Seeing Helios electron data through the eyes of Solar Orbiter: modelling the angular response of EPD/EPT and its application to the full inversion of Helios Events

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ABSTRACT

The pitch-angle distribution of electron intensities is an essential piece of information in order to understand the transport processes undergone by the particles in their journey from their acceleration sites to the spacecraft and, to infer properties of the particle sources such as their intensity and duration. In a previous work, we modelled fifteen solar relativistic electron events observed at different heliocentric radial distances by the Helios spacecraft (Pacheco et al. 2019). We used a Monte-Carlo transport model and an inversion procedure to fit the in-situ observations, and inferred both the electron mean free path in the interplanetary space and the injection histories of the electrons at two solar radii from the Sun. We applied a full inversion procedure, that is, we considered both the angular and the energetic responses of the Helios/E6 particle experiment in the modelling of the electron events.

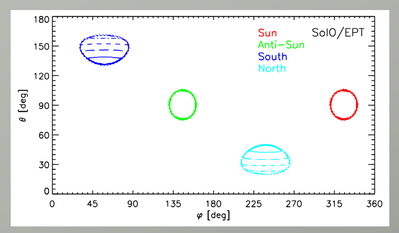
By using the same methodology as previously employed for ACE/EPAM, STEREO/SEPT and Helios/E6 instruments, we have modelled the angular response of the Electron Proton Telescope (EPT) of the Energetic Particle Detector (EPD) on board Solar Orbiter. Here, we present the study of the modelled angular response and its application to several of the solar energetic particle (SEP) events previously modelled as if Solar Orbiter were located at the Helios position. We compare the pitch-angle distributions measured by Solar Orbiter and Helios at different phases of the intensity-time profile of the SEP events, that is, near the particle onset, peak and on the decay of the event, and for different interplanetary magnetic field orientations provided by the Helios measurements.

We found that despite Helios were spinning spacecraft which gathered electron information from eight angular sectors, the four Solar Orbiter/EPD/EPT fields of view will often offer similar angular coverage. We also found that, under specific circumstances, EPT can obtain better pitch angle distribution information than Helios, specifically when the interplanetary magnetic field points away from the ecliptic. We expect, then, that Solar Orbiter will provide us with numerous and valuable observations that will permit us to untangle the transport effects that electrons, protons and ions suffer in their journey through interplanetary space.

SOLAR ORBITER/EPD-EPT

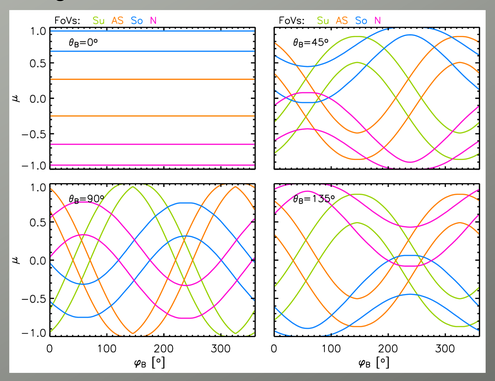
MODELLING SolO/EPD-EPT

We modelled the angular response of the 4 EPT fields of view



Pacheco et al. (2020), in preparation to be submitted to A&A.

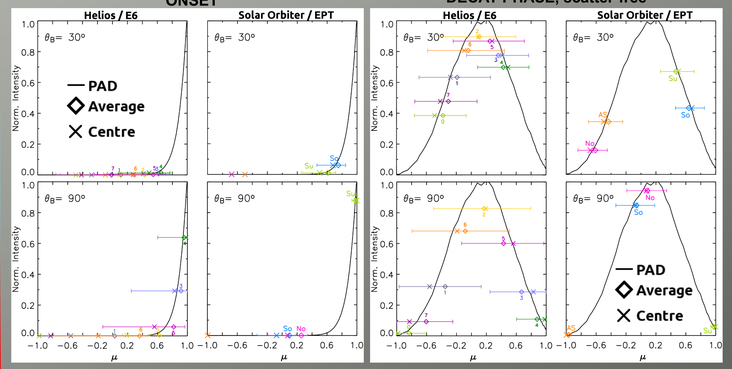
And compute the pitch-angle response regarding magnetic field direction for each field of view



Pacheco, PhD thesis (2019)

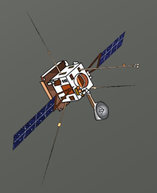
COMPARISON HELIOS/E6 – SolO/EPT OBSERVATIONS

Applying the modelled angular responses, we compared how Helios/E6 and SolO/EPD-EPT would observe different synthetic PAD



Pacheco, PhD thesis (2019)

- EPT shows in general good coverage of the PADs, comparable to E6.
- EPT synthetic observations can trace the given PAD.
- EPT generally presents better coverage out of the ecliptic plane than E6. That will be useful when studying events occurring with non-ideal IMF.



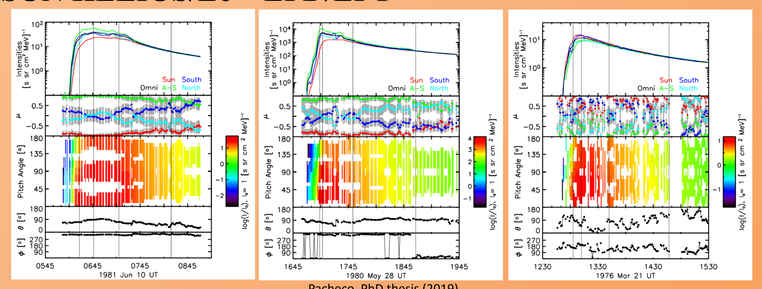
COMPARISON HELIOS/E6 – EPD/EPT

HELIOS EVENTS AS OBSERVED BY SolO/EPT

We applied the EPT modelled angular response to the result of the inversions of the near relativistic events observed by Helios (Pacheco et al., A&A, 2019) getting:

- Field-of-view Intensities
- Pitch-angle Distributions

Only possible on times when Helios magnetic field was available



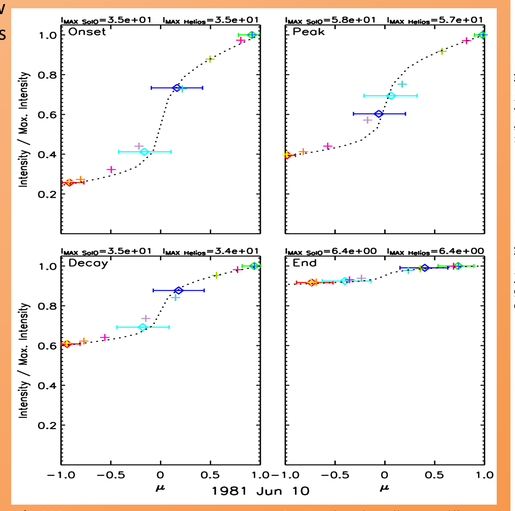
Pacheco, PhD thesis (2019)

COMPARISON HELIOS/E6 – SolO/EPT OBSERVATIONS

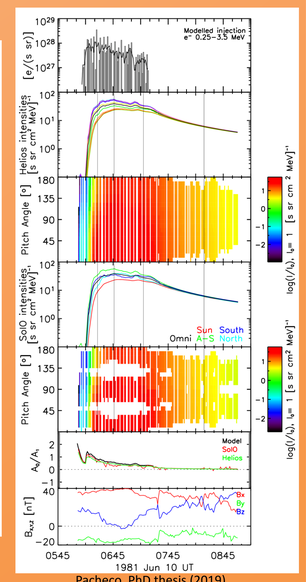
We compared the PAD observed by each field of view (sector) of SolO/EPT (Helios/E6) and the actual values of the model at four different times of the events:

GENERAL REMARKS:

- Solar Orbiter/EPT offers a good pitch-angle coverage of the modelled events.
- We found different pitch angle coverage configurations, depending on the direction of the local IMF.
- In most of these configurations we can recover a good picture of the PAD.



- We can reconstruct approximately the "actual" PADs from the EPT observations



Pacheco, PhD thesis (2019)

SUMMARY

- We modelled SolO/EPD/EPT angular response and studied the pitch angle coverage of the instrument at diferent IMF scenarios.
- We tested the modelled EPT responsed applied to different synthetic PAD and compare it to E6.
- We found that EPT shows equivalent coverage for particles arriving through an IMF close to t he ecliptic plane and genererally better coverage when the IMF is not in the ecliptic plane.
- We applied the previously modelled response of SolO/EPD/EPT to three of the Helios electron events modelled by Pacheco et al., A&A (2019).
- We obtained the intensities of each field of view and the pitch-angle distributions that Solar Orbiter would have observed at that position in the space.
- We found that solar Orbiter will be able to provide comparable pitch-angle coverage to Helios for those events with particles arriving through an IMF close to the ecliptic plane.

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