HHFW Power Absorption Modeling - Towards a Comparison of Modeling Codes

C.K. Phillips (PPPL)

NSTX RF Team

P.T. Bonoli (PSFC-MIT)

E.F. Jaeger (ORNL)

T.K. Mau (UCSD)

A. Rosenberg(P.U.)

Unique and Important Features of HHFW Heating

- densities and temperatures in ST comparable to conventional tokamak but B field is an order of magnitude smaller so dielectric constant is high

- Using $\omega \sim k_\perp V_A \sim N\Omega_{ci}$ and $v_{th} \sim \rho_i \Omega_{ci}$ find:

$$k_\perp^2 \rho_i^2 \sim N^2 \beta >> 1 \quad \text{in an ST (FLR questionable)}$$

- Using $\omega \sim k_\perp V_A \sim N\Omega_{ci}$ find:

$$\frac{\lambda_\perp}{a} \approx \frac{0.45}{N\ a} \frac{\sqrt{A_i}}{Z_i} \frac{1}{\sqrt{n_i / 10^{19}}} << 1$$

so WKB may be ok for propagation except near cyclotron harmonics?

- Plasma β is high so electron TTMP damping is strong relative to conventional tokamaks

- $B_p \sim B_T$ so sheared 2D equilibrium likely to be important

Five Different Codes Will Be Compared for NSTX Data

- **HPRT** — warm plasma ray paths; WKB full hot plasma absorption and wave polarizations; 2D EFIT equilibrium; data for profiles
- **CURRAY** — cold plasma propagation; local hot plasma absorption using order reduction; 2D EFIT equilibrium; polynomial fits to profile data [being upgraded to hot plasma model]
- **METS** — 1D full wave hot plasma, no FLR approximation; polynomial fits for profiles; $B_T \sim 1/R$; $|B|$ includes B_p specified through q profile
- **TORIC** — 2D full wave hot plasma, FLR approximation used; moments description for equilibrium; [can also use EFIT]
- **AORSA-2D** — 2D full wave hot plasma, no FLR approximation; analytically specified equilibrium and profiles

NSTX Data Used for Comparisons

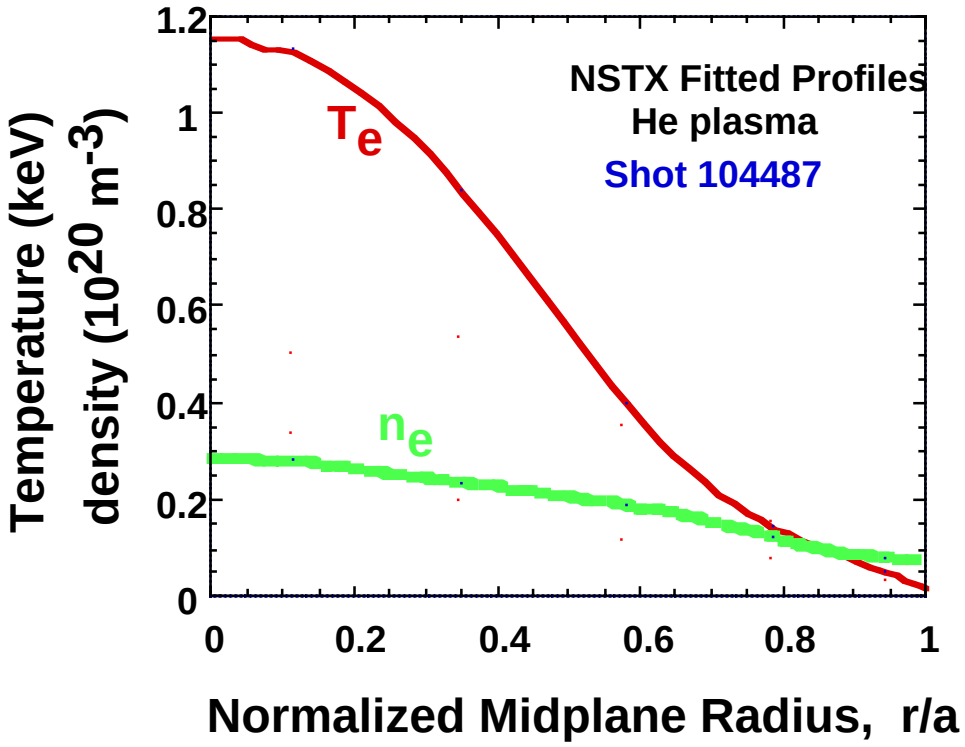
- some comparisons done for shot 104487

B_T ~ 0.285T @ R=1.005m

n_{e0} ~ 2.8e19 cm^{-3}

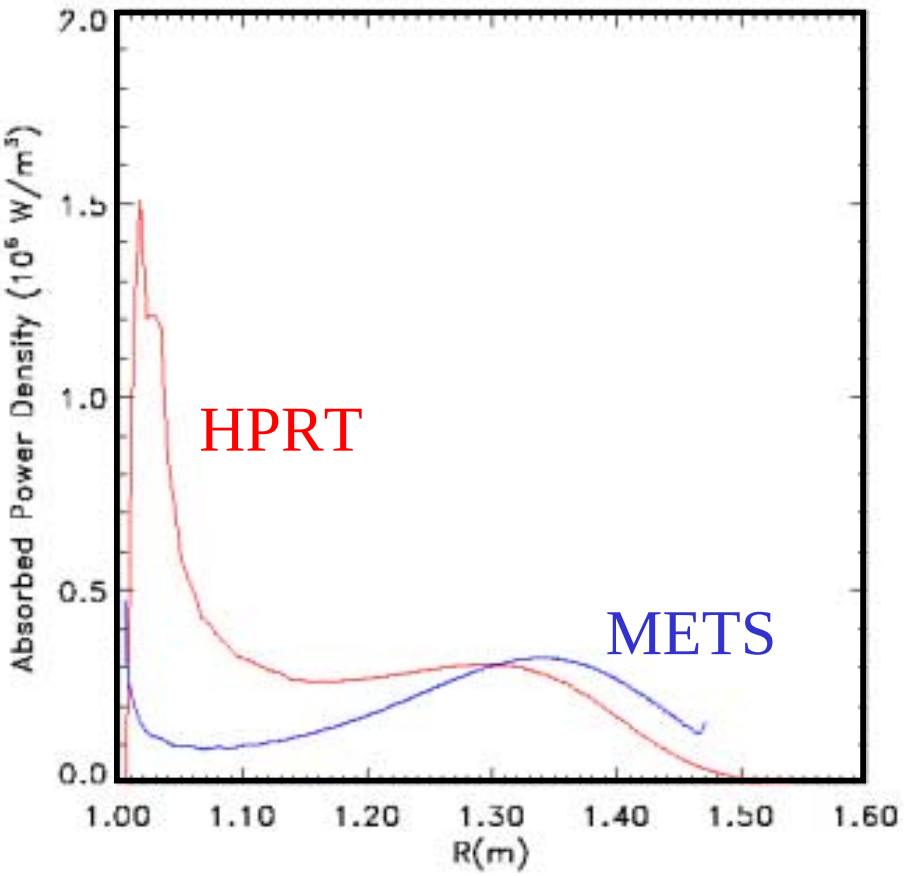
T_{e0} ~ 1.17 keV

$k_{//,A}$ ~ 14 m^{-1}



- For APS, will use shots 105830 (high T_{eo} case) and 105913 (HHFW +NBI case)

Good Qualitative Agreement Between HPRT and METS in 1D Limit



•HPRT run with:

1 ray launched on midplane
$B_p = 0$

to mimic 1D METS model along midplane.

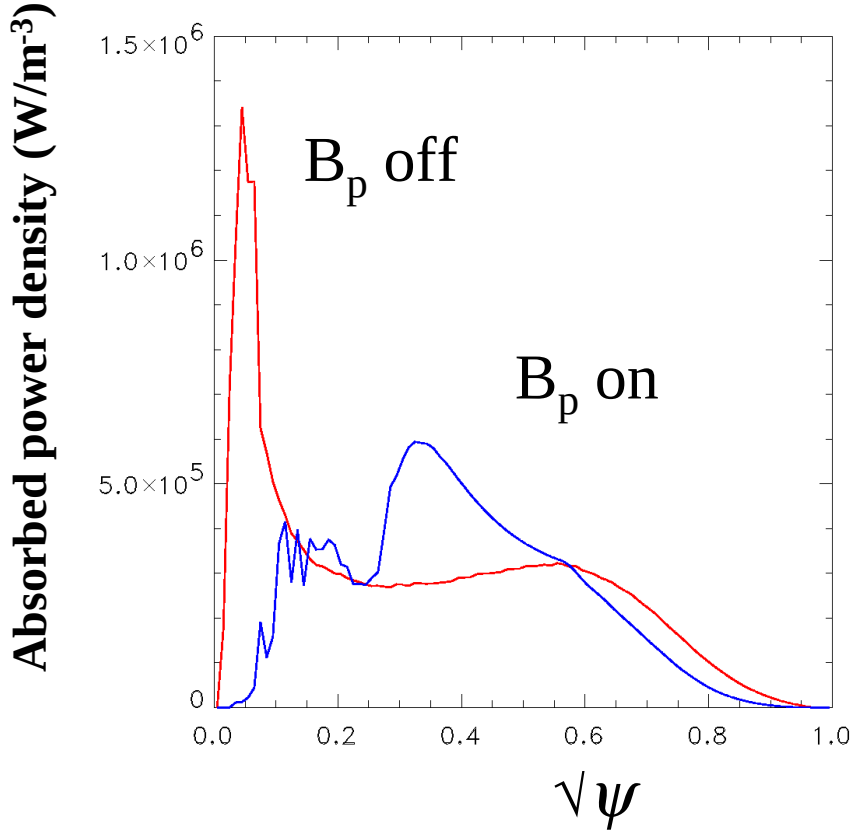
•Remaining differences may be due to:

•equilibrium profile differences
•METS used fits to plasma profiles and approximate B field profile
•HPRT equilibrium is up/down asymmetric

•WKB vs. full wave models

Poloidal Field Shifts Power Absorption Towards Plasma Core

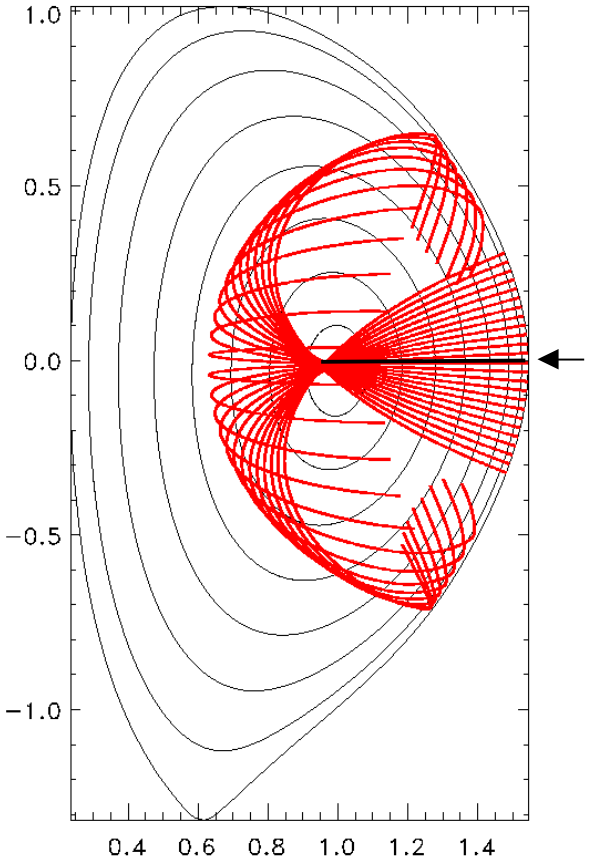
Shot 104487, He



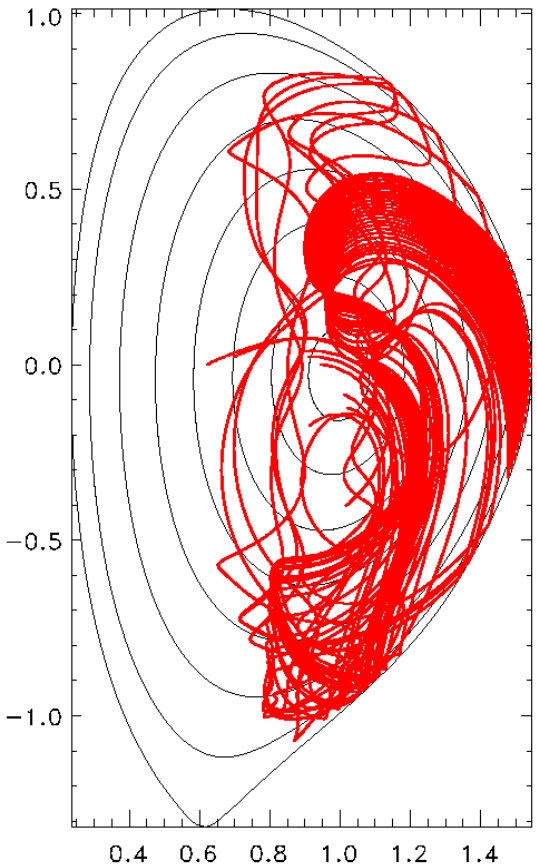
HPRT with 25 rays

Poloidal Field Strongly Modifies HPRT Ray Paths

B_p off

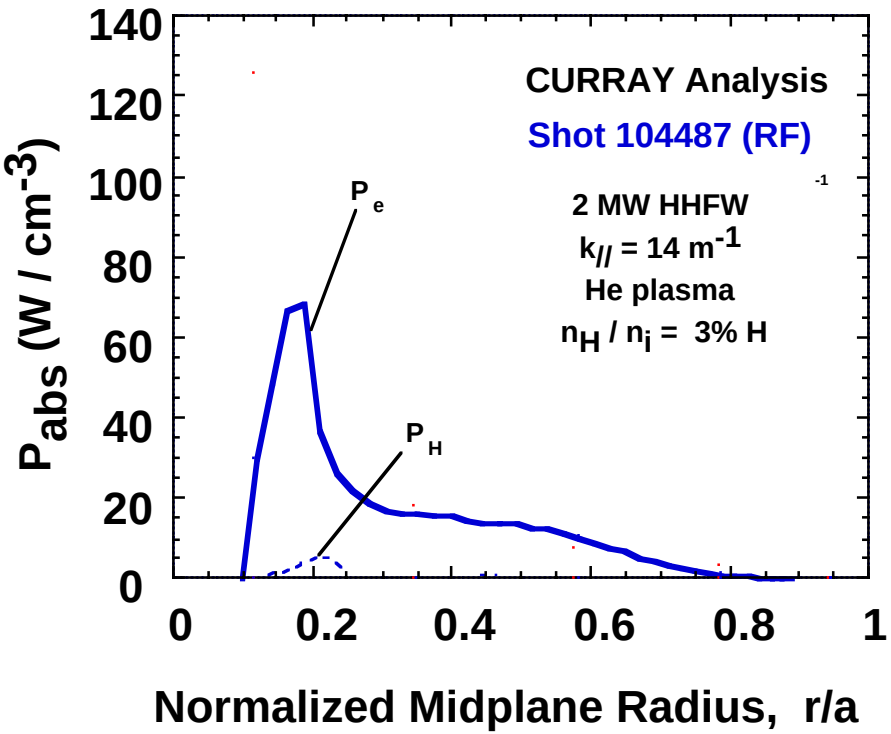


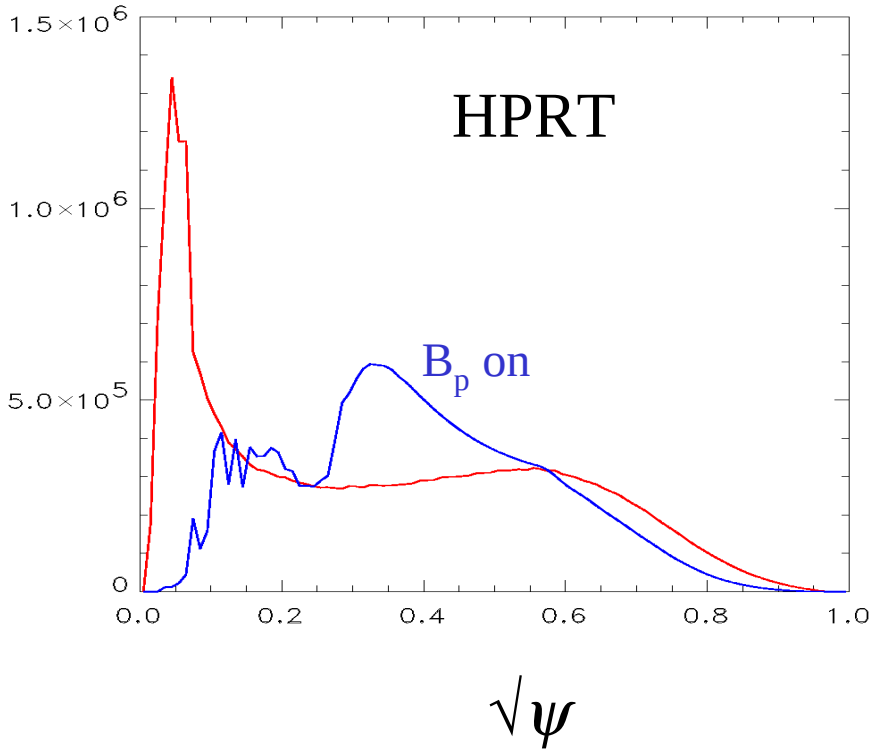
B_p on



$$\mathbf{k_{//}} \sim \frac{\mathbf{m}\ \mathbf{B_p}}{\mathbf{r}\ \mathbf{B}} + \frac{\mathbf{n}\ \mathbf{B_T}}{\mathbf{R}\ \mathbf{B}}$$

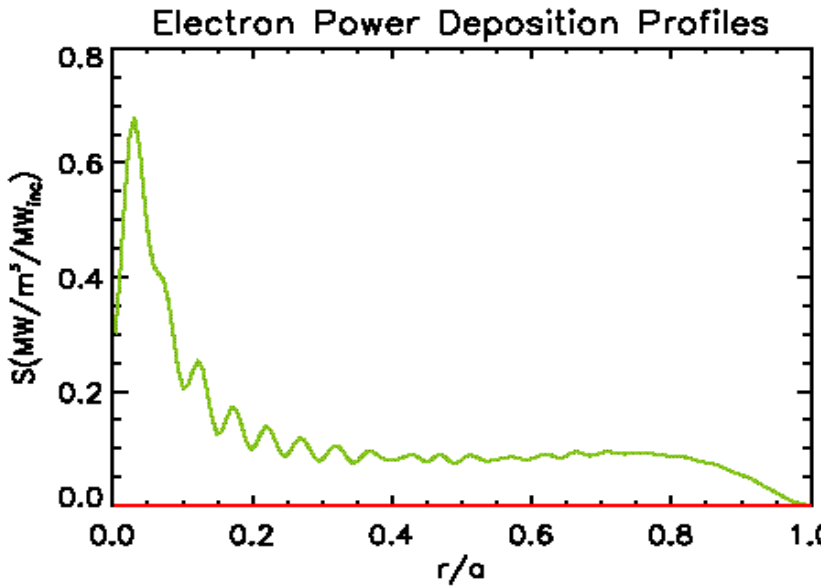
Qualitatively Similar Power Deposition Found with CURRAY and HPRT



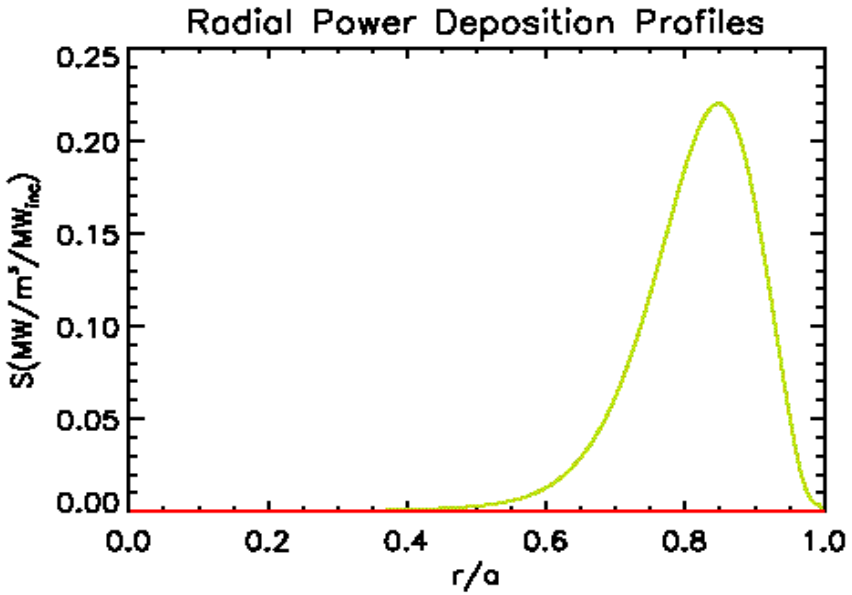


•More detailed comparisons using same equilibrium input underway

Approximate Absorption Models Under Consideration for TORIC



- with ion FLR terms and $B_p = 0$



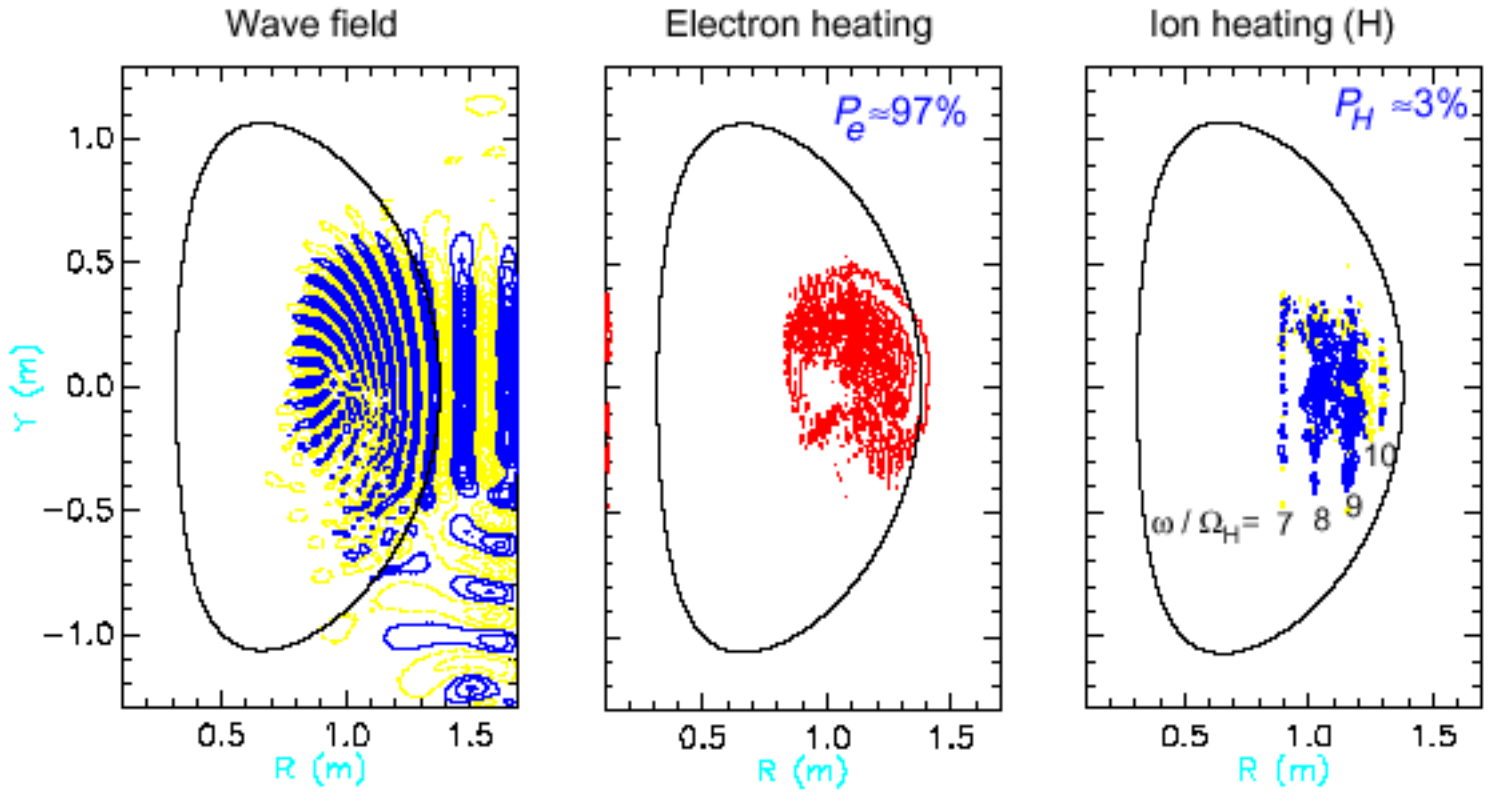
- with zero ion FLR terms and $B_p = 0$

- similar to METS profile

• zero ion FLR model may be adequate for electron damping regime in TORIC [Ono has shown P_e in zero ion FLR limit nearly same as full model if $\beta_i < 0.5$]

•reduced order corrections to ion damping terms under study

AORSA-2D Provides Most Complete Model



B_T = 0.25 T n_{e0} = 3e19 m^{-3} T_{e0} = 2 keV T_{io} = 1 keV
99% D / 1% H plasma

- will be used to verify range of validity of faster but less complete models

Summary and Plans

- **Qualitative agreement found among the various codes:**
  - **Strong single pass electron damping, mostly off-axis**
  - **Some innercore absorption due to 2D equilibrium and B_p**

- **Detailed comparisons to be done for 2 NSTX discharges:**
  - **105830 high Te0 case**
  - **105913 HHFW combined with NBI**

- **Codes to be benchmarked against experimentally measured power deposition profiles when data is available**