Substantial Fast-Wave Power Flux in the SOL of a Cylindrical Model; Comparison with Coaxial Modes

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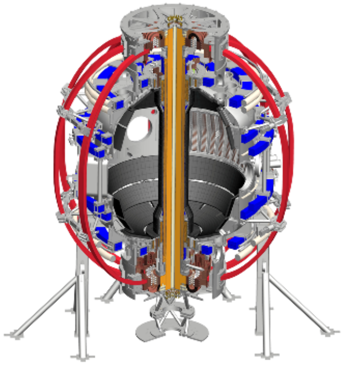
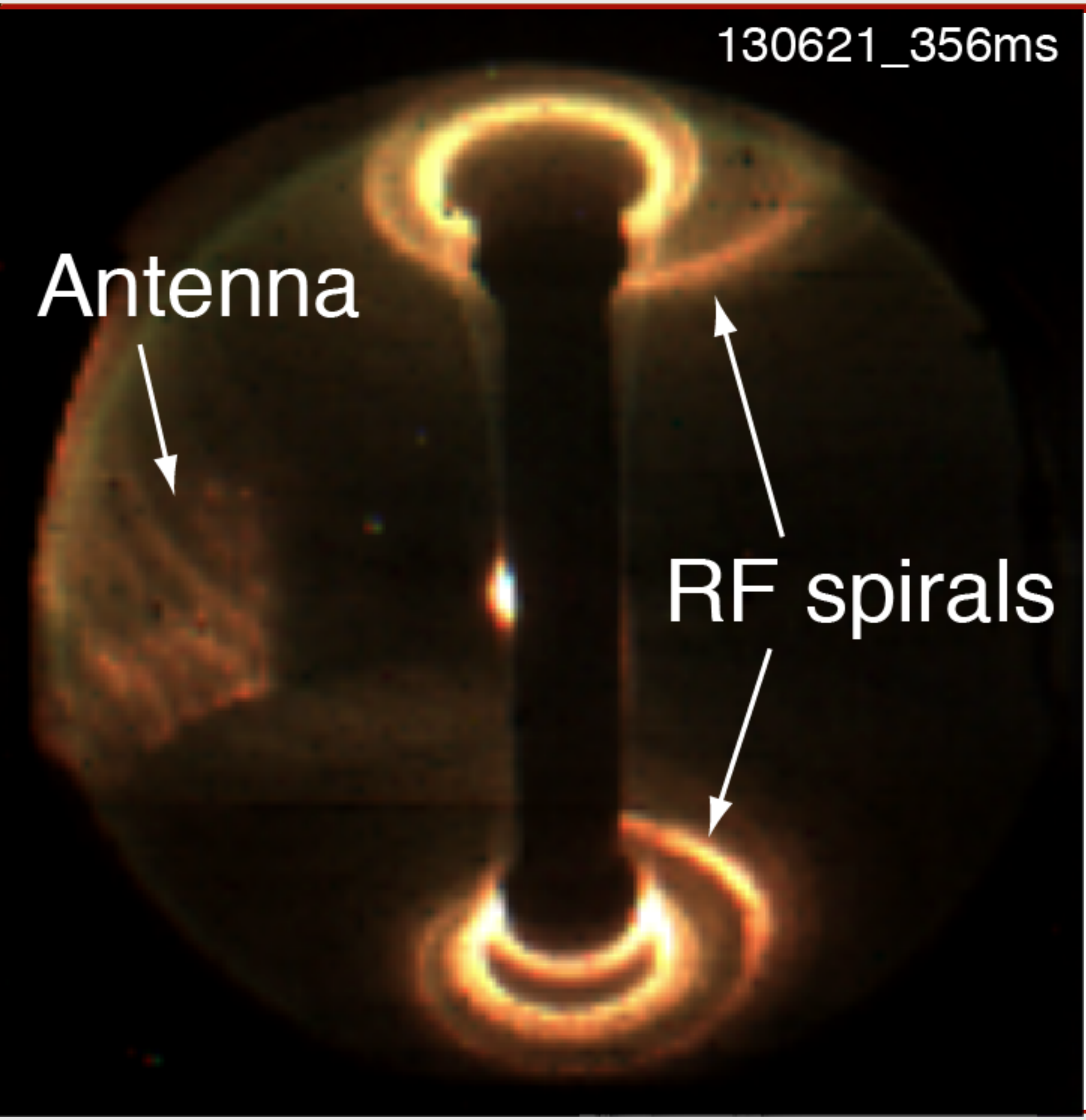
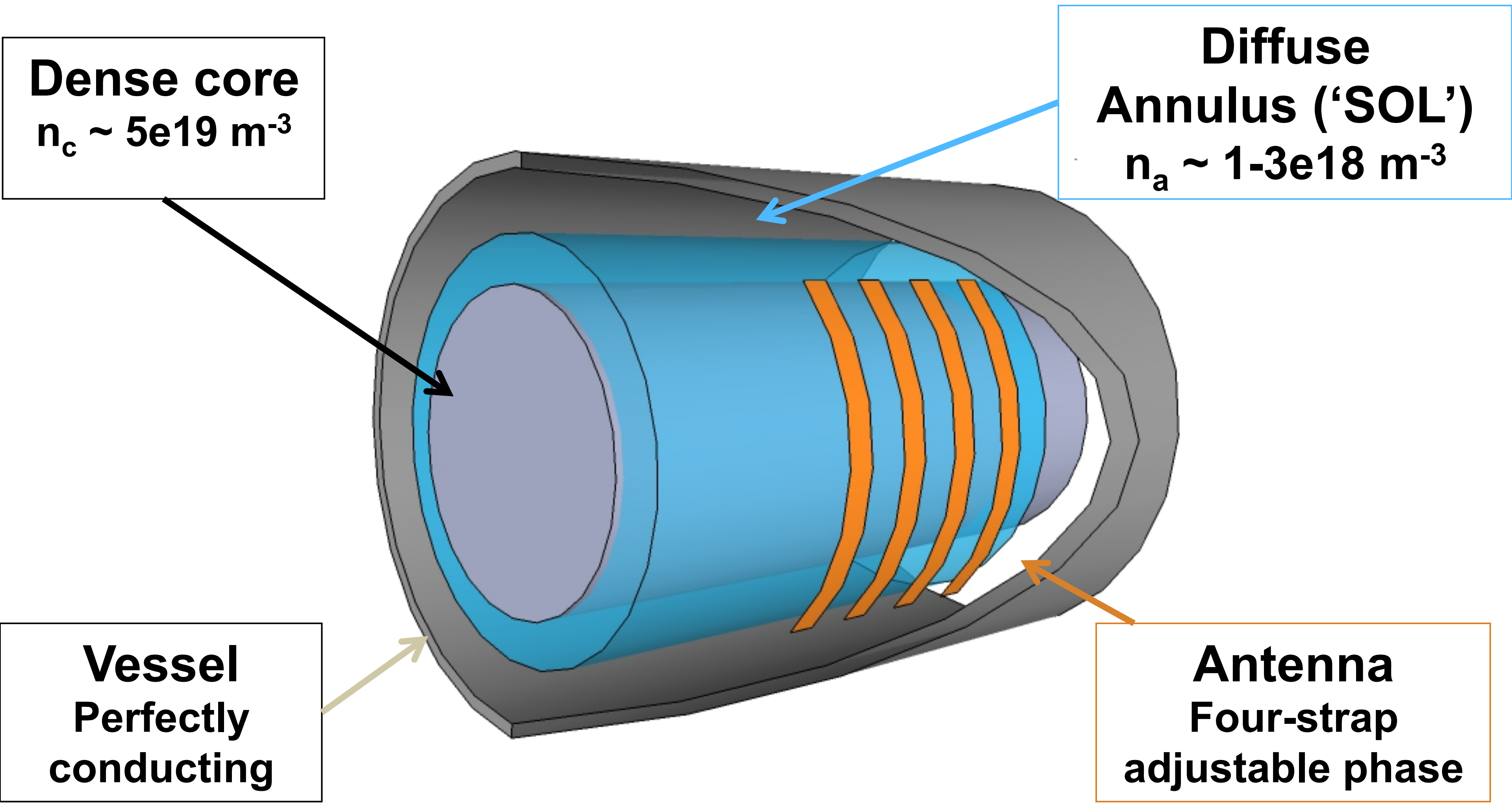


Up to 60% of coupled HHFW power is lost directly to divertor of NSTX



- RF power deposited in bright spirals on divertor
- Is *fast wave* power propagating through SOL to divertor?
  - J.C. Hosea *et al*., *Phys. Plasmas* **15**, 056104 (2008)
- Cylindrical cold plasma model computes modes that DO conduct significant power in edge
  - Distinct from fictitious "coax modes"

Cylindrical cold-plasma model
can be used to study the underlying physics

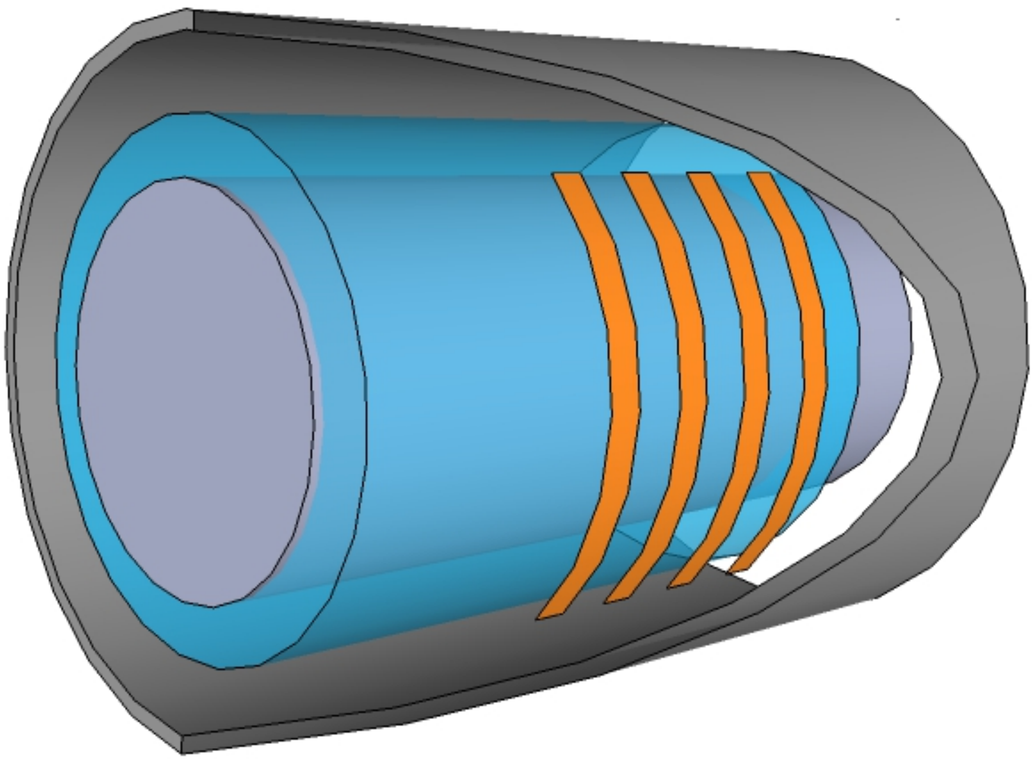


Cylindrical model solves for discrete set of modes with solutions matched across boundaries

- A mode has the form

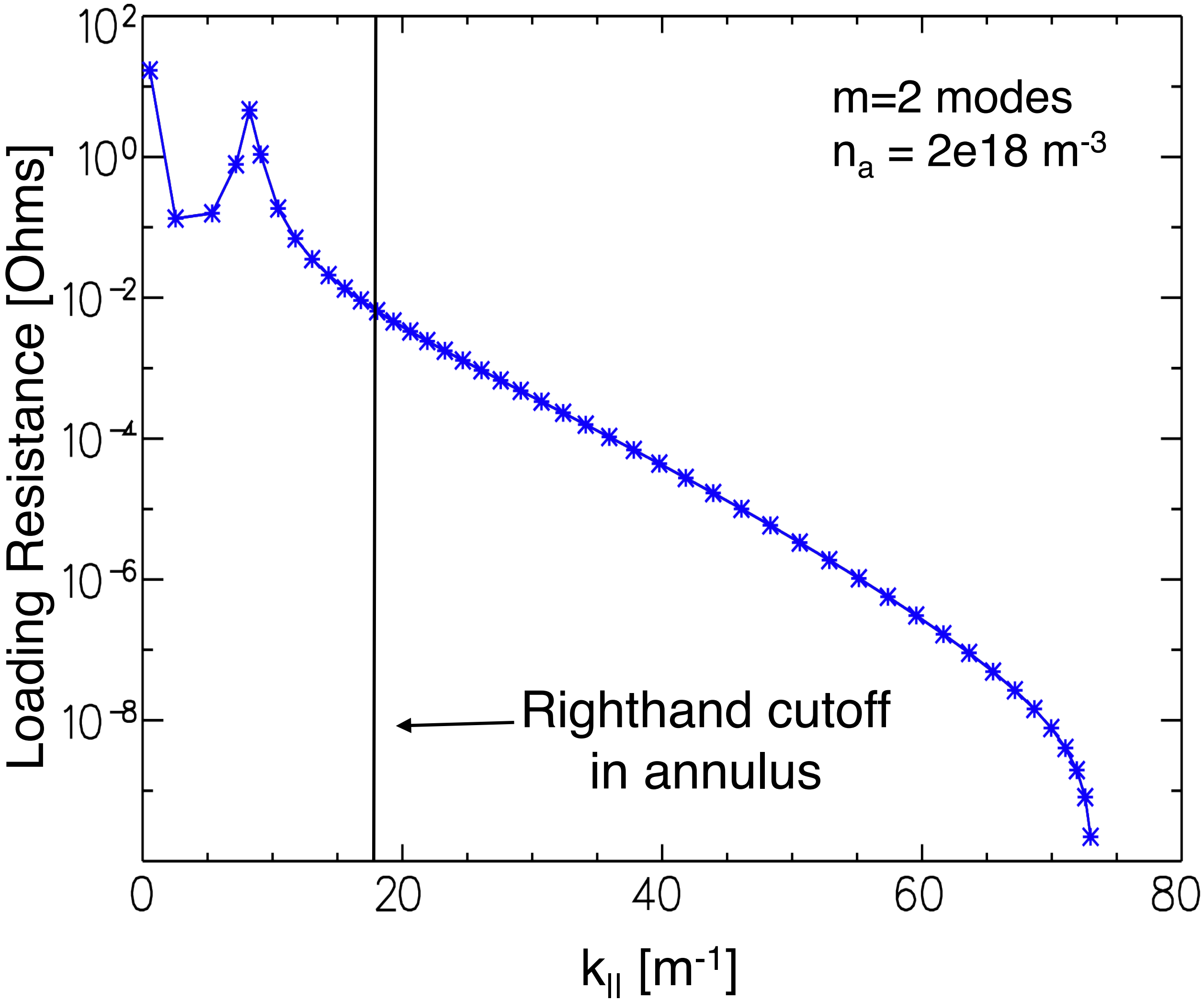
$$H_\theta = H_\theta(r)e^{im\theta+ik_{||}z-i\omega t}$$

- Solve Maxwell's equations in each region and match solutions at interfaces



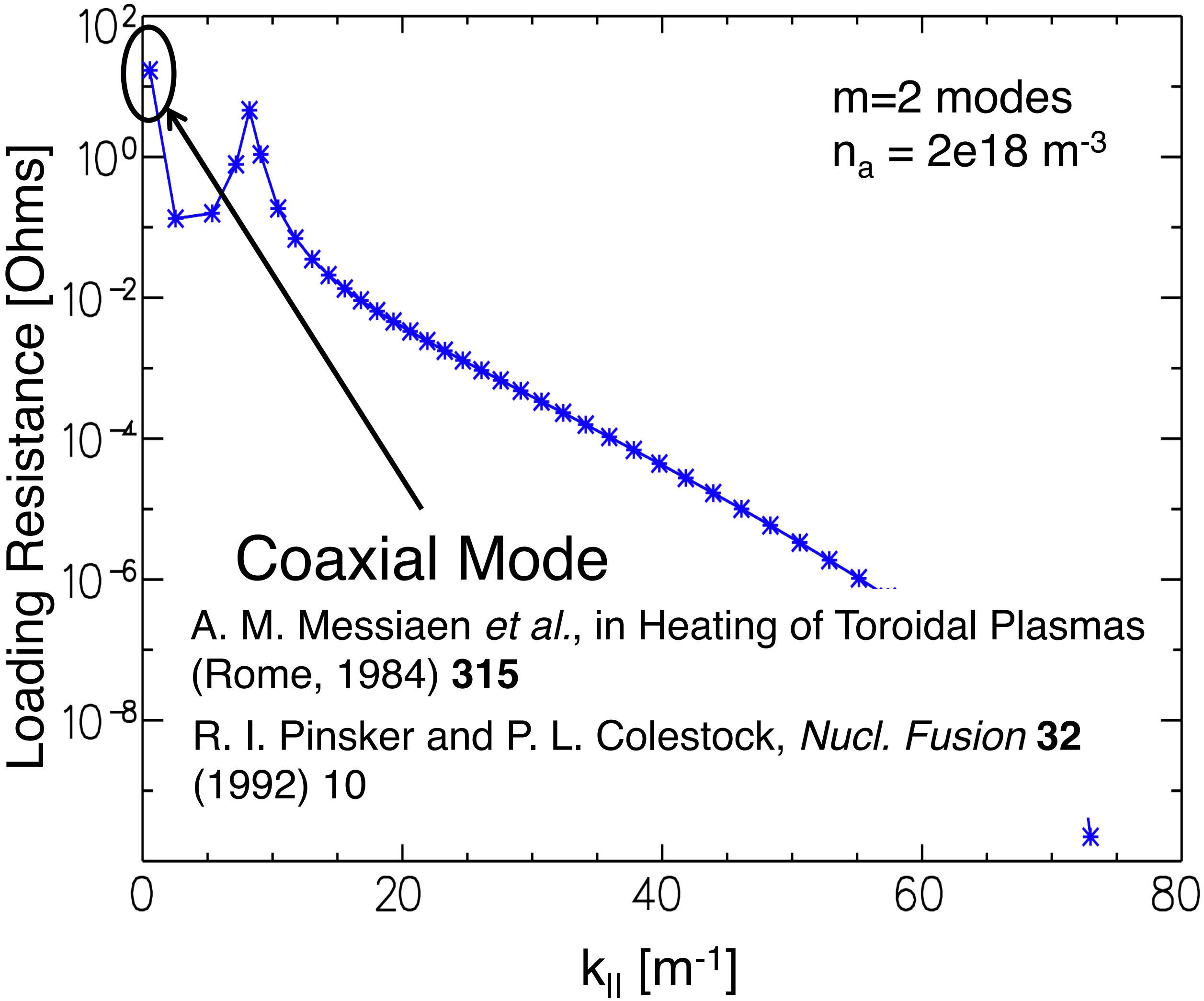
- Slow wave is retained
  - Slow wave is very cutoff
  - Numerical gymnastics required to preserve accuracy
- Only discrete $k_{||}$ are allowed since system is bounded

Cylindrical model computes two peaks in loading resistance



- First peak is a single low-$k_{||}$ mode
- Second peak is broader at larger $k_{||}$ but below R-cutoff in annulus

First peak can be identified with a "coaxial mode" mentioned loosely in ICRF literature

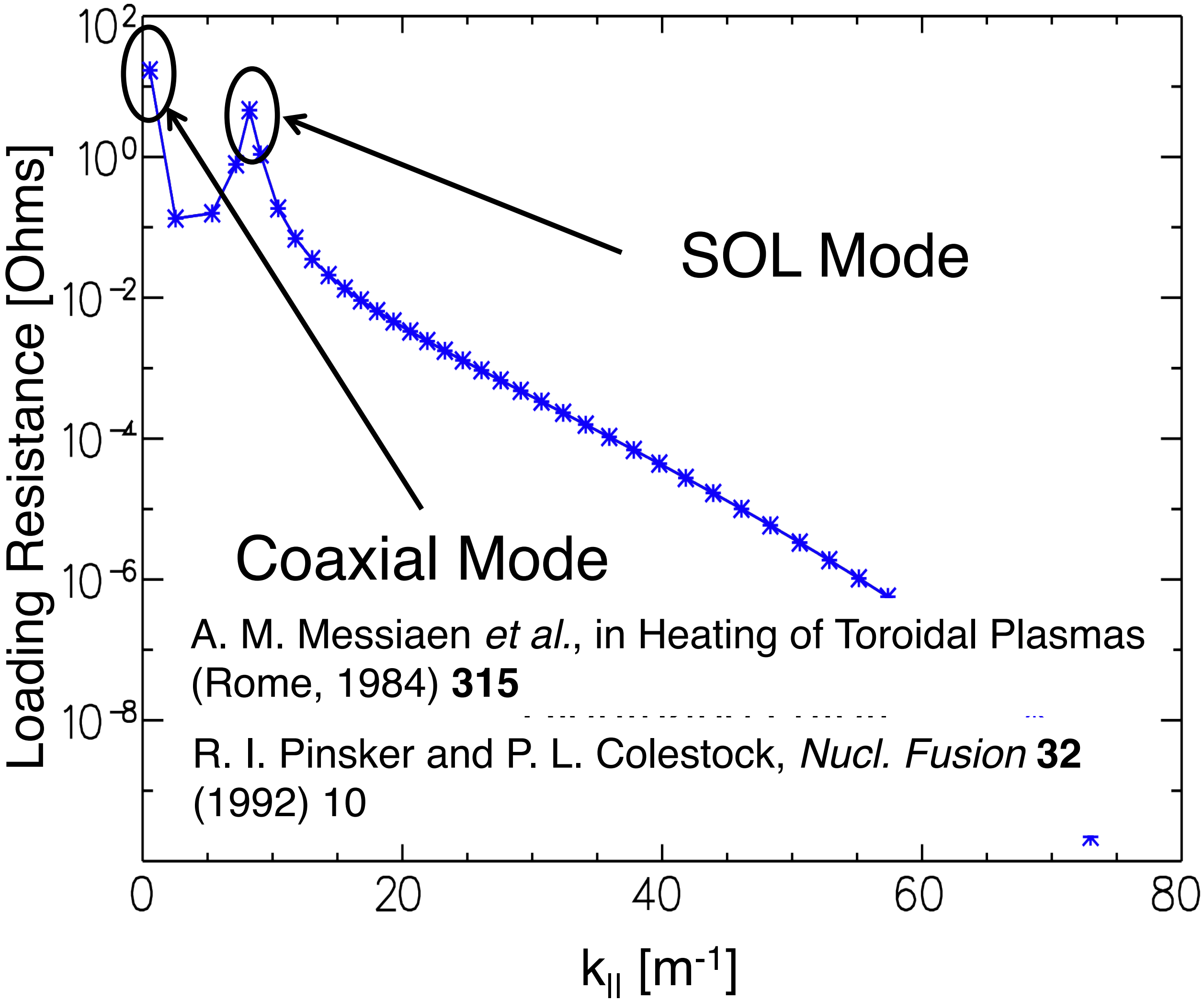


A. M. Messiaen *et al.*, in Heating of Toroidal Plasmas (Rome, 1984) **315**

R. I. Pinsker and P. L. Colestock, *Nucl. Fusion* **32** (1992) 10

- "Coaxial mode"
  - Analogous to modes in coaxial cable
  - Conducts a lot of wave power in vacuum region
  - Spurious mode

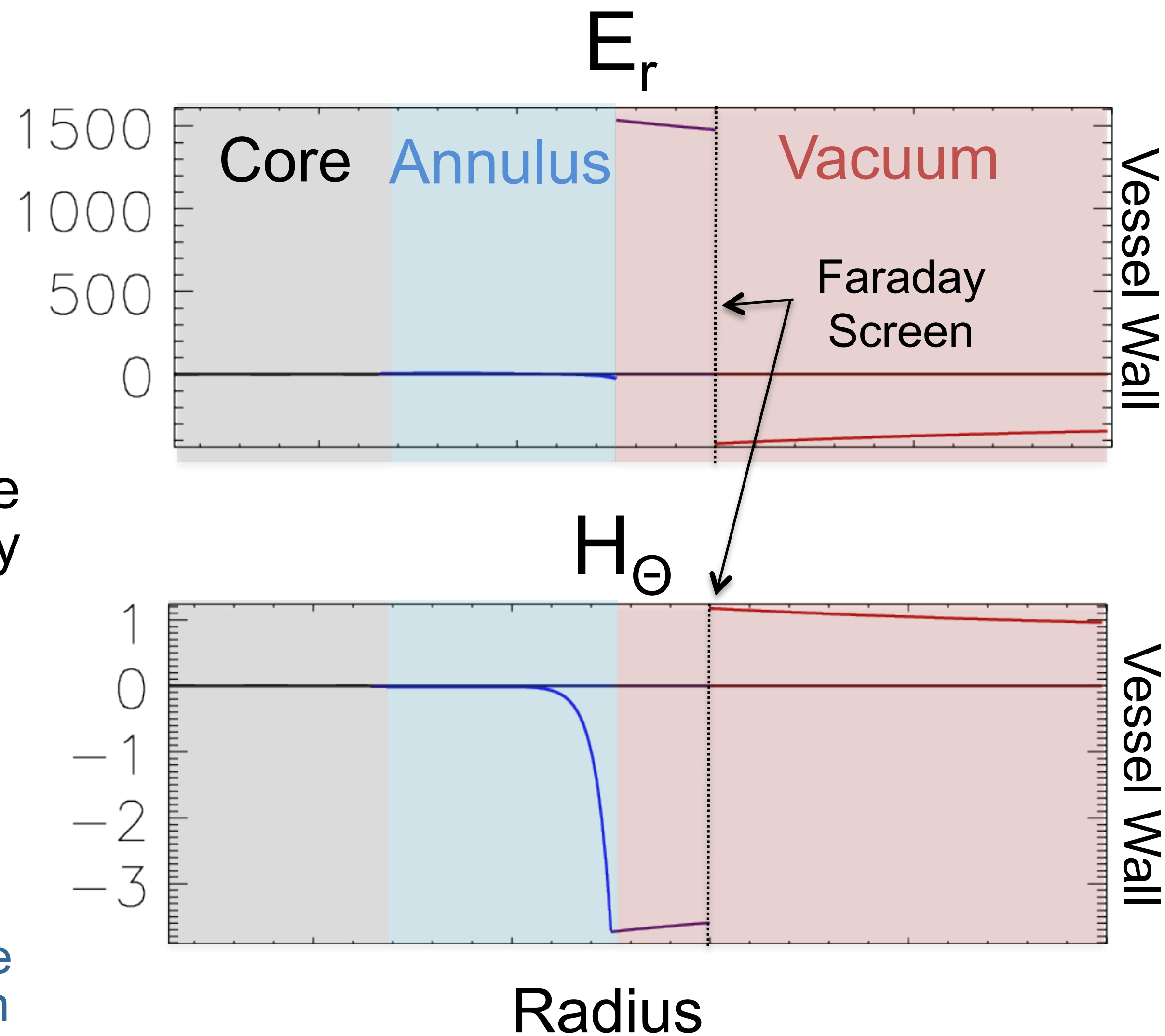
Second peak is distinct from coax mode
Could be relevant to SOL losses on NSTX



- "Coaxial mode"
  - Analogous to modes in coaxial cable
  - Conducts a lot of wave power in vacuum region
  - Spurious mode
- "SOL" mode
  - Conducts > 50% power in annulus
  - $k_{||}$ below R-cutoff and depends on annulus density

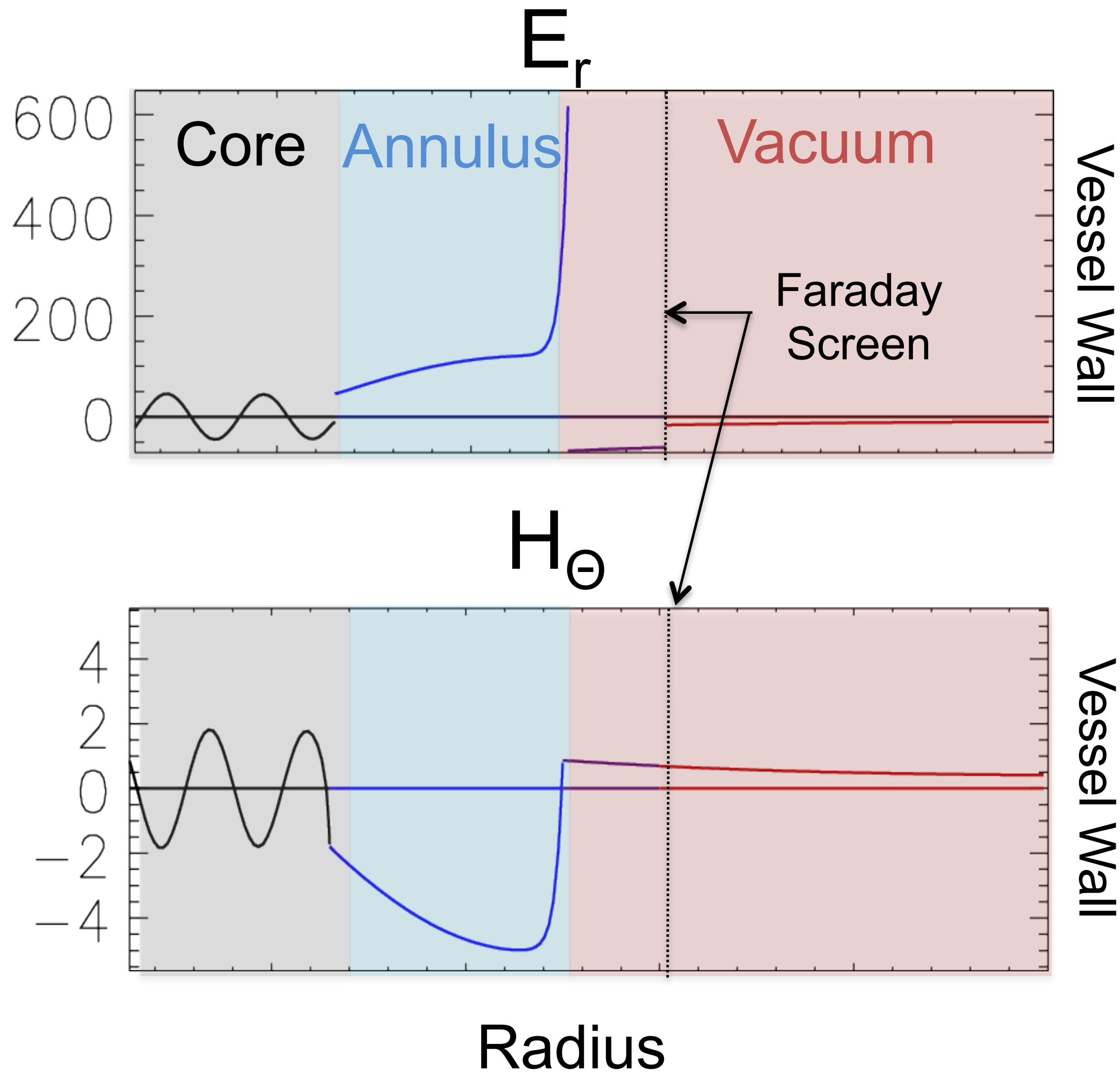
Coax mode does indeed have field structure of modes found in coaxial cables

- Coax mode has TEM (transverse electric & magnetic) structure
  - E_z and H_z vanish in vacuum
  - Fields excluded from plasma
- Current sheet & surface charge layer at Faraday screen
  - Mode would be cutoff without the screen
- Coax mode is likely fictitious!
  - Only exists due to infinite extent of Faraday screen in model

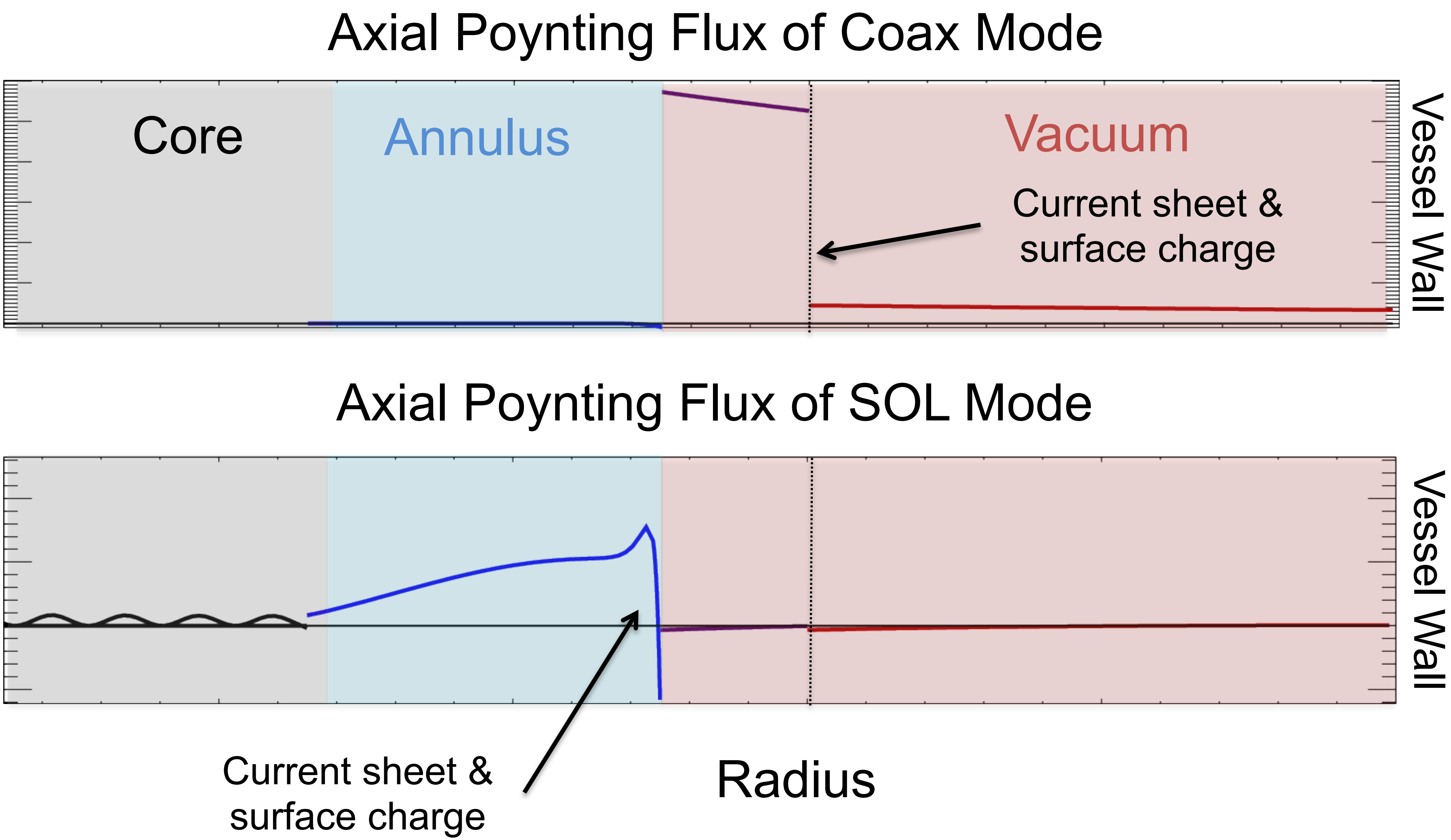


SOL mode is distinct from coax mode but also has a current sheet/surface charge

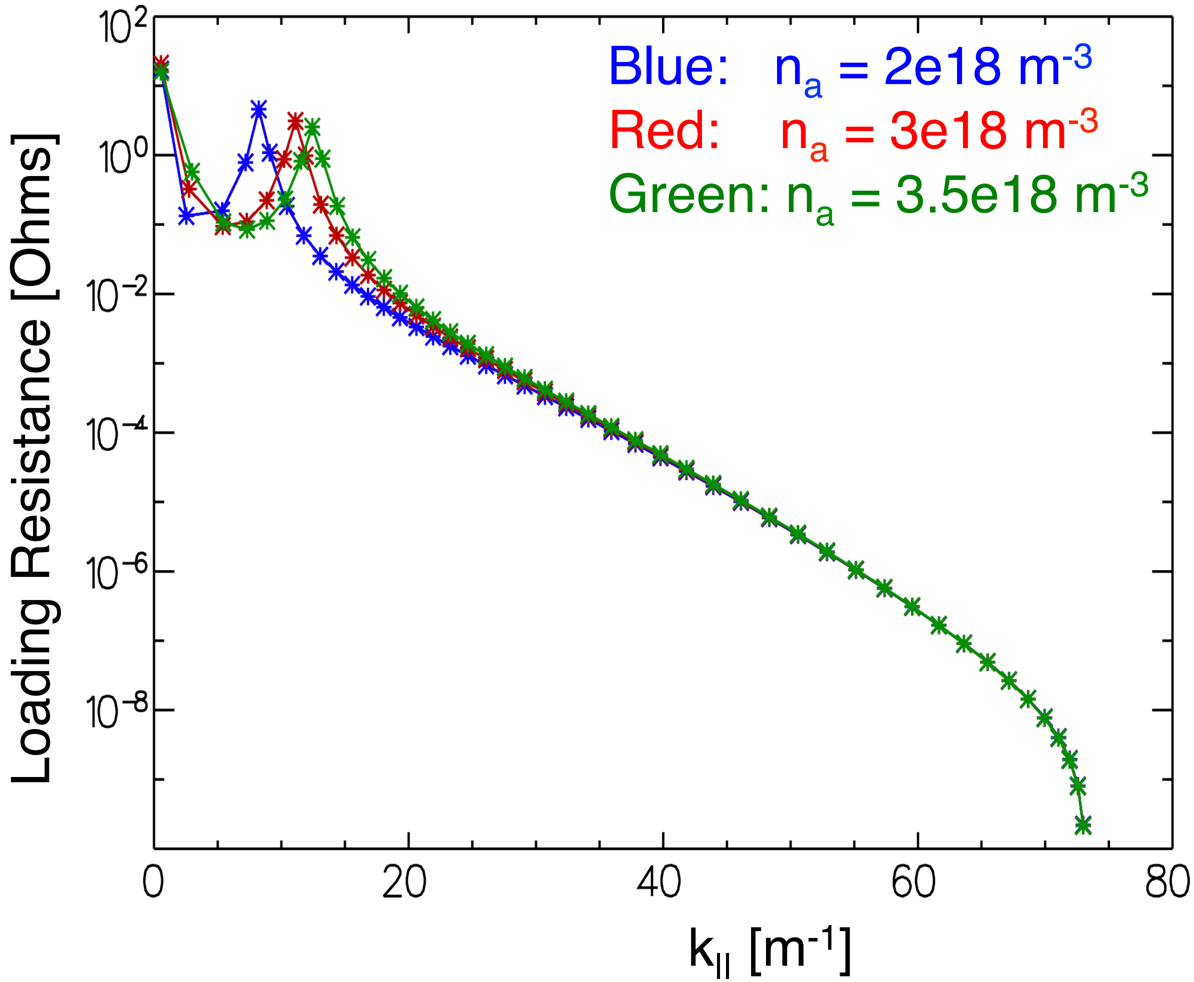
- SOL mode cannot be identified as a coax mode
  - It is not a TEM mode
    - $B_z \neq 0$ in vacuum
  - Conducts 36% of wave power in core
- Does have current sheet/surface charge
  - Occurs at annulus-vacuum boundary
    - Not at the Faraday screen
  - Current sheet supported by slow mode



Both modes conduct most power just inside current sheet/surface charge layer



SOL mode is sensitive to annulus density
Coax mode is unaffected



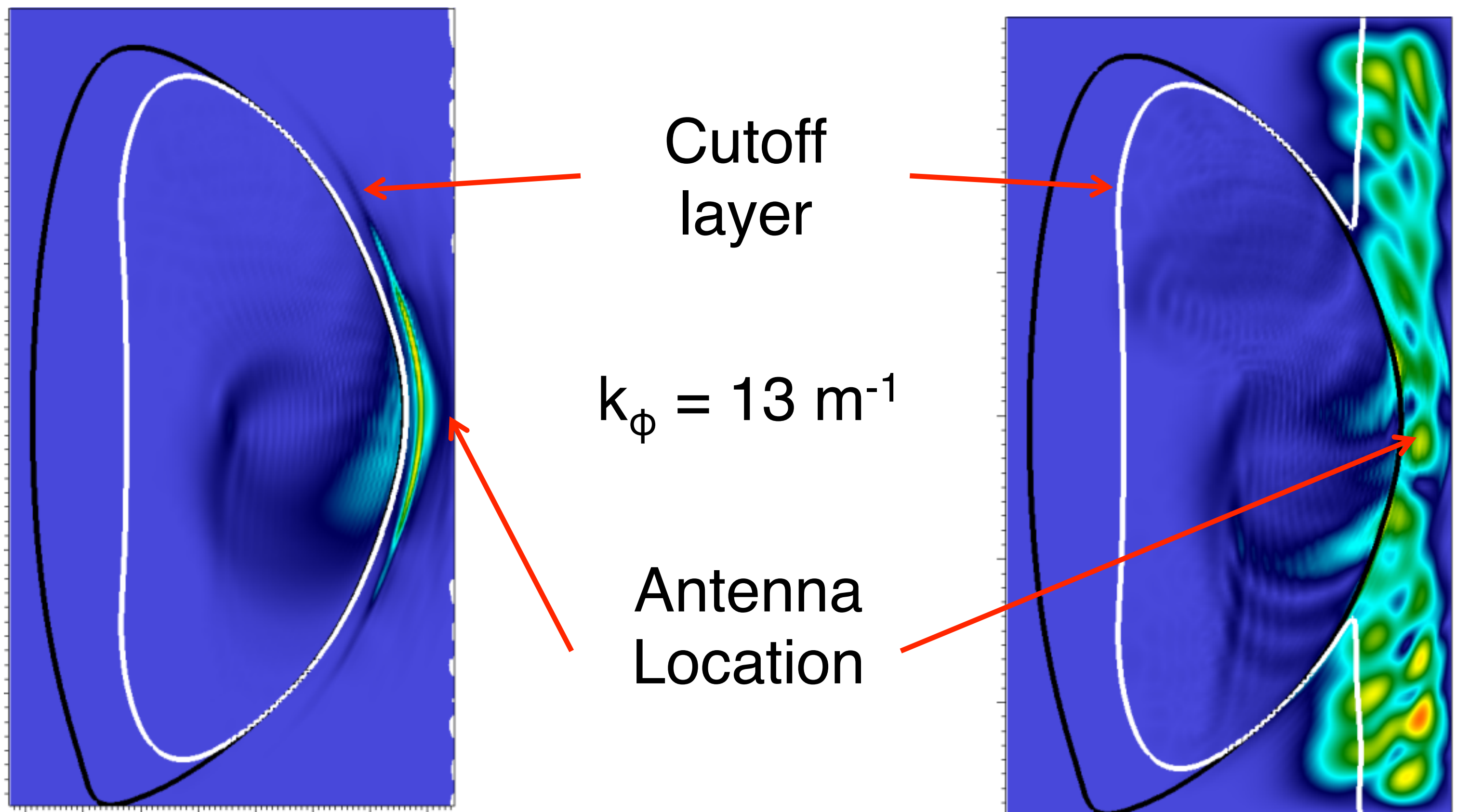
- SOL losses are very sensitive to edge density, as seen in:
  - experiments: J.C. Hosea *et al*., *Phys. Plasmas* **15**, 056104 (2008)
  - full-wave simulation: N. Bertelli et al., *Nucl. Fusion* **54** (2014) 083004
- Could adjust density to move SOL mode onto or off of peak of antenna spectrum
  - Maximize/minimize SOL power flux

Conclusions

- Cylindrical model predicts a class of modes, “SOL” modes, relevant to SOL losses on NSTX
  - Propagate significant power in annulus region
  - Sensitive to annulus density
- SOL modes are distinct from coax modes
  - Both modes thrive on a current sheet / surface charge layer
- Next step: 3D reconstruction of fields the assess how closely Poynting flux remains field aligned

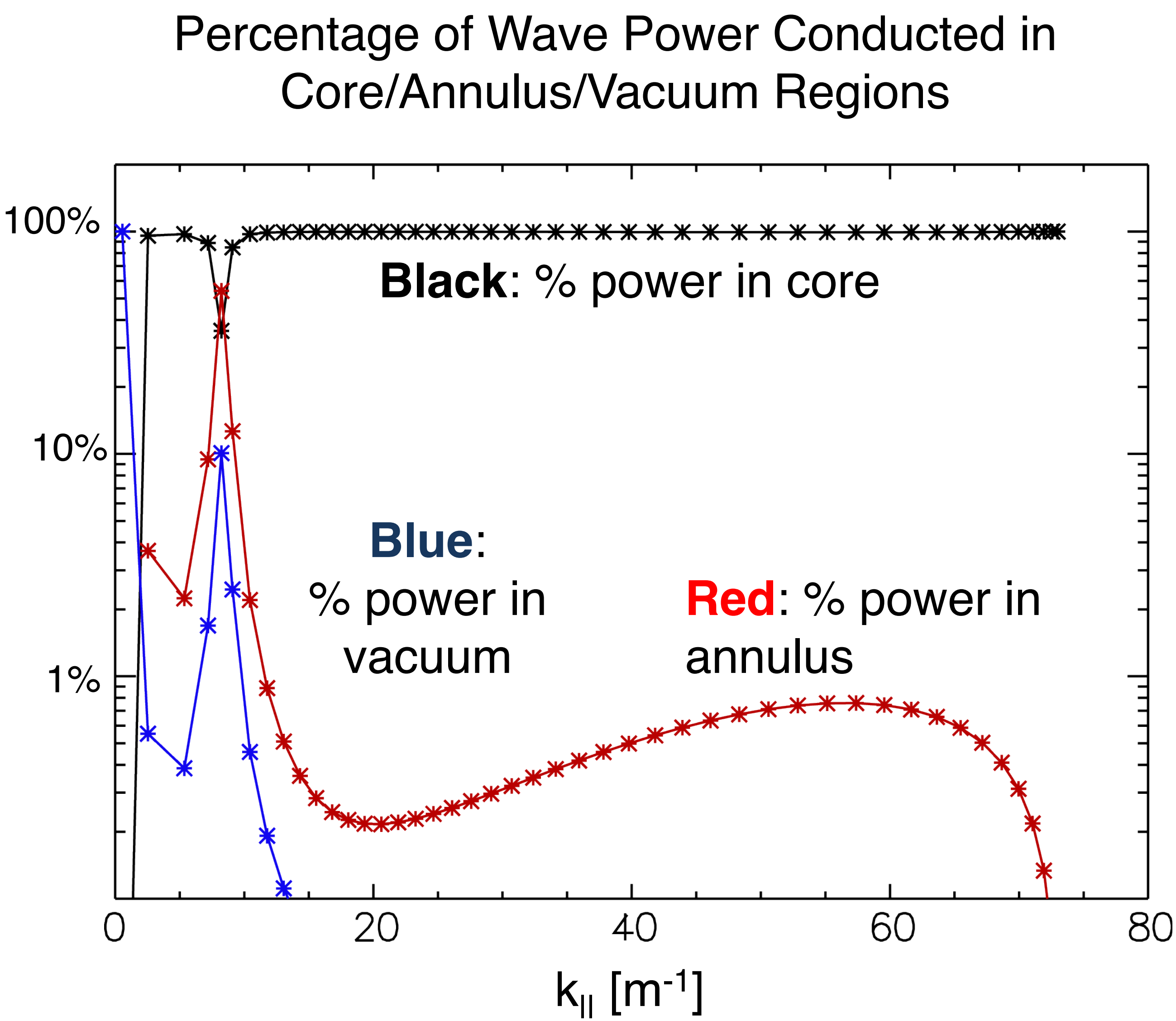
AORSA simulations show enhanced RF fields in SOL when R-cutoff opens in front of antenna

Lower SOL density (n_{ant} = 1e18 m^{-3}) | Higher SOL density (n_{ant} = 2e18 m^{-3})



N. Bertelli *et al.*, *Nucl. Fusion* **54** (2014) 083004

Coax mode power found vacuum region SOL mode power mostly in annulus



- Integrate axial Poynting flux over core/annulus/ vacuum
- Most modes conduct entirely in core
- Coax mode conduct entirely in vacuum region
- SOL mode:
  - 36% in core
  - 54% in annulus
  - 10% in vacuum

Raising annulus density shows multiple peaks: ¼- and ¾-λ structures in annulus