extending the linear fast wave solution to the wall

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+ the rf-SciDAC team

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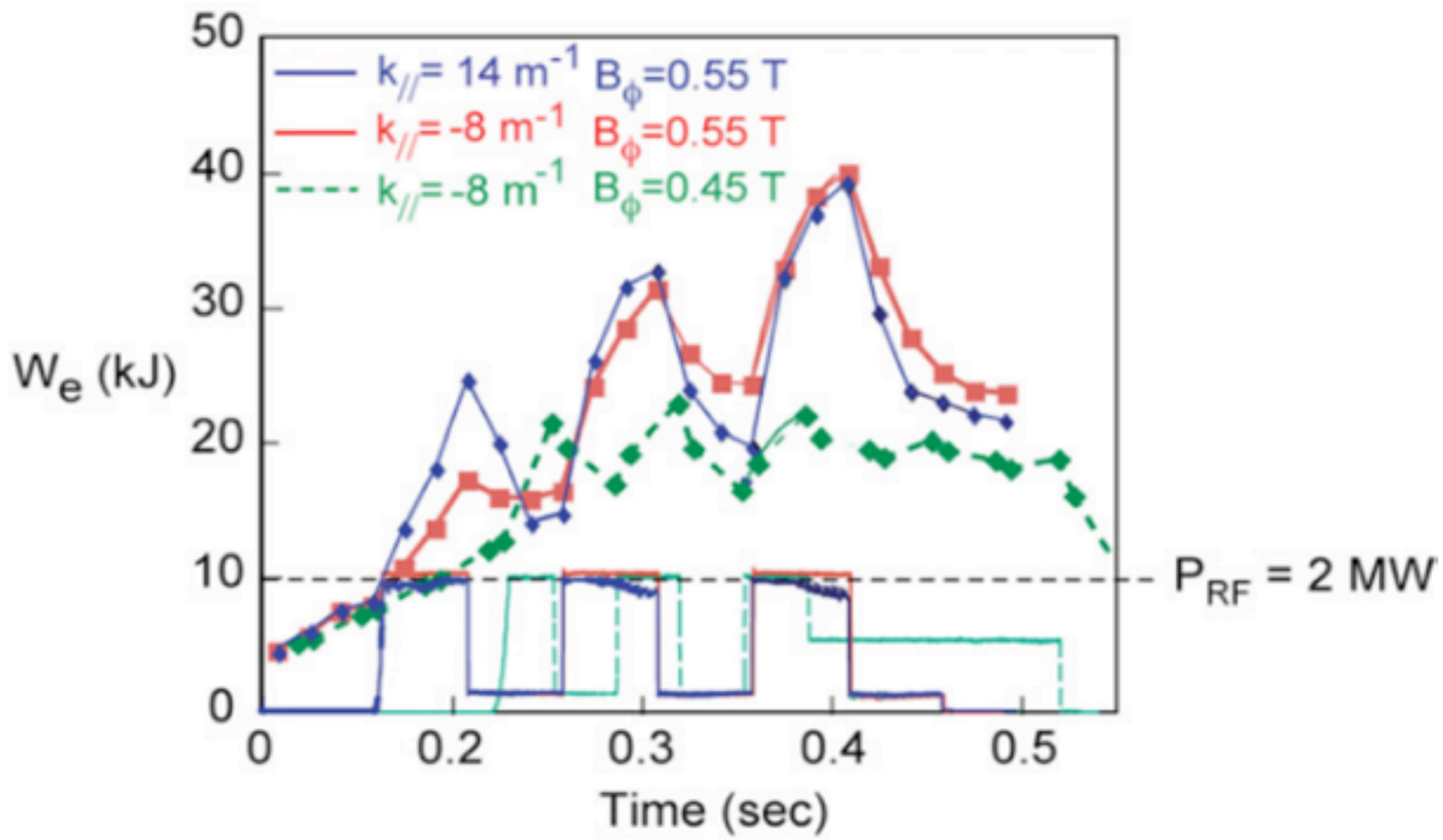
public demand

- questions for theorists at the 18th rf topical conference in Gent had a common theme ...
  - how and when will you simulate the entire antenna + edge + core system self consistently?
- why ... on NSTX and other Tokamaks, getting rf power into the core at long wavelengths can prove difficult and the edge is where all the action is

experimental observations



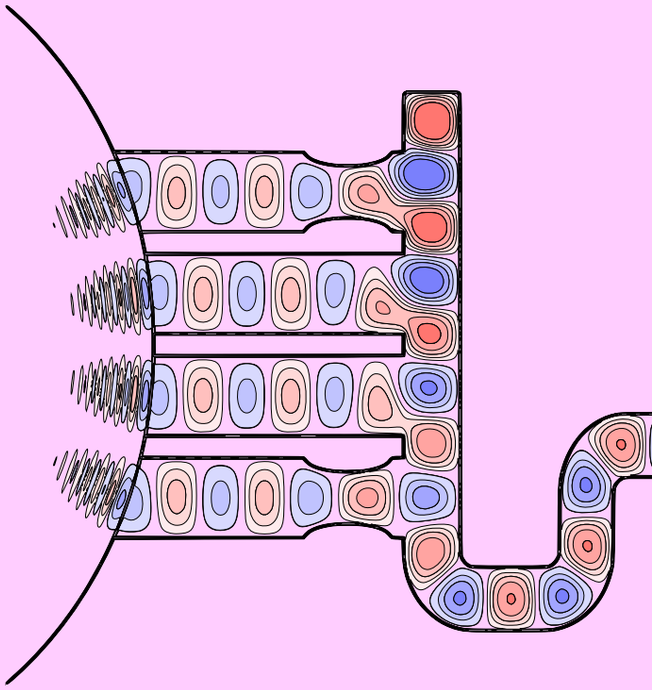
- recent papers by Phillips [Nucl. Fusion 2009] and Hosea [PoP 2008] show tuning the perpendicular fast wave cutoff location can dramatically improve core heating

what can we do with AORSA?

- if the problem is linear, i.e., only phenomena linearly related to the antenna (pump) frequency are important, AORSA can tell us under what conditions the fast wave amplitude is large in the edge
- PDI, rf sheaths, interaction of multiple frequencies are ignored

An interesting poster [Shiraiwa et al.] at the rf meeting described using the COMSOL package for entire system, on your desktop, lower hybrid calculations.

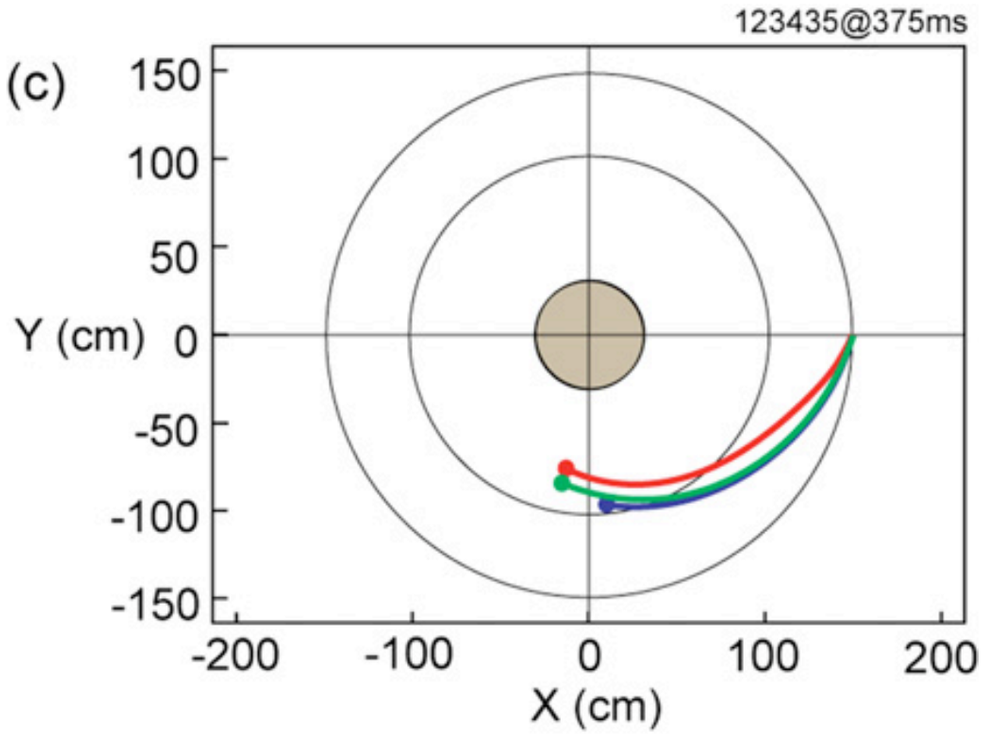
Still linear but extends the wave field calculation from the waveguide into the plasma core by creating a real space plasma dielectric.

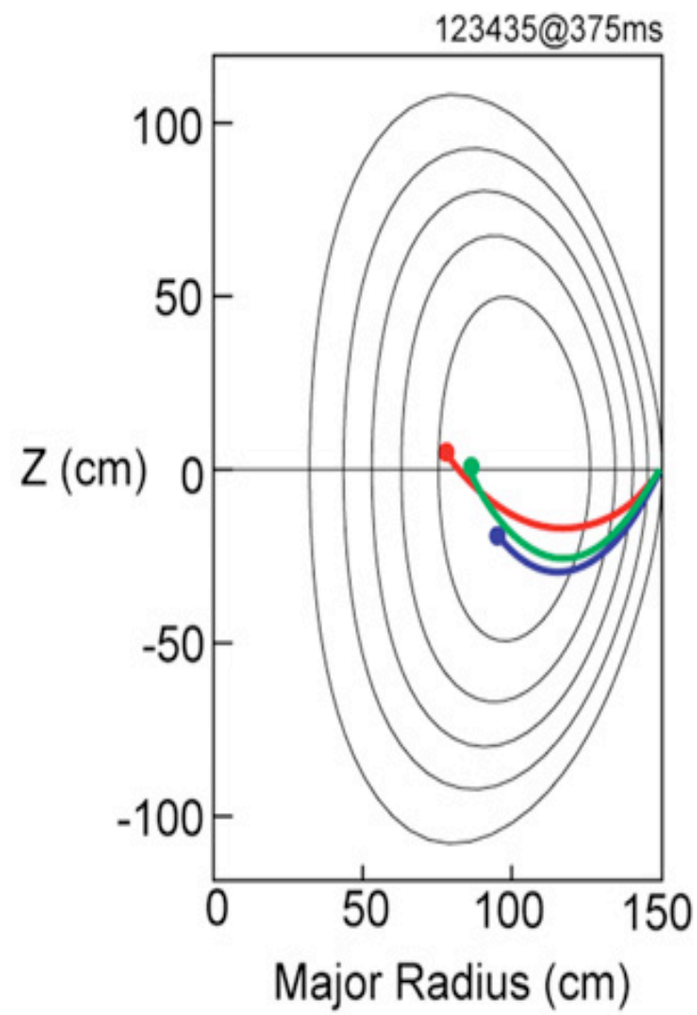


previous simulation

- GENRAY - ray tracing
- AORSA - full wave
- both are out to the Last Closed Flux Surface (LCFS)

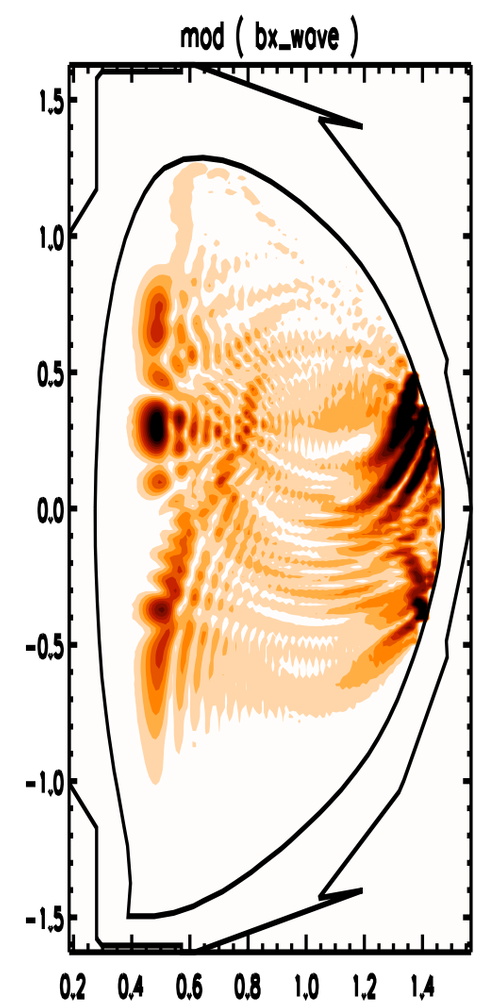
nPhi ~ -18, -12, -6





nPhi=-18

128797@400ms



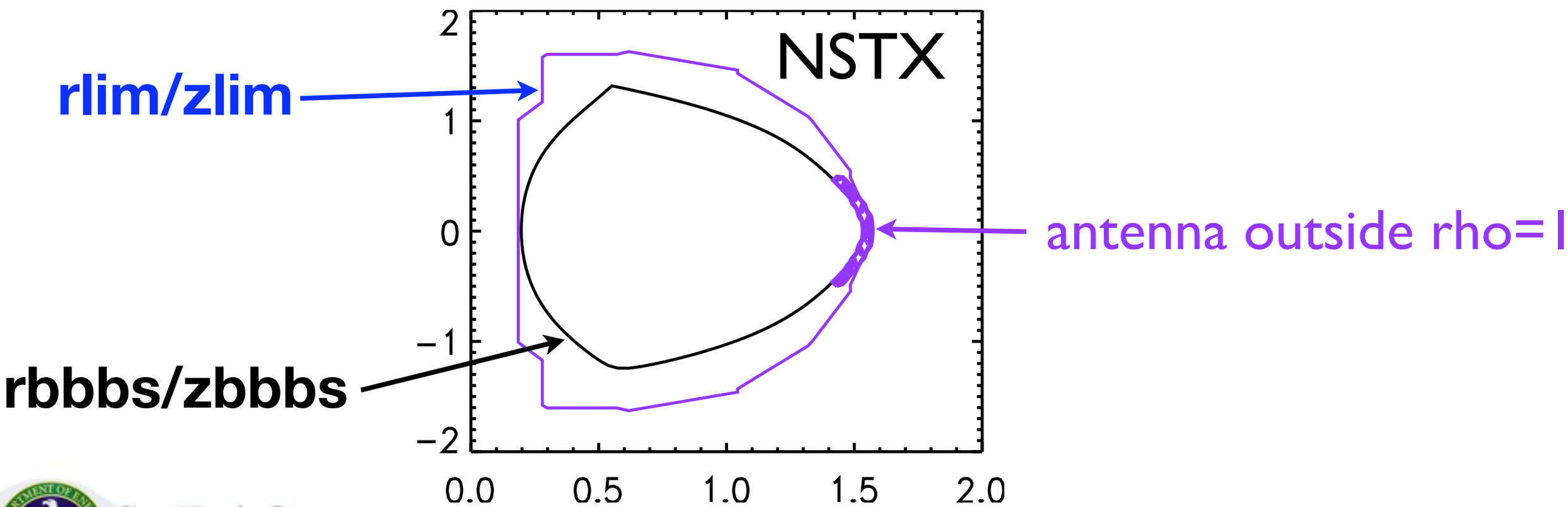
Phillips [Nucl. Fusion 2009]

AORSA overview

- solves Helmholtz type wave equation in 2D spectral basis
- e^iwt (linear in frequency)
- e^inPhi (toroidal decomposition)
- valid to All ORders in kPerp x rho, i.e., can handle high harmonic heating in contrast to finite difference or finite element codes
- non-maxwellian, multi-species
- quasi-linear self-consistency with Fokker-Planck type slow update of the 4D plasma distribution function. Achieved through coupling with CQL3D, Orbit-rf, sMC+rf, NUBEAM codes.
- computationally intensive

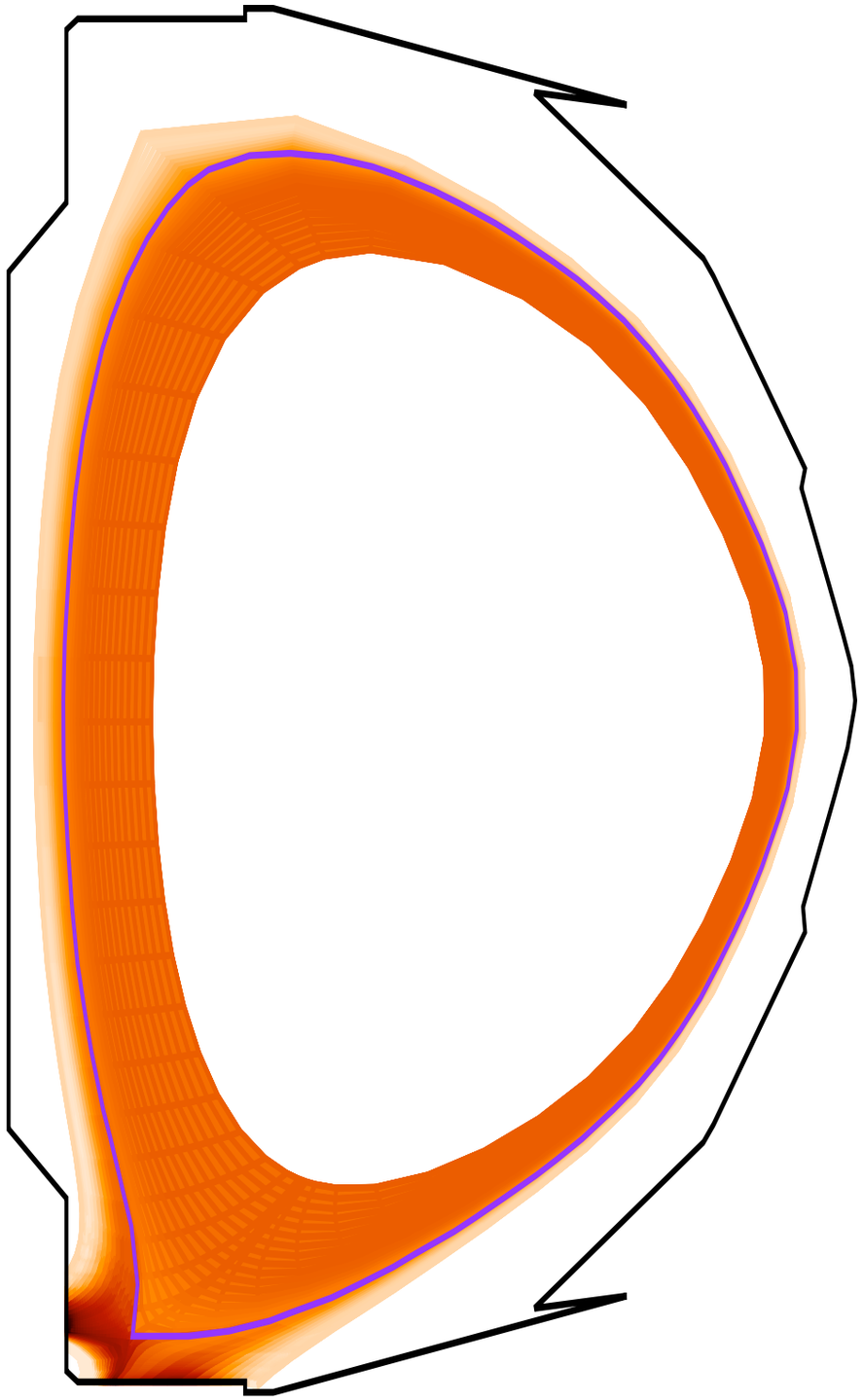
extend the boundary to the wall

- the AORSA boundary can be extended from the LCFS to the limiter as defined by an eqdsk file
- AOSRA works fine on open field lines, in contrast to flux surface codes like TORIC, why ... since the spectral decomposition is in R and z directions, NOT along a flux surface



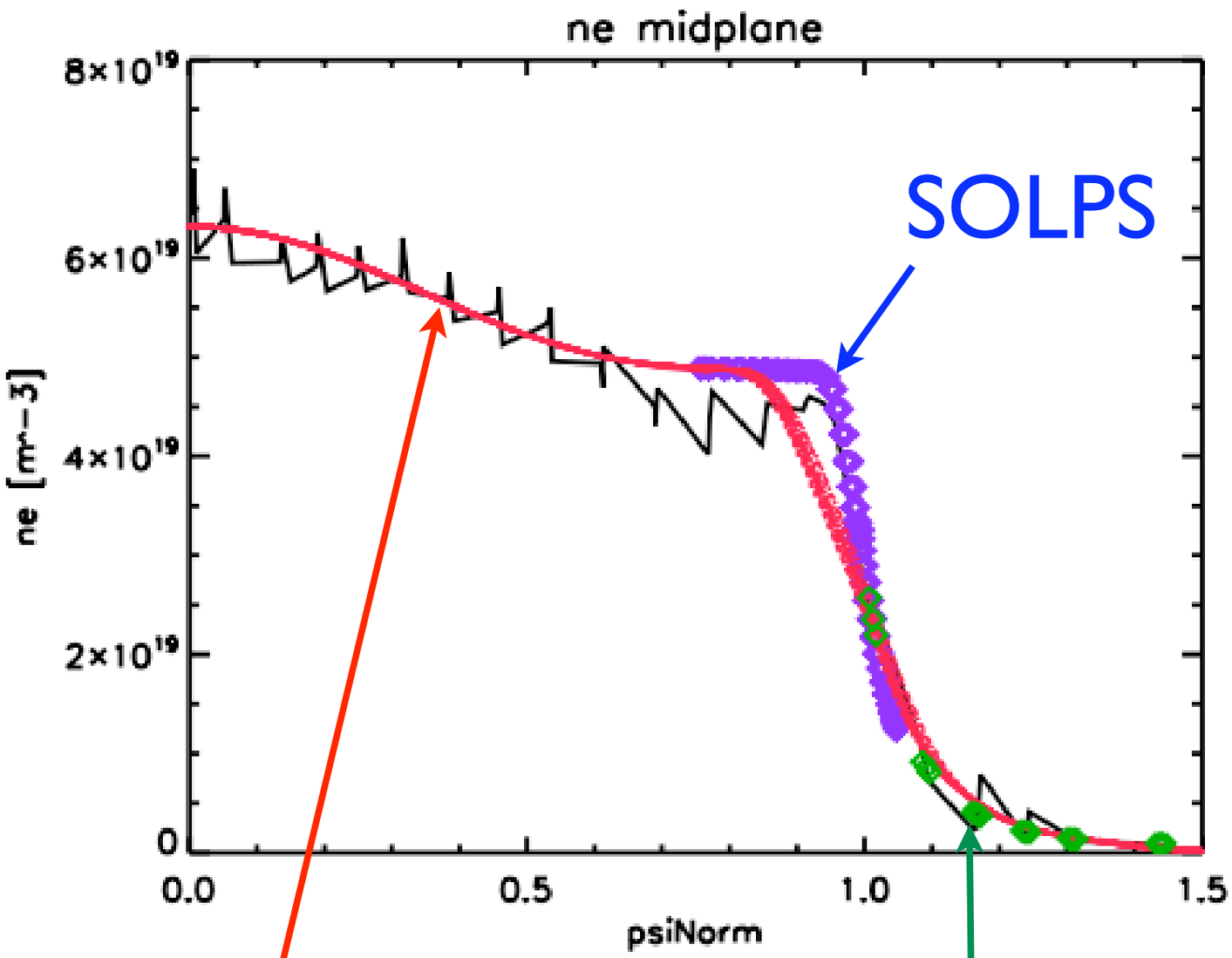
edge density and temp?

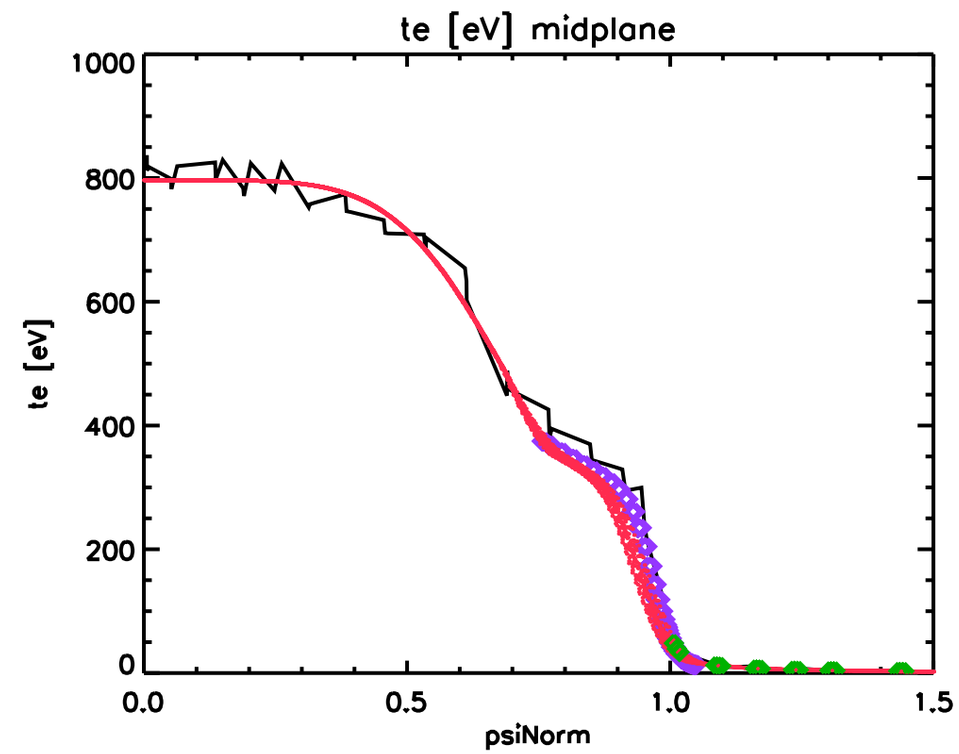
- we need to create 2D density and temperature profiles all the way to the limiter boundary
- Thompson scattering, reflectometer, charge exchange spec.,any more suggestions?
- SOLPS and perhaps UEDGE can help with this
- what we have so far - closed flux surface fit
  + SOLPS
  + exponential decay

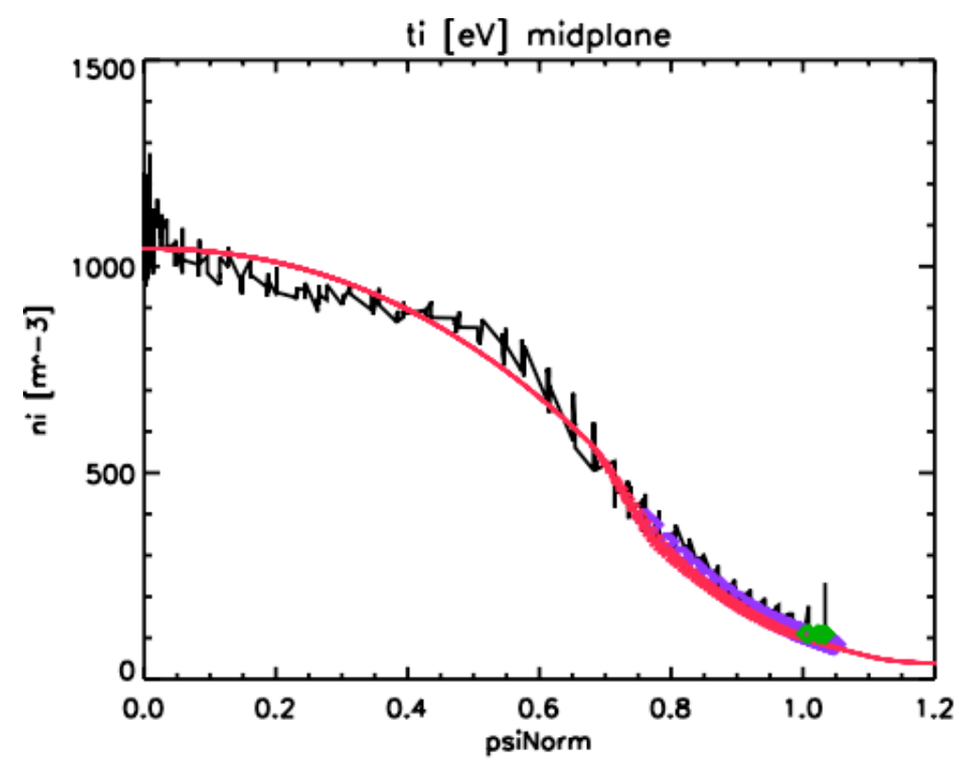


128797@400ms
Thanks to John Canik for this data.

create smooth profiles







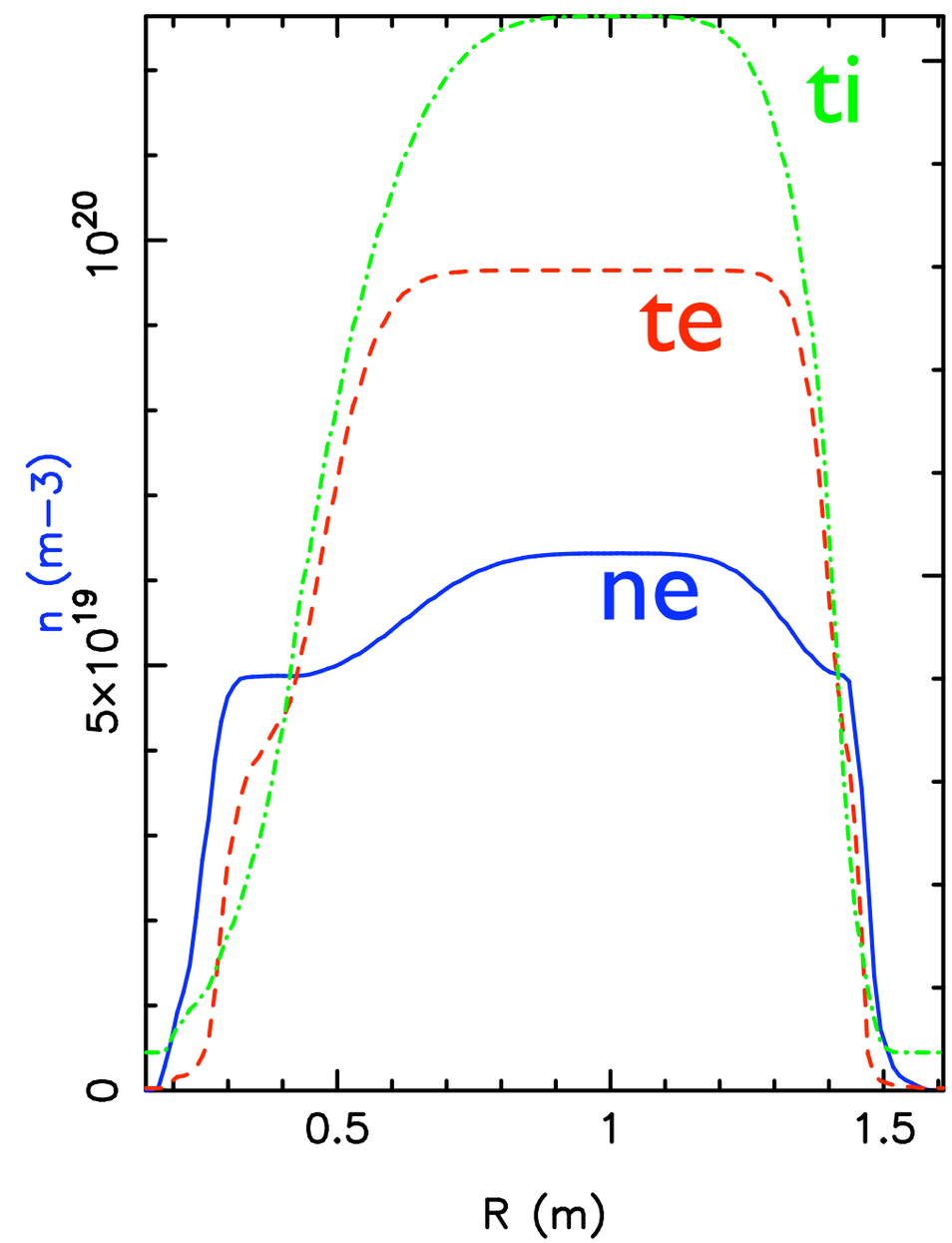
final smoothed result

exp decay

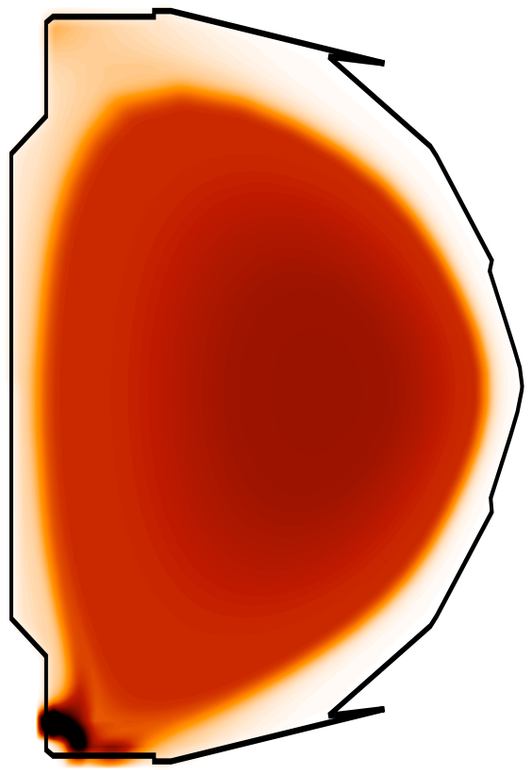
fast wave cutoff location I

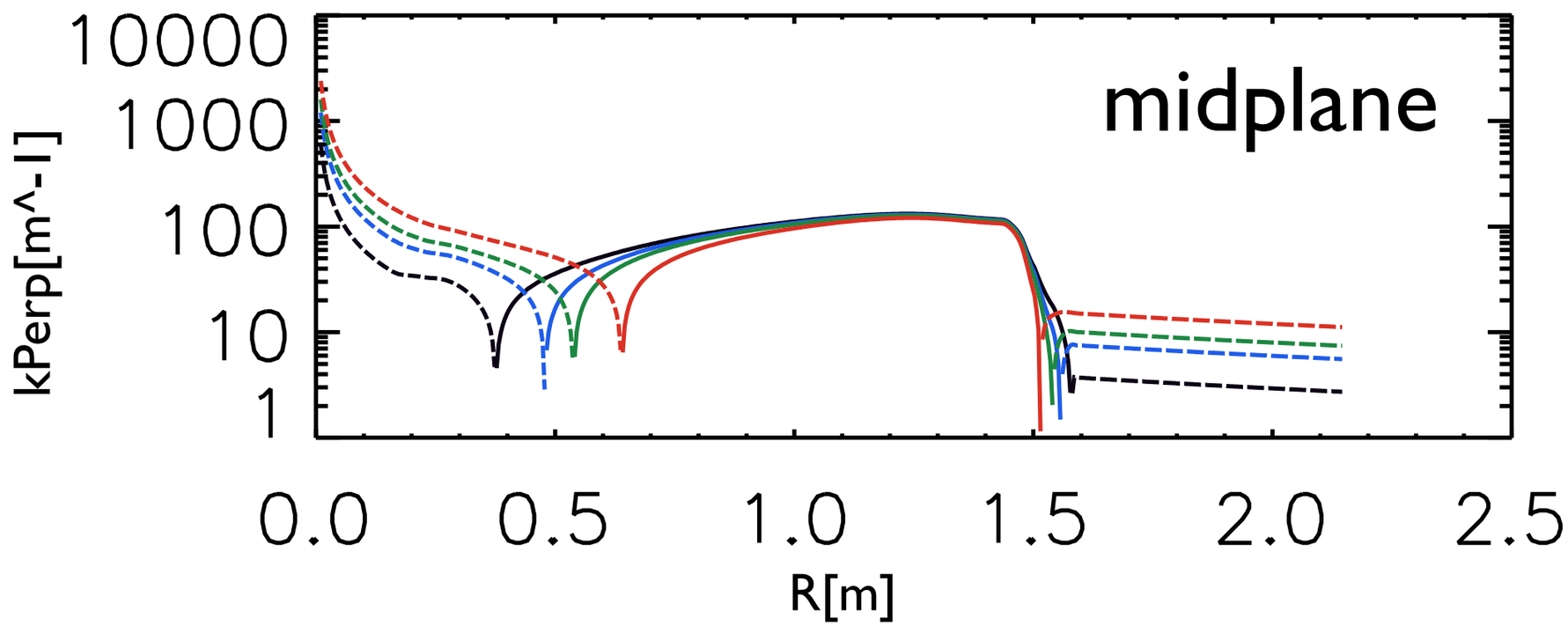
- by solving the cold plasma dispersion relation with kPar=nPhi x R for kPerp we can get some idea of the fast wave cutoff location
- this tells us where we might expect the wave to be propagating or evanescent
- depending on nPhi (antenna spectrum) the cutoff is in general somewhere between the antenna and the LCFS

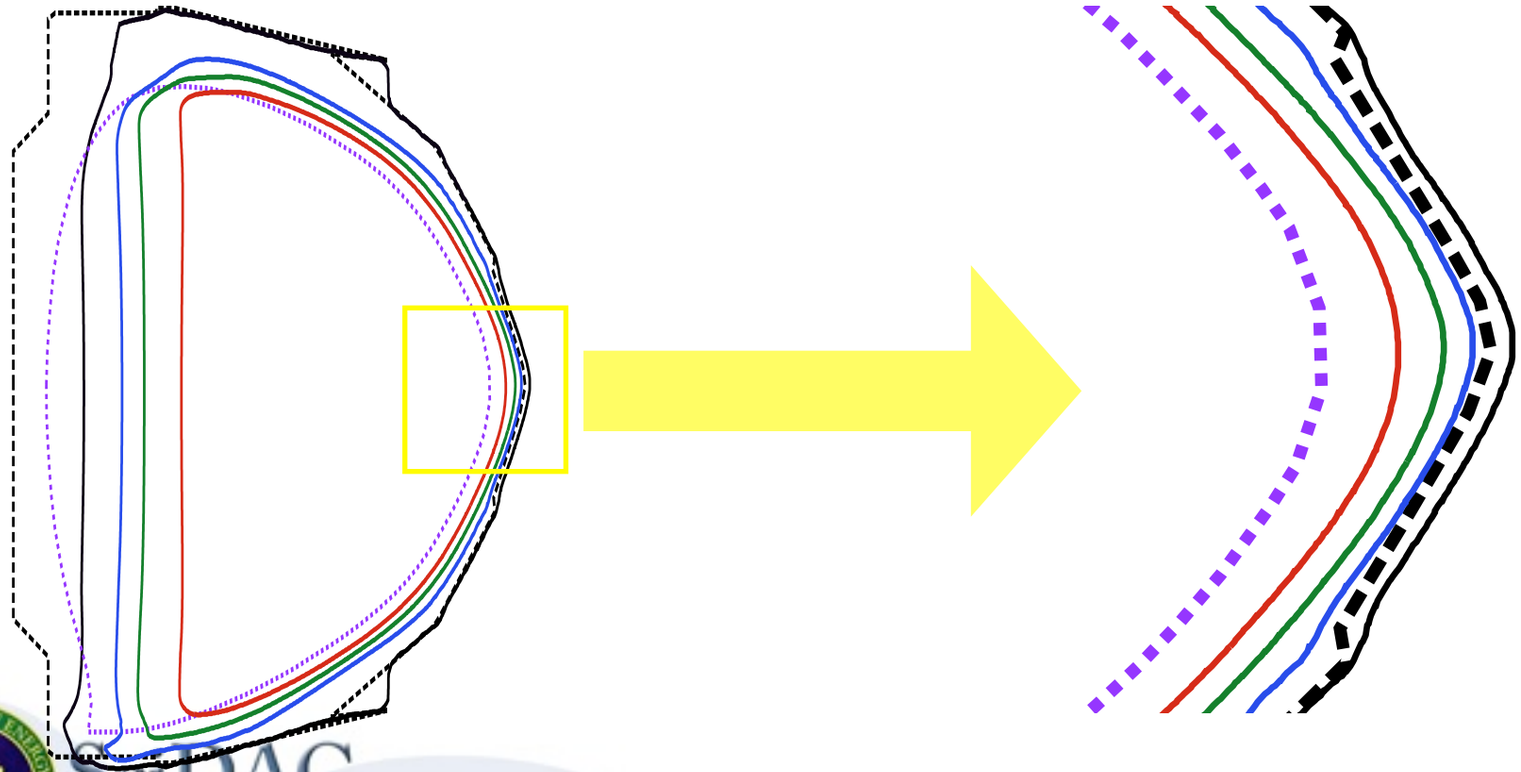
midplane density and temperature



fast wave cutoff location II



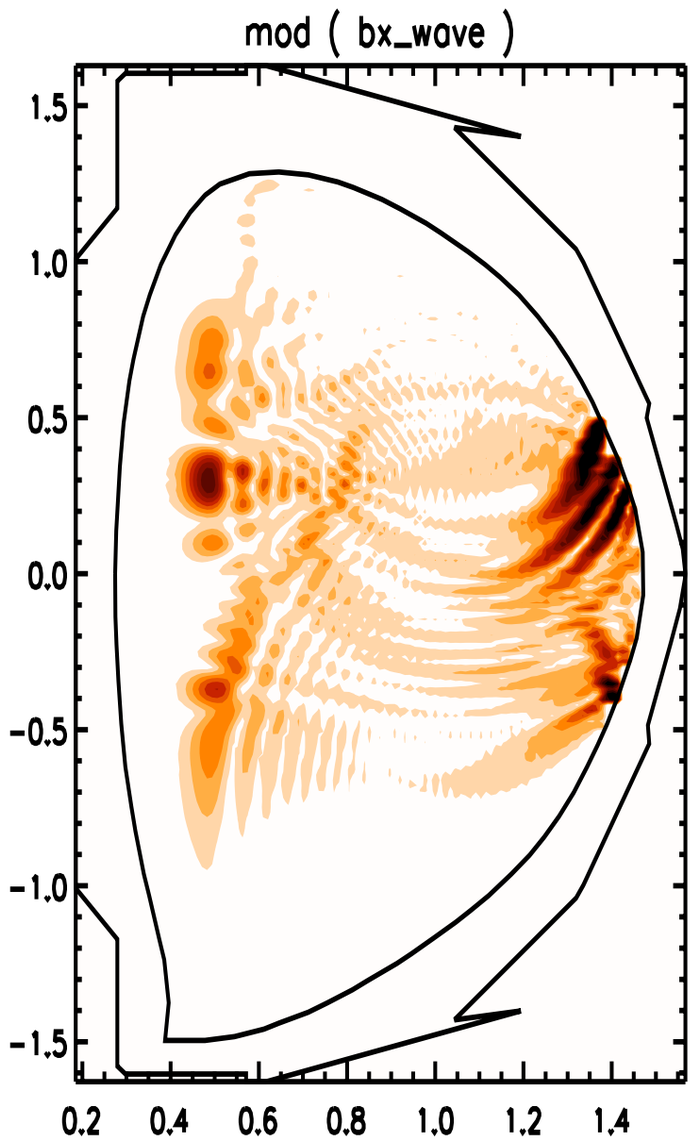


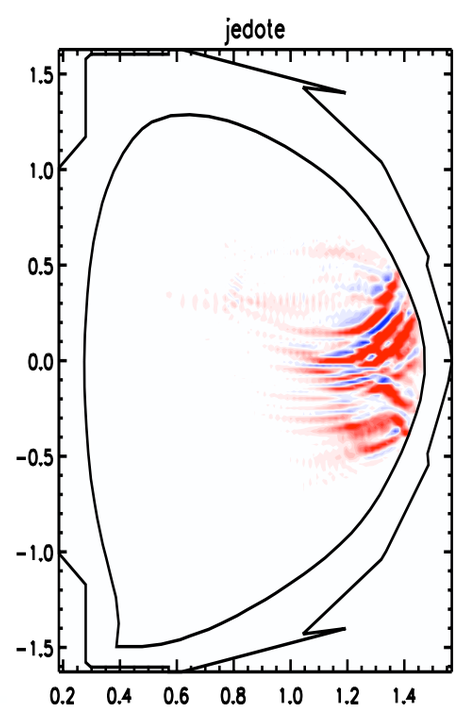


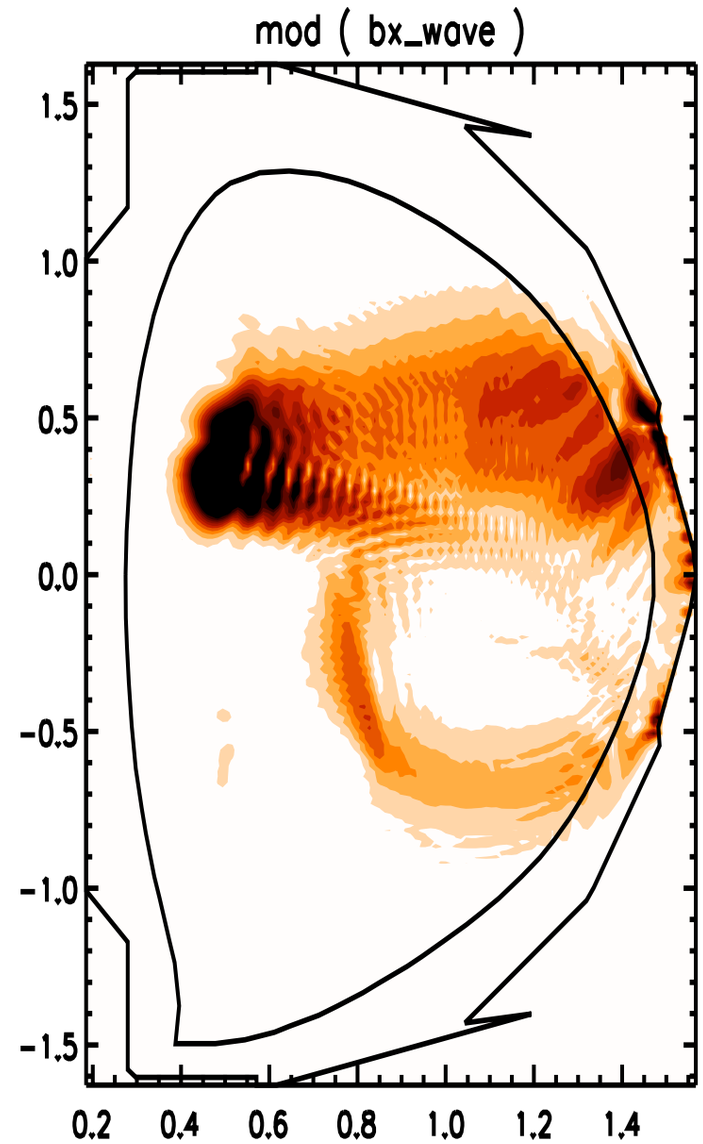
nPhi=-6,-12,-16,-24

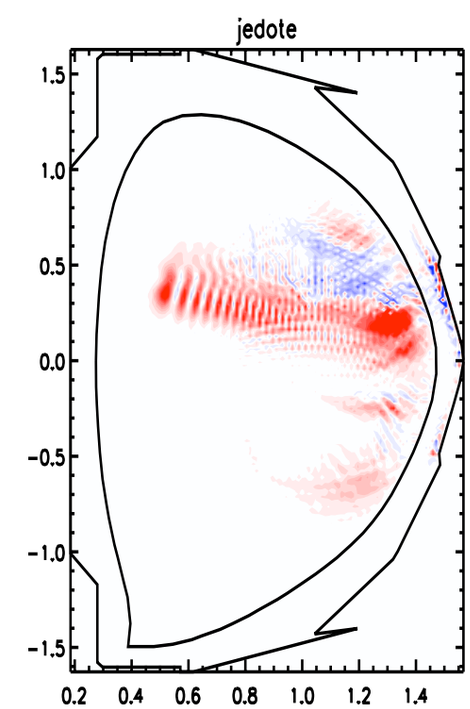
new boundary results

- NSTX HHFW, shot 128797@400ms, D ~1keV, maxwellian, 1MW@30MHz, nPhi = -18, 128x256

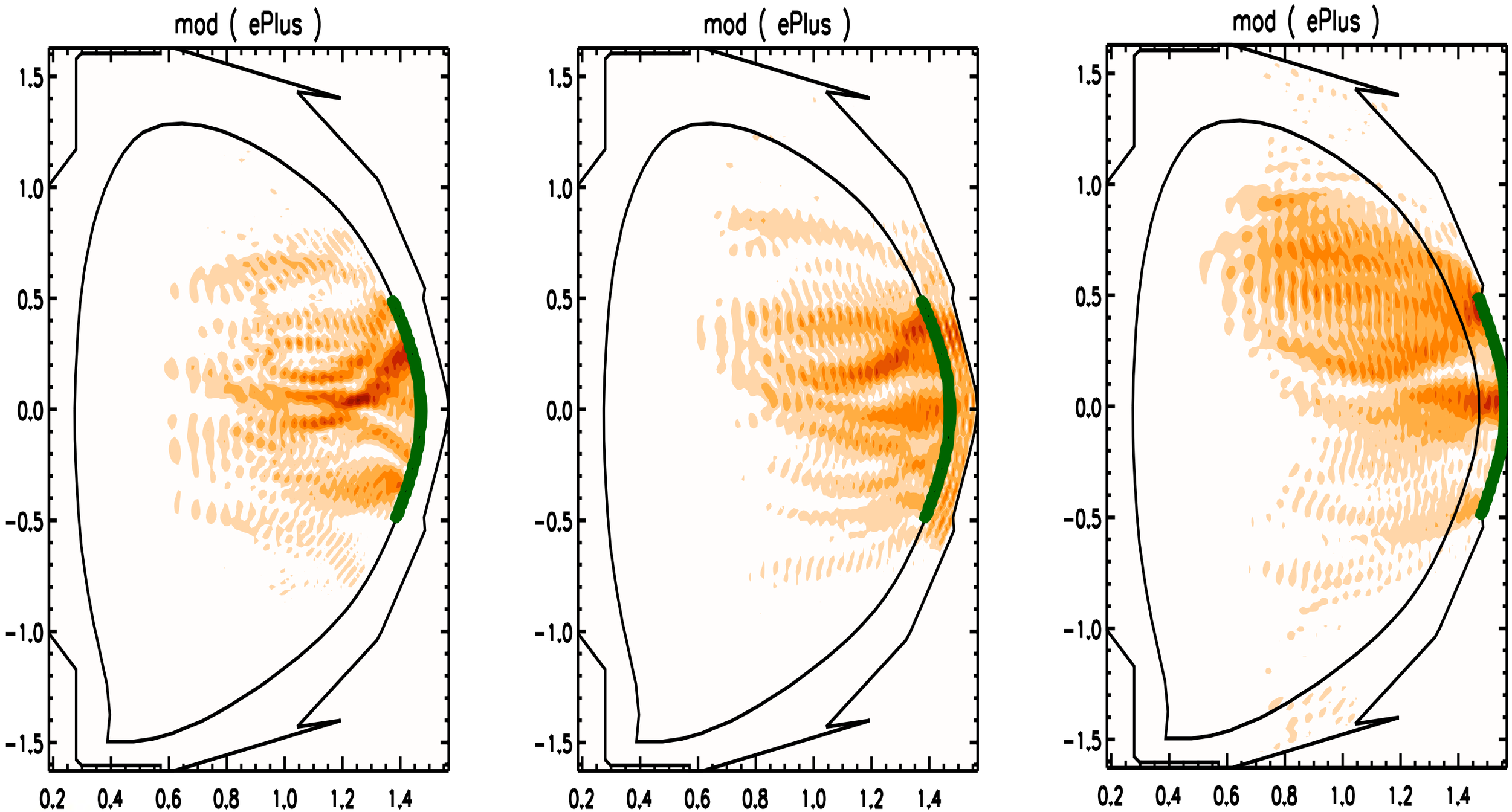






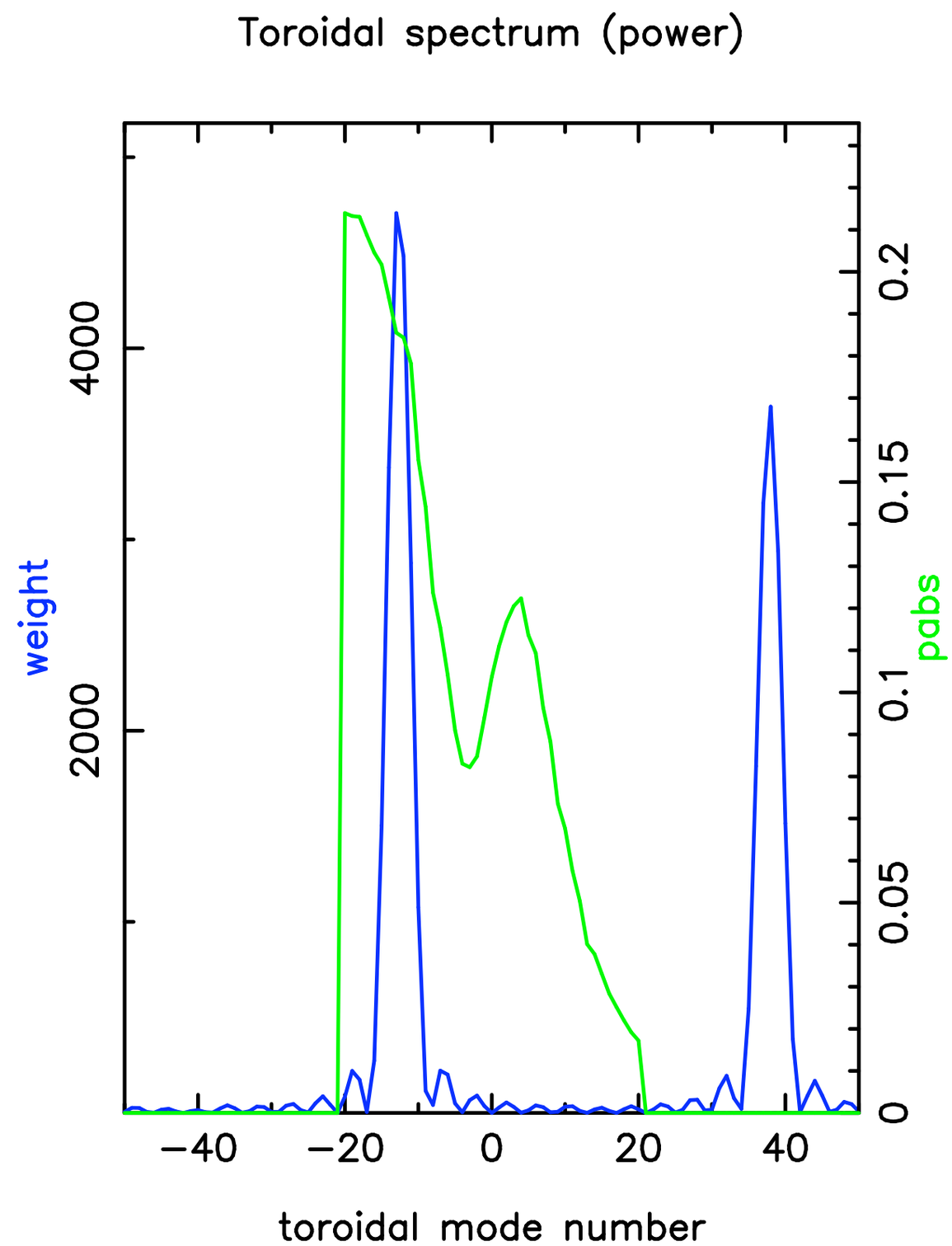


flat density and temp profiles

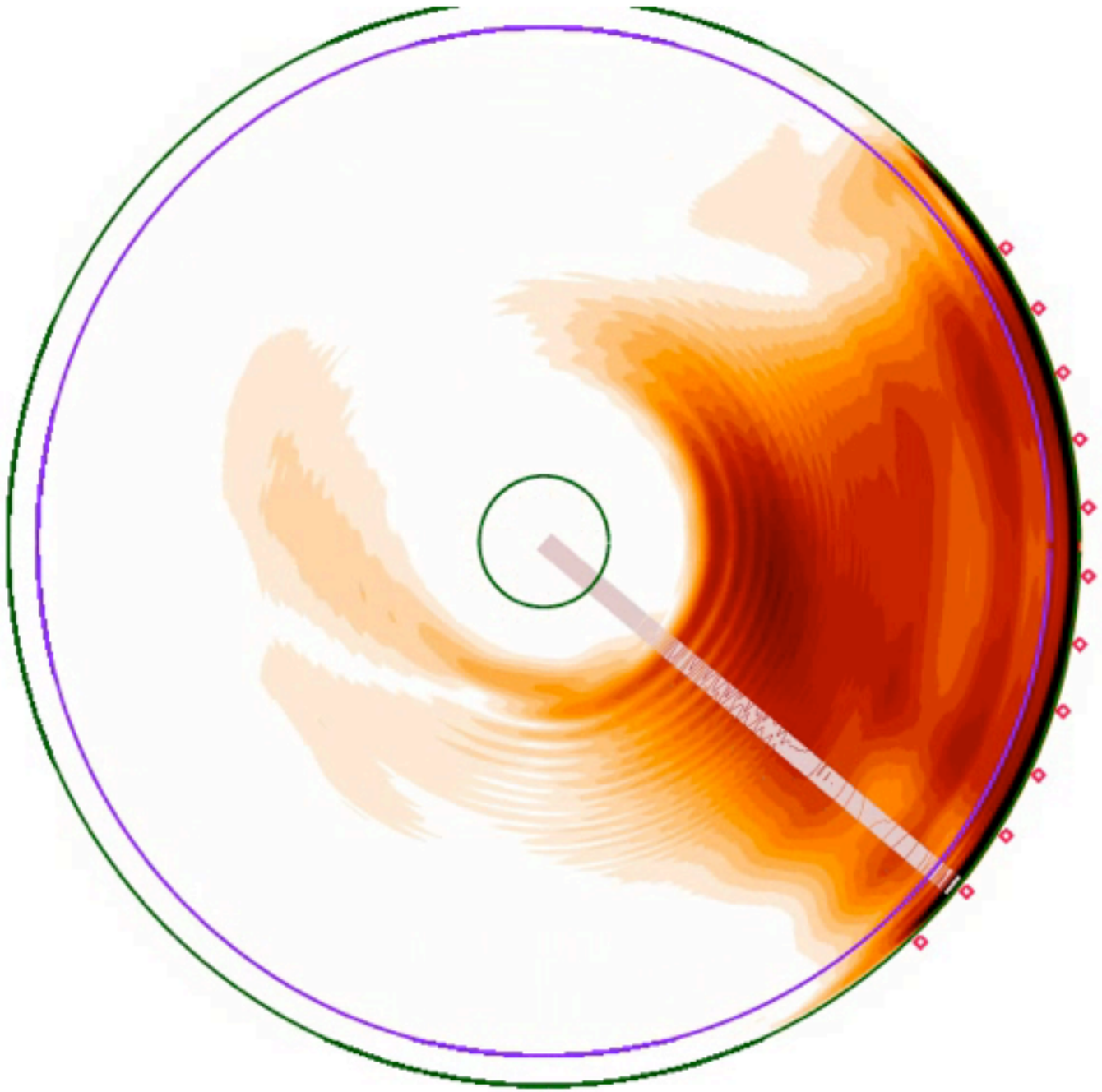


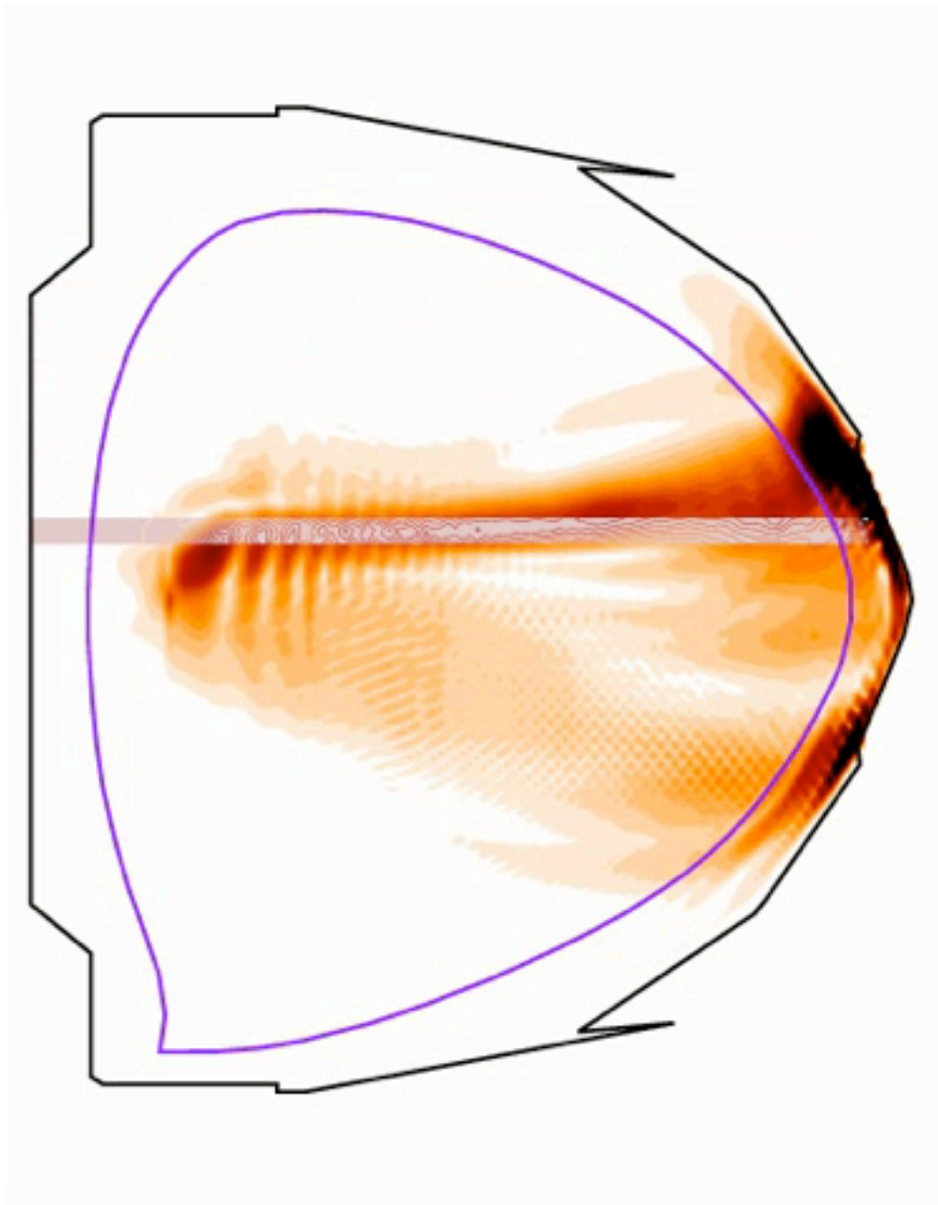
3D toroidal field structure

- using a spectrum of toroidal modes summed together we can construct the 3D wave fields
- for -90 degree antenna phasing
- here I have not used enough modes -20 to +20



3D field structure





future work

- run with -50 to +50 modes
- SOLPS run for shot #123435 (Hosea / Phillips case)
- implement a divergence free antenna current, not sure how this will affect these results
- what about a real edge treatment? rf-SciDAC discussions on a new rf code that can handle the edge physics correctly
  - time domain?
  - PIC?
  - require new computing capabilities [Jaguar-pf, GPUs]

my new tesla!
240 cores, 30000 threads, 1 TF