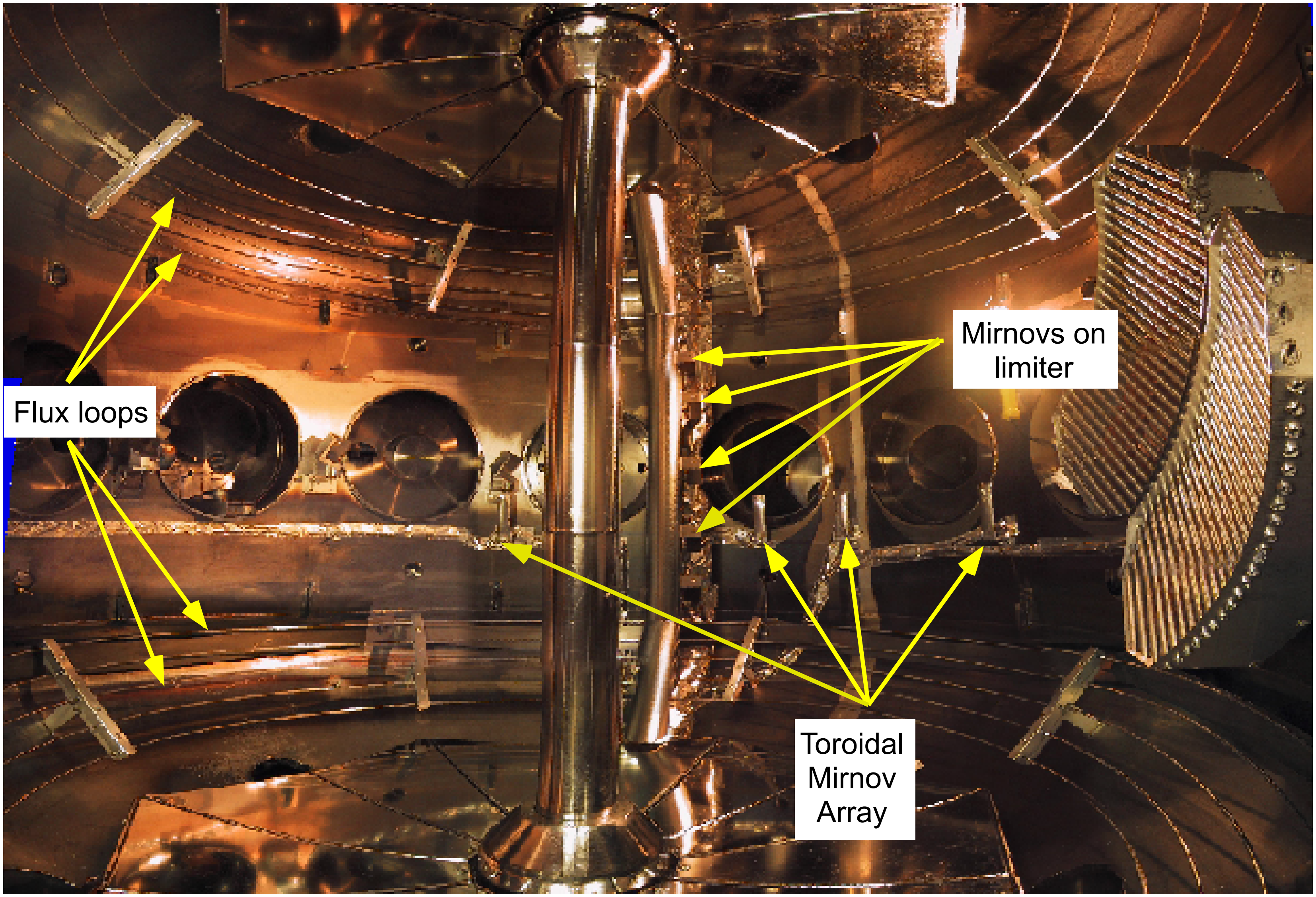
Abstract

Measurement capabilities for the Pegasus ST are increasing to support the scientific studies of plasma behavior at very-low A. Global parameters are obtained from equilibrium reconstructions constrained by a magnetics set consisting of internal and external fluxloops, a poloidal array of B coils, and a diamagnetic loop. Pulse height analysis using a CCD detector will give a time-resolved electron temperature profile with a shotwise spatial scan. A tangentially viewing bolometer array measures profiles of radiated power. A 280 GHz single-chord microwave interferometer is used to measure line-averaged density, while a CCD-based visible bremsstrahlung array gives an approximate density profile. SPRED provides an impurity spectrum between 10 - 110 nm at 5 kHz. MHD activity is characterized by Mirnov coil arrays and a 19 channel poloidal soft x-ray array. The proposed next generation of diagnostics includes time-evolving density, temperature and current profiles using active neutral beam spectroscopy.

Overview

- Pegasus has an extensive set of magnetics diagnostics for equilibrium and stability analysis
- The first generation of plasma diagnostics measure $<T_e>$, $N_e l$, $P_{rad}(r,t)$ and plasma shape
- The proposed next generation of plasma diagnostics will give profile measurements

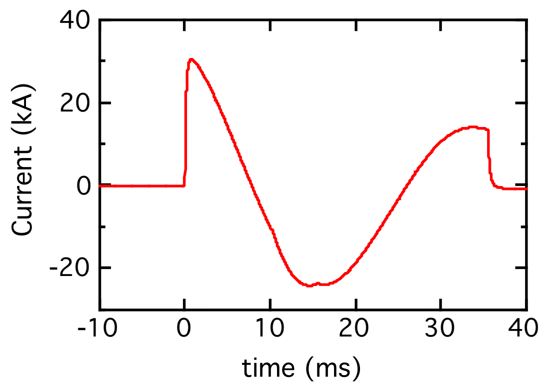
Magnetics used for Equilibrium Reconstruction & Mode Analysis



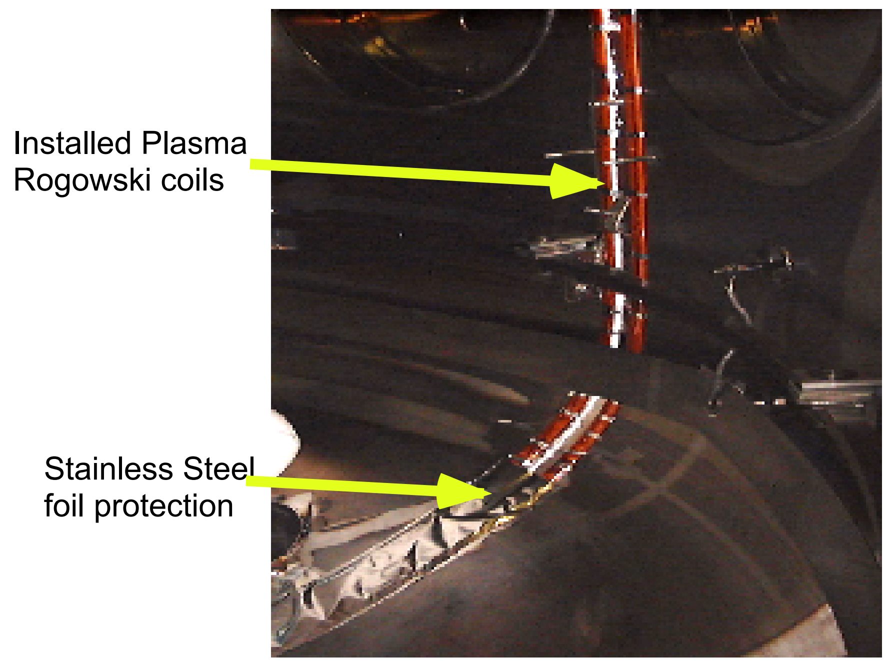
Internal Rogowski Coil for I_p

- Two coils installed for redundancy

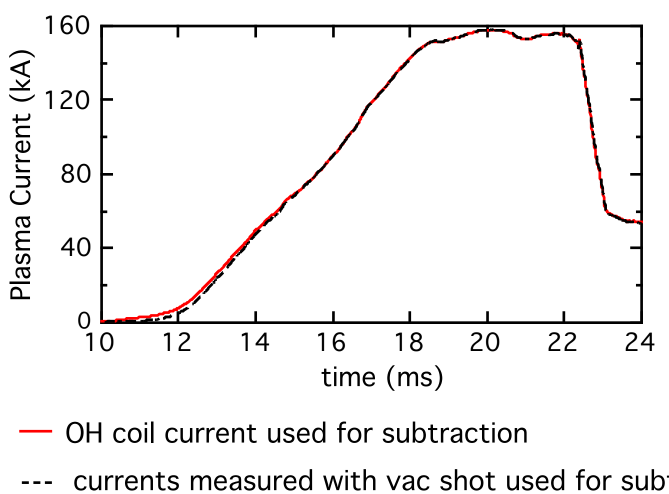
- The core armor and cones induce current in the plasma Rogowski
  - A vacuum shot accounts for these induced currents and is subtracted to get an accurate plasma current



Current measured with plasma Rogowski for vacuum shot

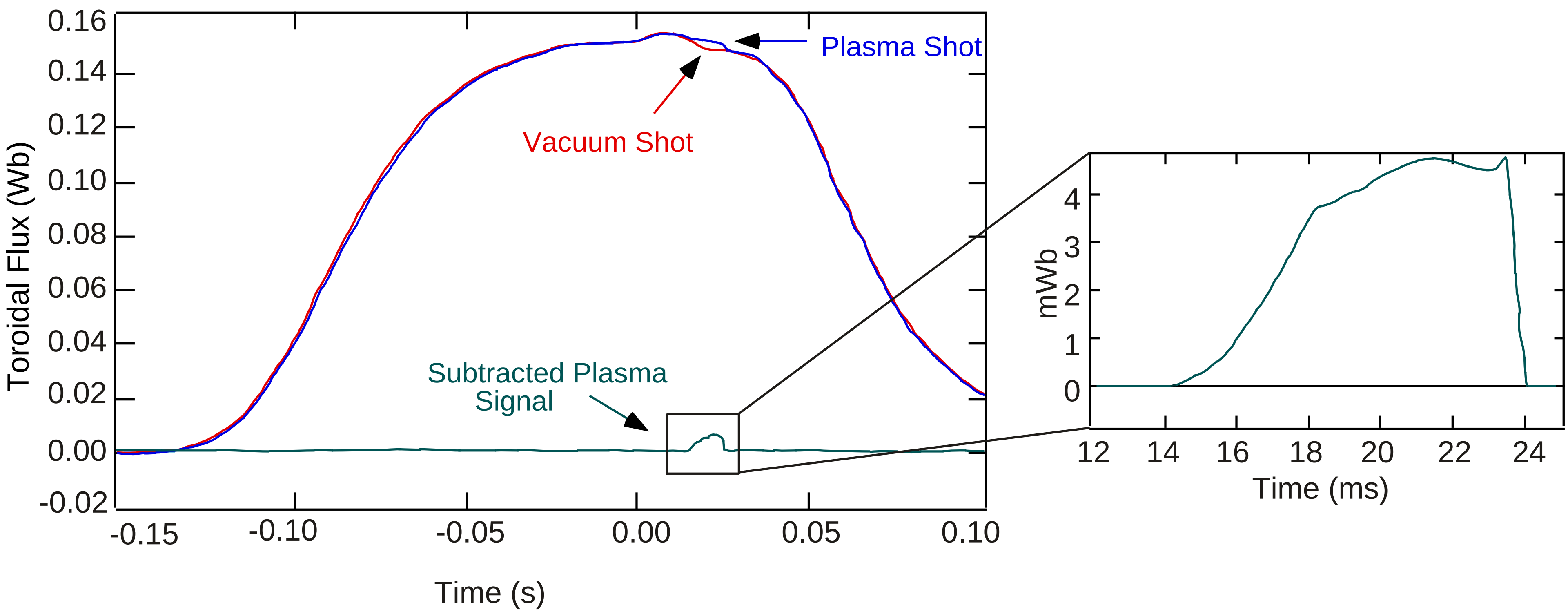


Installed plasma Rogowski coil and protective steel foil



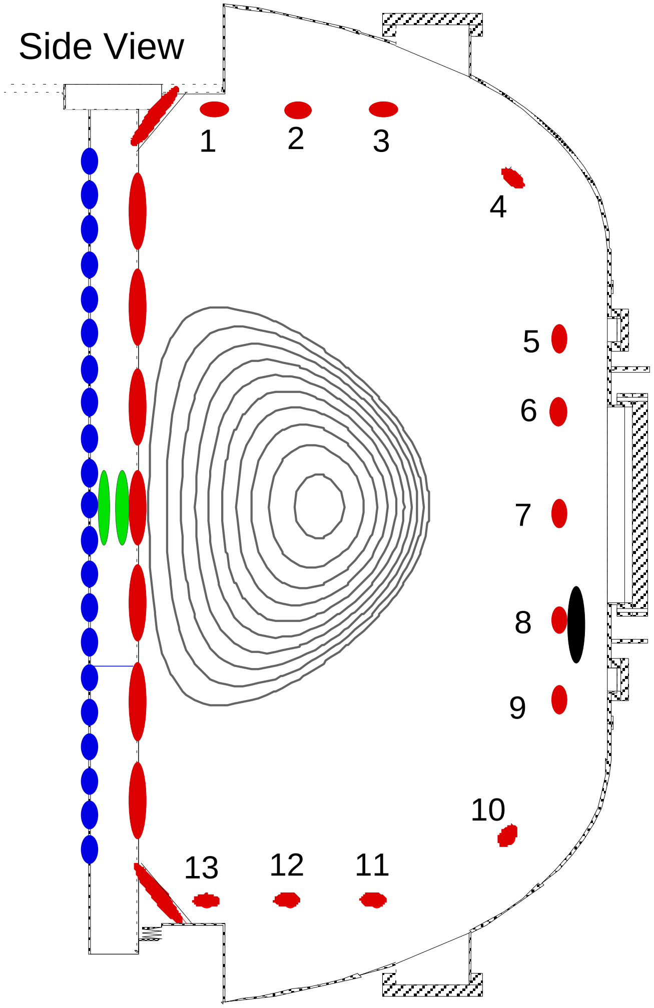
Diamagnetic Loop Used to Constrain Pressure

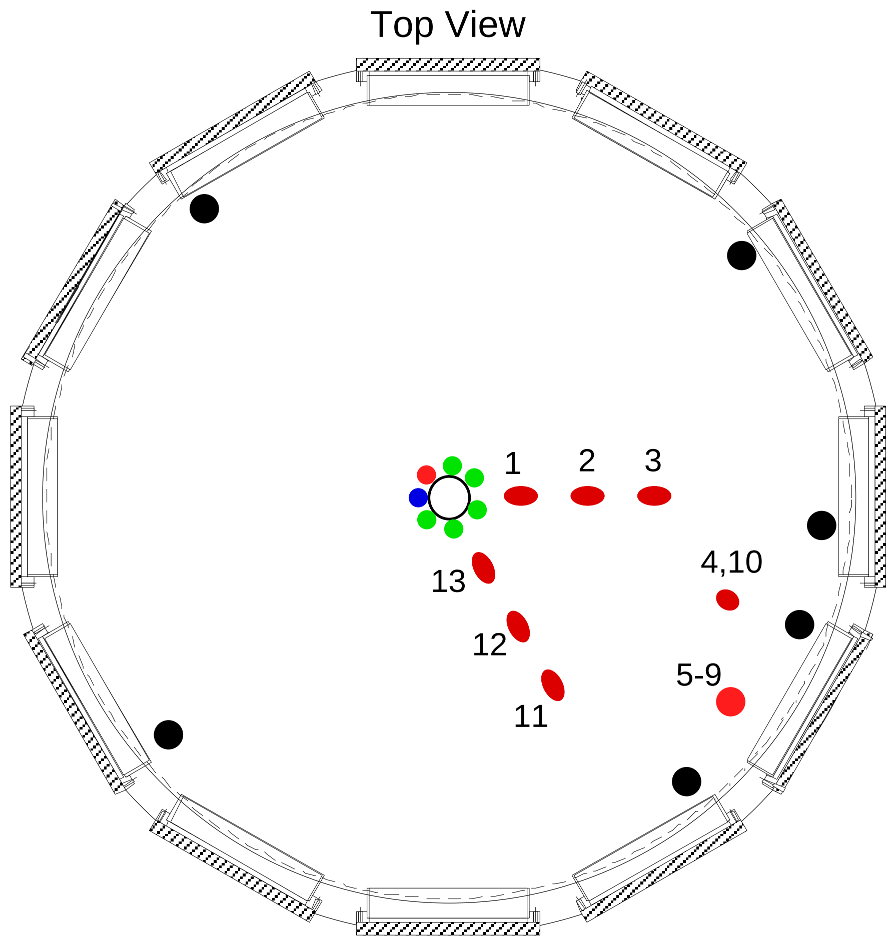
- For Pegasus, ΔB_{tor} due to plasma is relatively large.
  - Alignment to ±1mm is adequate.



- A compensation loop is used to remove signal noise due to TF switching transients

Schematic Layout of Mirnov Coils

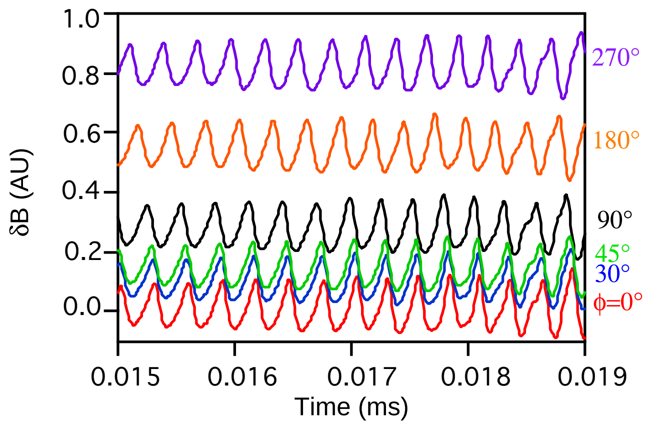




- "High-Res" Core Mirnov Coils (21)
- Poloidal Mirnov Coils (22)
- LFS Toroidal Mirnov Coils (6)
- HFS Toroidal Mirnov Coils (7)

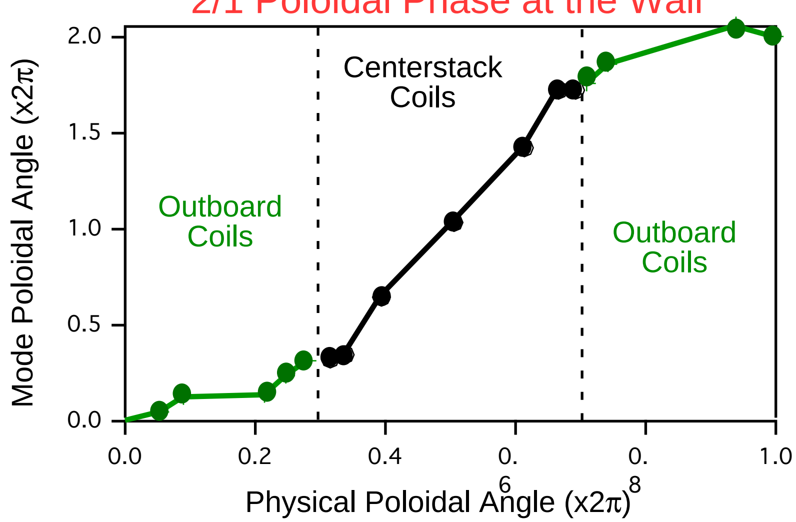
Mirnov Coils Allow Full Mode Identification

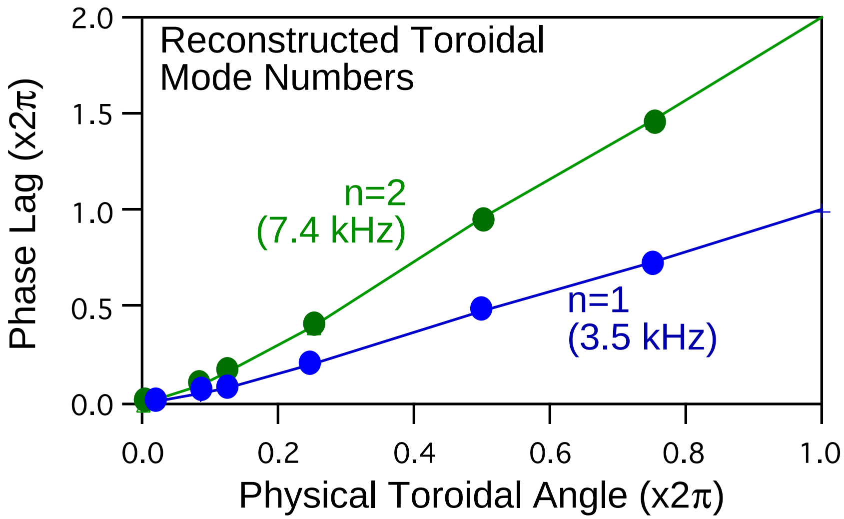
- The 6-coil LFS toroidal array is used to obtain values of n
  - Uneven coil spacing allows for resolution up to n=12



Toroidal Mirnov Signals

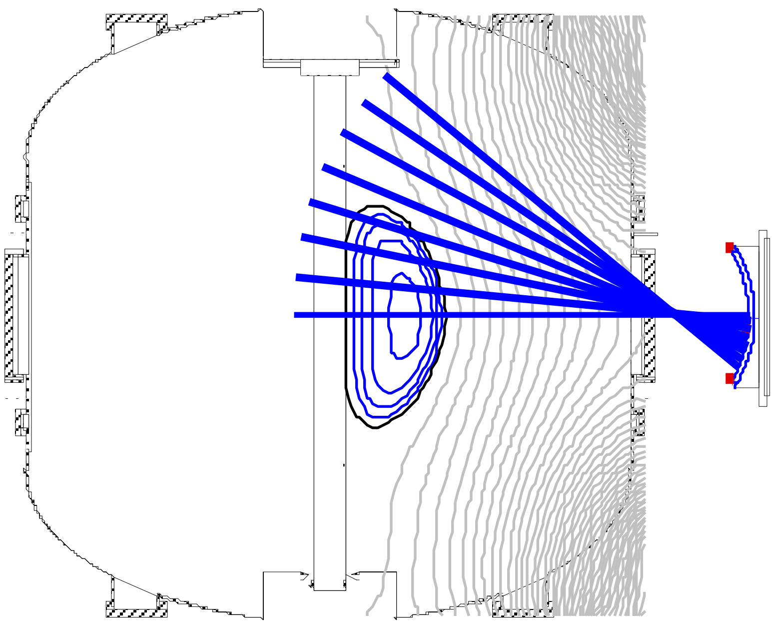
- Spectral techniques are used to extract resonant frequencies and phase delays
  - Cross-power gives spectrum
  - Cross-phase gives phase shift



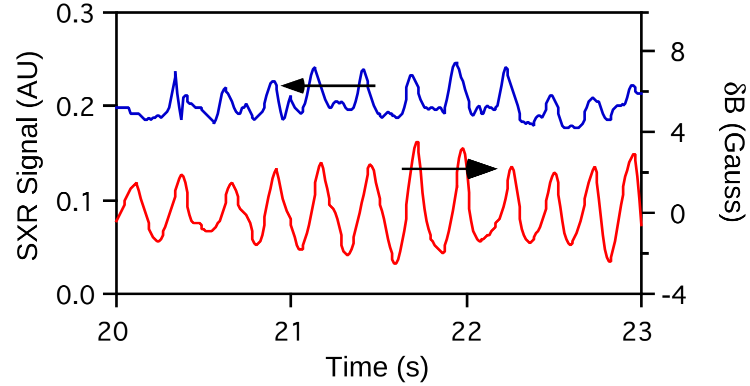


Soft X-Ray Array - MHD

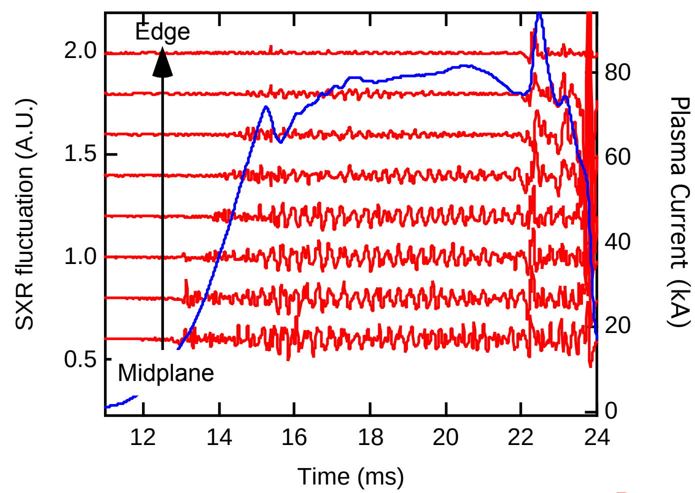
- 19 channel poloidal array of photodiodes (courtesy of PPPL)
  - external kinks observed and correlate with the visible camera images
  - 2/1 covers large portion of the plasma
  - 5 mil Be filters are used to get rid of most of the edge radiation
  - Ni filters will be used next spring to kill off the edge radiation completely



SXR View of a plasma



Correlation between Mirnovs and SXR



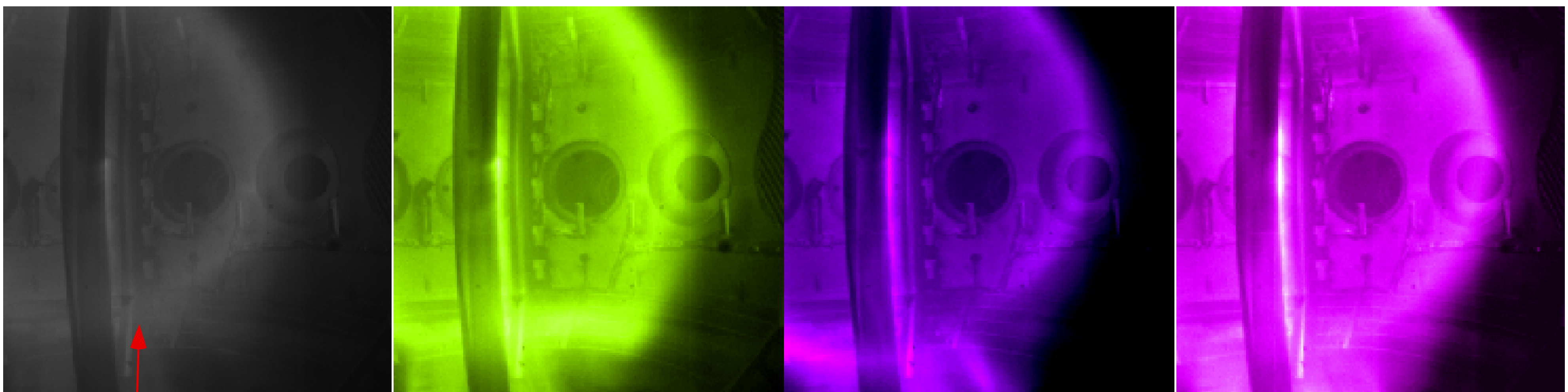
Large spatial extent of oscillations

Global Instabilities Visible on Camera

- DALSA 256 Camera
  - 1000 frames per second
  - 10 microsecond exposure/frame
  - 256x256 pixels
  - Local PC control

Shot 14701

16 ms 17 ms 18 ms 19 ms

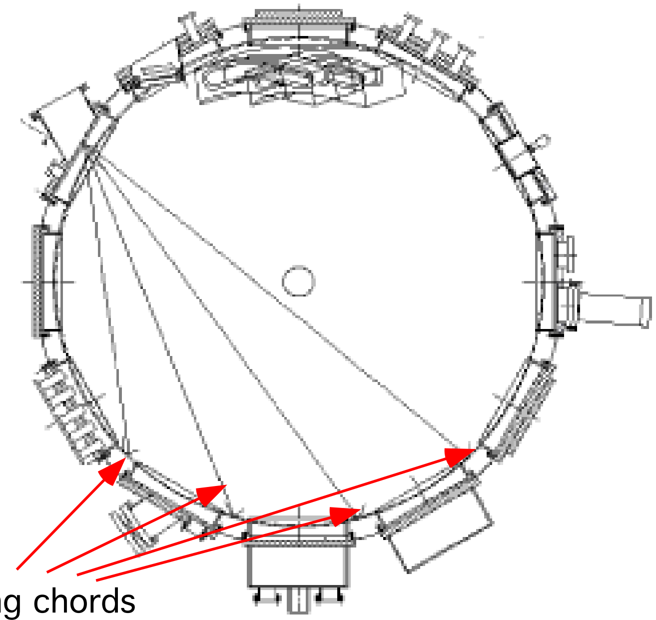


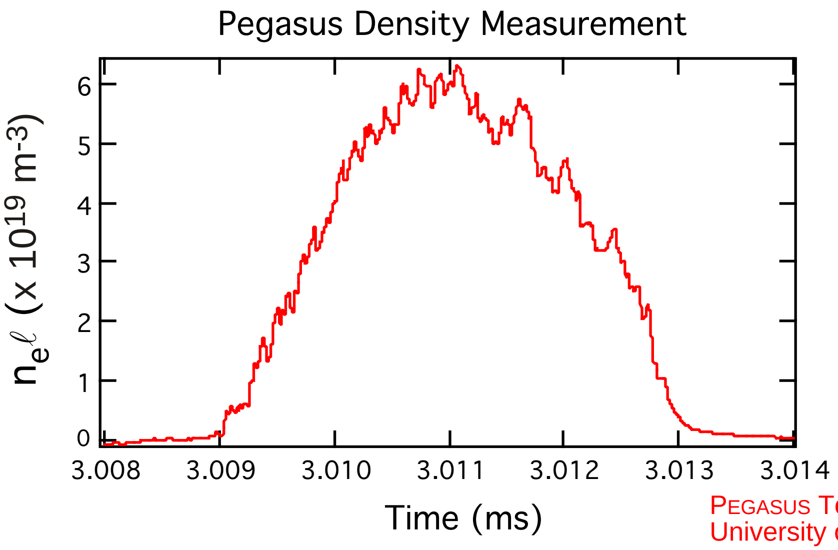
Center post

Visible distortions on plasma boundry

270 GHz Single Chord Interferometer for Line Integrated Density

• UCLA Collaboration



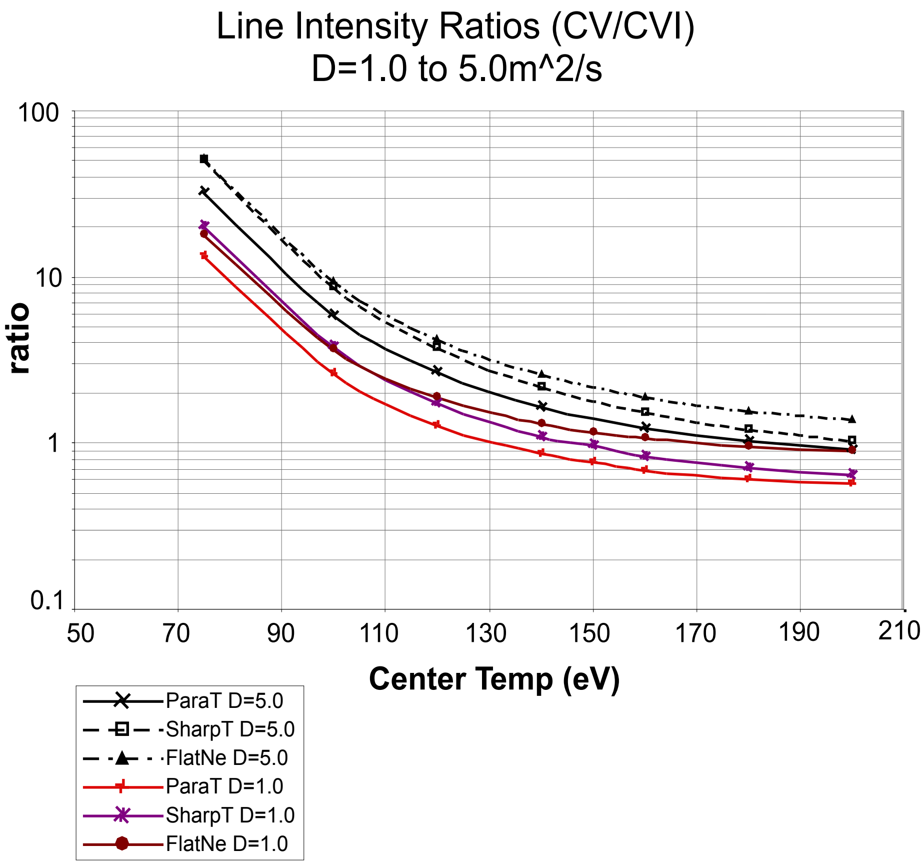


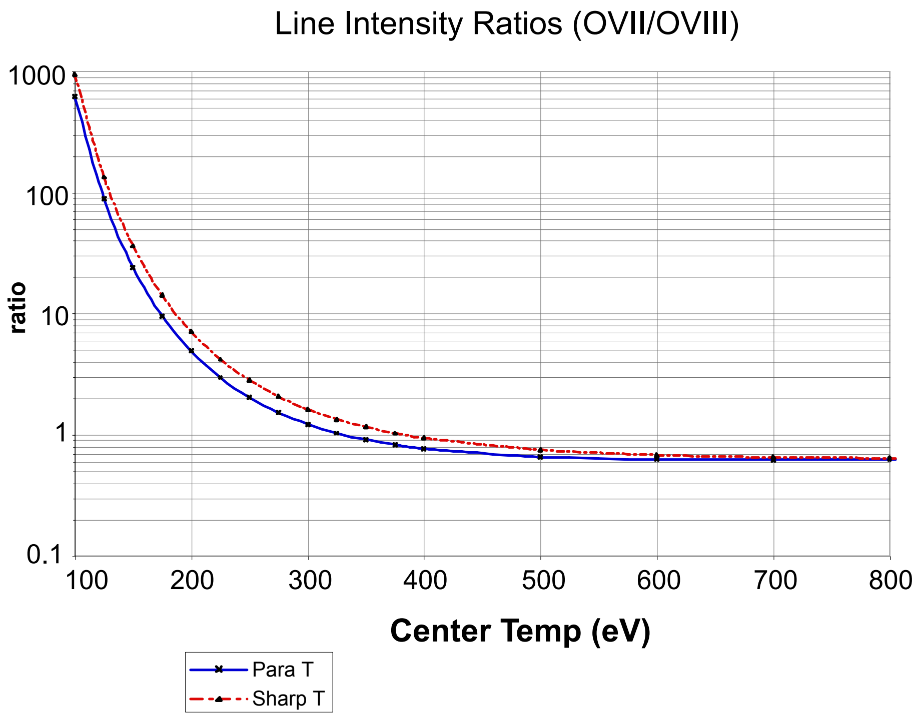
Spectroscopic Measurement of T_e up to 400 eV

- Ross filter system uses photodiodes to detect soft x-rays which depend heavily on T_e
- MIST results indicate applicable range of $T_e(0)$ for each species:

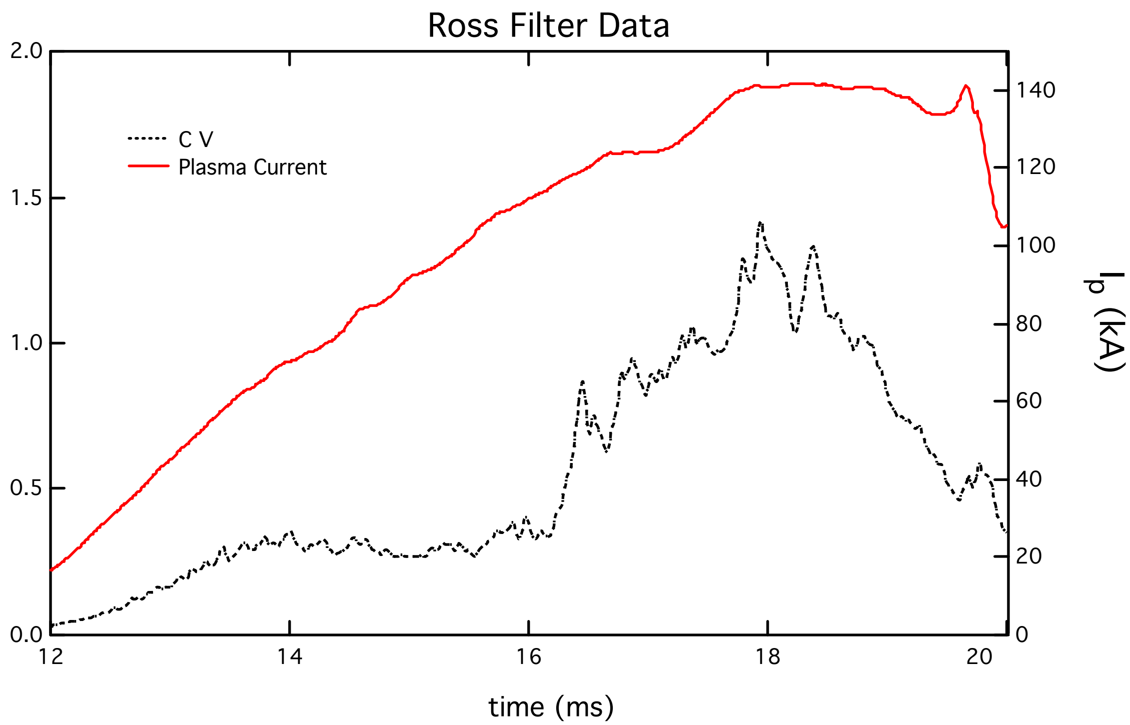
C: 70 to 150 eV

O: 150 to 400 eV





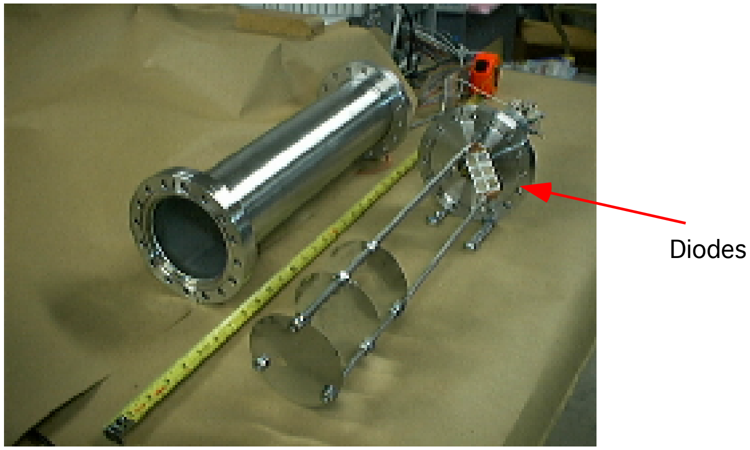
Ross Filters



- Set of six diodes installed on PEGASUS for T_e estimates
  - AXUV-100 diodes
  - 10 x 10 mm active area

- Filters isolate: Lyman-α line of each ion

CV	2000 Å Al, 2500 Å Ag, 1 μm CaF_2
CVI	4000 Å Al, 6000 Å V
OVII	5000 Å Al, 5000 Å Mn
OVIII	4000 Å Al, 4500 Å Fe

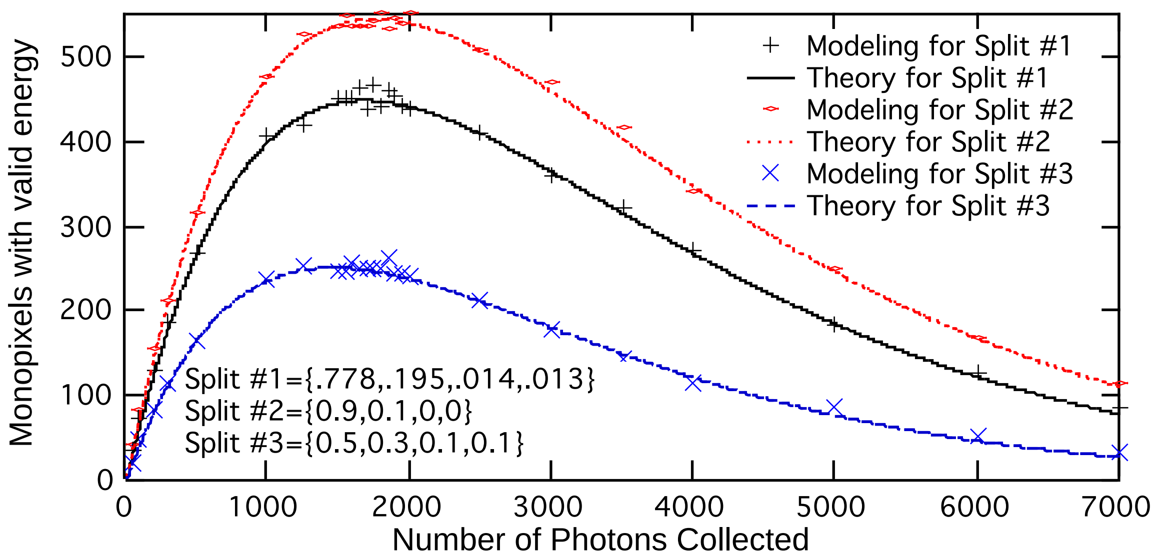


Time Resolved SXR Pulse Height Analysis: $T_e(t)$

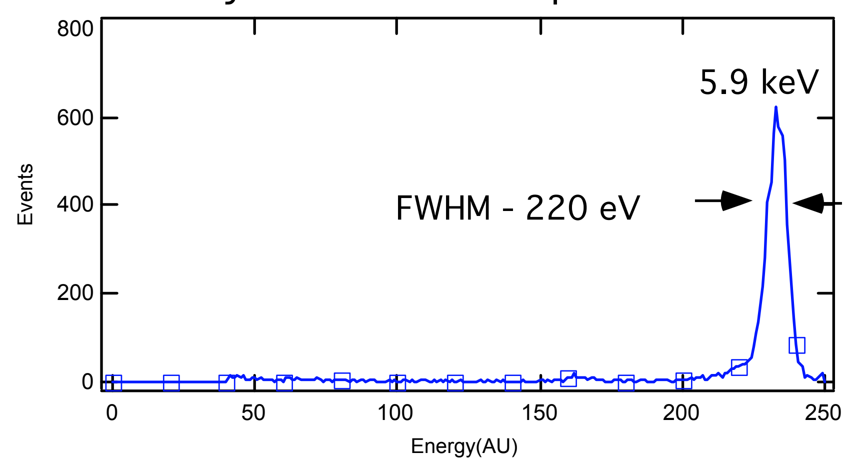
- Pulse Height Analysis systems measure SXR spectra
  - Individual photon energies are measured to reconstruct the plasma emissivity spectrum
  - This spectrum is used to estimate T_e

- A CCD is being developed as a time - resolved PHA detector
  - Thousands of pixels => Thousands of detectors
  - Increased count rates (better time resolution possible)
  - High energy resolution

Monte Carlo Modeling indicates good statistics without pulse pile-up

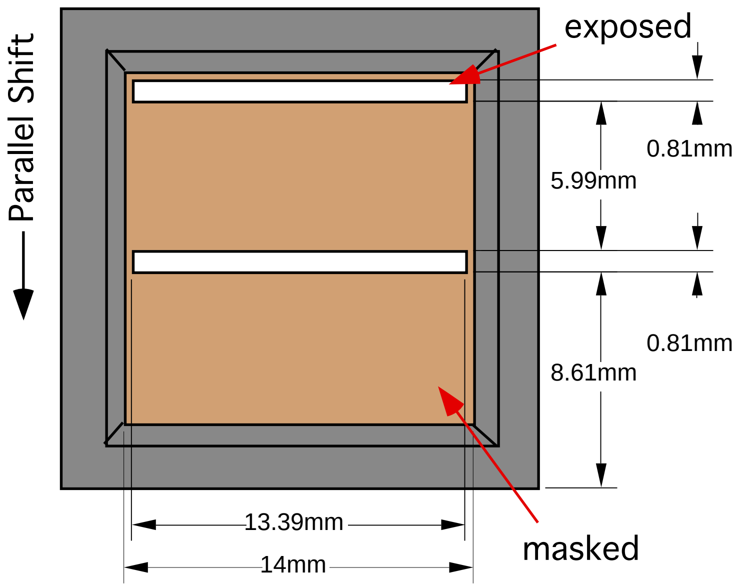


Laboratory tests show acceptable resolution



Iron Spectrum

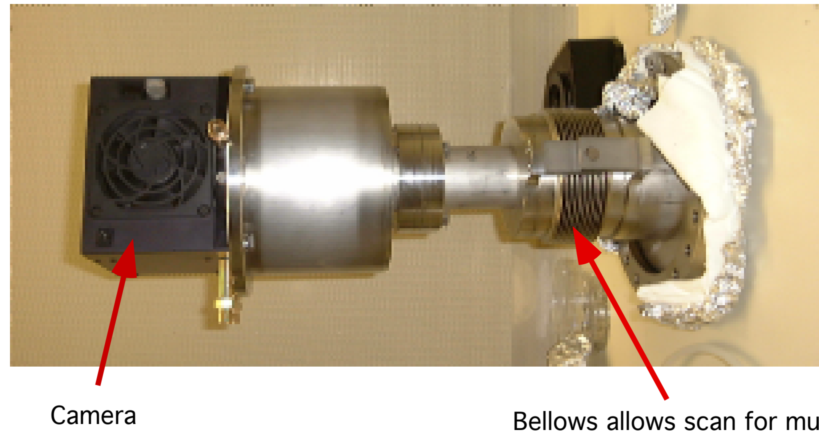
PHA/CCD System on Pegasus



Mask used for time resolution

- Exposed rows are shifted behind the mask at ~80 μsec per row
- Rows remain behind mask until plasma extinguished, and are then read out

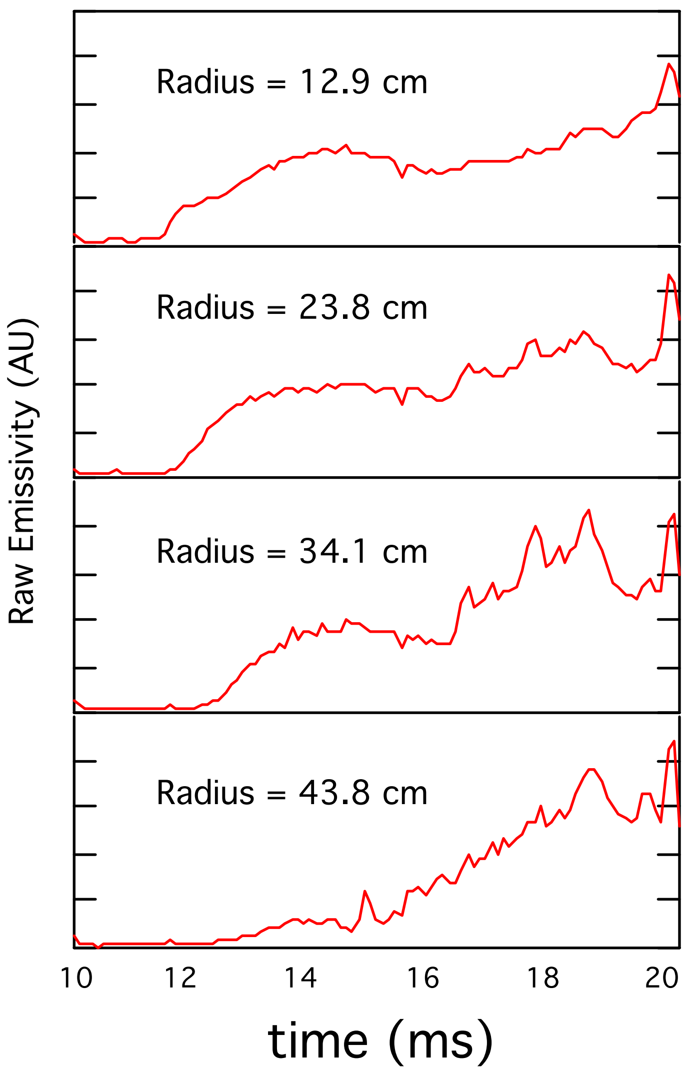
CCD SXR/PHA assembly ready for installation

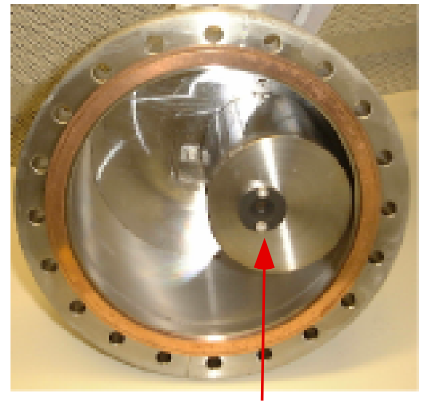


- The CCD/PHA system requires direct x-ray illumination of the CCD, therefore the chip must be place in machine vacuum
- A gold mask has been designed to add the capability of time resolution
- The split fraction of the camera is higher than expected
  - If this cannot be resolved, Si-drifted detectors may be used to get measurements of T_e in the keV range

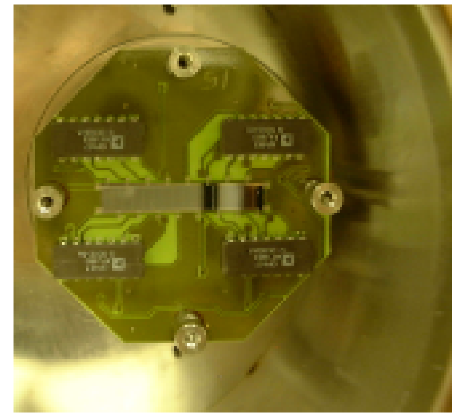
Bolometers

- 16 channel photodiode array installed

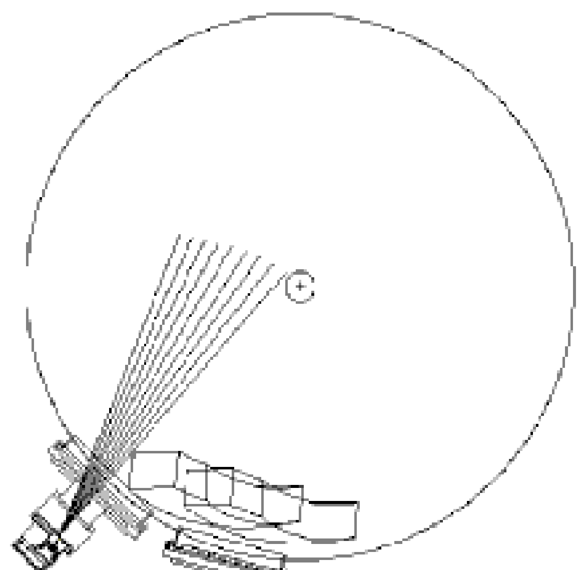




Pinhole imaging aperture



Diodes and pre-amp assembly

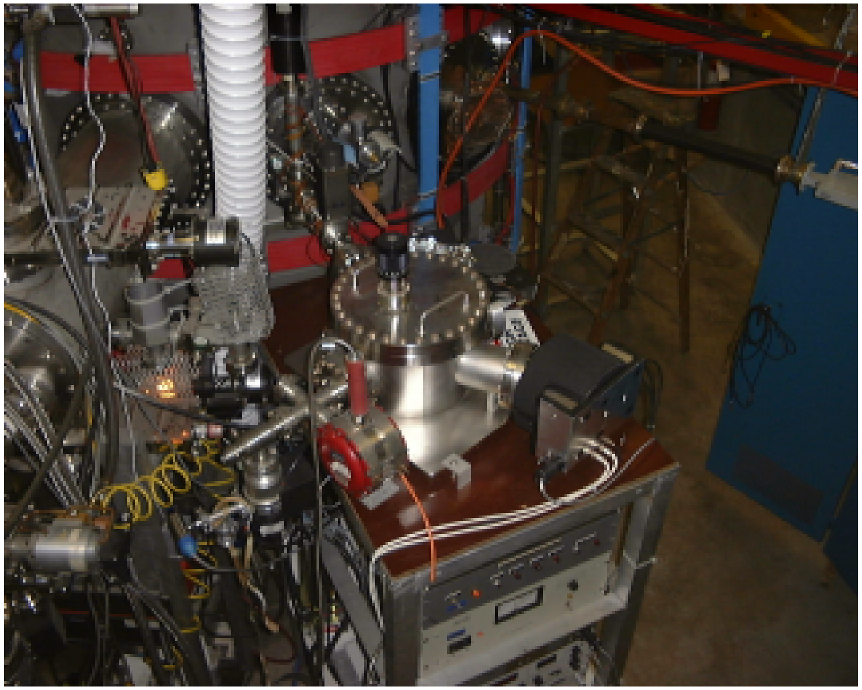


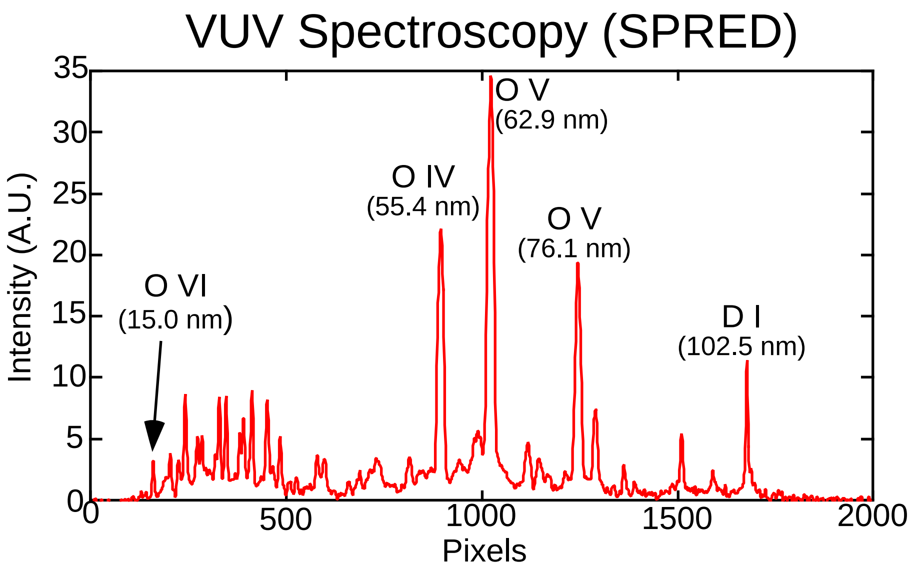
View of Plasma

High Time Resolution VUV Survey Spectrometer

- SPRED VUV Survey Spectrometer
  - 10 - 110 nm spectral range measured simultaneously
  - single radial view of plasma

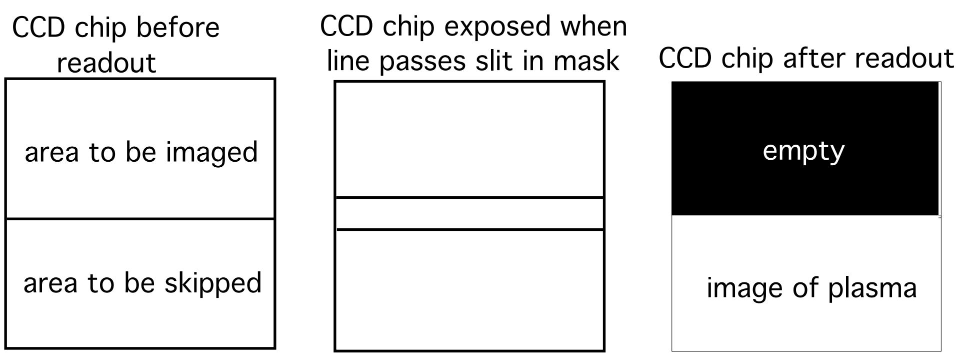
- New high -speed 1-D imaging detector
  - 2000 pixel 1-D camera (DALSA CL-C6)
  - VUV - visible image intensifier/convertor lens coupled to 1-D camera
  - Up to 4800 frame/sec sample rate
    $\Delta t \sim 0.2$ msec/frame



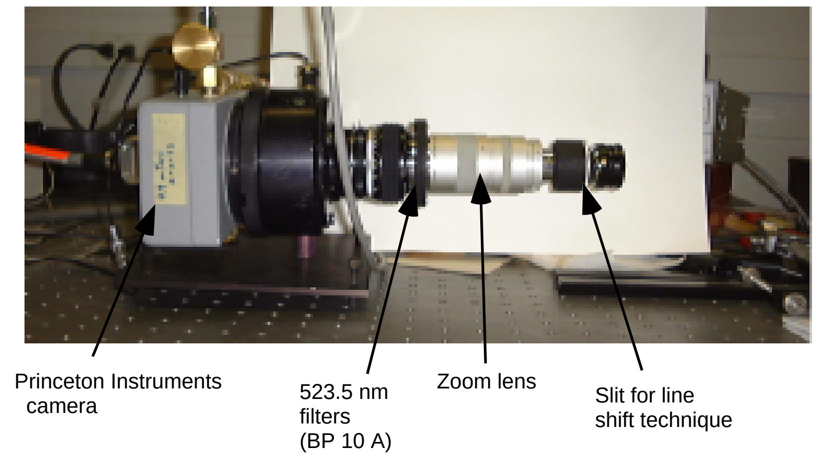


Visible Bremsstrahlung: Z_{eff} and N_e profile

- Visible Bremsstrahlung emissivity sensitive to electron temperature Z_{eff} and n_e^2

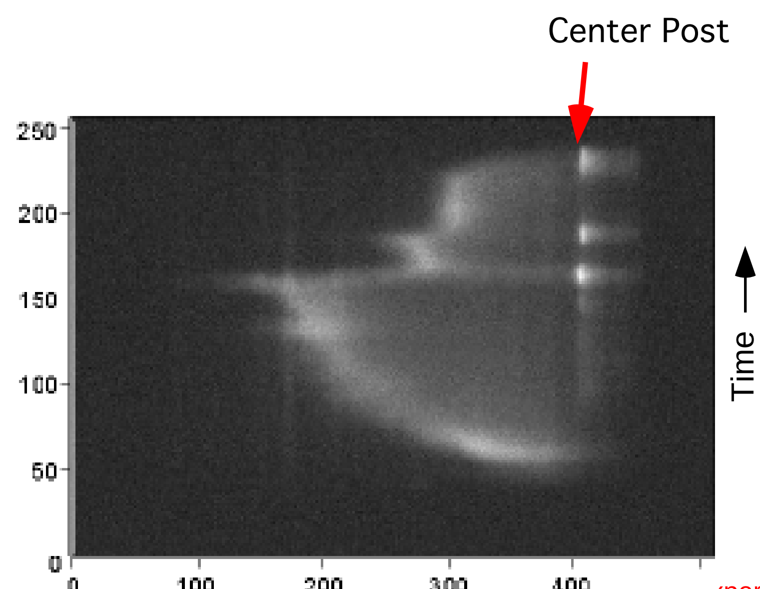


Line Shift Technique



- Slit frame transfer provides for time resolution

- Signal dominated by visible edge radiation
  - next generation will have improved filtering



Tangential SXR Plasma Imaging: j(R,t), P(R,t)

- Internal plasma measurements constrain equilibrium reconstructions and help determine j(R) profile

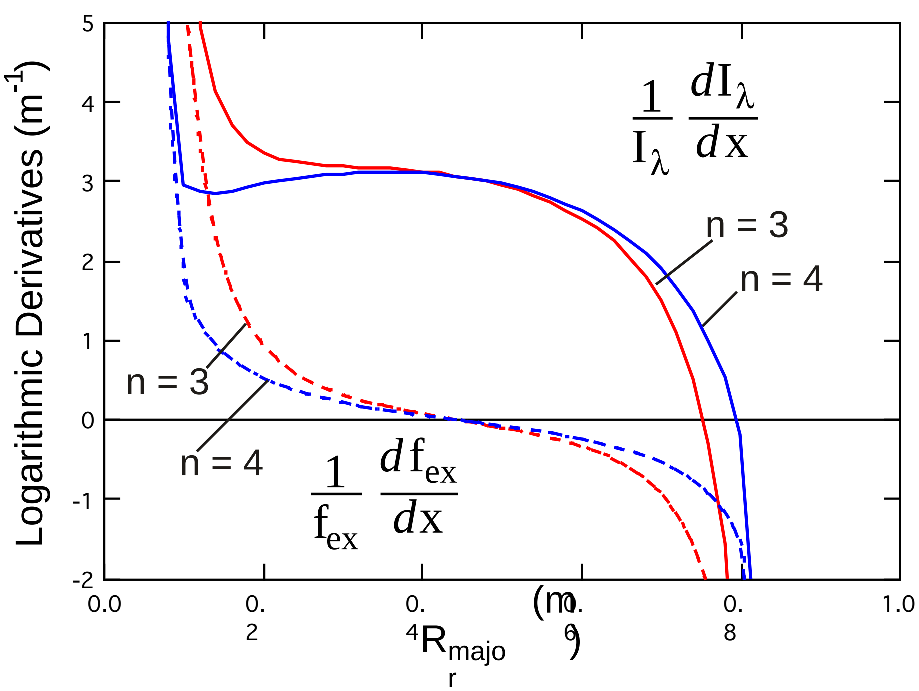
- Next generation of the SXR profile imaging system is in development
  - Direct soft x-ray illumination of the CCD chip
  - Ta mask used for time resolution

- See poster KP1.095 for more details

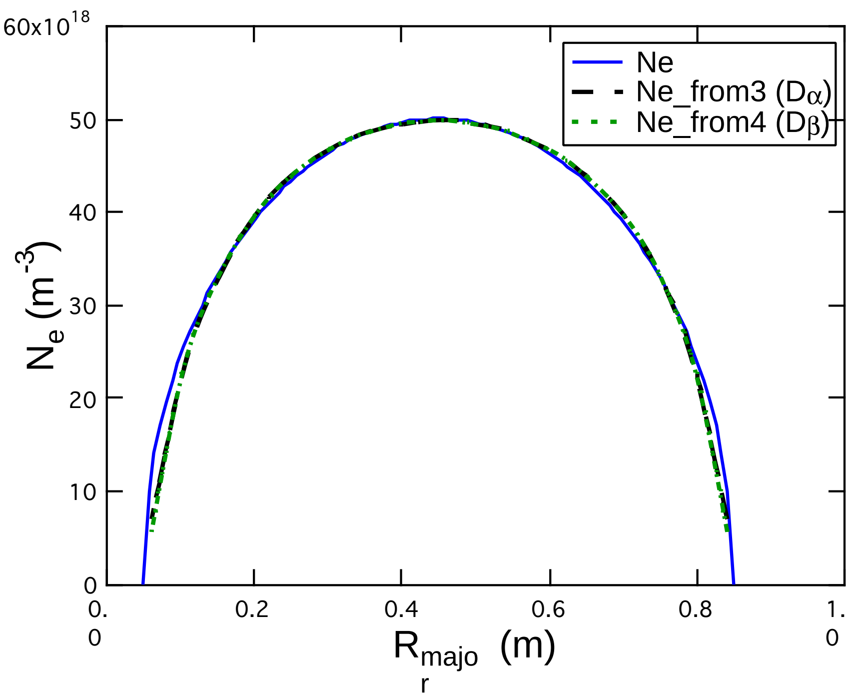
DNB Spectroscopy Provides a Variety of Internal Measurements

- In core plasma region, beam attenuation dominates the spatial variation of the H^0, D^0 line intensity, giving a simple local estimate of Ne
  - Use D_β line to minimize dependence of excitation rate on local plasma parameters
  - Use iterative solution to estimate the f_{ex} term and derive local $N_e(R,t)$ in the plasma periphery

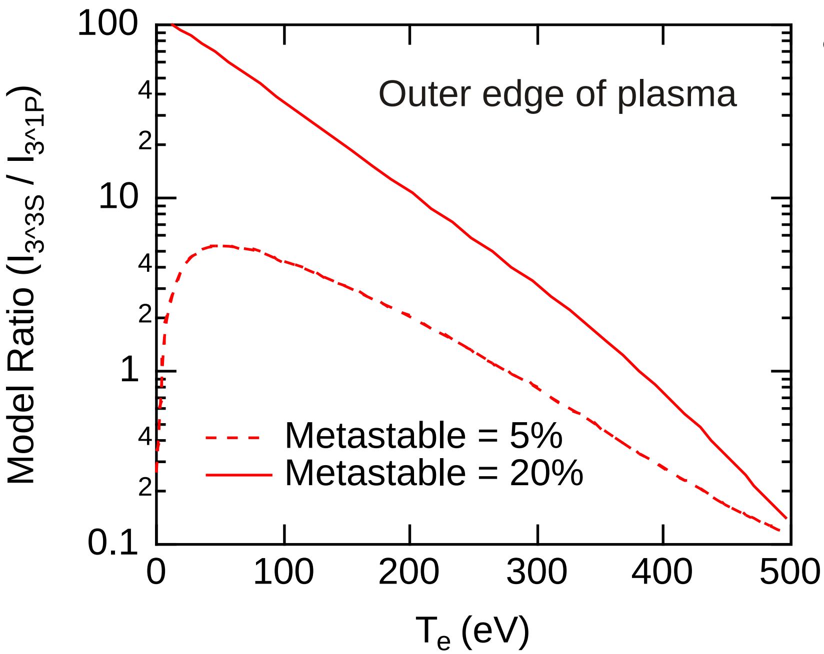
- Can recover the plasma density profile with good accuracy, even with no knowledge of the plasma temperature profile

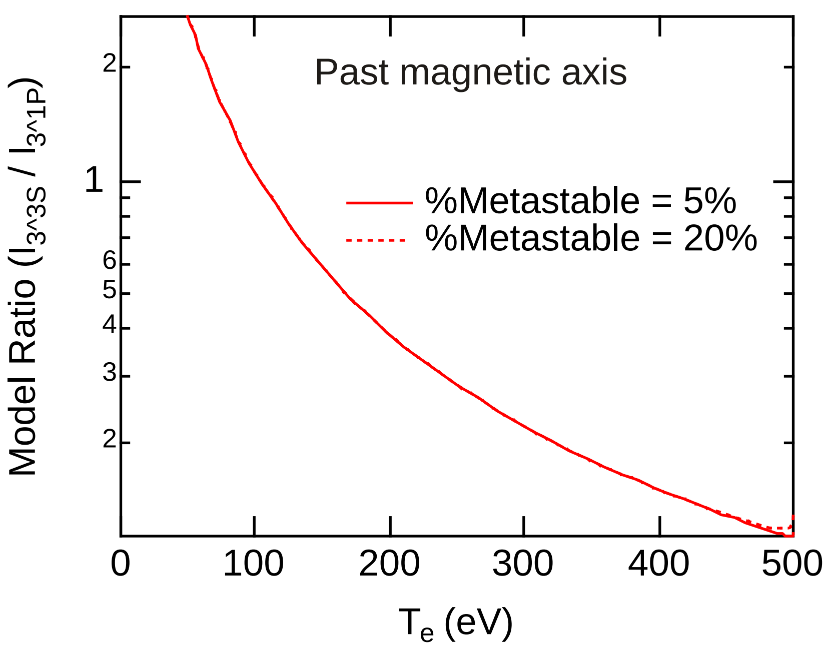


⇒



$T_e(r,t)$ Estimates Available from He^0 Beam Line Ratio Measurements

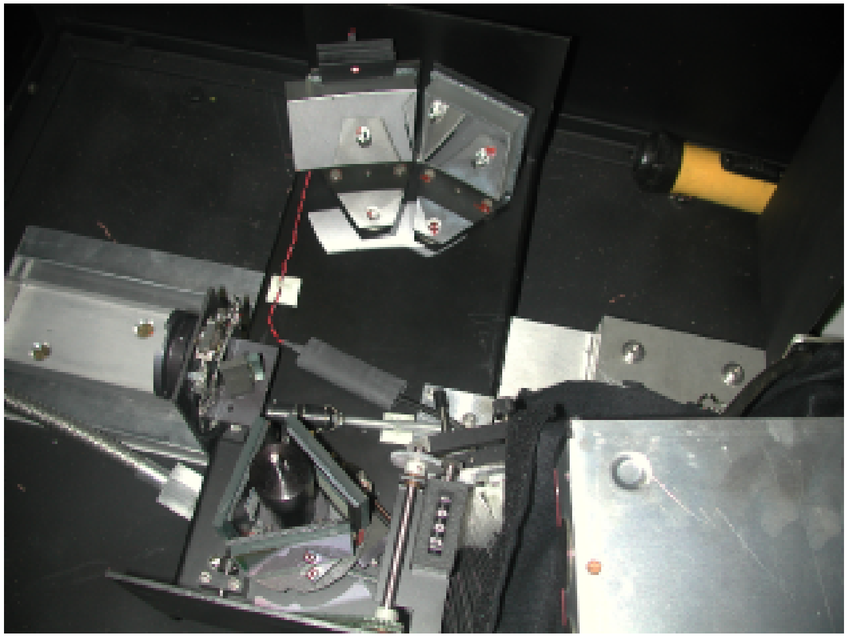




- Measurements past the magnetic axis are the key
  - At the outer edge, beam dynamics are in non-linear evolution
  - State populations are very sensitive to initial metastable fraction
  - Large differences seen in the ratios for different metastable fractions
  - Deeper inside the plasma, beam population has equilibrated
  - Line ratio is mainly sensitive to local temperature
  - Virtually no difference seen in the ratios for different metastable fractions

Future Work

• Thomson Scattering: Single point; spectrometer available; need laser and optics



Optics for the TS system

Detectors

• Li pellet injection
  - Measures the local magnetic field tilt - infers the j(r) and q(r) profiles
  - Compliment the CCD soft x-ray imaging system

Summary

- Global parameters are constrained during equilibrium fitting by magnetics
  - poloidal fluxloops for geometry
  - diamagnetic loop for plasma pressure
  - plasma Rogowski for total plasma current

- The first generation of plasma diagnostics measure $<T_e>$, $N_e l$, $P_{rad}(r,t)$ and plasma shape

- Next generation of diagnostics will provide time evolving density, temperature and current profiles
  - DNB spectroscopy
  - Thompson Scattering