RF modeling for NSTX-U

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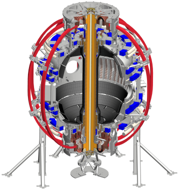

Outline

- Background
- Interaction between HHFW waves and core plasma
- Interaction between HHFW waves and SOL plasma

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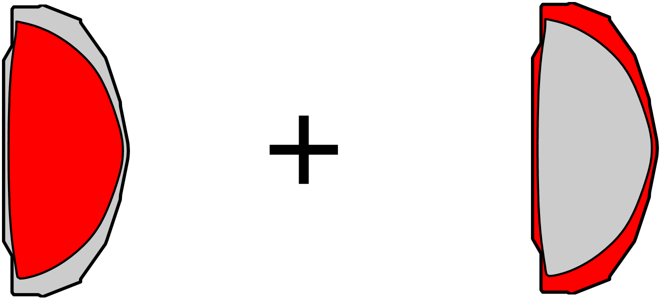
Background

RF modeling was generally more focused on core plasma

Need to consider core & SOL plasma together



- Electron absorption
- Interaction FW & fast ions

- RF SOL power losses
- RF effects on SOL plasma

Outline

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- Interaction between HHFW waves and SOL plasma

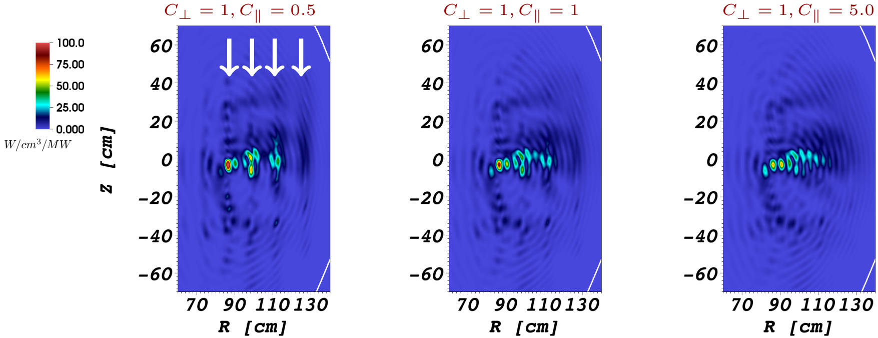
Interaction between HHFW waves and core plasma (1)

WHAT HAS BEEN DONE:

Extended full wave code TORIC to include non-Maxwellian ions effects for both HHFW and minority heating regimes

Interaction between HHFW waves and core plasma (1)

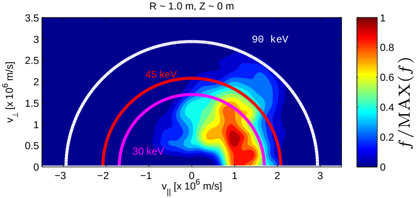
RESULTS: $v_{\text{th},\parallel} = \sqrt{2C_\parallel T(\psi)/m_\text{D}}$, $v_{\text{th},\perp} = \sqrt{2C_\perp T(\psi)/m_\text{D}}$, with constants $C_\parallel$ and $C_\perp$



- Arbitrary analytical functional form of the fast ions distribution function
  - bi-Maxwellian (plots above) & slowing down
  - straightforward to add new analytical functional forms
- The non-Maxwellian effects, generally, result in finite changes in the amount and spatial location of absorption

Interaction between HHFW waves and core plasma (2)

RESULTS:



Abs. fraction	f Maxw.	f non-Maxw.
Electrons	41.80 %	37.99 %
D-NBI	53.94 %	58.12 %

- Numerical fast ions distribution function
  - from NUBEAM particle list
- P2F code used to "smooth" the NUBEAM distribution function
  - useful tool also for energetic particles studies
- Need to close the loop with NUBEAM

Interaction between HHFW waves and core plasma (3)

Next steps:

- Paper in preparation on new code capabilities and first applications
- Add options to read a distribution function from CQL3D Fokker-Planck code
  - use the distribution function from CQL3D to include, for instance, finite orbit effects
  - possible comparison with FIDA data as done previously by D. Liu & R. Harvey
- Tests/benchmark of the RF kick-operator implemented in NUBEAM
  - in collaboration with Marina Gorelenkova
  - needed for a self-consistent evolution of the distribution function ($\rightarrow$ TRANSP)
- Similar work in minority heating regime
  - in collaboration with MIT

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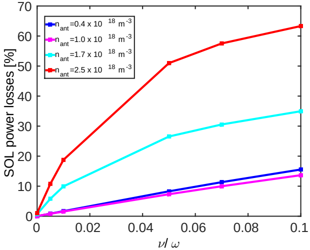
Interaction between HHFW waves and SOL plasma (1)

WHAT HAS BEEN DONE:

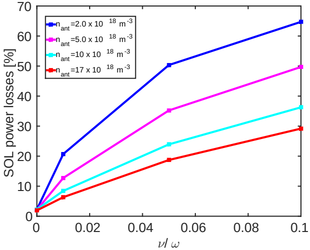
AORSA simulations and a sensitivity analysis on the artificial collisional damping in the SOL for NSTX/NSTX-U and a comparison to “conventional” tokamaks

RESULTS:

NSTX



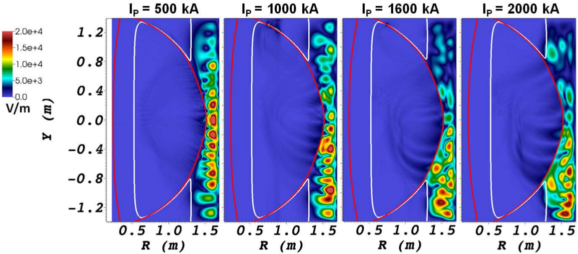
C-Mod



- RF power losses in the SOL increase for both NSTX and NSTX-U when the launched waves propagate in the SOL
  - optimization of the density in front of the antenna might be important
- Different behavior between HHFW & minority heating regimes

Interaction between HHFW waves and SOL plasma (2)

RESULTS:



- Magnetic pitch angle seems to play a significant role in the behavior of the RF field
  - However, no dominant effect influencing the presence of the RF field transition in the SOL (need further investigation)
- Bertelli, et al. Nucl. Fusion **56** (2016) 016019

Interaction between HHFW waves and SOL plasma (3)

Next steps:

- Realistic boundary geometry
- Density in the SOL
  - Poloidal dependence
- Very detailed behavior of RF field in front of the antenna
- "SOL effects"
  - RF sheaths, PDI, etc.

We have recently started a "new approach": **see Eun-Hwa Kim's talk**