Groupement de recherche
EMILI Étude des milieux ionisés Plasmas froids créés par décharge et laser

Stand Plasmas Magnétisés

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25-28 octobre 2021, Palaiseau

International benchmarks of 2D Particle-In-Cell codes

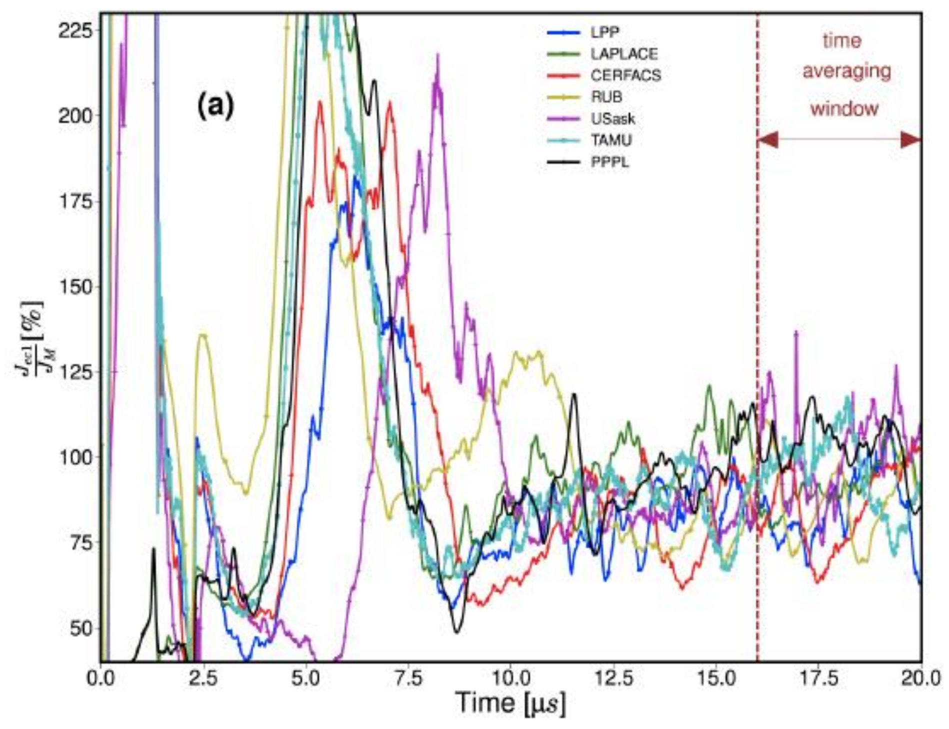
Importance of code verification

- Many instabilities are observed in low-pressure partially magnetized plasmas.
- Particle-In-Cell simulations (PIC) are used to guide/challenge theory and derive new fluid models
- Numerical noise may influence the results of PIC simulations by imitating the effect of collisions (Janhunen *et al.* PoP **25** (2018) 011608; *ibid*, **25** (2018) 082308)

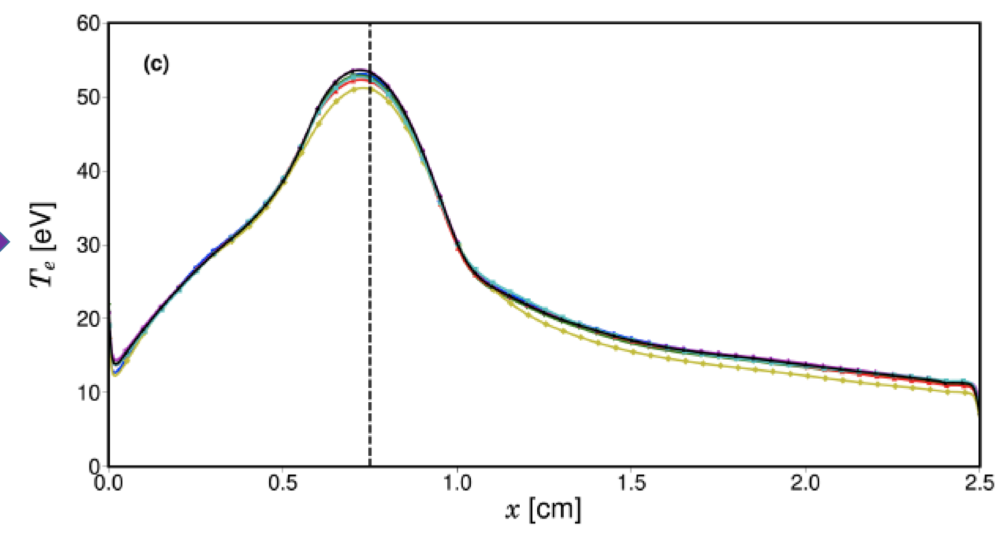
⇒ **Need to better understand the influence of numerical parameters**

2D axial-azimuthal benchmark [T. Charoy *et al.* PSST 28 (2019) 105010]

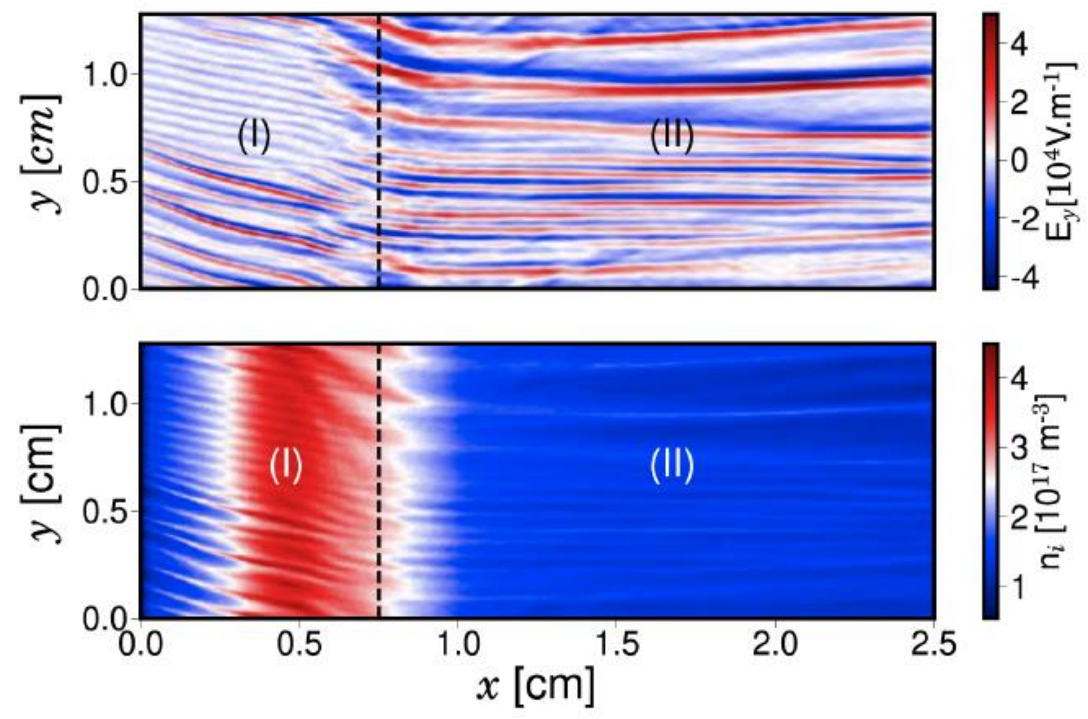
- 7 independently developed PIC codes have been benchmarked in the context of Hall thrusters
- Collisionless test-case – comparison at steady state (a low frequency oscillation remains)
- Computational times between 2.5 and 21 days (32 to 360 CPUs and 1 GPU)



Time evolution of current

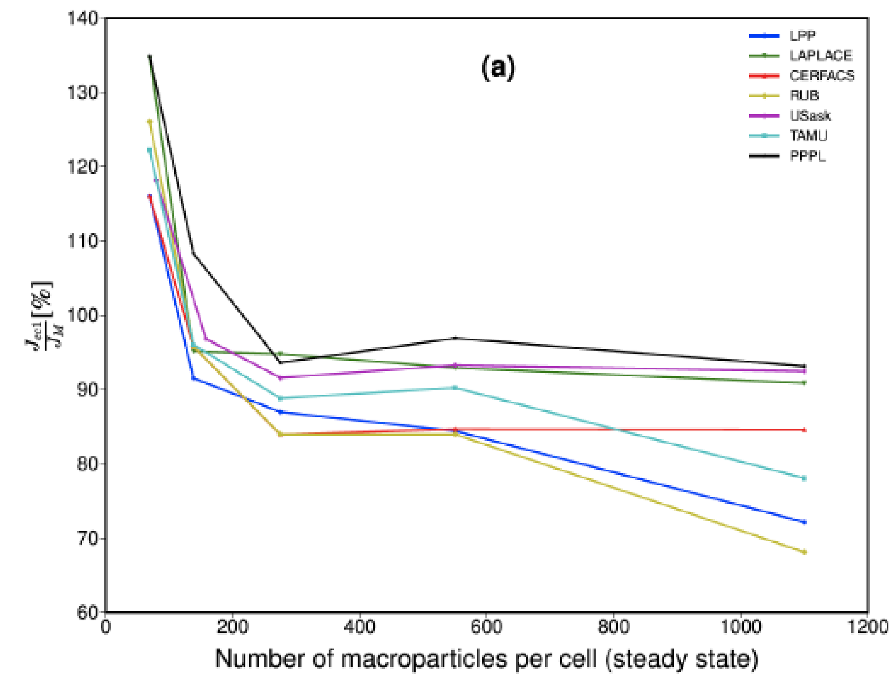


Azimuthally and time averaged axial profile of the axial electron temperature



2D axial-azimuthal maps of the azimuthal electric field (top) and ion density (bottom)

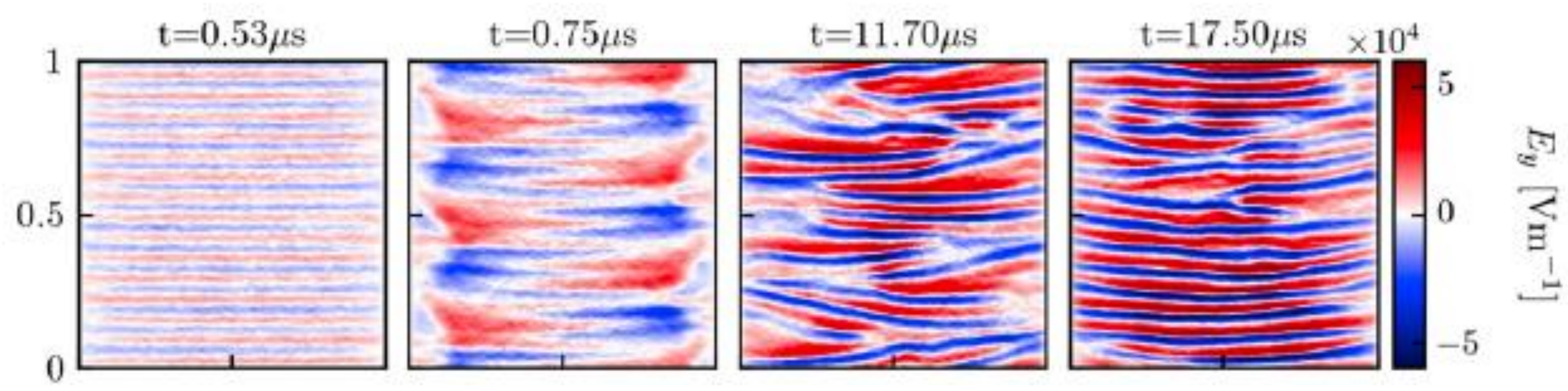
- Good agreement on time averaged and azimuthally averaged quantities (error<5%)
- All codes observe the ECDI (Electron Cyclotron Drift Instability)
- Need to have more than 250 particles per cell



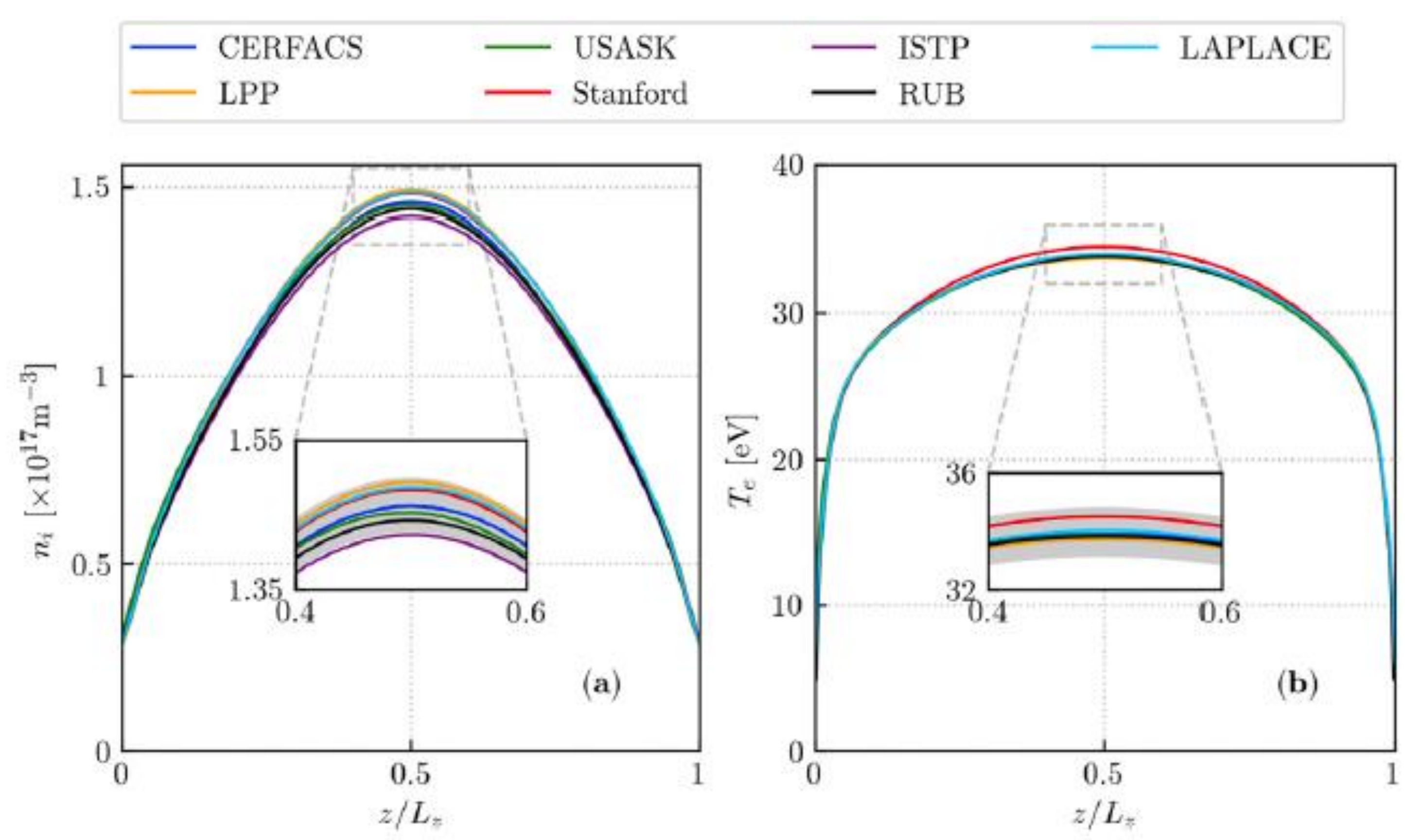
Effect of the statistic on the time evolution of the current

2D radial-azimuthal benchmark [W. Villafana *et al.* PSST 30 (2021) 075002]

- 7 independently developed PIC codes have been benchmarked in the context of Hall thrusters
- Collisionless test-case showing 2 instabilities at steady state: the Electron Cyclotron Drift Instability (ECDI) and the Modified Two-Stream Instability (MTSI)
- All codes have retrieved these 2 instabilities



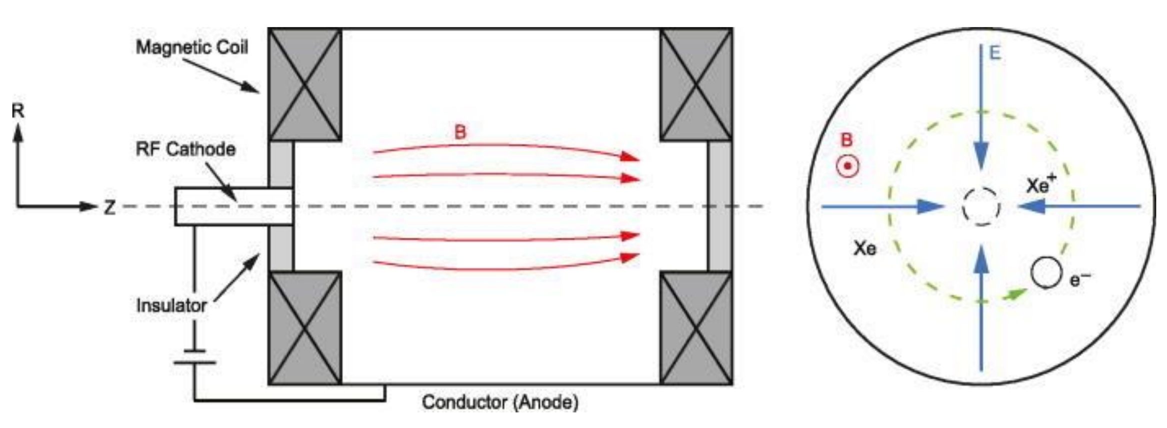
Typical 2D snapshots of azimuthal electric field profile Ey



Mean radial profiles of ion density (a) and electron temperature (b), averaged over 25–30 μs.

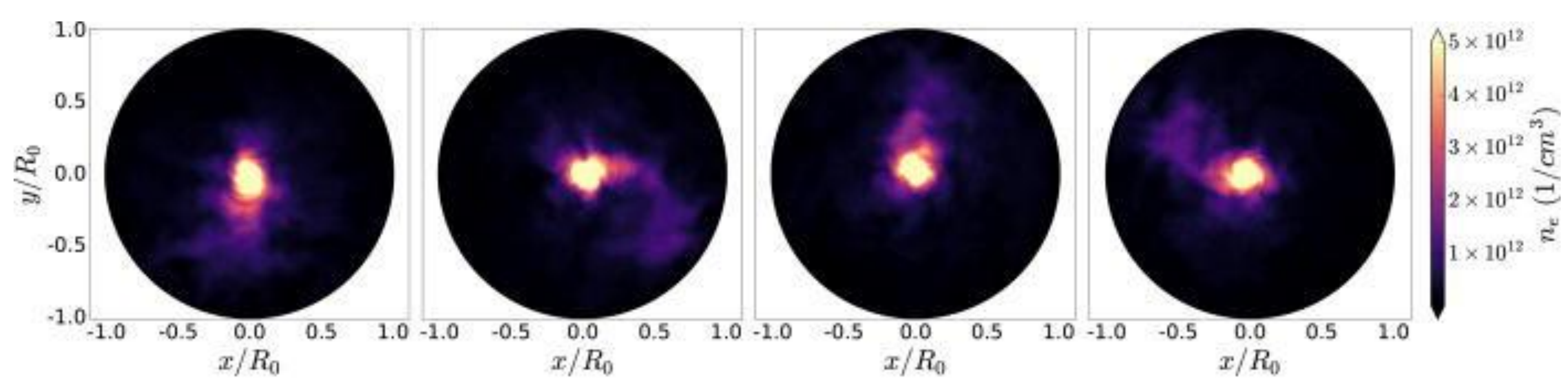
- Main plasma parameters were closely related within a 5% interval
- The number of macroparticles per cell was also varied and statistical convergence was reached: 100-200 particles per cell are needed

New 2D benchmark: Penning discharge



Typical Penning discharge configuration

- Based on work of T. Powis et al., PoP **25** (2018) 072110 – large structure, spoke rotation



Electron density contours of the collisionless Penning discharge at 4 simulation times

- Both collisionless and collision test-cases will be proposed
- Ongoing definition of conditions