U.S. DEPARTMENT OF ENERGY | Office of Science

NSTX-U

PF-1b Discussion

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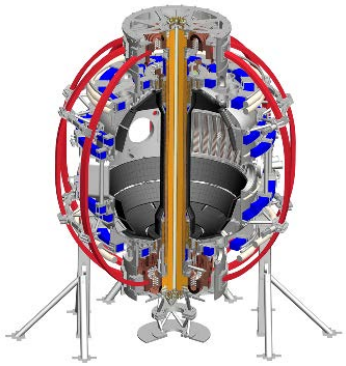
Dec 7, 2016

PPPL



What I Did

- Use idl ISOLVER to assess the ability to hold constant divertor shapes for a range of OH flux states.
  - Look at I_{OH} = [12,0,-24] states
  - +24 not considered because it is the pre-charge direction
  - Tried cases w/ and w/o PF-1b
- Assess cases with only a single X-point in each divertor.
  - No SFD, X, or SX cases.
- Tune divertor coil currents by hand.
- Multiple profiles:
  - 204112, efit02, t=0.6 for most cases, moderate l_i.
  - 134110, efit02, t=0.21 for low l_i case
  - 129011, efit02, t=0.5 for high l_i case
- In some cases, use 0D models for confinement and current drive to predict the rate of OH flux swing.

Summary

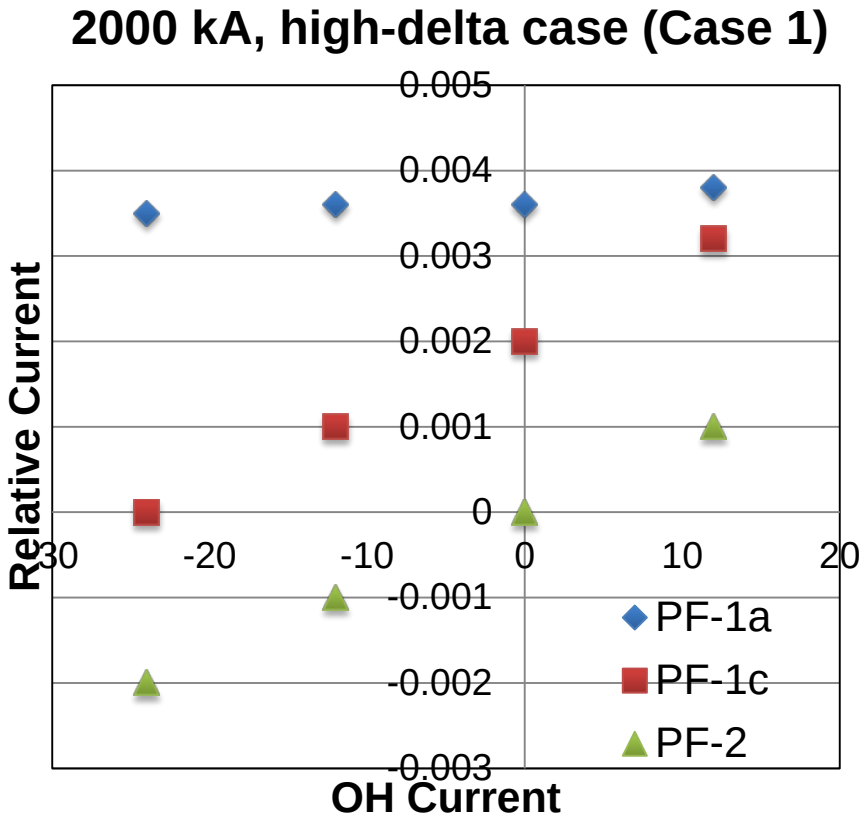
Case	I_P [kA]	β_N	l_i	Delta	OSP Radius [m]	Limiter	PF-1B	X-Point Fixed	OSP Radius Fixed	Flux Expansion Fixed
1	2000	4.5	0.63	High	---	NSTX-U	No	Yes	Yes	Yes
2	2000	4.5	0.66	Low	---	NSTX-U	No	Yes	Yes	Yes
3	2000	4.5	0.68	Medium	---	NSTX-U	No	Yes	Yes	Yes
4	700	4.5	0.54	High	0.51	NSTX-U	No	Yes	Yes	No
5	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
6	1300	4.5	---	Medium	---	CP	No	Yes	Yes	Yes
7	1300	4.5	---	Medium	---	CP	No	Yes	Yes	Yes
8	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
9	1300	4.5	0.61	High	---	NSTX-U	No	Yes	Yes	Yes
10	700	4.5	0.35	High	0.48	NSTX-U	No	Yes	Yes	No
11	700	4.5	0.65	High	0.51	NSTX-U	No	Yes	Yes	No
12	700	4.5	0.54	High	0.46	NSTX-U	No	Yes	Yes	No
13	700	4.5	0.54	High	0.41	NSTX-U	Yes	Yes	Yes	Yes
14	700	4.5	0.64	Medium	0.82	NSTX-U	No	Yes	Yes	Yes
15	700	4.5	0.58	Med-high	0.64	NSTX-U	No	Yes	Yes	Yes

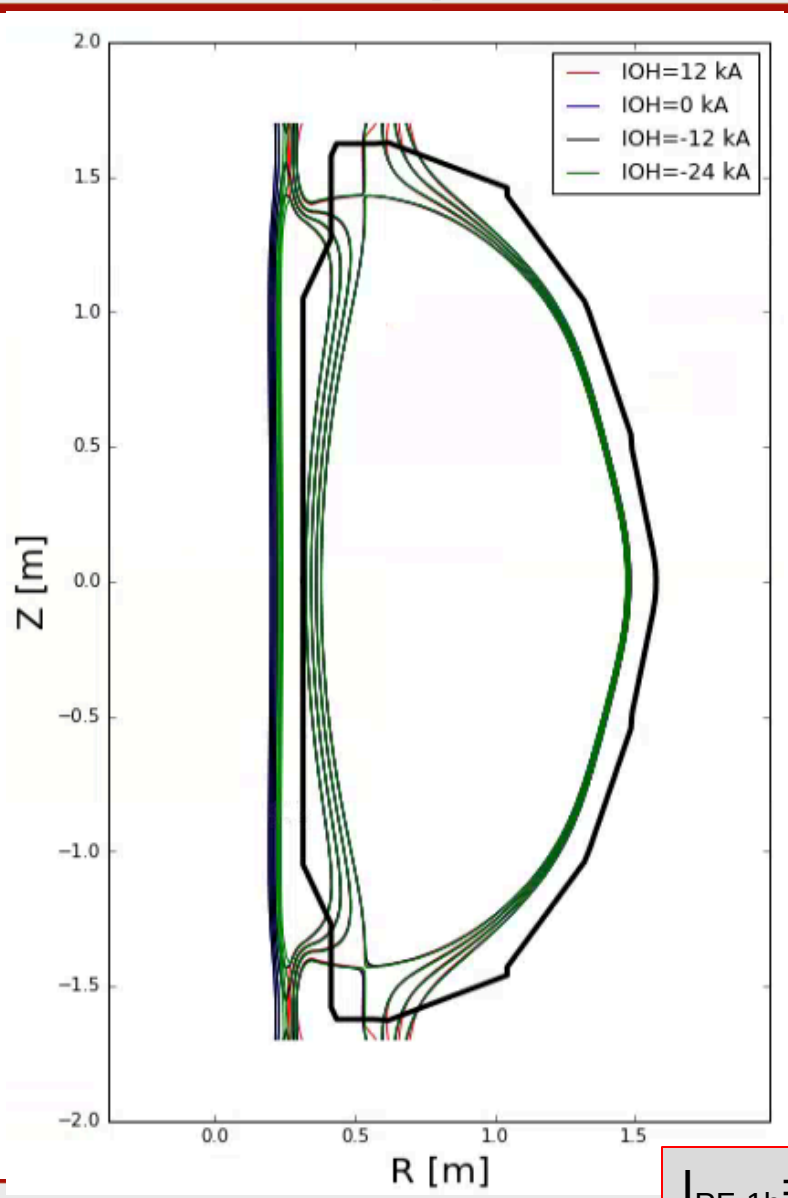
2 MA Cases

Easy to maintain X-point locations, R_{OSP}, R_{ISP}, Z_{ISP}, flux expansion outside of R_{OSP}

Case 1: 2 MA High-Delta H-Mode Fixed κ, δ, OSP Radius, Flux Expansion

- I_P= 2MA, l_i=0.65, β_N=4.5
- PF-2 goes negative

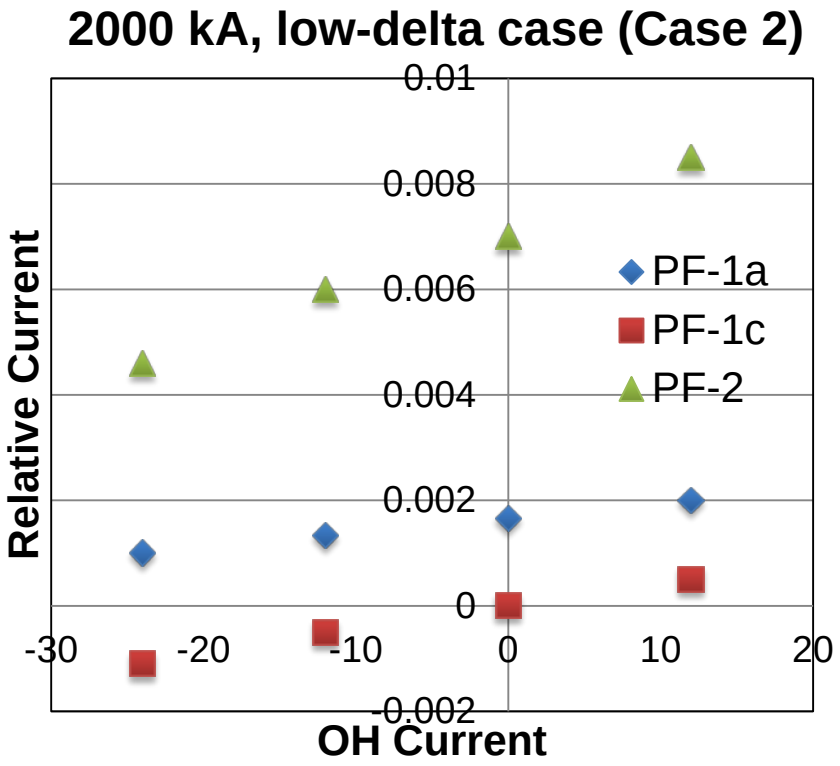


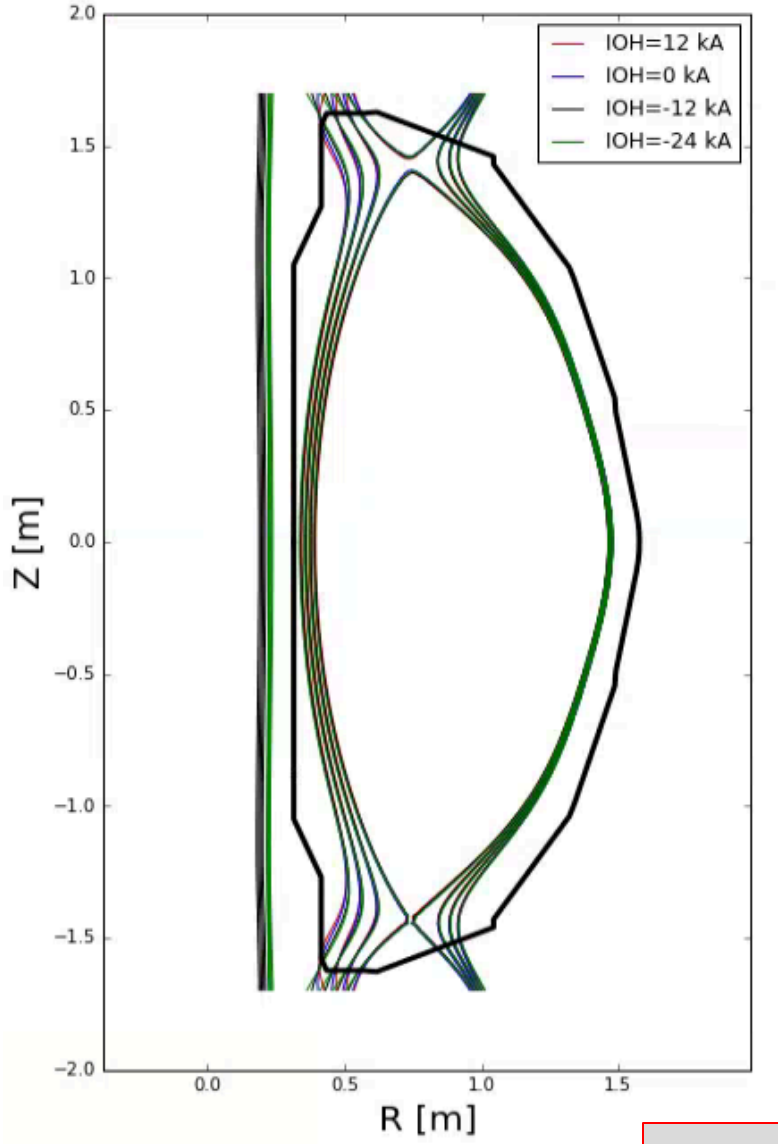


I_{PF-1b}=0

Case 2: 2 MA Moderate-Delta H-Mode Fixed κ, δ, OSP Radius, Flux Expansion

- I_P= 2MA, l_i=0.65, β_N=4.5
- Comparatively easy since the divertor features are farther from the OH.
- No change of flux expansion
- PF-1c goes negative

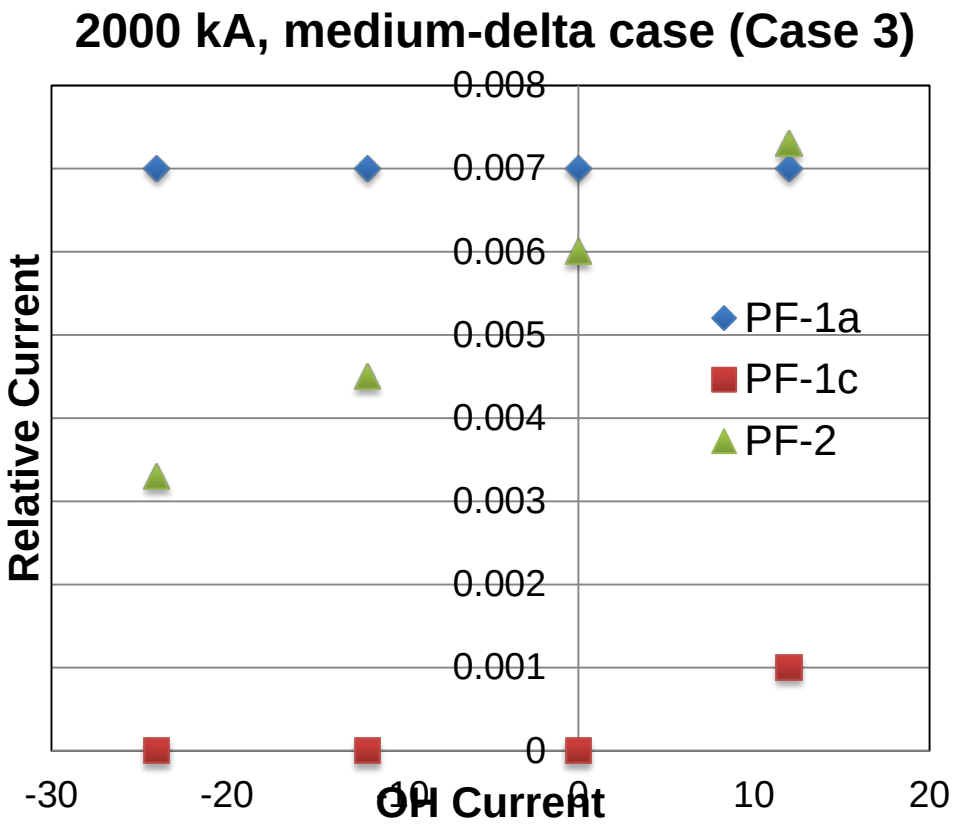


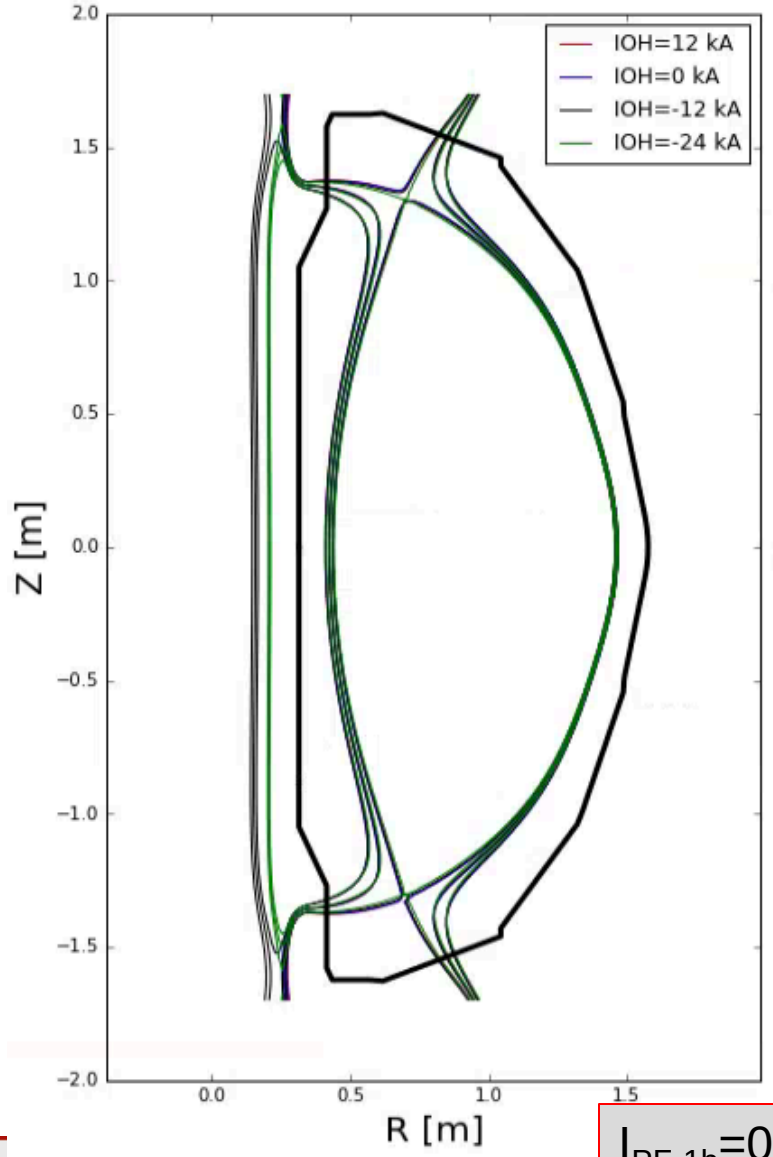


I_{PF-1b}=0

Case 3: 2 MA Moderate-Delta H-Mode Fixed κ, δ, OSP Radius, Flux Expansion

- I_P= 2MA, l_i=0.65, β_N=4.5





I_{PF-1b}=0

0.7 MA Cases

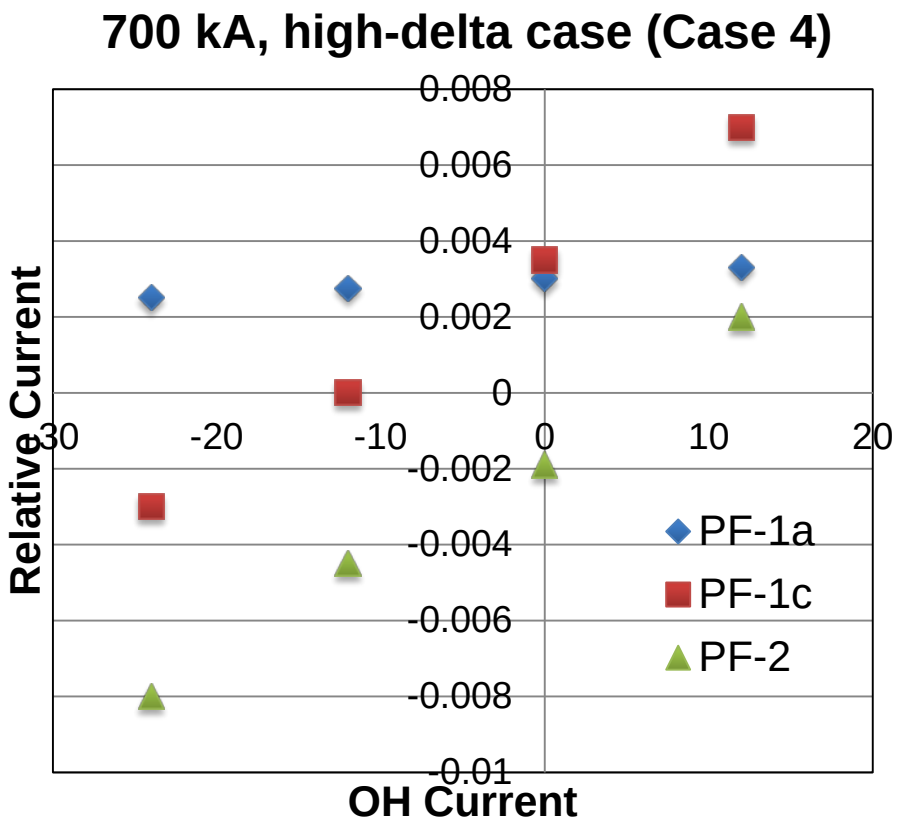
Easy to maintain X-point locations, R_{OSP}

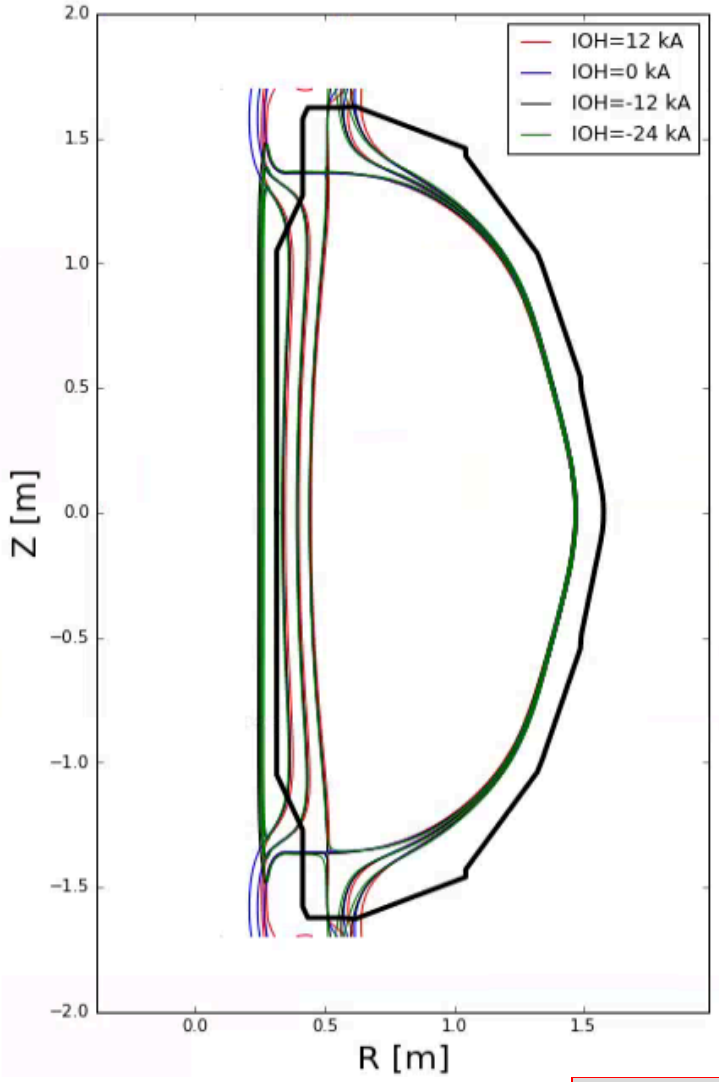
Flux expansion outside of R_{OSP} tends to drift for the lower-δ cases at the lower current:

OH current swing tends to decrease the flux expansion for fixed X-point and R_{OSP} at low-δ.

Case 4: 0.7 MA High-Delta H-Mode Fixed κ, δ, OSP Radius

- I_P= 0.7 MA, l_i=0.65, β_N=4.5
- PF-2 swings negative
- Project 2-3 kA OH swing per second, with P_{inj}=5 MW

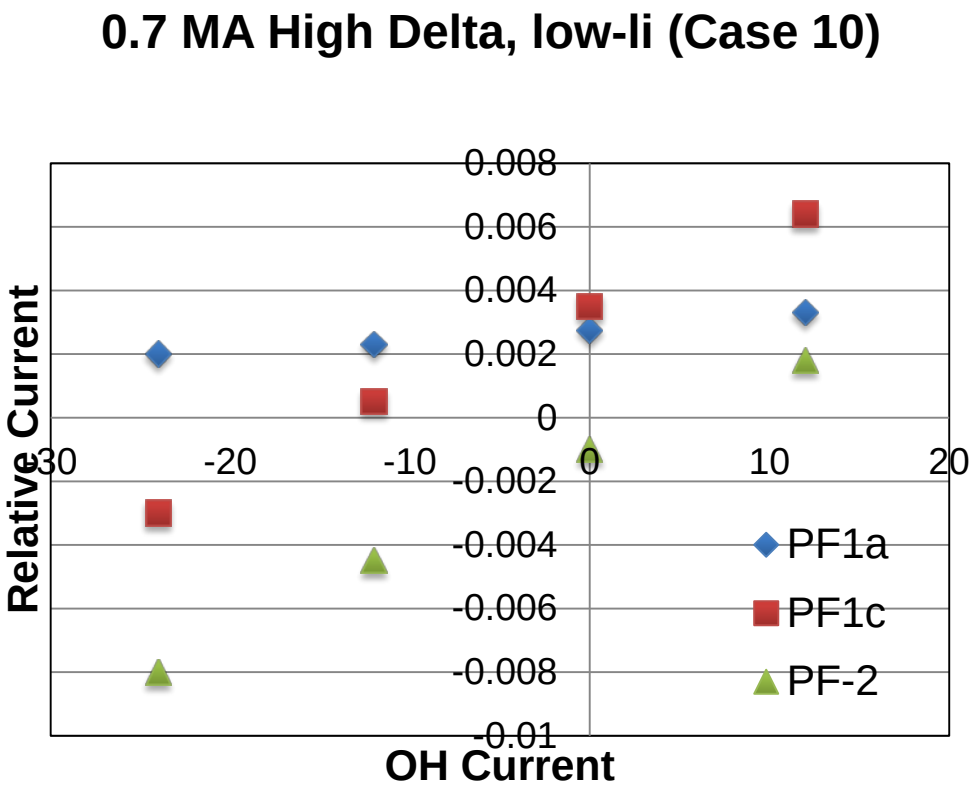


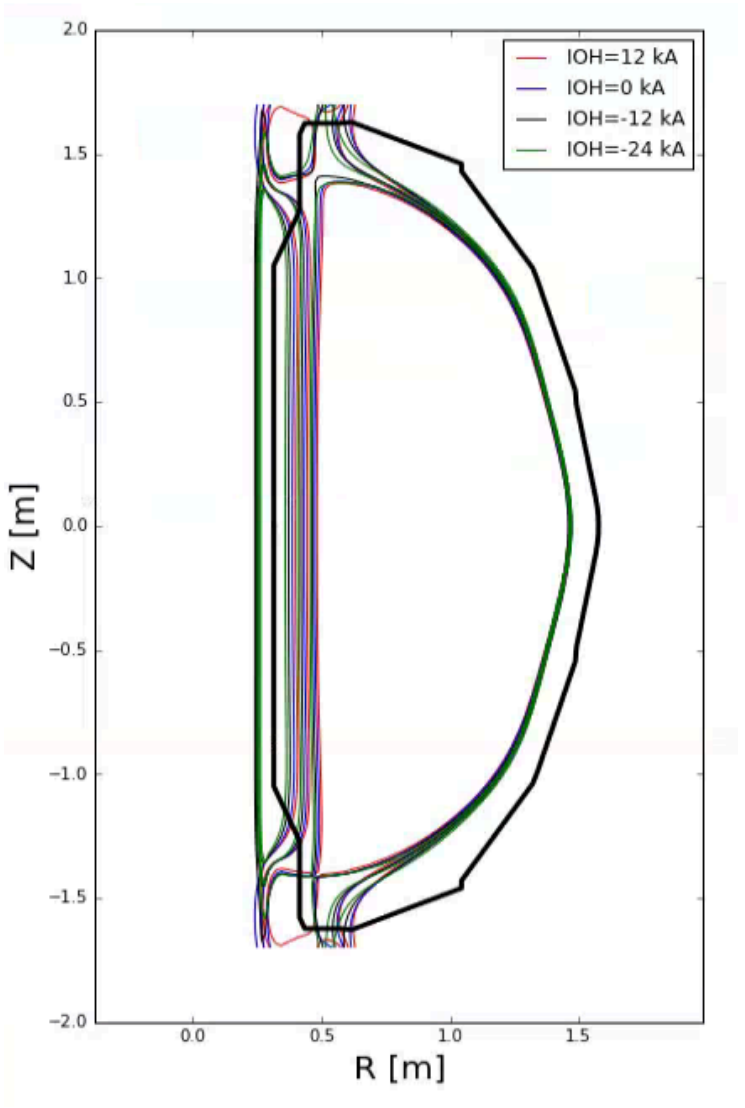


I_{PF-1b}=0

Case 10: 0.7 MA High-Delta H-Mode Fixed κ, δ, OSP Radius

- I_P= 0.7MA, l_i=0.35, β_N=4.5
- PF-1c and PF-2 both go negative

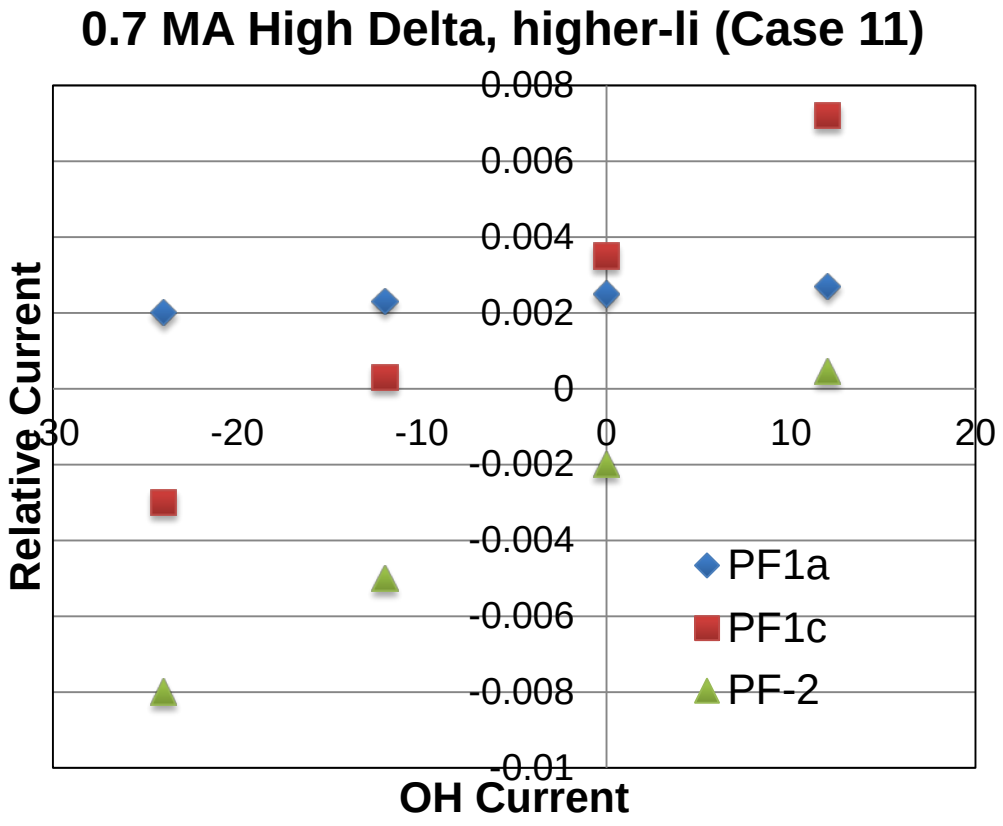


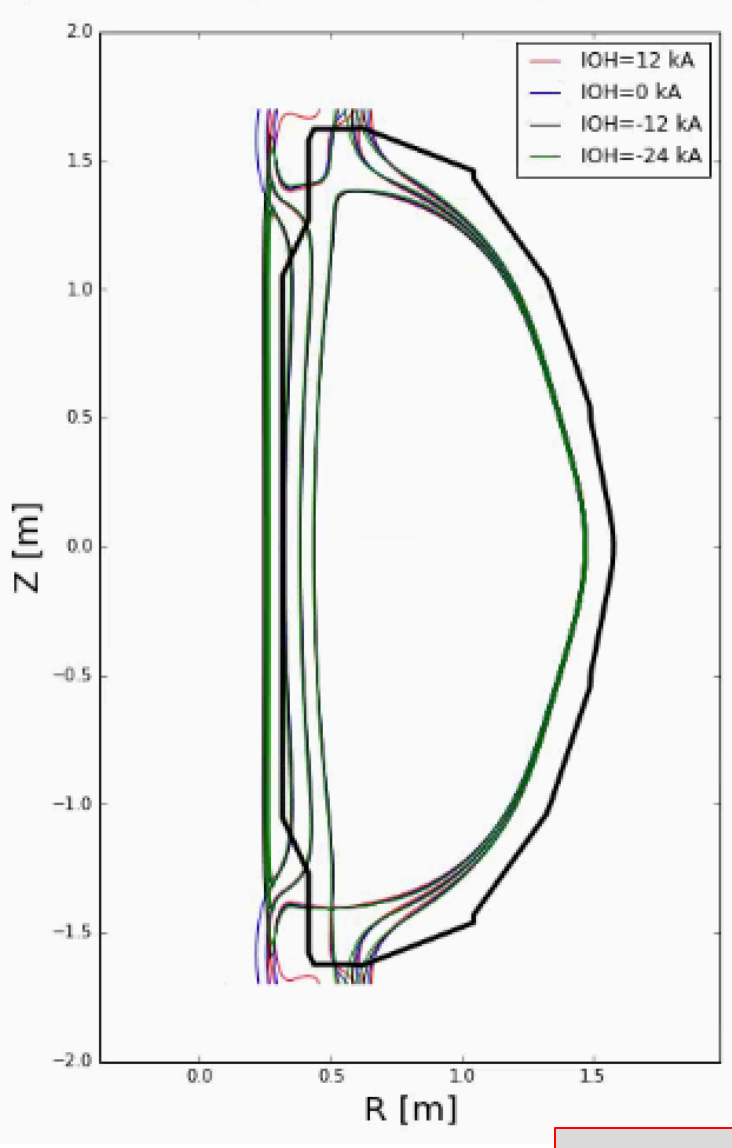


I_{PF-1b}=0

Case 11: 0.7 MA High-Delta H-Mode Fixed κ, δ, OSP Radius

- I_P= 0.7 MA, l_i=0.65, β_N=4.5
- PF-1c and PF-2 both go negative

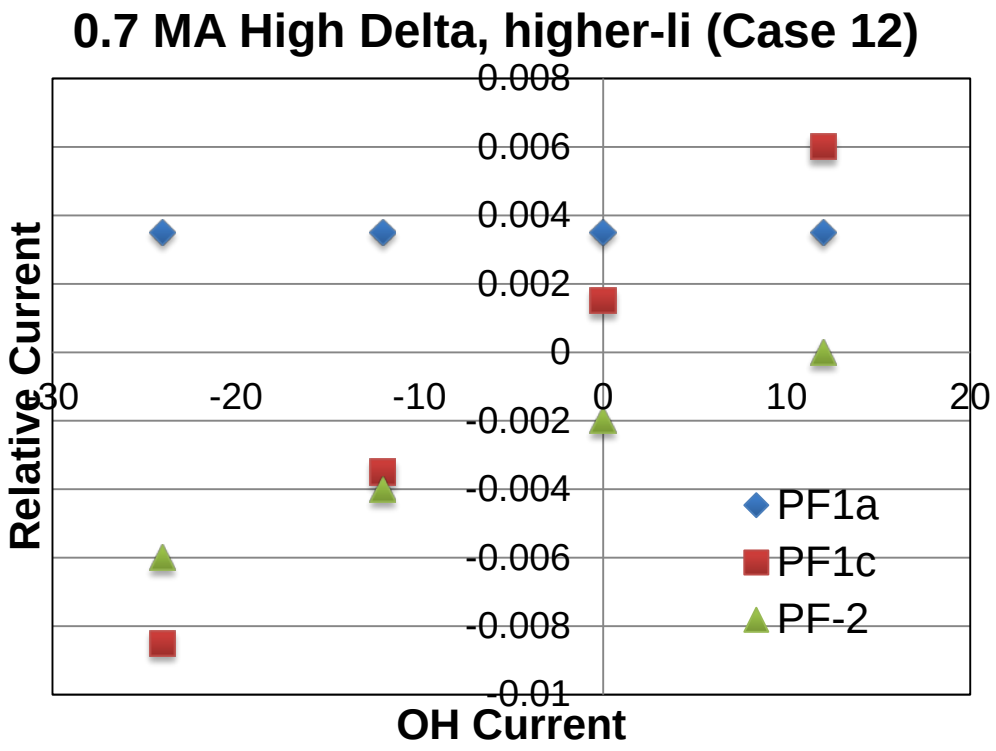


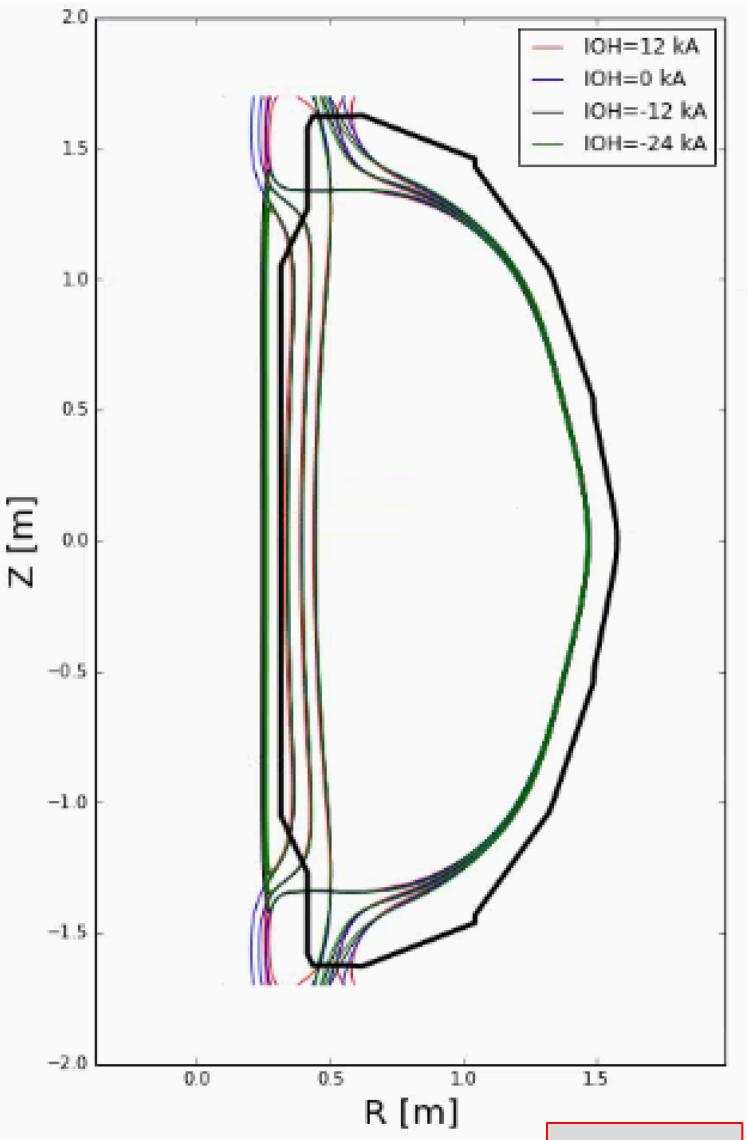


$I_{PF\text{-}1b}$=0

Case 12: 0.7 MA High-Delta H-Mode Fixed κ, δ, OSP Radius

- I_P= 0.7 MA, l_i=0.54, β_N=4.5
- OSP more in the corner…
- PF-1c and PF-2 both go negative

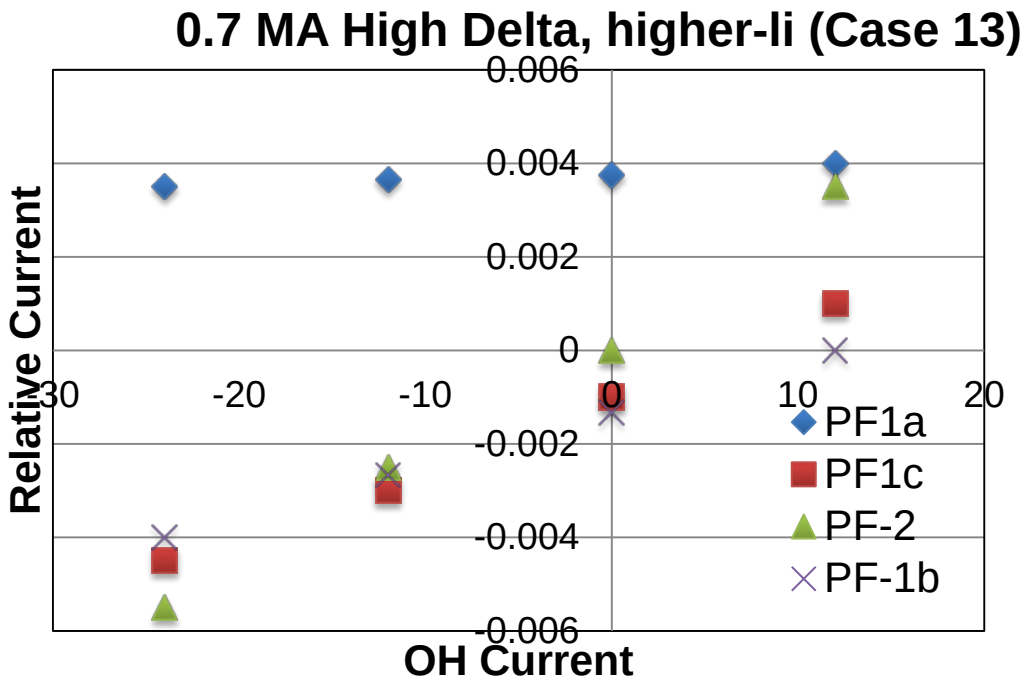


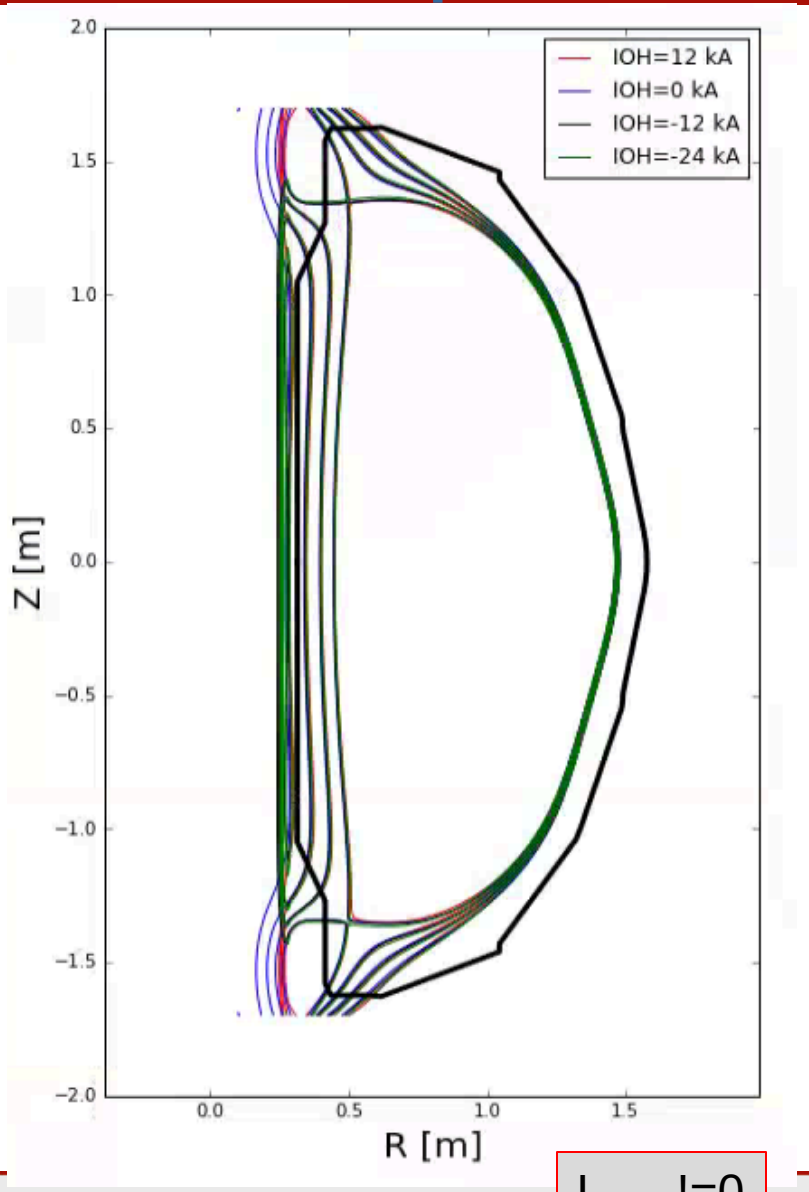


I_{PF-1b}=0

Case 13: 0.7 MA High-Delta H-Mode Fixed κ, δ, OSP Radius, Flux Expansion

- I_P= 0.7 MA, l_i=0.54, β_N=4.5
- Used Finite PF-1B Current
- PF-1c, PF-1c and PF-2 both go negative
- OSP more in the corner…





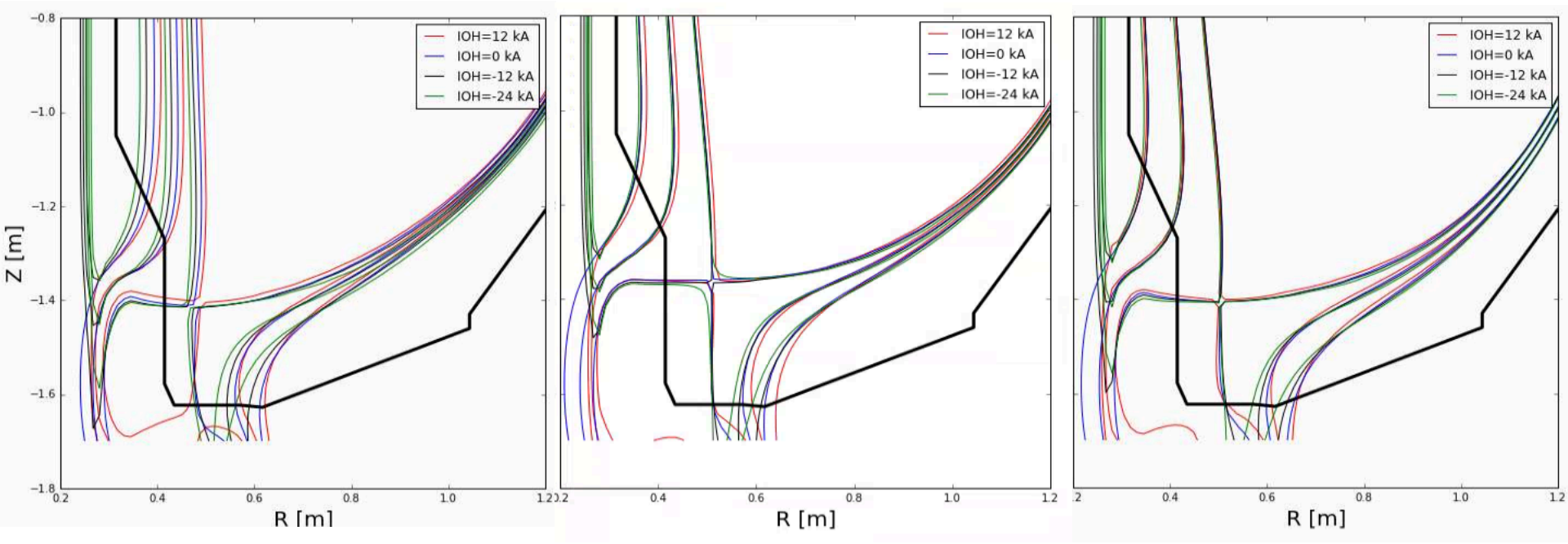
$I_{PF\text{-}1b}$!=0

Comparison: l_i Scan @ 700 kA for high-δ scenario, OSP Middle of IBDH

Case 10
l_i=0.35

Case 4
l_i=0.54

Case 11
l_i=0.65

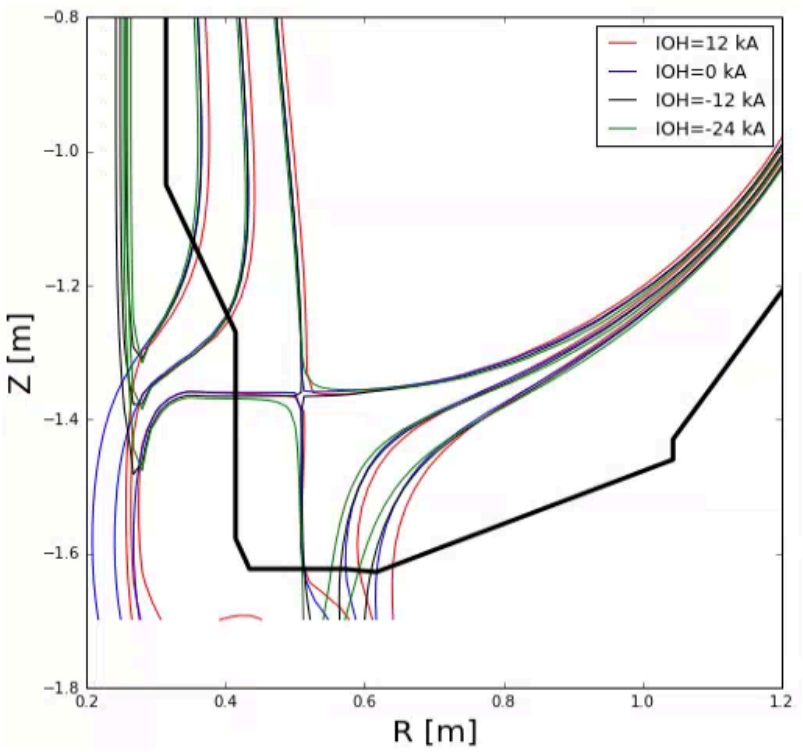


700 kA high-δ scenarios at β_N=4.5

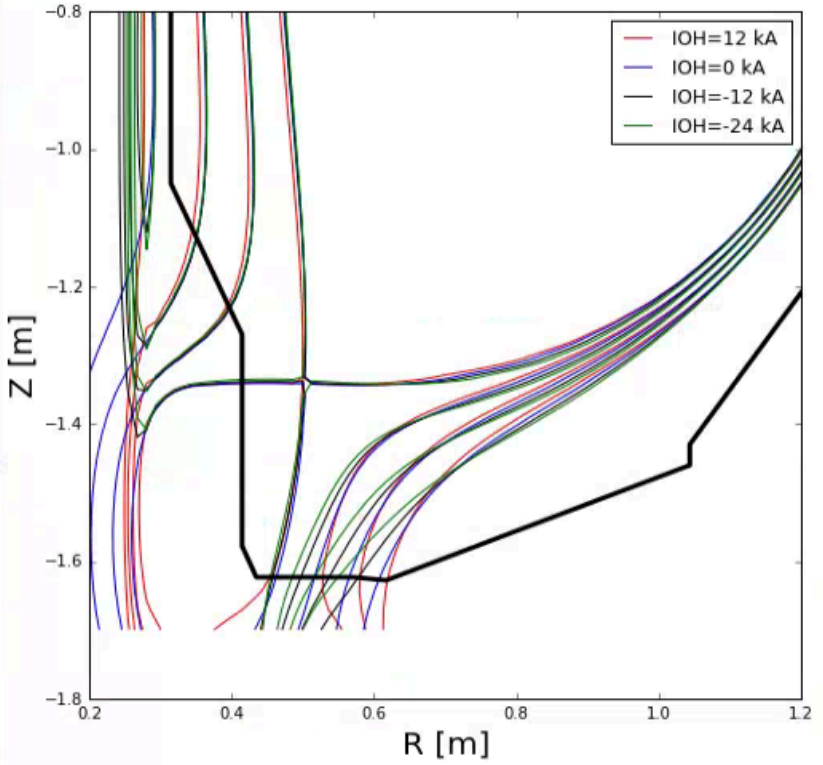
$I_{PF\text{-}1b}$=0

Comparison: Moderate l_i high-δ scenario OSP in mid-Tile or Corner

Case 4
OSP Mid-IBDH



Case 12
OSP Towards Corner

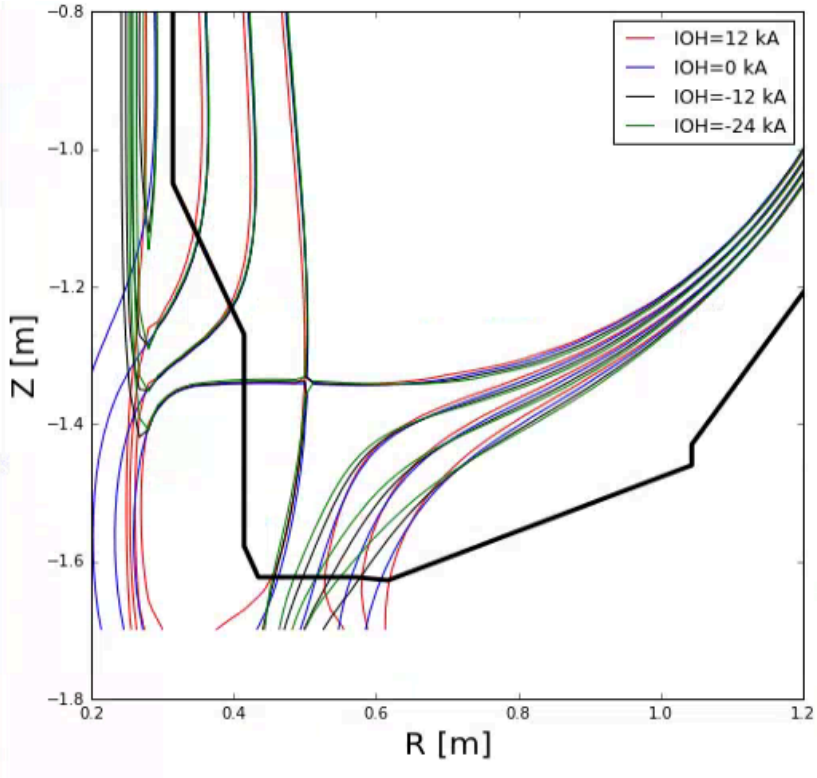


700 kA high-δ scenarios at β_N=4.5, l_i=0.54

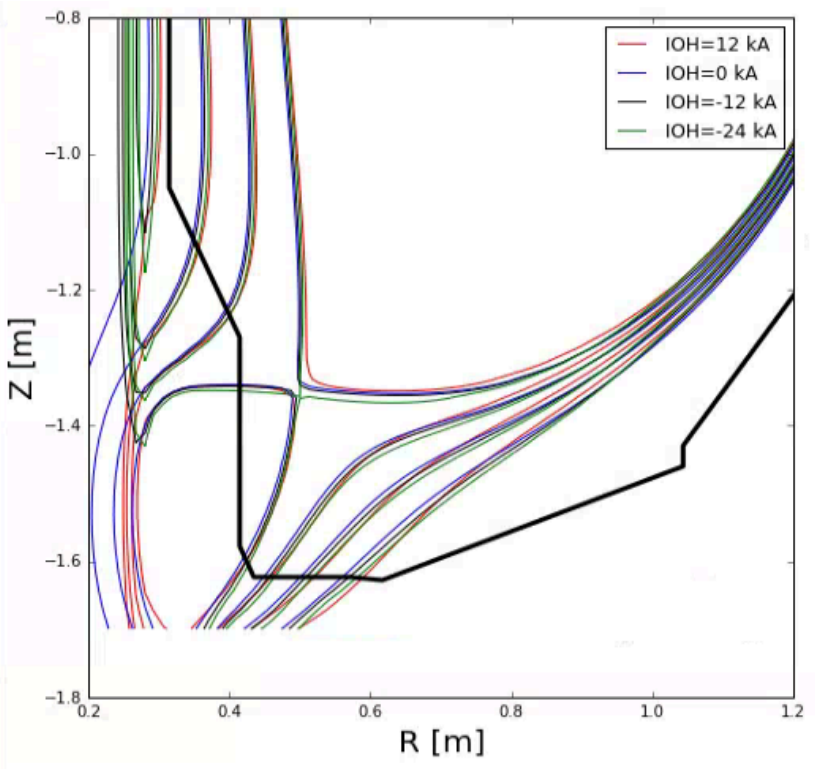
$I_{PF\text{-}1b}$=0

Comparison: Moderate l_i high-δ scenario w/ and w/o PF-1b, OSP near IBD Corner

Case 12
w/o PF-1b



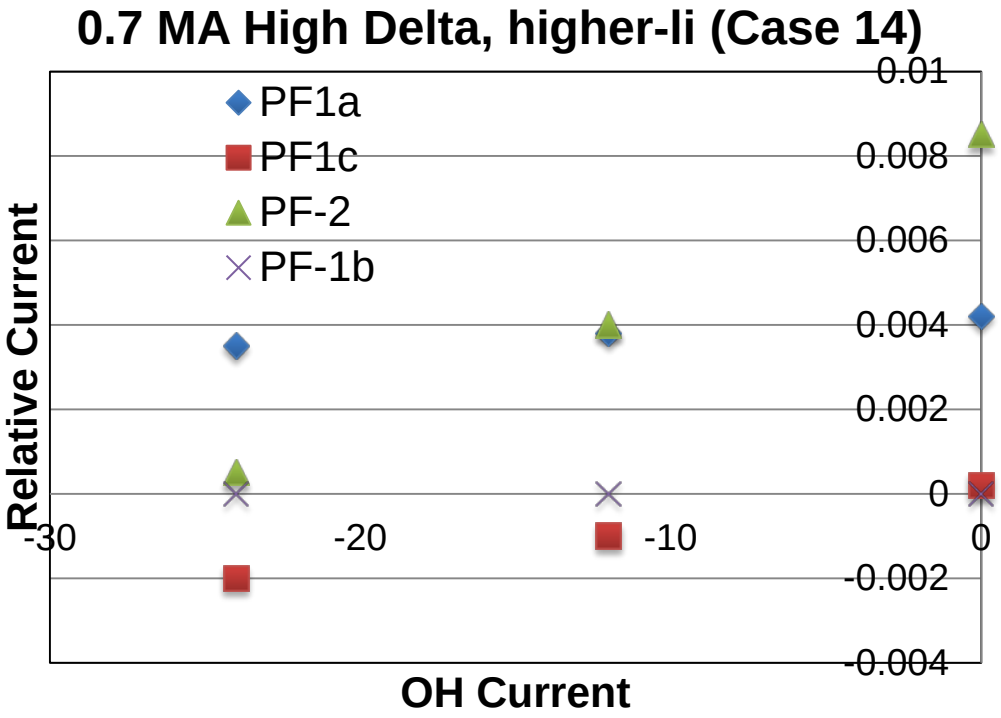
Case 13
w/ PF-1b

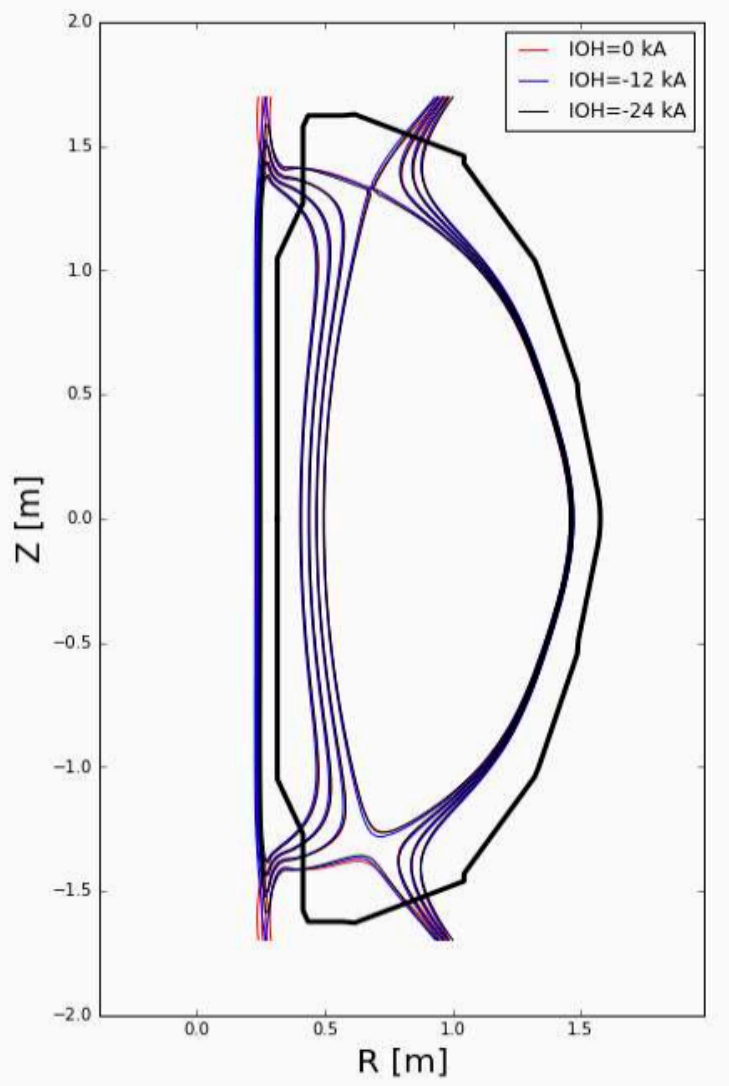


700 kA high-δ scenarios at β_N=4.5, l_i=0.54

Case 14: 0.7 MA Moderate-Delta H-Mode Fixed κ, δ, OSP Radius, Flux Expansion

- I_P= 0.7 MA, l_i=0.65, β_N=4.5
- Difficulty getting ISOLVER to run for +12 case due to multiple X-points
  - Currents for +12 kA case extrapolated
- PF-1c goes negative
- No appreciable change in shape, OSP radius, ISP height, flux expansion for range of OH states

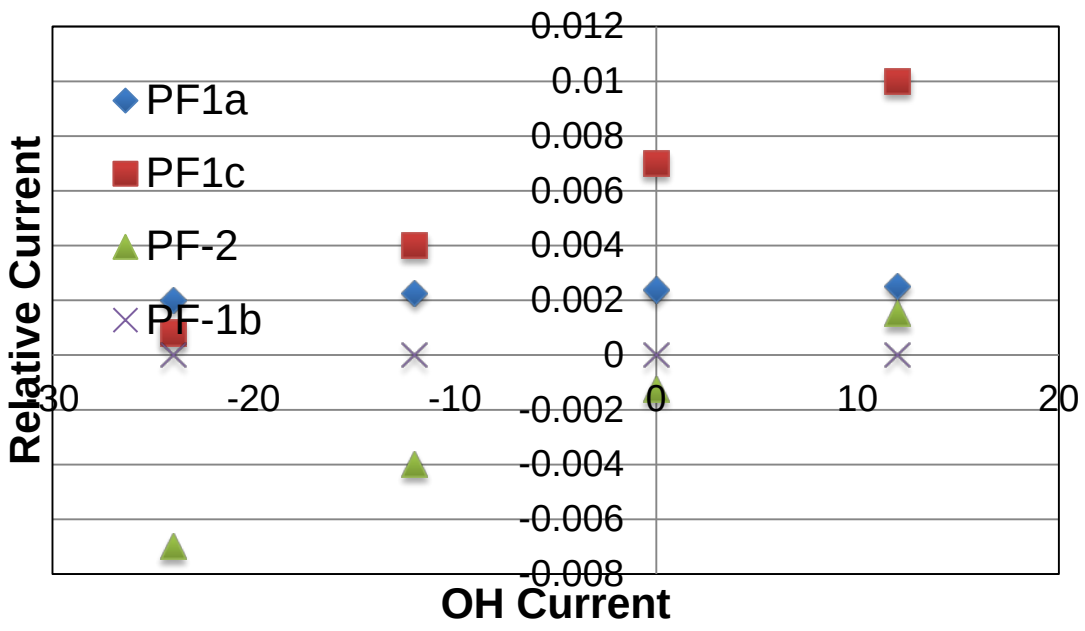


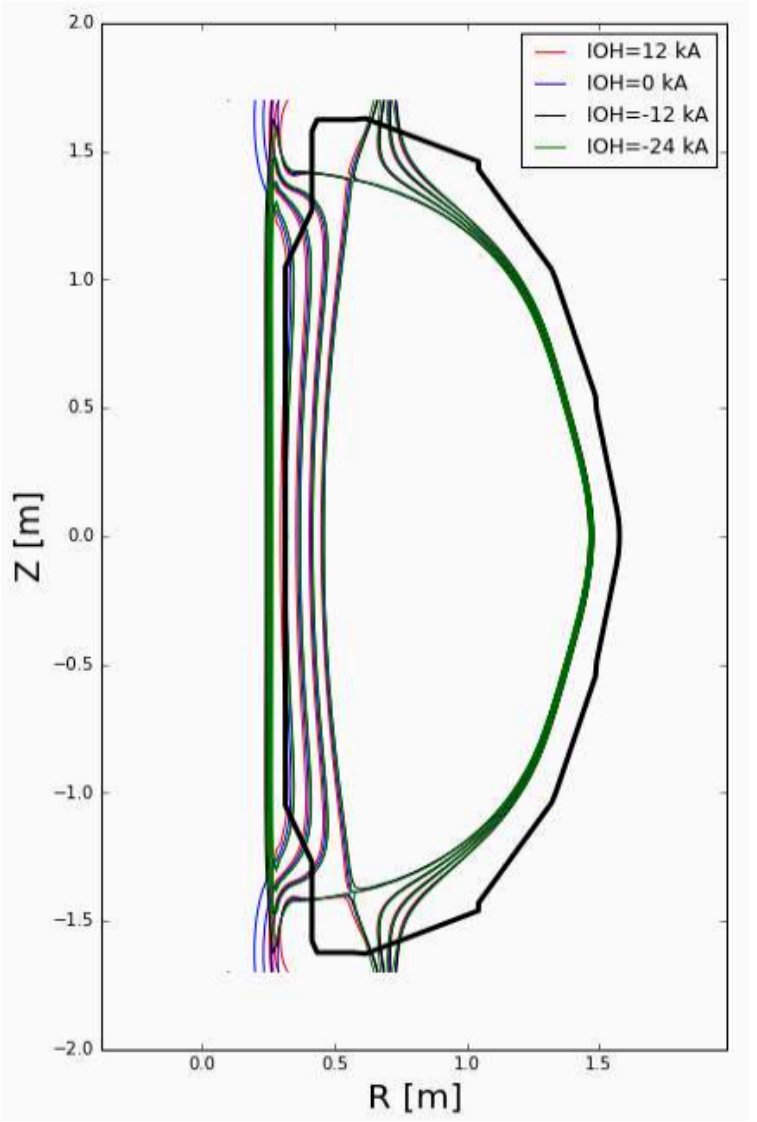


I_{PF-1b}=0

Case 15: 0.7 MA Moderate-Delta H-Mode Fixed κ, δ, OSP Radius, Flux Expansion

- I_P= 0.7 MA, l_i=0.65, β_N=4.5
- PF-2 goes negative
- No appreciable change in shape, OSP radius, ISP height, flux expansion for range of OH states



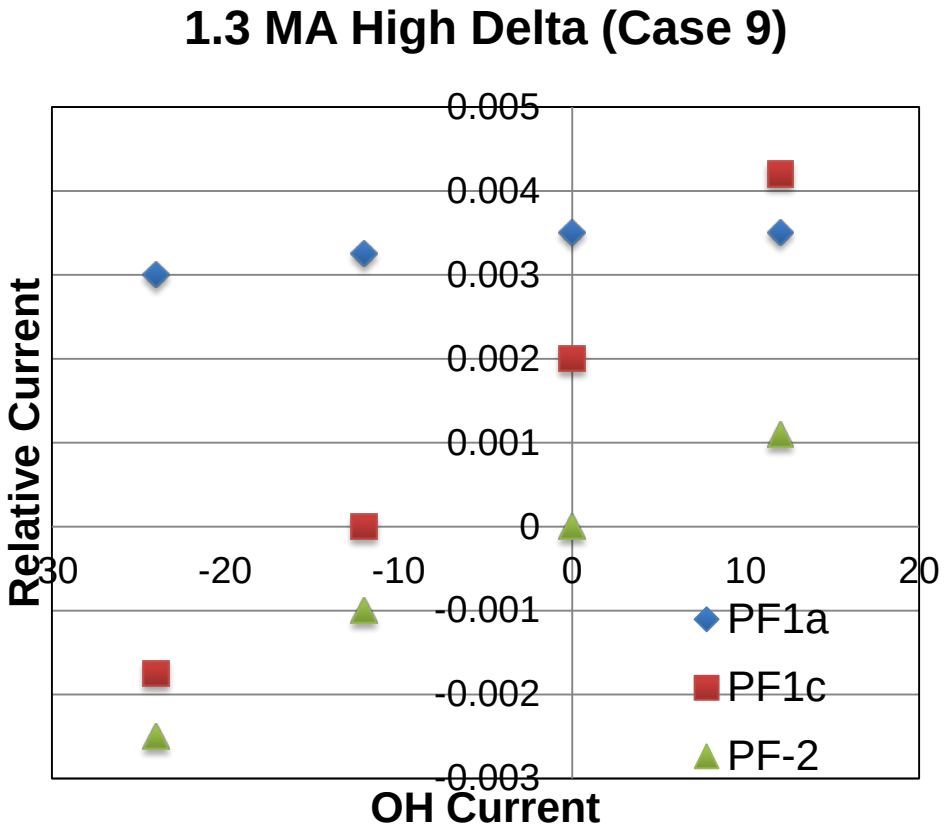


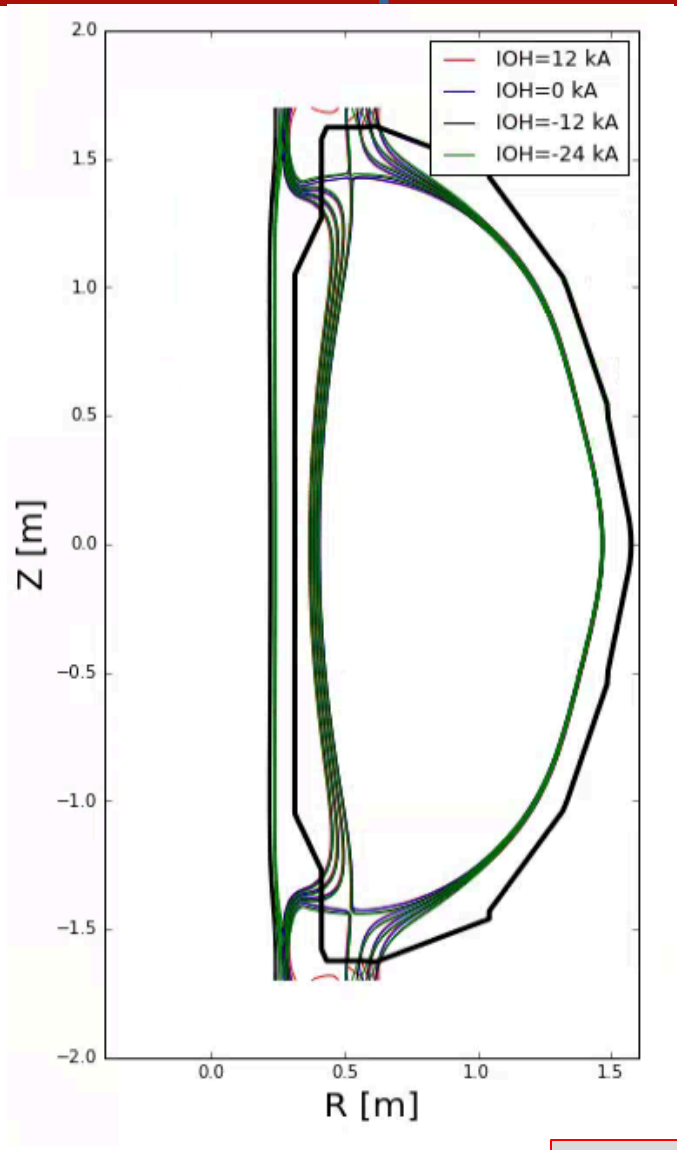
1.3 MA

Cases w/ and w/o CP Limiter

Case 9: 1.3 MA High-Delta H-mode Fixed κ, δ, OSP Radius, Flux Expansion

- I_P= 1.3 MA, l_i=0.61, β_N=4.5
- All divertor quantities constant across OH swing.

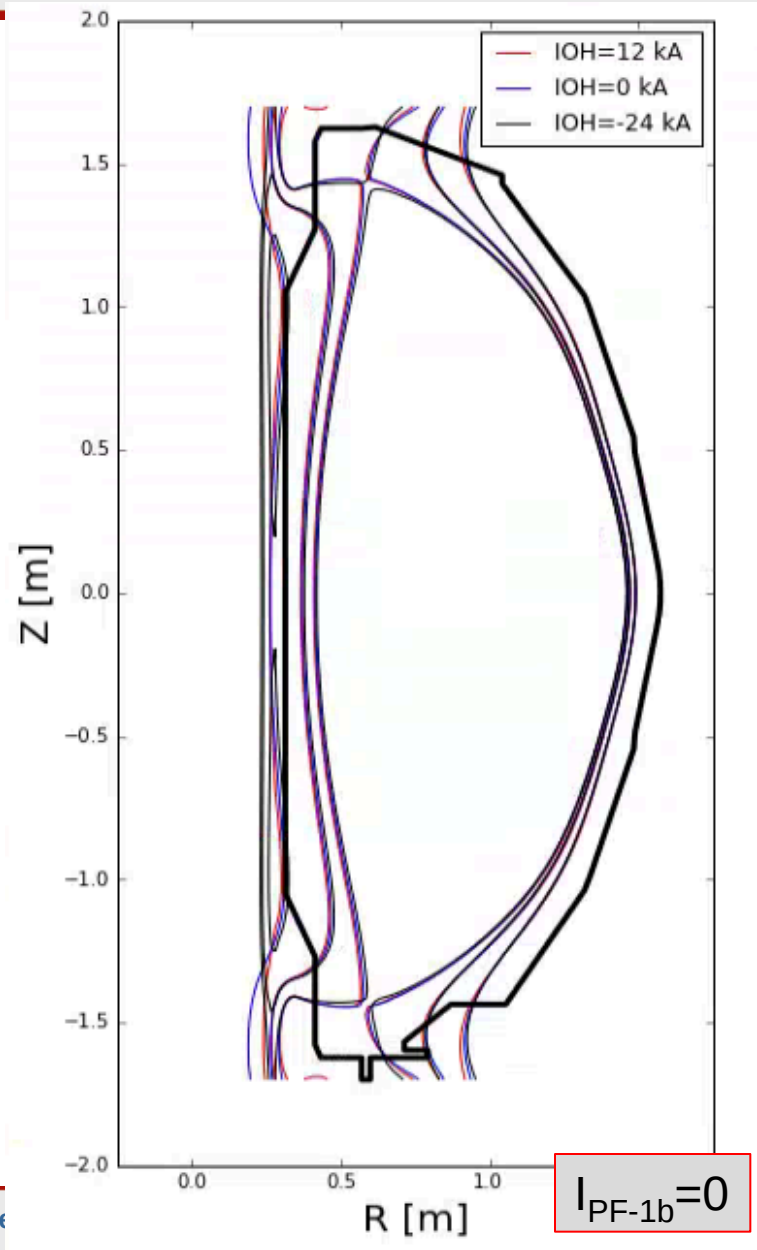




$I_{PF\text{-}1b}$=0

Case 6: 1.3 MA CP H-Mode

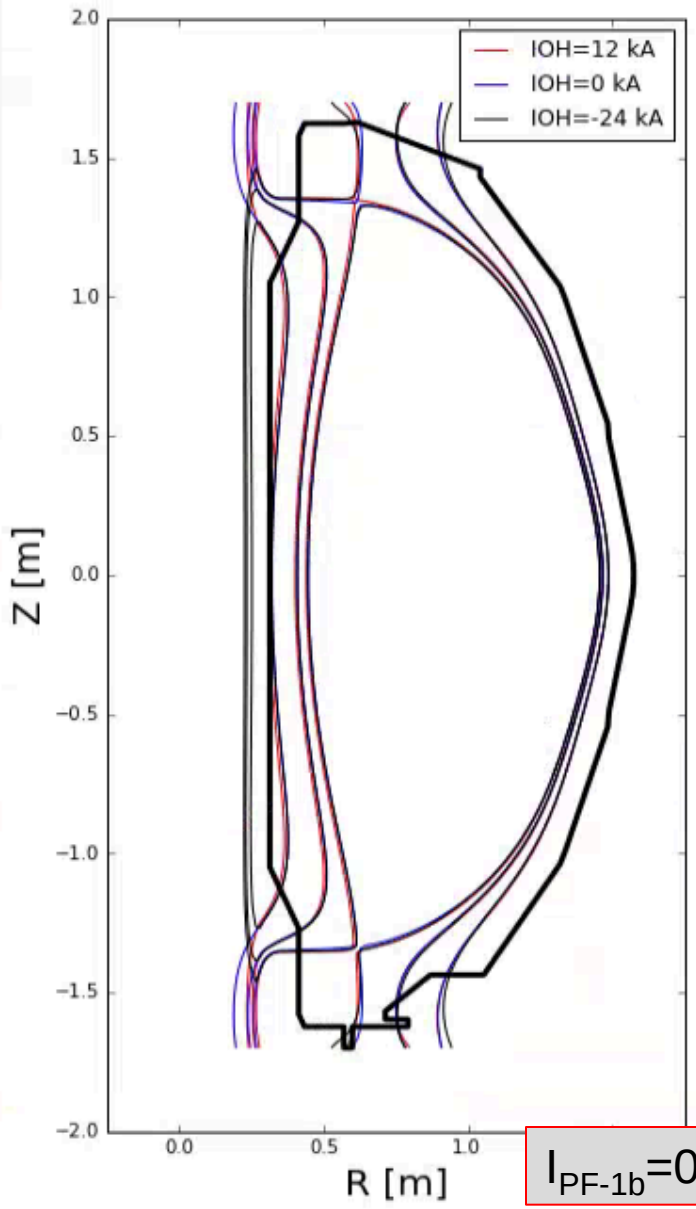
- I_P= 1.3 MA, l_i=0.65, β_N=4.5
- Minimal change in flux expansion, no change is X-point or SP positions.



I_{PF-1b}=0

Case 7: 1.3 MA CP H-Mode

- I_P= 1.3 MA, l_i=0.65, β_N=4.5
- Minimal change in flux expansion, no change is X-point or SP positions.



$I_{PF\text{-}1b}$=0

Upshot: Standard Divertor Operations w/o PF-1b

- Looked at many cases with moderate to lower flux expansion
- It is generally possible to maintain the X-point location, OSP radius and flux expansion for a wide range of shapes and plasma currents.
- The only case with time-varying flux expansion was a low current and high-delta case.
  - Problem is exacerbated at small R_{OSP}, low-l_i.
  - Slow I_{OH} evolution in lower I_P H-modes allows long periods (0.5-1 sec) with near constant divertor parameters.
  - PF-1b can eliminate the problem.
- Suggested steps to mitigate risk:
  - Get a bipolar PF-2
  - Install divertor gas feeds in the upper divertor for radiation control in the upper half.

For the standard divertor research program, it is extremely unlikely that we will ever require use of a PF-1b U/L coil.

Backup

Case 8: 1.3 MA High-Delta H-mode

- I_P= 1.3 MA, I_t [illegible]5, betaN=4.5
- ***Did use***
- Maintained c[illegible]
  - near-SOL flux exp[illegible]
  - X-Point location
  - ISP and OSP
- Still need t[illegible]e if -1b was strict[illegible]quired for this result.