SPIS-SCI validation studies for fields instruments

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SPIS simulations in support of plasma instruments for Cosmic Vision

A. Hilgers (ESA)	A review of spacecraft plasma interactions effects on plasma measurements
A. Masson (ESA)	Electron density measurements in the magnetotail with different instruments
M. Capacci (Laben)	Observation of SMART-1 plume plasma environment with the EPDP plasma diagnostic package and future activities
M. Capacci (Laben)	Charging active control: PLEGPAY experiment onboard ISS results; activities on future systems
D. Rodgers (ESA)	Plasma measurements onboard CHAMP spacecraft
H. Laakso (ESA)	Observation of spacecraft plasma interactions with Cluster
D. Kataria (MSSL)	Spacecraft-plasma interactions: an MSSL perspective
A. Eriksson (IRFU)	Cold plasma and electric field measurements in the Jovian system: possibilities and challenges
A. Hilgers (ESA)	Modelling of plasma environment of Cluster electrostatic sensors
A. Eriksson (IRFU)	Wakes in cold tenous plasmas: nuisance and blessing
S. Clucas (ESA)	MMS electrostatic environment simulation
D. Rodgers (ESA)	Champ and Swarm plasma environment modelling

E-field instruments & Langmuir probes

- Rely on electric coupling to plasma, sensitive to s/c-plasma issues
- Asymmetric antenna or s/c configuration
- Photoelectron clouds and currents
- Secondary emission currents
- Wake potential, asymmetric shielding

Example missions

- Some missions needing instrument simulations:
  - In space: Rosetta, Cassini, Cluster, THEMIS
  - Upcoming: Swarm, BepiColombo, MMS
  - Design phase: JUICE, Solar Orbiter, SP+
- In most cases, wide ranges of plasma parameters are encountered
  - Example: Debye lengths for Rosetta vary from a fraction of a mm (fully developed inner coma) to tens of meters (tenuous solar wind at 3 AU)
  - No single simulation setup can cover all this with just a change of parameter values
- Some include thin (mm) and long (tens of m) wire booms challenging to model
  - Cluster, THEMIS, MMS, BepiColombo MMO

SPIS-SCI developments

- Many important improvements for science users, for example:
  - Backtracking. Current to small areas (sensors) on big s/c can be measured at good accuracy without excessive number of particles.
  - Particle instruments and Langmuir probes. Possible to define detailed geometry, backtrack currents and step bias potential.
  - Photoemitting thin wires. Enables realistic modeling of influence on probes from nearby elements.
  - Parallellized particle pushing.

SPIS-SCI validation aims (field instruments)

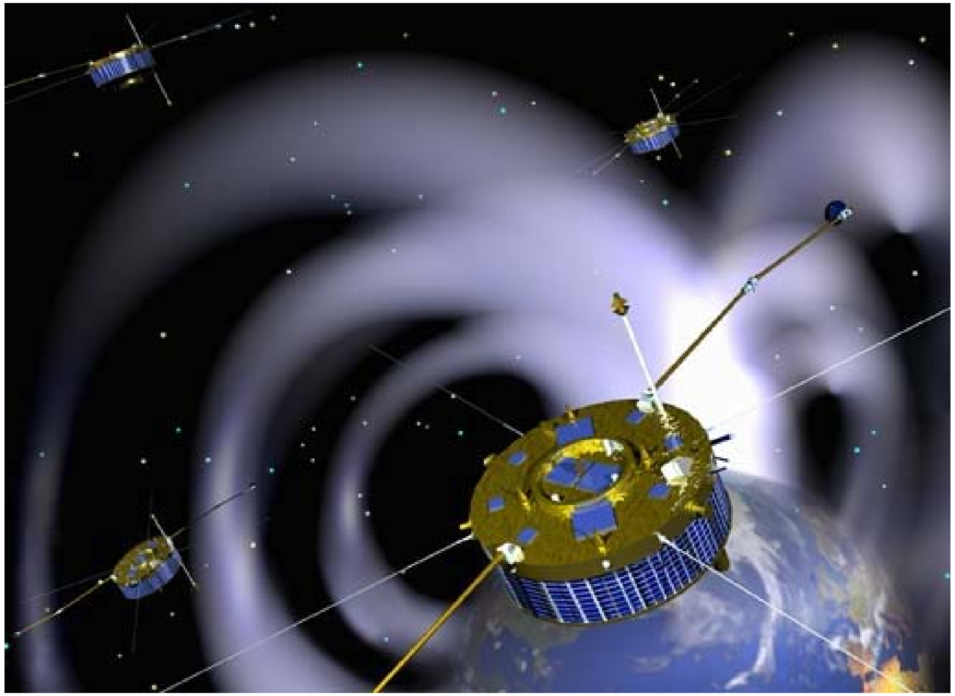
- Verify SPIS-SCI can be used for studying performance of E-field instruments and Langmuir probes
- Comparisons where possible:
  - Simplified analytical expressions
  - Other simulation results
  - Data

Cluster, THEMIS, MMS, Bepi MMO

- Missions with long wire boom electric fields
- Problematic to simulate in old SPIS
  - Particularly including photoemission
- SPIS simulations by Prakash (2007)
- Problem:
  - Large scale size disparity (mm to hundreds of m)
  - Simulation box needs to be hundreds of meters
  - Enormous number of particles needed in strict PIC approach to get reasonable number of particles to a small probe
- SPIS-SCI: Backtracking solves scale disparity issue
- SPIS-SCI also allows photoemitting thin wires, which also can be used as Langmuir probes

Cluster wire boom E-field instrument

- Cluster: 4 ESA s/c in orbit since 2000
- ≈2 x 20 RE
- Wire booms 88 m tip2tip



Cluster E-field features to study

- Sunward offset
  - Always in double probe instruments in tenuous plasmas
  - Around 1 mV/m on Cluster
  - Attributed to asymmetric photoemission
  - First simulated by Cully et al (2007)
- Enhanced wake
  - Ion flow diverted by strongly positive s/c in tenuous plasma
  - Can give signatures of up to 10 mV/m in data
  - First simulated by Engwall et al (2006)
  - No previous simulation includes the probes themselves

Biased elements

- Fig from Cully et al, JGR 2007
- Potentials:
  - Probe at Vp, about 1 V positive to <u>local</u> plasma
  - Thin wire at Vp
  - Guard at Vp – 6 V
  - Puck at Vp + 1.3 V
  - Boom at Vsc

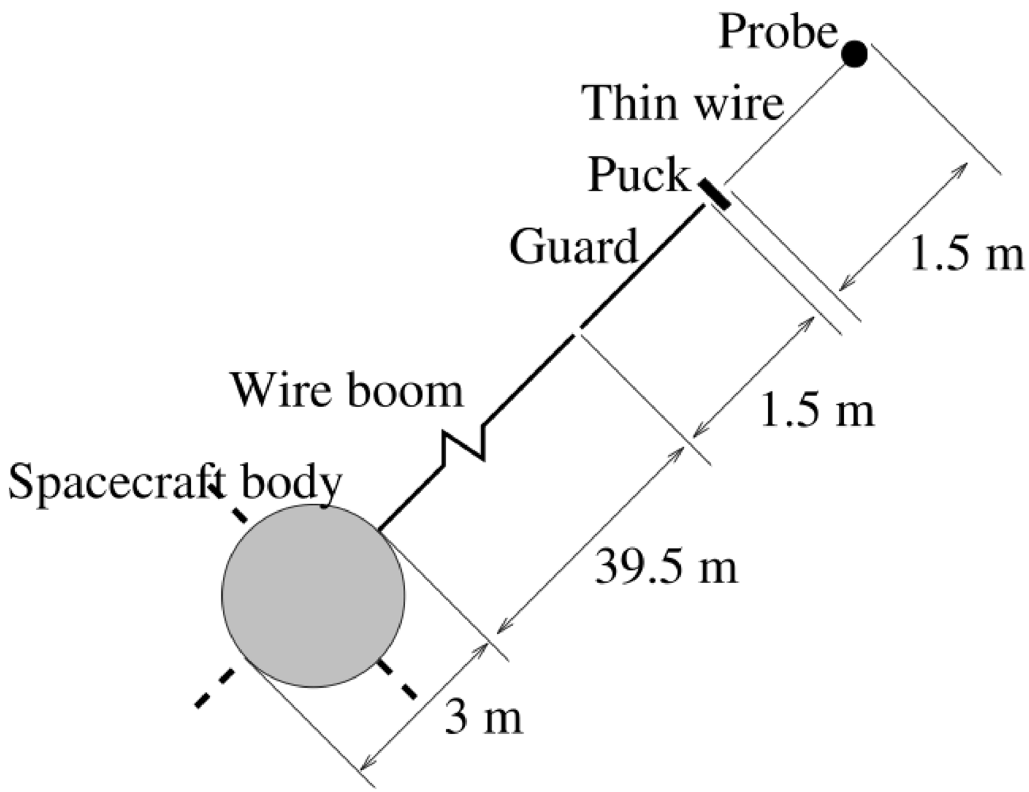
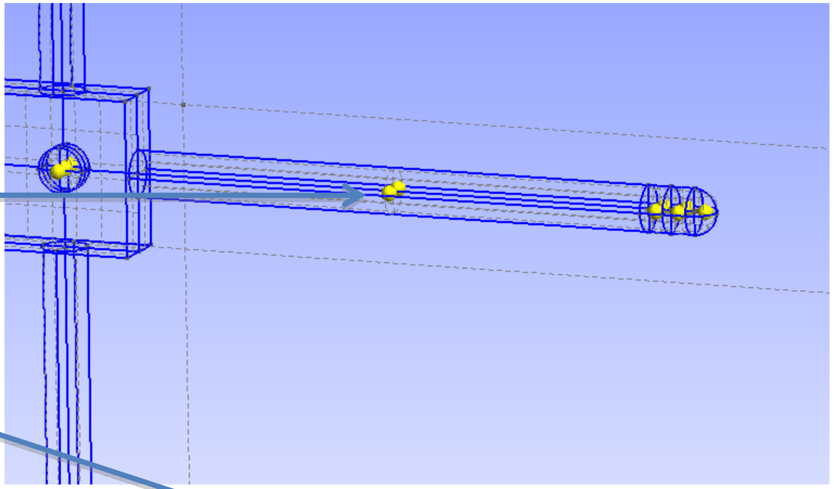
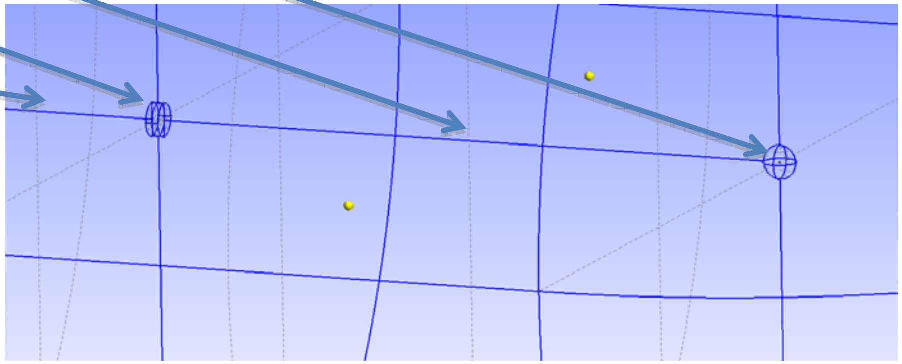


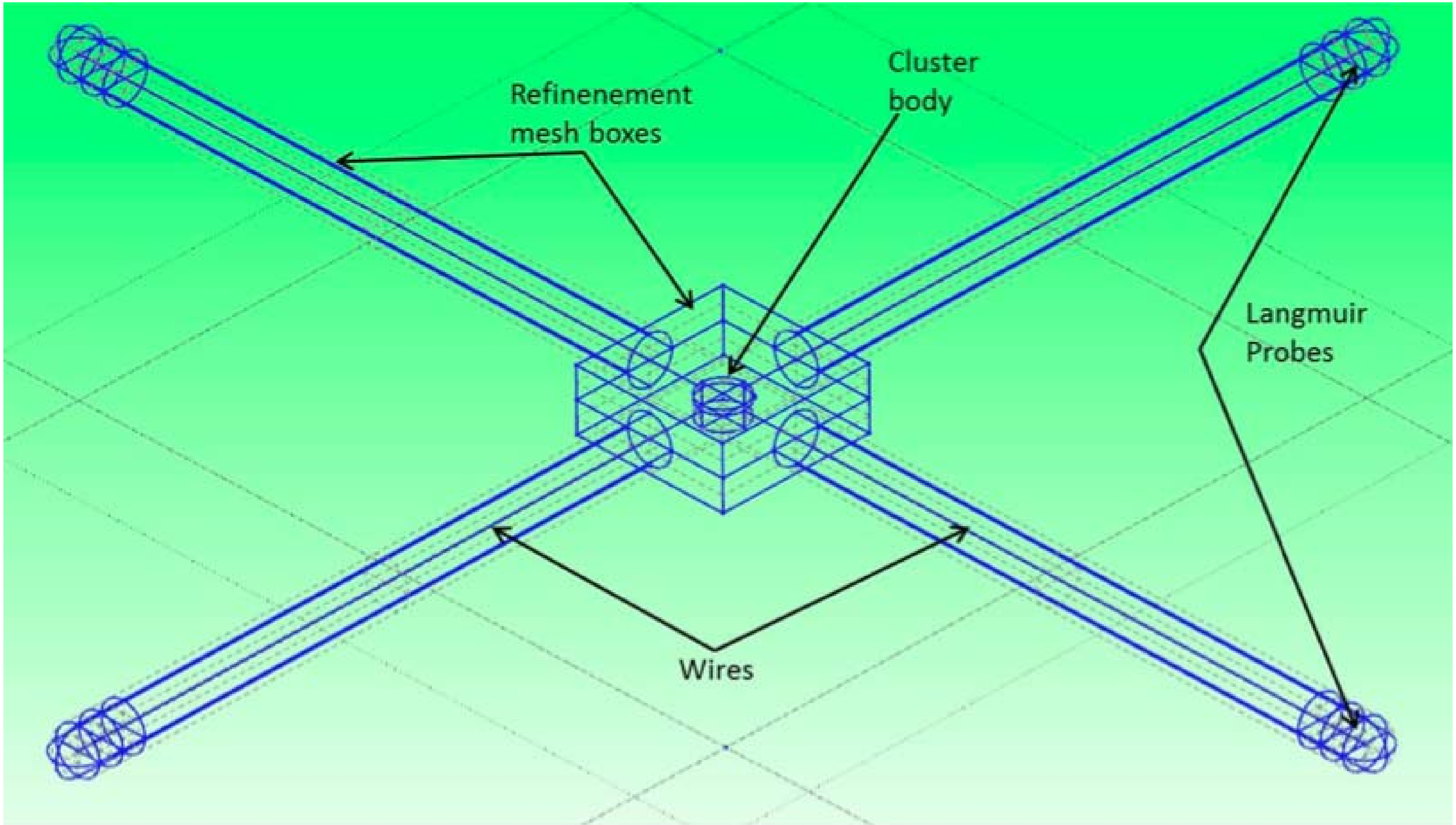
Figure 1. Geometry of the Cluster spacecraft and the EFW wire booms. There are four distinct electrical elements: (1) the spacecraft and wire booms, at a potential determined by the current balance in the plasma (but specified as a parameter in the simulation); (2) the guard, normally biased to 6 V below the probe; (3) the roughly cylindrical puck (preamplifier enclosure) (diameter of 8 cm and length of 3 cm), normally biased to 1 V above the probe; and (4) the thin (0.3 mm radius) wire and the probe, connected with a constant bias current to the spacecraft. The probe is a sphere with a diameter of 8 cm, and the wire radius (including the guard) is 1.1 mm.

SPIS CAD model

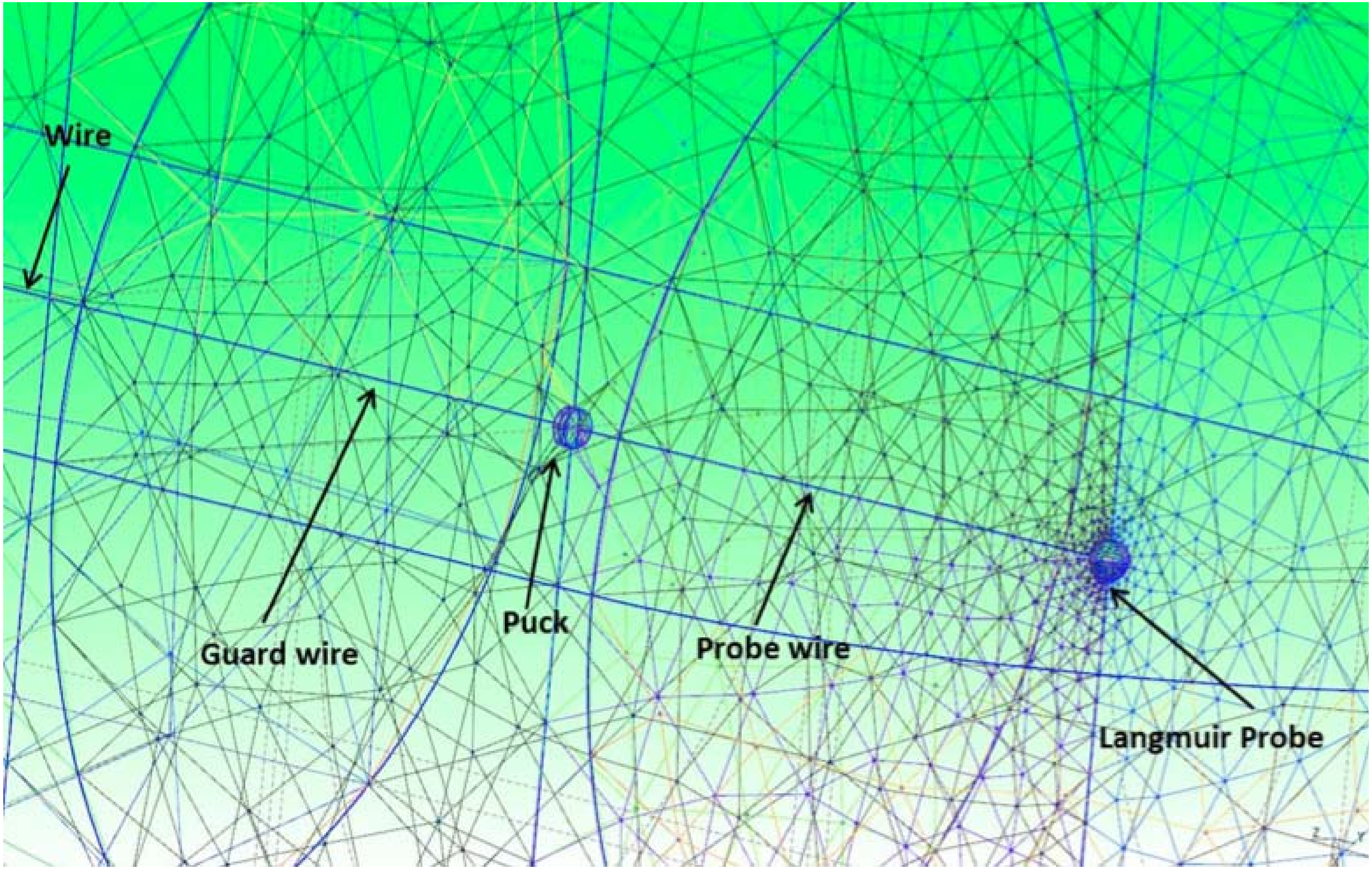
- Biased elements
  - boom (Vsc)
  - sphere (Vp)
  - thin wire (Vp)
  - puck (Vp + 1.3 V)
  - guard (Vp – 6 V)
- Need to simulate all four probes
- Very demanding simulation case





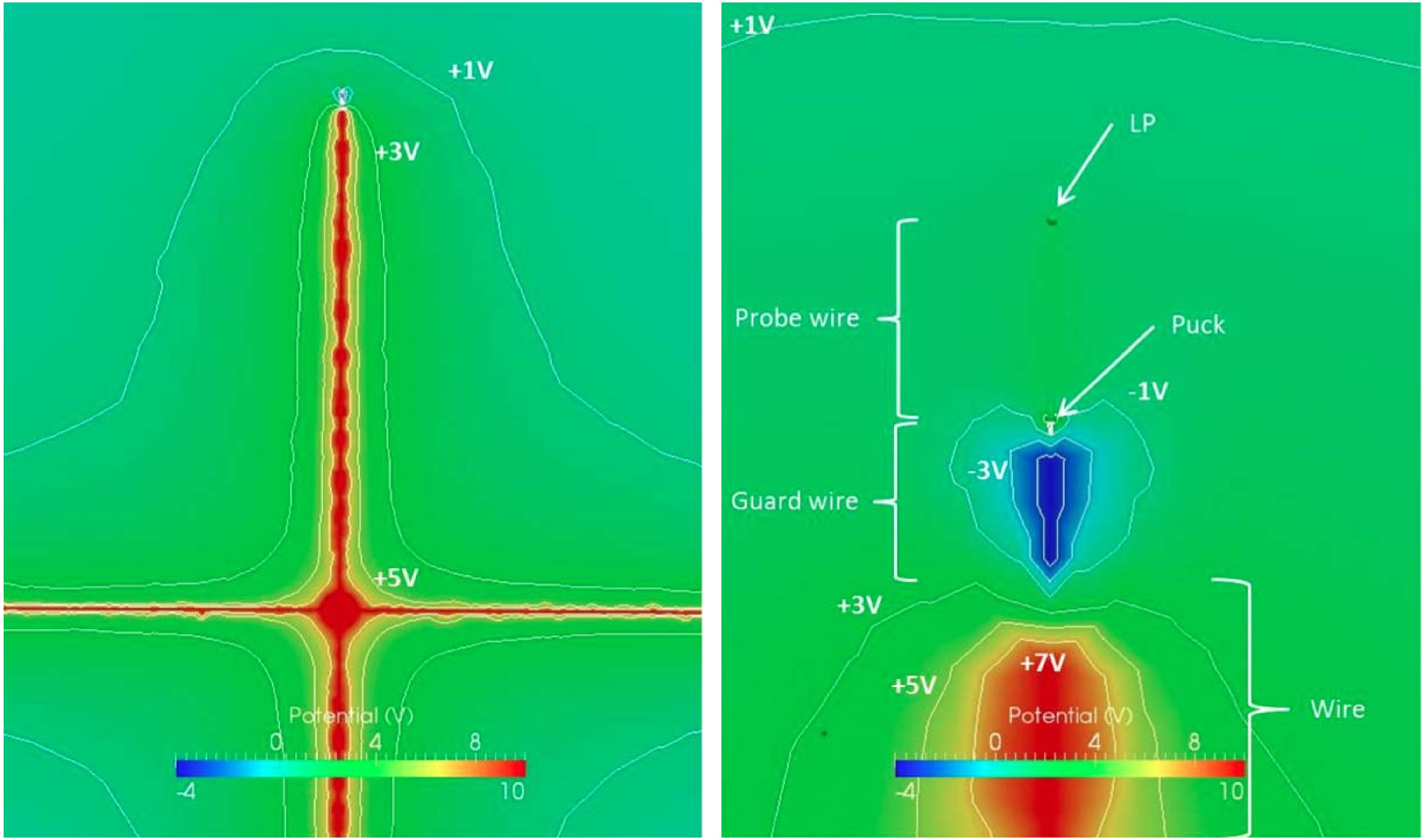


Cluster geometric model: large scale



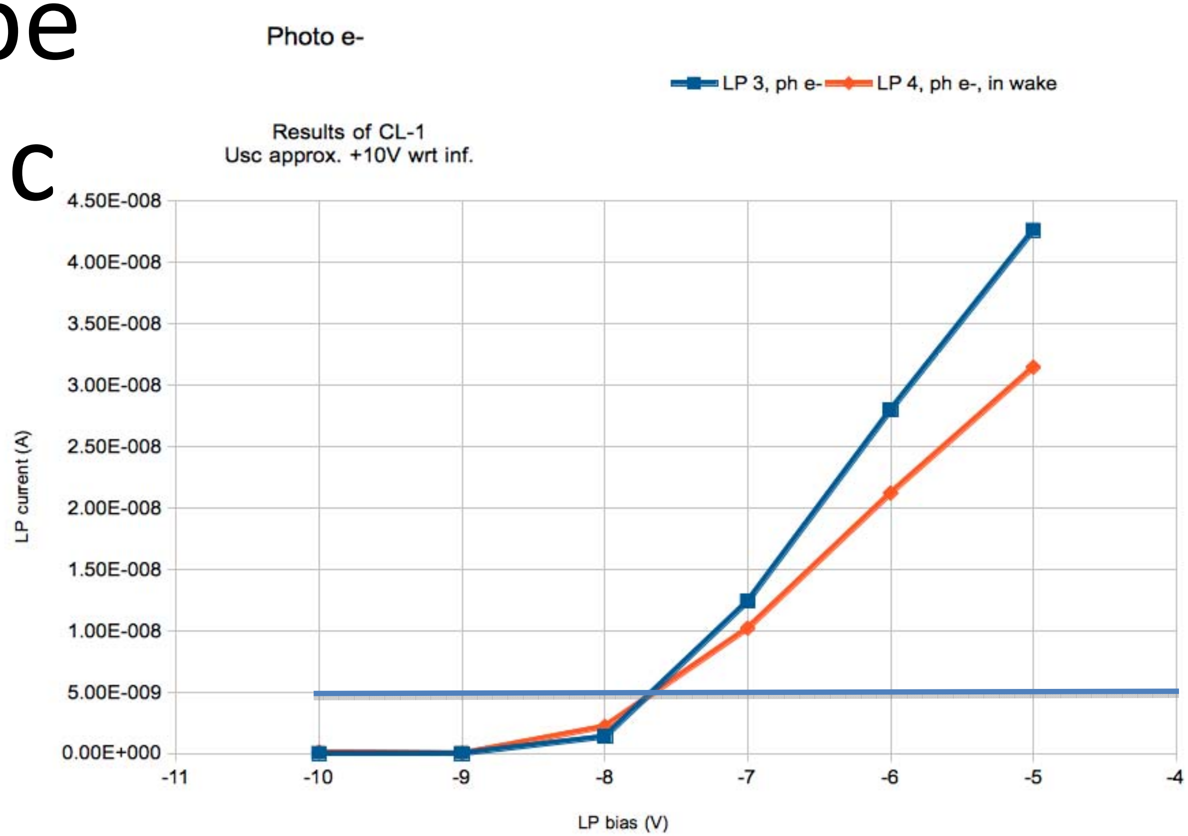
Cluster geometric model: details of mesh around probe

Cluster in solar wind (Vsc 10 V)

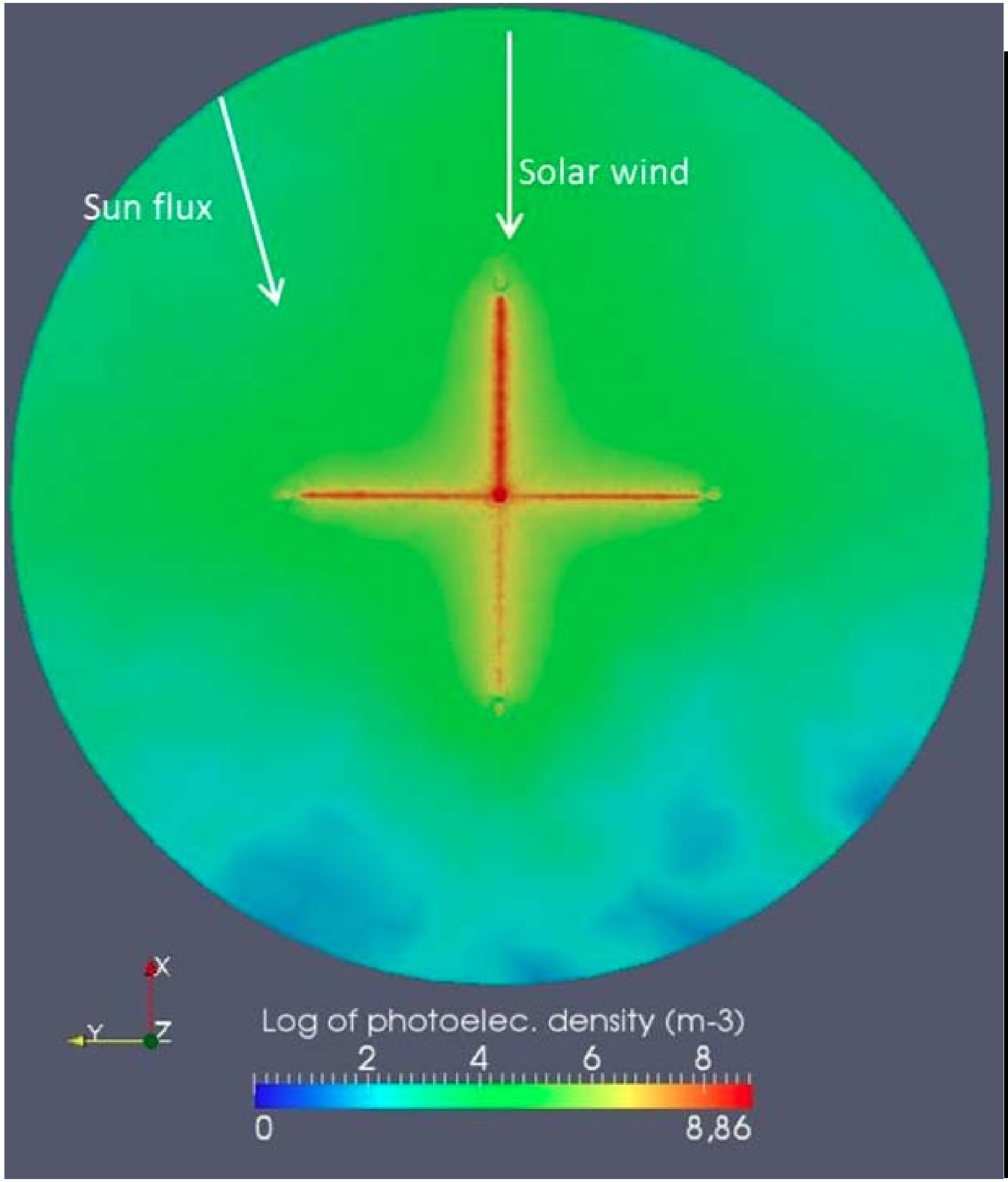


SPIS-SCI probe characteristic

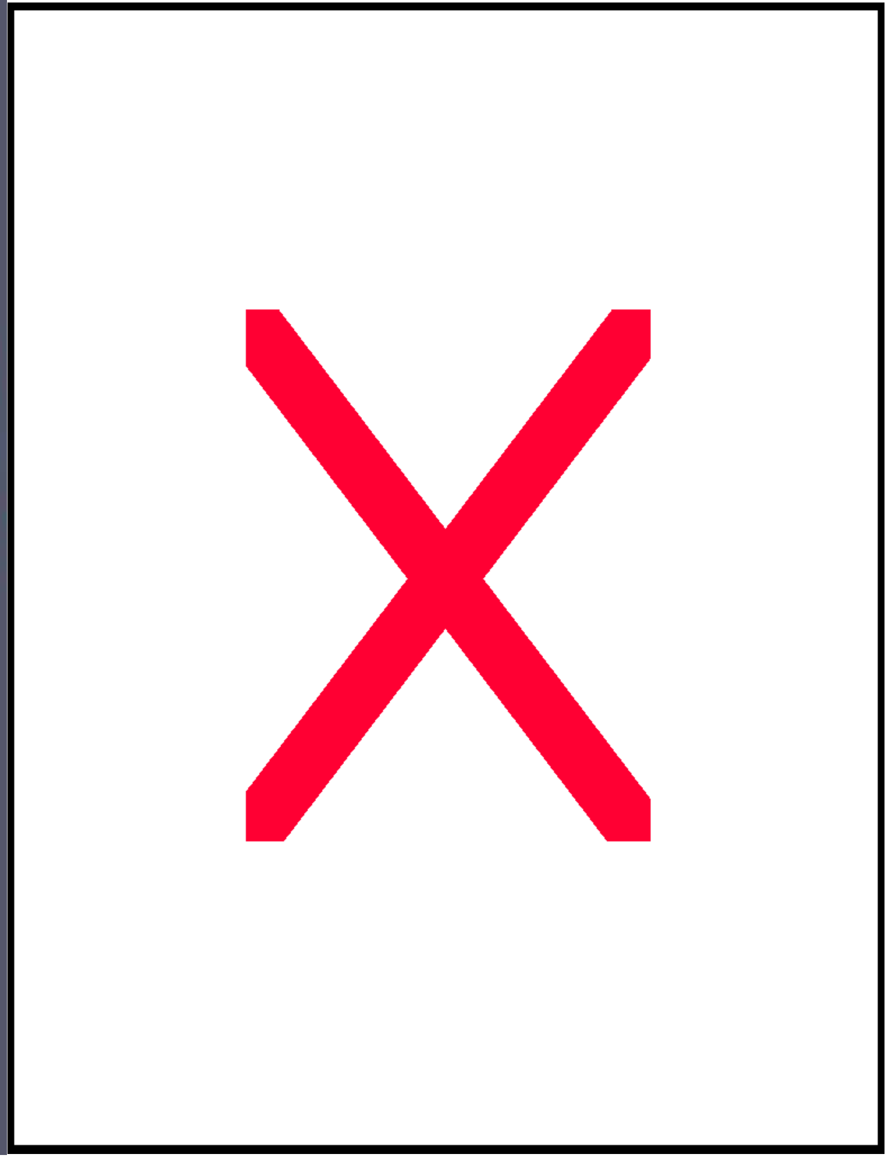
- Simulated for tv opposing probe (sunward-antisunward)
- Tenuous solar v plasma
- Horizontal shift at given (bias) current gives sunward offset



- Possible to study performance as function of environment, spin phase, UV flux...
  - Will require lots of CPU time, but is now possible



Guillemant/Nilsson SPIS-SCI simulation (Vsc = 10 V)



Cully et al (2007) (Vsc = 25 V)

What does this mean?

- Could be done before:
  - SPIS: Simulate potential pattern neglecting influence of thin wire photoemission
  - Cully vacuum code: Instrument performance in long Debye lengths
  - Miyake et al PIC code: Instrument performance in any plasma for distorted instrument geometry
- Can be done in SPIS-SCI:
  - Potential pattern including photoemission and secondary emission from every element
  - Instrument performance in any plasma
  - Detailed and realistic geometric model

Conclusions

- SPIS-SCI can be used to evaluate performance of plasma and field instruments
  - Particle trajectories
  - Blocking by s/c
  - Photoemission, secondaries
- The software demands an effort by the user
  - Need for training events
  - Need for support and documentation
  - Also a community issue – we can all help
- Parallellization of particle pusher means simulations take days rather than weeks
- SPIS-SCI really gives new possibilities in this field!