NSTX

Supported by

U.S. DEPARTMENT OF ENERGY | Office of Science

XP-1071: High Aspect-Ratio and Elongation Shot Development

S.P. Gerhardt

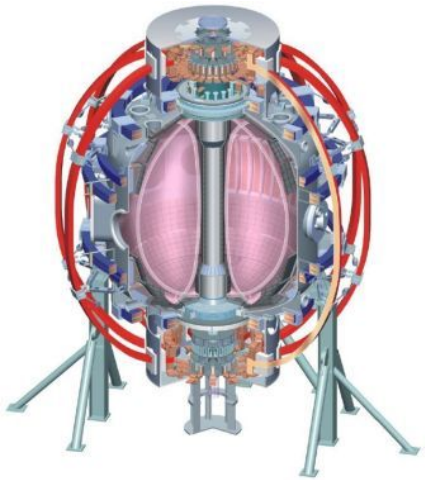
E. Kolemen, J.E. Menard, S.A. Sabbagh

and the NSTX Research Team

NSTX Late 2010 + Early 2011 Results Review

College W&M
Colorado Sch Mines
Columbia U
CompX
General Atomics
INL
Johns Hopkins U
LANL
LLNL
Lodestar
MIT
Nova Photonics
New York U
Old Dominion U
ORNL
PPPL
PSI
Princeton U
Purdue U
SNL
Think Tank, Inc.
UC Davis
UC Irvine
UCLA
UCSD
U Colorado
U Illinois
U Maryland
U Rochester
U Washington
U Wisconsin

Culham Sci Ctr
U St. Andrews
York U
Chubu U
Fukui U
Hiroshima U
Hyogo U
Kyoto U
Kyushu U
Kyushu Tokai U
NIFS
Niigata U
U Tokyo
JAEA
Hebrew U
Ioffe Inst
RRC Kurchatov Inst
TRINITI
KBSI
KAIST
POSTECH
ASIPP
ENEA, Frascati
CEA, Cadarache
IPP, Jülich
IPP, Garching
ASCR, Czech Rep
U Quebec

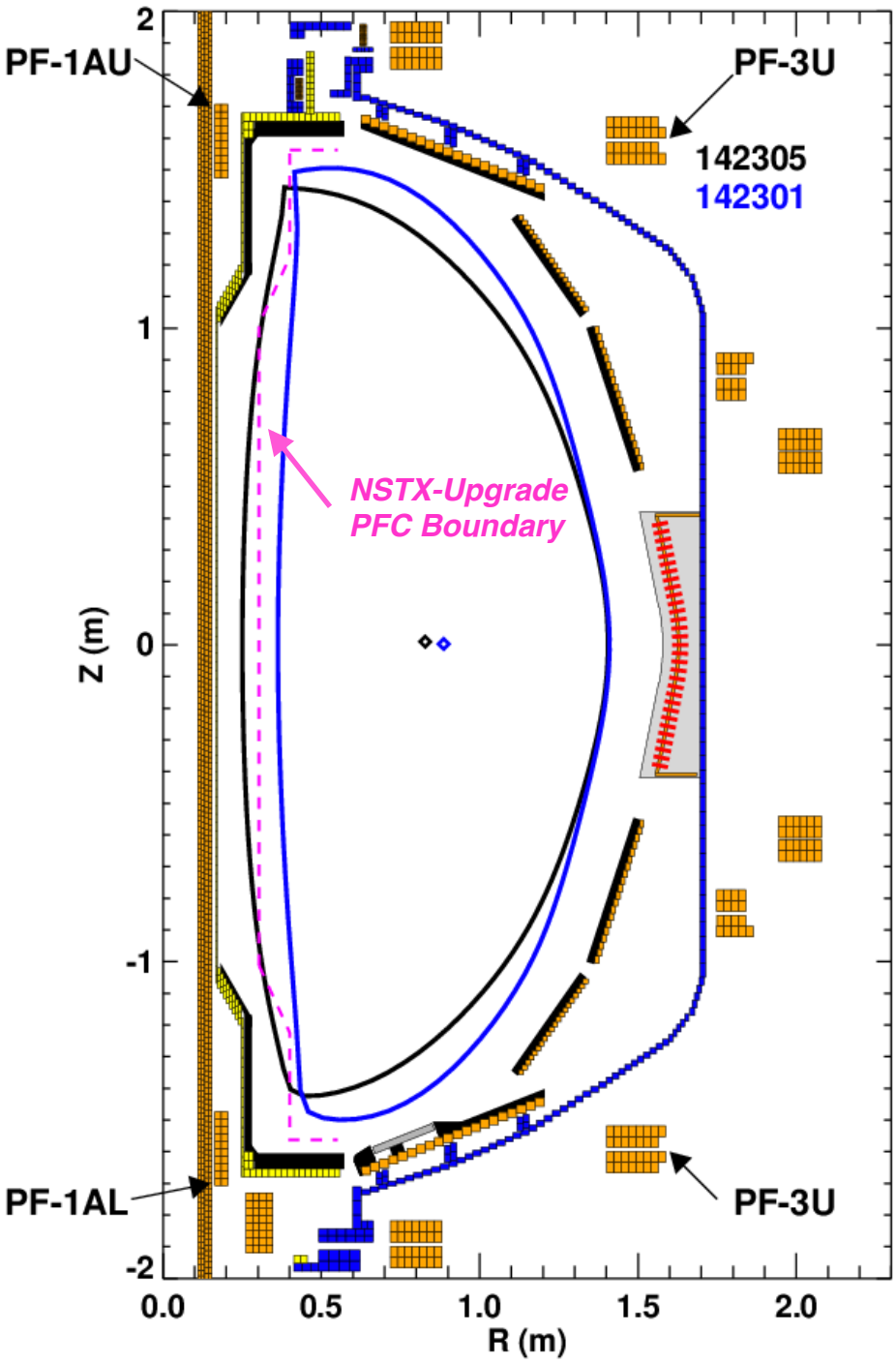


Overview of XP

- Why study plasmas with larger aspect ratio?
  - Get at the physics of the ST.
  - NSTX-Upgrade will have a larger aspect ratio.
  - Many next-step ST designs are at somewhat larger aspect ratio.
- Did a successful XP to start these studies.
  - Machine not optimal…single LITER before the day started.
- Day #1: 4 shots
  - Found a strong increase in the passive vertical growth rate vs A ($=R_0/a$).
- Day #2: 17 shots
  - Studied plasma performance vs. A and κ.
  - Plasmas with good performance were achieved for NSTX-U shapes.
  - Found that the l_i widow for n=0 stable operation may be much reduced.

New Shapes Were Developed

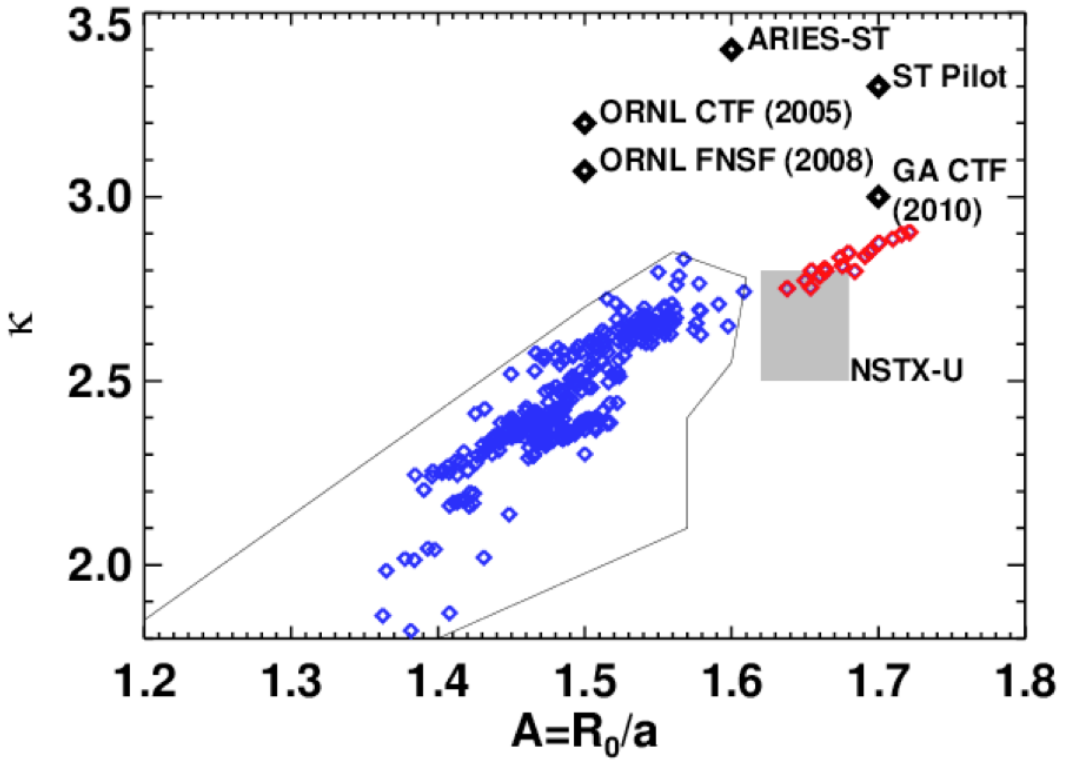
- Increase PF-1A currents to open the inner gap.
- Decrease PF-3 current to make the plasma taller.
- Fix outer gap.
- Two examples:
  - Black is close to fiducial
    - κ=2.4, A=1.45
    - $I_{PF\text{-}1A}$=11.5 kA, $I_{PF\text{-}3}$=4 kA
  - Blue is near extreme in scan
    - κ=2.8, A=1.65
    - $I_{PF\text{-}1A}$=19 kA, $I_{PF\text{-}3}$= 3 kA
- All sustained for a couple of τ_{CR}.



Discharges Are An Important Extension of the NSTX Operating Space

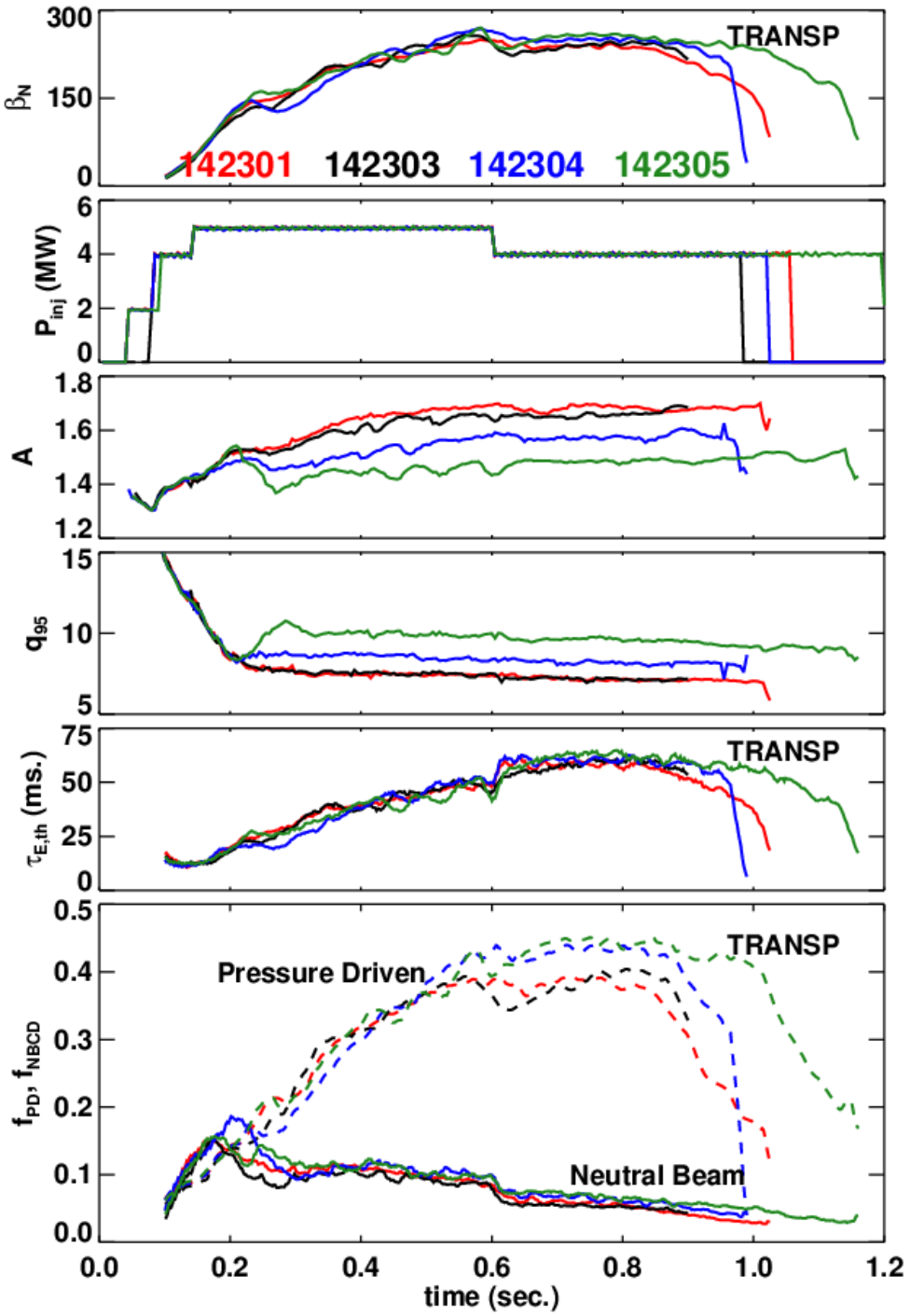
- Black lines enclose traditional NSTX operating space.
- Note strong coupling between aspect ratio and elongation.
- Record NSTX elongations for long(er) pulses and high(er) elongations.

Black Lines: Boundary of traditional NSTX operating space.
Blue Points: High-performance discharges.
Red Points: XP-1071, stable for at least 100 msec.



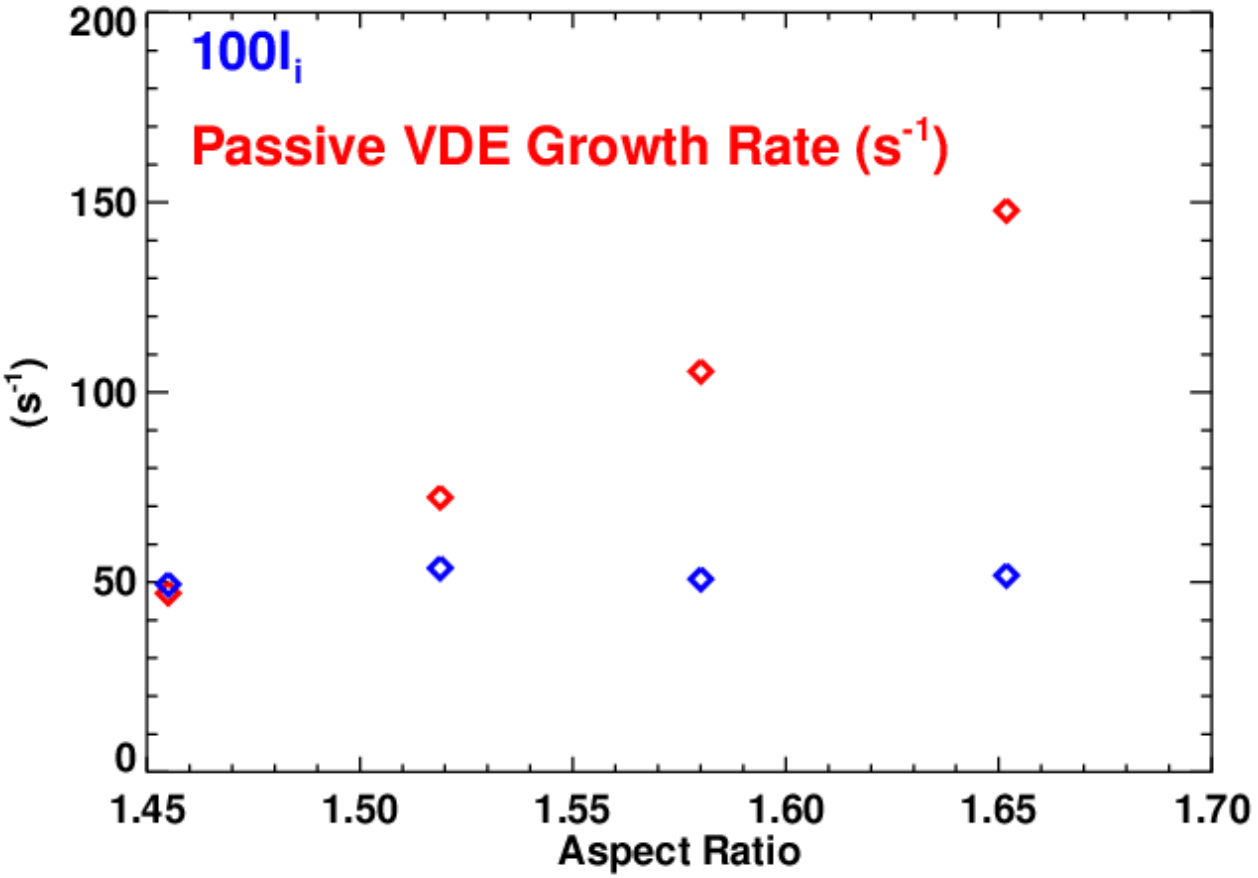
Good Performance Over a Range of Aspect Ratios

- I_P=900 kA, B_T=0.45 T
- Some drop in β_N at higher A (for fixed P_{inj}).
- Big hit in q_{95}. (10->7.5)
  - More ITER relevant way to get low-q_{95} RMP data?
- Confinement is degraded by ~10%.
  - H from 1.02 to 0.85.
- T_e is a bit lower, which hurts the NBCD.



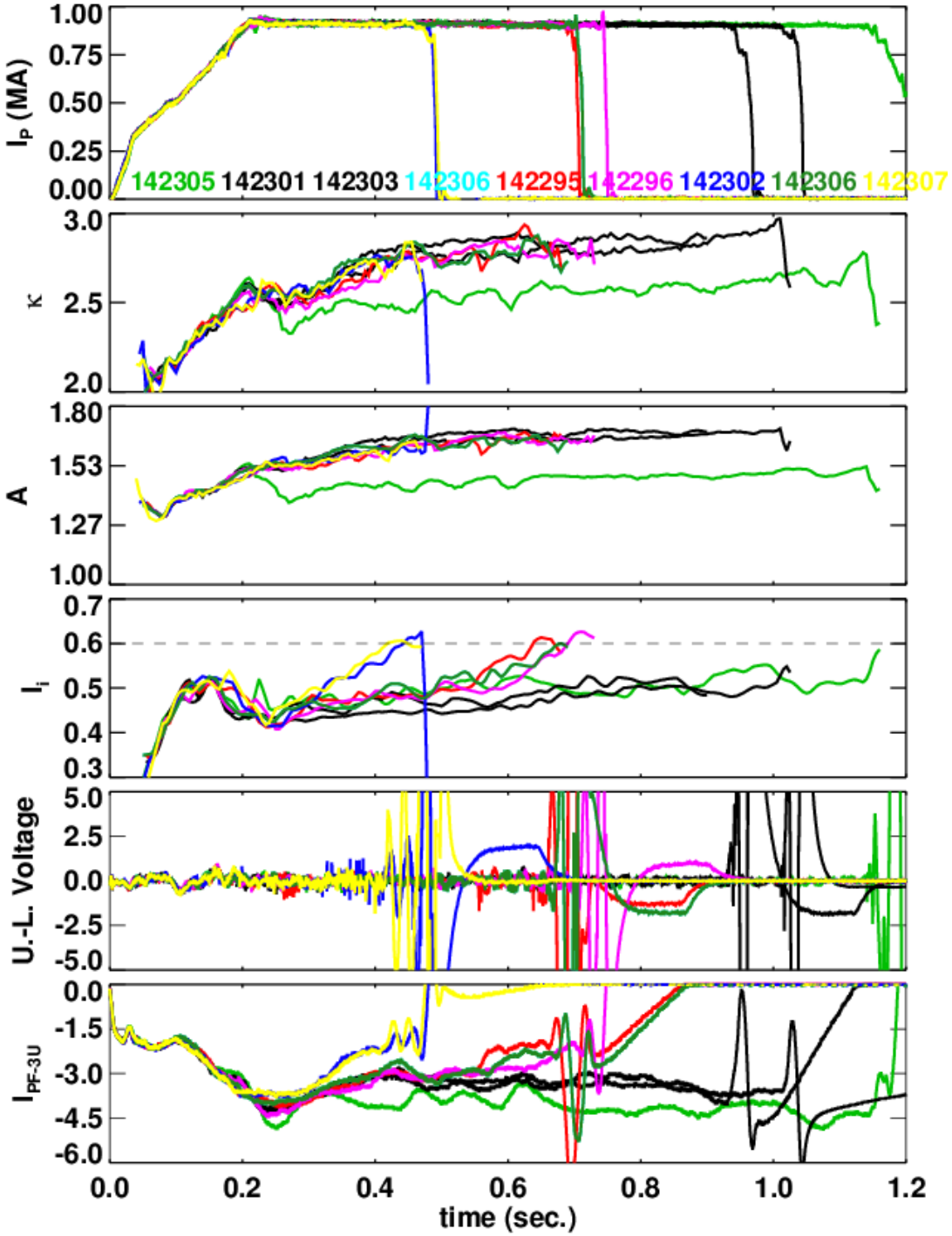
Passive Growth Rate Found To Increase With Aspect Ratio

Freeze Vertical Control, Allow the Plasma to Drift Vertically.



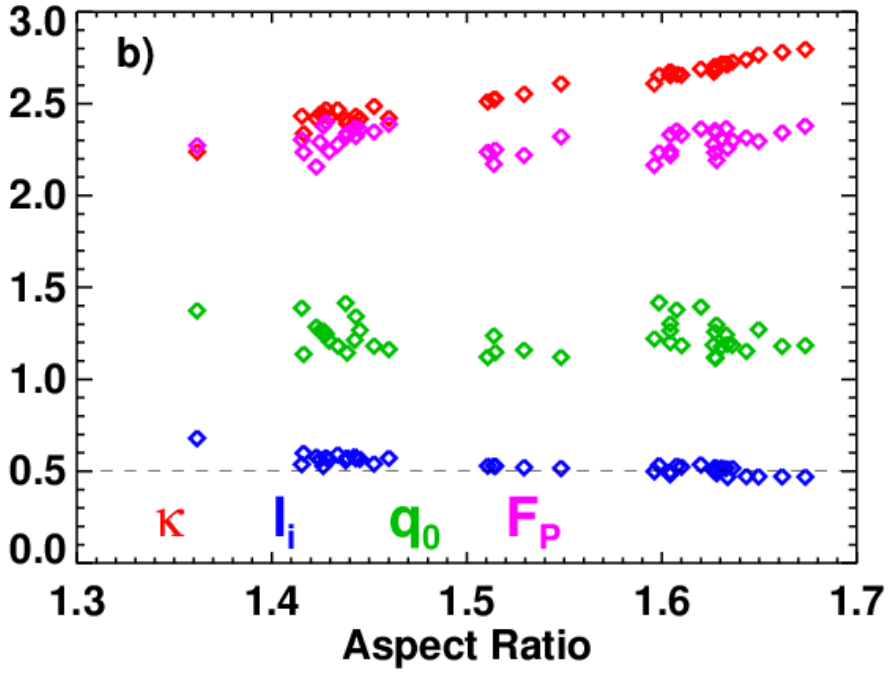
l_i MUST Be Kept Low To Avoid VDEs

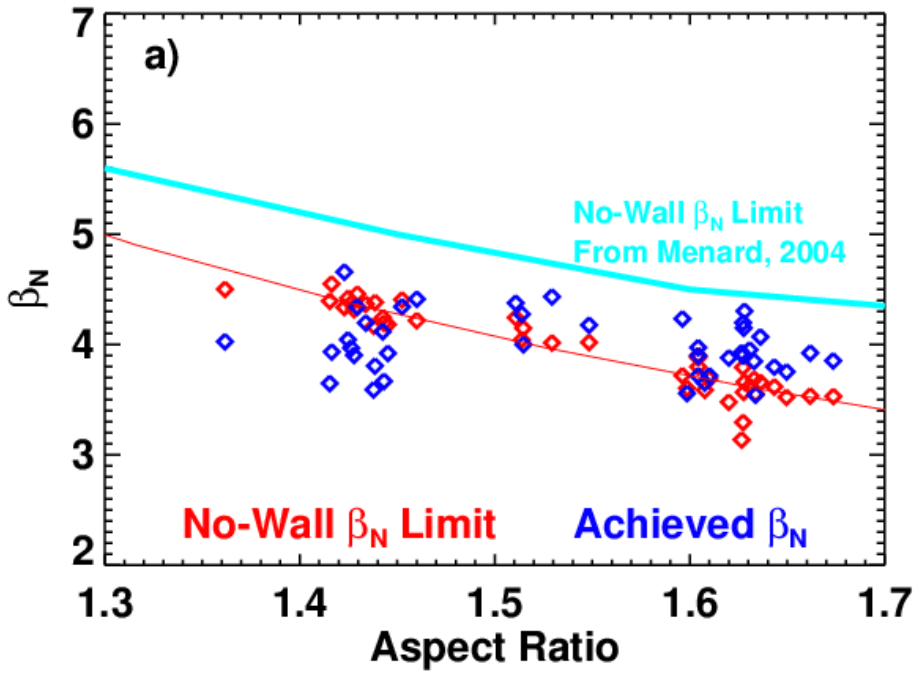
- 1 Fiducial (green) and 8 shots at higher aspect ratio.
  - Black cases vertically stable, the colored ones have VDEs.
- *VDE is always triggered when l_i=0.6*.
  - This is not a particularly high value.
  - Would preclude use of the scenario for many XPs.
- Motivates improvements to the n=0 controller?



Significant Reduction of the Calculated No-Wall β_N Limit in These Scenarios.

- Use actual equilibria, reconstructed with MSE, Te-Isotherm, magnetics.
- Scale pressure profile, compute δW for each one, find β_N where $\delta W=0$.
- Repeat for many many time slices and then sort those with similar q_0.
- l_i tended to decrease with A (except when it didn't), but no clear trend in F_P.
- XP did not actively push the β_N limit…need to revisit.





Summary

- XP was successful in creating unique high-A plasmas.
  - Readily achieved the NSTX-Upgrade aspect ratio.
  - Small performance degradation observed with increasing A.
  - Found that the l_i window is much reduced.
- Many questions to be answered…some of which include:
  - How does the achievable β_N depend on (high) A and κ?
    - And how does the choice of MHD control tools impact the answer?
  - Is there any core confinement improvement/degradation?
    - Separate effects for e- and i- channels?
  - Can the n=0 control be made more robust?
    - Increase the gain on the voltage difference, be more sophisticated?
  - Compatibility with more exotic divertors?