Status and plans for the H-1 Heliac experiment

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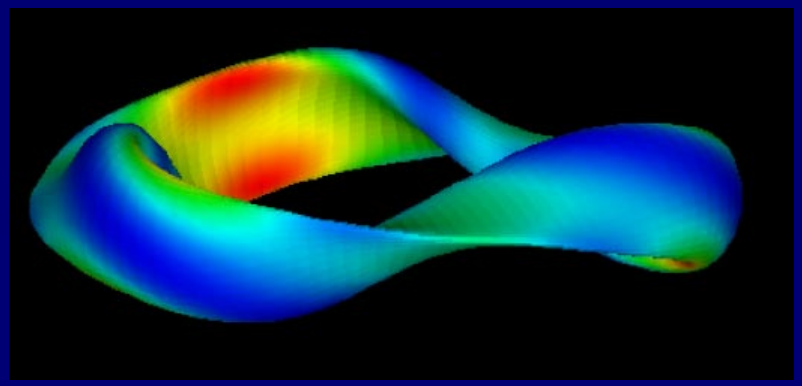
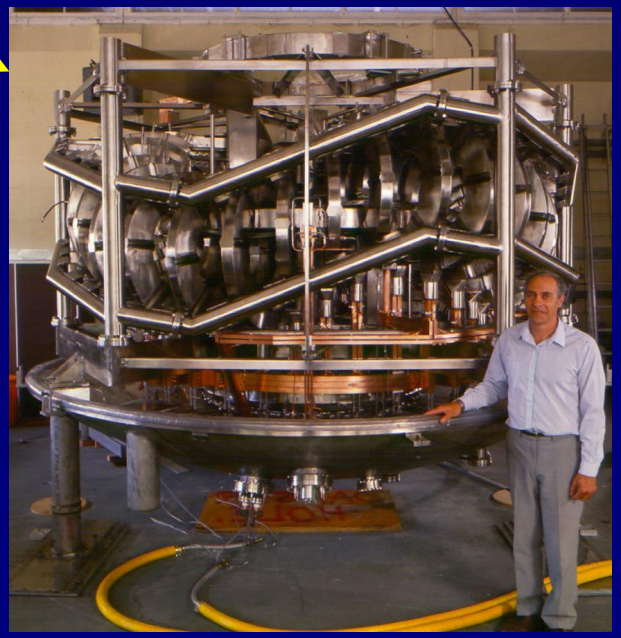
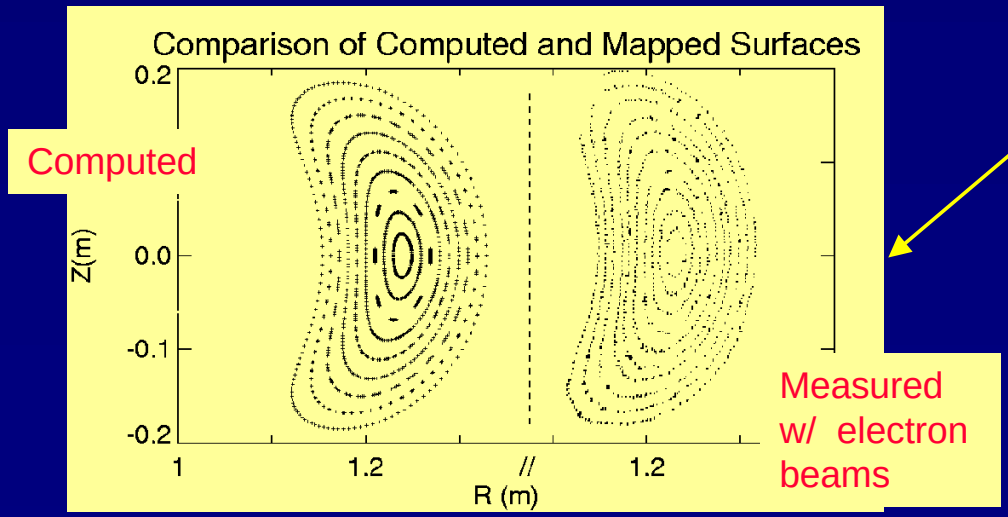
H-1NF Heliac: from concept to experiment



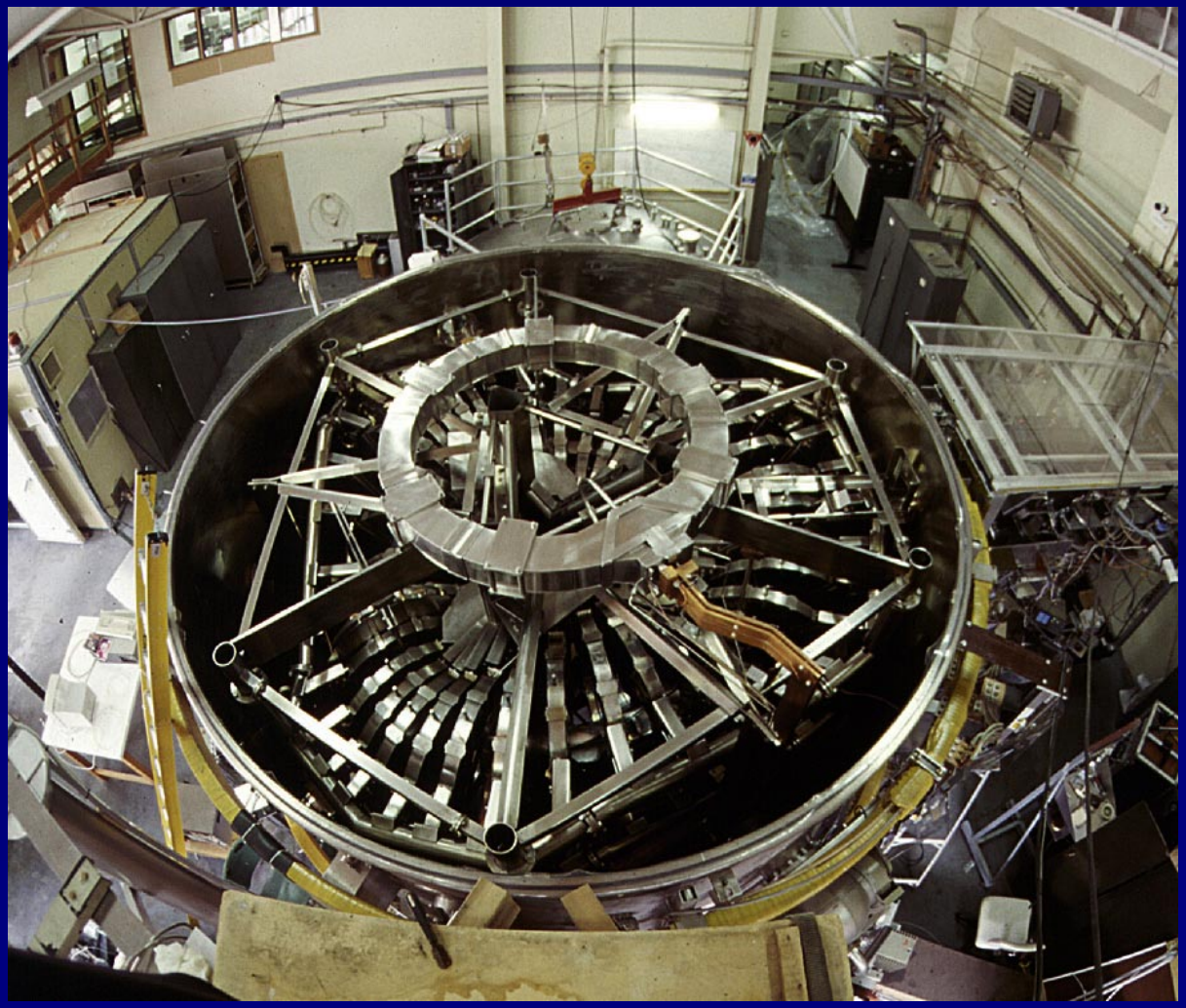
- Helical axis
- Huge flexibility in ι (0.6⇒2), well using helical control winding
- Fundamental toroidal conf. physics





Major radius = 1 m
Plasma minor radius = 0.2 m

Top view of H-1NF with vessel lid removed

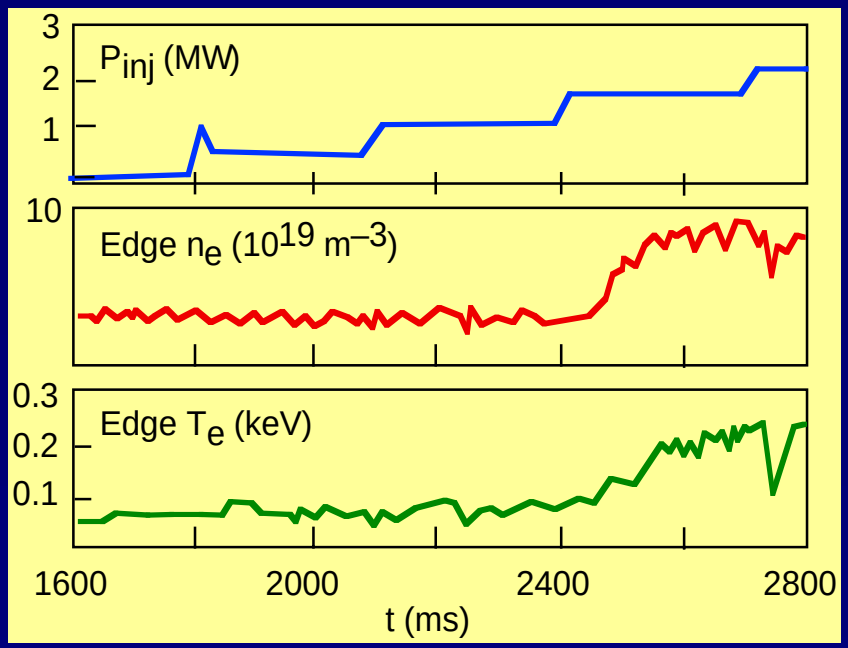


Interior panorama of H-1

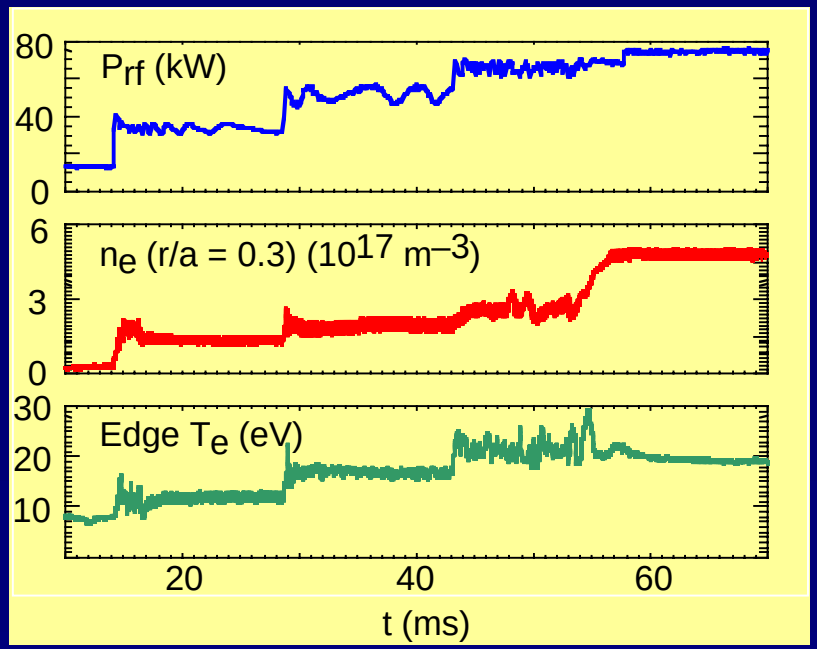
⇐ toroidal angle ⇒

H-1 operation at low field (< 0.2 T) & power (< 100 kW)
⇒ confinement transitions
⇒ similar to larger devices at 20 × higher power

D3D tokamak

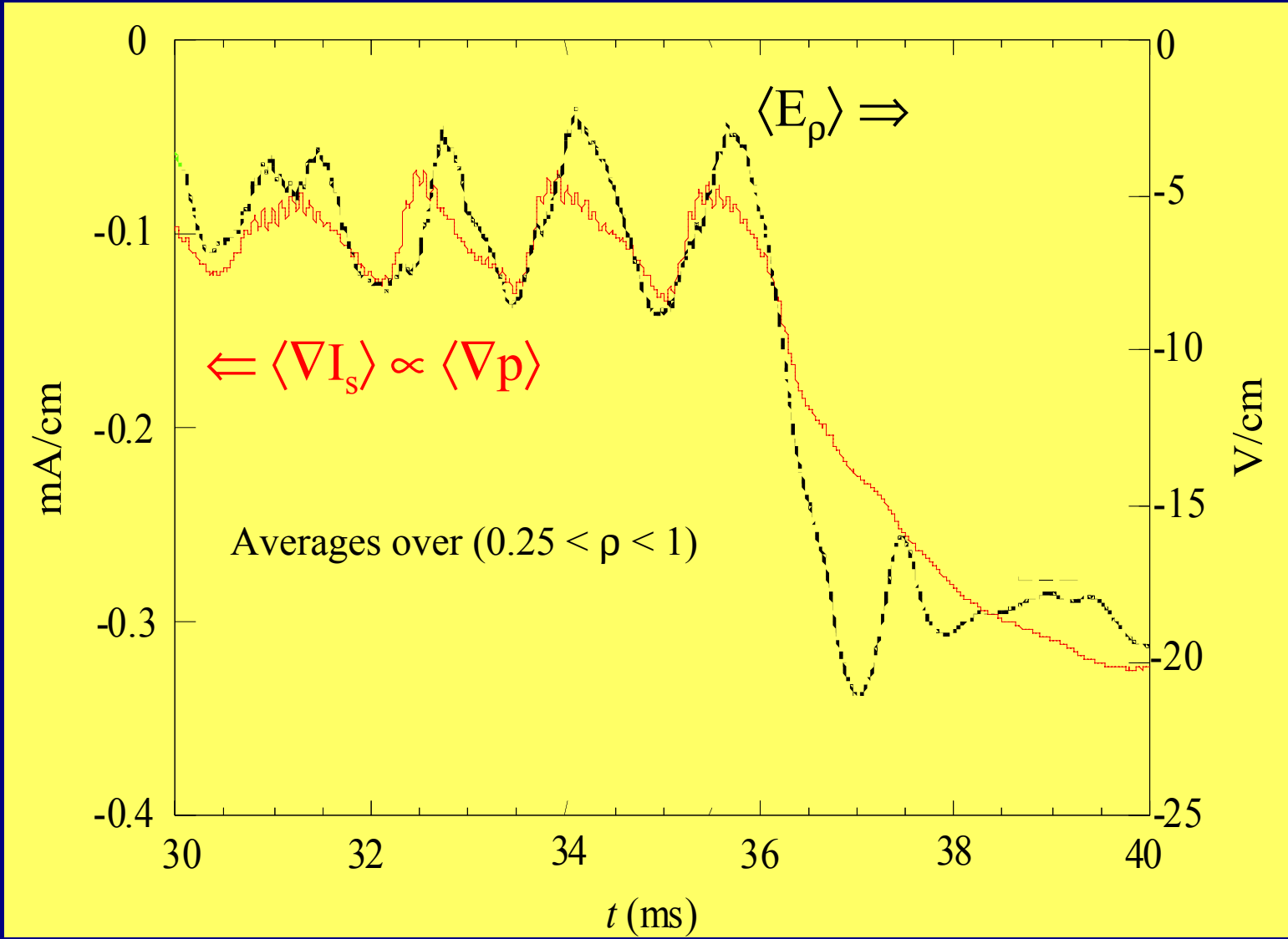


H-1



- Low temperatures in H-1 permit study w/ simple diagnostics.
- Change of n(r), turbulence suppression, even reversal of induced flux.
- Collaboration w/ larger exp'ts to elucidate mechanisms, recipes.

Radial electric field changes with ∇p



H-1 ⇒ H-1NF with additional capital funding of $6M

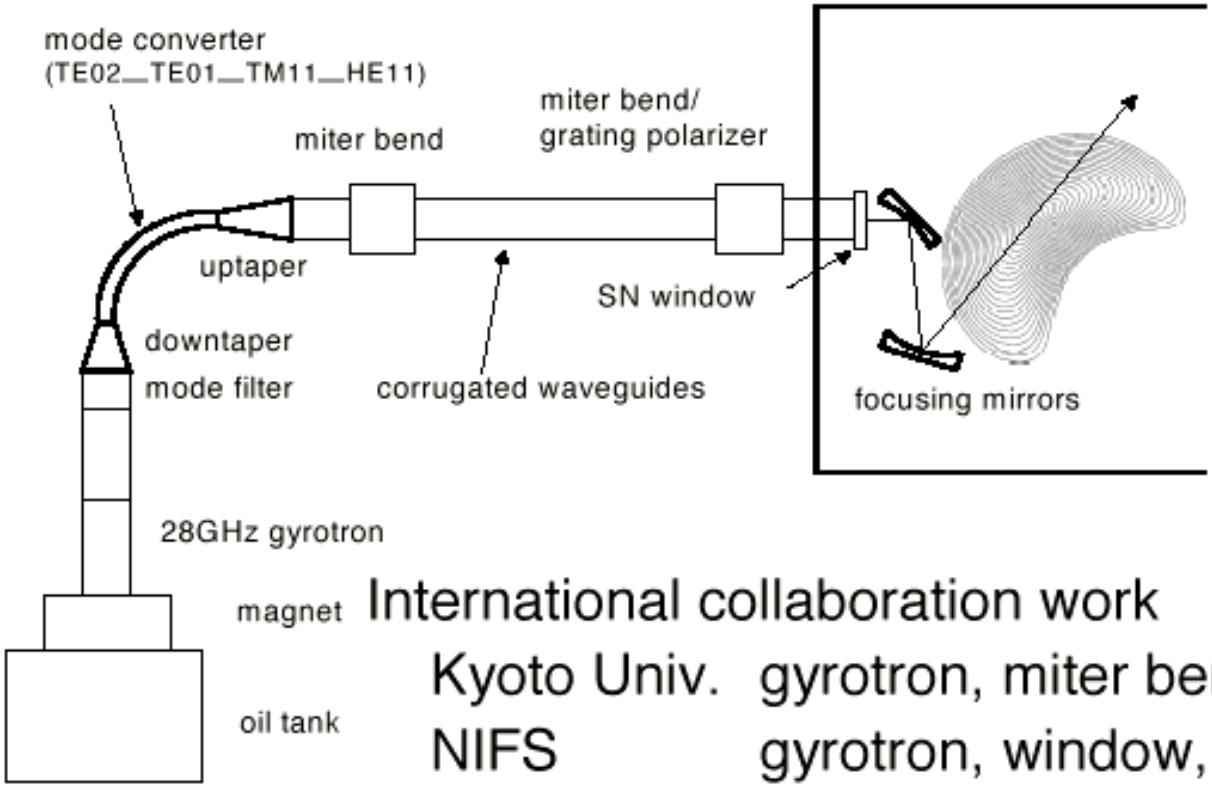
- Increase magnetic field: 2 kG ⇒ 10 kG
  - 14 kA DC-DC converter (ABB, Cegelec, TMC)
  - 6 month delay due to transformer mfg, stability problems
  - Now operational at 8 kA, full capability in October, 1999
  - Coil motions appear as expected
- Increase plasma heating power:
  100 kW (7 Mhz) ⇒ 500 kW
  - 200 kW, 28 GHz gyrotron from NIFS/Kyoto Univ. (Japan)
  - 250 kW, 6-26 MHz transmitter from Radio Australia
  - Decision on additional heating in 2000-2001
- Major port modifications on vacuum vessel
- Improve vacuum pumping system
- New diagnostics

Kyoto/NIFS gyrotron

Power	230 kW
Pulse length	40 ms
Beam voltage	80 kV
Beam current	8 A
Output mode	TE_{02}
Normal magnet	

Installed & tested

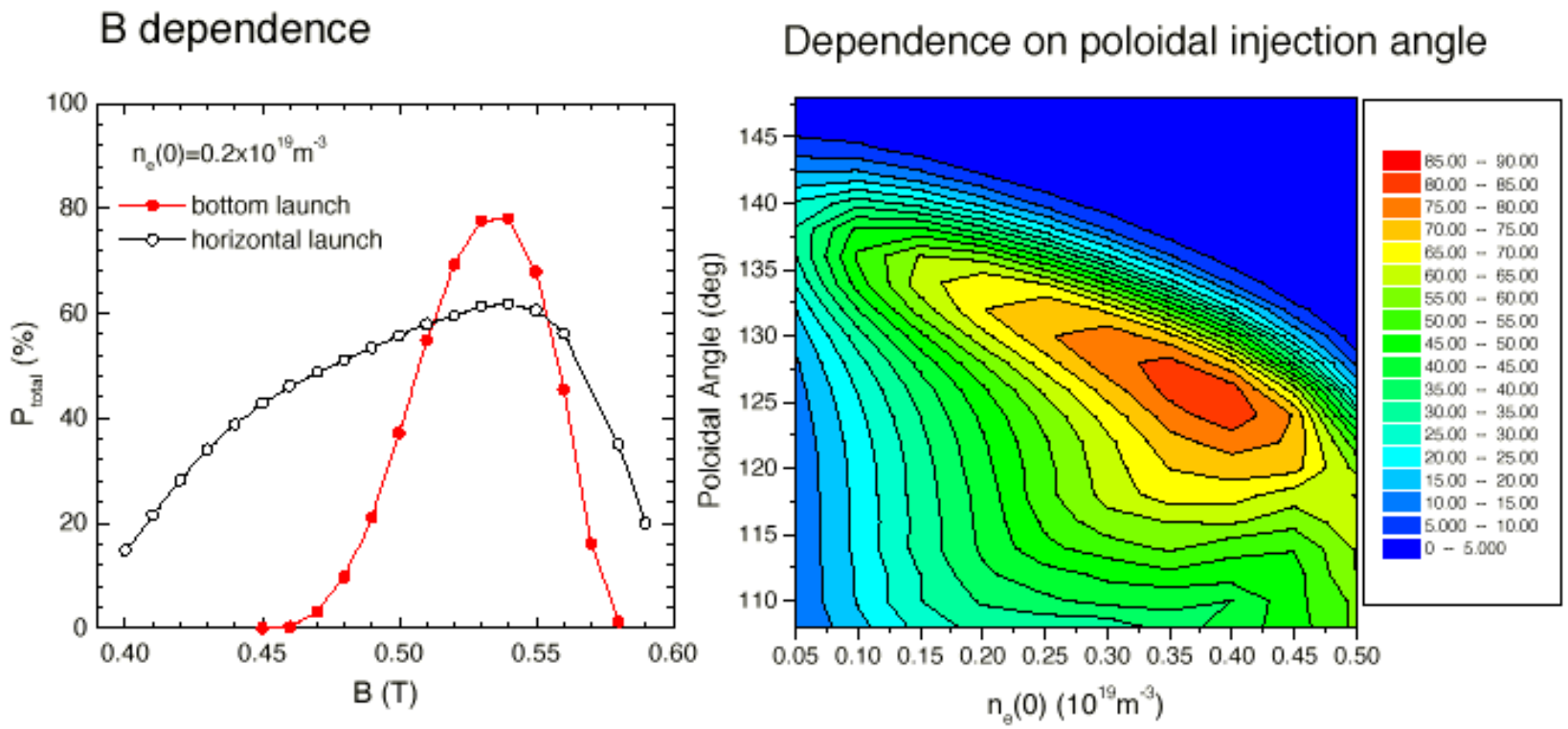
28 GHz ECH system



International collaboration work

Kyoto Univ.	gyrotron, miter bend, polarizer
NIFS	gyrotron, window, TE_{02} source
GA	converter, corrugated waveguide

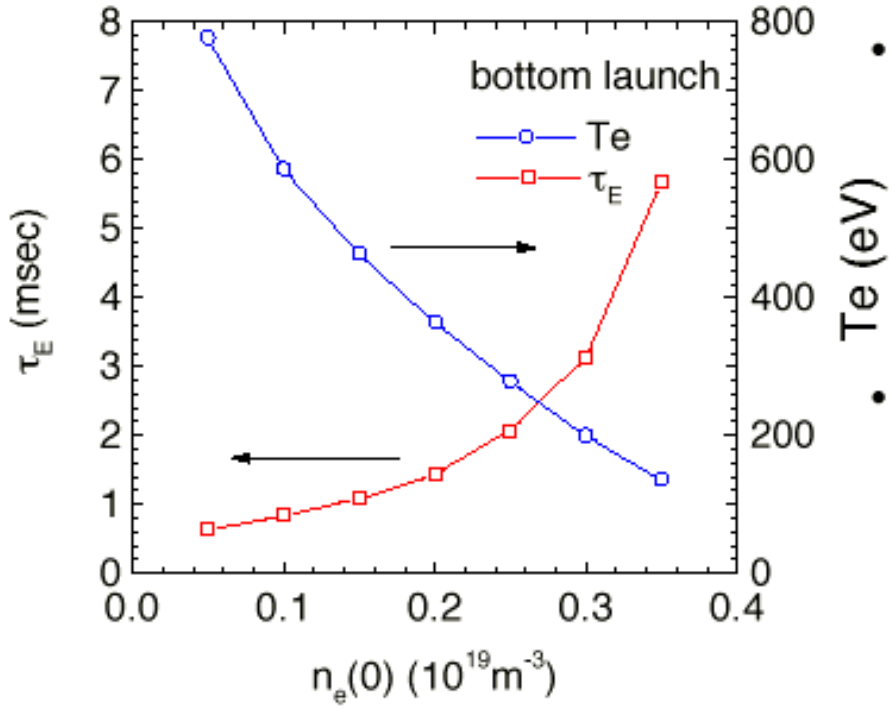
ECH launch geometry
⇒ optimised using ray tracing



Parameters expected for ECH at B = 0.5 T

- Accessible plasma parameters can be estimated in combination with ISS95 scaling law.

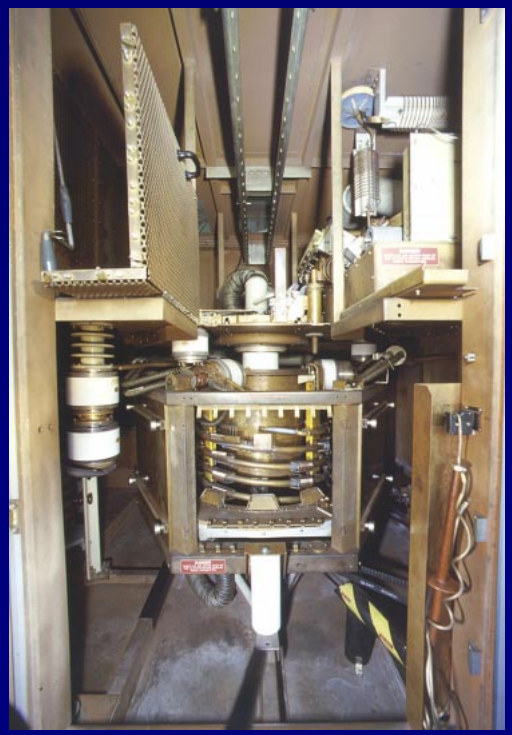
$$\tau_E = 0.079 a^{2.21} R^{0.65} P_{tot}^{-0.59} n_e^{0.51} B_t^{0.83} \iota_{2/3}^{0.4}$$



- 2nd X-mode heated plasma
  - T_e<800 eV
  - n_e<0.4x10^{19} m^{-3}
  - τ_E <5 msec
- Some improvement may be required for 1st O-mode ECH.

BBC transmitter (from Radio Australia)

- 6-26 MHz, 250 kW
- Refurbish by British Aerospace
- New coax from NIFS
- Use for helicon, ICRF heating

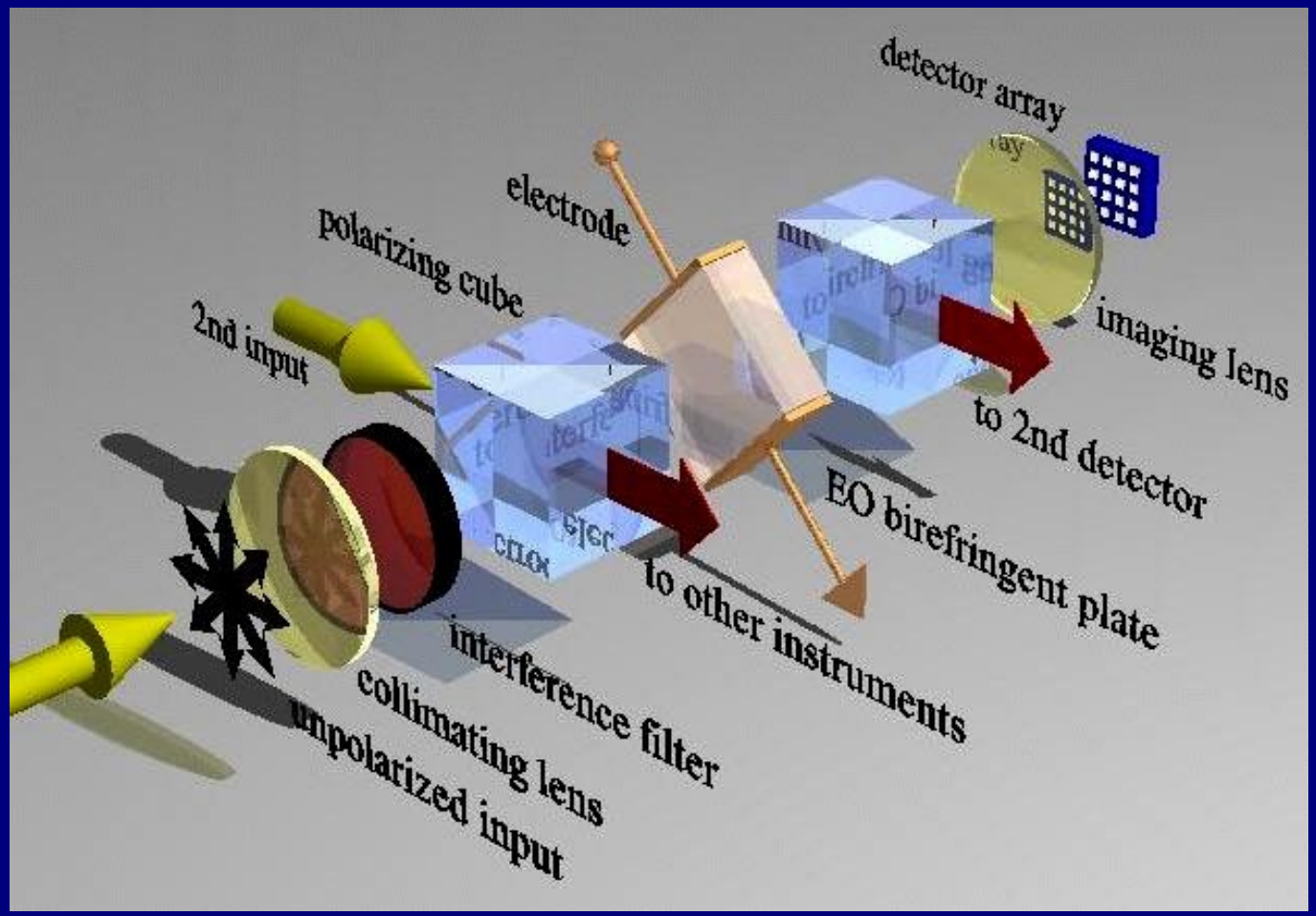


Diagnostics

- Existing
  - Magnetics
  - 2 mm interferometry
  - 2-D FIR tomography of density
  - Langmuir & magnetic probes
  - Electron beam (screen, rod) for flux surfaces
  - Edge bolometry
  - Survery spectroscopy
- New
  - Multichannel Thomson scattering
  - 2-mm microwave scattering
  - Tomographic, imaging, and correlation spectroscopy
  - Extended magnetic probes

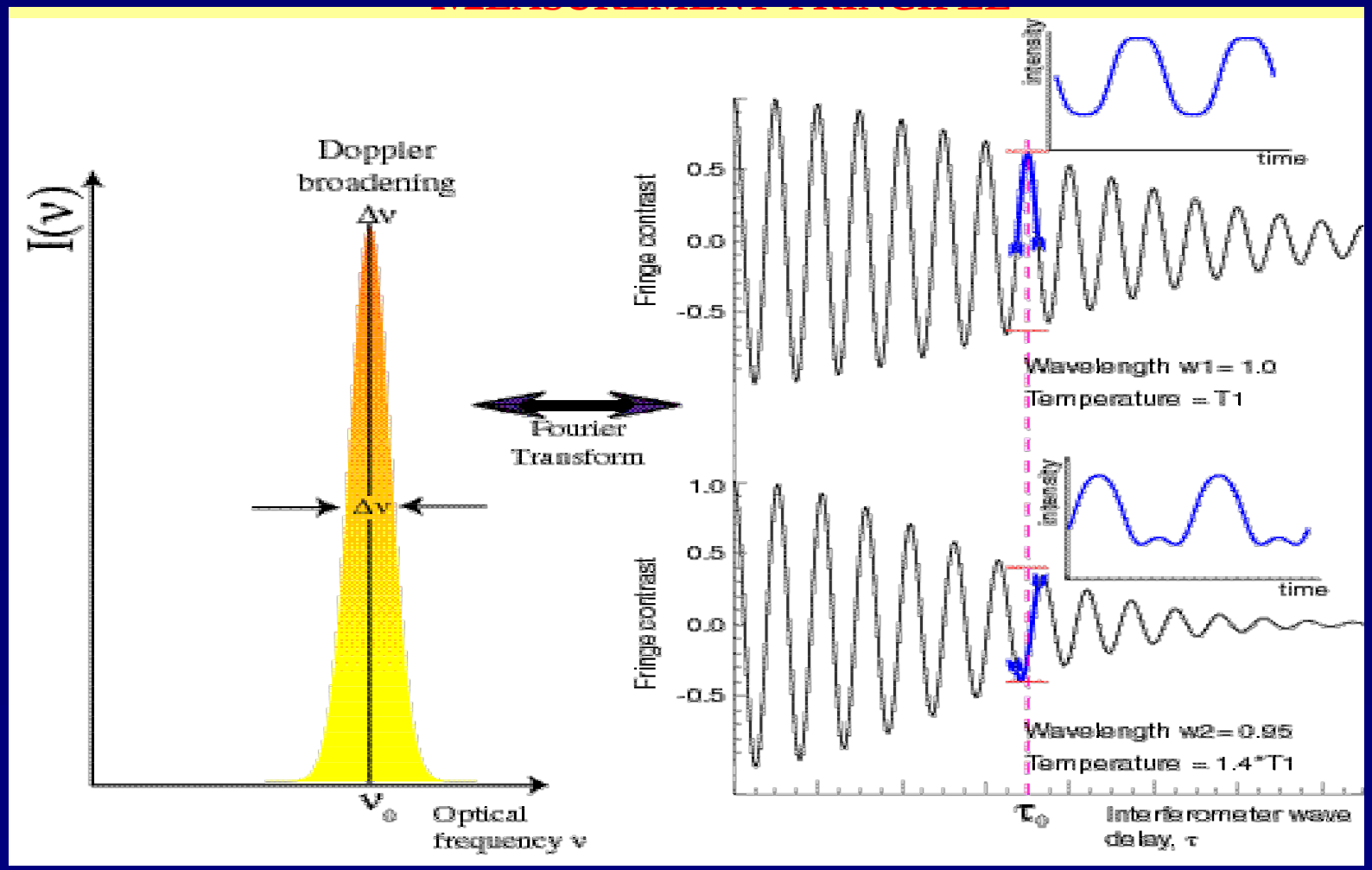
Extensive in-vessel work req'd for diagnostic installation

Schematic of Modulated Optical Solid-State Spectrometer



Compact Fourier-transform spectrometer for measuring line shapes and shifts using coherence interferometry

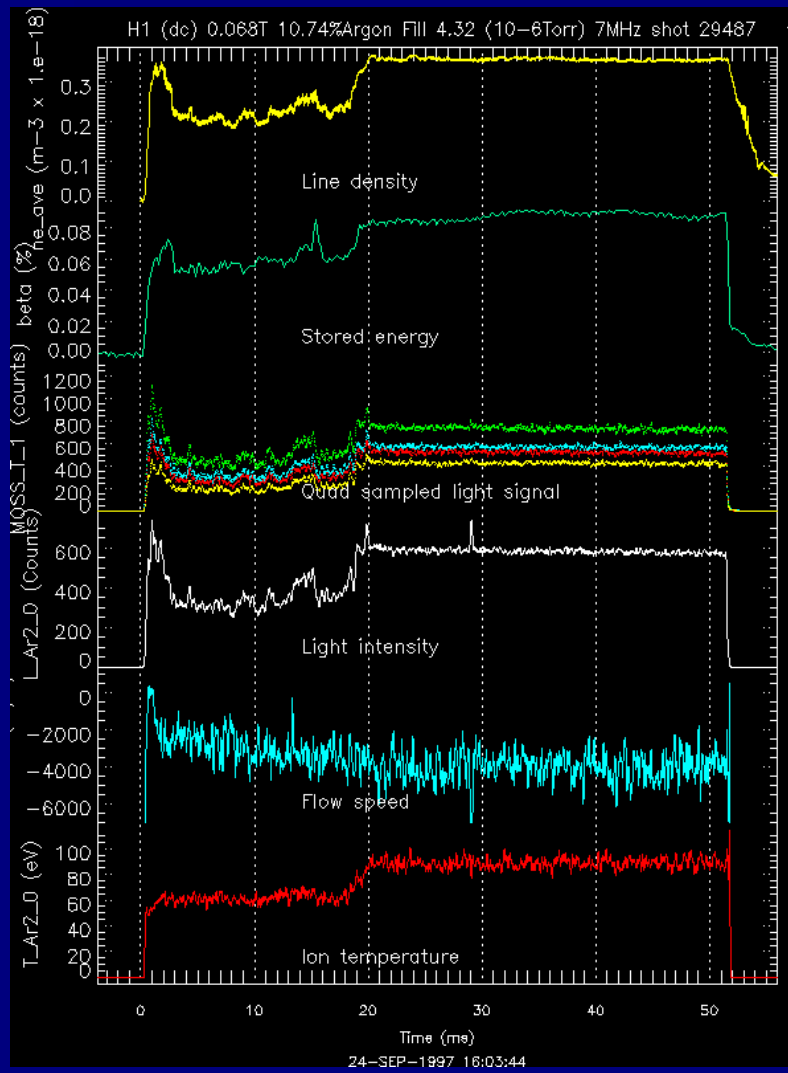
MOSS principle



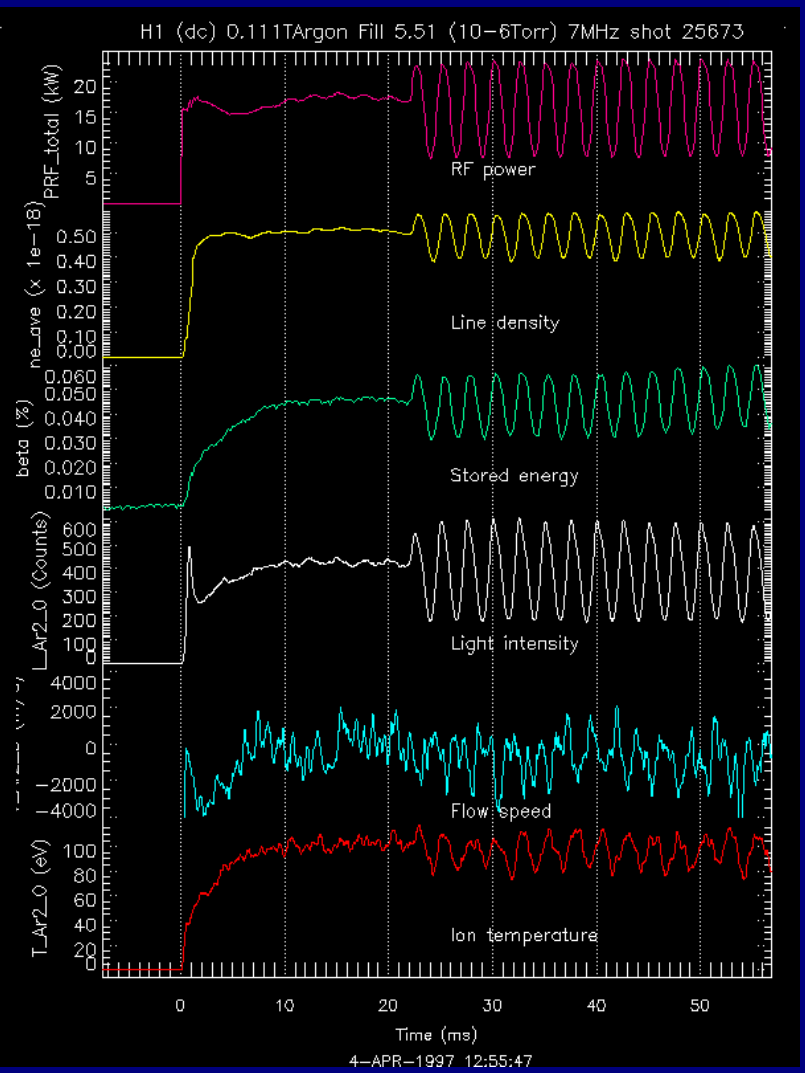
- Fringe decay gives broadening ⇒ temperature
- Fringe phase gives shift ⇒ flow

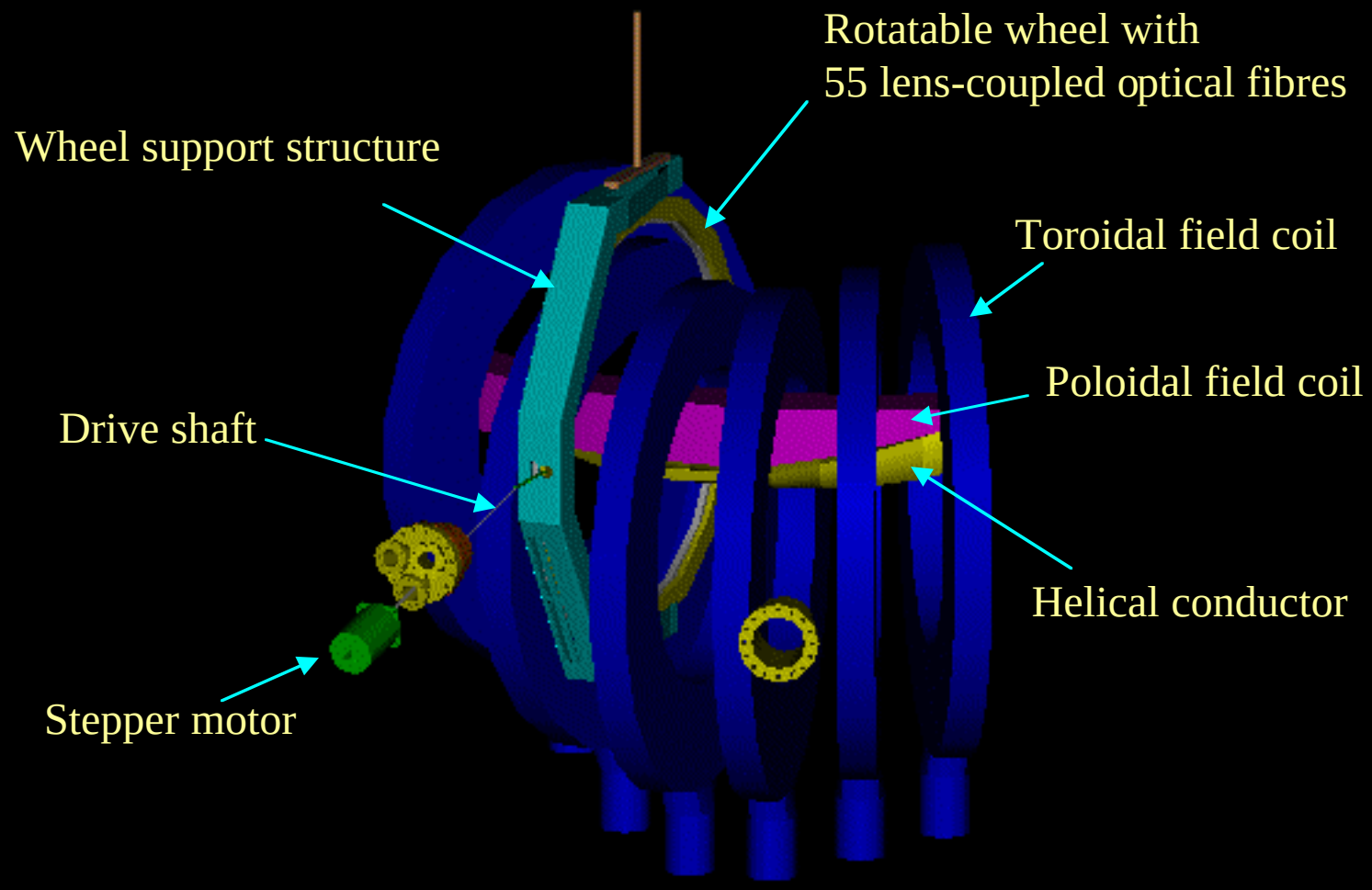
Sample H-1 data for single channel MOSS

L-H transition



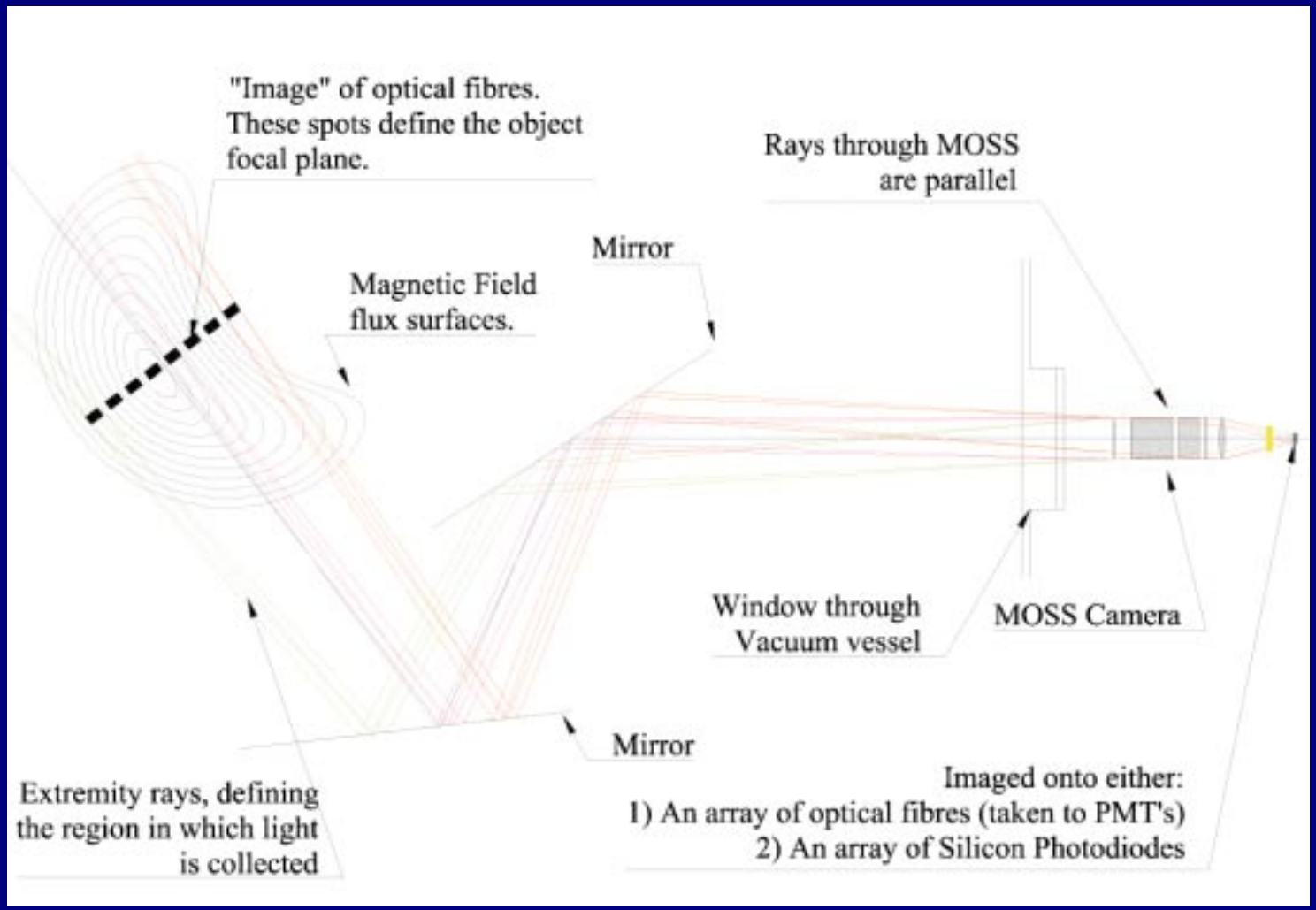
RF Power modulation





TOMOSS - TOMOgraphic MOSS spectroscopy system

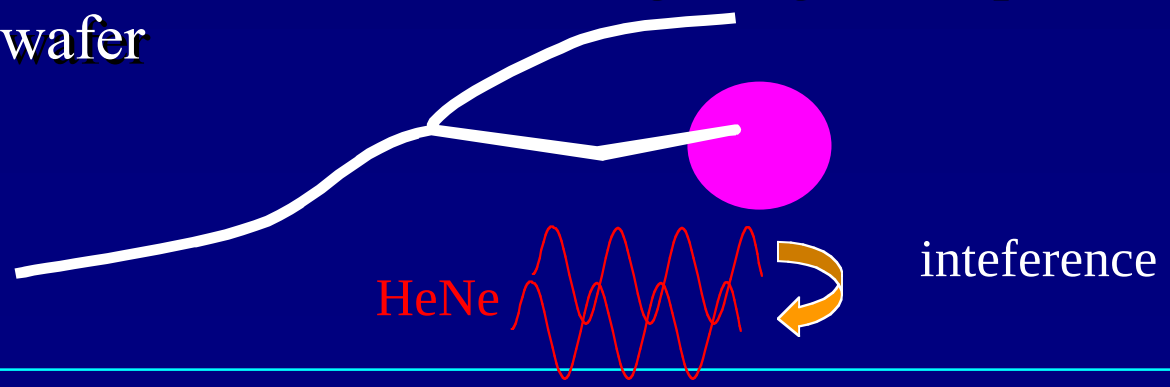
Layout for MOSS camera imaging in H-1NF



Fibre Optic Bolometry (Univ. of New England)

- Quartz fibre heated by particles or radiation
- Temperature (length) change sensed via HeNe interferometry
- Radial profile and directional information in H-1NF
- Test principle of electrostrictive sensing of e-field
- Initial success experiments in low T_e plasma in H-1, in single and multiple variants, with biasing to select species
- Generalising to external bolometer using integrated optical waveguide on wafer

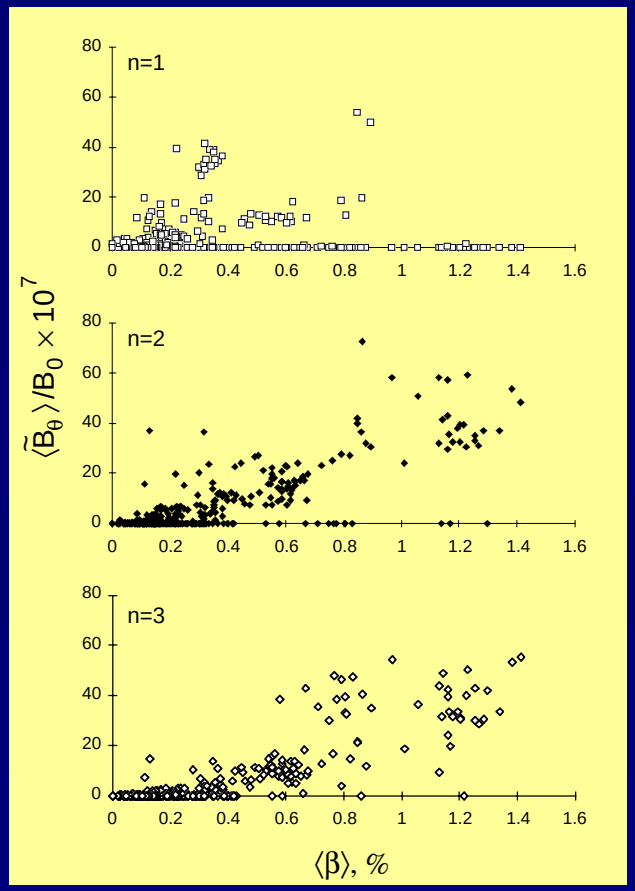
Fibre splitter feeds two arms of interferometer, one in plasma

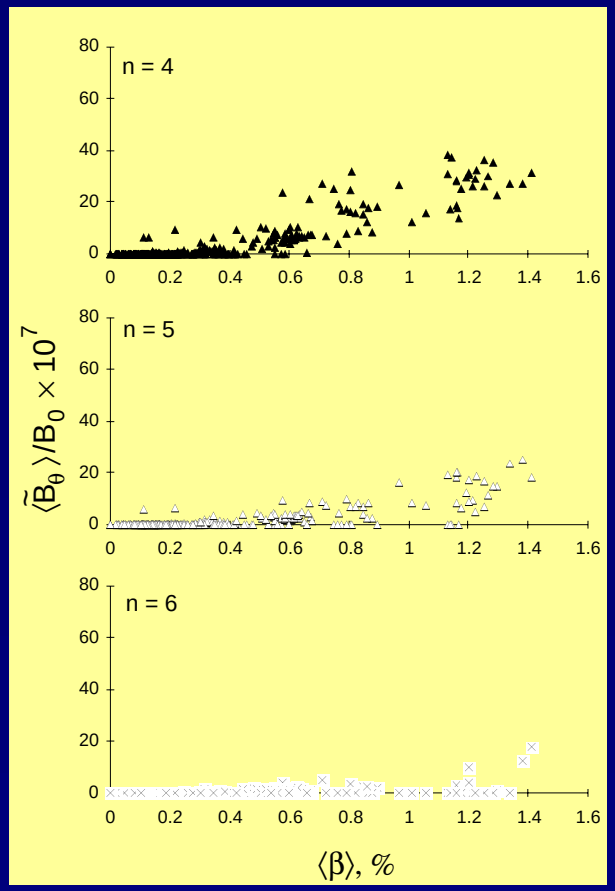


ATF, other helical sys. $\Rightarrow \tilde{B}$ visible even at low β

– Magnetic fluctuations measured outside plasma at low $\beta < 1$ %

– Toroidal mode number ($1/\lambda$) increases with β, coherence length drops





ATF

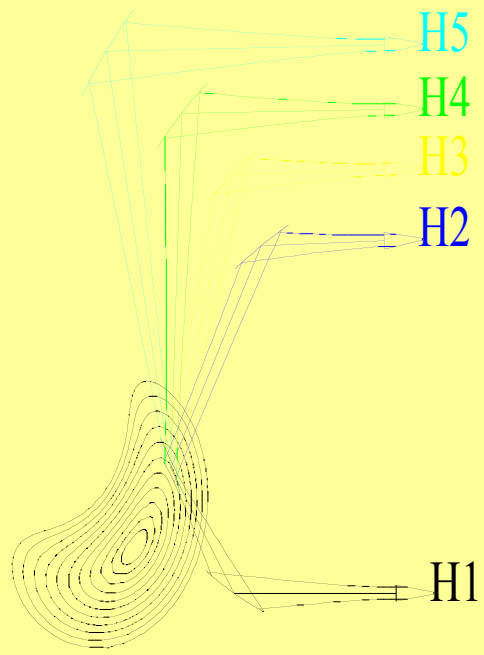
– In ATF, high n fluctuations were signature of good confinement (!)

– Do on H-1 with more probes, varied configurations . . .

– Localisation; interchange, ballooning distinctions

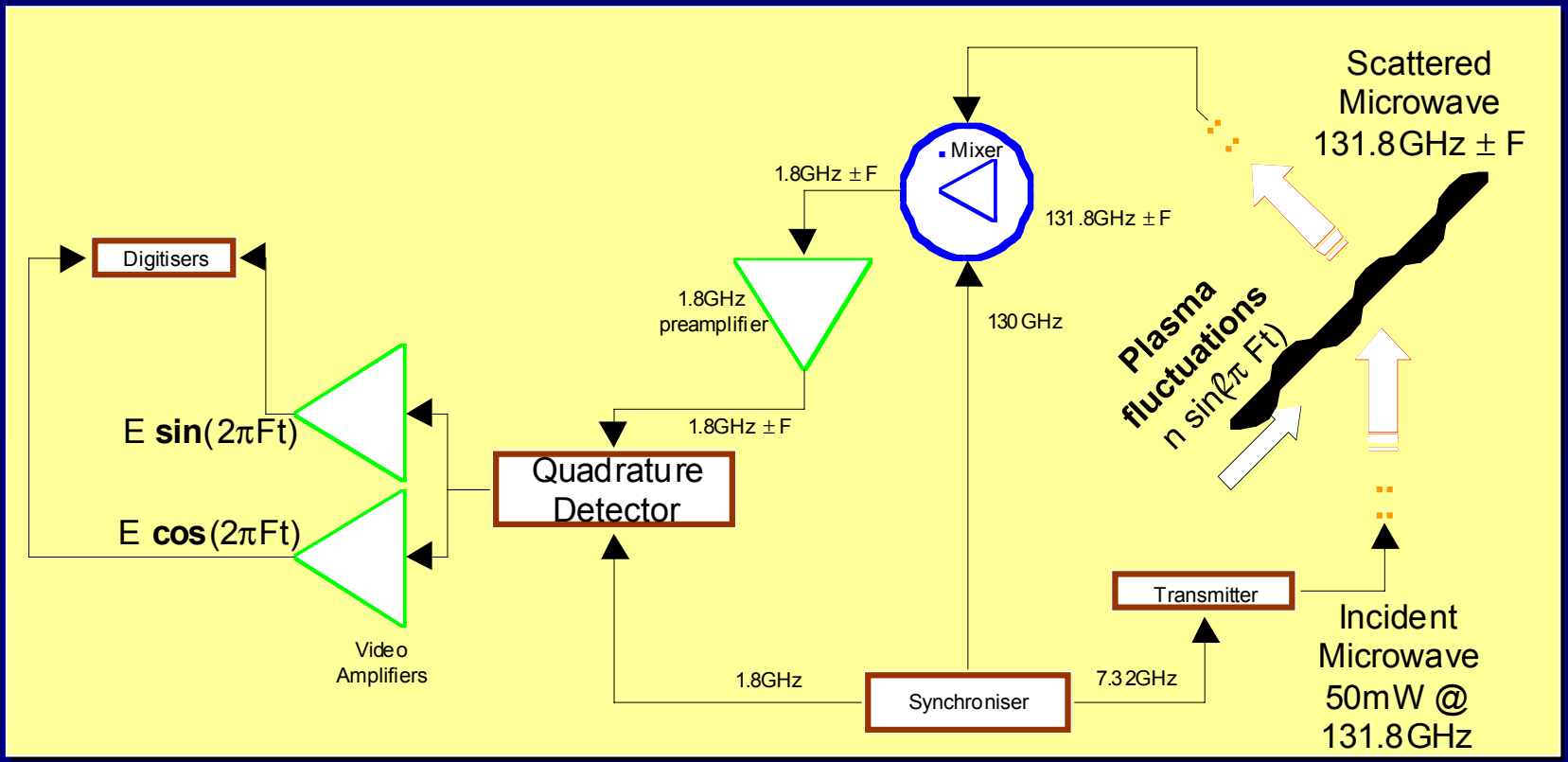
Microwave scattering

- Microwaves @ 132 GHz are are scattered by density fluctuations ⇒ k spectrum

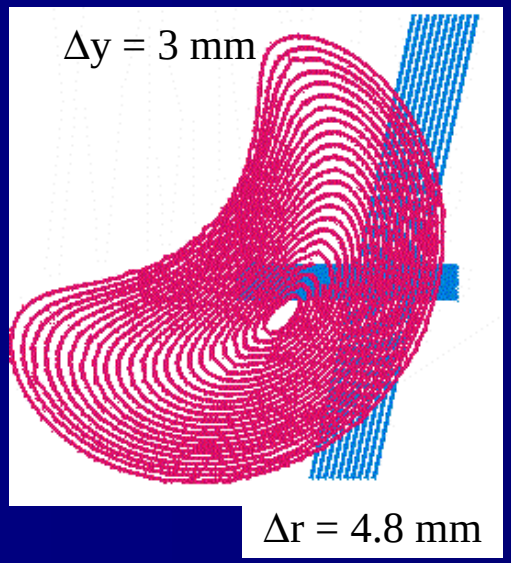


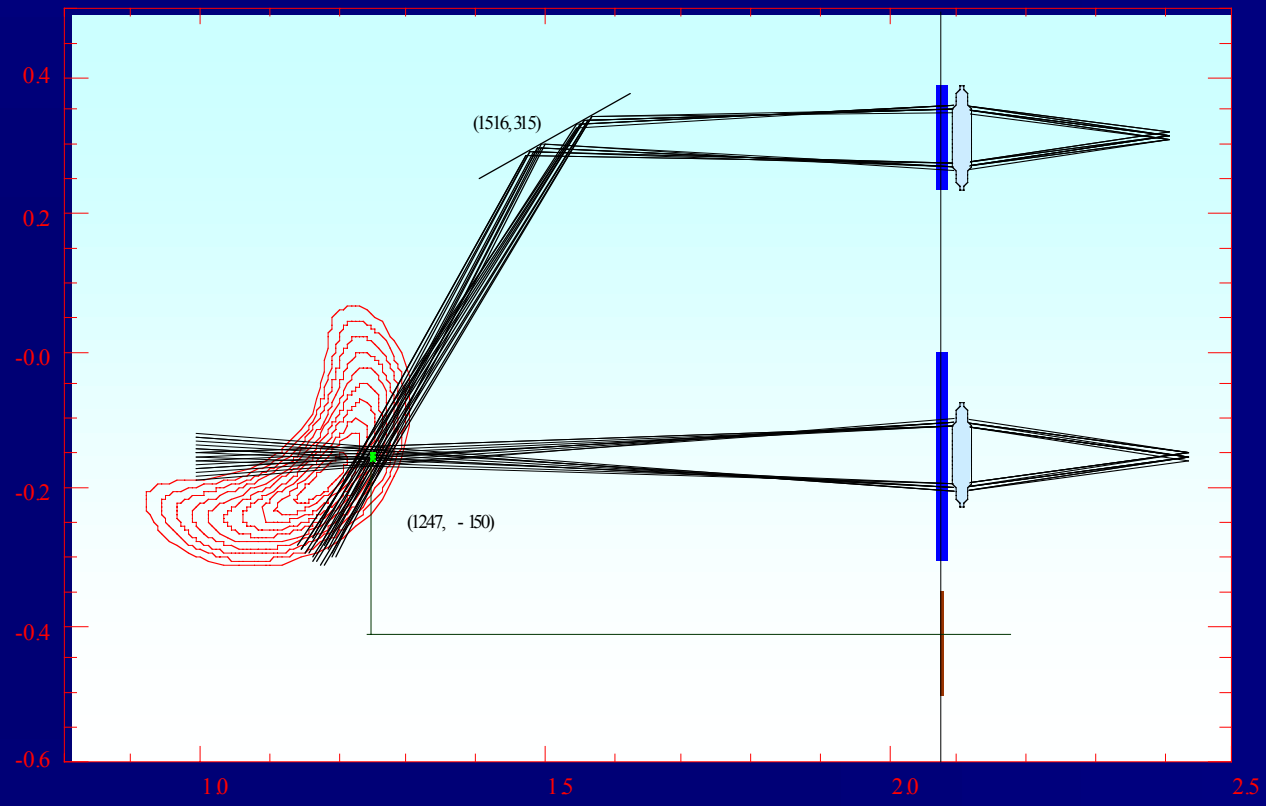
	Angle	k (cm^-1)	V (cm^3)
H5	20°	9.6	5.08
H4	35°	16.6	3.96
H3	50°	23.3	3.88
H2	65°	29.7	4.06

Microwave scattering uses heterodyne detection system



Correlation spectroscopy diagnostic





- 20 optical channels (2 x 10 x 1mm optical fibres)
- Wave number range $k_{pol} < 10\ cm^{-1}$

Conclusions & plans

- Facility: H-1 ⇒ H-1NF transition nearly complete
- Establish plasma regimes with ECH + ICRF at higher powers
- Commission new diagnostics
- Confinement transitions & turbulence
- Finite pressure effects
  - Equilibrium imaging using tomographic techniques
  - Fluctuations & stability
- Decide on heating strategy