sPHENIX Outer Hadronic Calorimeter Assembly, Testing, & Calibration

Daniel Richford for the sPHENIX Collaboration

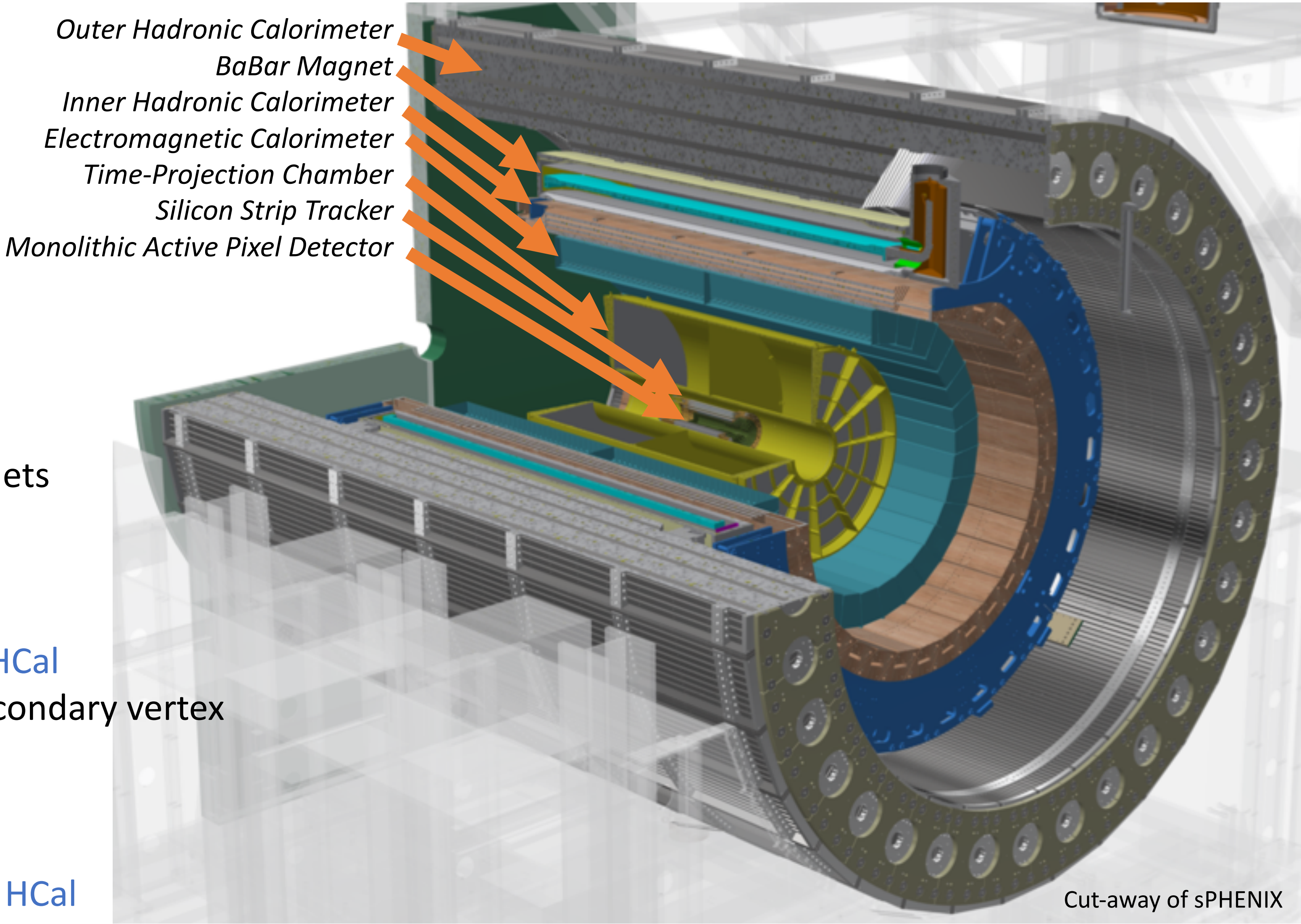
APS April Meeting 2021: Session T20

(Supported by DOE Award DE-SC0007017)

Detector Overview

Large Acceptance & High Rate
- $-1.1 < \eta < 1.1$
  - Covers the away-side jet & hadronic showers
- $0 \leq \phi < 2\pi$
- ~ 15 kHz with high livetime

Physics
- Υ-Family Quarkonia
  - high statistics
  - mass resolution
- Jets, Dijets, γ-Jet Correlations, Heavy-Flavor Jets
  - 20–70 GeV
  - all centralities
  - large acceptance
  - unbiased jet measurements — EMCal+HCal
  - precision measurement of displaced secondary vertex
  - electron-ID
  - direct-photons
- Fragmentation Functions
  - unbiased jet measurements — EMCal + HCal

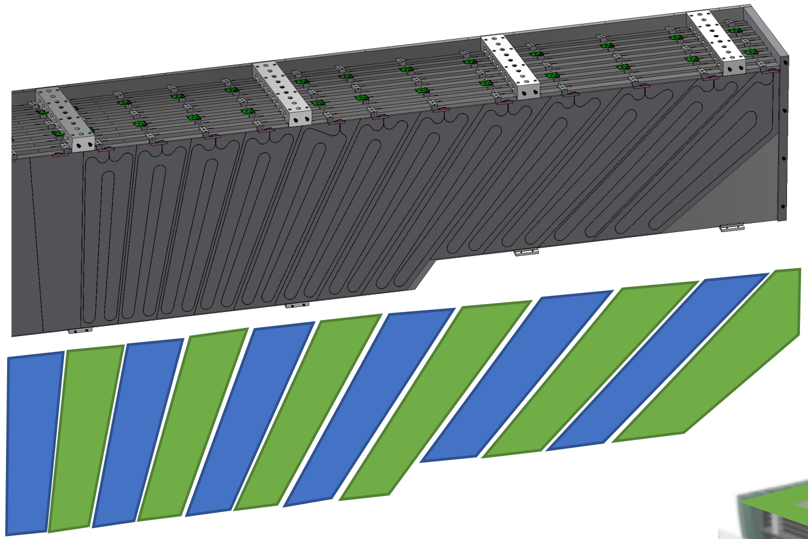


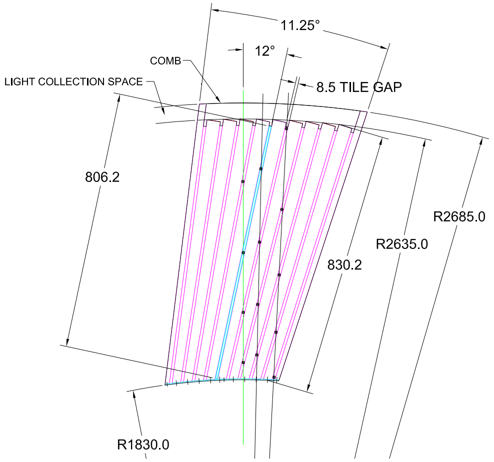
Cut-away of sPHENIX

Outer Hadronic Calorimeter

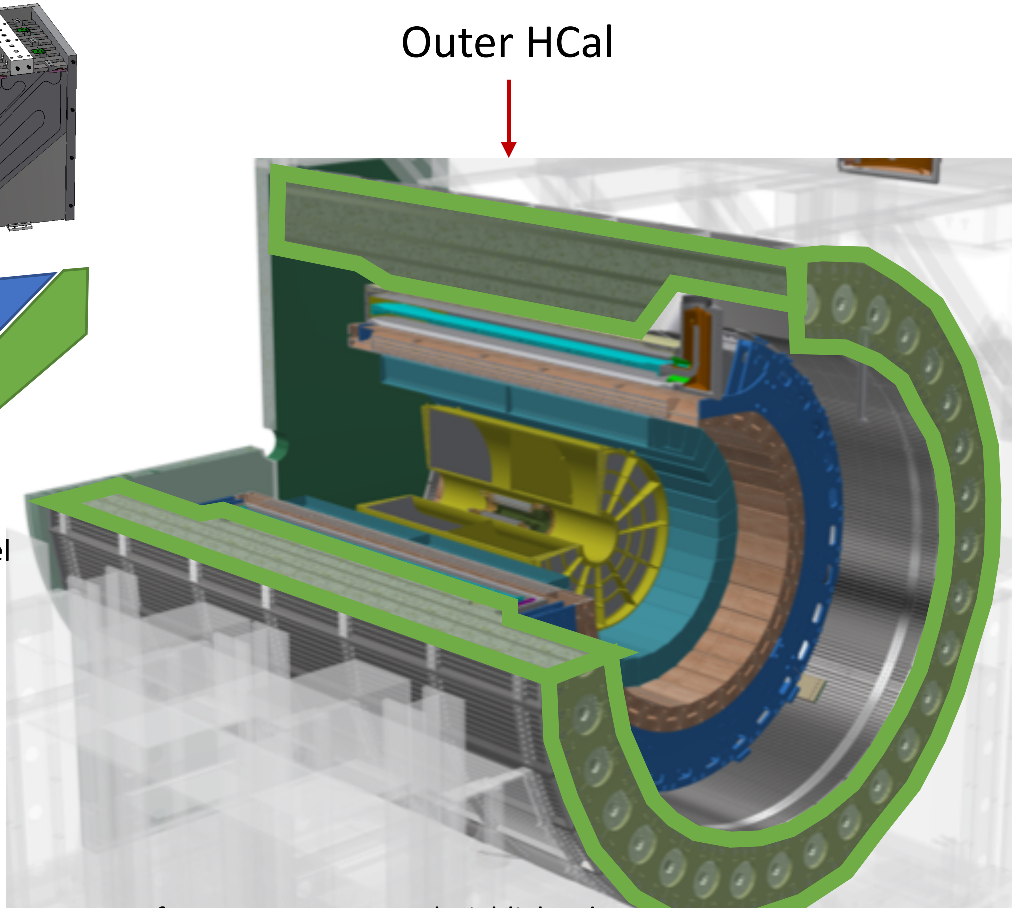
A first for RHIC!

- Acceptance
  - $-1.1 < \eta < 1.1$
  - $0 \le \phi < 2\pi$
- Use
  - Unbiased jet measurements
- Details
  - Cylinder around BaBar magnet
  - 32 azimuthal sector modules
    - low-carbon steel
    - 6.32m × 0.88m × 0.53m
    - ≈12t heavy
- Sampling detector
  - 7,680 scintillating tiles
  - Doped polystyrene
  - Tapered, tilted steel plates
- Arrangement of each sector
  - 5 tiles per cell, 24 cells in η by 2 cells in ϕ
  - Segmentation: $\Delta\eta/\eta_{total} \sim 0.1$, $\Delta\phi/2\pi = 0.1$


Scintillating tiles tilted in η from center of barrel



Scintillating tiles tilted in ϕ from radius



Cut-away of sPHENIX: Outer HCal Highlighted

Factory @ BNL AGS Fixed-Target Experimental Hall

Tool, Tile, Cable, Hardware Tent

10 Assembly Tables

Testing Electronics

Completed-Sector Storage

Assembly (1)

Person-Power & Time

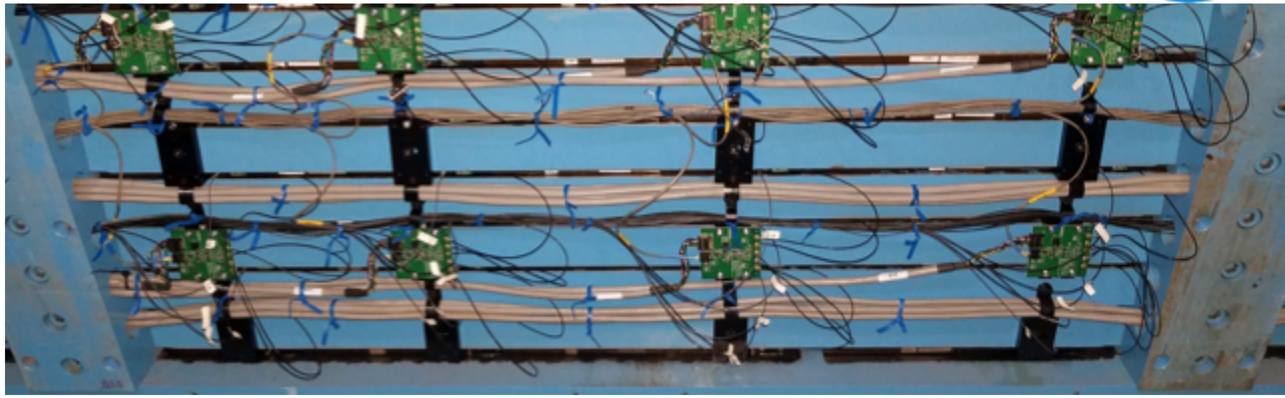
- ~ 42 people over ~ 1.5 years to develop assembly procedures, assemble the modules, and test
- Extreme heat in summer & cold in winter
- Pause for Covid
- Bulk of work done in last 6 months amid pandemic-safety restrictions

Assembly Process

- Tiles matched by similar response to cosmic muons
- Record IDs in a database, affix SiPMs, and install
- Tile installed and fixed in place
- Cabling: coax cables, wires, delicate fiber-optic cables
- Electronics

Assembly (2)

▲ *Fiber-optic cable installation by Veronica Canoa Roman before electronics boxes are installed*



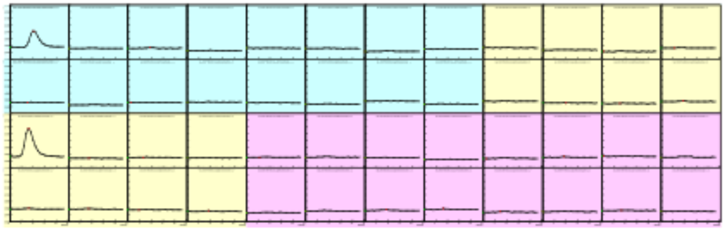
▲ *A portion of one sector with all its cables tied down*

▲ *Electronics; power, signal cables; LED drivers & fibers*

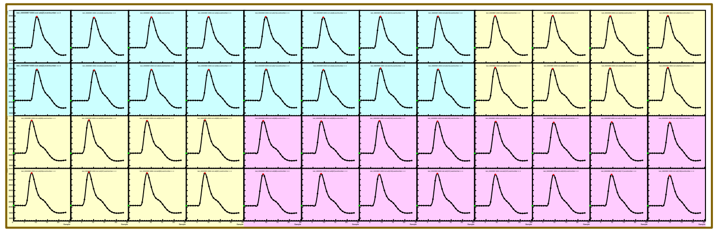
Sector Testing & Triggering

Tests

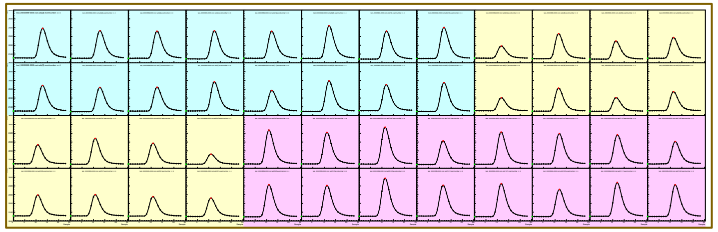
- Tower-ID Test: Check connections
- Test Pulse: Charge-injection to make sure that most of the electronics are working correctly
- LED Scan
  - tests the SiPMs and associated electronics
  - individual tiles’ response to fixed LED light
  - benchmark for changes
- Cosmics
  - Sector is divided into thirds
    1. Group’s sum is above a threshold; and
    2. At least two towers in group have their individual signal above another threshold
  - Each triggering event reads out the whole sector



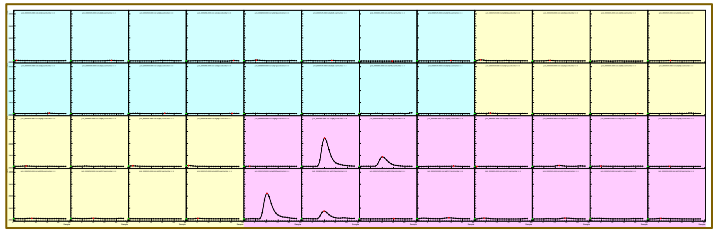
Tower ID test (sequence of single events)



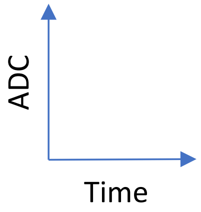
Test pulse (single event)



Tower-sum LED pulse (single event)



A single, triggered cosmics event



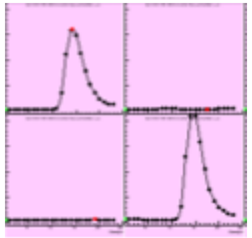
Calibration: Cuts, MIP Peak

Cuts for MIP Peak

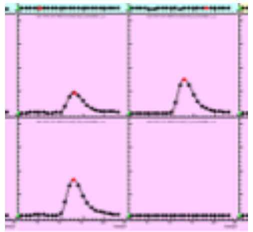
- Vertical towers hit[1], and
- No horizontally-neighboring towers hit[2]

Observations

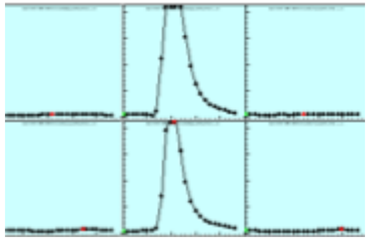
- Well-defined MIP peak after 10 min
- For statistics, we take 1 hour of calibration data



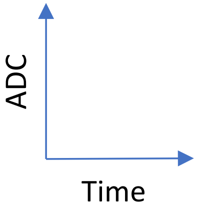
1. Vertical

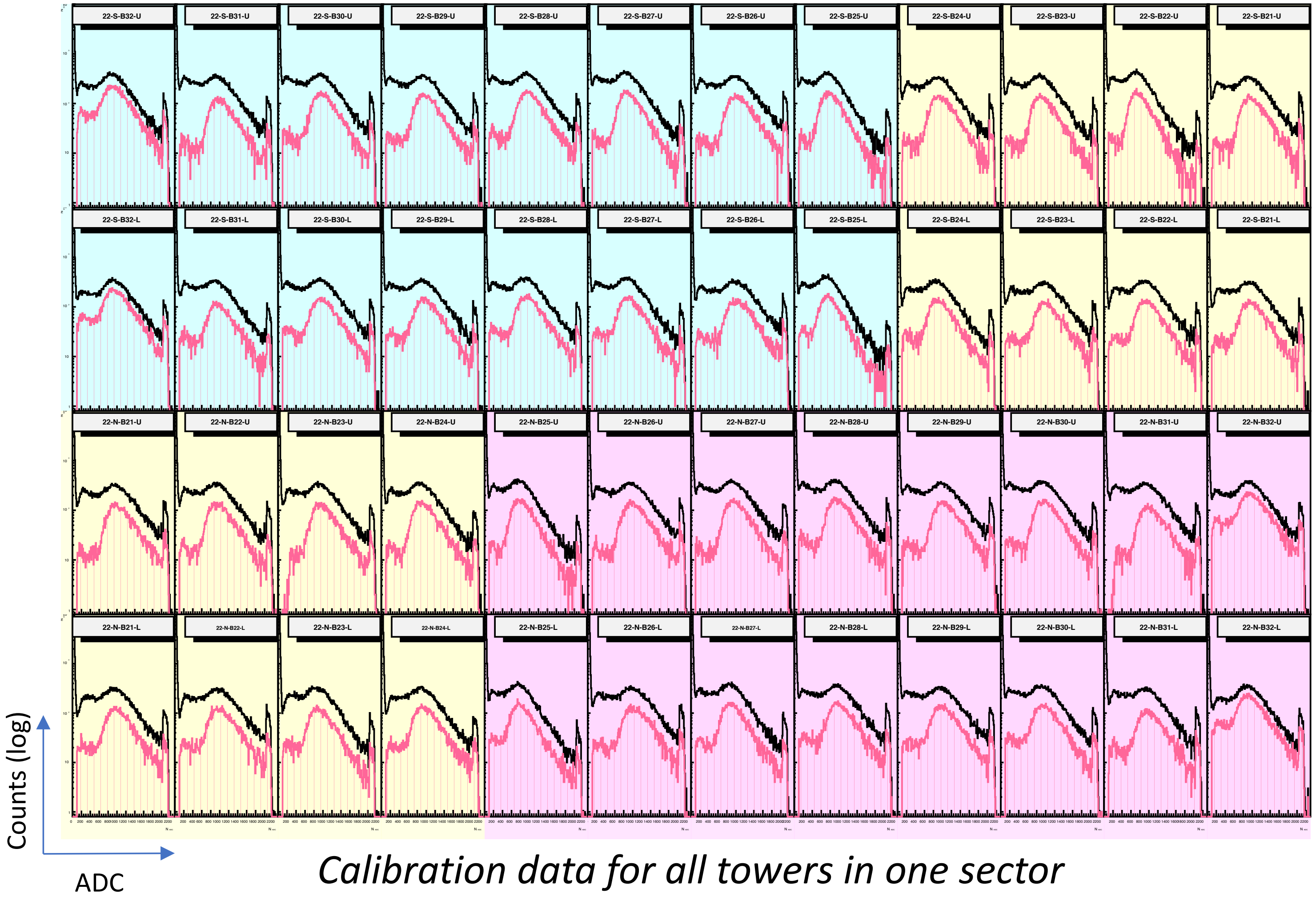


2. Neighbors



Accepted Event





*Calibration data for all towers in one sector over the course of 1 hour (**black** = no offline cuts; **red** = with offline cuts)*

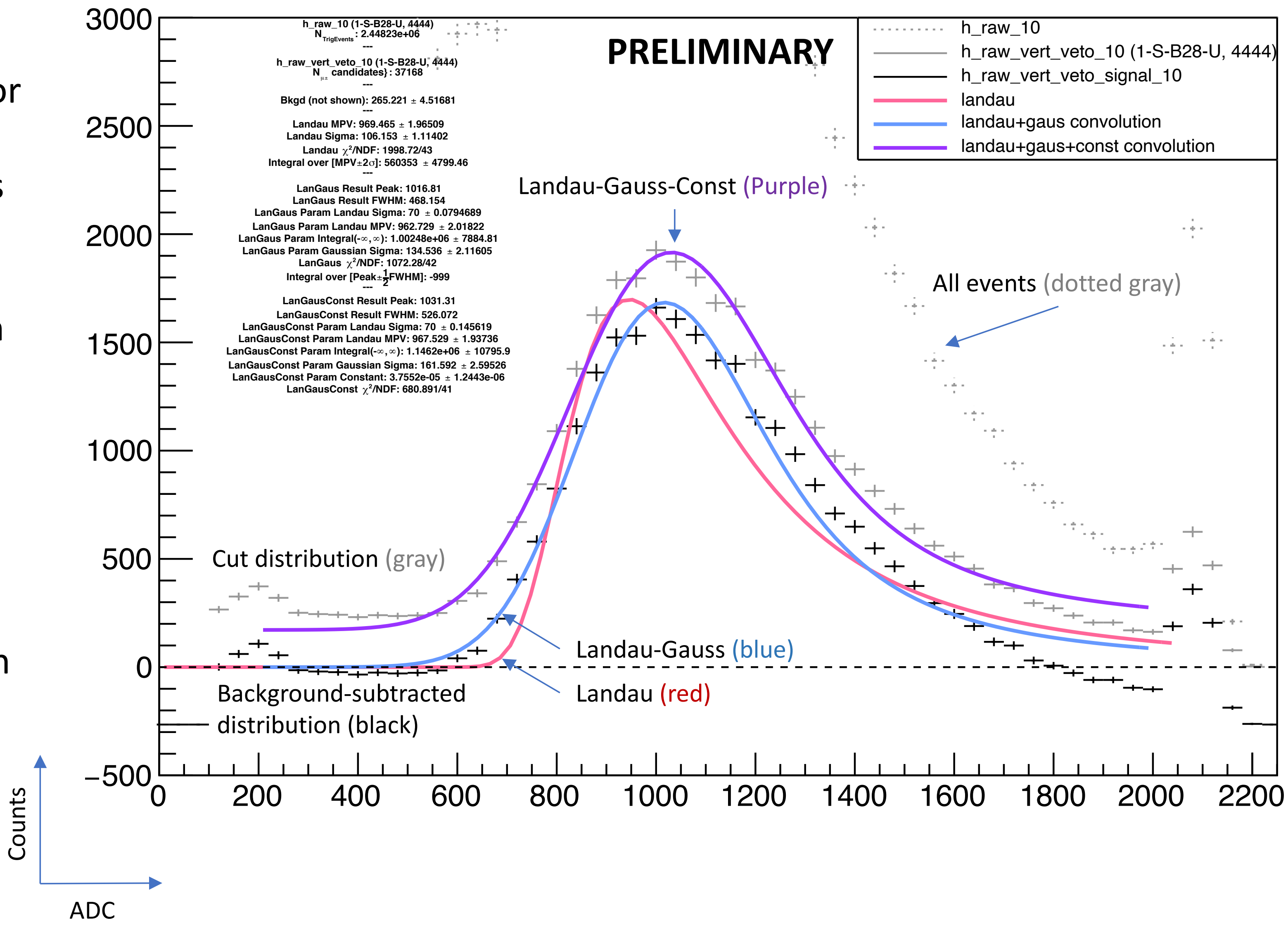
Fitting Cosmic Muon Events

Goals
- Stable peaks for all towers in each sector in their assembly orientation
- Translate those peaks into MIP energies for calibration

Process
- Bootstrap a fit of the whole distribution using preliminary or partial fits

Parameters to use as results
- Peak (mean MIP energy)
- FWHM
- Integral under FWHM

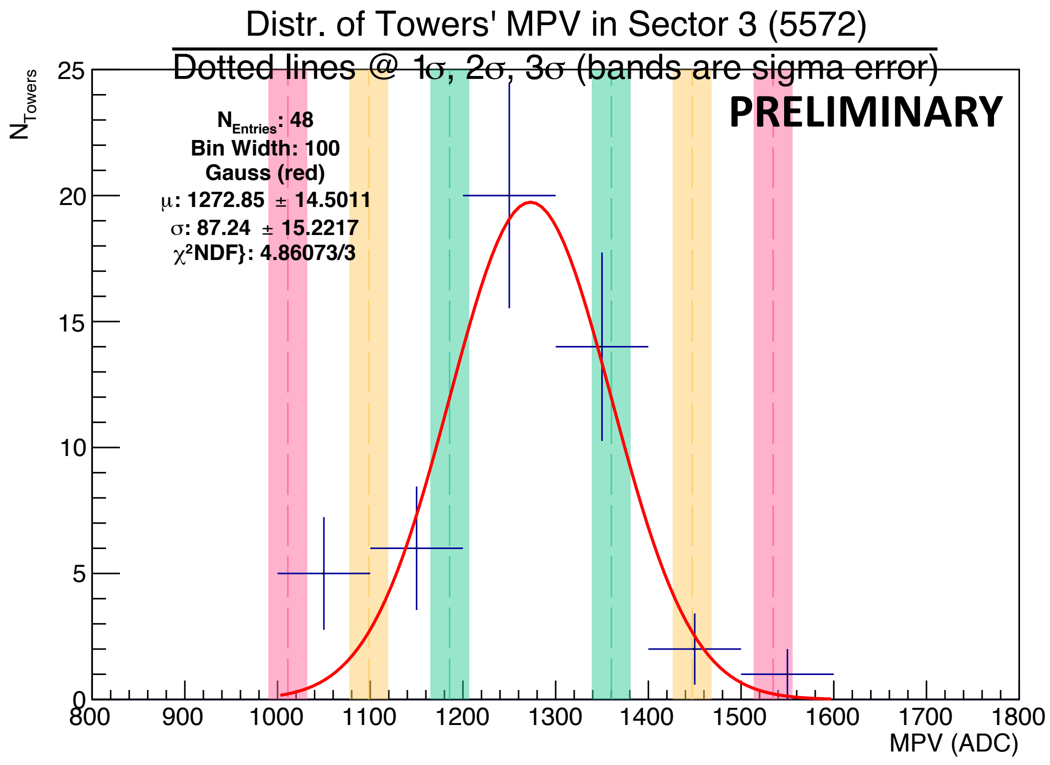
Results
- Landau+Gaussian+Constant convolution fits every tower in every sector
- Peak is consistent between different data-taking periods

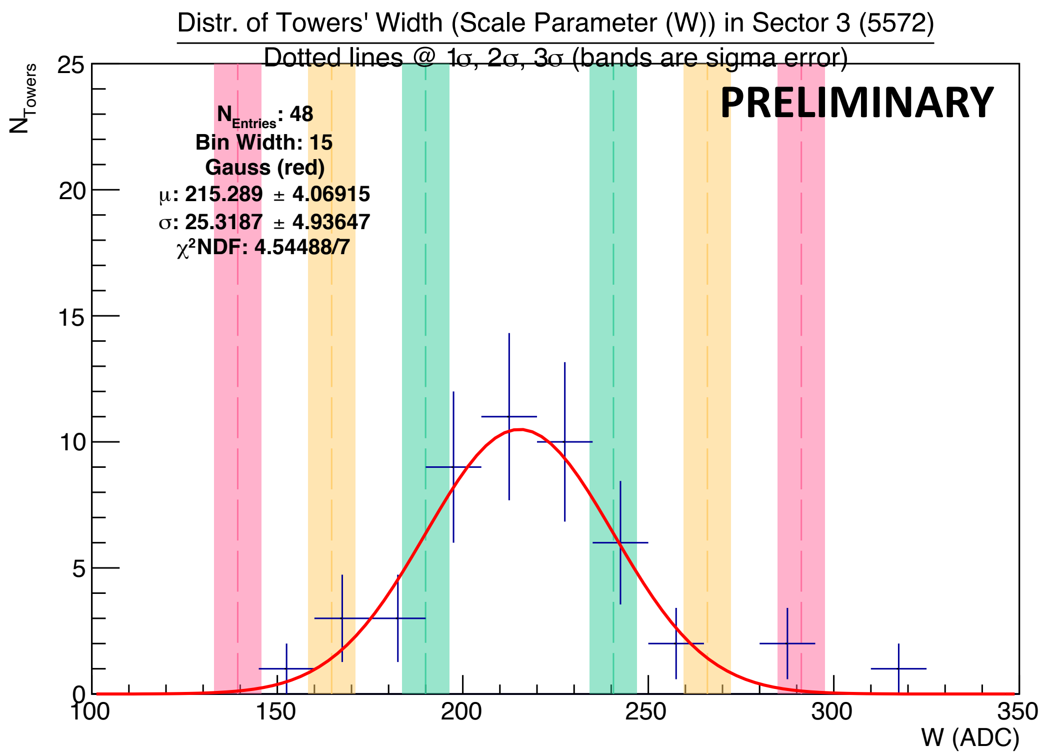


Cosmics Muon Results So Far (1)

Distribution of Cosmics Fitting results

- Different tower's peaks and widths roughly Gaussian
- Some outliers (beyond ±3σ or noticeably away from curve)
  - all outliers come from failed or inadequate fits
  - part of the width may come from issues with the fit
- All sectors exhibit similar distributions



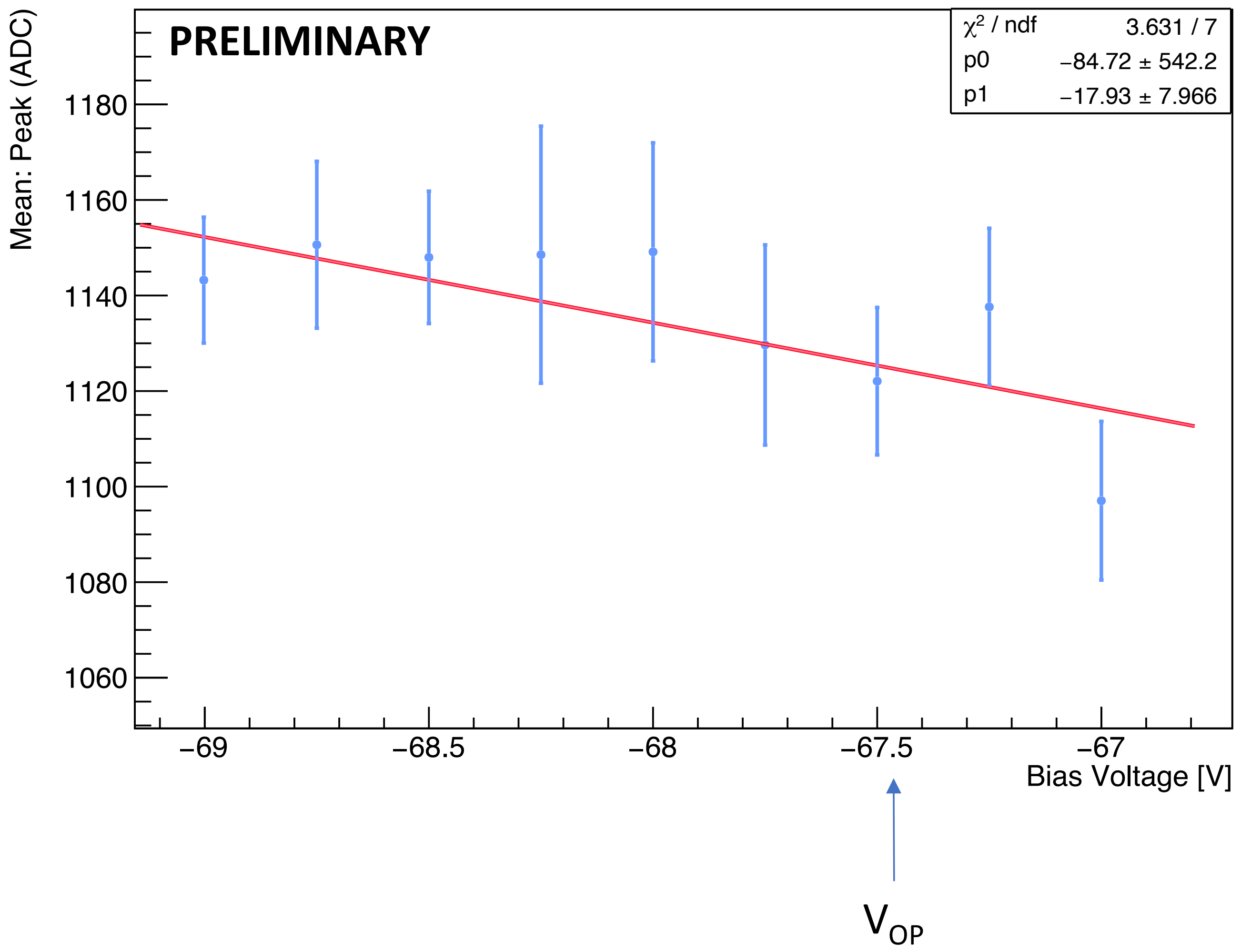


Cosmics Muon Results So Far (2)

Testing Bias-Voltage Dependence of MIP Peak

- The electronics support tuning the bias voltage supplied to each tower
- Distribution of means (as on slide 10) for all towers
- Varying bias voltage
  - V_{OP} = – 67.48 V
- Greater absolute-value bias voltage → higher ADC peak
  - ≈ 18 ± 8 ADC integers/volt
  - Wrinkle
    - testing using PHENIX 10-bit ADCs
    - sPHENIX will use 14-bit ADCs
  - Less-sensitive at greater abs-val bias
    - inadequate fitting as the peak spreads out beyond the range of the ADC

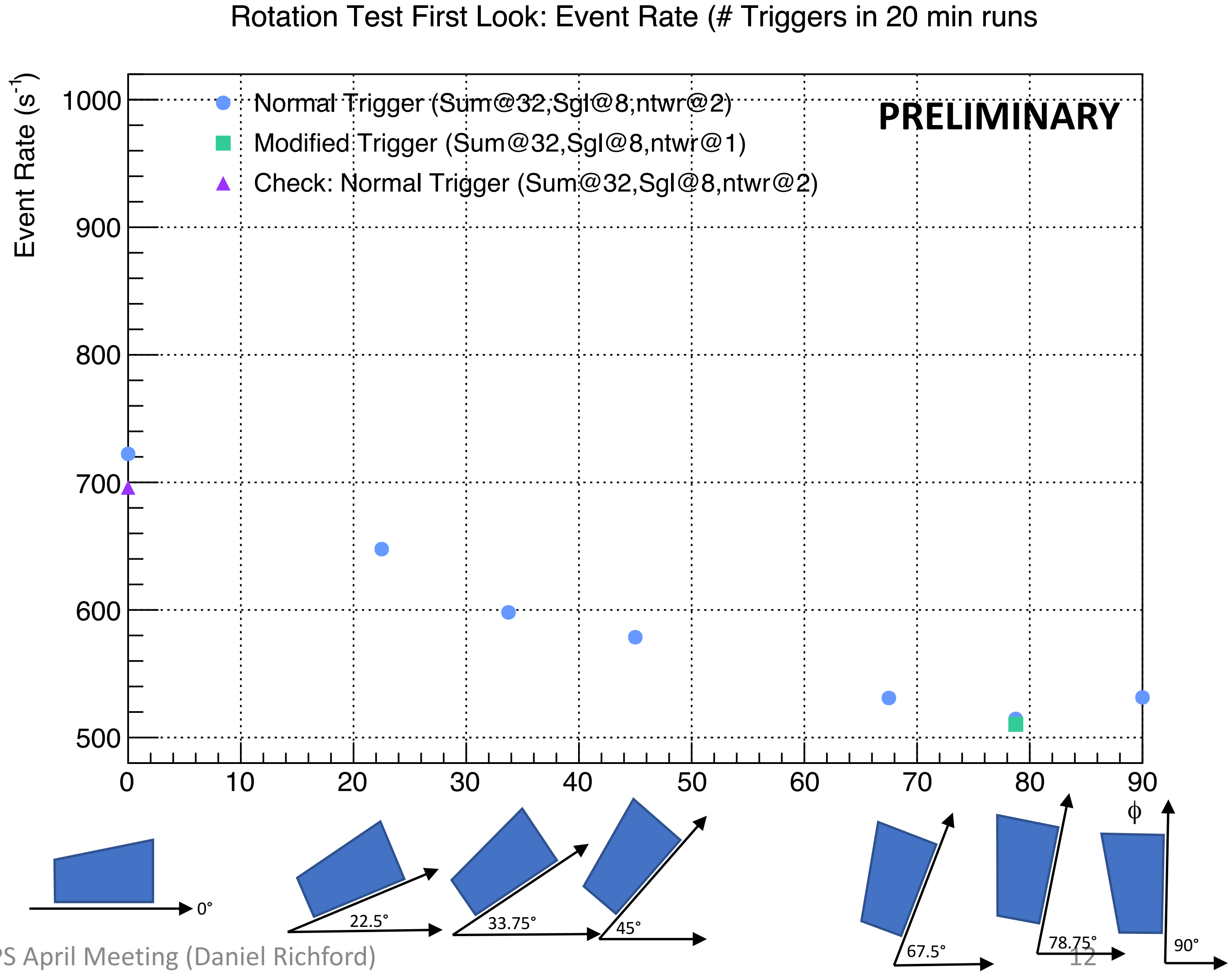
mean: Peak vs Bias Voltage (unnormalized)



Cosmics Muon Results So Far (3)

Self-Trigger & Cuts in Different Azimuthal Orientations

- Motivation
  - Validate GEANT simulation for calibration
  - First look at cosmics data for other orientations
- Trigger used for testing is not so sensitive to rotation
  - 700 trigger-events per second @ 0°
  - 500 trigger-events per second @ 90°



Outlook

- Translate our ADC measurements to muon energy
  - On-going effort
    - Refining fitting & cuts
    - Simulation
- Calibration in installation orientations
  - On-going effort
    - Accounting for cross-sectional area
    - Accounting for angular-distribution of muons
- Burn-in sectors before installation
  - Currently in progress
- Installation
  - Starting in June, 2021
- Inner HCal assembly begins

See Backup Slide 1 for the people & institutions contributing to assembly & testing

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BACKUP SLIDES

sPHENIX Outer Hadronic Calorimeter Assembly, Testing, and Calibration

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Back-Up Slide 1: People*

- Baruch/CUNY: Stefan Bathe, Eric Kolbusz, Zhiyan Wang (& DR)
- BNL: Aaron Allen, Carter Biggs, Steve Boose, Al Borrelli, John Haggerty, Edward Kistenev, Eric Mannel, Damon Miraglia, Sal Polizzo, Chris Pontieri, Rich Ruggiero, Frank Toldo … with help from the Collider-Accelerator Dept. and NSLS-II
- Colorado: Sruthy Das, Berenice Garcia, Daniel Lis, Jeffrey Ouellette
- GSU: Megan Connors
- ISU: Veronica Canoa, Ian Delk, T. Kroells, Milap Patel, E. Pottebaum, Ejiro Umaka, E. Walker
- Lehigh: Mingchian Chen, Anders Knospe, Tom Limoges, Rosi Reed
- Ohio: Justin Frantz, Ryan Frontz, Abi Pun, Michael Riehl
- Rutgers: Thomas Gosart, Tanmay Pani, Diptanil (Neil) Roy
- Wayne State: Grant McNamara, Veronica Verkest

*(Apologies to those I forgot to mention!)

Back-Up Slide 2: Abstract

The sPHENIX Detector is a new experiment at RHIC at BNL, designed to measure jets and upsilons in heavy-ion collisions, with an expected start of February 2023.

The sPHENIX hadronic calorimeters are used for the measurement of jets and comprise two steel/scintillator sampling detectors inside and outside of sPHENIX's cylindrical magnet. Overall, the outer calorimeter—to be finished in spring, 2021—has acceptance of $-1.1 \leq \eta \leq 1.1$ *and* $0 \leq \varphi < 2\pi$, *and a depth of 3.8 nuclear-interaction lengths. The 32 sectors comprising the outer calorimeter are built in a factory setting, with multiple sectors simultaneously being assembled (populated with scintillator and electronics), tested (using fixed LEDs to record scintillator response), and calibrated. Each sector is calibrated with cosmic muons.*

This talk discusses the design, assembly, and testing of the outer hadronic calorimeter. Status of testing and calibration using cosmic rays are shown.

(Supported by DOE Award DE-SC0007017)

Back-Up Slide 3: Summary

Daniel Richford
for the sPHENIX Collaboration
(CUNY Grad Center/Baruch)

Summary

- Physics Directly involving HCal
  - Jets, Dijets, photon-Jet correlations, HF-Jets
  - Fragmentation functions
- Design
  - Sampling calorimeter
  - Full azimuthal coverage x 2.2 units of pseudorapidity
- Assembly
  - Muon-response matched scintillator tiles
  - Dynamic electronics
- Testing & Calibration
  - Single-event and multiple-event diagnostics
  - Self-energy trigger
  - Offline cuts to constrain muon solid angle
  - Well-defined MIP peaks
  - Stable fitting for calibration