

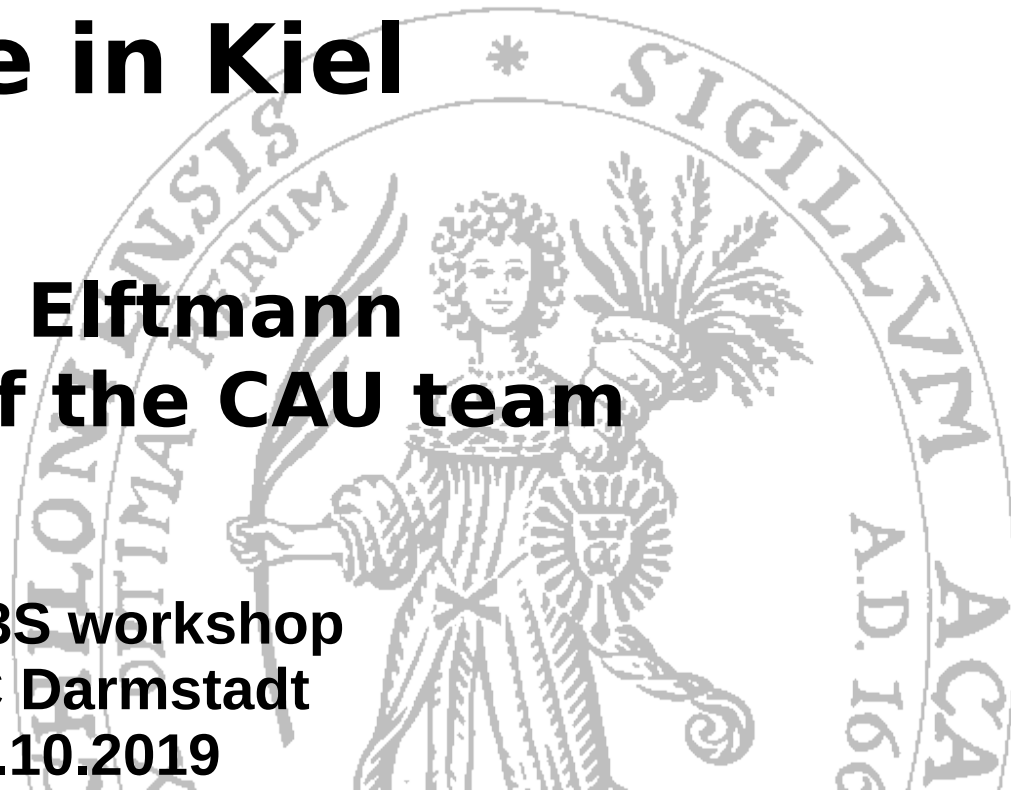
From keV to GeV

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Energetic Particle Instrumentation Made in Kiel

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on behalf of the CAU team

ESA D3S workshop
ESOC Darmstadt
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Energetic particle aspects of space weather:

- Radiation hazards for satellites
- Ionospheric disturbances (e.g. GPS, Galileo,...)
- Risks for human space exploration

Kiel University -

Institute of Experimental and Applied Physics

- Development, building and testing of space instrumentation for energetic particle detection
- Data provision to scientific community
- Data analysis, modeling and research

From Kiel to Space

Space missions with contributions from CAU Kiel



Chang'e 4 (2019-today)
Chinese lander to the far side of the moon
Lunar Lander Neutrons & Dosimetry (LND)

Ulysses (1990-2009)
Solar mission, which went outside of the ecliptic to observe the polar regions of the sun and explore the 3D structure of the heliosphere
Kiel Electron Telescope

Advanced Composition Explorer (ACE, 1997-today)
Specialises in detailed in-situ measurements of the solar wind

MSL/Curiosity (2011-today)
Mars mission to determine the suitability of Mars for the development of life in the past
Radiation Assessment Detector (RAD)

Apollo 16 and 17 (1972)
The last two moon landings
Cosmic Ray Detector Experiment

Solar and Heliospheric Observatory (SOHO, 1995-today)
Allows a wide range of optical and in-situ measurements of the sun
Electron Proton Helium Instrument (EPHIN), CELIAS

Galileo (1989-2003)
NASA mission, which explored Jupiter and its moons. Also carried a probe which descended into Jupiter's atmosphere
Energetic Particles Investigation (EPI) on board of the probe

Space Shuttle (1981-2011)
American spacecraft, which was used for a wide variety of experiments and other tasks
Several dosimetry experiments starting in 1982

STEREO A and B (2006-today)
Two spacecraft observing the sun from different angles, allowing a stereoscopic view of the sun, with optical and in-situ instruments
Solar Electron and Proton Telescope (SEPT), Plasma and Suprathermal Ion Composition (PLASTIC)

Long Duration Exposure Facility (1984-1990)
Various materials and some biological cells were exposed to open space and cosmic radiation
Free-Flyer Biostack Experiment

Helios 1 and 2 (1974-1986)
Inner heliosphere missions, which approached the sun closer than any other spacecraft so far
E6 Cosmic Ray Experiment

Solar Orbiter (2020-?)
Inner heliosphere mission, successor to Helios, which will observe the sun with in-situ and optical instruments from a distance of only 0.28 AU
Electron Proton Telescope (EPT), High Energy Telescope (HET) and Suprathermal Electrons and Protons (STEP)

International Sun-Earth Explorer (ISEE-2, 1977-1987)
Studied the interaction between solar wind and Earth magnetic field
Charged particle spectrometer

International Space Station (1998-today)
Permanently occupied space station used for a wide variety of scientific experiments
Dosimetry experiments including Matroshka and DOSTEL

Chandra X-Ray Observatory (1999-today)
Observes supernovas, black holes and other high-energy cosmic events
Includes EPHIN as a radiation monitor

Azur (1969-1970)
The first German satellite studied the magnetosphere and the Van-Allen radiation belts

Mir (1986-2001)
Russian space station, which enabled the first long-term stays of humans in space
Dosimetry experiments

Balloon Flights (ongoing)
Participation in the BECUS balloon program aimed at students with several instruments
FRED, REXUS, ADAM, TANOS

Flight Dosimetry (ongoing)
Dosimetry monitoring on intercontinental flights

Recent space missions:

- Ulysses - KET
- SOHO - EPHIN
- STEREO - SEPT
- MSL - RAD (*Mars*)
- Chang'E 4 - LND (*Moon*)
- Solar Orbiter - EPT, HET and STEP (Launch 2020)

Possible future missions:

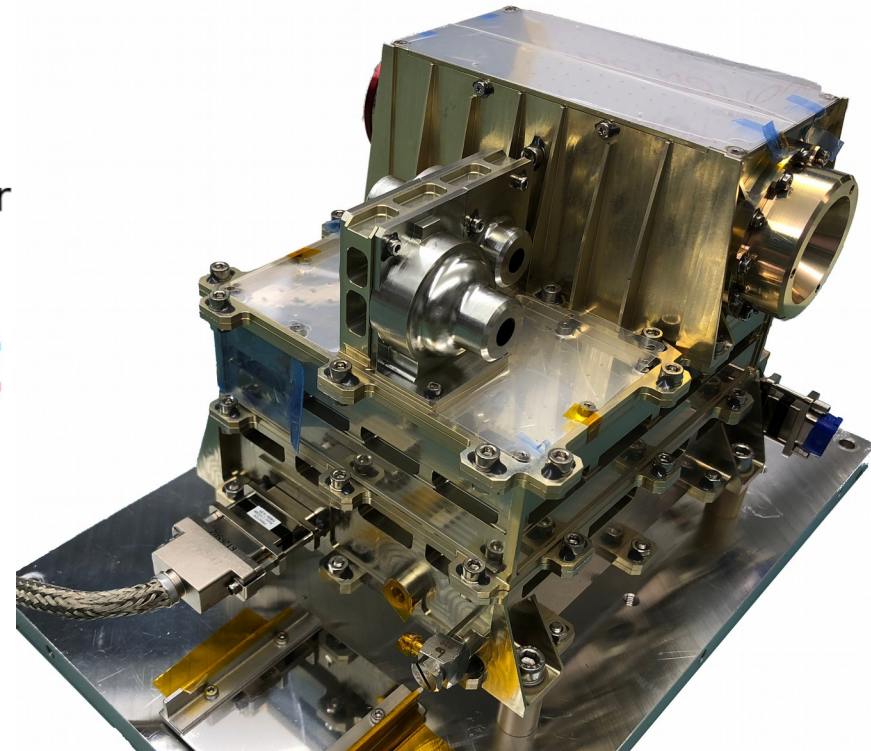
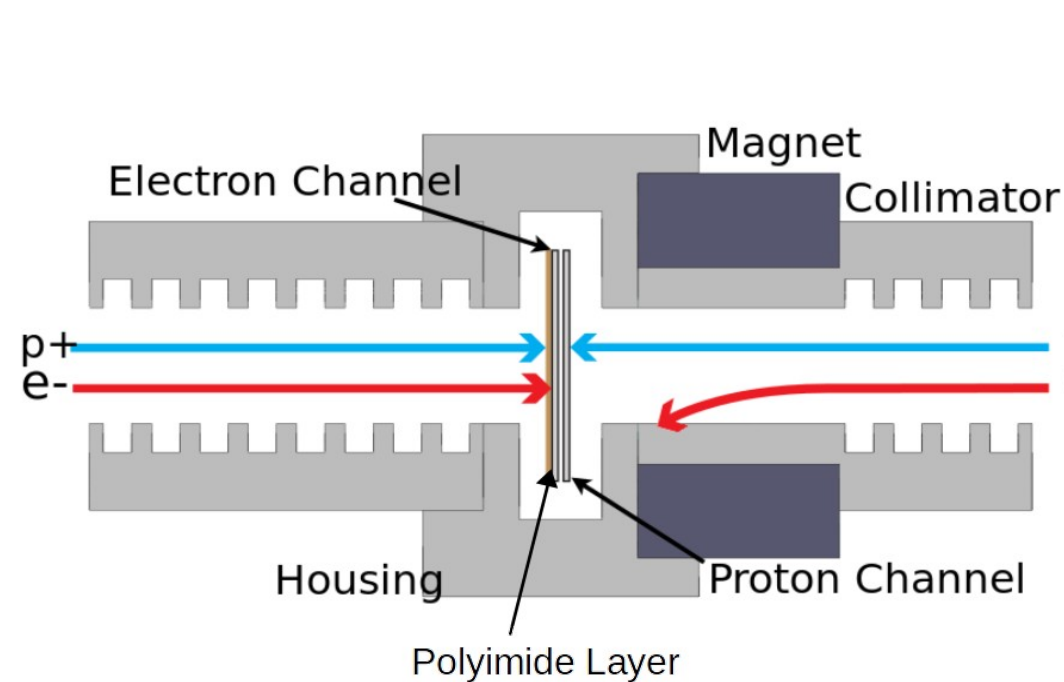
- H2sat - EPDP
- Lagrange - MEPS
- Daedalus *Near Earth Explorer* - HEI

Student projects:

- Bexus - Instruments for particle detection on balloon flights

keV Energy Range

Example Solar Orbiter - Electron Proton Telescope:



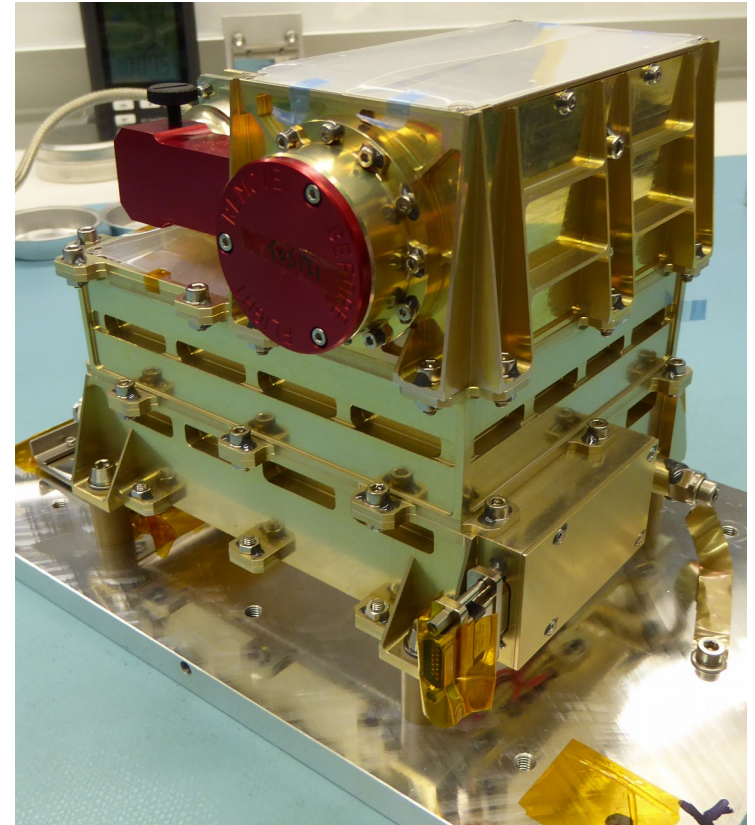
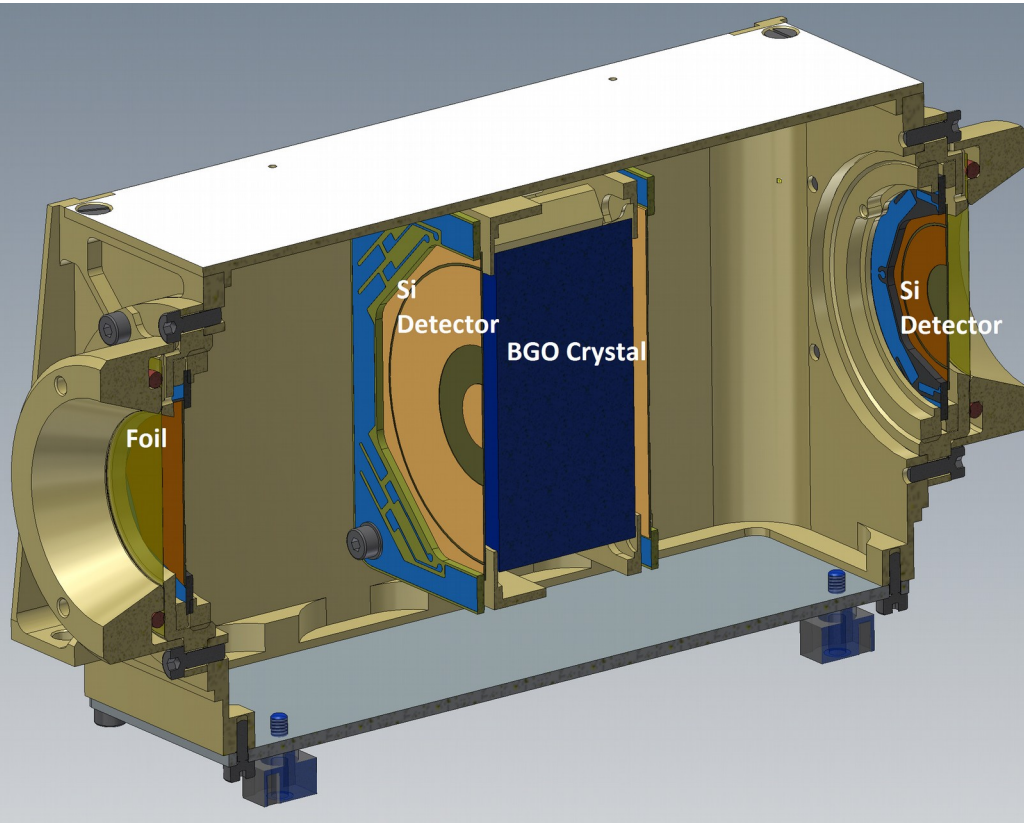
Achievable energy range for **stopping** particles:

Electrons: 30 keV to 400 keV

Protons: 30 keV to 6 MeV

GeV Energy Range

Example Solar Orbiter - High Energy Telescope:



Achievable energy range for **stopping** particles:

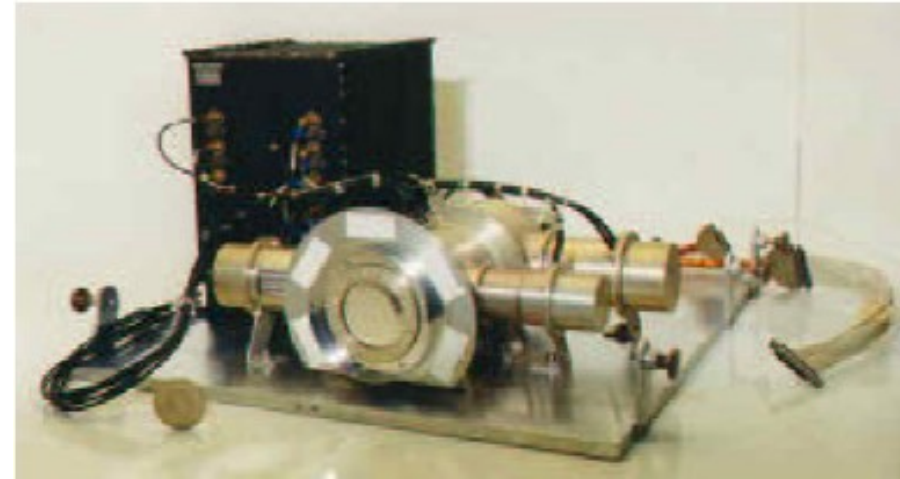
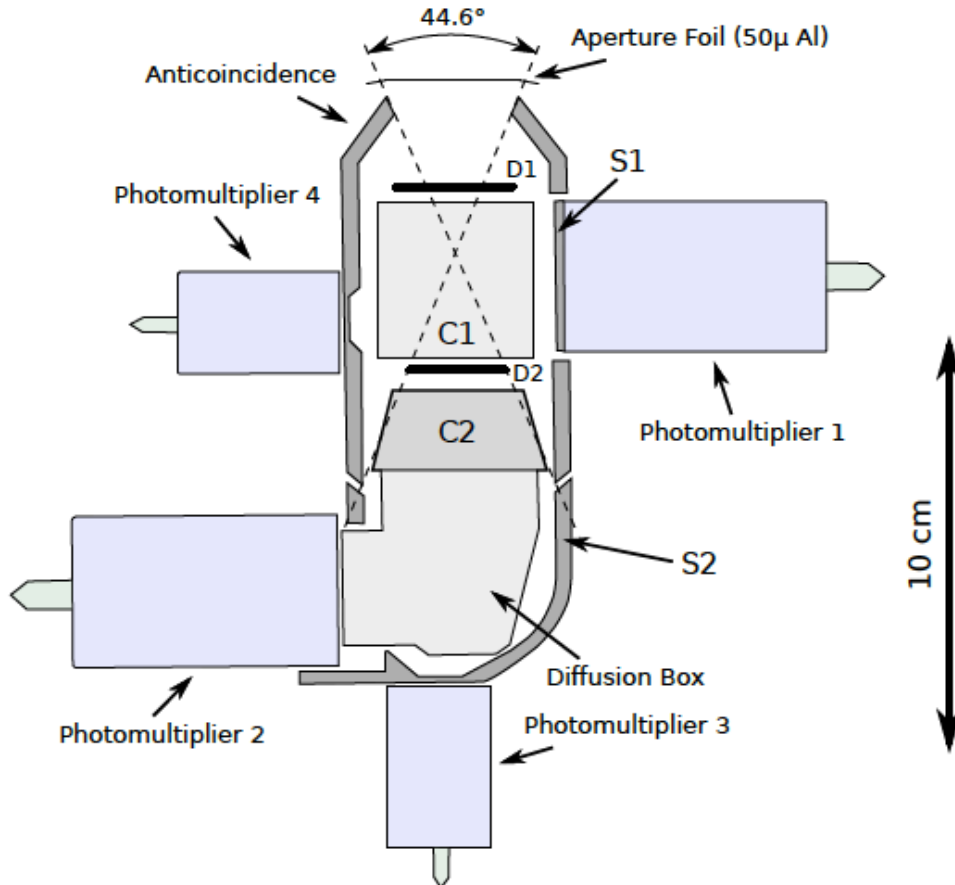
Electrons: 300 keV to 30 MeV

Protons: 6.8 MeV to 107 MeV

Fe ions: 0.023 to 0.47 GeV/nuc

GeV Energy Range

Example Ulysses - Kiel Electron Telescope

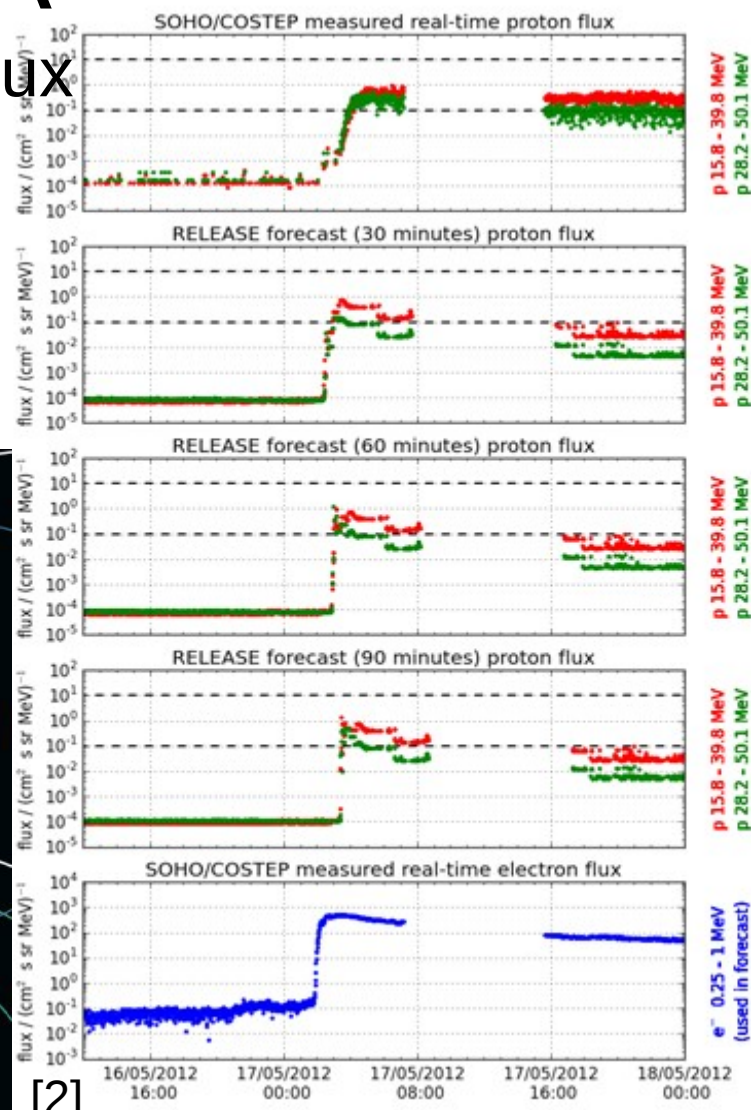
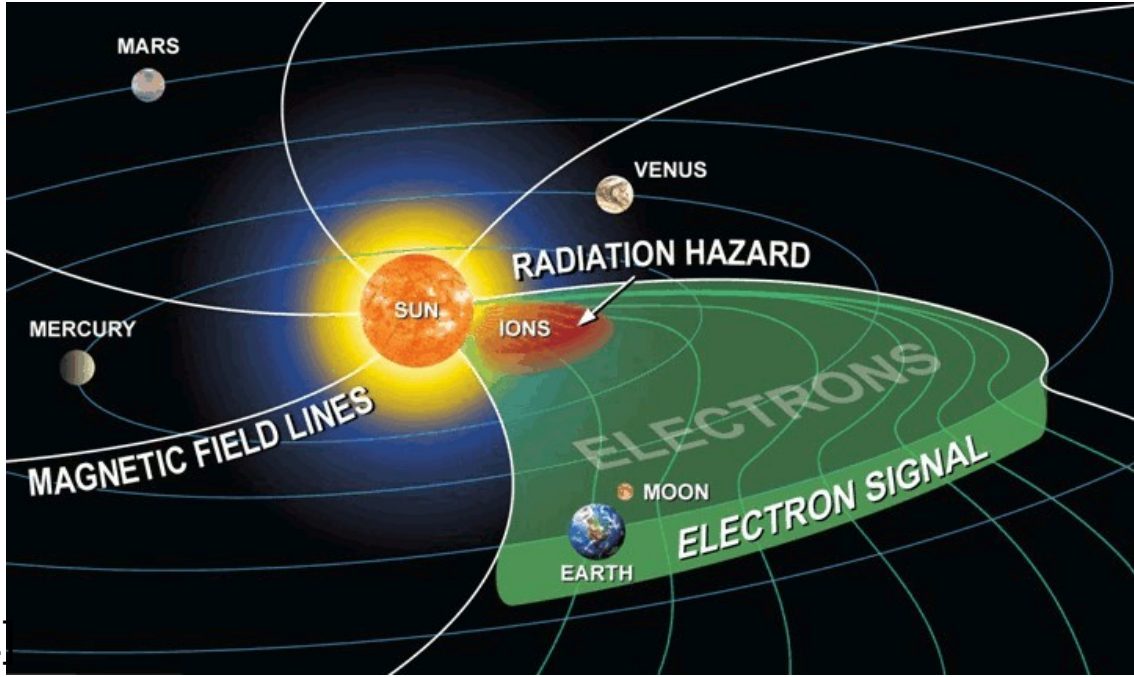


Achievable energy range for **stopping** particles:
Electrons: 4 to > 200 MeV
Ions: 30 to > 2000 MeV/nuc

Space weather forecast

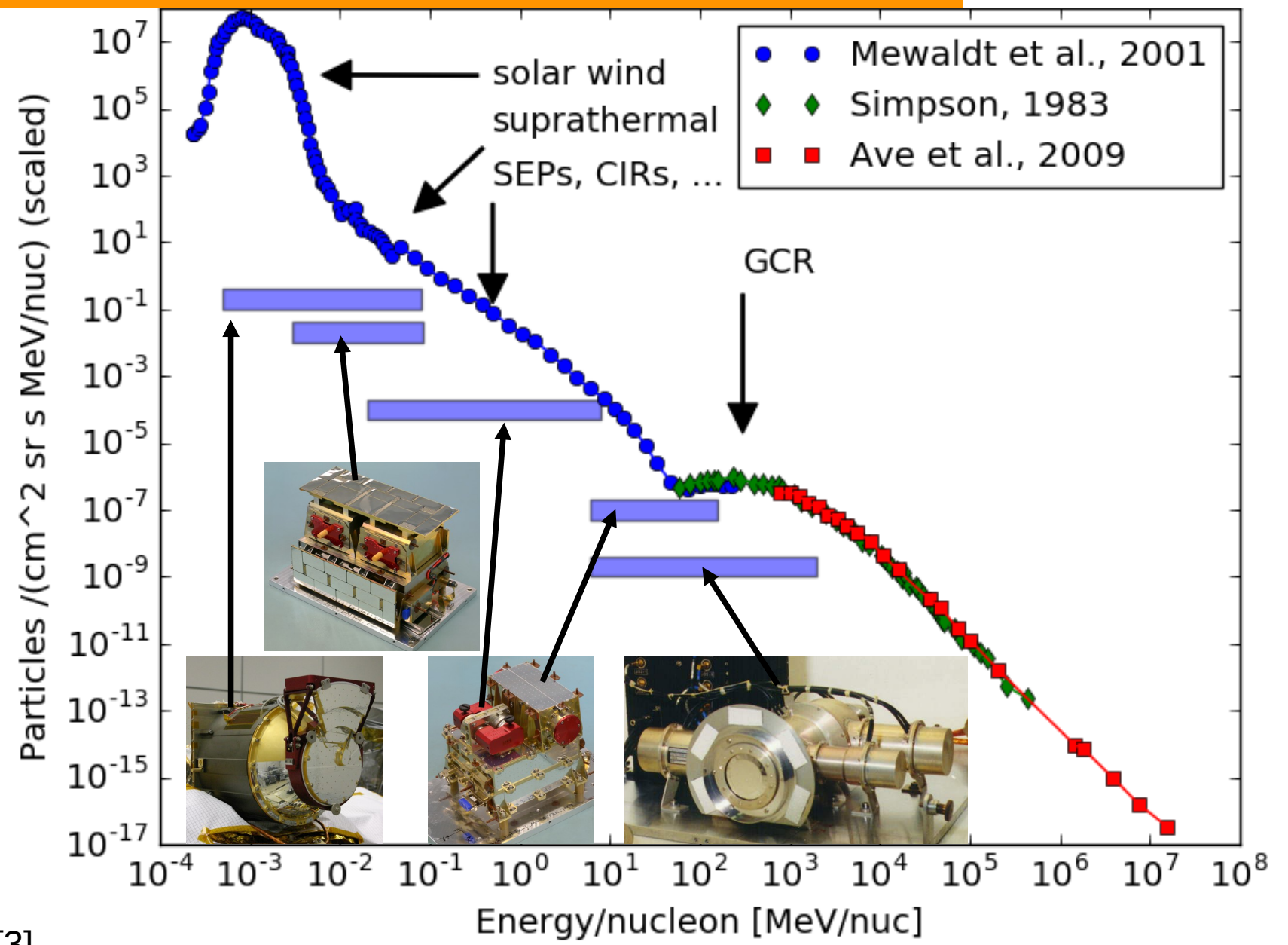
EU project HESPERIA

- Space weather forecast of proton flux with >30 min warning time
- Developed as real time application with warning system
- Possible adaptation / improvement using other missions



[1]

[2]



Sources:

[1]:<https://ccmc.gsfc.nasa.gov/models/modelinfo.php?model=REleASE>

[2]:<https://www.hesperia.astro.noa.gr/index.php/results/real-time-prediction-tools/release>

[3]:

Simpson, J. A. "Elemental and isotopic composition of the galactic cosmic rays." *Annual Review of Nuclear and Particle Science* 33.1 (1983): 323-382.

MEWALDT, R. A., et al. Long-term fluences of energetic particles in the heliosphere. In: *AIP Conference proceedings*. AIP, 2001. S. 165-170.

Ave, M. et al. Propagation and Source Energy Spectra of Cosmic Ray Nuclei at High Energies . In *The Astrophysical Journal*, Volume 697, Issue 1 (2009) : 106-114