MIT PSFC

Diagnostic Plans for NSTX-U

NSTX-U Diagnostic Planning Meeting
May 17, 2016

MIT PSFC is developing diagnostics for NSTX-U, targeting physics experiments in FY17 and FY18

Presentations Today

- **Advanced, Scanning Mirror Langmuir Probe** – Brian LaBombard
- **X-Ray Imaging Crystal Spectrometer** - John Rice
- **Augmented Gas-Puff Imaging** - Jim Terry
- **Multispectral Divertor Imaging** – Bob Mumgaard

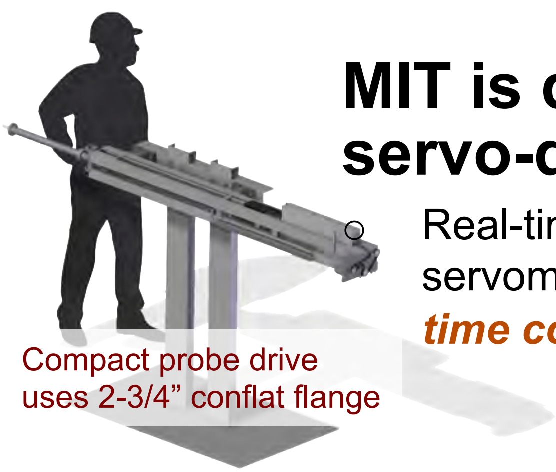
The following diagnostics are also begin considered, leveraging MIT expertise and hardware from Alcator C-Mod:

- Disruption Bolometers (FY17) – Bob Granetz
- Fast Two-Color Interferometer (FY18) – Jim Irby
- Polarimeter (FY19) – Jim Irby

Scanning Mirror Langmuir Probe -- MLP

C-Mod Scanning MLP is resolving profiles and turbulence with unprecedented detail, enabling new studies:

- *Physics of near and far SOL plasma turbulence; scaling of heat width*
- *SOL blob formation dynamics and statistics*
- *Coherent modes; pedestal gradient limiting modes (EHO, KBM)*
- *Time resolve ELM dynamics; boundary plasma flows, flow shear, relationship to Heuristic Drift model*
- *L-H threshold physics (flows, Er, limit cycle oscillations, GAMs)*
- *Density limit physics, ...*

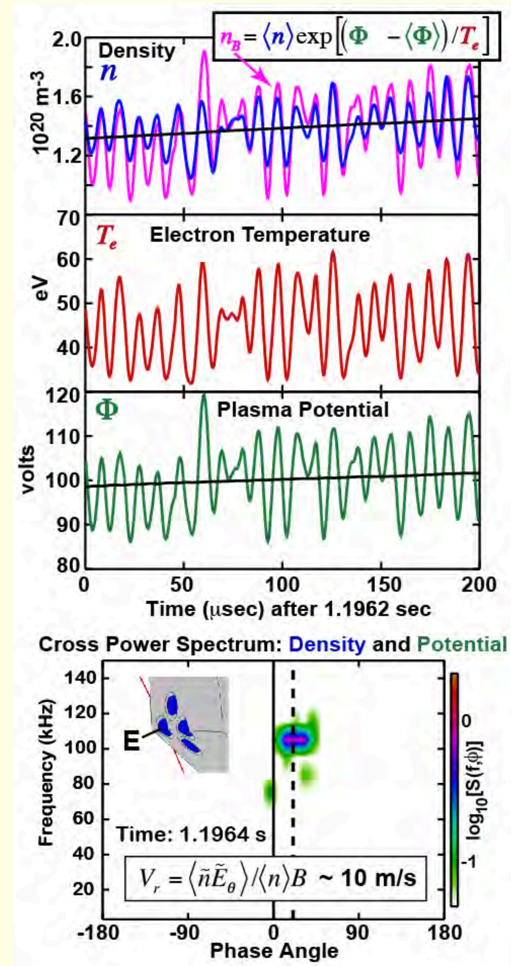


Compact probe drive uses 2-3/4” conflat flange

MIT is developing a next generation, servo-driven, scanning MLP system

- Real-time I_{sat}, V_f, T_e measurements (MLP) plus linear servomotor drive -- ***Sets plunge depth based on real-time computation of probe surface temperature***

MLP Resolves physics of Quasi-Coherent Mode



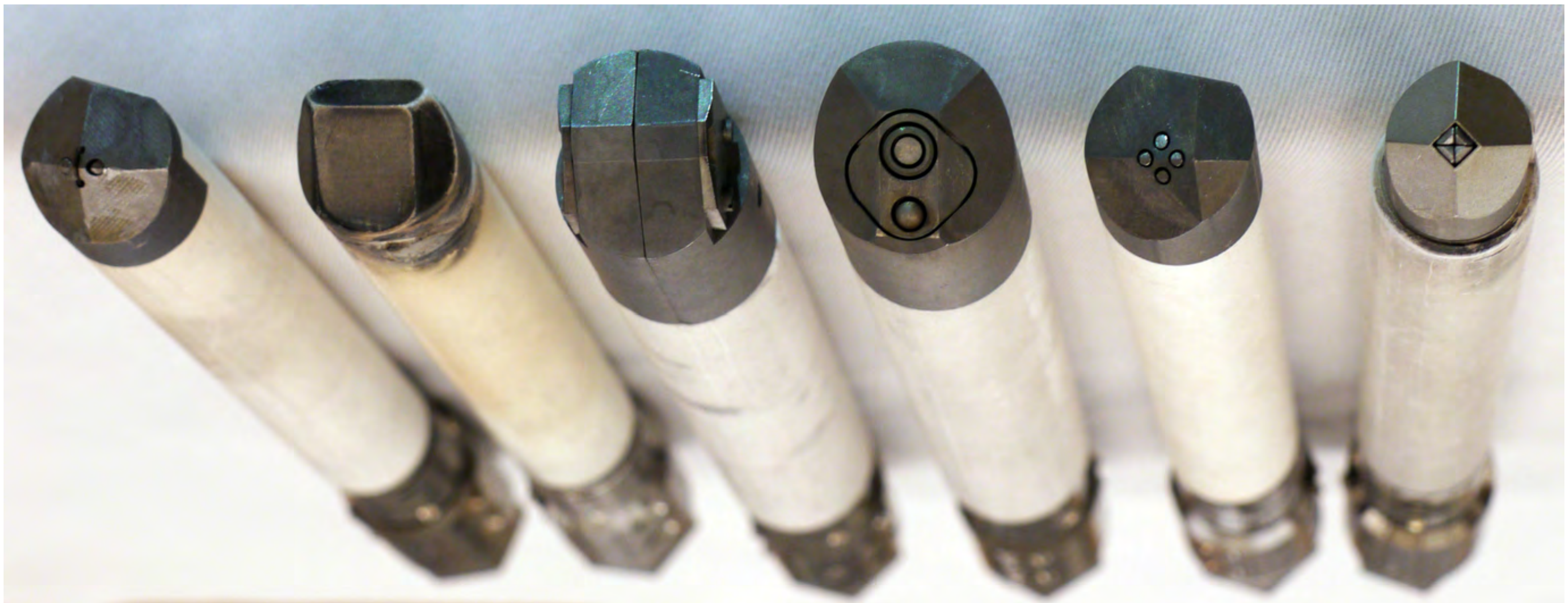
LaBombard, B., Phys. Plasmas **21** (2014) 056108

Prototype is now installed on Alcator C-Mod and is beginning operations/testing (FY16 campaign)

<u>Scientists:</u> Dan Brunner, Brian LaBombard

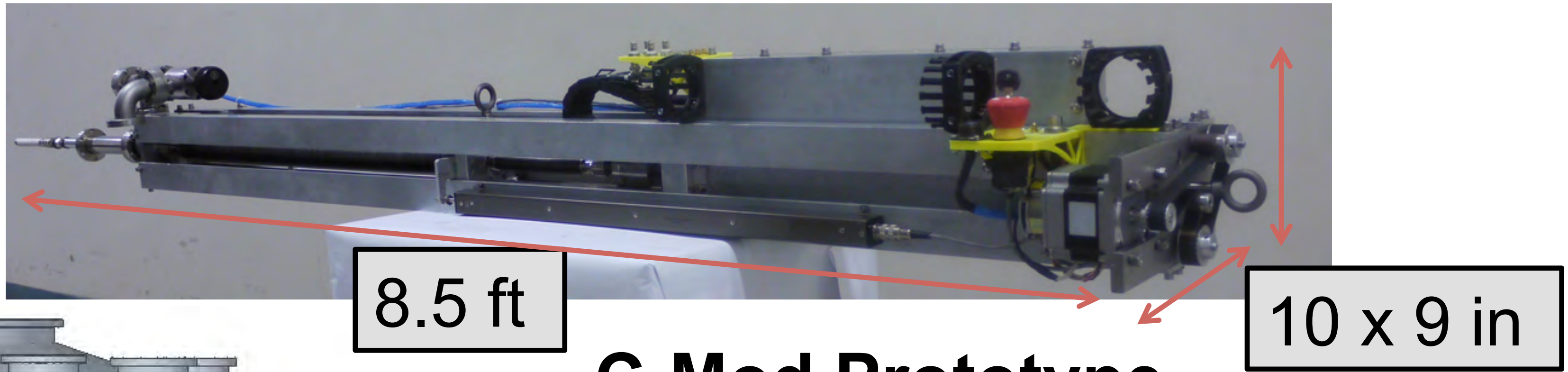
In addition to MLP, the servomotor probe drive can support a variety of specialized probe heads

Probes heads developed and used on C-Mod

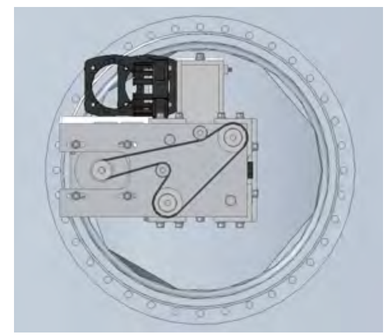


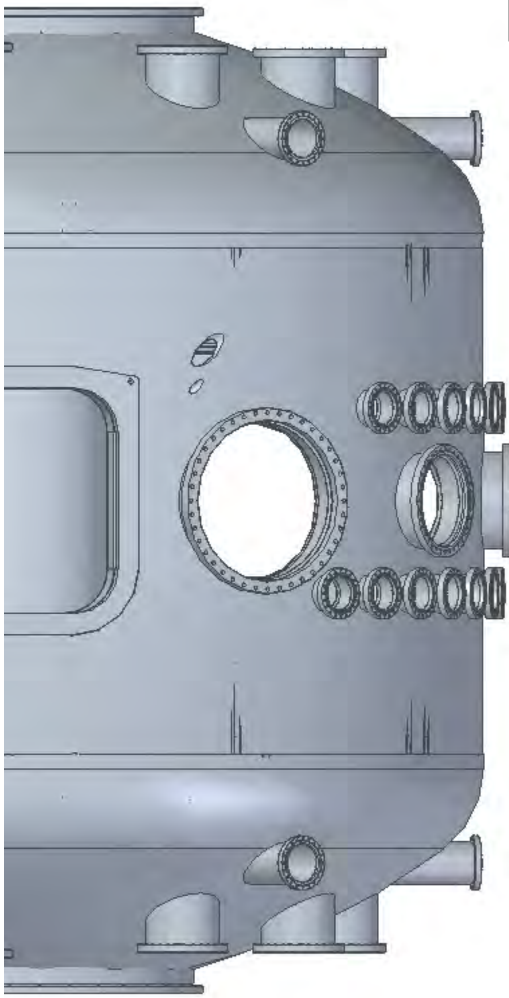
Probe drive uses 50 ohm coaxial cables up to probe head.
This enables the development of RF probe heads
– ideal for use at Bay-D, HHFW antenna location.

We are presently targeting Bay-D for the MLP



C-Mod Prototype

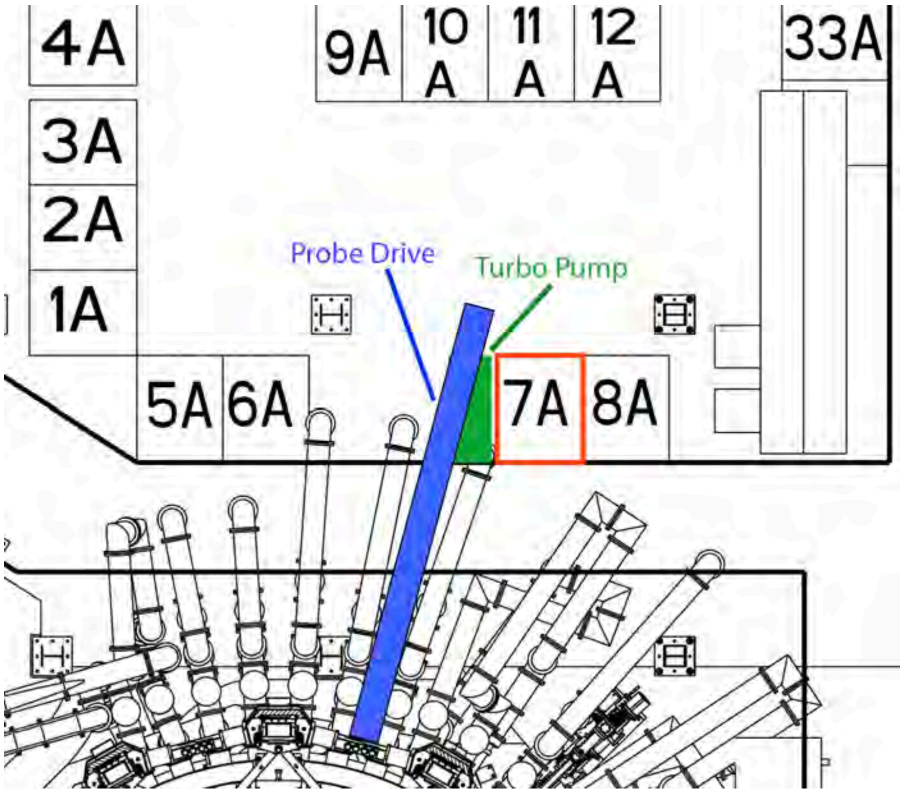




C-Mod system at Bay-D

- Can fit between HHFW coax
- Large flange can be modified to support two probes: MIT scanning probe and ORNL RF probe

Floor space and rack space for MLP system at Bay-D may be doable.



109 ft level

Area at and around rack 7A might accommodate electronics

MLP Electronics

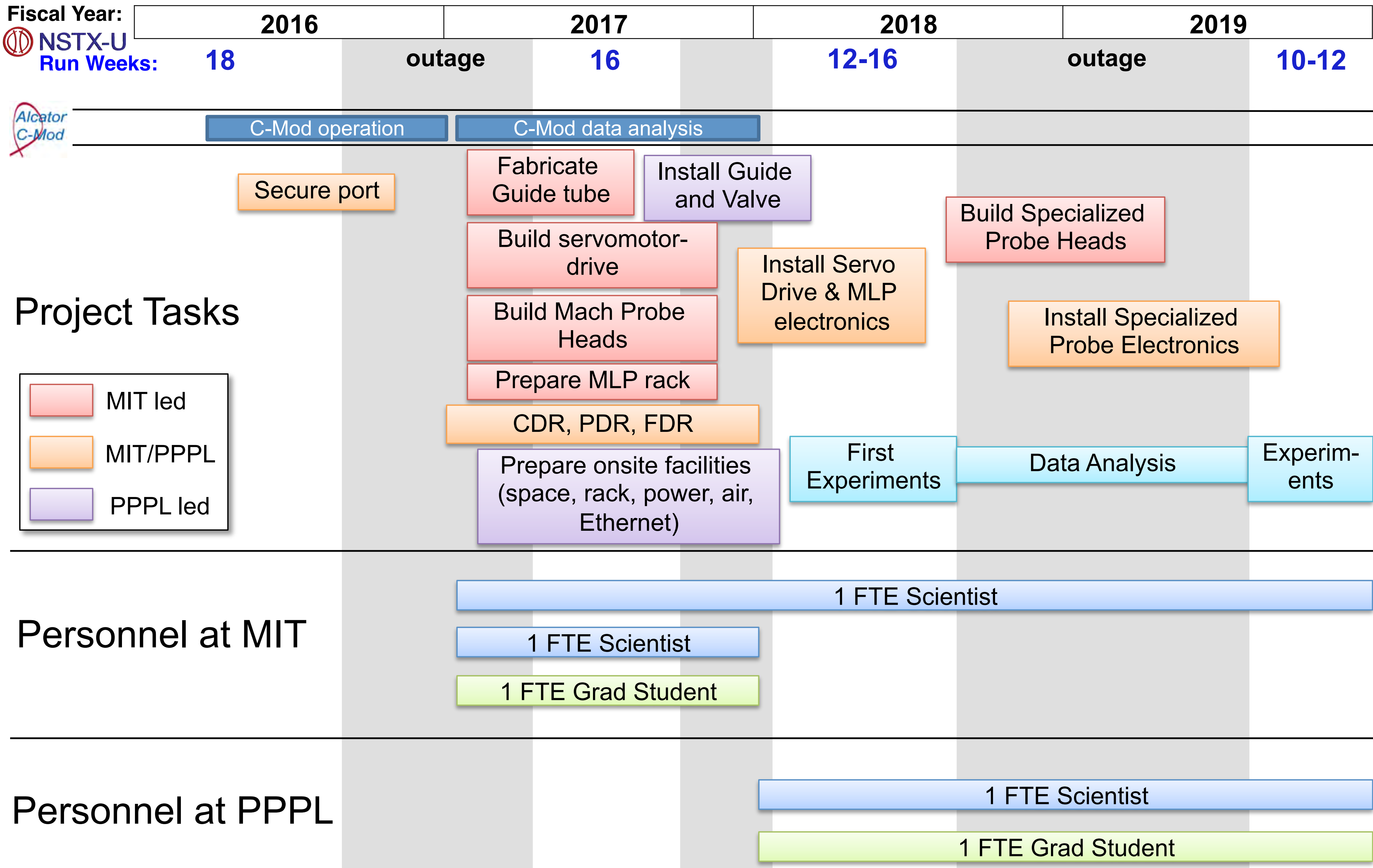
Servomotor Electronics

Rack Space Requirements:

- ½ rack space for MLP electronics
- < ½ rack space for servomotor electronics
- ½ rack space for 'advanced' bias systems and data acquisition

Change in egress pathway around scanning probe may be required.

Scanning Mirror Langmuir Probe - MLP



MIT lead scientist: Brian LaBombard **PPPL contacts:** Rajesh Maingi, Bob Kiata, Mike Jaworski, Brent Stratton, Bob Ellis

XICS on NSTX-U

Provides passive measurements of ion temperature and toroidal rotation profiles

also impurity density profiles (for impurity transport studies) and electron temperature profiles

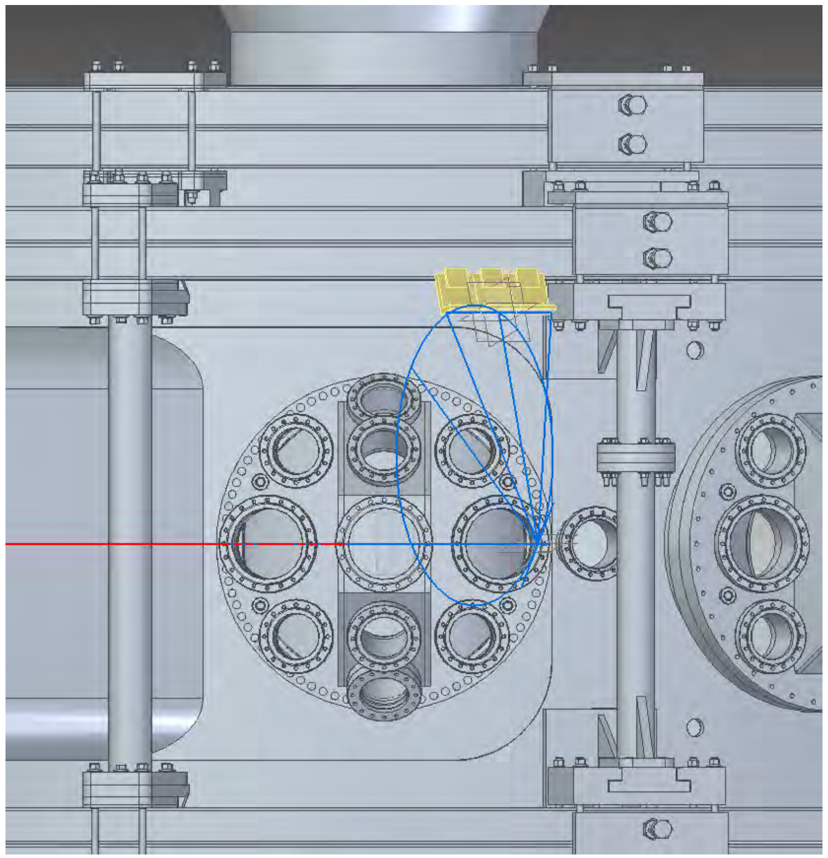
Comparison with CXRS

pros: much simpler interpretation of spectra
no background subtraction
faster time resolution
can be used to measure intrinsic or purely RF driven rotation
can be used for high z impurity transport studies

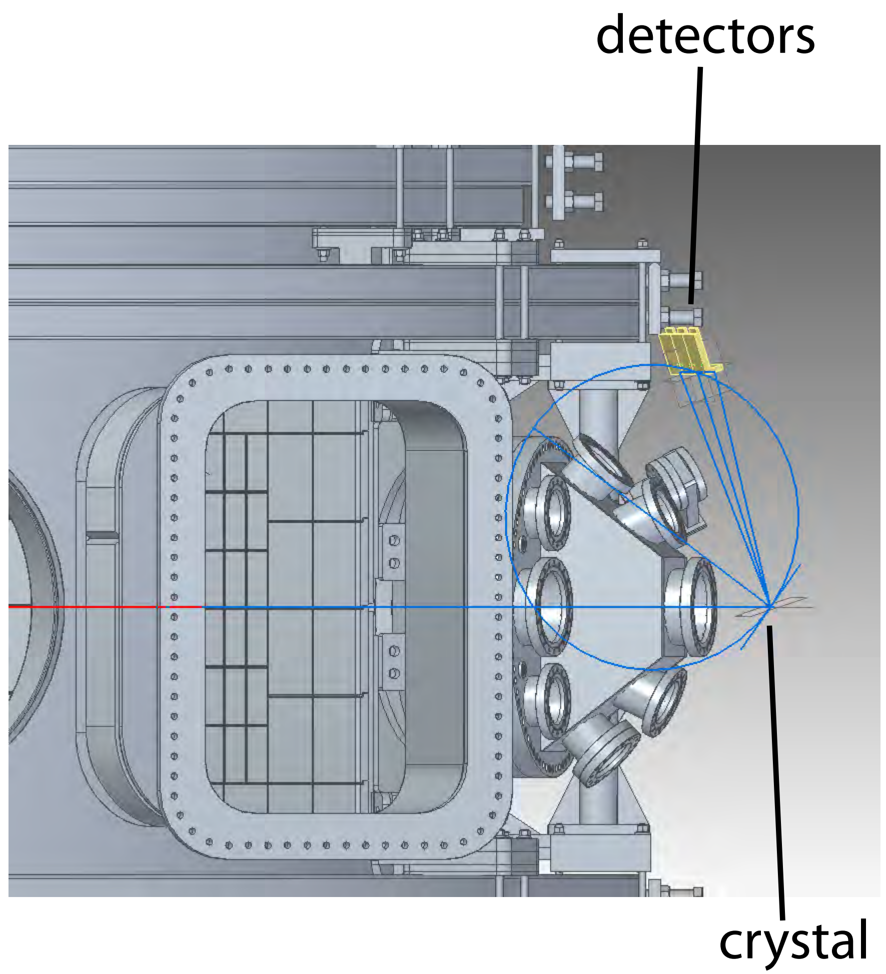
cons: requires impurity (argon) puffing
lower signal near the plasma edge
(argon can only work for electron temperatures below 4 keV)

XICS Layout on NSTX-U

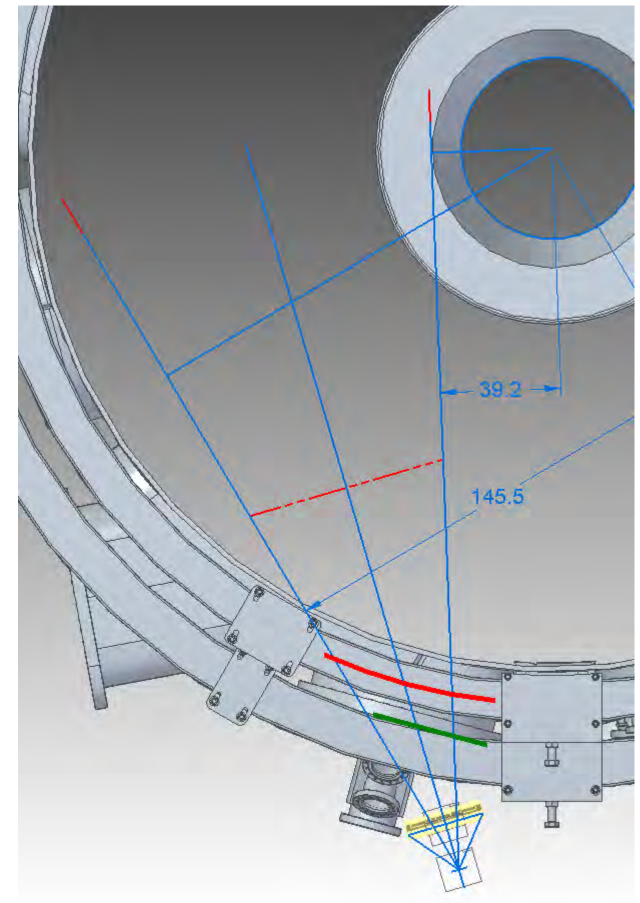
Requires swap of center port on Bay I for UCLA polarimeter port on Bay J, and modification of port flange
Will measure full toroidal cross section



radial view Bay J



side view



top view

XICS Timeline on NSTX-U

Layout ongoing with MIT engineers

PDR mid June

Need to decide on versatility:
- He-like argon only keeps system compact, less interference around port
- He-like calcium for impurity transport studies requires crystal swap and range of Bragg angles

PPPL owns detectors, order crystal(s), few month turnaround

Will determine vacuum system size, support stand

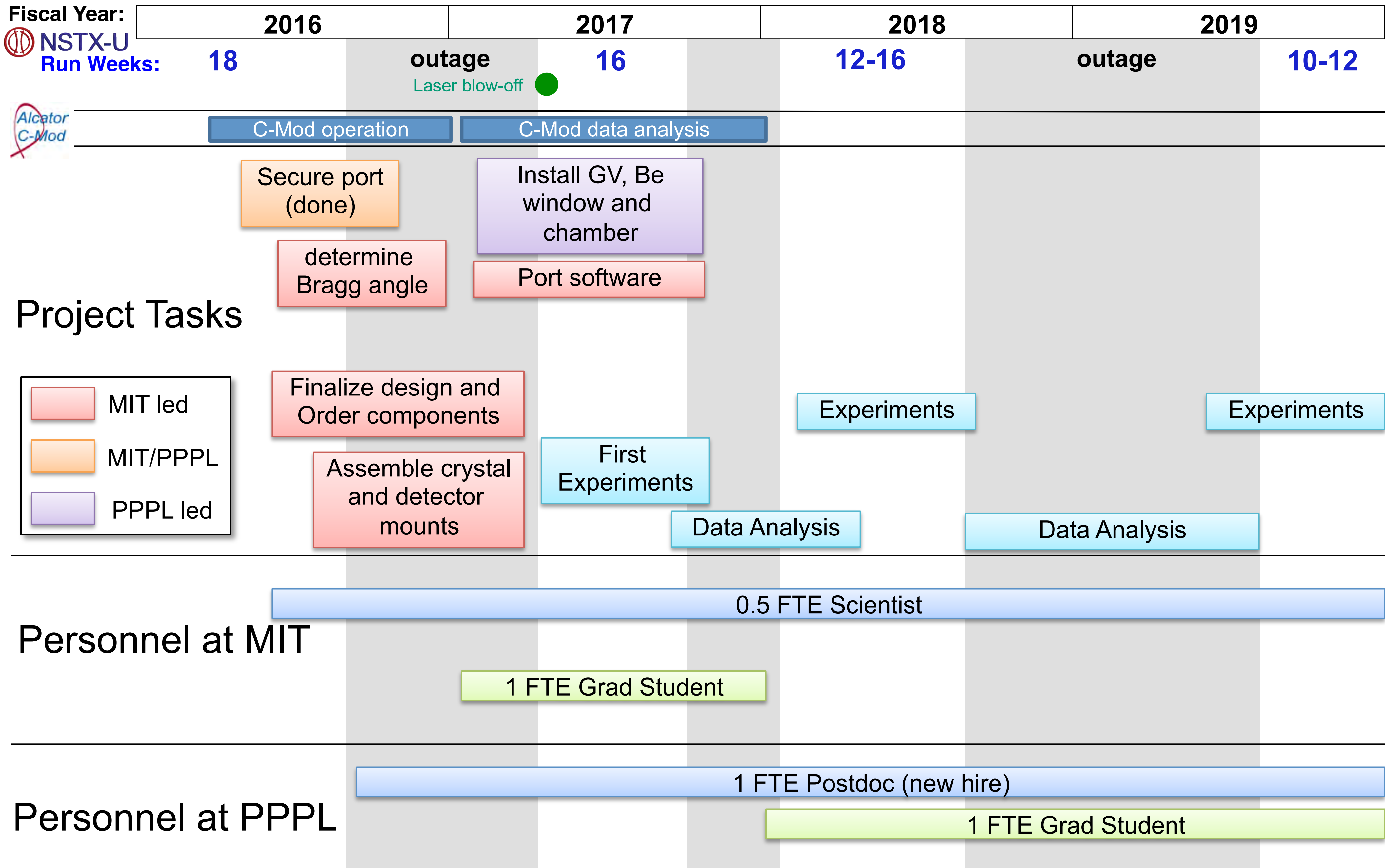
Bay J port cover will need to be modified

Analysis software for spectral inversions, tangential view

Interviewing Post Doc candidates, have grad student Norman Cao

No reason can't be ready for 2017 break

X-ray Crystal Imaging Spectrometer - XICS



MIT lead scientist: John Rice **PPPL contacts:** Manfred Bitter, Ken Hill, Brent Stratton, Luis Delgado-Aparacio

Augmented NSTX-U Gas-Puff-Imaging

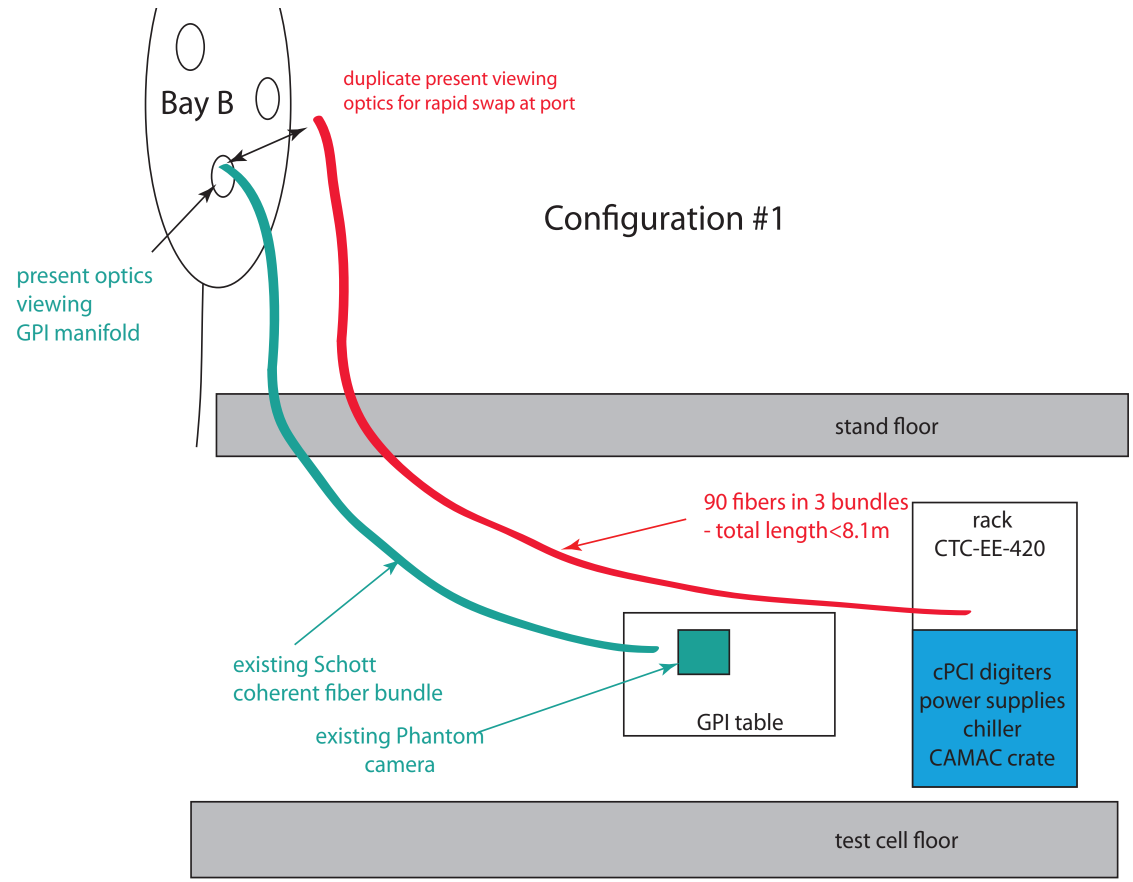
Presented by Jim Terry in collaboration with S. Zweben

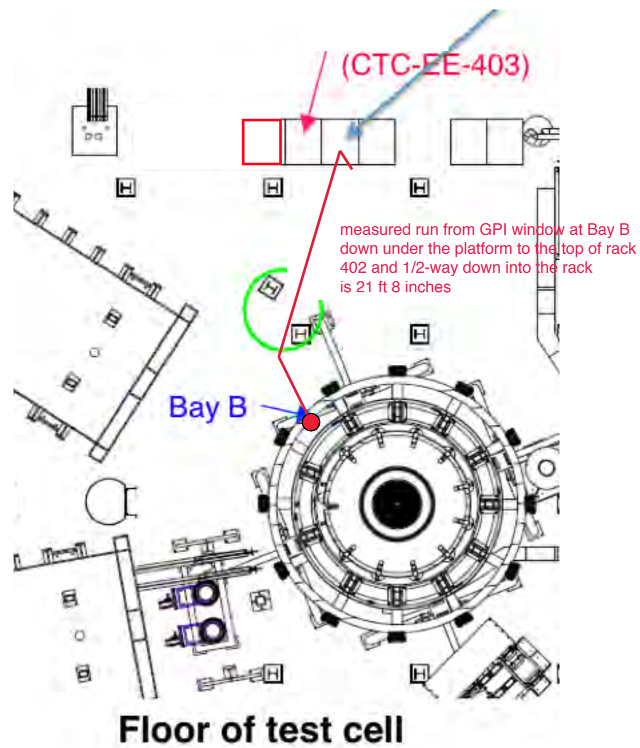
- We plan to install an APD-based GPI system to augment the existing fast-camera-based GPI on NSTX-U
- We will provide operational support for GPI in general

	APD-based detection	Camera-based using Phantom 7.10
Spatial resolution	9x10 pixels	64x80 pixels
Time resolution	$f_{Nyquist}$= 1 MHz	$f_{Nyquist}$=0.20 MHz
Sensitivity	optimal	lower signal-to-noise than APDs for same spot size
	Much more sensitive, with excellent time resolution, but poorer image quality	Excellent spatial resolution; best for visualizing the turbulent structures and their evolution

APD-based system to be integrated with present GPI on NSTX-U

Configuration 1 – Easy & rapid swapping of input optics at Bay B



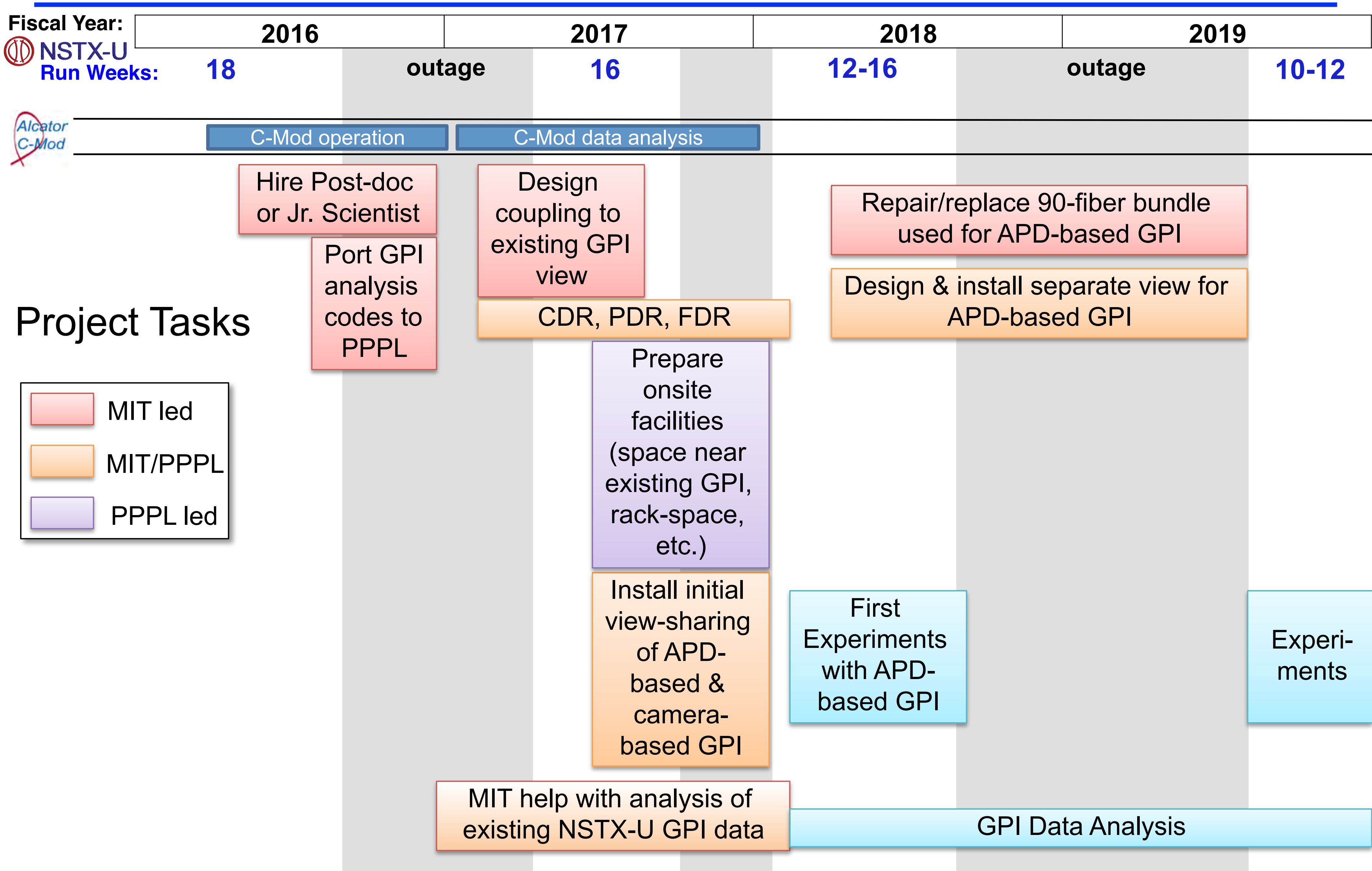


Configuration 2 – use beam-splitter on GPI table to direct image to both systems

Topics Addressed by NSTX-U GPI Systems

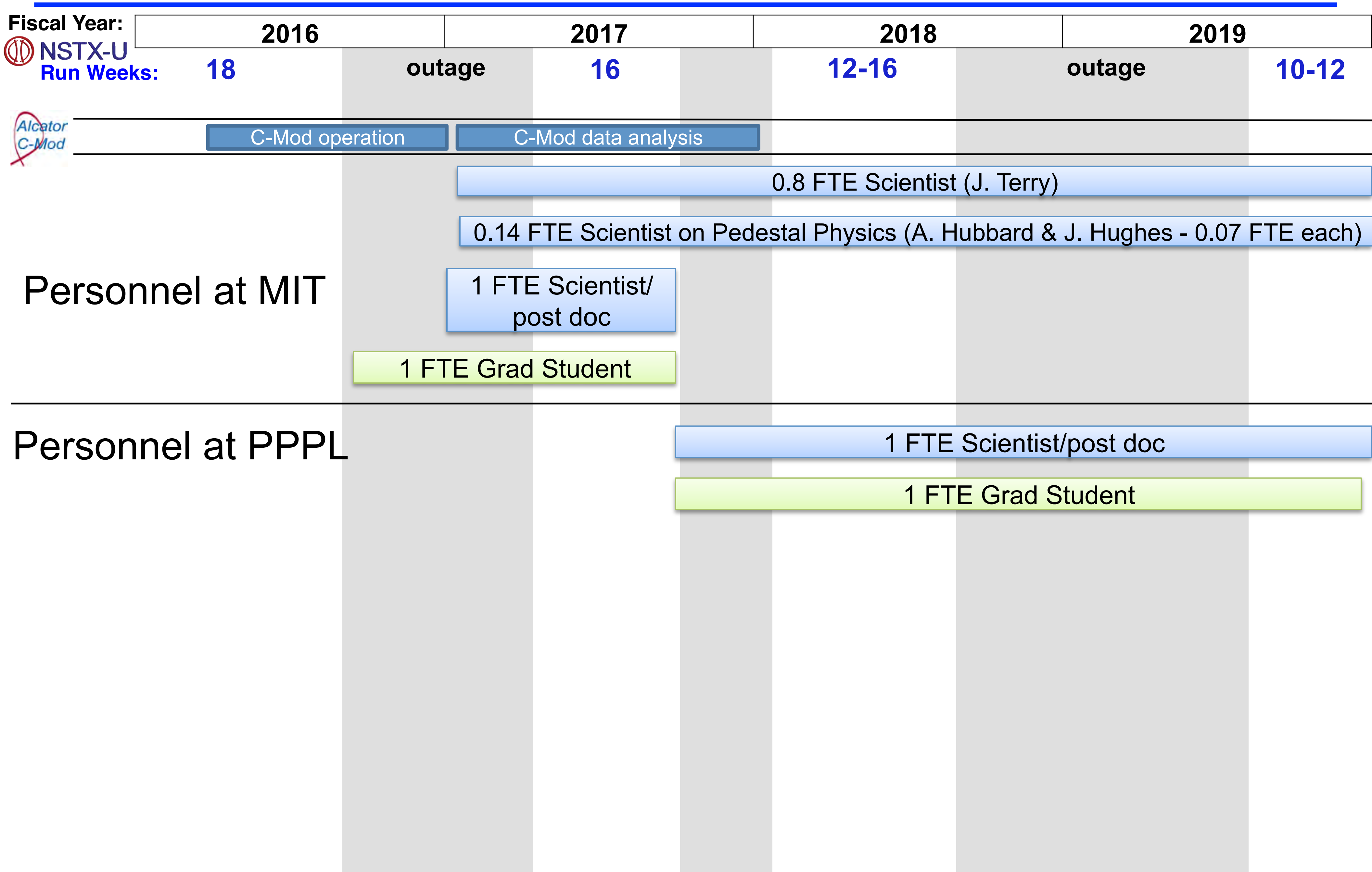
- *Physics of boundary plasma turbulence*
  - *Blob formation and motion, scaling with SOL conditions*
  - *Test of blob models for far SOL transport*
  - *Parallel Dynamics of blobs/filaments*
  - *Correlations to divertor n_e, T_e, pressure, & heat-flux profiles*
  - *Effects from application of 3-D fields*
- *Coherent boundary modes (EHO, KBM)*
  - *Mode structure identification*
  - *Externally driven modes (?)*
- *L-H transition physics*
  - *Local threshold conditions (flows, turbulence)*
  - *Role of divertor geometry, strike-point location, lithium*
  - *GAMs, zonal flows*
- *RF-SOL interaction dynamics (RF-induced flows, sheath effects)*

Enhanced Gas-Puff Imaging - GPI



MIT lead scientist: Jim Terry **PPPL contacts:** Stewart Zweben, Brent Stratton

Enhanced Gas-Puff Imaging - GPI



MIT lead scientist: Jim Terry **PPPL contacts:** Stewart Zweben, Brent Stratton

Advanced Multi-Spectral Imaging: Concept

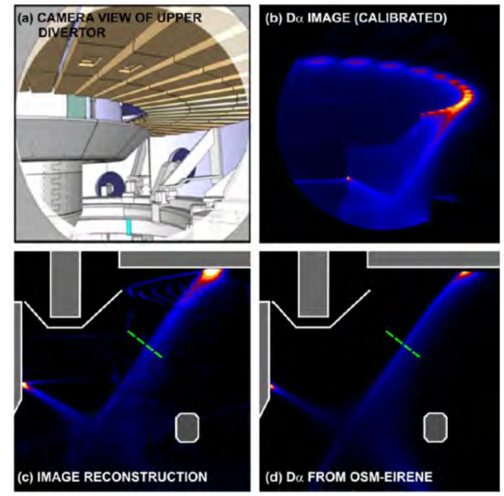
Divertor spectroscopy and filtered imaging:

- Many observable atomic lines
- Many physical processes at play, recombination, excitation, ionization, Stark broadening, …
- But each line only carries some information, not the whole picture

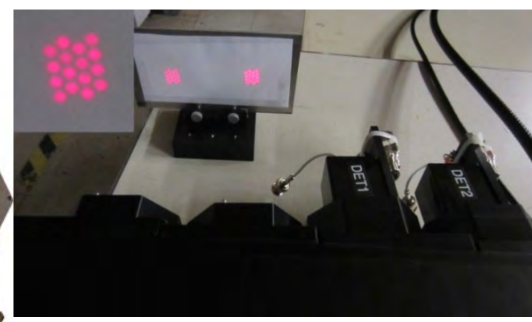
Advanced multi-spectral approach:
Image MANY atomic lines simultaneously on the same sightline to explore divertor physics using a recently developed imaging polychromator
(He, C, D, D-stark)

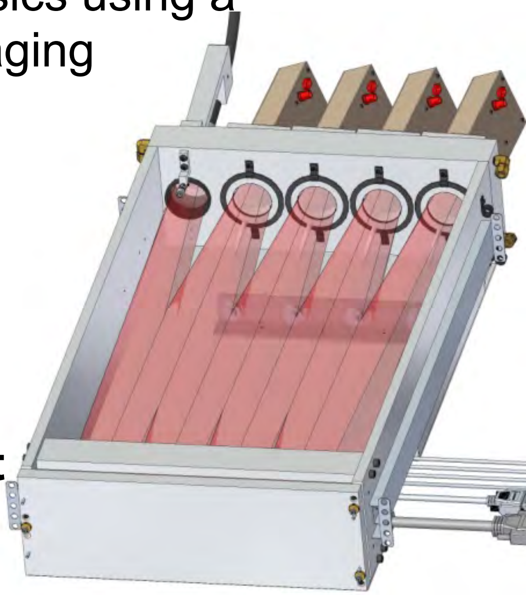
Many simultaneously imaged lines can provide a comprehensive data set to validate codes

Example: Dα imaging in MAST with inversion and comparison to OSM-EIRENE

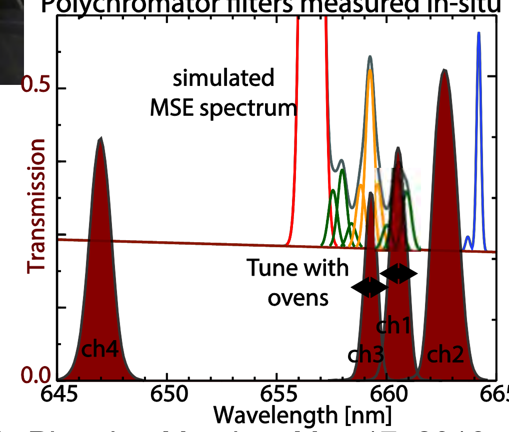


S. Lisgo et al., J. Nucl. Mater., **390–391** (2009) 1078–1080





Polychromator filters measured in-situ

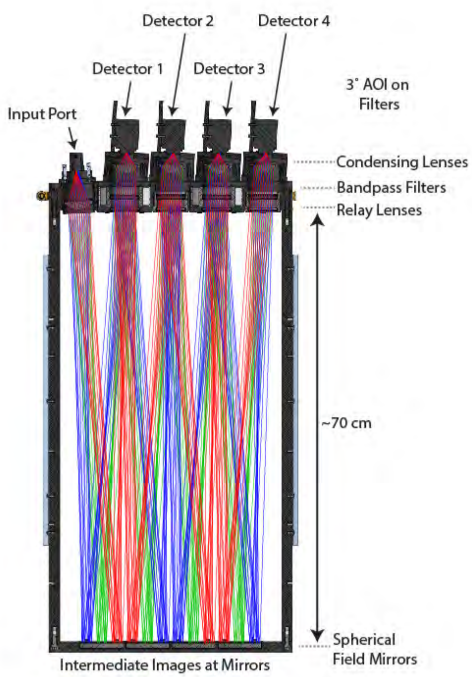


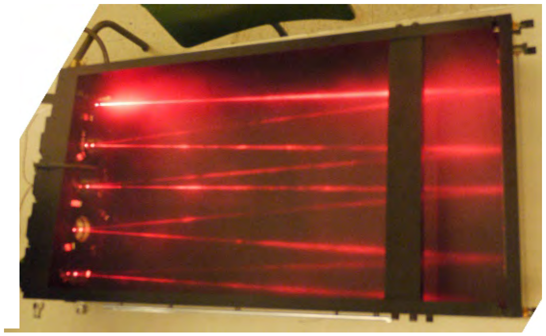
Advanced Multi-Spectral Imaging: Concept

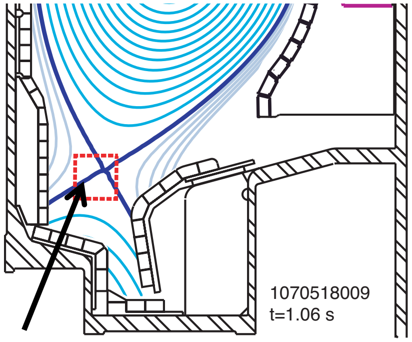
- **PPPL-Alcator collaboration developed high-throughput imaging polychromators for multi-spectral MSE—very useful**
  - 20-30x etendue of typical Thomson scattering polychromators – *optically fast*
  - New filter technologies and design– *spectral resolution of 10^{-4},full visible range*
  - Little degradation of each additional image –*many filtered images w/ same view*

- **FY16: Proof-of-principle and workflow development on C-Mod**
  - Helium line ratios and Stark broadening for n_e, T_e images
  - Balmer line ratios for recombination images
  - Mo, N, Ne lines for impurity influx and seeding

- **ORISE award to integration on NSTX-U in FY17-FY18**





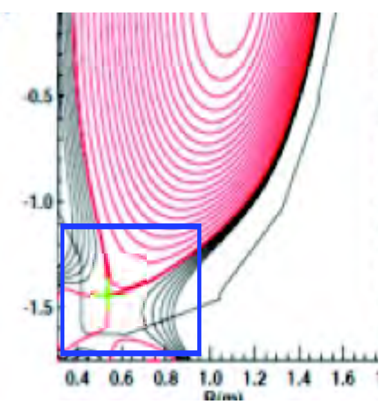


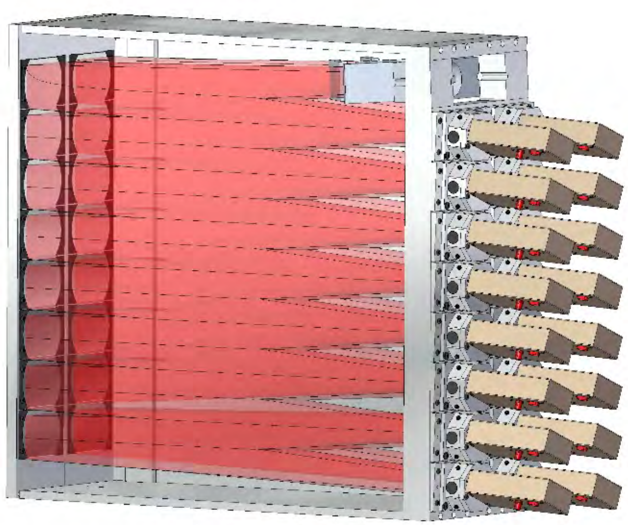
Optical design for 4 wavelength   Existing prototype hardware used for imaging the x-point through coherent fibers

Multi-spectral imaging of the NSTX-U divertor for T_e, n_e, recombination and impurities

- **Take lessons learned and workflow from C-Mod and apply technique to image divertor region on NSTX-U**
  - Take 4-wavelength system to NSTX-U, integrate into machine and group
  - Invert images or compare directly to synthetic diagnostics in simulations
  - Refined polychromator layout with 10-16 ports –*populate as funding allows*
  - Anticipate a large variety of filters available
    - Easy to swap out

Proposed view

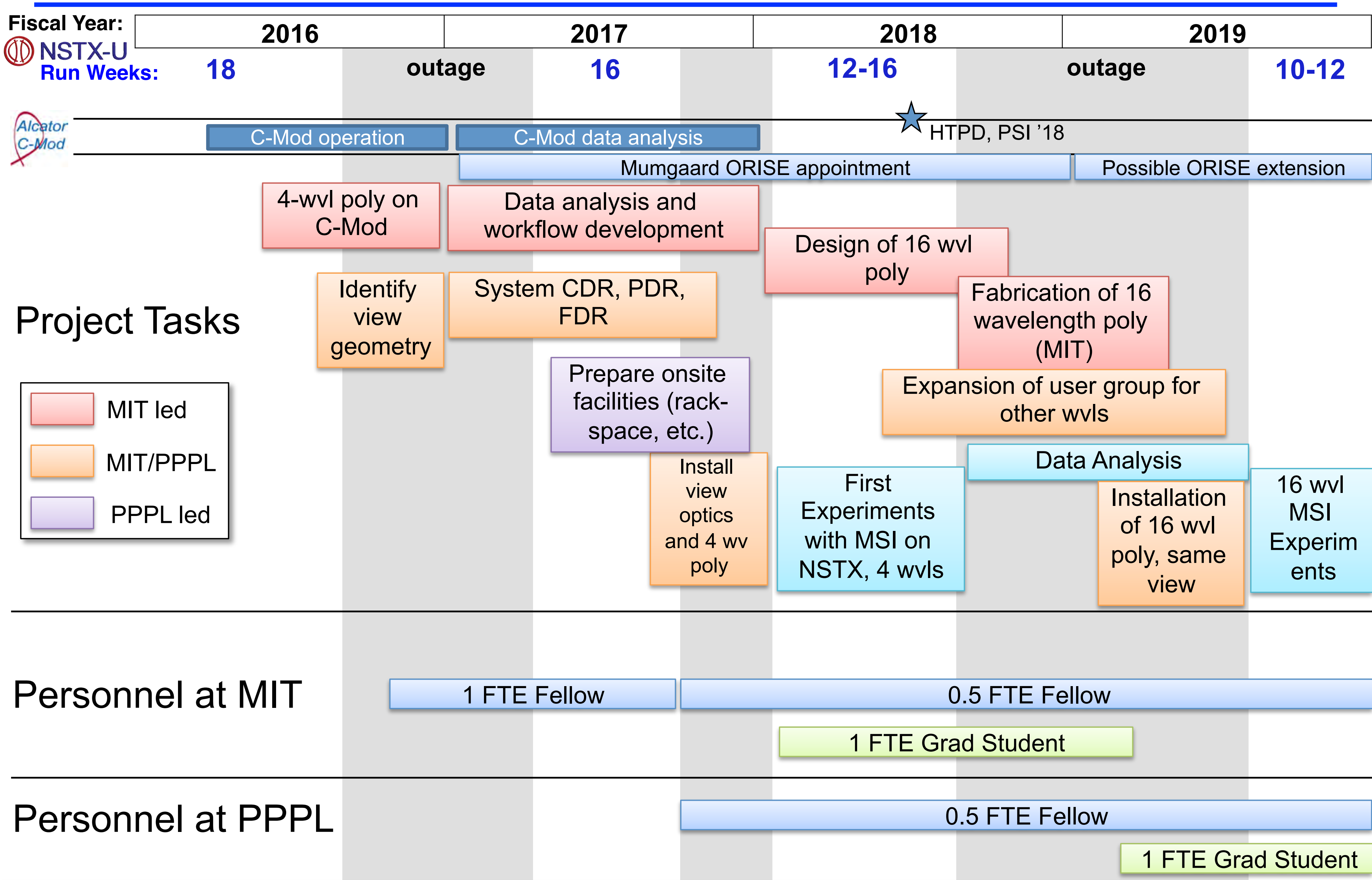




Line	Wavelength [nm]	Purpose
D Balmer	410, 434, 486, 656	Volume recombination
High n D	370-385	
C I	494, 538, 833	Impurity transport, erosion from ELMS
C II	392, 427, 514, 658, 678	
C III	407, 465, 570	
He I	389, 447, 588, 668, 707, 728	n_e, T_e images
He II	320, 468, 541	Higher temps
Continuum	-	Background subtraction
N I	746	Seeding experiments
N II	400, 463, 501, 568, 648, 661	
Ne I	640, 693, 703, 717, 724, 743	
Ne II	357, 366, 371, 373	
Dβ wide	486	Stark broadening for n_e
Dβ narrow	486	
Li I	323, 413, 460, 610, 670	Monitoring LLD and Li propagation
Li II	320, 325, 468, 478, 549	
Li III	516	
W I	361, 386, 401, 407, 429	High Z upgrade erosion
Mo I	380, 386, 390, 551, 553, 557	

- **Still evaluating possible ports/ collaborations/timeshares**

Multi-Spectral Imaging - MSI



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