Contamination of EAS measurements by low-energy S/C electrons

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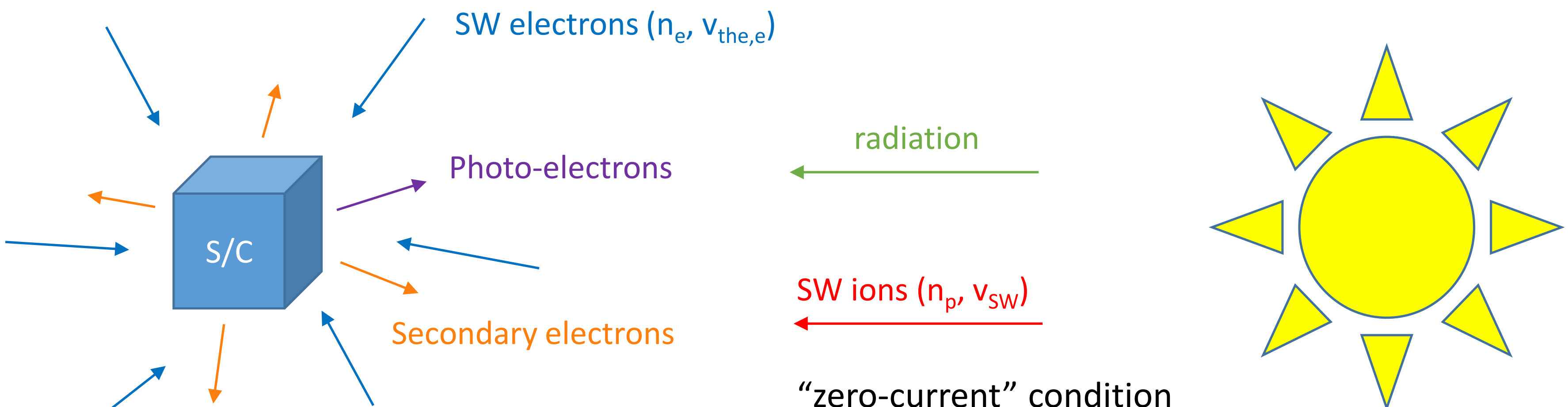
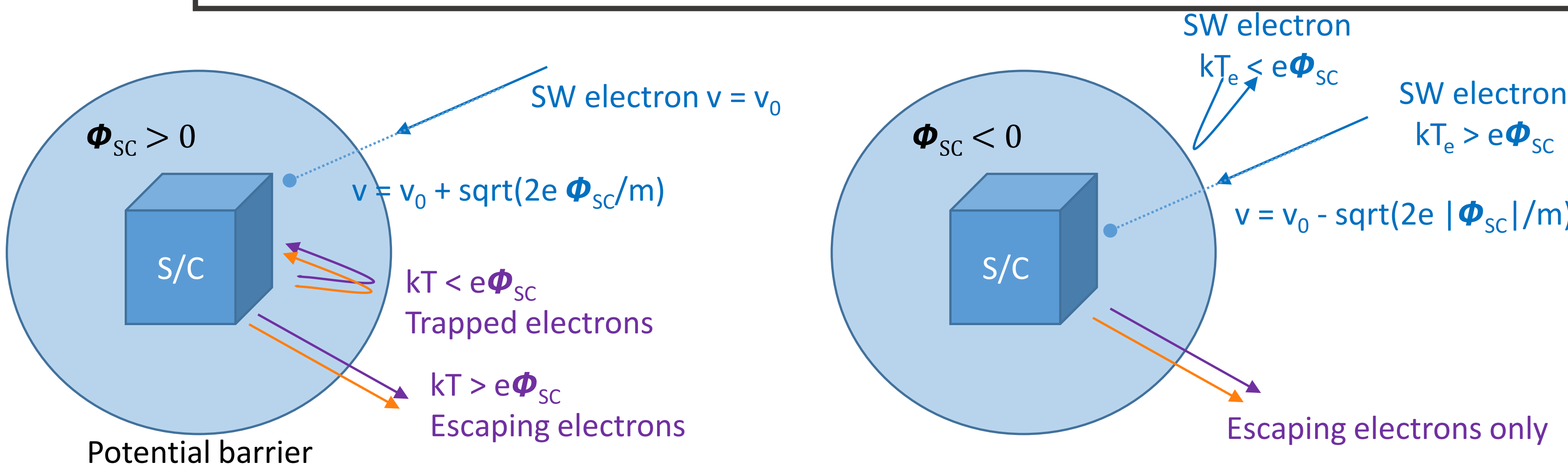
S/C charging - principals



“zero-current” condition

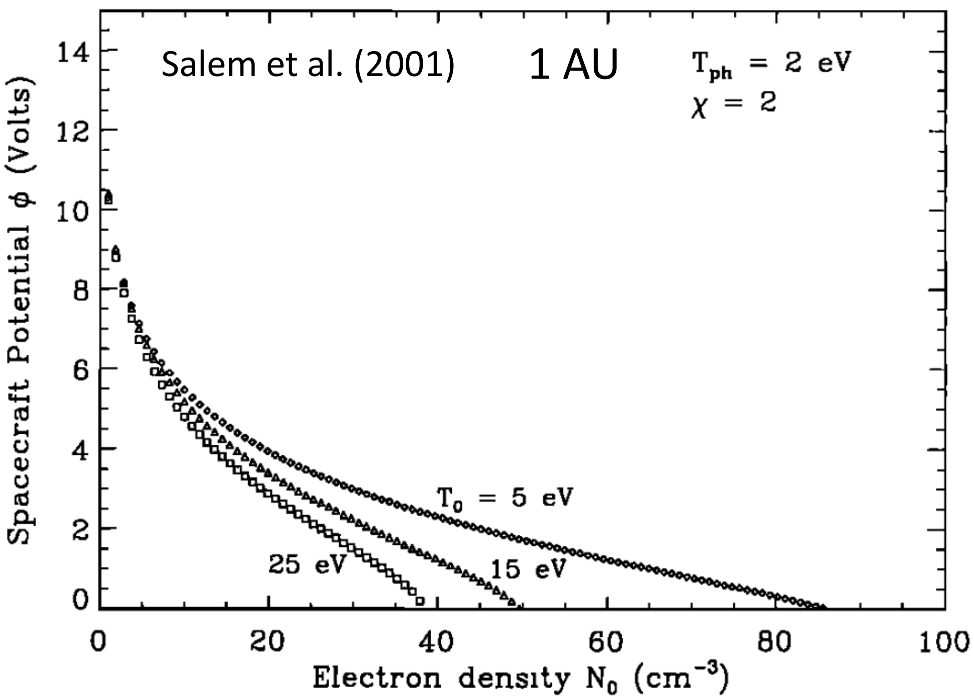
$$I_{SW,i}(\boldsymbol{\Phi}_{SC})+I_{SW,e}(\boldsymbol{\Phi}_{SC})+I_{ph}(\boldsymbol{\Phi}_{SC})+I_{se}(\boldsymbol{\Phi}_{SC}) = 0 \Rightarrow \boldsymbol{\Phi}_{SC} = ???$$

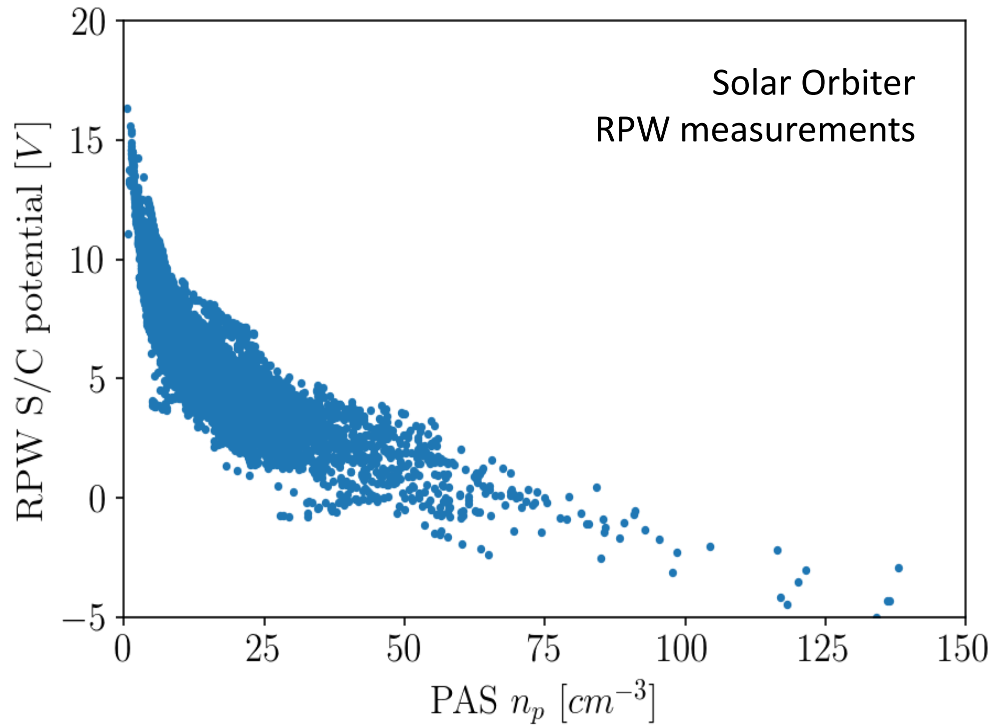


S/C potential - variations

$$I_{SW,e}(\boldsymbol{\Phi}_{SC}) = -\,I_{ph}\,(\boldsymbol{\Phi}_{SC}) \;\Rightarrow\; \frac{e\phi}{T_{ph}} - \ln\left[\frac{(1+e\phi/T_{ph})}{(1+e\phi/T_{e0})}\,\frac{96.15\,\chi}{N_{e0}\sqrt{T_{e0}}\,d_{AU}^2}\right] = 0$$

Salem et al. (2001)





$\boldsymbol{\Phi}_{SC}$ is decreasing with increasing electron density/temperature becoming negative for a sufficiently dense/hot plasma

$\boldsymbol{\Phi}_{SC}$ is mostly positive for Solar Orbiter ambient plasma conditions

S/C potential - variations

$$\mathrm{I}_{SW,e}(\boldsymbol{\Phi}_{SC}) = -\,\mathrm{I}_{ph}(\boldsymbol{\Phi}_{SC}) \;\Rightarrow\; \frac{e\phi}{T_{ph}} - \ln\left[\frac{(1+e\phi/T_{ph})}{(1+e\phi/T_{e0})}\,\frac{96.15\,\chi}{N_{e0}\sqrt{T_{e0}}\,d^2_{AU}}\right] = 0$$

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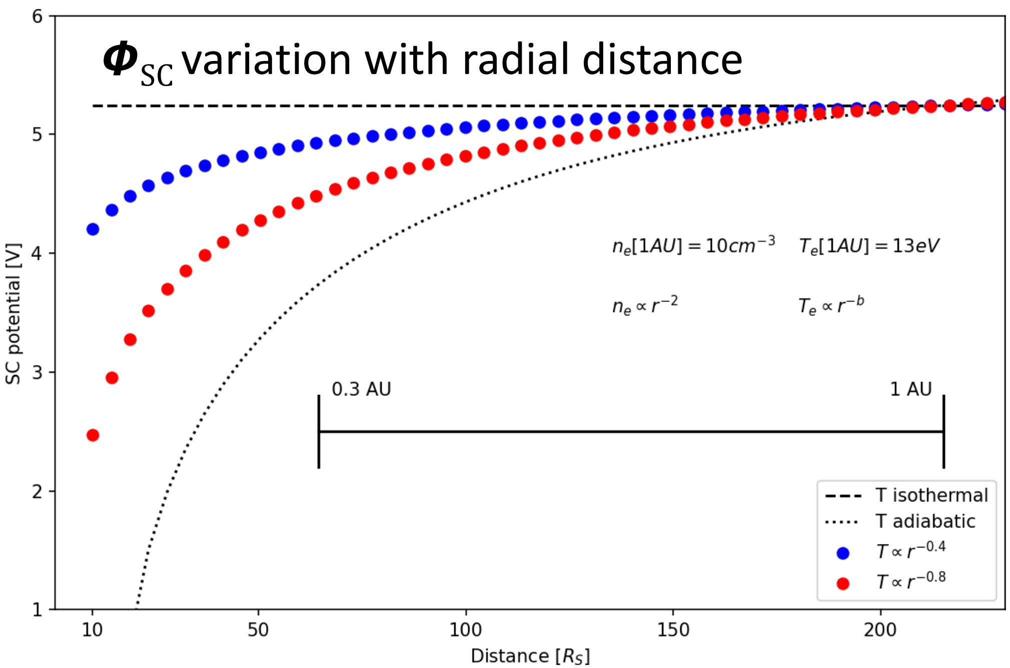
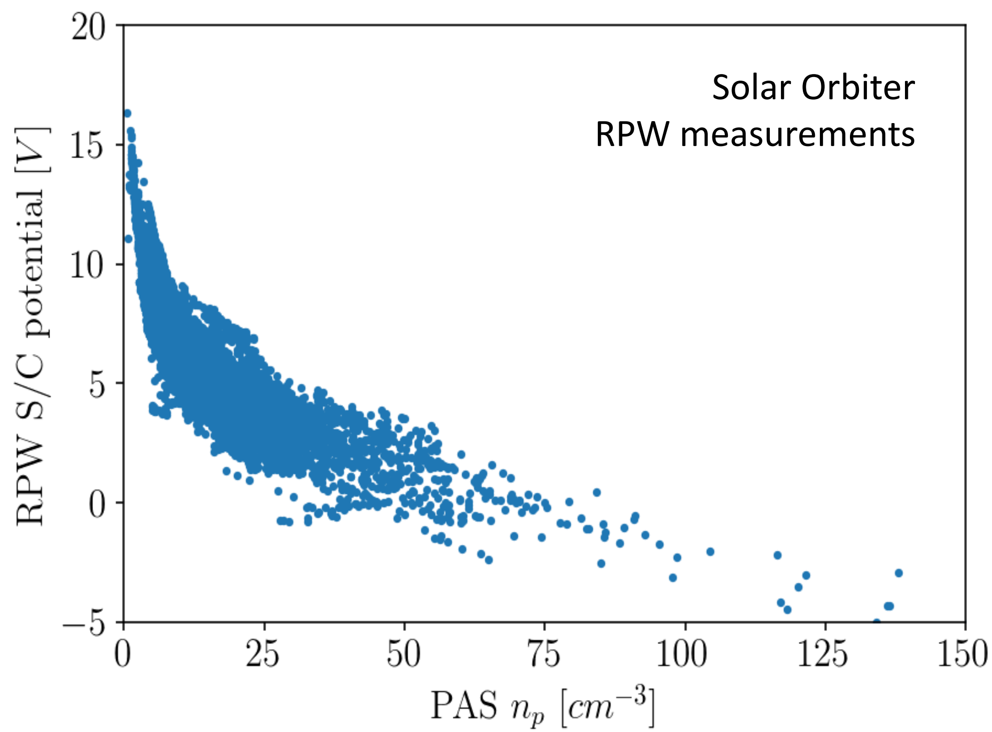


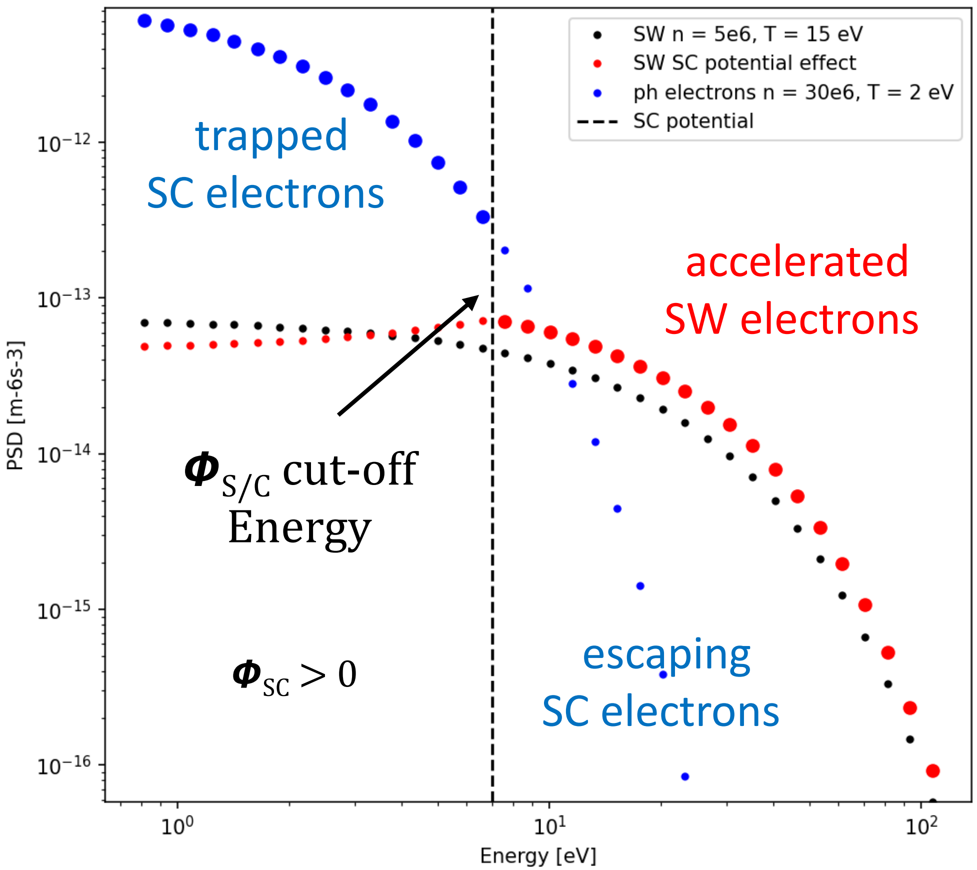


$\boldsymbol{\Phi}_{SC}$ shows small increase with radial distance due to the cooling of solar wind electrons

$\boldsymbol{\Phi}_{SC}$ is mostly positive for Solar Orbiter ambient plasma conditions

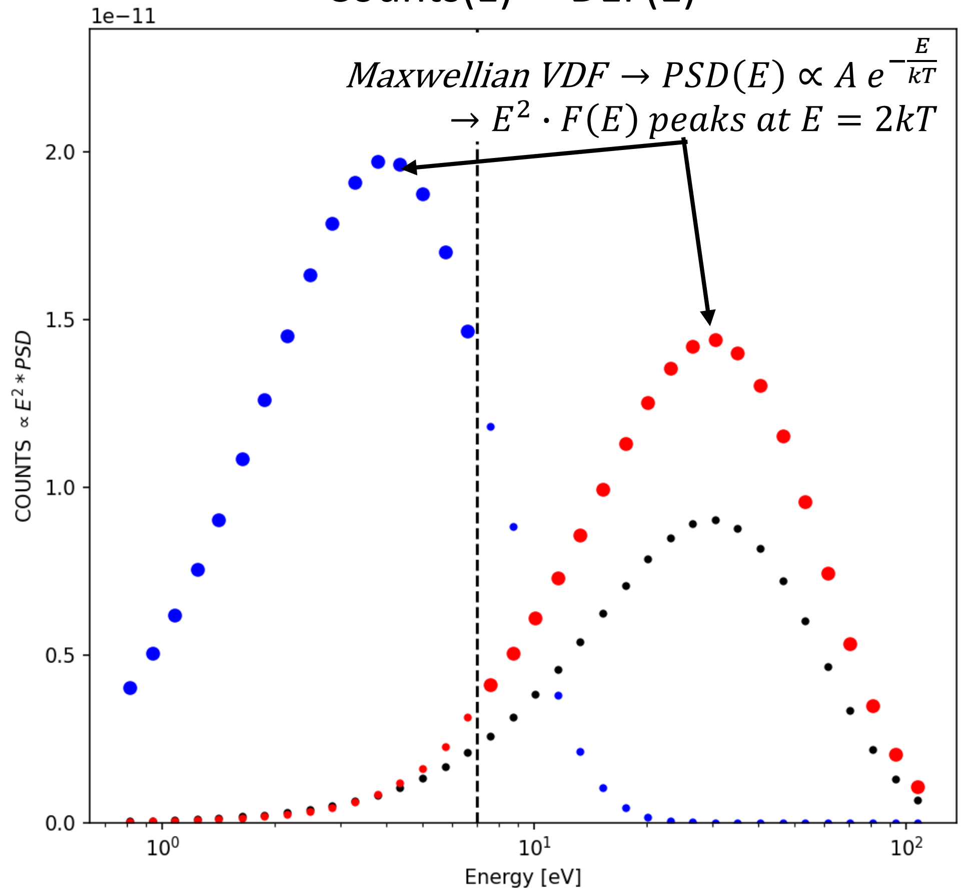
S/C potential effects on eVDF- model EAS measurements

PSD(E)



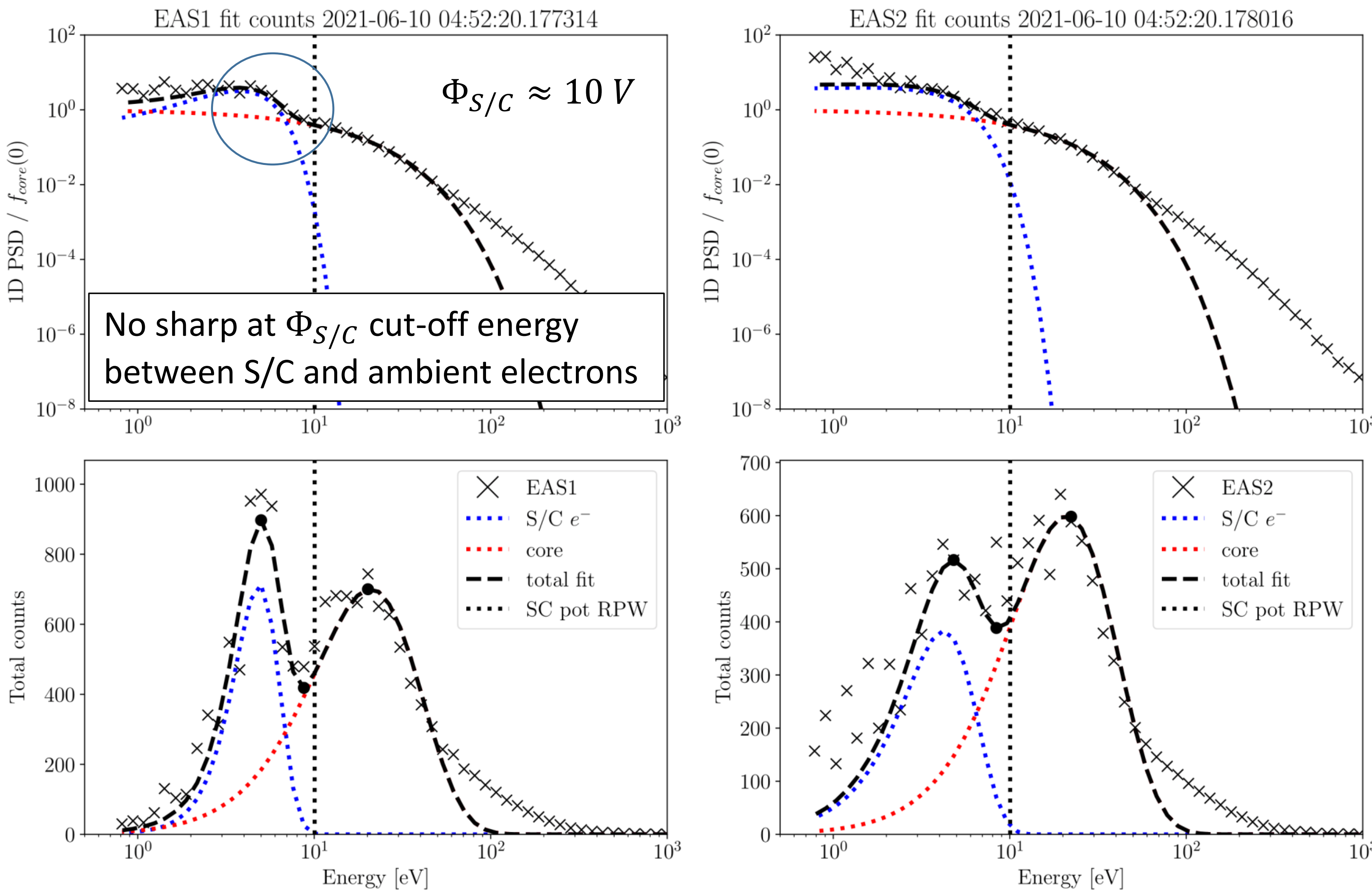
Step in PSD(E) at e $\Phi_{S/C}$

Counts(E) ∝ DEF(E)

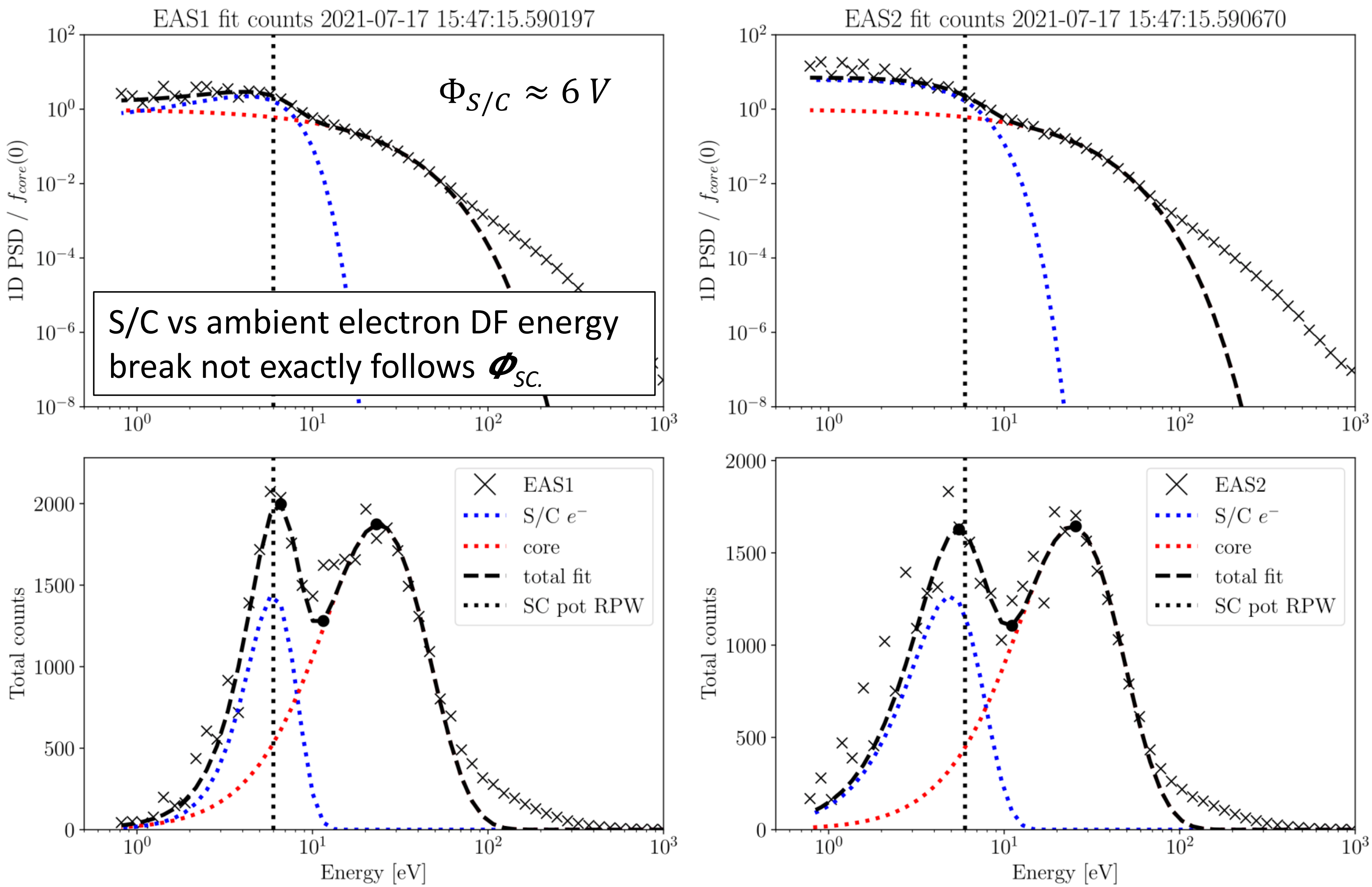


Two distinct peaks/populations in Counts(E)

EAS 1D VDF samples – S/C potential variations

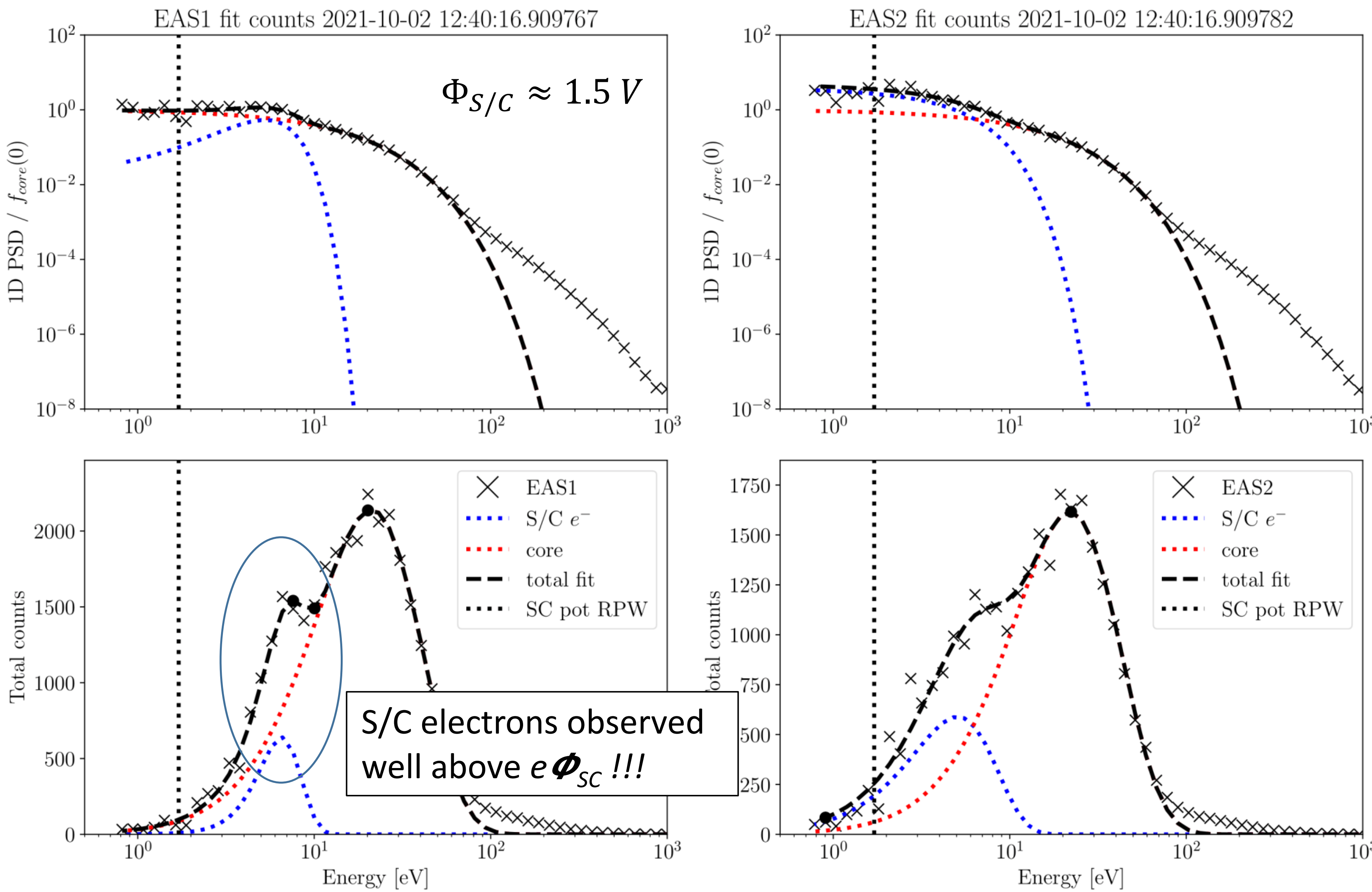


EAS 1D VDF samples – S/C potential variations

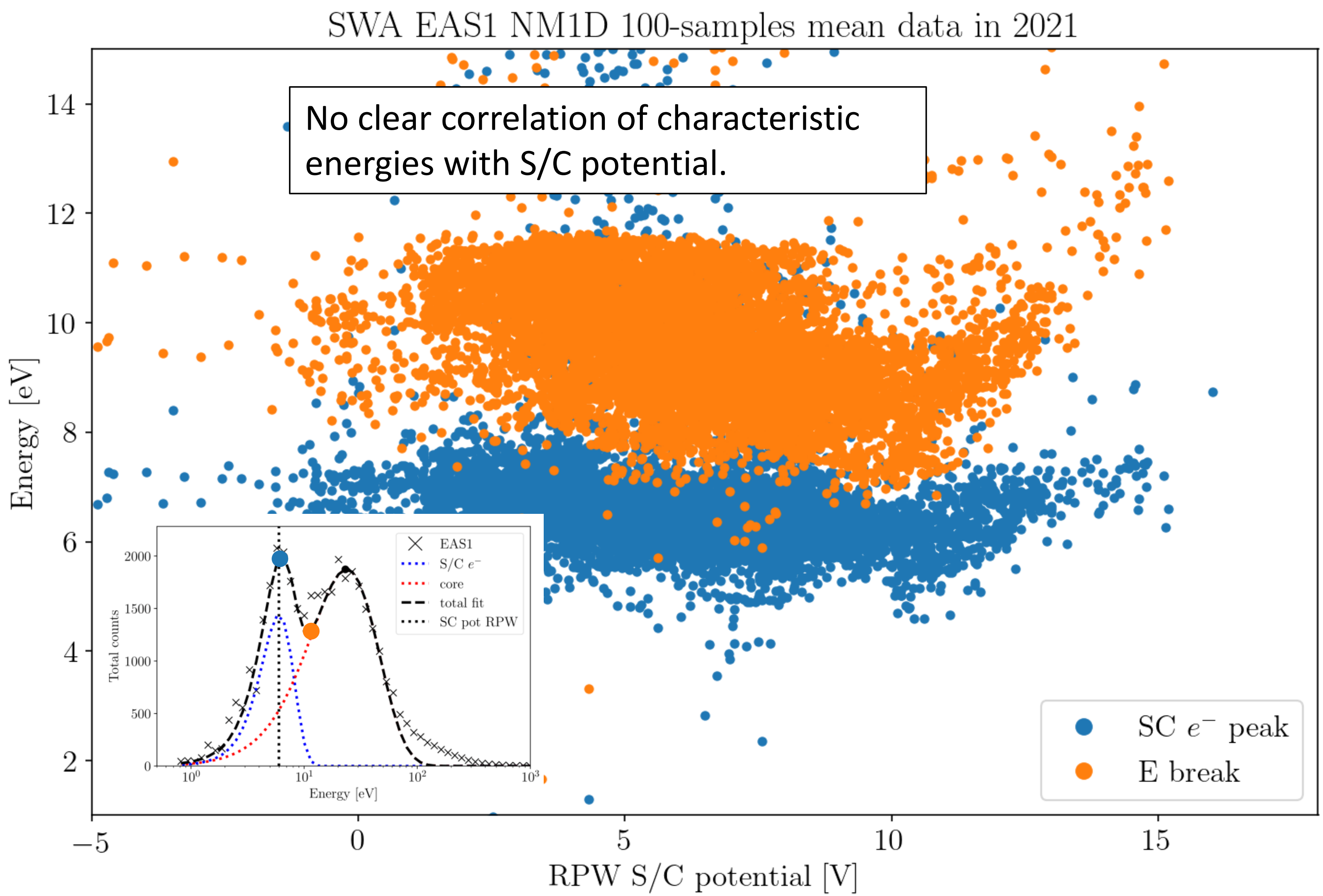


S/C vs ambient electron DF energy break not exactly follows $\boldsymbol{\phi}_{SC.}$

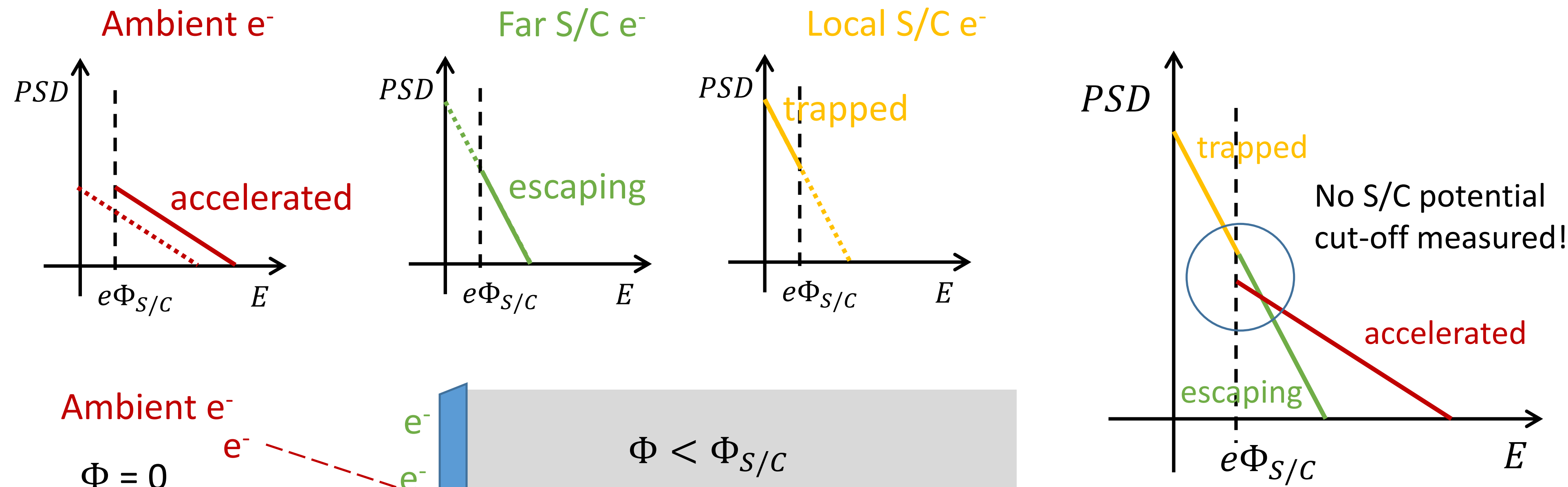
EAS 1D VDF samples – S/C potential variations

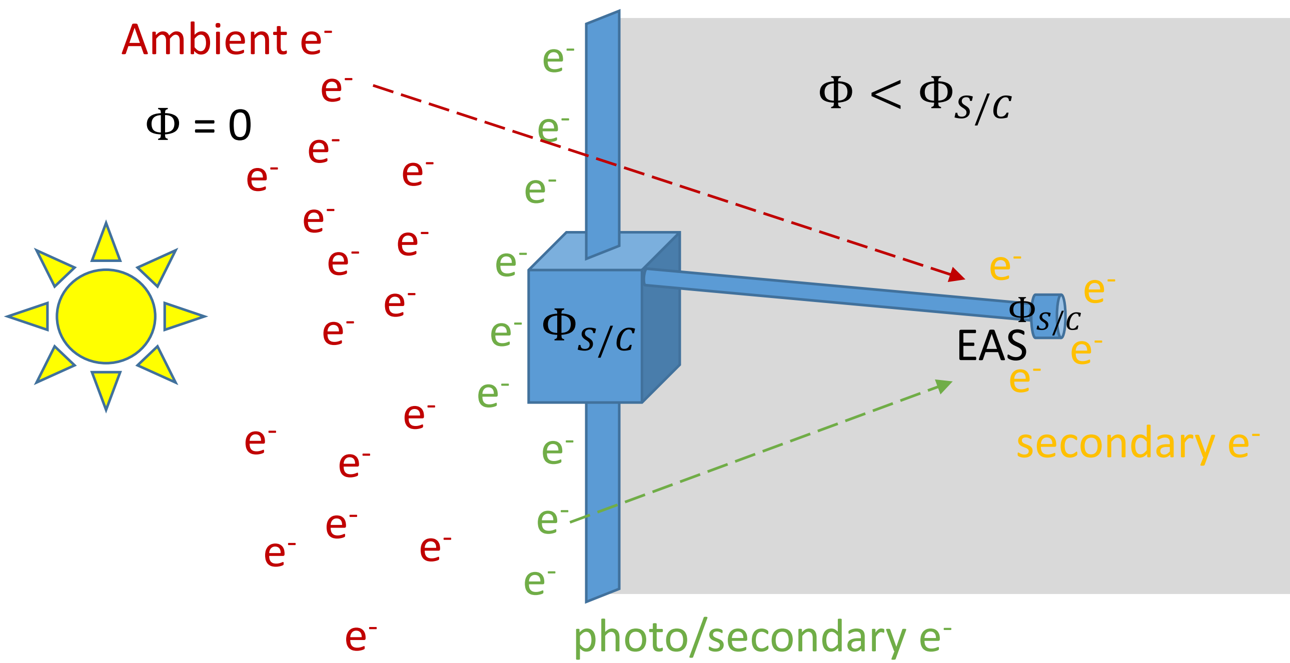


S/C to ambient electron energy breakpoints



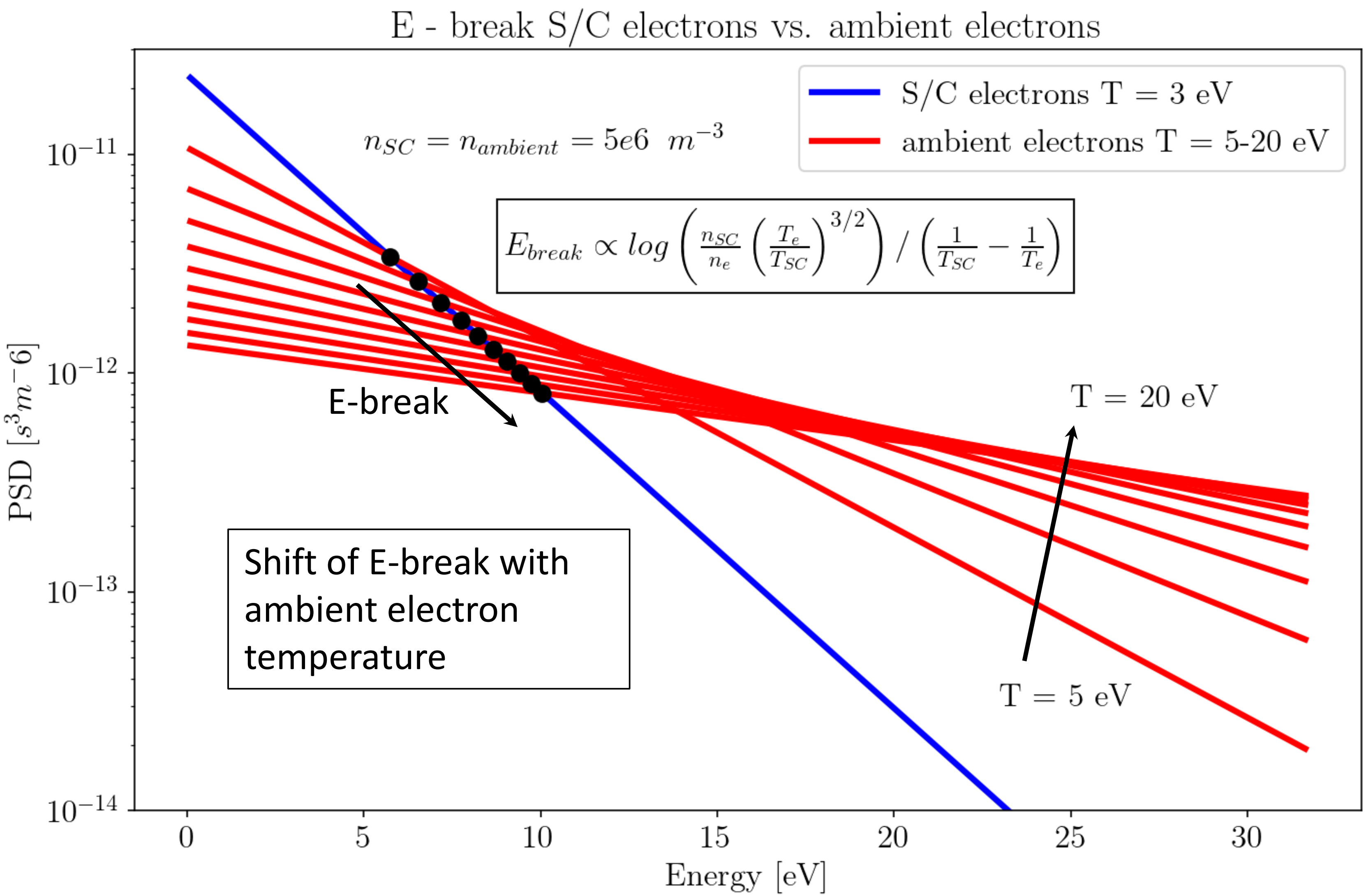
Non/Local S/C electrons at EAS



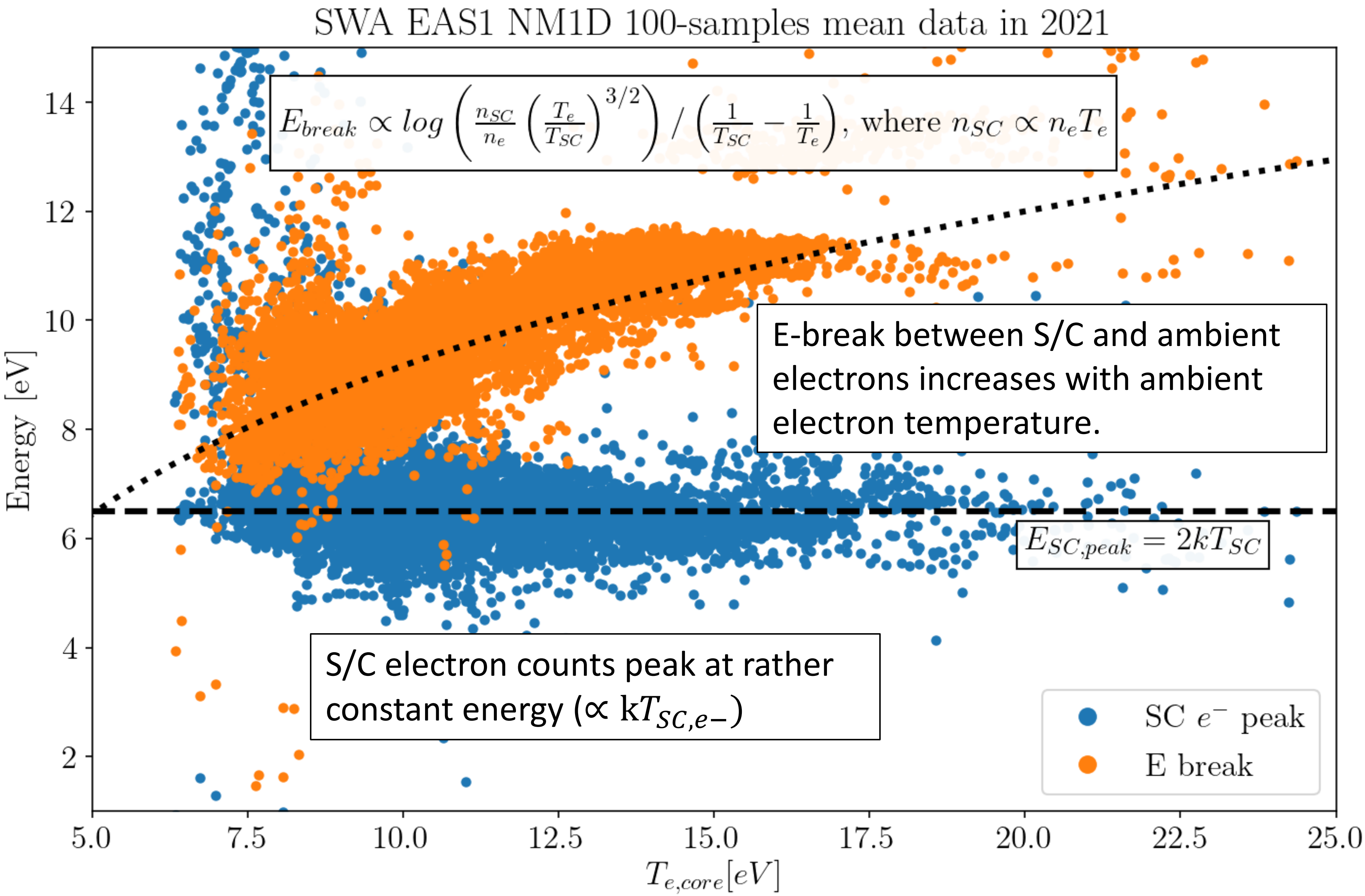


No clear cut-off in VDF between S/C and ambient observed around local $\boldsymbol{\Phi}_{SC}$ plausibly due to non-local S/C electrons impacting the EAS heads.

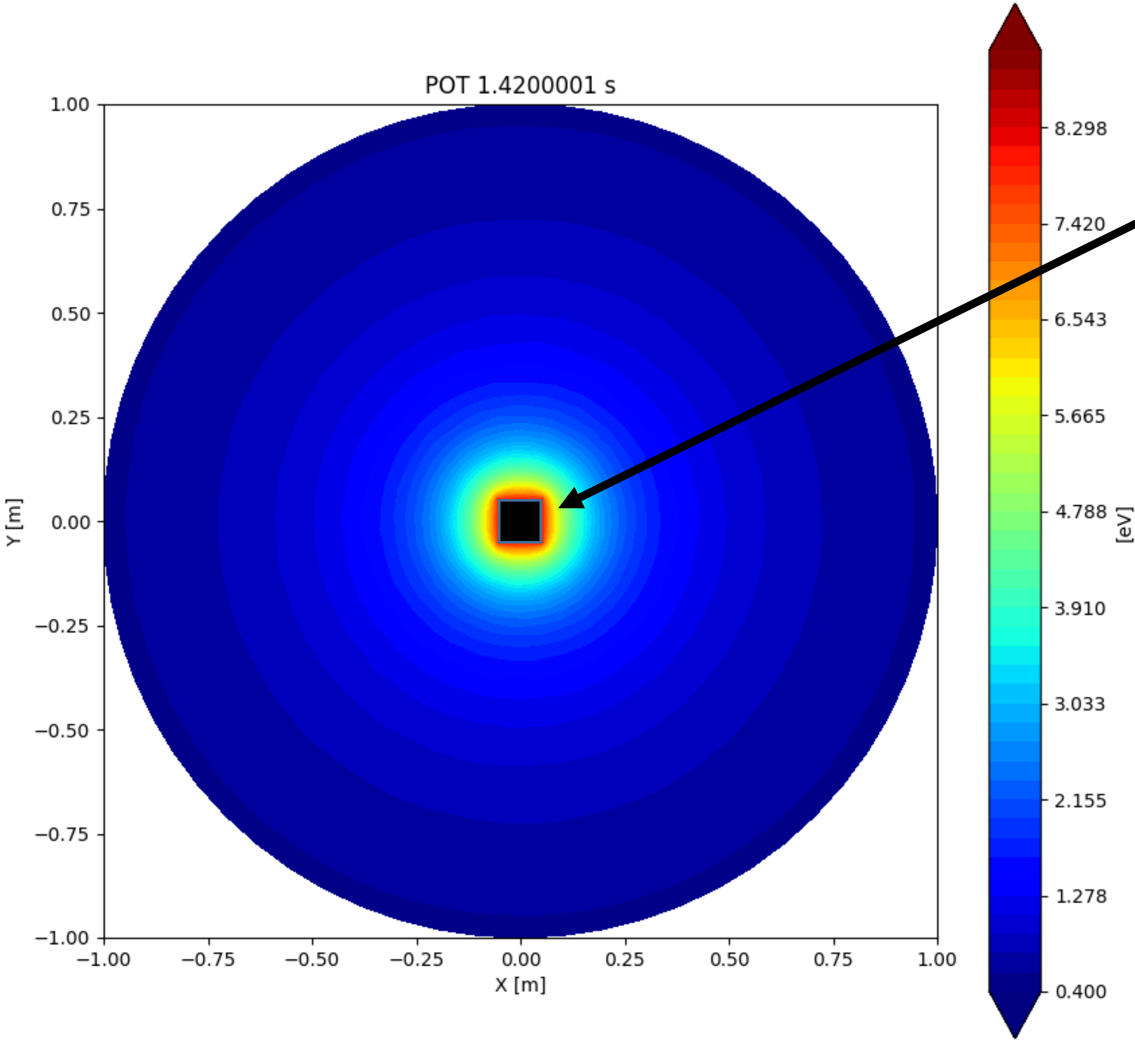
E-break for two Maxwellian VDFs



S/C to ambient electron energy breakpoints

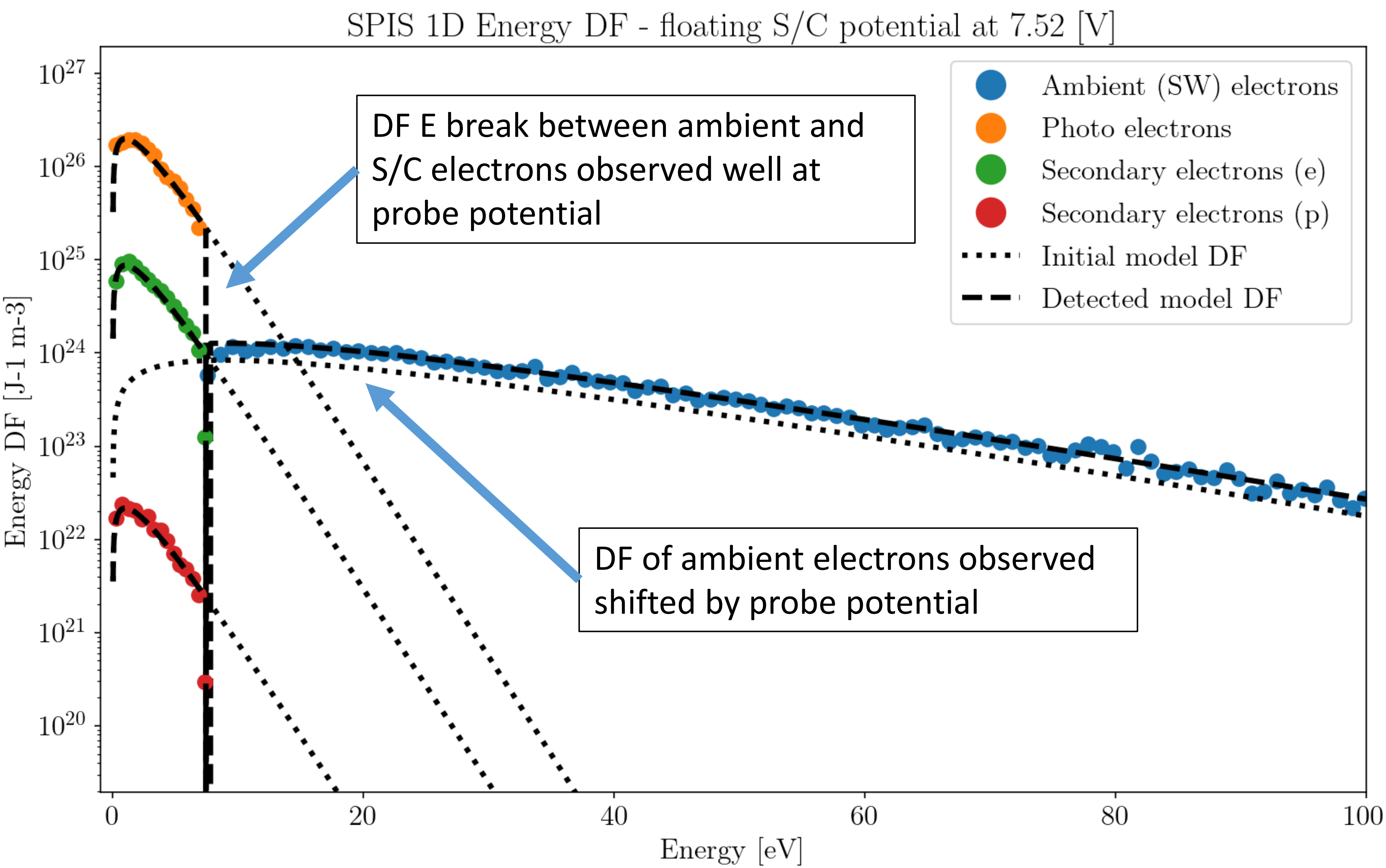


SPIS simulations – SETUP A

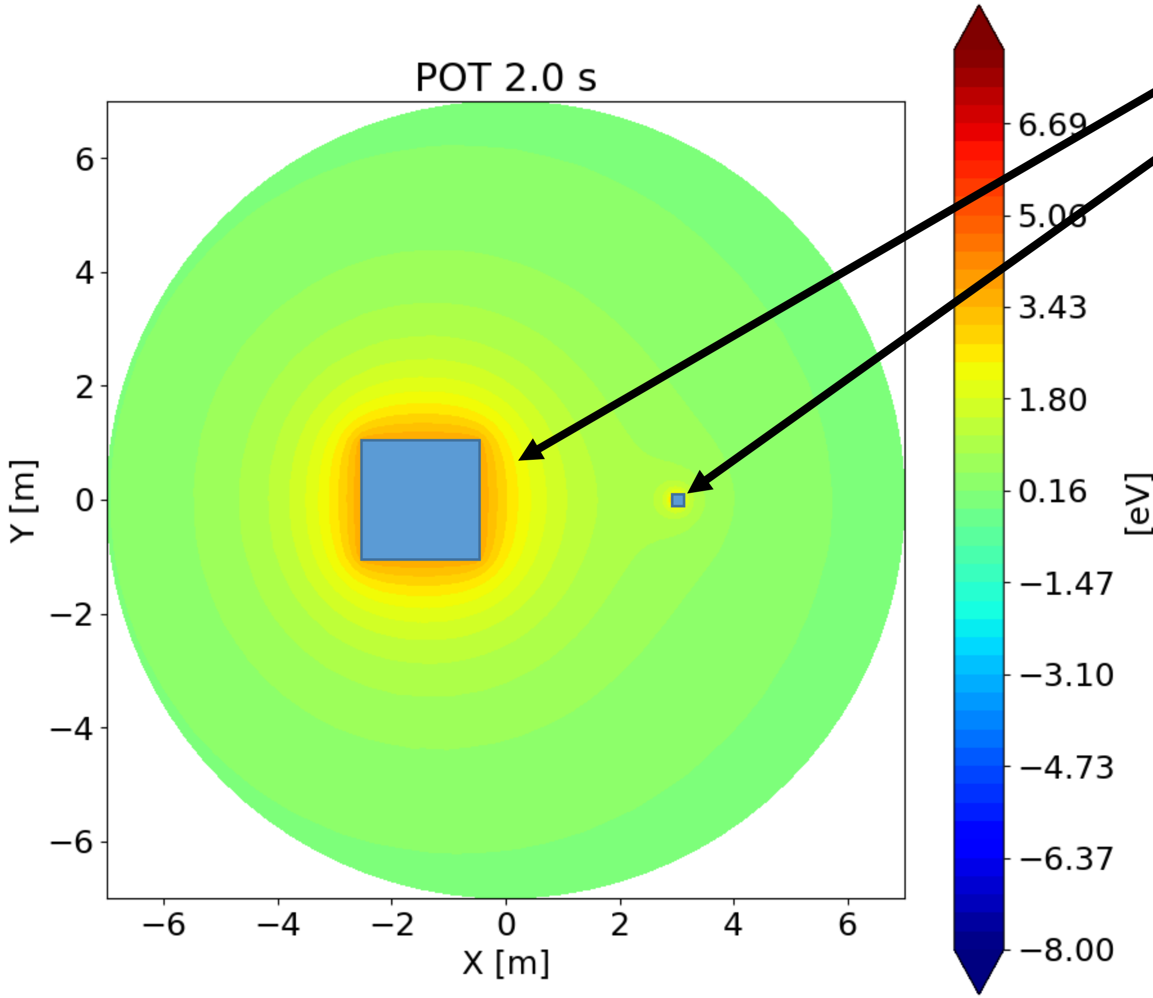


- No S/C body
- Single detector (cube shape)
- Photo/secondary electron emissions from detector's surface
- Ambient plasma conditions set to result in positive probe potential ≈ +7.5 V

SPIS simulations – SETUP A DF

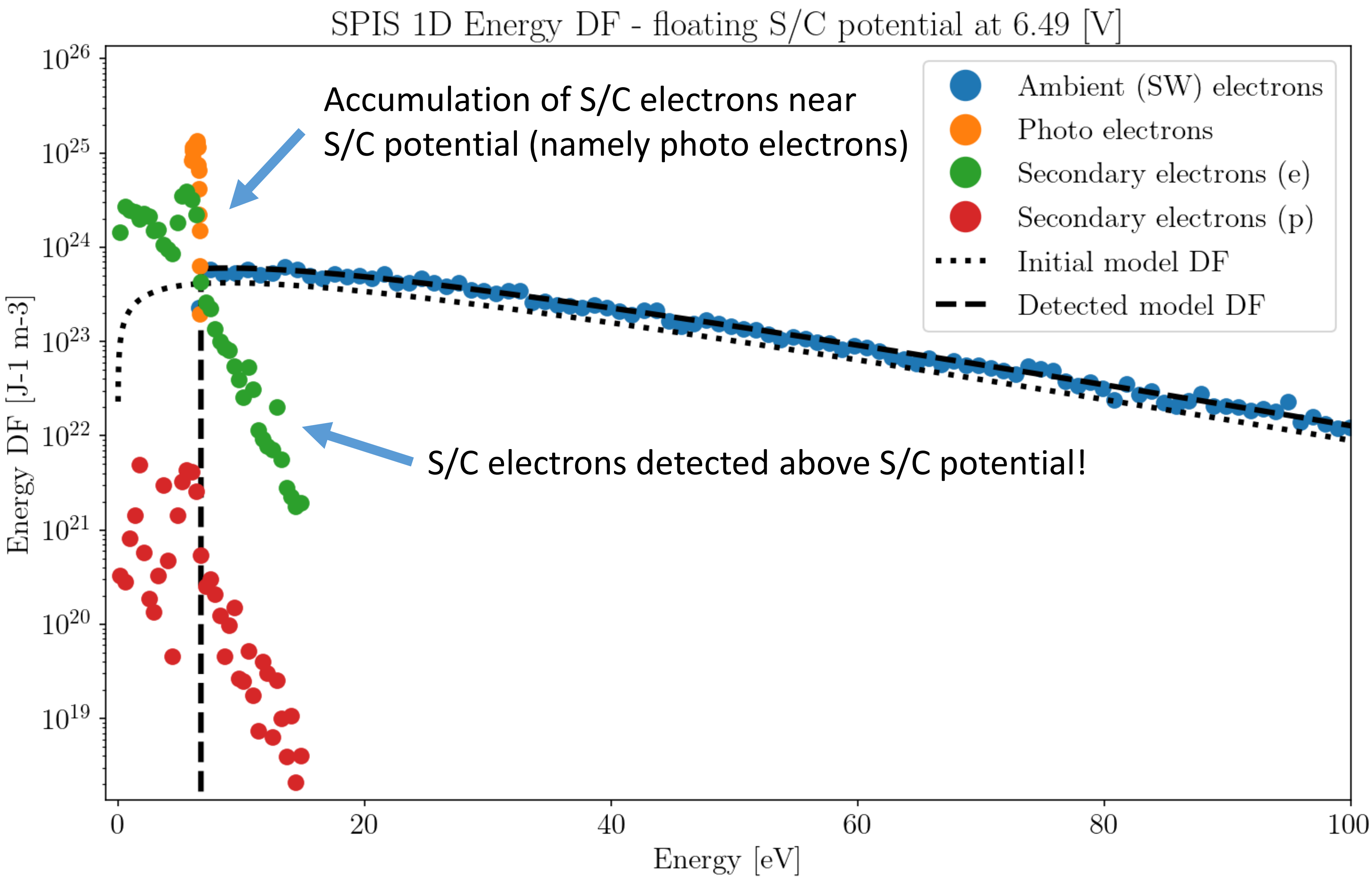


SPIS simulations – SETUP B

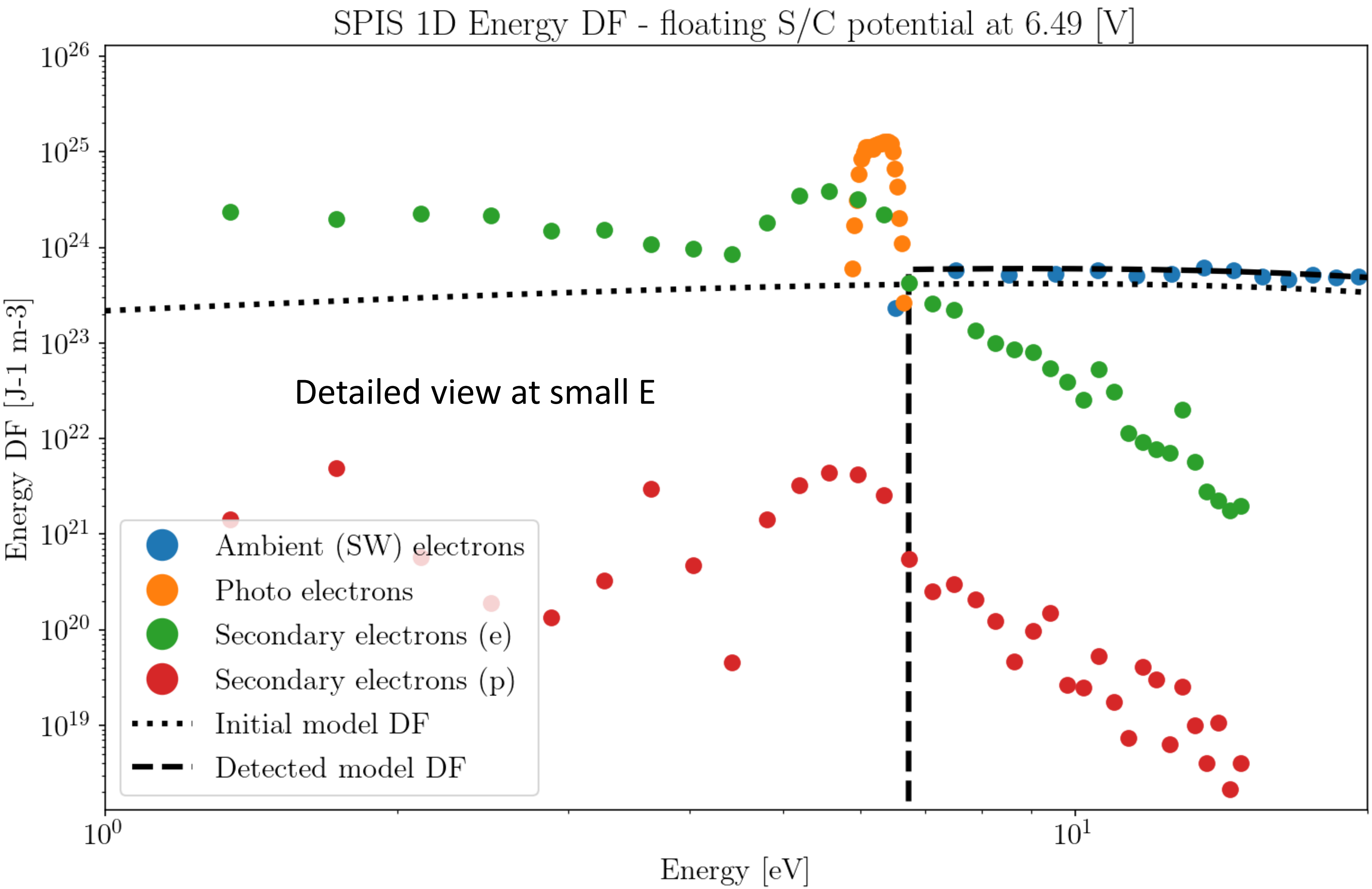


- S/C body
- Single detector in the shadow behind the S/C
- Photo/secondary electron emissions from S/C and probe surfaces
- Ambient plasma conditions set to result in positive probe potential ≈ +6.5 V

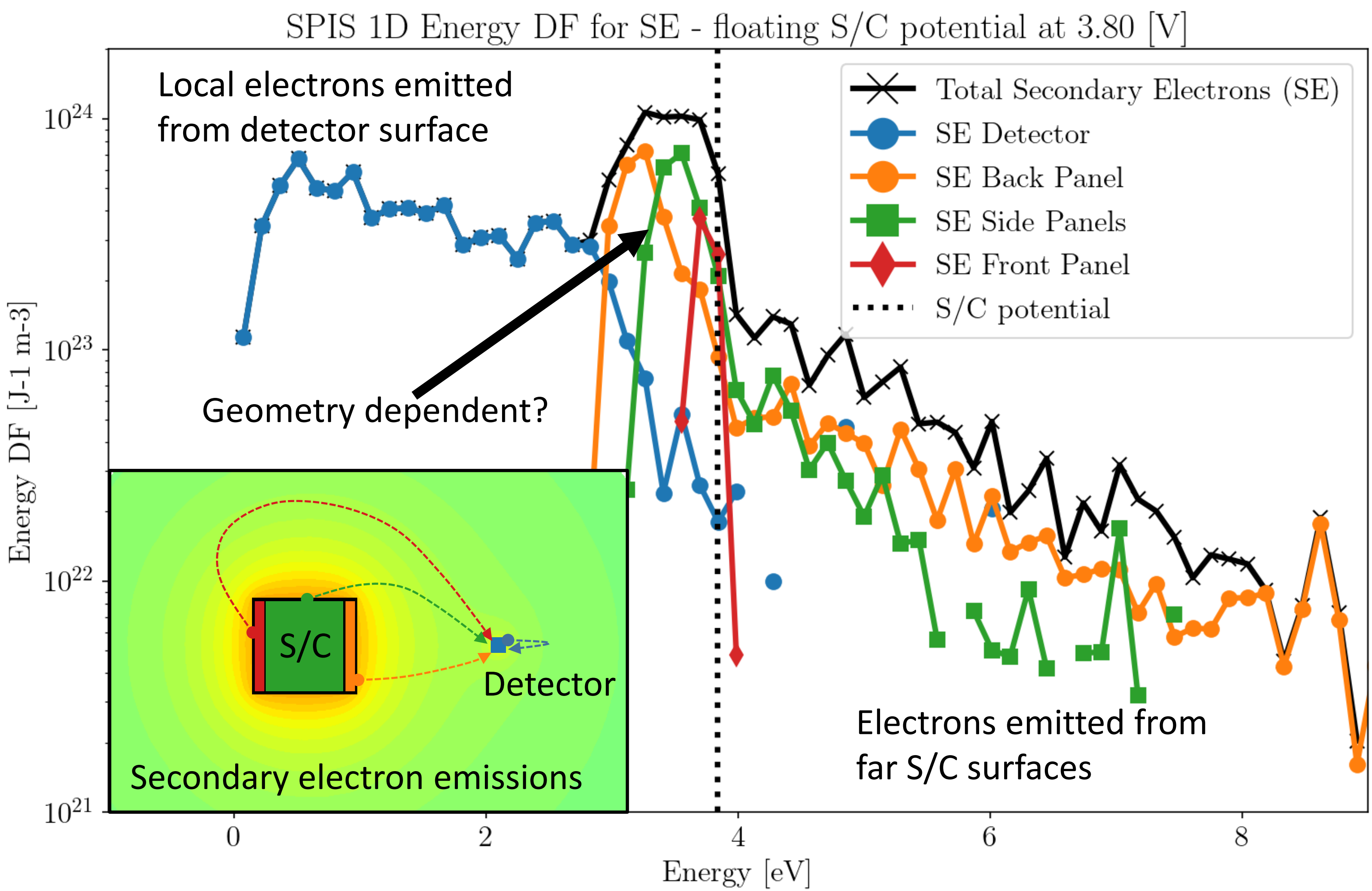
SPIS simulations – SETUP B +6.5V



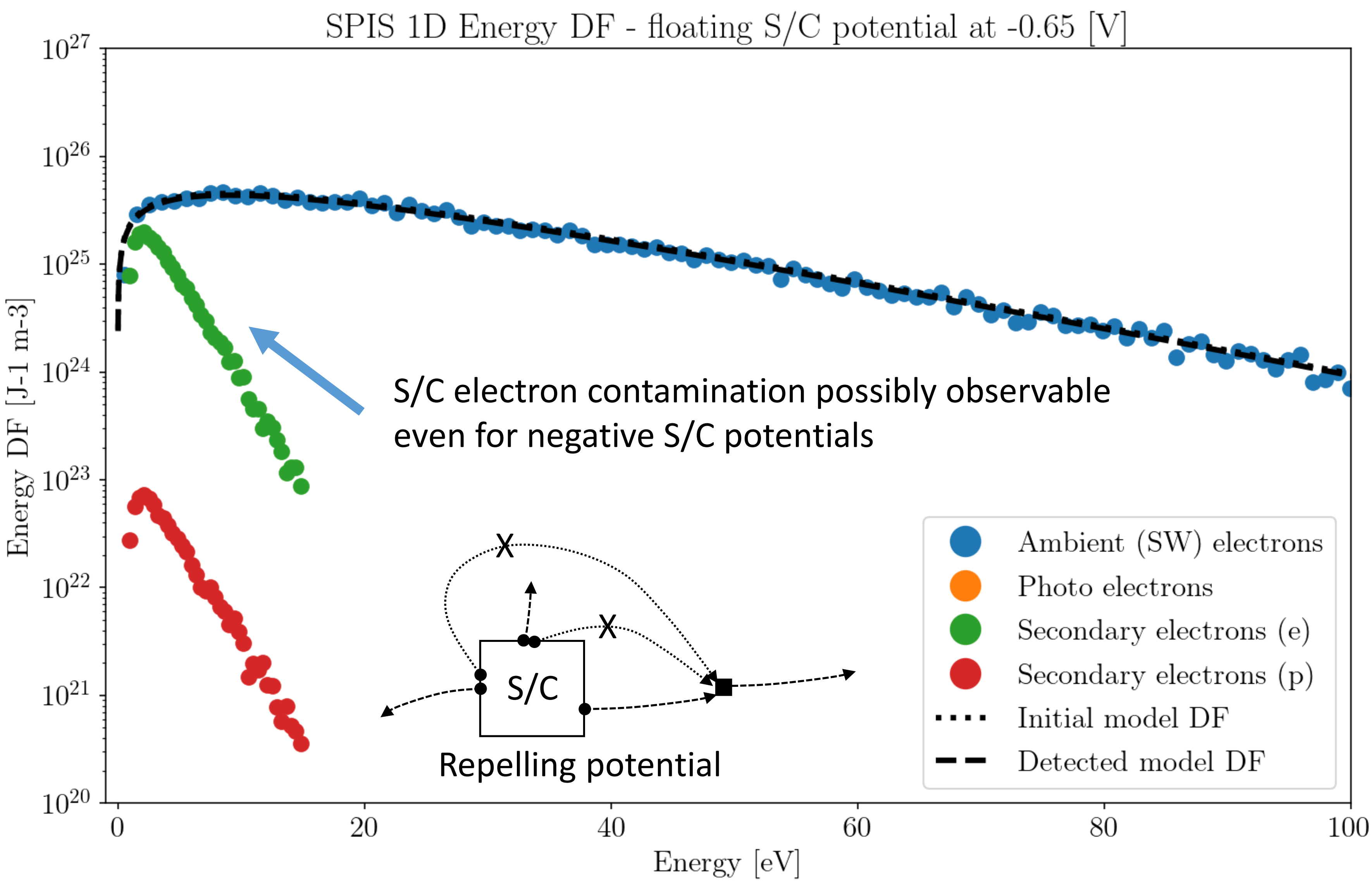
SPIS simulations – SETUP B +6.5V



SPIS simulations – SETUP B +6.5V
Sources of secondary electron emissions

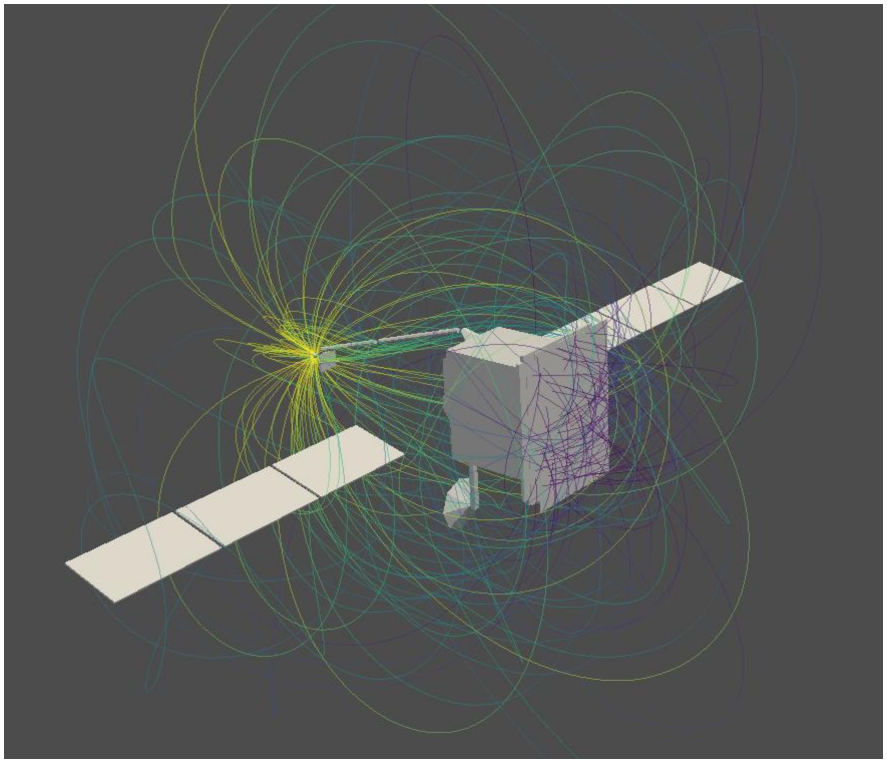


SPIS simulations – SETUP B -0.65V

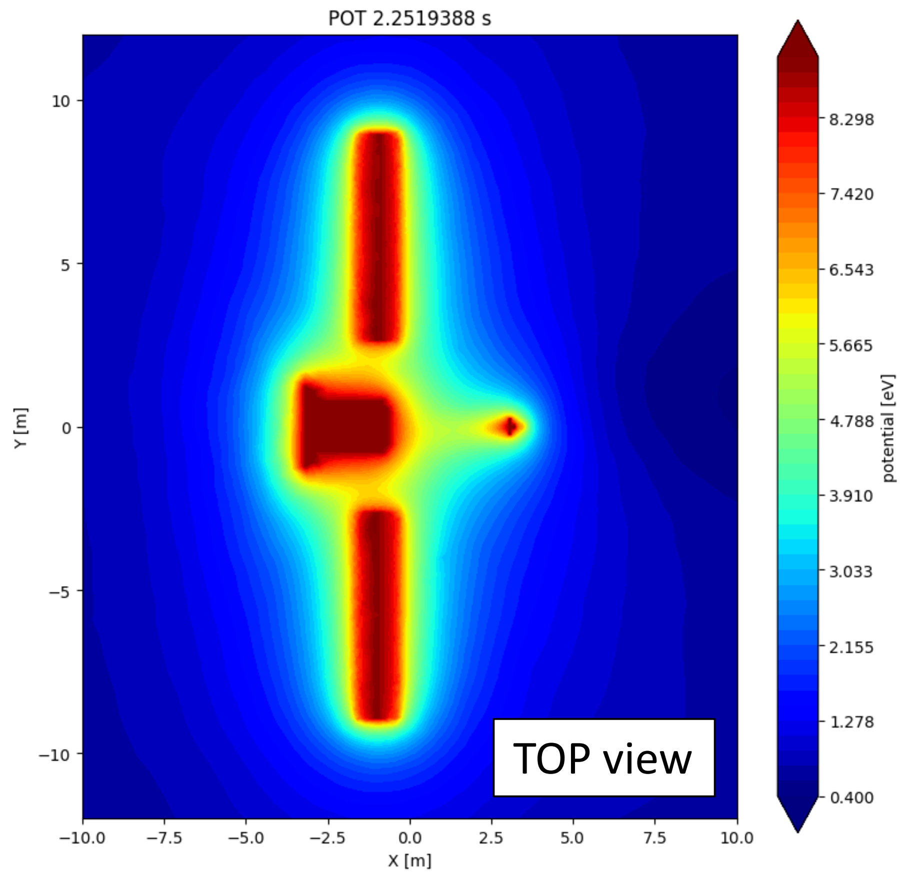


SPIS simulations – SETUP "SOLO"

Spacecraft Plasma Interaction Software – free 3D PIC modelling tool (ESA), see www.spis.org

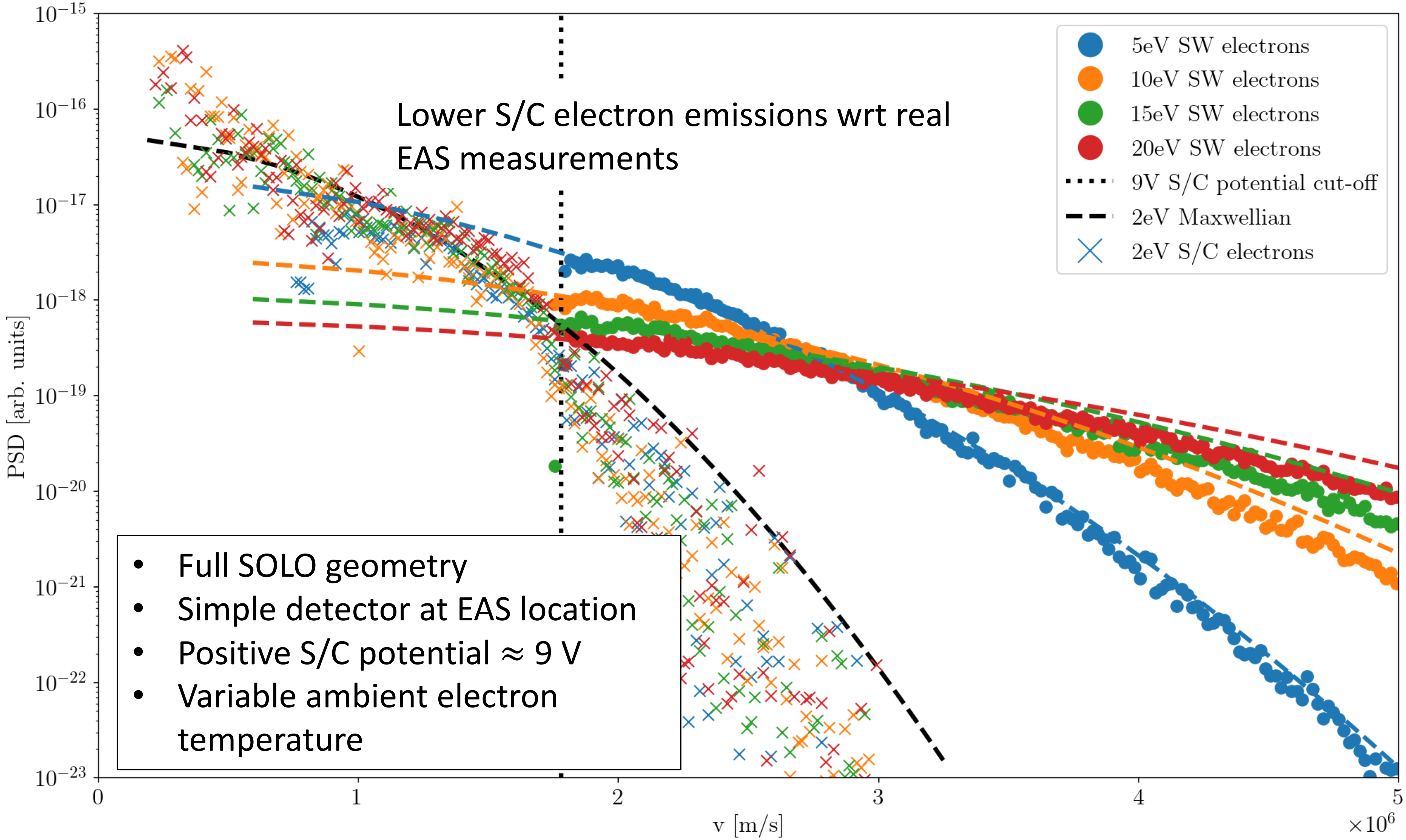


Sample trajectories of electrons emitted from the S/C surface and impacting the EAS heads.



S/C potential around the S/C body.

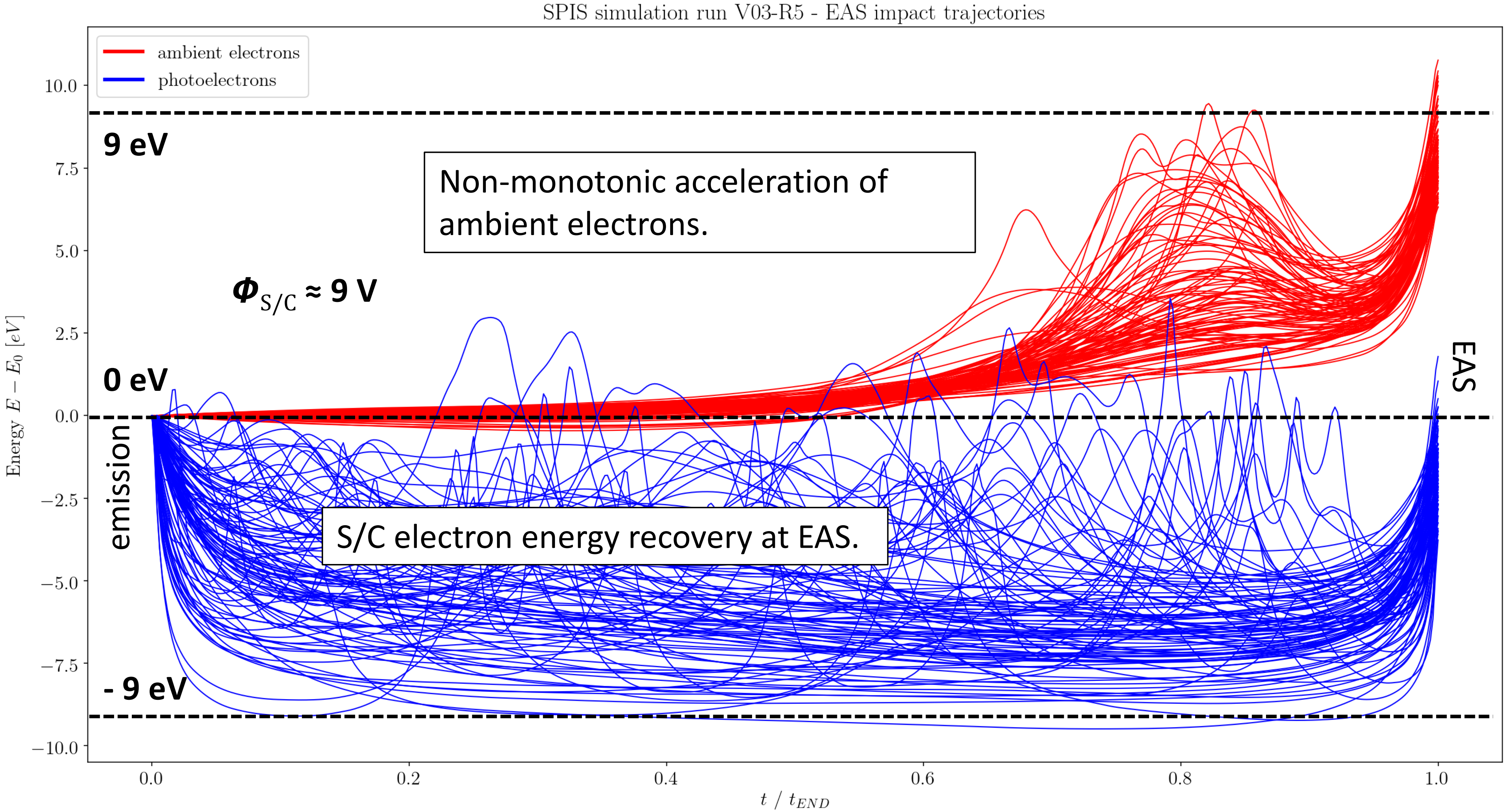
SPIS simulations – SETUP “SOLO”



Summary

- Performed analysis od EAS/RPW measurements from 2021
- Transition between S/C electrons and ambient solar wind electrons in measured EAS DF is
  - not steep but smooth
  - observable even above S/C potential
  - well correlated rather to local ambient electron temperature
- Such behavior is consistent for a detector placed away from the main S/C body and thus being polluted not only by local but also phot/secondary electrons emitted from far S/C surfaces
- Detection of far S/C electrons above the S/C potential confirmed by a simple model SPIS simulations
- Implications for EAS data analysis
  - Part of the E-range above the S/C potential is still polluted by S/C electrons and has to be carefully removed from data analysis
  - S/C potential can not be directly derived from EAS measurements but the analysis has to rely on RPW measurements
- Future work
  - Comparison of simplified models wrt models based on true Solar Orbiter geometry
  - S/C potential effects on 3D DF properties and derived DF moments (angular change in individual particle trajectories)

SPIS simulations – e⁻ trajectories to EAS



SPIS simulations – e⁻ trajectories to EAS