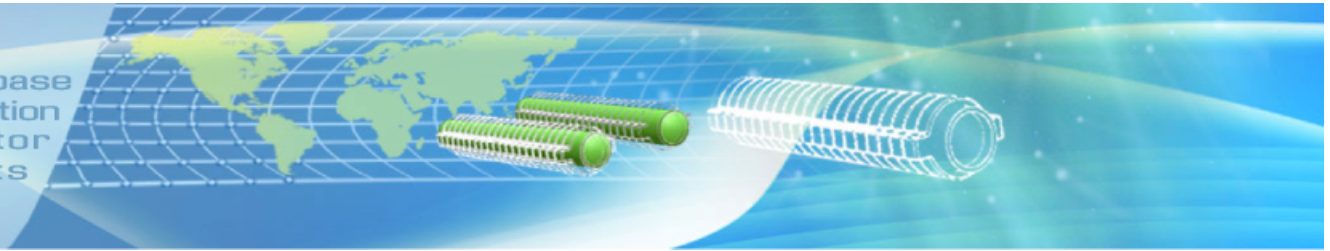




Real Time Database  
for High-Resolution  
Neutron Monitor  
Measurements



# NMDB - the European neutron monitor database

Karl-Ludwig Klein, [ludwig.klein@obspm.fr](mailto:ludwig.klein@obspm.fr)



for the NMDB consortium



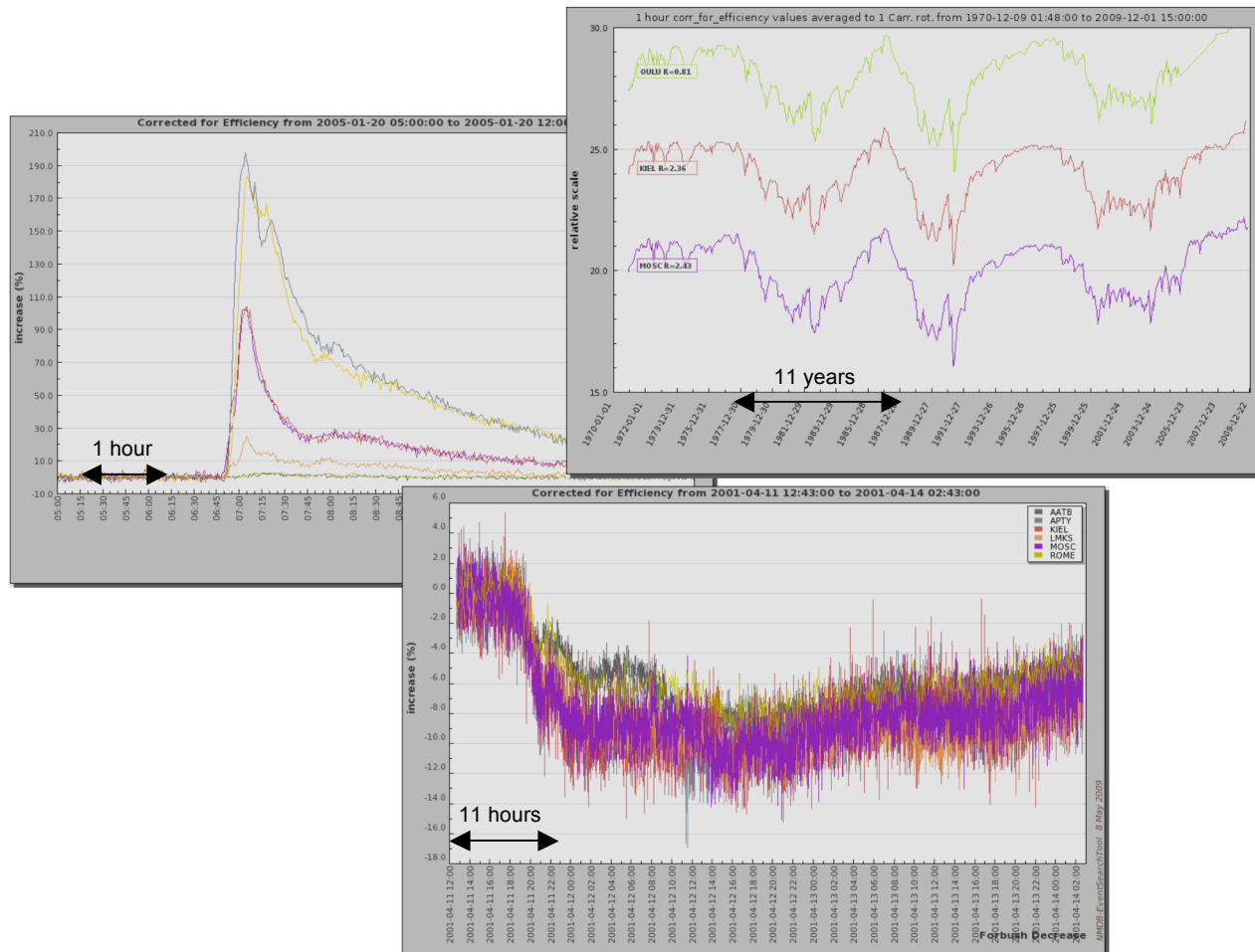
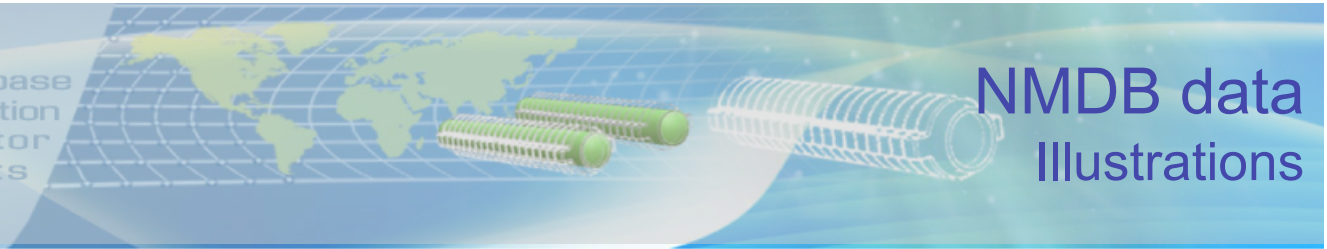


Real Time Database  
for High-Resolution  
Neutron Monitor  
Measurements

NMDB data  
Providers



- Initially (2008-09, FP7) 26 stations from Europe and some neighbouring countries (Asia)
- Historical data and real-time data (1 min resolution) - depending on station
- Since 2011: 10 further stations, Bartol Res Inst, Univ Delaware
- Perspective: Australia, South-Africa, Japan, America



- Long term trends (solar modulation)
- Individual events: Forbush effects & ground level events (GLE)
- Easy-to-use tool for data visualisation and retrieval (ASCII)

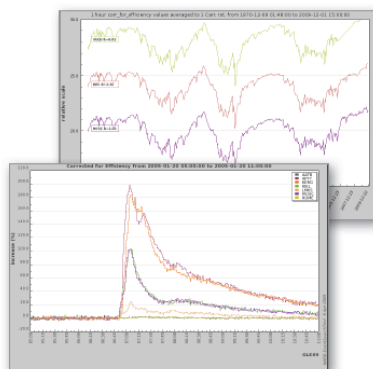


Real Time Database  
for High-Resolution  
Neutron Monitor  
Measurements

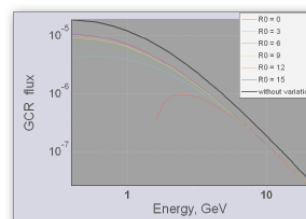
NMDB data  
Products

WWW.NMDB.EU

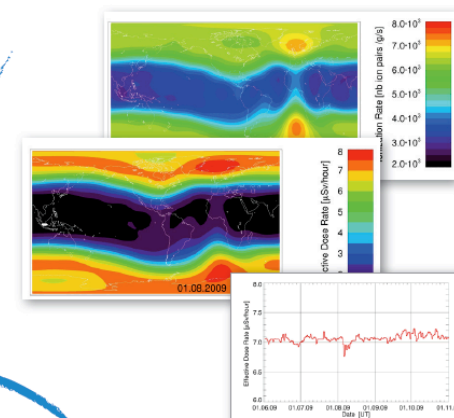
### NEST TOOL TO PLOT AND RETRIEVE DATA



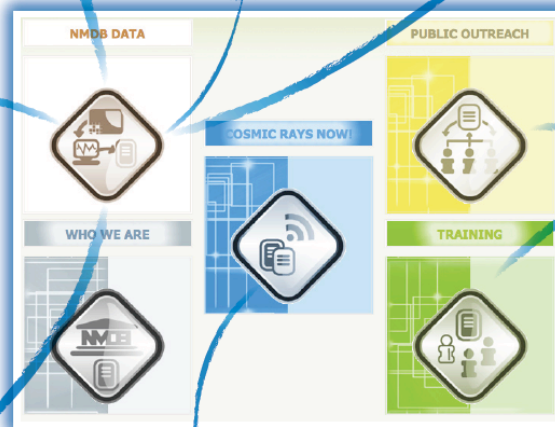
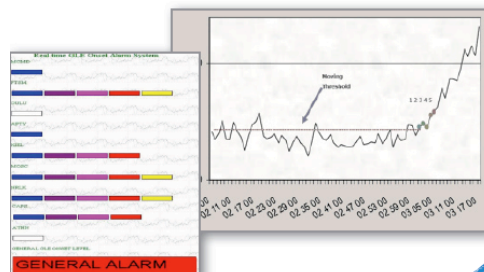
### SPECTRUM OF GCR



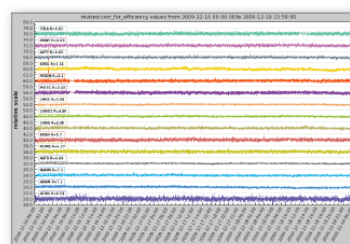
### IONISATION RATES AND DOSE RATES IN THE ATMOSPHERE (every 6 hrs)



### GLE ALERT IN REAL TIME



### COSMIC RAYS NOW !



### TRAINING AND PUBLIC OUTREACH

#### BOOK NAVIGATION

- NMDB Stations
- NMDB Online Access Tools and Data Products
- NMDB Data Products
- NMDB Documentation
- Public Outreach
- English
- NMDB Brochure
- Cosmic rays: high energy particles from the Universe
- Solar Wind, Heliosphere, and Cosmic Ray Propagation
- Cosmic rays and the Earth
- Measurement
- Impacts: Technological and biological effects of cosmic rays
- Neutron monitor network: fundamental research and applications
- A few technical details
- Glossary
- Questions ?
- Francisco
- Madrid
- El Estrecho
- Yvoir
- Budapest

#### English

What are cosmic rays?

When we look at the sky, we see bright objects: the Sun of course, planets, stars, nebulae... All this is light, electromagnetic waves, with wavelengths between, we can also detect electromagnetic waves that are invisible to the human eye, such as infrared or ultraviolet emissions, radio waves, X-rays.

Since the early 20th century we know that the Earth is not only hit by such waves, but also bombarded by charged particles: protons, ions, electrons that come in at nearly the speed of light. These particles are called cosmic rays, and they tell us a story about the Universe that we would not learn from light alone.

Where do they come from?

Cosmic rays come from places in the Universe where some kind of explosion occurs: the remnants of stellar explosions (supernovae), active galaxies, and also from the Sun.

How can we observe them?

Cosmic rays do not directly hit the ground, but collide with the atoms of the high atmosphere. That creates lots of secondary particles: protons, neutrons, muons and electrons. Because the primary particle has a maximum speed of about 200,000 km/s, two-thirds of the speed of light, a significant number of secondary particles, muons and other particles can be observed by ground-based particle counters near the magnetic poles.

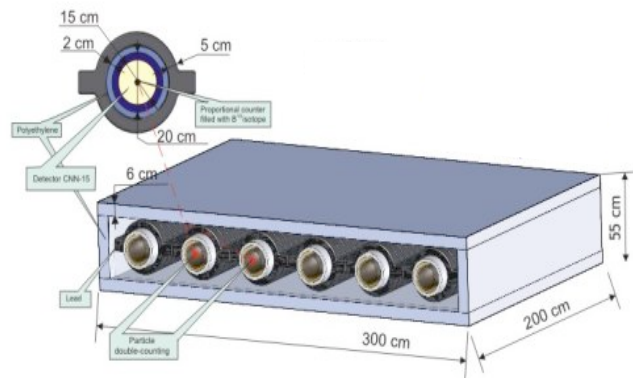
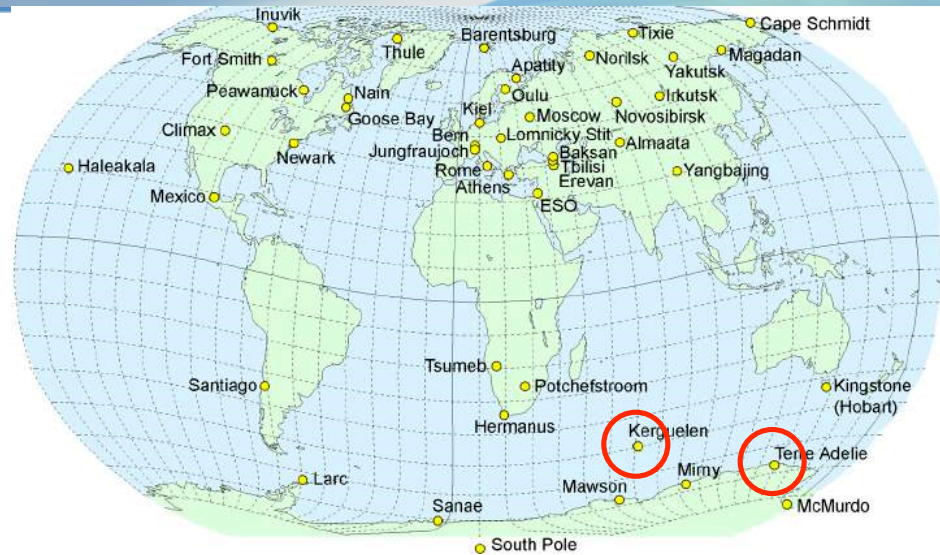
The magnetic field of the Earth is another filter, although it plays no role in the magnetic pole of the Earth. But the closer one comes to the equator, the faster the primary charged particle must be to get through.



# High energy particles from the Universe Detection at the Earth

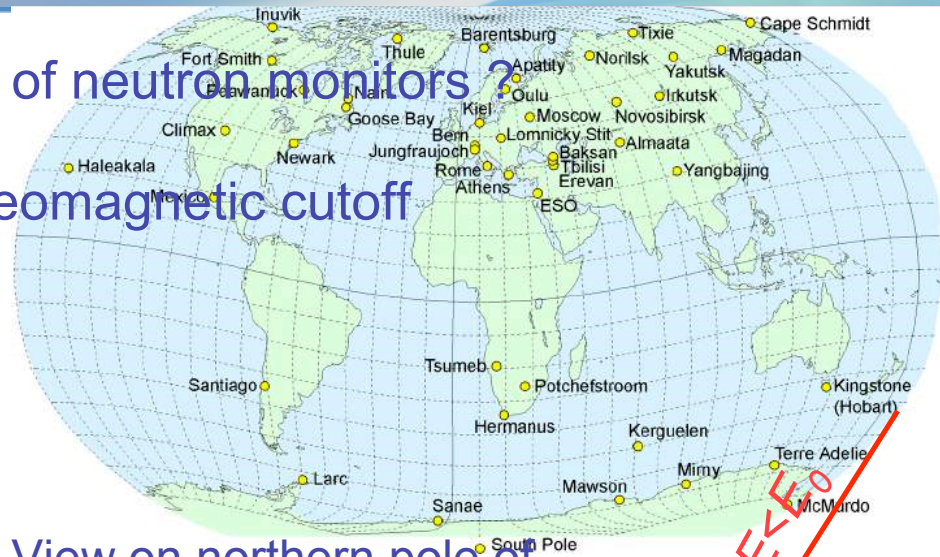
## Neutron monitor :

- Production of neutrons by secondary particles in a Pb ring
- Detection of the neutrons in the counter tubes
- Despite the name, the primary particles detected by a neutron monitor are most often protons or heavy nuclei !

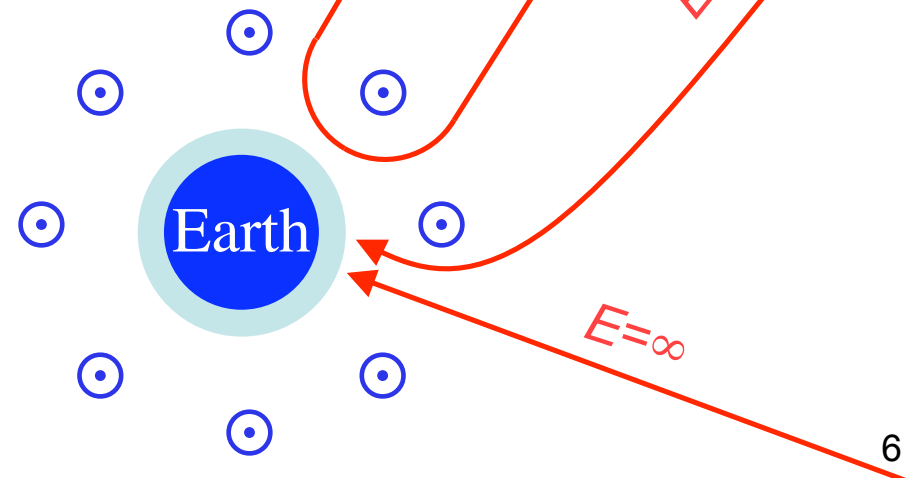


# High energy particles from the Universe Detection at the Earth

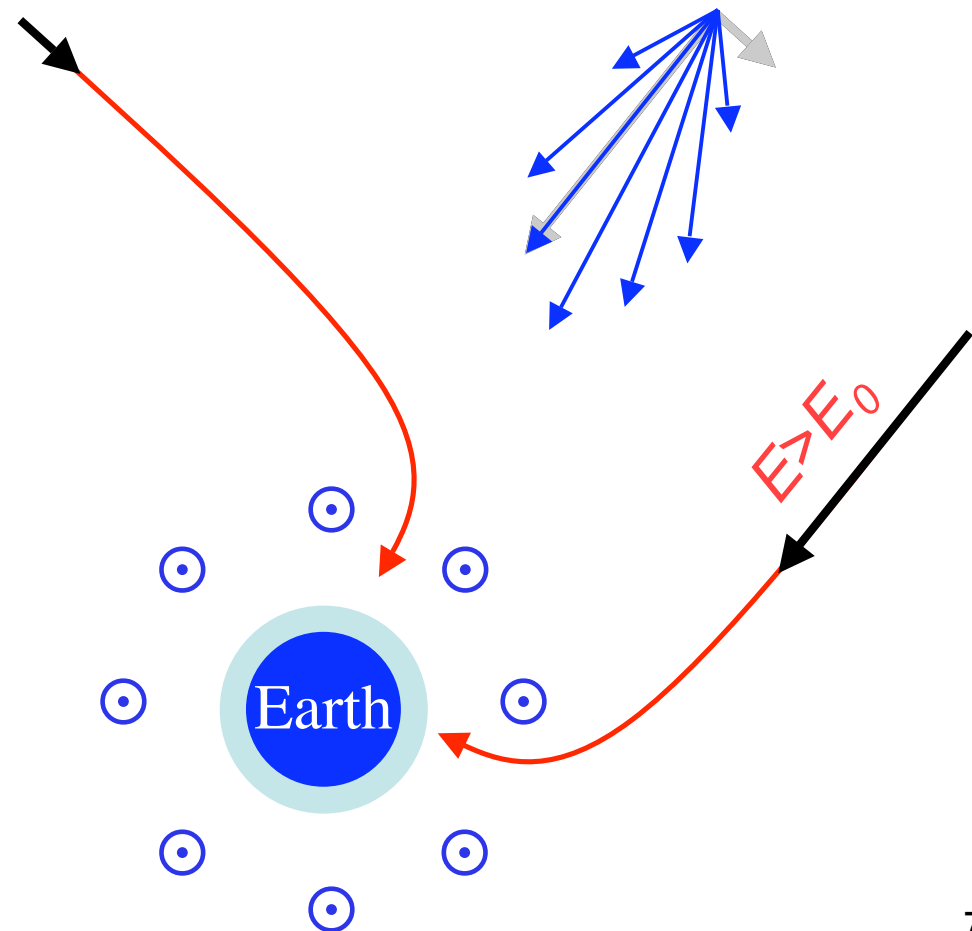
- Why a worldwide network of neutron monitors ?
- Spectroscopy using the geomagnetic cutoff



View on northern pole of  
the Earth; B towards the  
observer:

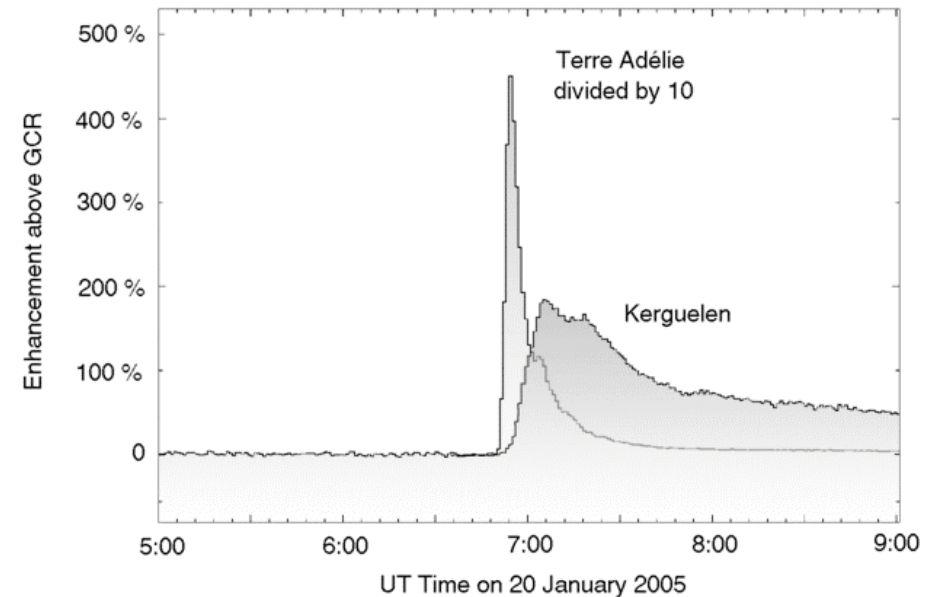
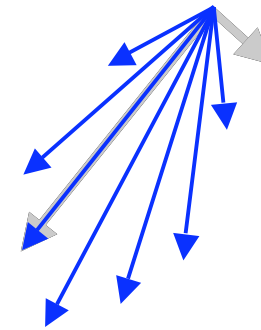


- Why a worldwide network of neutron monitors ?
- Spectroscopy using the geomagnetic cutoff
- Measurement of the angular distribution of the incoming particles using the asymptotic directions at the different sites.



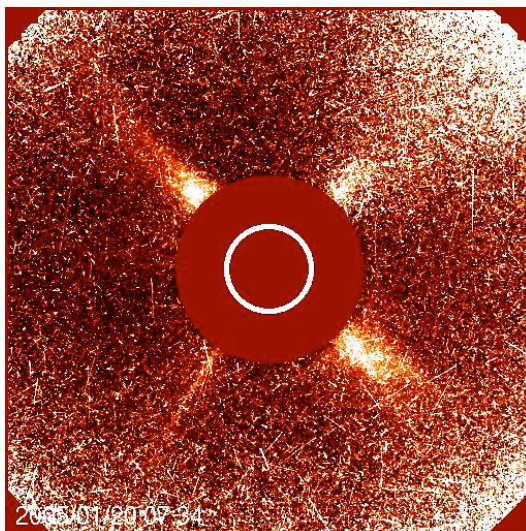
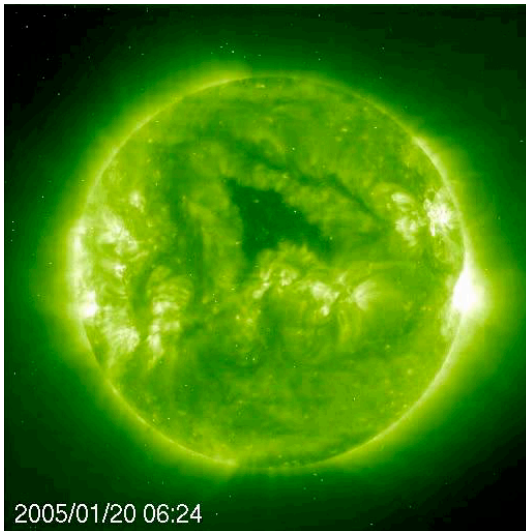


- Why a worldwide network of neutron monitors ?
- Spectroscopy using the geomagnetic cutoff
- Measurement of the angular distribution of the incoming particles using the asymptotic directions at the different sites.
- Illustration: 2005 Jan 20, Kerguelen Island and Terre Adélie - an initial pulse of highly collimated protons (TAd), followed by  $\sim$ isotropic protons.

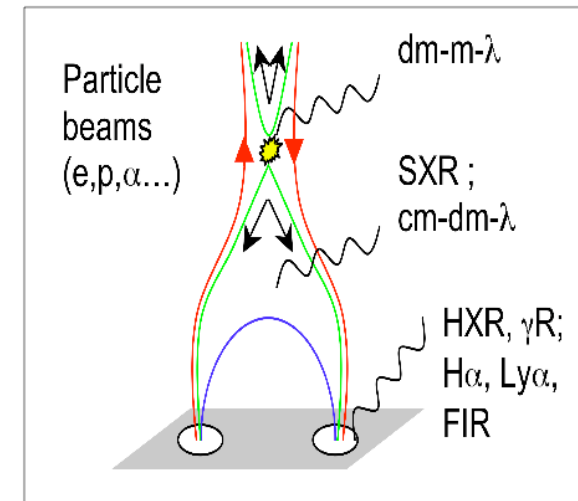




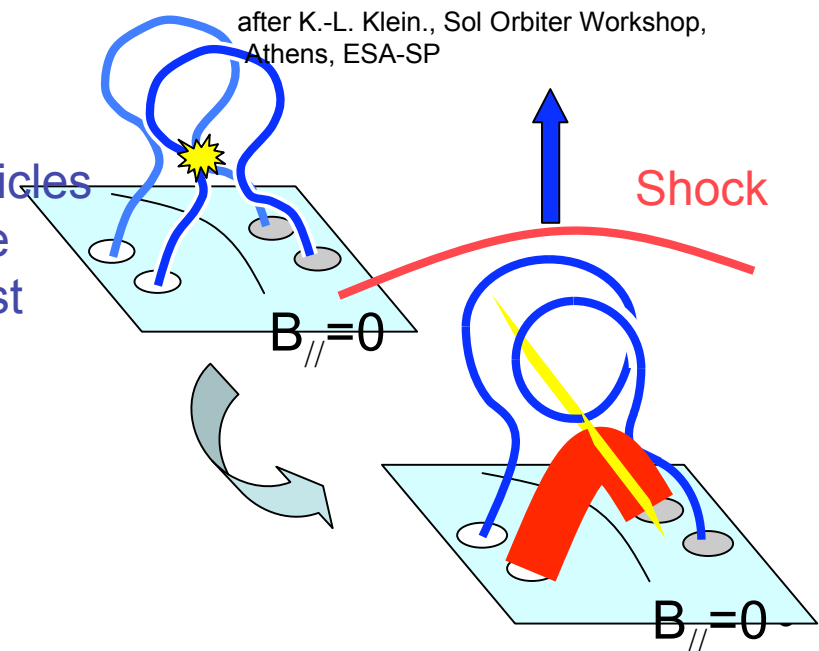
### At the Sun: flare & CME

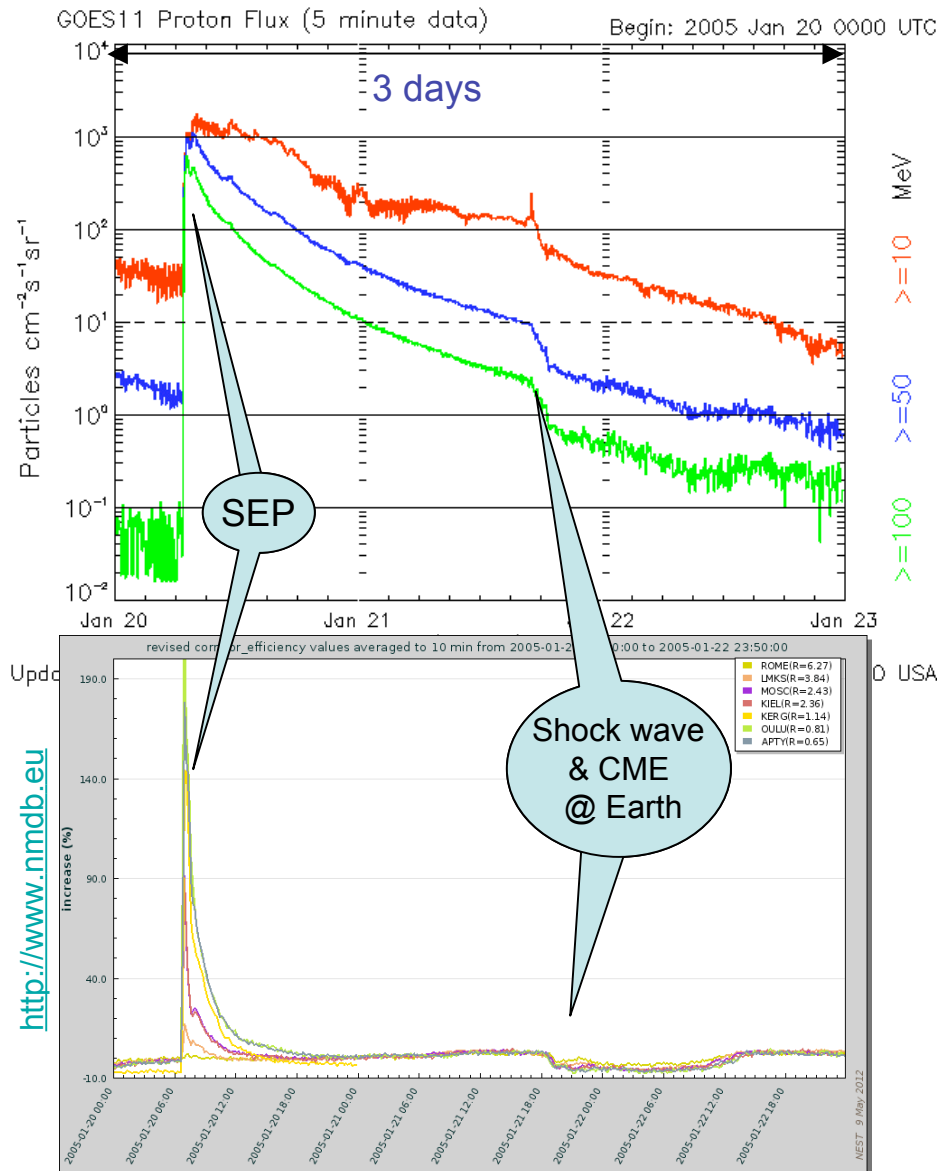


- “Flare acceleration”: particles accelerated in complex magnetic configurations in the corona (particles radiating  $\gamma$ R, HXR, radio; particles escaping along open field lines towards IP space).

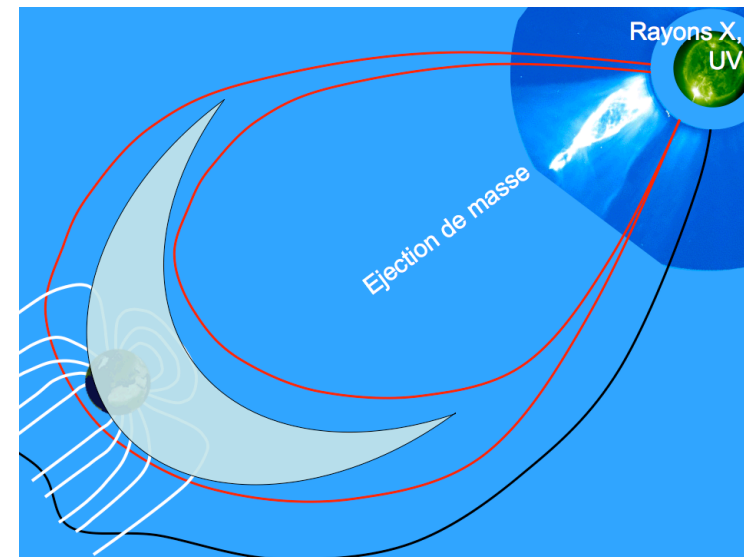
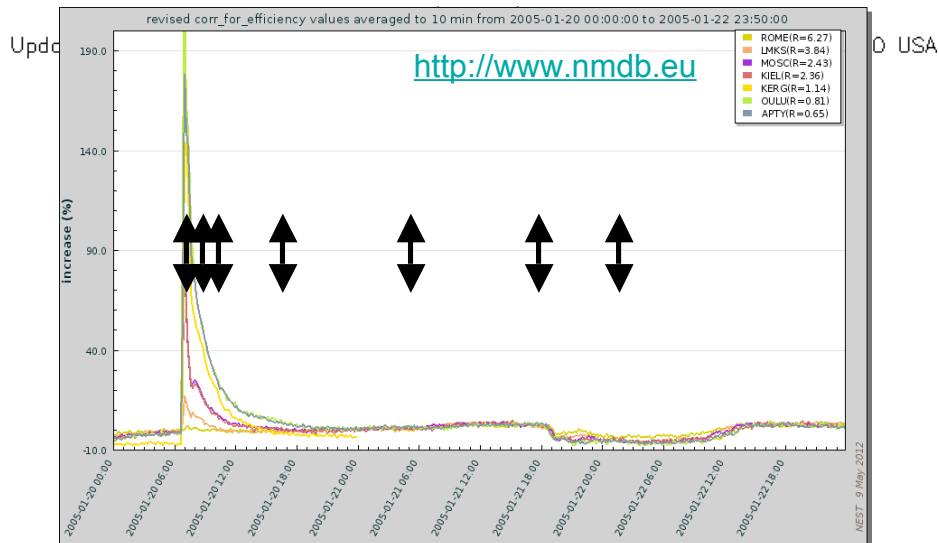
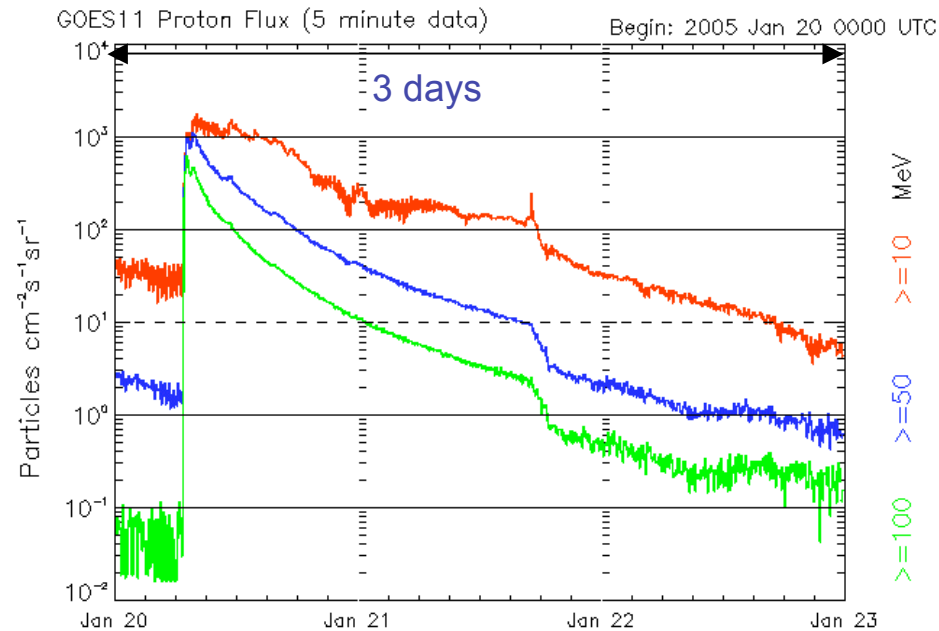


- CME shock acceleration: particles accelerated at the bow shocks of fast CMEs (mainly SEP=particles detected in situ); corona, IP space.





- SEP (solar energetic particles) event (protons 10 MeV - some GeV)
- At tens of MeV (GOES): duration > 1 day, solar particles + peak (at LE) as shock approaches Earth (energetic storm particle event; shock acceleration near Earth)
- At GeV (neutron monitors): short duration (tens of min - a few hrs), no signature of shock acceleration in IP space. Rare events: the most energetic protons accelerated in the solar atmosphere.



- Scenario: from the Sun to the Earth
  - Flare, particle acceleration
  - CME, particle acceleration (shock)
  - ICME, particle acceleration
  - ICME at Earth, shielding of galactic cosmic rays



Real Time Database  
for High-Resolution  
Neutron Monitor  
Measurements

# Neutron monitors and solar energetic particles

## Summary and outlook

- NMDB provides data from all European, some Asian and some US-American neutron monitors.
  - Time resolution up to 1 min, some in real time (space weather applications)
  - Data belong to the providers, but are free for use in scientific research.
- The project continues to work 3 years after the end of the FP7 funding.
- Hopefully further extension in the future (other American providers, South Africa, Australia, Japan ?)
- Special arrangements available for people who need data on a regular basis. Contact: Christian Steigies, University of Kiel, [steigies@physik.uni-kiel.de](mailto:steigies@physik.uni-kiel.de) or [questions@nmdb.eu](mailto:questions@nmdb.eu)
- Development of further tools (SEPServer, follow-up FP7 project ?) to provide physical data on relativistic solar particles as a complement to future space missions (Solar Orbiter, ...)