SuperTIGER Abundances of Galactic Cosmic-Rays for the Charge Interval Z=41-56 (Work in Progress)

Nathan Walsh
SuperTIGER

ICRC July 26, 2019

SuperTIGER Collaboration

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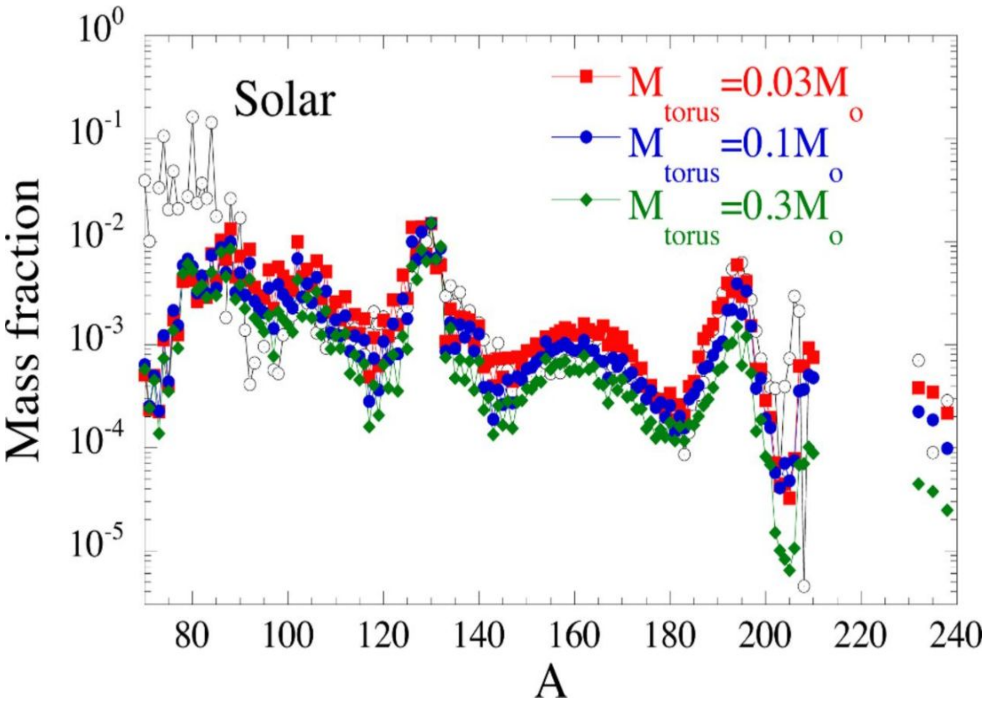
Science Objectives

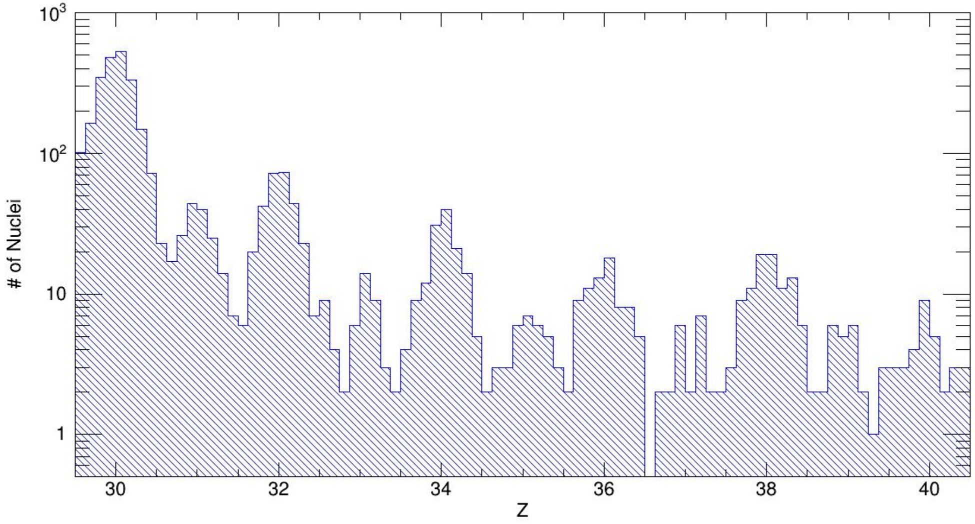
- SuperTIGER measures ultra heavy Galactic cosmic-rays (UHGCR) to test the OB association origin of cosmic rays at higher Z, in which 1) the GCRs are a mix of massive star material and normal ISM, and 2) refractory elements that condense in dust grains are preferentially accelerated compared to volatile elements residing in gas
- It is believed that both supernovae in OB associations and binary neutron star mergers produce r-process nuclei
- With SuperTIGER UHGCR measurements up to Barium (Z=56) we will be able to put constraints on the r-process production models of SNE and BNSM

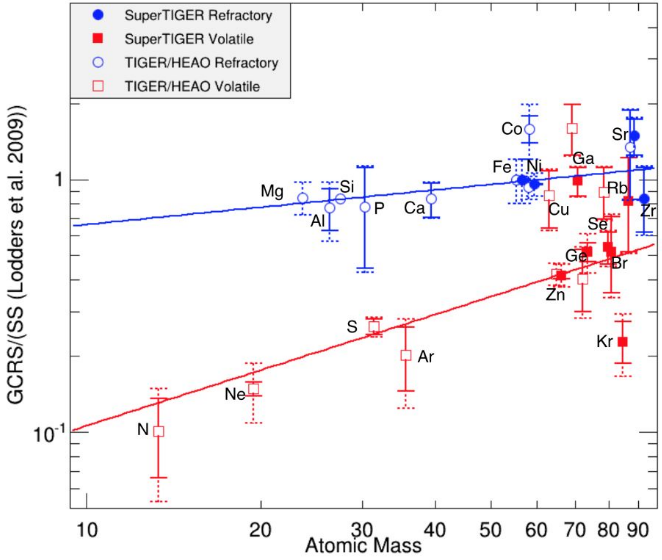


Some models suggest that all of the r-process nuclei could be produced by BNSM (Just et al. 2015)

Goals

- Improve upon the SuperTIGER charge assignment analysis done by Murphy in the Z=30-40 charge range
- Extend the charge assignment analysis to higher charges (up to Z=56)
  - Requires charge assignment to be redone as Murphy's analysis and corrections were designed specifically for the Z=30-40 range





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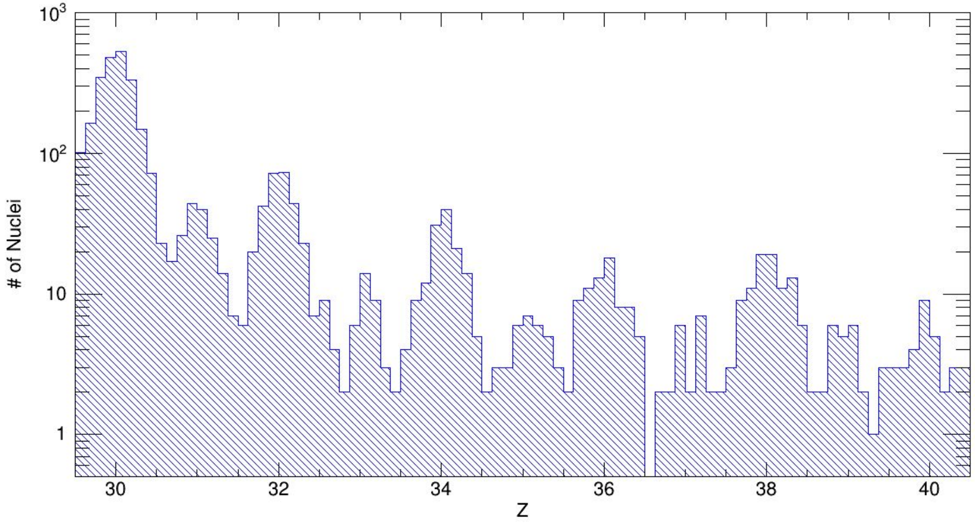
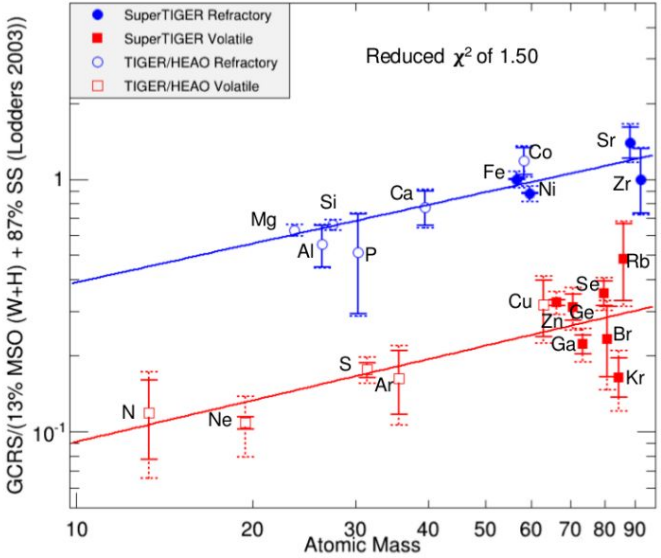
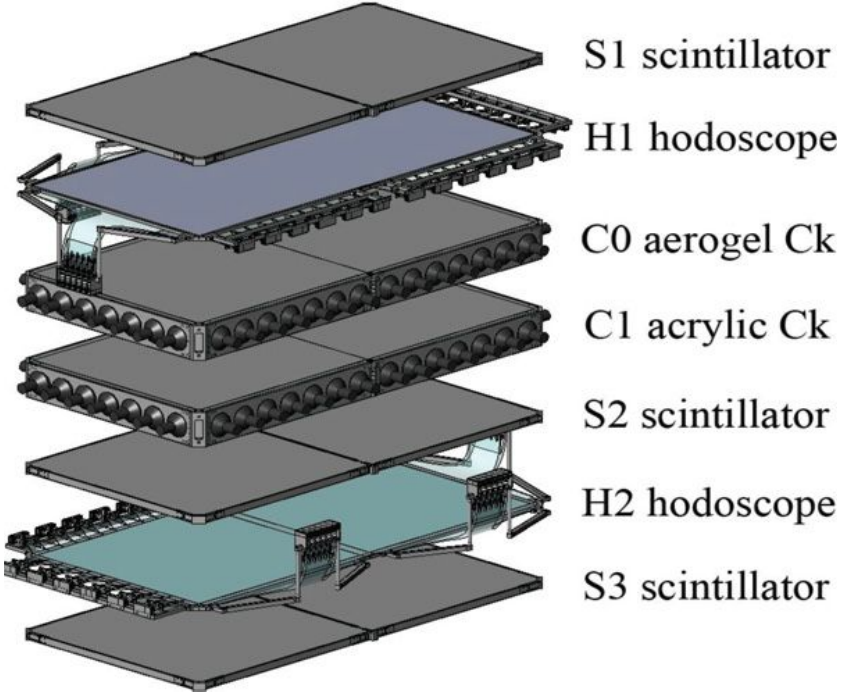


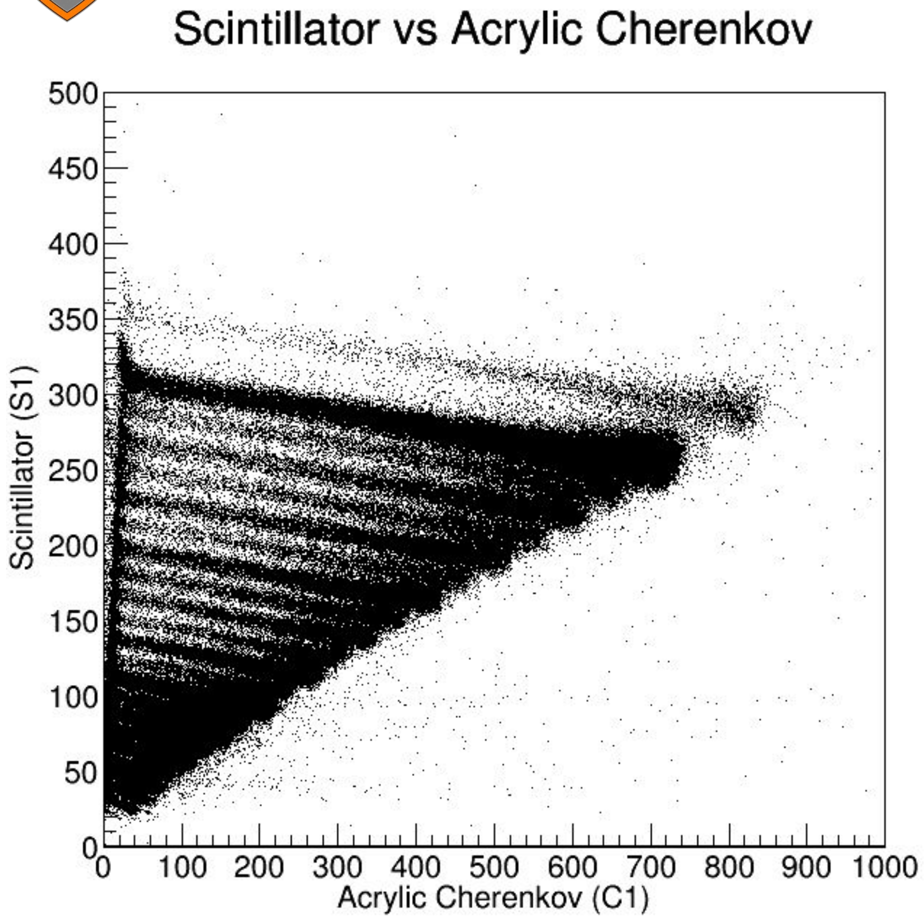


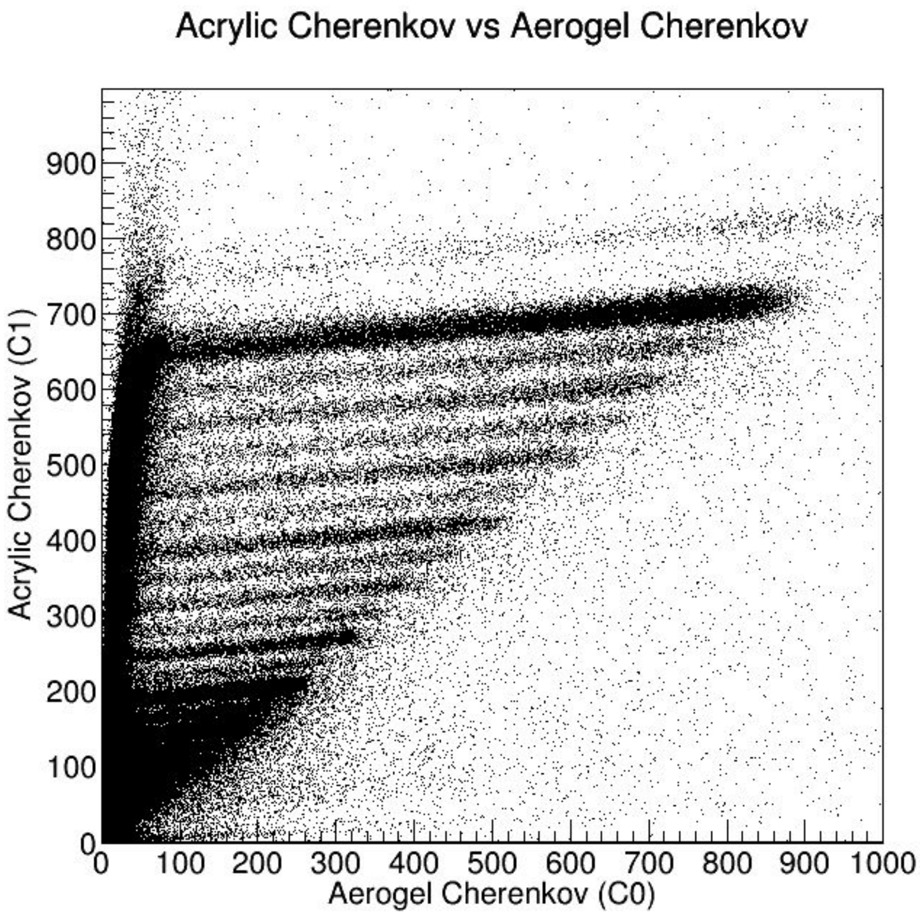
Instrument

- Flown on a long duration balloon from Antarctica
- Composed of 2 nearly identical modules
- GCR pass through entire detector and deposit energy in each layer
- The energy that is converted into light is measured by PMTs
- The sum of the PMT signals in each detector are used to derive the charge of each particle
  - $C \sim Z^2$ $S \sim Z^{1.7}$

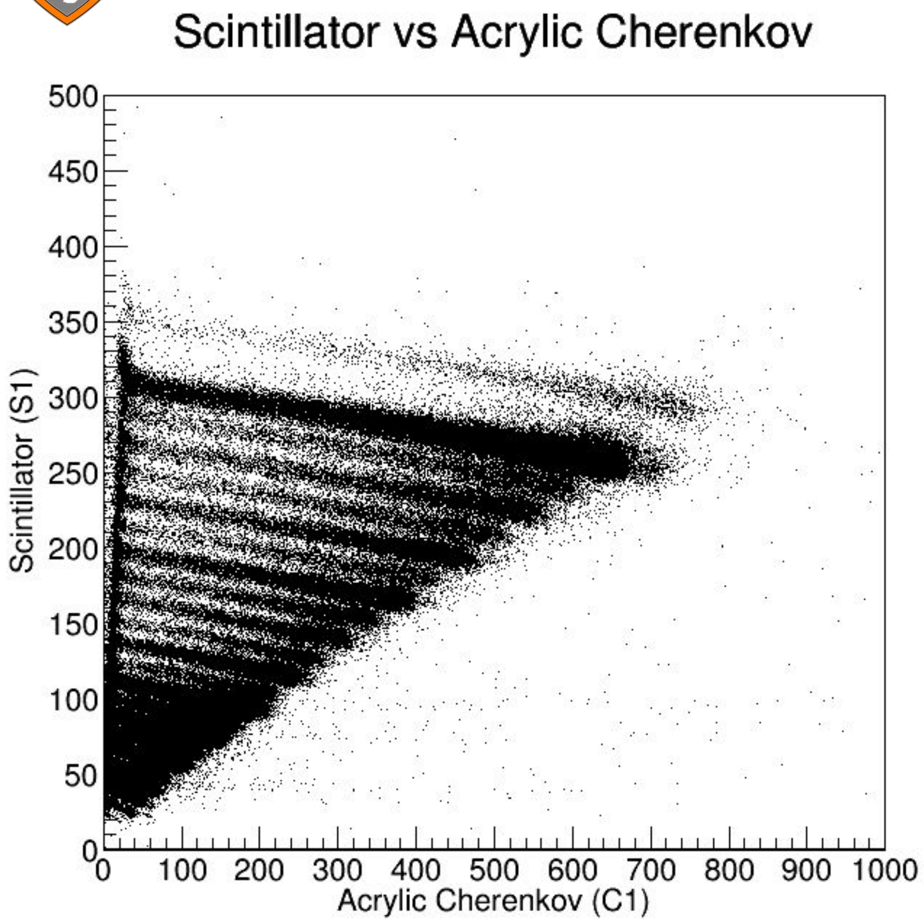


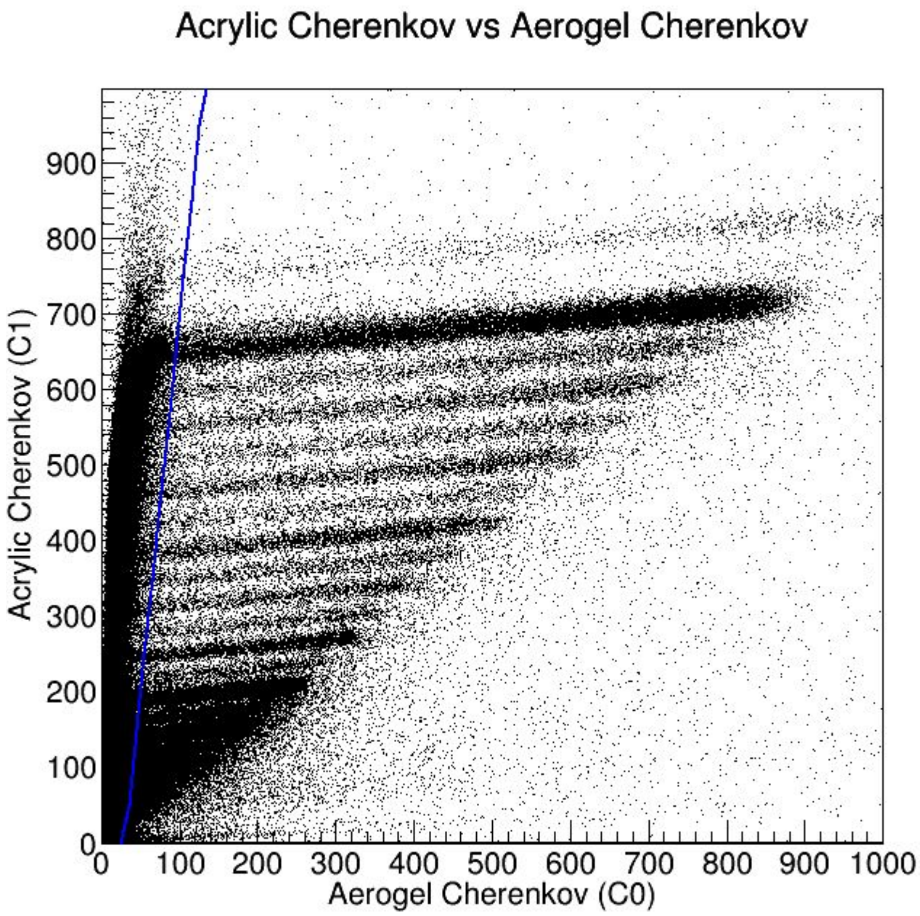
Signal Crossplots





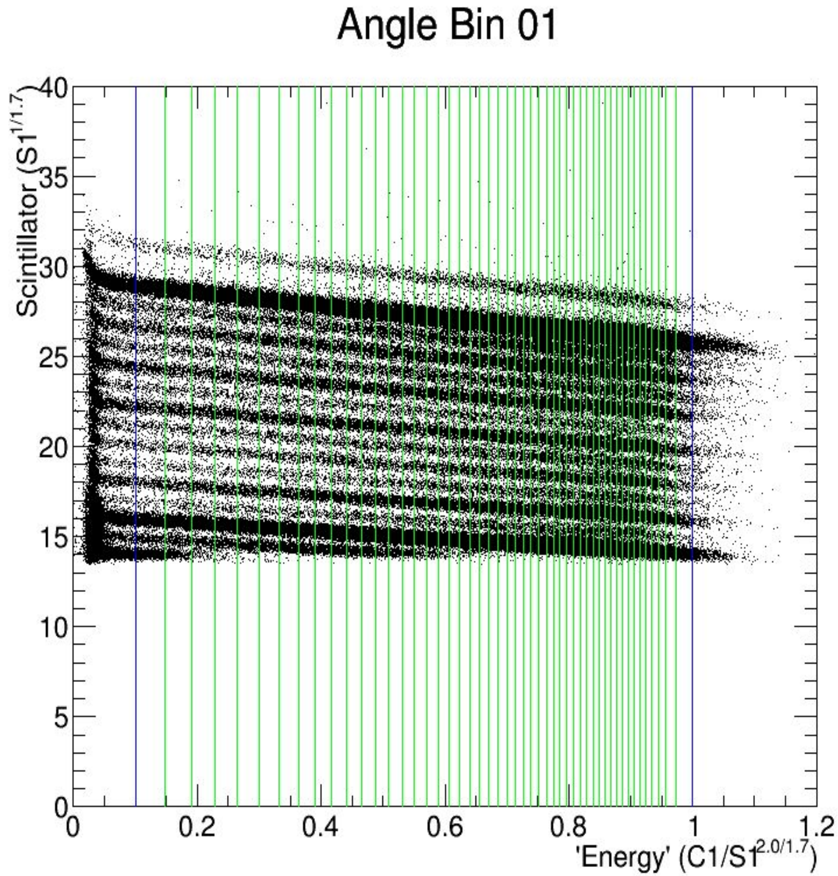
Aerogel Threshold Cut





Below C0: Scintillator vs Energy

- New method developed to treat particles with energy below the C0 threshold
- Plotting S signal vs our energy parameter for every angle bin allows us to find a fit to each charge band
- This is easier because it allows extrapolation up to the higher charges within each energy bin rather than for the particles that fall between lines of constant energy
- Each energy bin is then projected onto the y-axis to extract S1 peaks



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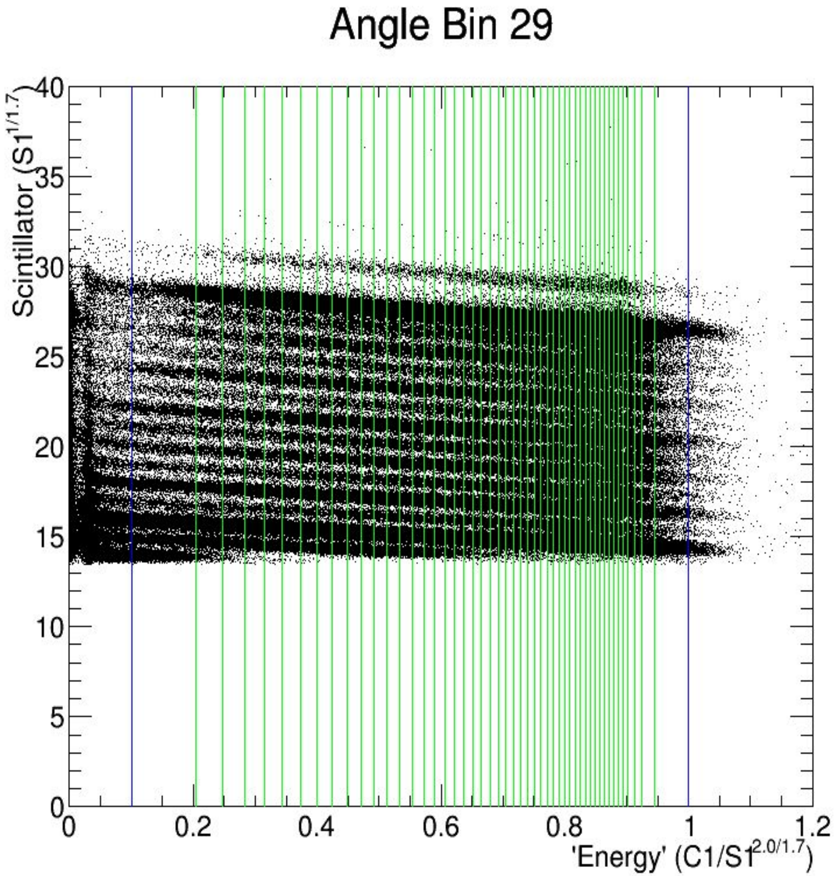
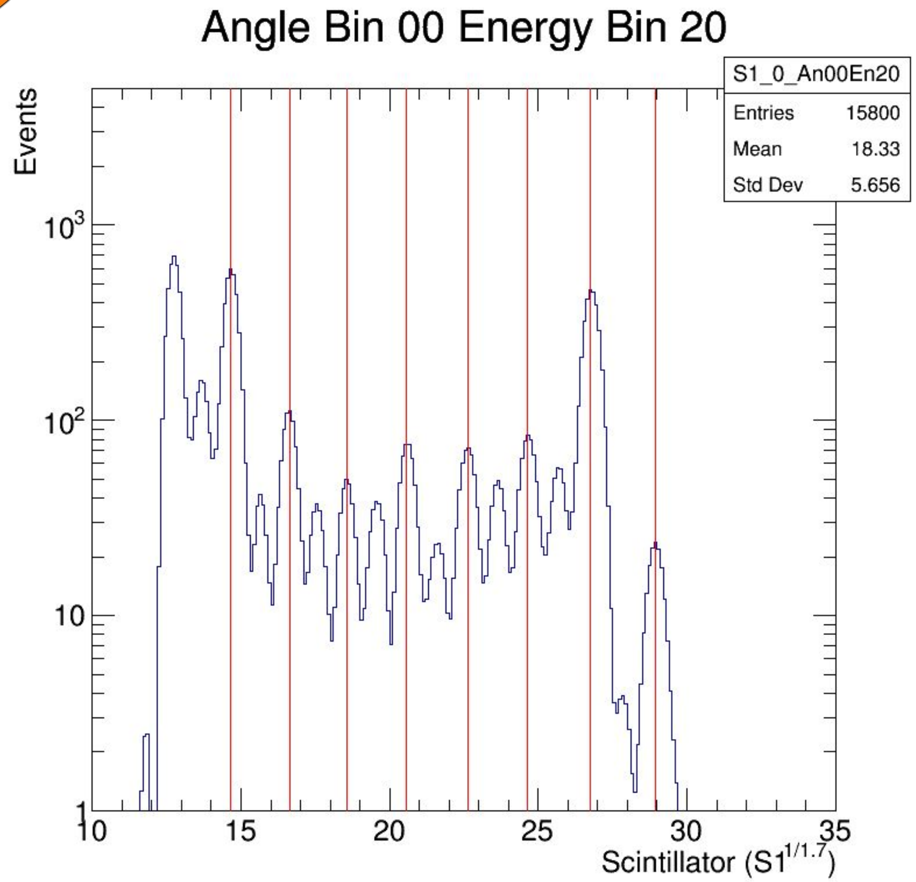
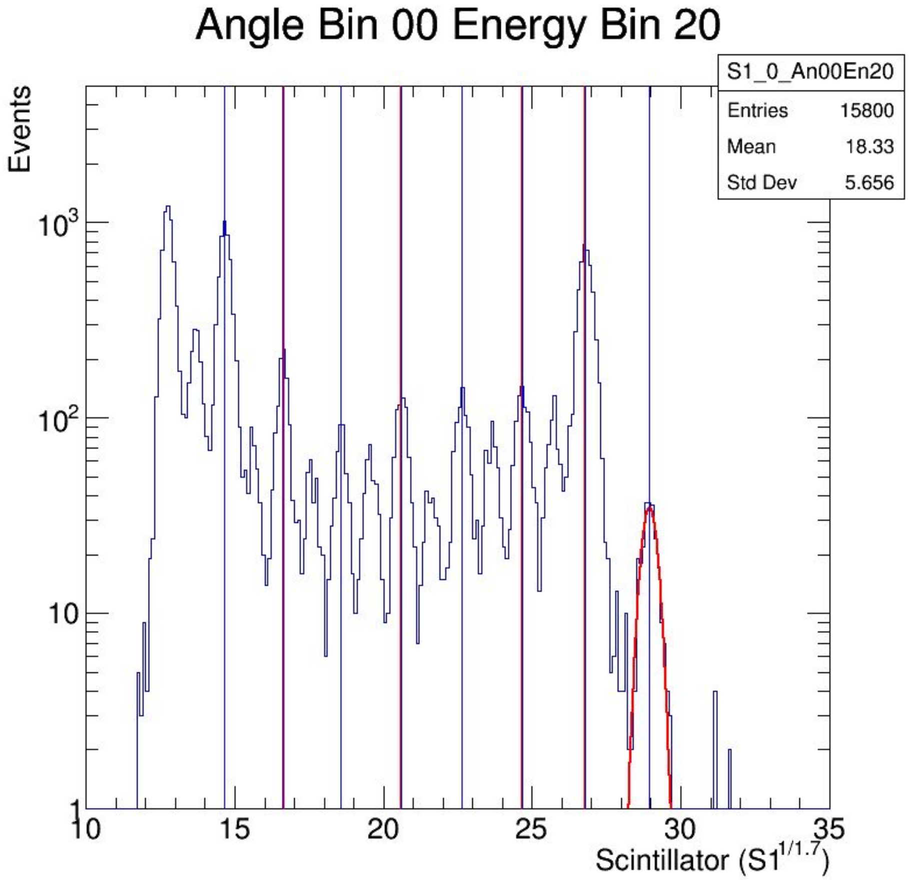


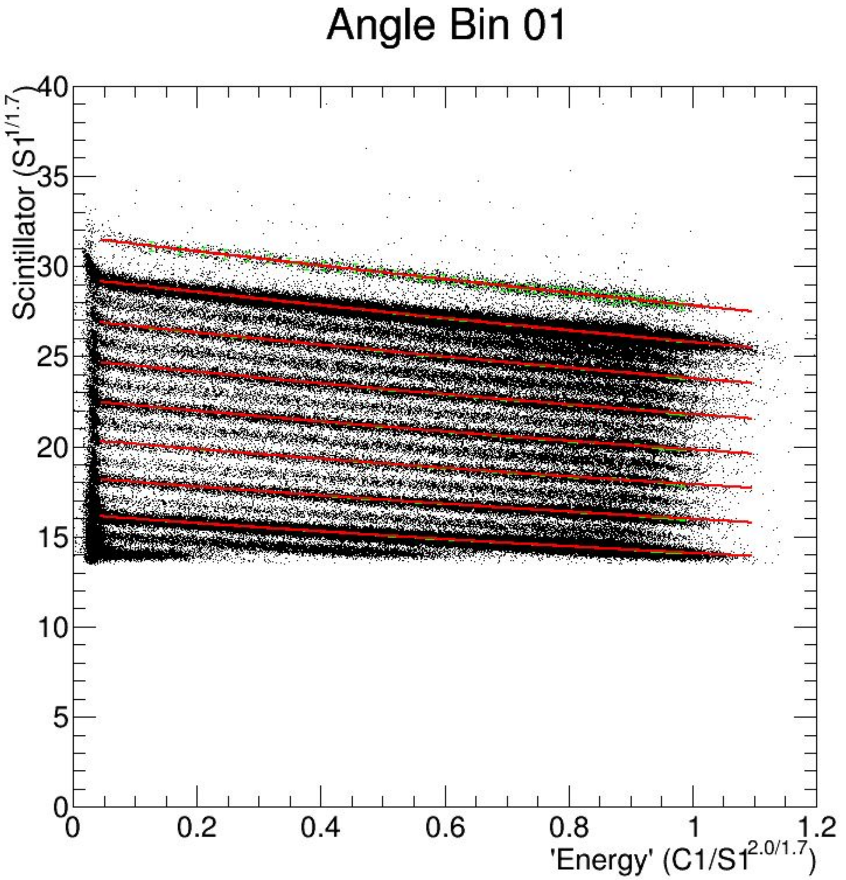
Peak Finding and Fitting





Scintillator vs Energy

- S peak positions are found for each even peak corresponding to a known element
- The peak positions are plotted for each energy bin within an angle bin and fit with a second order polynomial to model the shape of each charge band as it depends on energy
- Because we know how each even charge band depends on energy for a given angle bin we now have a good approximation for how S changes as you move from band to band



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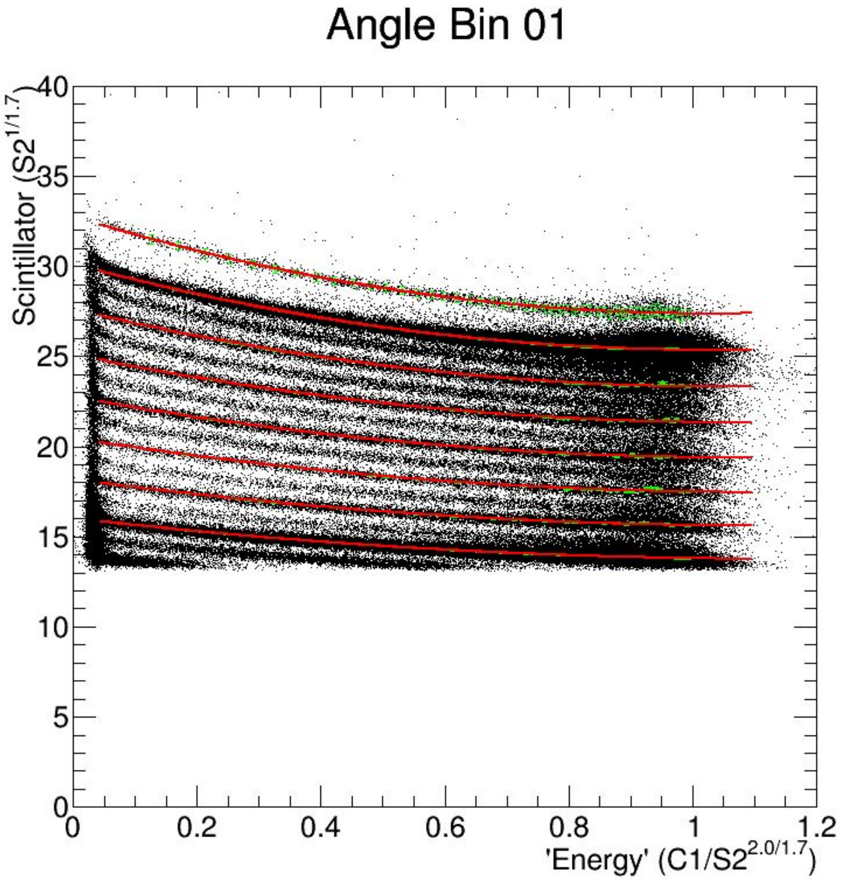
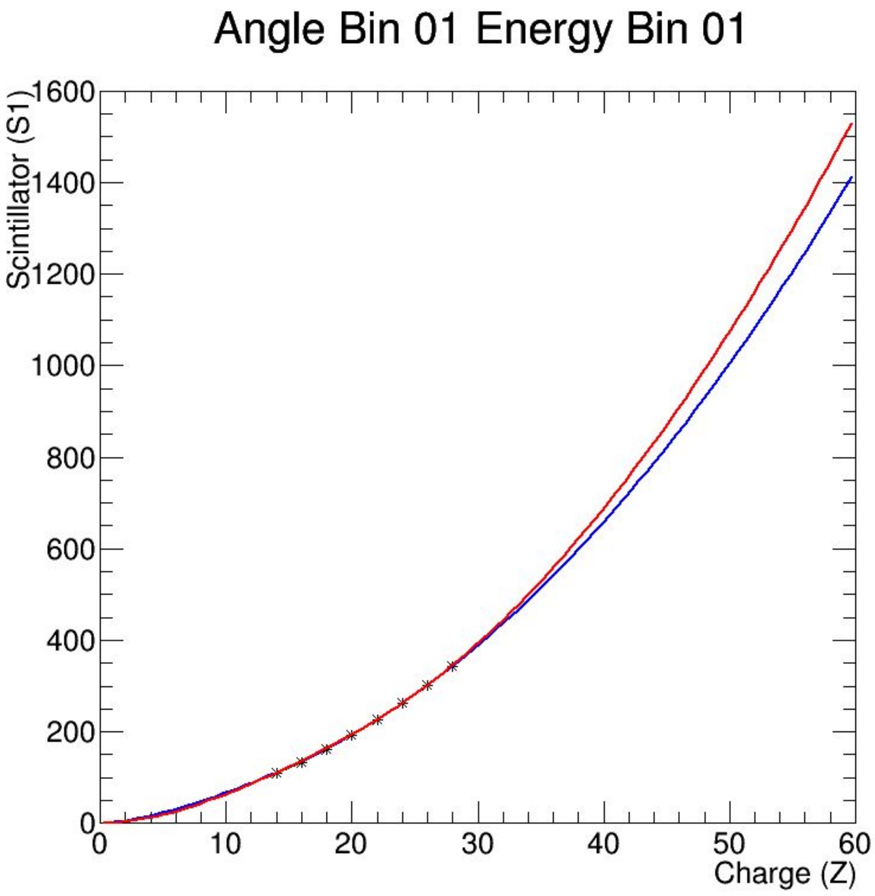
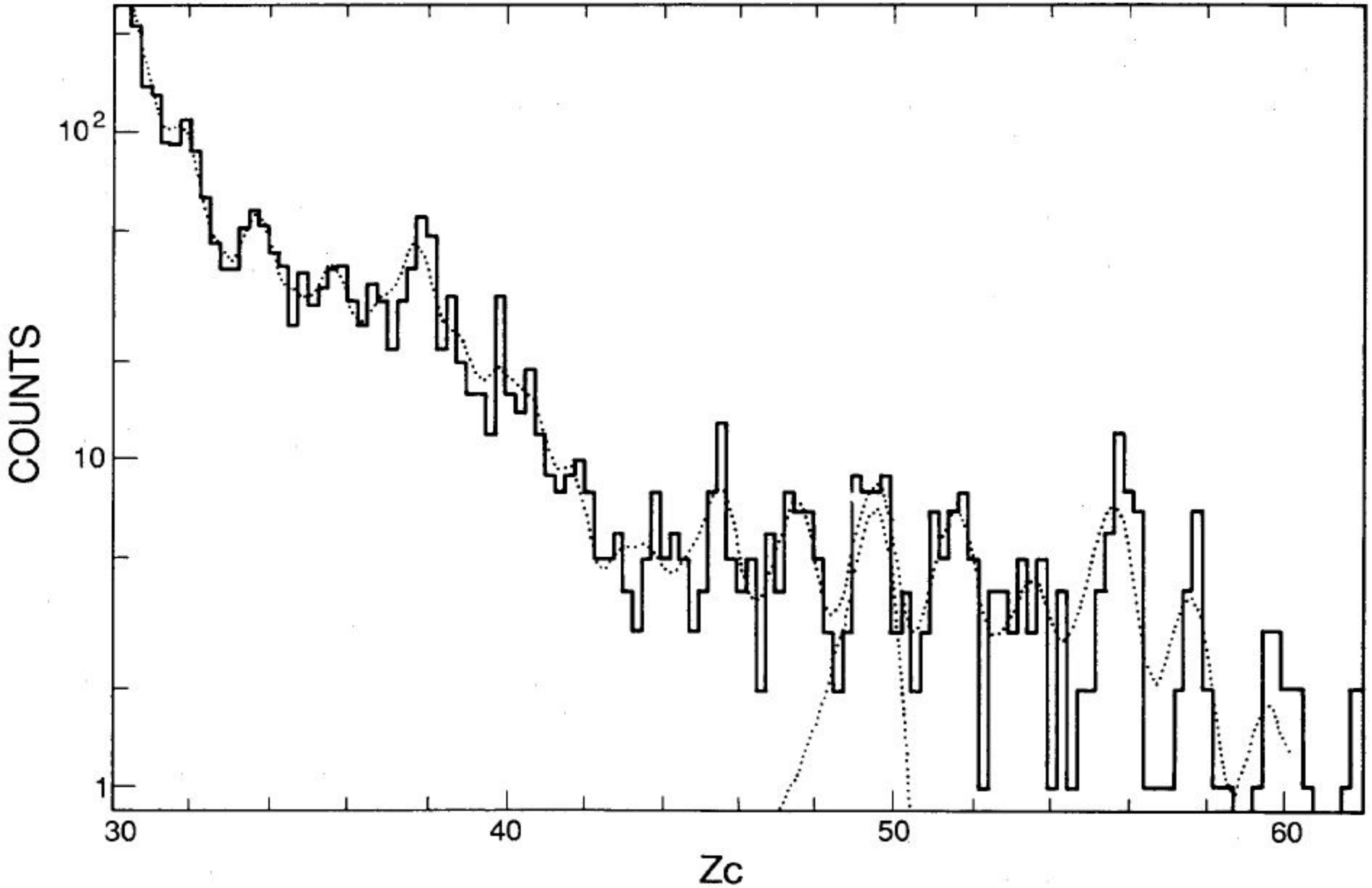


Saturation Model Fitting

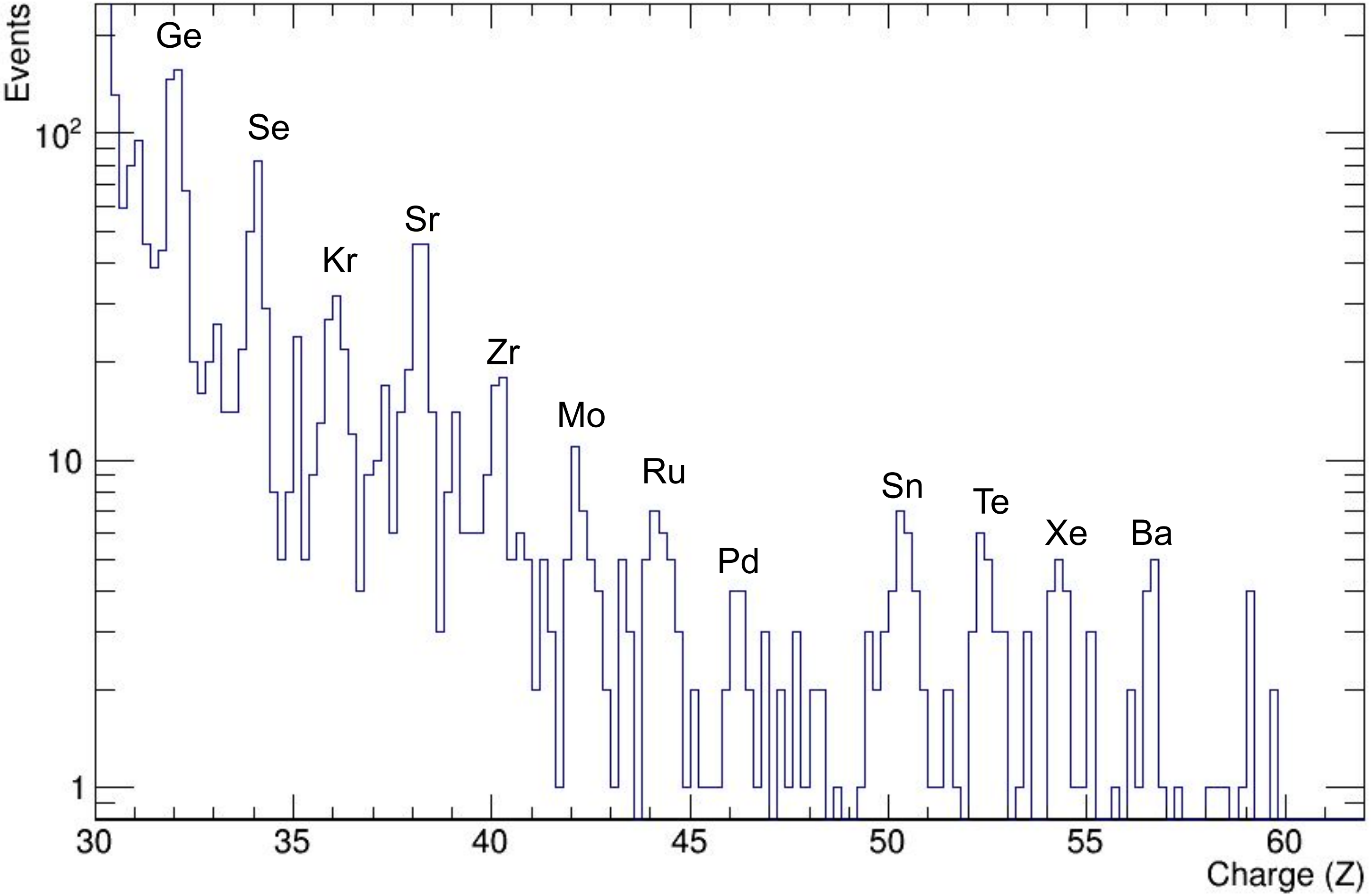
- Saturation models are fit to SvsZ plots in each angle and energy bin and extrapolated to the higher charges where are not sufficient statistics to form charge bands
  - Red = Voltz: $S = AZ^2+BZ^2\exp(-CZ^2)$
  - Blue = Tarle: $S = AZ^2/(1+BZ^2)+CZ^2$
- For all angle and energy bins we can determine the charge of a particle based on its S signal
- To improve resolution the charges determined by the S1 and S2 signals are averaged



Best Published 41≤Z≤60 Measurement: HEAO-3-HNE (Binns et al. 1989)



Preliminary Instrument Level Combined Above & Below C0 Charge Histograms



Further Work

- Propagation of instrument level abundances to top of the atmosphere and then back to the source to achieve GCRS abundance measurements
- Apply analysis technique to 10 days of low charge data on recovered SSDs
  - Telemetry data is subject to a high priority selection bias for lower charges (Z<24)
    - Will enable more accurate analysis of lower charges
  - We plan to cover the entire charge range measurable by SuperTIGER (Z=10-56) using only ST data from a single flight
- Apply analysis to SuperTIGER-2 data which we will collect in a flight planned for the Austral summer of 2019-20 (3rd season is the charm!)
  - The 2018-19 flight lasted under 7 hours during which ST-2's maximum altitude of 79,300 ft was and so no data was collected

Acknowledgements

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We thank the NASA Columbia Scientific Balloon Facility, the NASA Balloon Program Office, and the NSF United States Antarctic Program for the excellent and highly professional efforts that resulted in the record long-duration balloon flight for SuperTIGER and the successful recovery effort.

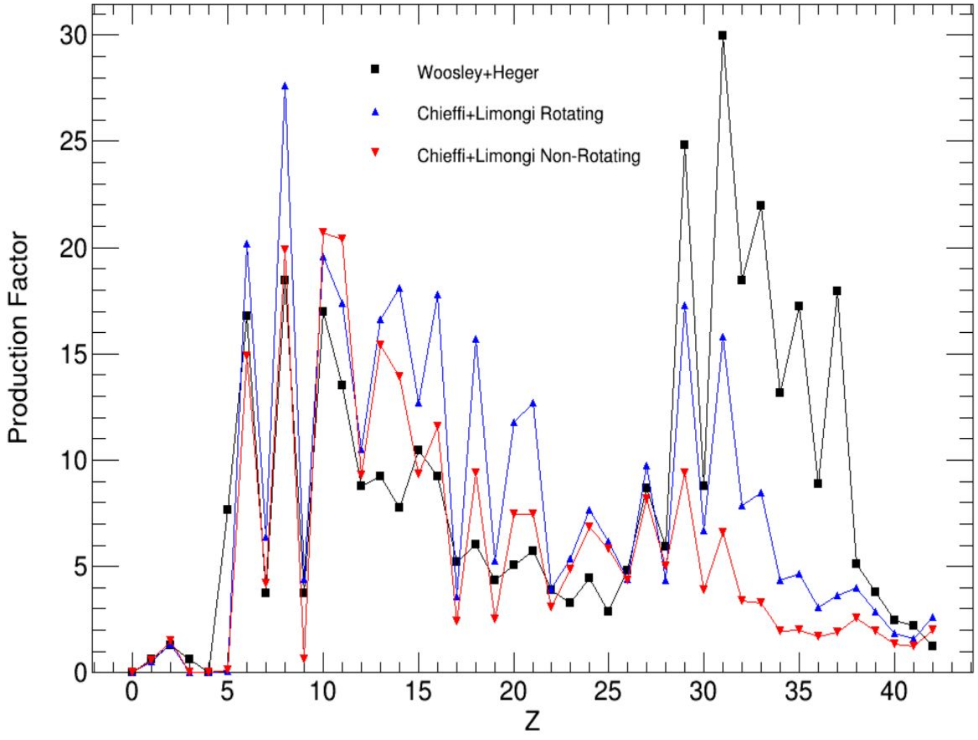
Backup Slides

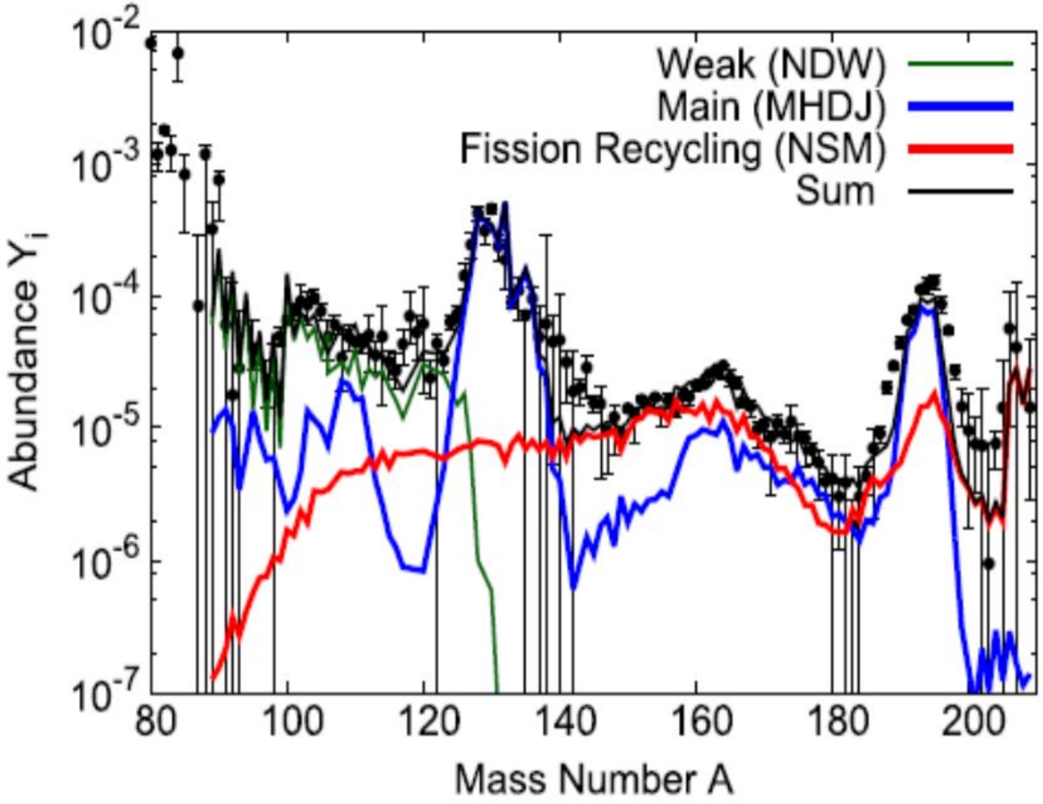
- Method
- Other Production Models
- ST2 recovery and status (slides by Brian Rauch)

Method

- For events with energy above the C0 threshold (Above C0), a cross plot of acrylic vs aerogel Cherenkov signal shows that events separate into charge bands
- For events with energy below the C0 threshold (Below C0), a cross plot of scintillation vs Cherenkov signal shows that events separate into charge bands
  - We are interested in charge range where we do not have a sufficient number of events to see the charge bands so we need to extrapolate from the ones that we can see
- To do this extrapolation we use models that estimate how scintillation light depends on the charge of the particle for a given energy
  - These models can be fit to a SvsZ plot so we must determine the S value in a given energy bin for each charge band we can see
- The model parameters can then be found for every angle and energy bin and used to determine the charge of particles that fall into these respective bins

Production Models

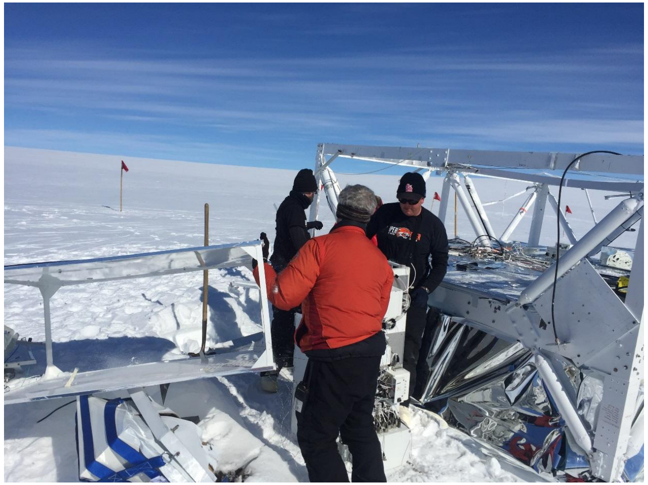




right: Shigaki et al. 2016

ST-2 2019 Recovery

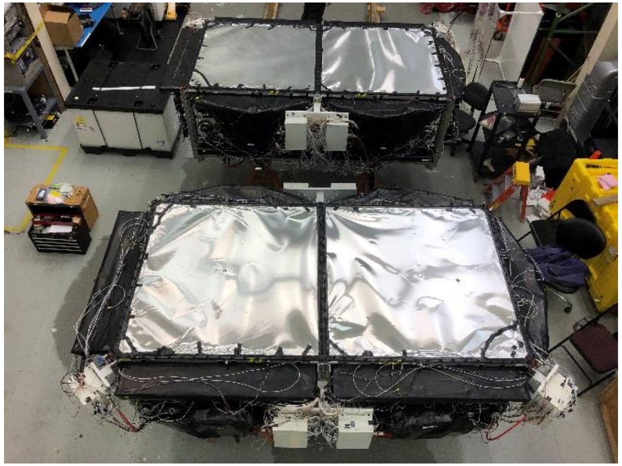
- Payload recovered in 3 days of field operations from McMurdo Station
- Two days with team of 4 supported by 2 Bell 212 helicopters:
- January 8 perform high priority recovery of attached hardware
- January 10: gondola and 2 instrument modules slung to Basler site
- January 11 team of 6 supported by a Basler breakdown and recover payload

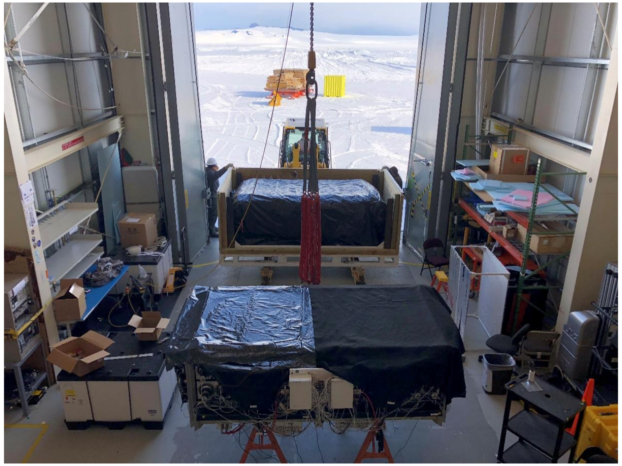


ST-2 Post-Recovery Status

- Instrument models were stacked, wired up and tested at LDB prior to shipment
- 96% of 552 electronics channels could be tested, all of which performed as expected for pedestal, LED and muon calibrations
- Remaining 4% could not be tested because of damaged cables or bulkhead connectors
- Damage mostly confined to top scintillator detectors

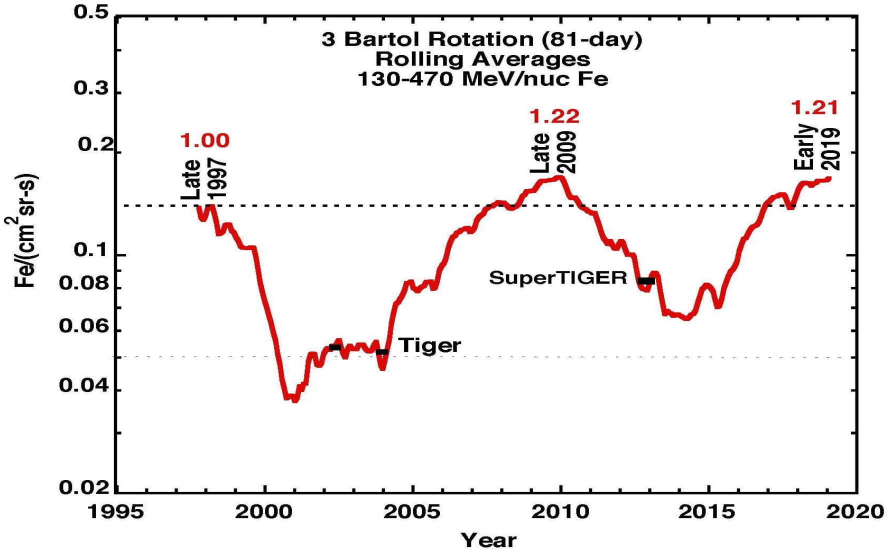
*Current Status: ST-2 is currently at CSBF in Palestine, TX for hang test





Favorable Solar Modulation

- Recently we have seen the lowest levels of solar activity in the space age
- Reduced solar wind strength allows more of the cosmic ray flux through
- 60 days of ST2 now would be ~1.7x 55 days of ST1
- Cosmic-ray intensity is nearing its cycle maximum
- Now is a very good time to fly SuperTIGER



Intensity of cosmic-ray iron nuclei detected by ACE as a function of time. The present solar minimum intensity is essentially equal to that of the space-age historic solar minimum in 2009. Note that the TIGER and SuperTIGER-1 flights occurred at considerably lower intensity levels.