# Accelerator Structure Breakdown Analysis Using Acoustic Sensors

## NLC Collaboration Meeting

## November 2002

Janice Nelson

# Contributors

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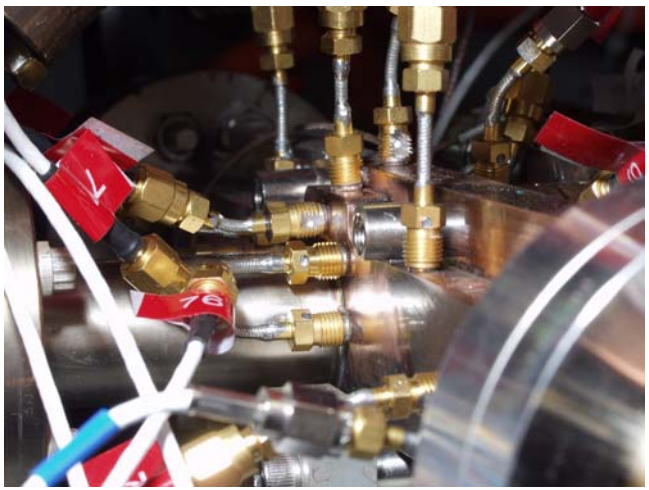
**+ students**

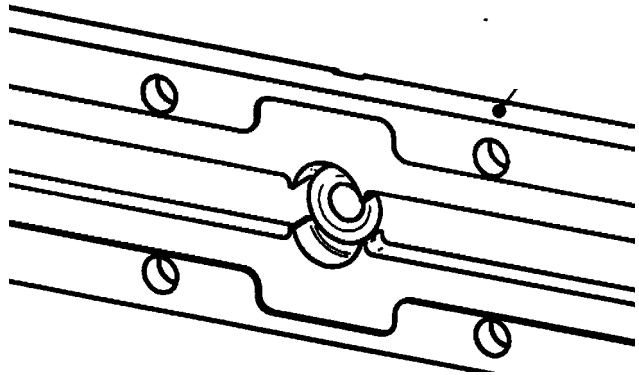
# Goals

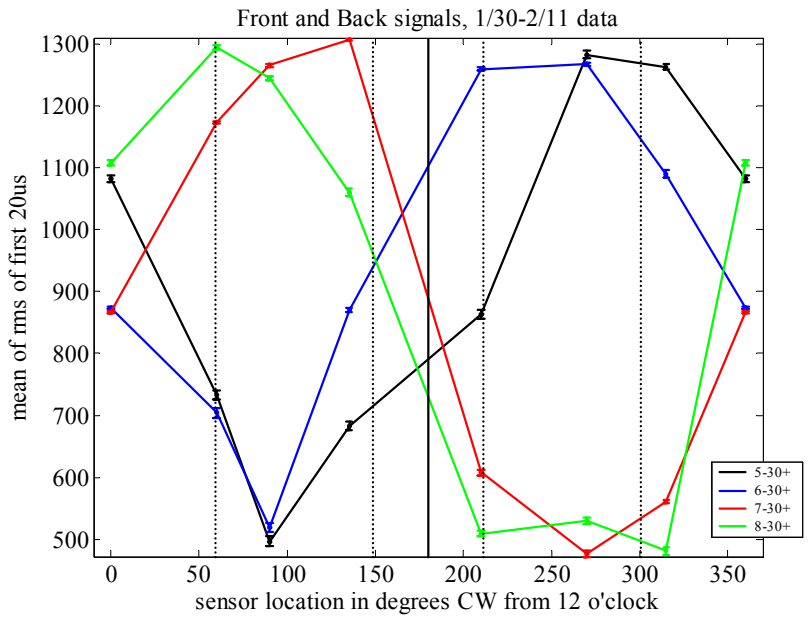
- From MAC Nov 2002:
  - "The physics of RF breakdowns are not yet understood..."
- mm accuracy of location of breakdown: which iris as well as azimuthal location
- Differentiate between theories of breakdown shape and source

# Input Coupler

- **Saw four distinctive breakdown patterns in the 7 sensors placed around beam pipe.**

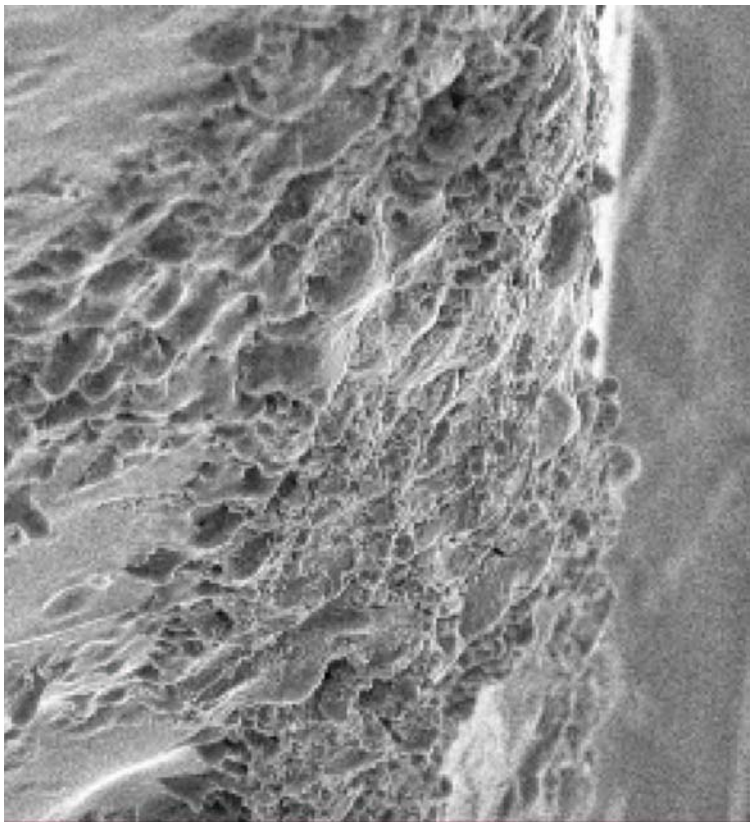


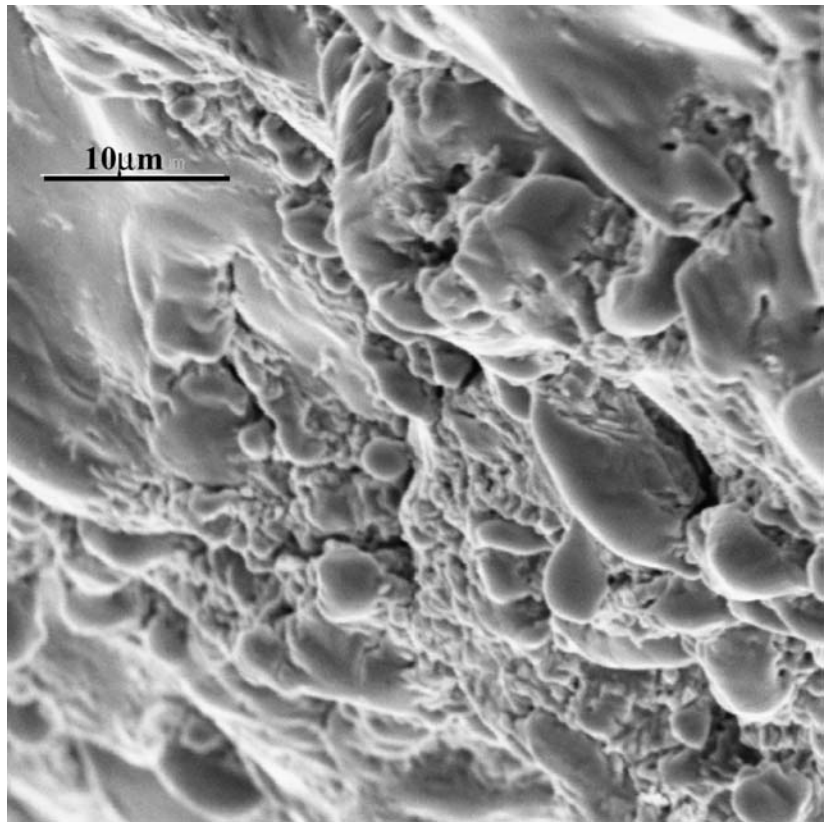




# Input Coupler Post-Mortem

- **Many pits and melted material seen along horns and iris.**



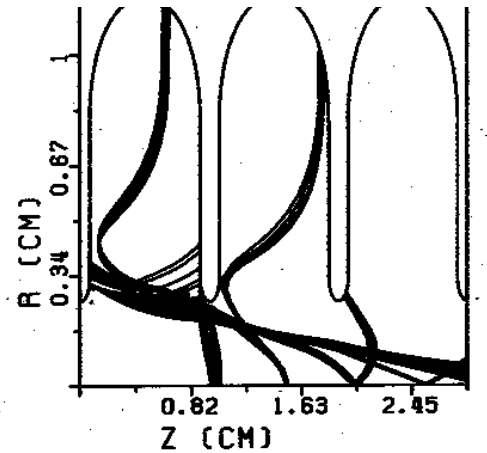


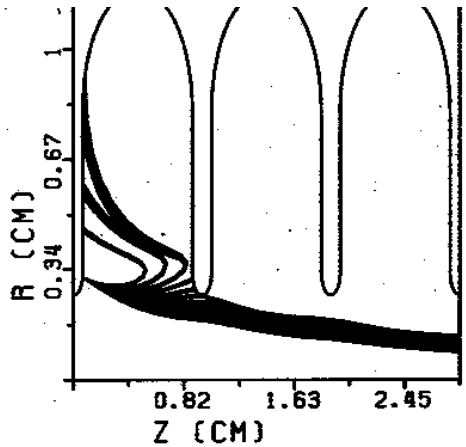
# Lab Tests

- Tried to extend resolution using higher frequency ultrasound, but discovered its attenuation in materials with large crystalline structure (i.e. annealed copper) becomes very large when the wavelength approaches the typical grain size.
  - Tests showed that it is not practical to use frequencies beyond ~600 kHz ($\lambda$~5mm). In our structures at 2 MHz, the attenuation is ~30 dB more than at lower frequencies.
  - We use our sensors between 100 and 300 kHz.
- A pseudo-arc pulser has been created, but no results yet.
- University groups are participating

# One Theory for Breakdowns in Structures

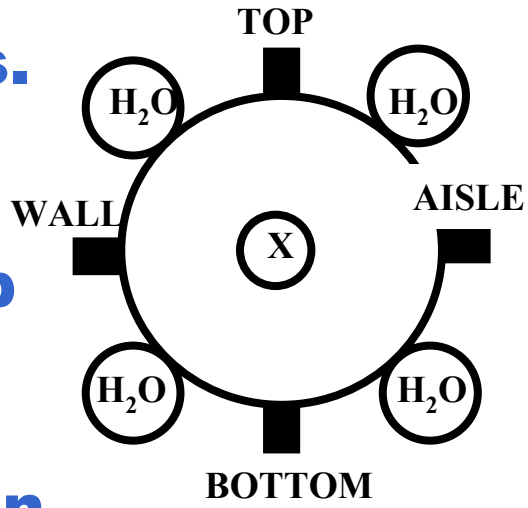
- **Example theory: (Bienvenue)**
  - **shows trajectories from a hypothetical source**
  - **predicts captured current and field loading**

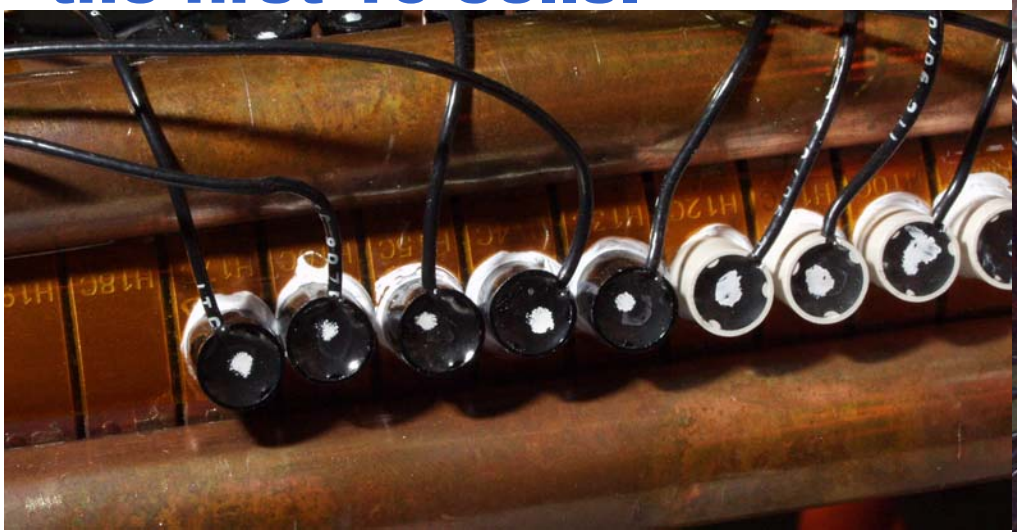


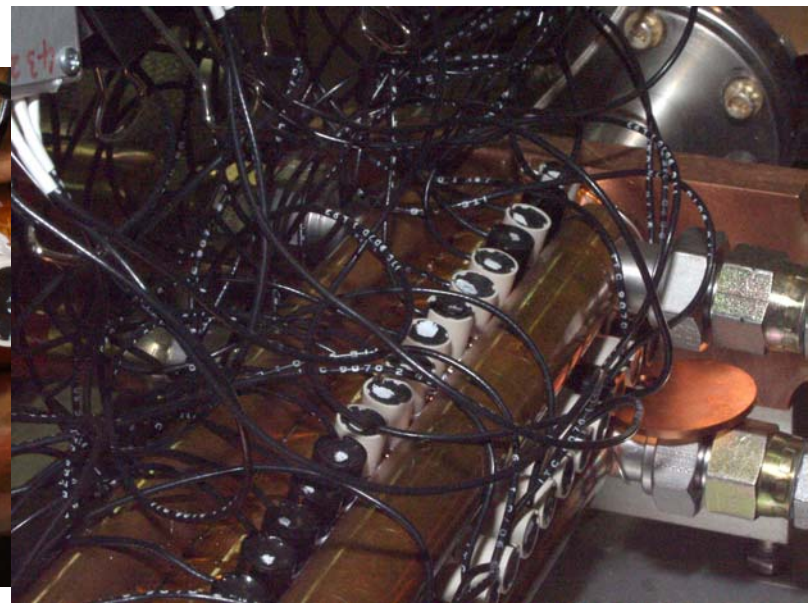



# H60VG3 Structure

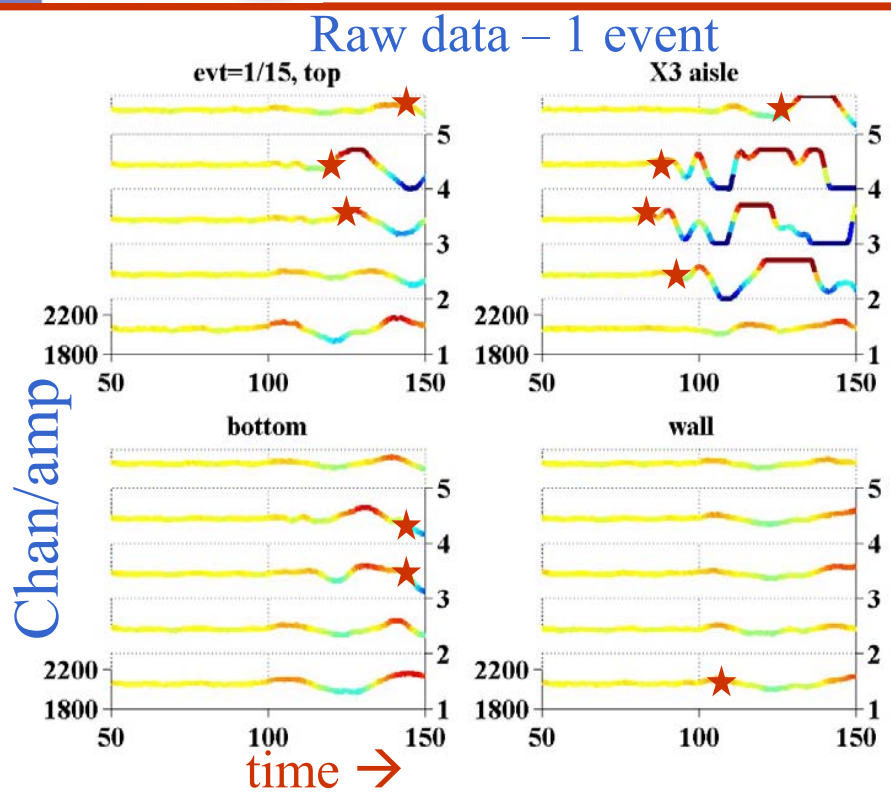
- 64 sensors, glued 4/cell for 16 cells.
- Analyzed data from 9/23 – 10/24/02, 240-400ns stable running. (Breakdowns during power ramp-up not analyzed yet.)
- Of ~13000 (!) files, 400 had reasonably sized breakdowns within the first 16 cells.

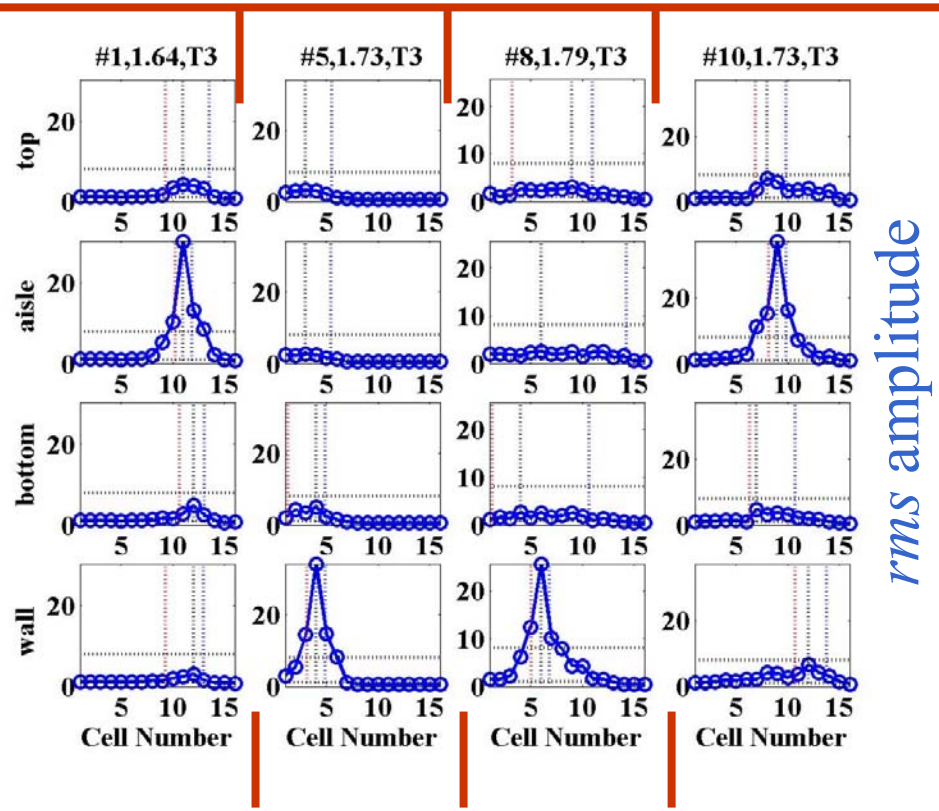




# H60 Analysis

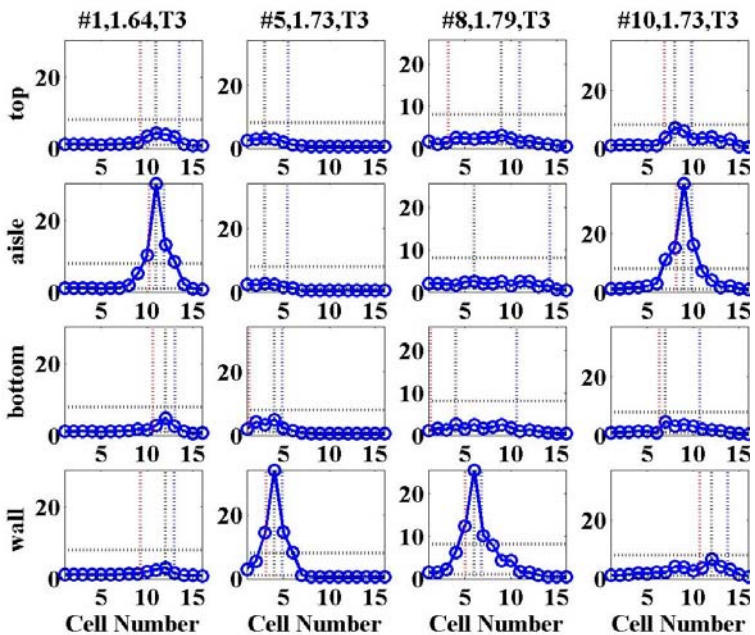


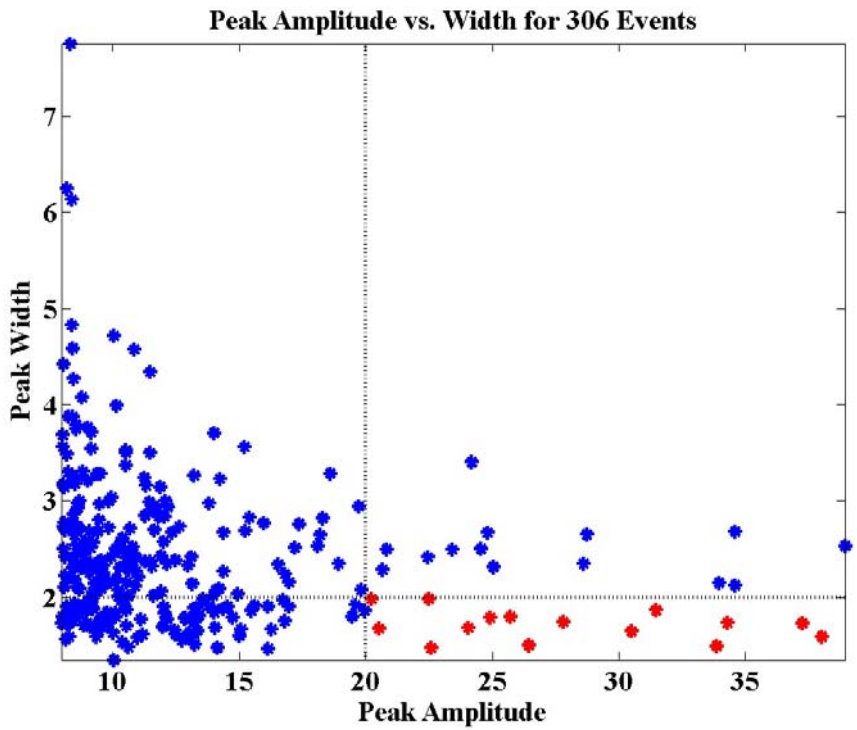

- **Chose to study the 15 events with very high amplitude and fewest sensors hearing the event (providing a potentially cleaner signal that may be easiest to analyze).**

# Event Selection

- **Plot of the normalized amplitude versus the peak width, for the biggest signal in each event.**
- **We chose only those with a normalized amplitude > 20 and a width < 2 channels.**

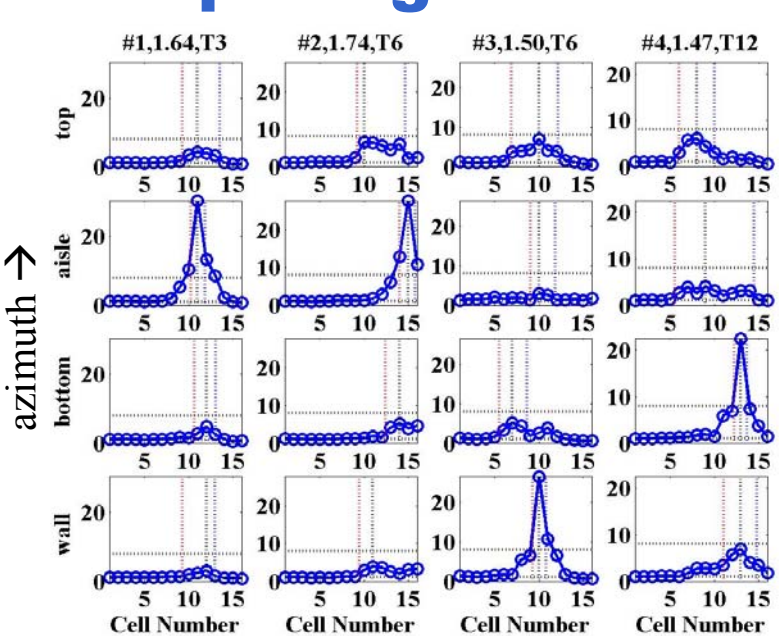


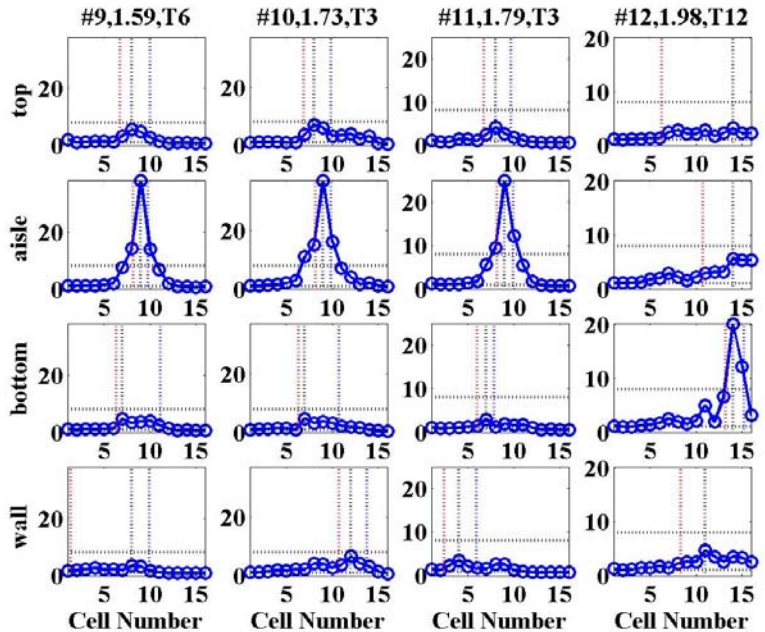

*rms* amplitude →



# Azimuthal resolution

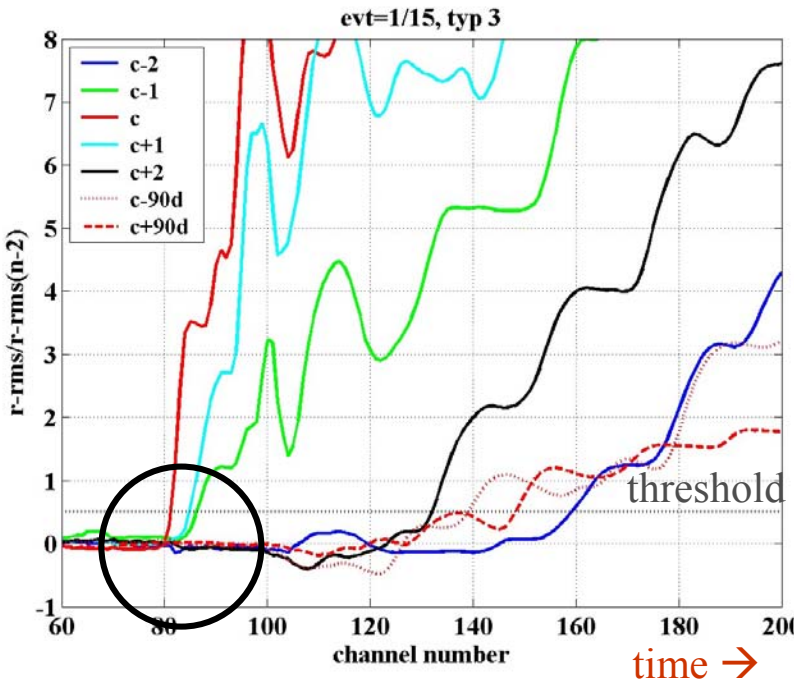
- Many events have very small signals in adjacent azimuthal neighbor sensors .
- This implies the sensors' resolution is less than the spacing between the 4 azimuthal sensors and about equal to the cell spacing.

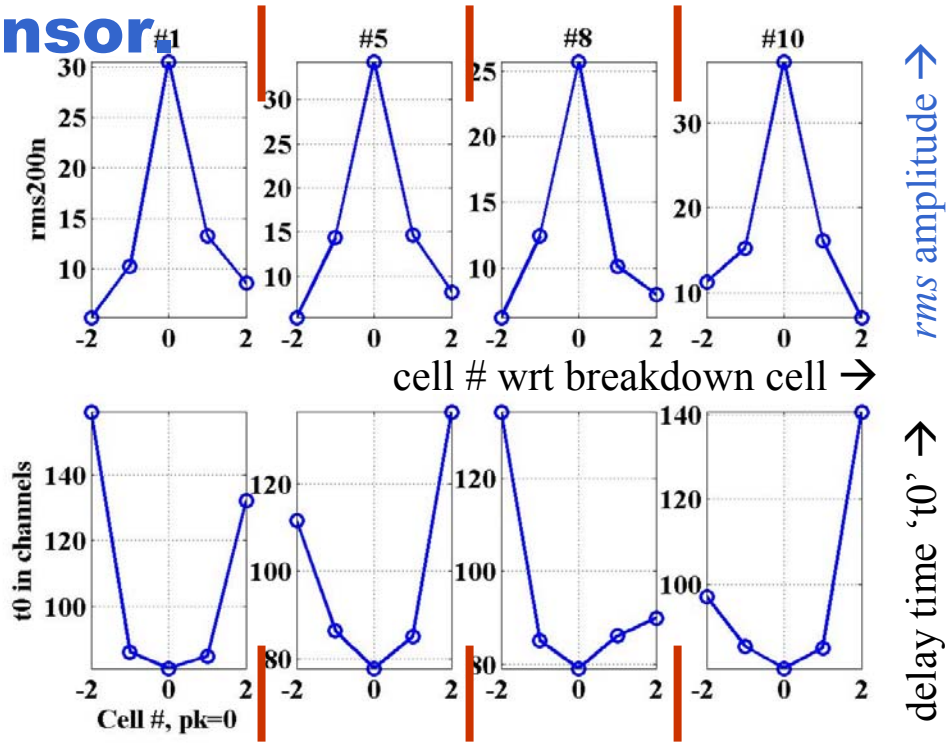


# Signal Timing

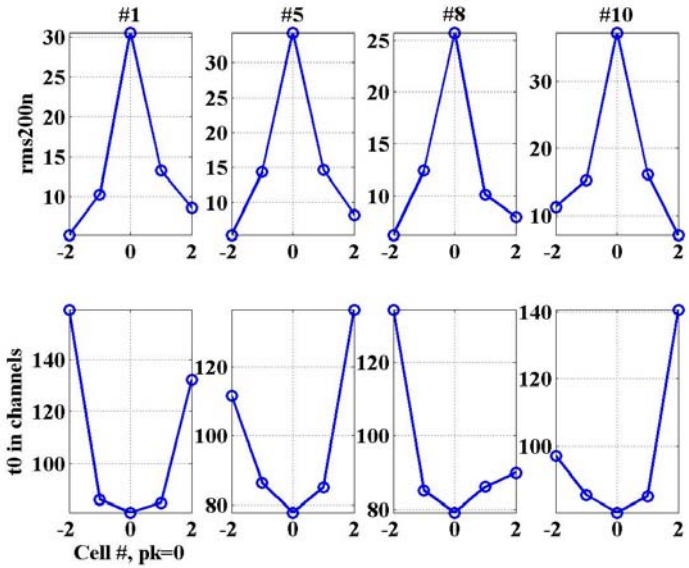
- When the "running" rms of a raw signal first crosses a threshold is used as time signal arrived at sensor



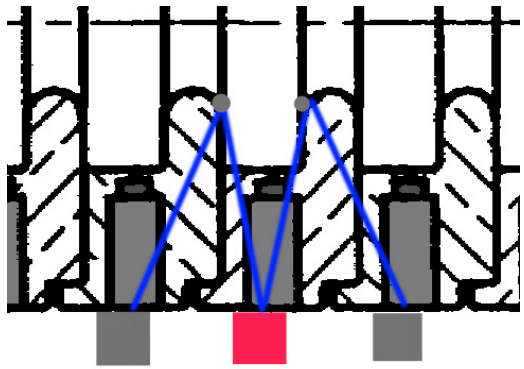

- Typical events have very strong symmetry – nearest axial neighbors have equal signals and equal delay with respect to max signal

# Signal Timing, cont.



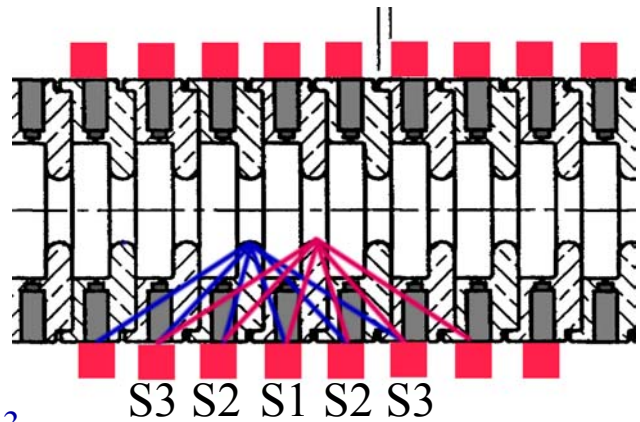

The sensors are between irises.

***Multi-iris events best explain the observed symmetry.***



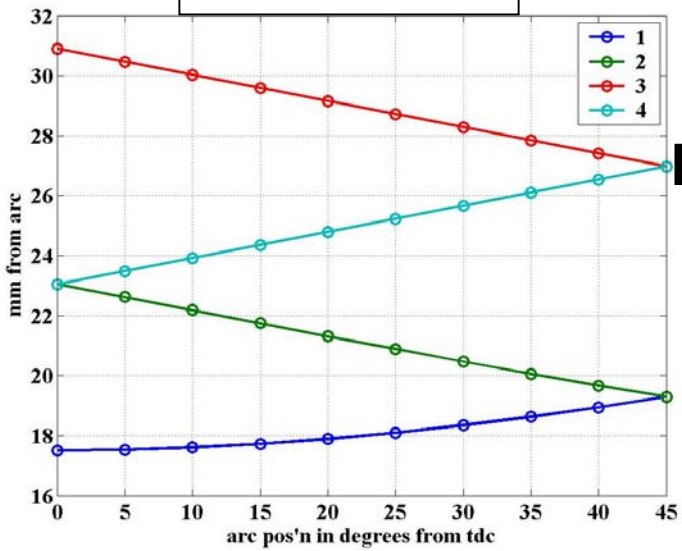
## Calculated Distances/Times

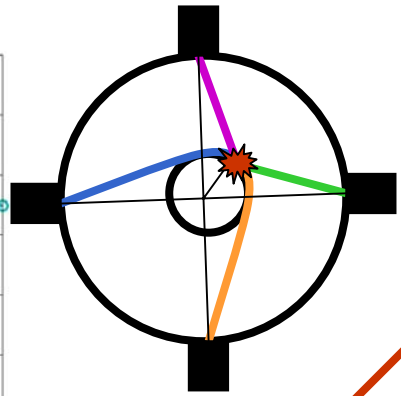
| Sensor | distance from iris(es) (mm) | weighted mean distance | Equivalent channels (3 mm/us) |
|---|---|---|---|
| S1 | 19 | 19 | 63 |
| S2 | 19, 28 | 22 | 73 |
| S3 | 28, 40 | 31 | 103 |

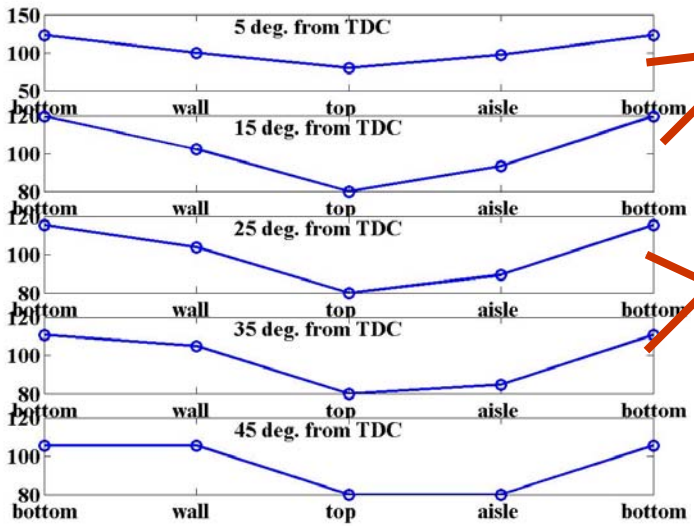


# Timing from Azimuthal Sensors

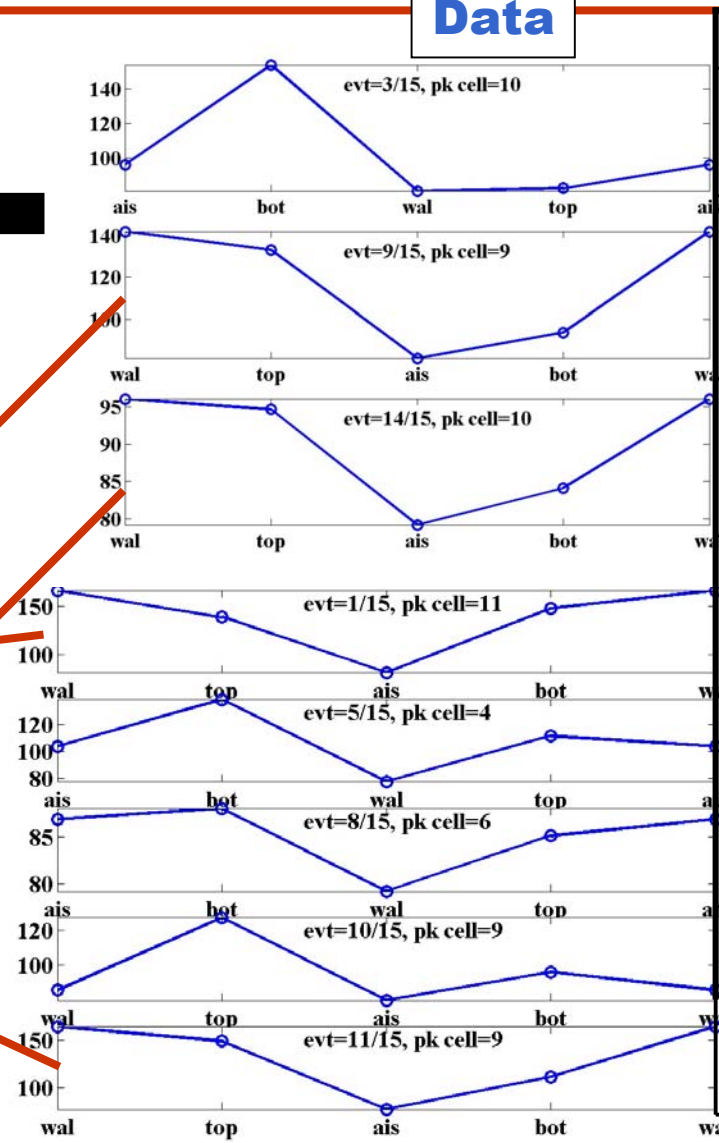
## Calculation






## Data



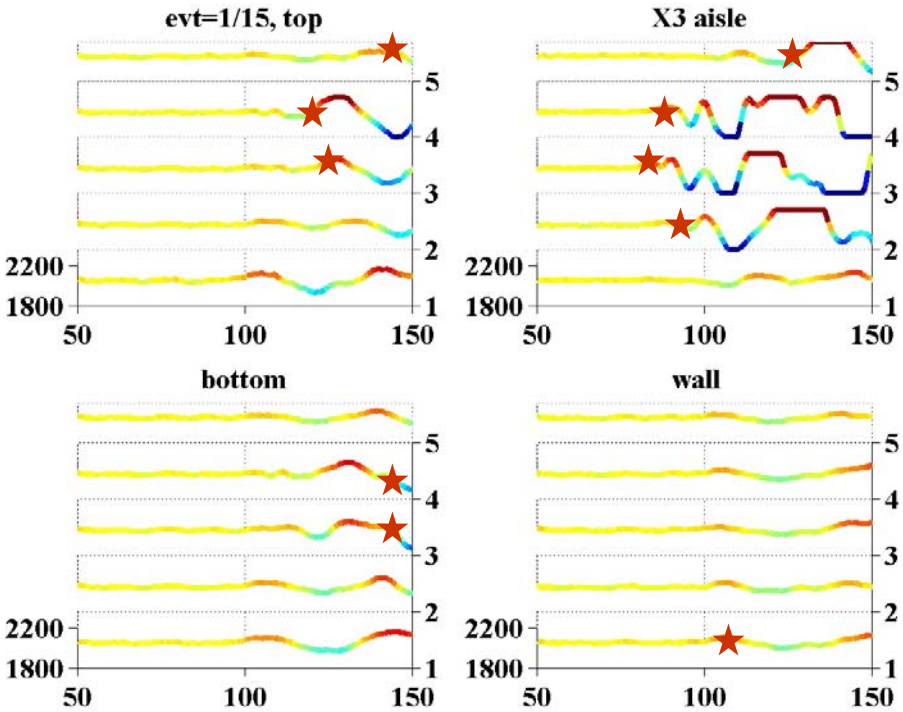

| Deg |
|---|
| 45 |
| 15 |
| 35 |
| 5 |
| 10 |
| 5 |
| 25 |
| 25 |

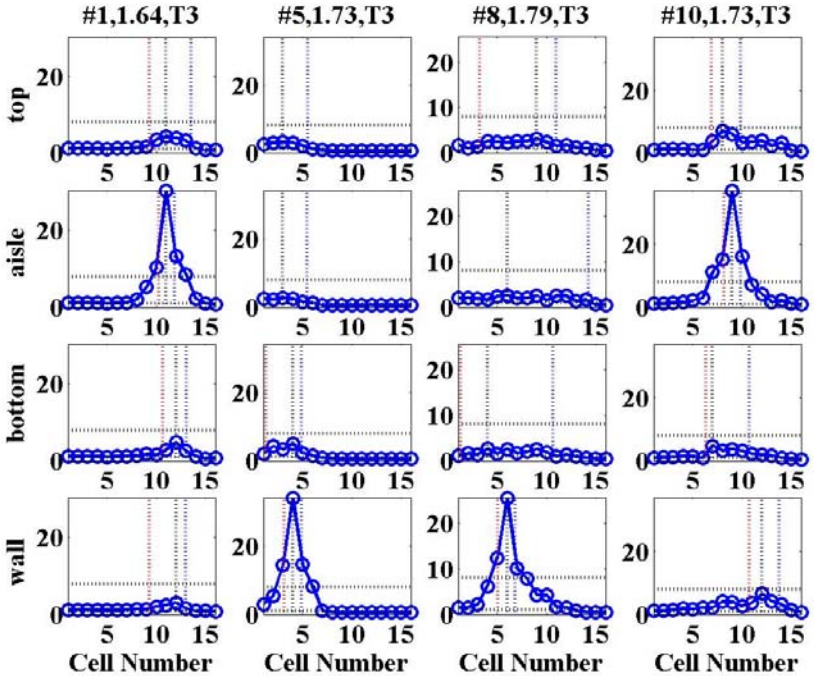
# Future Studies

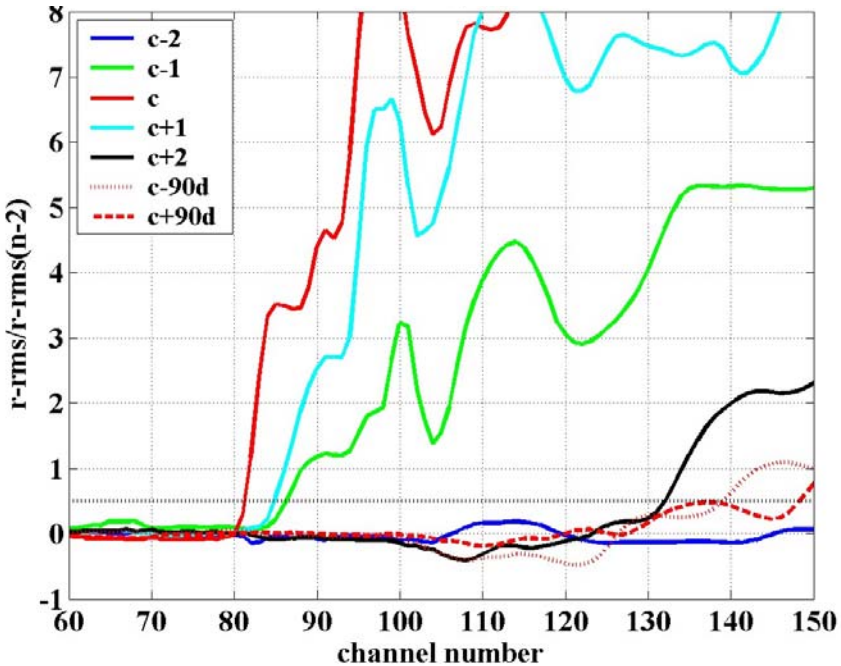
- Plans exist to increase the number of available digitizer channels and number of sensors
- Ultimately, try to connect this data with the microwave signals.

# Summary

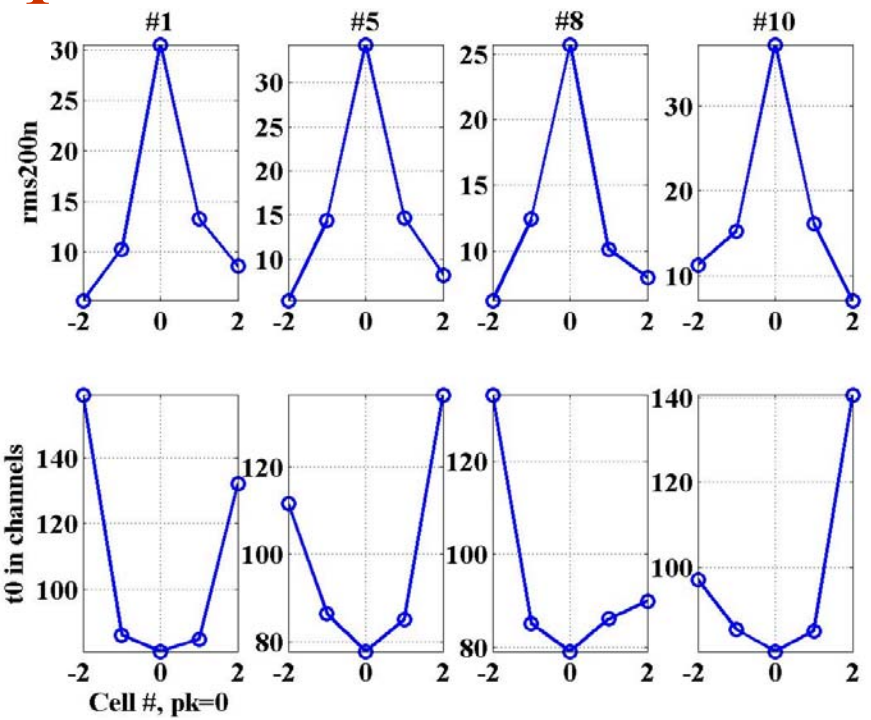
- These sensors were the only detectors to see breakdowns on the “horns” of the input coupler.
- See a handful of very high strength events in H60 structure that require a breakdown coming from more than one iris to explain the data.
- The resolution of these sensors is less than the spacing between the azimuthal sensors and about the width of one cell.
- If we had twice as many sensors and they were half the size, we could better pinpoint breakdown locations.

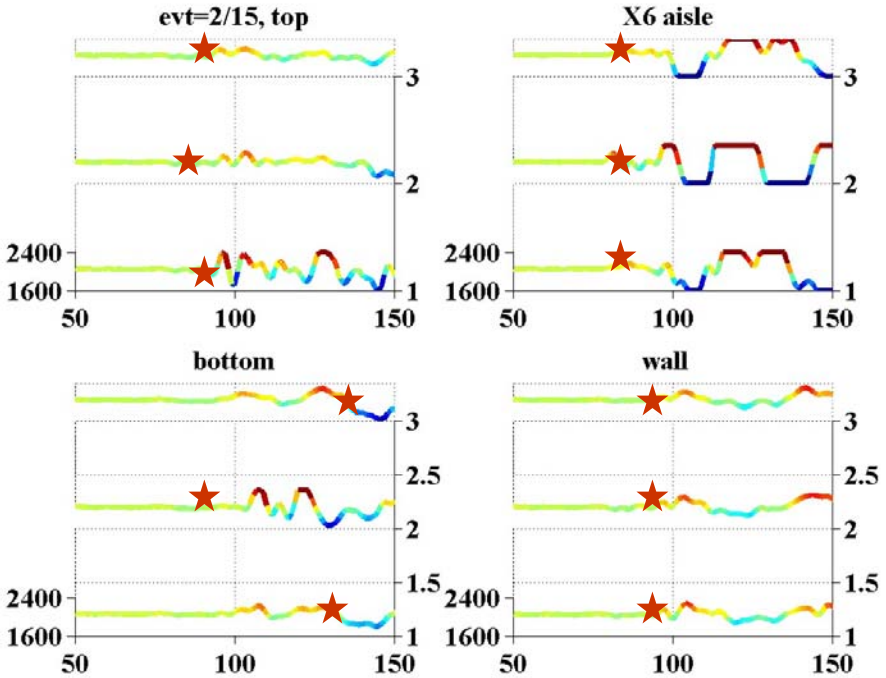

evt=1/15, top
X3 aisle
bottom
wall
2200
1800
50
100
150
1
2
3
4
5

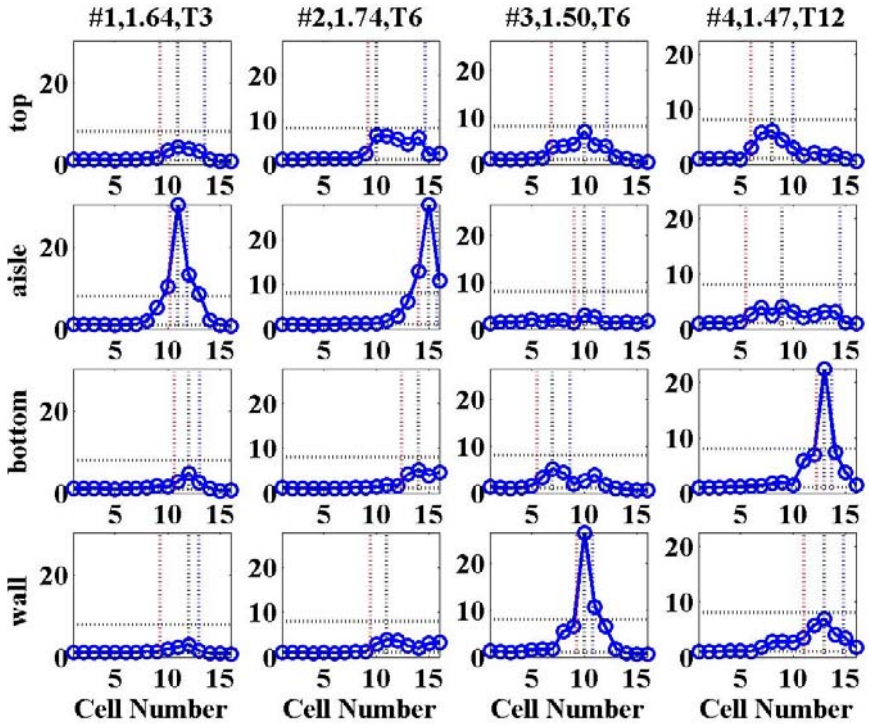

#1,1.64,T3
#5,1.73,T3
#8,1.79,T3
#10,1.73,T3
top
aisle
bottom
wall
Cell Number
0
10
20
5
10
15


c-2
c-1
c
c+1
c+2
c-90d
c+90d
r-rms/r-rms(n-2)
channel number
-1
0
1
2
3
4
5
6
7
8
60
70
80
90
100
110
120
130
140
150

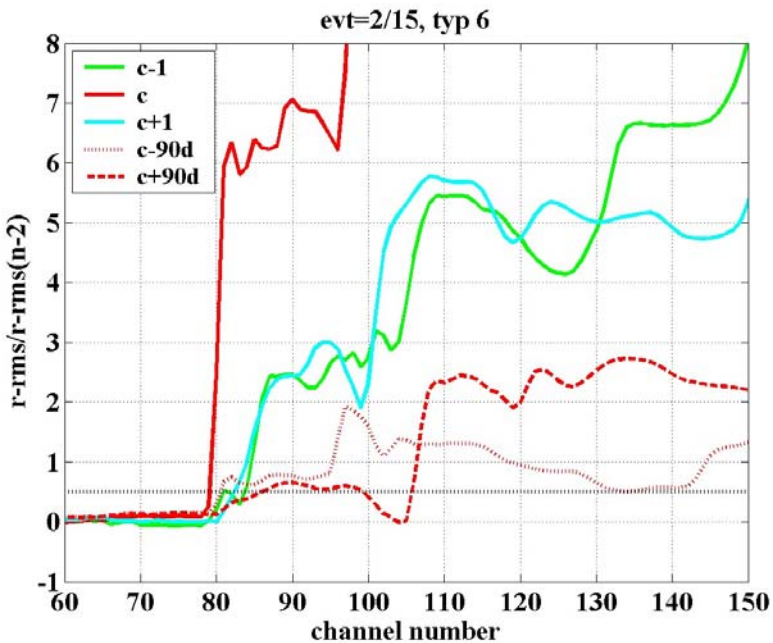
1


#1
#5
#8
#10
rms200n
t0 in channels
Cell #, pk=0
-2
0
2


evt=2/15, top
X6 aisle
bottom
wall


#1,1.64,T3
#2,1.74,T6
#3,1.50,T6
#4,1.47,T12
top
aisle
bottom
wall
Cell Number

2


evt=2/15, typ 6
c-1
c
c+1
c-90d
c+90d
r-rms/r-rms(n-2)
channel number



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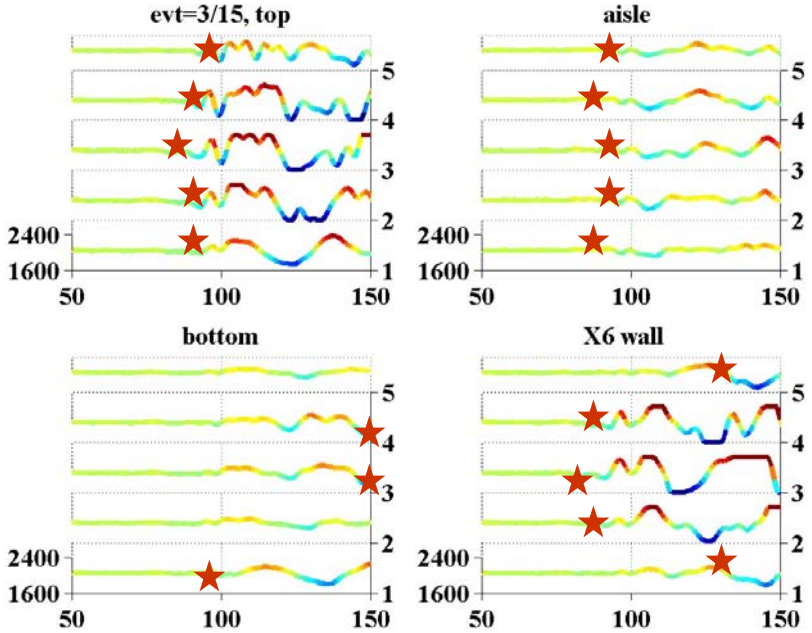
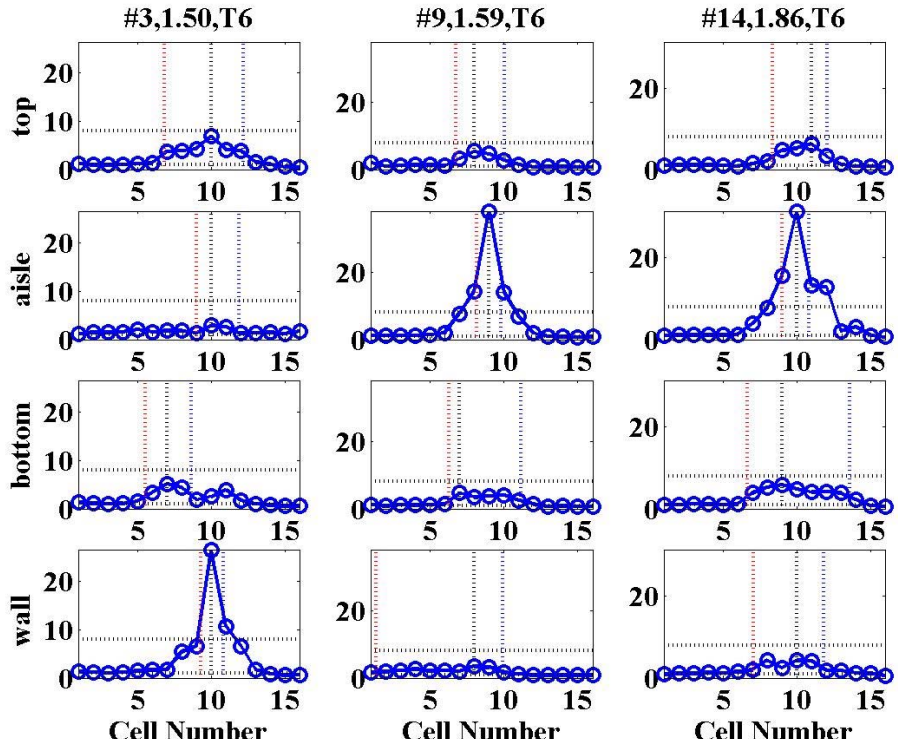
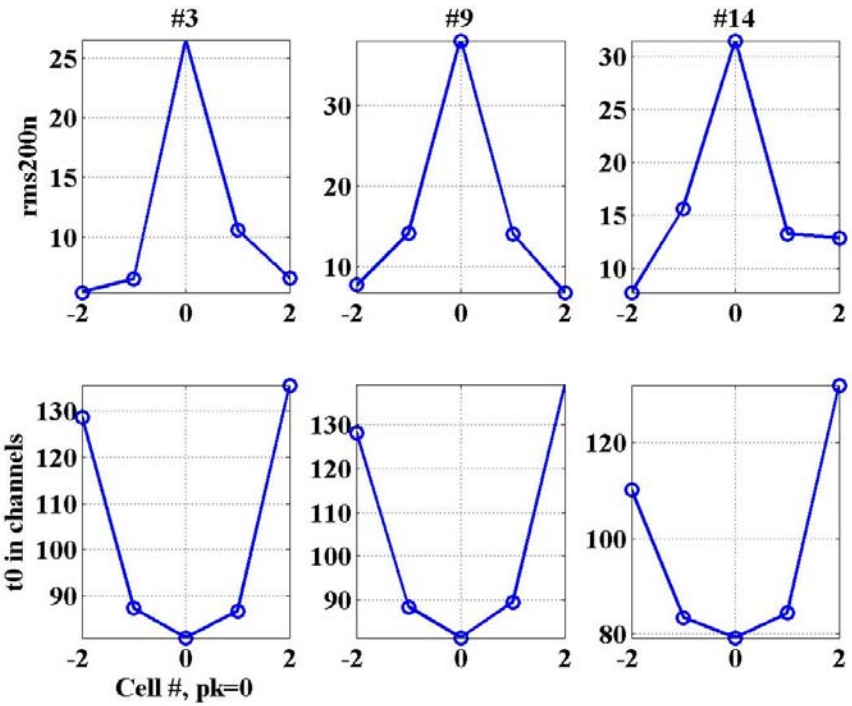
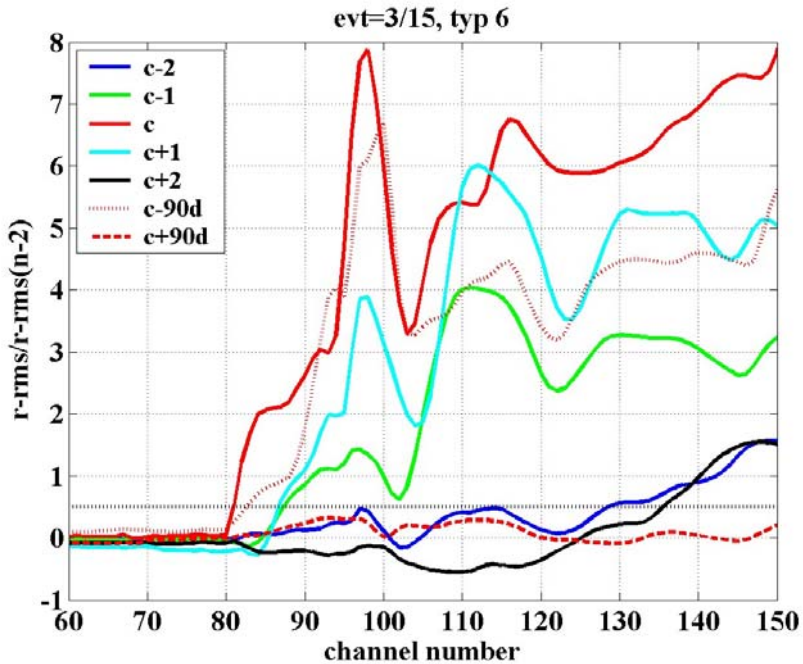
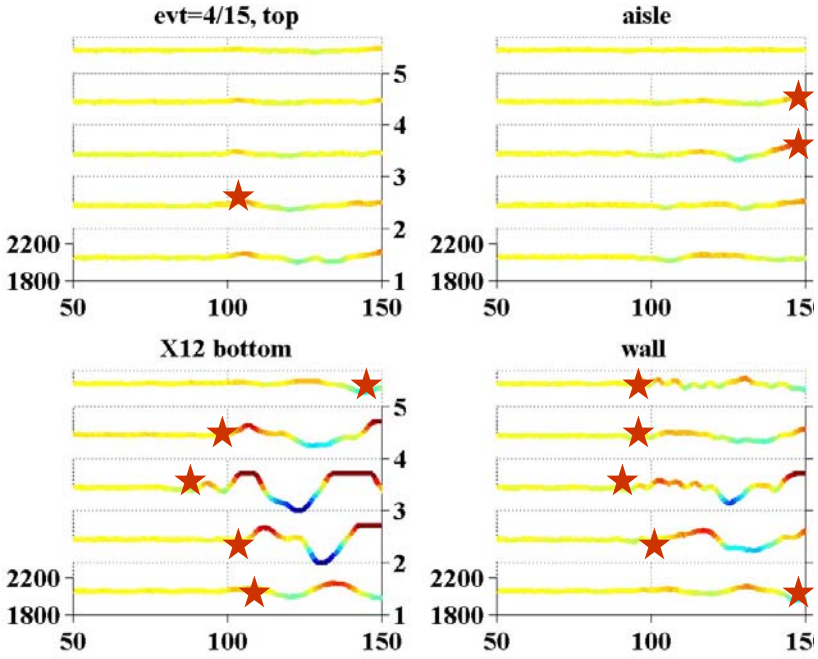

evt=3/15, top
aisle
bottom
X6 wall

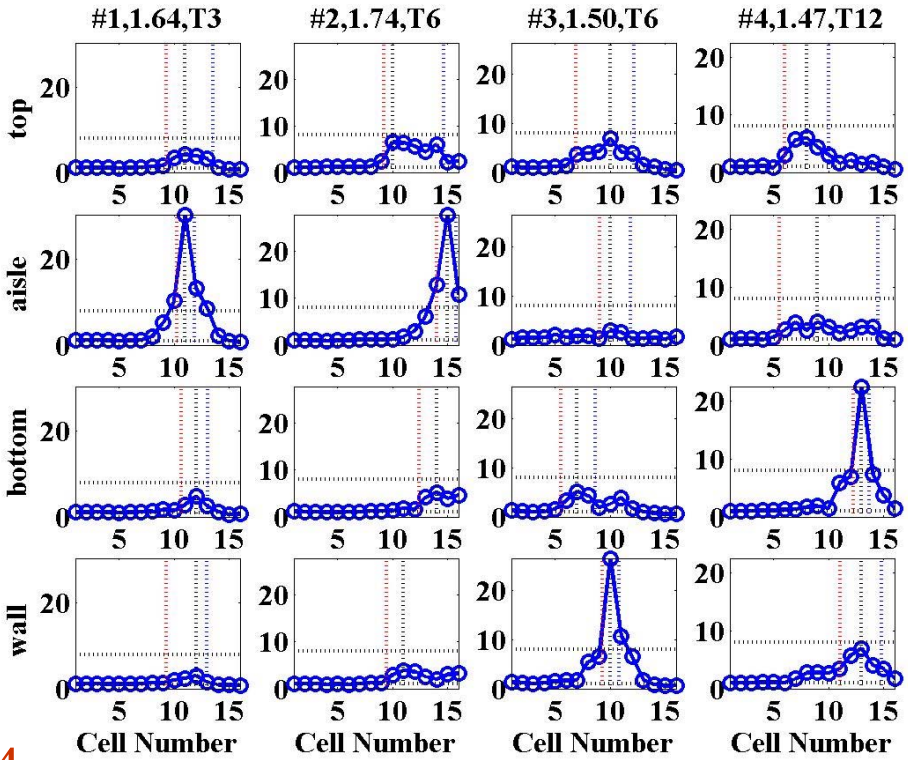

#3,1.50,T6
#9,1.59,T6
#14,1.86,T6
top
aisle
bottom
wall
Cell Number

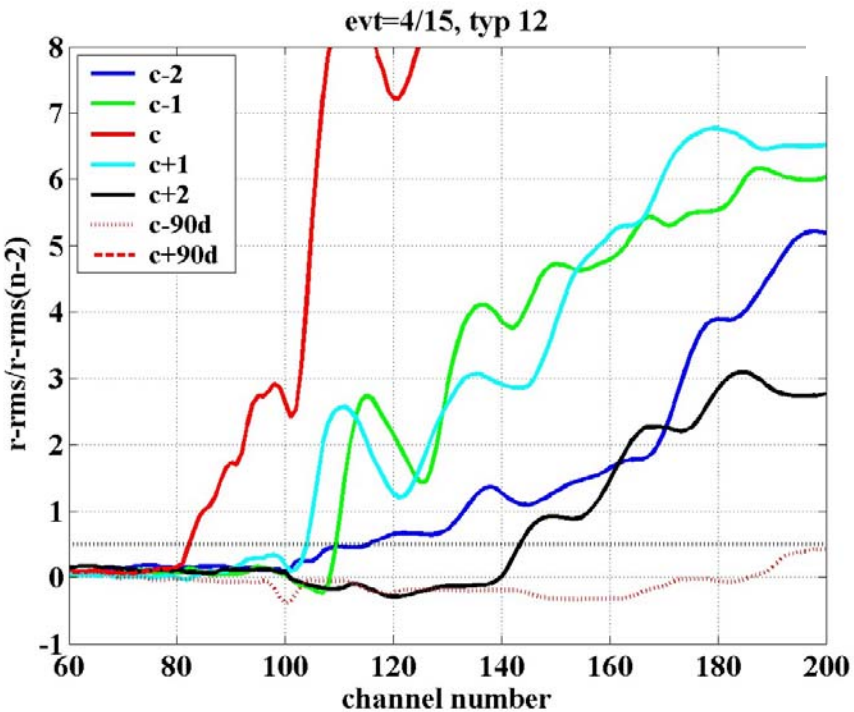

#3
#9
#14
rms200n
t0 in channels
Cell #, pk=0

3


evt=3/15, typ 6
c-2
c-1
c
c+1
c+2
c-90d
c+90d
r-rms/r-rms(n-2)
channel number

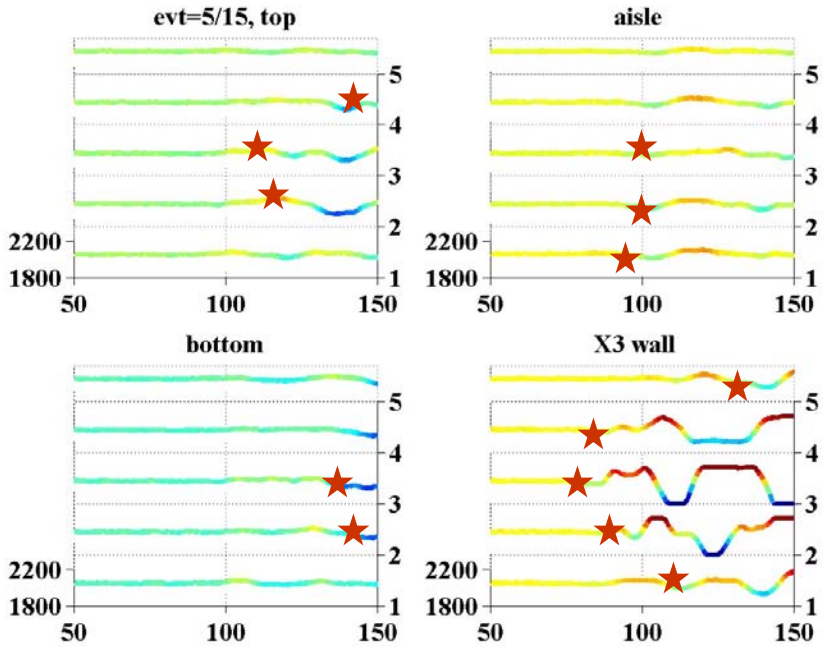

evt=4/15, top
aisle
X12 bottom
wall
2200
1800
50
100
150
1
2
3
4
5

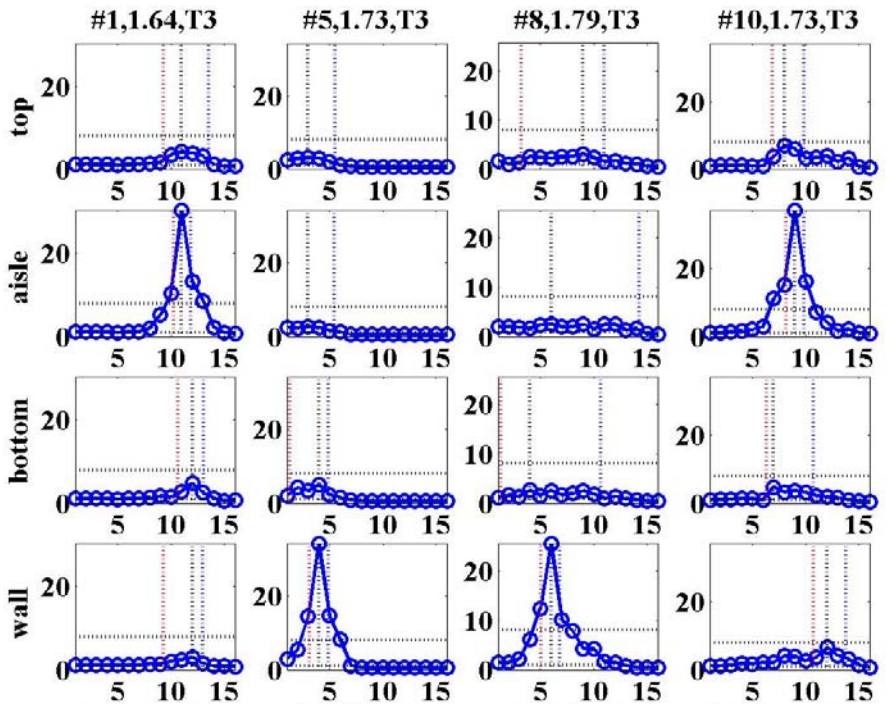

#1,1.64,T3
#2,1.74,T6
#3,1.50,T6
#4,1.47,T12
top
aisle
bottom
wall
0
10
20
5
10
15
Cell Number

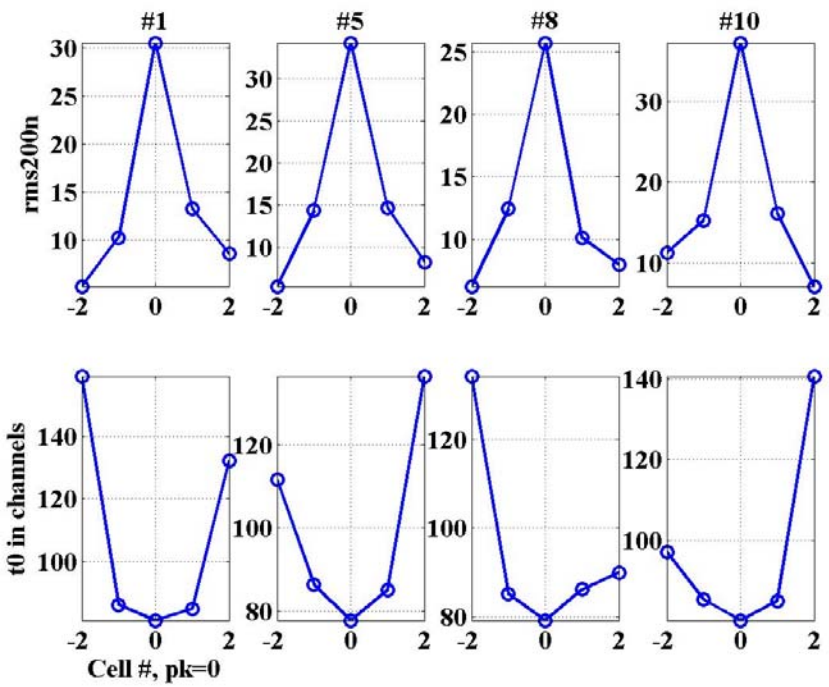

evt=4/15, typ 12
c-2
c-1
c
c+1
c+2
c-90d
c+90d
r-rms/r-rms(n-2)
channel number
-1
0
1
2
3
4
5
6
7
8
60
80
100
120
140
160
180
200



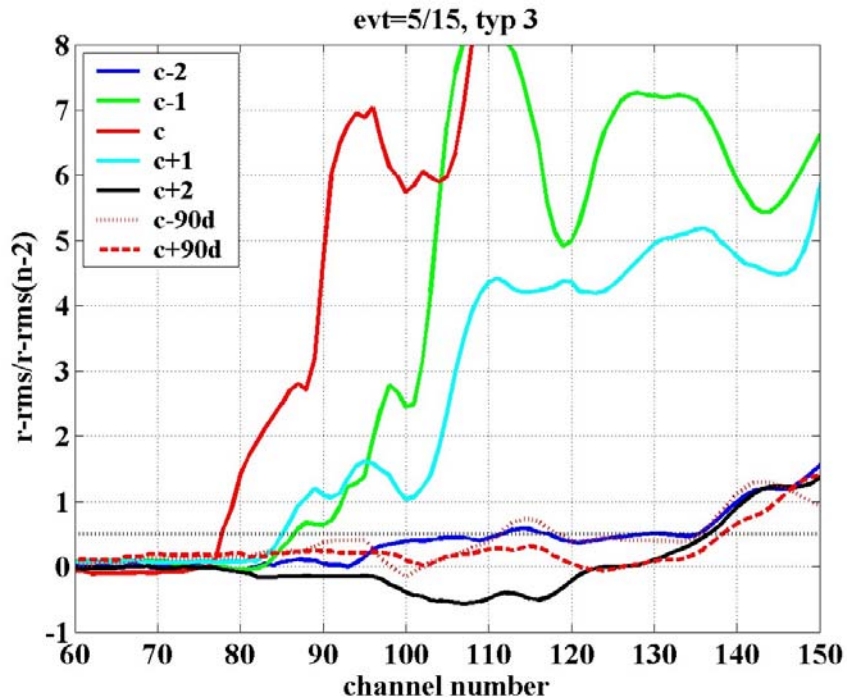
*J. Nelson*

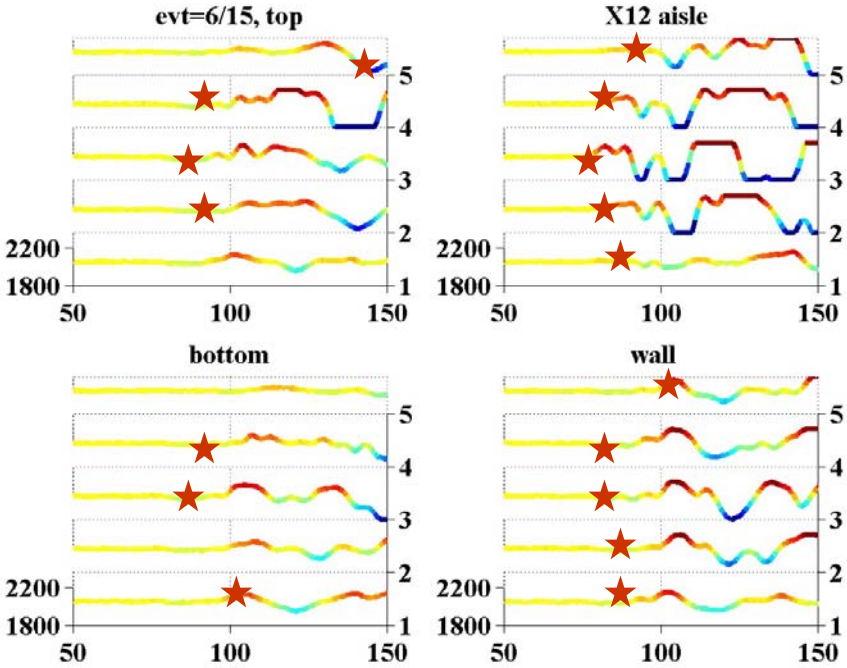

evt=5/15, top
aisle
bottom
X3 wall

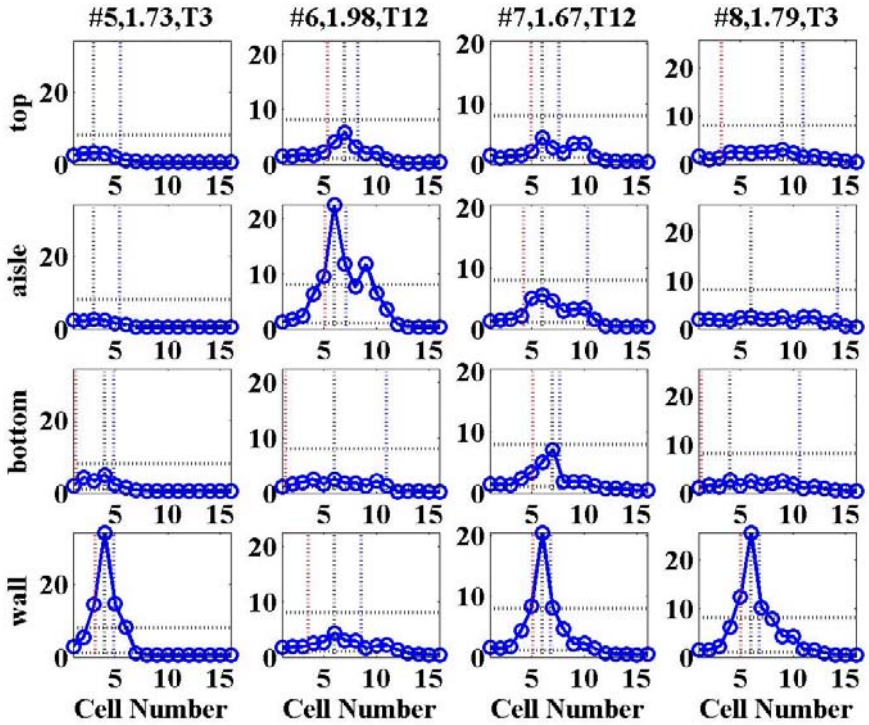

#1,1.64,T3
#5,1.73,T3
#8,1.79,T3
#10,1.73,T3
top
aisle
bottom
wall

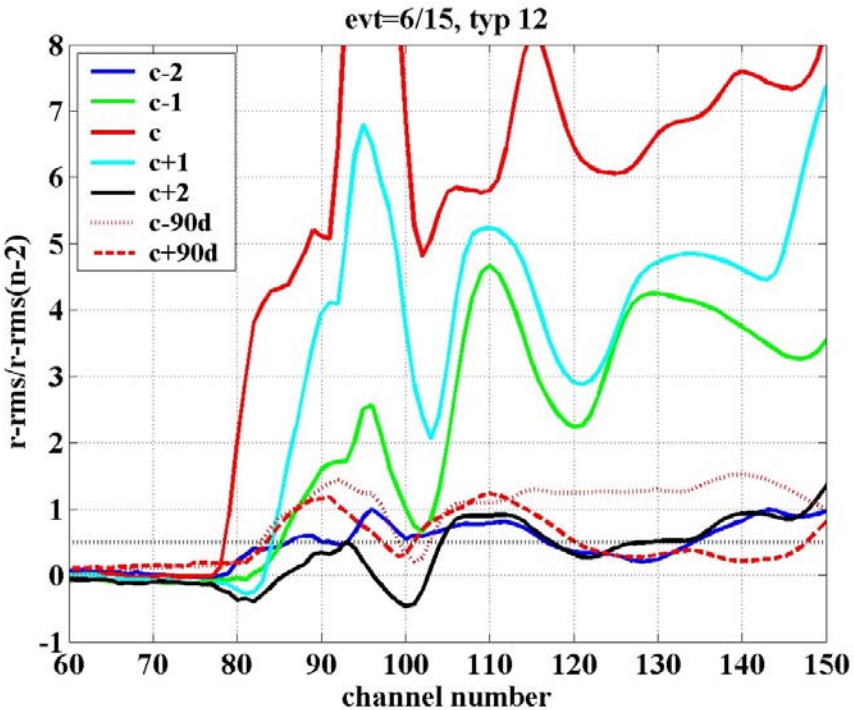

#1
#5
#8
#10
rms200n
t0 in channels
Cell #, pk=0

5


evt=5/15, typ 3
c-2
c-1
c
c+1
c+2
c-90d
c+90d
r-rms/r-rms(n-2)
channel number

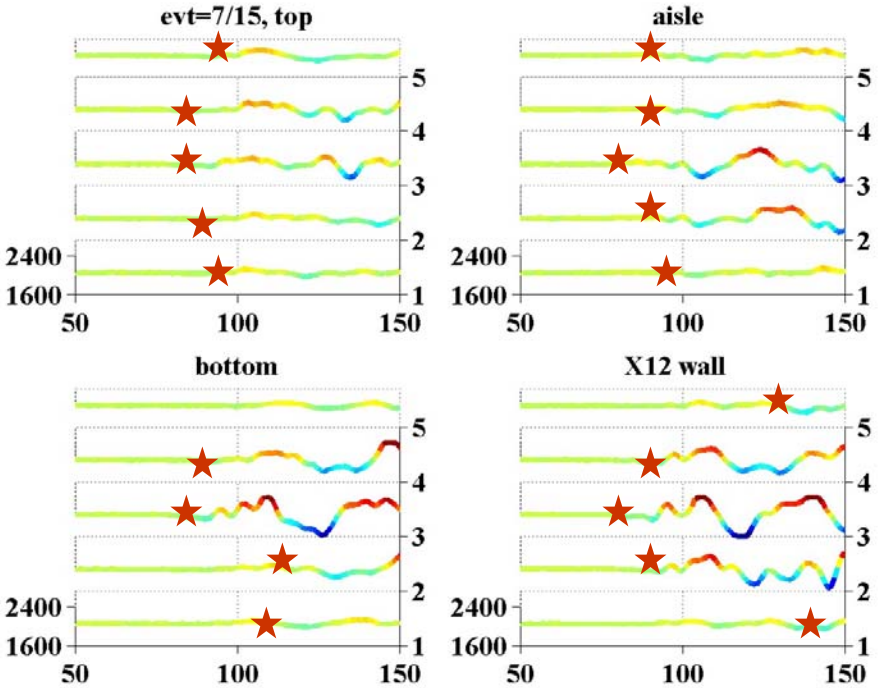

evt=6/15, top
X12 aisle
bottom
wall
2200
1800
50
100
150
1
2
3
4
5

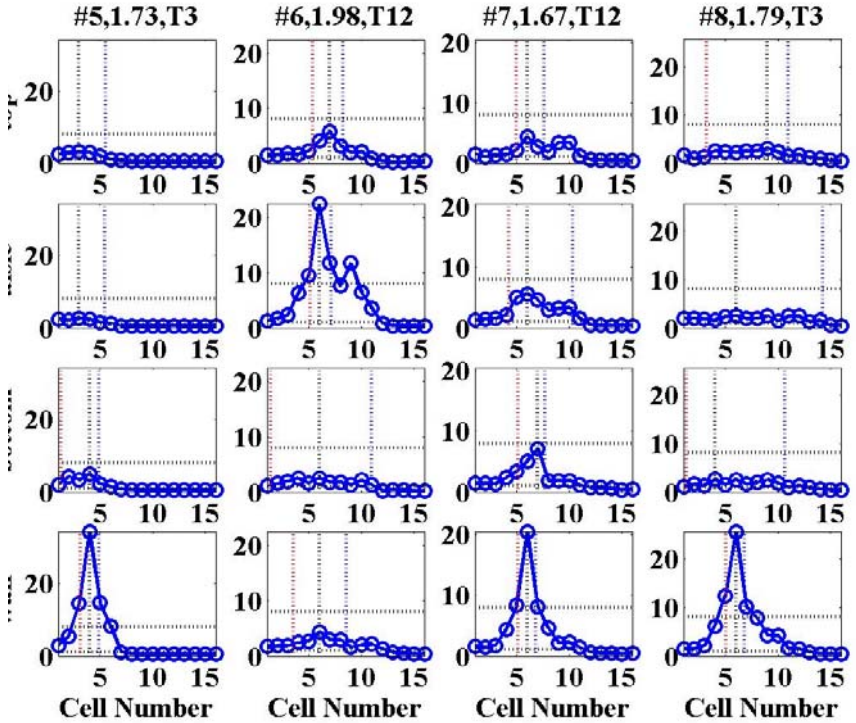

#5,1.73,T3
#6,1.98,T12
#7,1.67,T12
#8,1.79,T3
top
aisle
bottom
wall
Cell Number

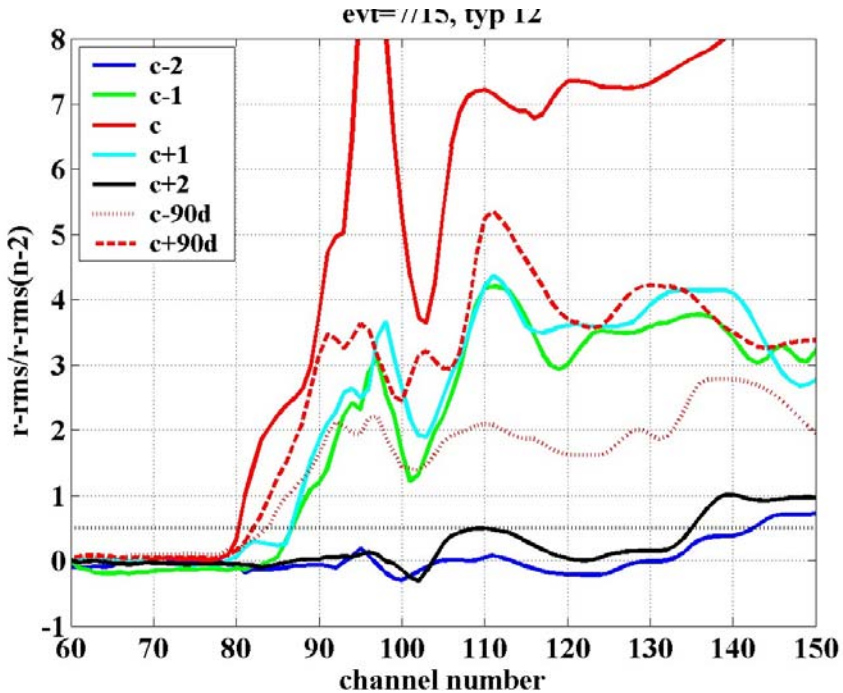

evt=6/15, typ 12
c-2
c-1
c
c+1
c+2
c-90d
c+90d
r-rms/r-rms(n-2)
channel number

6

*J. Nelson*

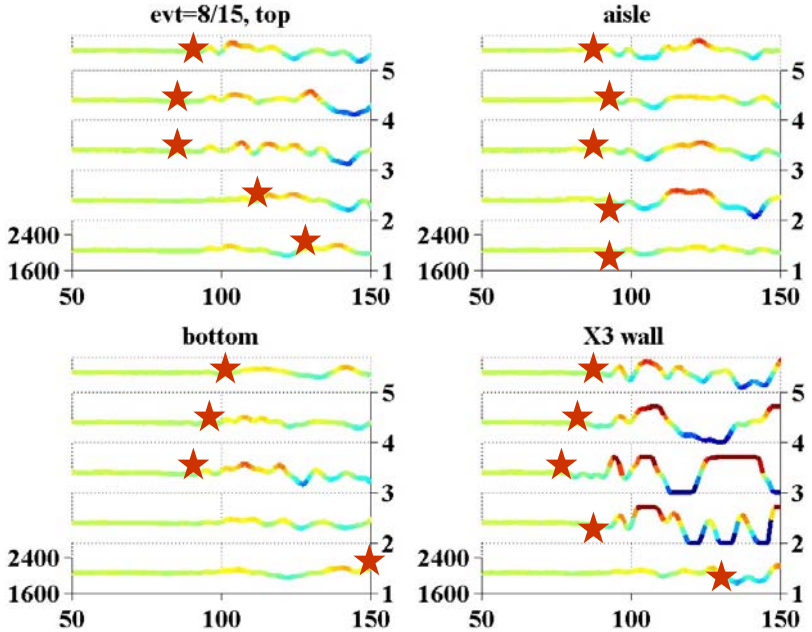

evt=7/15, top
aisle
bottom
X12 wall
2400
1600
50
100
150
1
2
3
4
5

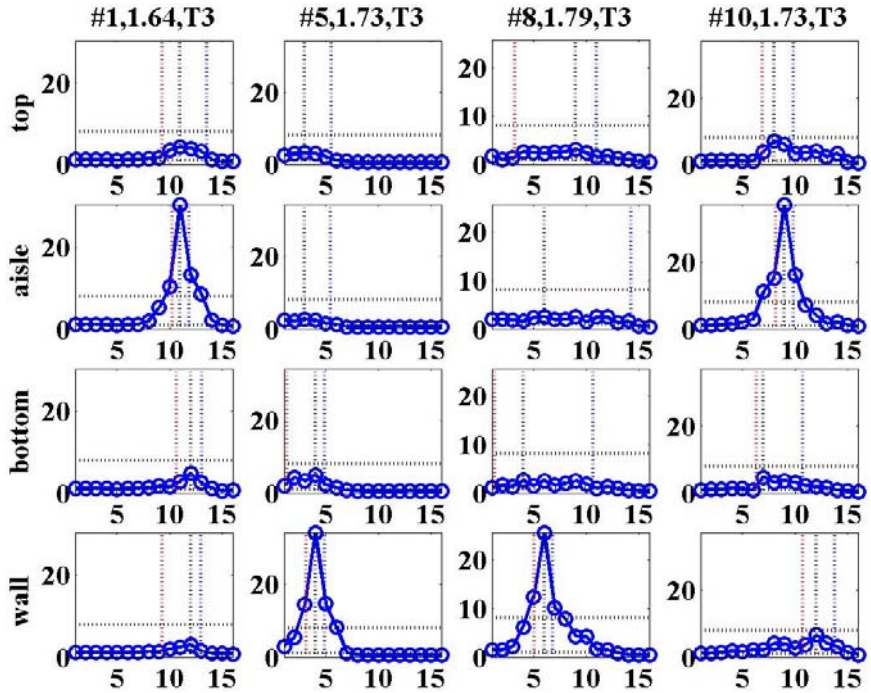

#5,1.73,T3
#6,1.98,T12
#7,1.67,T12
#8,1.79,T3
Cell Number
Cell Number
Cell Number
Cell Number


c-2
c-1
c
c+1
c+2
c-90d
c+90d
r-rms/r-rms(n-2)
channel number

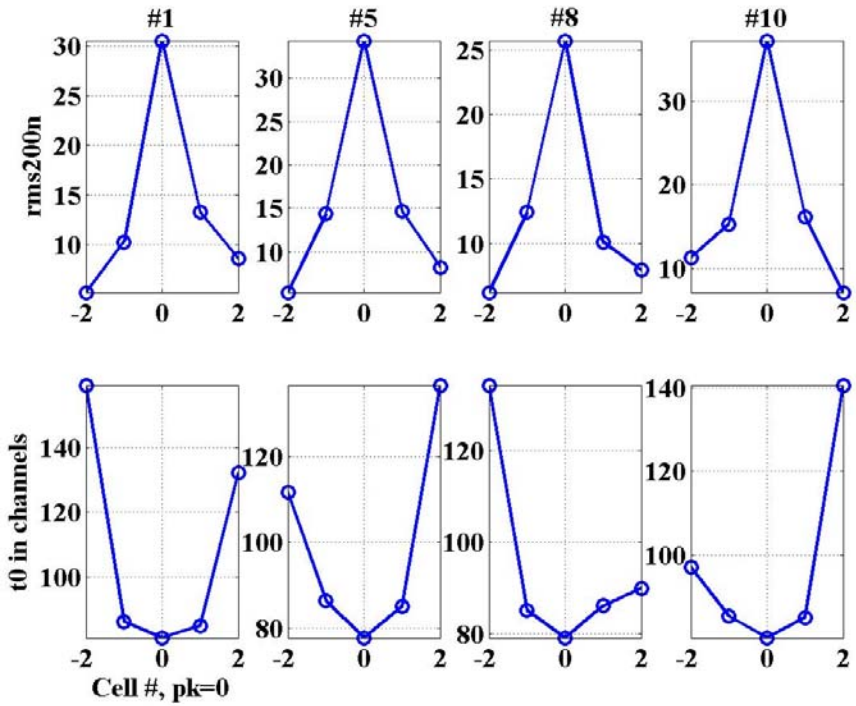
7

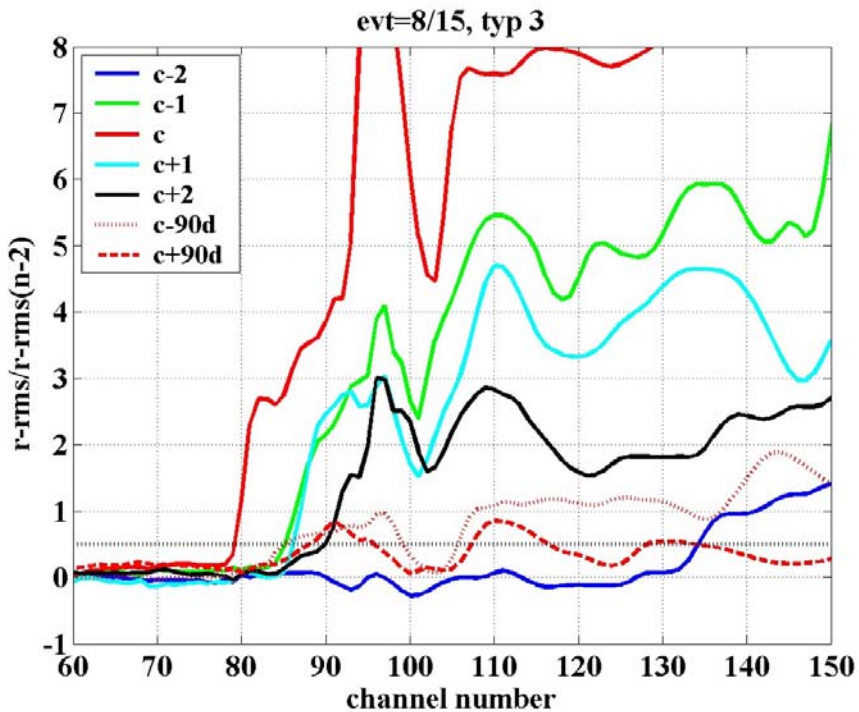
*J. Nelson*

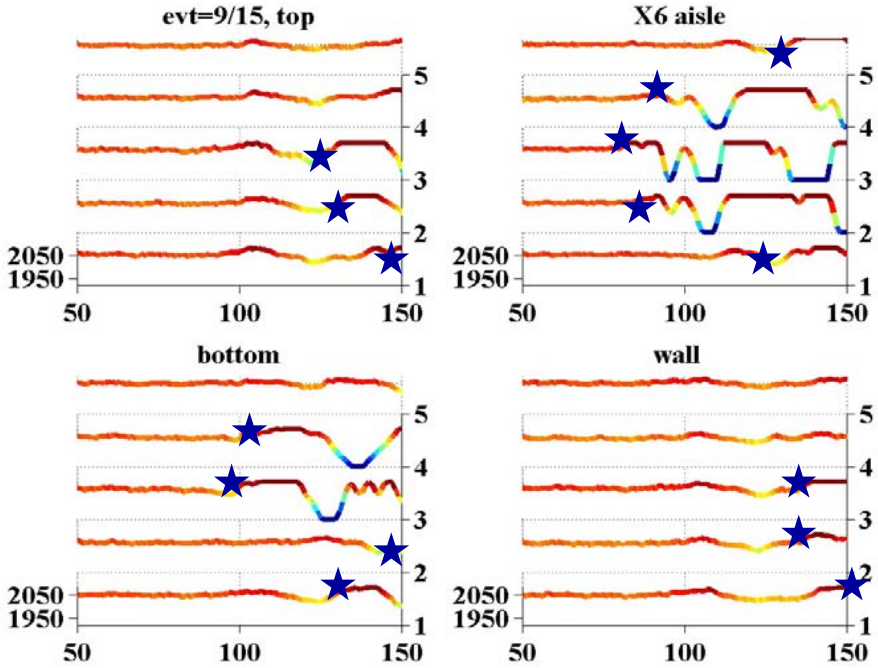

evt=8/15, top
aisle
bottom
X3 wall

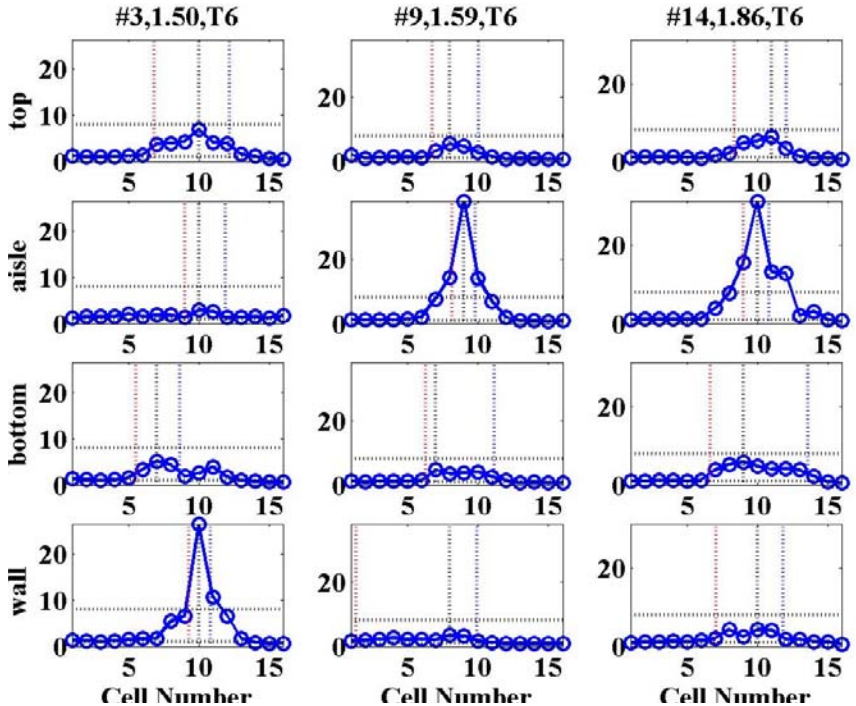

#1,1.64,T3
#5,1.73,T3
#8,1.79,T3
#10,1.73,T3
top
aisle
bottom
wall

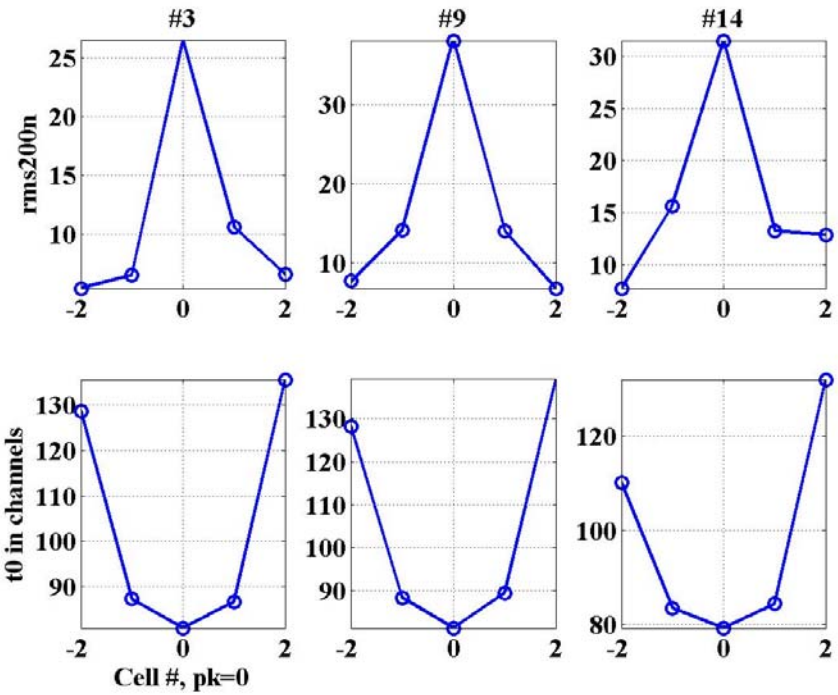


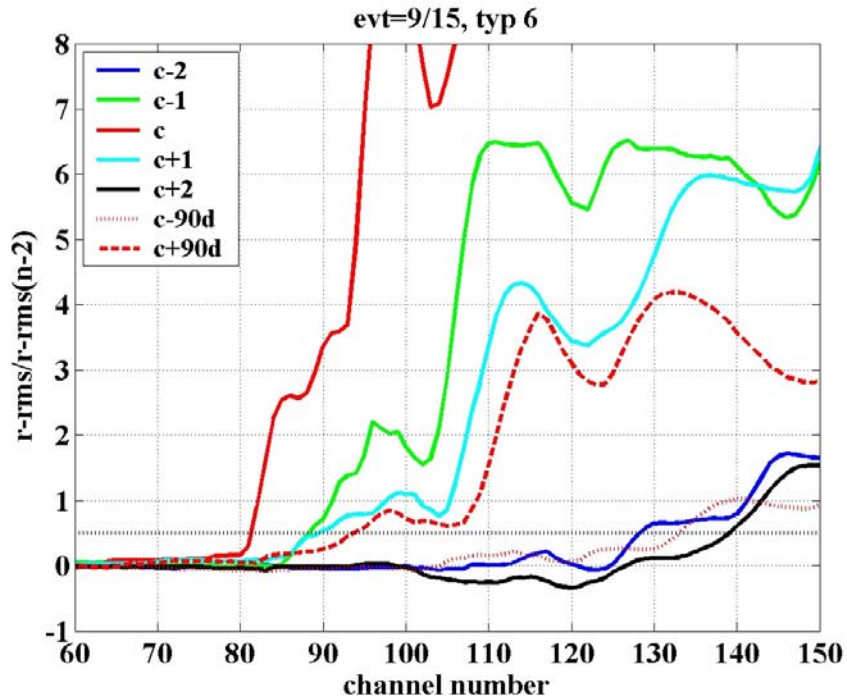

#1
#5
#8
#10
rms200n
t0 in channels
Cell #, pk=0

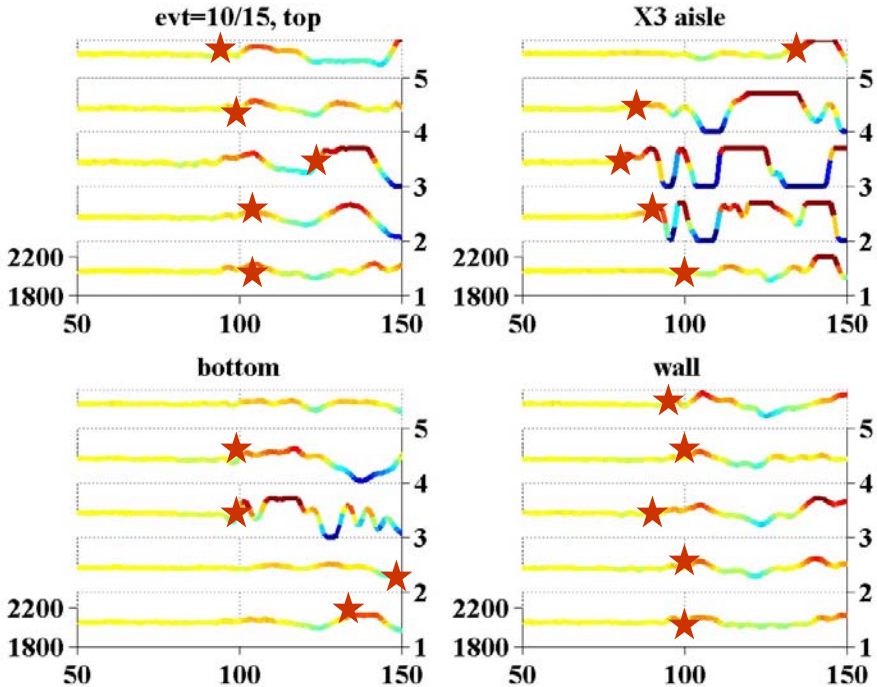

evt=8/15, typ 3
c-2
c-1
c
c+1
c+2
c-90d
c+90d
r-rms/r-rms(n-2)
channel number

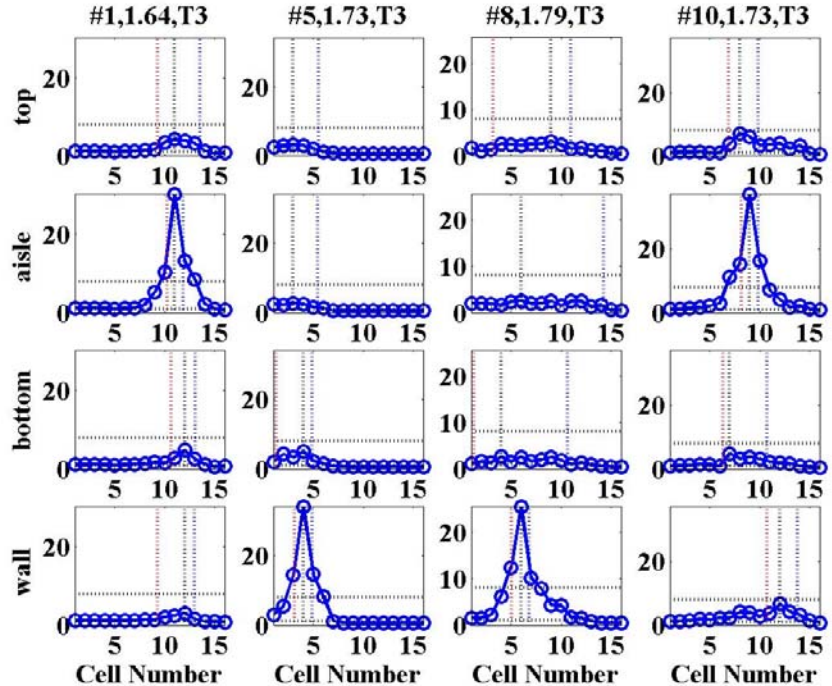

evt=9/15, top
X6 aisle
bottom
wall
2050
1950
50
100
150
1
2
3
4
5

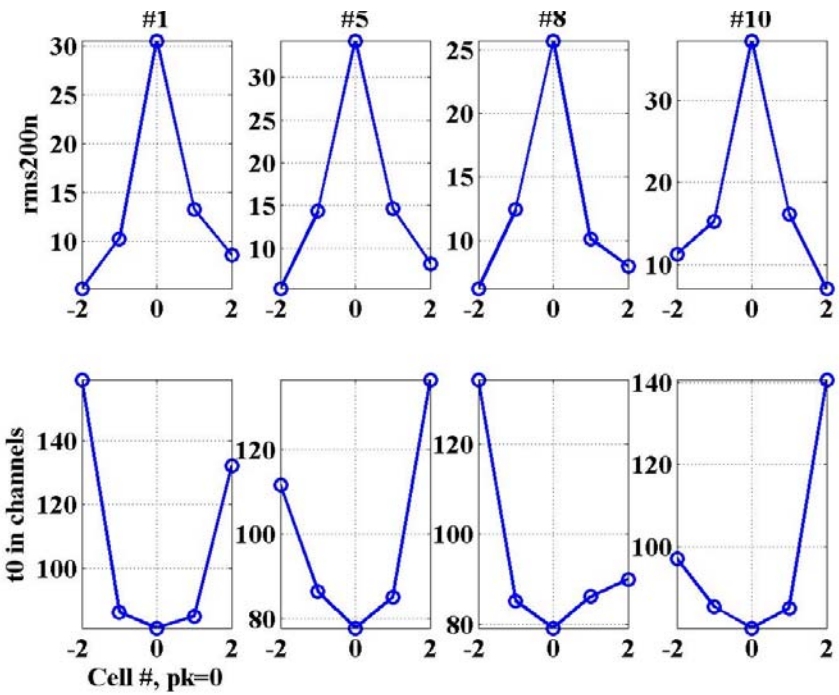

#3,1.50,T6
#9,1.59,T6
#14,1.86,T6
top
aisle
bottom
wall
Cell Number


#3
#9
#14
rms200n
t0 in channels
Cell #, pk=0

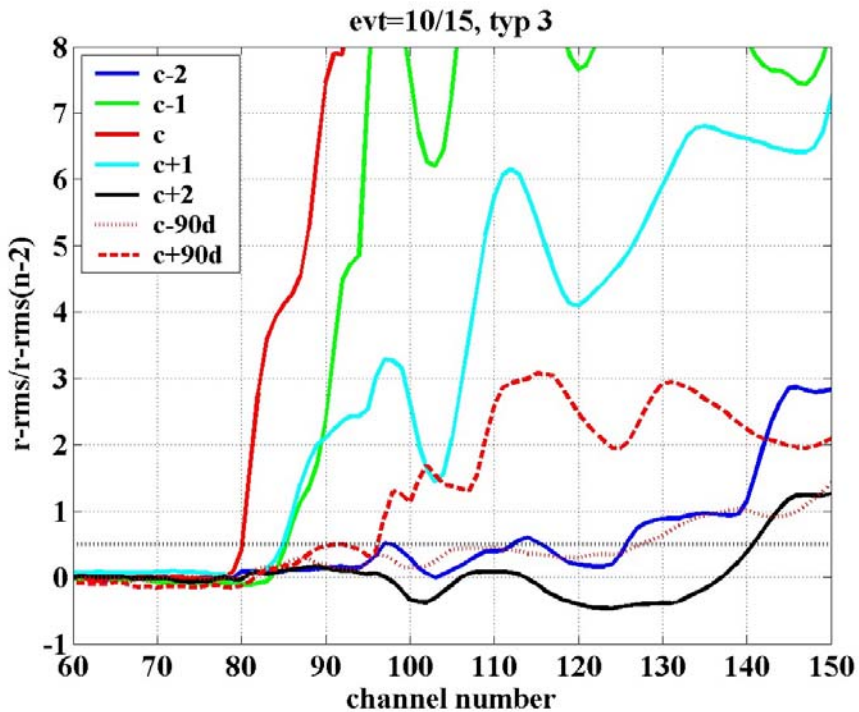

evt=9/15, typ 6
c-2
c-1
c
c+1
c+2
c-90d
c+90d
r-rms/r-rms(n-2)
channel number

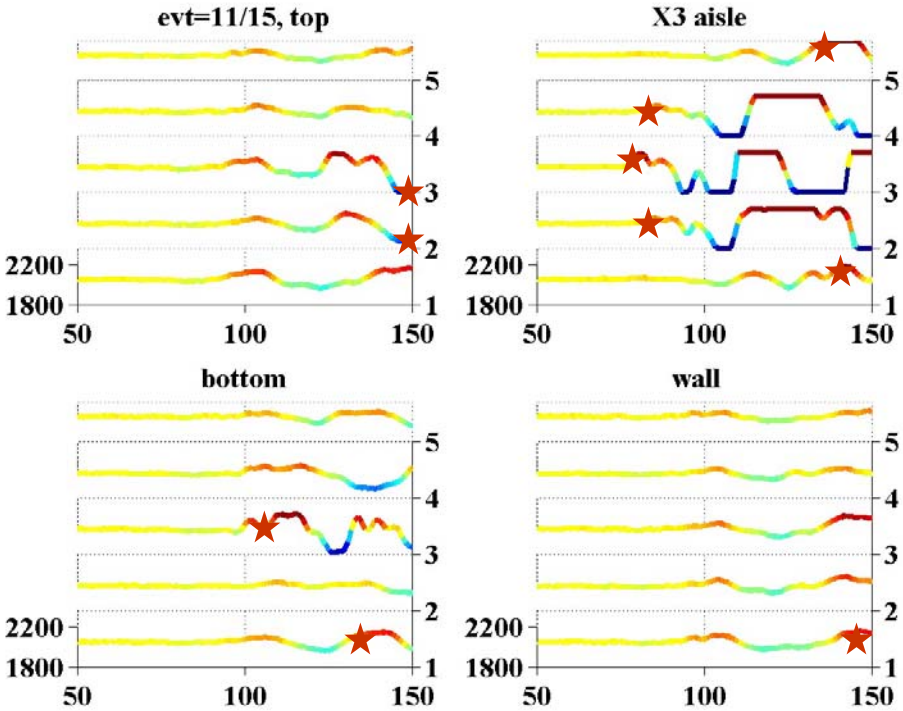

evt=10/15, top
X3 aisle
bottom
wall

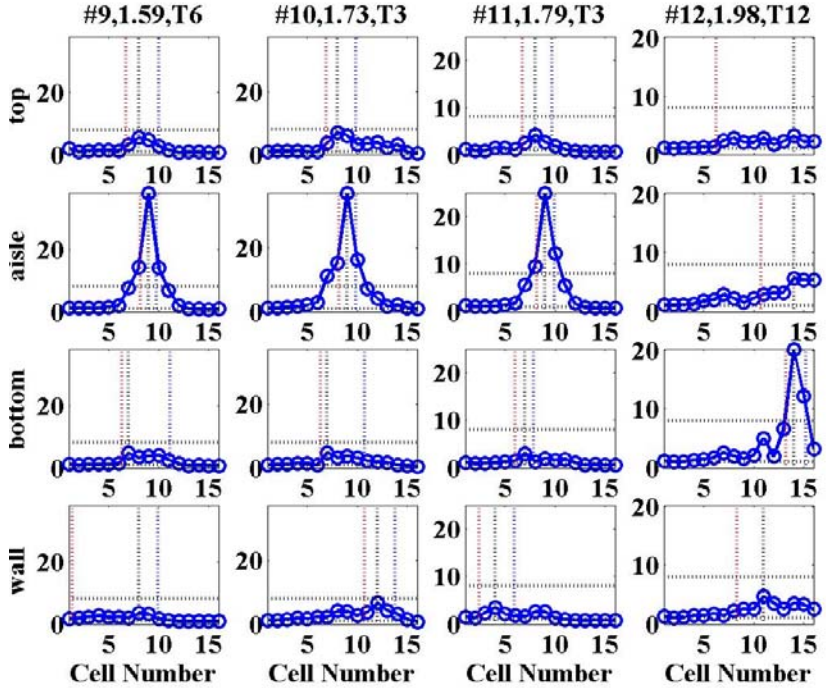

#1,1.64,T3
#5,1.73,T3
#8,1.79,T3
#10,1.73,T3
top
aisle
bottom
wall
Cell Number

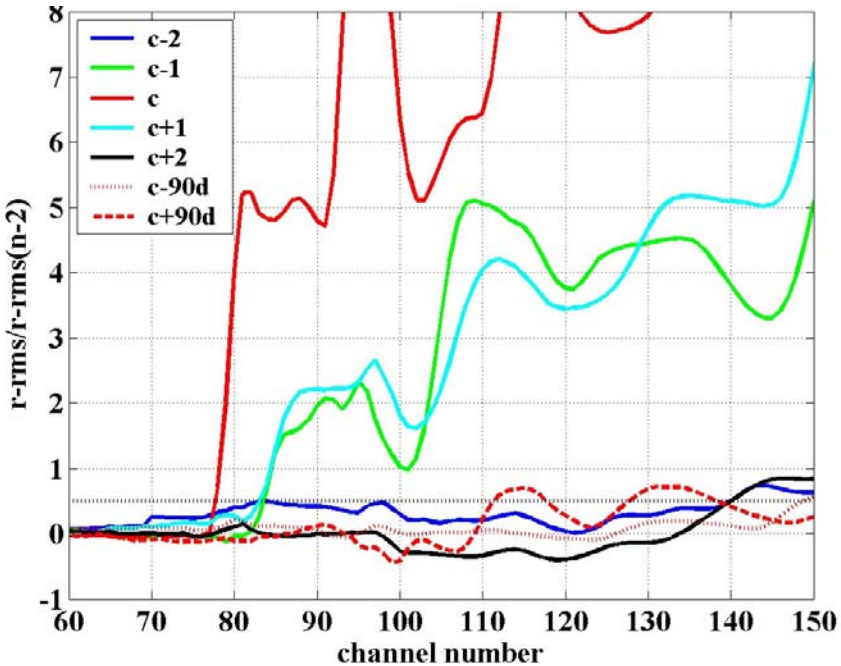

#1
#5
#8
#10
rms200n
t0 in channels
Cell #, pk=0




evt=10/15, typ 3
c-2
c-1
c
c+1
c+2
c-90d
c+90d
r-rms/r-rms(n-2)
channel number


evt=11/15, top
X3 aisle
bottom
wall
2200
1800
50
100
150
1
2
3
4
5


#9,1.59,T6
#10,1.73,T3
#11,1.79,T3
#12,1.98,T12
top
aisle
bottom
wall
Cell Number
0
5
10
15
20


c-2
c-1
c
c+1
c+2
c-90d
c+90d
r-rms/r-rms(n-2)
channel number
-1
0
1
2
3
4
5
6
7
8
60
70
80
90
100
110
120
130
140
150

11

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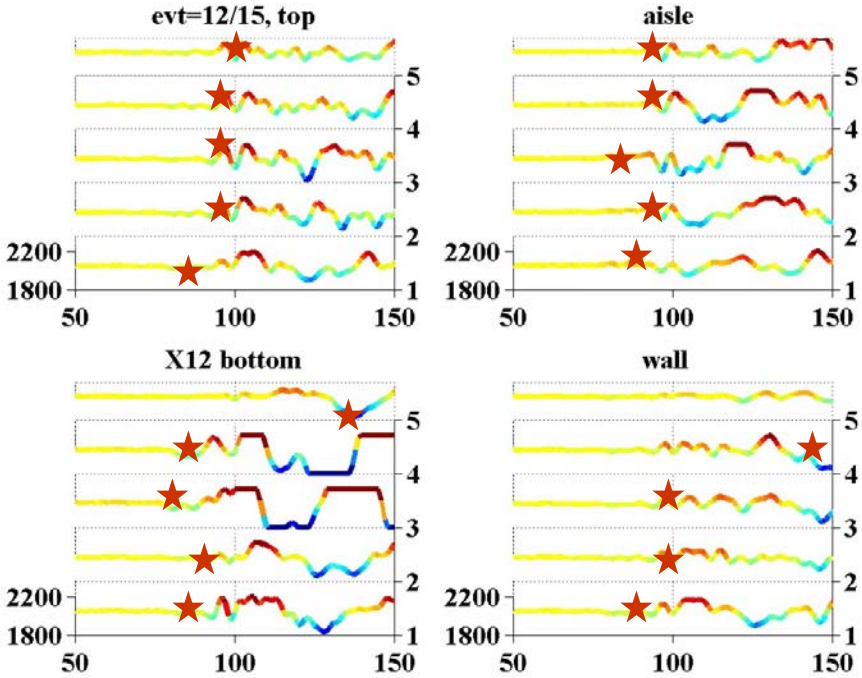
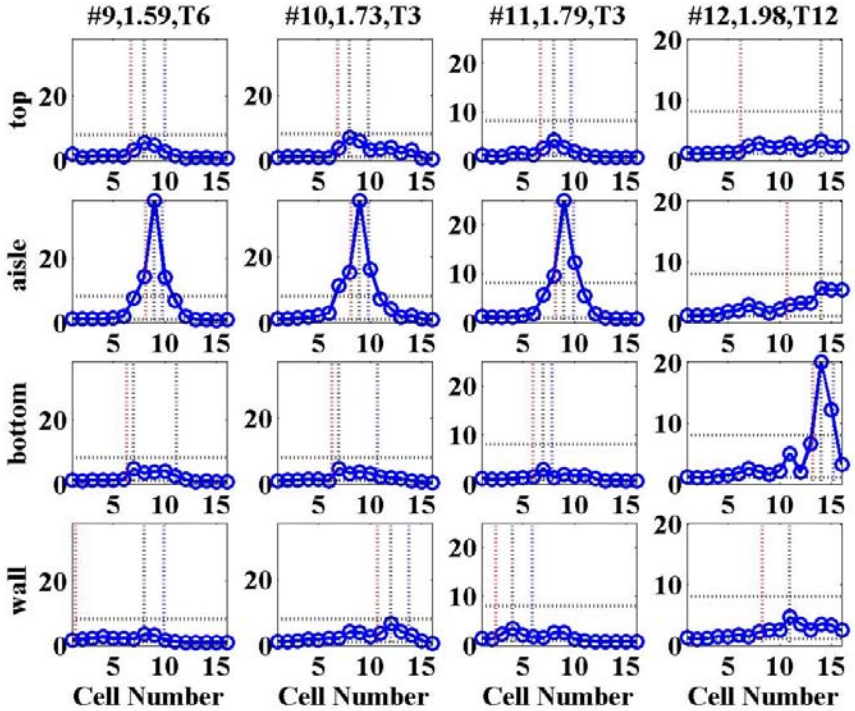
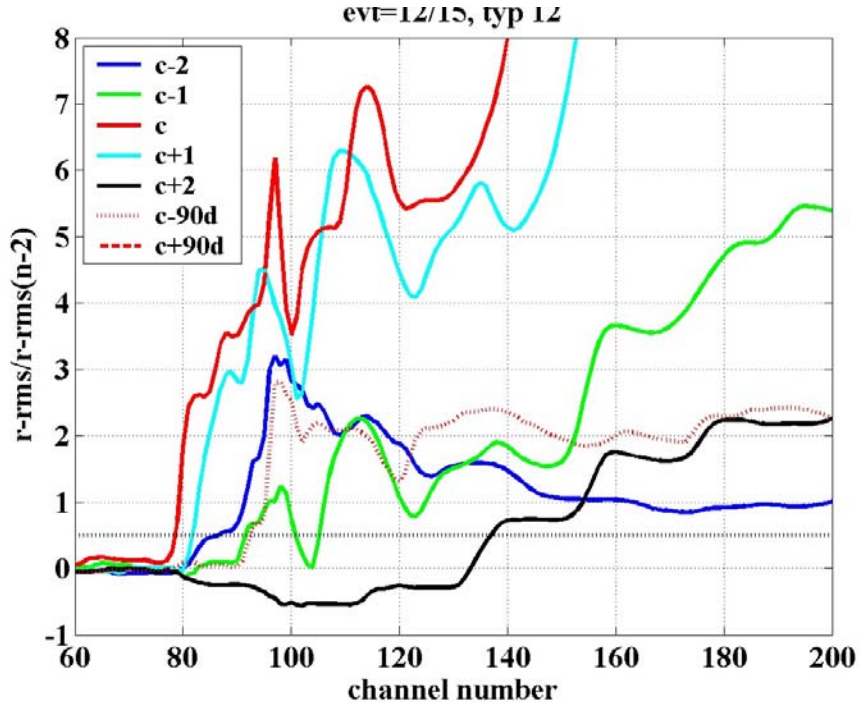

evt=12/15, top
aisle
X12 bottom
wall
2200
1800
50
100
150
1
2
3
4
5


#9,1.59,T6
#10,1.73,T3
#11,1.79,T3
#12,1.98,T12
top
aisle
bottom
wall
Cell Number
Cell Number
Cell Number
Cell Number


evt=12/15, typ 12
c-2
c-1
c
c+1
c+2
c-90d
c+90d
r-rms/r-rms(n-2)
channel number

12

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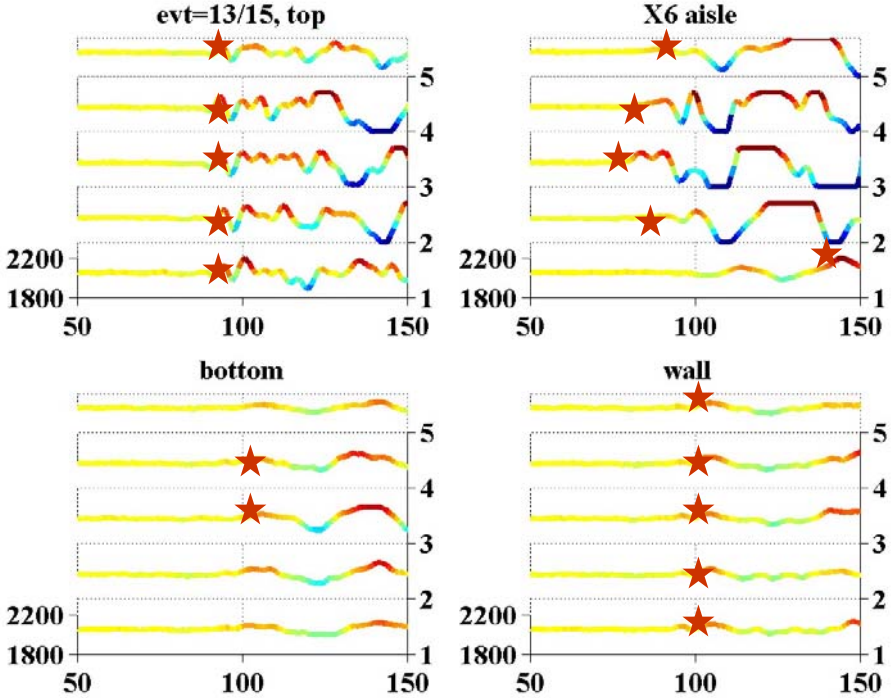
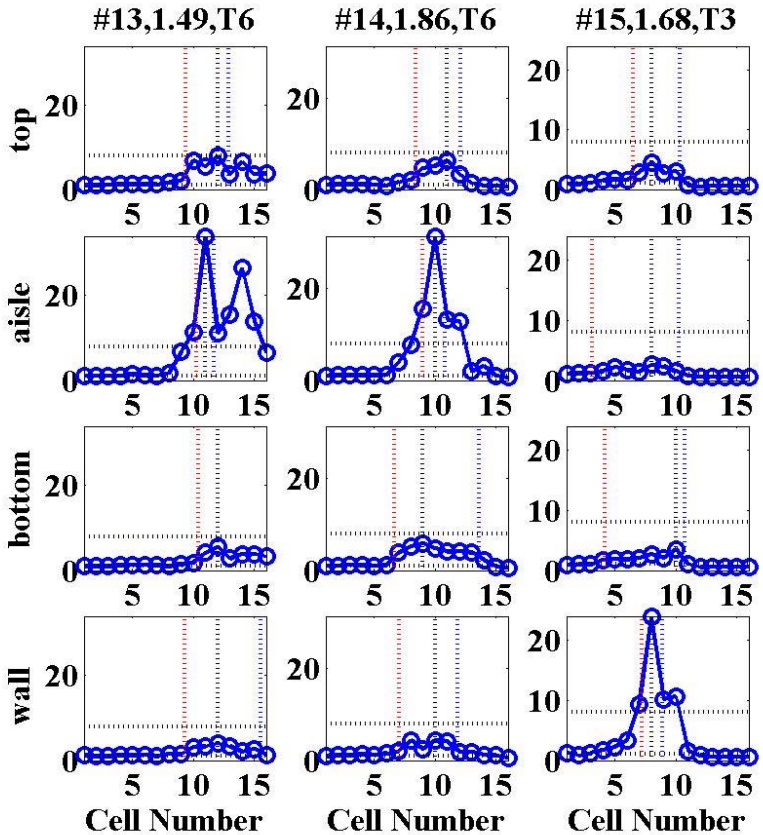
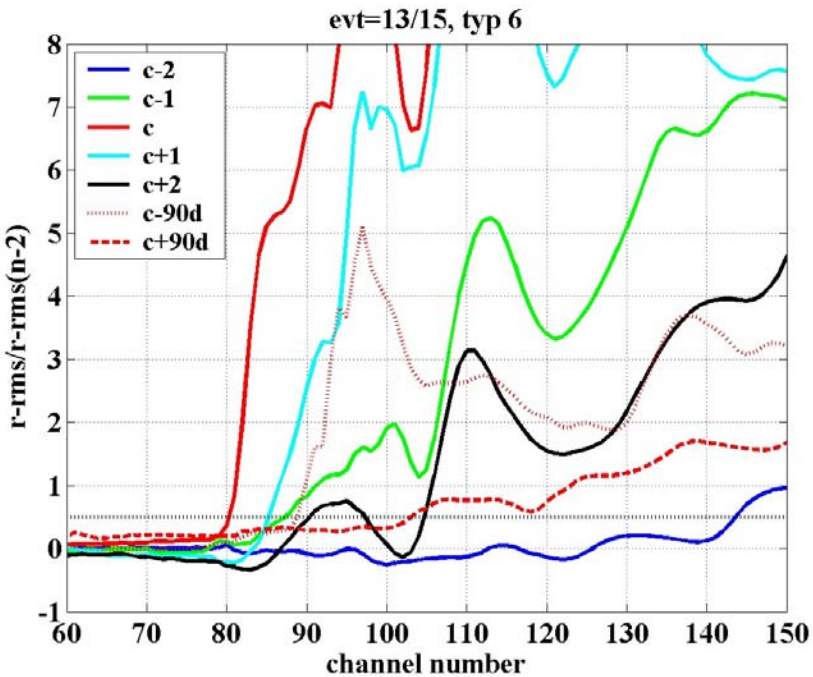
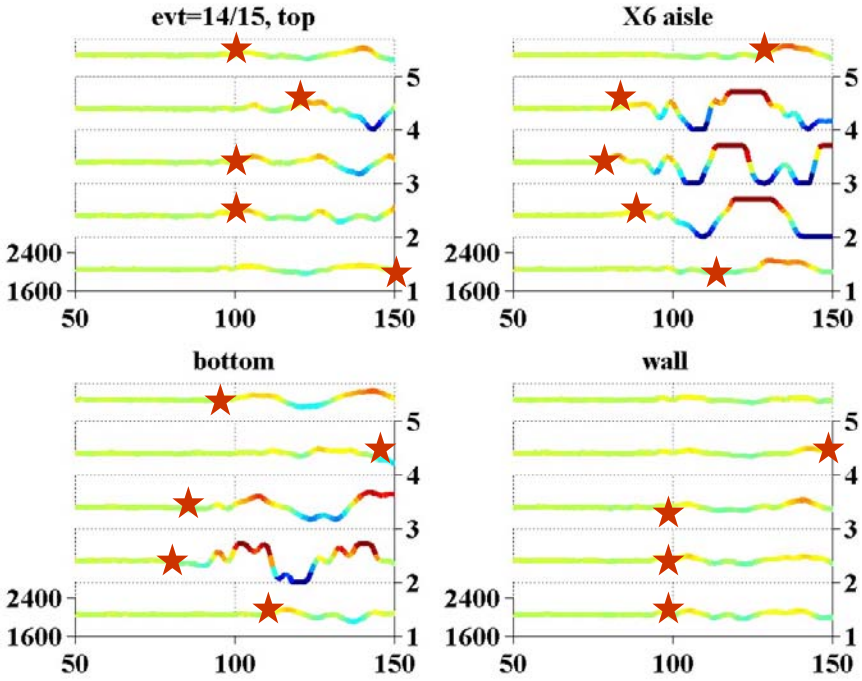

evt=13/15, top
X6 aisle
bottom
wall
2200
1800
50
100
150
1
2
3
4
5

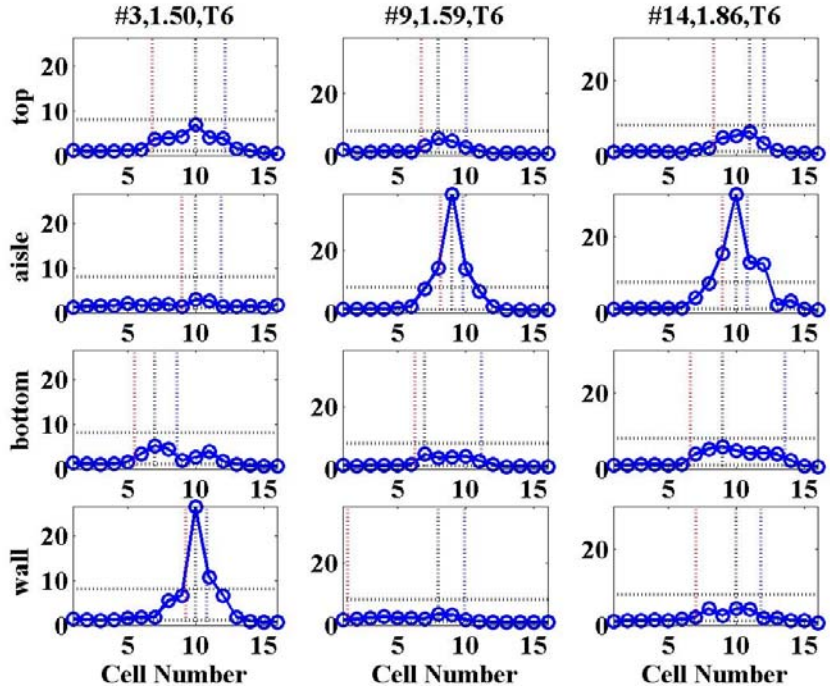

#13,1.49,T6
#14,1.86,T6
#15,1.68,T3
top
aisle
bottom
wall
0
10
20
5
10
15
Cell Number


evt=13/15, typ 6
c-2
c-1
c
c+1
c+2
c-90d
c+90d
r-rms/r-rms(n-2)
channel number
-1
0
1
2
3
4
5
6
7
8
60
70
80
90
100
110
120
130
140
150

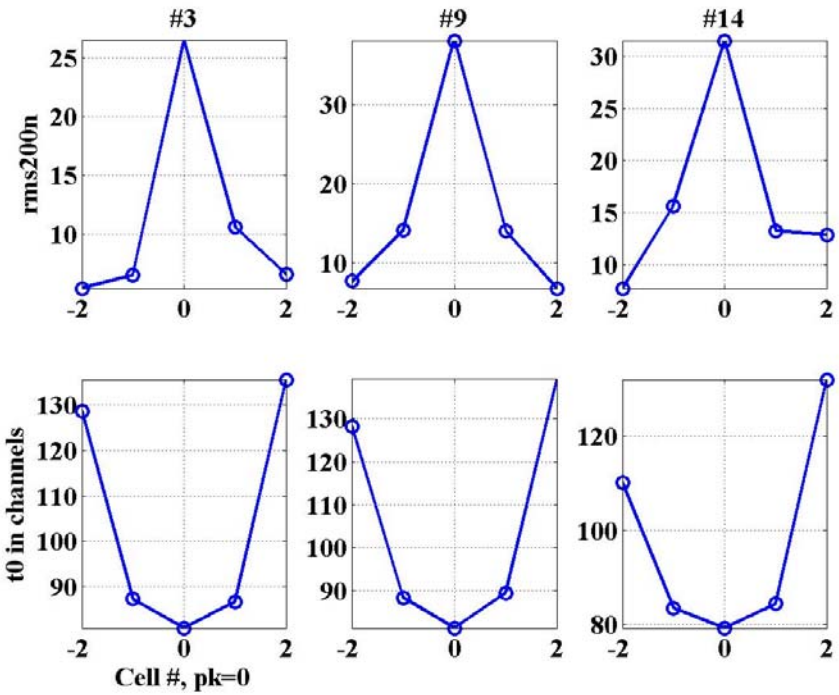
13

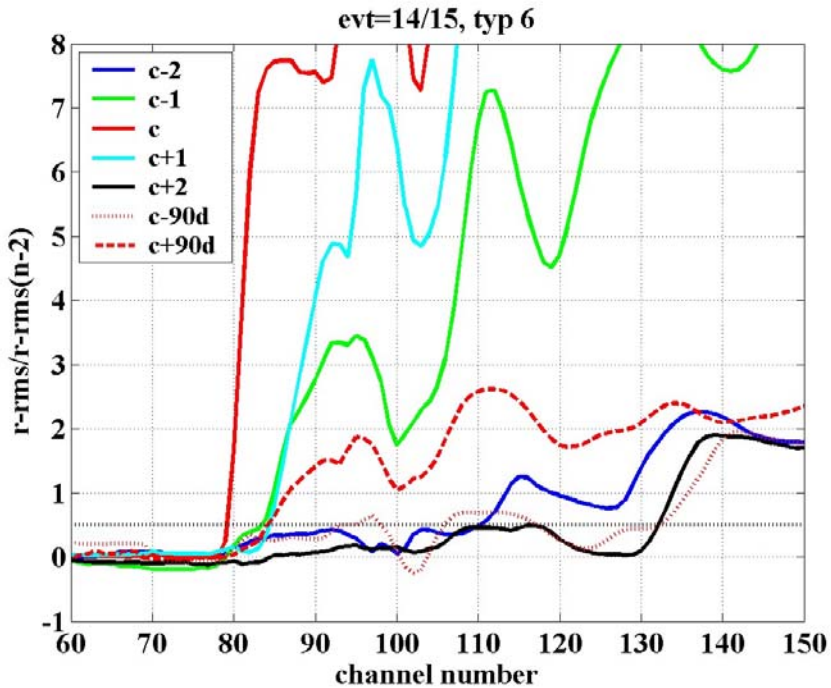
*J. Nelson*

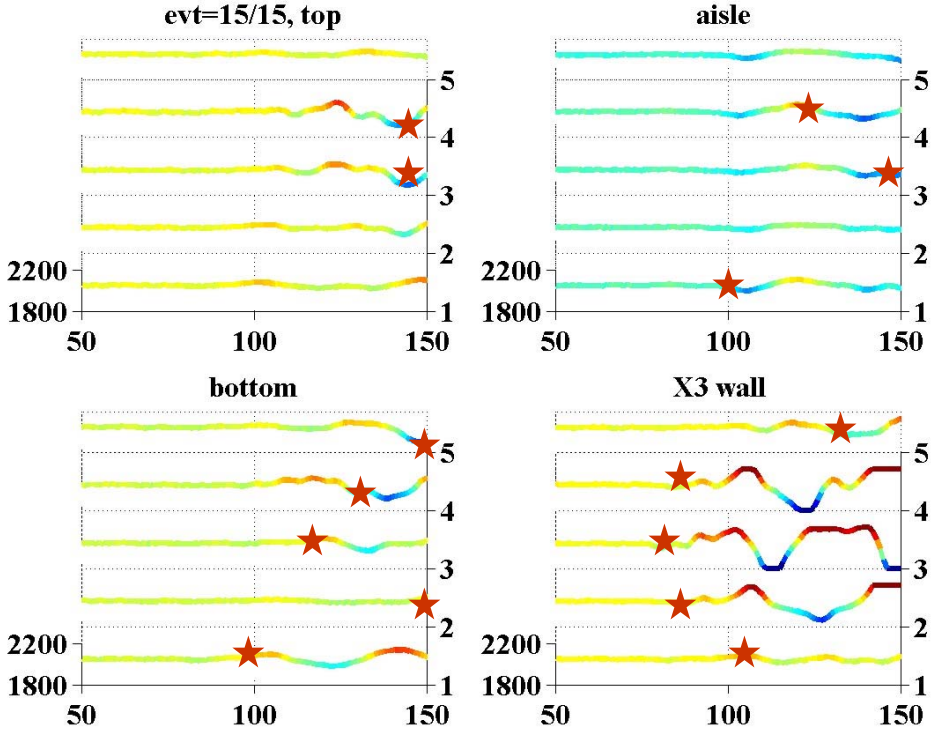

evt=14/15, top
X6 aisle
bottom
wall

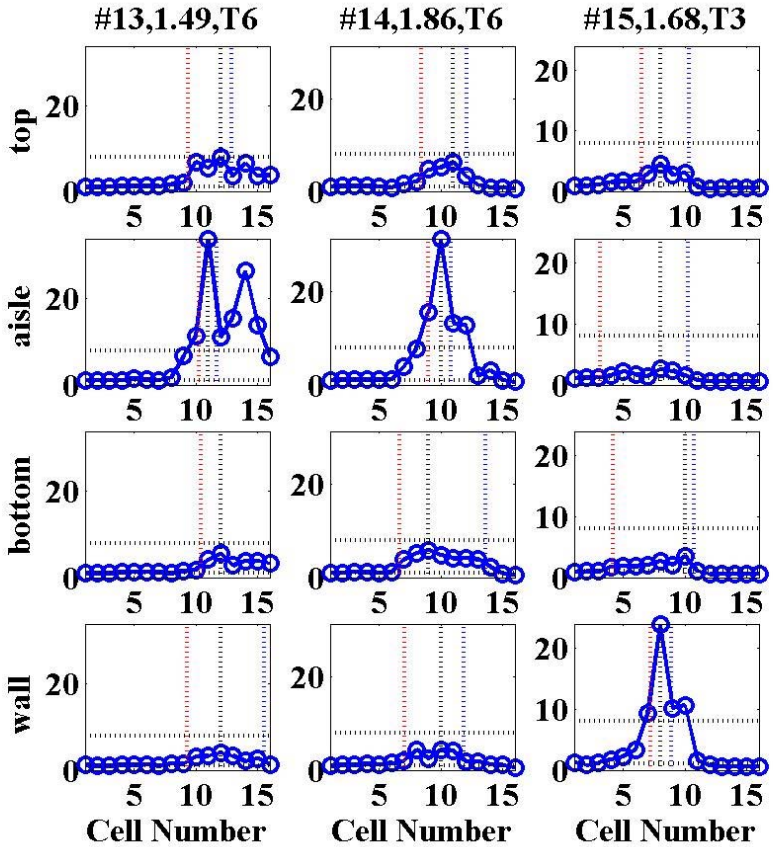

#3,1.50,T6
#9,1.59,T6
#14,1.86,T6
top
aisle
bottom
wall
Cell Number

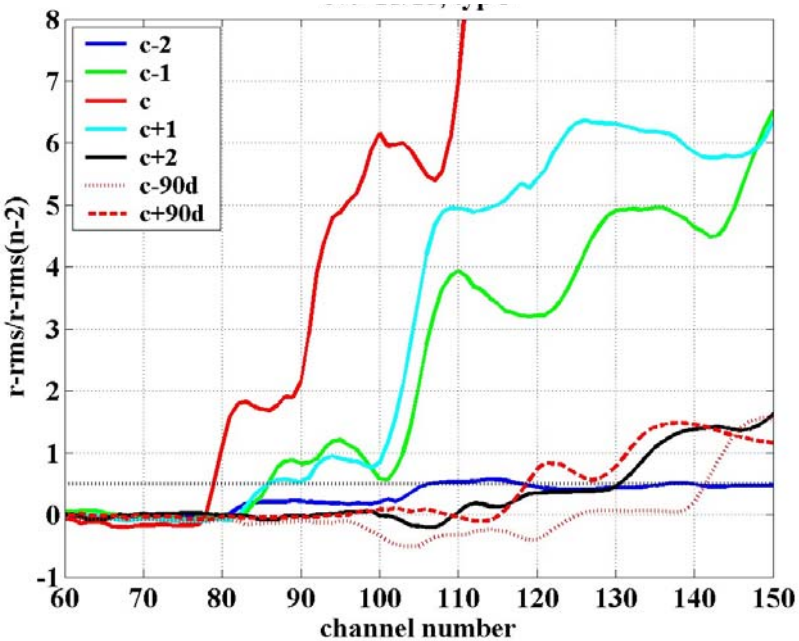



#3
#9
#14
rms200n
t0 in channels
Cell #, pk=0


evt=14/15, typ 6
c-2
c-1
c
c+1
c+2
c-90d
c+90d
r-rms/r-rms(n-2)
channel number


evt=15/15, top
aisle
bottom
X3 wall
2200
1800
50
100
150
1
2
3
4
5


#13,1.49,T6
#14,1.86,T6
#15,1.68,T3
top
aisle
bottom
wall
0
10
20
5
10
15
Cell Number


c-2
c-1
c
c+1
c+2
c-90d
c+90d
r-rms/r-rms(n-2)
channel number
-1
0
1
2
3
4
5
6
7
8
60
70
80
90
100
110
120
130
140
150



J. Nelson