NSTX

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# High speed IR camera diagnostic in NSTX


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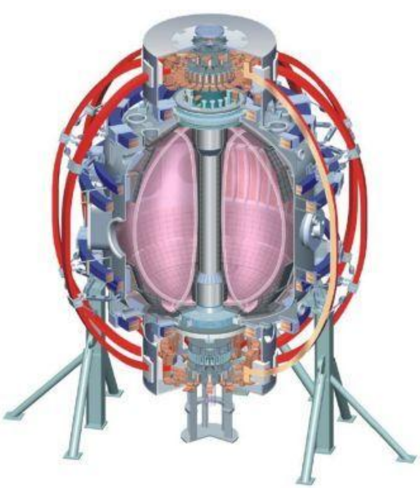


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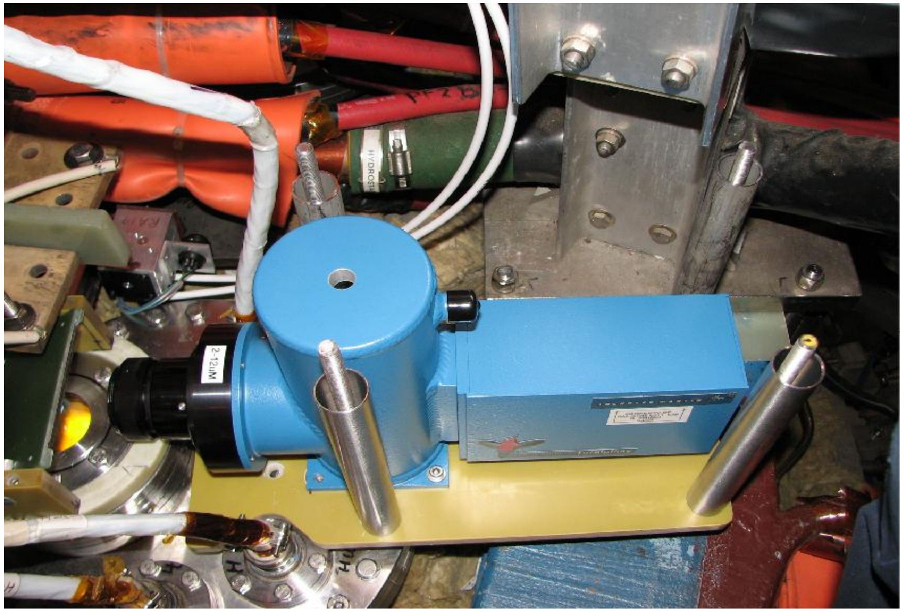
# Abstract

A new high speed infrared camera has been successfully implemented and produced reliable heat flux measurements on the lower divertor tiles in NSTX. High spatial and temporal resolutions enable us to investigate detailed structure of heat flux deposition pattern caused by transient events such as ELMs. A comparison of the data with a slow IR camera viewing the same region of interest shows a good agreement between the two independent measurements. Work is under way to evaluate the effect of hot spots and non-uniform temperature distribution on the tile surface temperature measurement and heat flux calculation. Data analysis for various plasma conditions is in progress.

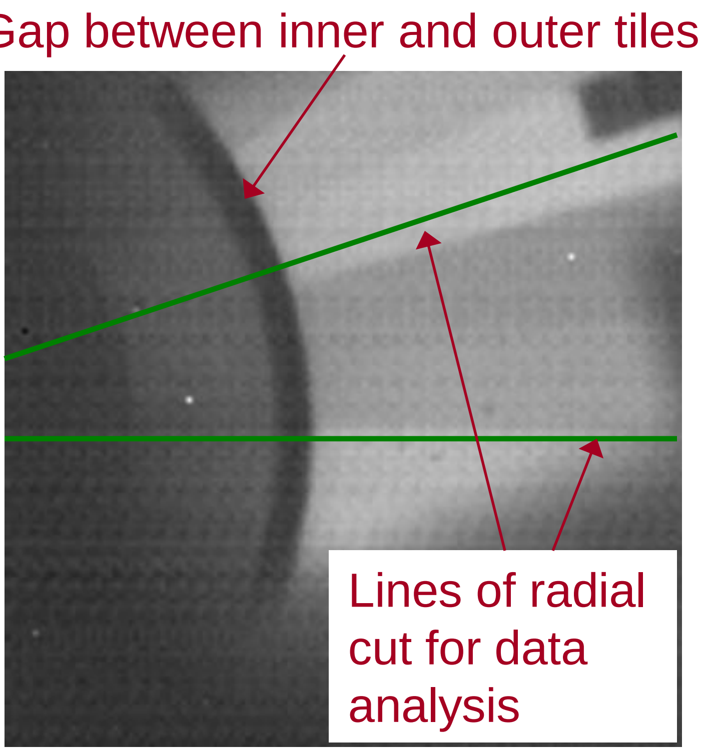
# Technical details of the IR camera




Camera installed on top of upper P2 coil of NSTX

- SBF ImagIR infrared camera
- Photovoltaic HgCdTe detector
- Wavelength range: 2-12μm
- Frame speed: 1.6 – 6.3 kHz
- Integration time: 0.1μs to 2ms
- Dynamic range: 14 bits
- Dewar hold time: > 10 hours
- Located on top of upper P2 coil
  → Resilient to strong EM noises
- Horizontal camera view
  → Mirror to relay the image

# IR image of lower divertor tiles

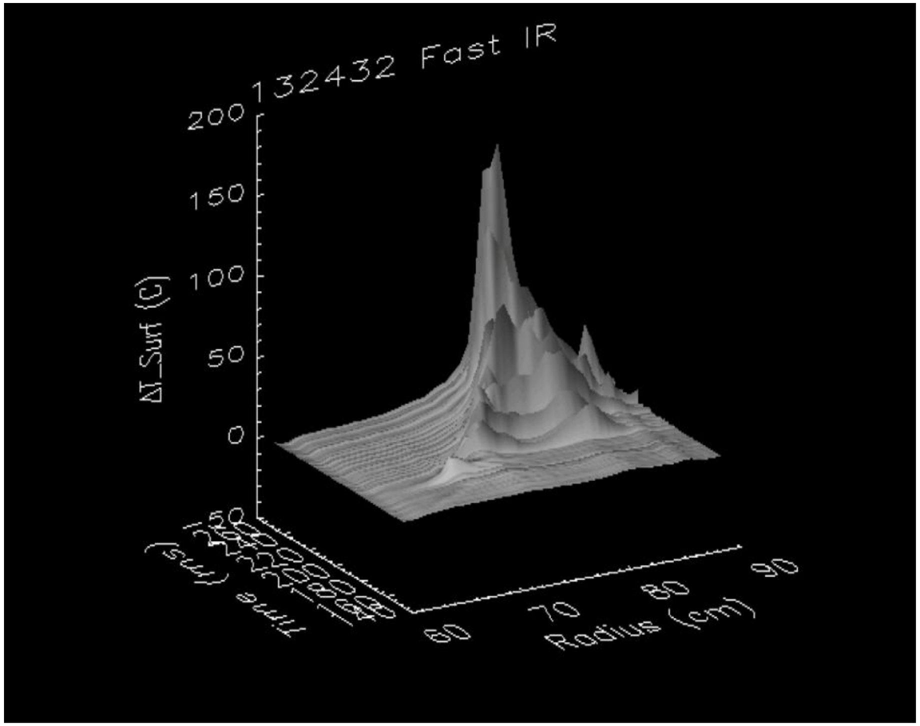


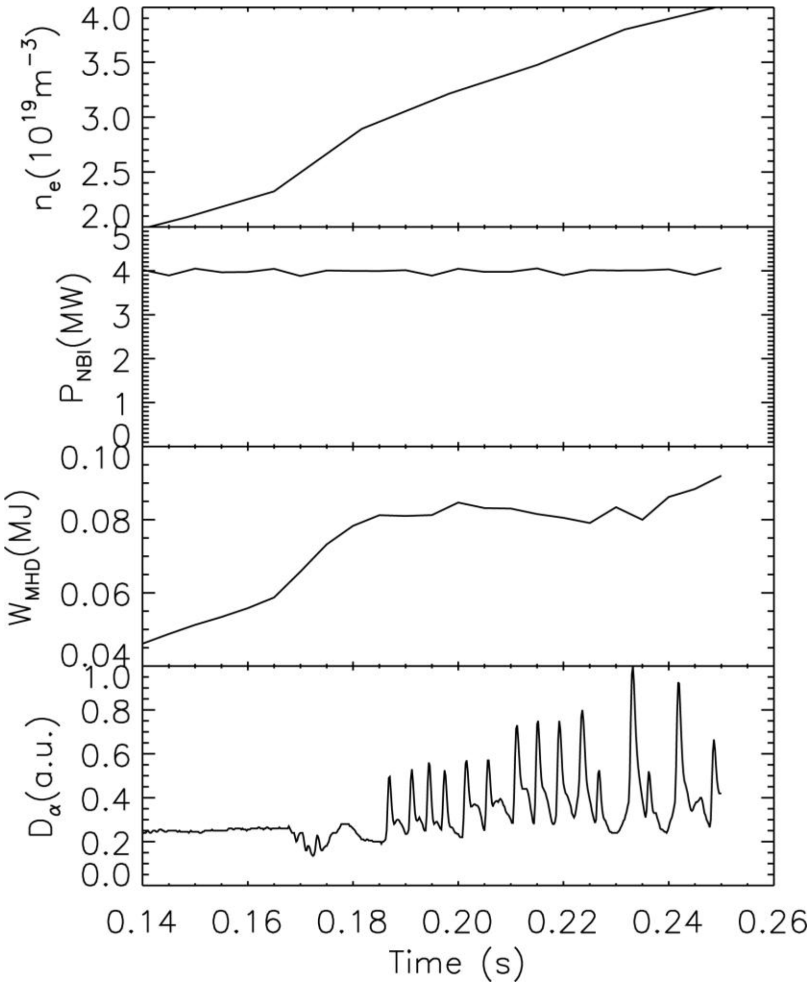

Camera image from the top of NSTX viewing lower divertor tiles

- Viewing down the lower divertor tiles from the top of the machine
- Full view: 128x128 pixels, 1.6kHz
- Narrower view: 96x32 pixels, 6.3kHz
- spatial resolution of 6.4mm
- Flexible selection of radial slices for data analysis

# Measured surface temperature

**1.6kHz**

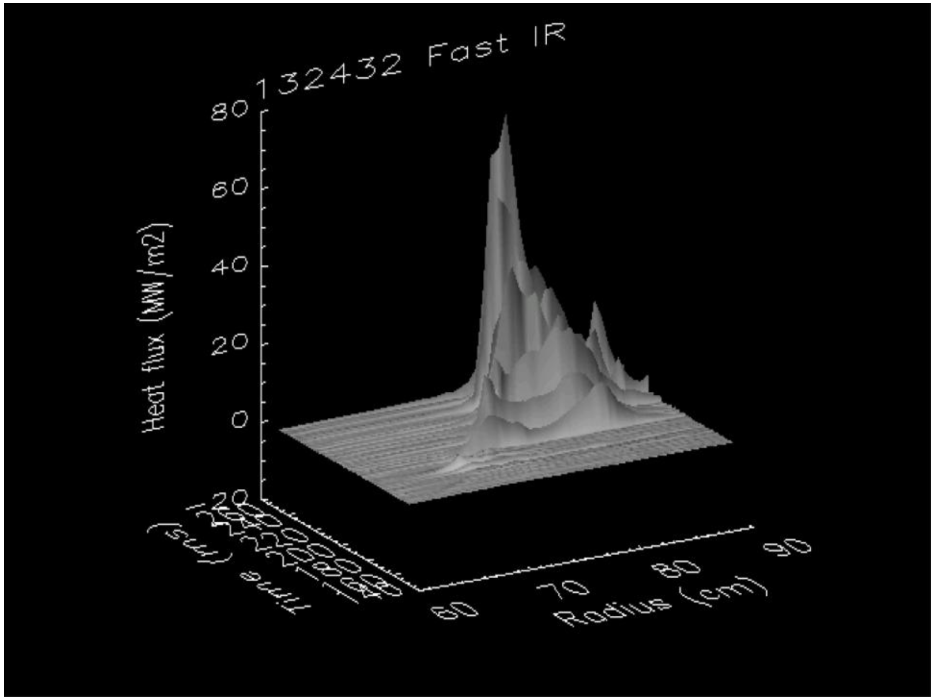


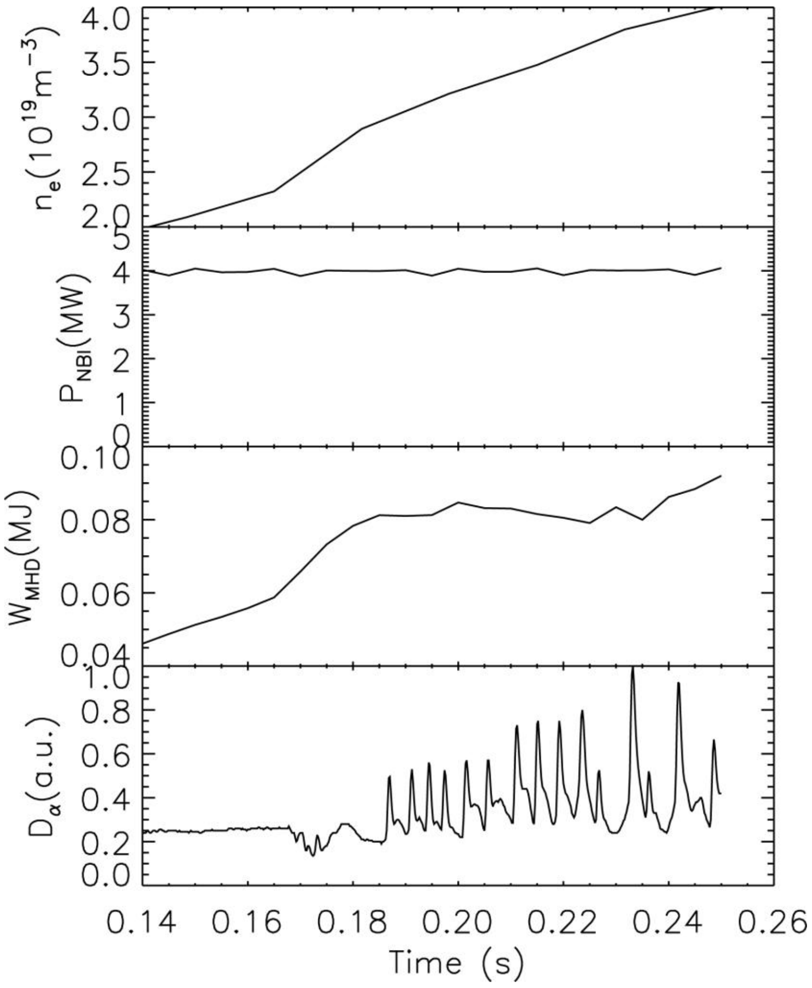




**Temperature profiles from measured surface emissivity**

# Calculated heat flux

**1.6kHz**

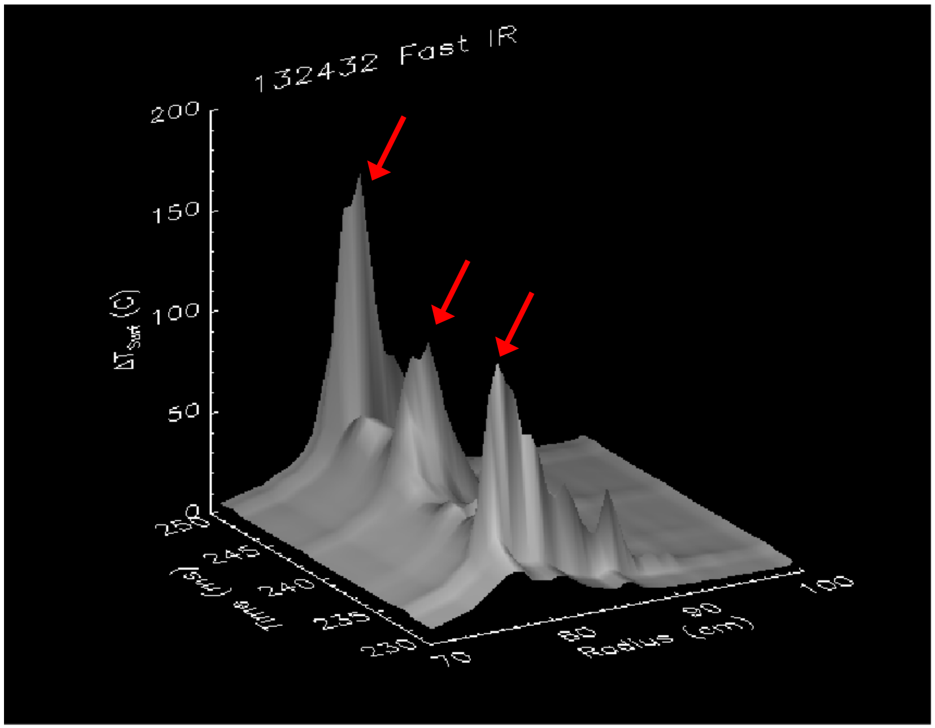


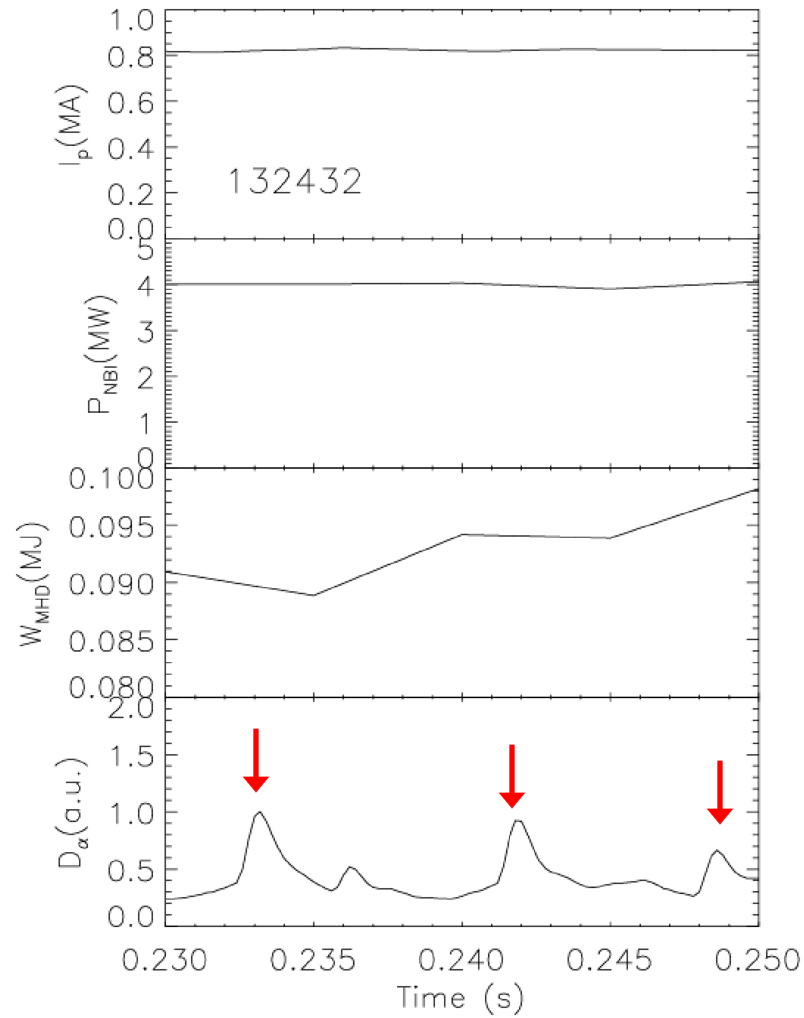




**Heat flux profiles from surface temperature by solving 1-D heat conduction equation (Ref. 1 and 2)**

# ELM resolved surface temperature

**1.6kHz**

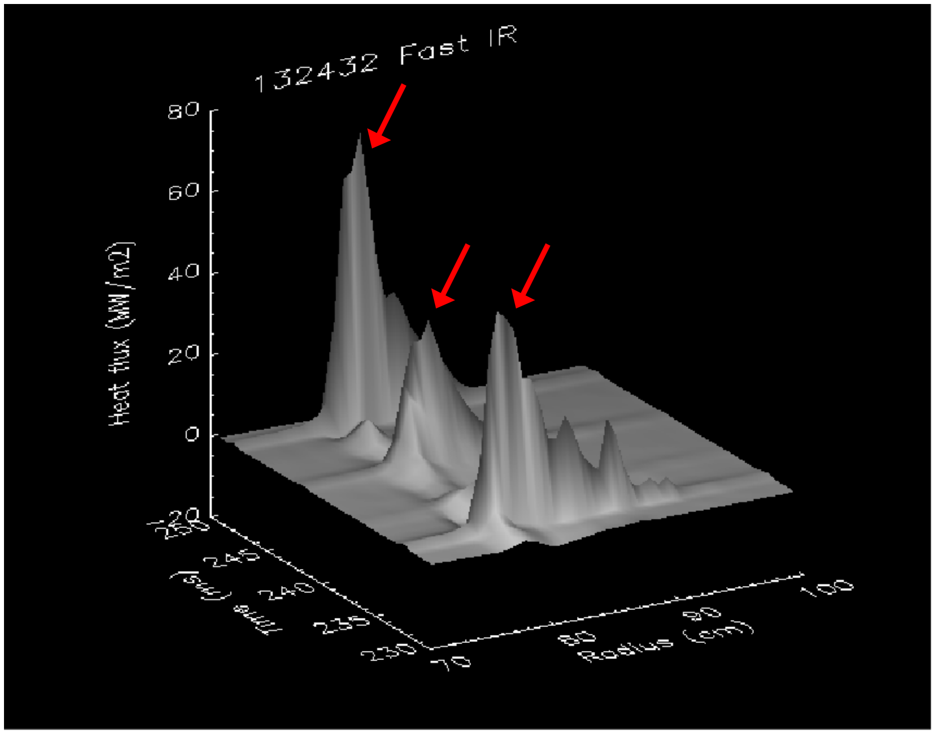


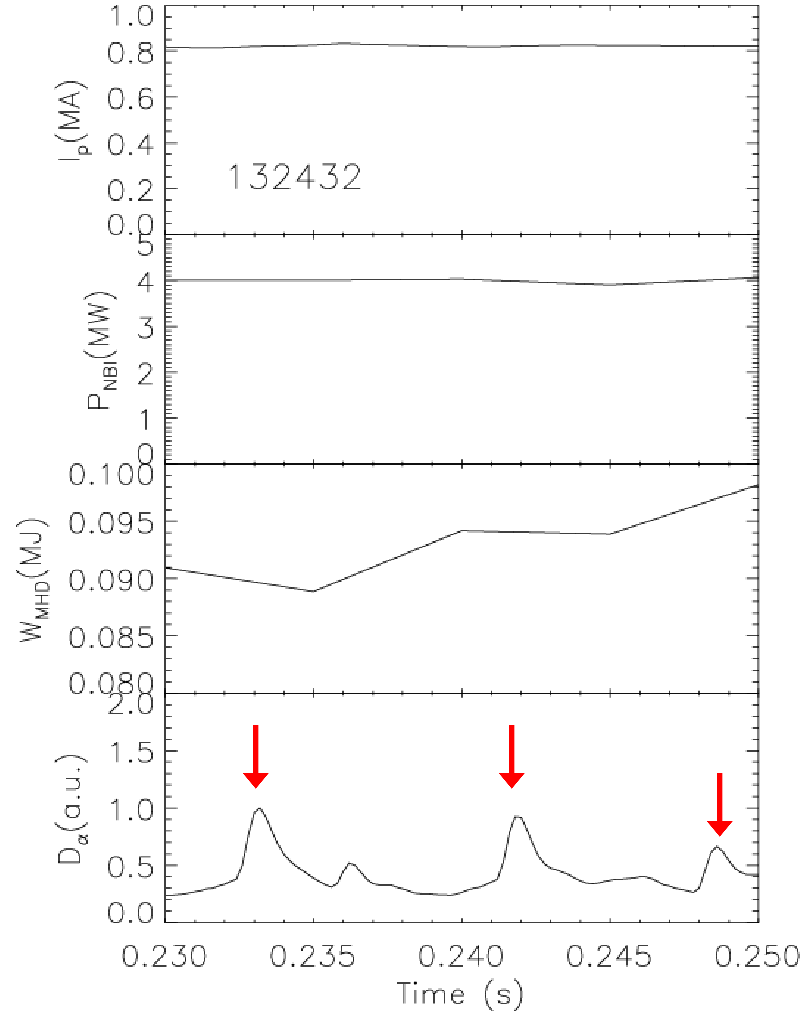




**Short ELM rise time gives only one frame for a rising ELM even at 1.6kHz**

# ELM resolved heat flux

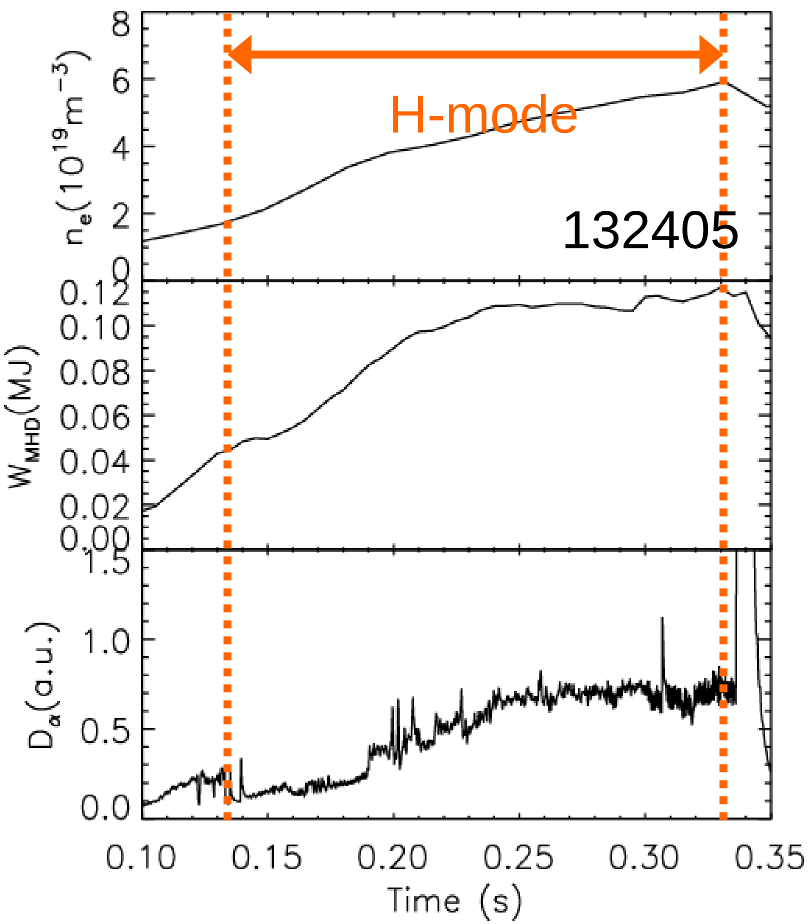
**1.6kHz**




**ELMs push strike point out by ~1cm**

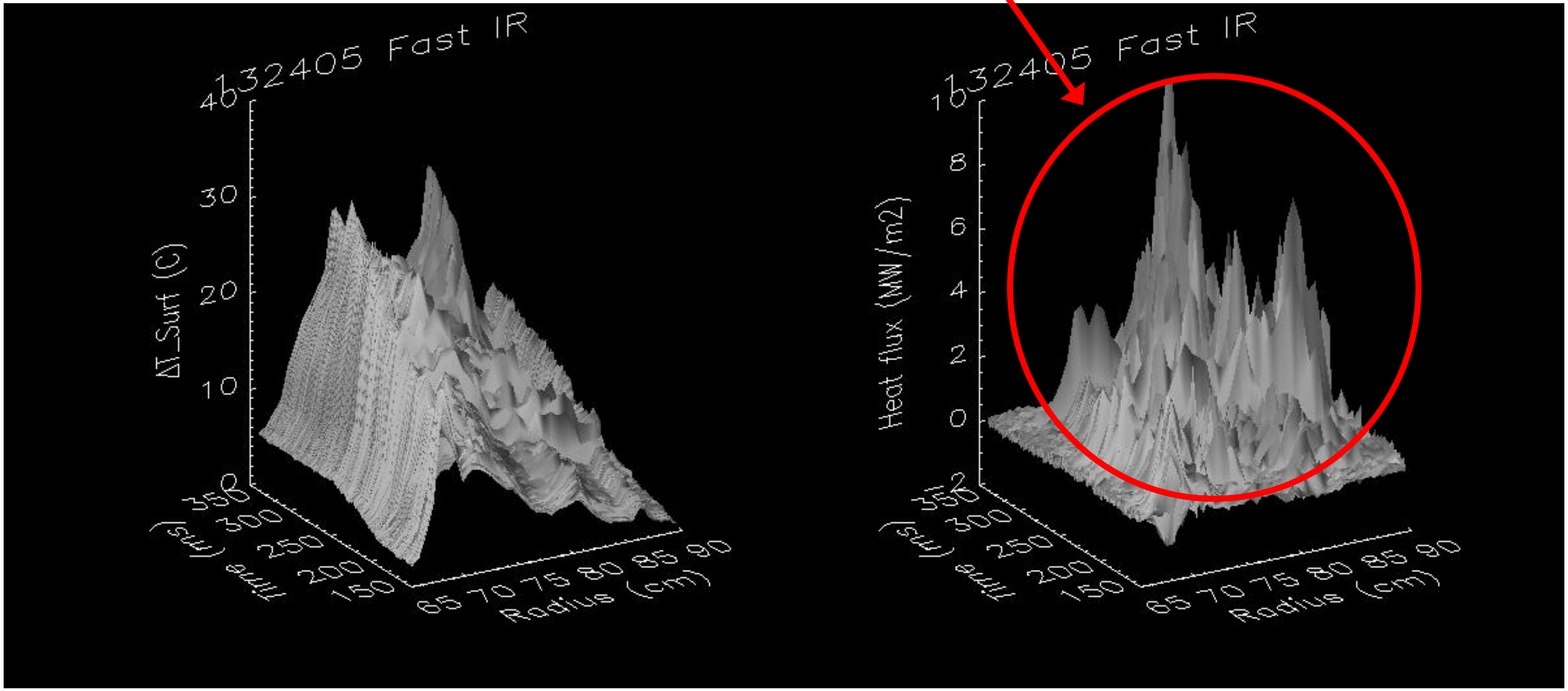
# Small, Type-V ELM H-mode plasma




- Small ELM H-mode disperses heat flux over a large area on the divertor tiles
- Many ELM filaments are observed in the radial direction and they produce rather flat heat flux profiles
- Dα trace do not distinguish sharp ELM peaks. This is consistent with the heat flux measurement in which peak heat flux is not sharply defined at the strike point

# Data for Type-V ELMs

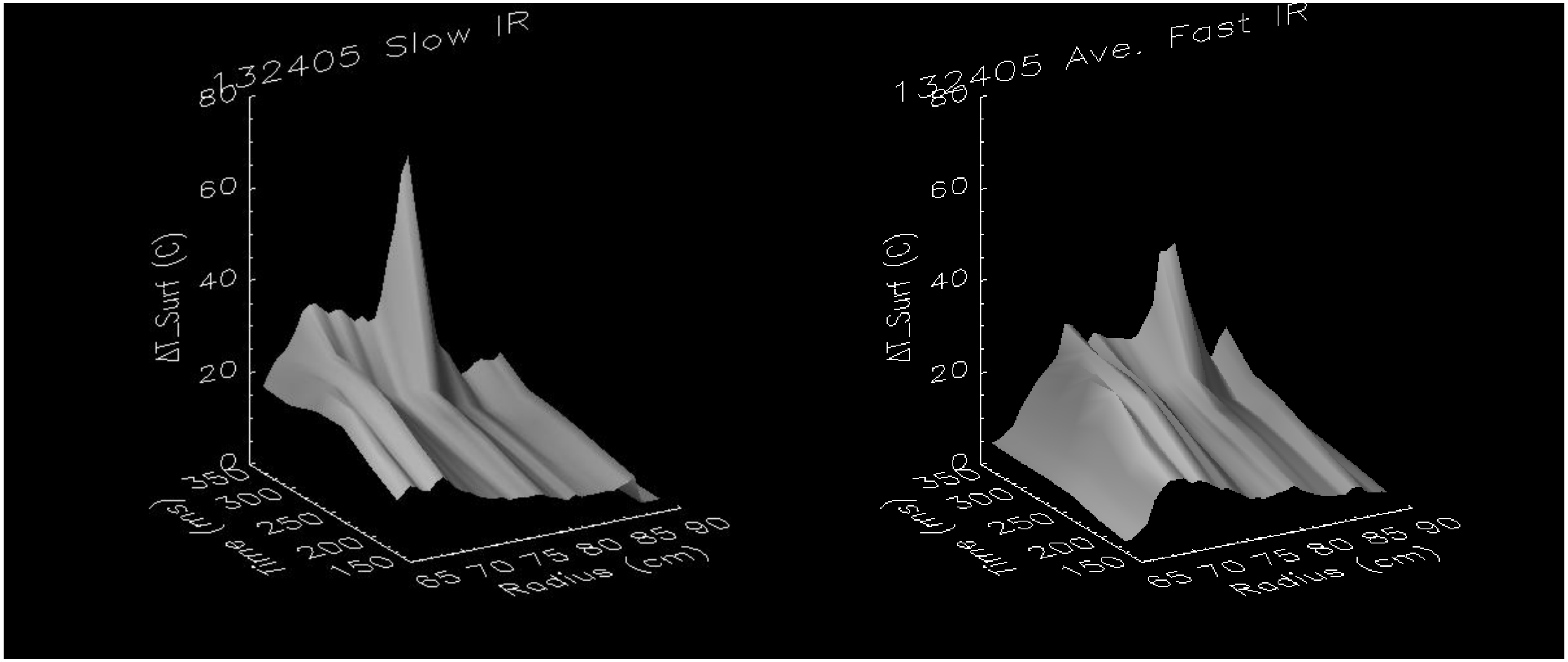
Many ELM peaks over a large divertor area




**Temperature profiles** **Heat flux profiles**

# Comparison btw fast and slow IR data – temperature

**30Hz** | **1.6kHz**

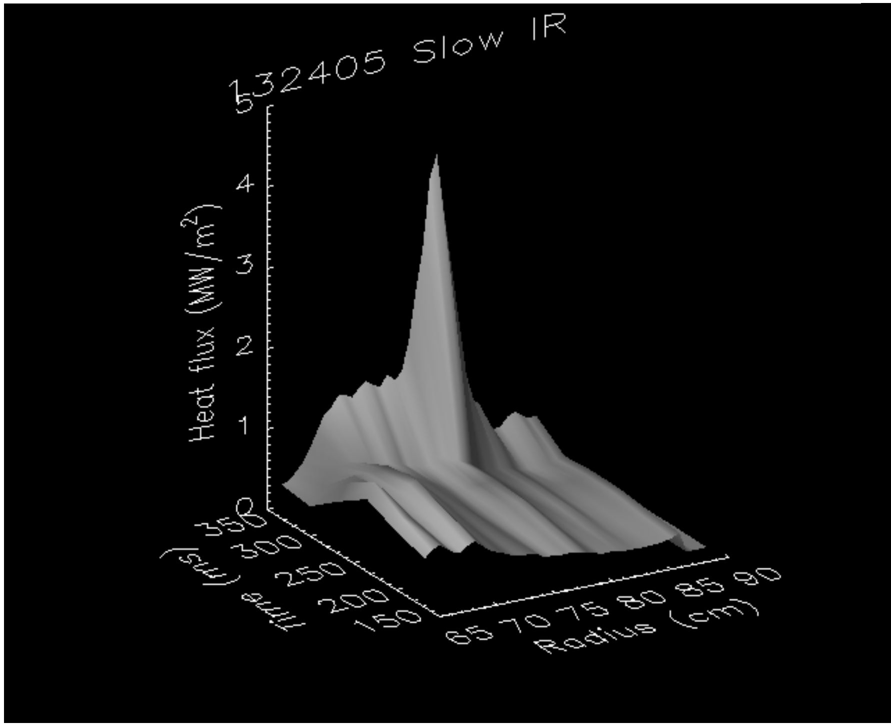



**Temp. profiles from slow IR**

**Time averaged temperature profiles from fast IR**

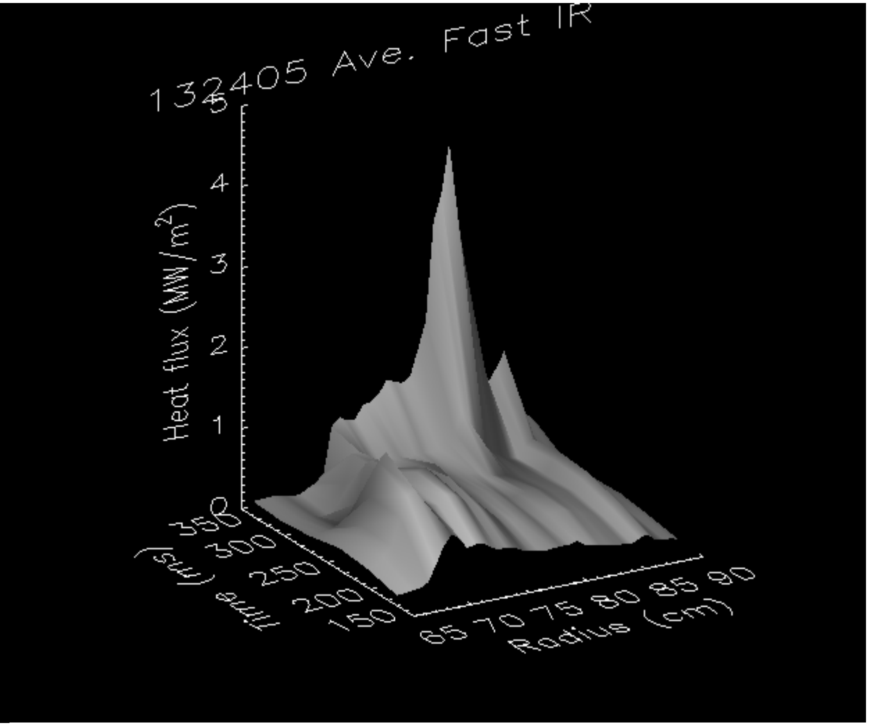
# Comparison btw fast and slow IR data – heat flux

**30Hz**




Heat flux profiles from slow IR

**1.6kHz**




Time averaged heat flux profiles from fast IR

# Unresolved issues and future work

**Known issues that can lead to temperature overestimation and therefore error in heat flux calculation, eg negative heat flux (Ref. 2-6)**

1. Non-uniform surface temperature caused by micrometric hot spots on the tile surface

   → Plan to use a longer wavelength (8-12 μm) to reduce contribution from hot spots to the temperature measurement

2. Disturbance of temperature measurement by IR radiation of plasma

   → Plan to use of a band pass filter (eg, 4-4.5 μm)

3. Surface state can give a great uncertainty in the temperature measurement

   → Plan to install a two color system for MWIR and LWIR

# Summary and Conclusions

- The new fast IR camera is working reliably to measure divertor heat flux with temporal resolution at 1.6 - 6.3kHz and spatial resolution of 6.4mm
- Temporal resolution is fast enough to resolve transient events such as ELMs → plan to raise the speed further up to 20kHz
- Time averaged temperature and heat flux profiles agree well with slow IR data
- Work is underway to improve the reliability of temperature measurement, eg use of LWIR, band pass filter, two-color system, etc

# References and acknowledgements

References

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