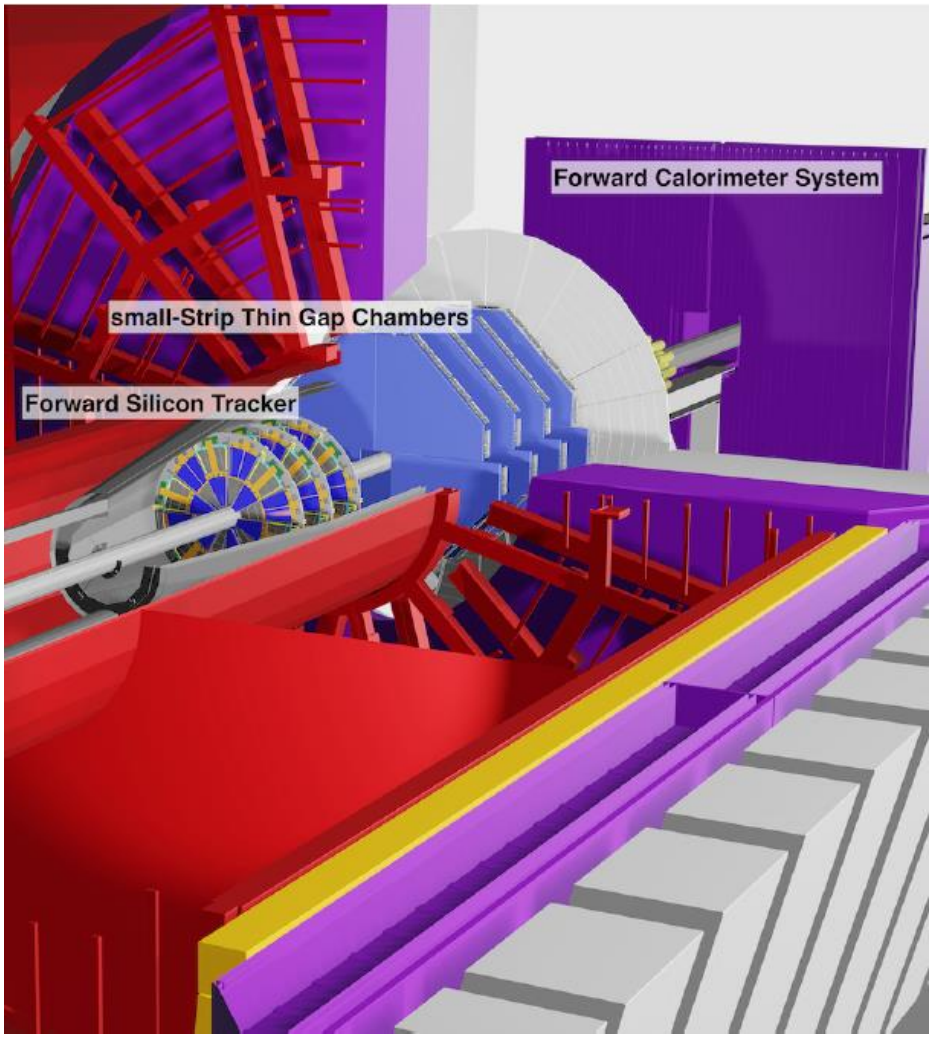
STAR Forward Silicon Tracker: Characterizing Prototype Module Performance with Cosmic Rays and Simulation Studies

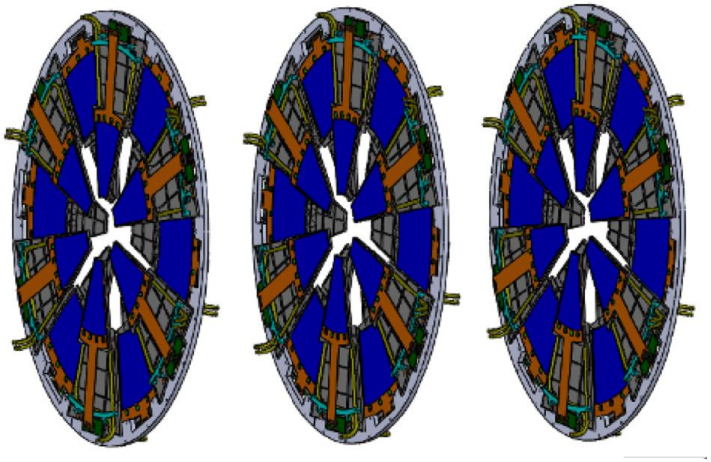
Gavin Wilks for the STAR Collaboration

University of Illinois at Chicago

Forward Silicon Tracker



- Part of forward upgrade, in addition to Forward Calorimeter System.
- Reuses existing infrastructure.
- Refer to Xu Sun's talk for more information regarding upgrade status and integration into STAR.

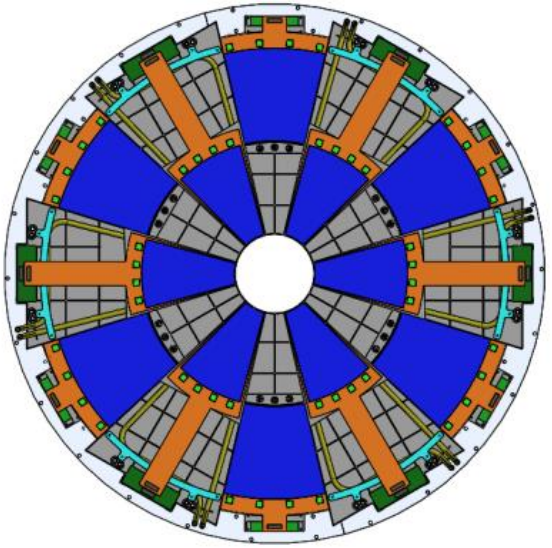


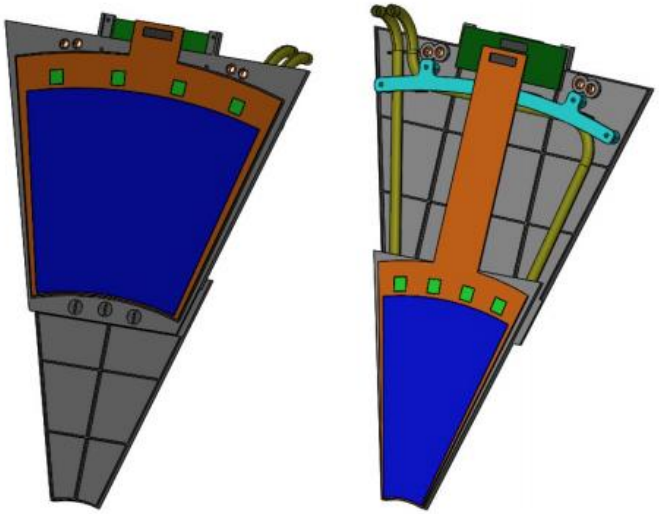
Forward Silicon Tracker

- Based on silicon strip sensor technology

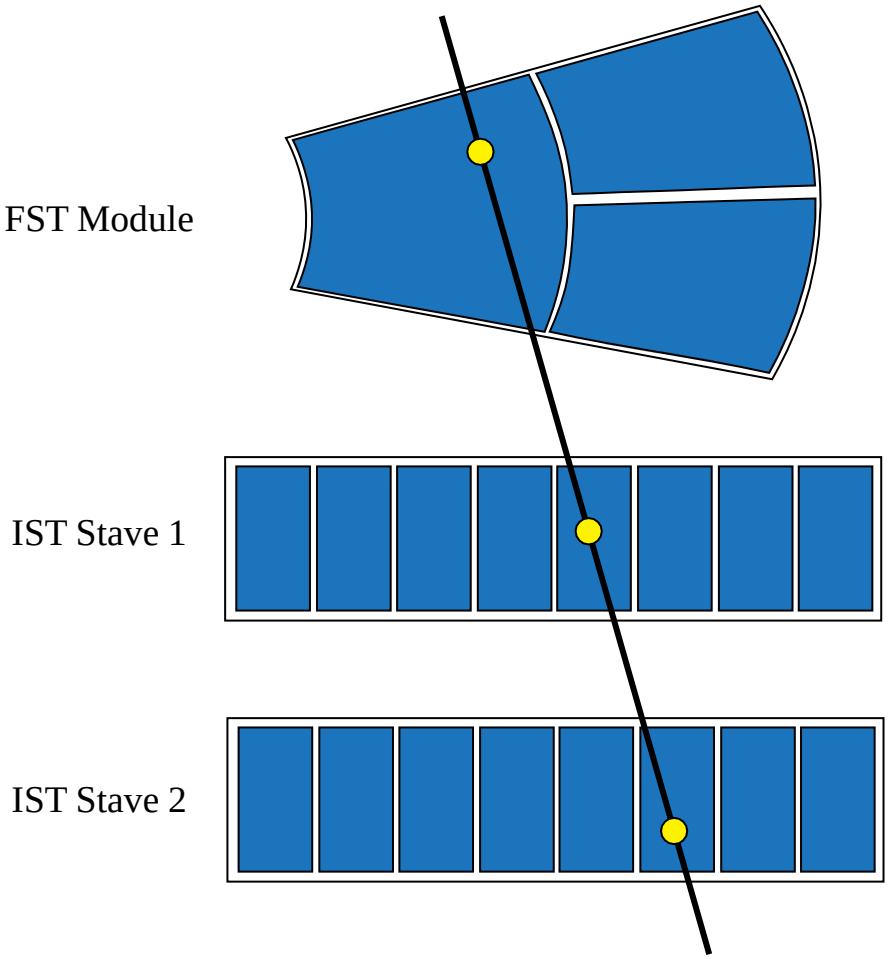
- Component of STAR forward upgrade
  - p_T measurement for charged particles
  - Full azimuthal coverage in rapidity range $2.5 < \eta < 4.0$

- Structure
  - Coarse radial (r) segmentation
    - 4 radial strips per sensor (Rstrips)
  - Fine azimuthal (φ) segmentation
    - 128 azimuthal strips on inner Si sensor
    - 64 azimuthal strips on 2 outer Si sensors
  - Three layers of FST disks
    - 12 modules in each disk (36 total)





FST Cosmic Ray Test Stand



- Consists of 2 Inner Silicon Tracker (IST) staves aligned with FST module

- Tracking Method
  - Find all simple clusters in IST staves 1 & 2
  - Project track to FST module (x_{proj},y_{proj})
  - Find clusters on FST using scan and simple algorithms (x,y)
  - Difference in projected and measured position on FST provides estimate of resolution ($x-x_{proj}$,$y-y_{proj}$)

Clustering Methods

Simple Clustering

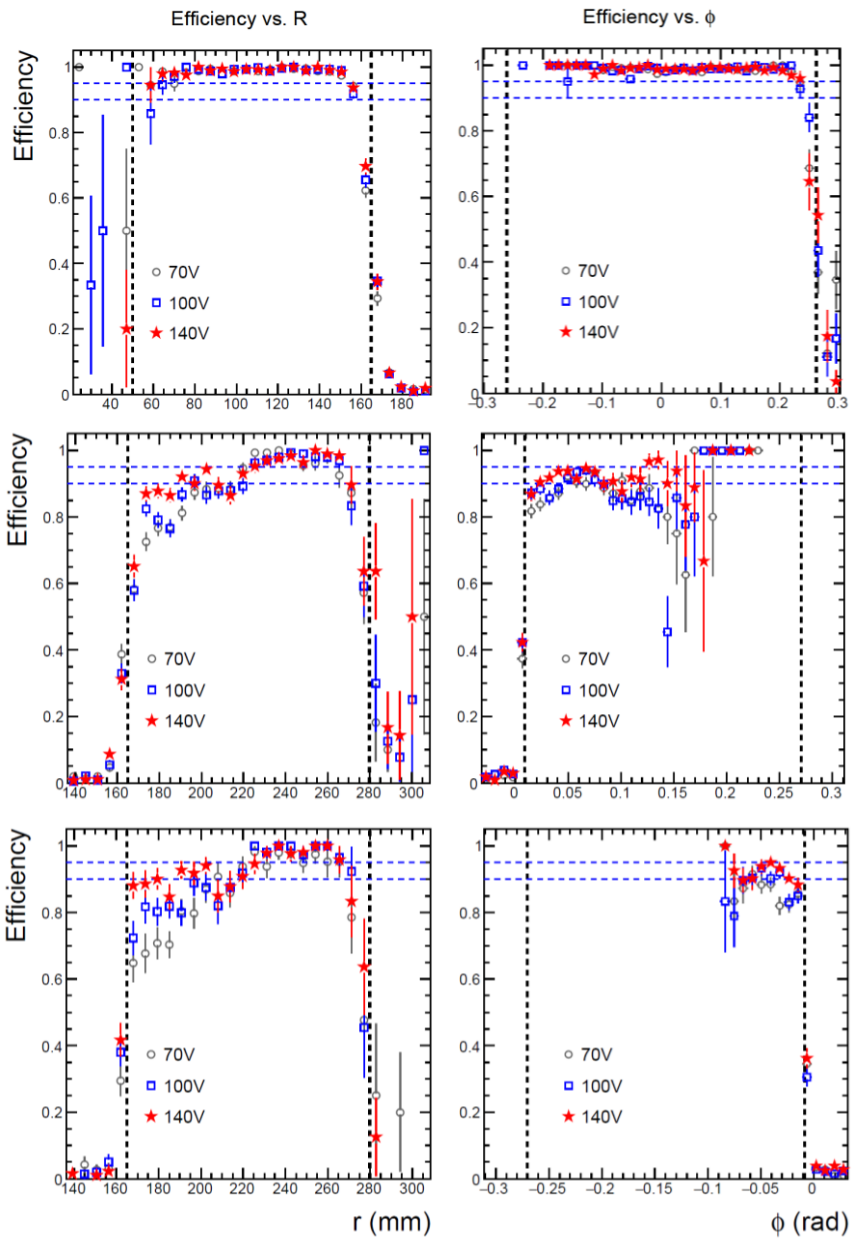
1. Find all hits (ADC>4*noise in 2 time bins) on FST.
2. Group neighboring hits into clusters.
3. Cluster position is given by the ADC-weighted center of the hits.

Scan Clustering – Radius

1. Find all seed hits (ADC>4*noise in 2 time bins) and recover hits with ADC>2.5*noise in 2 time bins or ADC>3.5*noise in 1 time bin in the same event window.
2. Group all the hits in the same and neighboring phi-segmentations to a seed hit into clusters.
3. Cluster's radial position is determined by the largest radius and phi position by the ADC-weighted center of the hits.

FST Detection Efficiency

- Definition:
  - Projected position is within FST acceptance.
  - Measured cluster is within FST acceptance.
- Inner sensor ≥ 95% for most of r and φ range at each voltage.
- Outer sensors:
  - Greater detection at higher voltages for lower projected r.
  - Similar detection at each voltage for greater projected r.
  - Higher voltage provides greater detection in φ.

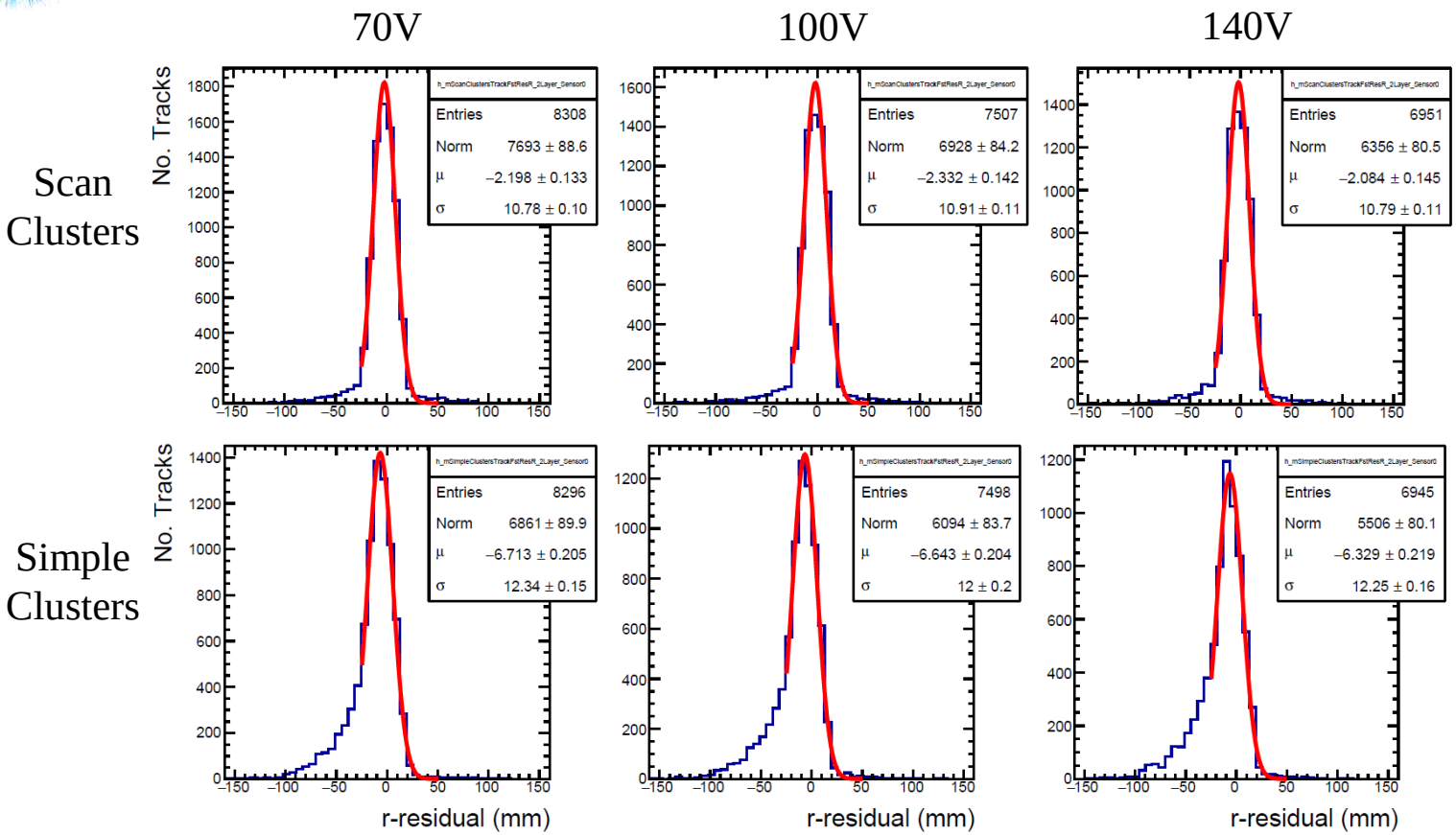


Inner Sensor

Outer Sensor 1

Outer Sensor 2

FST Spatial Resolution (Radial)

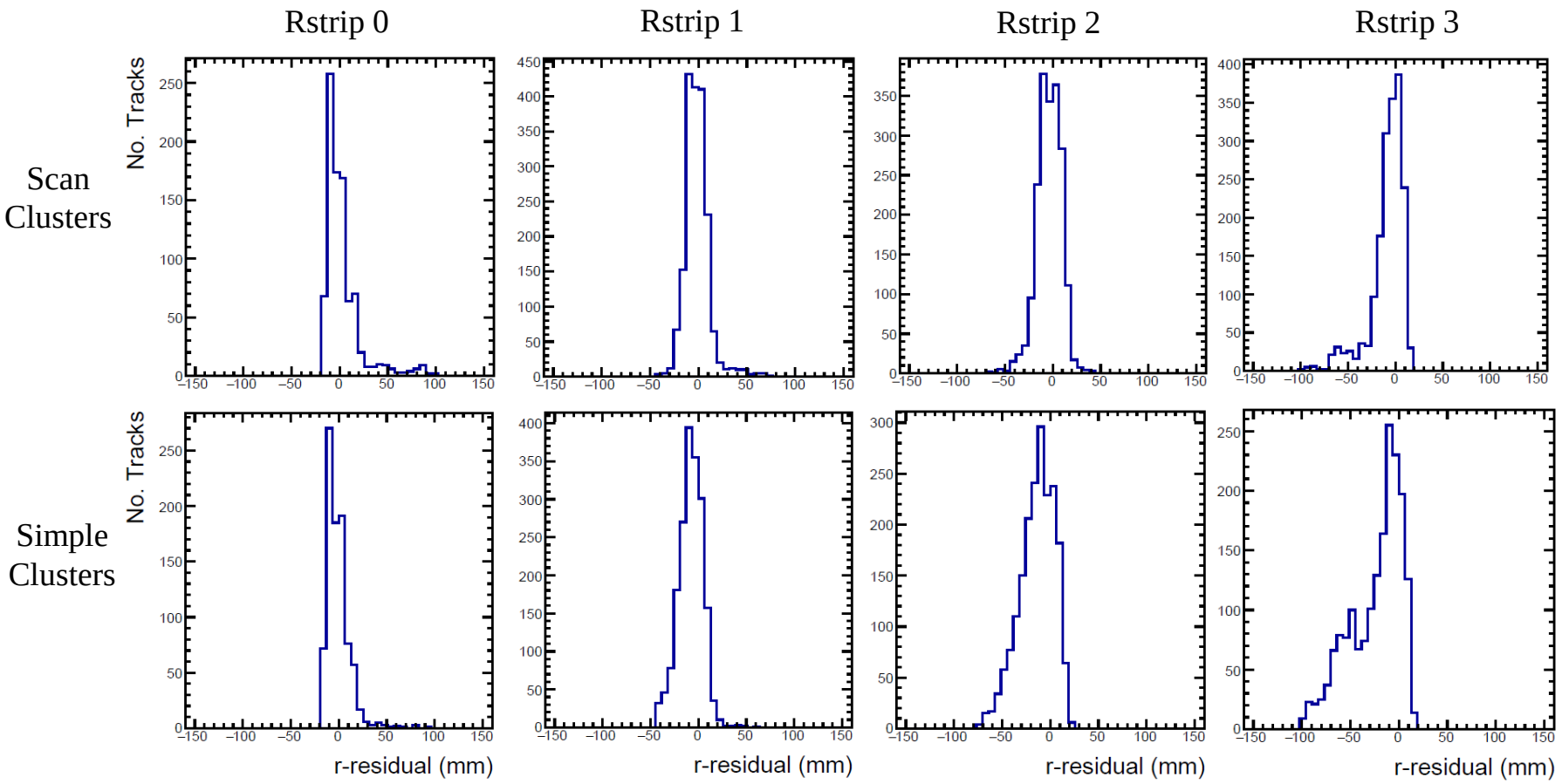


Resolution Summary

	70V (mm)	100V (mm)	140V (mm)
Scan	10.78 ± 0.10	10.91 ± 0.11	10.79 ± 0.11
Simple	12.34 ± 0.15	12.00 ± 0.20	12.25 ± 0.16

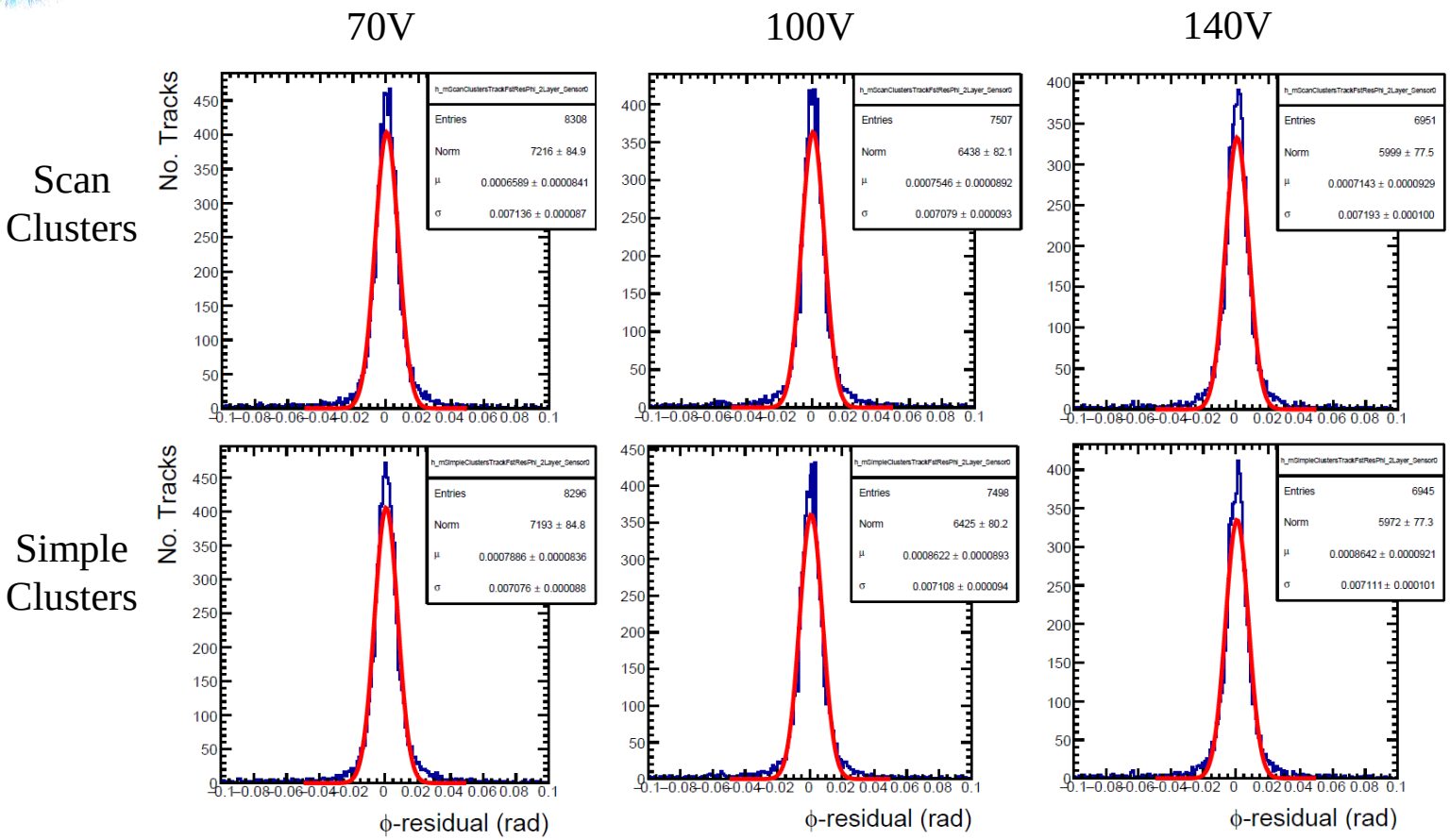
- Scan clustering reduces negative tail in residual distribution.
  - Provides greater resolution for radial position.
- Variation due to voltage is consistent within statistical uncertainties.

FST Spatial Resolution (Radial)



- Cross talk in Rstrips leading to detection on other Rstrips.
  - More prominent for outer Rstrips.
- Scan clustering reduces negative tail in residual distribution
  - Cross talk signal reduced for outer Rstrips.

FST Spatial Resolution (Azimuthal)



Resolution Summary

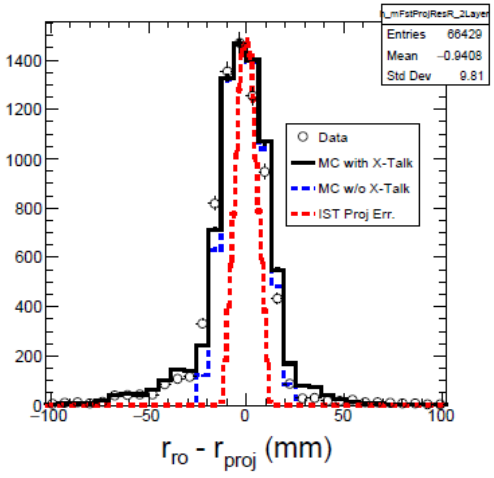
	70V (rad)	100V (rad)	140V (rad)
Scan	7.136E-3 ± 0.087E-3	7.079E-3 ± 0.093E-3	7.193E-3 ± 0.100E-3
Simple	7.076E-3 ± 0.088E-3	7.108E-3 ± 0.094E-3	7.111E-3 ± 0.101E-3

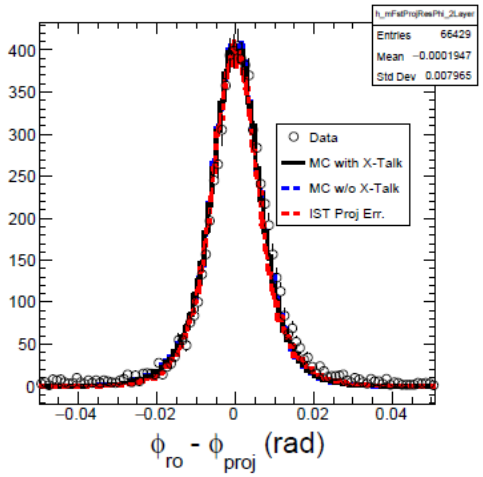
- Variations due to voltage and clustering algorithm are consistent within statistical uncertainties.

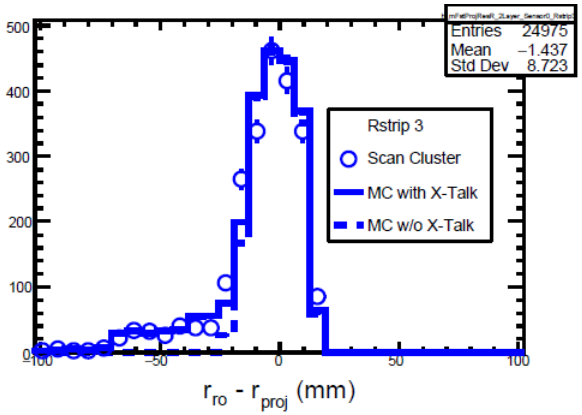
Toy MC Simulation

Procedure

1. Generate random angle for incident cosmic ray.
2. Create track through 2 IST and FST Module.
3. Use readout pixel position on IST staves and project track (projected FST position).
4. Use projected Rstrip to determine if readout position (original track) is shifted to another Rstrip using measured cross talk rates.
5. Drop FST hit based on projected Rstrip efficiency.







- Qualitatively reproduces residual and efficiency distributions from Test Stand.
  - Cross talk, detection efficiency and IST projection error.

Summary and Outlook

- Operating at 140V provides greater detection efficiency than 100V or 70V for lower radial position on outer sensors.
  - Slightly greater detection efficiency over φ.
- Spatial Resolution
  - Scan clustering provides greater radial resolution over simple clustering.
  - Voltage shows non-monotonic behavior.
  - Cross talk present between Rstrips.
- Toy MC qualitatively reproduces residual distributions for position.
  - Accounts for cross talk, detection efficiency and IST projection error.
- Apply cross talk and detection efficiency to STAR simulation.
  - Effect on momentum resolution.

Backup