NSTX

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Characterization of transient particle loads during lithium experiments on the National Spherical Torus Experiment

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2nd International Symposium on Lithium Applications for Fusion Devices

Princeton, NJ

04/27/2011

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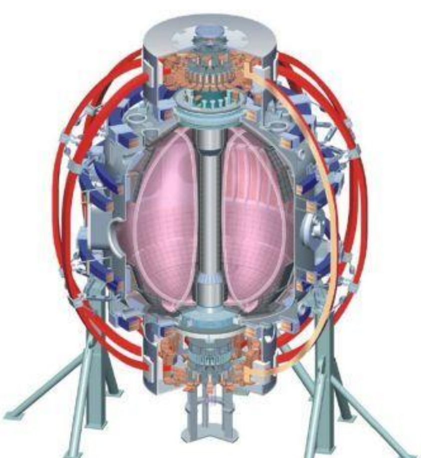

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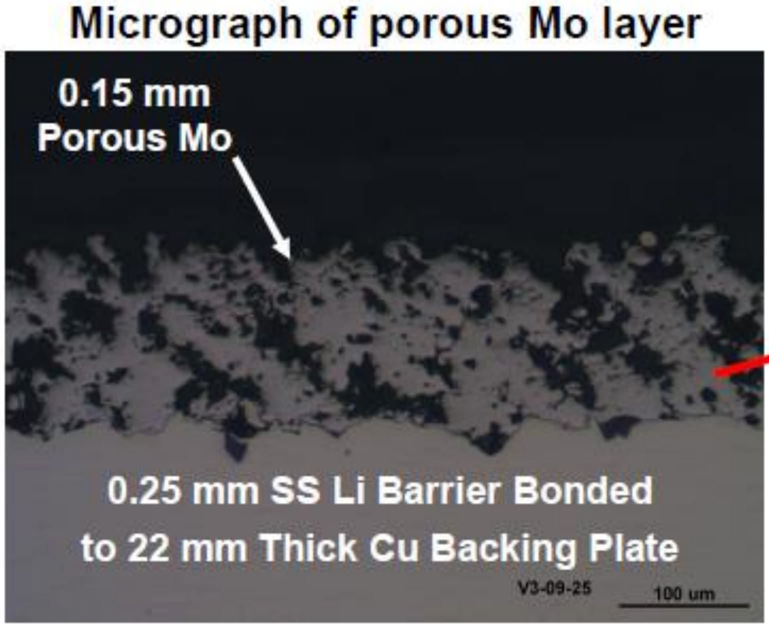
Presentation Outline

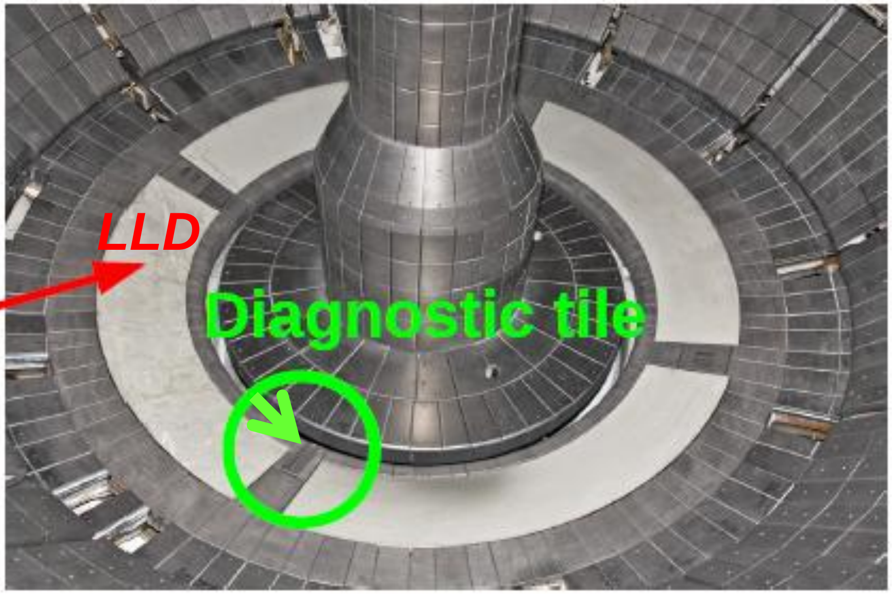
- Introduction
- High Density Langmuir Probe (HDLP) Array
- ELM characterization
  - Observation and Methodology
  - ELM characteristics and statistics
- Particle and Power Deposition Profiles during ELMs
  - HDLP Array for particle flux measurements
  - IR camera diagnostic for power deposition profiles
- Conclusions
  - The average heat load during ELMs on the LLD is ~1.5 MW/m^2
  - The fraction of ELM energy leading to temperature rise on the divertor material is only ~15%.

Introduction

- Transient events like Edge Localized Modes (ELMs) pose a serious problem to the plasma facing component (PFC) material.
- Lithium has shown to suppress ELMs in NSTX, however, some transient events still appear in some of the shots.
- To understand the effect of such transient events and their deleterious effects, ELM characterization and target deposition profile measurements are required.
- In addition, another motivation for this work is to understand the kind of heat loads the LLD experienced during the 2010 run campaign so that future designs can take this into consideration.
- For this purpose, the High Density Langmuir Probe (HDLP) array is used in this study.

High Density Langmuir Probe (HDLP) Array

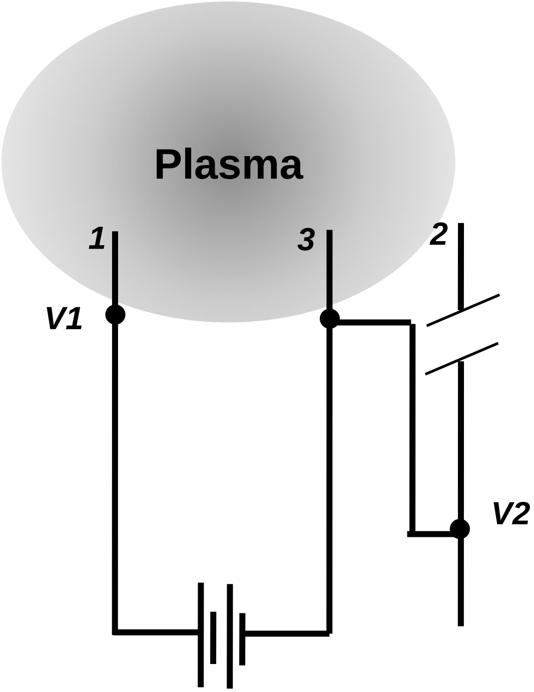




- 99 Probe (3 x 33) array
- Each Triple Langmuir Probe (TLP) is biased by an individual circuit board which contains a regulated, isolating DC power supply
- Time resolution of 4 μs when operated in triple probe configuration

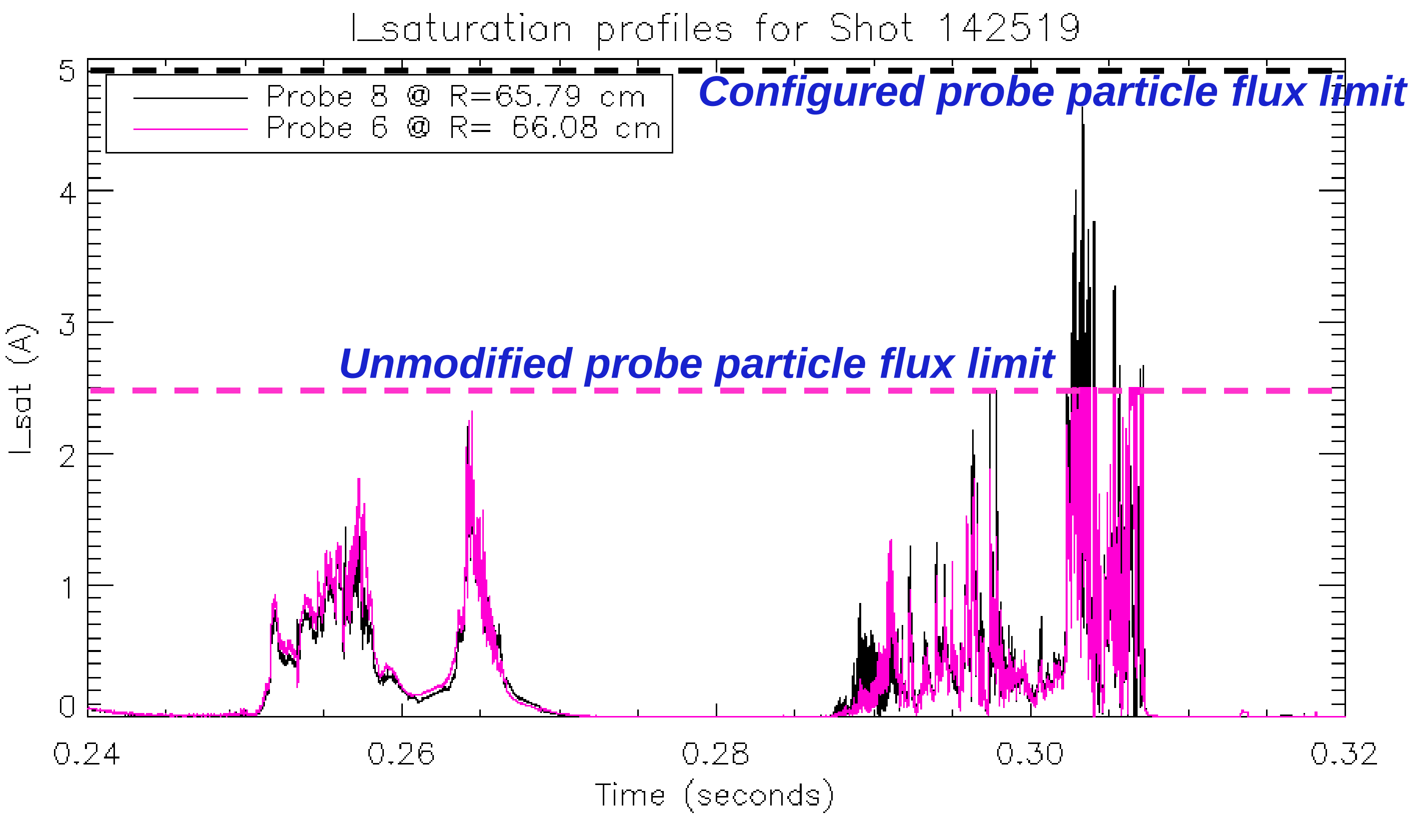
Probe configuration modified to measure particle flux

- Two Modifications
  - Increase the current saturation limit
  - Measure bias voltage
- The circuit is modified in such a way that instead of measuring floating potential on probe 2, V_3 is measured as V_2
- The difference in V_1 and V_2 gives the bias voltage, which is altered during an ELM like event
- Note that this reconfigured probe can not measure T_e and so the unmodified probe adjacent to this location is used for T_e measurements



V_3 is measured via V_2
$U_{bias} = V_1 - V_2$

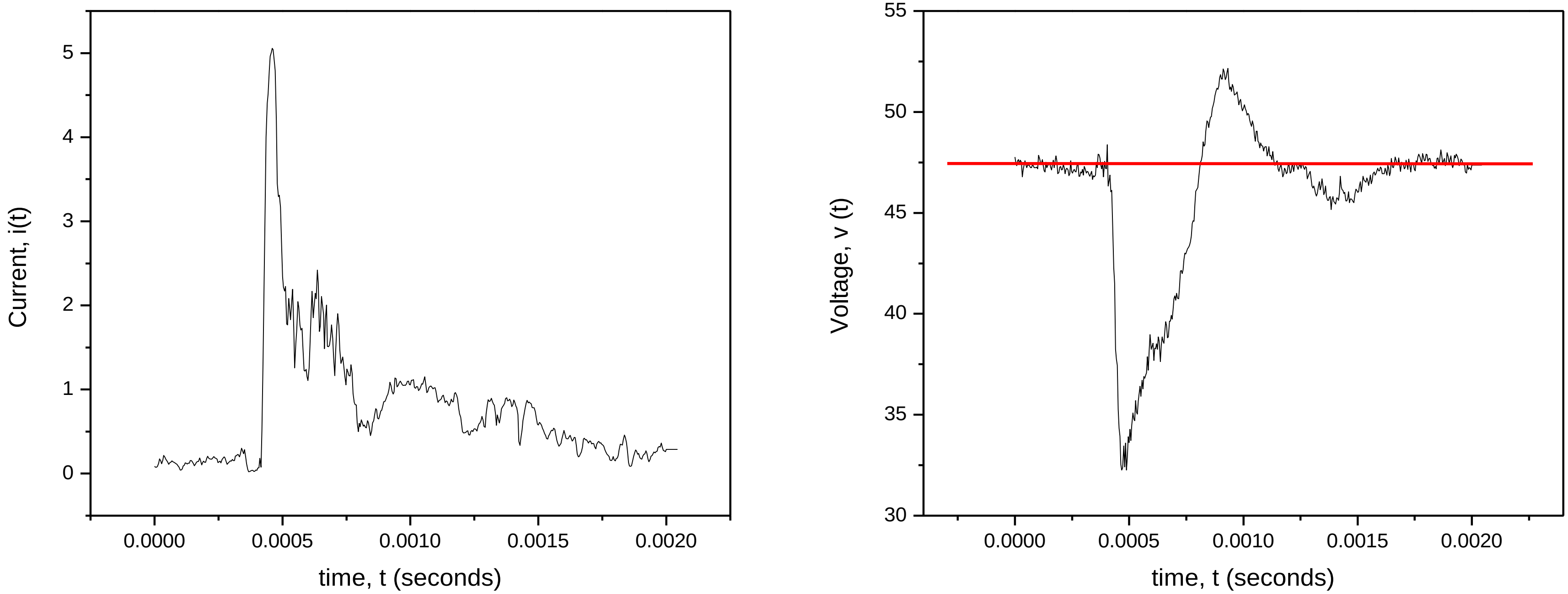
Unmodified probe is a good indicator of configured probe



- Now, the configured probe (probe 8) can measure up to 5 A (2 x amplification).
- For Te measurement, unmodified probe (probe 6) will be used as it is adjacent to the configured probe

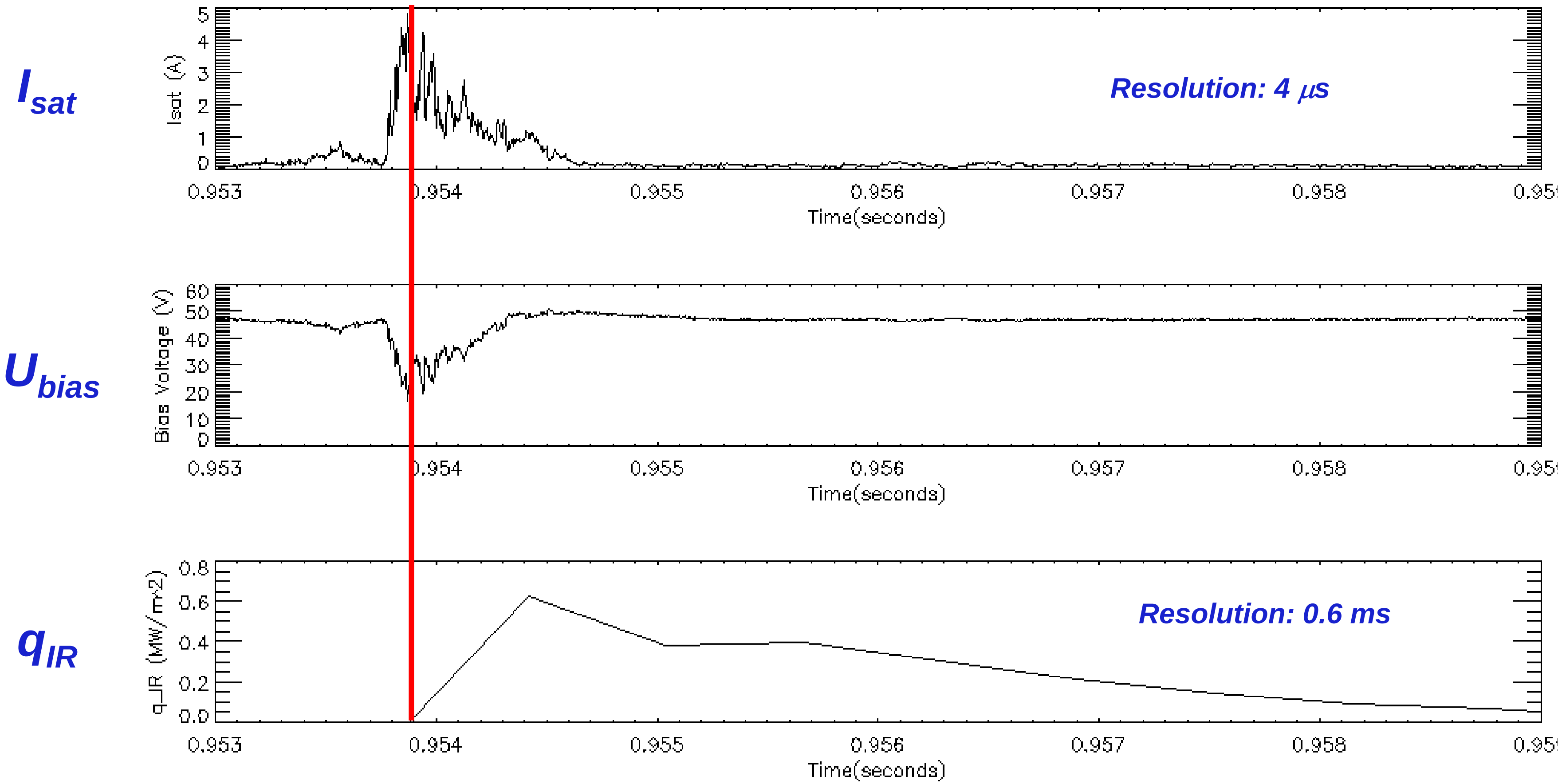
Reconfigured probe allows measurement of bias voltage

Typical measurement (shown here for shot #142255)



- The response of the system strongly depends on the current waveform, i(t),(its amplitude, and duration)
- The voltage bias in conjunction with I_{sat} can be used as a criterion to select transient events like ELMs.

Time occurrence of a transient event



- Transient events can be observed via many other diagnostics
- The current rise as seen by the Langmuir probe correlates well with other diagnostics

ELM data analysis

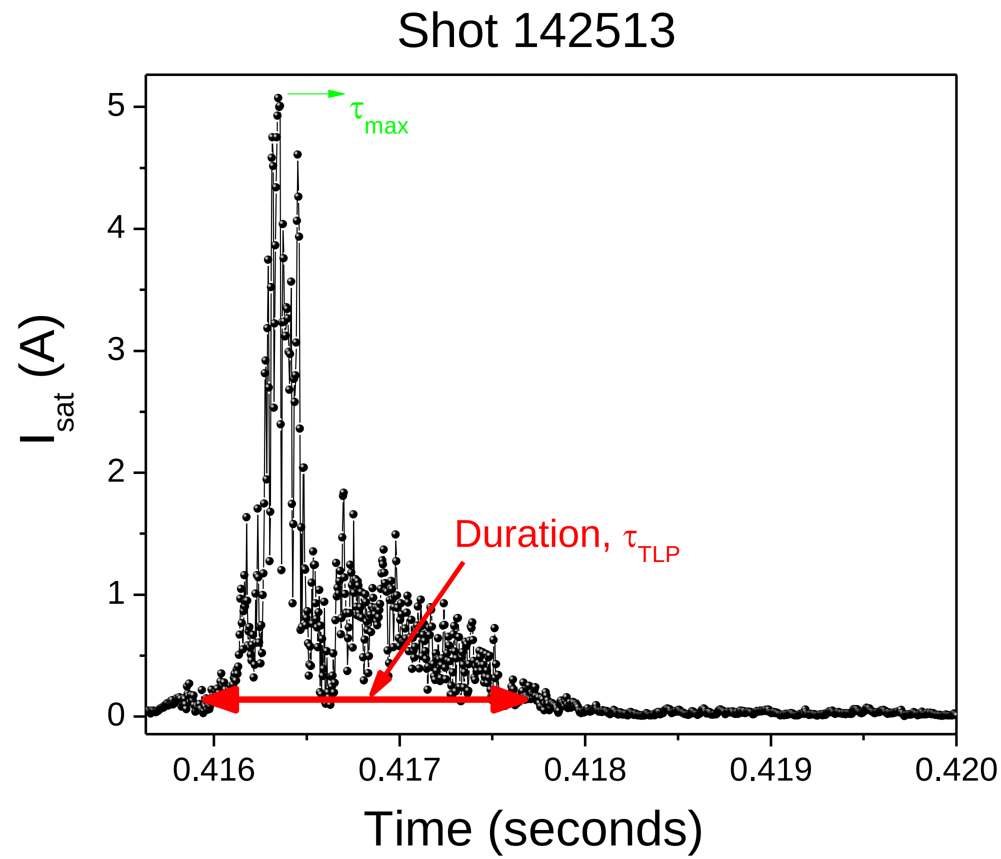
- For the current analysis, only one probe is used and is at a fixed location (r=65.79 cm)
- The circuit modification is effective only after shot#141617 and so only shots after the circuit modification during the FY10 run are included (~900 shots)
- Shots can not be compared directly due to differences in strike point locations and so shot comparisons are avoided
- Instead, selection of transient events is made based on the criteria imposed on the probe so that statistical analysis is possible
- Future work includes spatial measurements of particle flux from probes in order to make detailed comparisons with heat flux profiles and to obtain spatial width

ELM size definitions for the probe at fixed radius, r

$$\tau_{TLP} = t_n - t_0$$

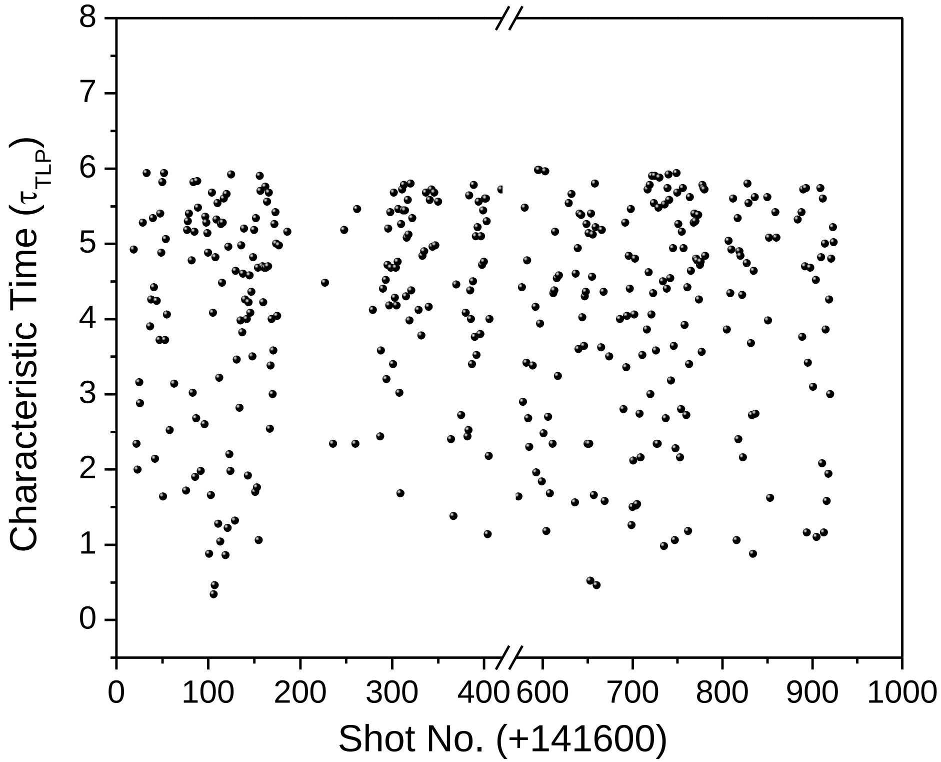
$$\Gamma = \frac{1}{A_p}\left[\frac{\int \left(\frac{I_{sat}}{e}\right) dt}{\Delta T}\right] \left({}^{\#}/_{m^2 - s}\right)$$

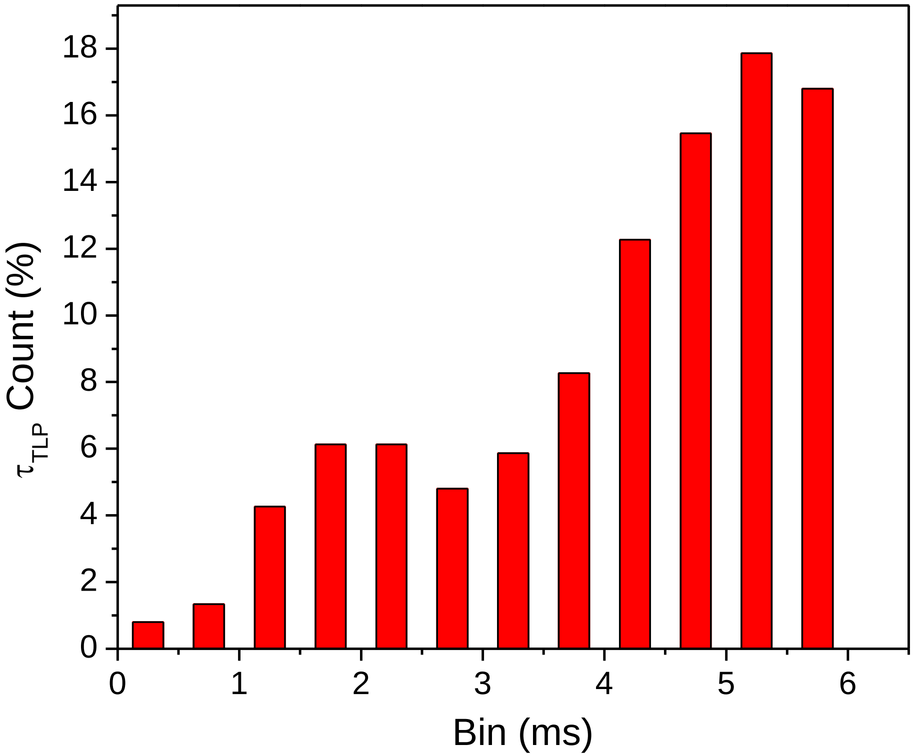
$$q_{TLP} = \Gamma * (kT_e)$$



Which parameter is better to represent ELM size?

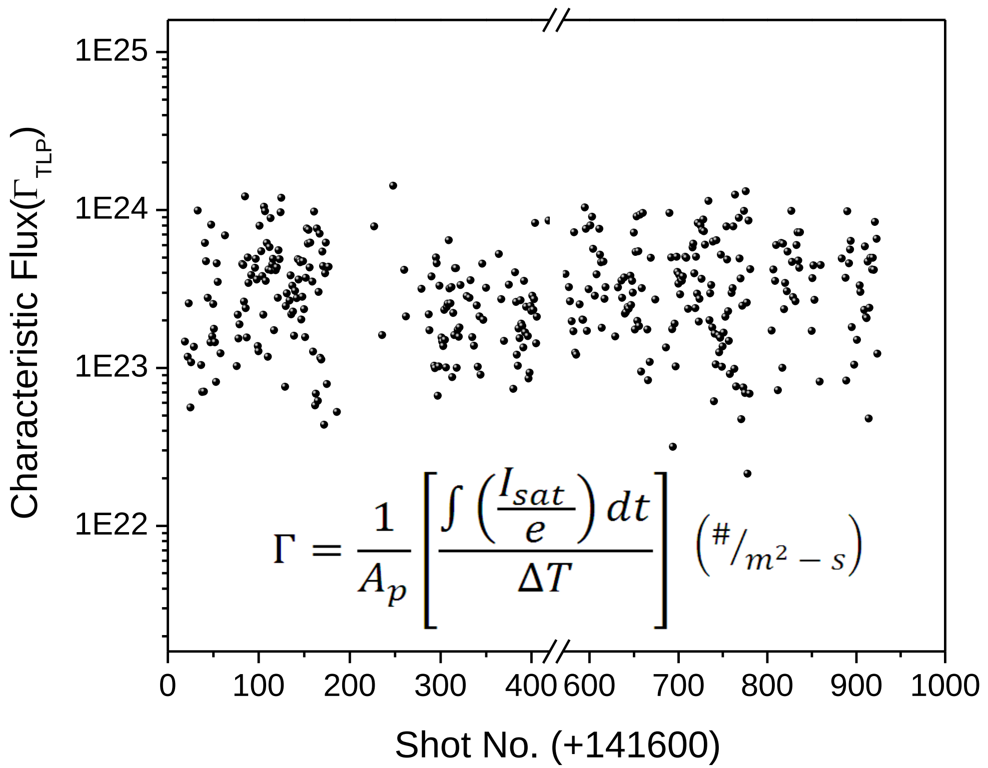
ELM Characteristic times (τ_{TLP})

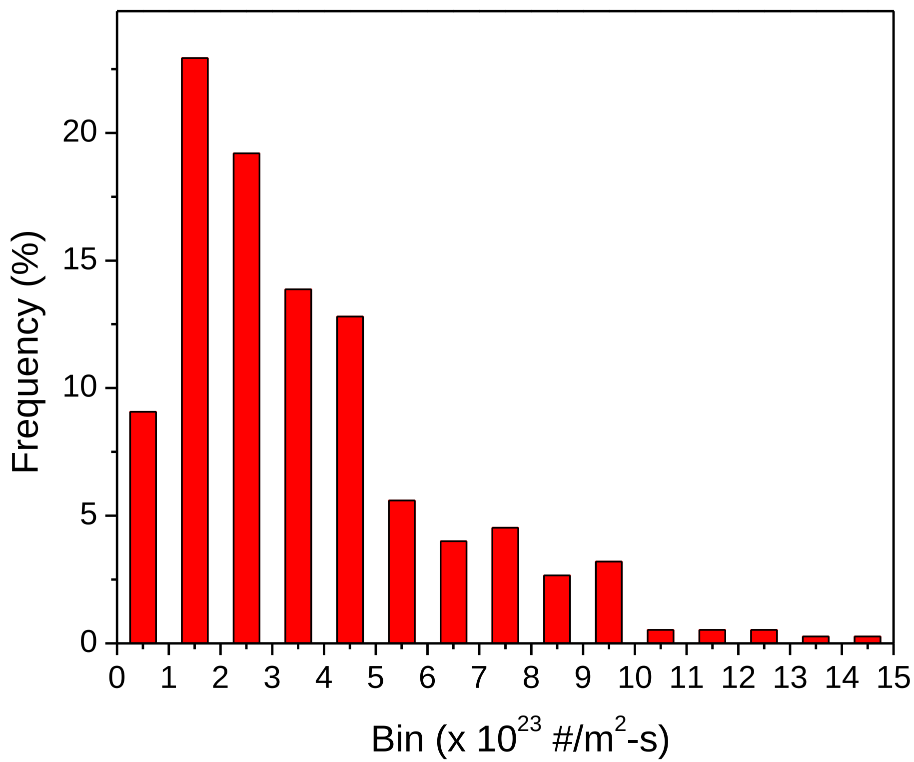




	N total	Mean	Std. Dev.	Minimum	Median	Maximum
τ_{TLP}	375	4.10333	1.44211	0.33998	4.5	5.98001

ELM Characteristic Flux (Γ_{TLP}) at the probe

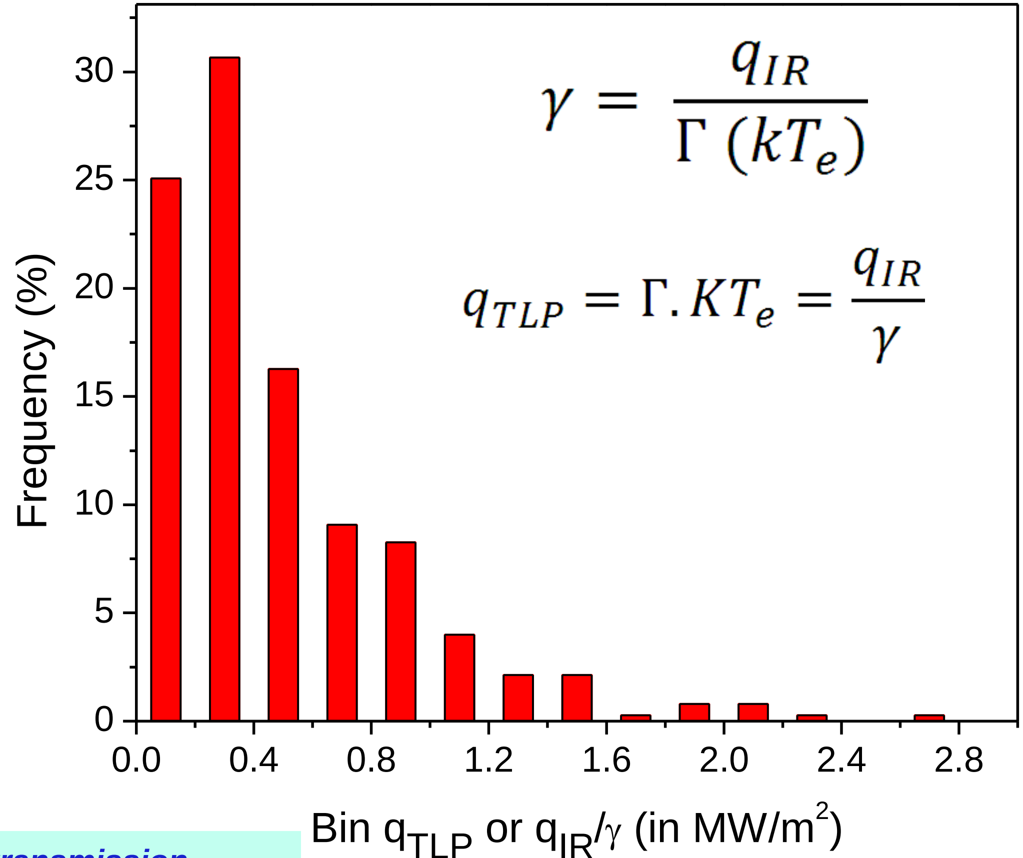




	N total	Mean	Std. Dev.	Minimum	Median	Maximum
Γ_{TLP}	375	**3.64E+23**	2.60E+23	2.14E+22	2.95E+23	1.43E+24

Power deposited during an ELM (q_{TLP}) on the probe

- Used an average Te value from probe 6
- Assuming γ=3 leads to an average heat flux of 1.5 MW/m^2 striking the probe surface
- These can serve as baseline comparisons for future run campaigns



$$\gamma = \frac{q_{IR}}{\Gamma\,(kT_e)}$$

$$q_{TLP} = \Gamma.KT_e = \frac{q_{IR}}{\gamma}$$

Josh Kallman,"Determination of effective sheath heat transmission coefficient in NSTX discharges with applied Lithium coatings," ISLA 2011

	N total	Mean	Std. Dev.	Minimum	Median	Maximum
q_{TLP} (MW/m^2)	375	**0.49657**	0.41911	0.02358	0.35503	2.64443

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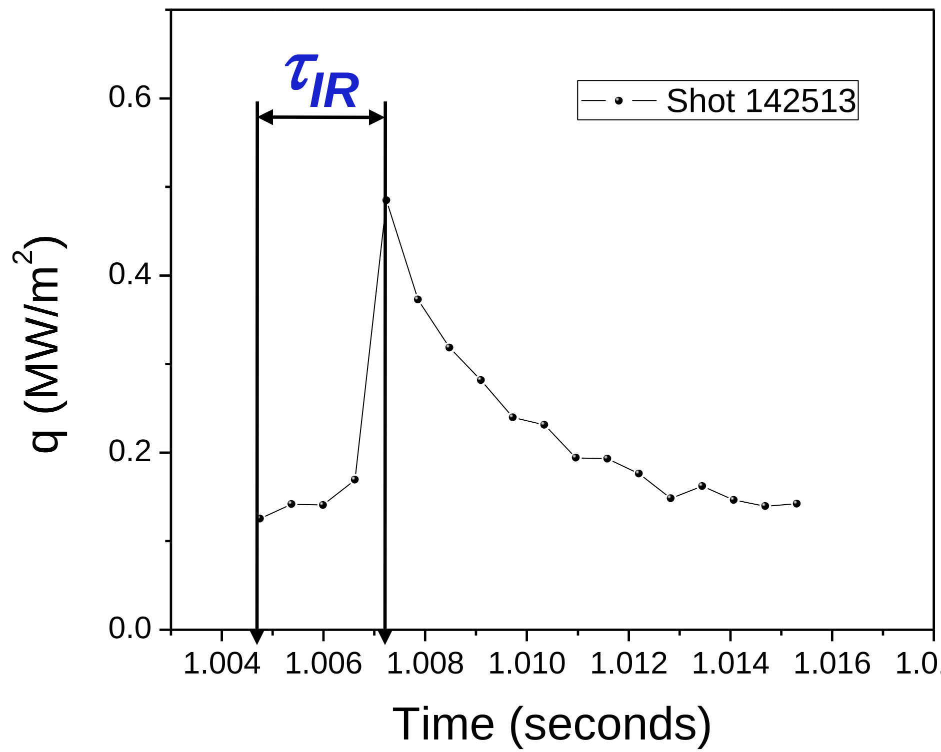
ELM Characteristics using IR camera heat flux profiles

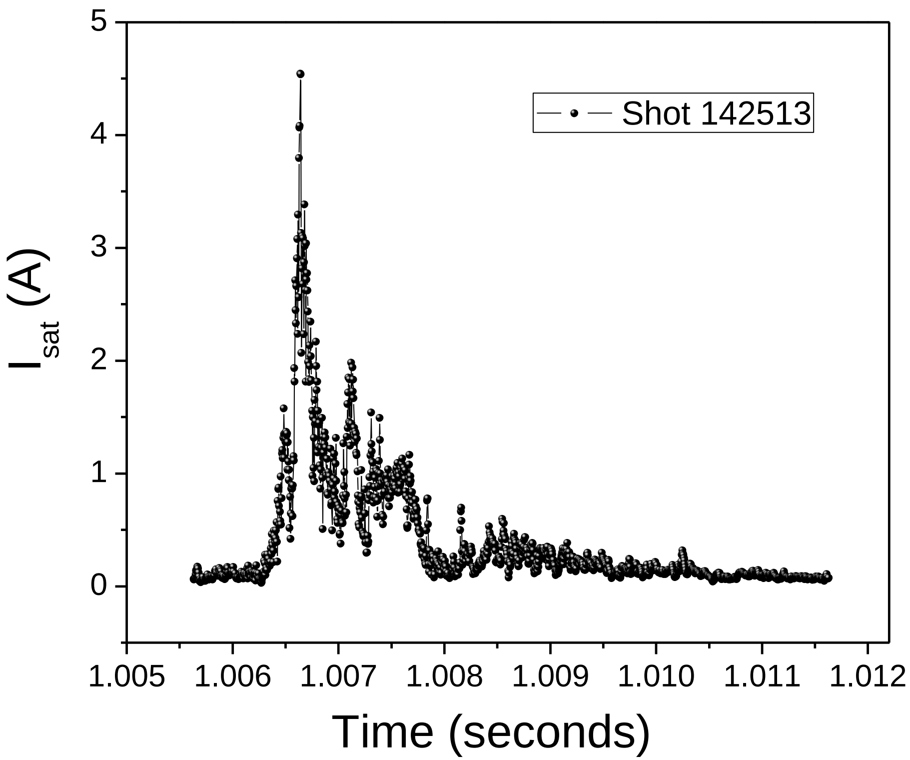
- The signal can be separated into two phases
- Time to reach the peak value for temperature or power is identical within the uncertainty
- Only the fraction (f_{peak}) of ELM energy that is deposited before τ_{IR} will lead to the maximum peak temperature on the divertor target during an ELM
- Flux mapping is used because of differences in geometry and toroidal location to compare the probe and IR camera measurements

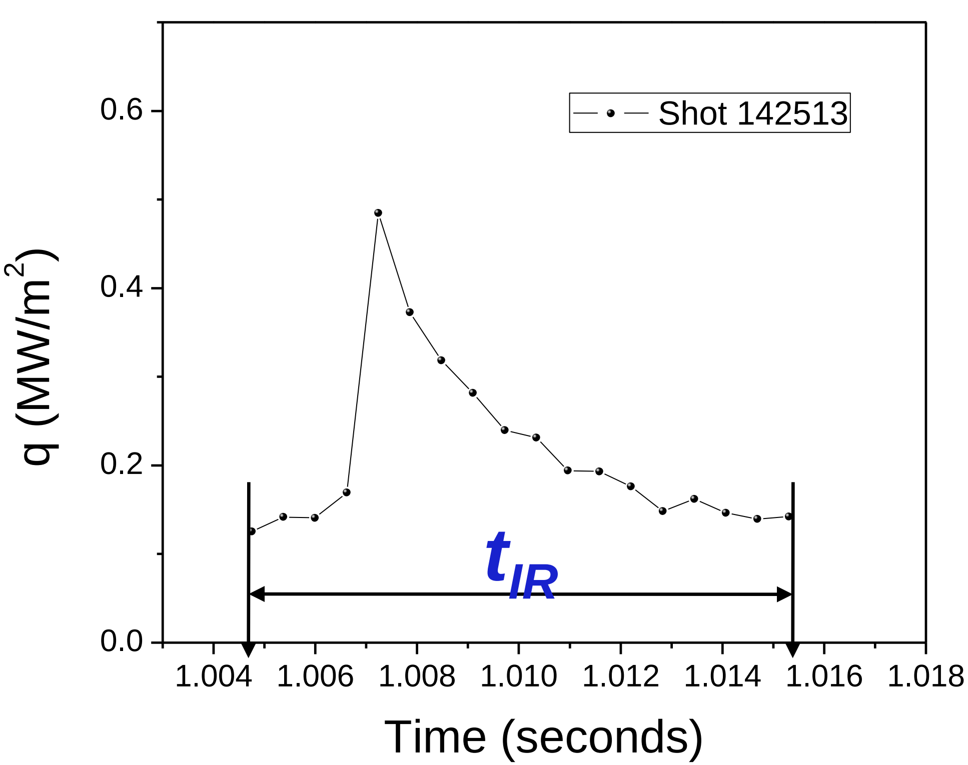


$$f_{peak} = \frac{E_{ELM}(t \leq \tau_{IR})}{E_{ELM}}$$

T.Eich et. al., Journal of Nuclear Materials 337-339 (2005) 669-676

Comparison of I_{sat} with q_{IR} profiles

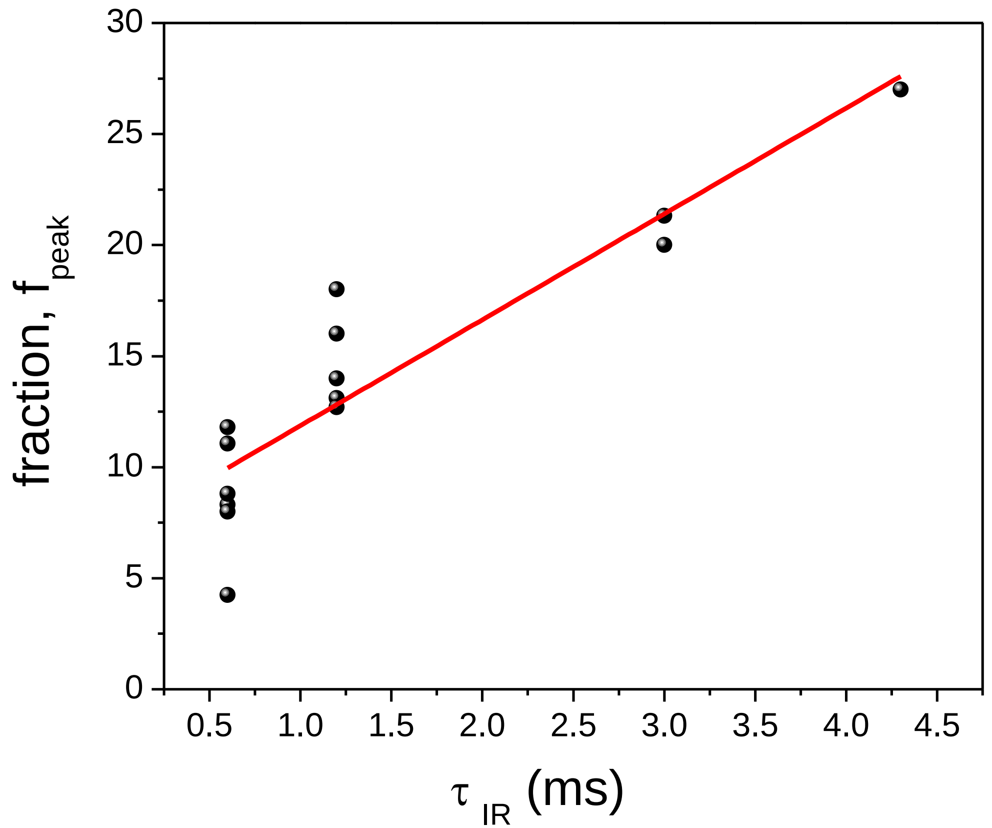




- Qualitatively, it can be seen that the duration of the IR profile is longer than I_{sat} signal
- Typical duration: t_{IR}~20 ± 8 ms > τ_{TLP}~2.7±0.9 ms

Variation of fraction, f_{peak} with characteristic time, τ_{IR}

- Typical times to reach the maximum heat flux of *few milliseconds* is observed
- A correlation between τ_{IR} and f_{peak} is observed
- The fraction of ELM energy leading to maximum temperature rise on the target is only 15 ± 8%.
- Further work is needed

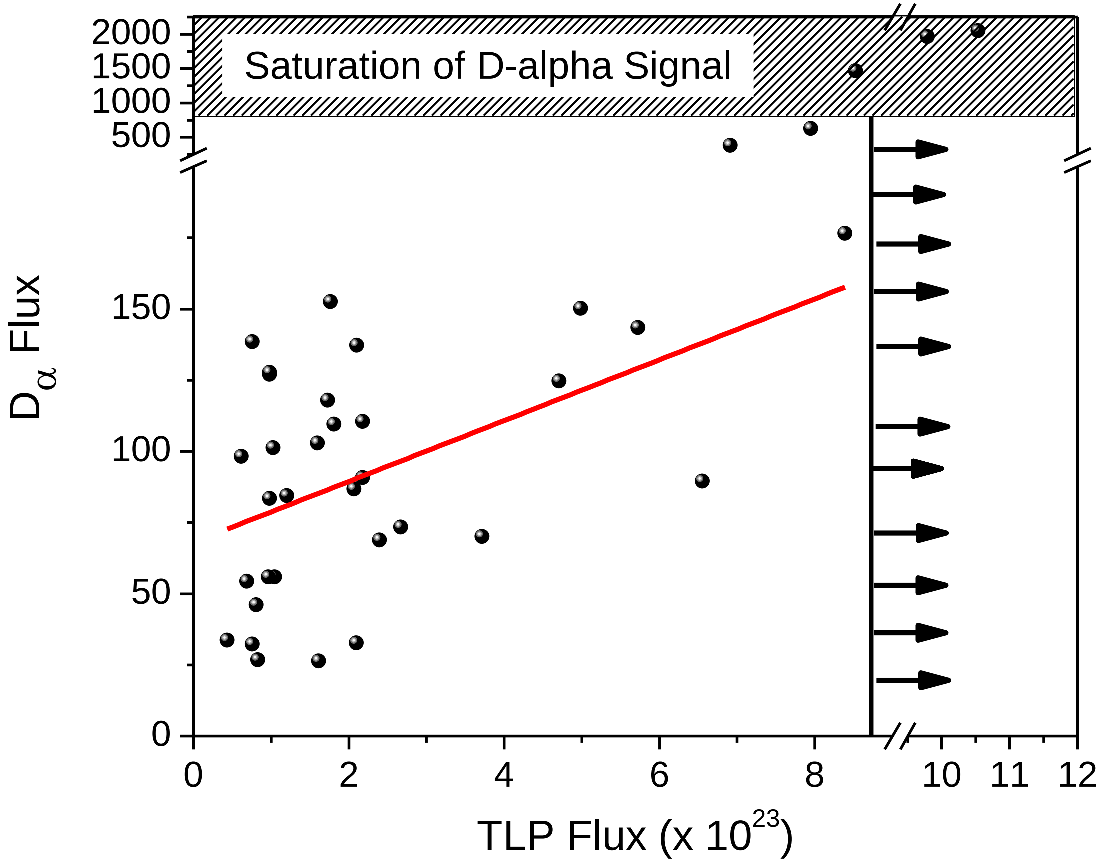


	Mean	Std. Dev.	Minimum	Median	Maximum
f_{peak}	14.705	7.84	4.24	12.9	27

f_{peak} =32 ± 8% [1]

[1] T.Eich et. al., Journal of Nuclear Materials 337-339 (2005) 669-676

Comparison of I_{sat} profile with D_α profile



- During an ELM, there is a correlation between particle flux measured by the probes and D_α signal
- Typical probe flux > 9 x 10^{23} /m^2-s causes saturation on the D_α signal
- From earlier statistics, 5% of the flux on probes is > 9 x 10^{23} /m^2-s

Conclusions

- Demonstrated the use of HDLP Array for characterizing ELMs
  - HDLP array provides particle flux measurements with a time resolution of 4 μs to allow studies within one ELM
  - A methodology was developed to characterize ELMs and ELM statistics are presented
  - An average of 1.5 MW/m^2 strikes the probe surface during an ELM
- A correlation was found between particle flux from the probes with D-alpha signal during the ELMs
- Comparison of heat flux profiles from IR diagnostic with the probe offers interesting analysis
  - The q_{IR} profiles are longer in duration than I_{sat} profiles
  - A correlation between τ_{IR} and fraction (f_{peak}) was seen – only 15 ± 8% of the ELM energy deposited leads to an increase in target temperature

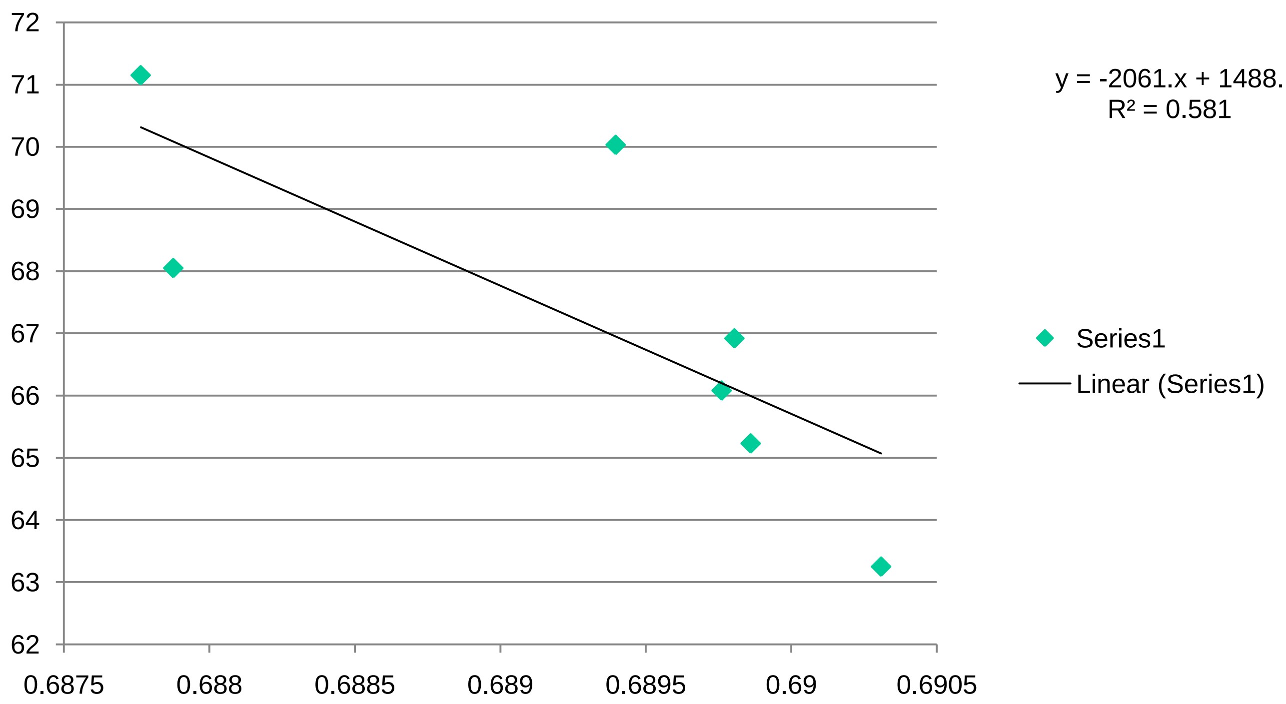
THANK YOU!

BACK UP SLIDES

Future Work

- ELM characteristics routine
  - An automated software for determining the occurrence of ELMs and recording their characteristics in real-time. This will enable to see the differences in the ELM characteristics for various experiments being planned in the FY 11 campaign on NSTX
- One or two particle flux probes at different radial locations on HDLP array will be configured to measure particle flux. This will enable spatial studies of ELM like spatial width.
- Enlarge the database in order to understand fraction (f_{peak}) values and perform detailed heat transfer modeling to understand the thermal response of the system
- Total ELM energy balance

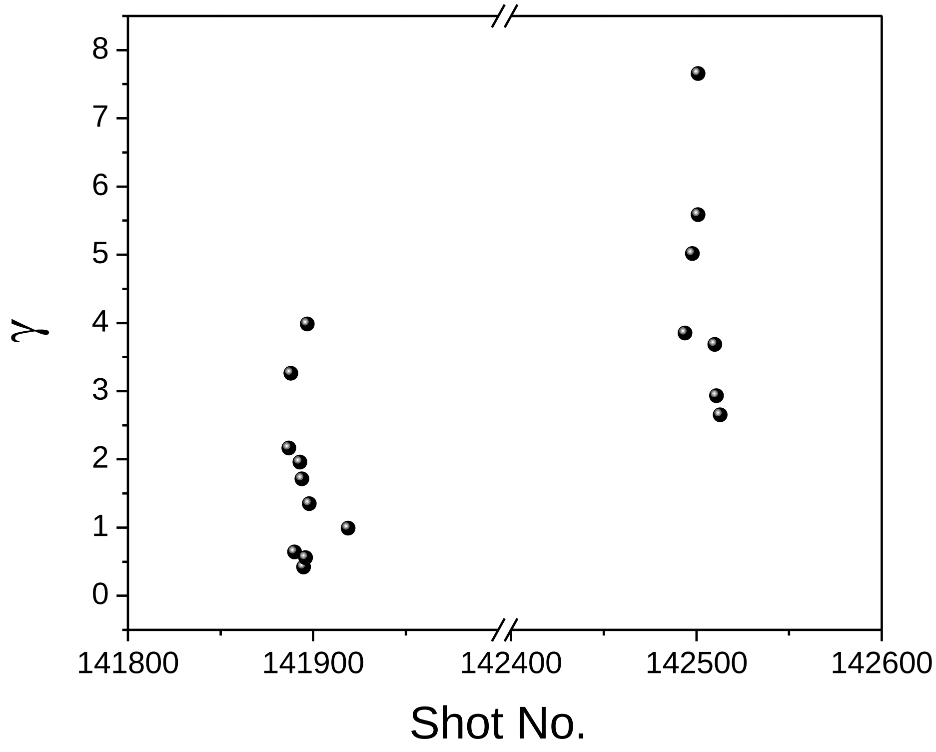
Radial Propagation Velocity of ELM



Sheath Heat Transfer Coefficient (γ)

$$\gamma = \frac{q_{IR}}{\Gamma\,(kT_e)}$$

$$\Gamma = \frac{1}{A_p}\left[\frac{\int\left(\frac{I_{sat}}{e}\right)dt}{\Delta T}\right]\left({}^{\#}/_{m^2}-s\right)$$



	Mean	Std. Dev.	Minimum	Median	Maximum
γ	2.82044	1.86897	0.41702	2.65154	7.65217