NSTX

Supported by

U.S. DEPARTMENT OF ENERGY | Office of Science

Effect of non-axisymmetric magentic perturbations on divertor profiles in NSTX H-mode plasmas

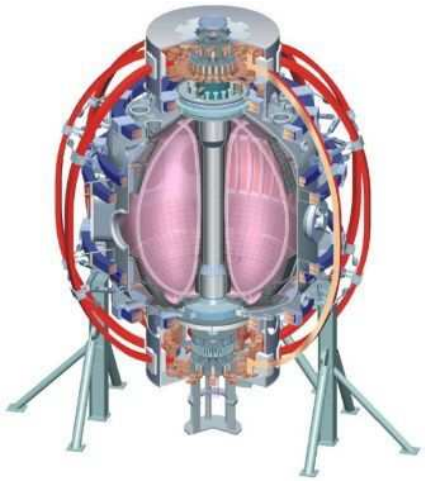
College W&M
Colorado Sch Mines
Columbia U
CompX
General Atomics
INEL
Johns Hopkins U
LANL
LLNL
Lodestar
MIT
Nova Photonics
New York U
Old Dominion U
ORNL
PPPL
PSI
Princeton U
Purdue U
SNL
Think Tank, Inc.
UC Davis
UC Irvine
UCLA
UCSD
U Colorado
U Illinois
U Maryland
U Rochester
U Washington
U Wisconsin

Joon-Wook Ahn, ORNL

J.M. Canik, R. Maingi, T.K. Gray, A.G. McLean (ORNL), A.L. Roquemore, J.-K. Park (PPPL), V.A. Soukhanovskii (LLNL)

and the NSTX Research Team

37th EPS Conference
Dublin, Ireland
June 21-25, 2010



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

Motivation

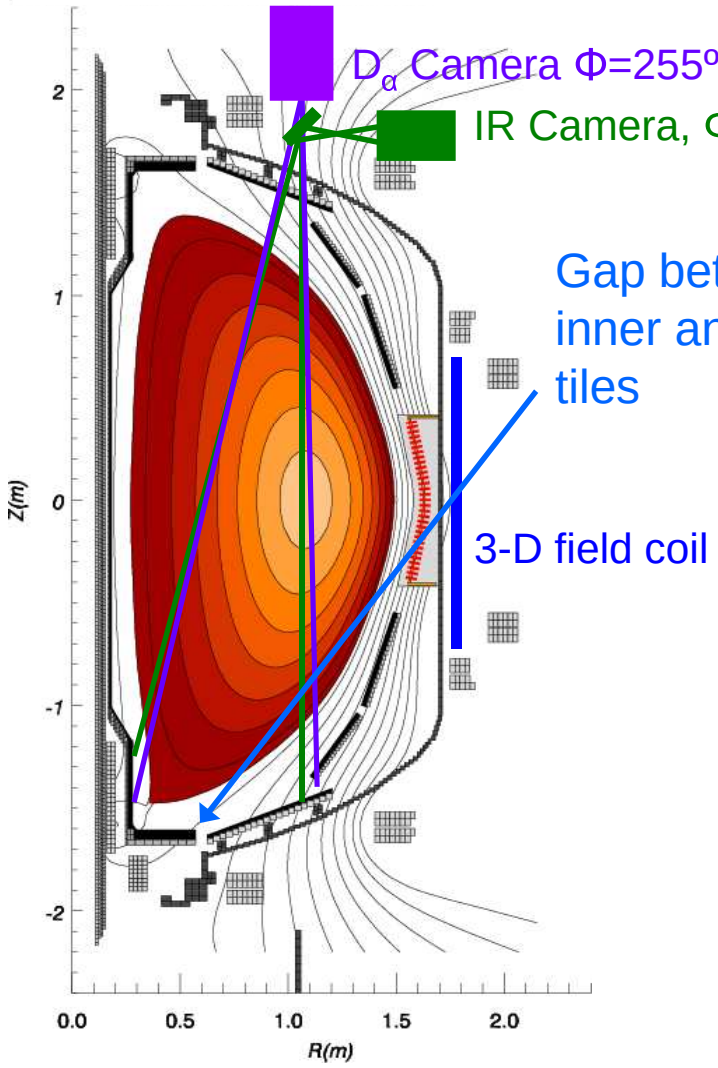
- Small external magnetic perturbations used for ELM control
  - ELM suppression (DIII-D) and mitigation (JET)
  - ELM triggering (MAST, NSTX)

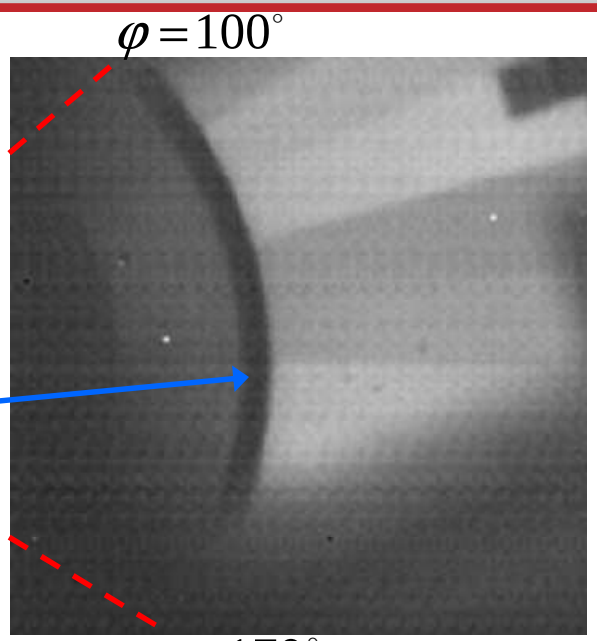
- The 3-D nature of RMP application can cause toroidally asymmetric heat and particle deposition

- Understanding of heat and particle transport in the presence of 3-D fields, both externally applied and internally arisen, is important for divertor performance projections

- The proposed use of 3-D field triggered ELMs in a controlled manner requires detailed understanding of heat and particles deposition pattern during the ELMs

Divertor heat flux and D_α measurement in NSTX



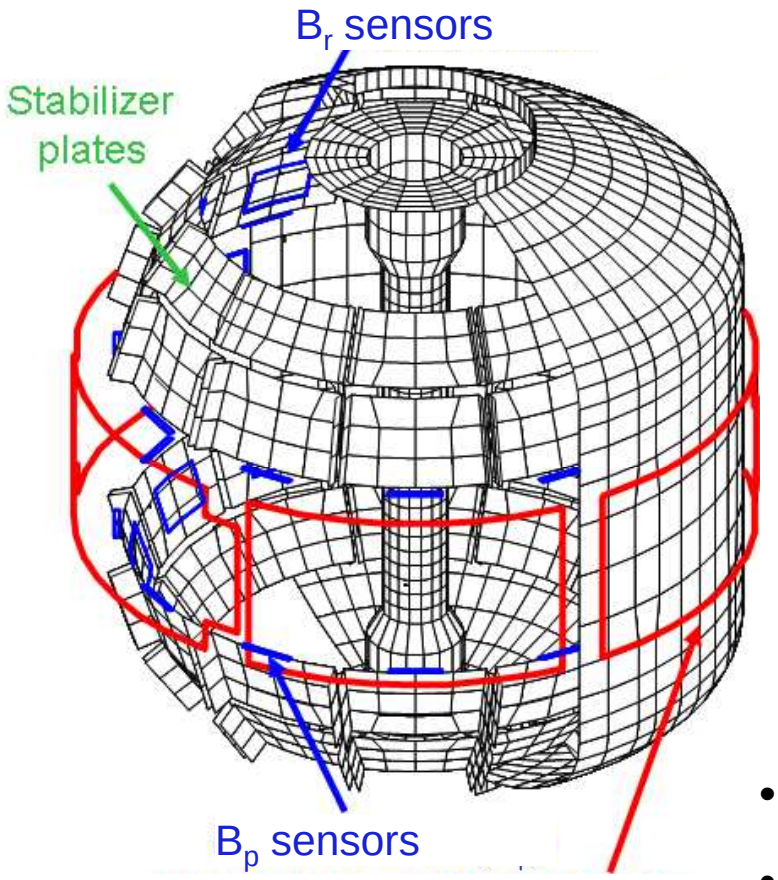


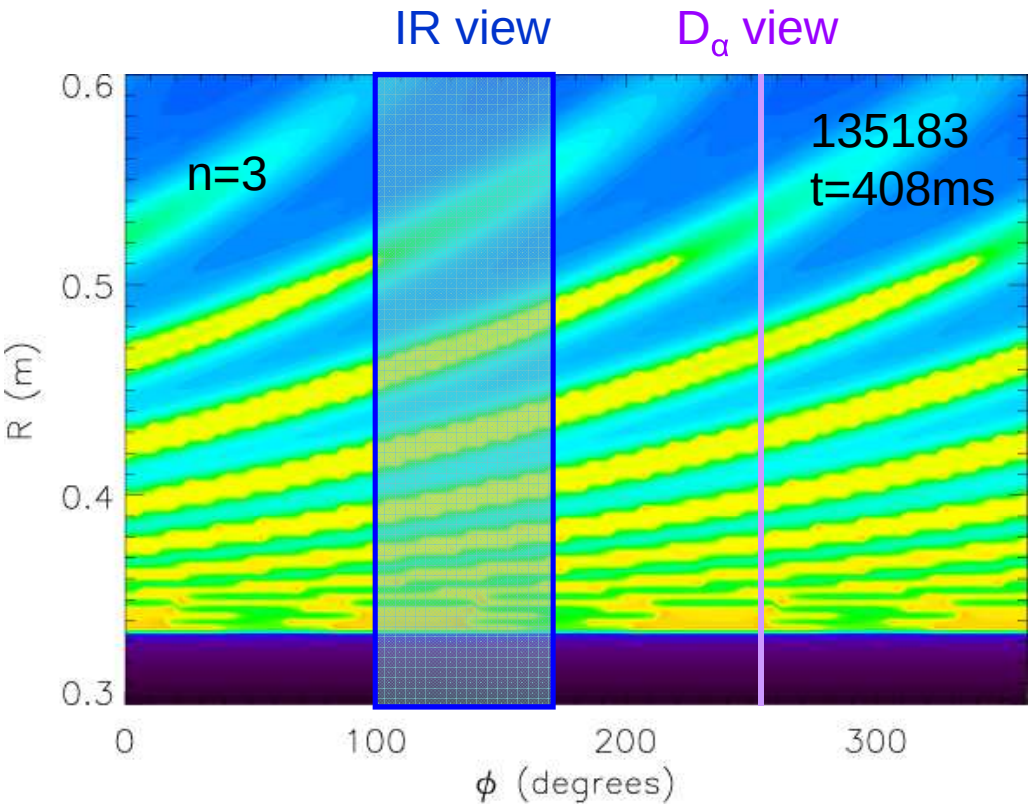
Thermography details: J-W. Ahn. RSI (2010), 023501

- Wavelength range: 8-10μm 3-10μm
- Frame speed: 1.6 (128x128) – 6.3 (96x32) kHz
- Spatial resolution : 5-7mm
- 2-D heat conduction model (THEODOR)[1] for heat flux calculation $q(t) = -k\nabla T$

[1]International collaboration with IPP Garching, A. Hermann

Strike point splitting is predicted by 3-D field application

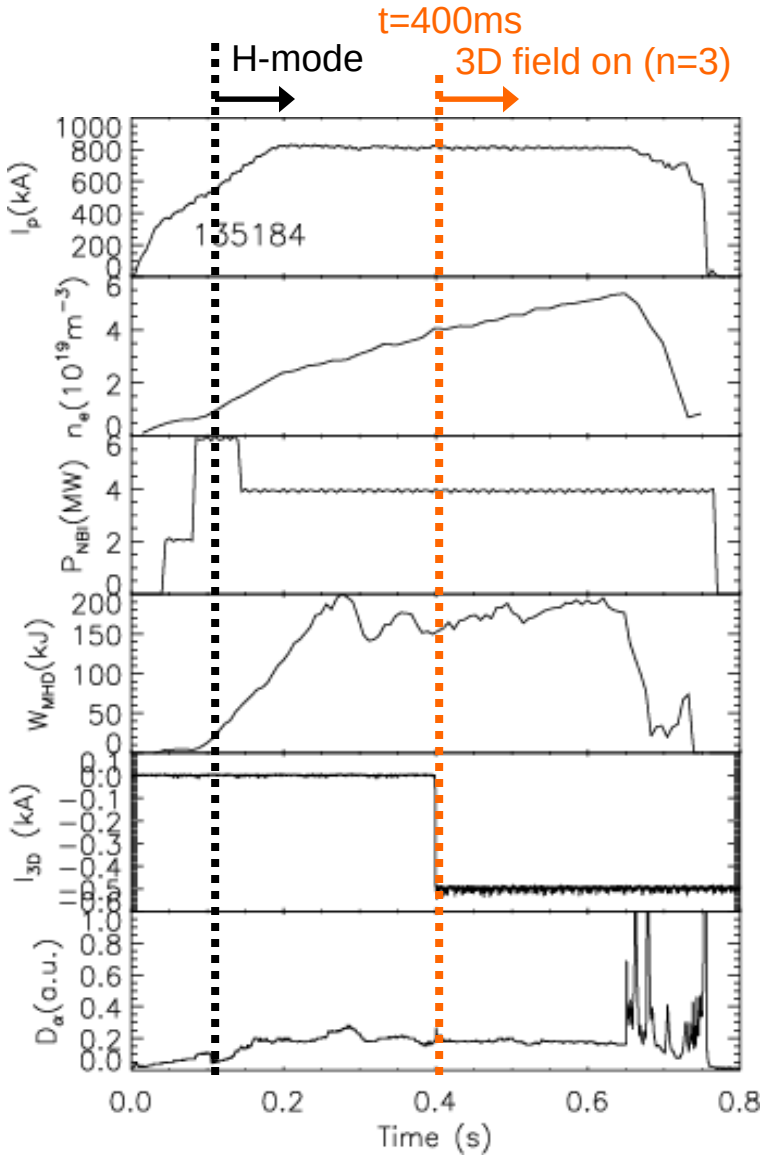




- 3-D fields (n=1, 2, 3) can be applied externally
- Connection length for field lines at divertor target, computed by vacuum field line tracing (J.M. Canik)
- Field line tracing uses superposition of vacuum n=3 fields and 2-D equilibrium fields

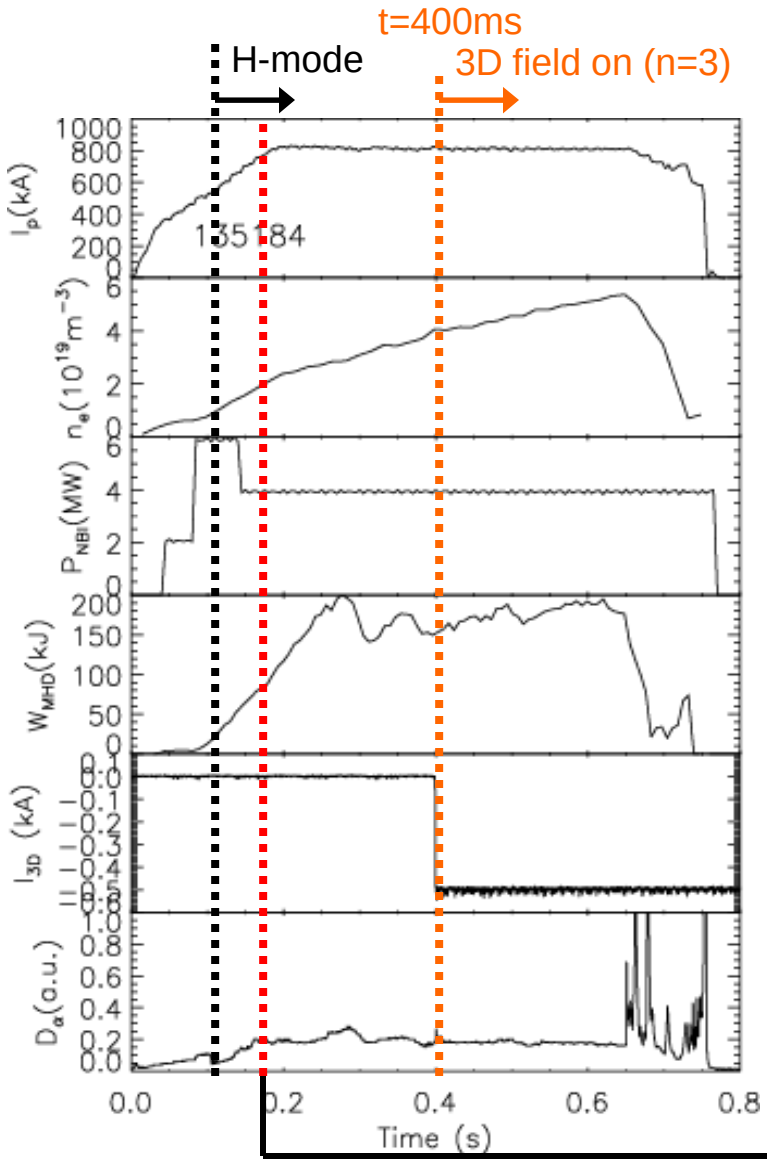
J-W. Ahn, Nucl. Fusion (2010), 045010

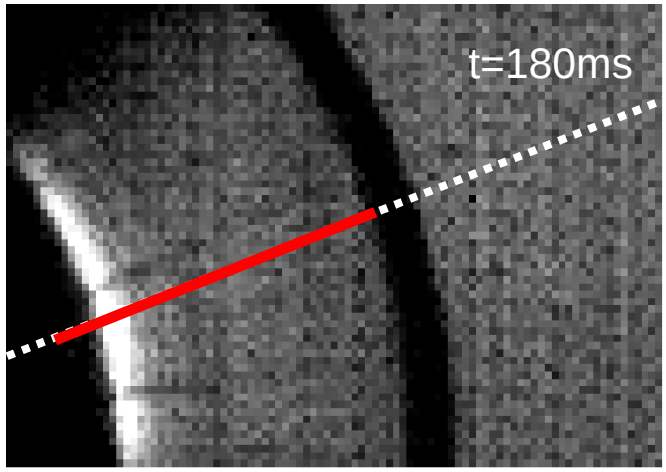
Discharge evolution for Lithium enhanced ELM-free H-mode

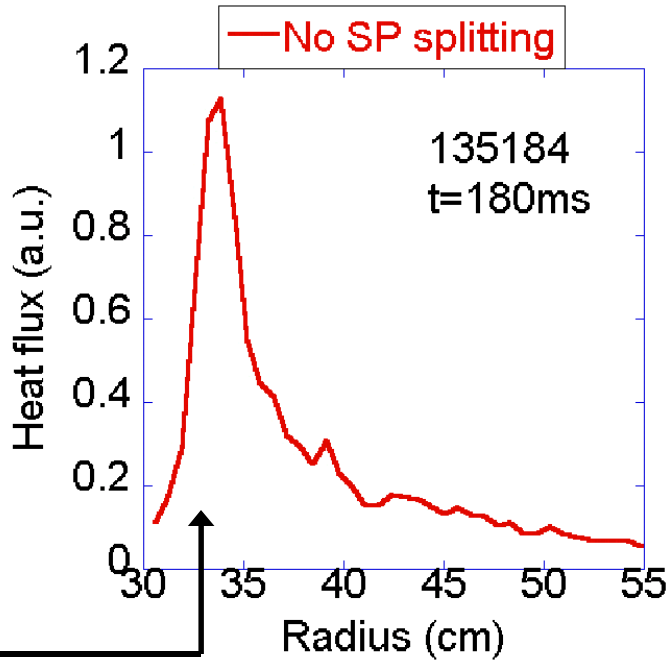


- L-H transition at t=110ms and the whole H-mode period stayed in ELM-free regime due to low recycling by lithium coating
- n=3 fields were applied from t=400ms with amplitude below the threshold limit to trigger ELMs

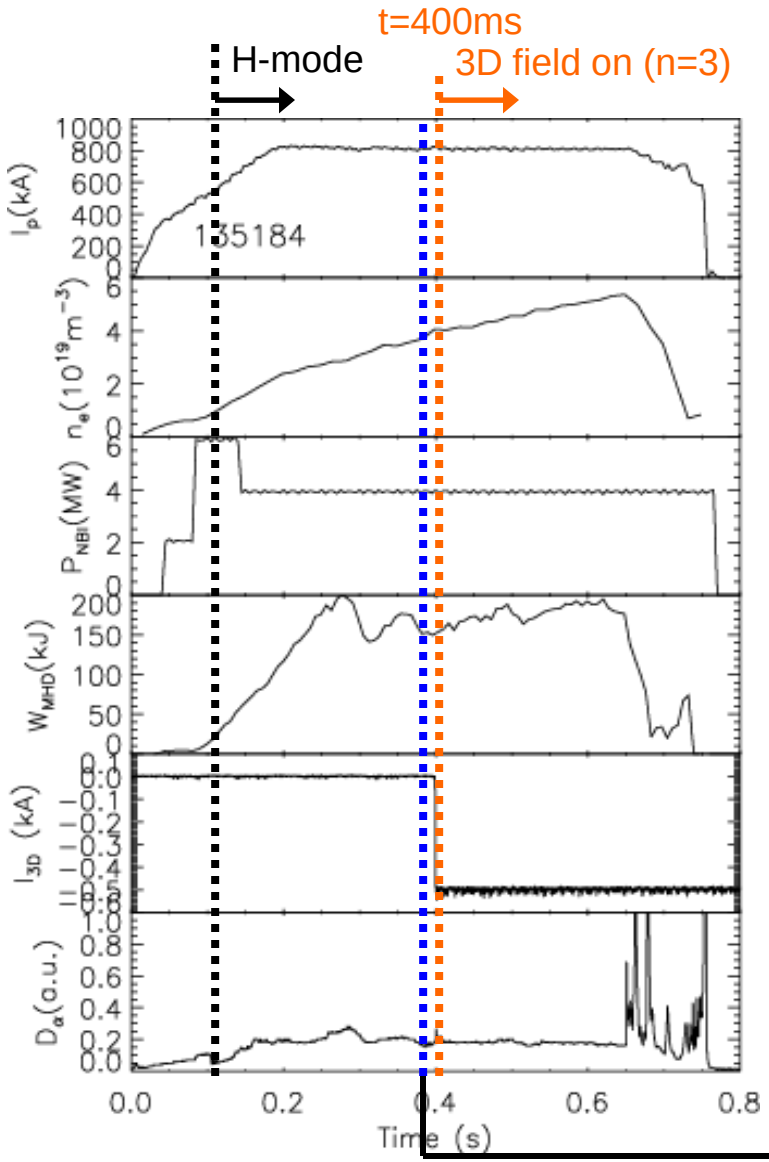
Nearly monotonic profile at early stage of discharge

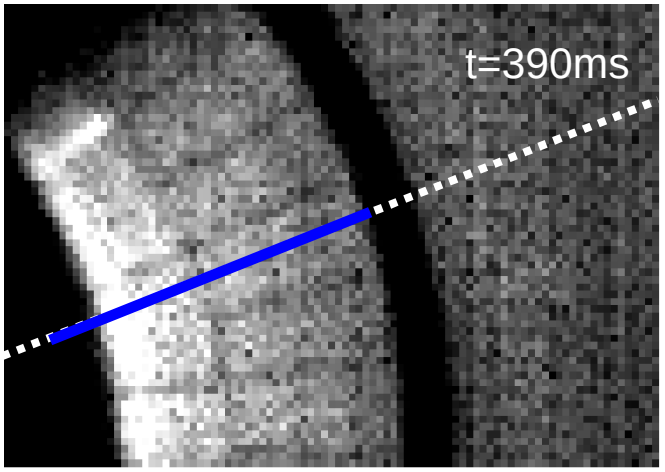


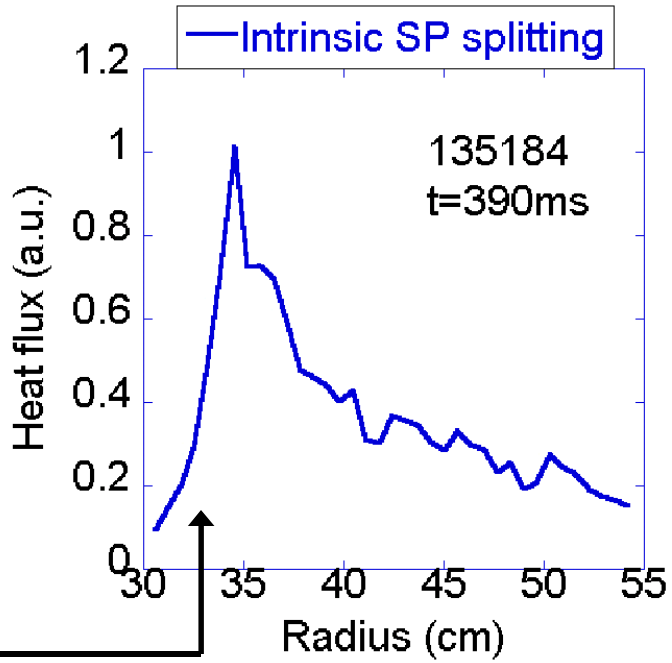




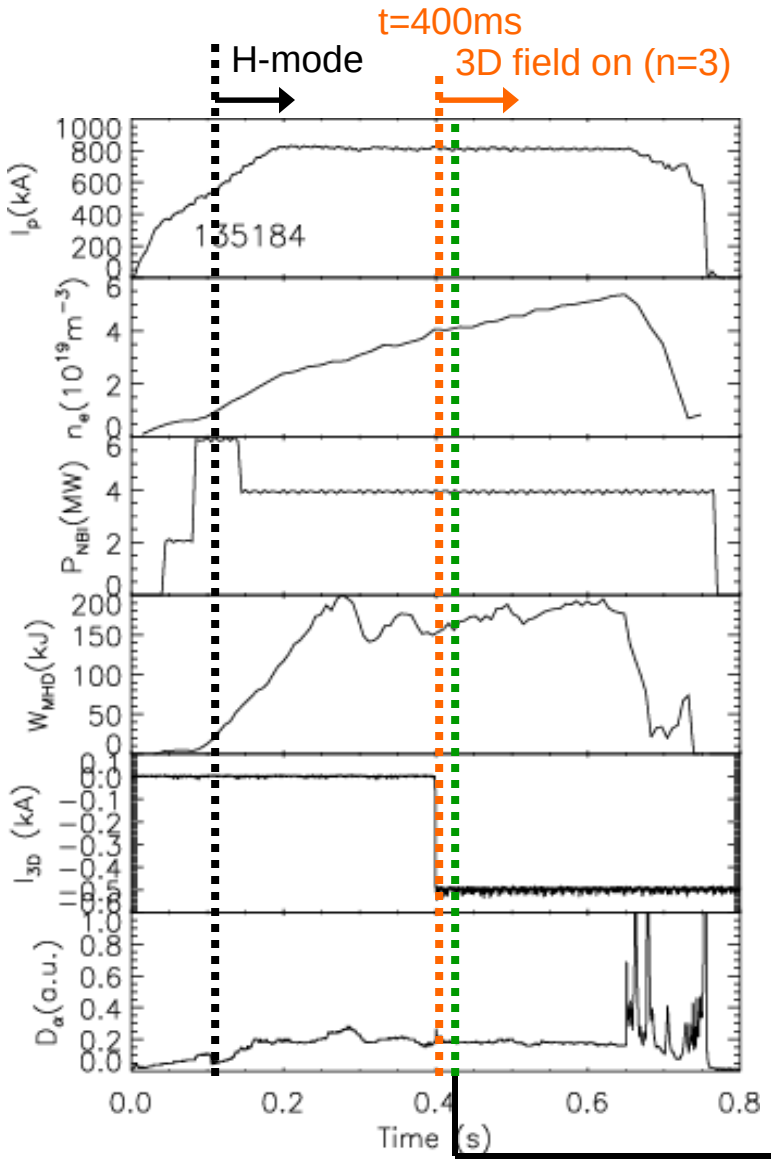
‘Intrinsic strike point splitting’ before 3-D field application

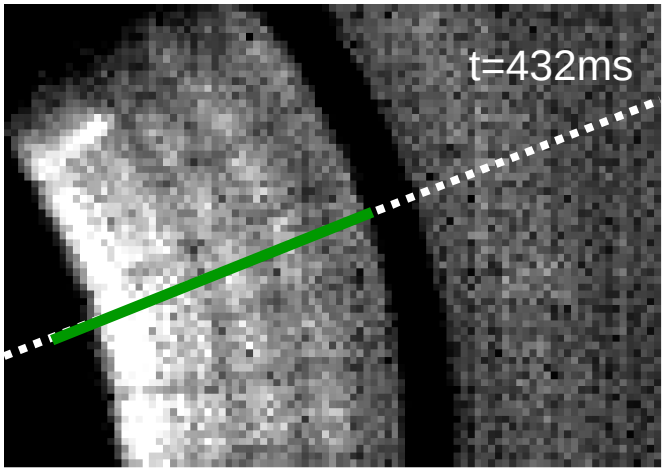


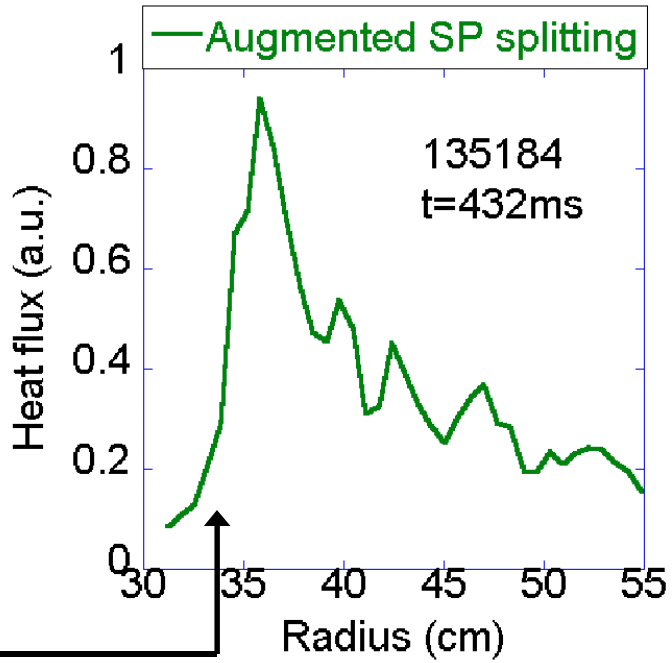




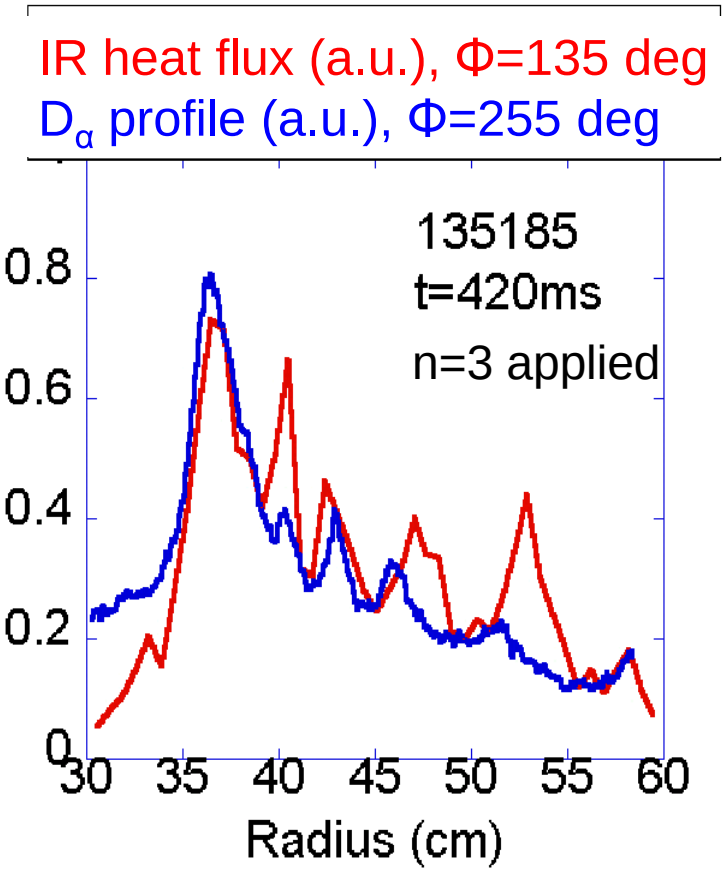
‘Augmented strike point splitting’ by 3-D field application





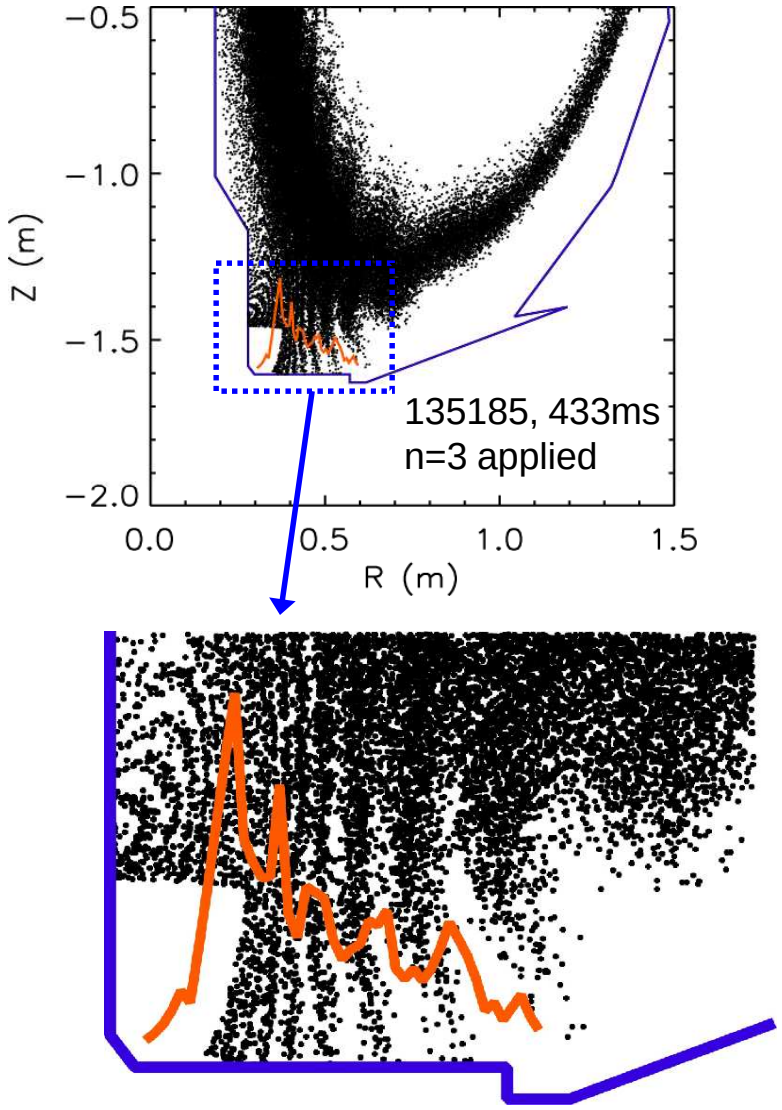


Strike point splitting is consistent with the applied n=3 periodicity



- The profile modification is expected to have n=3 periodicity (120º) due to the imposed n=3 field structure
- Locations of local peaks and valleys in the heat flux (IR camera at 135º) and D_α (at 255º) profiles are similar

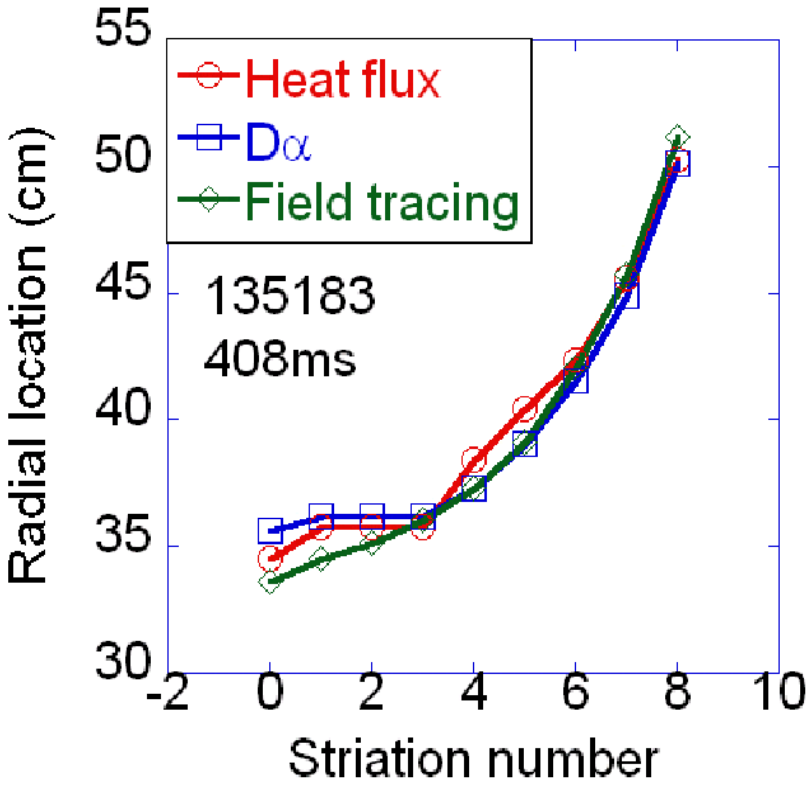
Distribution of lobe locations agrees well between measurement and vacuum field line tracing



- Measured heat flux profile (orange) overlaid with vacuum field line tracing plot
- Dense regions in the puncture plot correspond to long connection length lobes, therefore expected to have higher heat and particle fluxes

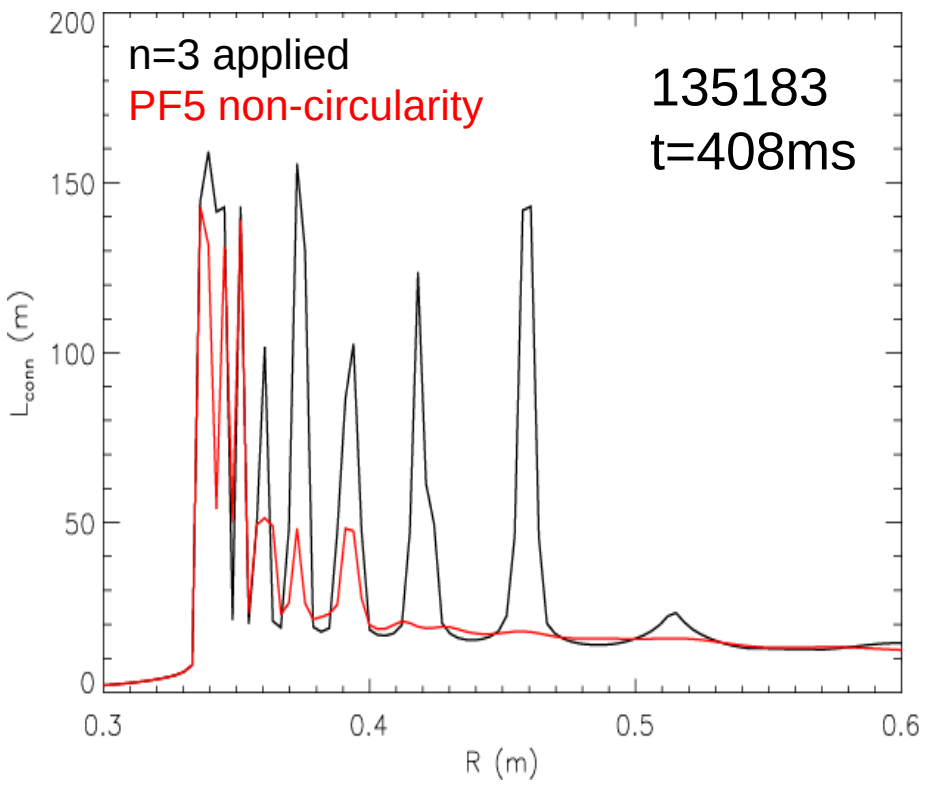
J-W. Ahn, Nucl. Fusion (2010), 045010

Radial location of striations agrees between measurement and modeling



- Radial location and the width of striations increase with striation number
- Radial location of local peaks for all three profiles (heat flux, D_α, L_c from field line tracing) agree with each other quite well

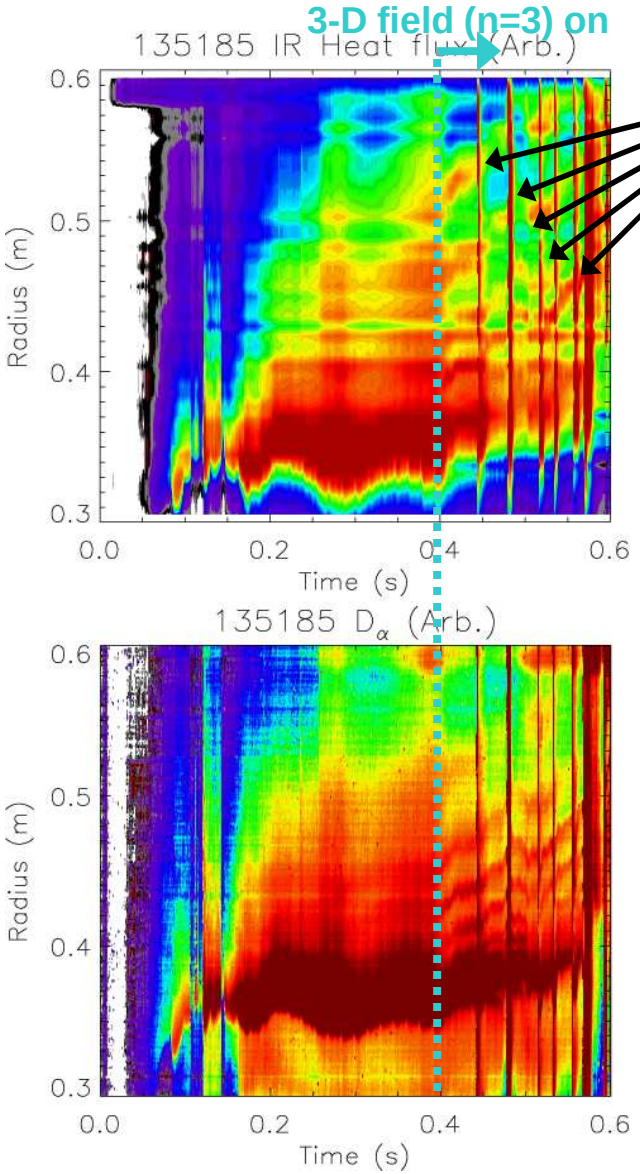
Intrinsic error field may be one of the sources for intrinsic strike point splitting



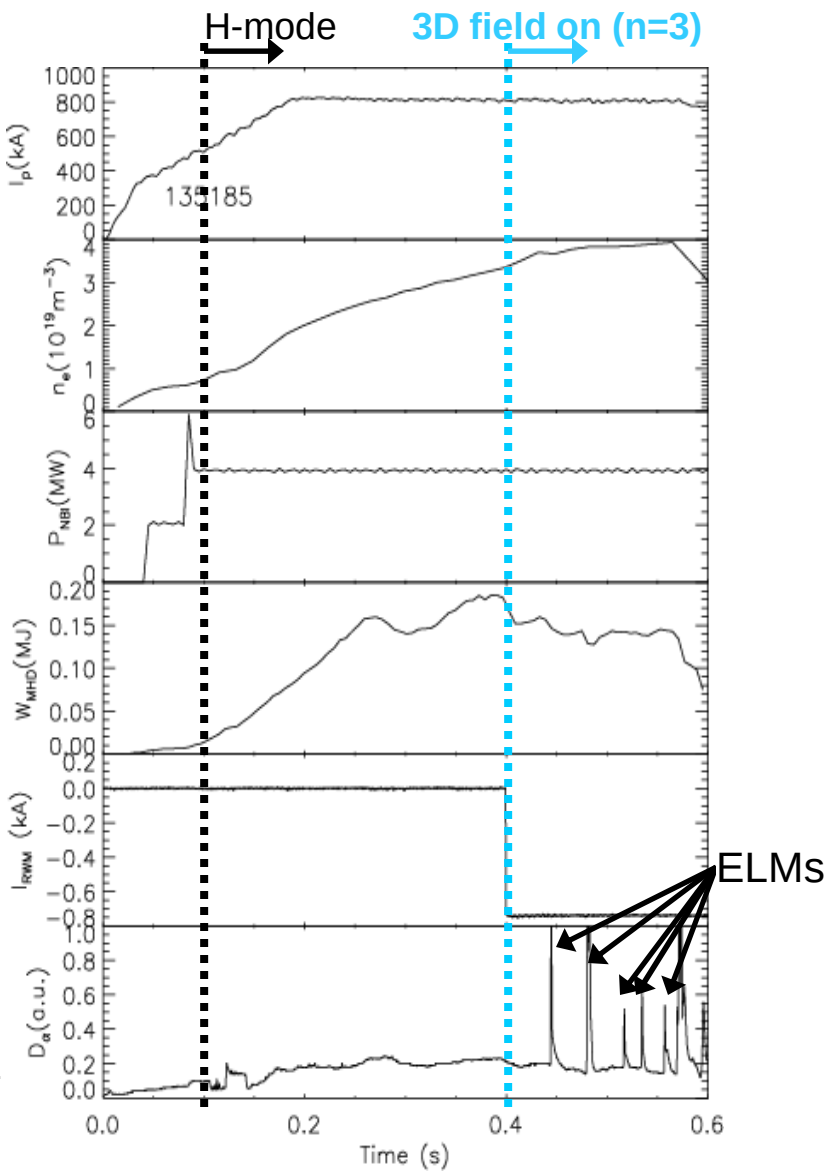
- Vacuum field line tracing modeling for intrinsic error fields from the non-circularity of PF5, n=3 component is known to be dominant component[1]
- Radial location of local peaks agree between PF5 and n=3 application cases, consistent with experimental observations in NSTX

[1]J.E. Menard, Nucl. Fusion (2010), 045008

Imposed n=3 fields cause strike point splitting and trigger ELMs

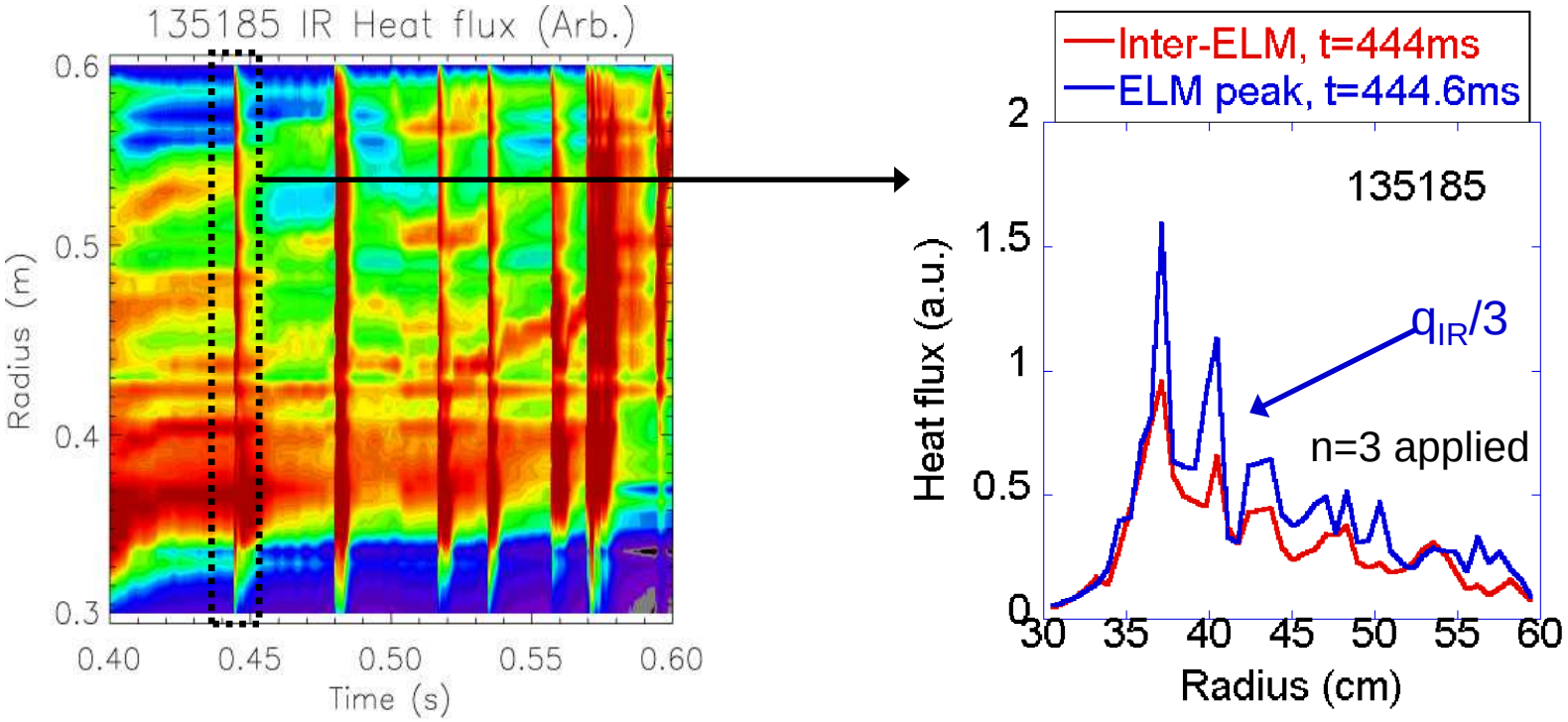


ELMs triggered by 3-D field application[1]



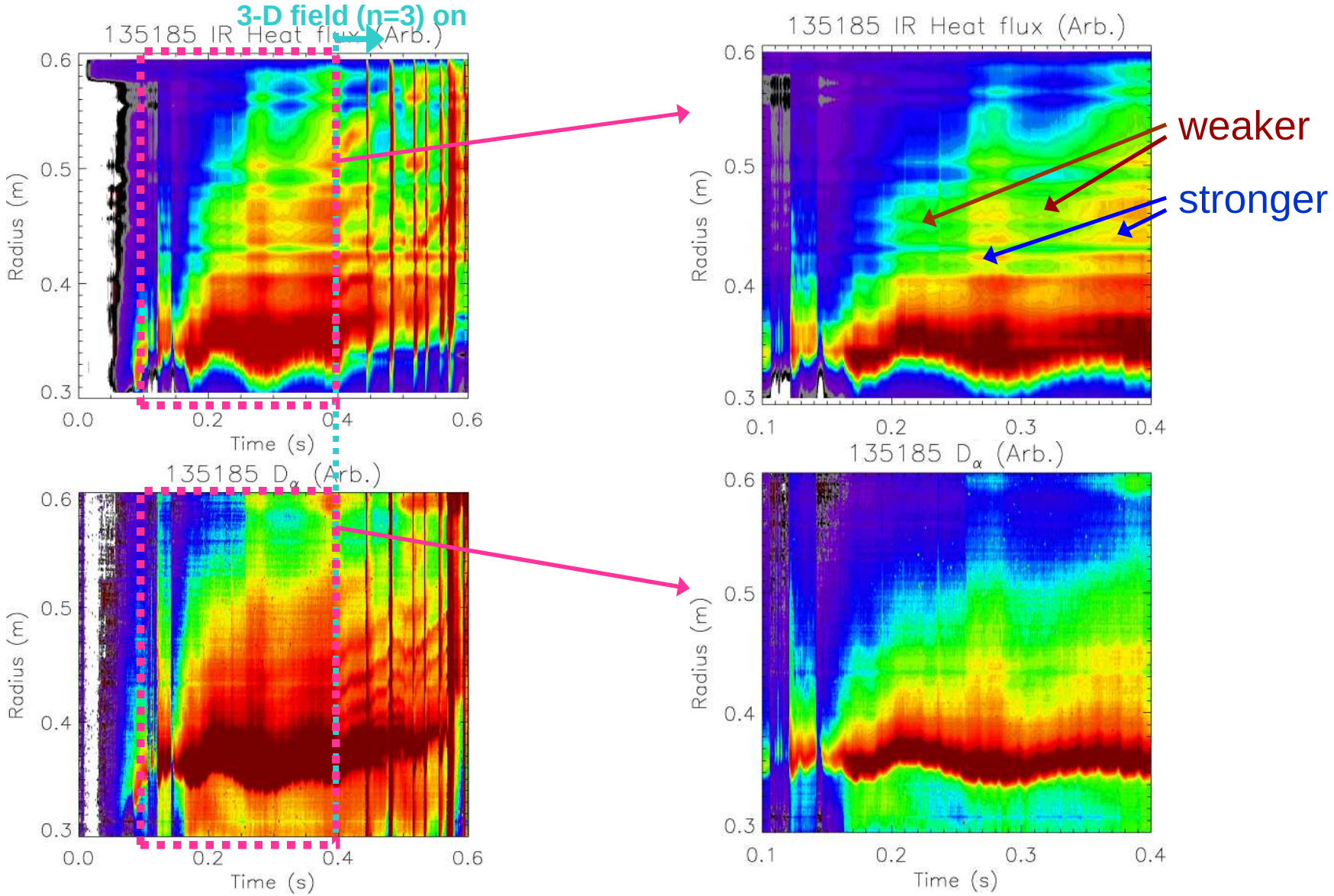
[1]J.M. Canik, PRL (2010), 045001

Heat flux profile from ELMs triggered by n=3 fields appears to follow imposed field structure

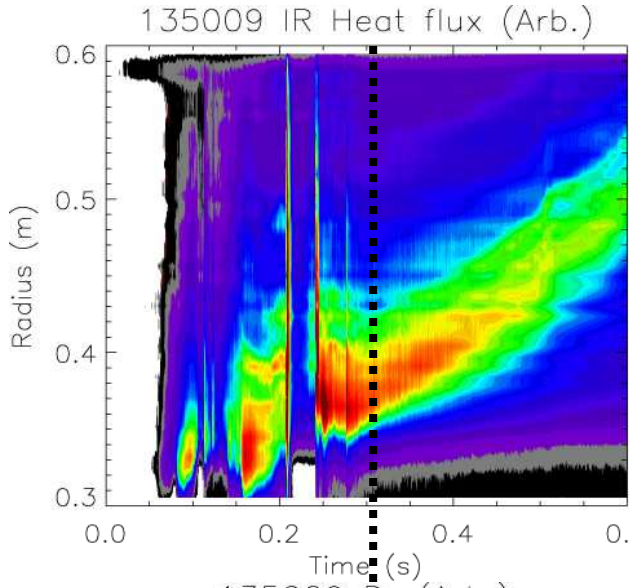


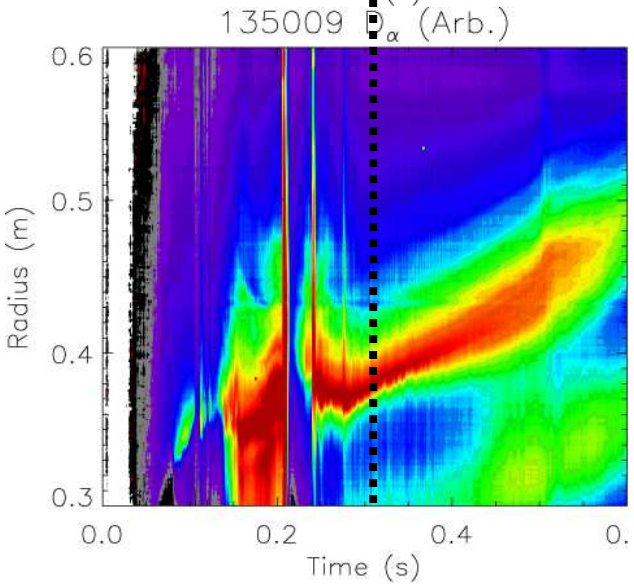
- Striations in the heat flux profile appear in the same locations as was before the ELM
- 3-D field triggered ELMs appear to be phase-locked to the externally applied perturbation structure

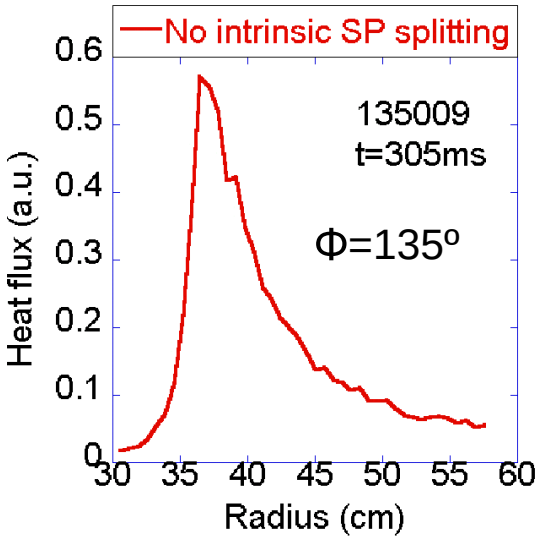
Degree of intrinsic strike point splitting varies in time during the discharge

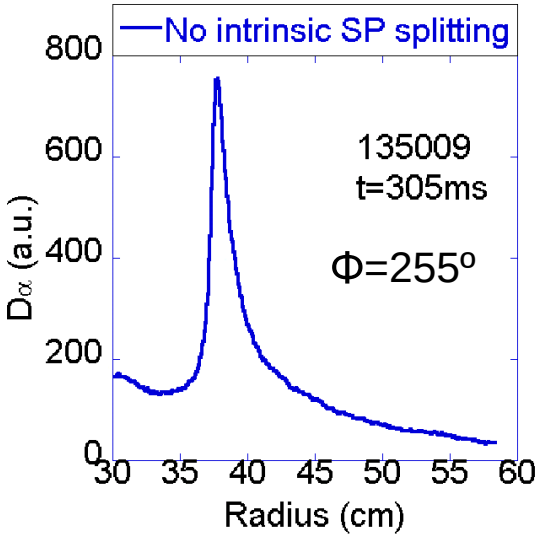


Intrinsic strike point splitting is not ubiquitous in NSTX



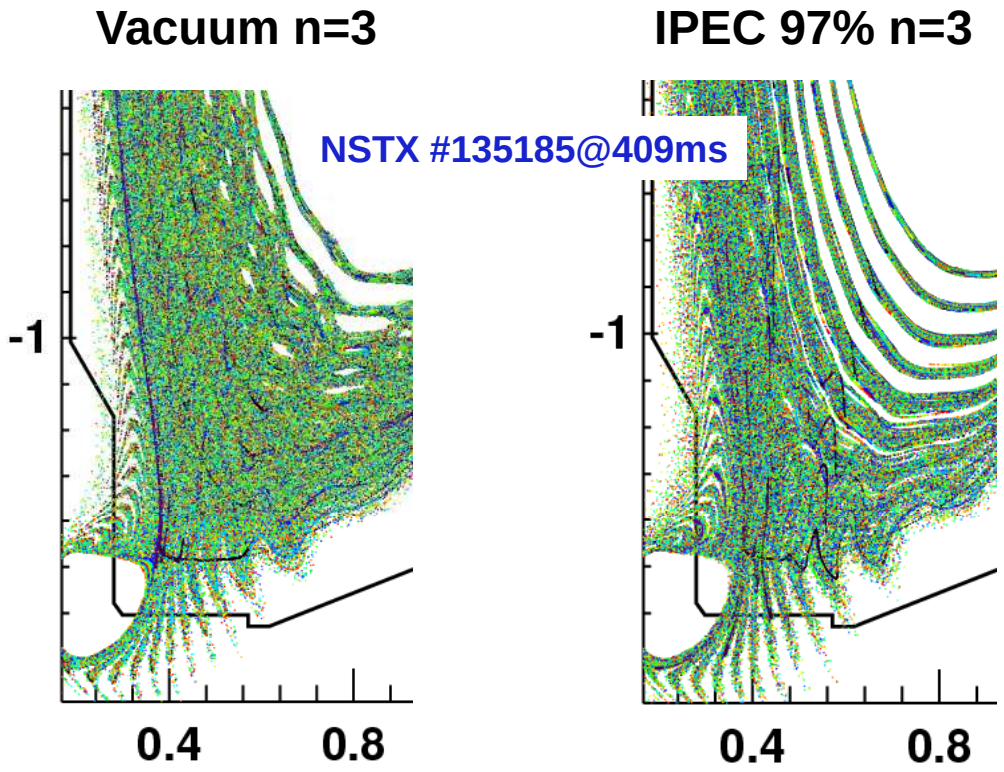






- In other discharges, both heat flux and D_α profiles show no sign of intrinsic strike point splitting
- What causes the difference?

Plasma response inside separatrix appears unimportant for the formation of lobe structure



- Plasma response computed by Ideal Perturbed Equilibrium Code (IPEC)[1], an ideal MHD code capable of solving 3-D equilibrium with free boundary
- Radial location and spacing of generated lobes are little affected by the plasma response inside the separatrix

[1]J.-K. Park, Phys. Plasmas (2007), 052110

Vacuum field line tracing provides good agreement with measured lobe structure in divertor profiles

- Measured heat and particle flux profiles show strike point splitting at the divertor target with the effect of both,
  - Intrinsic 3-D fields, intrinsic error fields may be one of the sources
  - Imposed 3-D fields by external coils
- The expected periodicity of measured divertor profiles for imposed 3-D fields was confirmed experimentally
- Inclusion of plasma response does not affect the structure of split strike point significantly
- 3-D field triggered ELM heat flux appears to largely follow split strike point channels

Future work

- More data for various n numbers (n=1 and 2)
- Quantify sources of intrinsic strike point splitting
- Figure out toroidal mode number for natural ELMs
  - Compare with field line tracing result with various n numbers composed
  - Use of wide angle camera will further help
- Investigate effect of collisionality and q95
- Rotate applied 3-D fields to find out toroidal hot spots if any

Sign up for a copy