MAST Status & Plans

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EURATOM/CCFE Fusion Association

CCFE is the fusion research arm of the **United Kingdom Atomic Energy Authority**

Jointly funded by EURATOM & EPSRC

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Present MAST status

- Recent engineering break, incl. TS installation & TF maintenance, completed on schedule

- Upgraded TS commissioned into plasma, calibrated & first data obtained

- 28GHz gyrotron (ORNL) system commissioned and first experiments carried out
  - performance limited by transmission line problems

- Disruption mitigation valve commissioned & first data obtained

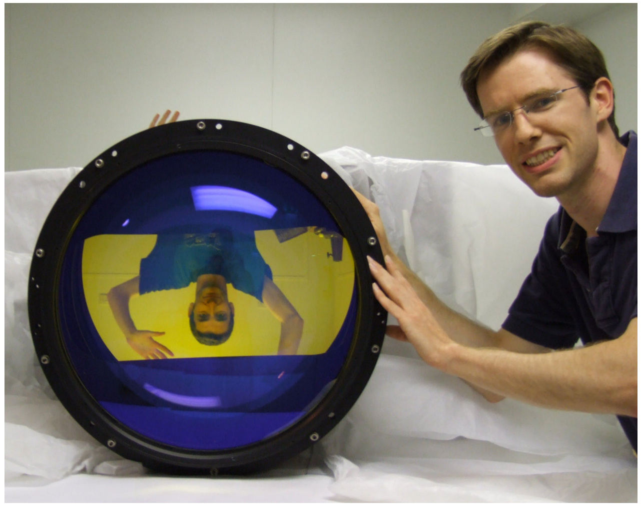
- Two PINI sources operating at ~2MW (S-PINI) and ~1.5MW (SW-PINI) respectively – aim to condition to higher power during present campaign
  - presently recovering from bend magnet failure on S-PINI
  - p/s problems affected SW-PINI performance, now believed to be resolved
  - spare PINI & new HVPS ordered (delivery 2010)
  - further improvements in hand (DECEL supplies, crowbar, bend magnets..)

Nd:YAG TS upgrade

Collaboration with York University. COMPLETE

Stage 1: Replace 4 0.9J, 50Hz lasers by 8 1.5J, 30Hz lasers increasing temporal resolution and enhancing burst mode capability for NTM, ELM, pellet studies etc.

Stage 2: New collection system and spectrometers, 120 spatial points, ~ 10mm resolution (now installed – first profiles obtained). High resolution edge TS and 300pt ruby TS single pulse system retained.



Scannell et al Rev. Sci. Inst. 2008

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Nd:YAG TS laser triggering system

- A 'Smart' laser triggering system has been developed to provide flash lamp and Q switch pulses for all the lasers – based on Field Programmable Gate Arrays (FPGAs)

- Can synchronise Thomson scattering measurements to:
  - Start of shot
  - Pellet injection
  - NTM phase
  - Other MHD events…..

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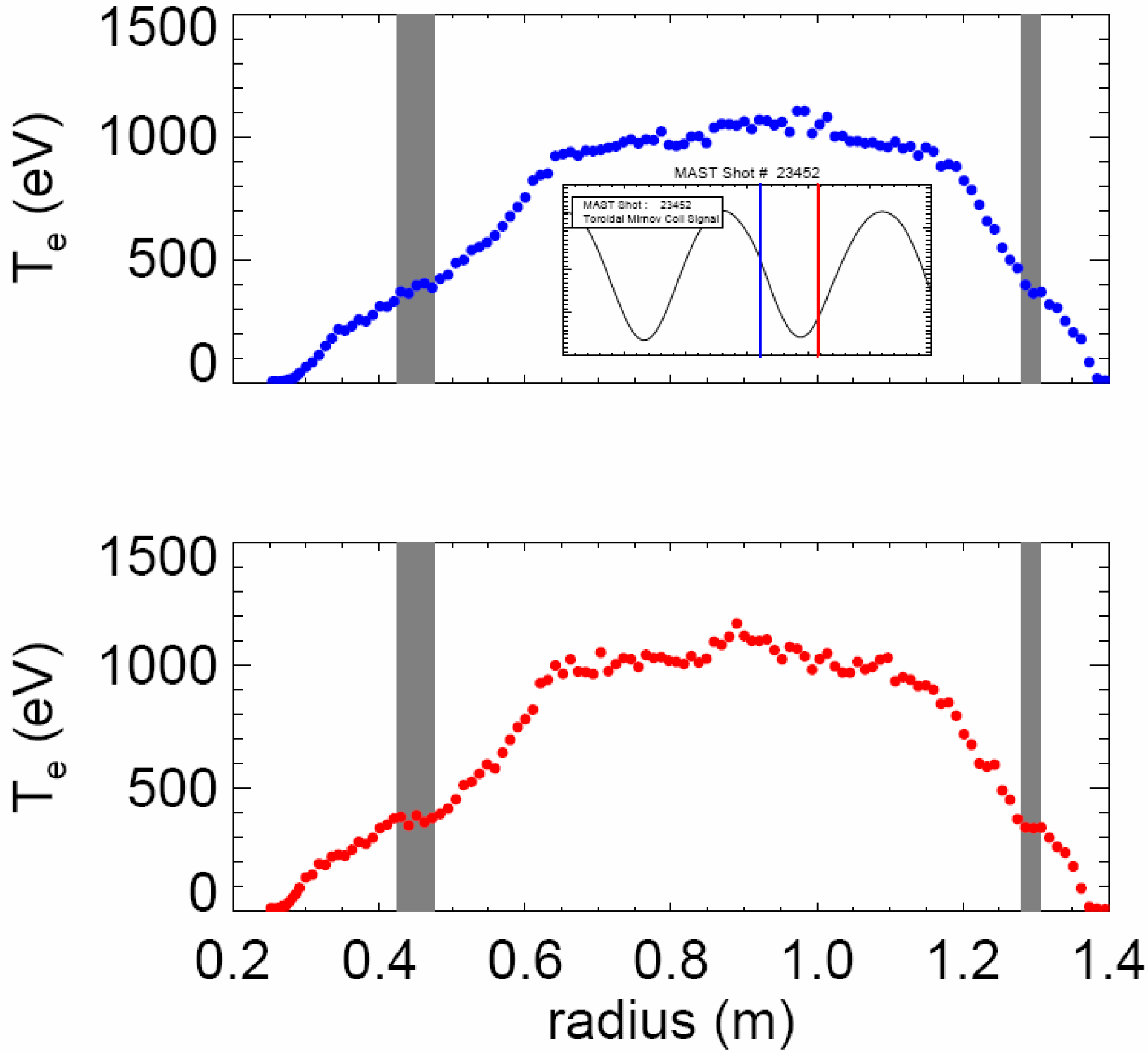
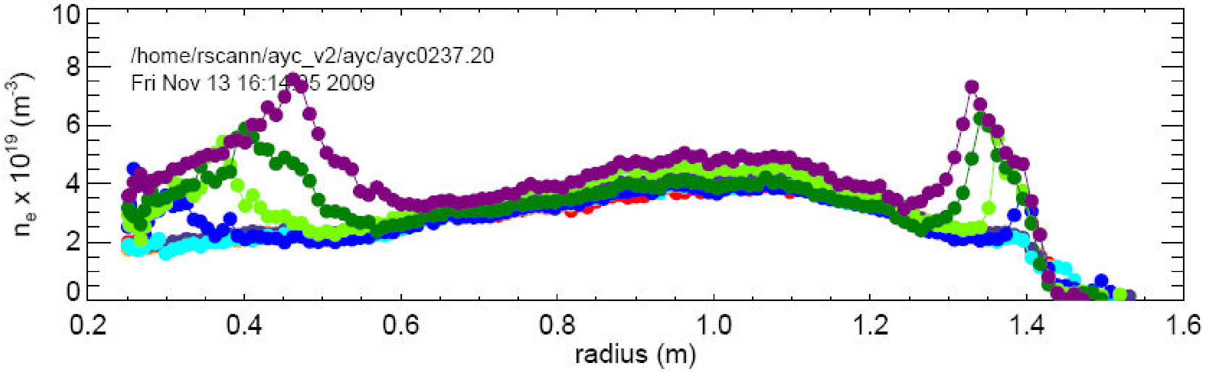
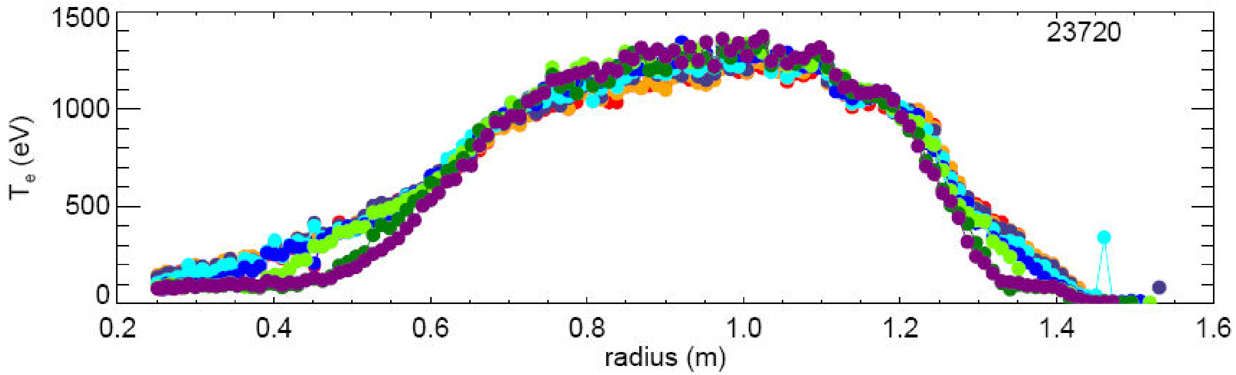
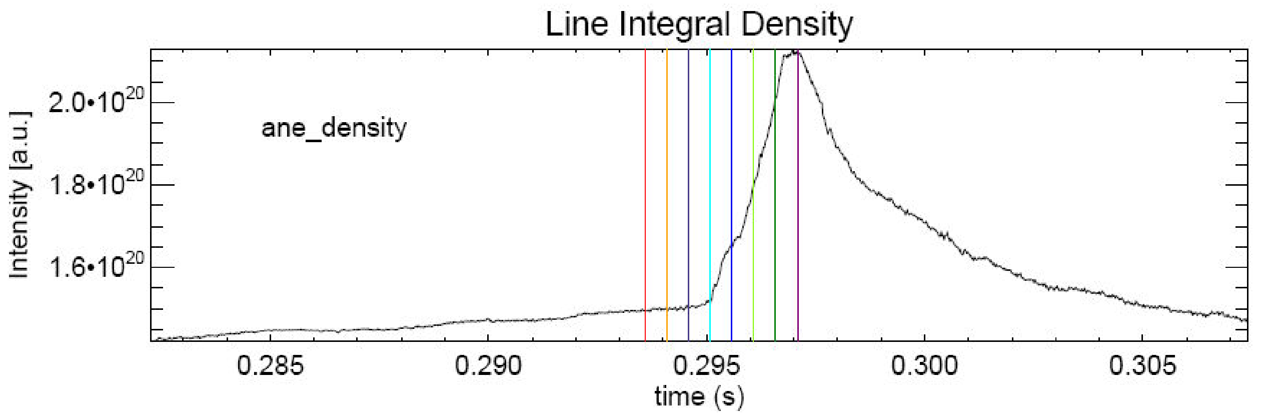
Nd:YAG TS upgrade – magnetic islands



Nd:YAG TS upgrade – pellet deposition







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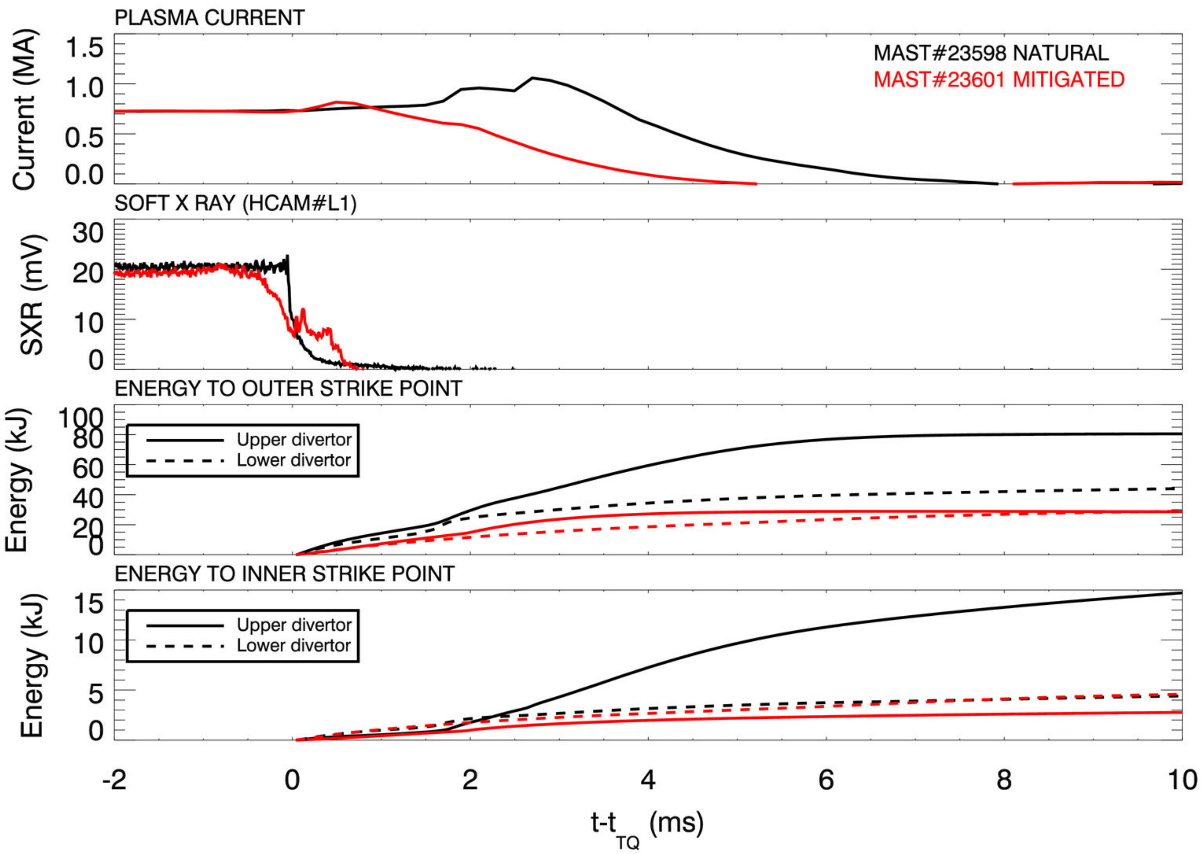
Disruption mitigation

- Heat loads reduced significantly with disruptions mitigated by MGI (collaboration with FZJ Julich, York University)



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Other new capabilities 2008-09

- ELM control/TAE coils: 6 + 6 internal array (n = 3)

- Multi-channel MSE
  - 37 spatial channels, better than 3cm, 2ms resolution

- Divertor science facility
  - Deployed for dust injection experiments

- Improved edge, imaging & spectroscopic capabilities
  - long wavelength IR camera, filtered fast camera, second filtered divertor camera, new spectrometers, retarding field analyzer (CEA collaboration)

- Plasma control and long pulse datacq developments on-going

Multi-chord MSE

MSE constrained EFIT now routine

MSE target performance:

35 spatial channels

R ~ 0.7 – 1.5 m

ΔR ~ 2.5 cm

Δt ≤ 5 ms

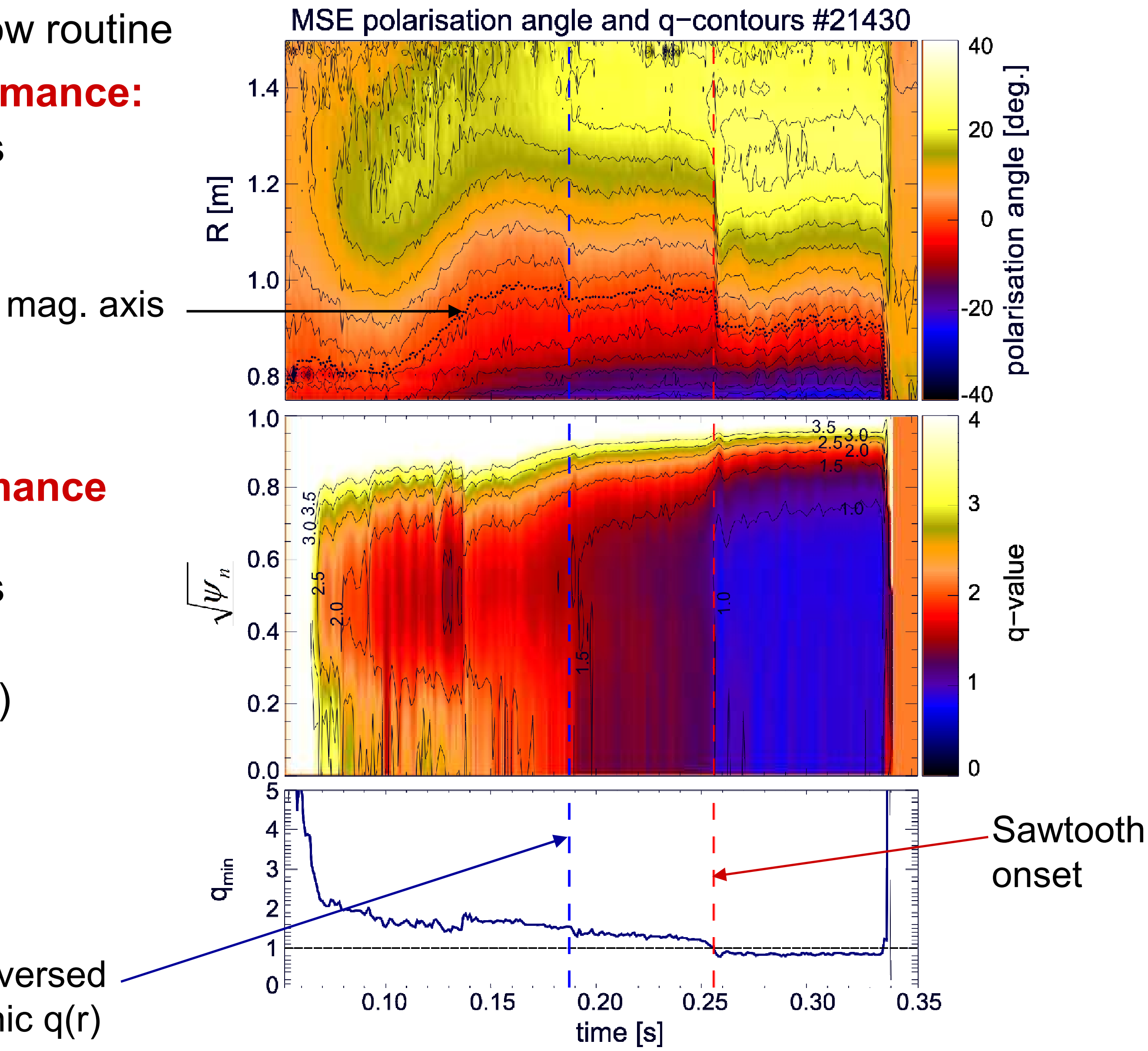
Δα ≤ 0.5°

Measured performance (e.g.#21430):

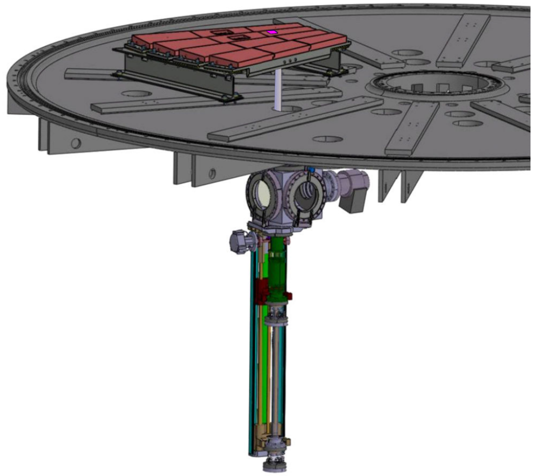
37 spatial channels

Δα ≤ 0.5°

Δt = 2.0 ms (All ch.)



Divertor Science Facility (DSF)



❑ The DSF can support a wide range of potential activities, e.g.

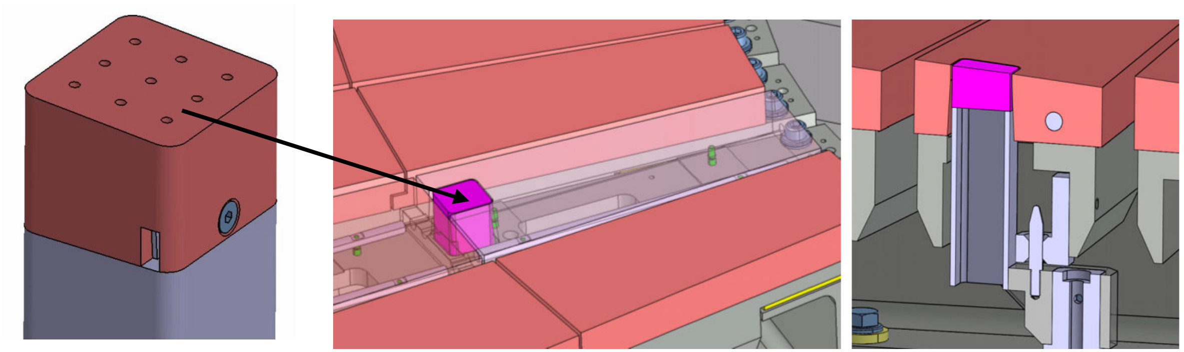
- Tile gap deposition studies (‘castellated’ probe) (ITPA DSOL-13, IPP Garching)

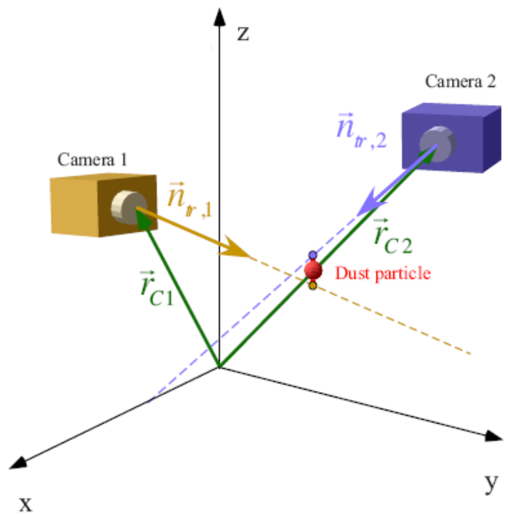
- Diamond film exposure (Heriot-Watt University)

- Impurity injection (DCU)

- Dust injection + stereoscopic IR imaging (EU-PWI, FZJ, RAL, Imperial College)
  - Injection of particles with known shape/size to benchmark dust transport codes (e.g. DTOKS). W and C injected so far.
  - IR cameras synchronized in time and frame rate allow dust trajectories to be tracked

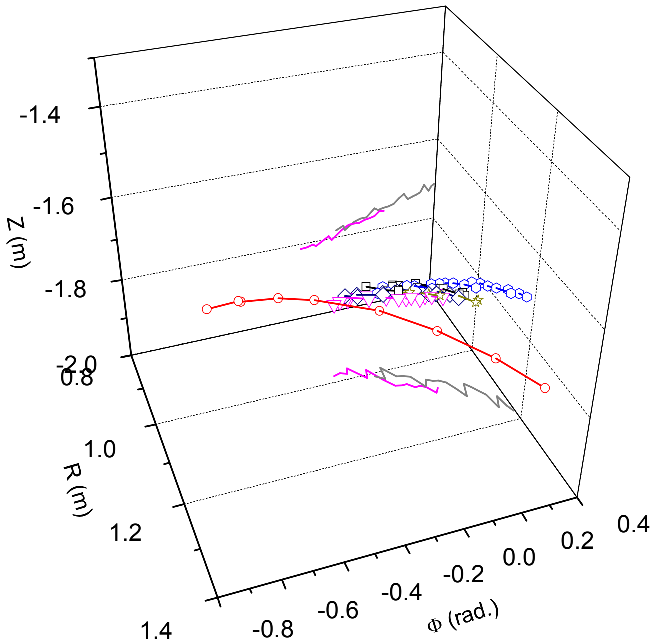
DIMPLES TO HOLD DUST



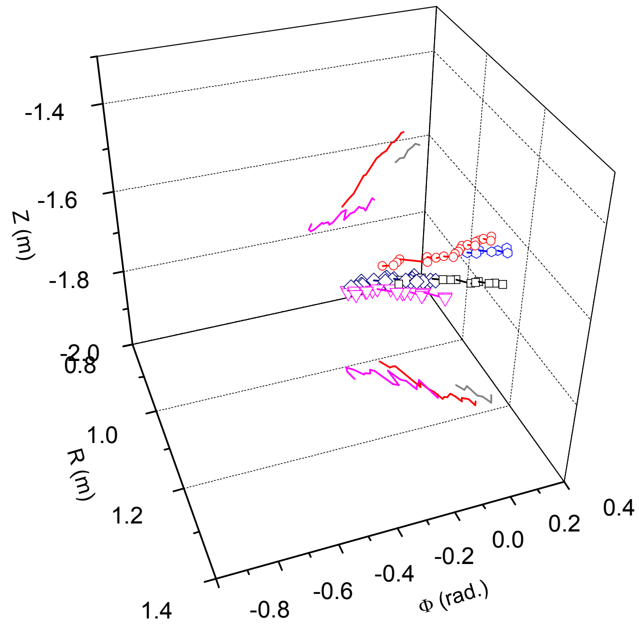


Dust transport

Reconstructed tracks for carbon



Reconstructed tracks for tungsten

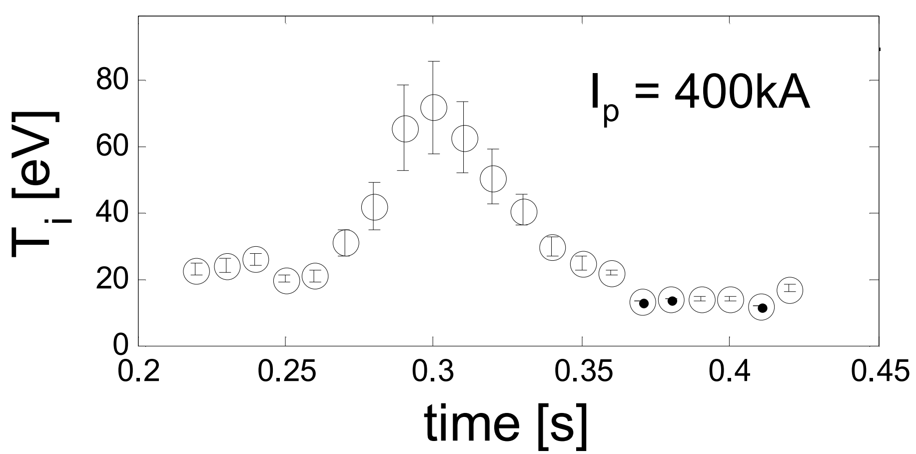


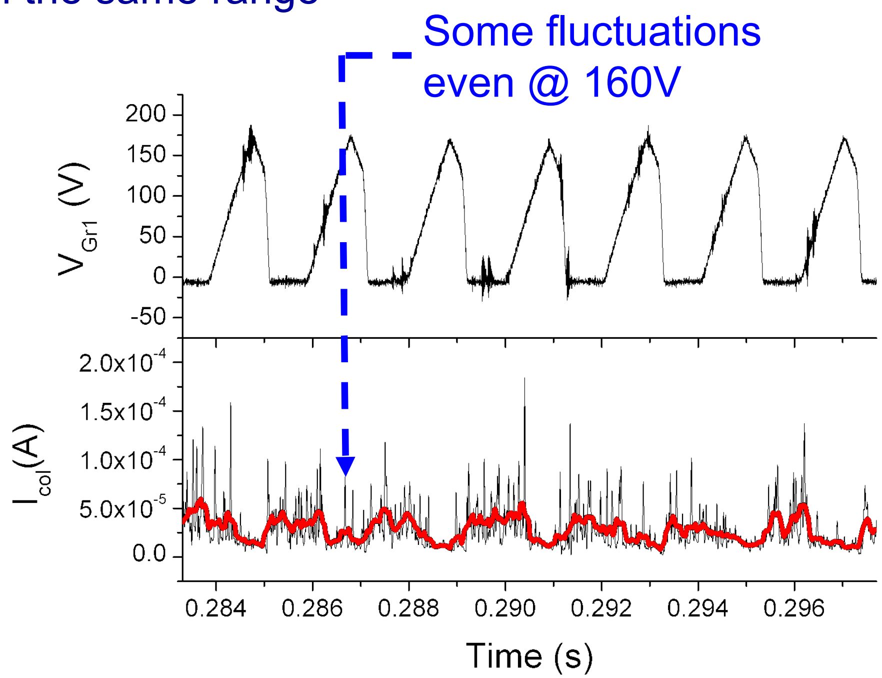
- Particles move in the direction of B_t and are directed upwards
- Velocities in the range 5-70 $m.s^{-1}$

- Particle velocity lower than for carbon particles
- Vertical motion more pronounced
- Particle size at the limit of LWIR detection threshold

SOL ion energy measurements

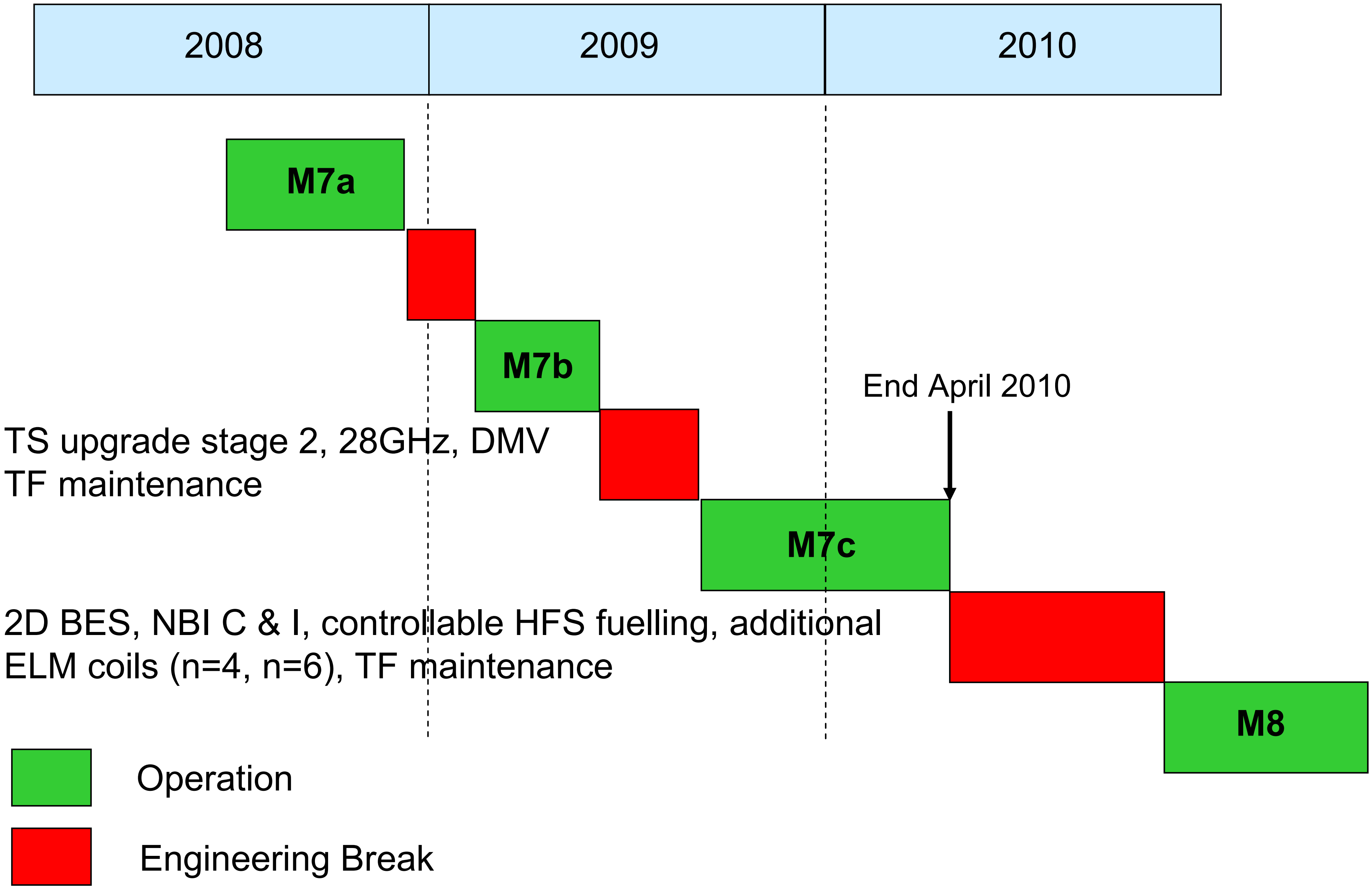
- Measurements of ion energies in the SOL recognised as a priority research area (EFPW Cork Dec 2008)
- First measurements using RFA on loan from CEA show T_i ~ (2-3) x T_e
  - T_i ranging from 15eV to 70eV when plunging from $r-r_{sep}$ = +2cm to $r-r_{sep}$ = -2cm
  - TS measurements give T_e from 5eV to 30eV on the same range
  - much higher energies observed in fluctuatior





- Ion energy in ELM filaments - large signals observed as far as 20cm from the LCFS and up to 500V of biasing, cf. JET (analysis on-going)
- Project launched to build RFA modules for the reciprocating probe and the Divertor Science Facility (DSF)

Revised operating schedule



M7 organisation

ELM control programme *Andrew Kirk, Eric Nardon*

Performance Optimisation
Hendrik Meyer
Geof Cunningham

Confinement & transport
Martin Valovic
Anthony Field

Stability
Simon Pinches
Ian Chapman

Exhaust/edge
Steve Lisgo
Gregory De Temmerman
Patrick Tamain

Scenario development *Geof Cunningham + Session Leaders*

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ITPA Commitments

Good progress

TC-1	Confinement scaling in ELMy H-modes: β degradation
TC-4	H-mode transition and confinement dependence on ionic species √
TC-8	QH/QDB plasma studies √
TC-11	He profiles and transport coefficients
TC-12	H-mode transport and confinement at low aspect ratio √
PEP-6	Pedestal structure and ELM stability in DN
PEP-16	C-Mod/ MAST/ NSTX small ELM regime comparison
PEP-19	Basic mechanisms of edge transport with RMPs √
PEP-21	The spatial and temporal structure of type II ELMs Dec 2009
PEP-23	Quantification of requirements for ELM suppression by magnetic perturbations from internal off-mid-plane coils √
PEP-25	Inter-machine comparison of ELM control by magnetic field perturbations from mid-plane RMP coils √
DSOL-2	Hydrocarbon injection to quantify chemical erosion Not doing
DSOL-13	Deuterium co-deposition with carbon in gaps of PFCs Jan 2010
DSOL-15	Inter-machine comparison of blob characteristics √
DSOL-16	Determination of the poloidal fueling profile √
DSOL-21	Introduction of pre-characterized dust for dust transport studies in the divertor and SOL √

√ = new data in 2009

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ITPA Commitments

MDC-1	Disruption mitigation by massive gas jets √
MDC-2	Joint experiments on resistive wall mode physics
MDC-4	Neoclassical tearing mode physics - aspect ratio comparison √
MDC-5	Comparison of sawtooth control methods for neoclassical tearing mode suppression √
MDC-12	Non-resonant magnetic braking √
MDC-14	Rotation effects on neoclassical tearing modes √
MDC-15	Disruption database development (√)
EP-1	Measurement of damping rate of intermediate toroidal mode number Alfvén Eigenmodes (√)
EP-2	Fast ion loss and redistribution from localised AE √
IOS-5.1	Ability to obtain and predict off-axis NBCD √

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M7c:outstanding studies (1)

Substantial new data desired:

- EBW start-up studies at 28GHz (EU/US/JA collaboration)
- Exploit new TS e.g. NTM island transport etc (with York U)
- Exploit DMV – first data on disruption mitigation obtained (with York U)
- TAE damping (vs. beta, q etc) following system improvements (Warwick, York, Imperial College..)
- Investigate β-limits and study effects of toroidal flows and fast ions on pressure limits. Measure RFA of applied field from internal coils.
- Assess intrinsic error field in MAST at high-β, including higher *n* components, and aim to improve performance with EFC
- Confinement scaling - β degradation

M7c:outstanding studies (2)

Extension/completion of on-going studies:

- Pellet fuelling & particle transport
- Further ELM control studies (e.g. ITER-like shape, influence of rotation, interaction with pellet fuelling)
- Performance optimisation e.g. further ITB and hybrid mode studies
- Complete NTM aspect-ratio comparison and studies of the effect of rotation on NTM onset in co-NBI (to complement existing counter-Ip scan)
- Complete non-resonant magnetic braking (n =2, n = 3) studies & cf theory (with Columbia U./PPPL)
- Extend NBCD studies to higher power
- Further radiative detachment studies
- Complete ELM/pedestal IEA/ITPA co-ordinated experiments
- Further exploitation of DSF (collaboration with CEA and UK universities)
- ……….. etc

M8 organisation

Campaign Areas — *Drivers*

Exhaust	Confinement & transport	Stability	Current drive physics & profile optimisation
Kieran Gibson (York U.)	*Martin Valovic*	*Simon Pinches*	*Rob Akers*
…..(new recruit)	*Anthony Field*	*Ian Chapman*	*Mikhail Turnyanskiy*
…..EU	*Walter Guttenfelder (Warwick U.)*		*David Keeling*
			Vladimir Shevchenko

Main thrust

- **ELM & pedestal physics** — *Andrew Kirk, Hendrik Meyer, Liang (FZJ)*

Other priorities

- **MAST Upgrade physics** — *Hendrik Meyer et al*
- **Exploitation of new capabilities (e.g. TS upgrade, 2D BES …….etc)**

Operational efficiency

- **Scenario development** — *Geof Cunningham + Session Leaders*
- **Diagnostic optimisation** — *Neil Conway & diagnostic R.O.s*

M8 organisation

- Links to ITPA, EFDA rationalised

MAST Campaign Area	Equivalent ITPA Topical Group(s)	Relevant EFDA Topical Groups/Task Forces
Current drive physics & profile optimisation	Integrated operating scenarios	Heating & current drive
Confinement & transport	Confinement & transport	Transport
Stability	MHD stability Energetic particles	MHD
Exhaust	Scrape-off layer and divertor	PWI

- High level thrust on ELM & pedestal physics (incl. ELM control, L-H transition physics) (PAC recommendation)
  - high profile ITER i/p, world class diagnostics, first class theoretical back-up

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ITPA priorities

MAST is well placed to make a strong contribution in the following areas:

- H-mode access & pedestal physics
- ELM control (incl. effects of RMPs on pedestal transport etc.) and alternative ELM regimes
- Disruption mitigation
- First wall divertor/wall heat loads (incl. effects of ELM control and disruption mitigation)
- Fuelling & particle transport
- Plasma rotation and momentum transport
- Electron transport
- Fast particle instabilities (incl. TAE damping), fast ion losses and impact (e.g. on NBCD)
- NTM control (via improved understanding of onset thresholds)

EFDA Work Programme

❑ Strong overlap with ITPA high priority R & D (as expected) with the addition of edge turbulence (characterisation of filamentary and intermittent edge and SOL turbulence).

❑ In particular, ELM control, disruption mitigation, L-H transition physics, pedestal physics are priority topics where we expect MAST to make a prominent contribution.

TRANSPORT, MHD: MAST can contribute to almost all key areas

HEATING, CURRENT DRIVE & FUELLING: MAST well placed to study off-axis current drive & rotation capability of NBI plus pellet fuelling physics

PWI: Will focus on transient heat loads in 2010 (PAC recommendation)

DIAGNOSTIC developments (priority financial support):

- Fast ion D_α measurements, FIDA (with FOM)
- neutron emission (with Uppsala University, Sweden)
- 2D BES (with HAS, RMKI Hungary)
- fast edge Doppler spectroscopy for high frequency velocity (v_ϕ) fluctuations

M8 (2010-11) – new capabilities

- Additional ELM coils (n = 4, n = 6) (PAC recommendation)
- 2D BES system for long wavelength turbulence measurements (with HAS, RMKI Budapest) – EFDA Task
- Collimated neutron detector (with Uppsala Univ.) – EFDA Task
- EBW emission imaging diagnostic (with York University) – EPSRC project
- Edge Doppler spectroscopy improvements for high frequency (≤ 100kHz) velocity (v_ϕ) fluctuation measurements (new detector – tender evaluation this week) – EFDA Task

Under development/consideration:

- Controllable mid-plane HFS fuelling
- Fast Ion D-Alpha (FIDA) diagnostic (with FOM) – EFDA Task
- Retarding field analyzers for edge T_i measurements
- Phase Contrast Imaging (PCI) system to extend turbulence measurements to higher wave-number (with NIFS, Japan) (PAC recommendation)

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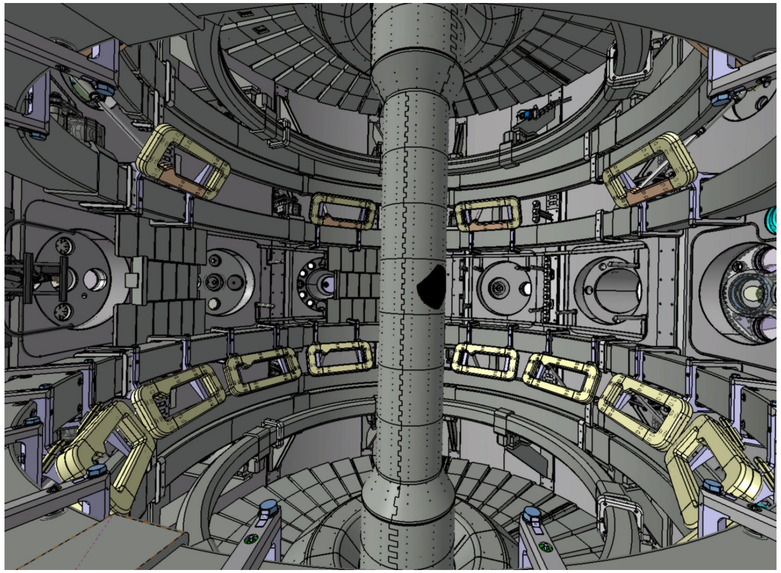
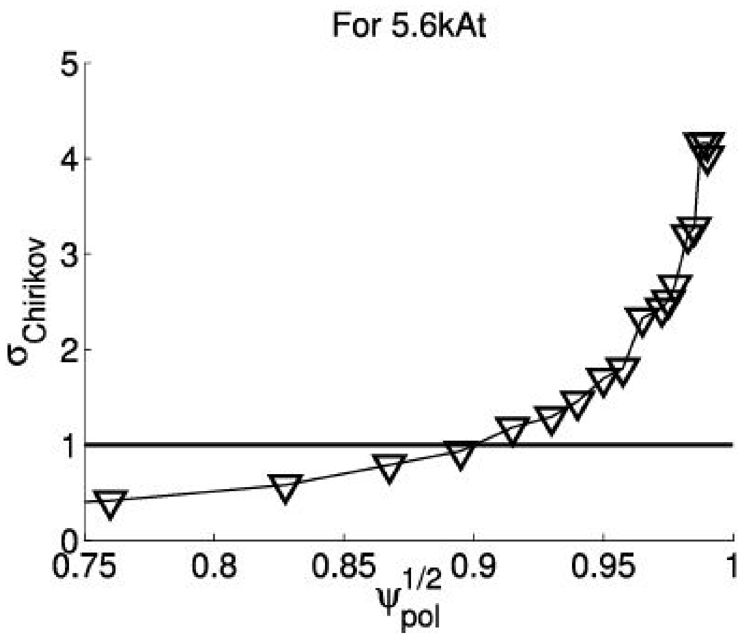
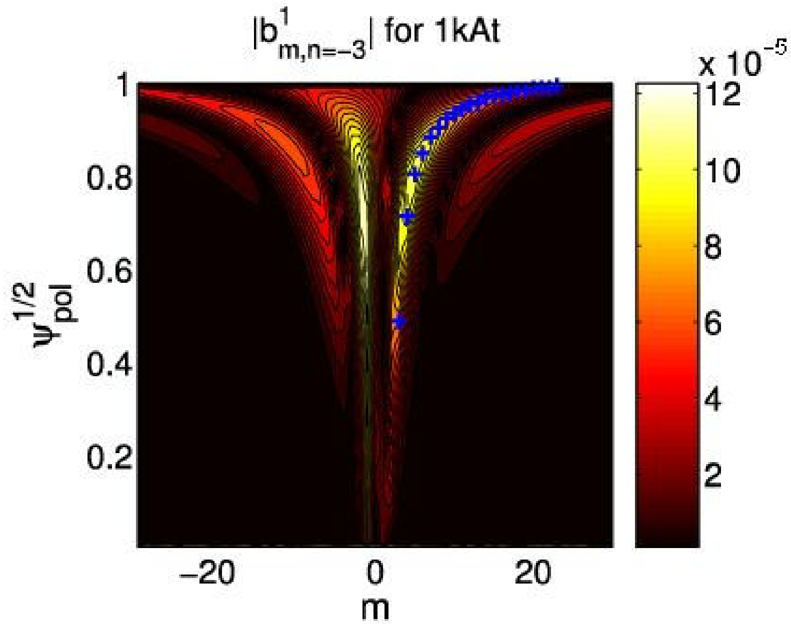
2010 – 6 additional ELM control coils

- Will install 6 additional coils in lower array

- Allows n=4 and n=6 configurations as well as better alignment to q_{95}~ 5 discharges





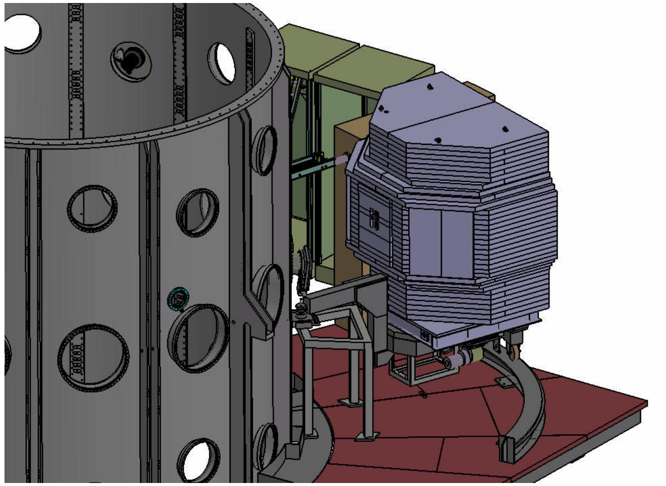


Collimated Neutron Detector

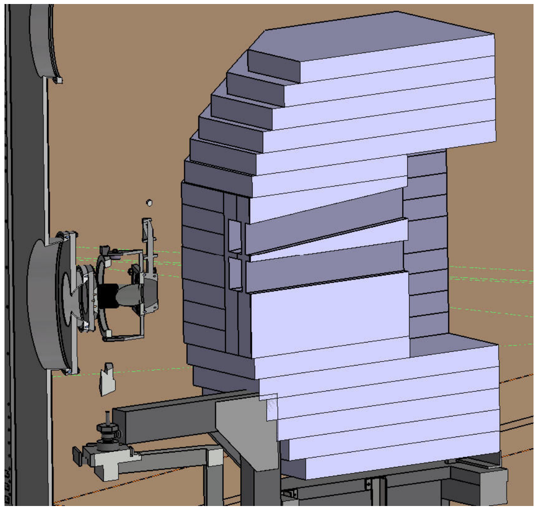
Collaboration with Uppsala University, Sweden – EFDA Task

❑ Flexible/modular neutron shielding (to allow collimator optimization)

❑ 4 channels (NE213 detectors) – orientation allows simultaneous monitoring of central and off-axis lines of sight and accommodates both DND and vertically displaced SND plasmas



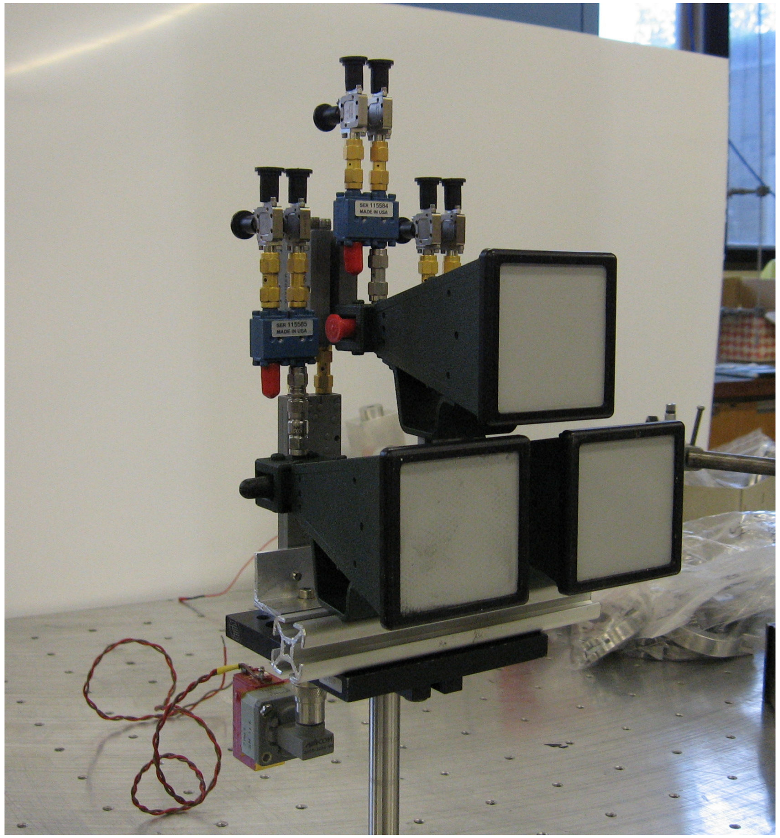
❑ Installation on the NPA rail (allows toroidal scanning)



EBW microwave imaging system

Collaboration with York University

- Combines aperture synthesis and phased array techniques with direct digitization of vector IF signals
- 3 dual polarized quad ridged horn antennas (10 – 40GHz)
- 12-bit fast (100MS/s) ADCs



Exploring the potential of electron Bernstein wave emission as an edge plasma current density profile diagnostic (preliminary results using a fast spinning mirror system obtained in M7b)

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