MAST/NSTX Collaborations and MAST Campaign 2004

Plenary Session, NSTX Research Forum, FY 2004
PPPL, Princeton, NJ, 10th-12th November 2003

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A. Sips (IPP, Garching)

Internal transport barrier formation

Motivation:

- Develop advanced ST scenario with ITB to optimise performance (BS current, confinement)
- Study ITB formation physics in ST configuration (turbulence suppression, existence criteria, etc)

MAST:

- Scenario developed from conventional tokamak
- Strong flow shear and weak/reversed magnetic shear produced ITBs in ion and electron channels (ctr-NBI)
- Turbulent transport suppressed to ion N.C. level

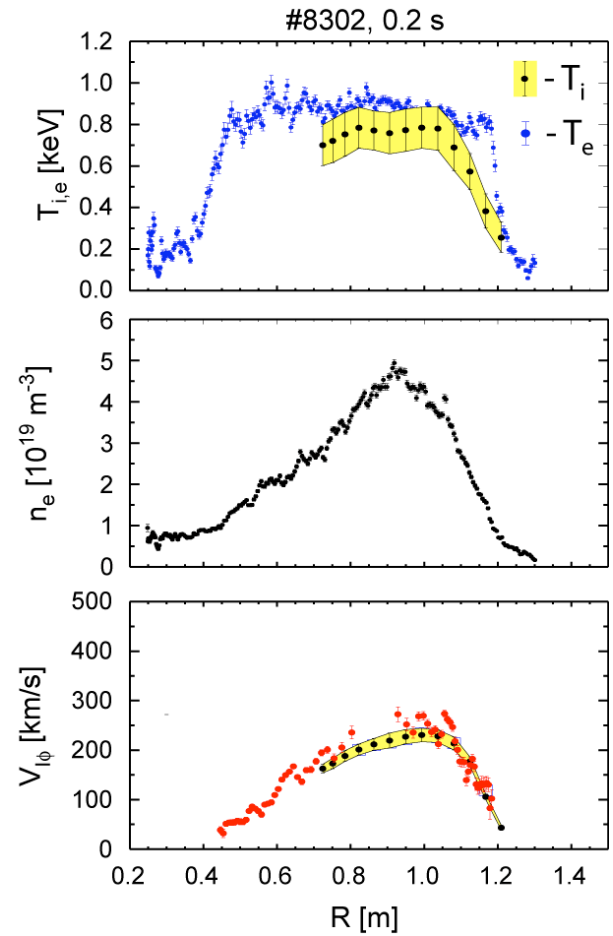
NSTX:

- Evidence for transport barrier in H-mode discharges
- MAST/NSTX ITB 'identity' experiments proposed

ITPA activities:

- Testing of existence criteria (Fujita, EPS '03)
- Discussion of ITB 'similarity' experiments

eITB with counter-NBI



Martin Peng, E. Synakowskii, Anthony Field, Clive Challis, George Sips

Pedestal scaling 'similarity' experiments

Aim:

ITPA Pedestal Group activity to test pedestal models and improve scalings for ITER

Method:

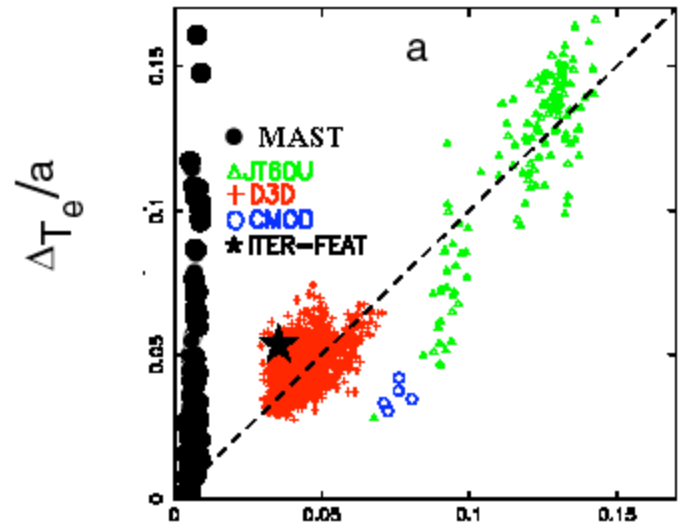
NSTX and MAST same shape (a, □ ,□) as DIII-D but very different R and B_t

Allows assessment of influence of A, B_t and wall proximity on:

- Pedestal parameters (height, width and gradient) at matched □, □*, □*
- Radial extent, amplitude and frequency of ELMs

MAST/NSTX comparison to assess influence of close fitting wall on pedestal structure and fuelling

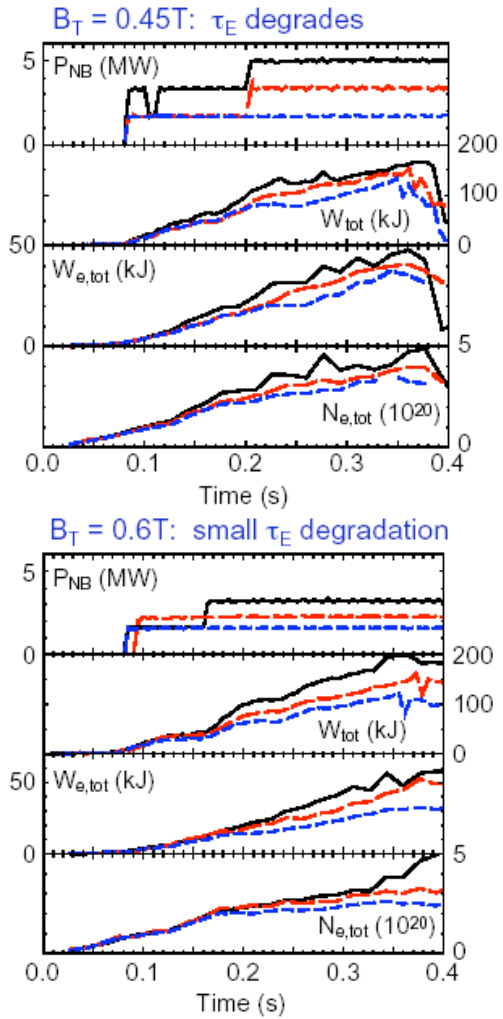
Empirical □T_e scaling
(derived without MAST data)



$$\Delta_* = 0.044 \times \rho_{*s}^{0.38} (B_T / B_p^{Ave})^{0.27} n_{*G}^{0.19} \times \kappa^{-0.98} (1+\delta)^{0.52} \varepsilon^{-2.3}$$

Rajesh Maingi, Tom Osborne, Andrew Kirk, Glen Counsell, Howard Wilson, Phil Snyder

Confinement scaling



Aim

- Develop a confinement scaling using MAST and NSTX data suitable for predicting performance of future devices:

  $\tau_E \quad P^x B_t^y n_e^z$, where x is a function of B_t, I_p, etc

NSTX:

- Power degradation stronger in L-mode than IPB scaling
- Is a function of B_t in H-mode

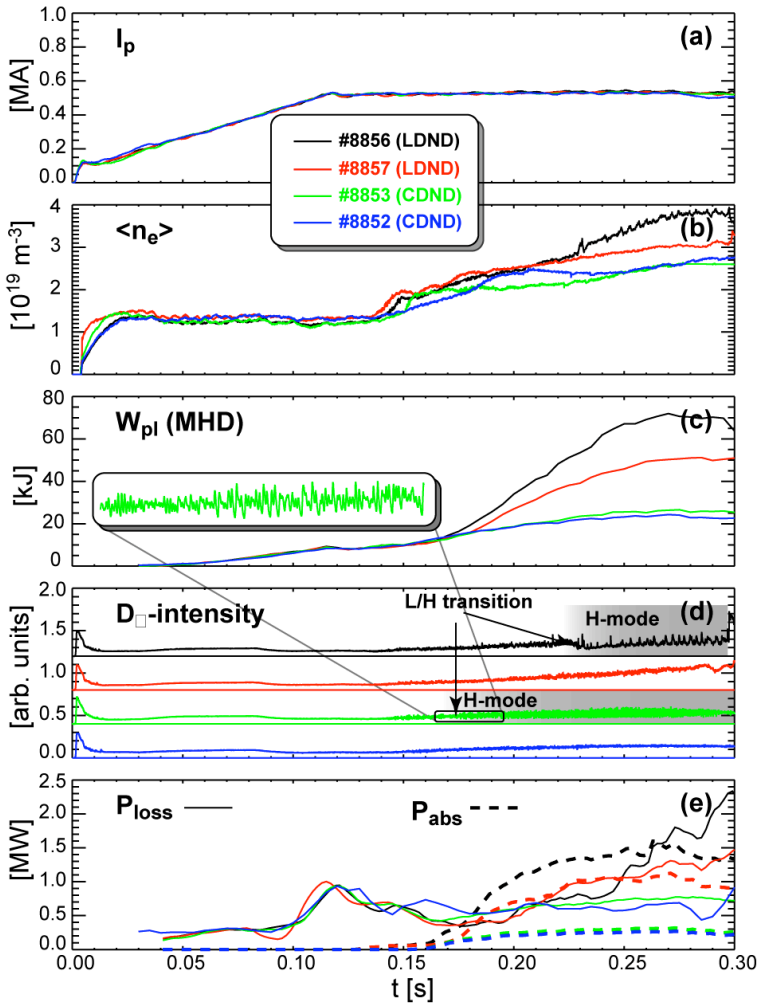
MAST:

- 5 MW NBI to be available in '04 (3 MW so far)
- Determine confinement scaling in NSTX 'identity' discharges to investigate influence of wall proximity, SND/DND

ITPA activity:

- DIII-D shows confinement independent of at fixed * and *, whereas IPB(y,2) confinement scaling degrades with 1/
- Overlap with these experiments to extend scaling at fixed * and * to low *R/a*

H-mode access: Role of magnetic configuration



Observation

Lowest $P^{L/H}$ in balanced DND configuration on MAST (and also recently in AUGD) **BUT** in an LDND configuration on NSTX and DIII-D

Aim

Determine $P^{L/H}$ as function of ΔR_{Sep} in NSTX and MAST with similar shape and start-up technique

MAST experiments

So far confirmed that $P^{L/H}$ ~ 0.53 MW in CDND and ~ 1.2 MW in LDND in MAST/NSTX 'identity' discharges

NSTX experiments

Repeat experiments in NSTX to investigate the influence of wall proximity, etc on $P^{L/H}$

Hendrik Meyer, Rajesh Maingi

H-mode access: Influence of fuelling location

Motivation

- HFS refuelling improves H-mode access and quality, both on NSTX and MAST
- Test theory based models in ST geometry, e.g. neo-classical theory of influence of neutrals

MAST

- Edge toroidal rotation and E-field higher with HFS fuelling as predicted by NC theory

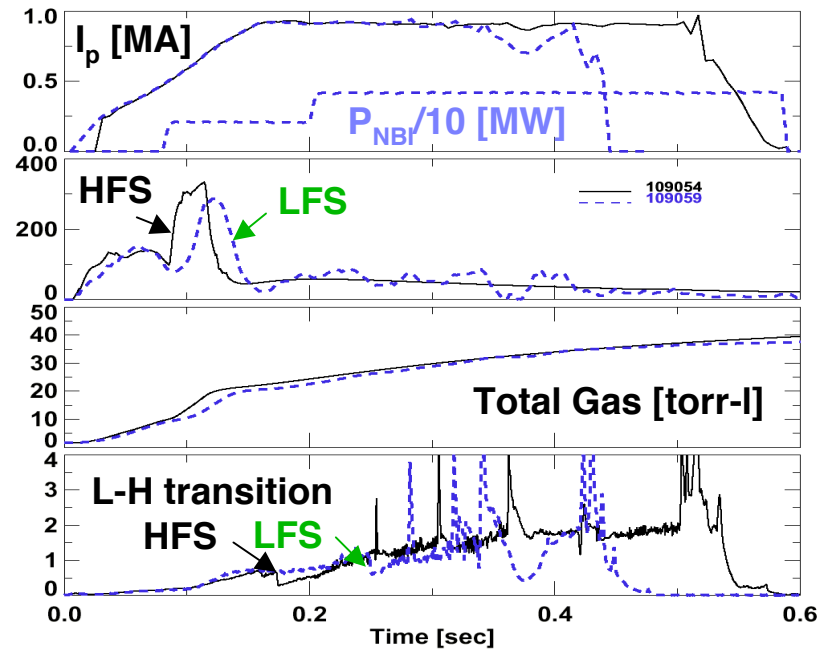
NSTX

- Multiple fuelling locations, 51-channel CHERS and poloidal flow measurement
- Increased co-I_p flow in HFS fuelled discharges with NBI heating (agreement with NC theory)

Collaborations

- Execution and interpretation of experiments
- Possible alternative theoretical models

Improved H-mode access with HFS fuelling on NSTX



Rajesh Maingi, Anthony Field, Per Helander

Non-solenoid start-up

Aim:

Investigate start-up scenarios for the ST that do not use central solenoid (absent in CTF or STPP)

MAST:

Merging compression:

Routinely gives 0.5 MA of hot plasma (PF coils in vessel)

Induction from PF coils:

Field null and flux swing from PF coils alone (planned)

RF start-up:

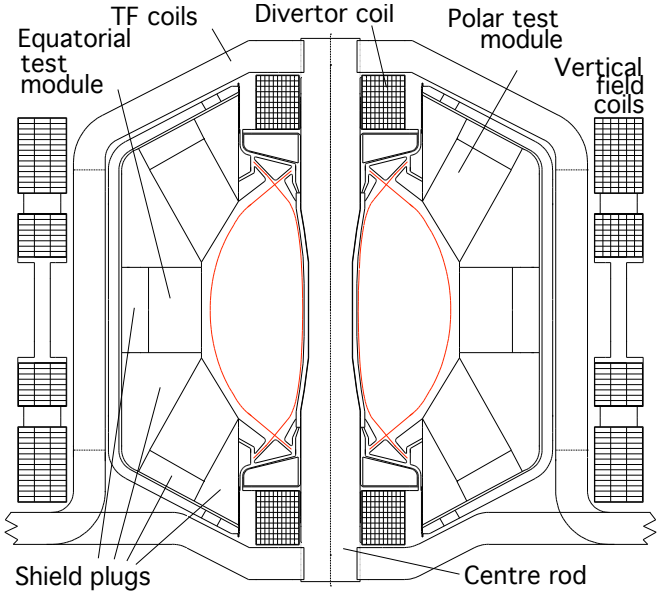
few kA from 60 GHz, tests with 28 GHz planned

NSTX:

CHI: Can give ~ 400 kA transient current

Induction from PF coils: As MAST scheme

UKAEA CTF Design



Wonho Choe, David Gates, Alan Sykes, M. Gryaznevich

Neutral particle diagnostics

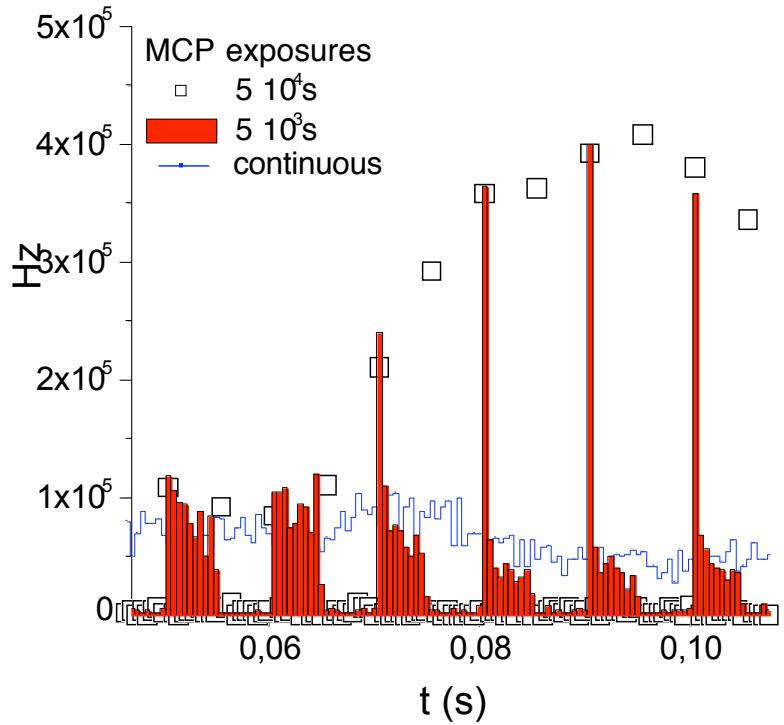
MAST NPA on loan from PPPL

MCP Gating:

- Gating MCP avoids saturation and allows neutron background subtraction
- MAST electronics to be used in tests on NSTX

Compact electrostatic NPA

- Compact 'stripping foil' NPA installed on NSTX for monitoring fast events
- Assess capability to measure core ion temperature
- Instrumentation available for loan to MAST



Physics

- IRE induced ion acceleration (co-/counter-NBI, theory)
- Neutral beam profile measurements (attenuation, divergence)
- MHD induced energetic ion losses (ORBIT, beam energy)
- Energetic ion measurements during L/H-transitions

Sid Medley, Mikhail Tournianski, Rob Akers, Per Helander

Fuelling systems

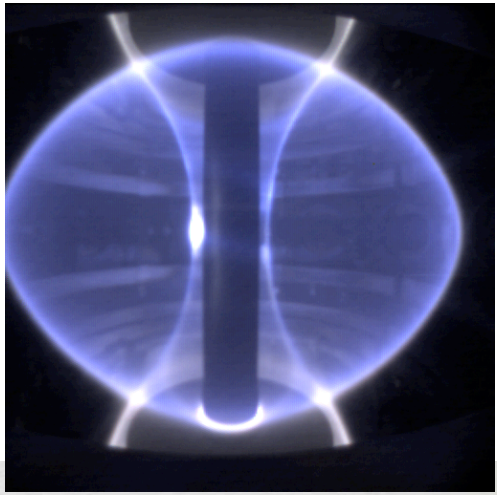
HFS refuelling:

- Pioneered on COMPASS-D and MAST
- Collaboration on center-stack, mid-plane injector on NSTX
- Improves H-mode access and quality
- Collaboration on role of neutrals in H-mode access

Supersonic LFS injector:

- Supersonic 'Laval' nozzle developed with CDX-U at PPPL
- Commissioning and testing on NSTX in 2004
- Mach 8 (1.8 km/s) for low divergence and high flux (~ 10^{22} s^{-1})
- Expect increased fuelling efficiency
- May improve density control by raising wall saturation limit
- Diagnostic applications (He line ratios, cold pulse propagation)
- May be particularly beneficial in MAST with large vessel/plasma volume ratio

HFS Fuelling on MAST



NSTX Supersonic injector

Rajesh Maingi, Henry Kugel, Vlad Soukhanovskii, Anthony Field

EBW studies

MAST

- 1 MW 60 GHz with steerable launcher available
- EBW radiometers: scanning 16-60 GHz, multi-channel 54-66 GHz.
- EBW CD start-up scenario planned with existing 28 GHz, 200 kW gyrotron

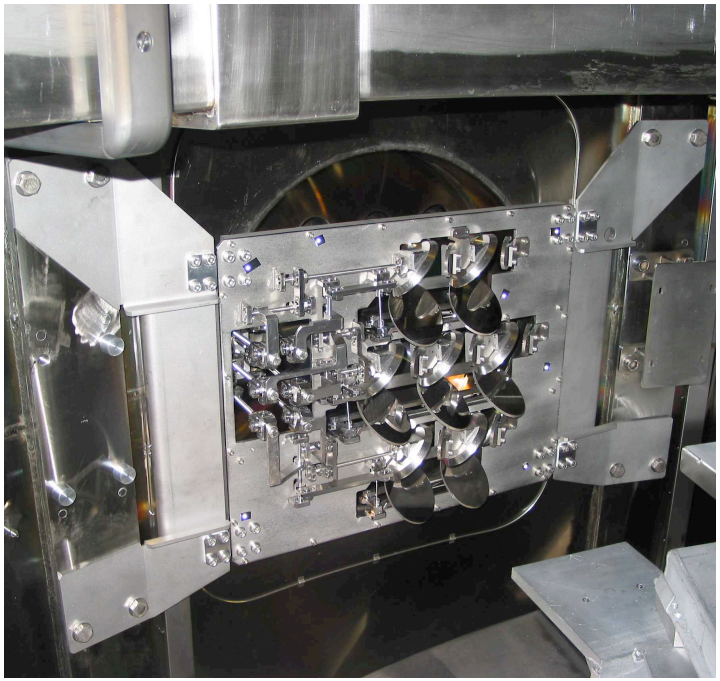
NSTX

- EBWE radiometer: Optimise emission by X-B tunnelling using limiter
- Planned 3 MW, 15 GHz EBW system for localised current drive (1 MW gyrotron '04-'05).

Collaborations

- EBW emission studies and interpretation
- Modelling (mode conversion, propagation and CD)
- EBWH and CD experiments and interpretation

Steerable EBW launcher on MAST



Gary Taylor, Phil Efthimion, Bob Harvey, Vladimir Schevchenko

MAST Upgrades 2004

presentfor M4

Load assembly

- Shaped P2 armour
- Thicker inner strike-point tiles
- Controllable HFS gas and pellet feeds
- MAST Improved Divertor MID

Heating

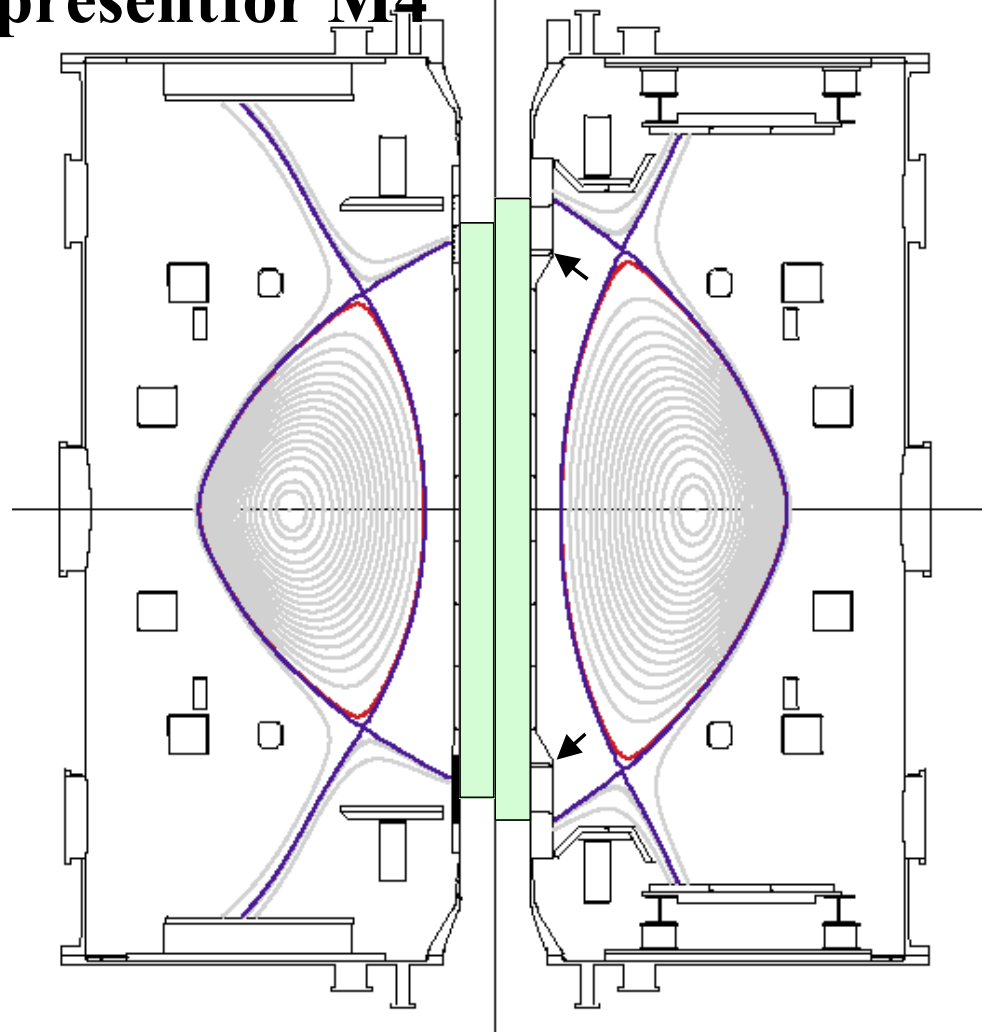
- Reliable long pulse NBI at higher pow
- Re-aligned EBW antenna

Coils and PSUs

- Longer, more robust centre column
- P2 coils repositioned ± 0.1 m
- Reversible P2 current
- Higher plasma elongation
- Error field correction coils

Digital Control System

Diagnostics



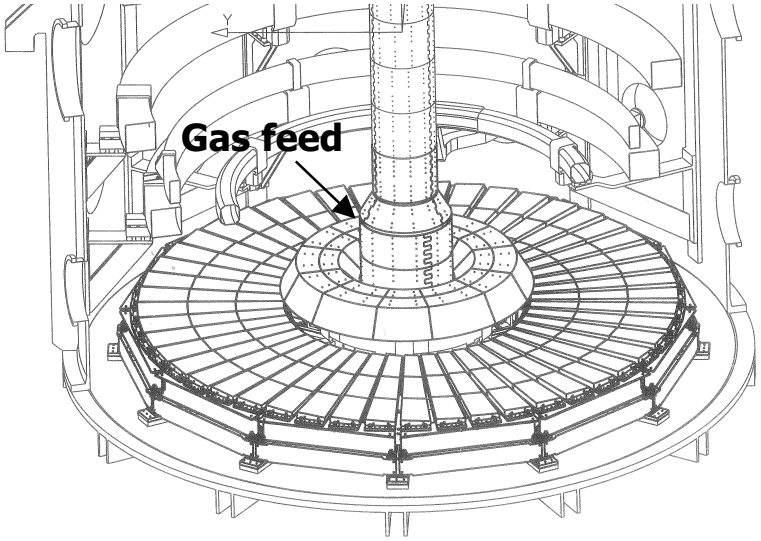
UKAEA Fusion Working with Europe

Centre Column and Divertor

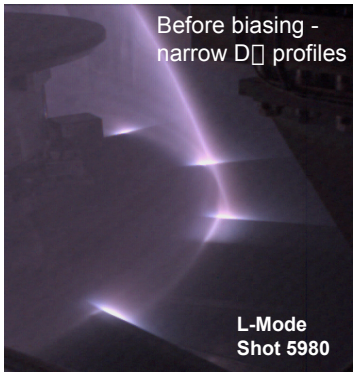
Central column

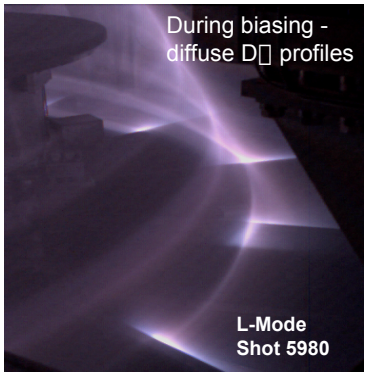
- Extended solenoid by ± 0.1 cm
- Strengthened 'tail' section
- 1 Vs from ± 55 kA swing

MAST Improved divertor



MID retains biasing facility

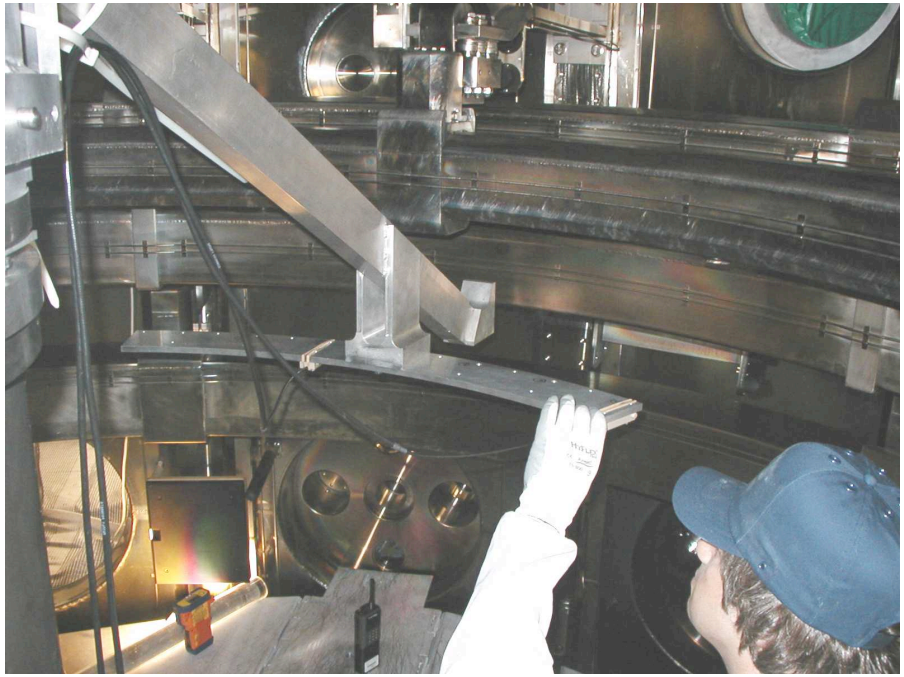




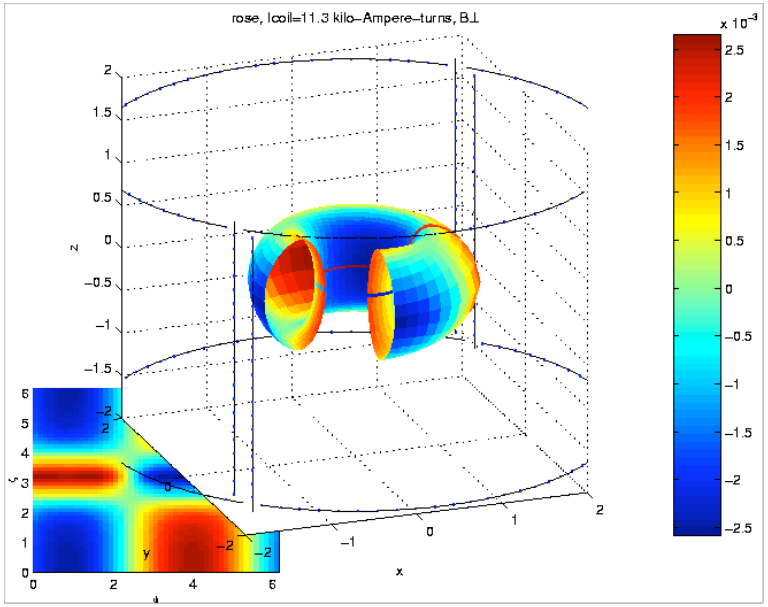
Error field correction

Measurements

- Static error fields due to coil misalignments measured in situ
- Error field from P4U ~ 1 mT at q = 2 with typical P4 current



Correction field (q = 2)



Correction system

- Project underway to install correction coil system for M4 campaign
- Four coils external to vessel utilising existing fast amplifiers
- Correction field ~ 5 mT at q = 2

NBI Systems

M4 campaign

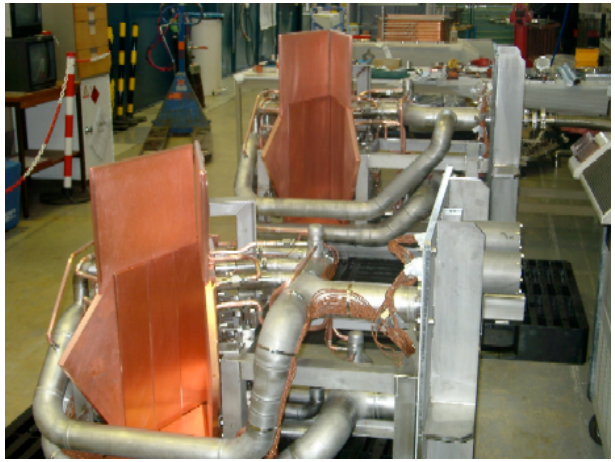
SW line: ORNL injector, ~ 2.5 MW in D^0 for 0.4 s

S line: JET style PINI, 2.5 MW in D^0 for 5 s

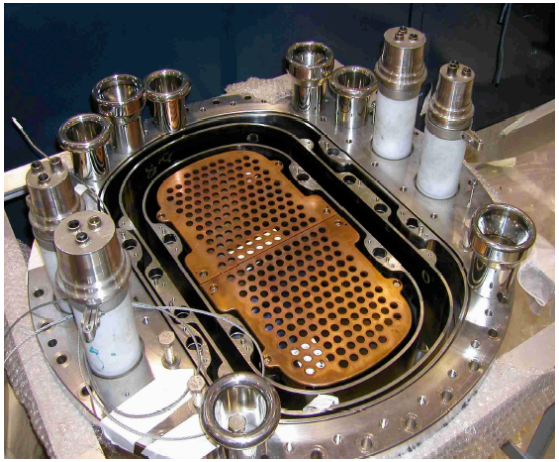
M5 campaign

JET-style PINIs on both S and SW lines, 5 MW for 5 s

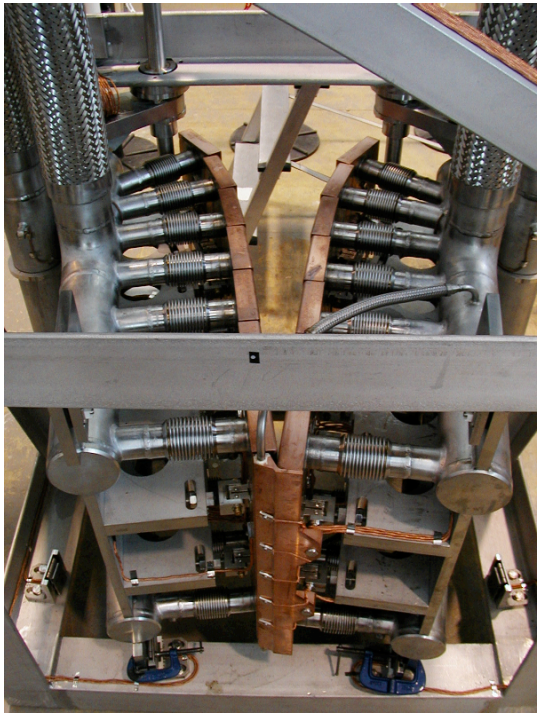
Residual Ion Dumps (with hyper-vapotrons)



Extraction grids of JET PINI



Cooled calorimeter (closed position)



Diagnostic enhancements

Thomson scattering

- Combined Ruby and NdYAG systems: Polariser to halve stray & plasma light
- Improved alignment and calibration systems

Bolometry

- 16 tangential chords: 12 co- and 4 counter-NBI viewing for fast ions (complements 16 poloidal chords)

CXR

- New CCD camera - real-time readout for long pulses
- New transmission spectrometer (reduce inter-chord cross-talk)
- BES and CXR intensity imaging in one camera system - helps data unfolding

Scanning reflectometer (16 to 60GHz)

- Wave guides re-aligned
- Scan period decreased from 100μs to 10μs

Infra-red imaging

- Increased field of view (wide angle lens) and additional port views

Soft X-ray imaging

- Tangential viewing directly illuminated CCD

Physics Goals and Schedule

Plasma exhaust & disruptions

- Structure and impact of ELMs
- Divertor biasing
- Disruption studies

H-mode regimes

- H-mode access physics
- ETB formation and structure
- Regimes with tolerable ELMs
- Confinement scaling studies

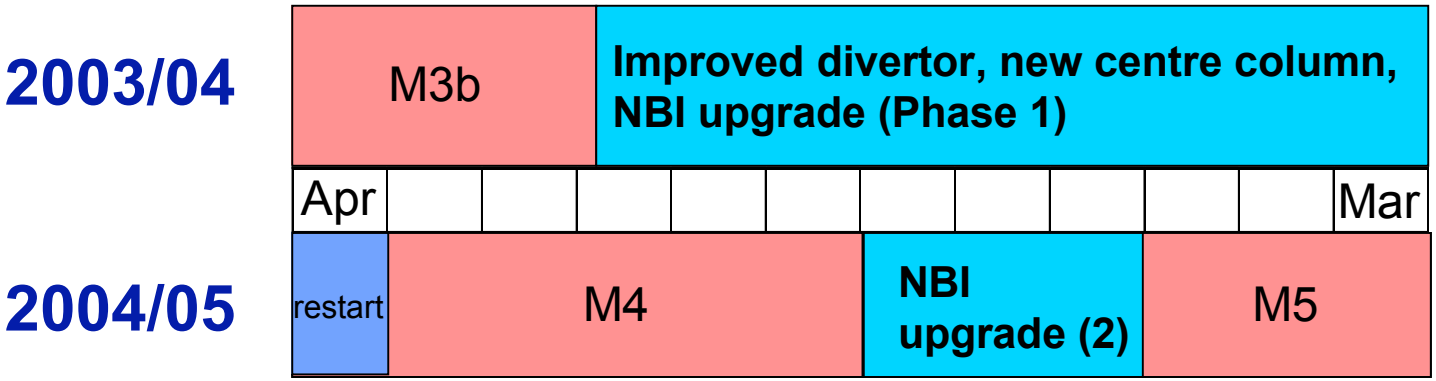
Non-solenoid start-up

Internal transport barriers

- Formation conditions
- Existence criteria
- Transport analysis
- Micro-stability and turbulence

Operational limits

- Beta limits, NTMs
- High-β operation with optimised control

NBI current drive

EBW Heating