NSTX

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High-Resolution Edge Impurity Transport Measurements with the ME-SXR Diagnostic

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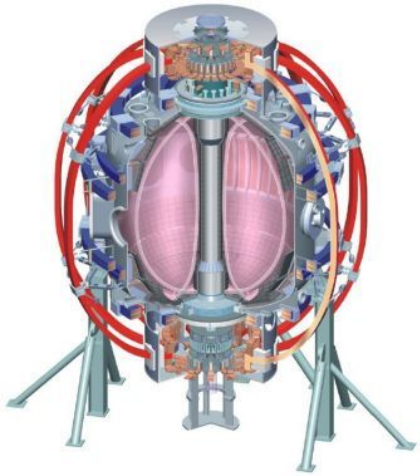

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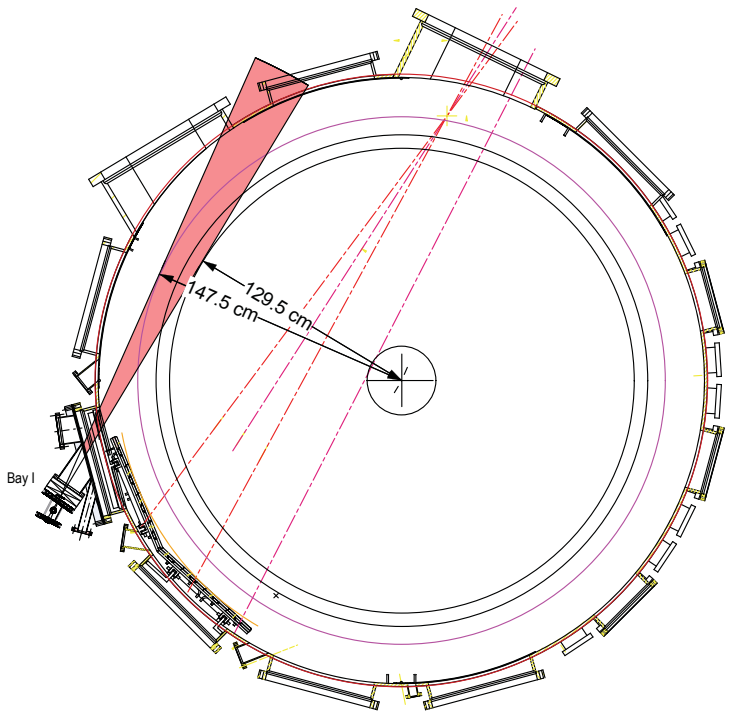
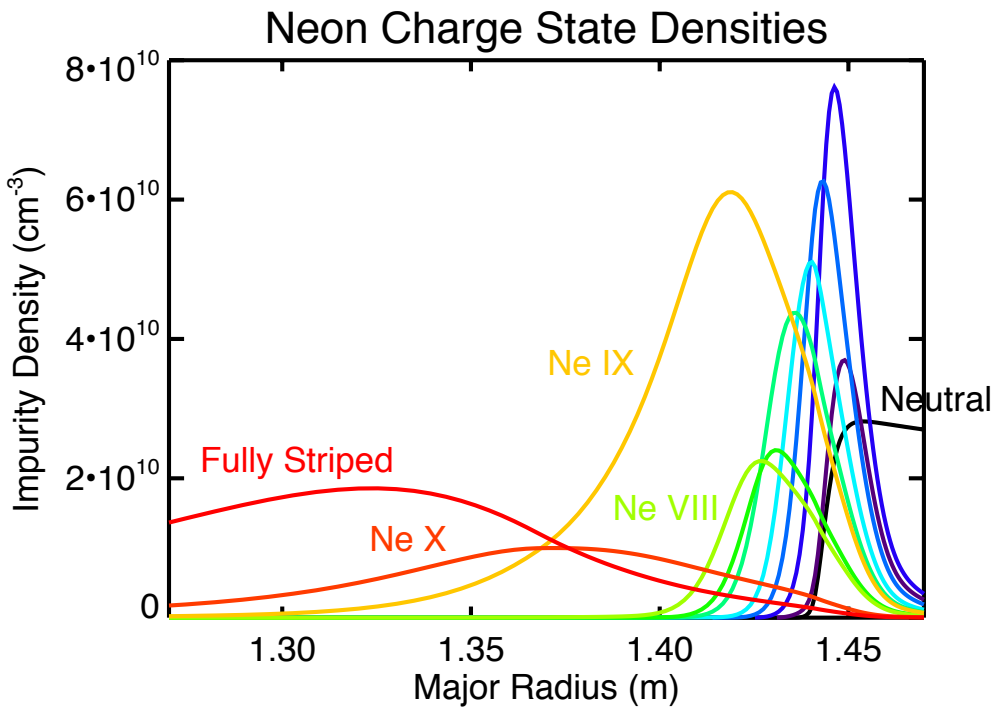
Outline

- ME-SXR is a compact x-ray diagnostic providing edge T_e, n_e, and impurity profile info with high spatial and time resolution
- Measurements of neon gas puffs from early FY2011 with a partial diagnostic look as expected
- Impurity transport modeling with a synthetic x-ray diagnostic is being implemented to determine diffusive and convective impurity transport coefficients
- Plans for the FY2011-12 run campaigns include impurity transport measurements as part of larger experiments to characterize multi-channel transport in NSTX

Five 20-Channel Photodiode Arrays have a Radial Resolution of ~ 1 cm, with Coverage from *r/a* ~ 0.6 to the SOL

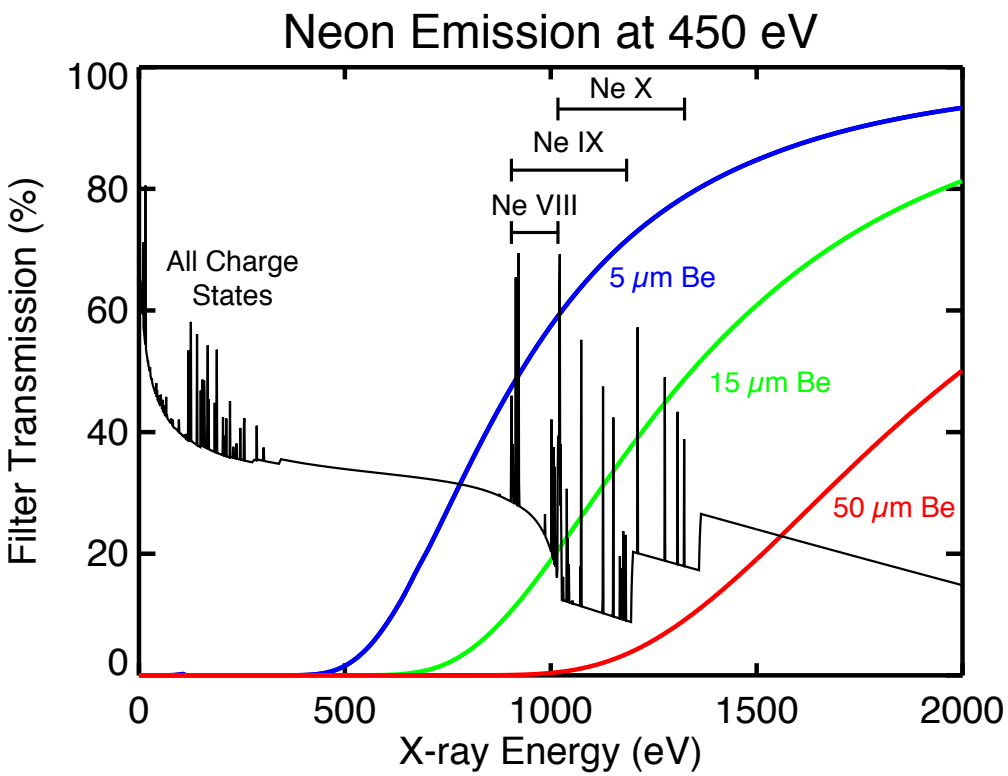
- Plasma profiles have steep gradients in the edge, thus improved spatial resolution (vs core diagnostics) is required
  - Similarly, more filters are needed for the wide range of temperatures, and variable amps for the large variability in emission intensity





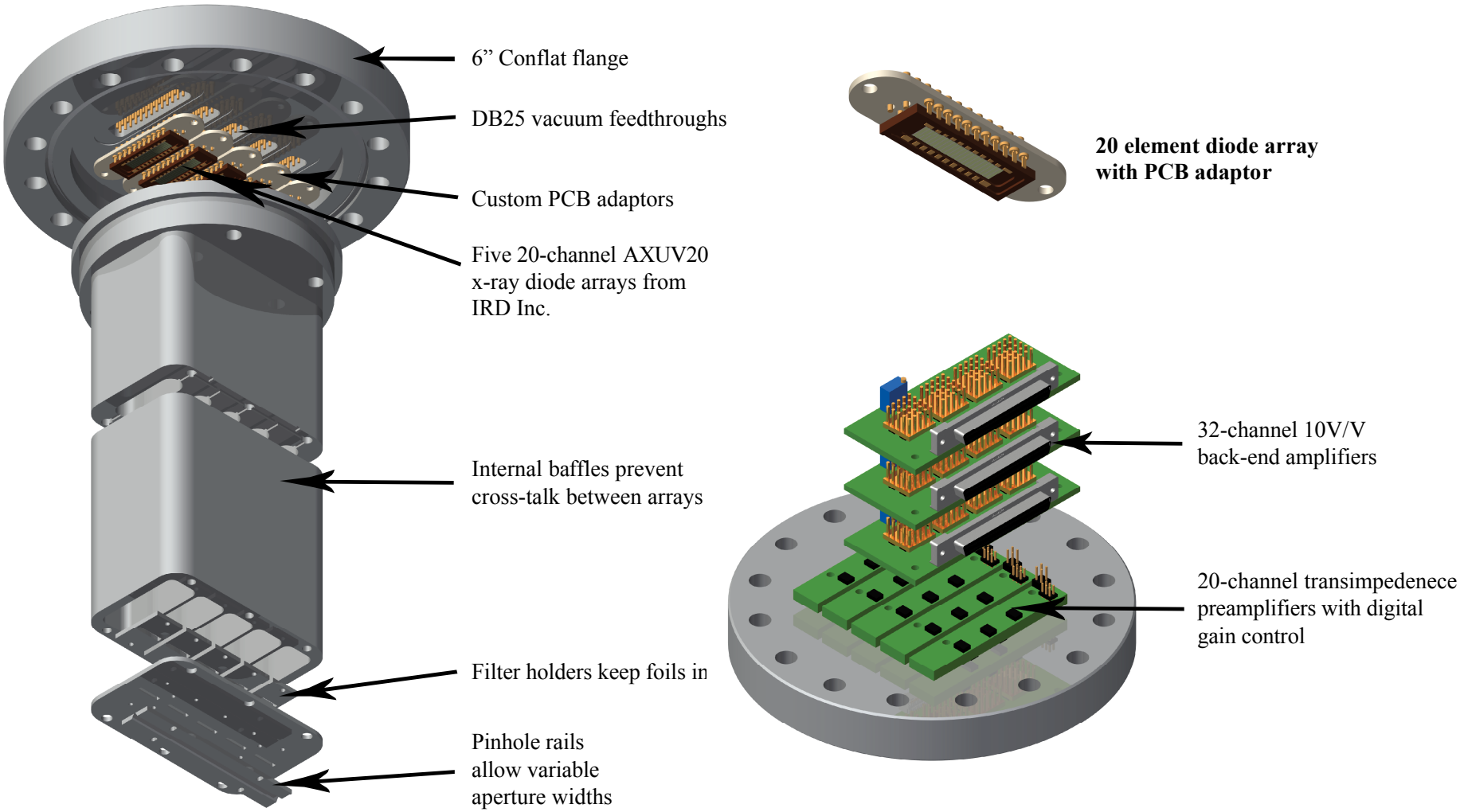
Different Filters Provide Spectral Resolution, and Variable-Gain Amplifiers Provide Good Time Resolution

- Four arrays have filters (0.3 μm Ti, 5 μm Be, 15 μm Be, 50 μm Be), and the fifth array has no filter (bolometry)
- Preamplifiers have digitally-controlled variable gains and are the limiting factor on time resolution



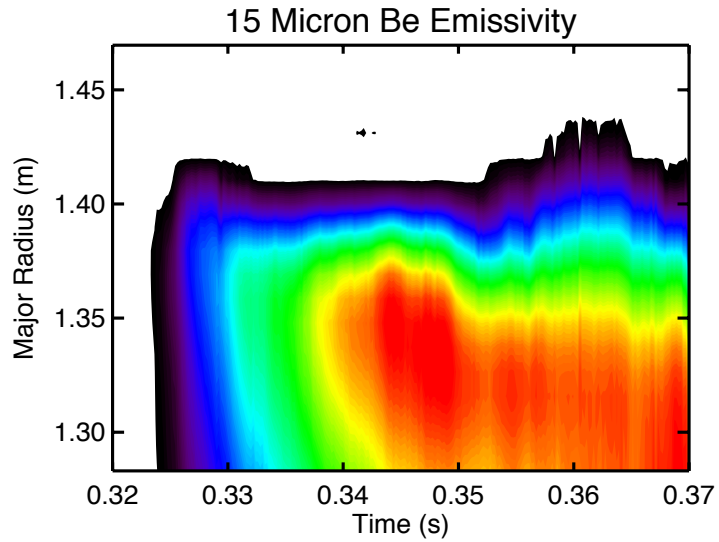
Gains	Bandwidth
25 kΩ	300 kHz
100 kΩ	120 kHz
500 kΩ	50 kHz
1 MΩ	35 kHz
2 MΩ	26 kHz
5 MΩ	16 kHz
10 MΩ	11 kHz
20 MΩ	6 kHz

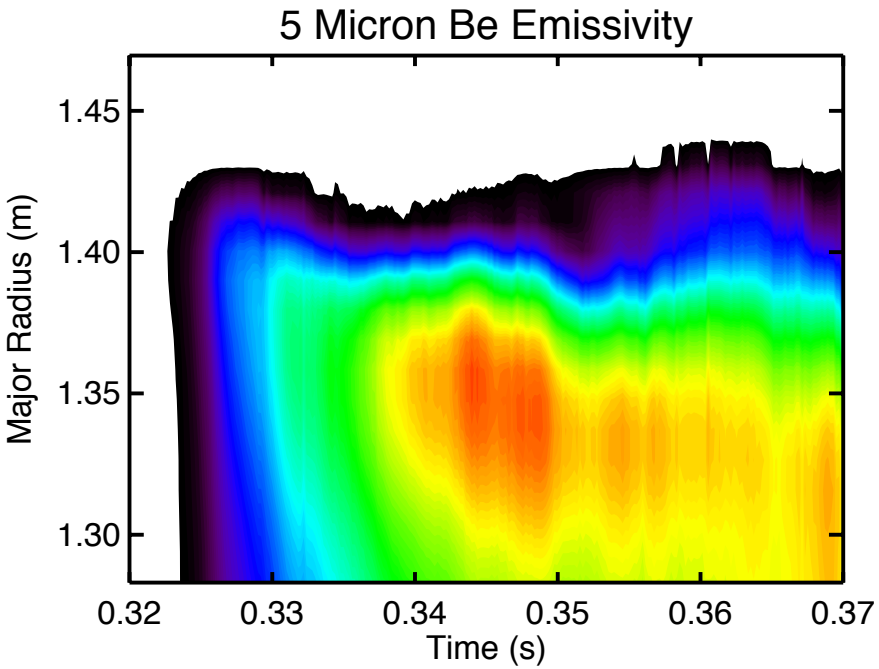
ME-SXR is a Compact Diagnostic Providing Edge T_e, n_e, and Impurity Profile Info with High Spatial and Time Resolution

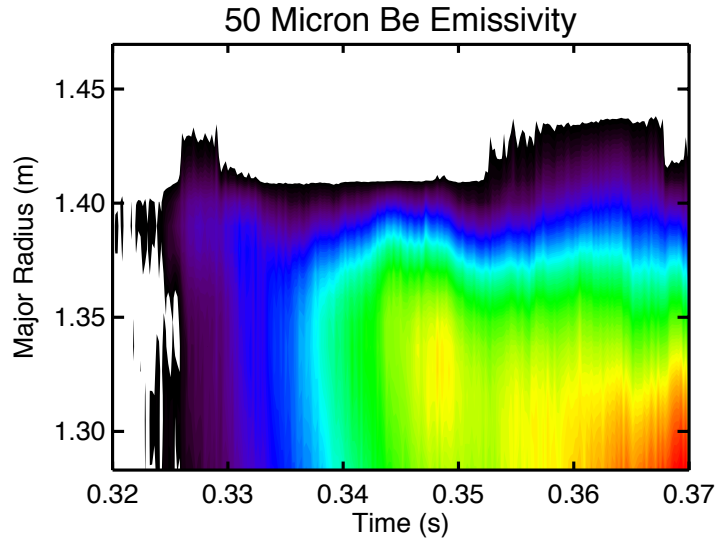


Initial High-Resolution Inversions of Profile Measurements Following a Short Neon Gas Puff Look as Expected

- Inverted data looks to be a good match to modeled profiles using reasonable transport profiles
- Only part of the diagnostic was used during the last run







Impurity Transport Modeling with a Synthetic X-ray Diagnostic can be Used to Understand Measured Profiles

- Measured x-ray intensity depends on electron temperature, electron density, and impurity density

$$I = G \cdot R_{diode} \int_{chord} dl\, n_e(l) n_{I,Z}(l) \int_0^\infty dE\, T_{filt}(E) \cdot [P_{cont}(E, T_e(l)) + P_{line}(E, T_e(l))]$$

EFIT Thomson Scattering ADAS

- $n_{I,Z}$ depends on ionization/recombination/charge exchange rates (ADAS) and on impurity particle transport (STRAHL)

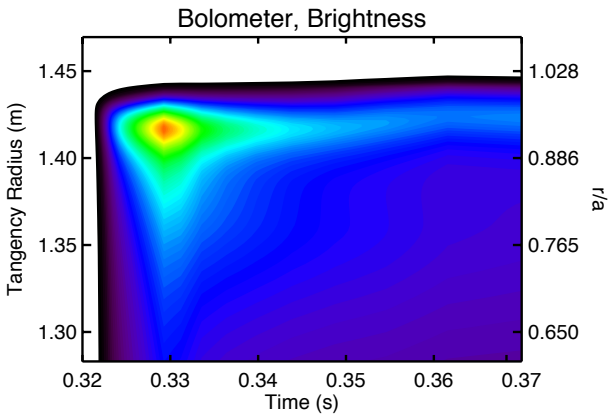
$$\frac{\partial n_{I,Z}}{\partial t} = \frac{1}{r}\frac{\partial}{\partial r} r \left(D^* \frac{\partial n_{I,Z}}{\partial r} - v^* n_{I,Z} \right) + Q_{I,Z}$$

$$\begin{aligned} Q_{I,Z} = & -(n_e S_{I,Z} + n_e \alpha_{I,Z} + n_H \alpha^{cx}_{I,Z}) n_{I,Z} \\ & + (n_e S_{I,Z-1}) n_{I,Z-1} \\ & + (n_e \alpha_{I,Z+1} + n_H \alpha^{cx}_{I,Z+1}) n_{I,Z+1} \end{aligned}$$

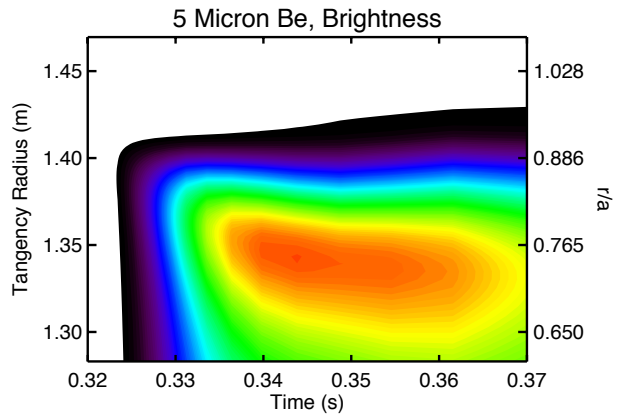
- D, v, and $Q_{I,0}$ (an additional source term from impurity gas puffing and recycling) are free parameters that are adjusted to fit synthetic data to ME-SXR measurements

The Synthetic Diagnostic Produces X-ray Emission Profiles Closely Matching Those Measured with ME-SXR

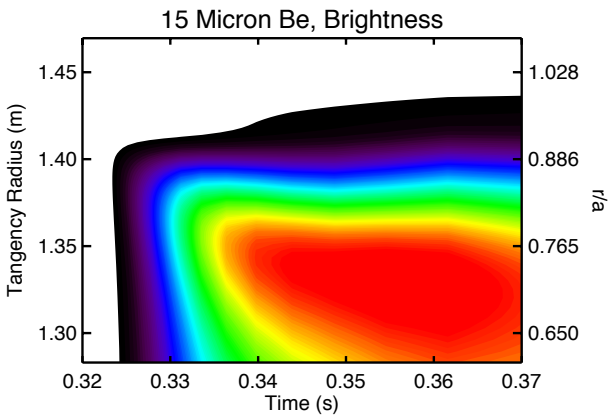
- Neutral source term calculated from neon puff flow rate
- Guesses for transport coefficients: D = 0.5 m^2/s in the core, increasing to 0.8 m^2/s in the edge, v = -10 m/s in the edge



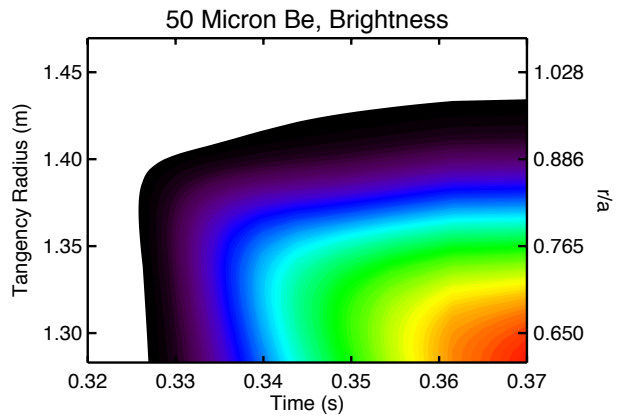
Low Charge States



H-, He-, Li-like



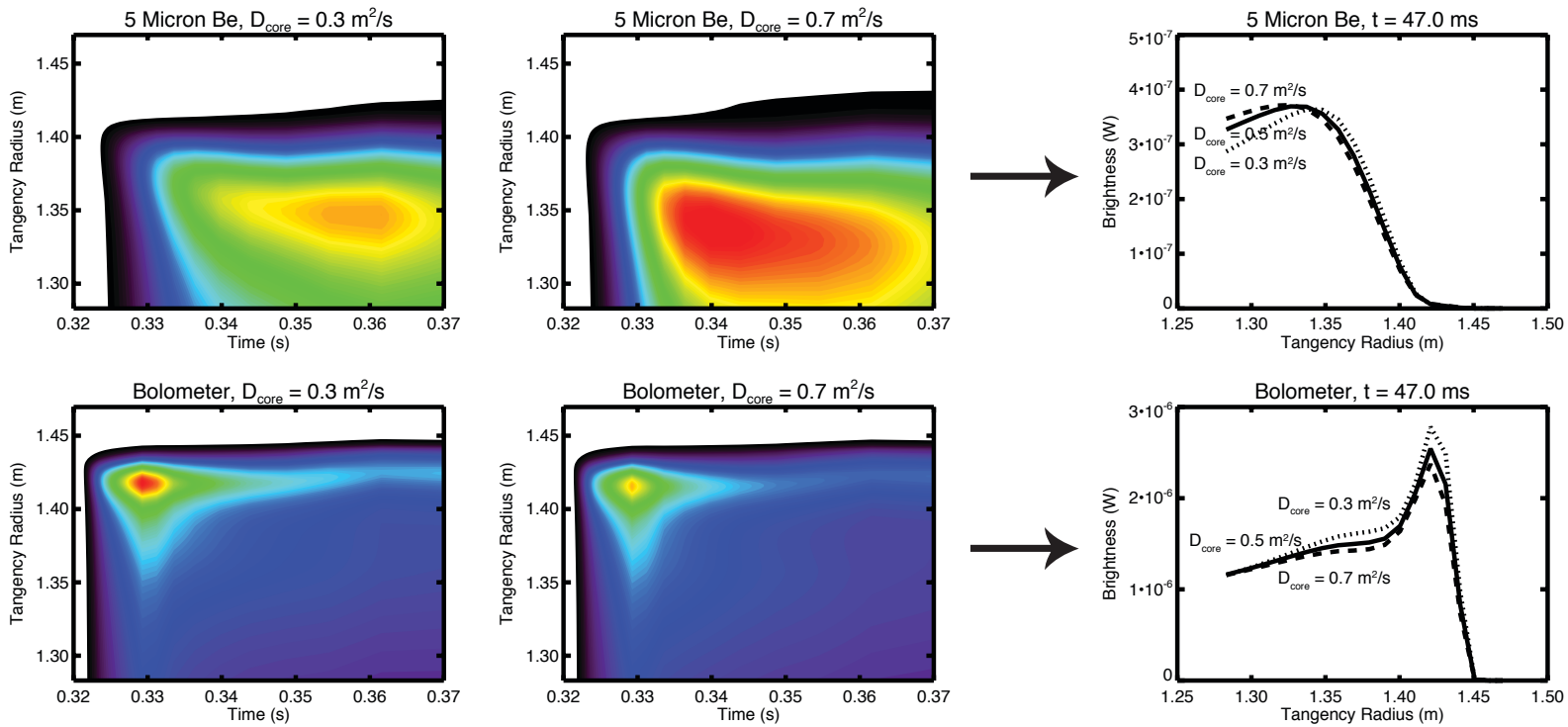
H-, He-like, Fully Stripped



Fully Stripped

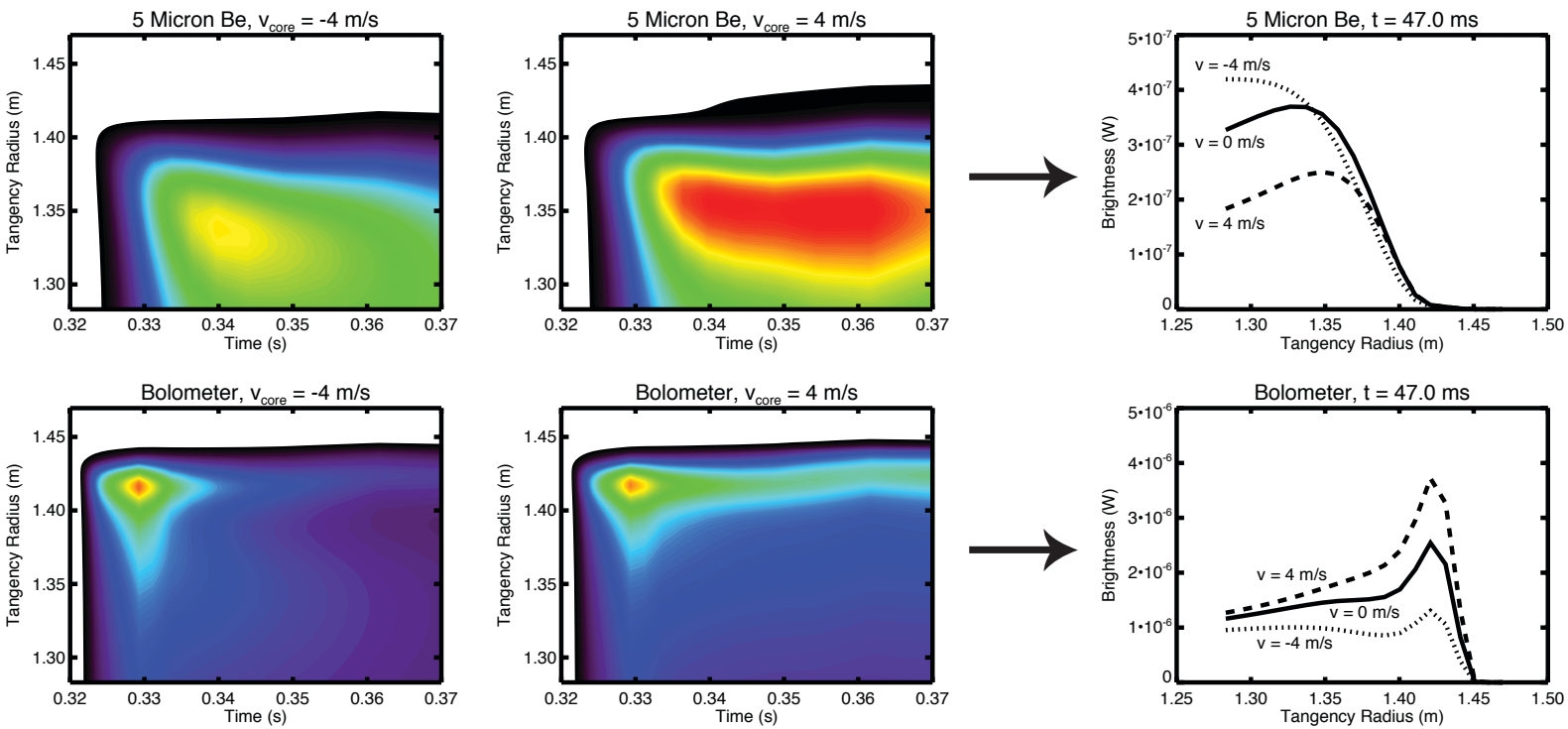
Diffusion is Best Measured Shortly After the Gas Puff

- In the case of larger diffusion, neon is initially transported more rapidly towards the core
- After about 50 ms in this simulation, D = 0.3 m^2/s and D = 0.7 m^2/s are difficult to distinguish



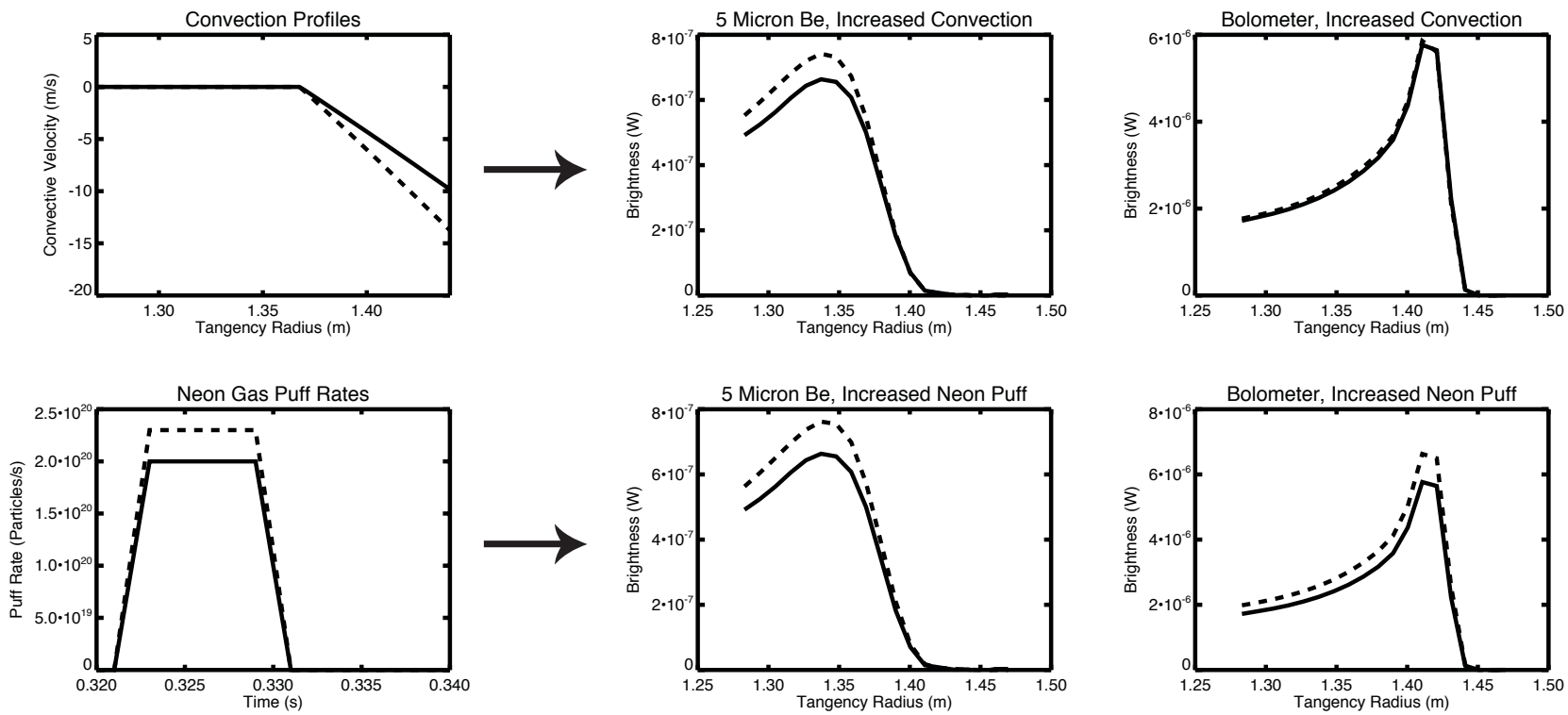
Convection Changes the Neon Charge State Distribution, Causing Different Responses on Each Array

- Inward convection transports neon ions towards the core, where they are stripped of electrons
- Outward convection keeps neon in the edge, where it remains in a lower charge state



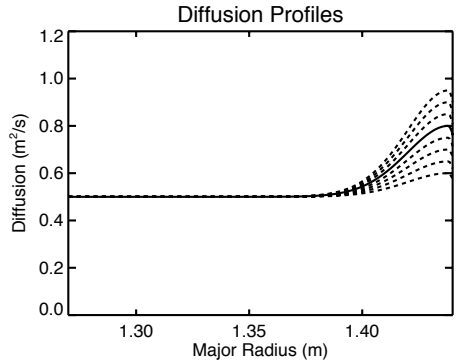
The Bolometer Array Enables the Differentiation of Effects of Increased Convection from those of an Increased Ion Source

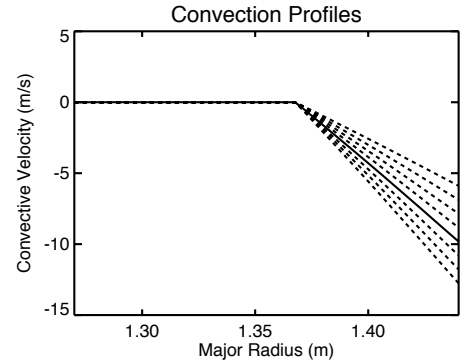
- Increased inward convection increases filtered signals without a significant change to total power
- An increased gas puff increases all charge state densities, and thus all signals, uniformly

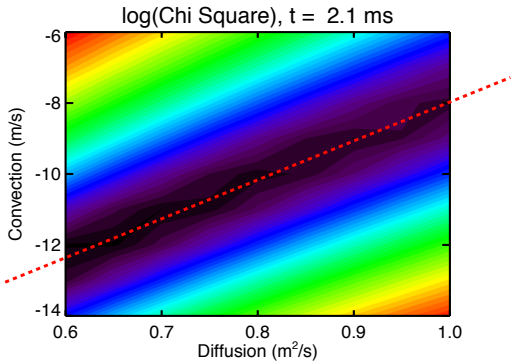


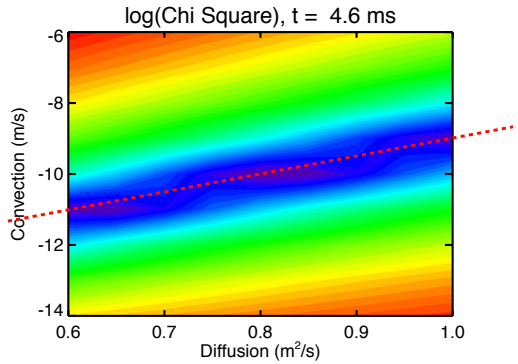
A Perturbation in Impurity Density is Needed to Distinguish the Diffusive and Convective Transport Coefficients

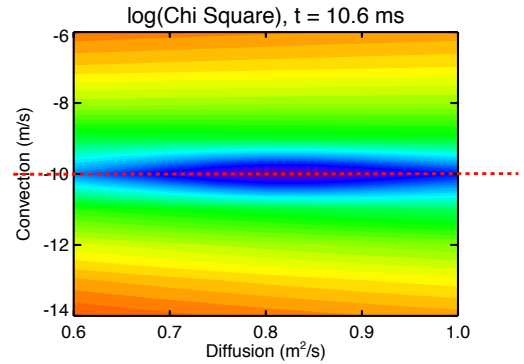
- Chi square of fits to simulated data for array of *D* and *v* profiles:

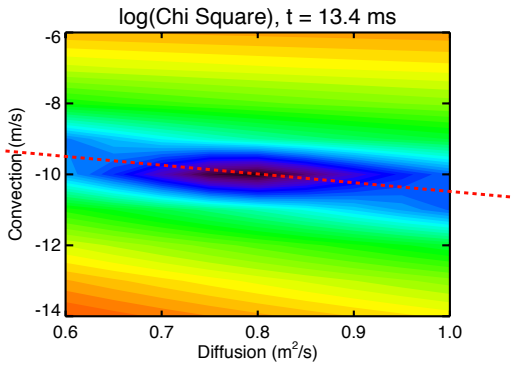


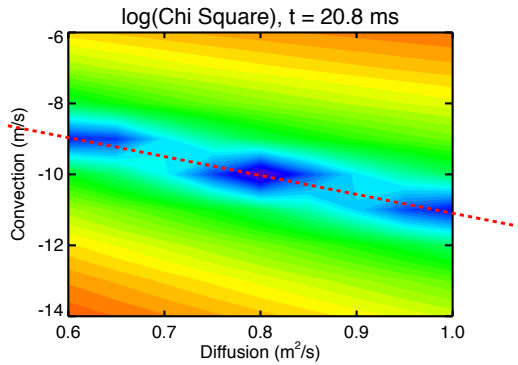


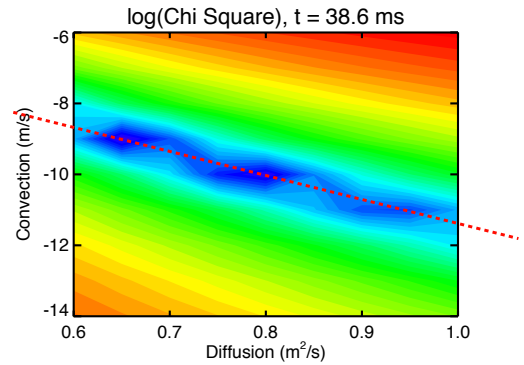






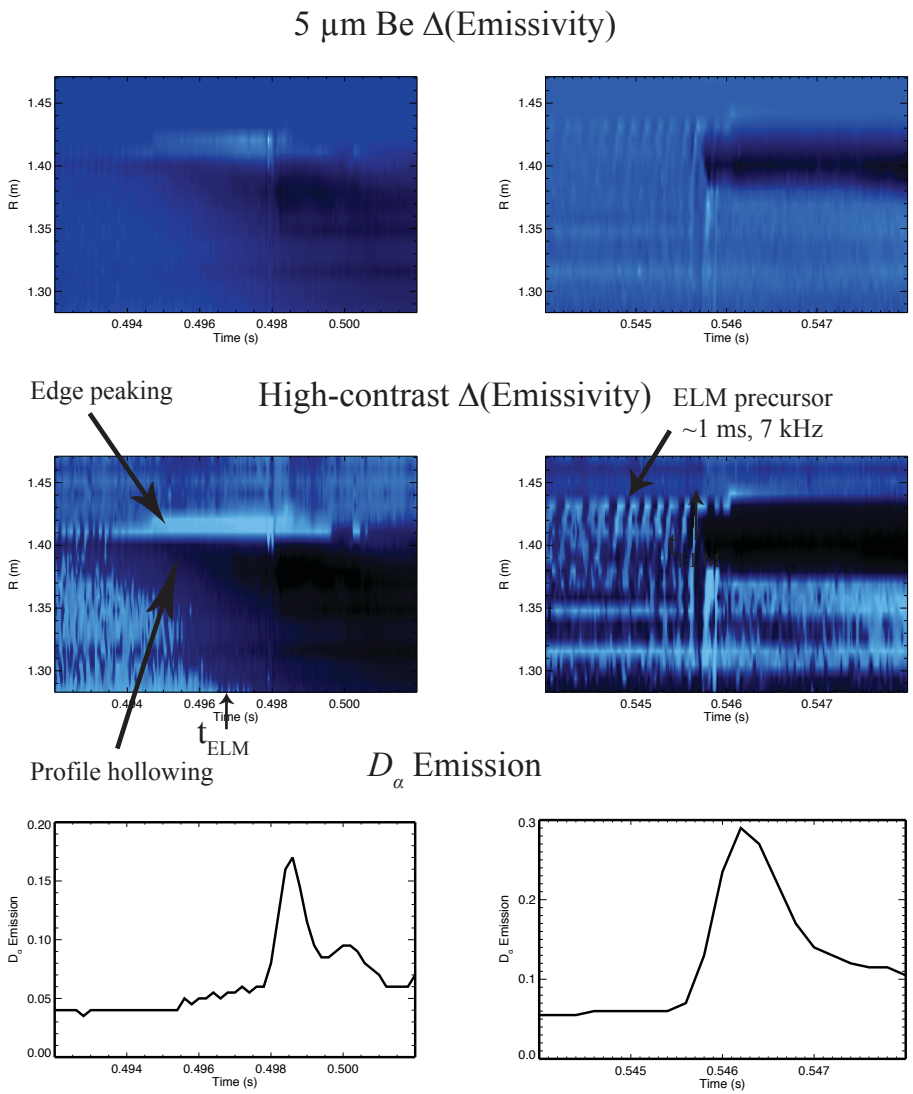






Impurity Transport Measurements are an Integral Part of Two Joint "Mega XPs" During the FY2011-12 Run Campaign

- Transport of multiple impurities will be measured as part of the FY2012 OFES 3 Facility Joint Research Milestone investigating multichannel transport
  - Early in the run tests will be performed to optimize SGI+impurity injection for combines particle/impurity transport measurements
- 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 operating, and a fitting routine (likely MPFIT) will be used to find the diffusion and convection profiles that produce x-ray emission profiles best fitting measurement across time on all five arrays

Backup

The Novel Capabilities of the ME-SXR System Allow an Examination of Various ELM Phenomena in NSTX