State of the Tracker MC

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CM 42 RAL
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Outline

- Purpose

  Using the Geant4 physics simulation and various statistical models, simulate the entire process of tracker data taking from particle interaction with a scintillating fiber to output signal in the MLCR.
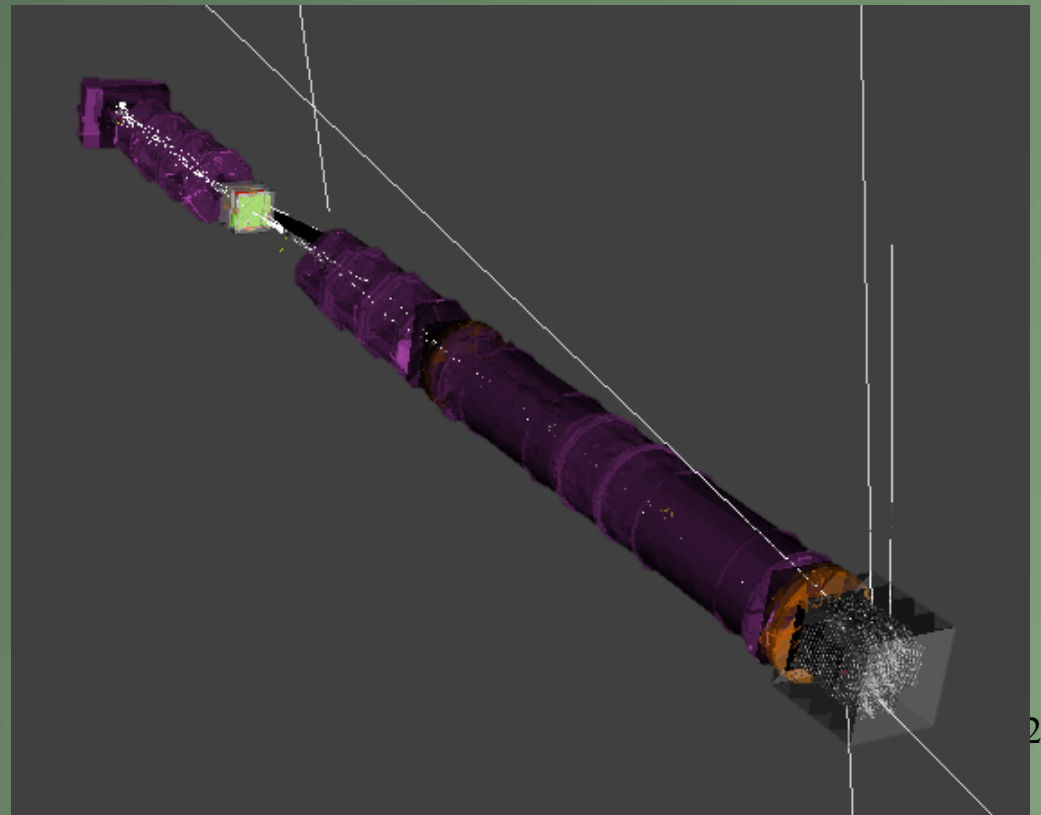
- Geometry

- Creating Hit/Digit

- Additional Noise

- Unresolved Issues

- Final Comments

Geometry

- Need for accurate environment
  - Within the scope of the purpose
    - Inside trackers
  - Exceeds the scope
    - Within the solenoid bore
   - Between the trackers

Geometry: Inside Trackers

- Fiber placement
  - Individual fibers are placed within a region defined by the plane's active region
    - Views U&V – 32.0cm diameter of 37.8cm
    - View X – 31.7cm diameter
    - No overhang outside this area
  - Fibers are placed in correct doublet layer geometry
   - Unlikely to change over time
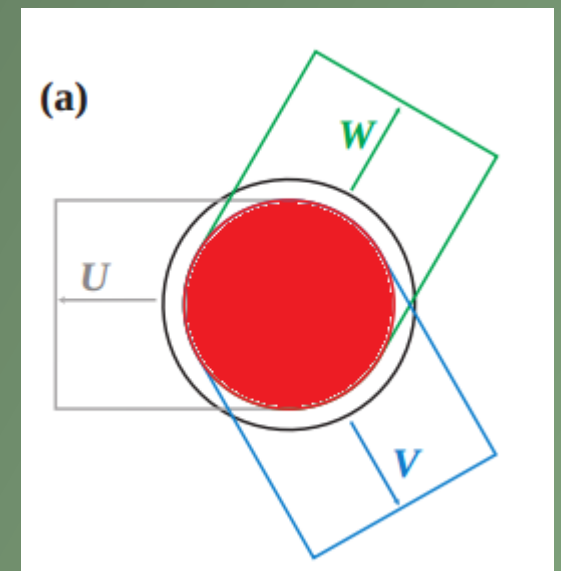
Geometry: Inside Trackers

- Station Placement
  - Figures come from CMM measurement carried out at Imperial College
    - Give station position relative to a z-axis that runs from the center of Station 1 to the center of Station 5.
    - Does not give station rotation relative to one another
    - Likely to change as data taking starts and we learn more about our trackers
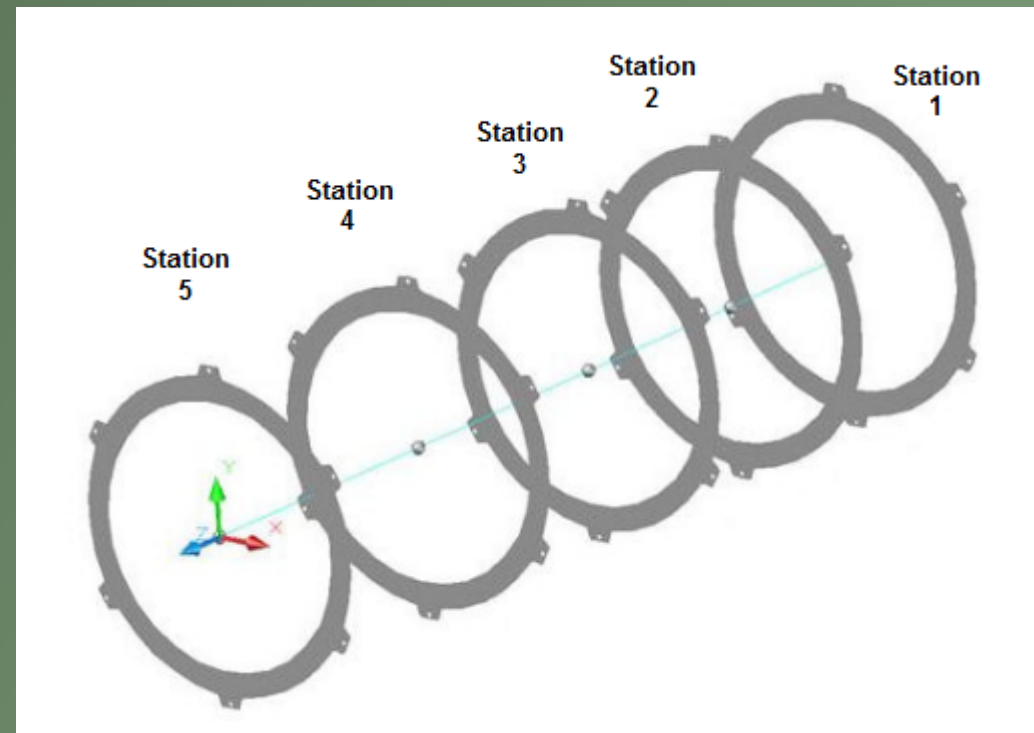
Geometry: Extras

- Tracker He window added

- Many alignment studies with MC are underway

  - Trackers within bore

  - Trackers relative to magnetic field

  - Trackers relative to each other

  - Stations relative to each other
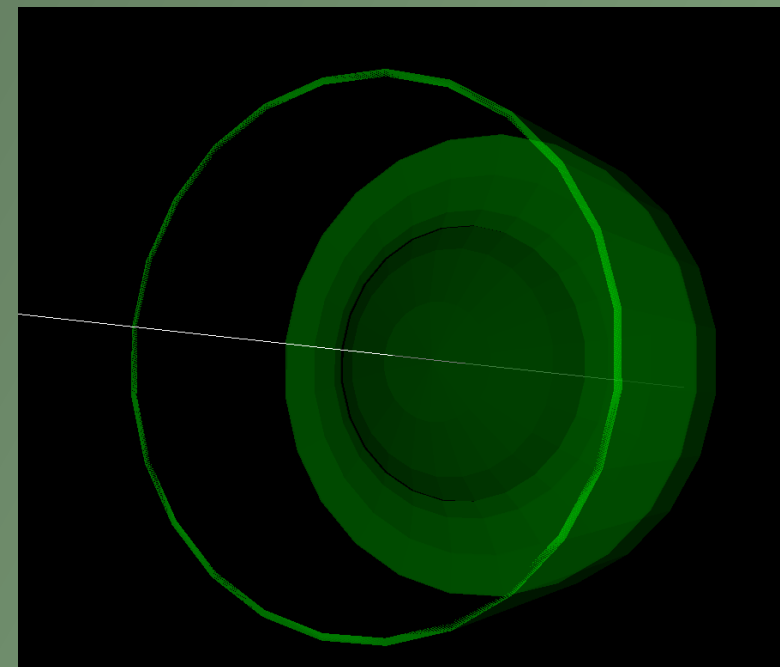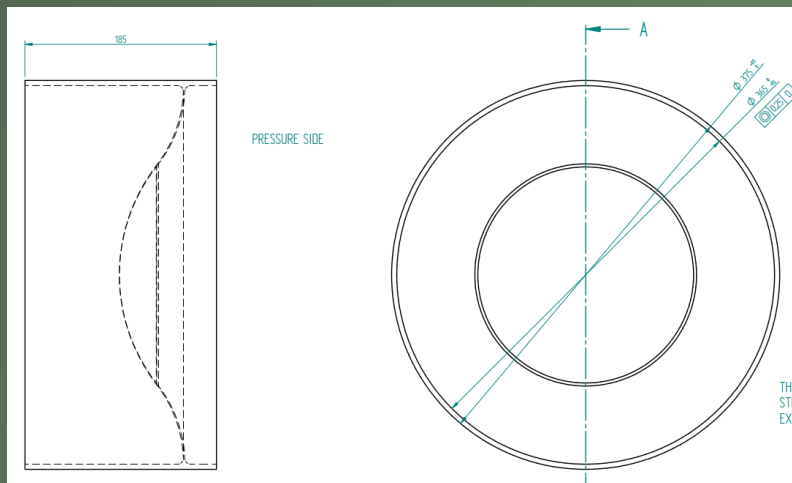
Creating Hits/Digits

- Creating Hits
  - Initiated by Beam Simulation module within MAUS
    - When particle steps through material Geant4 calculates energy loss and multiple scattering
      - Many hits recorded as particle traverses material
    - If that material is tagged as a scintillating fiber the event is stored for processing by Tracker MC

Creating Hits/Digits

- Creating Digits
  - The process by which we take the sum of all the energy deposited into the fiber and transform it into a data type that can be read by the tracker reconstruction
    - Energy Conversion
    - Signal Smearing
    - Signal Digitization
    - Channel Mapping

Creating Hits/Digits
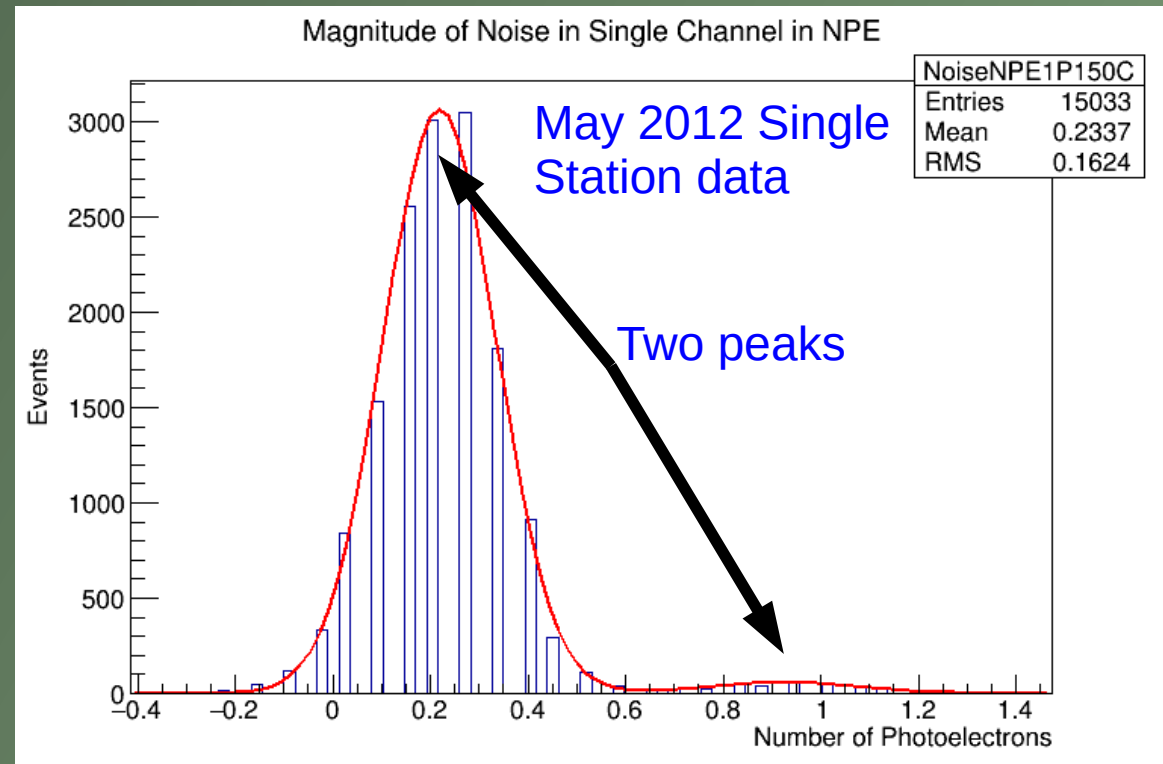
- Energy Conversion

    - Short version: take the total energy deposited into the fiber (in MeV) during the event and multiply it by 174.7, the result is the raw NPE

    - TL;DR: the raw light output is a function of:

• Fiber Conversion Factor	• Fiber Trapping Efficiency
• Fiber Mirror Efficiency	• Fiber Transmission Efficiency
• VLPC Quantum Efficiency	• Fiber MUX Transmission Efficiency

    - Integer number of PE passed to electronic simulation

Creating Hits/Digits

- ## Signal Smearing

  - Input integer PE is expanded via Gaussian

  - Simulates:
    - Uncertainty in VLPC electron avalanche
    - Noise in ADC

Magnitude of Noise in Single Channel in NPE

May 2012 Single Station data

Two peaks

NoiseNPE1P150C	
Entries	15033
Mean	0.2337
RMS	0.1624

Raw:
$\mu_1 = 0.219$ $\mu_2 = 0.928$
$\sigma_1 = 0.116$ $\sigma_2 = 0.150$
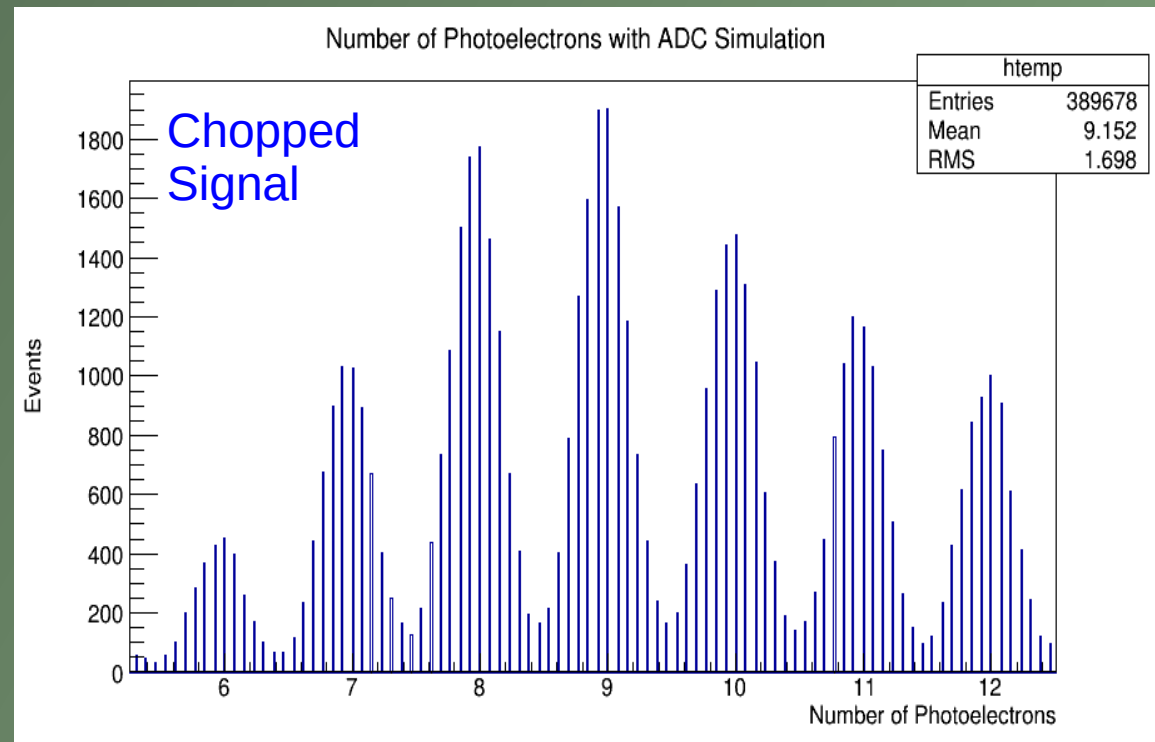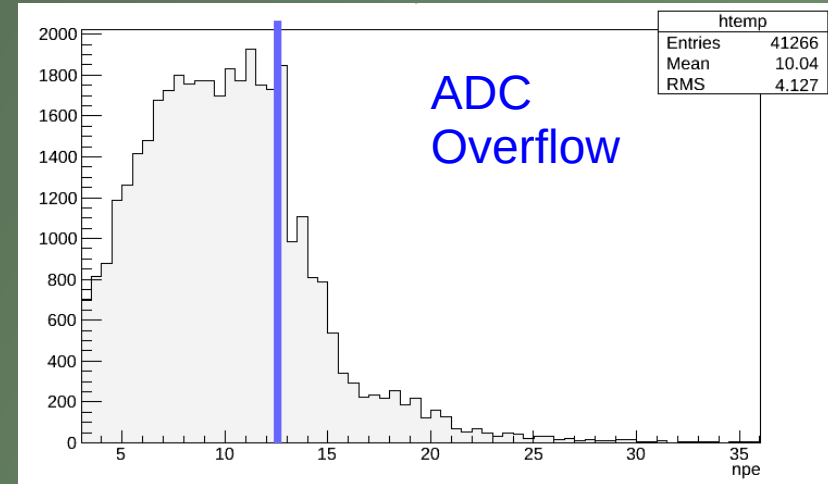Corrected:
$\mu'_1 = 0$ $\mu'_2 = 1$
$\sigma'_1 = 0.163$ $\sigma'_2 = 0.212$

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Creating Hits/Digits

- Signal Digitization
  - ADCs have 2^8 buckets
    - Overflow not measurable
  - Simulation works backwards
    - Start with PE
    - Translate that to bits
    - Transform back to PE
  - Effect is to "chop" data

ADC Overflow

Number of Photoelectrons with ADC Simulation

Chopped Signal

Creating Hits/Digits

- Channel Mapping
  - Each channel has its own calibration
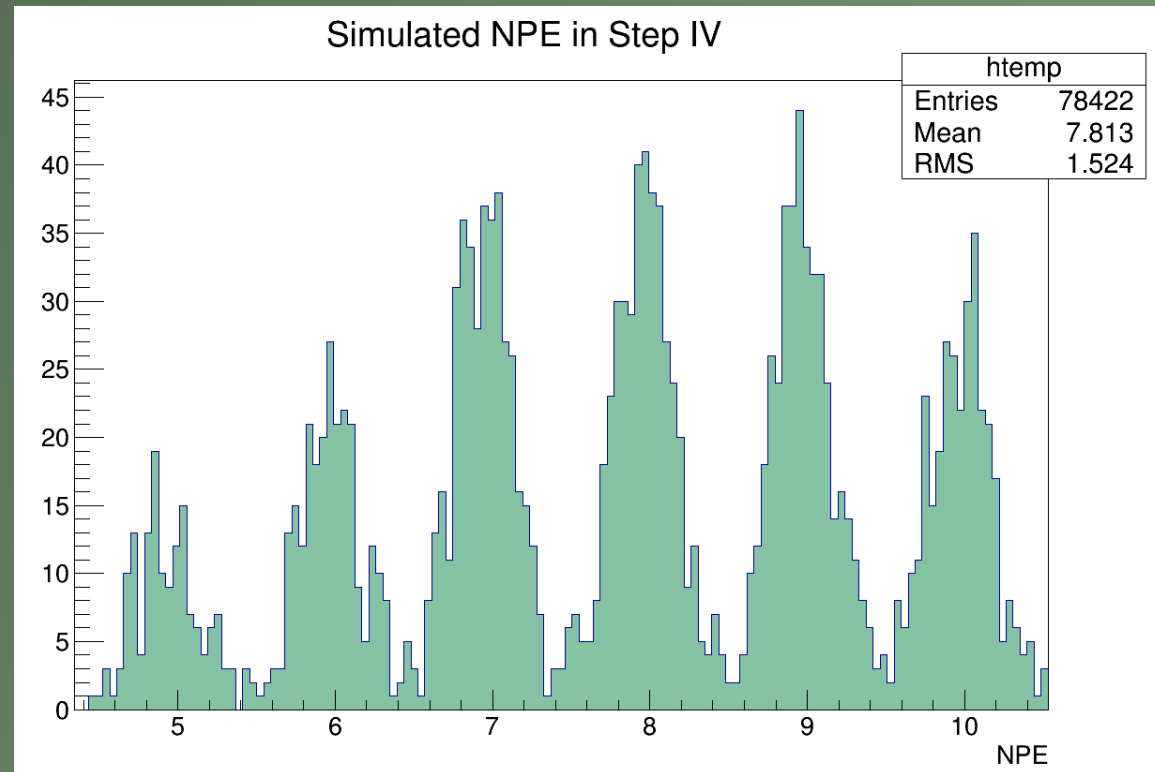   - Adjusts:
      - Spacing between bins
      - Pedestal or number of bins before overflow
      - Bad Channels
  - MC mapping generated from lab 7 mapping
    - Lab 7 mapping averages and sigmas
    - Gaussian generated MC mapping
  - When mapping in CDB MC will be able to read that
    - Not completely implemented...

Simulated NPE in Step IV

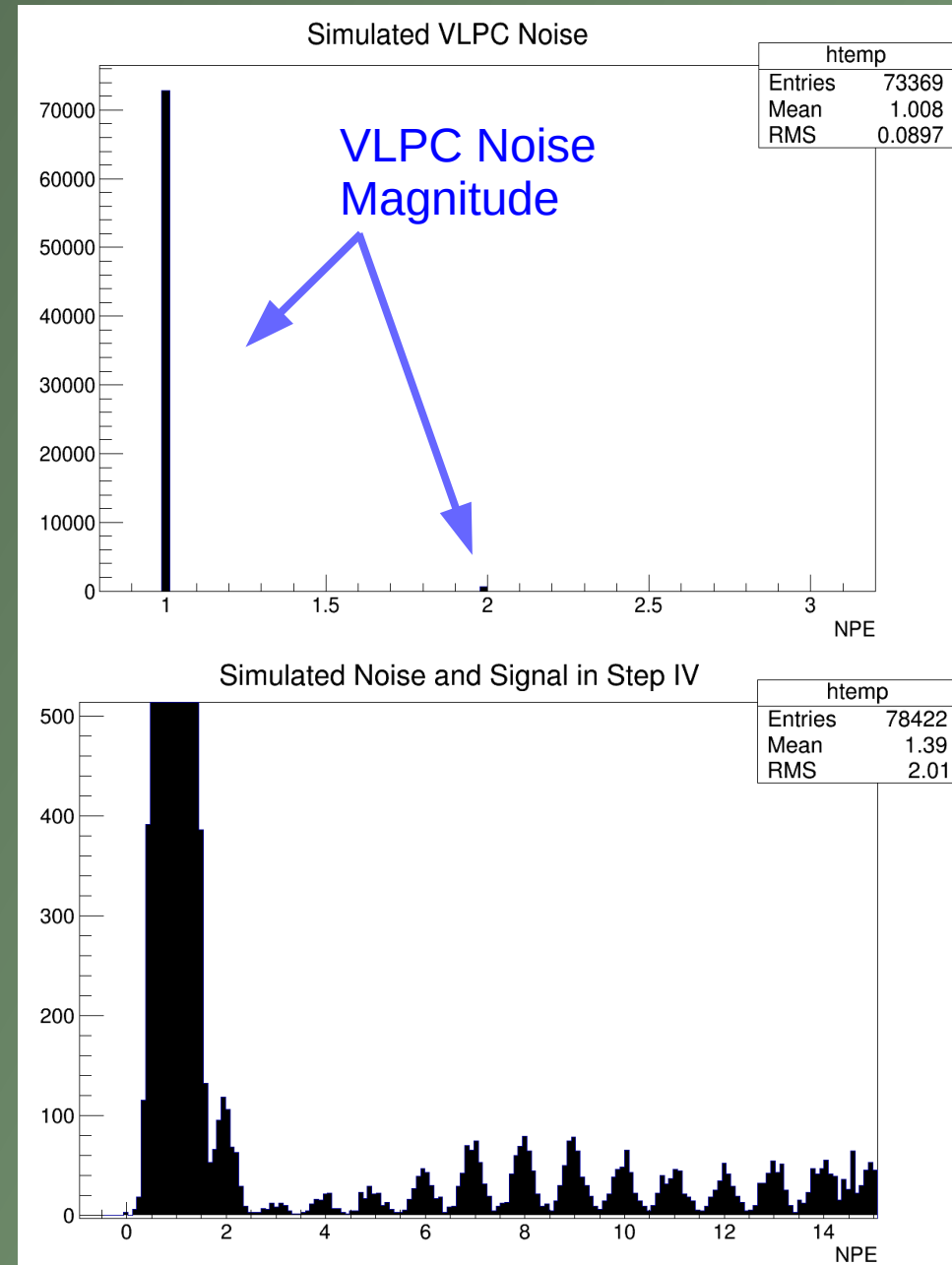| htemp	
Entries	78422
Mean	7.813
RMS	1.524

NPE

Additional Noise

- Two additional sources of noise are included in the Tracker MC
  - Poisson: Thermal Excitation of VLPCs
  - Gaussian: X-ray Excitation from RF Cavities
  - Run from its own MAUS mapper, must be included if you want noise!
    - Flags included in configuration file to turn these on/off
- Handled differently than other MC results
  - SciFiNoiseHit data branch in MAUS
  - Merged during digitization
 - Invisible to recon

Additional Noise

- Thermal Excitation of VLPCs
  - Thermal energy knocks loss an e- which starts an avalanche with no PE present
  - Described by Poisson, λ ~0.015
  - To save on CPU cycles:
    - Number of active channels determined
    - Active channels picked from list
    - Magnitude determined from list, 1 – 4 PE possible
      - Greater than 4 PE is negligible
      - Beyond machine precision?

Simulated VLPC Noise

VLPC Noise Magnitude

htemp	
Entries	73369
Mean	1.008
RMS	0.0897

Simulated Noise and Signal in Step IV

htemp	
Entries	78422
Mean	1.39
RMS	2.01

Additional Noise

- X-ray Excitation from RF Cavities
  - Just started working on this
  - Assumes average 10 hits per plane
    - Scales with $1/r^2$
  - Gaussian Magnitude about 10 PE
    - Developer's Fiat
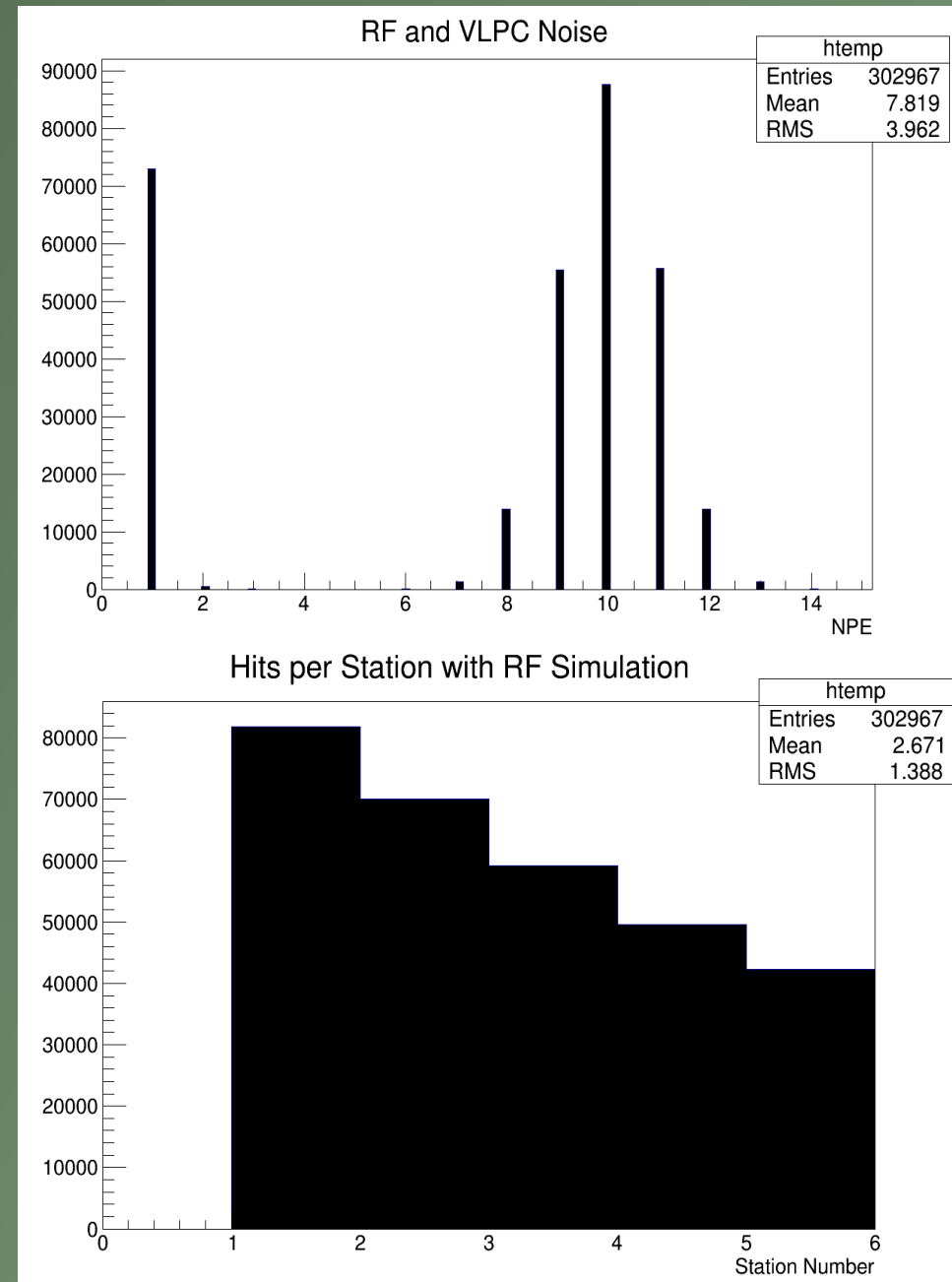
Unresolved Issues

- Additional channel mapping to simulate imperfect calibrations.

- Additional material simulation inside bore

- Increased precision/accuracy in all noise simulations

- Analysis of recon with noise

- Code clean up, lower CPU overhead

Final Comments

- Everything is uploaded to tracker development branch

  - Update configuration files! New default variables and changed values.

- Ready for use by public

- Documentation on the way