U.S. DEPARTMENT OF ENERGY | Office of Science

NSTX-U

CHERS Status

Initial Analysis with NB Modulation

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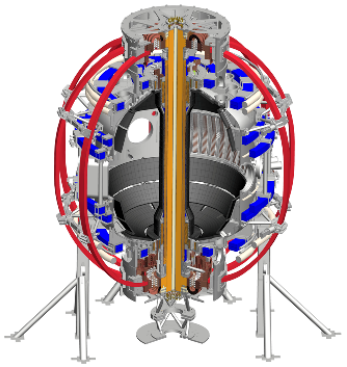
NSTX-U Physics Meeting
PPPL
Monday, July 18, 2016

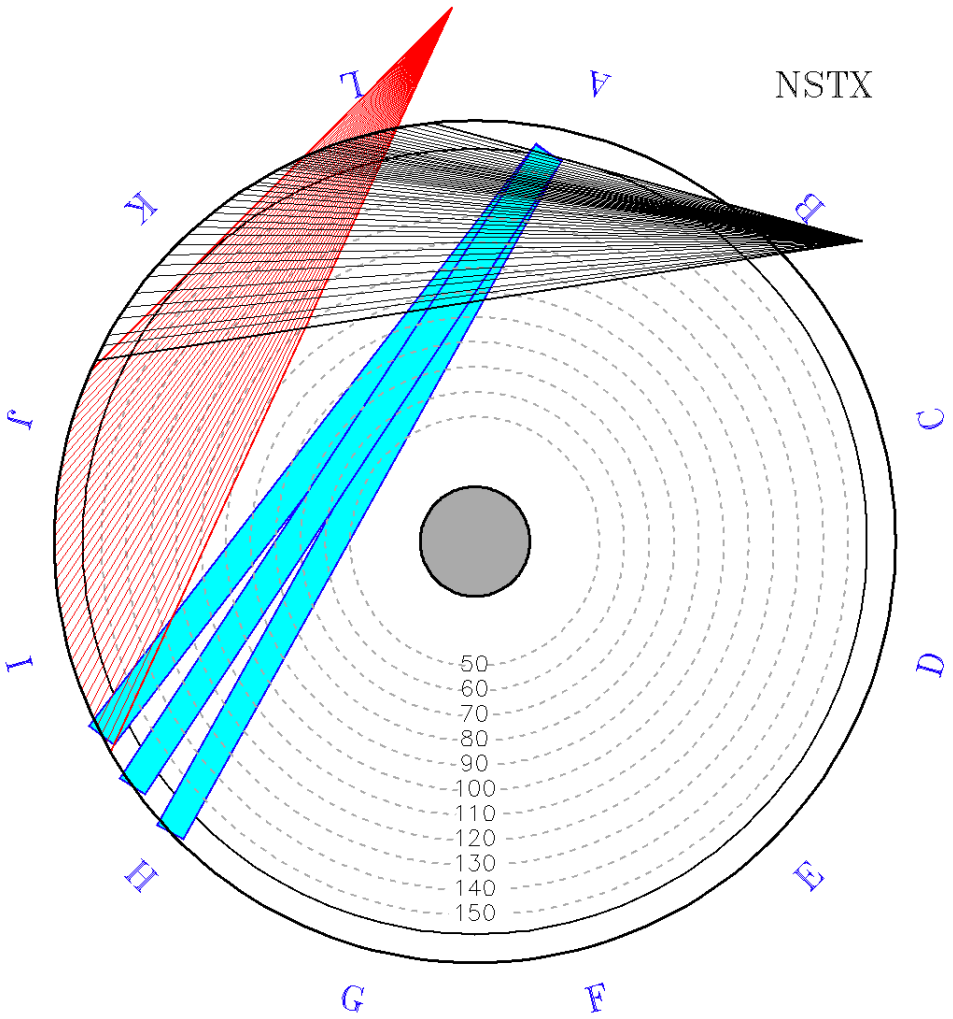
PPPL



NSTX-U CHERS Status

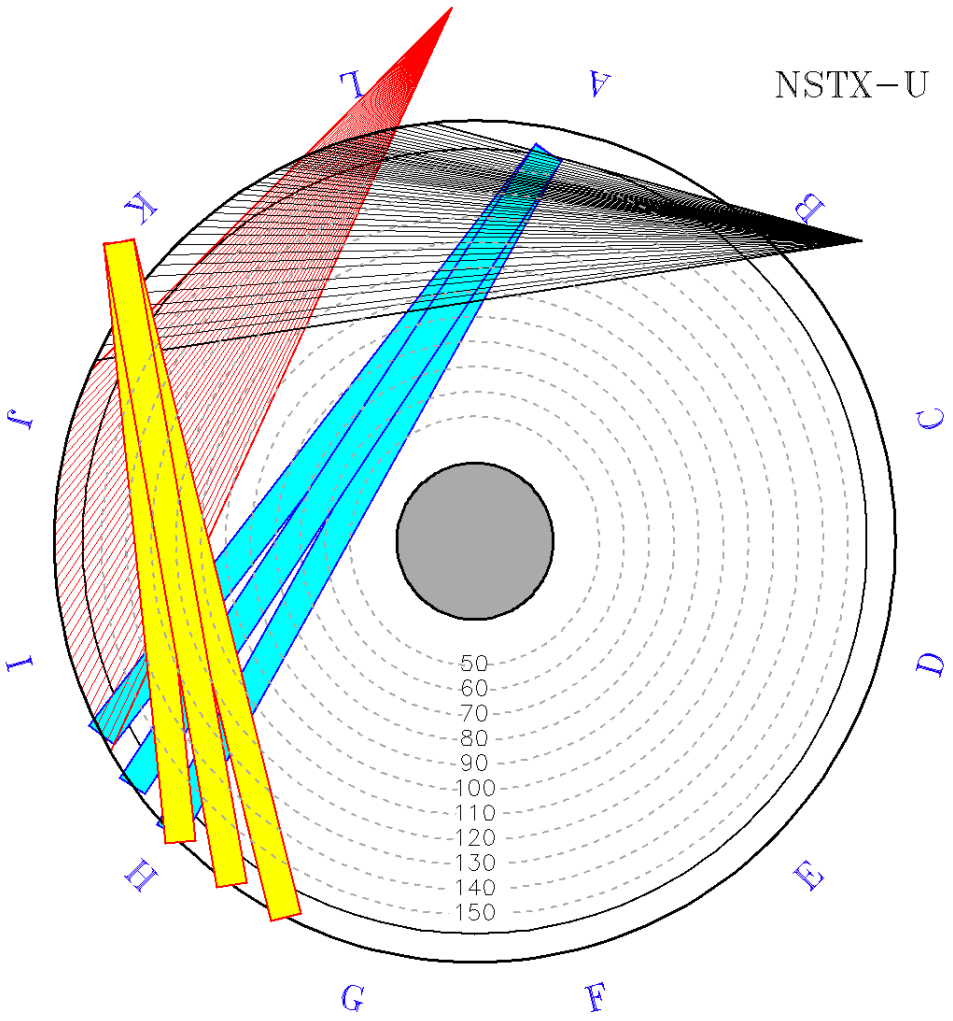
- T_i, V_t, N_c measured with charge exchange recombination spectroscopy (CHERS)
- NSTX-U CHERS hardware the same as on NSTX
- CHERS/MSE window was replaced during outage
- CHERS diagnostics routinely acquiring data
- Automatic analysis routinely operating
  - Times with only NB1 operation are analyzed in the same way as on NSTX
  - Times when NB2 is on are ignored
- Number of discharges analyzed > 500
- XMP developed to determine best strategies to measure T_i, V_t, N_c when NB2 is operating

CHERS views on NSTX



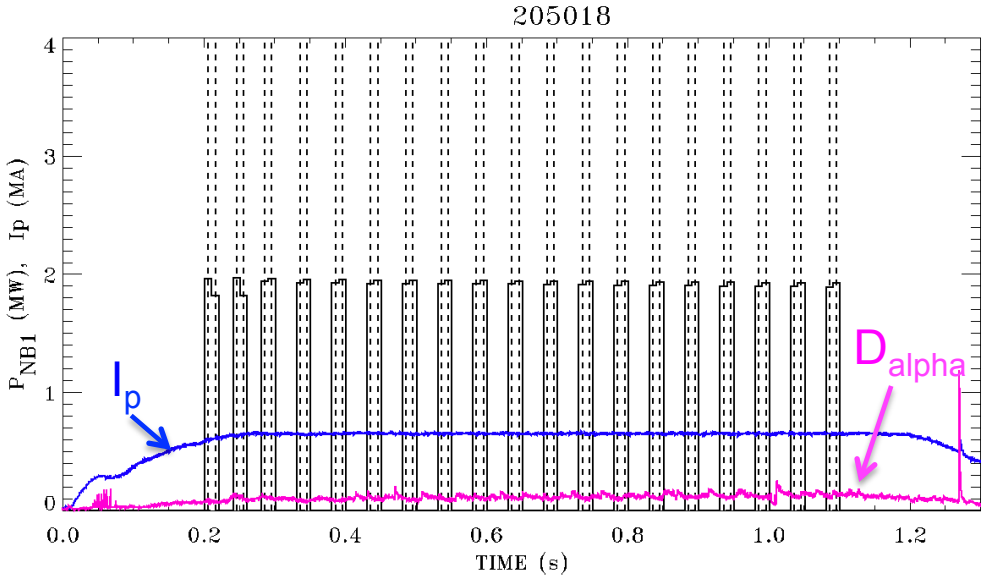
- CHERS Active views
  - Optimized views across NB1 for excellent spatial resolution
  - Views CX emission and background emission for C^{5+}
- Background views
  - View parallel to NB1
  - View *only* background emission
  - Background measurement *simultaneous* with active measurement
- Analysis
  - Spectra from active view corrected using background spectra
  - Assume toroidal symmetry of background emission
  - Careful calibration across two views required

CHERS Views on NSTX-U



- NB2 compromises the CHERS background view on NSTX-U
  - Bright CX emission contaminates background views
  - Large tangency radii of NB2 sources do not allow a localized measurement
- No useful measurement from CHERS background view with NB2 operation
- Two options to determine background
  - Notch NB2 source(s)
  - Modulate NB1 source
    - Temporally shifted background measurement
- Analysis options
  - Same as NB1 analysis if NB2 is notched
    - Reduced time resolution
  - Modulating NB1 source with assumption that the background emission is constant in time

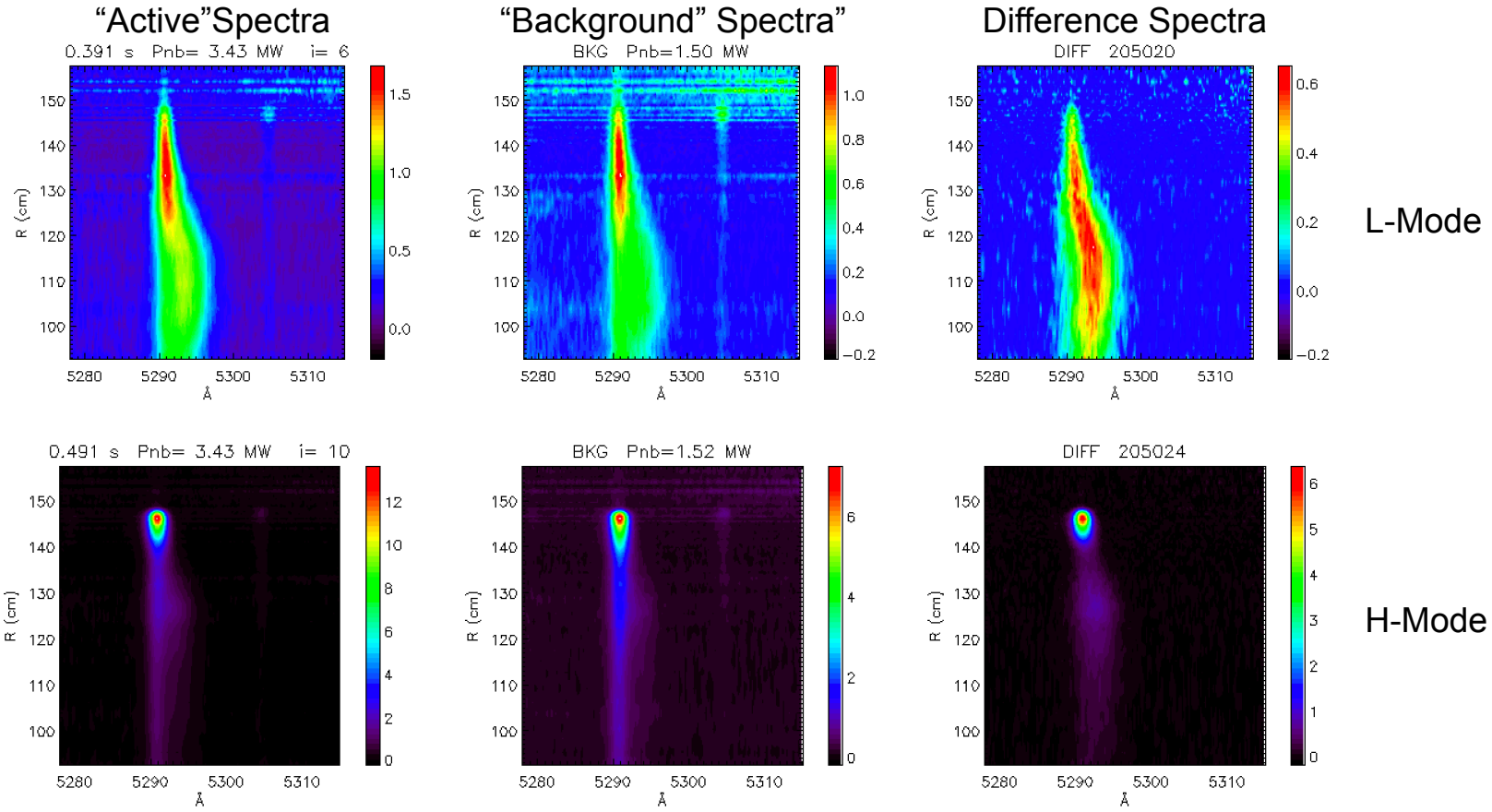
XMP-114 CHERS NB Modulation Study



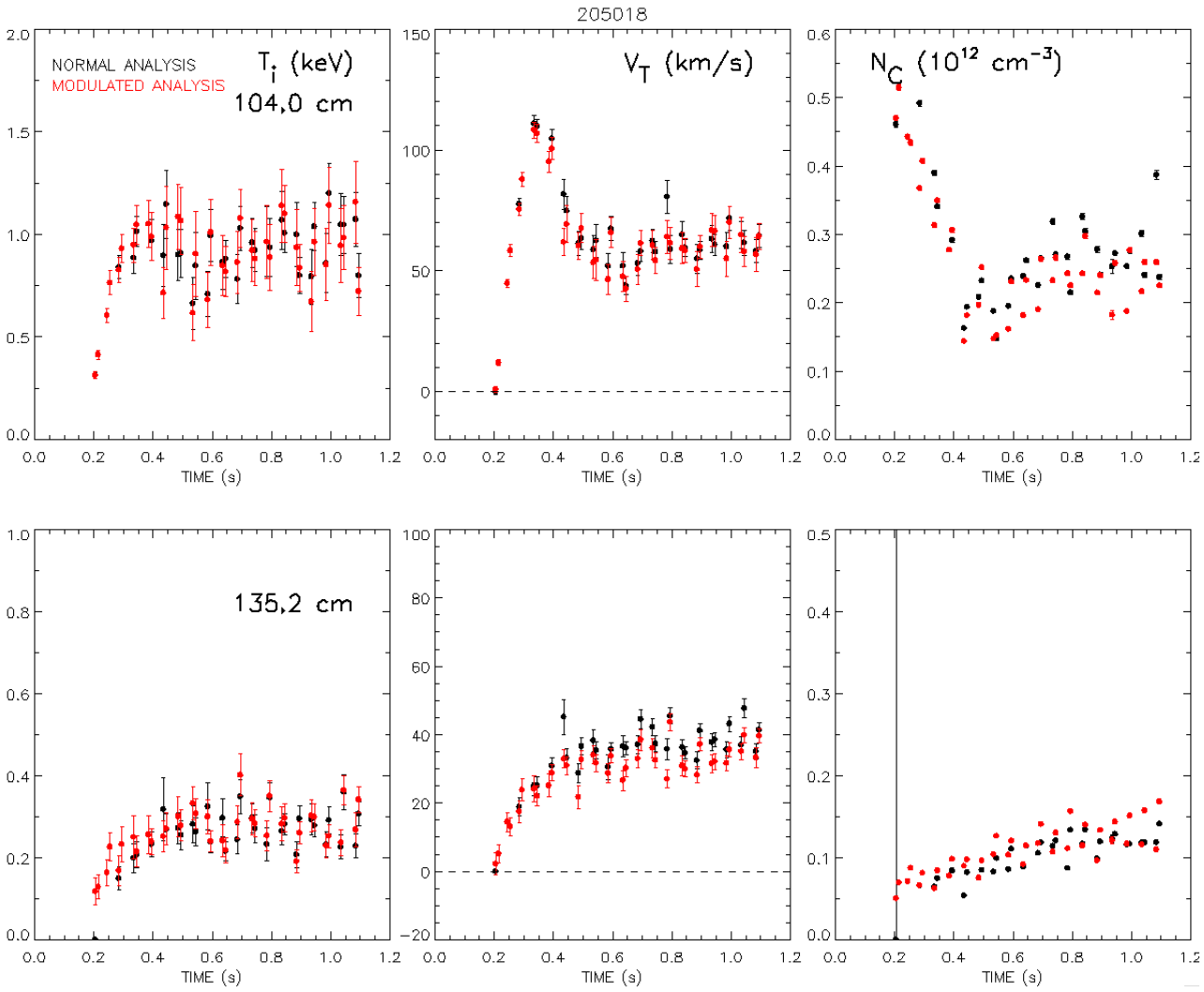
- XMP-114 was begun 24 Jun '16
  - First two cases completed
    - Modulation of single NB1 Source
    - Modulation of one NB1 Source + second NB1 source
    - Using only NB1 allows comparison between standard and modulated analysis
  - Modulated source NB1C @ 90 kV
    - Reliable modulation with NB1C
    - Adequate S/N @ 90 kV
    - 20 ms ON, 30 ms OFF
  - Cases with NB2 yet to be done
- Preliminary analysis code developed
  - Identifies "modulated beam" frames
    - Indicated by vertical dashed lines in figure
  - Identifies corresponding "background" frames
    - Interpolates using "before" and "after" frames
  - Fits background subtracted spectra
  - Corrects for atomic physics issues as before
- Single Source Modulation
  - Low density L-mode
- Two sources with one modulated
  - H-mode develops
  - Strong MHD at times

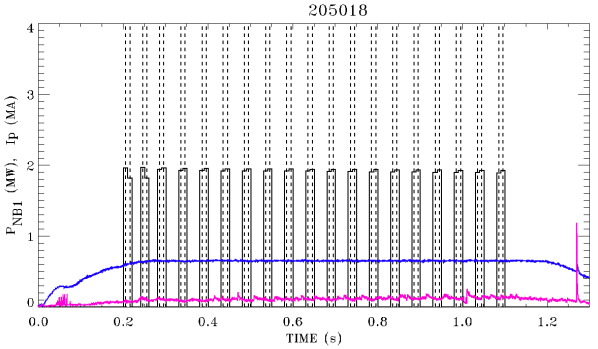
Raw spectra shows extraction of CX spectra from modulated beam

- CX emission from a single modulated beam source extracted from CX emission from two sources and background emission
  - Interpolated spectra, Wavelength versus Radius
  - L-mode case shows higher rotation in core
  - H-mode case shows strong emission near edge



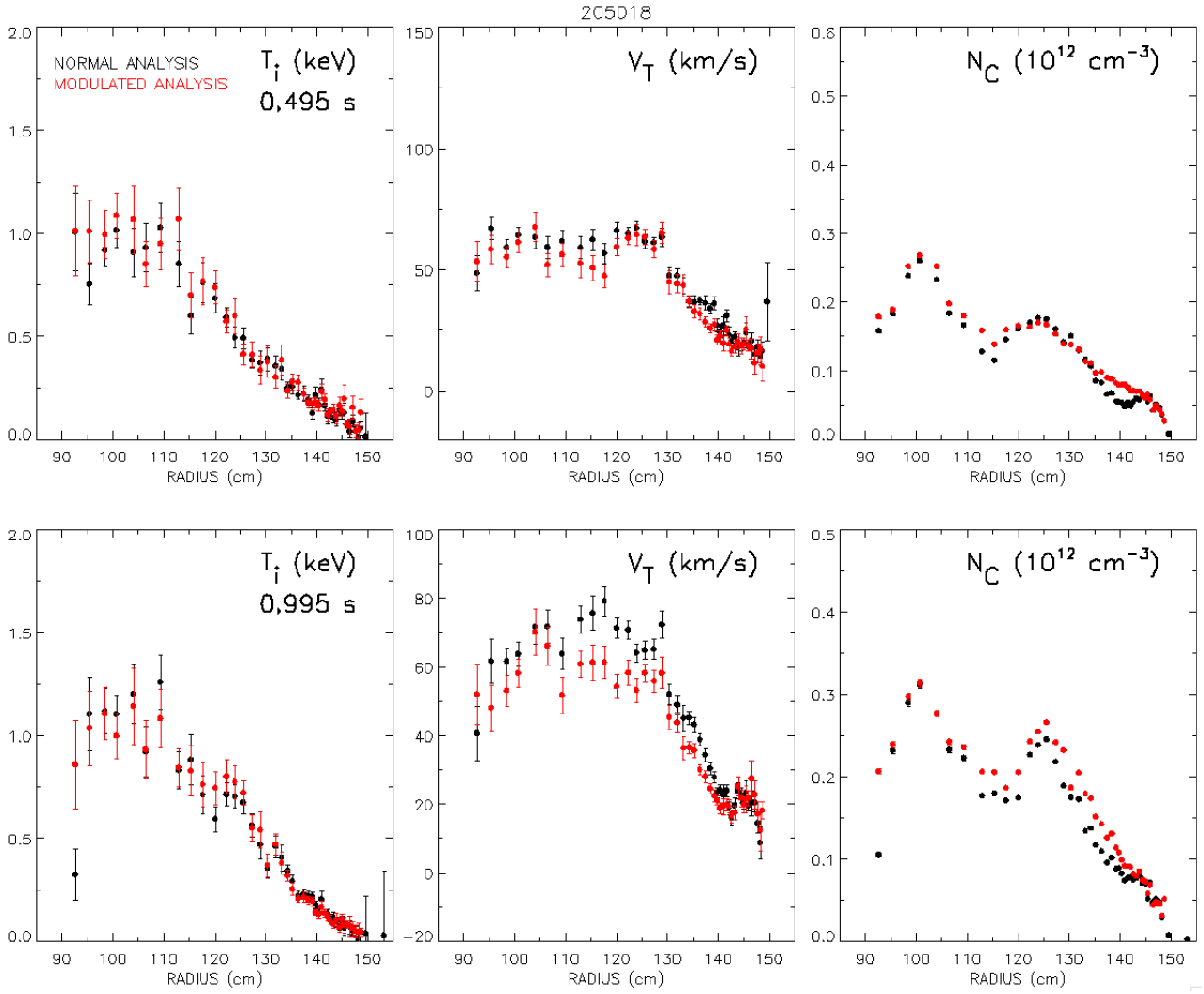
Comparison of time histories for single modulated NB1 source

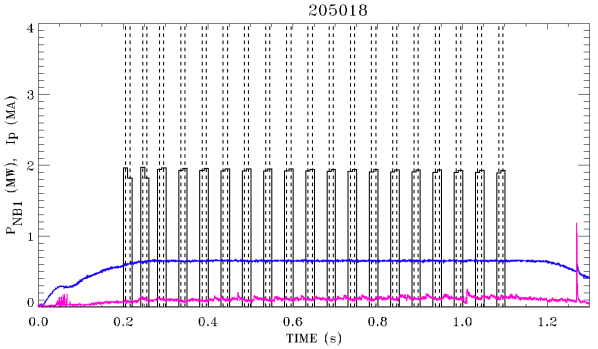




- Modulated analysis yields similar values to standard analysis
- Error bars comparable for both
  - Both analyses based on single source
- Signal to Noise adequate with one NB1 source modulating

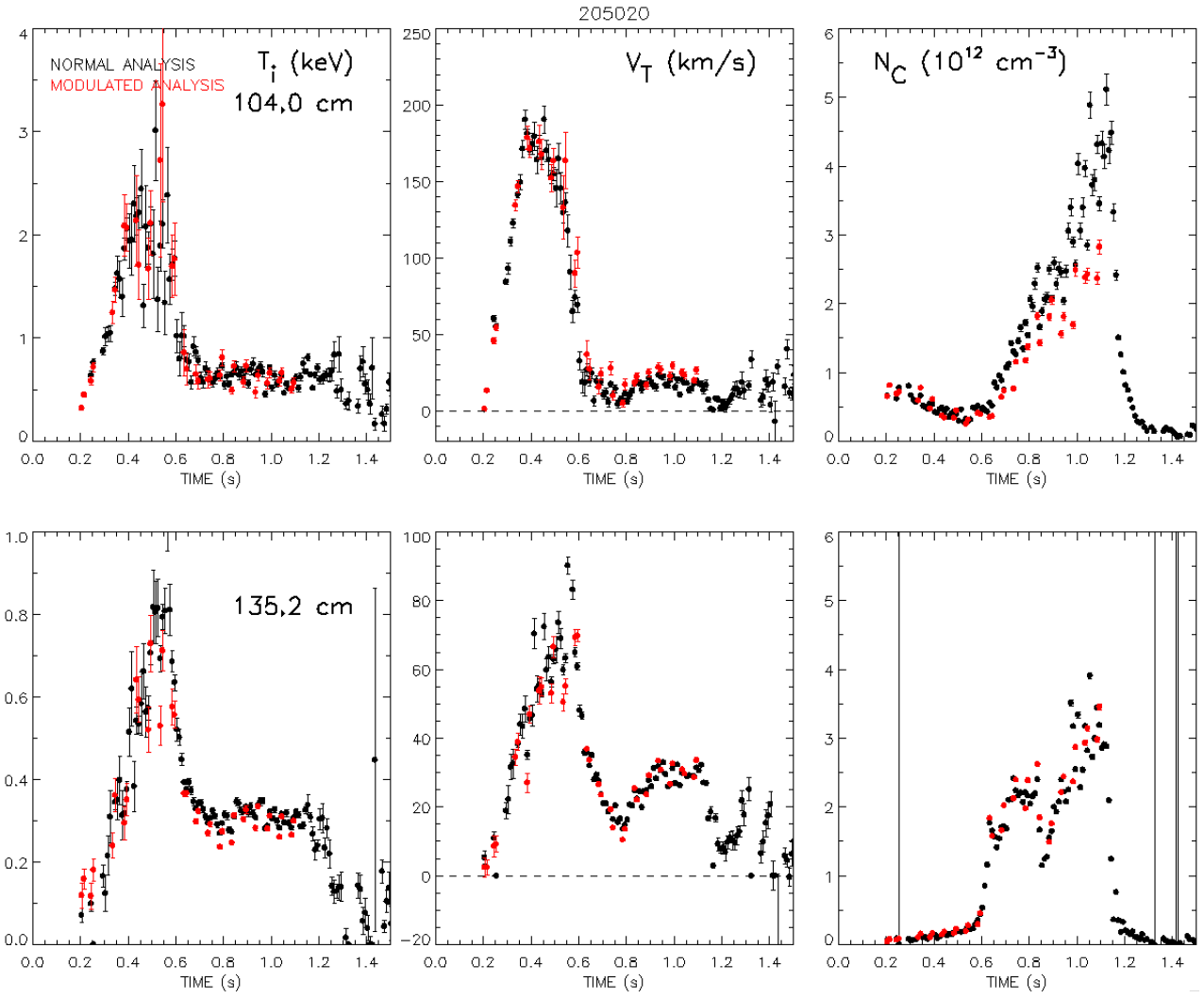
Comparison of profiles for single modulated NB1 source

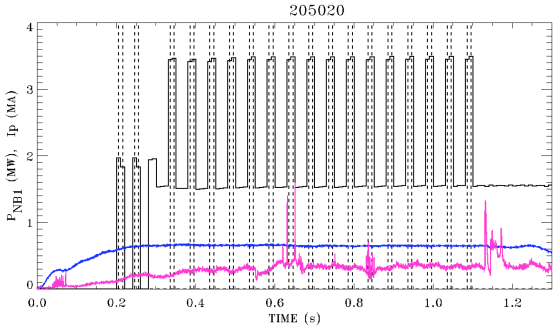




- Modulated analysis yields similar values to standard analysis
  - Minor differences at some radii outside of statistical 1σ error bars
- Error bars comparable for both
- Signal to Noise adequate with one NB1 source modulating

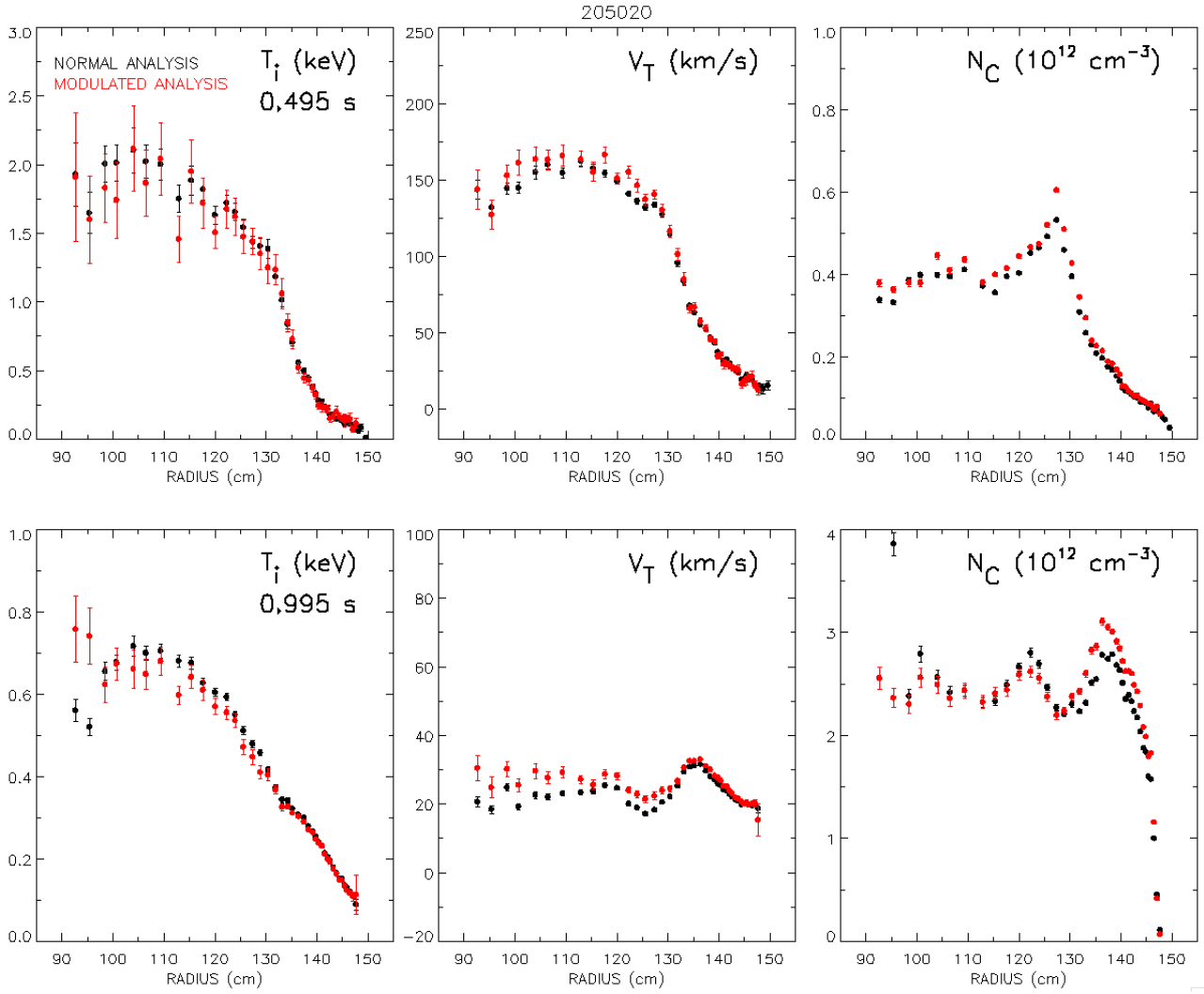
Comparison of time histories for single modulated NB1 source plus one steady NB1 source

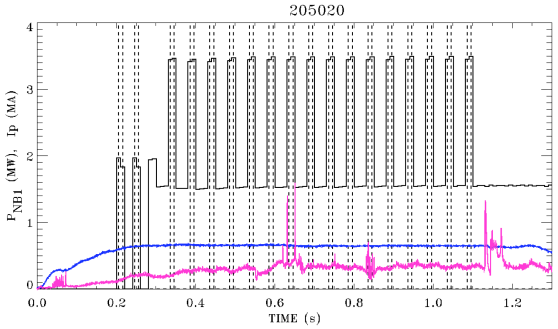




- Modulated analysis yields similar values to standard analysis
  - Differences outside of statistical 1σ error bars
- Error bars larger for modulated analysis
  - Only 1 source for modulated analysis
  - Two sources for standard analysis at modulated times
- Interpolated background well-behaved for this discharge
- Lower time resolution, reduced temporal coverage with modulated analysis

Comparison of time histories for single modulated NB1 source plus one steady NB1 source

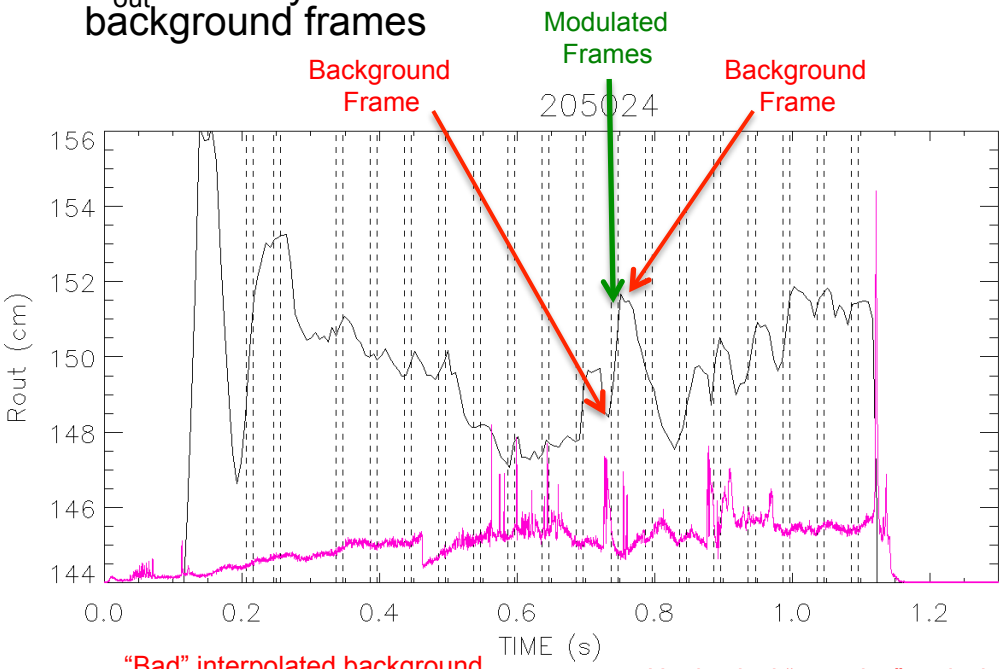


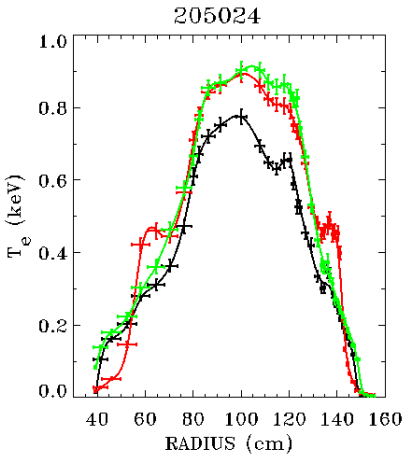


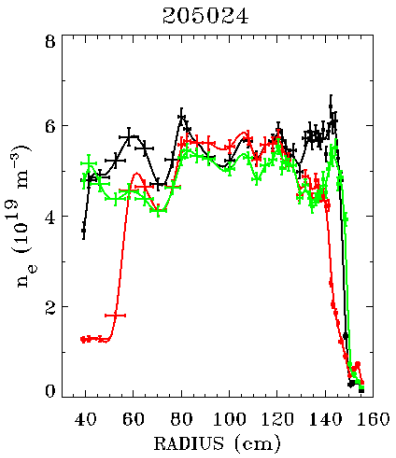
- Modulated analysis yields similar values to standard analysis
  - Minor differences at some radii outside of statistical 1σ error bars
- Error bars larger for modulated analysis
  - Only 1 source for modulated analysis
  - Two sources for standard analysis at modulated times
- CX Signal improved by higher carbon content at later times

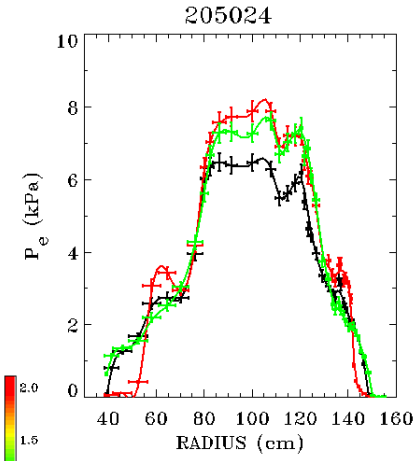
Plasma motion affects background integrity

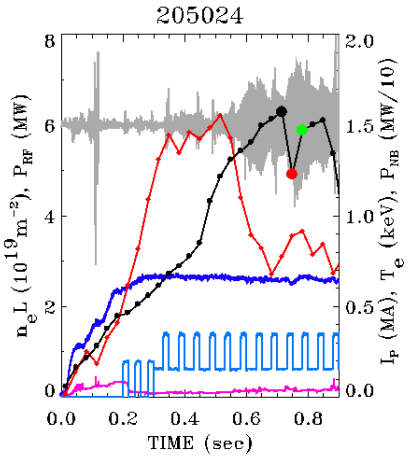
- Collapse of H-mode and recovery span measurement interval
- R_{out} shifts by 3 cm between “before” and “after” background frames





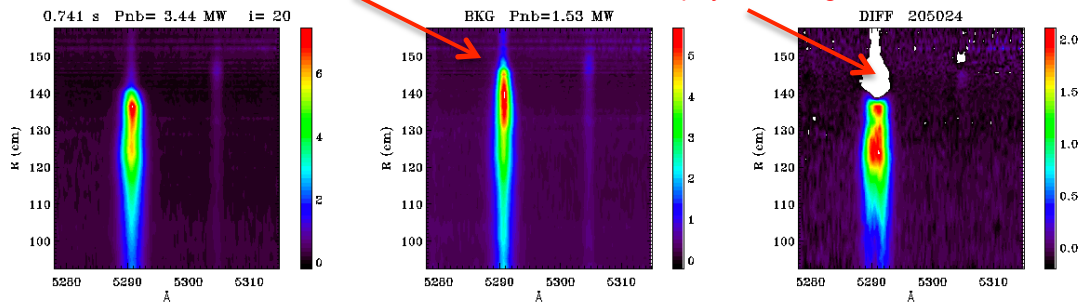






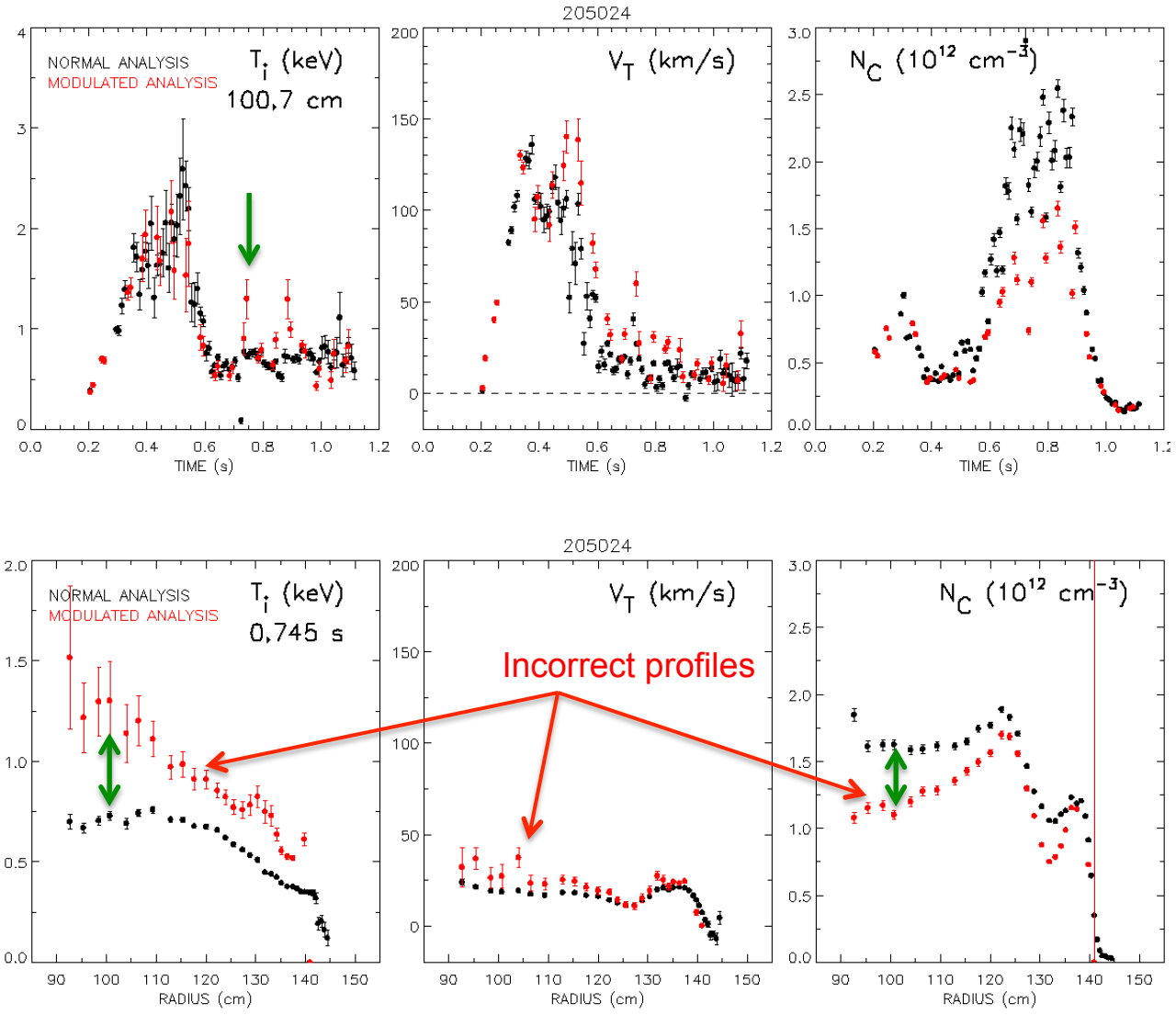
“Bad” interpolated background

Unphysical “negative” emission



- Interpolated background spectra not appropriate for active spectra
- Need to detect “bad frames” for auto analysis code to work

Flawed analysis when background emission varies over period of modulation



- Temporally shifted background frames are problematic
  - Difficult to insure constant background over wide modulation cycle (20 ms blip + 20 ms background)
- Analysis yields erroneous profiles at times with bad interpolated background
- CHERS data may be lost due to
  - Plasma motion
  - MHD
  - Large ELMs
  - L-H transitions
  - H-L transitions
  - Large gas puffs
  - Granule injection

Initial results with NB1 modulation analysis are encouraging

- Single NB1 source modulation from XP-114 suggests that CHERS measurements may be obtained while NB2 sources are on
  - S/N seems adequate when 90 kV source used for modulation
  - Improved S/N over NSTX aided by new viewing window
  - XMP-114 cases using NB2 sources still need be run and analyzed
- Temporal resolution using modulated NB1 source is reduced
- Time interval for modulated beam sources is limited
  - 20 beam blocks/source/shot
- Error bars for CHERS are larger for modulated analysis
  - Consistent with using single NB1 source
  - Summing spectra over the 20 ms blip reduces error AND further reducing temporal resolution
- Interpolated background is temporally shifted from active measurement time
  - Background foiled by changes in plasma position, confinement regime, etc.
- Time window for measurement is ≥ 40 ms over which background emission should be constant
- CHERS data may be lost due to changes in background emission over modulation cycle

Recipe for Modulated Beams, CHERS with NB2

- For a single NB2 source, NOTCH source for 10 ms or more
- For multiple NB2 sources, BLIP one NB1 source
- Start and end times of Notch or Blip should be multiple of 10 ms
- Use only RELIABLE sources for beam blocks
- Use higher voltage (90 kV) for modulated NB1 sources

- Modulation Constrained
  - NB Blips should be 20 ms wide
  - Number of blips currently limited to 20 beam blocks/source/shot
  - Multiple NB1 sources (if reliable) could be used to extend time range for modulated analysis

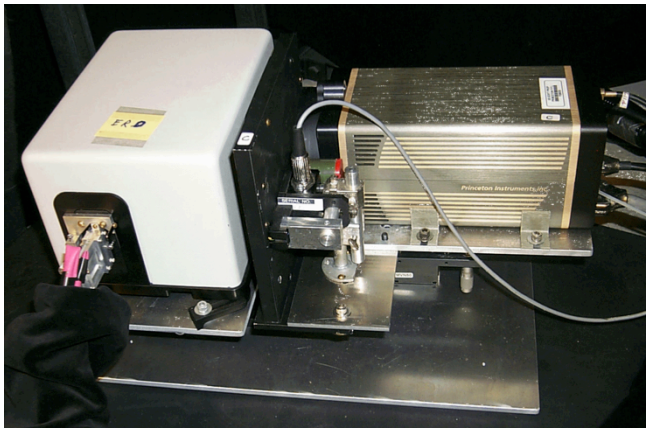
- Modulation or Notching of NB sources controlled by physics operator using waveform for beam blocks
  - Waveforms with beam timing should be prepared ahead of time and made available to the physics operator

- If NB2 is ON: No Notch, No Blip, No CHERS data!

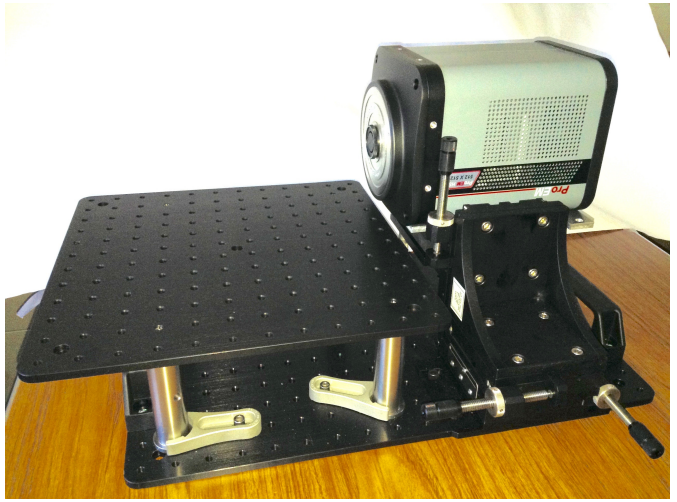
CHERS Upgrade for FY2017

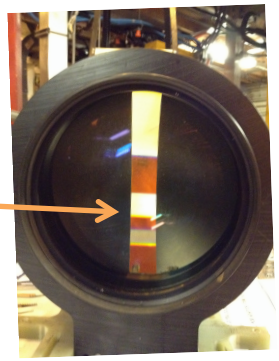
- New cameras for better reliability and performance
  - Existing cameras unsupported
    - Pentamax,19 years old
    - 12 bit digitization, 5 MHz readout
    - 100 Hz data acquisition
  - New cameras have been purchased
    - ProEM-HS
    - 16 bit digitization, 20 MHz readout
    - Up to 500 Hz data acquisition
- CHERS S/N improvement of 2-3
  - Improved support of NB modulation
  - Higher QE Camera
  - Higher transmission filters
  - Another factor of 1.4 increase with wider MSE aperture
- Eliminate Choppers
  - Variable exposure time
- New spectrometer mounts

Present Holospec spectrometer, chopper, Pentamax camera



New ProEm-HS camera & mount





CHERS/MSE Lens