U.S. DEPARTMENT OF ENERGY | Office of Science

NSTX-U

NSTX-U PF1B discussion

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PPPL
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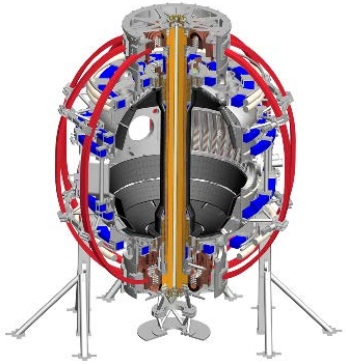
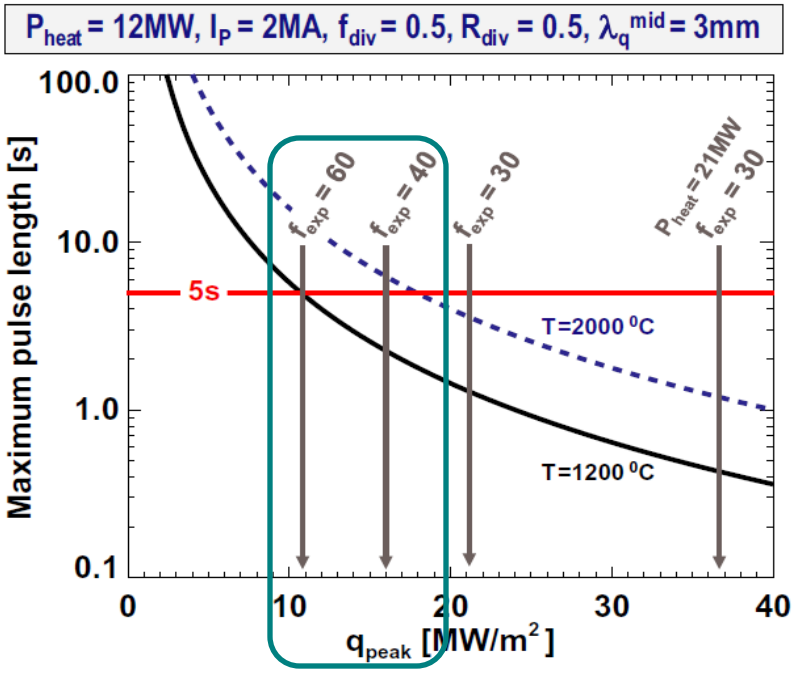


What are requirements for NSTX-U shape and divertor control – what are PF1 requirements?

- Simplistic version of roles of PF1 coils:
  - PF1A provides high-δ (up to 0.7) divertor for I_P = 2MA
  - PF1C → ability to control flux in divertor, have intermediate δ (δ = 0.4-0.5) higher than from PF2 alone (δ = 0.2-0.3)
  - PF1B assists in fine control of divertor flux – especially for maintaining stationary advanced divertors during OH swing
- Some form of advanced divertor (SFD- / X) is likely required to mitigate high heat flux in 2MA, 5s, 10-12MW pulses
  - Goal: such shapes should ideally also be compatible with cryo-pump for n_e control

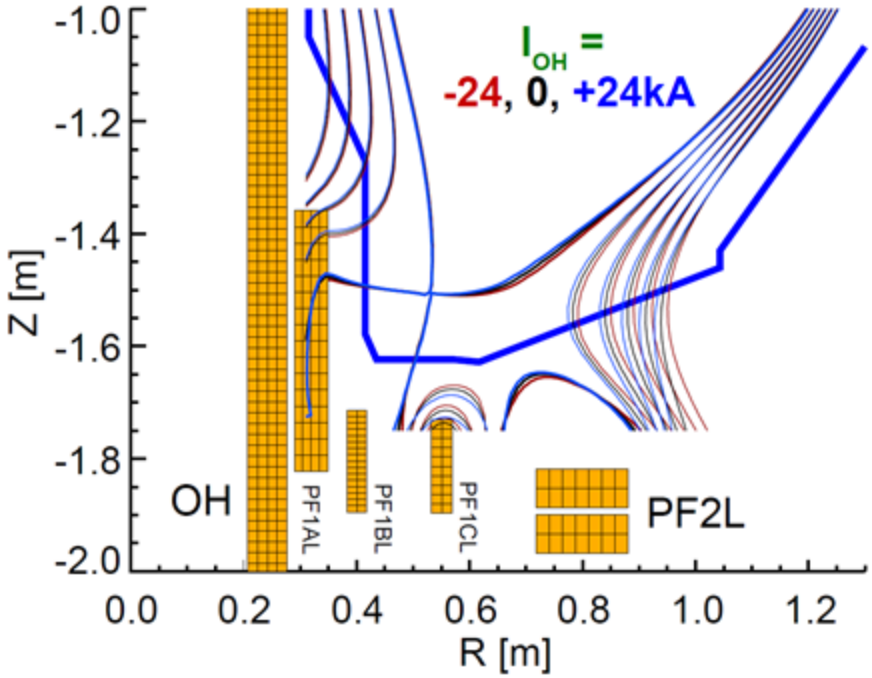


PF1B enables boundary shape, divertor flux / field, and power exhaust to be stationary during OH flux changes

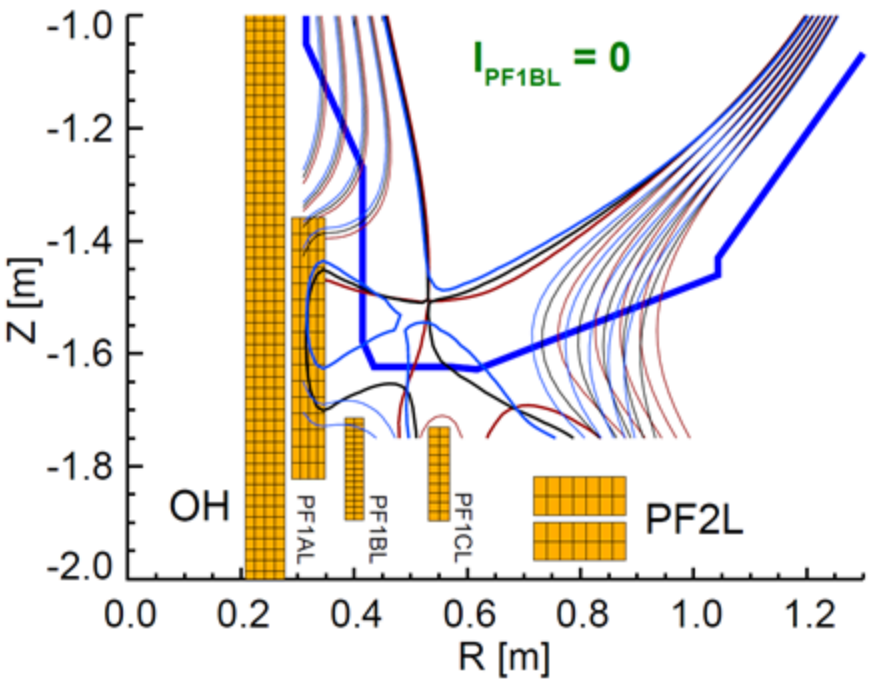
- I_{OH} = +24kA causes largest variation in strike-point location
  - Impact may be larger early in shot at lower I_P → lower PF1A,C current
- Less variation between I_{OH} = 0 (~2MA SOFT) → -24kA (EOFT)

➢ Impacts ramp-up, 2MA flat-top may be ok for standard divertor

2MA equilibrium: PF1B current ≠ 0



2MA equilibrium, PF1B current = 0



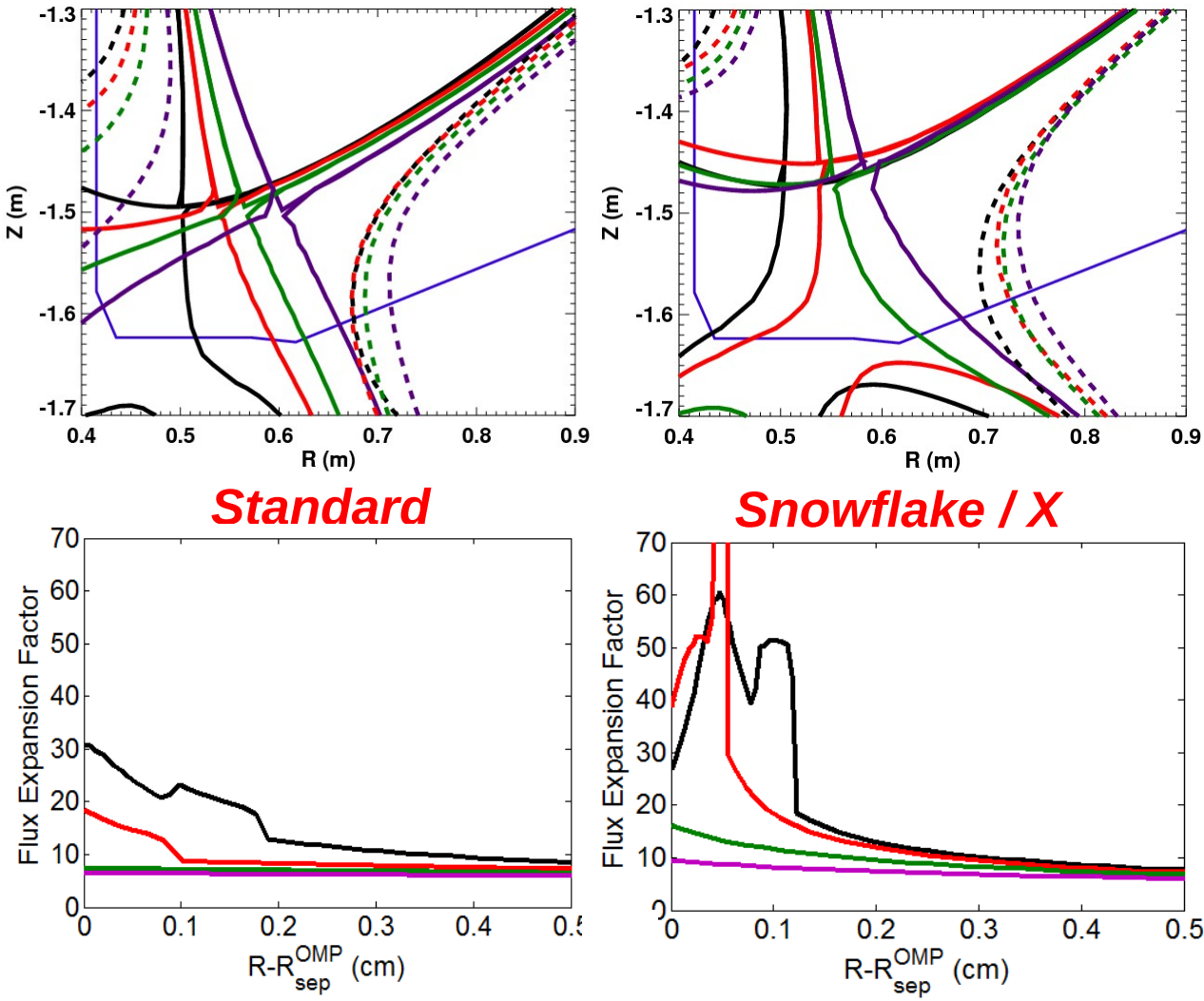
From Figure 44 in J. Menard, et al., Nucl. Fusion 52 (2012) 083015

Are SFD-/X shapes cryo-pumpable w/o PF1B?

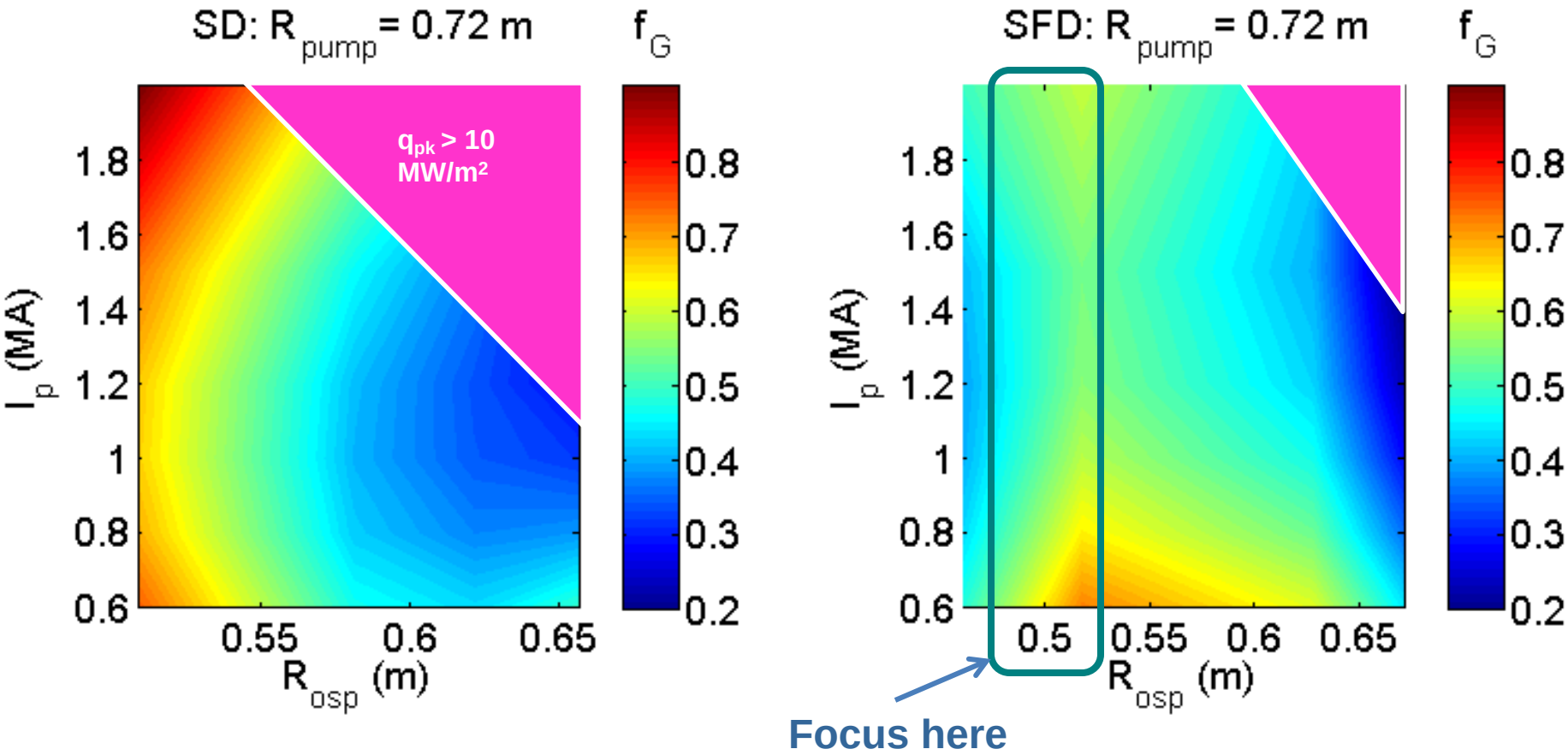
- Plasma shapes used in cryo-pump physics design allowed PF1B current, and had $I_{OH} = 0$
  - Equilibria were generated to vary strike point position for both conventional and SFD divertor configurations, since strike-point location vs. pumpability was the most critical trade-off in cryo-pump design
  - Did not study impact of OH swing since previous studies showed PF1B aided holding flux distribution during OH swing, and PF1B was assumed to be available when/if needed
- Need to revisit impact of time-varying OH and impact of no PF1B coil on controllability and pumpability of advanced shapes
  - Conventional shapes less impacted (?) and covered by SPG

Cryo-study: Equilibria w/ range of R_{OSP} and flux expansion used to map heat flux profiles, assess candidate pump entrance locations

- Standard and snowflake divertors considered
  - Four R_{OSP} each
  - ψ_N=1.0,1.03 shown
  - Movement of ψ_N=1.03 strike line is much less than that of R_{OSP}
- Flux expansion, flux surface geometry used to convert midplane heat flux profile (from scaling) to divertor flux
  - As R_{OSP} is increased, flux expansion is decreased



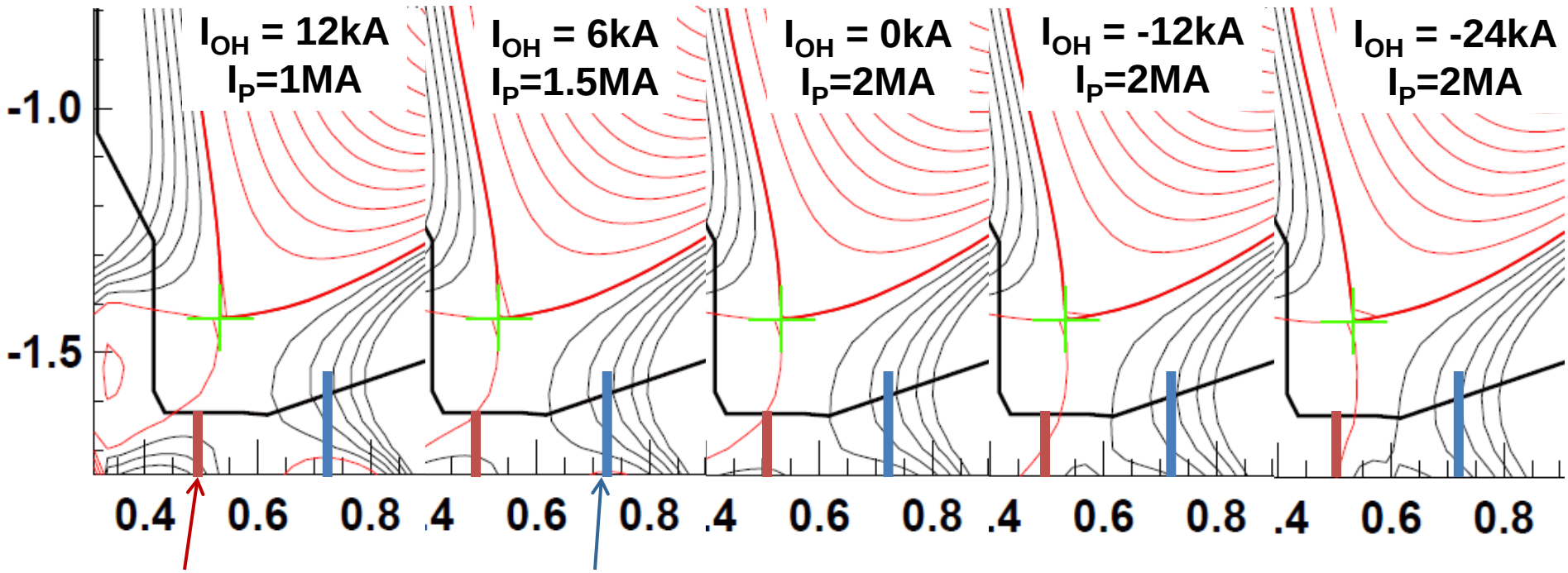
Optimized plenum geometry (R_{pump} = 0.72m) capable of pumping to low density n / n_G ~ 0.5 for a range of R_{OSP}, I_P



- **Equilibrium $f_{Greenwald}$ can be reduced down to < 0.5**
  - **Moving R_{OSP} closer to pump allows lower n_e, limited by power handling**

Preliminary analysis of SFD- w/o PF1B

- During 1 → 2MA ramp and 2MA flat-top, appears possible to have $q_\perp$ at plenum entrance roughly fixed, while keeping strike-point on inner target
  - Strike-point sweeps outward 3-7cm → flux compression

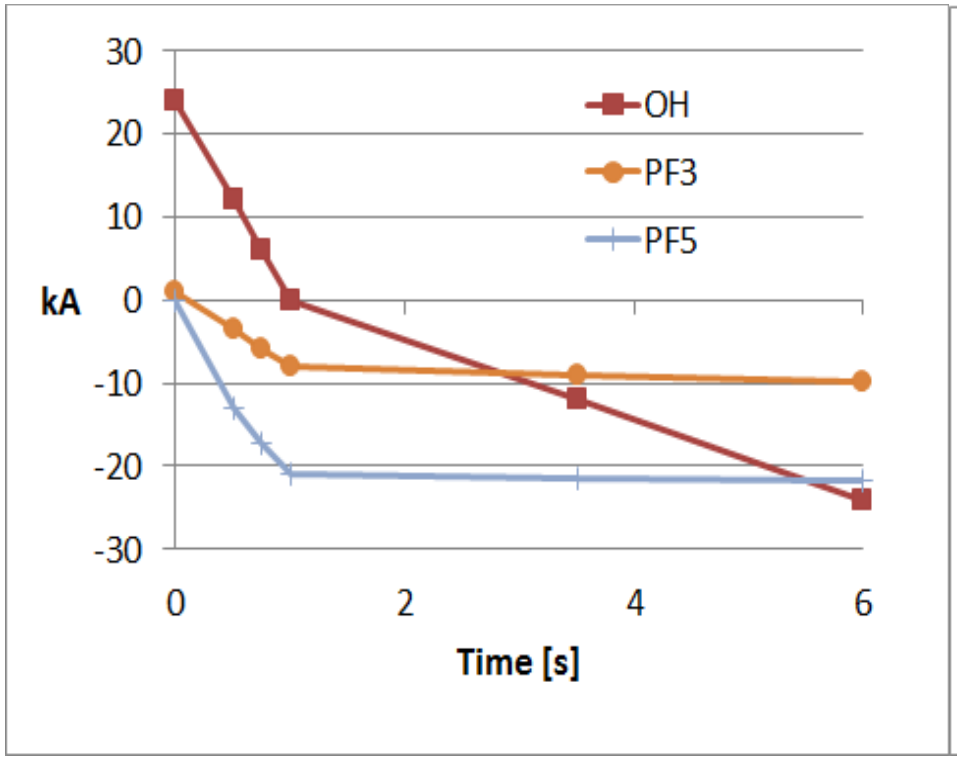


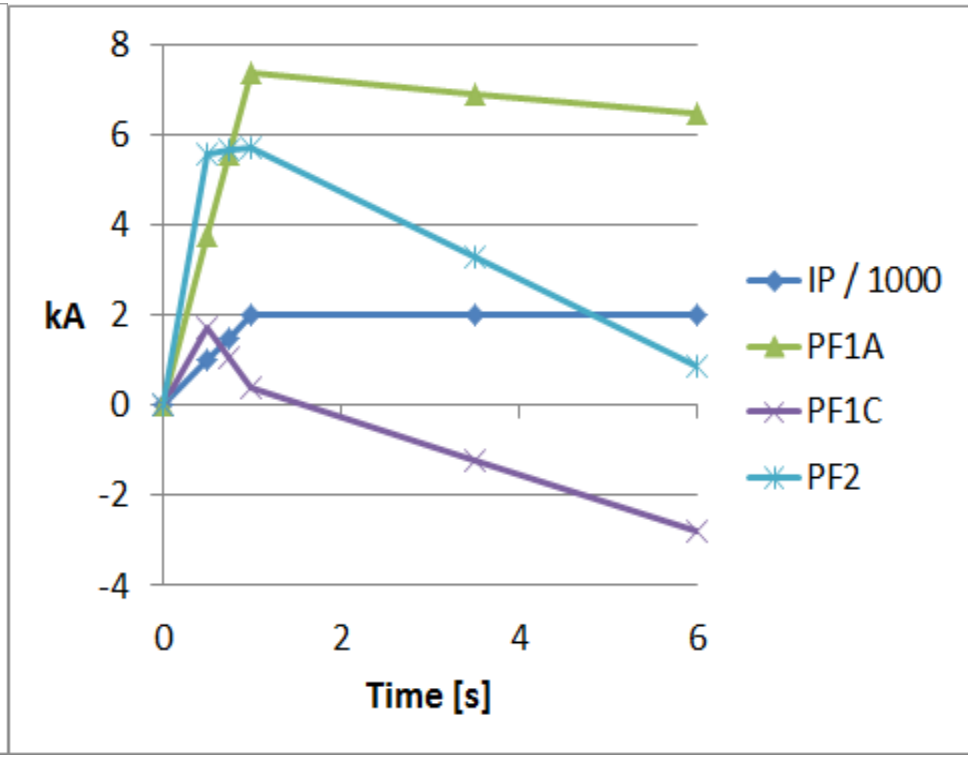
R=0.5m → SP target

R=0.72m → CPD plenum entrance

Probably need bipolar PF1C if no PF1B

$I_P = 1 \rightarrow 2MA$, $\beta_N = 4$, κ=2.5-2.6, l_i = 0.5-0.6





Possible next steps

- Compute estimated heat fluxes at cryo-entrance and on inboard tiles to see if consistent with heat-flux limits and density required at entrance for effective pumping

- Repeat calculations with PF1B included to assess differences / variations in flux profiles, and changes in plasma boundary and shaping

- Decide if strike-point sweeping range is acceptable w.r.t. physics goals and operational goals/limits