Use of Energy Measurements in the CALET Ultra-Heavy Cosmic-Ray Analysis

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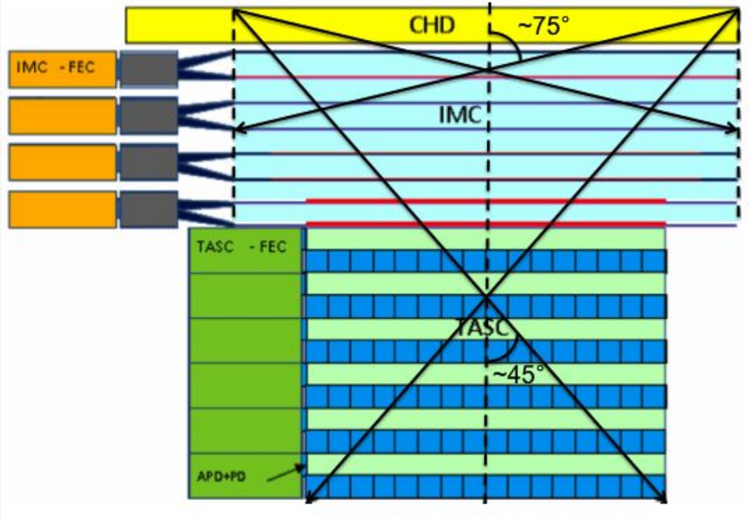
Ultra-Heavy Cosmic Ray Science

- Ultra-heavy cosmic rays (UHCR) provide clues into the source of all cosmic rays, their acceleration mechanism, and nucleosynthetic sources, e.g., r-process nuclei.
- Instruments that can do UHCR measurements for $30 \leq Z \leq 40$ with single element resolution:
  - CALET on ISS in earth's magnetosphere with energy range, E > 1 GeV/nucleon
  - SuperTIGER which measures at similar energies to CALET.
    - Note as stratospheric balloon payload is has different systematics such as requiring atmospheric corrections.
  - ACE-CRIS at the L1 Lagrange point outside magnetosphere, energy range ~100 – 500 MeV/nucleon.

Ultra-Heavy Cosmic Ray Science

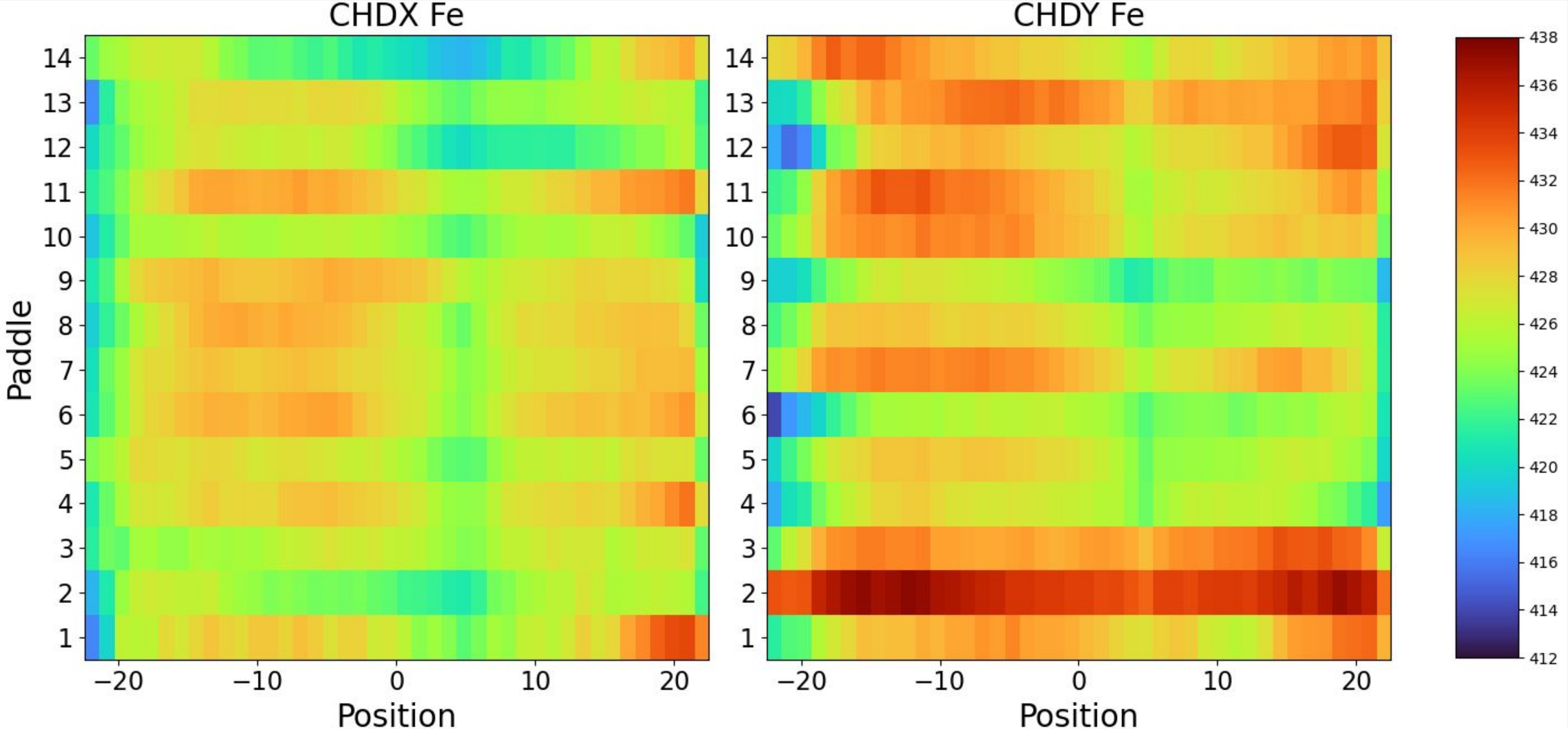
- This analysis uses ~6.5 years of CALET UH-trigger data from 10/2015 through 02/2022. This UH-trigger dataset has ~4× the geometry factor of the standard nuclei trigger. (~230 million events)
- We constrain the analysis to events that pass through the TASC. (~38 million events)
- This reduces statistics but the energy information allows for an improved charge assignment. Allowing us to trade statistics for better resolution.



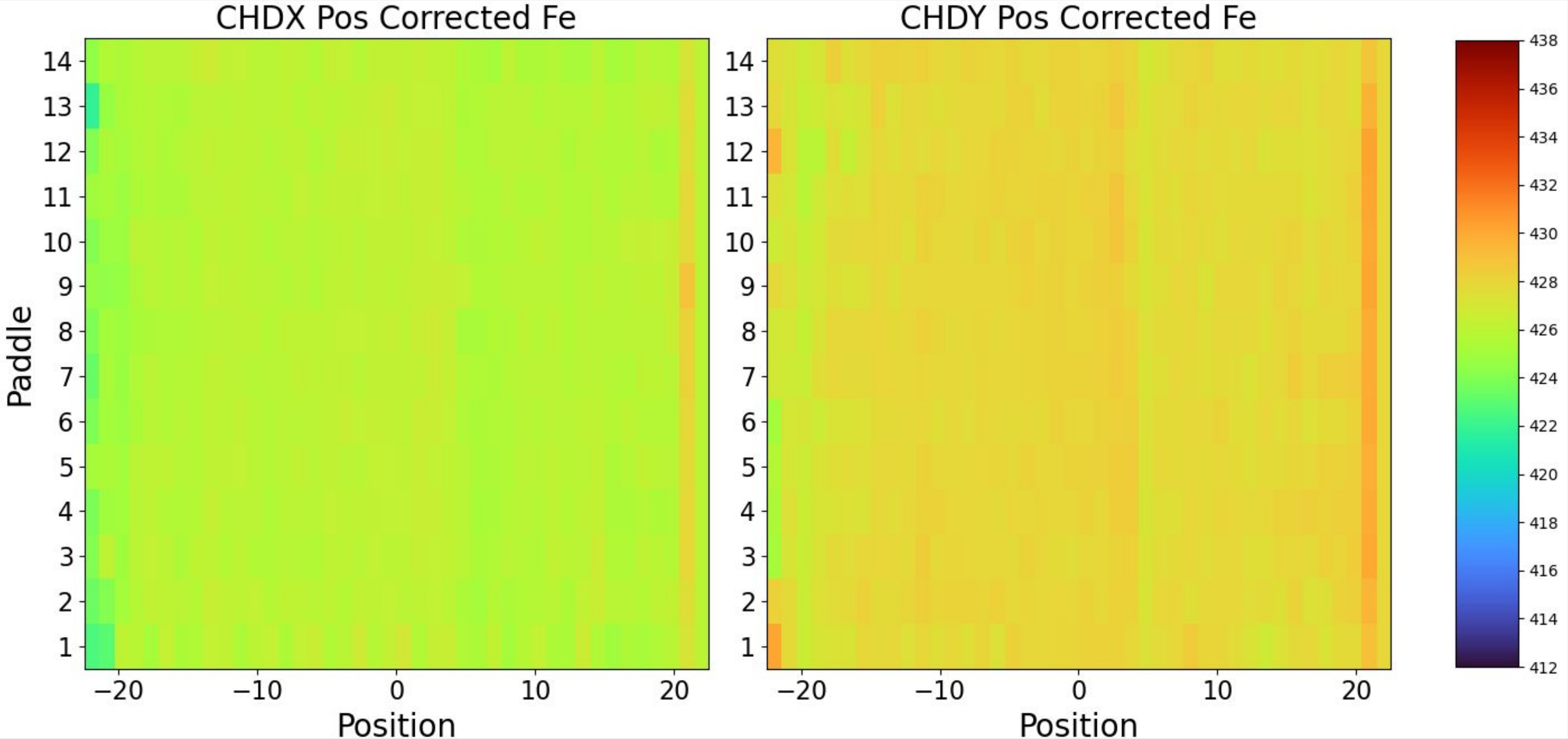
CHD Corrections

- This analysis has three corrections for optimizing the CHD signal for UH events:
- Position
  - Each CHD paddle is divided into 42 subsections, which are then normalized to the full layer mean for both the $_{14}$Si and $_{26}$Fe peaks.
- Time
  - Using the position corrected signal, the CHD paddles are normalized to the full layer $_{26}$Fe peak over time increments that have 300 events occur in each individual paddle.
- Energy
  - UH events are divided into energy bins of ~40000 $_{26}$Fe events, we then peak fit over each energy bin for charge assignment.

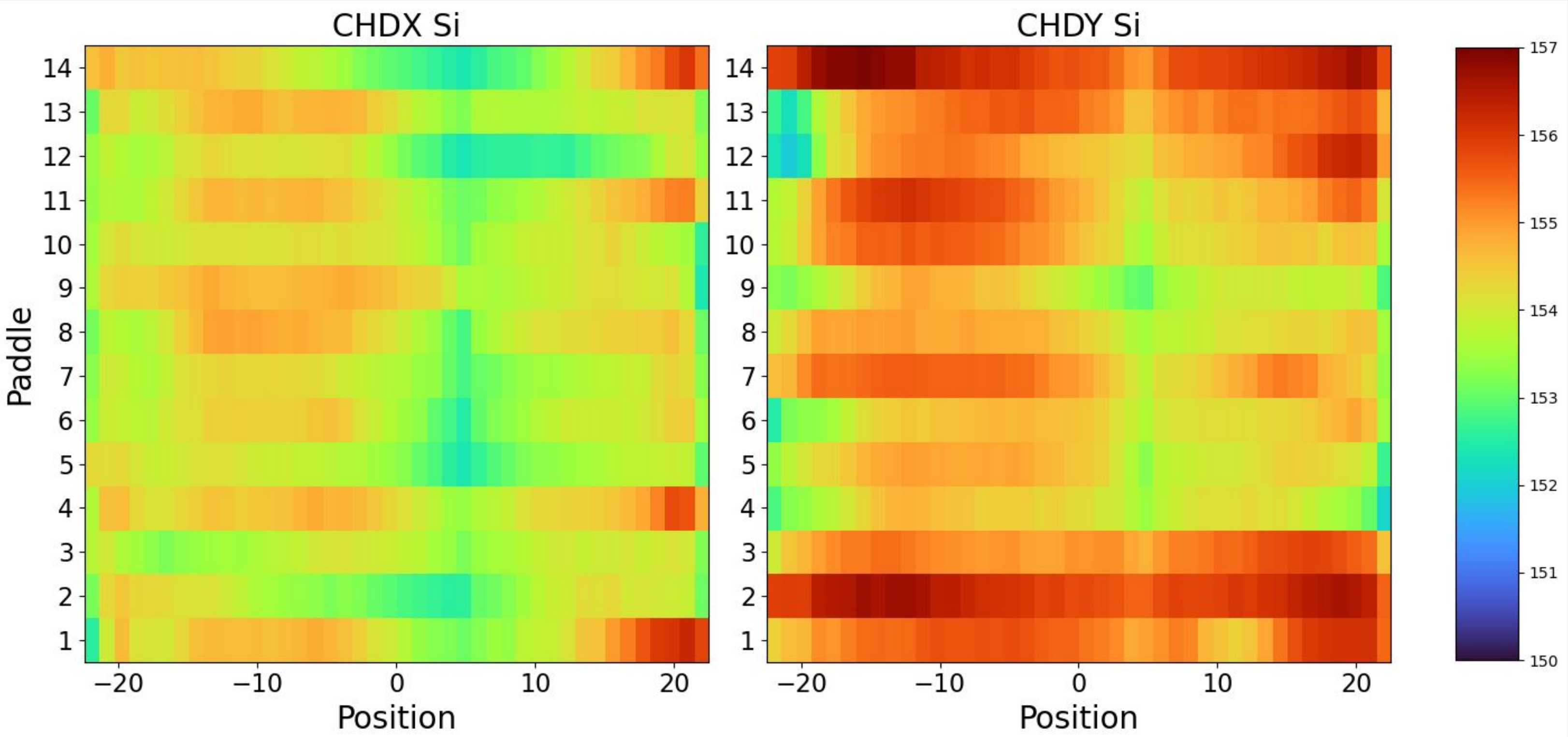
CHD $_{26}$Fe Signal Before Position Corrections



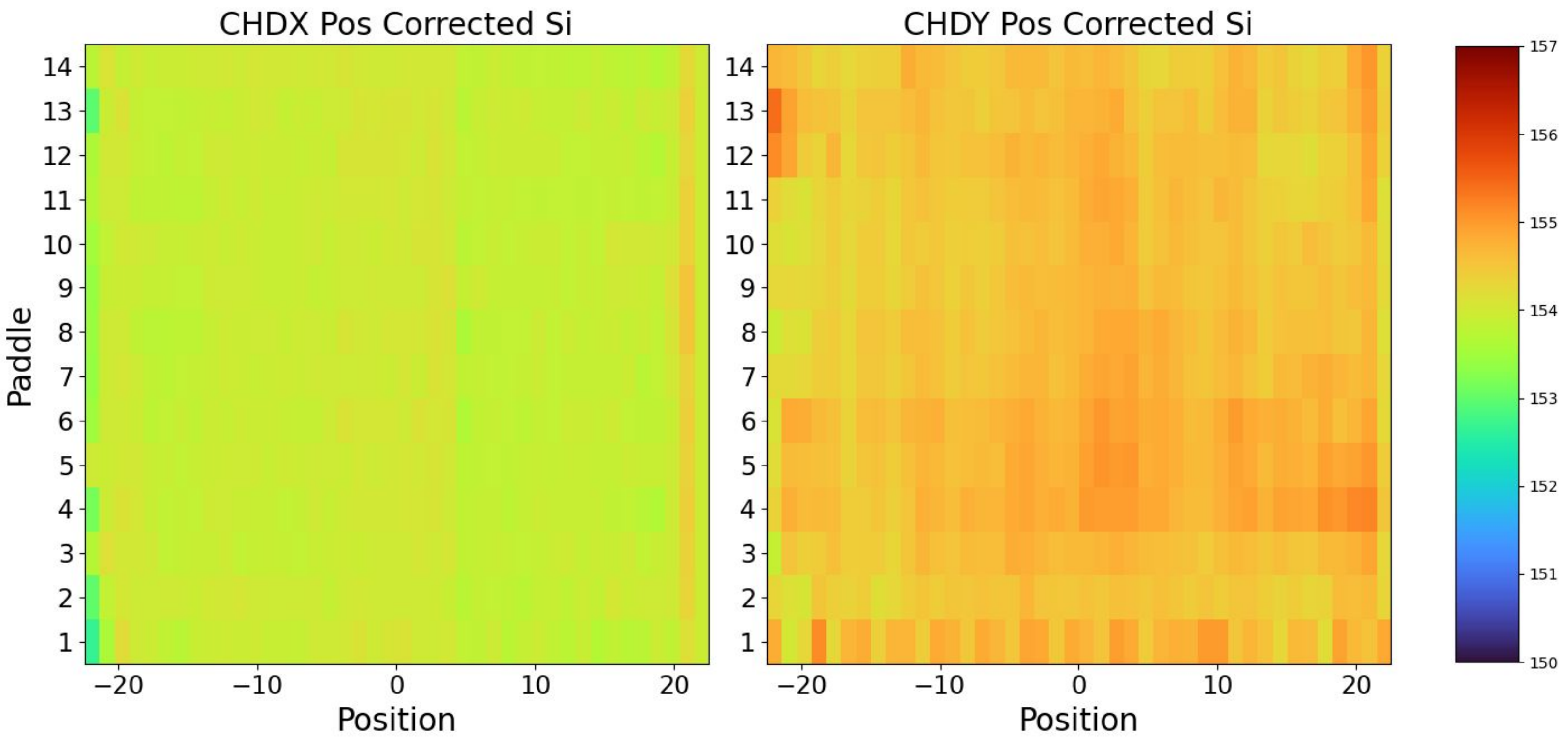
CHD $_{26}$Fe Signal After Position Corrections



CHD $_{14}$Si Signal Before Position Corrections

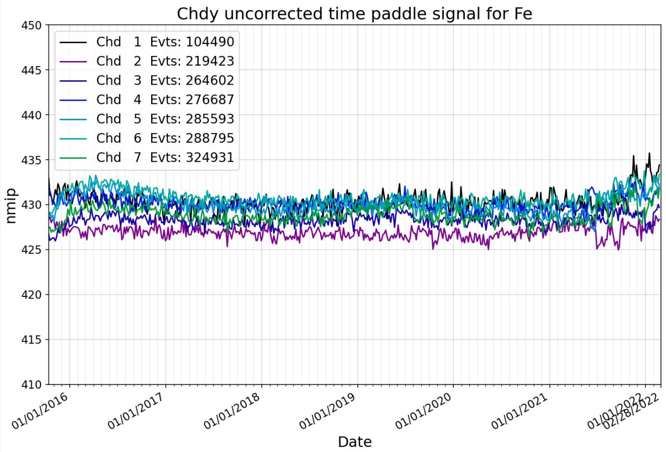


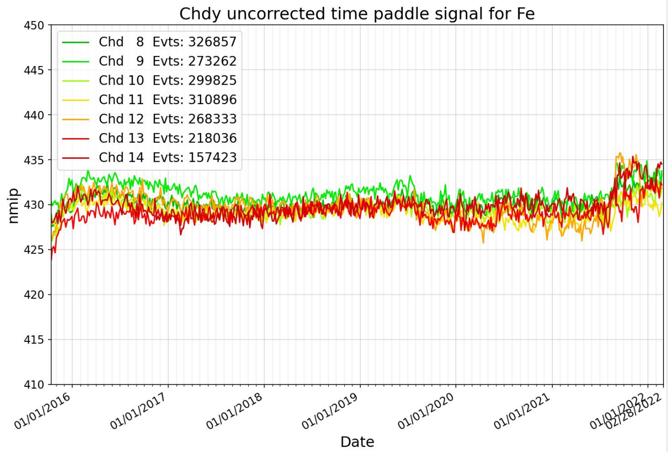
CHD $_{14}$Si Signal After Position Corrections



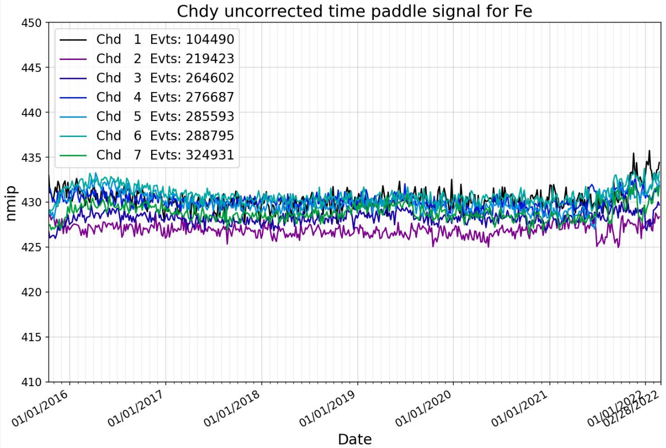
CHD $_{26}$Fe Signal Before Time Corrections

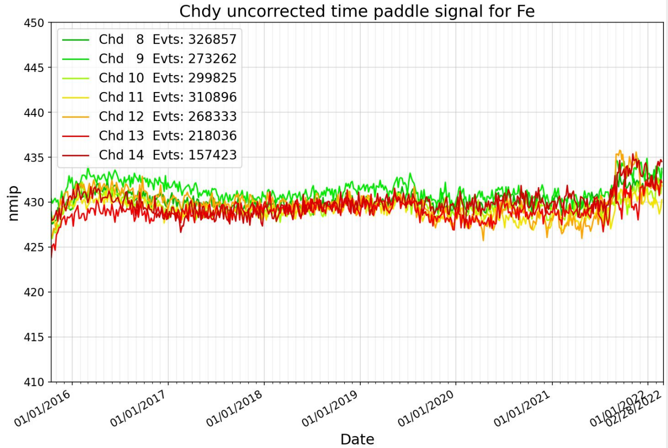
CHDX





CHDY

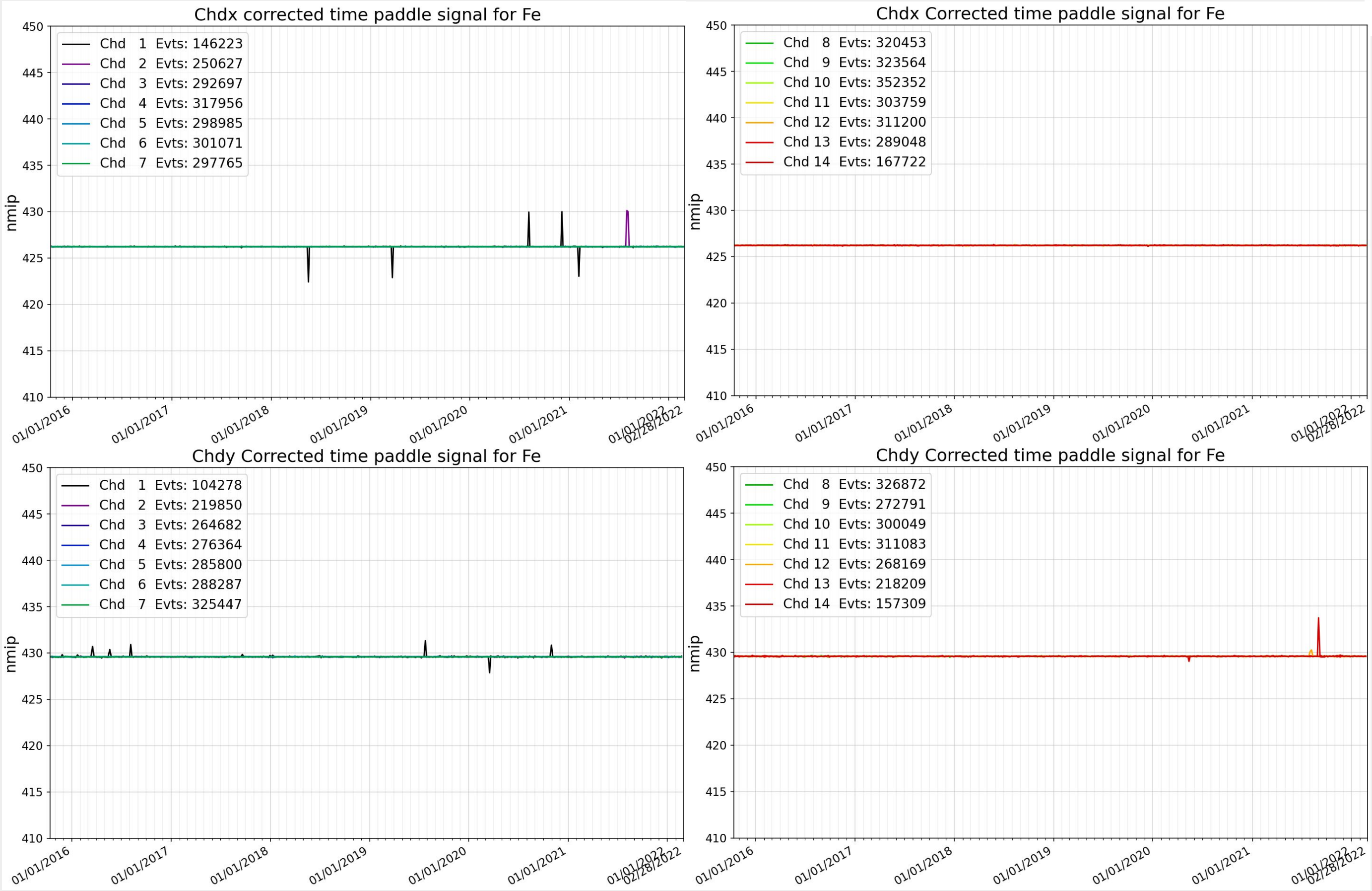




CHD $_{26}$Fe Signal After Time Corrections

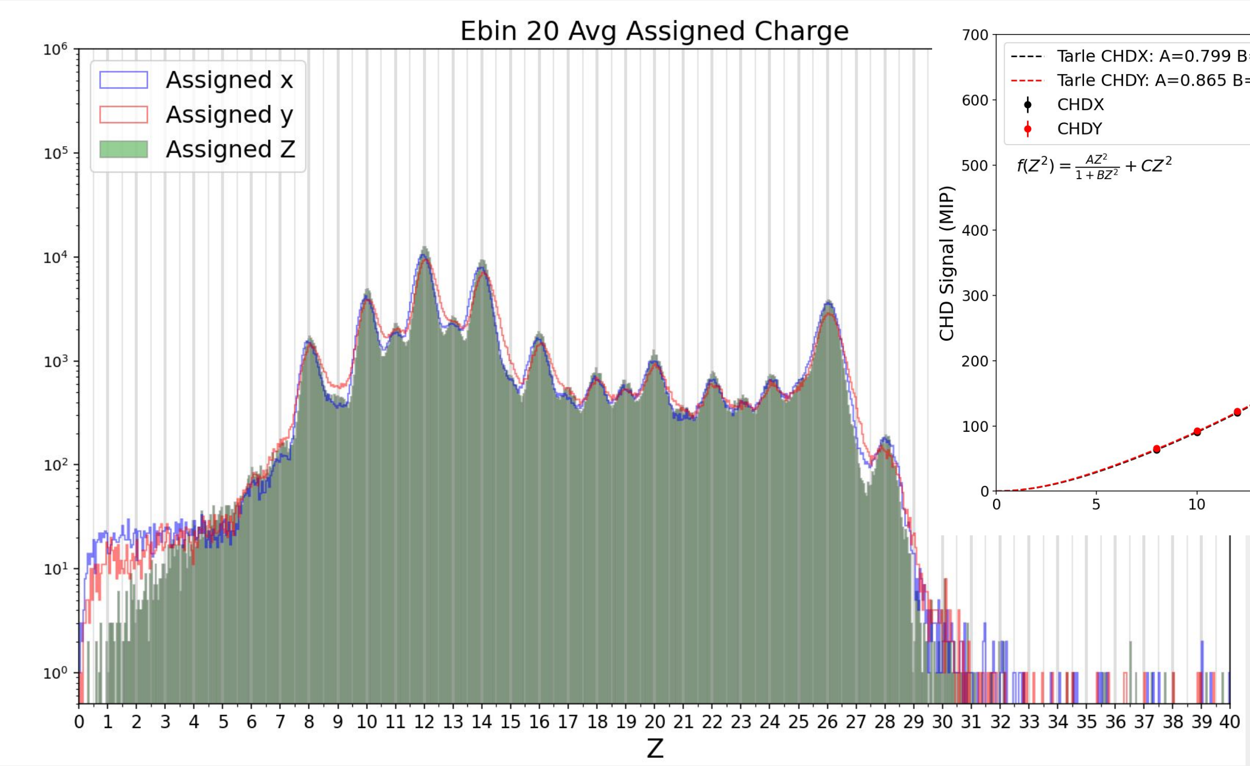
CHDX

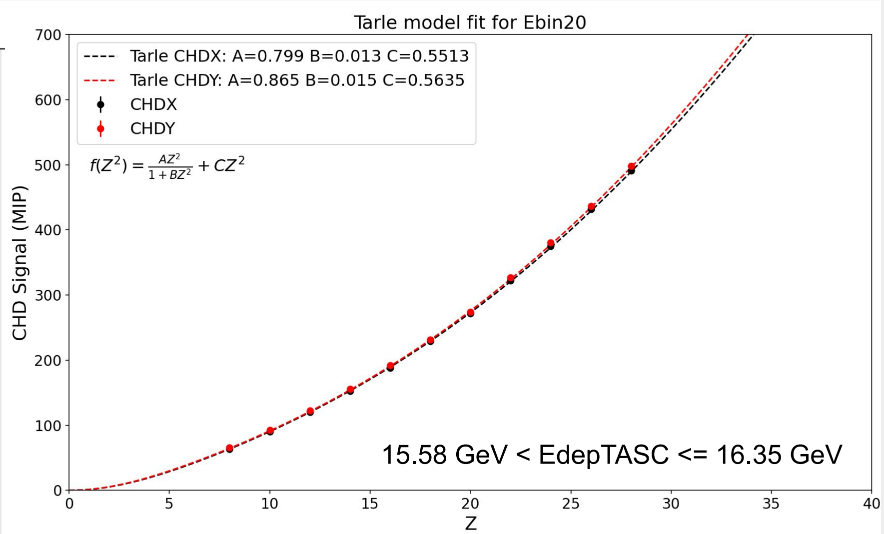
CHDY



CHD Energy Corrections

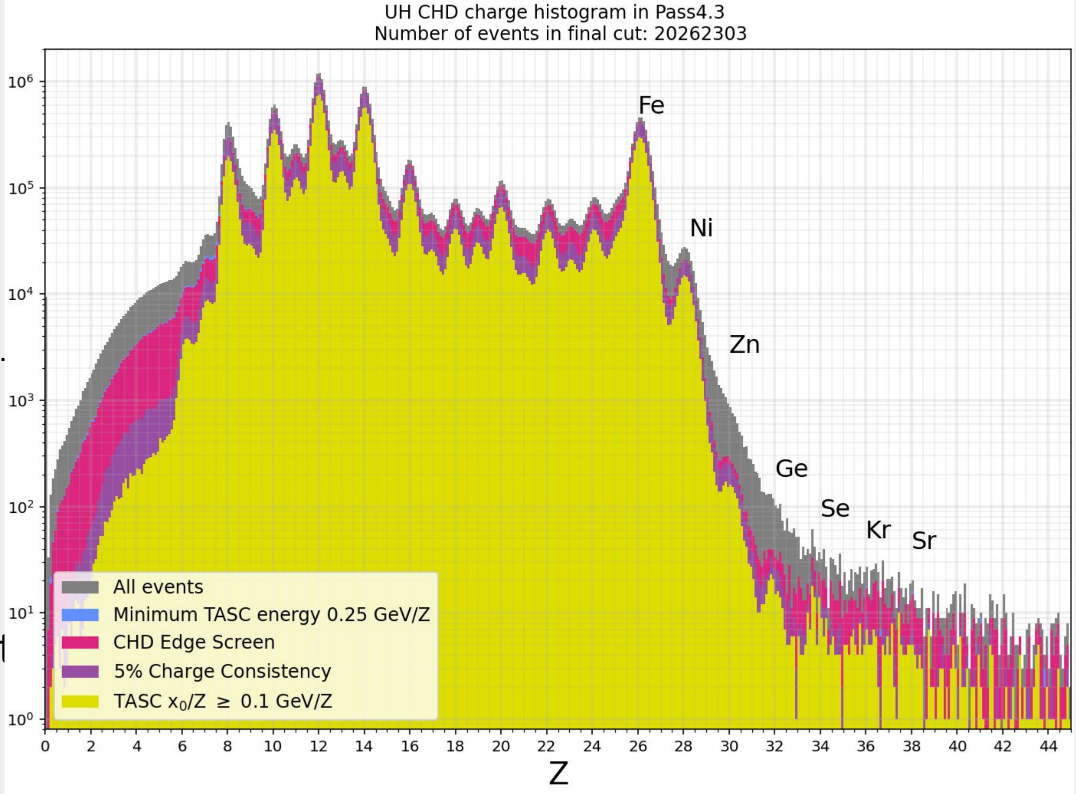
As an example, this one of 65 energy bins.





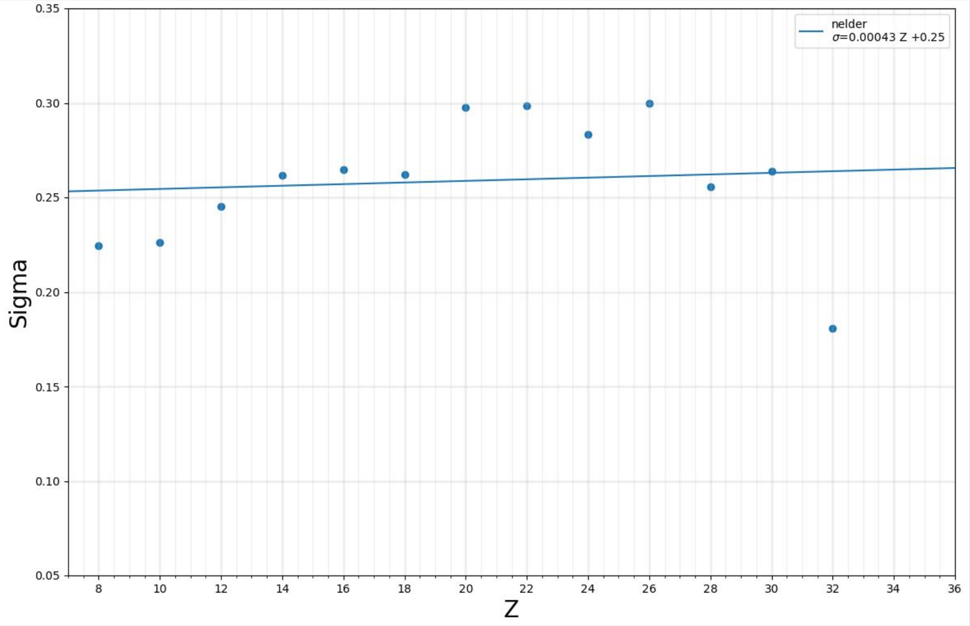
Event Screening

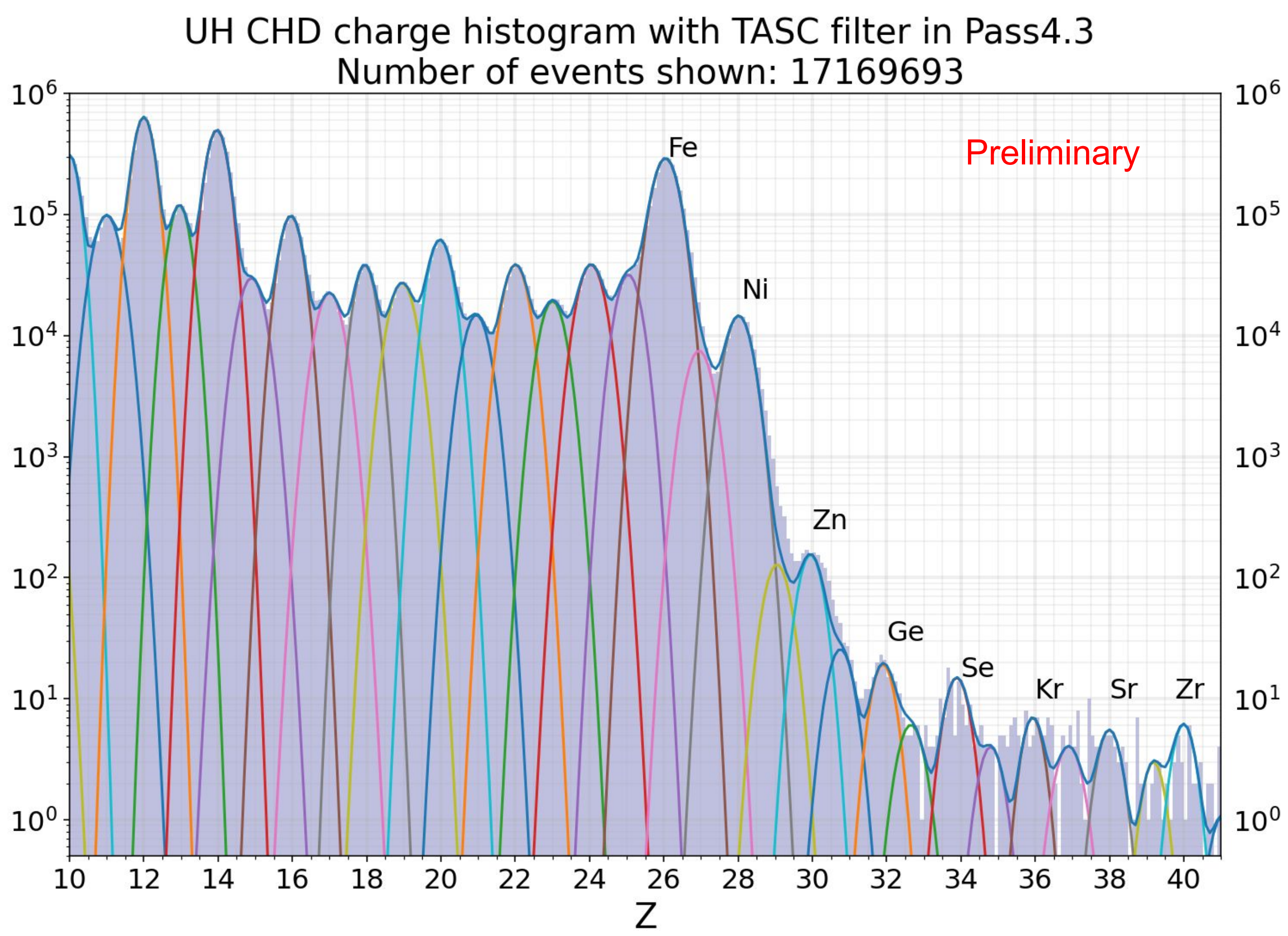
- For consistency the following events are screened in the analysis
  - Events with energy less than 0.25 GeV/Z. These energy bins were the most smeared, and a reliable peak fitting could not be done.
  - A position screen to account for the lack of statistics in the edge cases of the individual paddles.
  - A consistency screen that requires CHDX and CHDY to be within a 5% percent difference.
  - A minimum energy screen in the first layer of the TASC, to account for fragmentation and splashback.



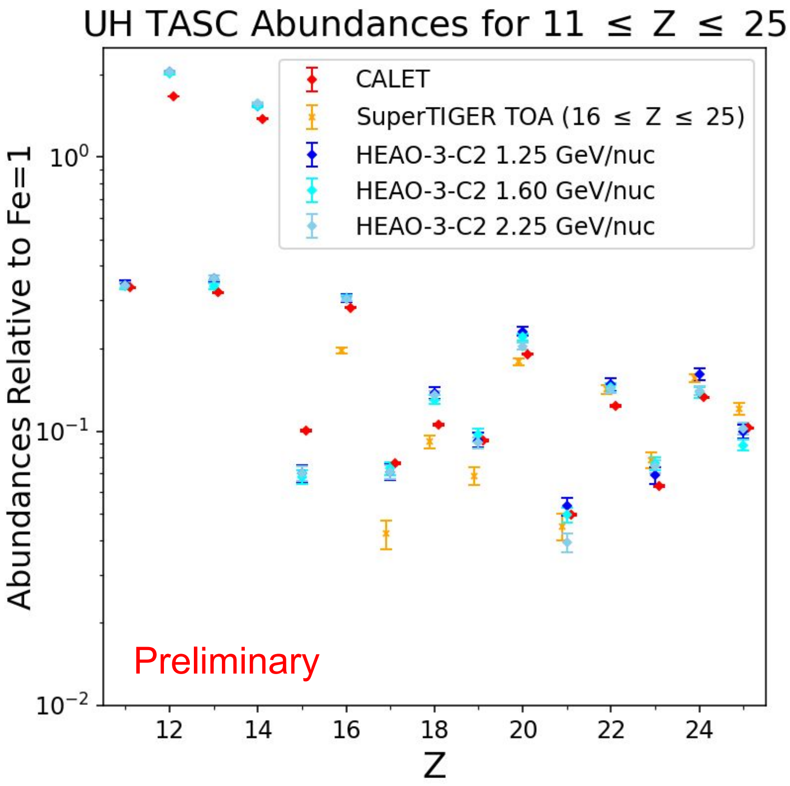
Determination of Abundances

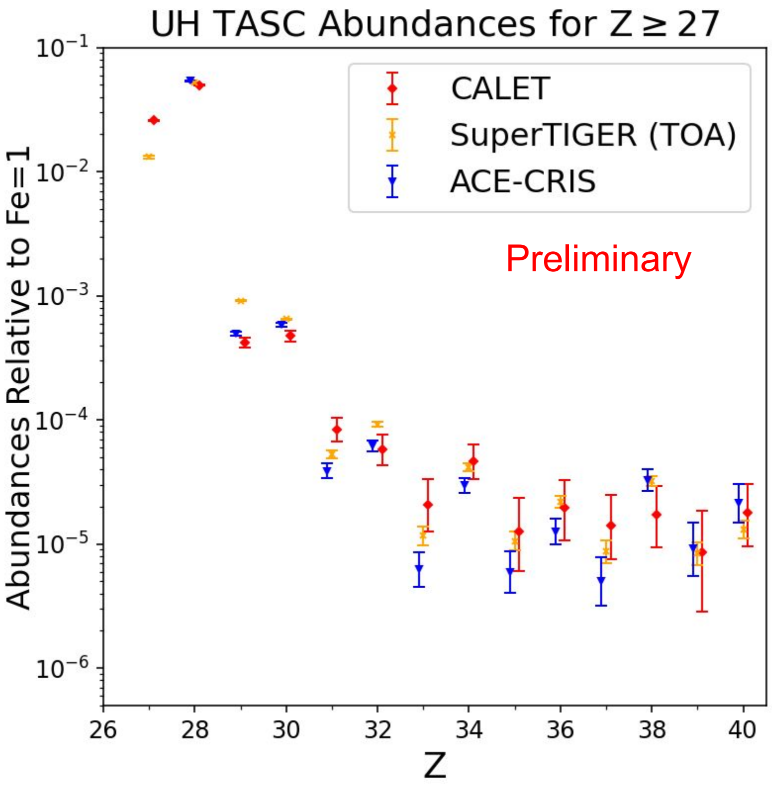
- The fit is done in multiple steps.
  - Iteration one has constraints on peak position to determine sigmas for each peak.
- The sigmas from the even peaks over 8 ≤ Z ≤ 32 are linearly fit to extrapolate out to Z=40 (Shown on right)
- Second fit using the linearized sigma equation with a maximum-likelihood multiple-Gaussian fit




UH CHD charge histogram with TASC filter in Pass4.3
Number of events shown: 17169693
Preliminary
Fe
Ni
Zn
Ge
Se
Kr
Sr
Zr
Z
10
12
14
16
18
20
22
24
26
28
30
32
34
36
38
40
10^6
10^5
10^4
10^3
10^2
10^1
10^0

Relative Abundances





Future Work / Acknowledgements

- Determine energy dependent relative abundances for comparison with non-UH abundances from HEAO-3-C2.
- Use simulations to estimate or determine the systematic errors from charge misidentification, fragmentation, etc
- Results to be submitted to ApJ in the near future.
- With CALET planned to operate until at least 2024, statistics will to continue improve.

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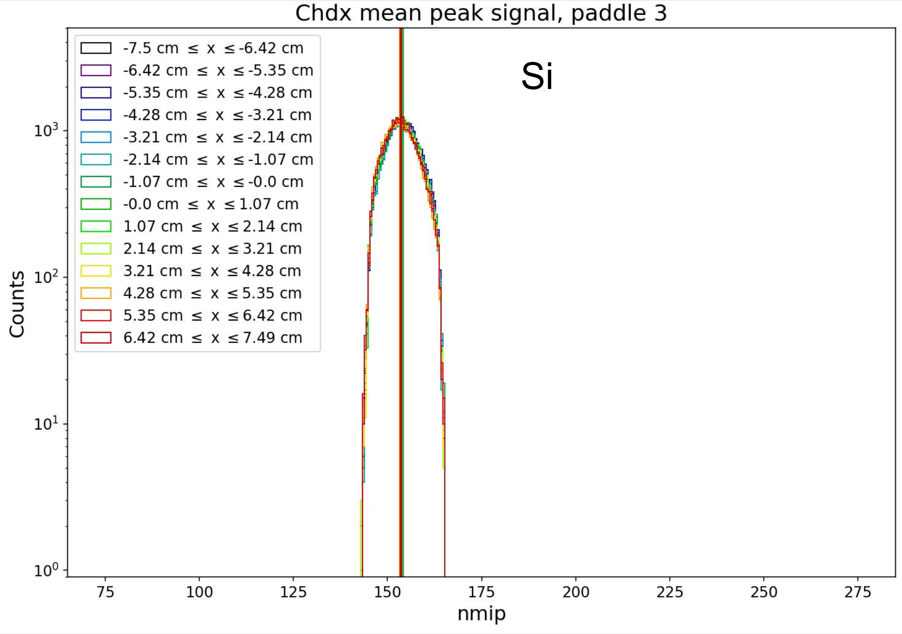
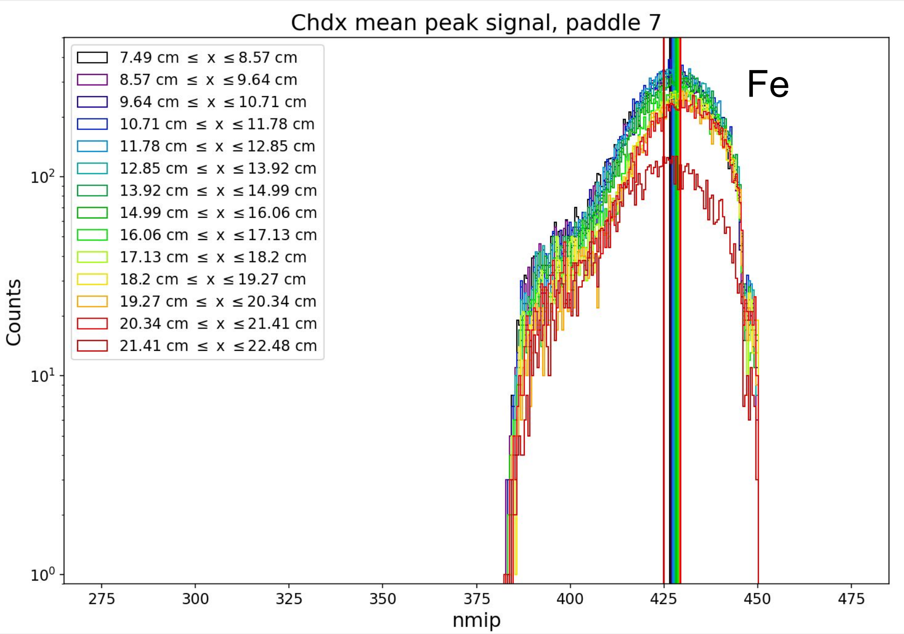
The material contained in this document is based upon work supported by a National Aeronautics and Space Administration (NASA) grant or cooperative agreement. Any opinions, findings, conclusions or recommendations expressed in this material are those of the author and do not necessarily reflect the views of NASA.

Backup slides

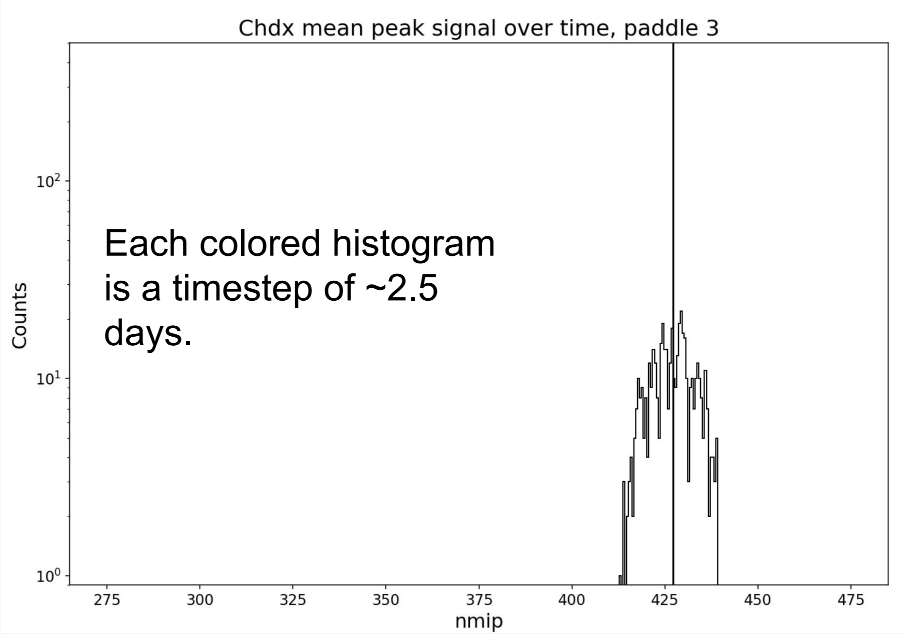
Position Corrections for individual paddle segments



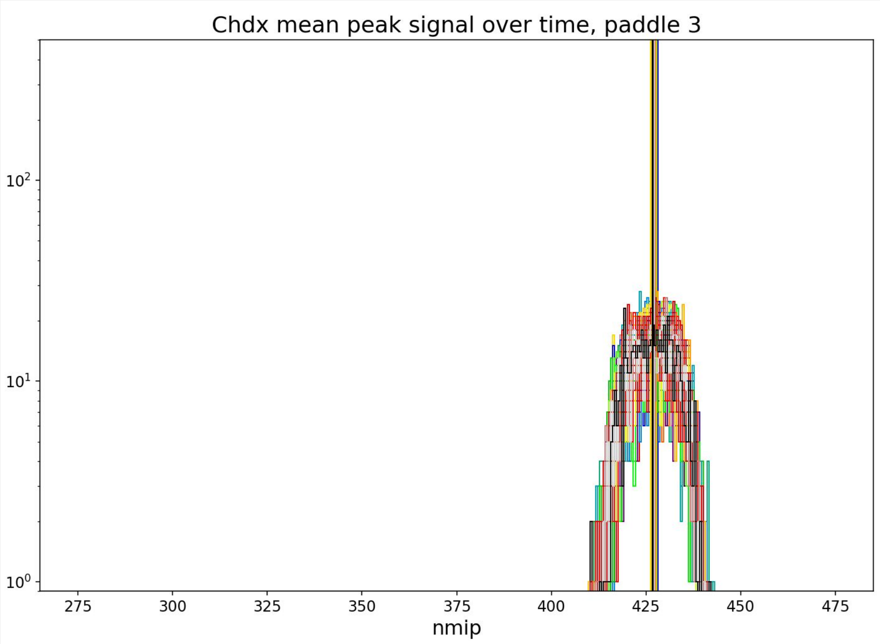


Time Correction Peaks

Example peaks from the time correction.



Each colored histogram is a timestep of ~2.5 days.



Charge Smearing

Charge smearing at lower energy.

Red lines show peak fitting routine’s attempt at finding peak position for Tarle charge assignment.