New concepts for RF heating of NCSX

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26 January 2001

Introduction

- RF heating concept originally advanced for the “saddle coil” incarnation of NCSX was constrained by:
  - Conformal shell with densely packed saddle coils
  - Limited outboard access for launchers
  - No inboard access at all
  - Need to avoid beam ion damping from Day 1
  - Desire to operate over a wide range of magnetic field
- Solution: High Frequency Fast Wave (HFFW)
  - 350 MHz direct electron heating (no ion interactions)
  - Folded waveguide launchers
  - New, klystron RF sources

Introduction

- Constraints have now changed
  - Modular coil set has modified access possibilities
    - » In particular, location of antennas on the high field side now conceivable
  - Ion heating is now desirable
  - Cost has become a more significant factor
    - » Check for the 350 MHz klystrons might bounce
- New solution:
  - Mode conversion with a **high field side launch**
  - Use 2 existing FMIT units to provide ~3 MW at 25 MHz (Day 0)
    - » Share with NSTX, retuning when switched between machines
  - Modify 2 more FMIT or other units for added 4 MW (7 MW total)
    - » New units can be reworked to operate at or below 20 MHz
    - » Several possible sources for these units

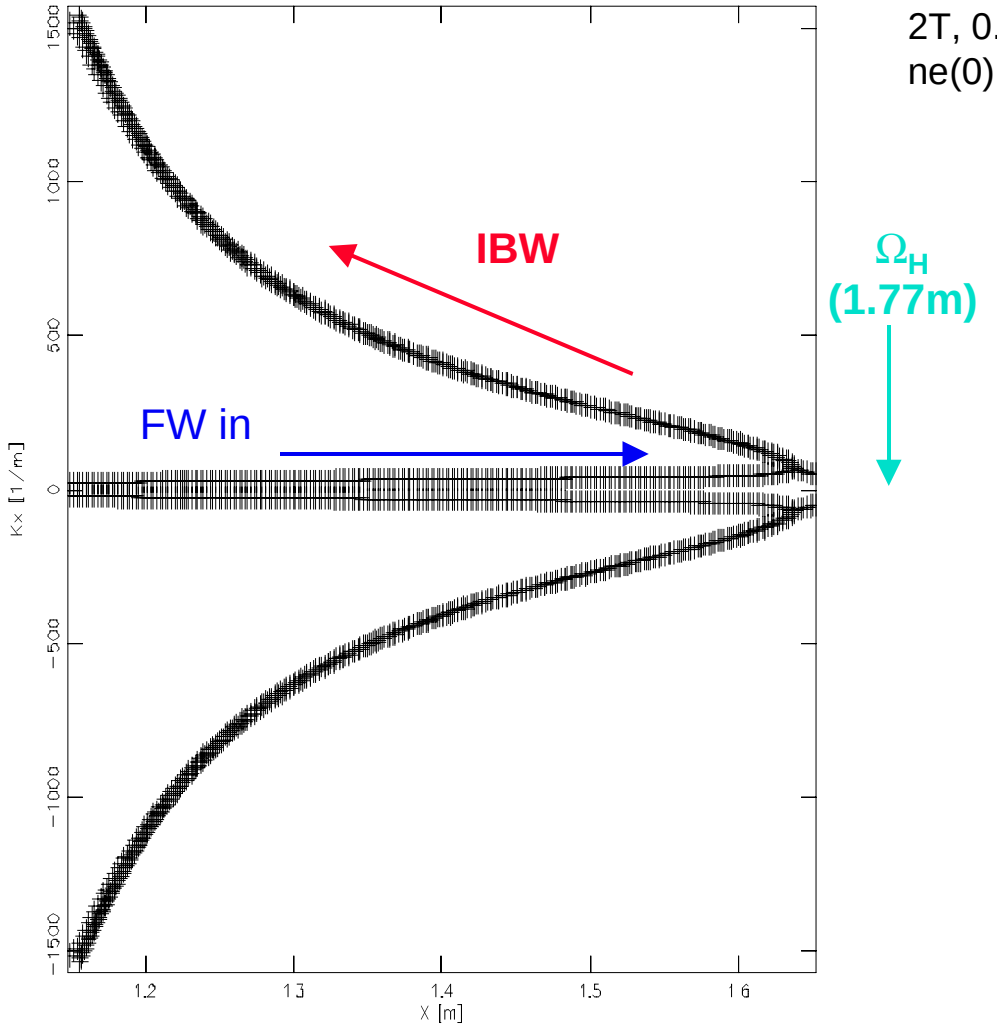
25 MHz operational constraints

- Present thoughts are that the existing tunable FMIT units will not operate below 25 MHz, and still retune to 30 MHz for NSTX
  - Lowest usable magnetic field for on-axis power deposition: 1.6 T.
    - » Places the hydrogen cyclotron fundamental on-axis
  - Lowest usable field for 30 MHz is 2 T
  - Unlike HFFW, the frequency of the rf sources must be tuned to the magnetic field
- Have already shown that absorption is too weak for direct electron heating in this frequency range
- Machine is somewhat small to rely on conventional minority hydrogen heating
- Most promising solution: mode conversion heating
  - Demonstrated on TFTR, C-mod, Asdex-U
  - Successful on Wendelstein, LHD, CHS (with a high field side launch)

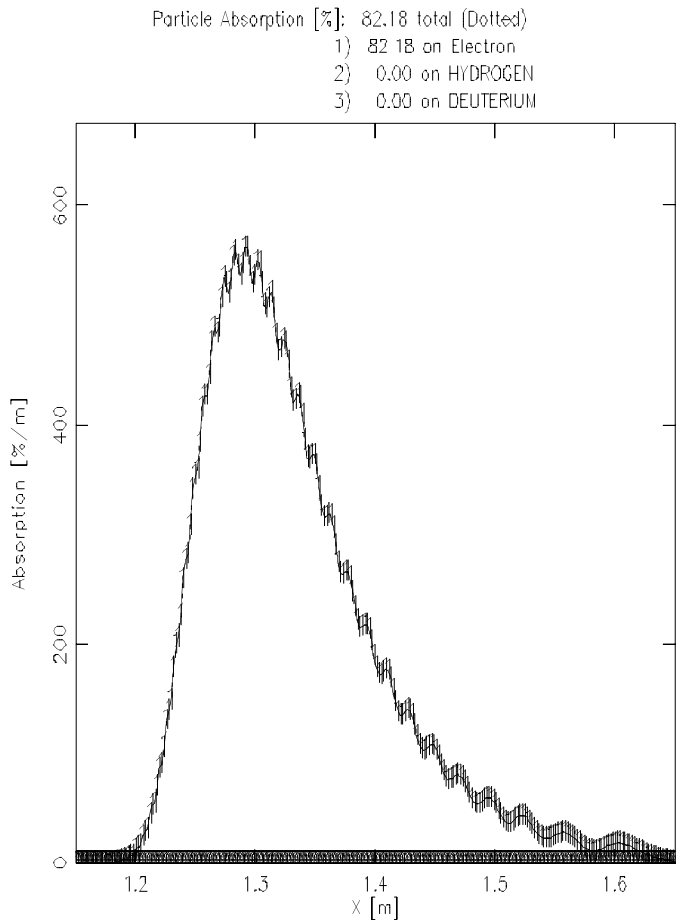
Mode conversion heating

- Mode conversion heating involves launch of a fast magnetosonic in a plasma which is a mix of two ion species
  - Fast wave is mode converted to a heavily damped ion Bernstein wave
  - Conversion occurs at the ion-ion hybrid layer
  - For a high field side launch, the fast wave has direct access to the slow (Bernstein) wave root
  - Expect 100% per pass absorption of the wave
- Have performed preliminary analyses with a 1-D hot plasma dispersion relation code, and with the 1-D full wave code METS95
- Good results with D-H, H - He3 mixes
  - Majority D/minority H provides electron heating with broad deposition profiles at ~2T.
  - Majority He3/ minority H for lowest magnetic field (~1.6T) operation
  - Minority He3/ majority H for high field (~2.2T) operation
    - » No significant absorption on H-beams

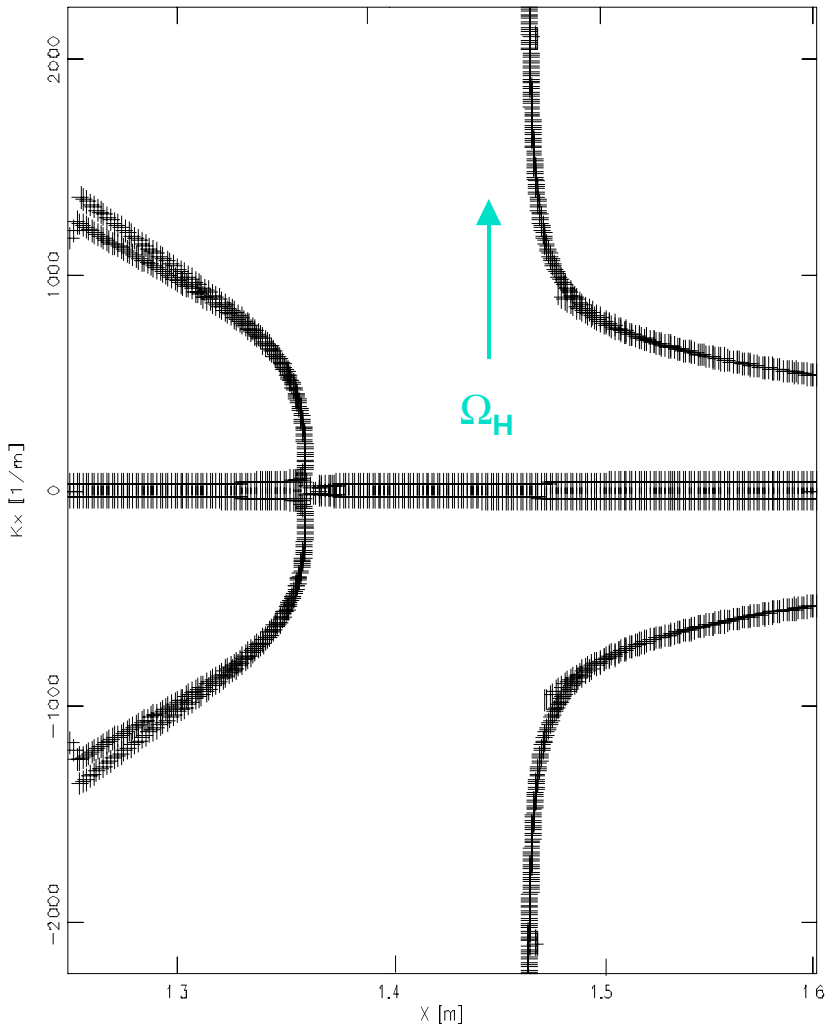
Mode conversion in 90%D/10%H can provide electron heating with broad deposition profiles



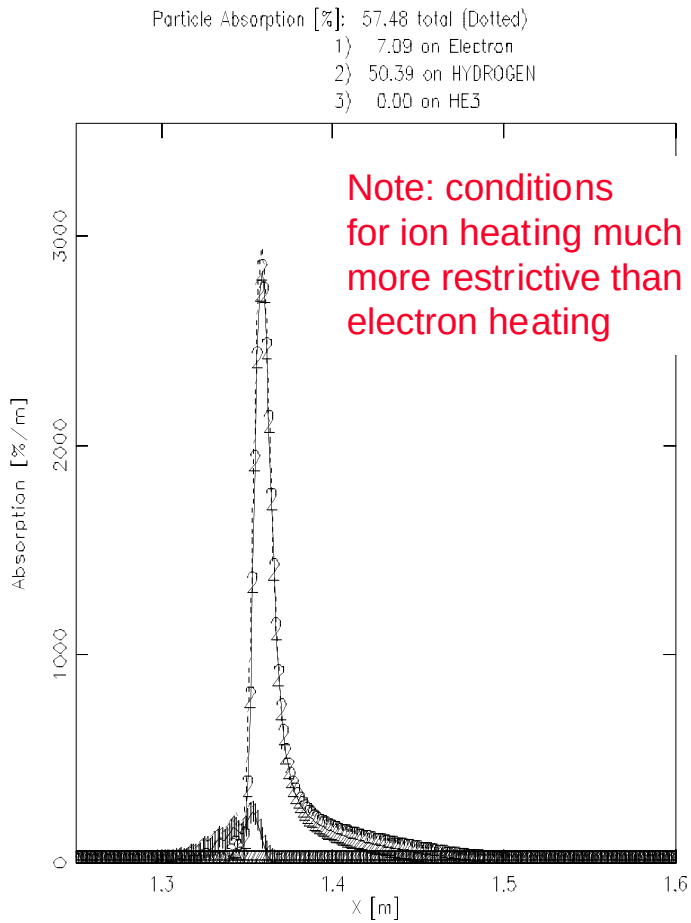
2T, 0.9D 0.1H, 25 MHz, Te(0) = 1 keV, ne(0) = 5e19, k_par = 9 inv. m



Mode conversion with minority H/majority He3 can provide central ion or electron heating at 1.6T (25 MHz launch)

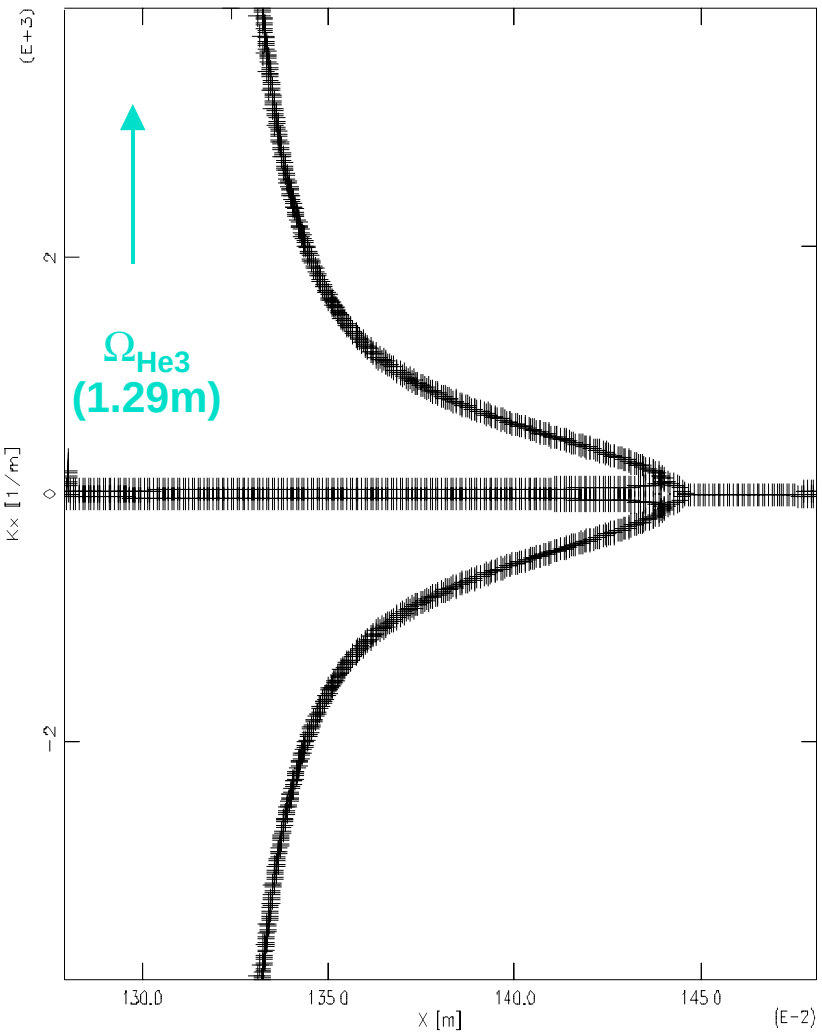


10% H ("high light ion minority" in He3, T_H = T_He3 = 1 keV, ne(0) = 5e19, B=1.6T, k_par = 12 (high!)

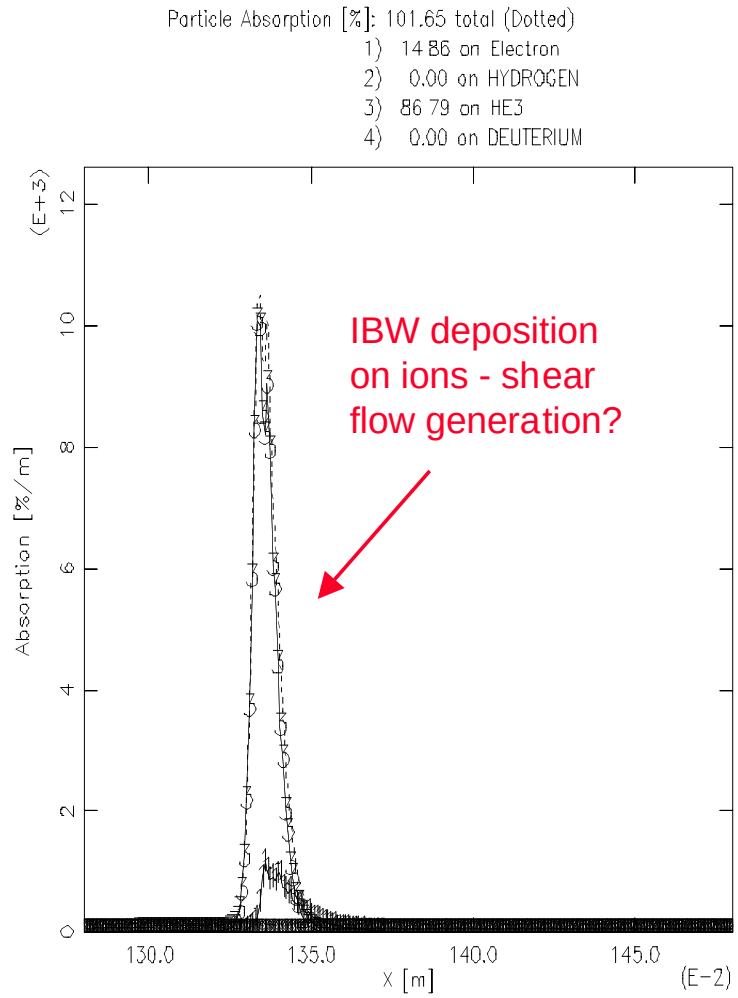


Note: conditions for ion heating much more restrictive than for electron heating

Majority H/minority He3 provides core ion or electron heating at higher fields (~2.2T)



10%He3 at 2.0 keV in 70% H at 1.0 keV (with an added 10% D impurity), ne(0) = 1e20, 2.2T, k_par = 6 inv. m

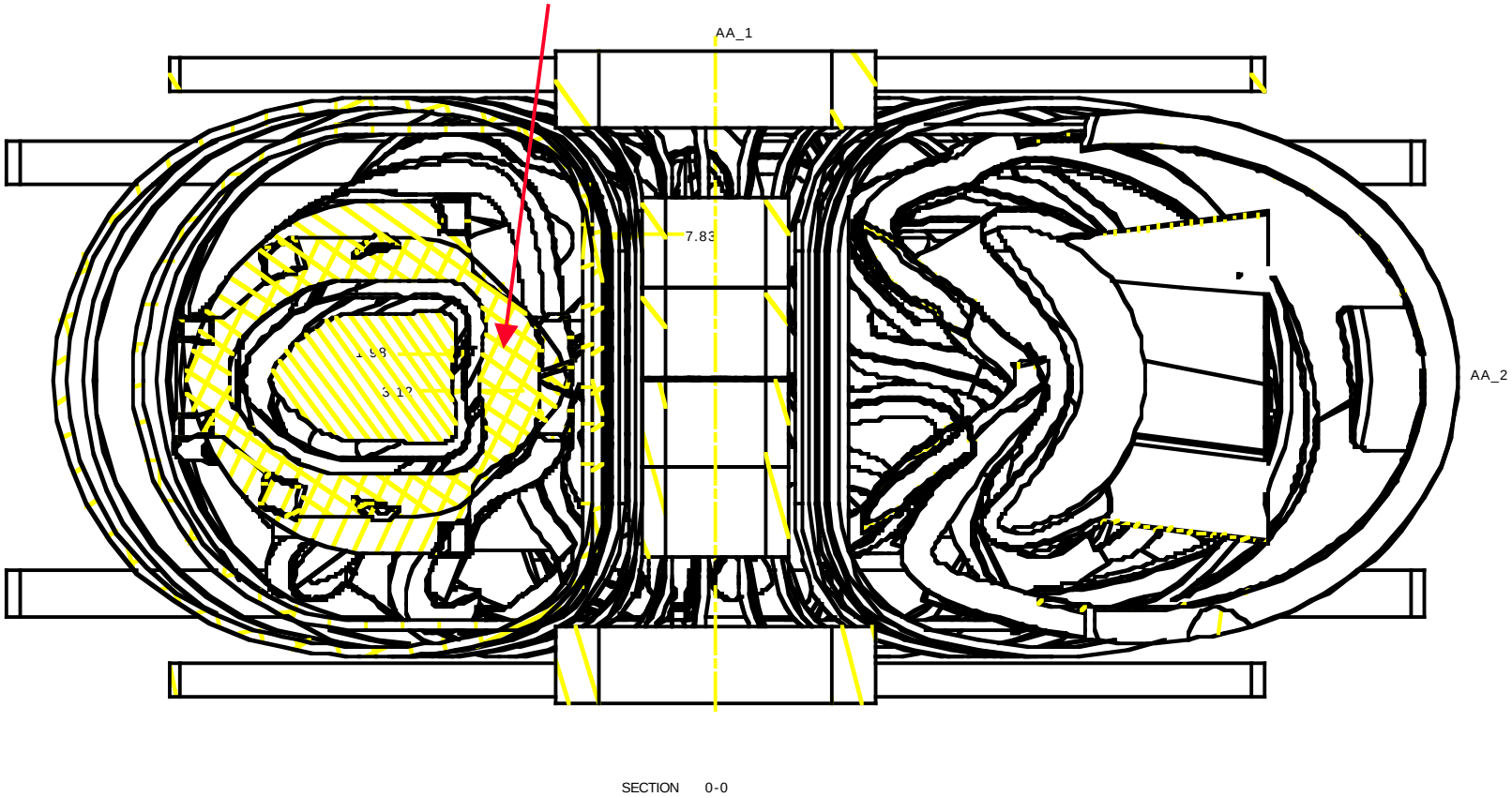


Summary of mode conversion scenarios

- Electron heating
  - Broad or localized deposition, in H - He3 or H - D
  - Can be core localized down to 1.6 T (for 25 MHz)
- Current drive
  - Best suited to scenarios with localized power deposition (H - He3)
  - On or off axis
- Ion heating
  - High minority concentrations can be heated to minimize tails
    - » Typically 10% H or He3 minorities
  - He3 minority scenario would lend itself to investigation of shear flow effects

Antennas

Insert antennas here



Antennas

- High field side launchers, centered at “bullet” cross-section
  - Long (~1m total toroidal extent) is desirable
  - Tall (~75 cm) is desirable
  - 3 locations are desirable
- Favor a combline
  - Large area, low power density antenna with only 2 coaxial feeds/antenna
  - Small radial build - it will fit!
  - Large plasma - antenna separation acceptable
    - » Need detailed calculations, but 10 cm may be tolerable
  - Inherently suited to current drive
- **Summary:**

  » Looks very promising!