

# ILC 9mA $P_K/Q_L$ studies at FLASH

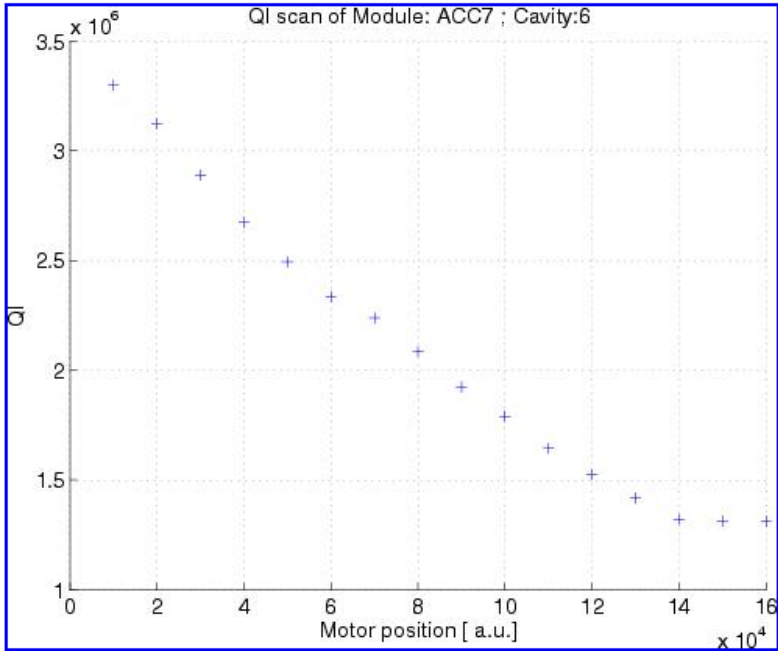
shift summary and time logs

Feb 4-8 2011

# 5 LLRF shifts : overall view

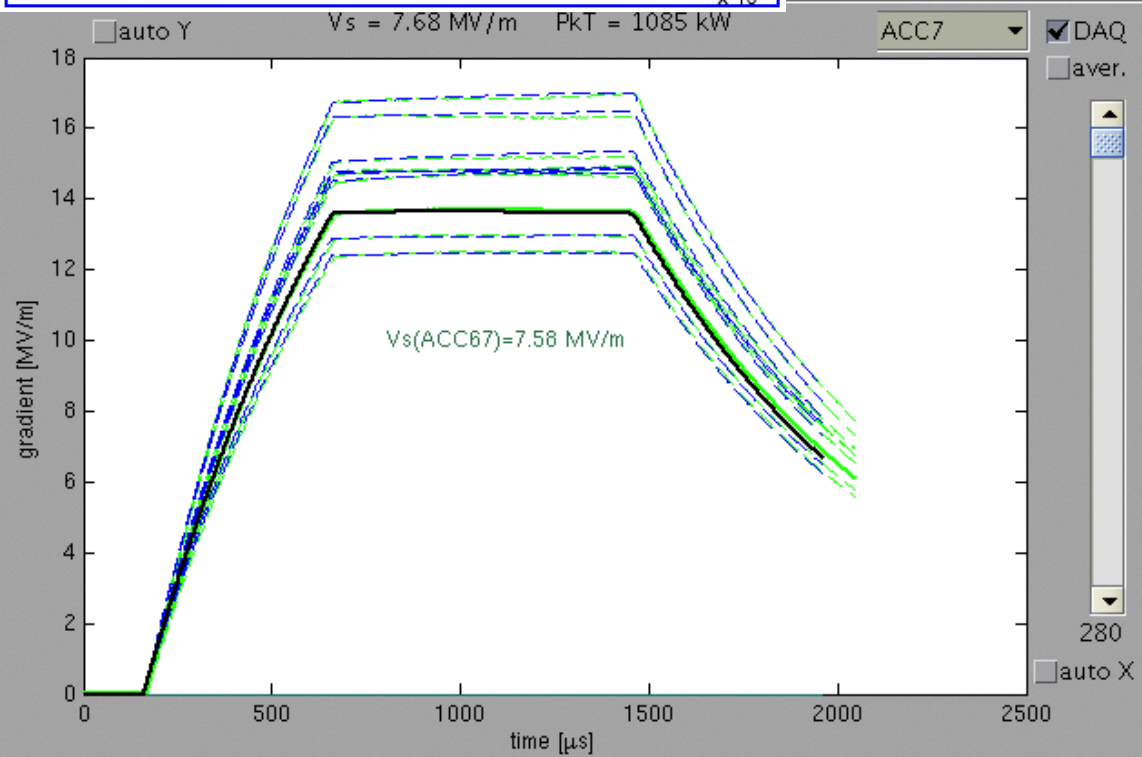
- **Friday 2/4 night shift:**
  - no beam
  - ACC6/7 vector sum calibration 100 bunches, 1 MHz, 1.6 nC
  - QL tuners characterization for ACC6/7
  - simulator calibration to reflect ACC6/7 power distribution
- **Saturday 2/5 night shift:**
  - 1mA beam, low gradient (100 MeV – 200 MeV)
  - Successfully implemented QL adjustments to flatten cavity gradients
  - beam loading tilts correction (all tilts below 1%) using simulator predicted values
  - Simulated values are reliable
- **Sunday 2/6 night shift:**
  - 1.6mA beam, low gradient (200 MeV)
  - low gradient, beam loading tilts  $Q_L$  correction (below 1%)
  - beam current scan
  - QL scan
- **Monday 2/7 night shift:**
  - 3.0mA beam, 200 MeV
  - QL adjusted for gradient flat at 3mA
  - beam scan from 0.9 to 4.5 mA
  - 4.5mA beam, 300 MeV
  - QL adjusted for gradient flat at 4.5 mA
  - beam current scan
- **Tuesday 2/8 afternoon shift:**
  - 4.2mA beam, 360 MeV
  - Lorentz force detuning compensation
  - Use calculator to predict  $Q_L$  → gives very accurate prediction
  - Flatten ACC6/7 gradients tilts to  $\sim 1.5\%$
  - beam current scan

Friday Feb. 4 night shift



### Friday 2/4 night shift – highlights:

- no beam
- ACC6/7 vector sum calibration 100 bunches, 1 MHz, 1.6 nC
- $Q_L$  tuners characterization for ACC6/7
- simulator calibration to reflect ACC6/7 power distribution



Cryomodules

Cryomodule ACC7

	V lim [MV/m]	QL [ $\times 1e6$ ]	Pk [dB]	Det [Hz]
1	29.0	3.09	8.75	-41
2	31.0	2.93	8.68	-53
3	34.0	3.00	8.68	34
4	30.0	3.05	8.45	-31
5	35.0	3.04	7.55	28
6	39.0	2.97	7.8	-2
7	27.0	2.96	9.85	-28
8	26.0	2.97	10.17	-44

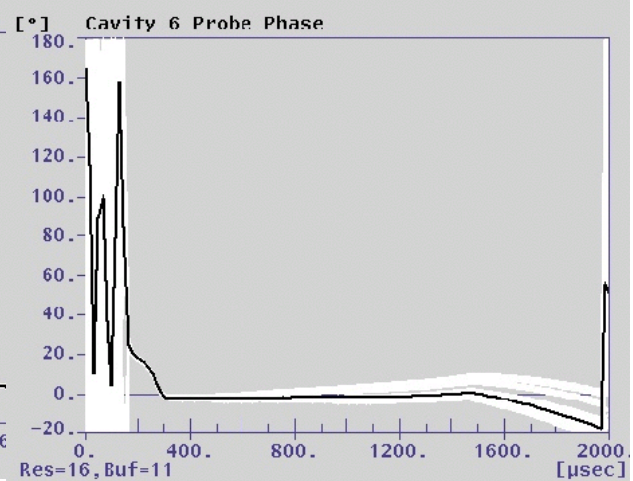
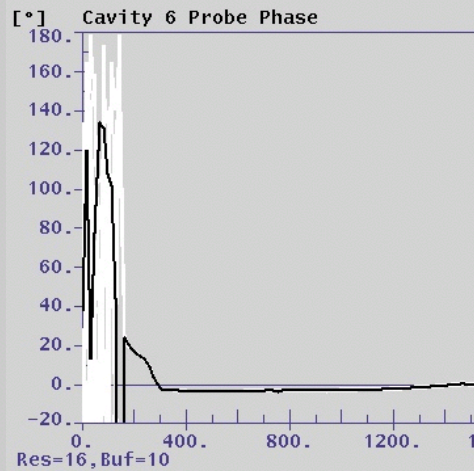
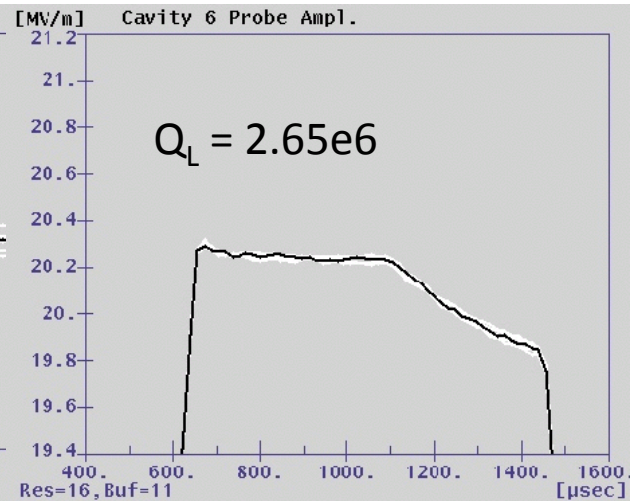
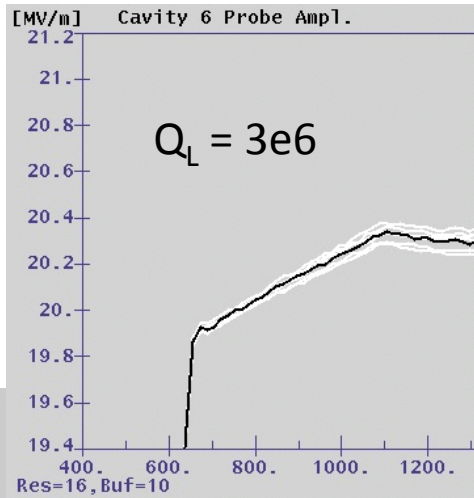
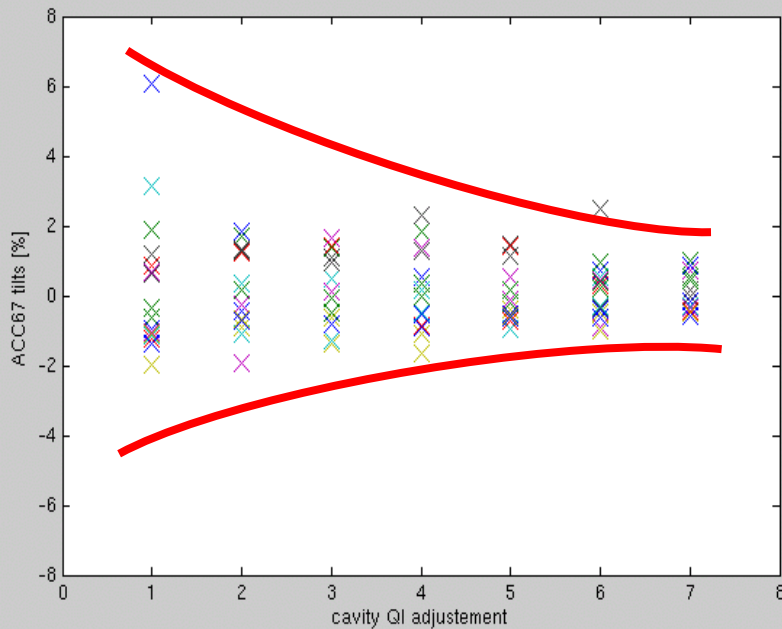
# Friday Feb. 4 night shift

- ACC6 QL range scans
  - Cav1:
  - Cav2:
  - Cav3:
  - Cav4:
  - Cav5:
  - Cav6:
  - Cav7:
  - Cav8:
- ACC7 QL range scans
  - Cav1: 1.2 → 3.3
  - Cav2: 2.0 → 3.7
  - Cav3: 1.7 → 3.7
  - Cav4: 1.2 → 3.7
  - Cav5: 1.2 → 3.3
  - Cav6: 1.6 → 3.2
  - Cav7: 1.2 → 3.2
  - Cav8: 2.2 → 4.5

Saturday Feb. 5 night shift

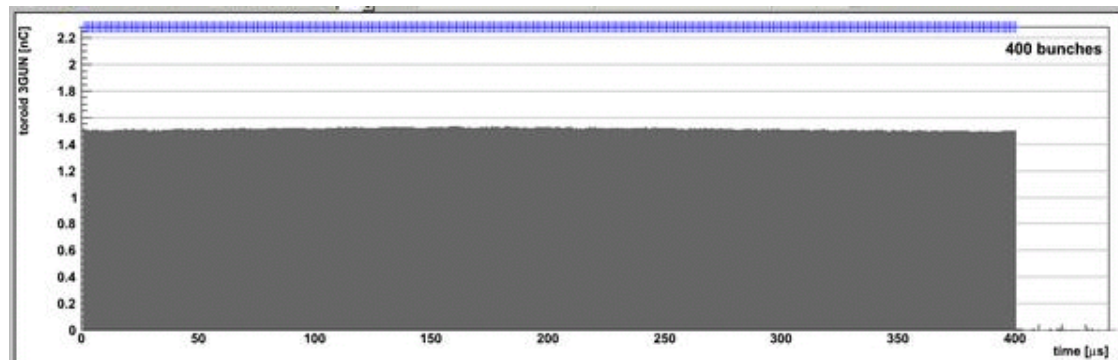
## Saturday 2/5 night shift – highlights:

- 1mA beam, low gradient (100–200 MeV)
- Successfully implemented QL adjustments to flatten cavity gradients
- beam loading tilts correction (all tilts below 1%) using simulator predicted values
- Simulated values are reliable



ACC6	cav1	0.87 %
ACC6	cav2	1.01 %
ACC6	cav3	0.44 %
ACC6	cav4	0.70 %
ACC6	cav5	0.71 %
ACC6	cav6	-0.17 %
ACC6	cav7	0.15 %
ACC6	cav8	-0.17 %

ACC7	cav1	0.55 %
ACC7	cav2	-0.43 %
ACC7	cav3	-0.30 %
ACC7	cav4	-0.32 %
ACC7	cav5	-0.50 %
ACC7	cav6	-0.01 %
ACC7	cav7	-0.57 %
ACC7	cav8	0.45 %

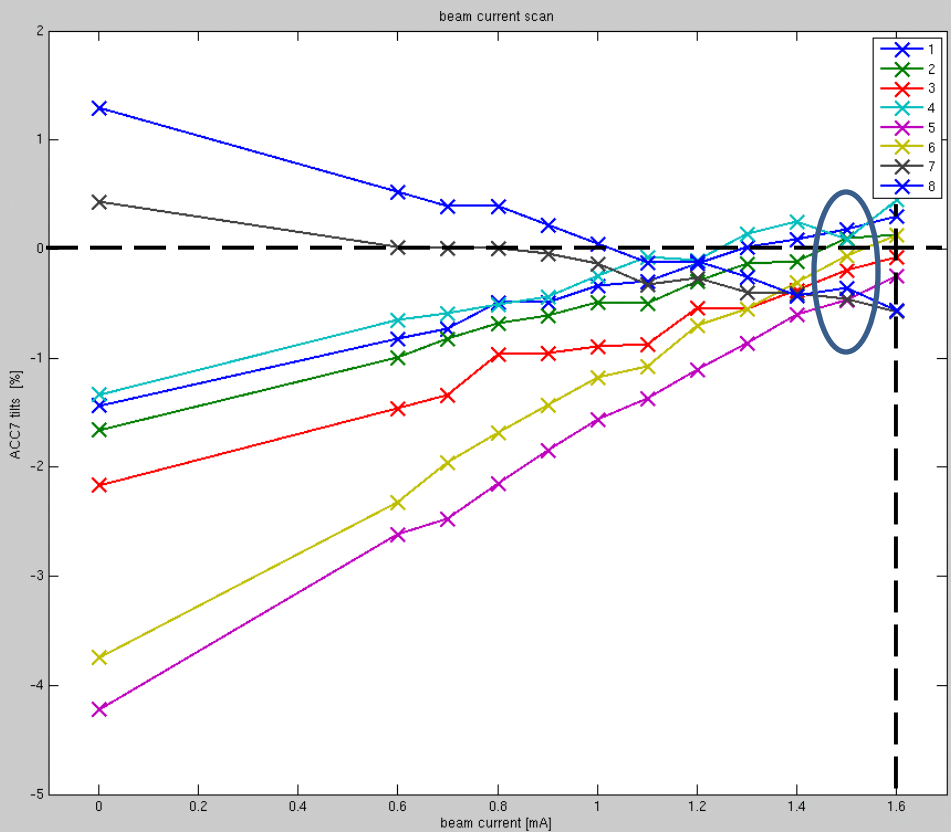


# Saturday Feb. 5 night shift

- ACC6-cav4: QL → 2.8e6 2:13 am
- ACC6-cav5: QL → 3.4e6 3:07 am
- ACC6-cav1: QL → 2.5e6 3:25 am
- ACC6-cav2: QL → 2.9e6
- ACC6-cav6: QL → 3.3e6 4:08 am
- ACC6-cav3: QL → 2.85e6 4:34 am
- ACC6-cav7: retune + beam on 4:36 am
- Turn FB off 4:41 am
- ACC7-cav6: QL → 2.65e6 4:55 am
- Beam ON/OFF 5:29 – 5:30am



Sunday Feb. 6 night shift



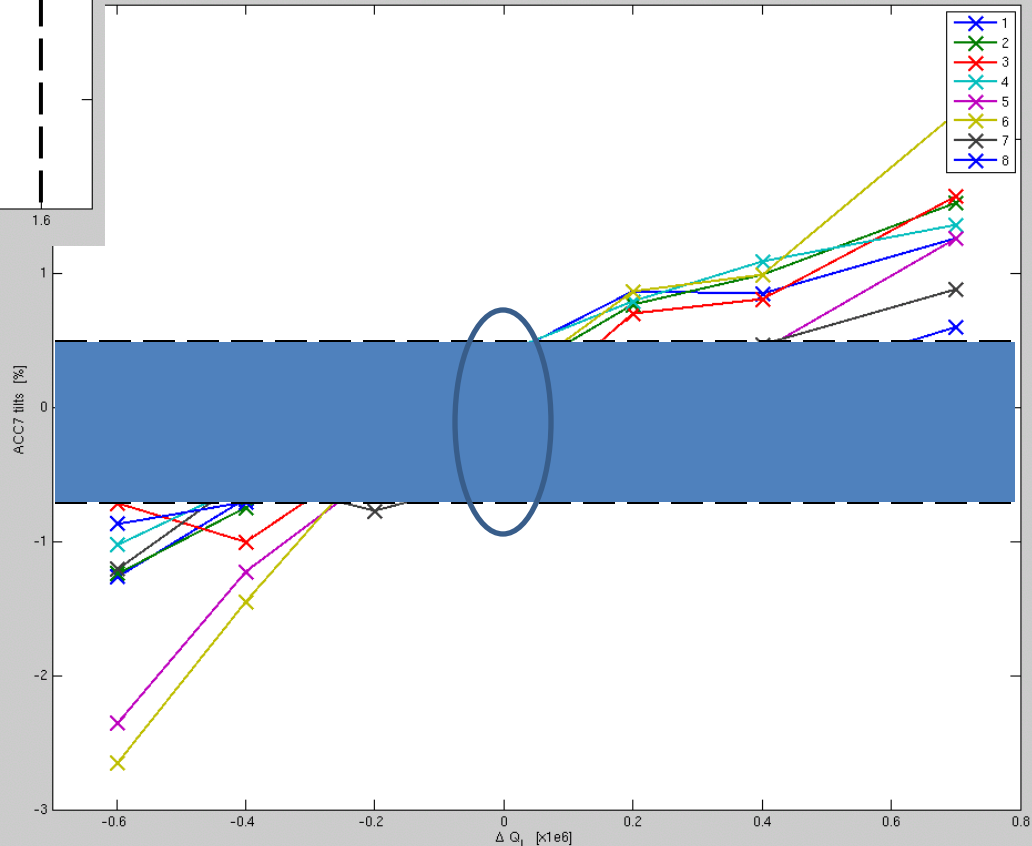
## Sunday 2/6 night shift – highlights:

- 1.6mA beam, low gradient (200 MeV)
- beam loading tilts  $Q_L$  correction (below 1%) (several cavities at once, with beam on)
- beam current scan
- $Q_L$  scan

ACC7-cav0= -0.23 %  
 ACC7-cav1= 0.35 %  
 ACC7-cav2= 0.17 %  
 ACC7-cav3= -0.03 %  
 ACC7-cav4= 0.32 %  
 ACC7-cav5= -0.15 %  
 ACC7-cav6= 0.15 %  
 ACC7-cav7= -0.58 %  
 ACC7-cav8= -0.59 %

Ql config is for ACC7:

cav1 : 2.8 e6  
 cav2 : 2.8 e6  
 cav3 : 2.8 e6  
 cav4 : 2.8 e6  
 cav5 : 2.5 e6  
 cav6 : 2.5 e6  
 cav7 : 3.1 e6  
 cav8 : 3.2 e6



# Sunday Feb. 6 night shift

- Initial conditions 23:44 – 23:54
- ACC6 QL adjustments
  - ACC6-cav5: QL → 5.5e6
  - ACC6-cav6: QL → 5.5e6
  - ACC6-cav1: QL → 3e6
  - ACC6-cav2: QL → 3e6
  - ACC6-cav3: QL → 2.9e6
  - ACC6-cav8: QL → 3.4e6
- Beam OFF 1:04 am
- Beam ON/OFF 1:26 – 1:27 am
- ACC7 QL adjustments
  - ACC7-cav1: QL → 2.8e6
  - ACC7-cav2: QL → 2.8e6
  - ACC7-cav4: QL → 2.8e6
  - ACC7-cav5: QL → 2.5e6
  - ACC7-cav6: QL → 2.5e6
- Beam ON/OFF 2:00 -2:02 am
- ACC7-cav3: QL → 2.8e6 2:25 am
- ACC7-cav8: QL → 3.2e6 2:51 am

# Sunday Feb. 6 night shift (cont'd)

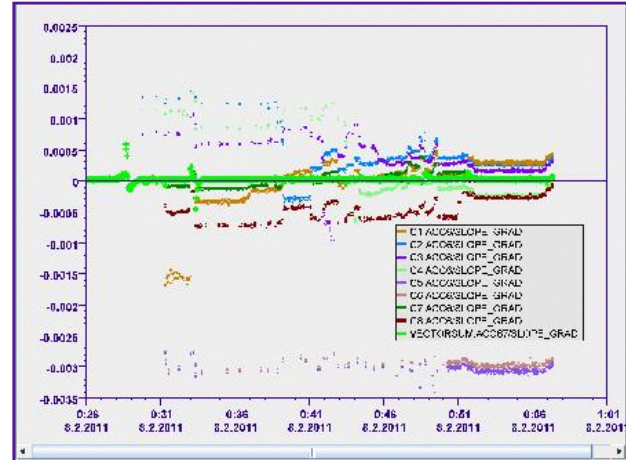
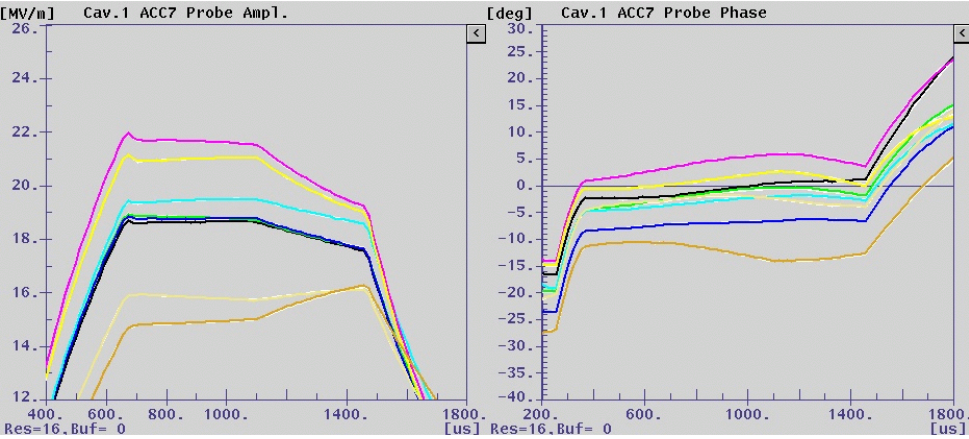
- Beam scan times
  - 3:03 am 1.6nC
  - 3:04 am 1.5nC
  - 3:06 am 1.4nC
  - 3:07:11 am 1.3nC
  - 3:07:49 am 1.2nC
  - 3:09:11 am 1.1nC
  - 3:10:43 am 1.0nC
  - 3:11:49 am 0.9nC
  - 3:13:13 am 0.8nC
  - 3:14:32 am 0.7nC
  - 3:15:32 am 0.6nC
  - 3:19:57 am 0nC
  - 3:20:56 am 1.6nC

# Sunday Feb. 6 night shift (cont'd)

QL scan

<b>ACC7</b>	<b>0</b>	<b>-0.2</b>	<b>-0.4</b>	<b>-0.6</b>	<b>+0.2</b>	<b>+0.4</b>	<b>+0.7</b>
Cav1	2.8	2.6	2.4	2.2	3.0	3.2	3.5
Cav2	2.8	2.6	2.4	2.2	3.0	3.2	3.5
Cav3	2.8	2.6	2.4	2.2	3.0	3.2	3.5
Cav4	2.8	2.6	2.4	2.2	3.0	3.2	3.5
Cav5	2.5	2.3	2.1	1.9	2.7	2.9	3.2
Cav6	2.5	2.3	2.1	1.9	2.7	2.9	3.2
Cav7	3.1	2.9	2.7	2.5	3.3	3.5	3.8
Cav8	3.2	3.0	2.8	2.6	3.4	3.6	3.9
<b>TIME</b>	<b>3:20:56</b>	<b>3:54:40</b>	<b>4:05:21</b>	<b>4:13:25</b>	<b>4:35:45</b>	<b>4:43:22</b>	<b>5:01:59</b>

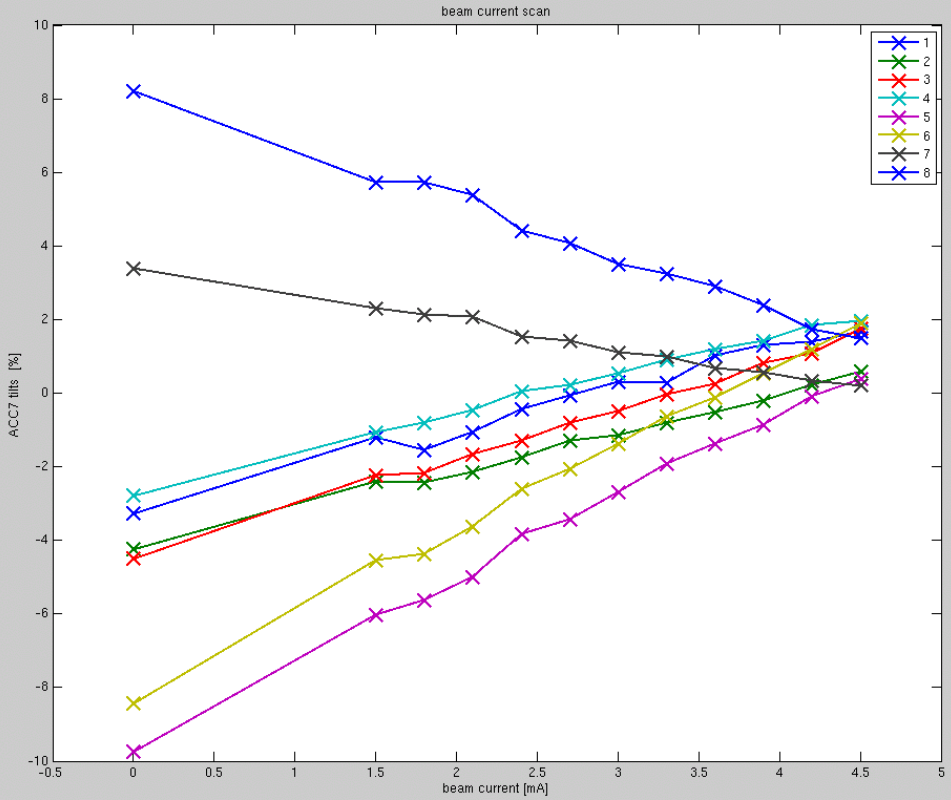
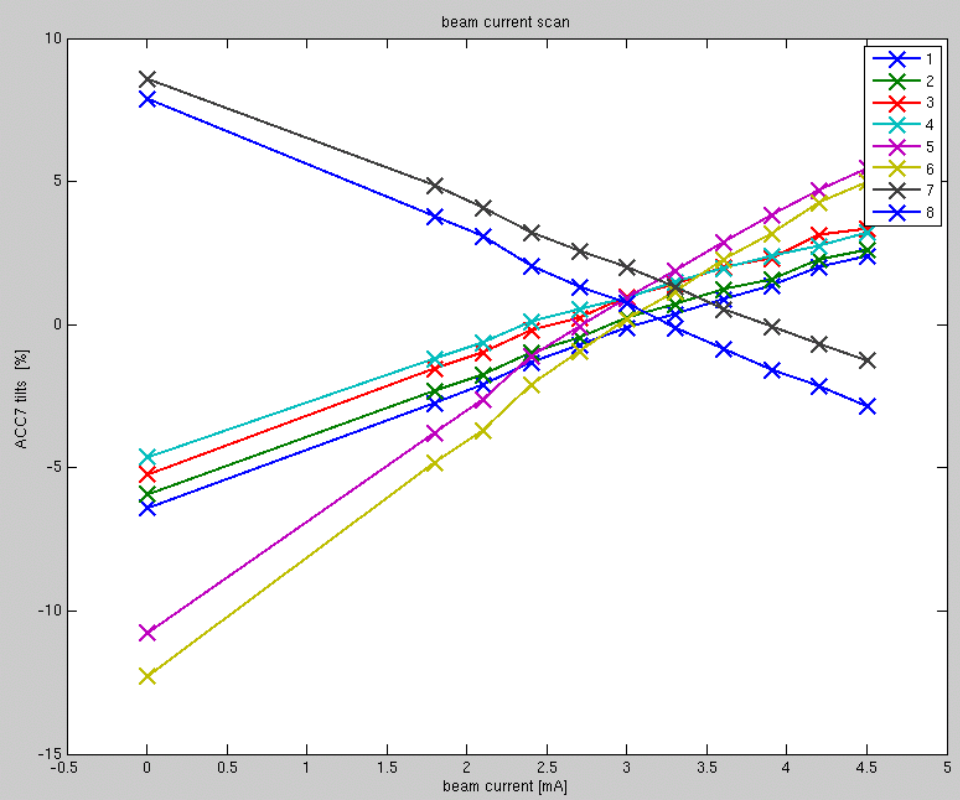
Monday Feb. 7 night shift



**Monday 2/7 night shift – highlights:**

- 3.0mA beam, 200 MeV
- $Q_L$  adjusted for gradient flat at 3mA
- beam scan from 0.9 to 4.5 mA

- 4.5mA beam, 300 MeV
- $Q_L$  adjusted for gradient flat at 4.5 mA
- beam current scan



# Monday Feb. 7 night shift

- Initial conditions, 1nC, 3MHz 23:10
- Initial tilts 23:19:36
- ACC6 QL adjustments
  - Cav1: QL → 2.2e6
  - Cav2: QL → 2.2e6
  - Cav3: QL → 2.4e6
  - Cav4: QL → 2.4e6
  - Cav5: QL → 4.1
  - Cav6: QL → 4.0
  - Cav7: QL → 3.5e6
  - Cav8: QL → 4.0e6
- End of ACC6 QL adjustments 0:52 am
- ACC7 QL adjustments
  - Cav1: QL → 2.2e6
  - Cav2: QL → 2.2e6
  - Cav3: QL → 2.2e6
  - Cav4: QL → 2.0e6
  - Cav5: QL → 1.9e6
  - Cav6: QL → 1.9e6
  - Cav7: QL → 2.7e6
  - Cav8: QL → 2.7e6
- End of ACC7 QL adjustments 1:08 am
- Tuning ACC7 1:33 am



# Monday Feb. 7 night shift (cont'd)

- Beam current scan
  - Reference 1:34:23 am
  - 0.6nC                    1:37:28 am
  - 0.7nC                    1:38:09 am
  - 0.8nC                    1:38:30 am
  - 0.9nC                    1:38:56 am
  - 1.0nC                    1:39:20 am
  - 1.1nC                    1:39:46 am
  - 1.2nC                    1:40:39 am
  - 1.3nC                    1:41:31 am
  - 1.4nC                    1:42:12 am
  - 1.5nC                    1:42:59 am
  - 0nC                        1:43:44 am
- Beam ON (drift / stability analysis)    start 2:07 am

# Monday Feb. 7 night shift (cont'd)

- Increased energy to 300 MeV ( $V_{\text{sum}} \sim 18.75$  MV/m), 4.5 mA
- ACC6 QL adjustments
  - Cav1: QL predicted (2.5e6)    implemented (2.4e6)
  - Cav2: QL predicted (2.5e6)    implemented (2.4e6)
  - Cav3: QL predicted (2.5e6)    implemented (2.4e6)
  - Cav4: QL predicted (2.6e6)    implemented (2.4e6)
  - Cav5: QL predicted (4.0e6)    implemented (4.3e6)
  - Cav6: QL predicted (4.0e6)    implemented (4.4e6)
  - Cav7: QL predicted (3.7e6)    implemented (2.85e6)
  - Cav8: QL predicted (3.7e6)    implemented (2.86e6)
- ACC7 QL adjustments
  - Cav1:QL predicted (2.6e6)    implemented (2.4e6)
  - Cav2:QL predicted (2.6e6)    implemented (2.4e6)
  - Cav3:QL predicted (2.5e6)    implemented (2.4e6)
  - Cav4:QL predicted (2.4e6)    implemented (2.4e6)
  - Cav5:QL predicted (2.1e6)    implemented (2.1e6)
  - Cav6:QL predicted (2.2e6)    implemented (2.2e6)
  - Cav7:QL predicted (3.5e6)    implemented (2.8e6)
  - Cav8:QL predicted (3.8e6)    implemented (2.9e6)
- ACC6/7 adjusted                    4:17 am
- ACC4/5 corrected                   4:22 am
- Beam 3mA                            4:51 am
- Beam 4.5 mA                        4:57 am

# Monday Feb. 7 night shift (cont'd)

- Beam current scan 4.5mA, 300 MeV
  - 1.5nC                    5:46:14 am
  - 1.4nC                    5:47:00 am
  - 1.3nC                    5:47:20 am
  - 1.2nC                    5:47:46 am
  - 1.1nC                    5:48:06 am
  - 1.0nC                    5:48:27 am
  - 0.9nC                    5:48:52 am
  - 0.8nC                    5:49:26 am
  - 0.7nC                    5:49:58 am
  - 0.6nC                    5:50:13 am
  - 0.5nC                    5:50:51 am
  - 0nC                      5:51:36 am

Tuesday Feb. 8 afternoon shift

## Tuesday 2/8 afternoon shift – highlights:

- 4.2mA beam, 360 MeV
- Lorentz force detuning compensation
- Use calculator to predict QL  $\rightarrow$  very accurate prediction
- Flatten ACC6/7 gradients tilts to  $\sim 1.5\%$  (tuned for 4.2mA)
- beam current scan to 4.5 mA

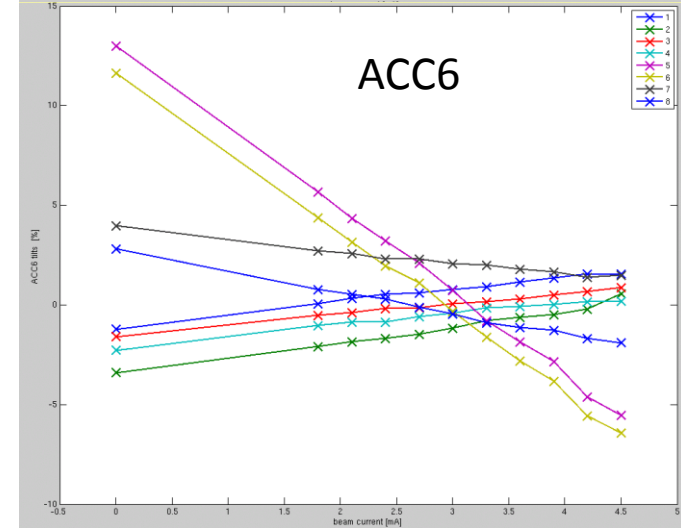
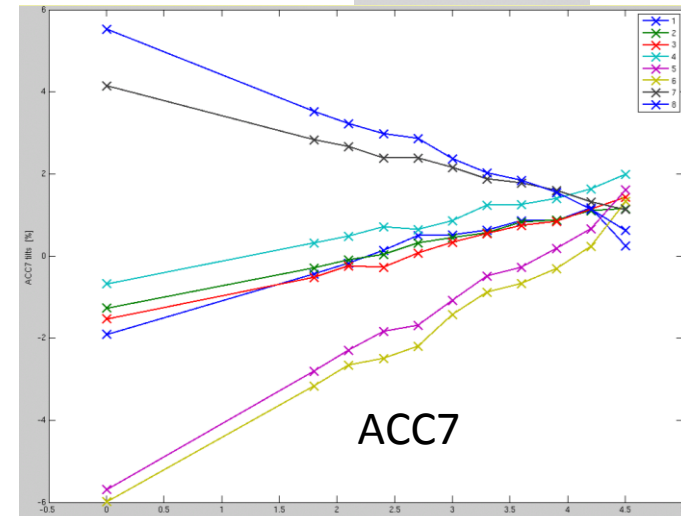
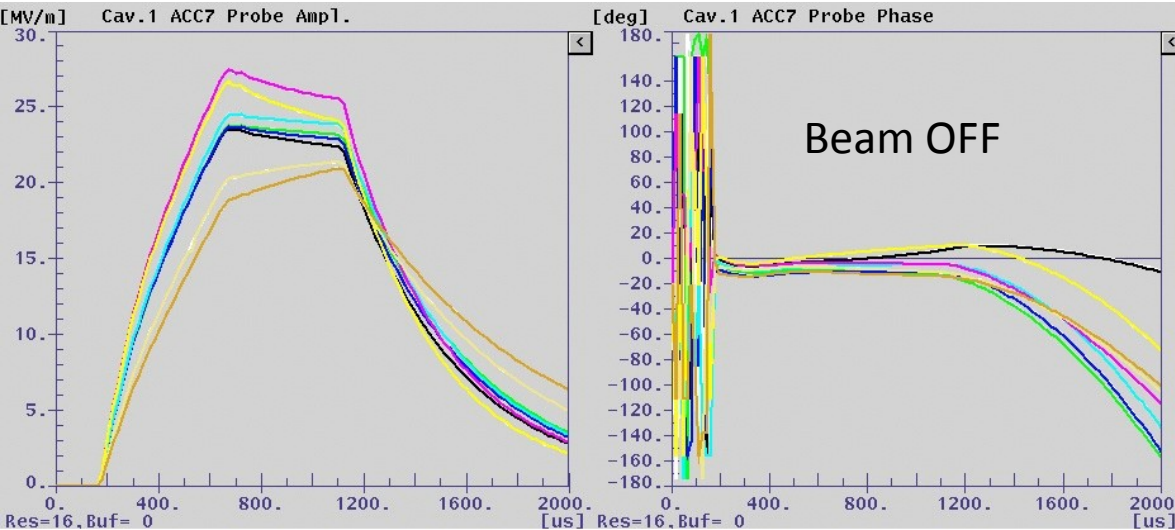
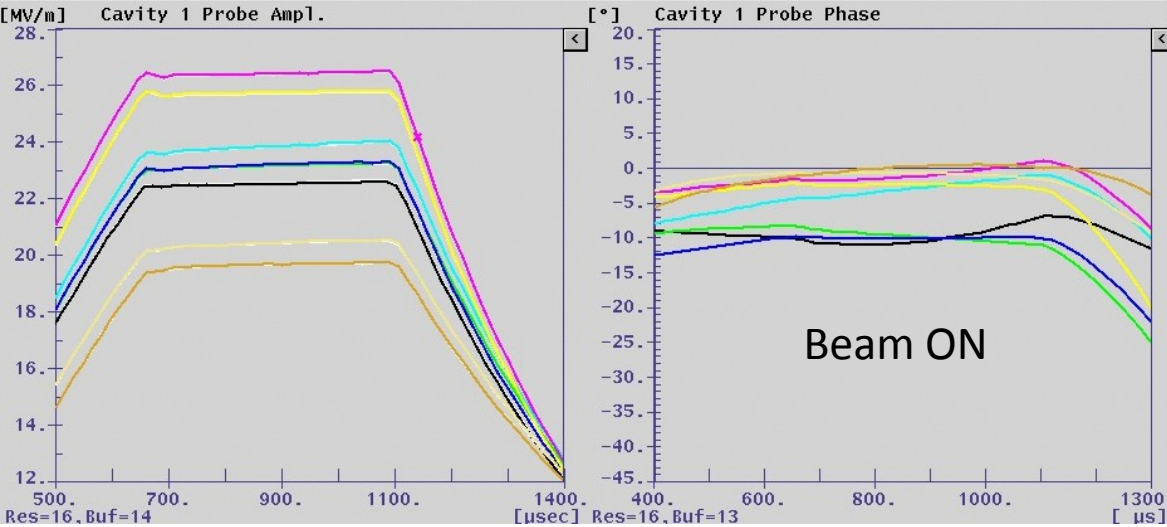
## ACC7 Q<sub>L</sub> values

Predicted

Implemented

cav1. 1.78 e6  
 cav2. 1.74 e6  
 cav3. 1.85 e6  
 cav4. 1.88 e6  
 cav5. 3.25 e6  
 cav6. 3.12 e6  
 cav7. 2.37 e6  
 cav8. 2.40 e6

Cavity#	Loaded Q
1	1.79e+06
2	1.77e+06
3	1.84e+06
4	1.91e+06
5	3.28e+06
6	3.10e+06
7	2.37e+06
8	2.28e+06



# Tuesday Feb. 8 afternoon shift

- 500 usec flat top (shorten to prevent quench)
- 1.4nC, 3MHz beam stable 19:08
- Adjusted piezo
- Adjusted ACC7 according to Gustavo's values 19:58
- Adjusted ACC6 according Gustavo's values 20:34
- Tilt measurement 20:52
- Beam scan
  - 1.5nC 21:02:04
  - 1.4nC 20:50:37
  - 1.3nC 20:53:01
  - 1.2nC 20:53:27
  - 1.1nC 20:53:41
  - 1.0nC 20:54:03
  - 0.9nC 20:55:34
  - 0.8nC 20:56:53
  - 0.7nC 20:58:59
  - 0.6nC 21:00:07
  - 0nC 21:07:04
- Tilt measurement 21:26
- Readjustment of piezo

# A few comments

- Overall, machine very reliable and up all the time
  - Some hysteresis with frequency tuner
  - No end cap for  $Q_L$  tuners
- Tuning the cavity plays a crucial role in getting the gradient flat
  - Static detuning
  - LFD compensation
- Easier to flatten cavities:
  - at lower gradients (less LFD)
  - at lower currents (less beam loading, smaller  $Q_L$  corrections)
- Simulation is reliable to predict  $Q_L$  values
- No solution to flatten cavity traces for maximum gradient