NSTX-U

NSTX-U is sponsored by the
U.S. Department of Energy Office of Science
Fusion Energy Sciences

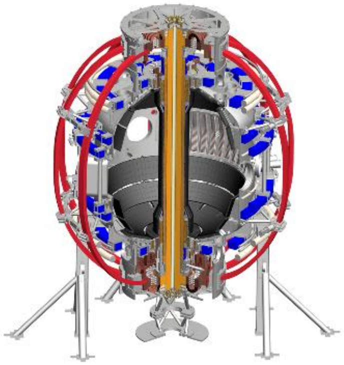
Effects of the H species in the HHFW performance in NSTX/NSTX-U

Nicola Bertelli

E.F. Jaeger (XCEL), R. W. Harvey (CompX), J.C. Hosea, E.-H. Kim, R.J. Perkins, G. Taylor, and E.J. Valeo, (PPPL)

APS-DPP 2017

PPPL



Abstract

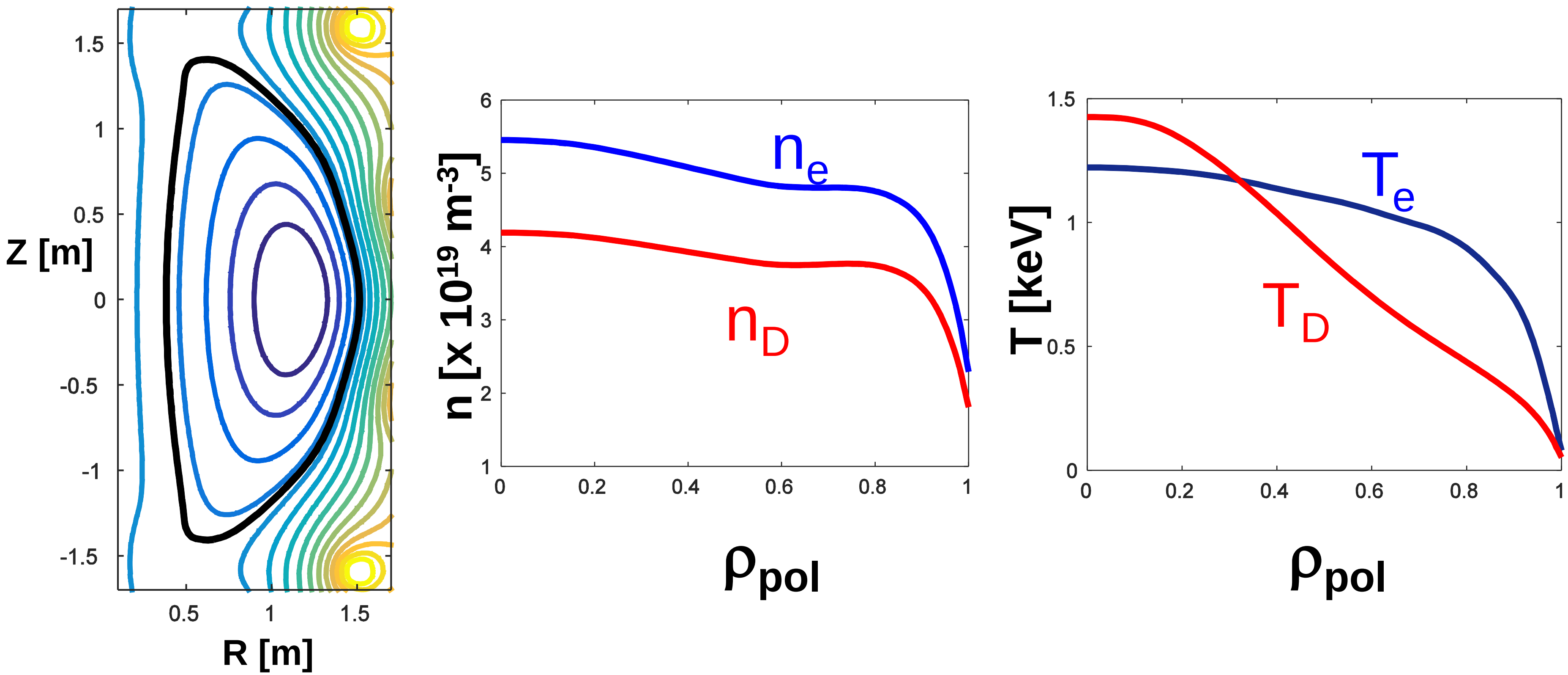
One of the goal of NSTX-U is to operate at full eld (B = 1 T). For this magnetic field, the first and second harmonics of hydrogen (H) are located at the high-field side and in the core plasma, respectively. In principle, part of the high-harmonic fast-wave (HHFW) injected power can be absorbed by the H population reducing the electron and/or the fast-ion heating. For this reason, full wave simulations results of NSTX-U scenarios with different H concentrations for wave frequencies of 30 and 60 MHz will be presented and discussed. Plasma scenarios with and without neutral beam injection (NBI) will be considered. Furthermore, the balance between the beam ion and electron power absorption will be analyzed comparing both NSTX and NSTX-U plasmas.

Outline

- NSTX-U "Scenarios" considered
- Antenna frequency = 30 MHz
  - H Concentration scan
    - w/ & w/o NBI
- Antenna frequency = 60 MHz
  - H concentration scan
    - w/ and w/o NBI

NSTX-U "Scenarios" considered (1)

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



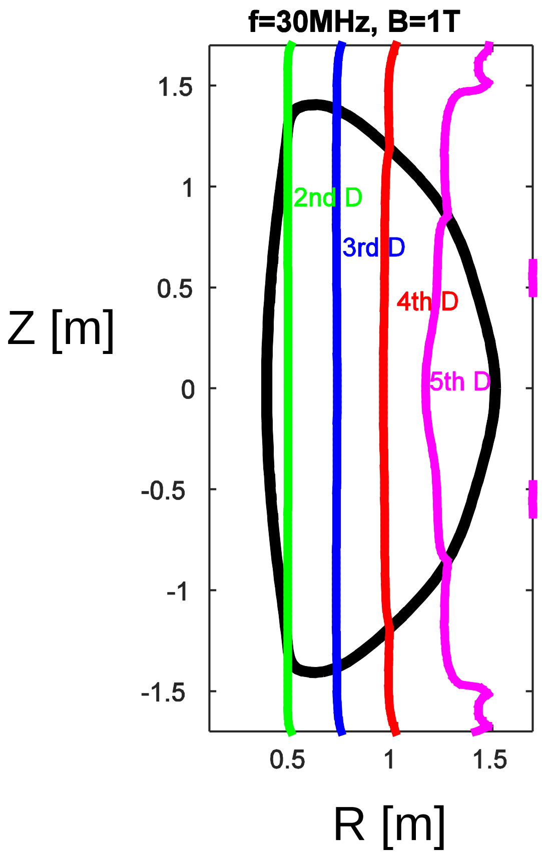
NSTX-U “Scenarios” considered (2)

- NSTX-U plasma
  - B = 1T
- H concentration scan:
  - $n_H / n_e = 1\%$
  - $n_H / n_e = 2\%$
  - $n_H / n_e = 5\%$
  - $n_H / n_e = 10\%$
- w/ and w/o NBI
- Two antenna frequencies
  - 30 MHz and 60 MHz
- Three nphi values: -5, -12, -21
- Employed full wave code AORSA

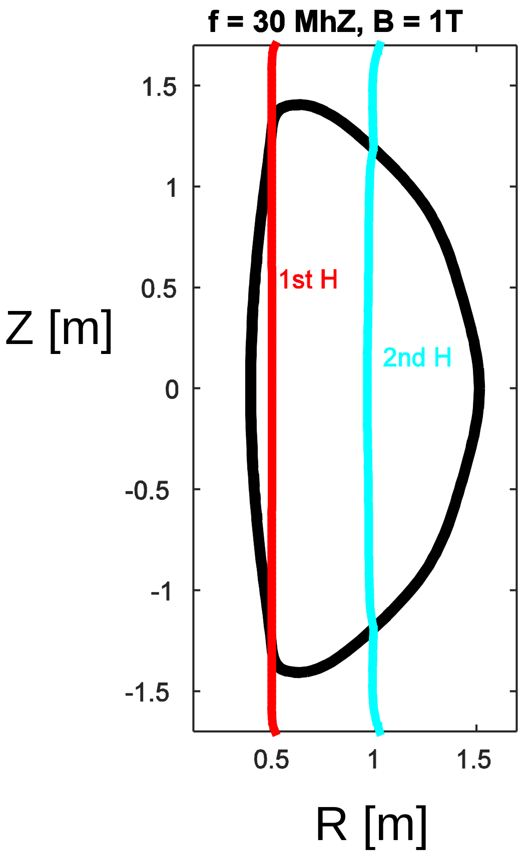
NSTX-U "Scenarios" considered (3)

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

D resonances

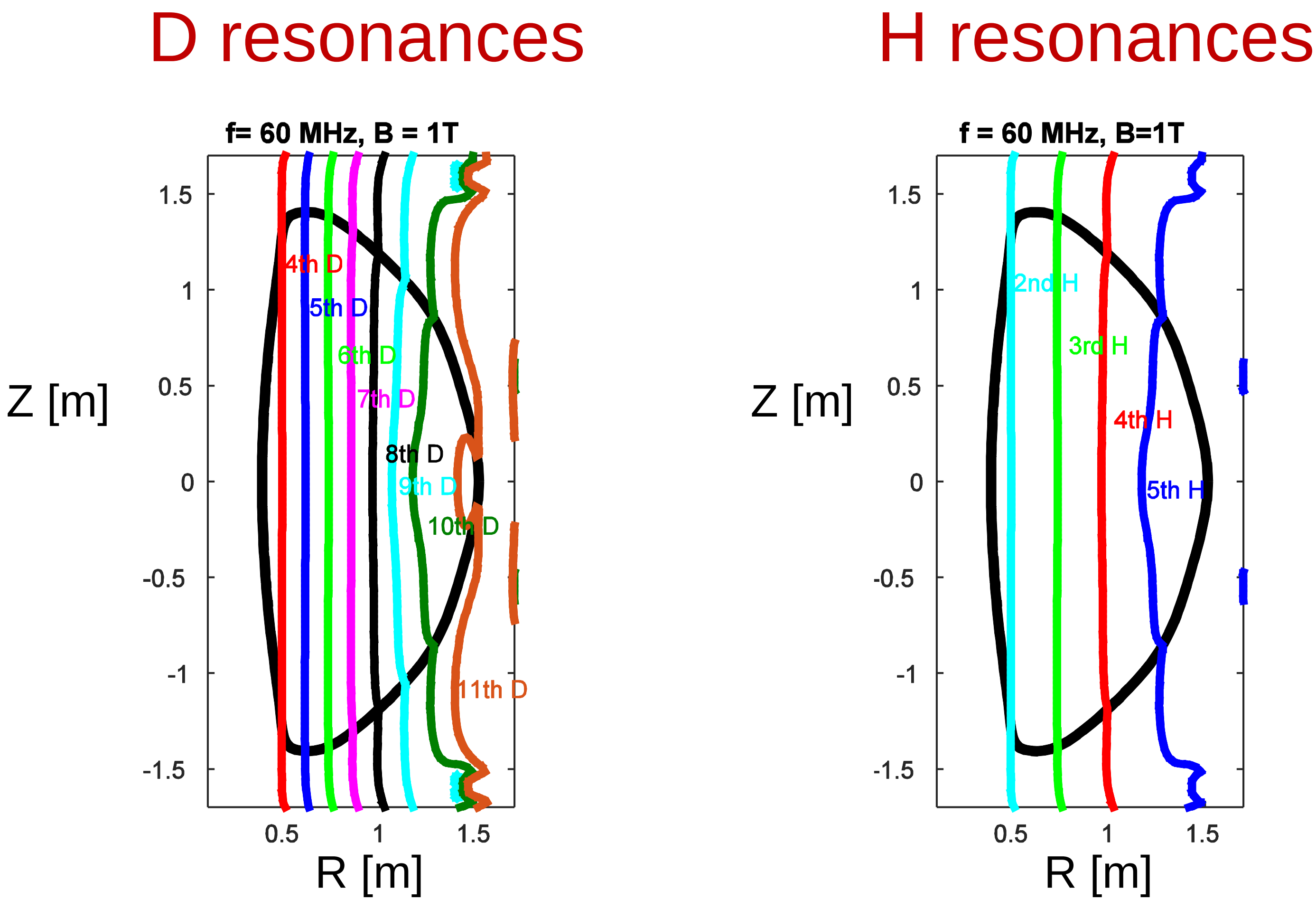


H resonances



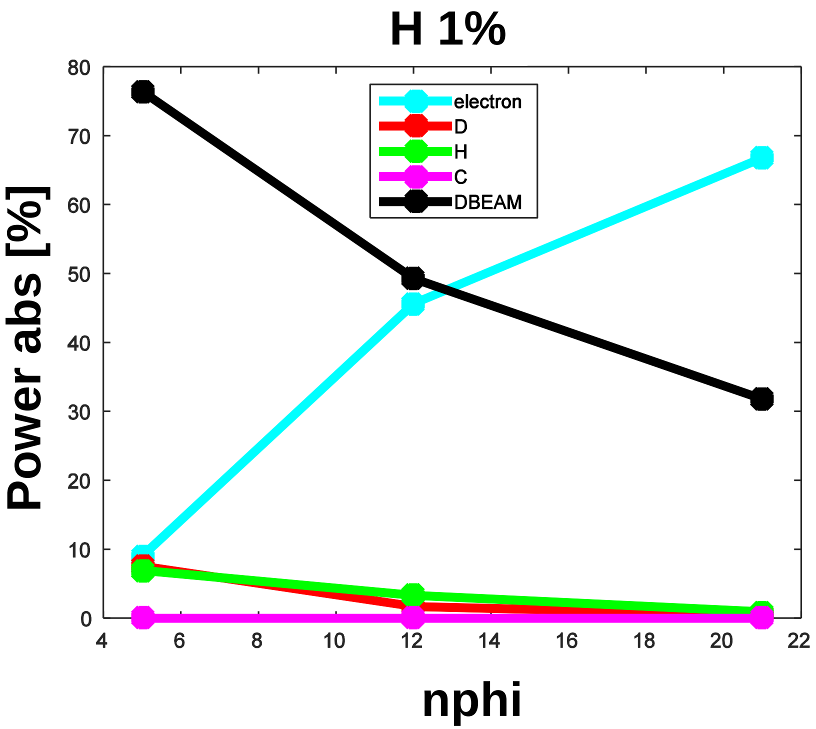
NSTX-U "Scenarios" considered (4)

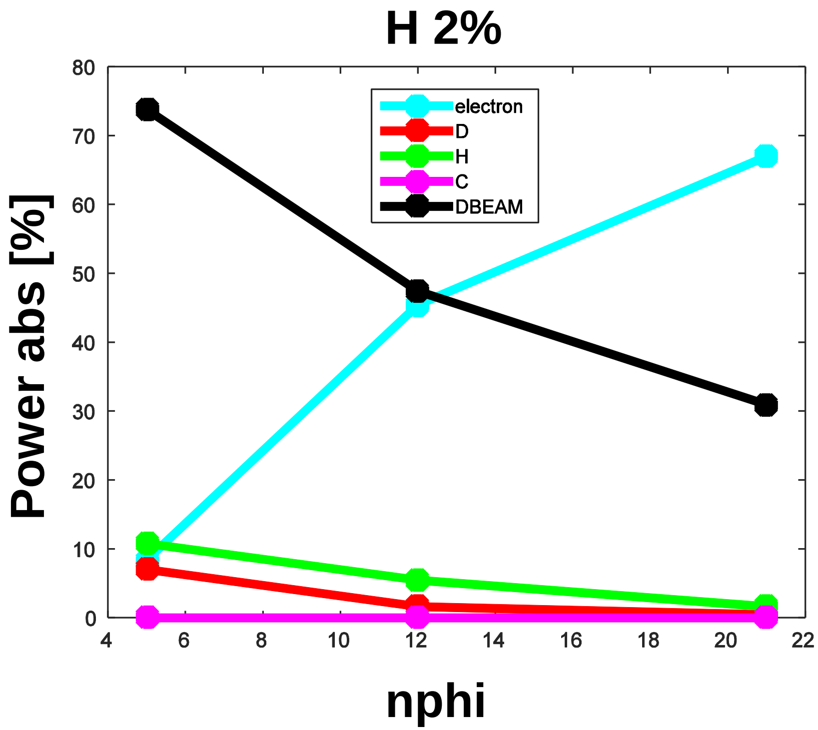
- NSTX-U plasma: **B = 1 T and f = 60 MHz**



f = 30 MHz, H 1%, 2%, 5% and 10% with NBI

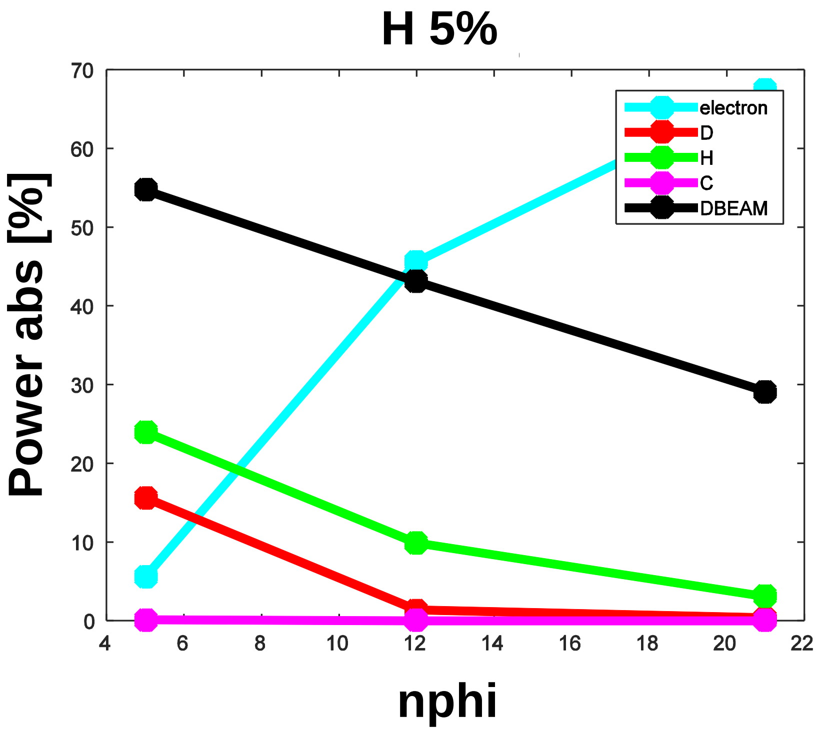
Power absorption vs. toroidal wave number

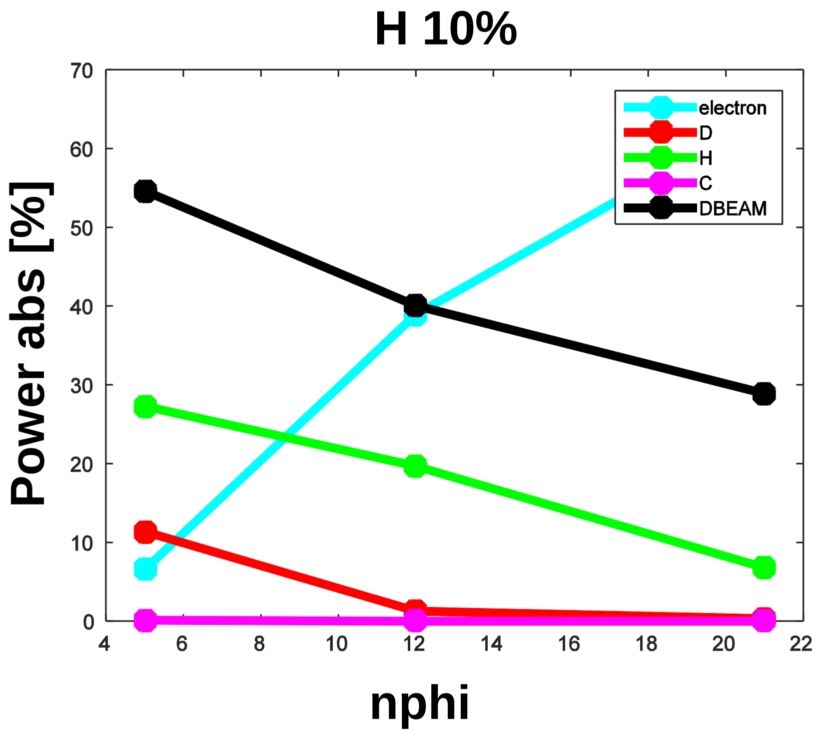




- Electron absorption increases with larger nphi
- (Fast) Ion abs. decreases with larger nphi
- Not significant H power absorption for H 1% & 2%

Power absorption vs. toroidal wave number



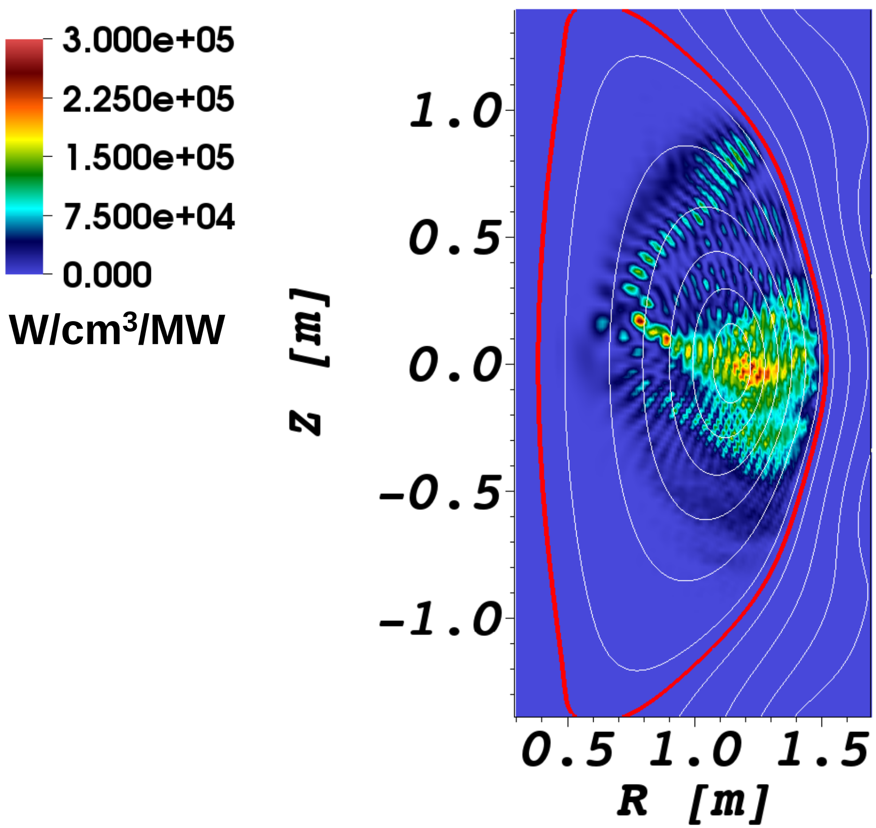


- Not significant H power absorption for 5%
  - except for nphi = |5| & H 10% and nphi = -5)
- The "heating phase" (nphi = |21|) is quite good for electron absorption

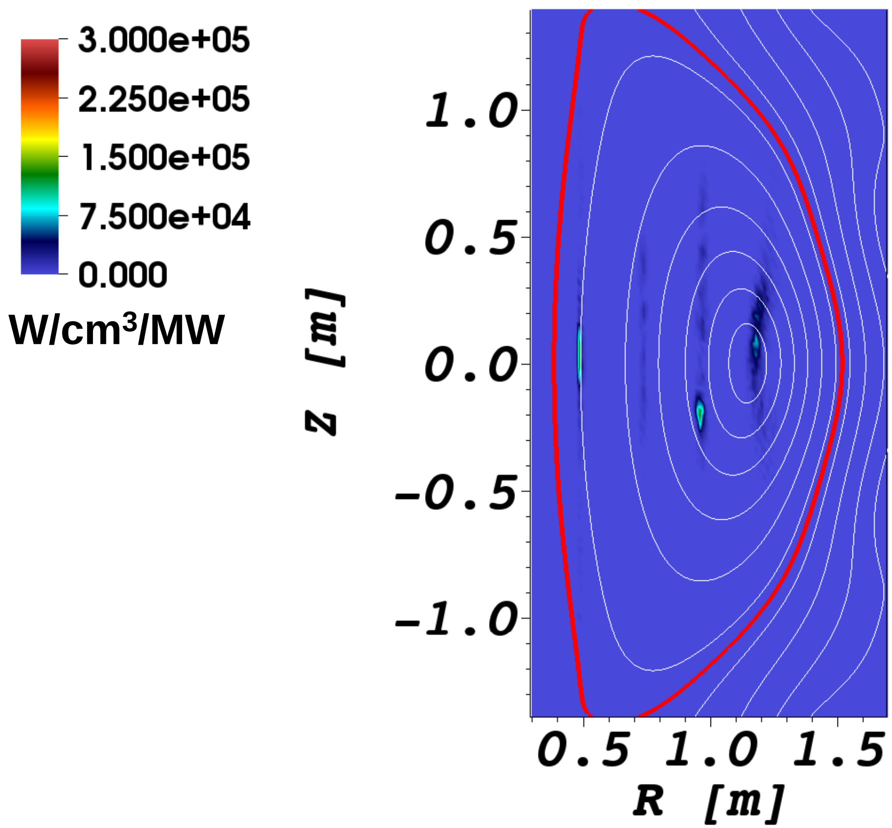
2D Power deposition profiles (1)

10% H concentration case & nphi = -12

Electron power deposition



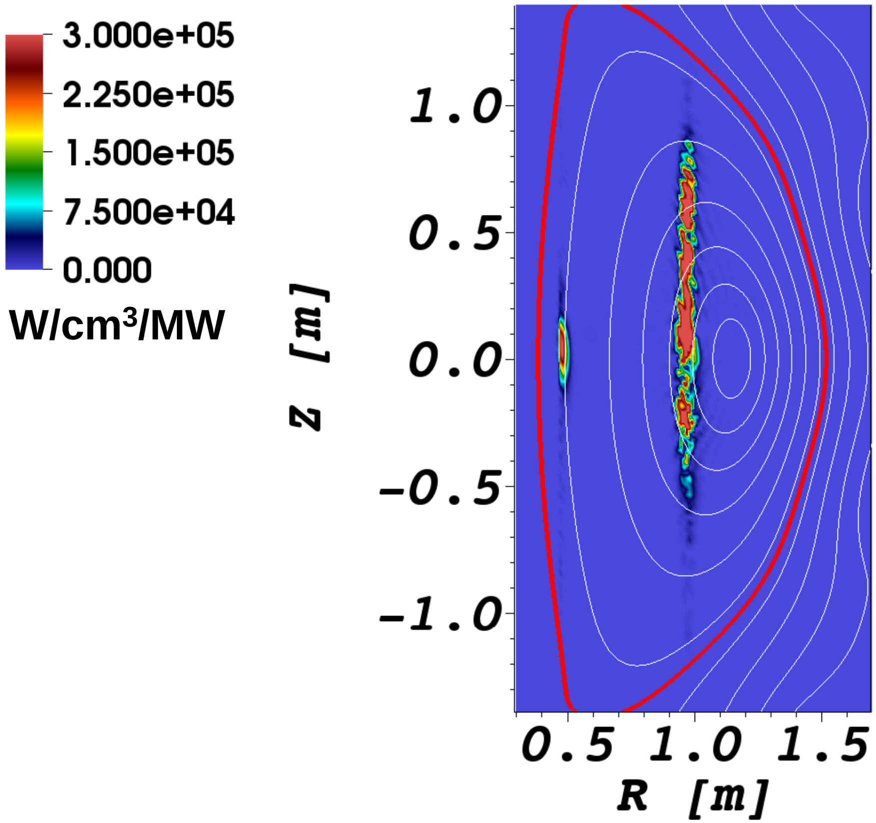
D thermal power deposition



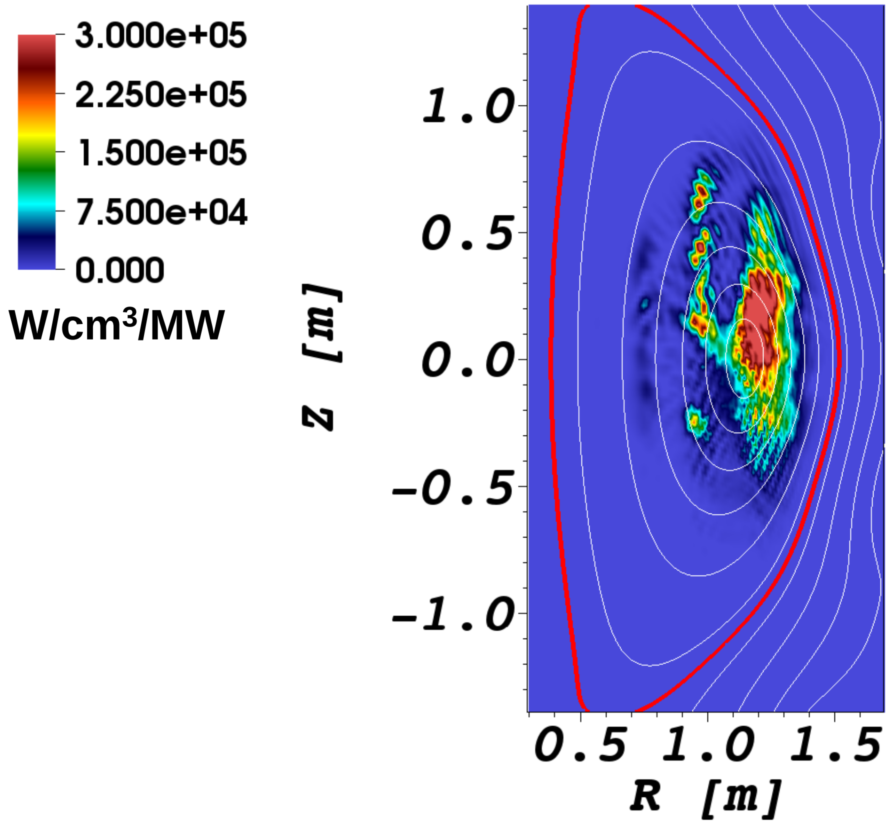
2D Power deposition profiles (2)

10% H concentration case & nphi = -12

H power deposition



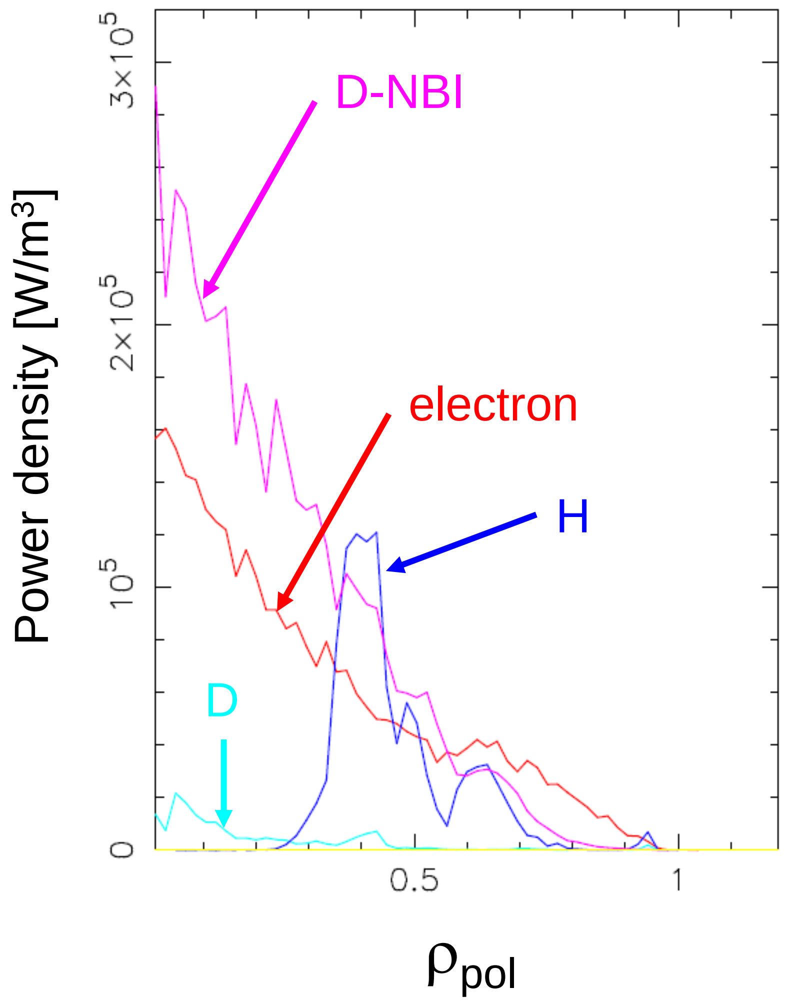
D-NBI power deposition



Flux surface avg deposition profiles

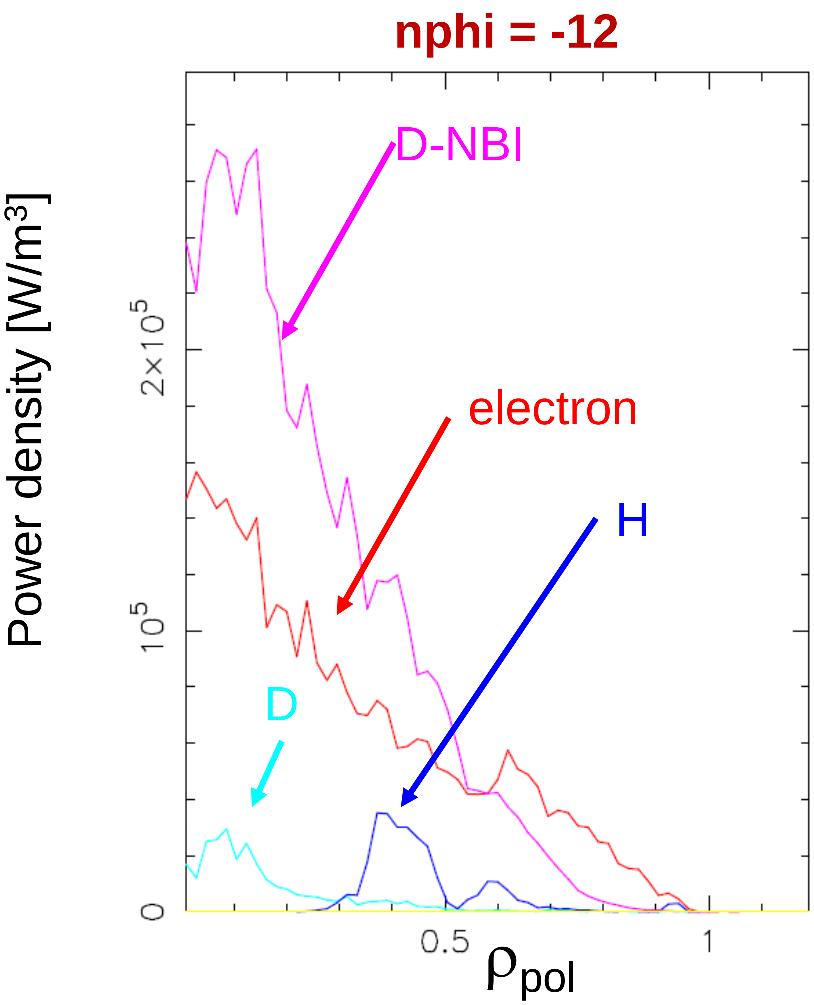
10% H concentration case & nphi = -12

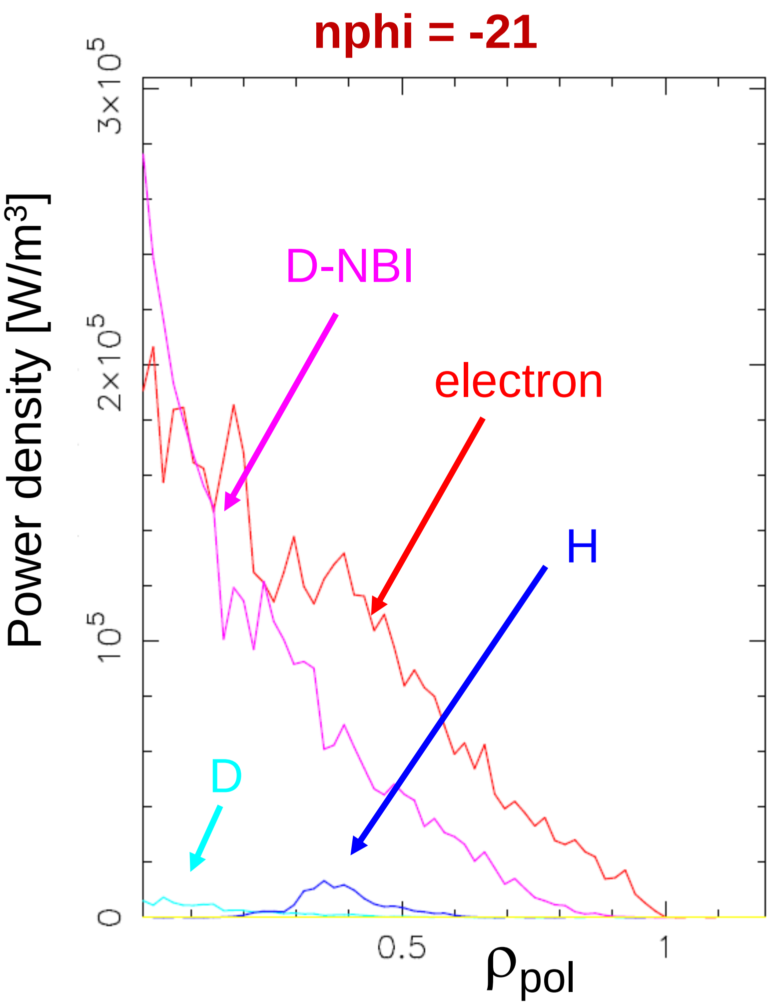
- Electron & D-NBI power depositions peaked on axis
- H power deposition localizedon 2nd H resonance
- Thermal D & C are basically negligible



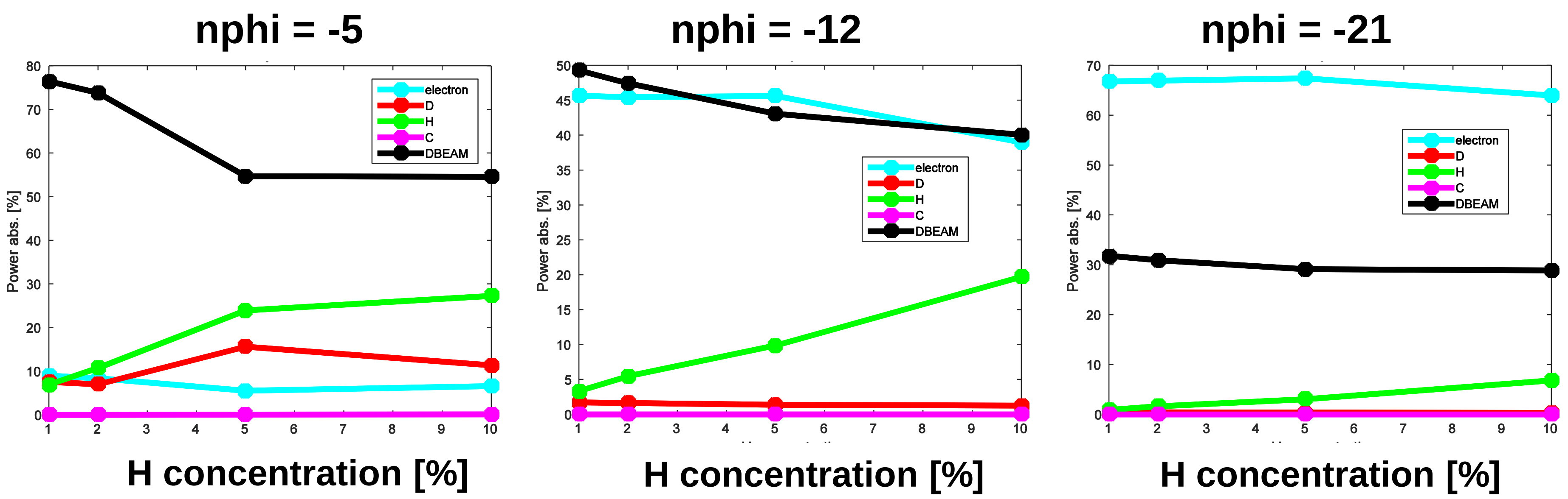
Flux surface avg. deposition profiles

2% H concentration





Power absorption vs. H concentration

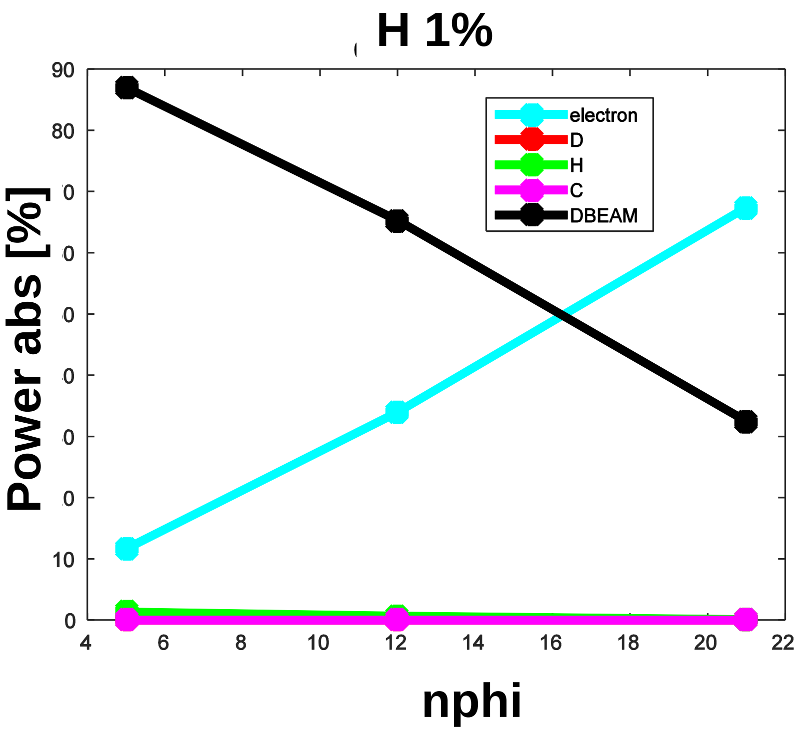


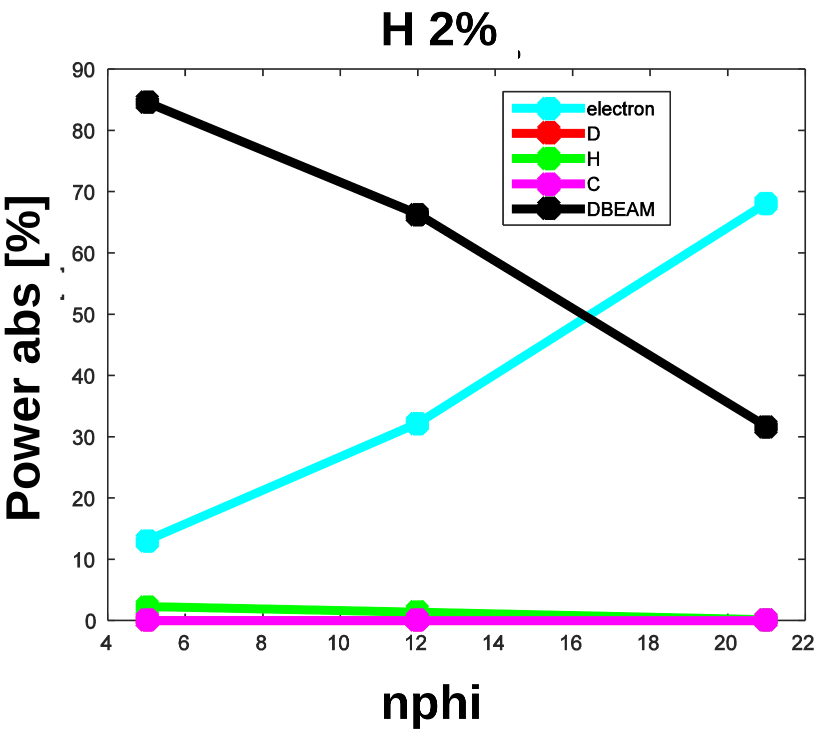
- H power absorption increases with larger H concentration and decreases for larger nphi

- In general, no significant impact by H concentration
  - nphi = -21 case is basically independent from H concentration

f = 60 MHz, H 1%, 2%, 5% and 10% with NBI

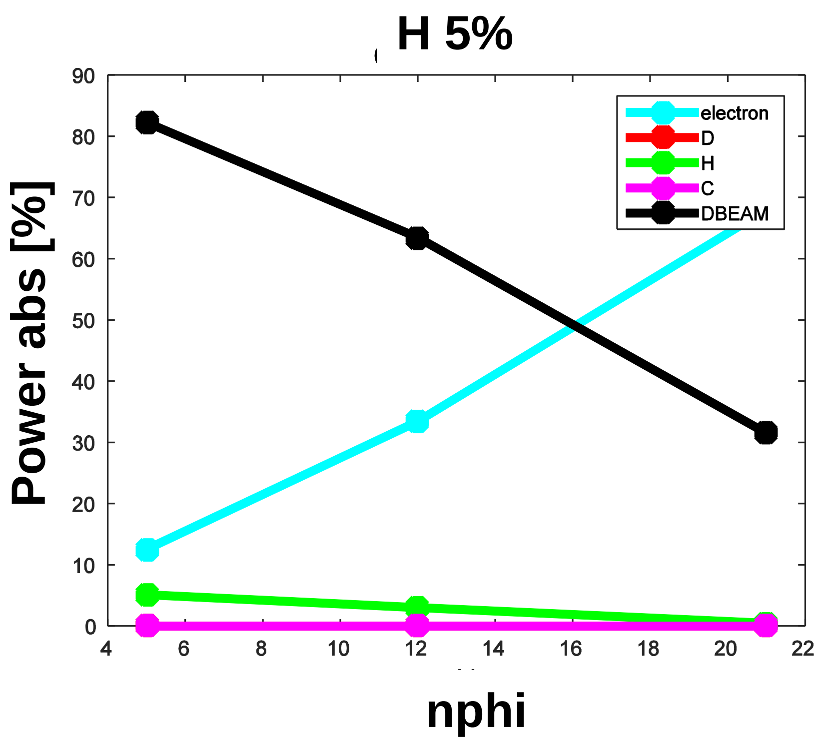
Power absorption vs. nphi

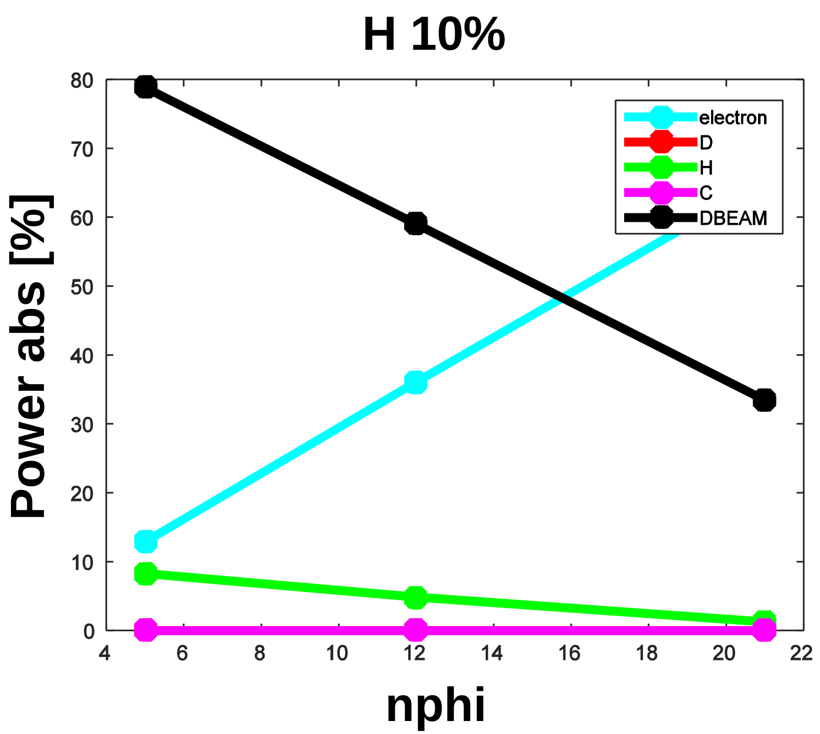




- Similar conclusions as f=30 MHz case
  - Electron absorption increases with larger nphi
  - (Fast) Ion absorption decreases with larger nphi

Power absorption vs. nphi

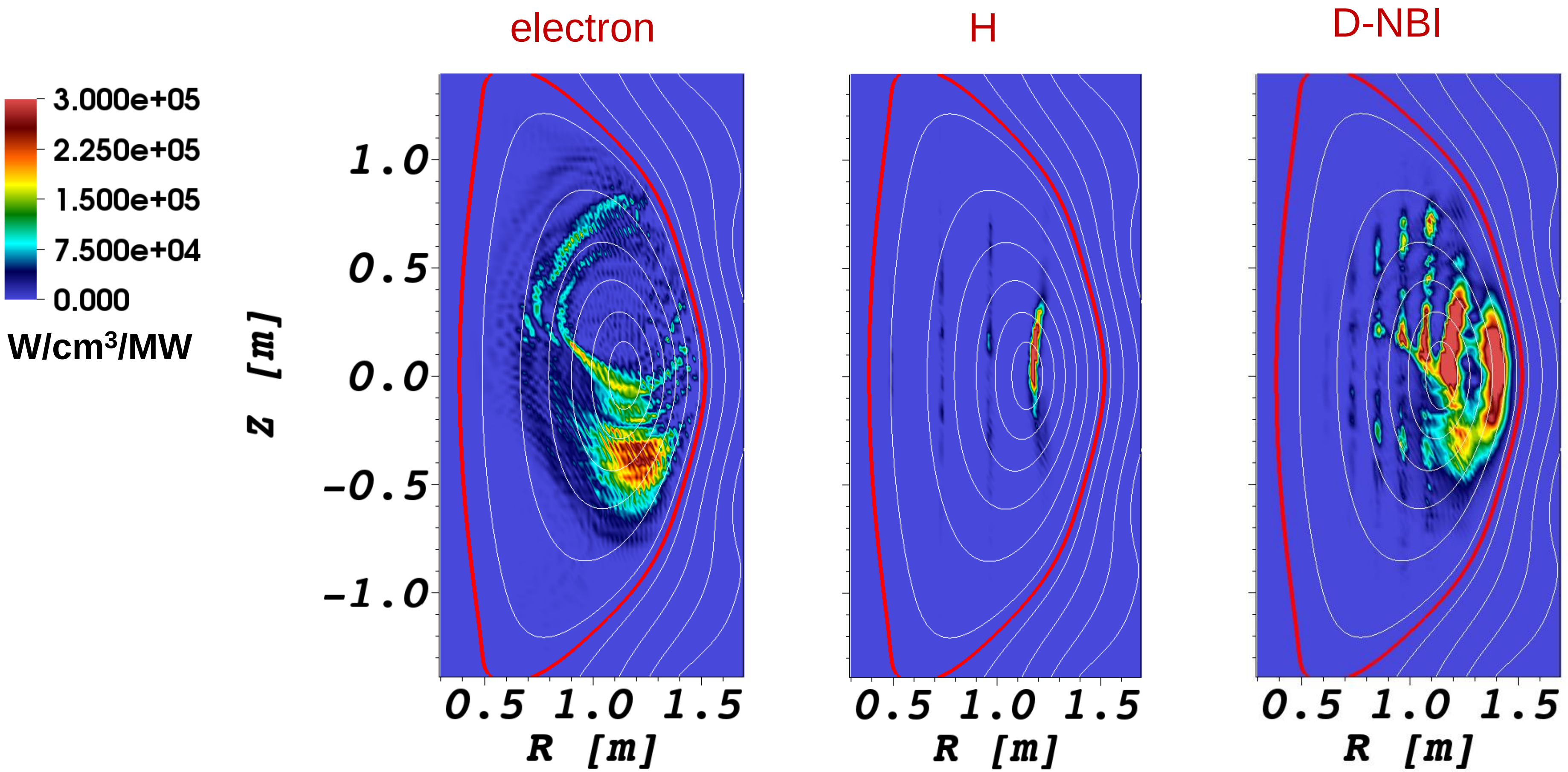




- H abs. increases with larger H concentration
- nphi = -21 (“heating phase”) is quite good for electron abs.
- No D & C contributions

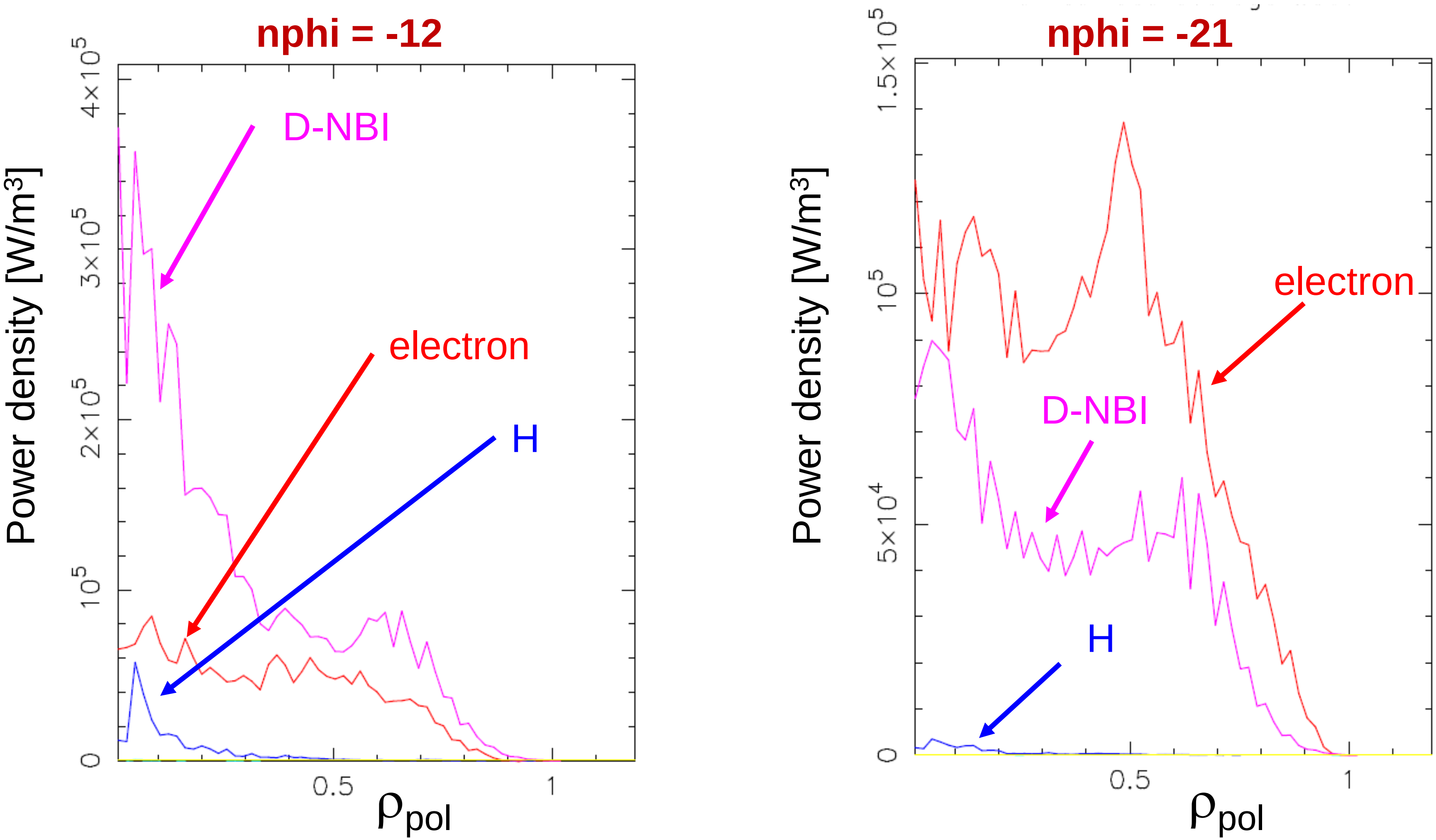
2D Power deposition profiles (1)

10% H concentration case & nphi = -12

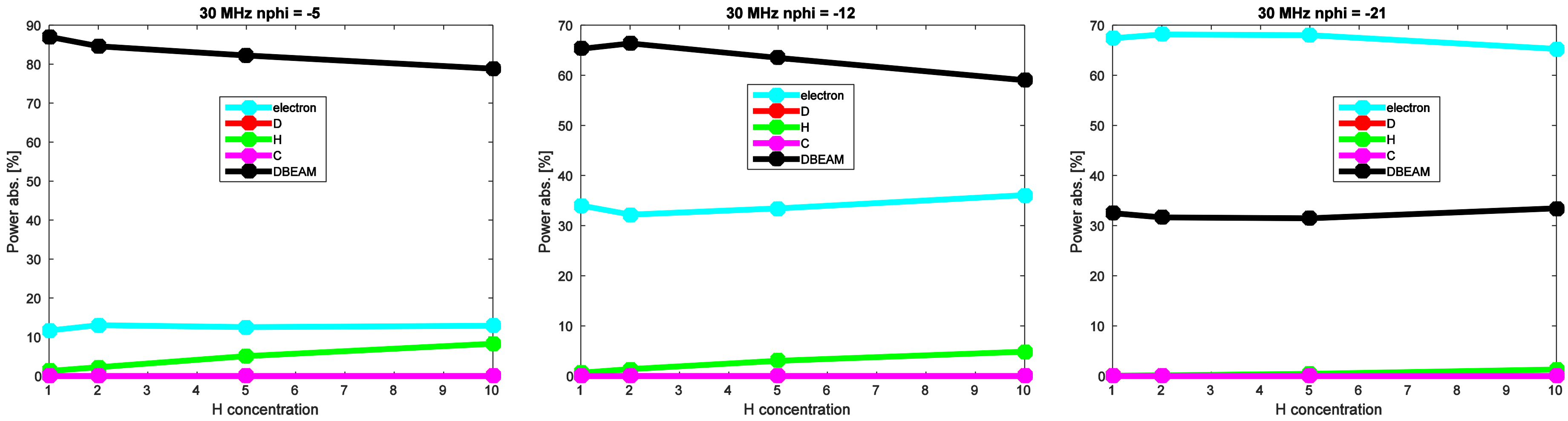


Flux surface avg. deposition profiles

2% H concentration



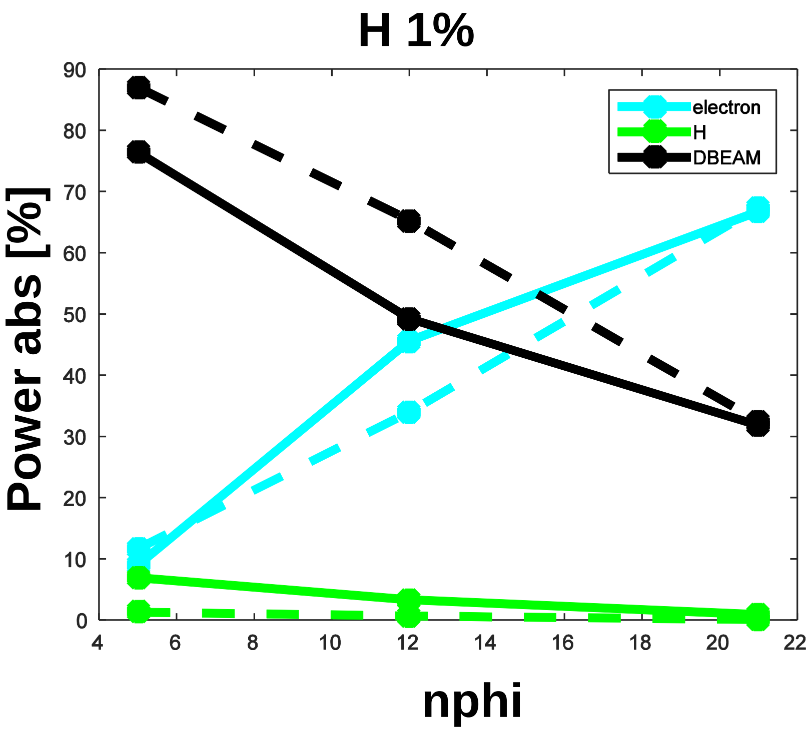
Power abs. vs. H concentration

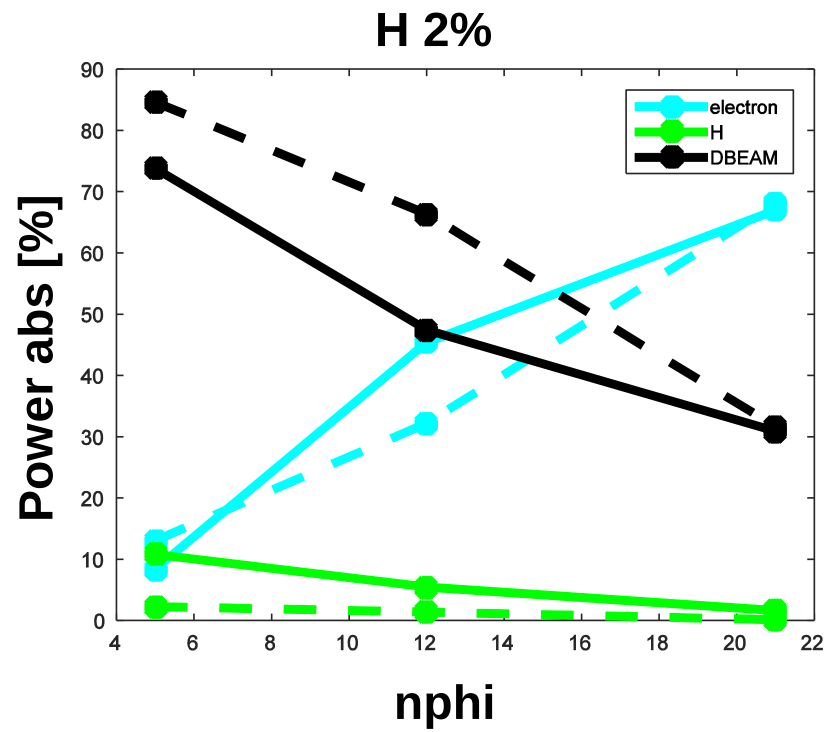


- H abs increases with larger H concentration and decreases for larger nphi
- Power abs. is almost independent from H concentration

Comparison between f = 30 and 60 MHz H 1%, 2%, 5% and 10% with NBI

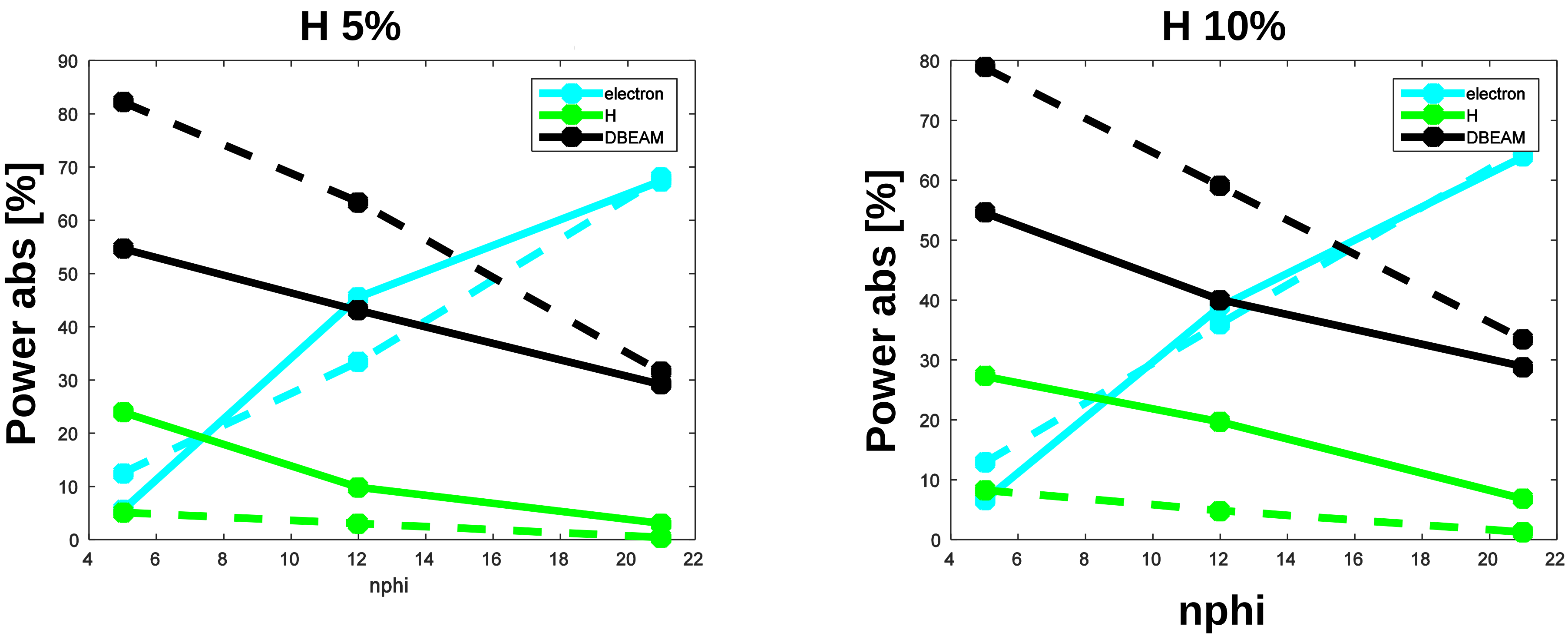
Power absorption vs. nphi (f = 30MHz solid, f = 60MHz dashed curves)





- 60 MHz case has higher fast ion abs. than 30 MHz case for nphi = -5 and -12
- For nphi = -21, power abs. very similar between two cases

Power abs. vs. nphi (f = 30MHz solid, f = 60MHz dashed curves)



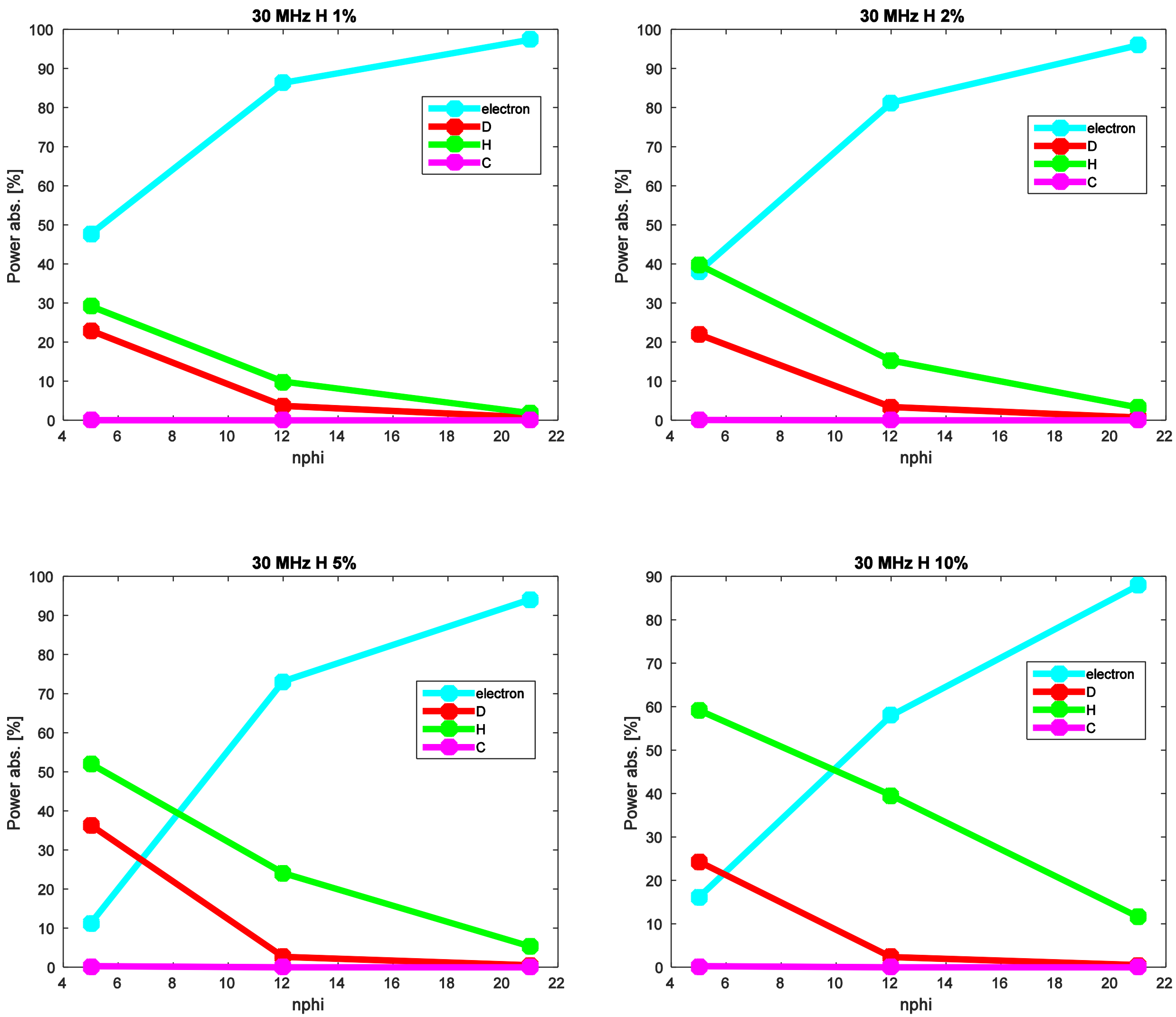
- Small H power absorption except for 10% concentration and lower nphi

Conclusions for f = 30 and 60 MHz with NBI

- Current drive phase (i.e, nphi = - 5) it seems to be bad
- Large electron damping for nphi = -21 (i.e. heating phase)
  - however, ~30% of power to fast ions
  - NO significant differences between f = 30 and 60 MHz
- For nphi = -5 and -12, higher fast ions abs. for 60 MHz case than 30MHz case
- H absorption is significant (~10-30%) at low nphi and high H concentration (> 5%)
- In principle, HHFW might modify either the electron or the ion temperature (through H species)
  - Could be interesting for transport studies
  - See cases without NBI below

f = 30 MHz, H 1%, 2%, 5% and 10%
NO NBI

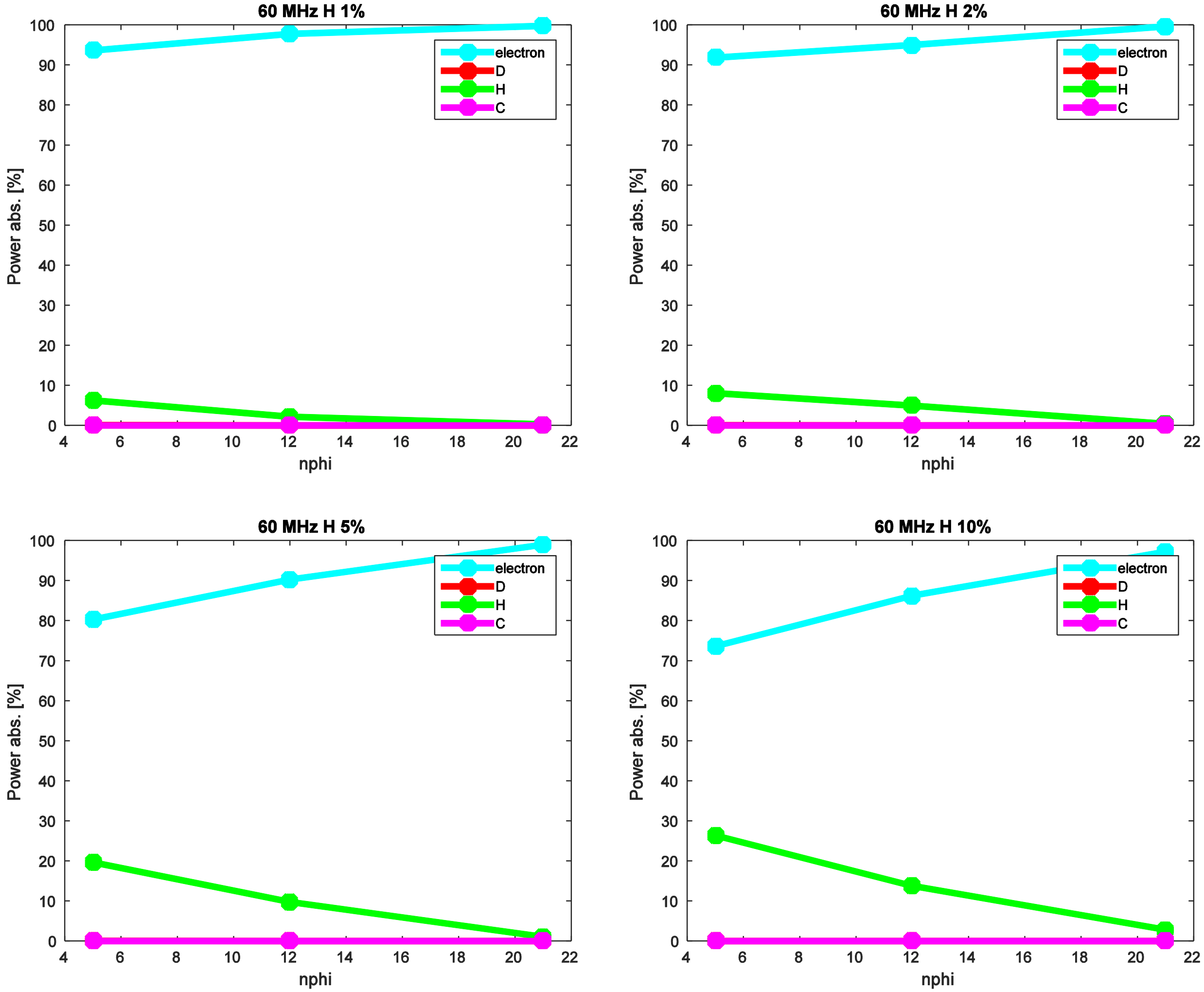
Power absorption vs. nphi



- For nphi = -12 and -21: dominant electron abs.
  - Except for H 10%
- Larger H absorption for higher H concentration
- Possible H ions accelaration due to HHFW

f = 60 MHz, H 1%, 2%, 5% and 10%
NO NBI

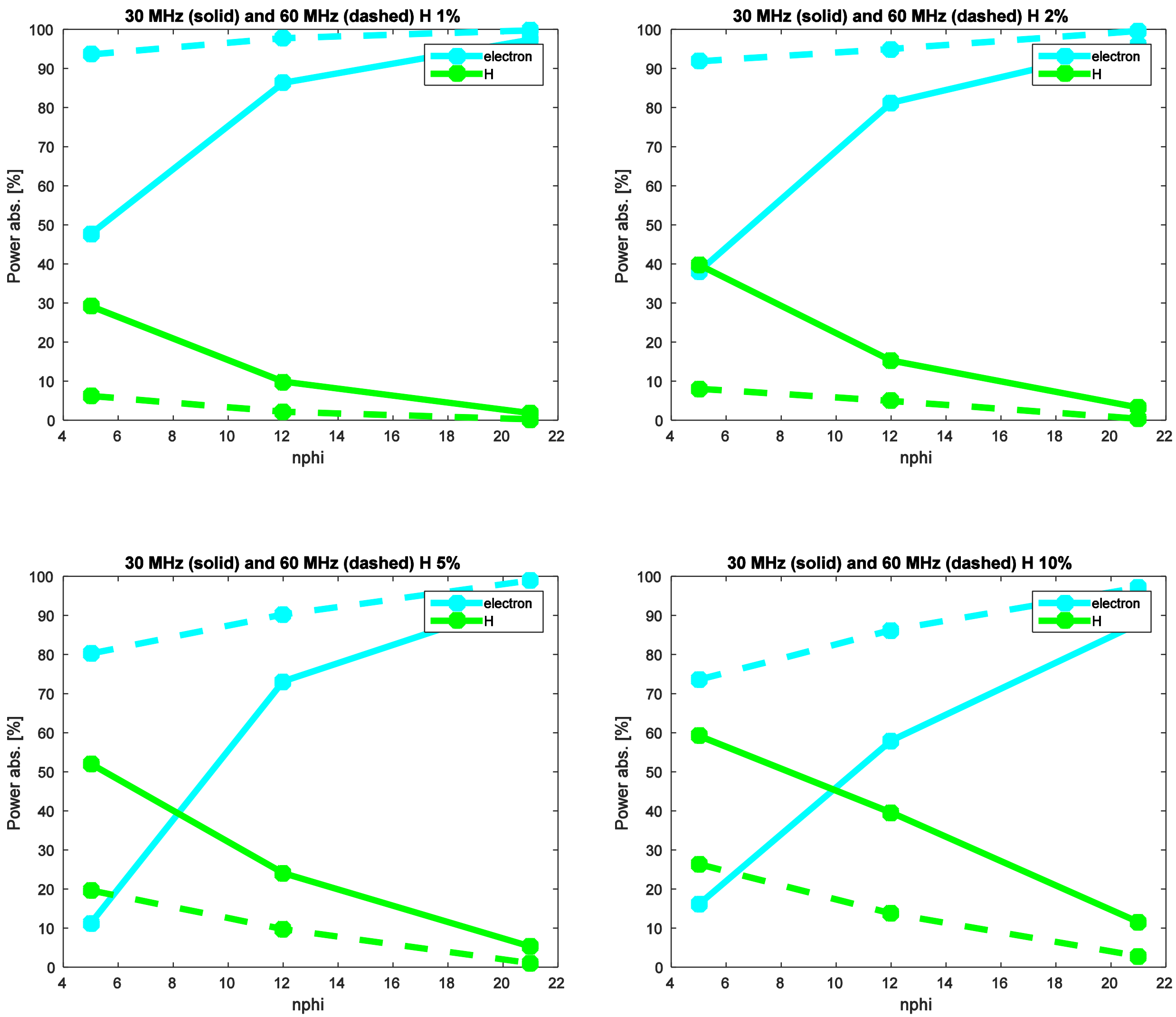
Power absorption vs. nphi



- Dominant electron abs. for all cases

Comparison between f = 30 and 60 MHz
H 1%, 2%, 5% and 10%
NO NBI

Power abs. vs. nphi (f = 30MHz solid, f = 60MHz dashed curves)



- Dominant electron abs. for all nphi for 60 MHZ case
- Significant H abs. for for nphi = -5 and -12 for 30MHz case

Conclusions for f = 30 and 60 MHz without NBI

- Large electron damping for all nphi for 60 MHz
- No significant differences between f = 30 and 60 MHz cases for nphi = -21
- Dominant H absorption for nphi = -5 and for 30 MHz case
- Dominant electron absorption for nphi = -12 and for 30 MHz case & H concentration < 5%

Future steps

- Additional AORSA simulations for NSTX-U scenarios concentration scan
  - B scan
  - H concentration scan
  - Temperature and density “scan”
  - H plasma
  - w/ & w/o NBI
  - frequency = 15, 30, and 60 MHz
- AORSA runs for NSTX cases (one or two cases)
  - Temperature and density “scan”
  - H concentration scan
  - w/ & w/o NBI
- Repeat simulations above with AORSA+CQL3D
  - In case of H & NBI, consider both non-Maxwellian species