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Extraterrestrische Physik

The SupraThermal Electrons, Ions and Neutrals (STEIN) detector for Solar Orbiter

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Abstract :

Solar Orbiter will be launched in 2017 and reach a perihelion of 62 Solar radii (about 0.3 AU). This will allow unprecedented coordinated remote-sensing and in-situ studies of the physics of the Sun, corona, and inner heliosphere.

The SupraThermal Electrons, Ions and Neutrals (STEIN) detector will measure electrons from 2 keV to 100 keV and protons and neutral atoms from 4 keV to 100 keV. It has two viewing directions covered with an array of 32 semiconductor detector (SSD) pixels each. An electrostatic deflection unit is used to separate charged and neutral particles.

In this work, we will show results of ongoing GEANT4 simulations to study the angular and energy response of the telescope, which give implications for the layout of the pixel detectors.

The Energetic Particle Detector (EPD) :

The Energetic Particle Detector (EPD) will measure charged particles in an energy range from a few keV/nuc up to hundreds of MeV/nuc. It consists of five different sensors to cover this energy range and allows excellent pitch-angle coverage (Figs. 1 and 2).

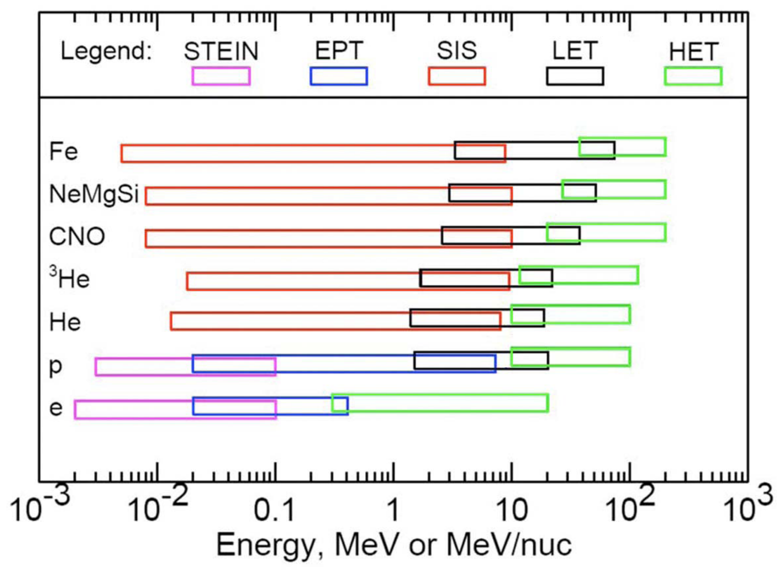

Figure 1: Energy ranges of the EPD instrument suite

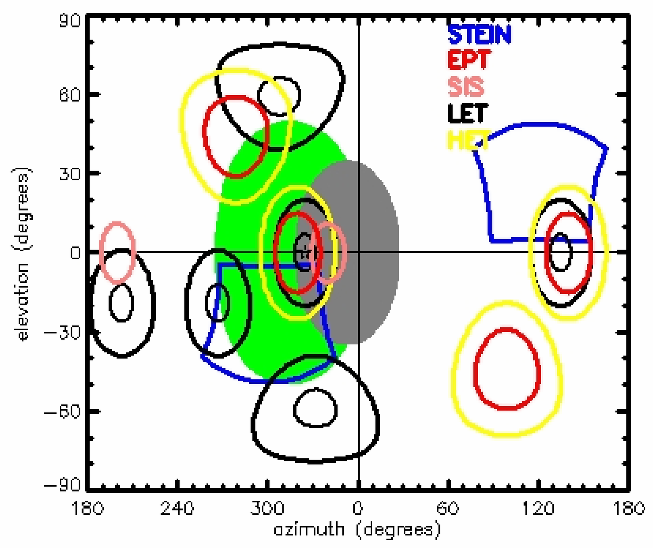

Figure 2: Fields-of-View of the different EPD instruments. The green and gray ellipses represent the nominal magnetic field direction.

As it can be seen in Figure 2, STEIN will detect the particles incoming parallel and antiparallel to the Parker Spiral. The particles detected are electrons protons (ions) and neutrals in the same energy range as protons (ions).

STEIN :

The SupraThermal Electron, Ion and Neutrals (STEIN) sensor will be able to detect

- Ions from 4 keV (fast solar wind) up to 100 keV
- Electrons from 2 keV up to 100 keV (see Fig. 3)
- Neutral Atoms from 4 keV up to 100 keV

Separation of the different species is achieved by an electrostatic deflection unit inside the sensor head. Particles are deflected according to their energy to charge ratio, and deposit their kinetic energy in an array of 32 semiconductor detector pixels.
The deflection on the incoming particles trayectories depends on their energy and charge. At high voltages, particles with low energy may not hit the pixels, as they collide with the electrostatic plates. For this reason, an alternating field in the plates is necessary. The basic detection principle is sketched in Fig. 4.

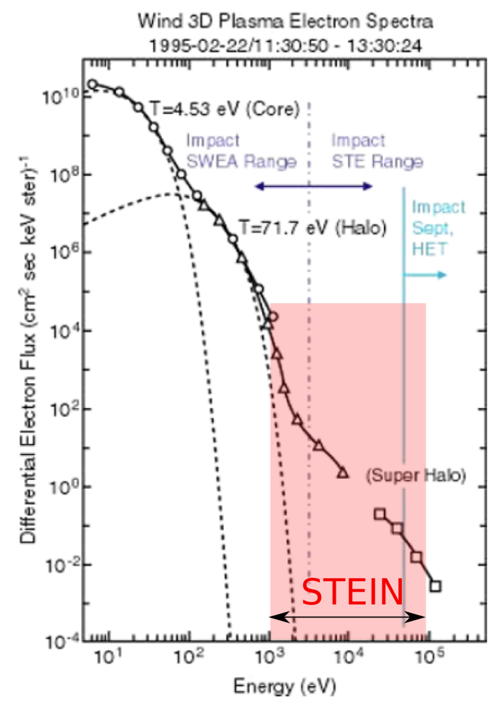

Figure 3: Quiet-time electron spectra measured by the WIND 3D Plasma and Energetic Particle instrument. Detector (Lin et. al.[(a)],taken from Luhmann et. al.[(b)]). Highlighted in red is the nominal energy range of STEIN.

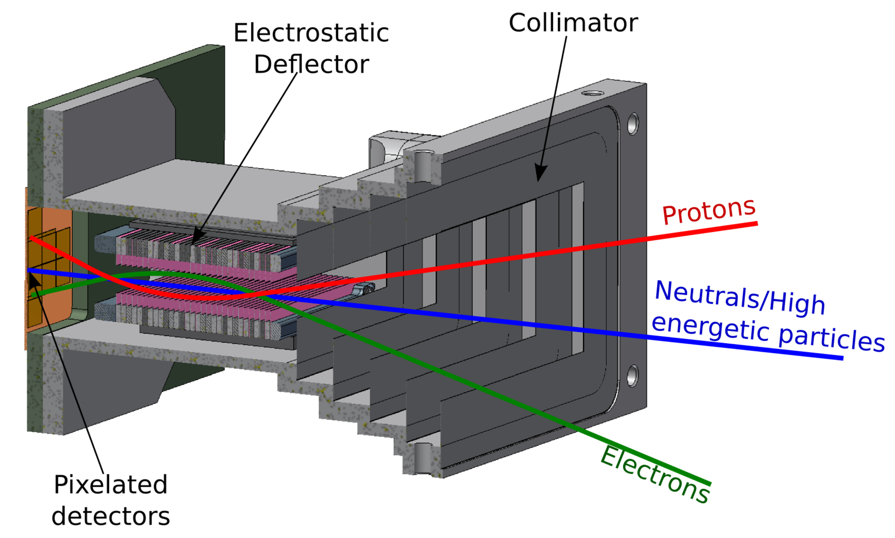

Figure 4: Schematic of one sensor head showing the detection principle of STEIN. Particles are separated according to their E/q ratio and deposit their energy in the pixelated solid state detector.

The energy loss of the particles in the semiconductor detectors will be measured by the IDefX ASIC (CEA, Saclay, France). This ASIC is capable of measuring 32 different channels with low power consumption (about 110 mW).
The detector array will be passively cooled at temperatures ranging from -90 to -30 °C. To achieve this, the electronic box will be thermally decoupled from the detecting telescope and semiconducting pixels, which will be nearest to the Solar orbiter boom in order to use it as a heat sink. STEIN is expected to work protected from the sun heat, but during maneuvring it will probably get exposed to sunlight. The collimators are specially designed in order to avoid direct light to come to the pixels.

Simulations :

In order to approximate the response of the sensor we perform Monte Carlo simulations of particle tracks inside the sensor head. The electrode geometry is imported directly from the CAD models into the SIMION® software suite to calculate the electric fields. Afterwards the full geometry and the calculated fields are imported into a GEANT4 simulation. This offers the advantage to use the extensive library of physical processes available in GEANT4 to better understand the trajectories and interactions of especially electrons inside the telescope.

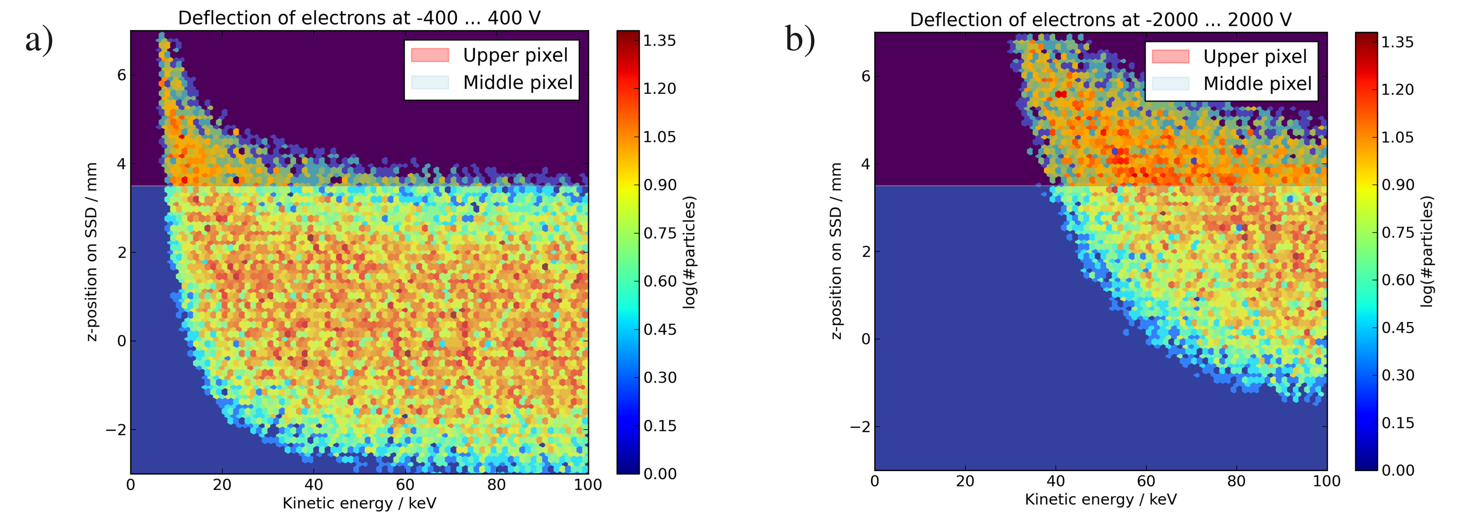

Figure 5: 2D histogram map of deflected electrons on the SSD detector plane for (a) 800V and (b) 4000V deflection voltage. The shaded areas denote suggested pixel locations. It is clearly visible how a higher deflection voltage increases the lower detectable energy threshold

Analysis of the simulation results is used to estimate the sensors response function depending on deflection voltage and particle energy. Additionally, tools to assess the detector angular response based on the SSD pixel locations are being developed to optimize the final pixel placement, with respect to the expected particle spectral composition.

Outlook :

To determine the optimal pixel distribution, further studies of the sensor response is necessary. GEANT4 simulations will provide us with detailed information about the interactions of especially electrons with the different parts of the telescope.
Furthermore, tests with the ASIC and detectors will be performed using an ECR ion source and an electron gun for particles in the keV energy range at the University of Kiel. The ion source will additionally be able to produce neutralized particles, which can also be detected by the telescope.
This research will allow us to utilize the full potential of the STEIN detector design to not only investigate the solar wind and solar events, but also the propagation of energetic neutral atoms (ENAs) in the heliosphere in in the low to medium keV energy range.

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Poster download

(a) Lin R, Larson D, Ergun R, et al., others. Observations of the solar wind, the bow shock and upstream particles with the WIND 3D plasma instrument. Advances in Space Research. 1997;20(4-5):645–654.

(b) Luhmann JG, Curtis DW, Schroeder P, et al. STEREO IMPACT Investigation Goals, Measurements, and Data Products Overview. Space Science Reviews. 2007;136(1-4):117-184.