



Z_{eff} Measurement from Bremsstrahlung Radiation on HSX



K. Zhai, A. Briesemeister, F. S. B. Anderson *HSX Plasma Laboratory, Univ. Wisconsin*

Z_{eff} measurement from Bremsstrahlung radiation

$Z_{\text{eff}} = \sum_i n_i Z_i^2 / \sum_i n_i Z_i$ Effective ion charges Z_{eff} is an important parameter for evaluating impurity content in fusion plasma study. A profile of Z_{eff} can give significant information for particle transport and impurity behavior.

Bremsstrahlung radiation is the source of plasma continuum radiation, which occurs when free electrons encounter an ion and radiate. It takes two forms of free-free transition and free-bound transition. At low frequency, the free-bound contribution is negligible. Thus the bremsstrahlung radiation is approximated as,

$$4\pi j(\nu) d\nu = \sum_i n_e n_i Z_i^2 g_{ff} \left(\frac{e^2}{4\pi\epsilon_0} \right)^3 \frac{32\pi^2}{3\sqrt{3}m^2 c^3} \left(\frac{2m}{\pi T} \right)^{1/2} e^{-h\nu/T} d\nu$$

$$= 5.03 \times 10^{-54} n_e^2 T_e^{-1/2} g_{ff} Z_{\text{eff}} d\nu$$

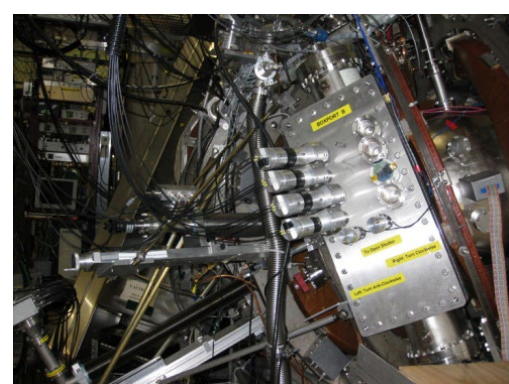
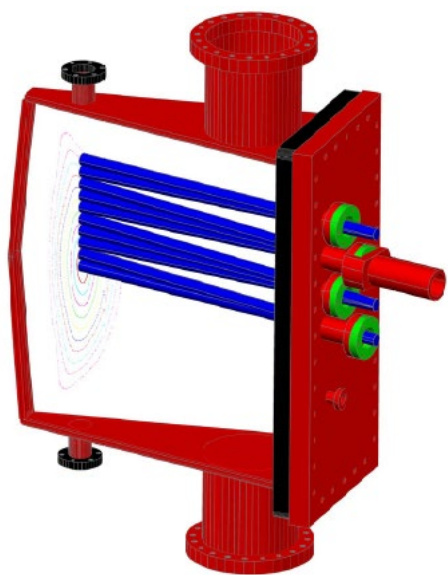
g_{ff} is Gaunt factor which is approximated as, $g_{ff} = \frac{\sqrt{3}}{\pi} \ln \left| \frac{4T}{1.78 h\nu} \right|$

HSX Z_{eff} measurement system and initial results

System setup

HSX Z_{eff} measurement uses HSX CHERS poloidal view system. It is equipped with four collection lenses, a ten channel fiber bundle, a 75-cm Czerny-Turner spectrometer (Princeton Model: AM-507-6) and a fast frame CCD camera (Princeton Model: Photonmax:512B).

Each view cylinder has a 2cm diameter. Measurements are made along ten chords at different radial locations. Four single lenses couple the collected radiation to ten fibers which is then input to the spectrometer-CCD system.

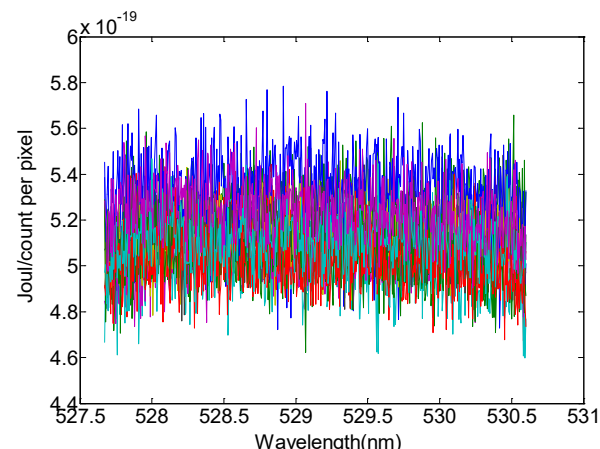


Boxport picture with poloidal view



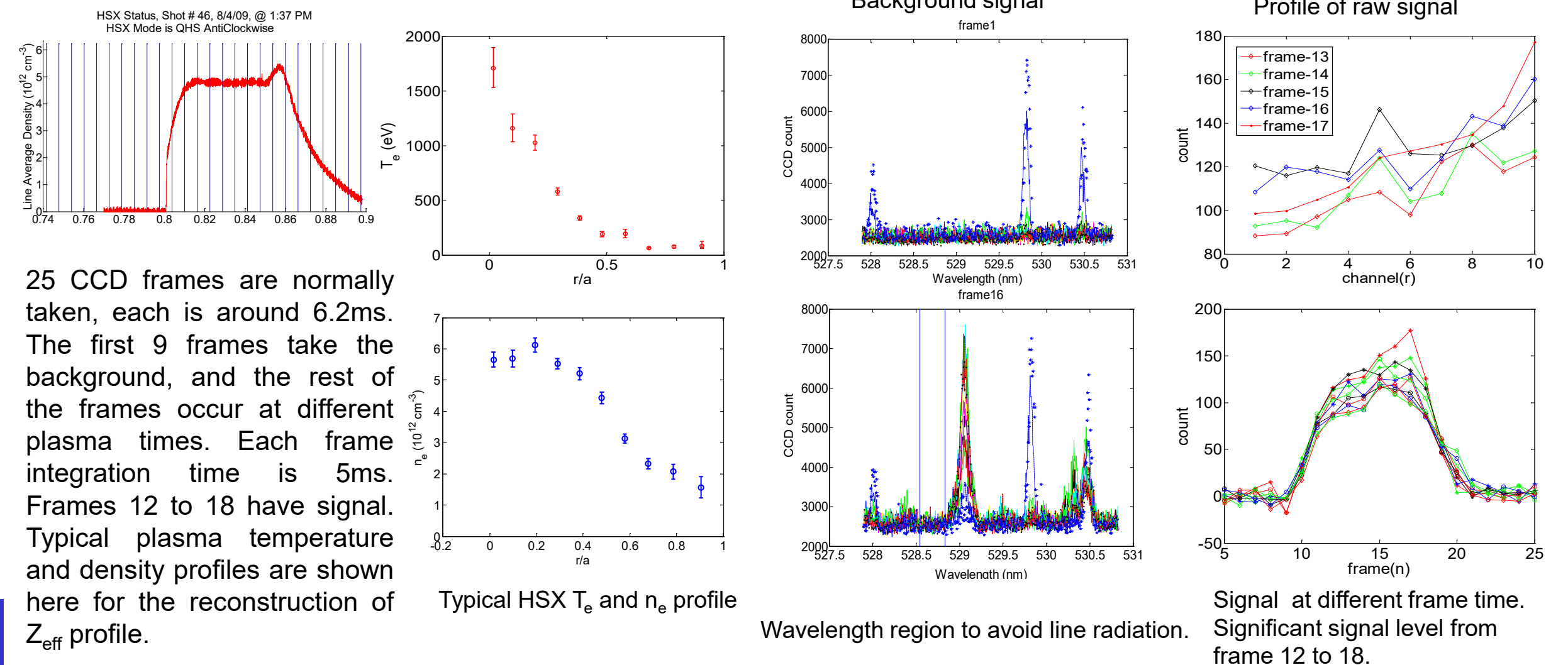
Ten-fiber bundle coupled to the spectrometer and imaged on the CCD, providing ten local measurements.

Absolute intensity calibration: By using an absolutely calibrated integrating spheres, we calibrate the response of each pixel on the CCD surface to certain amount photon energy at the wavelength range of measurement.



Ten channel intensity calibration

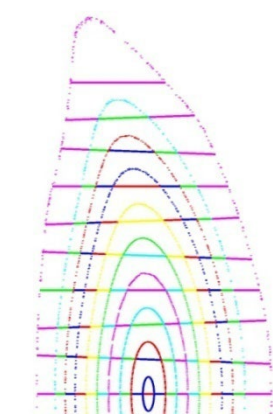
HSX parameters and raw signal



Z_{eff} profile : Reconstruction of the raw signal

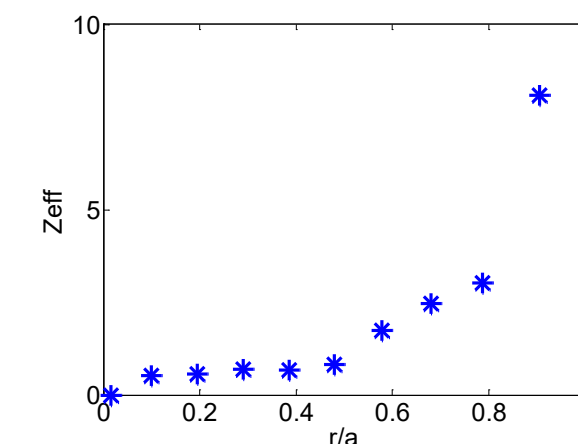
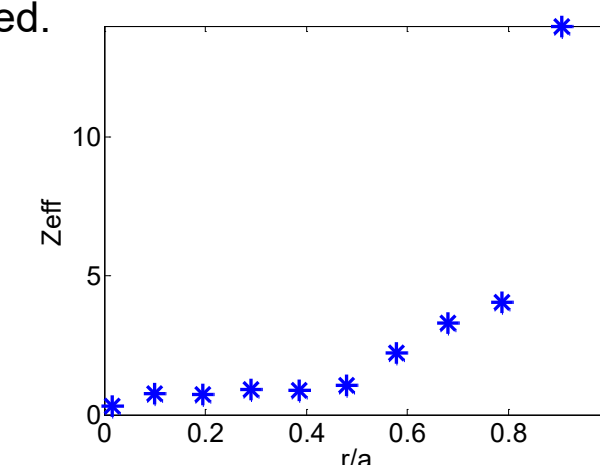
The measured raw signal is chord integrated. It is needed to reconstruct the raw signal to get the local measurement.

$$\begin{pmatrix} B(T_{e1}, N_{e1})L_{1,1} & 0 & 0 & \dots & 0 \\ B(T_{e1}, N_{e1})L_{2,1} & B(T_{e2}, N_{e2})L_{2,2} & 0 & \dots & 0 \\ \dots & \dots & \dots & \dots & \dots \\ \dots & \dots & \dots & B(T_{e9}, N_{e9})L_{9,9} & 0 \\ B(T_{e1}, N_{e1})L_{10,1} & B(T_{e2}, N_{e2})L_{10,2} & \dots & B(T_{e9}, N_{e9})L_{10,9} & B(T_{e10}, N_{e10})L_{10,10} \end{pmatrix} \begin{pmatrix} Z1 \\ \cdot \\ \cdot \\ \cdot \\ Z10 \end{pmatrix} = \begin{pmatrix} S1 \\ \cdot \\ \cdot \\ \cdot \\ S10 \end{pmatrix}$$



Chord length of different channels in HSX flux surface

With the chord-length as shown and the T_e , N_e profiles from Thomson scattering measurement, the Z_{eff} profile is calculated.



By adding an additional length to the chord length of the edge region, the edge Z_{eff} is reduced. A better edge modeling is necessary to interpret the data.

Summary

1. Z_{eff} measurement using Bremsstrahlung radiation has been set up on the HSX.
2. Initial experiments show significant signals.
3. Future work will focus on the error tracking and reconstruction algorithm.