NSTX

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The impact of elongation and aspect ratio on the global stability of ST plasmas
XP-1142

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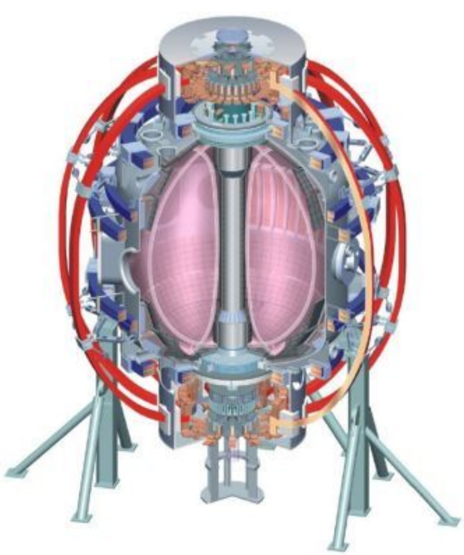
Stefan Gerhardt, et al.

MHD TSG Group Review



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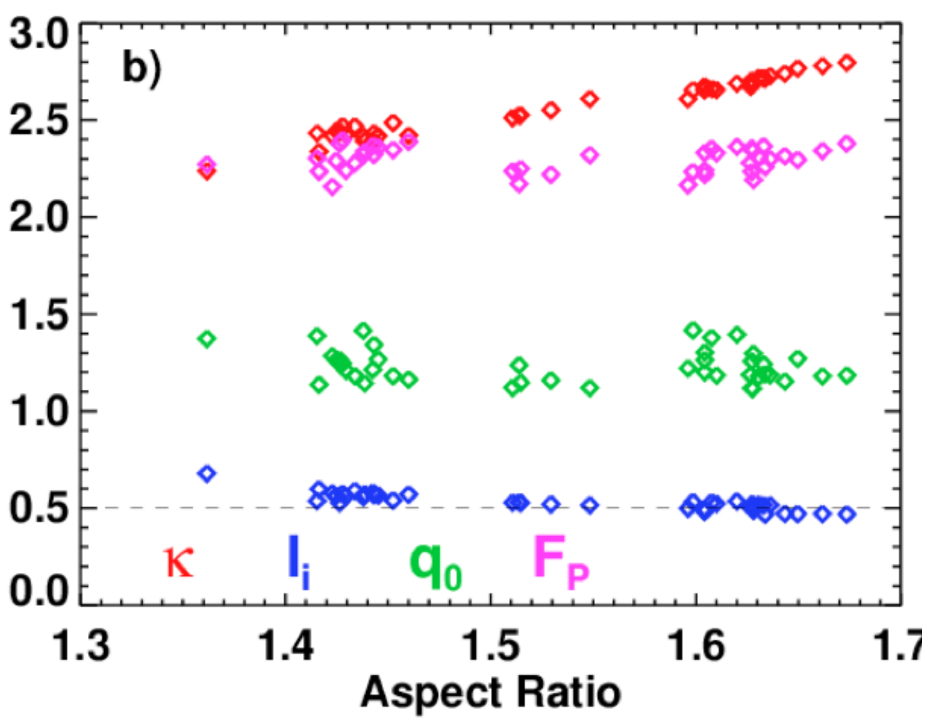
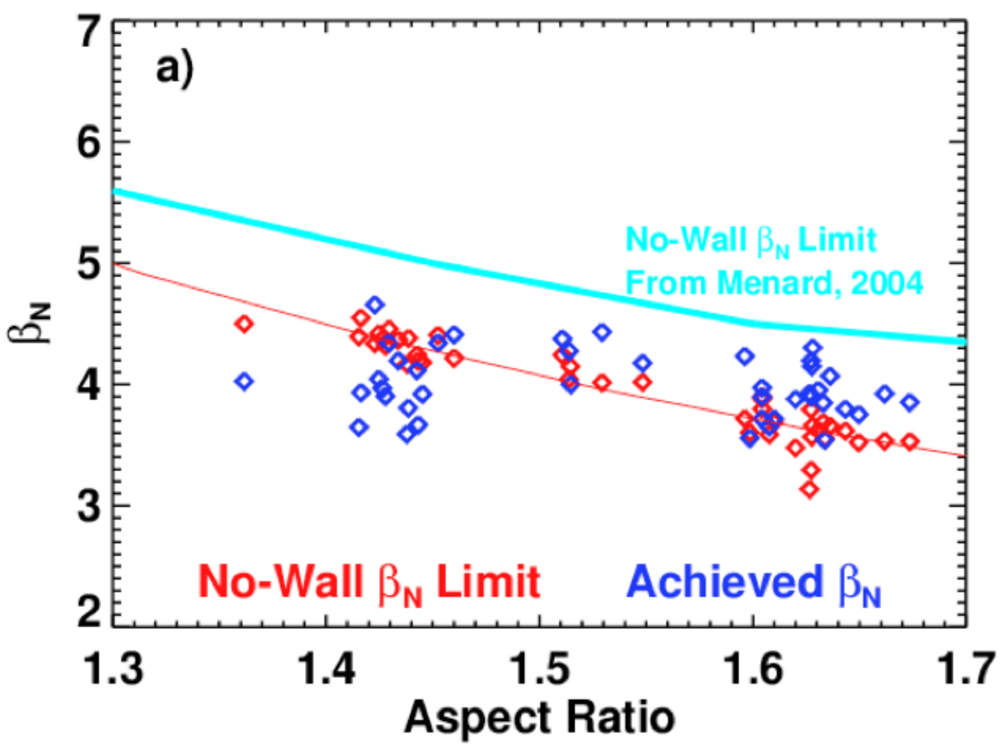
Big Picture

- NSTX has a large database of stability results with A<1.55 and κ<2.4.
  - NSTX upgrade will run at larger values of both these parameters, while needing β_N~4.5-6.5.
- It is hard to scan these parameters independently in NSTX…
- *Relevant Milestone Text: The maximum sustainable normalized beta will be determined versus aspect ratio (up to A=1.7) and elongation (up to 3) and compared to ideal stability theory using codes such as DCON and PEST.*
- Propose to do three types of scans:
  - Scan #1: Mixed κ & A scan at fixed outer gap and β_N (12 shots).
    - Use RFA analysis to look for passive instability.
  - Scan #2: A scan at fixed kappa (8 shots).
    - Test the disruptive β_N limit.
    - Look for tearing effect…destabilizing the GGJ term in MRE.
  - Scan #3: Kappa scan at fixed A (8 shots).
    - Test the disruptive β_N limit.
  - Scan #4: Go to highest possible elongation and aspect ratio (6 shots).
    - Test the disruptive β_N limit.
- Goals:
  - Determine if, within the achievable range of A and κ, there is a measurable change in global stability. Does n=0 or n=1 limit the strongly shaped, higher-A, high-β operating space? Do kinetic effects obscure the (somewhat modest) aspect ratio change.
  - Collect data validating (or not) the β-limit assumptions for NSTX Upgrade.

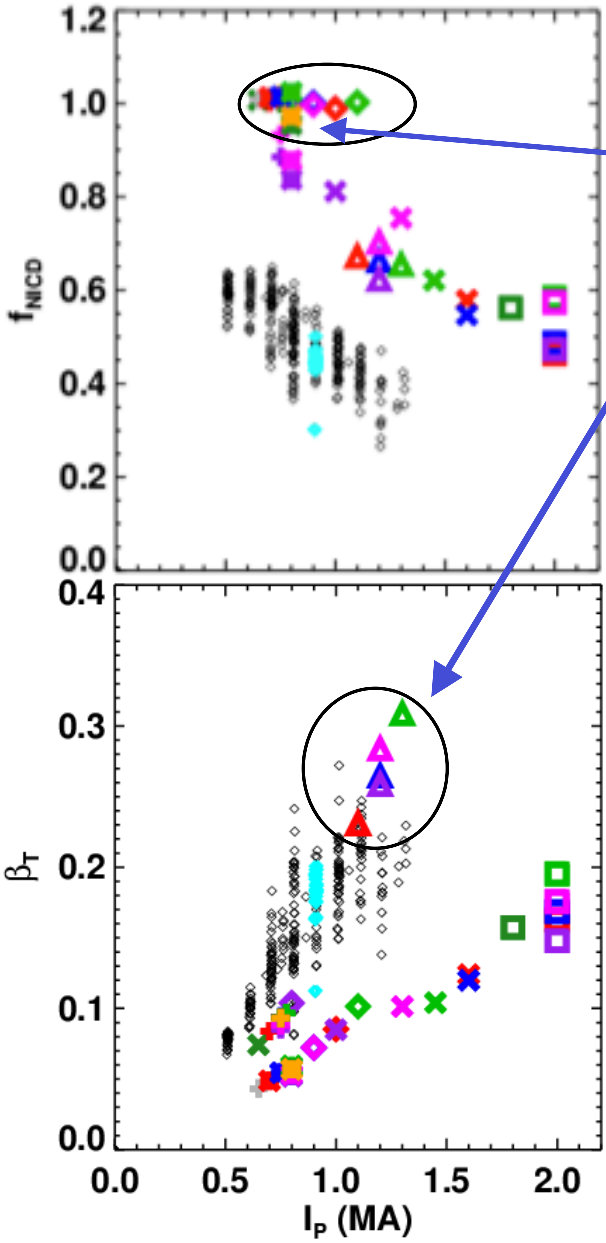
We know that ideal stability limits are reduced as the aspect ratio increases

- Discharges from XP-1071. Use experimental shapes and profiles.
- No-wall β_N limit reduced by 0.75-1 units as the aspect ratio is increased.
- No effort made to assess the β_N limit in these scans…were run with a constant input of 4 MW.

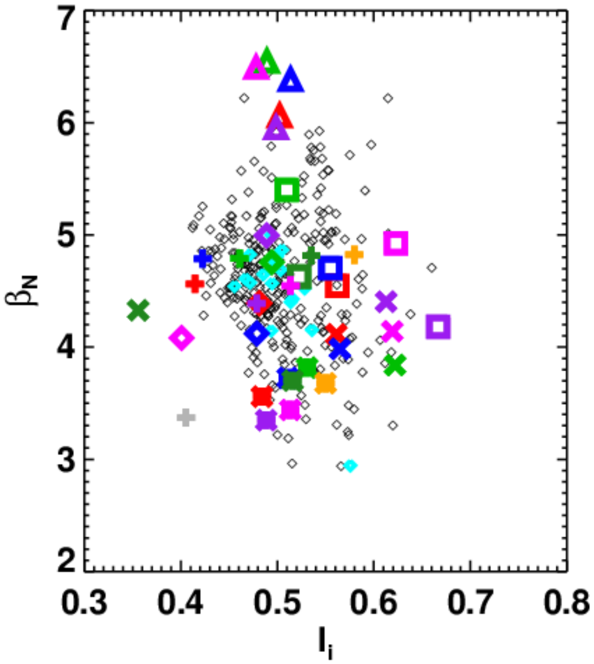


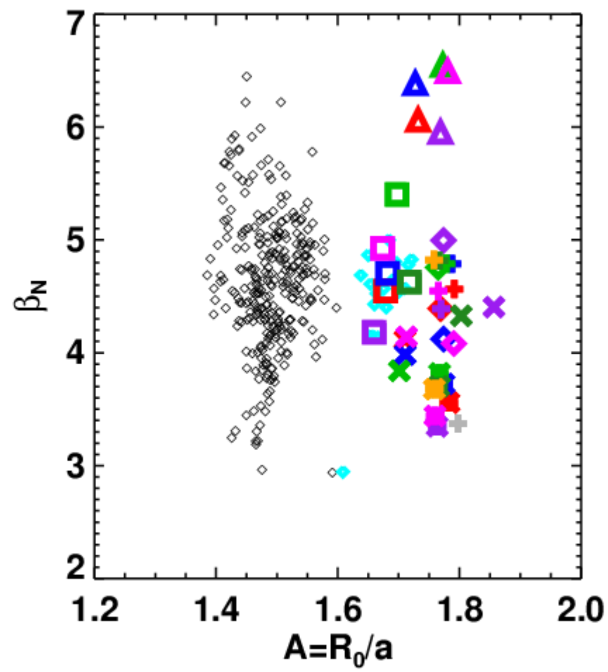


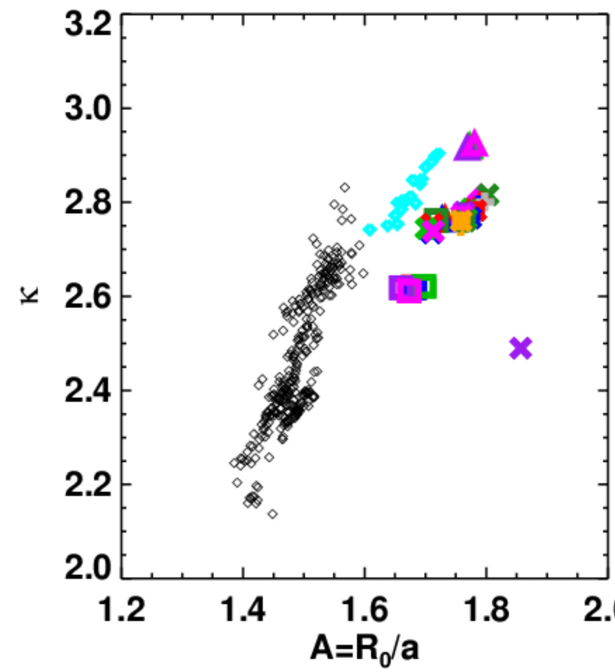
High-Performance Scenarios For NSTX-Upgrade Will Need High β_N at Larger A and κ



Optimize for:
High-f_{NI} at large I_P
High-β_T (with q_{min}>1)

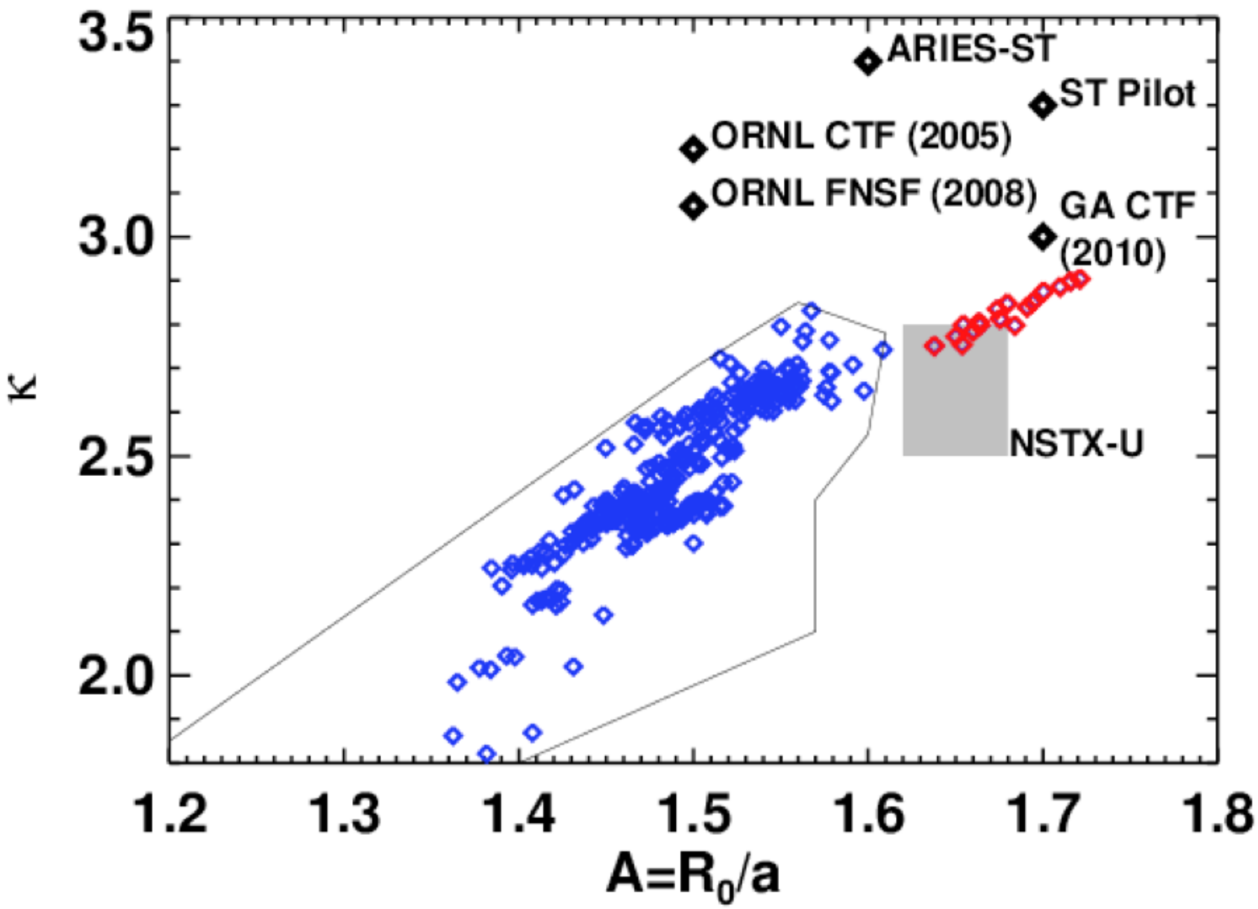






In General, It is Hard to Scan A and κ Independently

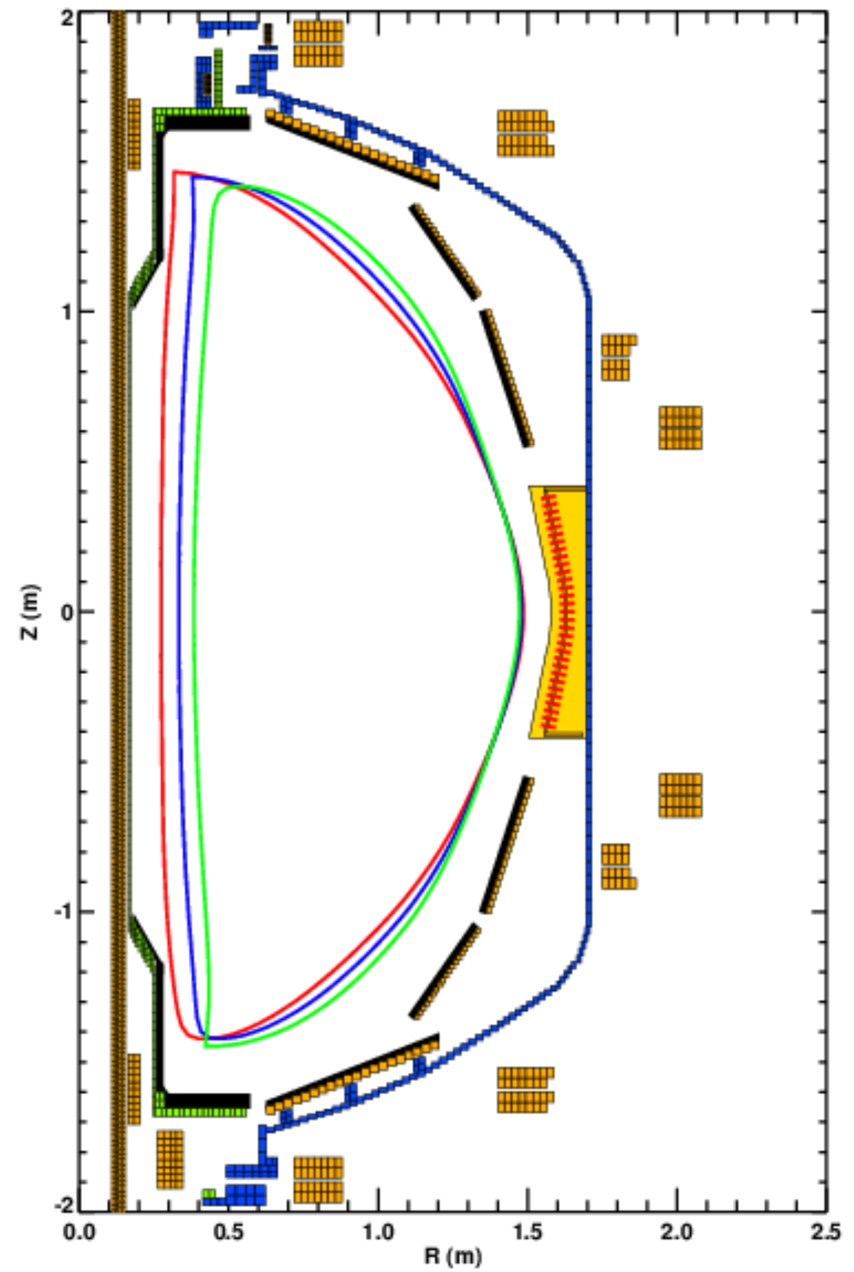
- Fundamental Issue: the inner gap is not an independently controlled quantity.



Scan of Kappa and A can be Achieved by Scanning the Inner Gap at Fixed Outer Gap.

- This method was used in XP-1071.
  - Was able to rapidly complete scan.
  - High-A limit set by PF-1A current limit.
- This scheme facilitates RFA measurements
  - Maintains approximately constant distance between plasma boundary and RWM B_P sensors.
  - Shapes have 8 cm outer gap to increase signal levels.

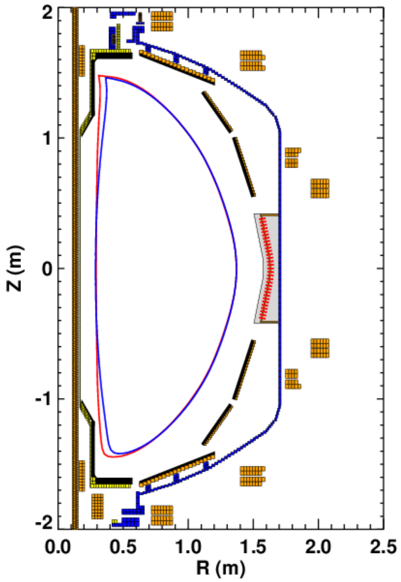
A	κ	I_P	q_{95}	I_{PF-1A}
1.71	2.63	700	9.8	19.6
1.58	2.49	700	12.48	13.3
1.46	2.37	700	18.3	7

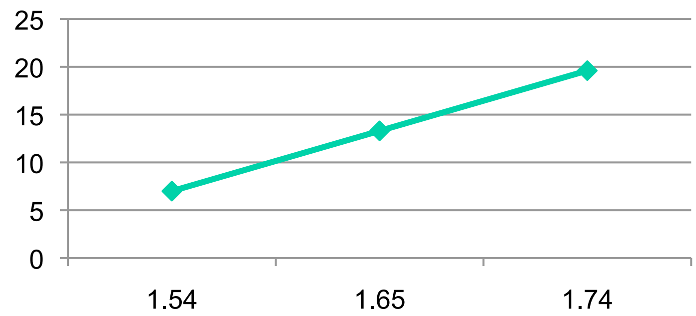


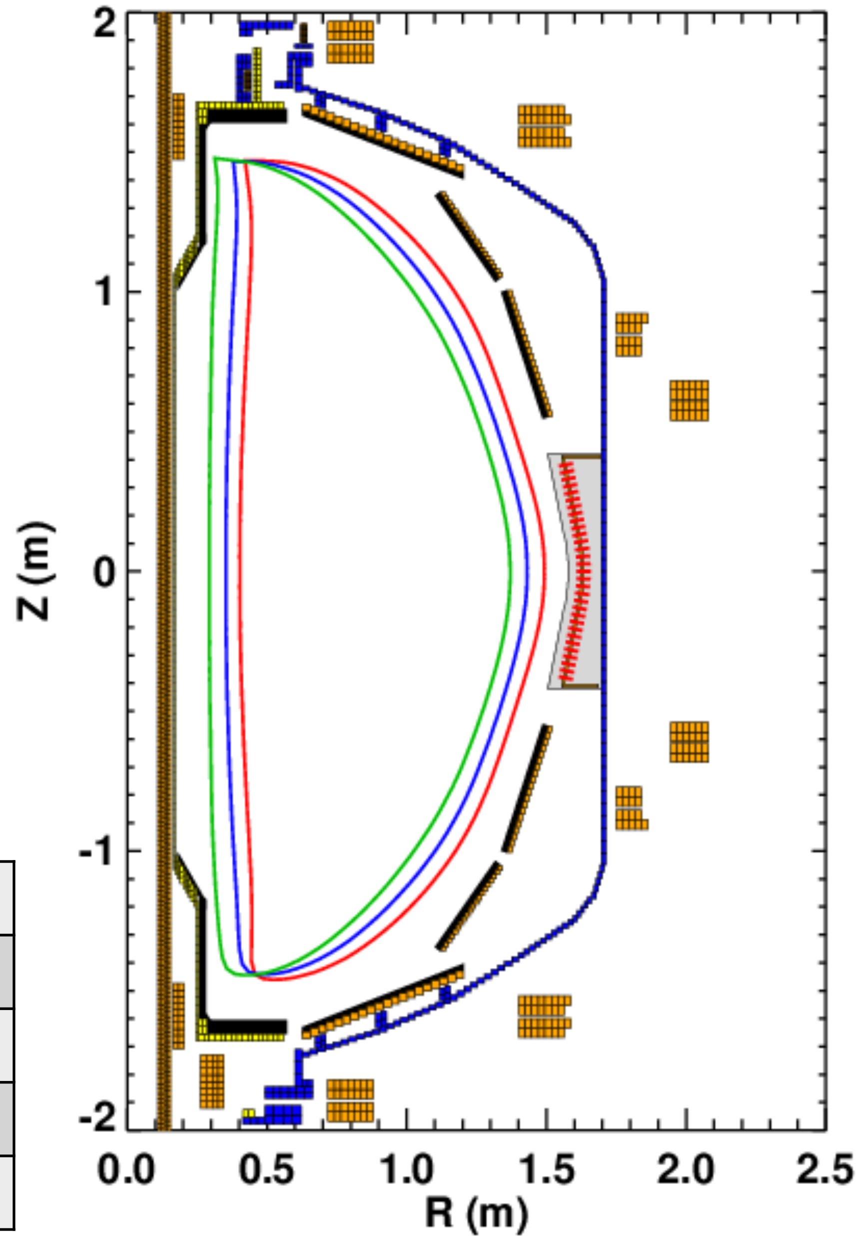
Scan of A at Fixed Kappa With Constant I_P or Constant q_{95}

- High aspect ratio limit set by the PF-1A coil current limit.

700 & 1000 kA



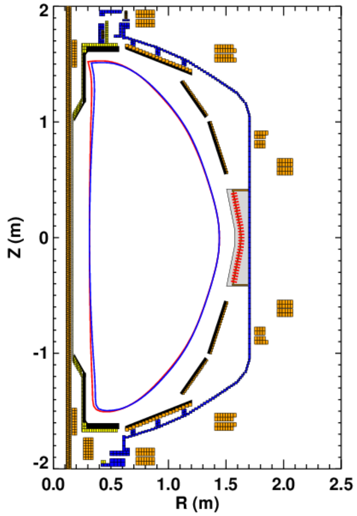


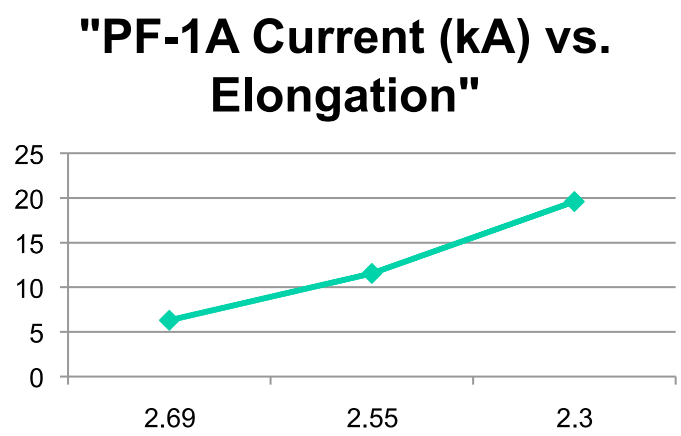


A	κ	I_P	q_{95}	$I_{PF\text{-}1A}$
1.53	2.64	1000	9	18.9
1.54	2.7	700	18	7
1.65	2.69	700	12	13.3
1.74	2.67	700	9.5	19.6

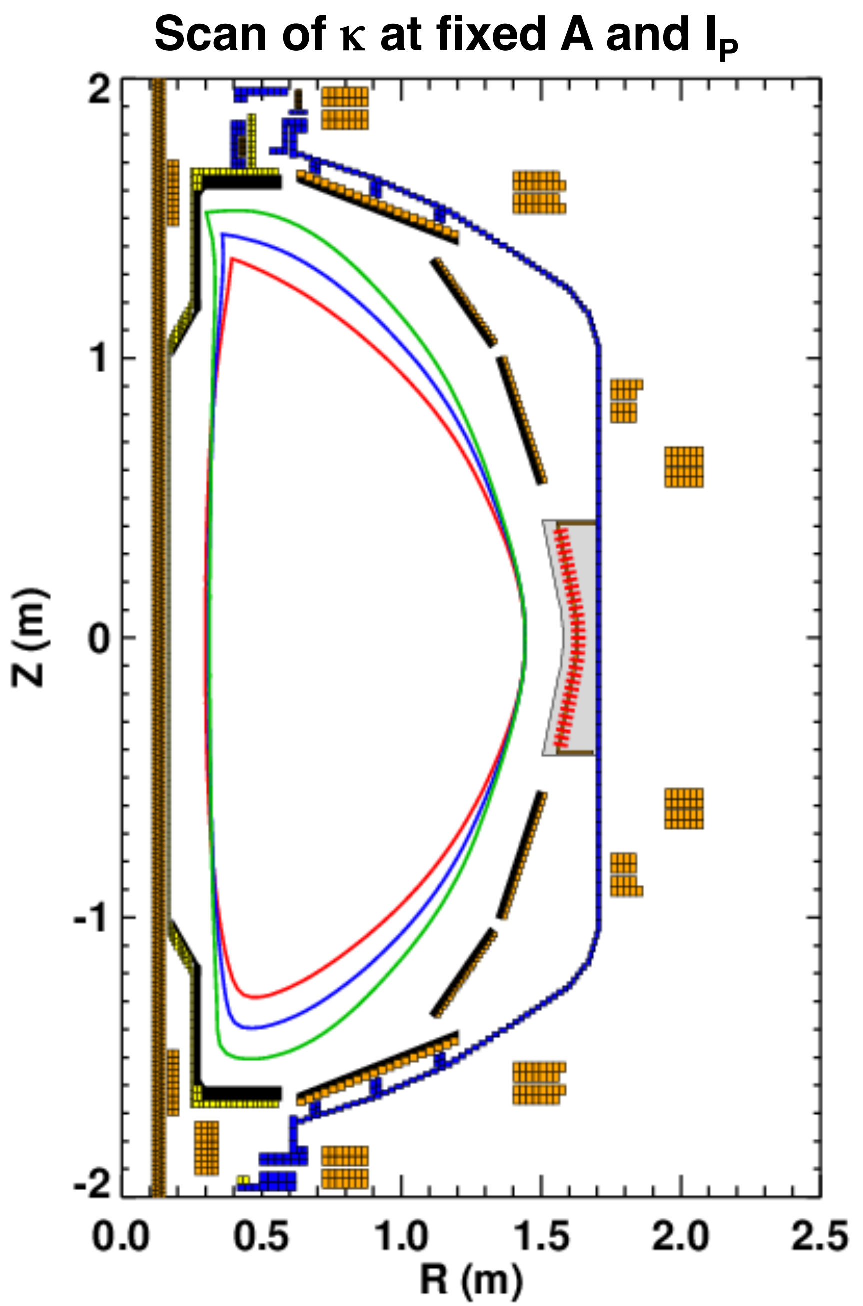
Scan of Kappa At Fixed A. With Constant I_P or Constant q_{95}

- Low elongation limit is set by current limit on the PF-1A coil.
  - Otherwise the inner gap shrinks
  - 700 kA plasma need 19.6 kA of PF-1A





A	κ	I_P	q_{95}	I_{PF-1A}
1.56	2.66	825	12.1	10.7
1.55	2.69	700	17.9	6.3
1.55	2.55	700	13.9	11.6
1.52	2.3	700	12.03	19.6

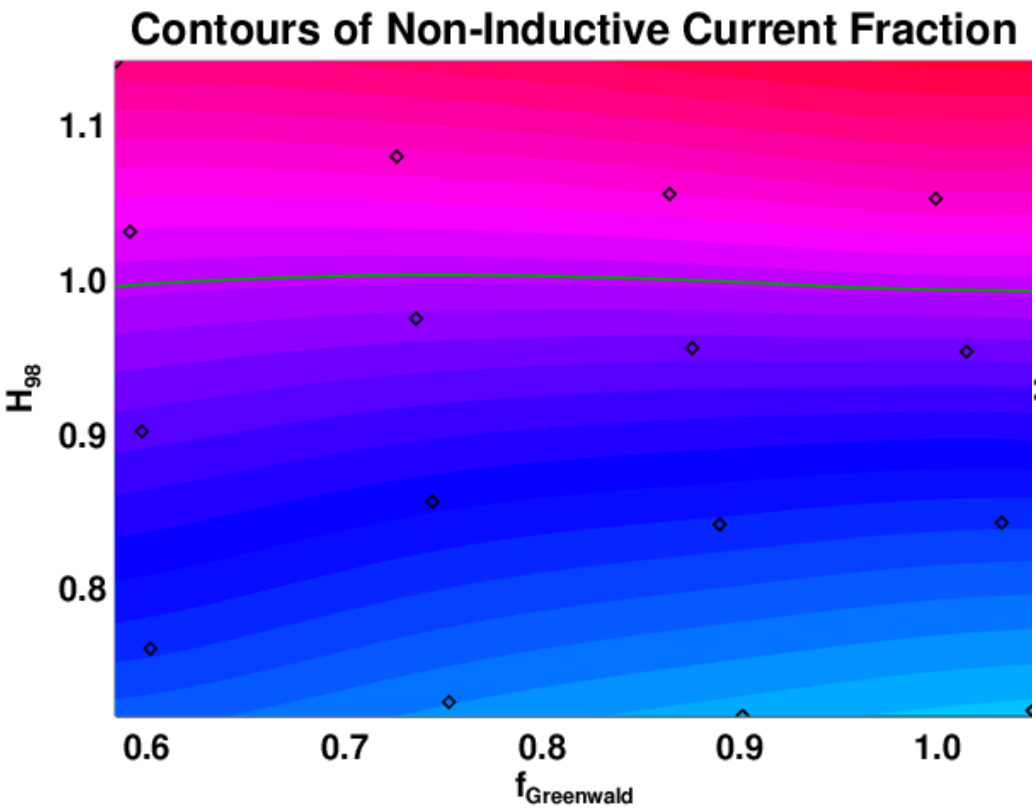


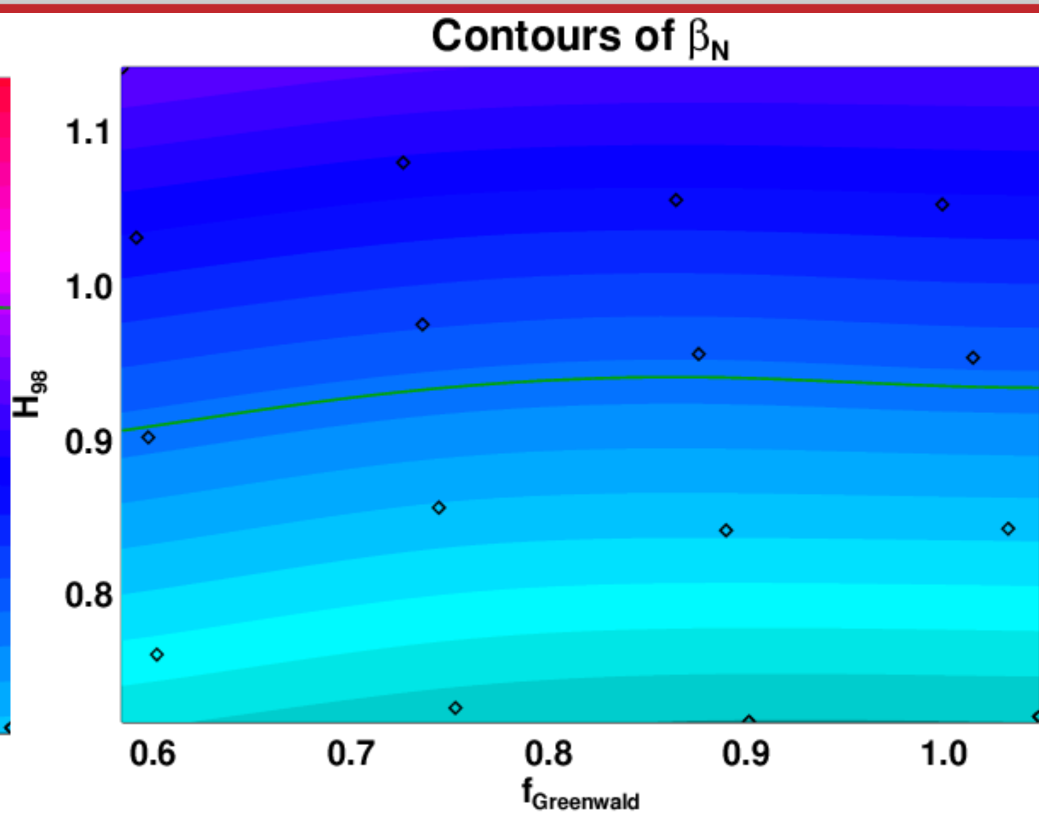
XP Plan Summary

- Plan
  - Step 1: Inner gap scan for RFA measurements. (12 shots)
    - Use three shapes.
    - Make RFA measurements at β_N=4 and 4.5 (or 5?) (use β_N controller?).
      - 30 Hz co-propagating waves. No magnetic breaking.
    - Do we see much stronger RFA as the aspect ratio is increased (and no-wall limit is reduced)?
  - Step 2: Aspect ratio scan at fixed kappa. (6 shots)
    - Use β_N controller to ramp to the disruptive β_N limit
  - Step 3: Kappa scan at fixed A. (6 shots)
    - Use β_N controller to ramp to the disruptive β_N limit.
  - Step 4: Go to very high elongation(~3) and aspect ratio (1.75):
    - Use β_N controller to ramp to the disruptive β_N limit.
- Questions/Comments
  - Should use slow n=1 control only, to better isolate stability limits?
  - ASC XPs designed to improve the vertical control system and develop discharge shapes should be attempted before this XP.
- Analysis: Experimental equilibrium analysis with EFIT & LRDFIT, TRANSP for data integration, comparison to ideal stability theory (DCON & PEST), something for RFA measurements?

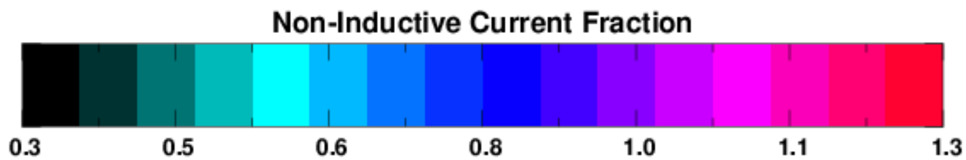
Backup

Interesting NSTX-U Scenarios have β_N~4.5 (and Greater)



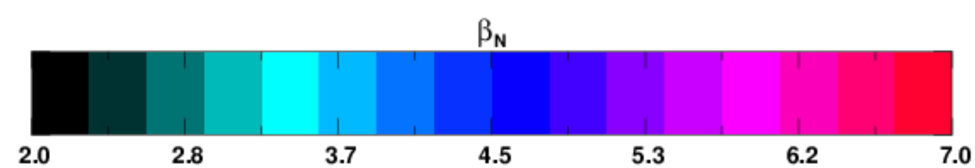


1.0 T, 900kA, A=1.65, κ=2.7, R_{tan}=[50,60,70,110,120,130] 90 kV Beams



Scan #20

.0 T, 900kA, A=1.65, κ=2.7, R_{tan}=[50,60,70,110,120,130] 90 kV Beams



Scan #20

We want to confirm/test that β_N~5 is sustainable at the highest κ and A achievable.