Calibrating the CAL in flight: Galactic Cosmic Ray Calibration

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Overview

- Data Collection
  - Charge injection for electronics
    - Similar to tests on the ground
  - Galactic Cosmic Ray (GCR) heavy ions for crystals
- Simulation
  - Additions to GLEAM
  - Results of initial studies
- Analysis
  - Analysis procedures
  - Structure within GLEAM

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GCR Summary

- GCR Calibration
  - Similar in principle to muons on the ground
  - Tagged by “CNO Flag” onboard
  - Collected in parallel with science data
  - ~MIP energies
  - $dE/dx \propto Z^2_{particle} \Rightarrow$ much larger energy deposition available than for Z=1 muons or protons
  - Species abundances (for the important ones):
  - Range of:
    - C (2 GeV/n) 440 g/cm^2
    - Fe (2 GeV/n) 110 g/cm^2
    - CAL contains 72 g/cm^2 of CsI (vertical incidence)
    - $\Rightarrow$ only highest Z species and or GCR at high incidence will stop in CAL

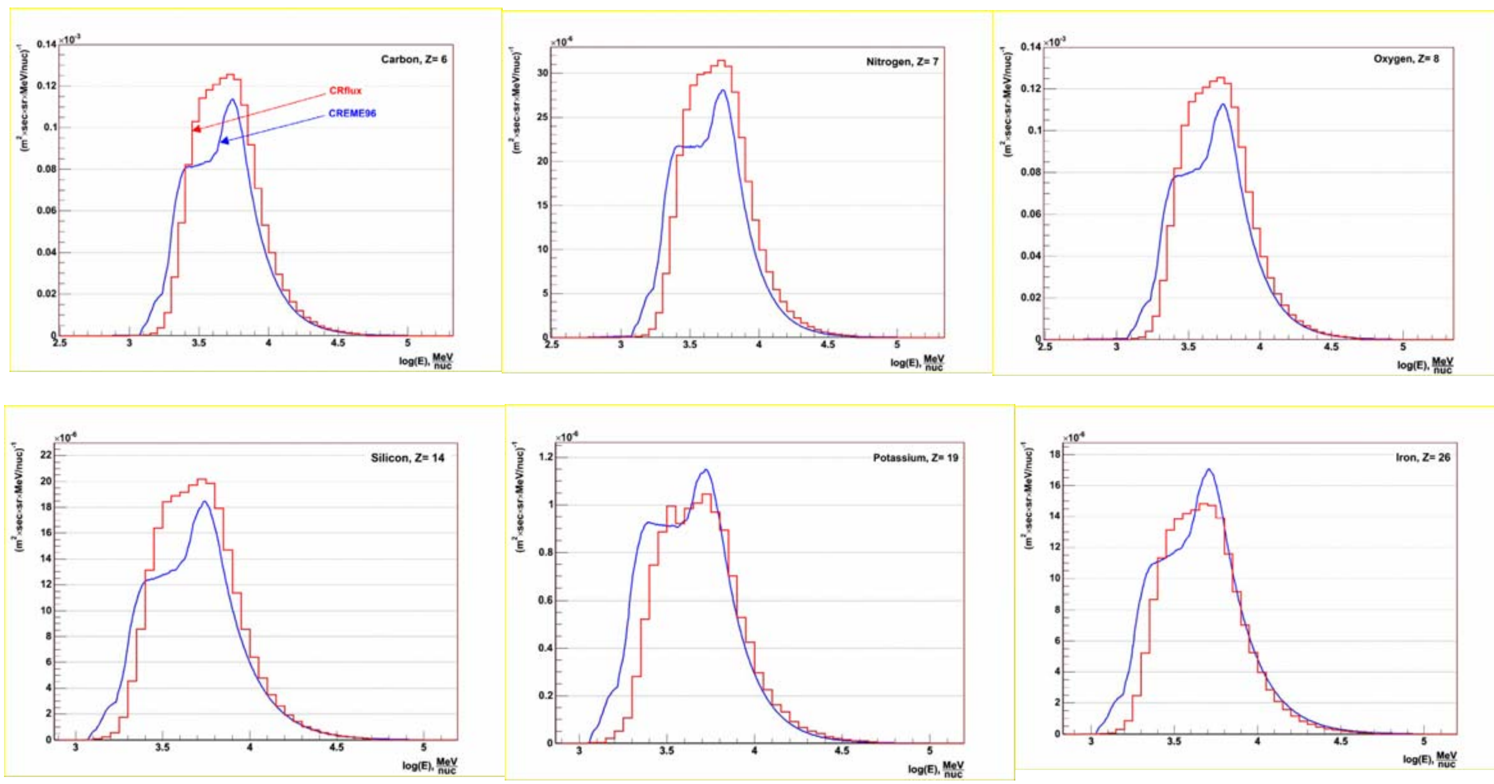
Species (Z)	Abundance Relative to H	Enormal (MeV)*
He (2)	14%	45
C (6)	0.38%	400
N (7)	0. 096%	550
O (8)	0.35%	720
Ne (10)	0.062%	1120
Mg (12)	0.073%	1610
Si (14)	0.054%	2200
Fe (26)	0.041%	7600

* Does not include quenching effects

Range	5-σ Emin (MeV)	Emax (MeV)	MeV/ADC
LEX8	2	100	0.03
LEX1	2	1000	0.27
HEX8	60	8000	2.2
HEX1	60	70000	19

Simulations – GCR Source

- **Need a GCR heavy ion "gun"**
  - **Benoit produced CRHeavyIonPrimary**
  - **Tested against CREME96**



Simulations – Nuclear Interactions

- **Needed model for nuclear interactions**
  - **Benoit produced nuclear interaction module based on EPAX parameterization of fragmentation cross sections**
    - **Cross sections for production of various projectile fragments**
    - **Ignores target fragments, but they are produced with very low kinetic energy and thus produce local energy deposit**
  - **Comparison of total cross section to published results**

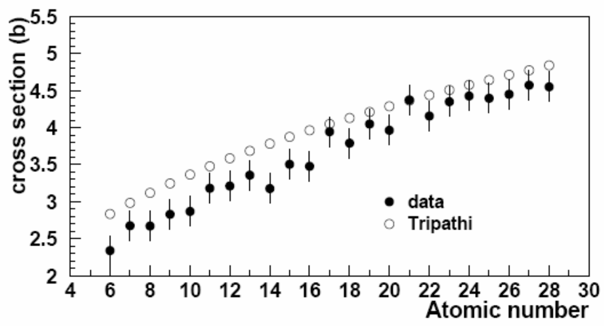
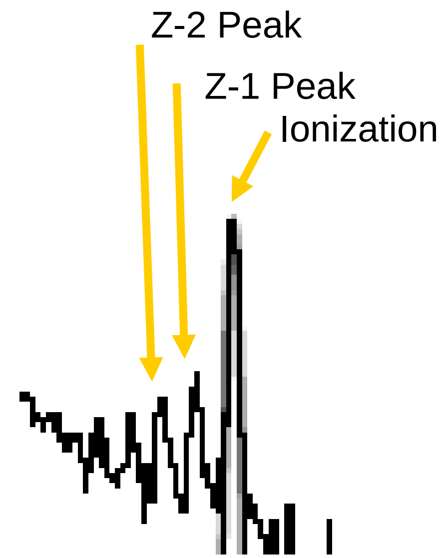


Fig. 16. Experimental cross sections deduced from the decrease in yield of the ionization peak as a function of the ion atomic number (solid dots). The Tripathi cross-sections are shown for comparison (open dots).

Simulations – Nuclear Interactions

- **Production of projectile fragments in nuclear interactions**



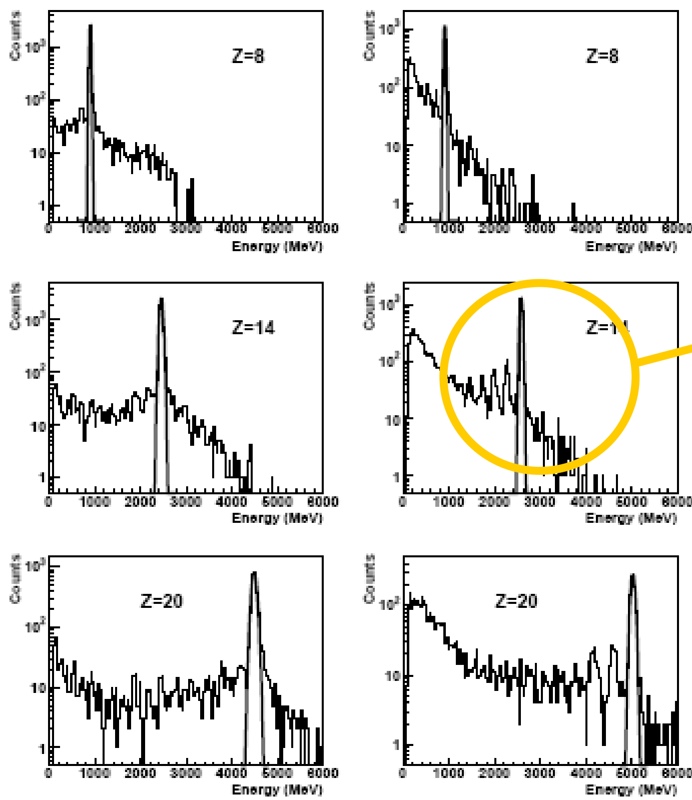
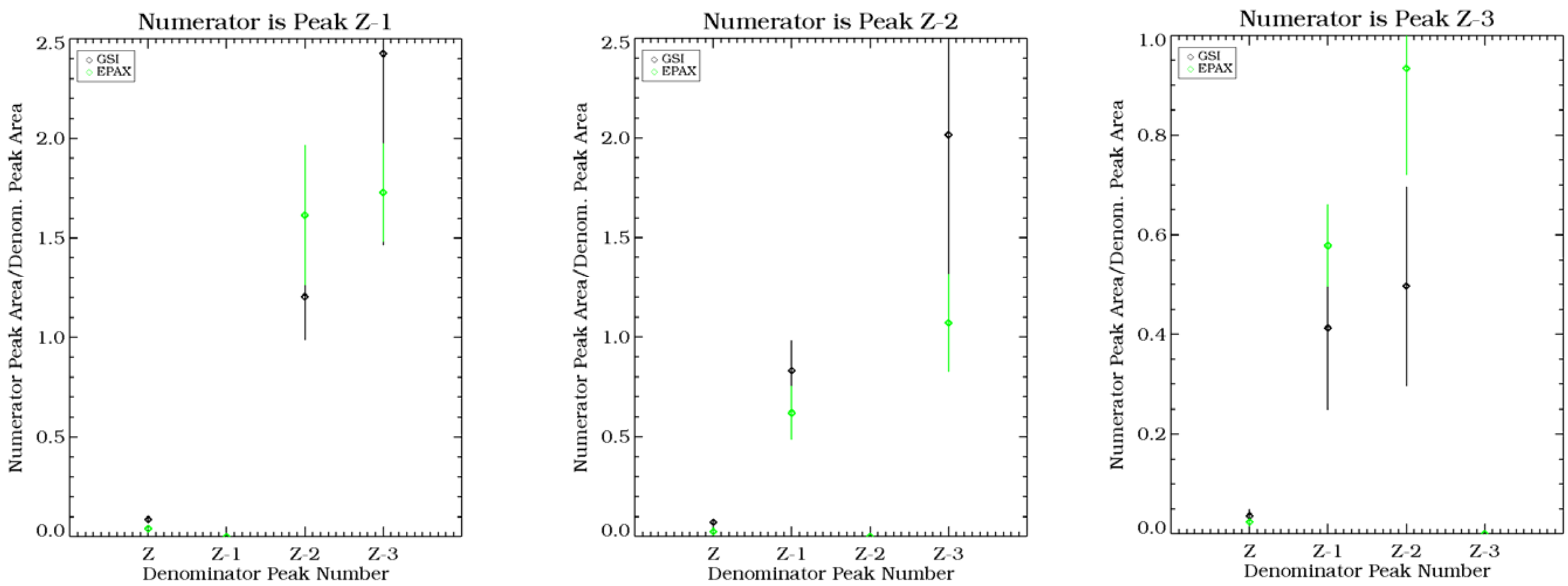


Fig. 5. Deposited-energy distributions measured in the first (left) and last (right) EM layers for 1.7 GeV/nucleon O, Si, Ca ions, from top to bottom respectively. The secondary peaks at lower energy correspond to charge-changing events in which the primary ions lost 1, 2, 3, ..., protons. The solid curves correspond to the gaussian fits of the ionization peaks.

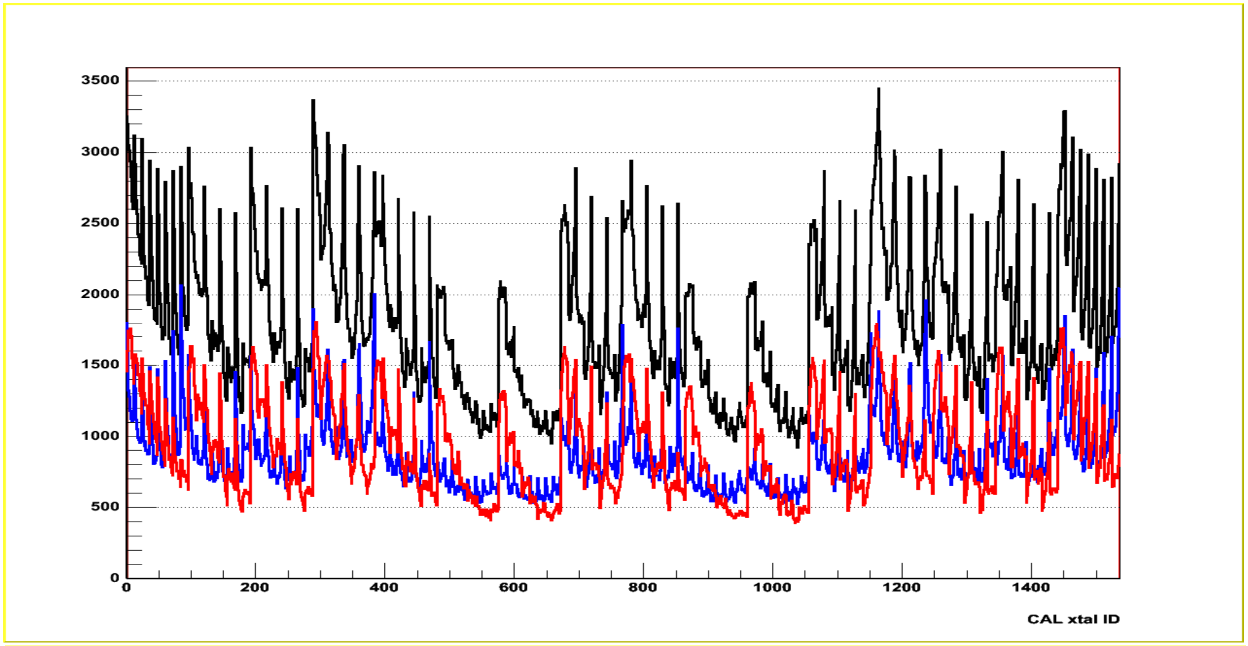
Simulations – Nuclear Interactions

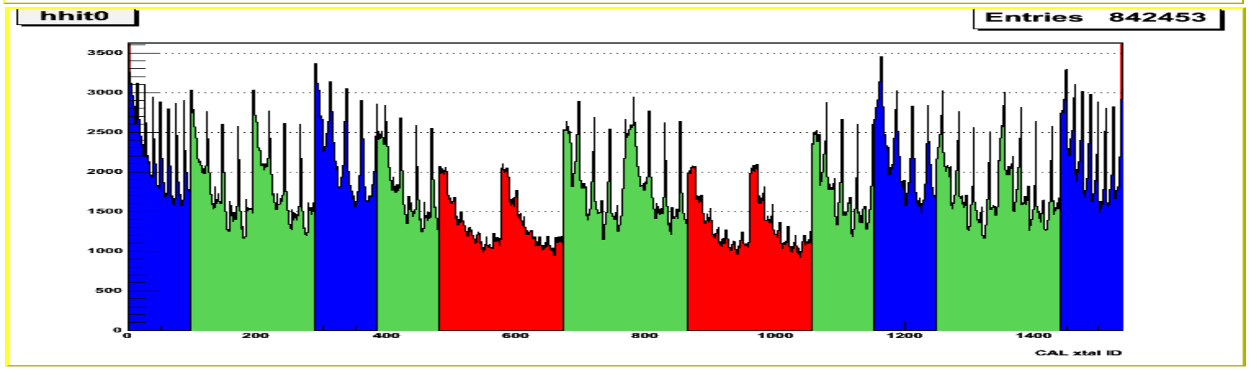
Compare G4/EPAX ratios of fragment peak integrals to GSI data (Note that EPAX is a functional representation tuned to match GSI data):



These results show that G4/EPAX is consistent with our GSI results. Given origin of EPAX, it is not a complete validation!

Sim Results – Required Collection Time





Carbon

Total xtal hits

Xtal hits for interacting events

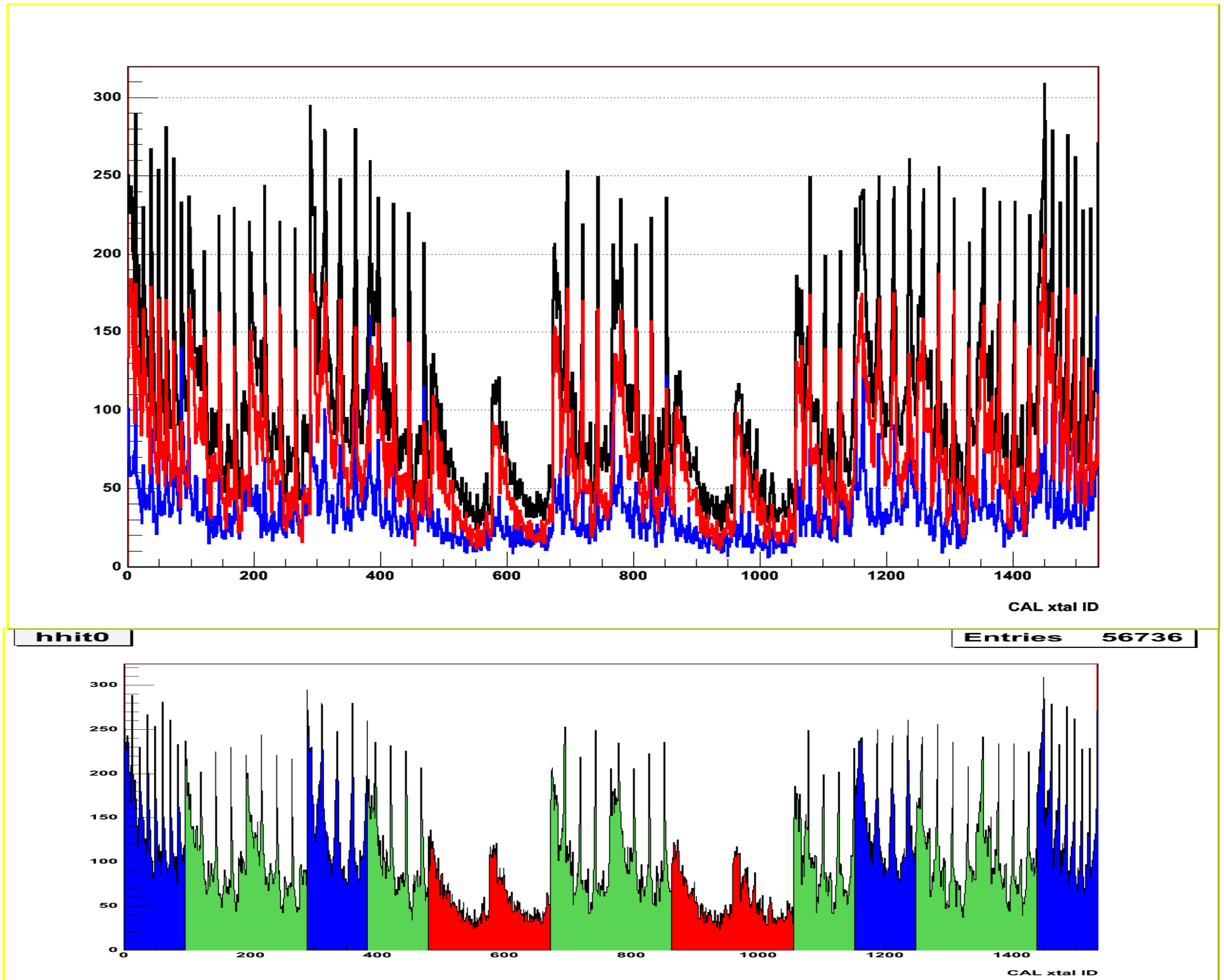
Xtal hits for noninteracting events

4 Central Twrs

4 Corner Twrs

8 Edge Twrs

Sim Results – Required Collection Time



Iron

Total xtal hits

Xtal hits for interacting events

Xtal hits for noninteracting events

4 Central Twrs

4 Corner Twrs

8 Edge Twrs

Sim Results – Required Collection Time

Carbon

Total Simulated Exposure: 127537 sec

Carbons Entered CAL: 527171

Carbons Interacted: 318244

Interaction Fraction: 60%

Hits/Xtal (MIN / MAX / MEAN)

Total:	920 / 3453 / 1786
Noninteracting:	522 / 2064 / 864
Interacting:	381 / 1807 / 922

Required Exposure for 1000 hits/xtal min.

Total:	1.6 days
Noninteracting Only:	2.8 days

Iron

Total Simulated Exposure: 144593 sec

Irons Entered CAL: 42761

Irons Interacted: 30985

Interaction Fraction: 72%

Hits/Xtal (MIN / MAX / MEAN)

Total:	23 / 309 / 104
Noninteracting:	6 / 161 / 35
Interacting:	11 / 213 / 69

Required Exposure for 1000 hits/xtal min.

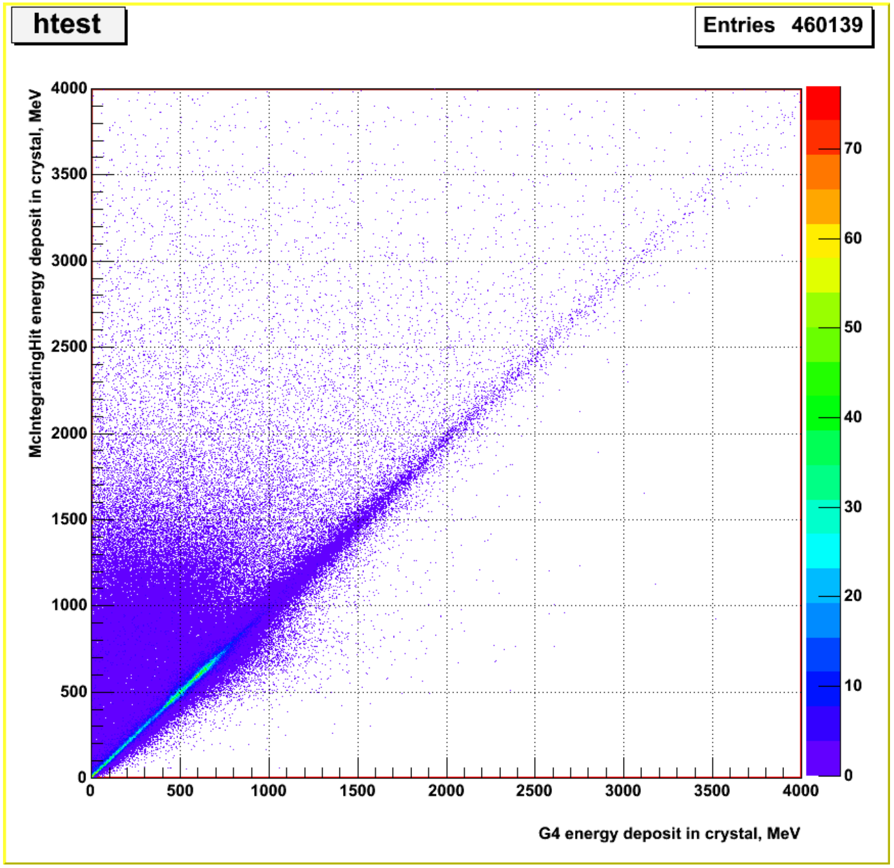
Total:	73 days
Noninteracting Only:	279 days

Sim Results – Required Collection Time

- **Notes**
  - These numbers are for TKR or CALLO or CALHI trigger
  - Requiring TKR trigger will increase required collection times by ~x2
  - Use C/N/O to calibrate LEX ranges
    - C+N+O rate ~x2 larger than C alone
  - Use Ne/Mg/Si to calibrate HEX8
    - Si also can be used to calibrate HEX1 low end
  - Need to consider non-uniform requirement along length of xtal

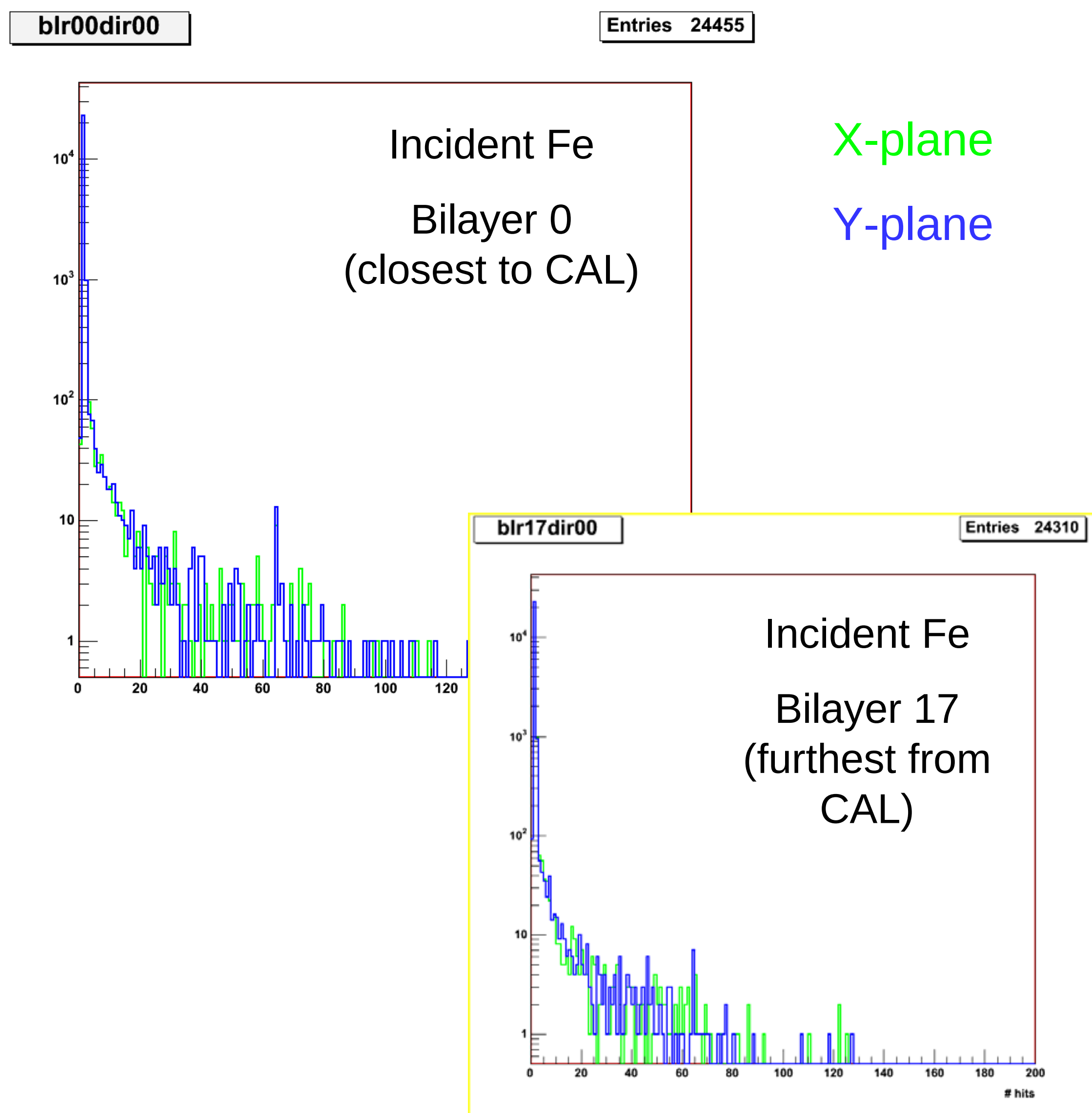
Sim Results – Is dE/dx what we really see?

- **Incident C nuclei**
  - Each point is hit in xtal "above" any nuclear interaction
  - X-axis: dE/dx (including delta electrons) as determined by G4 (Ein – Eout)
  - Y-axis: MCIntegrating hit for that xtal
  - Calibration procedure assumes that we know energy deposit given path through xtal using dE/dx
  - Events on diagonal actually deposit dE/dx
  - Events off diagonal either lose delta electrons to other xtals or collect them from other xtals
  - Cloud of events above line are probably nuclear interaction products (still investigating)



Sim Results – Is 14-hit GTRC Buffer a Problem?

- **TKR team proposes reducing GTRC buffer size to 14 hit strips**
  - **Prevents GTCC buffer overflow**
- **Some concern that GCR events will produce large number of hits in TKR due to delta electrons**
  - **Leads to long TKR Recon processing times**
  - **Might overflow buffers**
- **Simulate C and Fe to investigate number of hits in TKR planes**

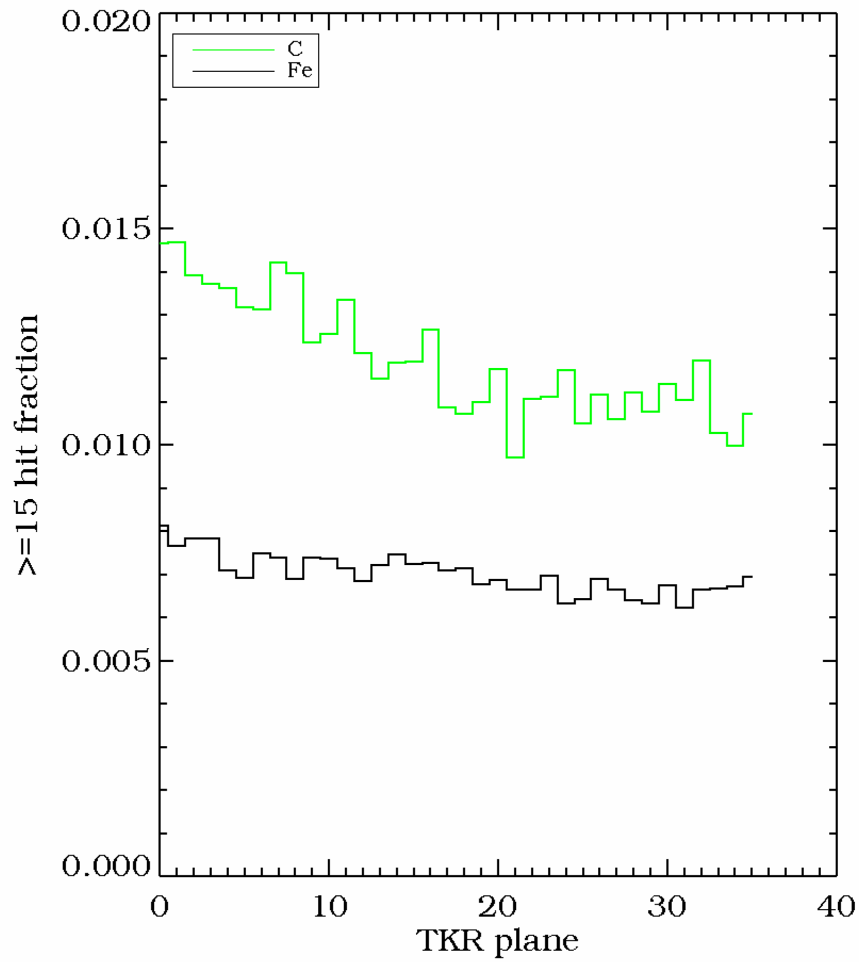


Sim Results – Is 14-hit GTRC Buffer a Problem?

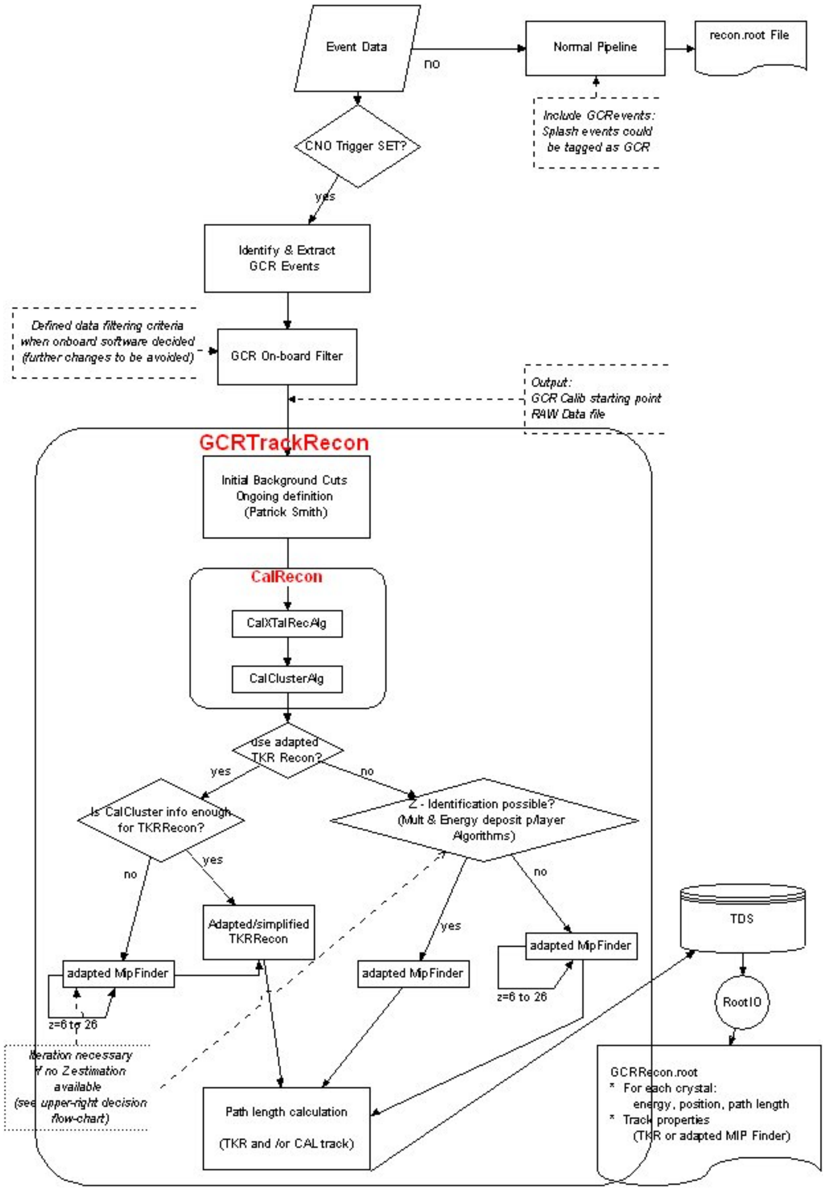
- **Initial indication is:**

  NO

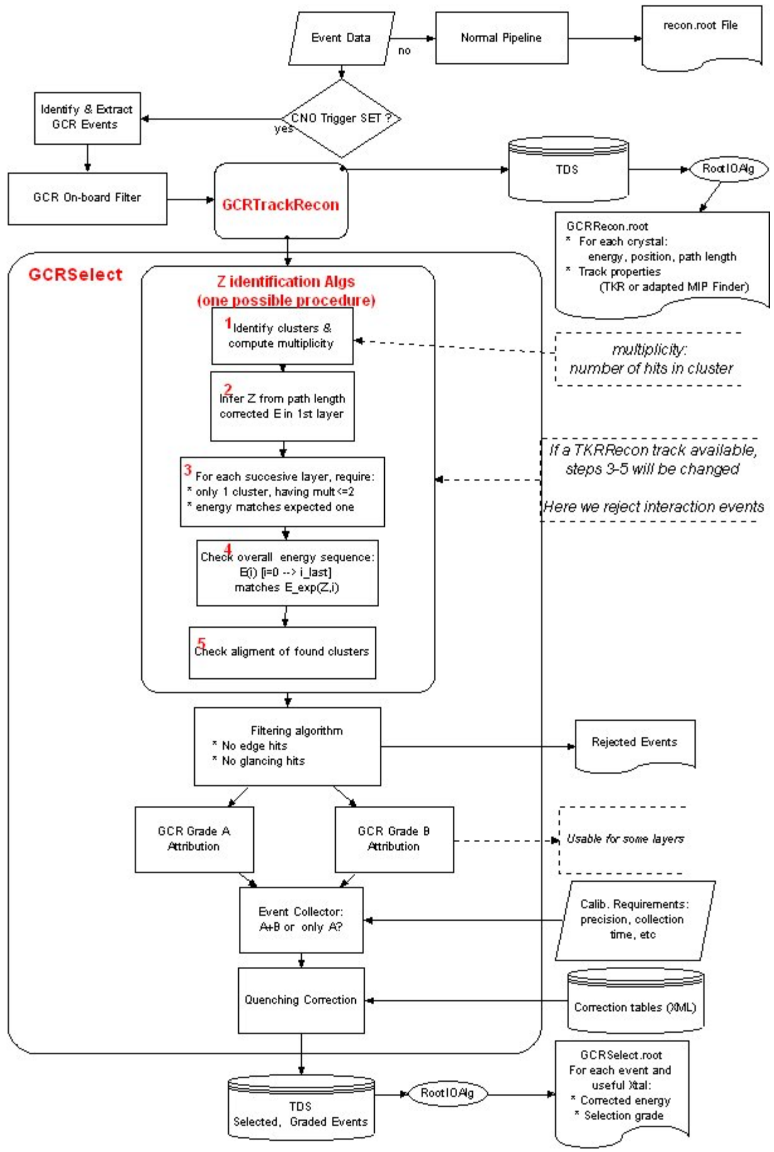
- **Less than 1.5% of GCR events will overflow GTRC buffer with 14-hit limit**
- **BUT –**
  - **We don't understand why C has more hits than Fe!**
  - **Delta electron production should scale as Z^2!**
  - **Spectrum shape independent of Z**
  - **So Fe should have many more hits**
  - **Stay tuned for further analysis…**



GCR Calibration Analysis



GCR Calibration Analysis



GCR Calibration Analysis