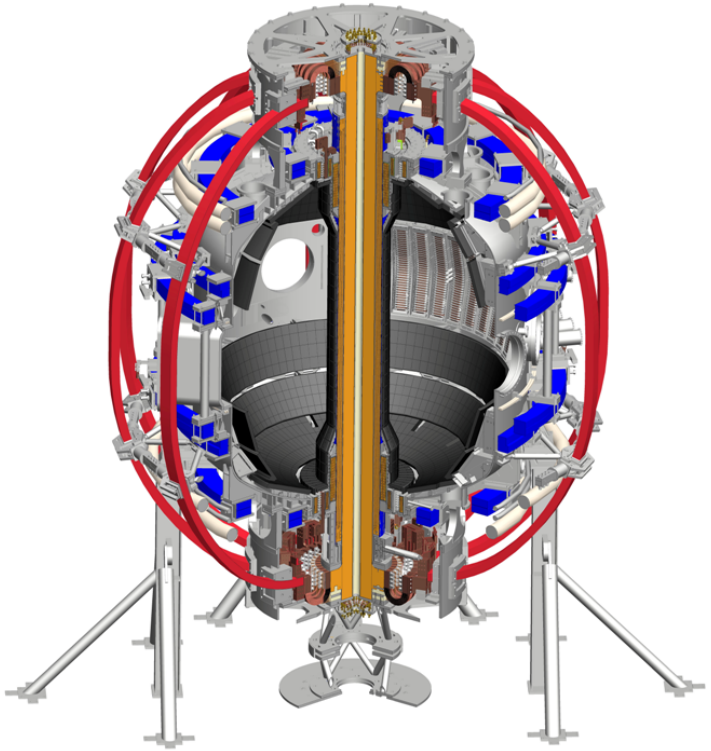
U. Wisconsin research plans for 2016-2019:

Diagnostic Development for Long-Wavelength Instability Exploration in Spherical Torus Plasmas



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R. Fonck, M. Kriete
University of Wisconsin-Madison

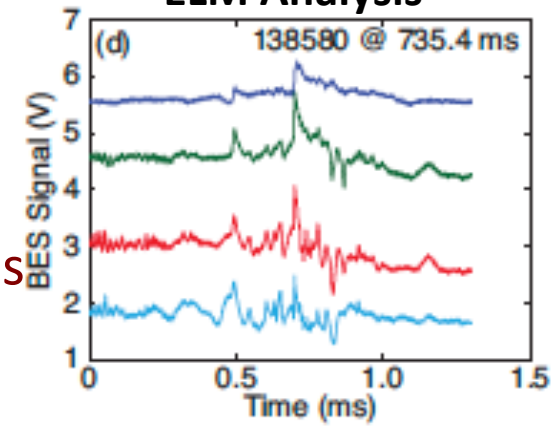
NSTX-U Collaborator Meeting
May 17, 2016

Supported under U.S. DOE Grant: DE-SC0001288

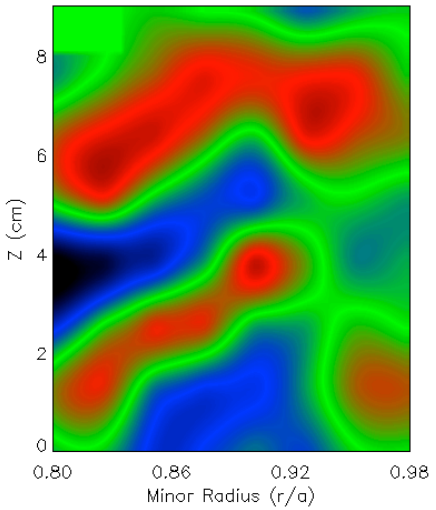
Advancing Instability Measurements on NSTX-U

- Increasing and expanding diagnostic capability
  - Edge and core 2D measurements with BES
  - 2D impurity measurements at Alfven timescales
- Physics of turbulence and transport
  - L-H transitions, pedestal/ELM dynamics, core turbulence, impurity transport
  - Comparison with and validation of simulations
- Educating graduate students
  - Outstanding research opportunities at NSTX-U
- Coordinate multiple research programs
  - NSTX-U, DIII-D, Pegasus & Diagnostic Dev. (UW)

ELM Analysis

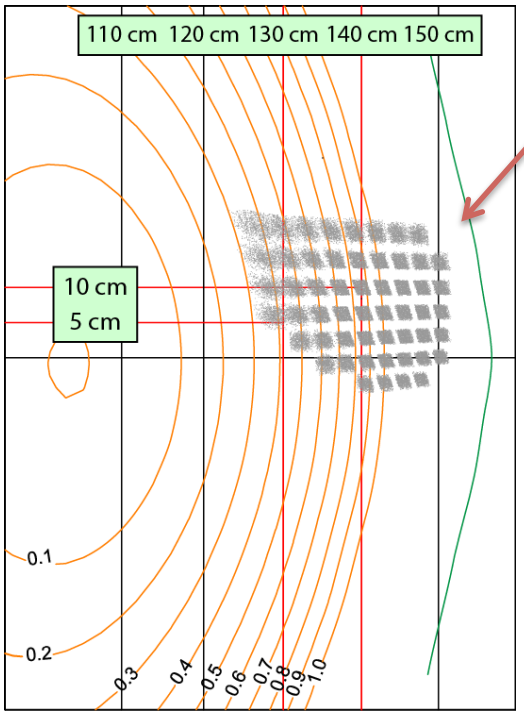


2D Turbulence



New Capability Implemented During Upgrade

Populated 2D Fiber Mount
(R140 view)

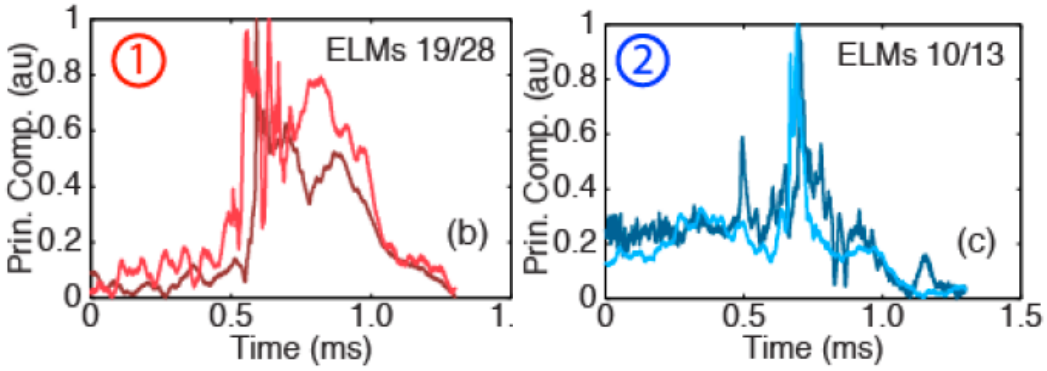


- 2D array covering outer plasma and edge regions
  - 54 sightlines in approx. 9 rad. × 7 pol. configuration
- 48 detection channels
  - 32 previous + 16 new
  - New detectors, electronics, and DAQ in operation on NSTX-U
  - 2 MHz sampling captures Alfven timescales

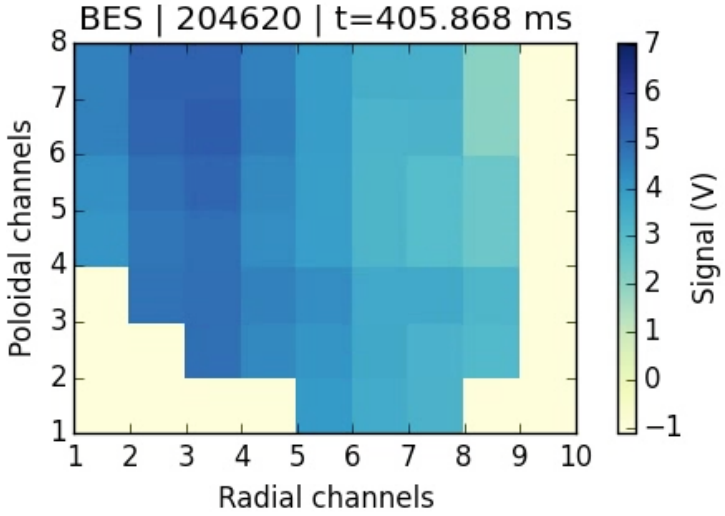
New Scientific Capabilities Under Development

- Scientific versatility with 2D measurements and analysis
  - Turbulence, ELMs, EHOs, xAE and EP modes, velocimetry/Reynolds stress, GAMs, ZMF zonal flow, L-H transition dynamics
- ELM analysis capability
  - Categorization via spatiotemporal correlation, statistical analyses
- Upcoming Presentations (D. Smith)
  - HTPD-2016 invited talk; 2016 IAEA-FEC presentation

Fast ELM Behavior for different ELM flavors



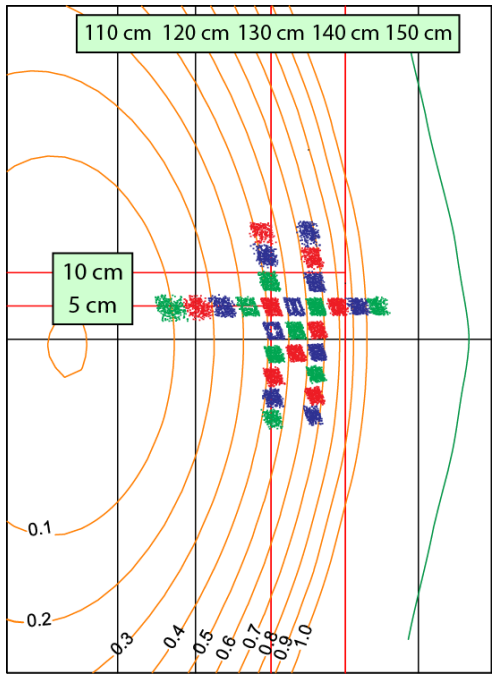
ELM Dynamics



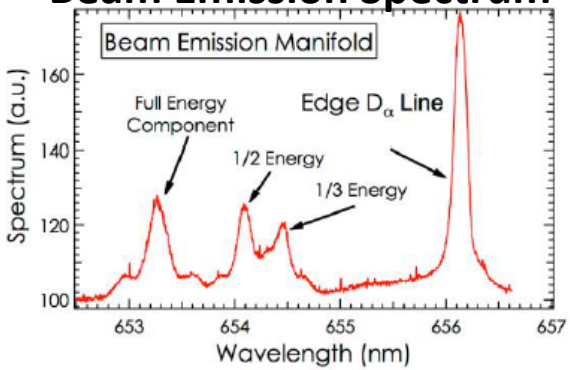
Planned Diagnostic activities

- 16-channel detector expansion (48 → 64 channels)
  - Supports all research activities
- 2D impurity measurements with BES
  - Survey spectrometer to identify CX/impurity emission lines
  - Future $\tilde{E}_\theta$ capability (UW diagnostic dev.)
- Seek to implement 2D core coverage at "R130" port
  - Requires new fiber bundles (PPPL)
- Design study for toroidally-displaced sightlines on NB2
  - n-number measurement for ELMs, xAEs, GAMs, ZMF Zonal Flow

Core "R130" View

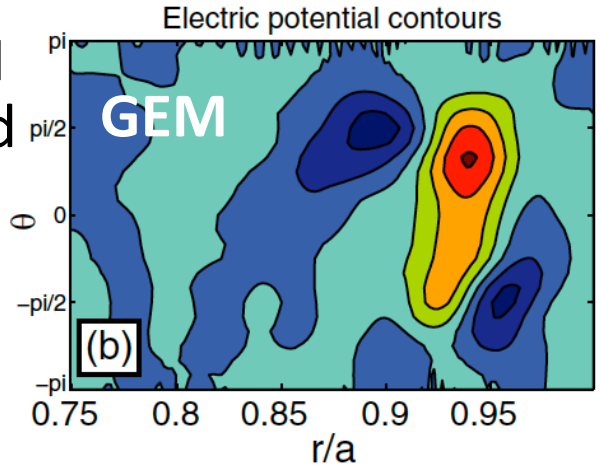


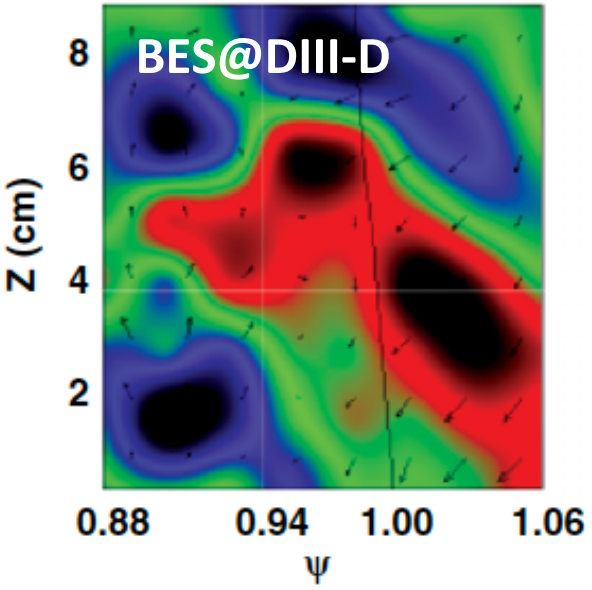
Beam Emission Spectrum



2D Turbulence & Instability Dynamics

- XP-1511: Multi-machine investigation of L-H power threshold vs aspect ratio, M. Bongard
  - Transferred (D. Smith) with hiatus of Pegasus H-mode research
  - Accomplish similar goals with turbulence emphasis
  - Turbulence velocimetry across the L-H transition
- Turbulence variation with ν^*, $\boldsymbol{\rho}^*$, ϵ
  - New NSTX-U capabilities; DIII-D collaboration
- ELMs and xAE/Energetic Particle-Driven modes
- Comparison & validation of simulation codes
  - For Example: GTS, GEM, GYRO, XGC, BOUT++
- 2D observation of RF wavefield
- Turbulence with non-axisymmetric 3D fields





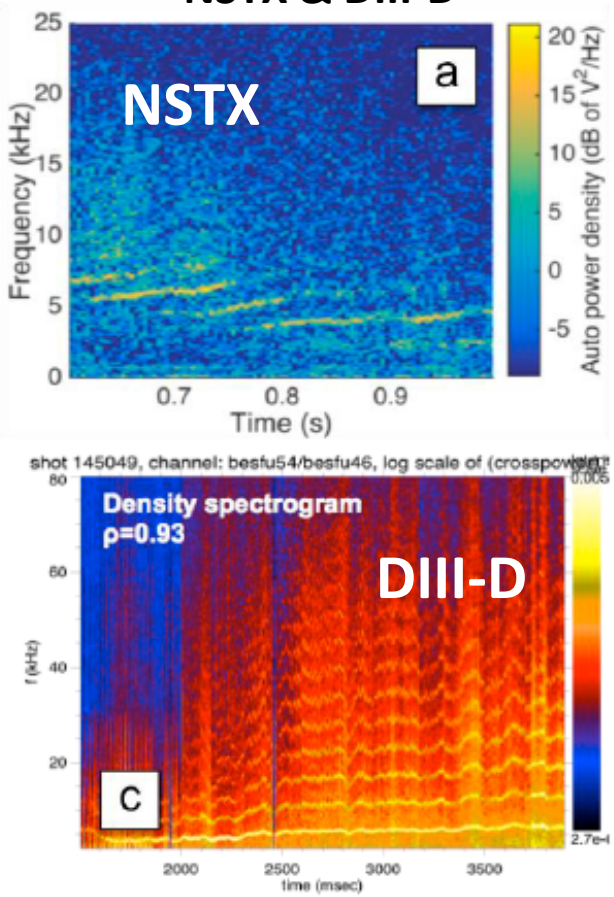
Impurity dynamics at Alfven timescales

- Implement survey spectrometer to identify candidate spectral lines
  - Impurity emission: coronal emission in sightline
  - Charge Exchange emission: localized to NB1 intersection
- Replace BES optical filters for impurity/CX measurements
  - Leverage high-throughput optics and high-speed detectors
- Development path
  - Single sightline → radial array → core/edge 2D coverage
- Aligns with NSTX-U impurity transport research plans

Integrating Campus and Large Experiment Research Activities

- UW Graduate student
  - Matt Kriete visiting PPPL (now + summer)
  - Develop potential thesis topics (summer)
- Future Post-doctoral Researcher
  - Joint with UW/DIII-D collaboration
    - 50% FTE each
  - Leverage 2D BES systems on NSTX-U & DIII-D
    - Nonlinear ELM dynamics; pedestal
  - Mentor students in on-campus and large facility research
  - Pegasus H-mode collaboration (future)
  - Diagnostic development
- Summary:
  - New diagnostic & scientific cap. at NSTX-U
  - Educational opportunities
  - Cross-machine collaborative research

Edge Harmonic Oscillation
NSTX & DIII-D



Appendix: BES measurements will support a variety of experiments

2D Multi-field Turbulence

- 2D low-k turbulence dynamics with ExB shear variations (RMP, NBI tangency)
- 2D low-k turbulence dynamics with variations in collisionality and neoclassical transport
- Flow field observations to study the impact of Reynolds stress, ZMF zonal flows, or GAM zonal flows on low-k turbulence
- Particle transport observations derived from multi-field turbulence measurements in various boundary regimes (lithium deposition, boronization, cryo-pumping)
- Particle transport observations in ELMy and ELM-free regimes
- Particle transport observations for perturbative experiments to untangle diffusive and convective pinch contributions to particle transport
- LH transition dynamics with ExB shear variations (RMP, NBI tangency)
- LH transition dynamics with triangularity/Rx variation

2D Impurity Dynamics

- Impurity flushing observations during triggered ELMs (RMP, pellet/granule injection)
- Impurity dynamics with various PFC strategies (lithium, boron, carbon, high-Z metals)
- Radiative impurity species (e.g, Helium, Nitrogen, Neon, Argon)
- Impurity accumulation in ELM-free regimes
- Impurity dynamics with EHO activity in ELM-free H-mode regimes
- Untangling impurity diffusivity and convective pinch with perturbative impurity injection (granule/pellet injection, laser blow-off, gas puffing)

2D Nonlinear ELM Dynamics

- ELM evolution on Alfven timescales with RMP application (NSTX-U, DIII-D, and Pegasus)
- ELM evolution on Alfven timescales with rotation variation from NBI (NSTX-U and DIII-D)
- ELM evolution on Alfven timescales at low-n peeling boundary (NSTX-U and Pegasus) and the high-n ballooning boundary (DIII-D)
- ELM evolution on Alfven timescales with edge collisionality variation (NSTX-U, DIII-D, and Pegasus)
- ELM evolution on Alfven timescales with pellet/granule triggering (NSTX-U and DIII-D)

Wave/particle interactions and Alfven/EP modes

- 2D RF wavefield observation
- Fast-ion/Alfven eigenfunctions with variations in NB tangency
- Fast-ion/Alfven eigenfunctions with RMP-induced rotation variation
- Eigenfunctions for stationary, chirping, and bursting modes
- Eigenfunctions with q-profile variations
- Explore CAE eigenfunctions for coupling to kinetic Alfven wave
- Explore core GAE eigenfunction for GAE-induced electron thermal transport