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**ENERGY**

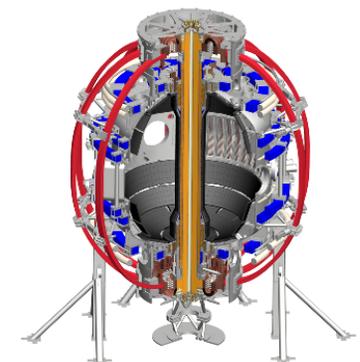
Office of  
Science



# Edge Loss Modeling and Plans

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NSTX-U Result Review Meeting  
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# 2D Full-wave (FW2D) code has been developed

- Wave equations : **frequency** domain

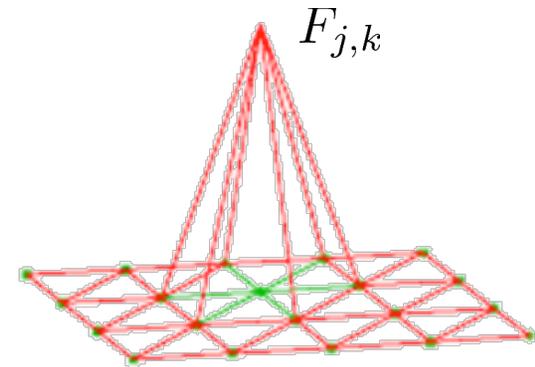
$$\nabla \times (\nabla \times \vec{E}) - \left(\frac{\omega}{c}\right)^2 \epsilon \cdot \vec{E} = 4\pi \frac{i\omega}{c^2} \vec{j}_{ext}$$

- Finite element method**

- Discretize E-field components into a sum over basis functions;

$$E_b(r, z) = \sum_{j,k} E_{b,j,k} F_{b,j,k}(r, z)$$

Sum over nodes j of triangles k



- Take inner product of wave equation with each  $F_{j,k}$ , integrate curl term by parts
- Solve the matrix!

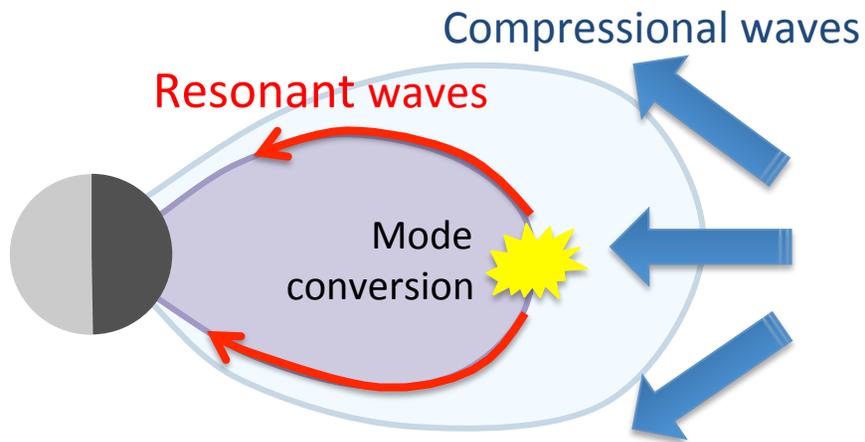
## Advantage

- ✓ *Speed – Fast*
- ✓ *Flexibility – Various Boundaries Shapes*

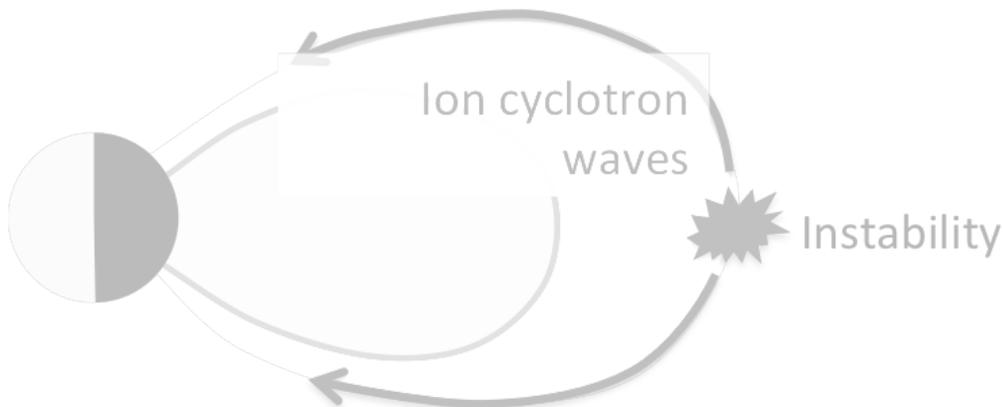
[e.g., Brambilla, 1999; Kim, Johnson, Valeo, and Phillips, 2015, Geophys. Res. Lett.]

# FW2D has been adopted to **space** and **tokamak** plasmas

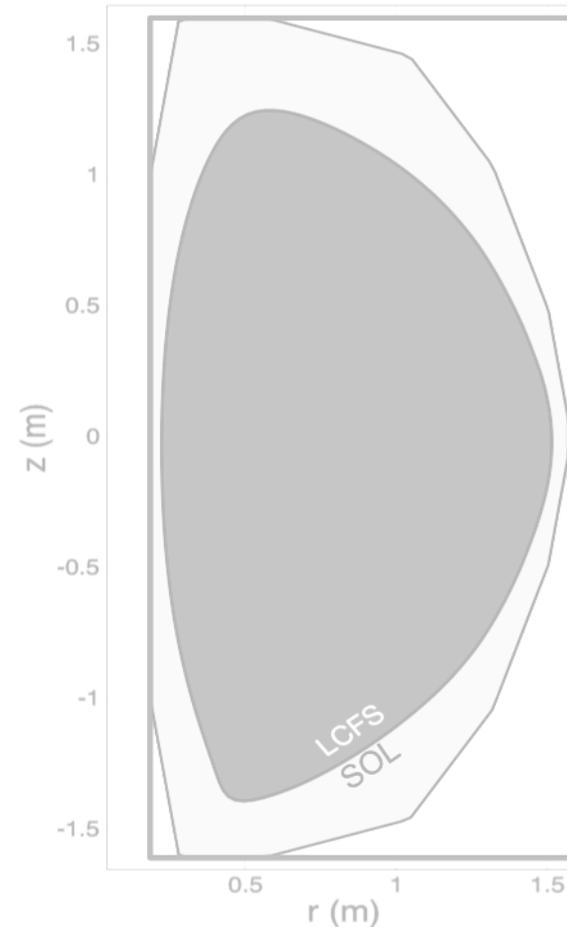
## Externally driven waves in space



## Internally generated waves in space

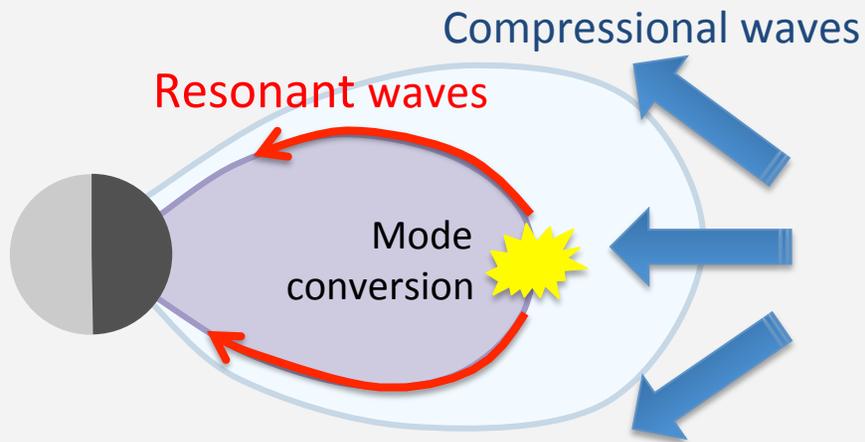


## Fast waves in the SOL

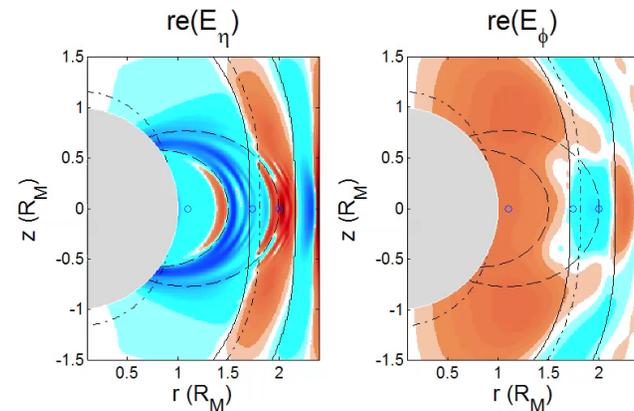


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## Externally driven waves in space

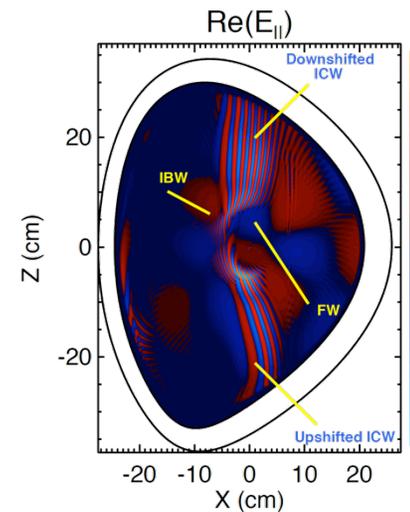
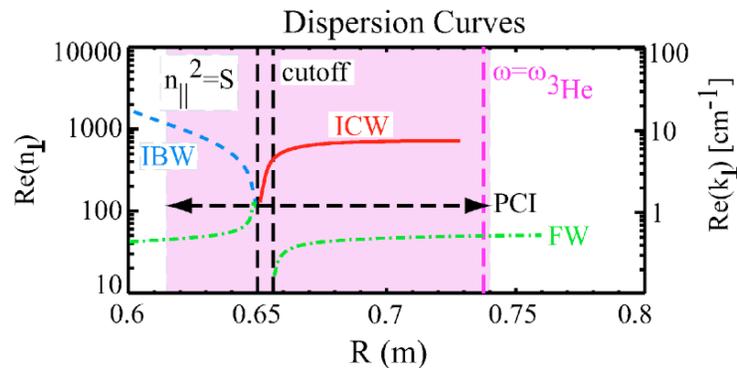


## Mode conversion at Mercury



[Kim et al., 2015, GRL]

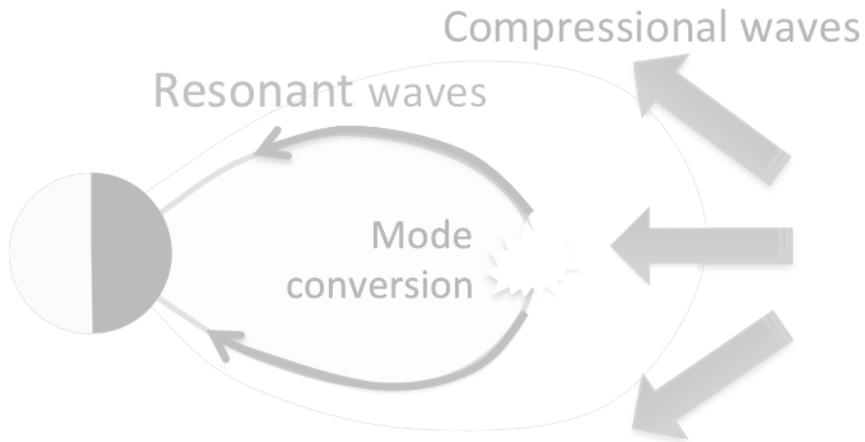
## cf. Mode conversion in the tokamak



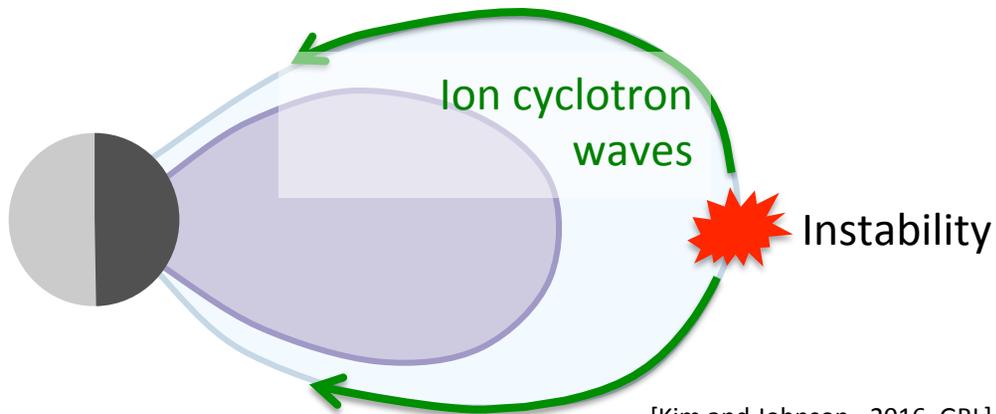
[Wukitch et al., 2005]

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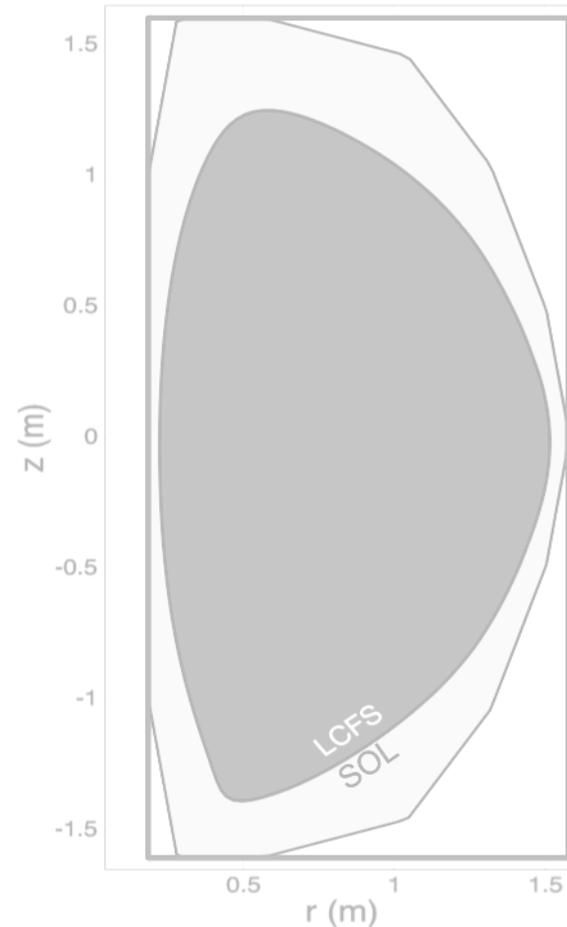


## Internally generated waves in space



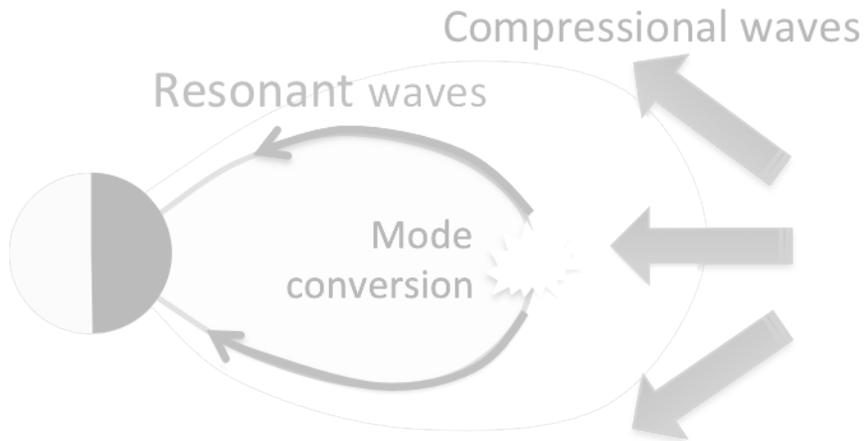
[Kim and Johnson., 2016, GRL]

## Fast waves in the SOL

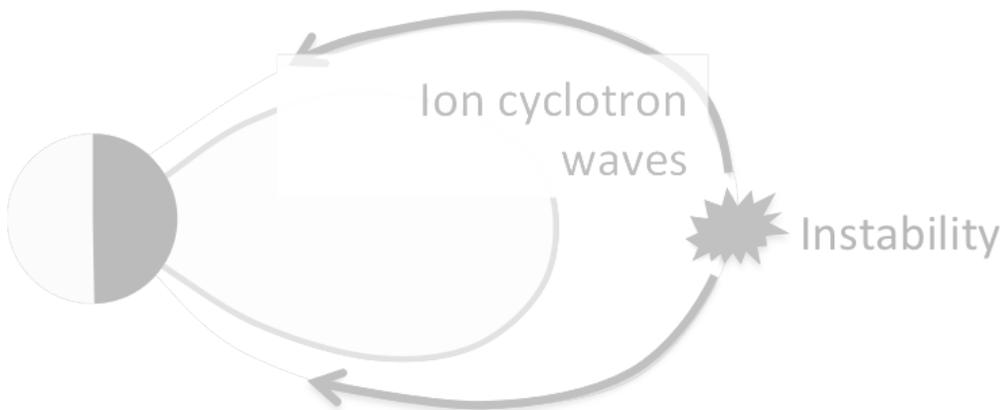


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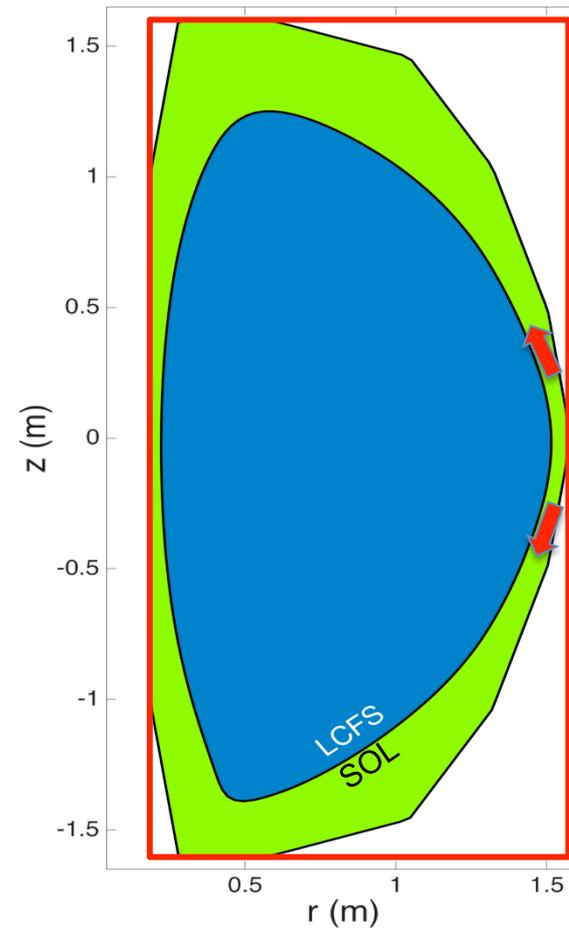
## Externally driven waves in space



## Internally generated waves in space

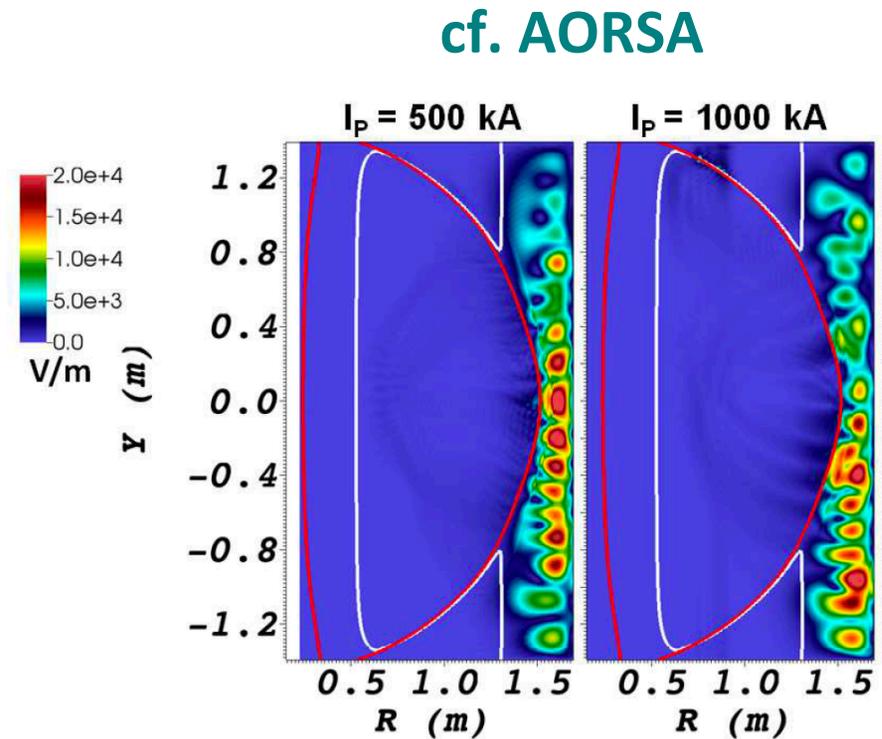
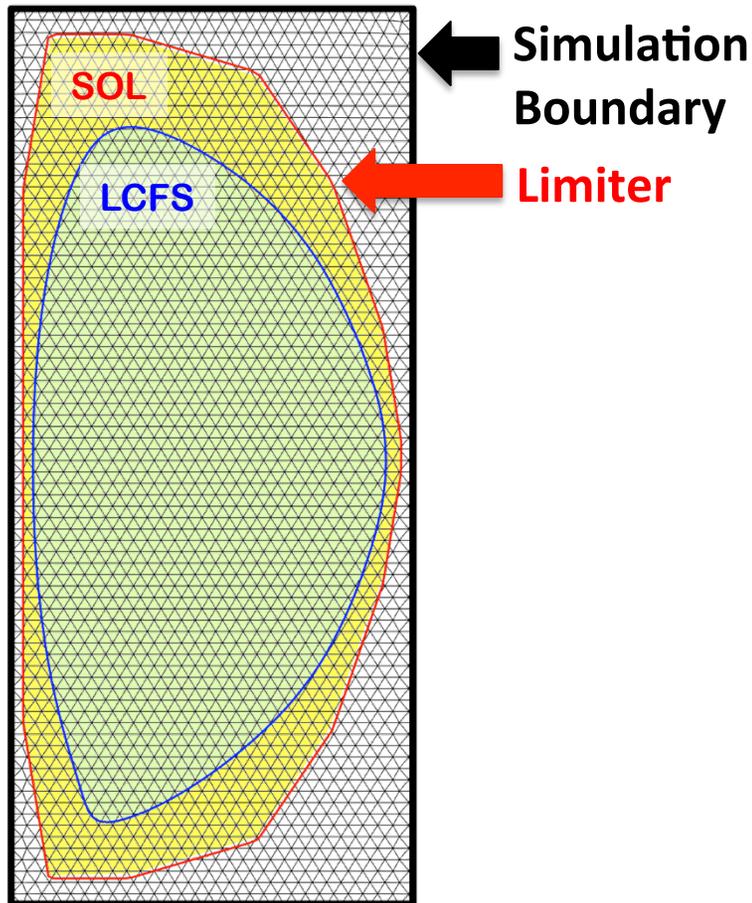


## Fast waves in the SOL



# FW2D can adopt a **realistic boundary**

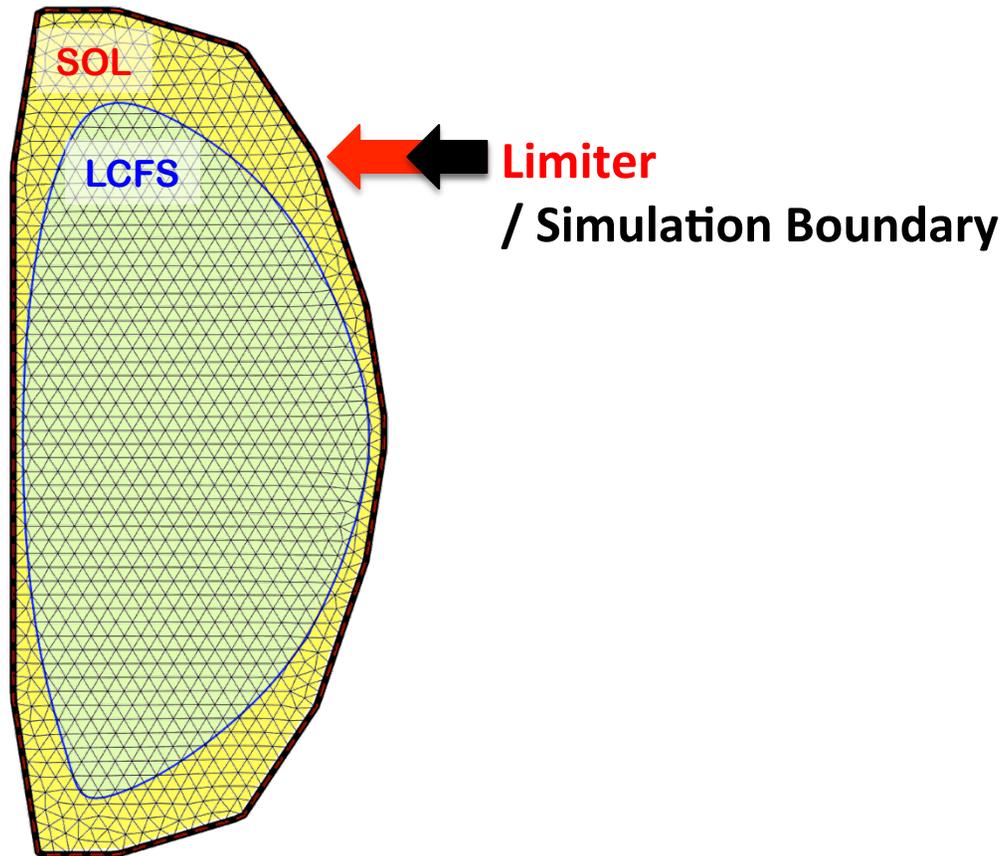
- Rectangular Boundary (**NOT** a realistic boundary)



[Bertelli et al., 2016, Nucl. Fusion]

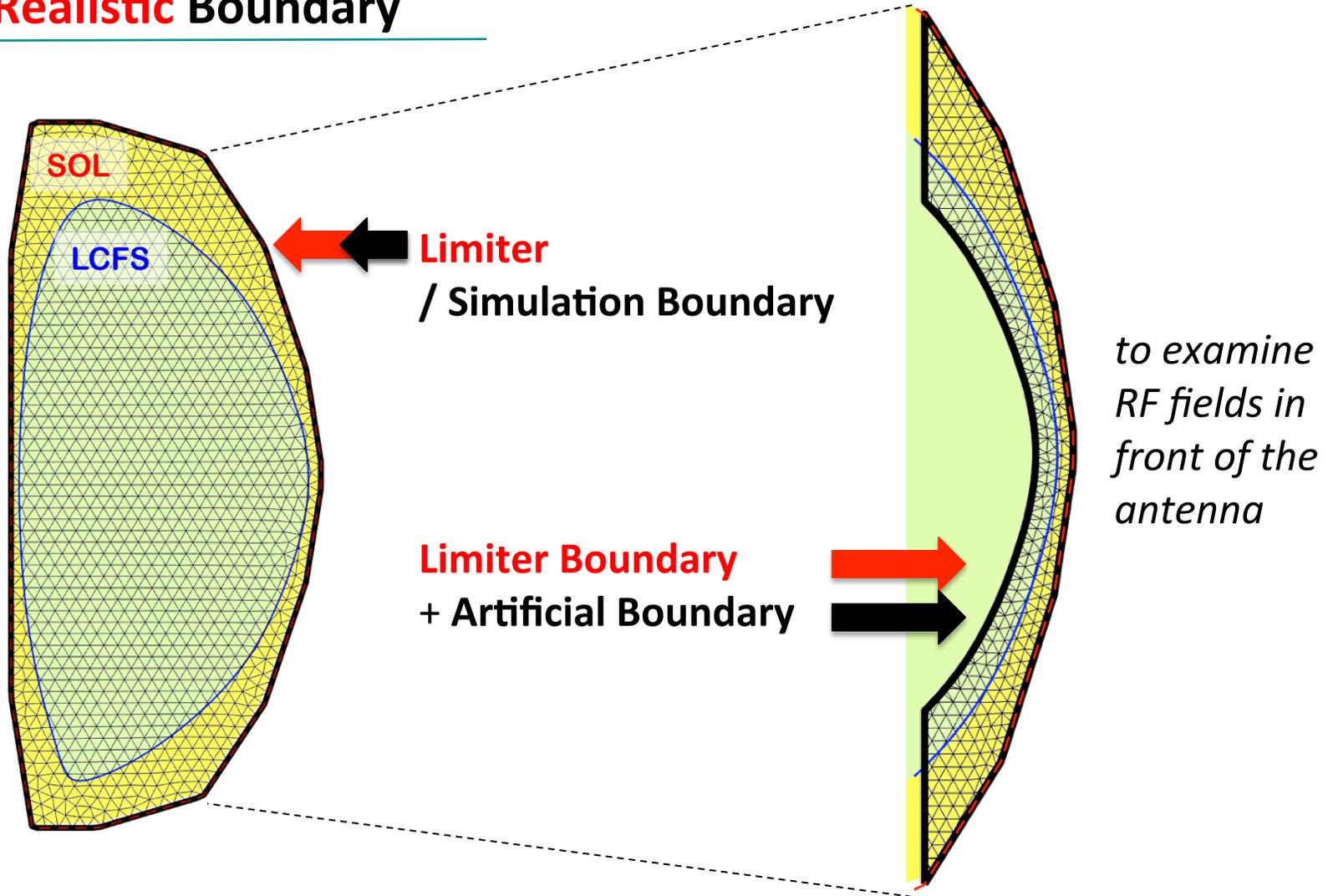
# FW2D can adopt a **realistic boundary**

- Realistic Boundary

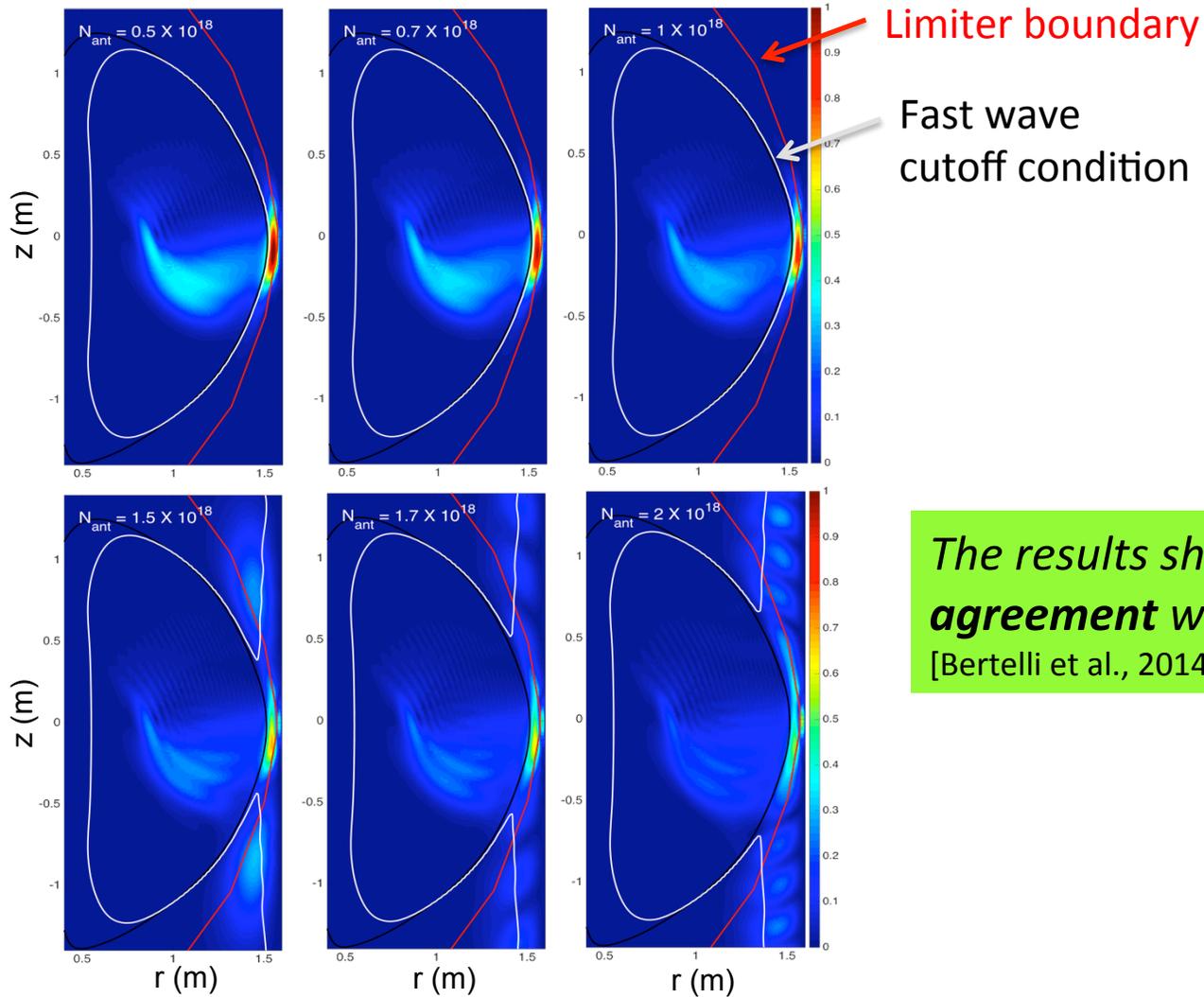


# FW2D can adopt a **realistic boundaries**

- **Realistic Boundary**



# HHFW in the SOL plasma has been initially examined using FW2D code in rectangular boundary



*The results shows good agreement with AORSA*  
[Bertelli et al., 2014]

# HHFW in the SOL plasma has been initially examined using FW2D code in rectangular boundary

## Next step

- Benchmark / compare to AORSA
- Parallelize
  
- Realistic boundary geometry
- Density in the SOL ...
- Very detailed behavior of RF field in front of the antenna

## Future plan

- Include kinetic effects
- Extend to 3D

## TEST results in realistic boundary geometry

