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		2. Assess requirements for fast-ion phase-space engineering techniques through selective excitation/suppression of \*AE modes
			1. Investigate \*AE dynamics and associated fast ion transport mechanisms
				1. Compare experimental results with theory & numerical codes
			2. Develop physics-based models for \*AE-induced fast ion transport, e.g.:
				1. Stochastic transport models
				2. Quasi-linear models
			3. Assess modifications of \*AE dynamics using NB, HHFW and active \*AE antenna as actuators
	2. Research Plans
		1. **Year 1:**
			1. Compare (classical) TRANSP predictions with FIDA for 2nd NB line
			2. Measure fast-ion transport with tangential FIDA
			3. Measure \*AE eigenfunctions with BES and reflectometers **[Crocker]**
			4. Compare eigenfunctions to predictions performed in FY12-14 **[Crocker]**
			5. Test prototype \*AE antenna **[Fredrickson]**
		2. **Year 2:**
			1. Characterize \*AE activity driven by more tangential 2nd NBI
			2. Compare to existing (more perpendicular) NBI
			3. Use tangential+perpendicular FIDA, NPA/ssNPA to characterize distribution function modifications induced by \*AE modes
			4. Improve NPA analysis tools in TRANSP to include ‘halo’ density
			5. Extend simulations to operations with full 1T magnetic field
			6. Compare measured \*AE damping rates with models & theory **[Fredrickson]**
			7. Characterize scenarios with combined NBI+HHFW (see Wave Heating and CD plans, Sec. 6.2.1.1) **[Taylor, Podestà, Heidbrink]**
		3. **Year 3:**
			1. Extend study of \*AE activity driven by different NBI configurations to full 1T, 2MA scenarios
				1. Extend to non-linear physics and multi-mode physics (coupling between different classes of MHD modes: TAE+kinks, CAE/GAE+TAE, CAE/GAE+kinks)
			2. Compare numerical and theoretical simulations to data on mode dynamics, mode-induced fast ion transport
			3. Optimize \*AE antenna design for efficient coupling to \*AE modes **[Fredrickson]**
			4. Consider replacing 2 HHFW antenna straps with optimized \*AE antenna (with Heating and CD group) **[Taylor, Fredrickson, Podestà]**
			5. Extend simulations of \*AE-induced fast ion transport to FNSF/Pilot
		4. **Year 4:**
			1. Utilize \*AE predictive capability to optimize/minimize \*AE activity during non-inductive current ramp-up with 2nd NBI
			2. Compare simulations to experimental results
			3. Assess performance of upgraded \*AE antenna **[Fredrickson]**
			4. Measure stability of high-*f* \*AEs; assess capability of mode excitation **[Fredrickson]**
		5. **Year 5:**
			1. Assess requirements for "fast-ion phase-space engineering" techniques through selective excitation of \*AE modes **[Podestà, Gorelenkov, Fredrickson]**
			2. Actuators: NBs, HHFW, active \*AE antenna
			3. Extend simulations of \*AE-induced fast ion transport to FNSF/Pilot current ramp-up phase
			4. Assess implications for FNSF/Pilot design (eg: optimum NBI geometry), expected NB-CD
	3. Summary timeline for tool development to achieve research goals
		1. Theory and simulation capabilities
			1. ORBIT - gyro-center particle following **[Podestà, White]**
				1. Stochastic transport by TAEs
			2. SPIRAL - full-orbit particle following **[Kramer]**
				1. Fnb response to kinks, CAE/GAE, TAE modes
				2. Compare with gyro-center simulations w/ ORBIT
			3. NOVA, PEST – ideal MHD **[Gorelenkov]**
				1. (Ideal) mode eigenfunctions
				2. Linear stability/damping rates
			4. HYM – non-linear, hybrid/MHD **[Belova]**
				1. Research goals:

Study excitation of GAE and CAE modes, and their effects on particle confinement **[Belova]**

Detailed comparison with experimental results **[Kramer, Fredrickson, Crocker, Medley]**

* + - * 1. Plans:

Study the effects of the sub-cyclotron modes on fast ion distribution function in NSTX/NSTX-U **[Belova]**

Study the effects of finite frequency (Hall term) on the stability properties of the NBI-driven sub-cyclotron frequency modes **[Belova]**

Effects of GAE modes on the electron transport **[Gorelenkov, Belova]**

Add sources and sinks in the HYM numerical model **[Belova]**

Perform long time scale nonlinear numerical simulations to study the nonlinear evolution of unstable modes **[Belova]**

* + - 1. M3D-K – non-linear, self-consistent **[Fu]**
				1. Add realistic model of Fnb (from NUBEAM/TRANSP)
				2. Full mode dynamics, fast ion transport
			2. Quasi-linear models **[Gorelenkov]**
				1. Fnb response to given set of modes; testing on DIII-D, then NSTX-U
			3. Reduced models to be included in NUBEAM/TRANSP **[Podestà, White]**
				1. 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
			4. FIDASIM + Fnb evolving codes (long term: NUBEAM) **[Heidbrink]**
				1. Infer Fnb from set of data (FIDA, NPA, neutrons, …)

* + 1. Diagnostics
			1. Diagnostics under development during NSTX-U Outage period:
				1. Tangential FIDA – complement existing systems
				2. Fusion source profile via charged D-D fusion products – test on MAST in FY13 **[Darrow]**
				3. Fixed sightline E//B NPA – must be re-located **[Medley]**
				4. Upgraded ssNPA **[Liu, Heidbrink]**
				5. \*AE antenna for stability measurements, excitation of \*AE mdoes **[Fredrickson]**
			2. New/upgraded diagnostics **[Podestà with input from diagnosticians]**
				1. BES expansion & increased resolution
				2. Neutron collimator
				3. Profile reflectometry with increased frequency range
				4. FIDA & BES Imaging
				5. Radial polarimetry, currently testing on DIII-D
				6. Toroidally-displaced in-vessel multi-energy DXR arrays
				7. Dual-energy, ultra-fast SXR arrays
				8. VB imaging of \*AE modes
				9. BES passive FIDA view
		2. Other facility capabilities including plasma control
			1. 2nd more tangential NBI to modify fast-ion distribution function
			2. \*AE antenna to study stability of (possibly drive) high-f CAE/GAEs, TAE
				1. Goal: direct measurements of damping rate of stable \*AE modes
				2. Target high-f modes

NSTX-U will have unique capabilities for CAE/GAE studies

Complement JET, MAST data for TAEs

* + - * 1. With upgrades, assess requirements for “phase space engineering” – e.g.: assess capability of driving modes, compare to other actuators such as NBI, HHFW