

# Report 06/29/2020

P. Hacker



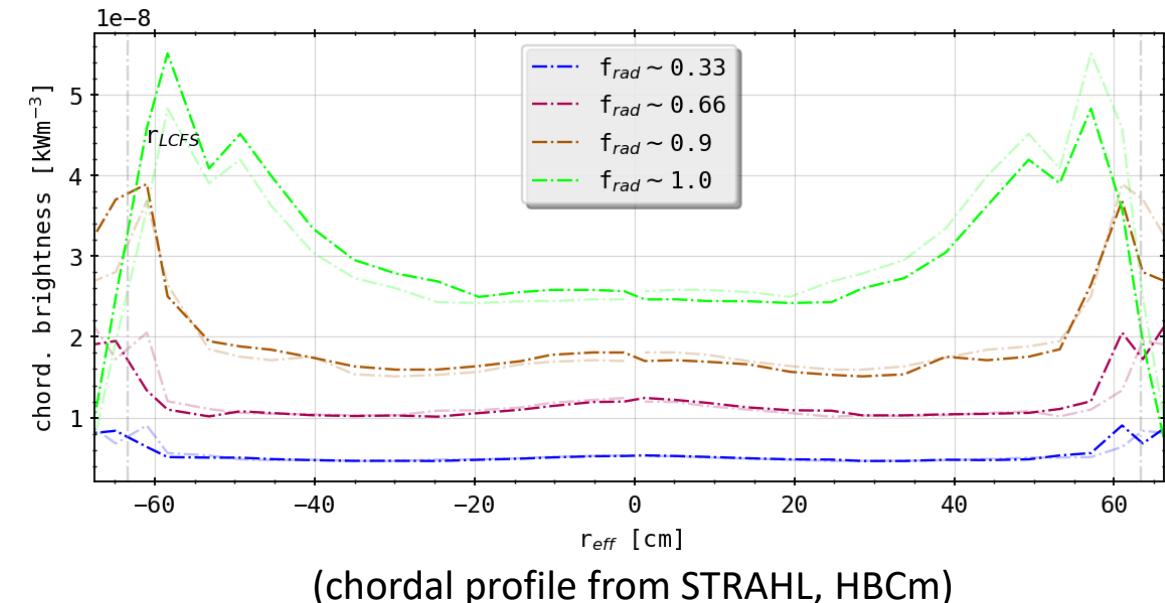
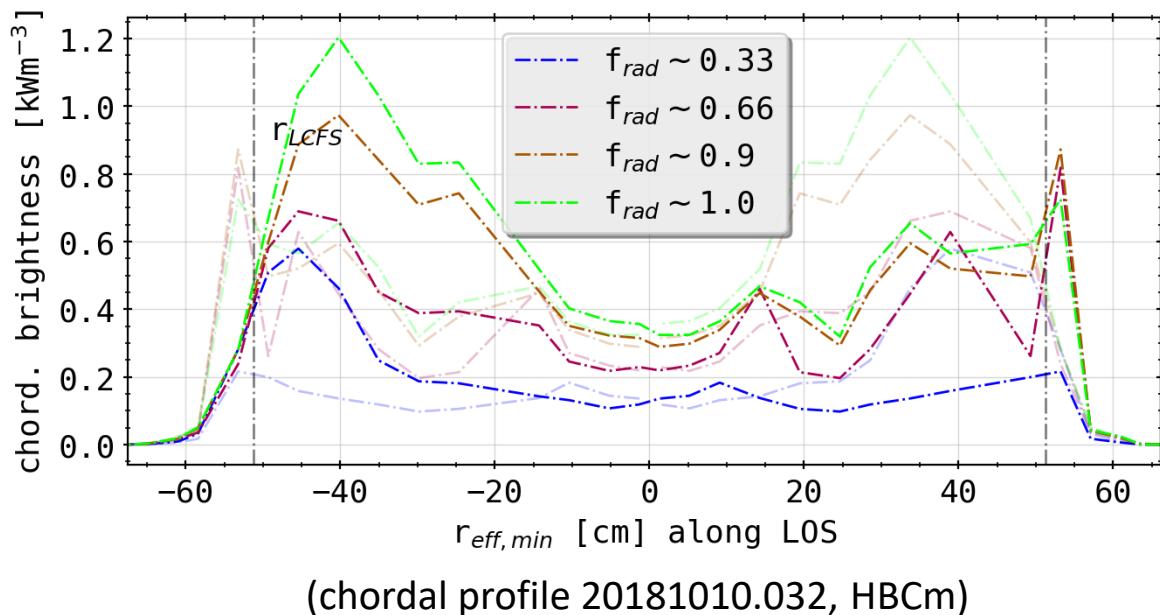
# Previously: Geometry Sensitivity Study



- prime radiation feedback controlled discharge 20181010.032 exhibits transitions from attached to detached states and back (90%-100% radiation fraction)
- calculate STRAHL radiation profiles with given electron temperature and density at distinct radiation fraction levels to investigate intrinsic (oxygen and carbon) impurity radiation
- STRAHL profiles show asymmetric chordal profiles after forward calculation with emissivity matrices, though being symmetric

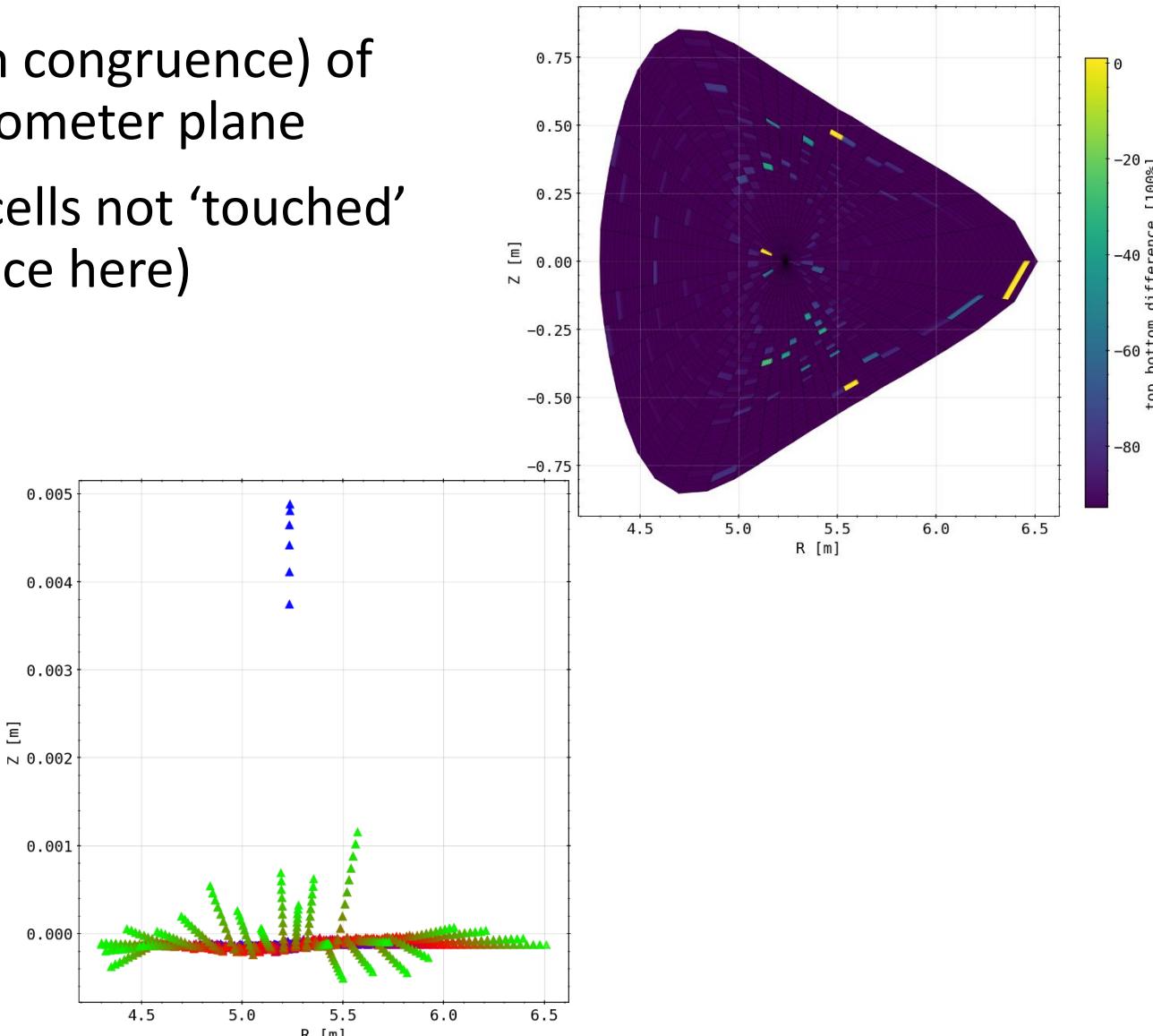
# Previously: Geometry Sensitivity Study

- STRAHL profiles show asymmetric chordal profiles after forward calculation with emissivity matrices, though being intrinsically symmetric



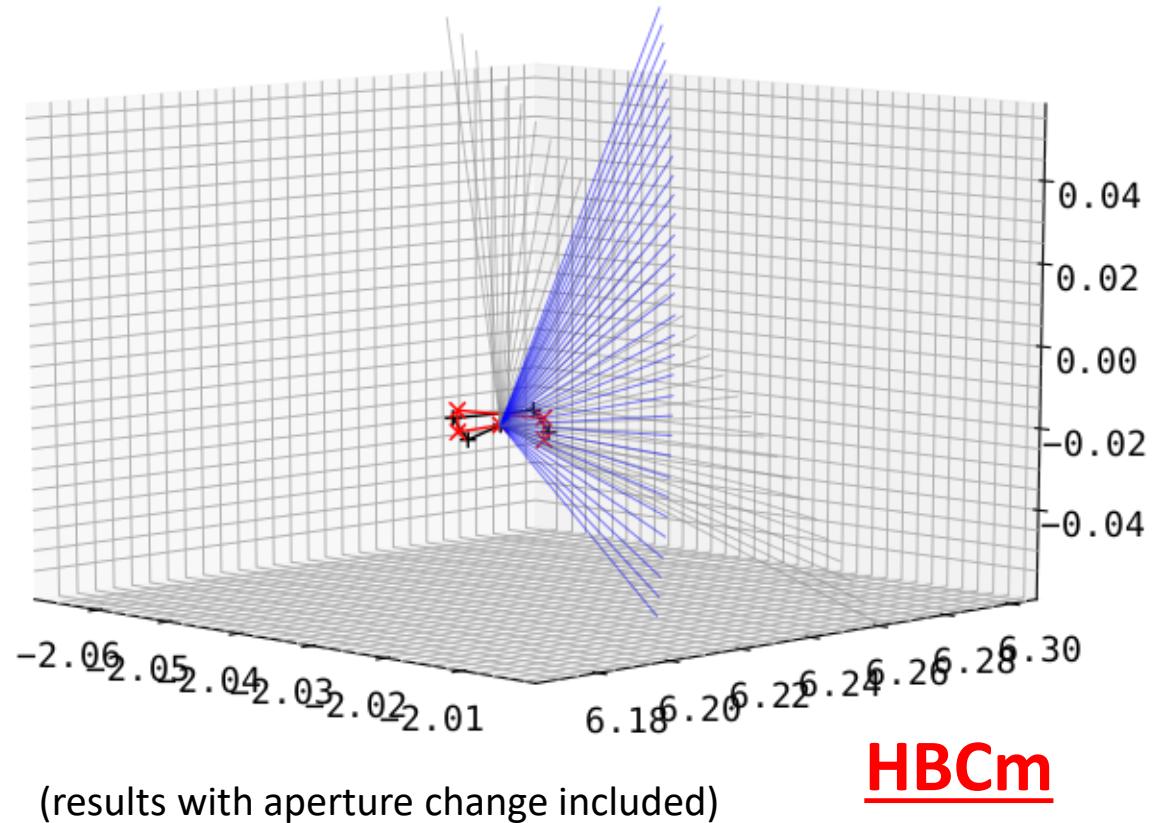
# Results: Symmetry of Emissivity Matrix and Mesh

- checking the symmetry (read: top-bottom congruence) of the emissivity matrix projected to the Bolometer plane
- slight deviances overall, especially some cells not ‘touched’ by channels at all (equaling 100% difference here)
  
- checking symmetry mesh matrix
- blue to red to green means further outside the magnetic axis, i.e. ‘larger’ fluxsurfaces/fluxtubes
  
- entire mesh dispositioned downwards (still oriented around magnetic axis)
- increasing deviance with distance

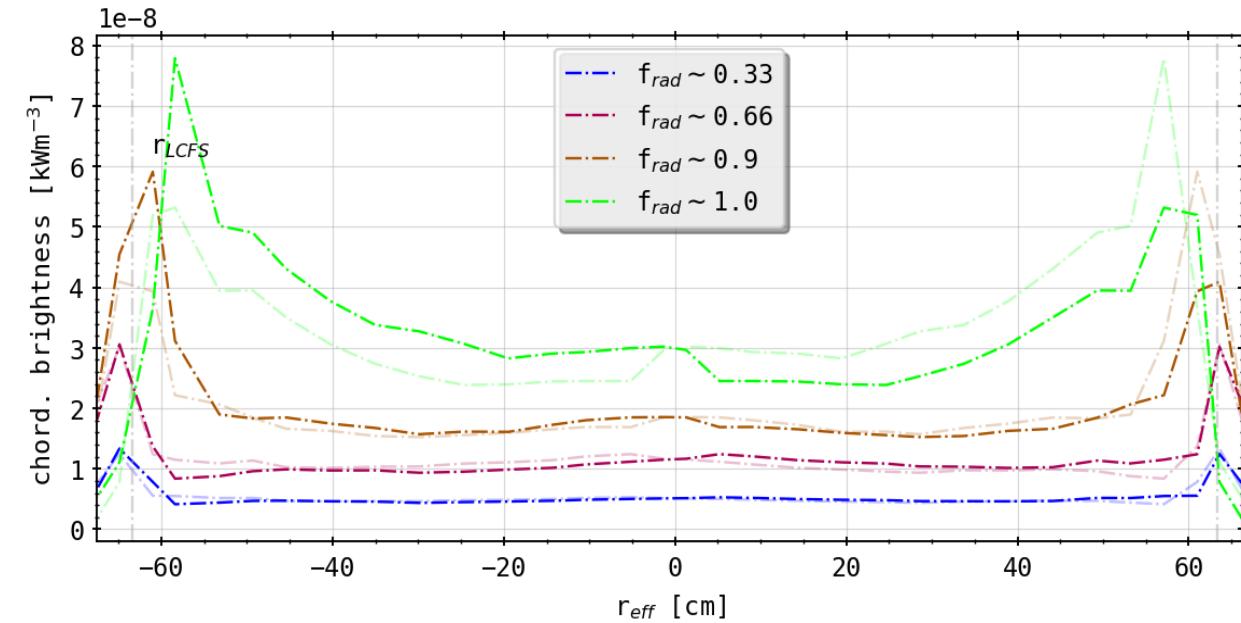


# Results: Tilting the Detector Fan Up/Down

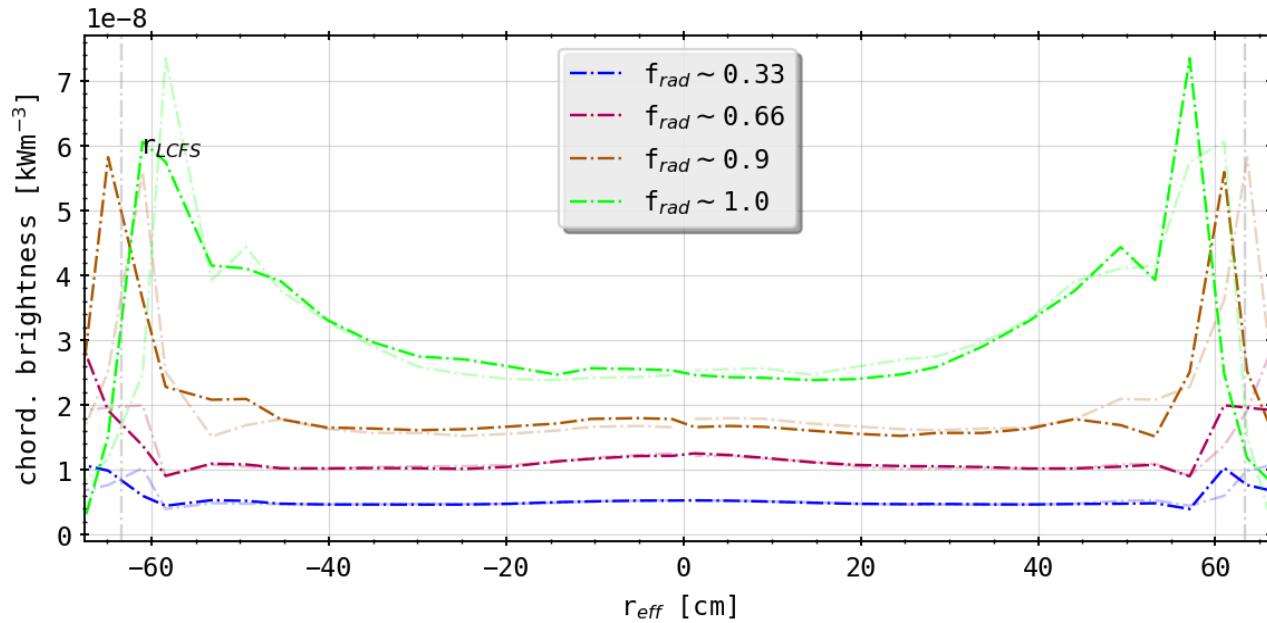
- deviance in STRAHL possibly results of intrinsic geometry
- ALSO: testing more effects that could change the intrinsic geometry, which can not be analysed theoretically
- take symmetric arrays and tilt the entire fan including the aperture poloidally (grey to blue and black to red)



# Results: Different Tilts from As-Built Geometry



(0.5° tilt (down))



(-0.5° tilt (up))

- asymmetry switchable/changed around
- alignment better now upside (tilt down!)
- radial movement as before and in original

# First Summary

- geometry sensitivity study yields great insight on how the camera setup and errors effect forward calculations
- results show that variety and possibly a combination of measurement and intrinsic geometry errors are responsible for further asymmetries in results

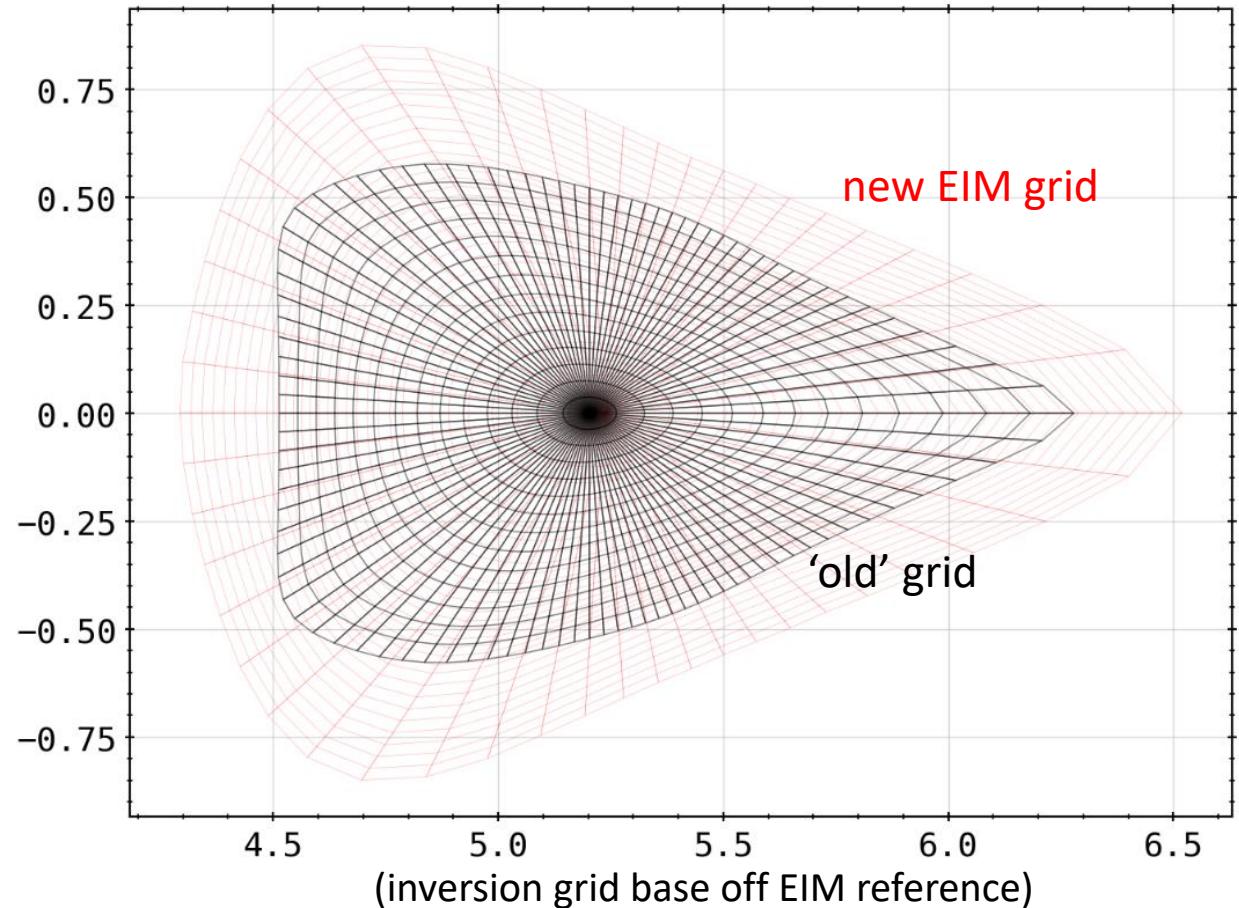
Camera geometry adequate to resolve radial shifts in 2D from STRAHL?

→ need 2D tomography of radiation distribution

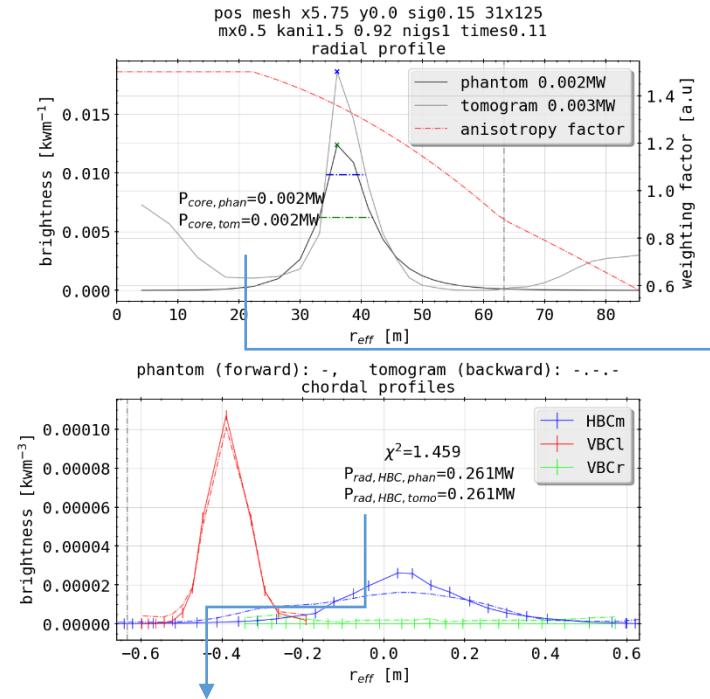
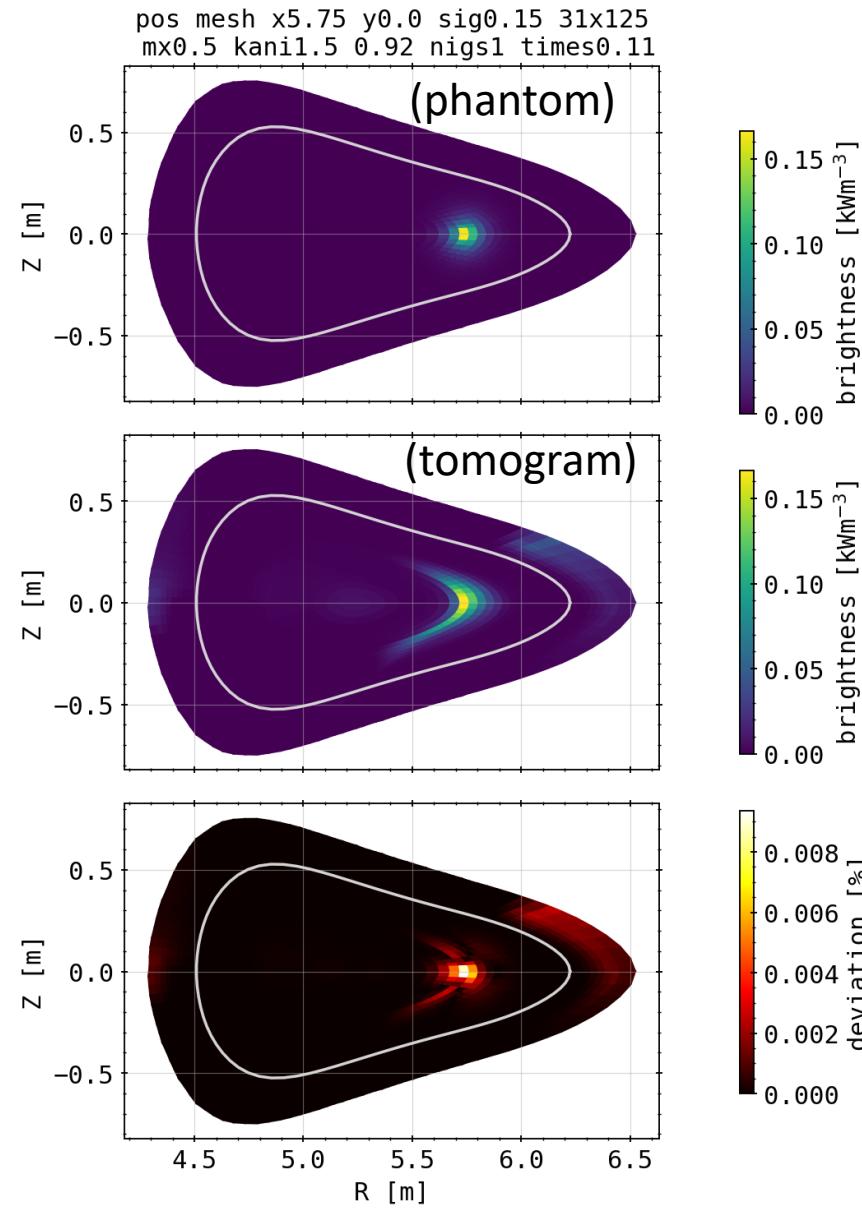
- benchmark Minimum Fischer Regularization method for 2D inversion with variety of phantom radiation profiles with various distinct or mixed characteristics

# Previously: 2D Tomography - First Results

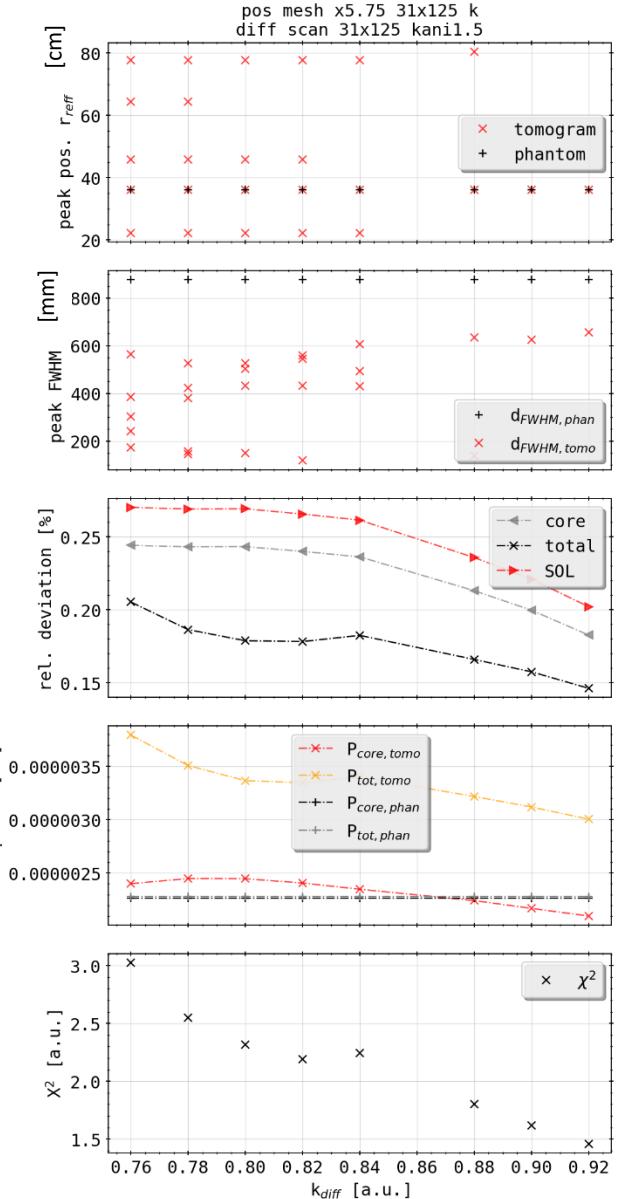
- set up forward calculation of chordal brightness profile from the 2D results of tomography as shown before
- change inversion domain according to magnetic configuration used in experimental or standard in case of phantoms



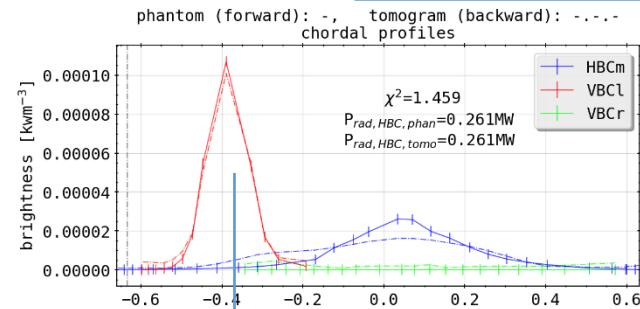
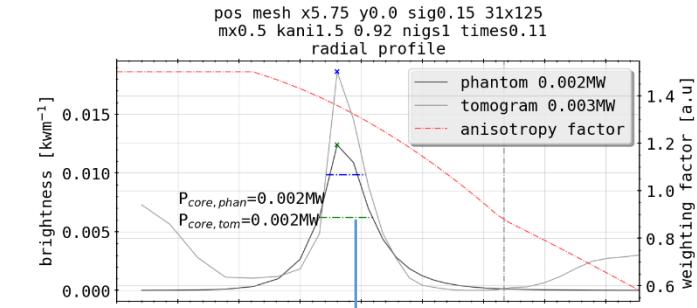
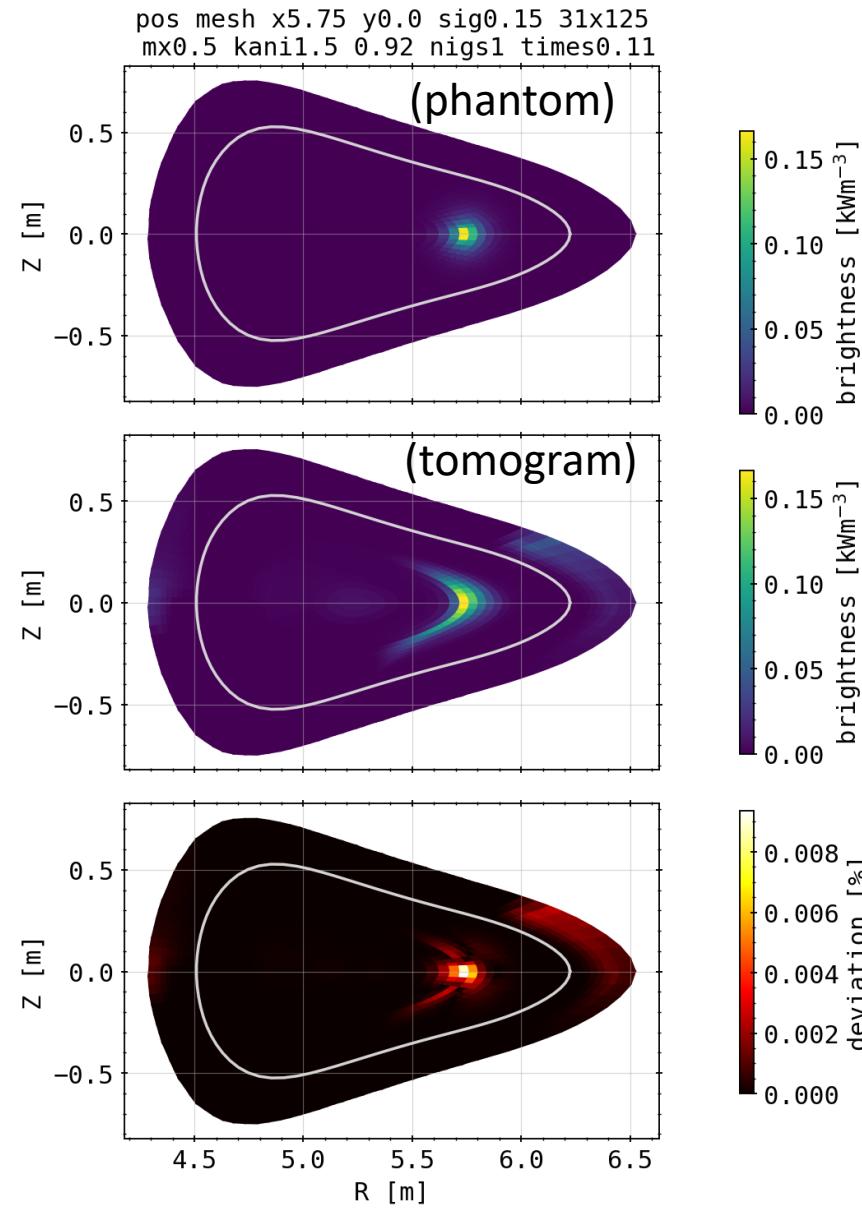
# Phantom Test: Single Spot Off-Center



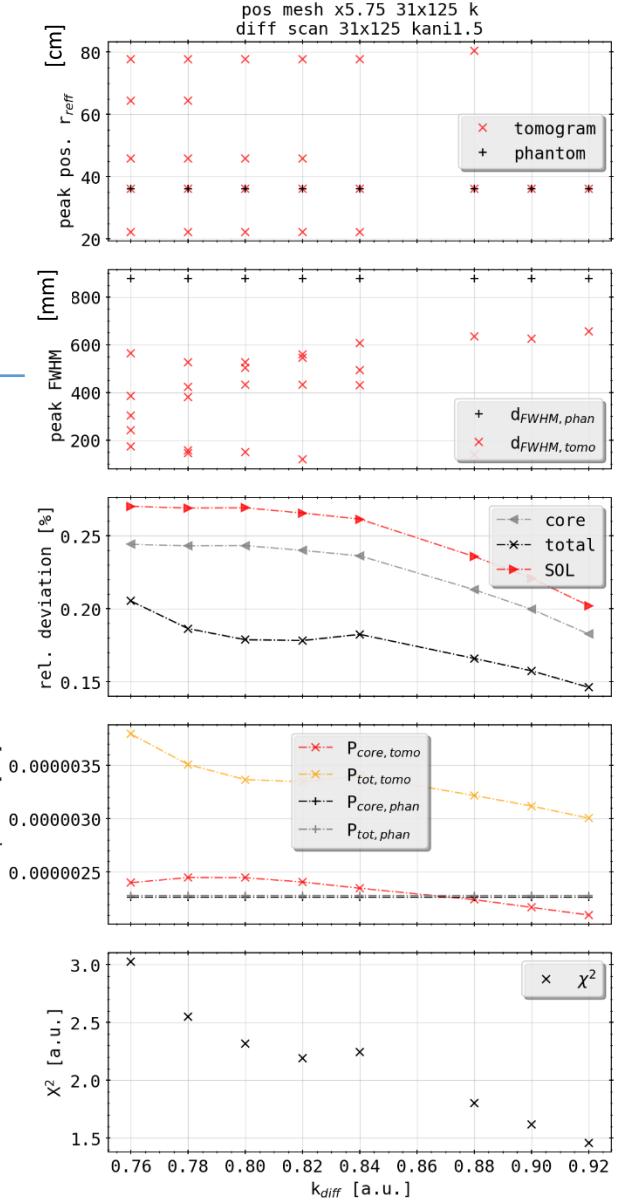
- radiation power calculated as usual like in experiments
- total & core power estimated by hollow cylinders of fluxsurfaces from radial profile (unit errors, fix needed)



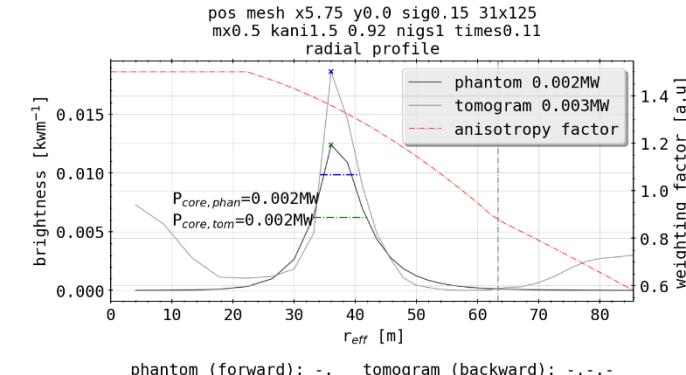
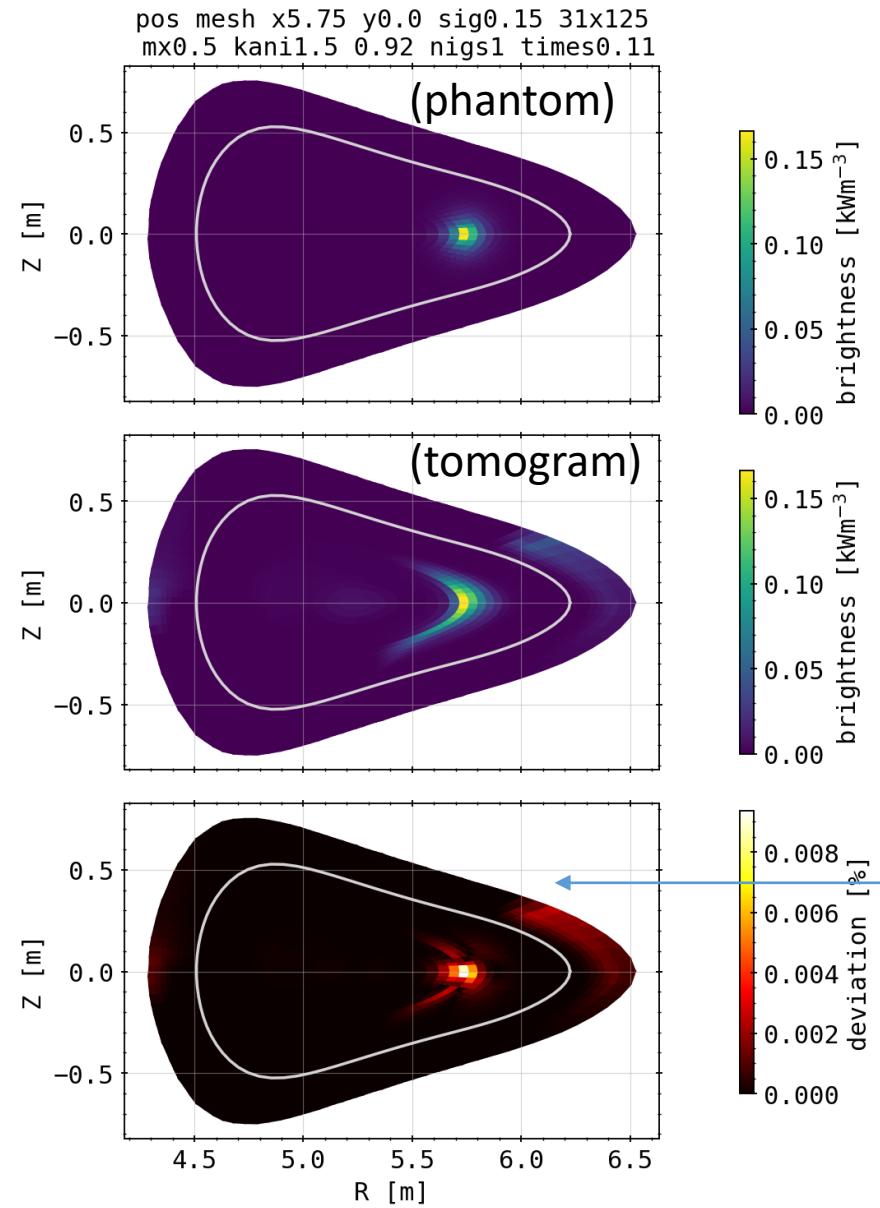
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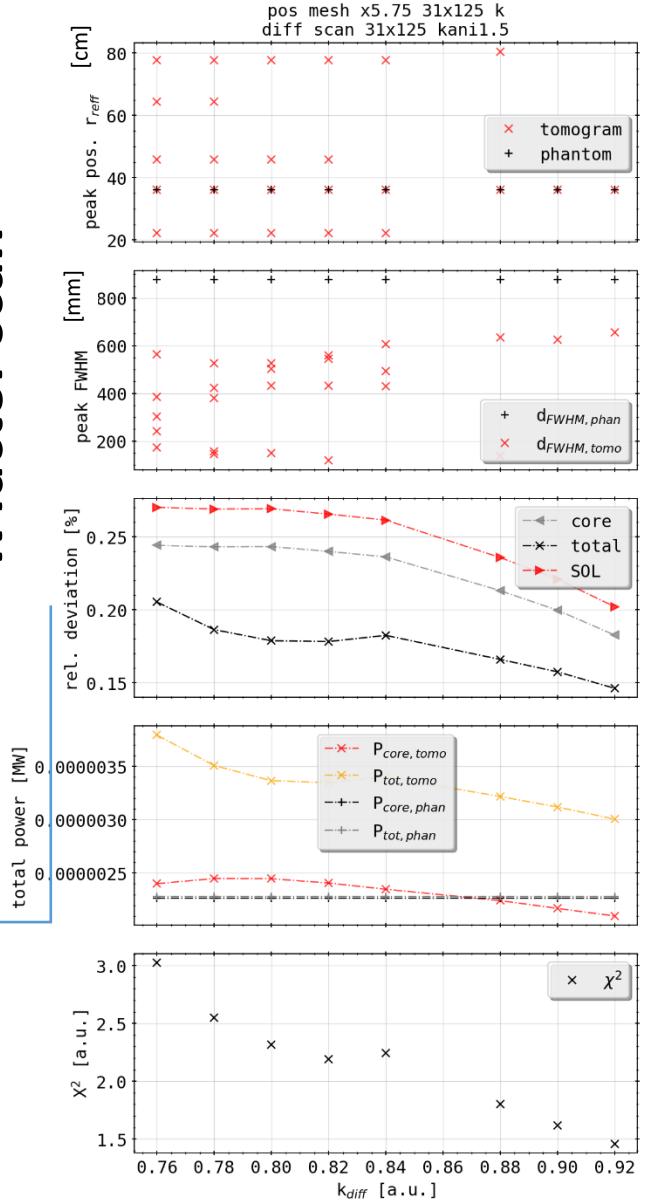
- radial profile peak localization and width of distribution
- forward and backward calculated chordal profiles



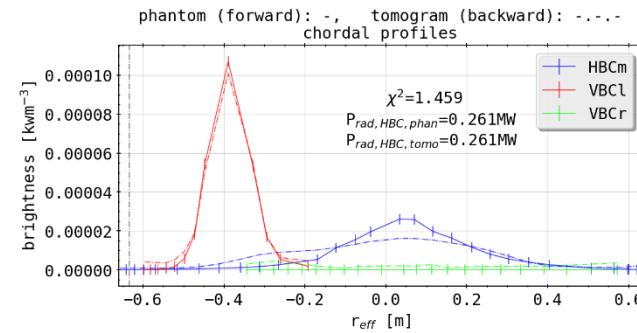
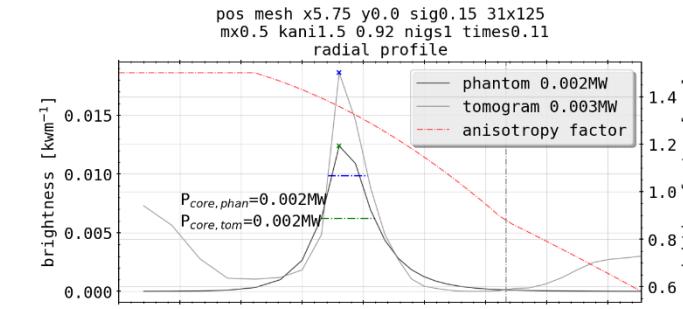
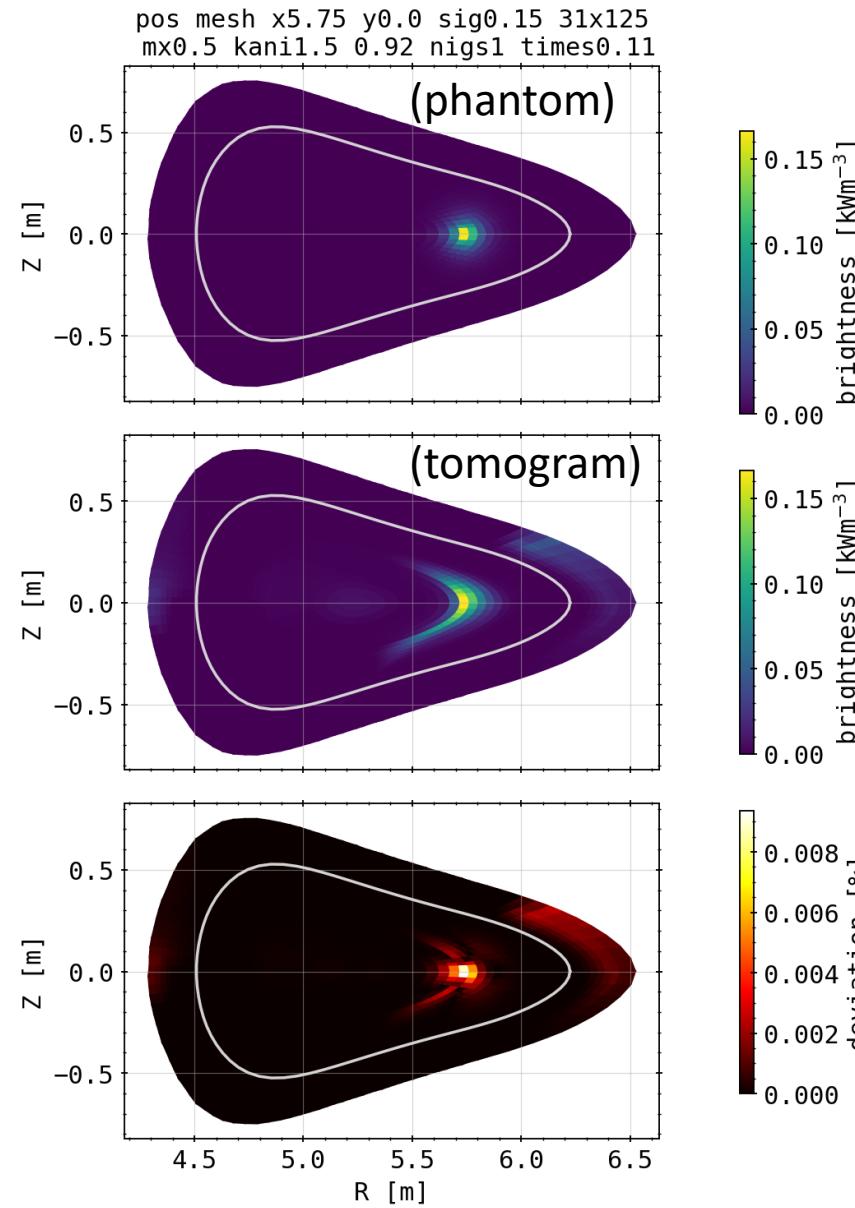
# Phantom Test: Single Spot Off-Center



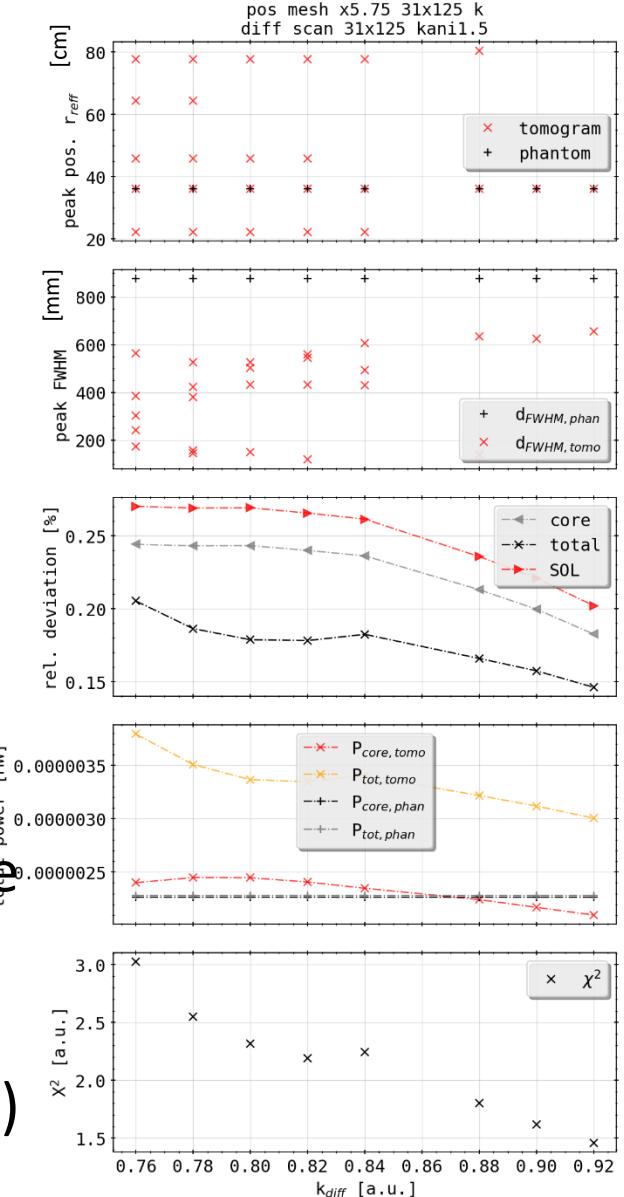
- $\chi^2$  quality does not necessarily equal best tomogram, hence the need for 2D relative deviation as measure to find best fit
- deviation percentage relative to area of cell & domain



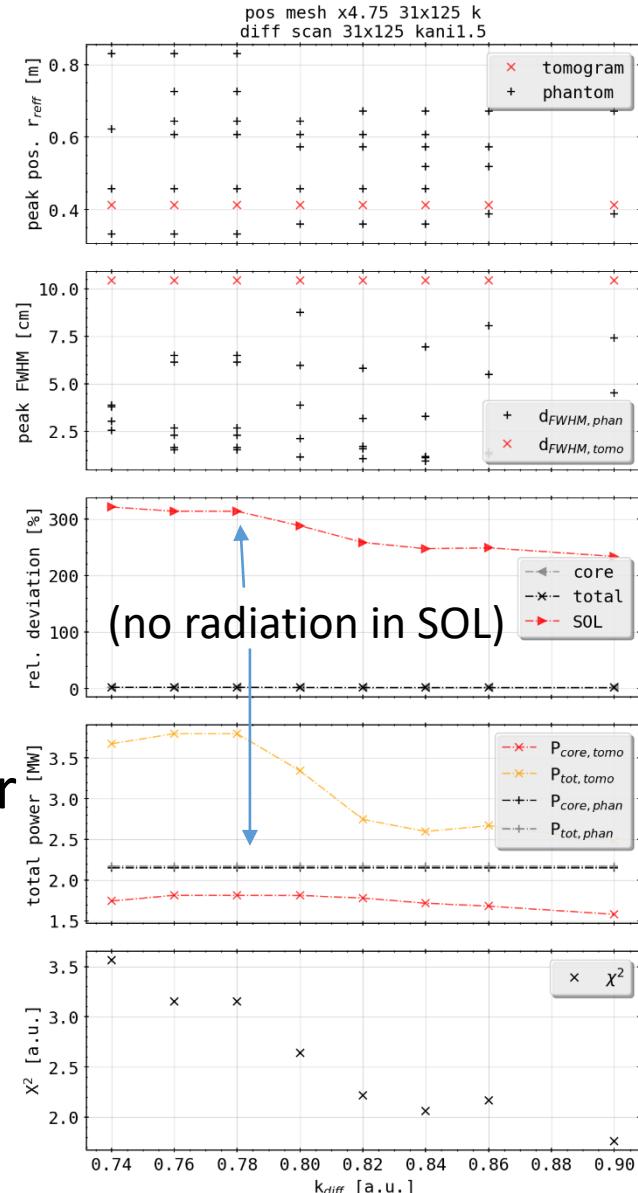
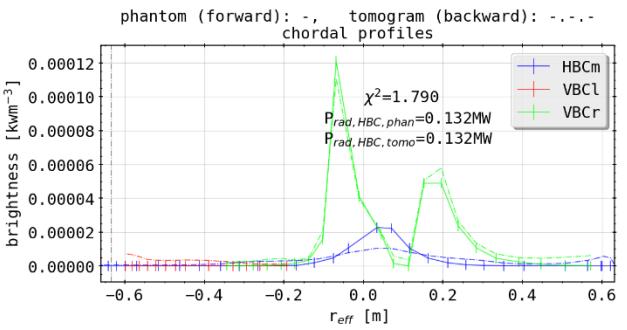
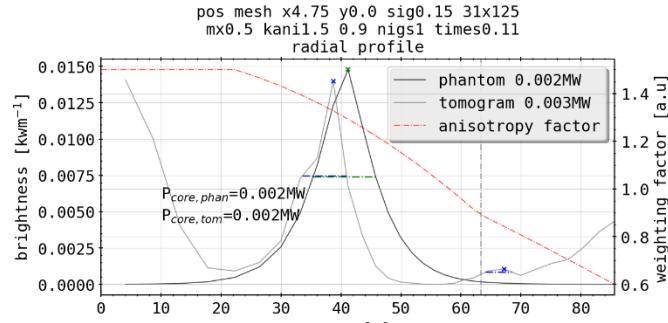
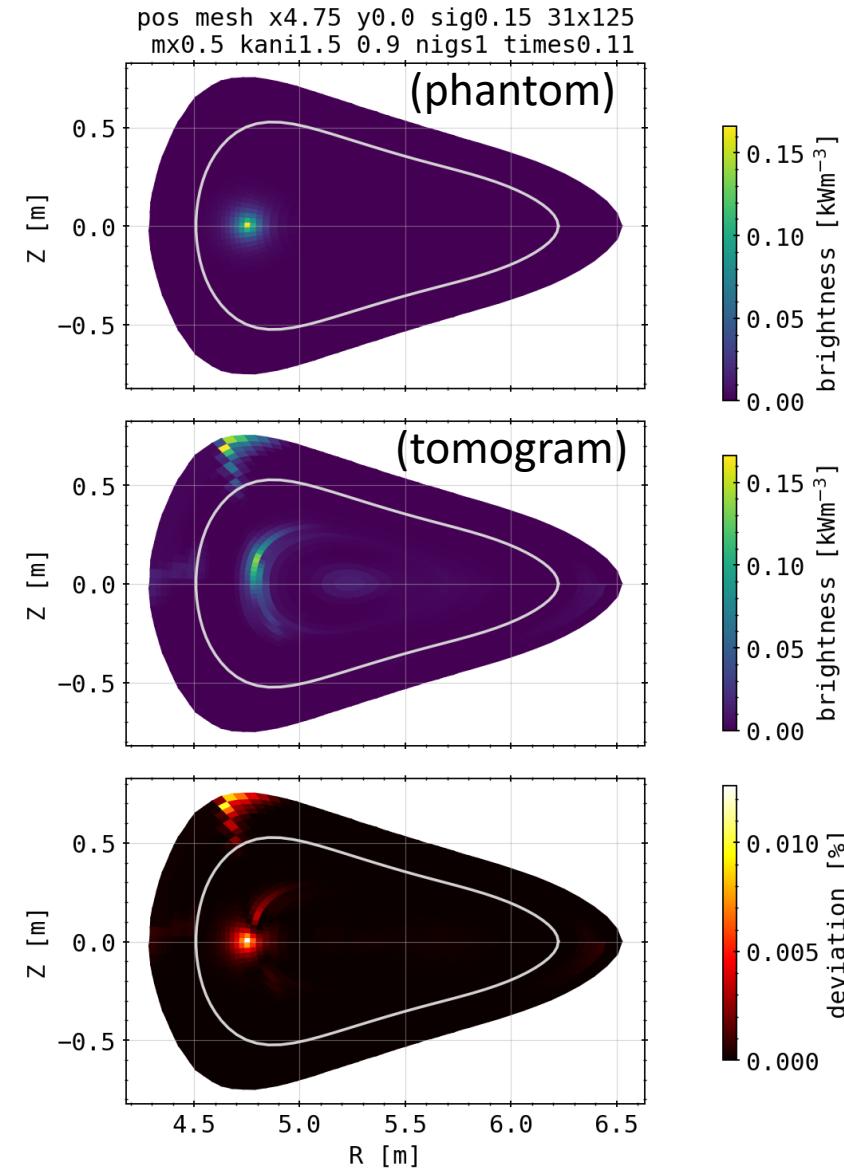
# Phantom Test: Single Spot Off-Center



- smoothing along fluxsurfaces,  
according to K factor weighting
- deposition of emissivity at edge due  
to too many free parameters
- bad reconstructions yield entirely  
different profiles (radial, multi peak)



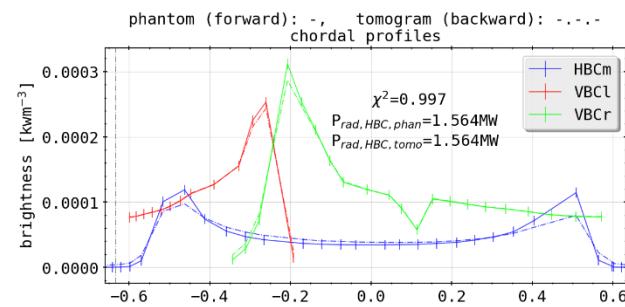
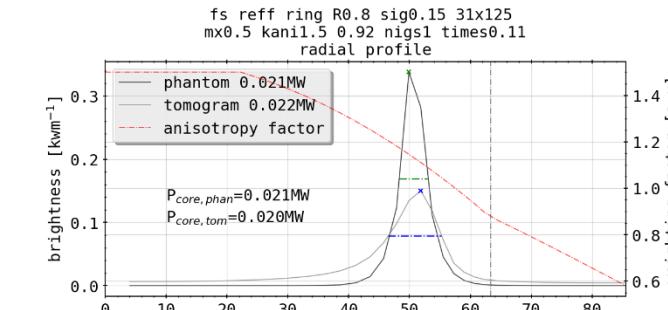
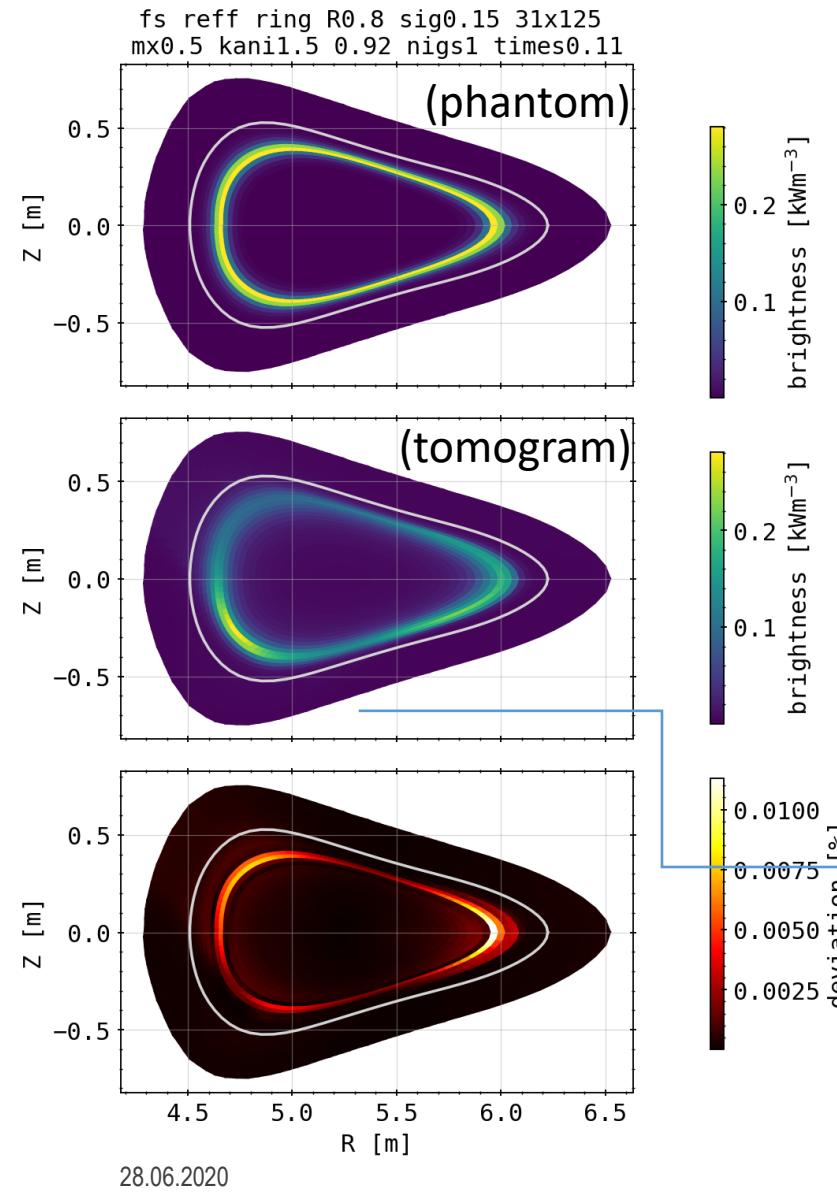
# Phantom Test: Single Spot Off-Center (inboard)



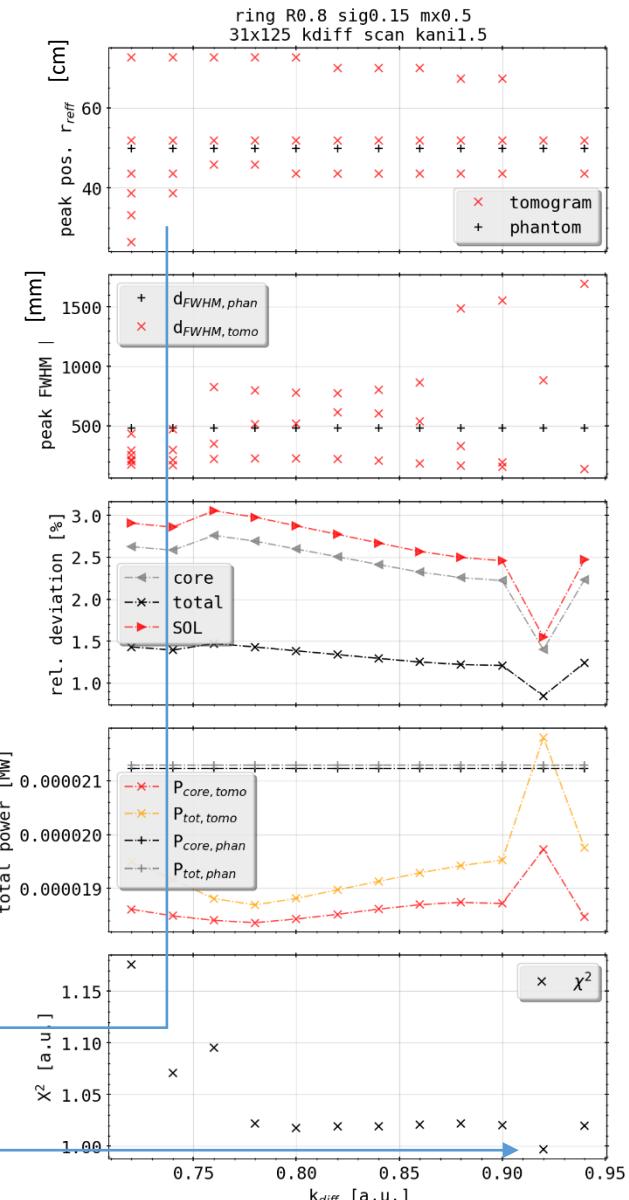
- line of sight density on inboard side too low, mostly dominated by VBCl/r
- pixel bank on edge only graced by VBC detector, strong deposition
- overall reconstruction quantitatively/qualitatively worse

## K factor scan

# Phantom Test: Core Bright Ring

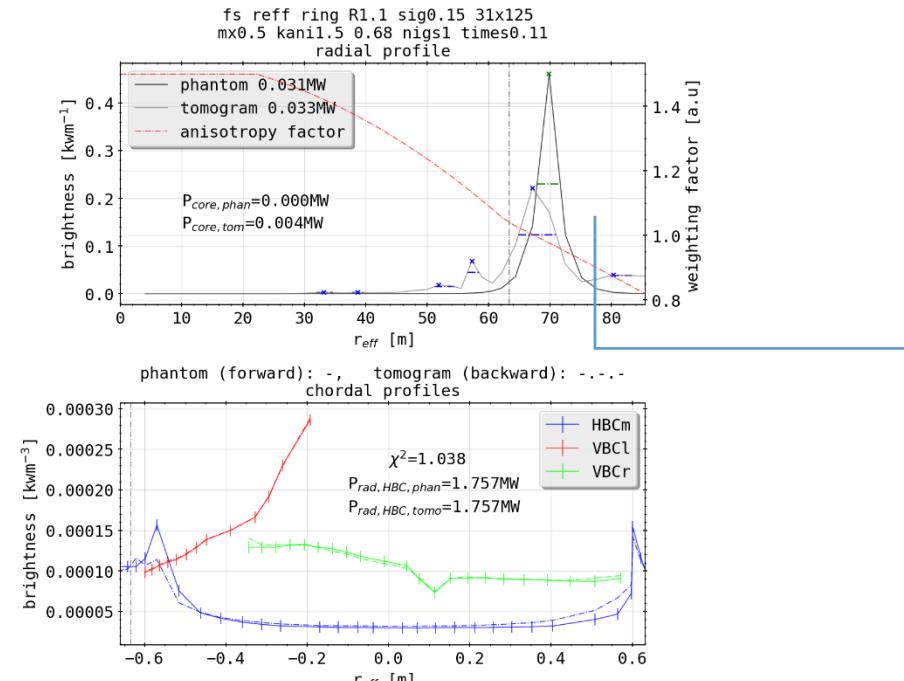
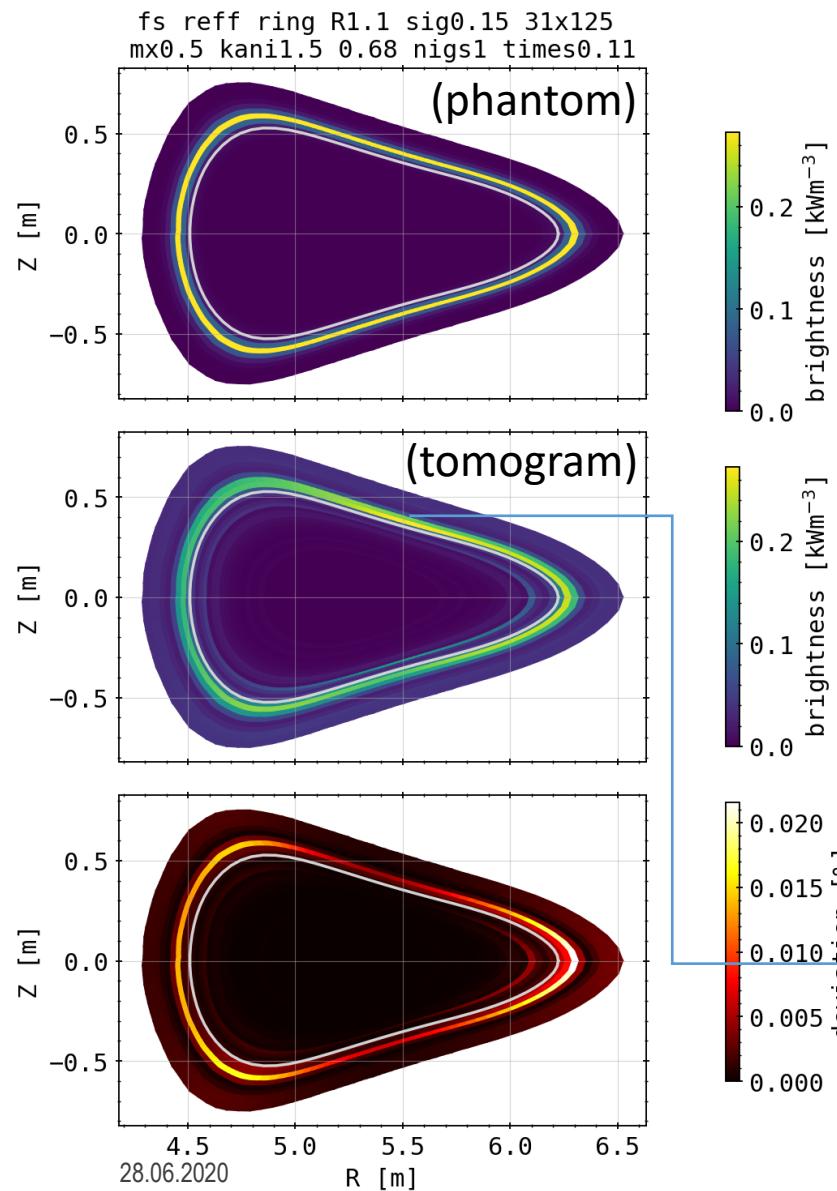


- exists best (not ideal?) set of weighting factors to find solution
- poloidal anisotropy where higher LOS density (intersection HBC-VBC, close to VBC aperture)
- bad reconstructions yield radial profiles with shells/large sigmas

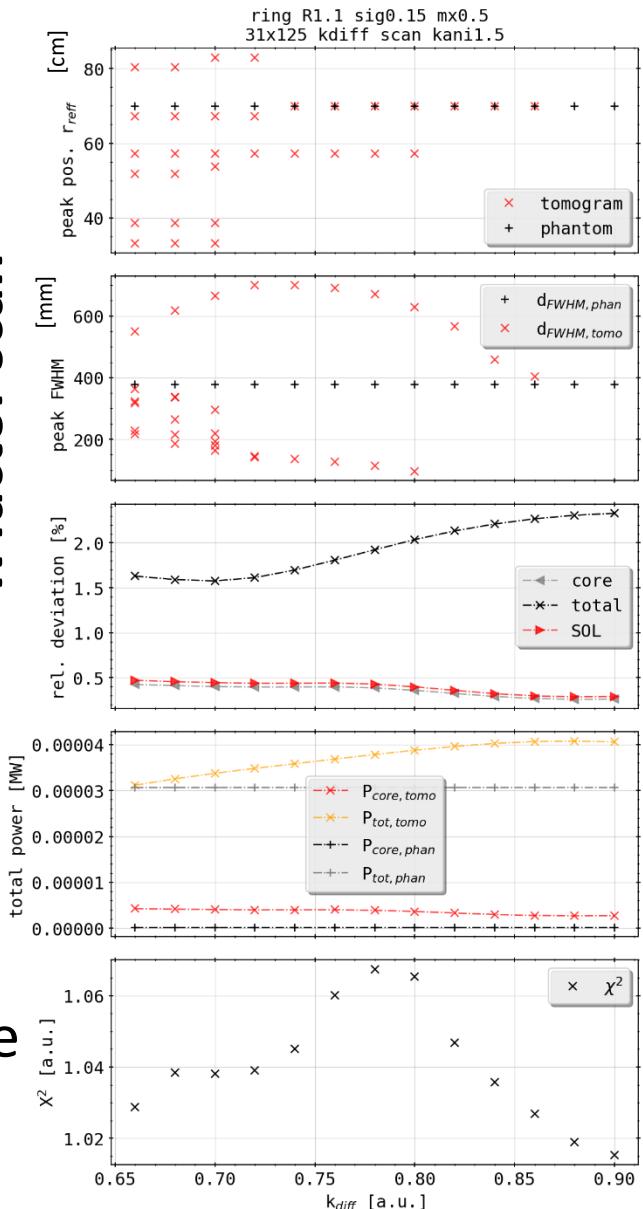


K factor scan

# Phantom Test: SOL Bright Ring

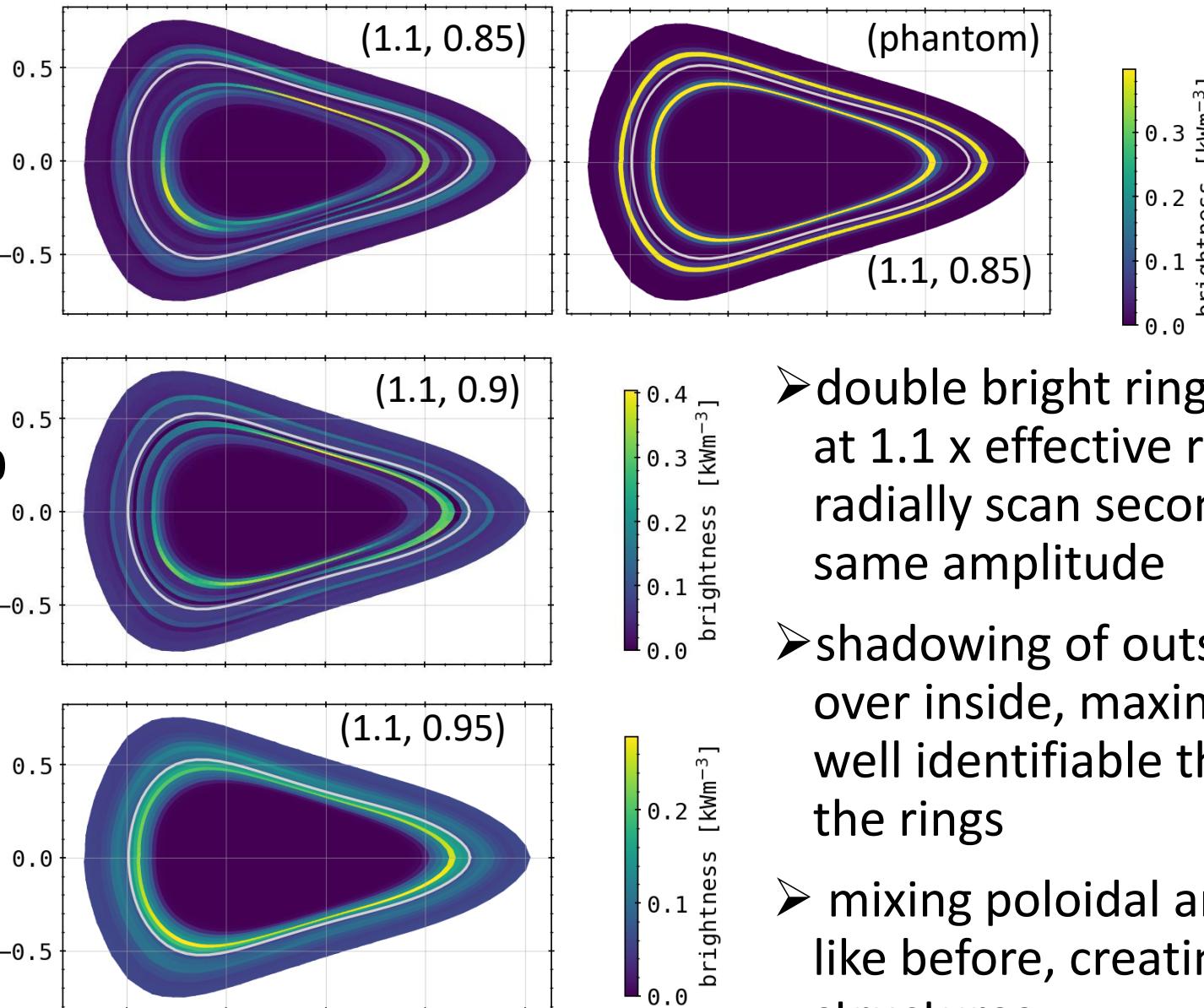


- expectedly best K factor fit is on different end of spectrum (SOL focused?)
- similar behavior with LOS density, but now upside-centered where line integration of HBC is very large
- radial reconstruction slightly worse

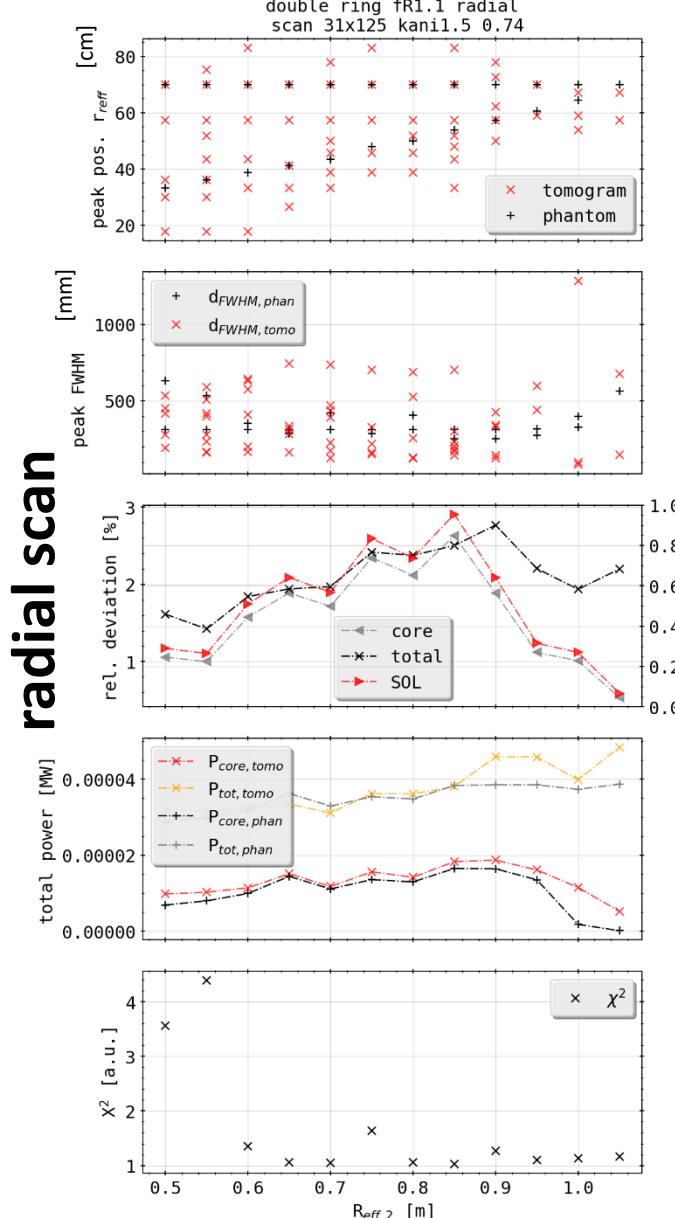


# Phantom Test: Double Bright Rings

tomograms

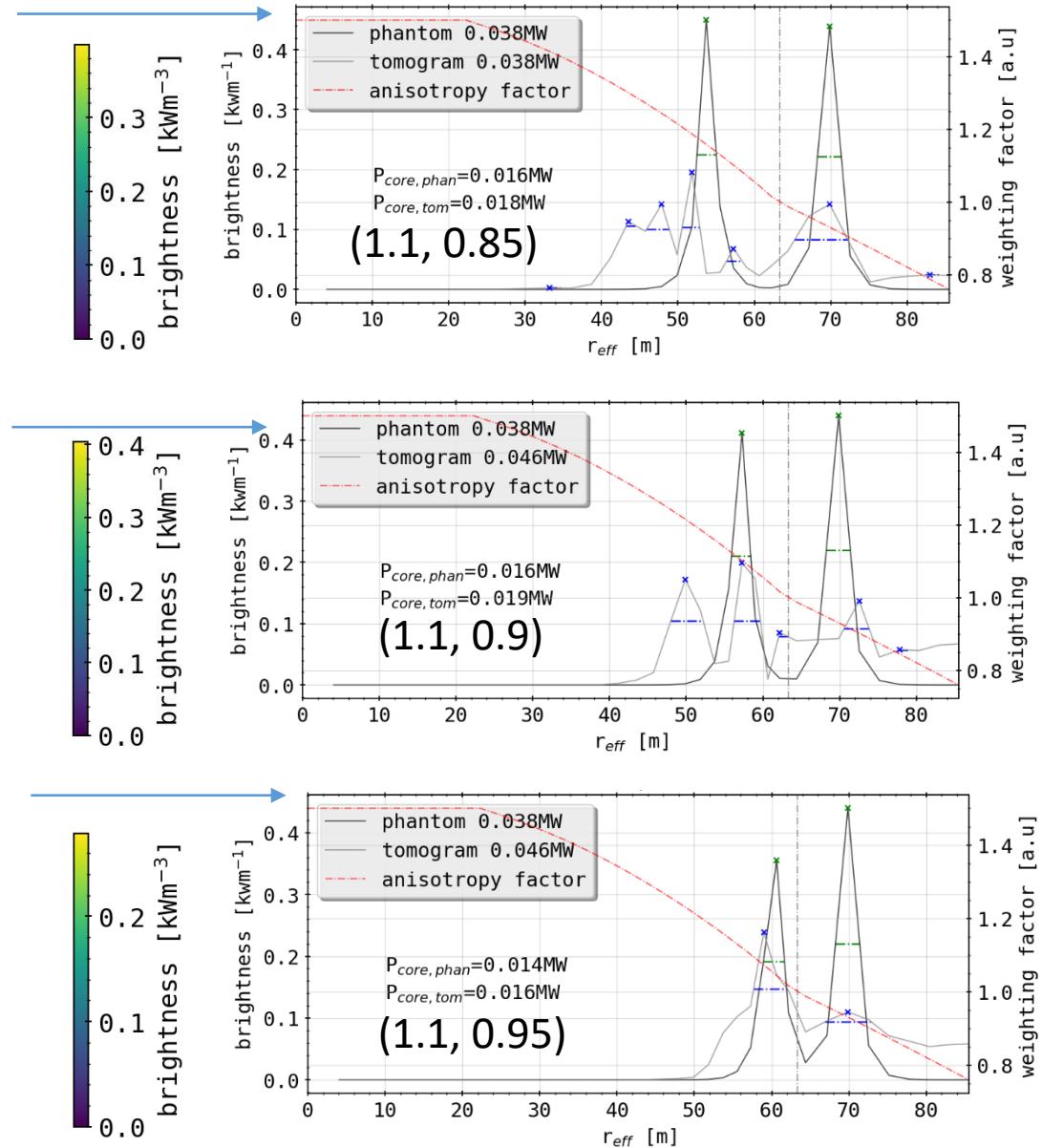
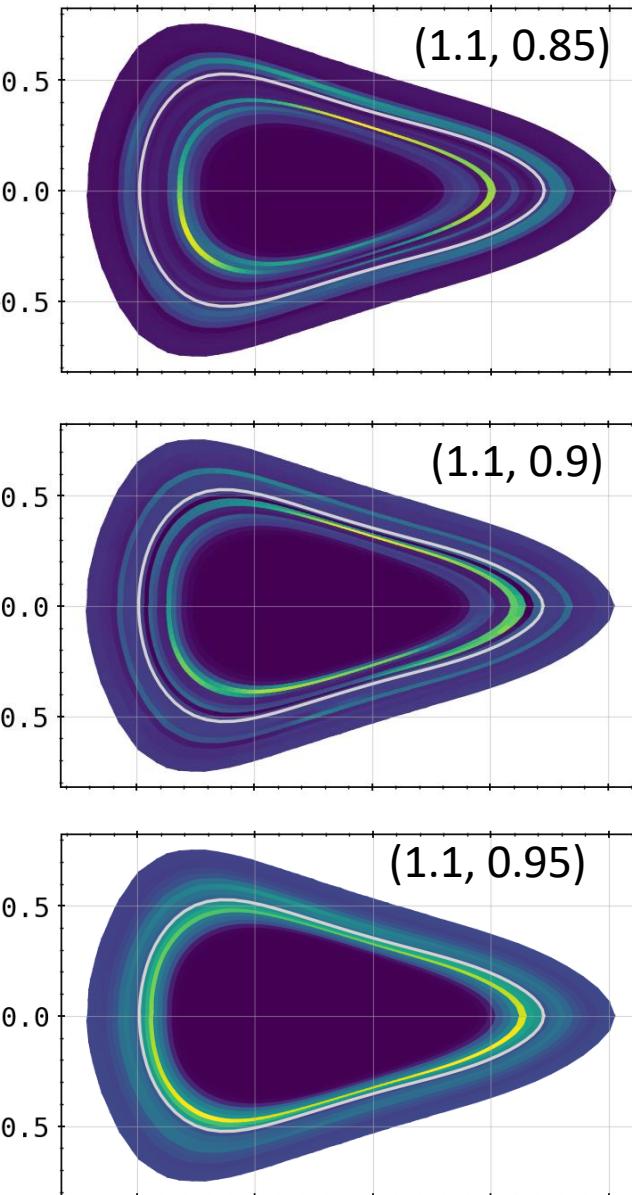


- double bright rings, one fixed at  $1.1 \times$  effective radius, then radially scan second one with same amplitude
- shadowing of outside ring over inside, maxima not very well identifiable the closer the rings
- mixing poloidal anisotropies like before, creating shell structures

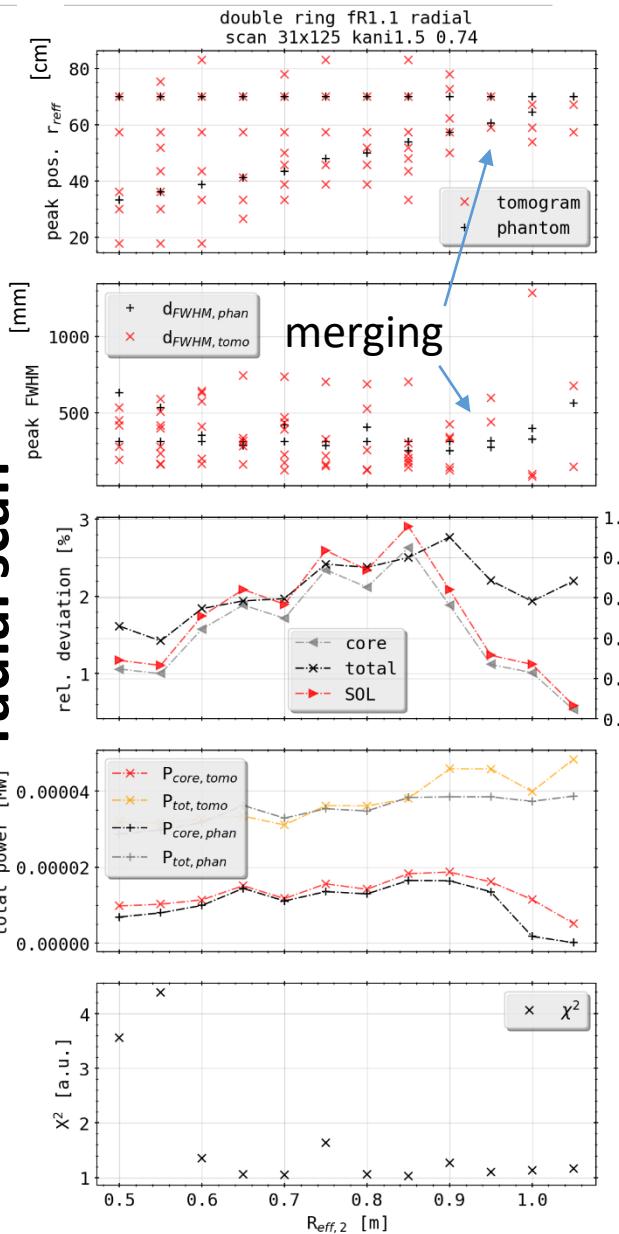


# Phantom Test: Double Bright Rings

## tomograms

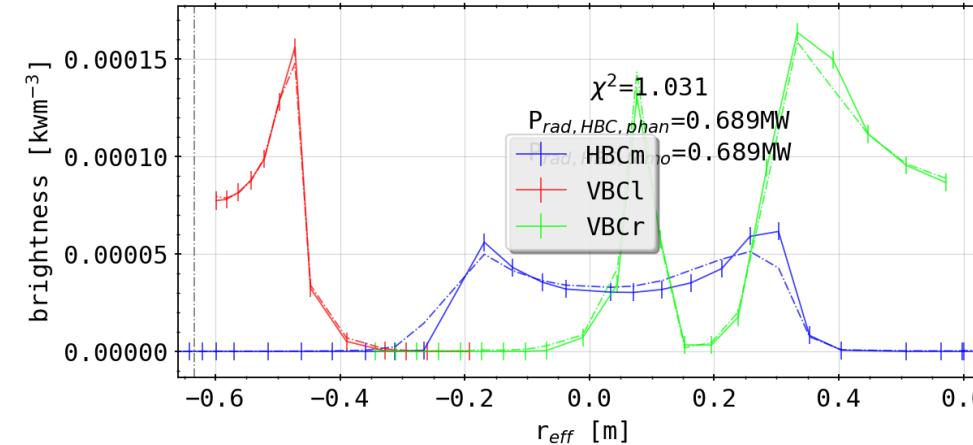


## radial scan

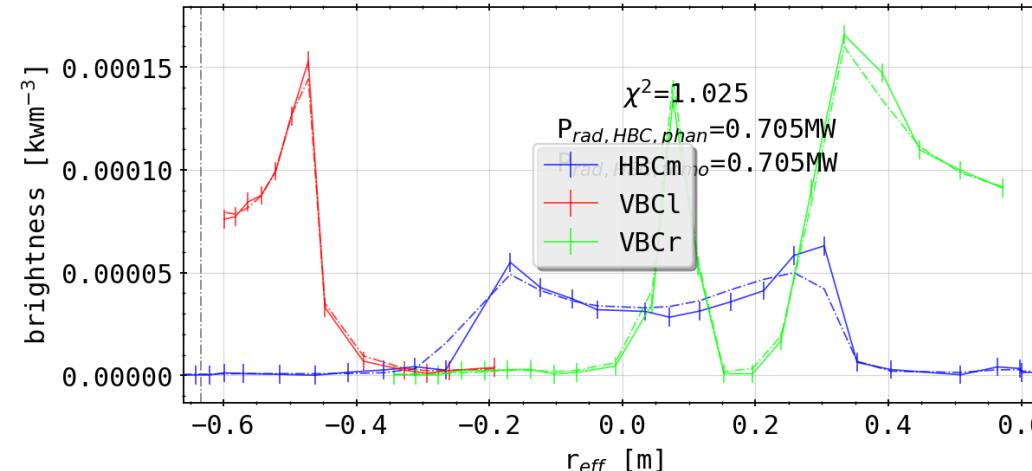


# Phantom Test: Bright Ring Radial Scan w(w/o) 2.5% noise

- adding random 2.5% of maxima of random noise to chordal data to go into reconstruction method on intrinsically symmetric profiles
- test robustness of method towards asymmetry in signals, gauging what eventually might be something discussed earlier in the geometry analyses with STRAHL

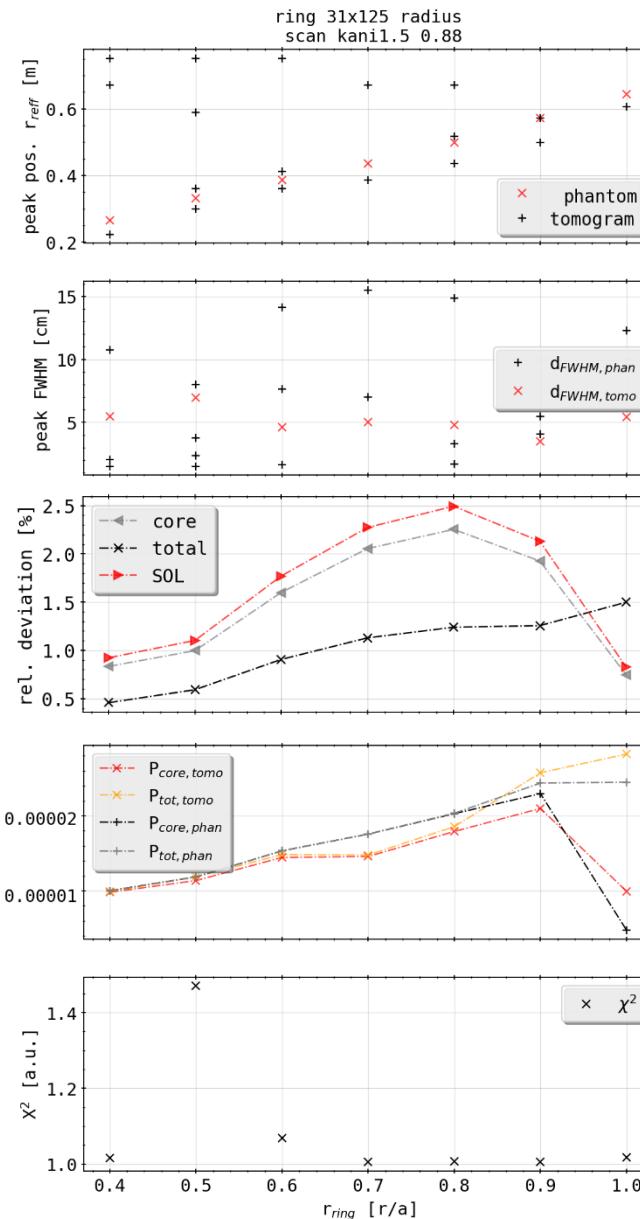


2.5% random noise  
to chordal data

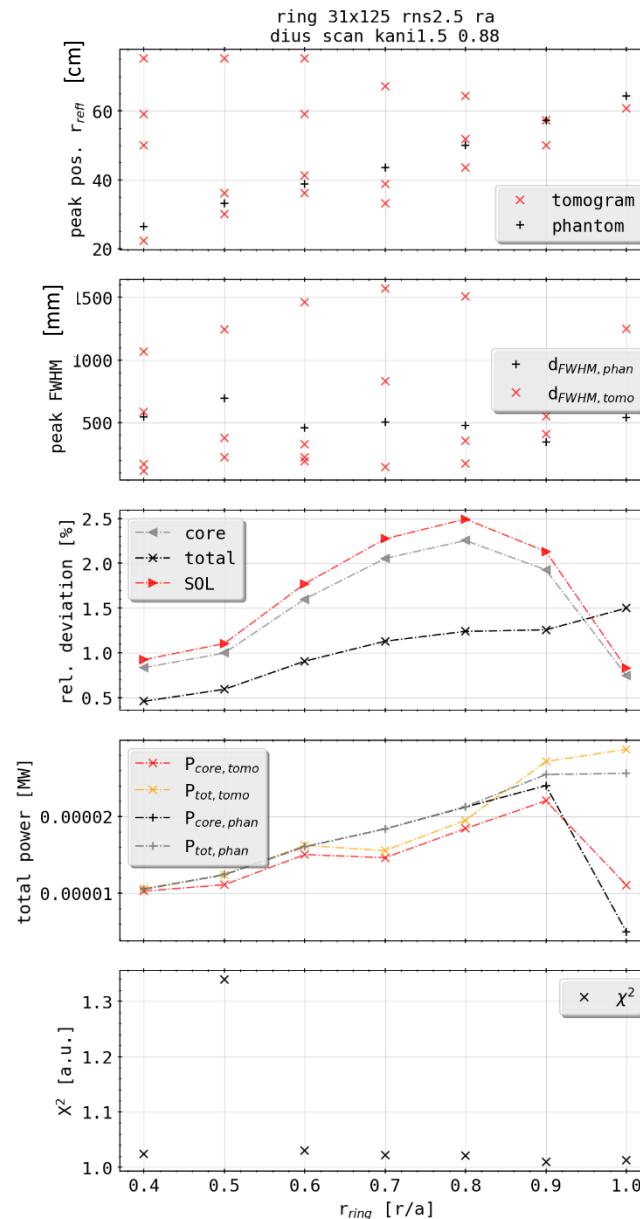


# Phantom Test: Bright Ring Radial Scan w(w/o) 2.5% noise

w/o noise



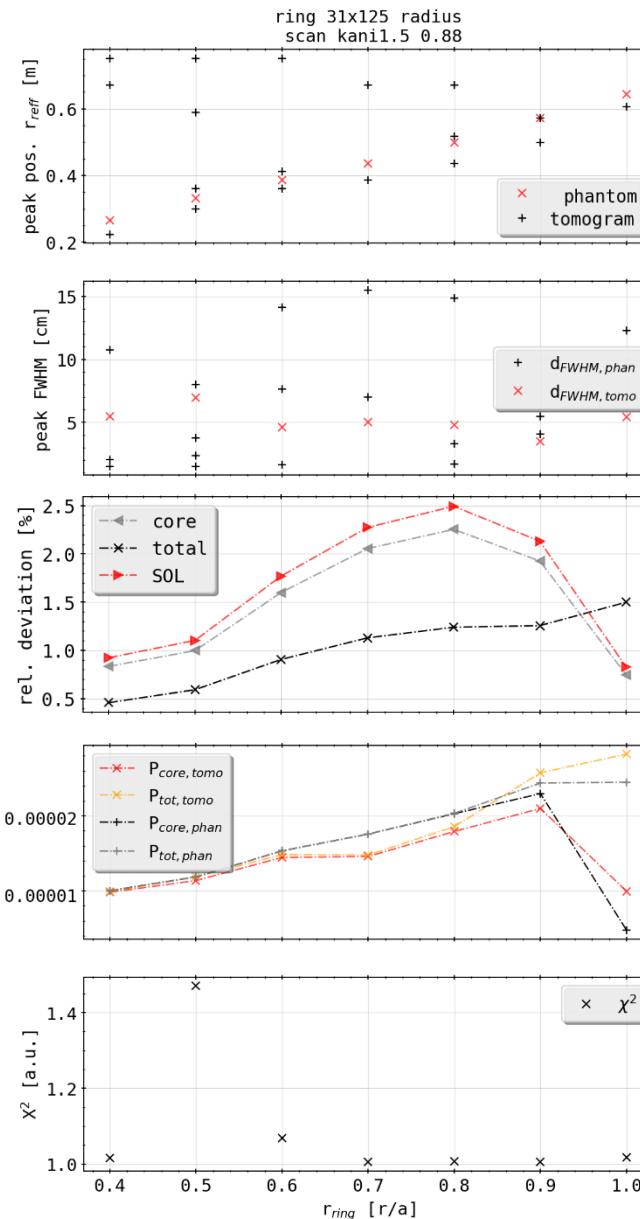
with noise



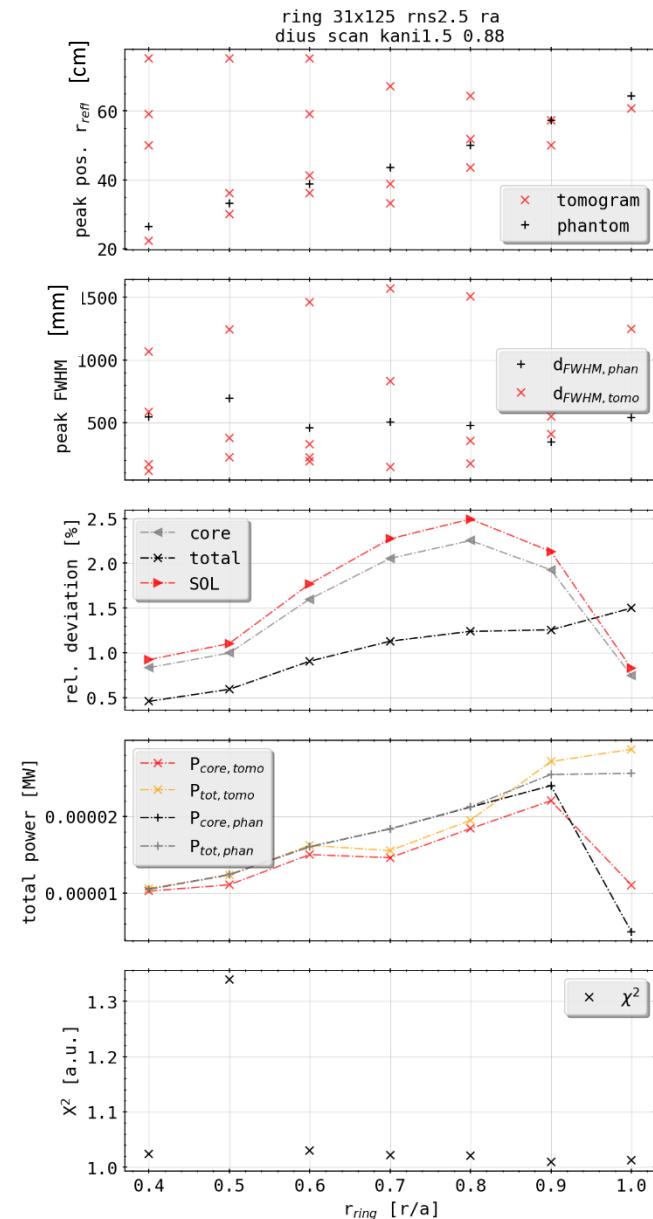
- inversion not affected by *reasonable* amount of measurement error
- 2.5% smaller than experimentally experienced error
- *Gaussian error propagation* yields much smaller level of deviance, but need to check orders/units of measurements again (based off of 6 measured quantities)

# Phantom Test: Bright Ring Radial Scan w(w/o) 2.5% noise

w/o noise



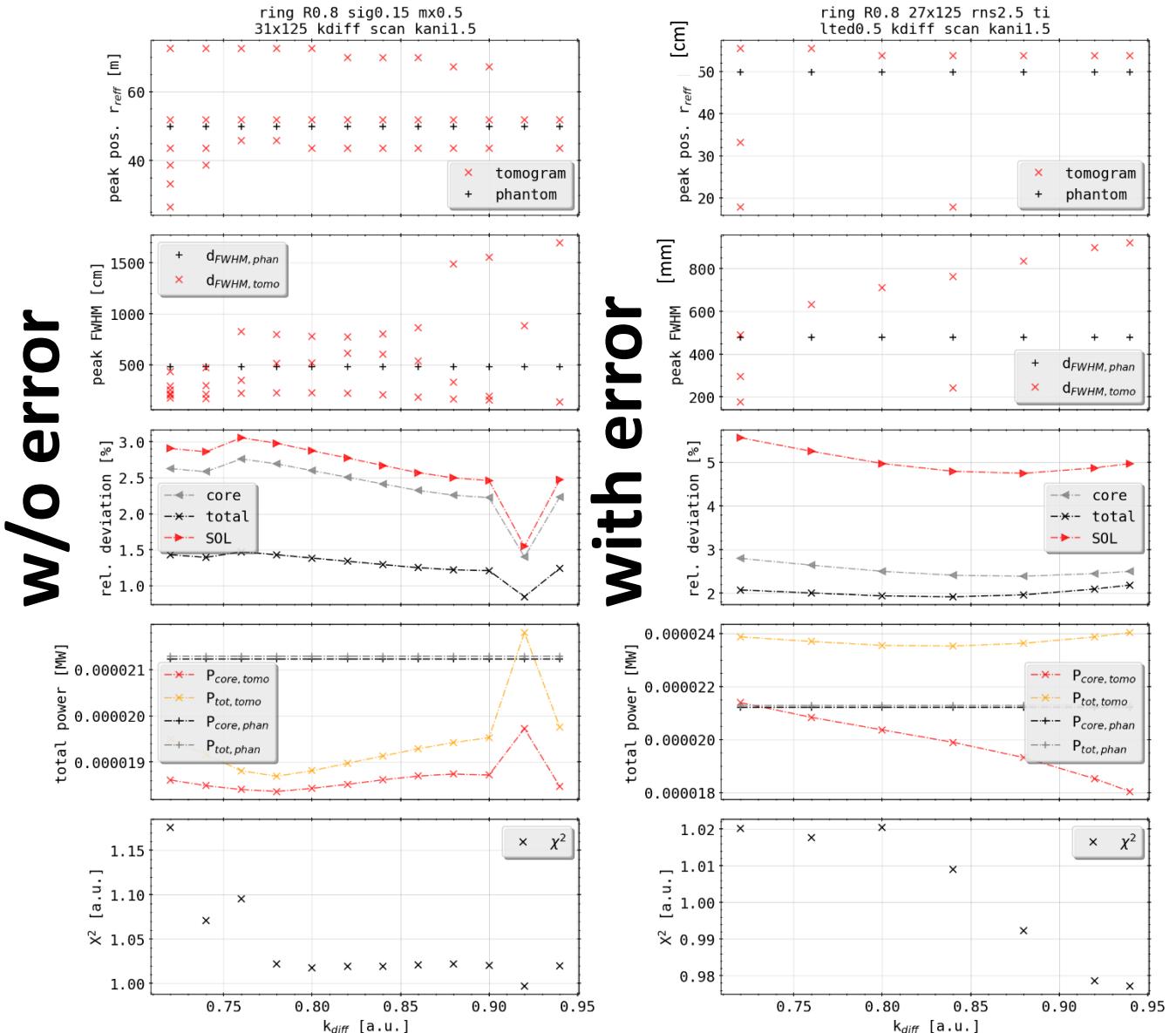
with noise



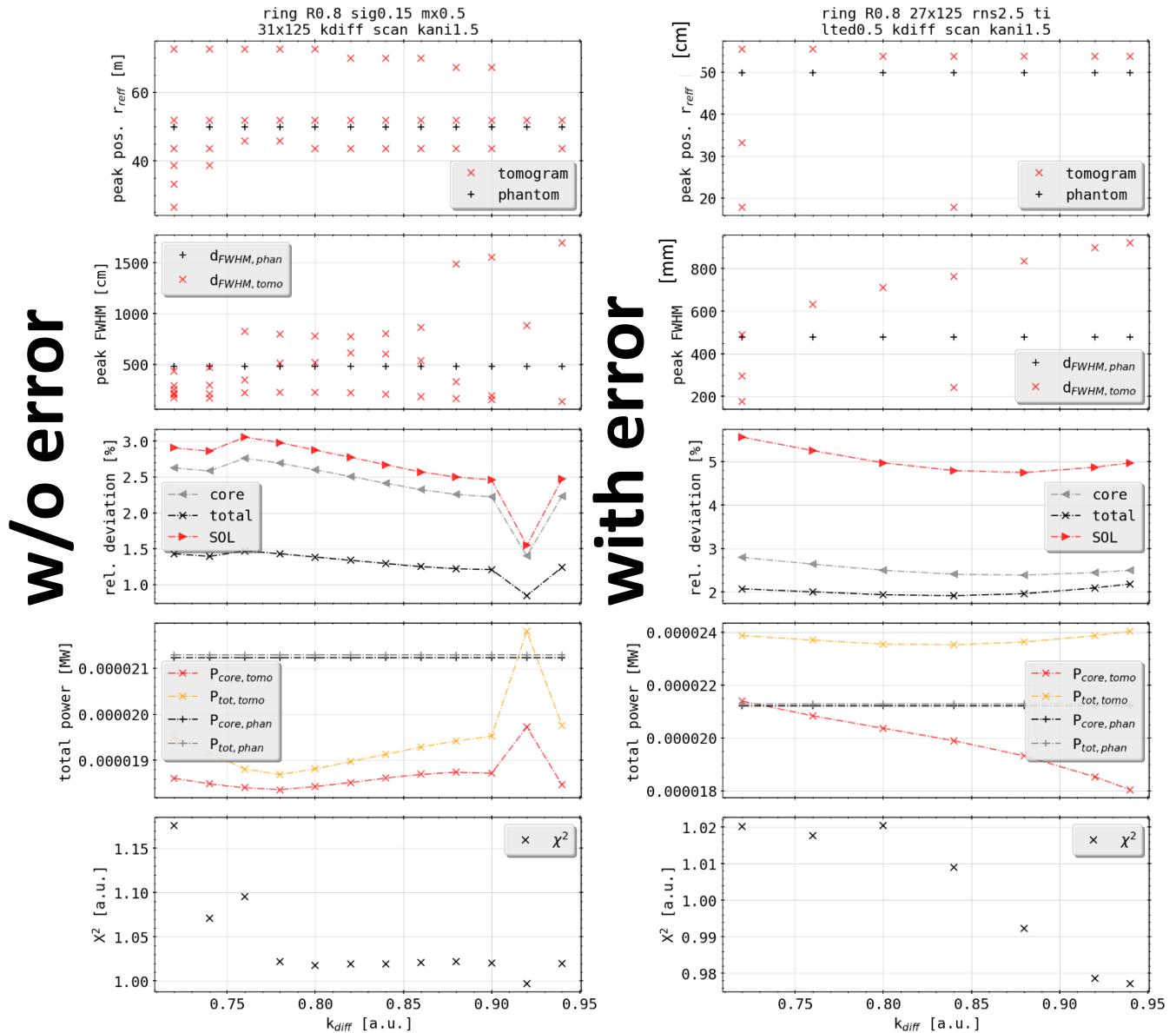
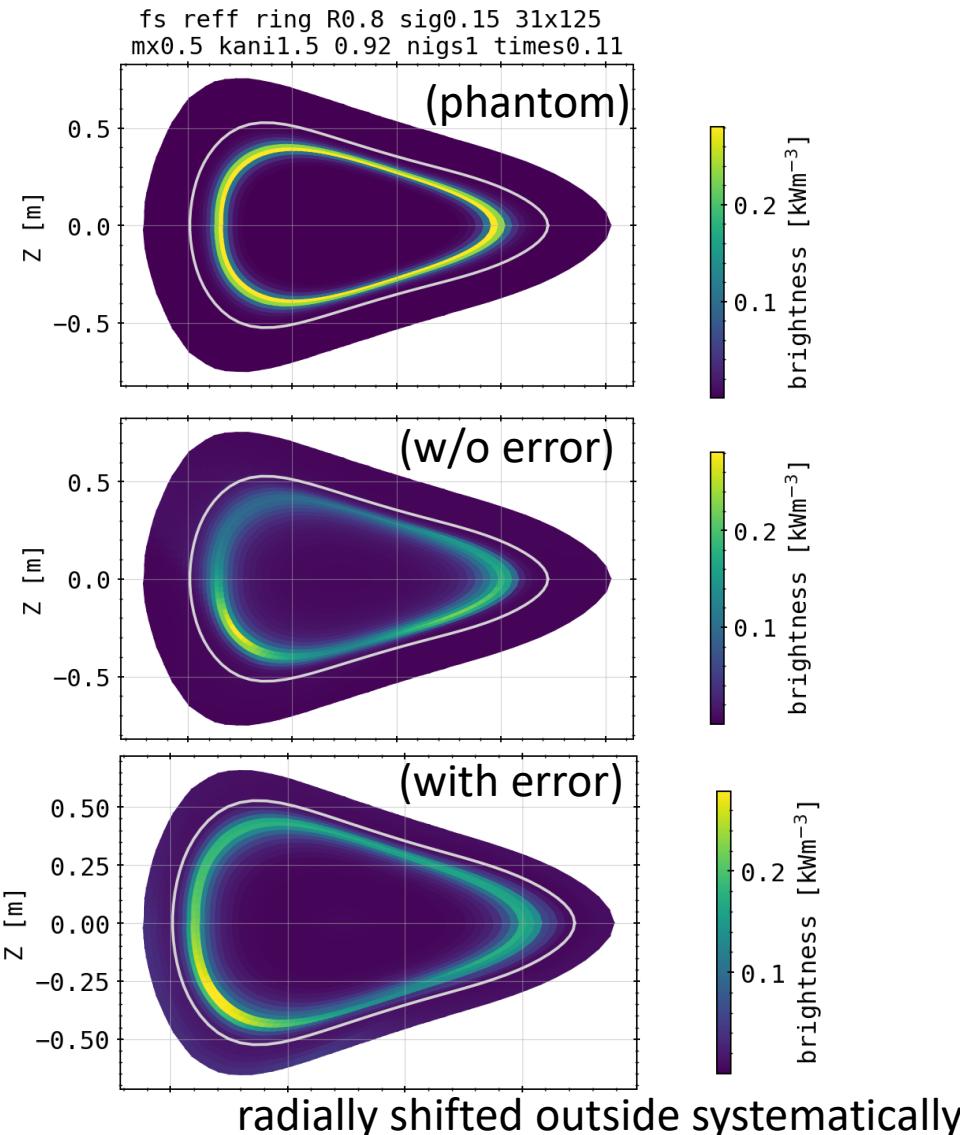
- radial scan shows for one set of K factors there is best set of numbers for reconstruction (radially, 2D)
- inverse of previous problem (set of K for profile): suggesting unique solution for principle shape of phantom

# Phantom Test: Ring with 2.5% Random Error and Tilted Camera

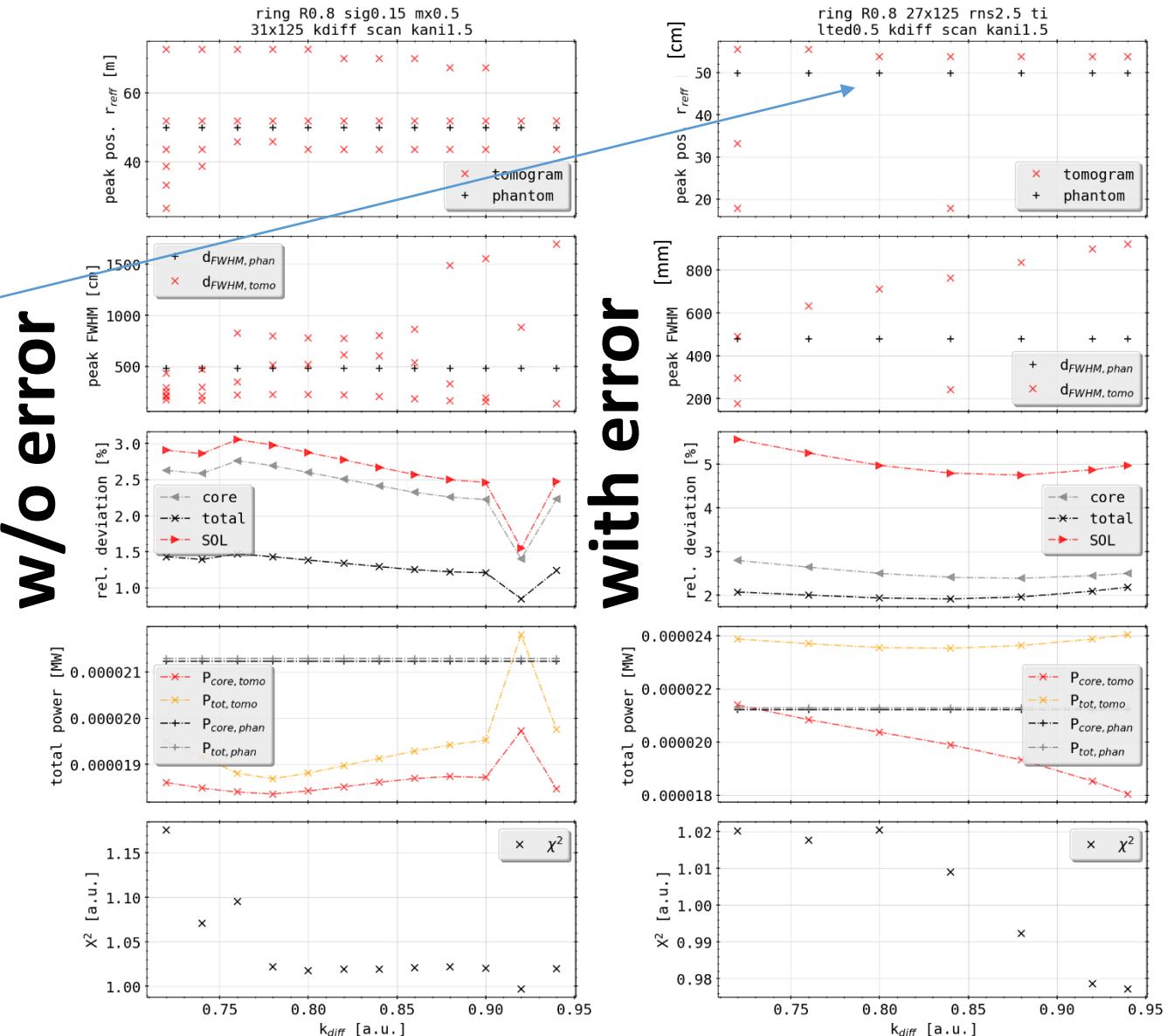
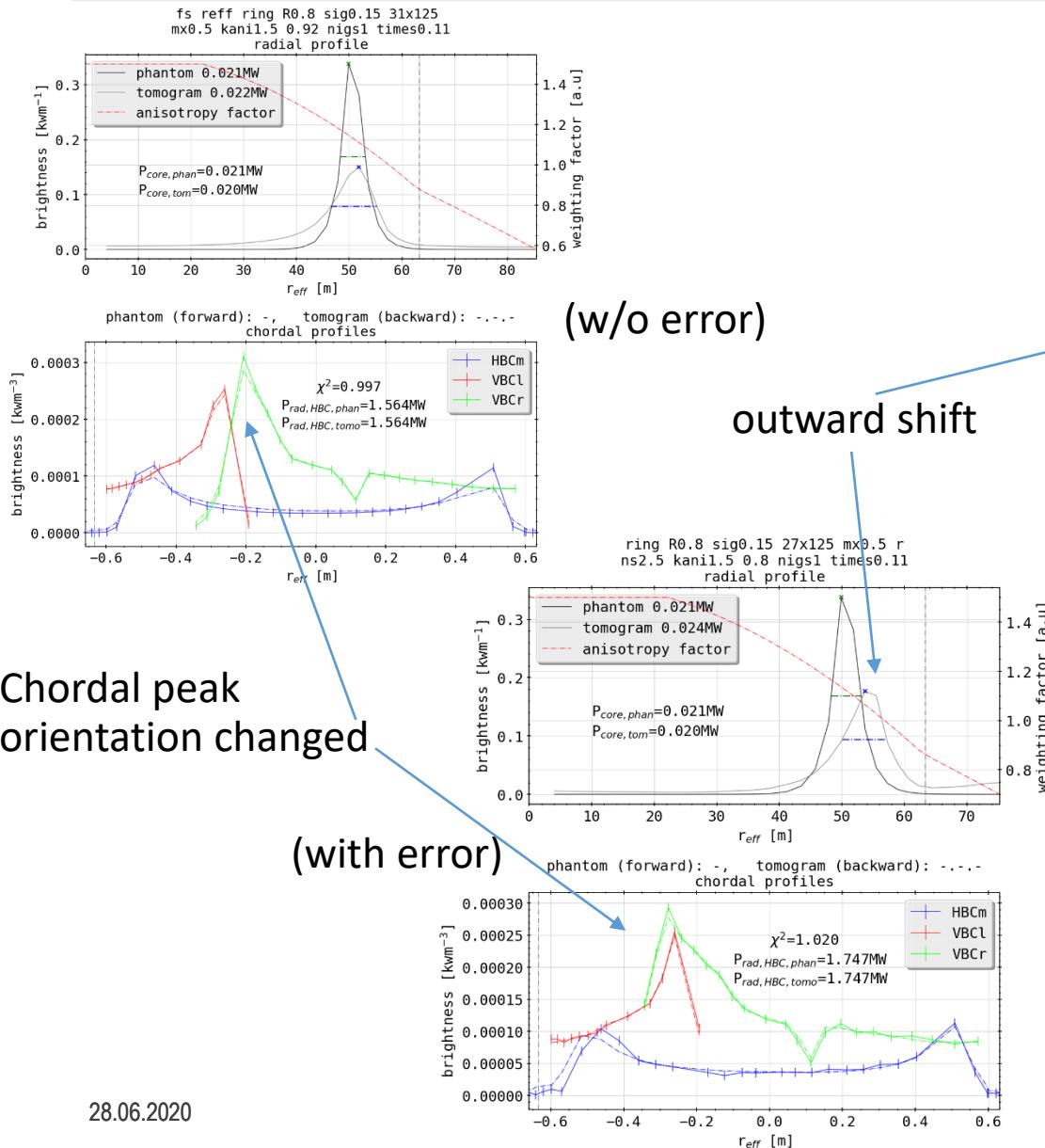
- use geometry previously set up when investigating the effects of errors to emissivities
- add similar 2.5% noise to chordal profile, simulating actually measured experimental profile
- change of best fit parameters according to 2D deviation and  $\chi^2$  measurement
- standard error in peak localization radially changed and increased



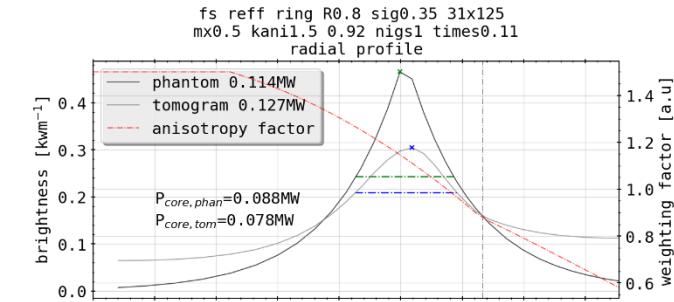
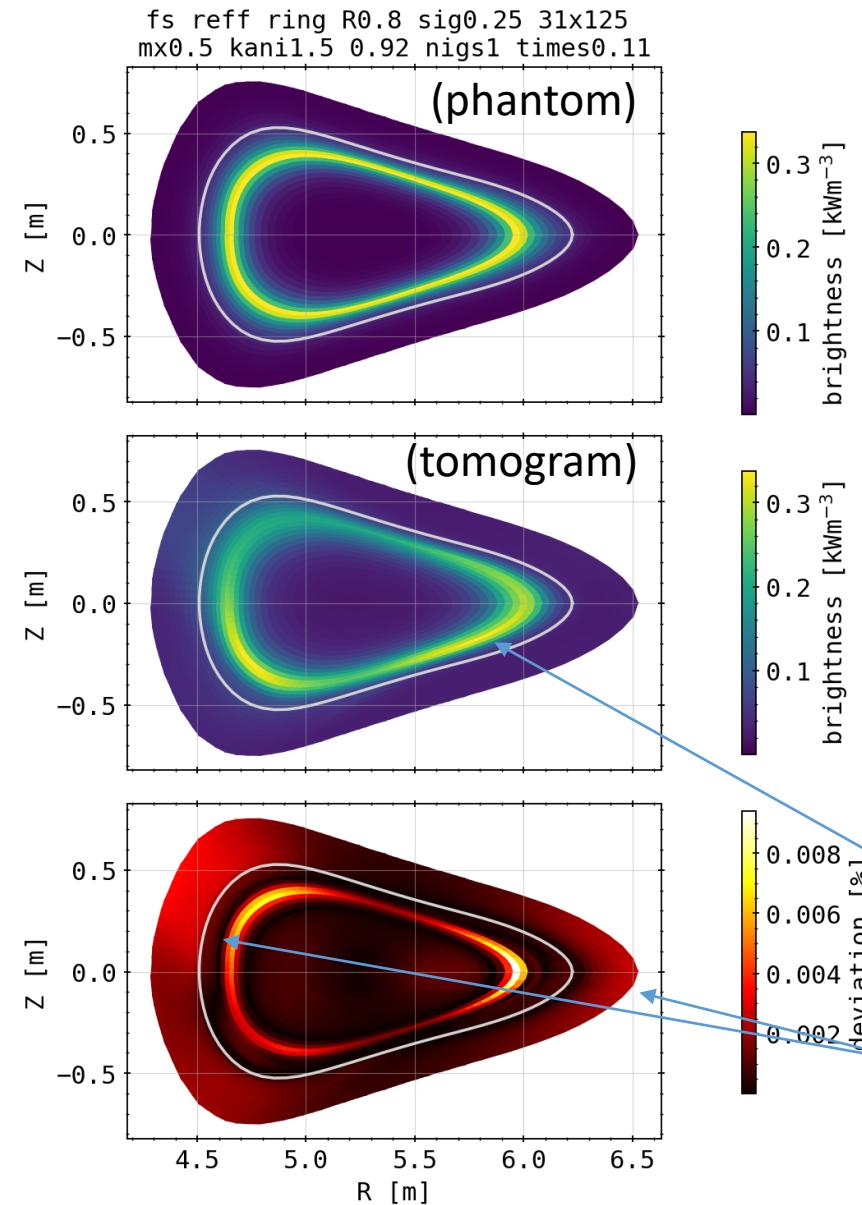
# Phantom Test: Ring with 2.5% Random Error and Tilted Camera



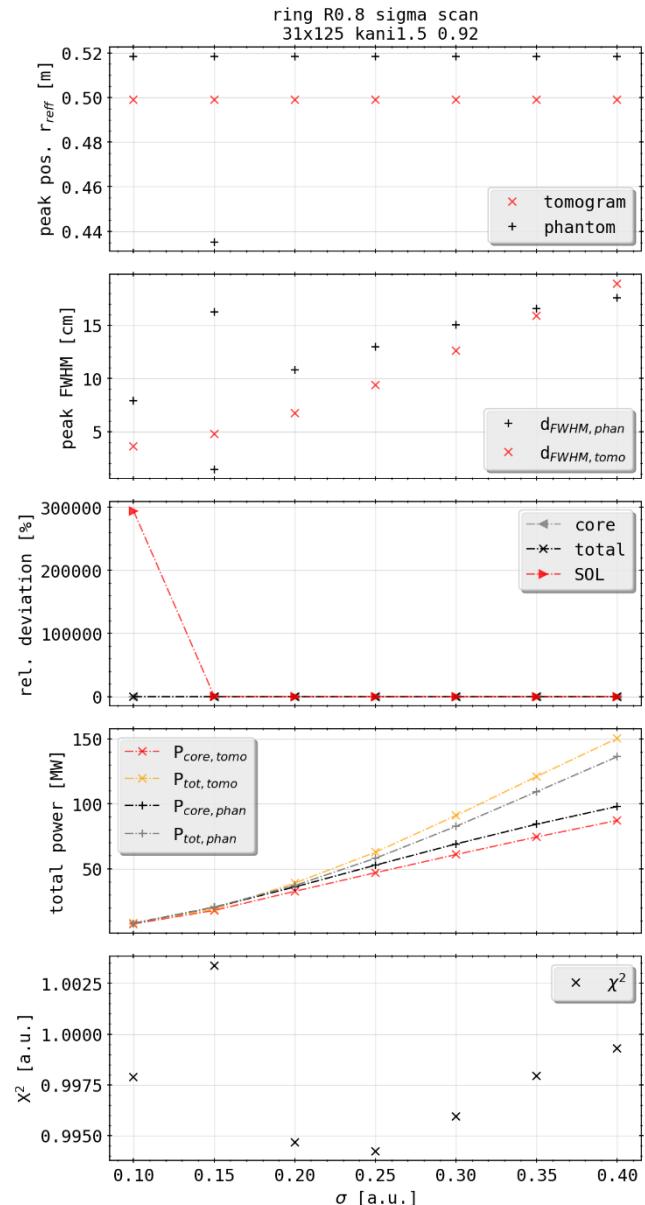
# Phantom Test: Ring with 2.5% Random Error and Tilted Camera



# Phantom Test: Bright Ring Sigma Scan

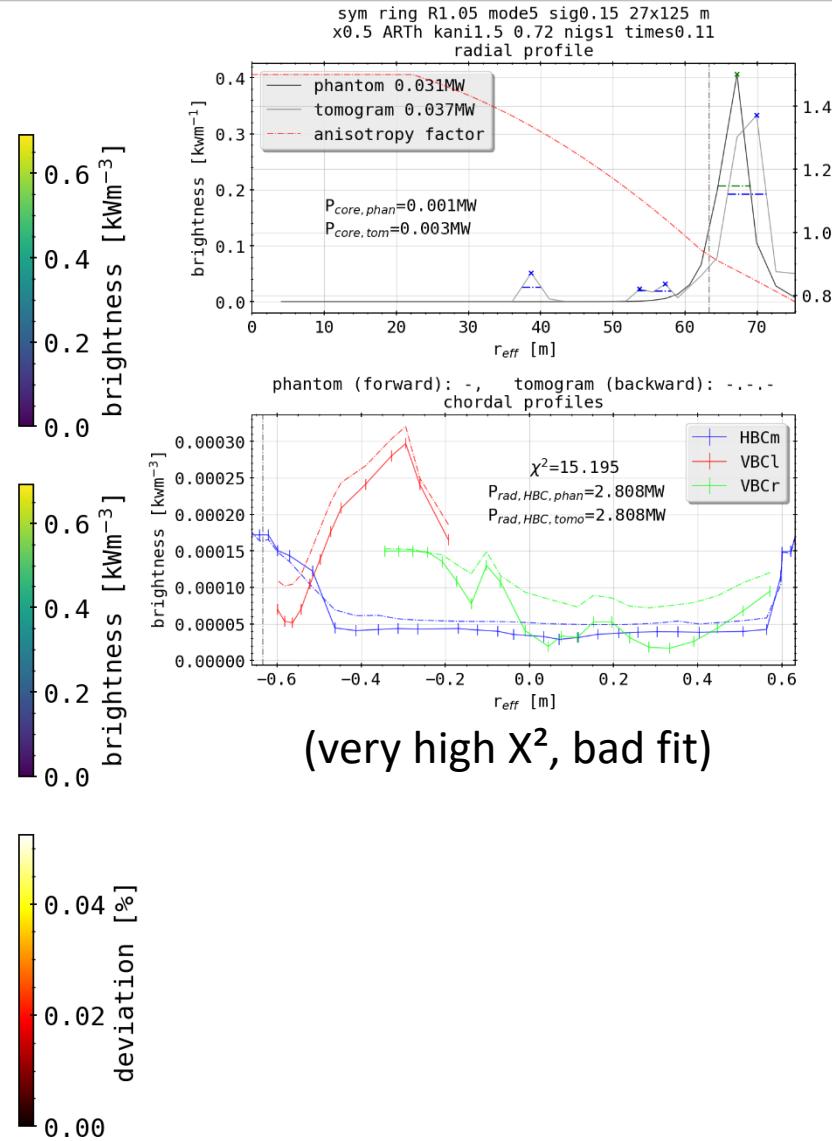
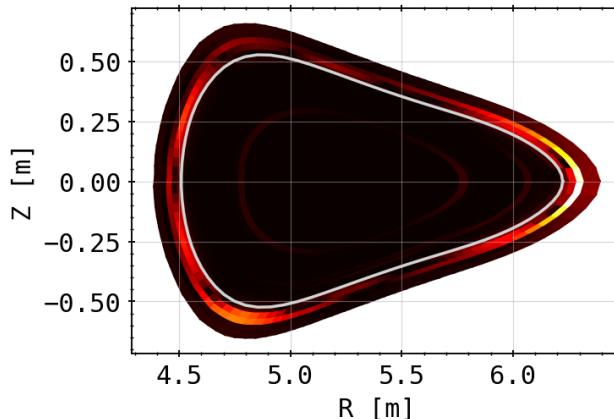
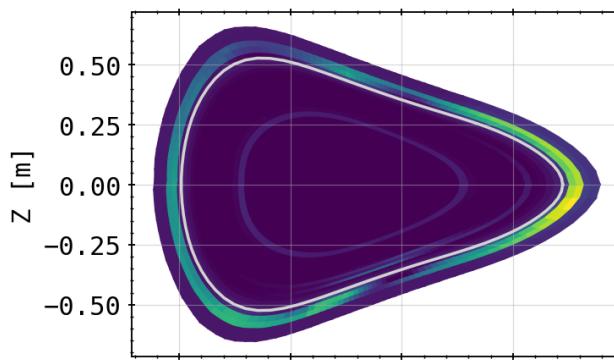
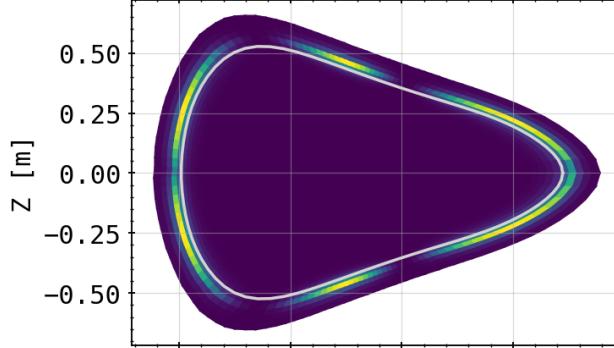


- altering radial profile of bright ring
- general profile representable, poloidal asymmetries persist
- large sigmas cause deposition again beyond LCFS



# Phantom Test: Symmetric Island Mimic (mode = 5)

sym ring R1.05 mode5 sig0.15 27x125 m  
x0.5 ARTh kani1.5 0.72 nigs1 times0.11

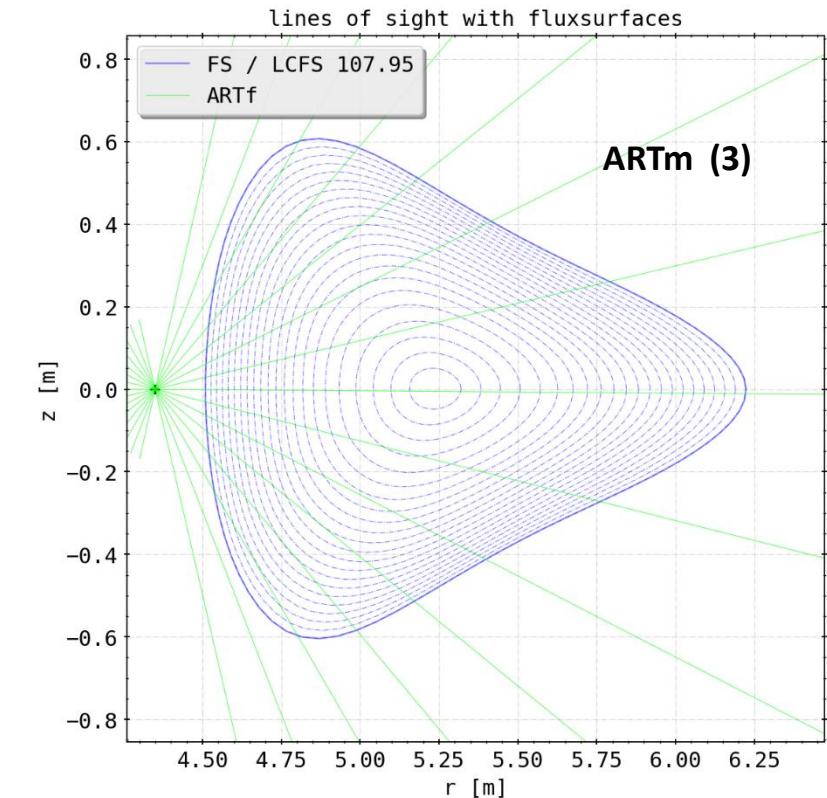
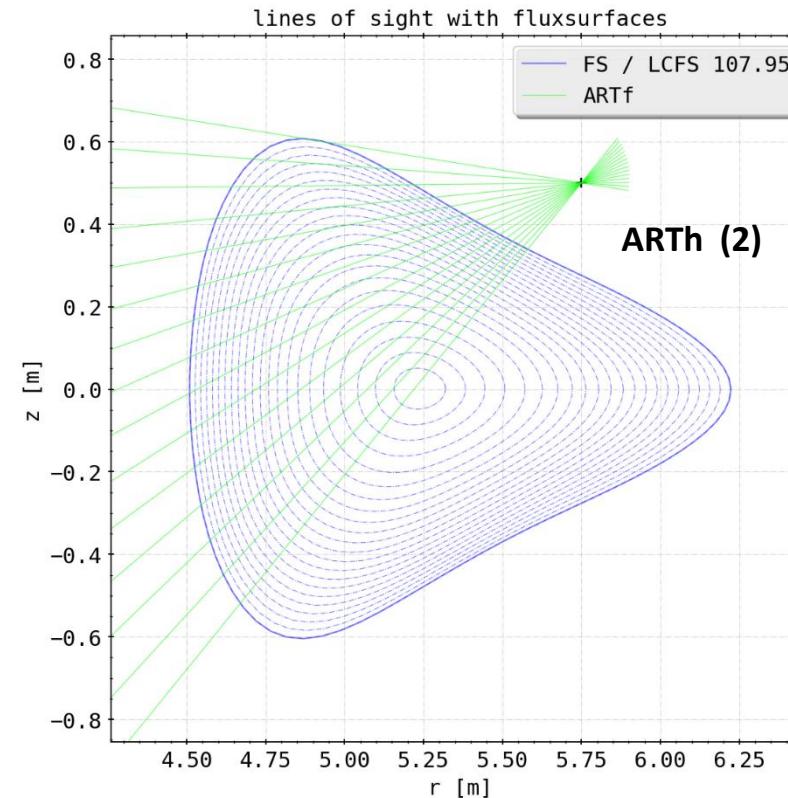
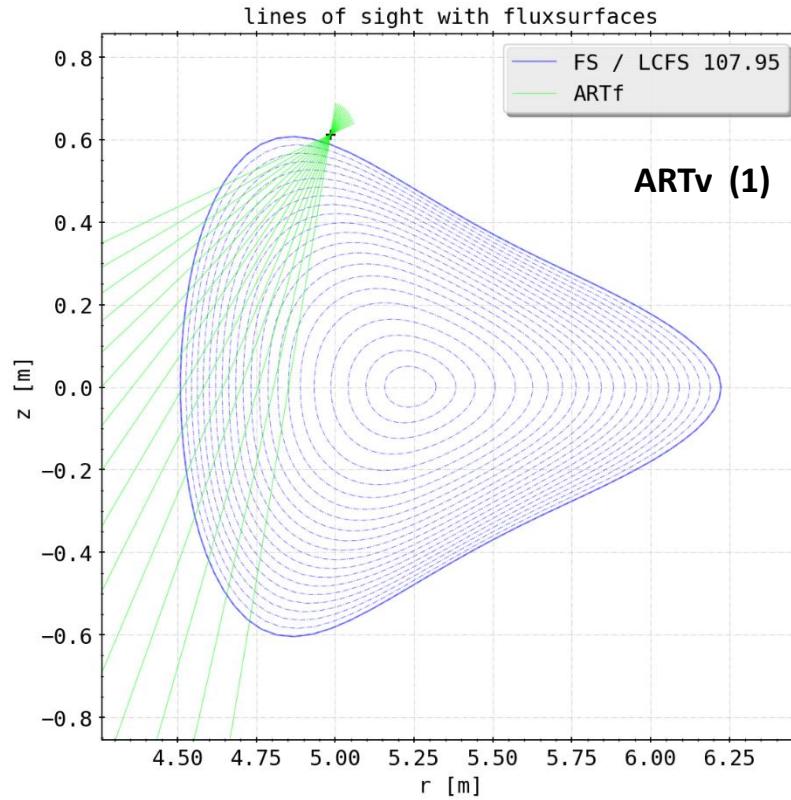


- bad reconstruction overall, radial positioning however good
- poloidal structure only somewhat distinguishable on outboard and lower side
- LOS density on inboard side too low to resolve islands

Fix by higher LOS count/more cameras at different positions or angles?

# Phantom Test: New Cameras

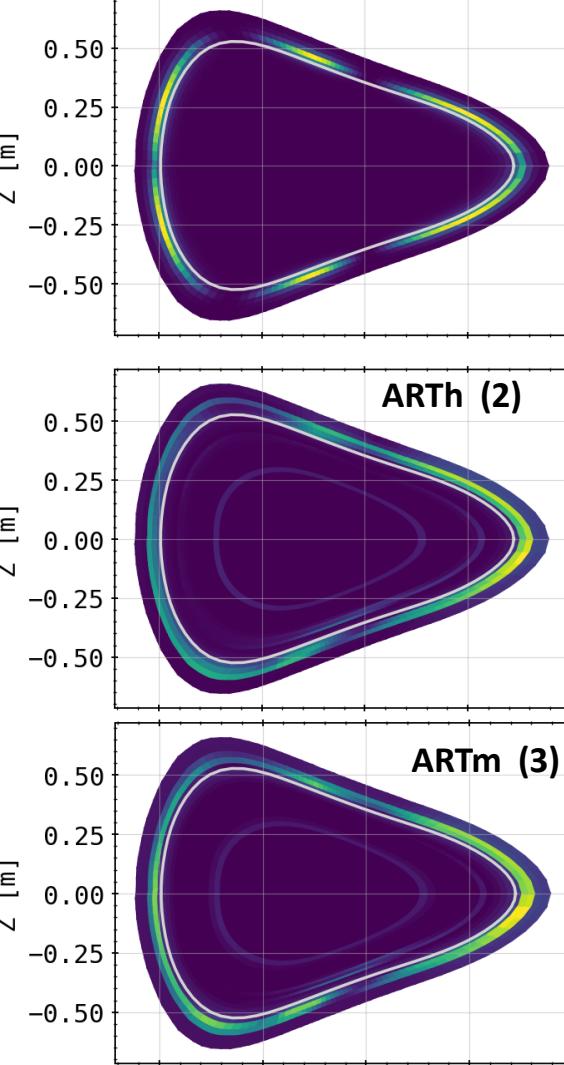
- adding new cameras at possible (1. 2) or impossible (3) positions, 15 channels, 1 at a time



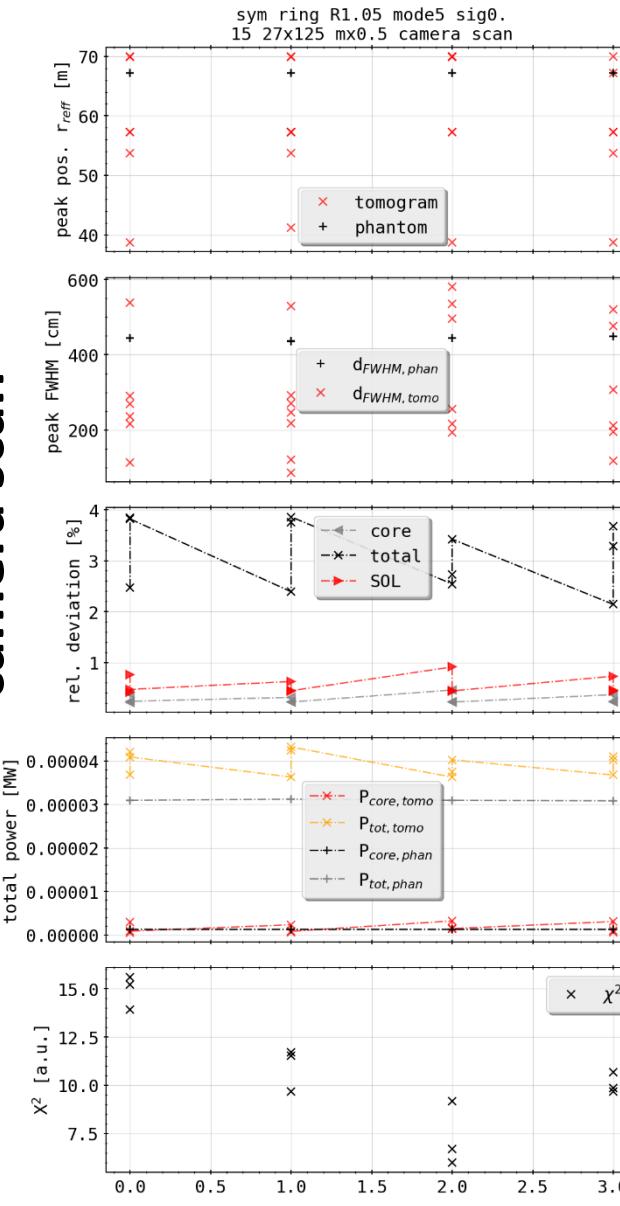
# Phantom Test: Symmetric Island Mimic (New Cameras)

```
sym ring R1.05 mode5 sig0.15 27x125 mx0.
5 ARTh kani1.5 0.72 ARTf nigs1 times0.11
```

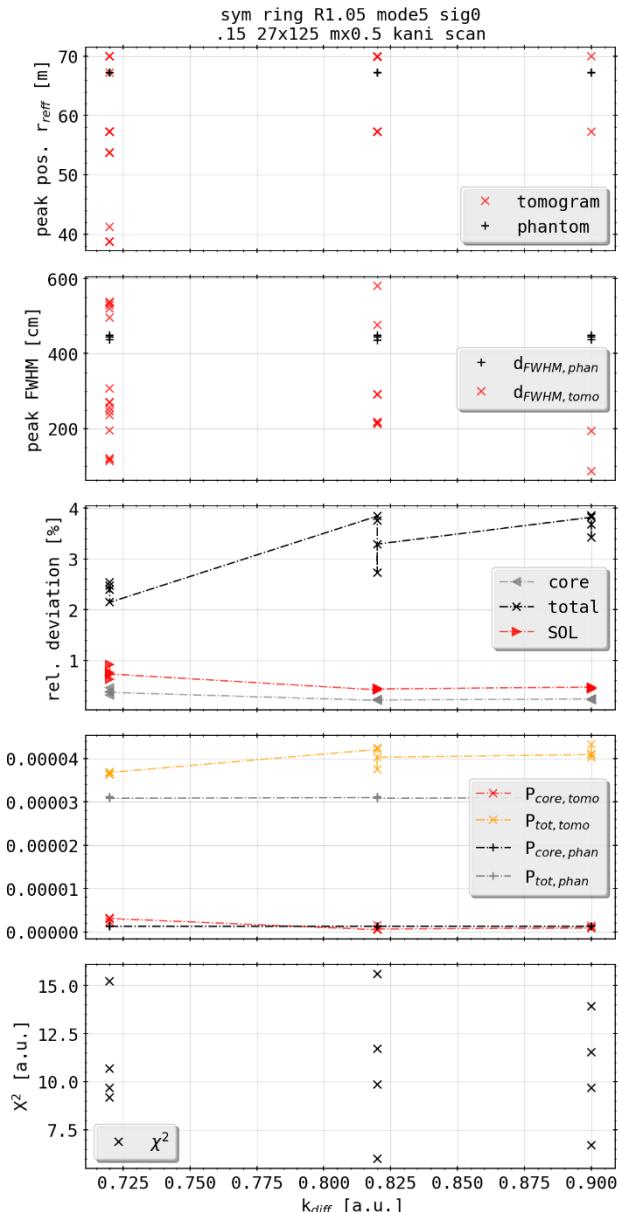
**tomograms**



**camera scan**

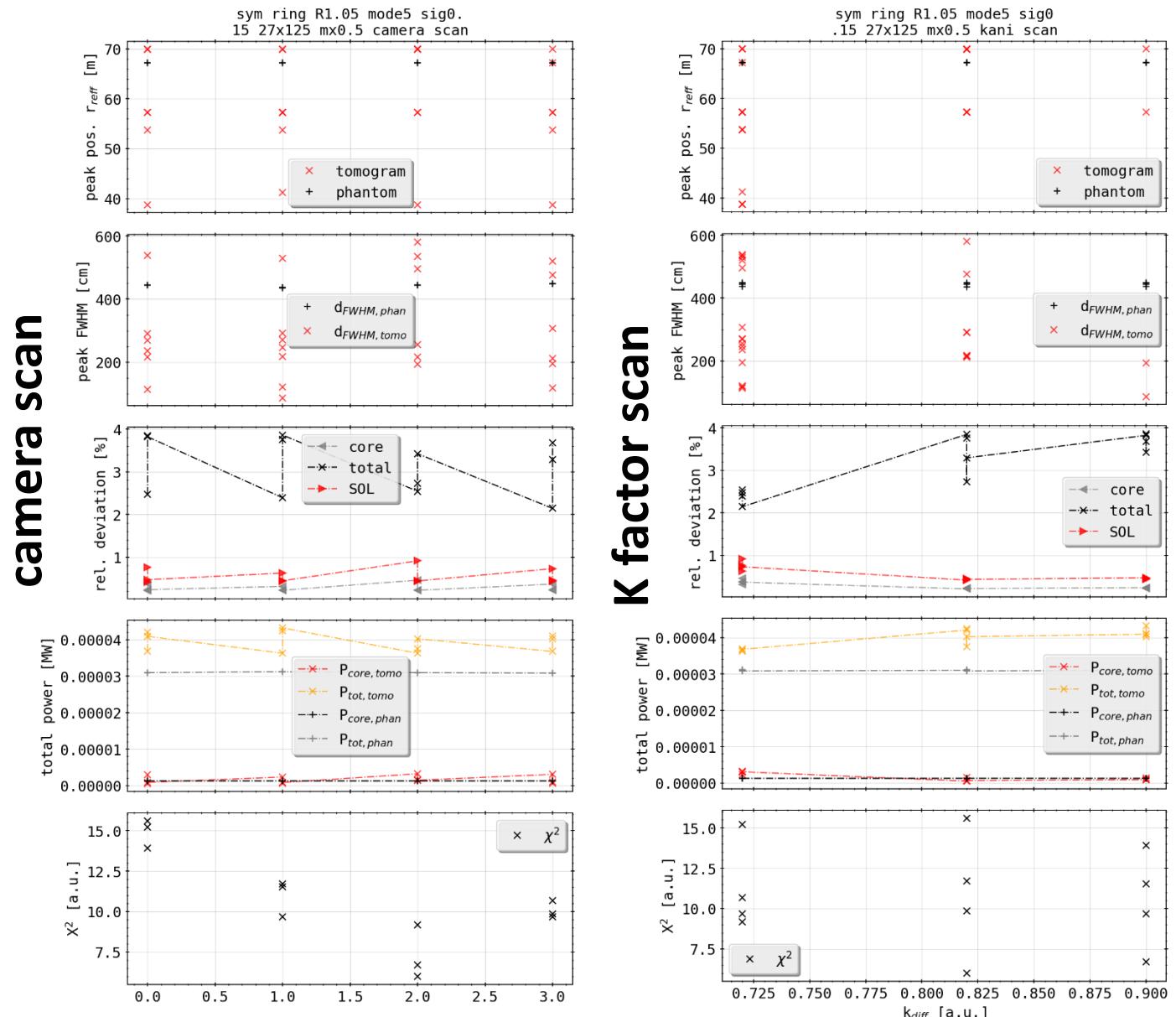


**K factor scan**

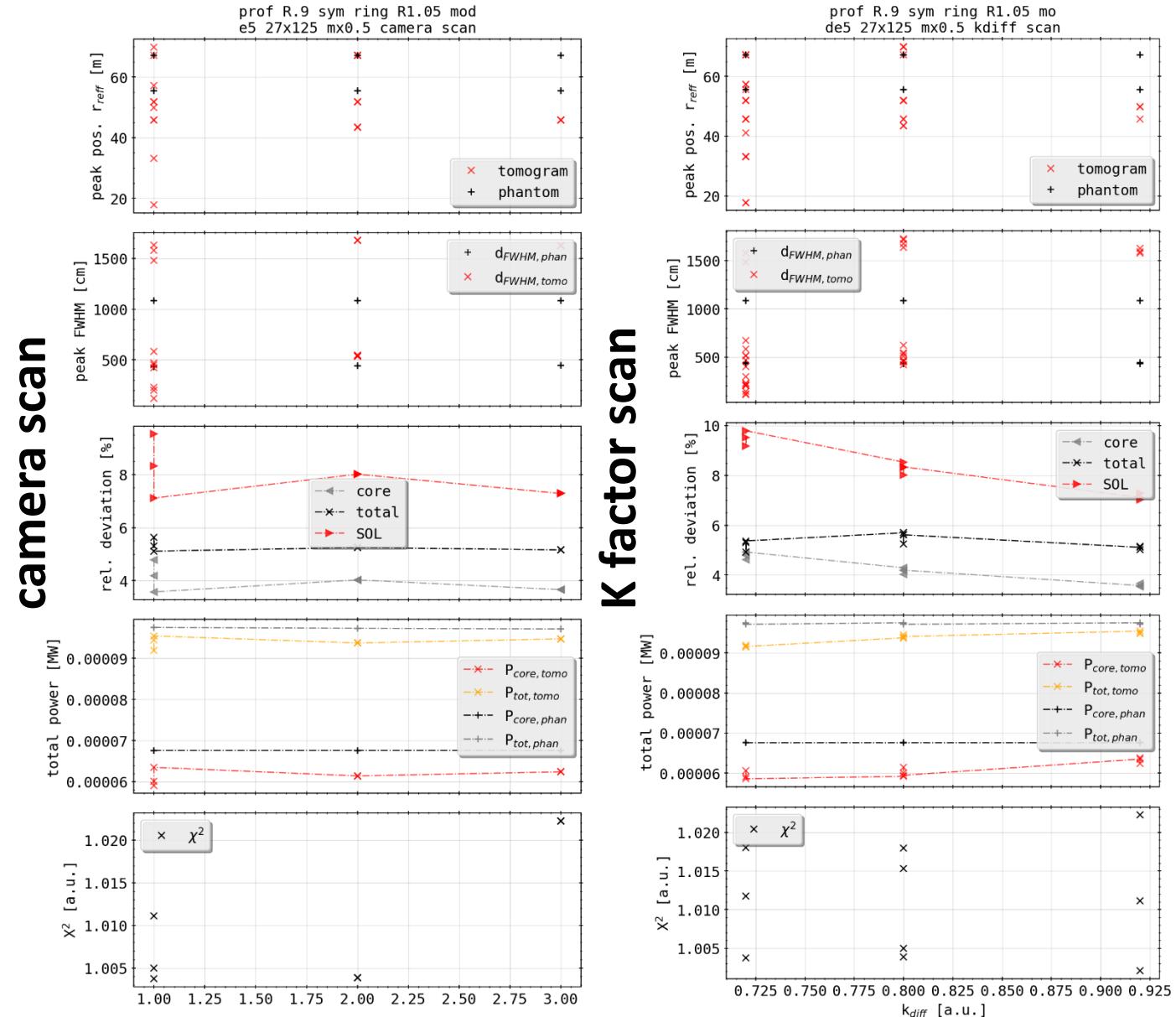
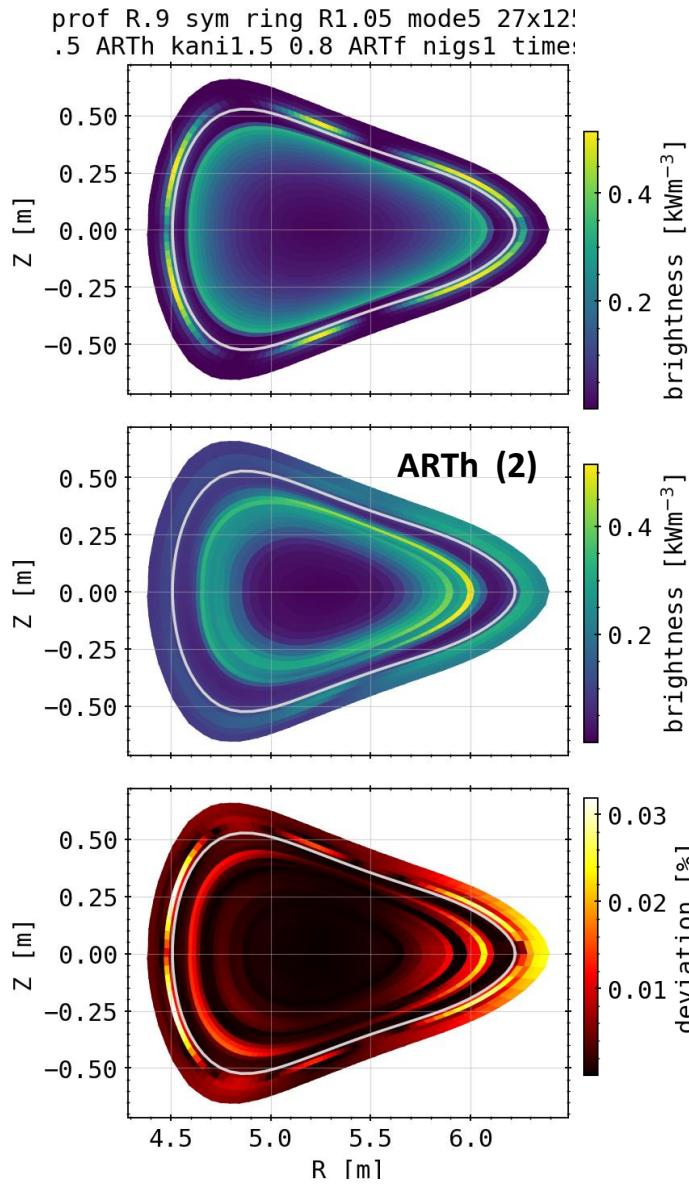


# Phantom Test: Symmetric Island Mimic (New Cameras)

- ARTh seems to be best arctificial, additional camera according to  $\chi^2$
- 2D reconstruction not inherently better though, inboard characteristics are still no resolvable with given restrictions (coverage, number of channels, pinhole positions, ...)
- different approach to K factor might help, TBD

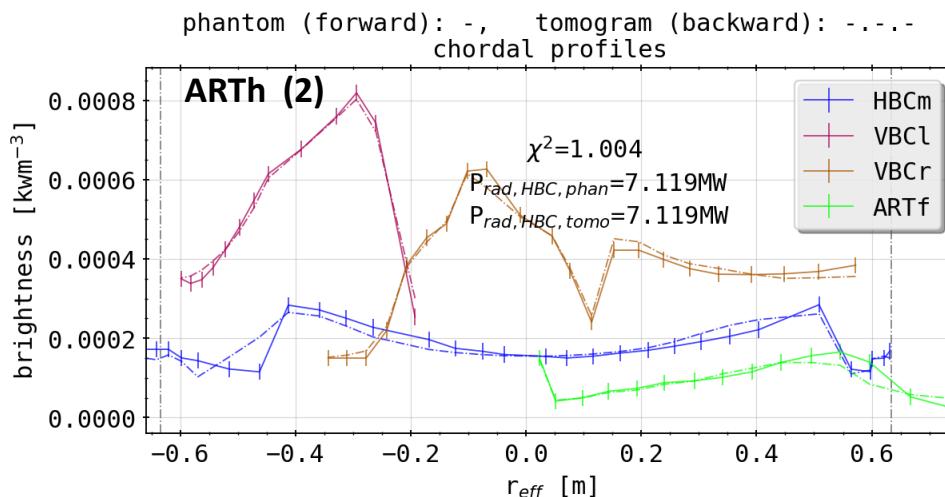


# Phantom Test: Island Mimic and Radial Profile

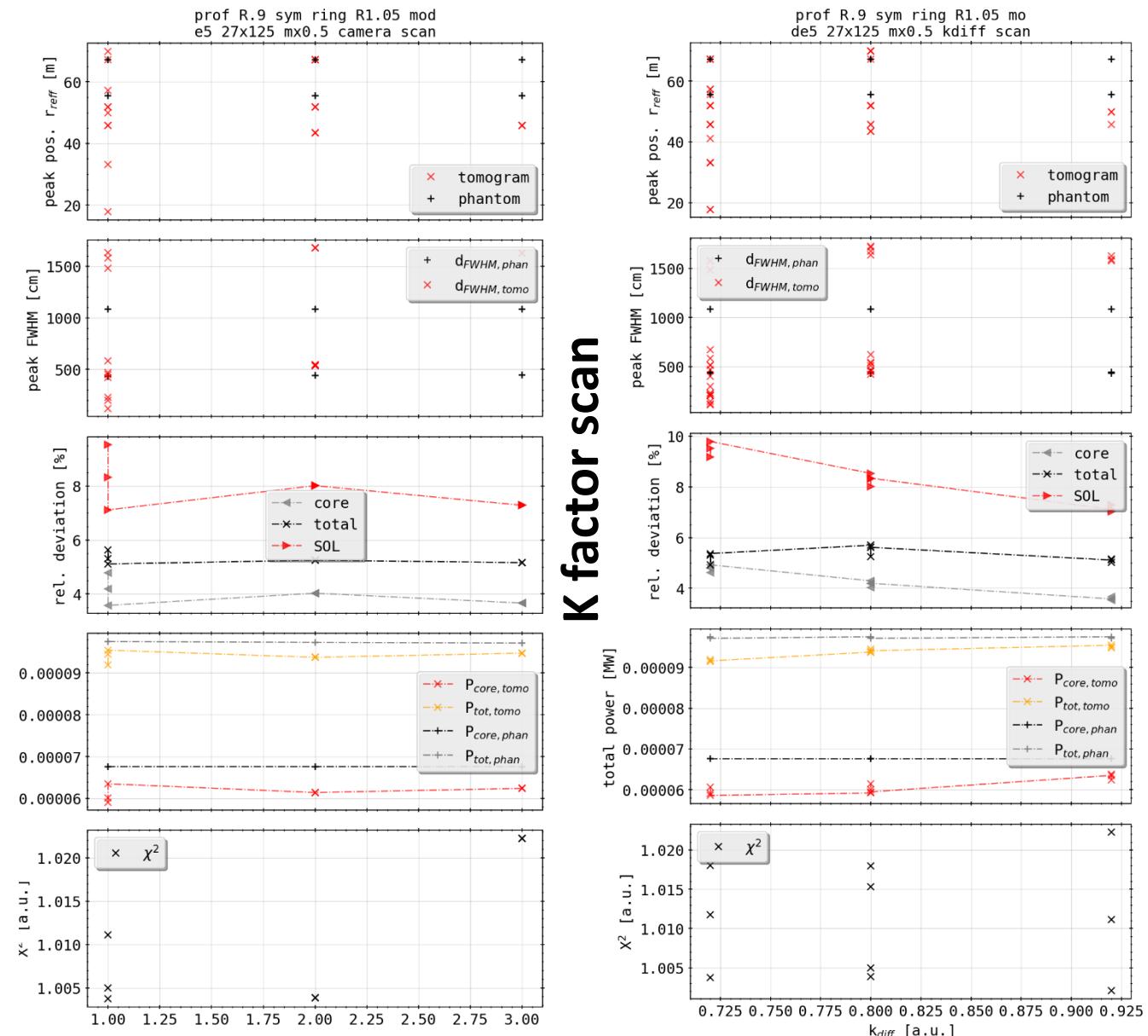


# Phantom Test: Island Mimic and Radial Profile

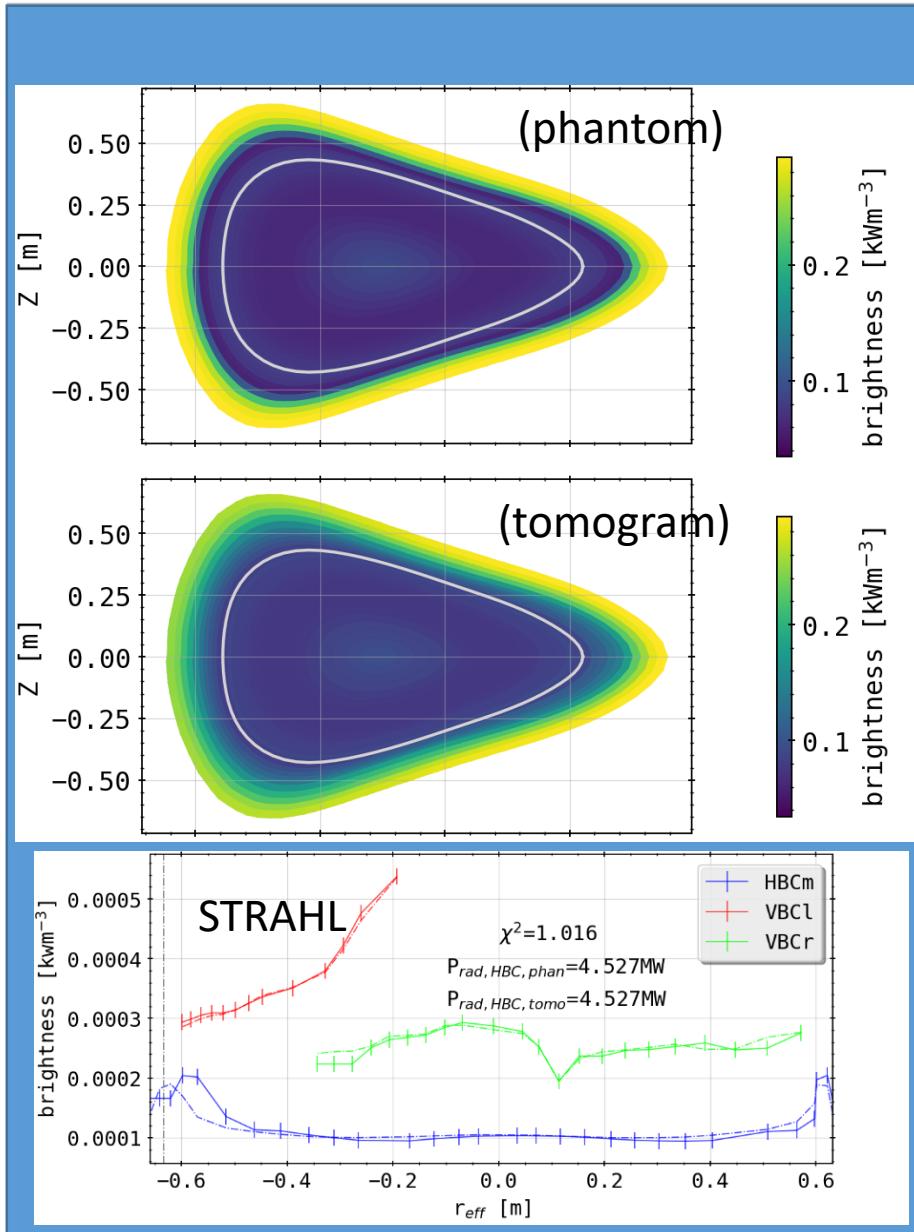
- radial profile inside shadowing over island structure
- virtually not reproducible if poloidaly symmetric emissivity profile is superimposed
- outside emissivity focused in front of HBC
- $\chi^2$  fits overall better



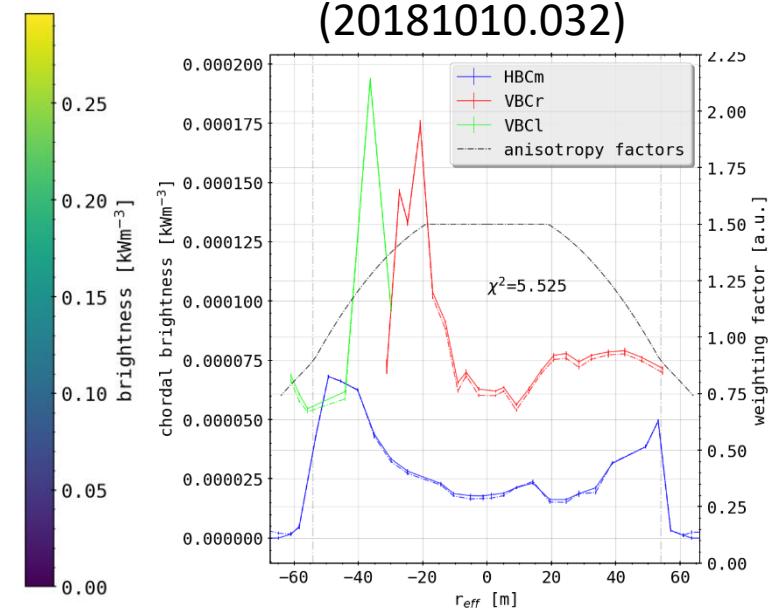
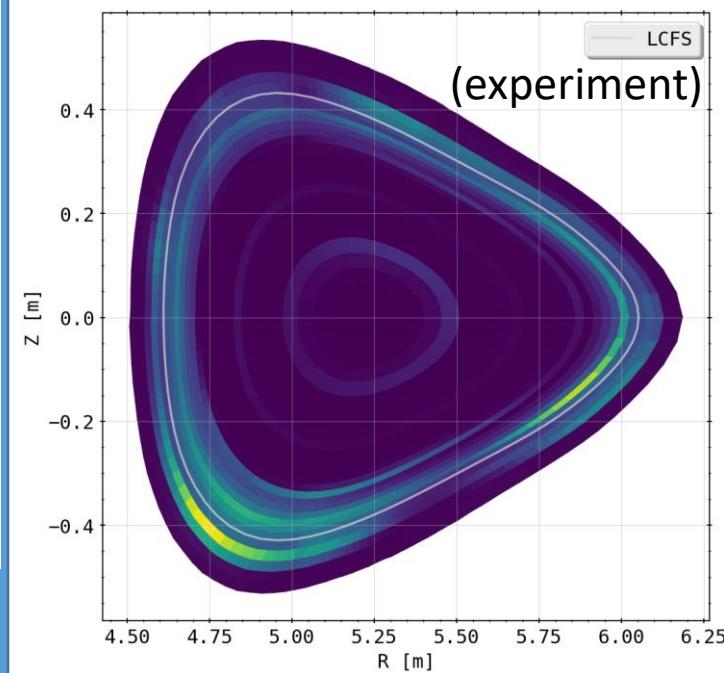
america scan



# STRAHL and XP: 20181010.032 Comparison

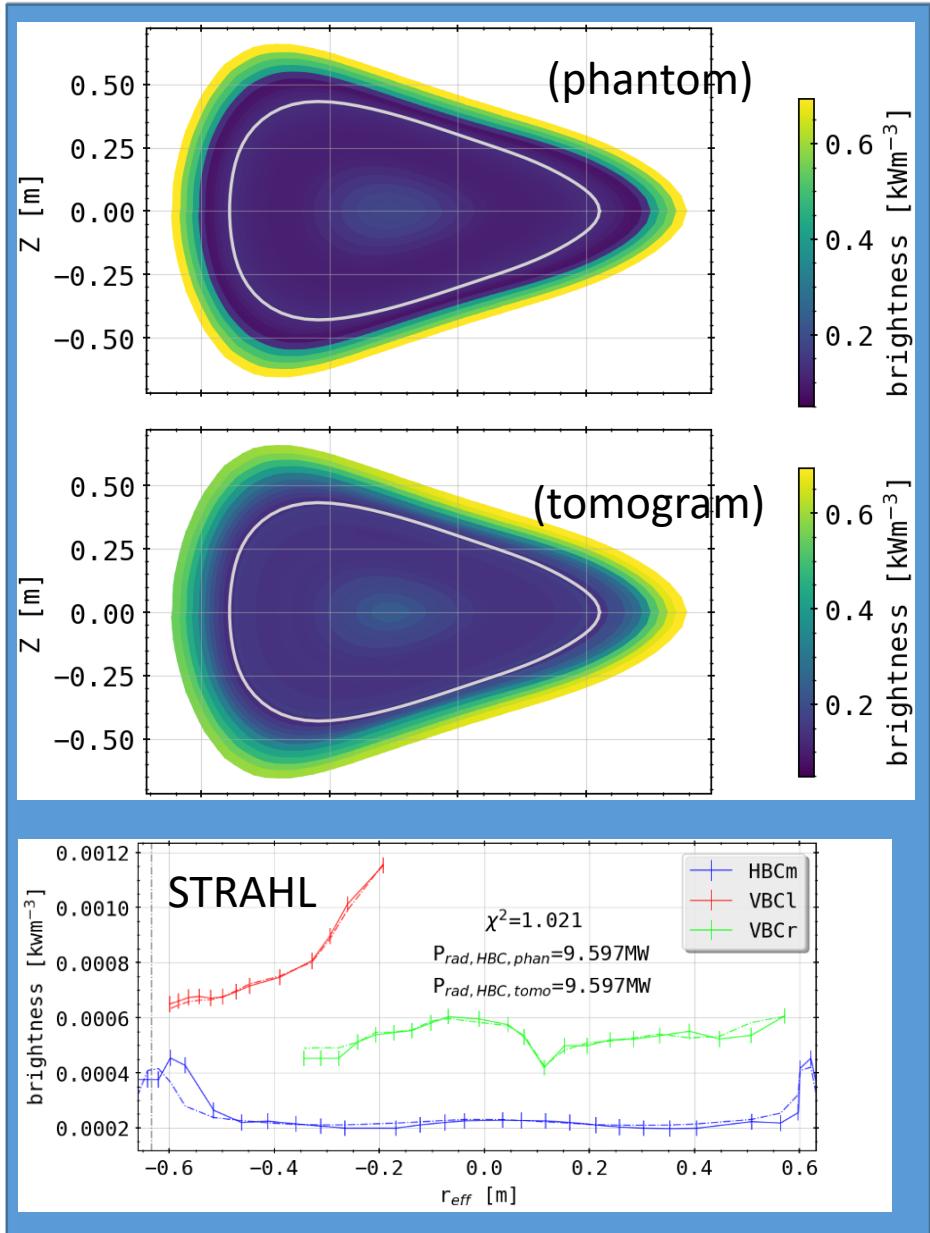


radiation fraction = 33%

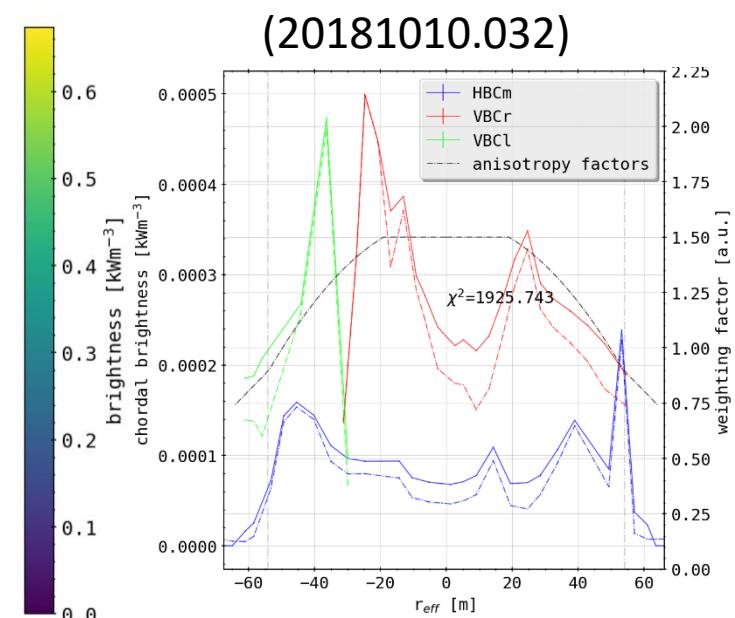
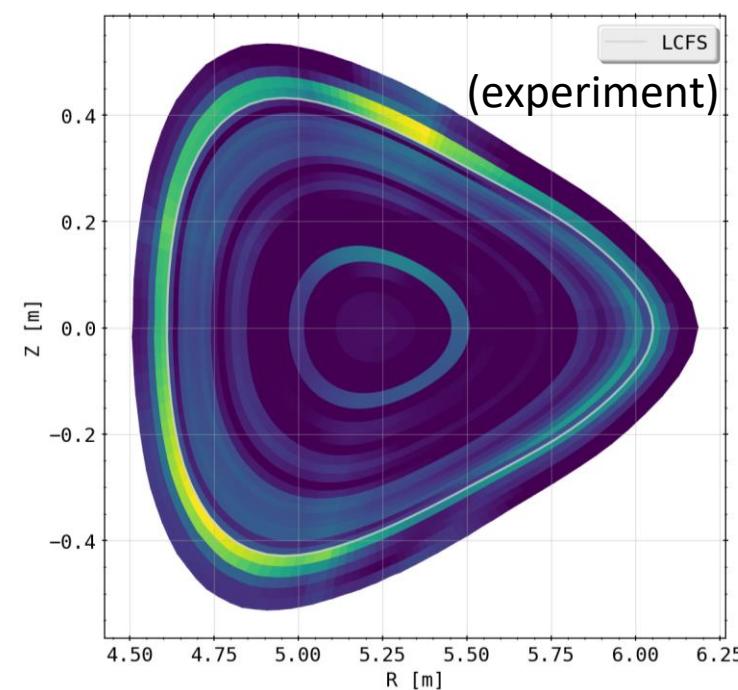


(already large  $\chi^2$ )

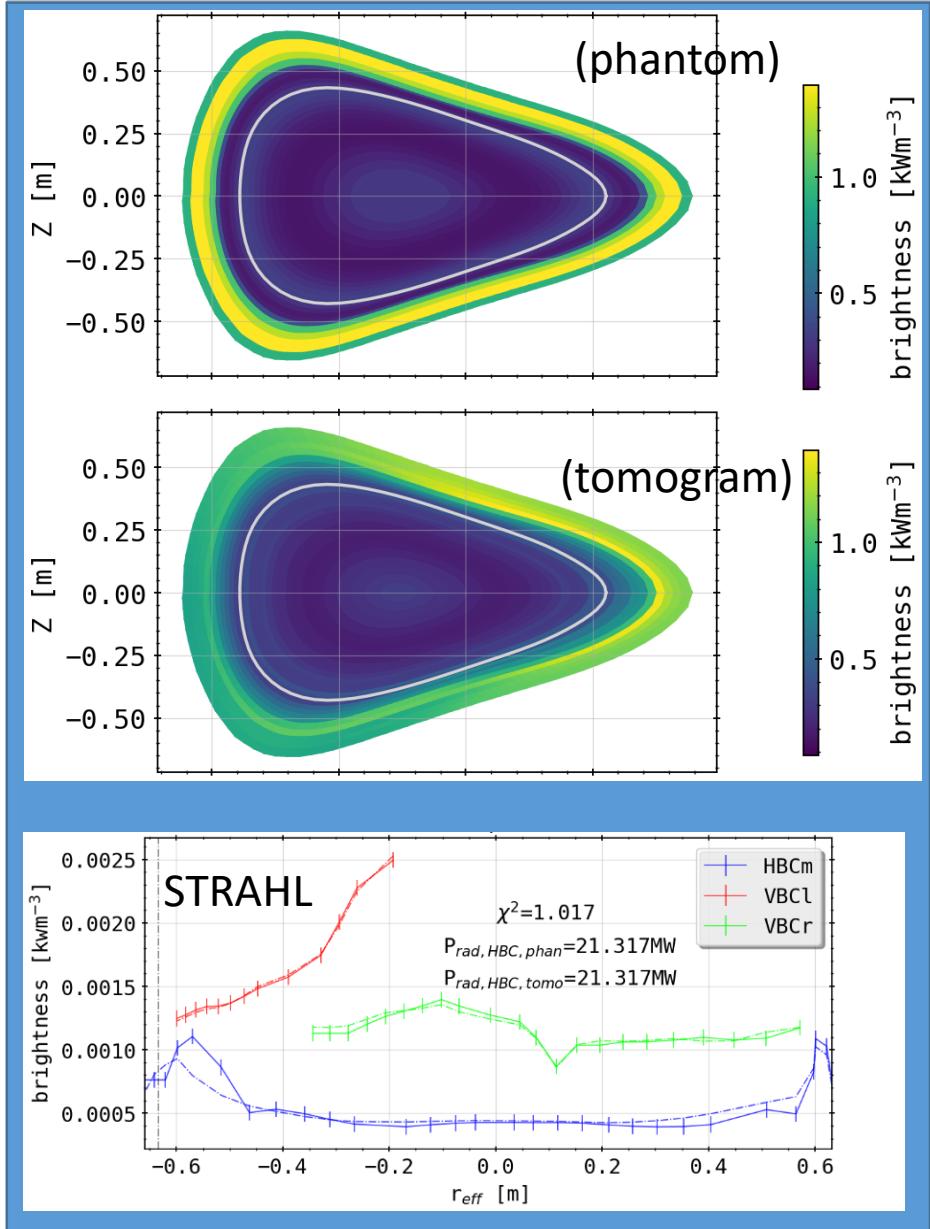
# STRAHL and XP: 20181010.032 Comparison



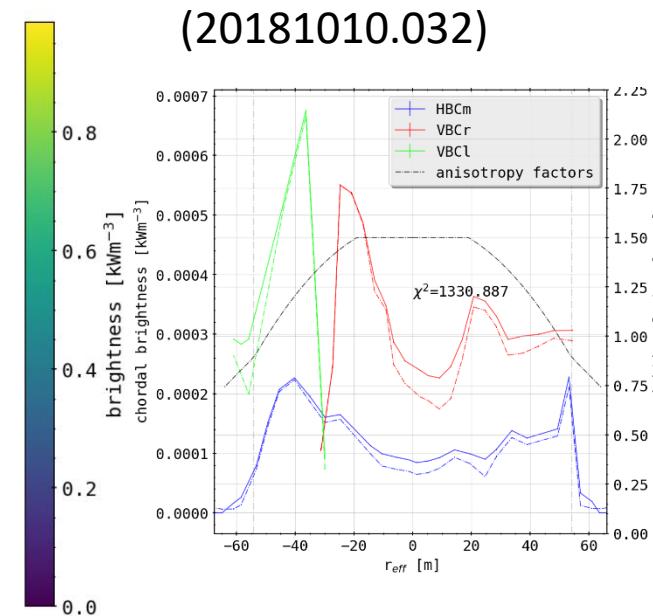
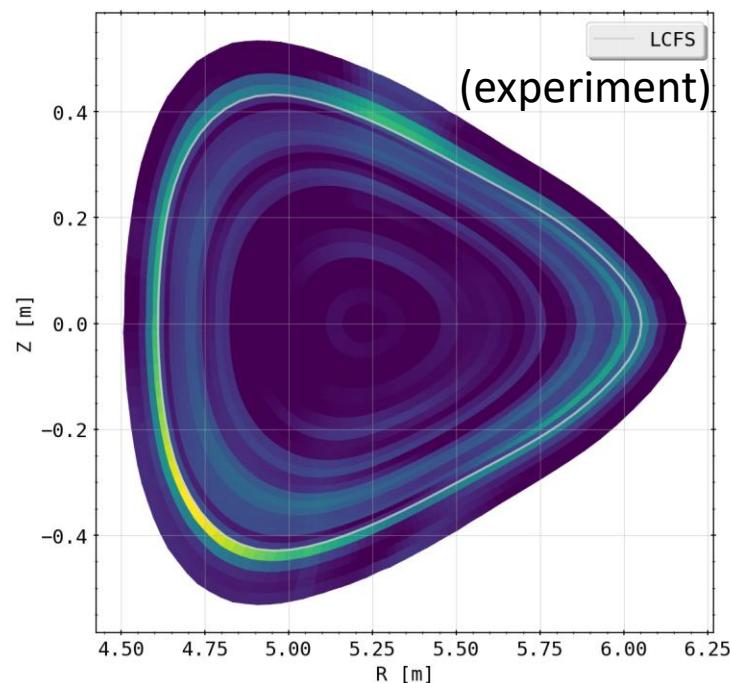
**radiation fraction = 66%**



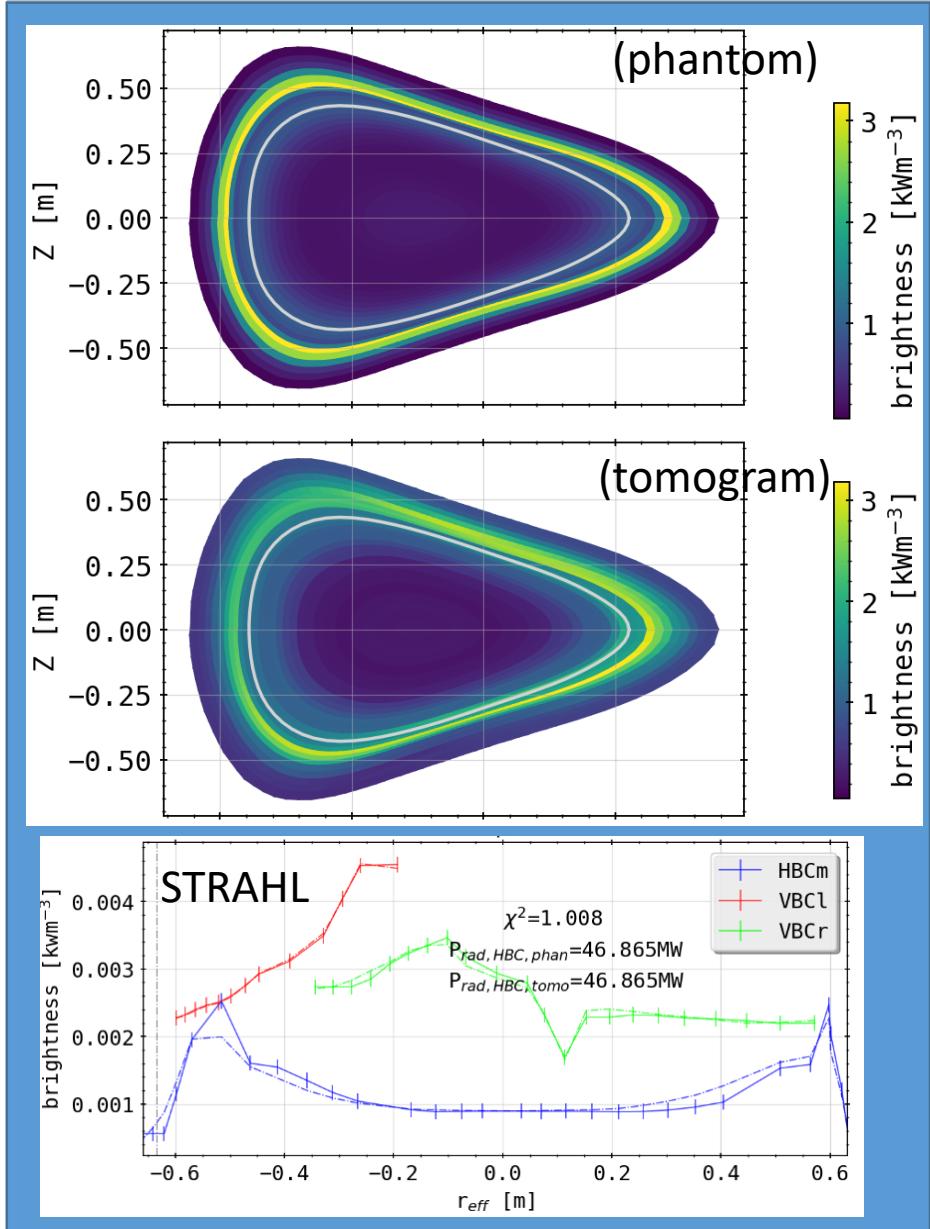
# STRAHL and XP: 20181010.032 Comparison



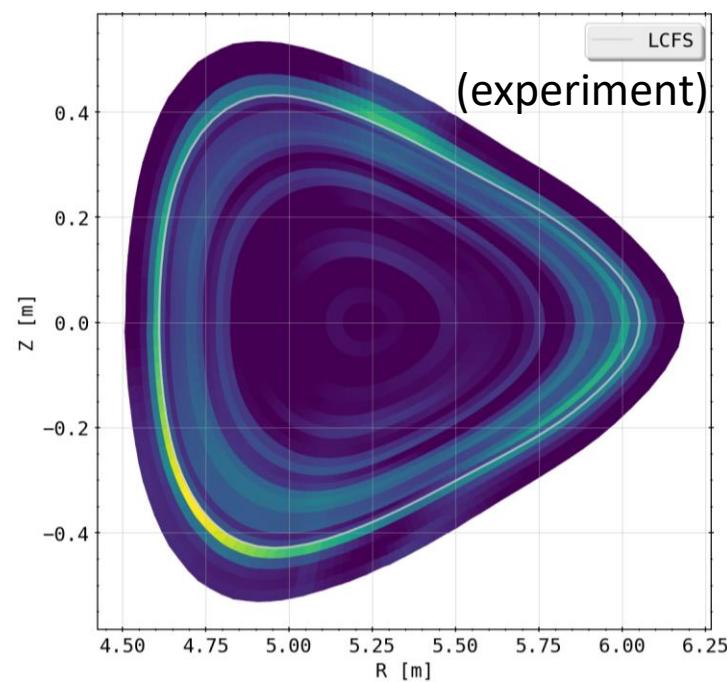
radiation fraction = 90%



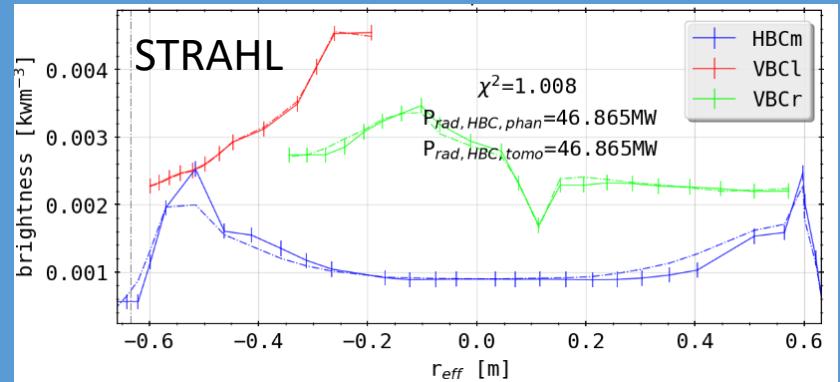
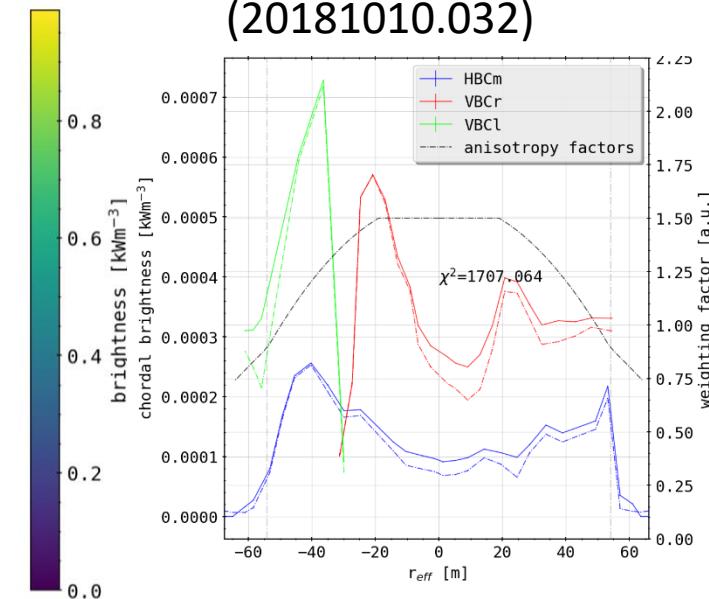
# STRAHL and XP: 20181010.032 Comparison



**radiation fraction = 100%**



(20181010.032)



# Preliminary Conclusion and Outlook

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- likely good (best?) resolution of inversion domain, both with reasonable accuracy and calculation time is 27x75 cells (radial times poloidal, 21 fluxsurfaces build the plasma core)
  
- additional radial or poloidal points only add time to calculation and possible free parameters to fit emissivity (avoidable by changing the gradients along the aforementioned dimensions accordingly)

# Preliminary Conclusion and Outlook

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- considering a given emissivity profile shape, there exists an ideal set of K factors constraining the ratio of poloidal and radial gradients according to the  $\chi^2$  optimisation
- not necessarily the same as defined by the lowest 2D deviation, whose optimisation also yields an optimal set of K factors
- radial positioning of profiles is subject to the selection of K factors over the radius

# Preliminary Conclusion and Outlook

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- poloidally distributed profiles are, so far the data set, near impossible to reconstruct properly (especially on the inboard side)
- asymmetric characteristics can be property of the underlying emissivity profile to the tomography, however some are introduced due to the line of sight geometry
- combinations of profile shapes, especially poloidally symmetric and any else become hard to distinguish from one another (see ring and island mimic)

# Preliminary Conclusion and Outlook

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- bright spots on-/off-axis and, e.g. bright rings can be separated from each other depending on the distance
- individual bright sheaths can no longer be reconstructed radially when closer than 0.2m
- STRAHL reconstructions are largely accurate in position and value
- reference XP 20181010.032 difficult to invert, subject to better profiles of K factors?

# Preliminary Conclusion and Outlook

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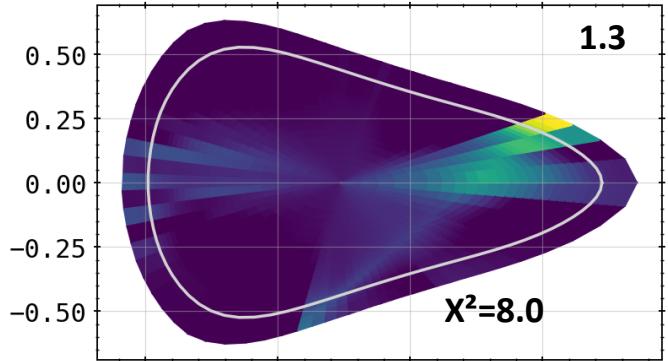
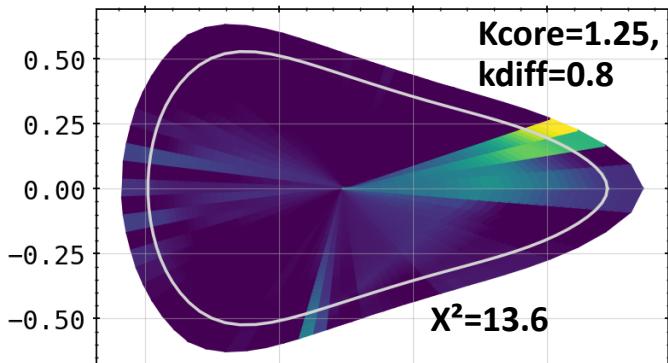
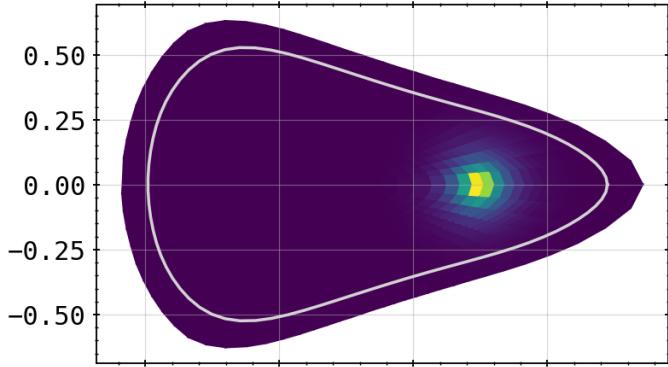


- possibly find better approach to K factor profile shape for island mimics or combinations (double rings as well?) and asymmetric phantoms
  
- check orders of magnitude/units of results for plausibility

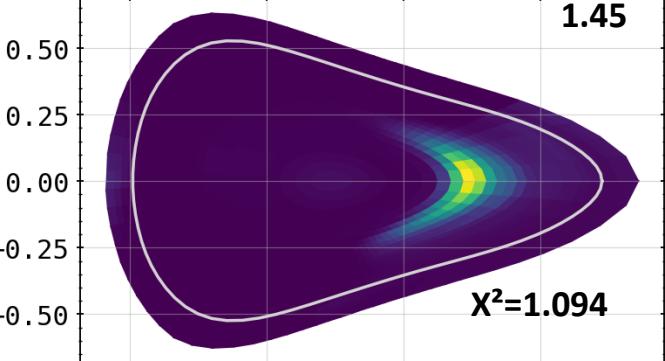
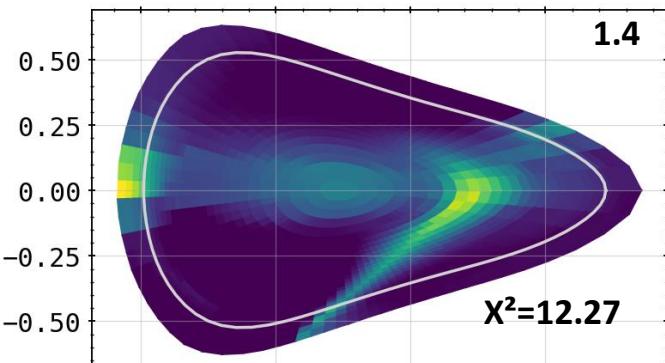
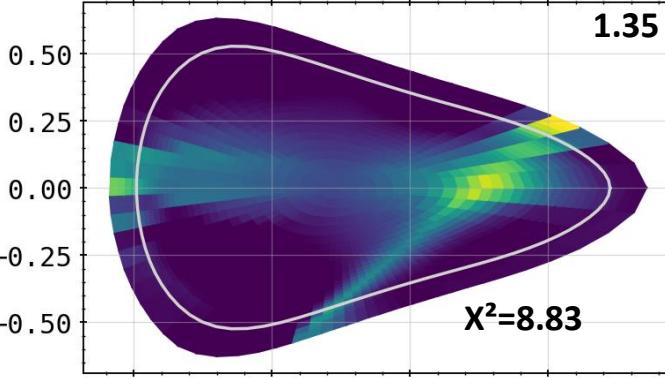


# Phantoms: Asymmetric Spot Core Scan

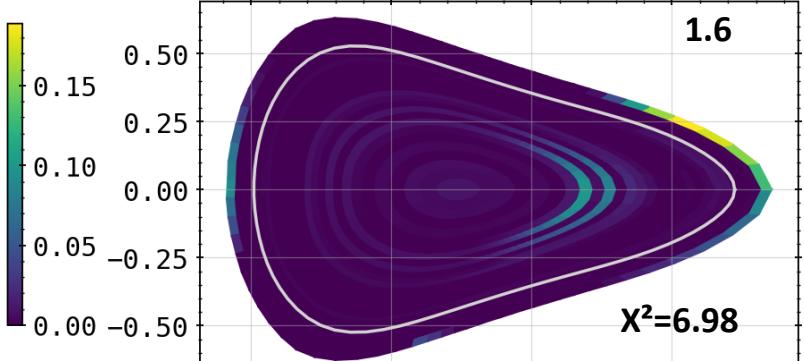
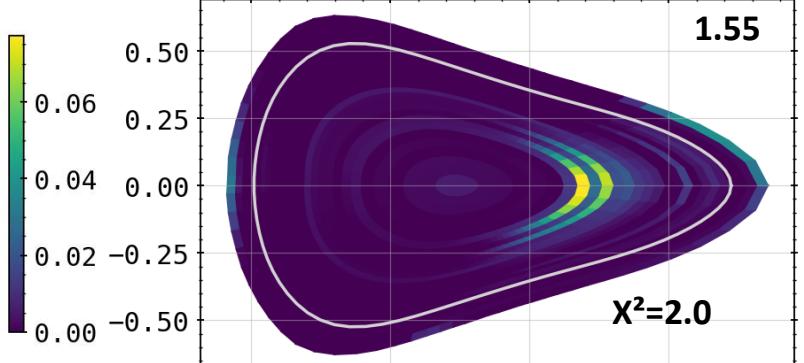
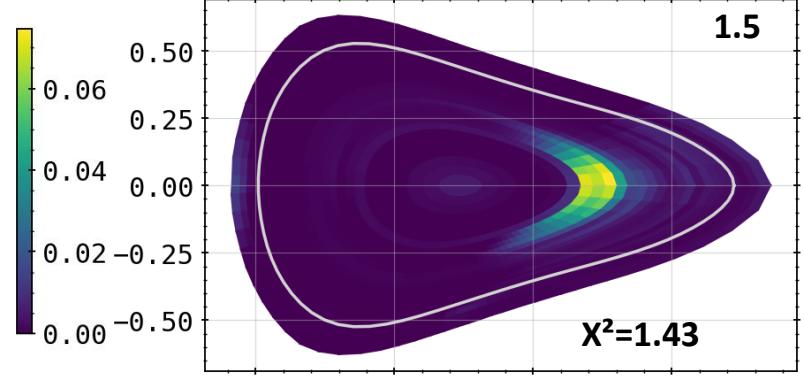
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mx0.5 nigs1 times0.11



brightness [power/volume]



brightness [power/volume]

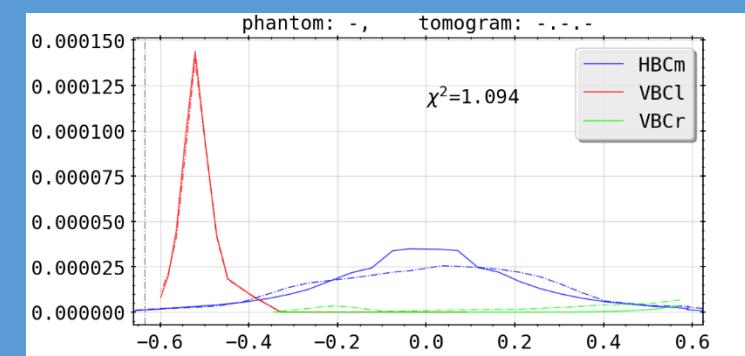
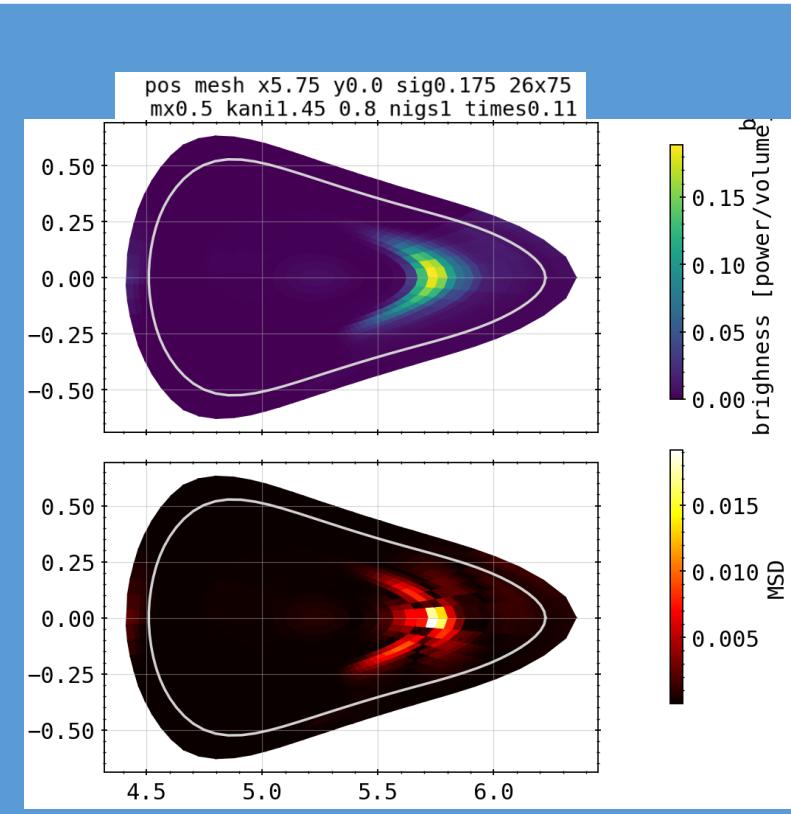
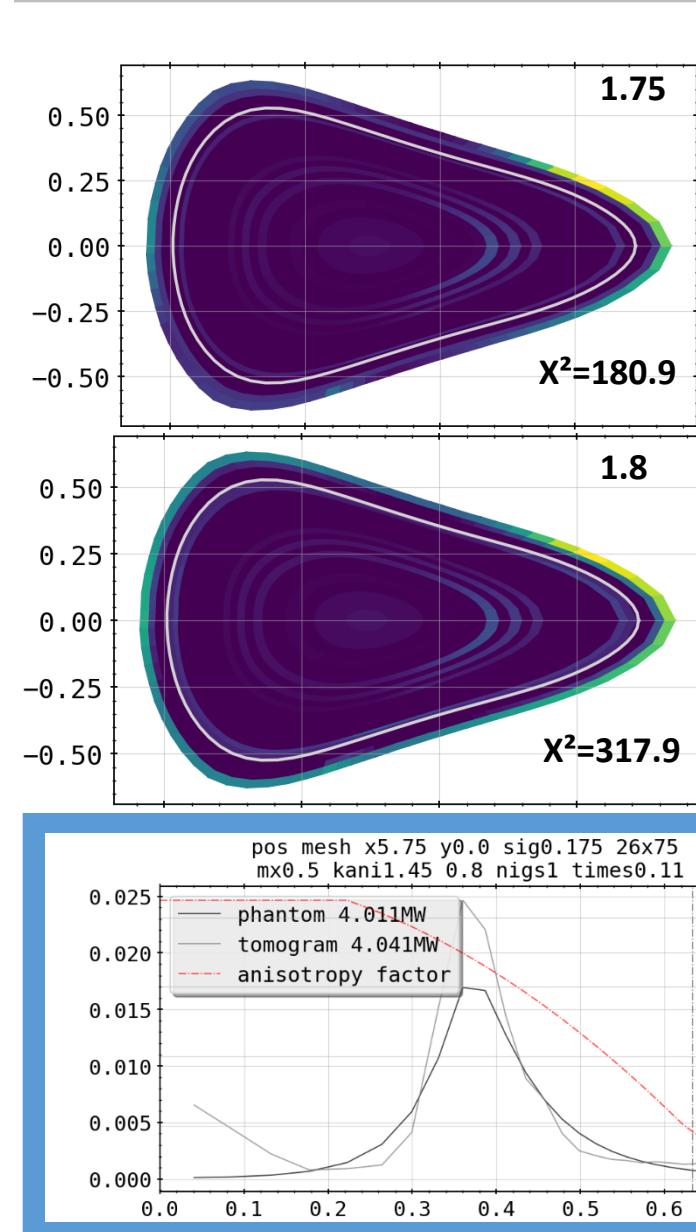
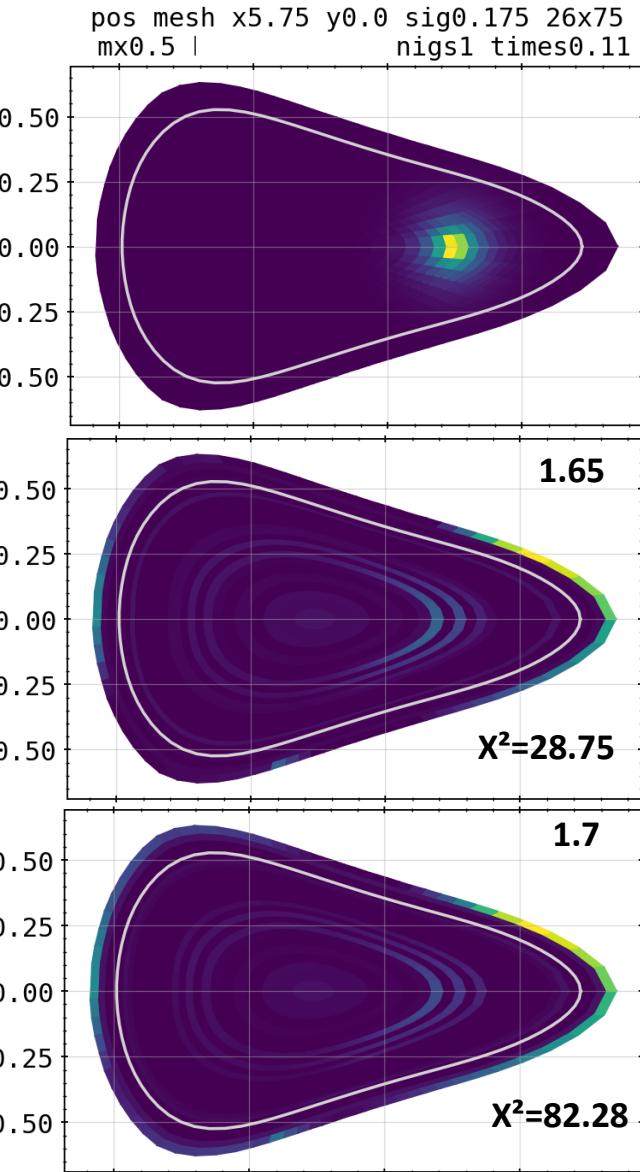


brightness [power/volume]

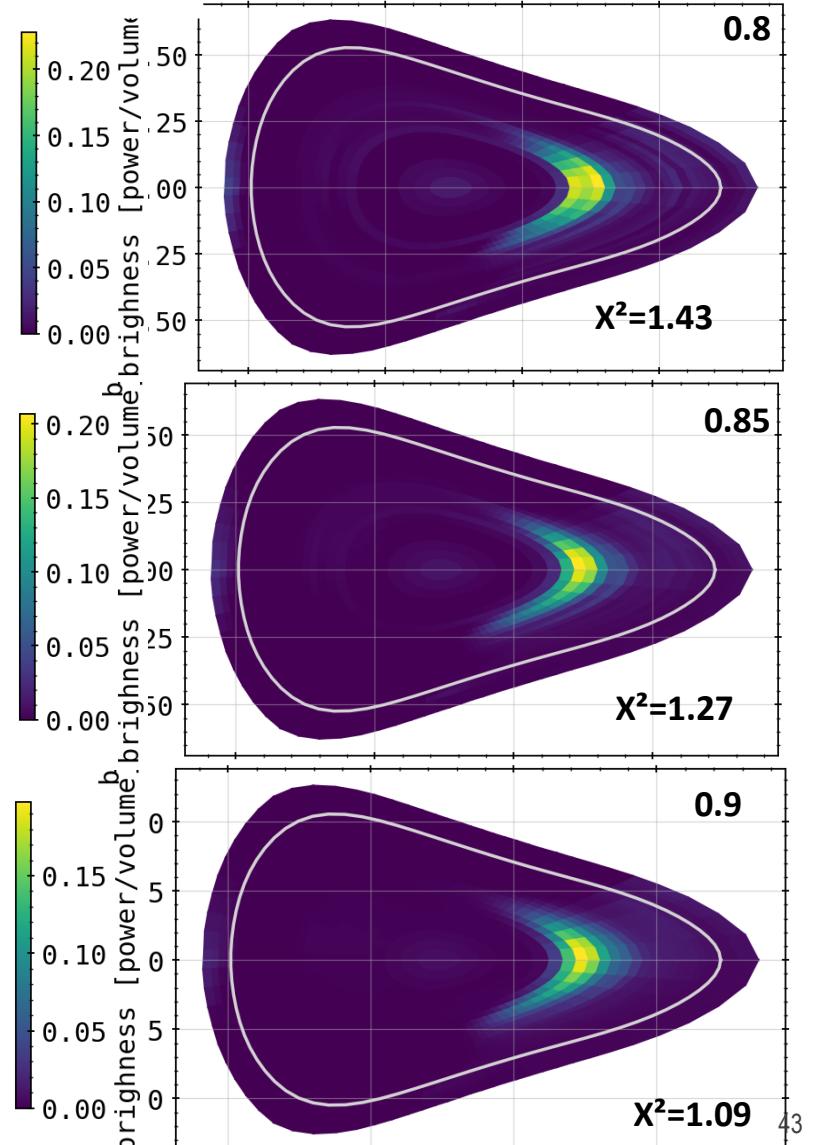
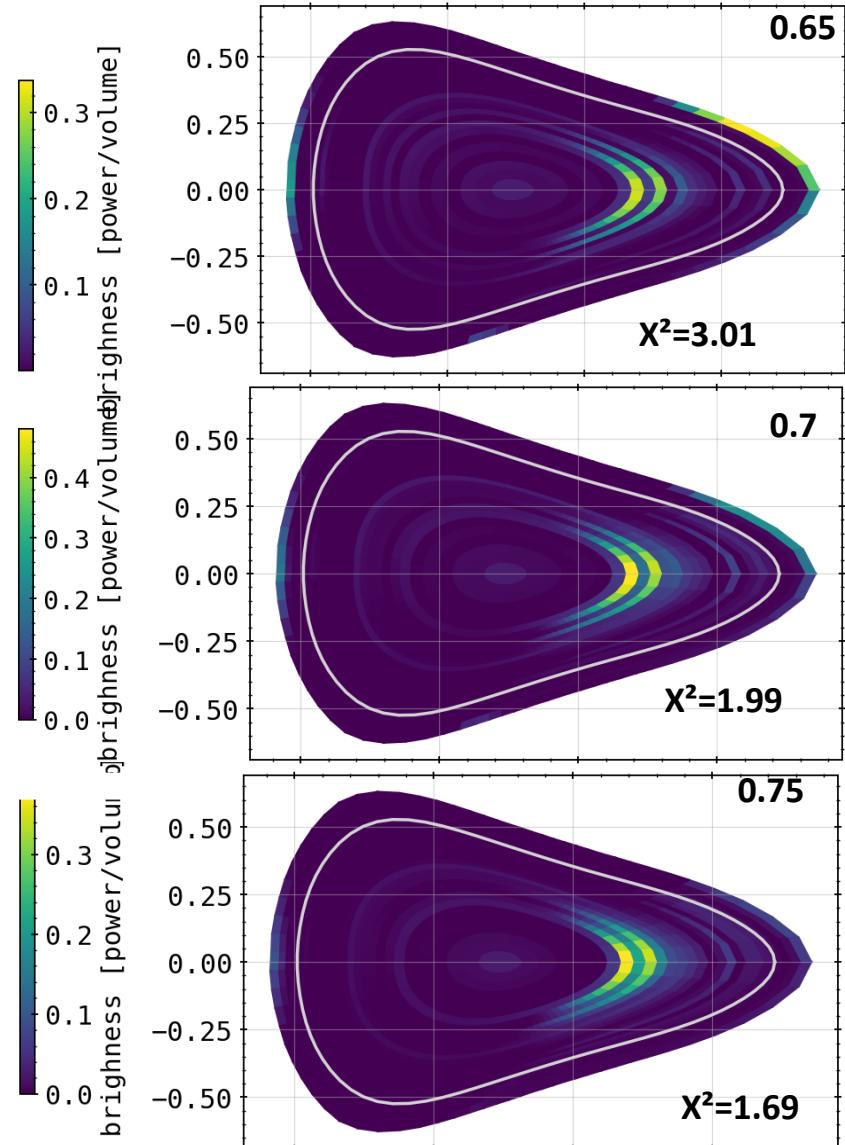
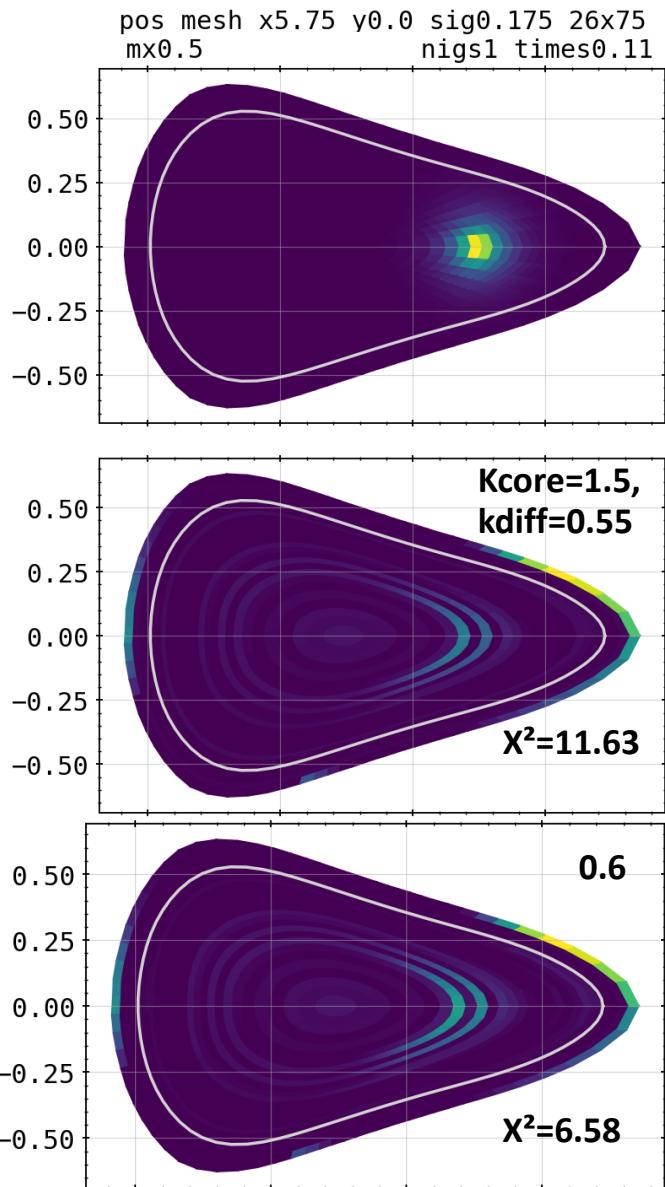
brightness [power/volume]

brightness [power/volume]

# Phantoms: Asymmetric Spot Core Scan



# Phantoms: Asymmetric Spot Edge Scan



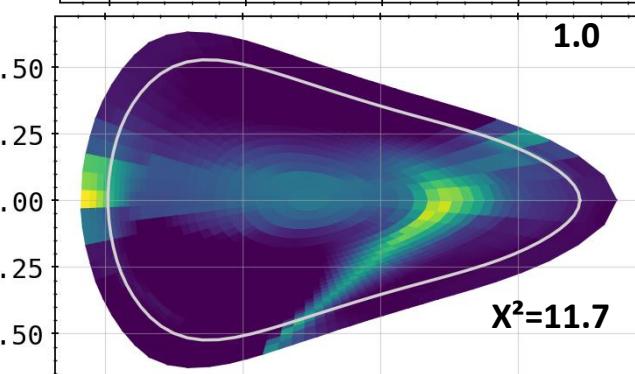
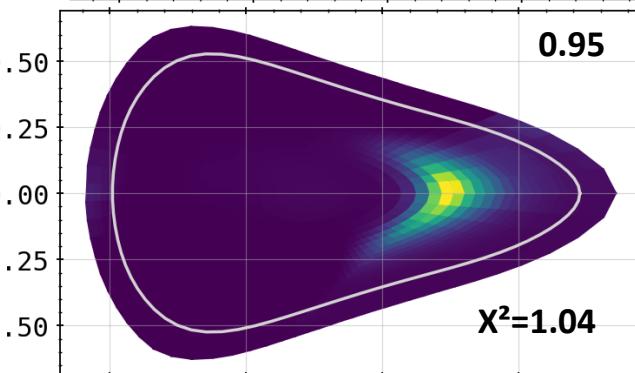
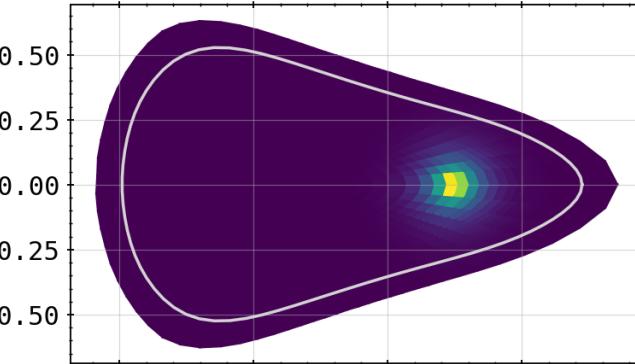
brightness [power/volume]

brightness [power/volume]

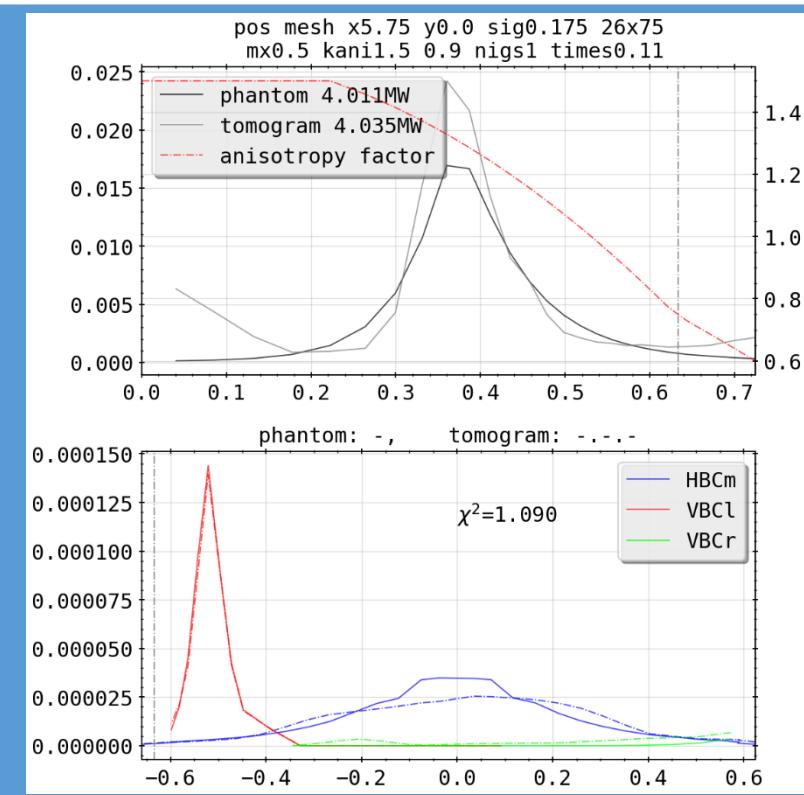
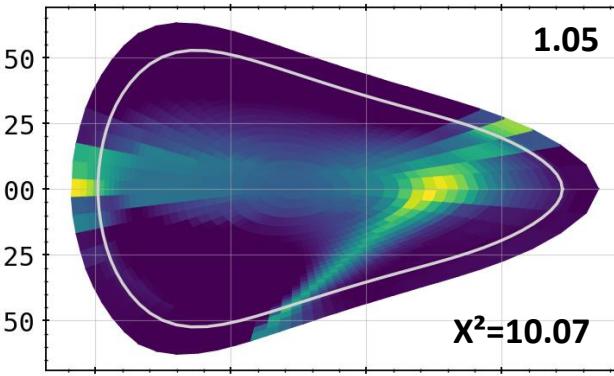
brightness [power/volume]

# Phantoms: Asymmetric Spot Core Scan

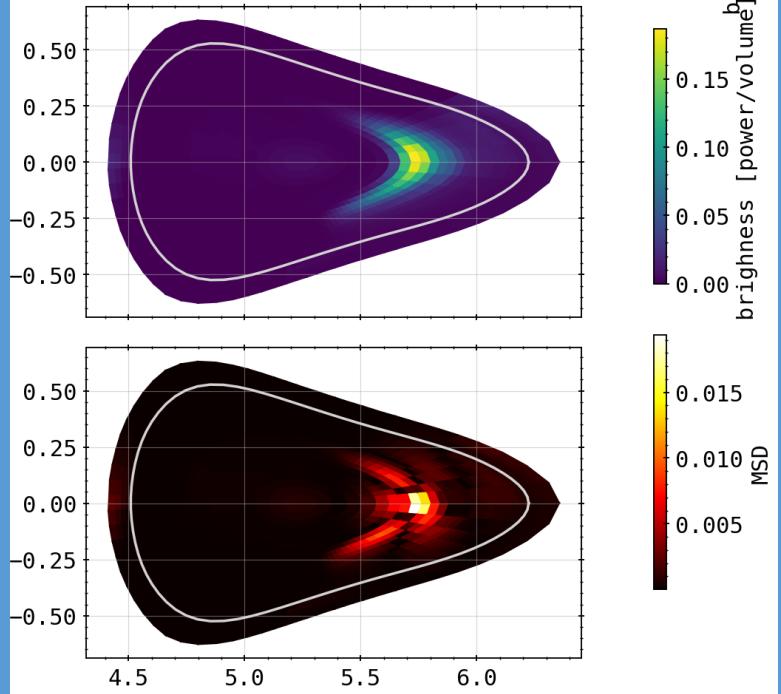
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mx0.5 1 nigs1 times0.11



brightness [power/volume]



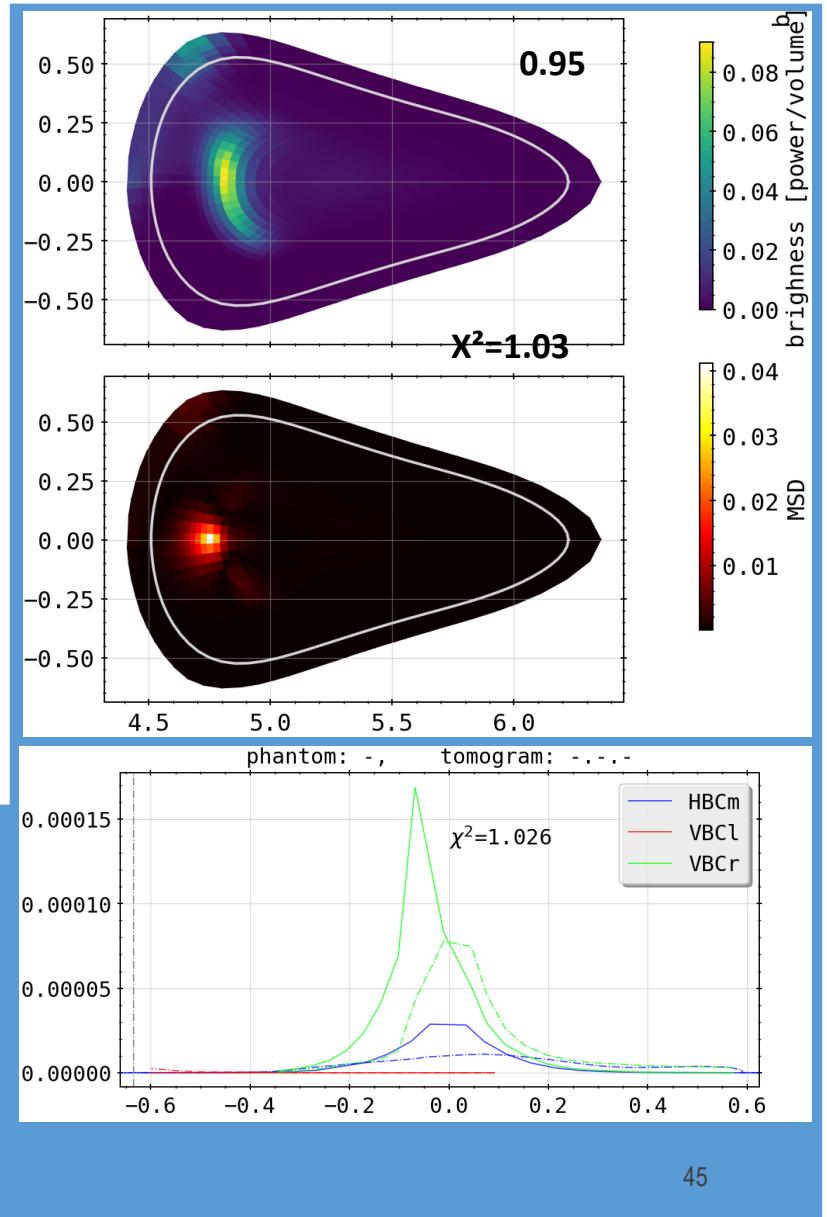
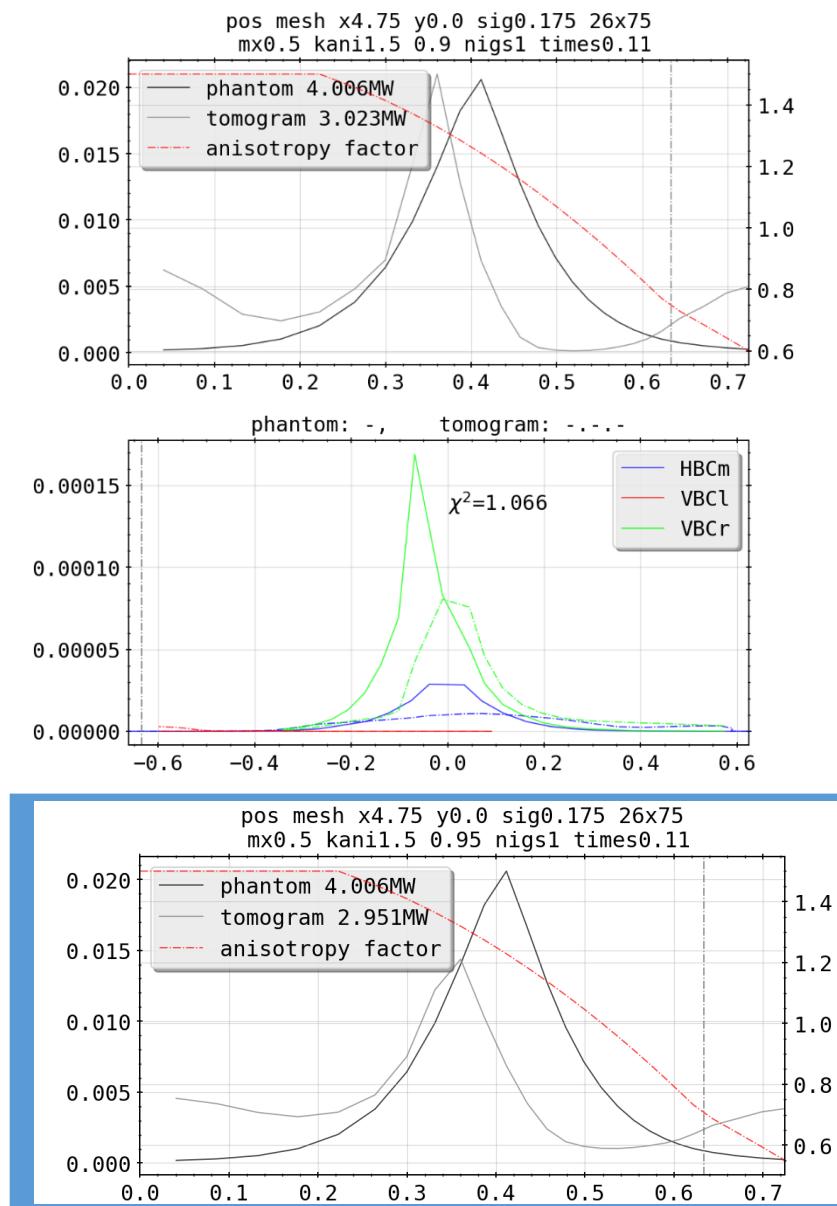
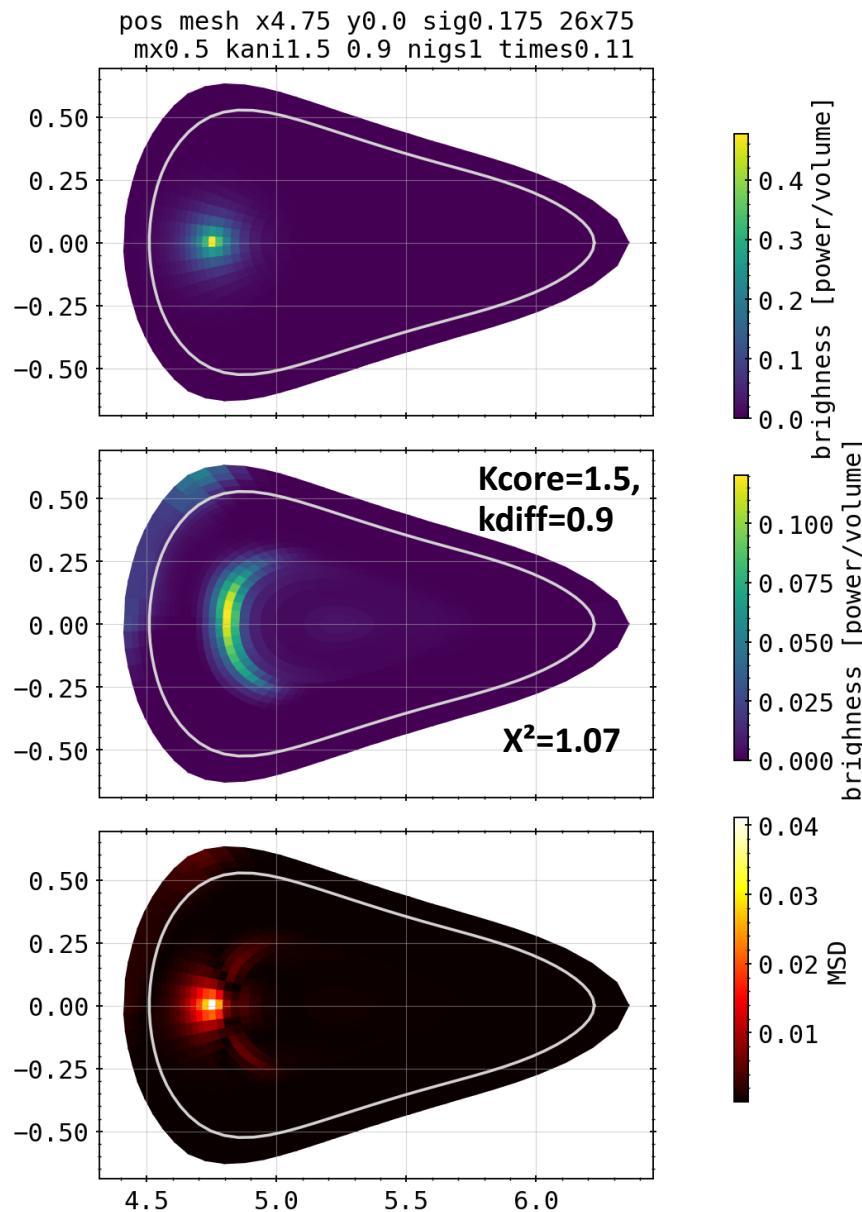
brightness [power/volume]



brightness [power/volume]

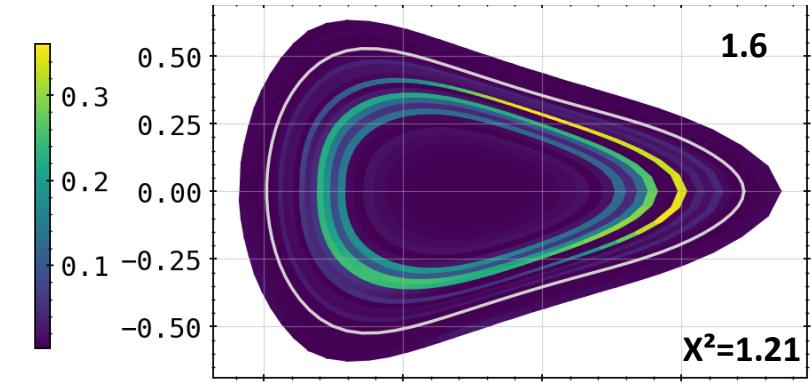
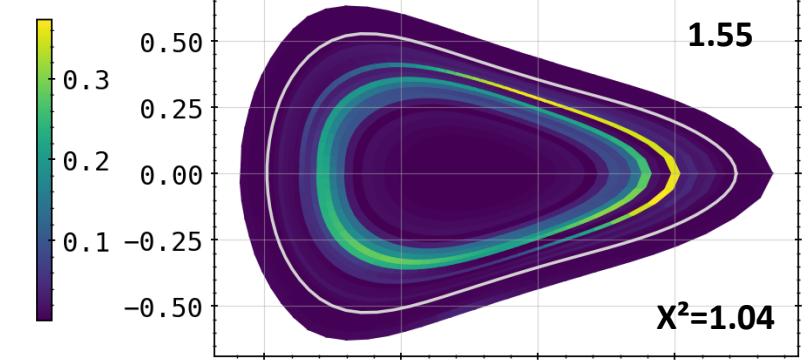
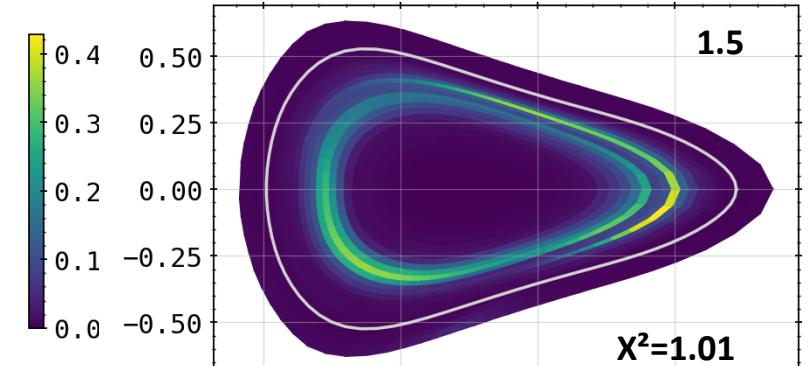
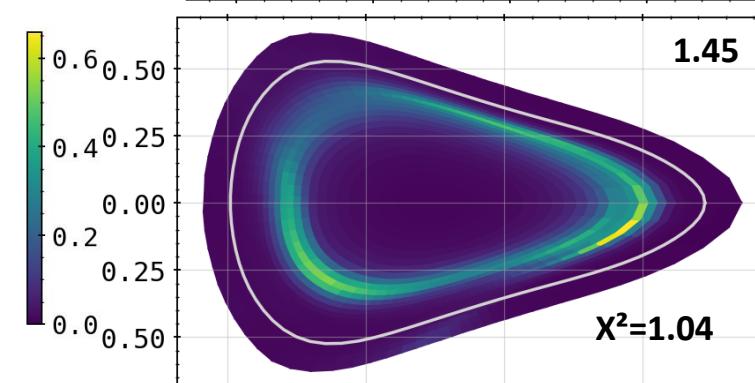
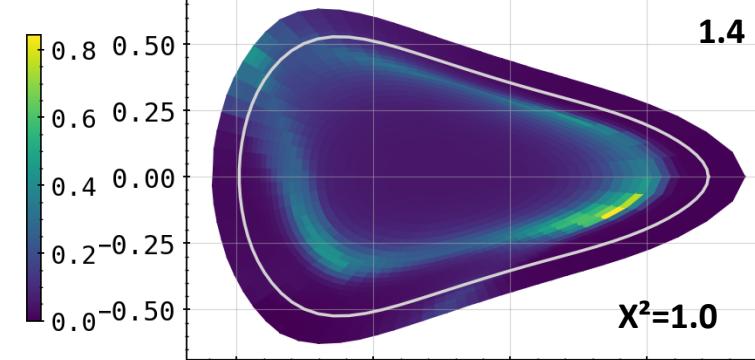
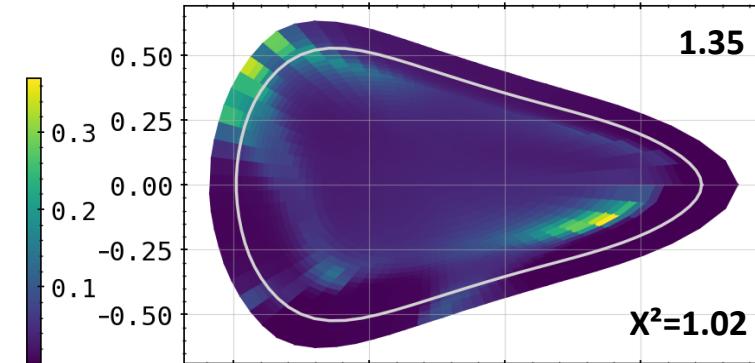
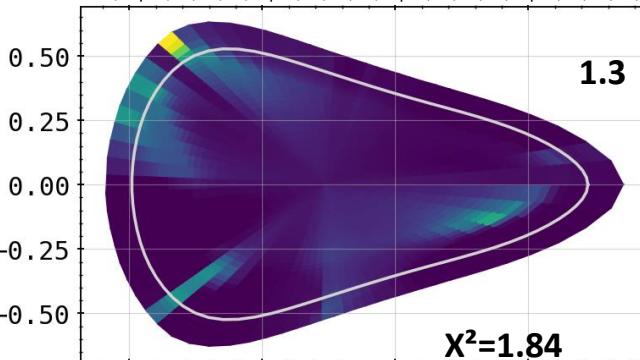
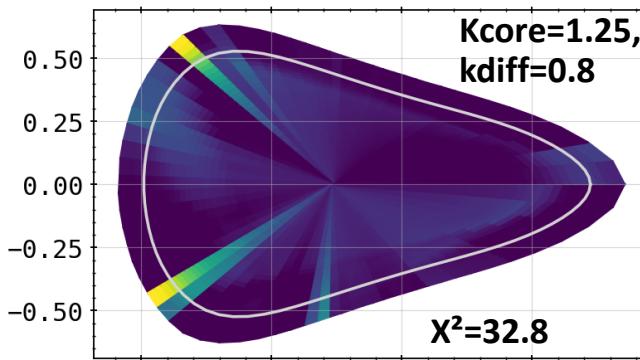
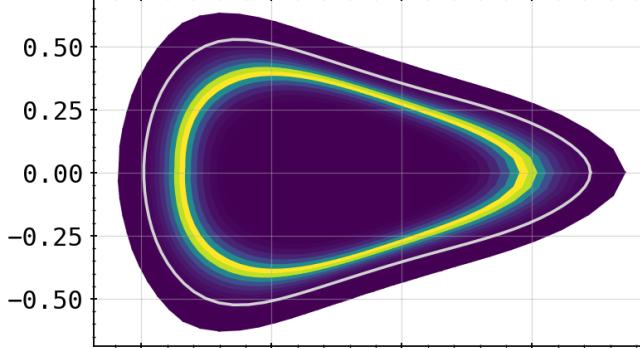
MSD

# Phantoms: Asymmetric Spot (Flipped) Edge Scan

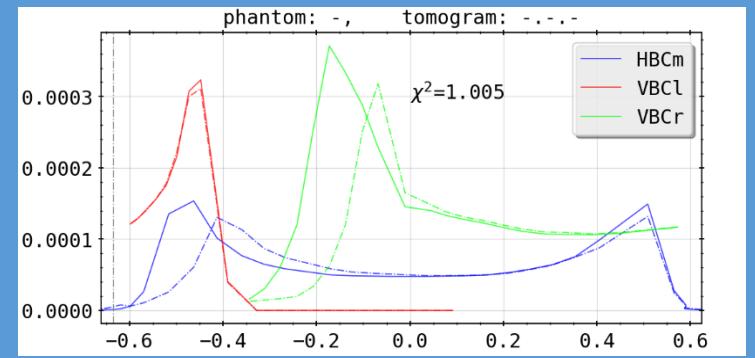
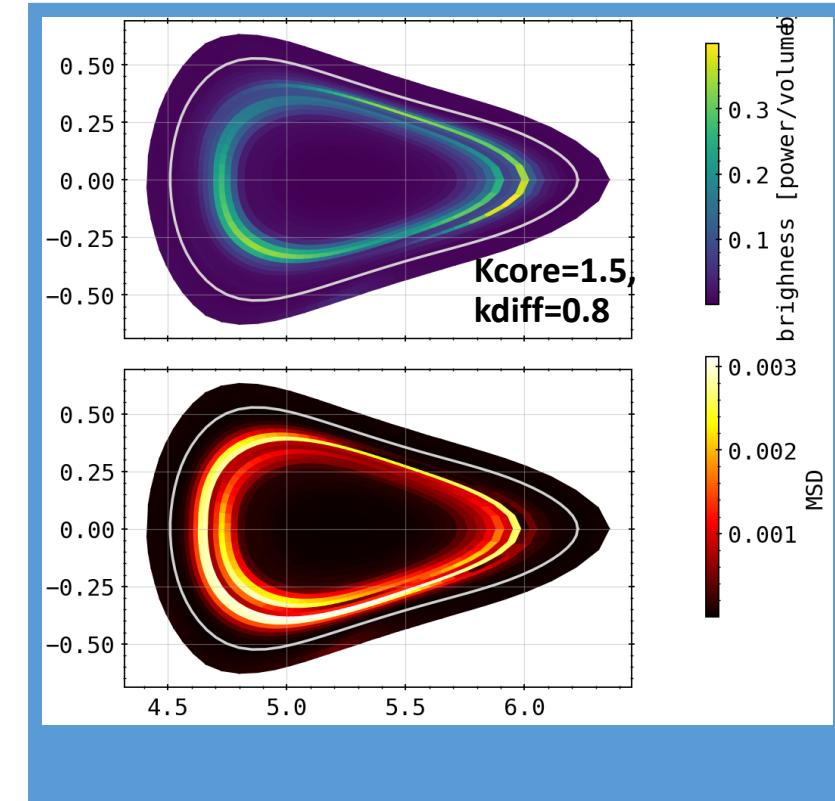
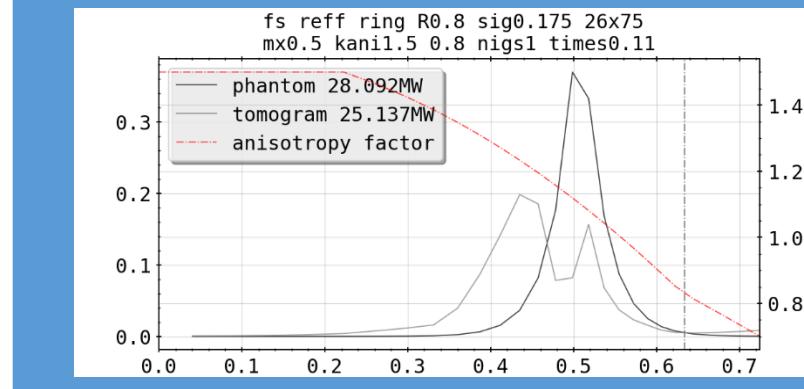
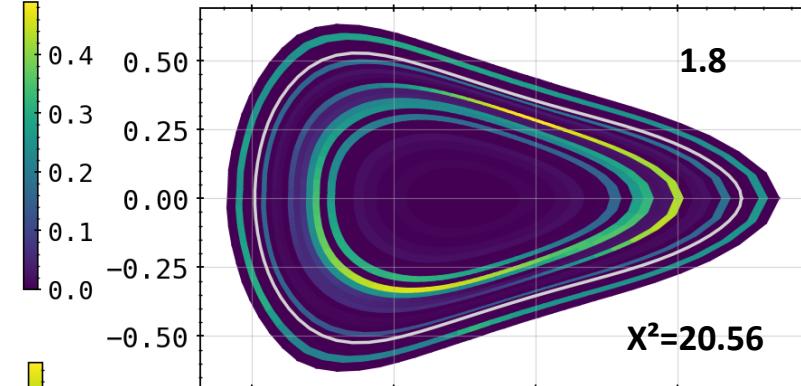
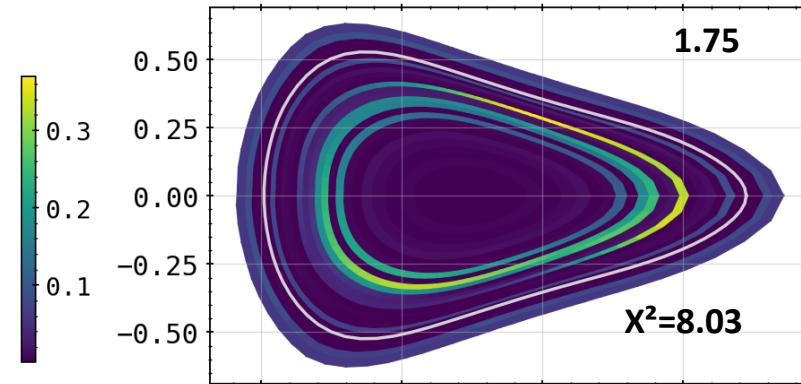
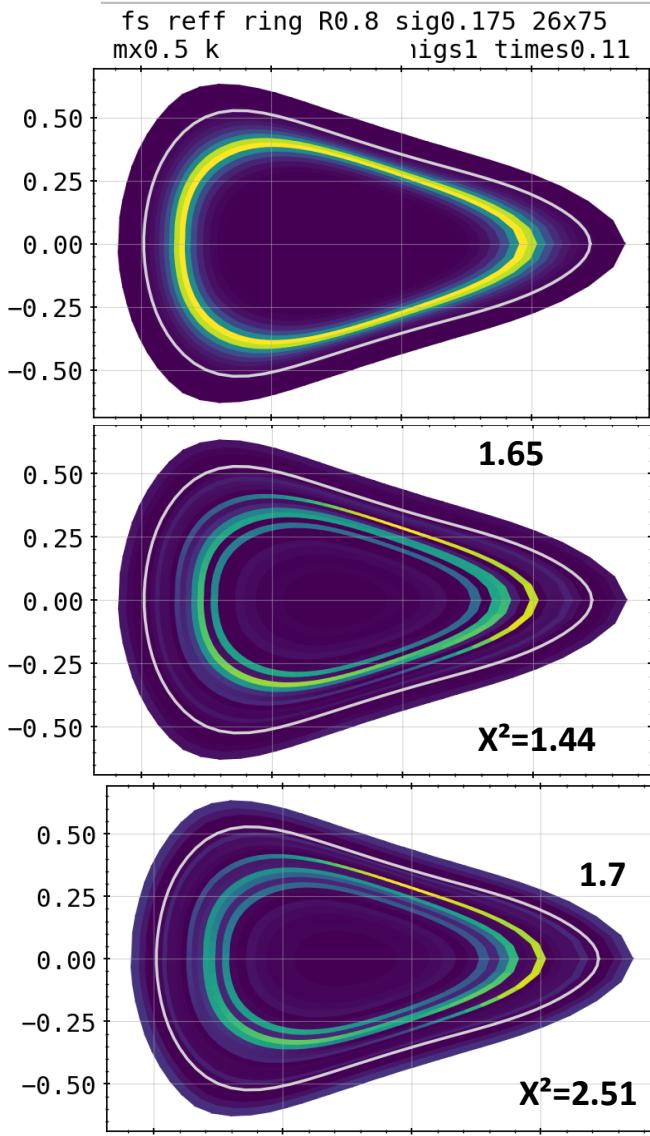


# Phantoms: Ring inside LCFS Core Scan

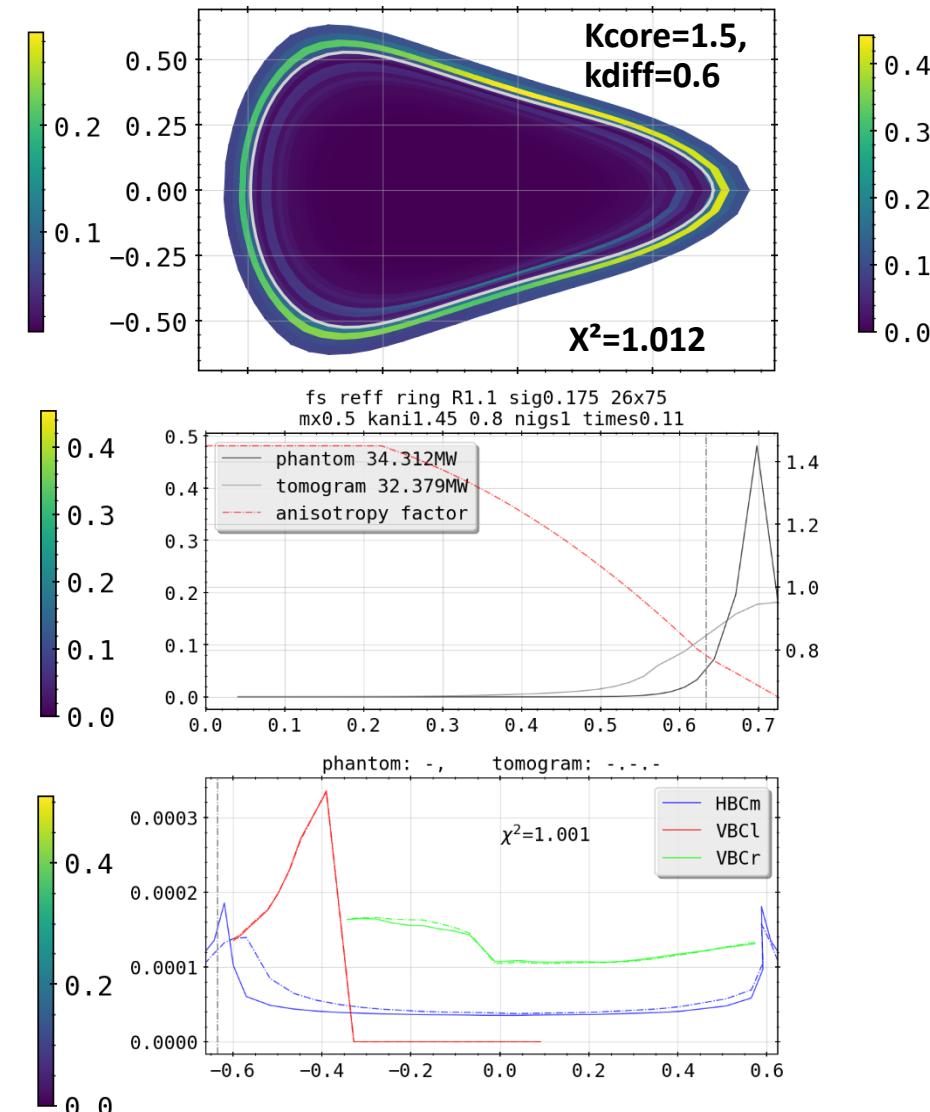
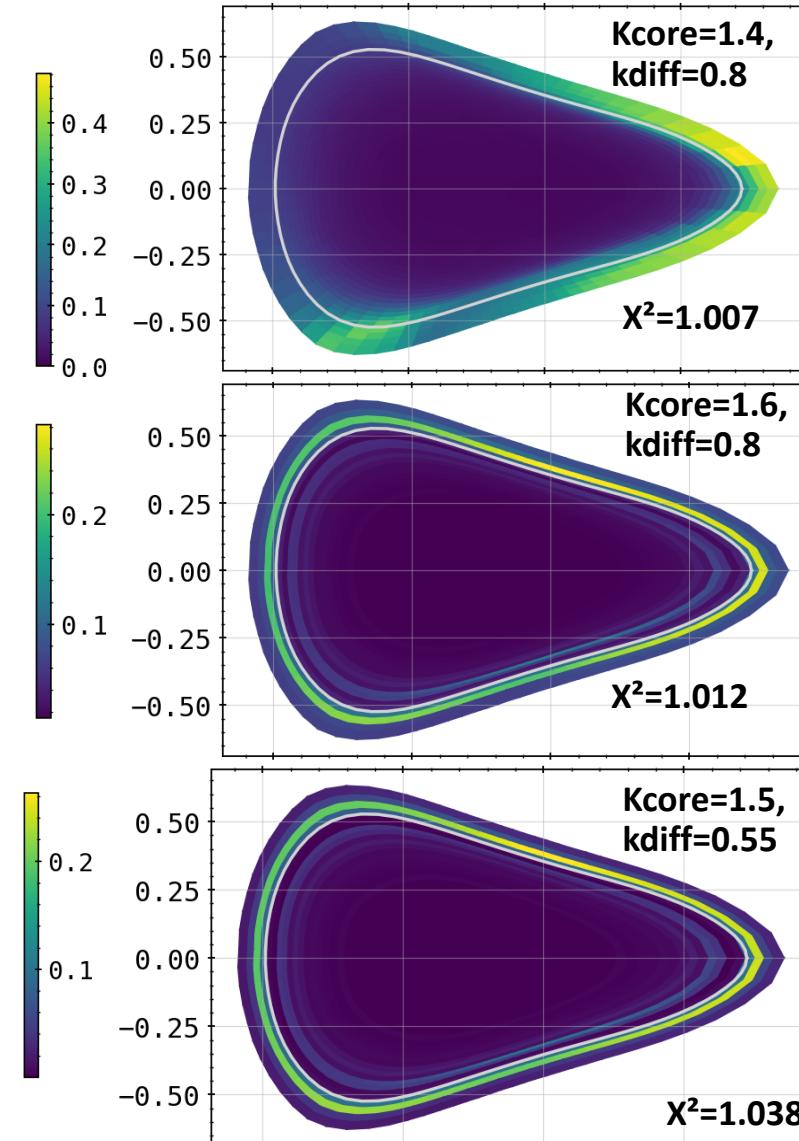
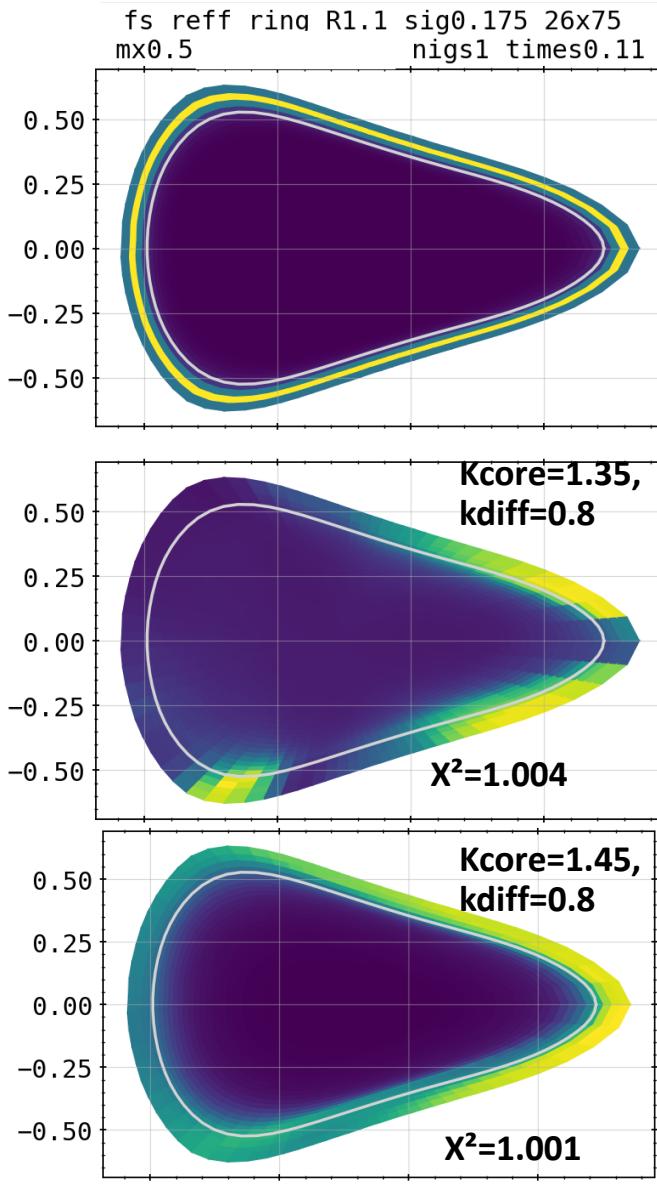
fs reff rina R0.8 sig0.175 26x75  
mx0.5 nigs1 times0.11



# Phantoms: Ring inside LCFS Core Scan

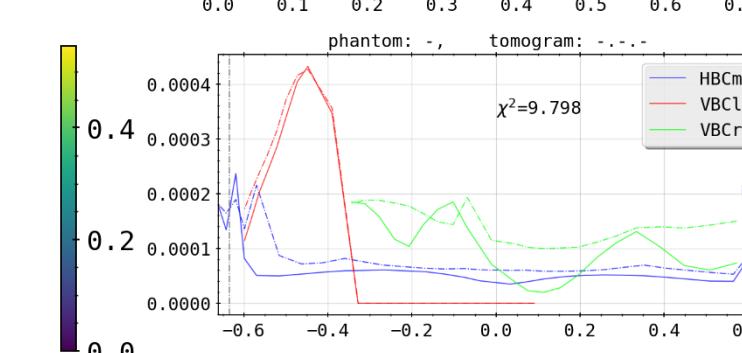
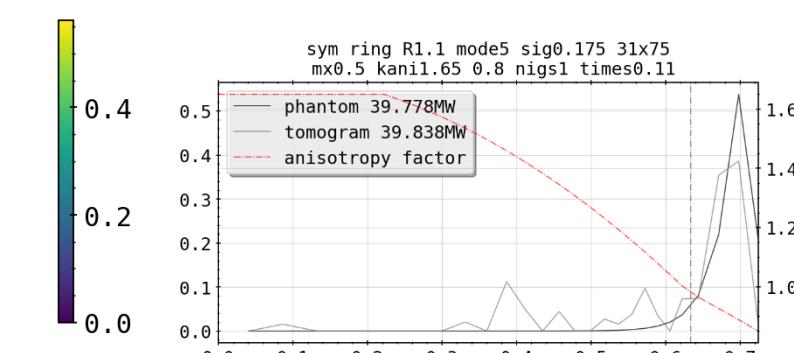
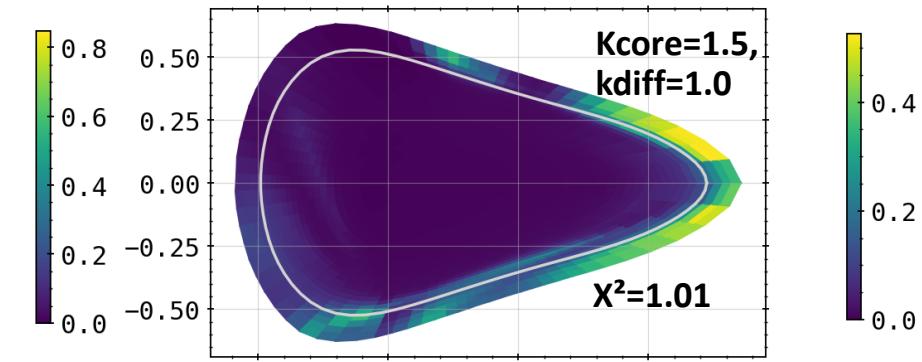
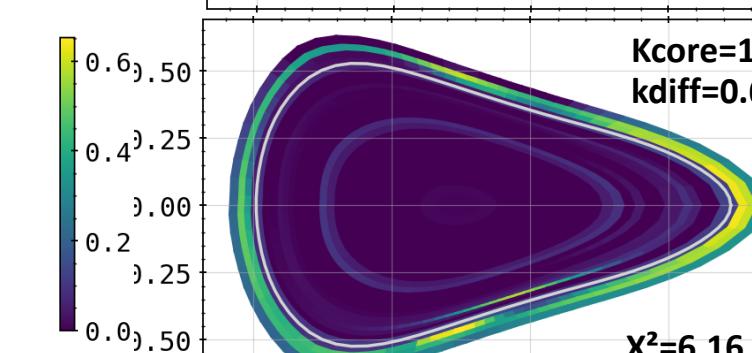
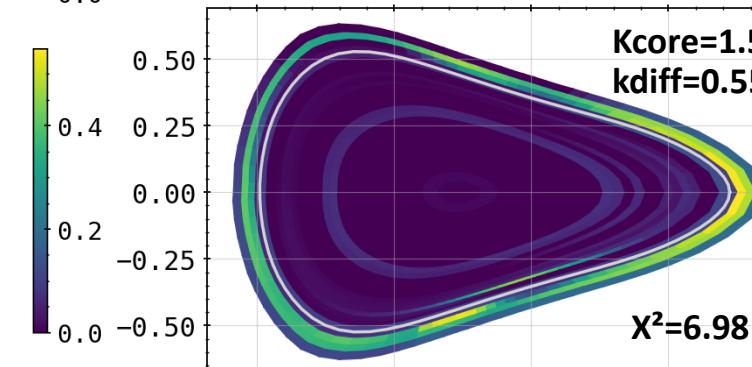
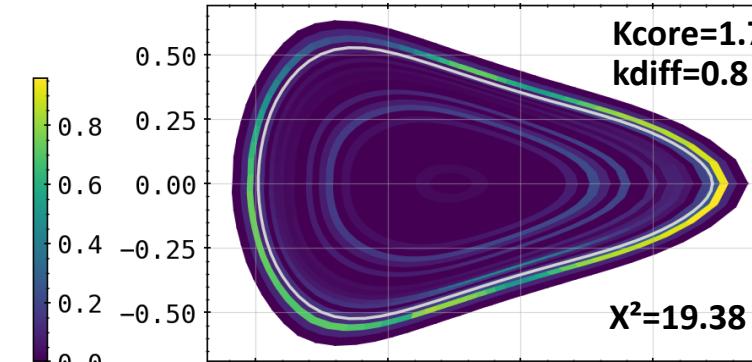
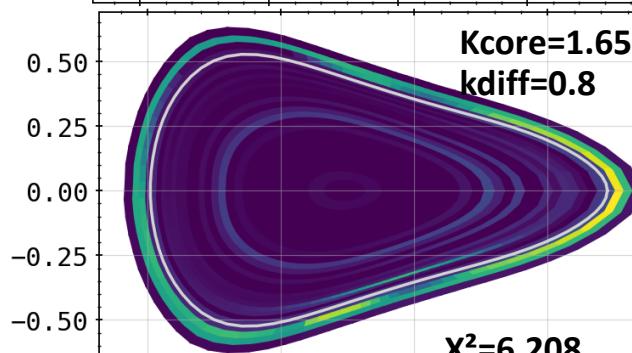
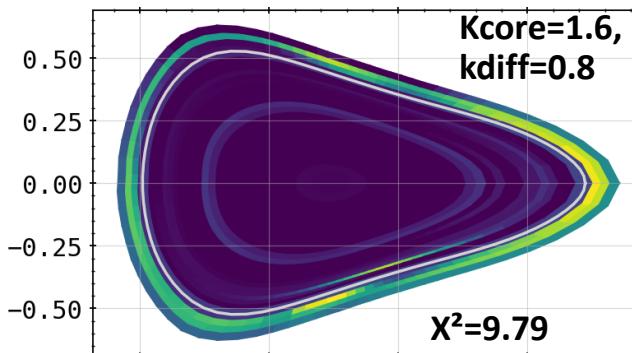
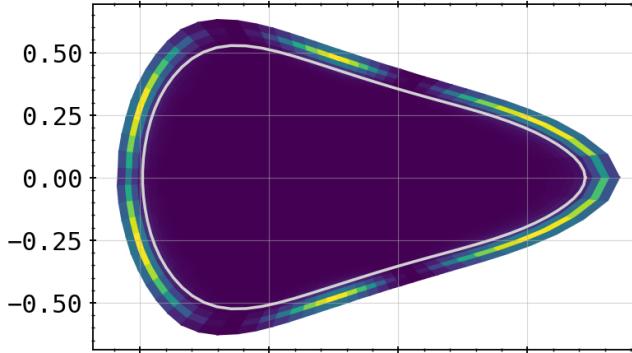


# Phantoms: Ring outside LCFS Scan

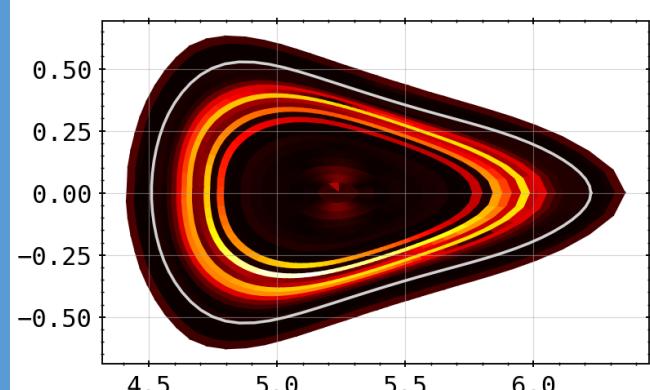
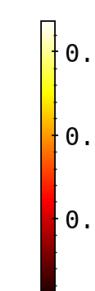
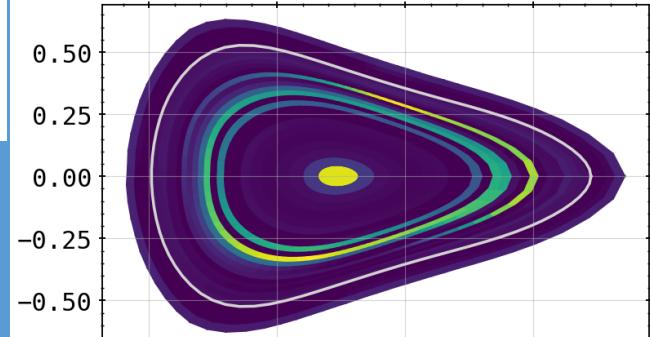
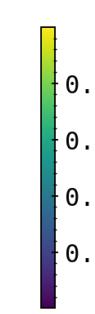
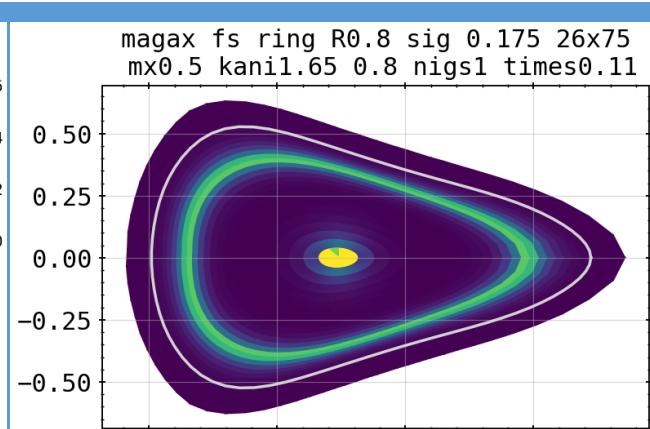
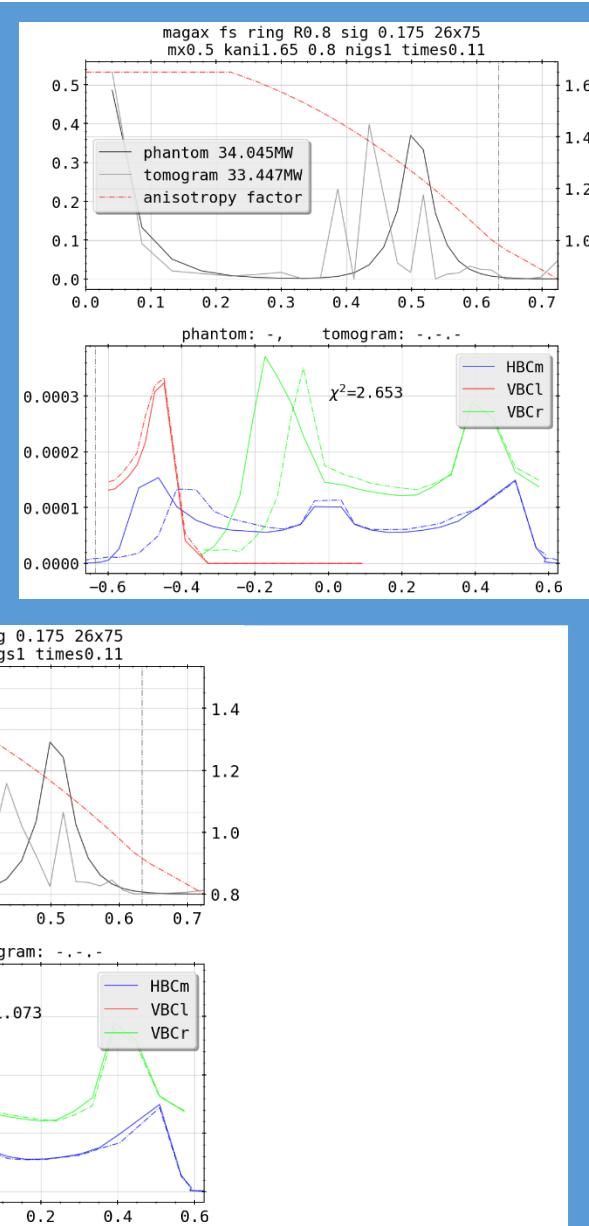
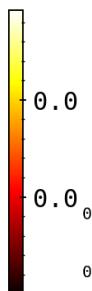
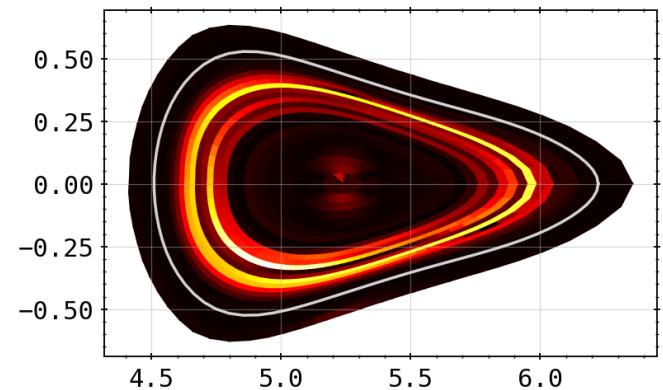
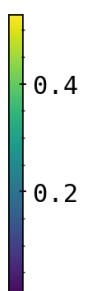
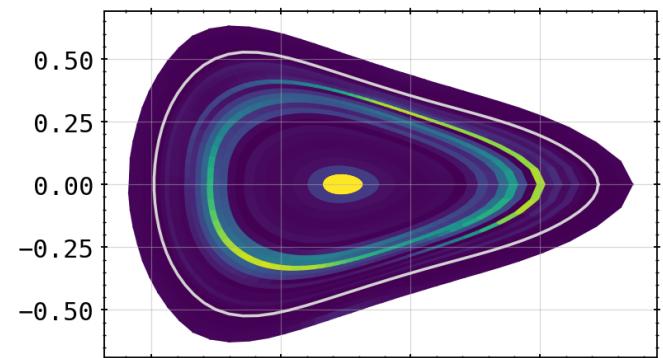
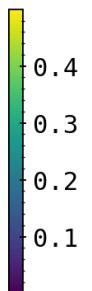
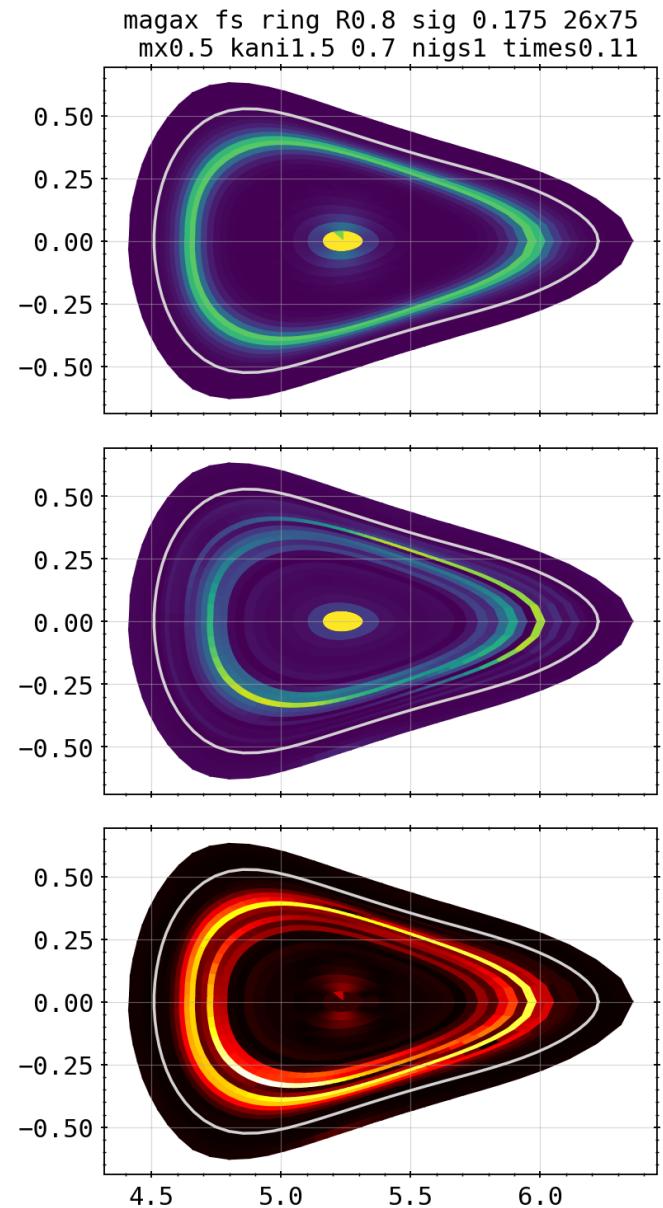


# Phantoms: Island Mimic outside LCFS Scan

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mx0.5 nigs1 times0.11

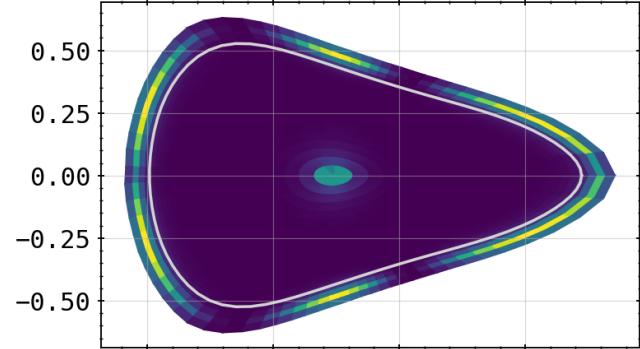


# Phantoms: Combinations

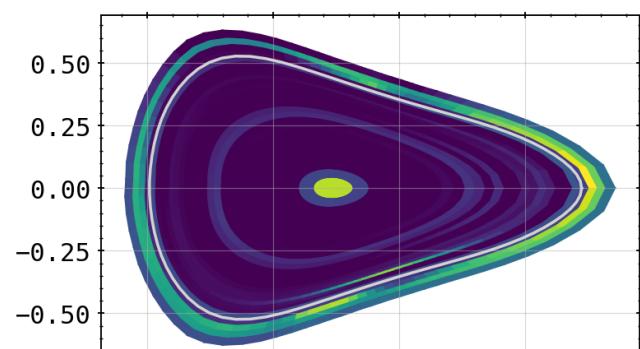


# Phantoms: Combinations

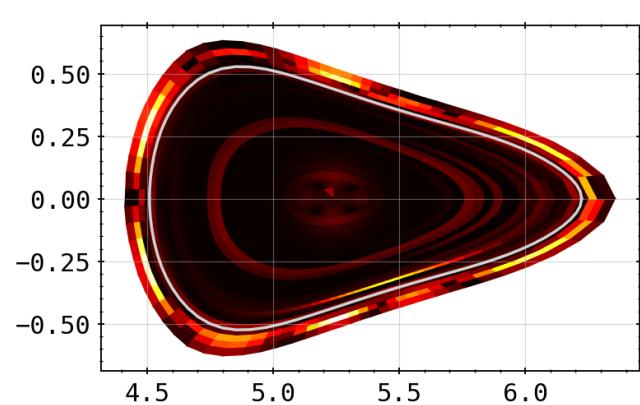
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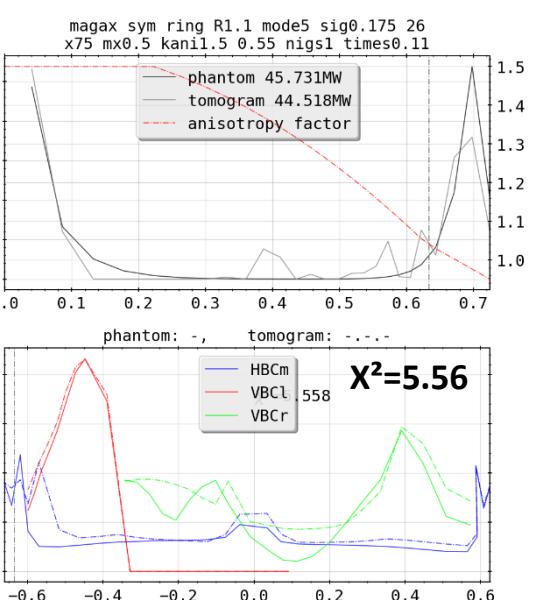
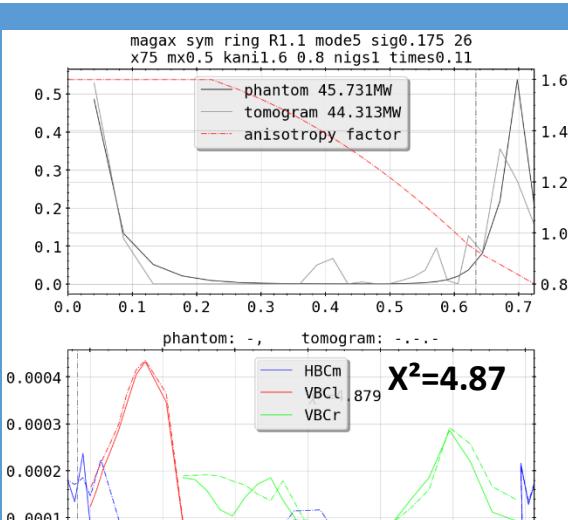
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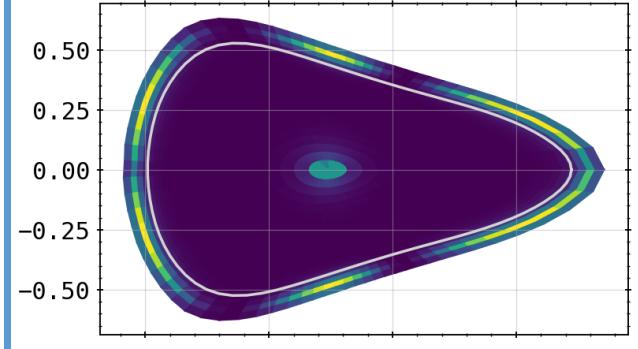
brightness [power/volumetric]



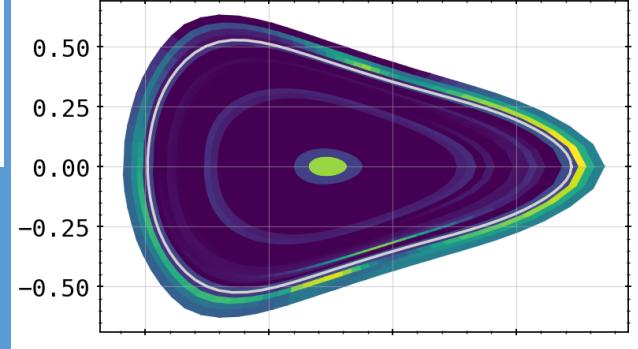
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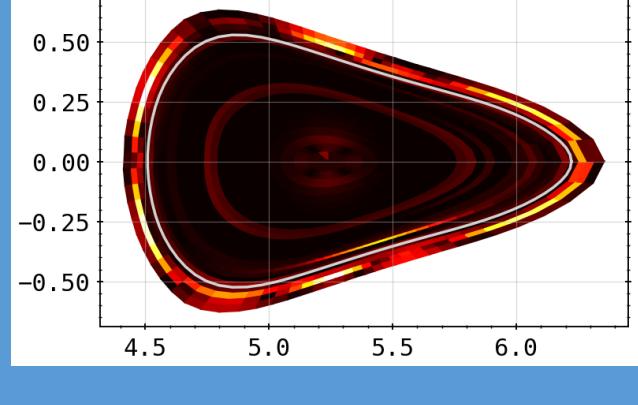
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x75 mx0.5 kani1.6 0.8 nigs1 times0.11



brightness [power/volumetric]

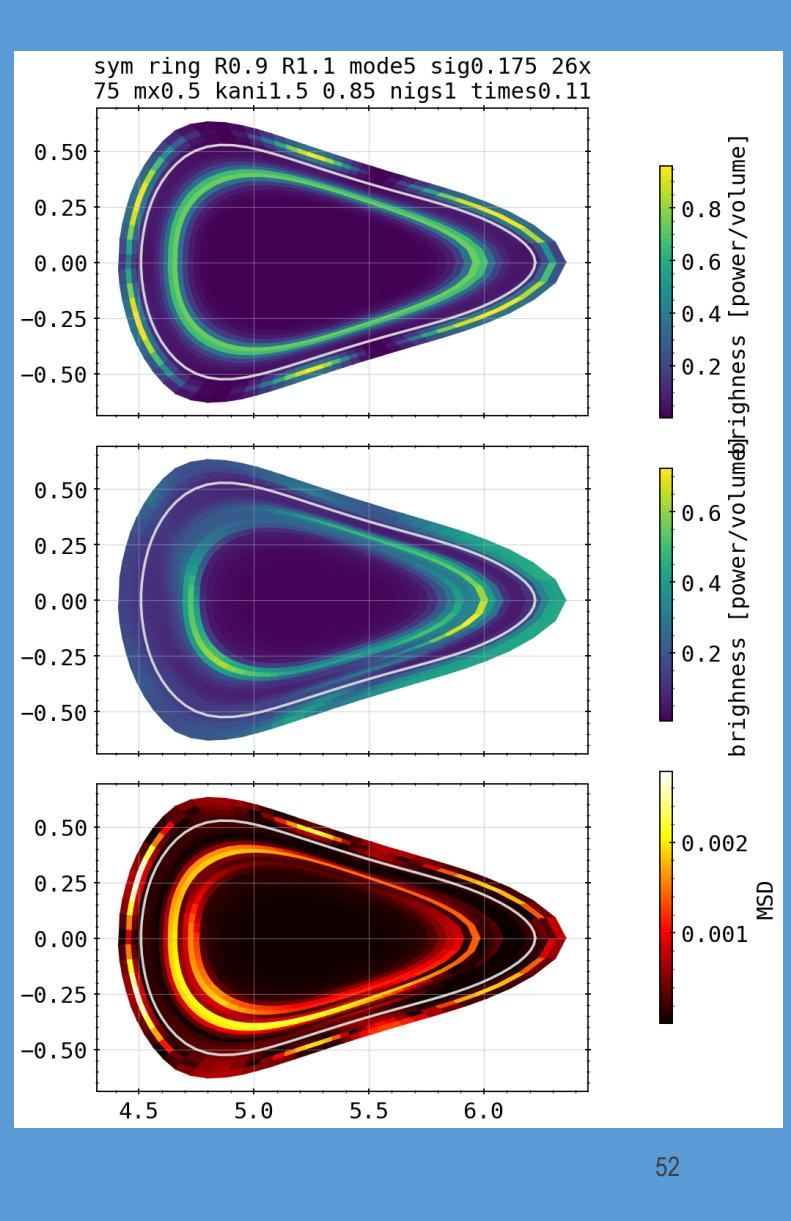
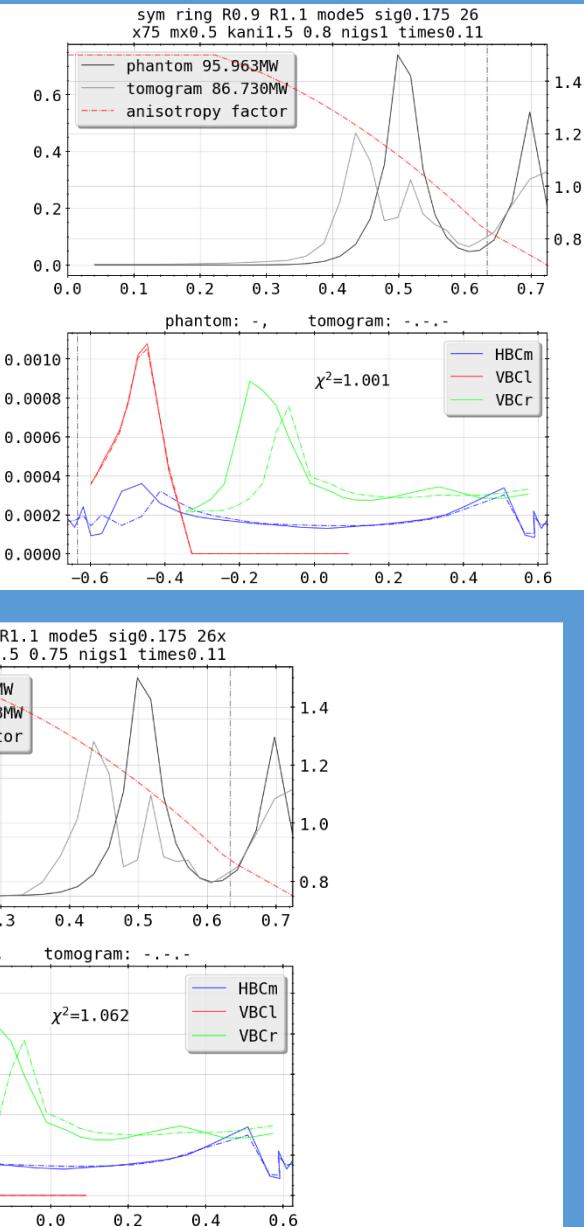
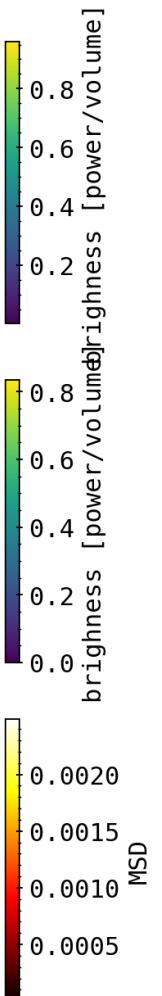
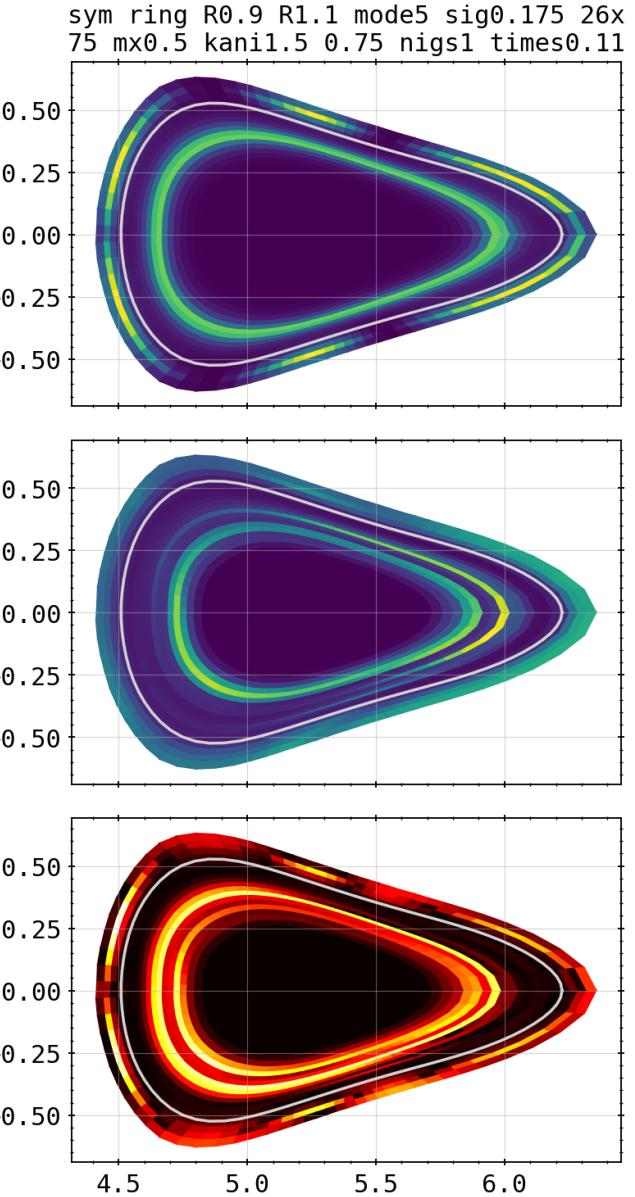


brightness [power/volumetric]



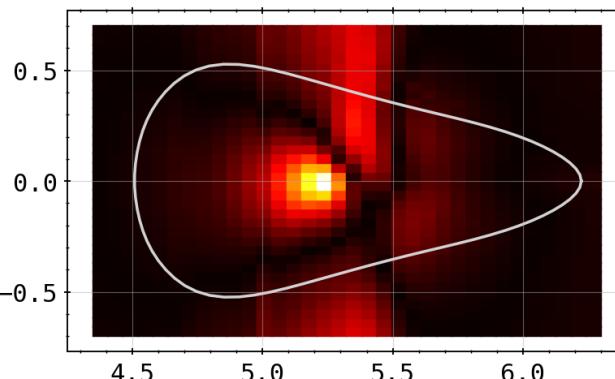
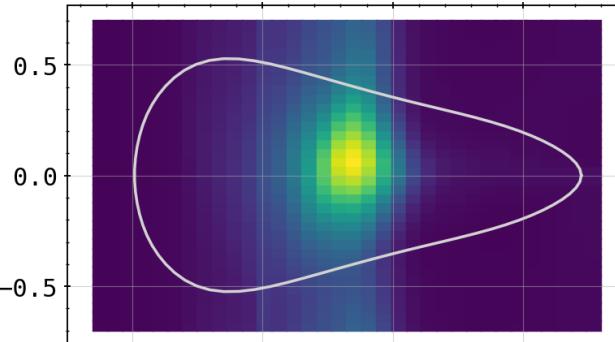
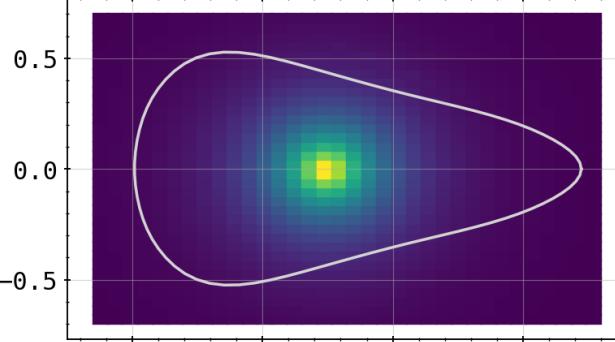
brightness [power/volumetric]

# Phantoms: Combinations

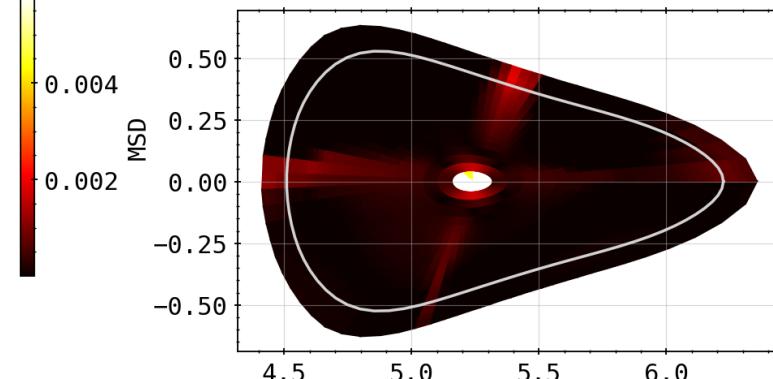
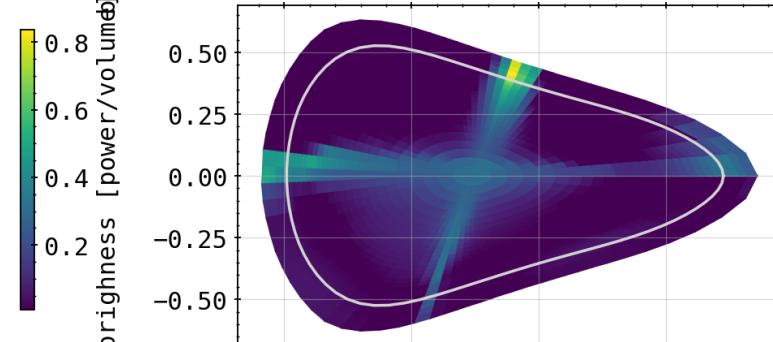
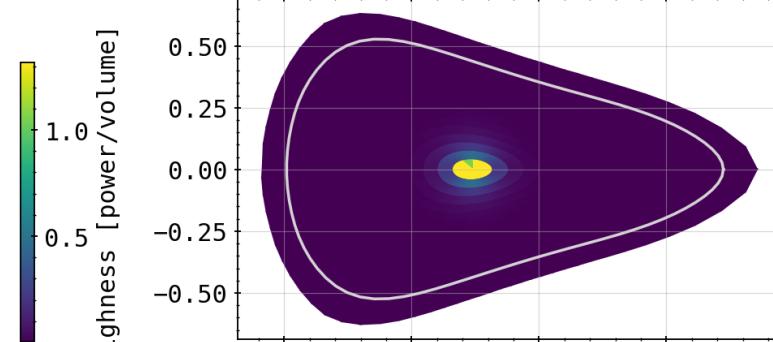


# Revisited: Cartesian Test, No Anisotropic Weighting

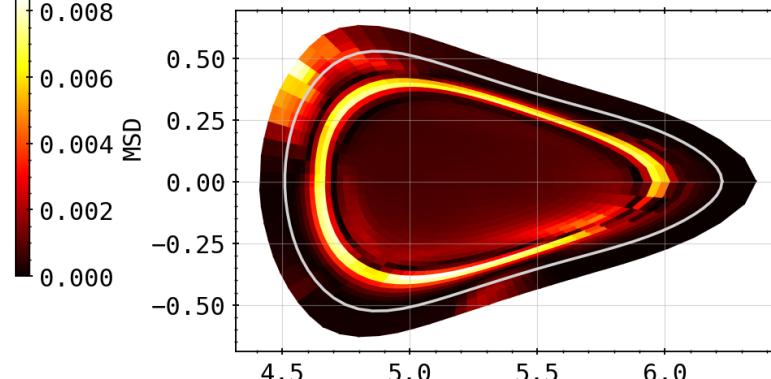
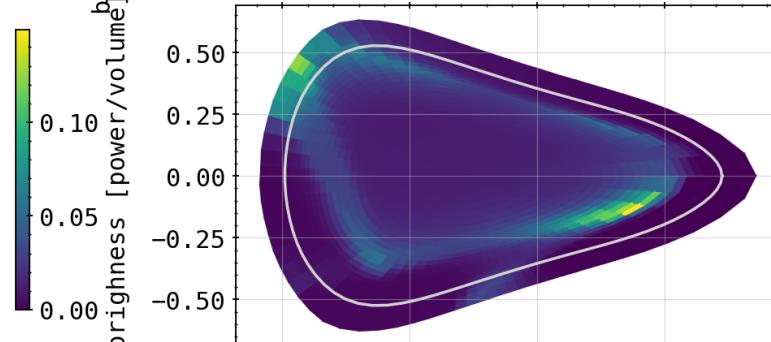
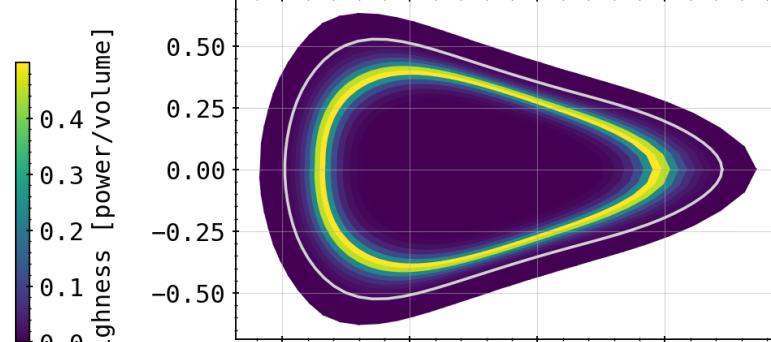
pos x5.25 sig0.3 34x34 cartesian mx1.5  
kani1.5 0.8 nigs1 times0.11 cartesian



magax dist R0.0 sig0.175 26x75  
mx0.5 no ani nigs1 times0.11



fs reff ring R0.8 sig0.175 26x7  
5 mx0.5 no ani nigs1 times0.11

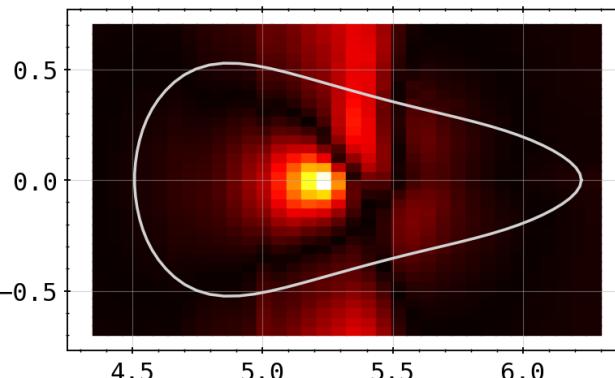
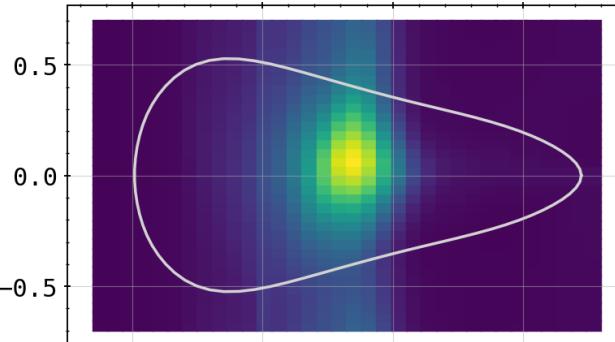
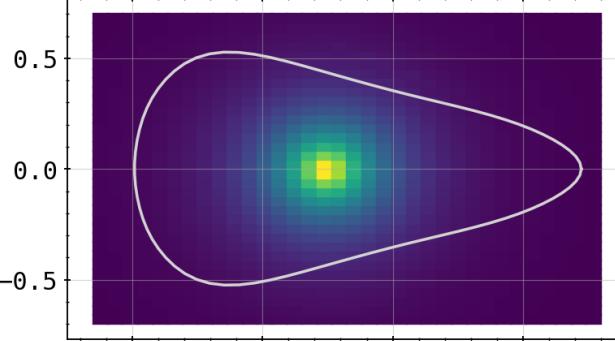


brightness [power/volume]  
brightness [power/volume]  
brightness [power/volume]

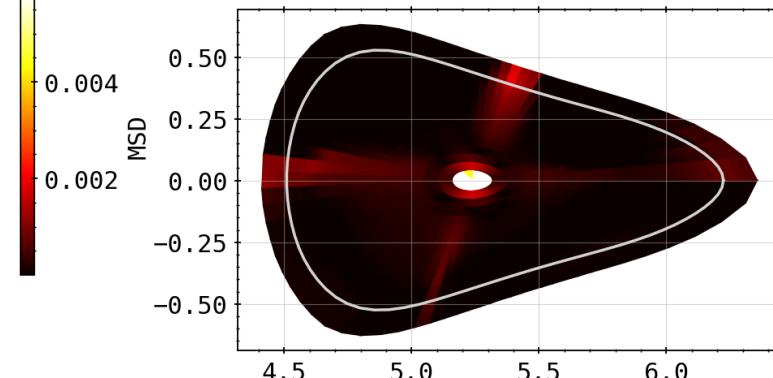
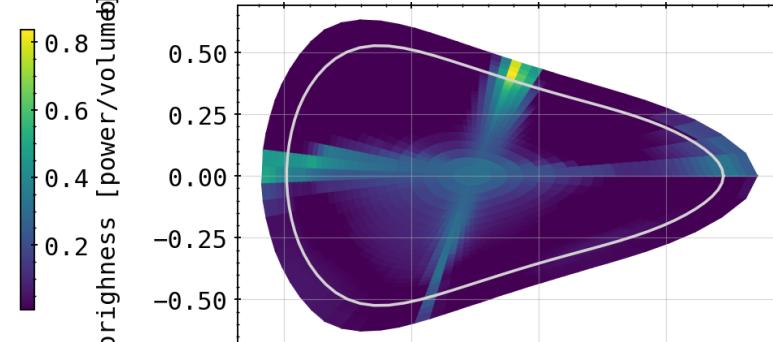
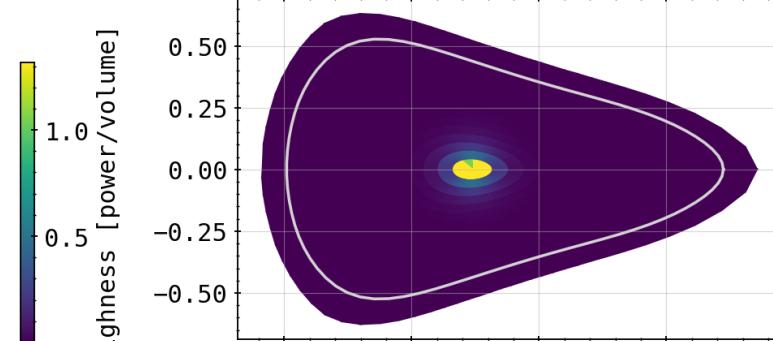
MSD  
MSD

# Revisited: Cartesian Test, No Anisotropic Weighting

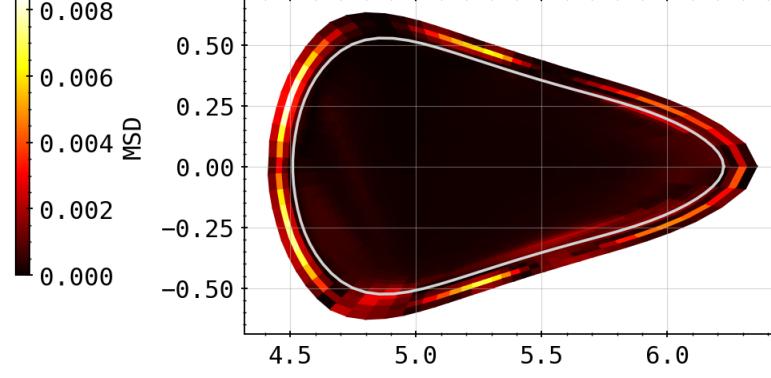
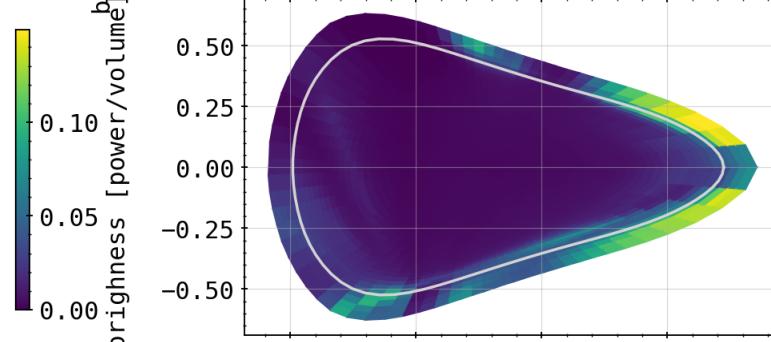
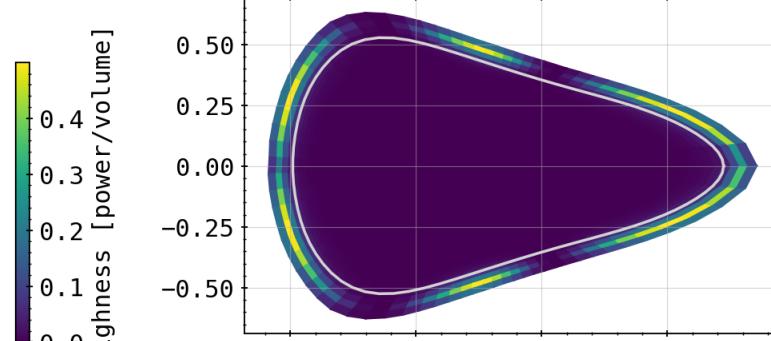
pos x5.25 sig0.3 34x34 cartesian mx1.5  
kani1.5 0.8 nigs1 times0.11 cartesian



magax dist R0.0 sig0.175 26x75  
mx0.5 no ani nigs1 times0.11



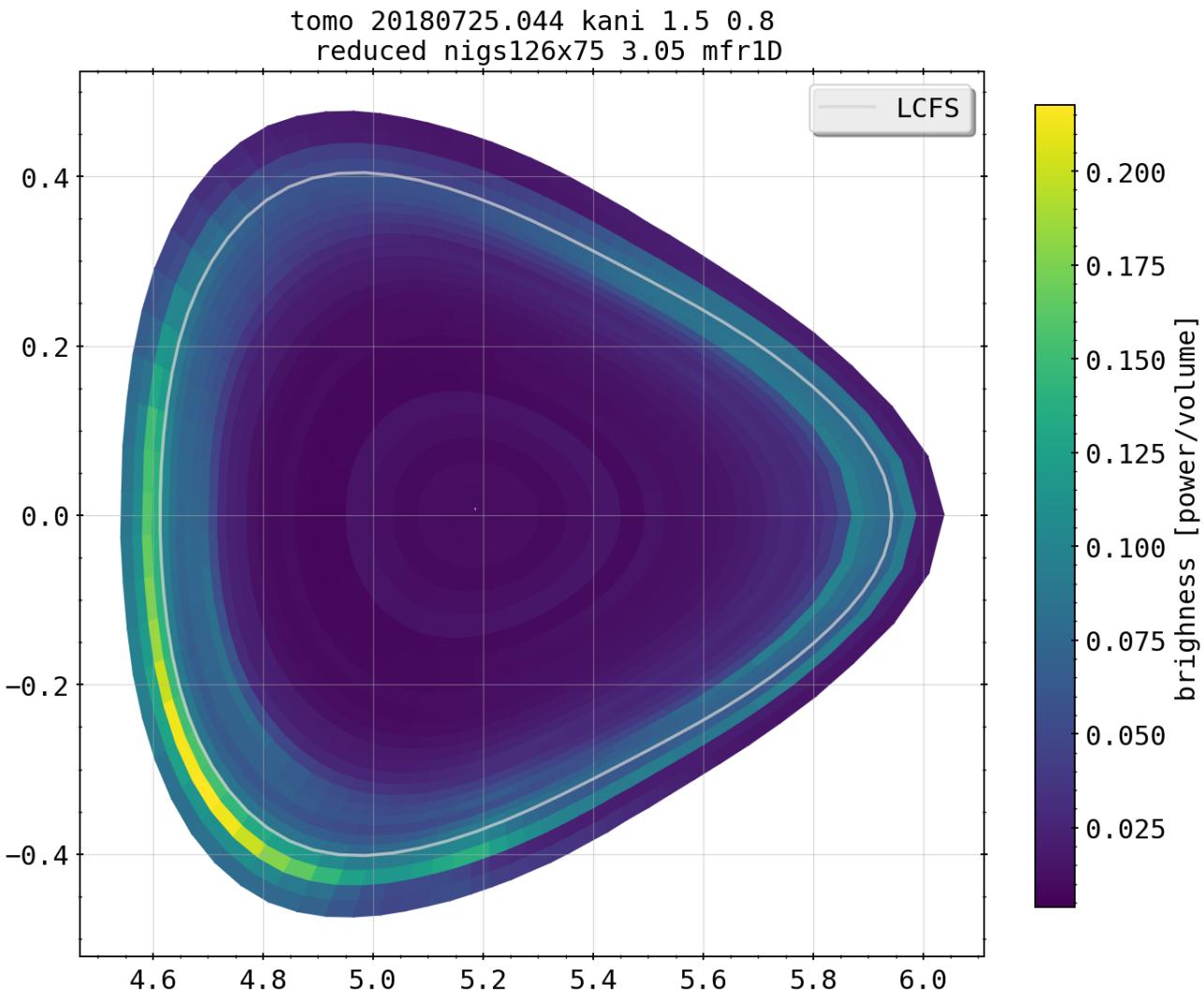
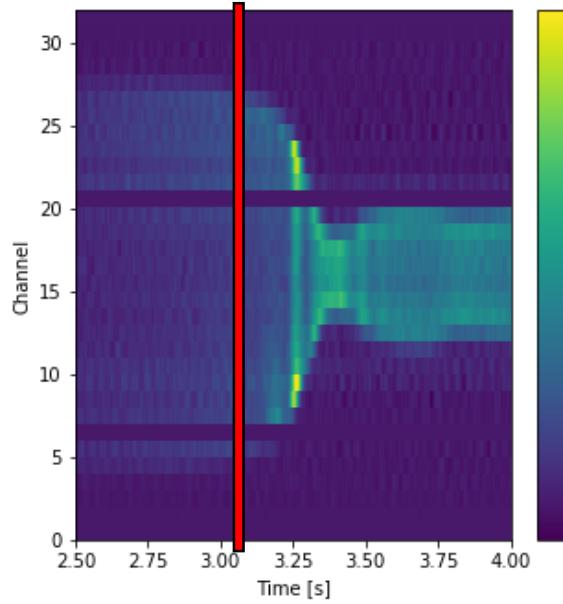
sym ring R1.1 mode5 sig0.175 31x  
75 mx0.5 no ani nigs1 times0.11



# Revisited: Test of 20180725.044

➤ KJM magnetic configuration

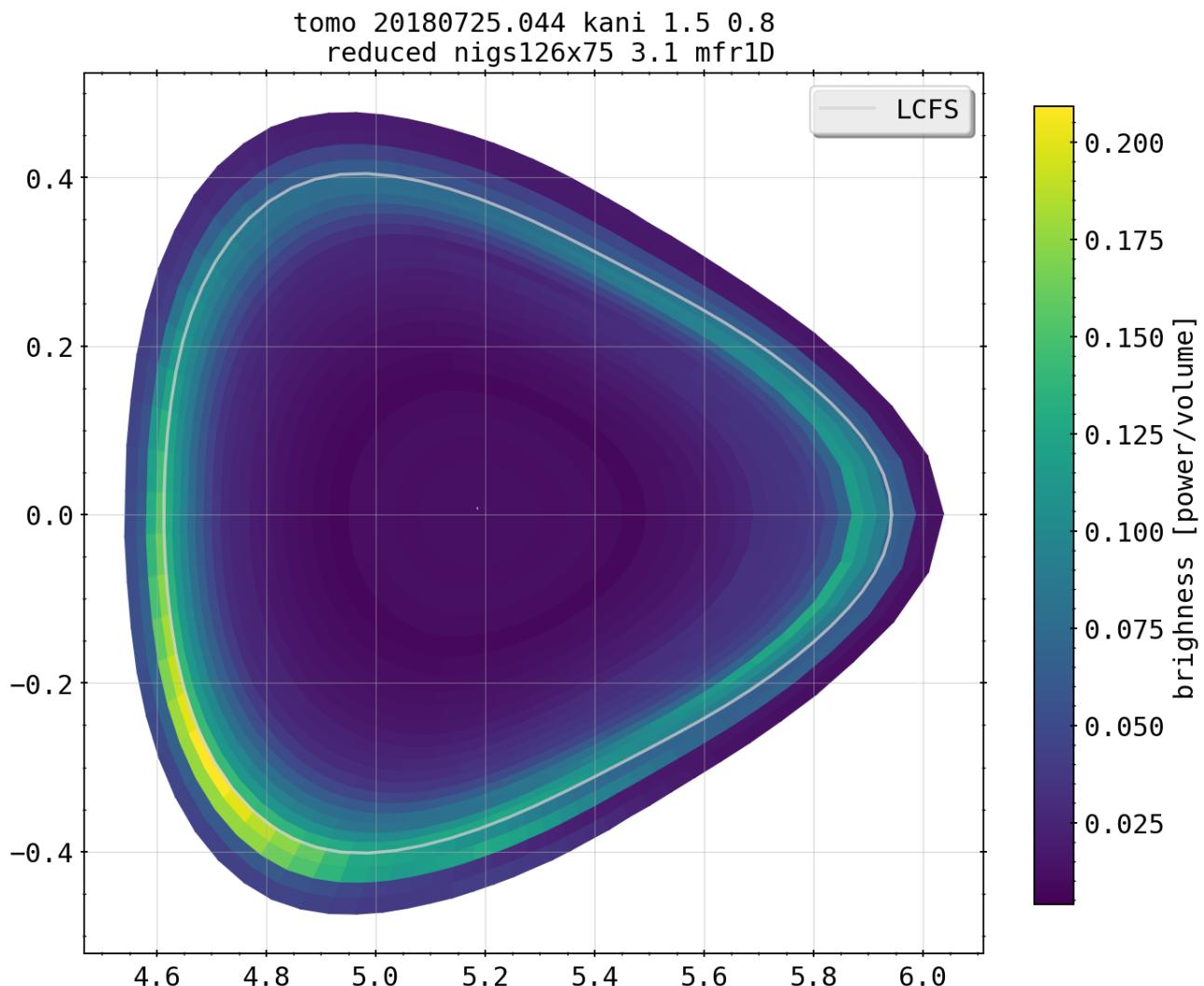
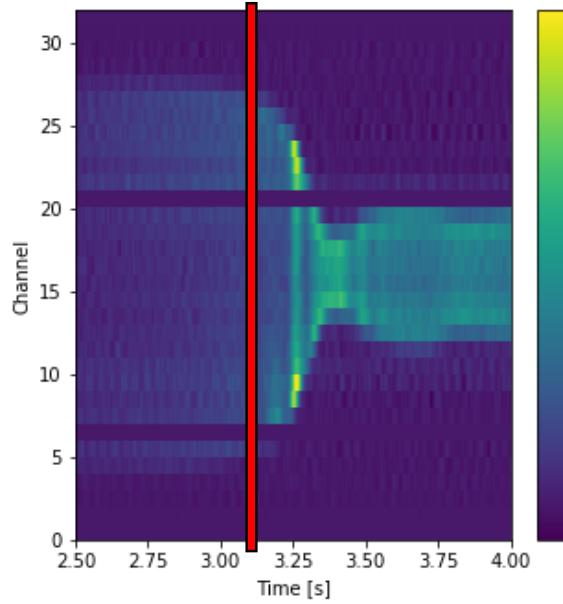
chordal profile HBCm



# Revisited: Test of 20180725.044

➤ KJM magnetic configuration

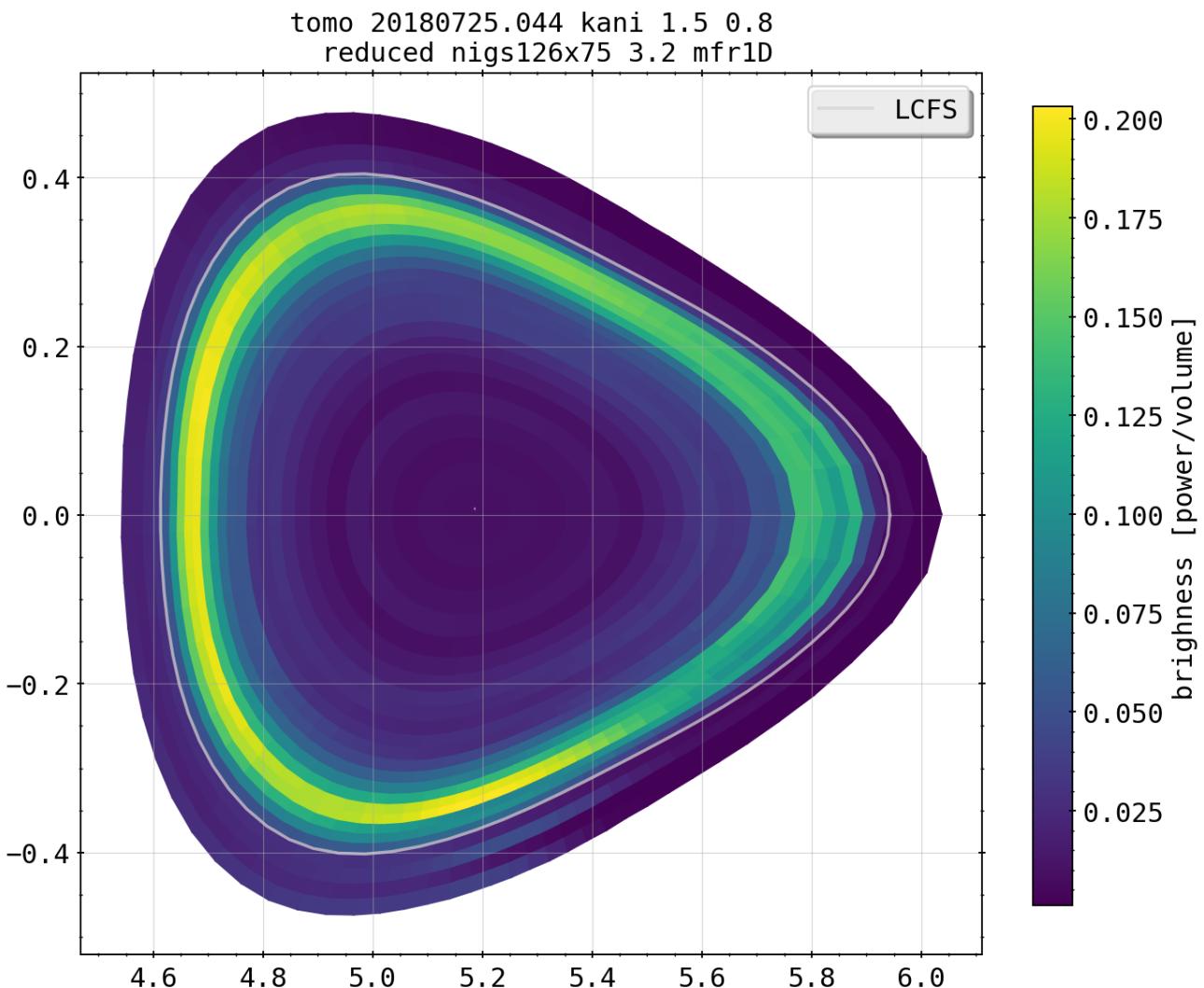
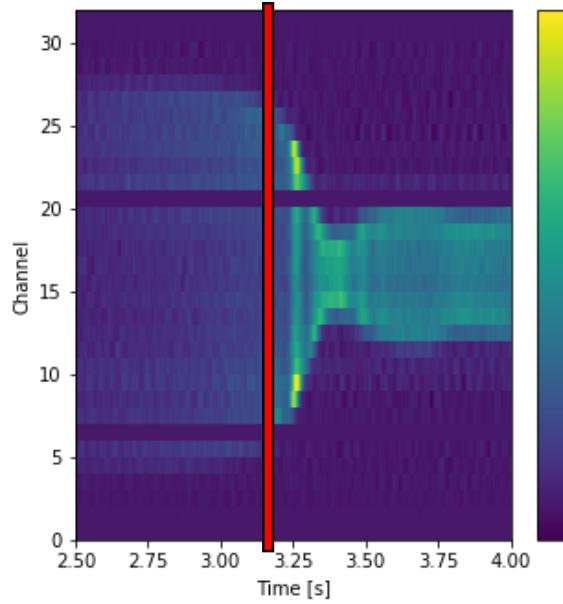
chordal profile HBCm



# Revisited: Test of 20180725.044

➤ KJM magnetic configuration

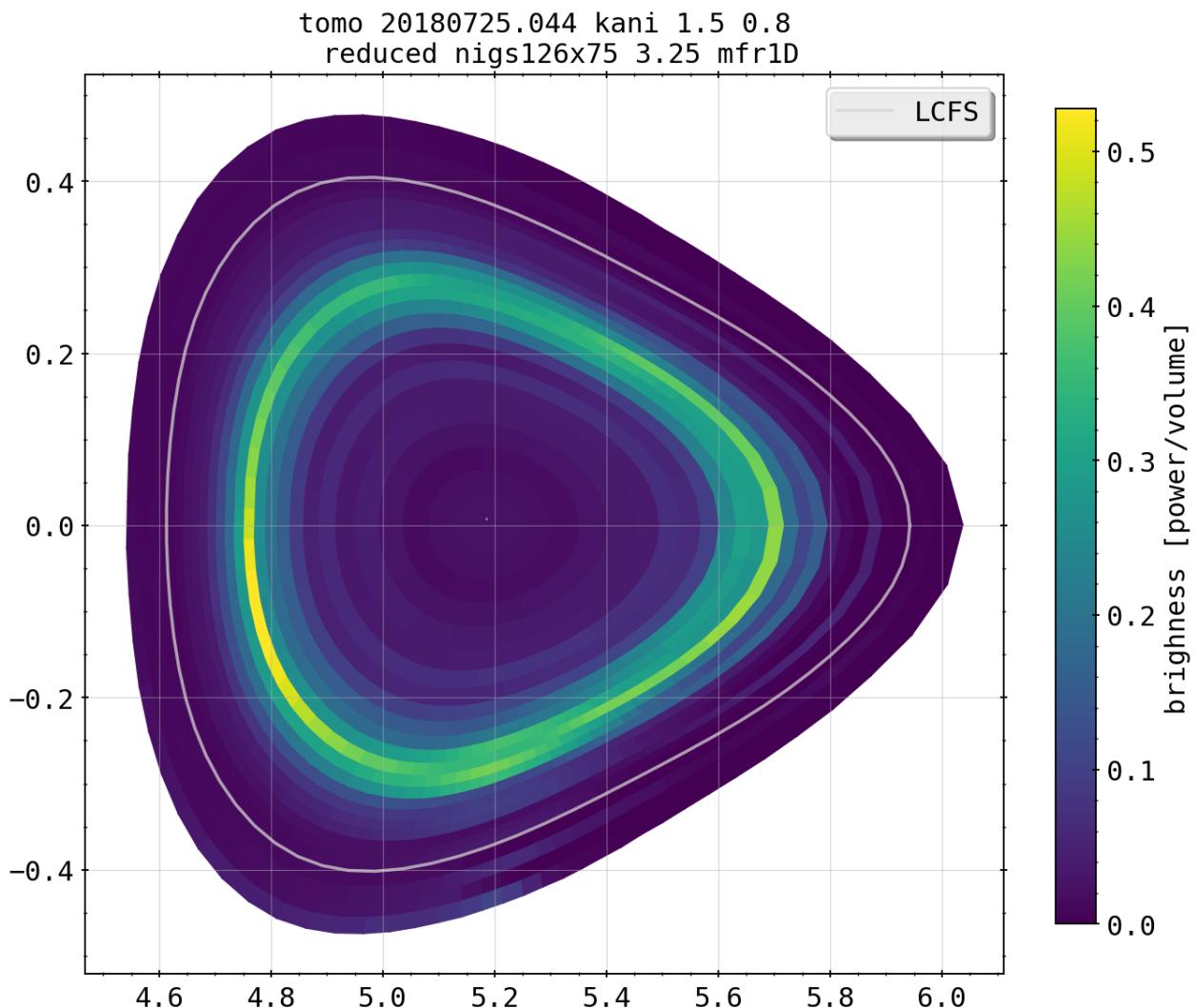
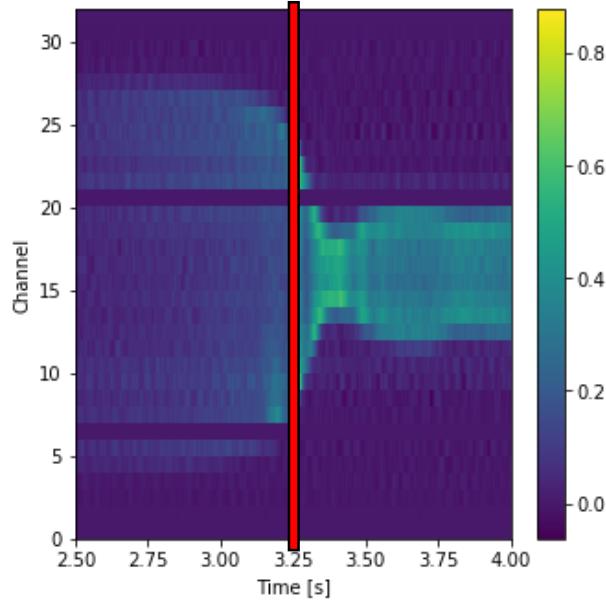
chordal profile HBCm



# Revisited: Test of 20180725.044

➤ KJM magnetic configuration

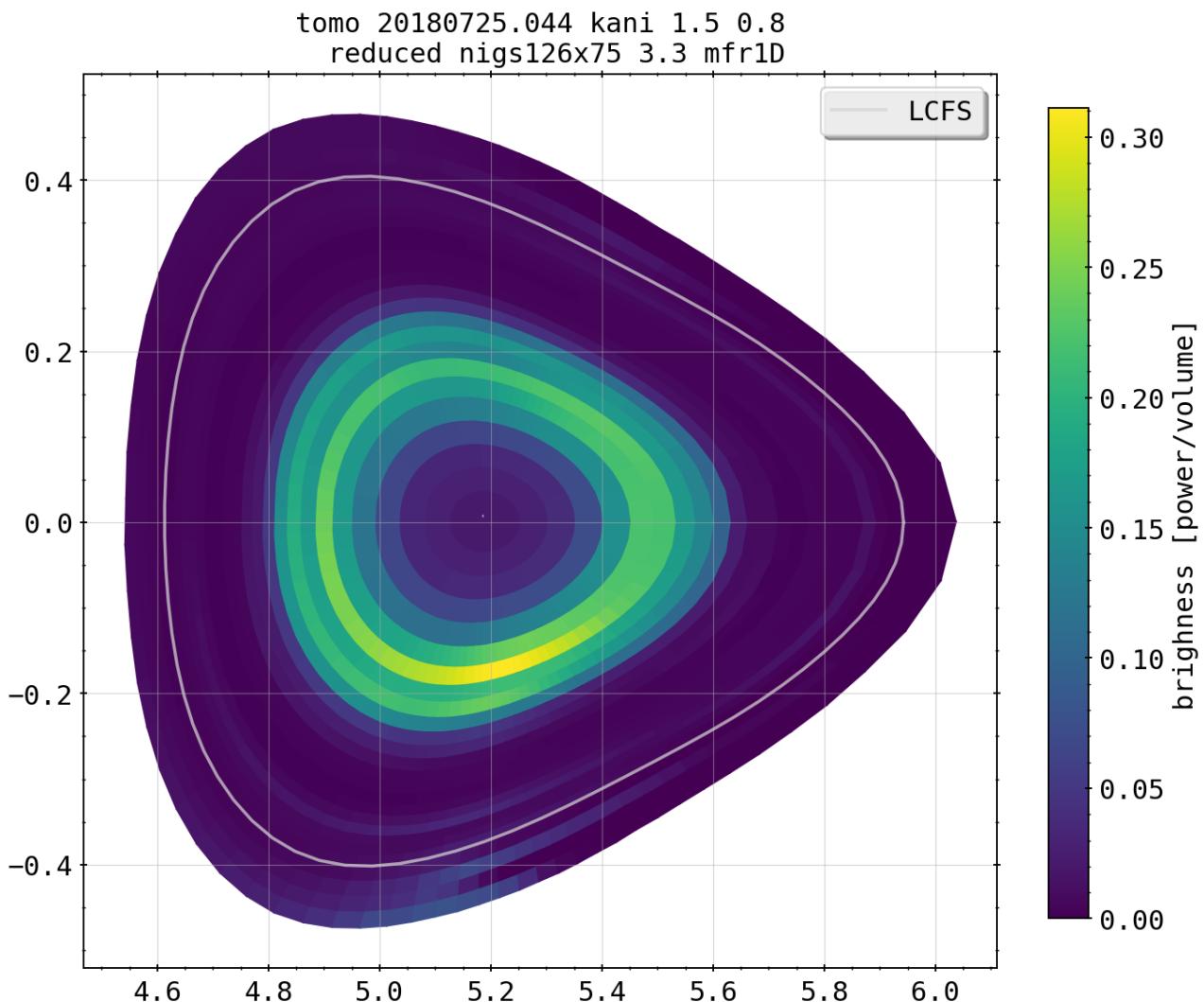
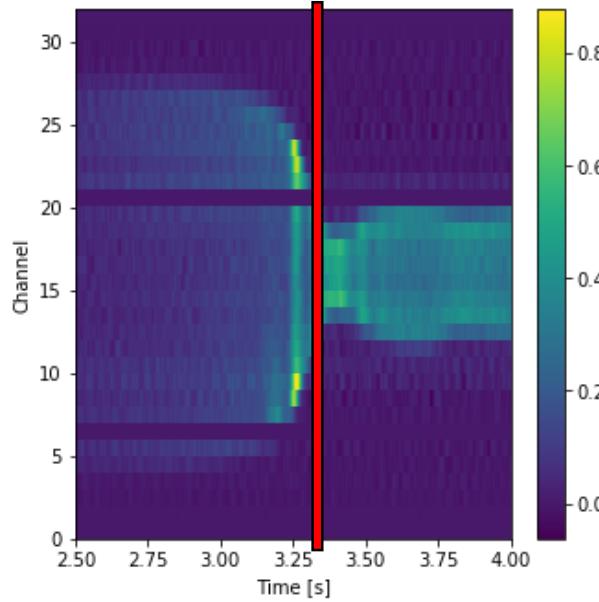
chordal profile HBCm



# Revisited: Test of 20180725.044

➤ KJM magnetic configuration

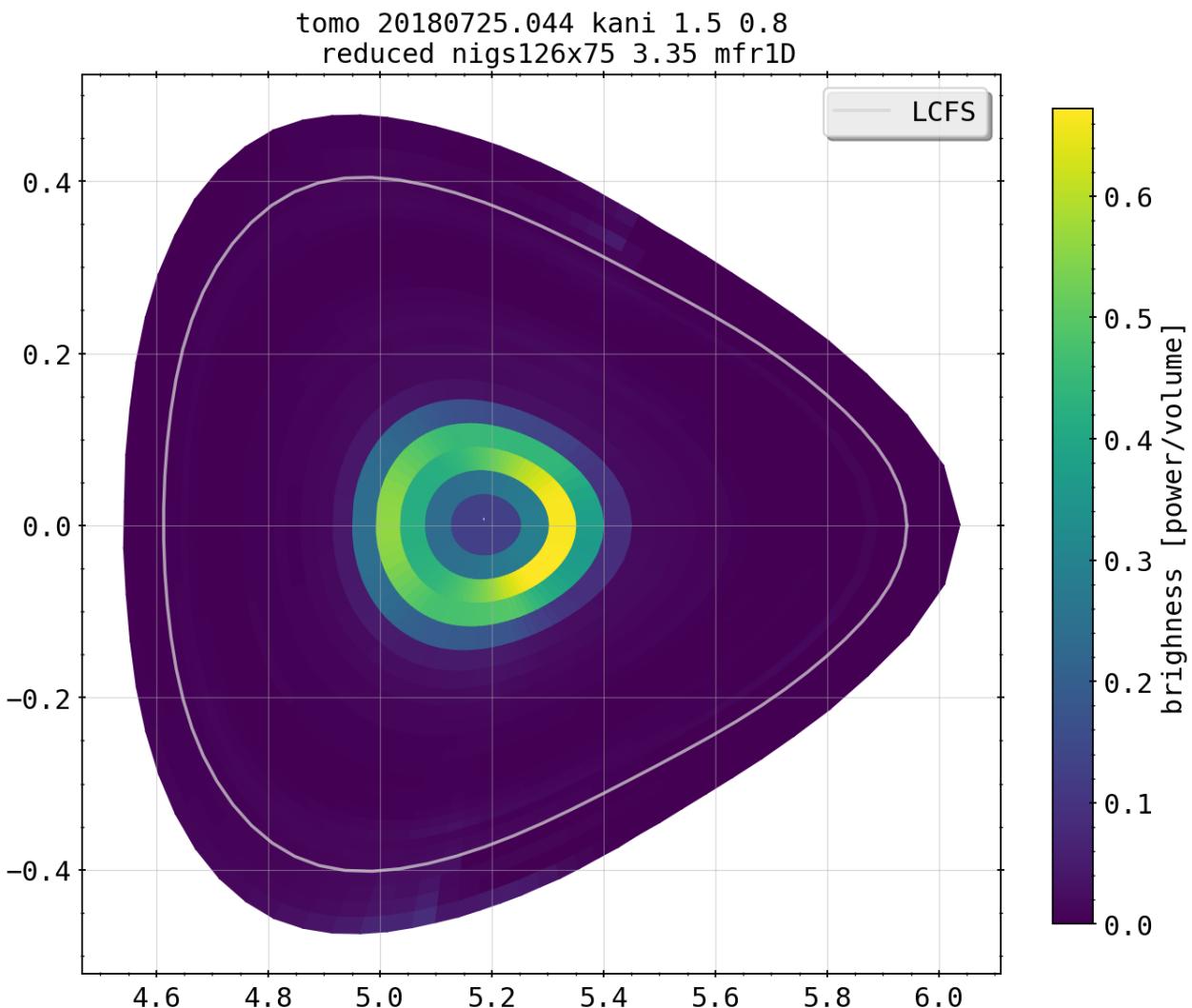
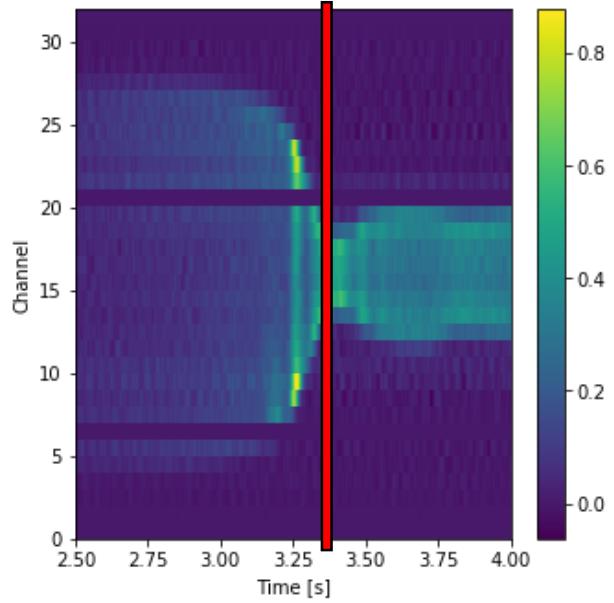
chordal profile HBCm



# Revisited: Test of 20180725.044

➤ KJM magnetic configuration

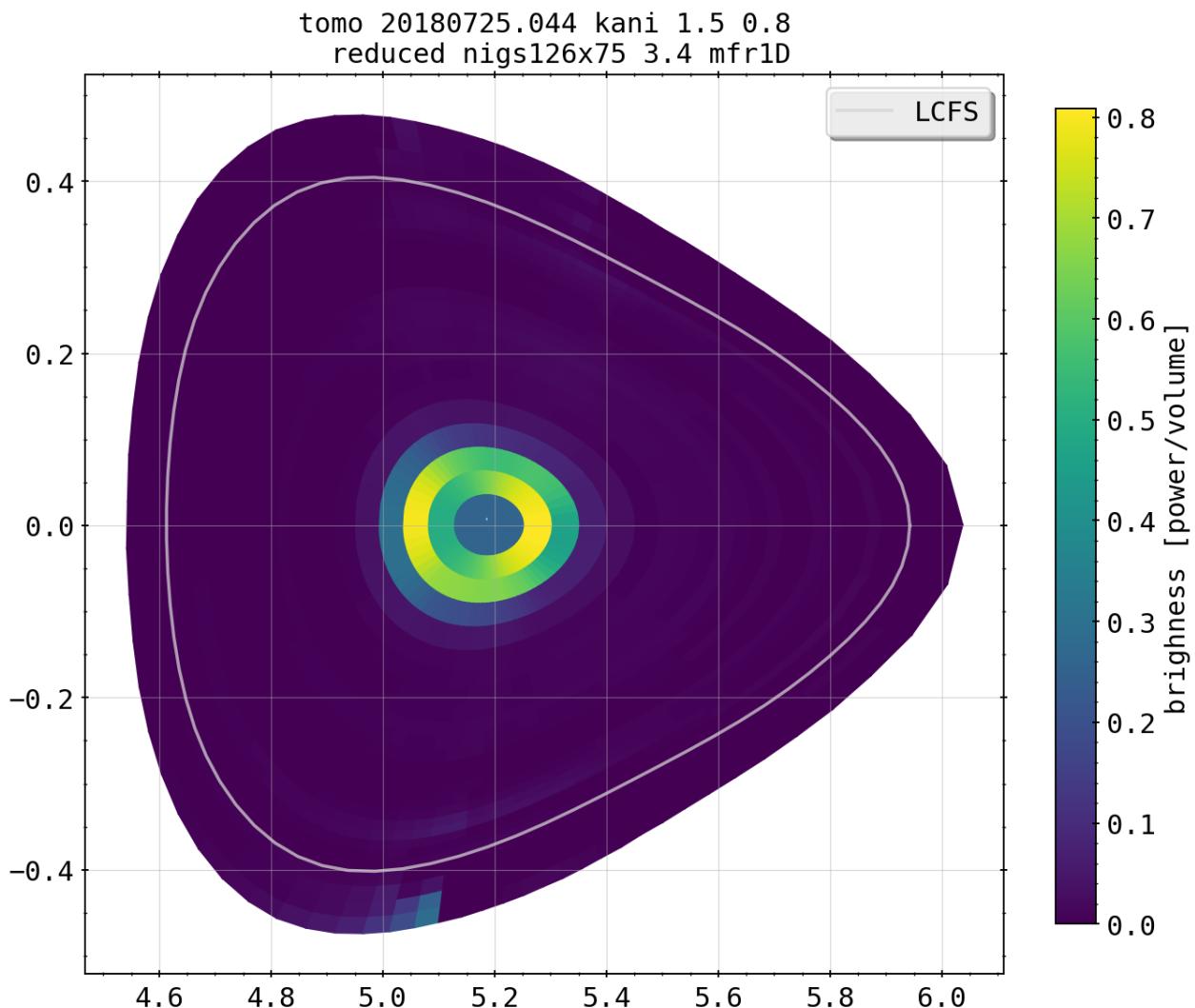
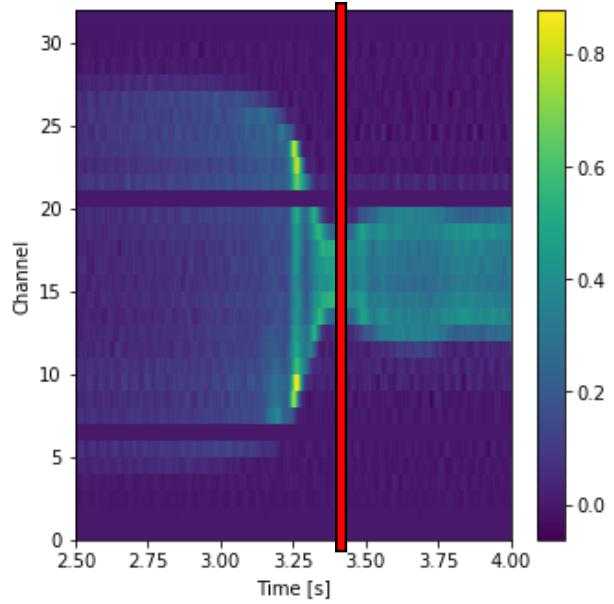
chordal profile HBCm



# Revisited: Test of 20180725.044

➤ KJM magnetic configuration

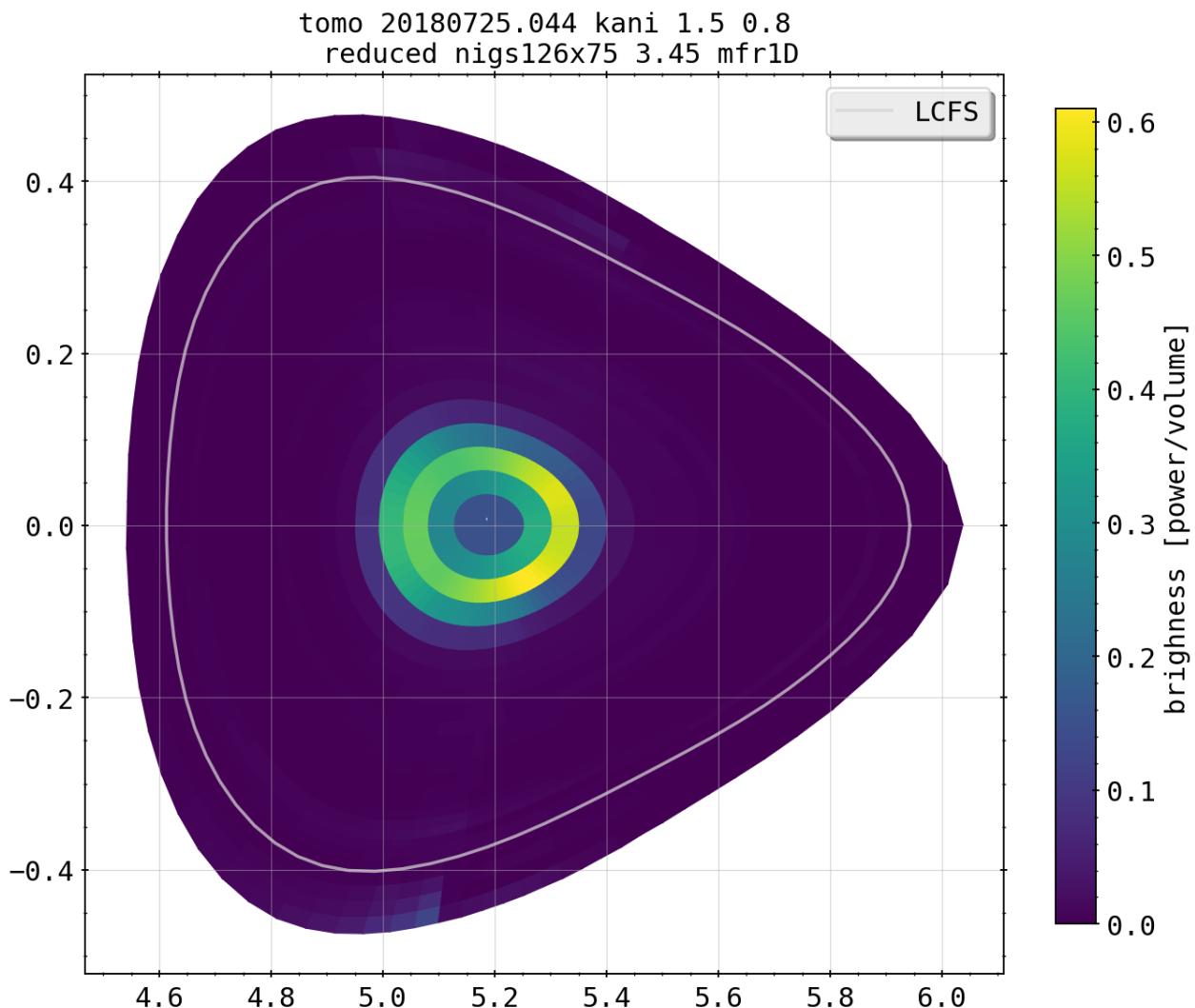
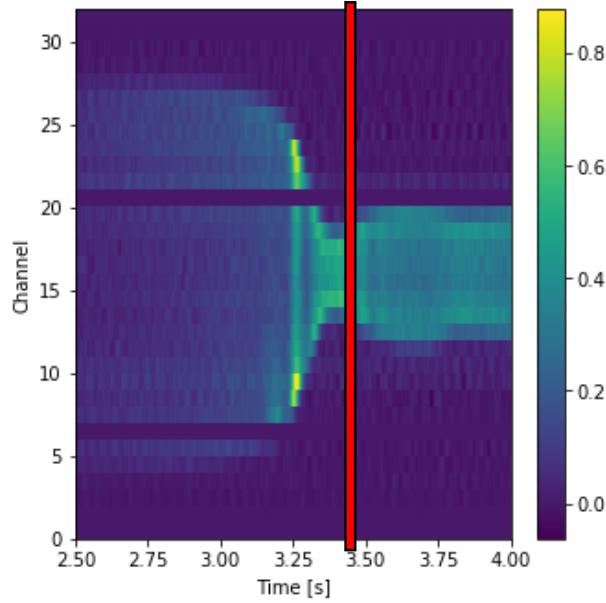
chordal profile HBCm



# Revisited: Test of 20180725.044

➤ KJM magnetic configuration

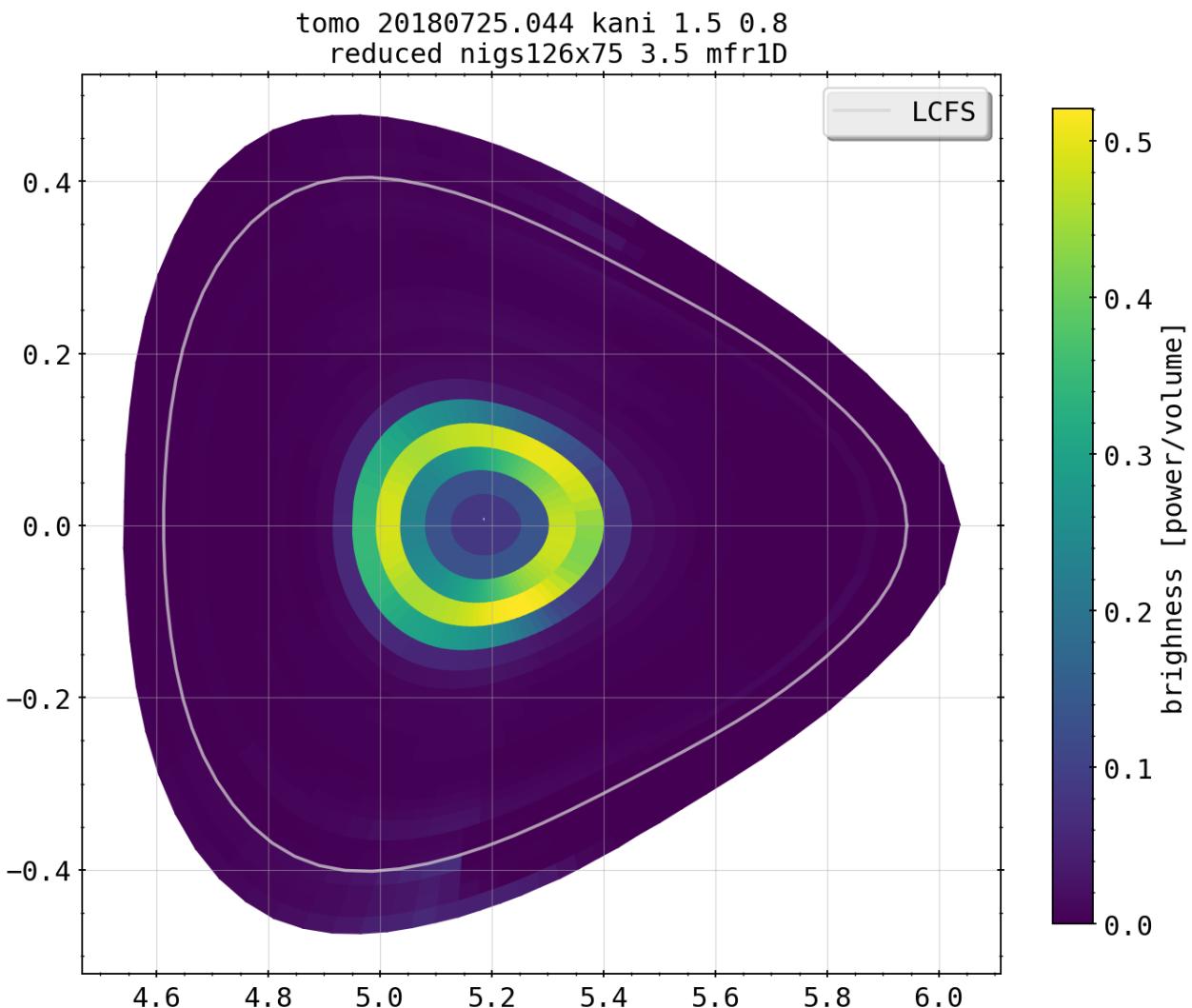
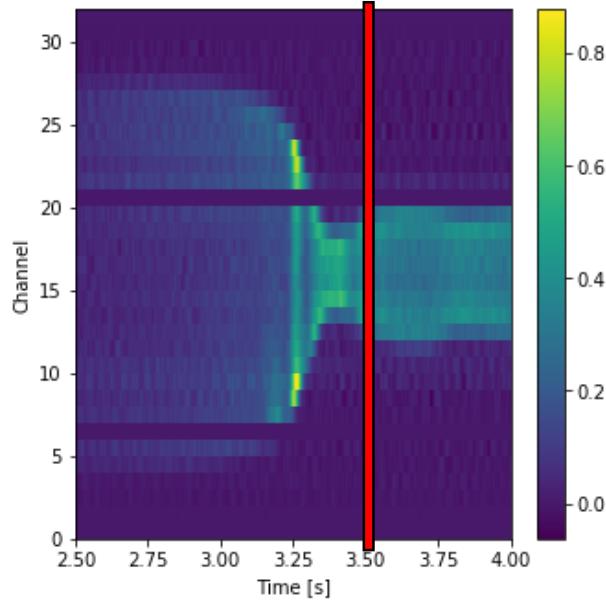
chordal profile HBCm



# Revisited: Test of 20180725.044

➤ KJM magnetic configuration

chordal profile HBCm



# Revisited: Test of 20180725.044

➤ KJM magnetic configuration

chordal profile HBCm

