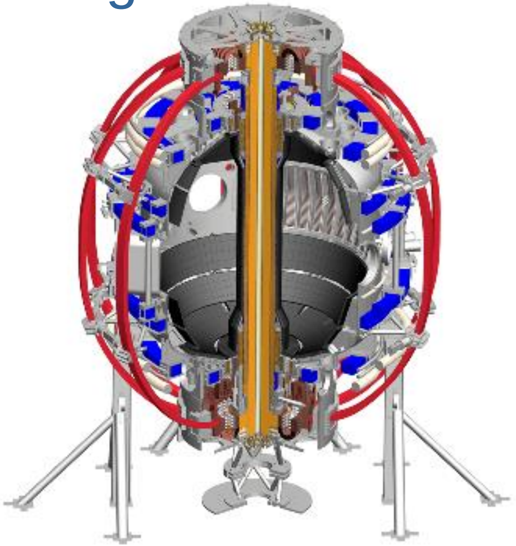
NSTX-U

NSTX-U is sponsored by the
U.S. Department of Energy Office of Science
Fusion Energy Sciences

Overview of Objective 1
NSTX-U 5 year plan (2021-25)

Extend confinement & stability physics basis at low-A and high beta to lower collisionality relevant to burning plasma regimes



Walter Guttenfelder
on behalf of the NSTX-U team

February 8, 2021

PPPL

Primary deliverables and impact of Objective 1

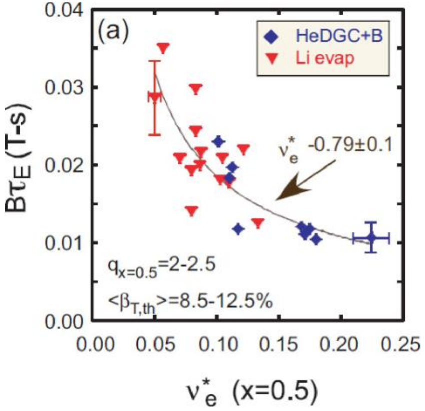
Five-year deliverables:

- Assess confinement & pedestal scaling at full capability, understand achievable limits, and project to future devices
- Assess and manipulate energetic particle (EP) distribution for high-confinement, high-f_{NI} scenarios, and project to future devices

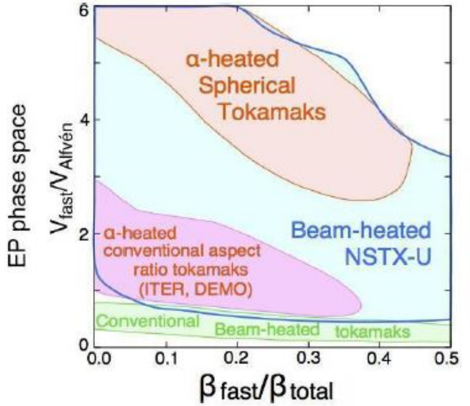
Impact:

- Enable physics-based scenario and configuration optimization of future tokamak concepts

τ_E vs. ν_* (w/ different wall conditioning)



EP phase space accessible in NSTX-U



Objective 1 is organized into 3 Thrusts

- **Thrust 1:** Characterize and understand H-mode performance at lower collisionality using increased $B_{T,}$ I_p, P_{NBI}

- **Thrust 2:** Identify transport and stability mechanisms that determine core and pedestal profiles and overall performance

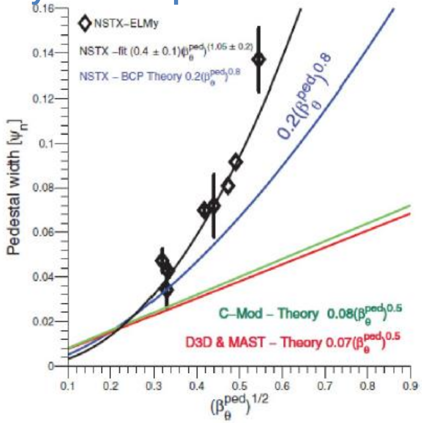
- **Thrust 3:** Develop reduced stability and transport models required to run and validate integrated predictive simulations

Thrust 1: Characterize and understand H-mode performance at lower collisionality using increased B_{T}, I_p, P_{NBI}

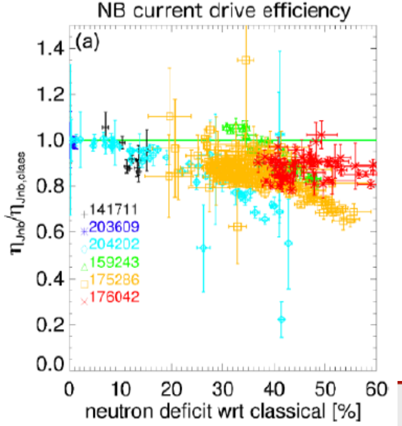
- Deliverables:
  - Measurement of τ_E & pedestal structure to lower ν_*, especially in high performance plasmas suitable for high f_{BS}
  - Measurement and understanding of fast ion dynamics and EP instabilities to validate NBI deposition, project BP α-physics
  - Optimization of integrated core-edge performance using flexible shaping, wall conditioning and NBI

- Impact:
  - Establishing thermal and EP confinement and scaling at low-A and reduced ν_* critical for optimizing aspect ratio and geometry for 100% non-inductive pilot plant concepts

ELMy H-mode pedestal width vs. β_{pol}



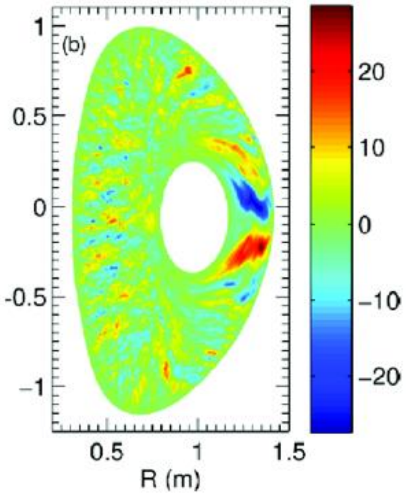
NBI CD efficiency vs. neutron deficit



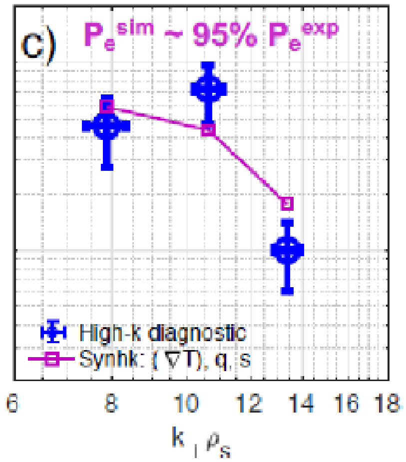
Thrust 2: Identify transport and stability mechanisms that determine core and pedestal profiles and overall performance

- Deliverables:
  - Validate core and pedestal mechanisms responsible for anomalous losses at low-A and reduced ν_*, and their collective roles in determining profiles

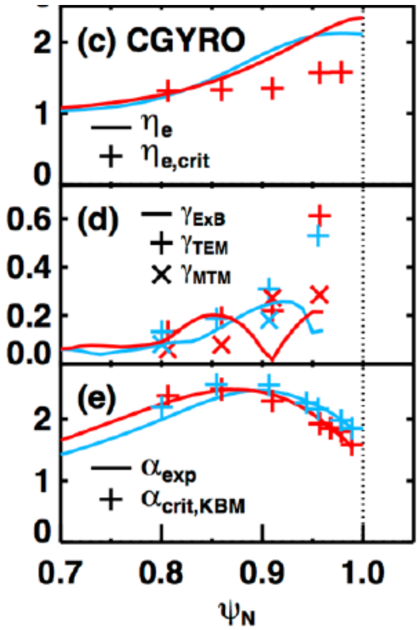
δB_r (G) from MTM simulation



Measured high-k scattering compared to ETG sim + synthetic diagnostic



Predicted GK pedestal instabilities in H/EPH modes



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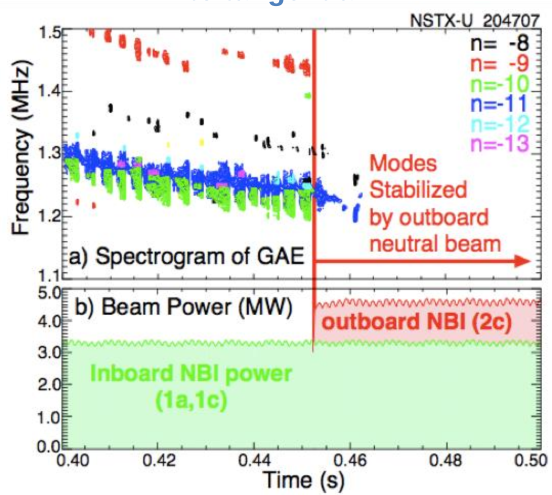
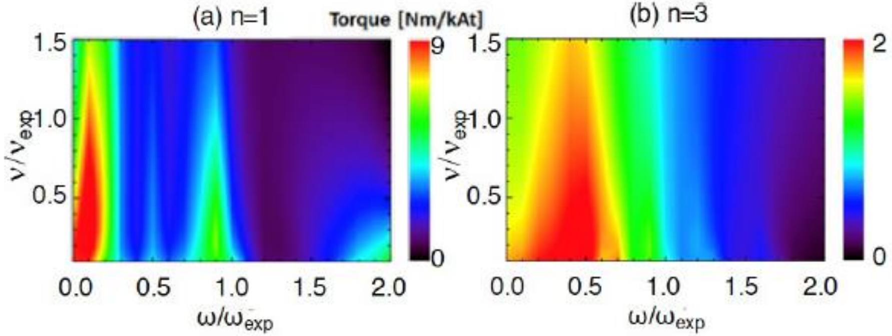
  - Demonstrate confinement optimization and EP phase-space engineering through validated understanding using flexible NBI, 3D fields, HHFW

Suppression of GAE due to tangential NBI



Predicted NTV torque vs. ν_* and rotation



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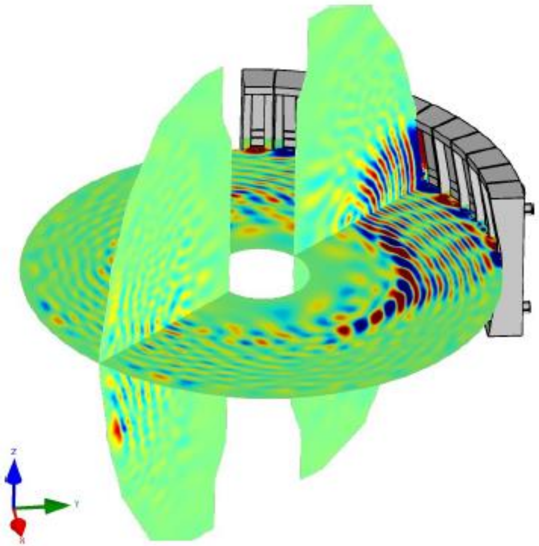
  - Demonstrate confinement optimization and EP phase-space engineering through validated understanding using flexible NBI, 3D fields, HHFW
  - Validation of HHFW coupling and SOL loss physics, optimization of HHFW coupling with NBI

- Impact:
  - A validated, self-consistent, understanding of thermal and EP transport, sources, and sinks is critical to optimize performance and enable physics-based predictions beyond 0D scalings

Predicted 3D HHFW wavefield including SOL & antenna

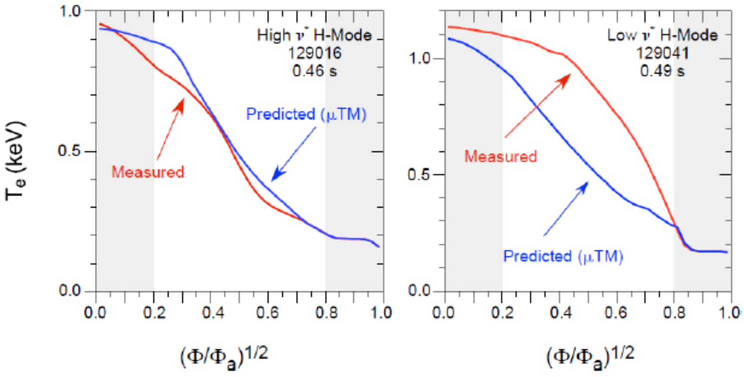


Thrust 3: Develop reduced stability and transport models required to run and validate integrated predictive simulations

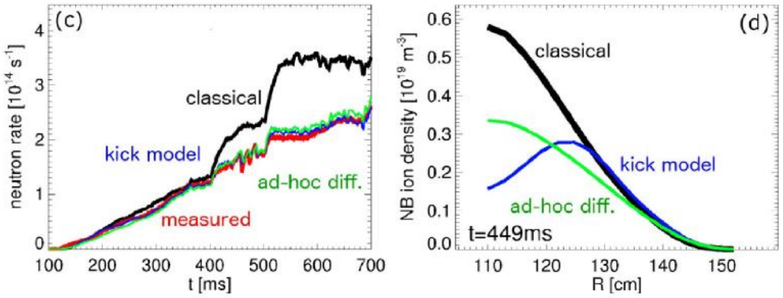
- Deliverables:
  - Reduced models for core & pedestal thermal and EP transport
  - Validation of full-discharge dynamics with increasing integration of reduced models
  - Integration of low-A reduced models with those at conventional-A to enable configuration optimization of next step devices

- Impact:
  - Integrated predictive simulations enable projection of full-discharge dynamics for current and future devices

Predicted T_e profiles using Lehigh MTM model



Predicted neutron rate and NBI ion density



Highest priority deliverables in the first run campaign

- Establish confinement and pedestal structure scaling at expanded I_p, B_T , P_{NBI} → lower ν_* (initial focus on boronization-only)
- Begin investigating the effect of lithium wall conditioning on pedestal structure and confinement
- Characterize all 6 NBI beam sources over expanded I_p, B_T, and begin addressing role of EP instabilities on NBI deposition

- Essential requirements beyond "first plasma" facility capabilities:
  - Streamlined workflow and support to enable robust, routine equilibrium, transport and EP analysis

Many validation and model development activities can be addressed immediately in the near-term (pre-ops)

- Spans many topical areas (transport, pedestal structure, energetic particles, 3D fields, RF heating)
- E.g. current FY21 Research Milestones (will soon be formulating FY22 Milestones)
  - R(21-1): ST pedestal transport modeling using gyrokinetics
  - R(21-3): Optimization of NBI mix for AE-mitigated scenarios
  - R(21-4): ST pedestal stability modeling and determination of stability thresholds associated with ELMs
- Plenty of existing NSTX data to utilize, aim to make projections for NSTX-U
- Will soon begin regular Science Group meetings to coordinate immediate, ongoing research & preparations for NSTX-U operations

Summary: Research in Objective 1 will advance physics basis to predict and optimize performance of NSTX-U and future fusion devices

- Advance understanding of thermal and fast-ion confinement at low-A and reduced collisionality needed to project high-gain, high-f_{BS} pilot plant scenarios

- Exploit new NSTX-U capabilities to validate key physical mechanisms, clarify the role of low-A on performance

- Integrate with physics basis at conventional-A to enable prediction, optimization of future concepts