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Chapter 6: NSTX-U Energetic Particles research goals and plans for FY14-18

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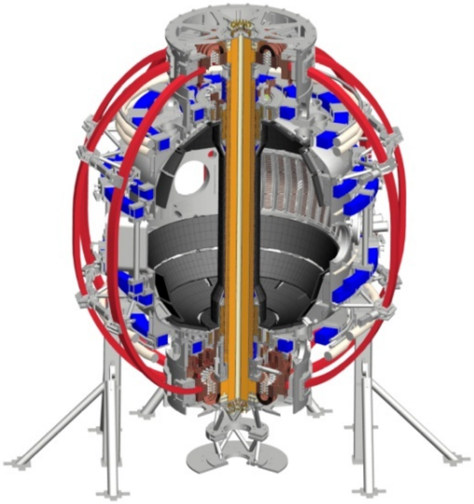

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- Overview of Research Goals & Plans

- Timeline for Tool Development

- Research Plans / Chapter outline

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EP research goals: enable projections to FNSF & ITER, assess "phase-space engineering" techniques

NSTX-U Energetic Particles Research Thrusts:

- Enable projections of *AE-induced fast ion transport to FNSF and ITER
- Assess requirements for fast-ion phase-space engineering techniques through selective excitation/ suppression of *AE modes

Required research:

- Investigate *AE dynamics and associated fast ion transport mechanisms
- Compare experimental results with predictions from theory & numerical codes
- Develop physics-based models for *AE-induced fast ion transport, e.g. stochastic transport models, quasi-linear models
- Assess modifications of *AE dynamics using NB, HHFW and active *AE antenna as actuators

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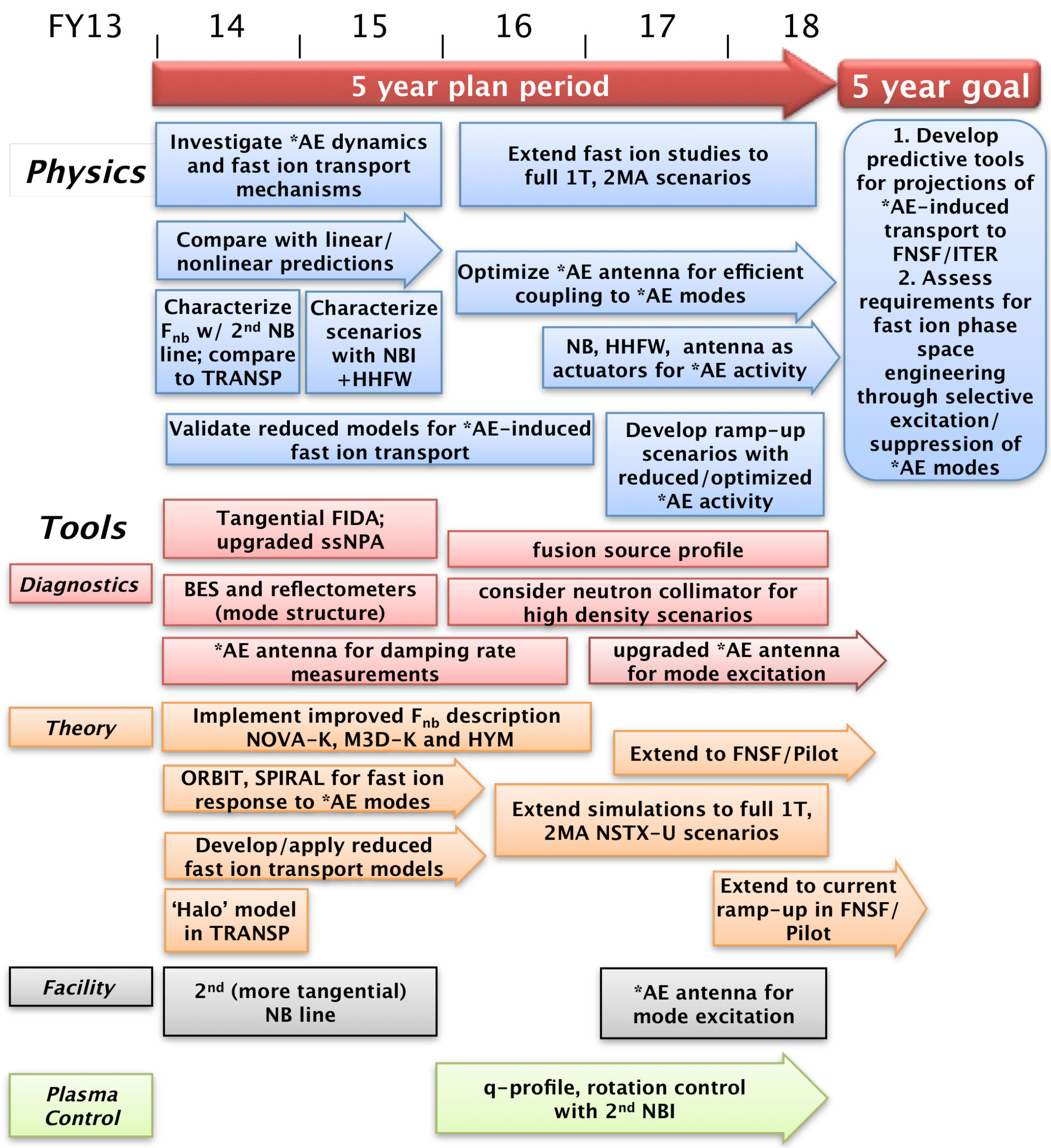
Energetic Particles Research Timeline



Theory and simulations capabilities

- ORBIT : Stochastic transport by TAEs **[Podestà,** White]
- SPIRAL : F_{nb} response to *AEs and low-f modes; compare w/ ORBIT **[Kramer]**
- NOVA, PEST : ideal mode eigenfunctions and linear stability **[Gorelenkov]**
- HYM : Excitation of GAE/CAE; detailed comparison with experiments; study electron thermal transport by high-f *AEs **[Belova,** Kramer?, Crocker, Fredrickson, Medley, Gorelenkov]
- M3D-K : Full mode dynamics and fast ion transport; adding improved model for F_{nb} from NUBEAM/TRANSP **[Fu]**

- Quasi-linear models : F_{nb} response to given set of modes; testing on DIII-D, then NSTX-U **[Gorelenkov]**
- Reduced models in NUBEAM/TRANSP **[Podestà,** White]
  - Fnb response to given set of modes; testing with NSTX data, then explore possibility of using the model in 'predictive' mode with *AEs from NOVA-K
- FIDASIM + Fnb evolving codes (long term: NUBEAM) : Infer Fnb from set of data (FIDA, NPA, neutrons, …) **[Heidbrink]**

Diagnostics

Diagnostics under development during NSTX-U Outage period:

- Tangential FIDA – complement existing "poloidal" systems
- Fusion source profile via charged D-D fusion products – test on MAST in FY13 **[Darrow]**
- Fixed sightline E//B NPA – must be re-located **[Medley]**
- Upgraded ssNPA **[Liu, Heidbrink]**
- Radial polarimetry, currently testing on DIII-D **[Crocker]**
- *AE antenna for stability measurements, excitation of *AE mdoes **[Fredrickson]**

New/upgraded diagnostics : **[Podestà** with input from diagnosticians]

- BES expansion & increased resolution
- Neutron collimator
- Profile reflectometry with increased frequency range
- FIDA & BES Imaging
- Toroidally-displaced in-vessel multi-energy DXR arrays; dual-energy, ultra-fast SXR arrays
- VB imaging of *AE modes
- BES passive FIDA view

Other facility capabilities including plasma control

- 2^{nd} more tangential NBI to modify fast-ion distribution function
- q-profile and rotation (v_ϕ) control
- HHFW to affect fast ions (velocity space), *AE stability

- *AE antenna to study stability of (possibly drive) high-f CAE/GAEs, TAE
  - Goal: direct measurements of damping rate of stable *AE modes
    - Target high-f modes : unique capabilities on NSTX-U for CAE/GAE studies
    - Complement JET, MAST data for TAEs
  - With upgrades, assess requirements for "phase space engineering" – e.g.: assess capability of driving modes, compare to other actuators such as NBI, HHFW

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Research plans for Year 1-2

- Compare (classical) TRANSP predictions with FIDA for 2nd NB line
- Measure fast-ion transport with tangential FIDA
- Measure *AE eigenfunctions with BES and reflectometers **[Crocker]**
  - Compare eigenfunctions to predictions performed in FY12-14
- Test prototype *AE antenna **[Fredrickson]**

- Characterize *AE activity driven by more tangential 2nd NBI
  - Compare to existing (more perpendicular) NBI
- Use tangential+perpendicular FIDA, NPA/ssNPA to characterize distribution function modifications induced by *AE modes
  - Improve NPA analysis tools in TRANSP to include 'halo' density
- Extend simulations to operations with full 1T magnetic field
- Compare measured *AE damping rates with models & theory **[Fredrickson]**
- Characterize scenarios with combined NBI+HHFW (with Wave Heating and CD group) **[Taylor,** Podestà, Heidbrink]

Research plans for Year 3-5

- Extend study of *AE activity driven by different NBI configurations to full 1T scenarios
  - Extend to non-linear physics and multi-mode physics (coupling between different classes of MHD modes: TAE+kinks, CAE/GAE+TAE, CAE/GAE+kinks)
- Compare numerical and theoretical simulations to data on mode dynamics, mode-induced fast ion transport

- Optimize *AE antenna design for efficient coupling to *AE modes **[Fredrickson]**
- Consider replacing 2 HHFW antenna straps with optimized *AE antenna (with Heating and CD group) **[Taylor,** Fredrickson, Podestà**]**

- Extend simulations of *AE-induced fast ion transport to FNSF/ Pilot

Research plans for Year 3-5 /cont

- Utilize *AE predictive capability to optimize/minimize *AE activity during non-inductive current ramp-up with 2nd NBI
  - Compare simulations to experimental results
- Assess performance of upgraded *AE antenna **[Fredrickson]**
- Measure stability of high-f *AEs; assess capability of mode excitation **[Fredrickson]**
- Assess requirements for "fast-ion phase-space engineering" techniques through selective excitation of *AE modes **[Podestà,** Gorelenkov, Fredrickson]
  - Actuators: NBs, HHFW, active *AE antenna, profile control (q, v_ϕ)
- Extend simulations of *AE-induced fast ion transport to FNSF/Pilot current ramp-up phase
- Assess implications for FNSF/Pilot design (eg: optimum NBI geometry), expected NB-CD