UKAEA Fusion Working in Europe

Investigation of Transient Phenomena on MAST using Thomson Scattering

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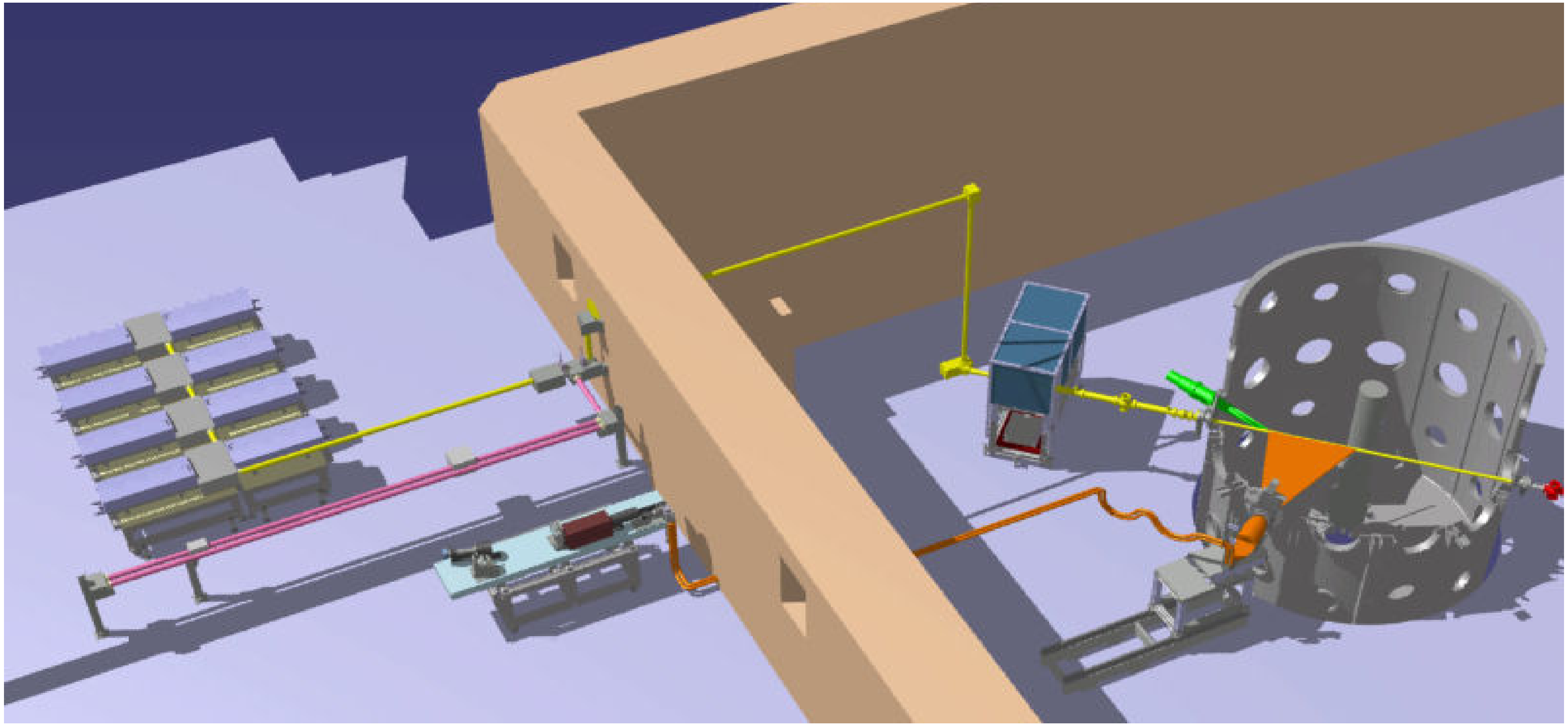
Overview

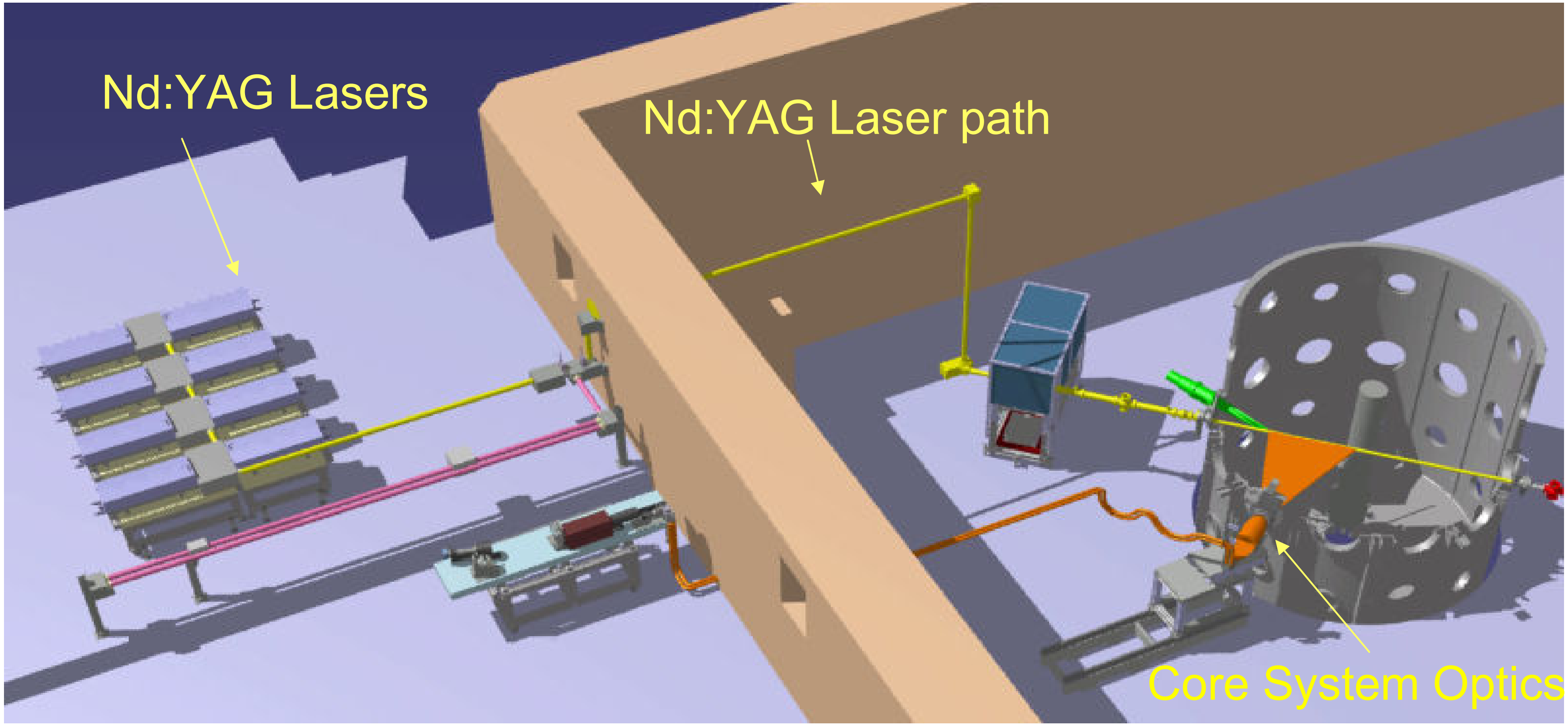
- The aim of this presentation is to outline the study of transient physics using Thomson scattering on MAST*:*
  - *Sawteeth*
  - *Pellets*
  - *Pressure gradient*
  - *Filaments*

- *And to show how these impact on the design of the planned TS upgrade*

TS System Layout



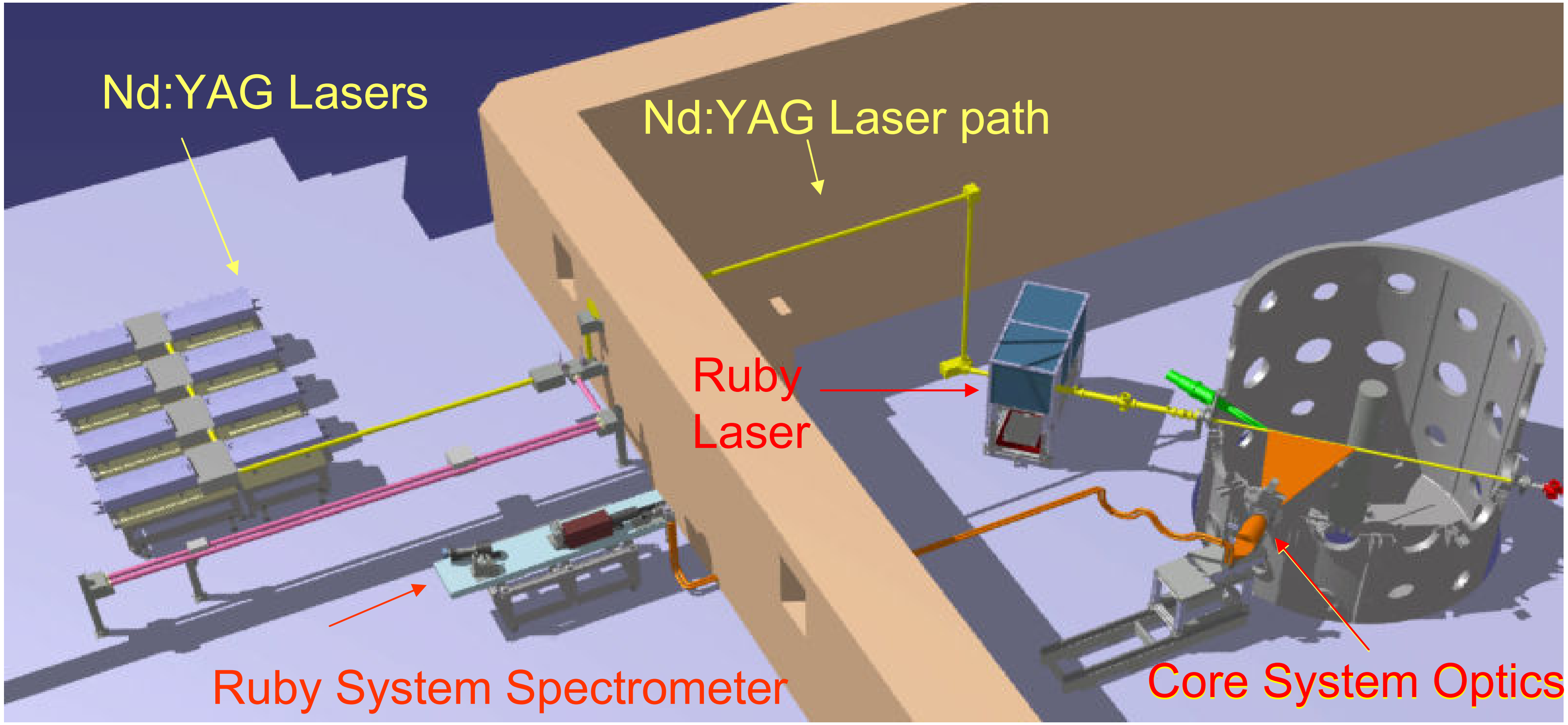
TS System Layout



Core Nd:YAG System

- 19 points
- 25-40mm resolution
- 200Hz
- 700 p.e./cm/10^{19}
- Burst of 4 lasers

TS System Layout



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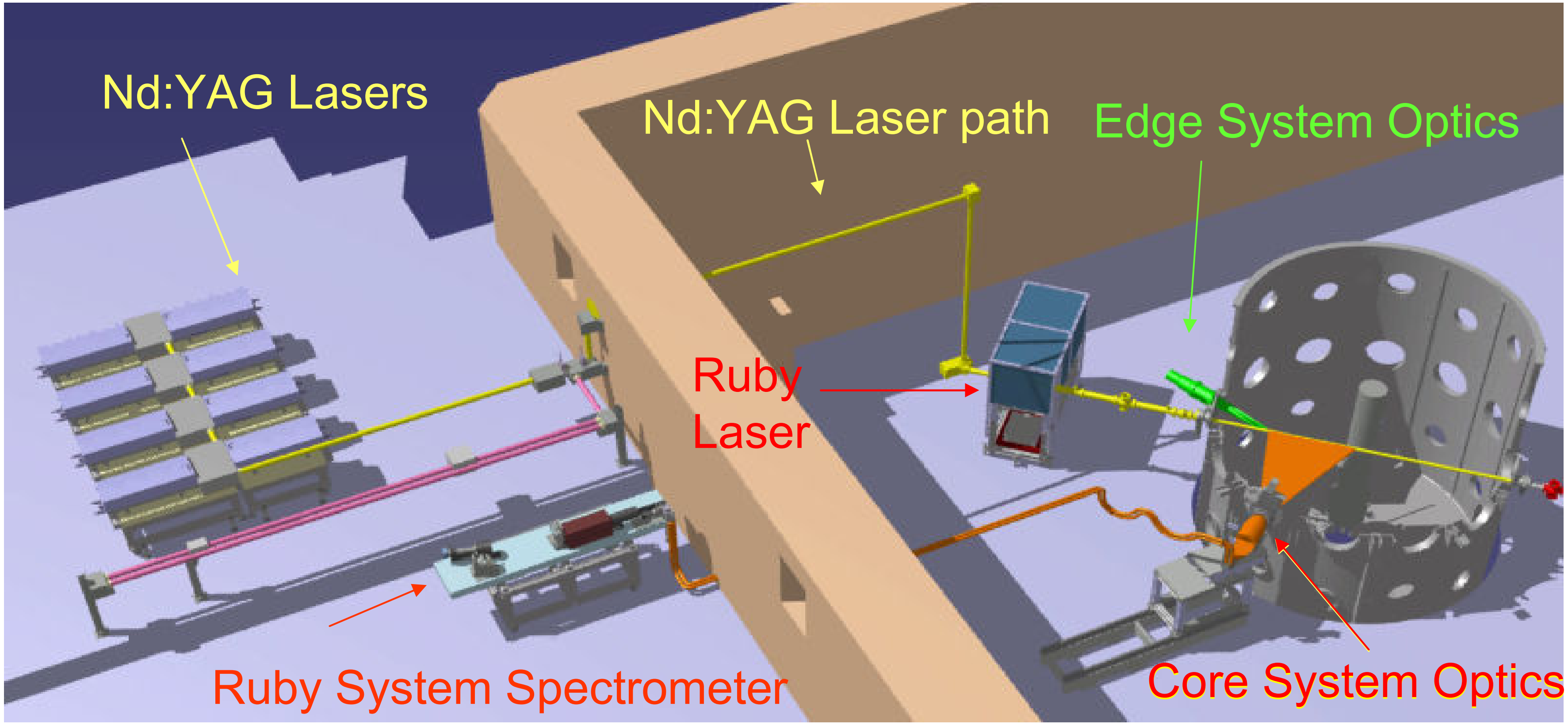
- Burst of 4 lasers

Ruby Laser System
- 300 points
- 10mm resolution
- Once per shot
- 2500 p.e./cm/10^{19}

TS System Layout

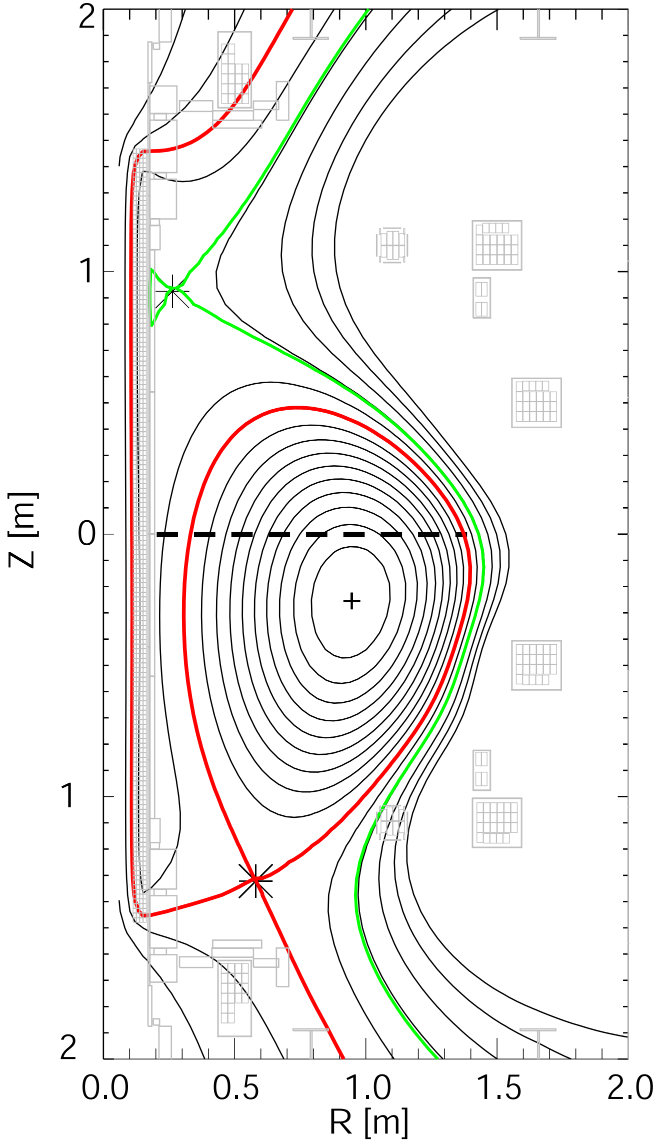


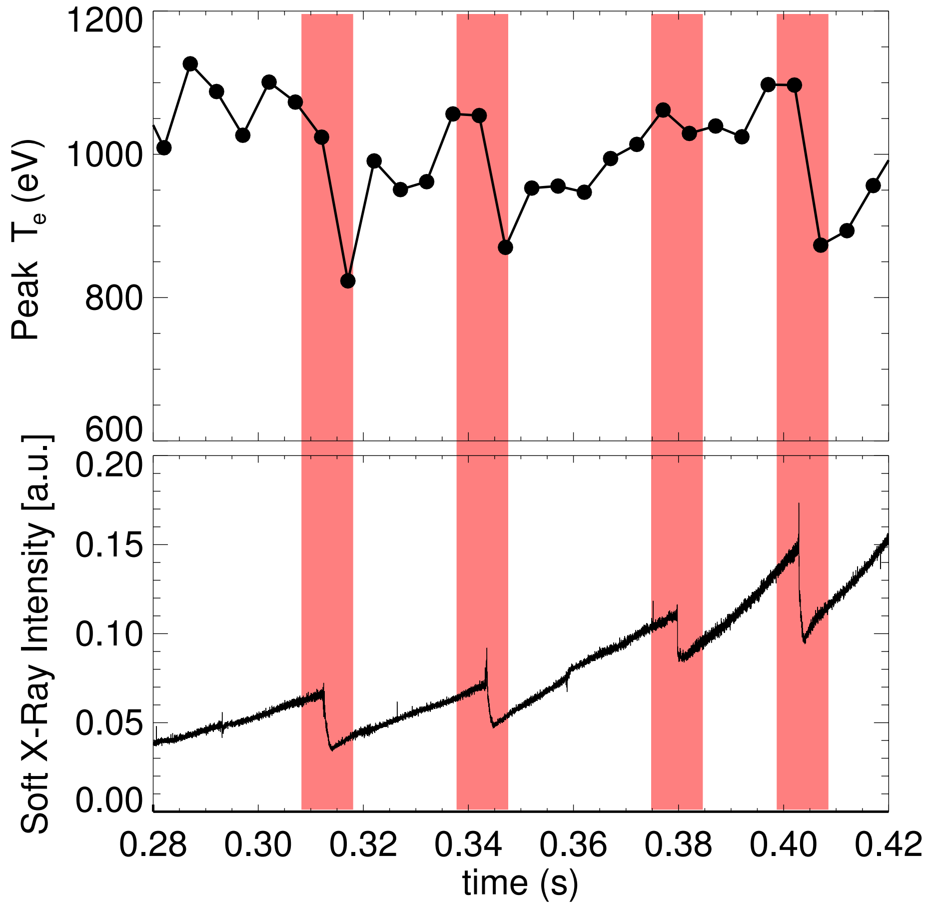
Core Nd:YAG System
- 19 points
- 25-40mm resolution
- 200Hz
- 700 p.e./cm/10^{19}
- Burst of 4 lasers

Ruby Laser System
- 300 points
- 10mm resolution
- Once per shot
- 2500 p.e./cm/10^{19}

Edge Nd:YAG System
- 16 points
- 10mm resolution
- 200Hz
- 2500 p.e./cm/10^{19}

Sawteeth

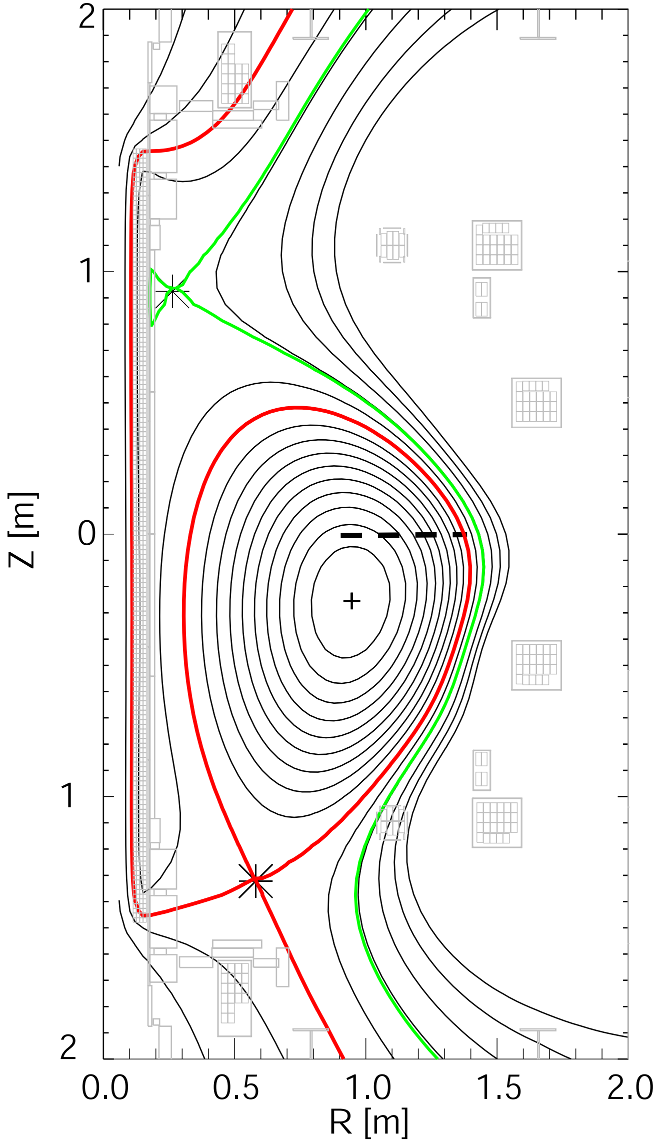


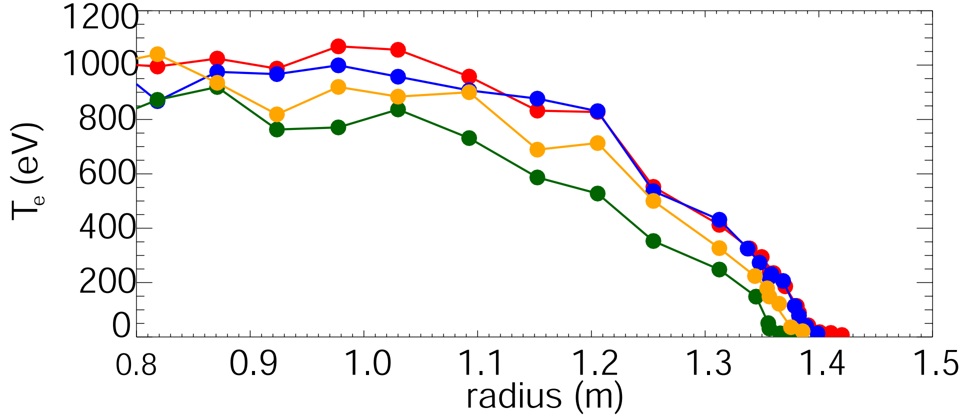


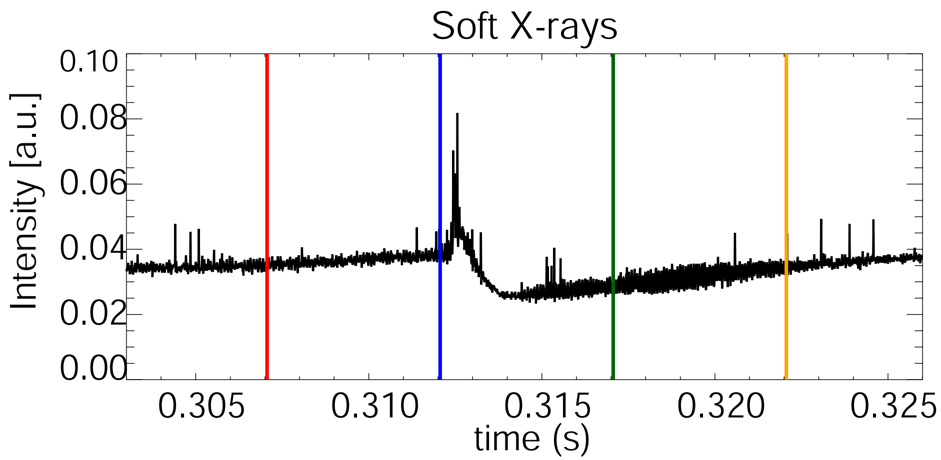
Example of a typical transient measurement using the core Nd:YAG TS system.

- Strongly off axis plasma, 20cm below typical.
- Plasma T_e collapses are particularly large during SND sawteeth. The average temperature collapse over the four sawteeth shown is 150eV.

Sawteeth

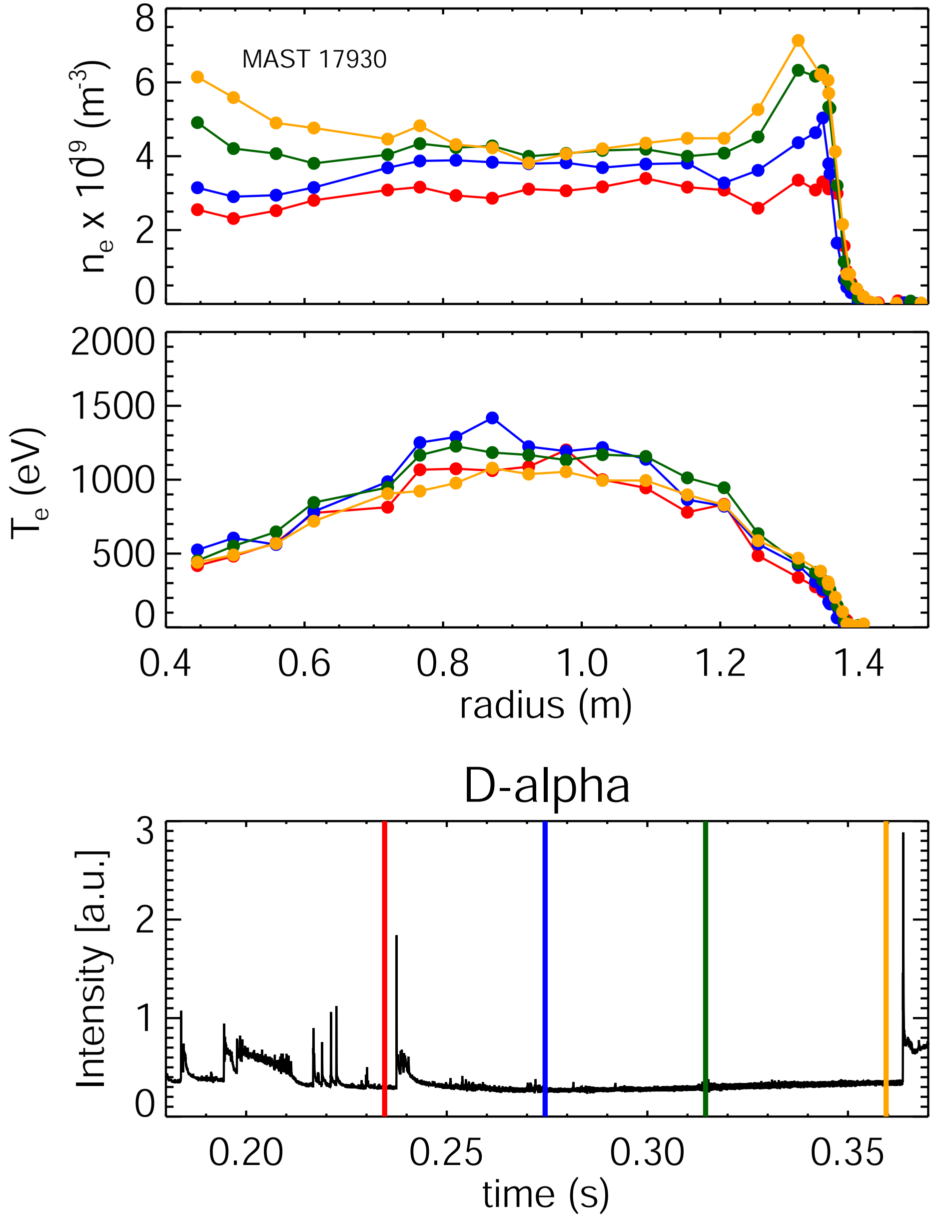






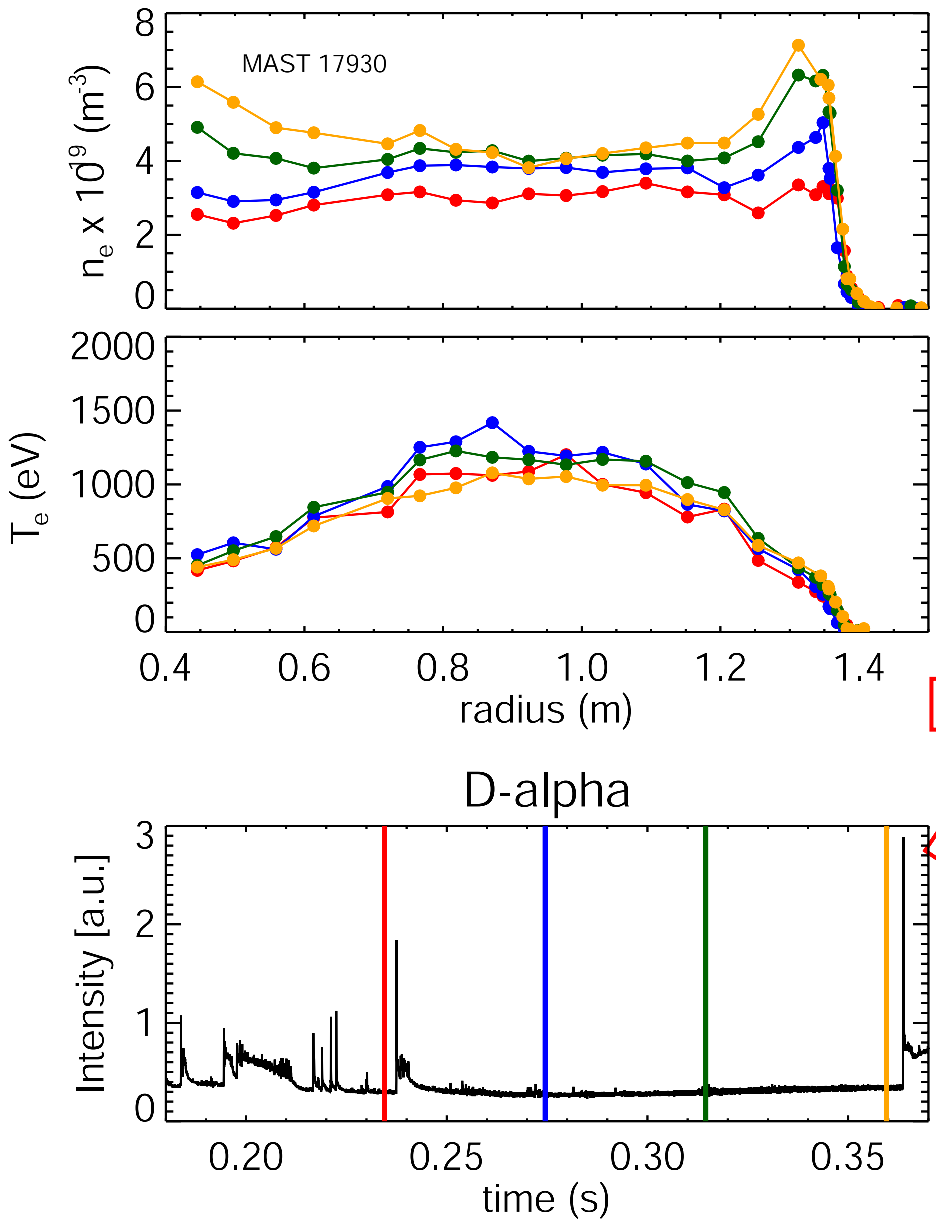
- Examining the radial profile for a single sawtooth shows the temperature collapses right across the plasma.
- The plasma edge has moved inwards by ~50mm wrt the pre-Sawtooth level.

Core TS data



- The profiles shown left were obtained over the course of a long ELM free H-mode during a high Beta campaign.
- Edge density builds up over the course of the H-mode and becomes significantly higher than the core density.

Core TS data



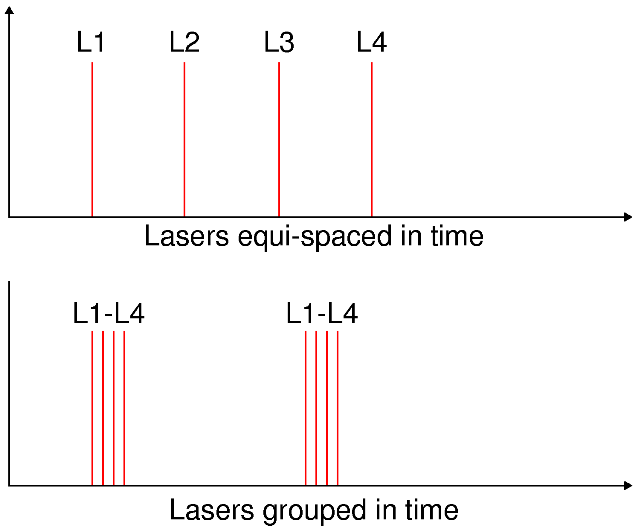
- *One of the primary uses of TS data is to input to modelling codes.*

Core TS data is also routinely used in TRANSP analyses

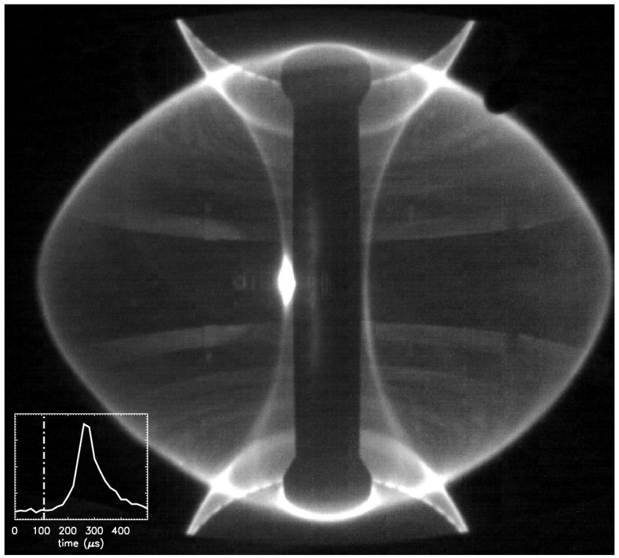
Plasma P_e measurement is used to act as a constraint to a *kinetic EFIT*

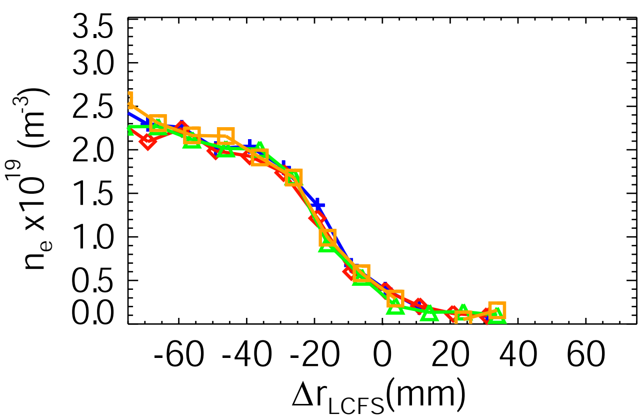
H-mode - Inter ELM period

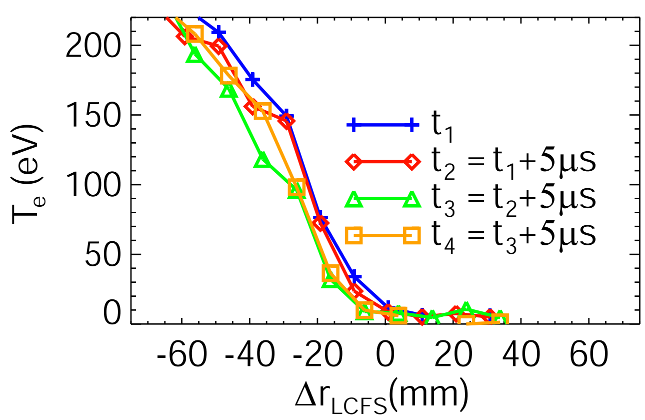
- Profiles taken during the inter ELM period with laser separation of Δ_T = 5μs.



- Camera picture is taken during the inter-ELM.
- No significant variation seen in the Thomson scattering n_e and T_e profiles. This is typical of the inter-ELM period.



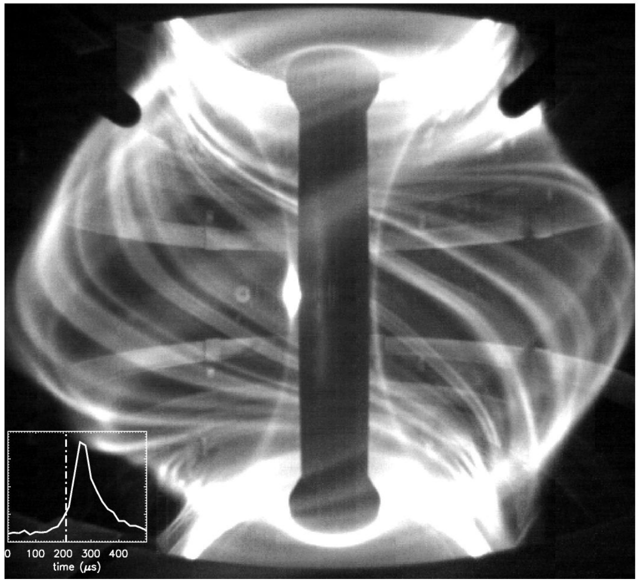


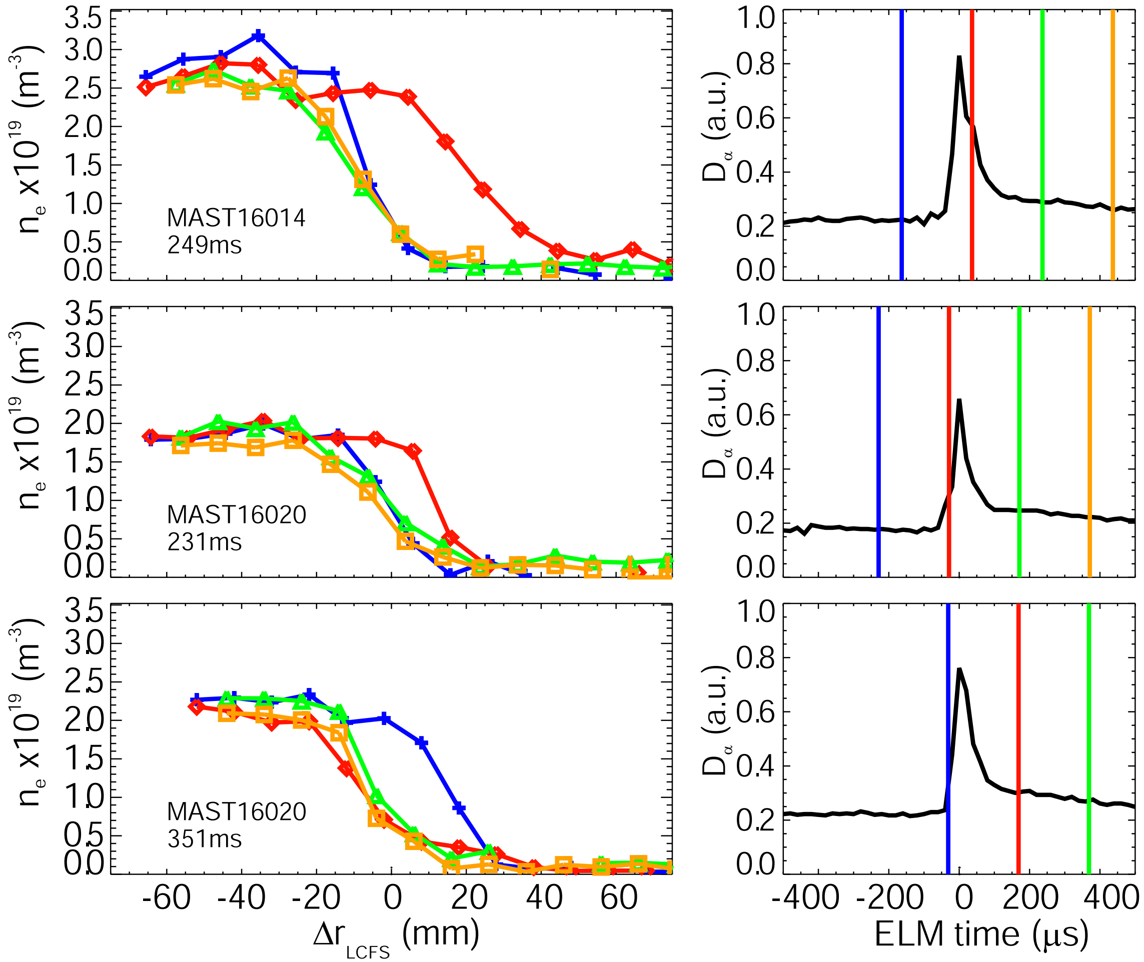


H-mode ELMing

- laser separation: Δ_T = 200μs

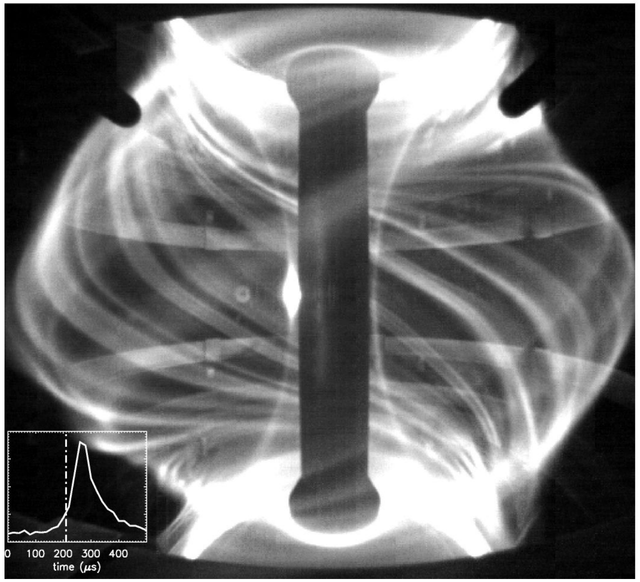
- During the ELM there are large protrusions of the plasma edge from the pre-ELM LCFS.

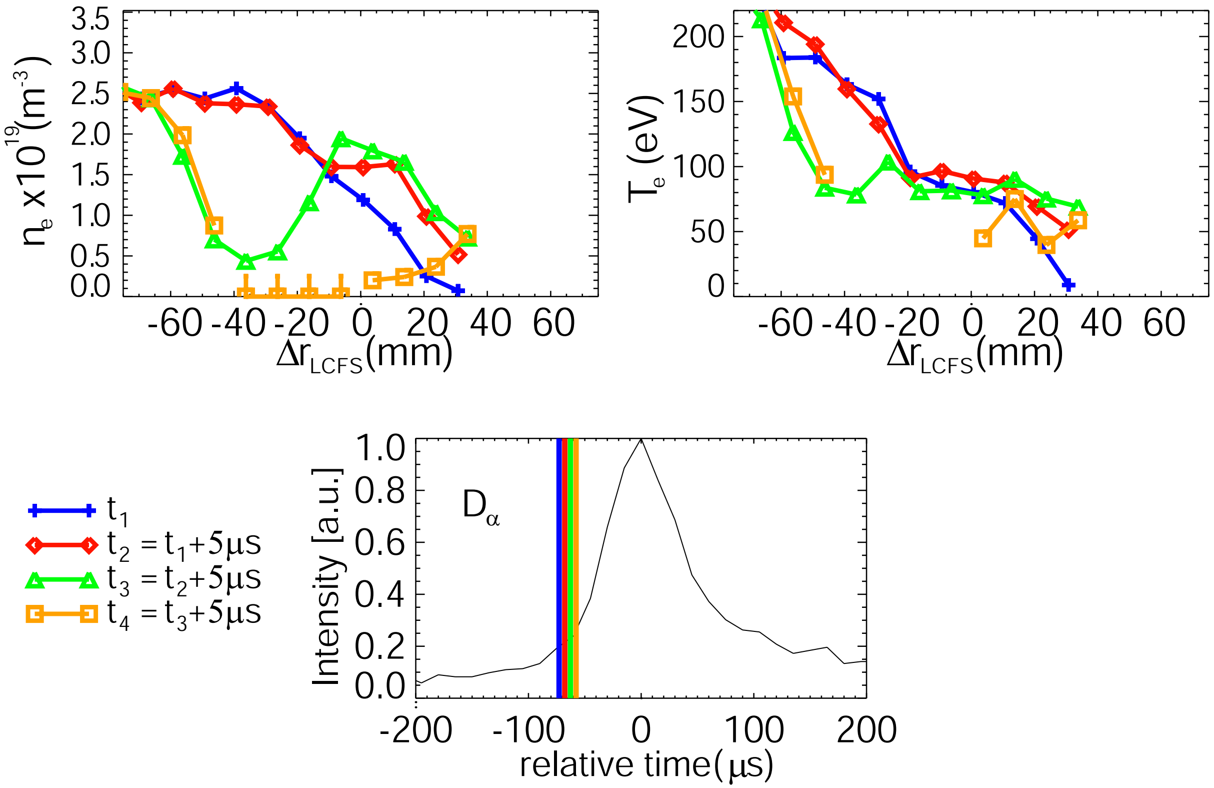




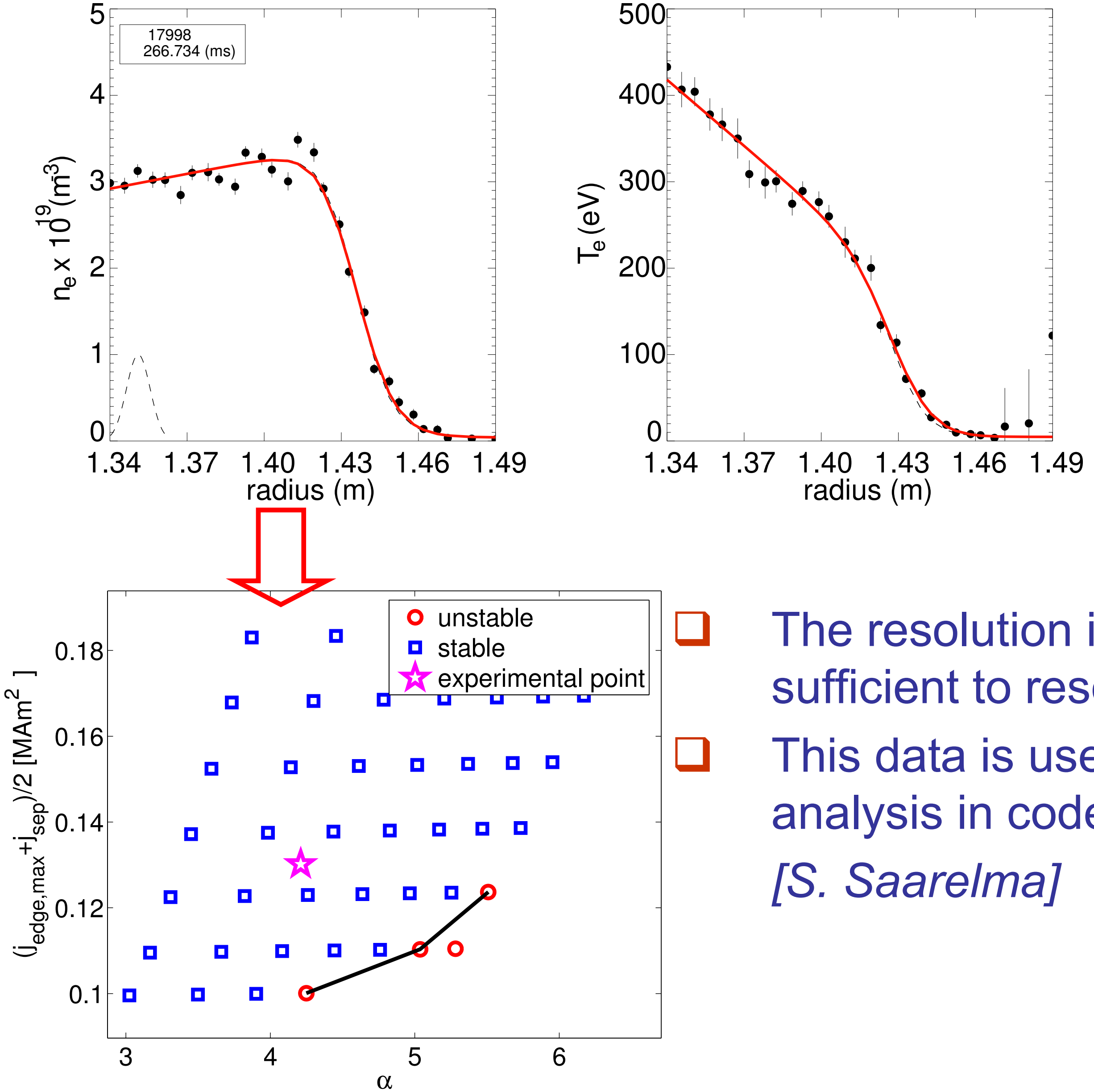
ELM filaments

- laser separation: Δ_T = 5μs
- As well as protrusions, filamentary structures are seen.
- This figure shows the expulsion of a filamentary structure from the plasma at pedestal temperature.





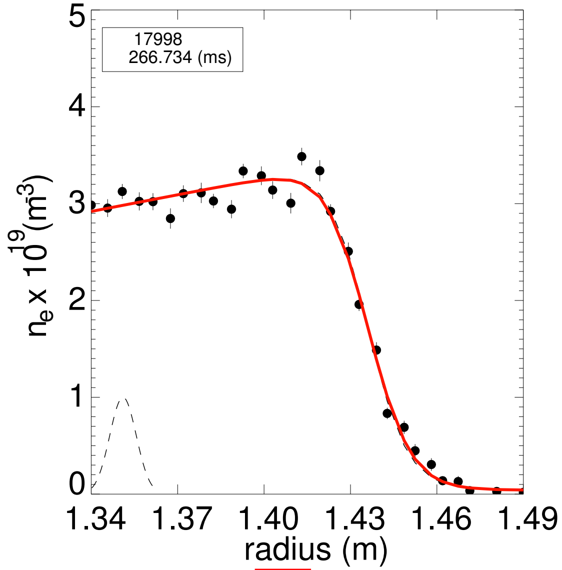
Edge TS data

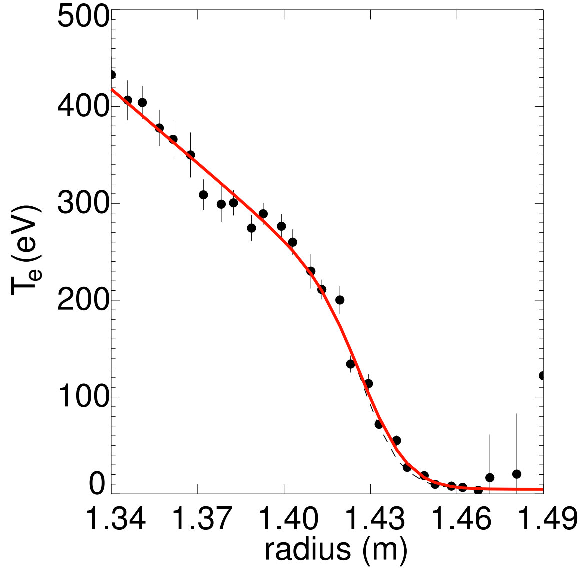


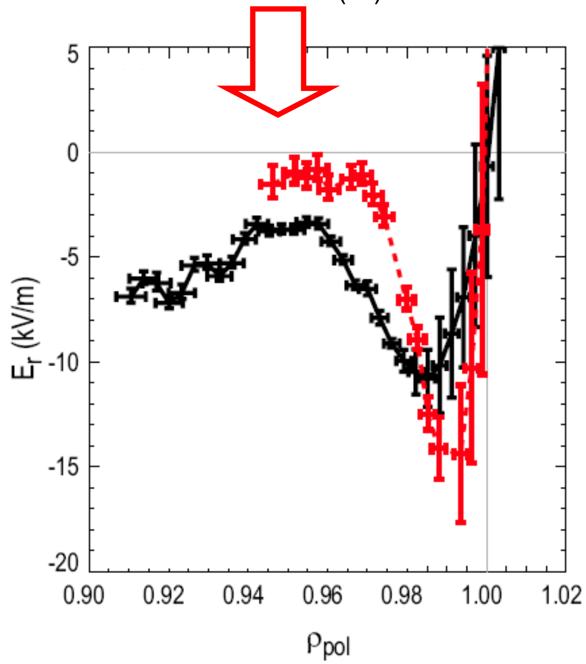
- The resolution in the edge region is sufficient to resolve the pedestal gradients.
- This data is used to perform MHD stability analysis in codes such as ELITE

[S. Saarelma]

Edge TS data





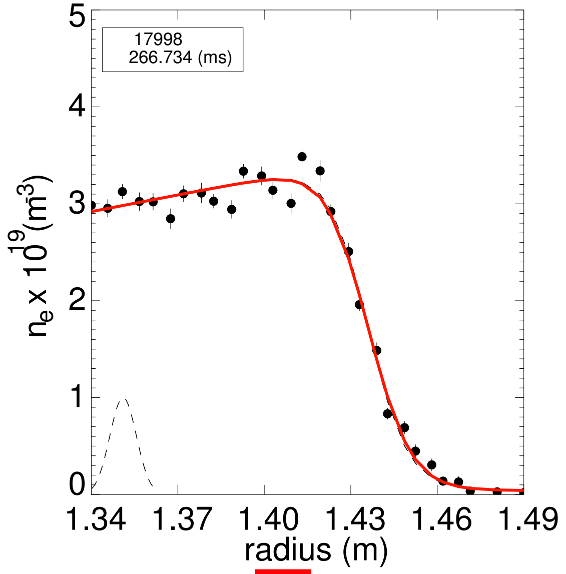


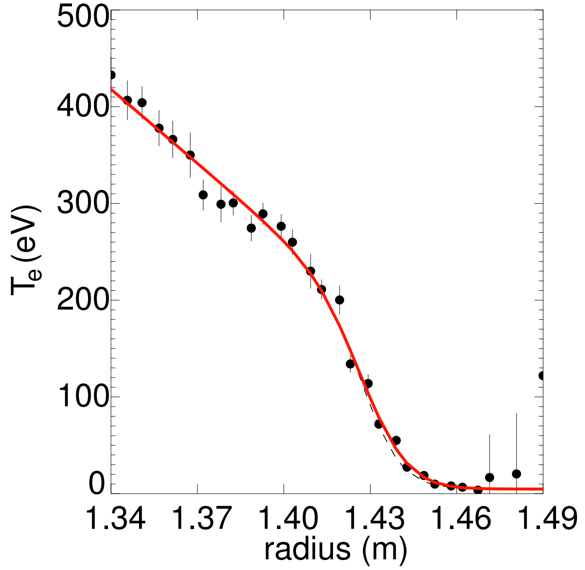
$$E_r \approx \frac{k_B T_\alpha}{q_\alpha}\left(\frac{1}{L_{T_\alpha}} + \frac{1}{L_{n_\alpha}}\right) + u_{\phi,\alpha}B_\theta - u_{\theta,\alpha}B_\phi$$

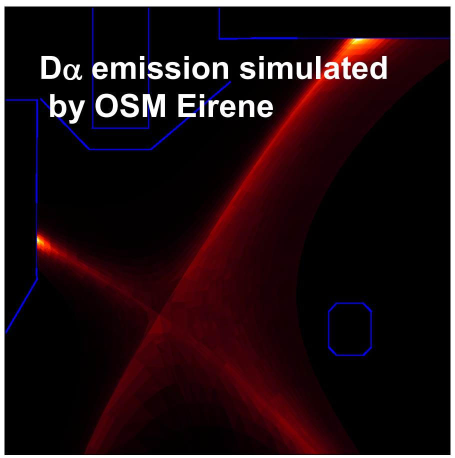
- The edge radial electric field is calculated from Helium
- TS Edge data is used to calculate the Helium emissivity to determine the Helium density profile diamagnetic contribution to E_r

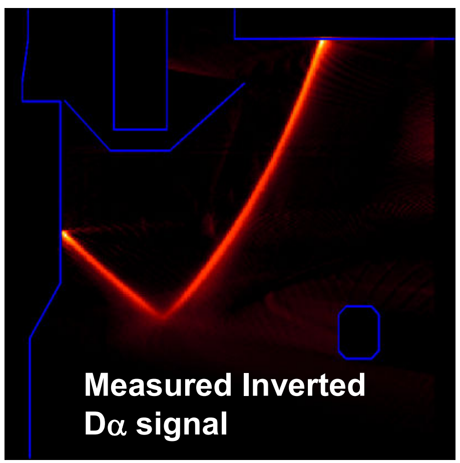
[H. Meyer IAEA-TM 2007]

Edge TS data





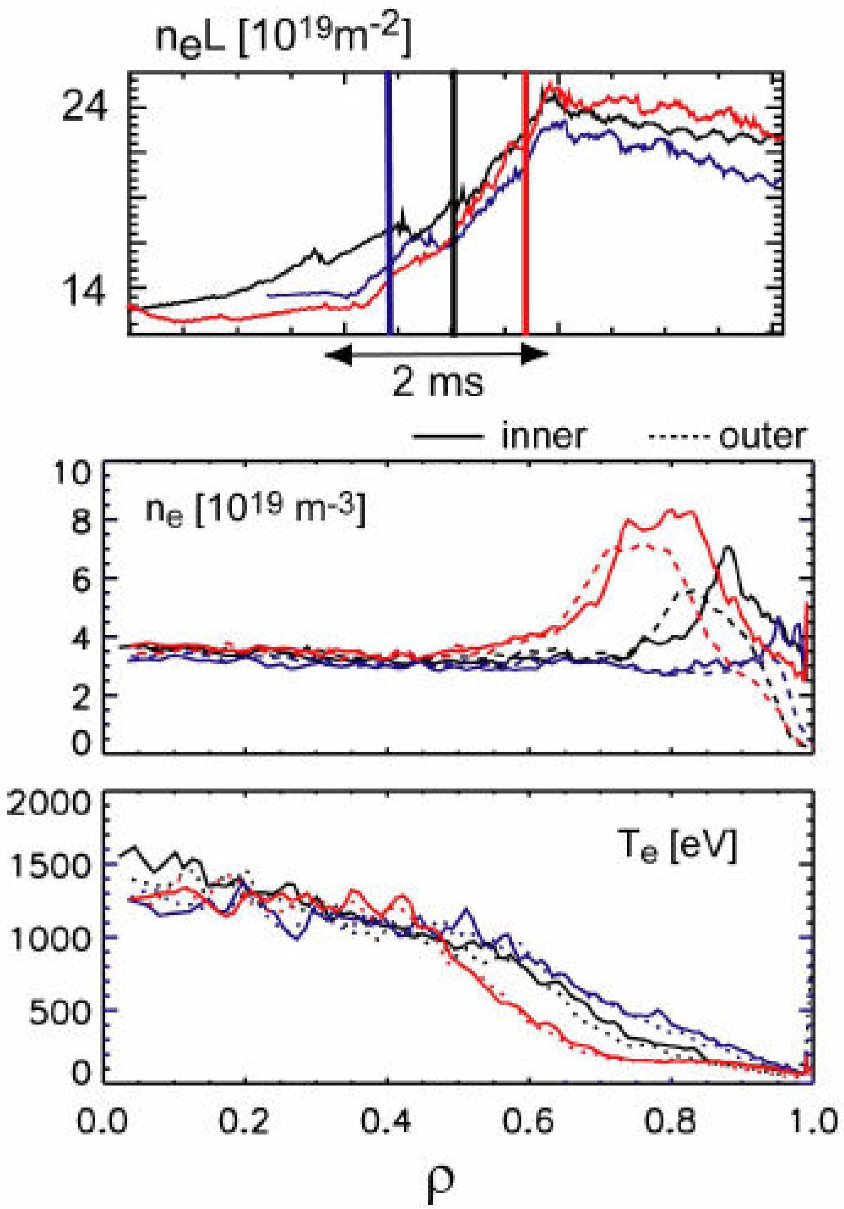




- SOL temperature and density data are used in OSM – Eirene to calculate ionisation in the pedestal region.
- Here images of D-alpha obtained from experiment are compared with simulation results.

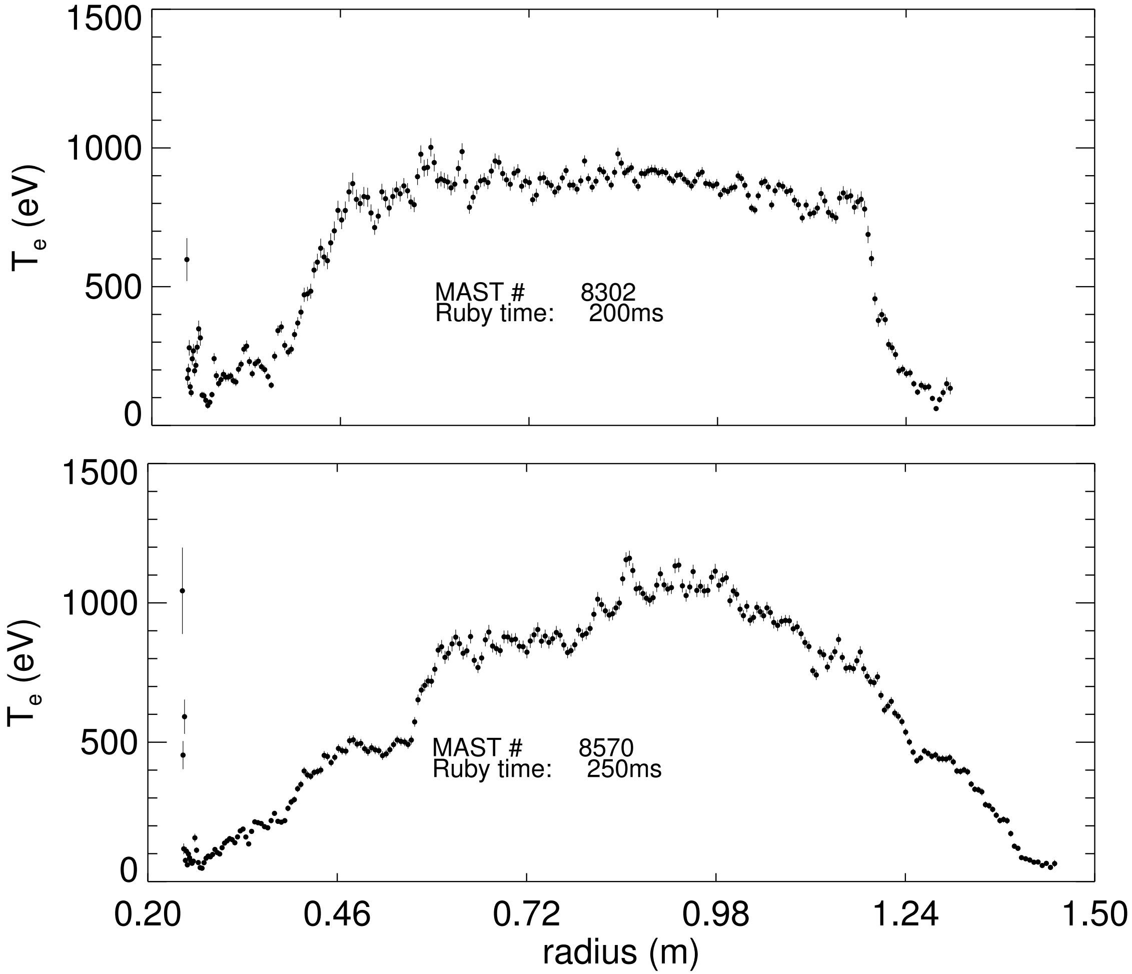
[S. Lisgo EPS 2007]

Pellet Deposition



- Pellet deposition profiles have been measured using the Ruby laser system.
- Here, three profiles are shown during the pellet ablation process. The timing with respect to pellet injection is obtained from interferometer data. (TS system triggered by the pellet).
- Profiles approximately constant along flux surfaces.

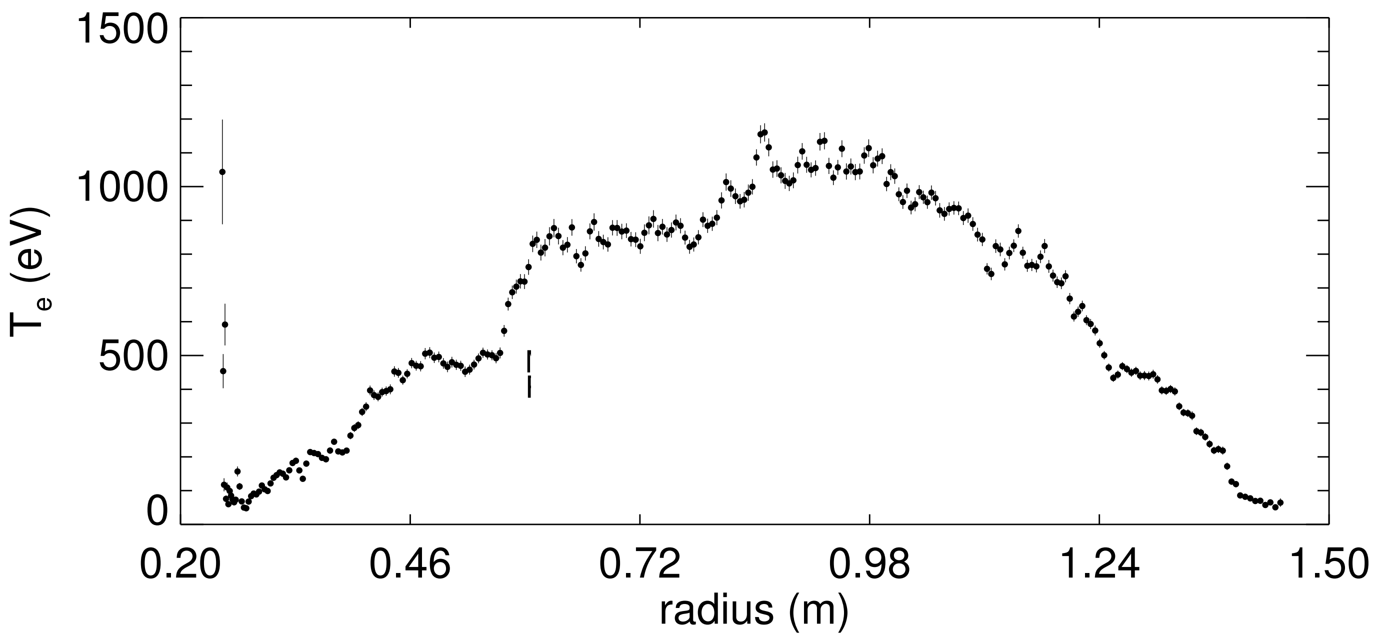
Ruby Thomson Scattering Results



- ITB measured in counter injection shot
- 3/2 island structure measured in the Ruby profile

- Currently these profiles can only be measured once per shot.
- We want to measure similar profiles using the Upgraded Nd:YAG system throughout a single MAST shot.

Proposed Upgrade, what to measure?



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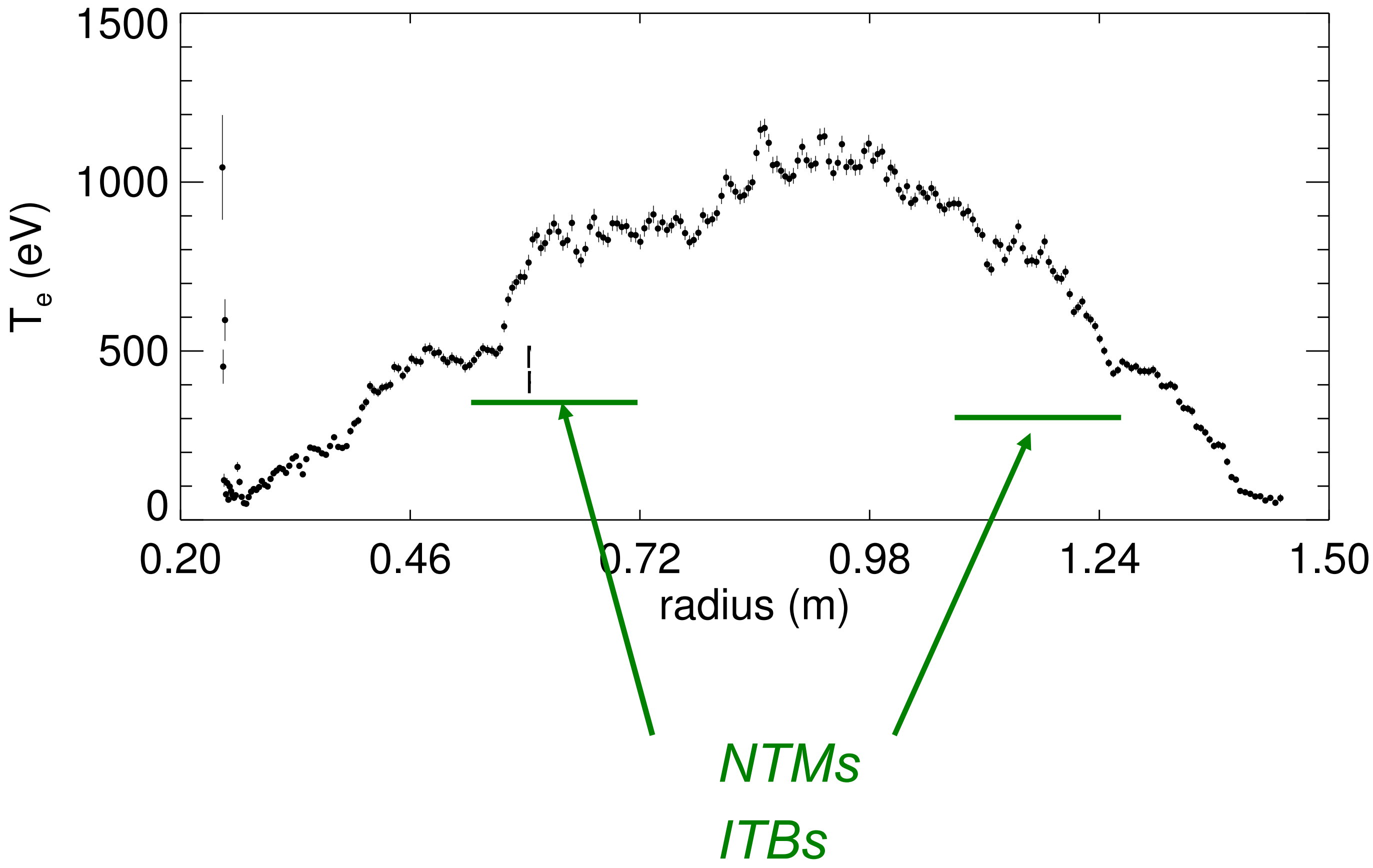

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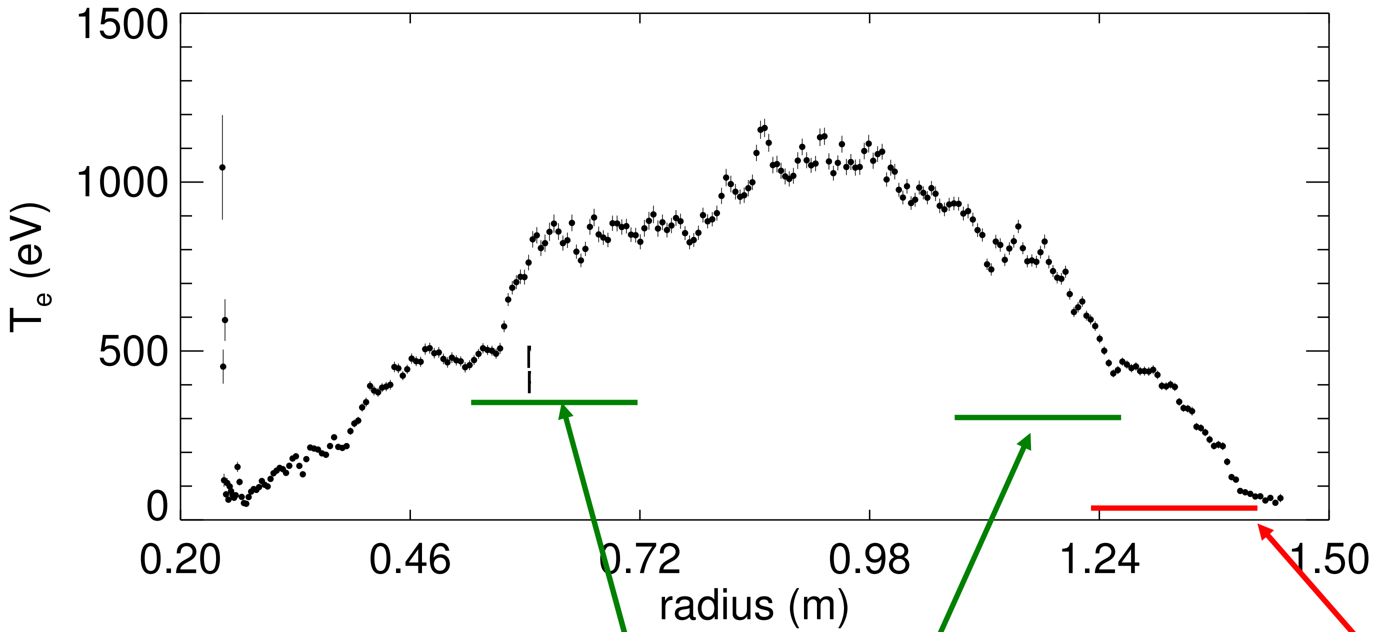


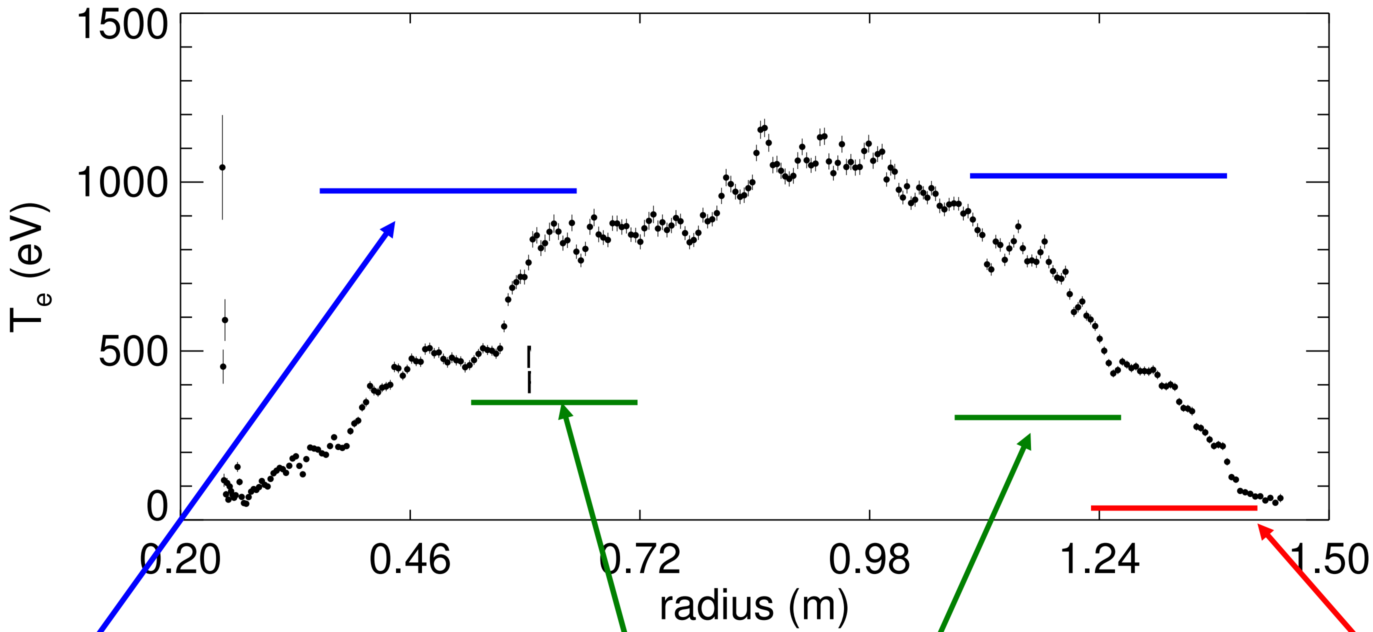
NTMs

ITBs

Edge Physics:

- *gradients*
- *ELM filaments*

Proposed Upgrade, what to measure?



Inboard & Outboard:

- *Plasma Rotation from density asymmetry*
- *Constraining EFIT*

NTMs

ITBs

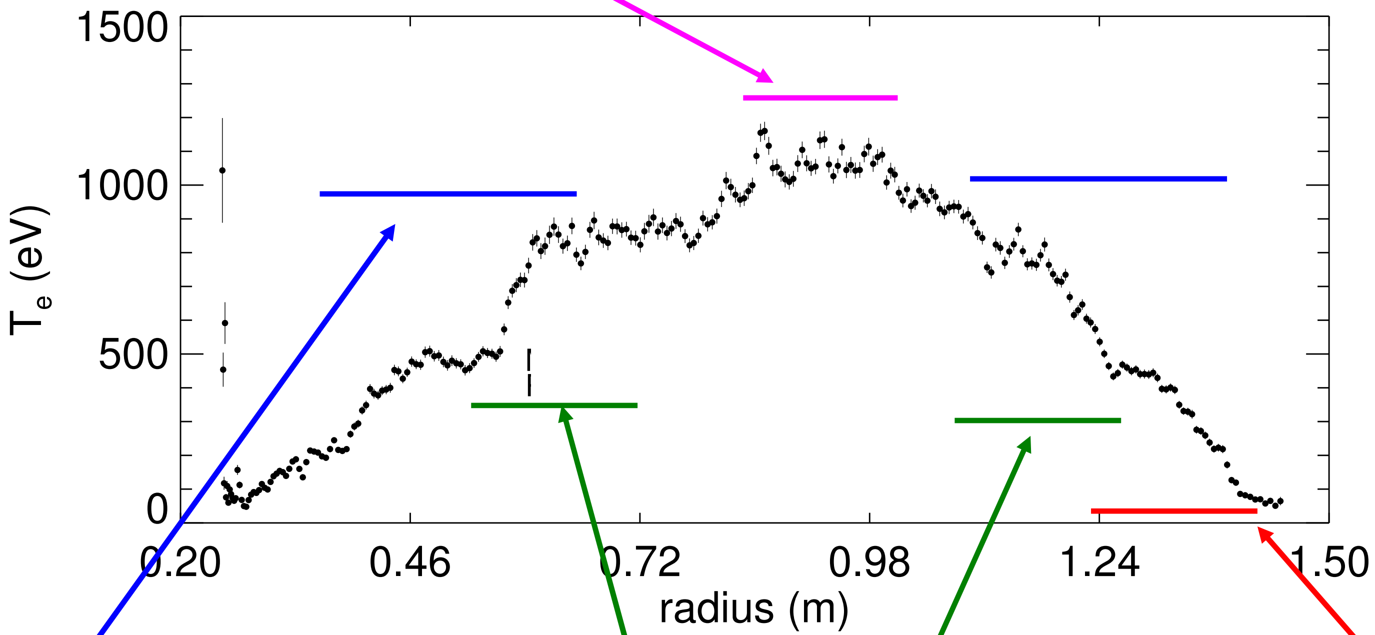
Edge Physics:

- *gradients*
- *ELM filaments*

Proposed Upgrade, what to measure?

Core:

- *density peaking*
- *sawteeth*



Inboard & Outboard:

- *Plasma Rotation from density asymmetry*
- *Constraining EFIT*

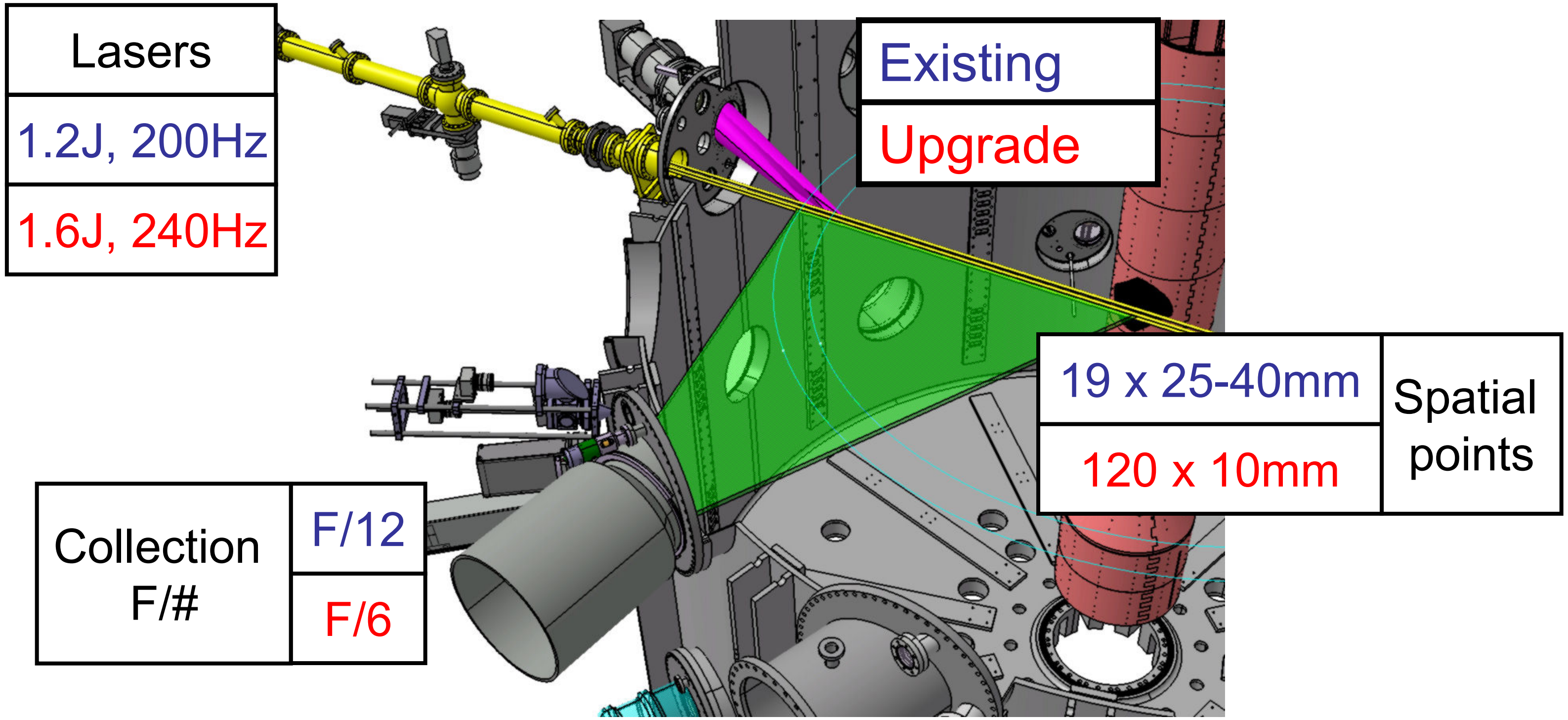
NTMs

ITBs

Edge Physics:

- *gradients*
- *ELM filaments*

How to achieve this?



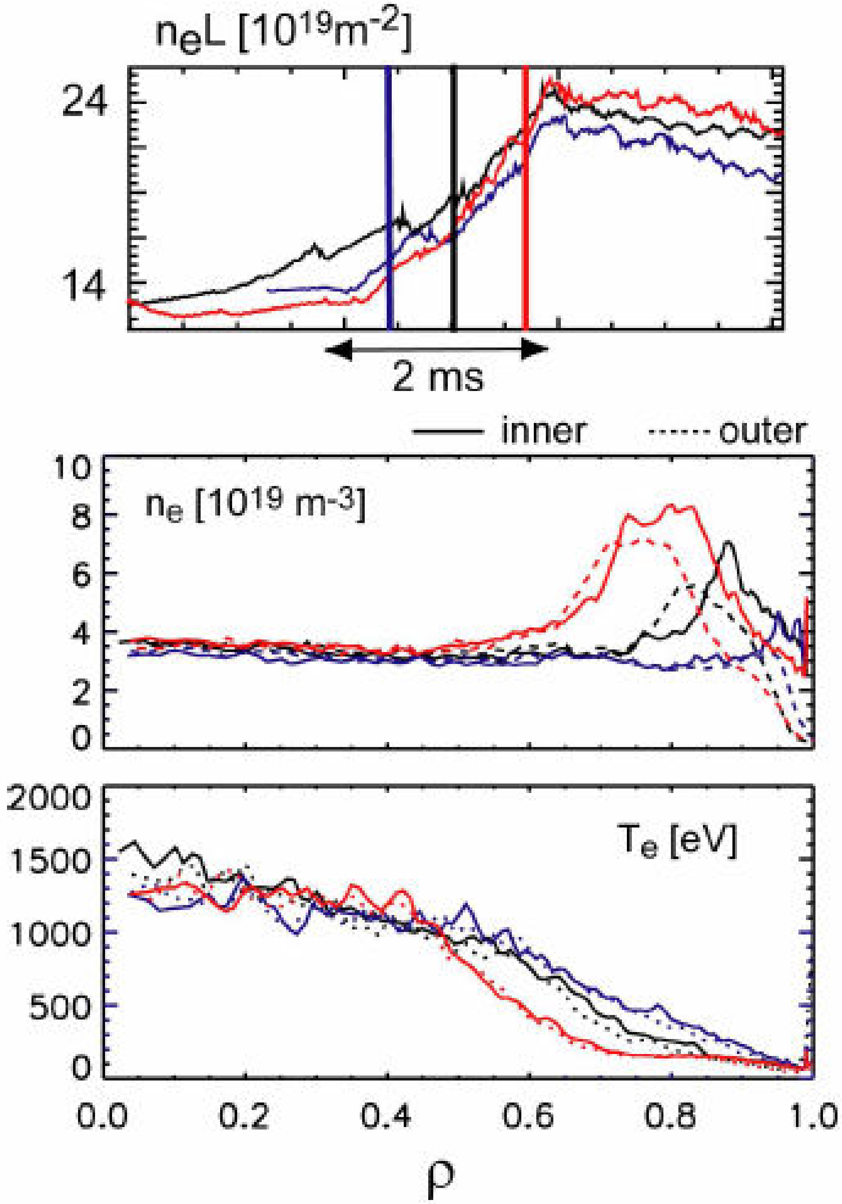
- The upgrade aims to provide better spatial resolution at lower error by:
  - Doubling the solid angle collected
  - Increasing the laser energy
- To increase the laser energy and increase the time resolution:
  - Switch from 4 x 50Hz 1.2J lasers to 8 x 30Hz 1.6J
  - Also allows for increased numbers of lasers in bursts

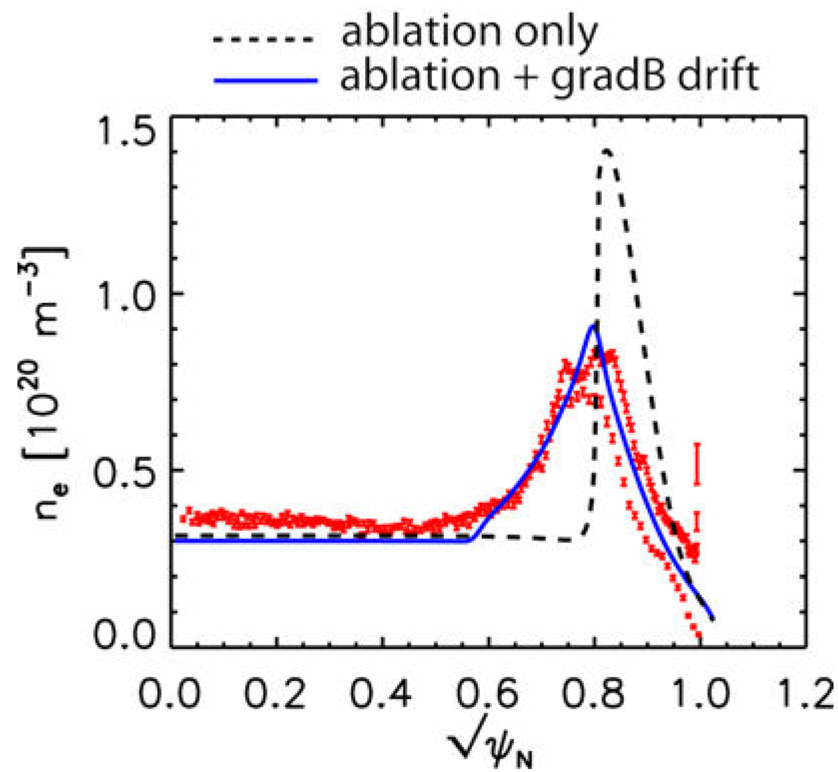
Questions?

The TS Upgrade is a collaboration between UKAEA, University of York and University College Cork.

This work is funded jointly by the UK Engineering and Physical Sciences Research Council and EURATOM.

Pellet Deposition





The pellet density profile cannot be explained by simple neutral gas and plasma shielding models.

A model using both ablation and *Grad*B drift is required to obtain density profiles similar to experiment.

[M. Valovic, L. Garzotti IAEA TM 2007]

ELM filaments

- laser separation: Δ_T = 5μs
- As well as protrusions, filamentary structures are seen.
- Here 3 sets of filaments ordered by distance from pre-ELM LCFS
- It may be seen that the filament temperature falls off rapidly as the filaments move from the plasma edge.