NSTX-U

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Fusion Energy Sciences

NSTX-U Milestone R18-2: Develop simulation framework for ST breakdown and current ramp-up

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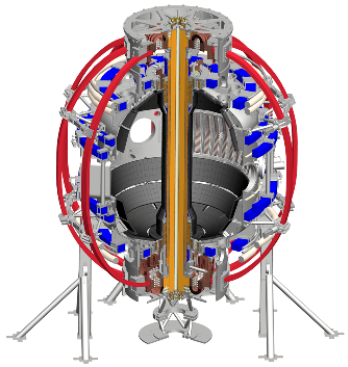
FY2018 Q2 Research Milestone Status
January 24, 2017

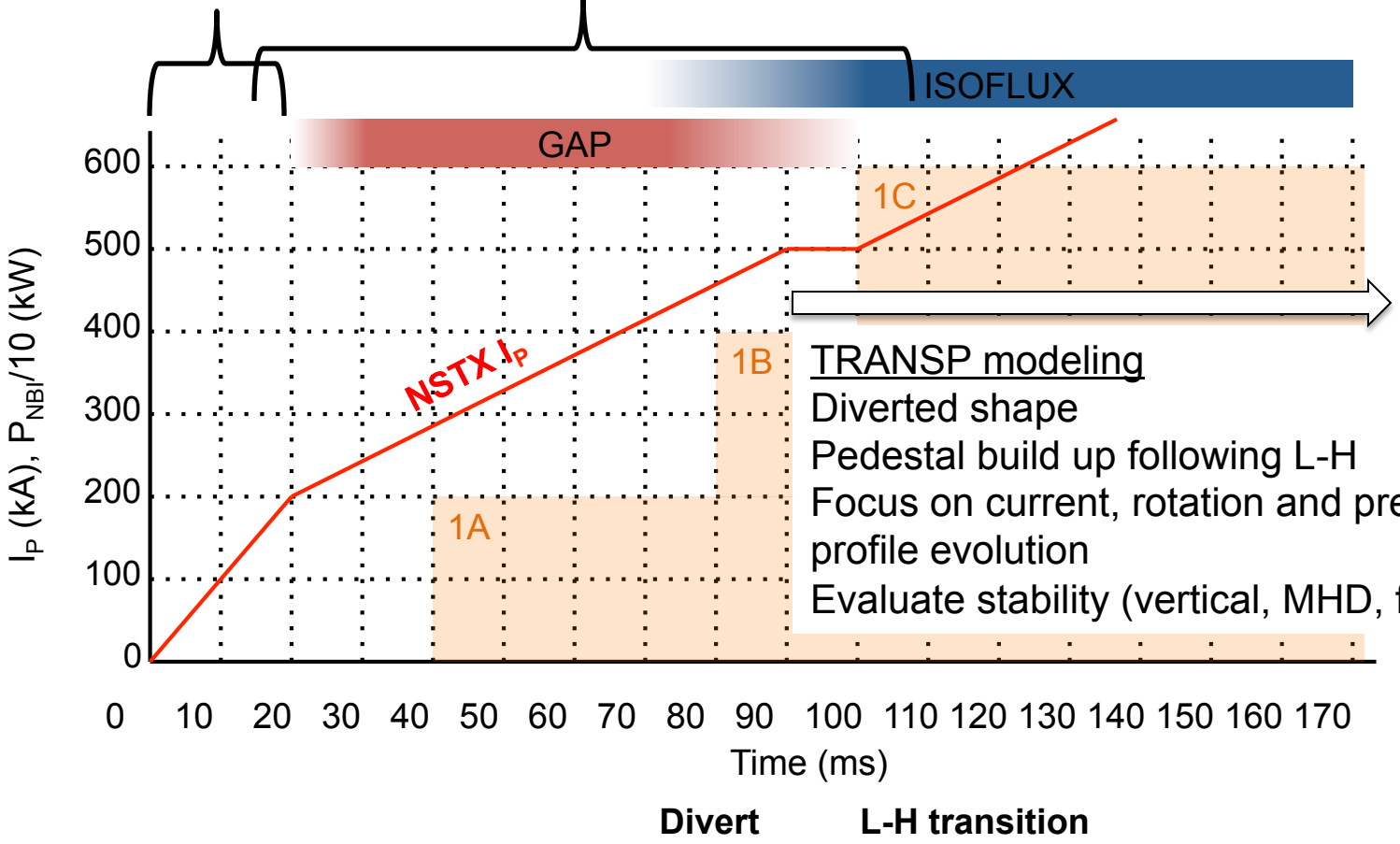
PPPL



Modeling tools will focus on different challenges within the ramp-up

LRDFIT vacuum field calculations
Null formation,
dB_Z/dt with passive stability

TOKSYS control modeling
Feedforward → GAP → ISOFLUX shape control
Transition from IWL → DN (L-mode)
Vertical stability at high κ



TRANSP modeling
Diverted shape
Pedestal build up following L-H
Focus on current, rotation and pressure profile evolution
Evaluate stability (vertical, MHD, fast ion)

Main elements of FY18 milestone

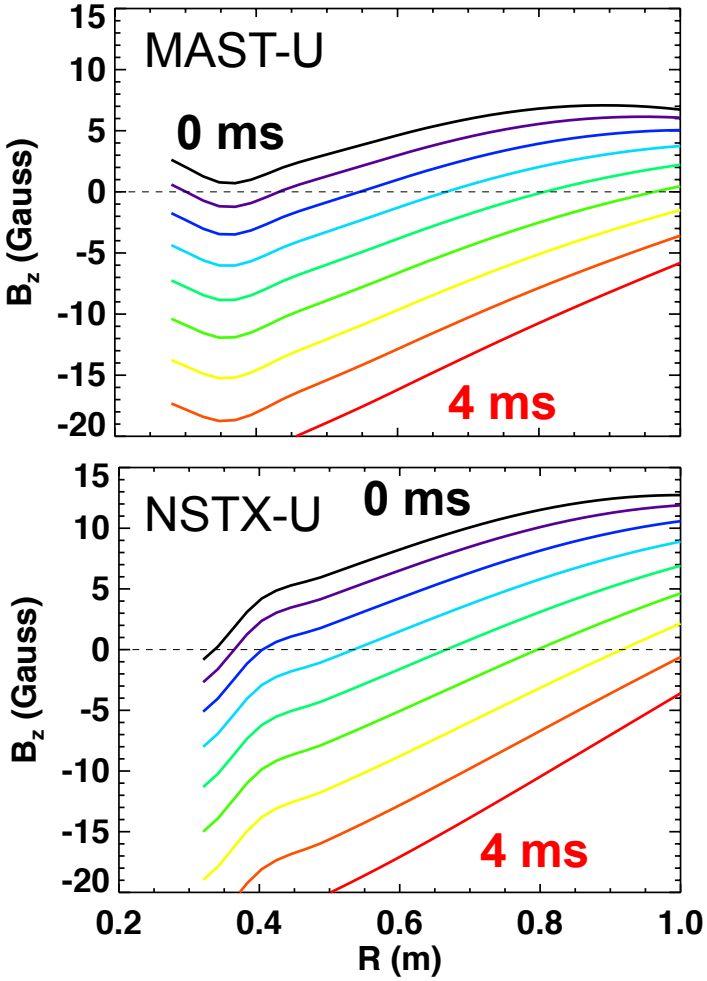
- Inductive startup calculations using LRDFIT
  - Quantify difference between model and experiment
  - Identify impact of V_{loop} and dI_p/dt on the null quality and field index
  - Includes NSTX-U and MAST-U analysis
- Control modeling focusing on IWL → DN transition
  - Using TOKSYS code from General Atomics
  - Reproduce vertical oscillation at time of diverting in model
  - Investigate control solutions for earlier time of diverting, eliminating vertical oscillation and test resiliency to scenario perturbations
- TRANSP calculations for heating and current drive
  - Compare predictive calculations to NSTX and NSTX-U ramp-up
  - Investigate impact of outer gap, density, NBI, dIp/dt …

Status of LRDFIT breakdown modeling

- Inductive breakdown simulations for NSTX(-U) and MAST(-U)
  - Demonstrated MAST-U can achieve similar breakdown metrics to NSTX-U within the voltage limits of PF coils

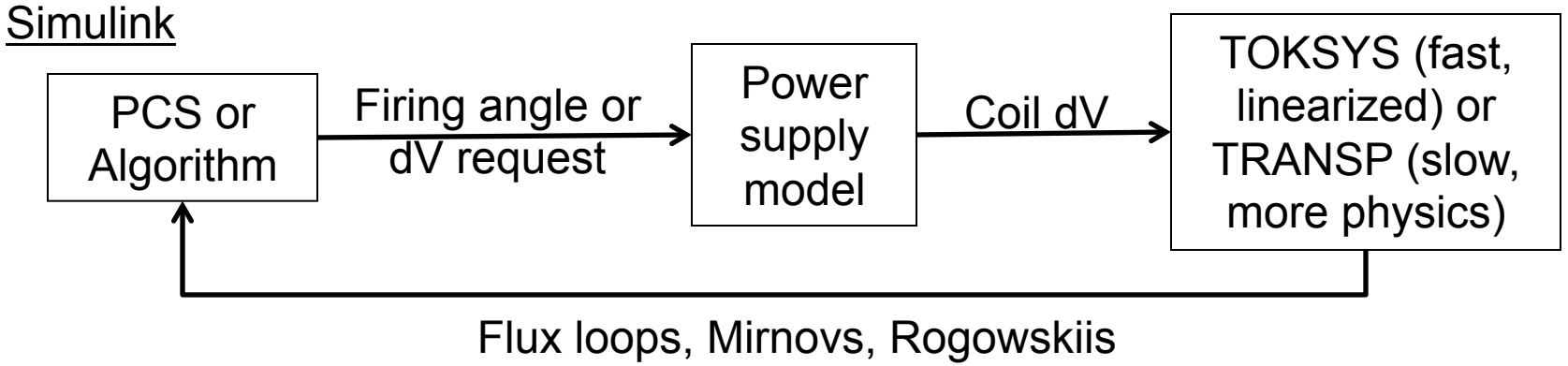
- Remaining goals for FY18:
  - [Q-3] Investigate potential sources of up-down asymmetry that scaled with I_{OH} on NSTX-U
  - [Q-4] Quantify impact on null quality and field index with V_{loop} and dI_p/dt on NSTX-U and MAST-U
    - Can we ramp I_p faster following breakdown?
    - MAST-U may provide supporting experiments summer of 2018

Midplane B_Z evolution over first 4 ms



Overview of TOKSYS and SIMULINK development

- FY18 goal: demonstrate a simulation framework for developing and testing shape control in ramp-up



- Aim is to establish closed loop test with PCS
  - End-to-end test and valuable for shot planning work
  - Ability to test algorithm outside of PCS will be maintained

- Simulink connects PCS to TOKSYS or TRANSP
  - TOKSYS provide fast (~ minutes) solution, enables large parameter scans

Present activities on TOKSYS and SIMULINK development

- [Q-2] Get PCS working in SIMULINK
  - Pat, Dan and Keith continue to debug with Mike Walker.
- [Q-2] Develop PS model in SIMULINK
  - Pat has a simplified PS model for algorithm testing
  - Dan has simple model for converting firing angle to dV
- [Q-2] Develop TOKSYS models for ramp-up phase
  - Pat has developed and validated wall model for NSTX-U using vacuum shots
  - Pat is leading development of linearized plasma models for NSTX-U ramp-up (20 – 500ms)
    - First test is examining how the interval of updating the linearized model impacts agreement with experiment

Control modeling goals for FY18 milestone

- [Q-2] Closed loop calculation of an NSTX-U discharge using PCS in simulink with TOKSYS and possibly TRANSP
  - Advances "shot simulator" capabilities
- [Q-3] Evaluate different TOKSYS models in ramp-up
  - Fixed shape, rigid shape, grad-Shafranov …
    - Fixed evolution of q profile, β_N
  - How often does linearized model need to change during different phases of the discharge?
- [Q-4] Reproduce different varieties of "the bobble" at the time of diverting
  - Start to investigate proposed solutions from FY17 milestone

Status of TRANSP calculations

- [Q2-3] Validation of TRANSP model for ramp-up period (Doohyun, Francesca)
  - NSTX w/ MSE (140358)
  - NSTX-U w/ CHERs (204202)
  - NSTX-U early H-mode development (202946, 203679, 204112) using NBI #2
  - Evaluate ability of flux-driven transport models to capture evolution of discharge in L- and H-mode ramp-up

- [Q3-4] Free-boundary predictions for NSTX-U
  - Start with validated predictive model of an NSTX-U rampup
  - Examine impact of NBI, outer gap, density, dIp/dt, κ, and/or timing of L-H transition on l_i

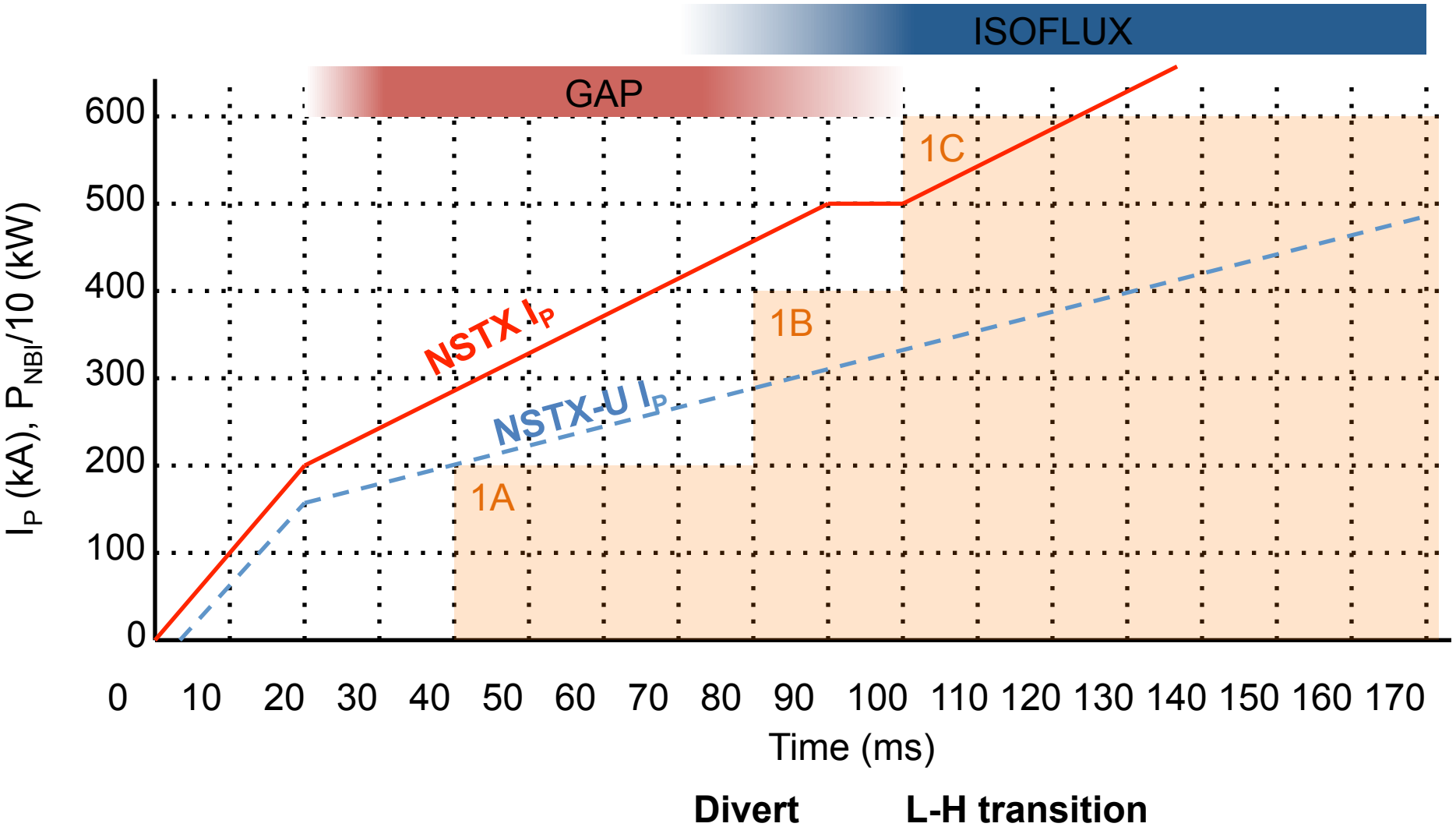
Milestone Summary

- 18-2: Demonstrate a framework for breakdown and ramp-up modeling
  - Validate models against experimental results
  - Show simulations can be employed to improve NSTX-U rampup (don't have to solve all the problems yet)
    - Start to answer some pertinent questions (what can mitigate the bobble, how important is the choice of the beams, …)

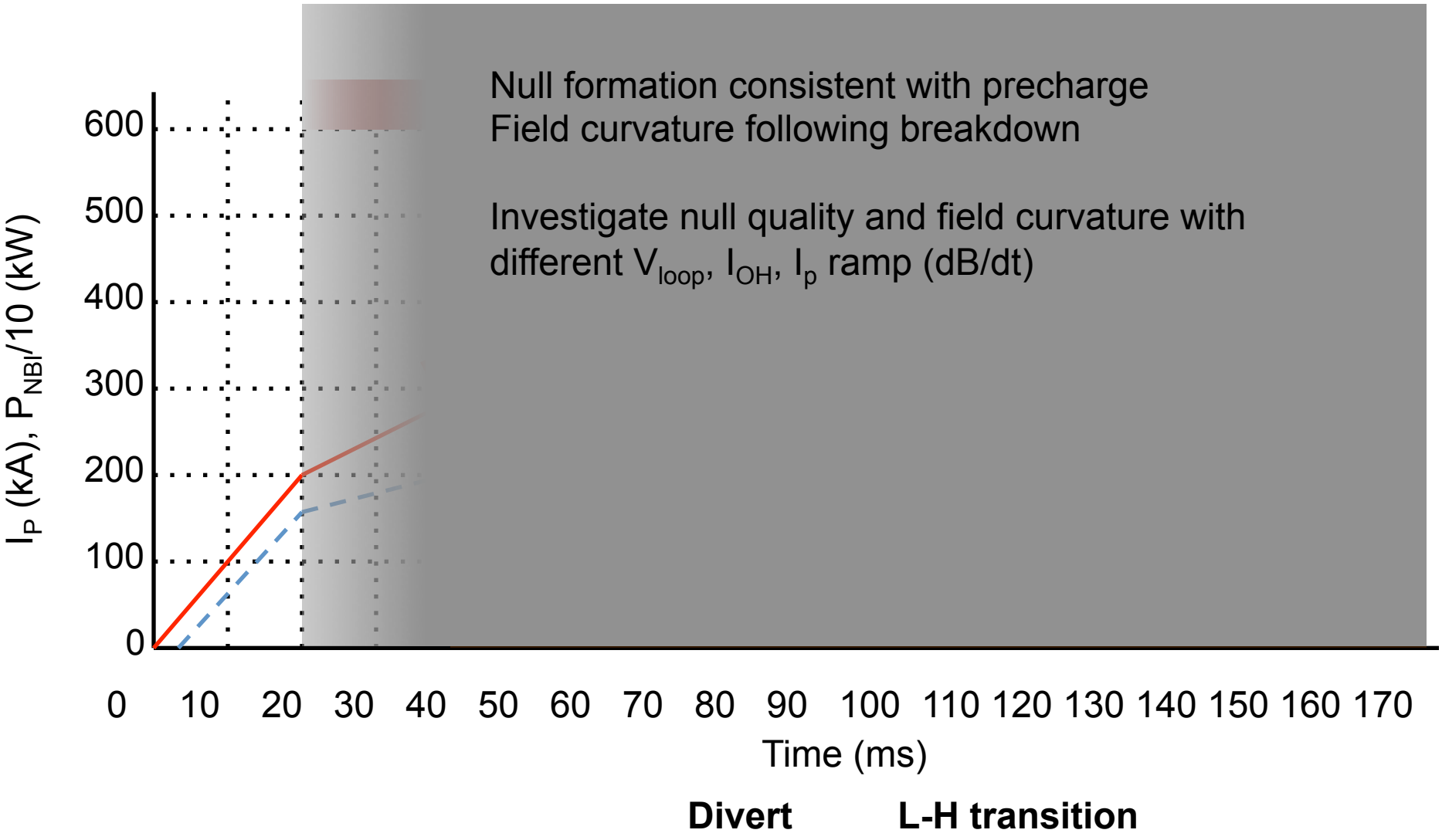
- 19-2: Optimize ramp-up for resiliency, low l_i, and stability using predictive models
  - Use TRANSP to improve linearized models for TOKSYS
  - Use TOKSYS to refine control models in TRANSP
  - Produce a solid plan for realizing high-performance discharges when NSTX-U resumes operation

Backup

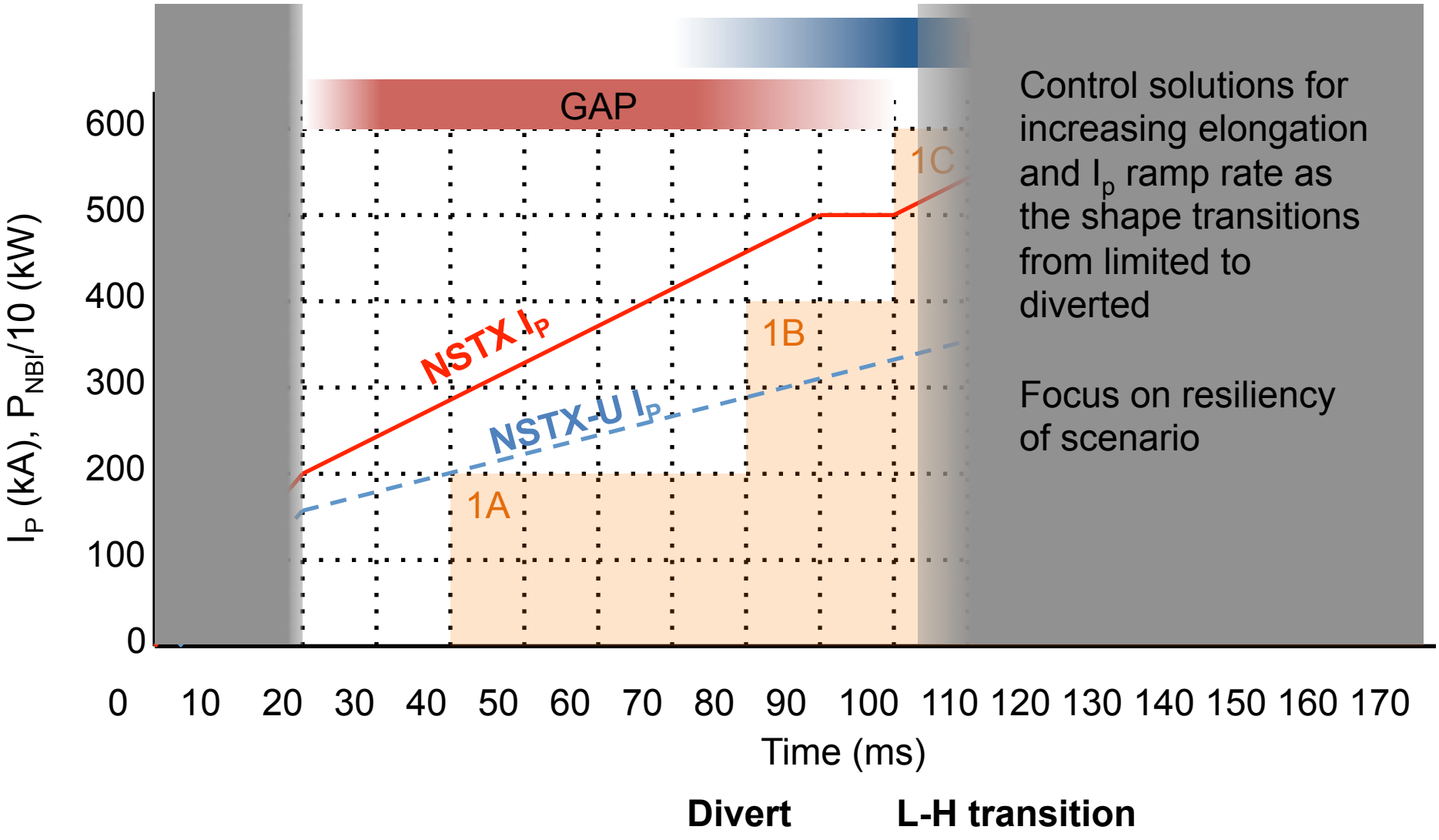
Typical NSTX ramp-up



LRDFIT modeling focus



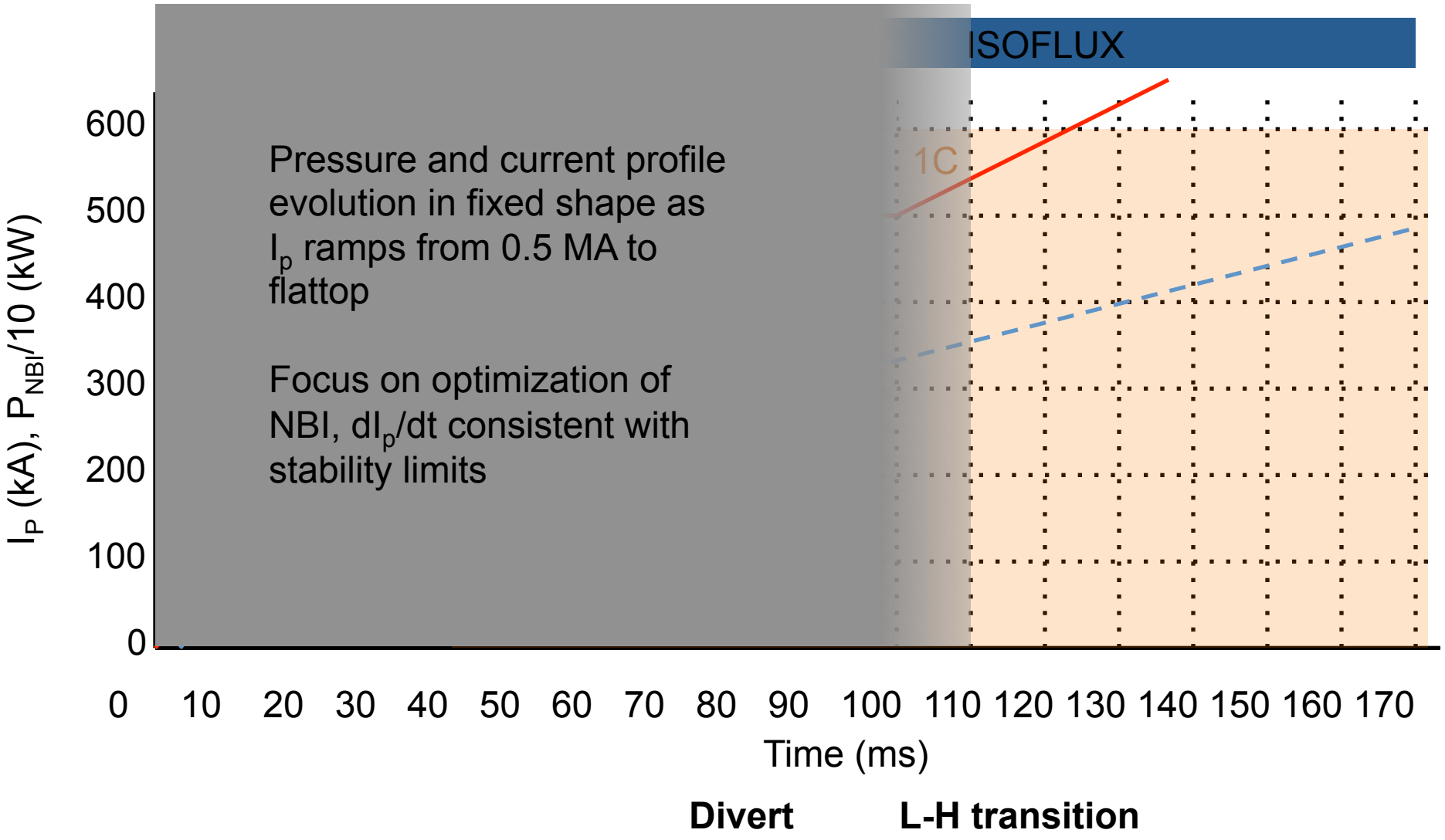
TOKSYS modeling focus



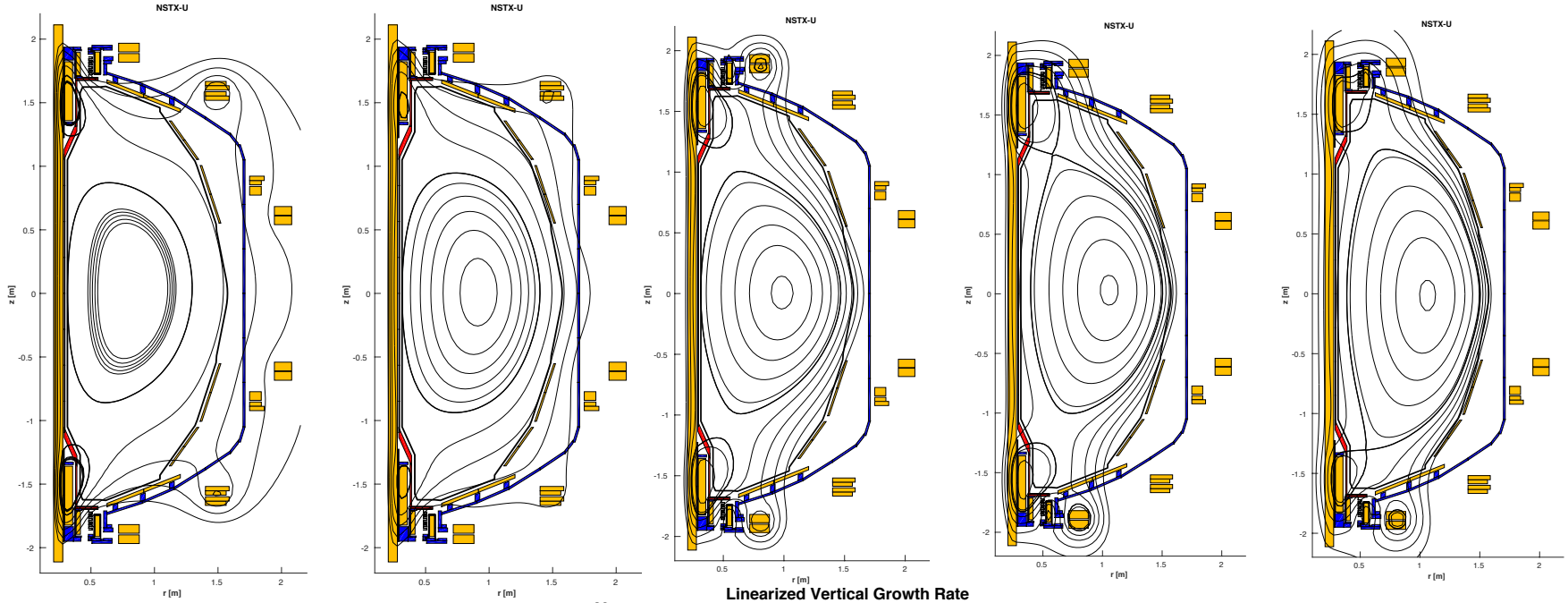
Control solutions for increasing elongation and I_p ramp rate as the shape transitions from limited to diverted

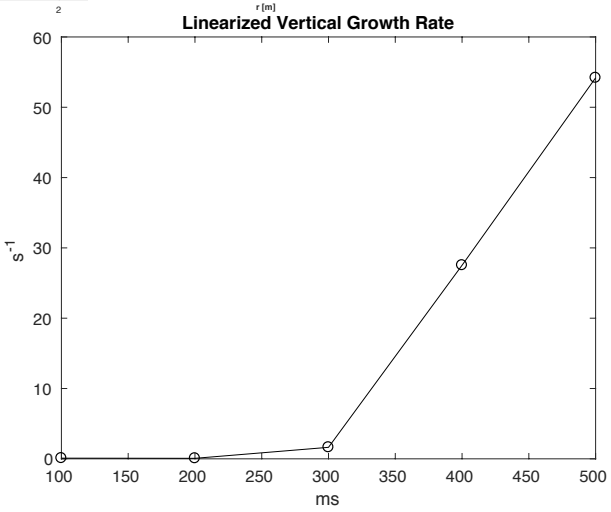
Focus on resiliency of scenario

TRANSP modeling focus



Linearized models generated for Shot 204118





TOKSYS work by
Pat Vail