Evolution the 2D Spatial Profile of Visible Emission During an ELM in the DIII-D Divertor

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UCSD

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GENERAL ATOMICS

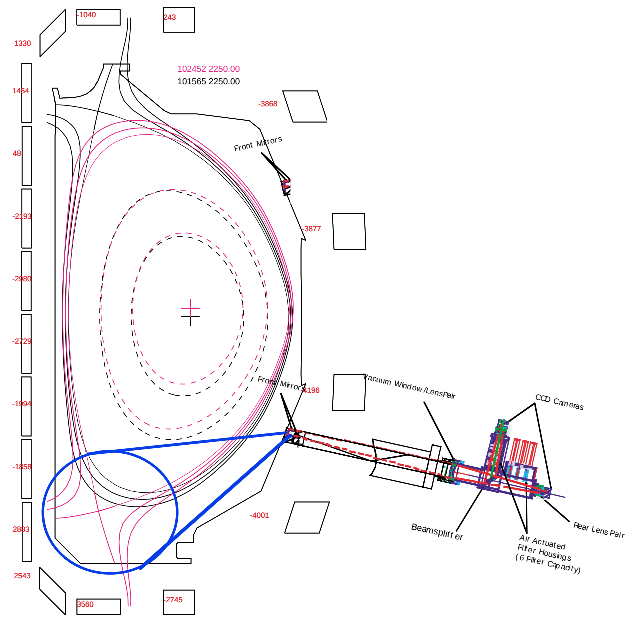
Motivation and Outline

- MOTIVATION - The transient particle and energy loads due to ELMs are a significant problem for the design of divertors in future tokamak reactors.
  - Detailed understanding of the effect of the ELM pulse on the 2D distribution of radiation in the divertor is needed,
    - to validate computer simulations,
    - to investigate mitigation schemes.

- OUTLINE - A new gated, intensified camera with wavelength filters views the lower divertor tangentially in DIII-D
  - Tomographic reconstruction techniques provide 2D ELM profiles
  - Carbon and deuterium emission during ELM evolution
  - Compare with ELM heat flux profiles.
  - Future Plans - obtain the temporal evolution of 2D divertor emission profile during ELMs.

Summary (1)

- First 2D images of divertor carbon and D_α emission during ELM obtained on DIII-D
  - A new fast gated, intensified camera is now operating on the tangential view of the lower divertor in DIII-D
  - Available gate time $\geq$ 1μsec, gain $\leq$ 20,000



- Initial data images in D_α and CIII visible emission show large changes during ELMs compared with the profiles between ELMs in the divertor
  - Substantial broadening of D_α at the outer target
  - Transition of CIII emission from strikepoints to X-point
- Qualitative comparison of TTV data with line integrated measurements and heat flux profiles during ELMs indicates consistency
  - Verification and detailed analysis awaits dedicated experiments.

Summary (2)

- Dedicated 2002 experiments proposed to study divertor and main chamber SOL ELM effects
  - Optimize large Type-I ELMs at low frequency
  - External triggering of camera with variable delay to synchronize camera gate on ELM evolution
  - Correlate camera images with other fast lower divertor diagnostics
    - Target j_{sat}, n_e, t_e - Floor probes, 19 channels, 1 MHz
    - Heat flux radial profile - IRTV (line scan) , 9.6 kHz
    - Line integrate emission - Filterscopes, 6 channels, 100 kHz
    - Volume n_e and T_e - Div. Thomson Scattering, 8 channels, 1ns @ 20 Hz
  - ELM evolution during propagation in the divertor should be measurable
  - Data will provide critical test of ELM simulation models
- Will attempt to image ELMs simultaneously at midplane SOL and in divertor.

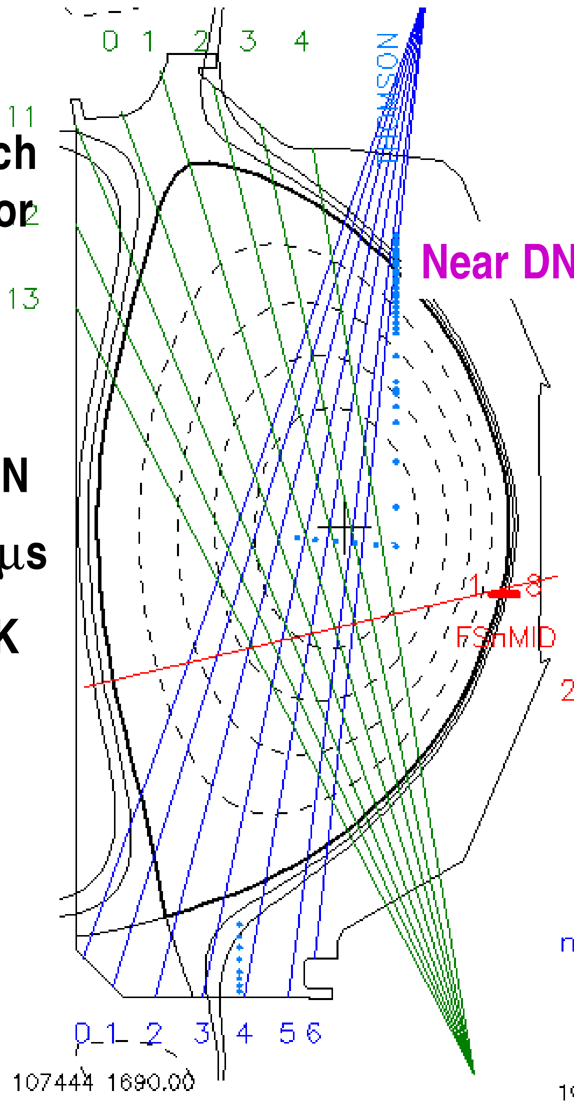
Discharge Parameters and Evolution

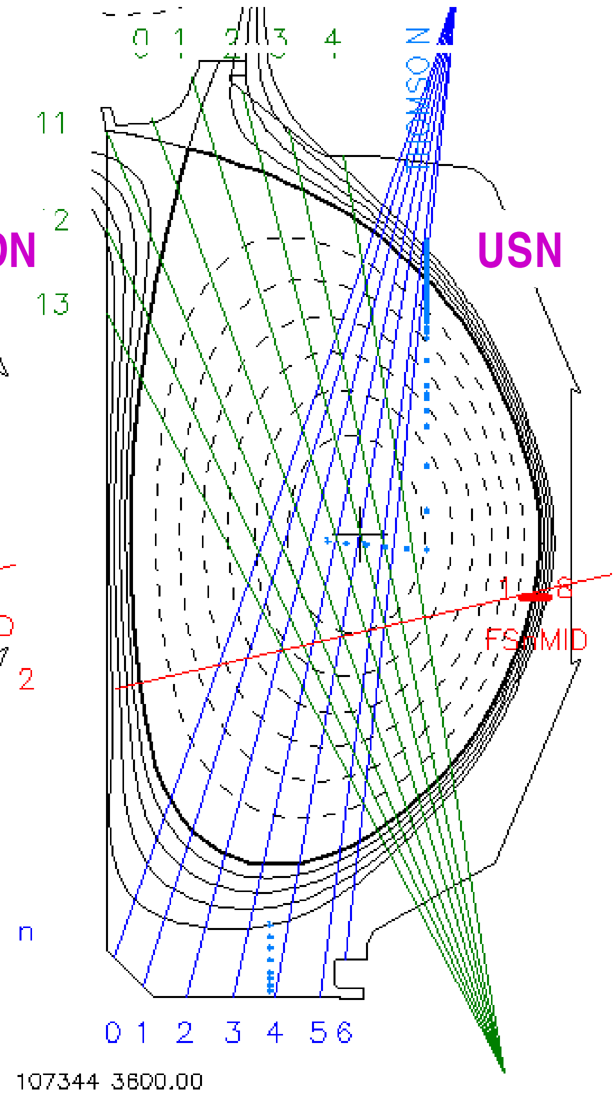
Emission during ELMs obtained in lower divertor of near DN (D_α and CIII - 465nm) and USN discharges (CIII only)

- **Discharges near DN**
  - Primary X-point may switch from lower to upper divertor at some times
- **Gated camera for this experiment:**

	DN	USN
– Integration time	6	100 μs
– Approx. gain	10	5 K

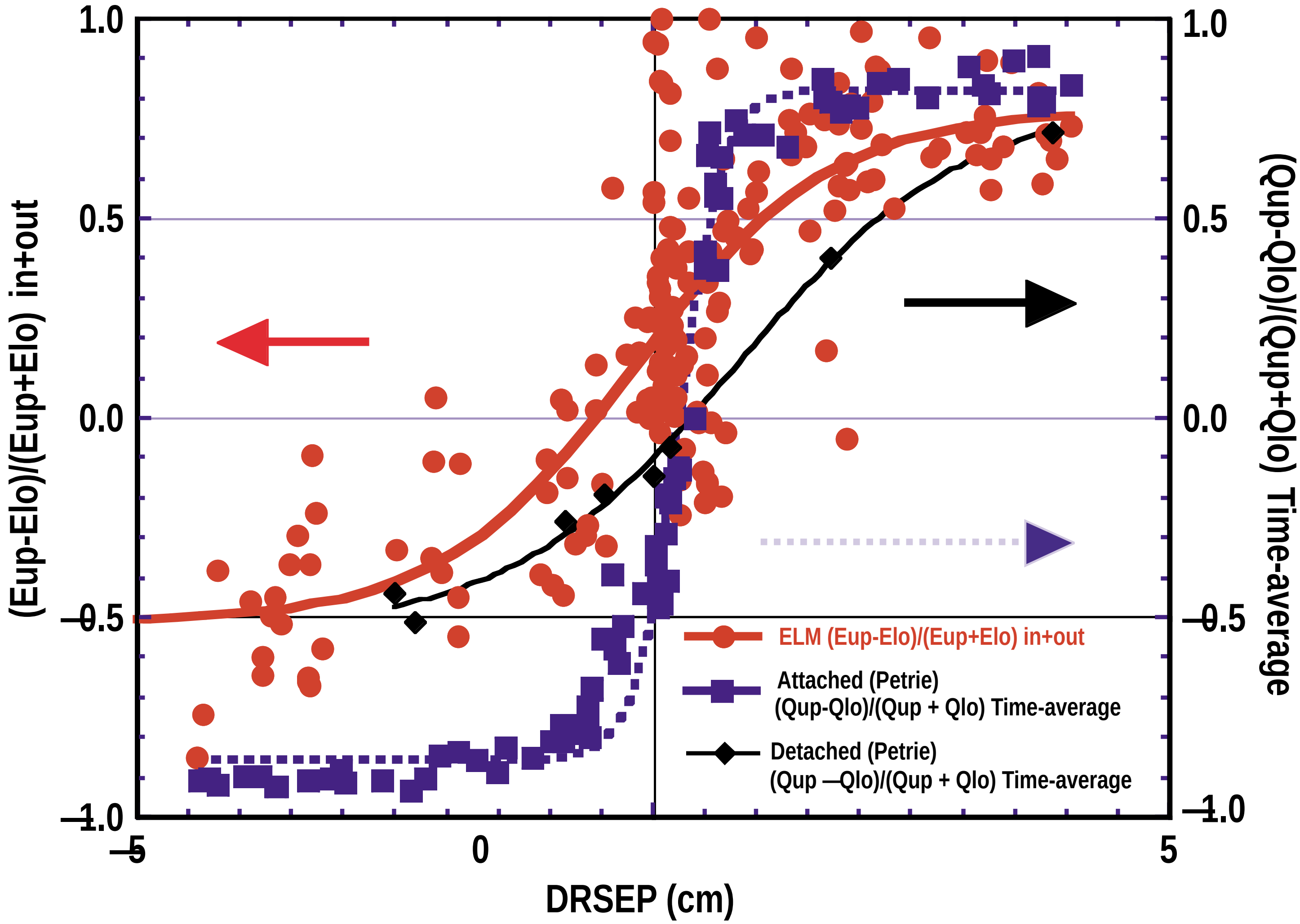
  - 17 msec field rate (30 frames/sec)
  - Internally triggered (not syncronized to ELMs)
  - Frame time $\pm$ 5 ms



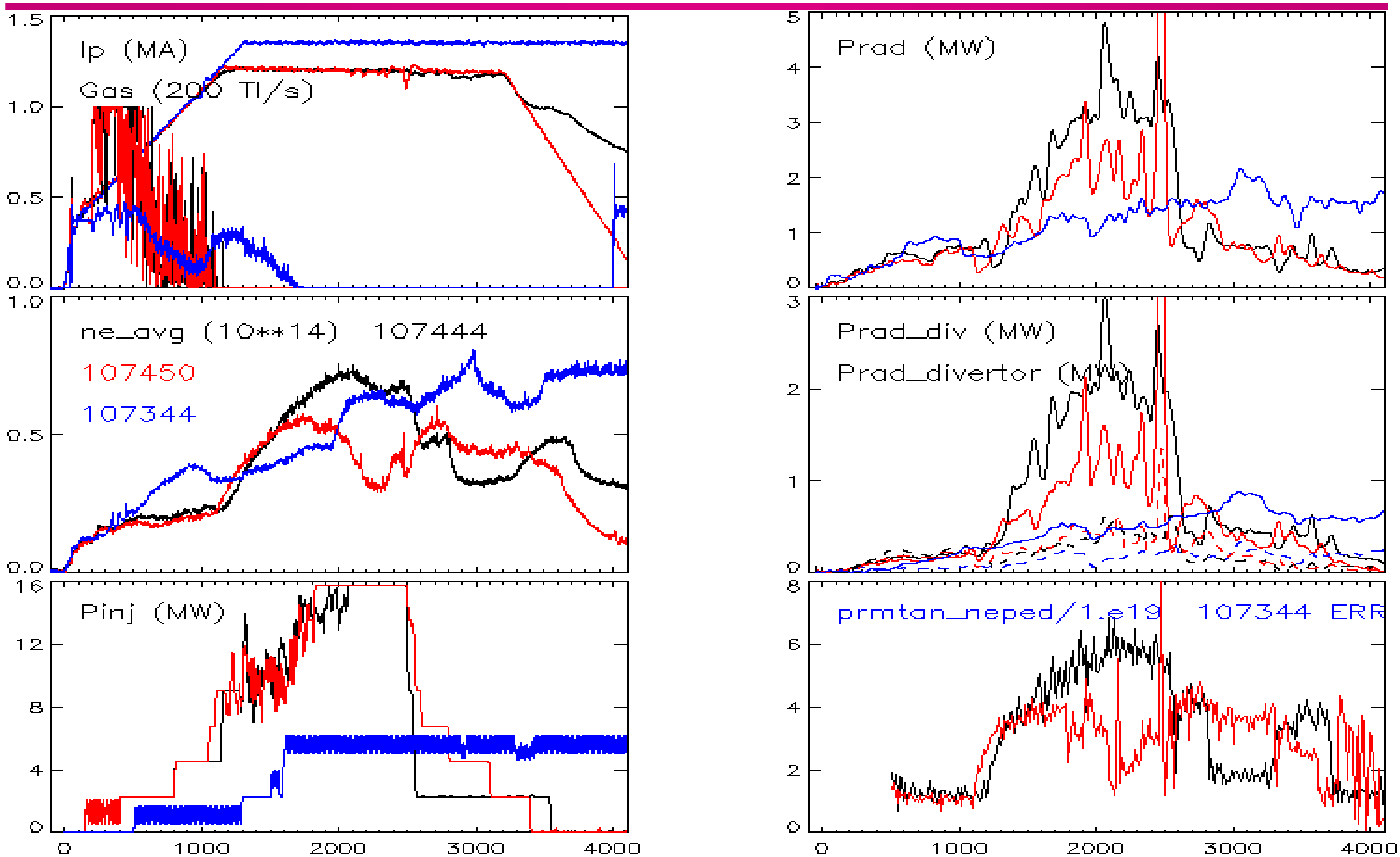


Shift of ELM energy from upper to lower divertor is not as sensitive to dRsep as for peak time averaged heat flux

Lasnier PSI00



Time history shows well matched DN discharges during time of CIII and D_α ELM emission images.



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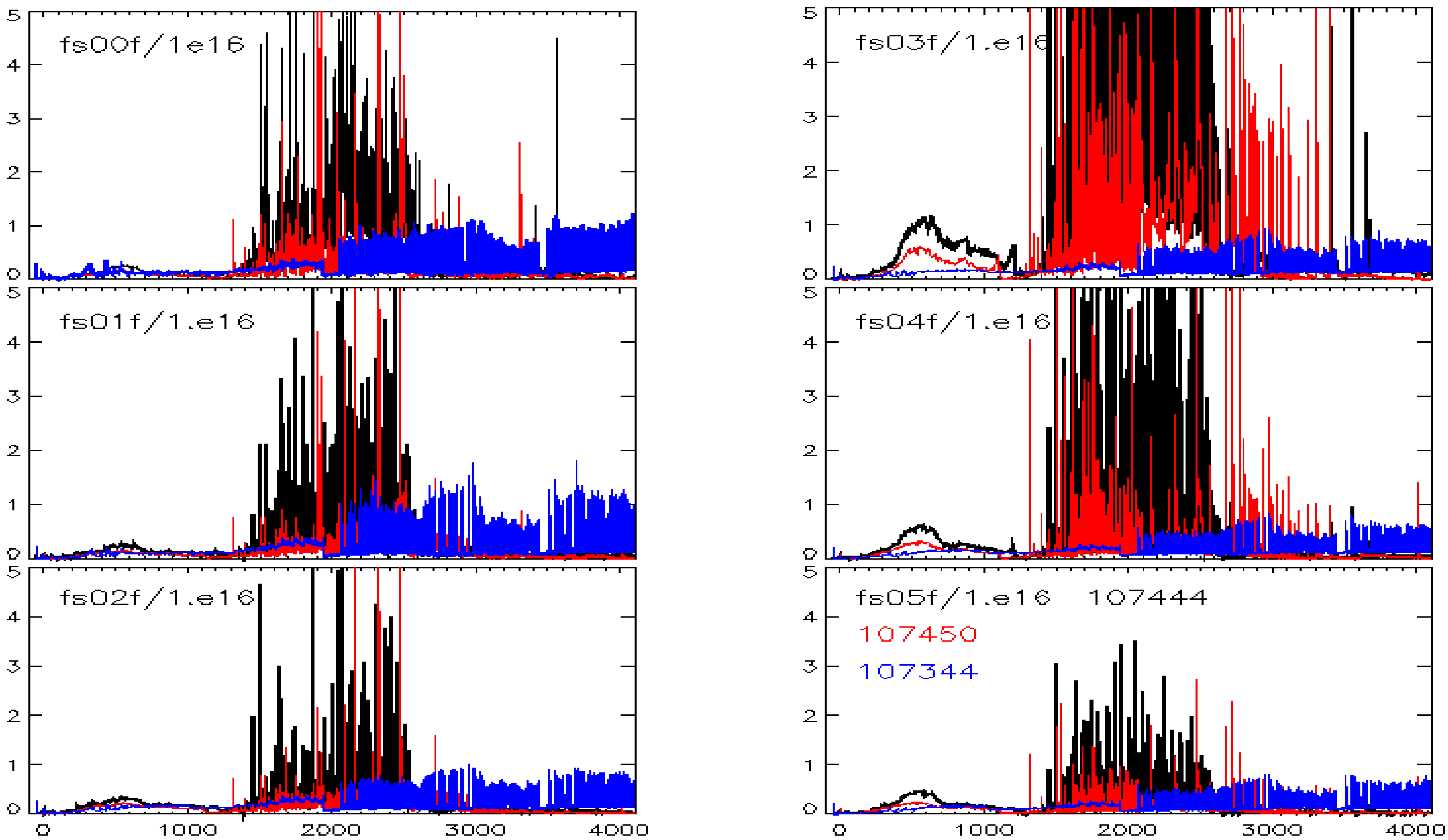
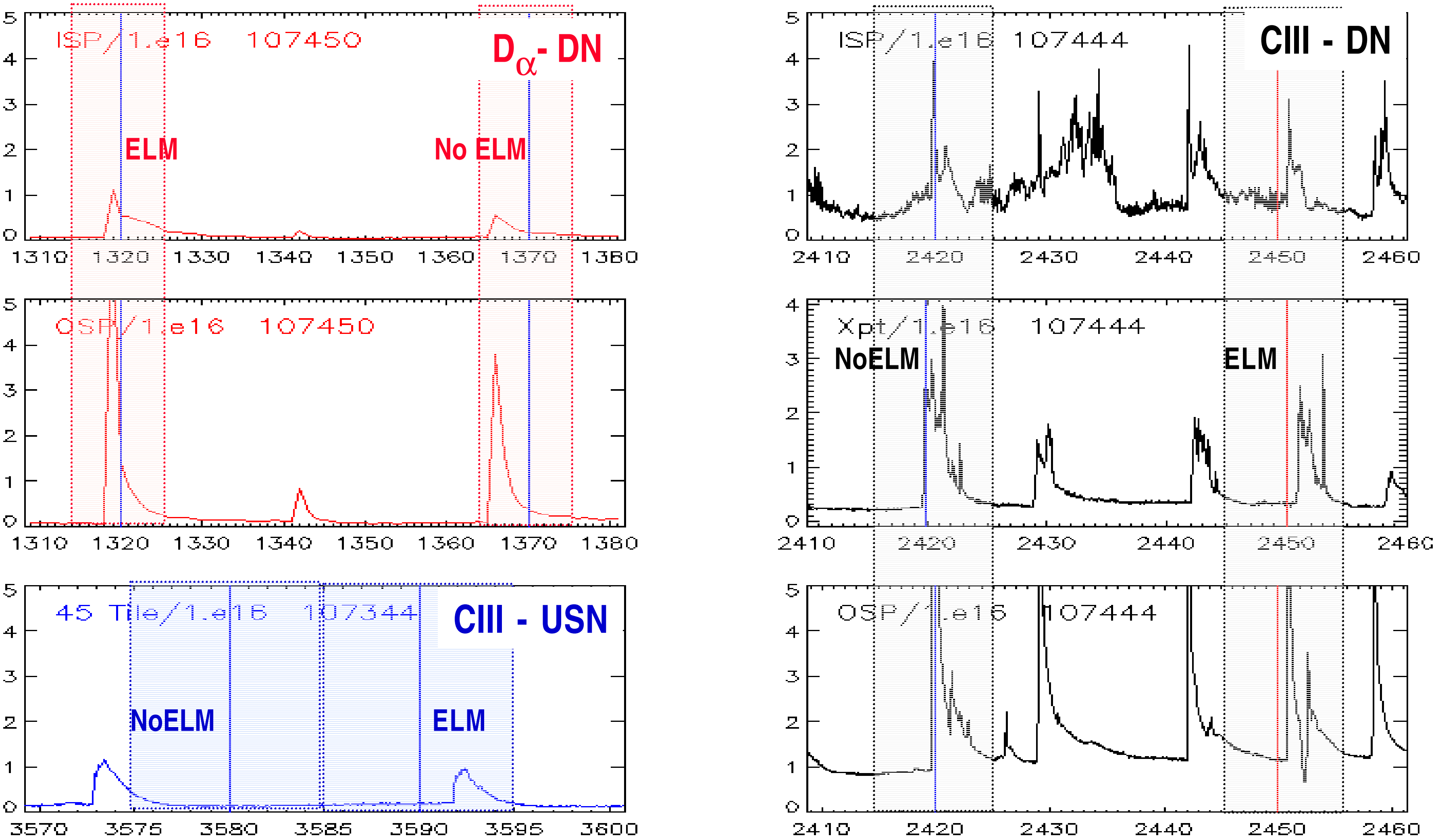
Line integrated fast D_α shows larger ELMs at OSP (fs03) than at ISP(fs00) in both LSN discharges.



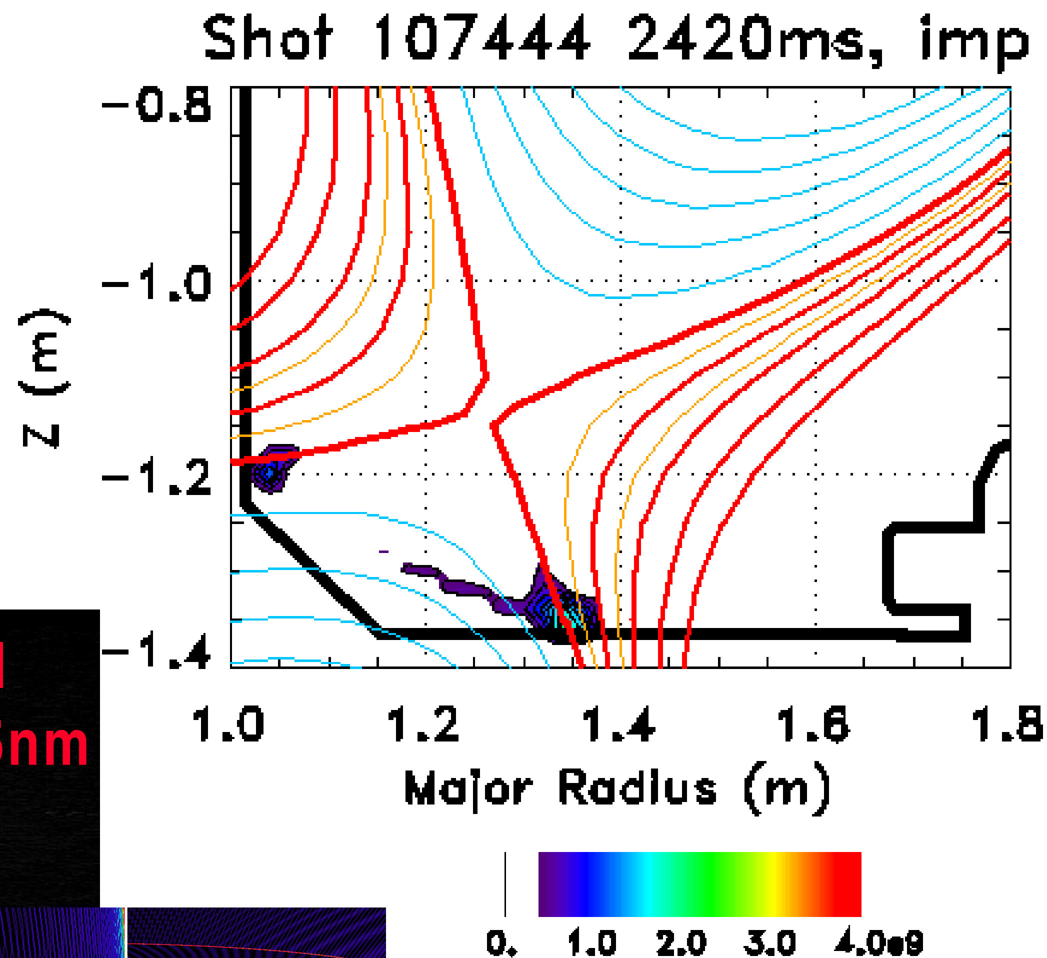
Line integrated fast D_α shows larger ELMs at OSP (fs03) than at ISP (fs00) in both DN discharges.

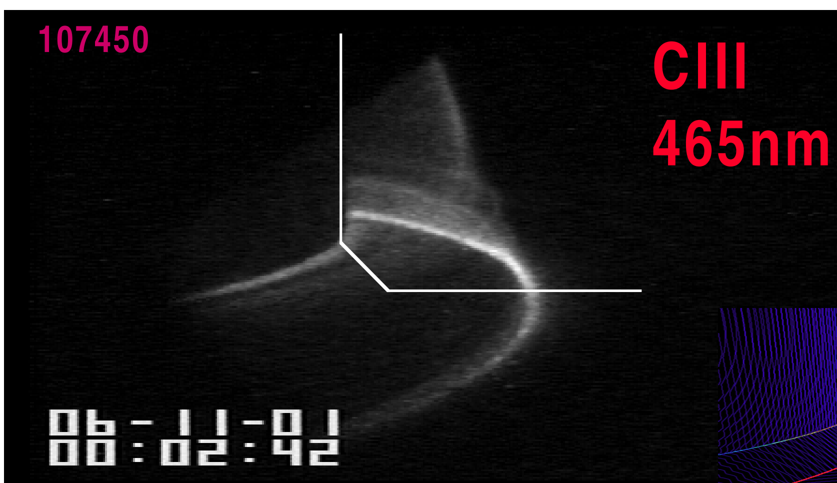


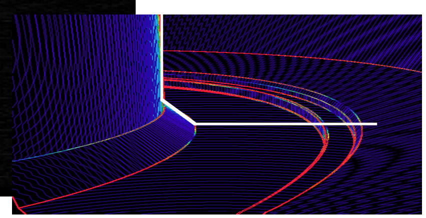
ELM Emission Reconstructions - DN

CIII visible emission between ELMs localized near strikepoints

- High power ELMy plasma with attached divertors
  - 100Hz ELMs vs. 60 Hz camera field rate
  - Between ELM image not verifiable



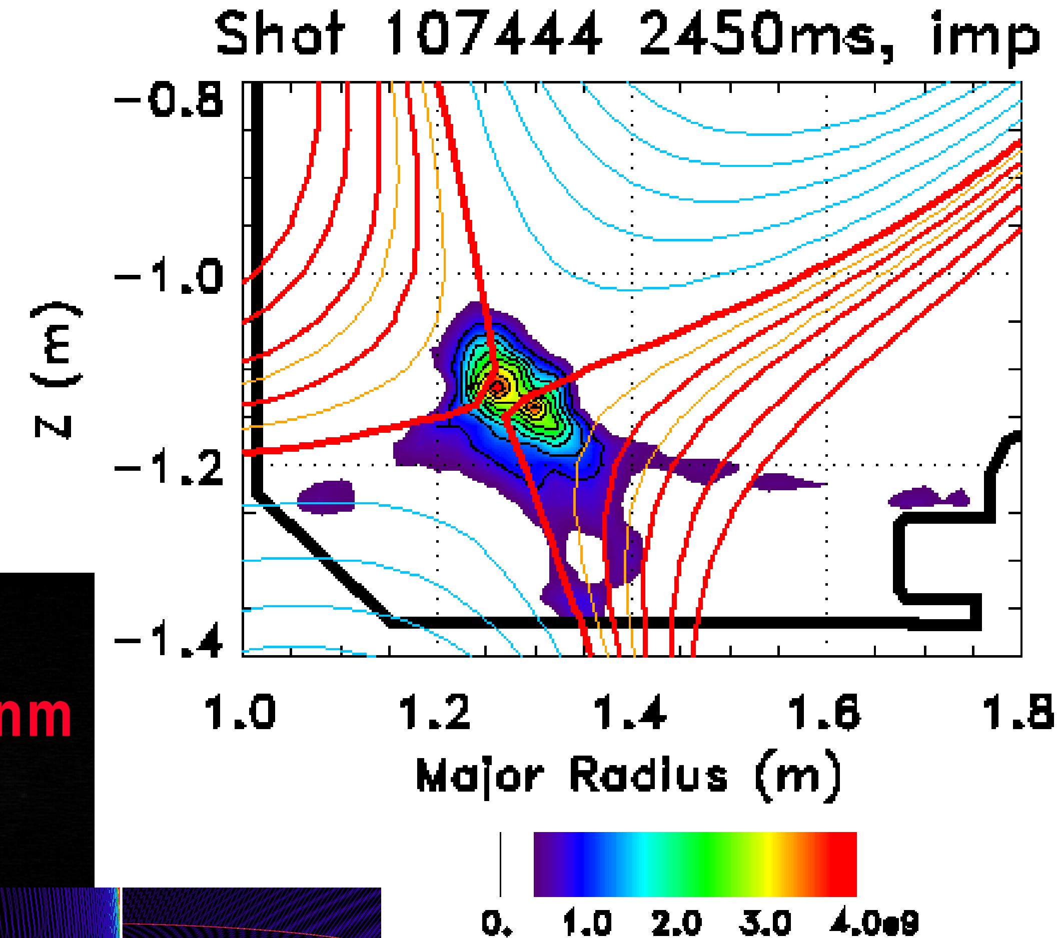


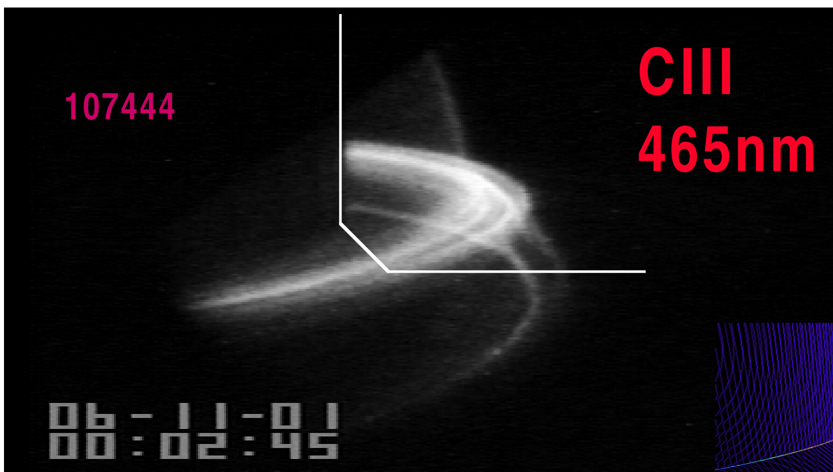


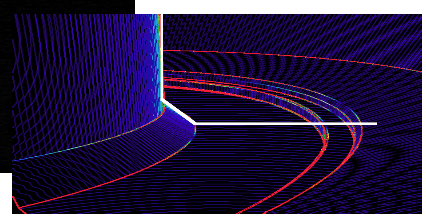
Tangential view

CIII visible emission during an ELM substantially different from between ELMs

- Emission near strikepoints reduced more than 2.5x
- Local emission near X-point increases factor of 20
- Profile resembles time averaged detachment profile

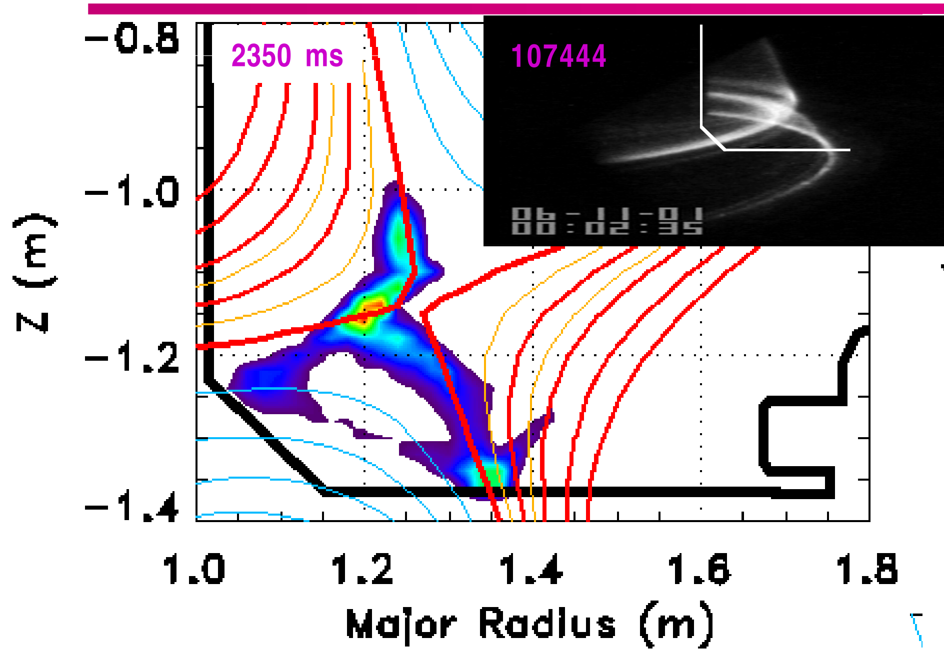


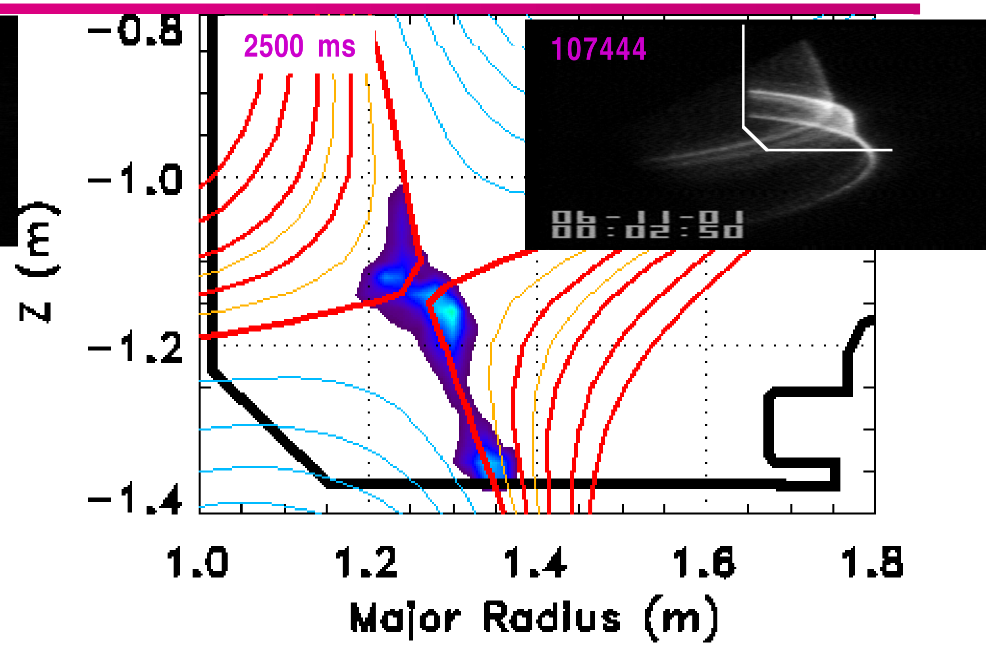


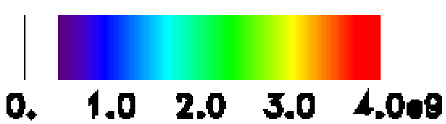


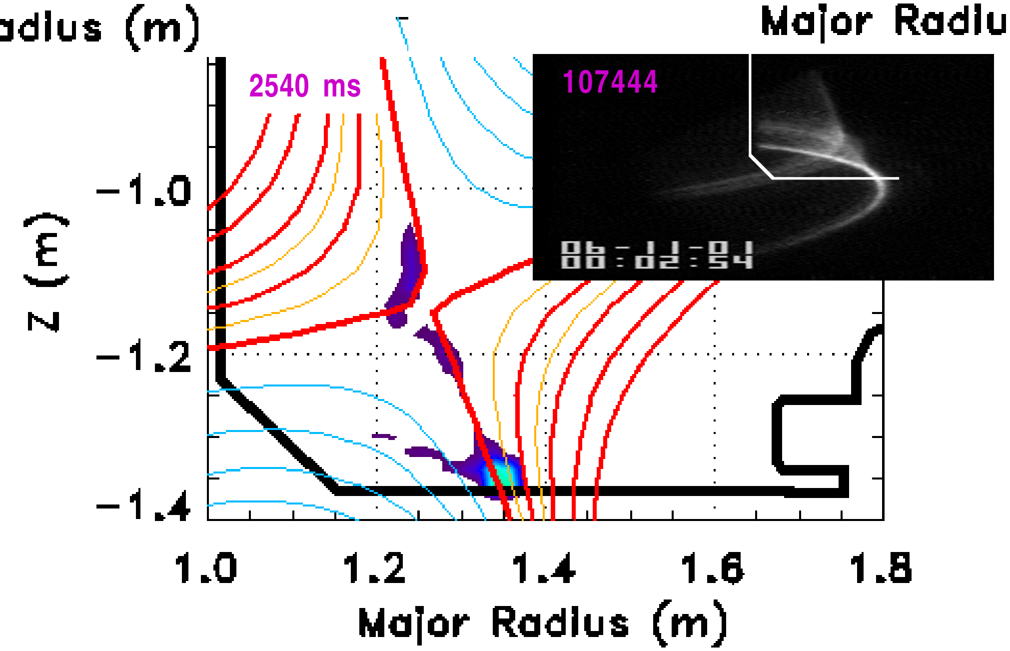
Tangential view

Other CIII visible images during ELMs show variety of profiles from different ELMs and timing during an ELM.









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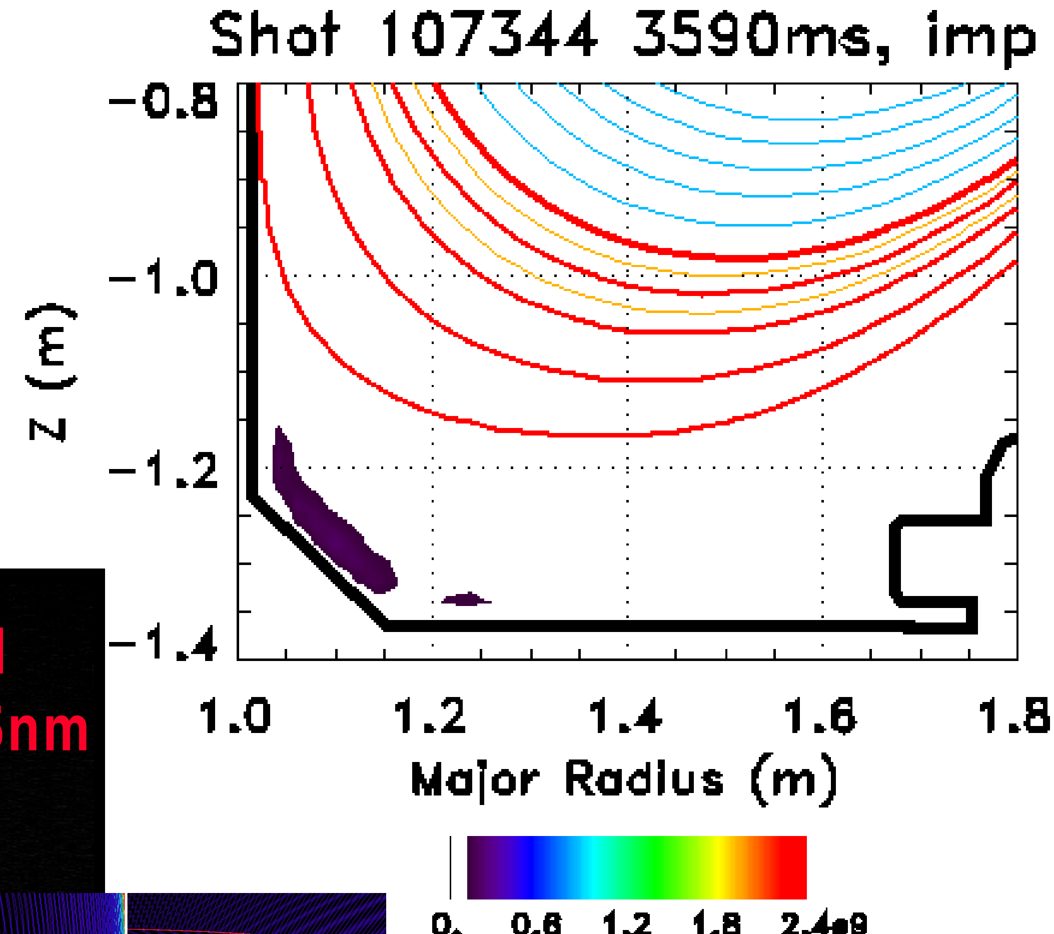
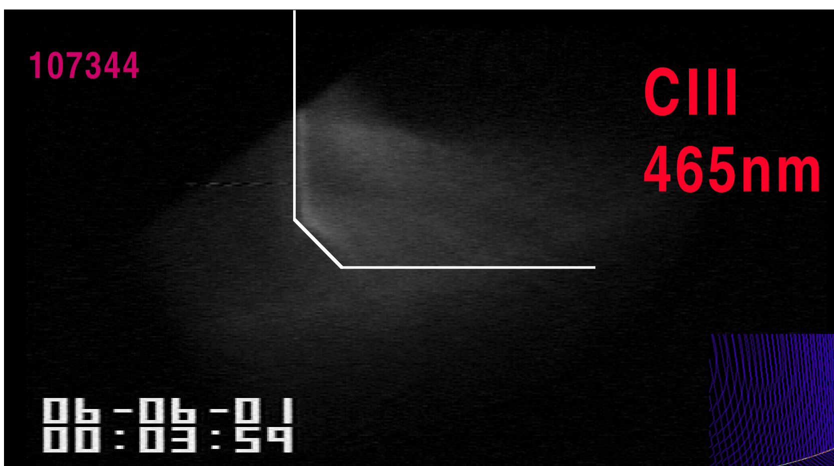
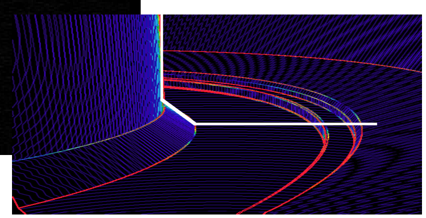
ELM Emission Reconstructions - USN

Lower diver tor CIII visible emission between ELMs in USN plasma at low intensity

- Low intensity seen on most camera frames



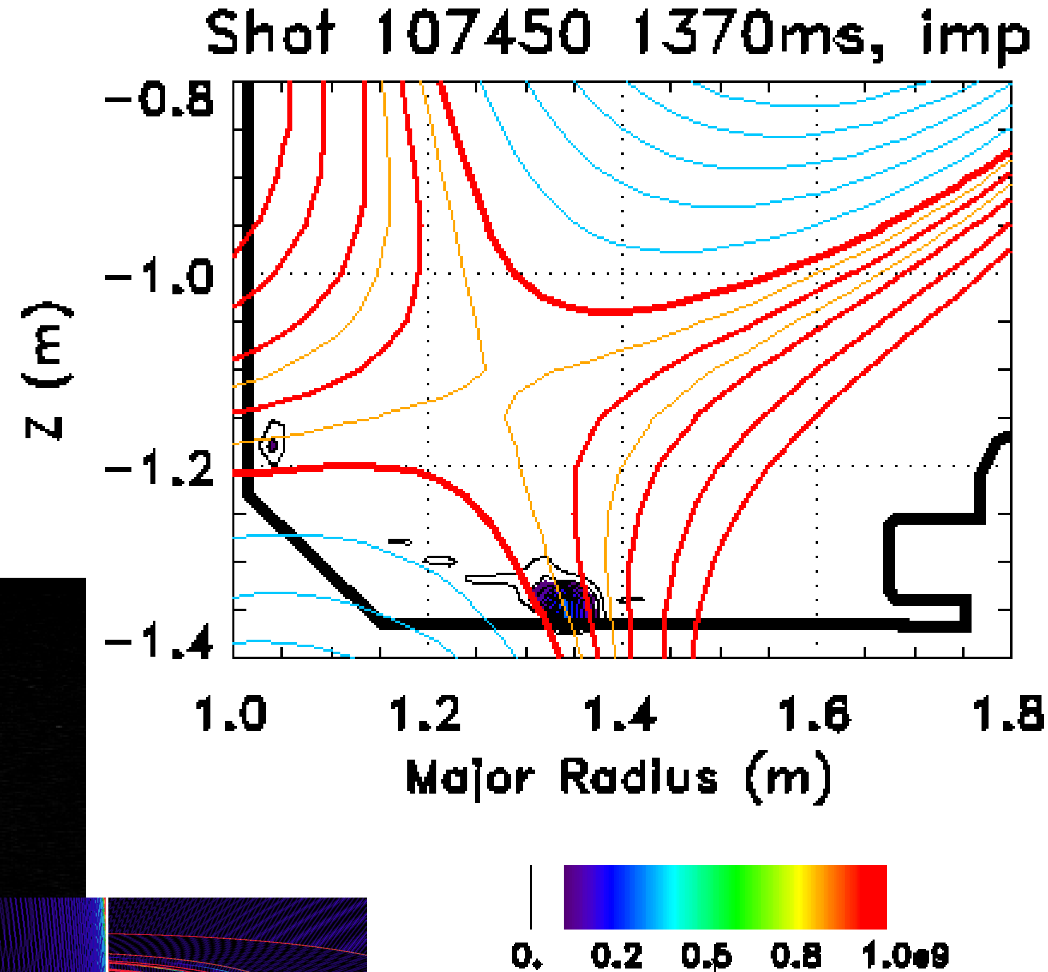


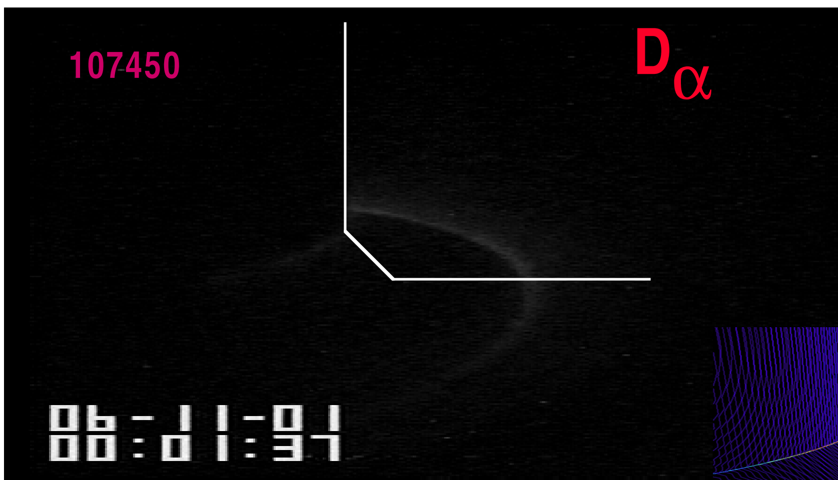


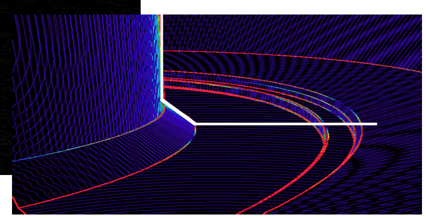
Tangential view

D_α emission between ELMs local to outer strikepoint

- Consistent with line integrated measurements
  - Some residual ELM effect may remain

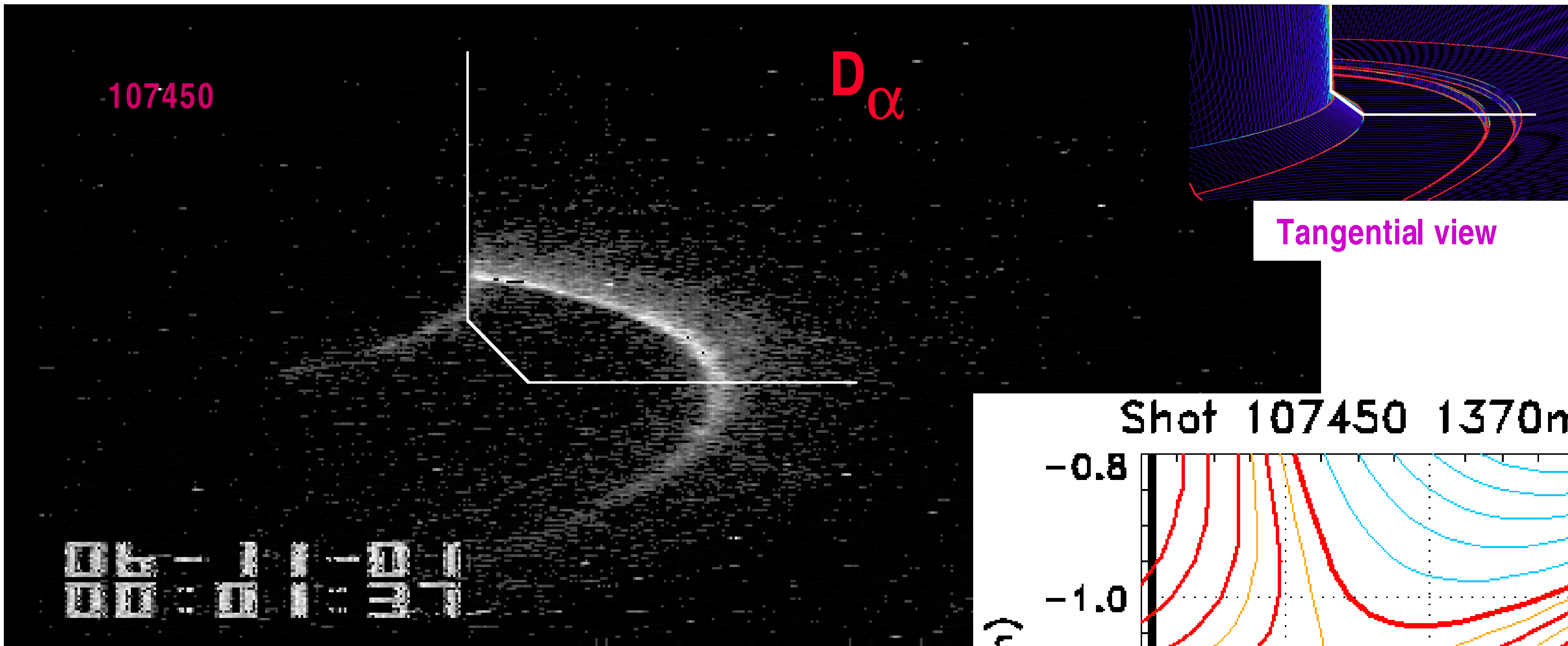


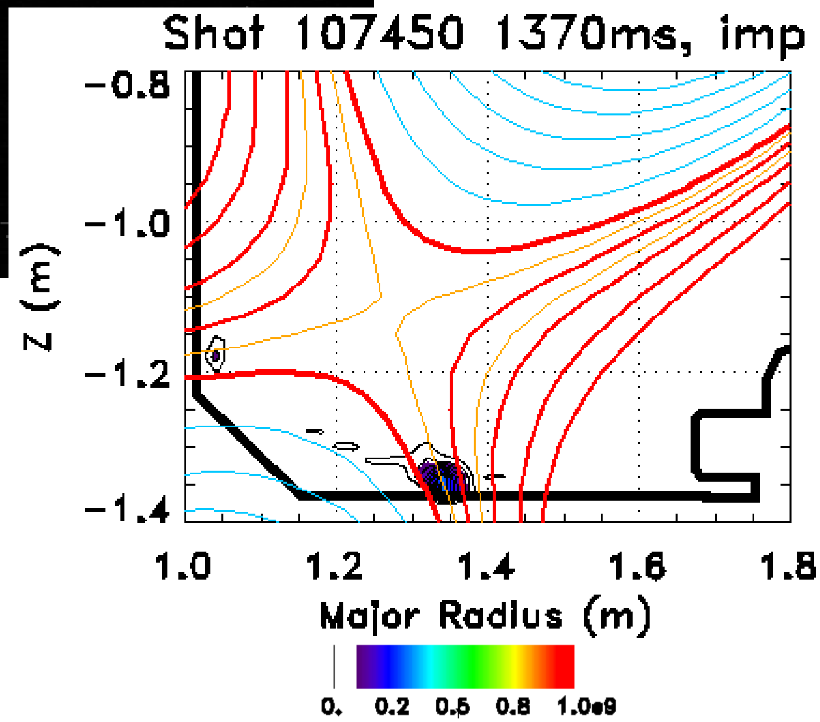




Tangential view

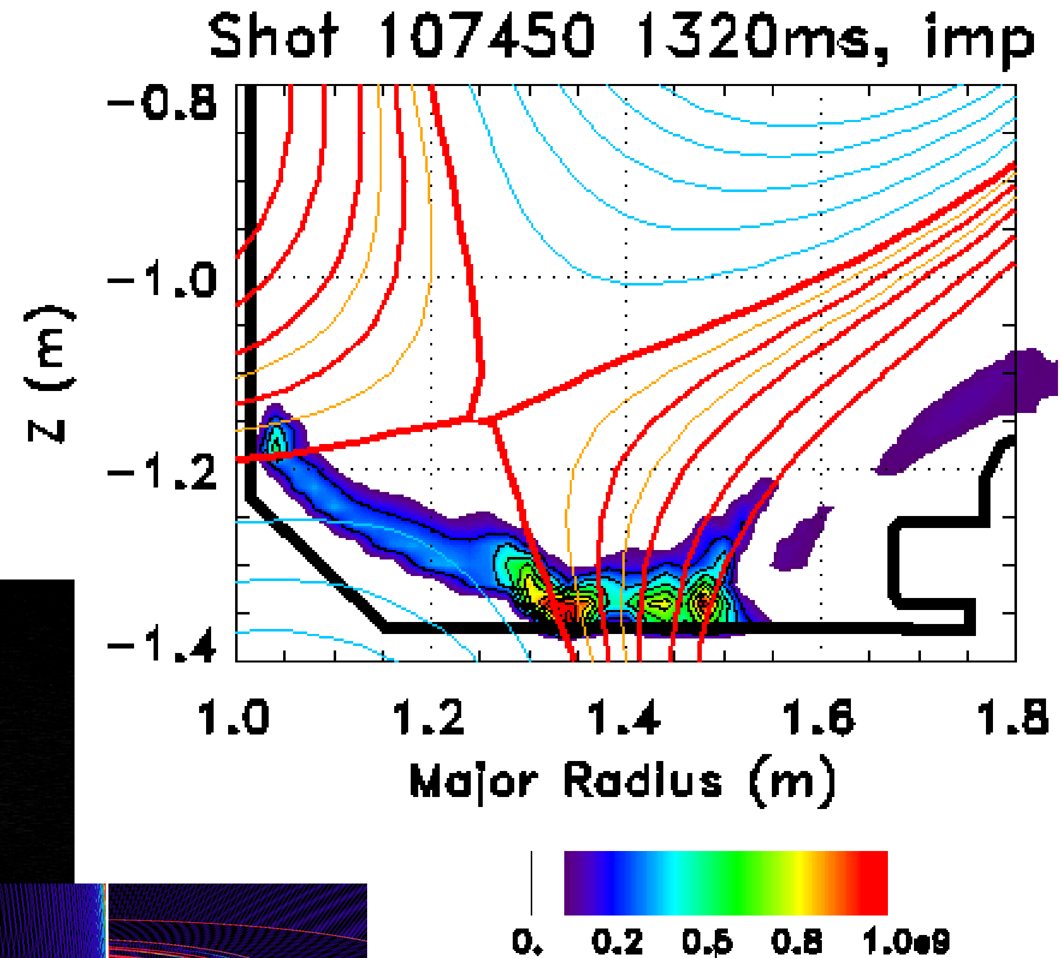
D_α between ELMs intensity enhanced by 10x

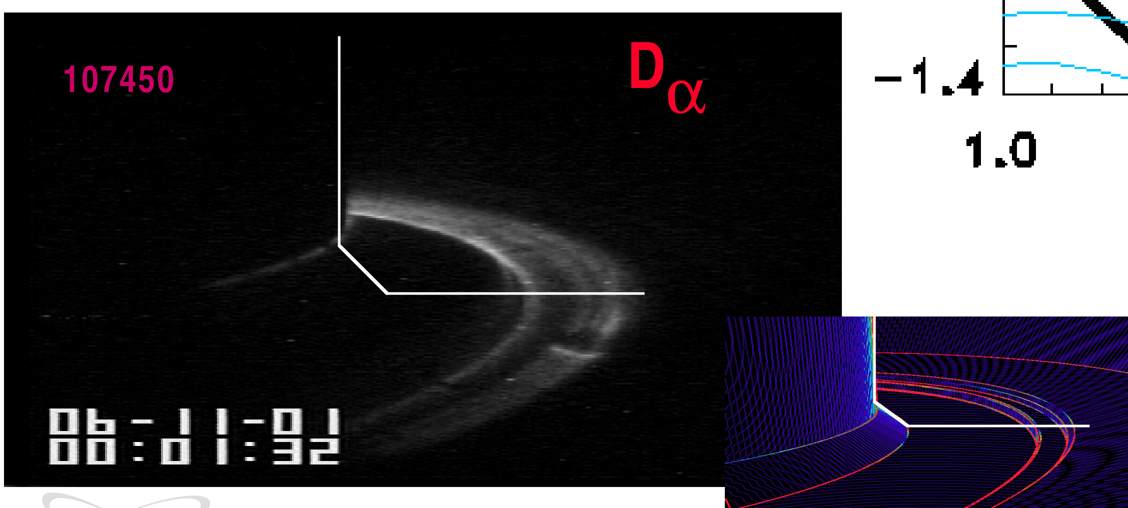




D_α emission during an ELM shows 15 cm broadening of profile in the outer SOL at the target

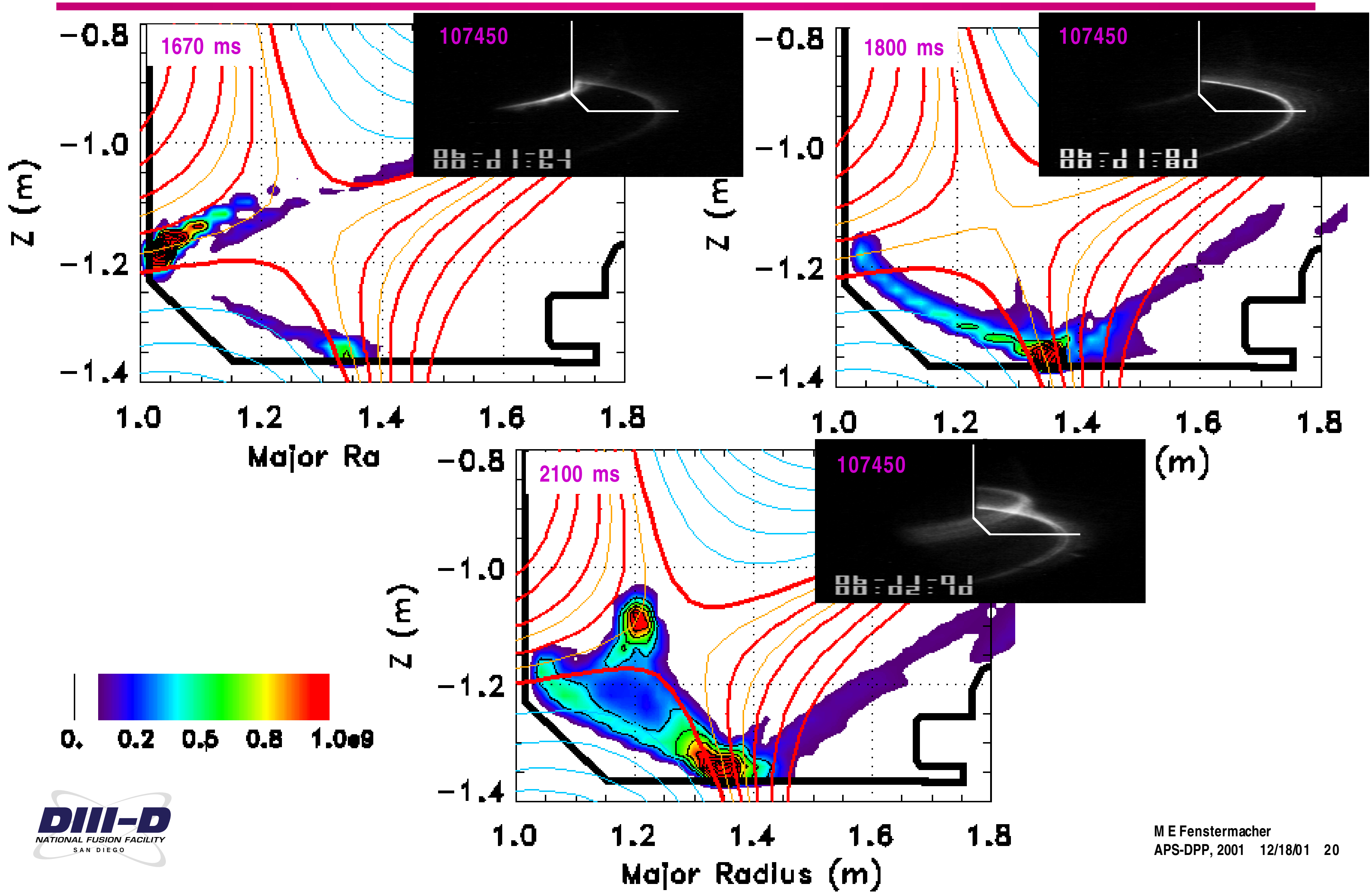
- **Broad profile reaches 4 cm flux surface mapped to midplane**
  - Intensity 40x higher than between ELMs





Tangential view

Other D_{α} profiles during ELMs show high intensity at either strikepoint or near the X-point



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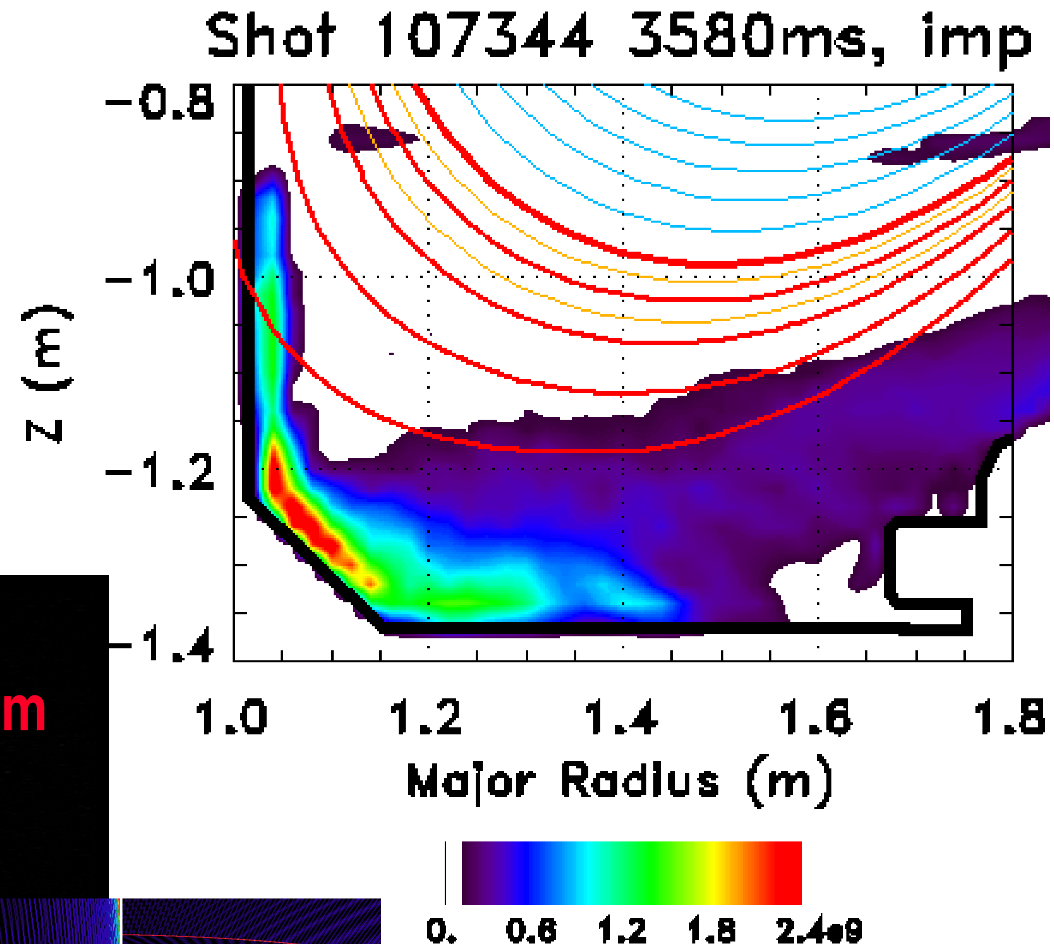
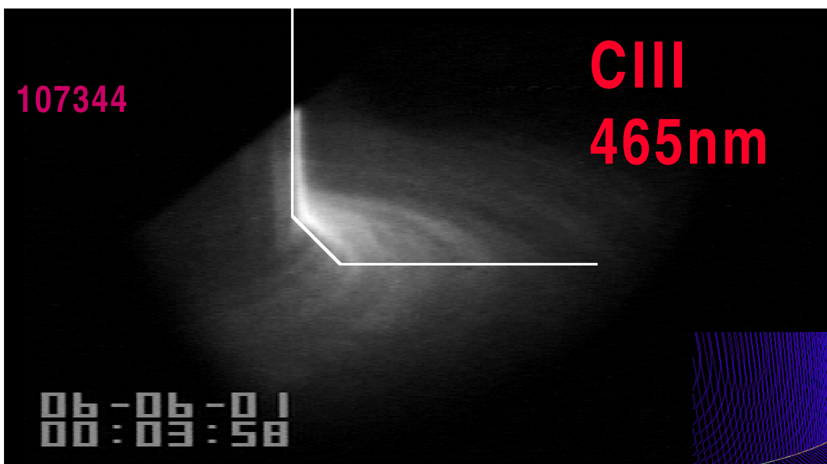
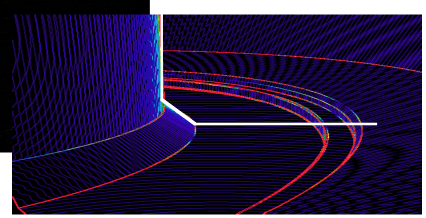
Lower divertor CIII visible emission during an ELM in an USN plasma 10x emission between ELMs

- Emission (source?) locaized to inner wall and 45 deg. tiles







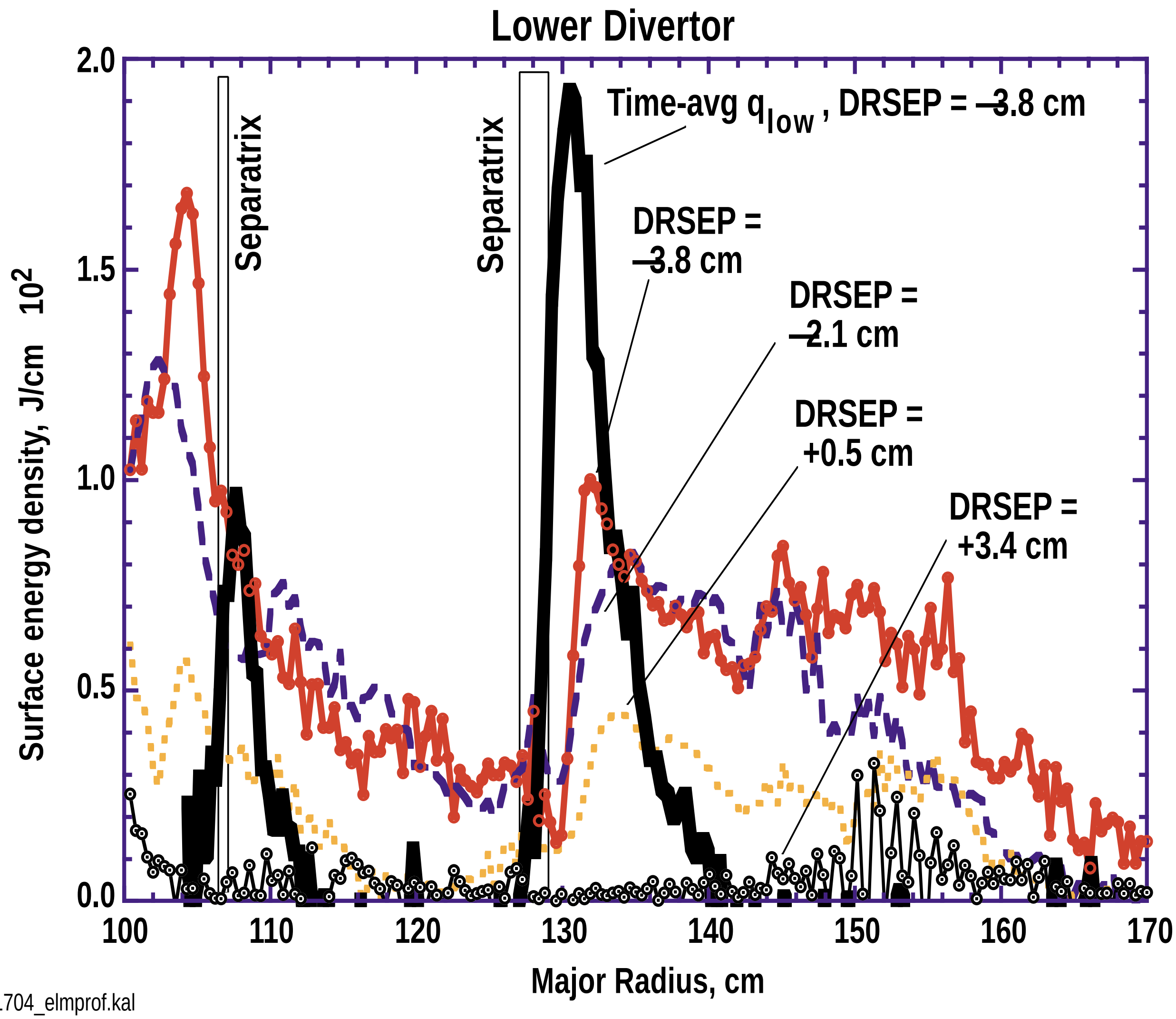
Tangential view

Comparison with Target Profiles

Lower divertor heat flux in near DN shape shows broad profiles during ELMs

Lasnier PSI00

- Discharge had dRsep sweep from LSN to USN
- Near DN
  - dRsep = 0.5 cm (yellow curve)
  - lower heat flux width is 2.5x broader than time averaged heat flux width



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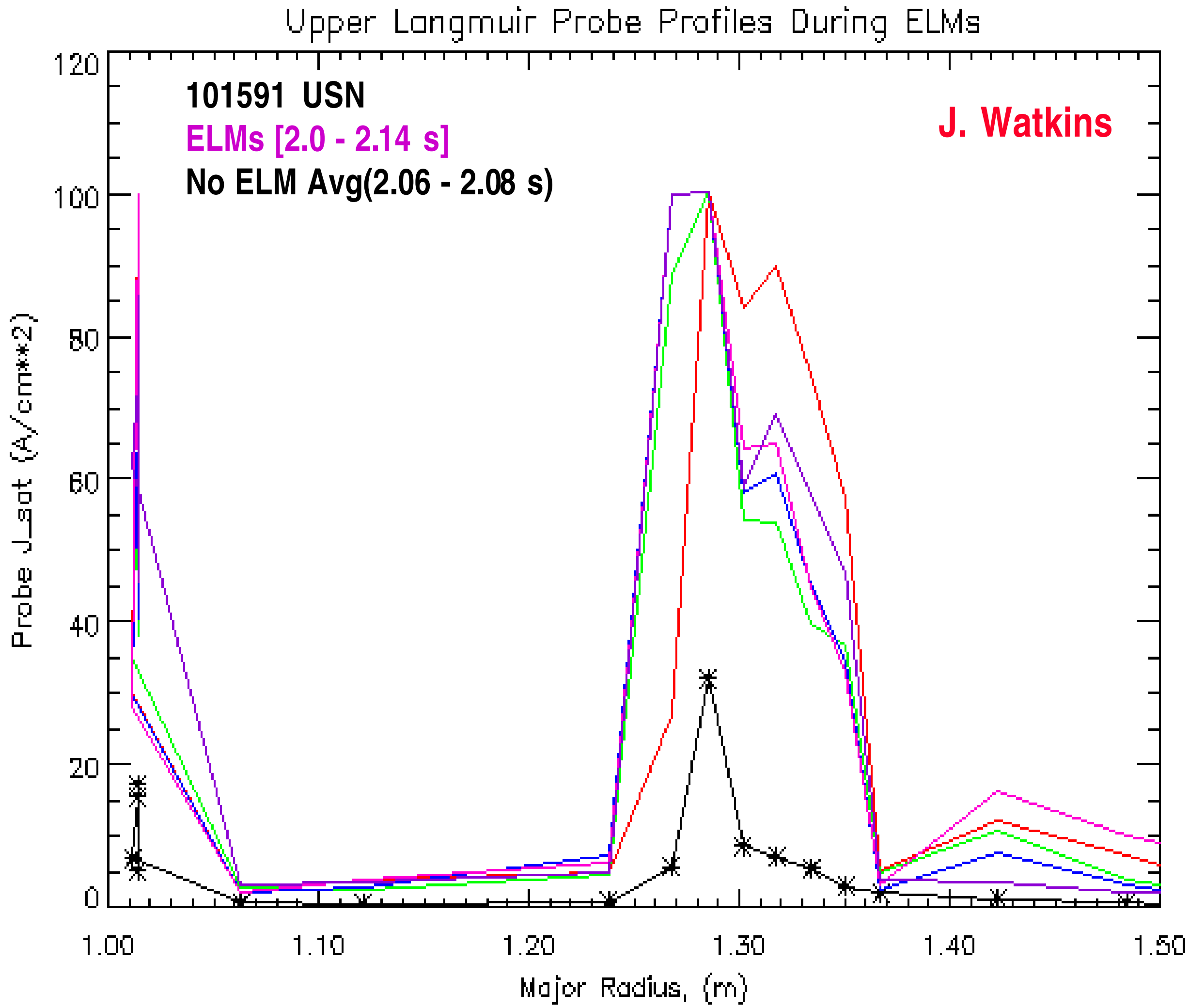
Target plate Jsat from probes also shows broad profiles during some ELMs

- Data from upper divertor probes
- Ion Grad-B drift toward upper divertor
- Pinj ~ 7 MW ELMing H-mode
- See J. Watkins poster LP1.035 for more details



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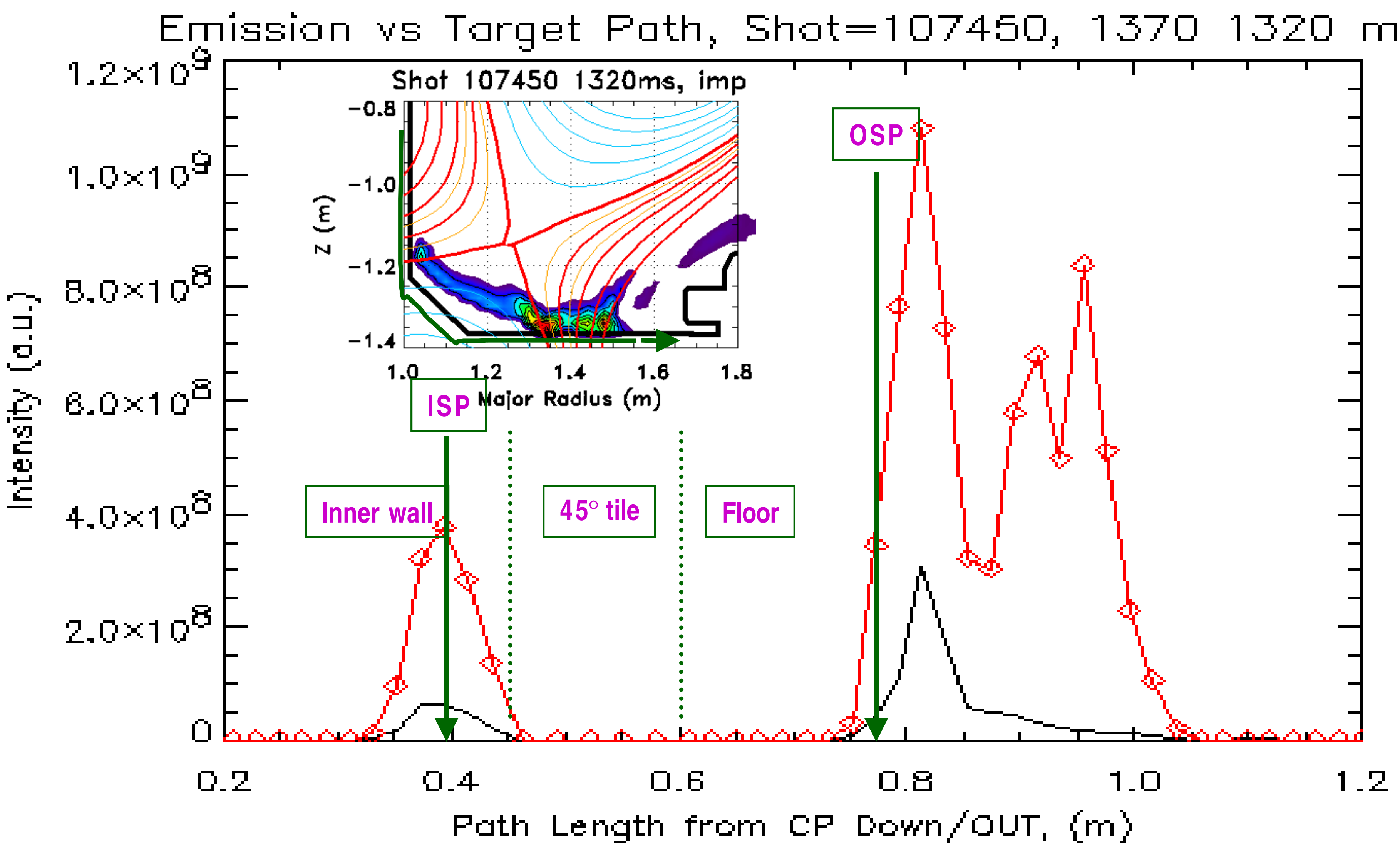
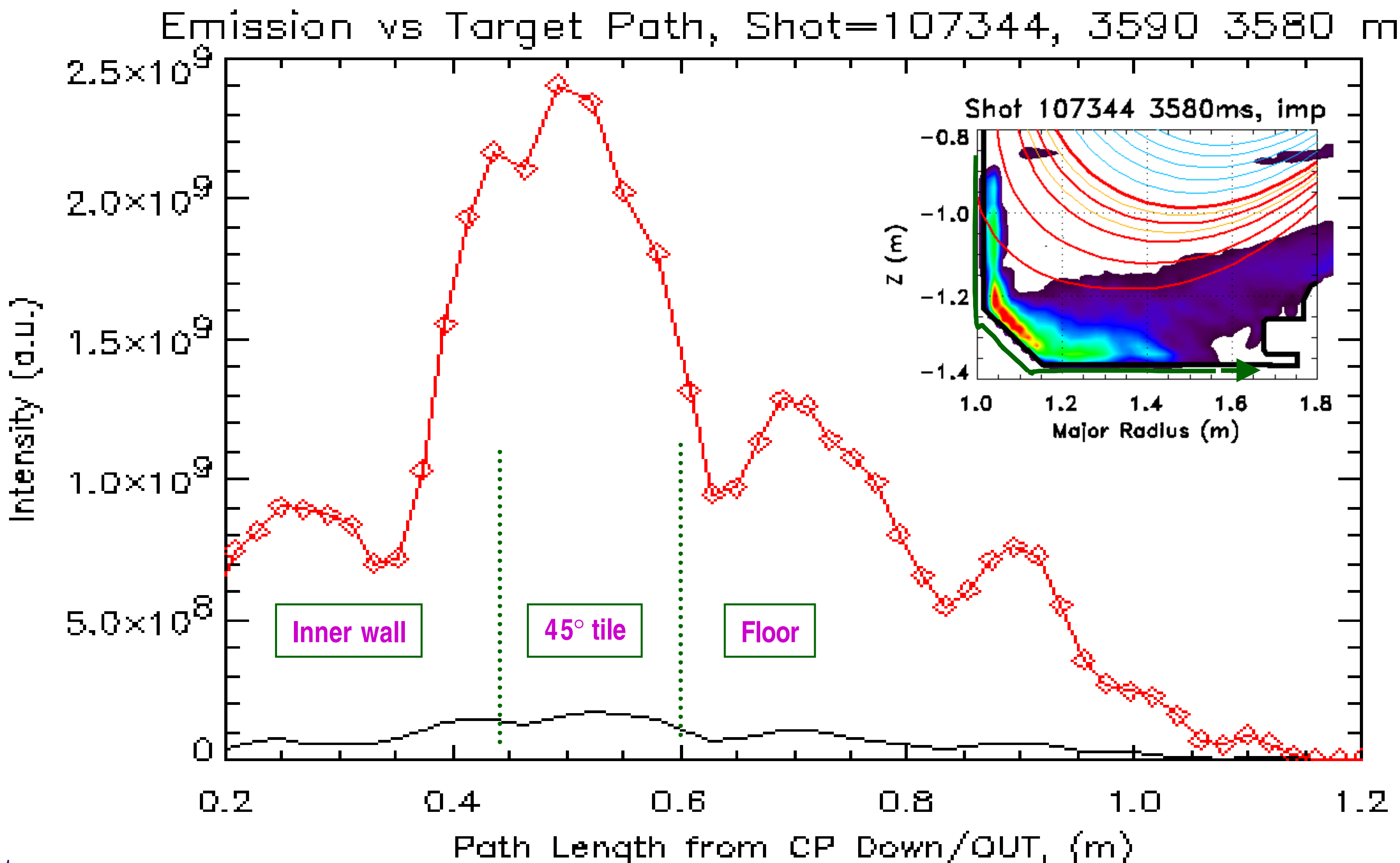
Broad D_α emission on outer target during ELM similar to broad heat flux profiles observed previously



CIII intensity near 45 degree tile during ELM is ~10x higher than between ELMs



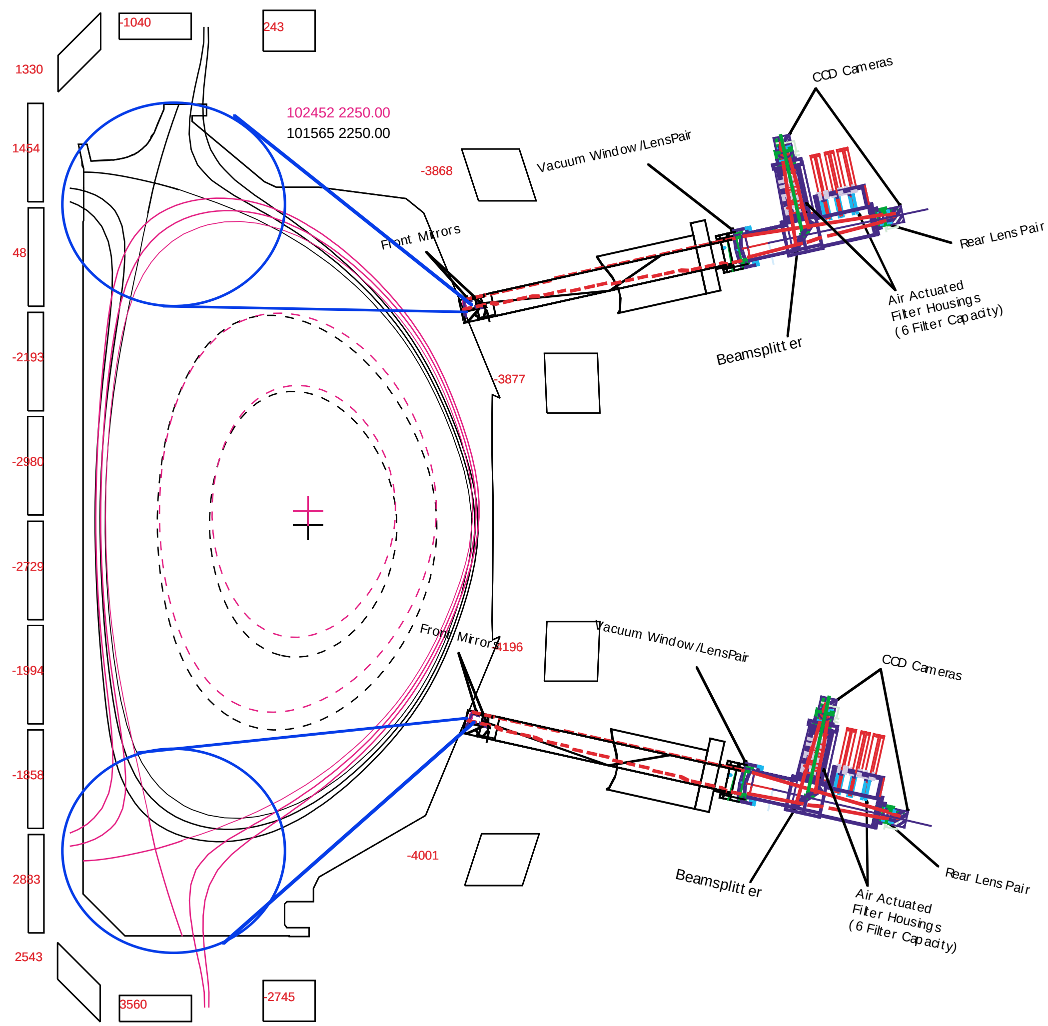
Summary and Future Plans

Summary

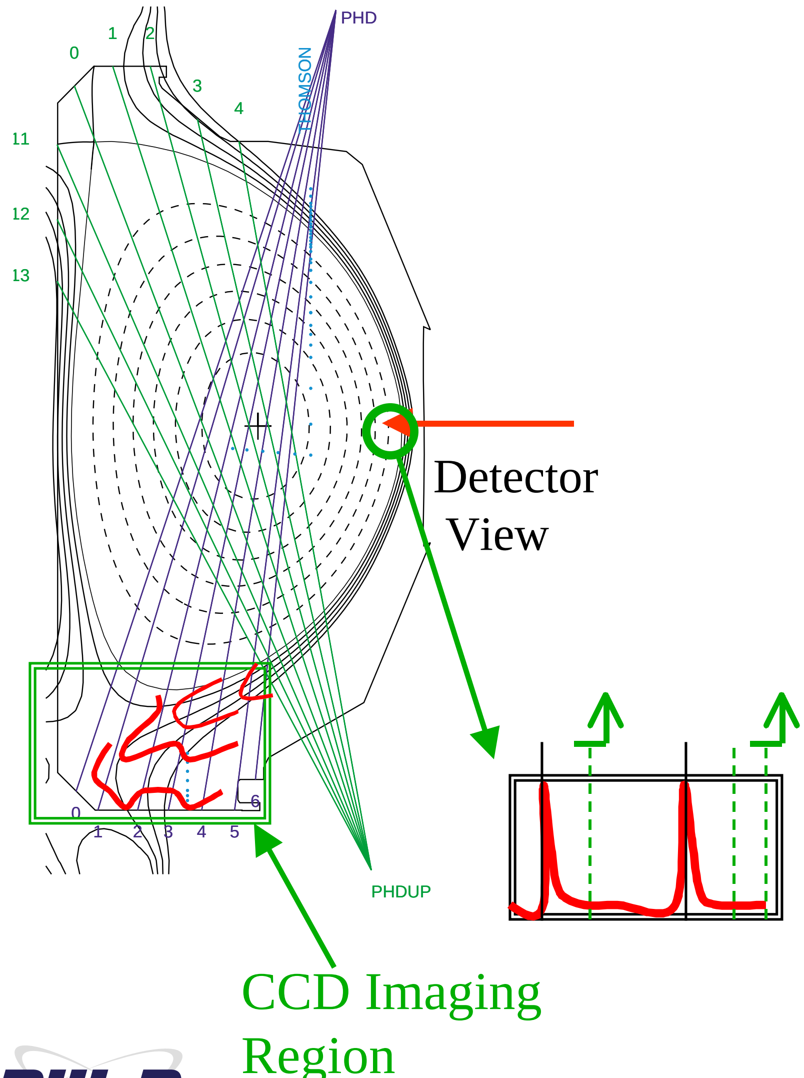
- A new fast gated, intensified camera is now operating on the tangential view of the lower divertor in DIII-D
  - Available gate time $\geq$ 1μsec, gain $\leq$ 20,000
- Initial data images in D_α and CIII visible emission show large changes during ELMs compared to the between-ELM profiles in the divertor
  - Substantial broadening of D_α at the outer target
  - Transition of CIII emission from strikepoints to X-point
- Qualitative comparison of TTV data with line integrated measurements and heat flux profiles during ELMs indicates consistency
  - Verification and detailed analysis awaits dedicated experiments.
- Future plans include external triggering of camera with variable delay to synchronize camera gate on ELM evolution
  - ELM evolution during propagation in the divertor should be measurable
  - Data will provide critical test of ELM simulation models

Gated intensified cameras can be installed on either lower or upper tangential view of the divertors

- Two gated, intensified cameras are available.
- Lower divertor systems now use optical relay system without fiber imageguide.
  - 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.



Future plans include high speed imaging of ELM evolution in the divertor and main chamber SOL



- Use upstream diode to gate cameras
- Simultaneously image ELM in main chamber SOL and in lower divertor
- Follow ELMs through the edge/SOL by varying trigger delay
- Compare to codes (UEDGE, B2-Eirene, EDGE2D etc.)

Fast triggering electronics detects ELM pulse at outer midplane and triggers gated cameras after variable delay