Impacts of minority hydrogen species on the HHFW performance with possible new NSTX-U parameters

NSTX-U

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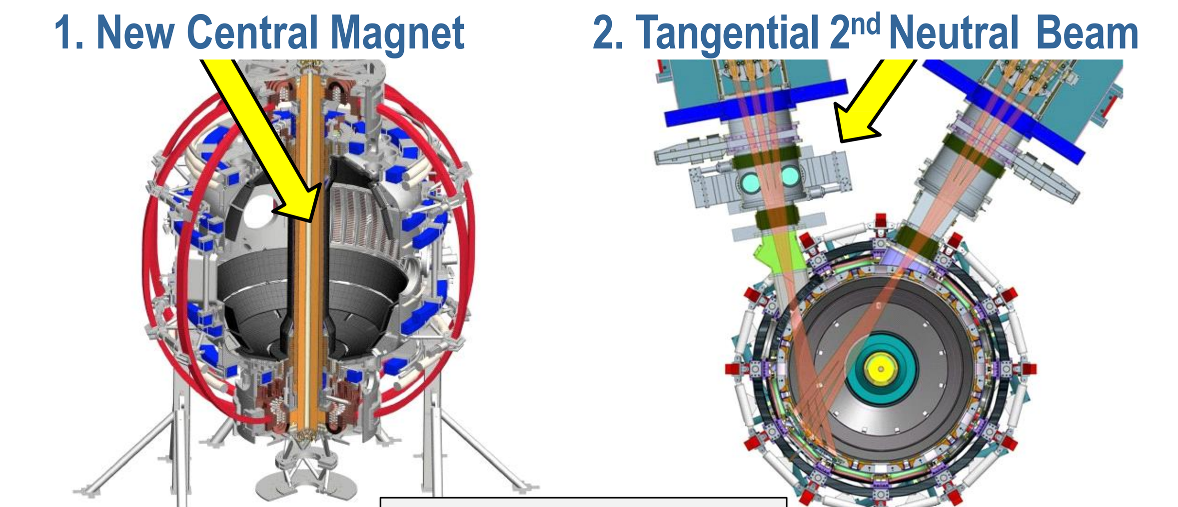
NSTX-U will have major boost in performance

1. New Central Magnet   2. Tangential 2nd Neutral Beam

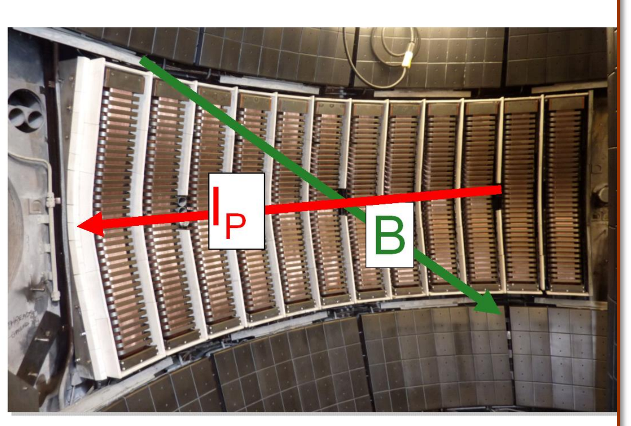


Performance goals:

- 2 toroidal field (0.5→1T)
- 2 plasma current (1→2MA)
- 5 longer pulse (1→5s)
- 2x heating power (5→10MW)
  - Tangential NBI→ 2x current drive efficiency

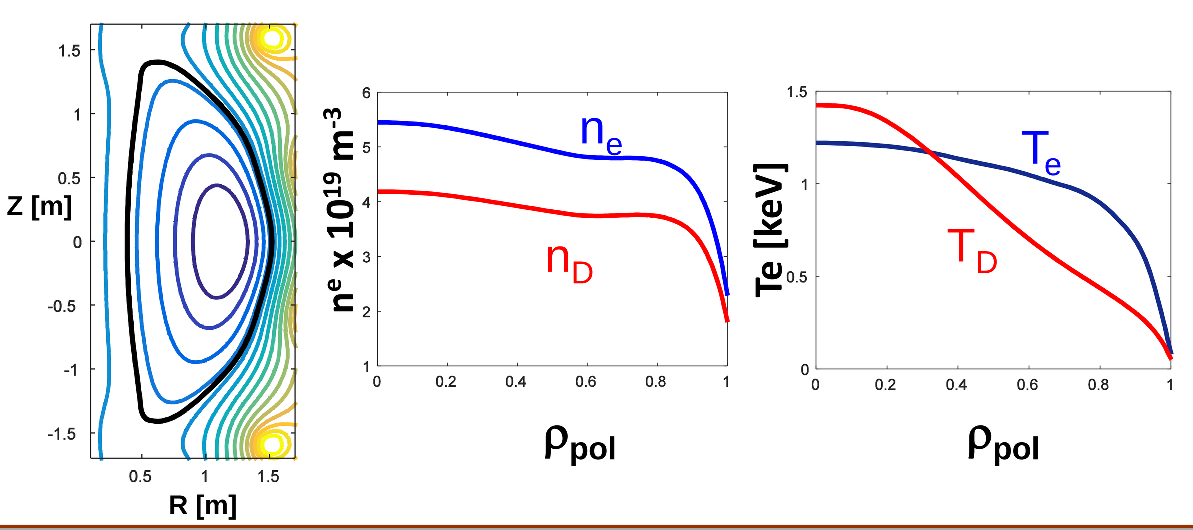
HHFW to heat electrons and drive current

- Same HHFW system used in NSTX
- 12-strap antenna located on the outboard midplane and extends 90º toroidally
- Wave frequency = 30 MHz, up to P_{RF} = 6 MW
- Well-defined spectrum
- $|n_\phi|$ = ±5, ± 12, and ±21 when $\Delta\phi$ = ±30º, ±90º, and ±150º



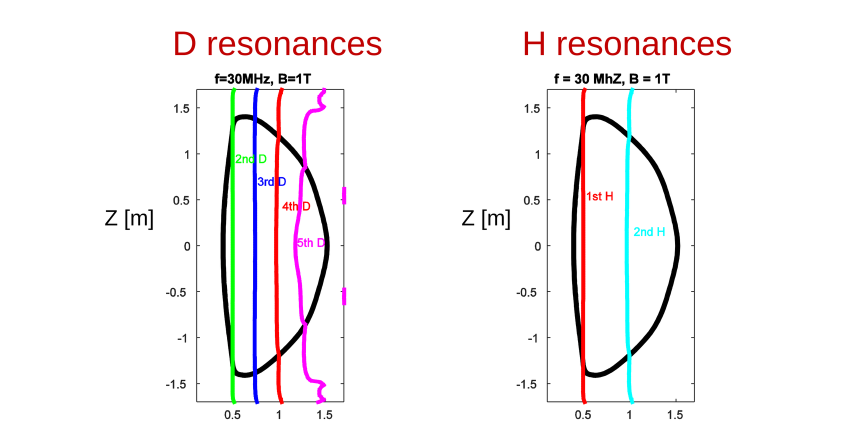
NSTX-U High Harmonic Fast Wave (HHFW) "Scenarios" considered

- NSTX-U plasma
  - B = 1T
  - Ion species: D, H, C, D_{BEAM}

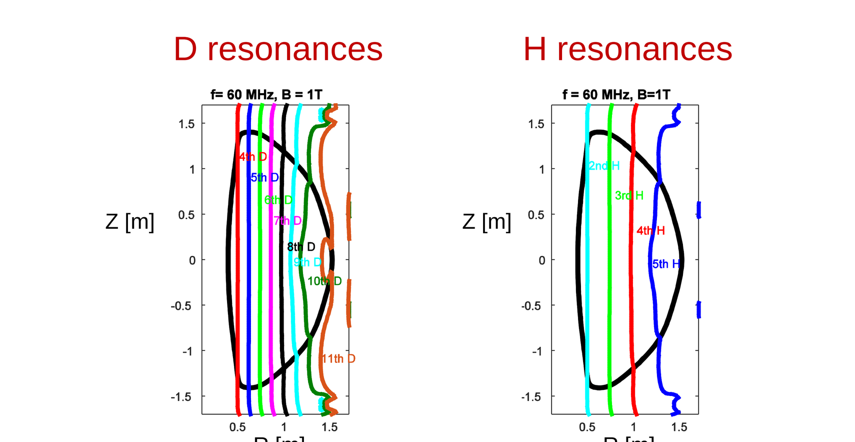


- H concentration scan:
  - n_H/n_e = 1%, 2%, 5%, 10%
- T_e & n_e scans for β_e constant
- n_{NBI} scan
- B scan:
  - B = 0.53, 0.63, 0.76, and 1 T
- w/ and w/o NBI
- Two antenna frequencies:
  - 30 MHz and 60 MHz
- Three n_ϕ values: -5, -12, -21
- Employed full wave code AORSA (Maxwellian plasma)

• NSTX-U plasma: **B = 1 T and f = 30 MHz**

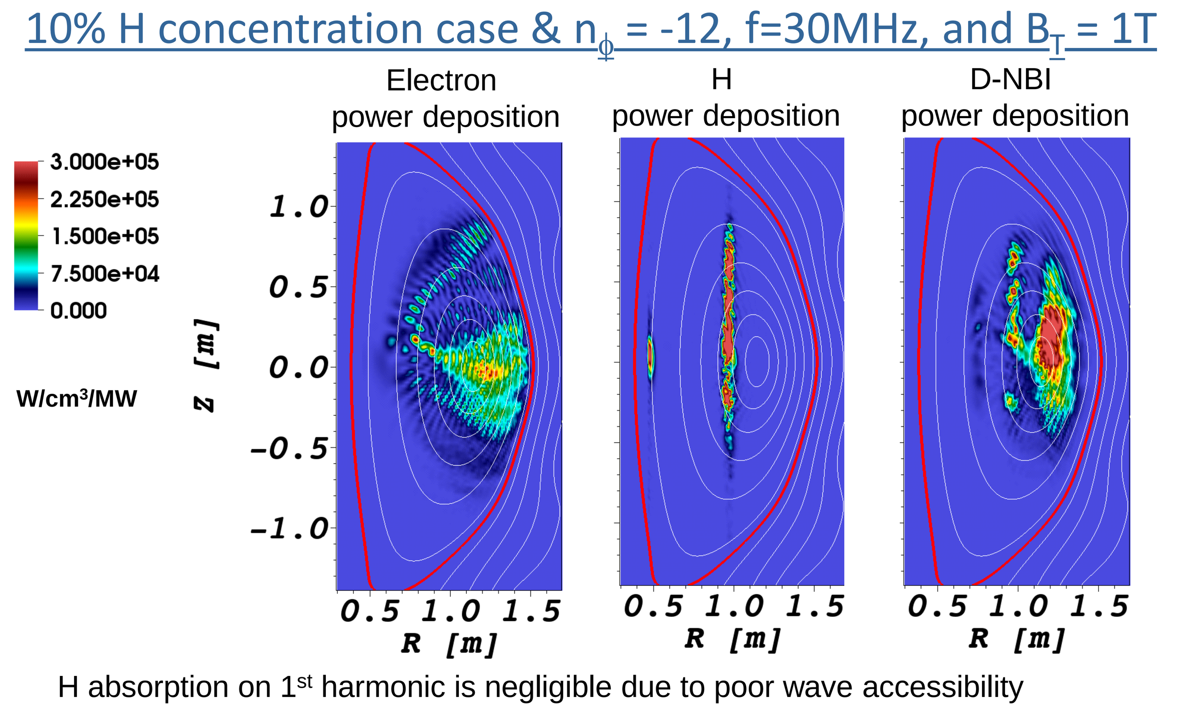


• NSTX-U plasma: **B = 1 T and f = 60 MHz**



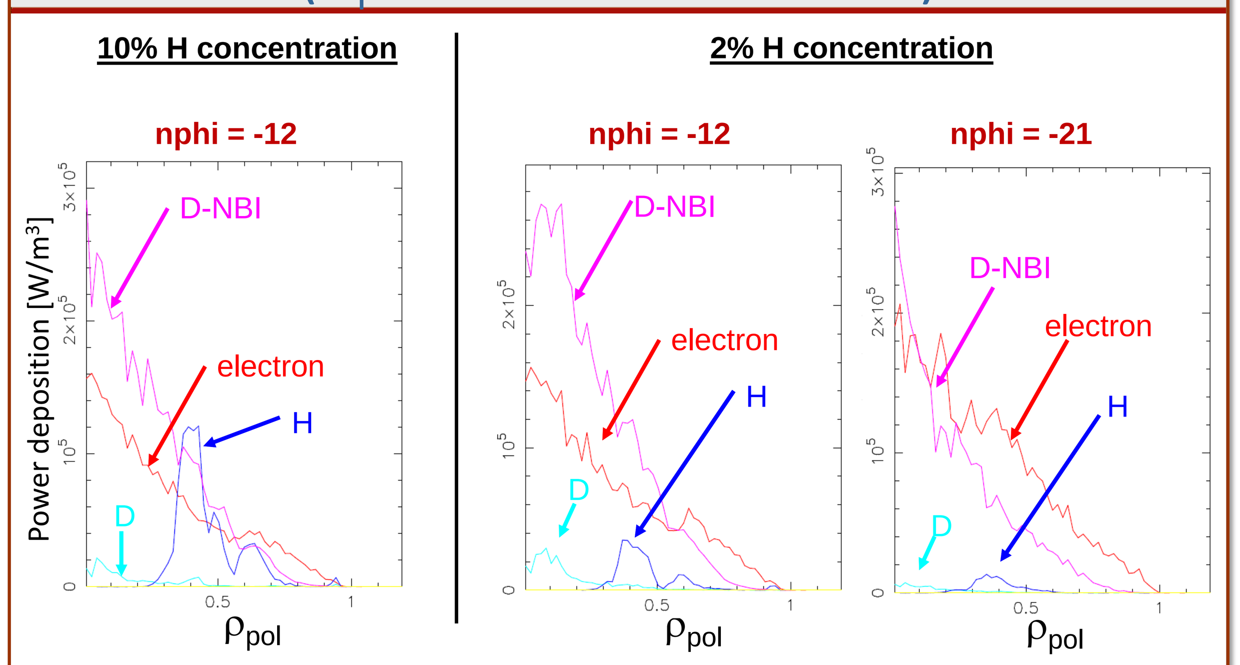
2D power deposition obtained by AORSA full wave code

10% H concentration case & n_ϕ = -12, f=30MHz, and B_T = 1T



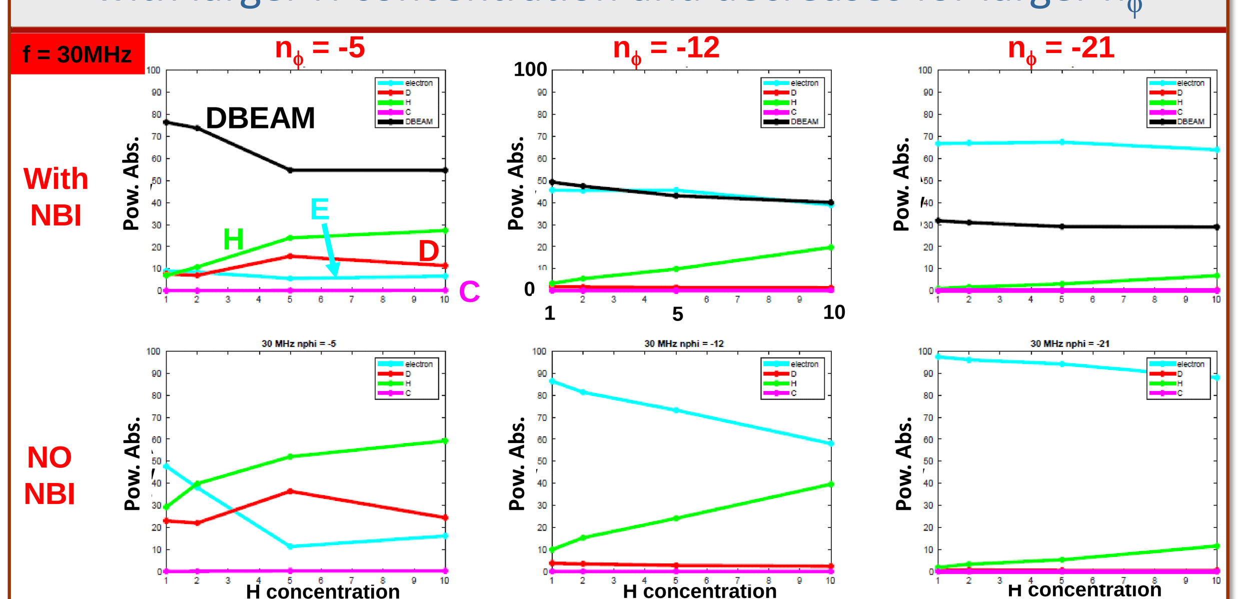
H absorption on 1st harmonic is negligible due to poor wave accessibility

Flux surface avg. deposition profiles (B_T = 1 T and f = 30 MHz)



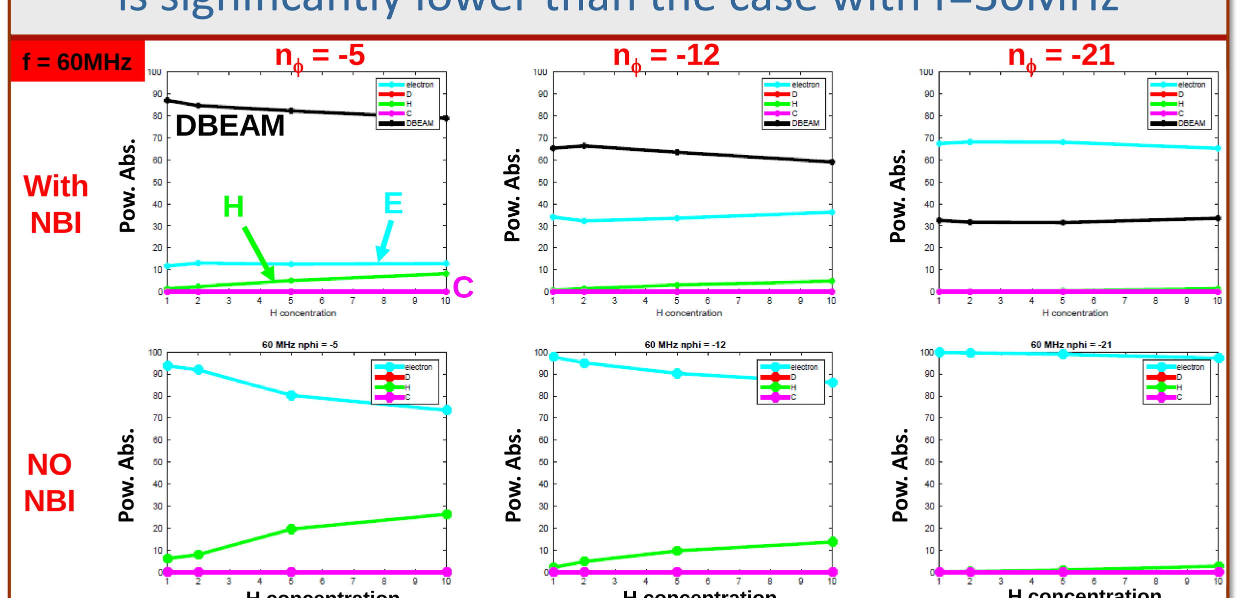
- Electron & D-NBI power depositions peaked on axis while H power deposition localized on 2nd H resonance
- H power absorption decreases with lower H concentration
- Thermal D & C are basically negligible

Hydrogen concentration scan: H power absorption increases with larger H concentration and decreases for larger n_ϕ



- W/ NBI: dominant electron & fast ions absorption (except for n_ϕ = -5)
- W/O NBI: significant H absorption at lower n_ϕ

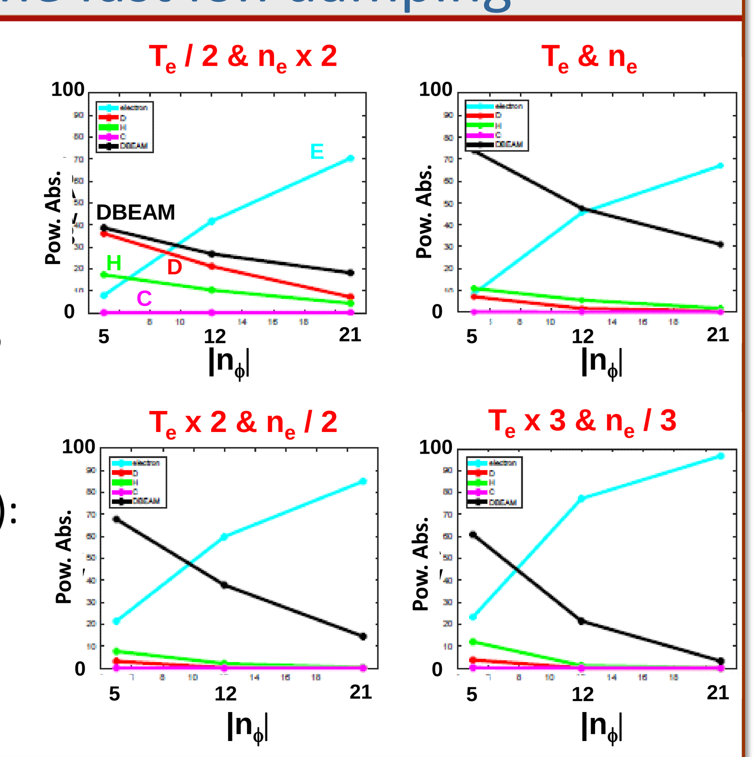
Hydrogen concentration scan: H absorption for f= 60MHz is significantly lower than the case with f=30MHz



Constant beta scan: Launching high $|n_\phi|$ reduces the fast ion damping

f = 30 MHz, w/ NBI, H 2%

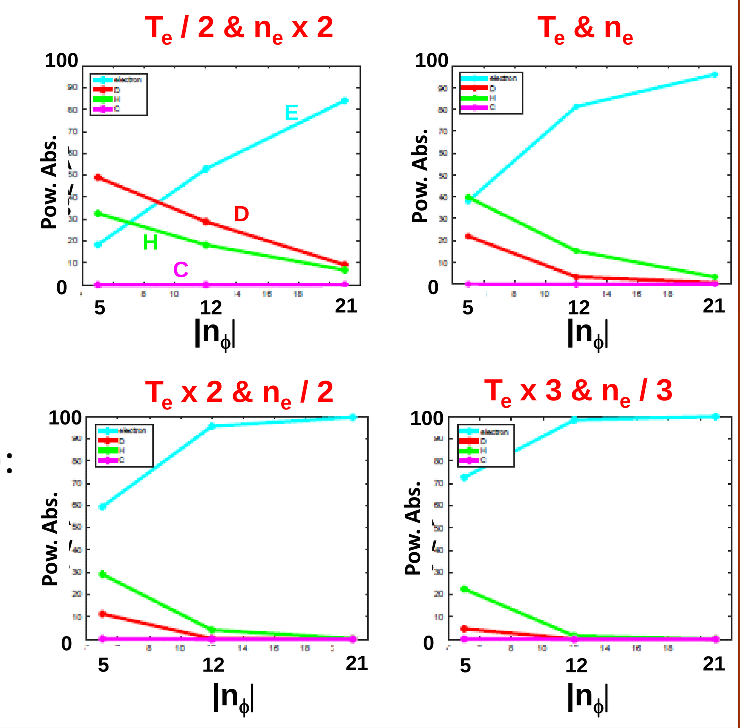
- Electron damping significantly increases with T_e and n_ϕ
- Dominant fast ions absorption for $|n_\phi|$ = 5
- The H role is quite marginal
- For 60 MHz (not shown):
  - higher fast ion abs. w.r.t. 30 MHz
  - Up to 20% H abs. for low $|n_\phi|$ and $T_i > T_e$



Constant beta scan: Dominant electron damping for $|n_\phi|$= 12 - 21

f = 30 MHz, w/o NBI, H 2%

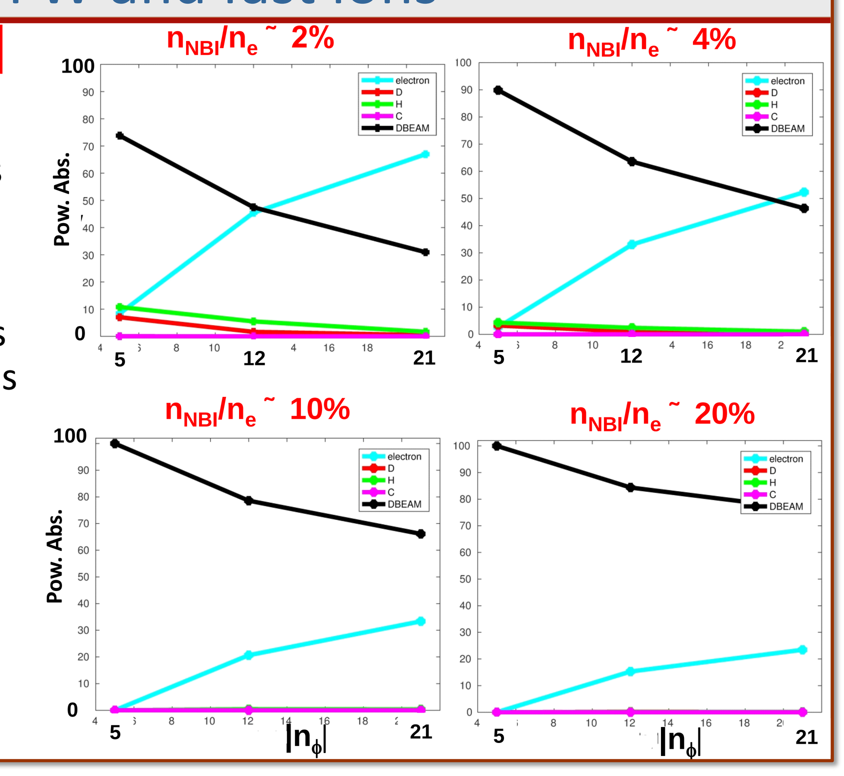
- Thermal D abs. can be significant at higher density and for Ti > Te
- H can play a role for low Te and high density
- For 60 MHz (not shown):
  - Large electron abs. even for low $|n_\phi|$ w.r.t. 30 MHz
  - Up to 45% H abs. for $T_i > T_e$



NBI fraction scan: Strong interaction between FW and fast ions

f = 30 MHz, w/ NBI, H 2%

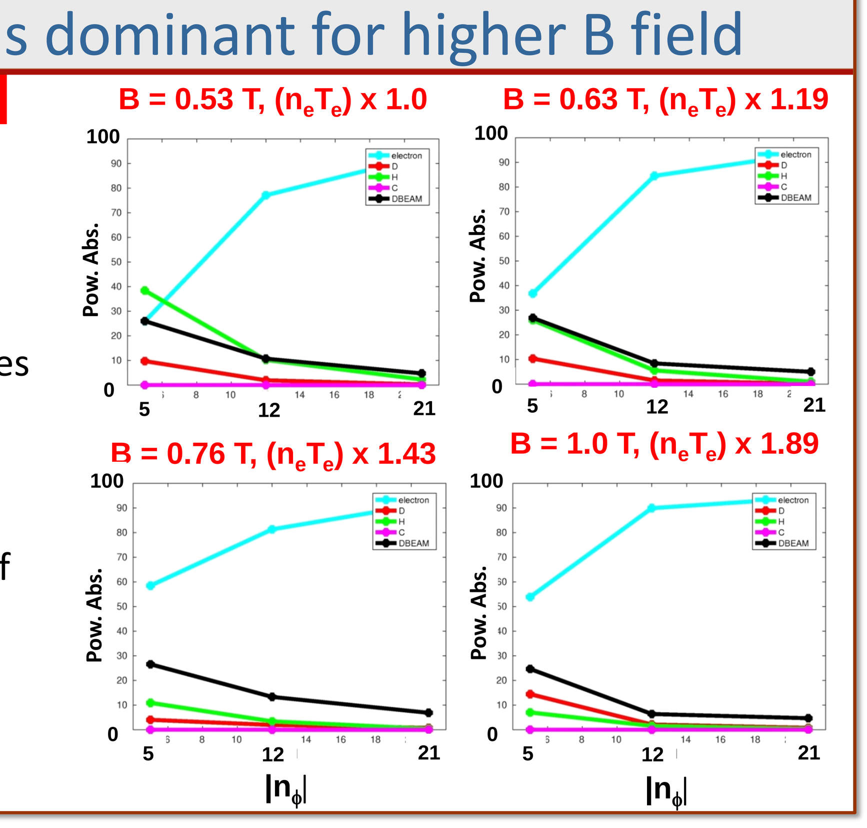
- Maxwellian fast ions (T_{eff} ˜ 25 keV)
- For n_{NBI}/n_e > 4%: most of the power is absorbed by fast ions for every n_ϕ
- No role of H
- To get electron damping: launch $|n_\phi|$ = 21



B_T Scan with constant beta-e: electron damping is dominant for higher B field

f = 30MHz, w/ NBI, H 2%

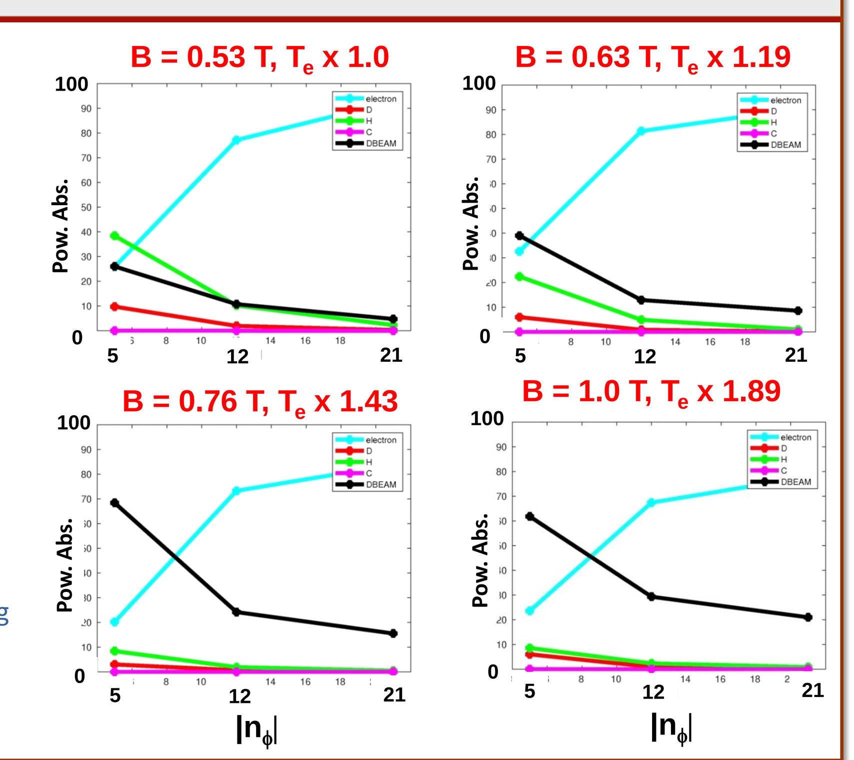
- β_e constant
- Same flux surface geometry for all cases
- H damping is higher with lower B and n_ϕ
- No significant role of D and fast ions



B_T Scan: T_e increases with B values

f = 30MHz, w/ NBI, H 2%

- Same n_e for all cases
- Same flux surface geometry for all cases
- No role of thermal D
- H damping can be significant for lower B & lower n_ϕ
- Significant fast ions absorption for B = 1 T
  - However, electron damping is dominant for $|n_\phi|$= 12



Conclusions

- A series of full wave AORSA simulations has been performed for NSTX-U B = 1 T scenarios
  - H concentration scan
  - T_e & n_e scans with β_e constant
  - n_{NBI} scan
  - B scan with β_e constant
  - B scan with T_e increases with B
- H has no significant role for 30MHz+NBI (large n_ϕ) & 60MHz. However, it can play an important role for 30MHz w/o NBI
  - Not included here non-Maxwellian H tail (future work)
- 60MHz has generally higher electron damping without NBI
- Significant interaction is found between fast waves and fast ions
- Higher field and higher temperature should increase the antenna coupling and the electron damping