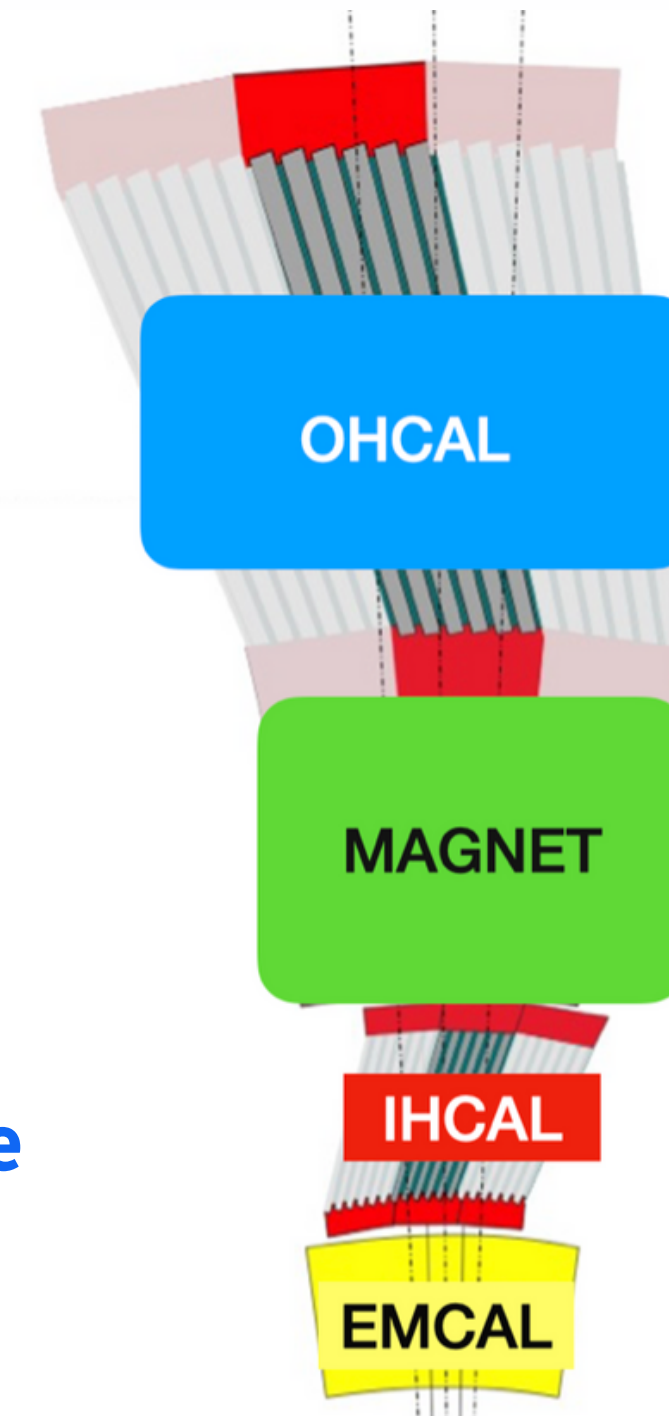
Statistical projections for jet yield as a function of distance from the event plane

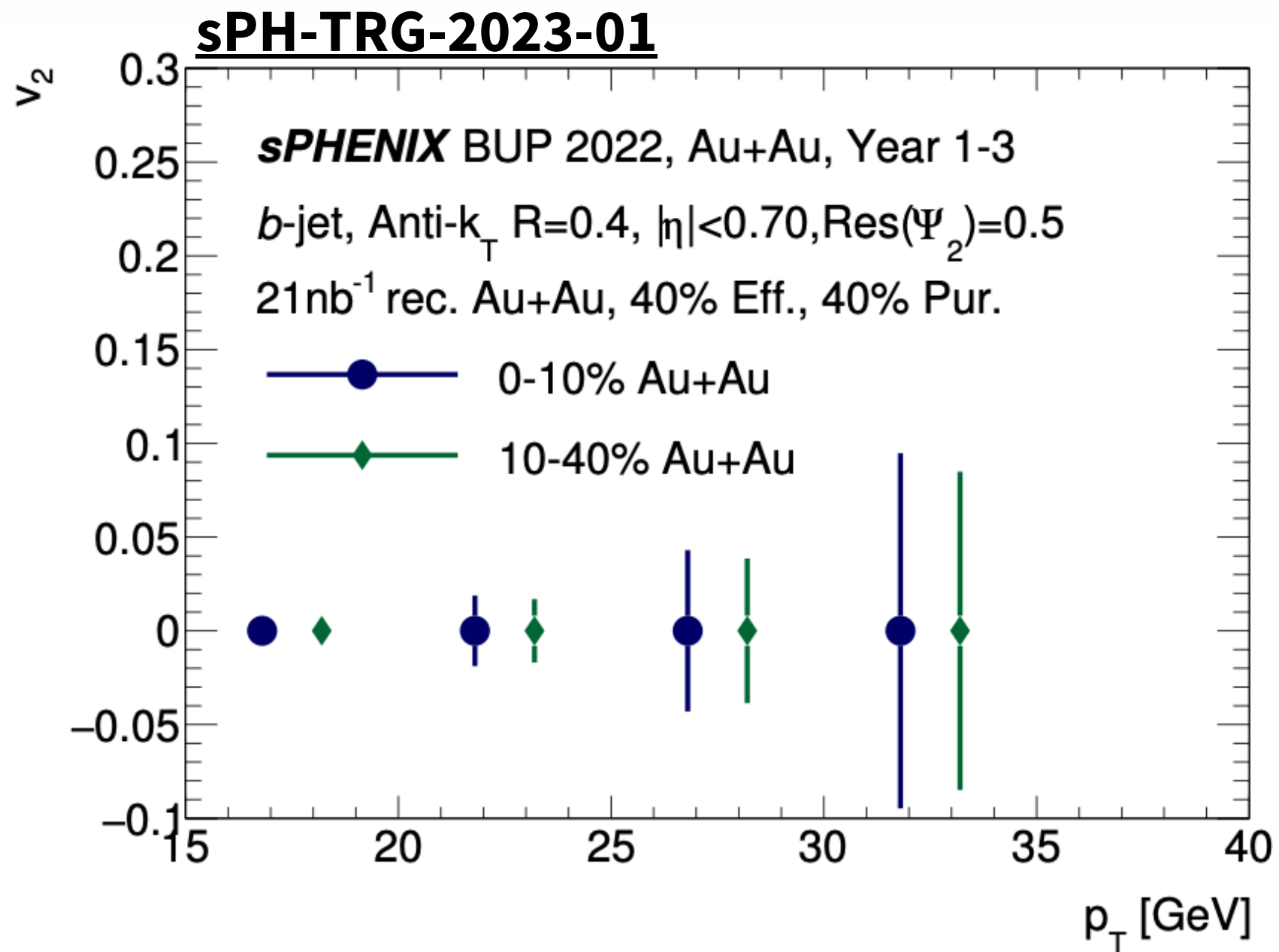
jet azimuthal anisotropy

Full jet energy measured with calorimeter system



- jet v_n : measure angular distribution of jets with respect to the event plane
- directly sensitive to the shape of the QGP

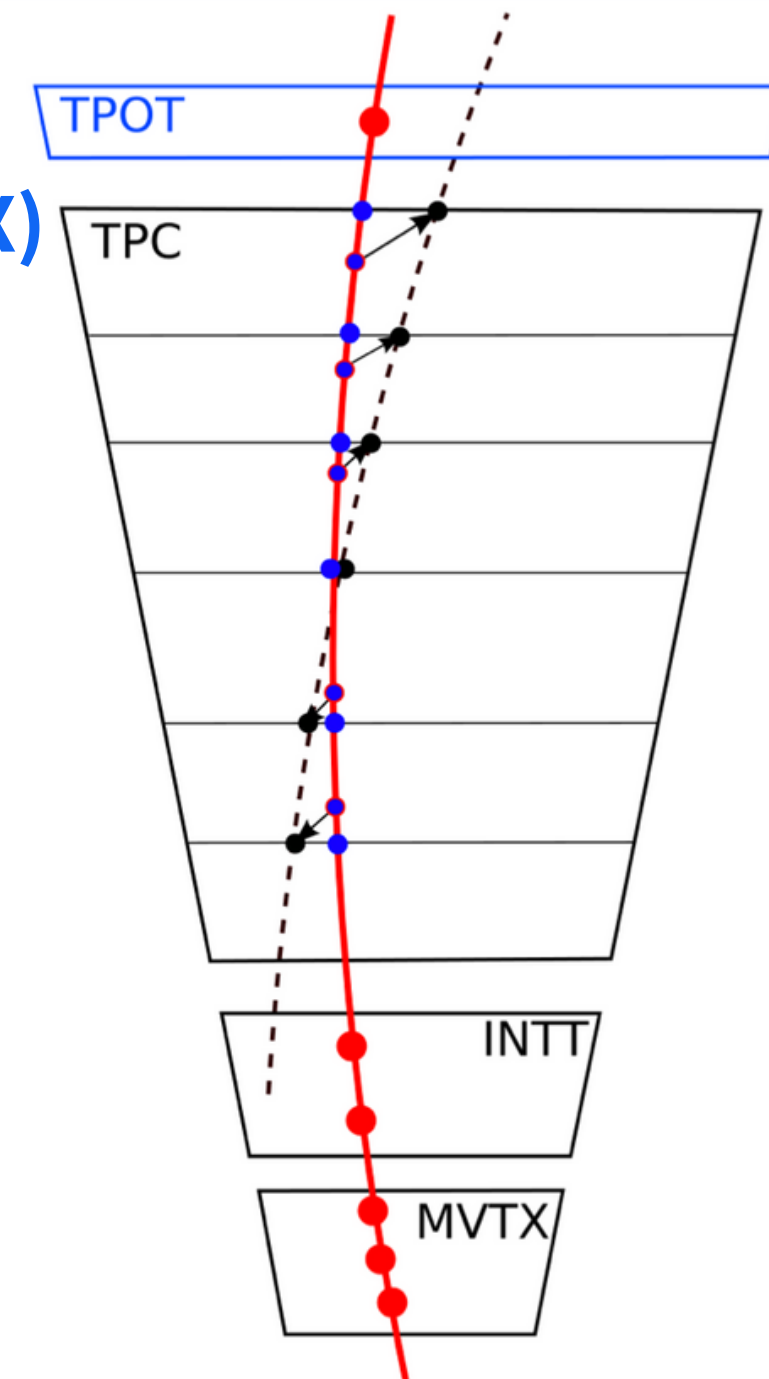
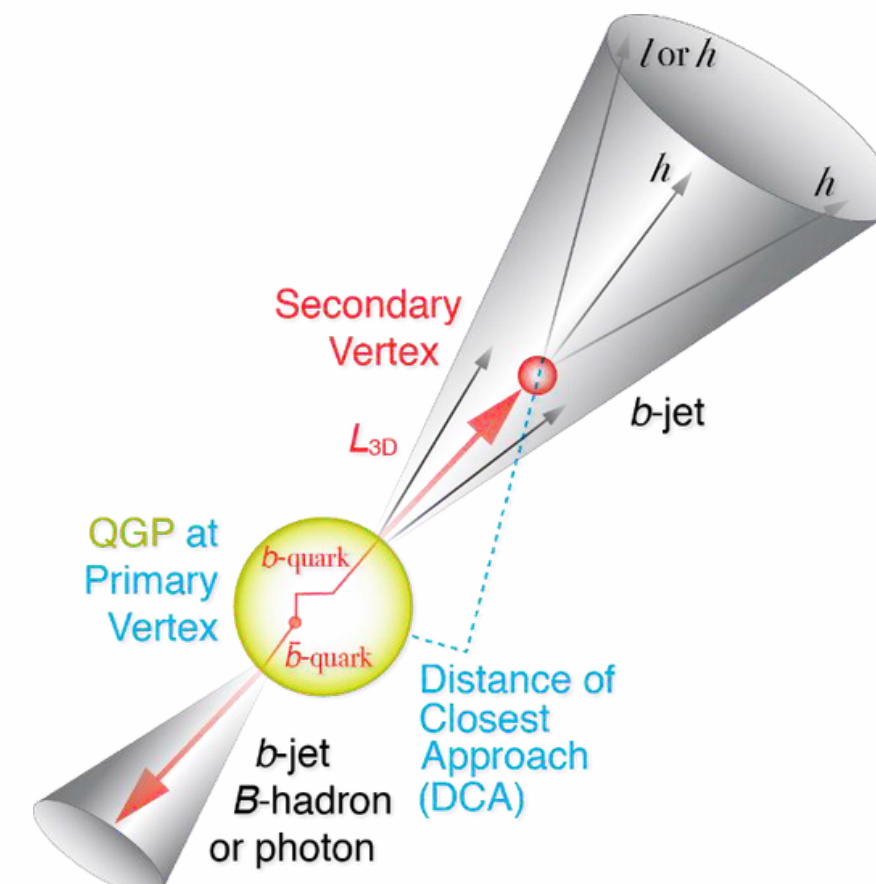




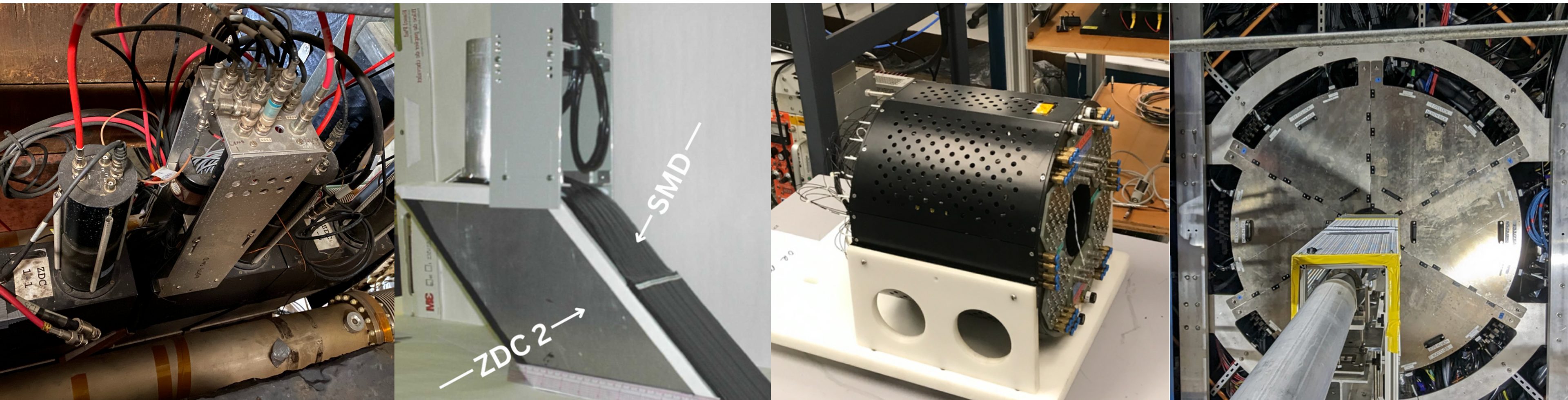
**Projected statistical uncertainties
of v_2 measurement of *b*-jets**

b-jet v_2

- **First *b*-jet tagging at RHIC**
- **Enabled by vertex tracker (MVTX)**
- **Probe path-length differential energy loss of the *b*-quark**



- sPHENIX has made great progress towards commissioning its detectors
- Active analysis of 2023 commissioning data for the measurement of “standard candles” ongoing
- We look forward to the upcoming p+p running in a few months!



Thank you!