The role of plasma response in divertor footprint modification by 3-D fields in NSTX

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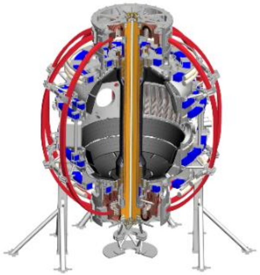


Motivation and outline

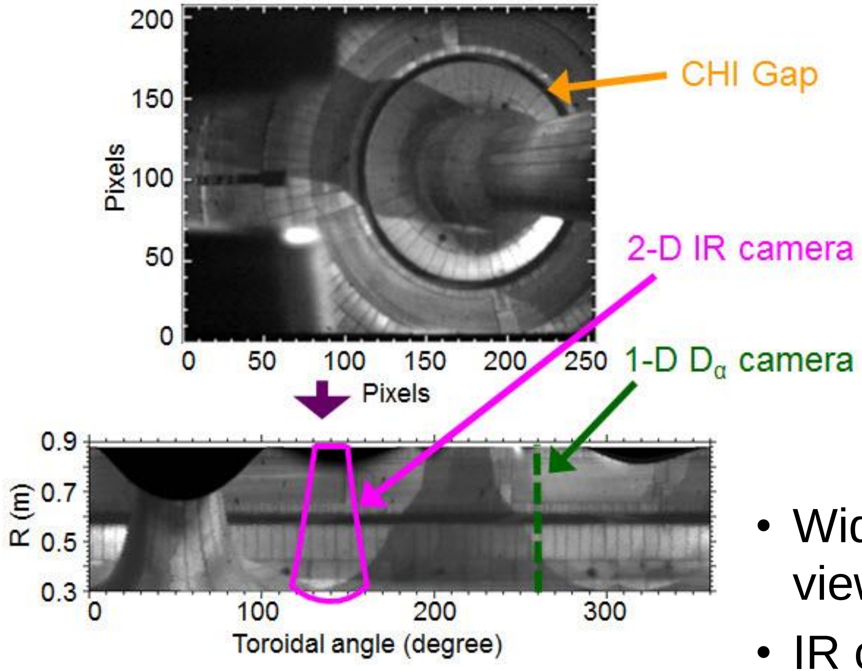
- Non-axisymmetric divertor footprints with 3-D fields are concern for future machines due to 3-D erosion and re-deposition

- 3-D footprints are strongly affected by plasma response → measurement is compared to field line tracing
  - Vacuum field line tracing
  - Ideal plasma response model (IPEC)
  - Different response for n=3 and n=1

- Compact size of NSTX provides wide angle view of divertor footprints → easier comparison to modeling

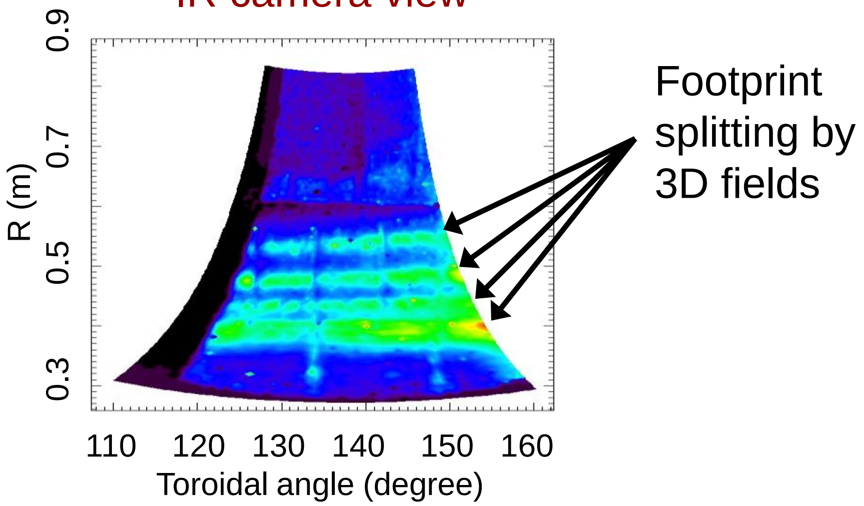
Visible and IR camera data provide images for 3-D heat and particle flux

Visible camera view



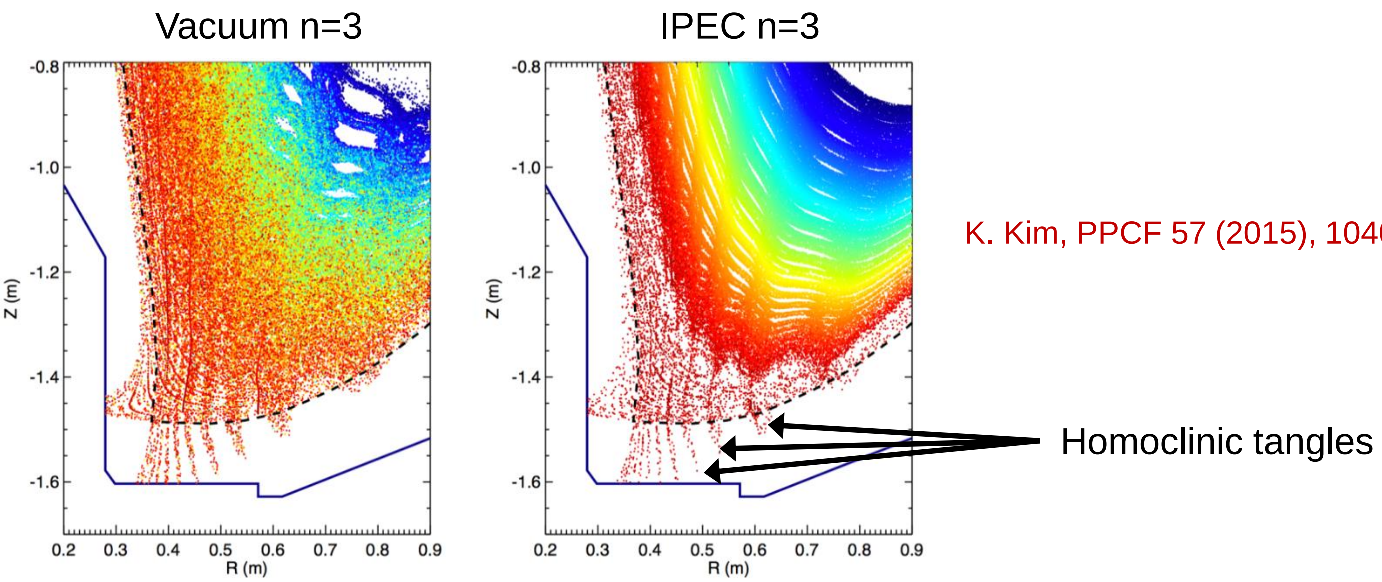
F. Scotti, RSI 83 (2012), 10E532

IR camera view



- Wide angle visible camera for nearly full toroidal view (Li-I filter, λ=670.9nm)
- IR camera for non-axisymmetric heat flux analysis
- Images re-mapped to (r, Φ) plane

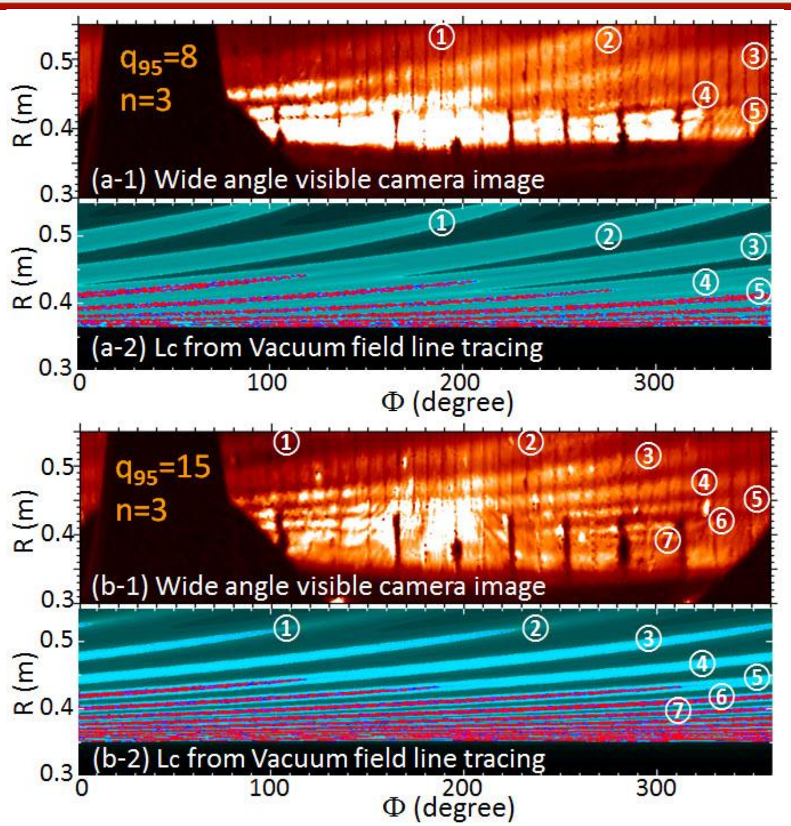
Field line tracing identifies lobes in the X-point region generated by 3-D fields, w/ and w/o plasma response



K. Kim, PPCF 57 (2015), 104002

- 3-D fields induce 3-D topology of perturbed field lines → lobe of homoclinic tangles
- Field line tracing simulation provides magnetic structure of 3-D lobes
  - Provide Poincare plot, divertor footprint, field line connection length profile, etc.
  - Compare results from vacuum approximation to that with ideal plasma response (IPEC)

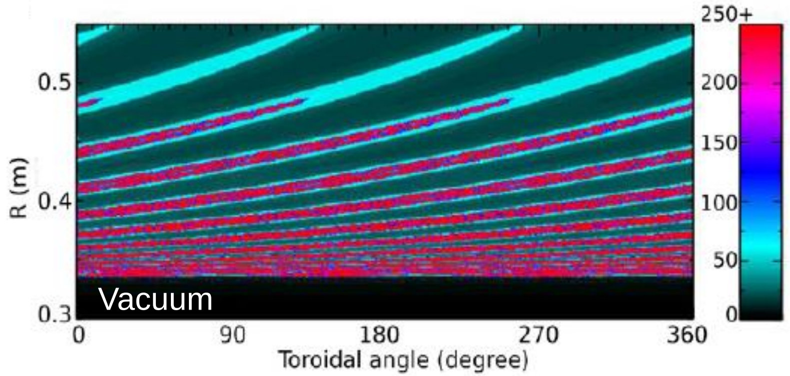
Vacuum approximation in agreement with footprints measurement for n=3 perturbation

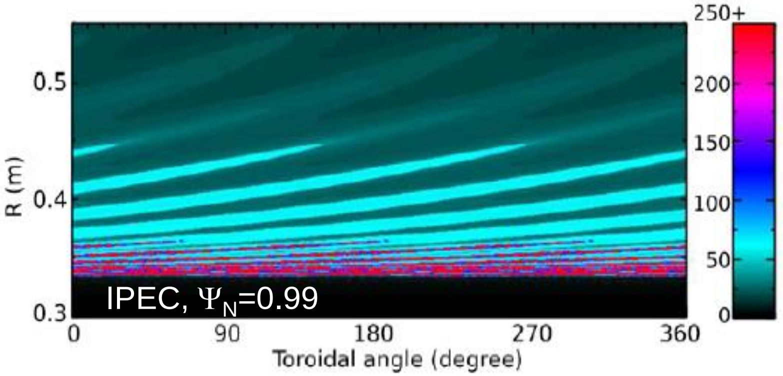


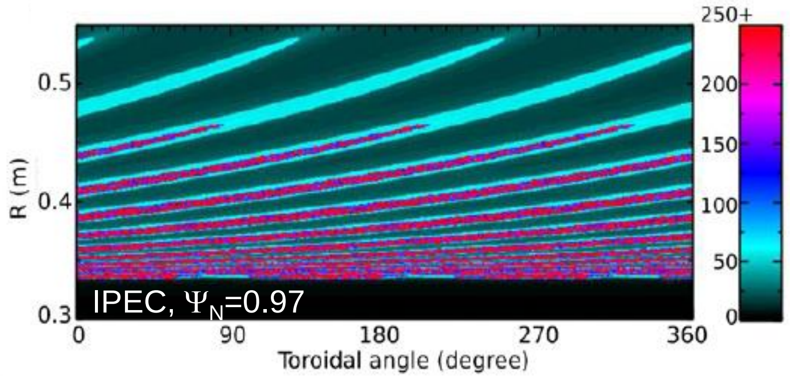
J-W. Ahn, PPCF 56 (2014), 015005

- Wide angle camera images enable comprehensive comparison to connection length (L_c) contour plot from vacuum field line tracing
- Both camera images and vacuum field line tracing produce more and narrower striations for higher q_{95}
- Good agreement between camera and vacuum field line tracing

Ideal plasma response weakens footprint striations but overall structure is similar to vacuum result for n=3



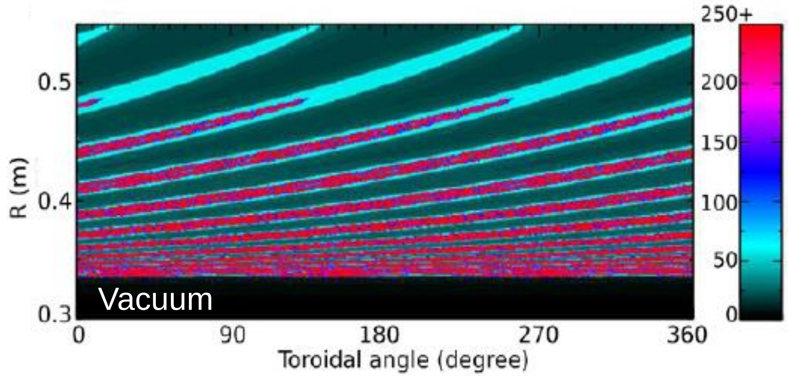


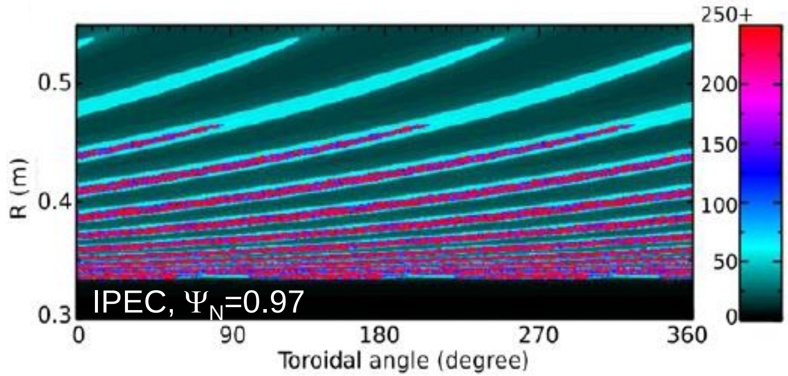


K. Kim, PPCF 57 (2015), 104002

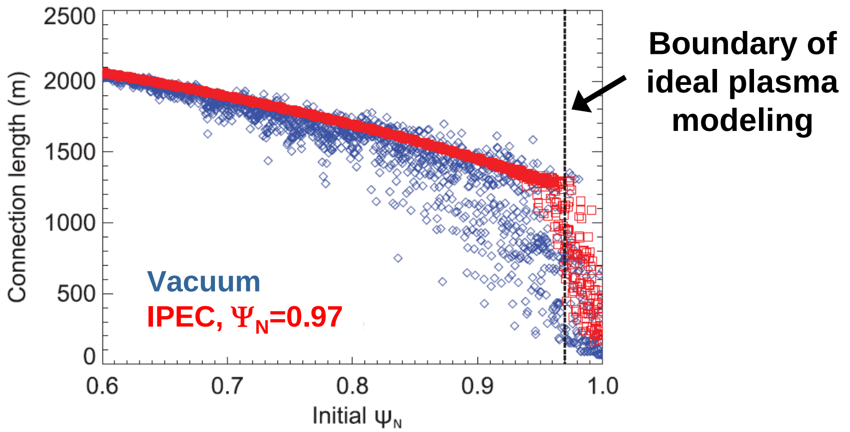
- Weakening effect from IPEC is affected by location of ideal plasma boundary
- Envelope of lobes not changed by response

Ideal plasma response shields applied 3D fields but overall structure is similar to vacuum result for n=3



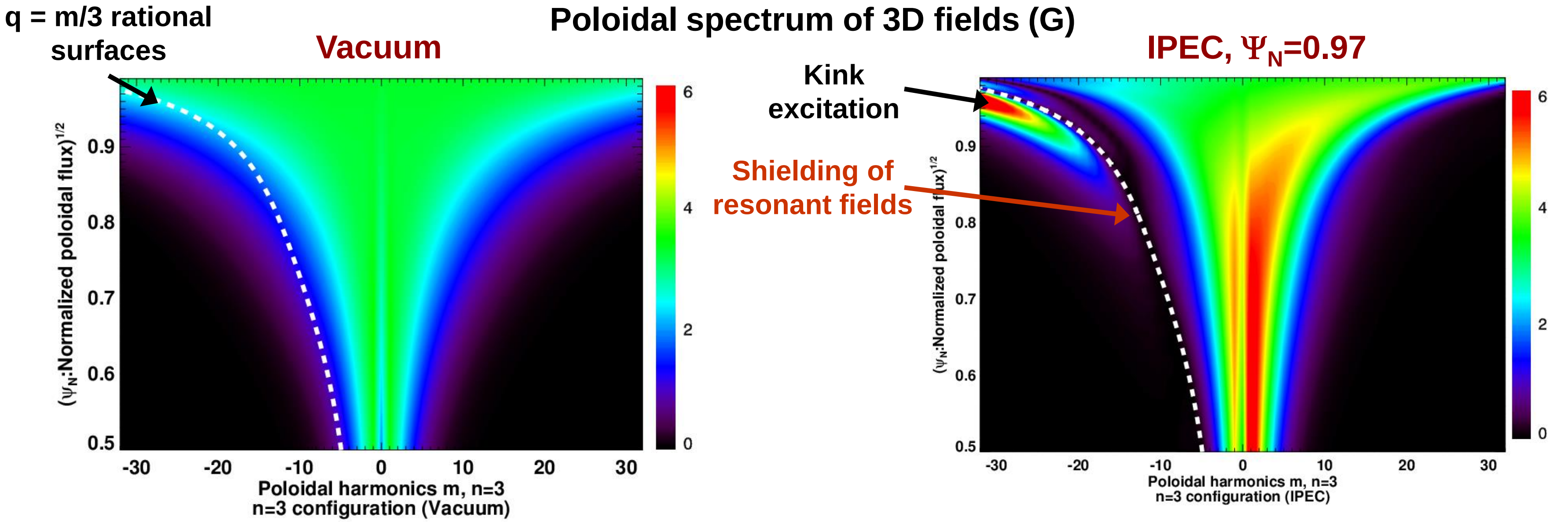


K. Kim, PPCF 57 (2015), 104002



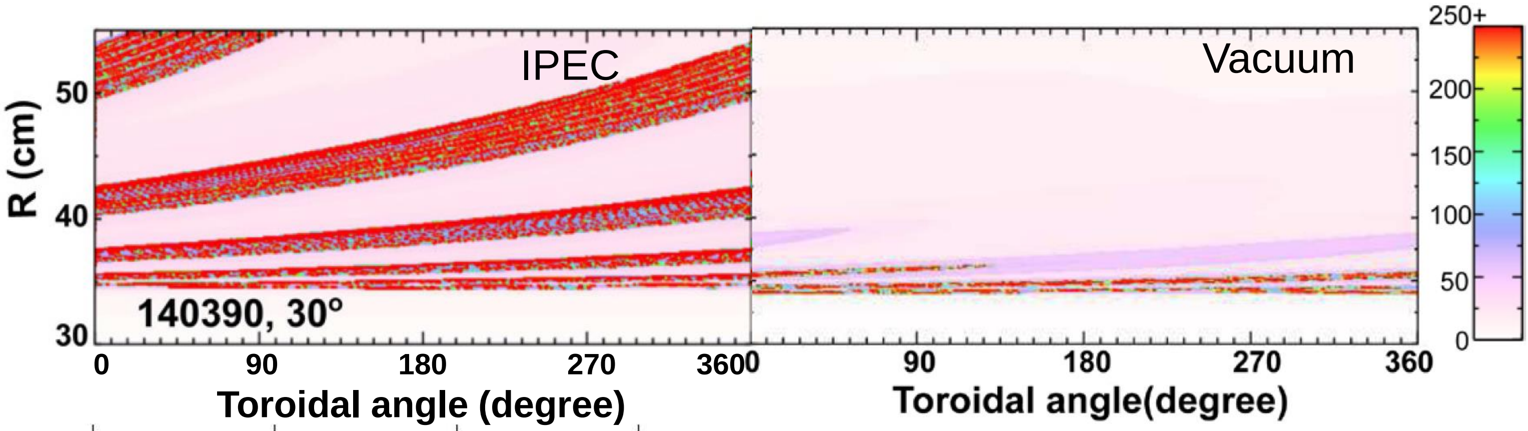
- Weakening effect from IPEC is affected by location of ideal plasma boundary
- Envelope of lobes not changed by response
- L_c profile inside separatrix shows modification of stochasticity and clear shielding effect by ideal plasma response

Shielding of resonant fields and amplification of kink response lead to weaker footprint splitting for n=3



- Resonant components are strongly shielded by ideal plasma response
- Non-resonant kink excitation is also observed
- Combined net effect is to shield the applied n=3 fields and weaken magnetic separatrix splitting

n=1 perturbation is very sensitive to plasma response – amplification of footprint splitting is observed



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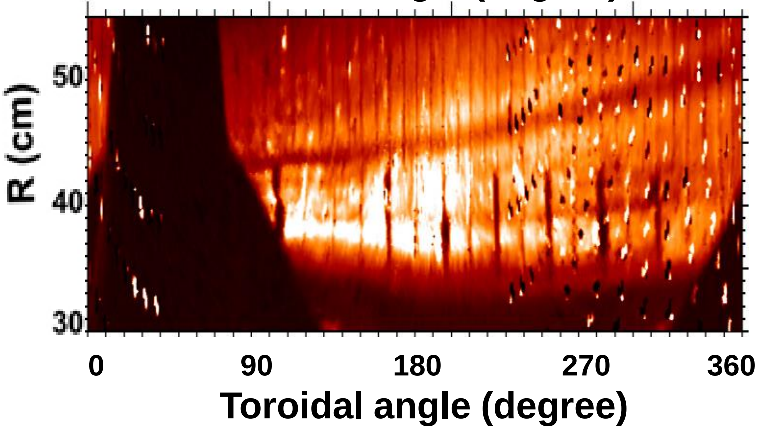
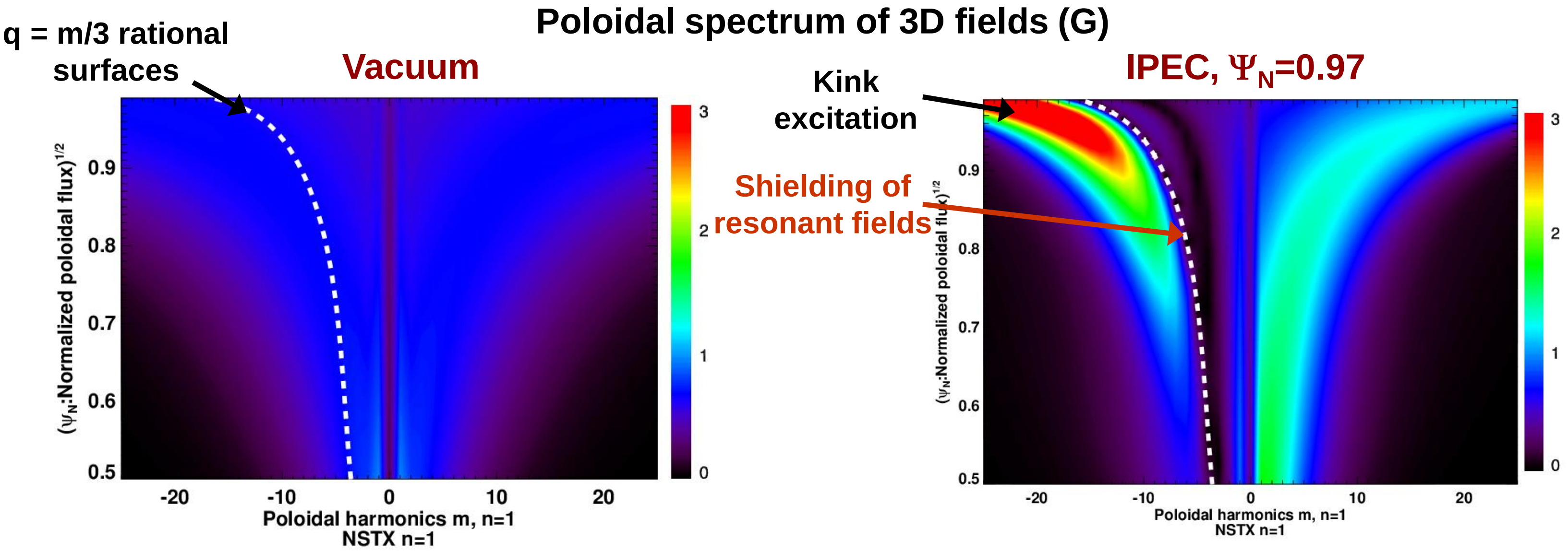


- Ideal plasma response dramatically amplifies n=1 separatrix splitting → better agrees with camera image
- Plasma response not only modifies amplitude, but also changes envelope of striations, unlike n=3

Strong kink excitation appears to be responsible for amplification of footprint splitting for n=1



- Resonant components are very weak in vacuum modeling and the ideal response only slightly shields them
- Non-resonant kink excitation is very strong
- Combined net effect is to significantly amplify the applied n=1 fields and splitting

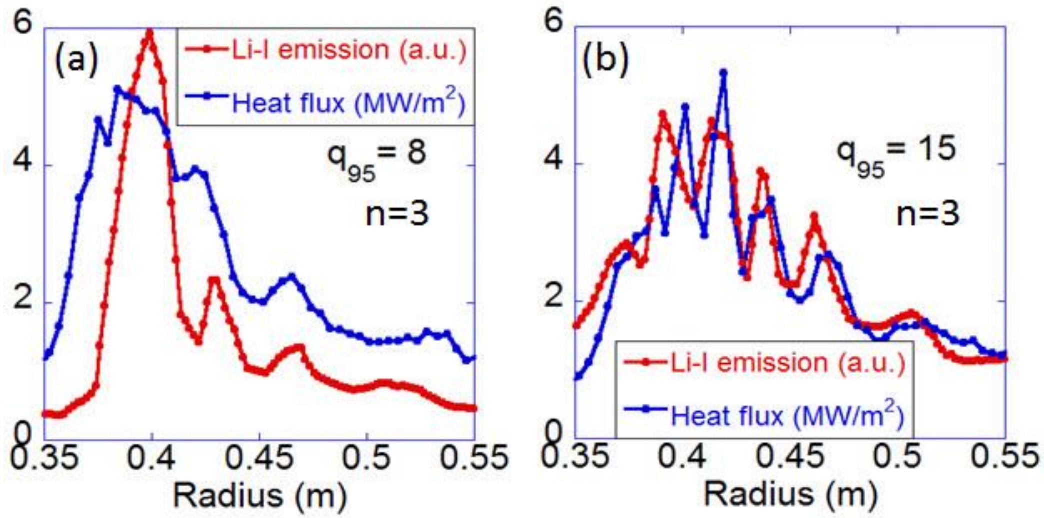
Summary and future works

- Field line tracing was successfully used for comparison to divertor footprints data generated by 3-D fields, w/ and w/o ideal plasma response
- For n=3:
  - Vacuum approximation good agreement with observation.
  - Ideal plasma response weakens n=3 footprint splitting, primarily due to shielding effect of resonant components. Sensitive to location of simulation boundary
  - Envelope of lobes not changed by plasma response
- For n=1:
  - Ideal plasma response significantly amplifies vacuum n=1 footprints, due to strong non-resonant kink excitation
  - Agreement of field line tracing with observation still to be improved

- Resistive plasma response simulation (M3D-C1) for magnetic modelling
- Use of edge 3-D transport simulation (EMC3-Eirene) for quantitative comparison to heat and particle flux measurements

Backup slide

Visible and IR camera data generally show good agreement for the location of 3-D striations



J-W. Ahn, PPCF 56 (2014), 015005

- IR heat flux profile and Li-I emission profile at $\Phi=145^o$
- Good agreement on the location of split strike points between IR and Li-I profile → Justifies use of both data for 3-D footprints study