Comparison of 2D Visible Emission Profiles from Detached Open and Closed Divertors in DIII-D

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Introduction & Summary

Abstract

- The 2D profiles of visible carbon and deuterium emission in the open geometry of the DIII-D lower divertor have contributed to our understanding of divertor detachment [1-3]. The profiles are obtained using tomographic reconstruction techniques applied to images from tangentially viewing video (TTV) cameras [4]. Two new TTV cameras are now operational with identical views of the tightly baffled upper divertor in DIII-D. Simultaneous carbon and deuterium images are obtained for power balance studies and to generate 2D profiles of recombination and ionization dominated zones in the divertor. The evolution of the 2D emission of carbon and deuterium in the closed divertor during ELMing H-mode plasmas with density ramps to detachment will be compared with profiles from identically prepared open divertor discharges.

  - *Work supported by U.S. DOE, Contracts W-7405-ENG-48 (LLNL) and DE-AC03-99ER54463 (General Atomics).

  - [1] M.E. Fenstermacher et al., PoP, 1761, 1997.
  - [2] M.E. Fenstermacher et al., PPCF, A345, 1999.
  - [3] M.E. Fenstermacher et al., EPS, Maastricht, 1999
  - [4] M.E. Fenstermacher et al., Rev. Sci. Inst., 974, 1997.

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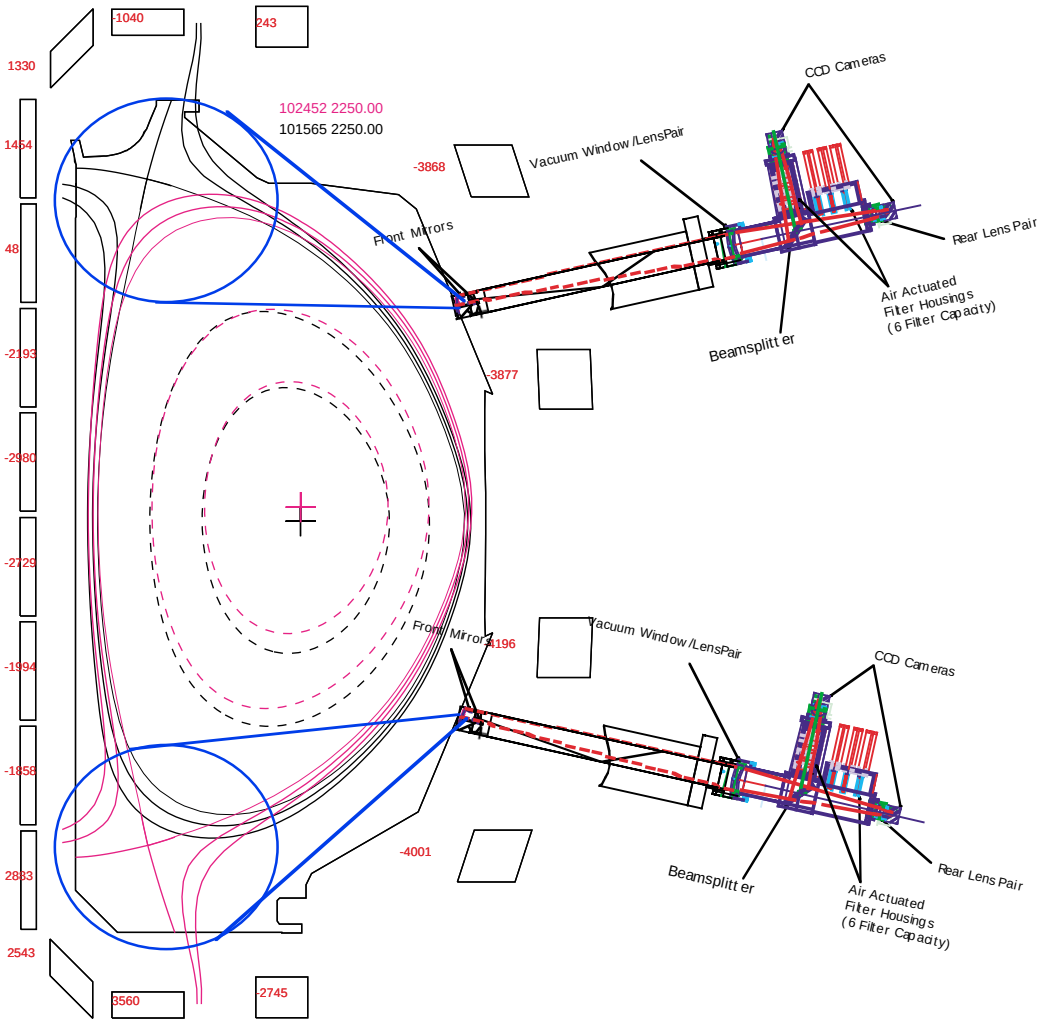
SUMMARY: Images of visible light emission from a tightly baffled divertor and an open divertor can now be compared in DIII-D.

- New tangential TV systems are now operational in both divertors on DIII-D
  - Optical relay systems; no fiber imageguides
  - No fiber browning effects; data obtained on all shots
- Comparisons of emission from the upper baffled (closed) vs. the lower (open) divertors are beginning.
  - Dedicated shots achieved with matched shape, current, power, ion Grad-B drift orientation.
  - Repeat shots used to get full spectroscopic measurements (carbon and deuterium).
- Detachment profiles and evolution are significantly different in the closed divertor compared with the open divertor.
  - At high triangularity the evolution from start of gas injection to detachment emission profiles seems to be much slower in closed divertor compared with open divertor.
  - Profiles are different in high vs low triangularity divertors (see also poster by Jalufka).

Diagnostics

Visible TTV systems have been upgraded and expanded on DIII-D.

- Lower divertor systems now use optical relay system without fiber imageguide.
  - Optical system is modification of design developed for VUV TTV.
  - Neutron browning effects eliminated.
  - Images obtained for all DIII-D shots.
- Similar visible systems now view the upper, baffled divertor on DIII-D.
- Both systems provide two images at different wavelengths simultaneously.



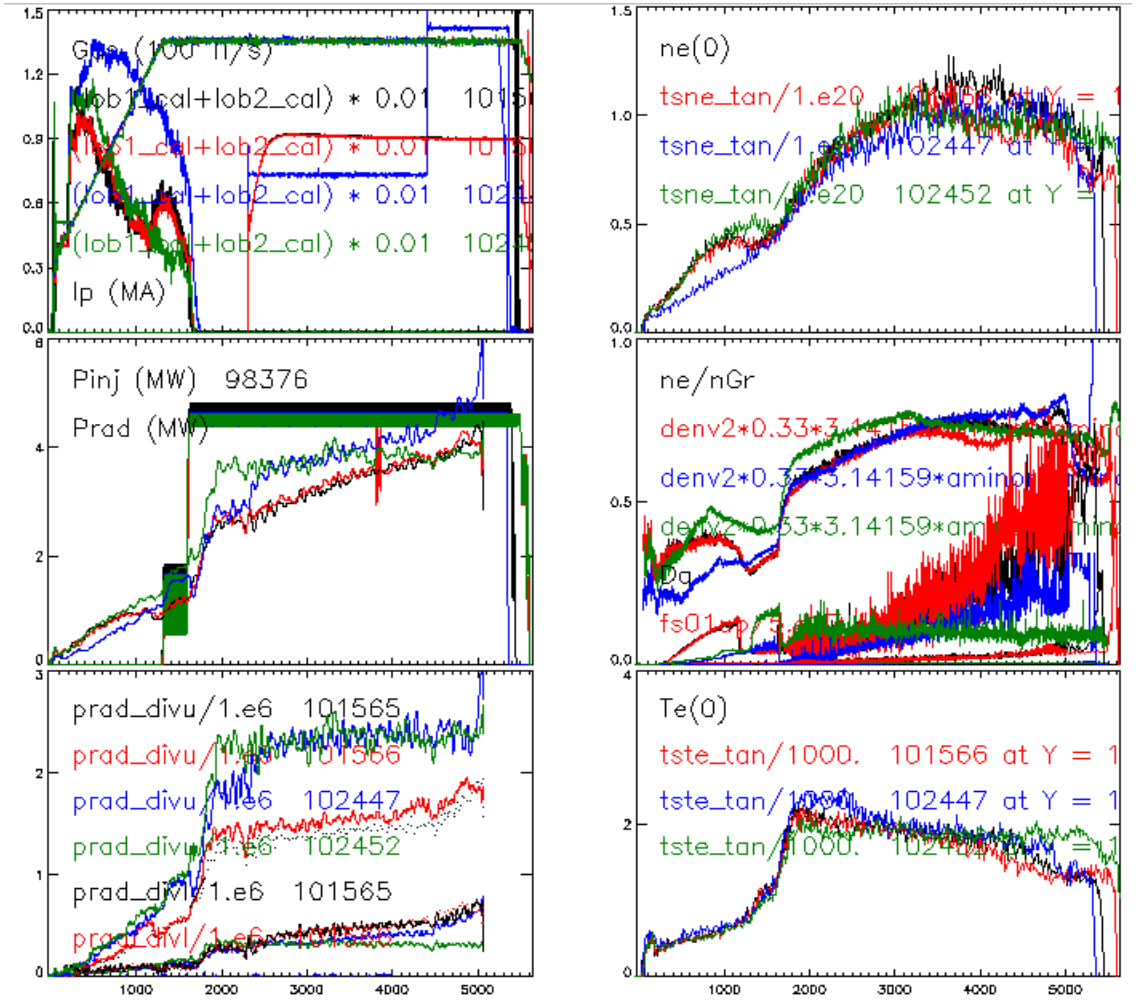
Discharges in this paper obtained a PDD phase by deuterium injection into the SOL of an ELMing H-mode plasma.

- **Common shot characteristics:**
  - Single null configuration
  - I_p = 1.35 MA, B_T = 2.1 T, R_0 = 1.68 m, a = 0.6 m
  - κ = 1.70, δ = 0.75 (X-point), δ = 0.30 (non-X-point)
  - Inner and outer gaps to vessel wall 6 - 8 cm; more than 5 power and 3 particle flux SOL widths
  - q_{95} = 4.1, P_{inj} = 4.6 MW
- **Gas injection rate varies somewhat to match the density evolution**
  - Deuterium gas injection rate = 7 - 12 Pa m^3/s (50 - 90 Tl / s)

Shot Descriptions

Time histories of shots with closed and open divertors show similar control parameters.

- Plasma current, neutral beam power, central temperature and density are well matched.
- Gas injection rates are comparable.
- Total radiation about 20% higher and radiation in the divertor 50% higher in the LSN open divertor shots.



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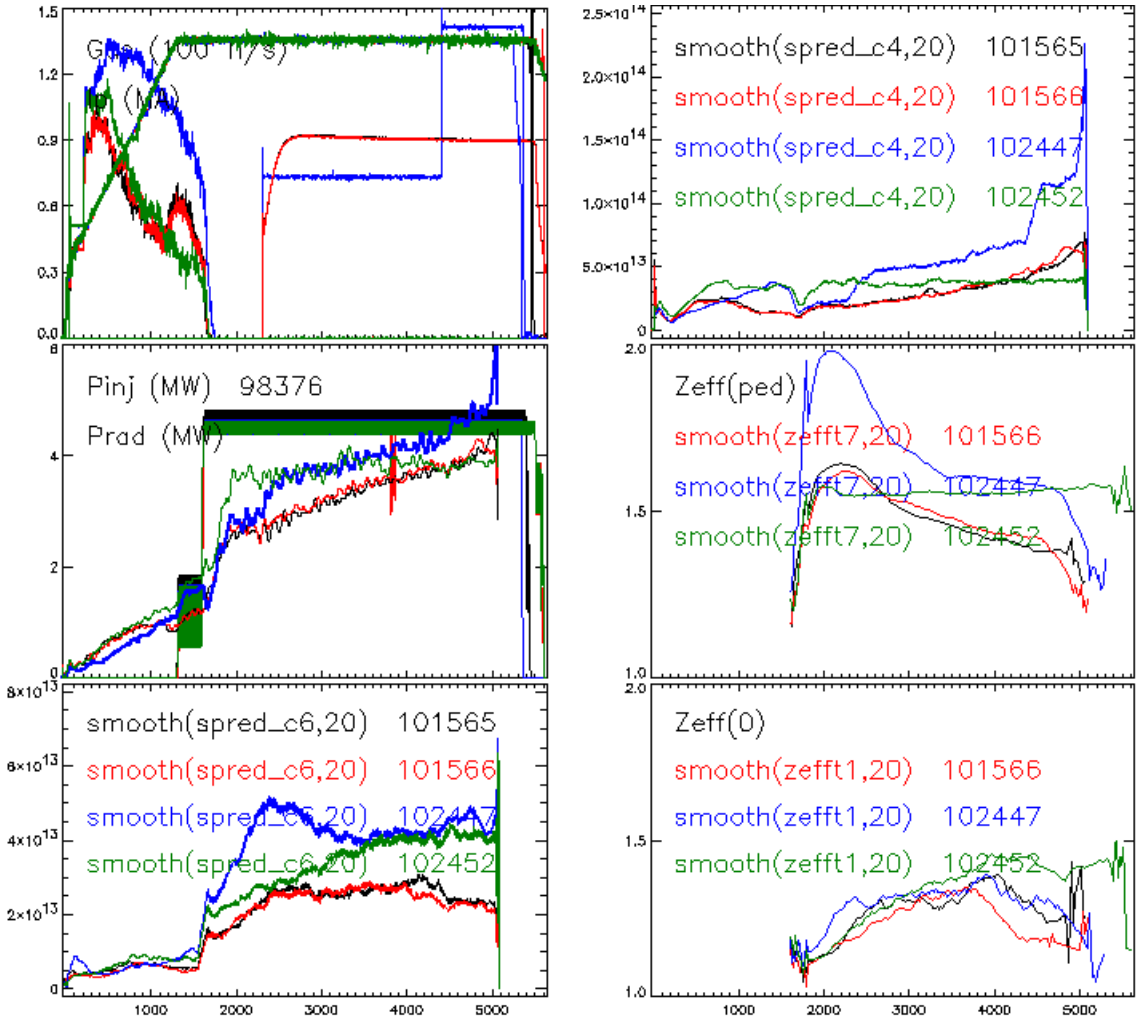
Time histories of shots with closed and open divertors show differences in core carbon and Zeff.

- Fully ionized carbon from SPRED higher in LSN open divertor configurations.
- Zeff in pedestal region also higher in LSN open divertor configuration.



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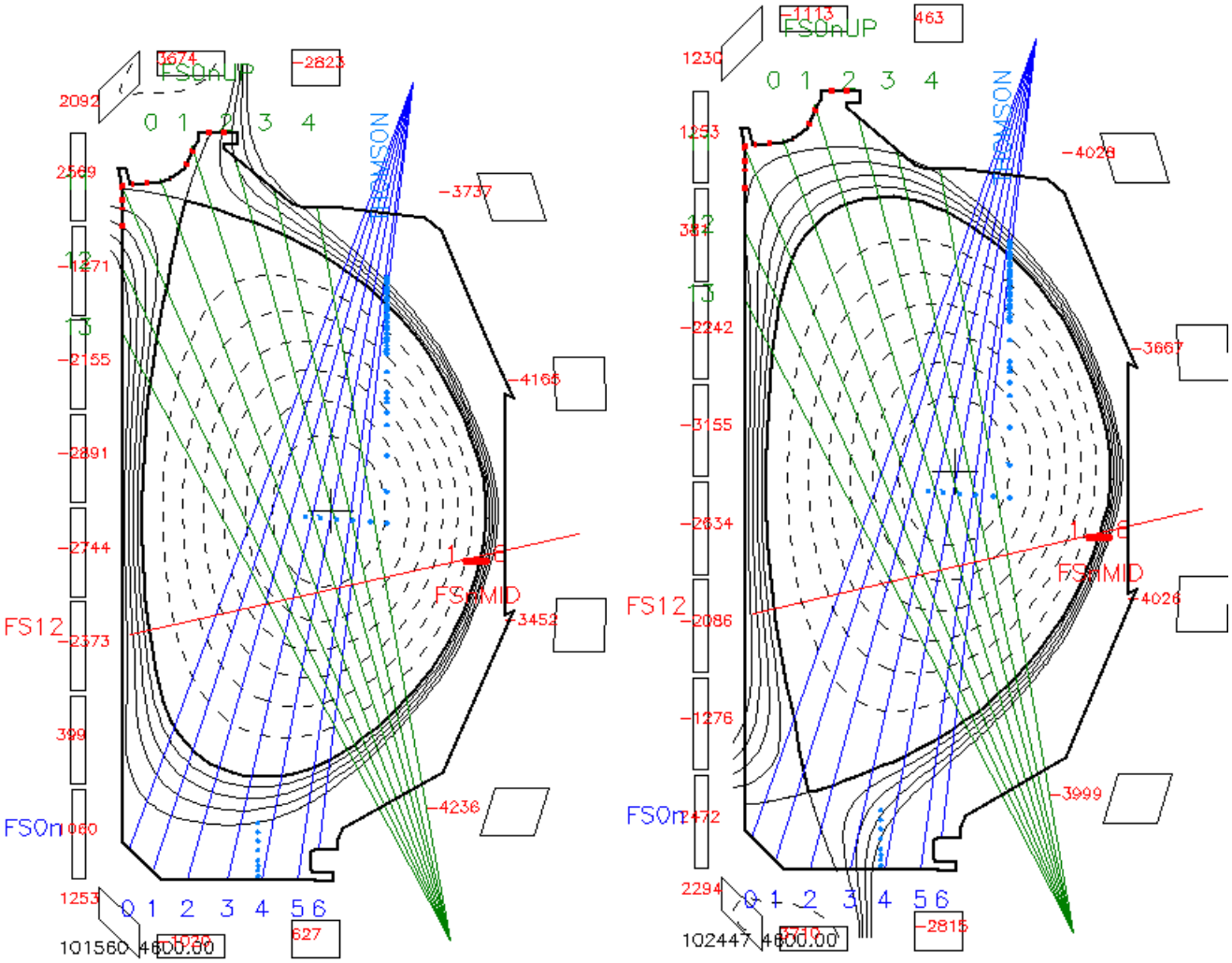
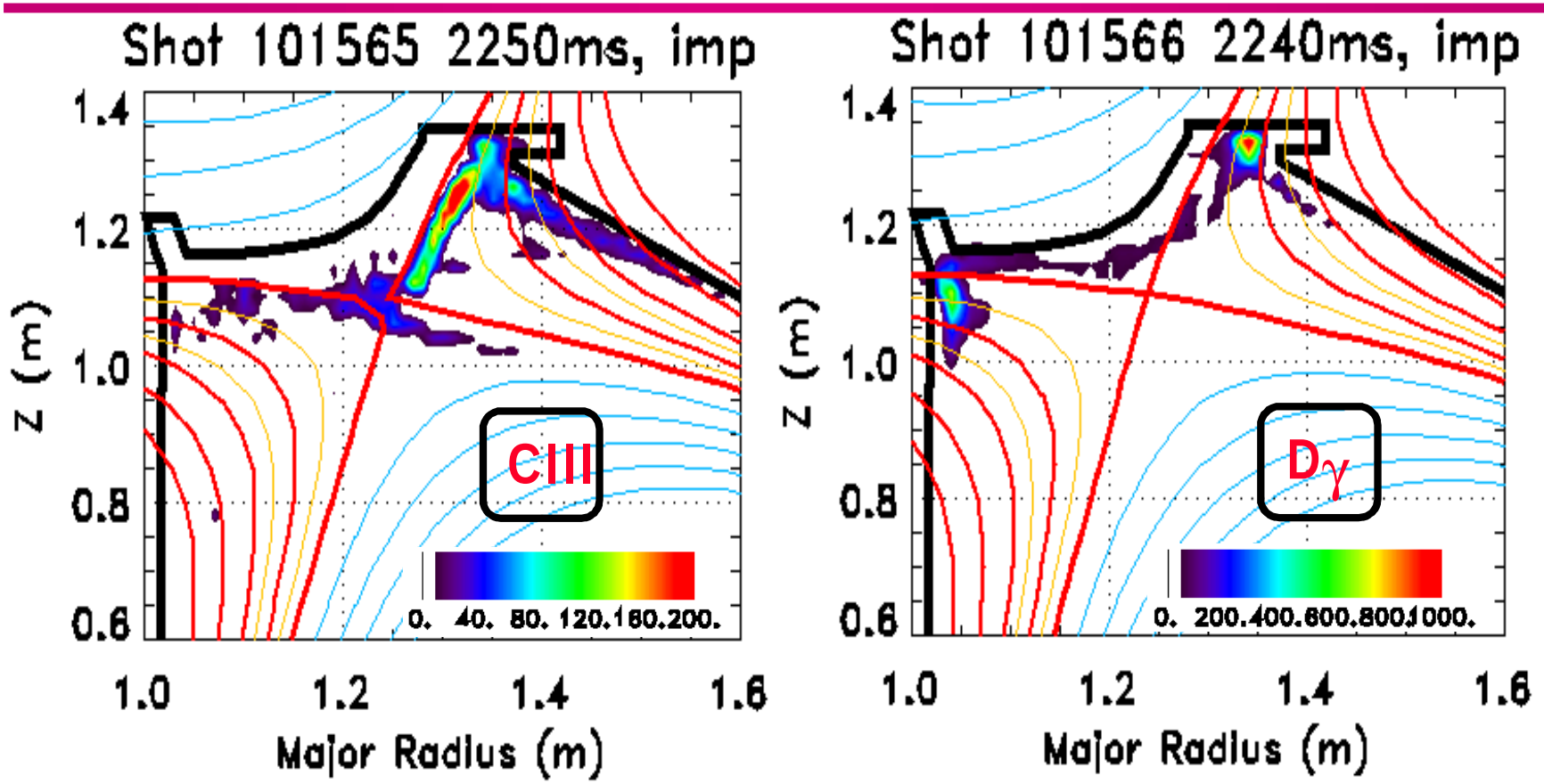
EFIT reconstructions show shot shapes are well matched

- Toroidal field is reversed in closed USN
- Ion Grad-B drift is always into the divertor.



CLOSED Divertor Profiles

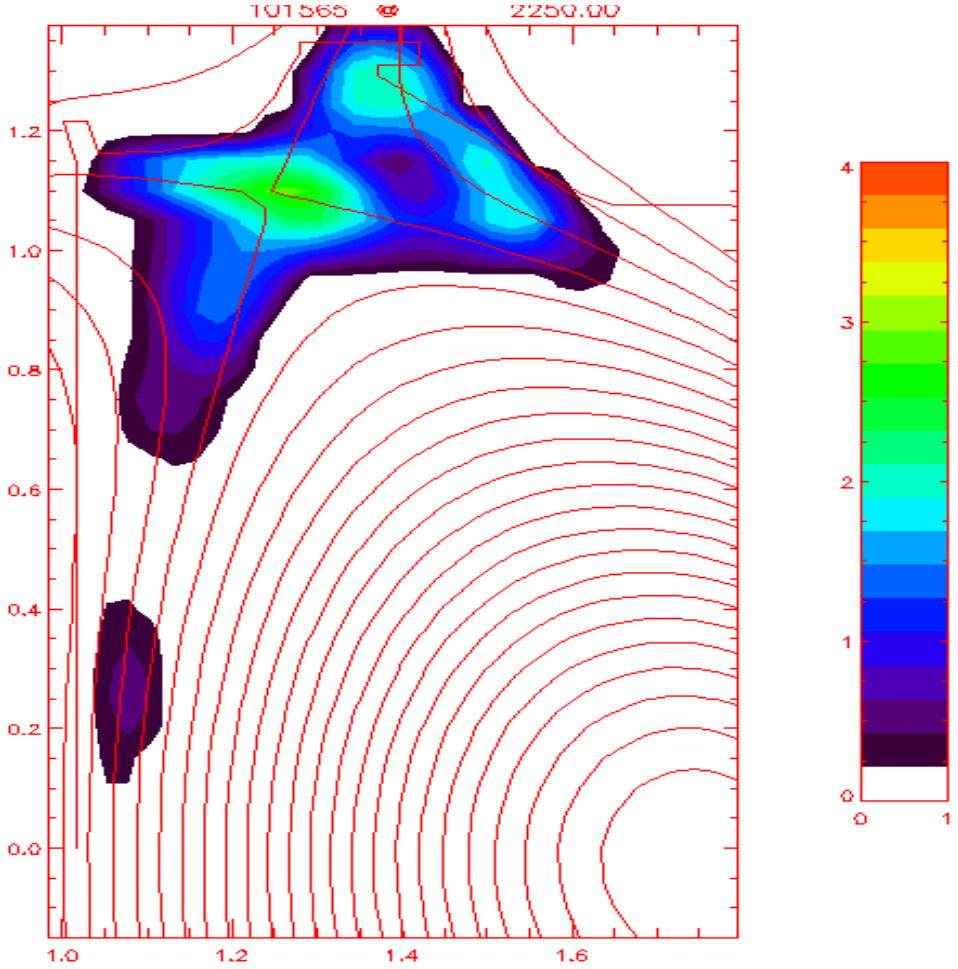
Attached closed divertor: Carbon profile extended along outer leg; D_g emission near separatrix strike points.



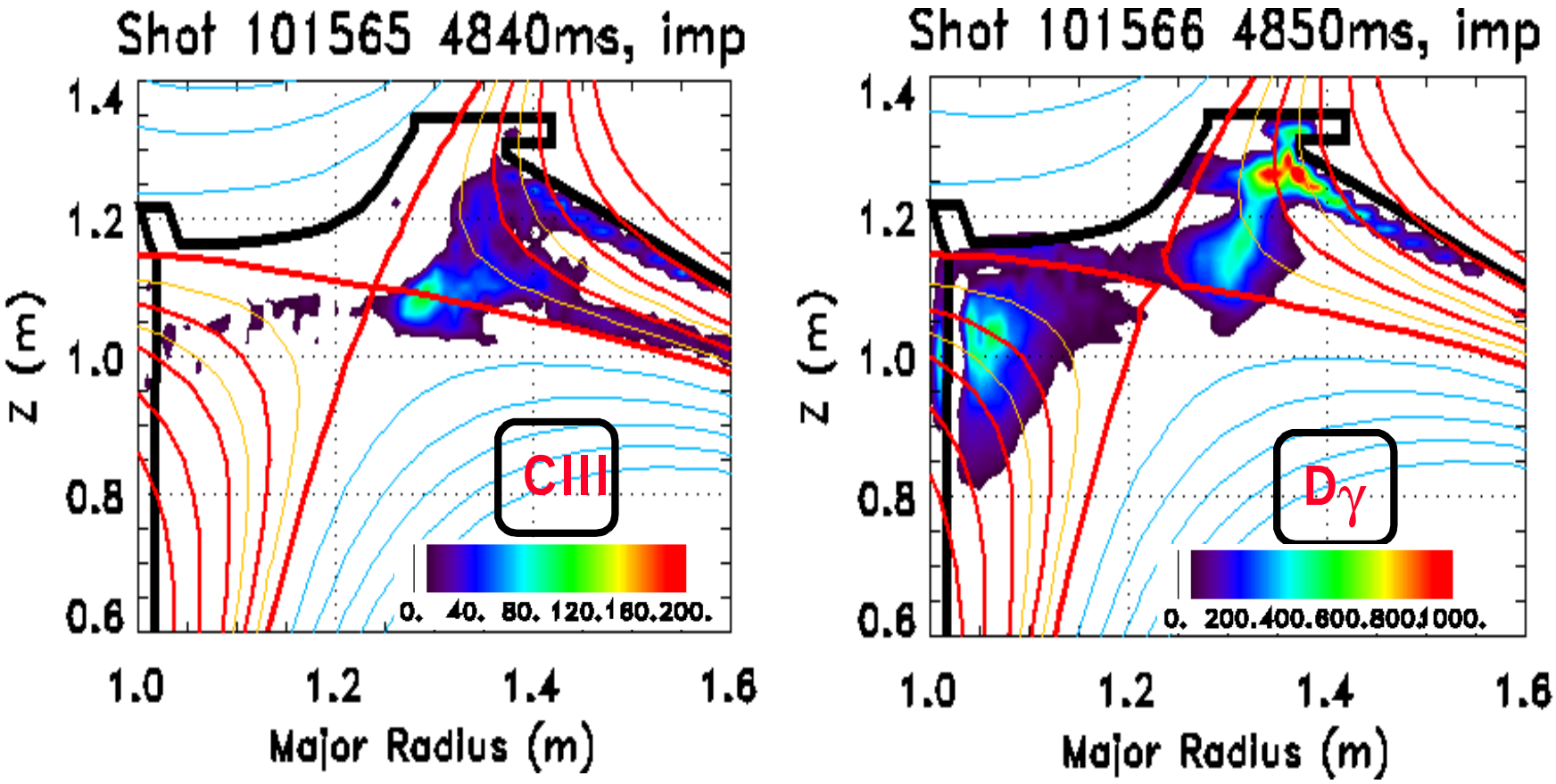
- Carbon profile is similar to total radiated power from bolometers.
- D_g emission concentrated near targets but somewhat outboard of outer strikepoint.
  - D_a emission not available from this shot series.

Attached closed divertor: Radiated power profile from bolometers shows maxima near X-point and outer baffle.

- Radiated power distribution:
  - Total: 3.1 MW
  - Core: 0.65
  - SOL: 0.54
  - Inner Div: 0.53
  - Outer Div: 1.35
- Peak in profile near OSP consistent with deuterium emission
- Local peak near X-point not reproduced by visible emission profiles.



Detached closed divertor: Carbon profile localized at X-point; D_g emission in far SOL and extends up divertor legs.



- Carbon emission intensity reduced from pre-puff profile.
- D_g emission extends up both divertor legs toward H X-point more than in attached plasma.

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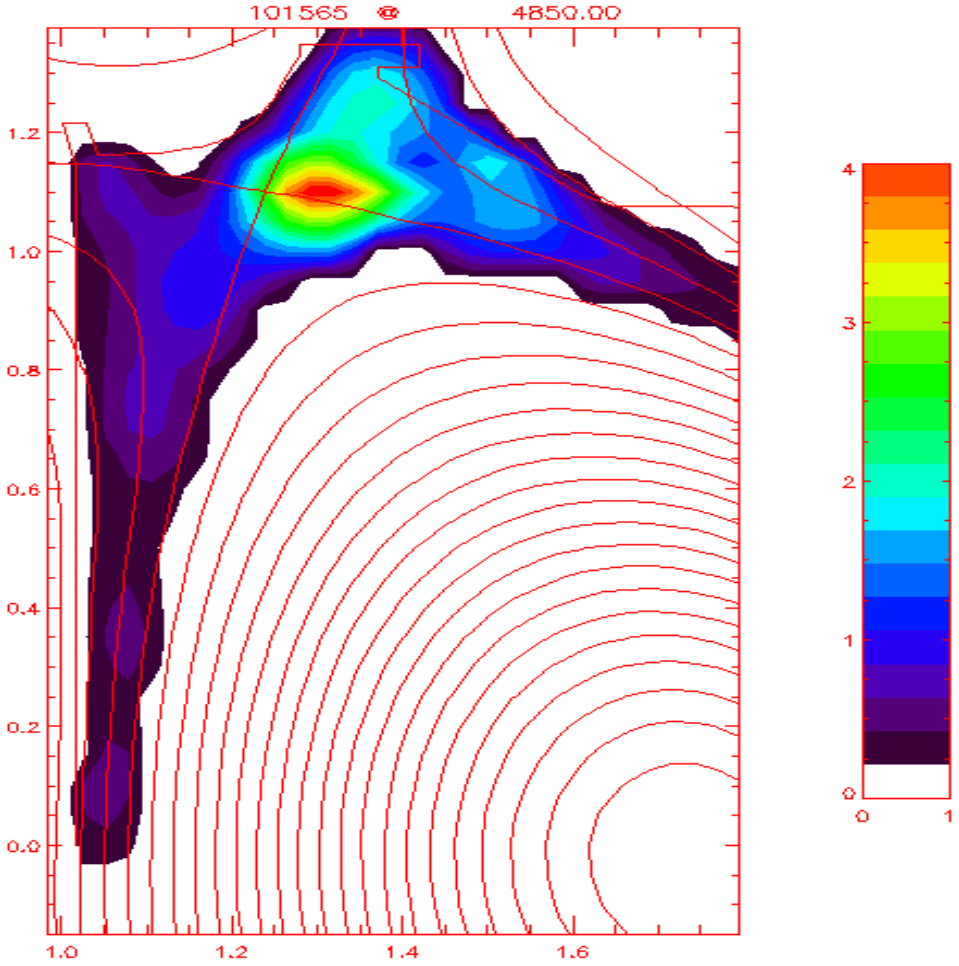
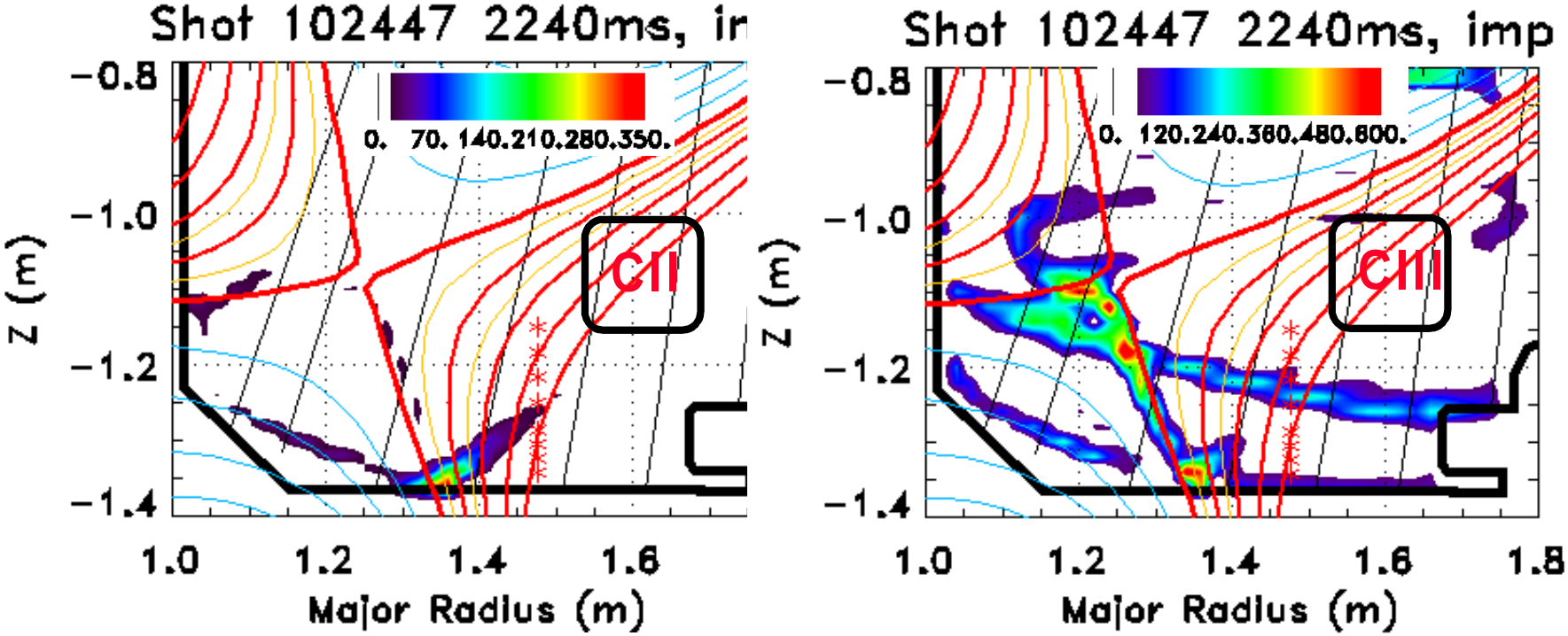
Detached closed divertor: Radiated power profile shows an increase near the X-point, extended radiation along outer baffle.

- Radiated power distribution:
  - Total: 4.33 MW
  - Core: 0.98
  - SOL: 1.16
  - Inner Div: 0.29
  - Outer Div: 1.90
- Peak near X-point consistent with carbon emission
- Extended radiation along outer leg to baffle nose consistent with deuterium emission.



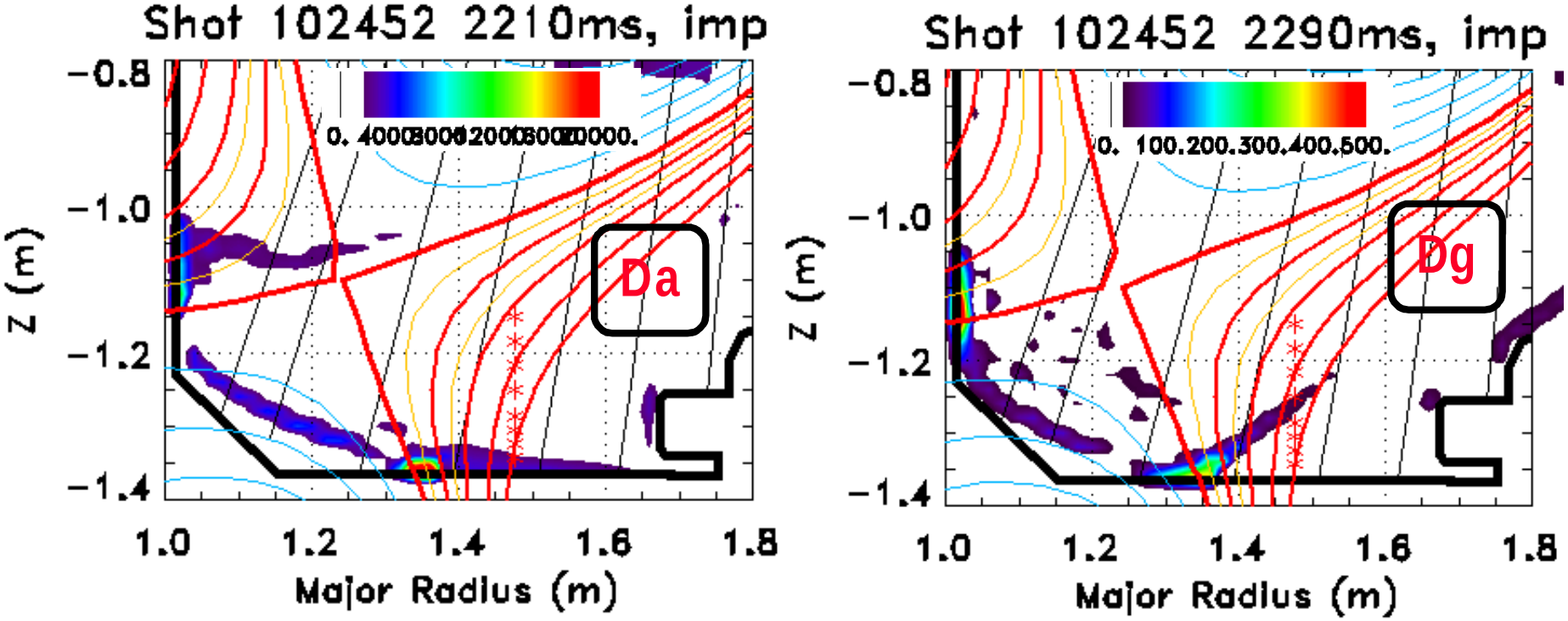
OPEN Divertor Profiles

Attached open divertor: Carbon profiles show source at outer strikepoint and emission along outer leg.



- Emission in CIII across fulx surfaces to outer baffle is probably an artifact of inversion.
- CIII emission is distributed along outer leg in pre-puff phase at high triangularity
  - Previous data at low triangularity showed peak in inner SOL at X-point.

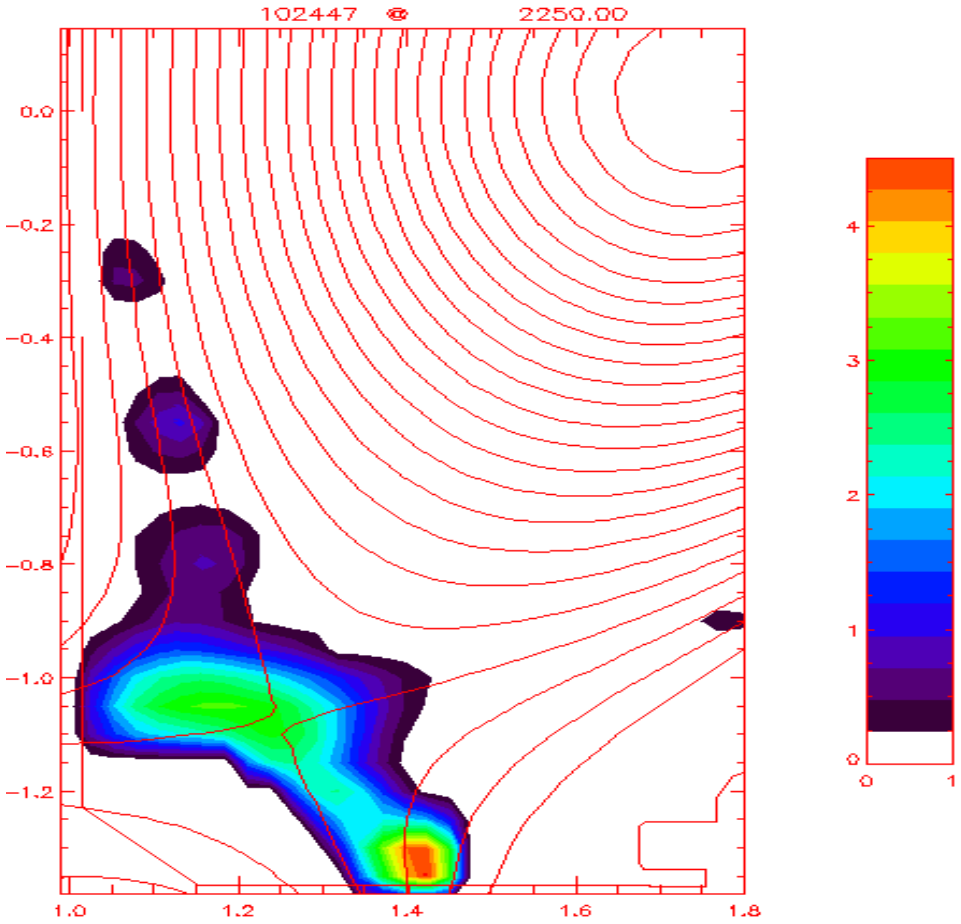
Attached open divertor: Deuterium profiles are very localized at strikepoints.



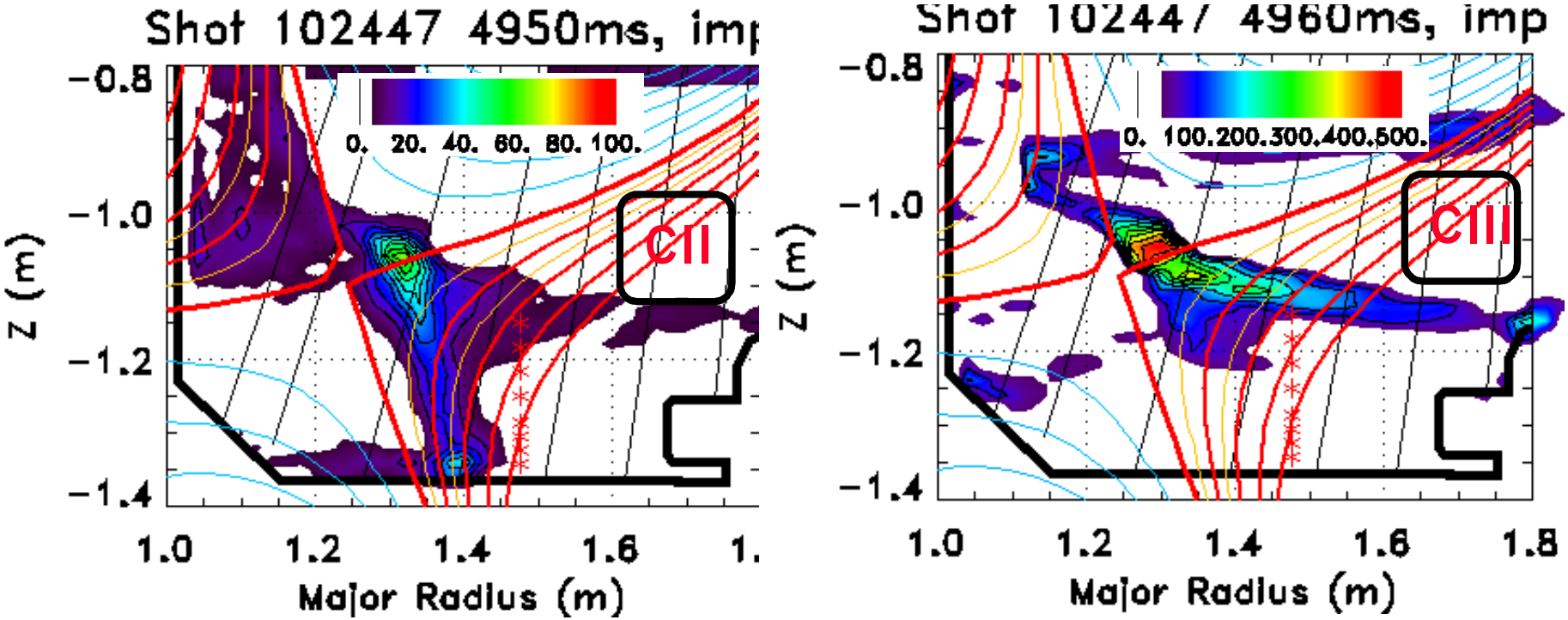
- D_alpha higher relative intensity at OSP vs ISP
- D_gamma higer relative intensity at ISP vs OSP
- Implication is that more recombination at ISP, ionization at OSP.

Attached open divertor: Radiated power profile from bolometers shows peak near OSP and across X-point region.

- Radiated power distribution:
  - Total: 2.9 MW
  - Core: 0.56
  - SOL: 0.51
  - Inner Div: 0.74
  - Outer Div: 1.11
- Peak across X-point region consistent with CIII profile.
- Peak at OSP consistent with D_alpha profile.

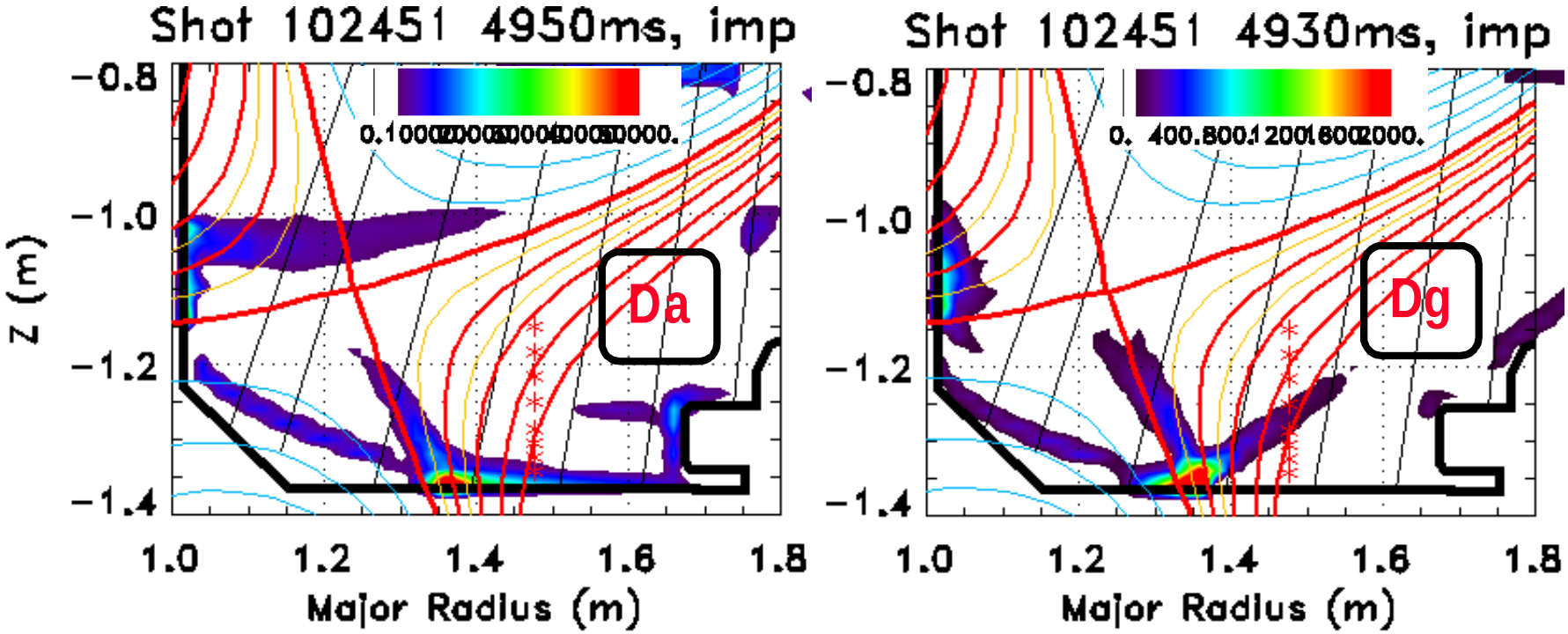


Detached open divertor: Carbon emission profile localized to outer SOL near X-point.



- CII extends down the outer divertor leg ==> outer leg Te ~ 5ev
- CIII localized in outer SOL above X-point.
  - Emission profiles from previous low triangularity divertors show steep poloidal Te gradient region in outer SOL above X-point.

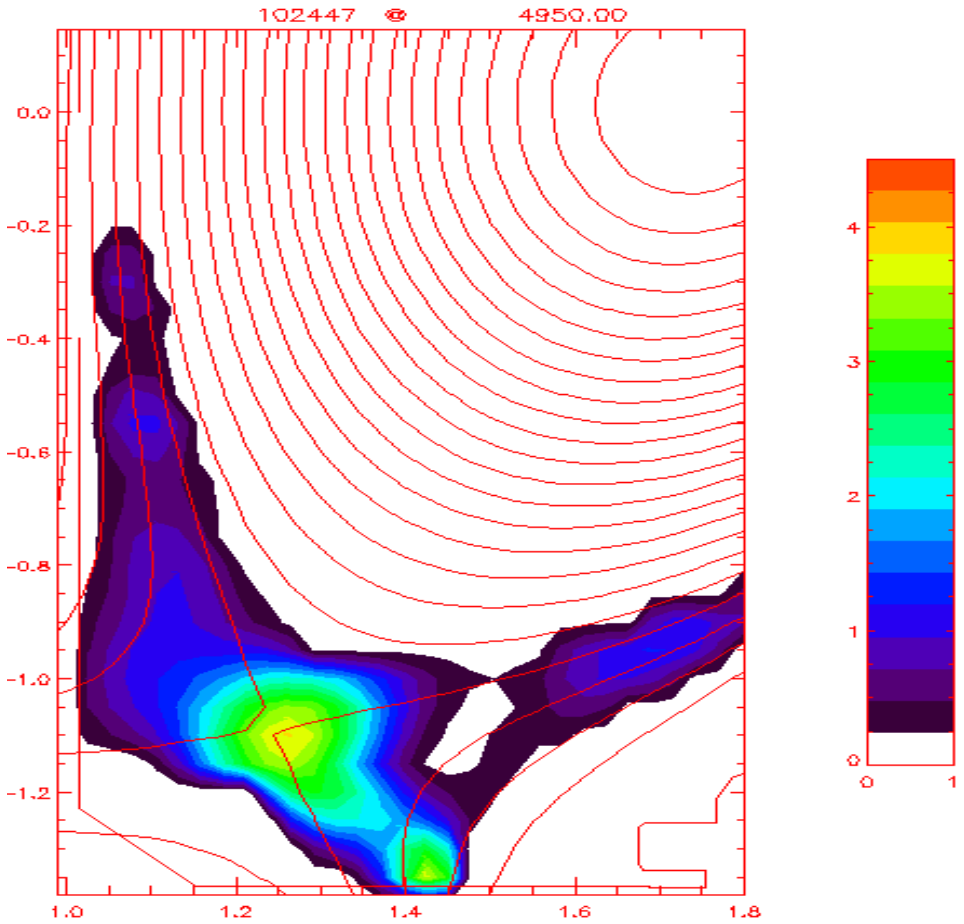
Detached open divertor: Deuterium emission local to outer target near OSP.



- Relative intensity between ISP and OSP similar for both D_alpha and D_gamma

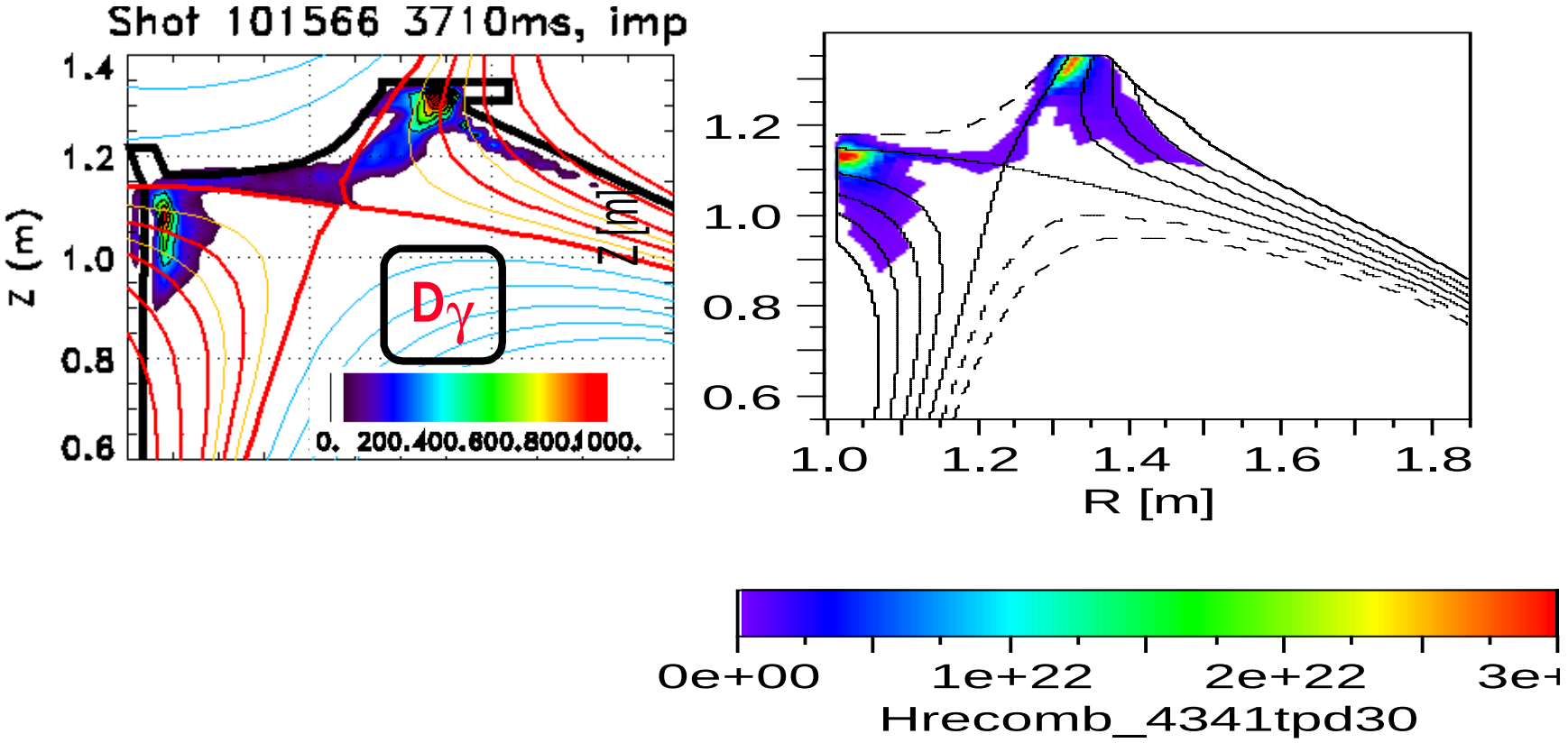
Detached open divertor: Radiated power profile show local peak at X-point and secondary peak outboard of OSP.

- Radiated power distribution:
  - Total: 4.45 MW
  - Core: 1.02
  - SOL: 1.11
  - Inner Div: 0.69
  - Outer Div: 1.63
- Peak near X-point consistent with CIII profile peak
- Peak outboard of OSP consistent with deuterium profiles.



Comparison of UEDGE simulations with closed divertor emission data is beginning (see Wolf poster)

- Dγ in Divertor-2000: shot 101566 and UEDGE simulation
- UEDGE simulations of deuterium profiles match well with image data
- Comparison of UEDGE carbon profiles and emission data in progress (see Jalufka).



Summary & Conclusions

SUMMARY:2D profiles of divertor emission from closed and open divertors can be compared in DIII-D.

- Visible camera systems in both upper (closed) and lower (open) DIII-D divertors are operational.
  - New optical relay system uses no fiber imageguide
  - Neutron browning effects are eliminated (absolute calibration may be possible now)
  - Data can be obtained on all shots
  - Dual camera system (beamsplitter) in both divertors should allow calculation of ionization and recombination zones from D_a/D_g ratios (in progress)
- Identical discharges with ion Grad-B into the divertor have been produced in closed and open configurations.
  - Density ramps to detachment and H-L back transition were done.
  - Evolution of transition to detachment appears to be much slower in closed divertor compared to open divertor (analysis in progress).
- Profiles of carbon and deuterium qualitatively similar in closed and open divertors in attached and fully detached phases. Evolution to detachment appears to be much slower in the closed divertor configuration.