IMP8 Observations of the Relative Onset Times of Relativistic Electrons and Protons in the January 20, 2005 Ground Level Event

William F. Dietrich
Consultant, US Naval Research Laboratory

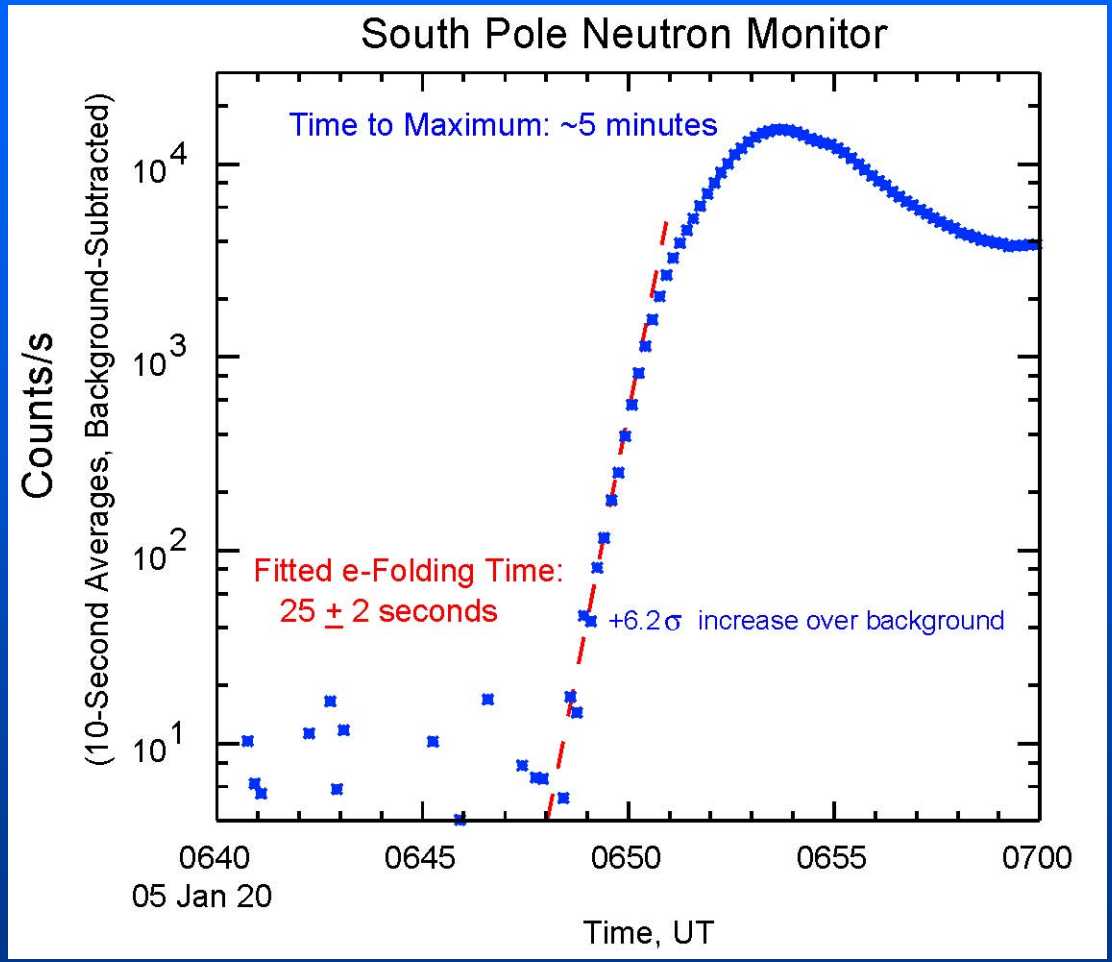
Allan J. Tylka
U S Naval Research Laboratory, Washington DC

with thanks to

Tom Armstrong, Dennis Haggerty, Säm Krucker, Horst Kunow, Andreas Klassen, Bob Lin, Cliff Lopate, Jerry Manweiler, and Ed Roelof

Spring 2006 AGU Meeting: SH 42A-02
Baltimore Convention Center, Room 318
Baltimore, Maryland
2006 May 25, 11:15

Background: January 20, 2005 GLE



Largest GLE since 1956

Very fast rise time

Hard particle spectra:

- *interplanetary (ACE, SAMPEX, GOES)*
- *in solar atmosphere (RHESSI)*

Relative onset times of electrons and relativistic protons constrain acceleration models

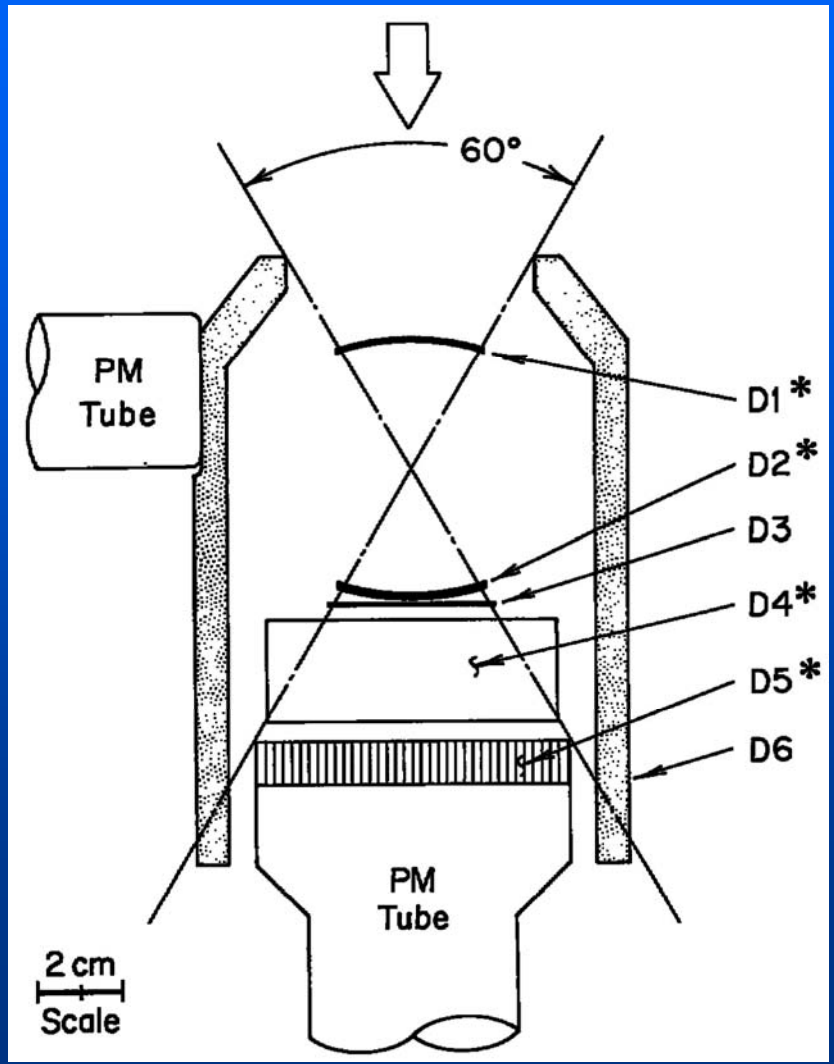
Estimated GLE Onset: 06:48:40 ± 10 s

Data provided by J.W. Bieber & the Spaceship Earth Collaboration

Cosmic Ray Nuclei Experiment (CRNE) on IMP8

PIs: J.A. Simpson (U. Chicago, deceased) & C. Lopate (UNH)

Garcia-Munoz, Mason, & Simpson, ApJ 201, L145-L148 (1975)



	Logic	Electrons (MeV)	Protons (MeV)
ID2	$D1 \cdot D2 \cdot \overline{D3} \cdot \overline{D6}$	0.7-2.0	10.8-19.5
ID3	$D1 \cdot D2 \cdot D3 \cdot \overline{D4} \cdot \overline{D6}$	2.0-12	19.5-27
ID4	$D1 \cdot D2 \cdot D4 \cdot \overline{D5} \cdot \overline{D6}$	12-50	27-95
ID5	$D1 \cdot D2 \cdot D4 \cdot D5 \cdot \overline{D6}$	>50	>95

CRNE: 2.05 cm^2-sr

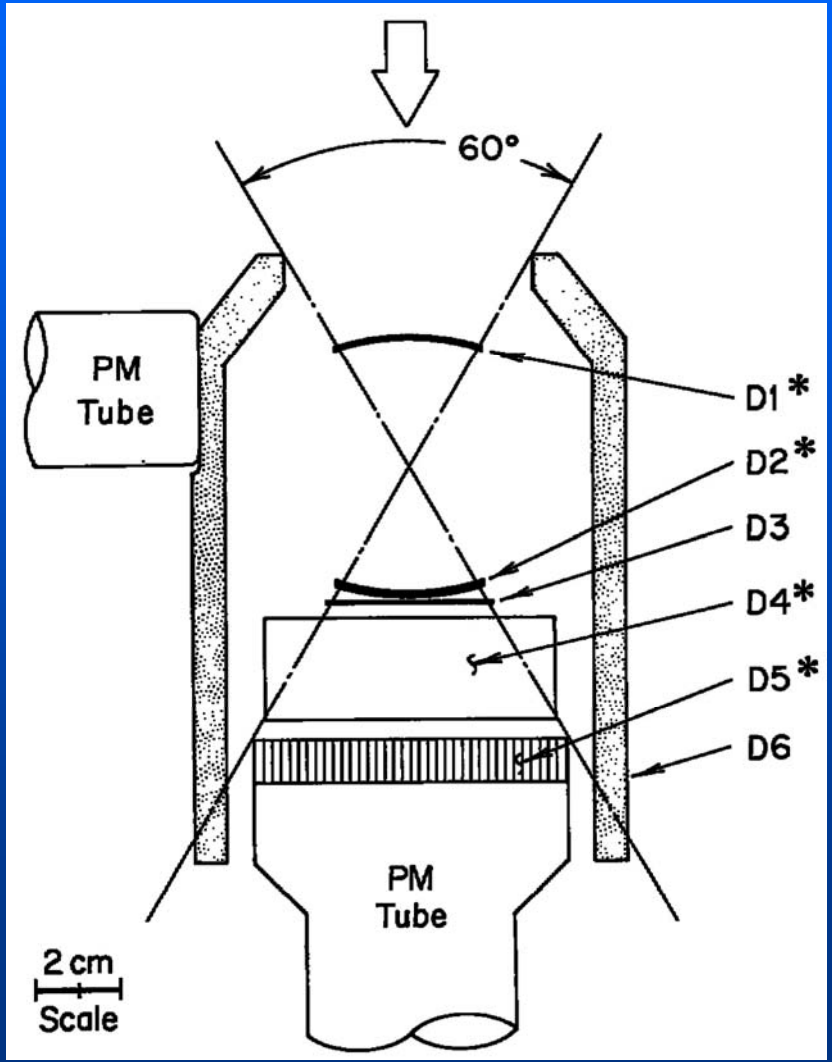
Instrument Axis in the Ecliptic

IMP8 Spin Rate: 24 rpm

IMP8 Spin Axis perpendicular to Ecliptic

CRNE Data: 8 spin-sectors

Cosmic Ray Nuclei Experiment (CRNE) on IMP8



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In ID2 and ID3, protons start to arrive

30-35 minutes after the electrons.

IMP8/CRNE Pulse-Height Matrices

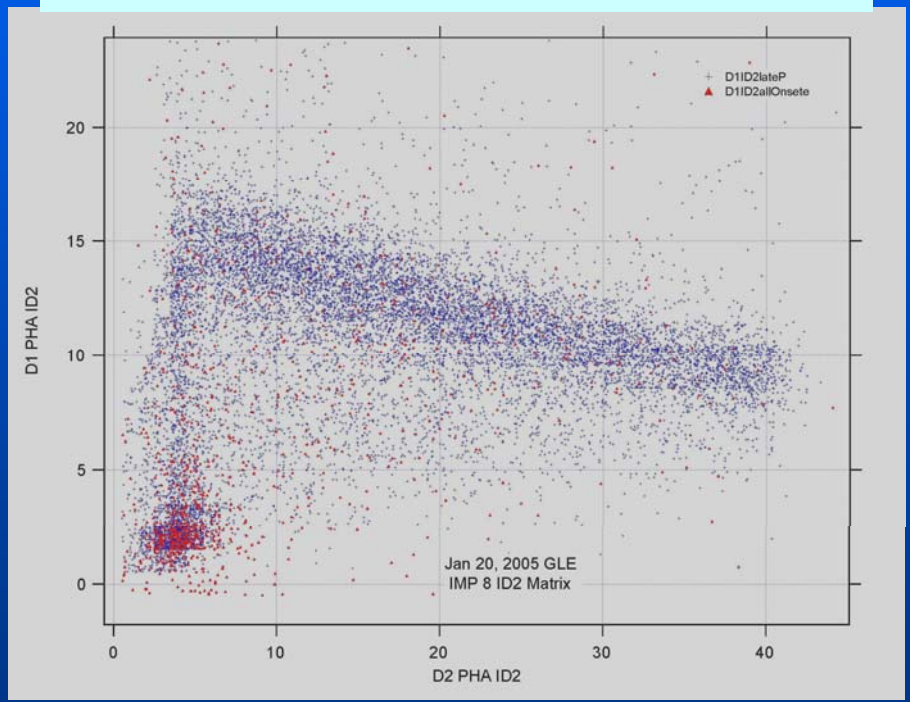
D1 vs. D2 for particles with D1 · D2 · $\overline{D3}$ · $\overline{D6}$

(~0.7-2.0 MeV Electrons & ~11-20 MeV Protons)

2005 January 20-21

Red: 20 Jan, 06:50-10:00 UT

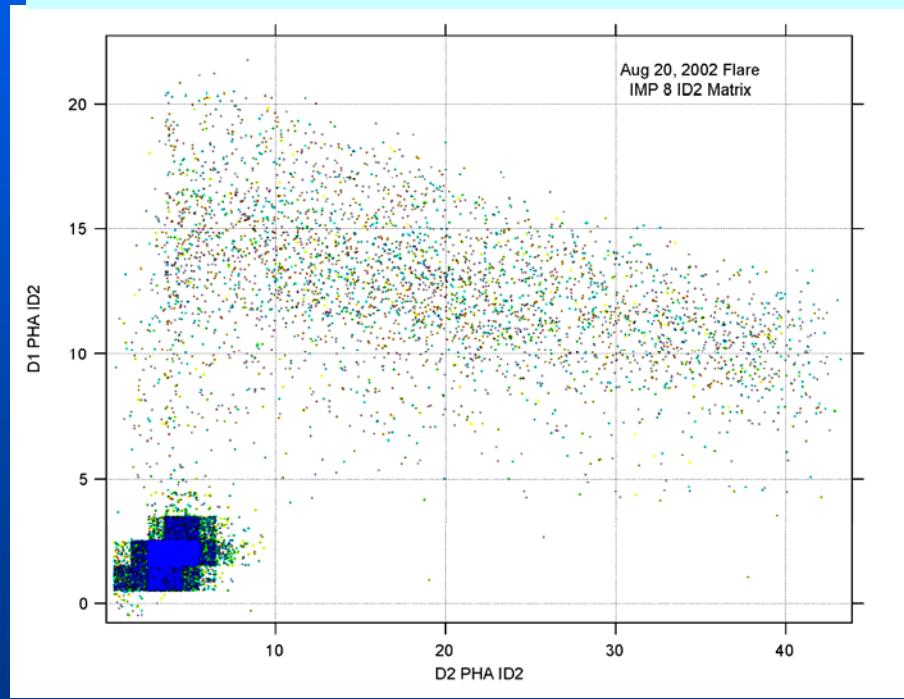
Blue: 21 Jan, 08:00-14:00 UT



2002 August 20

(A Very Large Impulsive Event)

e/p ~ 30

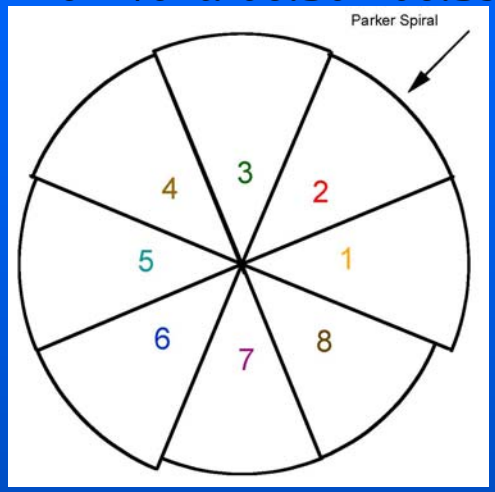


Note: PHA telemetry-limited to ~ 1.6 particles/s. We use counter rates for onset determinations.

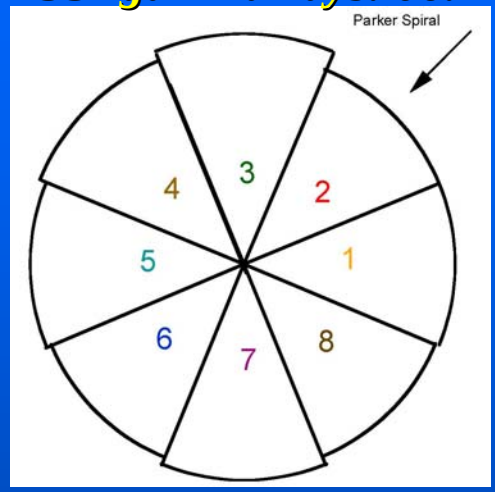
IMP8/CRNE ID2 Arrival Distributions

(Sun located at the top of this page; arrows indicate nominal Parker Spiral)

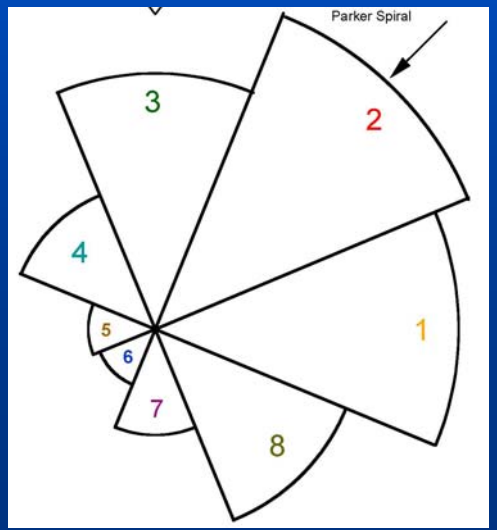
Pre-Event: 06:30 - 06:39



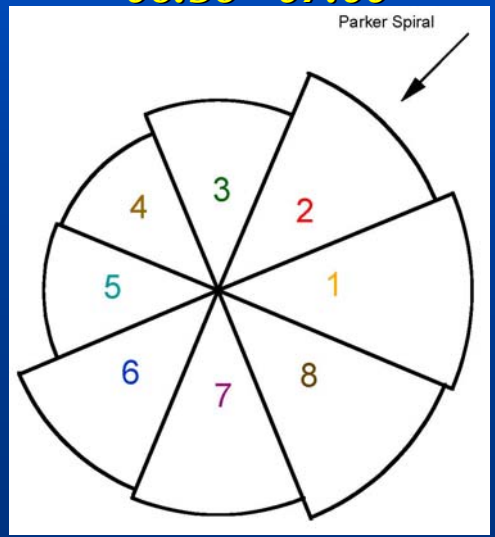
During RHESSI gamma-rays: 06:44 - 06:49



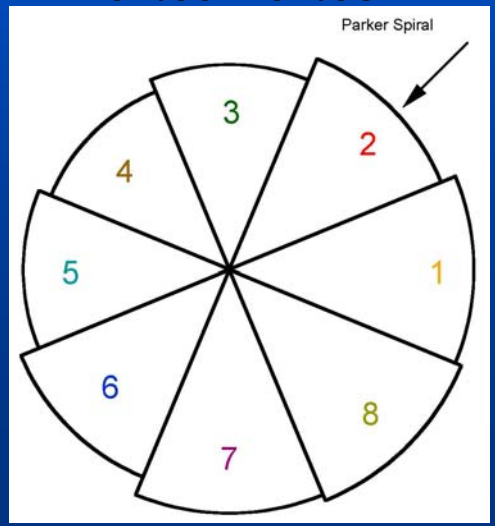
Onset: 06:52 - 06:56



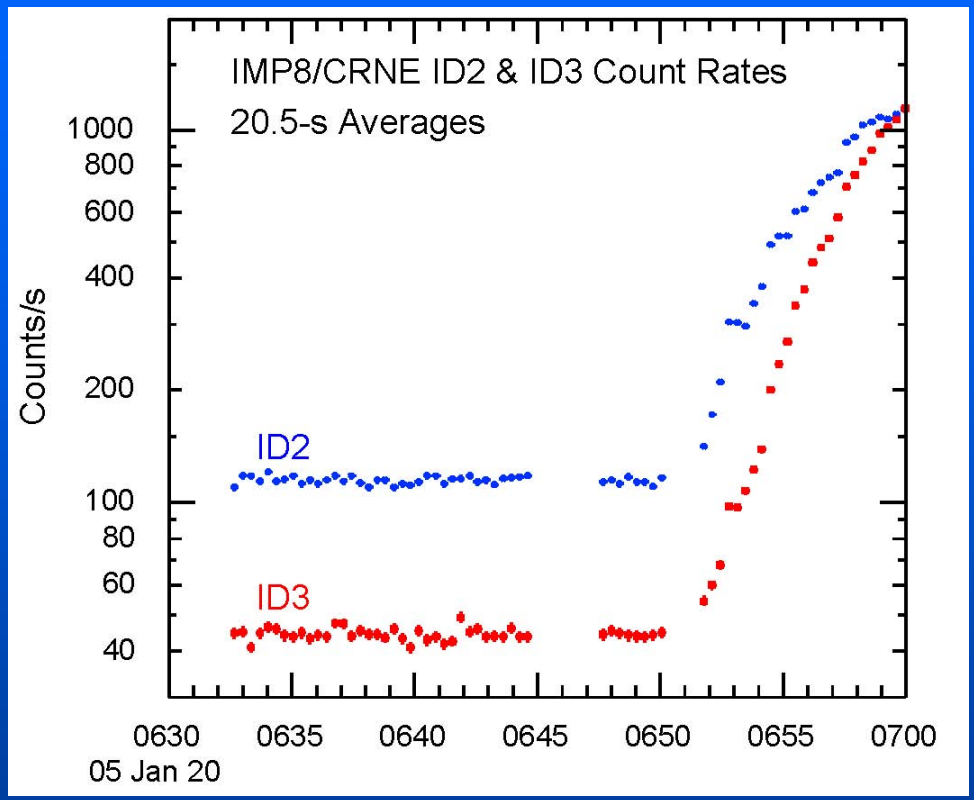
06:56 - 07:00

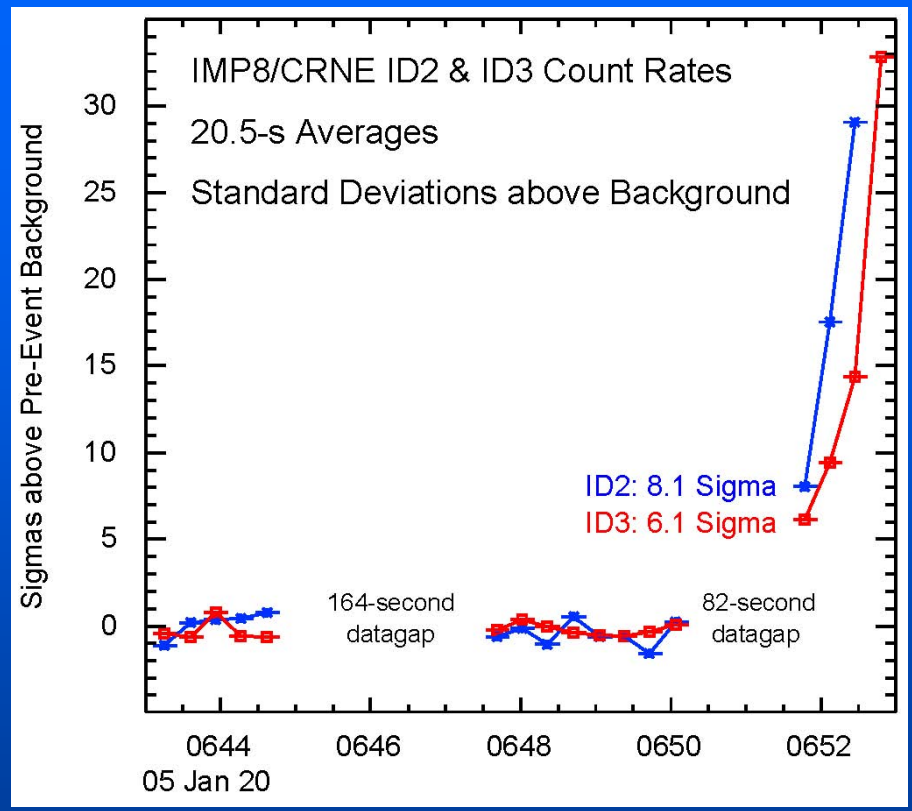


07:00 – 07:06



ID2 and ID3 Onsets



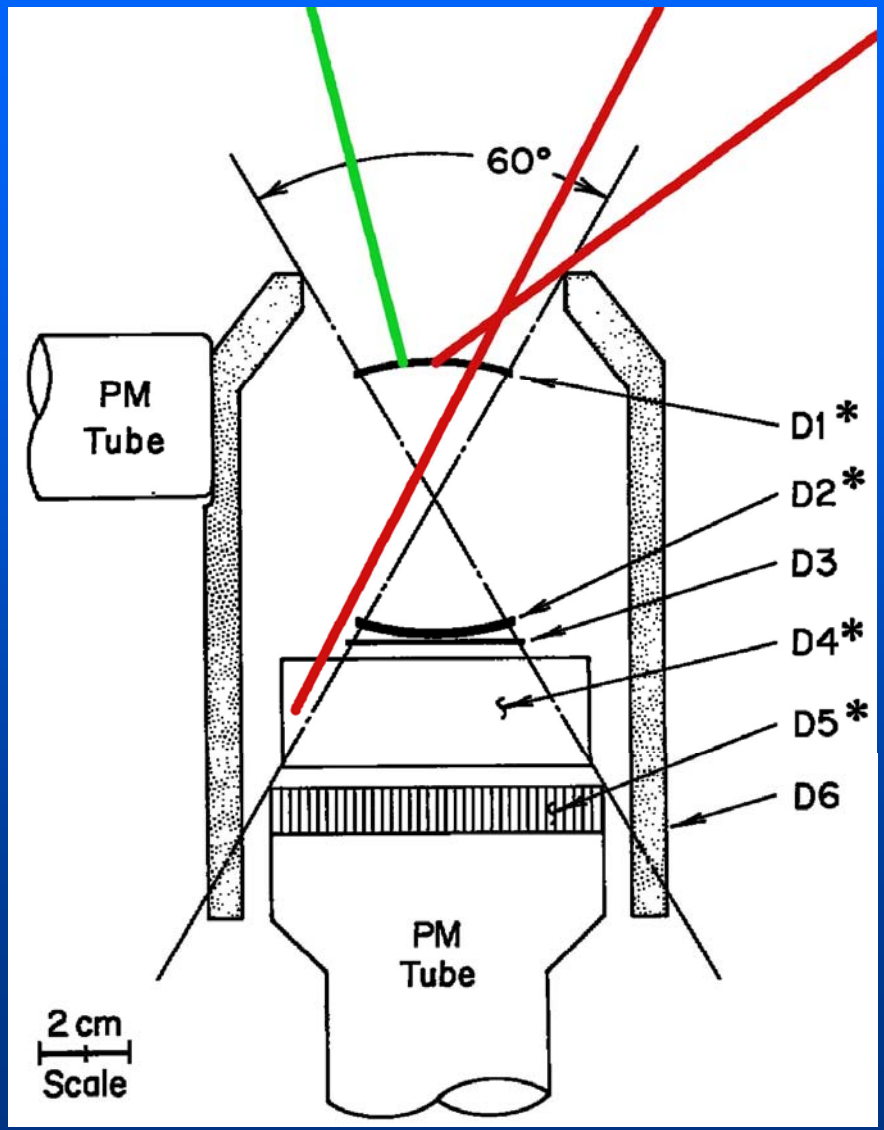


>6.1 sigma increases seen at 06:51:48 ± 10s

Increase observed right after an 82-s datagap

Real onset possibly as early as ~06:50

Count Rates in D1



Logic for D1 Counter:

$$D1 \cdot \overline{D2} \cdot \overline{D4} \cdot \overline{D6}$$

($\overline{D4}$ allows < 10 MeV)

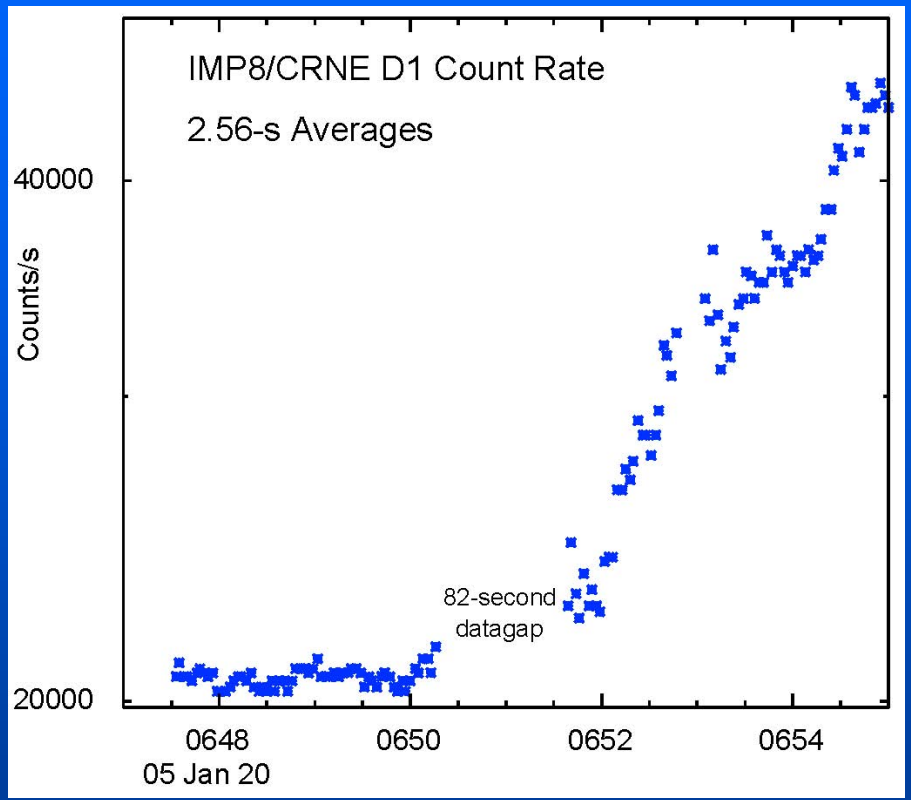
Wider angles gives GF ~ 20 cm^2-sr

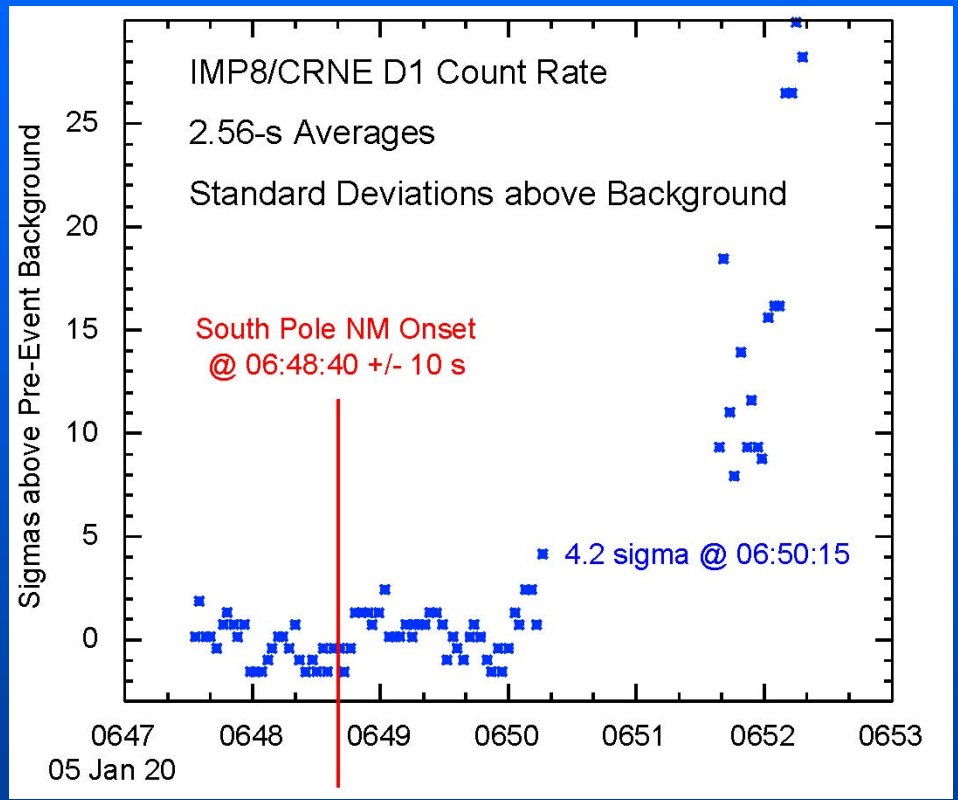
Electron Energy ~0.5 - ~ 11 MeV

Relativistic protons vetoed at D6

-- D1 count rate provides a more sensitive way to look for the onset of relativistic electrons.

IMP8/CRNE D1 Onset: Electrons >2 MeV

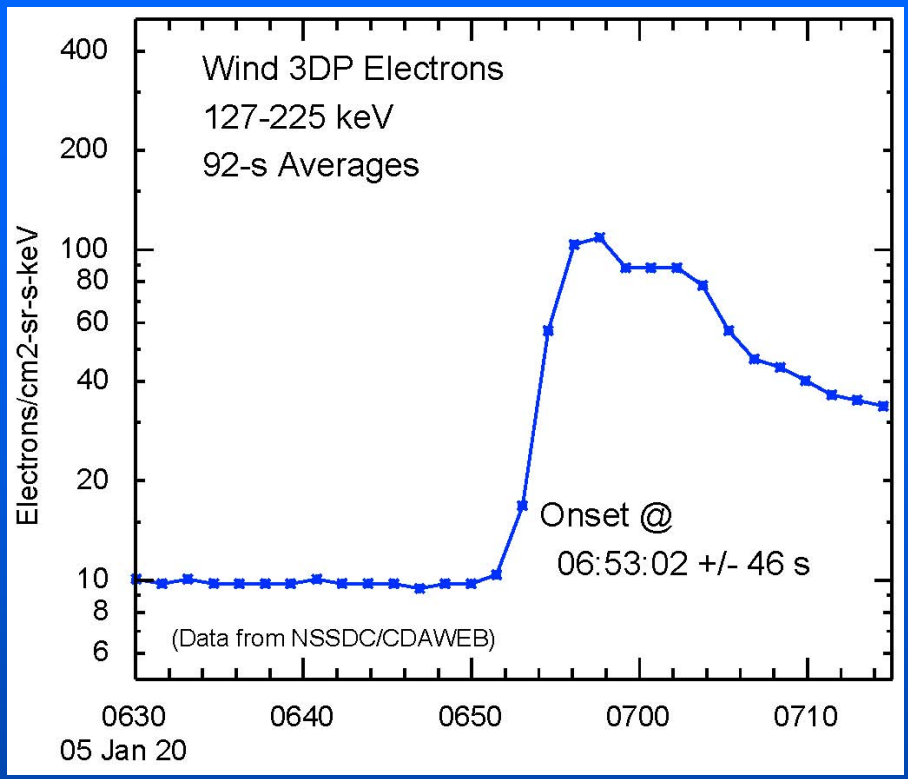


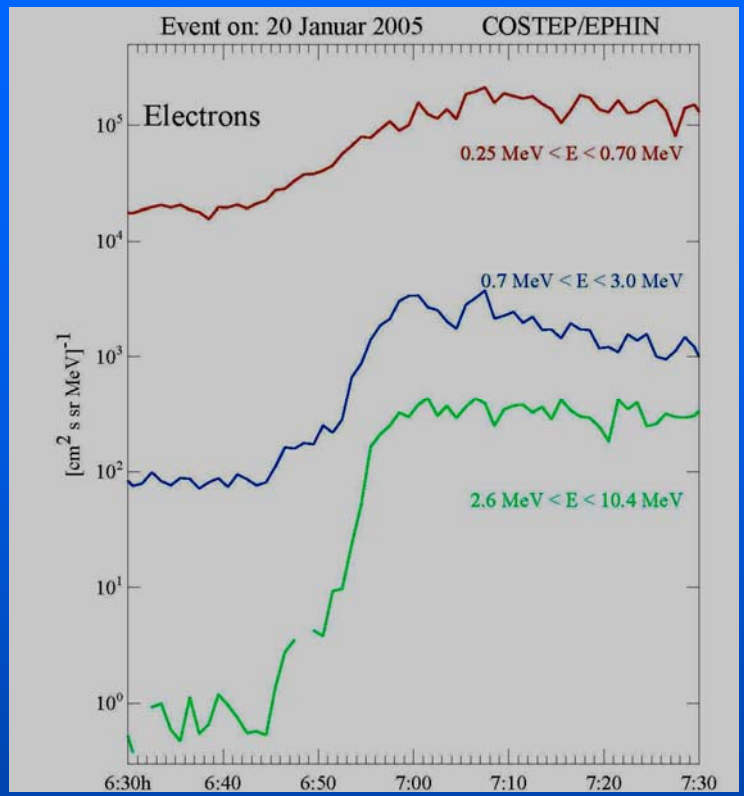


Electron Onset at 06:50:12 ± 5 seconds

1. 5 ± 0.2 minute delay between the onsets of relativistic protons & relativistic electrons near Earth

Wind/3DP and SOHO/COSTEP (Preliminary) Results





Electron channel at 127-225 keV

Onset at UT 06:53 ± 45 s.

Corrected for speed difference, corresponds to ~06:49 ± 1 minute for ~MeV electrons.

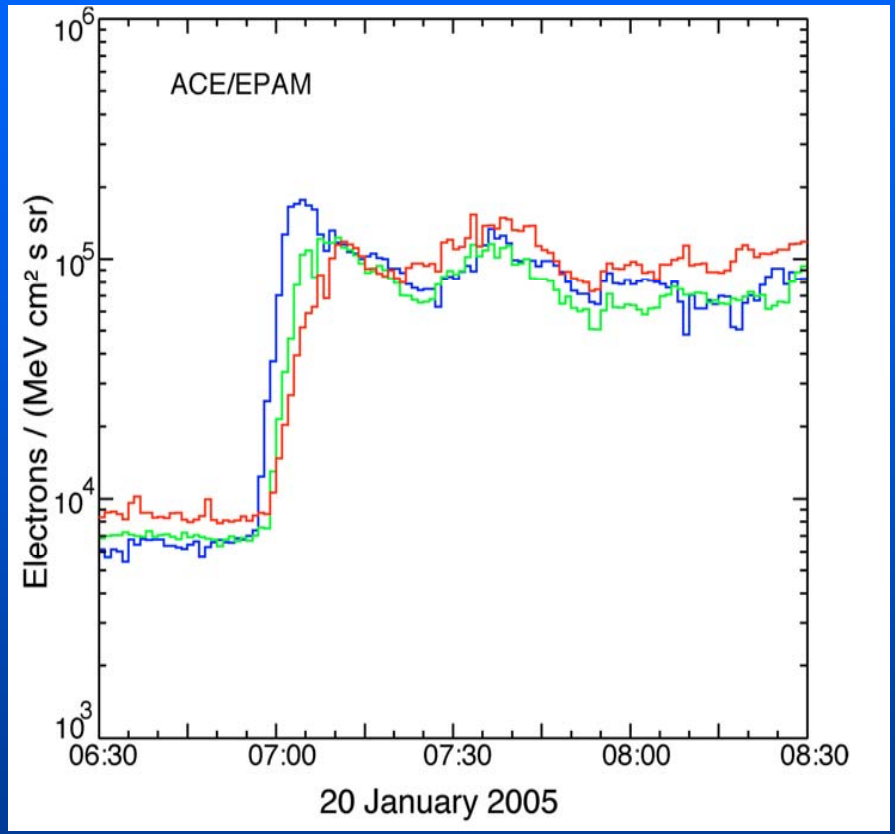
Photon contamination evident starting at 06:44

Estimated electron onset in 2.6 – 10.4 MeV channel at ~06:50.

Another instrument on IMP8 (APL's CPME) also observed electron onset at ~06:50 UT (T. Armstrong, private communication).

ACE/EPAM Results

G.M. Simnett, Astron. Astrophys. 445, 715-724 (2006)



06:57 Onset for ~250 keV electrons

After correcting for different particle speeds, Simnett (2006) reported that EPAM electrons departed the Sun ~6 minutes after the ~GeV protons observed by the neutron monitors.

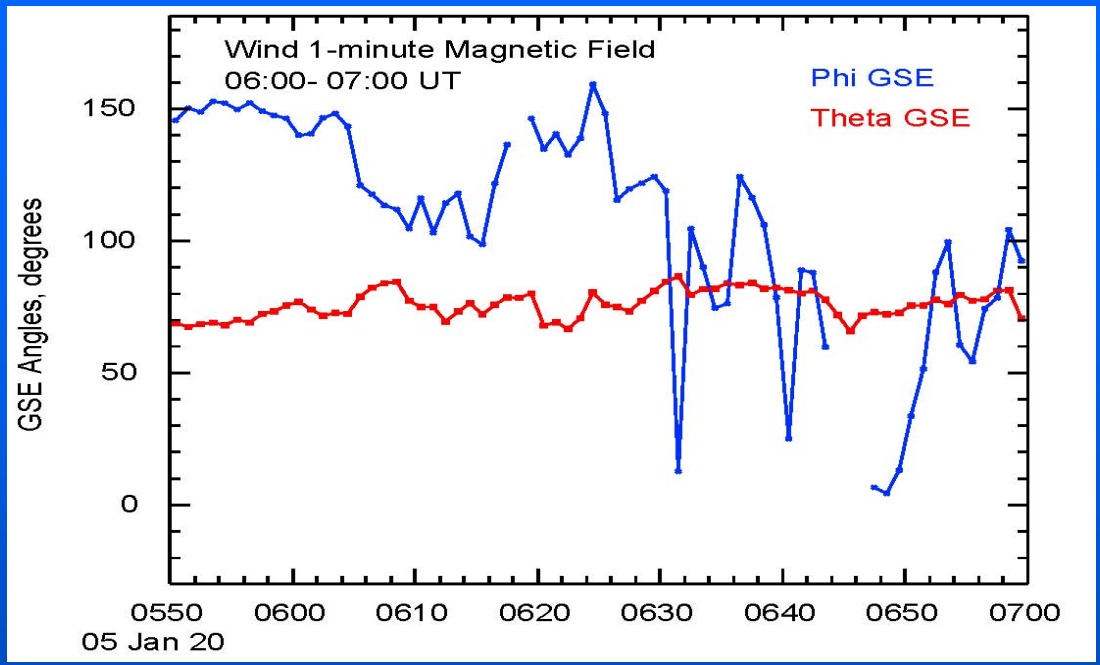
-- contradicts the IMP8, Wind, & SOHO results.

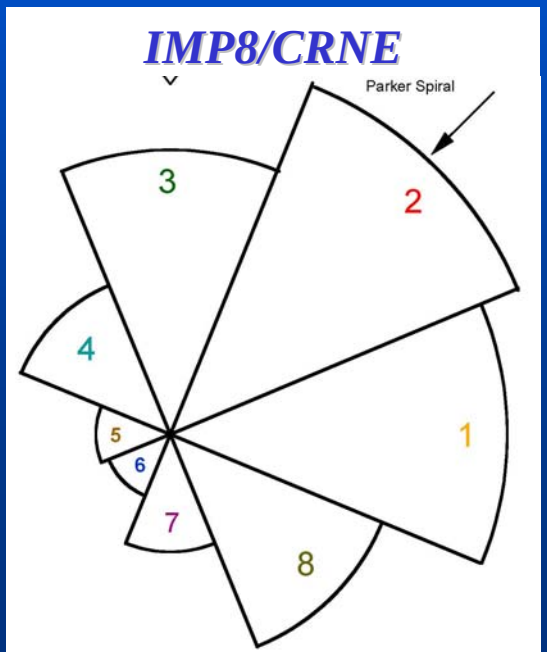
EPAM Website Announcement
April 13, 2006:

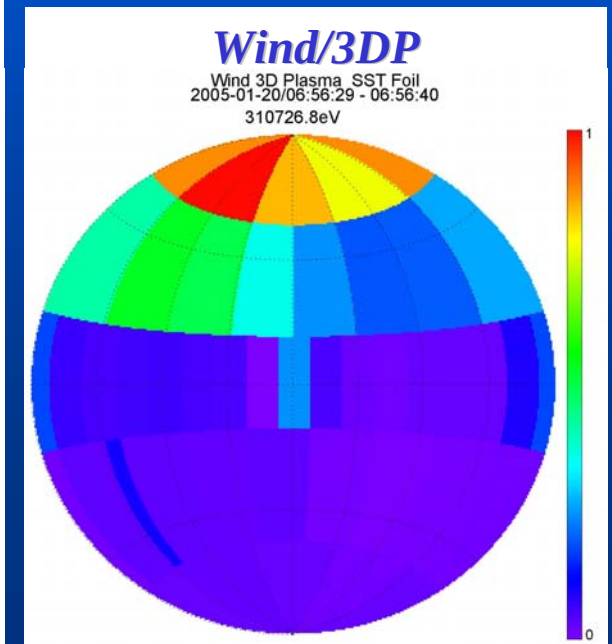
> *"The EPAM team has identified a timing drift in the EPAM data. This small timing drift is ~1 minute/year [since the launch of ACE in 1997]…"*

The 6-minute delay reported by Simnett (2006) is an artifact of this drift. After the EPAM data are corrected, they should agree well with the other satellites.

Arrival Directions and Magnetic Field







At the time of onset, the magnetic field had a very large component out of the ecliptic.

ACE/EPAM and Wind/3DP probably got a better view of the very first-arriving electrons than IMP8/CRNE.

(IMP8/CRNE had to wait for the pitch-angle distribution to broaden.)

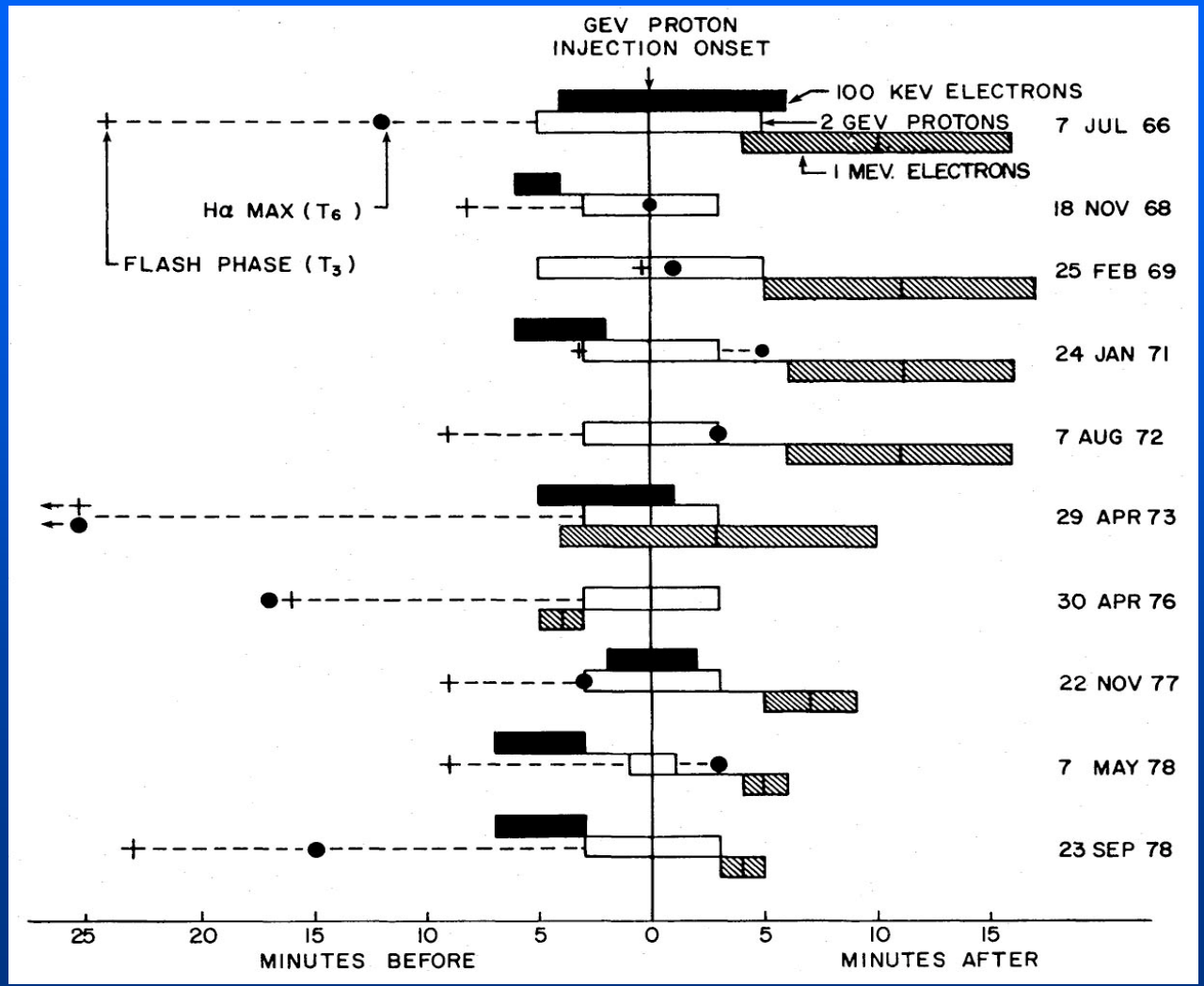
When corrected for electron speed, ACE & Wind may very well show an onset time even closer to that of the neutron-monitor protons.

We have found comparable electron delays in other GLEs:

	NM Onset at Earth	*IMP8/CRNE Relativistic Electron Onset at Earth*	*Electron Delay (min)*
2005 January 20	*06:48:40 ± 10 s (South Pole)*	*06:50:12*	*1.5 ± 0.2*
2001 April 15	*13:57:30 ± 30 s (McMurdo)*	*13:59:36*	*2.0 ± 0.5*
2000 July 14	*10:34:30 ± 30 s (South Pole)*	*10:37:07*	*2.5 ± 0.5*
1998 May 6	*08:07:30 ± 2.5 min (Oulu)*	*08:10:00*	*2.5 ± 2.5*
1989 Nov 15	*07:04:30 ± 30 s (Thule)*	*07:04:02*	*0 ± 0.5*
1989 Oct 24	*18:24:30 ± 30 s (McMurdo)*	*18:24:53*	*0.4 ± 0.5*

Cliver et al., ApJ 260, 362-370 (1982)

-- compared neutron monitor and electron onsets in GLEs from 1966-1978.



They found, on average, that ~1 MeV electrons were delayed by >5 minutes with respect to the NM onsets.

This is not what we are finding.

We believe that the longer delays reported by Cliver et al. probably reflected the limited sensitivity of the electron onset determinations.

Summary

IMP8/CRNE observed the onset of relativistic (>1 MeV) electrons near Earth at 06:50:12 UT on 2005 January 20. This result implies that relativistic electrons departed the Sun 1.5 ± 0.2 minutes after the relativistic protons observed by NMs. This residual delay may simply reflect limited electron sensitivity (due to high pre-event background and unfavorable viewing direction), rather than a real delay.

Preliminary examination of SOHO/COSTEP, Wind/3DP, and IMP8/CPME give a similar conclusion, after correcting for differences in electron speeds.

The Simnett (2006) report of a ~6 minute delay between the departures of relativistic protons and (near) relativistic electrons from the Sun is incorrect. This delay is the artifact of an ACE/EPAM data processing error, which is currently being rectified.

IMP8/CRNE sees comparable <2 minute proton/electron emission delays in other GLEs; the 2005 January 20 GLE is not unique in this regard. IMP8/CRNE electron delays are considerably smaller than the >5 minute delays reported by Cliver et al. (1982). We suggest that the Cliver et al. results were compromised by limited electron sensitivity.

The close correspondence in onset times makes it likely that the same acceleration mechanism is responsible for relativistic protons and relativistic electrons. (A quasi-perp shock is a good candidate in this regard.)

A Special Session at the 2006 SHINE Workshop

July 31 – August 4, in Zermatt, Utah

The Historic Solar Event of January 20, 2005: A Challenge for Current Theories on the Origins of Solar Energetic Particles?

For more information, please see:

http://creme96.nrl.navy.mil/20Jan05/

Or google:

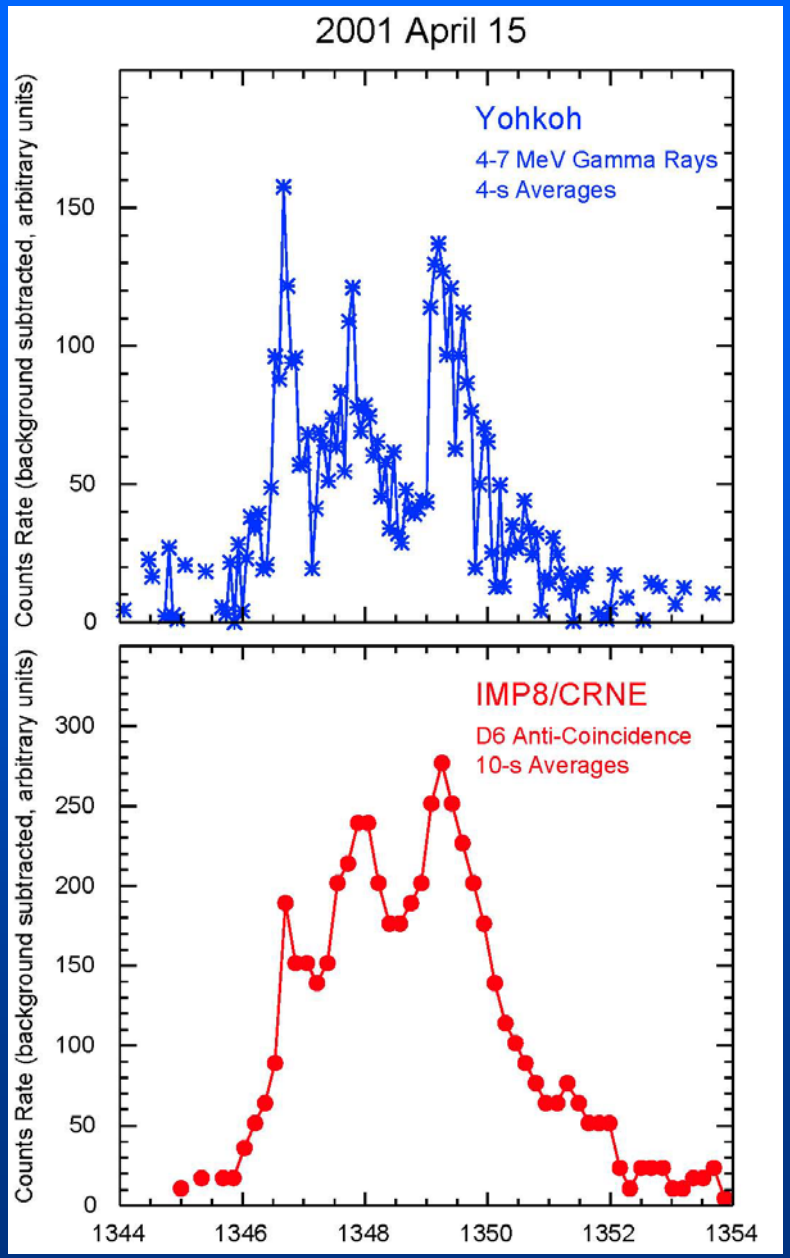
"solar event January 20"

Or follow the links at:

http://www.shinegroup.org

Backups

IMP8/CRNE Timing Accuracy

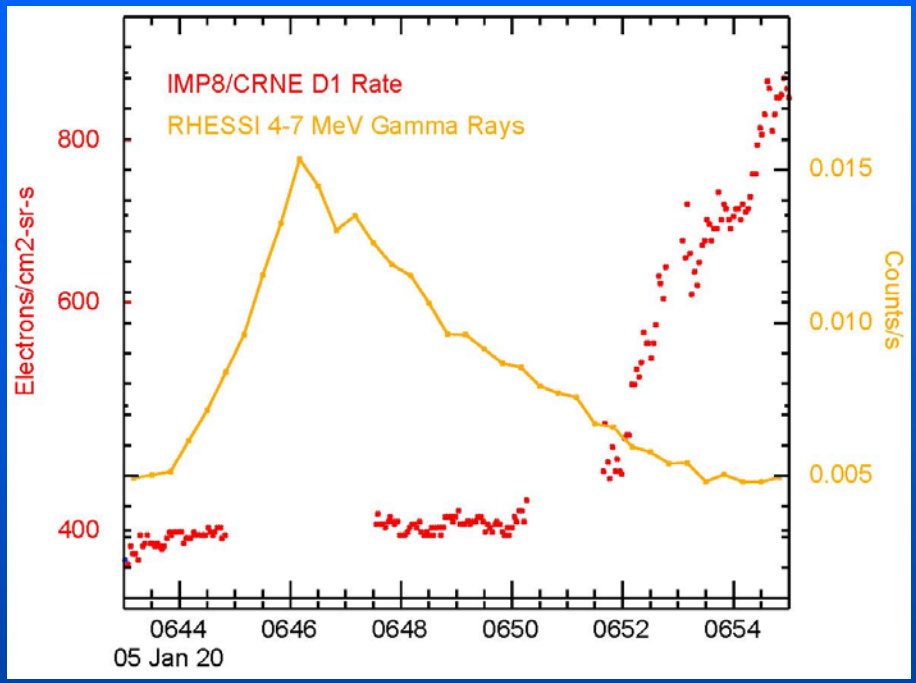


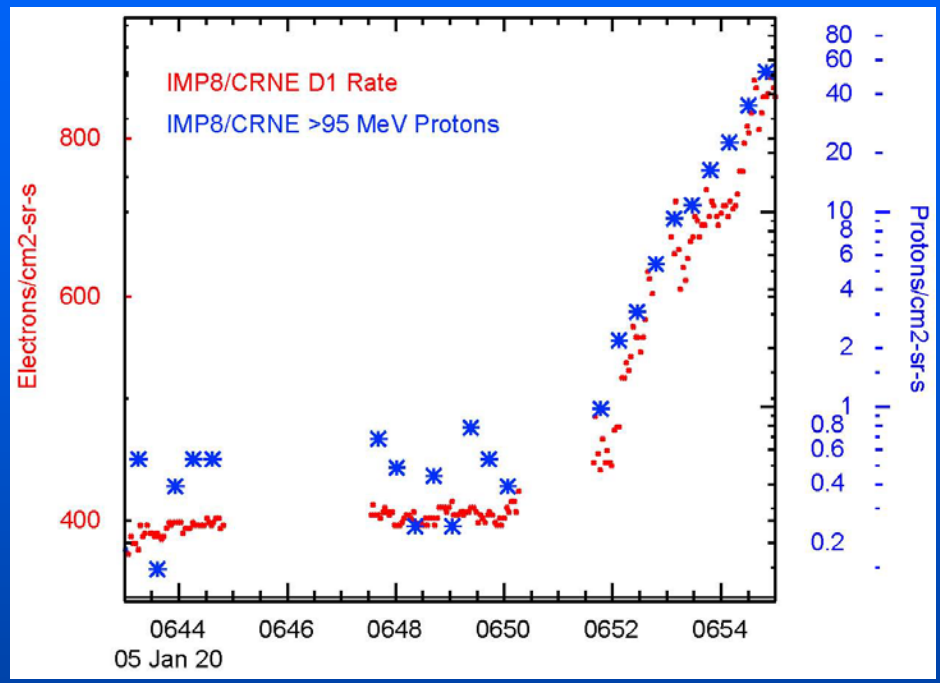
- *Before the onset of the 2001 April 15 GLE, Yohkoh observed 3 peaks in the time structure of gamma rays over a ~4 minute time period.*

- *Particle background levels were sufficiently low that IMP8/CRNE detected these gamma rays in its D6 anticoincidence shield.*

- *The IMP8/CRNE and Yohkoh times for these three peaks agree to within less than 5 seconds.*

Could photons or protons cause the D1 increase? No!



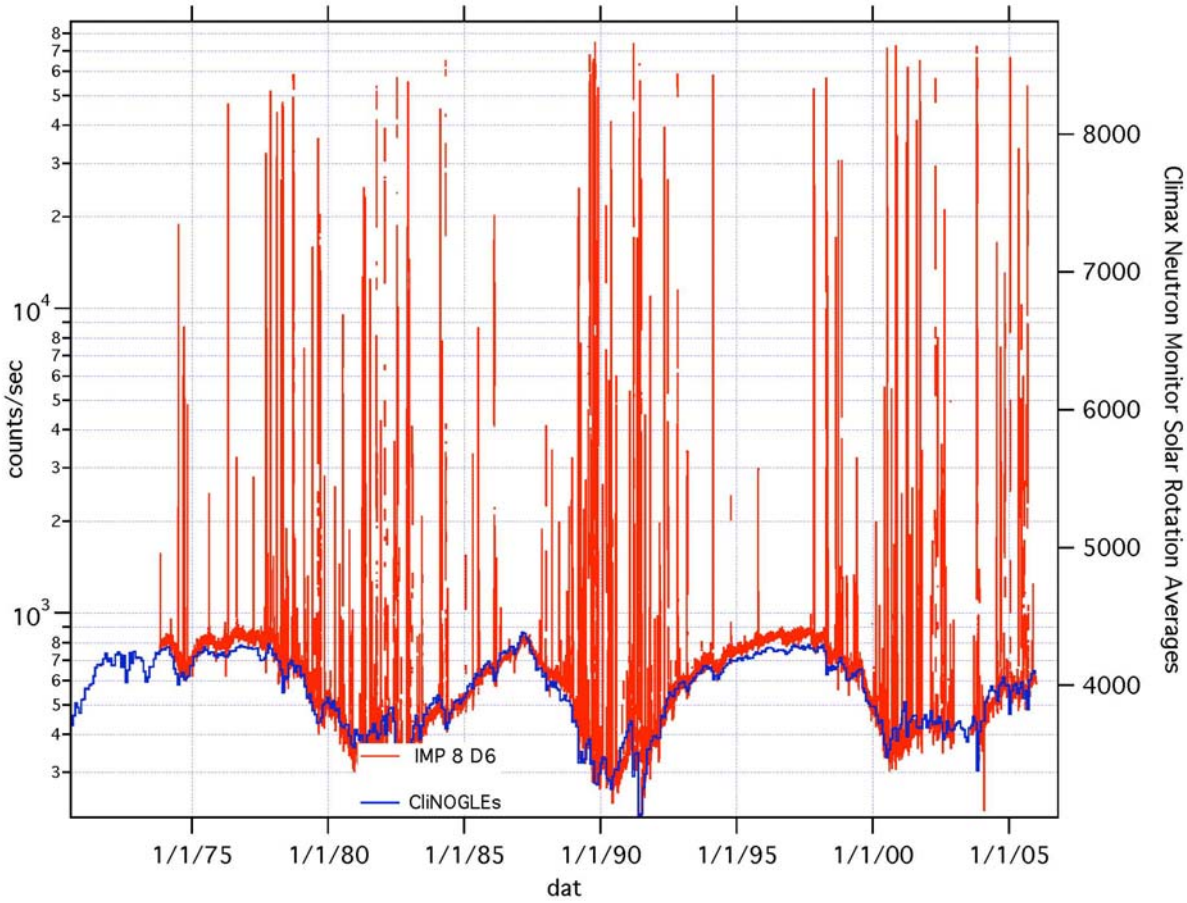


RHESSI gamma-rays are already declining when the D1 onset occurs at ~06:50 UT.

D1 rate is 100-times larger than the rate of relativistic protons.

IMP8/CRNE Instrument Stability

- *D6 anti-coincidence shield registers Galactic cosmic ray proton above ~1 GeV.*
- *Comparison with Climax Neutron Monitor over 33 years indicates no significant degradation in sensitivity.*

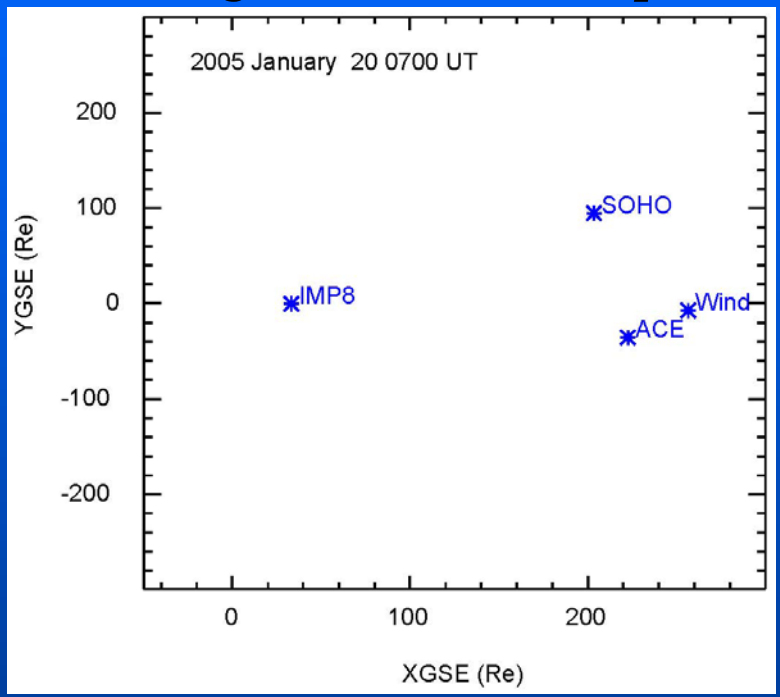


IMP8/CRNE D6 counts/s

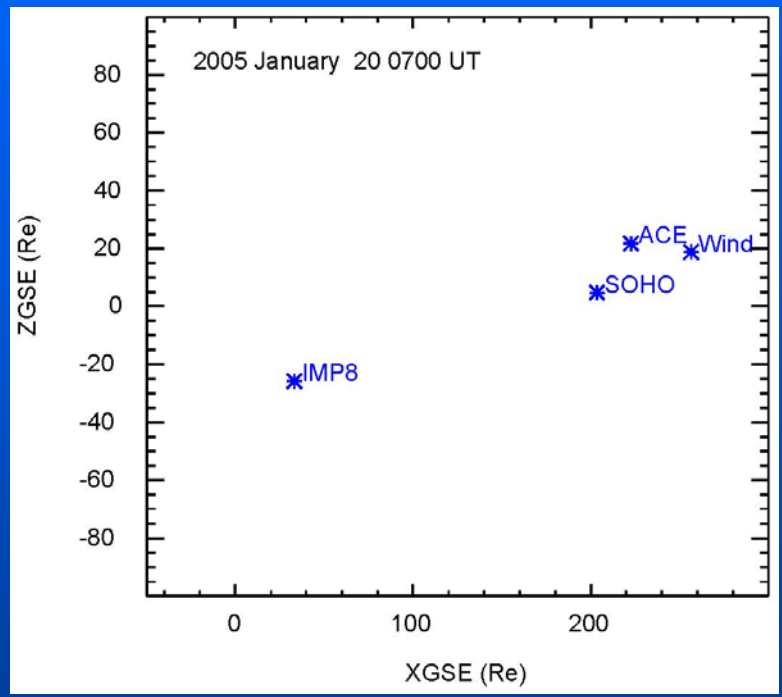
27-day averaged Climax NM count rate

Satellite Locations on 2005 January 20, ~0700 UT

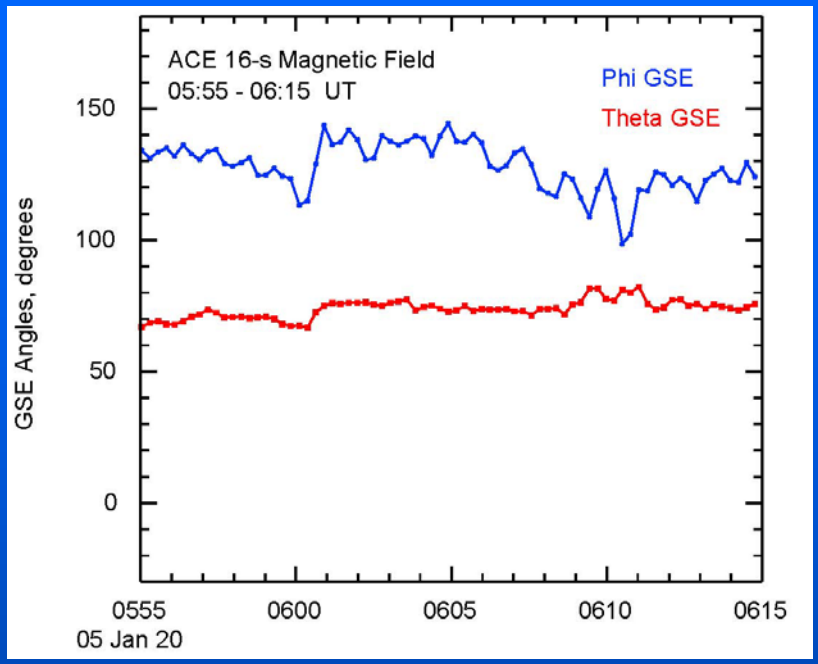
Looking down on the Ecliptic

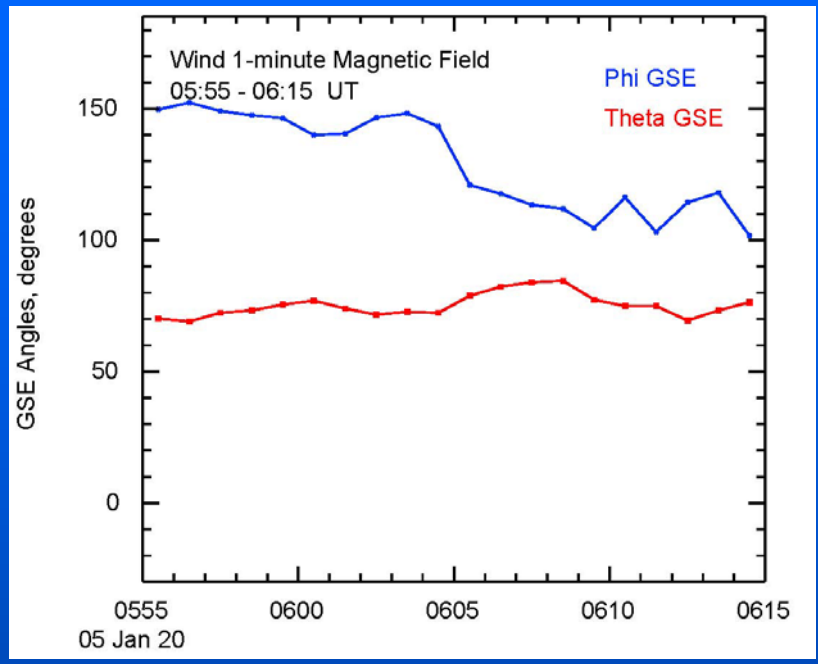


Looking perpendicular to the Ecliptic



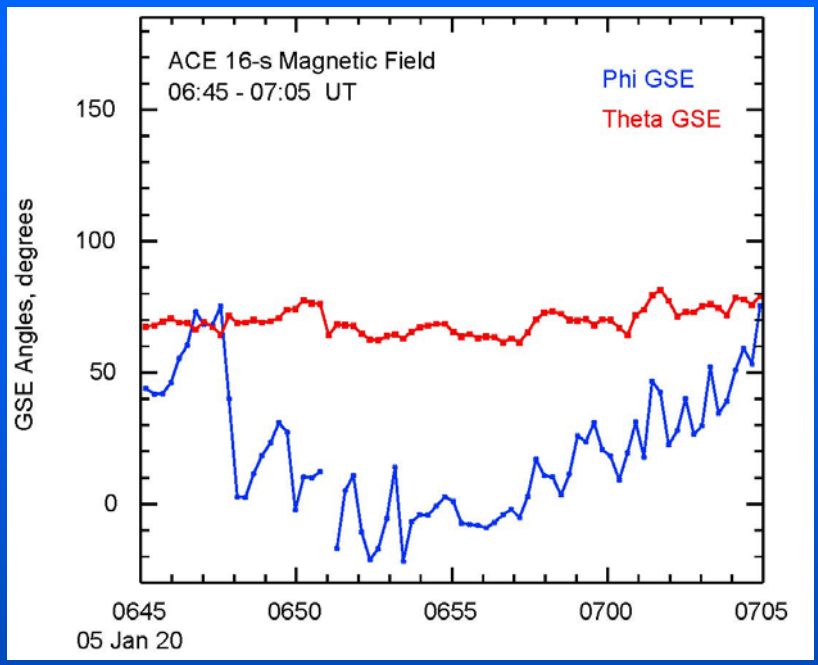
Magnetic Field Directions: at ~06:00 UT at L1

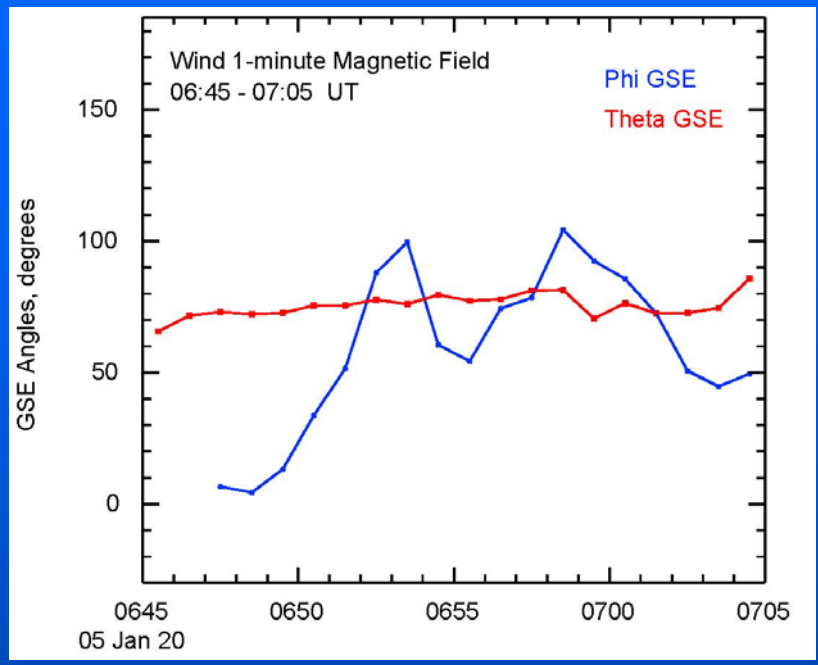




- *No magnetic field measurements on IMP8. But there are measurements from ACE & Wind at L1.*
- *After convection in the solar-wind (~500 km/s), these are the fields at IMP8 at the time of particle onset at ~06:50 UT.*
- *φ_{GSE} consistent with IMP8 onset in nominal Parker spiral sector. But the field has very large component perpendicular to the ecliptic.*
- *Electron PAD must be broad to get into IMP8 FOV at $\pm$ 30^{o} of the ecliptic.*

Magnetic Field Directions: at ~07:00 UT





- *Large component perpendicular to the ecliptic persists.*
- *Complicated field: φ_{GSE} very different on Wind & ACE.*