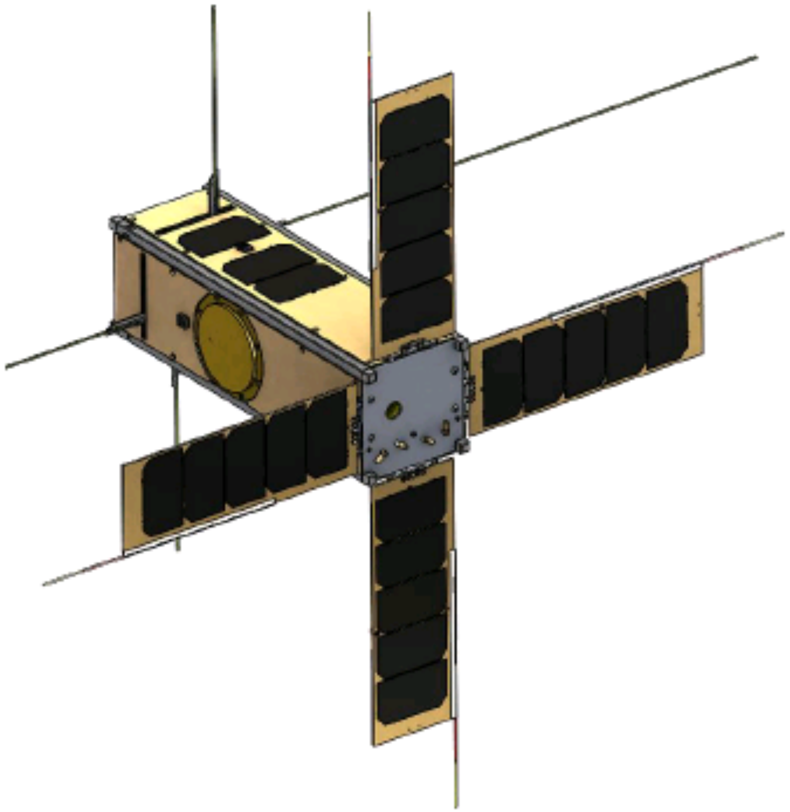

PICASSO spacecraft plasma interactions

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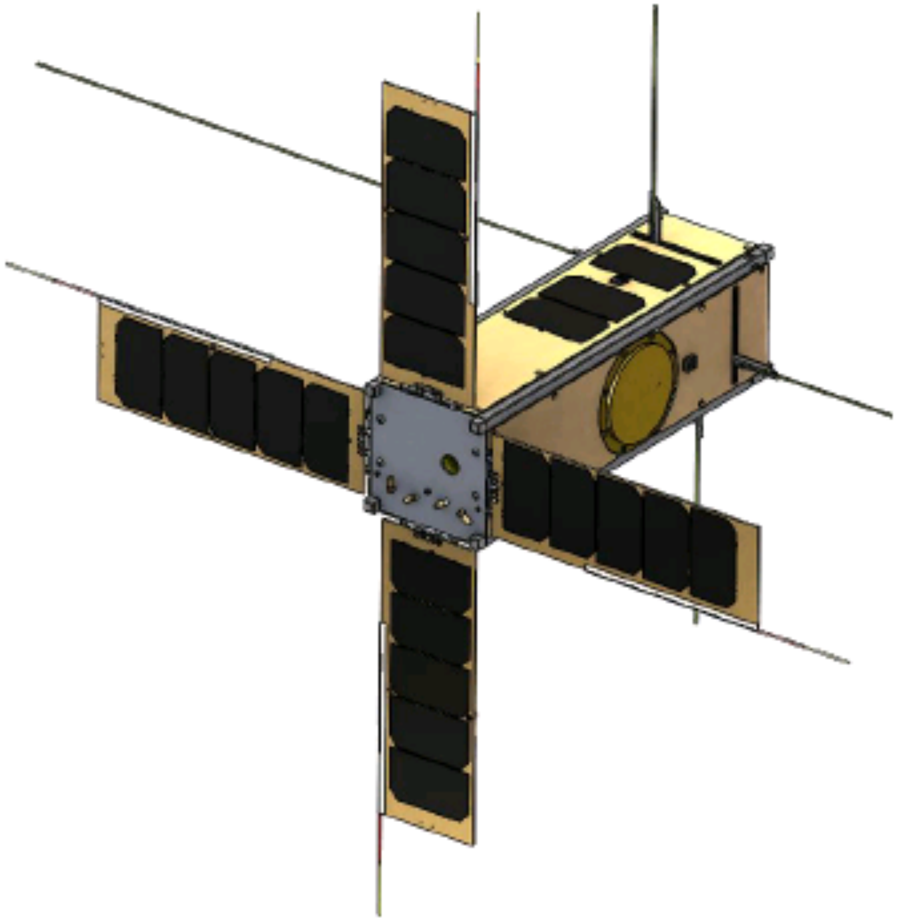
SPINE M23, 05/04/2017

Outline

- What is PICASSO?
- Objectives of SPIS simulations
- Presentation of work in progress:
  - Simulation assumptions and constraints
  - Preliminary results
- Encountered problems
- Conclusions & To Do

PICASSO spacecraft

- **PIC**osatellite for **A**tmospheric and **S**pace **S**cience **O**bservations (BIRA, VTT, Clyde Space, CSL)
  - Distribution of ozone in stratosphere
  - Profile of stratosphere temperature
  - Measure ionospheric electron density (Multi-needle Langmuir probe)



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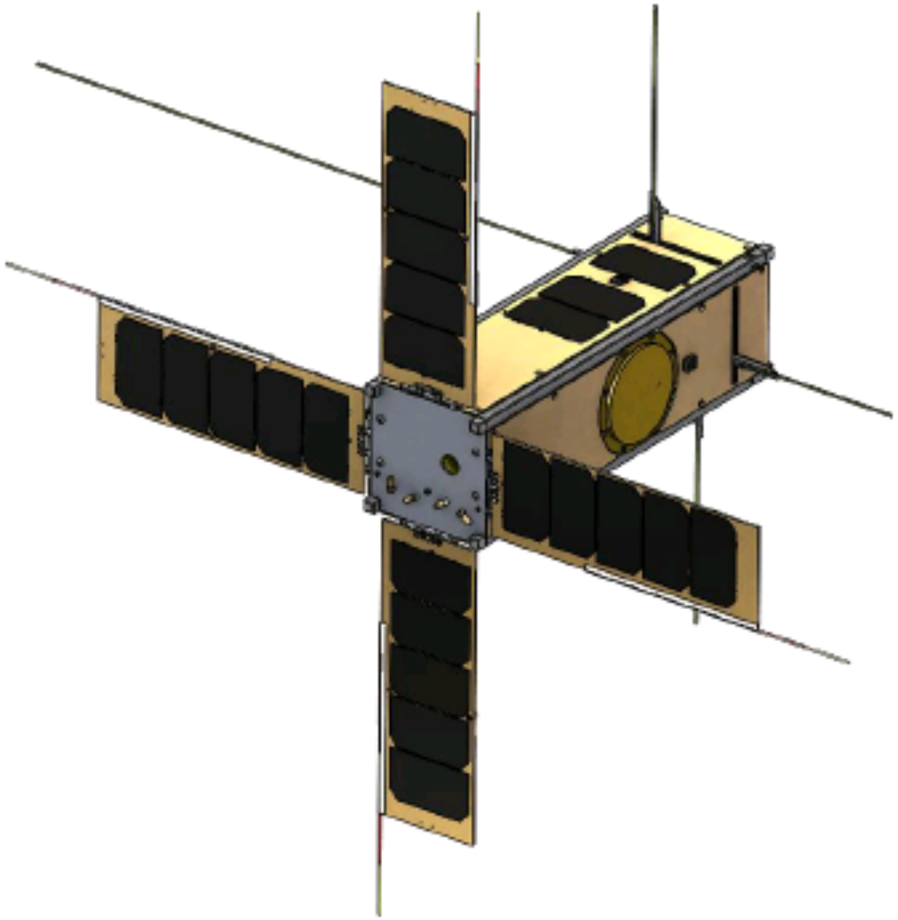
- Orbit
  - LEO: 500 (current baseline) - 700 km
  - High inclination: 98º→ Polar orbit crossing the auroral belts



Objectives: simulate PICASSO surface charging in SPIS

- PICASSO mission contraints:
  - Mesothermal regime ($v_e \gg v_{S/C} \gg v_i$) for a spacecraft with $v_{S/C} \approx 7000$ km/s (ram-wake effect)
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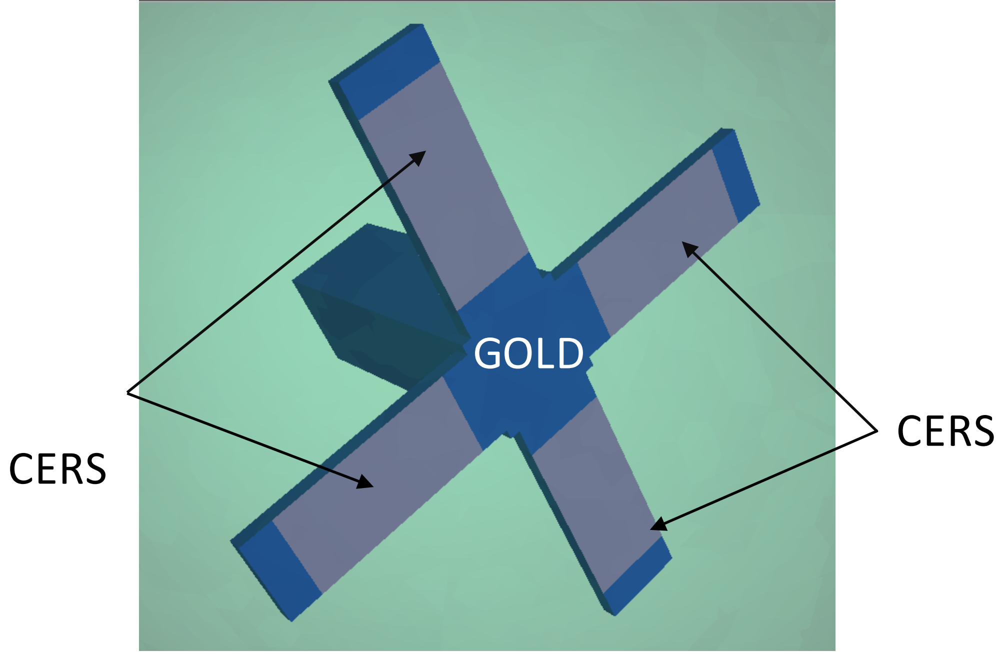
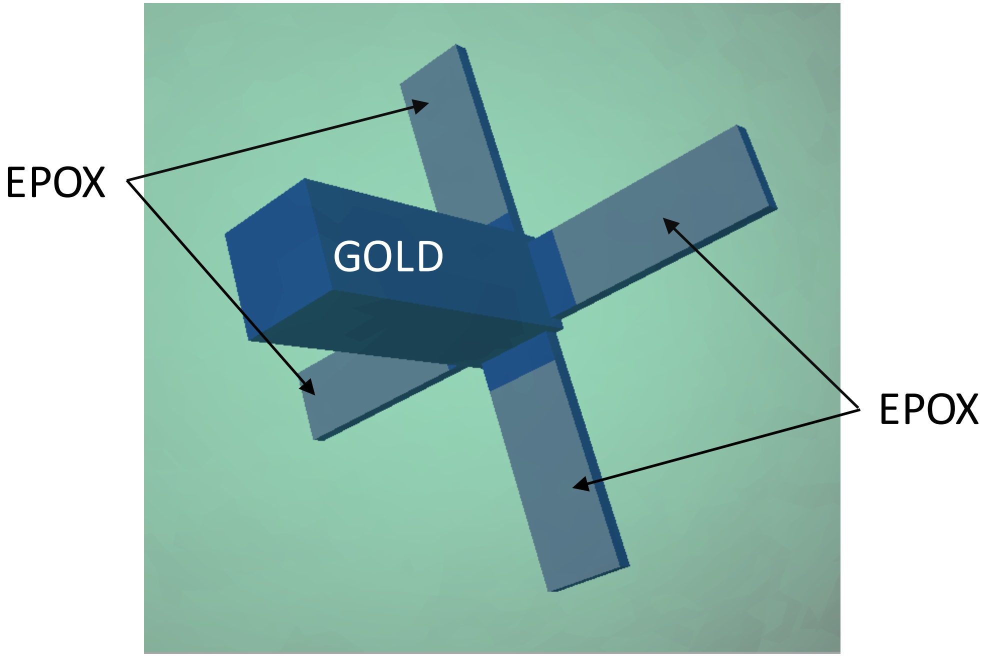
- 1) In the **LEO** ionospheric environment
  - Cold (0.2 eV) and dense (1×10^{10} m^{-3}) plasma
- 2) In an **auroral worst case** environment
  - Flux of precipitating high-energy electrons, depleted ambient plasma density

Geometry & surface materials

- 3U Cubesat
  - 0.3m x 0.1m x 0.1m
  - Material: GOLD
- 4 solar arrays (deployed)
  - 0.23m x 0.08m x 0.002m
  - Base material: GOLD
  - Solar cells material: CERS
  - Back of solar array material: EPOX (50µm)
- Use of a simple electric circuit
- Spacecraft orientation fixed in simulations:
  - CERS in ram surface
  - EPOX in wake surface





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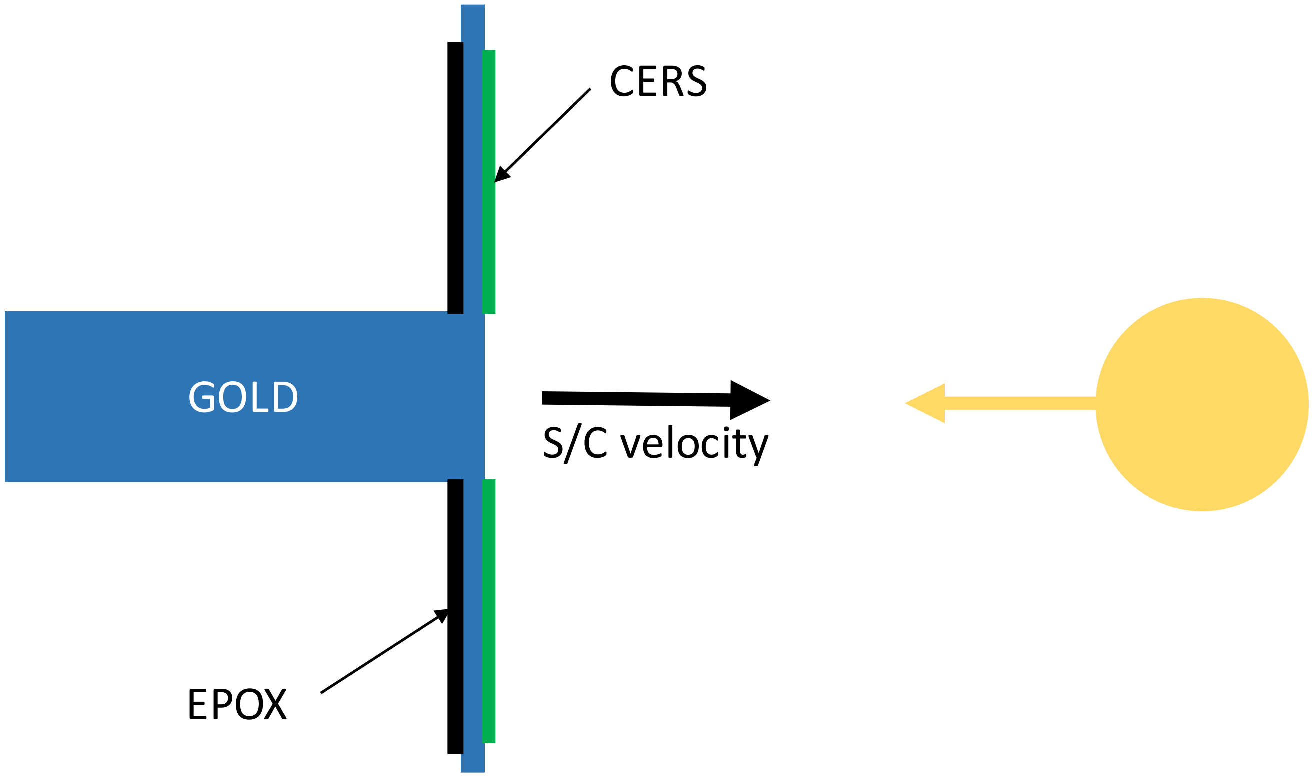
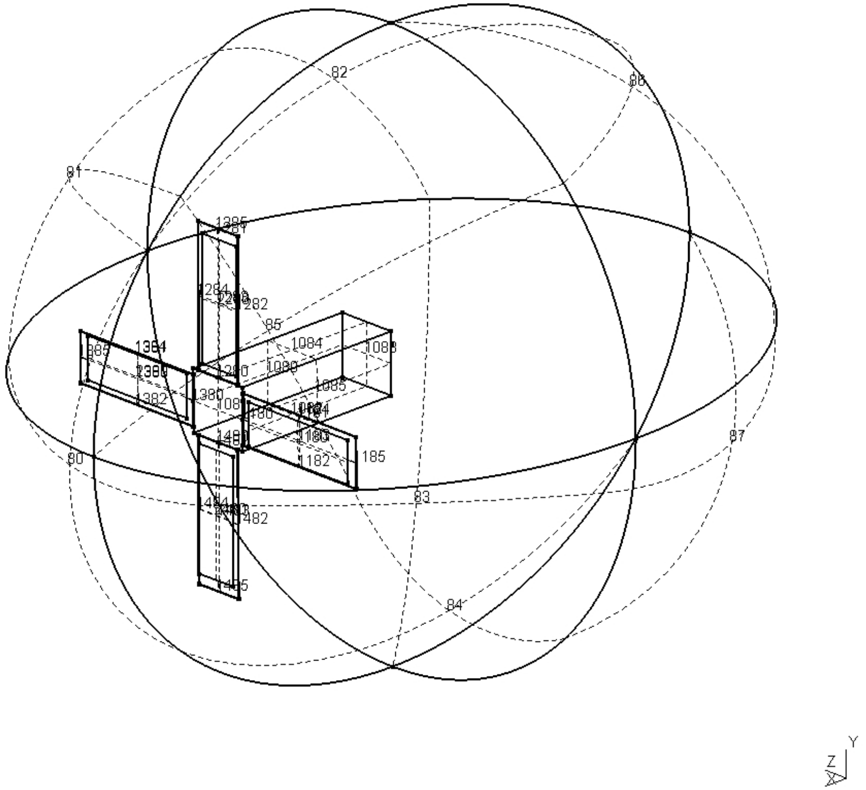


PICASSO simulations in LEO environment

- LEO ionospheric plasma

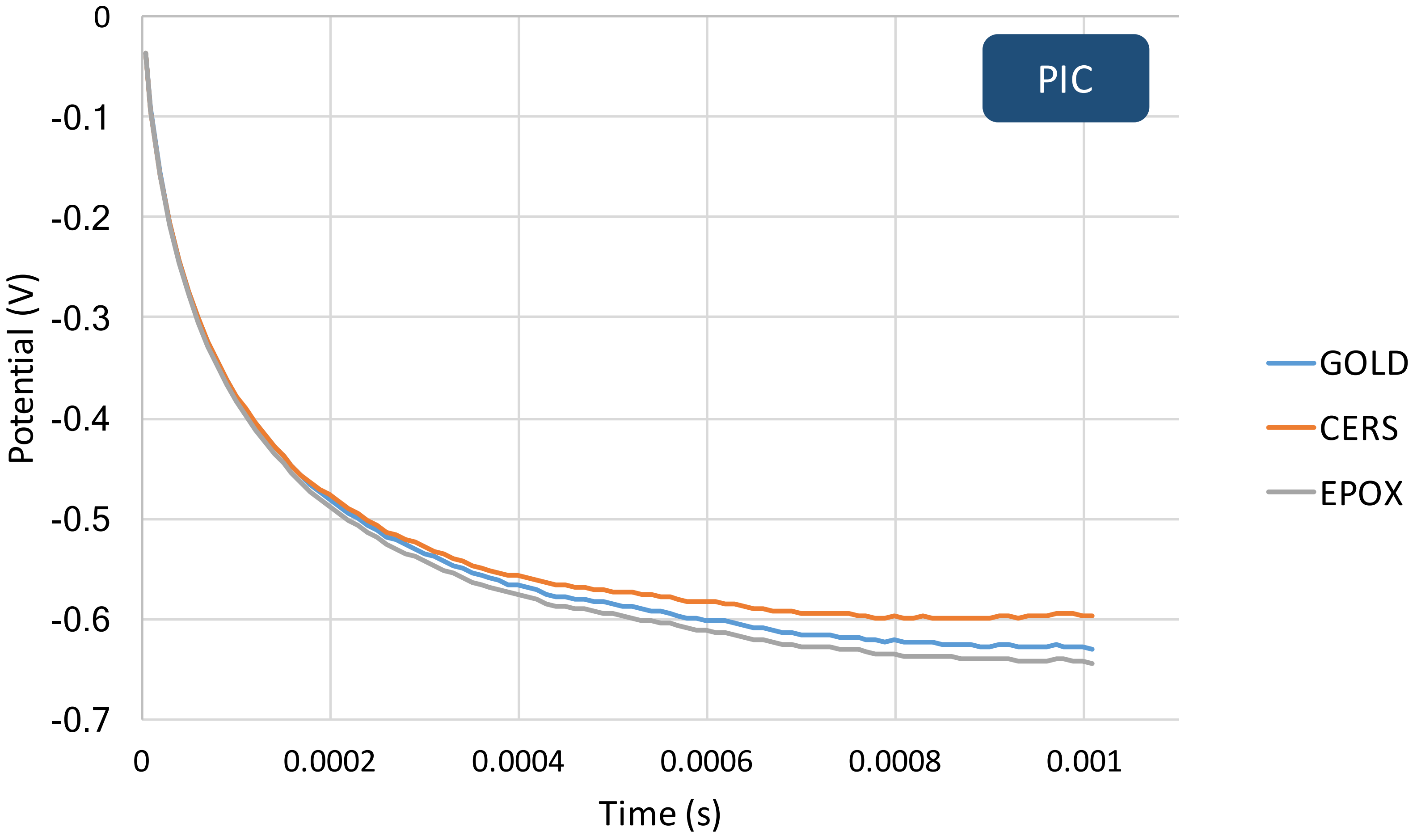
	electrons	ions (O^+)
Density (m^{-3})	$1x10^{10}$	$1x10^{10}$
Temperature (eV)	0.2	0.2
Drift velocity	0 km/s	-7500 km/s
Simulation method	Particle In Cell	Particle In Cell



- Short Debye length: $\lambda^2_D = \varepsilon_0 kT/e^2n \rightarrow 0.06$m, sheath around spacecraft
- Expected charging level $\propto$ kT

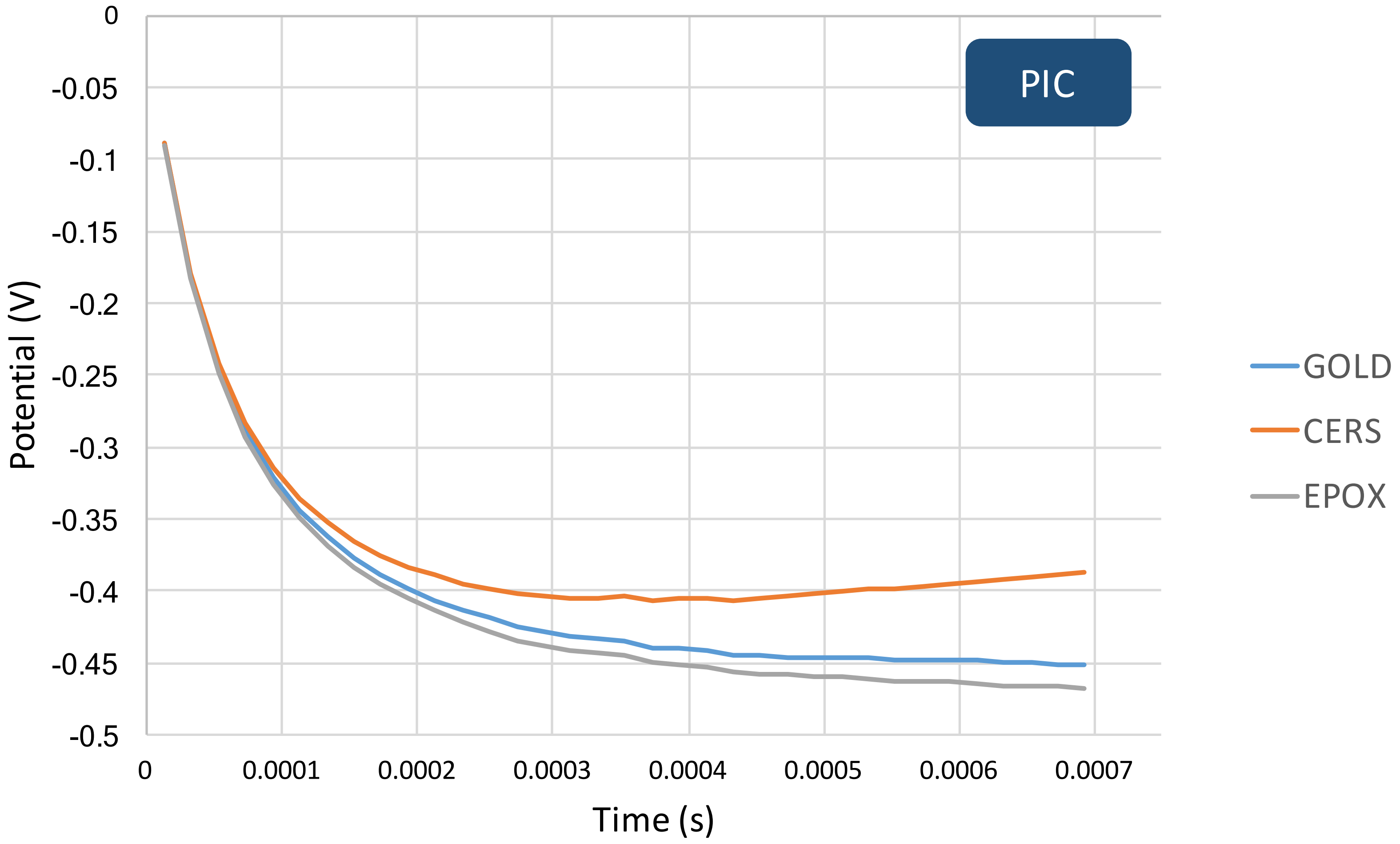
PICASSO in LEO environment

- Simulation in **eclipse**
- S/C body charging to ~ -0.65 V
- Very little differential charging between surfaces
- Results correspond to simulations using Maxwell-Boltzmann electron population



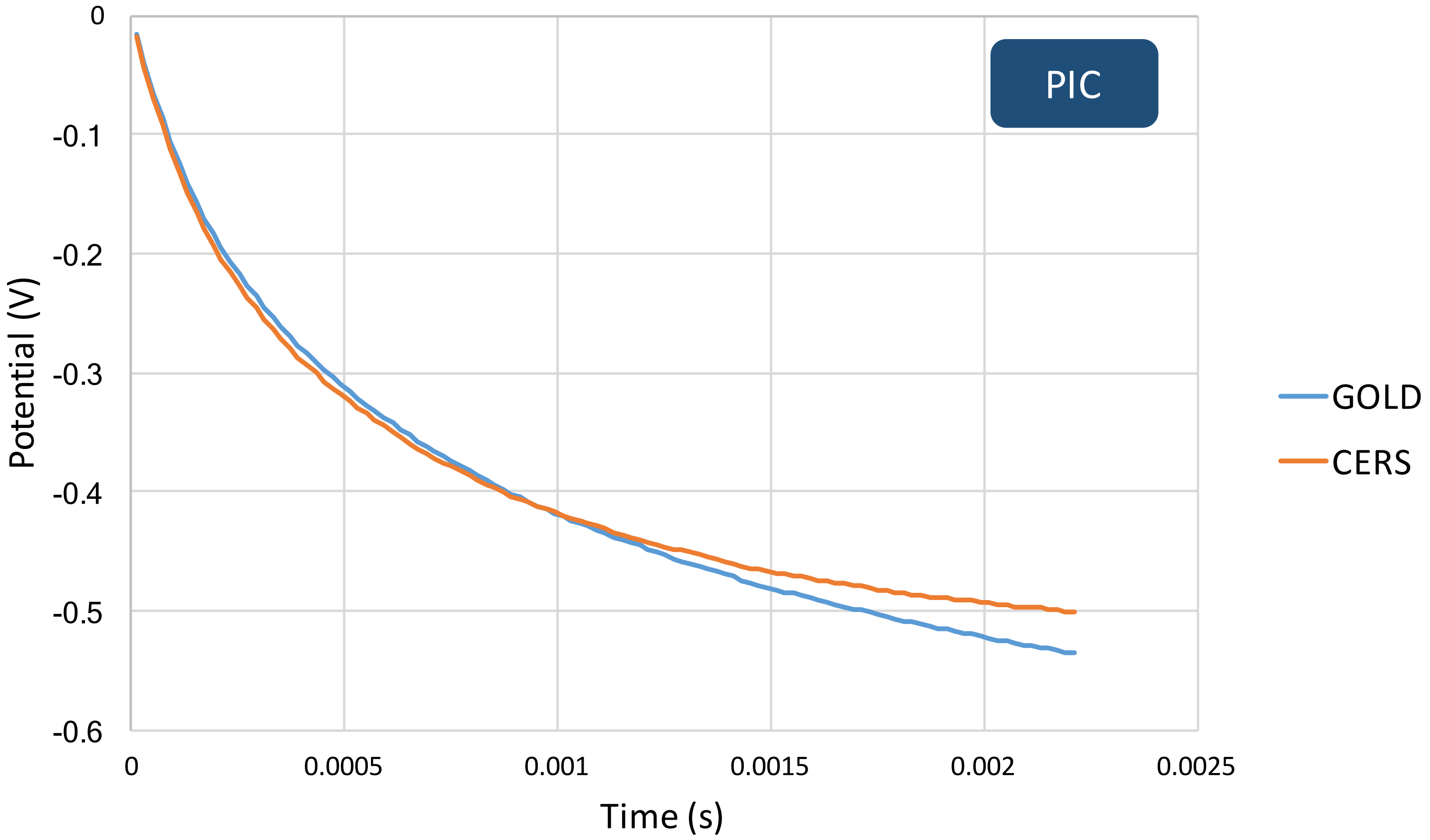
PICASSO in LEO enuironment

- Simulation in **sunlight**
- S/C body charging to ~ -0.45 V
- Little differential charging between gold and epoxy surfaces



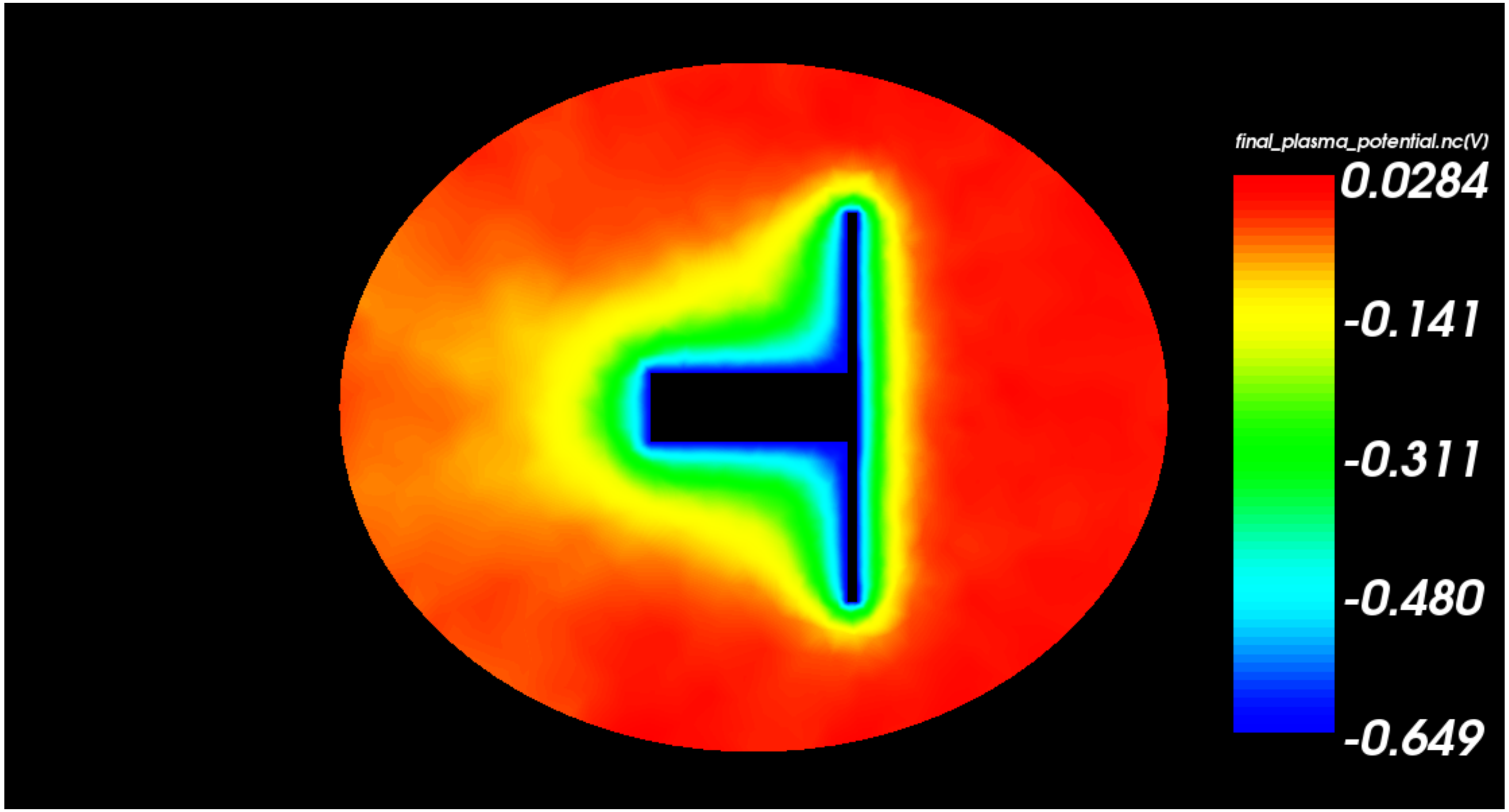
PICASSO in LEO environment

- Simulation with no epoxy layer on back of solar arrays
- Simulations indicate a comparable charging level as case with epoxy layer



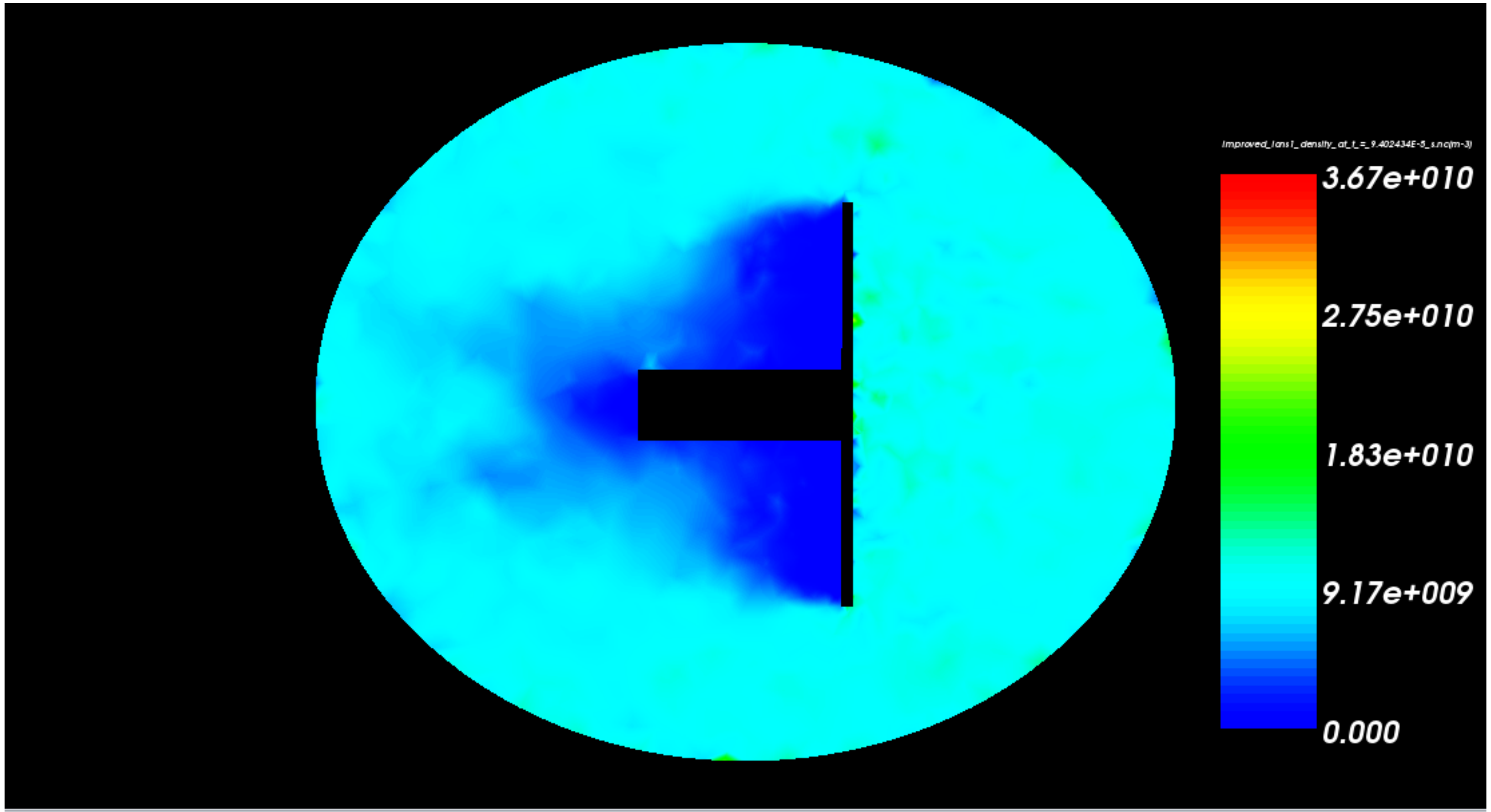
PICASSO in LEO environment

- Plasma potential cut in XY-plane



PICASSO in LEO environment

- Ion density cut in XY-plane: wake structure, almost no ions reach EPOX surface



PICASSO in auroral environment

- Spacecraft in LEO can charge up to high negative potential
- Criteria based on observations by DMSP spacecraft:
  - Ambient plasma density lower than 10^4 cm^{-3} (?)
  - High integral electron number flux (> 10^8 cm^2 s^{-1} sr^{-1}) for energetic electrons (> 14 keV)
  - Eclipse

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- This leads to the **ECSS** (-E-ST-10-04C) **worst case environment** distribution function

— For E ≤17,44 keV:

$$f(v) = 3{,}9 \times 10^{-18} \quad s^3 m^{-6}$$

— For E > 17,44:

$$f(v) = \frac{[N_0(m_e)^{3/2} \exp\{-(E - E_0)/kT_0\}]}{(2\pi kT_0)^{3/2}}$$

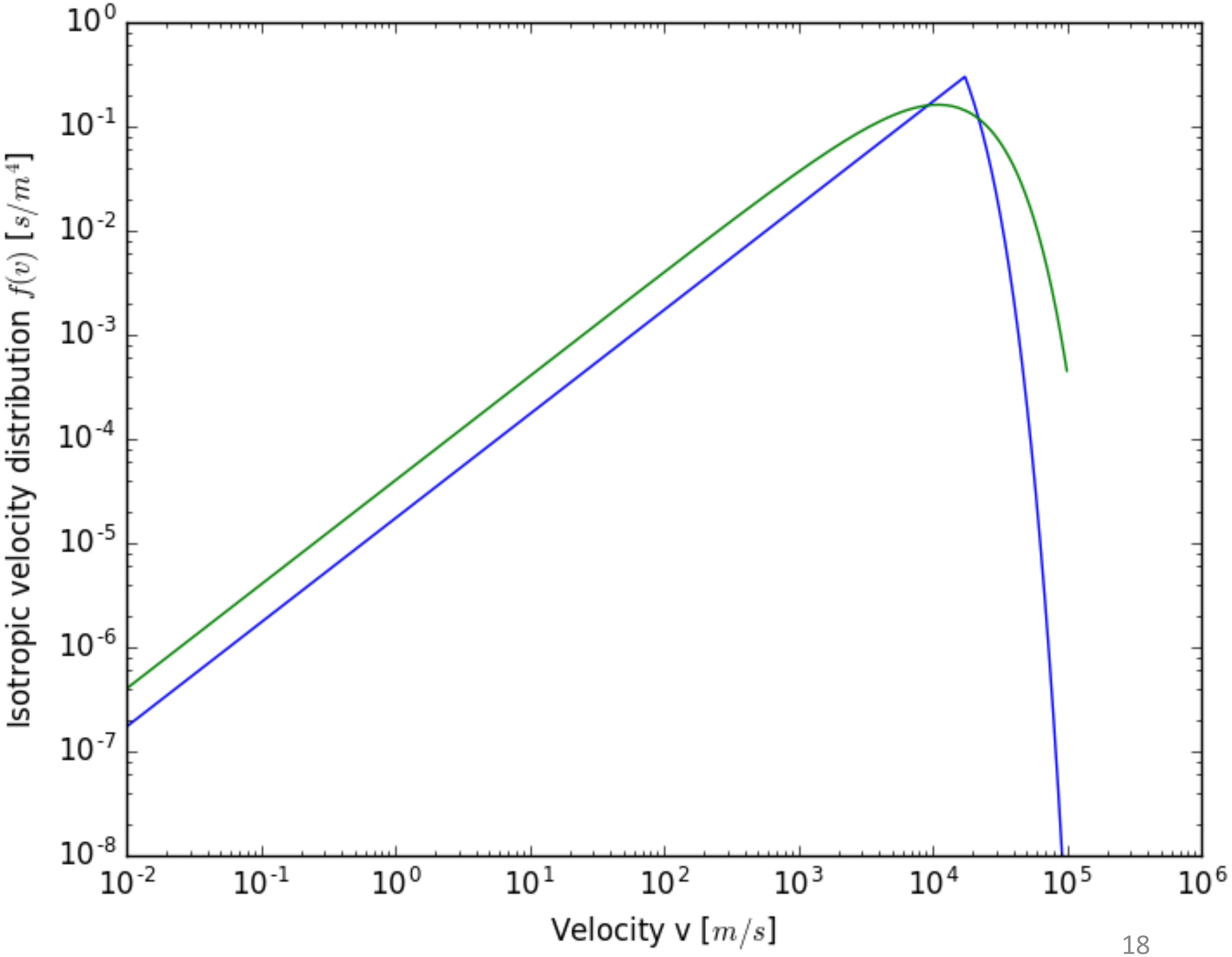
N_0 = 1,13E6 m^{-3}

kT_0 = 3,96 keV

E_0 = 17,44 keV

PICASSO in auroral environment

- Maxwellian fit[1] of ECSS distribution to allow for straightforward use in SPIS
  - N ~ $1*10^7$ m^{-3}
  - kT = 11 keV
- Allows for faster simulation times (electrons in Maxwell-Boltzmann, ions in PIC)
- Study effect of **background density**



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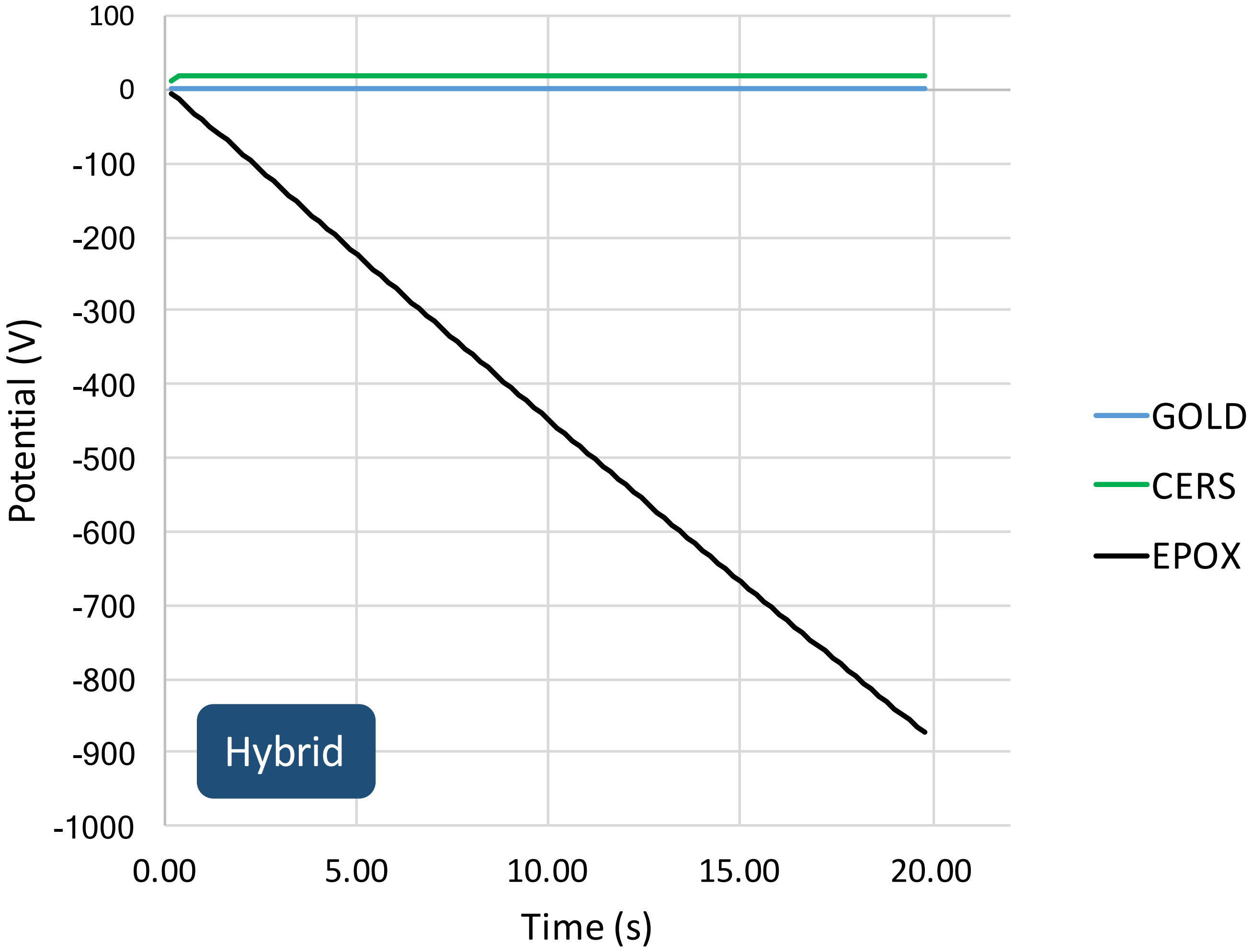
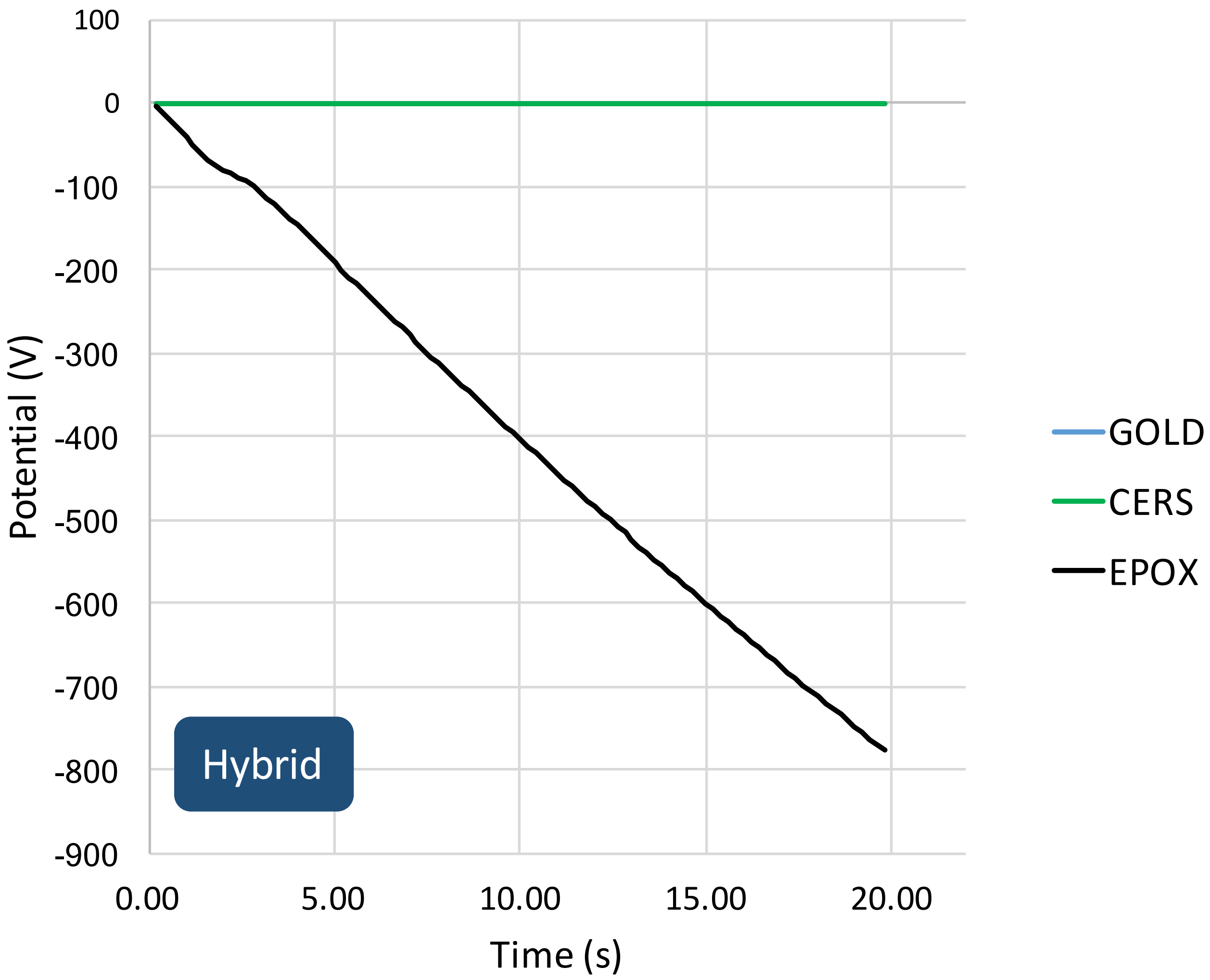
PICASSO in auroral environment



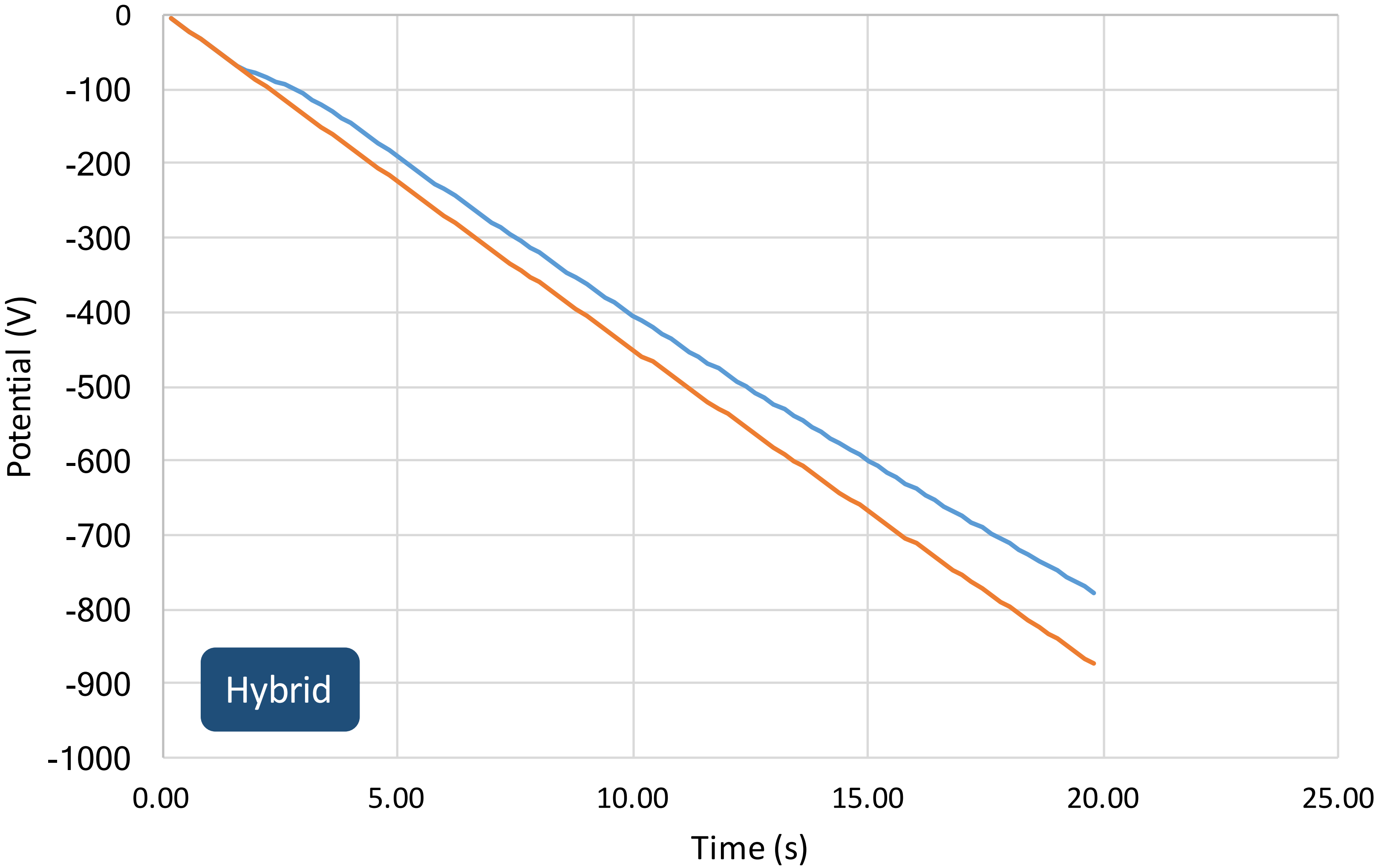
- Simulations using Maxwellian fit and background density of **1.25×10^8 m^{-3}** [ECSS]
- Gold and cover glass surfaces remain ~ 0V, Epoxy surface charges negatively to kV range

PICASSO in auroral enuironment



- Simulations using Maxwellian fit and background density of **$3x10^9$ m^{-3}**
- Gold and cover glass surfaces remain ~ 0V, Epoxy surface charges negatively to kV range

PICASSO in auroral environment

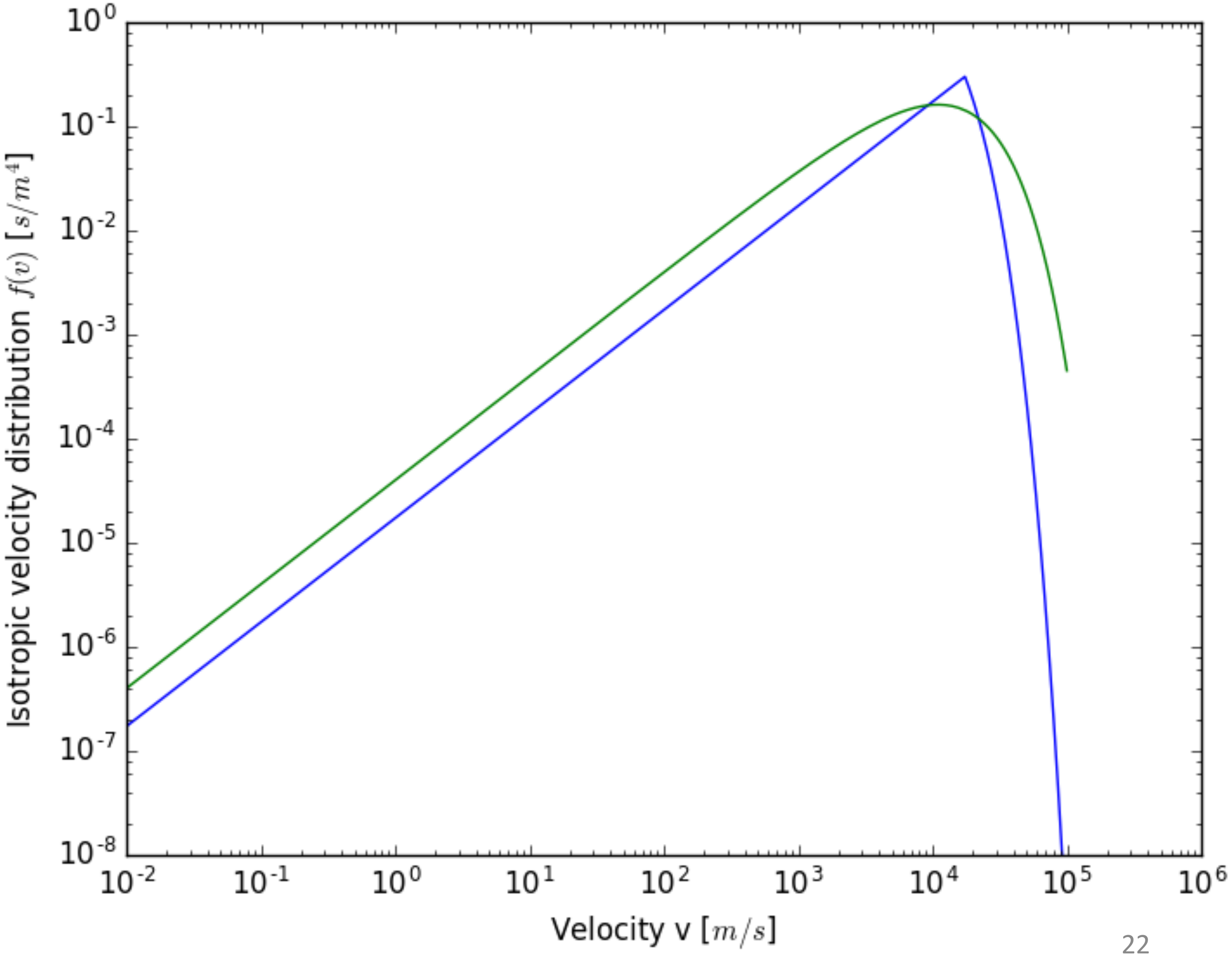


Epoxy surface charging levels with background plasma density:

- $N = 3 \times 10^9\ m^{-3}$
- $N = 1.25 \times 10^8\ m^{-3}$

PICASSO in auroral environment

- Maxwellian fit[1] of ECSS distribution to allow for straightforward use in SPIS
- → Use of **tabulated distribution function**
- Test feasibility of use in LEO/aurora simulations



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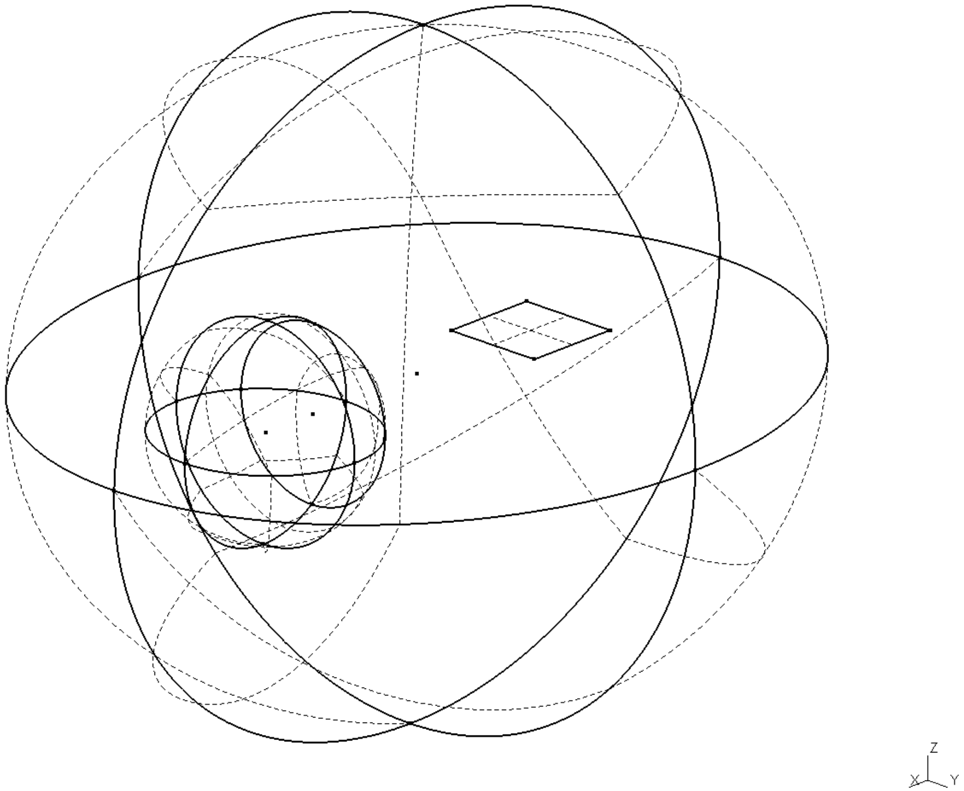
PICASSO in auroral environment

- Test to compare Maxwellian fit to actual ECSS distribution using virtual particle detector and spherical spacecraft geometry:

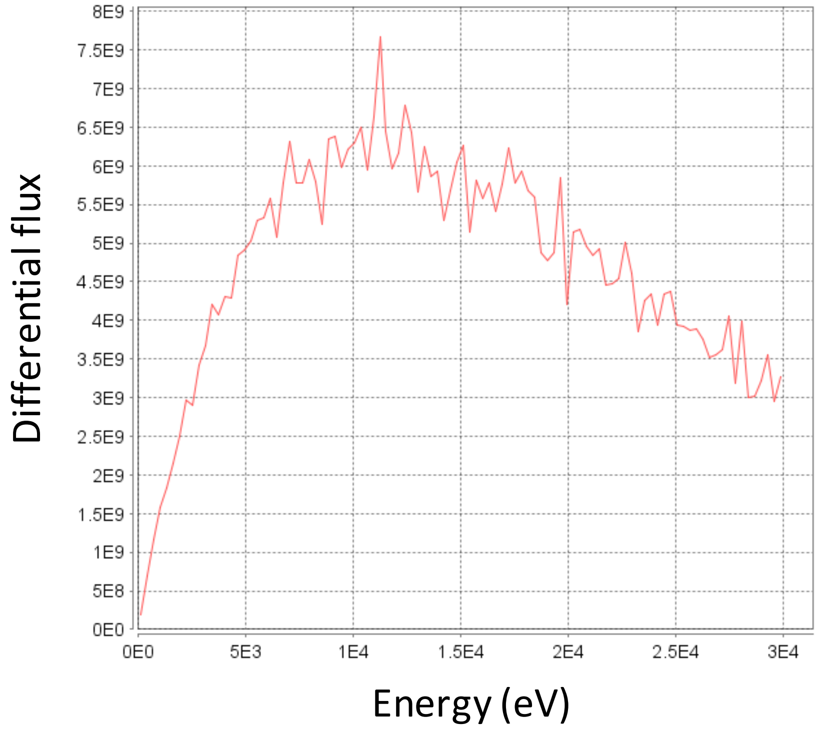
	Maxwellian fit	Tabulated DF
Temperature (eV)	11000	3960
Density (m^{-3})	1.231×10^7	1.13×10^6



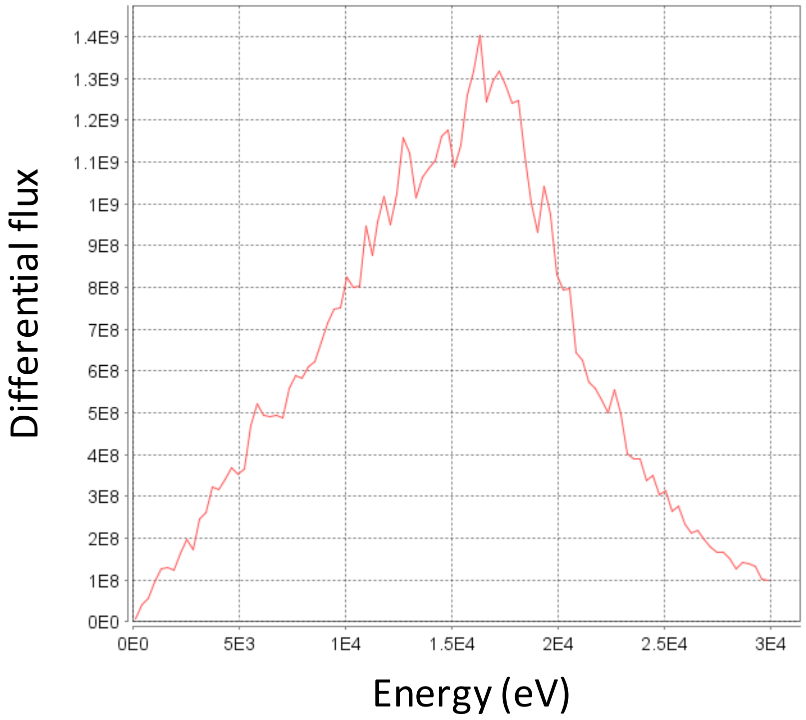
PICASSO in auroral enuironment

- Test to compare Maxwellian fit to actual ECSS distribution using virtual particle detector and spherical spacecraft geometry
- Differential flux measured in SPIS:

Maxwellian fit



Tabulated DF



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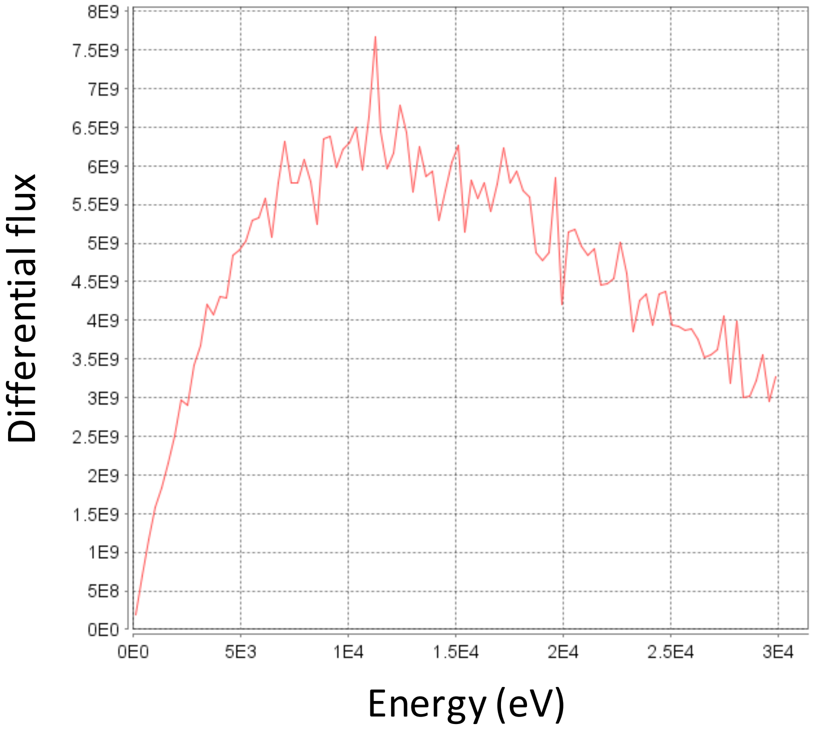

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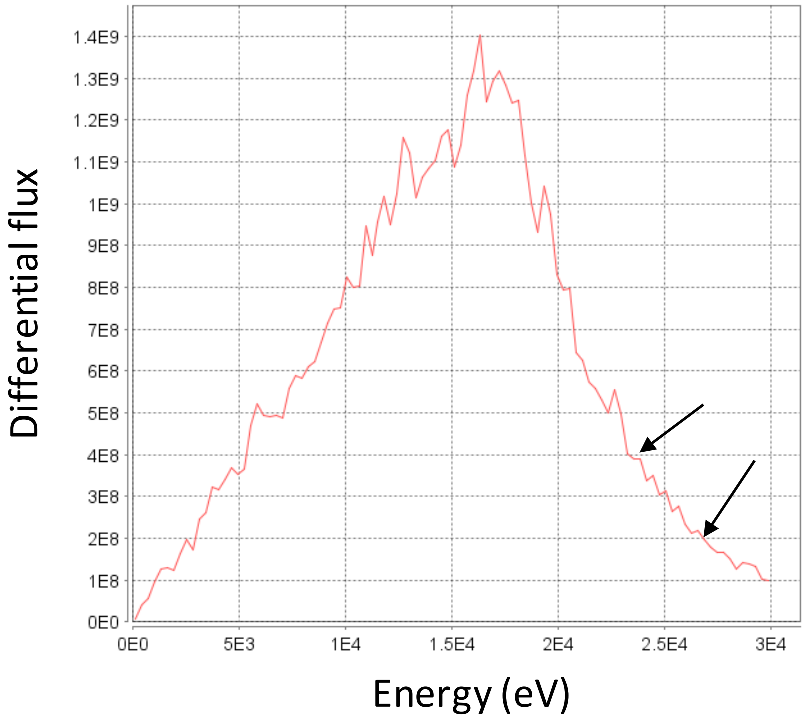
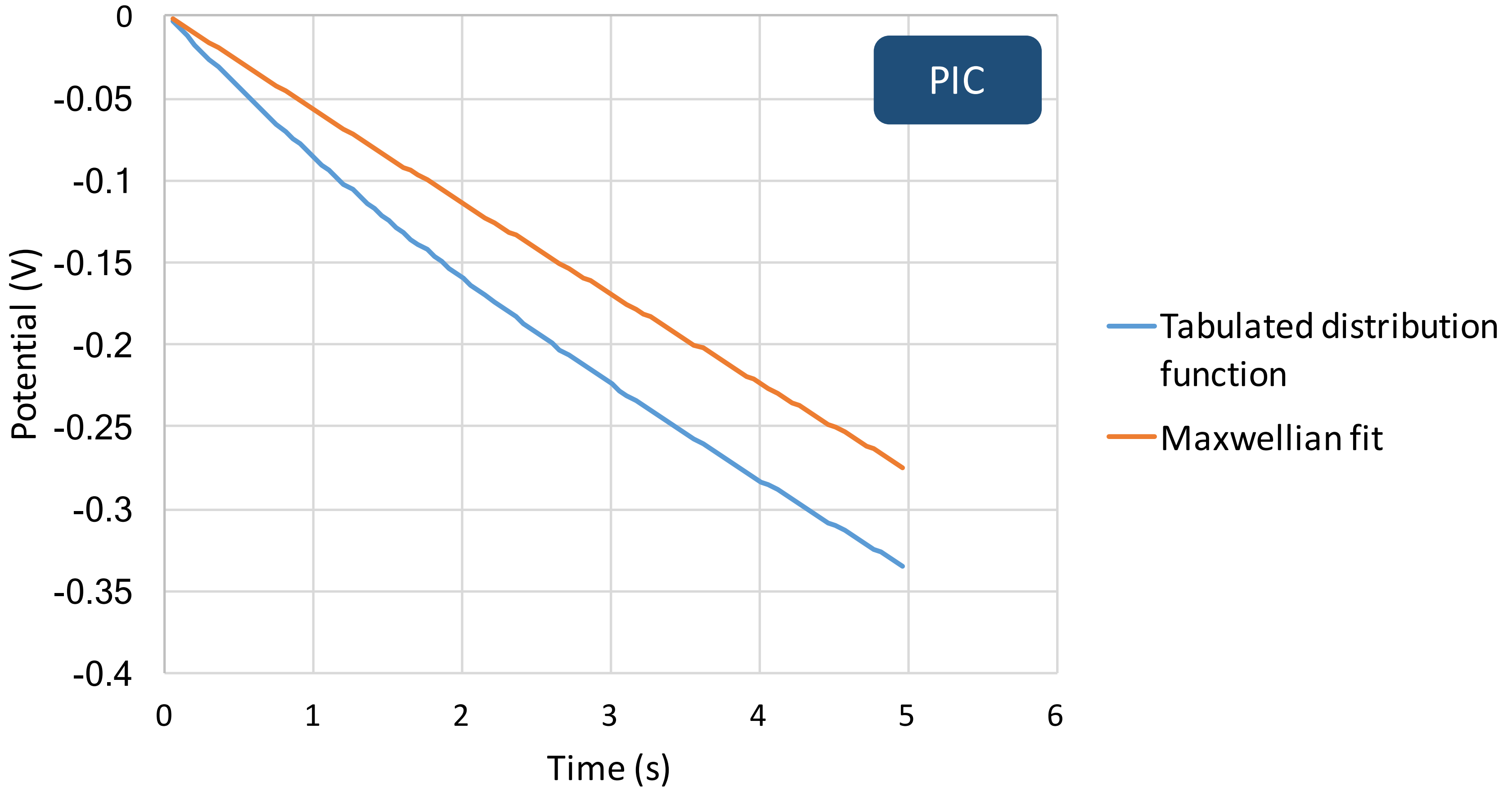


PICASSO in auroral environment

- Spacecraft charging level in SPIS, ambient plasma: $N = 3x10^9\ m^{-3}$ and $kT = 0.2$ eV in PIC



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- Mesh size requirements for CubeSat simulations: high resolution to resolve thin elements
- Validity limits of spacecraft capacitance setting: large numerical instabilities encountered

Conclusions & future work

- Expected charging levels for PICASSO in ionospheric plasma
- High negative charging possible for non-conductive surfaces (epoxy) in wake in auroral plasma

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- Solve simulation parameter issues!
- Study effect of background plasma in auroral environment
- Further testing of tabulated DF and analytical estimates for simple case (e.g. gold sphere)
- Test worst case ECSS on PICASSO geometry
  - including other S/C orientations
  - Use of a representative electrical circuit