Galactic Cosmic Ray Energy Spectra for Heavy Elements (Ne to Zn) from ~0.8 to ~10 GeV/nuc with the SuperTIGER Instrument

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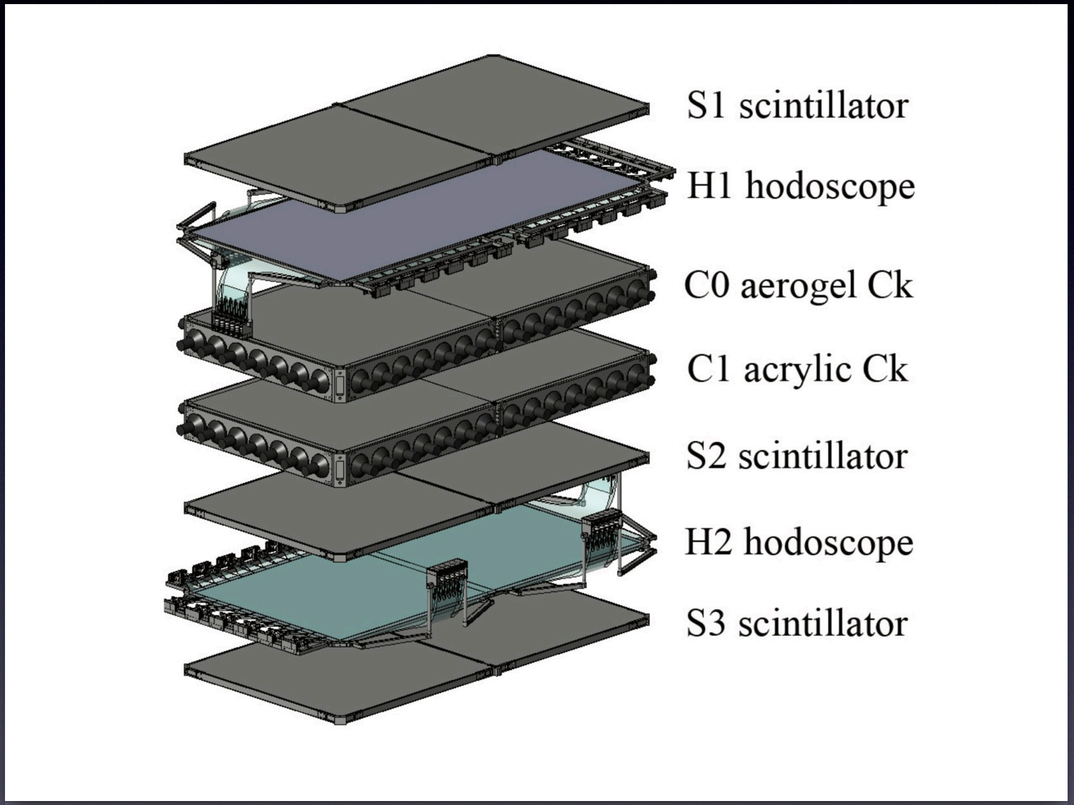
Madison, WI, USA
26 July 2019

SuperTIGER

- “Super” Trans-Iron Galactic Element Recorder
- **A balloon-borne cosmic ray instrument that can measure galactic cosmic ray abundances for Z=~10–60 for energies ~0.8-10 GeV/nuc**
- Primary Goals: Measure Z=30–60 abundances to test OB association models for cosmic ray origins
  - R.P. Murphy et al., ApJ 2016
  - N.E. Walsh et al., COSPAR 2018, E1.5-0040-18
  - N.E. Walsh et al., ICRC 2019, CRD3a
- Secondary Goals: Spectra, spectral features



2 modules (1 shown), effective geometry 3.9 m^2 sr
Plastic scintillators (for Z)
Acrylic (n=1.49) and Aerogel (n=1.043, 1.025)
Cherenkov Detectors (for Z, ß)

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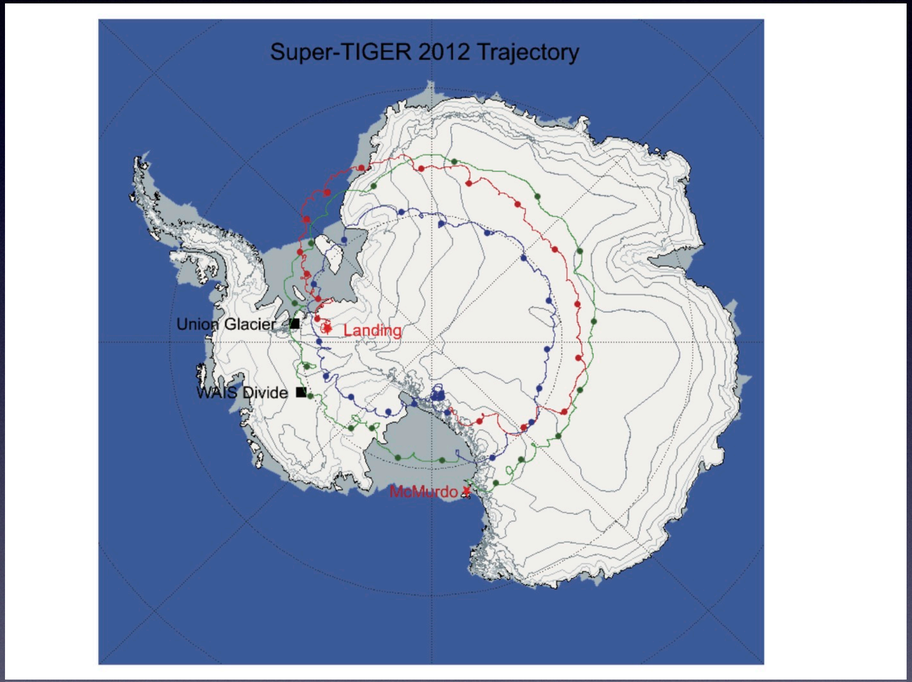
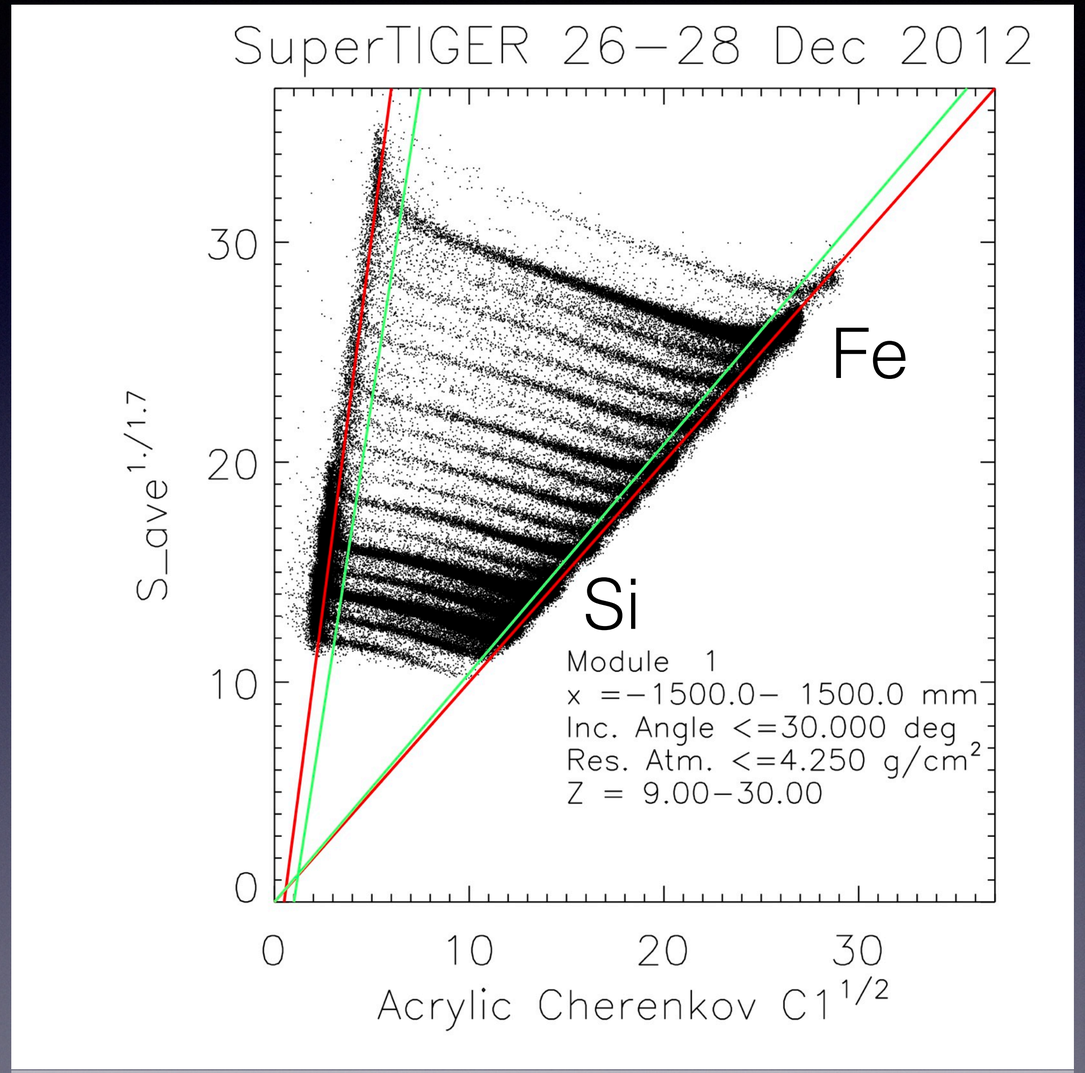
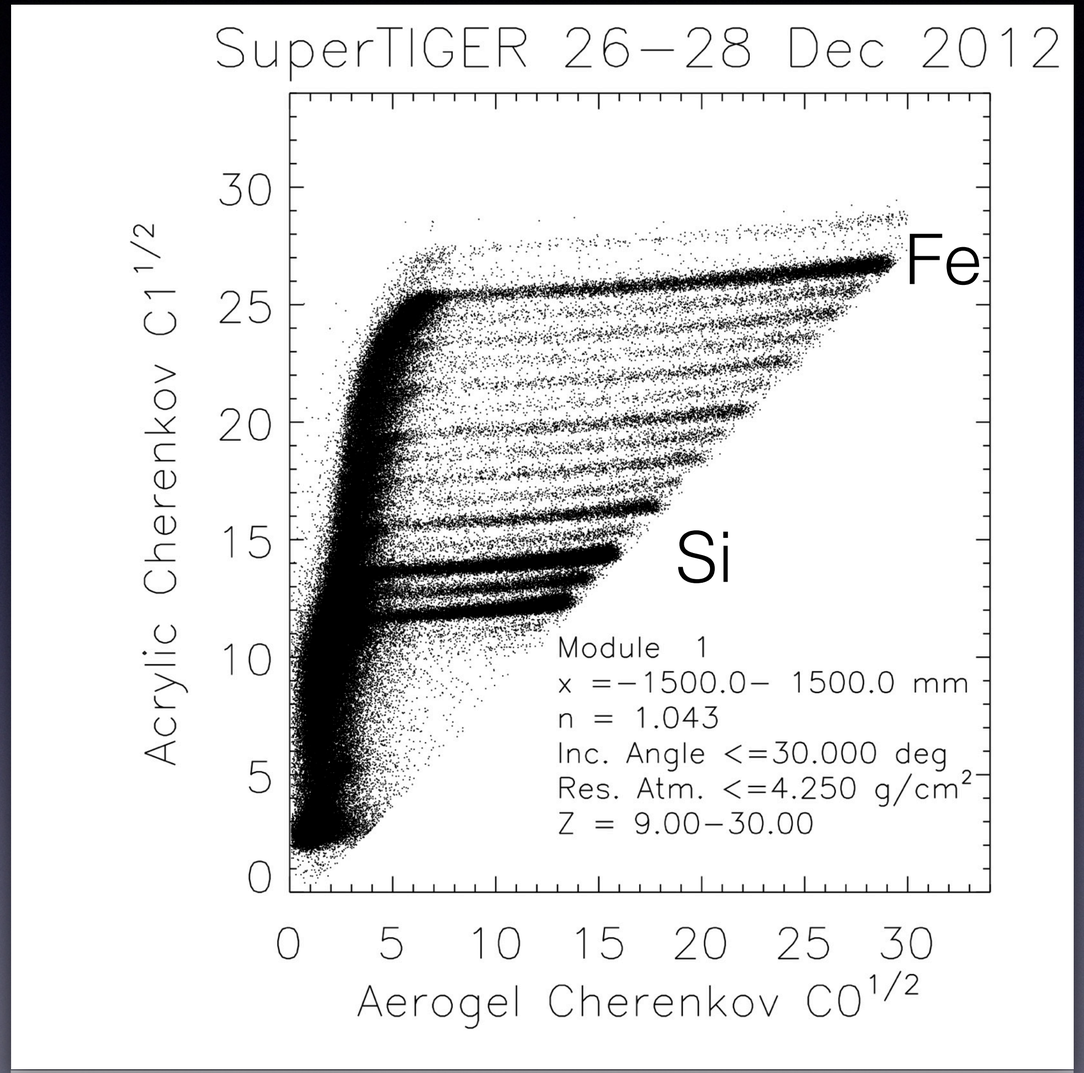


December 8, 2012 — February ~2, 2013
Record 55 day flight, avg altitude 125k ft.
~5×10^6 Fe events (used to map detector responses)

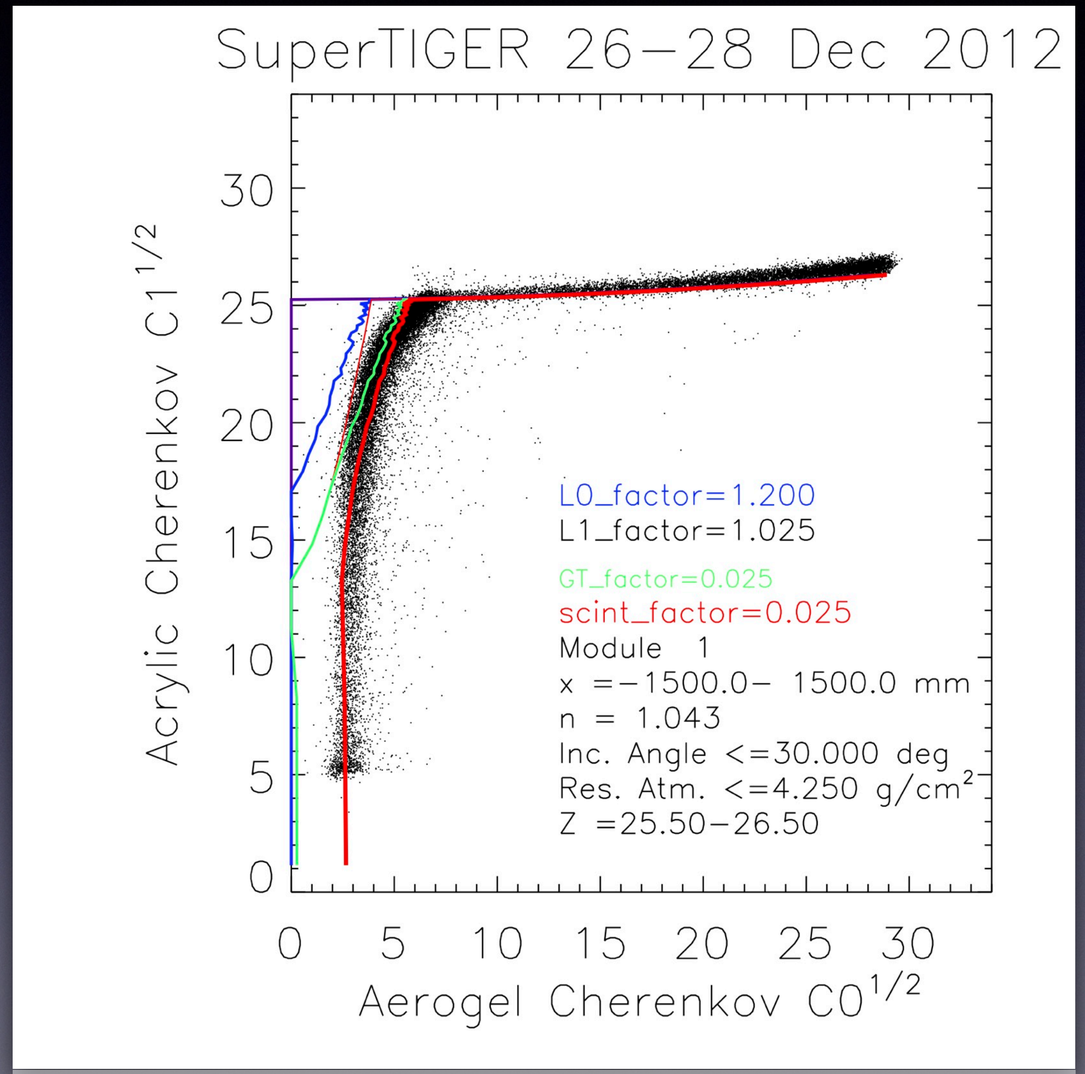
SuperTIGER

Line of Sight (LOS) Data





Analysis — Energy Scaling



- Aerogels n=1.043, n=1.025 (thresholds ~2.5 GeV/nuc, ~3.3 GeV/nuc)
- Background signals move the zero Cherenkov signal point
  - knock-ons
  - Scintillation
  - Goretex Cherenkov

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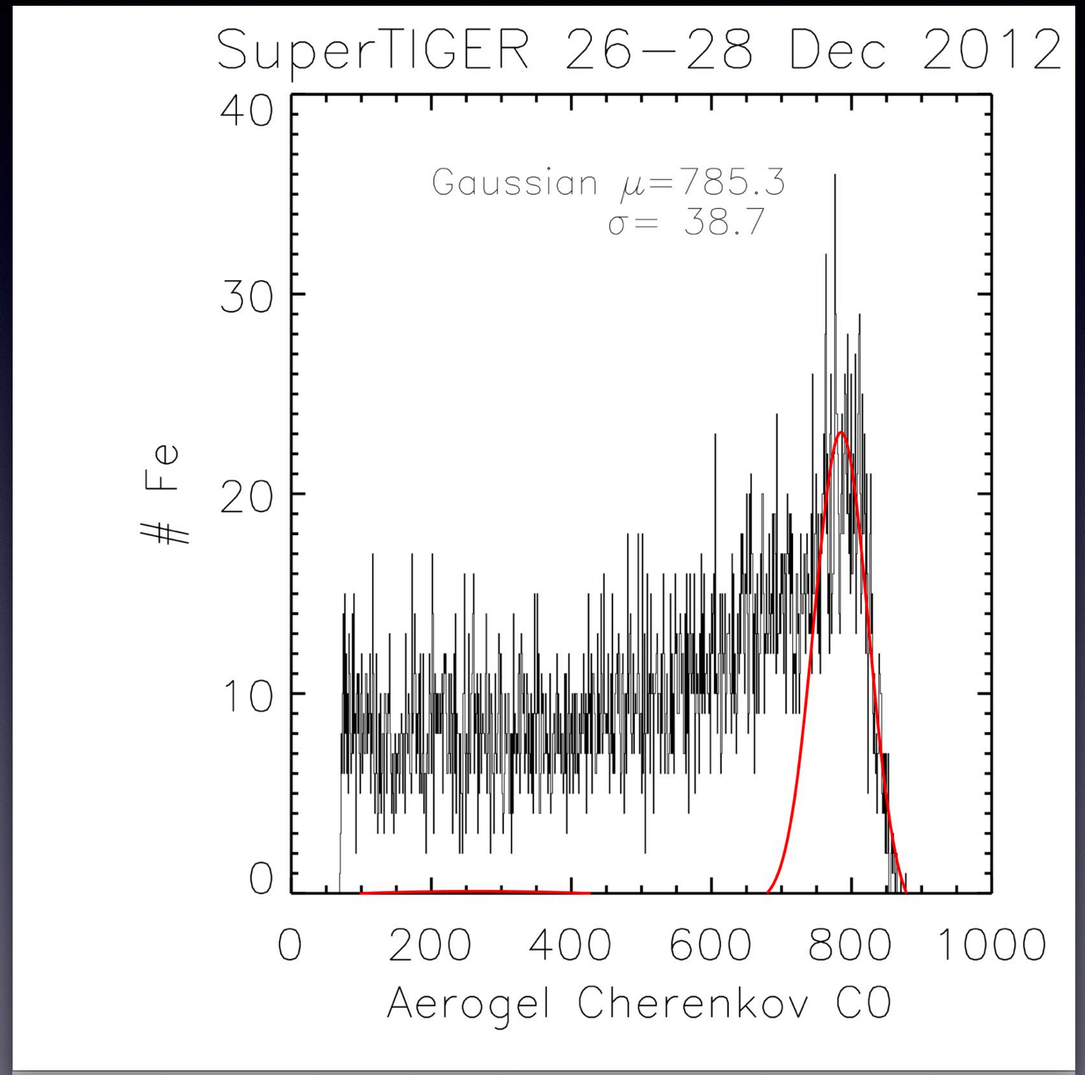

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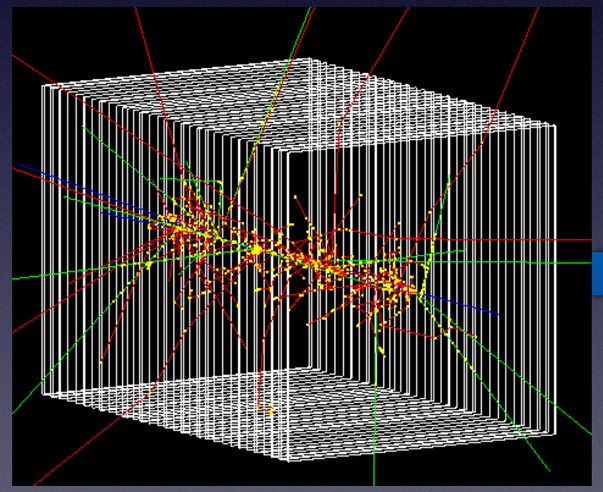
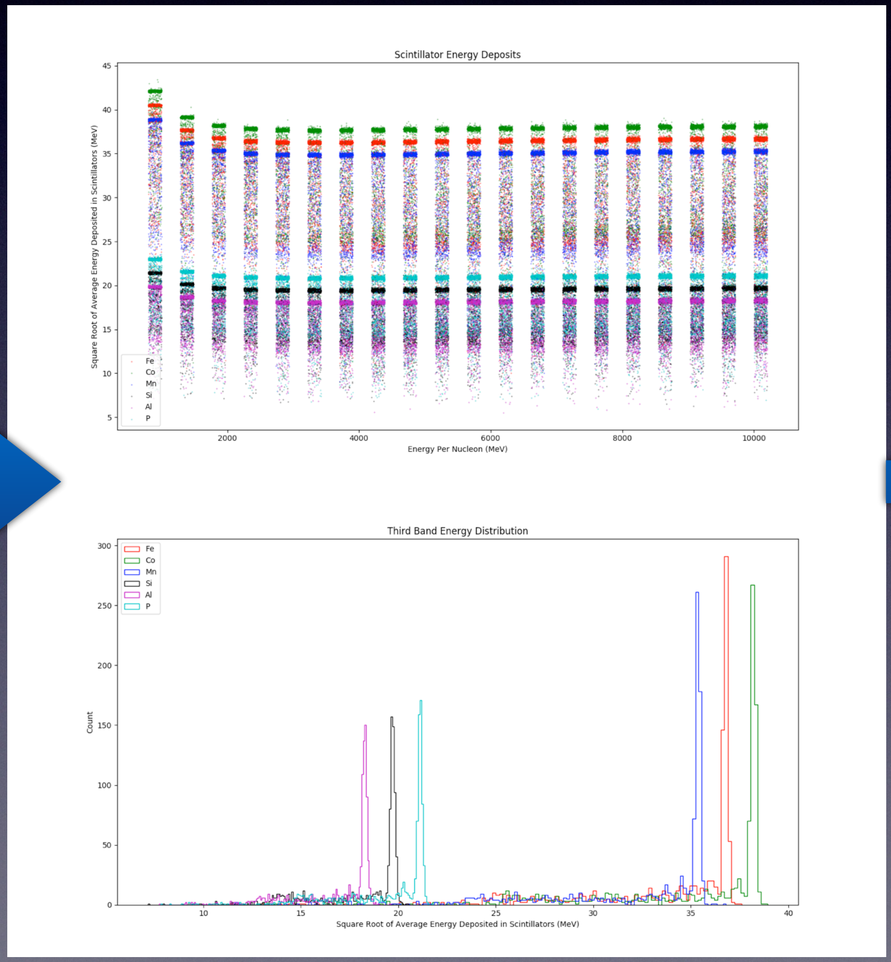
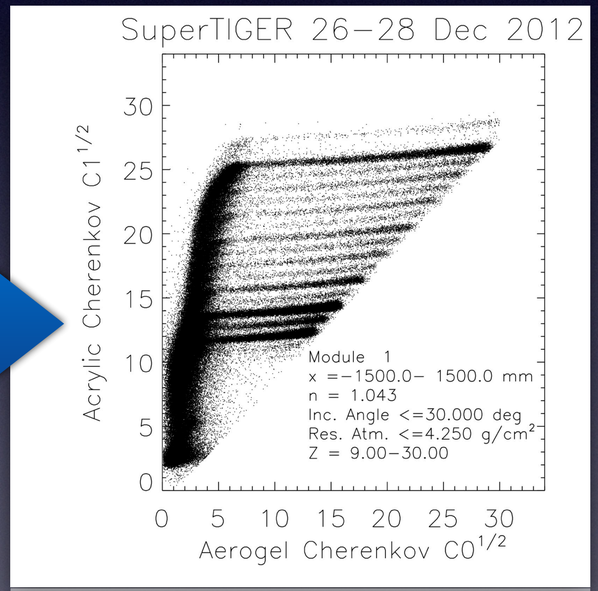
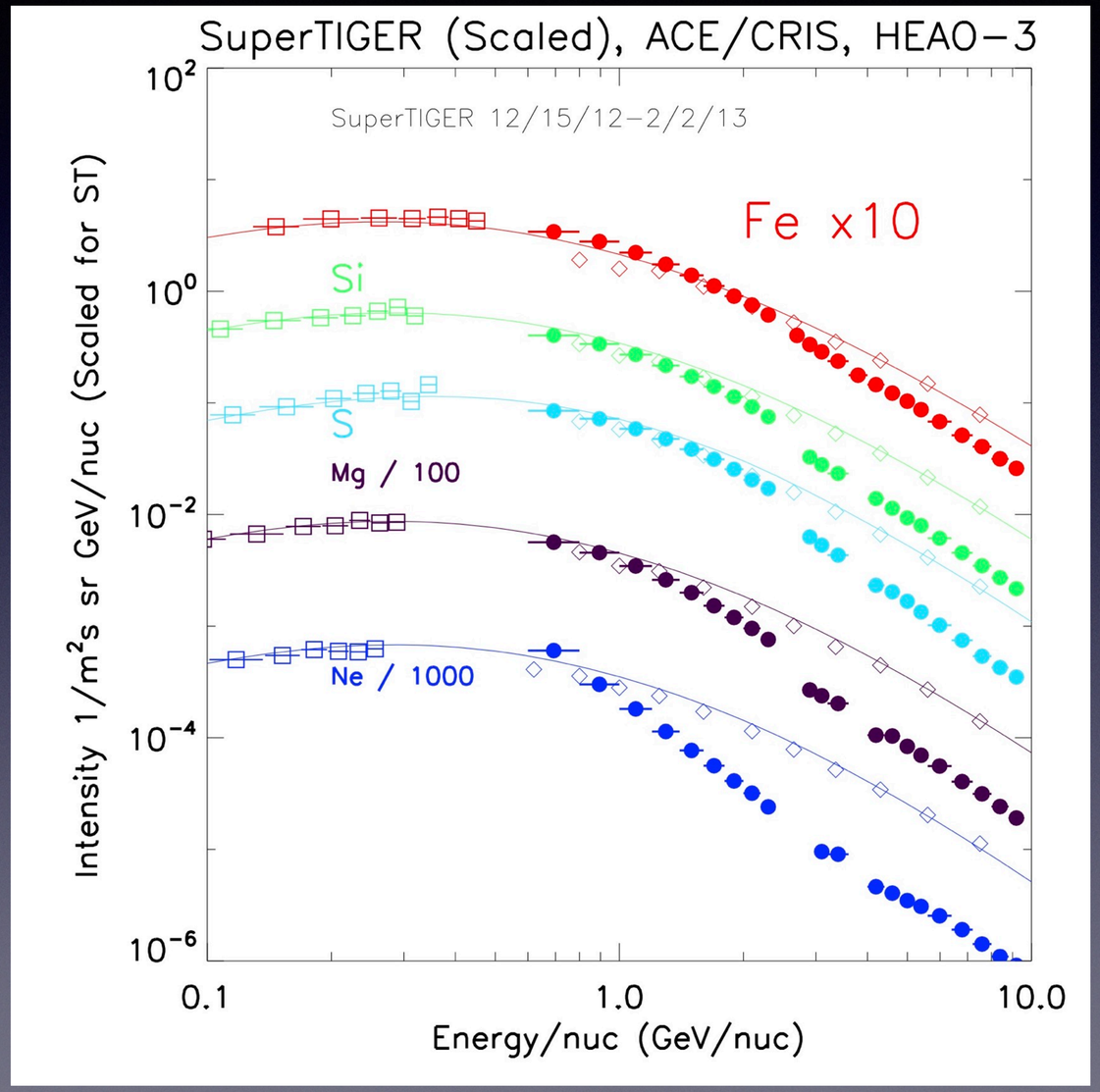
SuperTIGER GEANT4 Simulation Under Development







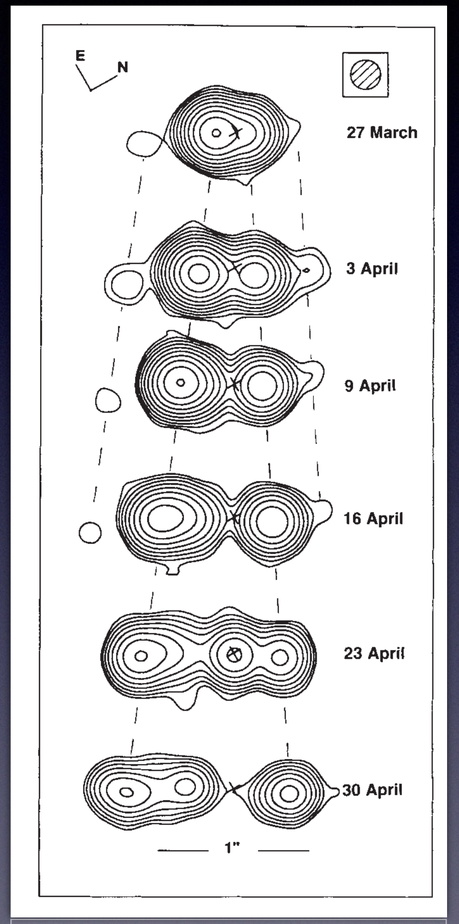
SuperTIGER Scaled Spectra



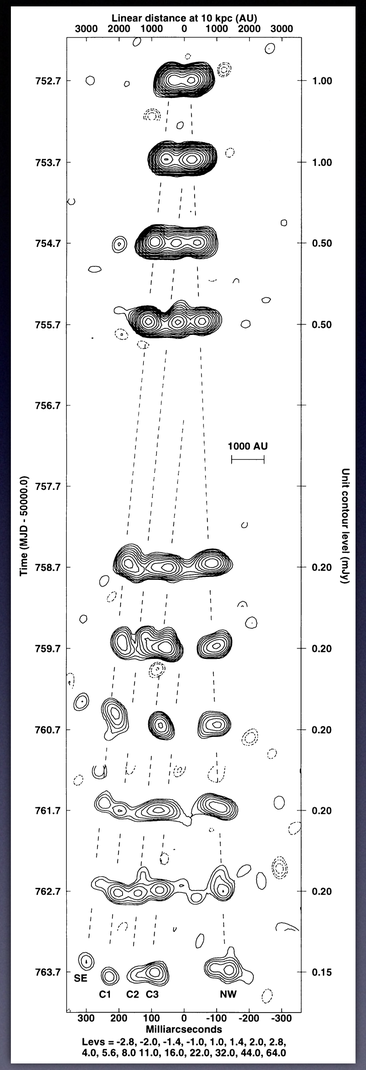
- SuperTIGER Fe, etc data (closed circles) at the instrument, **scaled** to approximate model and ACE data. Additional scaling to separate elements visually.
- ACE CRIS Data (open squares) from ACE Science Center (www.srl.caltech.edu/ACE/ASC) for the same dates as the SuperTIGER data.
- HEAO-3 Data (open diamonds) from Engelmann et al. 1990.
- Interstellar model: A.Davis et al., ***JGR,*** A12, 29,979, 2001
- Solar Modulation to 575 MV.

Microquasars

- Heinz & Sunyaev ("Cosmic Rays from Microquasars: A Narrow Component to the CR Spectrum?", ***Astron & Astrophys***, 390 (2002) 751)
  - Suggested that relativistic jets observed in micro-quasars like GRS 1915+105 and GRO J1655-40 might produce narrow features in some cosmic ray spectra.

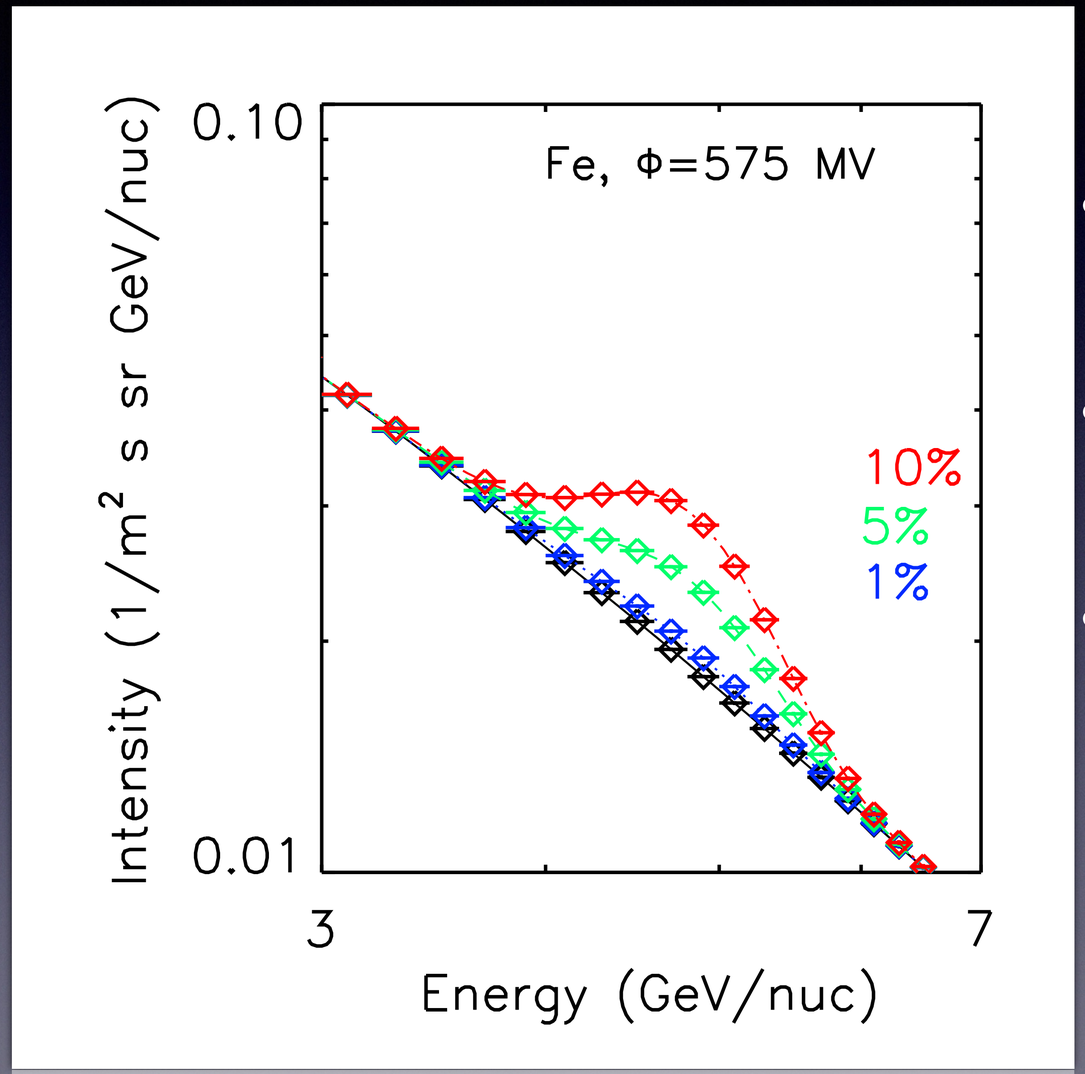


GRS1915+105
(Mirabel & Rodriguez,
Nature , 371, 46 (1 Sep 1994))



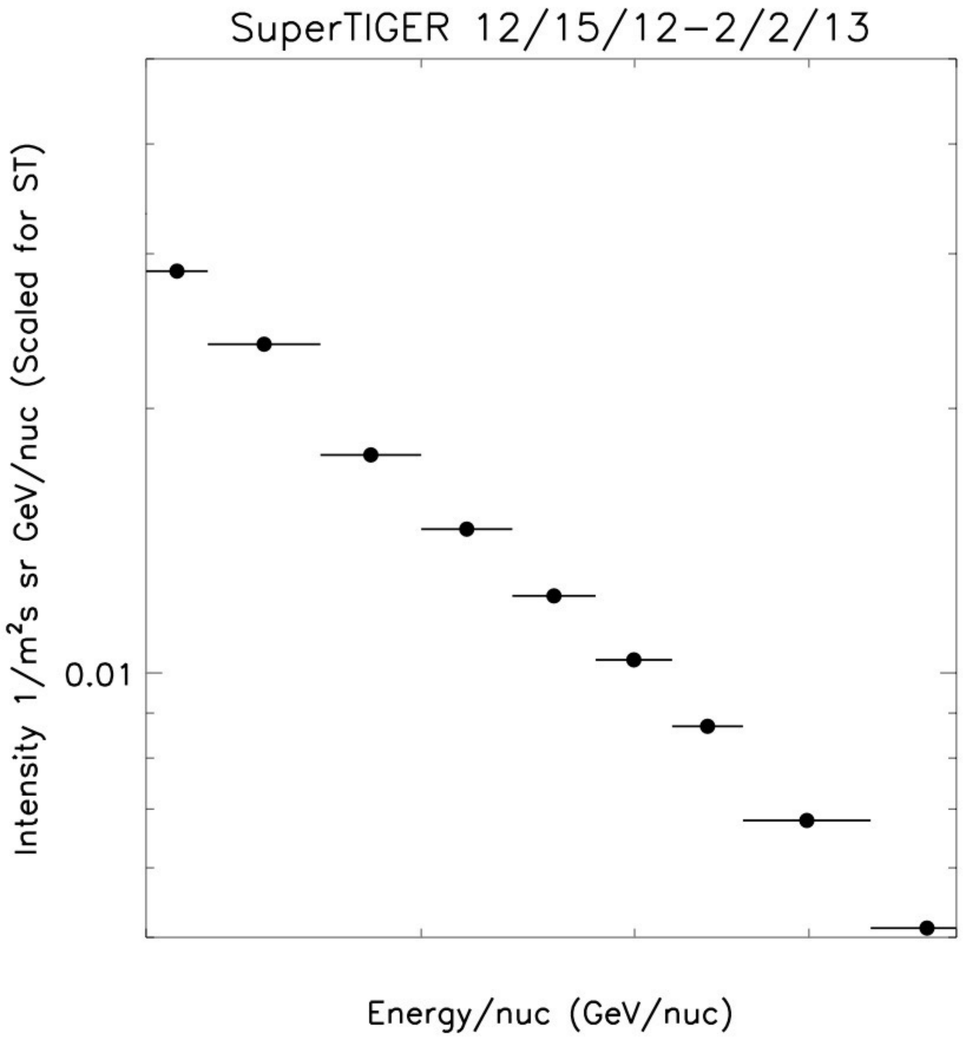
1997 MERLIN (radio) observations
of GRS1915+105
(Fender et al., Mon. Not. RAS, 1999)

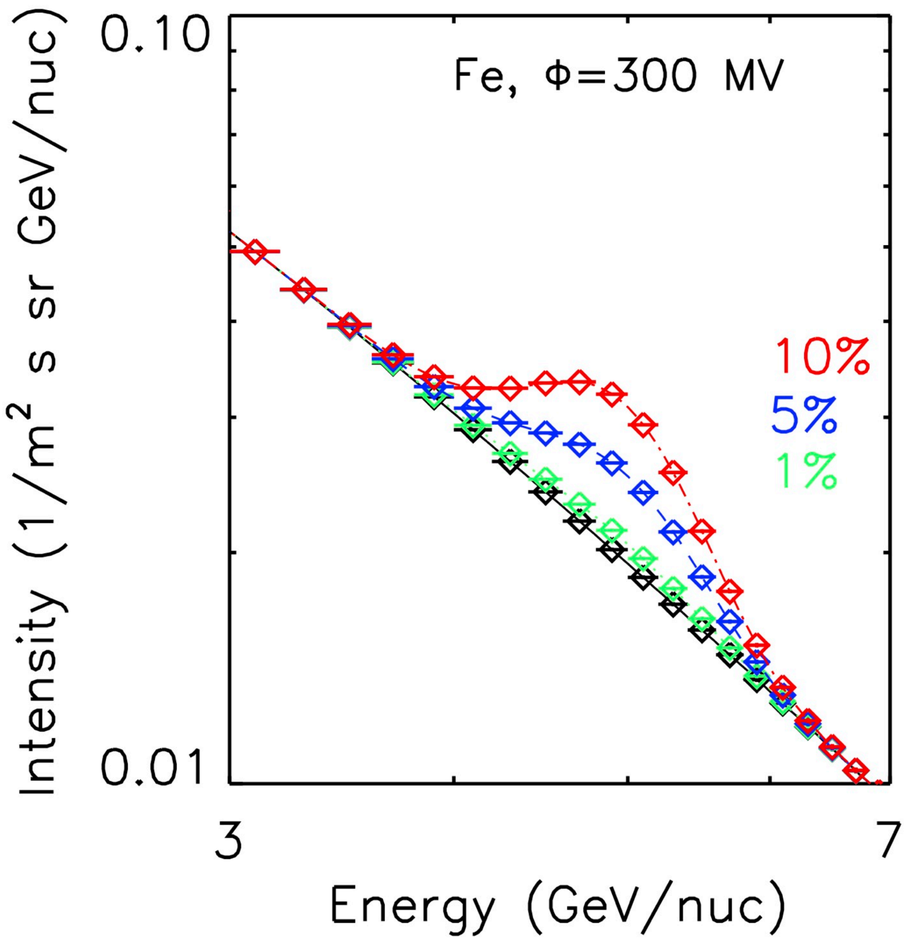
Microquasar Hypothetical Signature

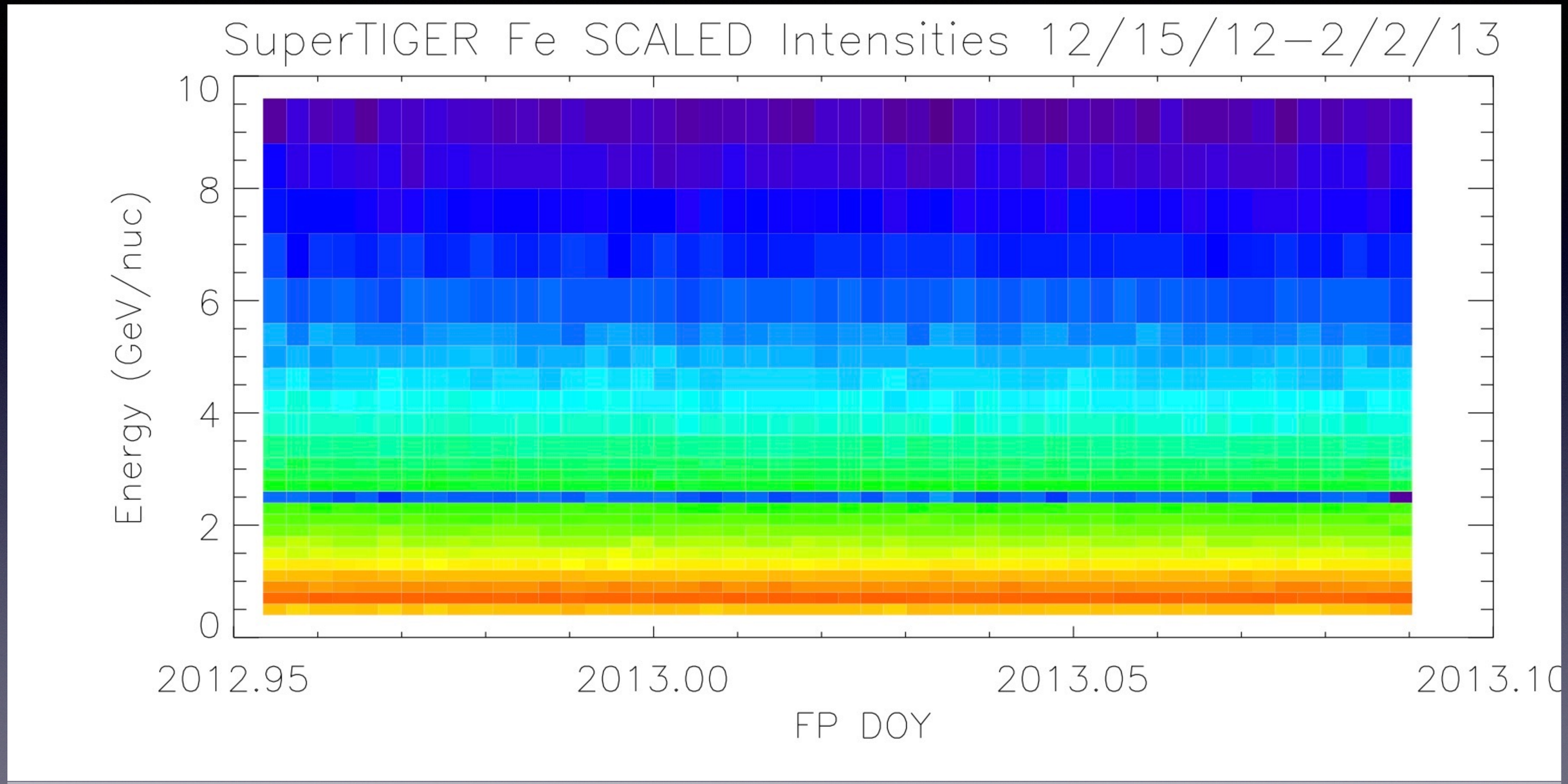


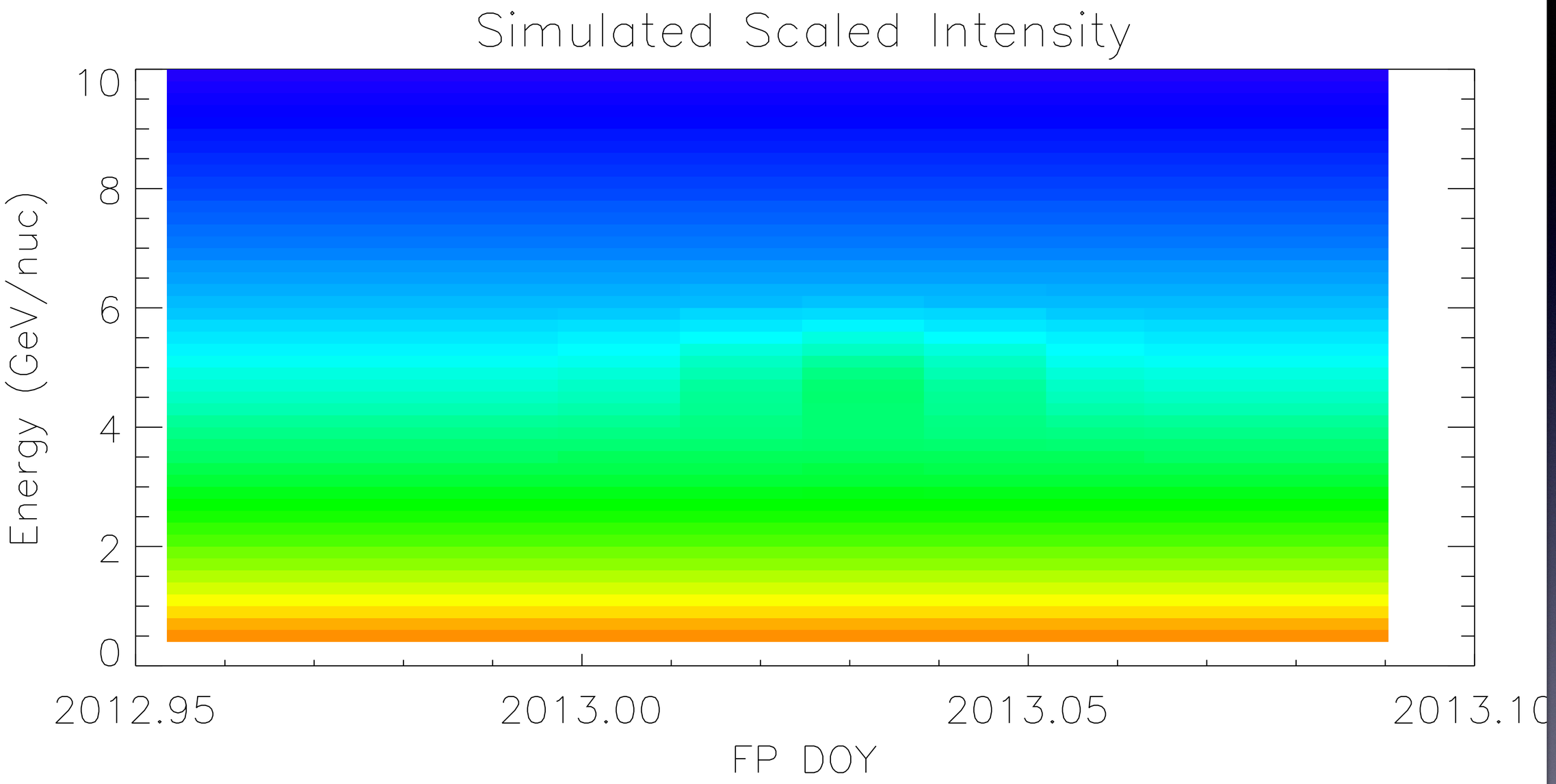
- Interstellar Fe beam at 5 GeV/nuc, width 0.5 GeV/nuc
- Interstellar model (black): A.Davis et al., ***JGR,*** A12, 29,979, 2001
- Solar Modulation is spherically symmetric diffusion calculation after Fisk, ***JGR*** (1971).

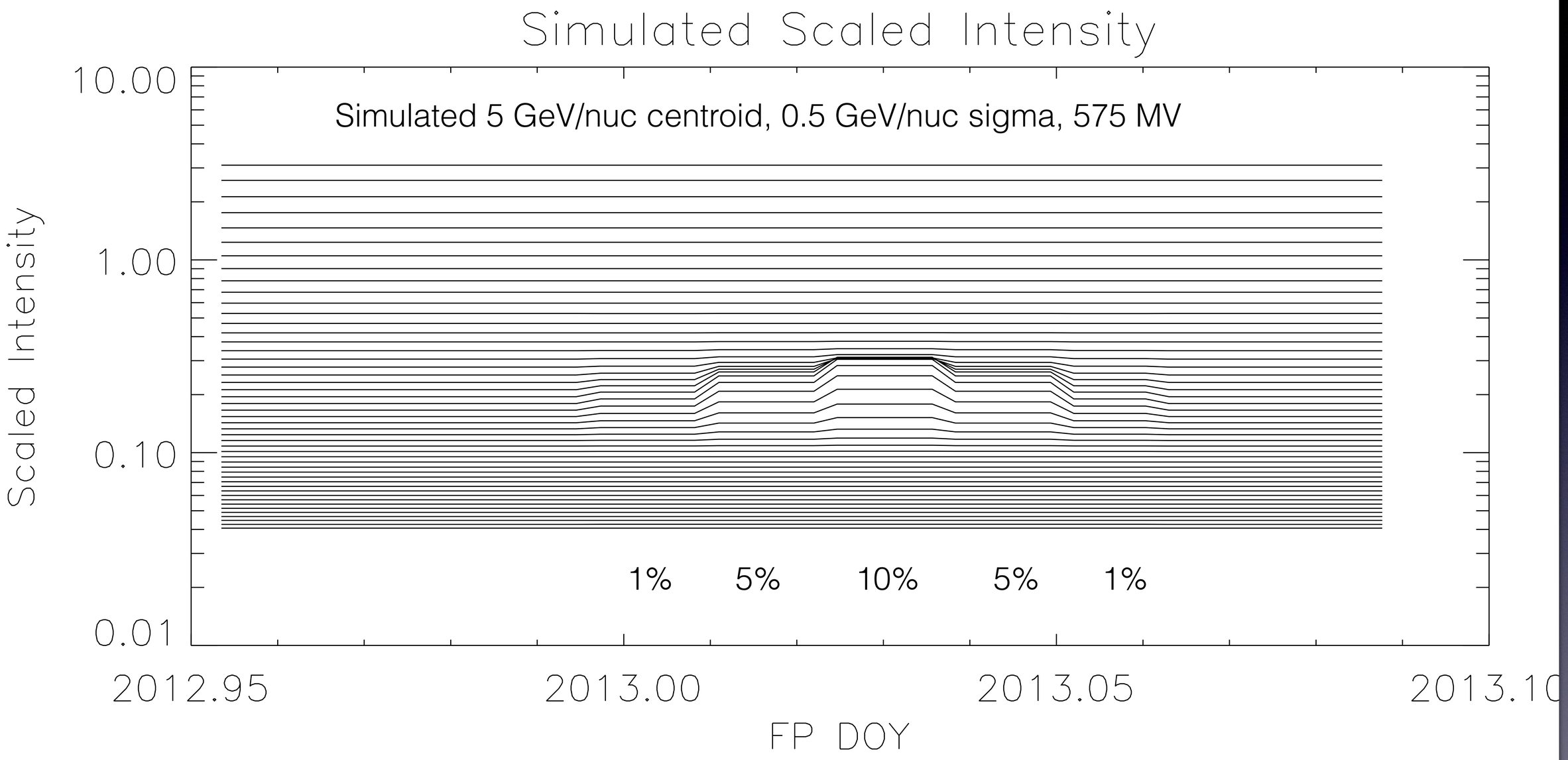
Fe Scaled Spectrum (Flight TDRSS, left)

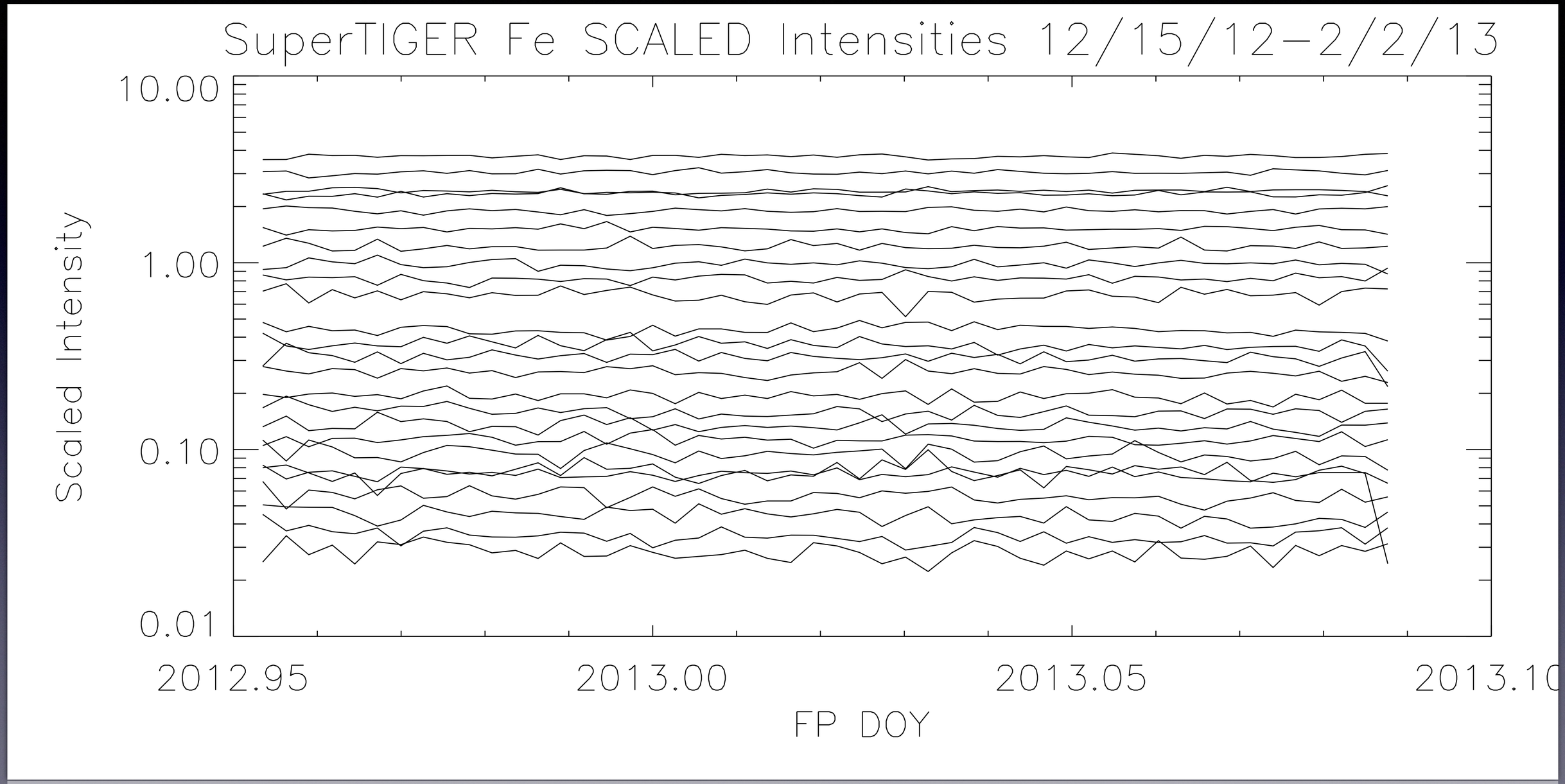





SuperTIGER Fe SCALED Intensities 12/15/12–2/2/13
Energy (GeV/nuc)
0
2
4
6
8
10
2012.95
2013.00
2013.05
2013.10
FP DOY


Simulated Scaled Intensity
Energy (GeV/nuc)
10
8
6
4
2
0
2012.95
2013.00
2013.05
2013.10
FP DOY


Simulated Scaled Intensity
Simulated 5 GeV/nuc centroid, 0.5 GeV/nuc sigma, 575 MV
10.00
1.00
0.10
0.01
Scaled Intensity
1%
5%
10%
5%
1%
2012.95
2013.00
2013.05
2013.10
FP DOY


SuperTIGER Fe SCALED Intensities 12/15/12–2/2/13
10.00
1.00
0.10
0.01
Scaled Intensity
2012.95
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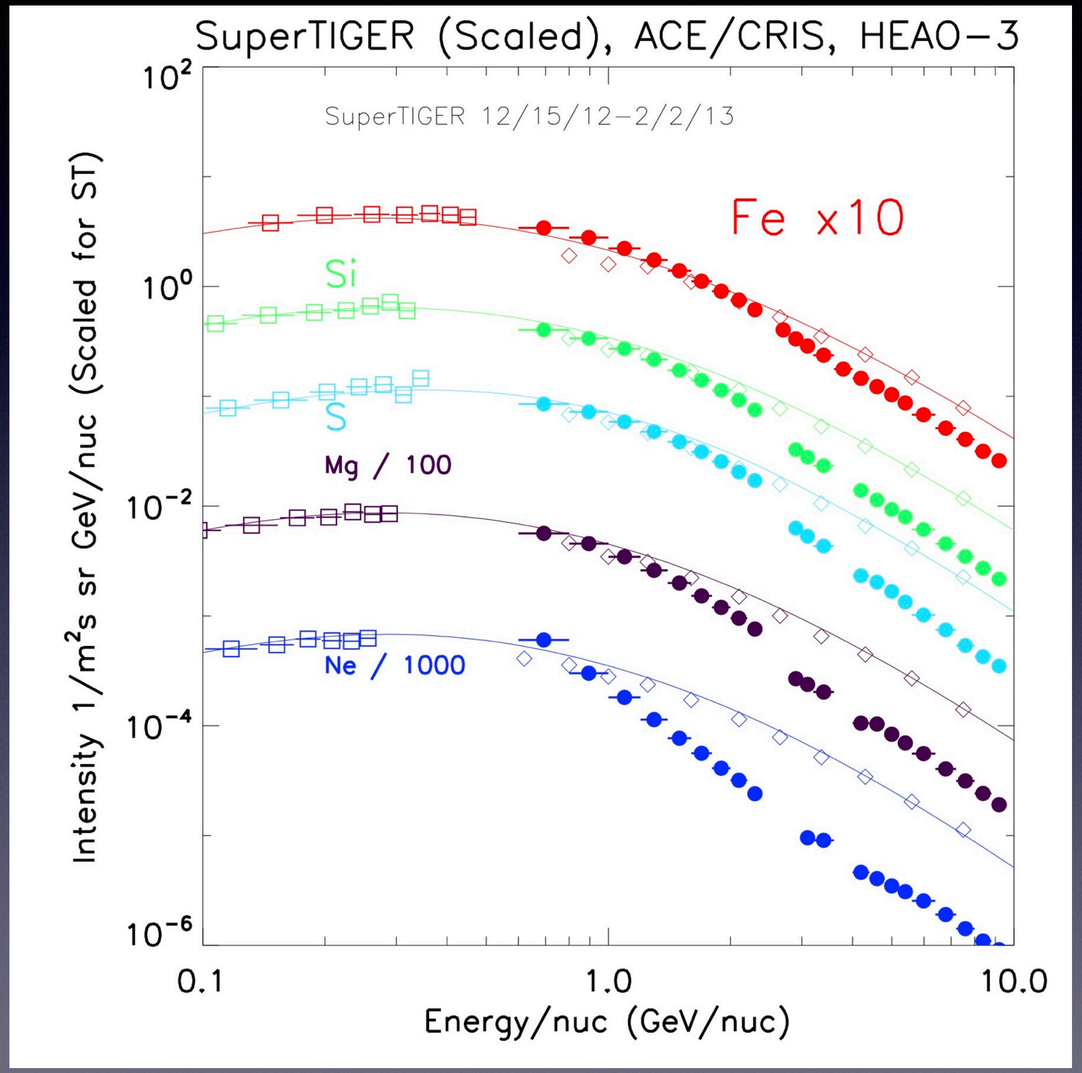
Conclusions and Further Work



- Still pursuing absolute spectra for publication
  - e.g. GEANT4 simulation for interaction losses; livetime calculations; **priority system** corrections; systematic uncertainties
- Even with absolute intensity calculations still in progress, we have sufficient statistics to rule out very large, narrow microquasar signatures in Fe (e.g. 5 GeV/nuc beam, 0.5 GeV/nuc width) for the duration of the SuperTIGER flight.
  - See also Geier et al., ASR 37 (2006) 1955-1959