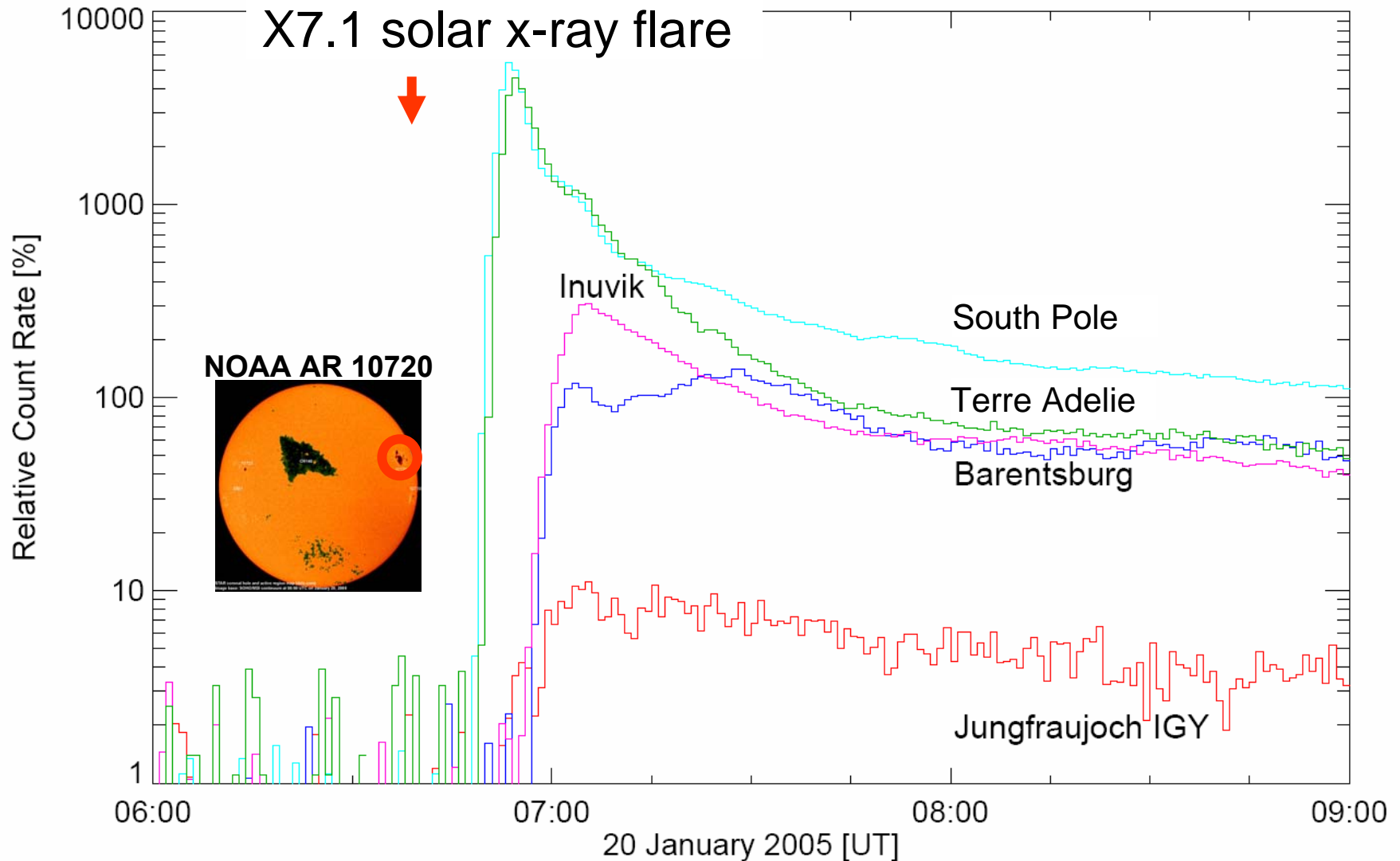


Characteristics of the
Cosmic Ray Ground Level Enhancements
on
January 20, 2005, and December 13, 2006,
as obtained from
Worldwide Neutron Monitor Data

Erwin O. Flückiger
R. Bütikofer, B. Pirard, L. Desorgher
Physikalisches Institut
University of Bern

erwin.flueckiger@space.unibe.ch

The 20 January 2005 GLE



The 20 January 2005 GLE

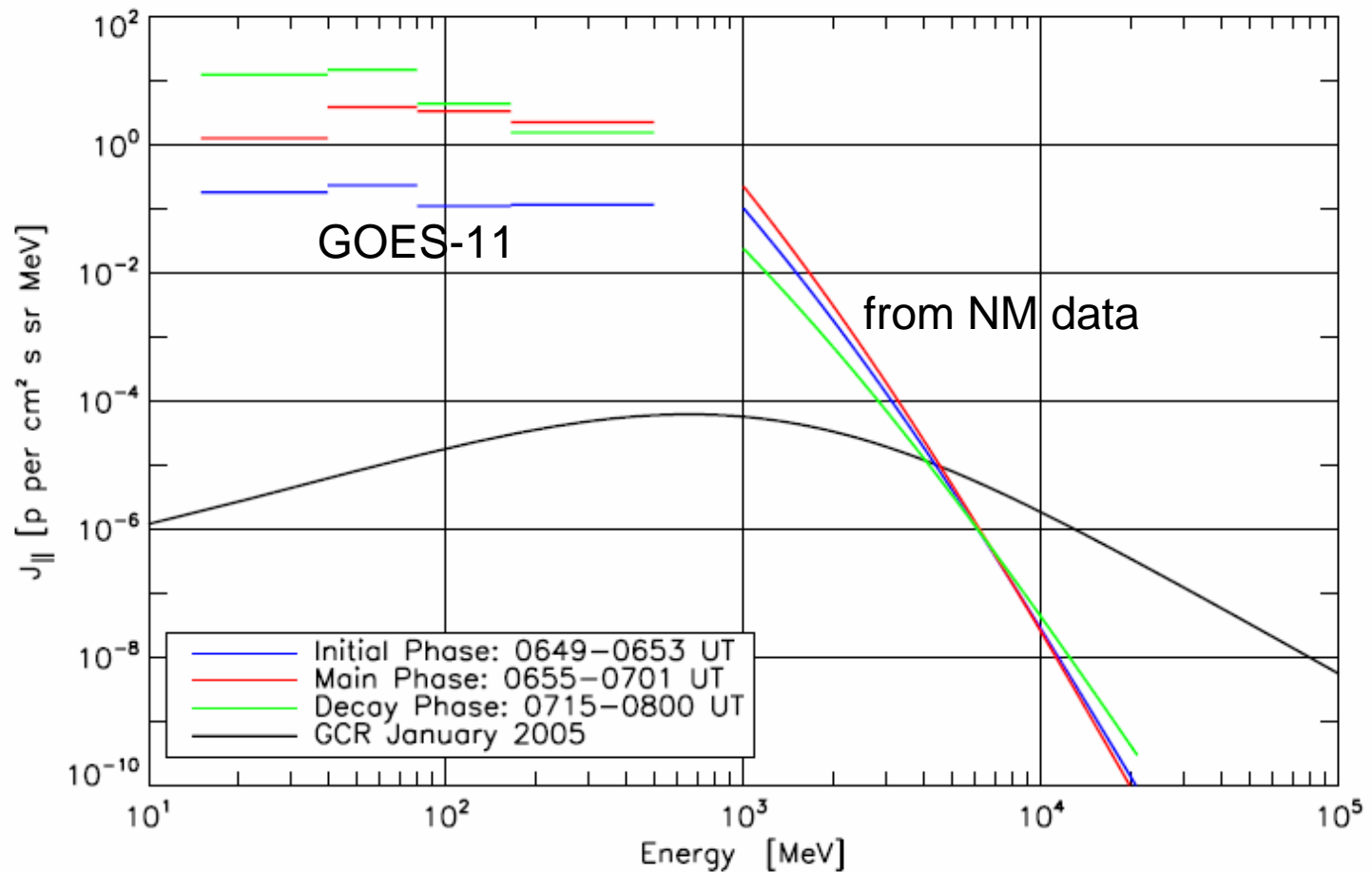
Progress since 29th ICRC

and SEE 2005 International Symposium

10 Papers at 30th ICRC

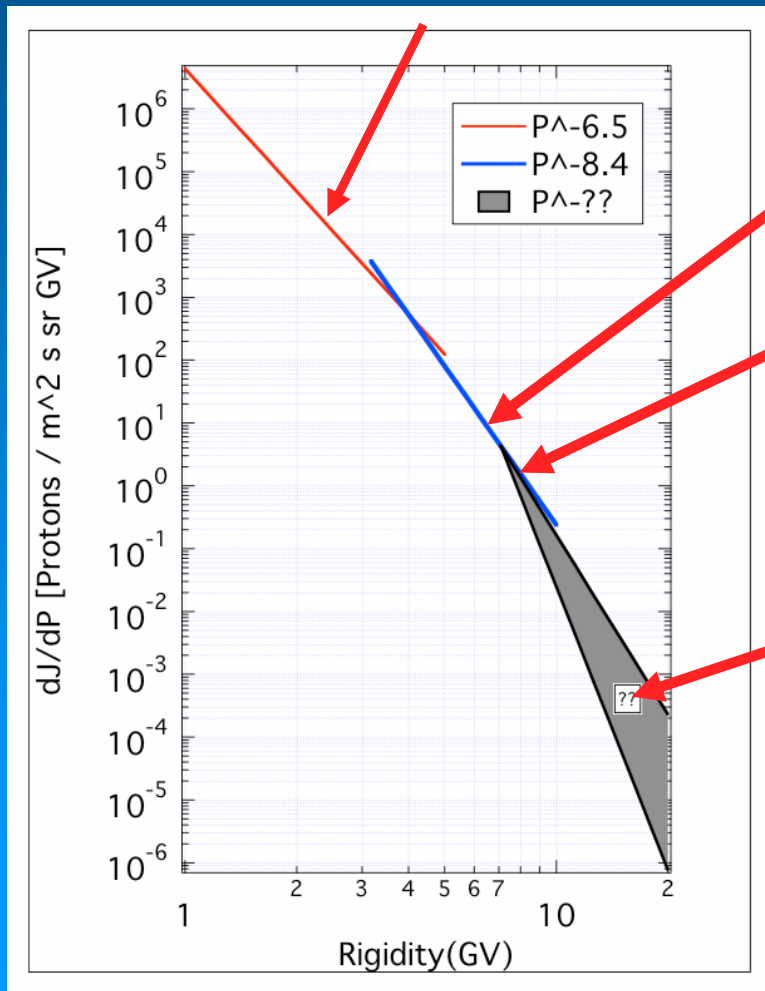
33	Dvornikov et al.	862	Moraal et al.
172	Kudela & Langer	897	McCracken & Moraal
643	Vashenyuk et al.	1152	Morgan et al.
658	Vashenyuk et al.	1009	Storini & Damiani
715	Shea & Smart	1182	Flückiger et al.

The 20 January 2005 GLE Spectrum



The 20 January 2005 GLE Spectrum

Durham/Mt. Washington



Milagro/Climax

Milagro/Milagro

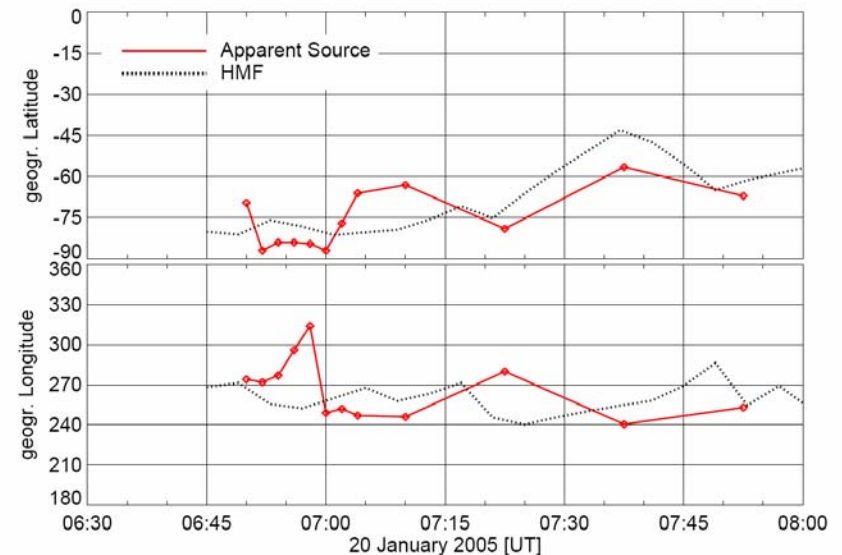
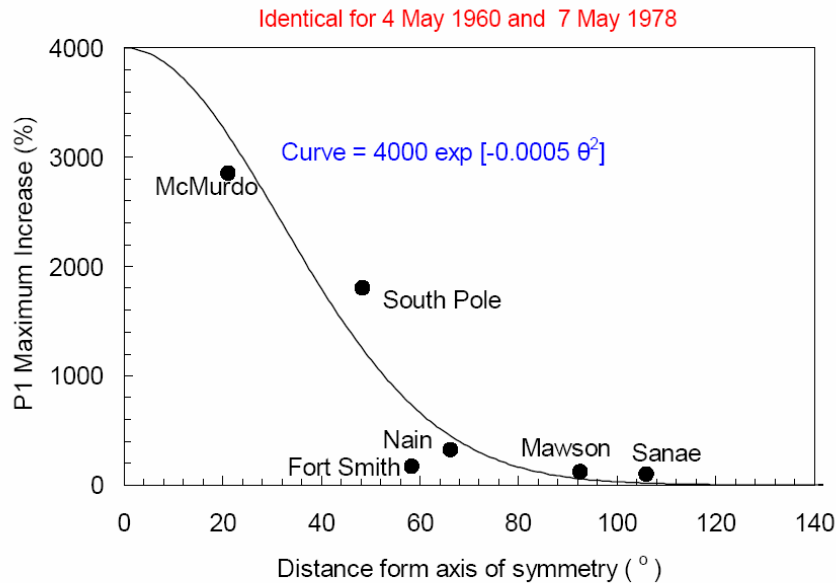
Higher, unanalyzed
Milagro channels

Spectral index softens from
6.5 to ~ 8 at ~ 4 GV

30th ICRC Paper 1152, Morgan et al.

The 20 January 2005 GLE

Pitch Angle Distribution, Apparent Source Direction

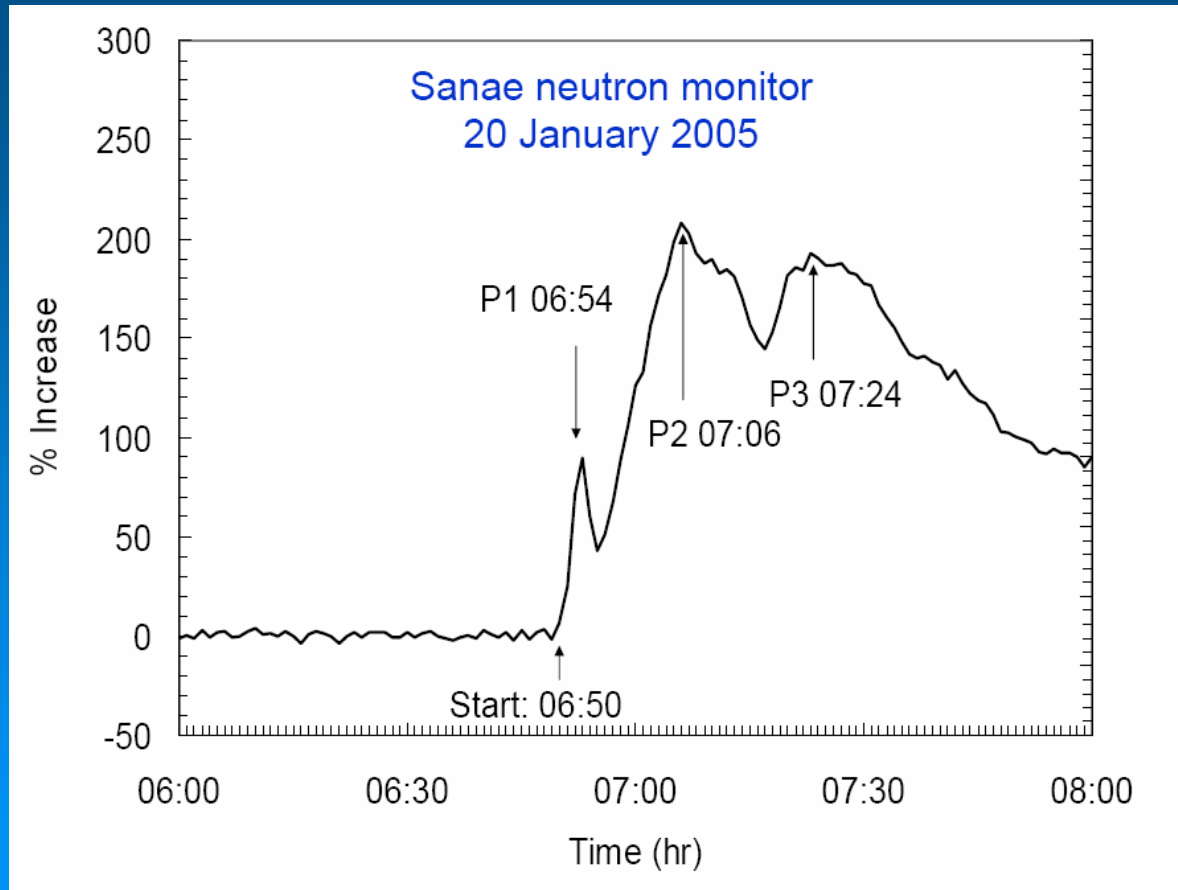


30th ICRC Paper 862, Moraal et al.

Bütikofer et al., 2006
see also this conference

The 20 January 2005 GLE

Two Acceleration Mechanisms?

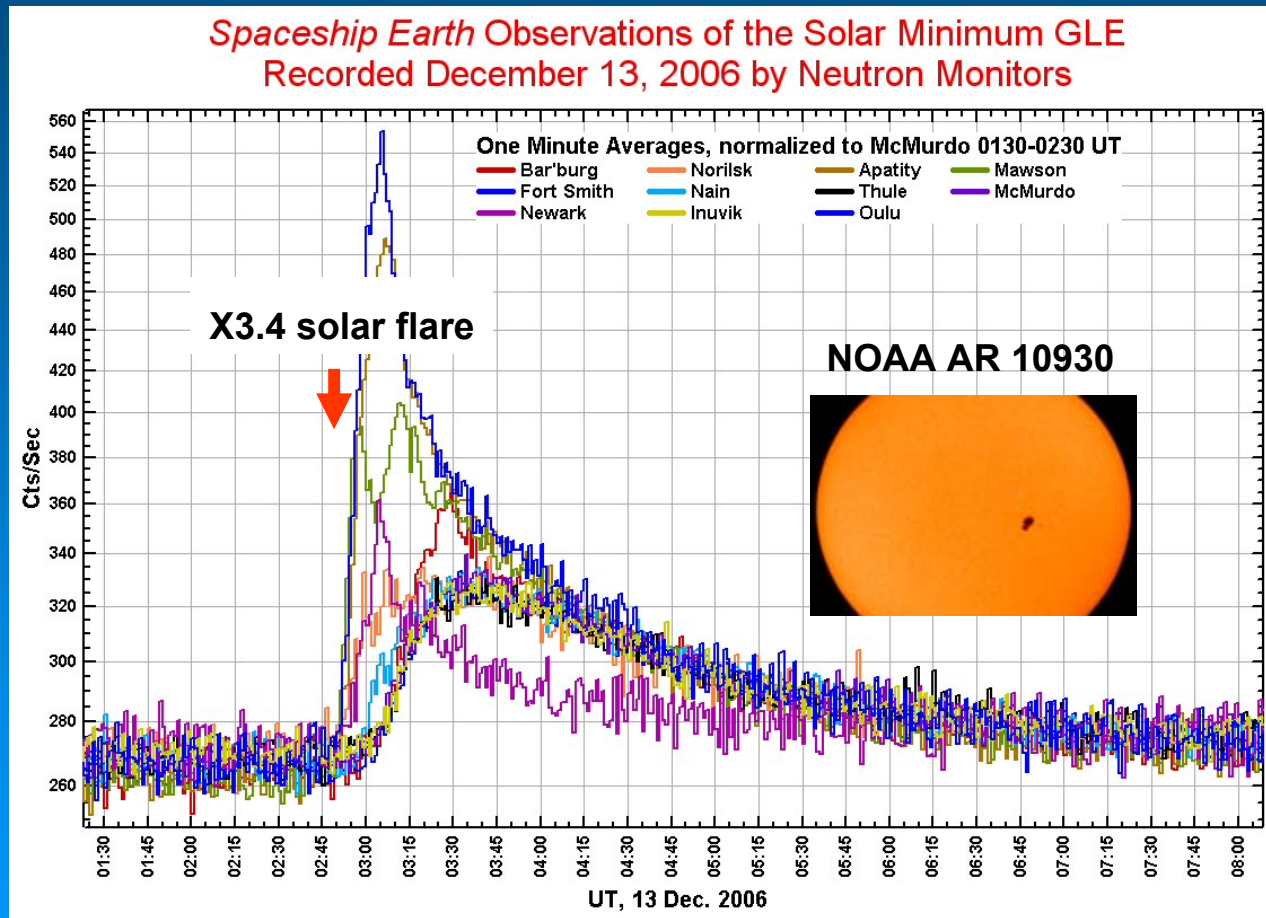


► THE GENERIC SOLAR ENERGETIC PARTICLE EVENT ?

30th ICRC Papers 862, Moraal et al., and 643, Vashenyuk et al.

see SEE2007 Papers by Moraal and Vashenyuk

The 13 December 2006 GLE

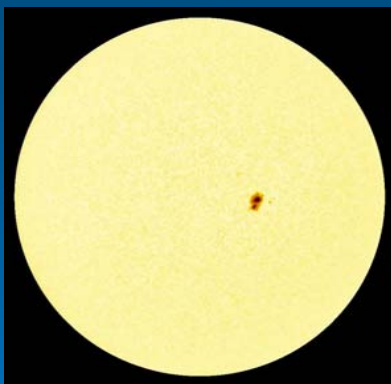


This GLE occurred near solar minimum, but it was a large event, exceeding 100% increase at Oulu

adapted from 30th ICRC Paper 376, Bieber et al.

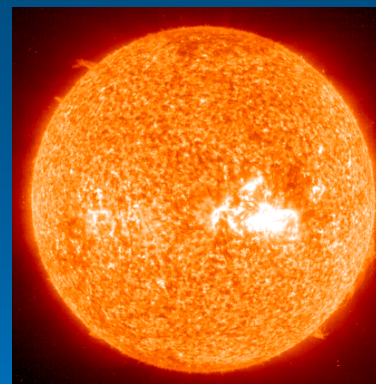
The Sun on 13 December 2006

White light

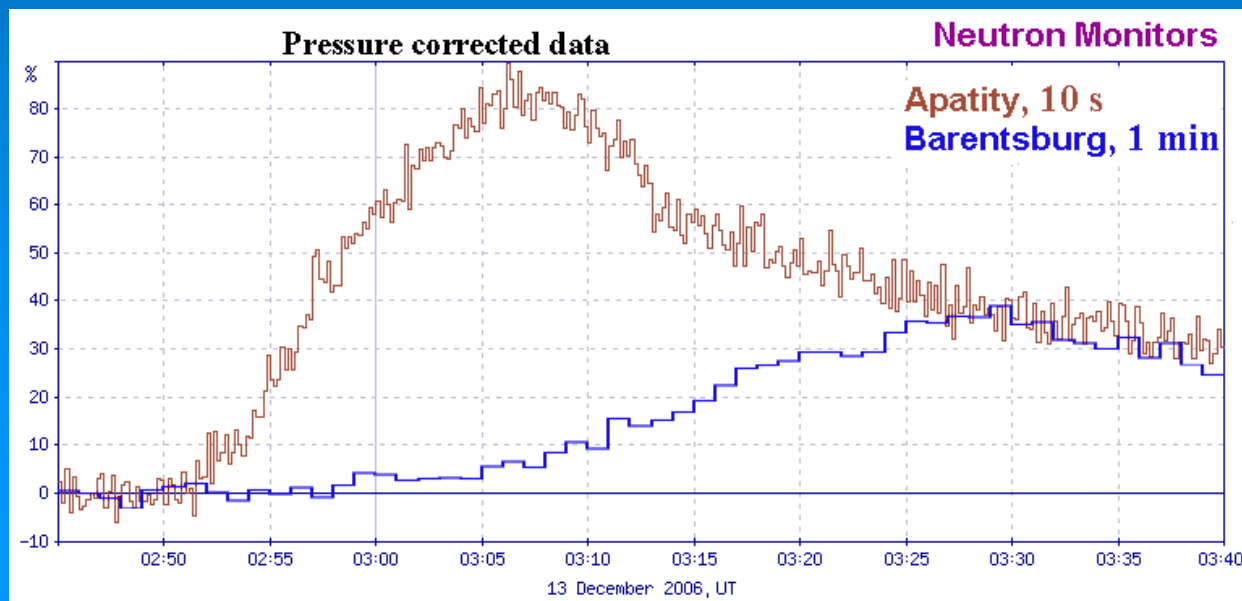


Active
region
AR10930

30 nm emission



Ground level effect of a solar flare X3.4/2B S06 W24 02.26 UT



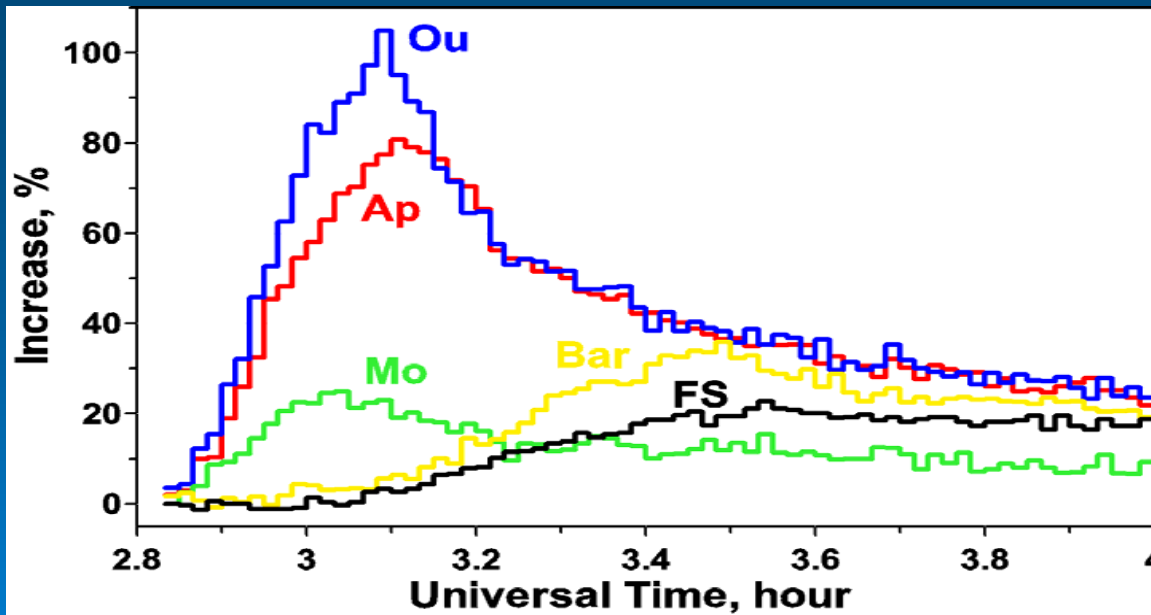
The 13 December 2006 GLE at the 30th ICRC

“A Maverick GLE” (376 Bieber et al.)

15 Papers

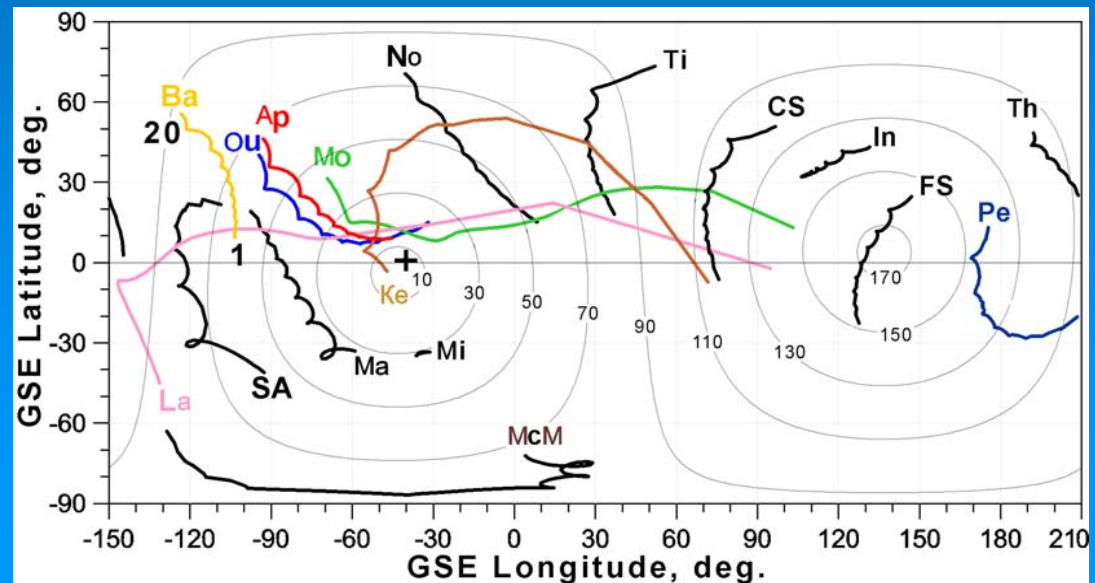
168 Stoker	357 Heber et al.
298 Timashkov et al.	412 Grigoryev et al.
362 Vashenyuk et al.	643 Vashenyuk et al.
376 Bieber et al.	658 Vashenyuk et al.
680 Balabin et al.	1002 Storini et al.
715 Shea & Smart	1073 Eroshenko et al.
897 McCracken & Moraal	1173 Tang
172 Kudela & Langer	1182 Flückiger et al.

The 13 December 2006 GLE



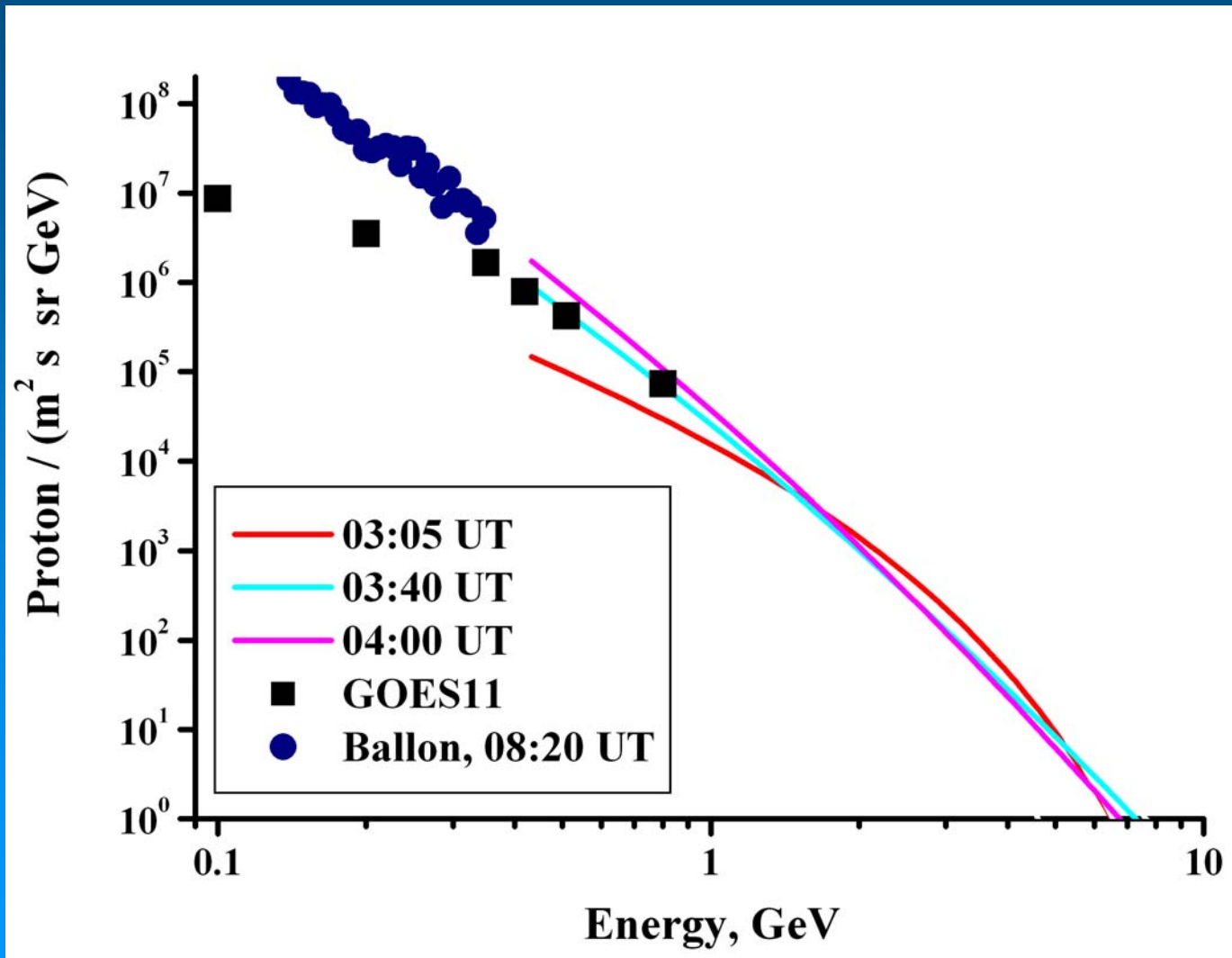
Increase profiles at
neutron monitors

Map of neutron
monitors' asymptotic
cones. Cross is IMF
direction from ACE data



30th ICRC Paper 643, Vashenyuk et al.

The 13 December 2006 GLE Spectrum



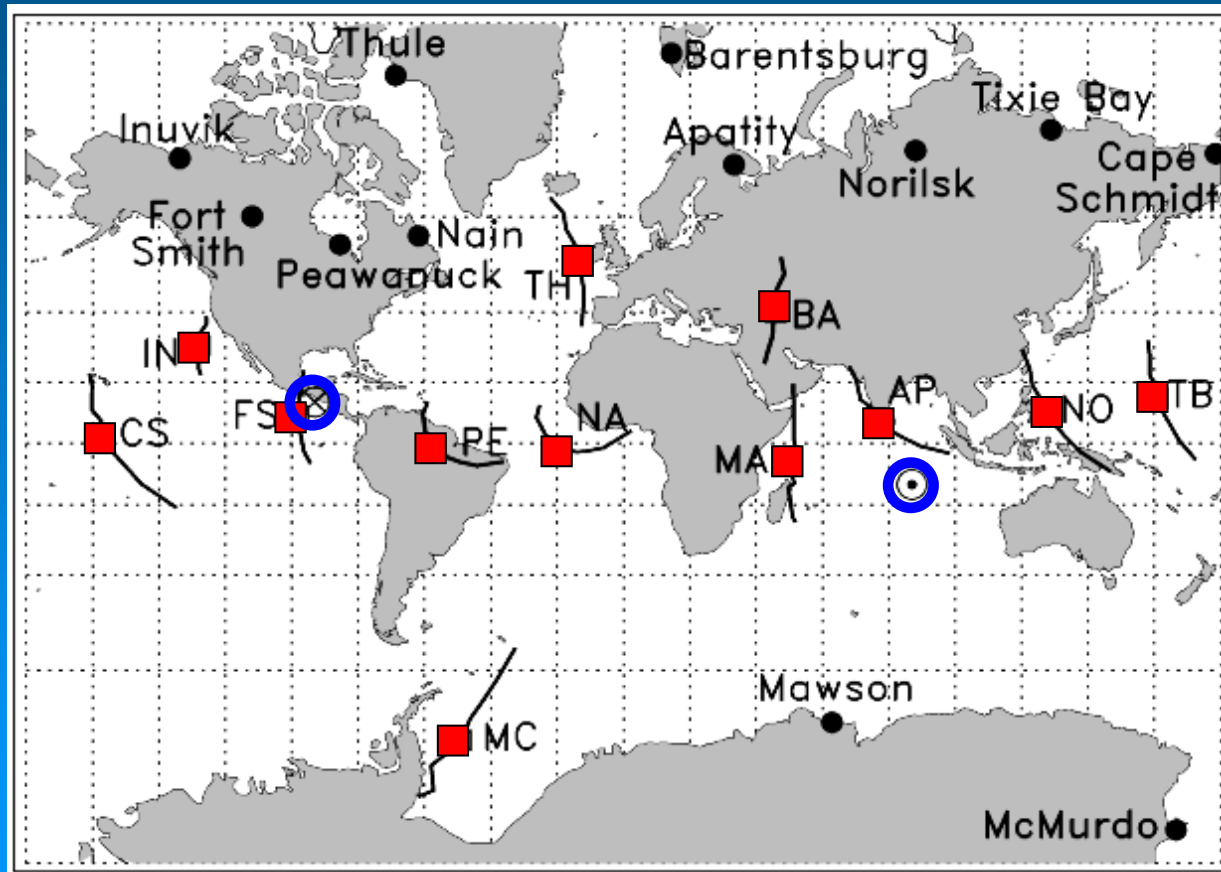
The 13 December 2006 GLE

Alternative Advanced Analysis

30th ICRC Paper 376, Bieber et al.

Spaceship Earth

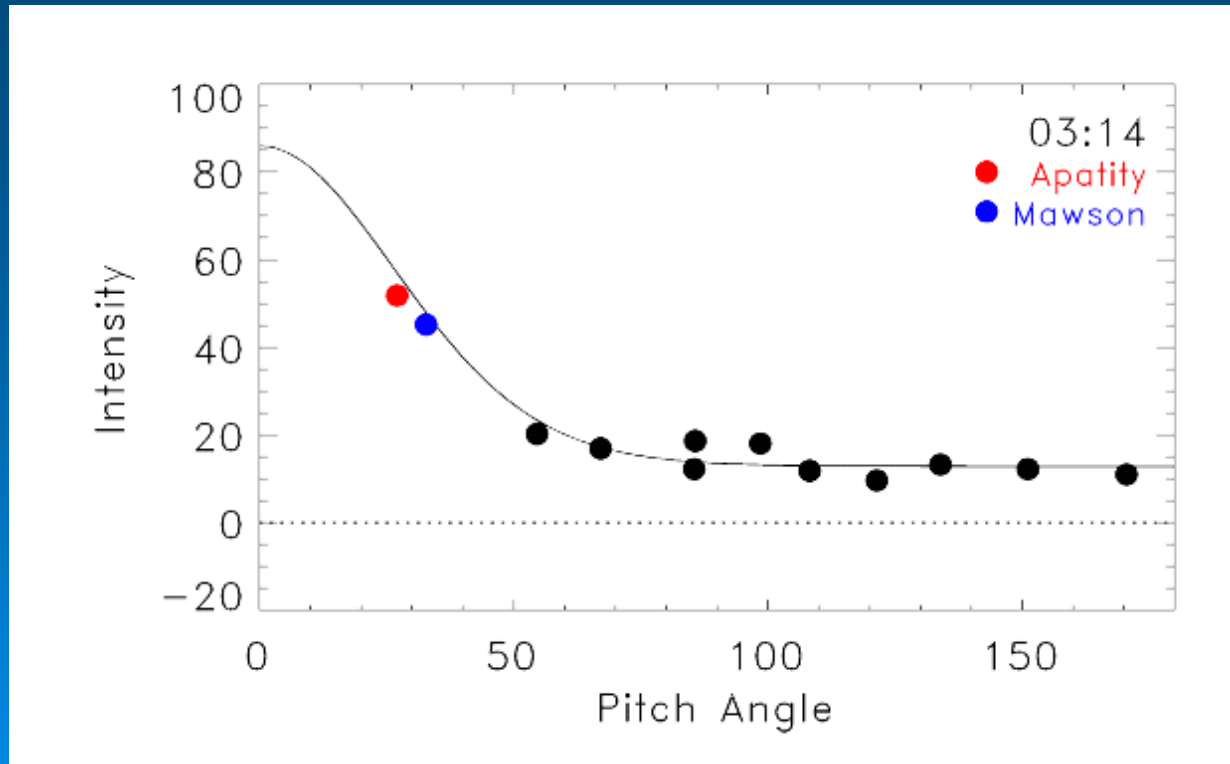
Asymptotic Viewing Directions at Start of Event



- Circles show station geographical locations
- Squares show asymptotic direction for a median rigidity solar particle
- Lines show range (10- to 90-percentile rigidity) of viewing directions for each station
- Circled dot and circled X denote nominal Sunward and anti-Sunward Parker directions, respectively

adapted from 30th ICRC Paper 376, Bieber et al.

Spaceship Earth Event Modeling: Step 1

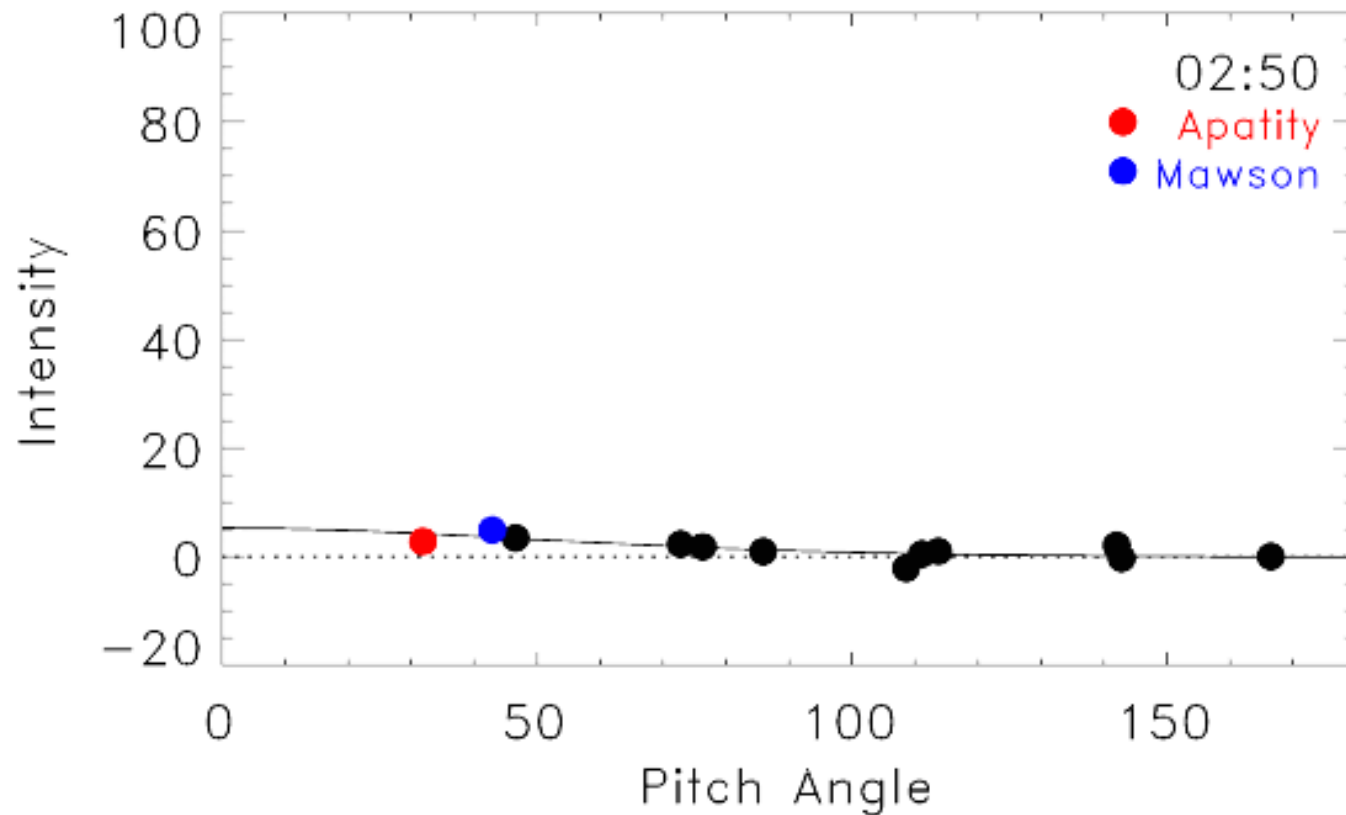


- Step 1: Individual station data were fitted to an angular distribution of the form

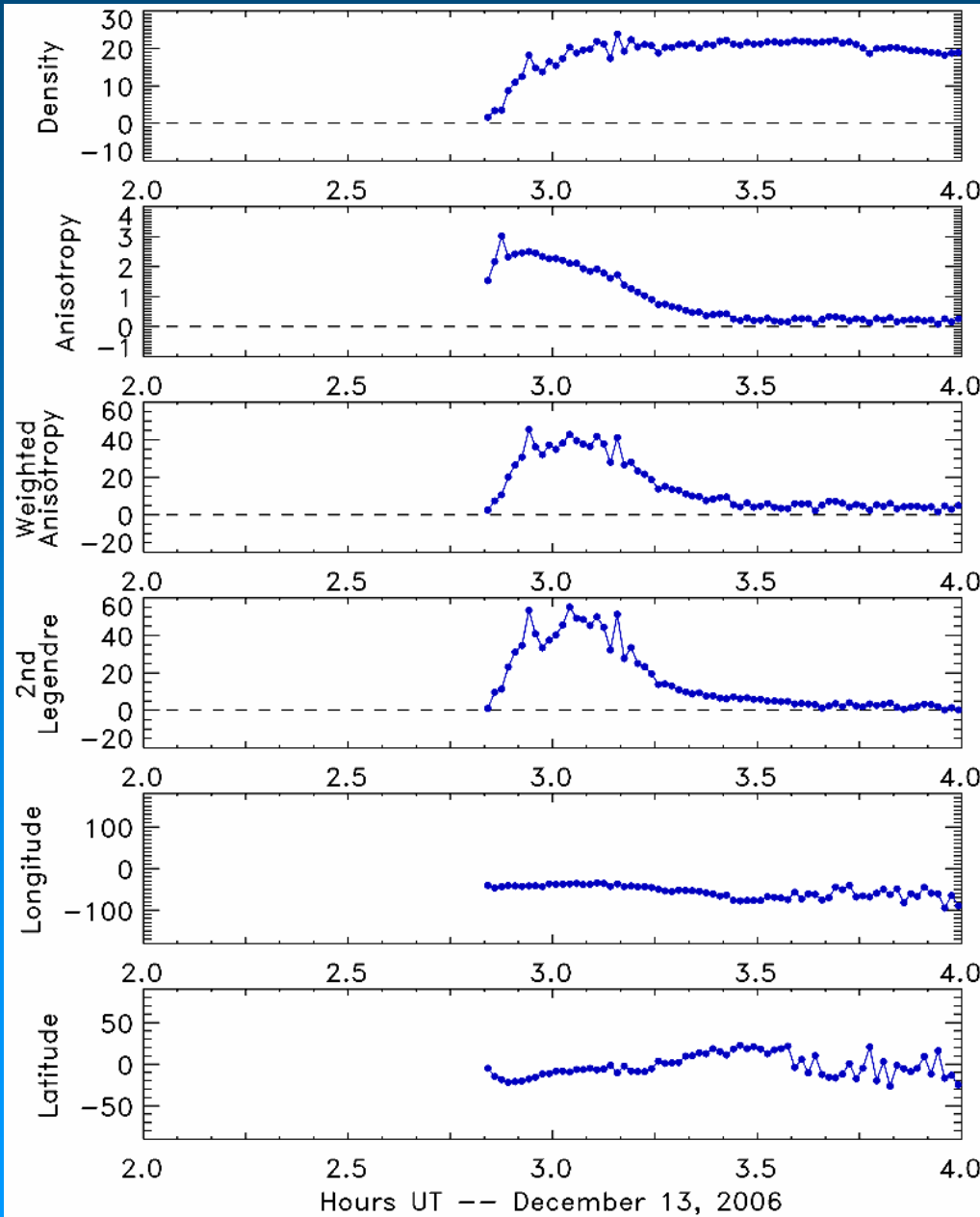
$$f(\mu) = c_0 + c_1 \exp(b \mu),$$

with μ cosine of pitch angle, and c_0 , c_1 , and b free parameters. The symmetry axis from which pitch angles are measured was also a free parameter.

Spaceship Earth Event Modeling: Step 1



Spaceship Earth Event Modeling: Step 2



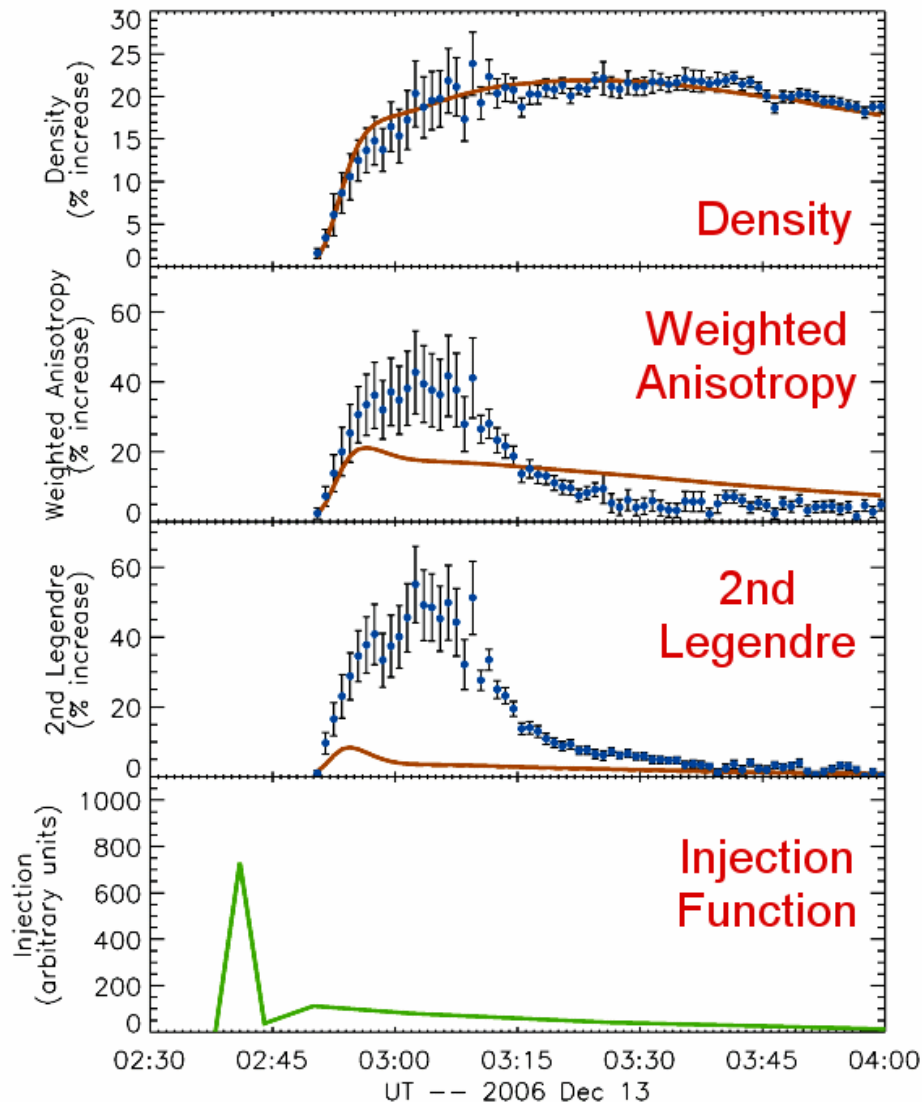
- Step 2:
The first 3 Legendre coefficients, f_0 , f_1 , f_2 , of the derived distribution were computed from $f(\mu)$.

They are shown at left as

- “Density”,
- “Weighted Anisotropy”, and
- “2nd Legendre.”

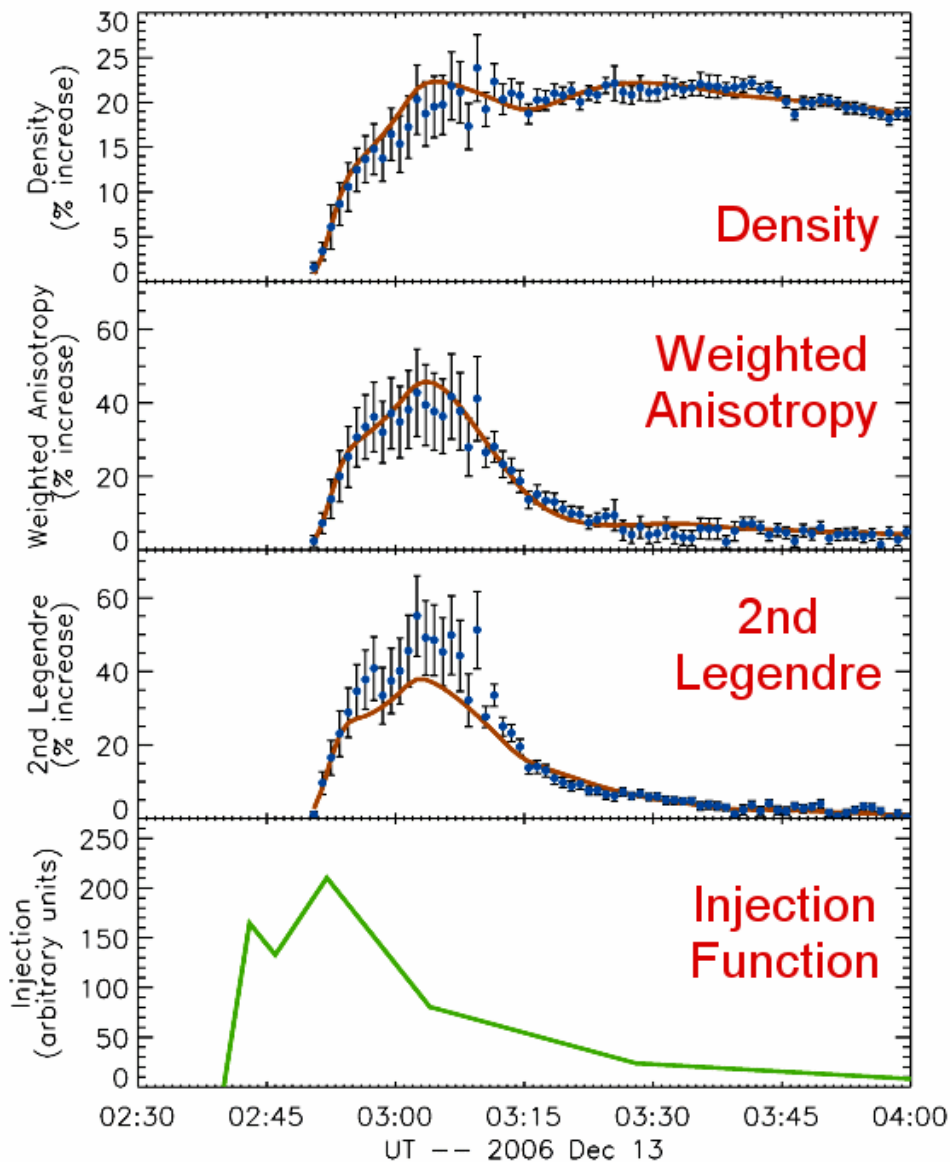
Longitude and latitude of the derived symmetry axis are also shown, as is the ordinary anisotropy, f_1/f_0 .

Event Modeling: Standard Parker Field



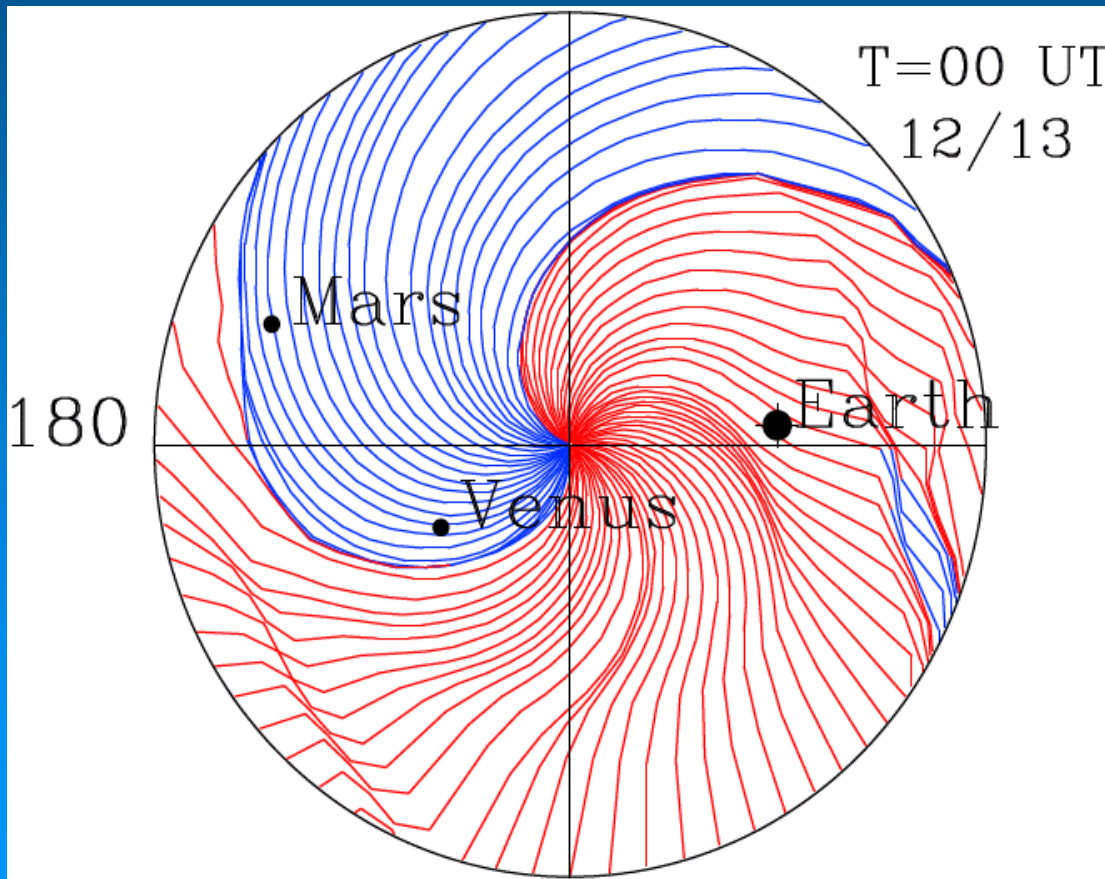
- Step 3: The Legendre coefficients as functions of time are fitted to numerical solutions of the Boltzmann equation. Free parameters are the scattering mean free path and profile of particle injection at the Sun, represented by a piecewise-linear function.
- A standard Parker IMF does not yield a satisfactory fit: The optimal mean free path of 0.23 AU provides a good fit to density, but not to weighted anisotropy or 2nd Legendre.
- Based on our experience modeling the Bastille event, we suspect a downstream magnetic mirror may be affecting transport in this event.

Event Modeling: Downstream Magnetic Bottleneck (Preliminary)



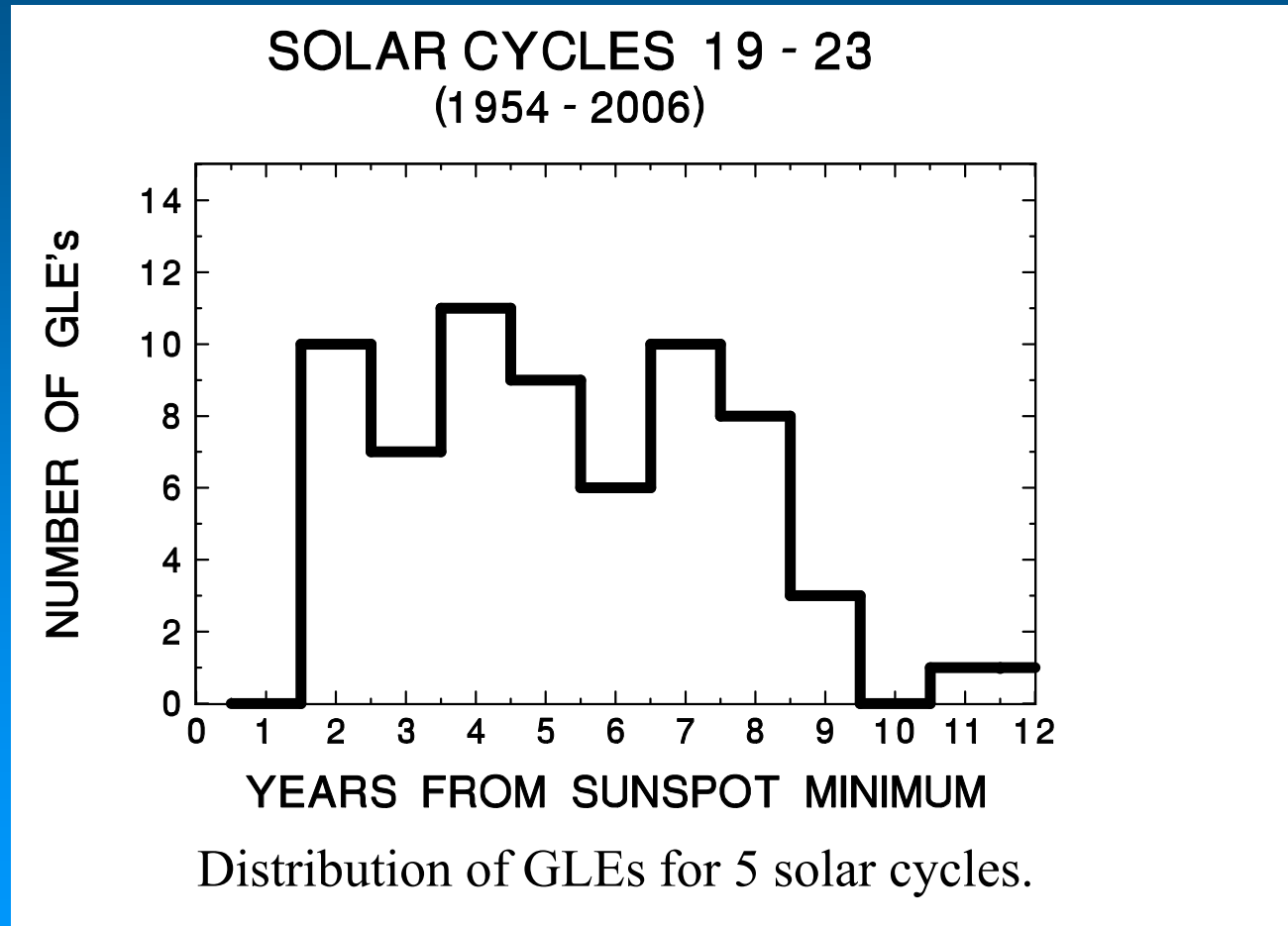
- A bottleneck fit works much better. Here, the optimal mean free path is much larger, 1.08 AU, and the optimal bottleneck location is at 1.52 AU.

A Downstream Magnetic Mirror is supported by a “Fearless Forecast” of the IMF Configuration



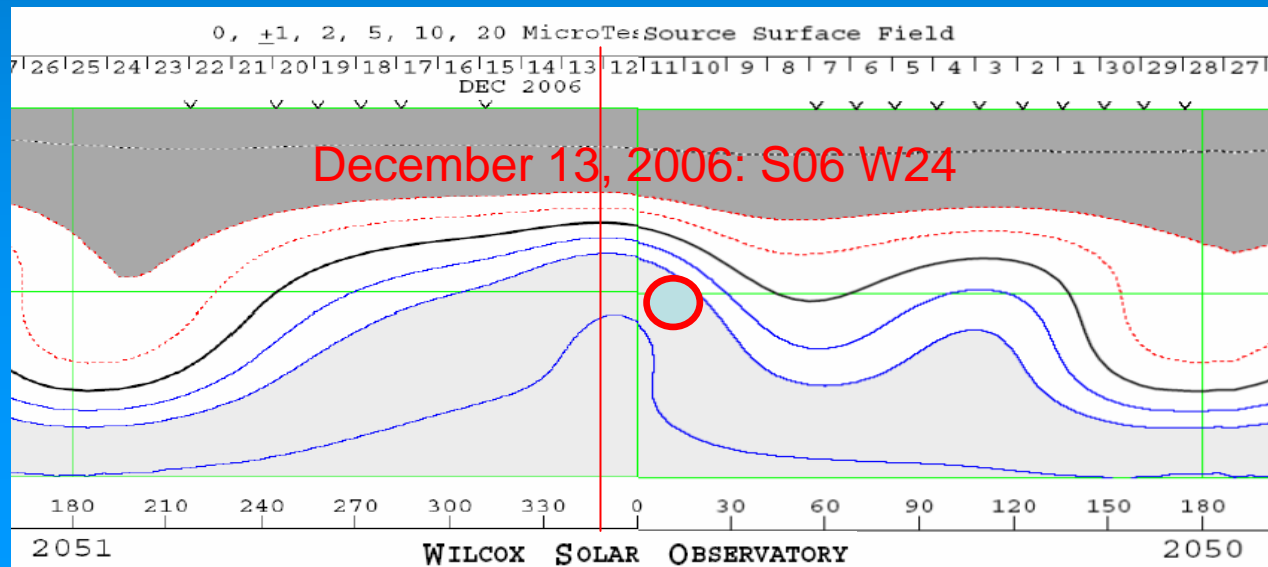
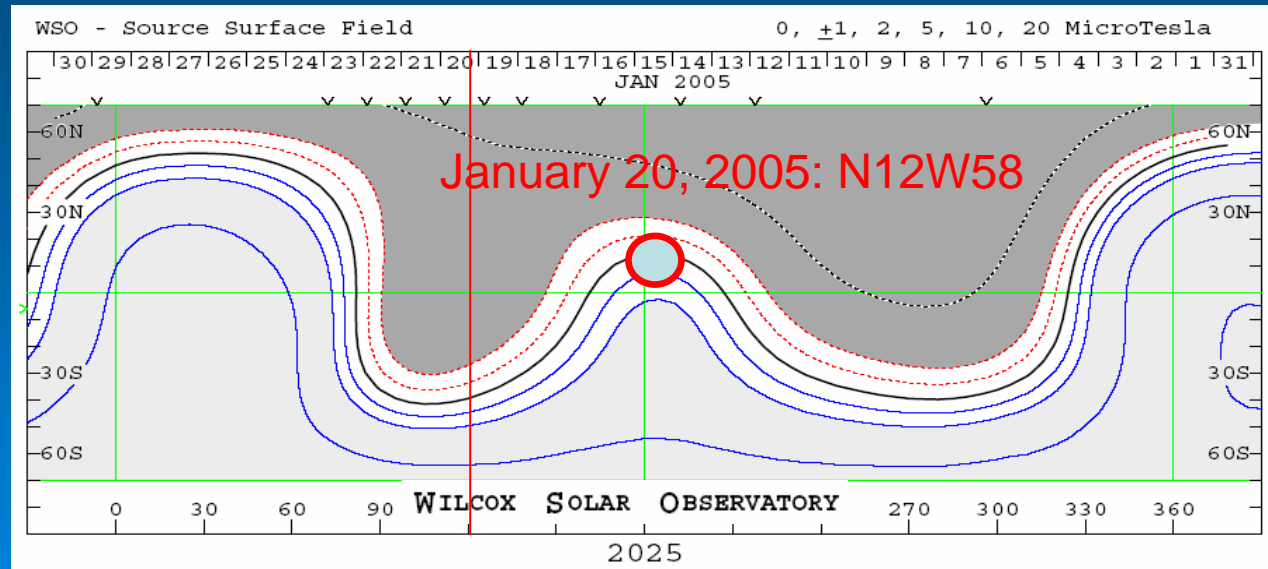
- A “Fearless Forecast” (left) suggests Earth was connected to a downstream compression region at ~ 1.6 AU at event onset
- This is reminiscent of the Bastille event, in which transport was affected by a downstream magnetic bottleneck (Bieber et al., *J. Geophys. Res.*, **567**, 622-634, 2002)

GLEs during Solar Cycles 19-23



Solar Extreme Events

Flare Location and Neutral Current Sheet



see
Shea et al.,
1995

Summary and Conclusions

- Two large GLEs near Solar Minimum – unusual? (see paper by Nymmik)
- Ongoing discussion about two mechanisms for particle acceleration at the Sun (on the basis of the 20 January 2005 GLE)
- New event modeling technique by Bieber et al. suggests „Downstream Magnetic Mirror” for 13 December 2006 GLE
- Location of 20 January 2005 flare was right on neutral line – a prerequisite for a SEE?
- Significance of global NM network confirmed! Perspectives for the future.

Looking forward to a stimulating Symposium!