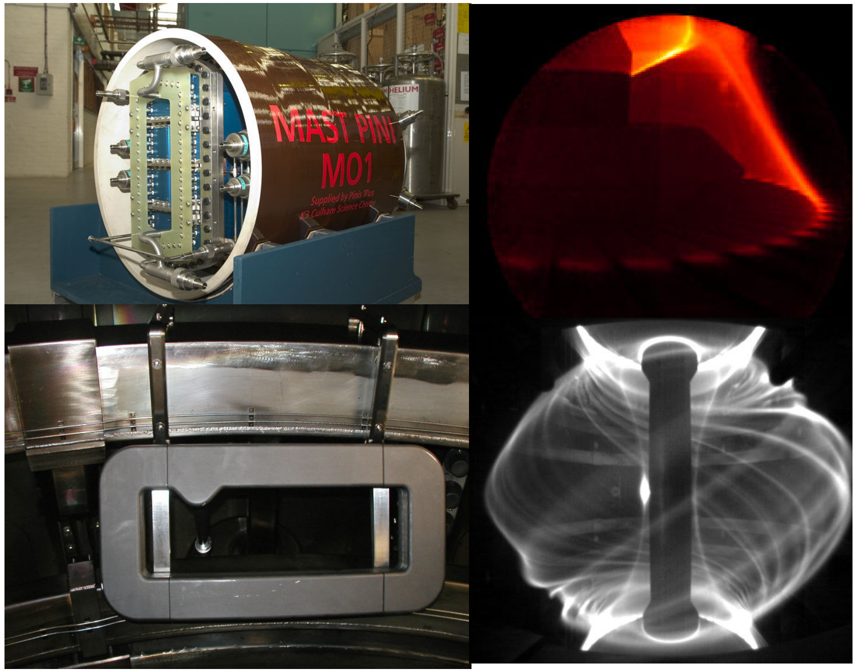
Recent results from MAST spherical tokamak

A. R. Field for the MAST team



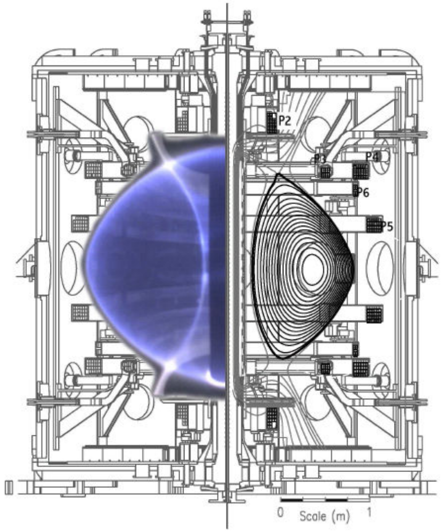
Overview:

- Technical enhancements
- Recent results
- Future plans

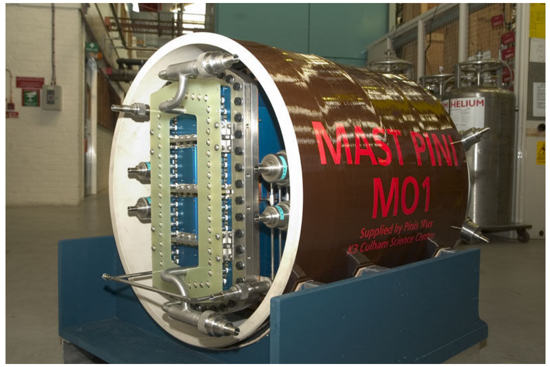
Technical enhancements

MAST Parameters

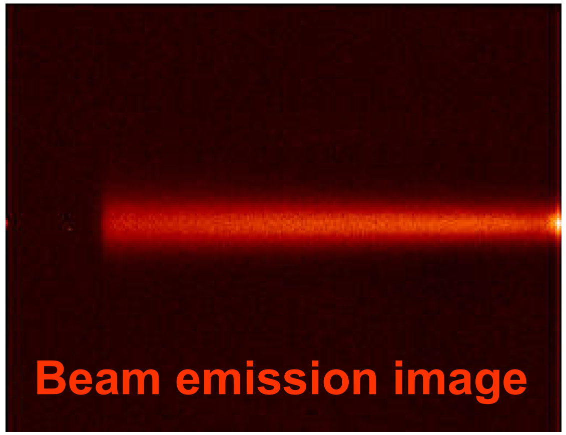
R = 0.85 m, a = 0.65 m (A ≥ 1.3)
κ = 2.5 (2.6), δ = 0.5 (0.5)
$I_p \leq$ 2 MA (**1.4 MA**), B_t = 0.52 T
$P_{NBI} \leq$ 5 MW (**3.8 MW** to date)
Pulse duration ≤ 5 s (0.7 s)



PINI source



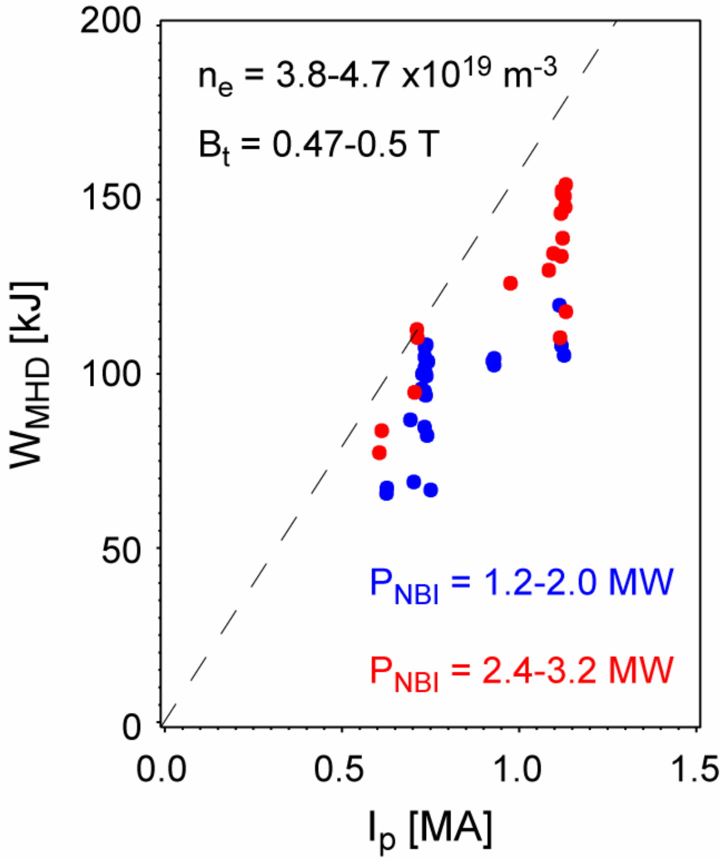
PINI beam path

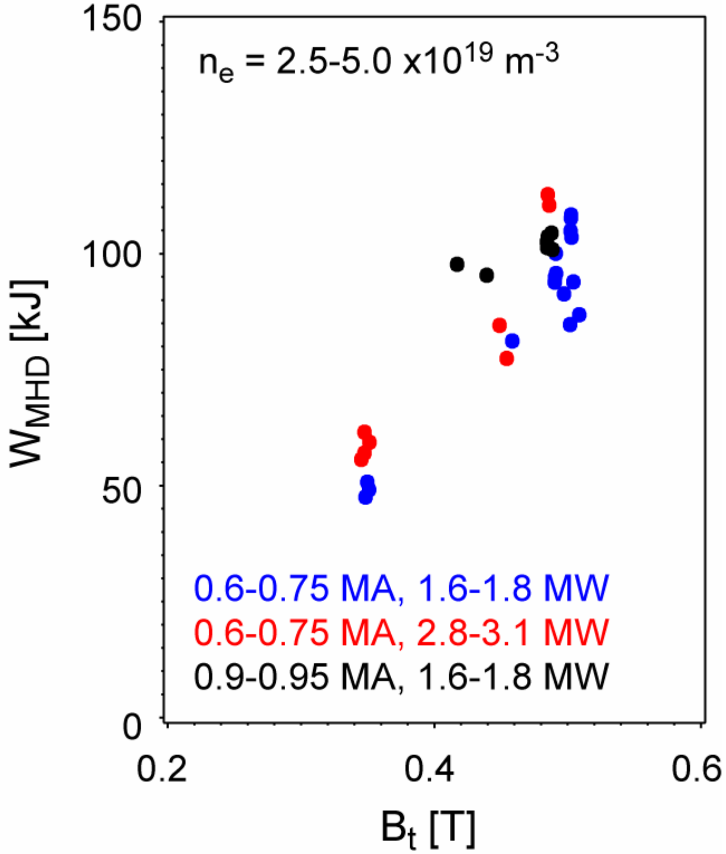


Recent enhancements include:

- PINI NBI source $P_{inj} \leq$ 2.5 MW, $E_0 \leq$ 75 keV, $t_{inj} \leq$ 5 s
- 28 GHz, 150 kW EBW start-up system
- Prototype TAE coil system, 3 i-coils
- High-resolution edge Doppler spectroscopy system
- Trial BES turbulence diagnostic

Extension of confinement database

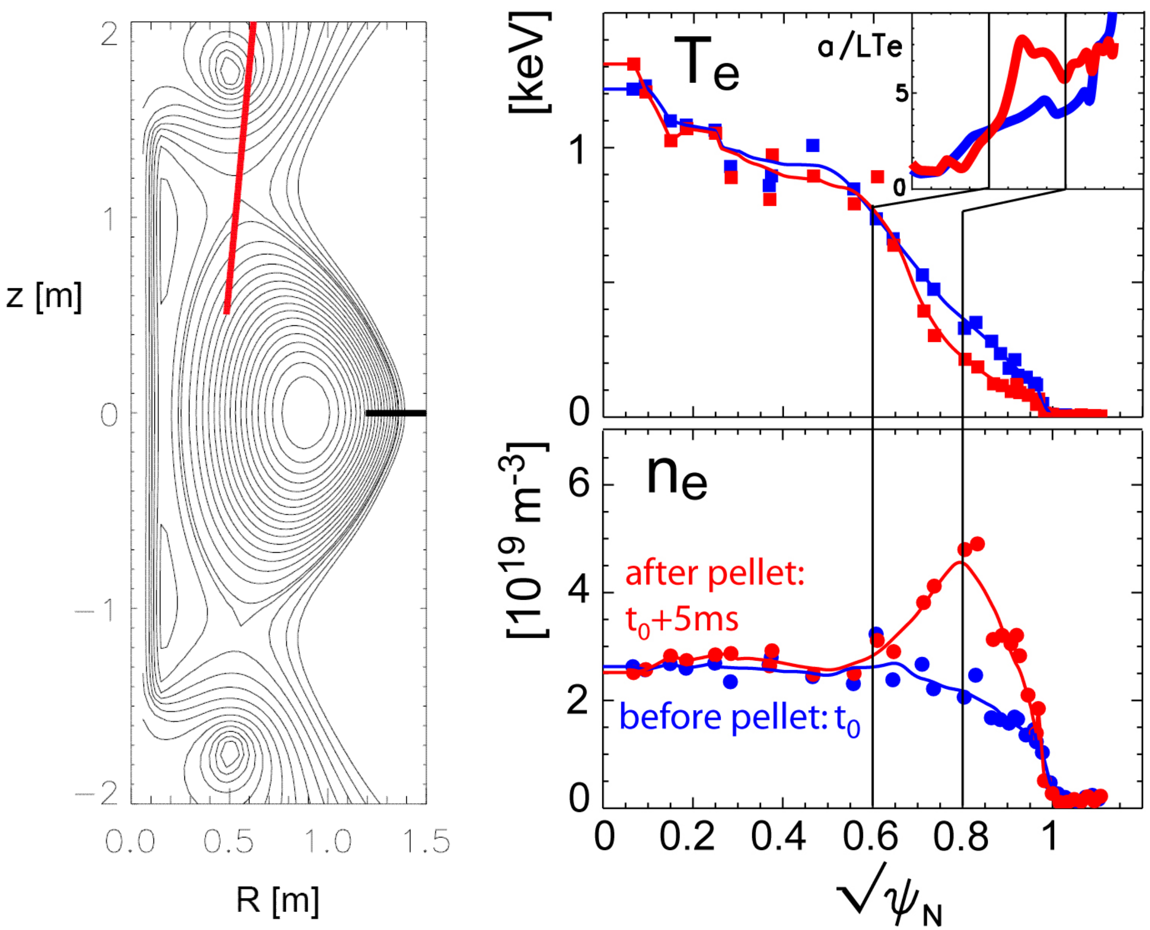


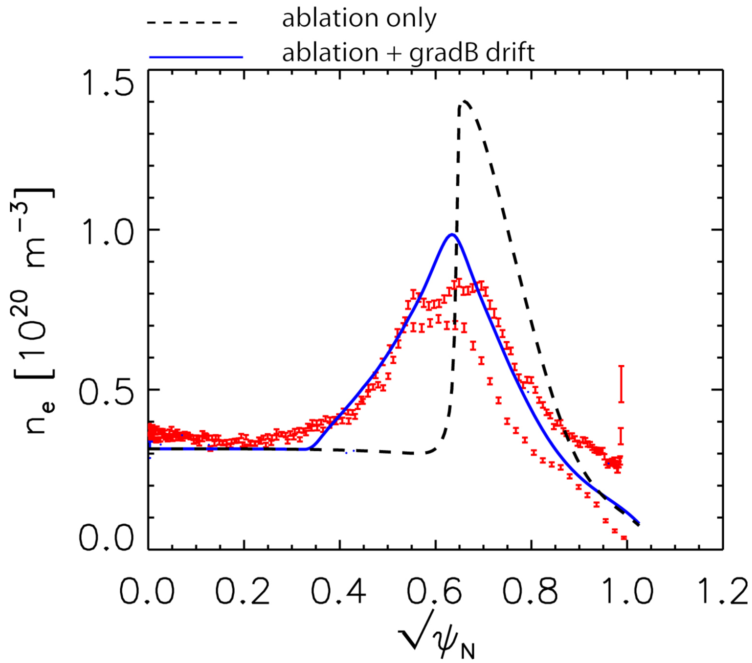


- Database extended to higher $I_p \leq 1.2$ MA, higher power and focusing on H-mode
- I_p scaling in H-mode to be determined but weaker than in L-mode, $\tau_{E,L} \propto I_p^{0.96}$
- Strong B_t scaling evident at constant I_p as on NSTX

Pellet deposition

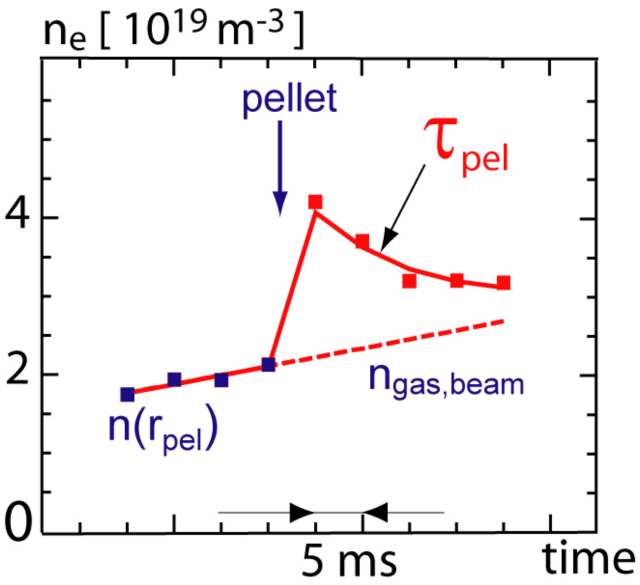
- Top/outboard launch, ≤ 6 pellets, 240-450 m/s
- Shallow injection radius mimics ITER situation

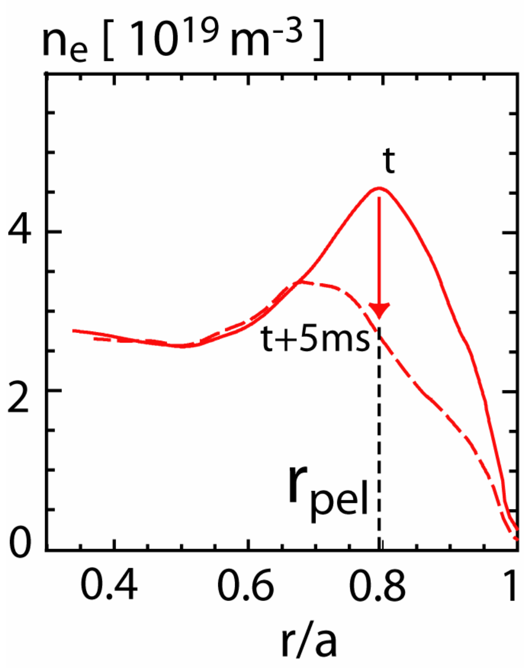


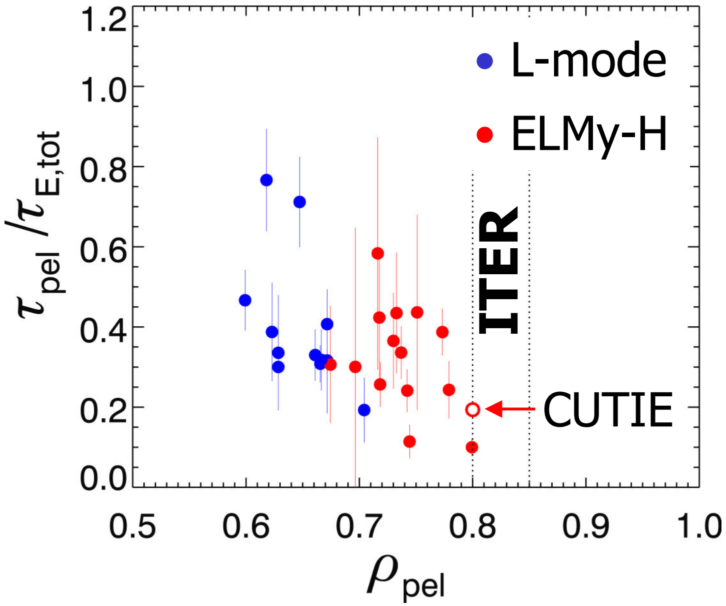


- Simulation requires ∇B drift
- Distinct zone with $\nabla n_e > 0$ and increased $\nabla \ln T_e$
- Modelling with GS2 and CUTIE
- Favourable inward turbulent transport

Pellet retention - ITER fuelling prediction







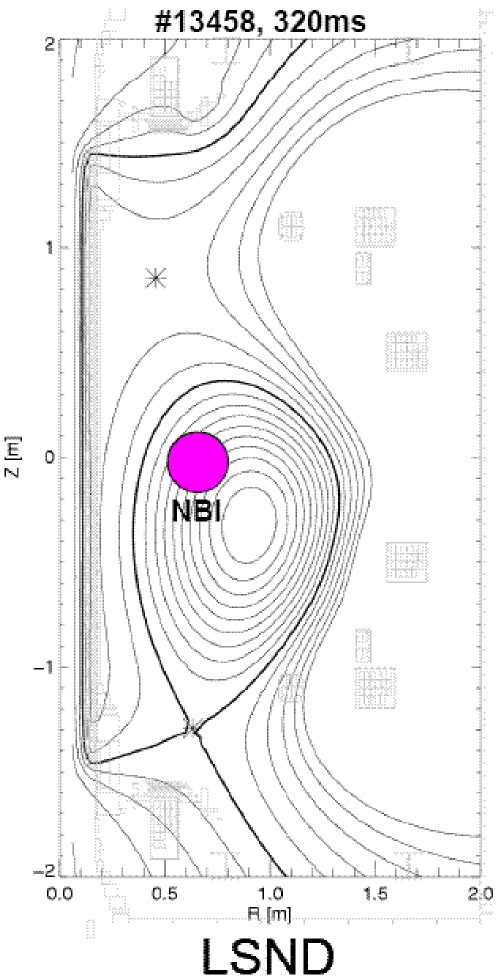
ITER Predictions:

- Normalised deposition radius ρ_{pel} similar to ITER value
- Measurement of τ_{pel}/τ_E allows prediction of τ_{pel} for ITER
- r_{pel} and τ_{pel} determine the fuelling rate Φ_{pel}
- Predicted Φ_{pel} ~ 70 Pa m^3s^{-1} for steady-state density
- 70% of design value of ITER steady-state particle throughput

UKAEA Fusion

Off-axis NBCD studies

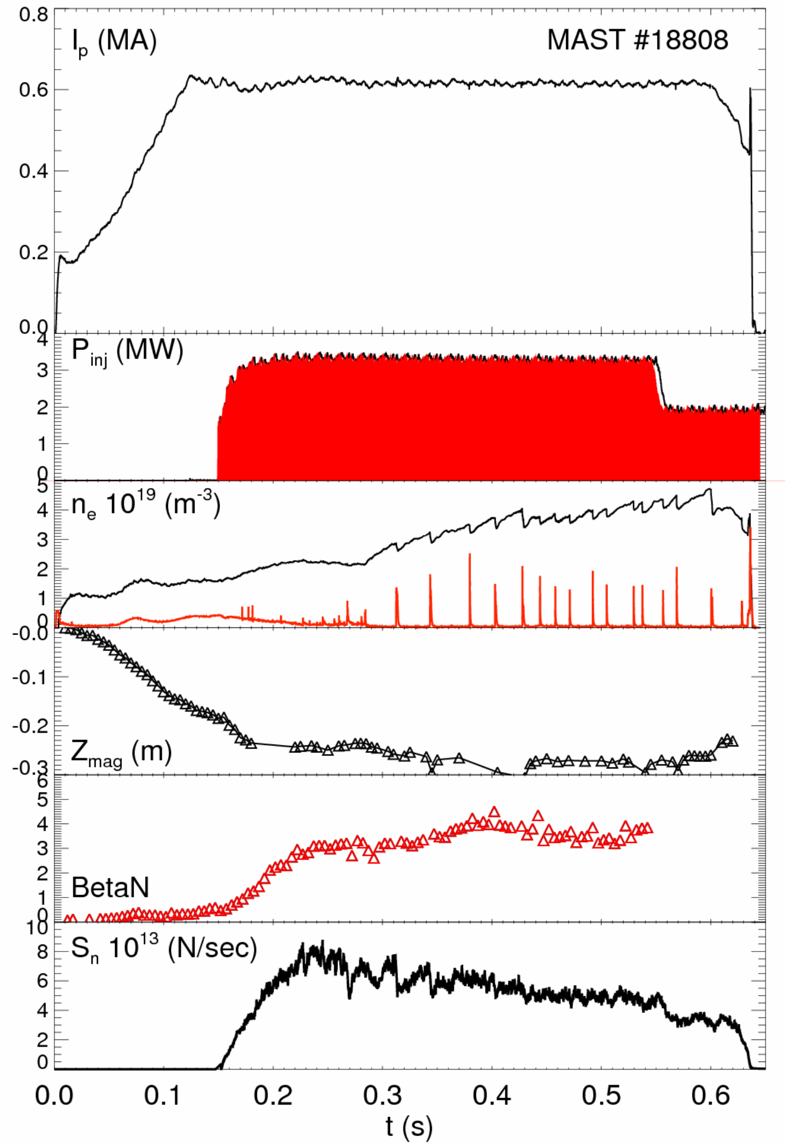
- Exploratory studies of off-axis NBCD in vertically displaced SND discharges
- Extended to higher power and duration in 2007



- 500 ms flat-top
- 350 ms H-mode

  (limited by I^2t and NBI)
- Sustained β_N ~ 3.5-4.0

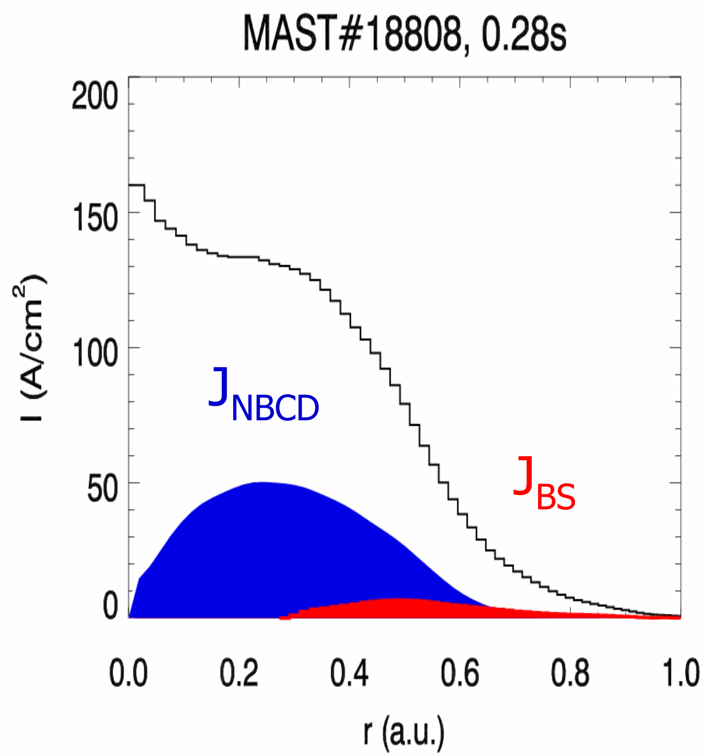
L-SND (3.6 MW NBI)



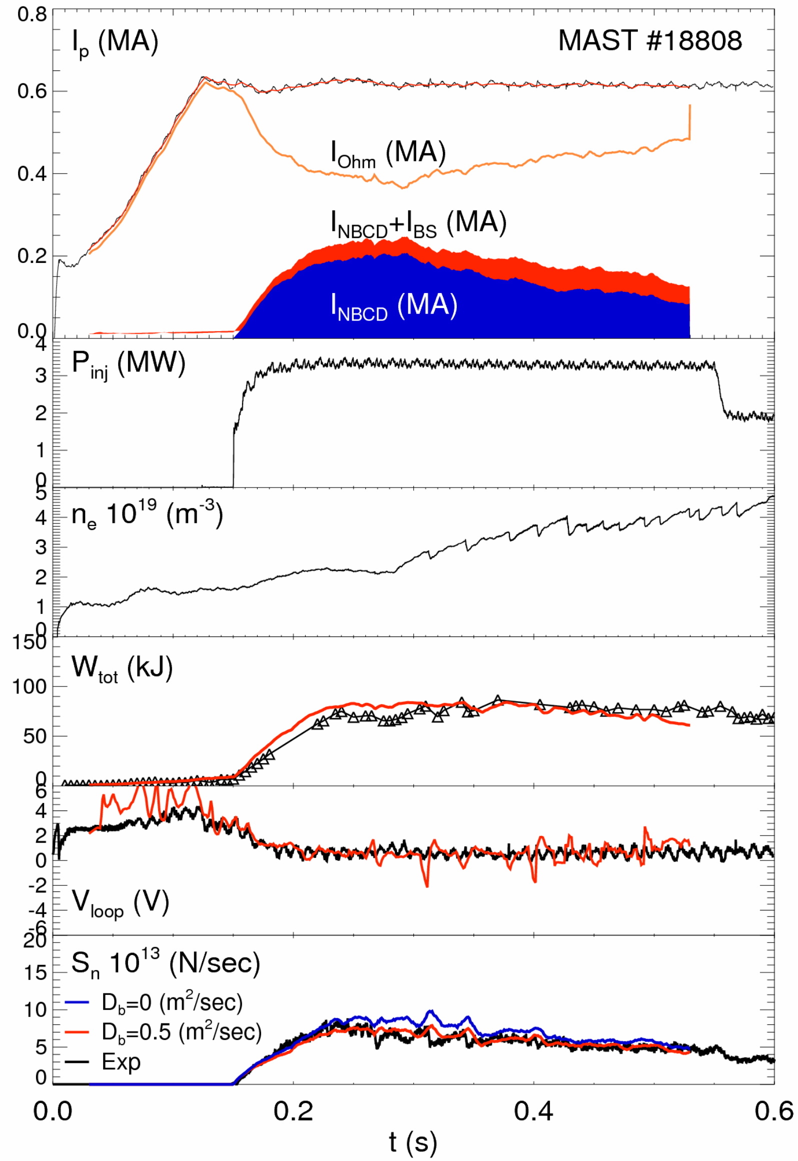
Off-axis NBCD studies

TRANSP simulation

- NBI driven current fraction, $I_{NBCD}/I_p \sim 30\%$
- Anomalous fast-ion diffusion 0.5 m^2s^{-1} required
- NBCD reduced by 10% but current stays off-axis
- Two PINI sources and MSE in 2008

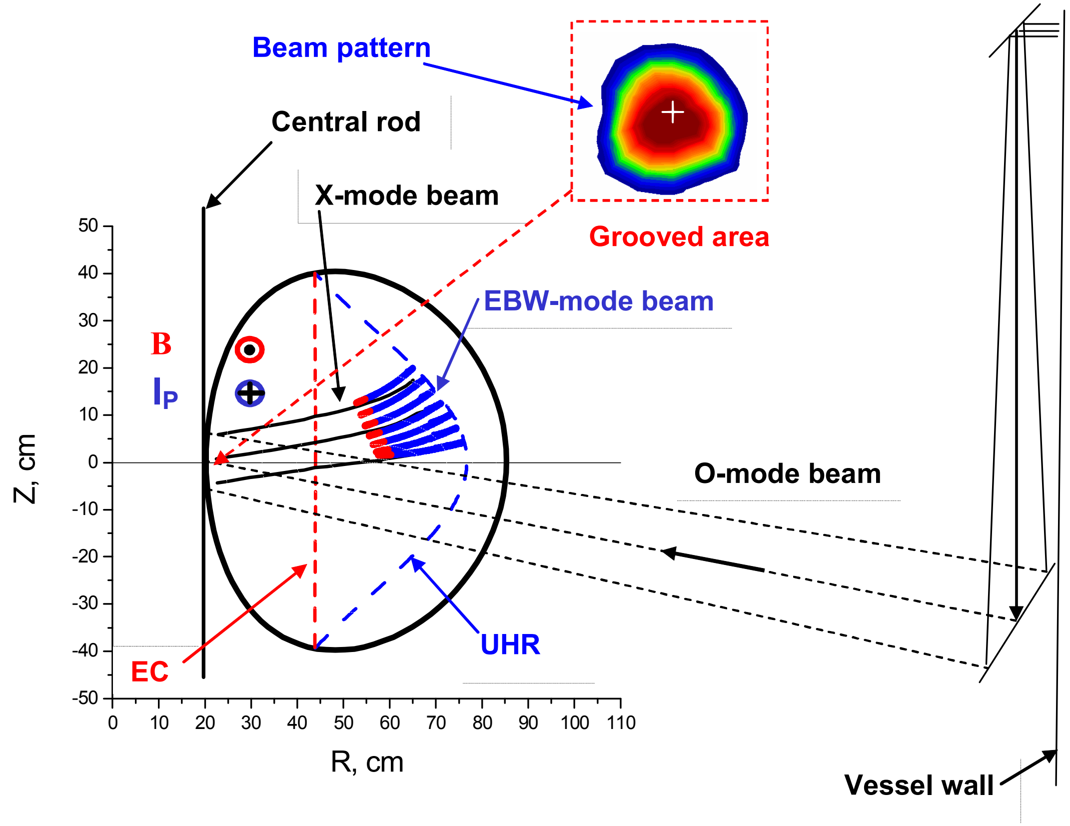


L-SND (3.6 MW NBI)

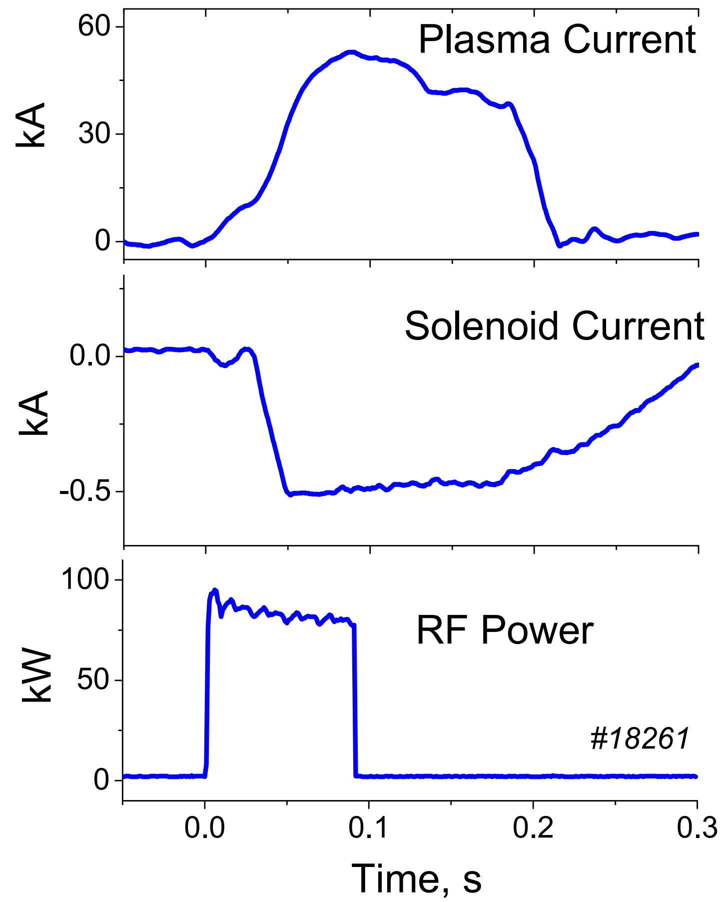


28 GHz EBW start-up system

P_{EC} ~ 100kW, 28GHz



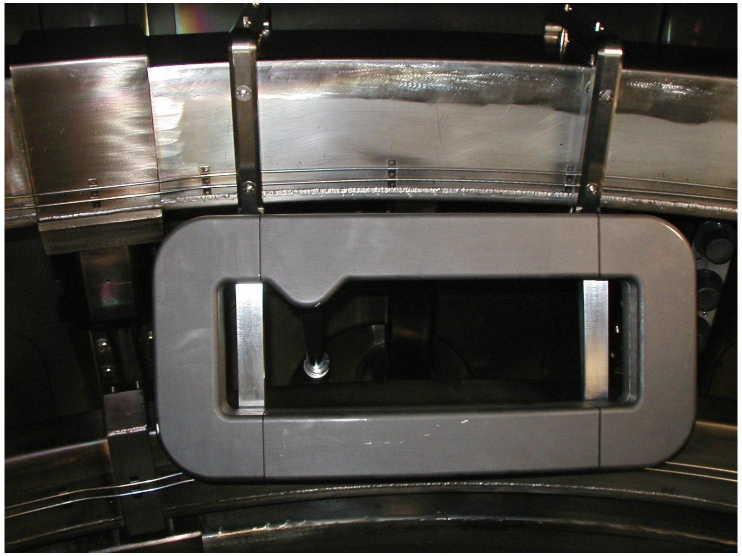
EBW + solenoid assist



- Up to 17 kA from EBW alone
- Up to 33 kA from EBW + vertical field ramp (no solenoid)
- Up to 55 kA from EBW + limited solenoid flux (0.5% of full swing)

TAE damping rate measurements

TAE Coil

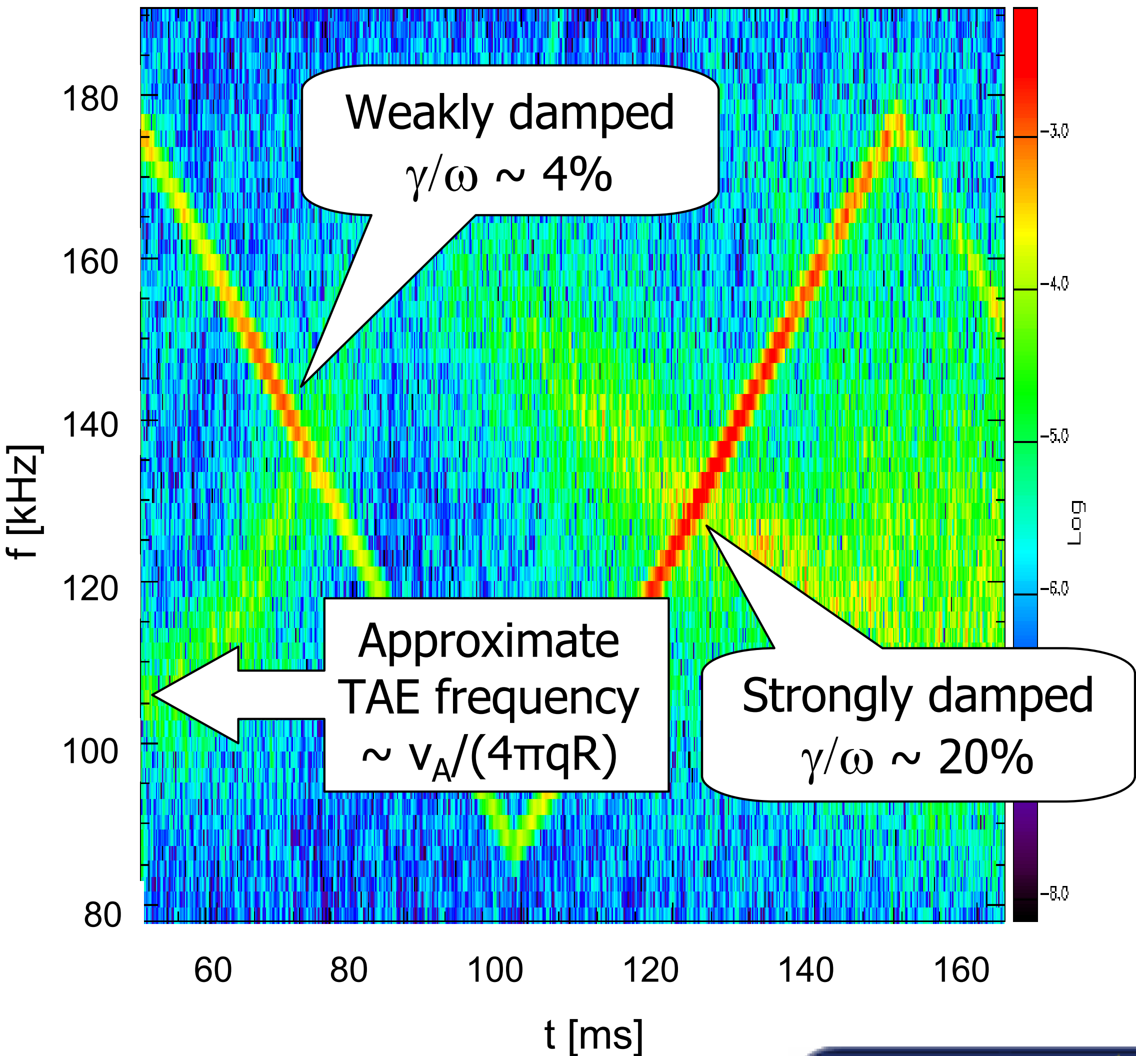


2007: Trial with 3 lower coils

- 10A AC ≤ 0.5 MHz
- 2kA DC for ELM control
- n = 1, 2 or 3 mode spectrum

2008: 2×6 coil arrays (upper/lower)

Active AE excitation



BES System: L-mode turbulence measurement

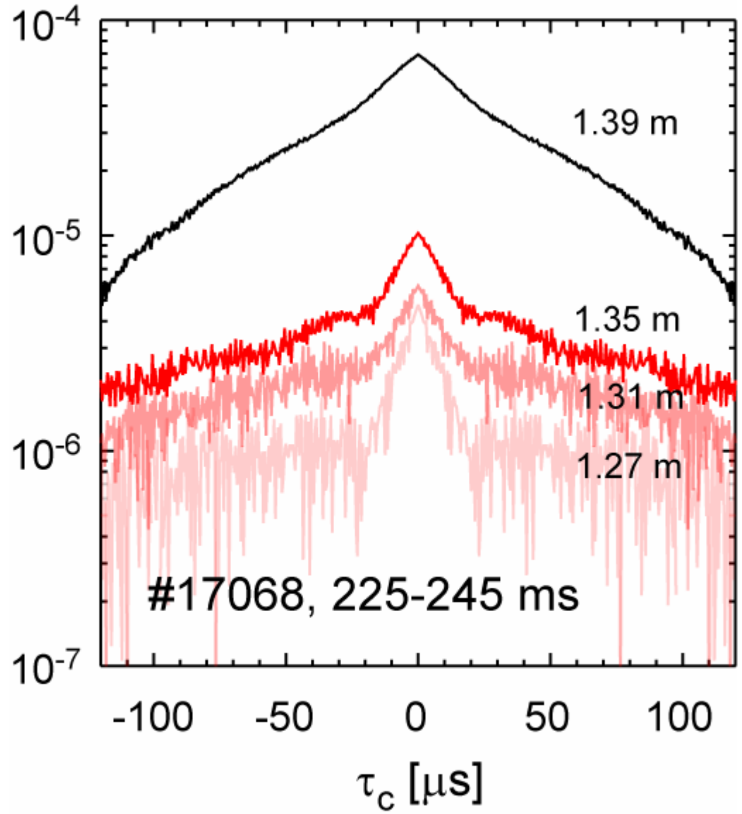
Trial System:

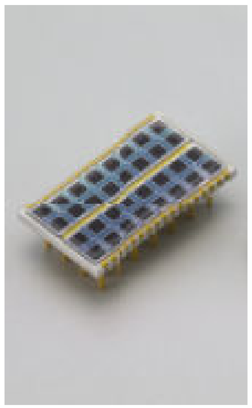
- BES measures density fluctuations from D_α emission from excited atoms in heating beam
- 8 channel, 1 MHz system shares CXRS optics
- Characterise meso-scale turbulence, $k_\perp \rho_i < O(1)$

BES Upgrade 2008:

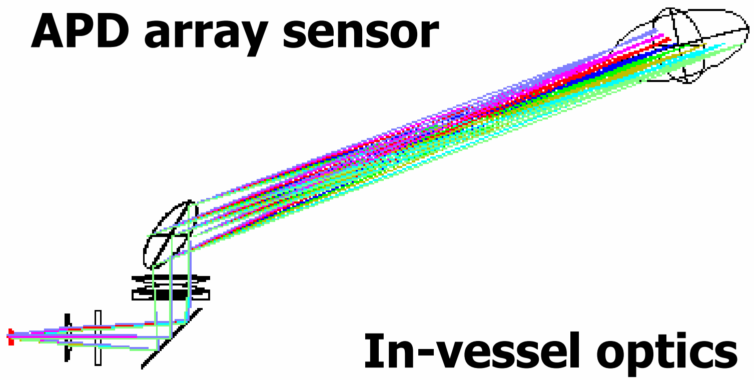
- Higher étendu (×50) in-vessel collection optics
- APD camera using Hamamatsu 8x4 array chip

Auto-correlation





APD array sensor



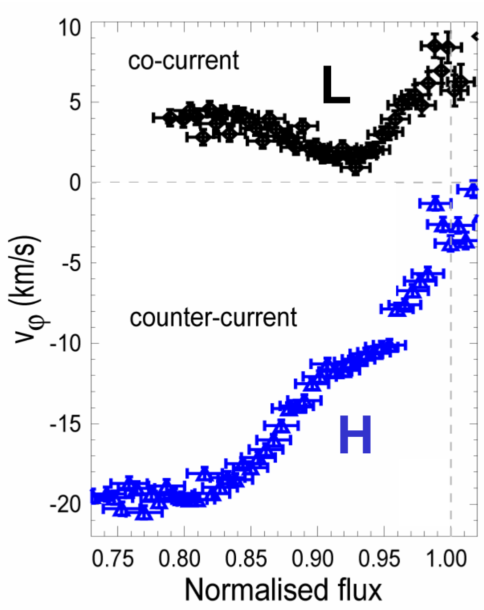
In-vessel optics

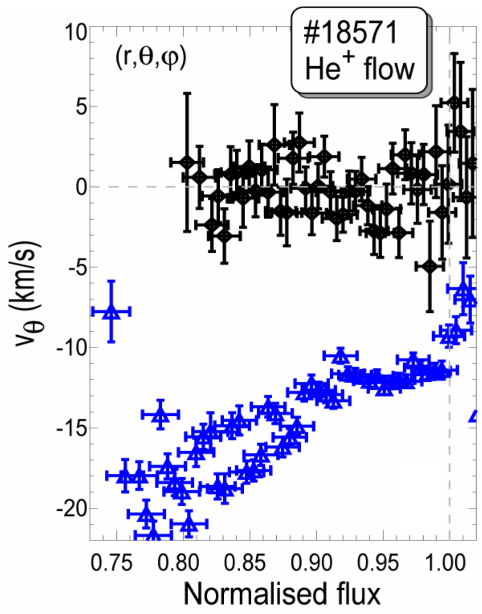
- Amplitude higher at edge than core
- Correlation time:
  Edge $\tau_c < 100\mu s$, Core: $\tau_c \sim 10\mu s$

High-resolution edge Doppler spectroscopy

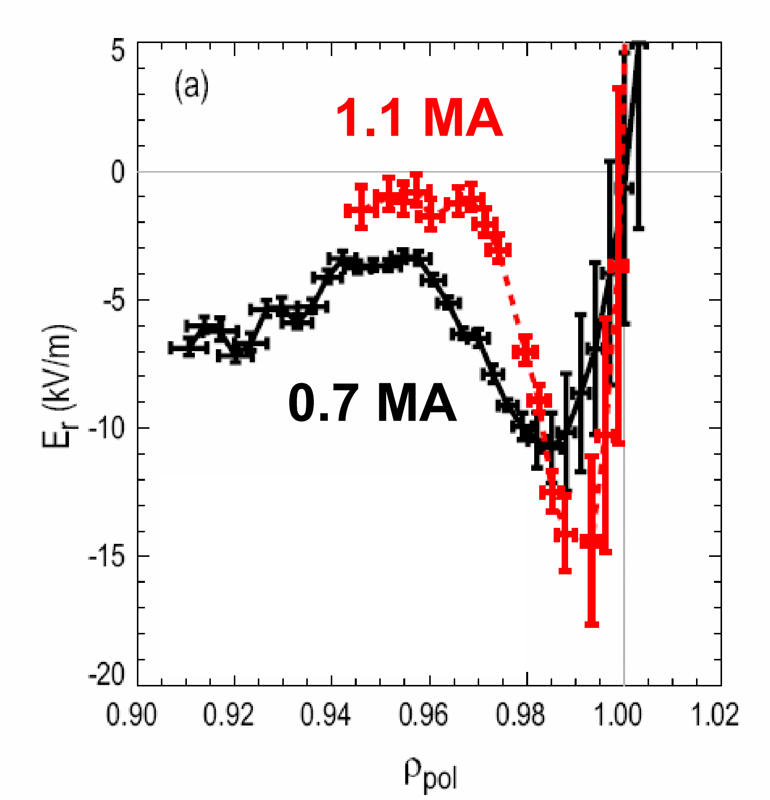
Velocity profiles – L/H-mode

Toroidal **Poloidal**





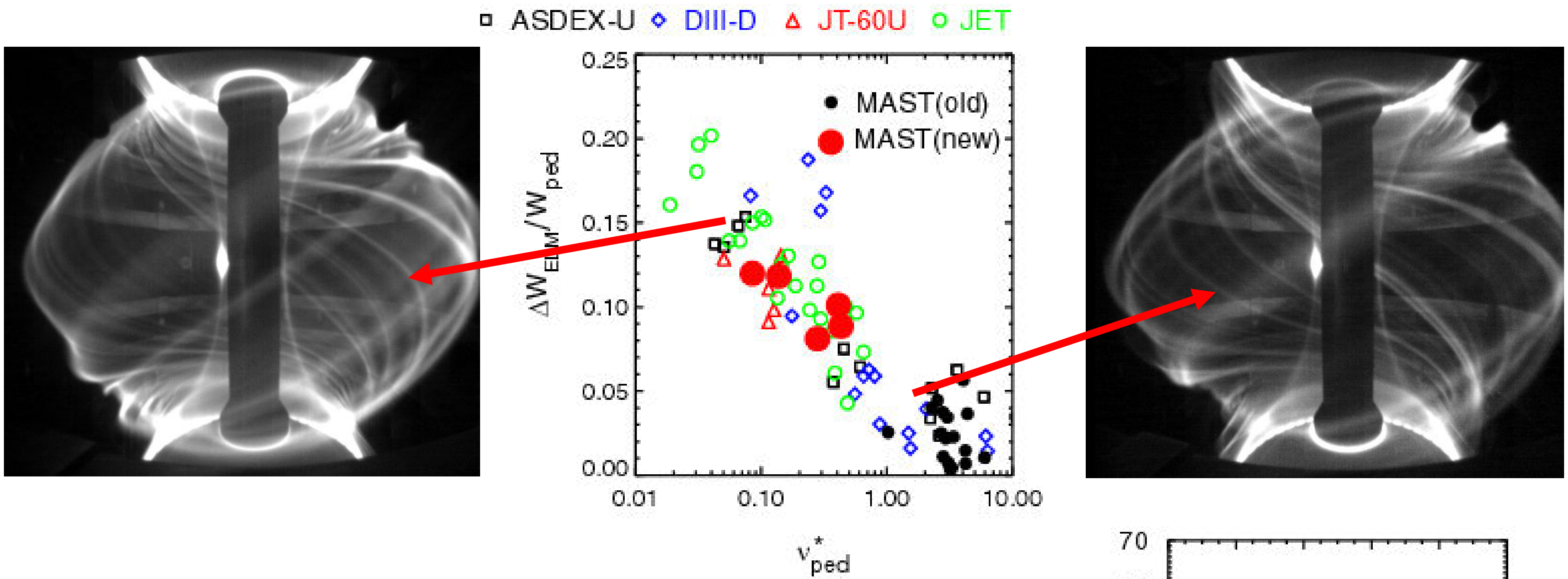
Edge E_r profile (H-mode)



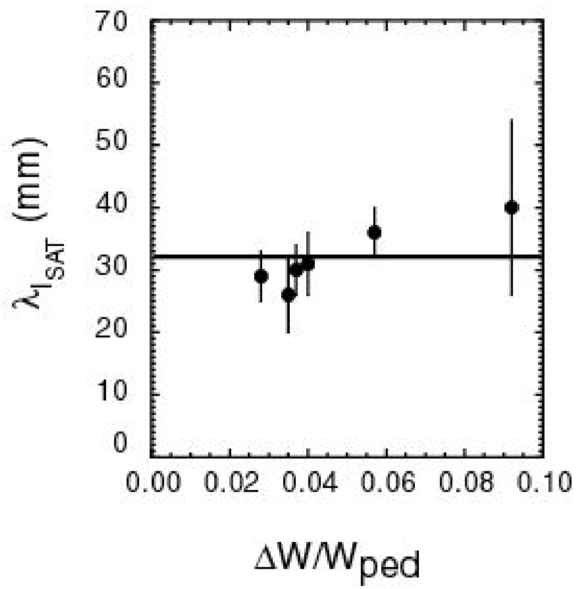
- 120 LOS: ≤ 64 toroidal, ≤ 64 poloidal
- $B_\theta \sim B_\phi$ at edge in ST
- V_ϕ and V_θ required to determine E_r
- $E_r \sim$ - 10-15 kV/m forms in ETB region
- E_r and ∇E_r increase with plasma current

Scaling of ELM properties with energy loss

Comparison of type I ELMs with different energy loss



- The number and size of the filaments is similar for large or small type I ELMs
- The radial efflux of ELMs also depends weakly on the ELM size, $\lambda = v_r L_{||}/c_s$
- Important for determining the fraction of ELM energy to first wall of future devices



Technical developments for 2008-9

2nd PINI source

- $P_{NBI} \leq 5$ MW for 5 s

ELM coil system

- Two 6 i-coil arrays, 6kA turns
- 1 cm island width > pedestal width

TS Upgrade

- 8 NdYAG lasers, 30 Hz, 1.6 J
- 120 spatial points, 1 cm resolution

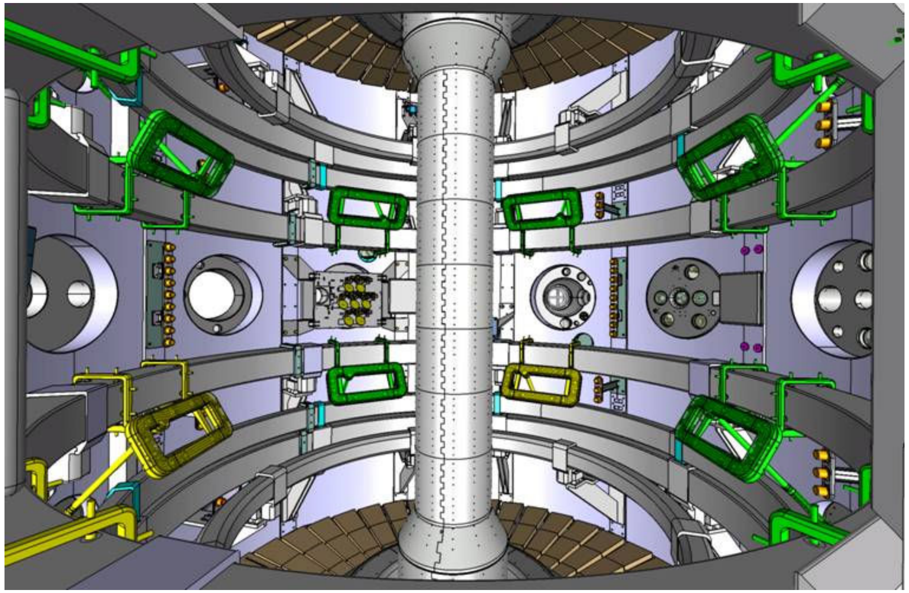
Multi-channel MSE

- 35 channels, 2.5 cm resolution

BES 2D imaging system

- 8x4 channel APD array camera

12 coil ELM control system



- Long-pulse DA system
- PC based digital control
- New NBI HVPS
- Higher power 28 GHz gyrotron (ORNL)
- Centre column chiller