FY18 ASC End of Q1

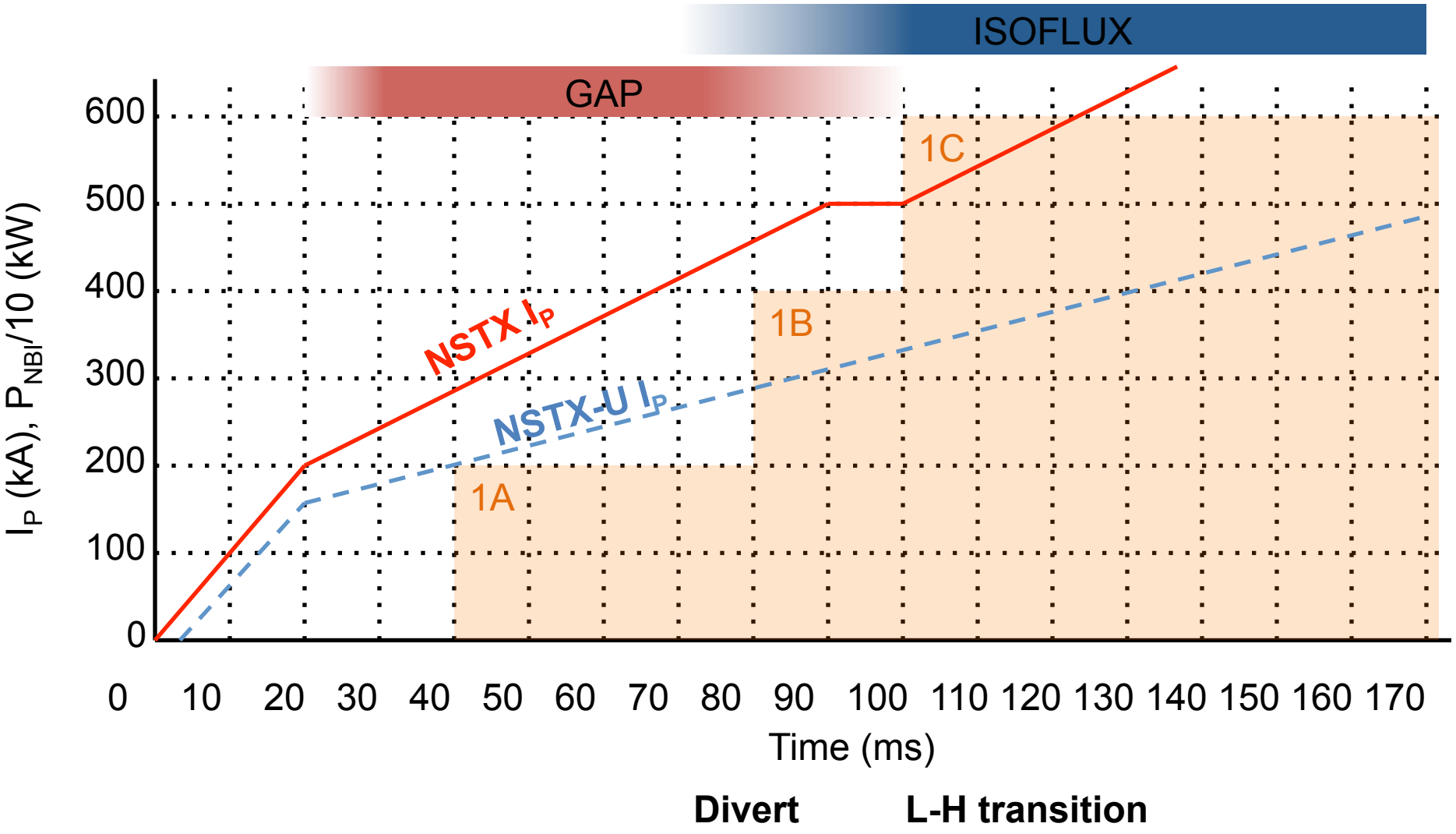
- Update on activities for FY18-2 milestone: “Develop simulation framework for ST breakdown and ramp-up”

- PAC meeting January 9-10
  - ASC dry run Wednesday, 12/20 at 9 AM

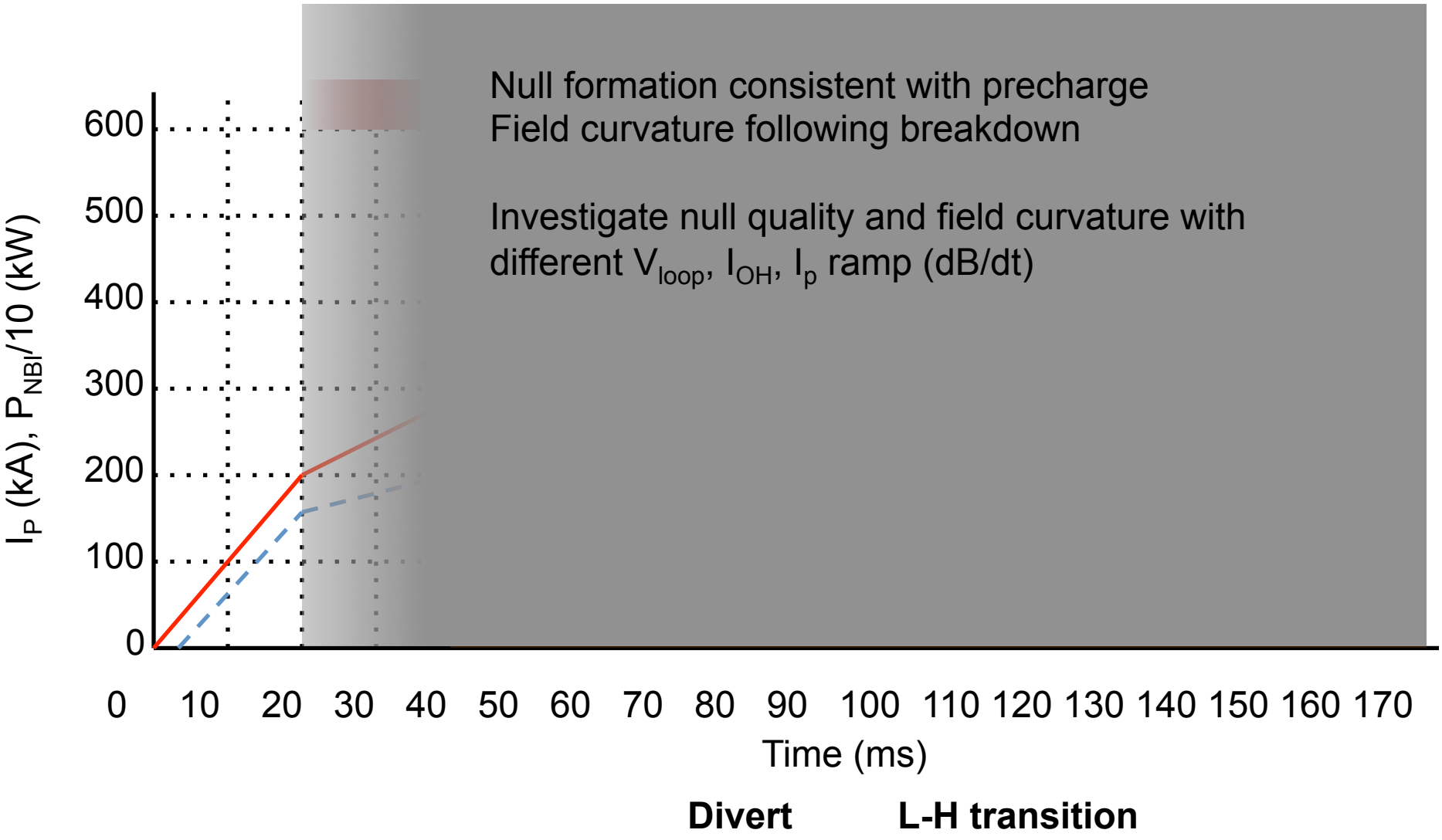
Elements of FY18-2 Milestone

- Develop TOKSYS model for ramp-up
  - Power supply model, wall model, free-boundary equilibrium
  - Test shape and vertical control algorithms in ramp-up
- TRANSP calculations of heating and current drive
  - Compare predictive calculations to existing data to identify acceptable assumptions and boundary conditions
  - Investigate impact of outer gap, density and NBI sources
- Inductive startup calculations using LRDFIT
  - Optimize breakdown and early ramp-up for a range of conditions, including target shapes and dI_p/dt

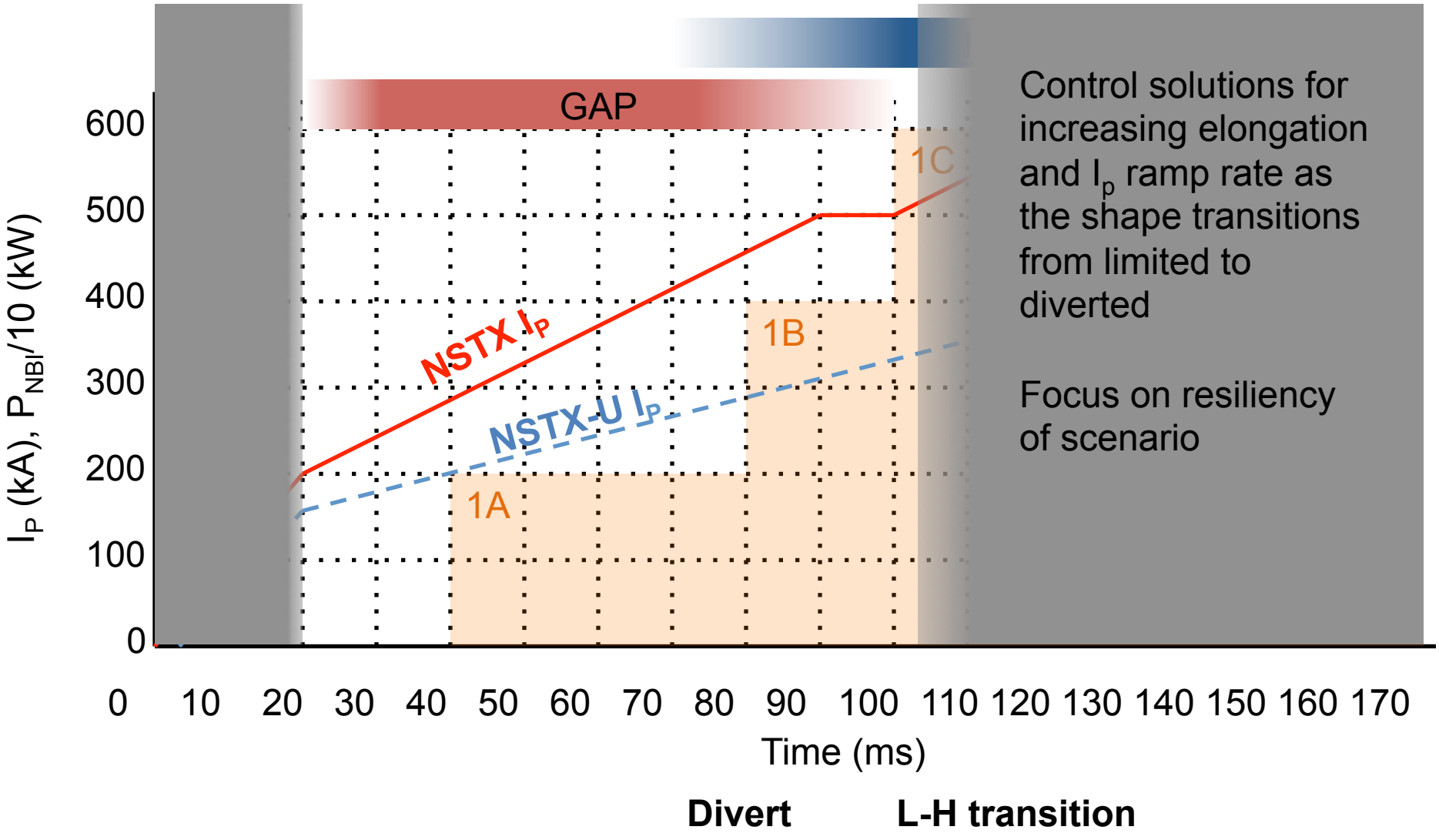
Typical NSTX ramp-up



LRDFIT modeling focus



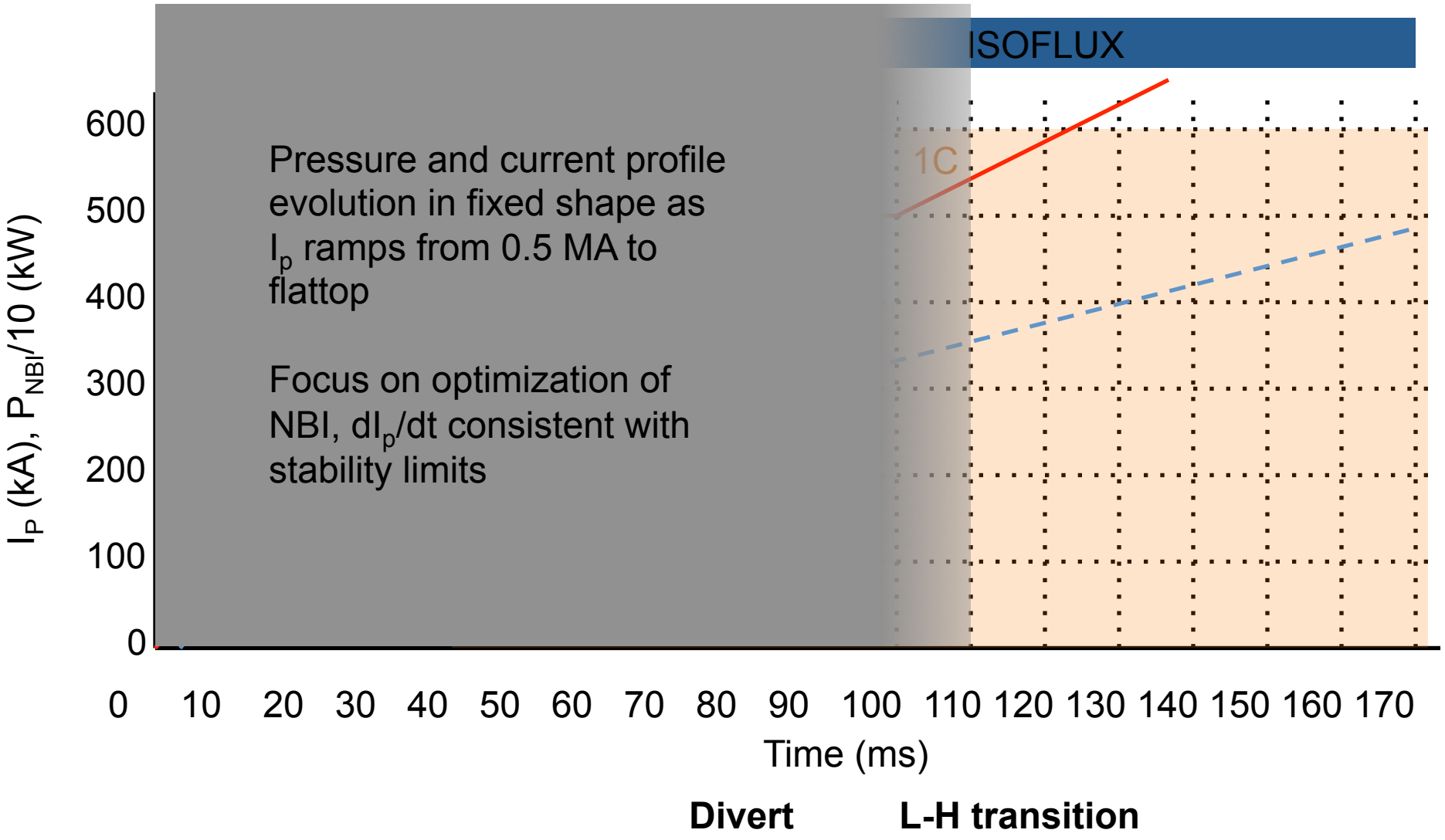
TOKSYS modeling focus



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



TOKSYS plans for ramp-up modeling

- Reproduce range of cases (bobble, dip, other) when transitioning from limited to diverted
  - Start with linearized equilibrium model, wall model, V_{loop}
  - ISOFLUX shape control
    - Hands on TOKSYS training in Dec/Jan
- Explore control and scenario solutions that might impact behavior at time of diverting
  - Minimize inner gap excursion
  - Divert LSN, move to DN
  - Fidelity of rtEFIT
    - Add offset to controller (rtEFIT is not in TOKSYS)
  - Changes to the wall (remove copper cooling tubes)

Pat presented slides

- Status of Framework for Simulation of Plasma Shape Evolution during Ramp-up
- Equilibrium for 204118 have been used to make linearized models for rampup
  - May want to try more resolution around time of diverting
  - Can interpolate between matrices in time-dependent solution
- First step would be to take the current for coils and see if reproduce the shot
- Francesca: TRANSP could be used to develop new equilibrium that deviate from the experiment
- Dan: Try different evolutions of beta, li

Extend TOKSYS model to earlier time

- Develop model of early ramp up
  - PCC control of limited shape transitioning to ISOFLUX
  - Explore control solutions for early diverting at high kappa
  - GS evolve or interpolate between linear models
  - How quickly can we divert, raise I_p, get to large kappa?
  - How sensitive are the scenarios to variations in free parameters?

- Reproduce VDE with wall and power supply model
  - Develop control that improves κ limits (l_i = 0.4 – 0.8)
  - Less critical, but could contribute to milestone report

Near-term TOKSYS tasks

- Develop model of diverting with ISOFLUX control
  - Use linearized model for shape – Pat has done this
    - Dan and Devon need to learn how to do this too
  - Wall currents (initialize assuming fixed V_{loop})
  - Meeting in late Dec/early Jan to have Pat train Dan and Devon

- Devon plans to write PCC and system algorithms for TOKSYS
  - Start in February, aim to complete by end of Q2

TRANSP modeling of ramp-up

- Perform TRANSP simulations of different NSTX-U or NSTX ramp-up cases
  - What choices of free-parameters best reproduce the experimental data?
  - Focus on cases with data with CHERS, MSE
    - Francesca has an NSTX case, Mario is using same case for EP analysis
    - Francesca and Dooyhun will show slides in January
    - Then do for an NSTX-U case
    - Free boundary gives insight into boundary changes that a controller cannot correct
- Provide insight into impact of NBI, dIp/dt, outergap
  - Optimize for broad P and J profiles
  - How does q-profile, pressure profile evolve?
  - Couple to MHD, EP stability codes?

Near-term tasks for TRANSP

- Devon will provide cases of interest for ramp-up to Doohyun
  - Devon will look for NSTX-U w/ beamline 1 that was trying for early H-mode
- Status update in January on NSTX and NSTX-U simulations

Near-term tasks for LRDFIT development

- Revisit NSTX-U null formation calculations
  - Is there any benefit to adding divertor coils to null formation scenario?
  - How fast can dB/dt be increased? What is the impact on the null dwell time, null quality and field curvature evolution?

- Including Ip in predictive LRDFIT needs development
  - Can filament current be added either with a fixed distribution or with some criteria to put it in regions of low Bp?
  - Can ISOLVER be coupled to LRDFIT to evolve boundary and current distribution of a zero-β equilibrium?
  - Could this be done in TOKSYS?
    - Talk to Mike Walker … he has time to help with NSTX-U. He has looked at ITER breakdown scenarios in TOKSYS

Next meeting

- Aim for end of January (mid Q2)
  - Francesca not available week 1/29

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NSTX-U

Status of Framework for Simulation of Plasma Shape Evolution during NSTX-U Ramp-Up

P. J. Vail and M. D. Boyer

ASC FY18-2 Milestone Update
PPPL
12/07/2017

CCFE
CULHAM CENTRE FOR FUSION ENERGY

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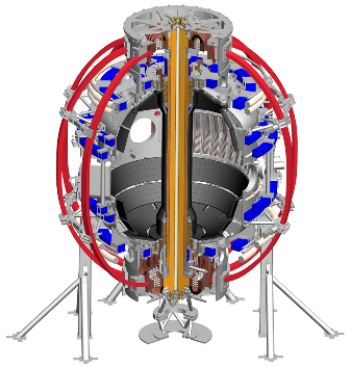
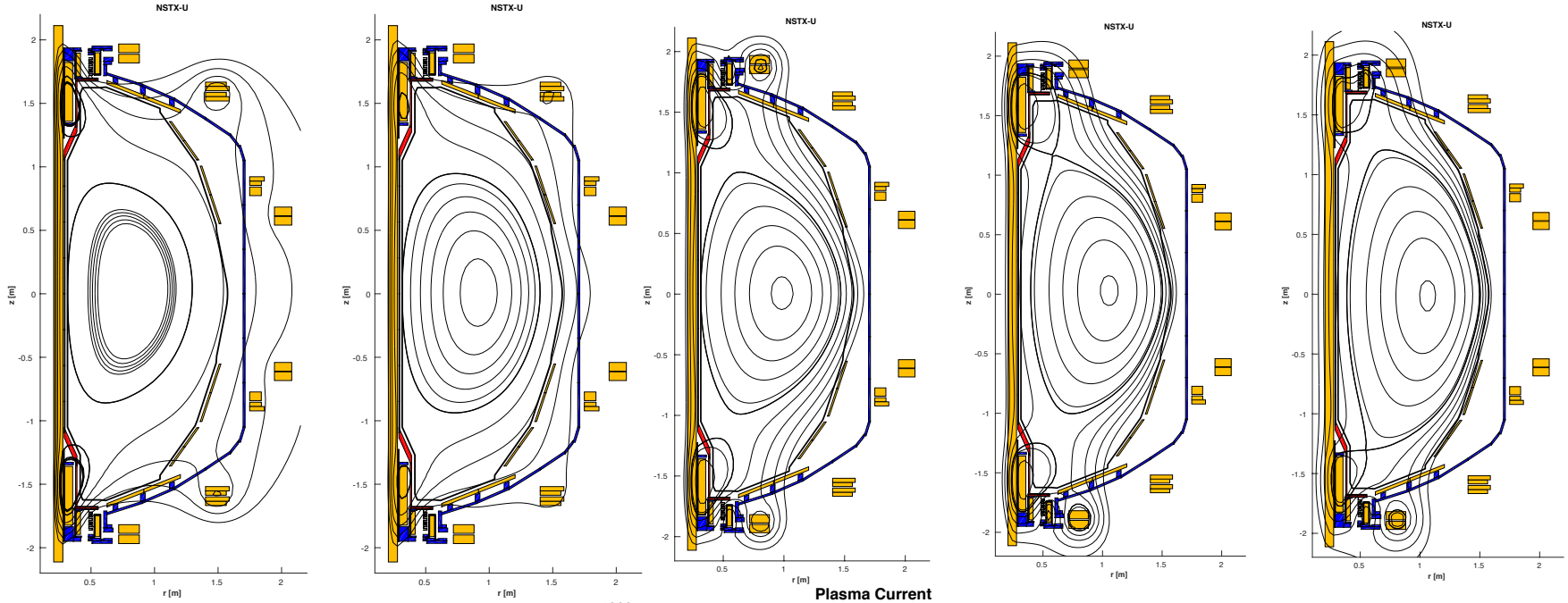
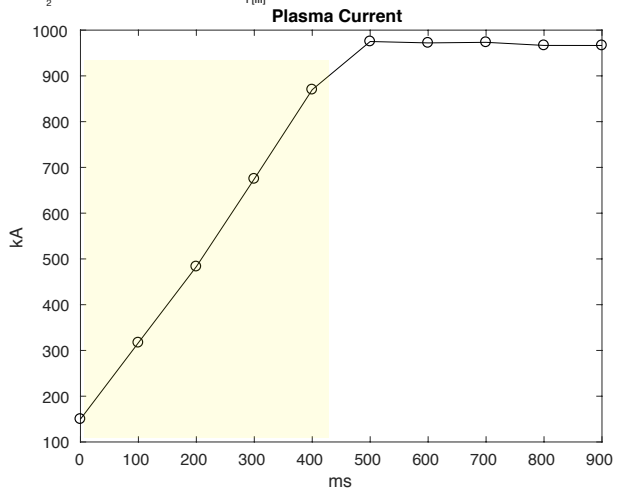


Several TokSys-compatible equilibria generated for Shot 204118





Formalism for linearized model development

Express the linearized circuit equations in state-space form
for use with model-based control design tools

$$\delta\dot{\mathbf{x}} = \mathbf{A}(t)\,\delta\mathbf{x} + \mathbf{B}(t)\,\delta\mathbf{u}$$

Perturbed currents

$$\delta\mathbf{x} = \begin{bmatrix} \mathbf{I_c} - \mathbf{I_{c}}_{eq} \\ \mathbf{I_v} - \mathbf{I_{v}}_{eq} \\ I_p - I_{p_{eq}} \end{bmatrix}$$

Perturbed voltages

$$\delta\mathbf{v} = \begin{bmatrix} \mathbf{V_c} - \mathbf{V_{c}}_{eq} \\ 0 \\ 0 \end{bmatrix}$$

$$\mathbf{A}(t) = -\left[\widehat{\mathbf{M}}(t)\right]^{-1}\mathbf{R}$$

$$\mathbf{B}(t) = \left[\widehat{\mathbf{M}}(t)\right]^{-1}\mathbf{V}$$

Resistance matrix $\mathbf{R}$

Map from voltages to coils $\mathbf{V}$

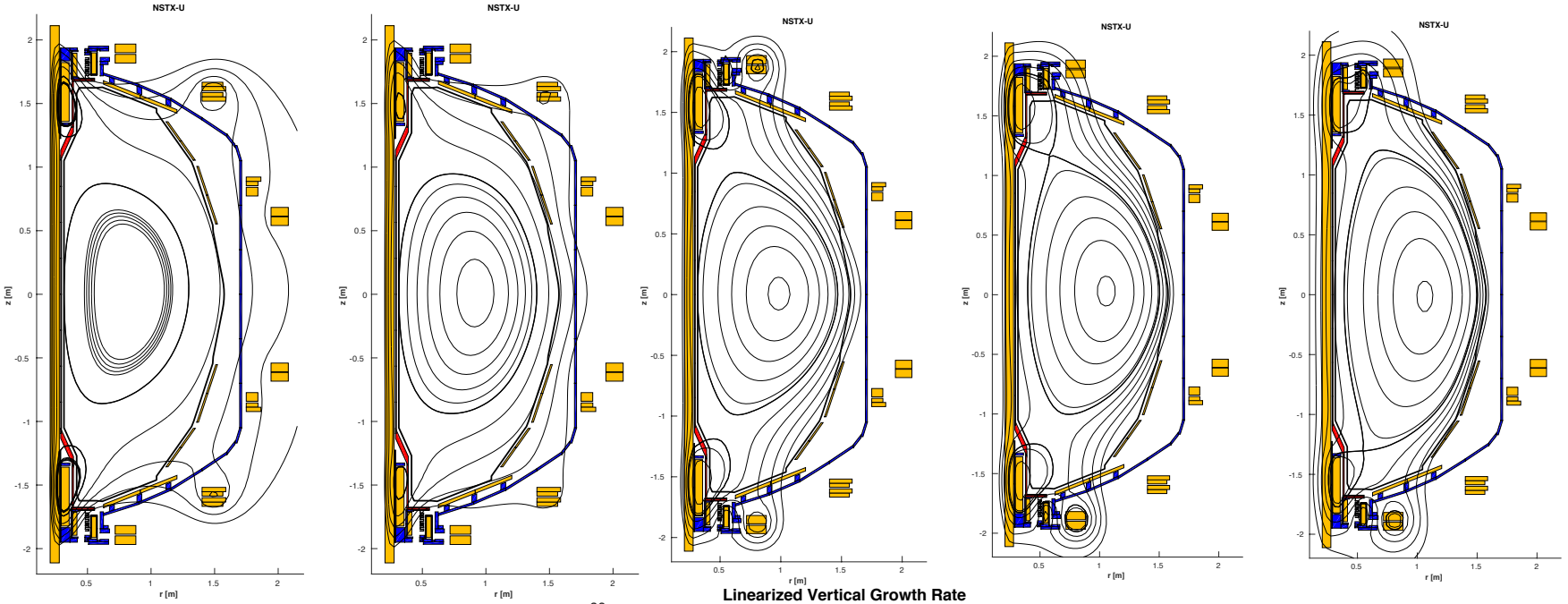
Time-dependent mutual inductance matrix

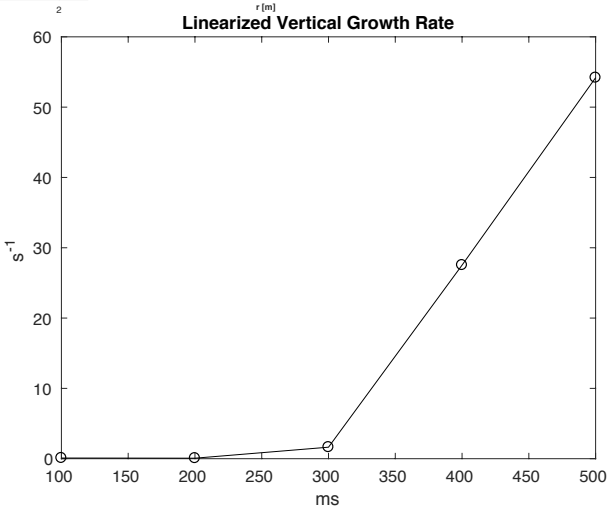
$$\widehat{\mathbf{M}}(t) = \mathbf{M} + \mathbf{X}(t)$$

Vacuum mutual inductances

Effective mutual inductance due to plasma motion

Linearized models generated for Shot 204118





Ramp-up simulation: Interpolate between linearized models