2.5D PIC modeling of rotating structures in a magnetized plasma column

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THE FRAMEWORK PROGRAMME FOR RESEARCH AND INNOVATION

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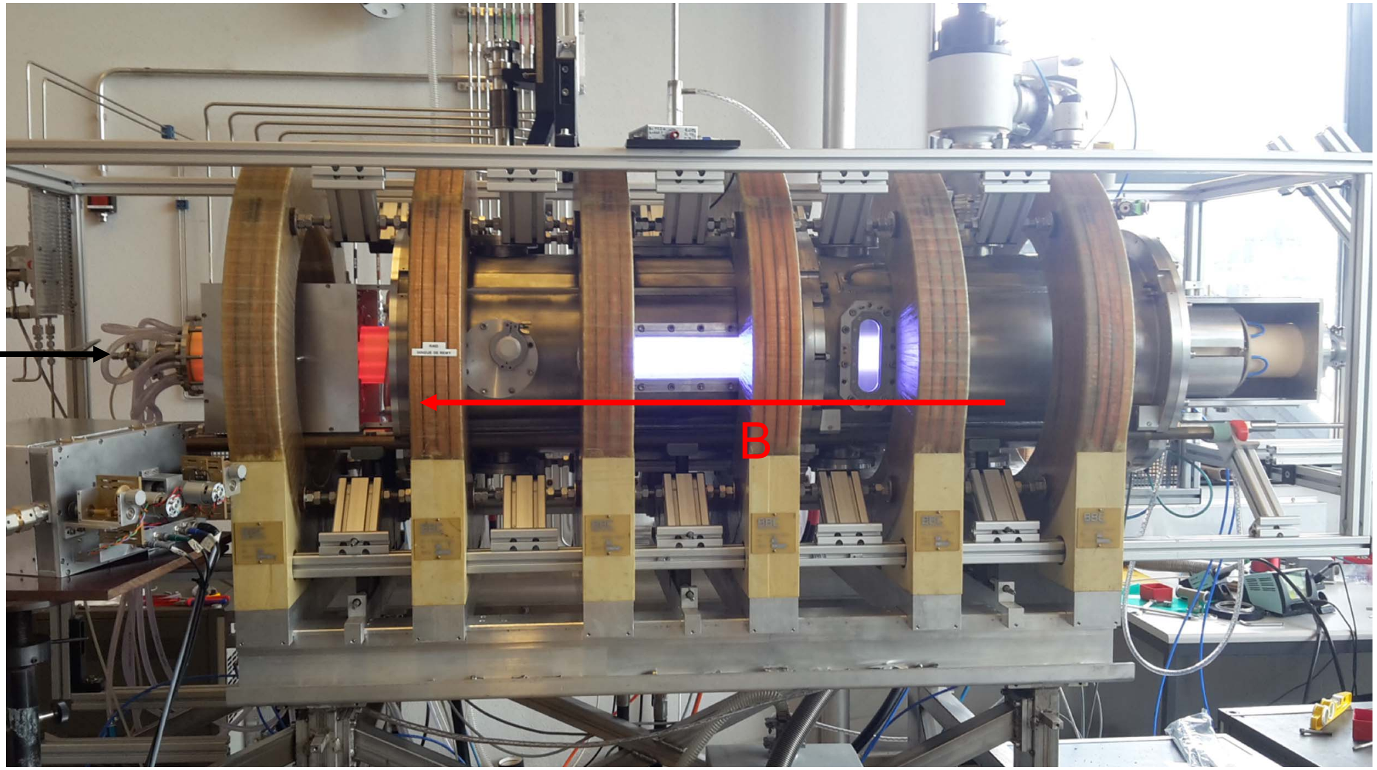
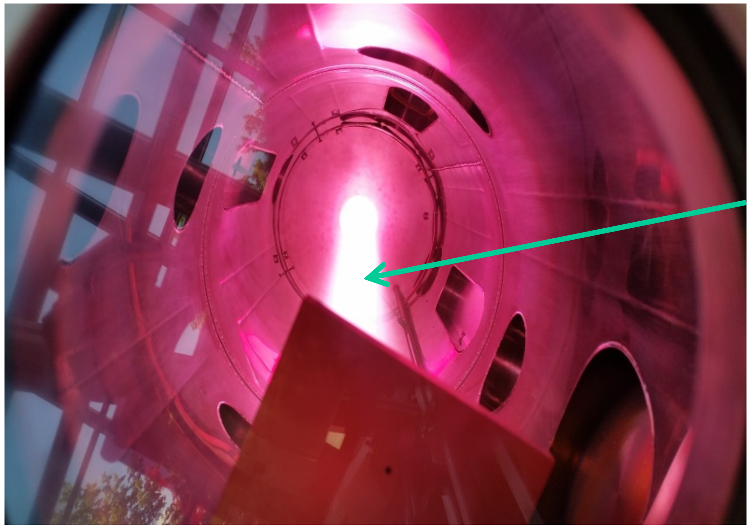
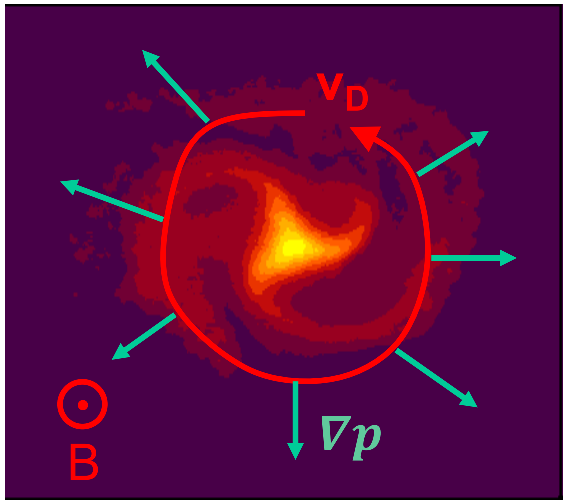
Experiments performed at SPC (EPFL, Switzerland) and IRFM (CEA, France)

Helicon





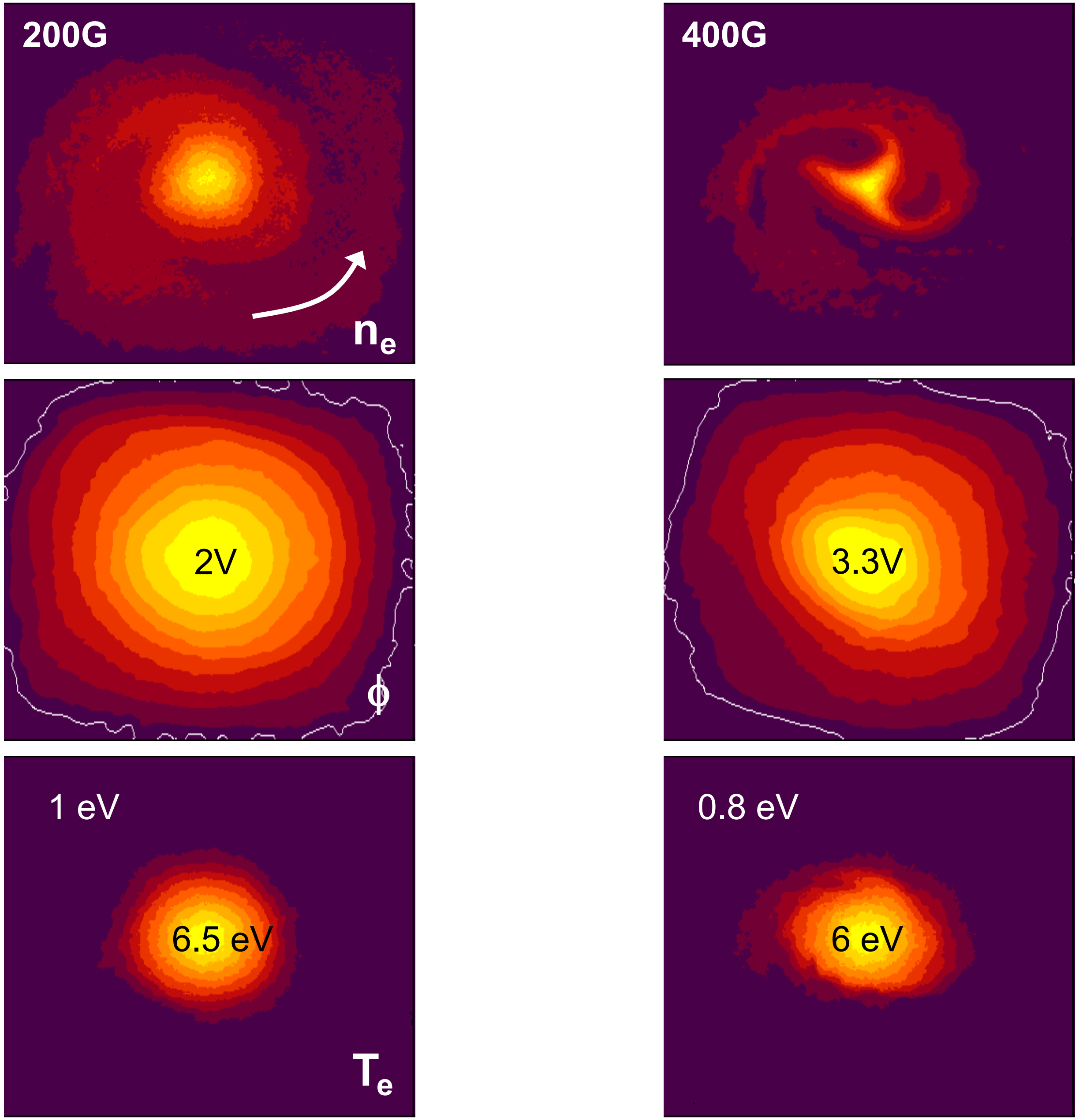
Plasma column
1.5 m in length



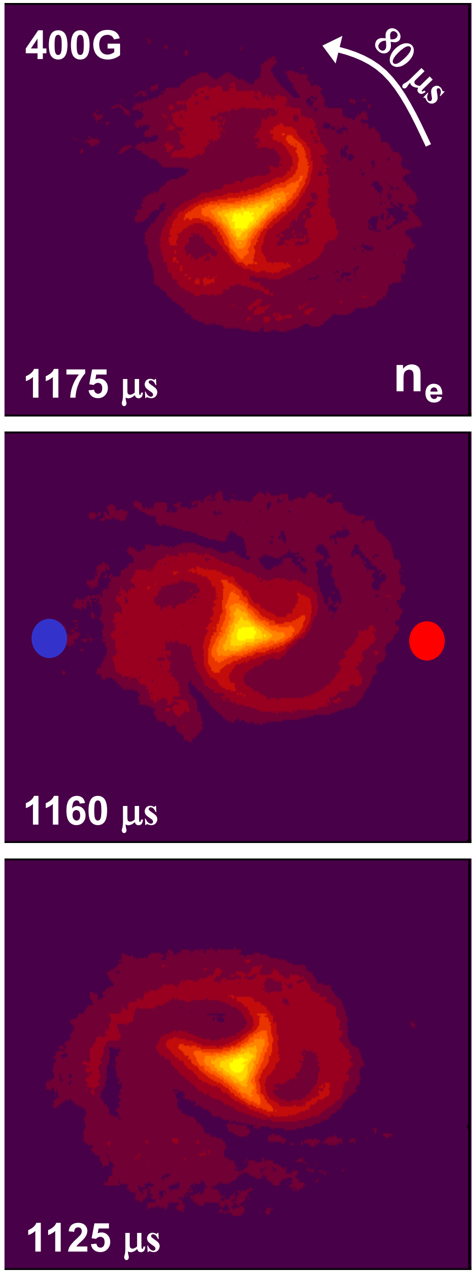
Principles of the 2.5D PIC-MCC algorithm

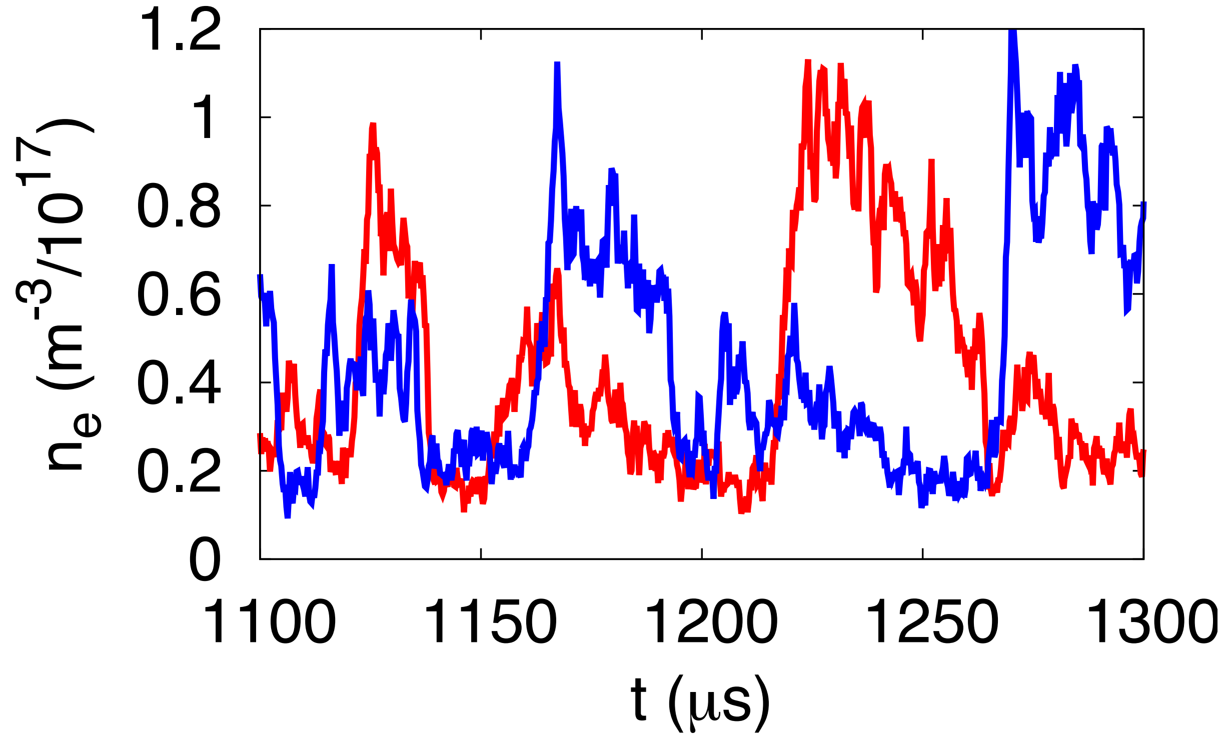
- Particle losses along the 3rd dimension evaluated analytically
- Mesh is 2-dimensional
  - Plasma properties along vertical axis hence not calculated
- Solely electrons are heated by an external power source
- Power absorption profile is gaussian
- Electron velocity is updated as $v = v_{old} + \Delta v$
  - Δv is sampled from a Maxwellian with $T_{eff} = 2/3\, P_{abs}/eN_m\nu_h$
  - Effect on the EEDF: $\langle v \rangle = \langle v_{old} \rangle$ and $\langle v^2 \rangle = \langle v^2_{old} \rangle + \langle \Delta v^2 \rangle$
  - Electrons do not artificially cross magnetic field lines that way
- Column of $10 \times 10 \times 100$ cm^3 in the model
- -10V at the end-plates
- Simplified chemistry: Electrons and H_2^+ ions. Cross-sections from LXCAT
- Loss term for ions is added. Neutral gas density is 10^{20} m^{-3}
- Algorithm parallelized with OpenMP and MPI. Multigrid solver for Poisson

Observation of large scale rotating structures in the model

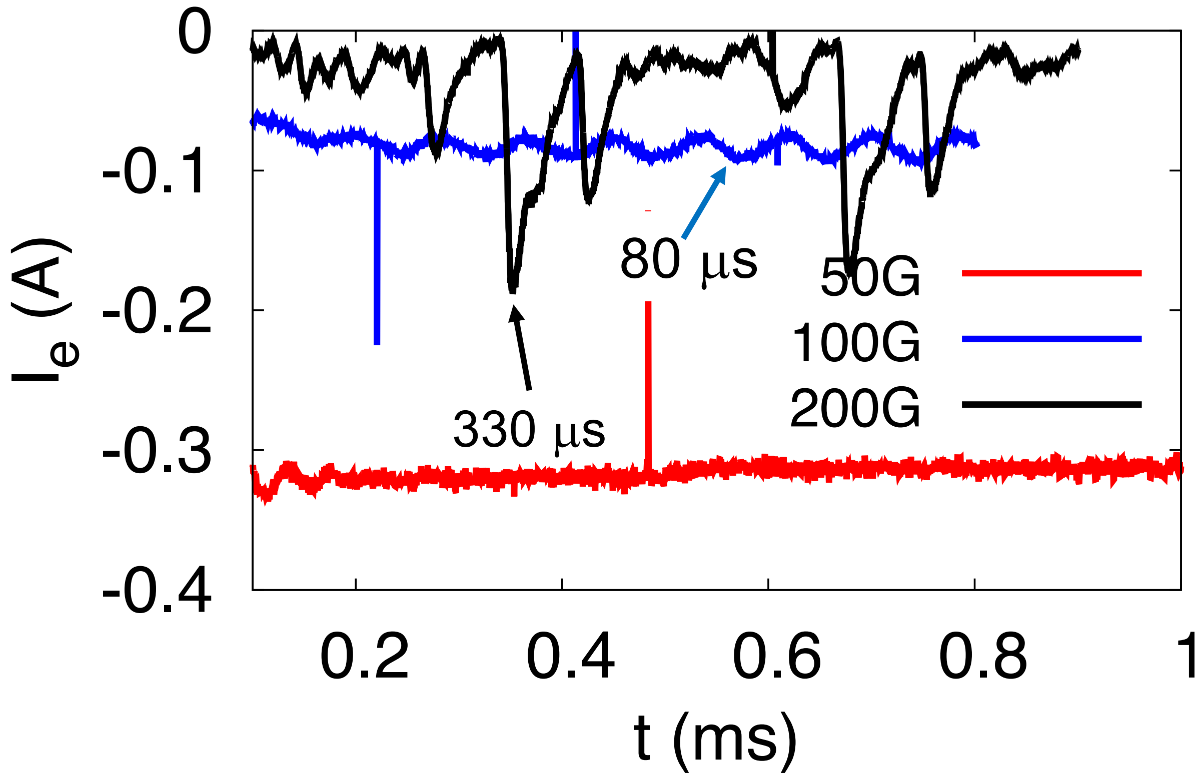


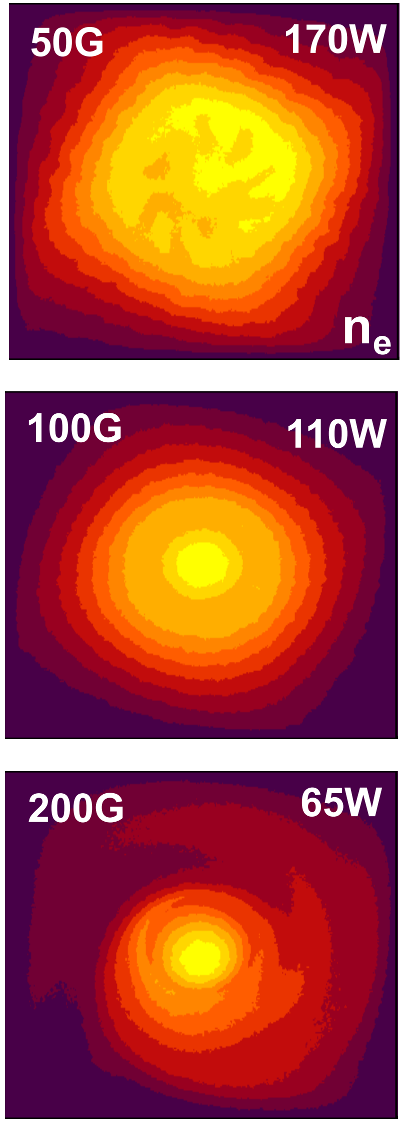
Evolution of the rotating structures over time





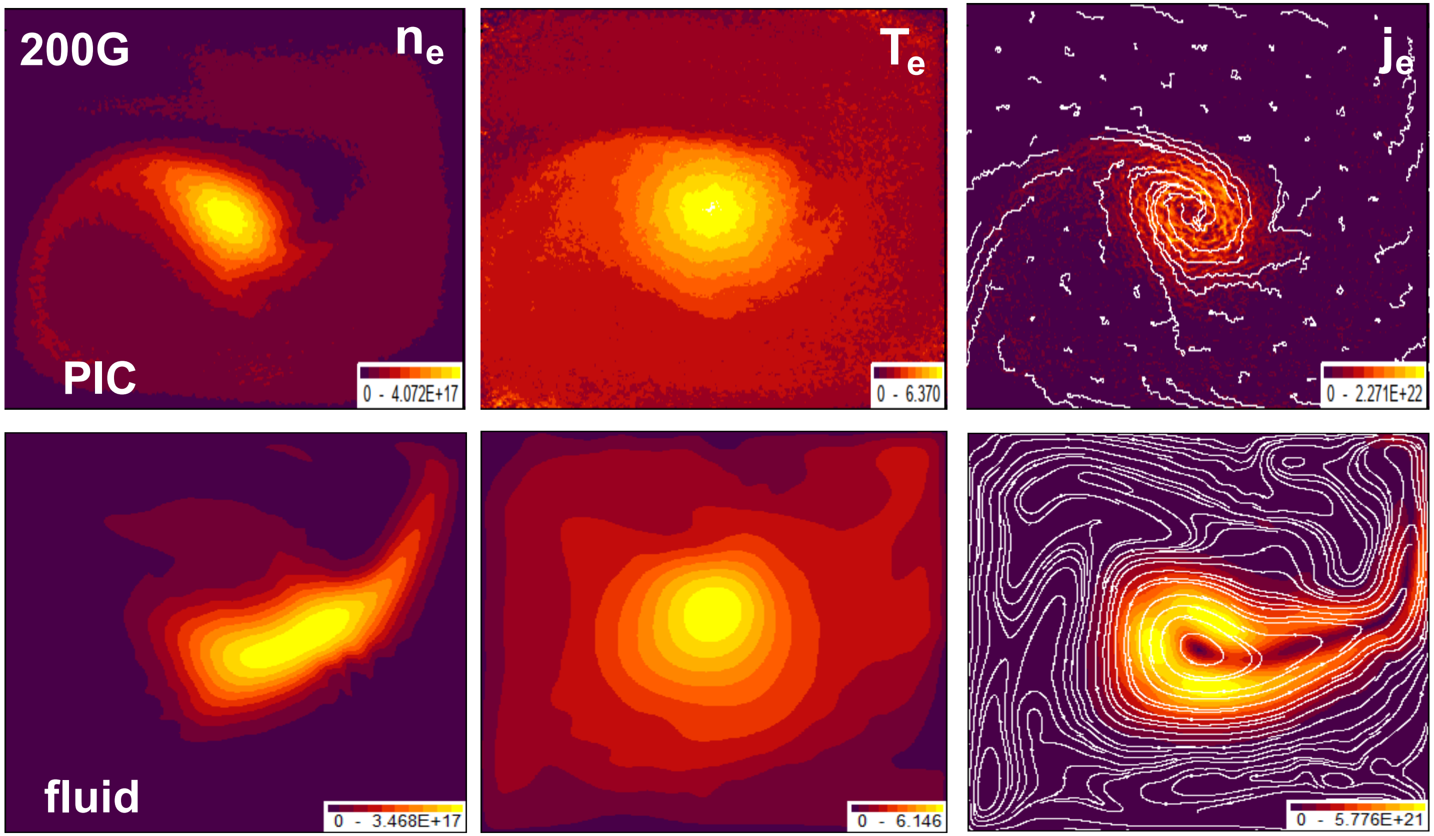
Current on the LHS wall vs. magnetic field strength





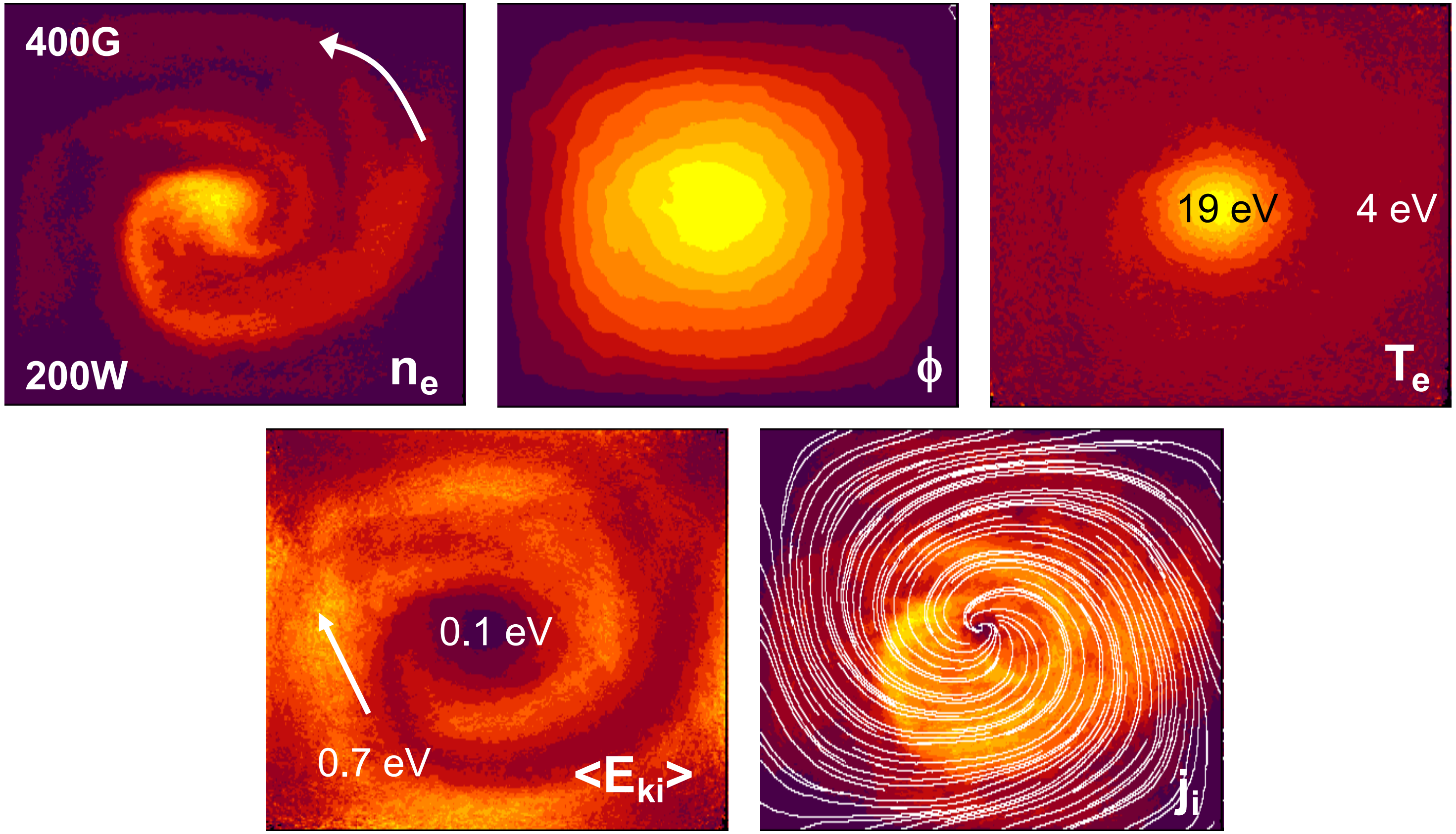
- Physical-chemistry is simplified: 3 reactions in total
- Ionization and elastic collisions against neutrals for both electrons and ions

Comparison 2.5D PIC vs. fluid modeling (work in progress)



The fluid model is developed by G. Hagelaar

Rotating structures are also observed in inert gases (Helium here)



Conclusion & perspectives

- What does destabilize the plasma?
  - Not Simon-Hoh because the pressure gradient and E-field are anti-parallel
- The instability has large scale structures the size of the simulation domain
  - The temperature gradient is large
  - Non-linear regime
  - Hence difficult to identify its type using standard analytical techniques
- What about losses on the end-plates? (vertically along the magnetic field lines)
  - Electron and ion losses are not equal
- Will perform scans vs. ion mass and magnetic field strength
- We are also investigating the effect of ionization on the arms