5 yr Plans for MHD Physics Studies using NSTX Fast Soft X-ray Camera, Divertor Langmuir Probes, and Plasma TV

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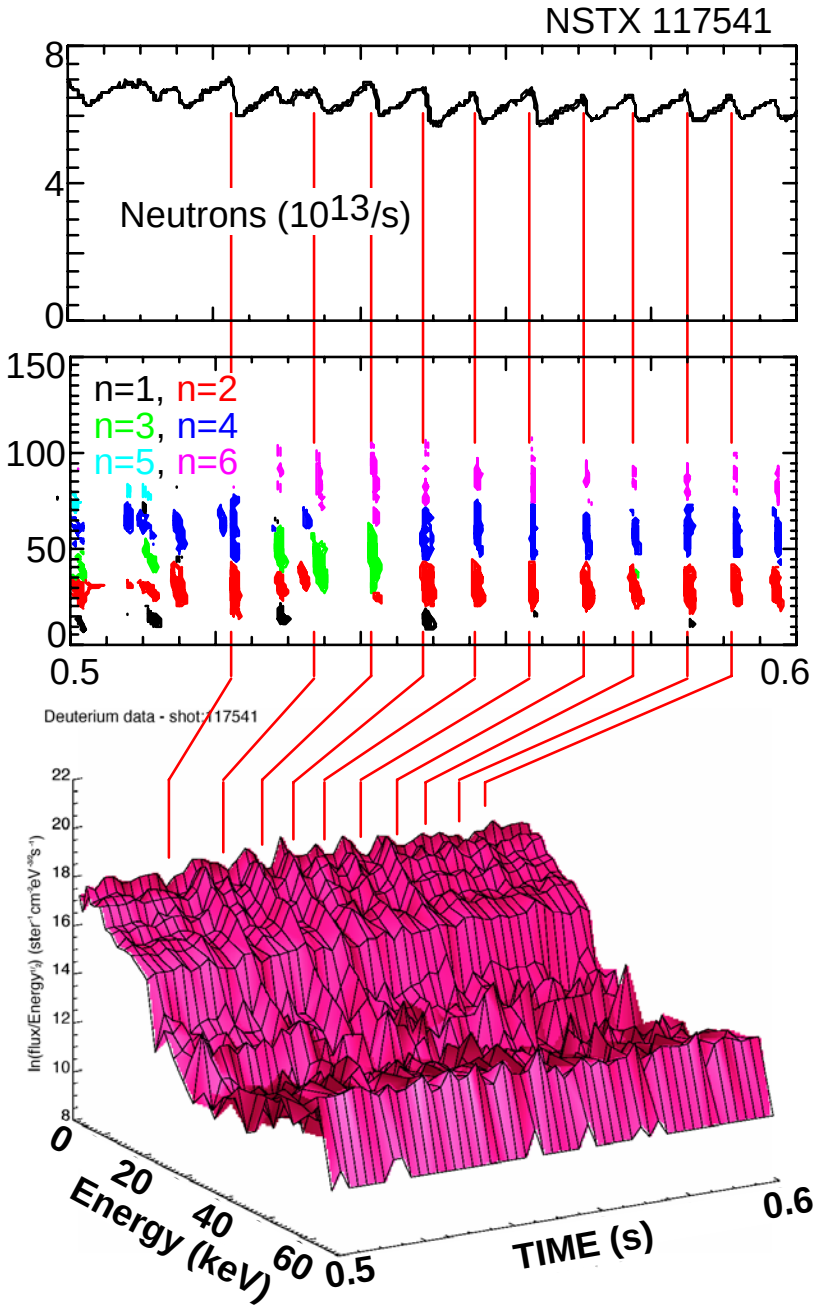
QuickTime™ and a
V420 codec decompressor
needed to see this picture.

Goal

- Goal: MHD physics studies on NSTX using fast soft x-ray camera Imaging.
- Have acquired plasma images at frame rates of 1-500 kHz
- Have observed a variety of MHD phenomena: internal reconnection events, disruptions, sawteeth, fishbones, tearing modes, etc.
- The main purpose is to obtain high quality fast data for a wide range of m,n modes
  - Special: Sawteeth, Fishbones, ELMs.

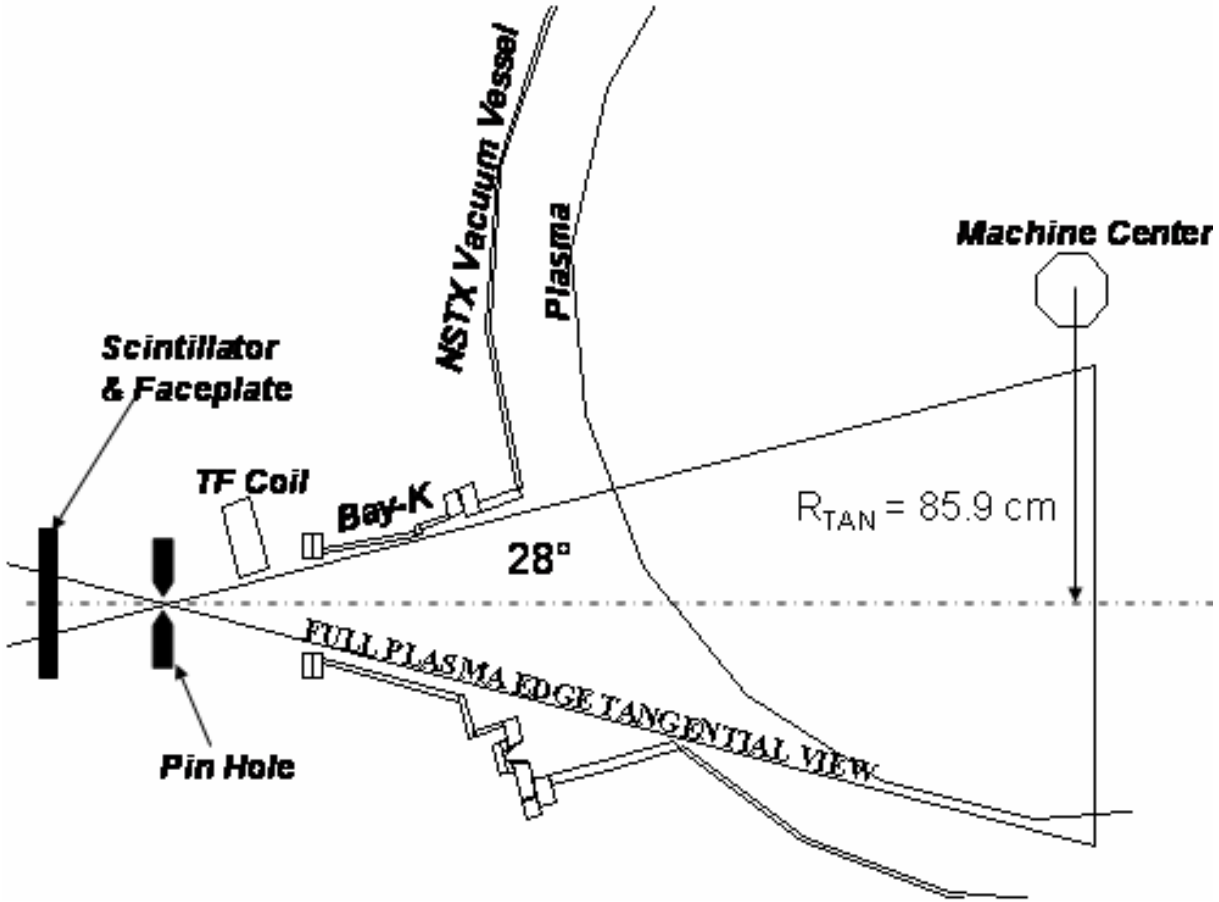
    (Fishbones 5 to 100 kHz; in core)
  - Important to NTHX and ITER due to fast particle (α's,etc.) losses.



Fast ions affected over all energies

- Strongest modulation is seen for lowest energies; below the "half" energy.
- Neutron drops of 10% suggest high energy ions also lost.
- Broad range of energy interaction consistent with bounce-resonances

Horizontal Field-of-View of Camera



- Optical axis inclined at 9º downward angle with respect to midplane

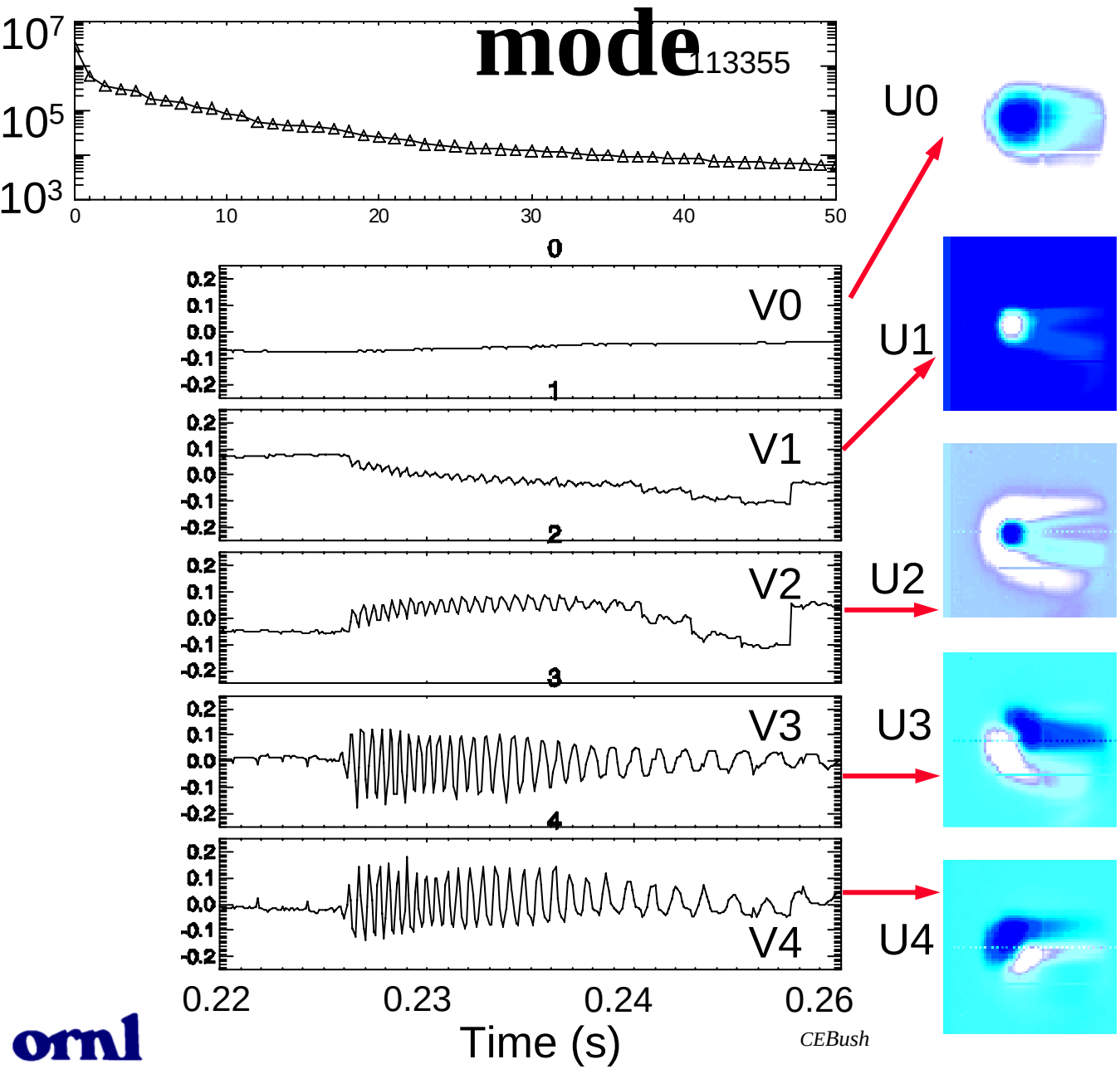
Continue to Develop Analysis Tools

- Tools for analyzing and modeling
  - Cbbst code - (by Leonid Zakharov) - simulates line integral. Very successful reconstruction of 3D data for m/n=1/1 mode
  - M3D non-linear resistive MHD code (Josh Breslau)
  - SVD determination of structure, mode, and time behavior
  - Other image decomposition techniques
- Need dedicated runtime.
  - Reliable, reproducible shots - Known event time
  - At 100 kHz, have 3 ms data window
  - At 500kHz get 0.6 ms of data
  - May need small puffs of high Z gas (He, Ne, Argon) to increase signal.
  - Develop reliable event trigger

Movie of 1/1 Mode

QuickTime™ and a
YUV420 codec decompressor
are needed to see this picture.

SVD Shows the m/n = 1/1 mode



The Singular Value Decomposition (SVD) yields the coherent fluctuaions in space "topos" U0-U4 and time "chronos" V0-V4 within a background of noise.

U0, V0 => global time evolution of the Plasma

*Ref. S. Ohdachi et al. Rev. Sci. Instrum., **74** 2136 (2003)*

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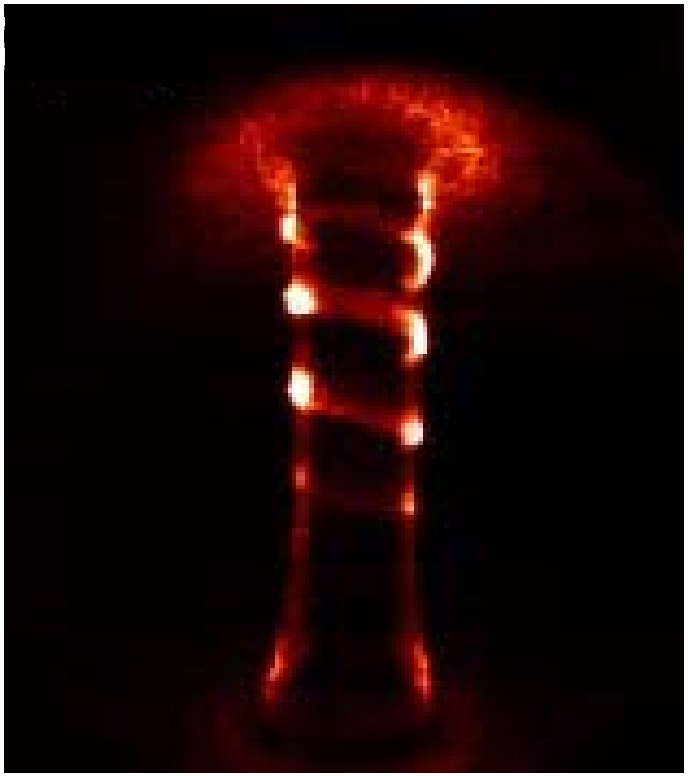
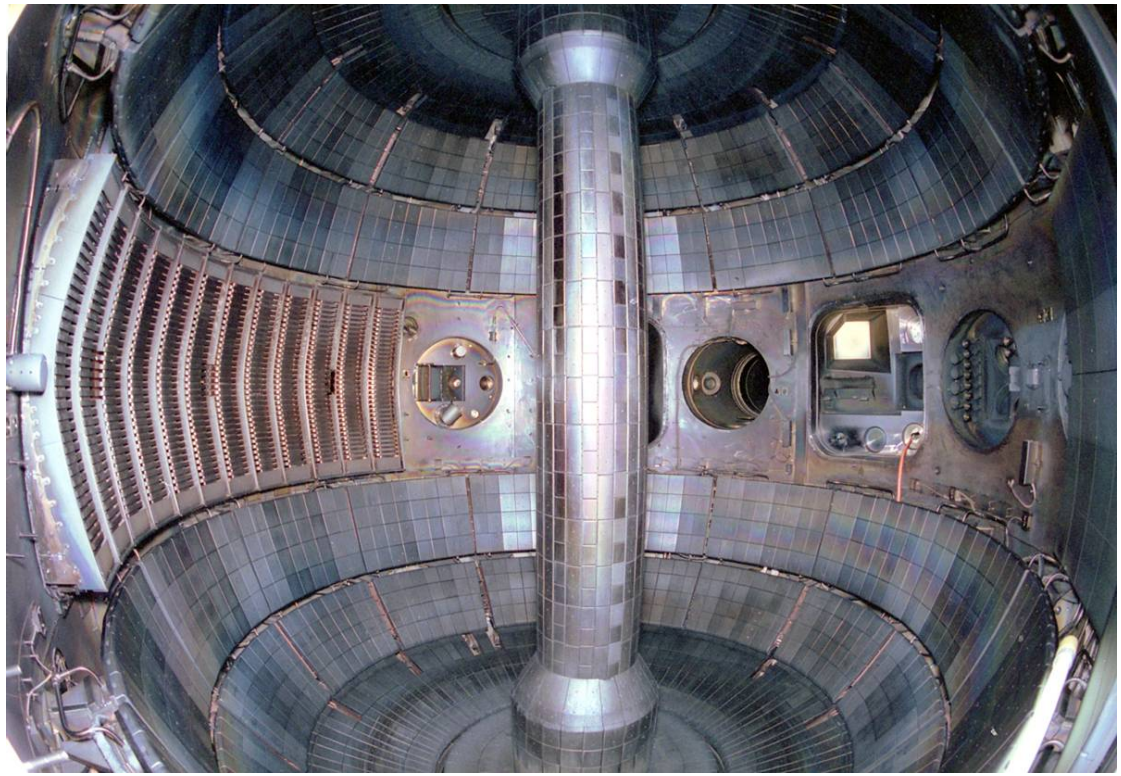
Run Plan

- Get reproducible sawtoothing shot
- Get EPM early, sawteeth later when $q_0 < 1$
- Run camera at 100kHz first
- Impurity puff if signal is too low.
  - Use SXR arrays to determine time of event also for expected signal level
- Change conditions to get other MHD events.
- Vary Be foil thickness and/or pinhole
  - Optimize for MHD studied
- Run Time: **1 day**
- Plasmas: H-mode, L-mode, and Helium

Fish Eye View of Full Plasma - shows macro-dynamics





- **Fast Camera - Fisheye view showing activity near centerstack**
  - **Normally run at 1000 frames/sec**
- **Fisheye view inside NSTX with no plasma**

Unstable Resistive Wall Mode

Shot 114147

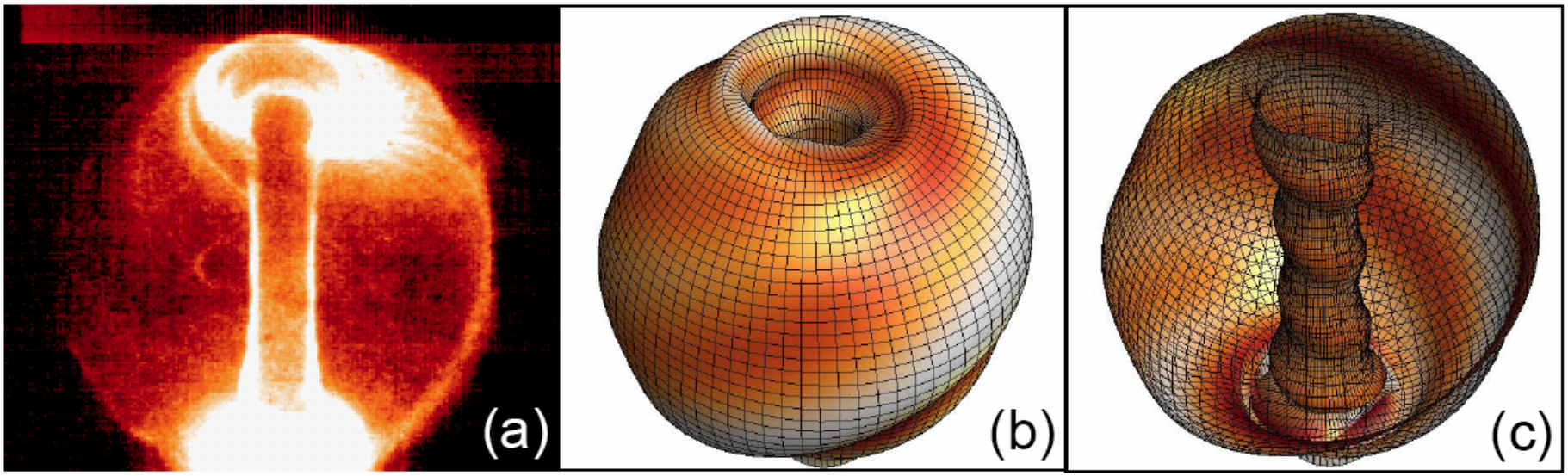
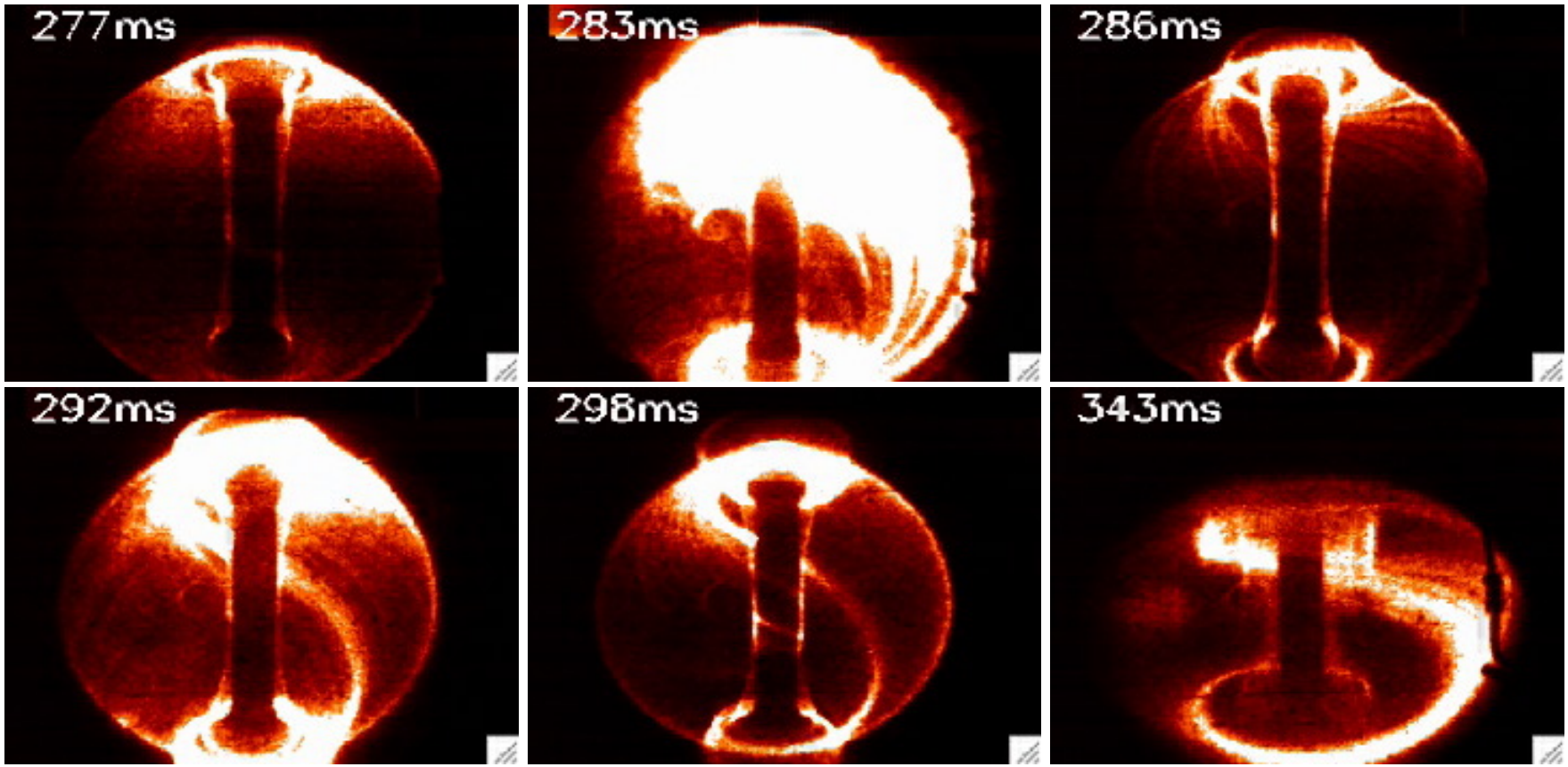


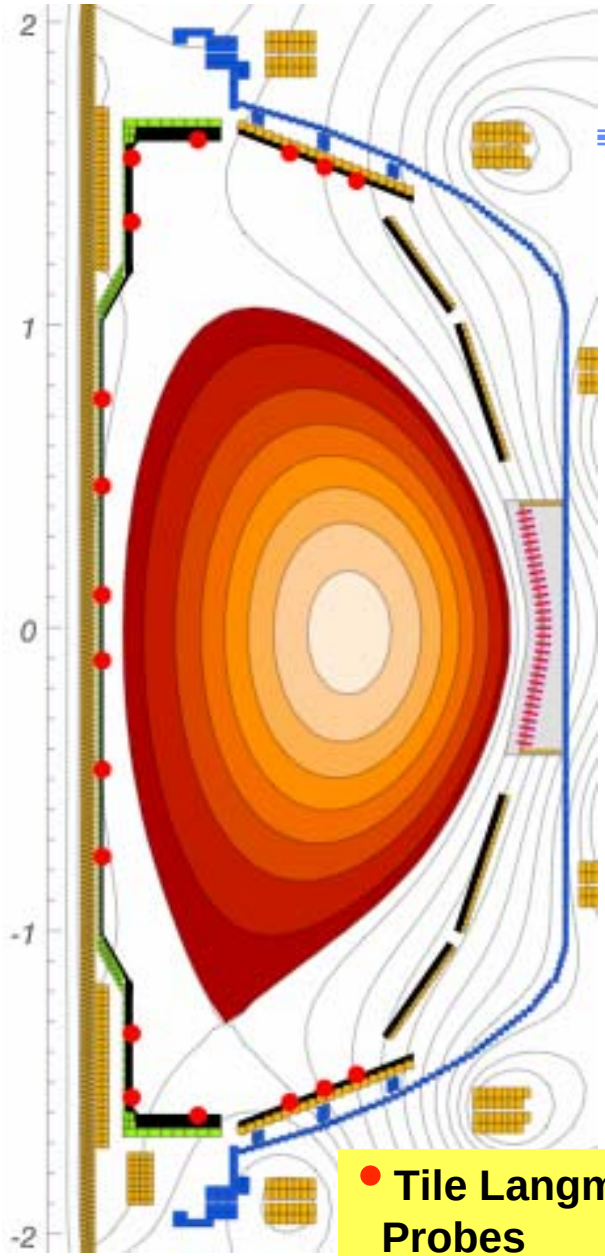
FIG. 2. Visible light emission (a) and DCON computed normal perturbed field (b,c) for the unstable RWM shown in FIG. 1a. (discharge 114147) at t = 0.268s.

Highest Normalized β ($\beta_N \approx 5.5\%$) Shot: Perturbed by an External Kink Mode

Shot 114463



Probes are installed in divertor, centerstack, and new electrode

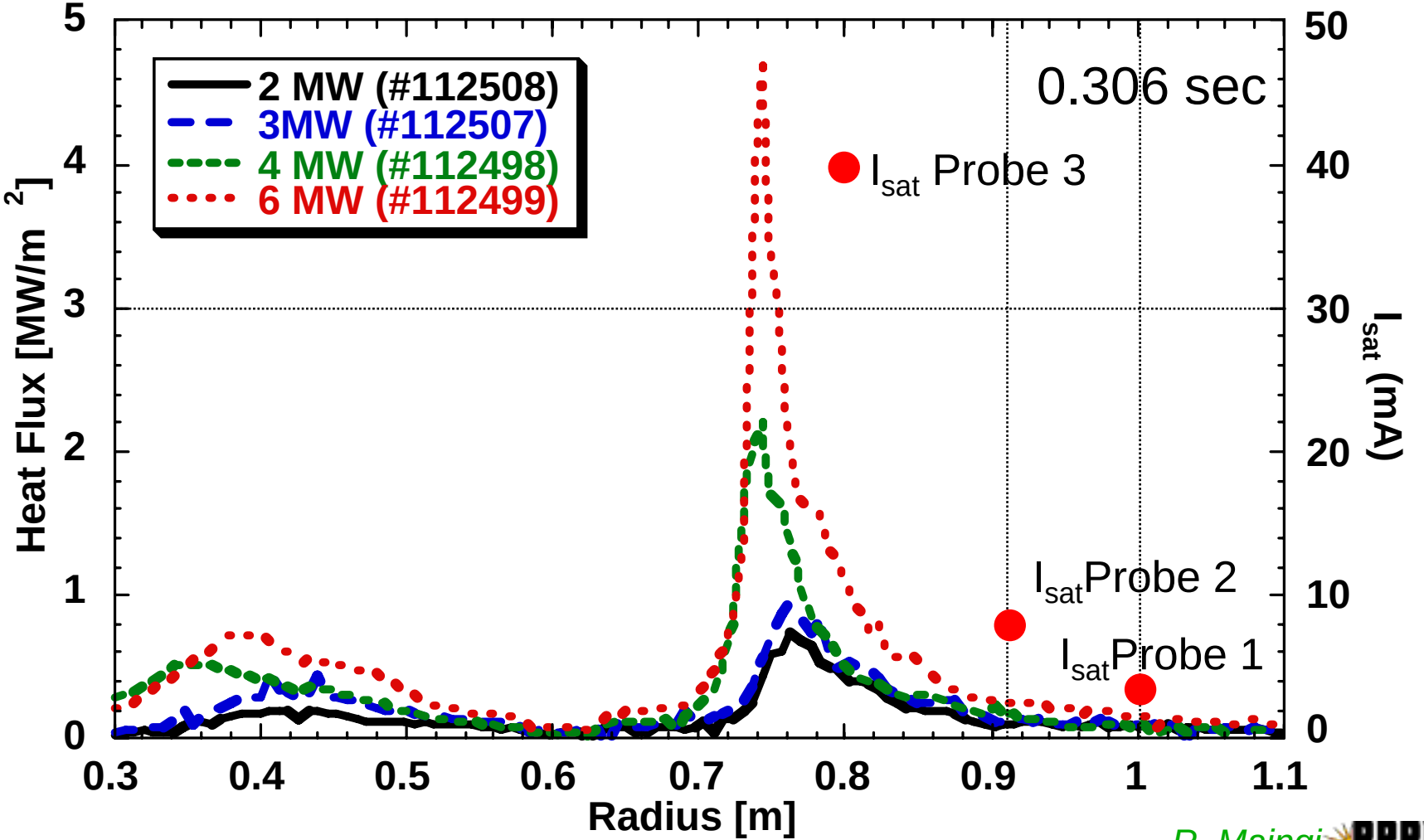


- Tile Langmuir Probes

- Flush mounted single probes
- Total of 27 probes, 6 top and 6 bottom divertors
  - Some along centerstack
  - 5 on new Electrode (fast)
- Have data for vast majority of shots
- Virtually no signal from centerstack probes when plasma is diverted
- Some I_{sat}, T_e, n_e data in Tree

Heat Flux Profile Becomes More Peaked with Increasing NBI Power

- Peak in I_{sat} occurs near peak heat flux
- In general peak I_{sat} is independent of P_b, heating power



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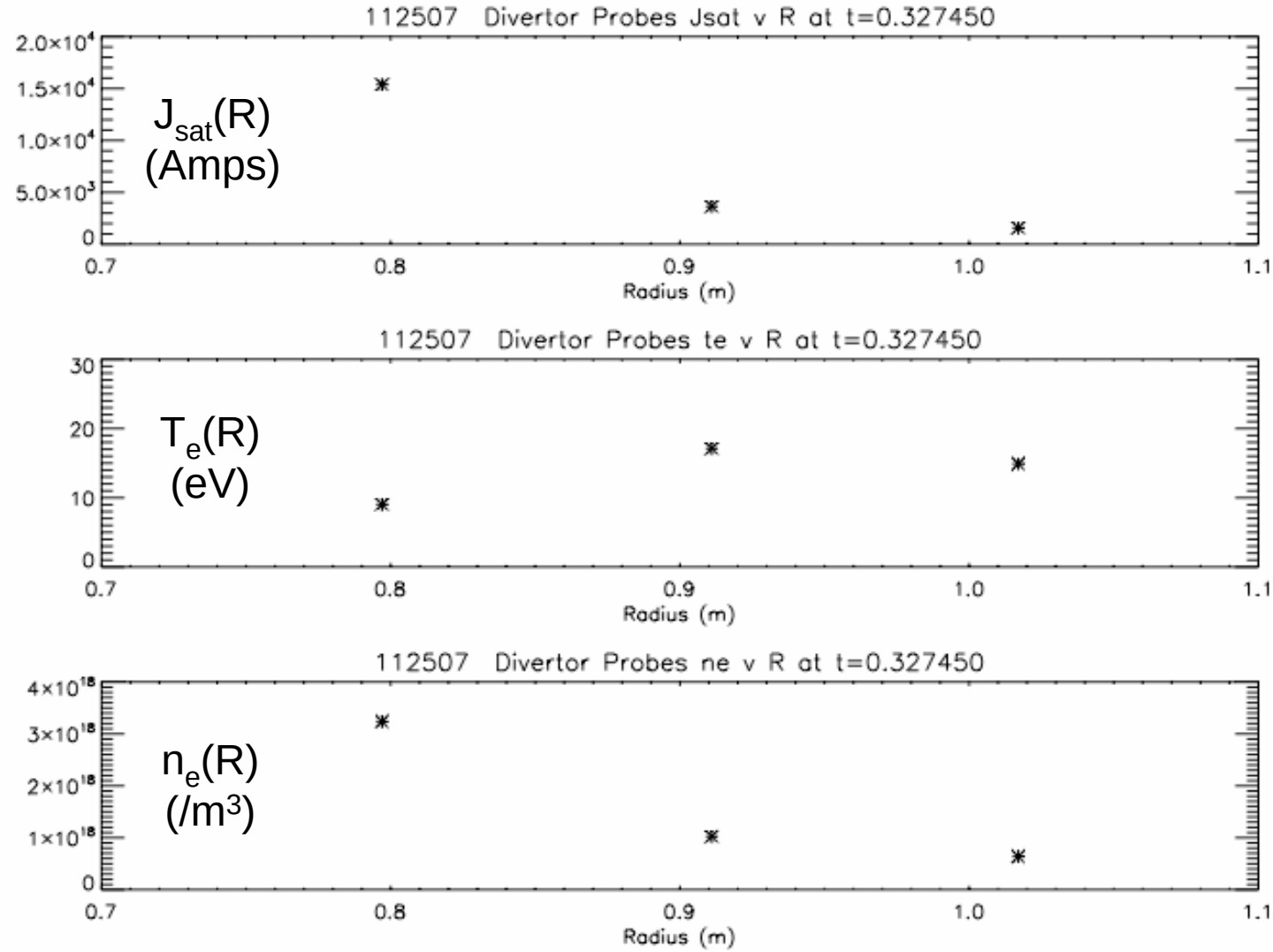
Radial Variation of J_{sat}, T_e and n_e on Divertor Plate for NBI Power = 3 MW

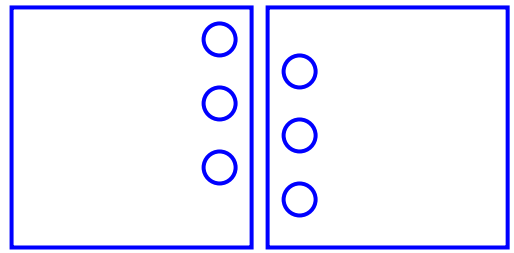


Better Probe Coverage Needed for Physics and Modeling

- Physics of interaction of MHD (Fishbones, ELM) perturbation with divertor and plasma edge depends on the edge plasma parameters
- Important data for edge / divertor modeling
- New fast probes (5 probes capable of 100 kHz) should provide correlations with FSCIC, and GPI blob data
  - As blobs move radially outward across the GPI view
- Plans to go to PC based data acquisition for the present and future probe system
  - better time resolution, better IV characteristics data
  - Probe fluctuation data ; correlations with fast soft x-ray camera
  - MHD and turbulence data (faster digitization)

Approach for Increasing Coverage

- Thermal stress studies
  - determine minimum safe distance between probes
- Minimum for next opening
  - 1st 5 probes spaced 1 -2 cm apart near outboard strike-point
  - 2nd 5 probes spaced similarly on inboard
- Longer range - better overall coverage; spatial resolution of 0.5cm (less?)



EXTRA

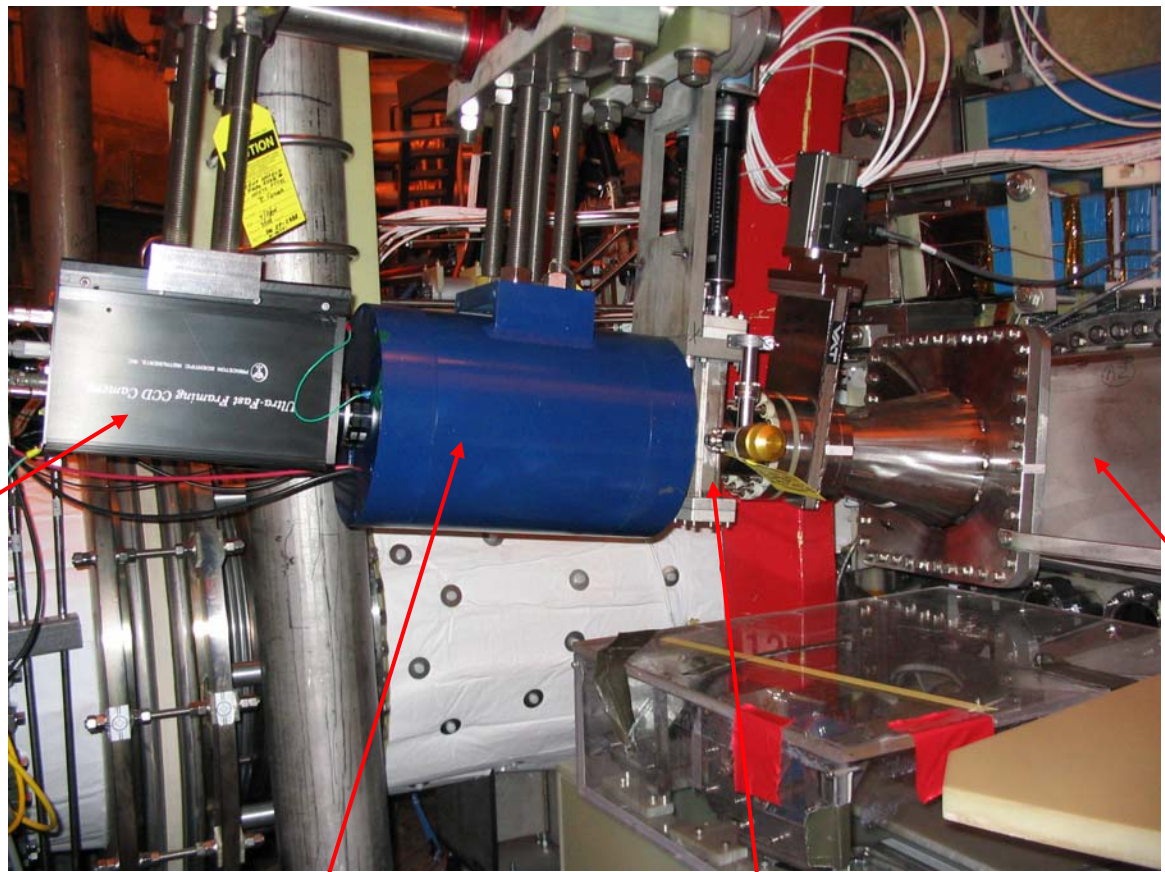
Fast Soft X-Ray Camera Features

- Pinhole camera with wide-angle tangential view of plasma [1,2]
- Based on Princeton Scientific Instruments PSI-5 CCD camera
  - 64 X 64 pixel image
  - Frame rates up to 500 kHz for 300 frames
- Soft x-rays (~1-5 keV) converted to visible light by fast P47 phosphor deposited on fiber-optic faceplate
- Electrostatic image intensifier and lenses demagnify image by 6:1 and couple light to CCD
- to be Remotely selectable pinholes (1-5 mm diameter) allow tradeoff of spatial resolution and signal level
- Remotely selectable beryllium foils allow low-energy cutoff varied

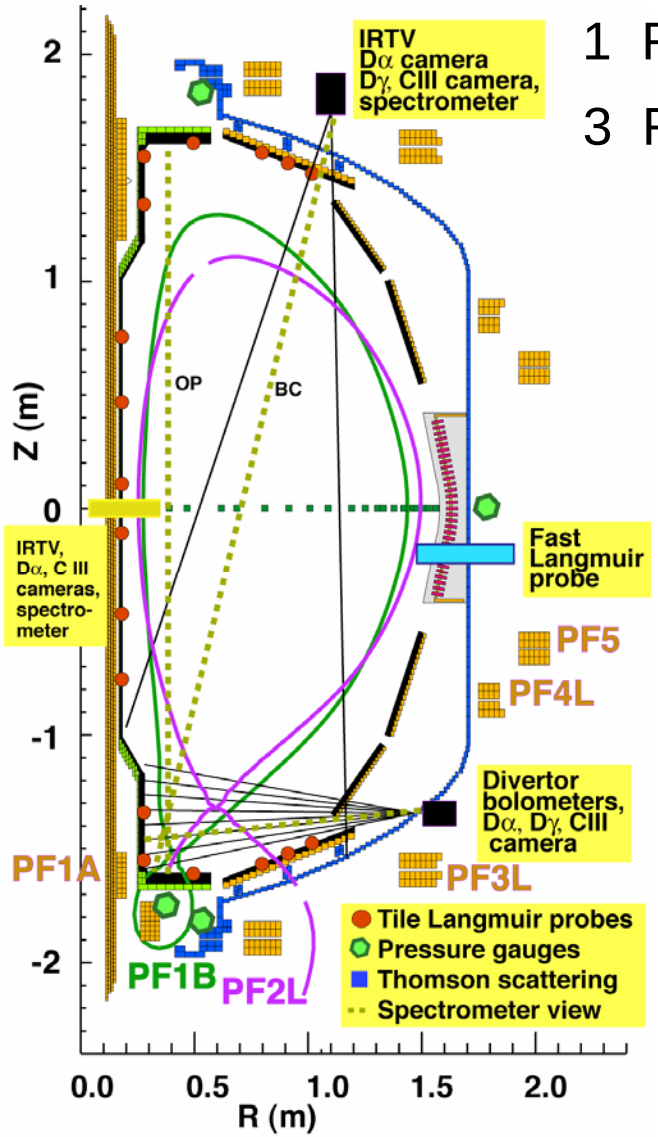
[1] S. von Goeler, *et al.*, Rev. Sci Instrum. **70** (1999) 599.

[2] B. C. Stratton, *et al.*, Rev. Sci Instrum. **75** (2004) 3959.

System Installed on NSTX



Divertor Langmuir Probes

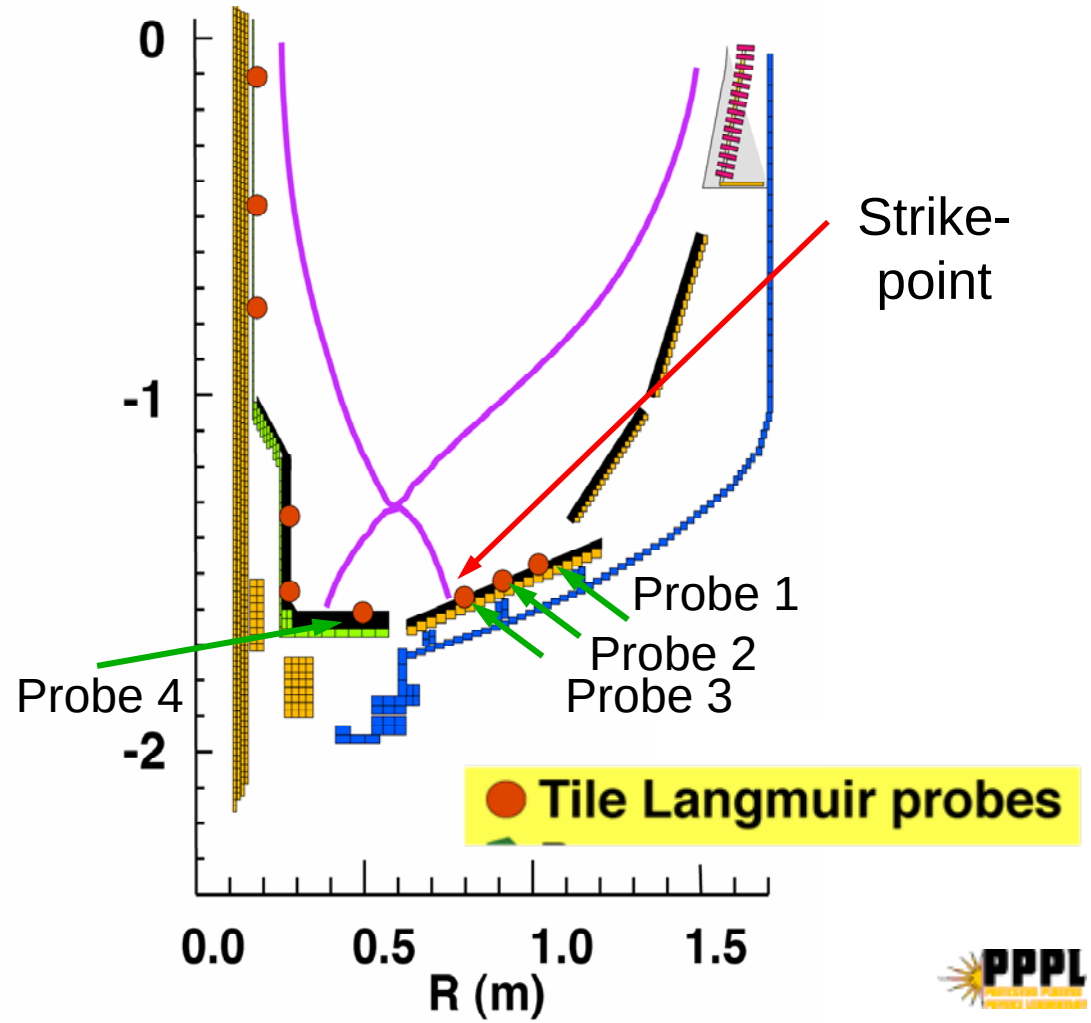


1 R(probe 1) = 1.02 m

2 R(probe 2) = 0.91 m

3 R(probe 3) = 0.80 m

4 R(probe 4) = 0.49 m



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