Impurity Transport Measurements with the New Multi-Energy Soft-X-ray Diagnostic on NSTX

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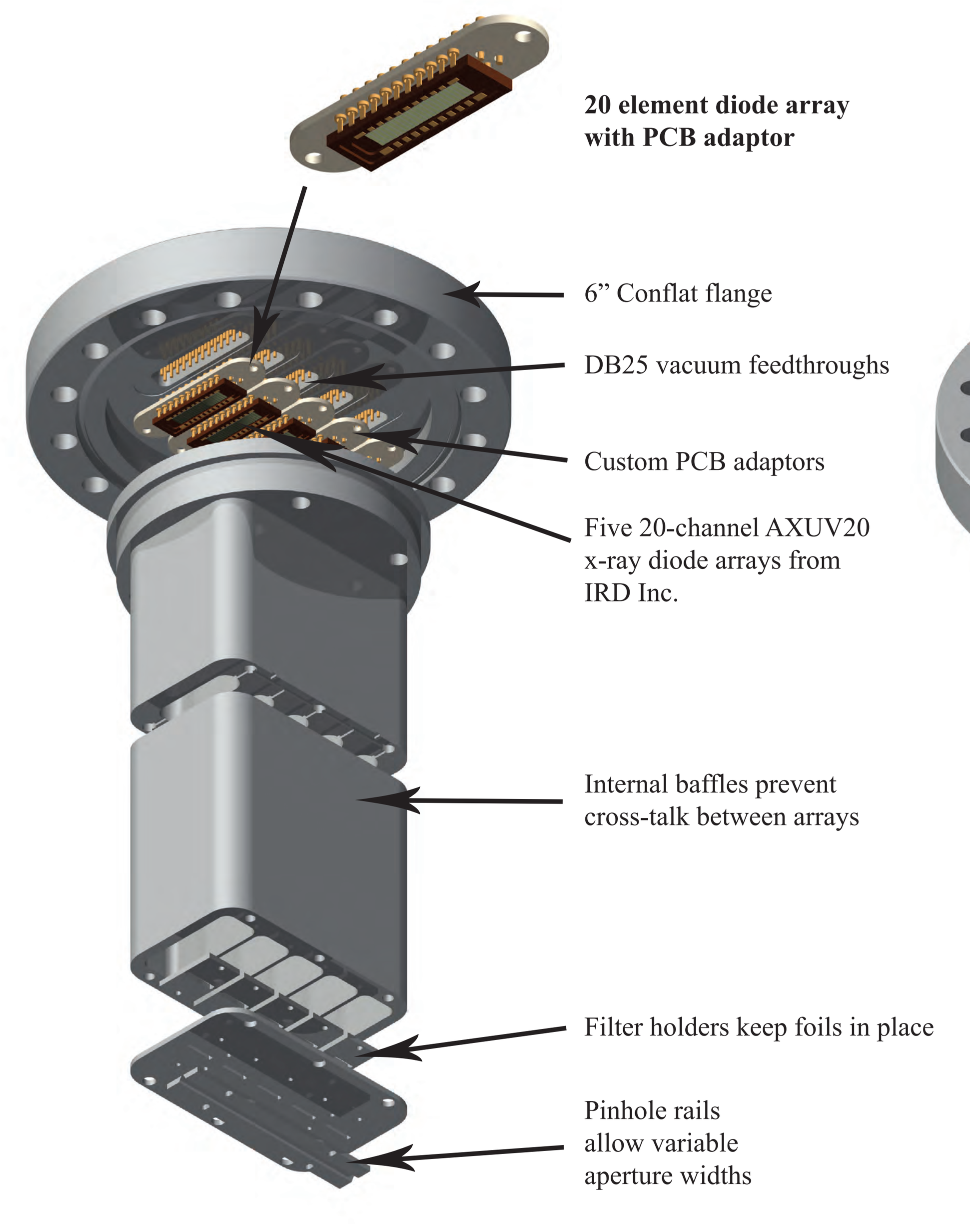
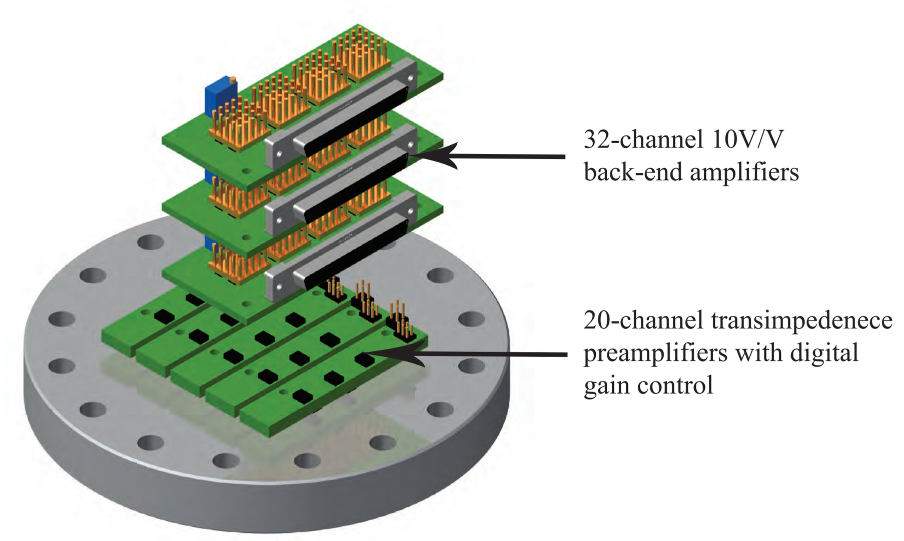
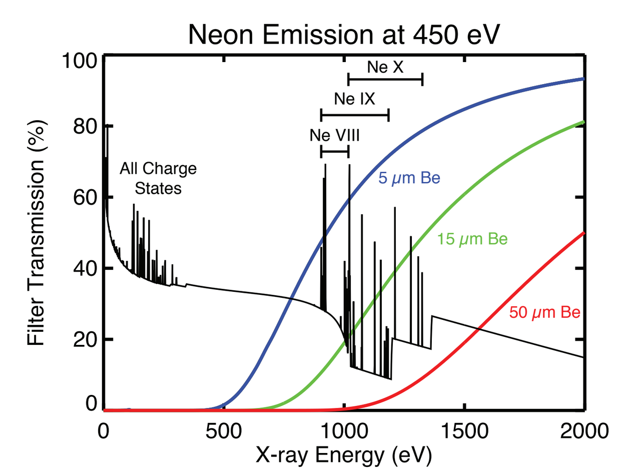
The Multi-Energy Soft-X-Ray Array is a novel compact diagnostic that provides T_e, n_e, and impurity profile information with high spatial resolution (< 1 cm) and fast time response (> 10 kHz)



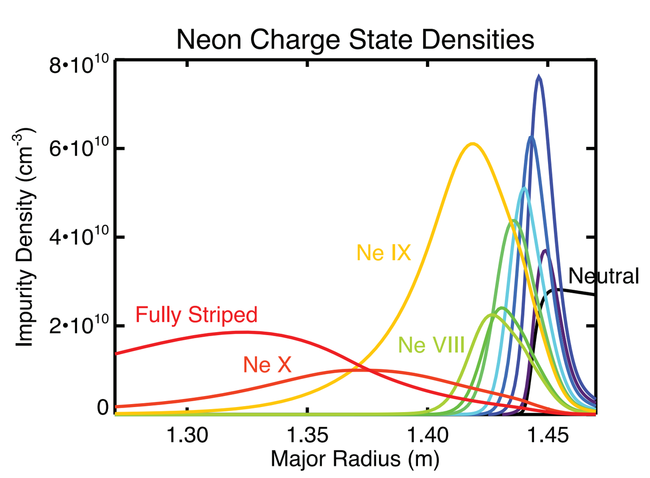
ME-SXR Diagnostic (actual size)



Electronics on back side of vacuum flange (actual size)



Transmission of Be filters overlaying a plot of important neon lines



Typical radial distribution of neon charge states (calculated by STRAHL)

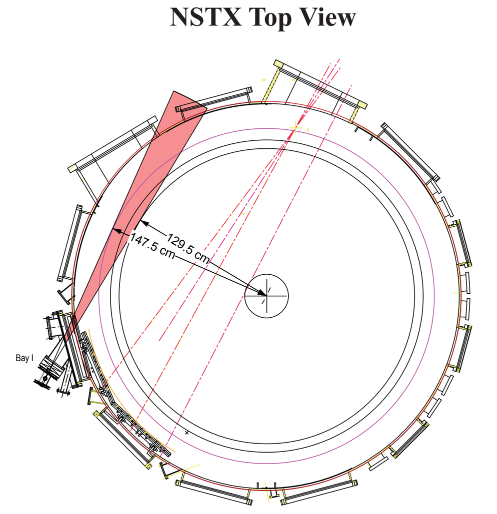
Each diode array looks through a different filter:

Bolometer (no filter)
0.3 μm Ti
5 μm Be
15 μm Be
50 μm Be

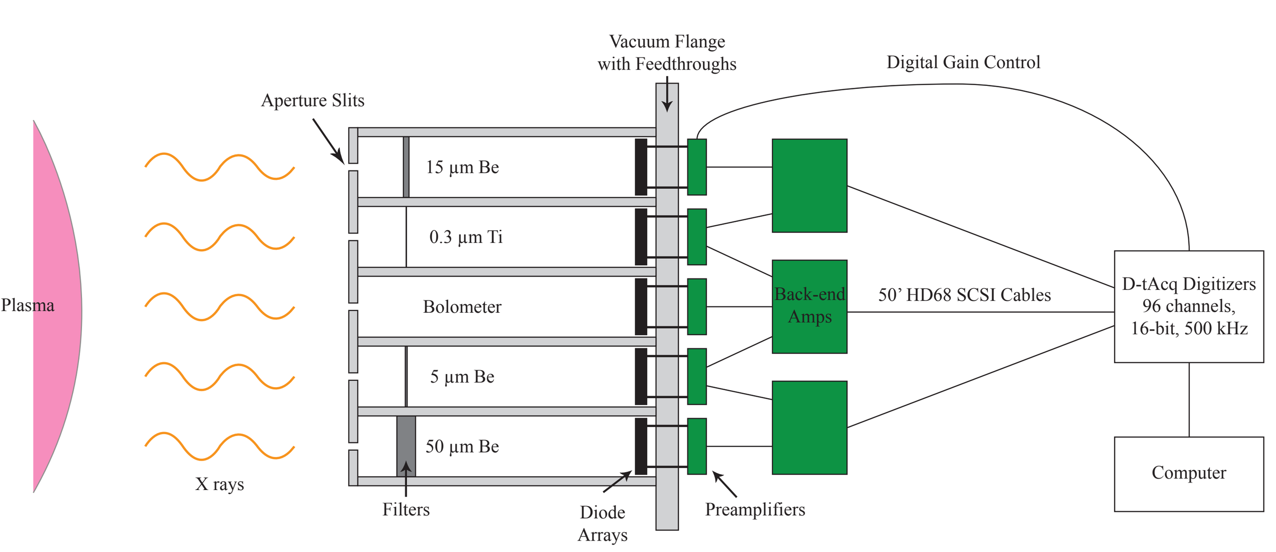
Gains	Bandwidth
25 kΩ	300 kHz
100 kΩ	120 kHz
500 kΩ	50 kHz
1 MΩ	35 kHz
2 MΩ	26 kHz
5 MΩ	16 kHz
10 MΩ	11 kHz
20 MΩ	6 kHz

Preamplifier gains are digitally controlled, with higher gains having providing less bandwidth

NSTX Top View

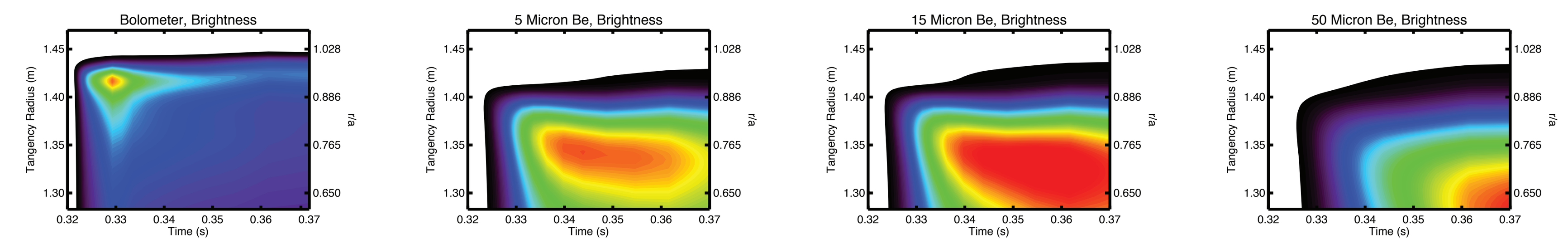


The ME-SXR diagnostic has a tangential view of the plasma edge (0.6 < r/a 1.1)



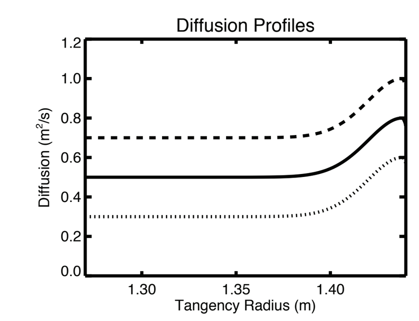
Impurity Transport Modeling with STRAHL is Used to Determine the Diffusive and Convective Transport Coefficients from X-ray Emission

STRAHL (R. Dux) is a radial impurity particle transport code
- Solves a radial transport equation for each charge state of an impurity, with source/sink terms due to ionization/recombination connecting them
- Ionization and recombination rates are from Atomic Data and Analysis Structure (ADAS)
- Neutral source is from user-defined gas puff at the plasma boundary and recycling of lost particles from the vessel wall
- Anomalous transport coefficients for diffusion (D) and convection (v) are provided by the user; neoclassical D and v may be calculated with NEOART, which is included with STRAHL
- Filtered x-ray emission from atomic lines and continuum are calculated from included neon atomic data; future plans are to use ADAS for emission coefficients
- Below are examples of x-ray emission profiles predicted by STRAHL

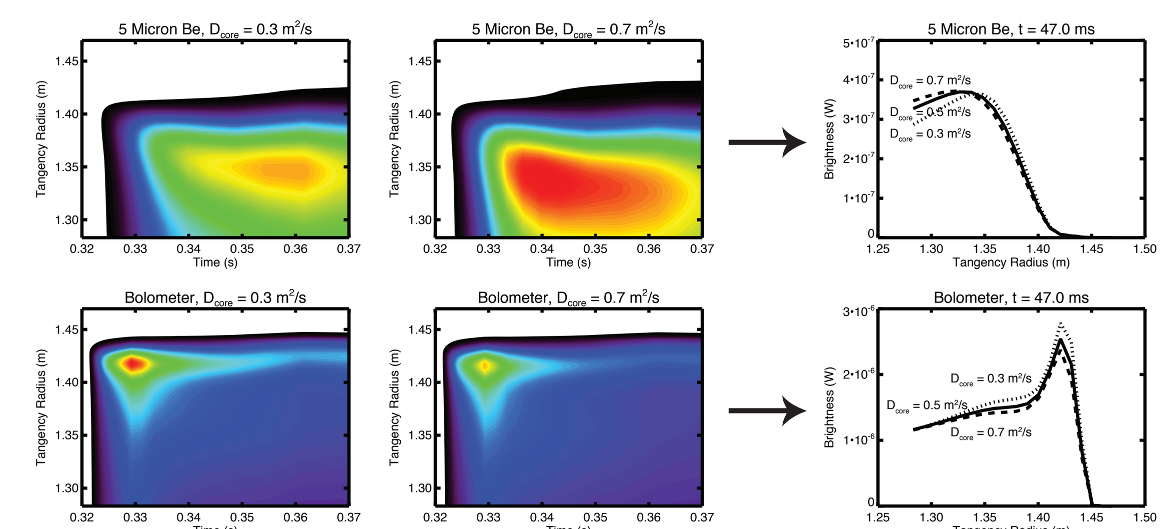


The bolometer measures low charge states of neon in plasma edge. *5 μm Be filter measures high charge states (H-, He-, Li-like) further in.* *15 μm Be filter measures high charge states and continuum from fully stripped neon.* *50 μm Be filter measures continuum from fully stripped neon in the core.*

Diffusion affects the rate at which the impurity density equilibrates



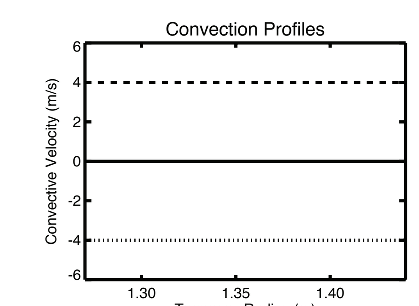
Radial diffusion profile for STRAHL runs shown above (solid), as well as the cases on the right.



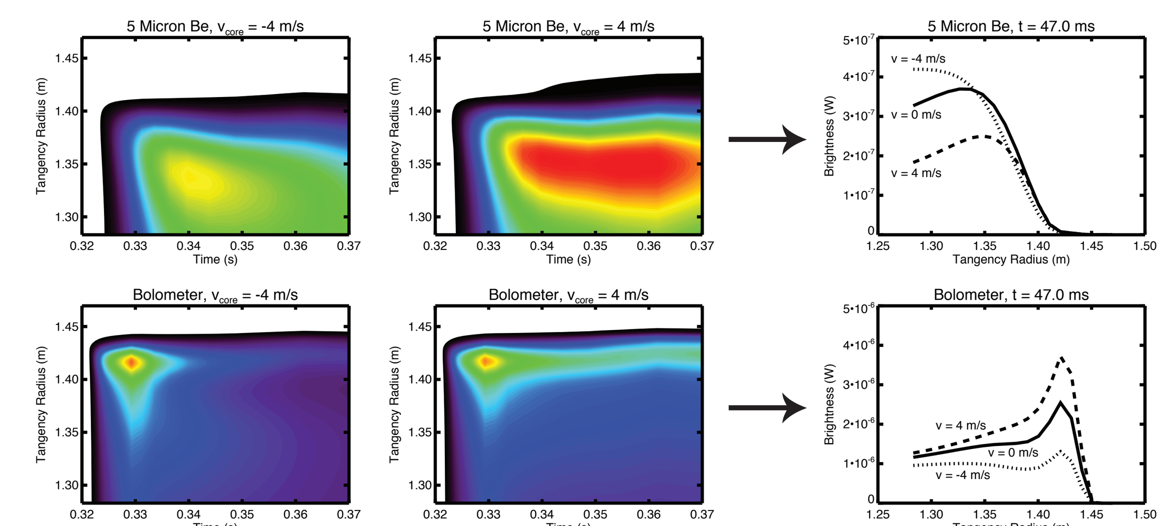
Expected x-ray emission through 5 μm Be filter and for the bolometer for various diffusions.

Late in time, the effect of diffusion on x-ray emissivity is small.

Convection affects the spatial, and thus charge state, distribution of impurities



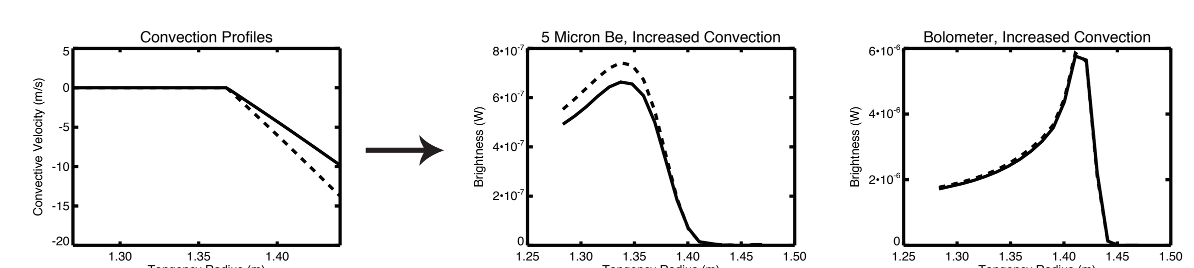
Radial convection profile for STRAHL runs shown above (solid), as well as the cases on the right.



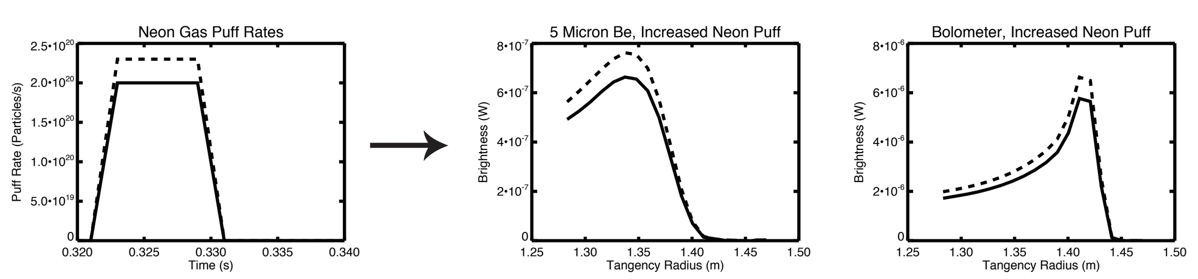
Expected x-ray emission through 5 μm Be filter and for the bolometer for various convections.

Late in time, convection has the opposite effect on the 5 μm Be and bolometer arrays.

The bolometer array is needed to determine the neon source term in the plasma edge

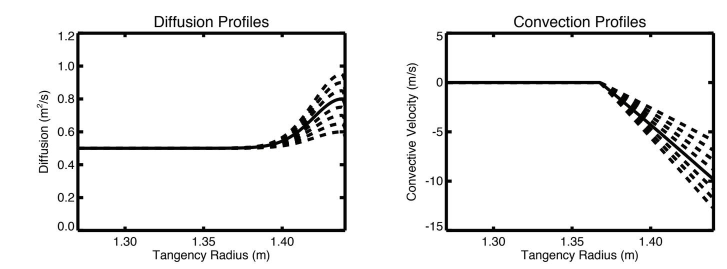


An increase in edge convection increases emission from higher charge states seen with the Be-filtered arrays, the same result as with increasing the total particle source from gas puffing. However, the bolometer signal remains relatively unchanged.

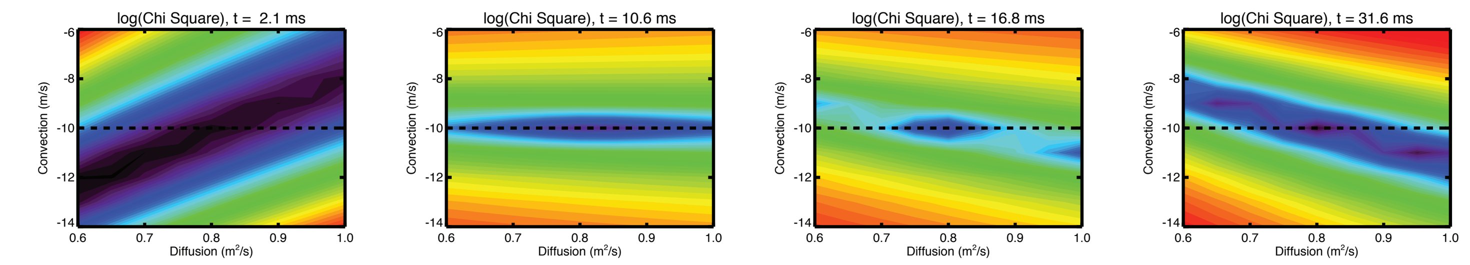


With an actual increase in gas puffing, emission increases uniformily across all array. Thus, the bolometer aray is needed to separate the effects of the two.

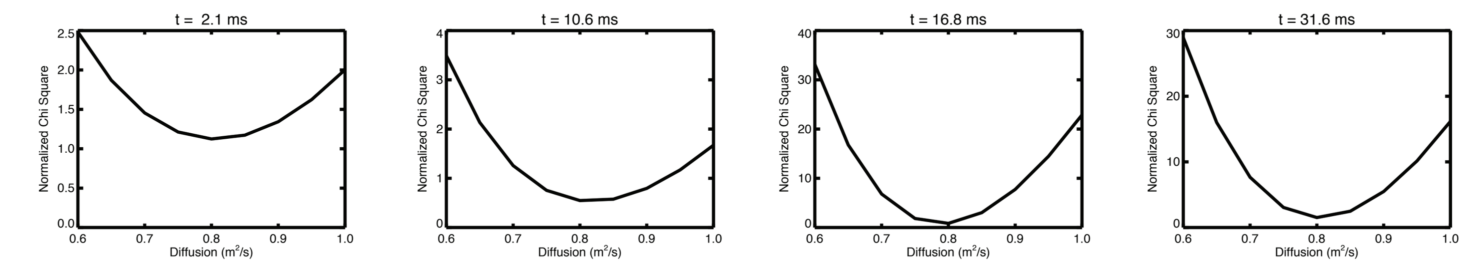
The Time Evolution of Emission from an Impurity Perturbation is Needed to Distinguish the Effects of Diffusion from Convection



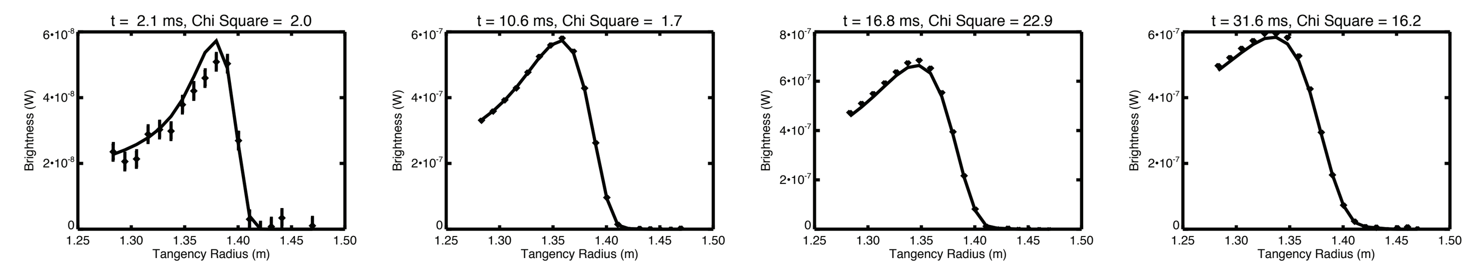
- STRAHL was used to generate simulated data for the profiles shown on the left (solid lines)
- STRAHL was then run with small variations in D and v (dashed lines) in the edge, the results were fit to the simulated data and a chi square was calculated in each case
- At each time point, v can only be found as a function of an unknown D
- This function of D changes in time throughout an impurity density perturbation, thus allowing D and v to be found separately, assuming they are constant on the timescale of the perturbation
- After the ~30 ms perturbation, x-ray emission begins to reach a steady state



Chi square of fits to simulated data for an array of D and v values at four points in time

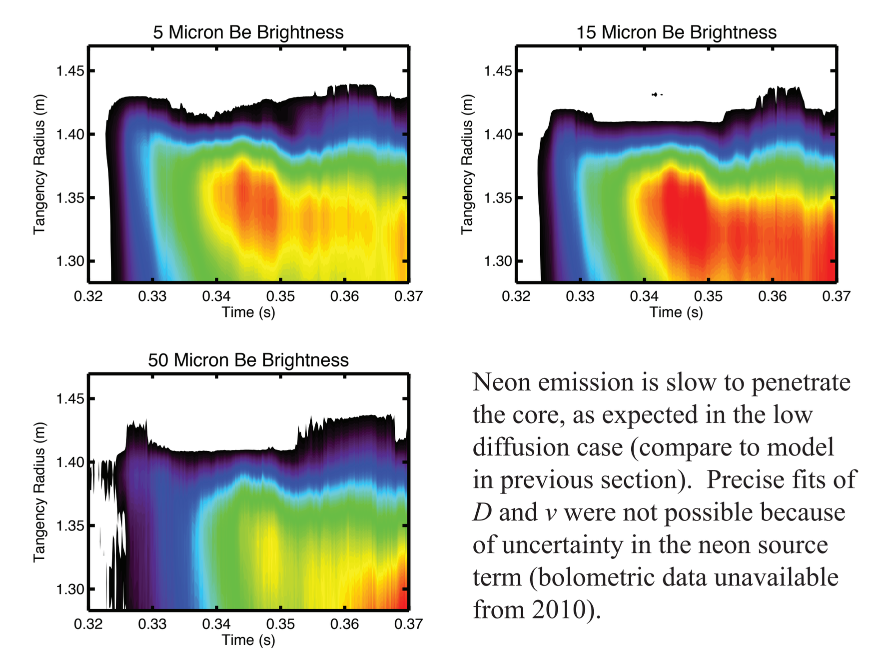


A cut along the dashed line from the plots above, showing how chi square varies as a function of D (constant v)



Radial profiles of 5 μm Be emission from simulation (points) with D = 0.8 m^2/s and a fit (line) with D = 1.0 m^2/s

Initial ME-SXR measurements of neon injection are consistent with the expectation of low diffusion in the plasma edge with the application of lithium to the walls



Neon emission is slow to penetrate the core, as expected in the low diffusion case (compare to model in previous section). Precise fits of D and v were not possible because of uncertainty in the neon source term (bolometric data unavailable from 2010).

Measurements of multiple impurities will be performed this year with the full diagnostic

- Transport of multiple impurities will be measured as part of the FY2012 OFES 3 Facility Joint Research Milestone investigating multichannel transport
- Transport of multiple impurities will be measured with the application of 3-D fields, as part of a larger NSTX experiment to study the effects of RMP coils on multichannel transport
- The full ME-SXR diagnostic will be in use, and STRAHL will be used to fit the best-fit diffusion and convection radial profiles to the x-ray measurements
- ADAS will be used to calculate emission from higher-Z impurites

The novel capabilities of the ME-SXR system allow an examination of the various mechanisms behind the different ELM phenomena in NSTX