Status and Plans for MSE-CIF on NSTX

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Princeton, NJ

Outline

- **Background and motivation.**
- **Birefringent filter development.**
- **Results and validation of data.**
- **Summary and plans.**

Low Polarization Fraction at Low Field

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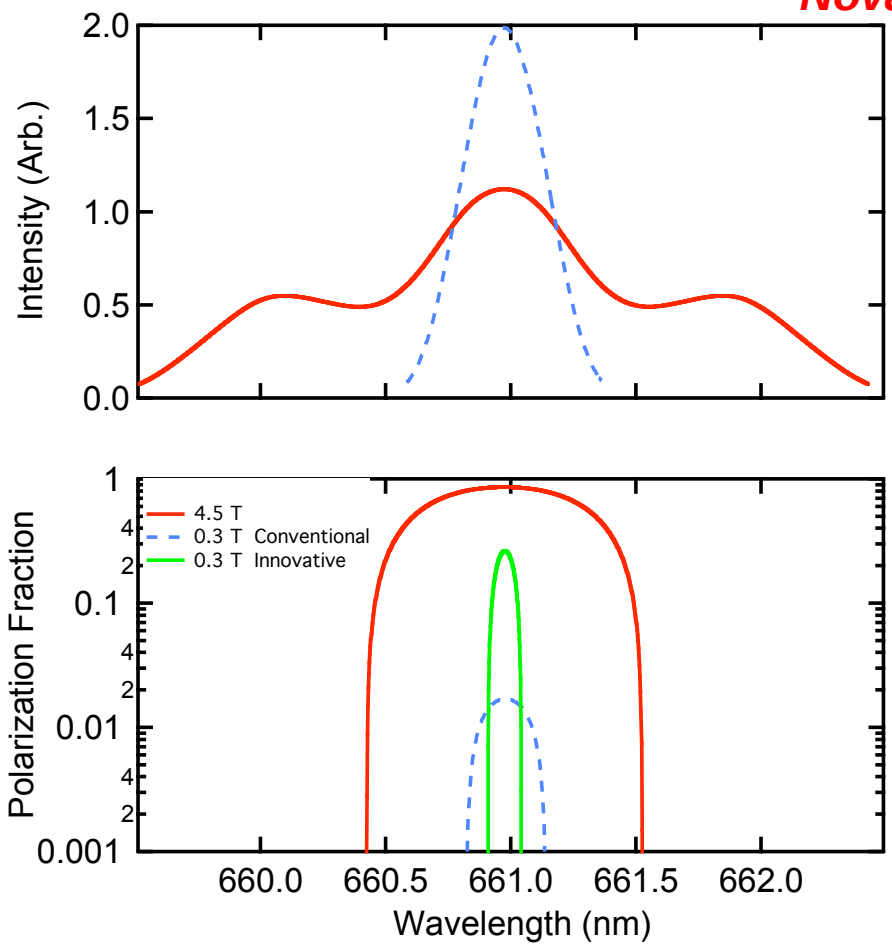

$$P_f = \frac{I_{\parallel} - I_{\perp}}{I_{\parallel} + I_{\perp}}$$

$$S/N \propto P_f \sqrt{I}$$

- **Numerical convolution of the MSE spectra including filter, beam, and optics broadening.**
- **Using conventional MSE approach overlap of spectral lines leads to a low($\sim$1%) polarization fraction. This is too low for a measurement.**
- **With innovative improvements in the optics design and filter, the polarization fraction can be raised to $\sim$30% at 0.3 T making a measurement feasible.**

MSE-CIF at Low Magnetic Field

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- **Innovations improve the polarization fraction.**

  1. **Optimize optics to reduce geometric spectral broadening.**
     - **Spectral broadening is from the finite optics and image size. Optimization of the optics can reduce the spectral width.**
  2. **Development of high resolution, high throughput filter to extend measurements to $\sim$0.3 T.**
     - **Wide field Lyot type birefringent filter meets requirements.**

Novel Optics Design to Reduce Geometric Doppler Broadening

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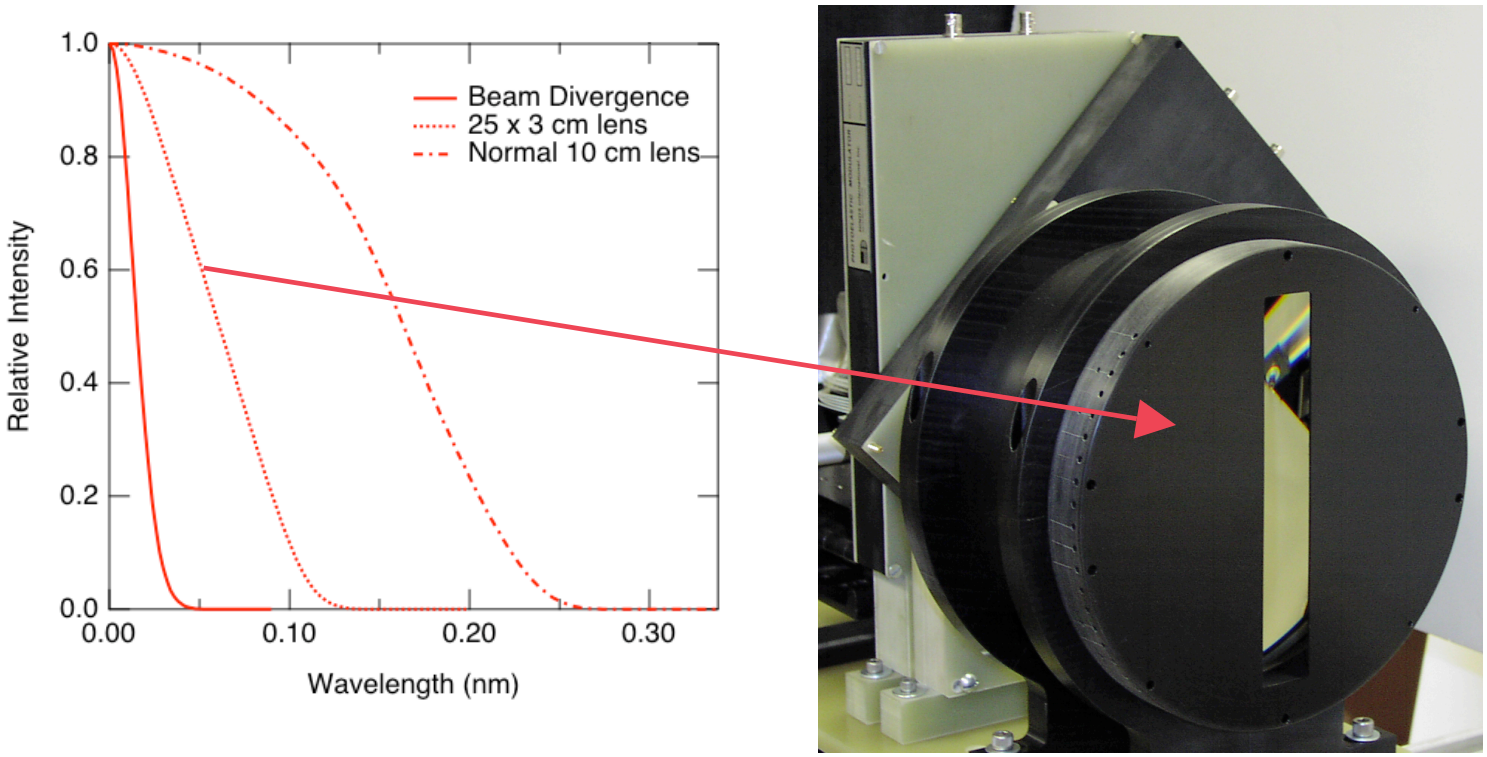

- **Novel optics design, combined with high throughput, high resolution birefringent filter, can increase the polarization fraction to ∼30%.**

High Resolution, High Throughput, Lyot Spectral Filter

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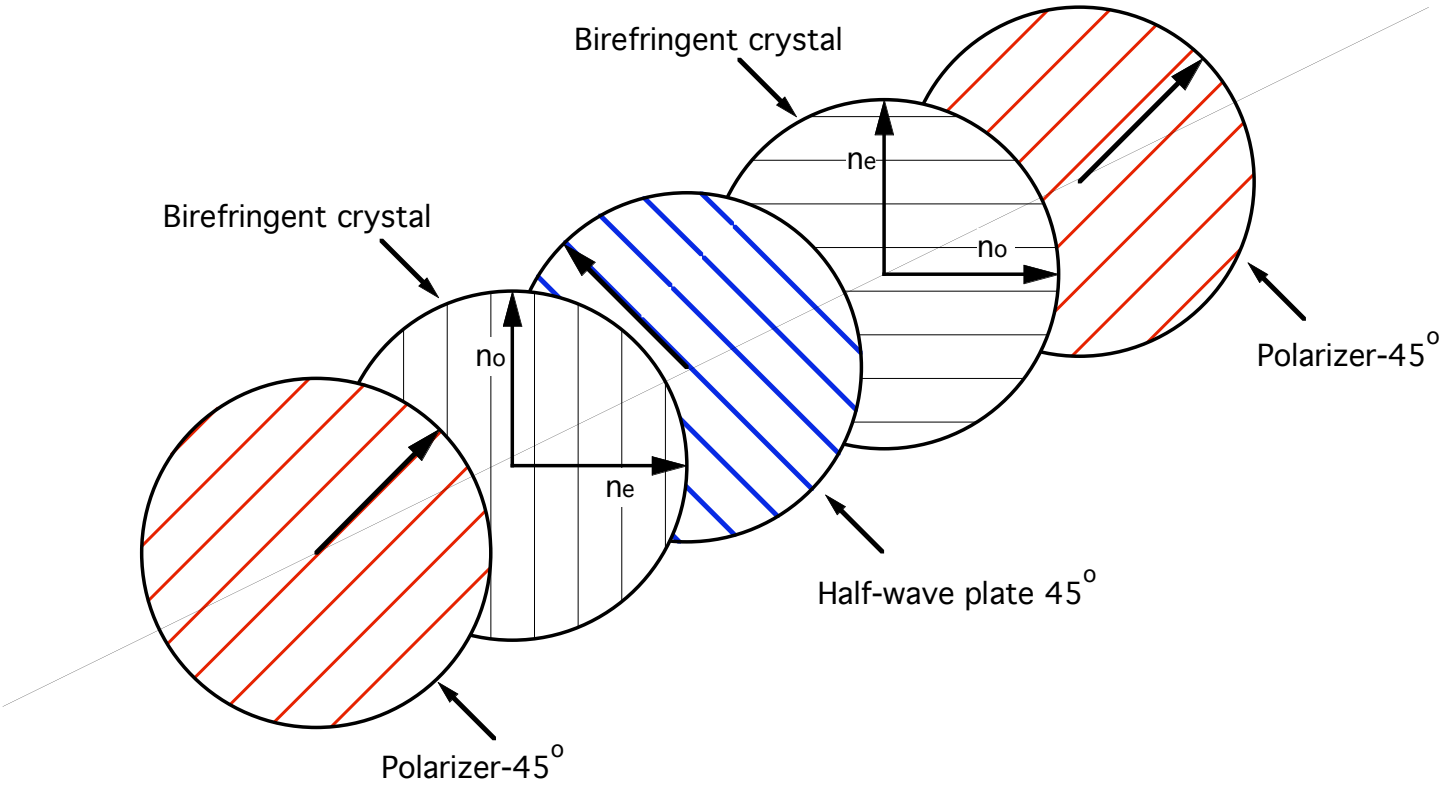

- **Required resolution and throughput can be satisfied with a wide-field Lyot filter.**
- **Flexibility in combining multiple stages to form spectral filter.**
- **Unique feature – *electro-optically tunable.***
- **Increased luminosity by a factor of 20-1000 relative to other instruments (grating spectrometer, Fabry-Perot, interference filter).**

Filter and Optics Enclosure

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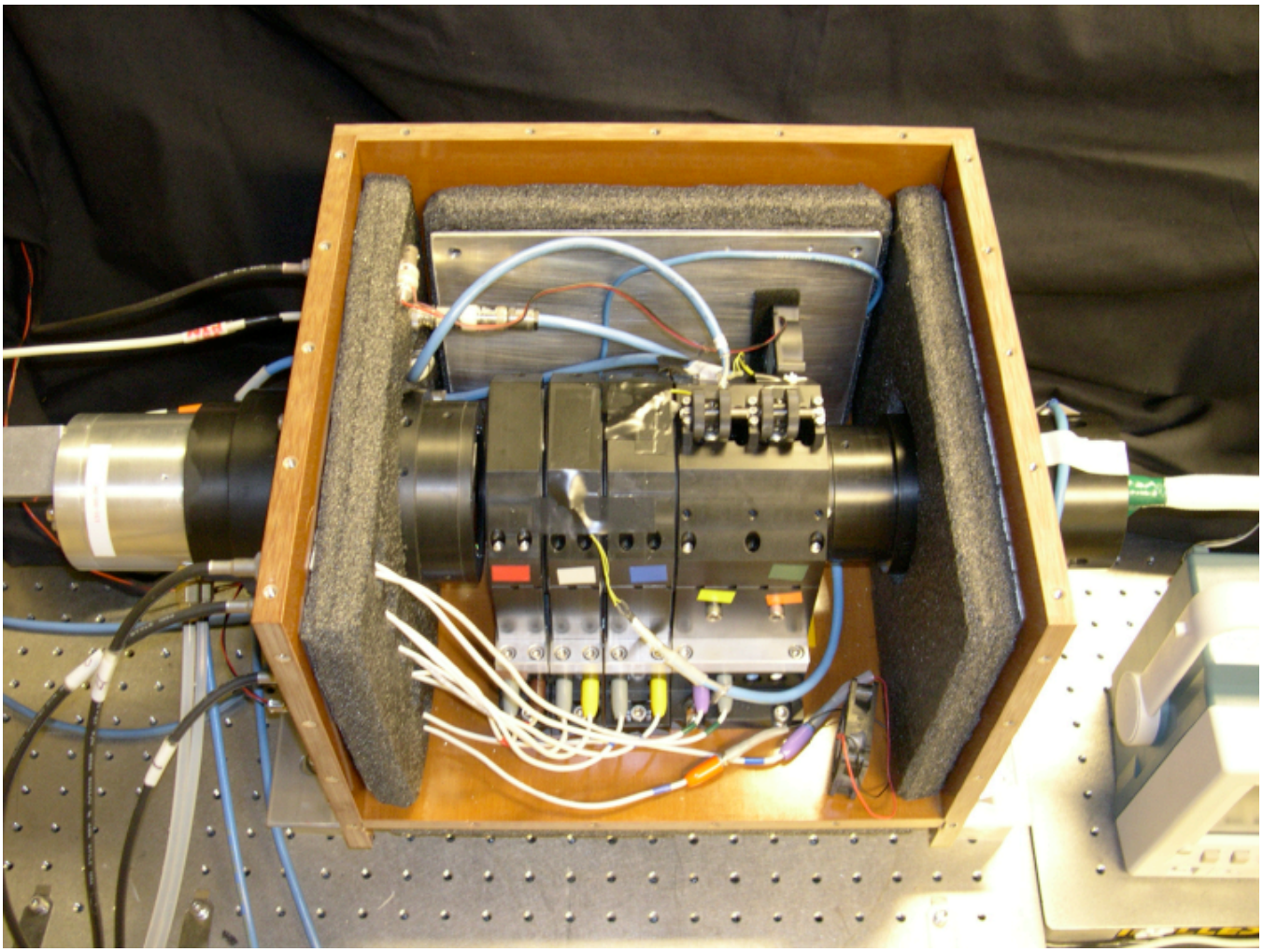

- **Enclosure containing Lyot filter, collimating and focusing optics, APD detector, HV for tuning, and temperature control.**
- **Compact and modular design for easy access and modification.**
- **Achieved a spectral FWHM of 0.062 nm.**

MSE-CIF Layout on NSTX

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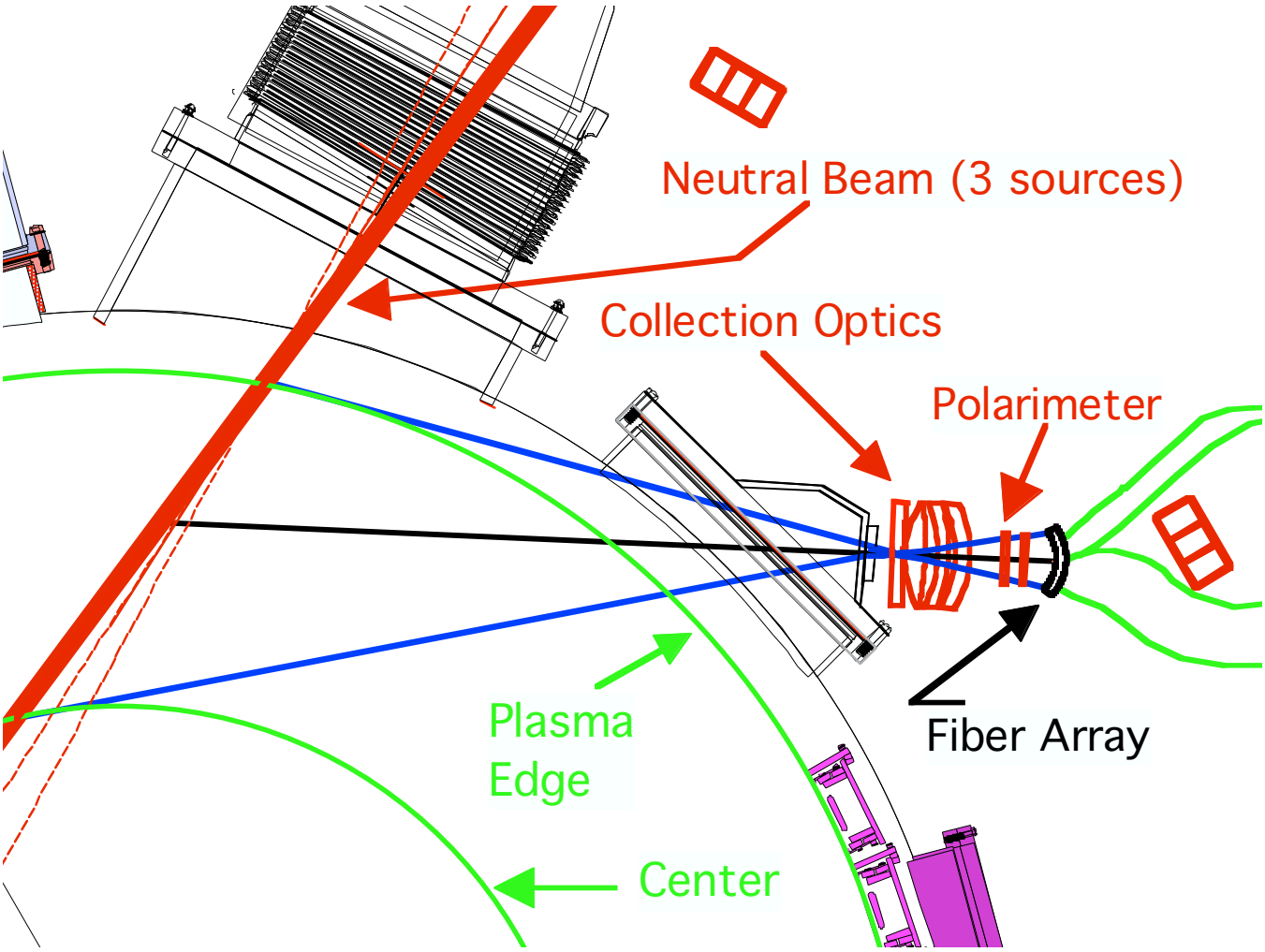

- **Tangential sight-lines at edge and center provide optimal spatial resolution over a wide field of view. [*Goldston & Goldston*, Rev. Sci. Instrum. 66, 5638(1995)].**
- **MSE and CHERS share collection optics, but have separate fiber arrays.**

Doppler Shifted Beam Emission

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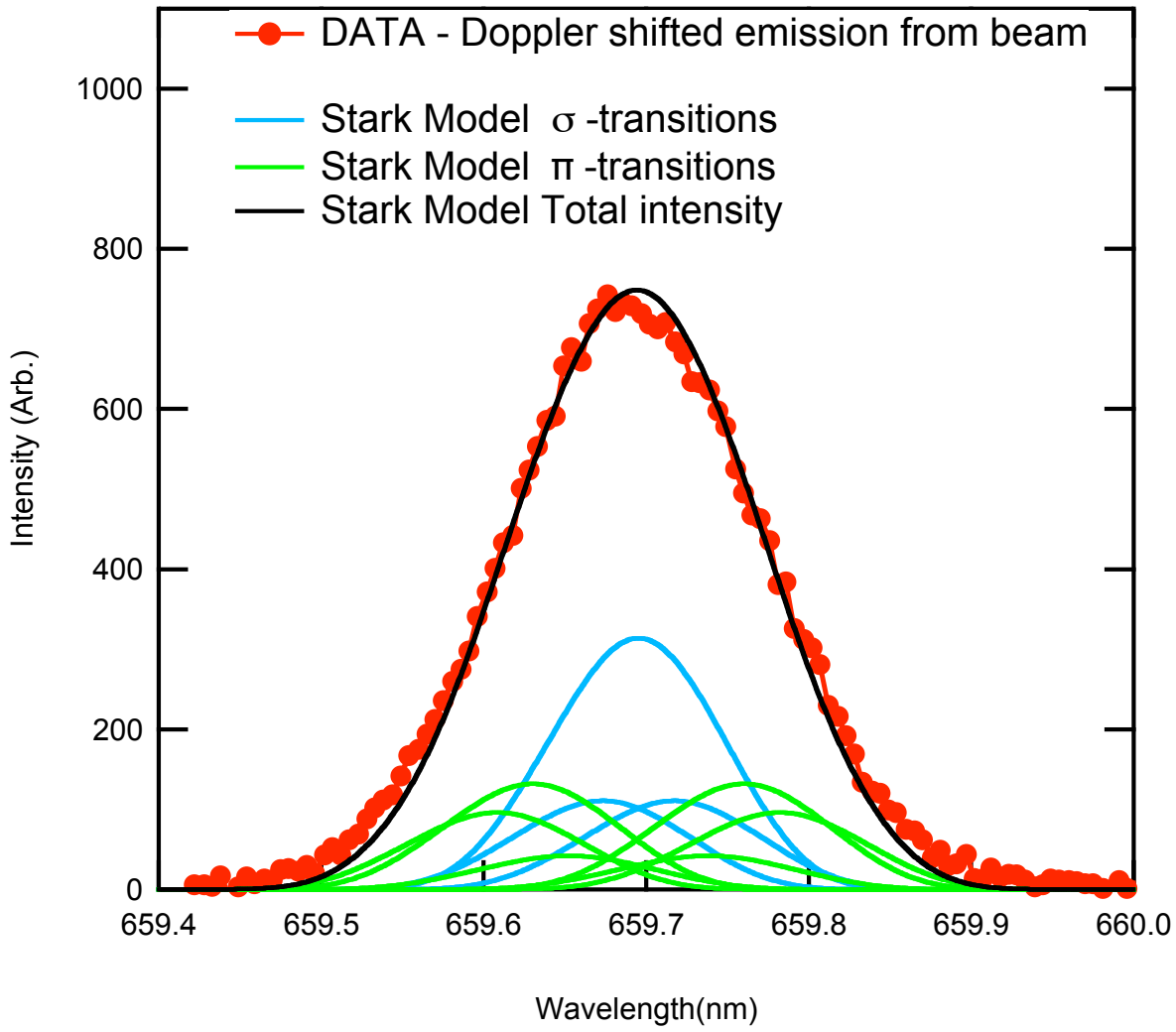

- **"First Light" was observed Jan. 2004.**
- **Spectrometer data from 90 kV deuterium beam at 3 kG.**
- **Data compares well with model including beam divergence, geometric broadening, and Stark shifts.**

Intensity and Polarization Model

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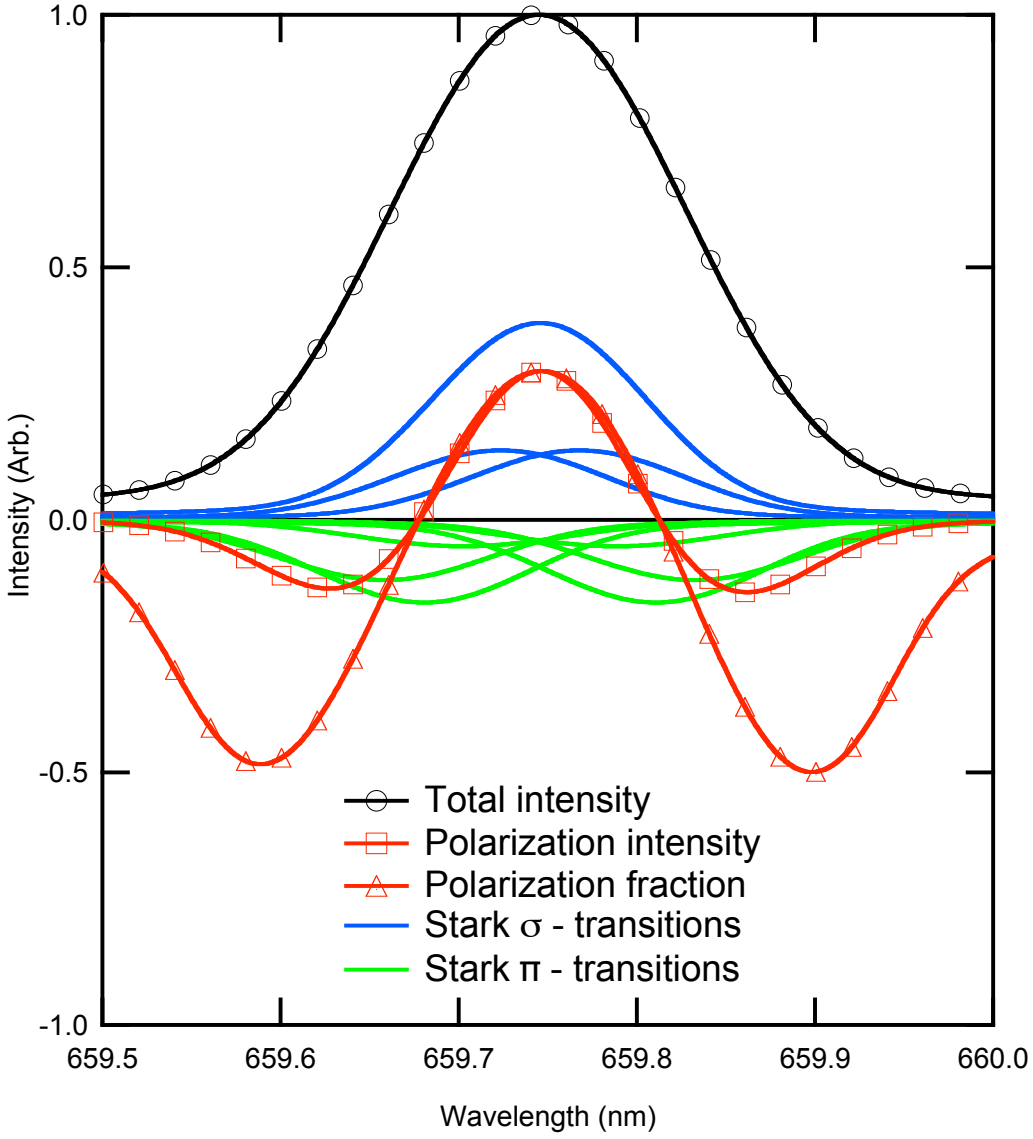

- **Model for 3 kG of intensity and polarization including birefringent filter.**
- **Obtaining this polarization fraction is key to a successful measurement.**

Polarization Fraction Data

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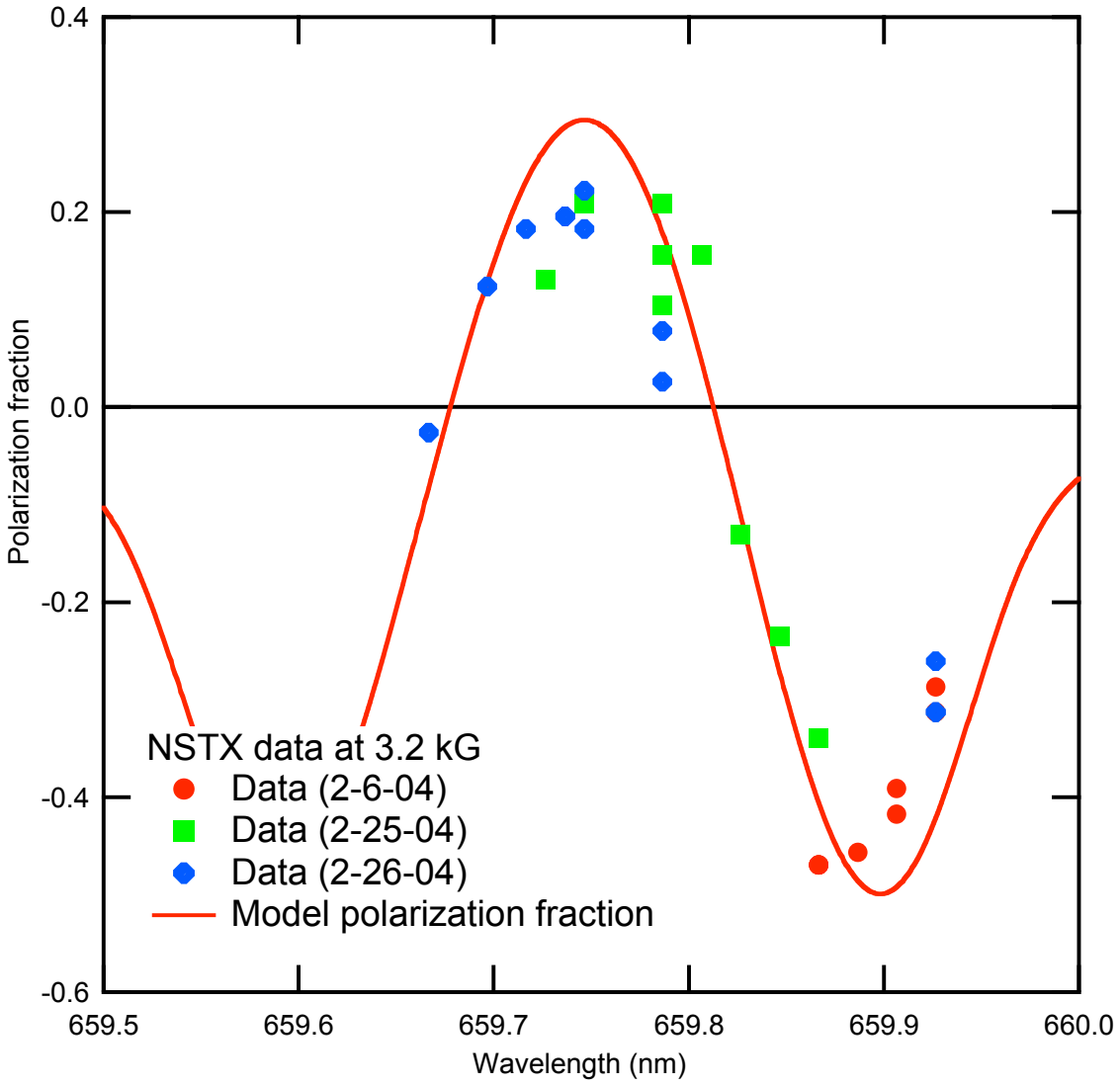

- **Polarization fraction model is consistent with data.**

MSE Calibration with Neutral Gas and Fields at 3 kG

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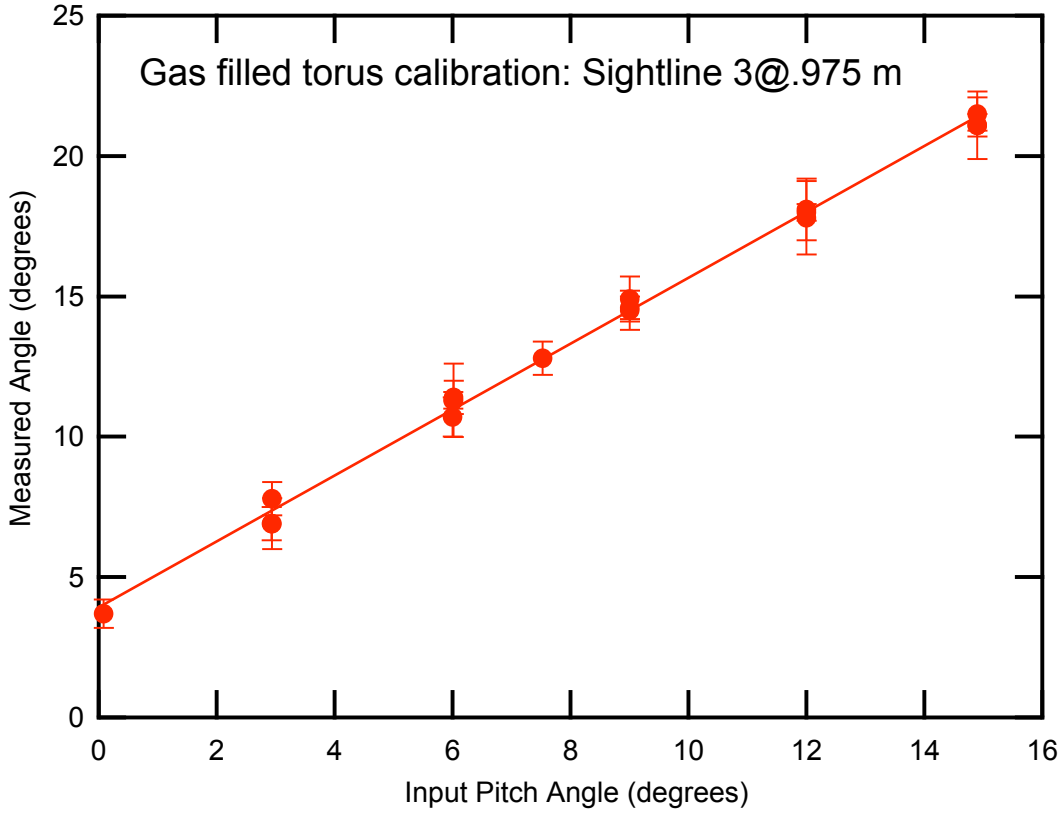

- **Calibration with beam into neutral gas and fields was successful.**
- **Offset from zero due to Faraday rotation from the toroidal field. No effect from the poloidal fields.**
- **We have a Preliminary calibration...some work yet to do on analysis software.**

MSE-CIF Data

Nova Photonics, Inc.

- **Eight channels successfully operated this past run period!**
- **However, limited to four detectors, due to vendor delivery delay.**
- **MSE-CIF has achieved a 0.2°/0.4° statistical uncertainty and 10 ms time resolution at 4.5/3.0 kG.**
- **The BIF spectral filter performed very well, but modification to reduce light leakage will be incorporated.**
- **In process of checking consistency of calibration. All data and calibration for 3 kG.**
  - **Compare to magnetic axis deduced from magnetics.**
  - **Smooth pitch angle profiles under various conditions.**
  - **Consistency of $q(0) < 1$ with sawteeth present.**

MSE Consistency: Magnetic Axis

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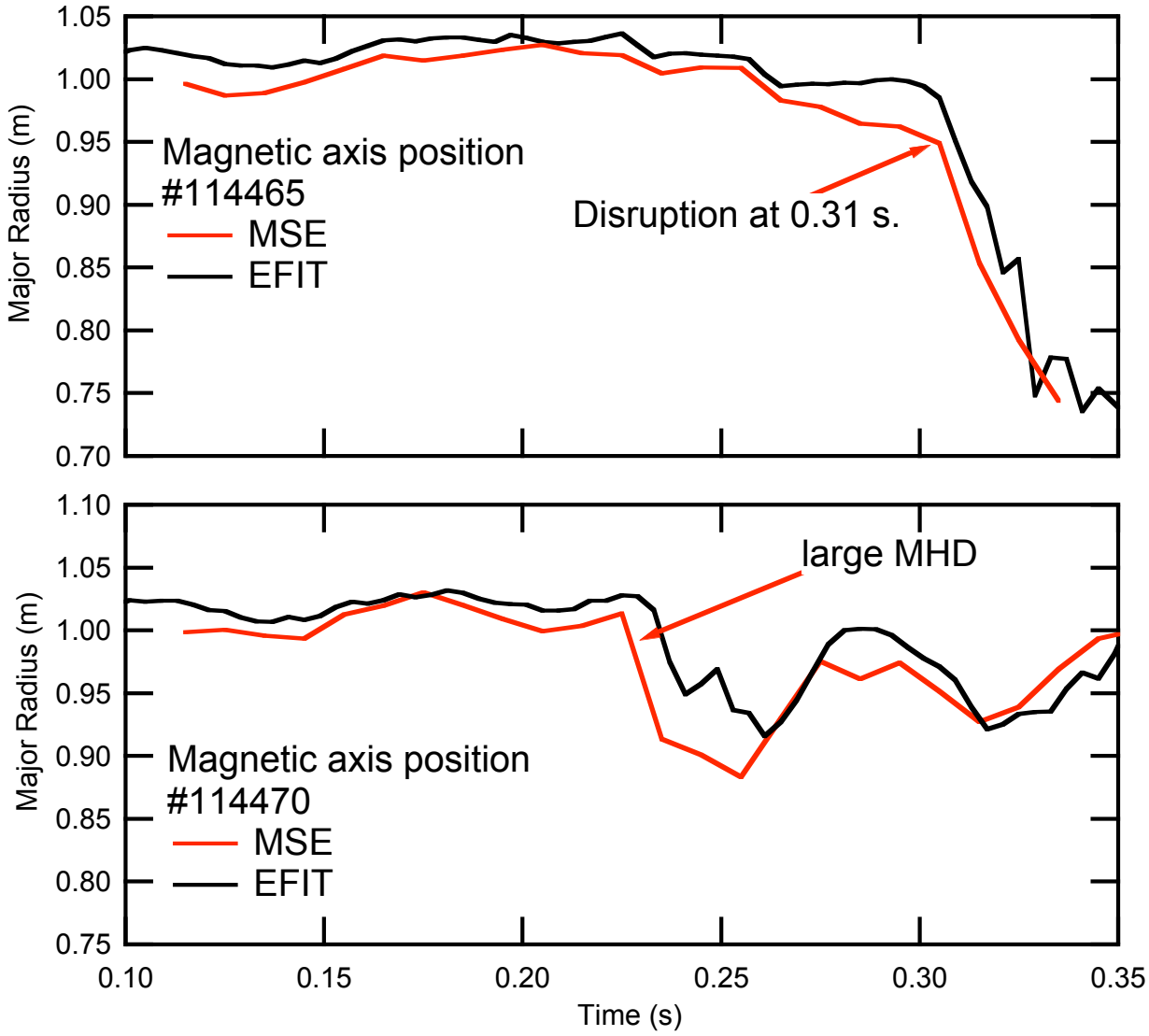

- **MSE magnetic axis from zero crossing of pitch angle.**
- **Magnetic axis evolution is consistent with EFIT and magnetics.**

MSE Consistency: Pitch Angle Profile

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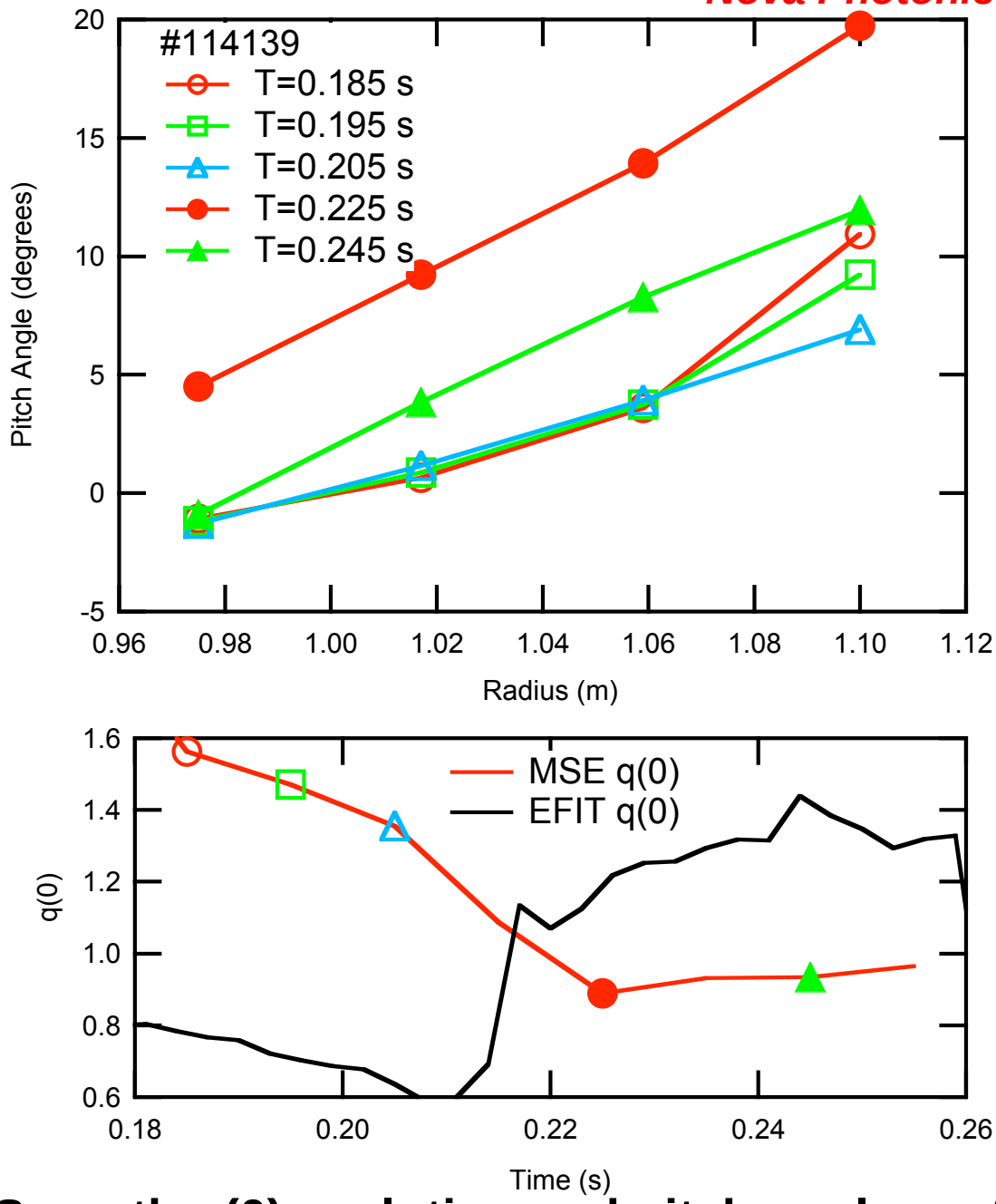

- **Smooth q(0) evolution and pitch angle profile.**
- **EFIT q(0) for reference.**
- **Upon completion of MSE calibration/validation we will incorporate MSE data into EFIT reconstruction. Next year it will be used between shots.**

MSE Consistency: Sawteeth

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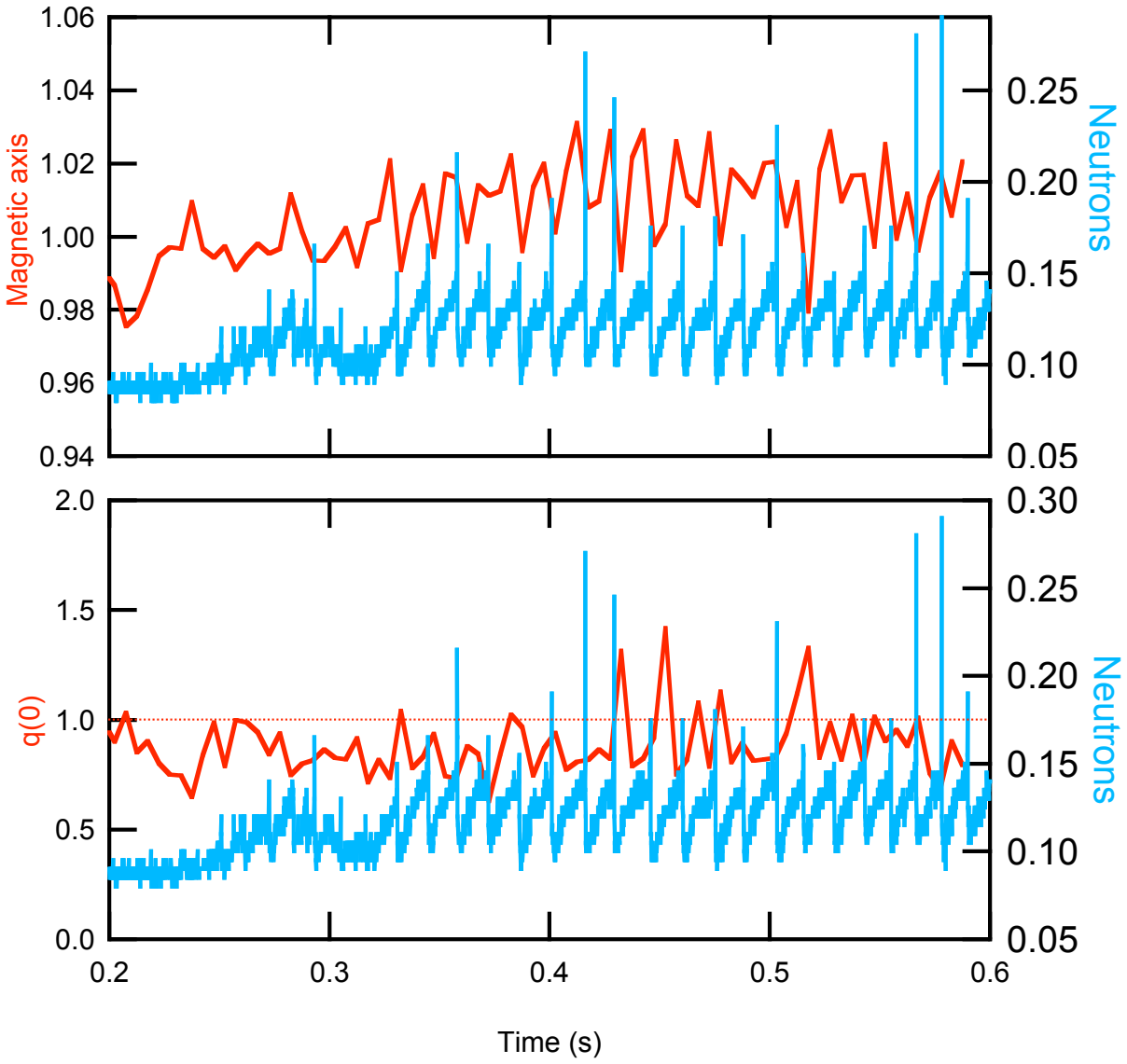

- $q(0) \sim 0.8$ **before sawtooth crash and rises to** $q(0) \sim 1$ **after crash. The magnetic axis shifts inboard ∼2 cm after sawtooth.**
- **MSE integration time is 5 ms. Sawtooth period is 15 ms.**

MSE-CIF Summary and Plans

Nova Photonics, Inc.

- **Eight channels with birefringent filters successfully operated this past run period!**
- **However, limited to four detectors, due to vendor delivery delay.**
- **MSE-CIF has achieved a 0.2°/0.4° statistical uncertainty and 10 ms time resolution at 4.5/3.0 kG.**
- **The BIF spectral filter performed very well; – some improvements will be incorporated.**
  - **Improve monitoring and tuning of filter.**
  - **Reduce light leakage from last stage.**
- **Preliminary calibration looks very good and appears consistent with magnetics data.**
- **Next year– start with 8 channels and increase to 14 during the run.**