Recent results from the Australian Plasma Fusion Research Facility

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Plasma Fusion
Research Facility

The Australian Plasma Fusion Facility: Results from H1 and "MAGPIE"

The Facility

The Upgrade (2010-2013)

Result Overview: H-1NF

- **Data mining**
- **Alfvénic Scaling**
- **Optical Measurements**
- **Radial Structure**

The Materials Diagnostic Test Facility - MAGPIE Results

- **Objectives**
- **Initial Operation**
- **Initial Results**

Conclusions/Future

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H-1NF: the Australian Plasma Fusion Research Facility

Originally a Major National Research Facility established by the Commonwealth of Australia and the Australian National University

Mission:

- Detailed understanding of the **basic physics of magnetically confined** hot plasma in the HELIAC configuration
- Development of advanced **plasma measurement** systems
- Fundamental studies including turbulence and transport in plasma
- Contribute to global research effort, maintain **Australian presence** in the field of plasma fusion power

MoU's for collaboration with:

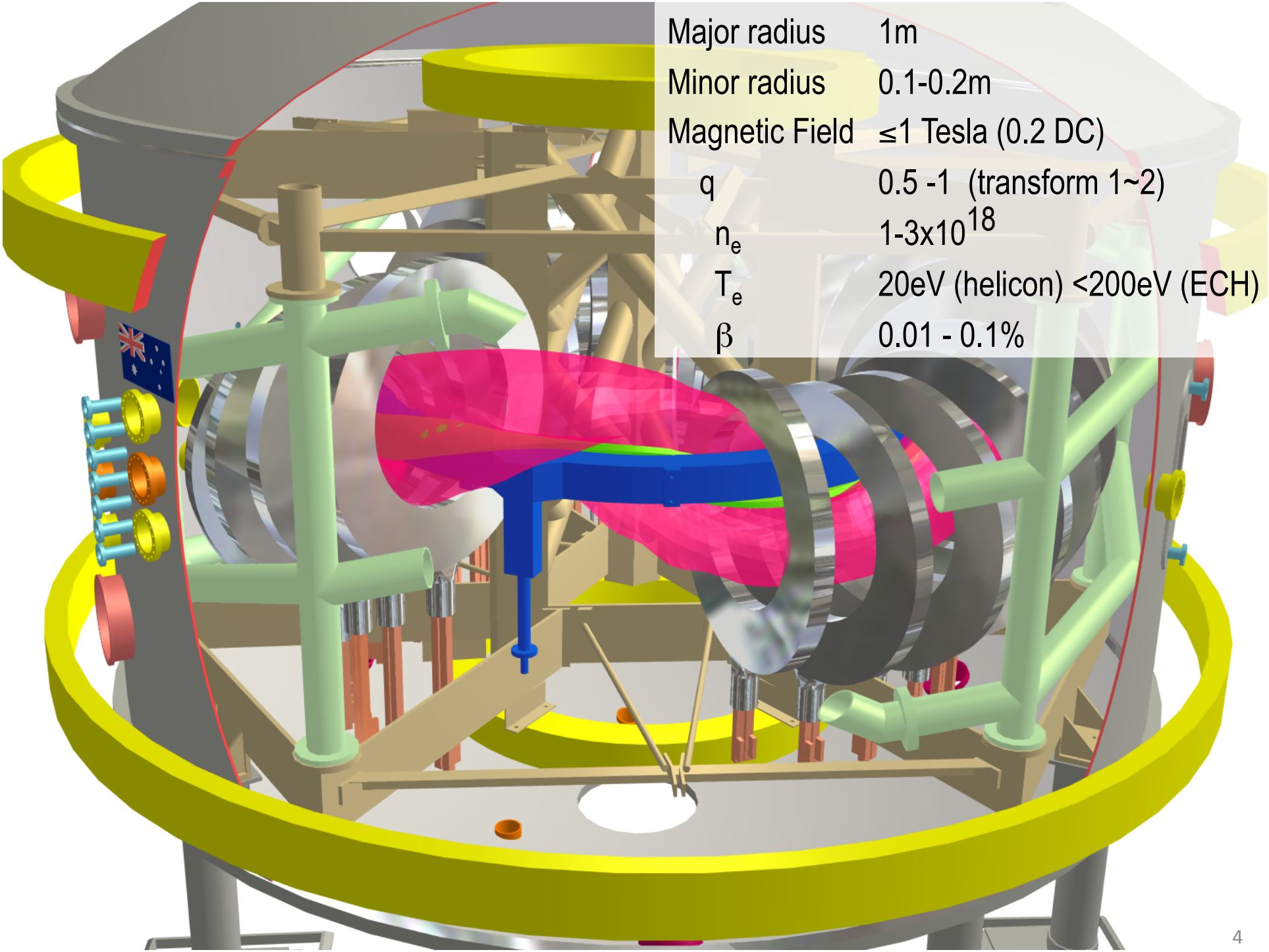
Members of the IEA implementing agreement on development of stellarator concept.

National Institute of Fusion Science of Japan, Princeton Plasma Physics Lab

Australian Nuclear Science and Technology Organisation

Australian Government | ansto Nuclear-based science benefiting all Australians

AINSE



Major radius	1m
Minor radius	0.1-0.2m
Magnetic Field	≤1 Tesla (0.2 DC)
q	0.5 -1 (transform 1~2)
n_e	$1\text{-}3\times10^{18}$
T_e	20eV (helicon) <200eV (ECH)
β	0.01 - 0.1%

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The Facility Infrastructure Upgrade 2010-2013

- Consolidate the facility infrastructure required to implement the ITER forum strategy plan
- Expand coverage to the full spectrum of ITER forum activities
  e.g. MDF above
- User friendly access to data

New/Upgraded Diagnostics

- 20 Channel hi-res imaging interferometer
- Synchronous and coherence imaging cameras
- Additional 48 channel helical Mirnov array
- LIF diagnostic (MDF)
- Imaging impurity camera

3rd configuration control parameter

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The Facility Infrastructure Upgrade (ctd)

Upgraded RF Systems

RF (4-20MHz) will be the "workhorse"

New system doubles power: 2x180kW systems.

New movable shielded antenna to complement "bare" antenna (water and gas cooled).

Advantages:

New system allows magnetic field scan while keeping the resonant layer position constant. e.g.scaling of MHD – e.g. Alfvénic? GAM?

Improved Impurity Control

Impurities limit plasma temperature (at present: C, O, Fe, Cu)

High temperature (>~100eV) desirable to excite spectral lines relevant to edge plasma and divertors in larger devices.

Strategy - Combine:

- Glow discharge cleaning for bulk of tank
- Pulsed RF discharge cleaning for plasma facing components.
- Low temperature (90C) baking , Gettering

Thomson 2 x 200kW 4-20MHz RF System

New cooled RF Antenna – helicon/ICRF

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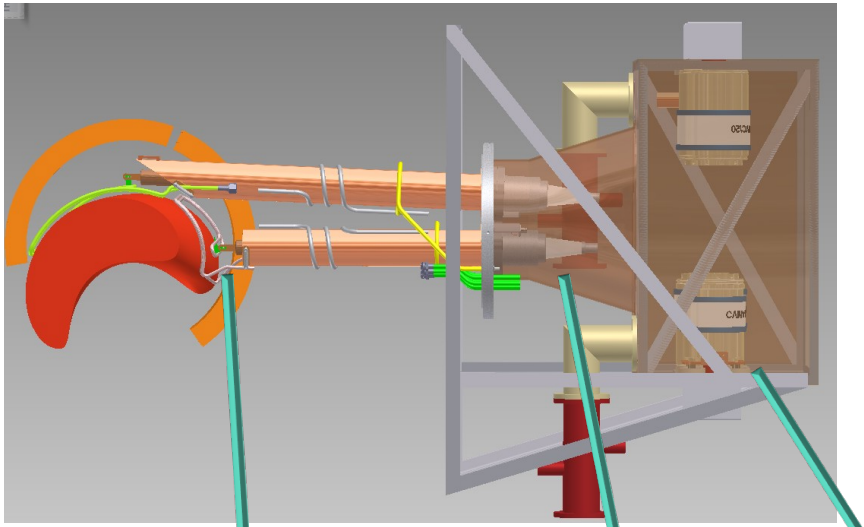
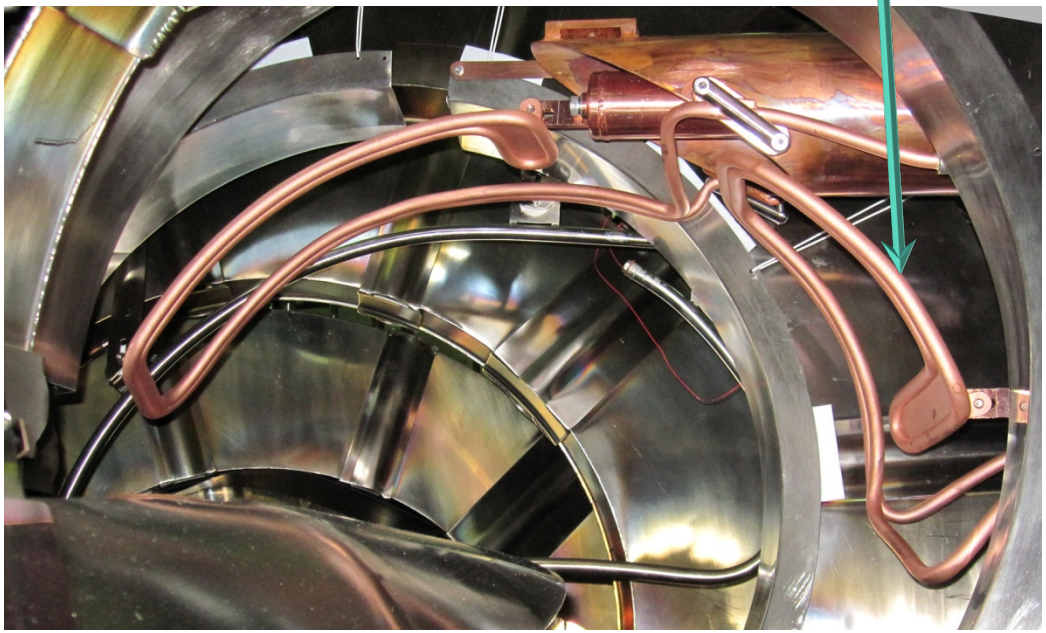
Antenna contoured to plasma shape

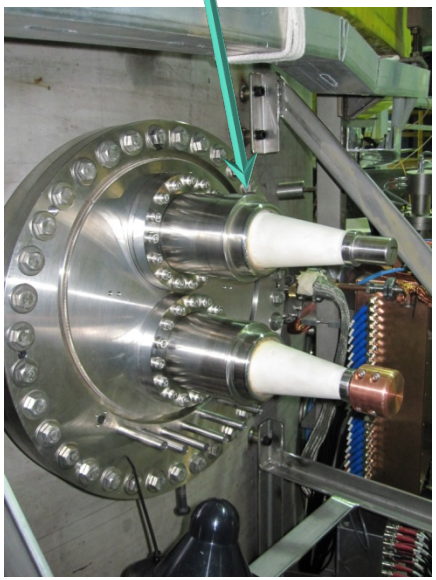


Insulators/

Vacuum feed through

Tuning box





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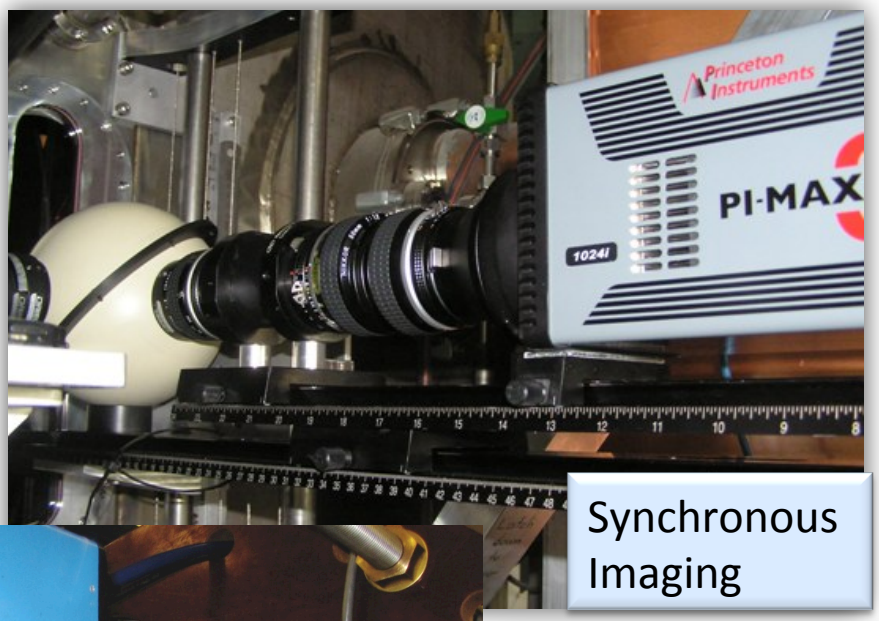
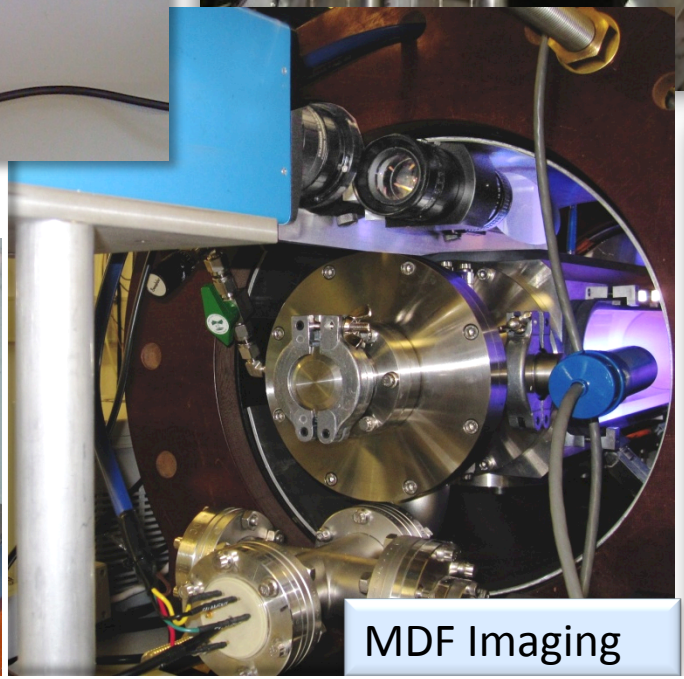
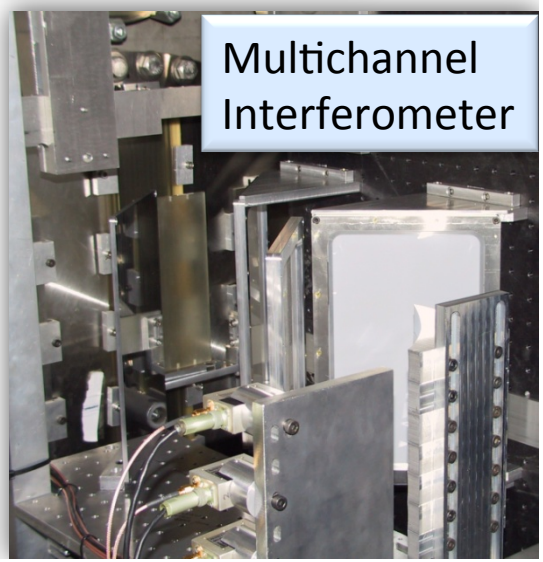
Diagnostic and Control Upgrades

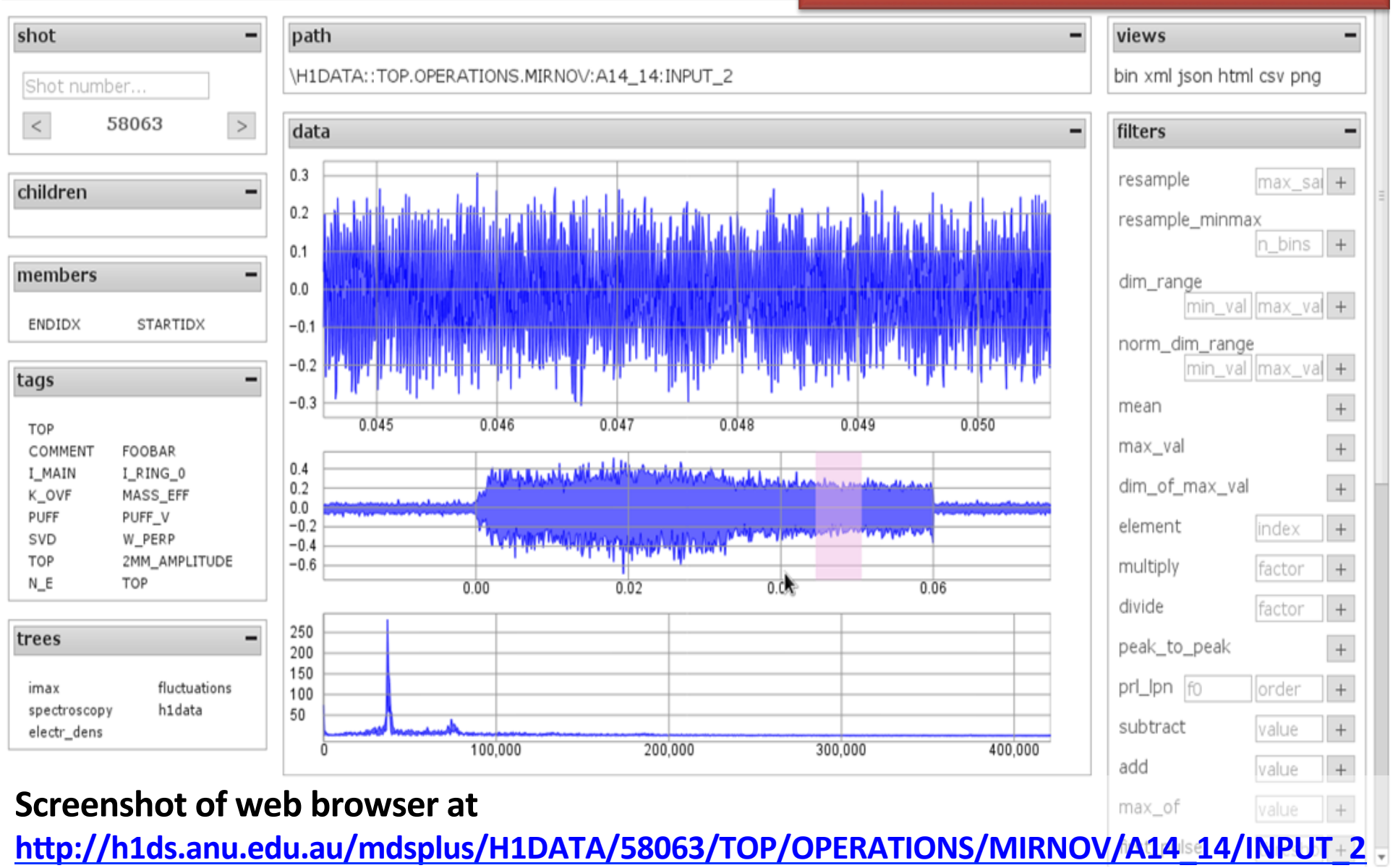






Powerful web-based data browser

- Low bandwidth required, open source
- Full data resolution accessible
- Same access for binary xml csv forms
  ~~firewall issues~~ ~~viewer software~~



Screenshot of web browser at
http://h1ds.anu.edu.au/mdsplus/H1DATA/58063/TOP/OPERATIONS/MIRNOV/A14_14/INPUT_2

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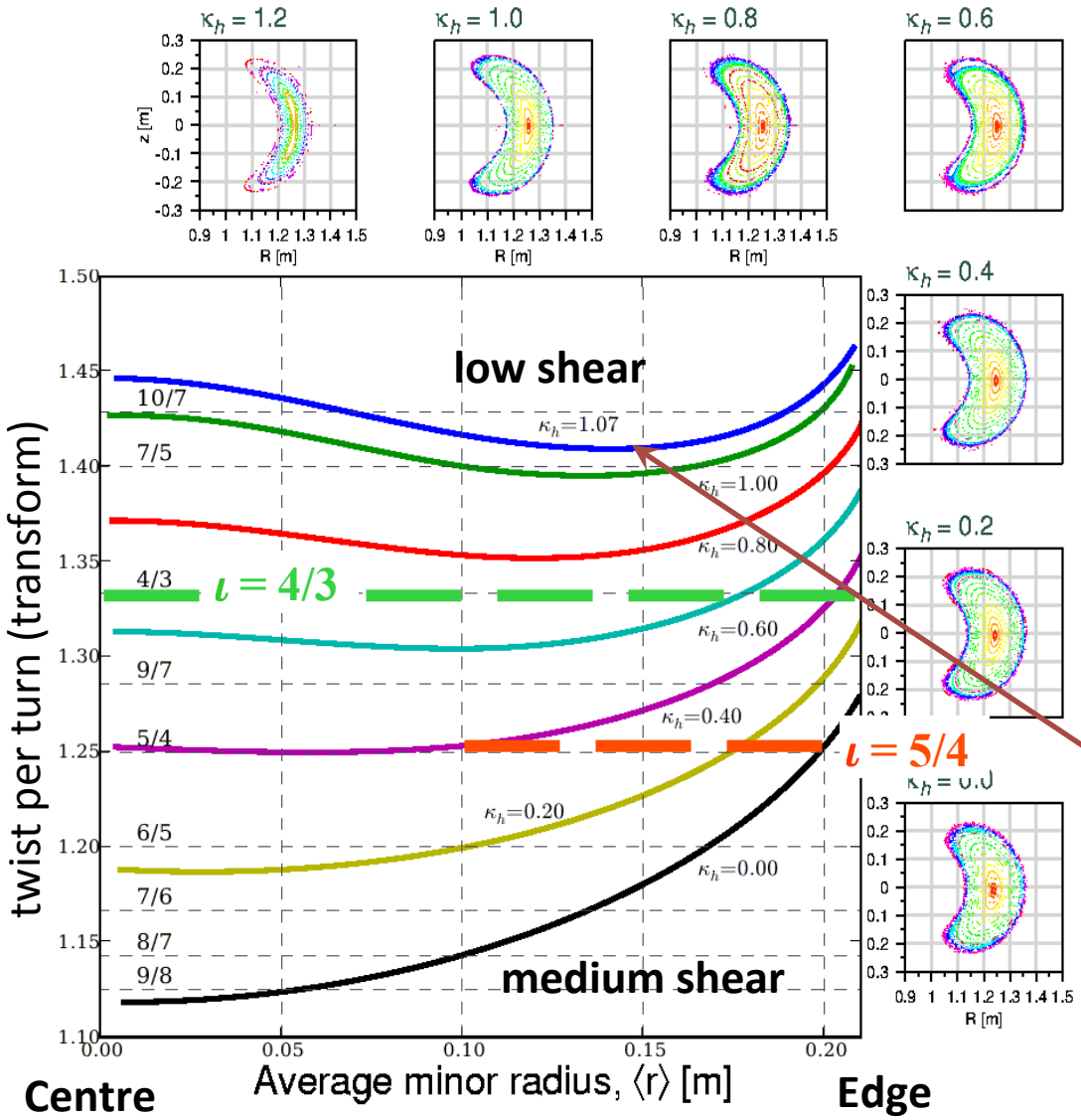
Overview of H-1 results

H-1 configuration is very flexible



- ***"flexible heliac"*** :
  helical winding, with
  helicity matching the plasma,
  ⇒ 2:1 range of twist/turn

- H-1NF can control 2 out of 3 of
  transform (ι)
  magnetic well and
  shear Δι (spatial rate of change)

- **Reversed Shear**
  → like Advanced Tokamak mode of operation

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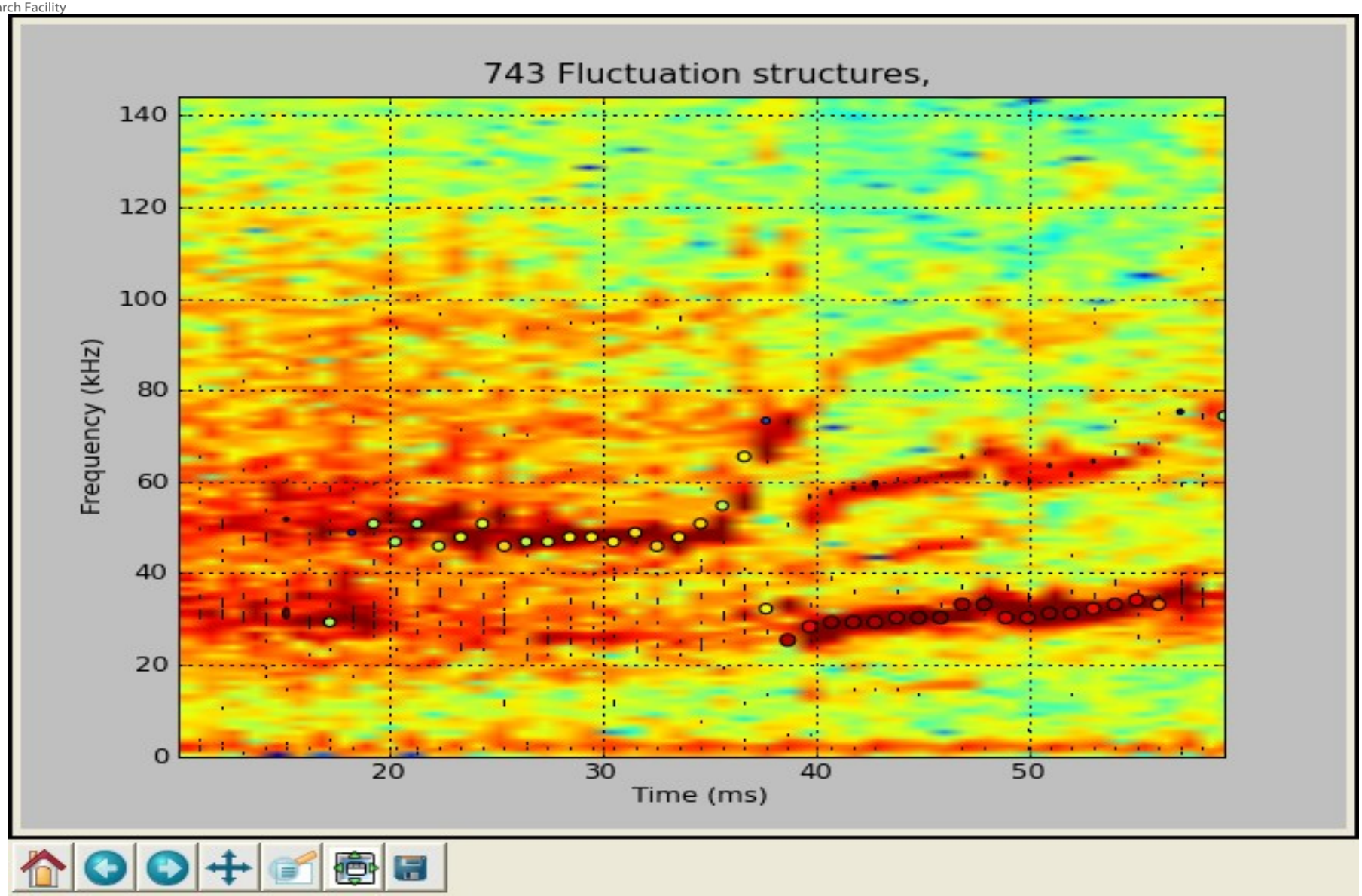
MHD/Mirnov fluctuations in H-1



Shaun Haskey
David Pretty

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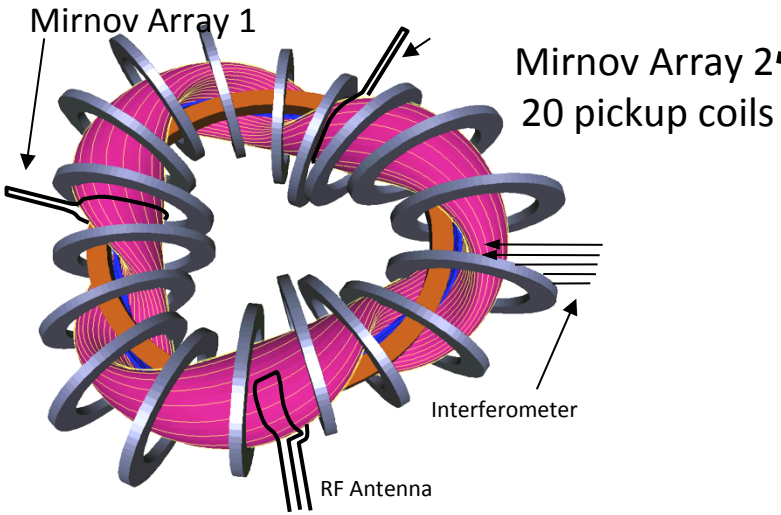
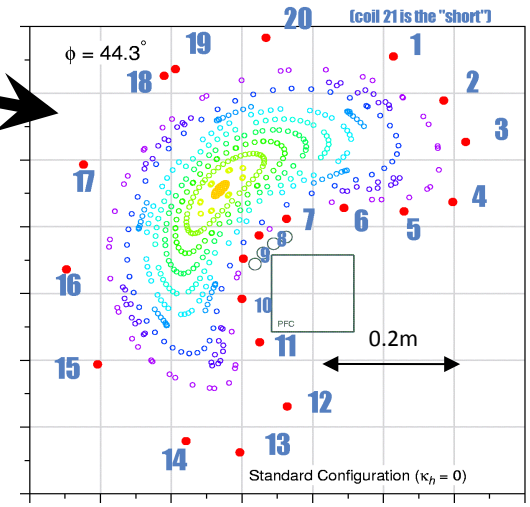
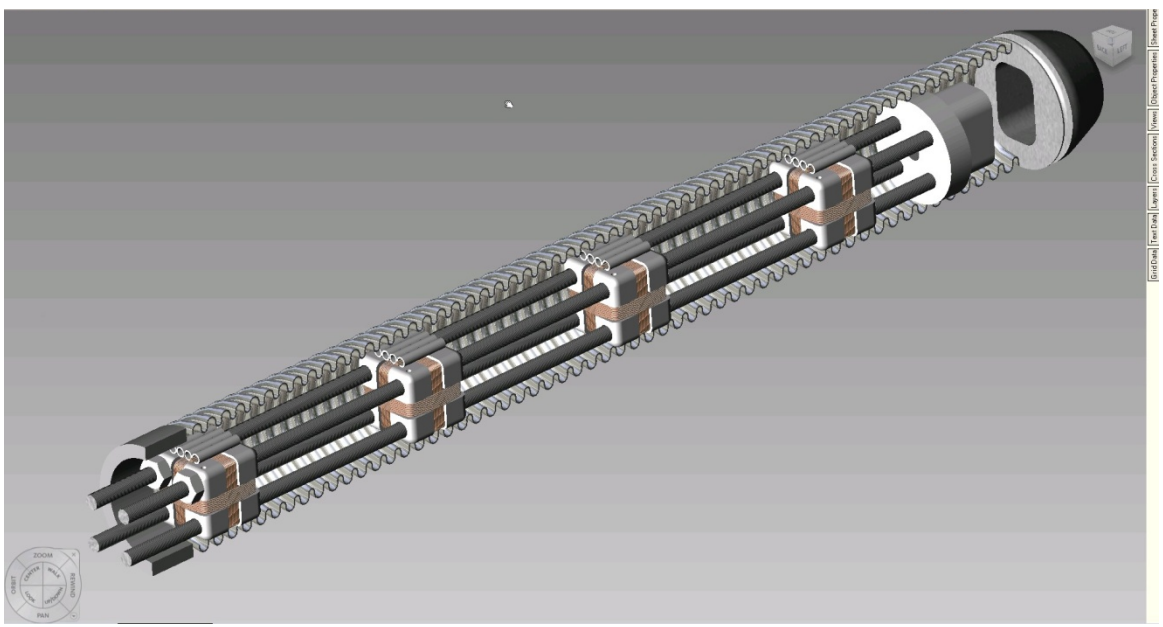
Three Mirnov Arrays (Toroidal)







New Toroidal Array

Coils inside a SS thin-wall bellows (LP, E-static shield)

Access to otherwise inaccessible region with

- largest signals and
- with significant variation in toroidal curvature.

Flucstruc analysis via SVD → phase vs ϕ

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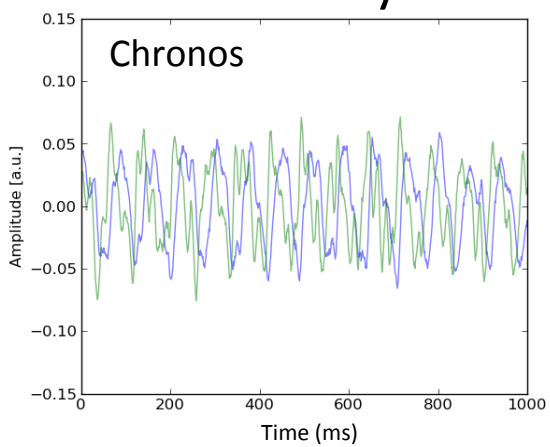
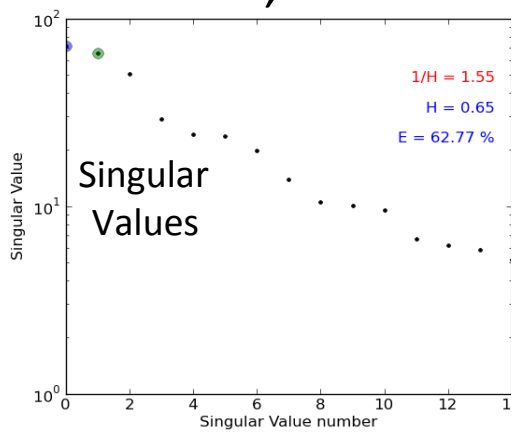
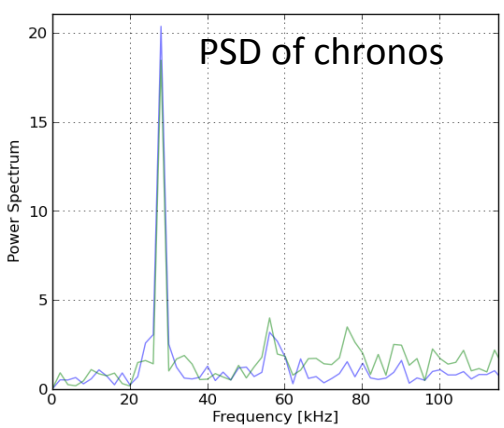
Singular vectors are grouped by similarity to separate simultaneous modes

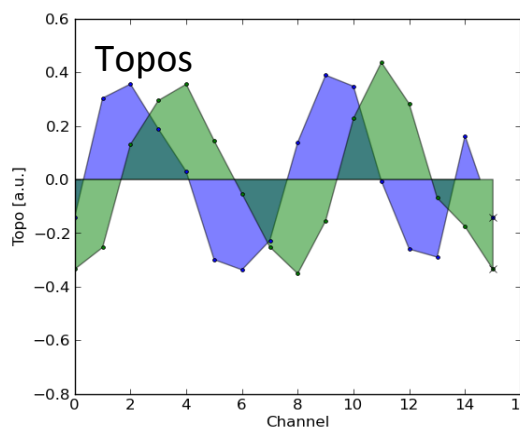
Follows plasma shape, amplitude variation is much less

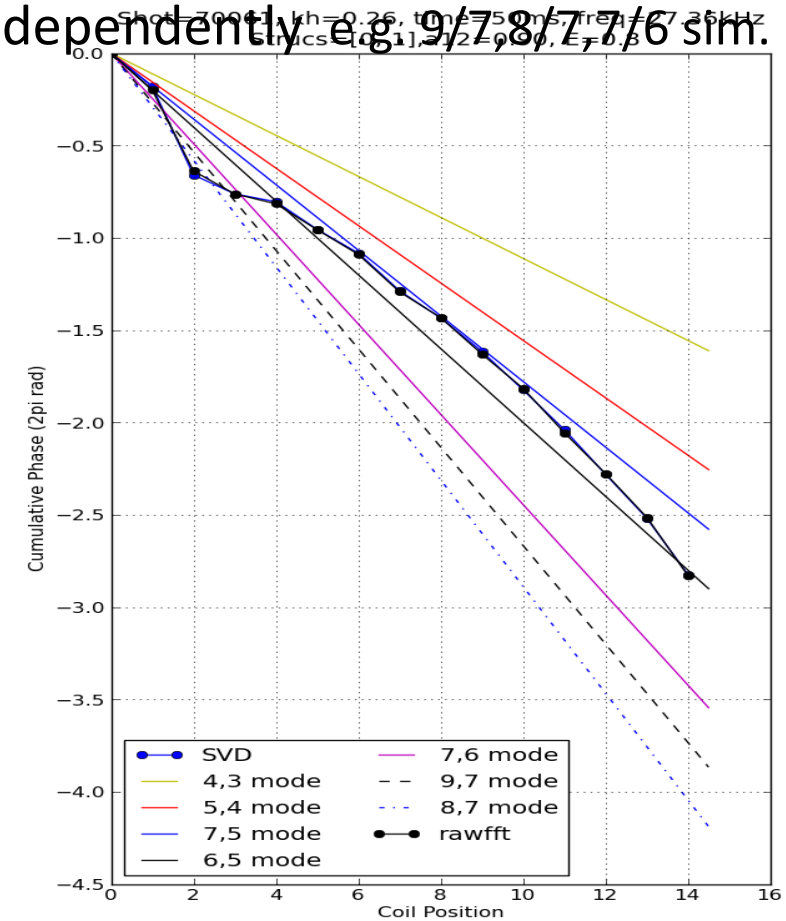
Helical Array resolves n and m, but not independently e.g. 9/7,8/7,7/6 sim.





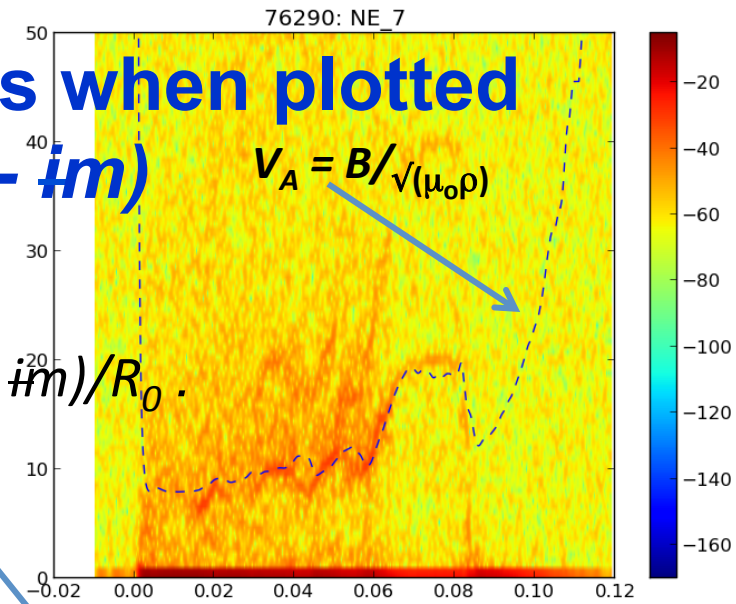


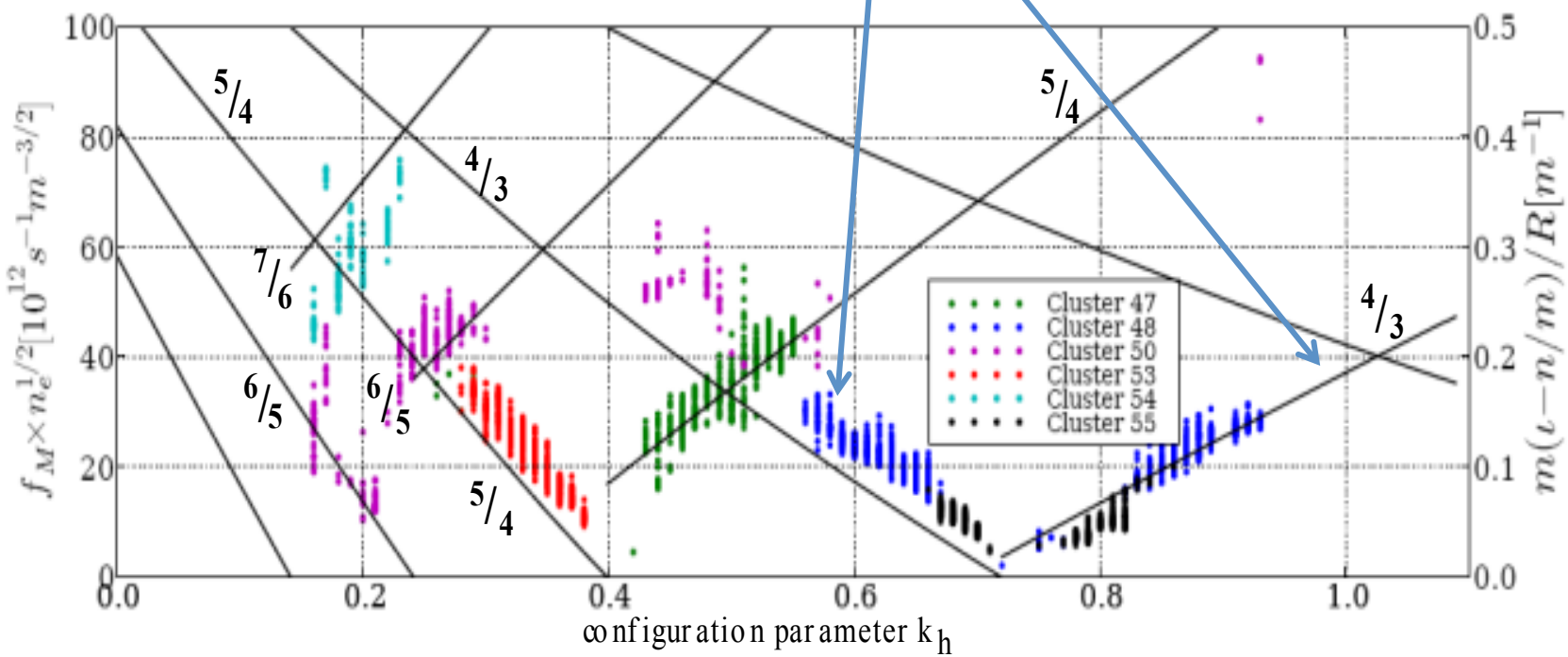




Modes cluster in V-shapes when plotted against $k_{||} \sim (n - \iota m)$

Shear Alfvén modes: $\omega = k_{||} V_A = V_A(n - \iota m)/R_0$.

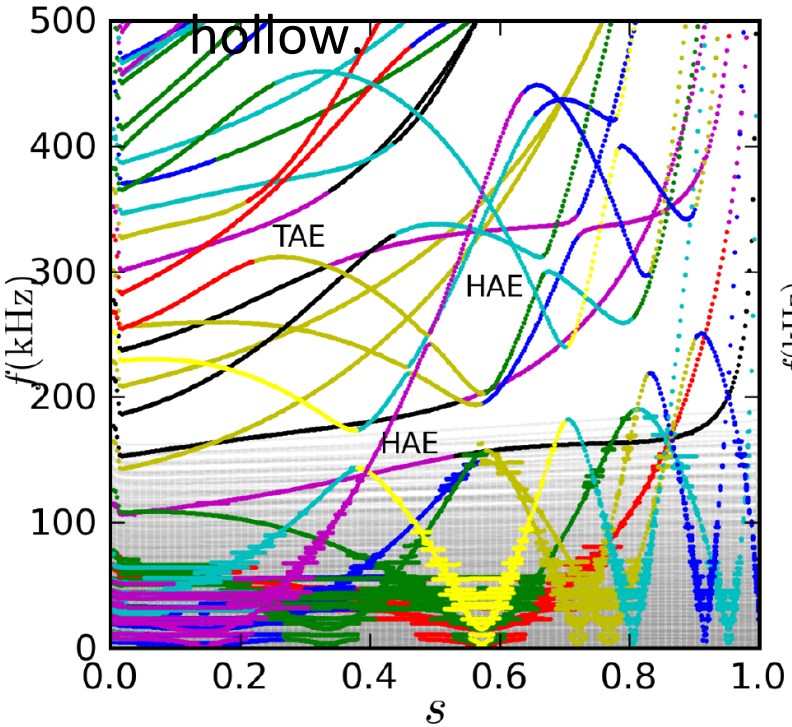


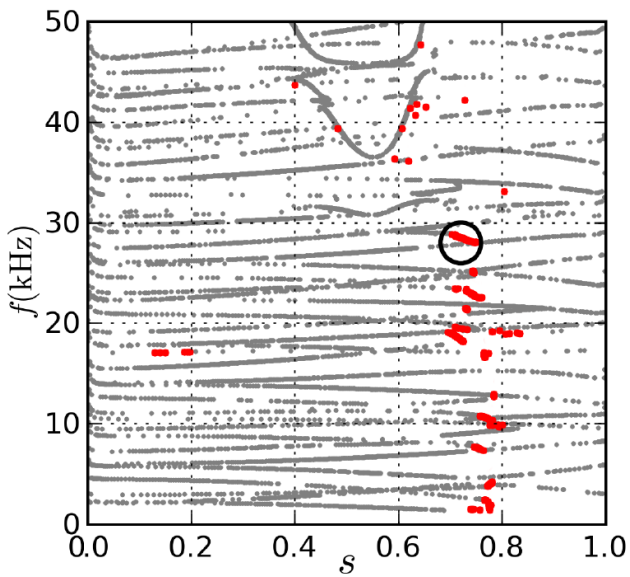


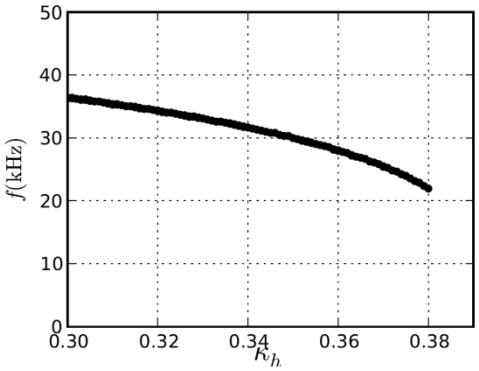
CAS3D Studies

Jason Bertram
Matthew Hole
Carolin Nührenberg

- Bumpiness (mirror) term in H-1 field requires hundreds of Fourier components to represent parallel displacement.
- This gives rise to a dense sound mode population in the range of interest (0-100kHz) – which interact with the shear modes.
- There are global modes here due to the finite beta gap (BAE)
- Such modes can exhibit a similar but weaker frequency dependence as our "whale tails" if the temperature profile is very hollow.







Can be resolved by:
B scan or
polarization study

Optical Imaging of Internal Mode Structure

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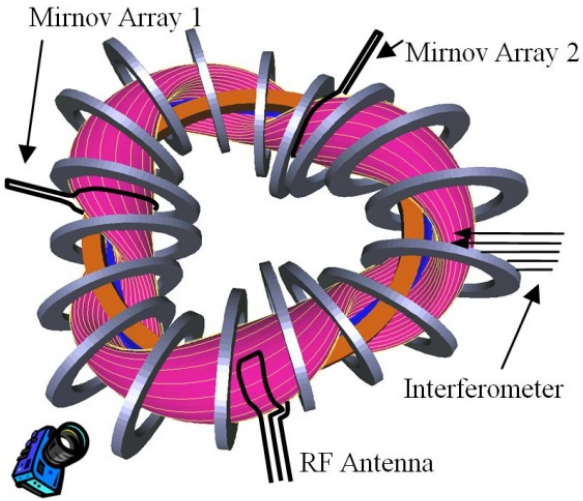
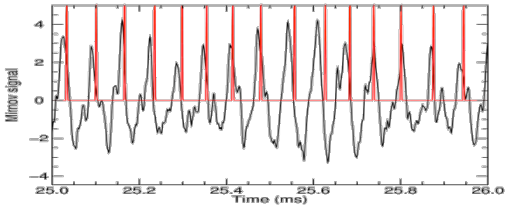
John Howard
Nandika Thapar
Jesse Read



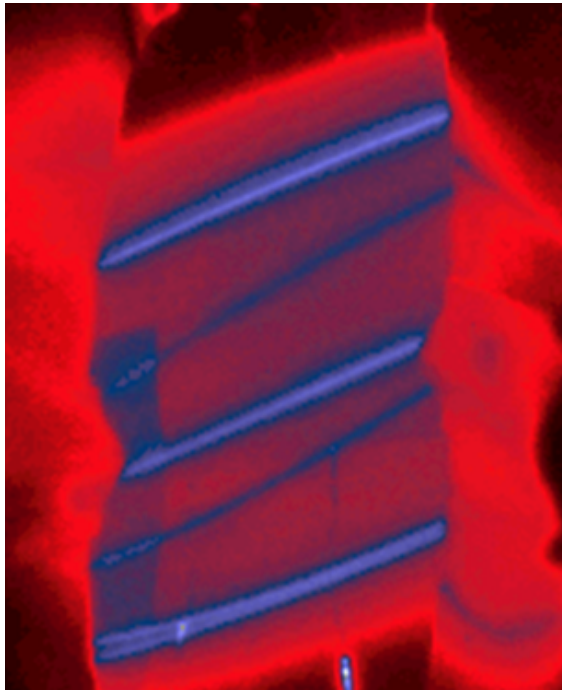
- Intensity ~ proxy for n_e
- CCD camera captures vertical view of plasma light, **synchronised** with the Mirnov signals, **averaged** over many cycles.

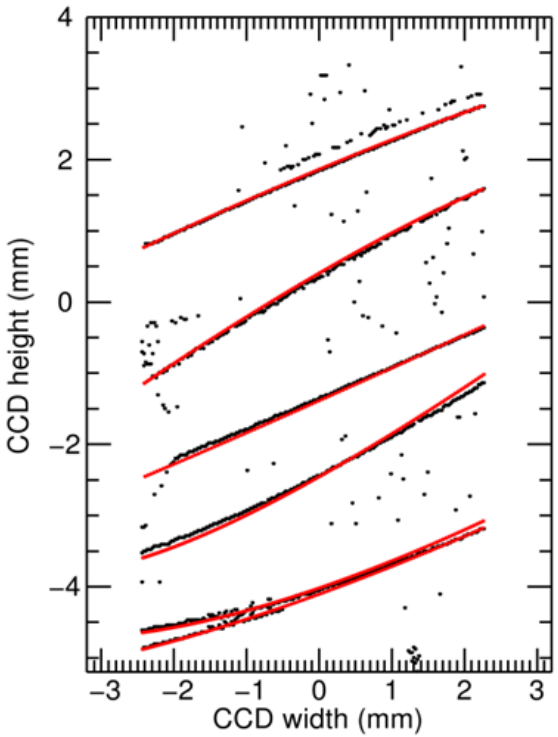
Phase locked loop waveforms



Calibrating View Geometry with eBeams

Field lines from accurate magnetic model (red) are matched with ebeam images (black)





J. Howard: Synchronous Imaging of MHD Modes in H-1

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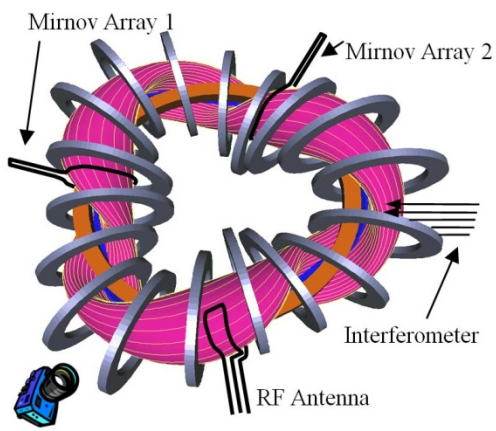
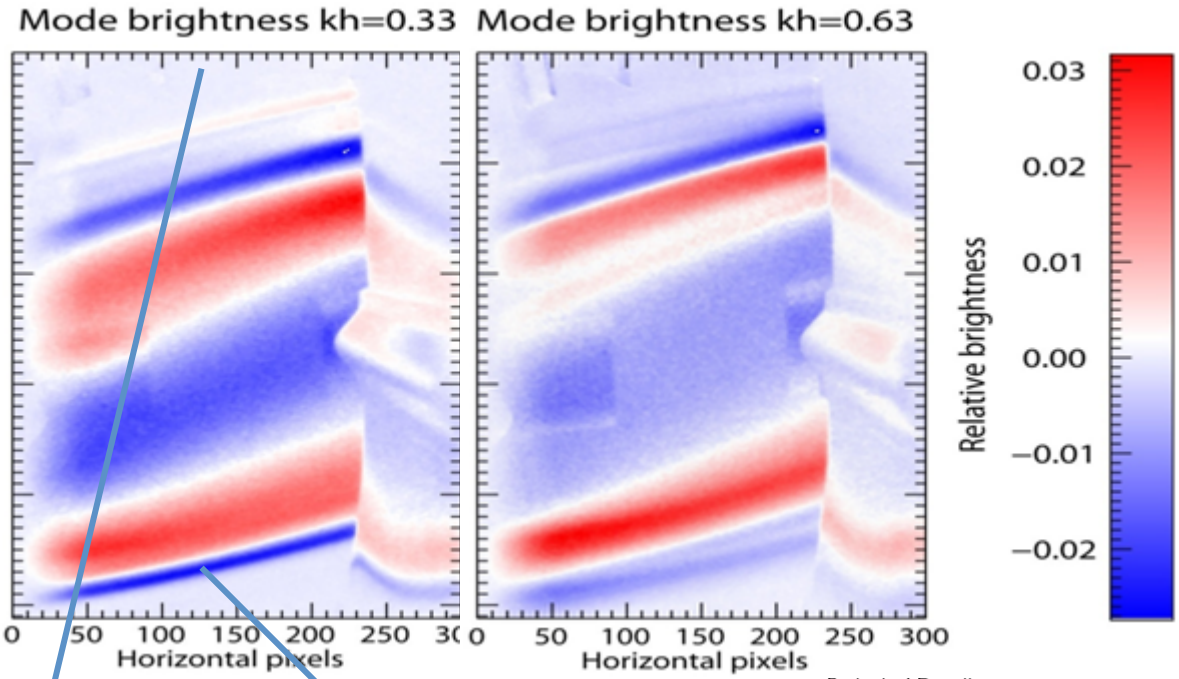
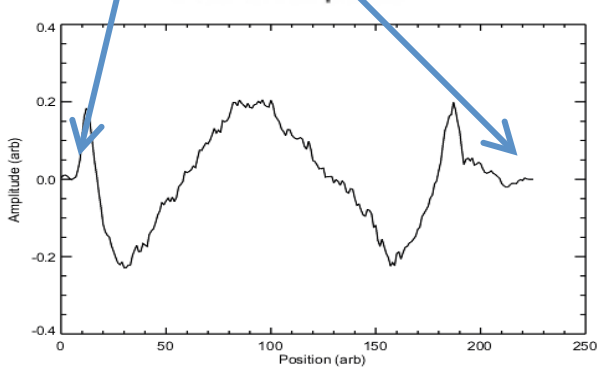
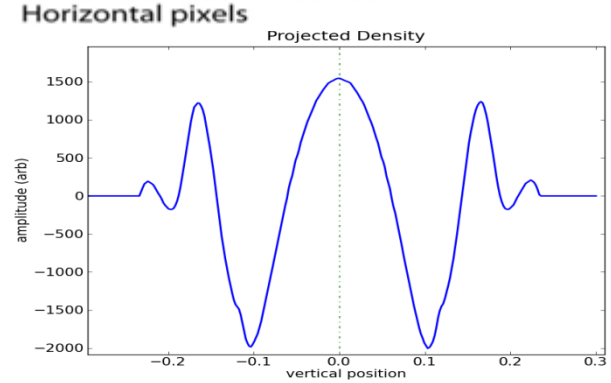




Vertical view of plasma light synchronised with the Mirnov signals and averaged over many cycles.



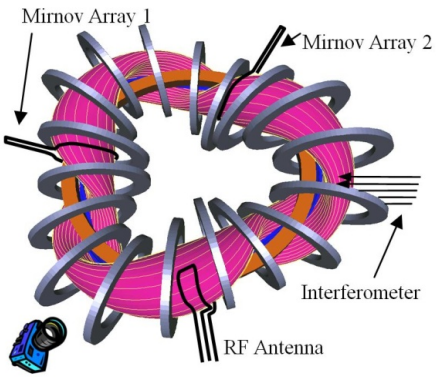


Left: Intensity profile at the cross-section of the dashed line

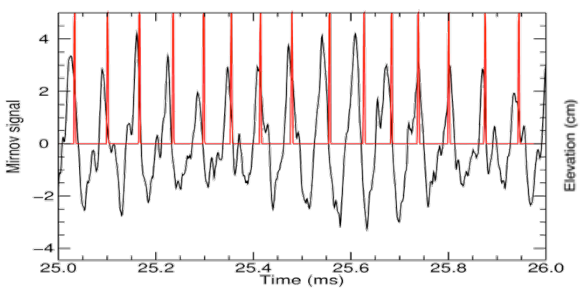
Right: CAS-3D MHD code prediction of electron density.

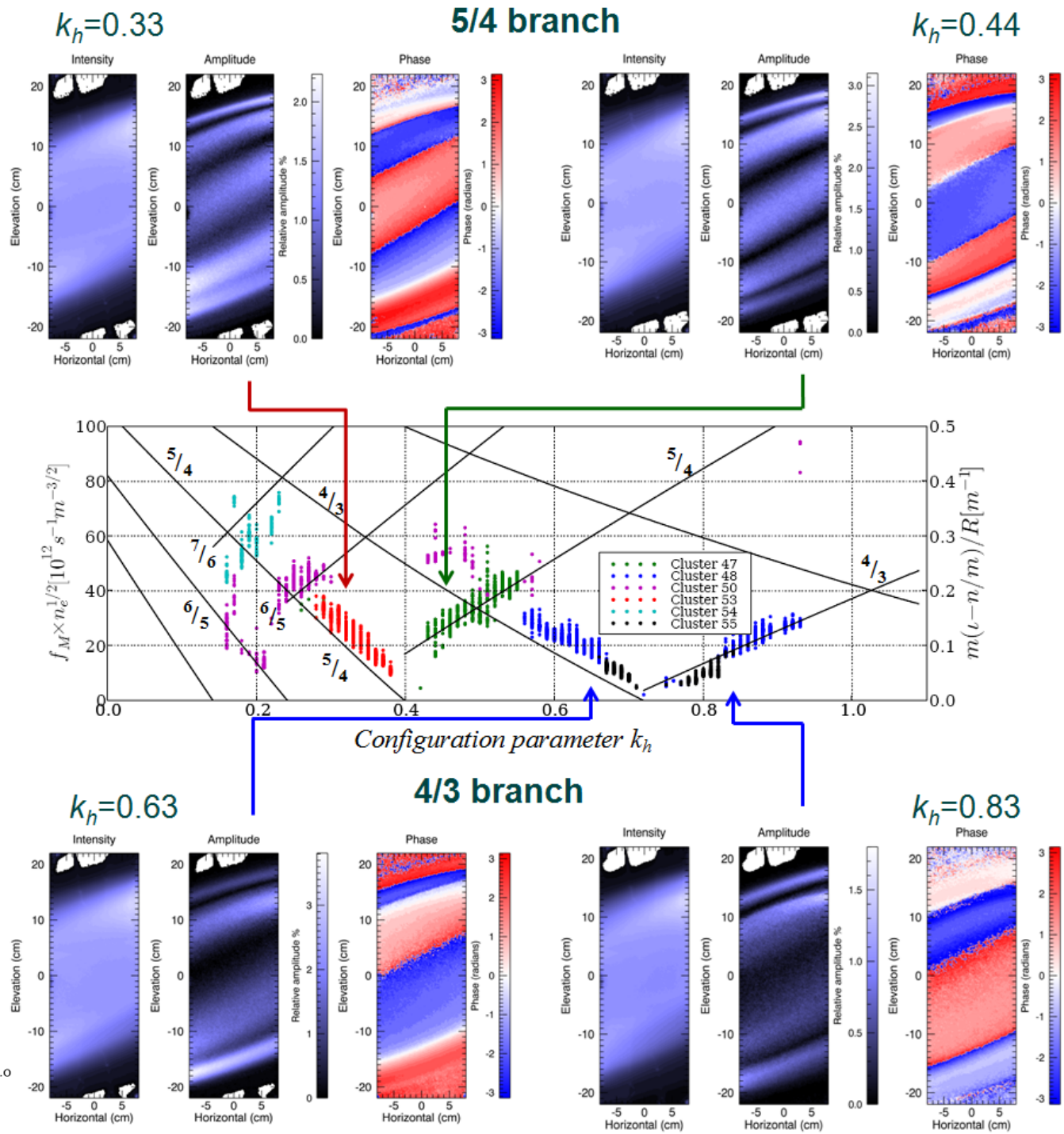
J. Howard, J. Read,
J. Bertram , B. Blackwell

Synchronous imaging: configuration scan



Vertical view of plasma light synchronised (gated intensified camera) with the Mirnov signals and averaged over many cycles.





Doppler Coherence Imaging on H-1

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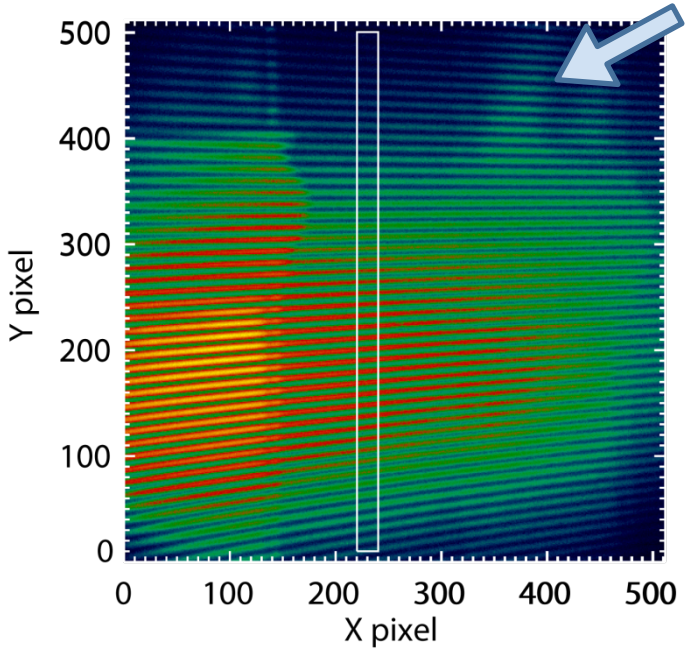
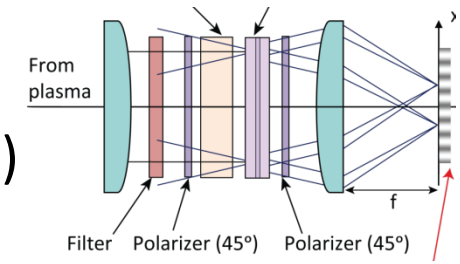


Raw spatial heterodyne image (0.1T Argon)

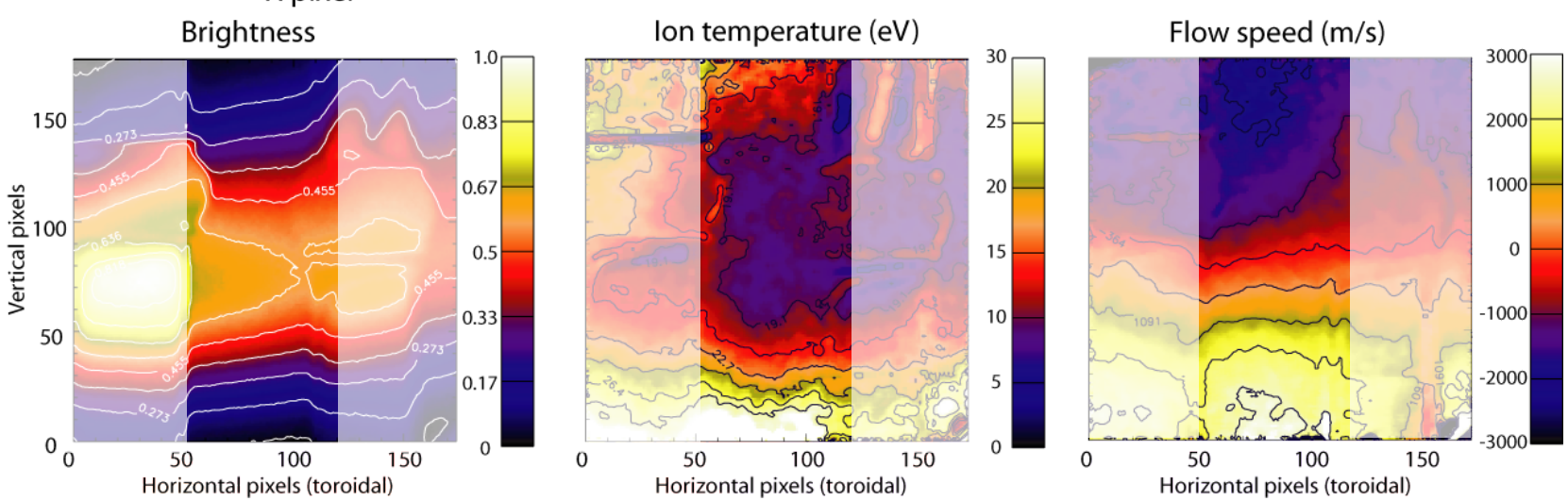


Interference fringes encode:

- velocity ← phase (shift)
- temperature ← contrast

Results:

- Ion temperature is hollow (10-25eV)
- Rigid rotation of +/- 3km/sec at outer radii
- Reflections from TF coils → some degradation



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Future

H-1

- Use all 3 axes of the Toroidal Mirnov Array → polarisation
- Bayesian MHD Mode Analysis
- Toroidal visible light imaging (Neon, He)
- Correlation of multiple visible light, Mirnov and $\tilde{n}_e$ data
- Spatial and Hybrid Spatial/Temporal Coherence Imaging
- 3rd control param→ Island, chaotic and open field line physics

Materials Diagnostic Facility (MAGPIE prototype)

- Need to understand the plasma first
- Plasma Surface Interaction physics
- Sample holder is currently in development
- Initial material testing is beginning soon…..
- Access to 80 kW RF, magnets and cooling from H-1 Heliac stellarator