Edge Profile reconstruction from experimental data at JET

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With input from: Alberto Loarte, Elena de la Luna and Geoff Maddison

What do we need to cover?

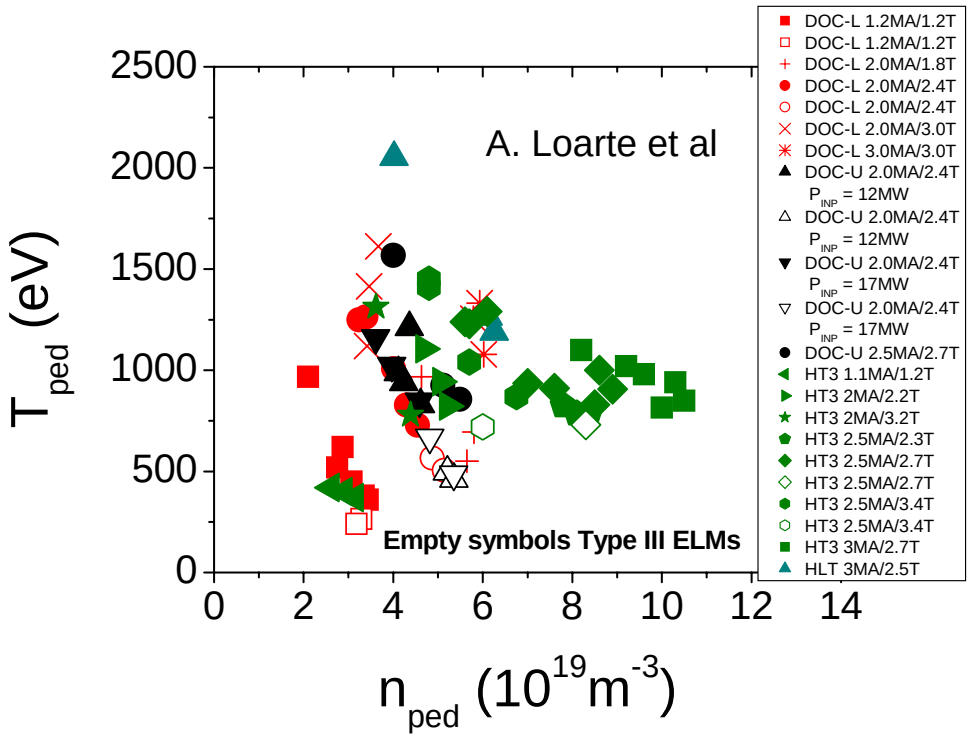
- Pedestal top parameters
- Pedestal Width
- Pedestal profile shape

Pedestal top

T_e: ECE. Works very well, but at limited plasma parameters:

B and n_e

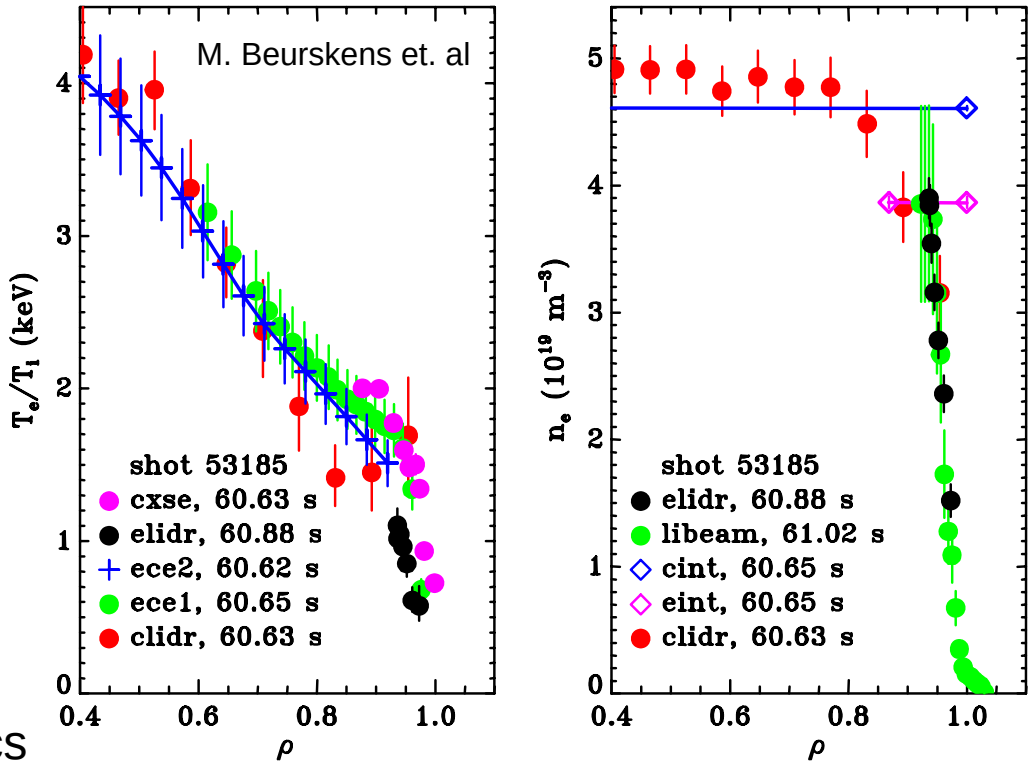
n_e: Interferometer edge channel; works well, but only average profile.



This is a well established technique and does not need much improvement. However covered plasma conditions limited by ECE

Pedestal width

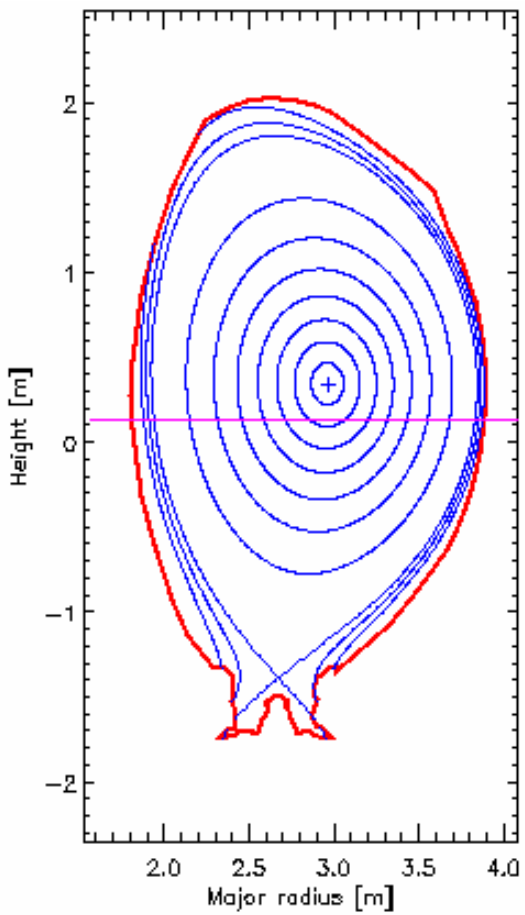
- ECE
- Edge LIDAR
- Edge charge exchange
- Li-beam
- interferometer

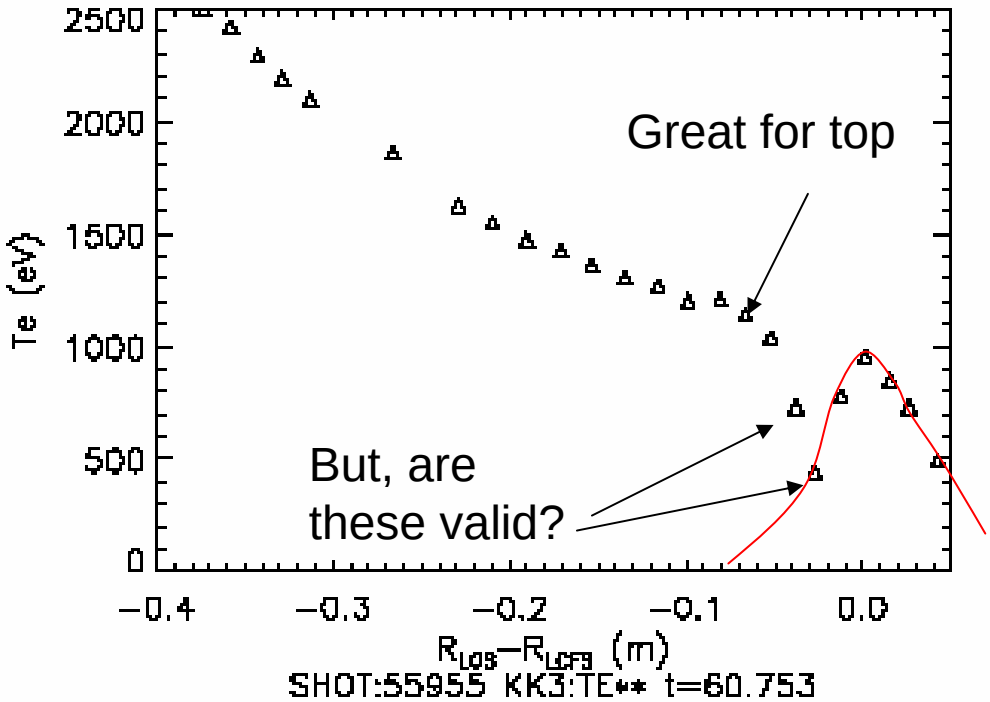


Suffers from:
- Difficulty to combine diagnostics
- EFIT mapping problems
- Poor temporal resolution for some plasma parameters

Ideally we would have one diagnostic @ $5f_{ELM}$ to cover full profiles to avoid mapping issues

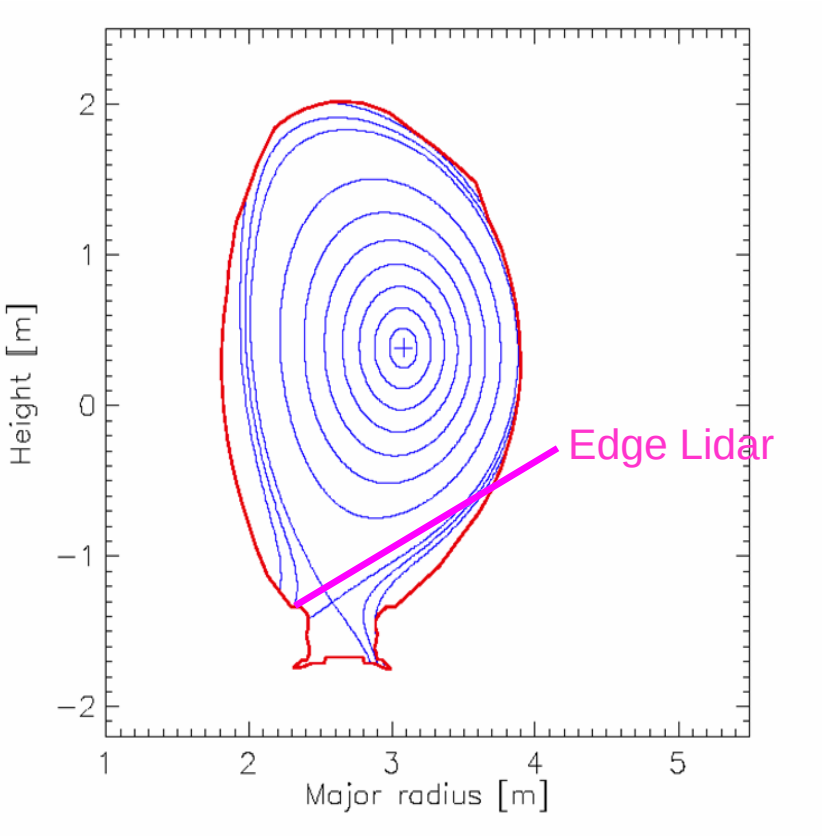
Profiles with ECE at JET



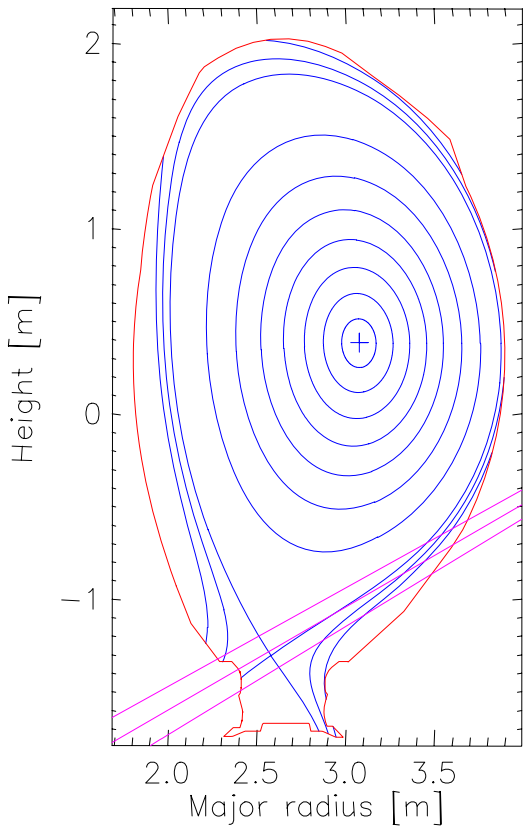


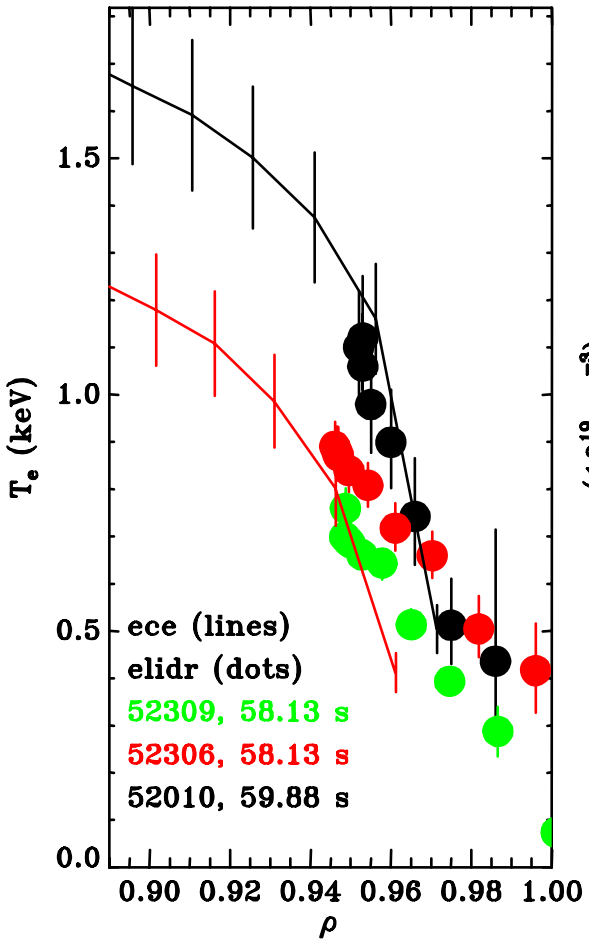
Edge LIDAR pedestal measurements

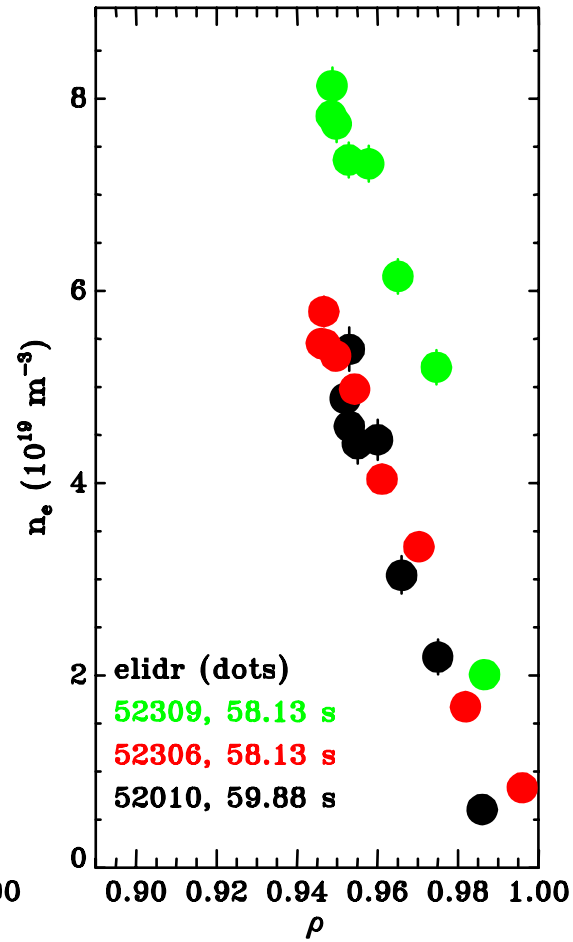
- Edge lidar has resolution of 12 cm (l.o.s.)
- Designed optimum shape to benefit from flux surface tangency



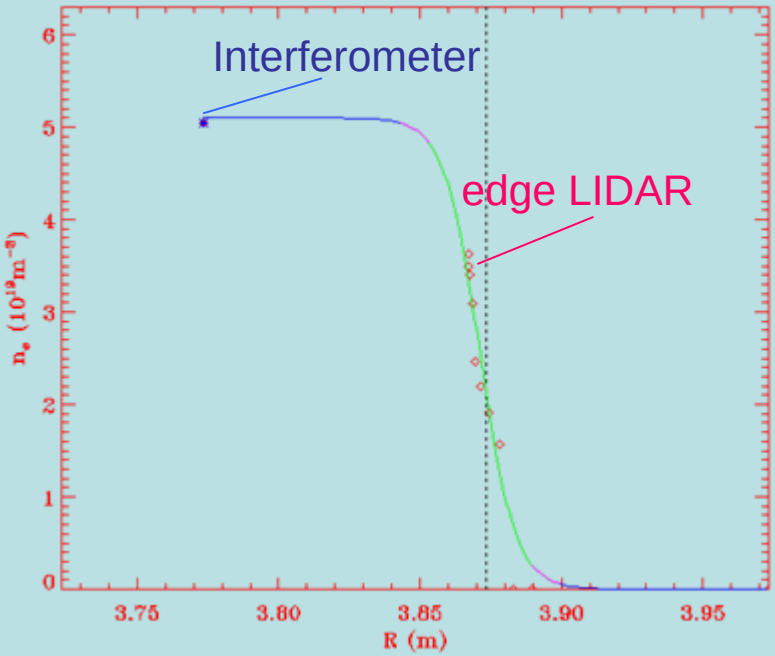
Profiles with edge LIDAR at JET

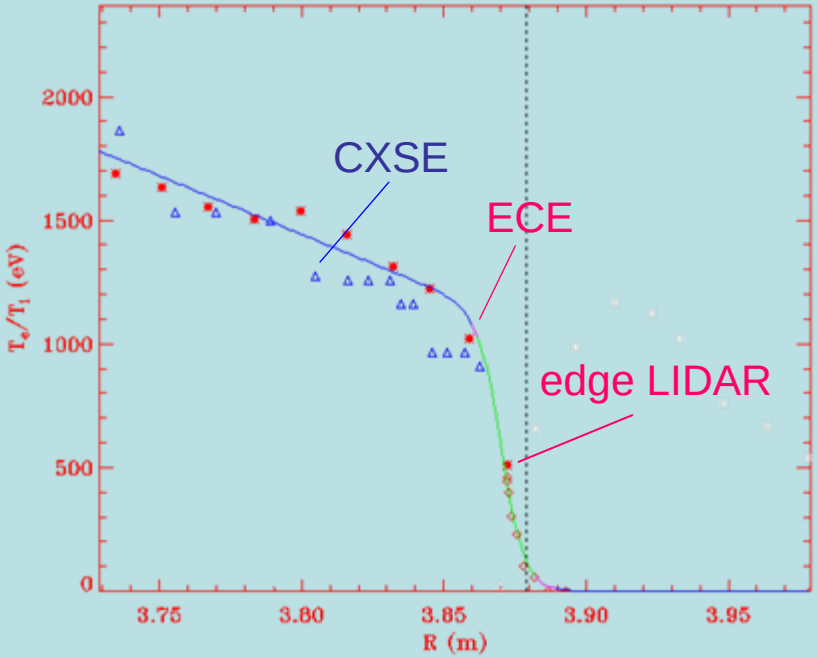






Pedestal reonstruction





Density:

-Edge interferometer L.O.S. for pedestal top

-Edge LIDAR (often only 1 or two good profiles per shot)

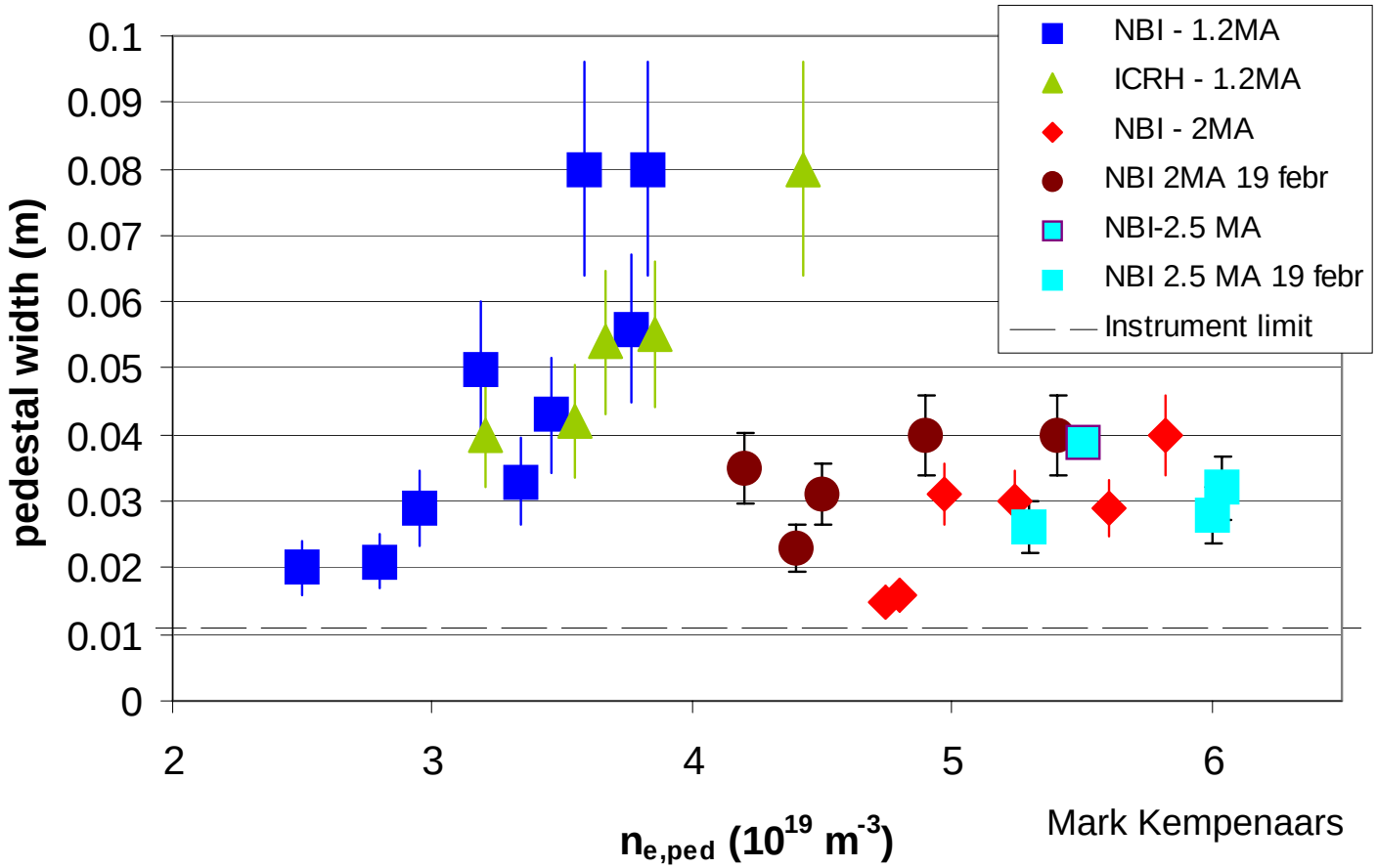
Temperature

-ECE

-Edge LIDAR (often only 1 or two good profiles per shot)

-Edge CXRS: often only top

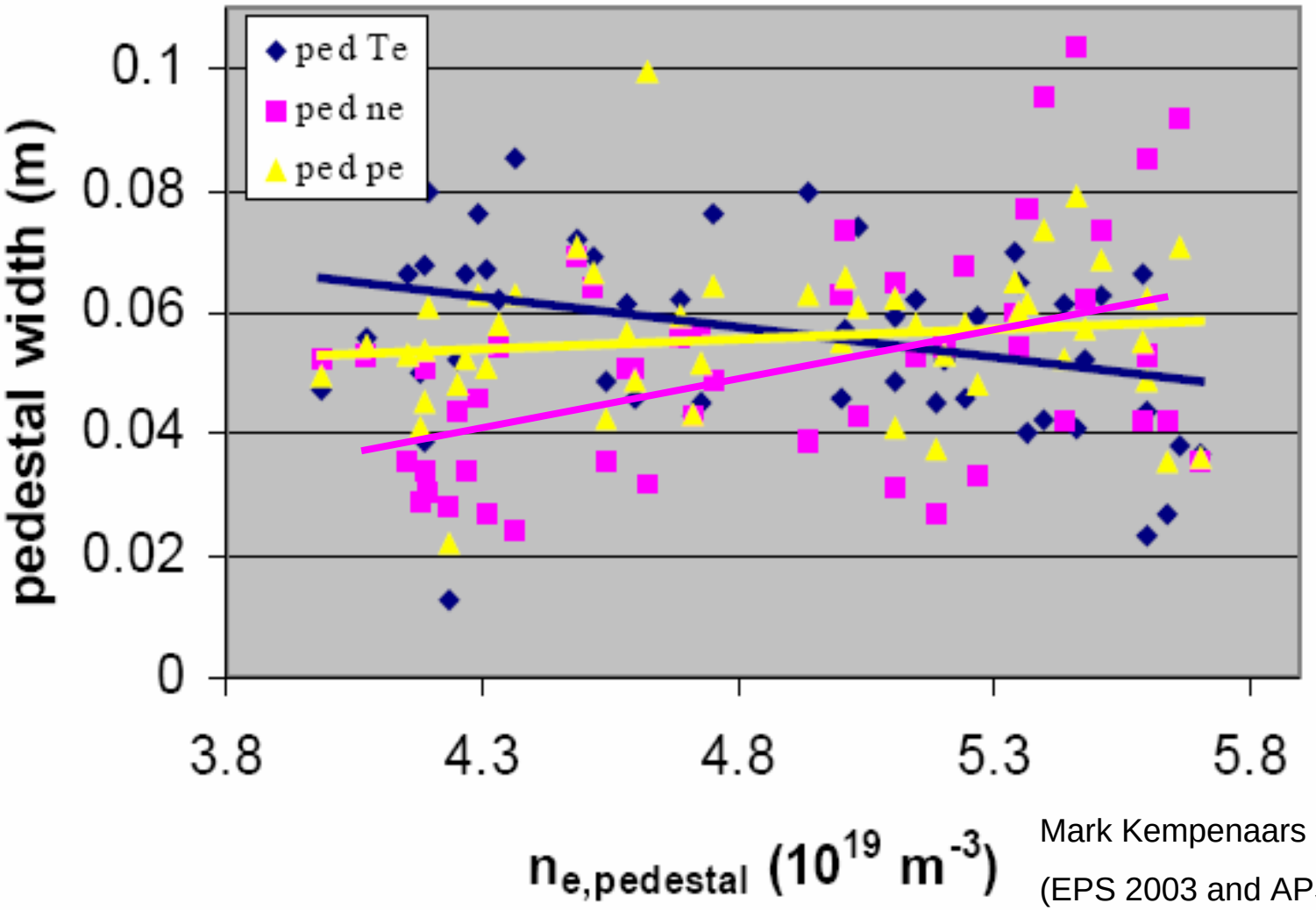
Preliminary experiments at JET 1.2 MA and 2-2.5 MA



Mark Kempenaars

(EPS 2003 and APS 2003….)

And for T_e, n_e and p_e (2.5MA only)



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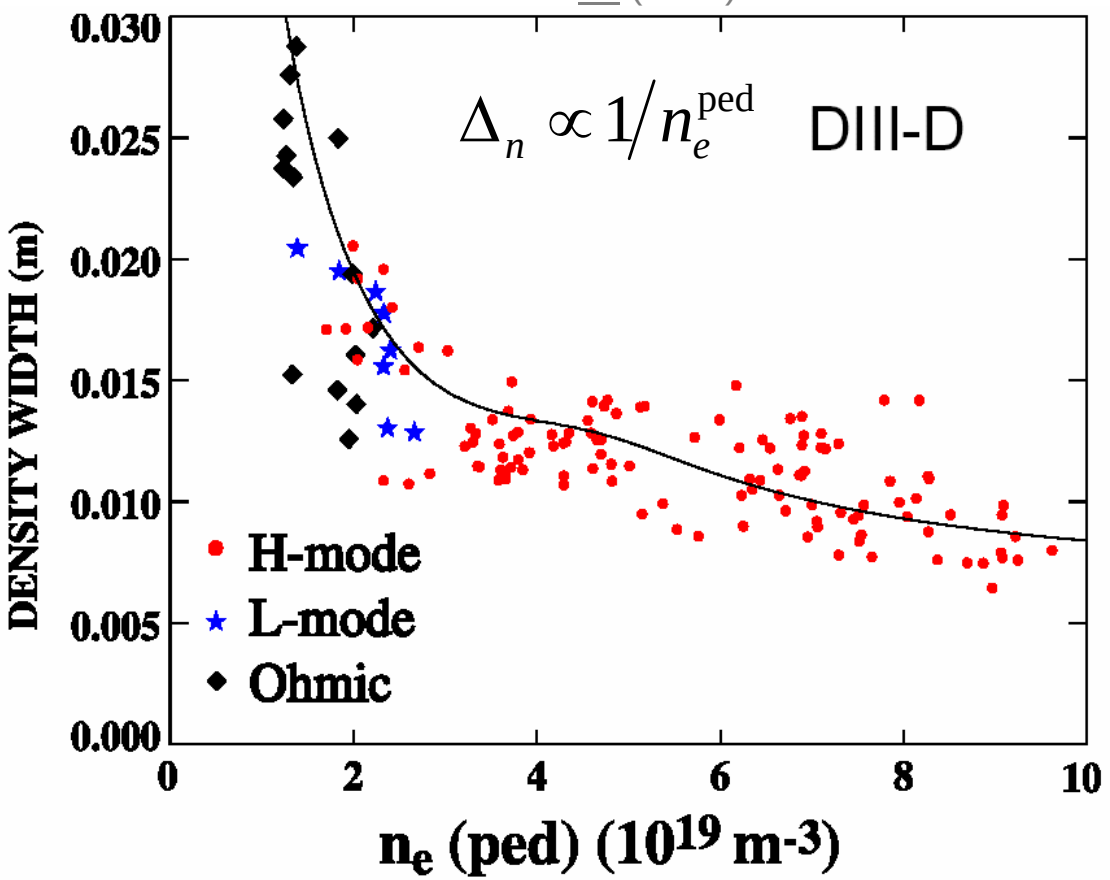
(EPS 2003 and APS 2003….)

How does this compare to other Tokamaks?

M Mahdavi et al *PoP* 10 (2003) 3984



$$D \frac{\partial n_i}{\partial r} = n_0 \, v_0$$

$$\downarrow$$

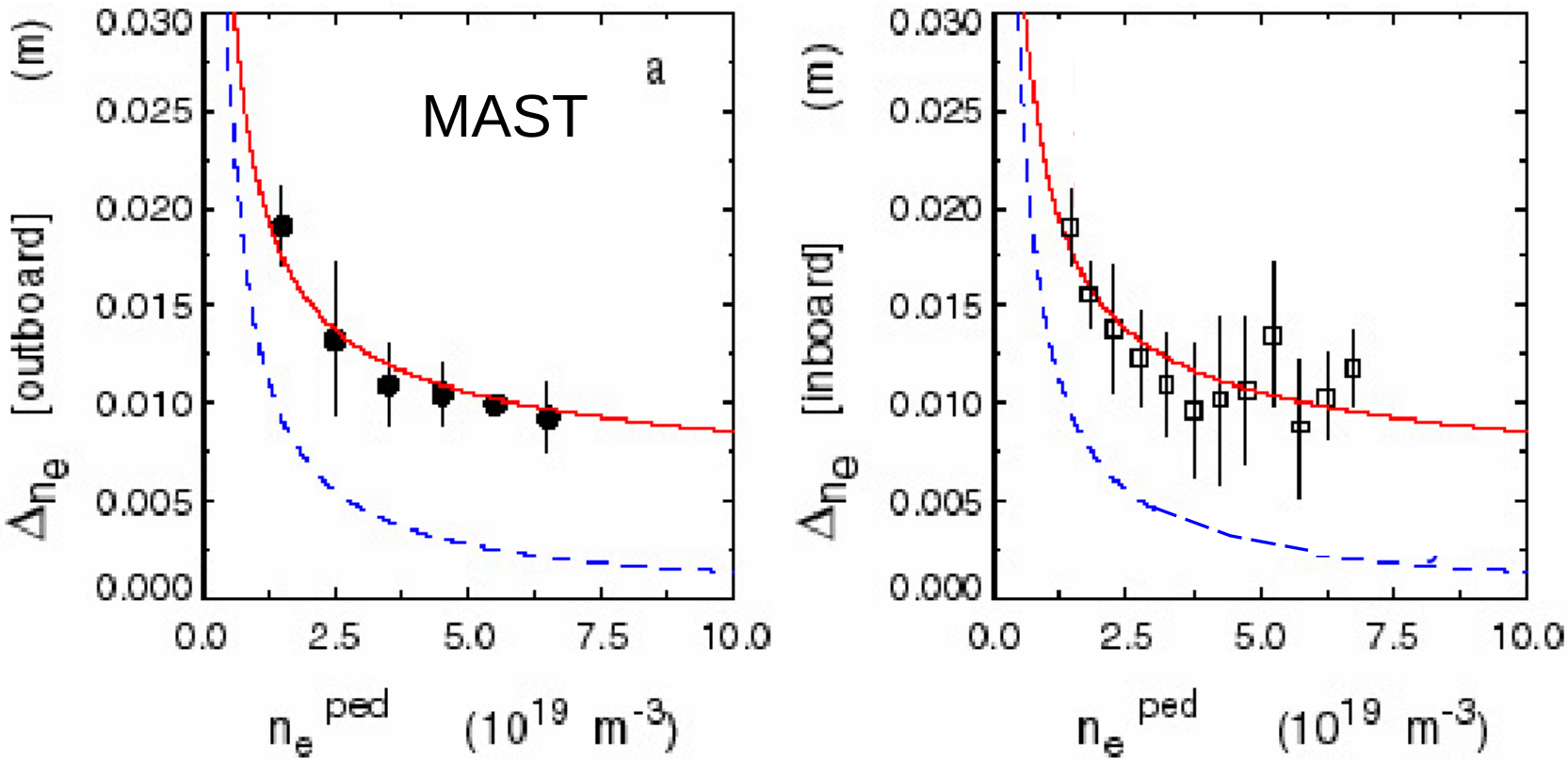
$$n_e(x) \propto \tanh(a\,x + b)$$

$$\downarrow$$

$$\Delta n_e \propto \frac{1}{n_e}$$

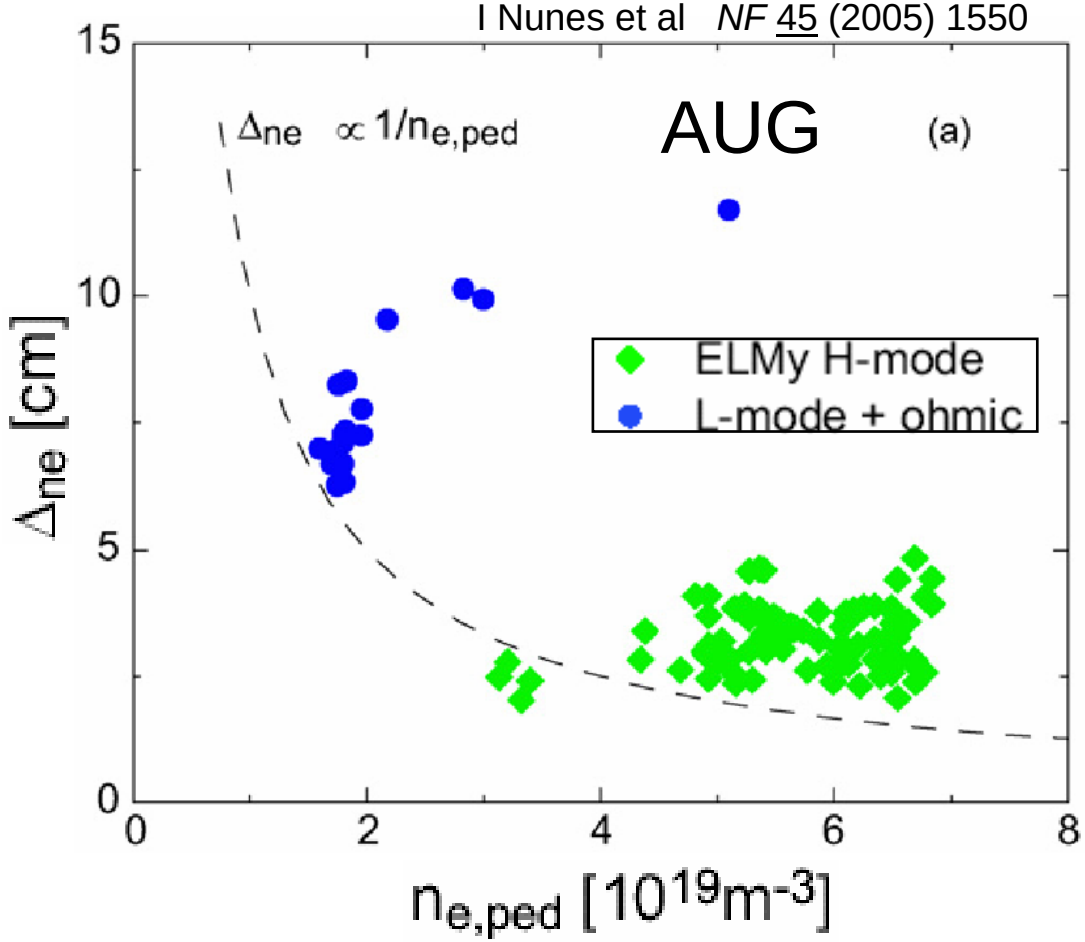
How does this compare to other Tokamaks?

A Kirk *et al* PPCF 46 (2004) A187

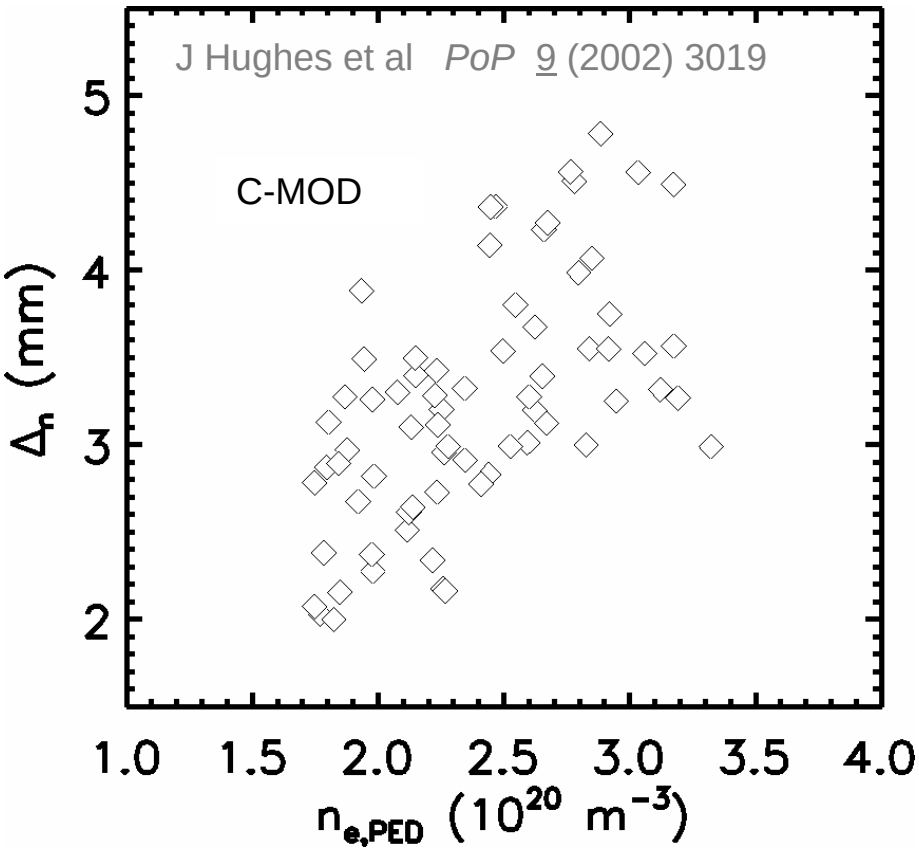


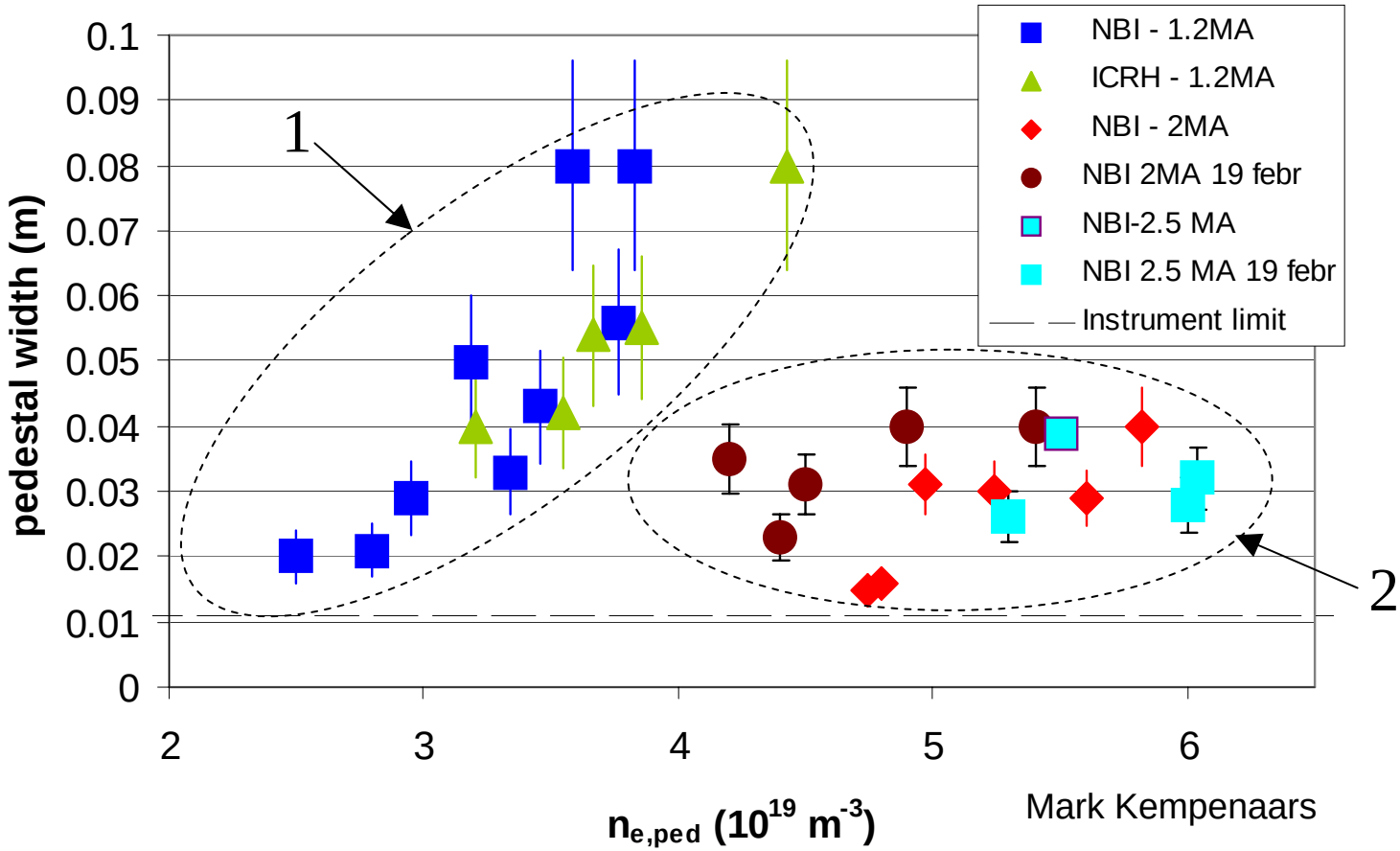
How does this compare to other Tokamaks?

I Nunes et al *NF* 45 (2005) 1550



How does this compare to other Tokamaks?





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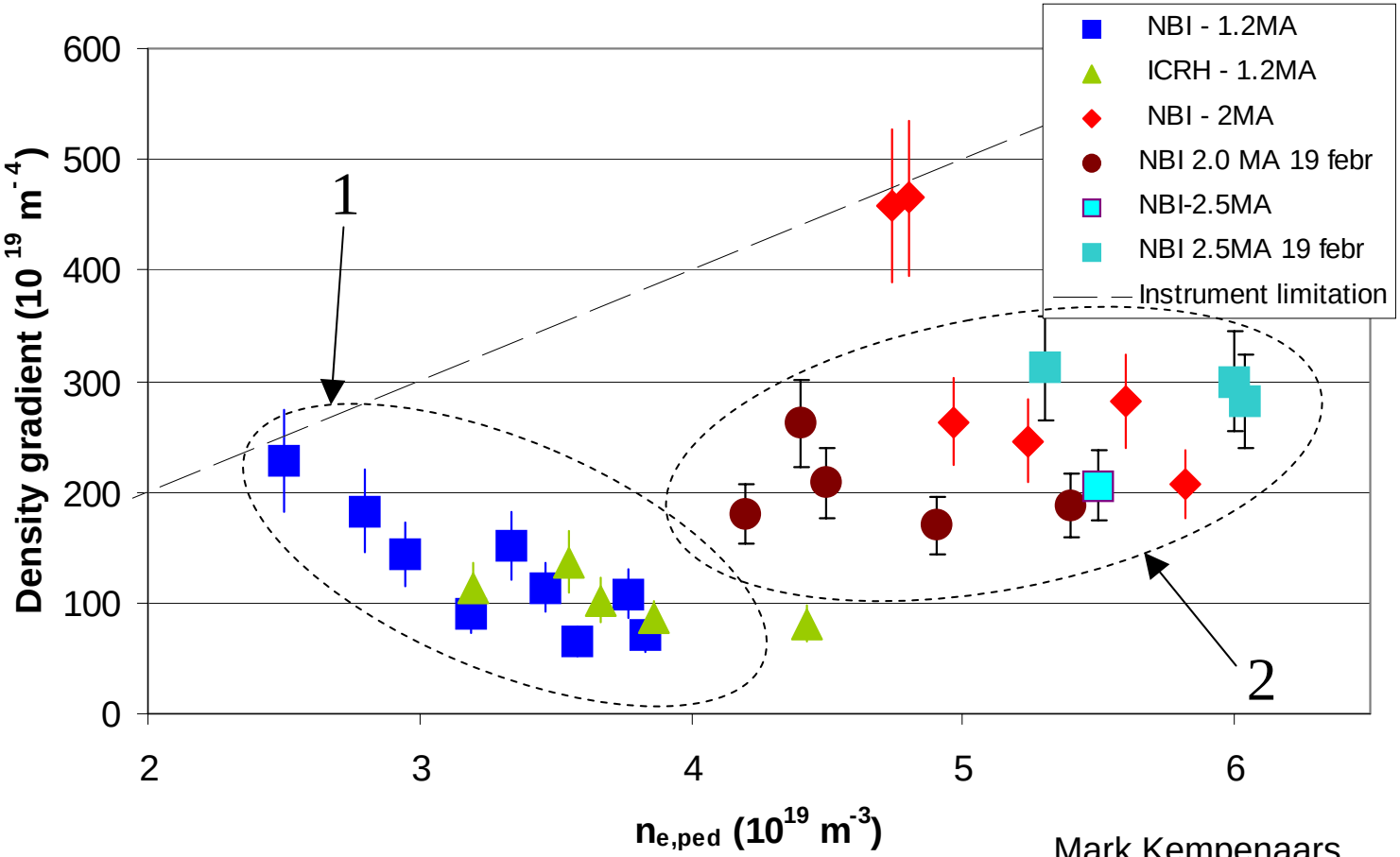
(EPS 2003 and APS 2003….)

Two regions;

-1- (1.2MA): increasing pedestal width with increasing fuelling

-2- (≥ 2MA): ~ constant pedestal width with increasing fuelling



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(EPS 2003 and APS 2003)

Two regions;

-1- (1.2MA): decreasing gradient with increasing fuelling

-2- (≥ 2MA): increasing gradient with increasing fuelling

Pedestal width at JET

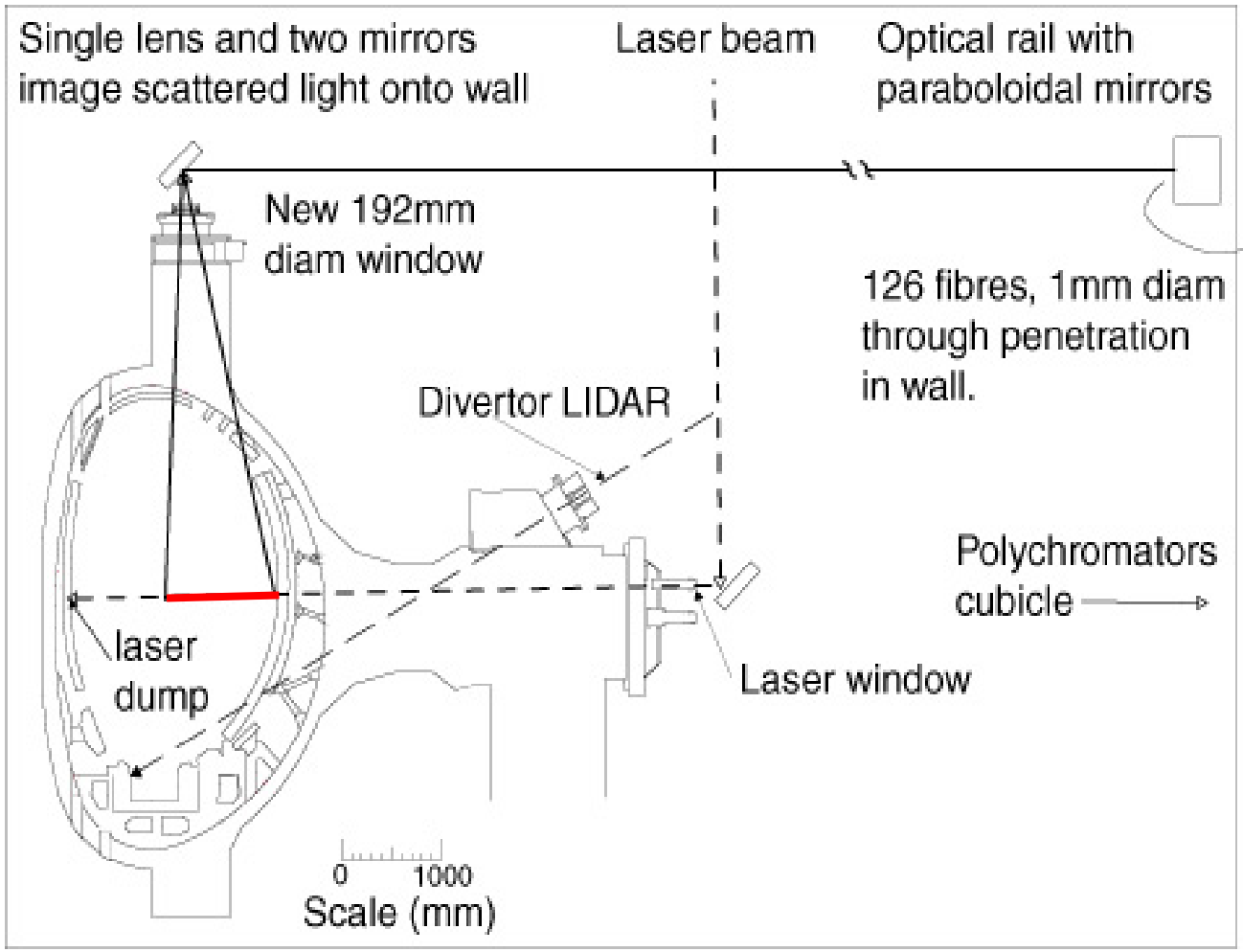
- Measurement is only possible when special shape is used
- Combining diagnostics is tricky because of EFIT mapping problems (E. Solano)
- Clearly the profile shape is not resolved (assume TANH)
- Stability analysis requires better resolving of pedestal profile shape.

Capabilities of Diagnostics:

Also E. de la Luna

Diagnostic	Parameter	Accuracy	Time	resolution	Restriction
ECE	T_e	< 5%	5 kHz	2-5 cm	B, ne, shine through
LIDAR TS	T_e and n_e	10-20%	1Hz	2-5 cm	Plasma Shape, rep.rate
Interferometer	n_e integral	1%	>kHz	-	Plasma Shape
CXRS: *Y. Andrew*	T_i	10%	>10 ms	5-8 cm	All beams on: low resolution
Li-beam	N_e	?	Limited	2 cm	Plasma Shape, not reliable…
HRTS	n_e and T_e	5-10%	20 ms	1.5 cm	Under construction
Reflectometry *S. Hacquin*	n_e	? (good)	1 ms	1 cm	B,n space/radial cover. (Hacquin)

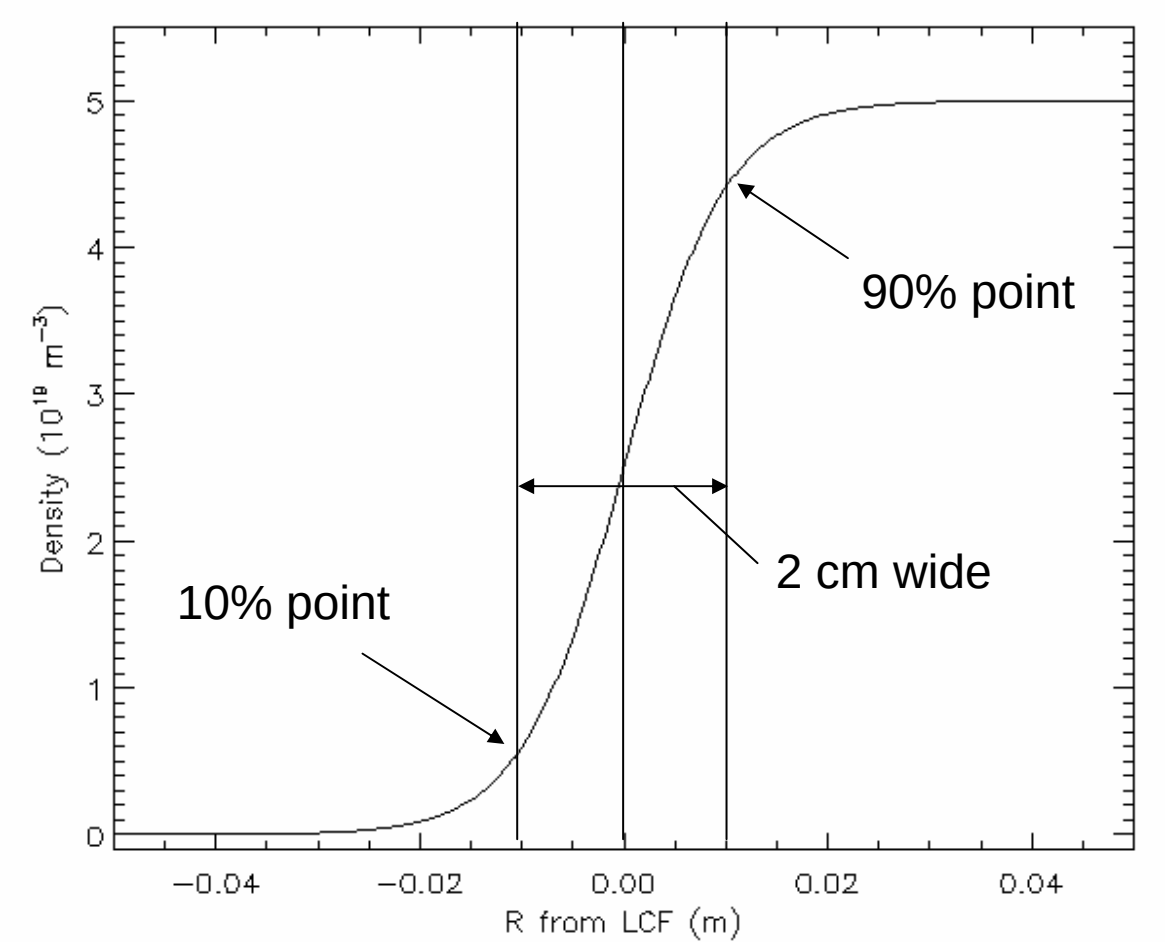
High Resolution Thomson scattering



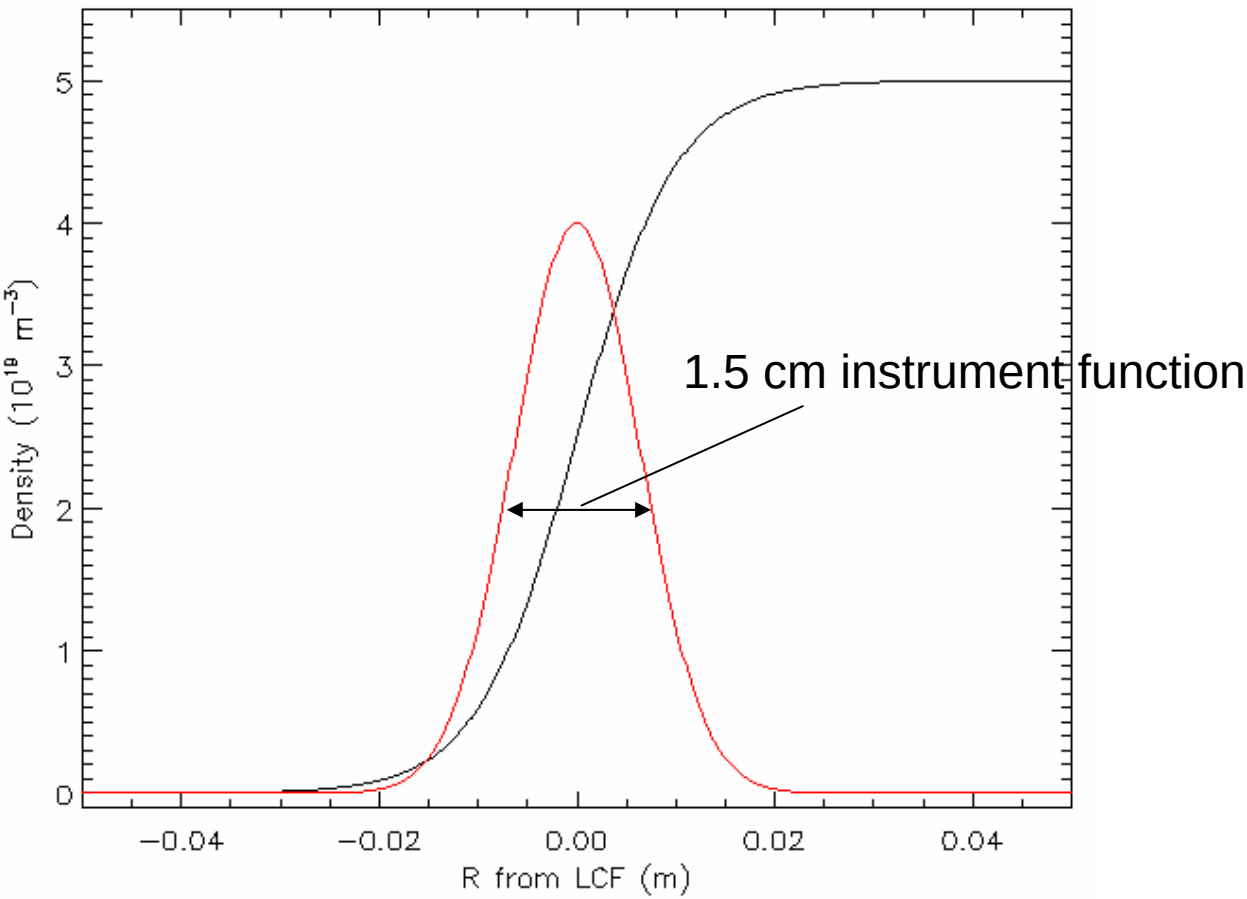
Status of the diagnostic

	HRTS Specified	HRTS now
Spatial resolution	1.5 cm	2.5 cm core 1.5 cm edge
Nr. of points	63	35
Time range	Full plasma	Heating phase
Frequency	20 Hz	20 Hz

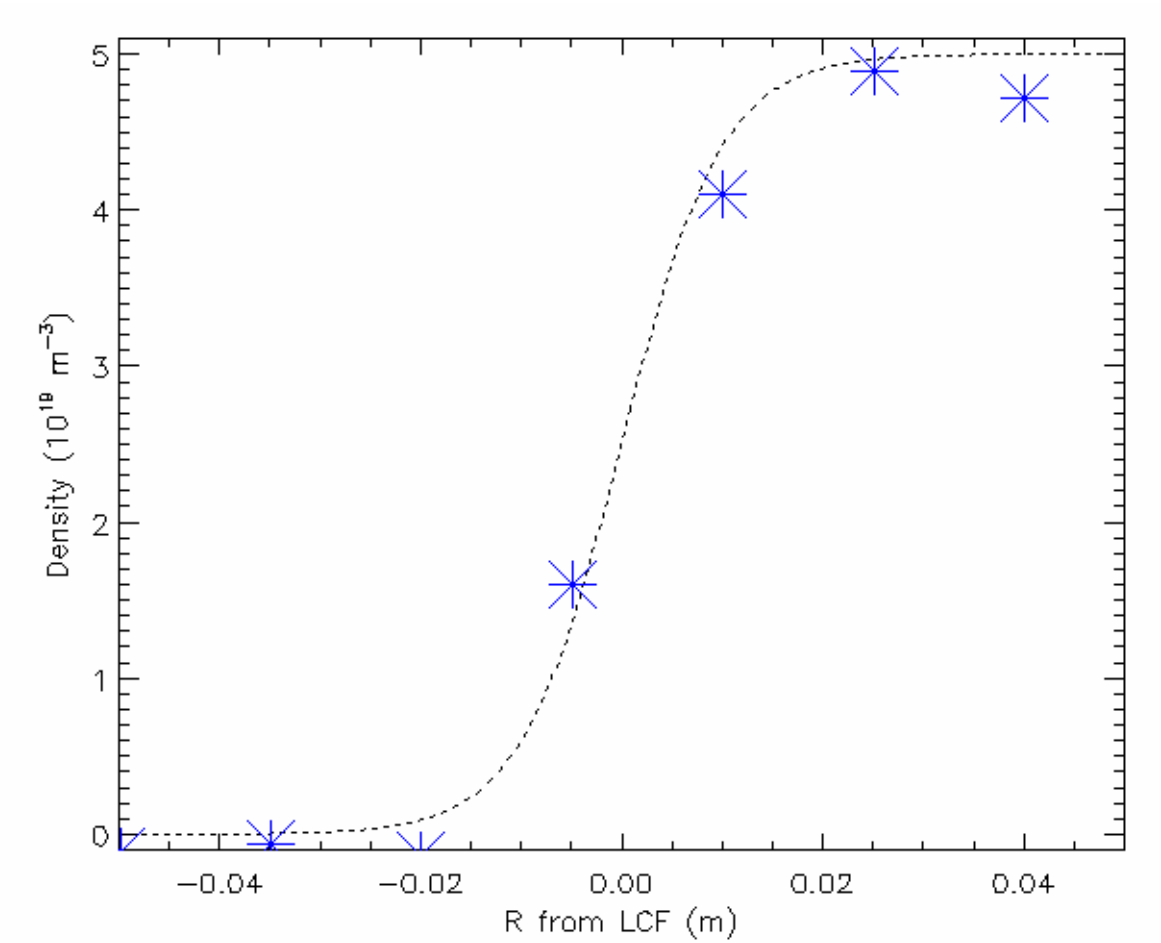
Performance simulation: Assume a pedestal of 2 cm wide



Look at it with 1.5 cm resolution



Look at it with 1.5 cm resolution

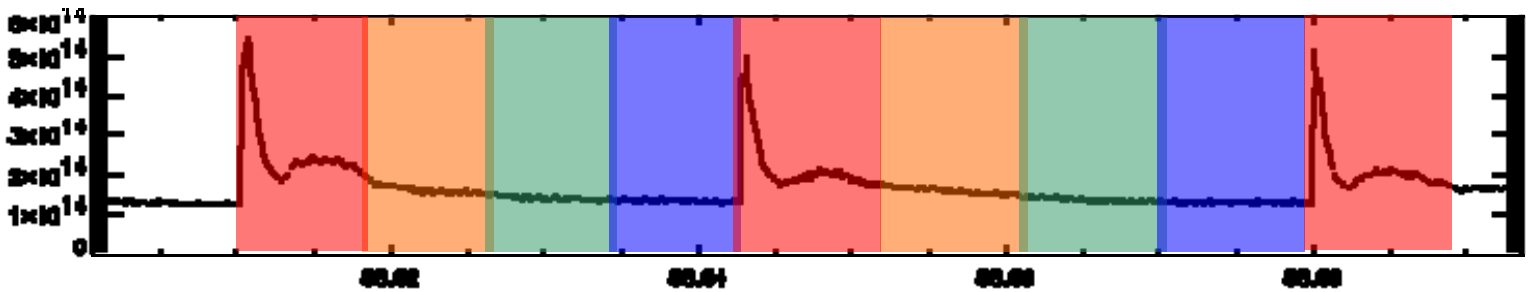


Even if HRTS will work to full Spec

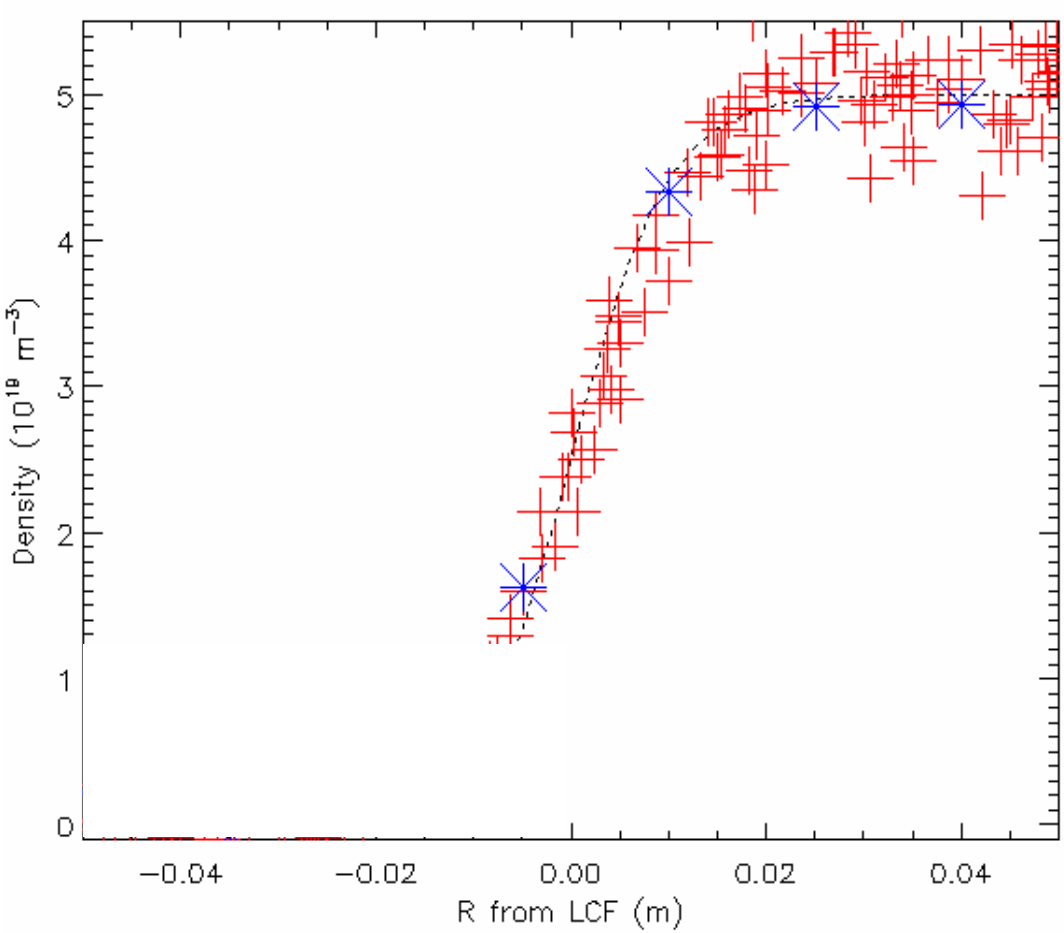
- There will be only 1 point on the gradient in this 2 cm wide pedestal
- ELM averaging will be required.
  (R. Behn/Y Martin)
- Is it possible at JET as well?

Simulation of experiment

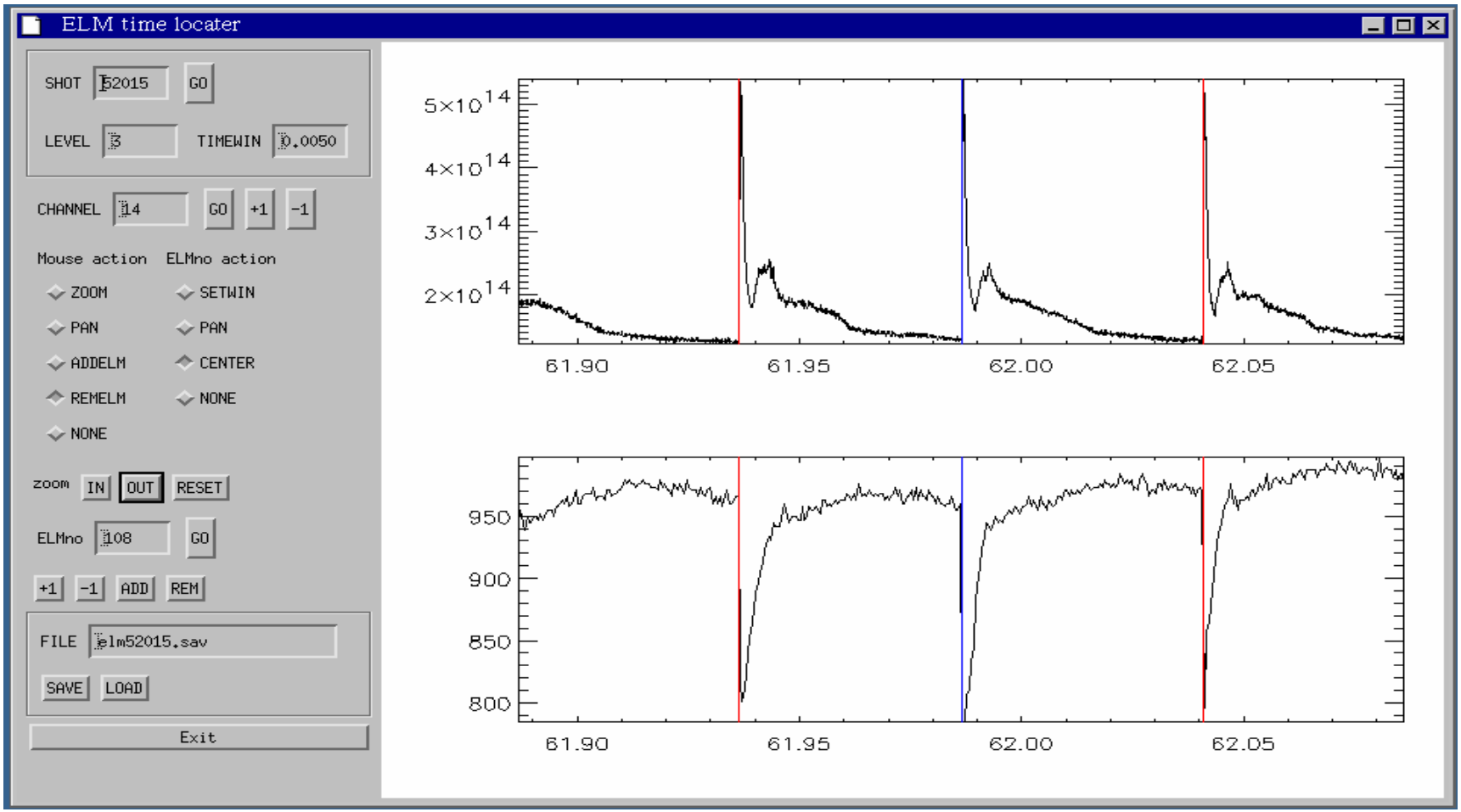
- Wiggle the plasma by 2 cm at 1Hz
- Assume 5 seconds stable ELM-mode
- This means 5*20=100 HRTS profiles
- Divide the ELM period in 4 parts (can choose)
- Meaning 25 profiles per phase
- Independent of ELM frequency



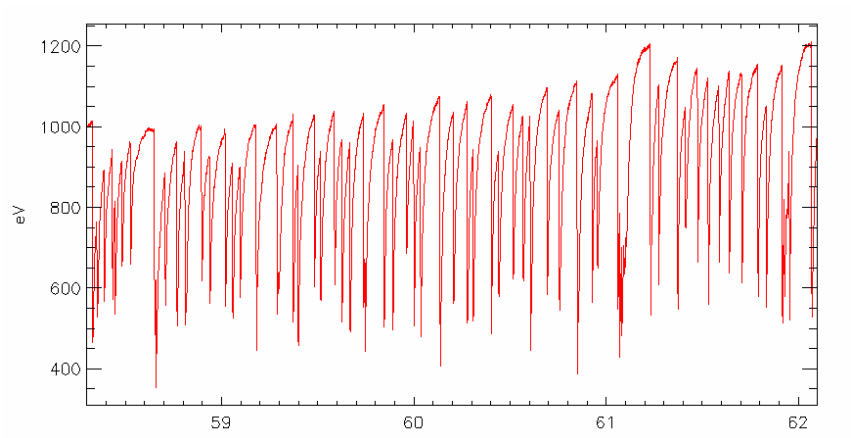
Combine 25 profiles incl. wiggle (1.5 cm resol.)

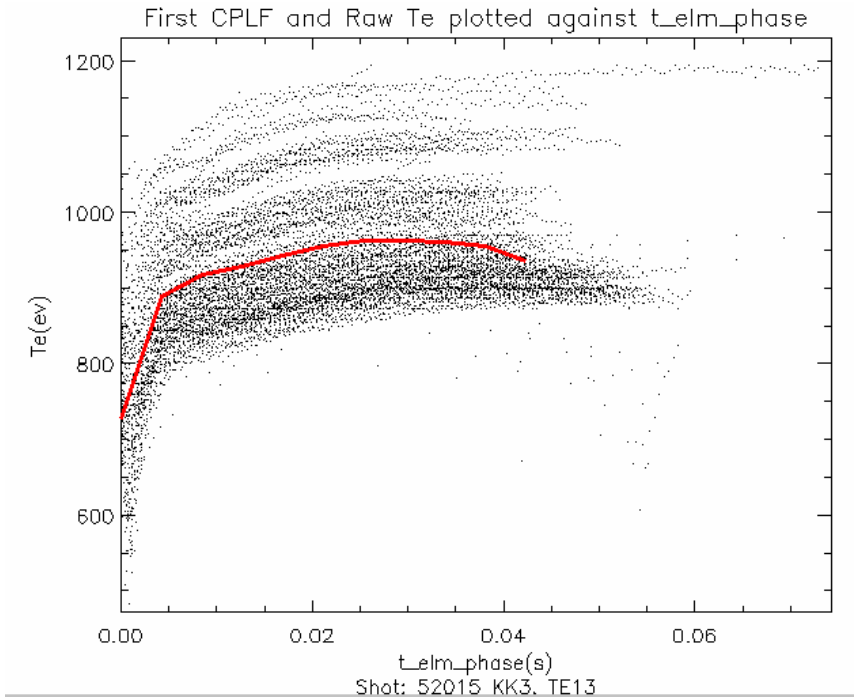


ELM time locating



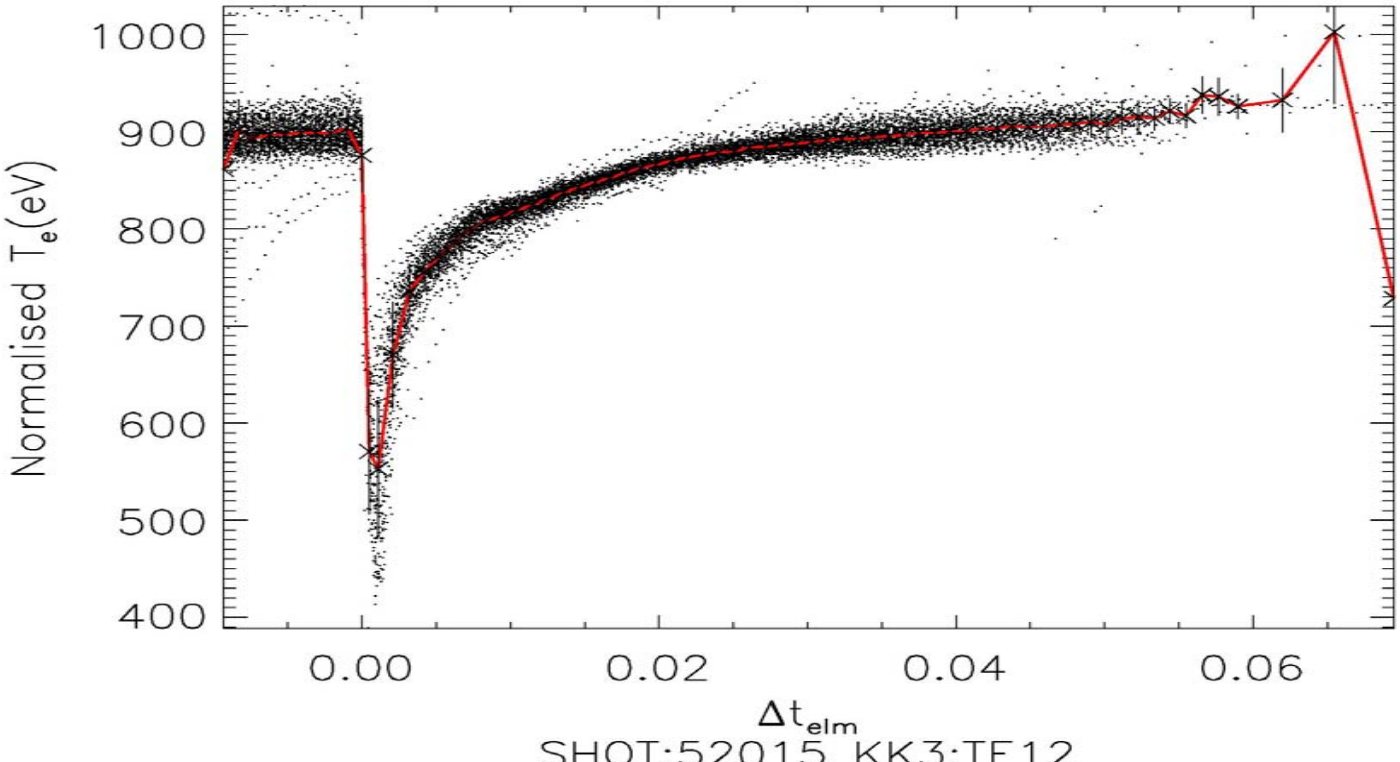
Is ELM averaging justified at JET?: Do experiment with ECE data





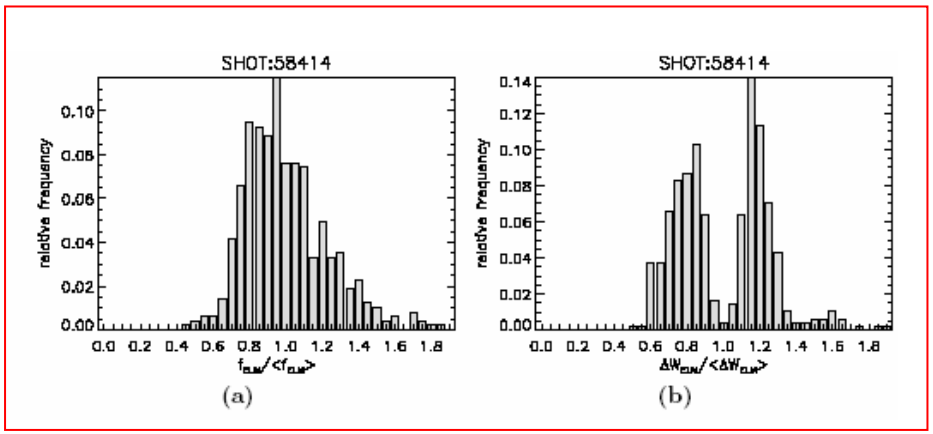
Apply ELM phase averaging

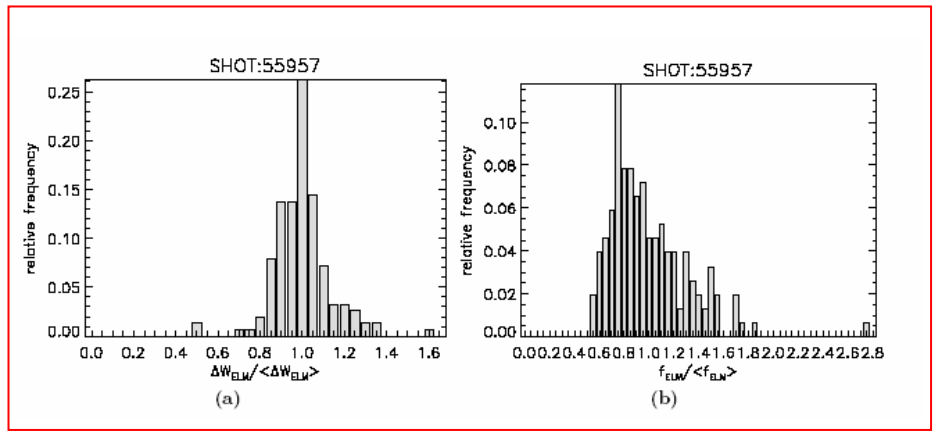
- Normalising ELM time traces results in good match



This is used to:

- Determine ELM statistics:





- Check validity of ELM averaging for less frequent measurements (edge LIDAR, CXRS, future HRTS)

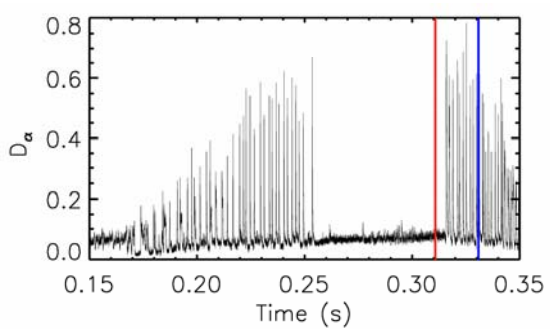
Conclusions

- Pedestal top is well determined with ECE and interferometry.
- Pedestal width only resolved in special plasma shapes with edge LIDAR, Interferometer and ECE
- New HRTS and Reflectometry will contribute greatly here and also in more precise determination of profile shape.

Availability of HRTS

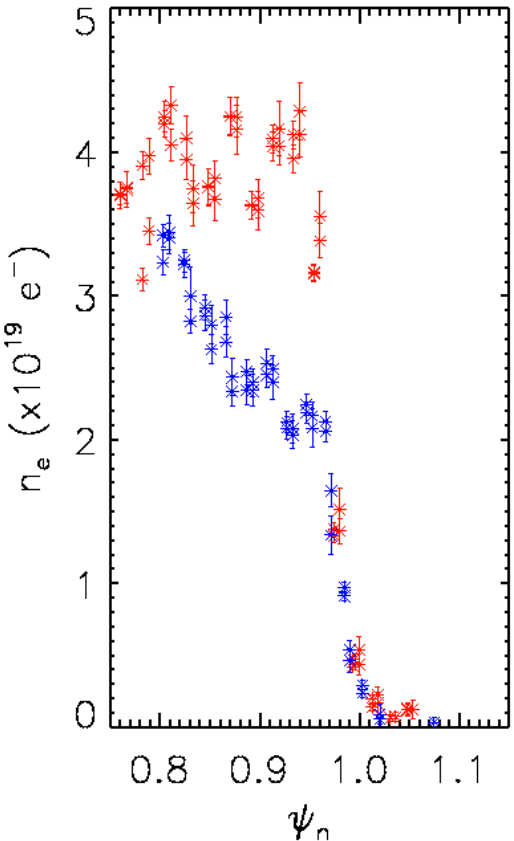
- The system is now being commissioned
- 5 milestones have been set
- **M1, 19 May**
  Get the laser into the vacuum vessel
- **M2: 19 June**
  Get first temperature profiles
- **M3: During Campaign**
  Shakedown of the system
- **M4: After C15-C17/18 (perhaps in retro)**
  Get first density profiles
- **M5: next year**
  have fully operational system

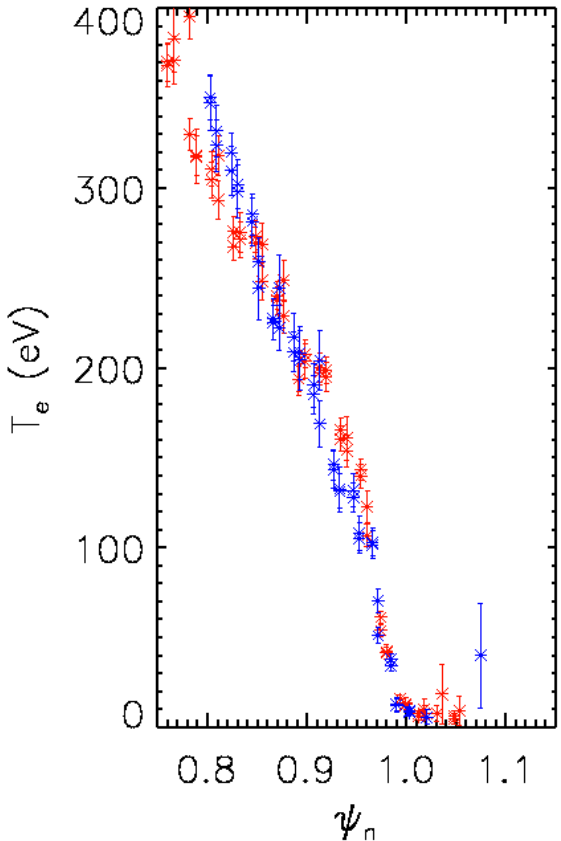
MAST – Pedestal Measurements



Inter ELM H-mode pedestal

H-mode Pedestal during ELMing





- *System has 10mm resolution - 2 sets of lasers follow different paths to obtain 5mm resolution*
- *Pedestal widths comparable to resolution*
- *MAST pedestals show purely convective losses – particle loss without drop in T_e pedestal*