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

Stand Plasmas Magnétisés

Journées 2021
25-28 octobre 2021, Palaiseau

Magnetized low-temperature plasmas

Generalities

- Magnetized plasmas extend across a wide range, from low-pressure plasmas to tokamak and astrophysical plasmas
- Many laboratory devices are **partially-magnetized**: electrons are strongly magnetized, while ions are weakly magnetized/unmagnetized. Magnetization increases the electron residence time, limiting electron losses on walls and enhancing ionization in the volume

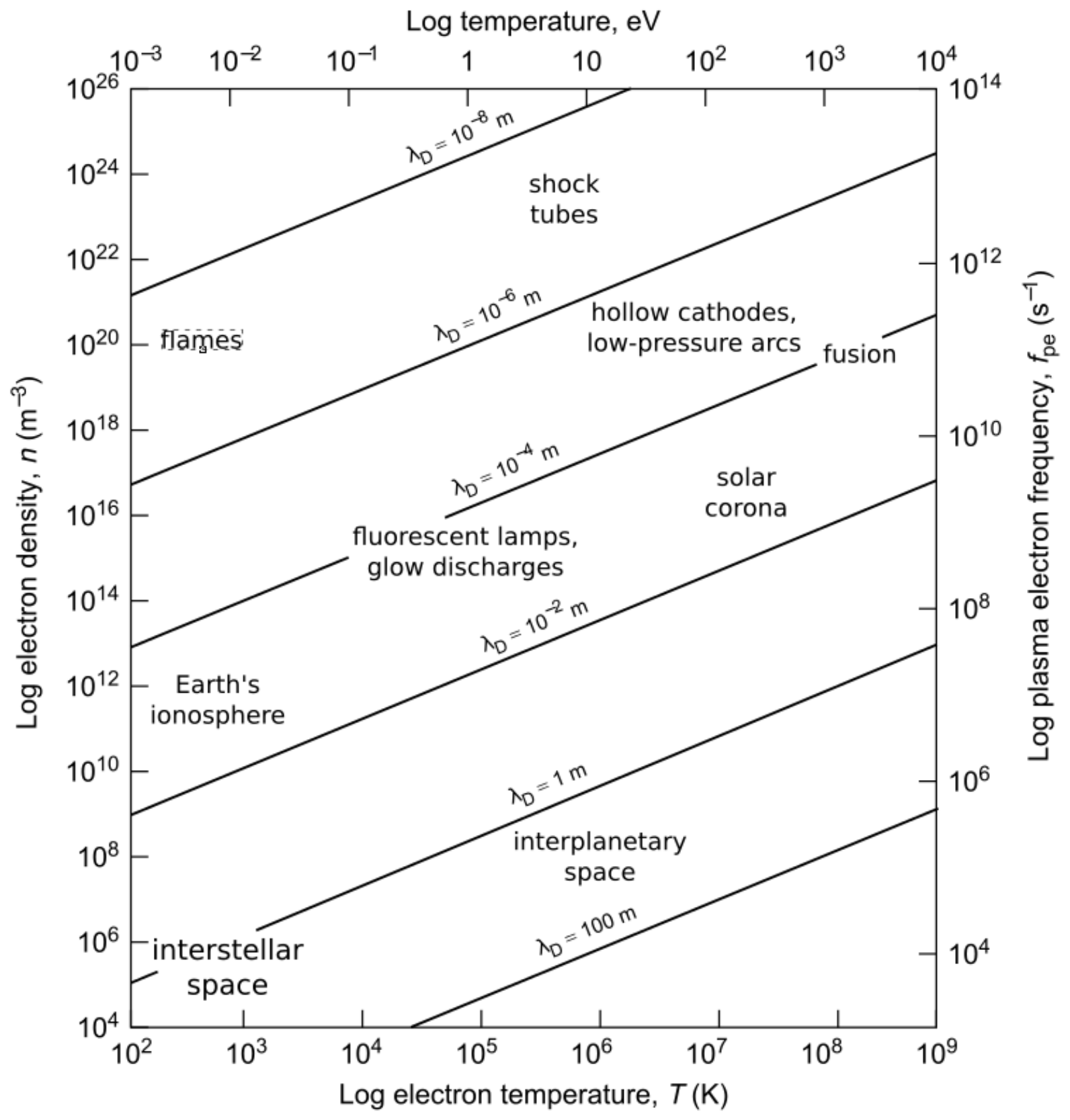
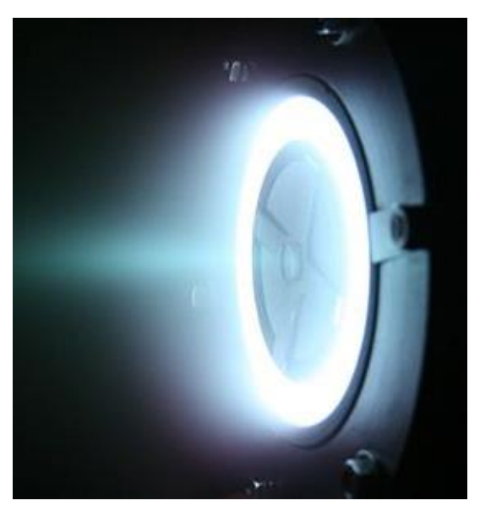


Illustration of diverse plasma regimes [1]

Applications

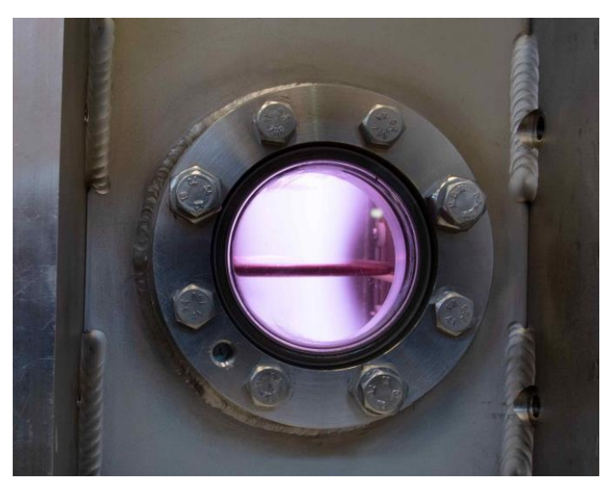
- Space propulsion



Hall thruster
ICARE-Exotrail
Orleans

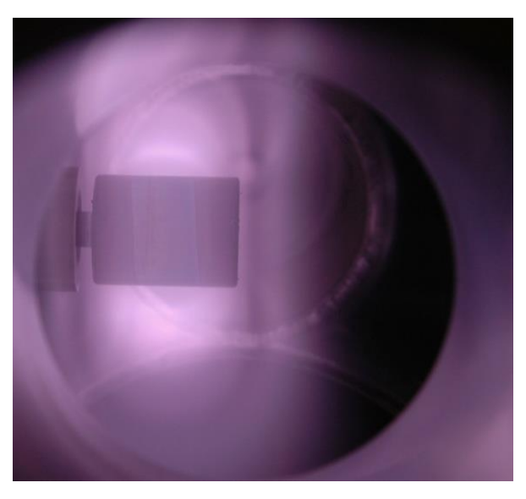
- Particle accelerators

ECRIS source
GANIL, Caen

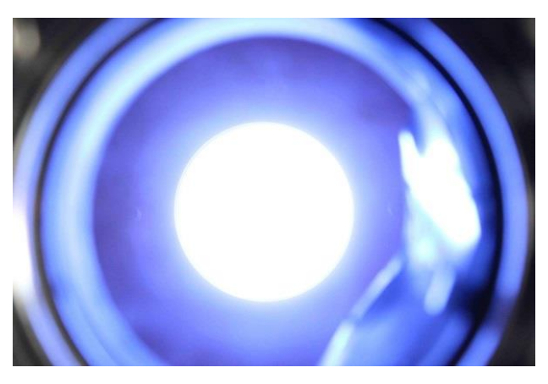


Cybele NBI source
CEA, Cadarache

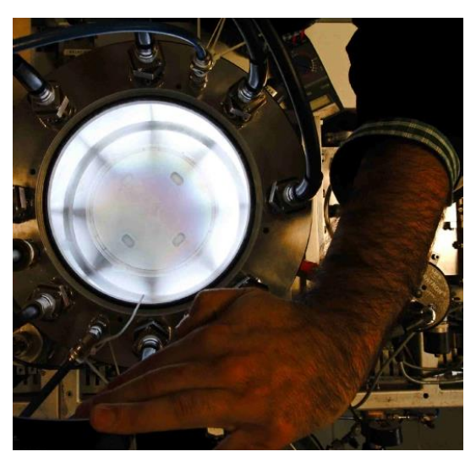
- Surface treatment



DECR plasma
LSPC, Grenoble

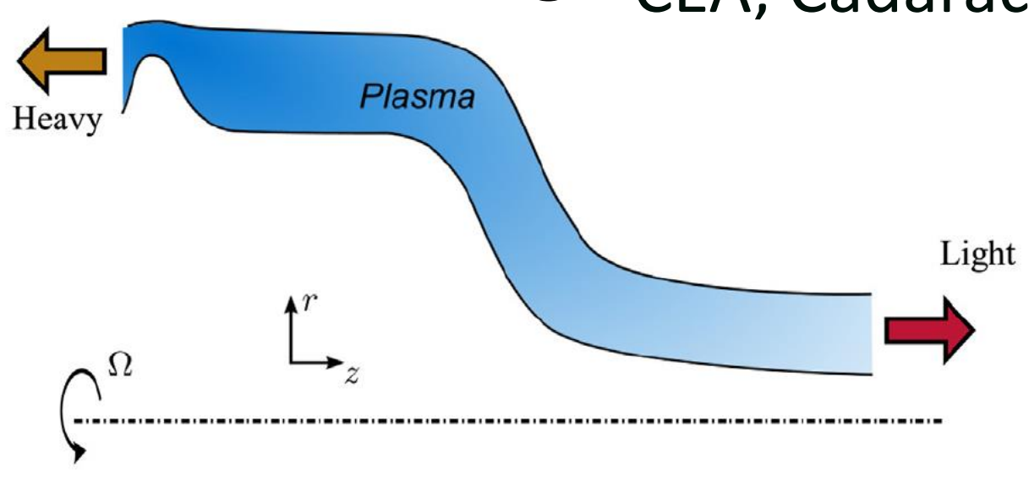


HiPIMS Magnetron
LPGP, Orsay



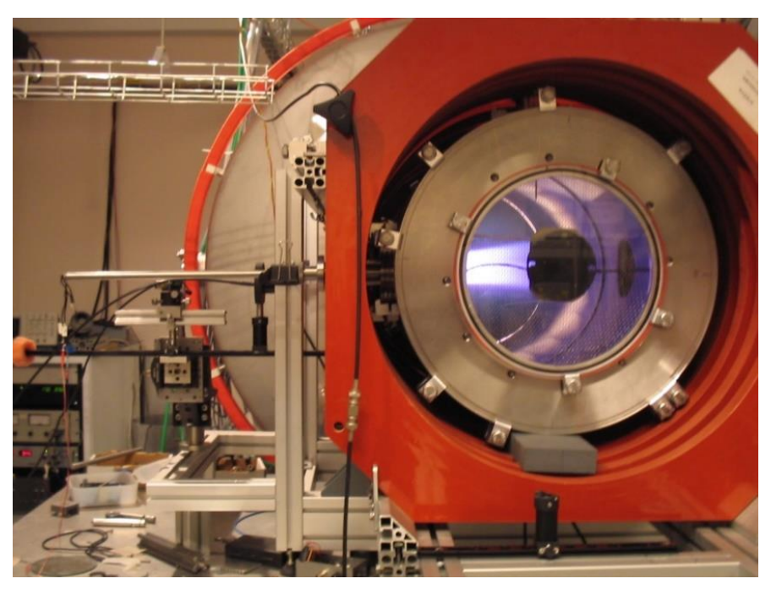
ECR plasma
LAPLACE, Toulouse

- Mass filtering

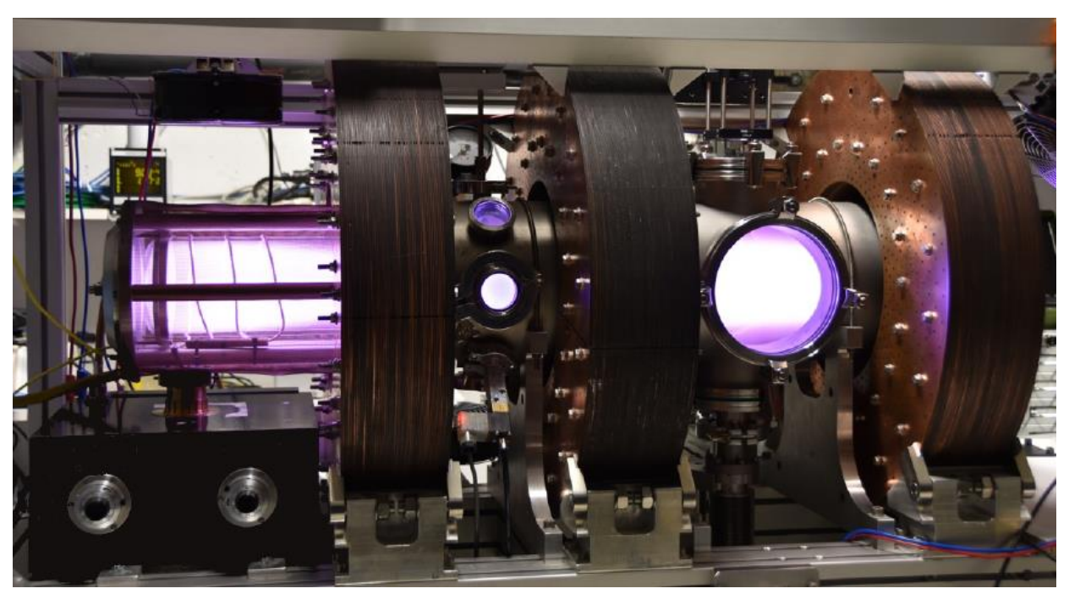


Magnetic centrifugal mass filter
Operation principle

- Basic physics



Mistral plasma source
PIIM, Marseille

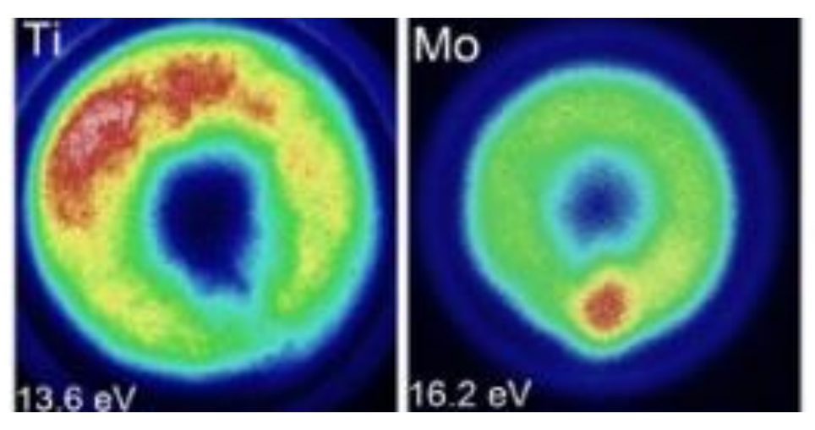


Von Karman plasma experiment,
ENS Lyon

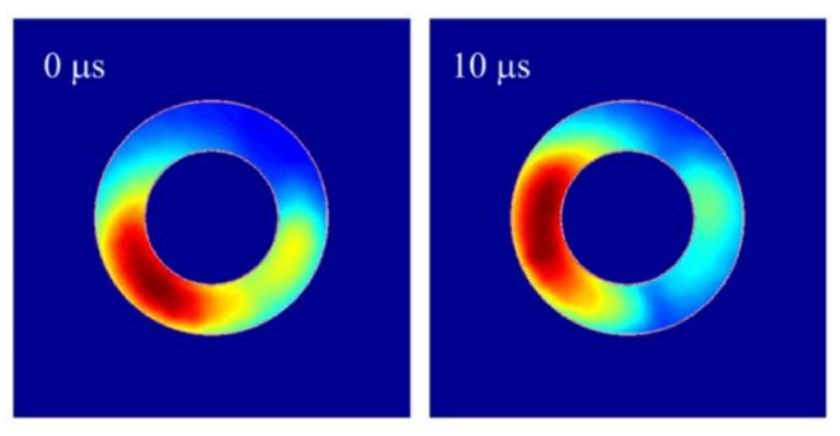
SPEKTRE plasma source, IJL, Nancy

Some key fundamental questions

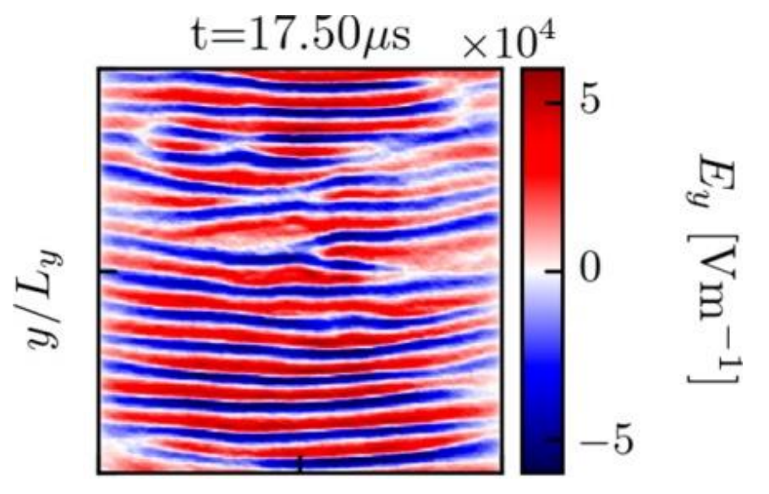
- What is the origin of self-organization instabilities in many ExB closed drift discharges [2-4]?



planar magnetron spokes



Hall thruster spokes



short scale mode

- What is the nature of plasma-surface interactions in these plasmas?
- Can we develop models capable of capturing the range of plasma behavior (large- and small-scale dynamics)?
- Can we ultimately link the source performance (efficiency, process outputs, stability, and so on) to the plasma behavior in a predictive way?

GdR modular plasma source

A common plasma source could aid the mutualization of research efforts across laboratories. It would be:

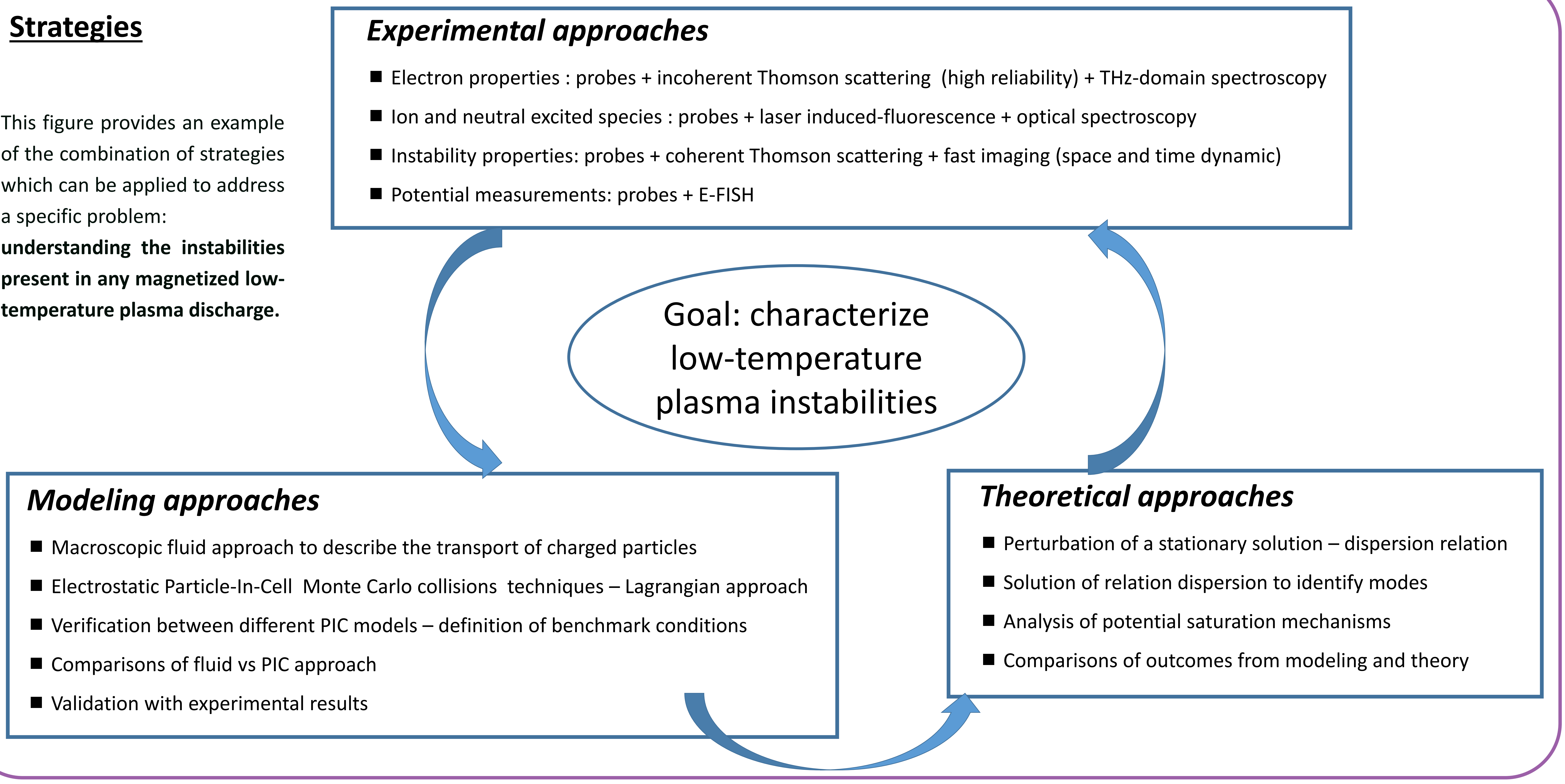
- a common tool shared by the GdR EMILI research groups
- diagnostics-accessible, for the characterization of temporal and spatial plasma properties
- simulated using existing and new modeling tools

References

[1] John Harry, *Introduction to Plasma Technology: Science, Engineering and Applications*, WILEY-VCH Verlag GmbH (2010).
[2] D. Lundin *et al*., High Power Impulse Magnetron Sputtering: Fundamentals, Technologies, Challenges and Applications, Elsevier (2019).
[3] S. Mazouffre *et al.*, *Plasma Sources Science and Technology*, 28, 054002(2019).
[4] W. Villafana *et al.*, *Plasma Sources Science and Technology*, 30, 075002(2021).

Strategies

This figure provides an example of the combination of strategies which can be applied to address a specific problem: **understanding the instabilities present in any magnetized low-temperature plasma discharge.**



Experimental approaches

- Electron properties : probes + incoherent Thomson scattering (high reliability) + THz-domain spectroscopy
- Ion and neutral excited species : probes + laser induced-fluorescence + optical spectroscopy
- Instability properties: probes + coherent Thomson scattering + fast imaging (space and time dynamic)
- Potential measurements: probes + E-FISH

Goal: characterize
low-temperature
plasma instabilities

Modeling approaches

- Macroscopic fluid approach to describe the transport of charged particles
- Electrostatic Particle-In-Cell Monte Carlo collisions techniques – Lagrangian approach
- Verification between different PIC models – definition of benchmark conditions
- Comparisons of fluid vs PIC approach
- Validation with experimental results

Theoretical approaches

- Perturbation of a stationary solution – dispersion relation
- Solution of relation dispersion to identify modes
- Analysis of potential saturation mechanisms
- Comparisons of outcomes from modeling and theory