Fast Electron Temperature Analysis using the Tangential Optical Soft X-ray Array

Presented by

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Motivation for TOSXR diagnostic

- The TOSXR system is designed to measure $T_e(R)$ with ~100μs time resolution and 4cm spatial resolution
  - attempts to provide 'ECE-like' functionality for the ST

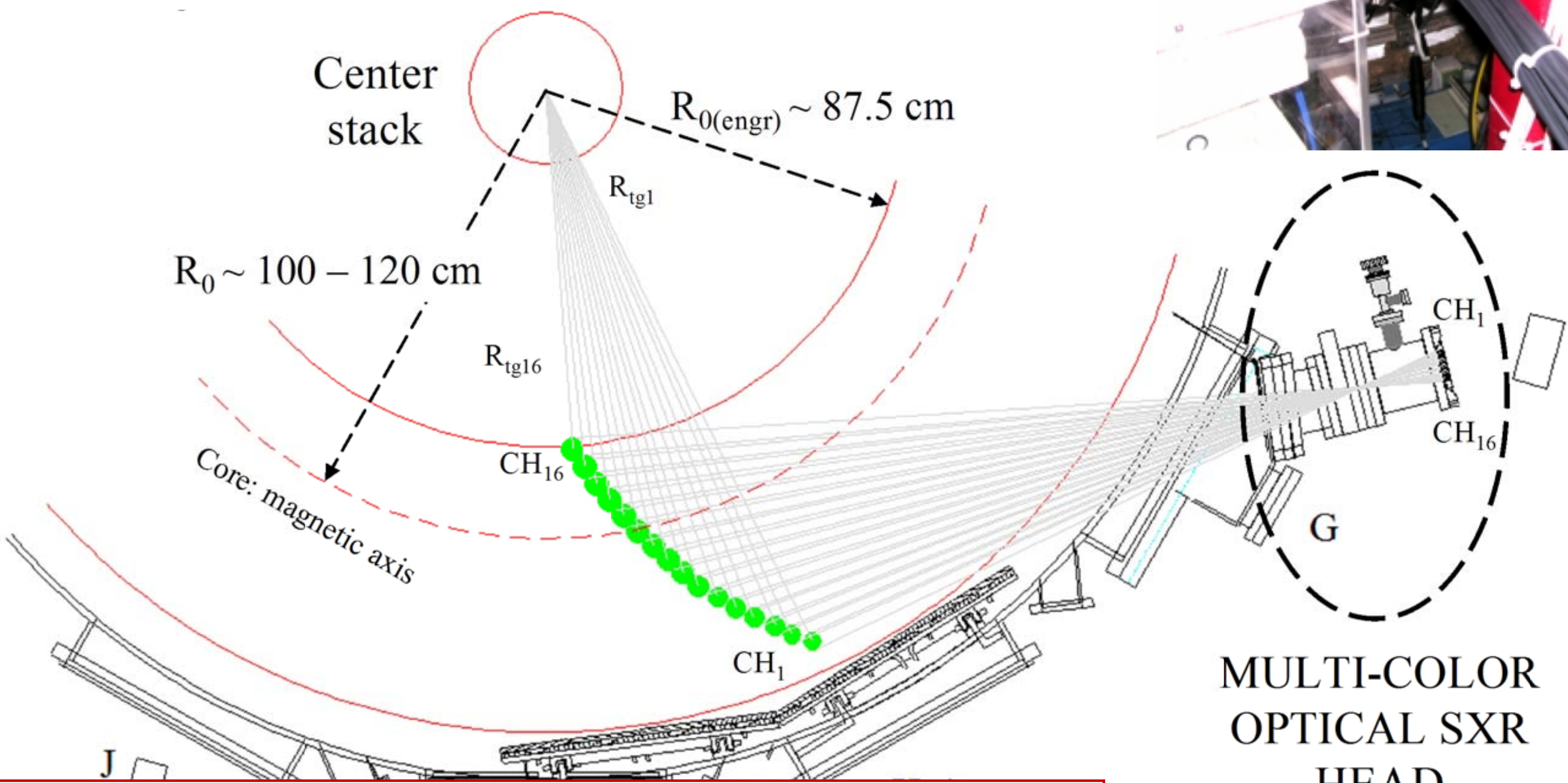
- Fast T_e measurements will be used for electron and transport and perturbation studies

- Also provides support for RF power deposition and heating studies

- Complements and is complemented by the poloidal SXR system for investigation of MHD modes (especially effects on T_e)

TOSXR layout schematic

- TOSXR field of view: Rtan - 88cm to 150cm
- Chord separation ~4cm

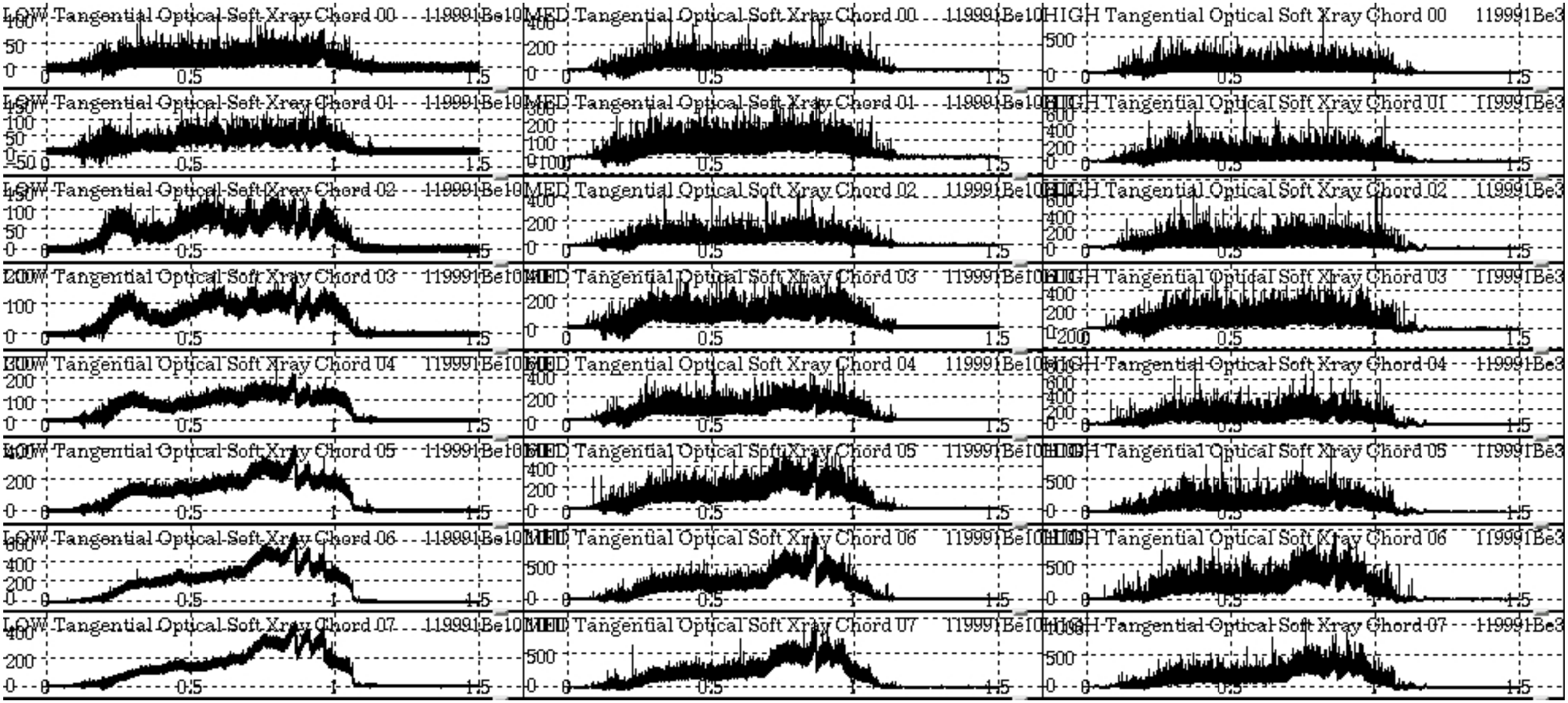


Vertically stacked arrays view the same plasma volume through a different Be foil thickness

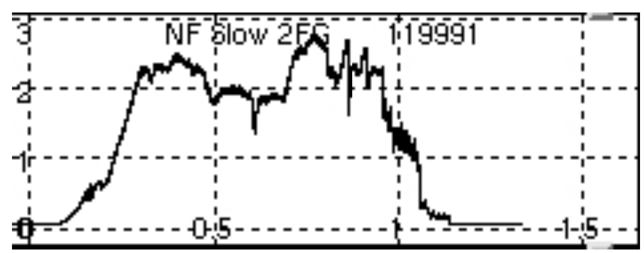
L. Delgado

Stacked arrays use Be filters for spectral discrimination of X-ray Emission

Be10μ　　　Be100μ　　　Be300μ



- Significant neutron background must be subtracted in high NB power discharges
- P_{neut} contributes to lower SNR, primarily for Be300μ array
- Binning data to 0.1-1ms used to improve SNR



(only 8 chords from edge to mid-radius are shown)

Accurate T_e profile reconstruction requires spectral modeling and inversion/projection of X-ray data

- TOSXR signals are line integrated X-ray intensity measurements
- T_e depends on spectral ratio of X-ray continuum emissivity

Reconstruction Method

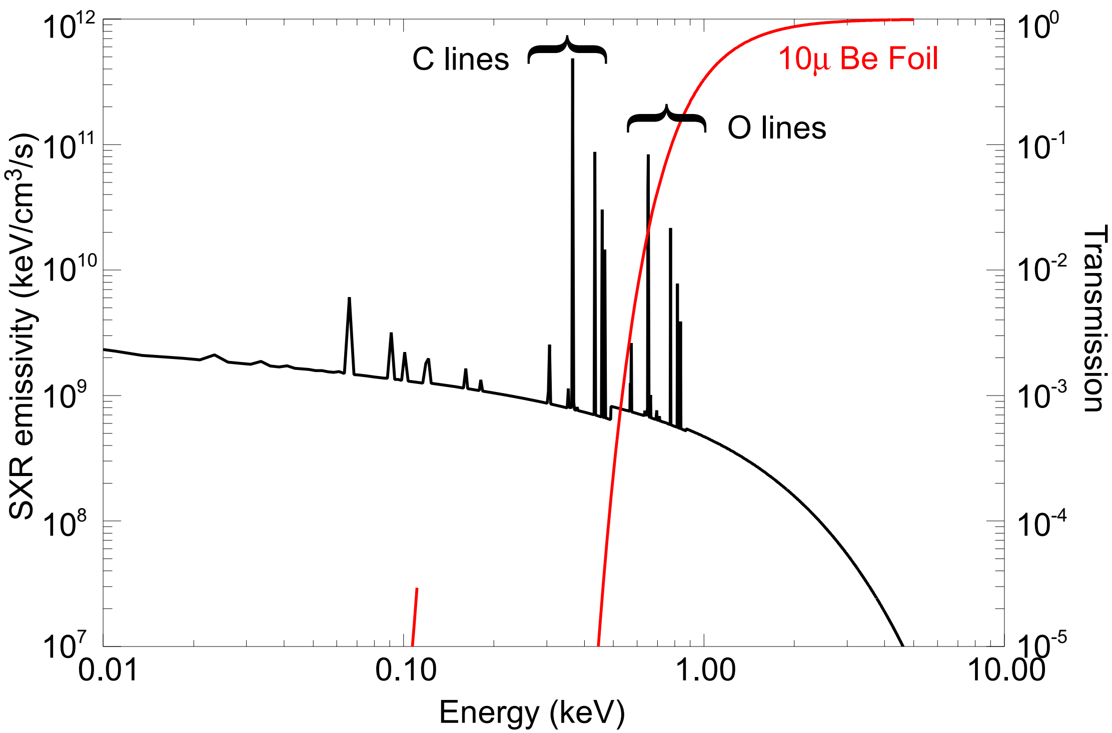
- Abel inversion of data will recover local emissivity/spectral ratios suitable for “clean” plasmas (low O, no high-Z impurities)
- Forward modeling incorporates impurity spectral line emission and projected fits to X-ray data to reconstruct $T_e(R)$ on ~0.1-1ms time scale
- Profile normalization using Thomson scattering can help compensate for unknown impurity concentrations
- This diagnostic will benefit greatly from time/spatially resolved spectroscopy (e.g. JHU Transmission Grating Spectrometer)

Chianti provides calculated X-ray spectra

- CHIANTI developed in the astrophysics community, uses high level IDL interface code to synthesize X-ray spectra for a given T_e, n_e, n_z

- Code uses a collection of experimentally measured and theoretically calculated emission lines

Synthetic X-ray spectrum & filter transmission curve



Plasma parameters

n_e = 1e13 cm^{-3}

T_e = 1keV

C = 5%

O = 0.25%

Spectral synthesis models C, O and higher-Z (Fe) impurity lines

Full 3-D treatment of detector FOV

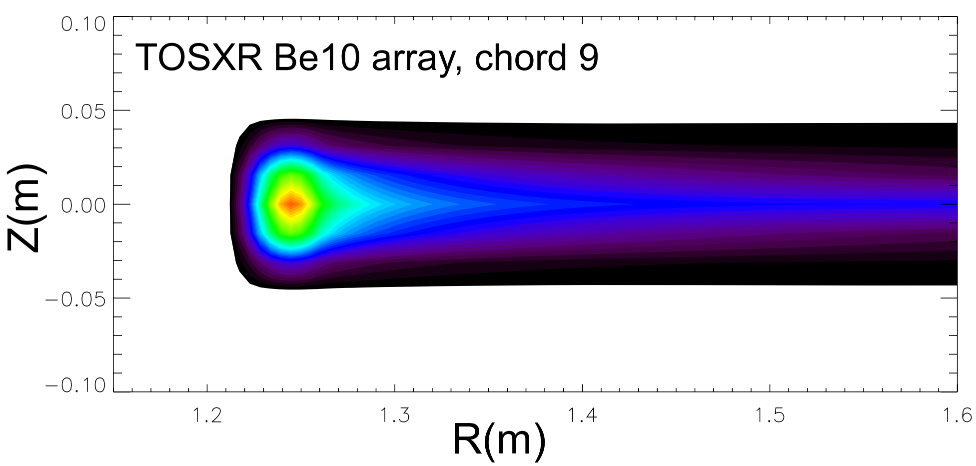
Intensity calculated from 3-D volume integral of emissivity and detector response

$$I = \iiint \varepsilon(R,Z,\varphi) g(R,Z,\varphi) dV \qquad I \approx \sum_{i,j,k} \varepsilon_{i,j,k} g_{i,j,k}$$

Detector response matrix element, g_{ijk} is volume integral of detector point response (calculated from subtended solid angle)

$$g_{i,j,k} = \int_{R_i - \frac{dR}{2}}^{R_i + \frac{dR}{2}} R\,dR \int_{Z_j - \frac{dZ}{2}}^{Z_j + \frac{dZ}{2}} dZ \int_{\varphi_k - \frac{d\varphi}{2}}^{\varphi_k + \frac{d\varphi}{2}} p(R,Z,\varphi)\,d\varphi \qquad p = \iint \frac{dA}{4\pi D^2}$$

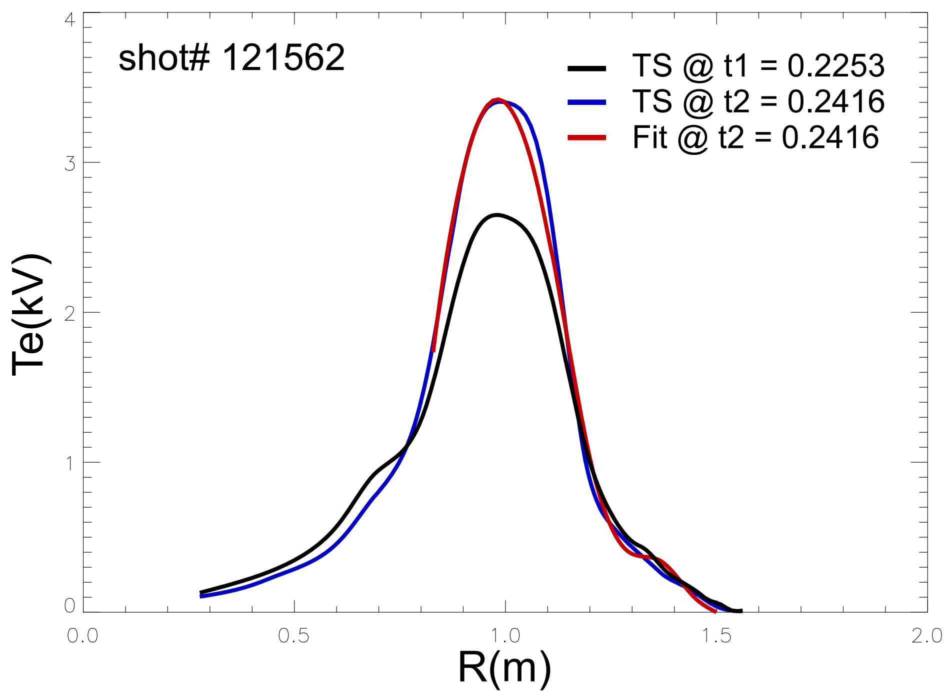
Axisymmetric detector response g(R,Z)

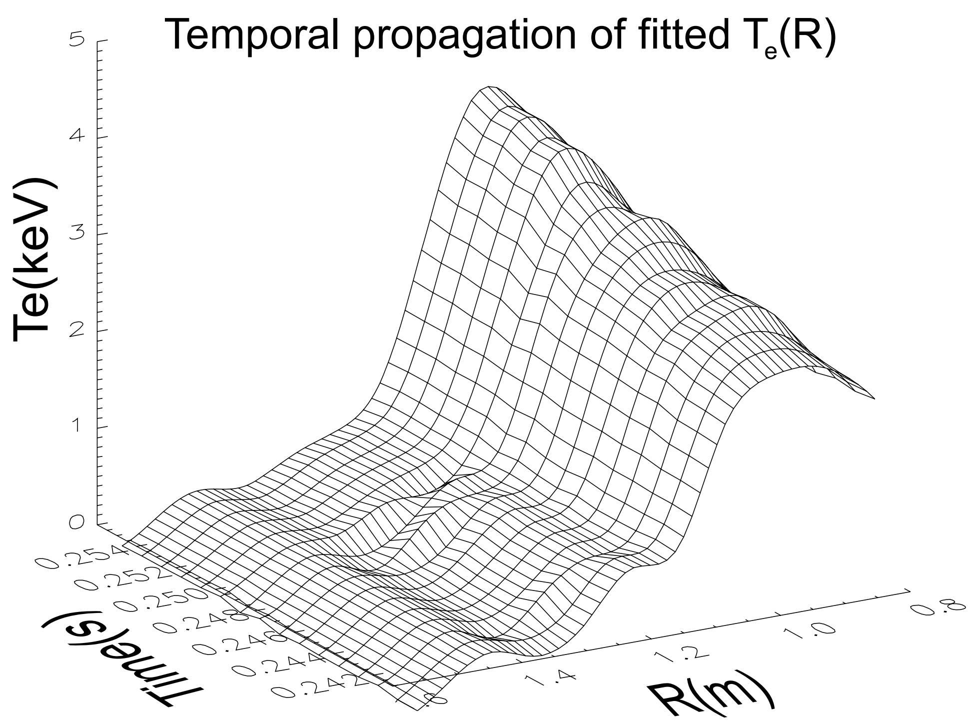


Pre-calculated response minimizes computational time during fitting

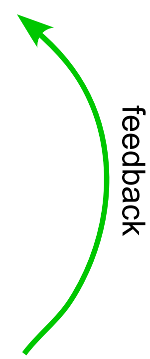
Important for high spatial resolution detectors (e.g. proposed SXR Edge Array diagnostic)

Initial forward modeling results demonstrate good agreement with TS electron temperature profile



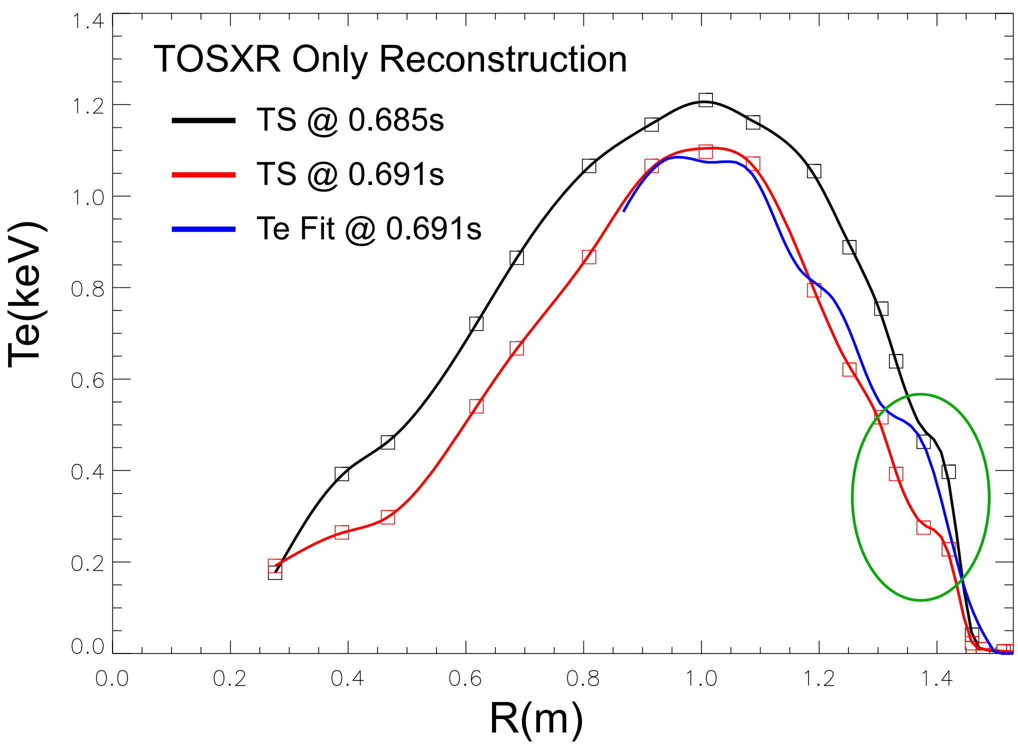


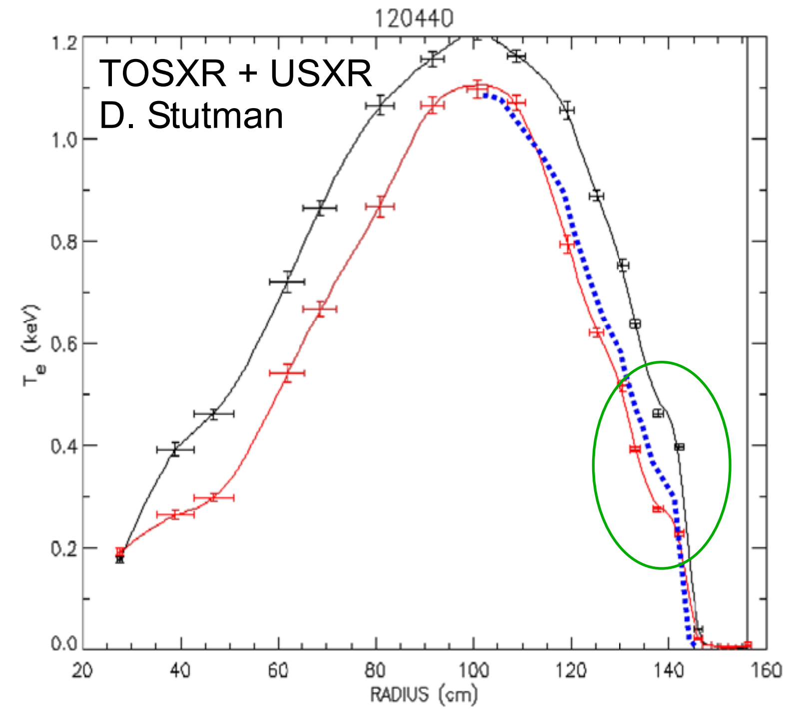
- Te/ne profiles modeled by 8-point splines
- Profiles used with measured/assumed impurity profiles to generate X-ray spectrum
- Spectral emissivities folded into projection calculation to generate filtered TOSXR intensity profiles
- Nonlinear LM least-squares fitting routine modifies Te/ne profile based on comparison between calculated and measured TOSXR profiles



H-mode T_e reconstruction is assisted by poloidal SXR system

Reconstruction of ELM @ .689s shot# 120440





- TOSXR system less sensitive to steep edge gradients
  low SNR at edge (reduced X-ray signal vs. neutron background)
  tangential integration and 4cm spatial resolution smooth out gradients

- System upgrades will improve system throughput and reduce neutron background for significant SNR improvement

- Accurate edge gradient reconstruction will require array with improved spatial resolution