Three Years of CALET Ultra Heavy Cosmic Ray Observations

Brian Flint Rauch and Bob Binns
for the CALET Collaboration
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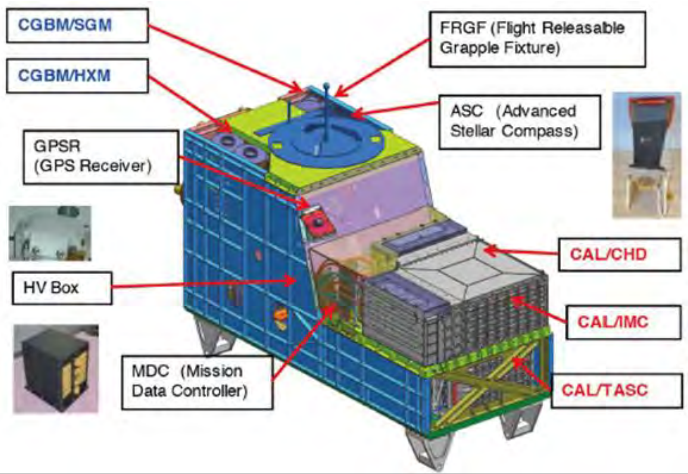
CALET Collaboration

O. Adriani[25], Y. Akaike[2], K. Asano[7], Y. Asaoka[9,31], M.G. Bagliesi[29], E. Berti[25], G. Bigongiari[29], W.R. Binns[32], S. Bonechi[29], M. Bongi[25], P. Brogi[29], A. Bruno[15], J.H. Buckley[32], N. Cannady[13], G. Castellini[25], C. Checchia[26], M.L. Cherry[13], G. Collazuol[26], V. Di Felice[28], K. Ebisawa[8], H. Fuke[8], T.G. Guzik[13], T. Hams[3], N. Hasebe[31], K. Hibino[10], M. Ichimura[4], K. Ioka[34], W. Ishizaki[7], M.H. Israel[32], K. Kasahara[31], J. Kataoka[31], R. Kataoka[17], Y. Katayose[33], C. Kato[23], Y.Kawakubo[1], N. Kawanaka[30], K. Kohri [12], H.S. Krawczynski[32], J.F. Krizmanic[2], T. Lomtadze[27], P. Maestro[29], P.S. Marrocchesi[29], A.M. Messineo[27], J.W. Mitchell[15], S. Miyake[5], A.A. Moiseev[3], K. Mori[9,31], M. Mori[21], N. Mori[25], H.M. Motz[31], K. Munakata[23], H. Murakami[31], S. Nakahira[20], J. Nishimura[8], G.A De Nolfo[15], S. Okuno[10], J.F. Ormes[25], S. Ozawa[31], L. Pacini[25], F. Palma[28], V. Pal'shin[1], P. Papini[25], A.V. Penacchioni[29], B.F. Rauch[32], S.B. Ricciarini[25], K. Sakai[3], T. Sakamoto[1], M. Sasaki[3], Y. Shimizu[10], A. Shiomi[18], R. Sparvoli[28], P. Spillantini[25], F. Stolzi[29], S. Sugita[1], J.E. Suh[29], A. Sulaj[29], I. Takahashi[11], M. Takayanagi[8], M. Takita[7], T. Tamura[10], N. Tateyama[10], T. Terasawa[7], H. Tomida[8], S. Torii[9,31], Y. Tunesada[19], Y. Uchihori[16], S. Ueno[8], E. Vannuccini[25], J.P. Wefel[13], K. Yamaoka[14], S. Yanagita[6], A. Yoshida[1], and K. Yoshida[22]

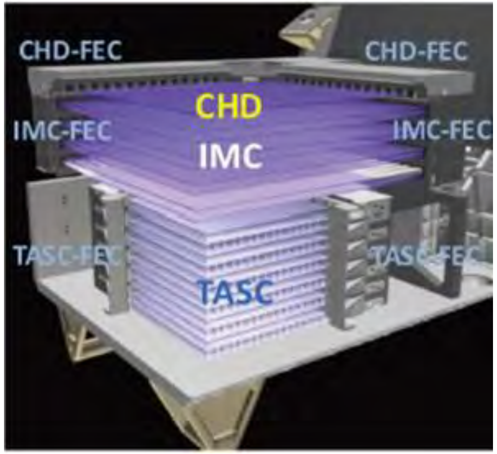
1) Aoyama Gakuin University, Japan
2) CRESST/NASA/GSFC and Universities Space Research Association, USA
3) CRESST/NASA/GSFC and University of Maryland, USA
4) Hirosaki University, Japan
5) Ibaraki National College of Technology, Japan
6) Ibaraki University, Japan
7) ICRR, University of Tokyo, Japan
8) ISAS/JAXA Japan
9) JAXA, Japan
10) Kanagawa University, Japan
11) Kavli IPMU, University of Tokyo, Japan
12) KEK, Japan
13) Louisiana State University, USA
14) Nagoya University, Japan
15) NASA/GSFC, USA
16) National Inst. of Radiological Sciences, Japan
17) National Institute of Polar Research, Japan
18) Nihon University, Japan
19) Osaka City University, Japan
20) RIKEN, Japan
21) Ritsumeikan University, Japan
22) Shibaura Institute of Technology, Japan
23) Shinshu University, Japan
24) University of Denver, USA
25) University of Florence, IFAC (CNR) and INFN, Italy
26) University of Padova and INFN, Italy
27) University of Pisa and INFN, Italy
28) University of Rome Tor Vergata and INFN, Italy
29) University of Siena and INFN, Italy
30) University of Tokyo, Japan
31) Waseda University, Japan
32) Washington University-St. Louis, USA
33) Yokohama National University, Japan
34) Yukawa Institute for Theoretical Physics, Kyoto University, Japan

CALET System Overview



CALorimetric Electron Telescope

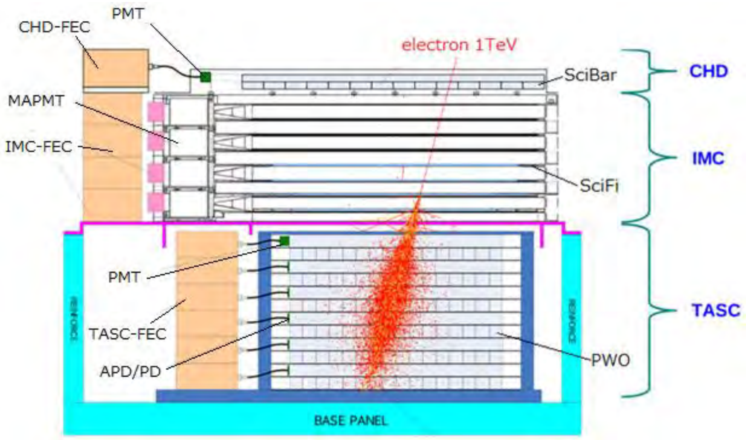
■CALorimeter (CAL)



- Mass: 612.8 kg
- JEM Standard Payload Size
  1850mm(L) x 800mm(W) x 1000mm(H)
- Power Consumption: 507 W(max)
- Telemetry:
  Medium 500 kbps (6.5GB/day)
  Low 50 kbps

■CALET Gamma-ray Burst Monitor (CGBM)

CALET-CAL Detector



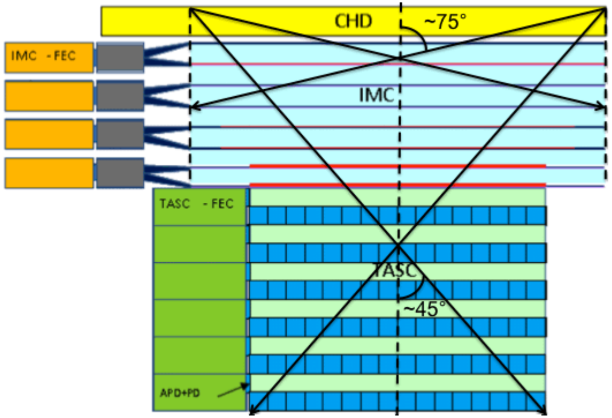
A 30 radiation length deep calorimeter designed to detect electrons and gamma-rays to 20 TeV and cosmic rays up to 1 PeV

- Geometric Factor:
  - 1200 cm^2sr for electrons, light nuclei
  - 1000 cm^2sr for gamma-rays
  - 4000 cm^2sr for ultra-heavy nuclei
- ΔE/E:
  - ~2% (>100GeV) for e, gamma
  - 30~35% for protons, nuclei
- e/p separation: ~10^5
- Charge resolution: 0.15 – 0.3 *e*
- Angular resolution:
  - 0.2° for gamma-rays > ~50GeV

	CHD (Charge Detector)	IMC (Imaging Calorimeter)	TASC (Total Absorption Calorimeter)
Function	Charge Measurement (Z=1-40)	Arrival Direction, Particle ID	Energy Measurement, Particle ID
Sensor (+ Absorber)	**Plastic Scintillator : 14 × 2layers** Unit Size: 32mm x 10mm x 450mm	**Scintillating fibers: 448 x 16 layers** Unit size: $1mm^2$ x 448 mm **Total thickness of Tungsten: 3 X_0**	**PWO log: 16 x 12 layers** Unit size: 19mm x 20mm x 326mm **Total Thickness of PWO: 27 X_0**
Readout	PMT+CSA	64 -anode MAPMT + ASIC	APD/PD+CSA PMT+CSA (for Trigger)@top layer

Ultra Heavy Cosmic Ray Analysis

- CALET has a special UH CR trigger utilizing the CHD and the top 4 layers of the IMC that:
  - has an expanded geometry factor of ~4000 cm^2sr
  - has a very high duty cycle due to low event rate
- Analysis presented here uses data with UH triggers and good trajectories
- Relative abundances of elements below $_{14}Si$ impacted as they only trigger at higher incidence angles
- UH analysis requires specialized data corrections and selections optimized for UH range using $_{26}Fe$

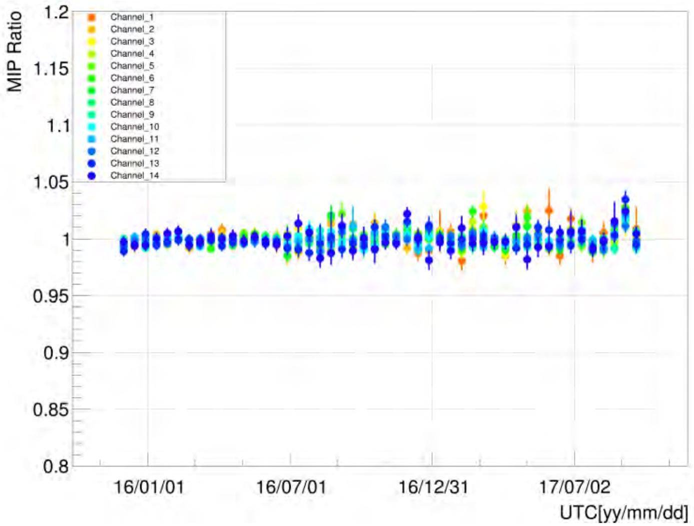


CALET UH Analysis Status

- Recently obtained ~3 years of CALET Level 2 PASS03.1 data
  - Previous work on 17 months of data
- Still applying previously developed analysis to new dataset
  - Present status of time and position response corrections shown
- Current results from analysis of 17 months of data shown
  - Application of selections and corrections
  - Comparison of CALET UH abundances with SuperTIGER & ACE

CALET Primary CAL Calibrations

CHDX



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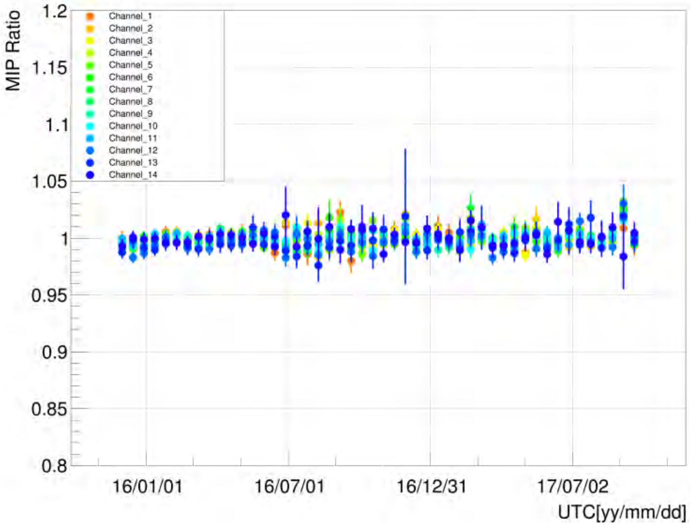
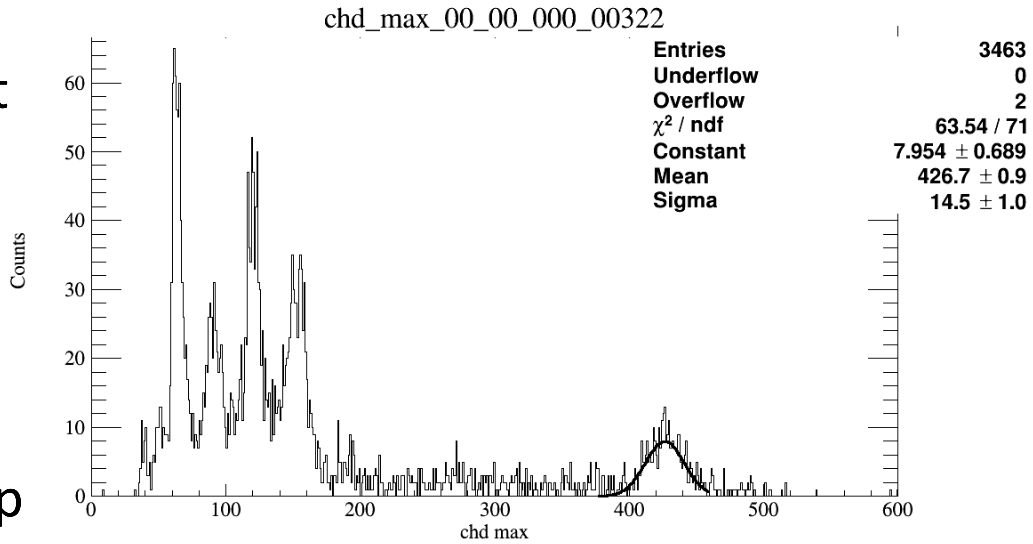
CHDY



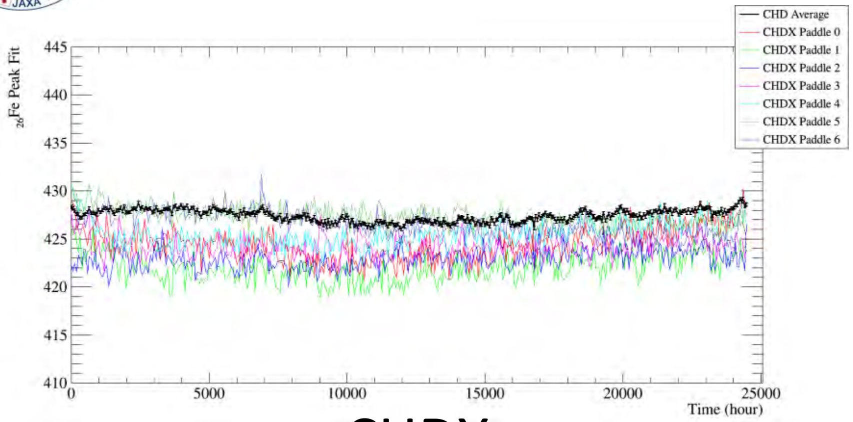
- Primary CALET CAL calibrations use noninteracting $_2$He and $_1$H
- CHD layers are well calibrated and stable with time
- Calibrations are optimized for CALET primary science

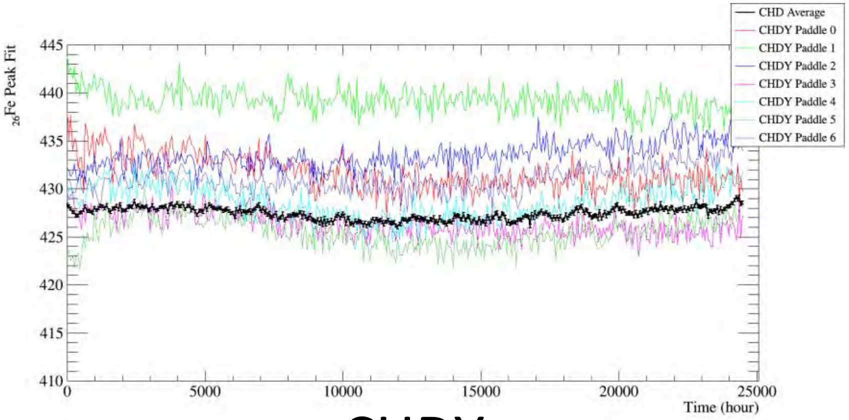
CHD $_{26}$Fe Time Corrections

- CHD time step histograms filled until at least 500 $_{26}$Fe range events in each CHD paddle
- In each time step $_{26}$Fe peaks fit with a Gaussian for each paddle and paddle average time steps calculated
- CHD paddle signals multiplied by the ratio of the mean of both layers over the full dataset to the paddle time step mean



CHD $_{26}$Fe Time Contours





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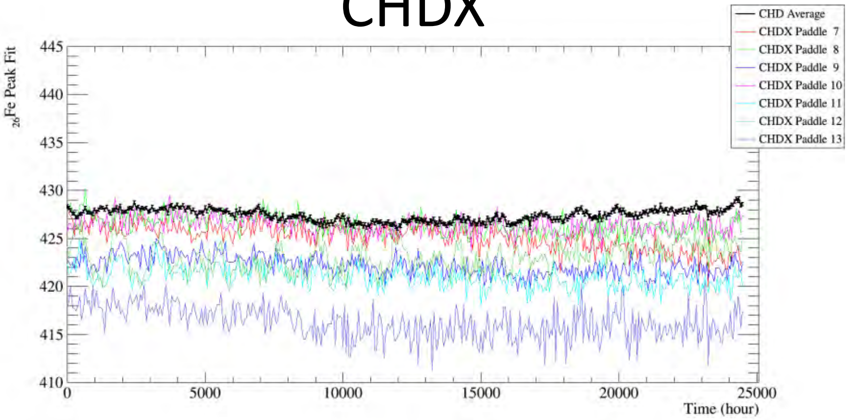
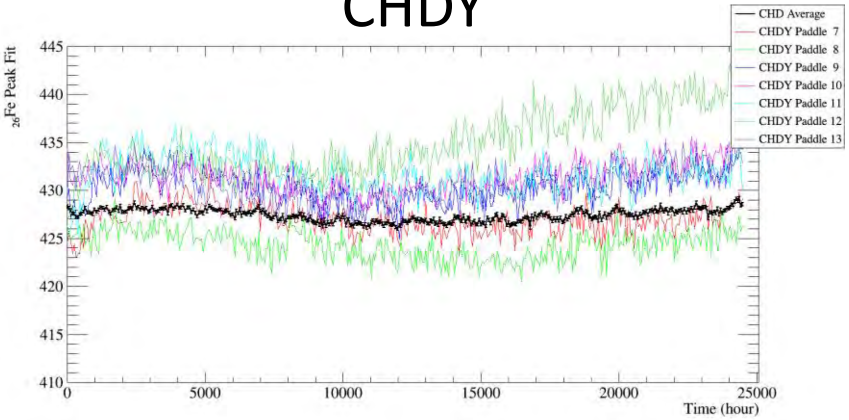
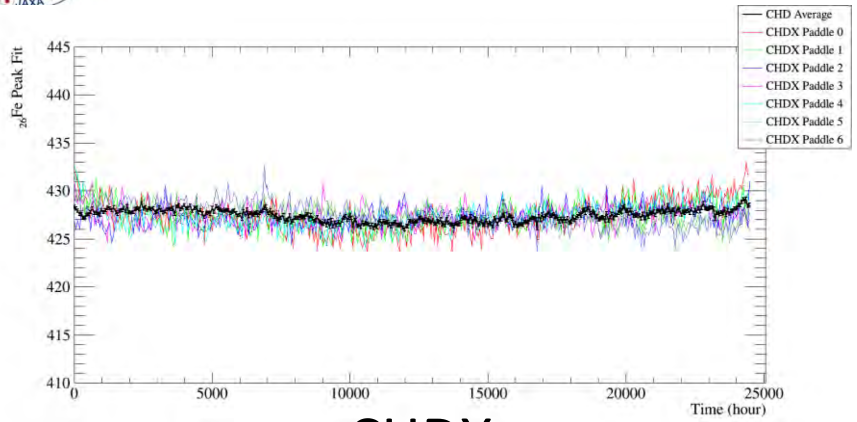
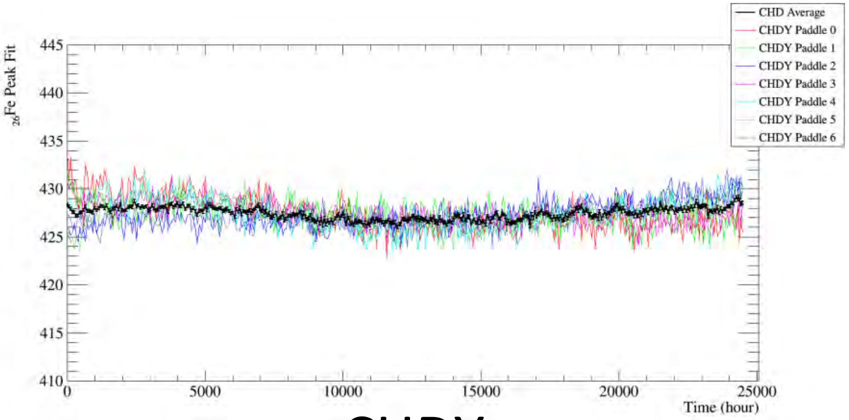




Corrected Time Contours





CHDX

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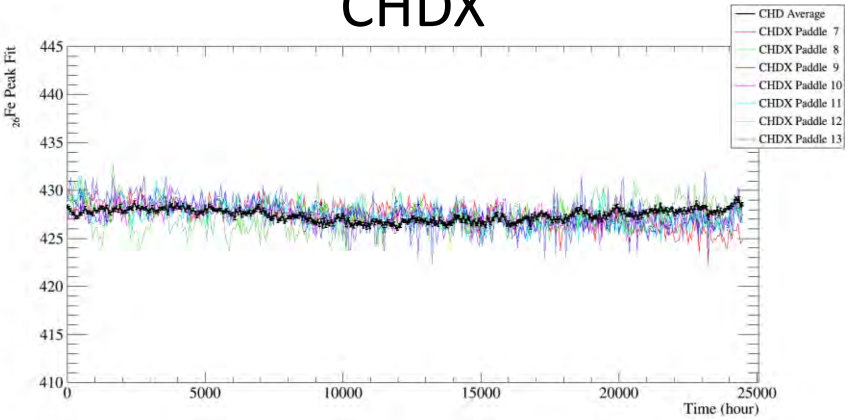
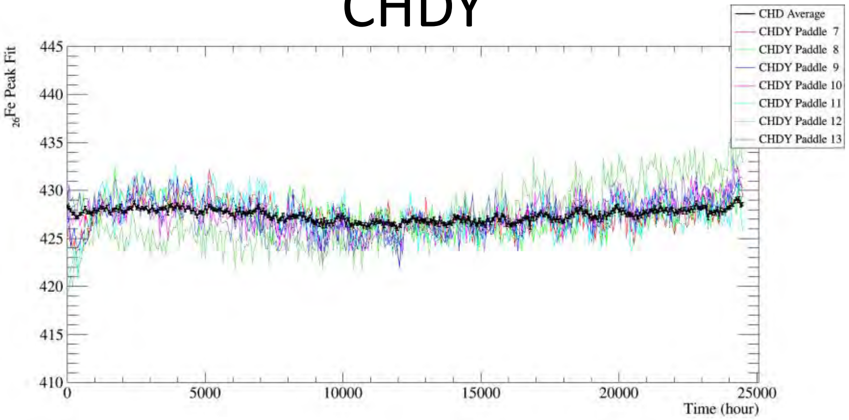
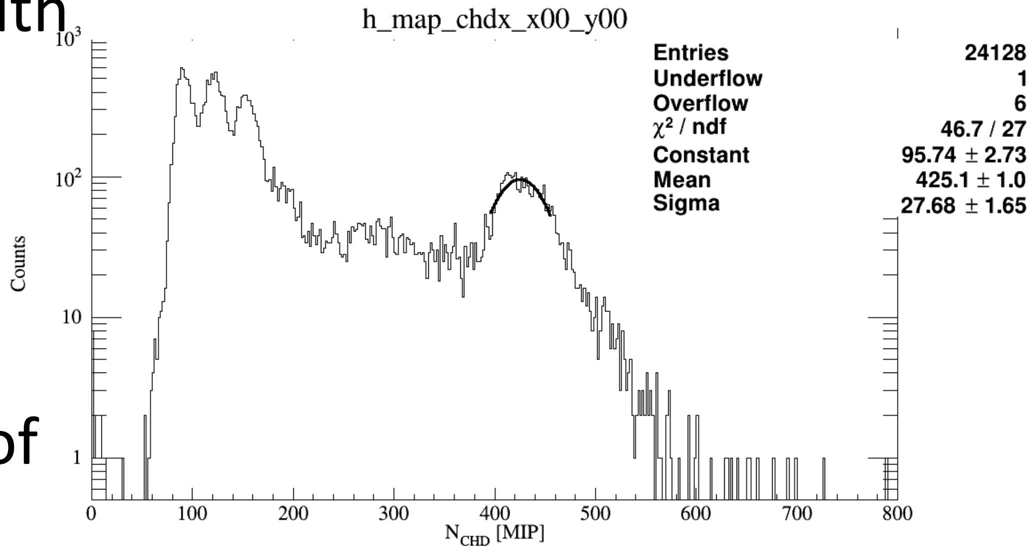




CHD Position Correction Method

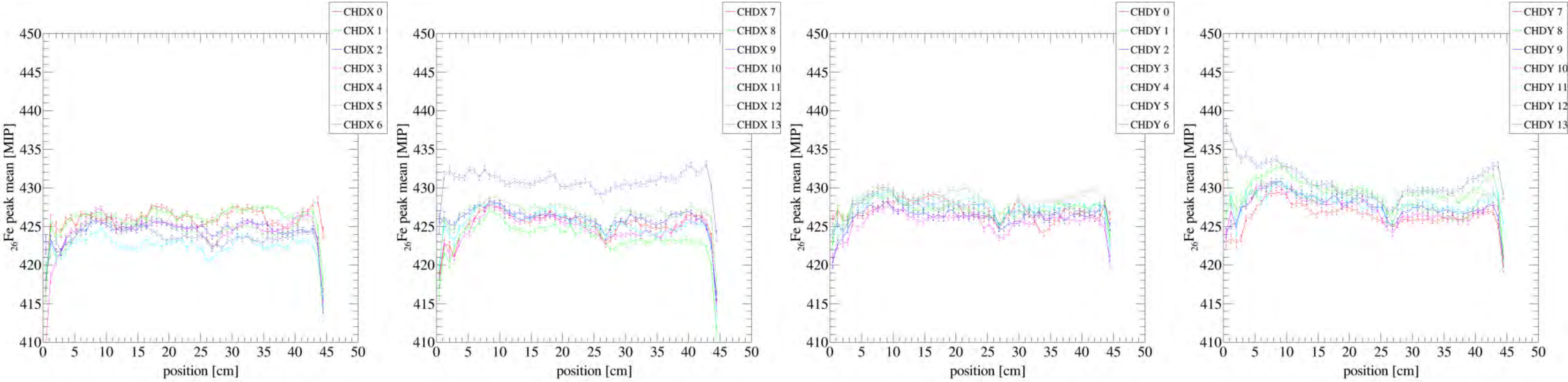
- CHD paddles divided into thirds of the paddle width (1.07 cm) segments
- $_{14}$Si and $_{26}$Fe peaks fit with Gaussian for each segment
- CHD paddle signal multiplied by the ratio of each layer mean to the segment mean



CHD $_{26}$Fe Position Dependence

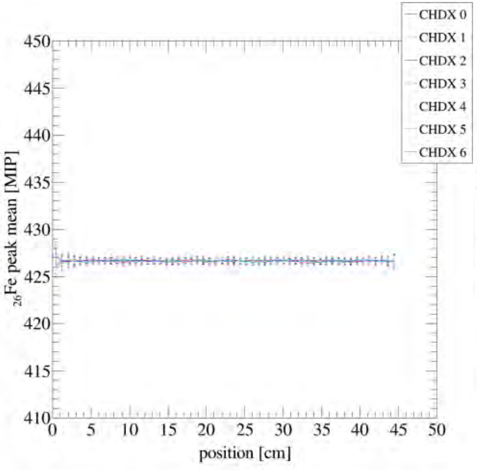
CHDX

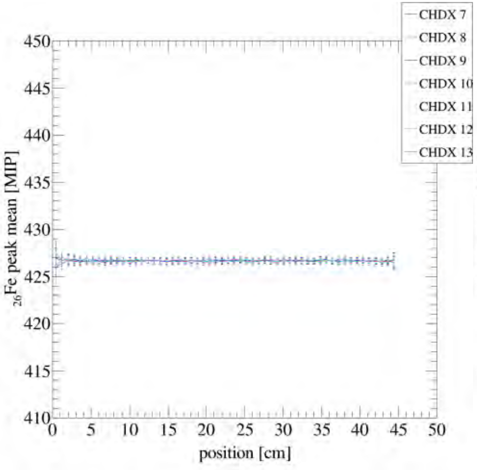
CHDY



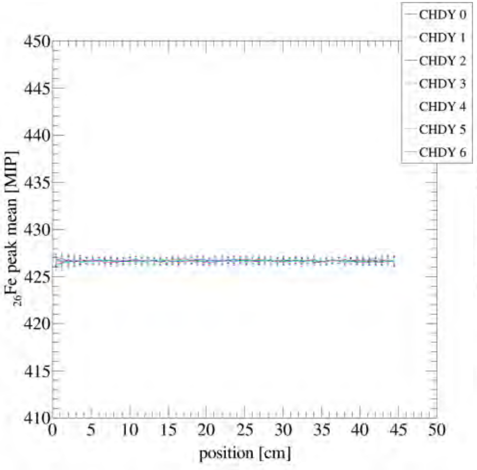
CHD $_{26}$Fe After Position Correction

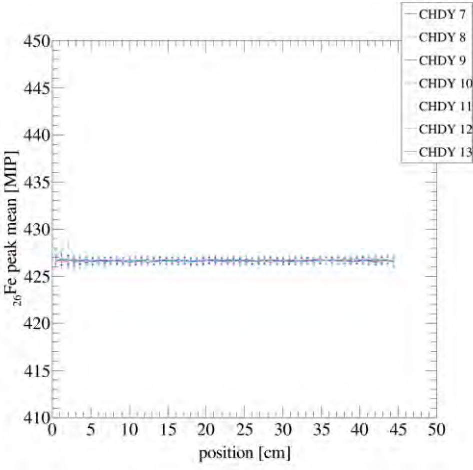
CHDX





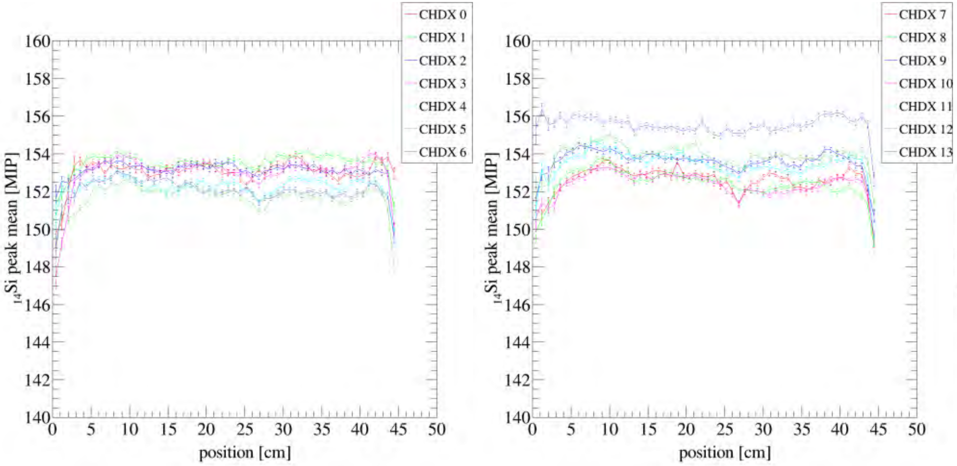
CHDY



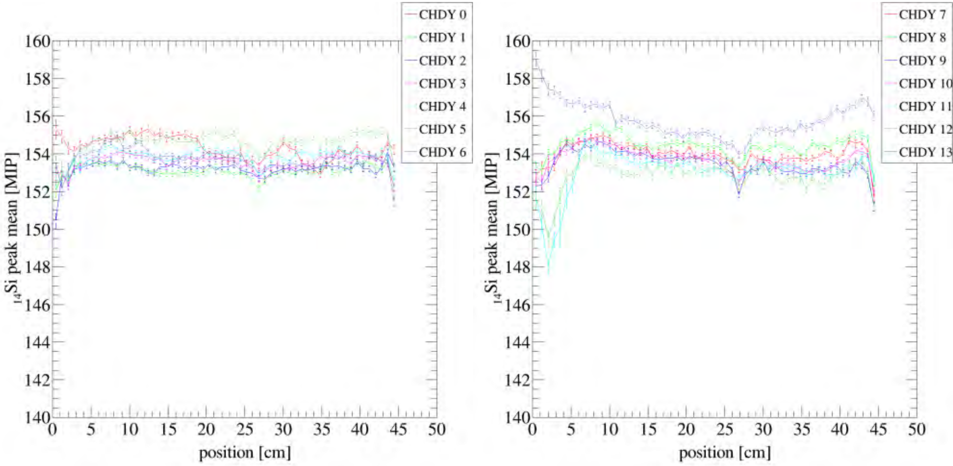


CHD $_{14}$Si Position Dependence

CHDX

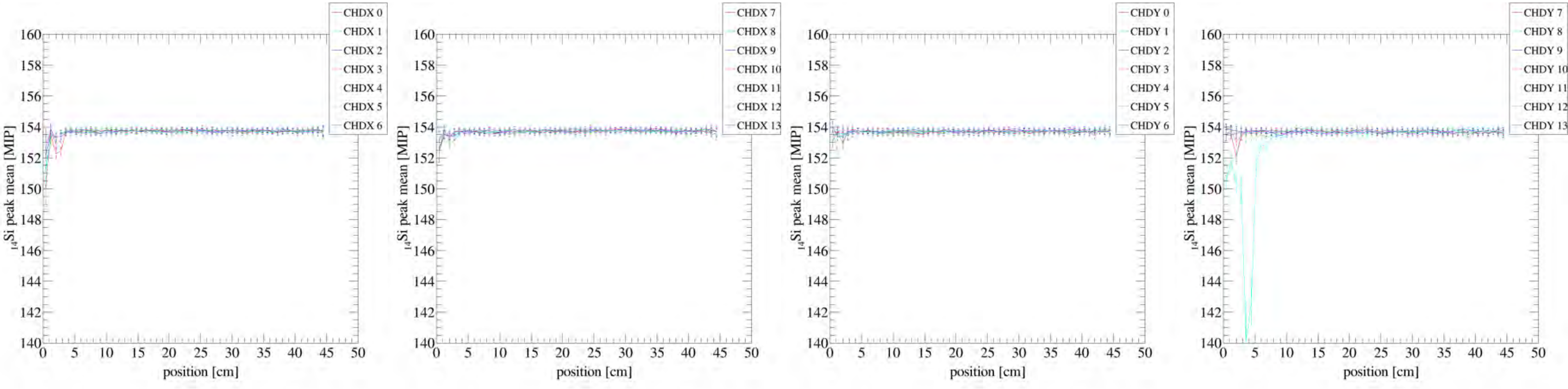


CHDY



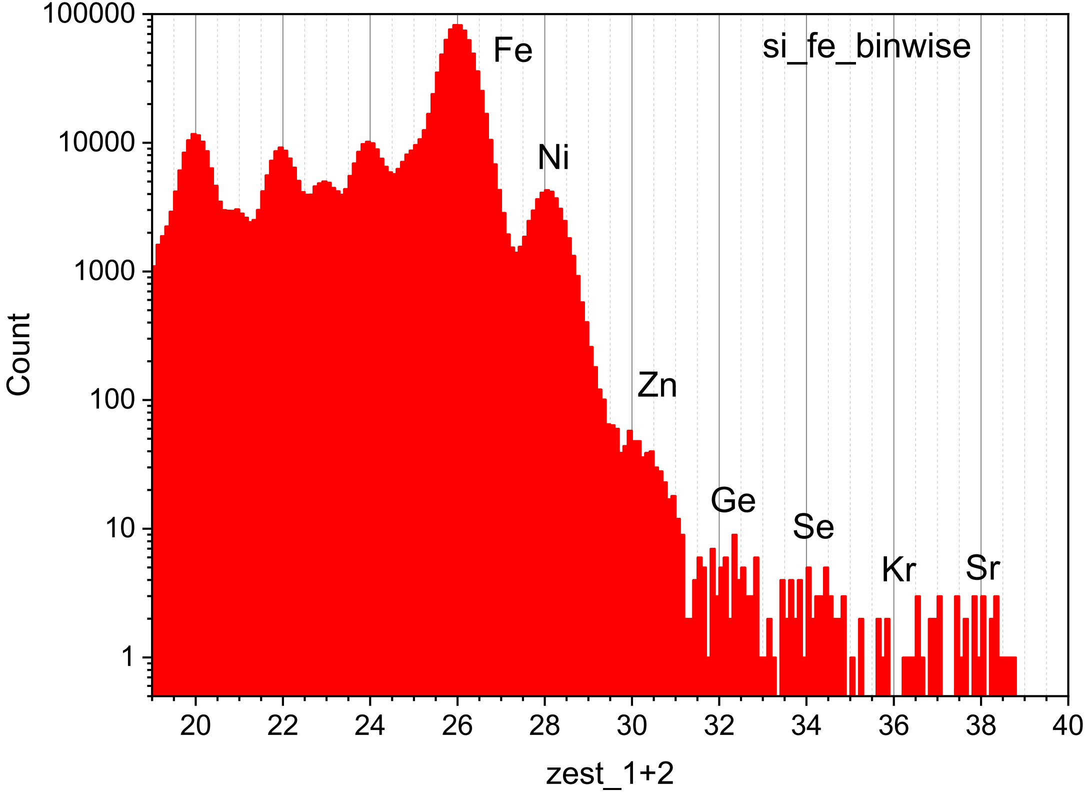
CHD $_{14}$Si After Position Correction

CHDX CHDY



Reduced Dataset Charge Histogram

- Selections on 17 month dataset:
  - Zest > 19
  - Theta < 45 deg
  - STRM > 4.5 GV
  - Z Consistency
  - IMC Energy Correction
- We can clearly see well resolved peaks for $_{32}$Ge, $_{34}$Se, and $_{38}$Sr.
- $_{30}$Zn is more than a shoulder, but is not clearly resolved. Even a small improvement in resolution would help a lot here.
- More statistics should be a major help in better defining the peaks
- Geomagnetic cutoff for each trajectory should help in rejecting low energy particles that are very likely broadening the distributions.



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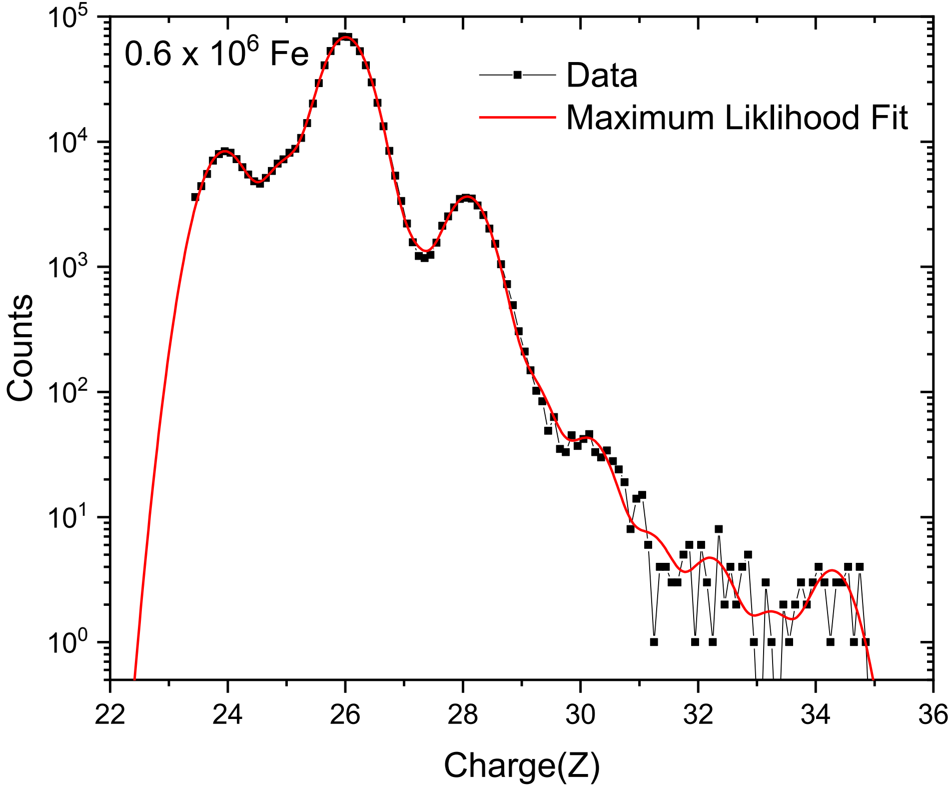
Event Distribution

- To estimate the abundances detected, we used a maximum likelihood fitting routine to fit the data.
- Fits reasonably good up to $_{34}$Se
- For higher charges, the low statistics resulted in poor fits.
- For even-Zs above $_{34}$Se ($_{36}$Kr & $_{38}$Sr) the abundances were initially estimated by taking cuts in the valleys.
- Using SuperTIGER abundances, half of the odd-Zs on either side of the even-Z charge was subtracted off of the $_{36}$Kr & $_{38}$Sr numbers to estimate their abundances.



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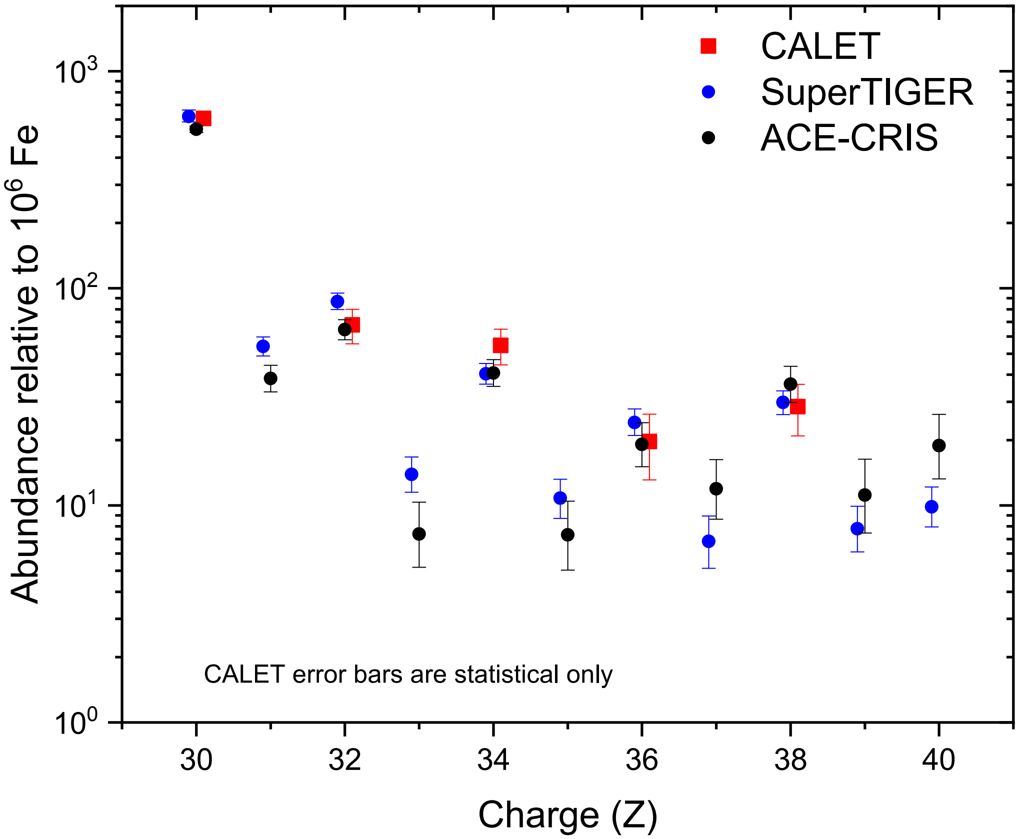
Comparing Relative Abundances

- The ACE and ST data are "in-space" abundances.
- The CALET data have not yet been corrected to the top of the instrument.
  - Those corrections will be small, so they will not change things materially.
- The agreement with ST and ACE-CRIS appears to be quite good.
- Additional data and anticipated improved resolution should result in reduced error bars.



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Summary

- Analysis results have been done on 17 months worth of data.
- Work in progress on ~3 year dataset that should help considerably in better defining the low-statistics peaks.
- At present we are able to resolve even-Z elements $_{30}$Zn, $_{32}$Ge, $_{34}$ Se, and it looks like we have a low-statistics peak at $_{38}$Sr.
- $_{30}$Zn peak is heavily overlapped by the $_{28}$Ni and $_{26}$Fe tails, but fit abundance agrees with other measurements.
- The CALET UH element ratios relative to $_{26}$Fe show good agreement with SuperTIGER and ACE abundances.
- Work that graduate student Wolfgang Zober is doing on cutoff rigidity for every event is expected to improve our resolution in charge by eliminating low energy particles which presently contribute to broadening our resolution in Z.