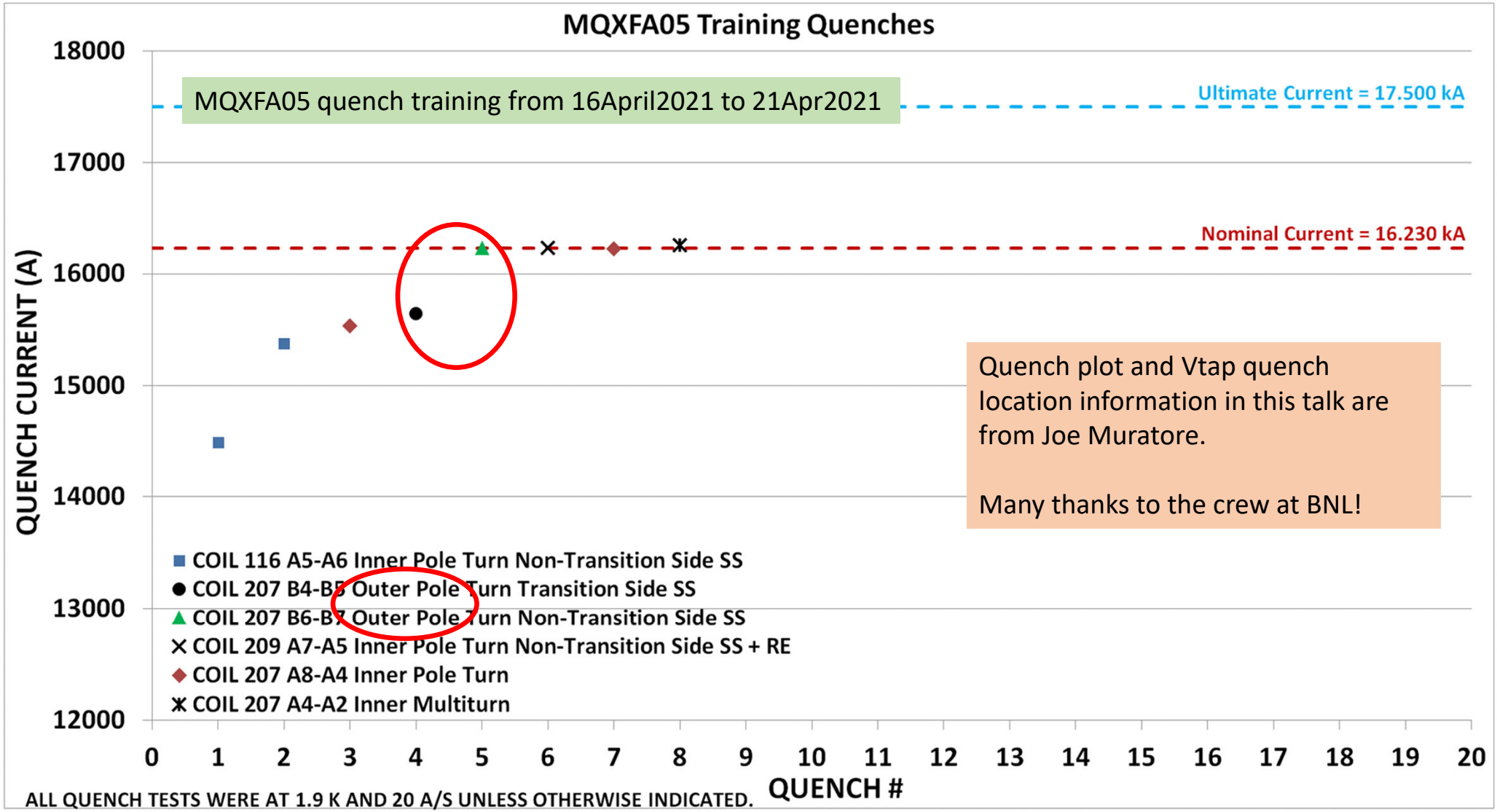
# MQXFA05 Quench Antenna Data
# (Work in Progress)

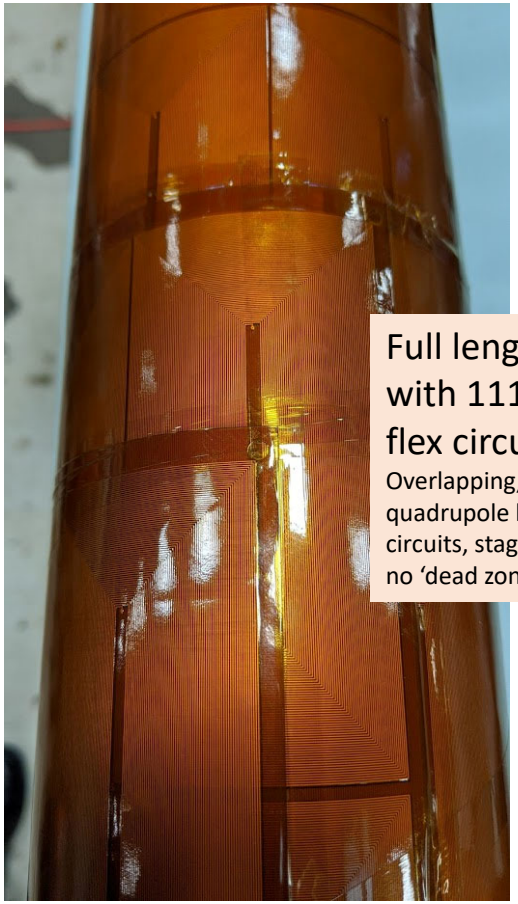
14May2021

J. DiMarco




Quench plot and Vtap quench location information in this talk are from Joe Muratore.

Many thanks to the crew at BNL!

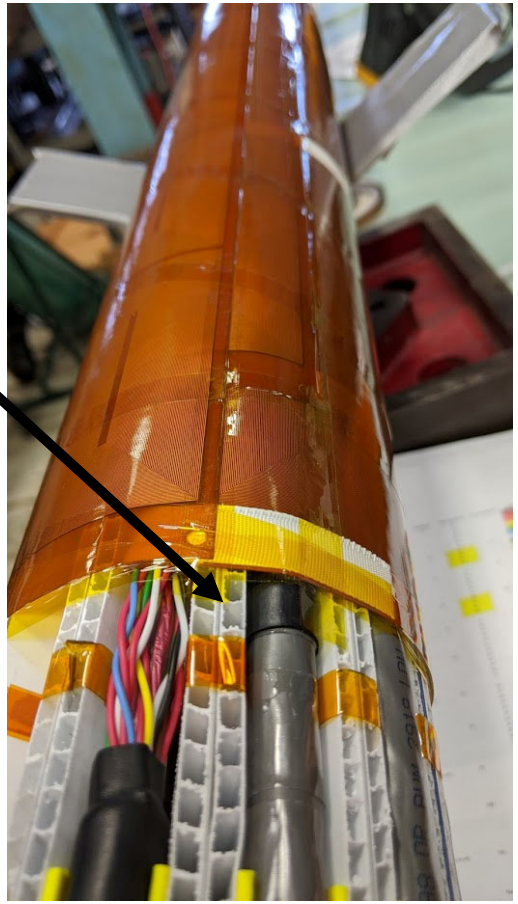


Full length Z-coverage with 111, 50mm-long flex circuits.

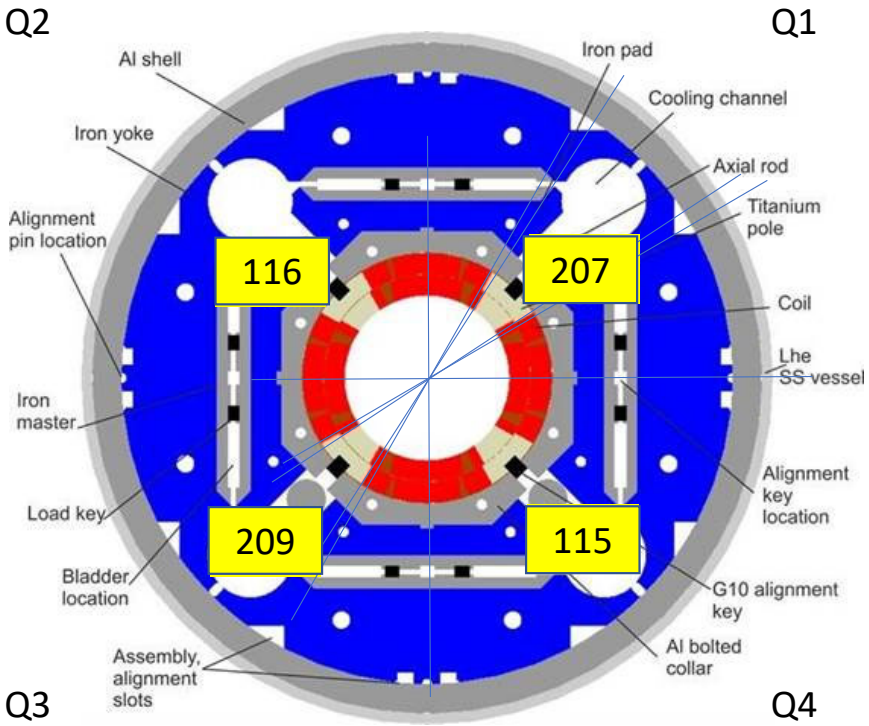
Overlapping, dipole and quadrupole bucked (DQBuck) circuits, staggered so there are no ‘dead zones’ in Z

Theta detection with 12, full-length DQBuck radial circuits

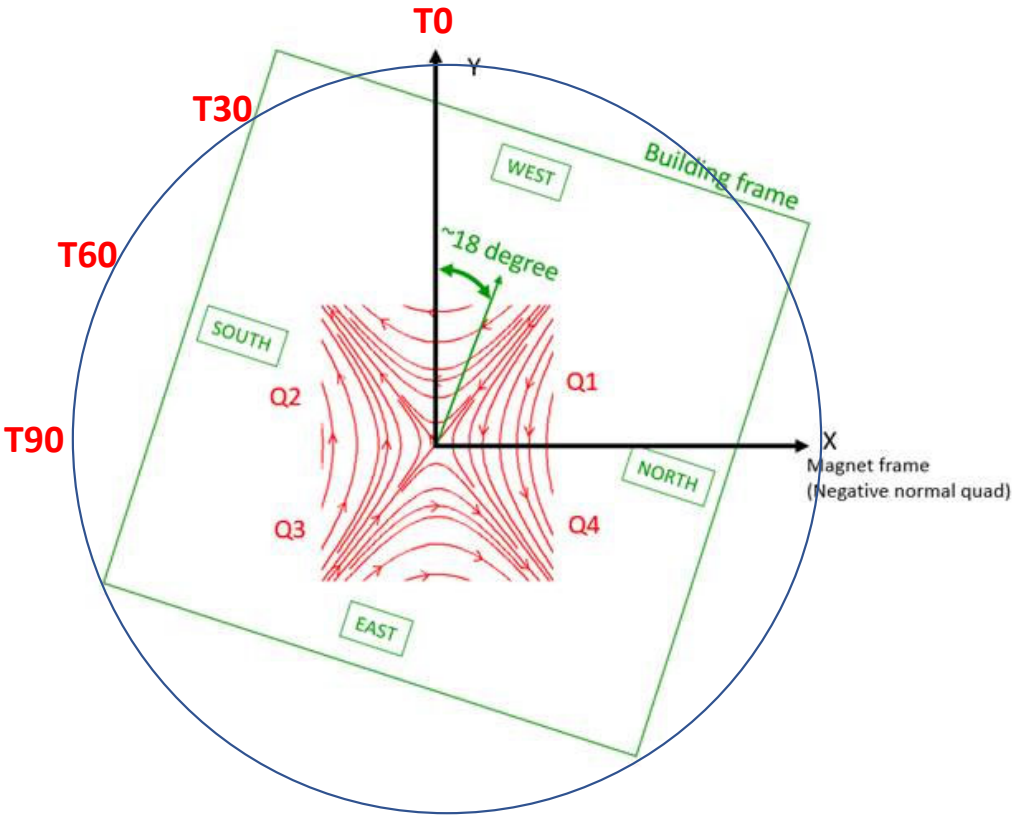
Positioned every 30 degrees.

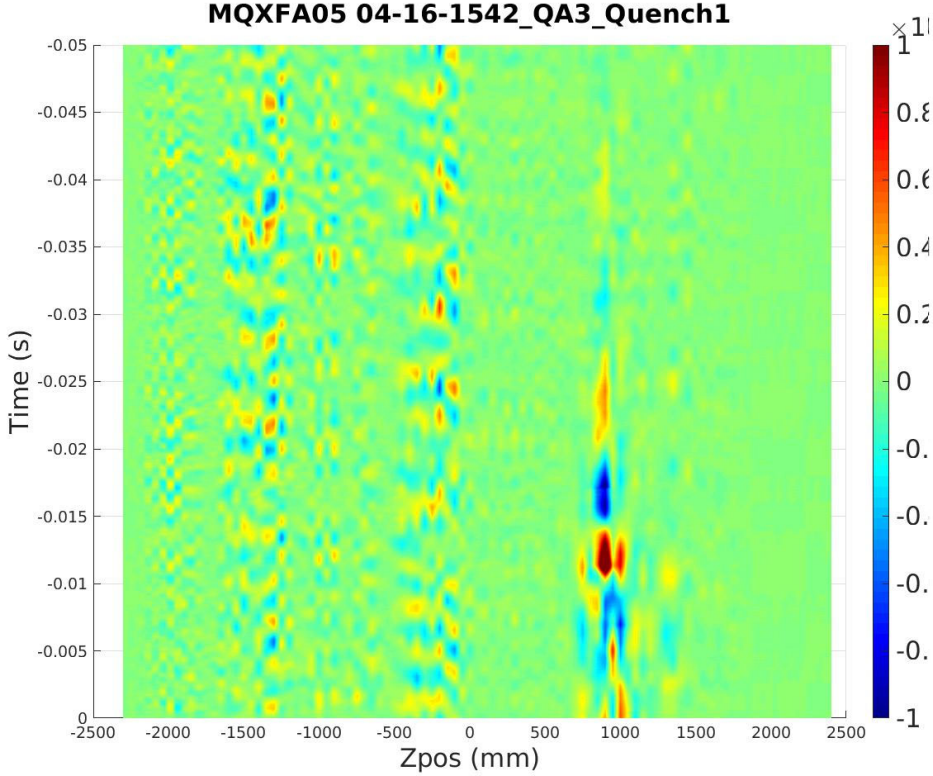


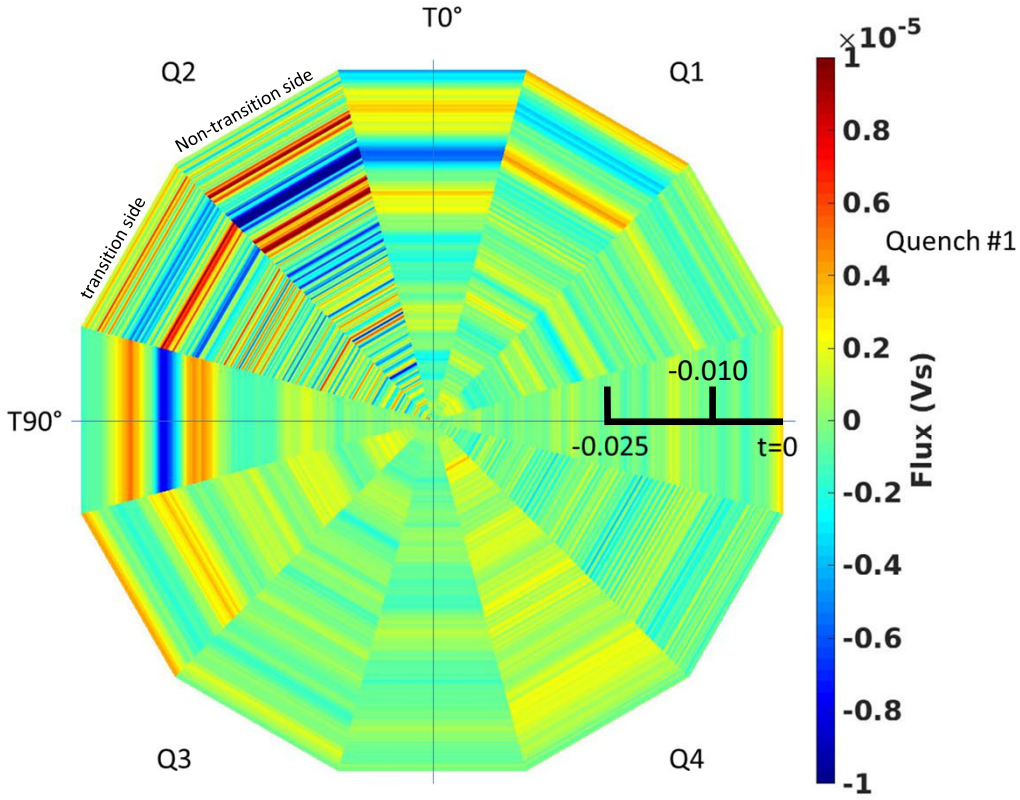
# Theta Antennas




Quench Antenna T0 placed along Y-axis





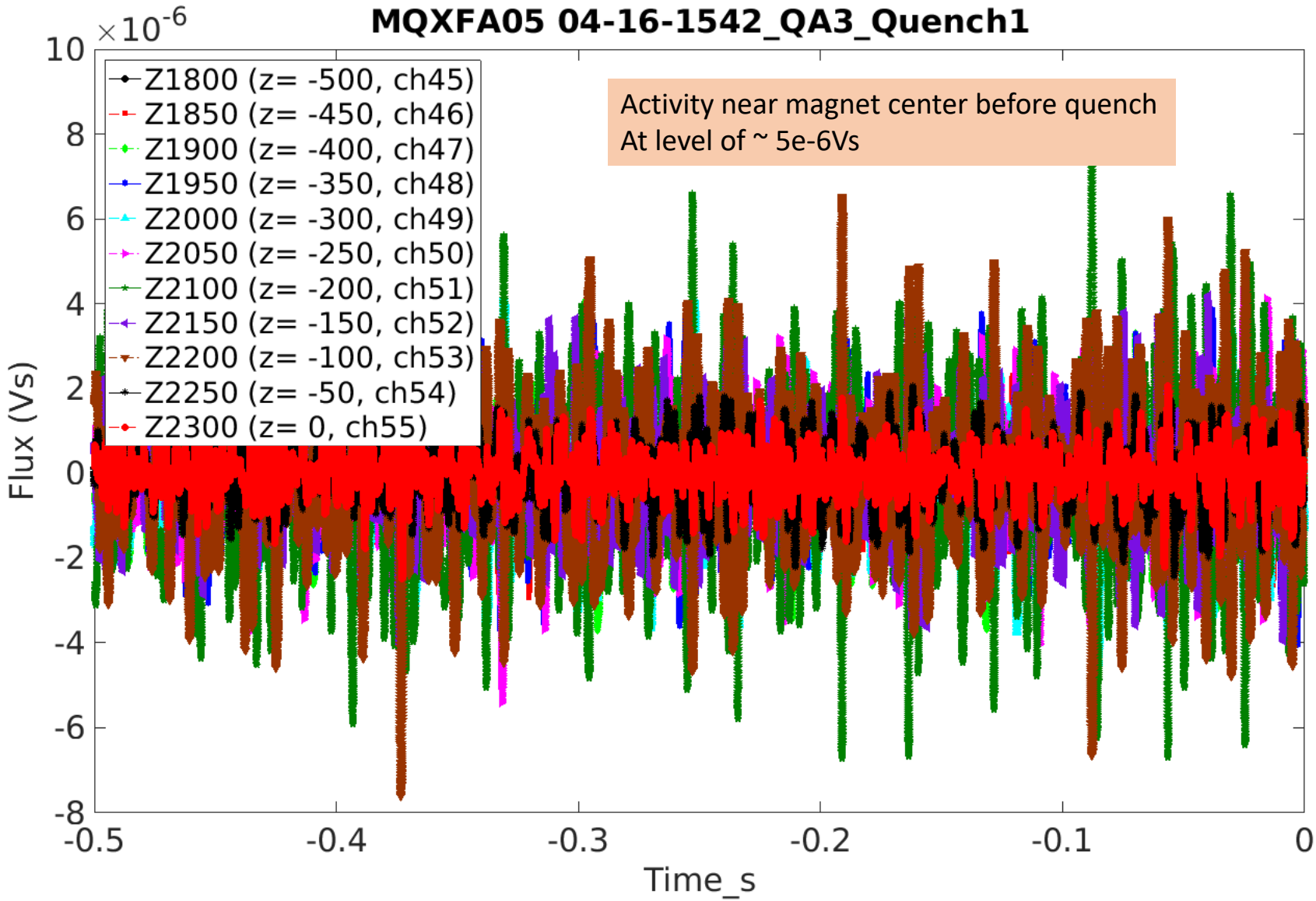

Qstart z=+900-950mm

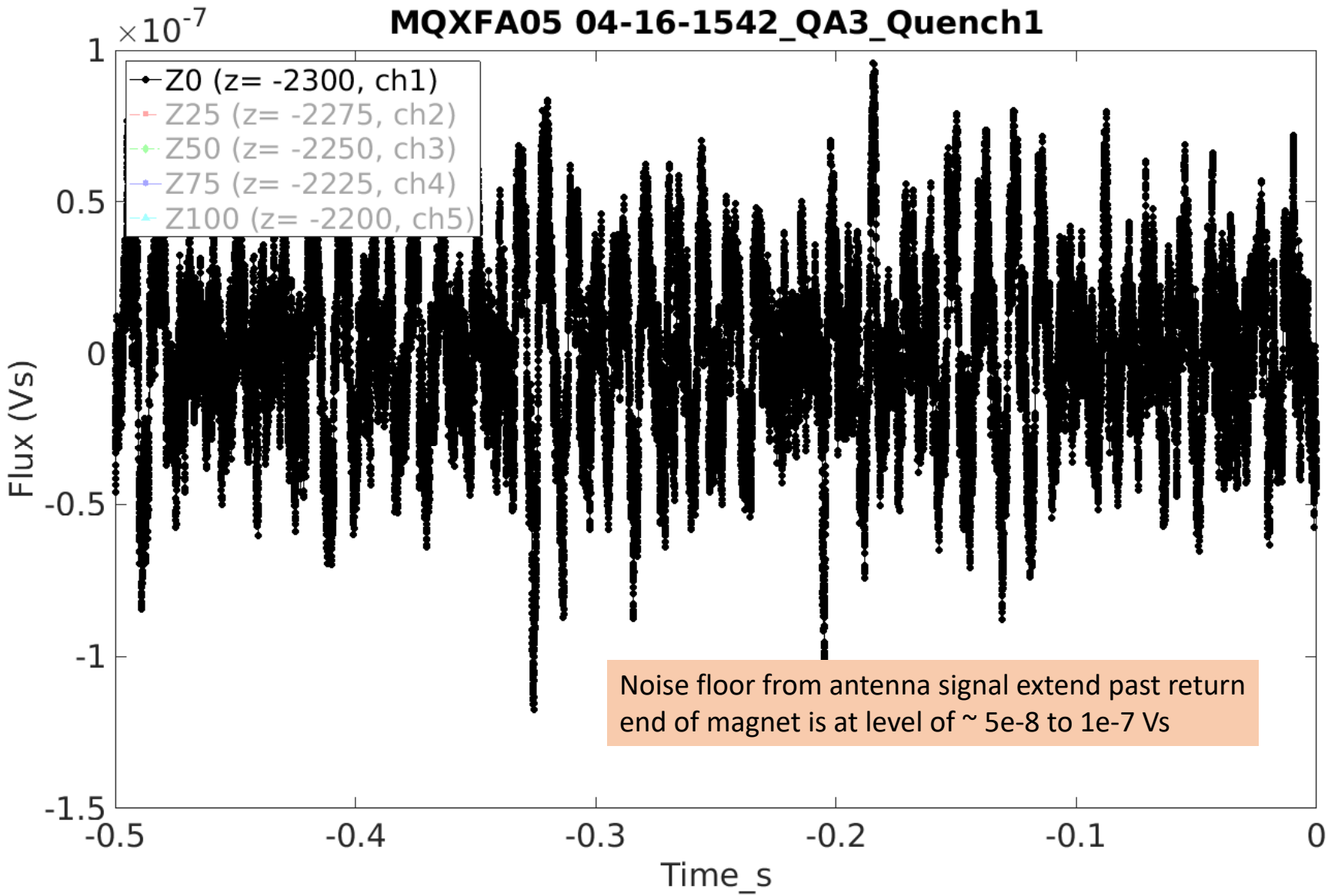
**MQXFA05 Quench #1 (Fri 16-Apr)**

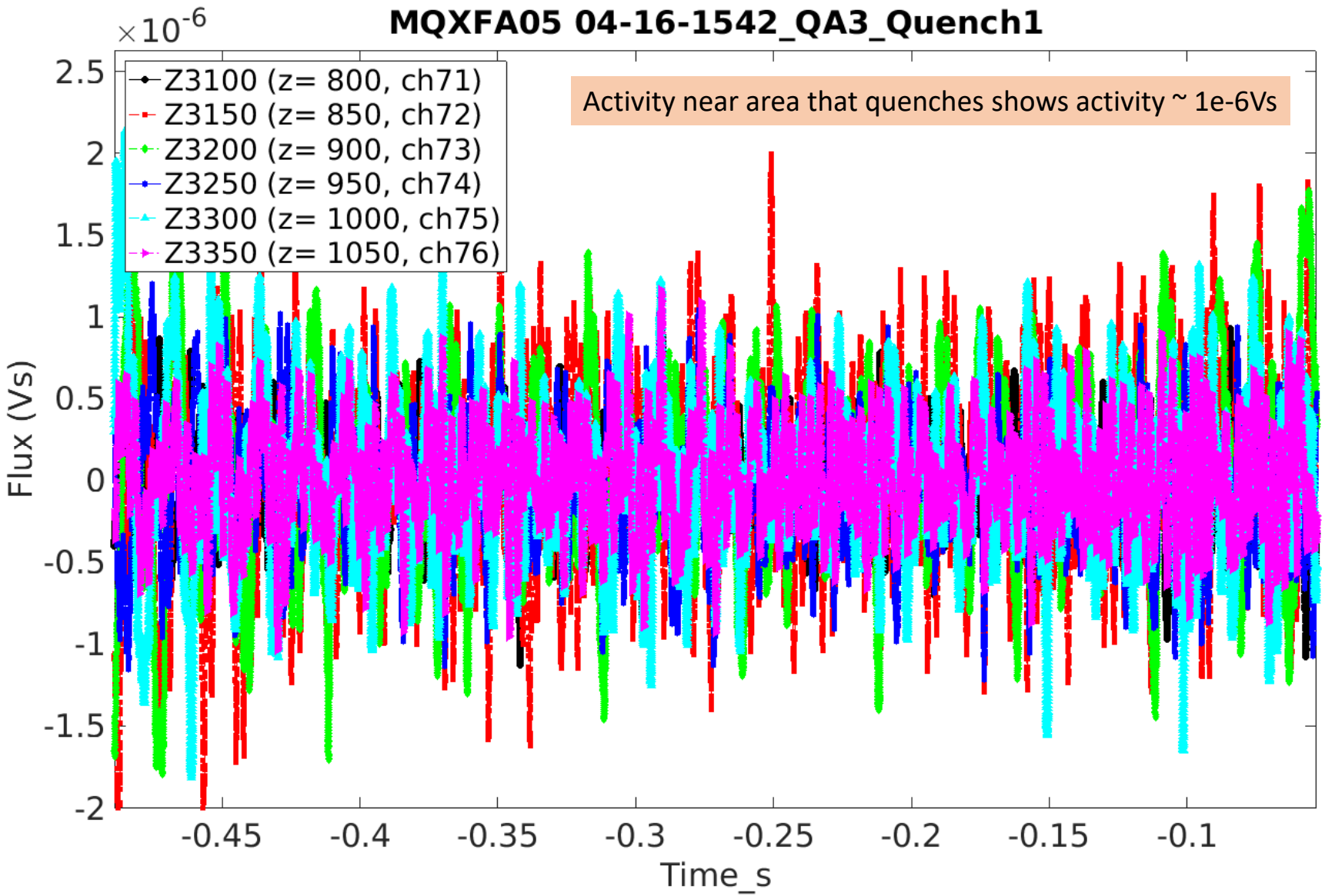
**$I_Q$ = 14486.10 A**

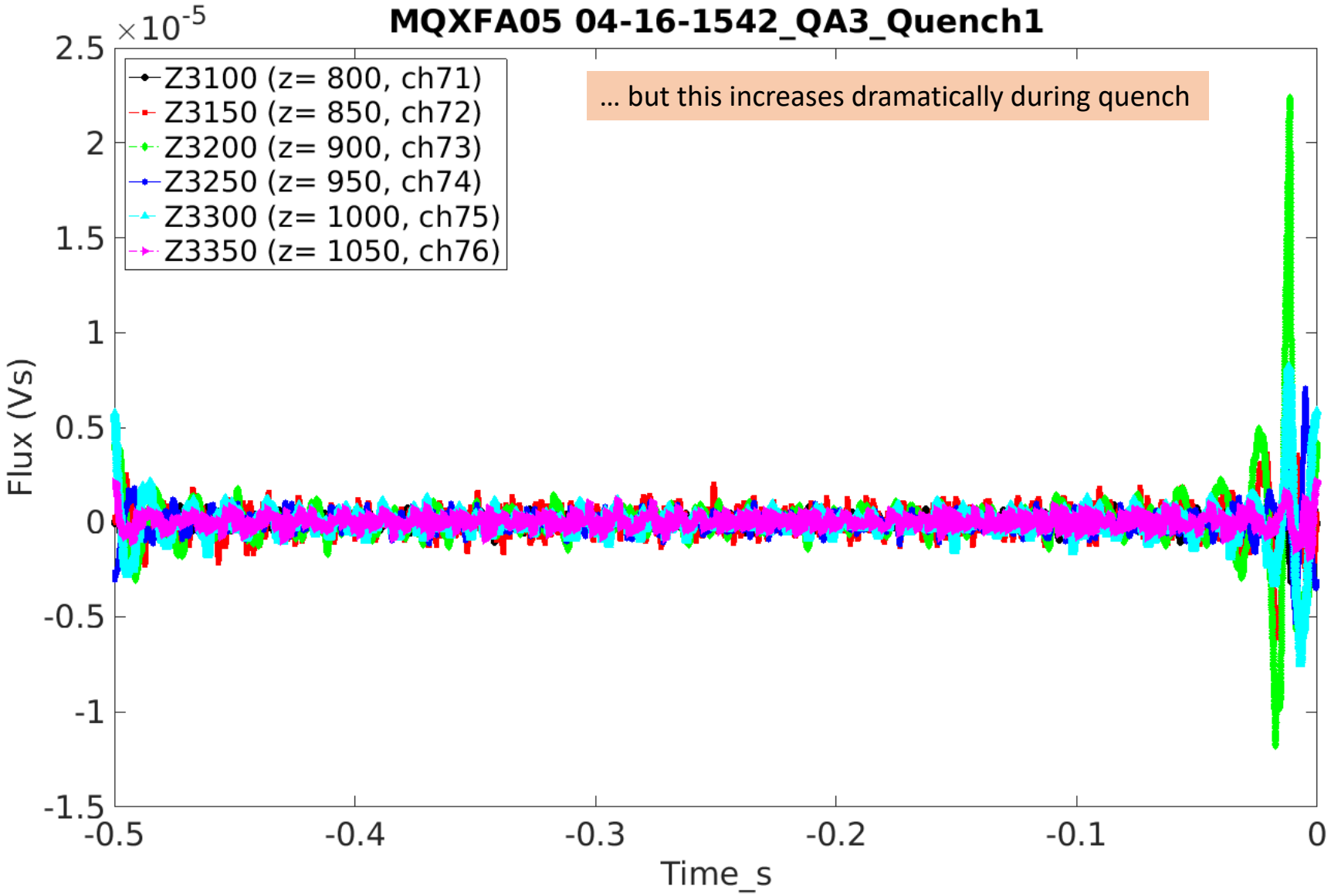
**QI = 24.3 MIIts**

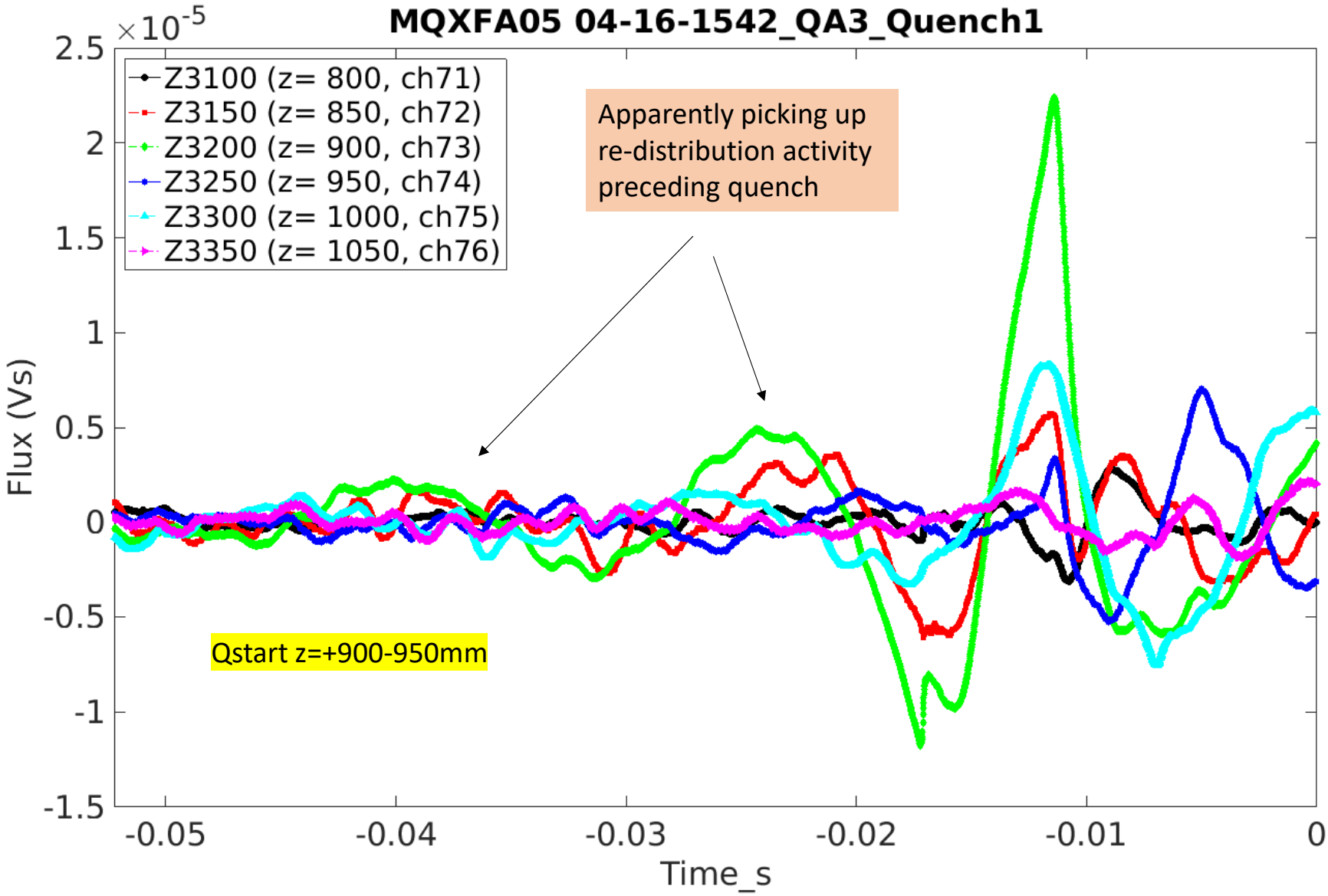
**Location = Coil 116 (Q2) A5-A6 inner layer pole turn non-transition side straight section**

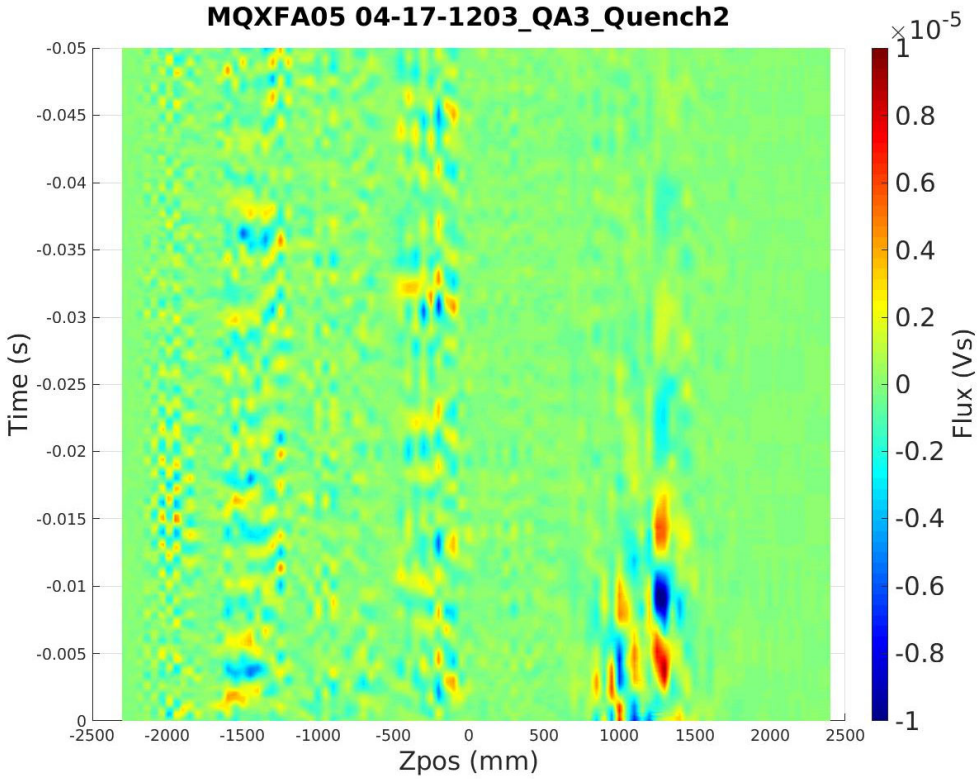

MQXFA05 04-16-1542_QA3_Quench1
×10^-6
Z1800 (z= -500, ch45)
Z1850 (z= -450, ch46)
Z1900 (z= -400, ch47)
Z1950 (z= -350, ch48)
Z2000 (z= -300, ch49)
Z2050 (z= -250, ch50)
Z2100 (z= -200, ch51)
Z2150 (z= -150, ch52)
Z2200 (z= -100, ch53)
Z2250 (z= -50, ch54)
Z2300 (z= 0, ch55)
Activity near magnet center before quench
At level of ~ 5e-6Vs
Flux (Vs)
Time_s
10
8
6
4
2
0
-2
-4
-6
-8
-0.5
-0.4
-0.3
-0.2
-0.1
0

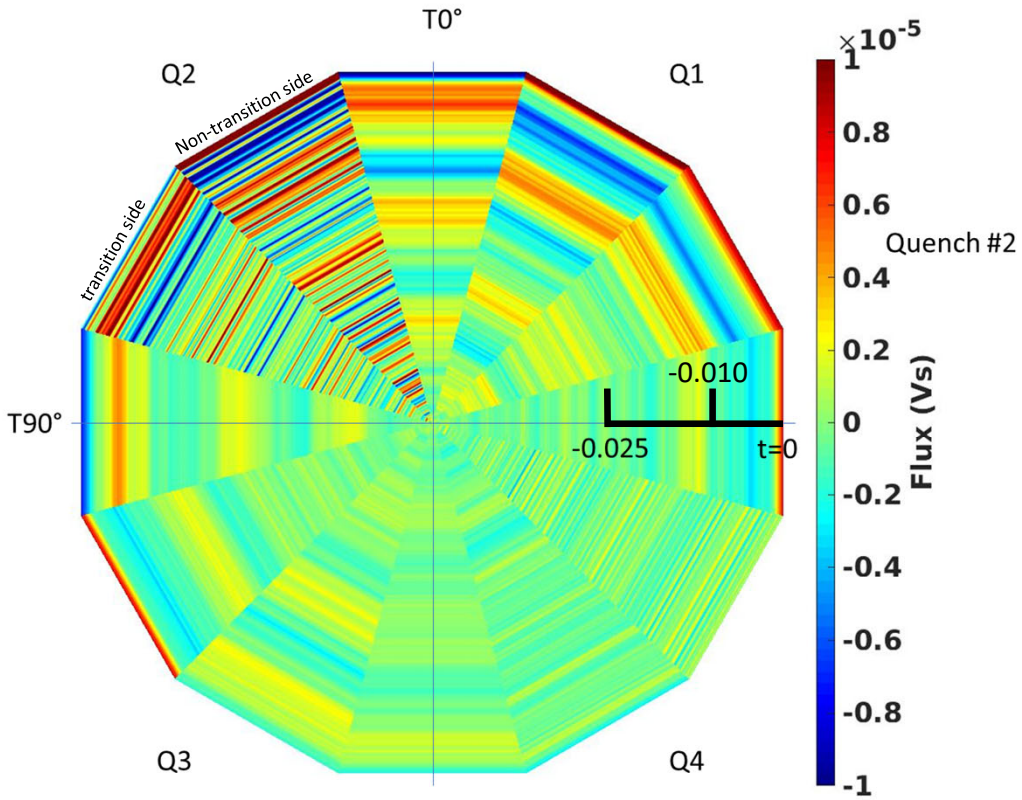

MQXFA05 04-16-1542_QA3_Quench1
×10^-7
1
0.5
0
-0.5
-1
-1.5
Flux (Vs)
-0.5
-0.4
-0.3
-0.2
-0.1
0
Time_s
Z0 (z= -2300, ch1)
Z25 (z= -2275, ch2)
Z50 (z= -2250, ch3)
Z75 (z= -2225, ch4)
Z100 (z= -2200, ch5)
Noise floor from antenna signal extend past return end of magnet is at level of ~ 5e-8 to 1e-7 Vs


MQXFA05 04-16-1542_QA3_Quench1
×10-6
Z3100 (z= 800, ch71)
Z3150 (z= 850, ch72)
Z3200 (z= 900, ch73)
Z3250 (z= 950, ch74)
Z3300 (z= 1000, ch75)
Z3350 (z= 1050, ch76)
Activity near area that quenches shows activity ~ 1e-6Vs
Flux (Vs)
Time_s
2.5
2
1.5
1
0.5
0
-0.5
-1
-1.5
-2
-0.45
-0.4
-0.35
-0.3
-0.25
-0.2
-0.15
-0.1


MQXFA05 04-16-1542_QA3_Quench1
×10-5
2.5
2
1.5
1
0.5
0
-0.5
-1
-1.5
Flux (Vs)
-0.5
-0.4
-0.3
-0.2
-0.1
0
Time_s
Z3100 (z= 800, ch71)
Z3150 (z= 850, ch72)
Z3200 (z= 900, ch73)
Z3250 (z= 950, ch74)
Z3300 (z= 1000, ch75)
Z3350 (z= 1050, ch76)
… but this increases dramatically during quench


MQXFA05 04-16-1542_QA3_Quench1
×10-5
2.5
2
1.5
1
0.5
0
-0.5
-1
-1.5
Flux (Vs)
-0.05
-0.04
-0.03
-0.02
-0.01
0
Time_s
Z3100 (z= 800, ch71)
Z3150 (z= 850, ch72)
Z3200 (z= 900, ch73)
Z3250 (z= 950, ch74)
Z3300 (z= 1000, ch75)
Z3350 (z= 1050, ch76)
Apparently picking up
re-distribution activity
preceding quench
Qstart z=+900-950mm




Q start ~ Z = +1300-1350mm

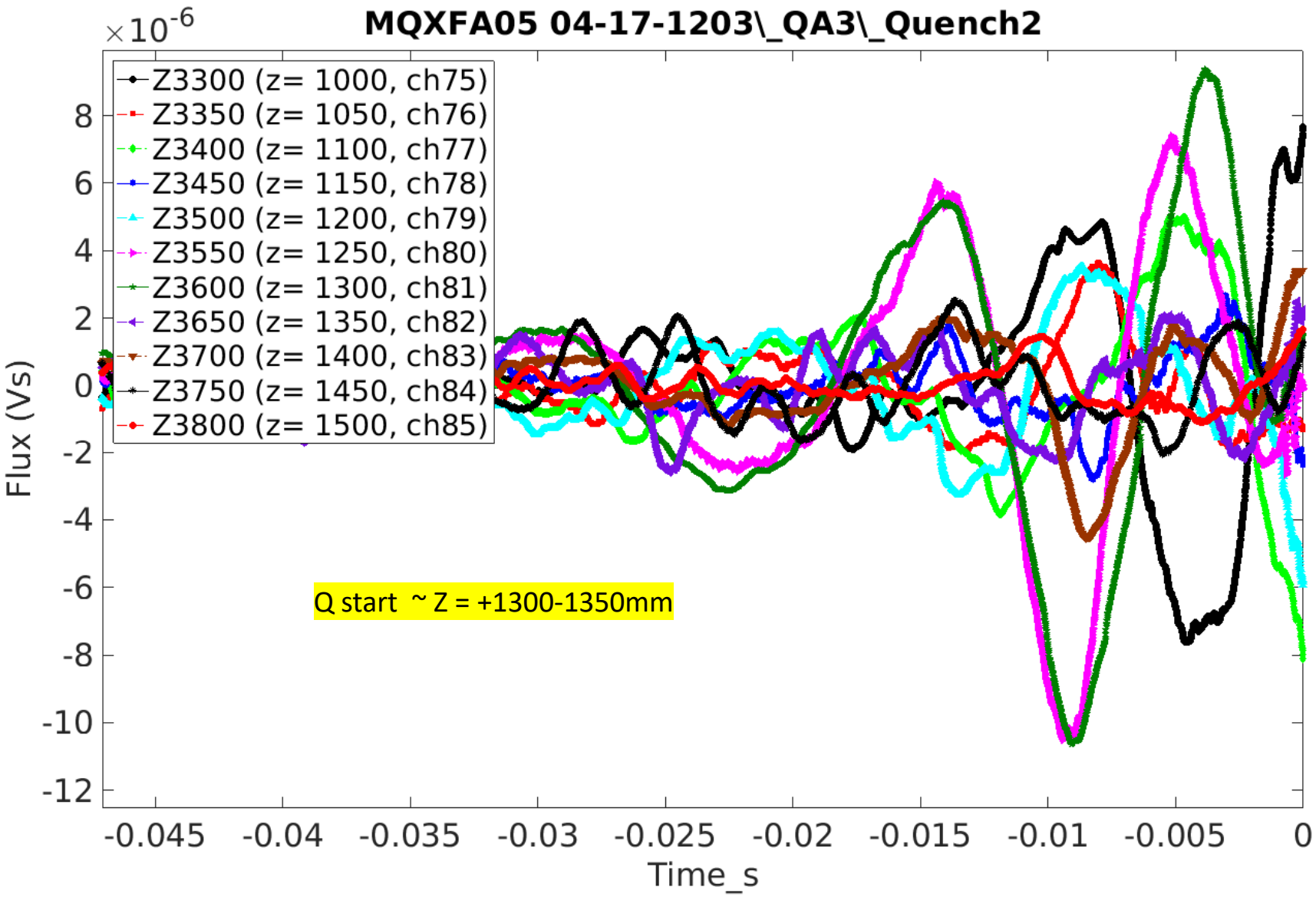
**MQXFA05 Quench #2 (Sat 17-Apr)**

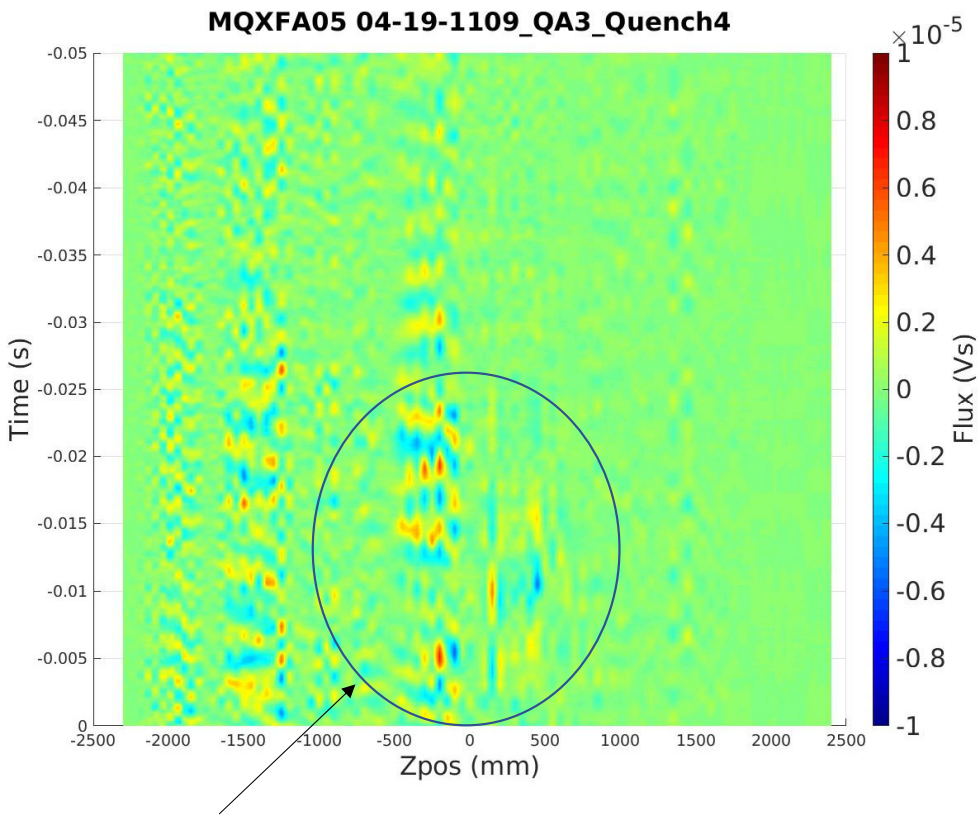
**$I_Q$ = 15377.05 A**

**QI = 24.6 MIIts**

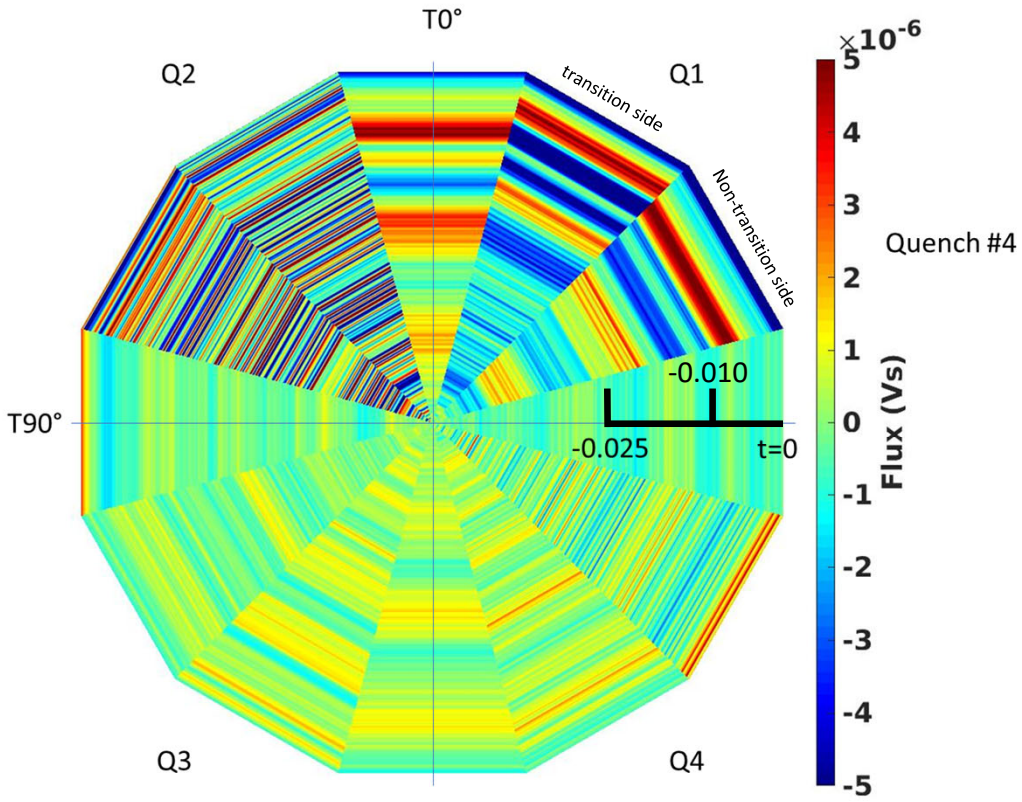
**Location = Coil 116 (Q2) A5-A6 inner layer pole turn non-transition side straight section** first

**Coil 116 (Q2) B7-B6 outer layer pole turn non-transition side straight section** 8 ms later


MQXFA05 04-17-1203_QA3_Quench2
×10-6
Z3300 (z= 1000, ch75)
Z3350 (z= 1050, ch76)
Z3400 (z= 1100, ch77)
Z3450 (z= 1150, ch78)
Z3500 (z= 1200, ch79)
Z3550 (z= 1250, ch80)
Z3600 (z= 1300, ch81)
Z3650 (z= 1350, ch82)
Z3700 (z= 1400, ch83)
Z3750 (z= 1450, ch84)
Z3800 (z= 1500, ch85)
Q start ~ Z = +1300-1350mm
Flux (Vs)
8
6
4
2
0
-2
-4
-6
-8
-10
-12
-0.045
-0.04
-0.035
-0.03
-0.025
-0.02
-0.015
-0.01
-0.005
0
Time_s




Detecting quench here?

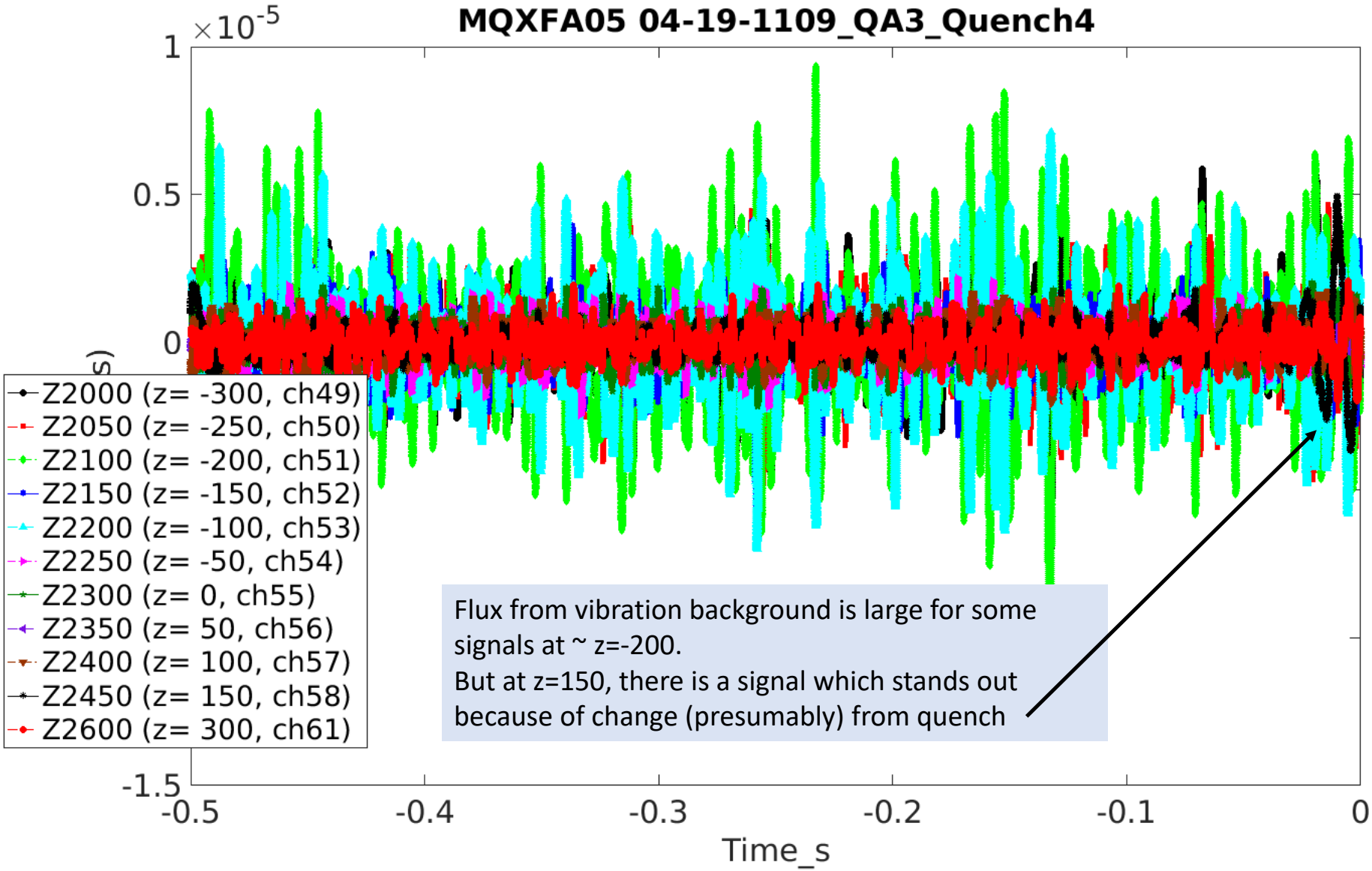


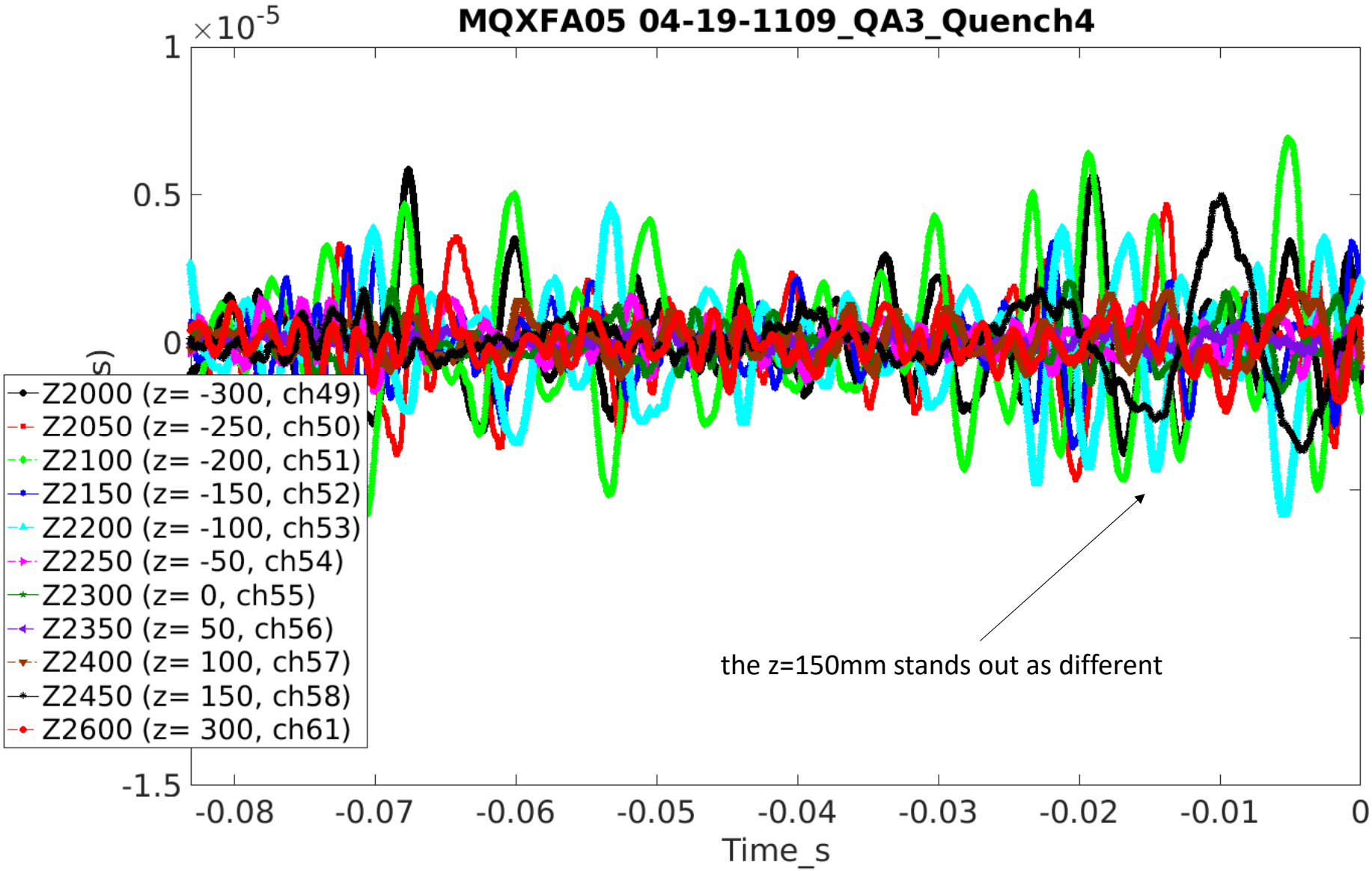

**MQXFA05 Quench #4 (Mon 19-Apr)**

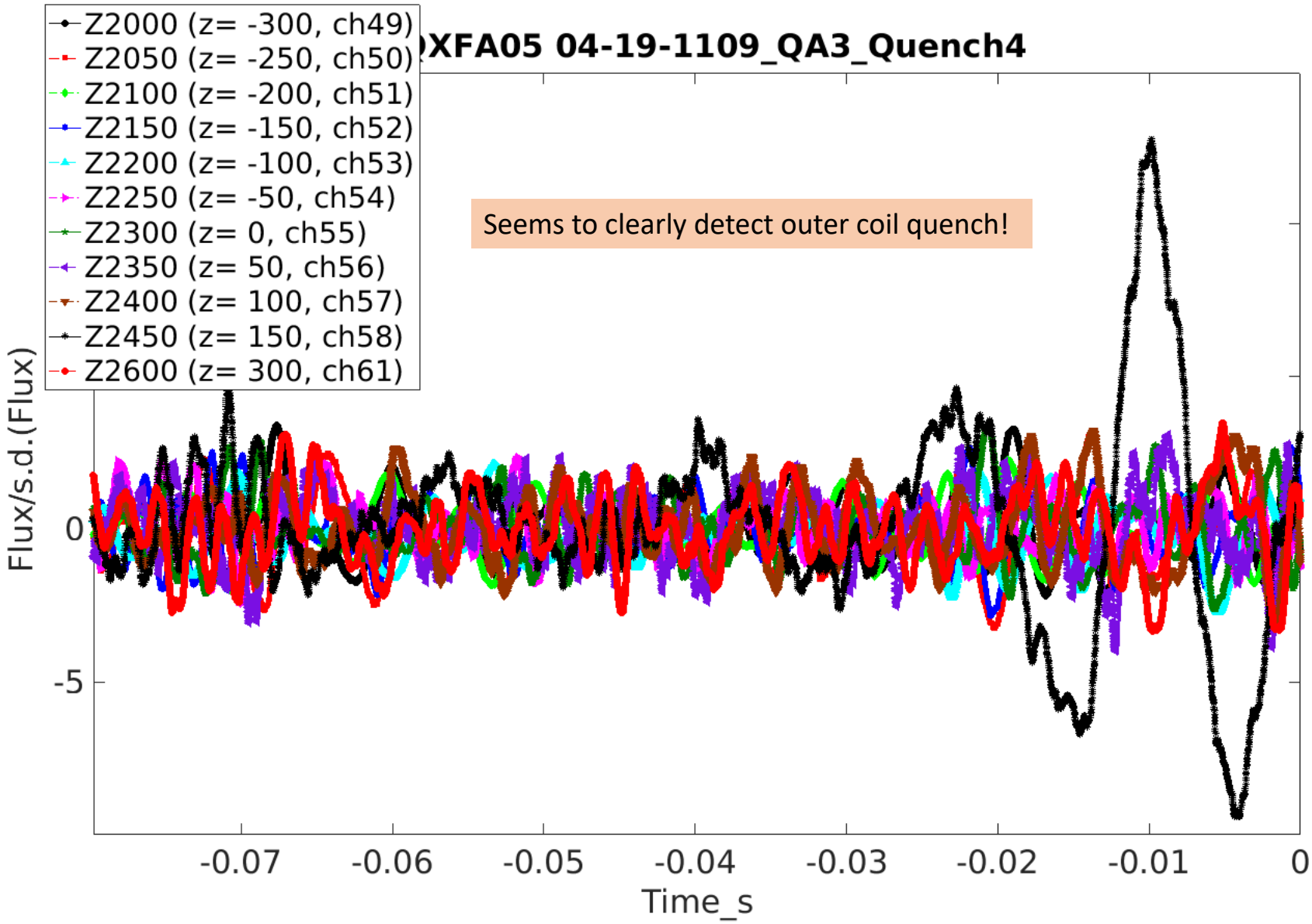
**$I_Q$ = 15646.89 A**

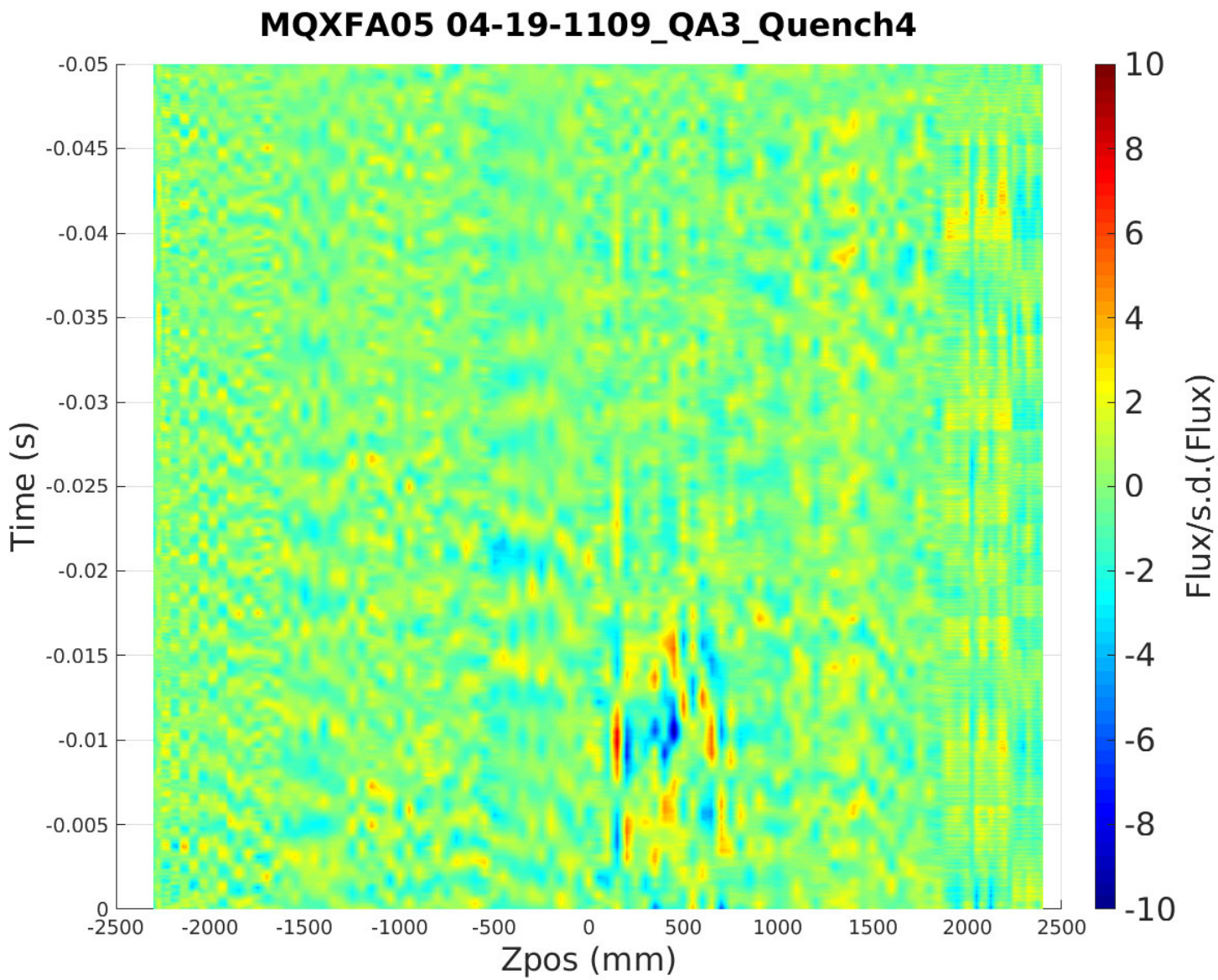
**QI = 25.3 MIIts**

**Location = Coil 207 (Q1) B4-B5 outer layer pole turn transition side straight section**

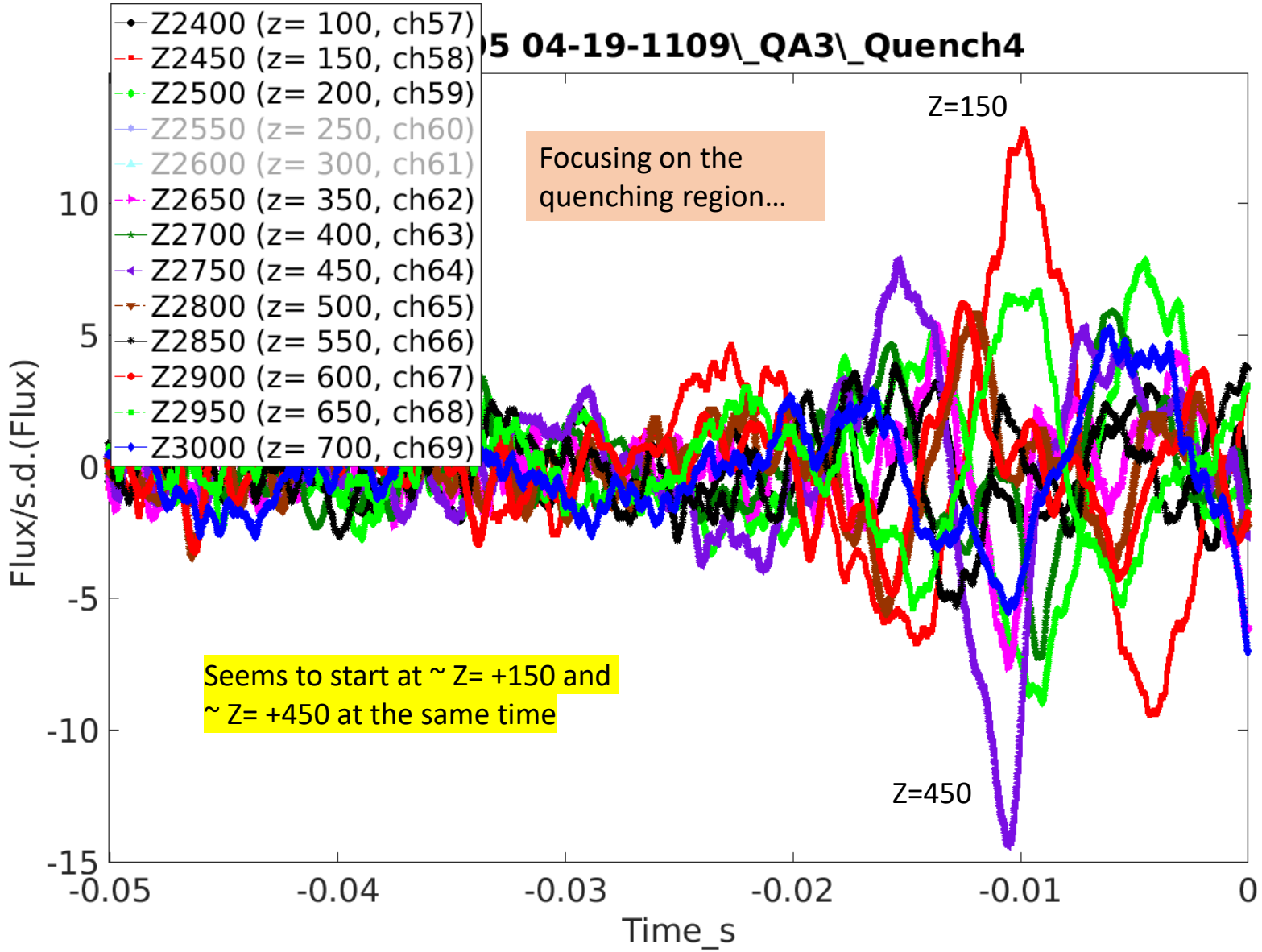

MQXFA05 04-19-1109_QA3_Quench4
×10-5
1
0.5
0
-1.5
-0.5
-0.4
-0.3
-0.2
-0.1
0
Time_s
Z2000 (z= -300, ch49)
Z2050 (z= -250, ch50)
Z2100 (z= -200, ch51)
Z2150 (z= -150, ch52)
Z2200 (z= -100, ch53)
Z2250 (z= -50, ch54)
Z2300 (z= 0, ch55)
Z2350 (z= 50, ch56)
Z2400 (z= 100, ch57)
Z2450 (z= 150, ch58)
Z2600 (z= 300, ch61)
Flux from vibration background is large for some signals at ~ z=-200.
But at z=150, there is a signal which stands out because of change (presumably) from quench

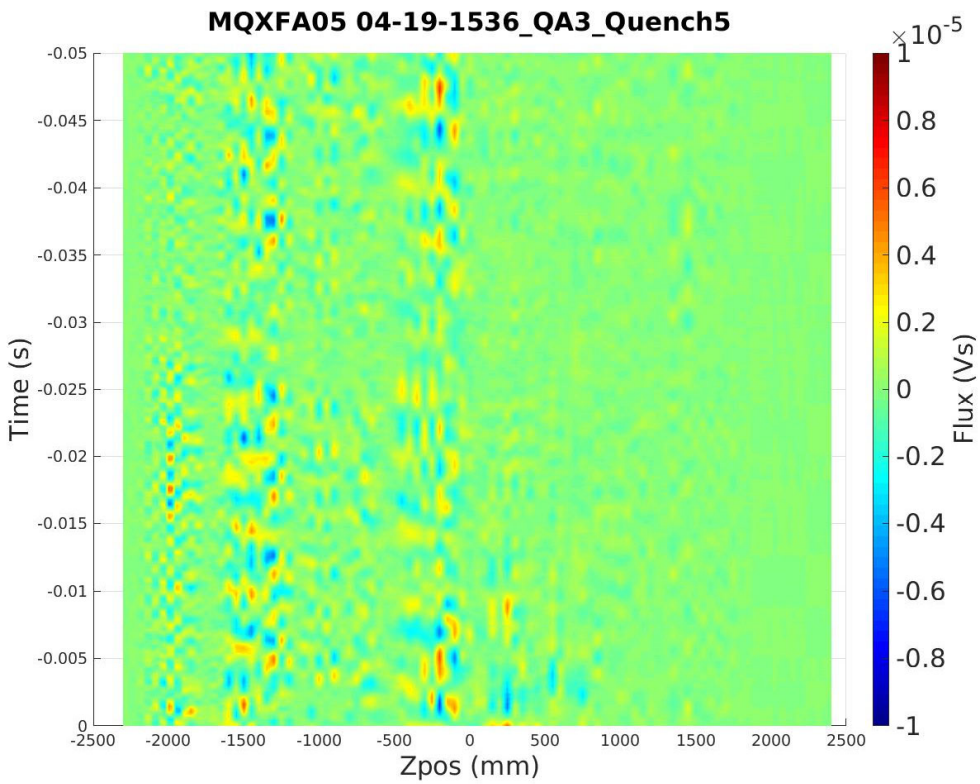

MQXFA05 04-19-1109_QA3_Quench4
×10^-5
1
0.5
0
-1.5
-0.08
-0.07
-0.06
-0.05
-0.04
-0.03
-0.02
-0.01
0
Time_s
Z2000 (z= -300, ch49)
Z2050 (z= -250, ch50)
Z2100 (z= -200, ch51)
Z2150 (z= -150, ch52)
Z2200 (z= -100, ch53)
Z2250 (z= -50, ch54)
Z2300 (z= 0, ch55)
Z2350 (z= 50, ch56)
Z2400 (z= 100, ch57)
Z2450 (z= 150, ch58)
Z2600 (z= 300, ch61)
the z=150mm stands out as different

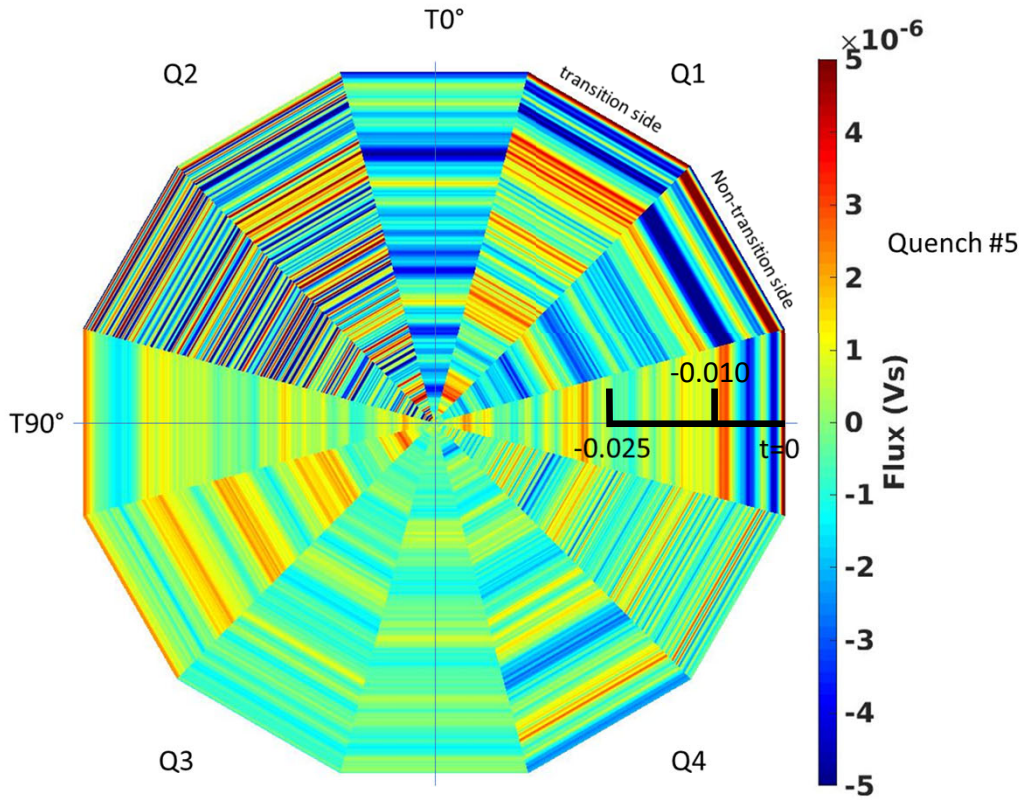

Z2000 (z= -300, ch49)
Z2050 (z= -250, ch50)
Z2100 (z= -200, ch51)
Z2150 (z= -150, ch52)
Z2200 (z= -100, ch53)
Z2250 (z= -50, ch54)
Z2300 (z= 0, ch55)
Z2350 (z= 50, ch56)
Z2400 (z= 100, ch57)
Z2450 (z= 150, ch58)
Z2600 (z= 300, ch61)
XFA05 04-19-1109_QA3_Quench4
Seems to clearly detect outer coil quench!
Flux/s.d.(Flux)
0
-5
-0.07
-0.06
-0.05
-0.04
-0.03
-0.02
-0.01
0
Time_s




Replotting data normalized to s.d. of flux fluctuation background of each channel (presumably stemming from mechanical vibrations)


Z2400 (z= 100, ch57)
Z2450 (z= 150, ch58)
Z2500 (z= 200, ch59)
Z2550 (z= 250, ch60)
Z2600 (z= 300, ch61)
Z2650 (z= 350, ch62)
Z2700 (z= 400, ch63)
Z2750 (z= 450, ch64)
Z2800 (z= 500, ch65)
Z2850 (z= 550, ch66)
Z2900 (z= 600, ch67)
Z2950 (z= 650, ch68)
Z3000 (z= 700, ch69)
5 04-19-1109_QA3_Quench4
Z=150
Focusing on the quenching region…
Seems to start at ~ Z= +150 and ~ Z= +450 at the same time
Z=450
Flux/s.d.(Flux)
Time_s
10
5
0
-5
-10
-15
-0.05
-0.04
-0.03
-0.02
-0.01
0



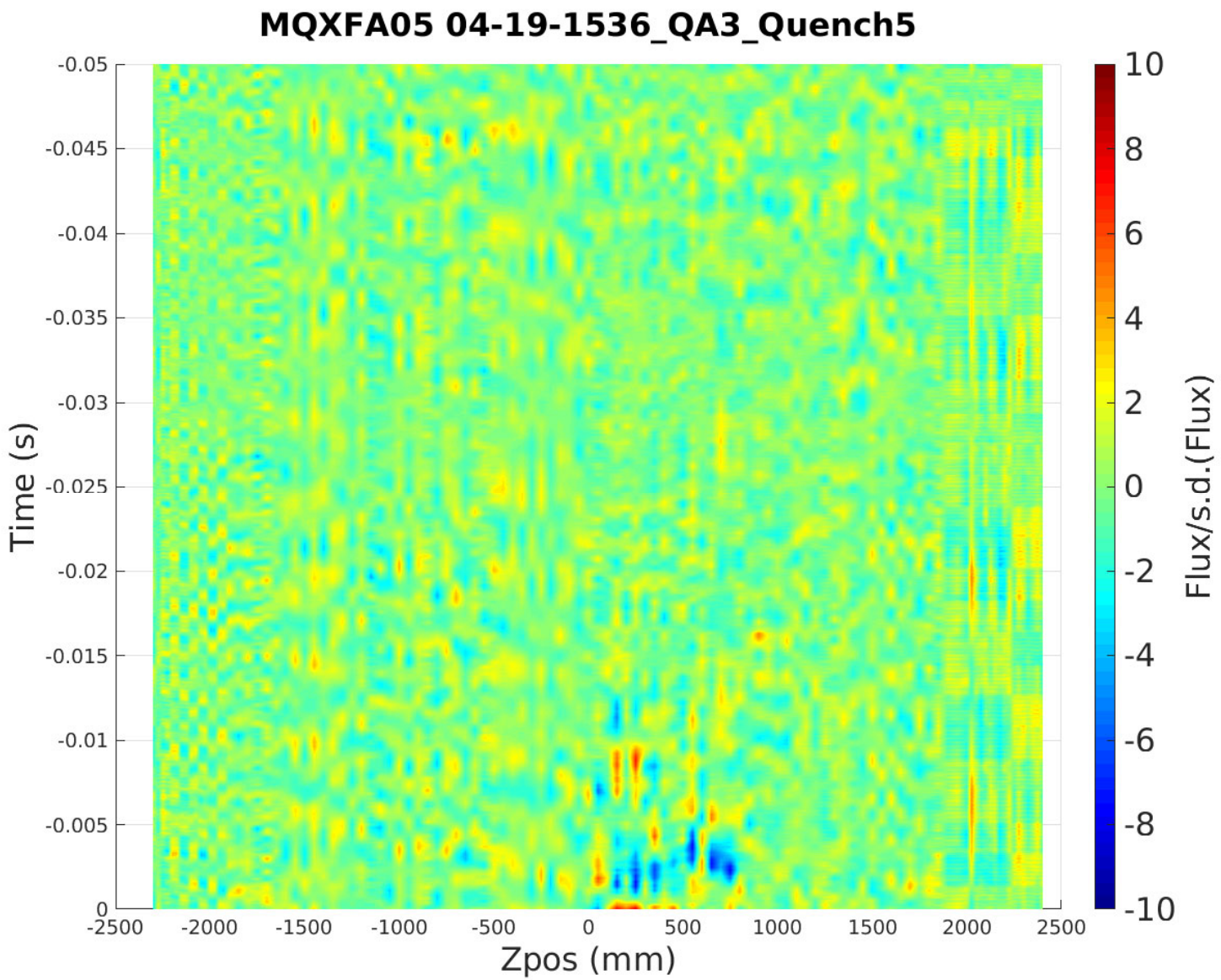



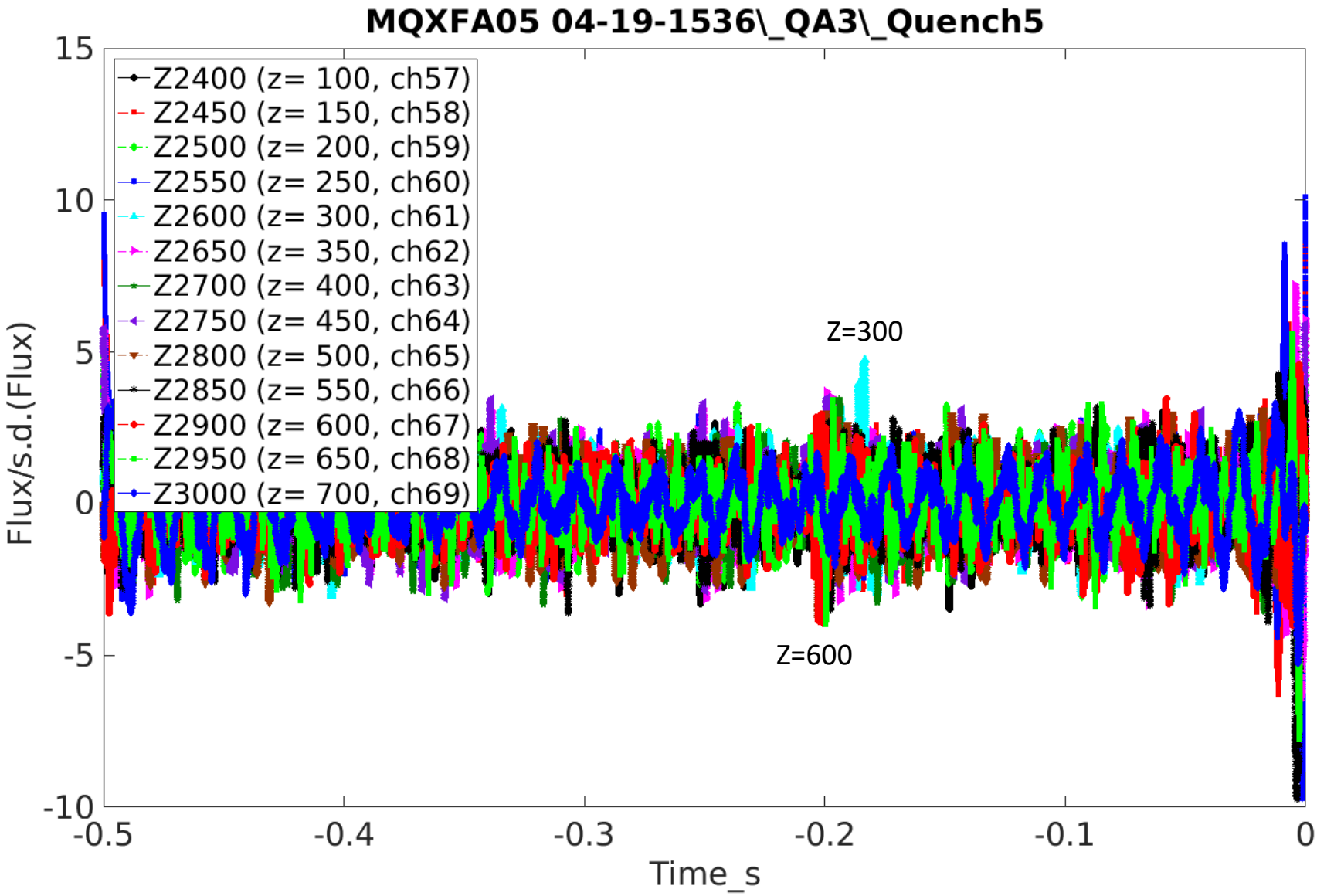

**MQXFA05 Quench #5 (Mon 19-Apr)**

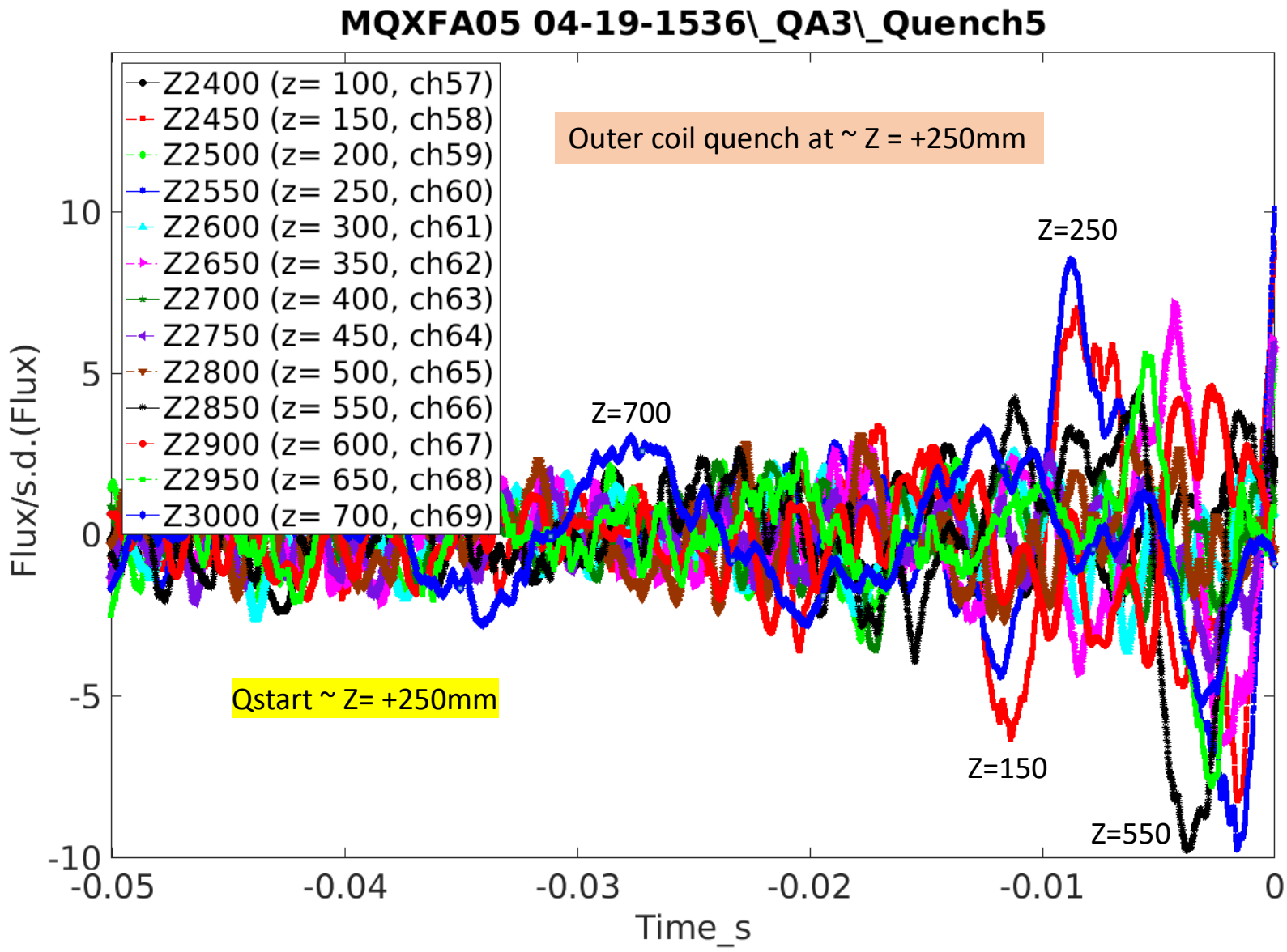
**$I_Q$ = 16230.15 A**

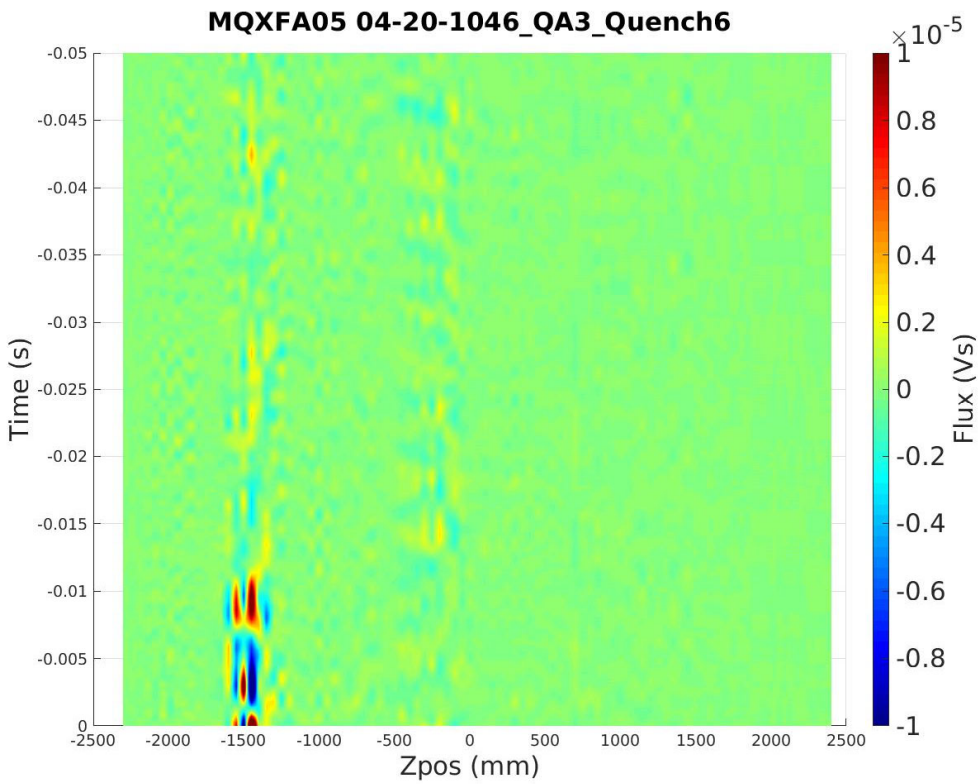
**QI = 25.3 MIIts**

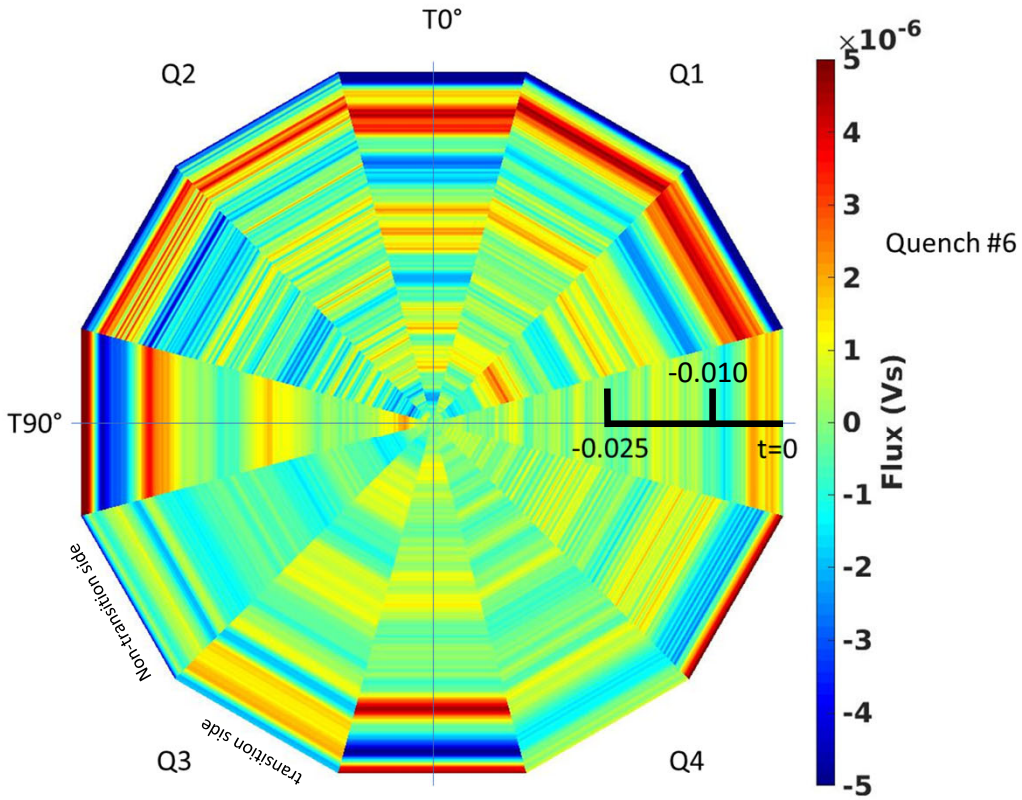
**Location = Coil 207 (Q1) B6-B7 outer layer pole turn non-transition side straight section**


MQXFA05 04-19-1536_QA3_Quench5
Time (s)
-0.05
-0.045
-0.04
-0.035
-0.03
-0.025
-0.02
-0.015
-0.01
-0.005
0
Zpos (mm)
-2500
-2000
-1500
-1000
-500
0
500
1000
1500
2000
2500
Flux/s.d.(Flux)
10
8
6
4
2
0
-2
-4
-6
-8
-10


MQXFA05 04-19-1536_QA3_Quench5
Z2400 (z= 100, ch57)
Z2450 (z= 150, ch58)
Z2500 (z= 200, ch59)
Z2550 (z= 250, ch60)
Z2600 (z= 300, ch61)
Z2650 (z= 350, ch62)
Z2700 (z= 400, ch63)
Z2750 (z= 450, ch64)
Z2800 (z= 500, ch65)
Z2850 (z= 550, ch66)
Z2900 (z= 600, ch67)
Z2950 (z= 650, ch68)
Z3000 (z= 700, ch69)
Z=300
Z=600
Flux/s.d.(Flux)
Time_s
15
10
5
0
-5
-10
-0.5
-0.4
-0.3
-0.2
-0.1
0


MQXFA05 04-19-1536_QA3_Quench5
Z2400 (z= 100, ch57)
Z2450 (z= 150, ch58)
Z2500 (z= 200, ch59)
Z2550 (z= 250, ch60)
Z2600 (z= 300, ch61)
Z2650 (z= 350, ch62)
Z2700 (z= 400, ch63)
Z2750 (z= 450, ch64)
Z2800 (z= 500, ch65)
Z2850 (z= 550, ch66)
Z2900 (z= 600, ch67)
Z2950 (z= 650, ch68)
Z3000 (z= 700, ch69)
Outer coil quench at ~ Z = +250mm
Z=250
Z=700
Z=150
Z=550
Qstart ~ Z= +250mm
Flux/s.d.(Flux)
Time_s
10
5
0
-5
-10
-0.05
-0.04
-0.03
-0.02
-0.01
0



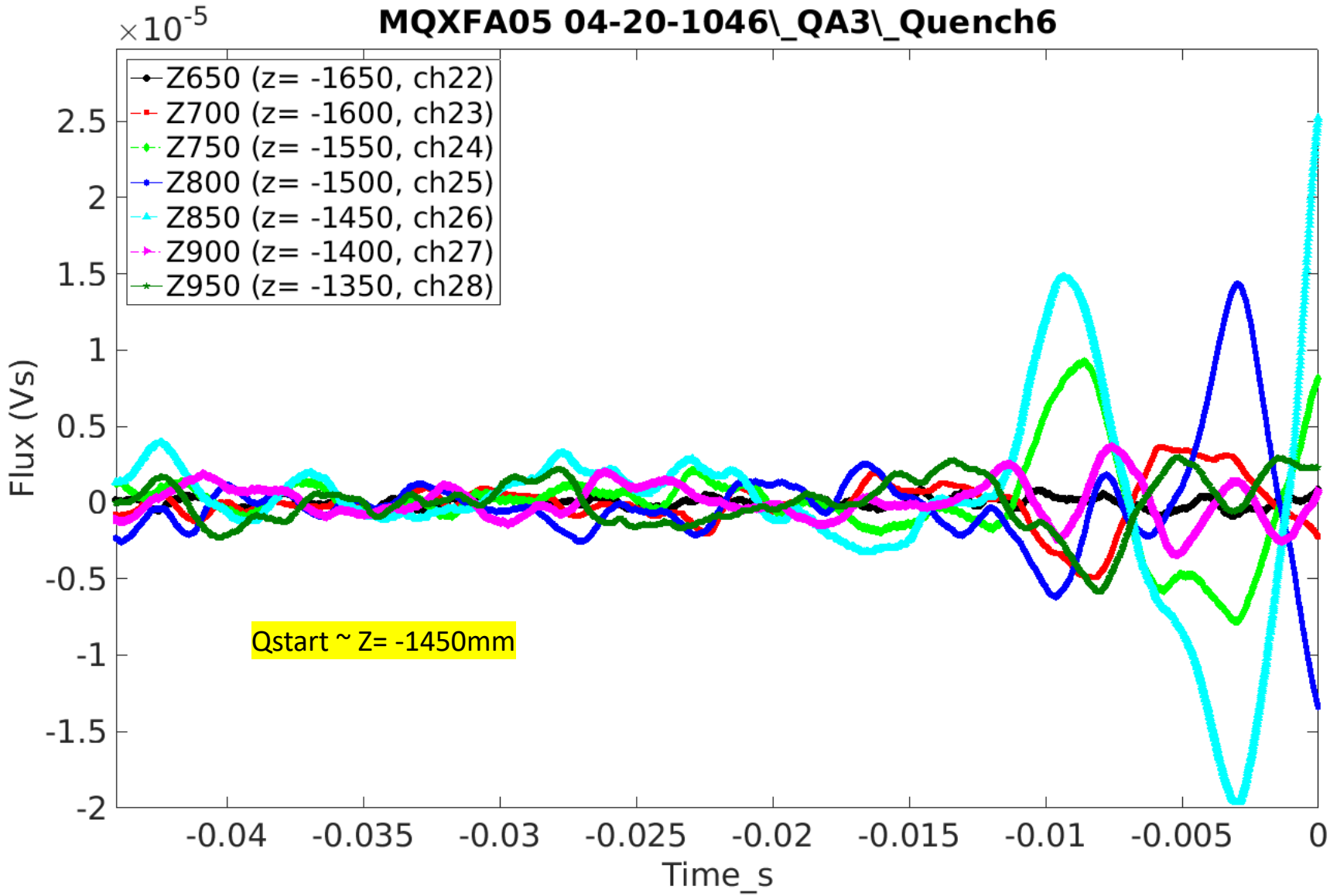



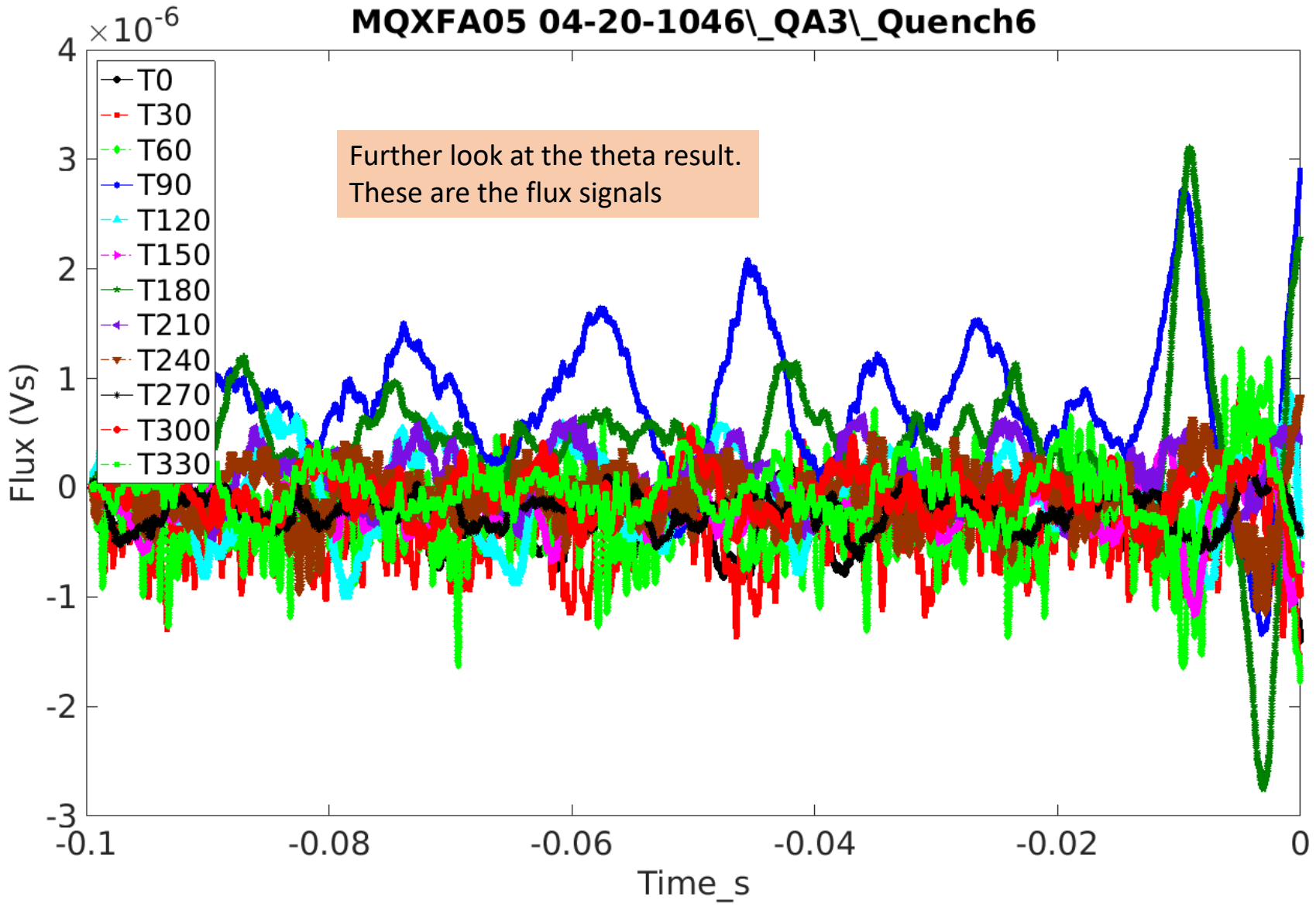

**MQXFA05 Quench #6 (Tue 20-Apr)**

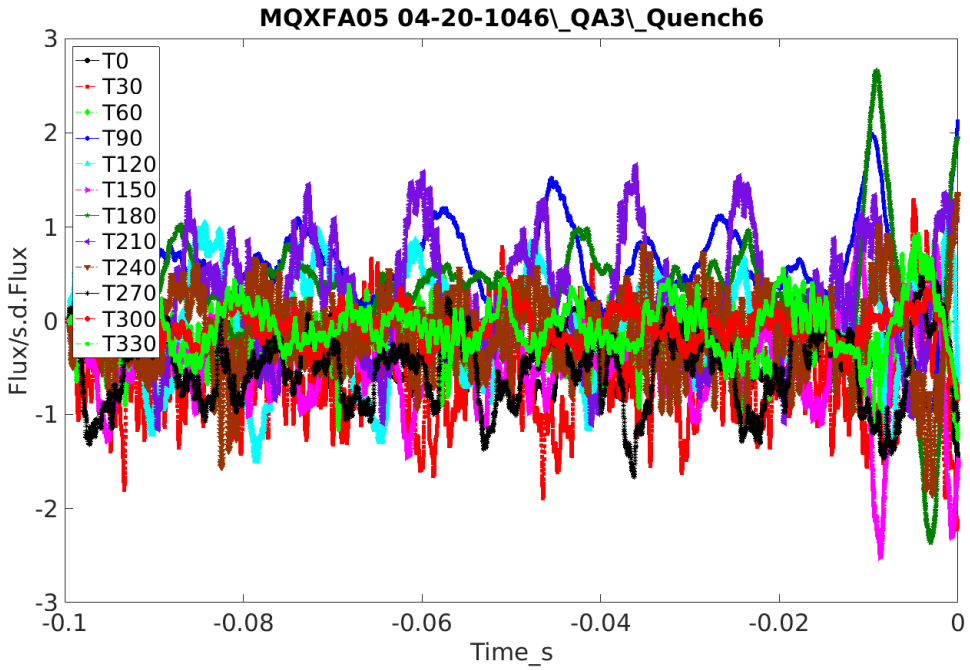
**$I_Q$ = 16230.90 A**

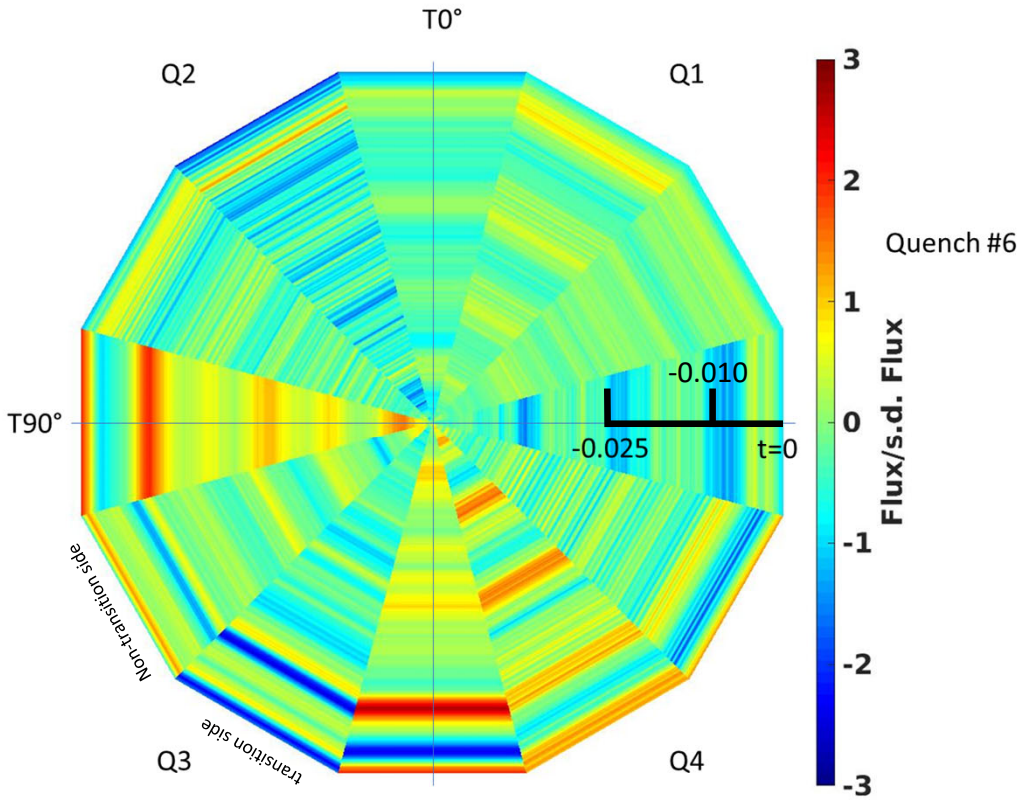
**QI = 24.9 MIIts**

**Location = Coil 209 (Q3) A7-A5 inner layer pole turn non-transition side straight section + return end section**

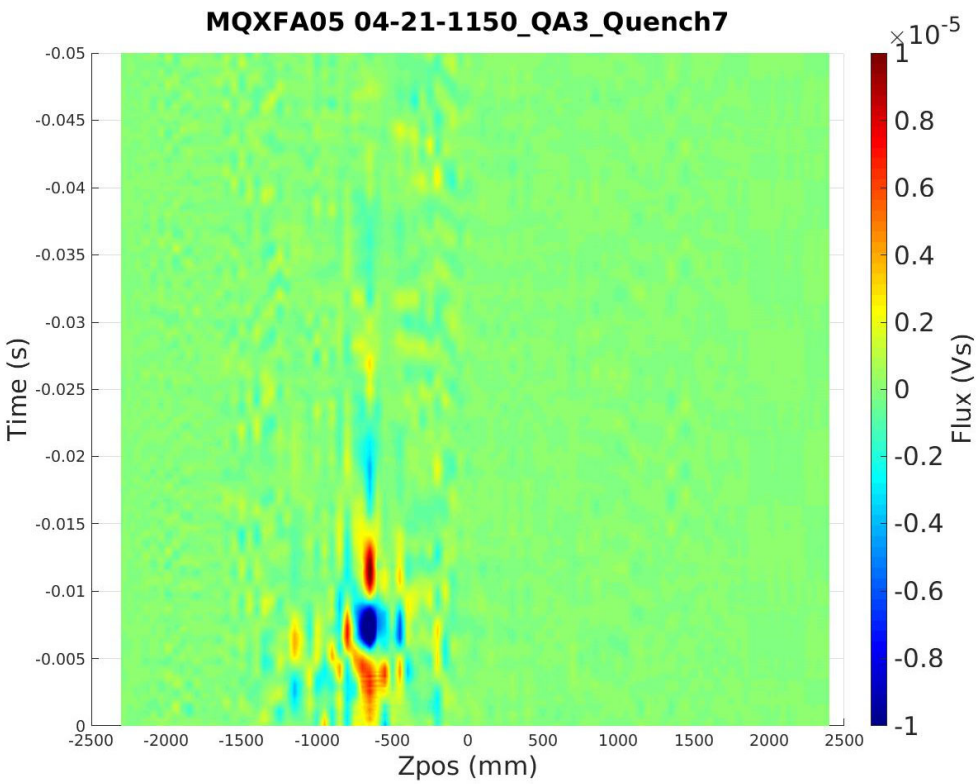

MQXFA05 04-20-1046_QA3_Quench6
×10-5
Z650 (z= -1650, ch22)
Z700 (z= -1600, ch23)
Z750 (z= -1550, ch24)
Z800 (z= -1500, ch25)
Z850 (z= -1450, ch26)
Z900 (z= -1400, ch27)
Z950 (z= -1350, ch28)
Qstart ~ Z= -1450mm
Flux (Vs)
Time_s
2.5
2
1.5
1
0.5
0
-0.5
-1
-1.5
-2
-0.04
-0.035
-0.03
-0.025
-0.02
-0.015
-0.01
-0.005
0

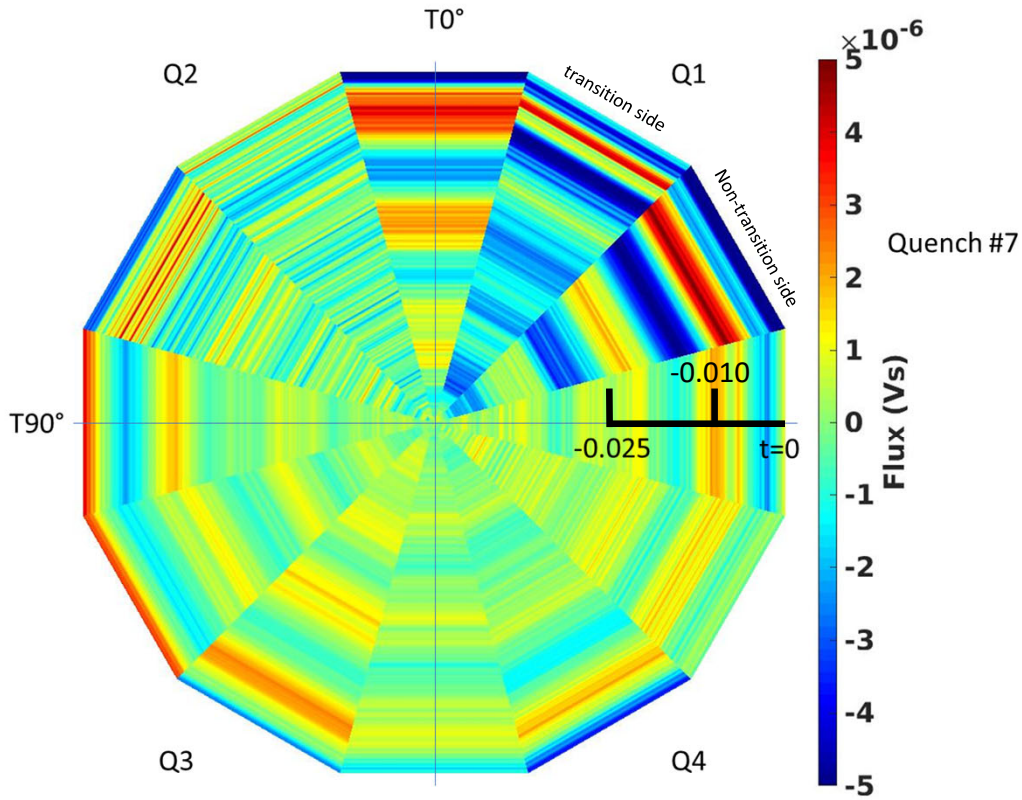

MQXFA05 04-20-1046_QA3_Quench6
×10-6
Flux (Vs)
Time_s
T0
T30
T60
T90
T120
T150
T180
T210
T240
T270
T300
T330
Further look at the theta result.
These are the flux signals




If try to look at flux changes normalized to s.d., seems that Q3 is quenching, but not finding the 'non-transition side pole' location. Perhaps there are multiple quenches that complicate the flux pattern (?)



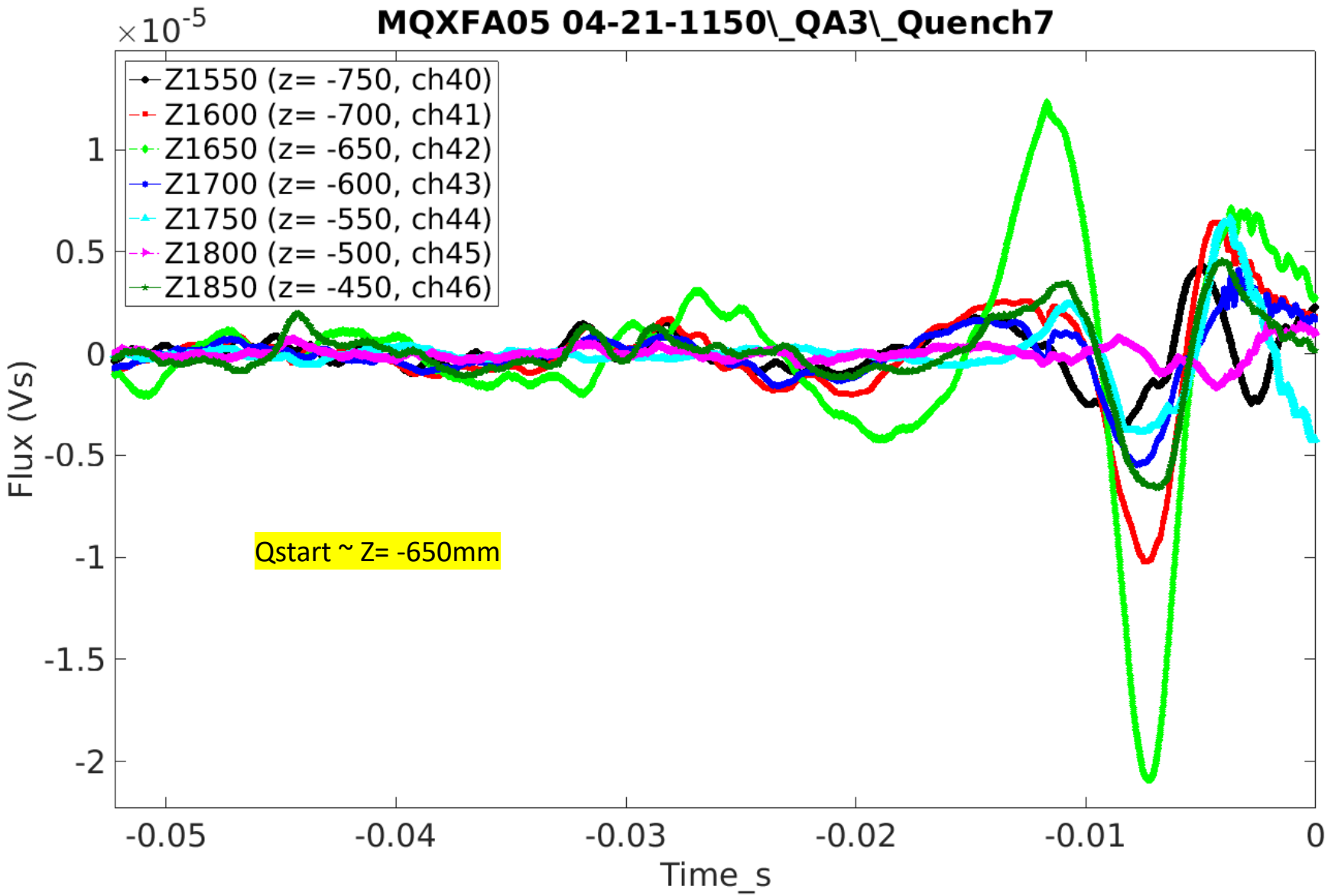



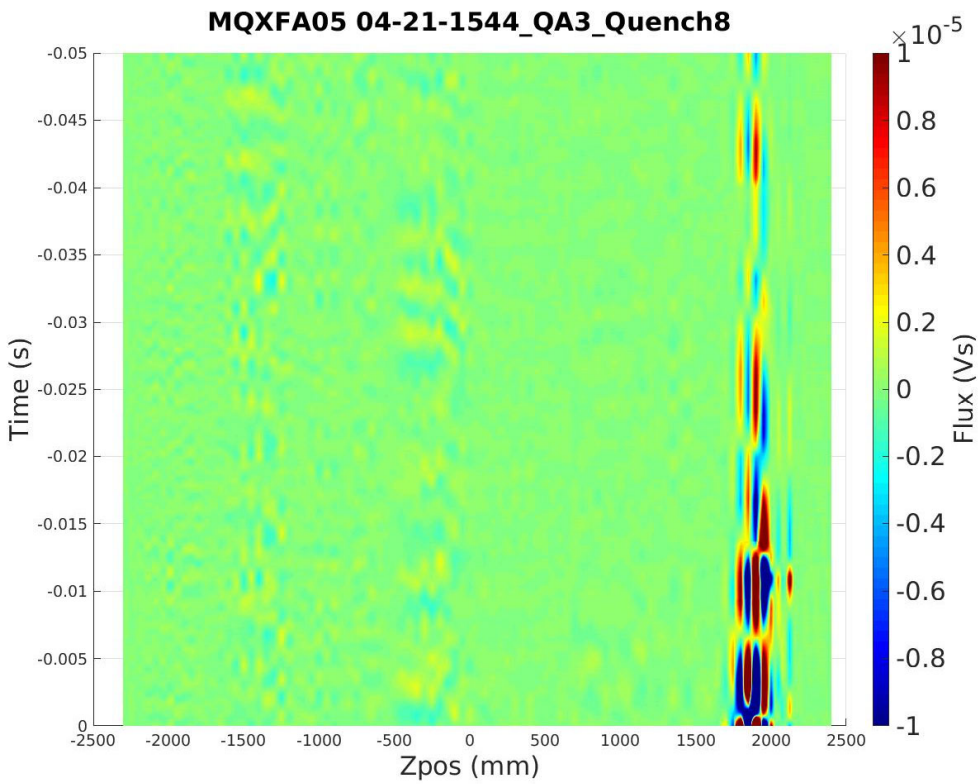

**MQXFA05 Quench #7 (Wed 21-Apr)**

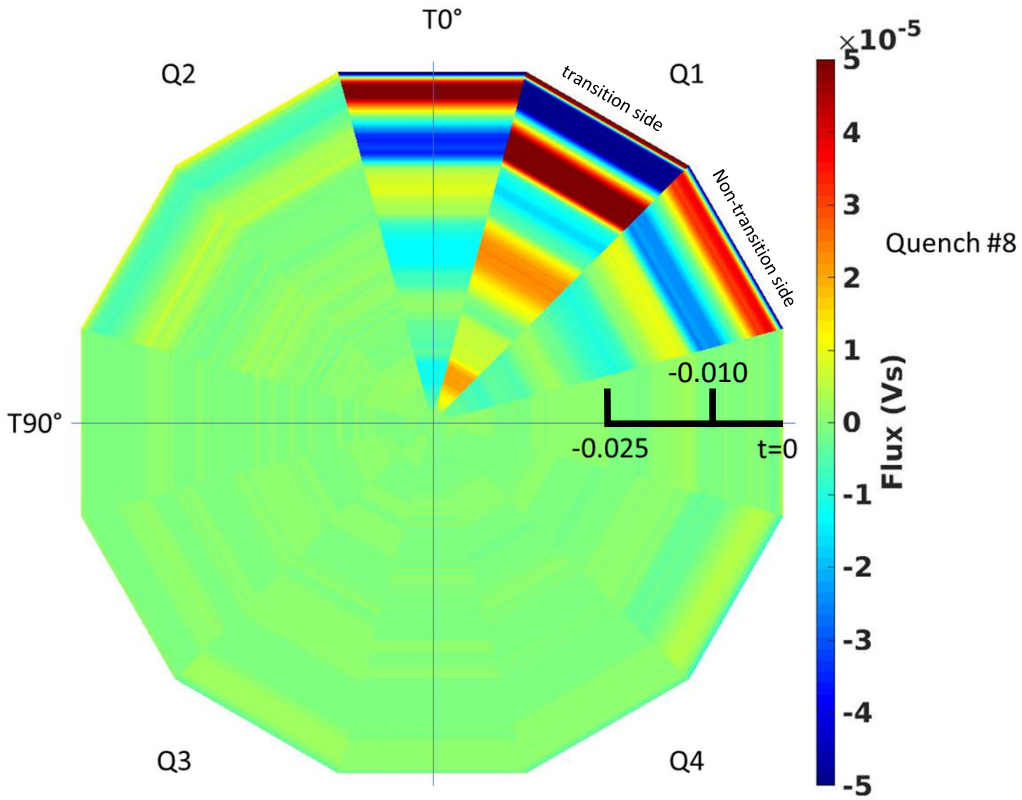
**$I_Q$ = 16225.79 A**

**QI = 24.7 MIIts**

**Location = Coil 207 (Q1) A8-A4 inner layer pole turn**


MQXFA05 04-21-1150_QA3_Quench7
×10-5
Z1550 (z= -750, ch40)
Z1600 (z= -700, ch41)
Z1650 (z= -650, ch42)
Z1700 (z= -600, ch43)
Z1750 (z= -550, ch44)
Z1800 (z= -500, ch45)
Z1850 (z= -450, ch46)
Qstart ~ Z= -650mm
Flux (Vs)
Time_s
1
0.5
0
-0.5
-1
-1.5
-2
-0.05
-0.04
-0.03
-0.02
-0.01
0



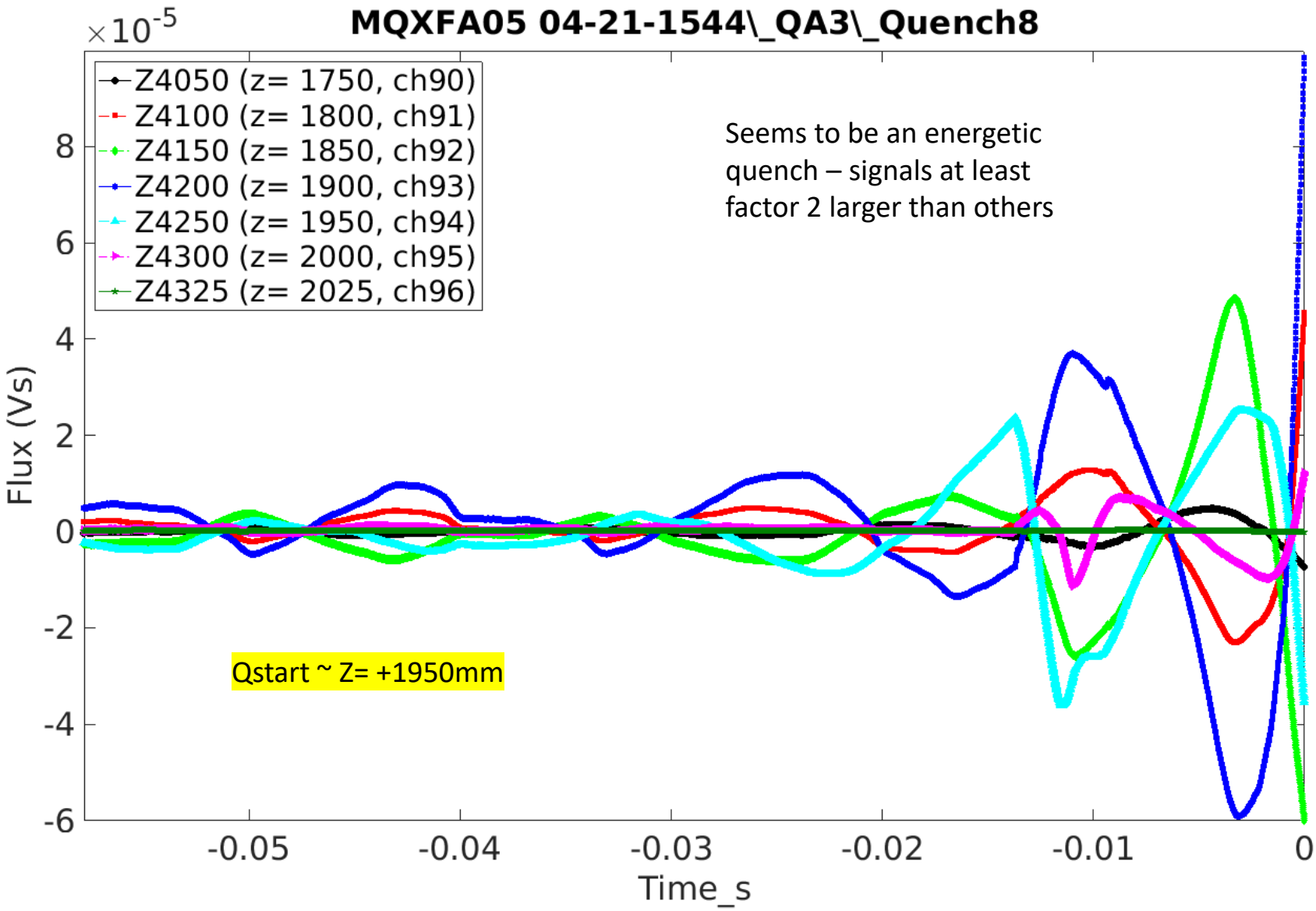

**MQXFA05 Quench #8 (Wed 21-Apr)**

**$I_Q$ = 16255.43 A**

**QI = 25.1 MIIts**

**Location = Coil 207 (Q1) A4-A2 inner layer multiturn** first

**Coil 207 (Q1) A8-A4 inner layer pole turn** 2 ms later


MQXFA05 04-21-1544_QA3_Quench8
×10-5
Z4050 (z= 1750, ch90)
Z4100 (z= 1800, ch91)
Z4150 (z= 1850, ch92)
Z4200 (z= 1900, ch93)
Z4250 (z= 1950, ch94)
Z4300 (z= 2000, ch95)
Z4325 (z= 2025, ch96)
Seems to be an energetic quench – signals at least factor 2 larger than others
Qstart ~ Z= +1950mm
Flux (Vs)
Time_s
8
6
4
2
0
-2
-4
-6
-0.05
-0.04
-0.03
-0.02
-0.01
0

Summary/next steps:

- Quenches were all clearly detected in Z antennas – including outer coil quenches(!).

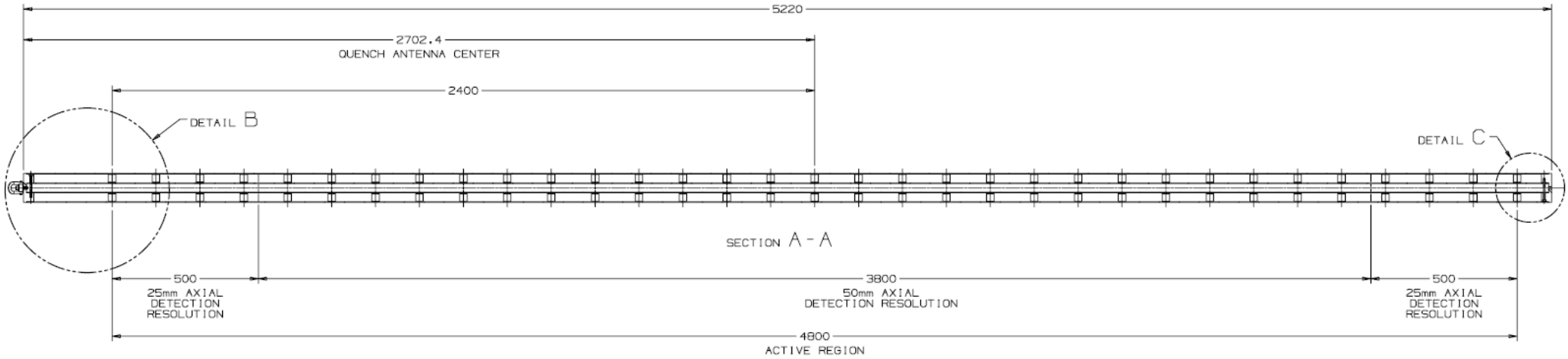
- Quenches were all also detected by Theta antennas and seemed to corresponded well with the voltage tap determinations even for outer coil quenches. Quench #6 is perhaps an exception – it showed quadrant but not single location. Further analysis needs to be done to understand this.

- Detection of outer coil quenches was perhaps aided by their being at the pole turn, but results are encouraging from sensitivity point of view.

- Need to get into more details of voltage tap data to understand additional features of data.

Back-up slides

QA active length 4800mm (+/- 2400 mm from QA center)

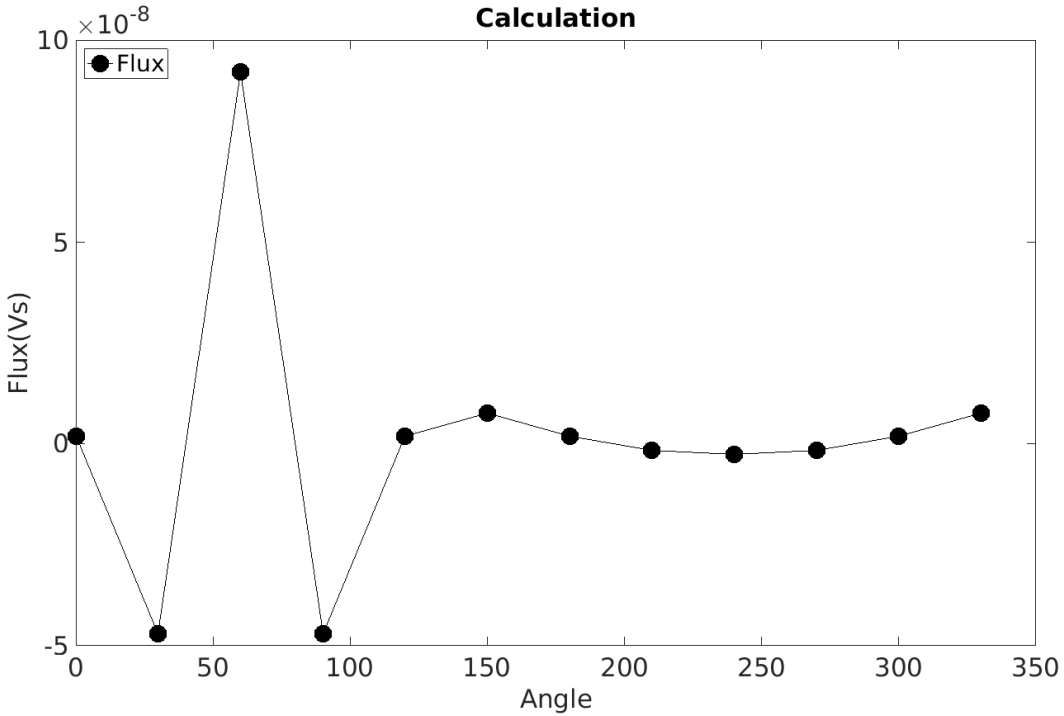



Center of QA about 96mm above magnet center when suspended.

Length of magnet coils at 1.9K = ~4530 mm
(4200 SS + 155 NLE + 175 LE) magnet center around 2250 from NLE

➔ Start of NLE of coil is 2100+155+96 = 2351 mm below quench antenna center or
~50 mm above QA z=0 (i.e. subtract 50mm from QA segment name to get quench z-position wrt NLE coil

TQA with quench at 60 deg



Z is from NLE
(QA bottom)

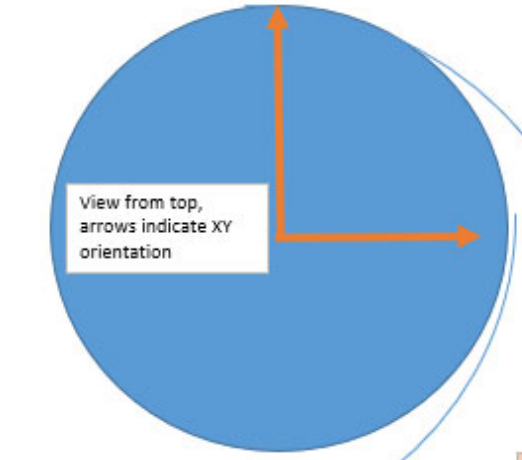
to find quench location, assuming 2 signals rise simultaneously, use the larger of the signals - the quench is within 0-50mm greater than the signal name (e.g. if z950 and z1000 rise at same time, the quench is in the region z=1000mm to z=1050mm). Similarly, if 4 signals rise simultaneously in the end regions, then quench is within 0-25mm greater than the signal name.

Quench antennas are manufactured with 6 antennas to a 'panel'. The panels are denoted p1 through p18 in this schematic.

The Z-extent of the panel is indicated by the repetition of the antenna signal over a length of the array. Each ZQA is 100mm long.

| z(mm) | phase 30° | | phase 0 | |
|---|---|---|---|---|
| 0 | | | z0 | |
| 25 | | | z0 | z25 |
| 50 | z50 | | z0 | z25 |
| 75 | z50 | z75 | z0 | z25 |
| 100 | z50 | z75 | z100 | z25 |
| 125 | z50 | z75 | z100 | z125 |
| 150 | z150 | z75 | z100 | z125 |
| 175 | z150 | z175 | z100 | z125 |
| 200 | z150 | z175 | z200 | z125 |
| 225 | z150 | z175 | z200 | z225 |
| 250 | z250 | z175 | z200 | z225 |
| 275 | z250 | z275 | z200 | z225 |
| 300 | z250 | z275 | z300 | z225 |
| 325 | z250 | z275 | z300 | z325 |
| 350 | z350 | z275 | z300 | z325 |
| 375 | z350 | z375 | z300 | z325 |
| 400 | z350 | z375 | z400 | z325 |
| 425 | z350 | z375 | z400 | p2 |
| 450 | z450 | z375 | z400 | |
| 475 | z450 | p4 | z400 | |
| 500 | z450 | | z500 | |
| 525 | z450 | | z500 | |
| 550 | z550 | | z500 | |
| 575 | z550 | | z500 | p1 |
| 600 | z550 | | z600 | |
| 625 | z550 | p3 | z600 | |
| 650 | z650 | | z600 | |
| 675 | z650 | | z600 | |
| 700 | z650 | | z700 | |
| 725 | z650 | | z700 | |
| 750 | z750 | | z700 | |
| 775 | z750 | | z700 | |
| 800 | z750 | | z800 | |
| 825 | z750 | | z800 | |
| 850 | z850 | | z800 | |
| 875 | z850 | | z800 | |
| 900 | z850 | | z900 | |

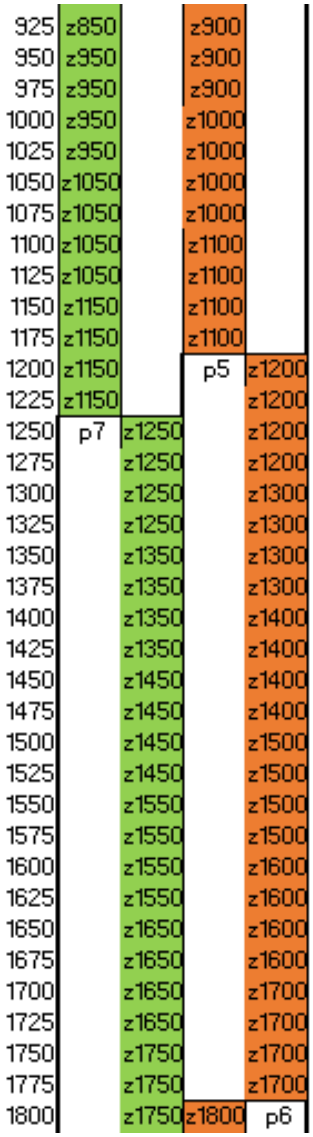
Top View

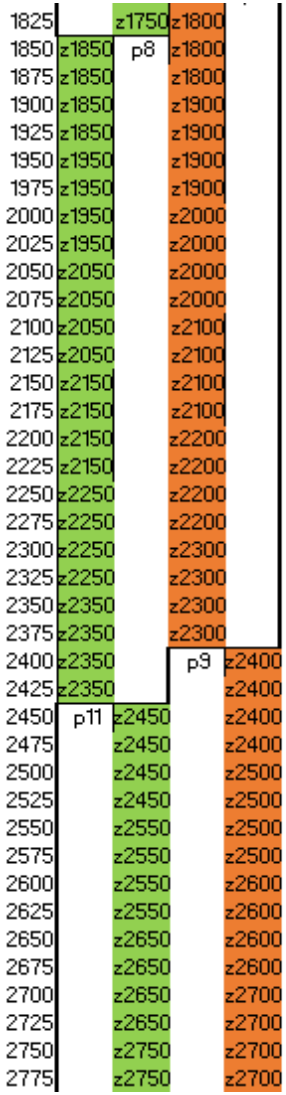


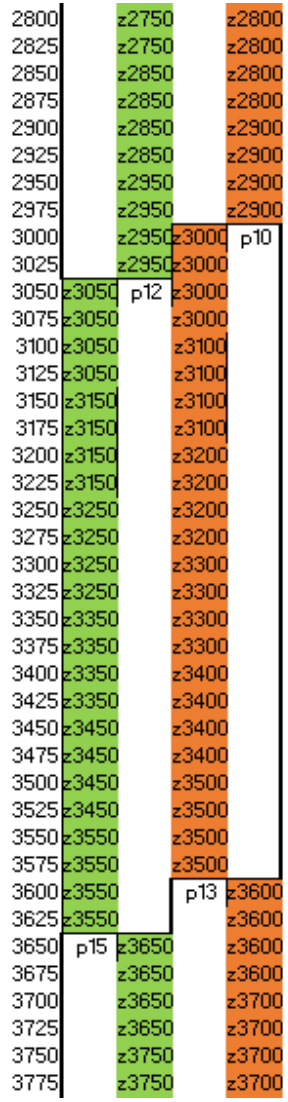

Panel with 30 degree angular shift

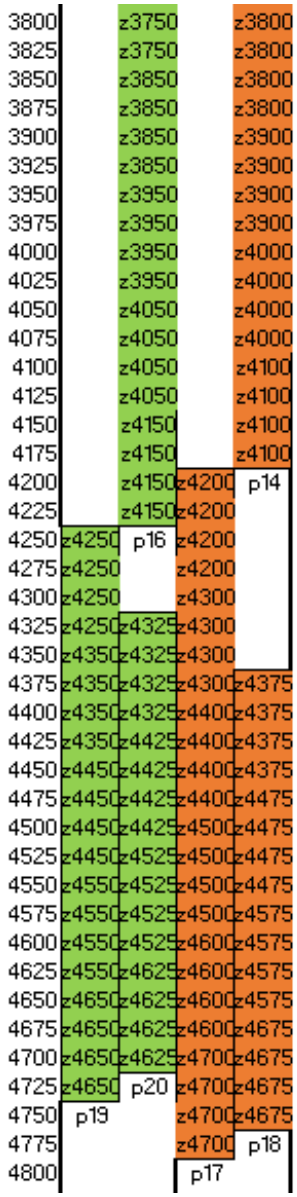
Panel with phase 0

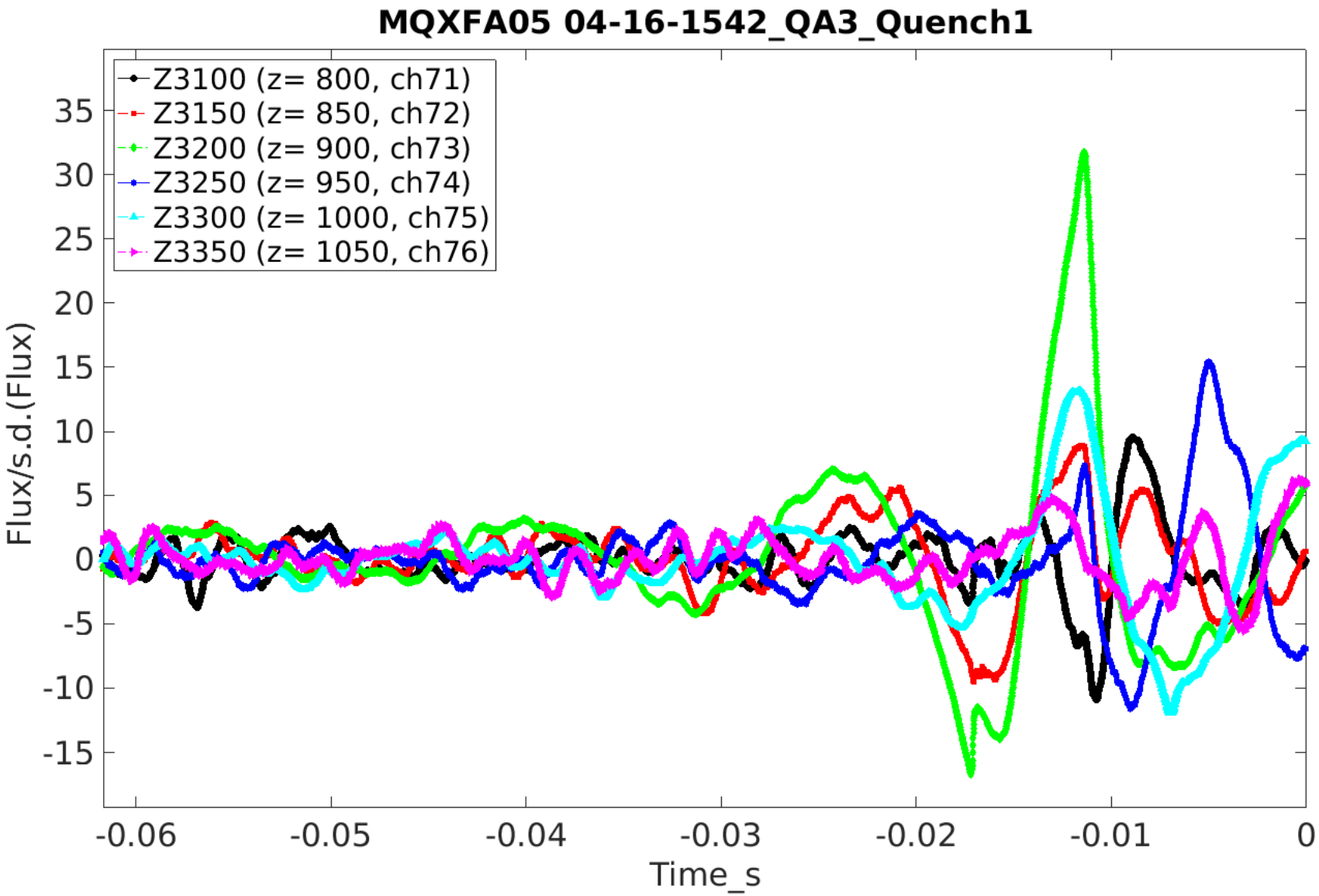
Note: There are FOUR layers in the end (two in the straight section) where panels are wrapped with a angular shift of 30 degrees (so that there are no azimuthal dead zones) as indicated in the sketch above.

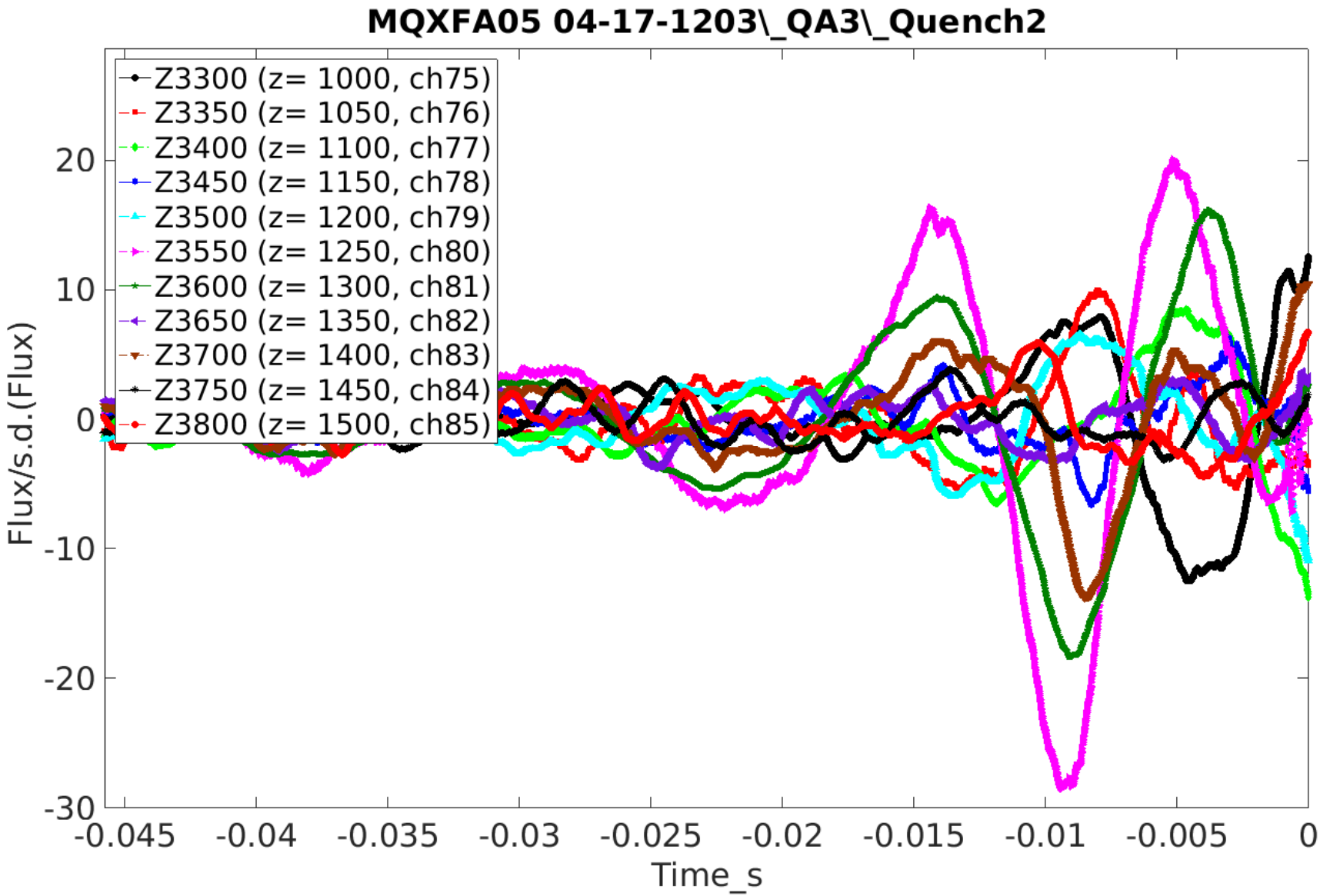

925 z850 z900
950 z950 z900
975 z950 z900
1000 z950 z1000
1025 z950 z1000
1050 z1050 z1000
1075 z1050 z1000
1100 z1050 z1100
1125 z1050 z1100
1150 z1150 z1100
1175 z1150 z1100
1200 z1150 p5 z1200
1225 z1150 z1200
1250 p7 z1250 z1200
1275 z1250 z1200
1300 z1250 z1300
1325 z1250 z1300
1350 z1350 z1300
1375 z1350 z1300
1400 z1350 z1400
1425 z1350 z1400
1450 z1450 z1400
1475 z1450 z1400
1500 z1450 z1500
1525 z1450 z1500
1550 z1550 z1500
1575 z1550 z1500
1600 z1550 z1600
1625 z1550 z1600
1650 z1650 z1600
1675 z1650 z1600
1700 z1650 z1700
1725 z1650 z1700
1750 z1750 z1700
1775 z1750 z1700
1800 z1750 z1800 p6

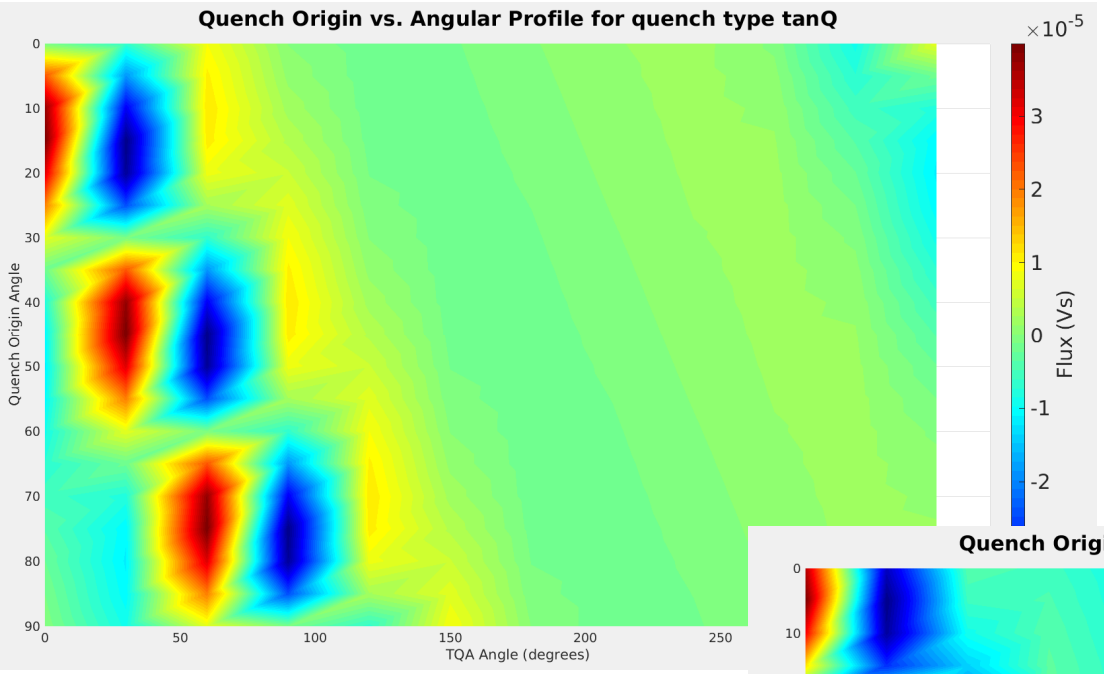

1825 z1750 z1800
1850 z1850 p8 z1800
1875 z1850 z1800
1900 z1850 z1900
1925 z1850 z1900
1950 z1950 z1900
1975 z1950 z1900
2000 z1950 z2000
2025 z1950 z2000
2050 z2050 z2000
2075 z2050 z2000
2100 z2050 z2100
2125 z2050 z2100
2150 z2150 z2100
2175 z2150 z2100
2200 z2150 z2200
2225 z2150 z2200
2250 z2250 z2200
2275 z2250 z2200
2300 z2250 z2300
2325 z2250 z2300
2350 z2350 z2300
2375 z2350 z2300
2400 z2350 p9 z2400
2425 z2350 z2400
2450 p11 z2450 z2400
2475 z2450 z2400
2500 z2450 z2500
2525 z2450 z2500
2550 z2550 z2500
2575 z2550 z2500
2600 z2550 z2600
2625 z2550 z2600
2650 z2650 z2600
2675 z2650 z2600
2700 z2650 z2700
2725 z2650 z2700
2750 z2750 z2700
2775 z2750 z2700

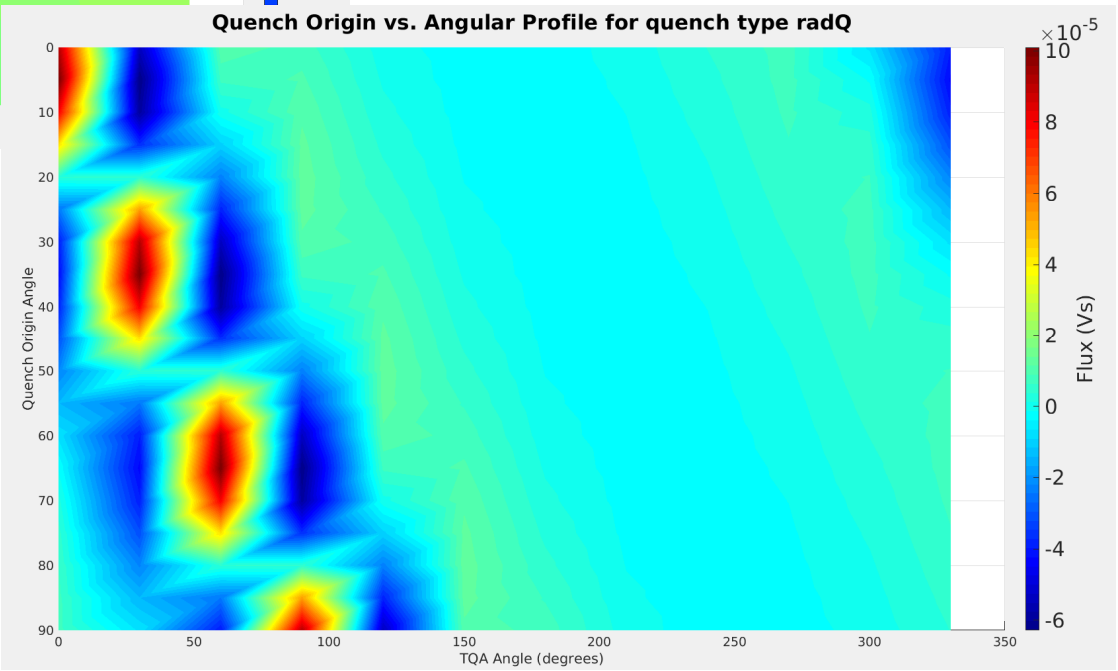

2800 z2750 z2800
2825 z2750 z2800
2850 z2850 z2800
2875 z2850 z2800
2900 z2850 z2900
2925 z2850 z2900
2950 z2950 z2900
2975 z2950 z2900
3000 z2950 z3000 p10
3025 z2950 z3000
3050 z3050 p12 z3000
3075 z3050 z3000
3100 z3050 z3100
3125 z3050 z3100
3150 z3150 z3100
3175 z3150 z3100
3200 z3150 z3200
3225 z3150 z3200
3250 z3250 z3200
3275 z3250 z3200
3300 z3250 z3300
3325 z3250 z3300
3350 z3350 z3300
3375 z3350 z3300
3400 z3350 z3400
3425 z3350 z3400
3450 z3450 z3400
3475 z3450 z3400
3500 z3450 z3500
3525 z3450 z3500
3550 z3550 z3500
3575 z3550 z3500
3600 z3550 p13 z3600
3625 z3550 z3600
3650 p15 z3650 z3600
3675 z3650 z3600
3700 z3650 z3700
3725 z3650 z3700
3750 z3750 z3700
3775 z3750 z3700


3800 z3750 z3800
3825 z3750 z3800
3850 z3850 z3800
3875 z3850 z3800
3900 z3850 z3900
3925 z3850 z3900
3950 z3950 z3900
3975 z3950 z3900
4000 z3950 z4000
4025 z3950 z4000
4050 z4050 z4000
4075 z4050 z4000
4100 z4050 z4100
4125 z4050 z4100
4150 z4150 z4100
4175 z4150 z4100
4200 z4150 z4200 p14
4225 z4150 z4200
4250 z4250 p16 z4200
4275 z4250 z4200
4300 z4250 z4300
4325 z4250 z4325 z4300
4350 z4350 z4325 z4300
4375 z4350 z4325 z4300 z4375
4400 z4350 z4325 z4400 z4375
4425 z4350 z4425 z4400 z4375
4450 z4450 z4425 z4400 z4375
4475 z4450 z4425 z4400 z4475
4500 z4450 z4425 z4500 z4475
4525 z4450 z4525 z4500 z4475
4550 z4550 z4525 z4500 z4475
4575 z4550 z4525 z4500 z4575
4600 z4550 z4525 z4600 z4575
4625 z4550 z4625 z4600 z4575
4650 z4650 z4625 z4600 z4575
4675 z4650 z4625 z4600 z4675
4700 z4650 z4625 z4700 z4675
4725 z4650 p20 z4700 z4675
4750 p19 z4700 z4675
4775 z4700 p18
4800 p17


MQXFA05 04-16-1542_QA3_Quench1
Z3100 (z= 800, ch71)
Z3150 (z= 850, ch72)
Z3200 (z= 900, ch73)
Z3250 (z= 950, ch74)
Z3300 (z= 1000, ch75)
Z3350 (z= 1050, ch76)
Flux/s.d.(Flux)
35
30
25
20
15
10
5
0
-5
-10
-15
-0.06
-0.05
-0.04
-0.03
-0.02
-0.01
0
Time_s


MQXFA05 04-17-1203_QA3_Quench2
Z3300 (z= 1000, ch75)
Z3350 (z= 1050, ch76)
Z3400 (z= 1100, ch77)
Z3450 (z= 1150, ch78)
Z3500 (z= 1200, ch79)
Z3550 (z= 1250, ch80)
Z3600 (z= 1300, ch81)
Z3650 (z= 1350, ch82)
Z3700 (z= 1400, ch83)
Z3750 (z= 1450, ch84)
Z3800 (z= 1500, ch85)
Flux/s.d.(Flux)
20
10
0
-10
-20
-30
-0.045
-0.04
-0.035
-0.03
-0.025
-0.02
-0.015
-0.01
-0.005
0
Time_s


Quench Origin vs. Angular Profile for quench type tanQ
Quench Origin Angle
TQA Angle (degrees)
Flux (Vs)
×10^-5
0
10
20
30
40
50
60
70
80
90
0
50
100
150
200
250
3
2
1
0
-1
-2


Quench Origin vs. Angular Profile for quench type radQ
Quench Origin Angle
TQA Angle (degrees)
Flux (Vs)
×10^-5
0
10
20
30
40
50
60
70
80
90
0
50
100
150
200
250
300
350
10
8
6
4
2
0
-2
-4
-6