NSTX Global Mode Stabilization Group Meeting

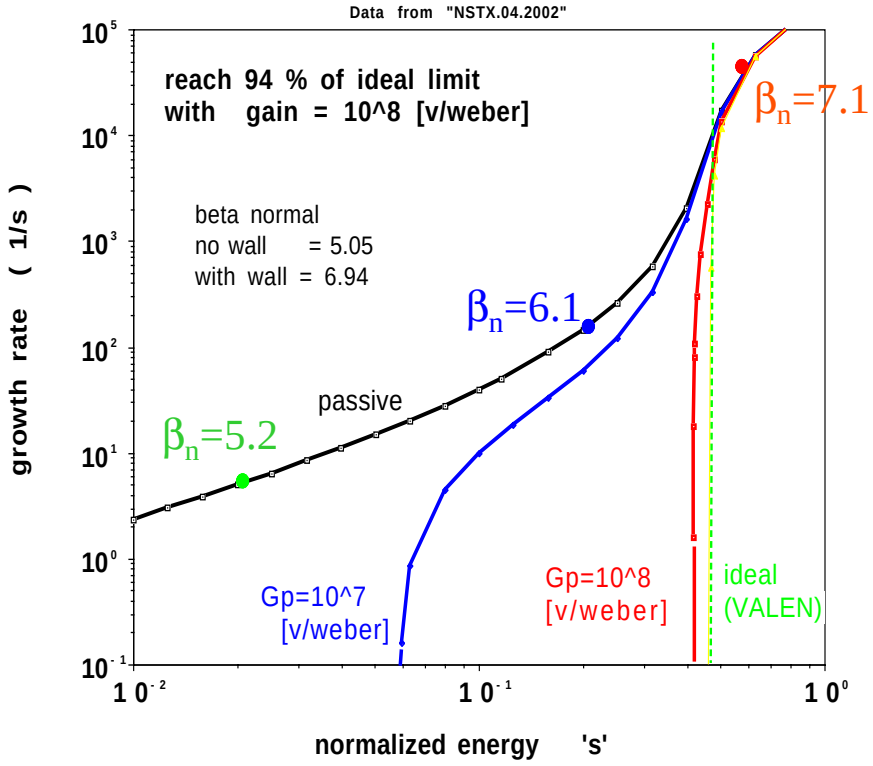
3 April 2003
pppl

Recent VALEN calculations Frequency Response for NSTX mode stabilization coils

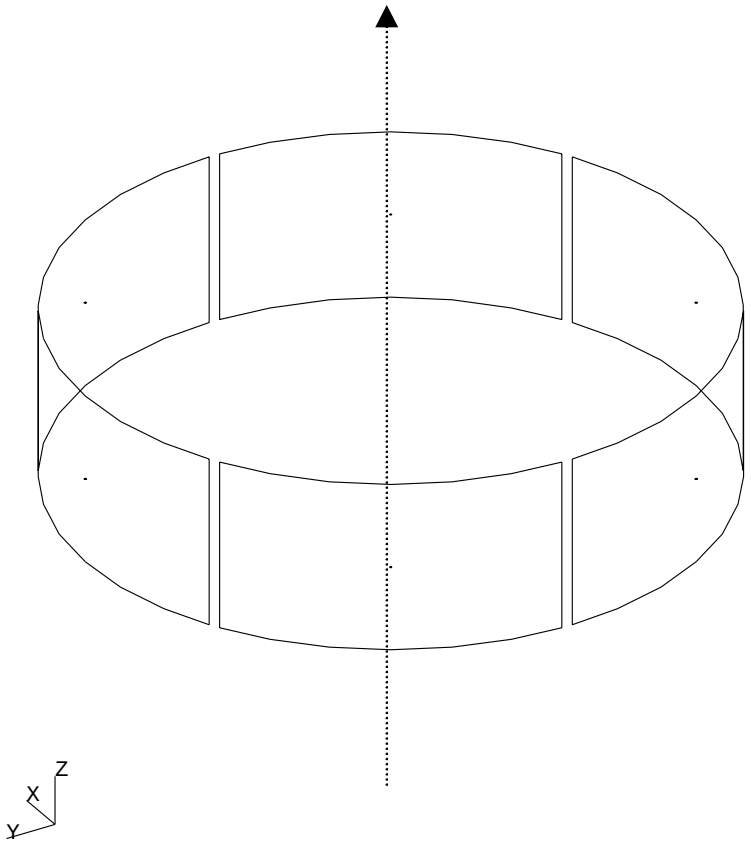
J. Bialek
Columbia University

- recall previous predictions (growth rate vs. normalized beta)
- Frequency Response Calculations for exterior & interior coils in NSTX
- Conclusions

Interior mid plane control coils sustain 94% of ideal wall limit

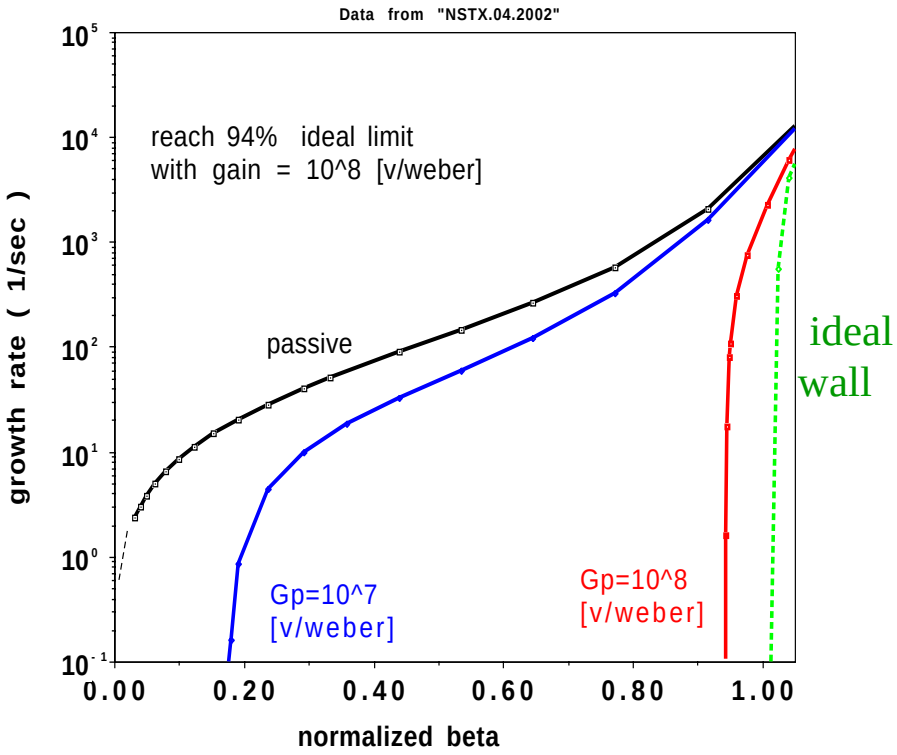


Sensors and control coils

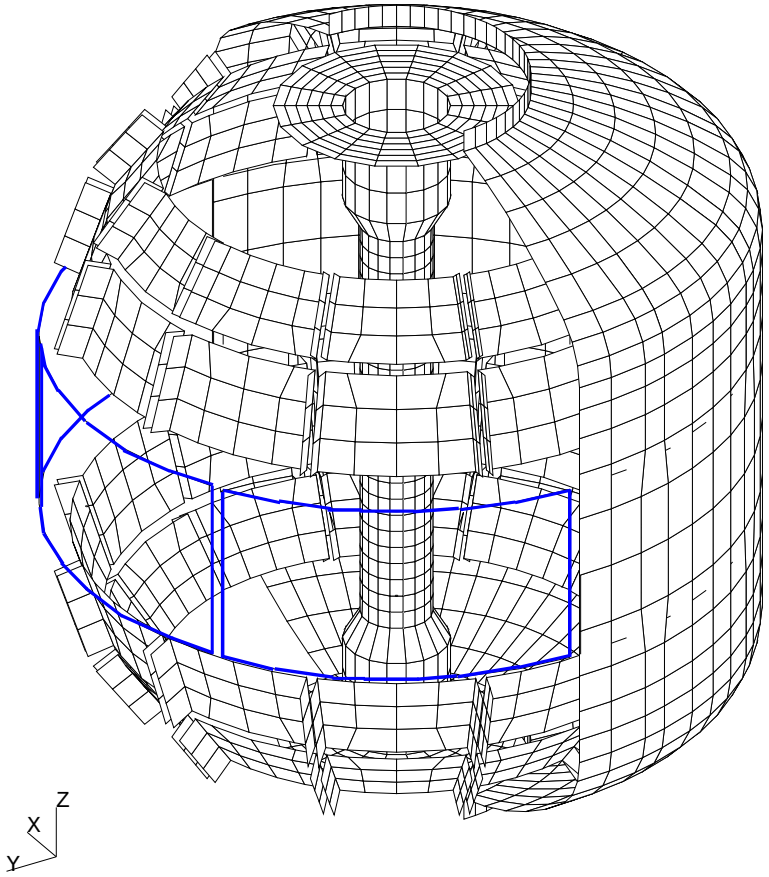


Interior mid plane control coils sustain 94% of ideal wall limit

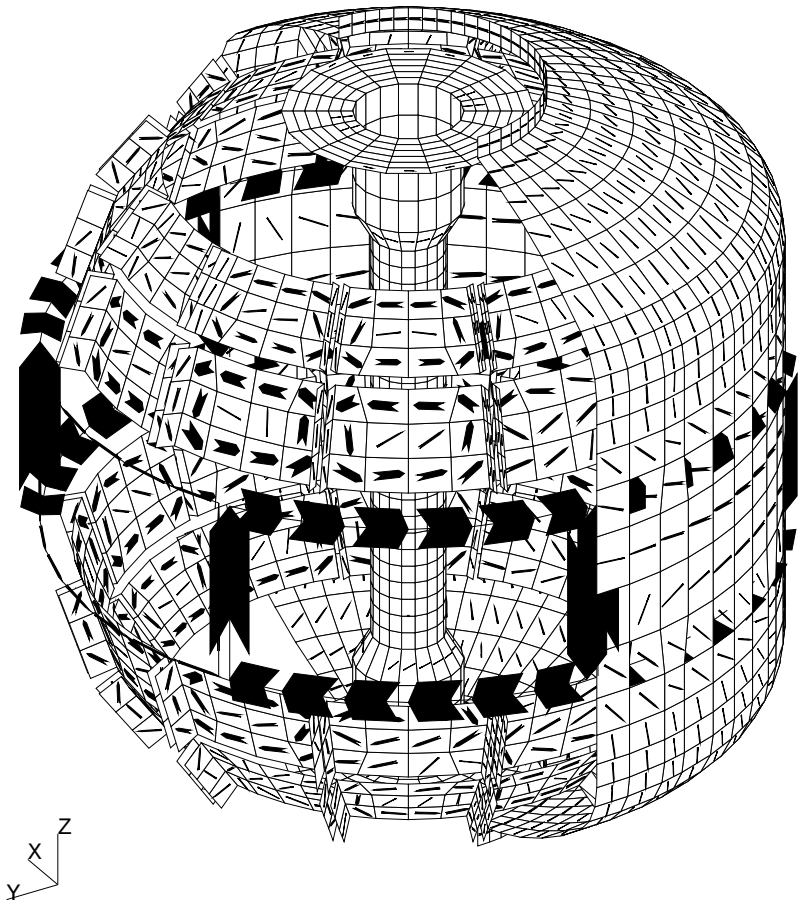
- 3 pair of interior mid plane control coils

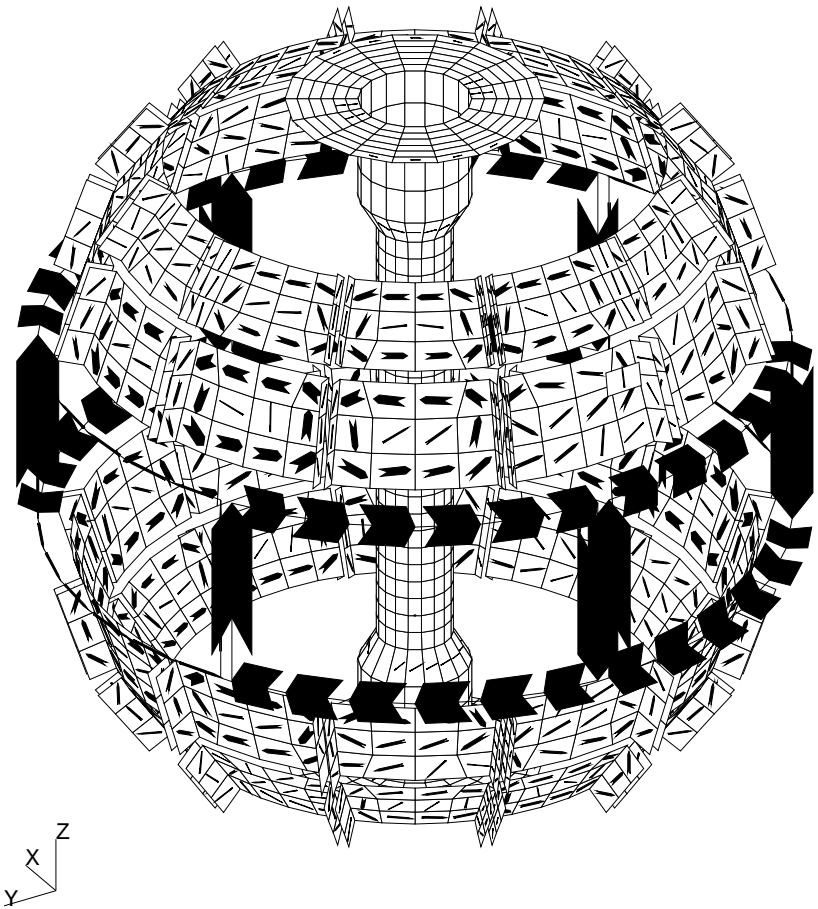


Cut away view of NSTX



Typical eigenvector interior control coils

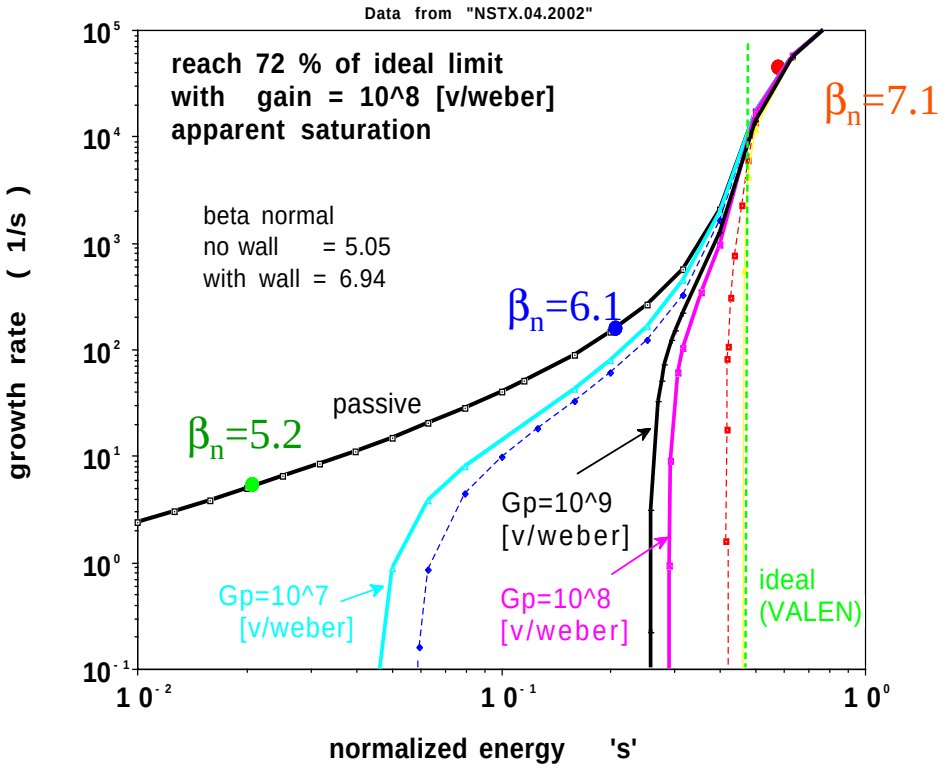




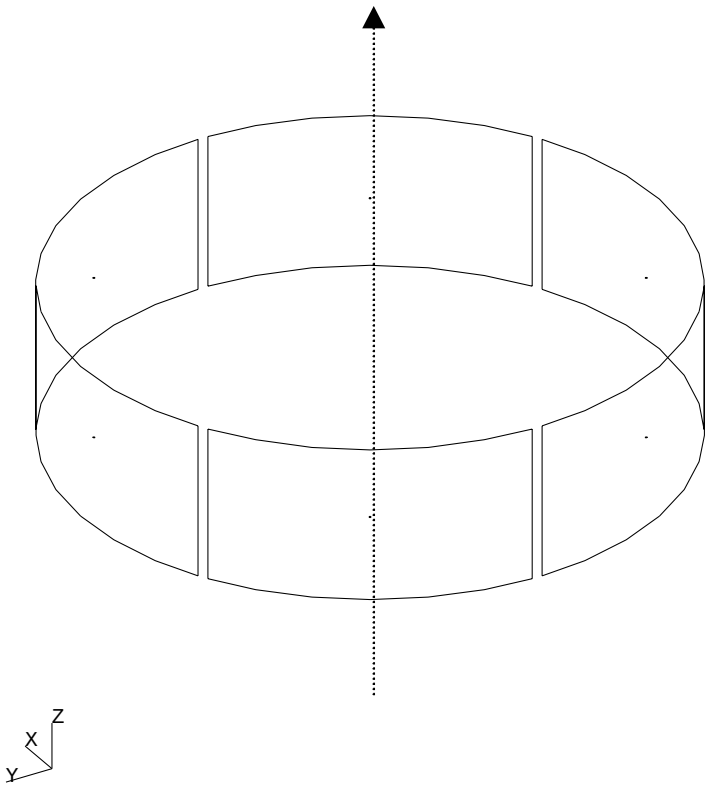
$G_p=10^7$ $\gamma=65.4$

Exterior mid plane control coils sustain 72% of ideal wall limit

- 3 pair of exterior mid plane control coils

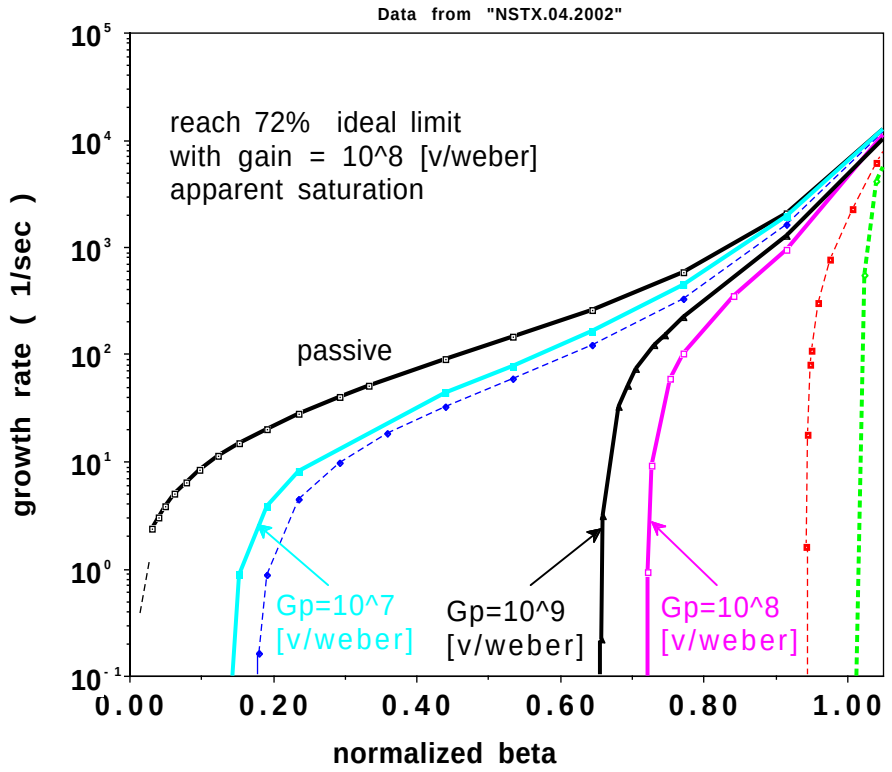


Sensors and control coils

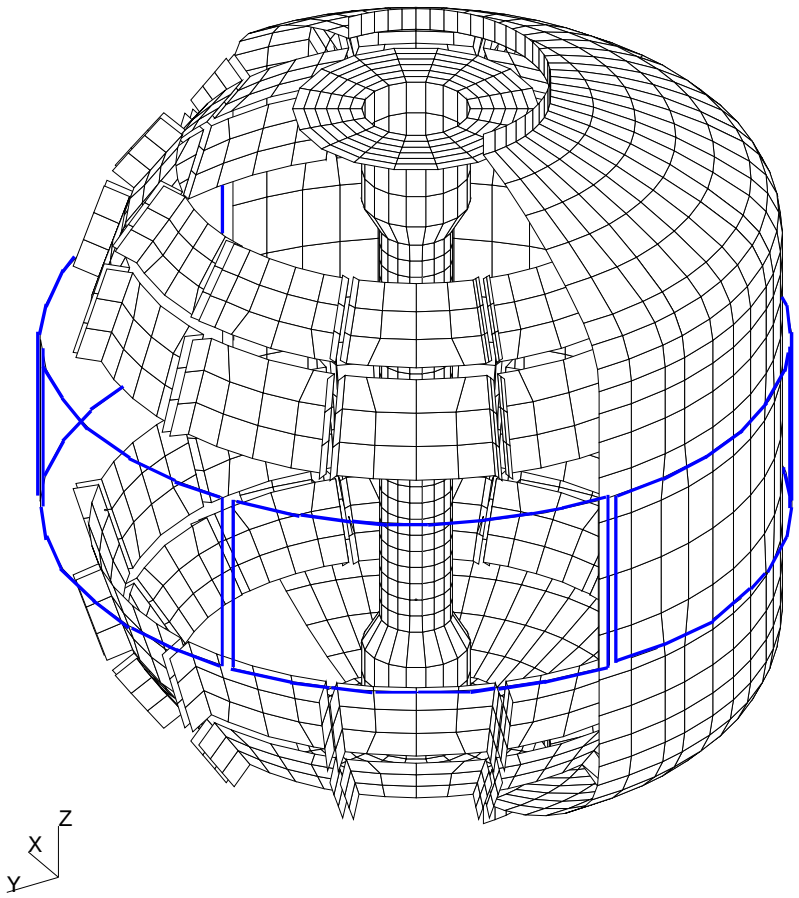


Exterior mid plane control coils sustain 72% of ideal wall limit

- 3 pair of exterior mid plane control coils

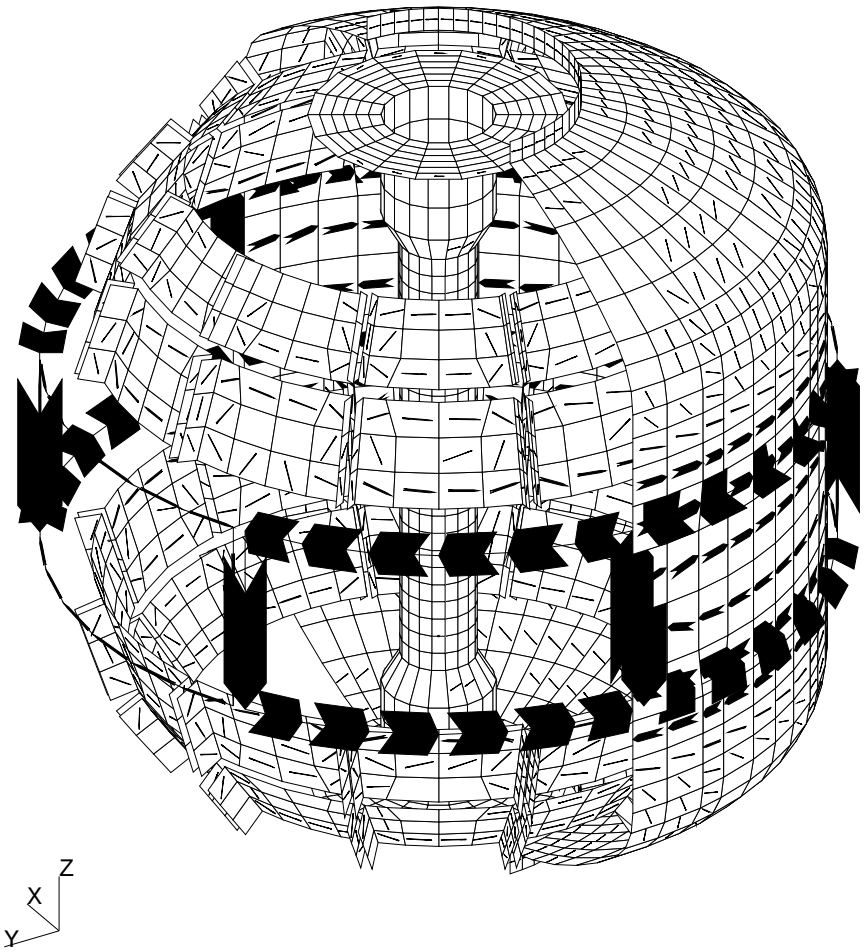


Cut away view of NSTX



Typical eigenvector exterior control coils

- Eigenvector shown is on the ideal branch of the dispersion curve
- Vacuum vessel shields out very fast fields from the exterior control coils
- $G_p=10^8$ γ=9.67e+4



Frequency Response Analysis: convert a steady state transient problem into linear algebra

$$[L]\left\{\frac{dI}{dt}\right\}+[R]\{I\}=\{V\}=\{V_0\}e^{i\omega t}$$

$$\{I\}\propto\{I_0\}e^{i\omega t}$$

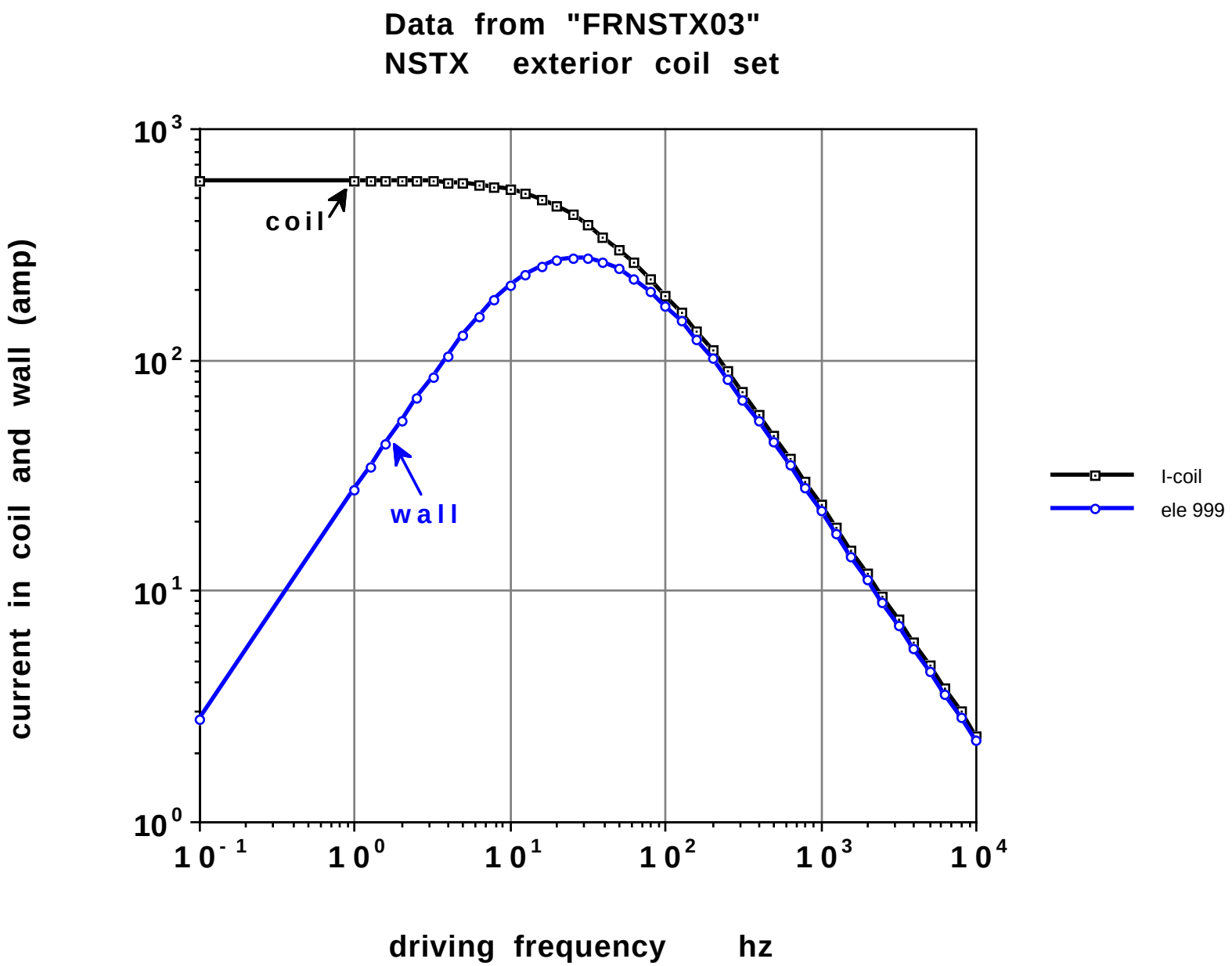
$$\{I_0\}=\{[L](i\omega)+[R]\}^{-1}\{V_0\}$$

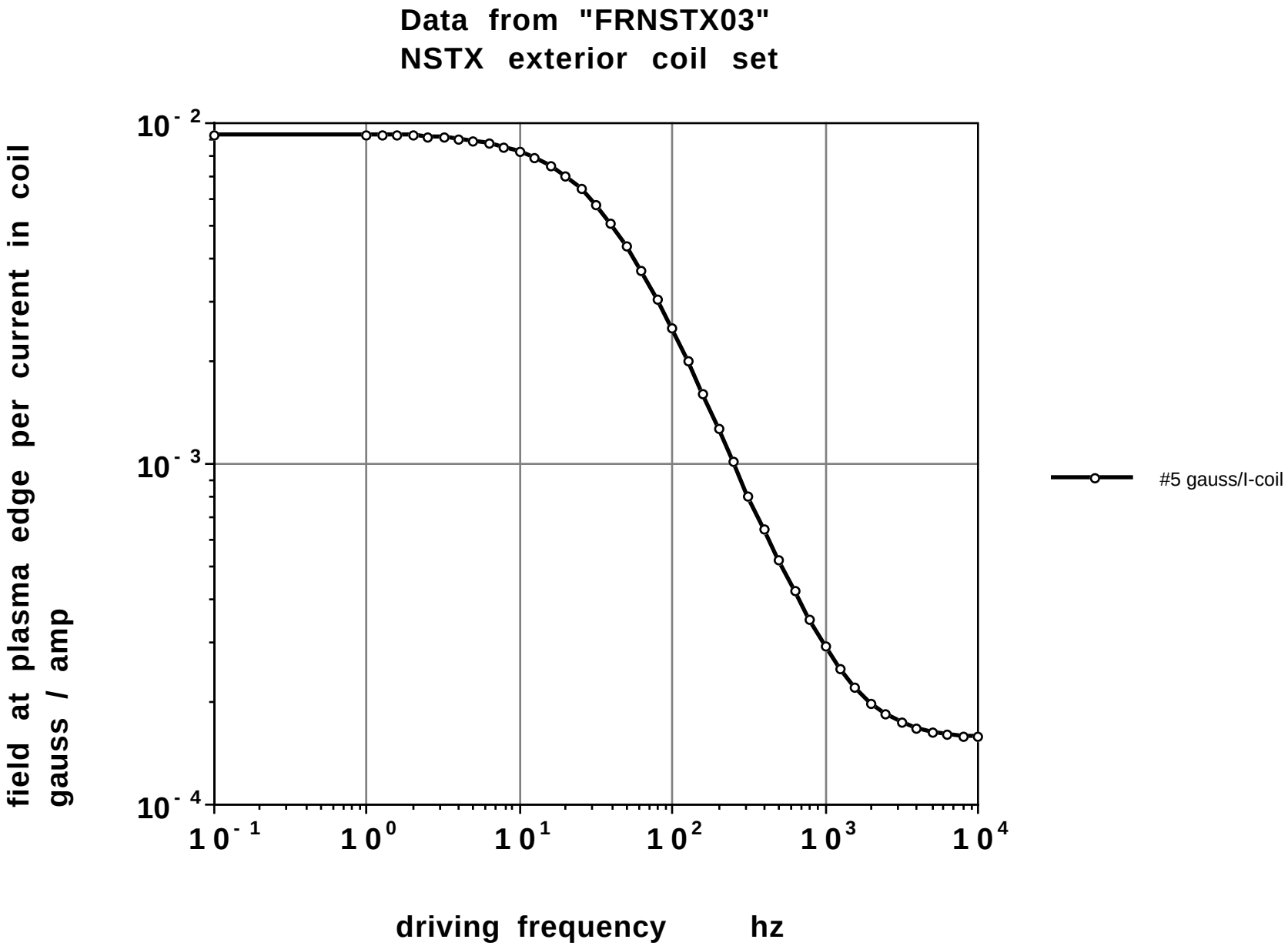
recall skin depth: $$\delta=\left[\frac{2\rho}{\omega\mu}\right]^{1/2}$$

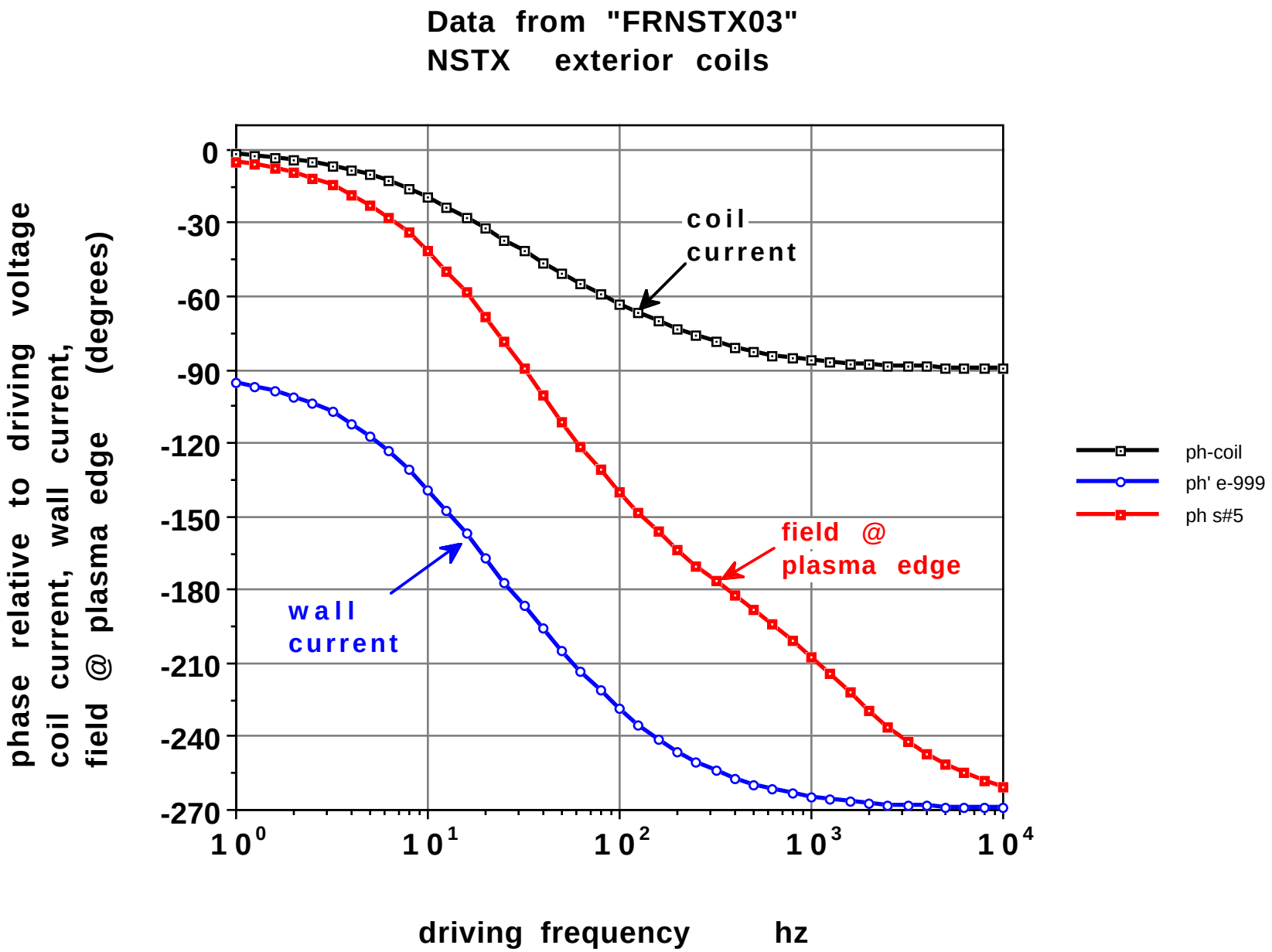
Important dimensions:
plasma edge @ R = 1.56m
NSTX VV Wall R ~ 1.7 m
thickness = 5/8" = 0.01587 m

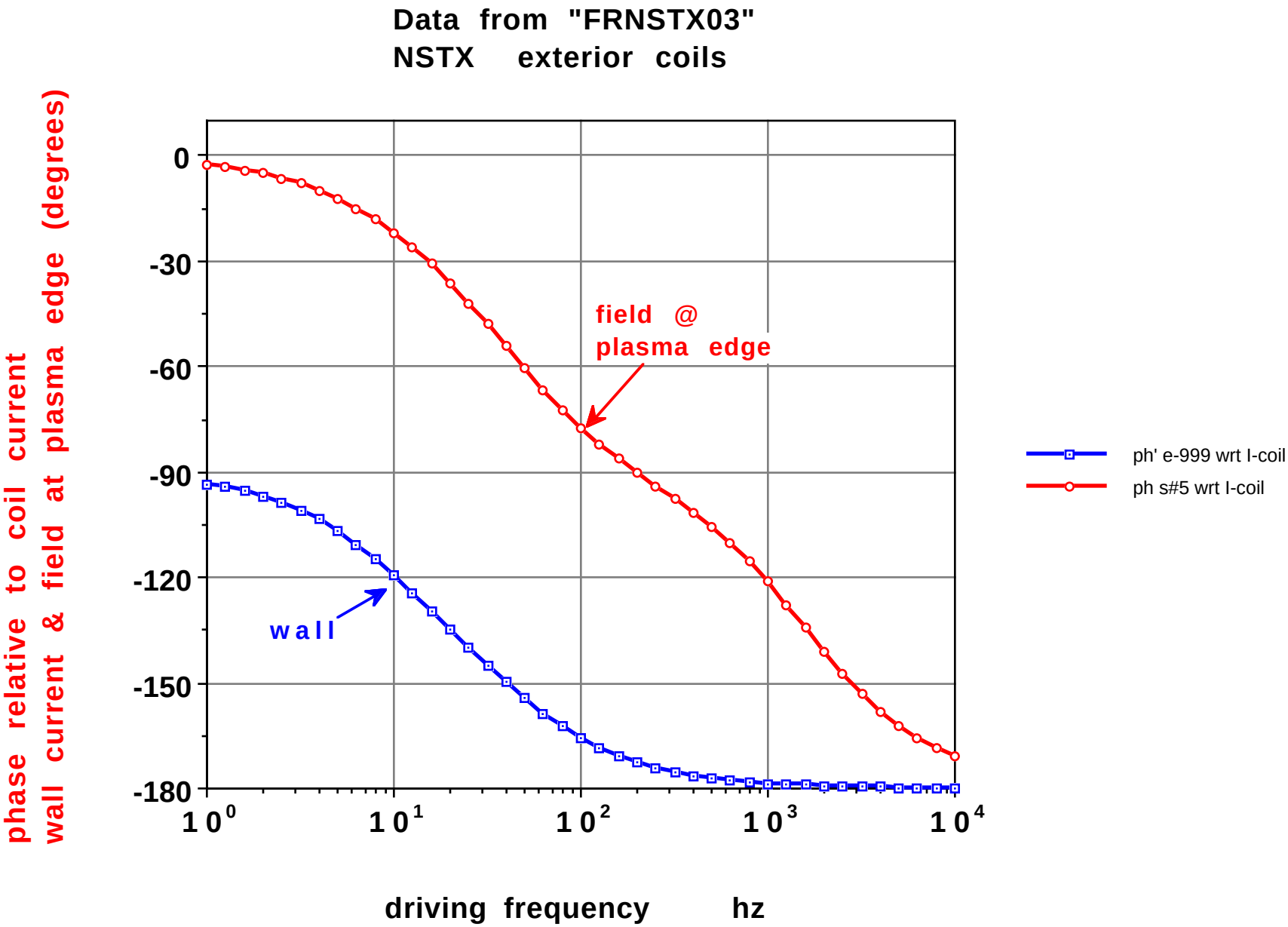
coils: 58. degree toroidal span
coils: z = +&- 0.45 m span

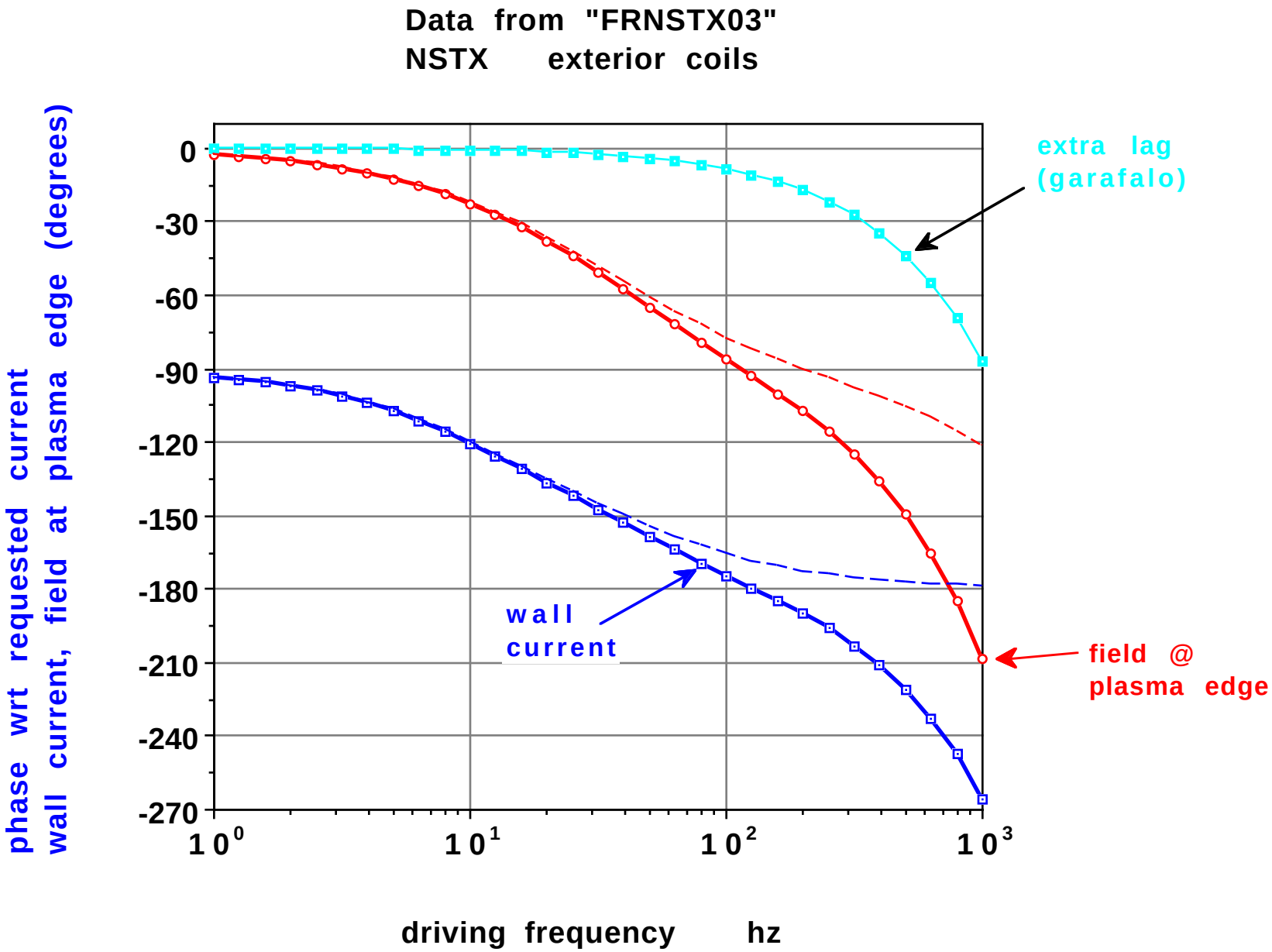
exterior coils @ R = 1.74 m
interior coils @ R = 1.66 m

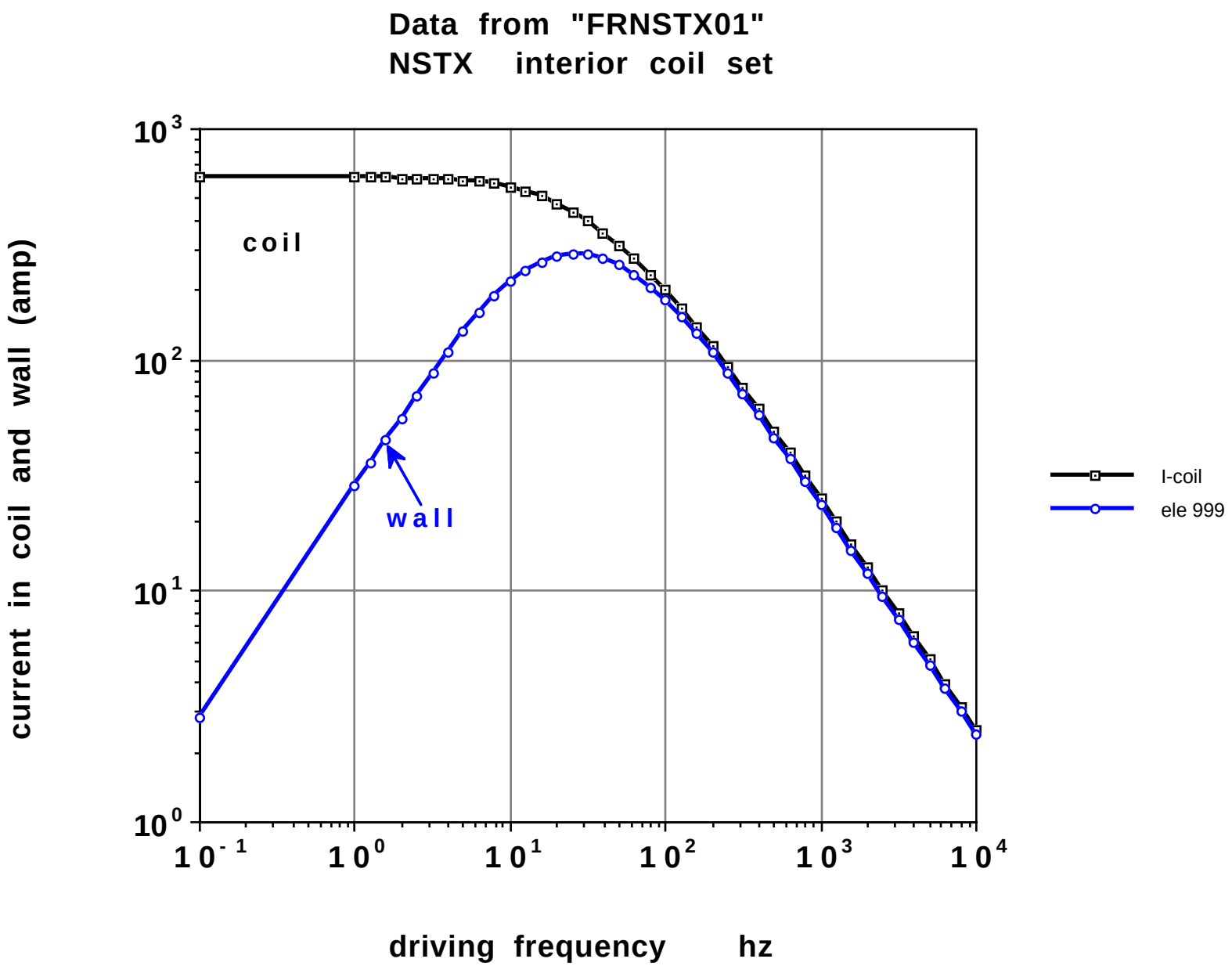

Data from "FRNSTX03"
NSTX exterior coil set
current in coil and wall (amp)
10^3
10^2
10^1
10^0
coil
wall
10^-1
10^0
10^1
10^2
10^3
10^4
driving frequency hz
I-coil
ele 999

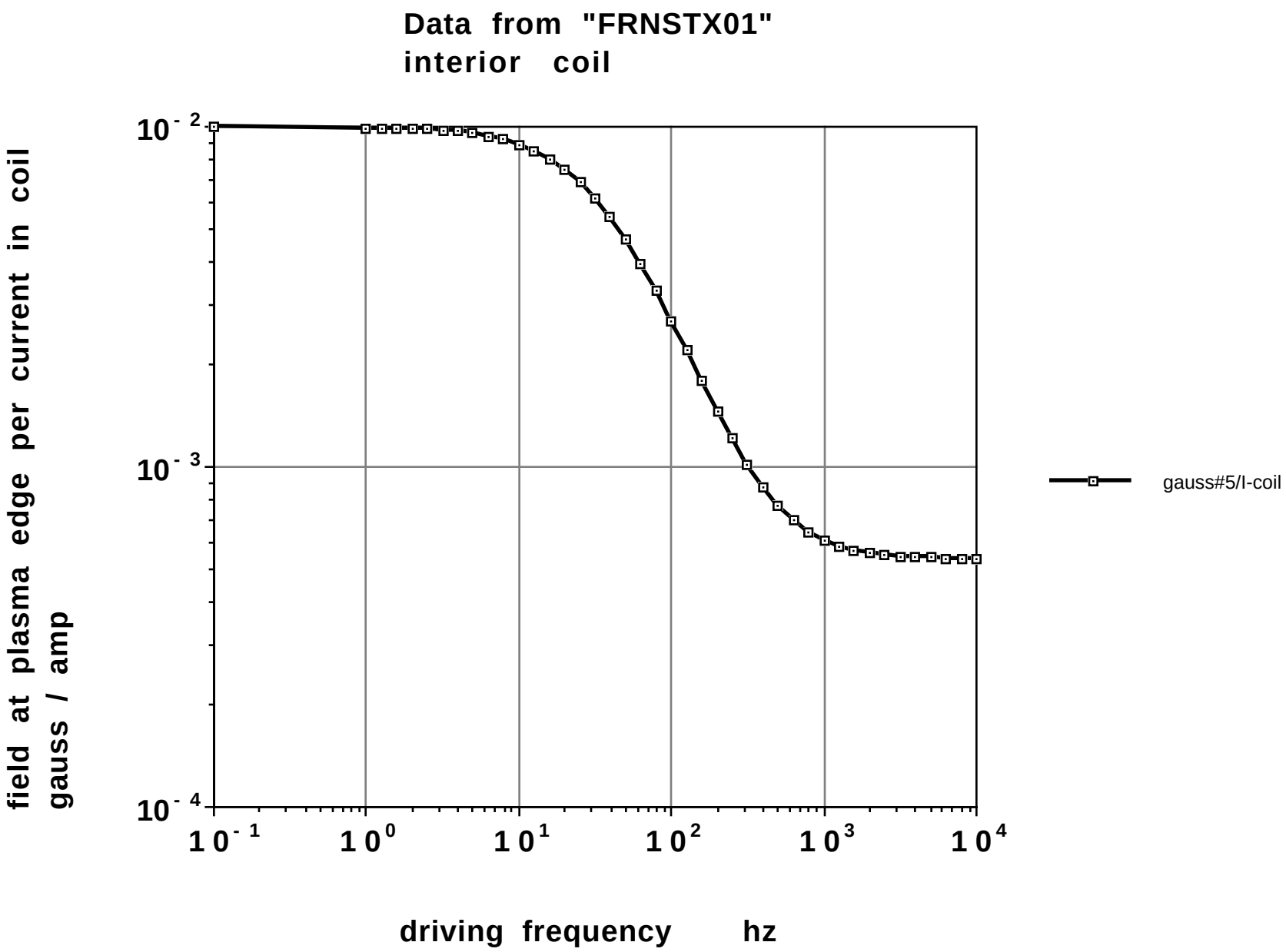

Data from "FRNSTX03"
NSTX exterior coil set
field at plasma edge per current in coil
gauss / amp
10 - 2
10 - 3
10 - 4
10 - 1
10 0
10 1
10 2
10 3
10 4
driving frequency hz
#5 gauss/I-coil

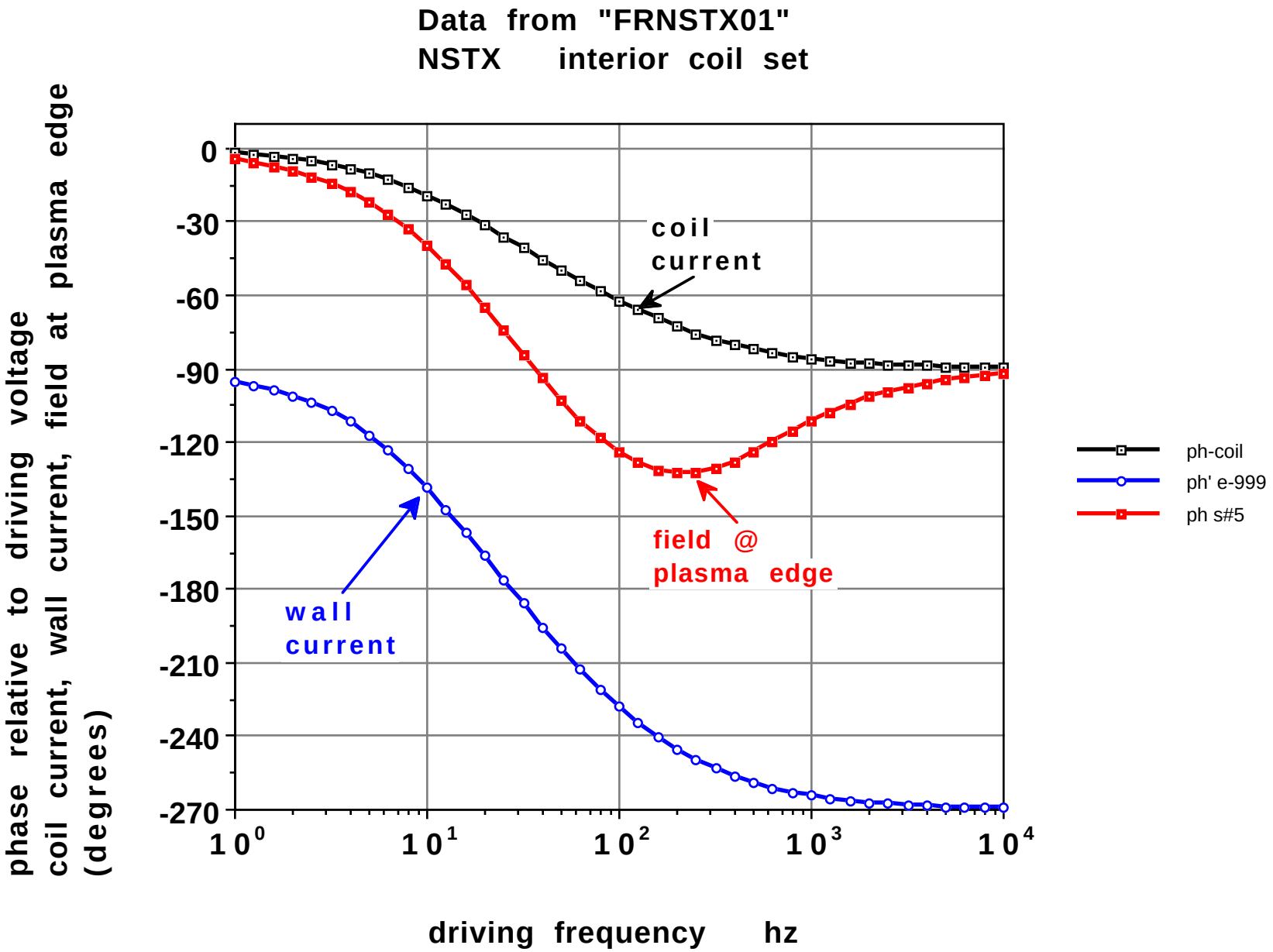

Data from "FRNSTX03"
NSTX exterior coils
phase relative to driving voltage
coil current, wall current,
field @ plasma edge (degrees)
0
-30
-60
-90
-120
-150
-180
-210
-240
-270
10^0
10^1
10^2
10^3
10^4
coil current
field @ plasma edge
wall current
driving frequency hz
ph-coil
ph' e-999
ph s#5

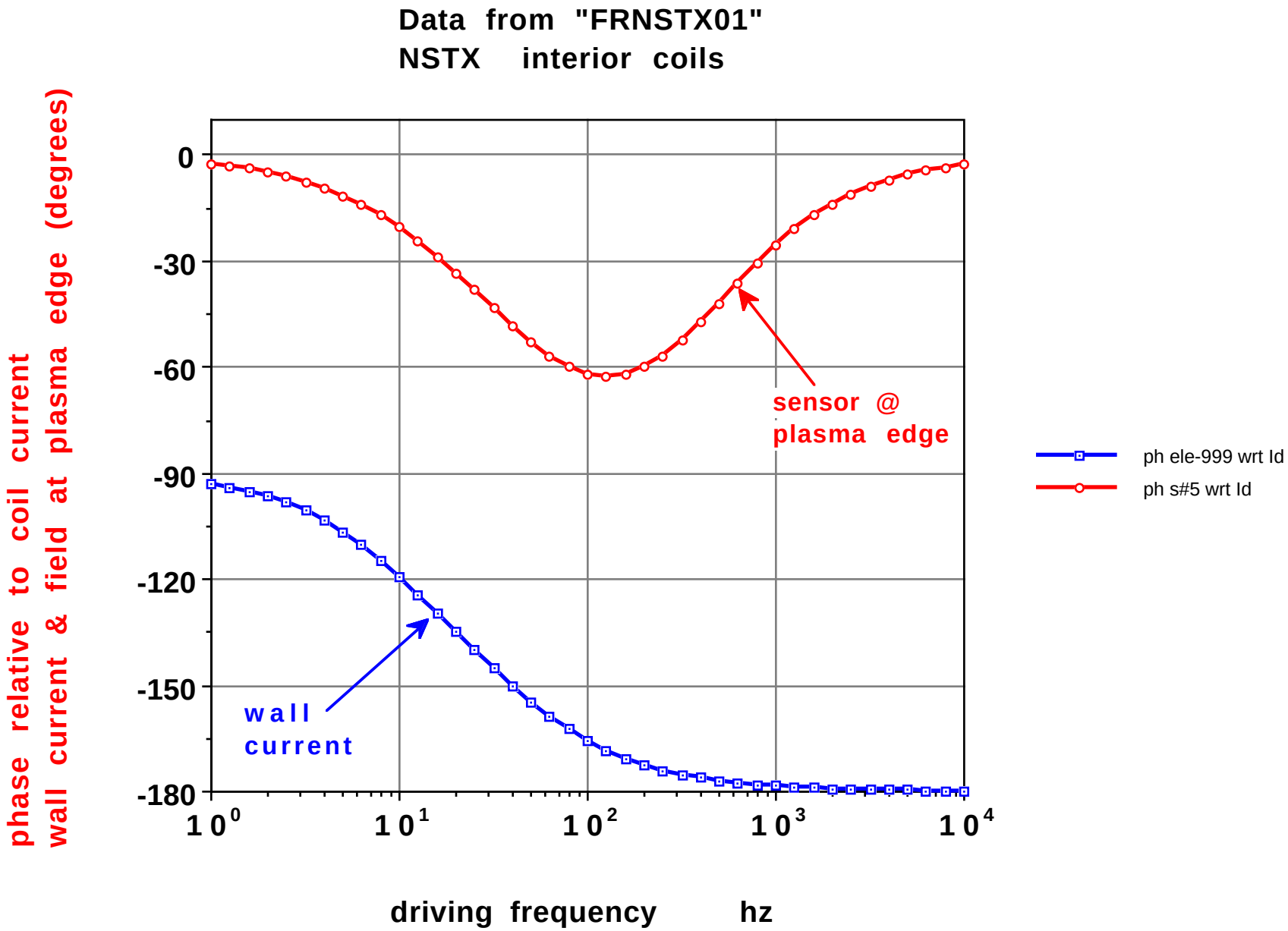

Data from "FRNSTX03"
NSTX exterior coils
phase relative to coil current
wall current & field at plasma edge (degrees)
0
-30
-60
-90
-120
-150
-180
10^0
10^1
10^2
10^3
10^4
field @
plasma edge
wall
driving frequency hz
ph' e-999 wrt I-coil
ph s#5 wrt I-coil

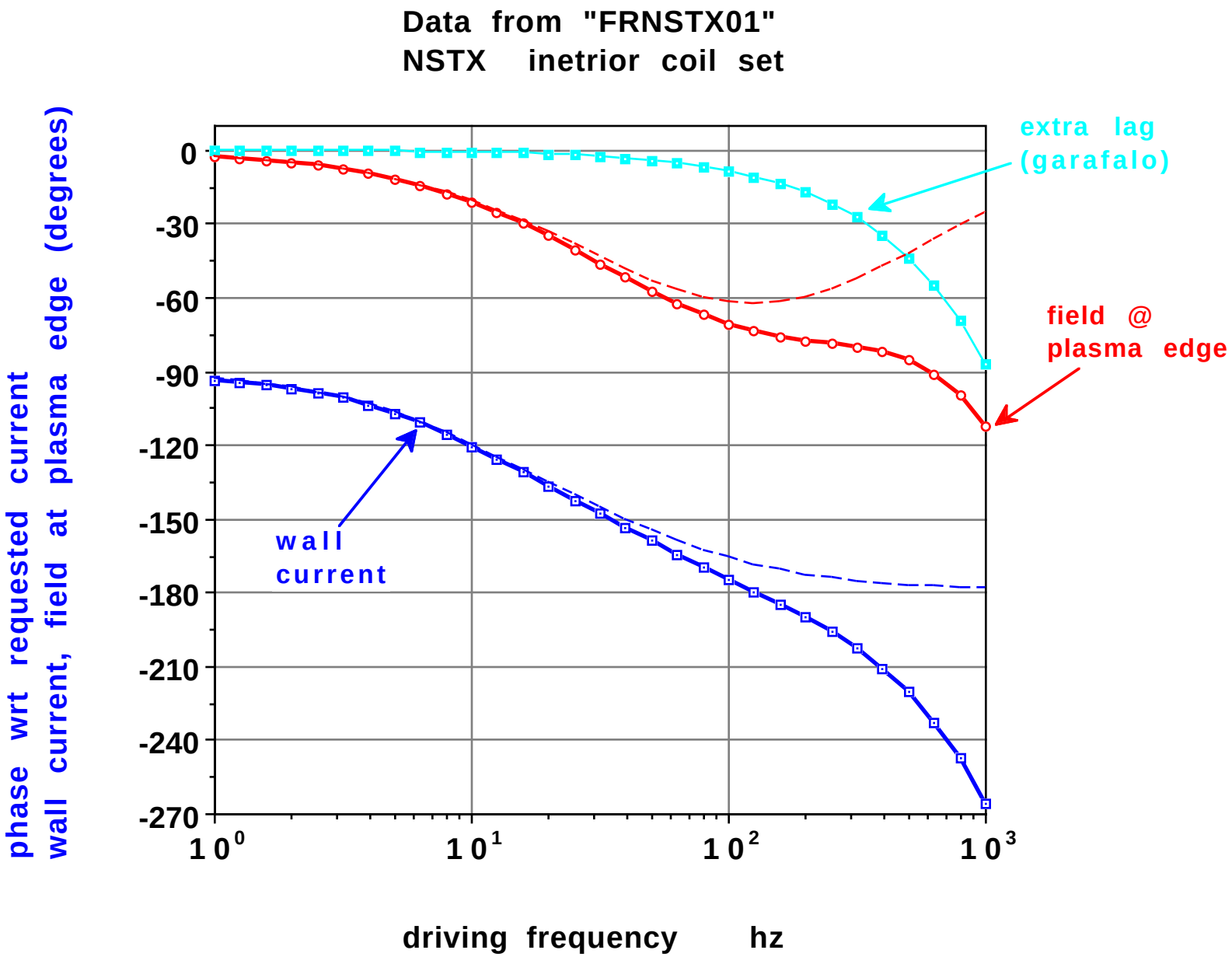

Data from "FRNSTX03"
NSTX exterior coils
phase wrt requested current
wall current, field at plasma edge (degrees)
0
-30
-60
-90
-120
-150
-180
-210
-240
-270
10^0
10^1
10^2
10^3
driving frequency hz
extra lag
(garafalo)
wall
current
field @
plasma edge

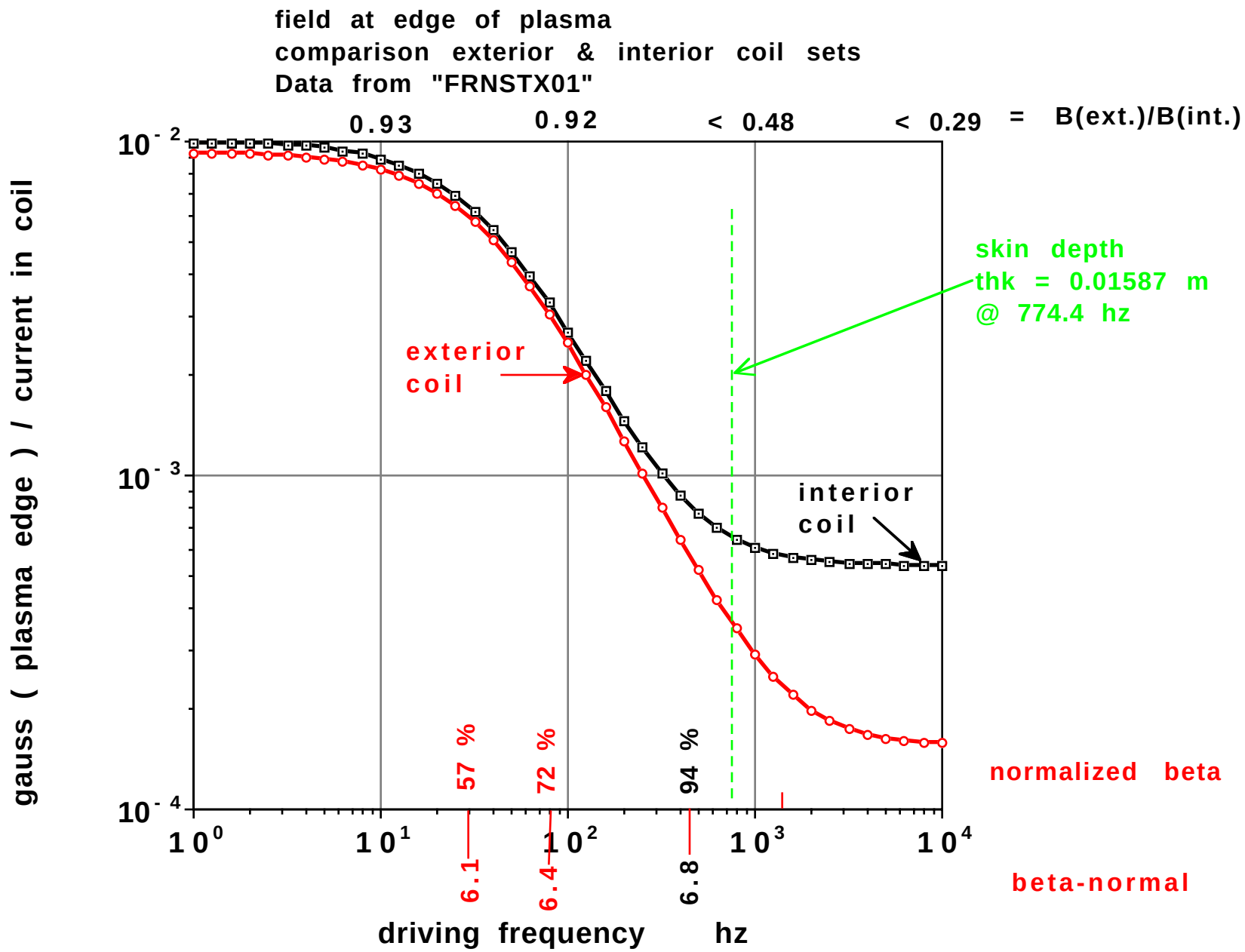

Data from "FRNSTX01"
NSTX interior coil set
current in coil and wall (amp)
10^3
10^2
10^1
10^0
coil
wall
10^-1
10^0
10^1
10^2
10^3
10^4
driving frequency hz
I-coil
ele 999

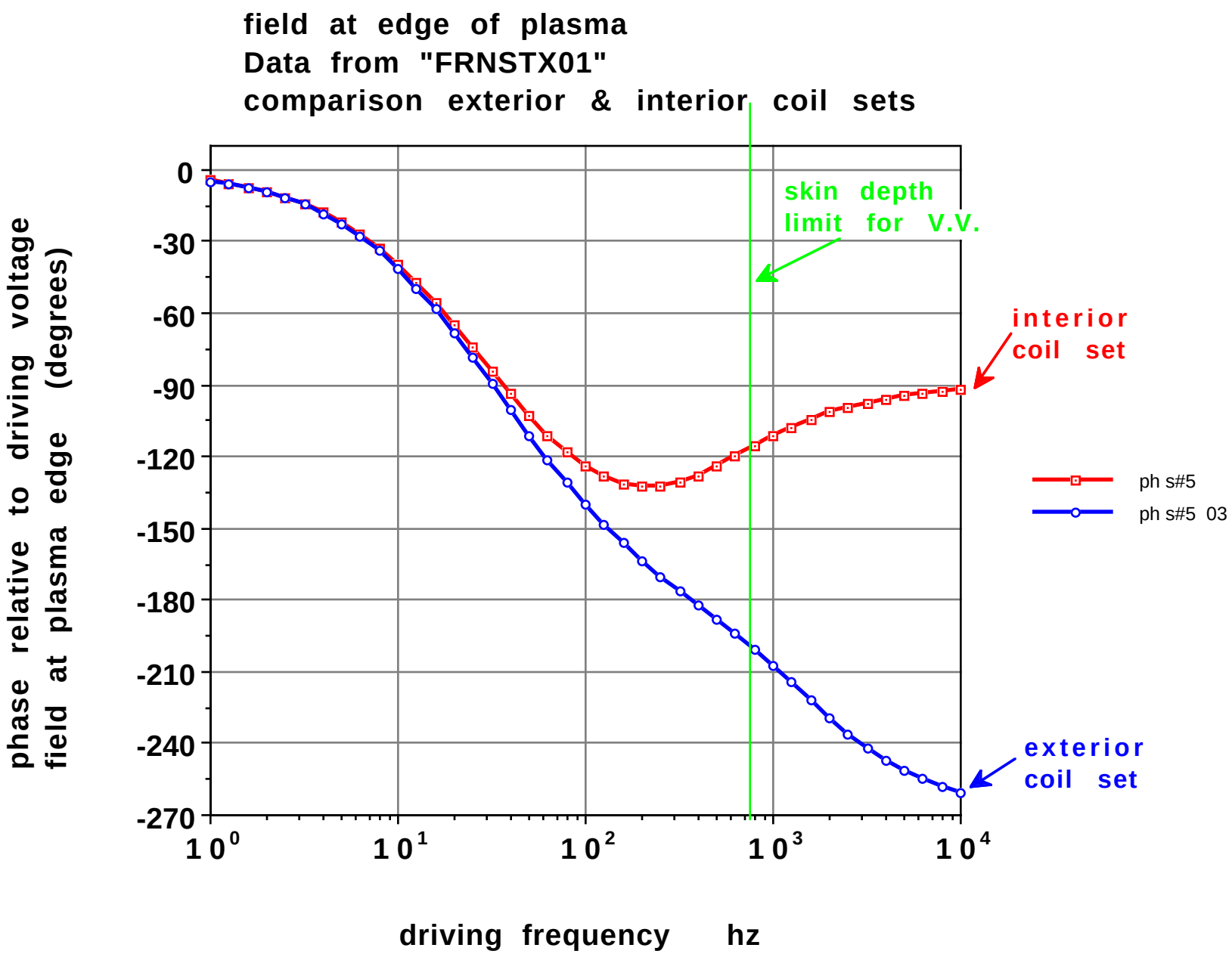

Data from "FRNSTX01"
interior coil
field at plasma edge per current in coil
gauss / amp
10 - 2
10 - 3
10 - 4
10 - 1
10 0
10 1
10 2
10 3
10 4
driving frequency hz
gauss#5/I-coil

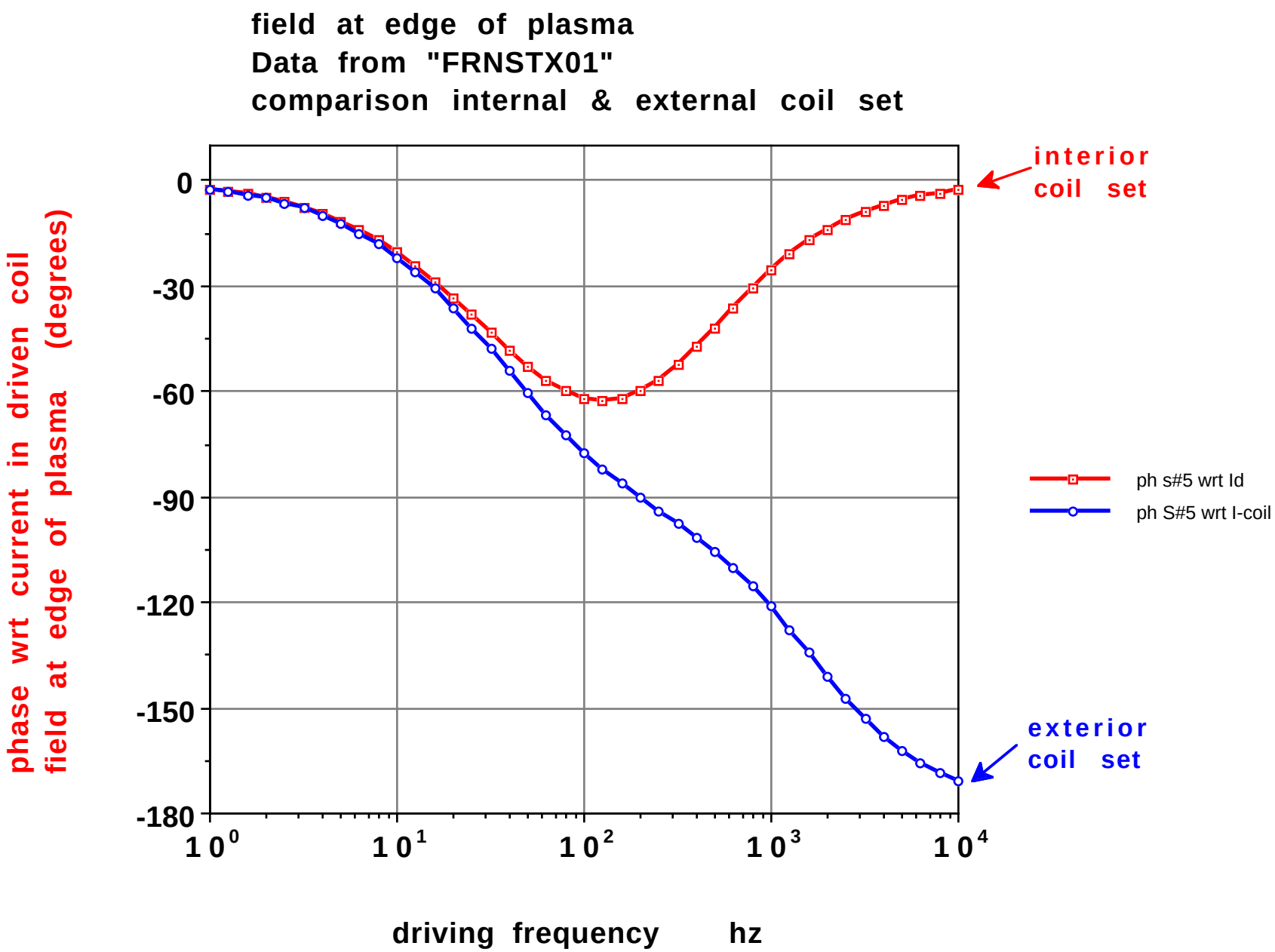

Data from "FRNSTX01"
NSTX interior coil set
phase relative to driving voltage
coil current, wall current, field at plasma edge
(degrees)
0
-30
-60
-90
-120
-150
-180
-210
-240
-270
10^0
10^1
10^2
10^3
10^4
driving frequency hz
coil current
field @ plasma edge
wall current
ph-coil
ph' e-999
ph s#5

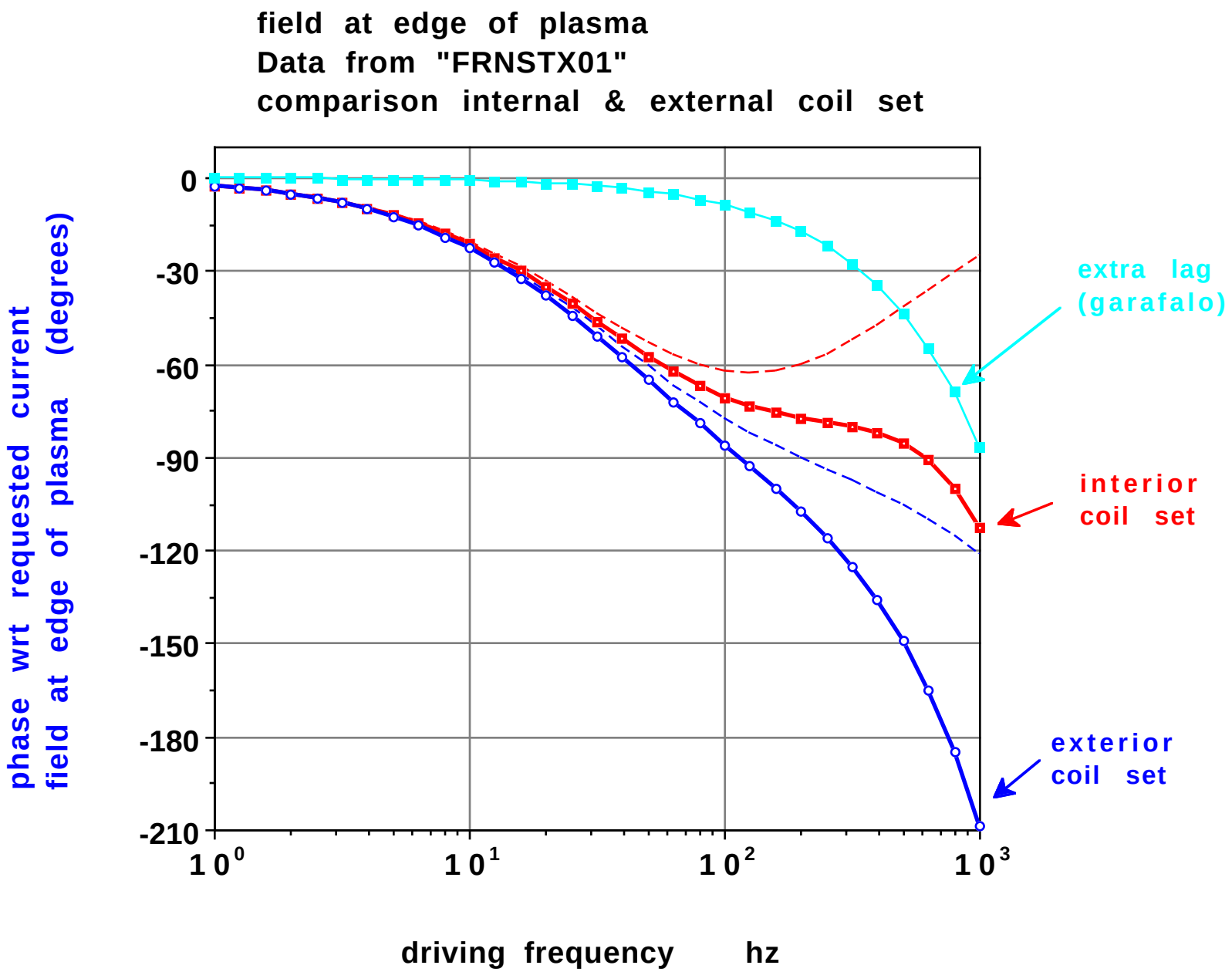

Data from "FRNSTX01"
NSTX interior coils
phase relative to coil current
wall current & field at plasma edge (degrees)
0
-30
-60
-90
-120
-150
-180
10^0
10^1
10^2
10^3
10^4
sensor @
plasma edge
wall
current
driving frequency hz
ph ele-999 wrt Id
ph s#5 wrt Id


Data from "FRNSTX01"
NSTX inetrior coil set
phase wrt requested current
wall current, field at plasma edge (degrees)
0
-30
-60
-90
-120
-150
-180
-210
-240
-270
10^0
10^1
10^2
10^3
driving frequency hz
extra lag
(garafalo)
field @
plasma edge
wall
current


field at edge of plasma
comparison exterior & interior coil sets
Data from "FRNSTX01"
0.93
0.92
< 0.48
< 0.29
= B(ext.)/B(int.)
gauss (plasma edge) / current in coil
10 - 2
10 - 3
10 - 4
skin depth
thk = 0.01587 m
@ 774.4 hz
exterior
coil
interior
coil
57 %
72 %
94 %
normalized beta
10 0
10 1
10 2
10 3
10 4
6.1
6.4
6.8
beta-normal
driving frequency hz


field at edge of plasma
Data from "FRNSTX01"
comparison exterior & interior coil sets
skin depth
limit for V.V.
interior
coil set
exterior
coil set
ph s#5
ph s#5 03
phase relative to driving voltage
field at plasma edge (degrees)
0
-30
-60
-90
-120
-150
-180
-210
-240
-270
10^0
10^1
10^2
10^3
10^4
driving frequency hz


field at edge of plasma
Data from "FRNSTX01"
comparison internal & external coil set
phase wrt current in driven coil
field at edge of plasma (degrees)
0
-30
-60
-90
-120
-150
-180
10^0
10^1
10^2
10^3
10^4
driving frequency hz
interior
coil set
exterior
coil set
ph s#5 wrt Id
ph S#5 wrt I-coil


field at edge of plasma
Data from "FRNSTX01"
comparison internal & external coil set
phase wrt requested current
field at edge of plasma (degrees)
0
-30
-60
-90
-120
-150
-180
-210
10^0
10^1
10^2
10^3
driving frequency hz
extra lag
(garafalo)
interior
coil set
exterior
coil set

CONCLUSIONS
VALEN FR analysis

- VALEN NSTX Frequency Response analysis shows NSTX with exterior coils may reach $\beta n = 6.1$ @ 30 hz, 6.4 @ 80.hz (**this is the limit !**)

- VALEN NSTX Frequency Response analysis shows NSTX with interior coils may reach $\beta n = 6.8$ @ 450 hz

- with exterior coils phase lag (wrt current at 30.hz) is 48. degrees, 50.7 if we have extra lag from power supply

- with interior coils phase lag (wrt current at 30.hz) is 43.3. degrees, 46.1 if we have extra lag from power supply. At 450. hz lags are 44.7 & 83.8 respectively.

- skin depth effects make NSTX VV wall opaque at 775. hz