NSTX

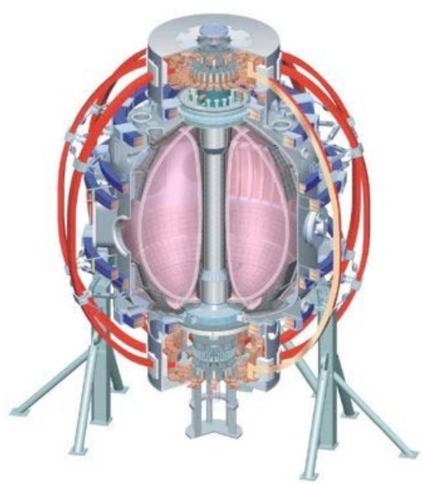
Supported by U.S. DEPARTMENT OF ENERGY Office of Science

Heat flux deposition for different ELM types and 3-D field application in NSTX

College W&M
Colorado Sch Mines
Columbia U
CompX
General Atomics
INL
Johns Hopkins U
LANL
LLNL
Lodestar
MIT
Nova Photonics
New York U
Old Dominion U
ORNL
PPPL
PSI
Princeton U
Purdue U
SNL
Think Tank, Inc.
UC Davis
UC Irvine
UCLA
UCSD
U Colorado
U Illinois
U Maryland
U Rochester
U Washington
U Wisconsin

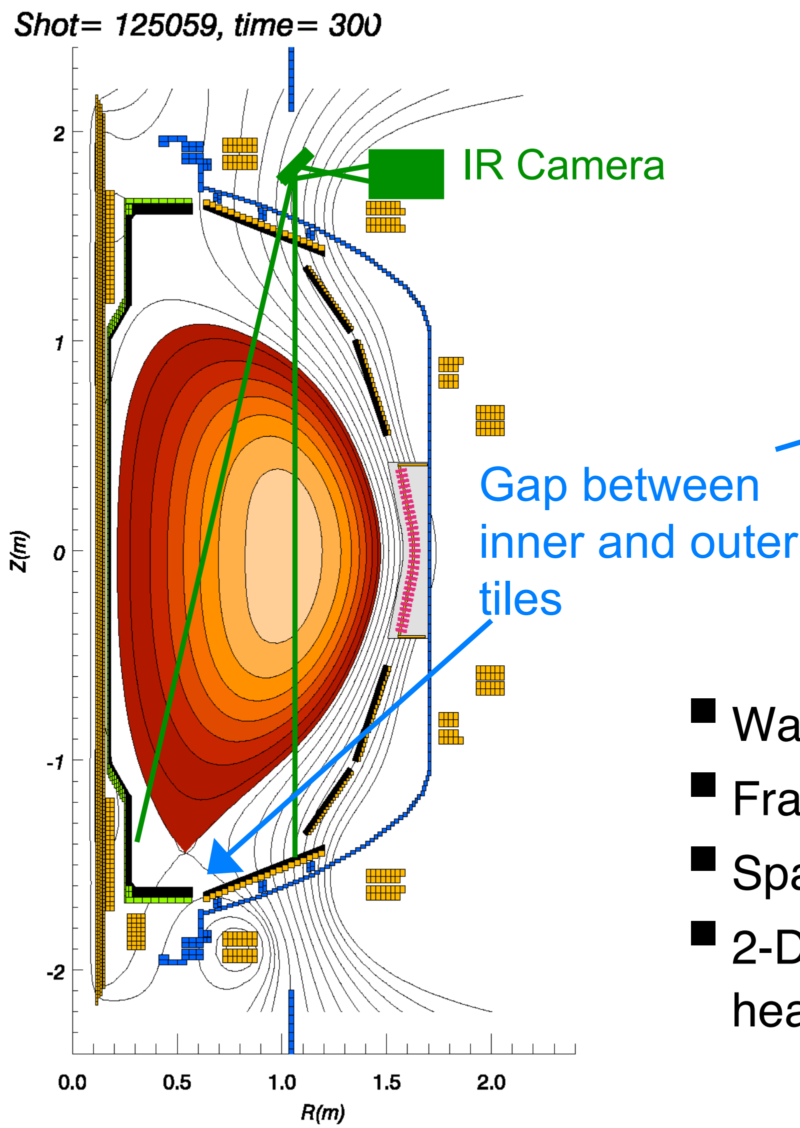
J-W. Ahn[1], T.K. Gray[1], A. Herrmann[2], J.M. Canik[1], R. Maingi[1], A.L. Roquemore[3], H.W. Kugel[3], and V. Soukhanovskii[4]

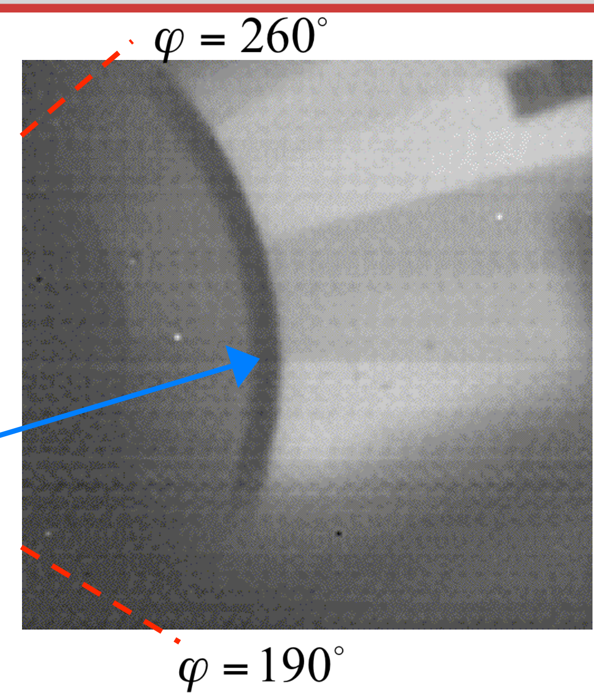
[1]Oak Ridge National Laboratory
[2] Max-Planck-Institut für Plasmaphysik
[3]Princeton Plasma Physics Laboratory
[4]Lawrence Livermore National Laboratory



Culham Sci Ctr
U St. Andrews
York U
Chubu U
Fukui U
Hiroshima U
Hyogo U
Kyoto U
Kyushu U
Kyushu Tokai U
NIFS
Niigata U
U Tokyo
JAEA
Hebrew U
Ioffe Inst
RRC Kurchatov Inst
TRINITI
KBSI
KAIST
POSTECH
ASIPP
ENEA, Frascati
CEA, Cadarache
IPP, Jülich
IPP, Garching
ASCR, Czech Rep
U Quebec

Divertor heat flux measurement in NSTX

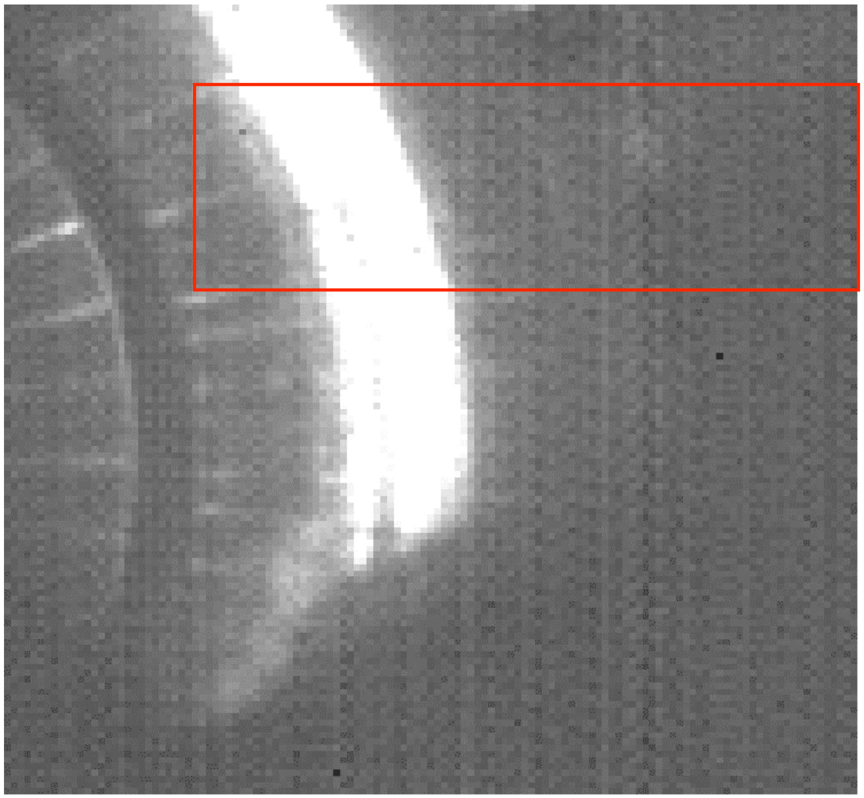




- Wavelength range: 8-10μm
- Frame speed: 1.6 (138x128) – 6.3 (96x32) kHz,
- Spatial resolution : 6.7mm
- 2-D heat conduction model (THEODOR)[1] for heat flux calculation, $q(t) = -k\nabla T$

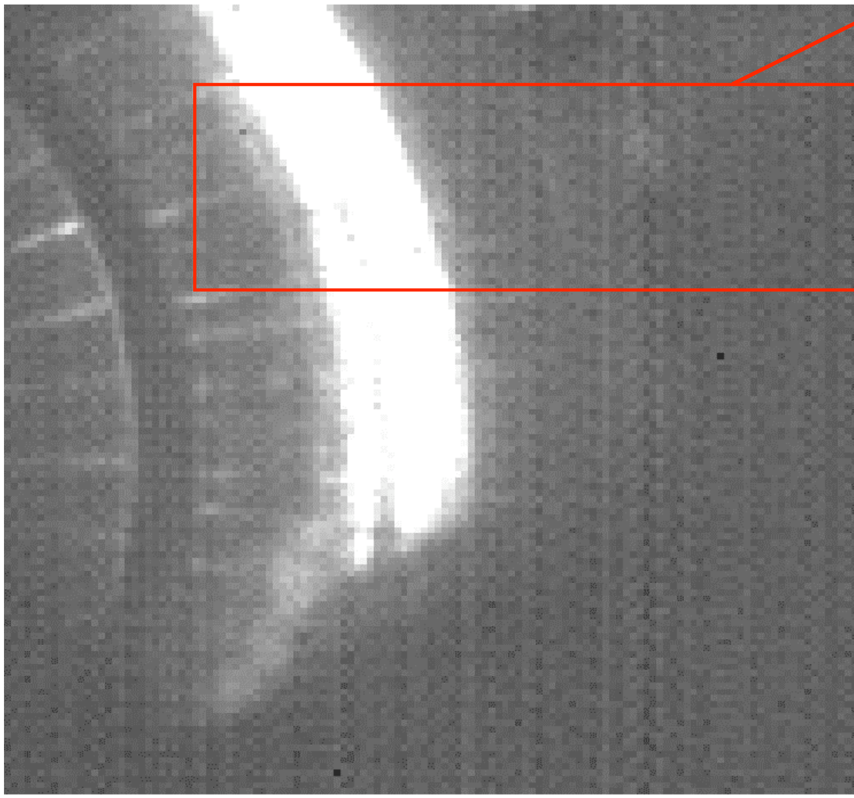
[1]International collaboration with IPP Garching, Germany

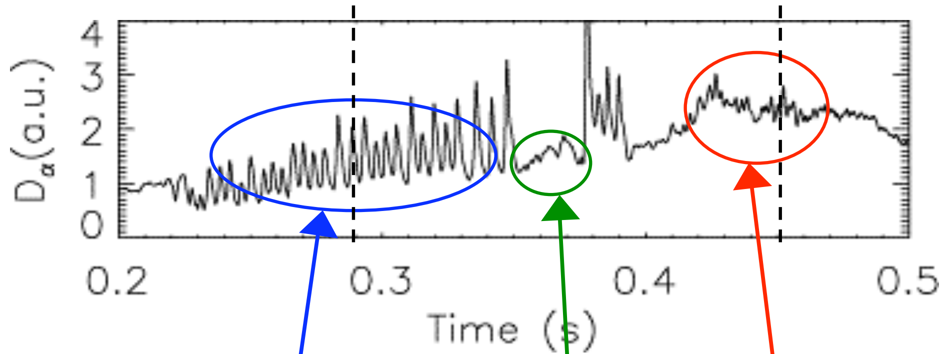
IR image of different ELMs



View from the top of NSTX
96x32 pixels, 6.3kHz

IR image of different ELMs

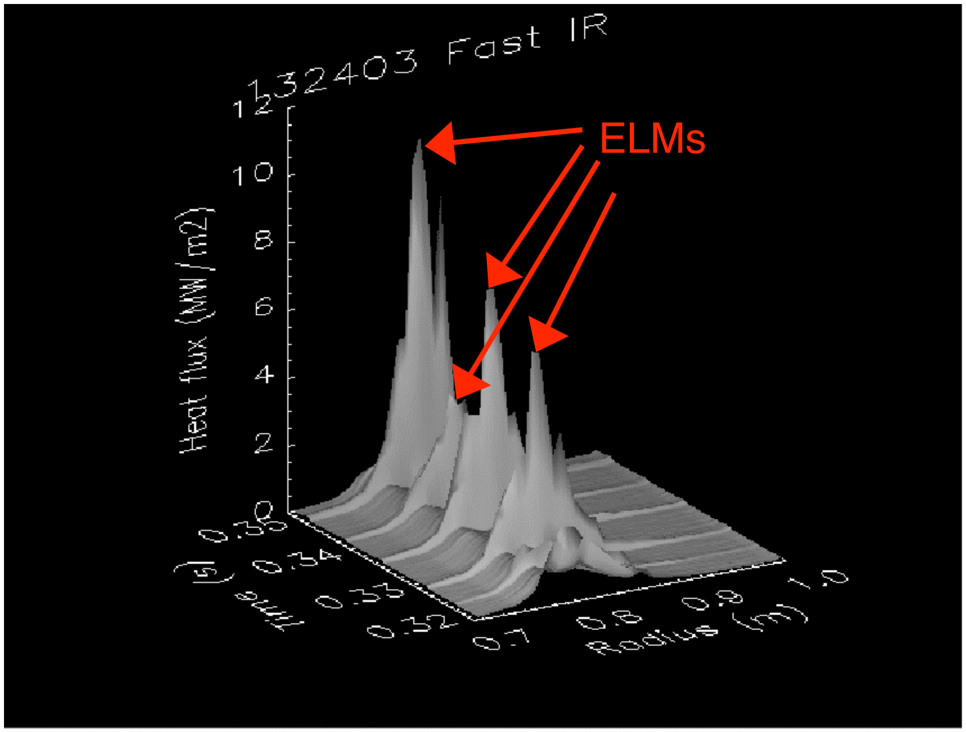




View from the top of NSTX

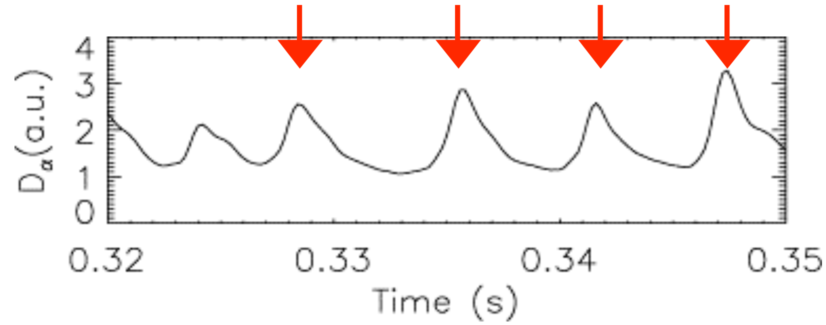
96x32 pixels, 6.3kHz

Measured heat flux profiles during ELMs



Type-III ELMy H-mode

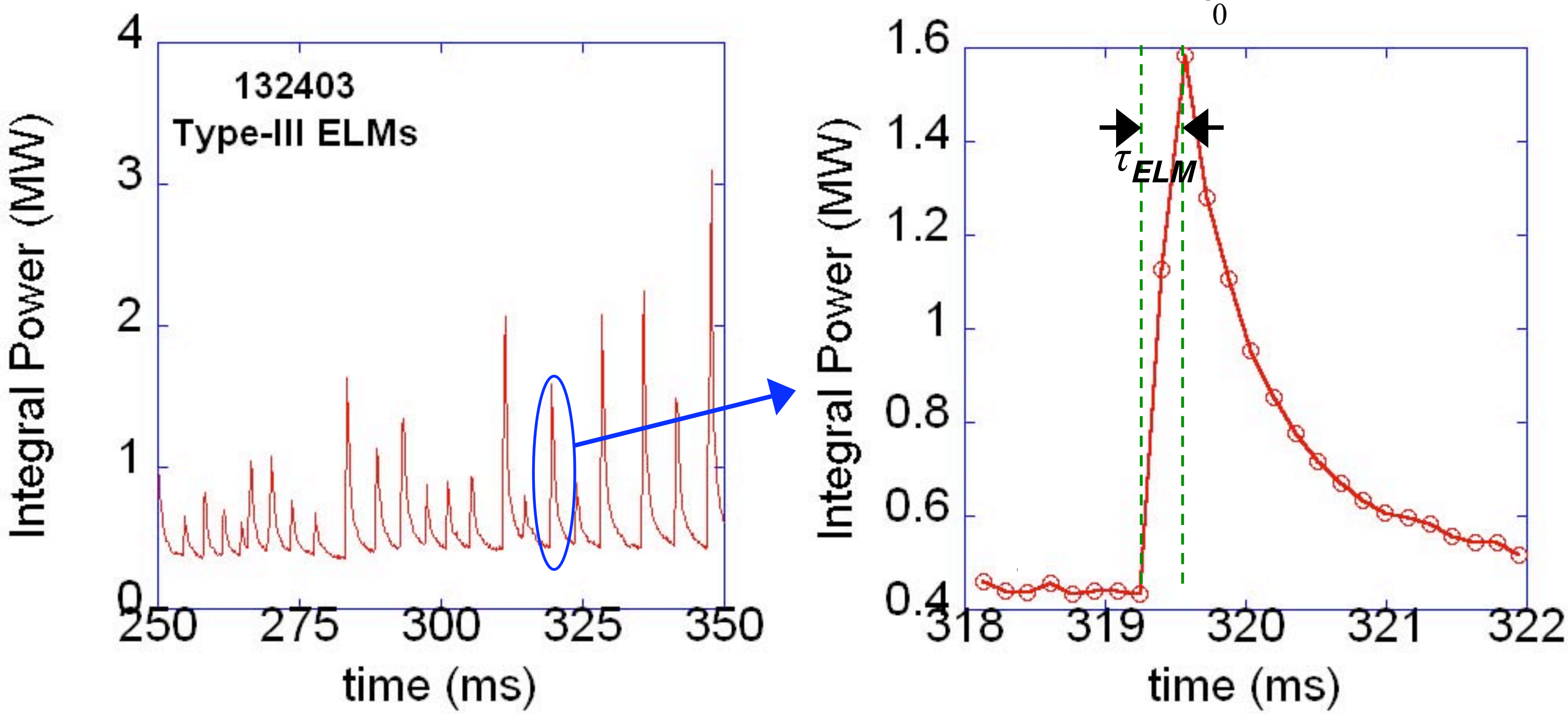
96x32 pixels, 6.3kHz



- ELM resolved heat flux profiles obtained:
- Location of peak heat flux shifts outward
- PFR profile broadens
- $q_{ELM,\ peak}$ = 30-80MW/m^2 (Type-I)
  3-10MW/m^2 (Type-III)
  1-1.5MW/m^2 (Type-V)

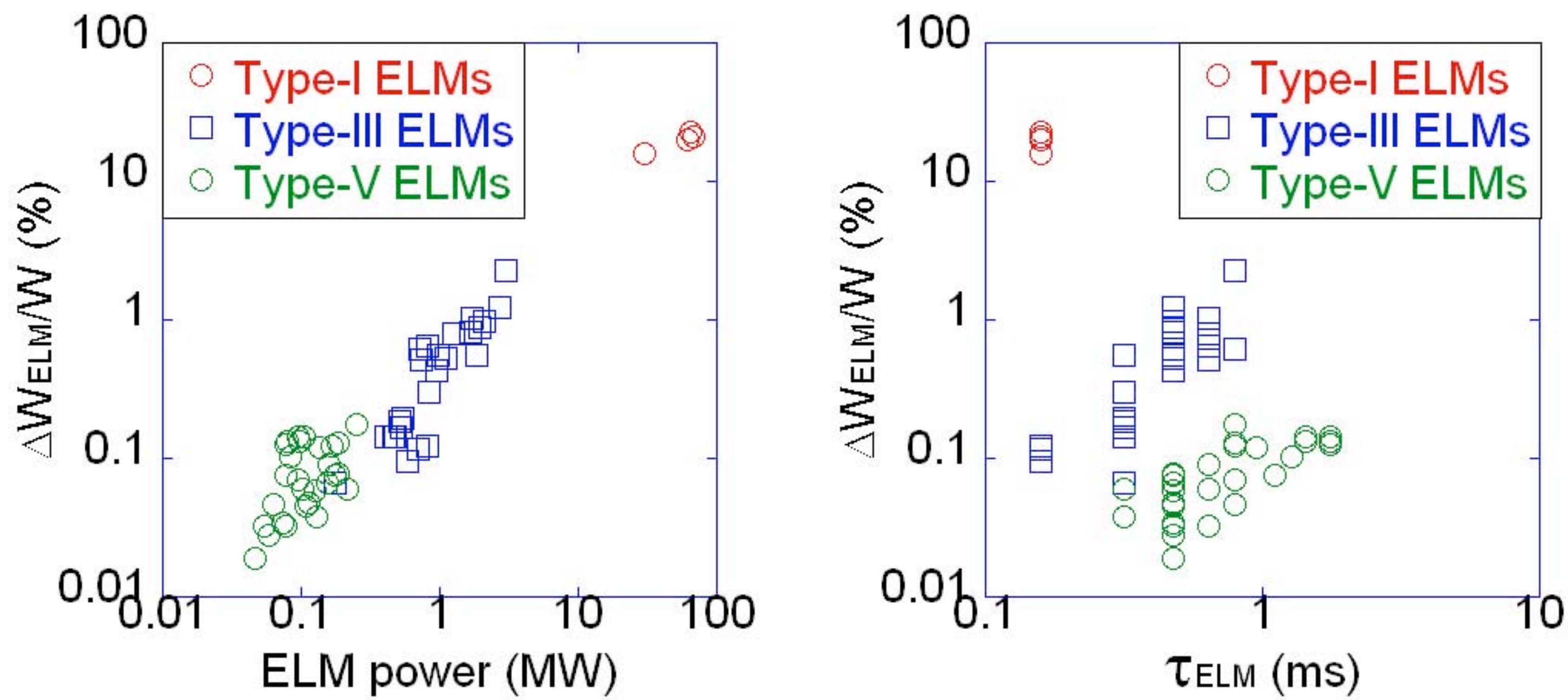
Temporal characteristics of ELM heat deposition

- Total power ejected by an ELM: $\Delta P_{ELM} = 2\pi r \int q(r)dr$
- Total energy ejected by an ELM: $\Delta W_{ELM} = \int_0^{\tau_{ELM}} \Delta P_{ELM} dt$

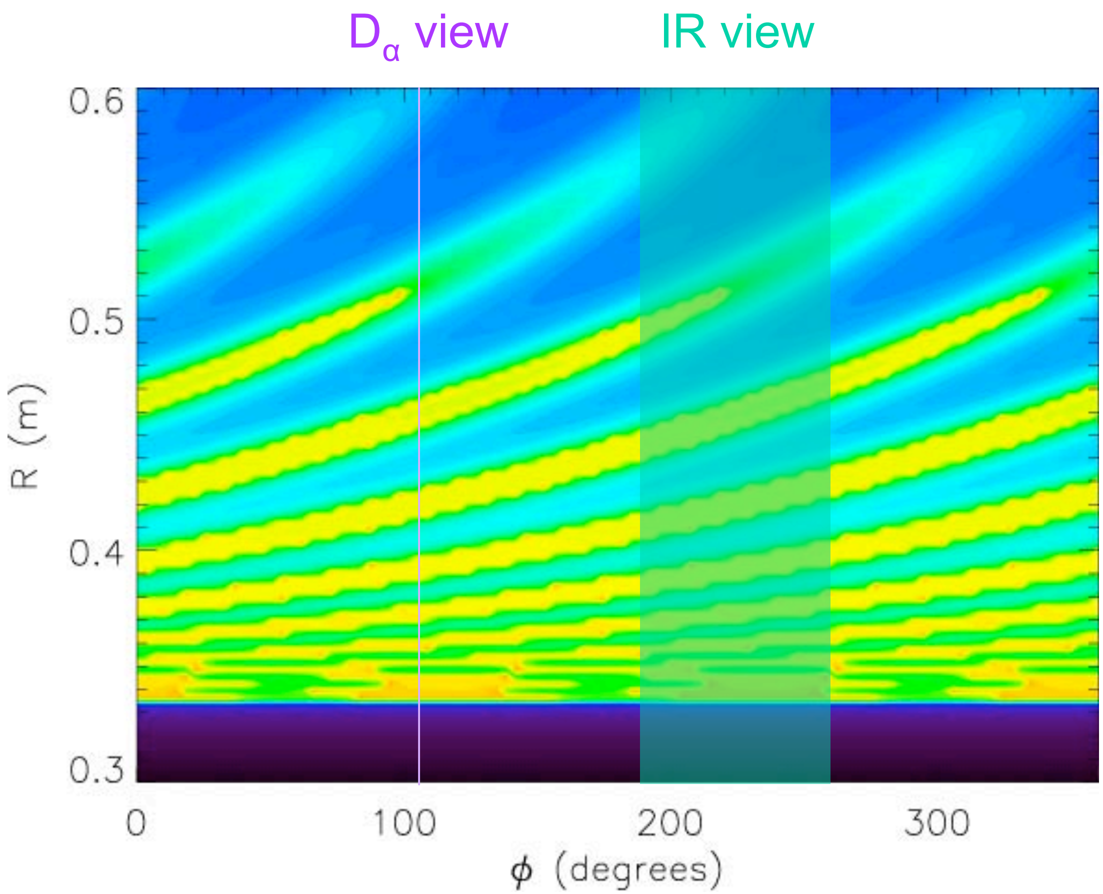


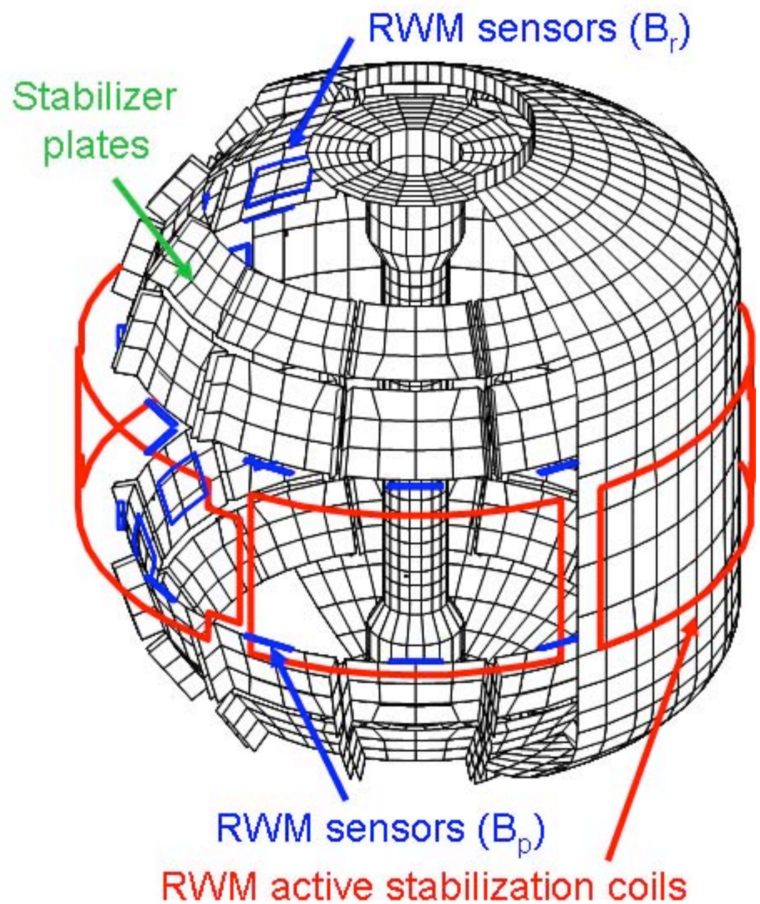
ELM power and rise time closely tied with $\Delta W_{ELM}/W$

- Good linear relation between ELM power and fraction of ejected energy
- ELM rise time increases with increasing fraction of ejected energy
- Very short τ_{ELM} for Type-I ELMs, need to increase IR temporal resolution



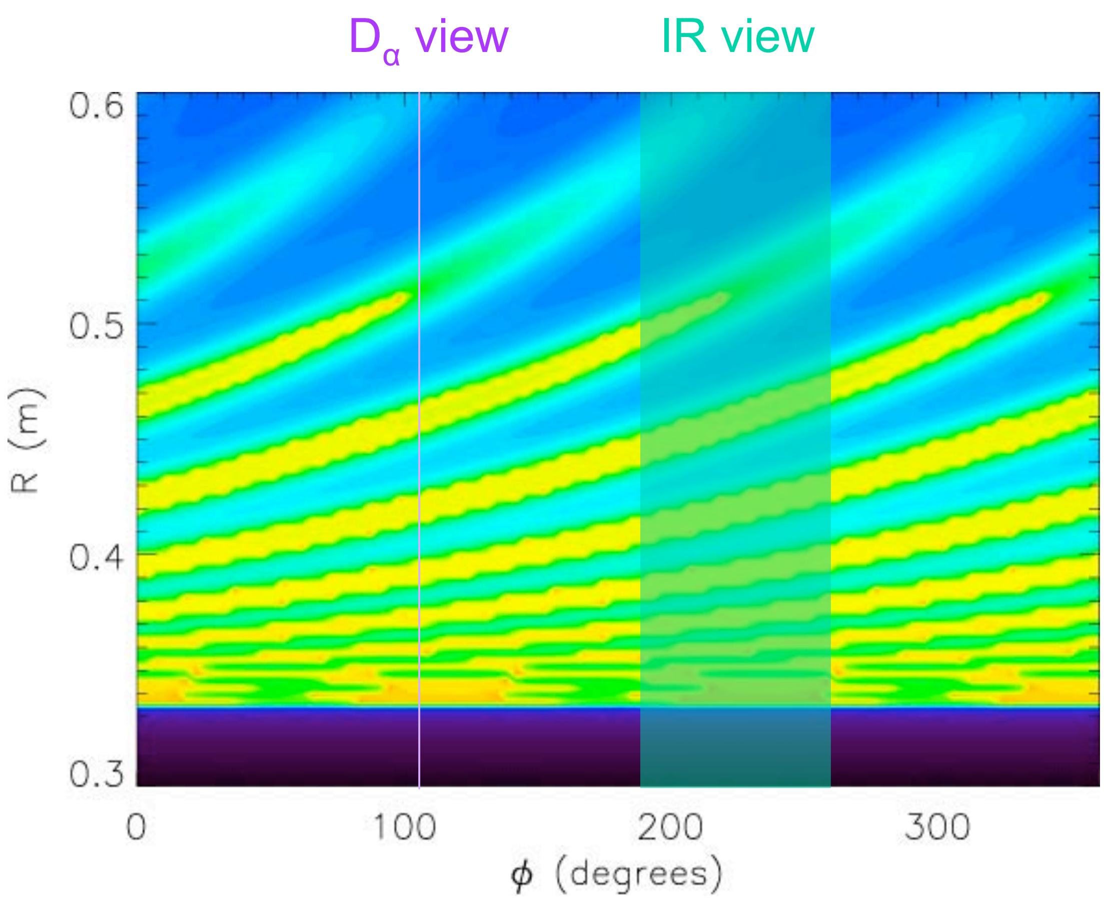
Predicted and observed 'lobes' by 3-D field application





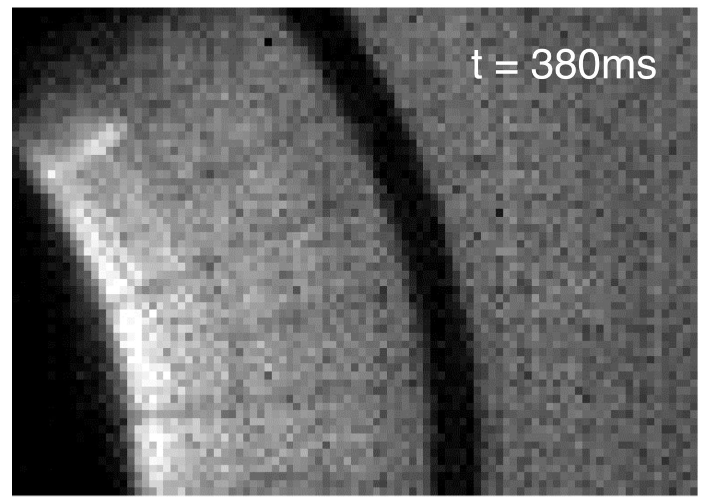
- Connection length for field lines at the divertor target, computed by a vacuum field line tracing
- n=3 3-D field was applied externally

Predicted and observed 'lobes' by 3-D field application



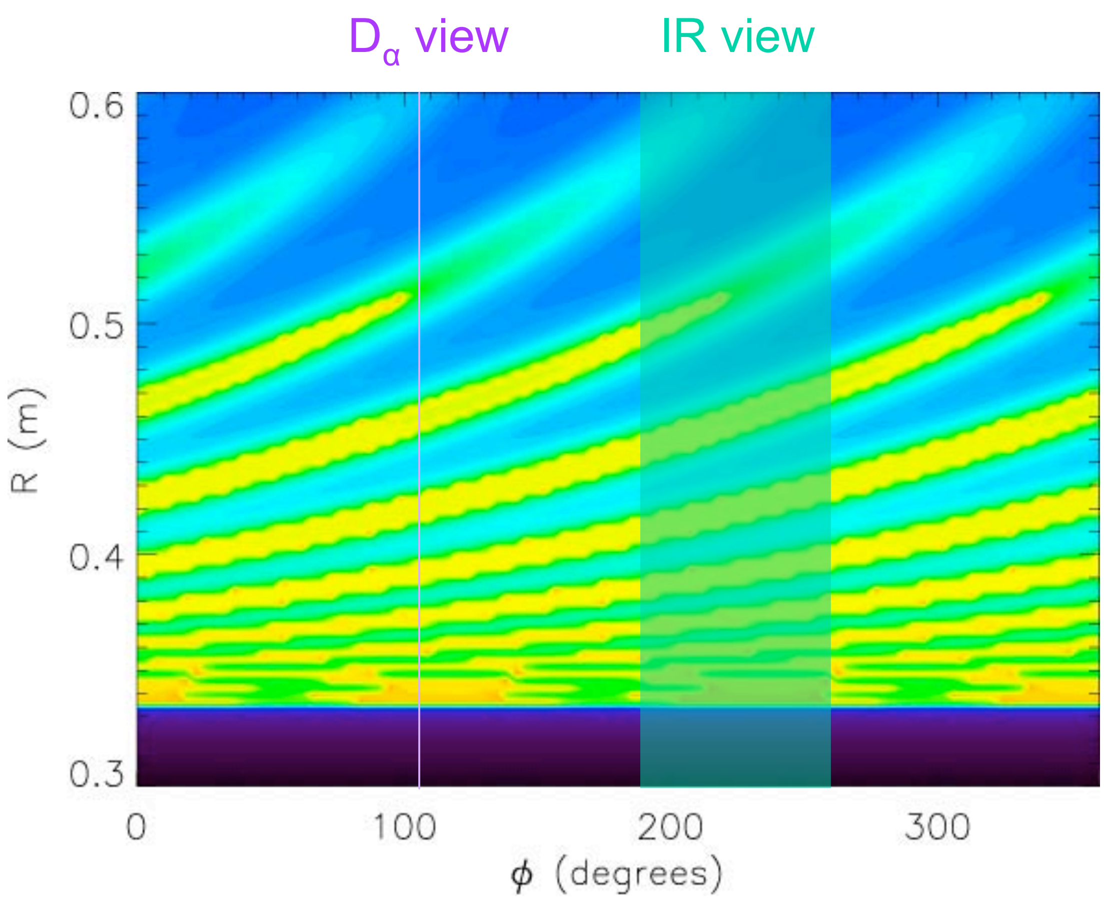
- Connection length for field lines at the divertor target, computed by a vacuum field line tracing
- n=3 3-D field applied

Before 3-D field application

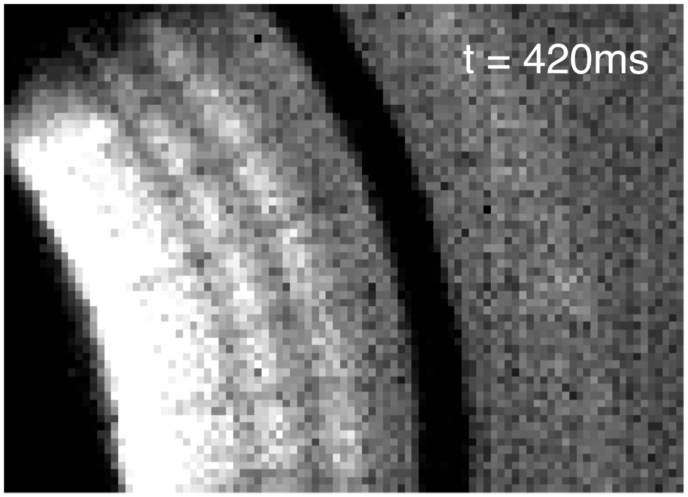


- The 'lobe' structure or the split of strike point is predicted

Predicted and observed ‘lobes’ by 3-D field application



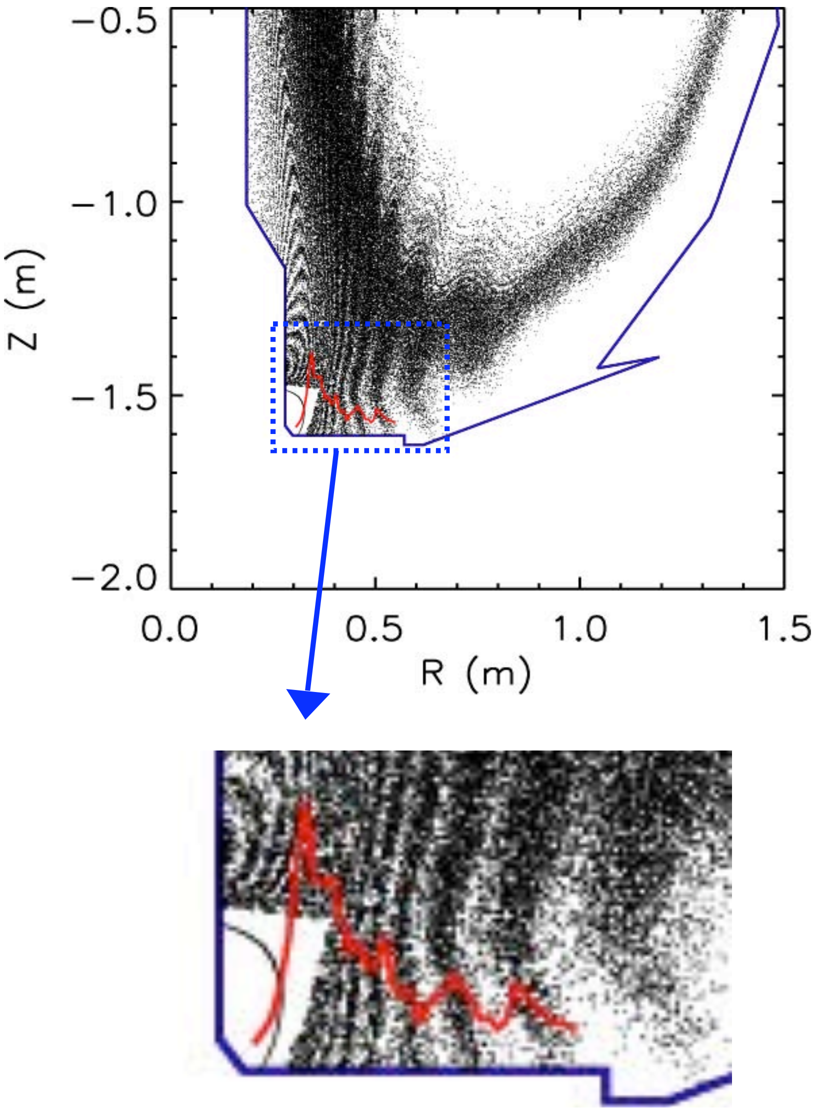
After 3-D field application



- Connection length for field lines at the divertor target, computed by a vacuum field line tracing
- n=3 3-D field applied

- The ‘lobe’ structure or the split of strike point is predicted and observed by the IR data
- The time response is consistent with the field line penetration time, 4-5ms

Comparison of profiles with field line tracing code

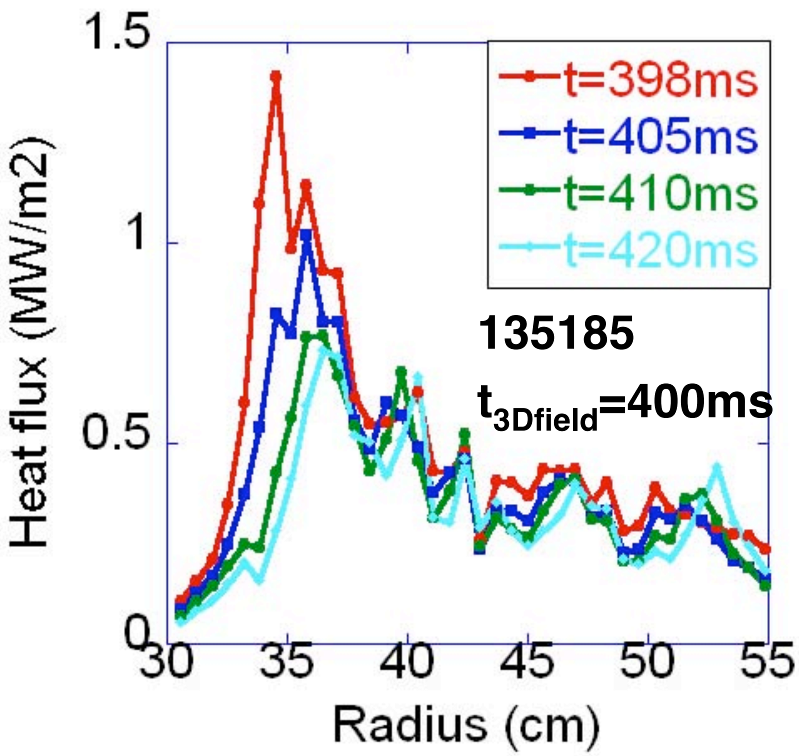


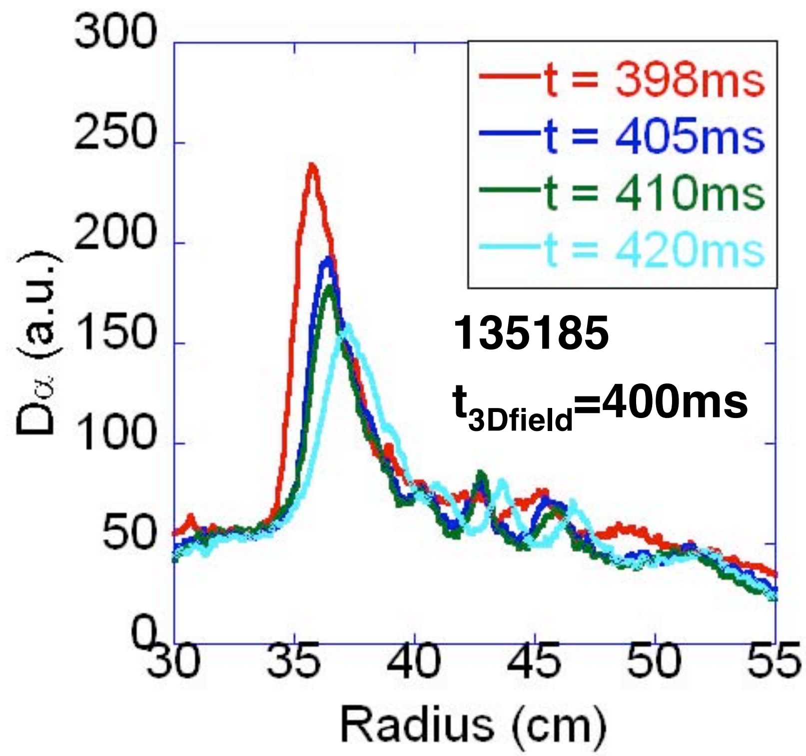
- Measured heat flux profile (red) overlaid with vacuum field line tracing plot
- Distribution of lobe locations qualitatively match
- Exact locations have some difference between the two

  → Field line tracing code tend to put strike point positions more widely distributed

Before and after 3-D field: change in divertor profiles

- The formation of lobes in both heat and particle profiles shortly after the 3-D field application is clearly seen
- It is not clear if the change in peak values is purely due to the 3-D field effect, investigation is in progress





Summary and future work

New high speed IR camera successfully measured transient heat flux onto the divertor target and the total ejected energy by ELMs

- $\Delta W_{ELM}/W$ = 10-20% (type-I), 0.5-3% (type-III), 0.02-0.2% (type-V)
- Order of ELM rise time: Type-I < Type-III < Type-V
- Fraction of ejected energy increases with ELM power and ELM rise time

Split strike points by the application of 3-D fields in H-mode were observed

- Measured heat and particle flux profiles clearly show multiple local peaks, representing striations at the divertor target, shortly after 3-D field application
- The location and spacing of the observed lobes were approximately consistent with the vacuum field line tracing result

- Hardware improvement for higher frame rate up to 20kHz being planned
- 2-color IR system to remove lithium coating effect on surface emissivity

This work was supported by the US DOE, contract numbers DE-AC05-000R22725, DE-AC02-09CH11466, and DE-AC52-07NA27344