NSTX-U is sponsored by the
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Milestone R18-4 progress and status
"Optimize EP distribution function for improved plasma performance"

M. Podestà
and all those who are contributing
PPPL

January 30th 2018

Main goals of Milestone R18-4

- Explore the use of different NBI sources and timing of NB injection to **improve plasma performance and reproducibility by affecting fast ion-driven instabilities**

- A **main focus** of this study is the **current ramp-up/early flat-top phase**, during which strong fast ion-driven activity can be destabilized

- **Contribute to scenario development** activities by the Advanced Scenarios and Control TSG, including the planned collaboration with (DIII-D and) MAST-U in FY17-18

- *Validation of the **'kick model' for scenarios with unstable fishbones** will be conducted in collaboration with MAST-U*

Achievements for Q1

- Explore the use of different NBI sources and timing of NB injection to **improve plasma performance and reproducibility by affecting fast ion-driven instabilities**

  - Suppression of GAEs with tangential NBI on NSTX-U
  - Path to mitigate/suppress counter TAEs on NSTX-U

  Papers presented at IAEA-TCM-EP in Sept. 2017, submitted to NF

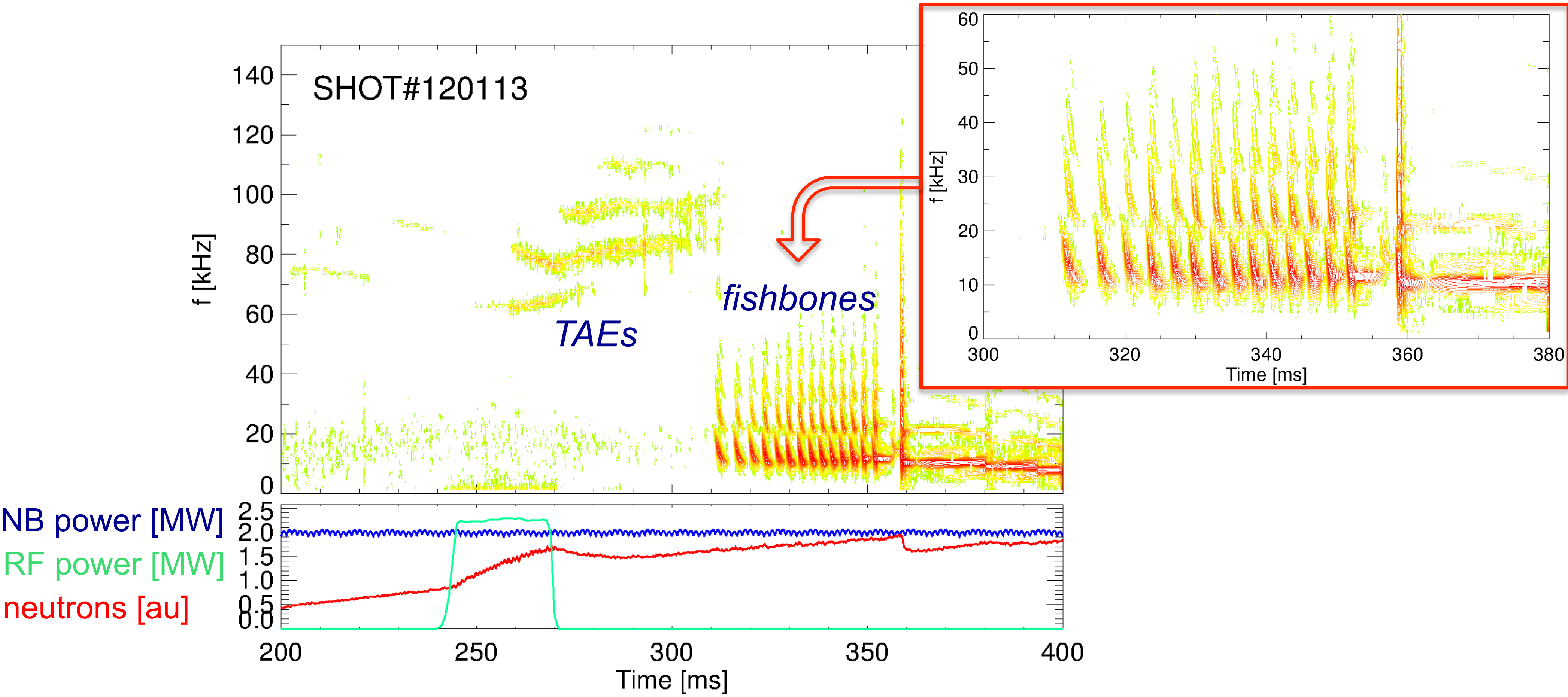
Plans for Q2 – Q4

- A **main focus** of this study is the **current ramp-up/early flat-top phase**, during which strong fast ion-driven activity can be destabilized

- **Contribute to scenario development** activities by the Advanced Scenarios and Control TSG, including the planned collaboration with (DIII-D and) MAST-U in FY17-18
  - Will support ASC-TSG Milestone R18-2 (see Battaglia's talk)
  - Contributing to I&T activities on high-q_{min} scenario development (Poli et al.); *also contribute to JRT-18*
  - Studying impact of lower NBI voltage on AEs for DIII-D ramp-up phase in high-q_{min} scenarios (*also JRT-18*)

Plans for Q2 – Q4

- *Validation of the **'kick model' for scenarios with unstable fishbones** will be conducted in collaboration with MAST-U*
  - Developing procedure for analysis of FB scenarios with kick model
  - Successful initial tests for NSTX scenarios



Plans for Q2 – Q4

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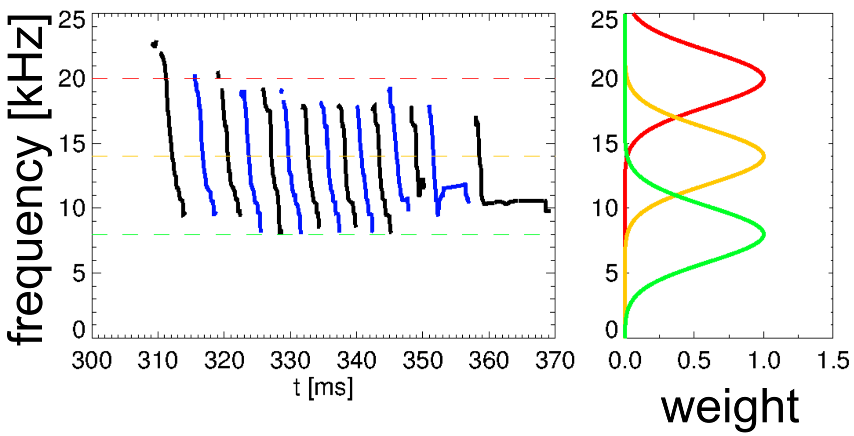
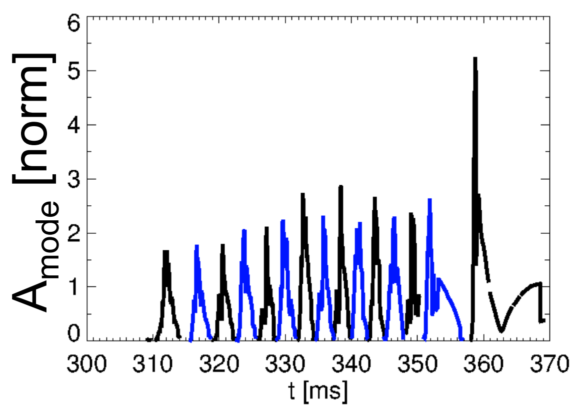
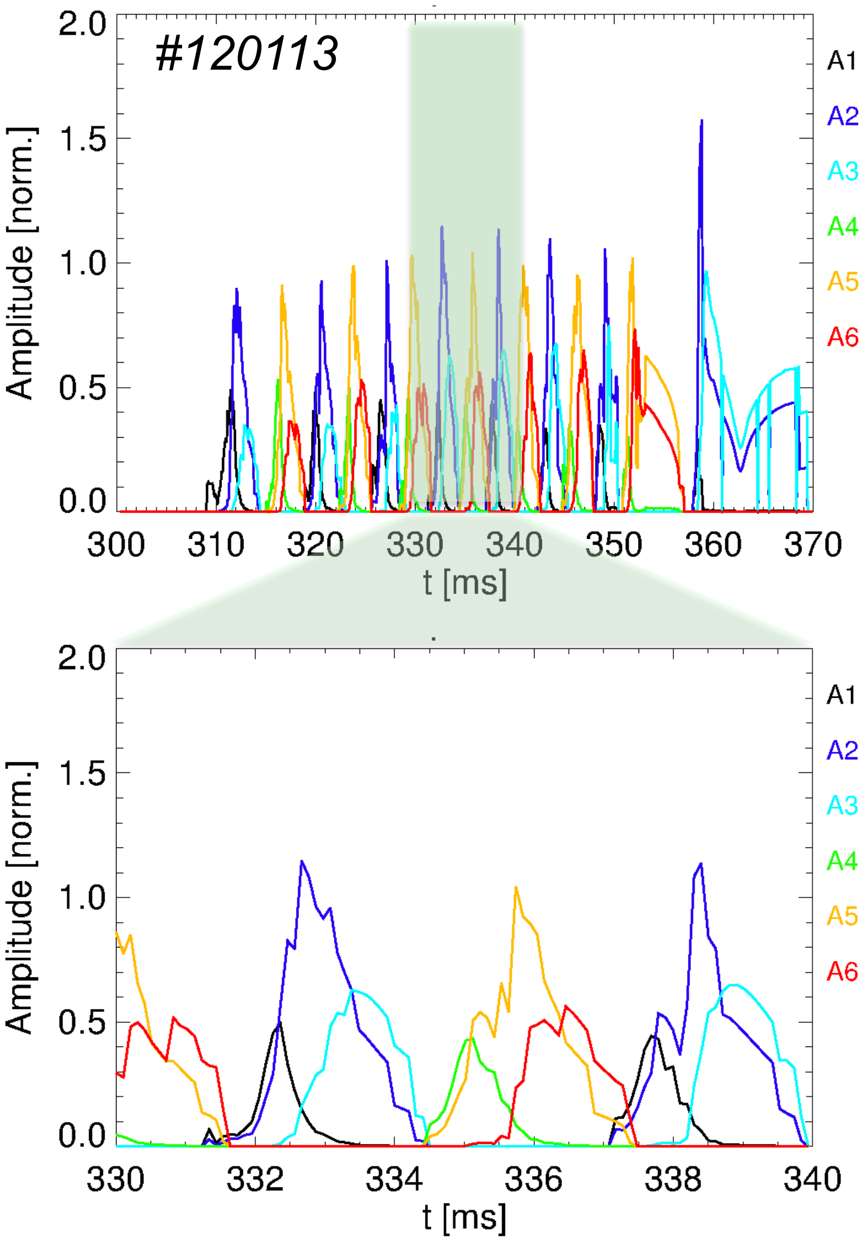


- Identify frequency and "amplitude" from Mirnov coils
- Define amplitude "weights" for selected frequencies during the frequency sweep

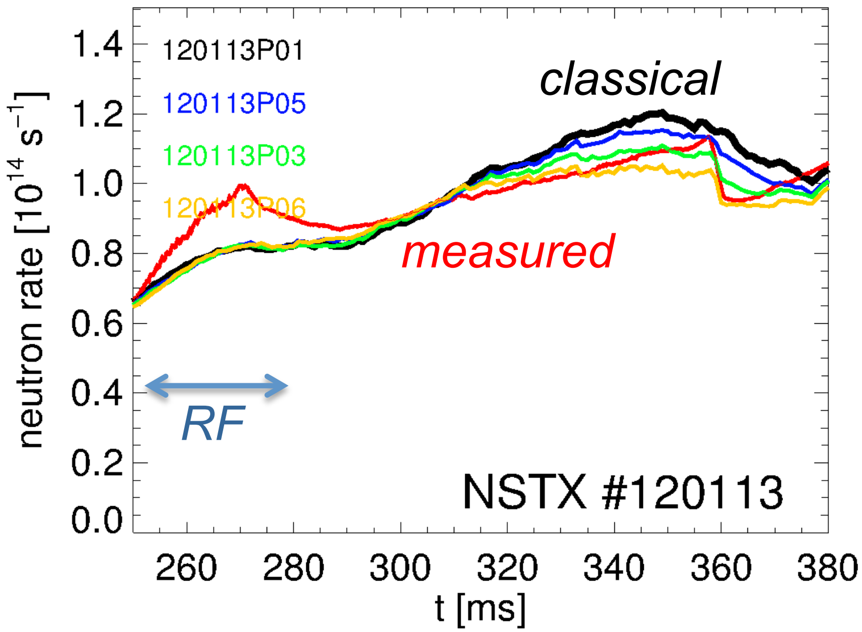


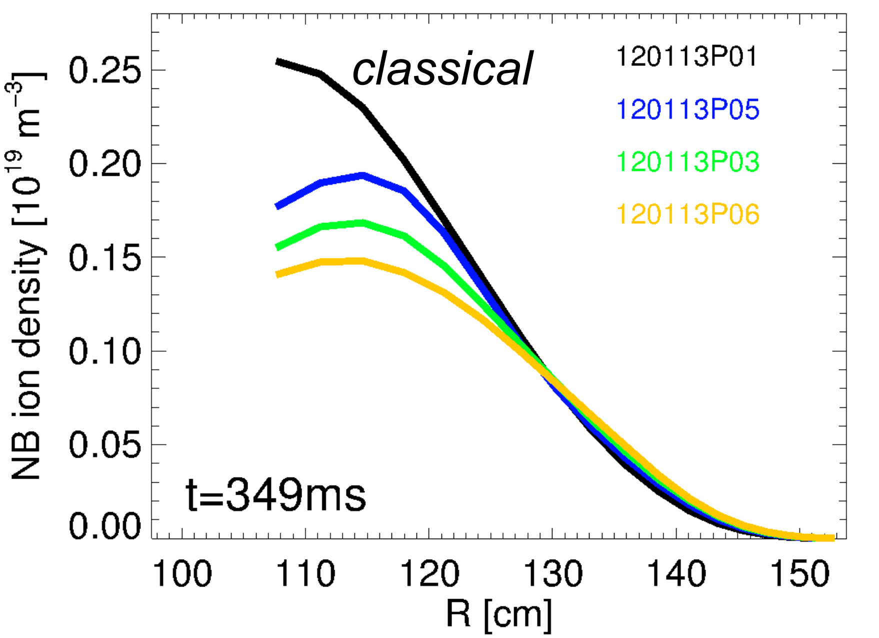
Plans for Q2 – Q4



- Identify frequency and "amplitude" from Mirnov coils
- Define amplitude "weights" for selected frequencies during the frequency sweep
- Split mode into subset of "modes" at different frequency
  - Compute kick probability for each mode, plug in TRANSP

Plans for Q2 – Q4





- Compute kick probability for each mode, plug in TRANSP
  - Reproduce measured reduction in neutron rate
  - “Measurable” effect on NB ion density profile

To be done:

> How many frequencies are required to model fb cycle?

> Implications for EP transport in phase space?

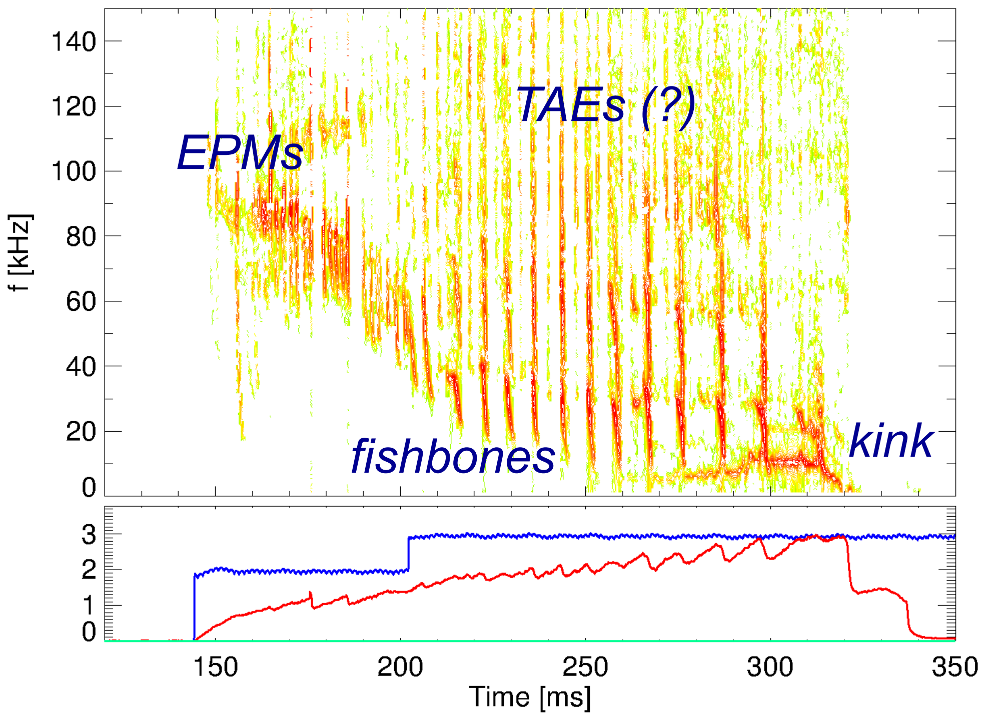
> Test with MAST data

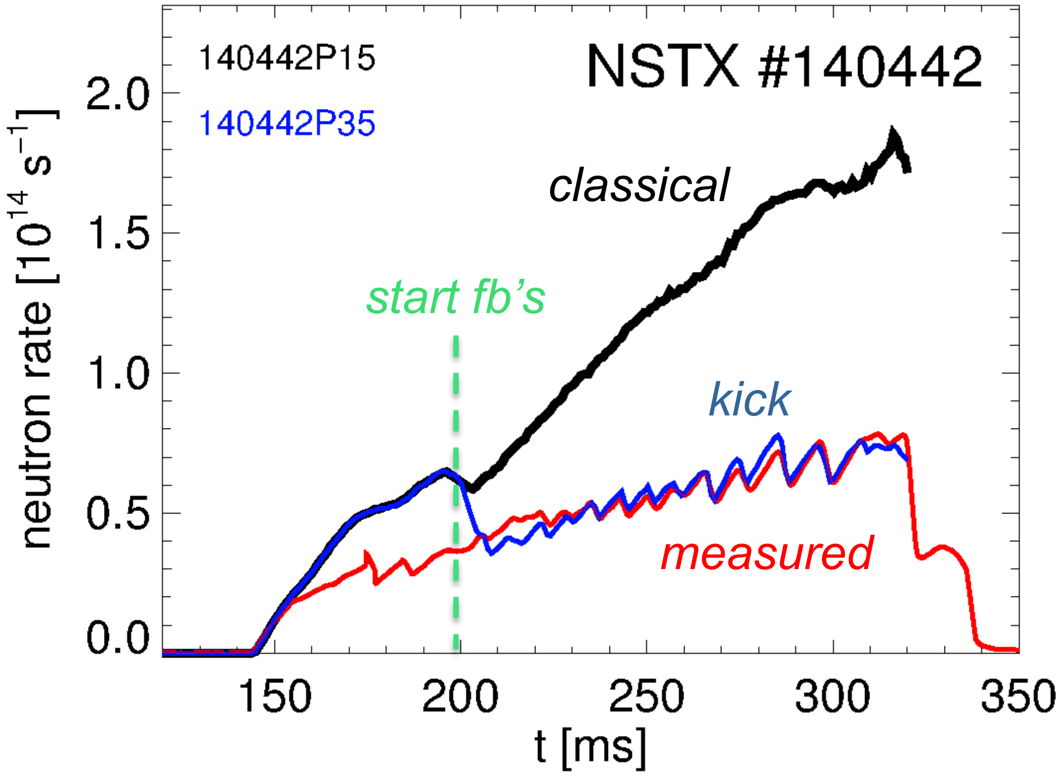
- *Compare to Neutron Camera, Fusion Product Array, etc.*

Plans for Q2 – Q4

Example #2

- Fishbones + many other modes
- Modeled as combination of:
  - *Steady transport (here using made-up "mode")*
  - *Intermittent transport by fishbones (analytic mode structure)*





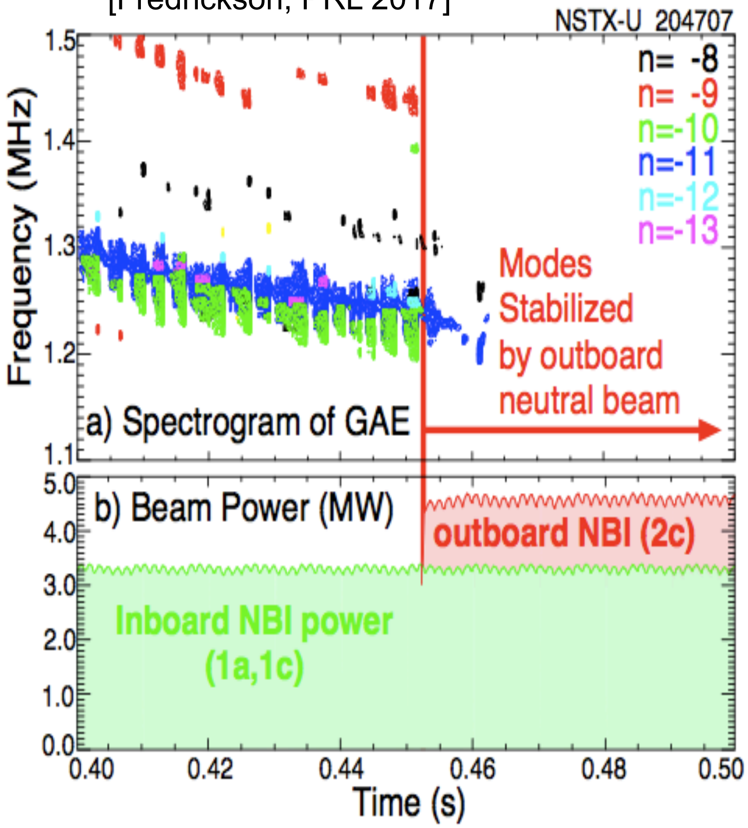
Summary of activities

- Contributing to I&T activities on high-q_{min} scenario development (Poli et al.); *also contribute to JRT-18*
- Studying impact of variable NBI voltage on AEs for DIII-D ramp-up phase in high-q_{min} scenarios (*also JRT-18*)
- Developing procedure to include fishbones in kick model
  - Plan validation on MAST data, perhaps extend to JET

Backup

2nd tangential NBI can efficiently suppress high-frequency GAE modes

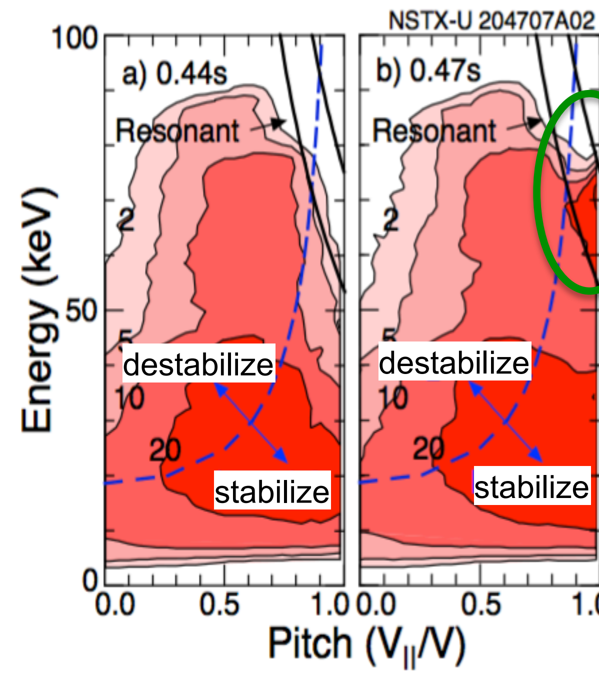
[Fredrickson, PRL 2017]



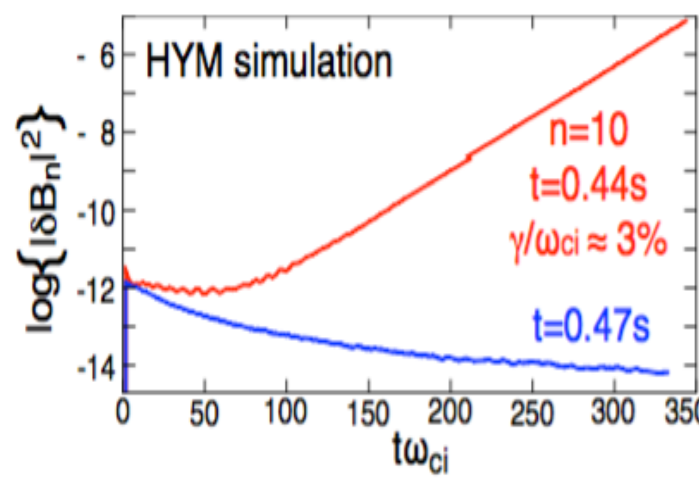
~1MW from 2nd NBI efficiently stabilizes GAEs

NUBEAM + analytic theory
[Gorelenkov, NF 2003]
reveal role of stabilizing particles from 2nd NBI

Results confirmed by HYM code, unique tool for $\omega_{AE} \sim \omega_{ci}$ instabilities

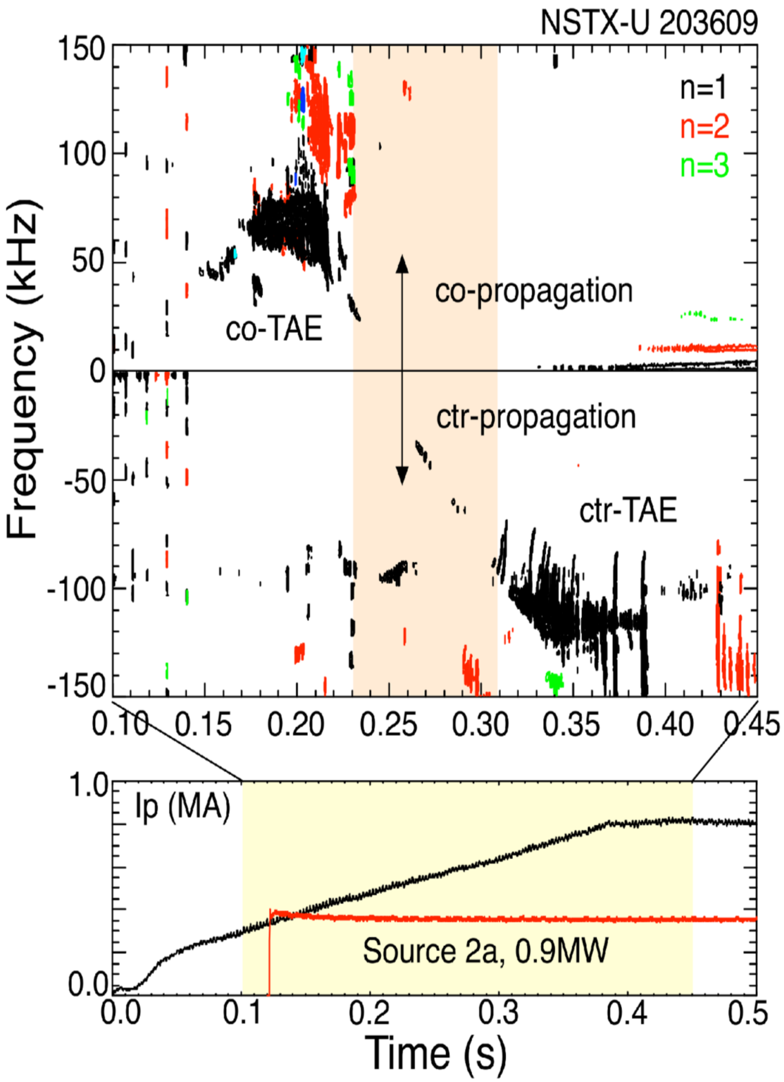


[Fredrickson, Belova - sub. NF]

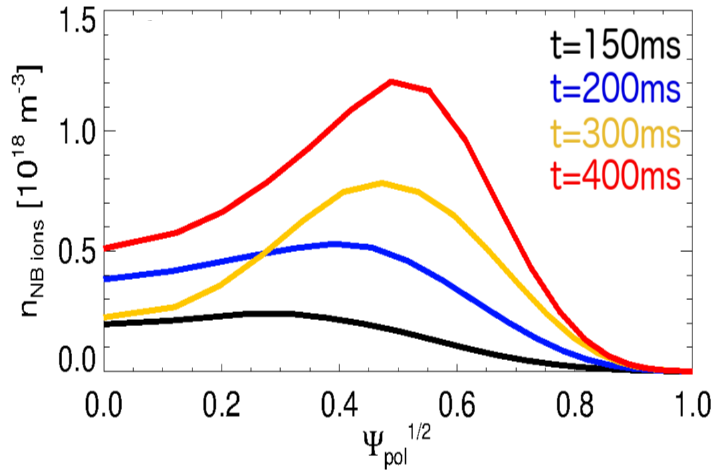


- *Leverage partnership with theory (PPPL, SciDAC-EP)*
- *Indicates path for AE control through tailored NBI + other actuators (RF, 3D fields)*

Counter-TAEs can be destabilized by off-axis co-NB injection from 2nd NB line

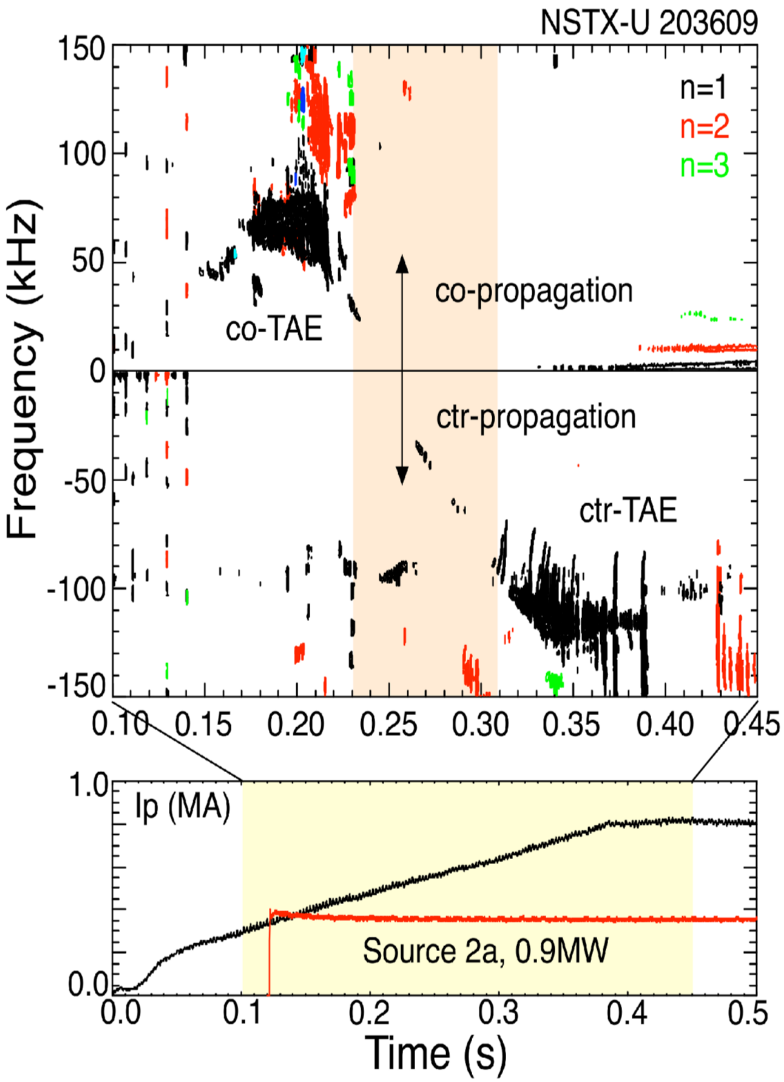


- Single NB source from 2nd NBI
- Low power, P_{NB}~1MW



- Off-axis NBI results in broad/hollow NB ion density profile
- A transition is observed from co-TAEs only to cntr-TAEs

Details of fast ion distribution explain destabilization of *counter*-TAEs by co-NBI



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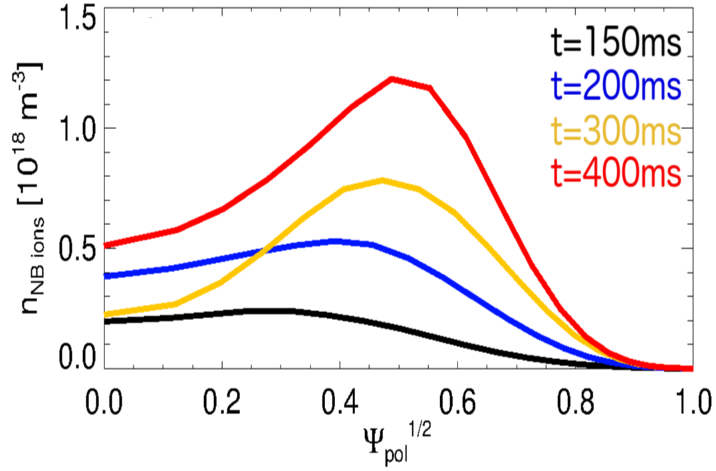
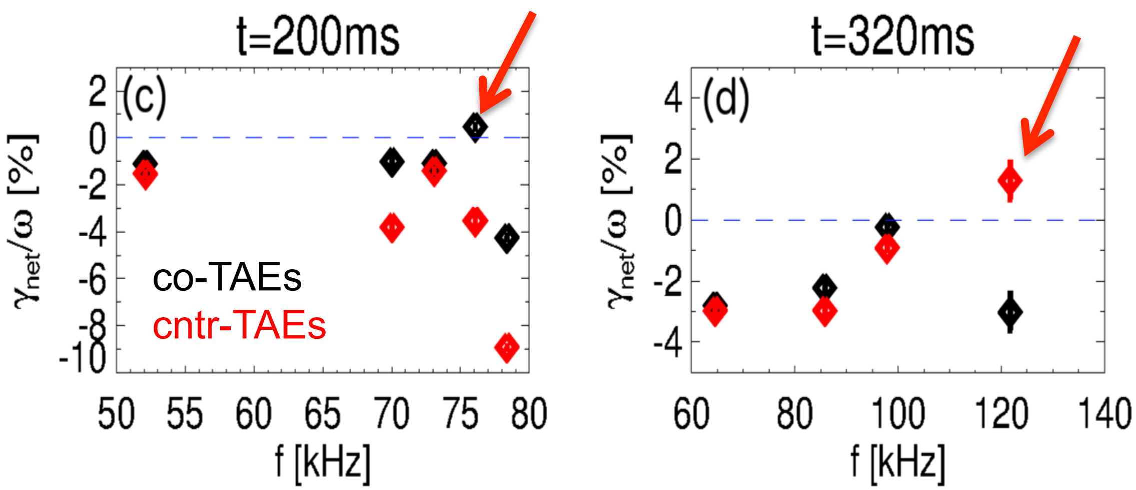
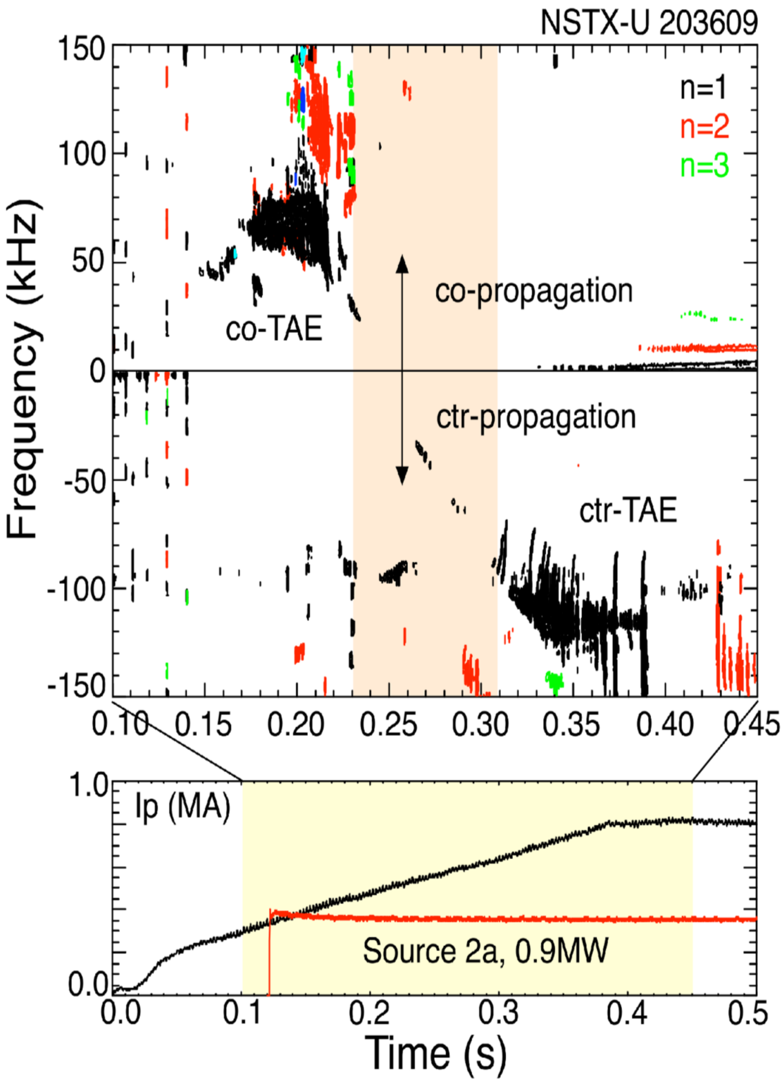


- Stability analysis with TRANSP + kick model recovers observations
- Drive results from competition between gradients in energy and canonical momentum



[Podestà, sub. NF]

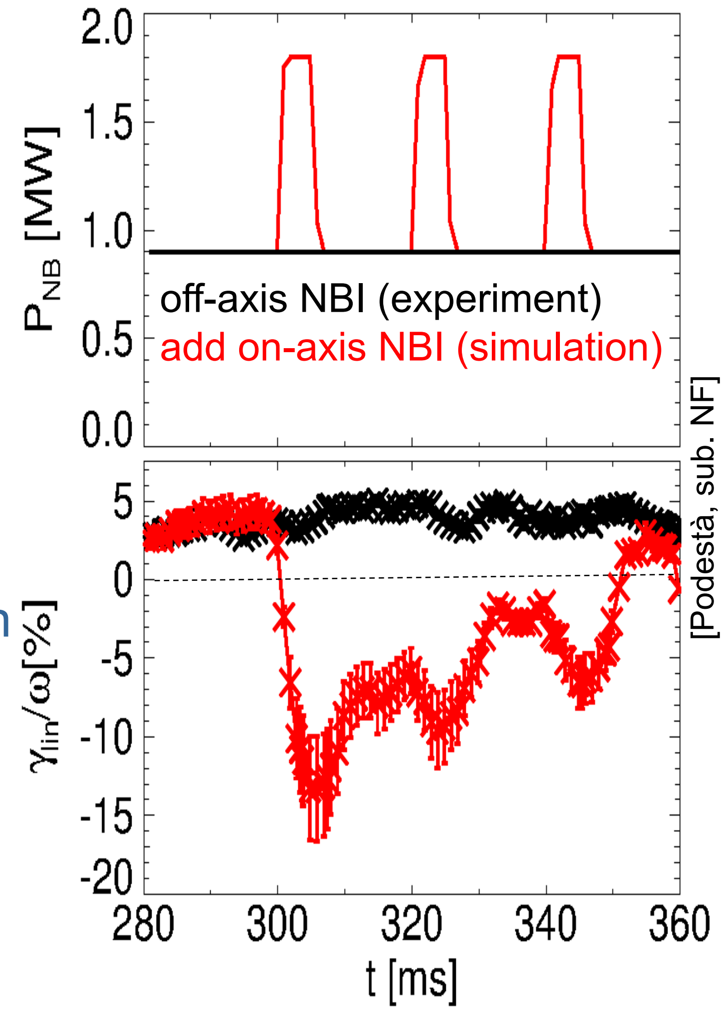
Understanding drive mechanisms leads to develop control strategies via NBI



- TRANSP: add 5ms *blips* from more perpendicular, on-axis NBI

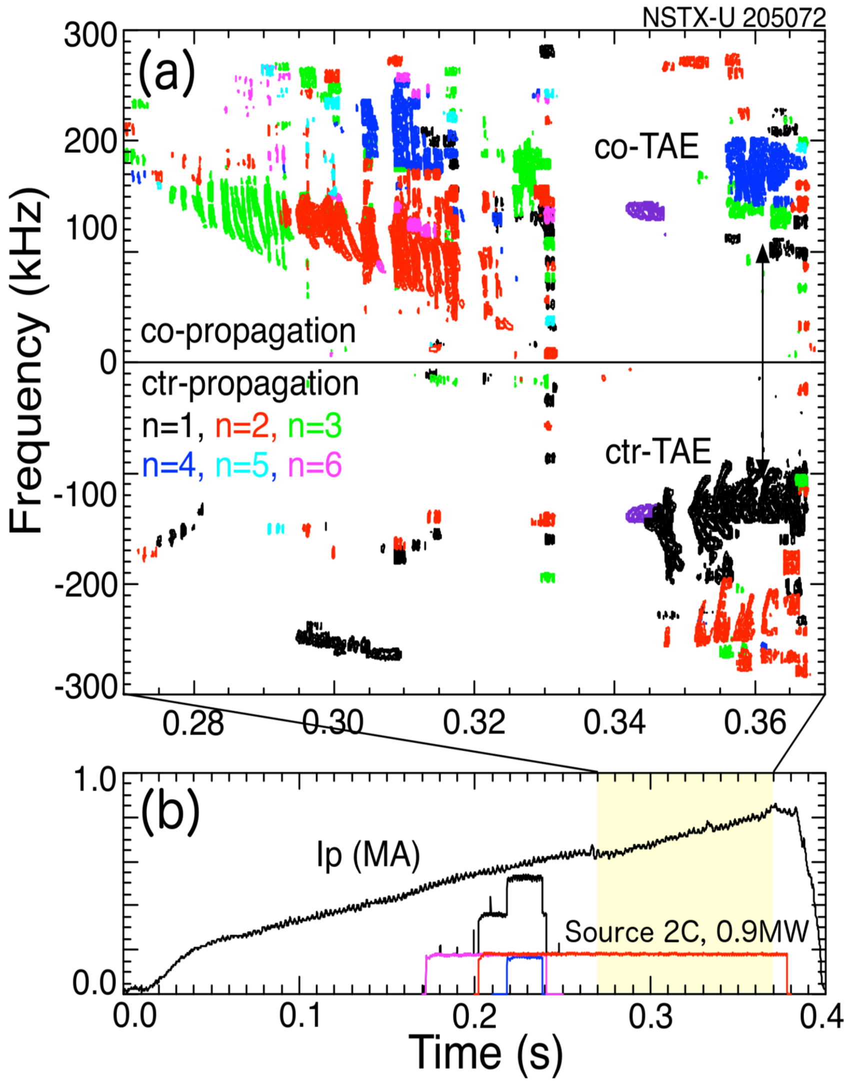
- On-axis NBI populates *stabilizing* phase space region

- Enough to suppress cntr-TAEs
  - Minimum perturbation to original scenario
  - > ***To be tested on NSTX-U***

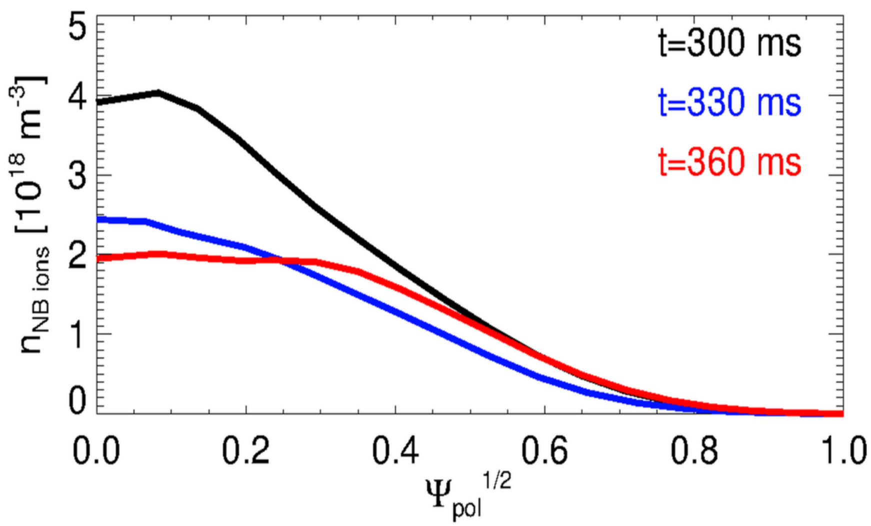


Counter-TAEs are *not* simply destabilized by inversion in radial EP density gradient

- NSTX-U with 2nd NBI only
- P_{NB}~1MW, tangential injection



- EP density (TRANSP) remains flat/monotonic in this case



- Stability analysis (TRANSP + kick model) recovers transition in unstable spectrum