Key Results of Discussion During MAST Research Forum 2004, of Interest to NSTX

MAST Research Forum
22-23 Jan 2004
John Adams Lecture Theatre

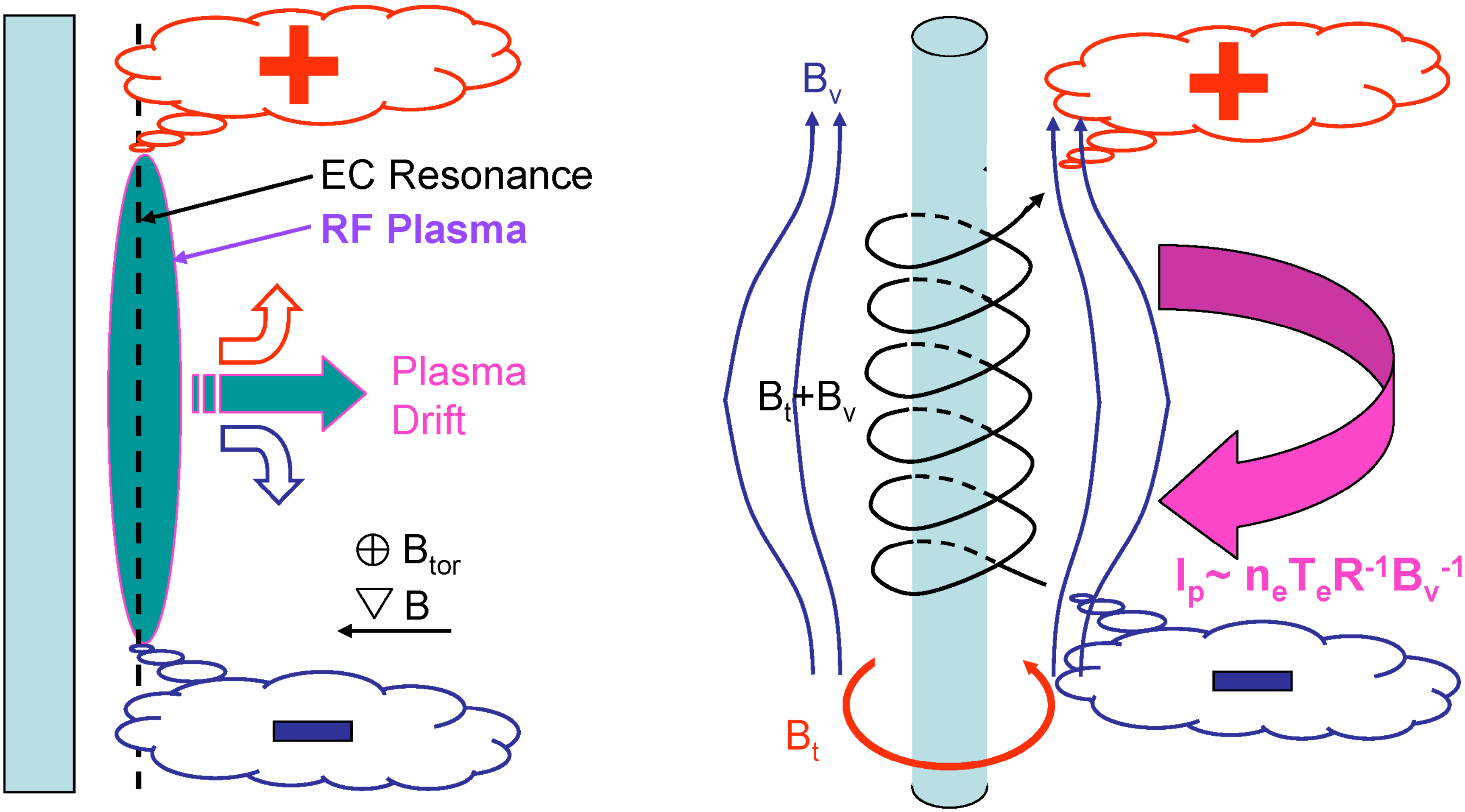
	Thurs 22 Jan	
9.00am	Introduction	BL/AS
9.20am	Integrated Scenario Development	GCu/TCH
10.30am	*COFFEE*	
11.00am	ELMs & Pedestal Physics	AK/HM
12.30pm	*LUNCH*	
1.30pm	Confinement Studies	MV/HM
3.00pm	*COFFEE*	
3.30pm	Transport & Turbulence	ARF/RA
5.00pm	*CLOSE*	

	Fri 23 Jan	
9.00am	NSTX Perspectives	M. Peng
9.30am	Disruptions & Divertor Biasing	GFC
10.30am	*COFFEE*	
11.00am	NBI & Fast Ion Physics	RA
12.00pm	Miscellaneous	BL
12.30pm	*LUNCH*	
1.30pm	EBW	VS/FV
3.00pm	*COFFEE*	
3.30pm	Start-up	AS/MG
4.30pm	Final Discussion	
5.00pm	*END*	

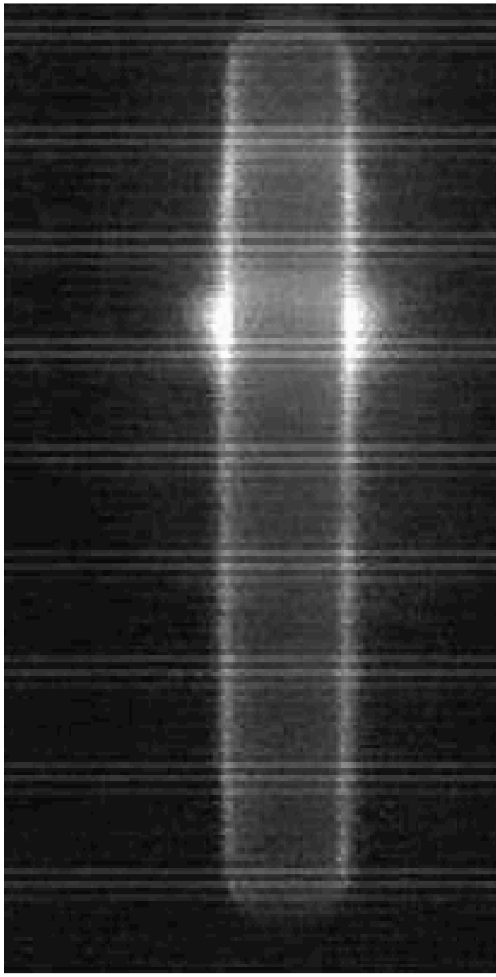
Focus on Topics of Interest to NSTX, as Advised by NSTX PAC-15th Meeting

- Exciting MAST-NSTX collaboration plans already well discussed
- Issues that will benefit from additional collaborations
  - Joint EBW H&CD tests
    - Slow startup
    - H&CD test
  - ST global confinement scaling database
  - Electron and ion linear and non-linear μ-instability calculations for measured and modeled plasmas
  - Test of CTF operational scenarios
- Issues that will benefit from additional collaborations
  - Aim for £25M
  - Major upgrades in NBI and RF (EBW)
  - Start in 2006

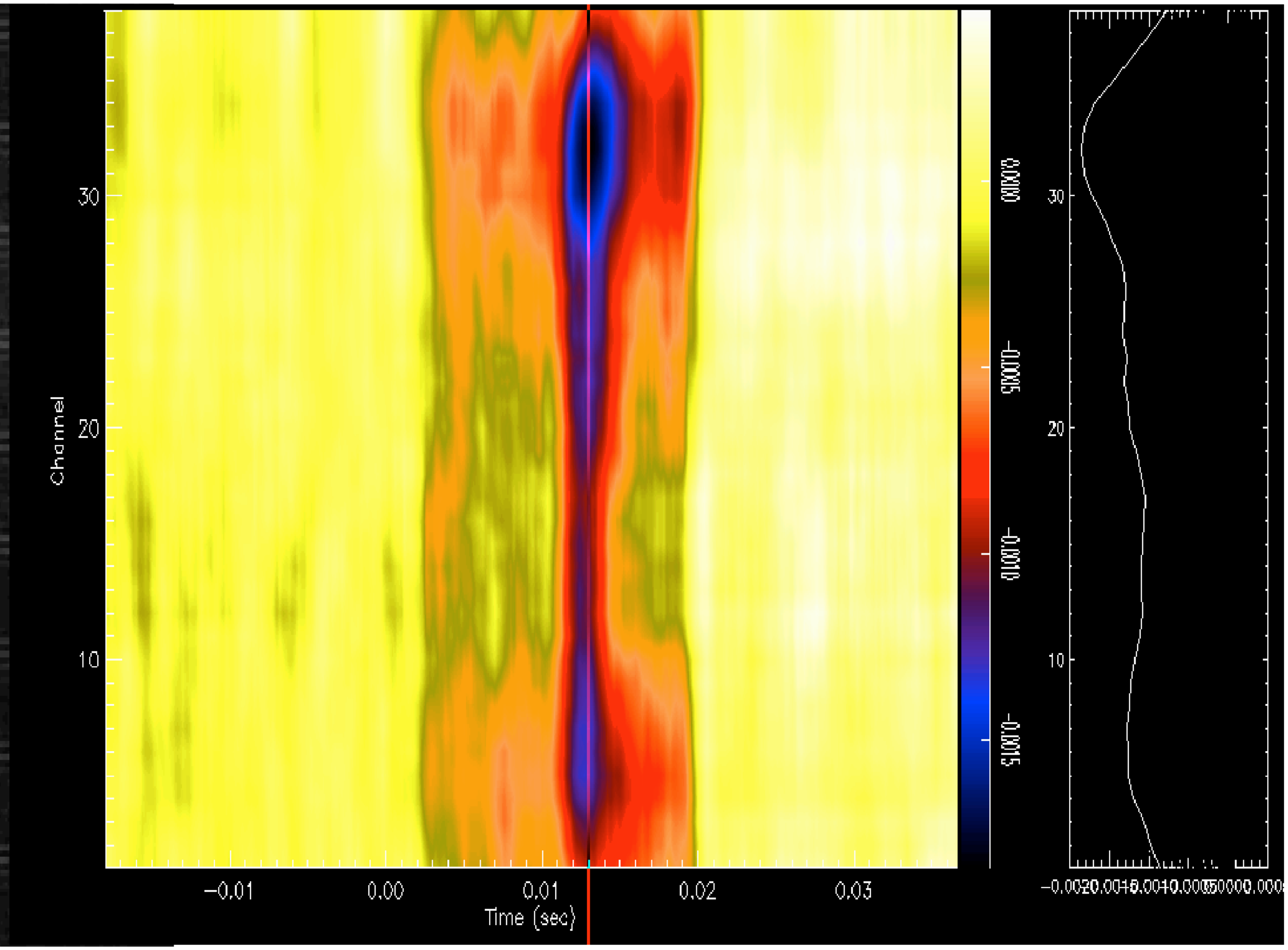
Pressure Driven Current



ECRH Breakdown in TF only

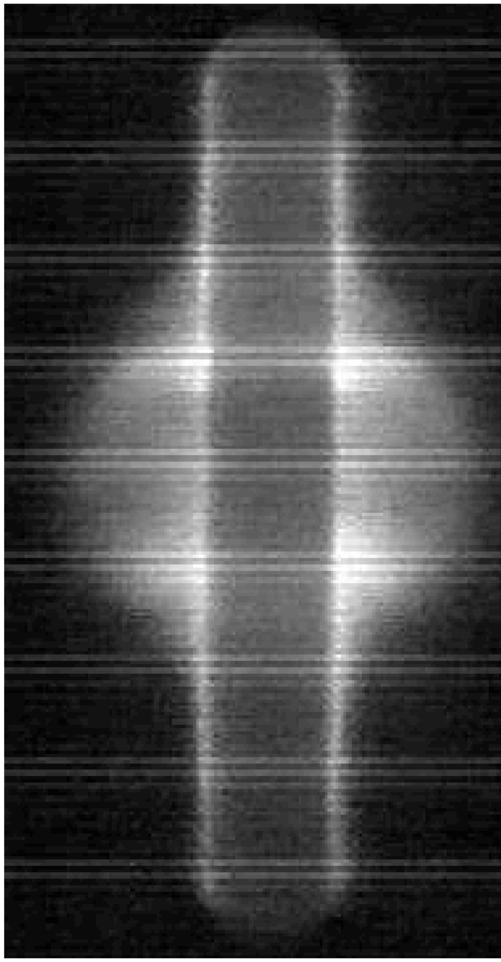


CCD image of the ECRH breakdown phase at ω_{ce} in a pure toroidal magnetic field

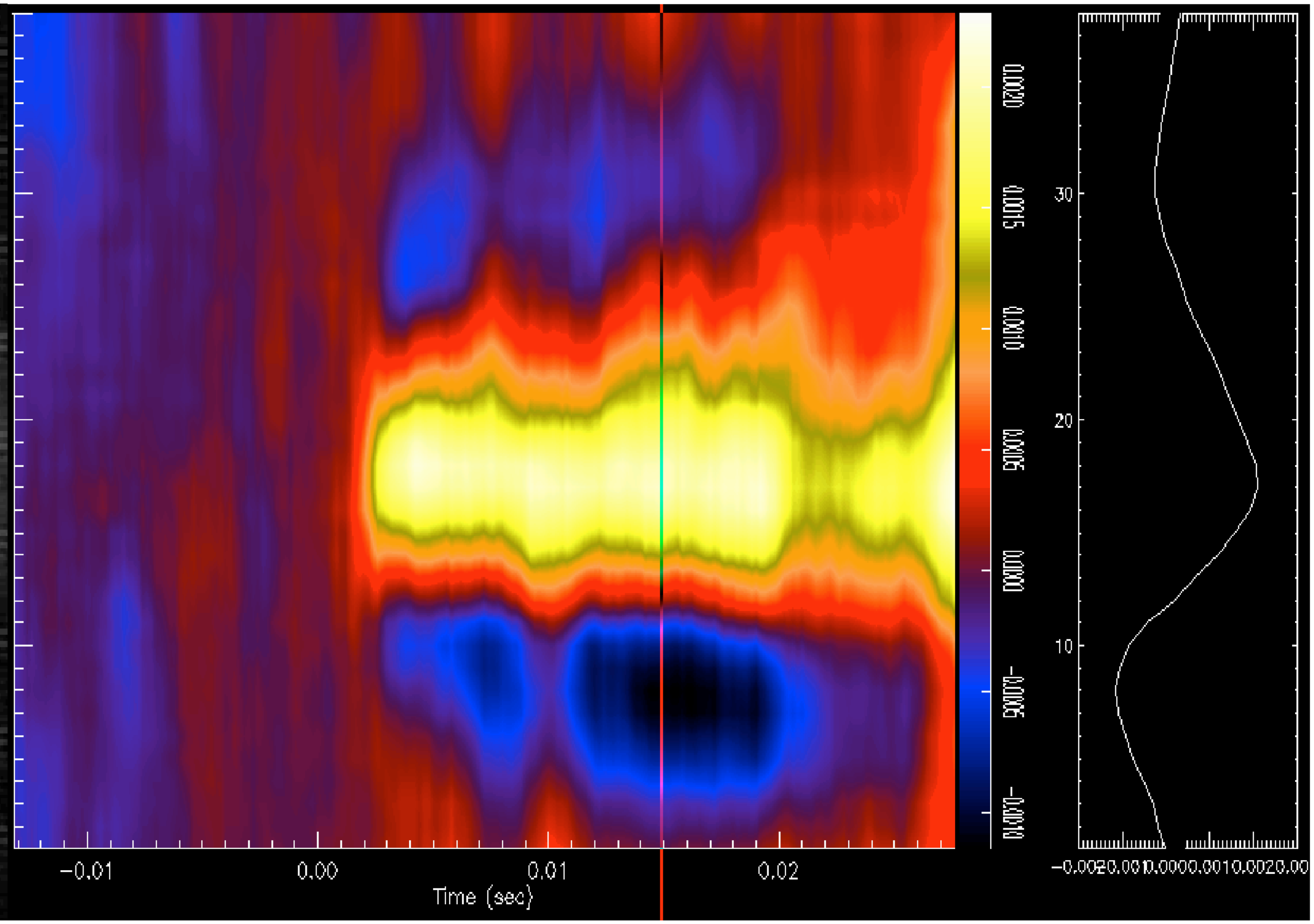


Vertical magnetic field induced by plasma during ECRH breakdown. ECRH pulse of 20 ms (0.3 MW), O-mode polarisation.

ECRH Breakdown in TF and Small Vertical Field



CCD image of the ECRH breakdown phase in toroidal and 5 mT vertical magnetic field

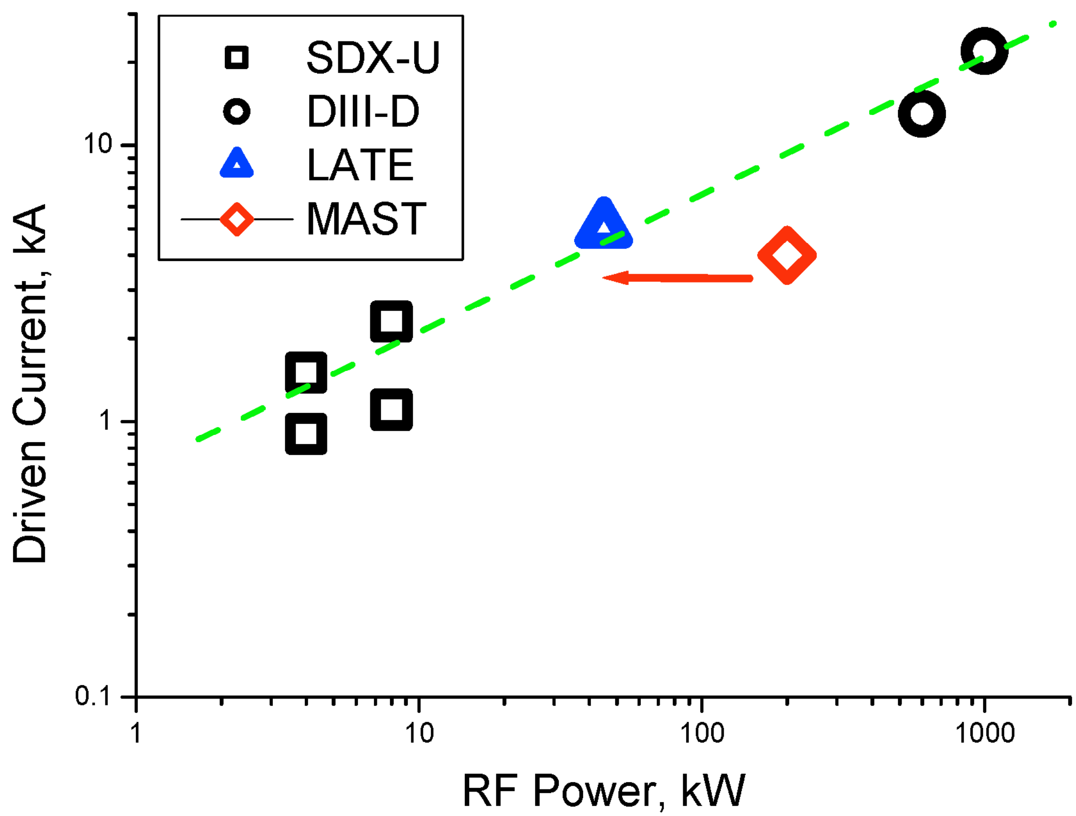


Vertical magnetic field induced by plasma during ECRH breakdown. ECRH pulse of 20 ms (0.3 MW), O-mode polarisation.

PDC Initiation Experimental Results

JT60-U O

MAST point must be shifted to lower power because only a fraction of the injected power passed through the EC resonance layer



Pressure Driven Currents achieved on different machines

RF Start-up Proposals

There are 3 proposals related to RF application in Start-up:

PDC scenario (C. Forest's scheme) ~ 2 days
- **scan over prefill gas pressure**
- **scan over Bv values, co- / counter- test**
- **launch / polarisation optimisation**
- **Bv ramp-up optimisation**

PDC + EBW CD assist ~ 1 day
- **O-X-B coupling optimisation**
- **EBW CD delay optimisation**

Merging Compression + EBW CD assist ~1 day
- **Optimisation of the target plasma for O-X-B coupling**
- **Launch and polarisation optimisation**

GENERAL PROBLEM is DIAGNOSTICS of SMALL PLASMAS

- **It is very desirable to equip TS with extra fibers / spectrometers to make inboard measurements possible**
- **Installation and calibration of HELIOS for inboard measurements is also very important**

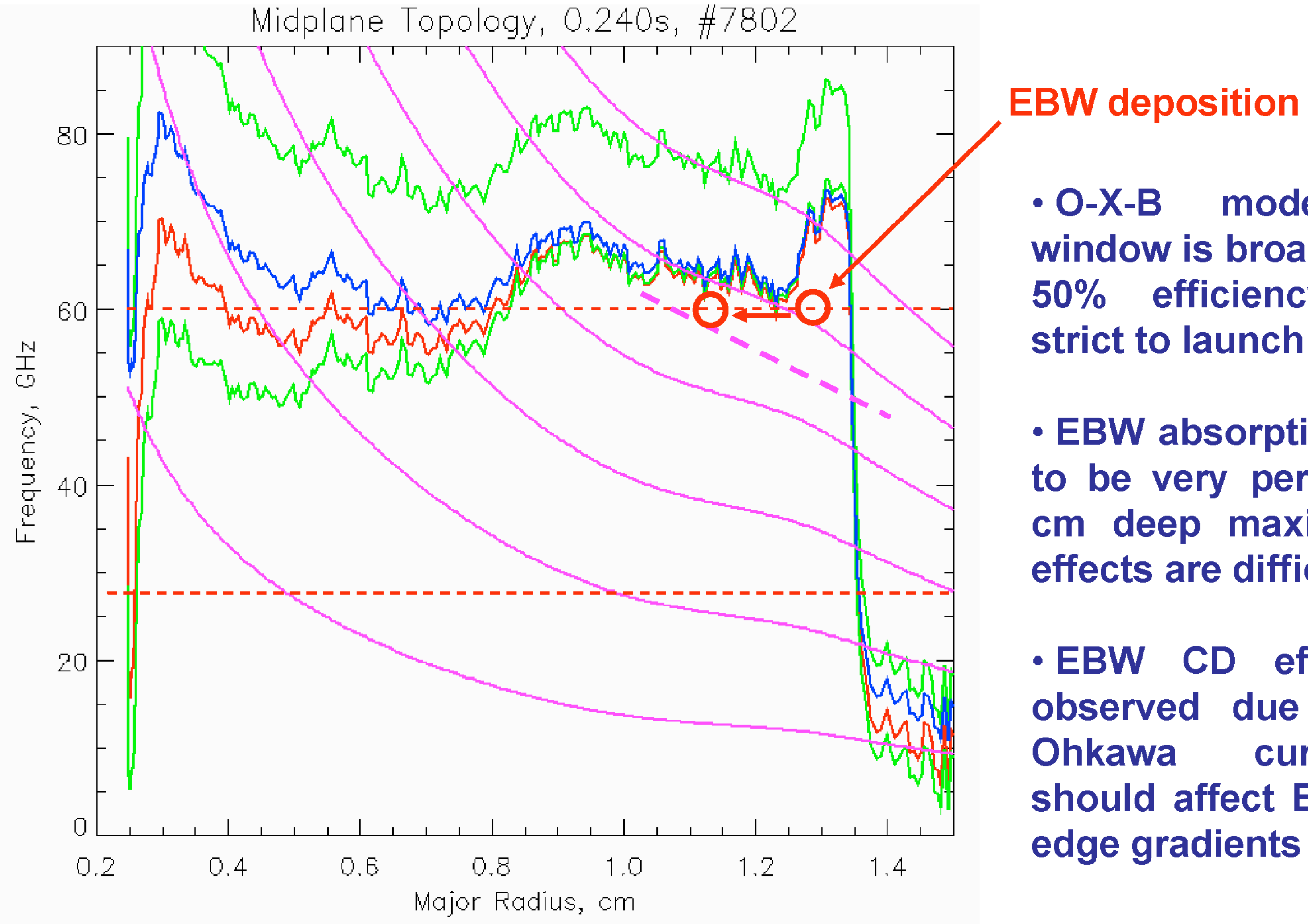
EBW Heating Experiments

High density ($n_e > 5\ 10^{19}\ m^{-3}$) is crucial for EBWH

There are four scenarios developed for EBW experiments:

- High density H-mode scenario-1 (modulated by ELMs)
- High density ITB - like scenario-2 (modulated by sawteeth)
- High density plasma produced by pellet injection (transient)
- High density L-mode (stationary)

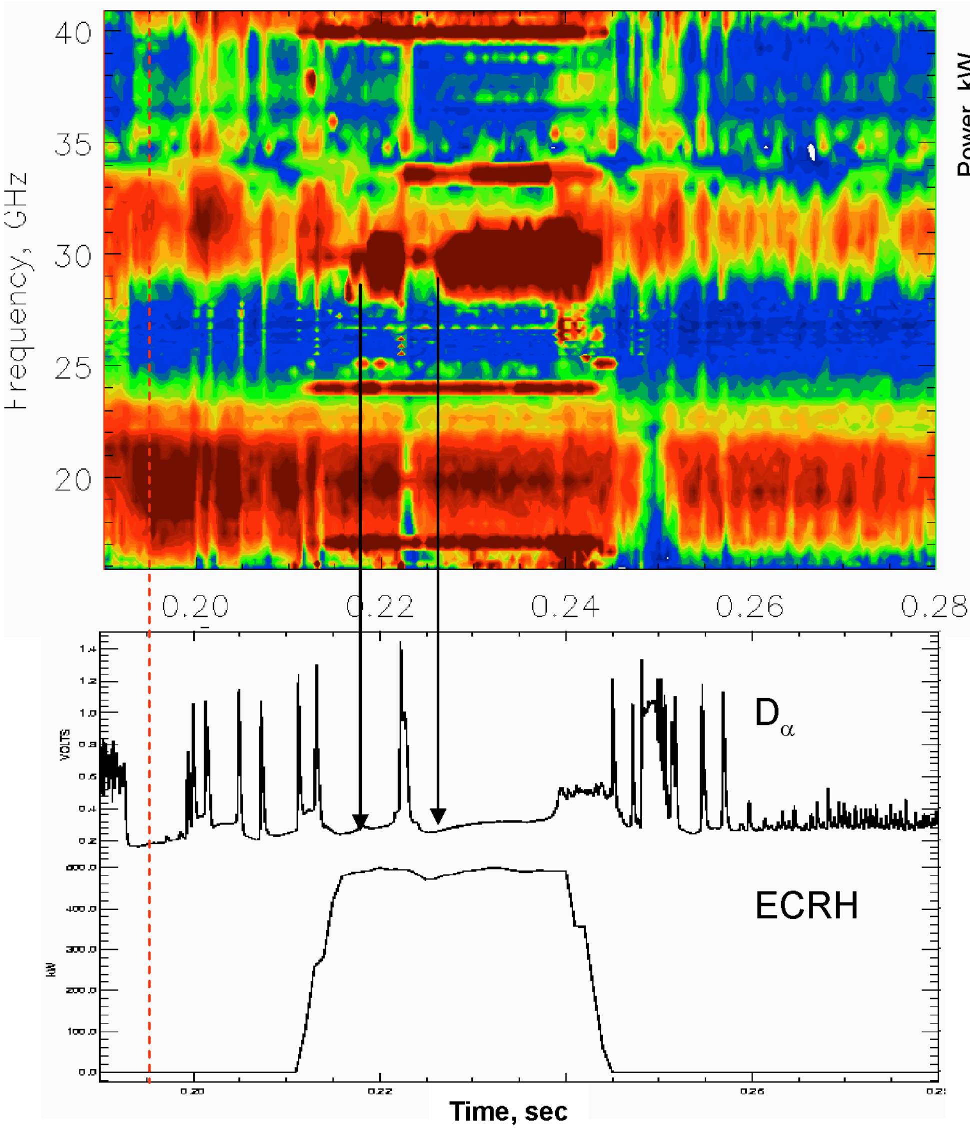
High density ELM-free H-mode Scenario



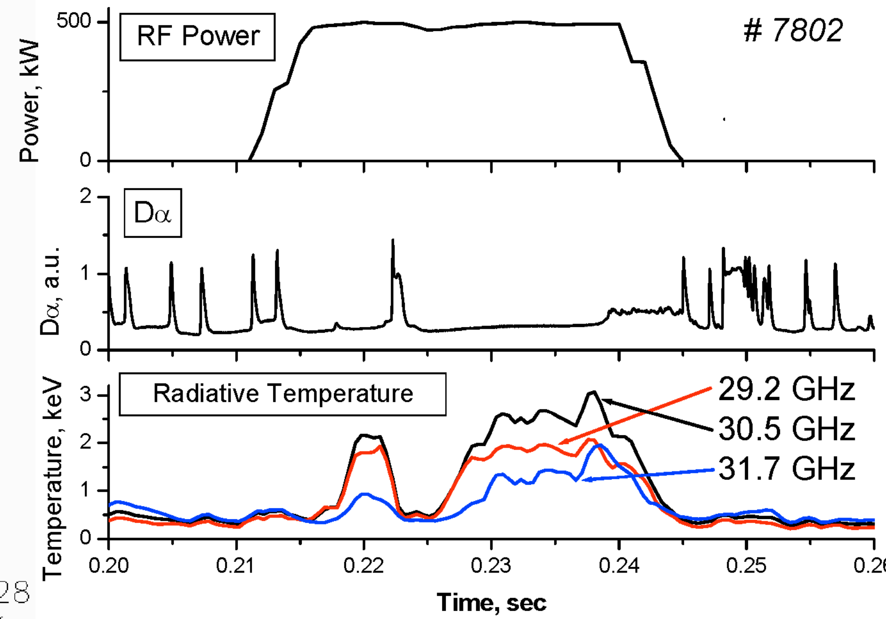
High density H-mode. Midplane resonance topology at I_{TF}=91.5 kA, calculated from EFIT and TS.

- **O-X-B mode conversion window is broad (about ± 5° at 50% efficiency). Not very strict to launch parameters**
- **EBW absorption is expected to be very peripheral, 15 -20 cm deep maximum. Heating effects are difficult to detect.**
- **EBW CD effects can be observed due to peripheral Ohkawa currents. They should affect ELM frequency, edge gradients etc.**

O-X-B Heating in High Density H-mode



EBW emission from ω_{ce} and $2\omega_{ce}$ harmonics during ECRH



EBW emission during ECRH pulse in ELM-free phase

- •Radiative temperature exceeds T_e by factor of 3-4 during ECRH pulse
- •Radiative temperature increase due to EBWH is always delayed by ~5 ms from the beginning of the ELM-free period
- •TS shows broadening of the scattered spectra at major radii corresponding to EBW power deposition

EBW Steerable Launcher in MAST

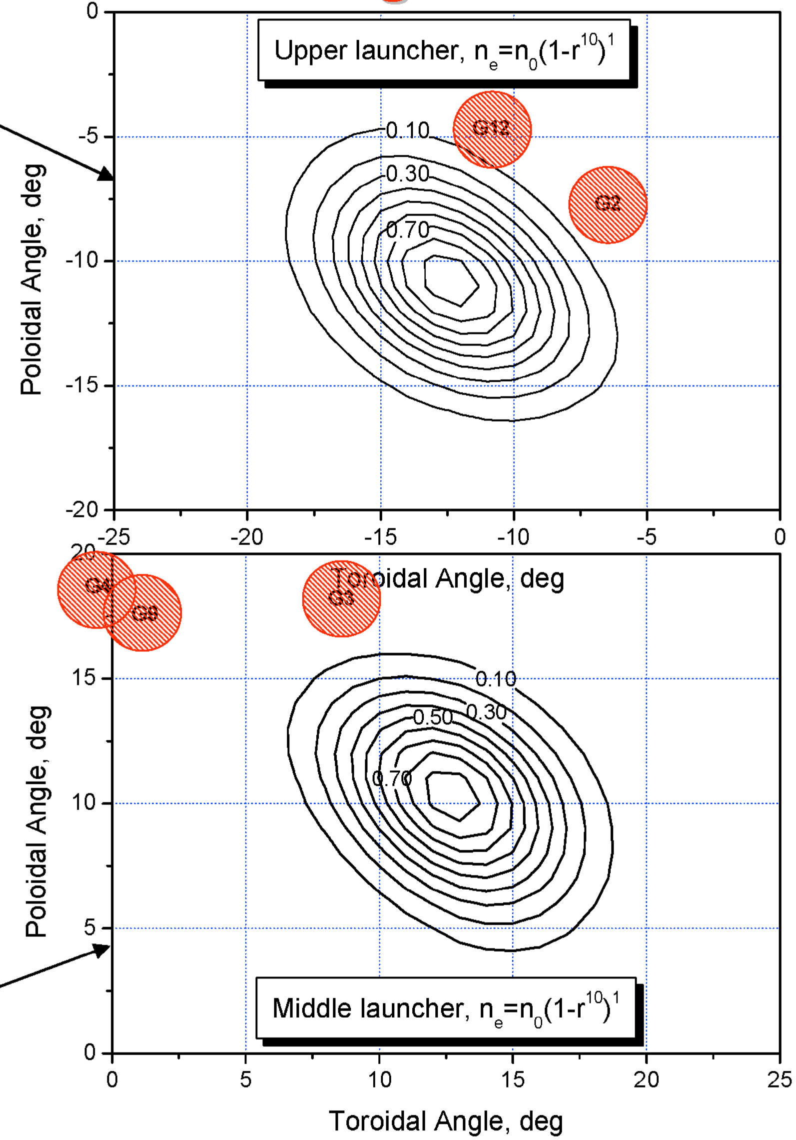
- Final polarisation can be chosen from linear to circular
- Resultant beam divergency is less than +/-2.5° (ω = 25 mm)
- Beams are grouped by the poloidal position 2-3-2
- Each group has a united remote control for poloidal and toroidal steering
- Poloidal steering range of +/-13°, toroidal +/-24°, accuracy of 0.5°

Mode Conversion Window and Antenna Alignment

Mode conversion angular windows estimated for Upper Bank of the EBW launcher. Beam patterns are superimposed assuming 'optimal' launch configuration.

- Even in the H-mode scenario-1 (widest coupling window) the mode coupling cannot exceed 10% for the Upper and Lower Banks and 5% for the Middle Bank.
- EBWH results presented above were obtained with 0.3 - 0.6 MW power and coupling efficiency <10%
- Power up to 1 MW is expected in M4. With aligned launcher the coupling efficiency must reach 80-90%
- EBWH effects must be stronger by an order of magnitude

Mode conversion windows estimated for Middle Bank in the high density H-mode scenario.



EBWH and CD Proposals

All four scenarios must be studied in M4 campaign with full RF power available (up to 1 MW) and properly aligned launcher

Every scenario study will include:

- Launch geometry / polarisation optimisation
- Launch angular scan if necessary
- TF scan (10-15%) within one EC harmonic to maximise EBWH or CD effects
- Co- / counter- comparison, reference shot generation
- 3-4 shots statistics accumulation for transient effects

Plant and special requirements

- full TF (I_{TF}=92 kA) is required for the majority of shots
- one NBI (P >1.5 MW) is required in all high density scenarios
- all standard diagnostics, TS, EFIT, EBW & LH radiometers, SXR are crucial

Each scenario requires 1 day in the beginning of M4 campaign plus 1 day at the end 4(1+1)= 8 and 1 day for Ohkawa CD (F.Volpe proposal) experiment, so 9 experimental days for the EBW thrust in total.

- high density scenarios are very sensitive to the vessel conditioning
- ECRH gyrotrons require a lot of conditioning
- First EBWH results have be analysed and we must have a chance to confirm most interesting of them

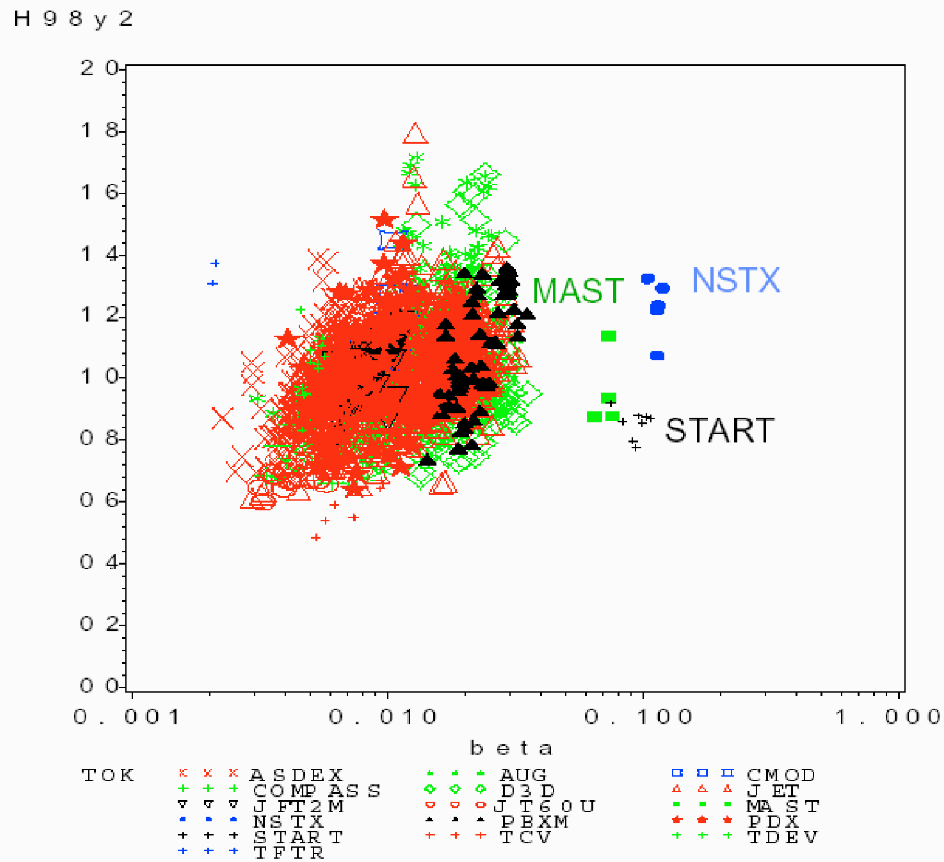
MAST data in H-mode confinement database

Broad agreement with IPBH98(y,2).

MAST data more compatible with dataset of conventional cross-sections

Large impact on β-dependence

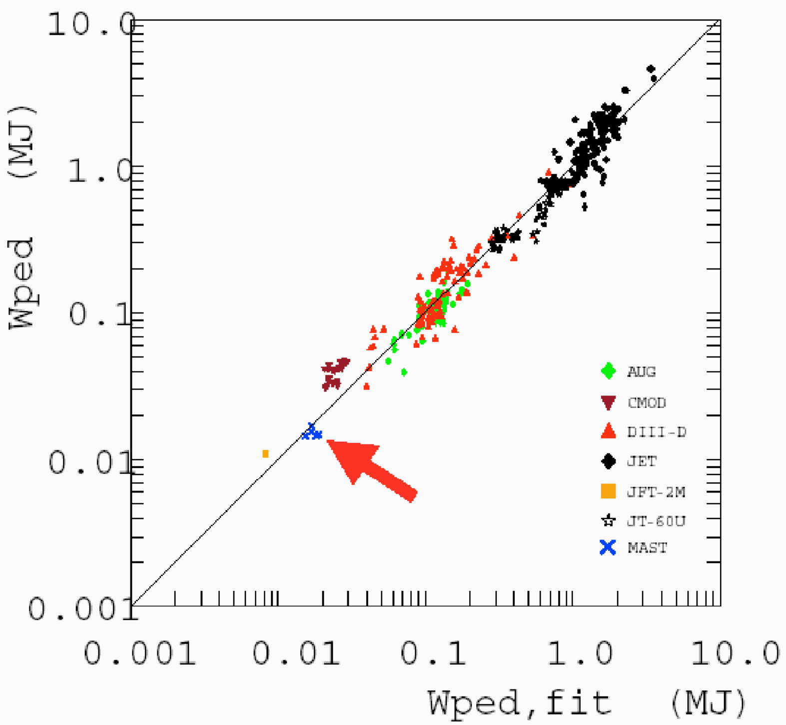
O Kardaun et al.
9th IAEA TM on H-mode Physics, 2003



MAST data in pedestal confinement database scaling

MAST data determine a/R dependence

$$W_{ped,fit} \propto \left(\frac{a}{R}\right)^{-2.13} I^{1.58} R^{1.08} P^{0.42} n^{-0.08} B^{0.06} \kappa_a^{1.81} m^{0.2} \left(q_{95}/q_{cyl}\right)^{2.09}$$



M Valovič EPS 2002

G Cordey et al Nucl. Fusion 2003

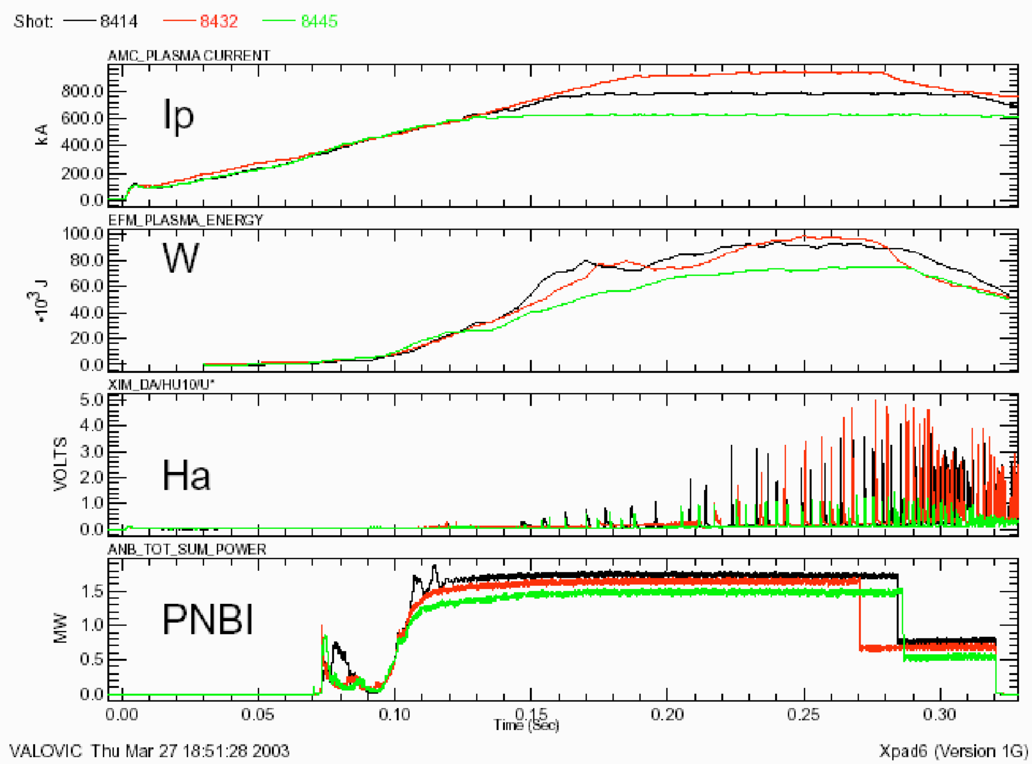
Beginning of scan with engineering parameters

Easiest is Ip.

Ip = 0.6-0.9 MA

Shots should satisfy the standards (dW/dt~0 for ~3τ_E, Ti data)

Scan not yet conclusive (beam power not constant and IP range small)

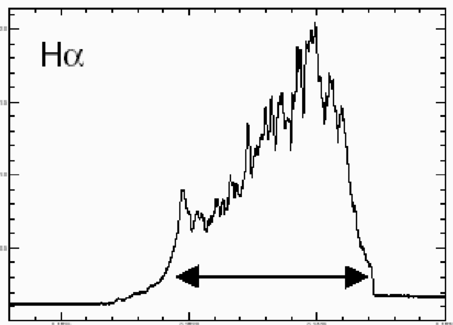


Particle transport with pellet fuelling

Pellets injected into NBI ELMy H-mode without permanent H-L transition.

Density increased by 1/3 behind pedestal without severe temperature collapse

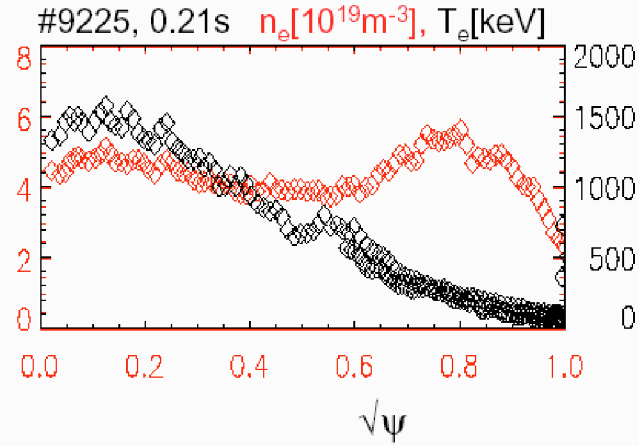
Pellet source is behind the pedestal

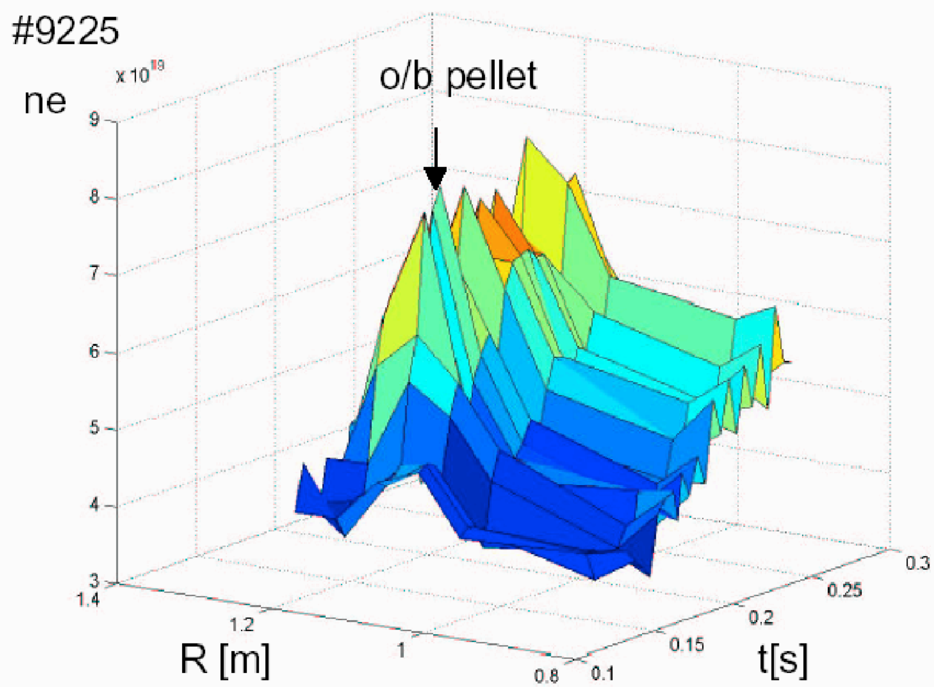


0.7ms x 285m/s=20cm

Good particle balance: $N=1x10^{20} \sim \Delta n_e V$

Steep density gradient persists for ~100ms.





M4 Confinement proposals

21	Ohmic Confinement Studies	AS
28	Expansion of H-mode confinement database	MV
26	Dimensionless heat transport scaling: β-scan, CTF-similarity, a/R-scan	MV
20	Deuterium transport including pellets	MV
27	Pellet trajectory	SS
33	Obtaining a peaked density profile mode with pellet injection	SS
34	Access to high-density H-modes by pellet pre-fuelling	GM
22	Confinement in counter- and co-current NBI discharges	HM
23	Confinement and exhaust control via the magnetic configuration	HM
24	He ash removal and core particle transport	HM
25	Impurity transport in MAST	HM
38	Profile consistency, profile stiffness	JC