

# ANALYSIS OF PLASMA EDGE PROFILES AT JET

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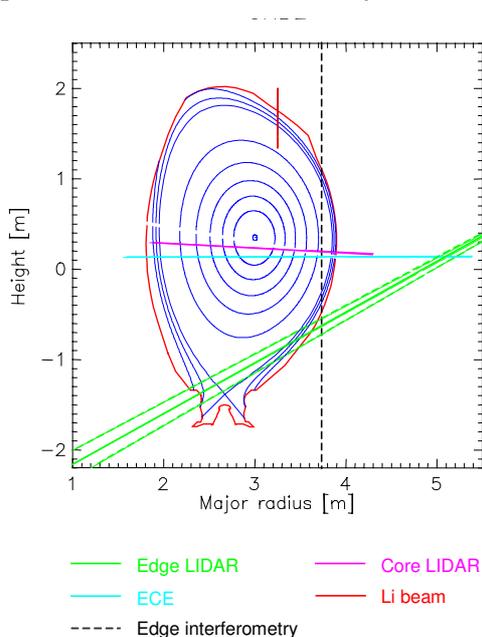
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## Introduction

JET plasma edge profiles from various diagnostics are combined to reconstruct the best edge  $n_e$ ,  $T_e$  and  $p_e$  profile. Diagnosing edge profiles is essential in, for example, pedestal studies, edge gradient studies, stability analysis and input for edge current models. The comparison and combination of various diagnostics gives complementary information and yields a tool for validation: Edge LIDAR monitors  $T_e$  and  $n_e$  from the SOL up to the pedestal top. Core LIDAR gives an indication of the  $T_e$  and  $n_e$  pedestal top. ECE measures  $T_e$  from the top halfway down to the SOL. The Li beam gives a spatially resolved multiple  $n_e$  pedestal measurement. Interferometry indicates the pedestal top of  $n_e$ , is used as a  $n_e$  calibration source, and can be used to reconstruct  $n_e$  profiles in swept plasmas.  $T_i$  measurements by CXS are important, but are not dealt with in this paper.



*Fig. 1 Diagnostic sight lines mapped onto flux surfaces.*

For comparison of the edge profiles, diagnostic lines of sight are carefully mapped onto the magnetic flux surfaces as calculated by the JET EFIT code (Fig. 1). The spatial mapping accuracy is  $\pm 2$  cm at the last closed flux surface in the magnetic mid-plane. Table 1 shows the capabilities of the diagnostics used in this analysis. The indicated resolutions are given for the magnetic axis of the plasma and do not necessarily represent the individual diagnostic resolution. This is particularly true for the edge LIDAR diagnostic whose mid-plane resolution benefits from mapping the diagnostic line of sight from a region with large flux expansion to the magnetic axis where the flux surfaces are strongly compressed.

The edge gradient measurement capabilities are presented via three examples of ELMy H-mode discharges that genuinely feature the steepest pressure gradients.

Table 1: resolution, penetration and limitation of edge diagnostics.

Diagnostic	Parameter	Resolution	Penetration	Comment
Edge LIDAR	$T_e / n_e$	2-5 cm	5-15 cm	Does not see pedestal
ECE	$T_e$	1-2 cm	Edge or core	Suffers from cut-off and shine-through
Li beam	$n_e$	1 cm	5-10 cm	Does not see pedestal if $n_e > 3.10^{19} \text{ m}^{-3}$
Interferometry	$n_e$	(2 cm) Abel inver.	20 cm	Line integrated near edge

### Type I to III ELM transition

High density ELMy H-mode discharges feature confinement loss at a certain density limit. At this limit the ELM behaviour changes from type I to Type III ELMs [1]. It is observed with the edge LIDAR diagnostic that in this transition the edge-pressure gradient becomes shallower. Fig. 2 shows the ELM behaviour and the change of edge  $T_e$ ,  $n_e$  and  $p_e$  gradient in the transition.

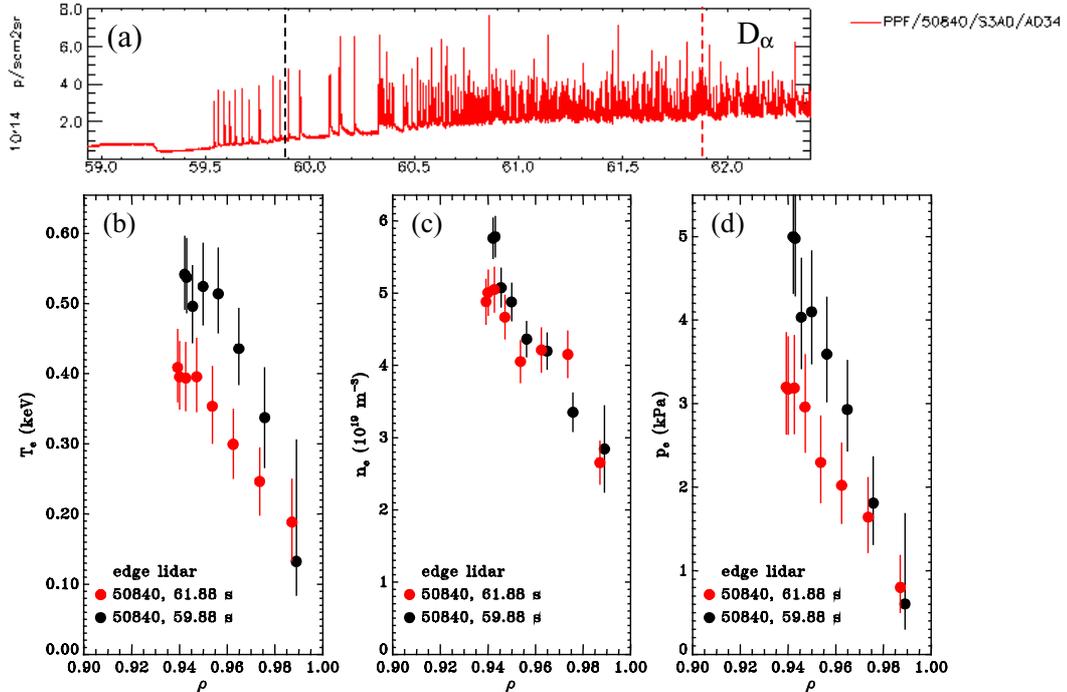


Fig. 2: (a)  $D_\alpha$  trace showing the ELM transition from Type I to Type III. Dashed lines indicate the edge LIDAR timing. (b, c, d)  $T_e$ ,  $n_e$  and  $p_e$  profiles by edge LIDAR. Clearly the edge  $T_e$  and  $p_e$  gradients have become shallower after the transition.

### Triangularity and edge pressure gradient.

At JET high triangularity means better confinement with higher edge pedestal pressure limits [2,3,4]. So far it has not been possible to compare edge gradients as a function of triangularity. A gas-scan experiment is performed in two shapes,  $(\delta_{\text{up}}, \delta_{\text{low}}) = (0.5, 0.45)$ ,  $(\delta_{\text{up}}, \delta_{\text{low}}) = (0.5, 0.3)$ . Fig. 3 shows that gradient comparison with edge LIDAR is limited by the instrument resolution (Fig 3). Combining edge LIDAR and ECE yields pressure gradients of 320kPa/m and 250 kPa/m for the subsequent cases (Fig 4 and 5). These gradients are still limited by the edge LIDAR resolution for  $n_e$  and therefore they cannot be distinguished. In the future, optimising penetration will improve resolution (Fig. 3).

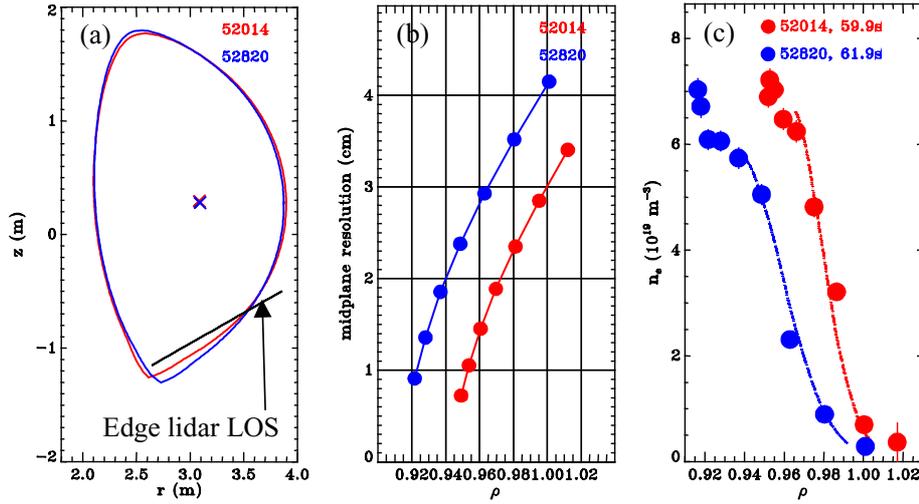


Fig 3. (a) Two shapes  $[(\delta_{up}, \delta_{low}) = (0.5, 0.45) = \text{red}, (\delta_{up}, \delta_{low}) = (0.5, 0.3) = \text{blue}]$  have different penetration for edge LIDAR and therefore (b) different resolution in the mid-plane. (c) Instrument resolution (drawn) limits gradient measurements in both cases.

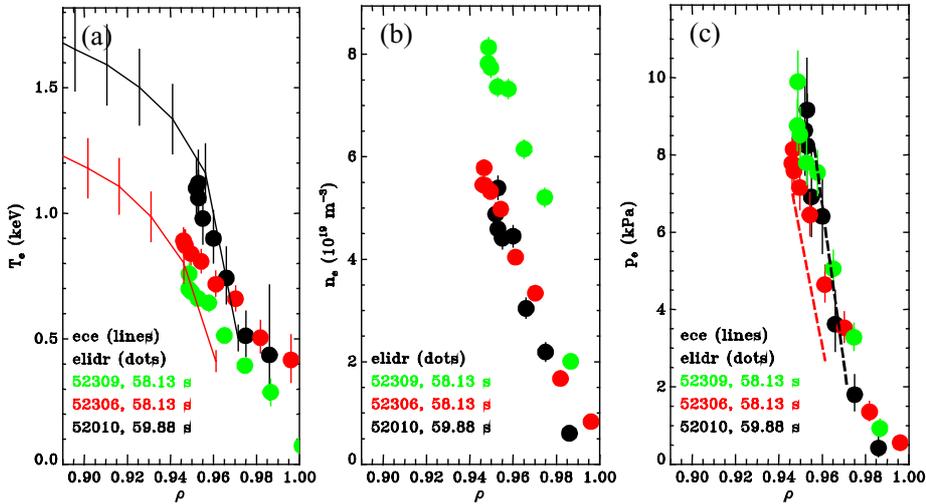


Fig. 4  $T_e$ ,  $n_e$  and  $p_e$  profiles by edge LIDAR and ECE for  $(\delta_{up}, \delta_{low}) = (0.5, 0.45)$ .  $p_e$  gradient does not vary within gas scan. Combined ECE and LIDAR yields highest  $p_e$  gradient.

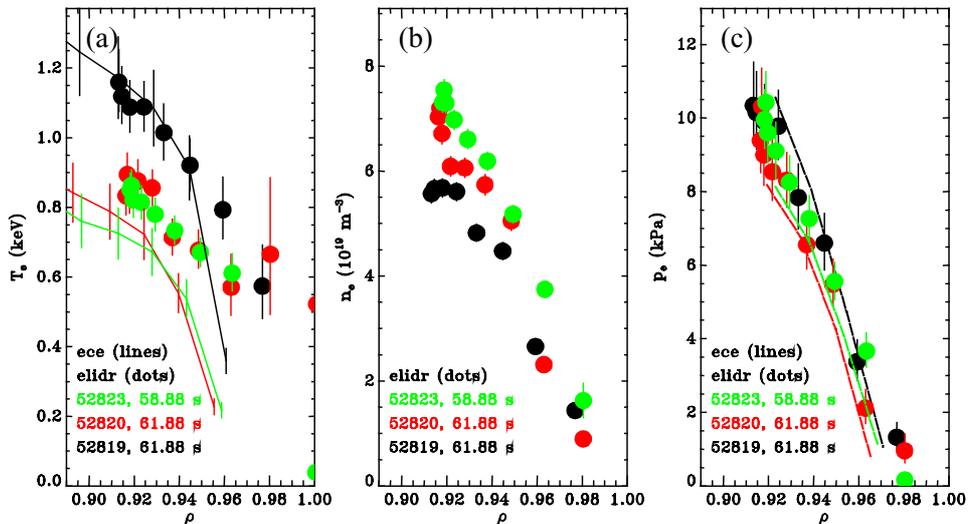


Fig. 5  $T_e$ ,  $n_e$  and  $p_e$  profiles by edge LIDAR and ECE for  $(\delta_{up}, \delta_{low}) = (0.5, 0.3)$ .  $p_e$  gradient does not vary within gas scan. Combined ECE and LIDAR yields highest  $p_e$  gradient.

## Pressure gradient with Li-beam and ECE.

For low density ELMy H-modes Li-beam measurements are possible. Under these conditions the higher spatial resolution of this diagnostic proves beneficial. An example is given of two discharges with different triangularity (Fig 6). The combined ECE, Li beam pressure profile shows gradients of 300-350 kPa/m.

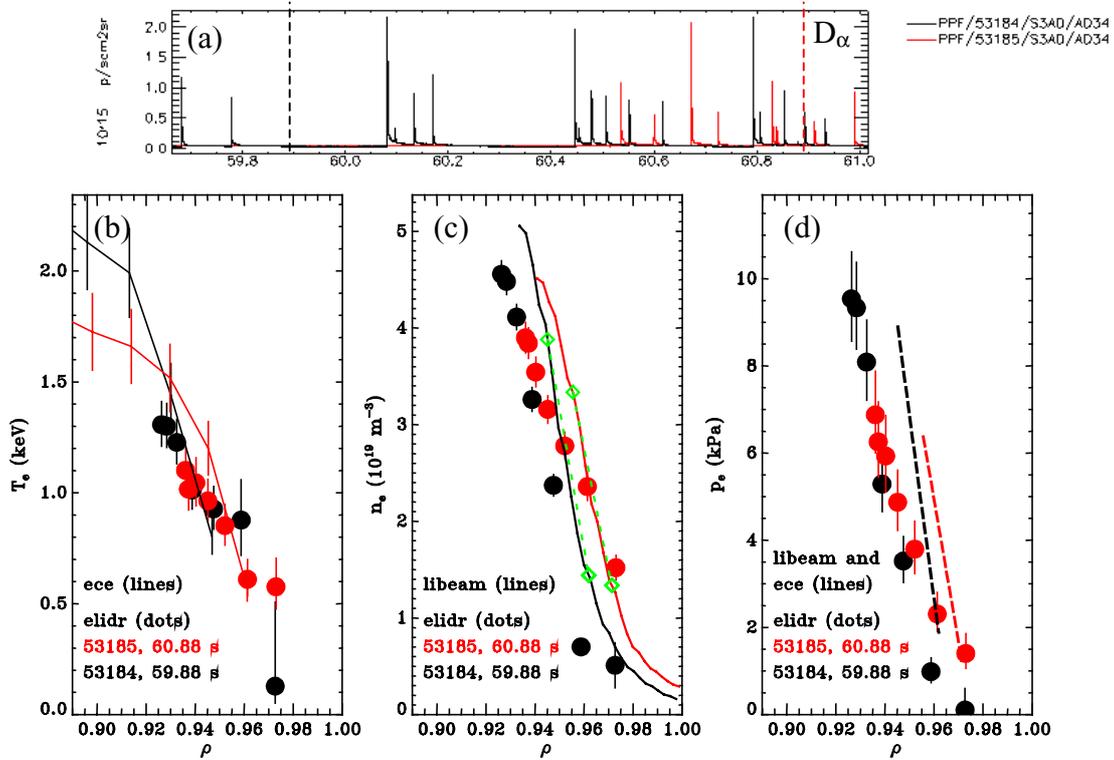


Fig. 6 (a) The edge LIDAR measurements are taken away from an ELM for both cases. (b), (c) and (d) show  $T_e$ ,  $n_e$  and  $p_e$  profiles by edge LIDAR, ECE and Li beam. Clearly ECE and Li beam measure steeper  $T_e$ , and  $n_e$  gradients resp. than edge LIDAR. For both plasmas the combined ECE, Li-beam pressure gradient therefore is steeper than in the edge LIDAR profile.

## Conclusions

True edge gradient measurements are observed up to the resolution limits of JET diagnostics. In practice this means that gradient measurements are possible in plasmas with degraded edge confinement (Type III ELMs). In type I ELMy H-modes, generally edge gradient measurements are limited by diagnostic resolution. Edge LIDAR is the only diagnostic with a direct edge pressure profile independent on EFIT equilibrium reconstruction for mapping purposes. Combining Li-beam and ECE yields edge pressure profiles with the best resolution possible at JET. Using these, electron pressure gradients of up to 300-350 kPa/m have been measured. However, the mapping error of EFIT of  $\pm 2$  cm in the midplane complicates the interpretation.

In a new experiment for edge gradient measurement the plasma shape will be optimised for optimum access of Li beam and edge LIDAR. The edge LIDAR penetration can be tuned to yield higher resolution ( $\geq 1$  cm, Fig. 3) at the steep edge gradient region. Taking into account that edge  $T_e$  is limited by parallel transport, the Li beam and ECE measurements can be shifted with respect to edge LIDAR to match the separatrix [3]. And sweeping experiments enable profile reconstruction from interferometry.

[1]R. Sartori, this conference

[2]G. Saibene, nucl. fusion, **39**, p1133, 1999

[3]A. Kallenbach, this conference

[4]G. Saibene, this conference.