S1 Global – Two hours of stable operation

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This note is an ad-hoc collection of pulse waveforms recorded during S1Global operation in the late afternoon 15 December, 2010. For this period, 7 of the 8 cavities in the S1Global cryomodule were powered by a single klystron, similar to the RDR baseline. The eighth cavity (C2, ACC11) could not be tuned to resonance and was not connected to RF power. The average gradient was 27MV/m. 7195 pulses were recorded at a rate of 1 Hz for 2 hours with a fast waveform sampling rate of 1 MHz. 2048 samples were recorded for each waveform under study. The total data sample is large: 7 cavity waveforms + a few other signals * 2048 sample points/waveform * 7195 pulses =150M numbers. A similar study of this data was reported by Shin Michizono and T. Matsumoto:

http://ilcagenda.linearcollider.org/getFile.py/access?contribId=2&resId=1&materialId=slides&confId=4993 .

(I don't know the RF feedback parameter set for this data.)

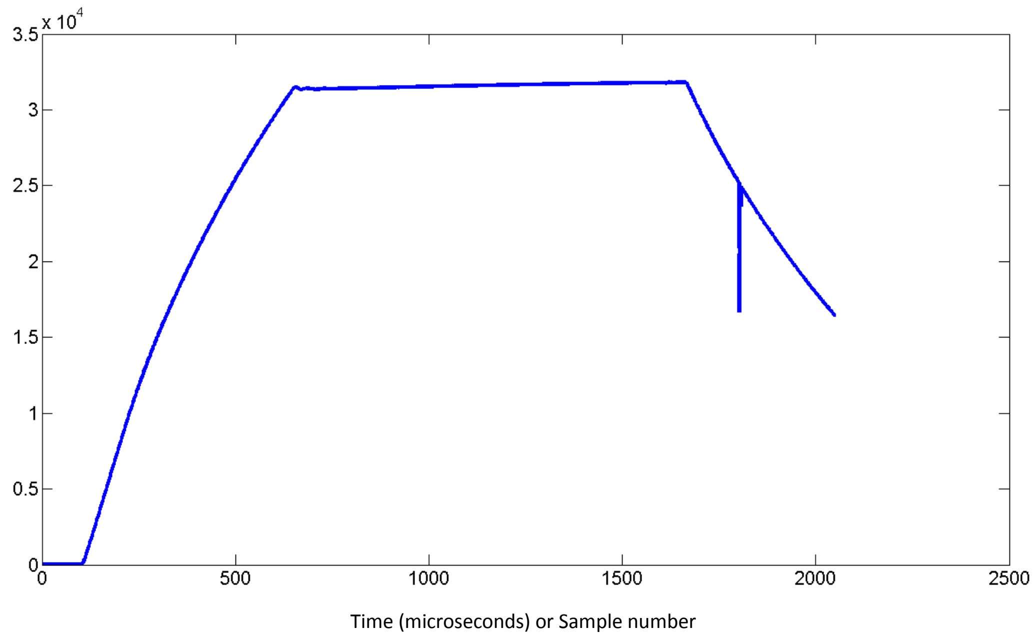

Figure 1 shows a typical cavity 6 (A2, MHI06) amplitude pulse. The fill is complete after 540 us, the flat-top is 1.0ms long and the characteristic decay time constant is t=.5 ms. Four segments of the flattop portion of the waveform, each twenty points long, were used for the figures below (i.e.,points A 751:770; B 1001:1020; C 1251:1270; D 1501:1520 in the above figure).

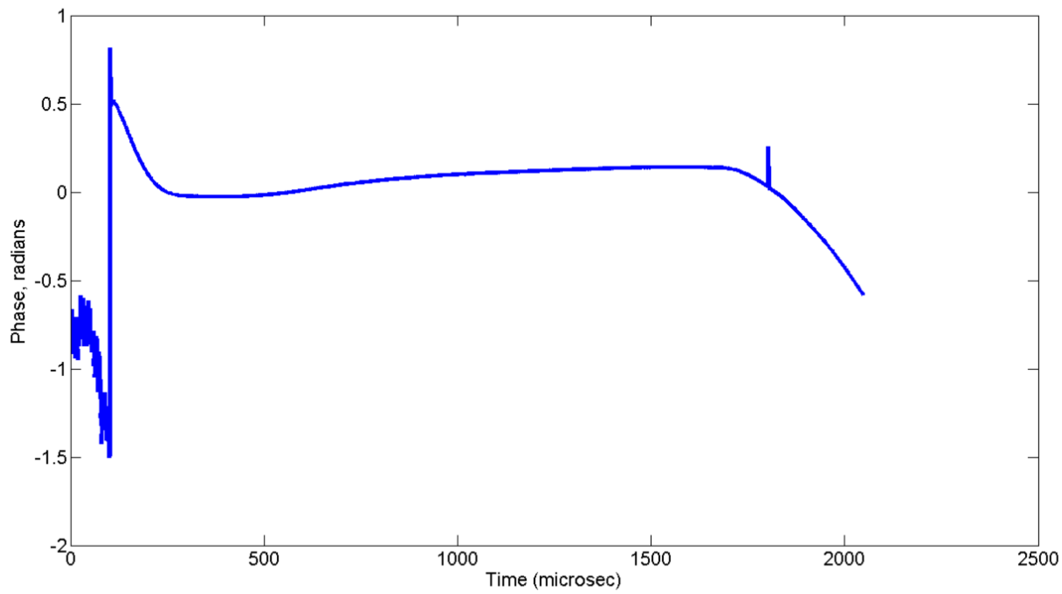

Figure 2 shows the phase as recorded during the same typical cavity 6 pulse. Without a beam reference, we should assume there is an arbitrary phase offset. An accurate phase reference is required to estimate the actual acceleration field a beam would see.

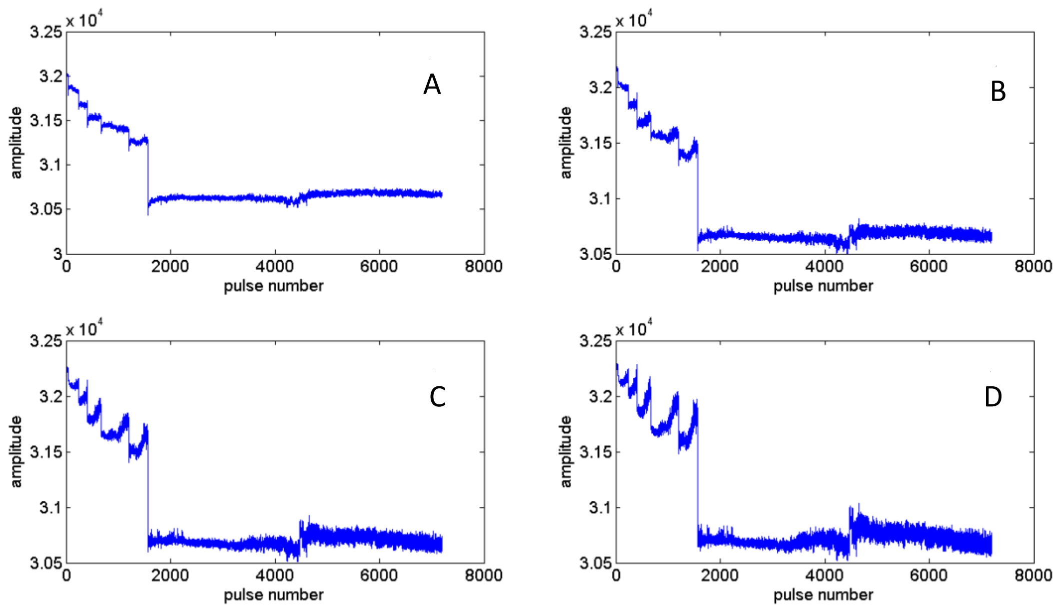

Figure 3: History record of an average 20 sequential samples of the cavity 6 amplitude during four sections (A-D above) of the flat-top spaced by 0.25 ms. (i.e., points: 751:770 (A); 1001:1020 (B); 1251:1270 (C); 1501:1520 (D)). At about pulse number 1563, (15-Dec-2010 17:04:46), a ‘manual’ change appears to have been made. The pulse to pulse stability is worse near the end of the flat top.

The figure below (figure 4) shows the same data for only those data that follow the time of the 'manual' change. The plots each use the same vertical scale, so it is easy to see that the pulse to pulse fluctuation of the twenty-sample average increases along the flat top.

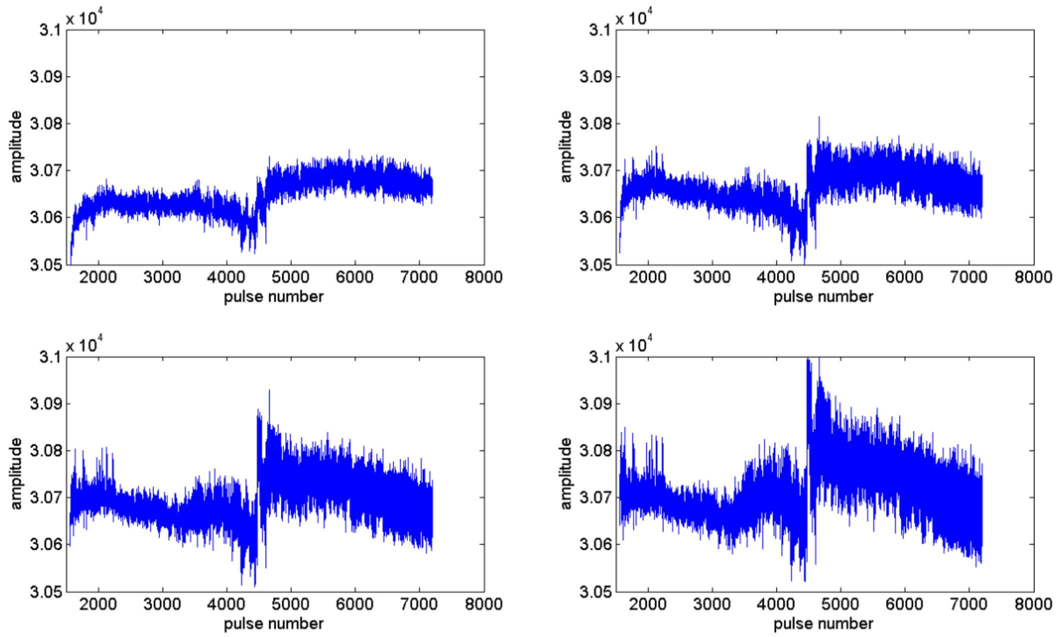

Figure 4: History record of a 20 point average of the cavity 6 amplitude seen in four waveform segments, starting from the apparent manual change seen in figure 3.

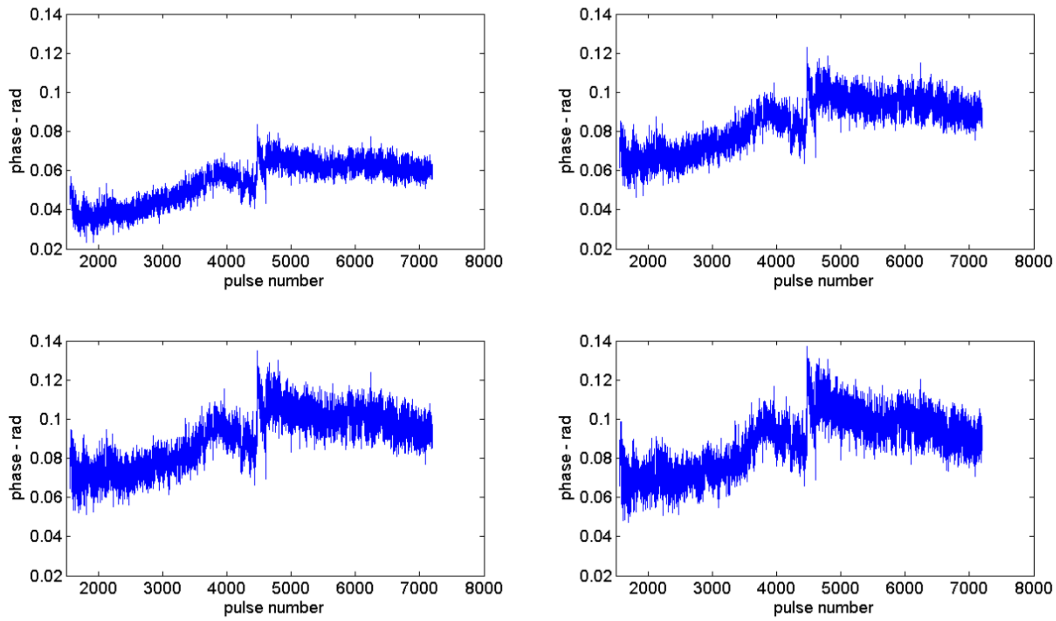

Figure 5: History record of the 20 sample average of the cavity 6 phase seen in four waveform segments during the same time as the amplitude history data in figure 4.

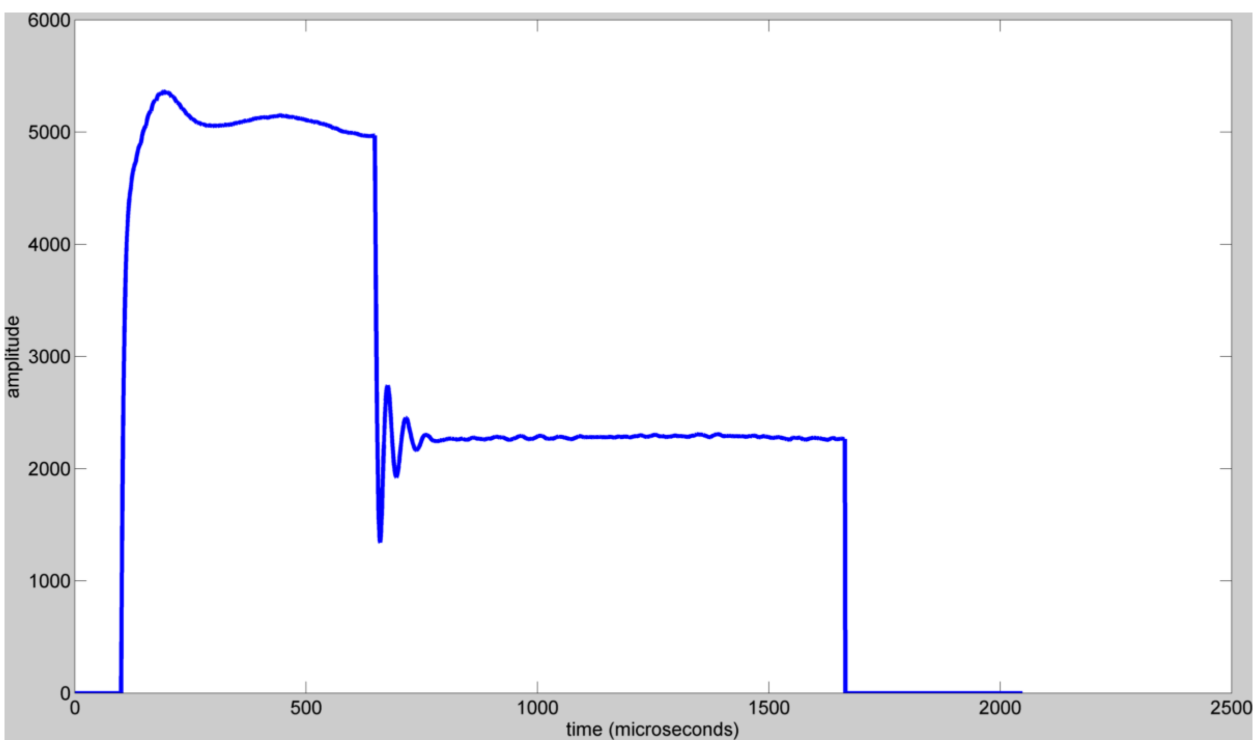

Figure 6: Typical multi-beam klystron output amplitude pulse recorded during this period. Initially, the 10 MW klystron is set to provide more power to reduce the fill time.

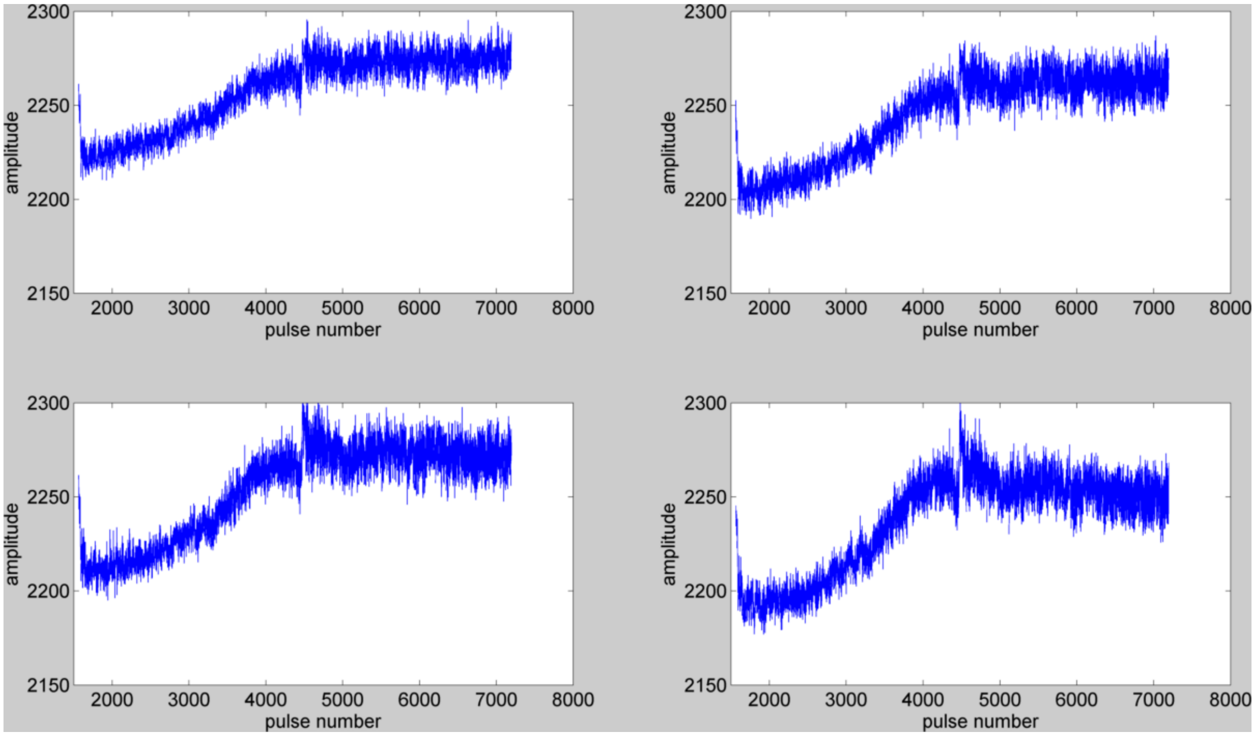

Figure 7: History record of the 20 sample point averages of the klystron amplitude seen in the four waveform segments. The increase in pulse to pulse fluctuations near the end of the waveform is also apparent, but is not as large as that seen in figure 4.

From the above figures, we see that:

1) the stability of cavity 6 amplitude and phase appears to be worse at the end of the flat top than it is in the start and the degradation appears to be worse near the end of the two hour interval and
2) the klystron output rises steadily (3%) while the cavity 6 amplitude does not increase.

Figure 9 show the mean and rms (respectively) of 100 consecutive pulse sequences of the flat-top amplitude data for the four waveform sample segments, A-D, for each of the seven cavities. Since each data point is an average of 20 waveform samples, the figure shows the real pulse to pulse fluctuations, not the waveform digitization error or electrical noise.

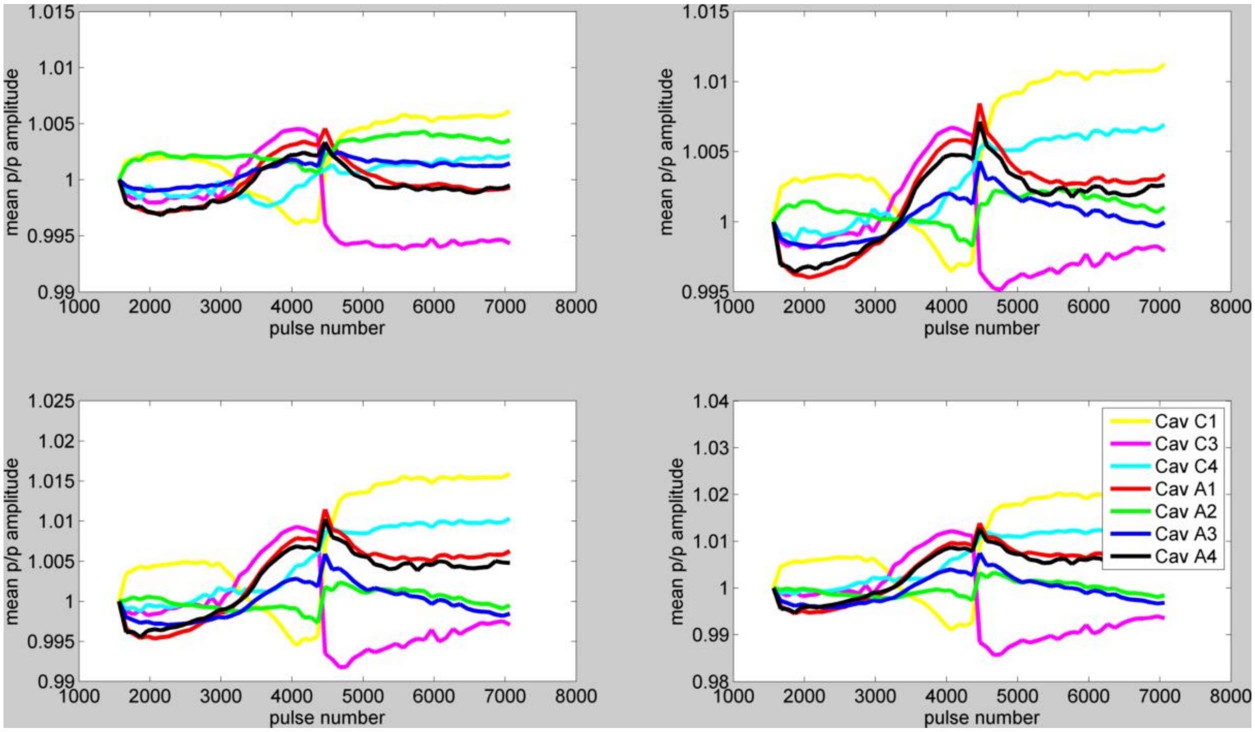

Figure 8. 100 pulse mean amplitude drift of each of the four segments along the flat top for each cavity for the roughly two hour interval. The data is normalized to the average for each cavity amplitude. The figure shows the field in each cavity is unstable, and that the instability changes along the flat top and is different for each of the seven cavities. Presumably each cavity became detuned during the two hour period. The behavior of cavity 3 (Z108) appears to differ from the other 6 cavities. Compare with slide 9 and slide 11 of the 25 January presentation.

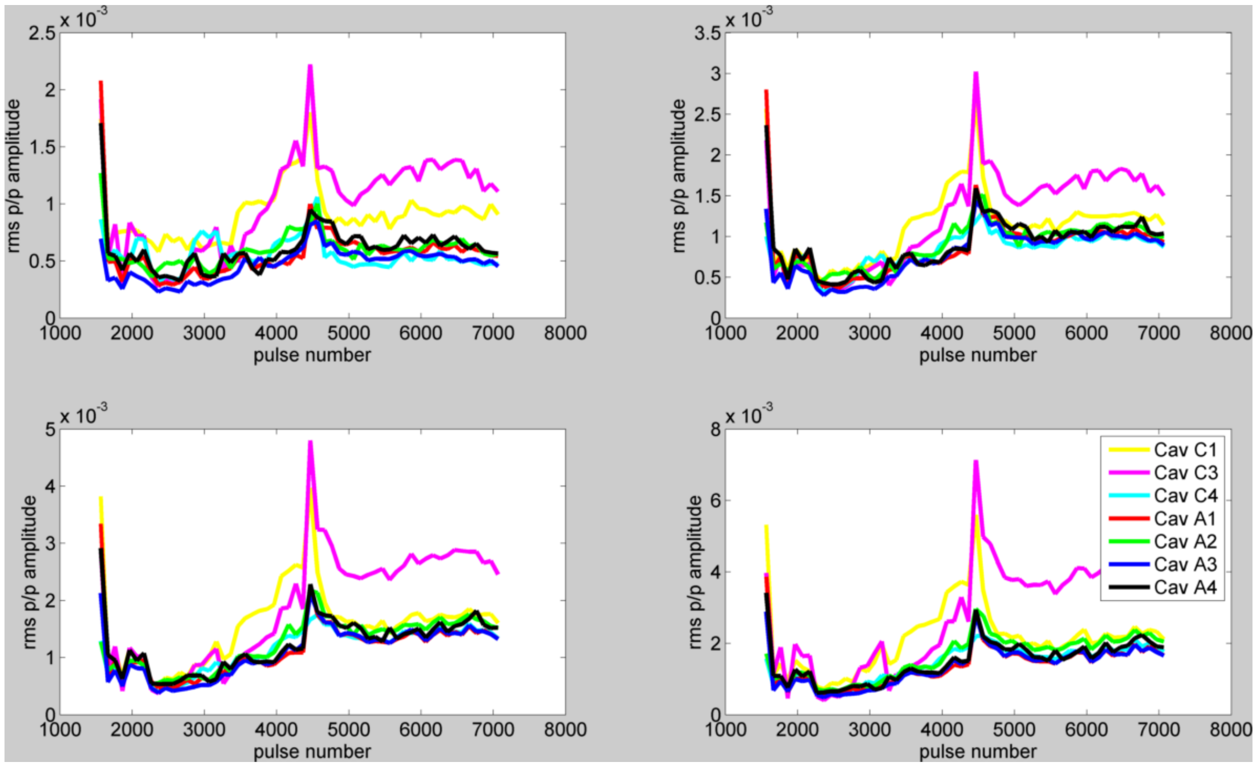

Figure 9: Pulse to pulse cavity amplitude stability. The figures show the normalized rms of 100 sequential pulses of the mean amplitude for the same four waveform segments, (A-D), vs pulse number during the two hour interval. One of the cavities, C3 (Z108), appears to have 2x poorer stability than the other 6. The other 6 cavities are quite similar.

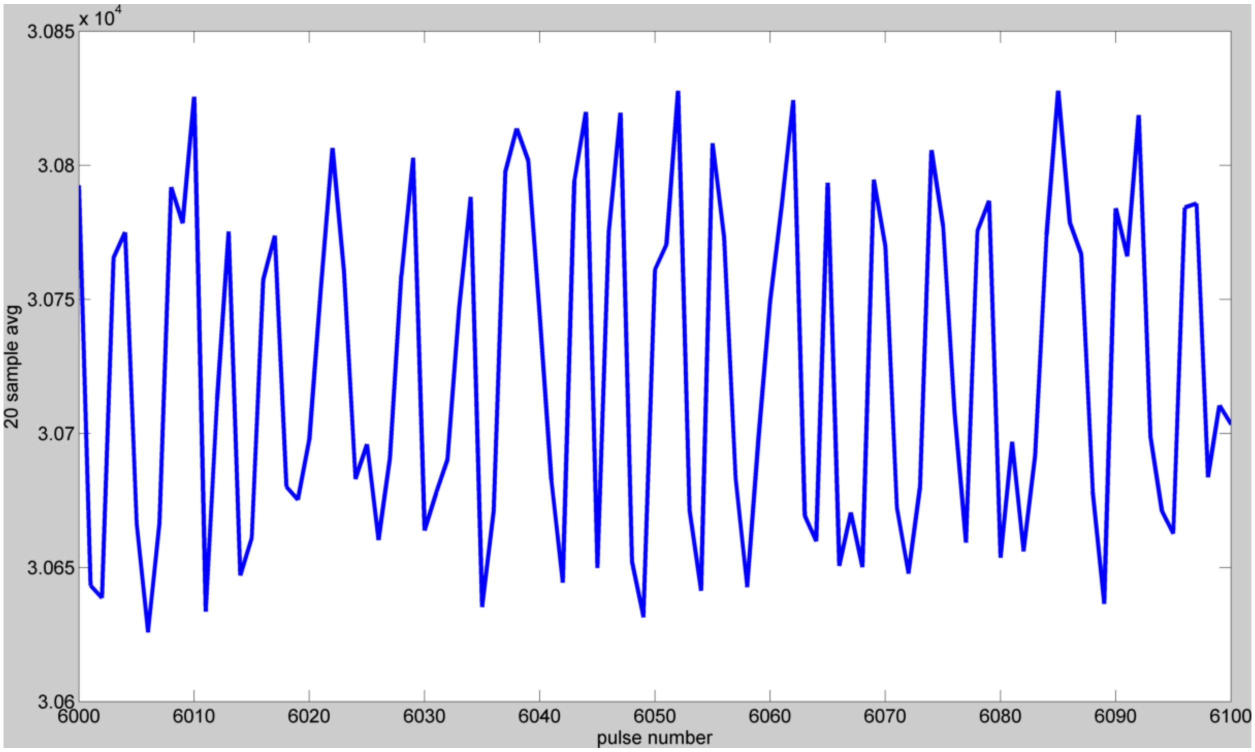

Figure 10: Close up of data in figure 4 (D –near the end of the flat top) from waveform 6000 to 6100 (cavity 6).

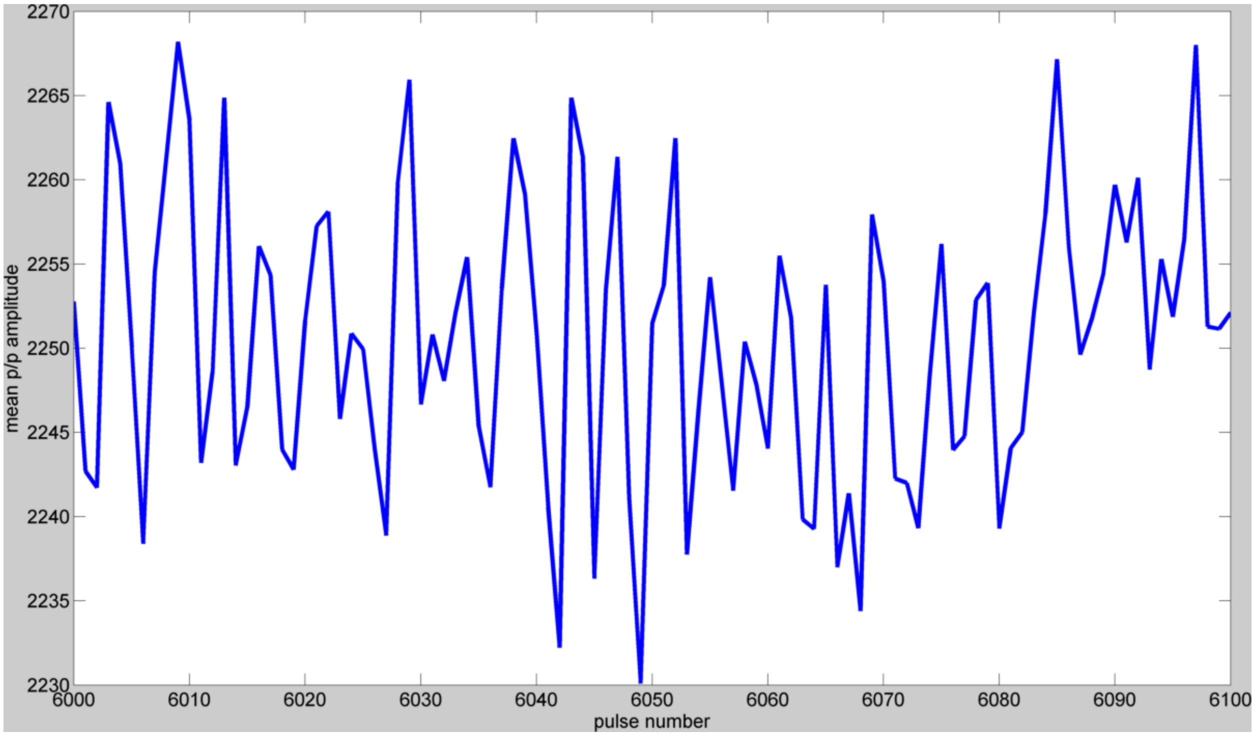

Figure 11: Close up of klystron amplitude data from figure 7 D.

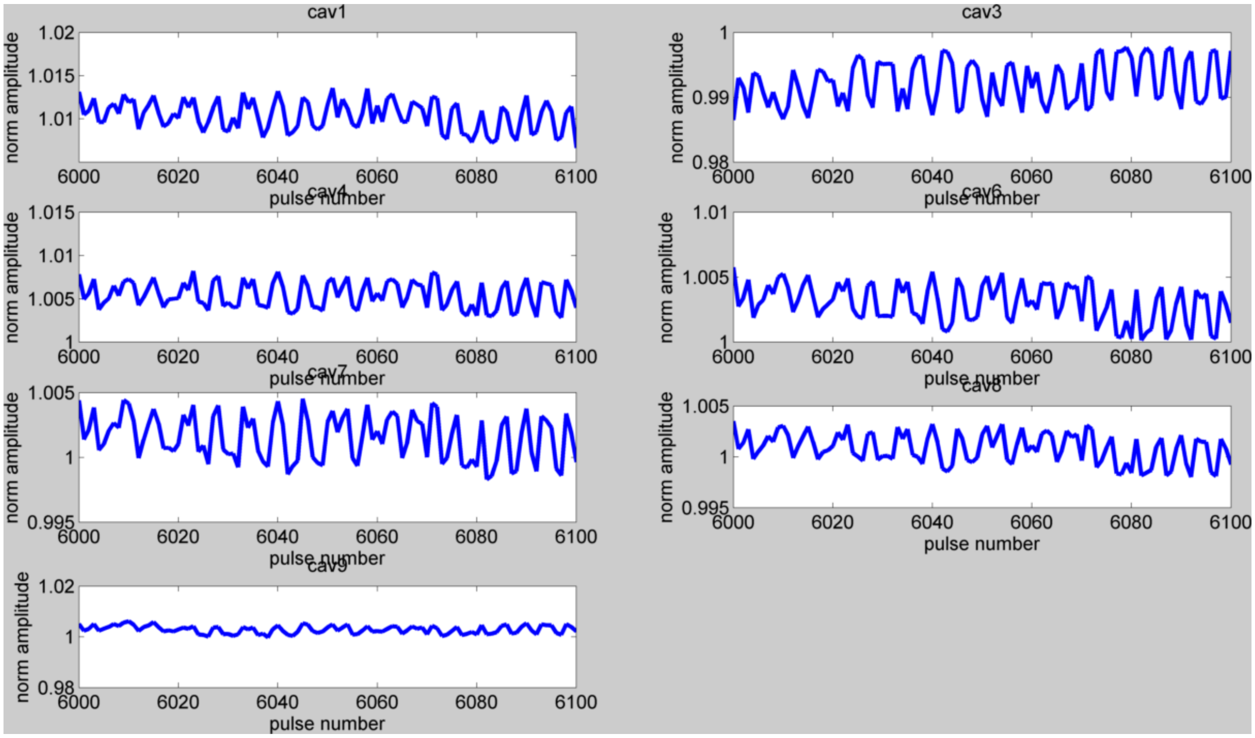

Figure 12. Normalized pulse amplitude, near the end of the flat-top, for pulse numbers 6000 to 6100, for each of the 7 cavities. The waveforms are quite correlated with each other and with the klystron amplitude. The waveform of cavity 3 is anti-correlated with the others.

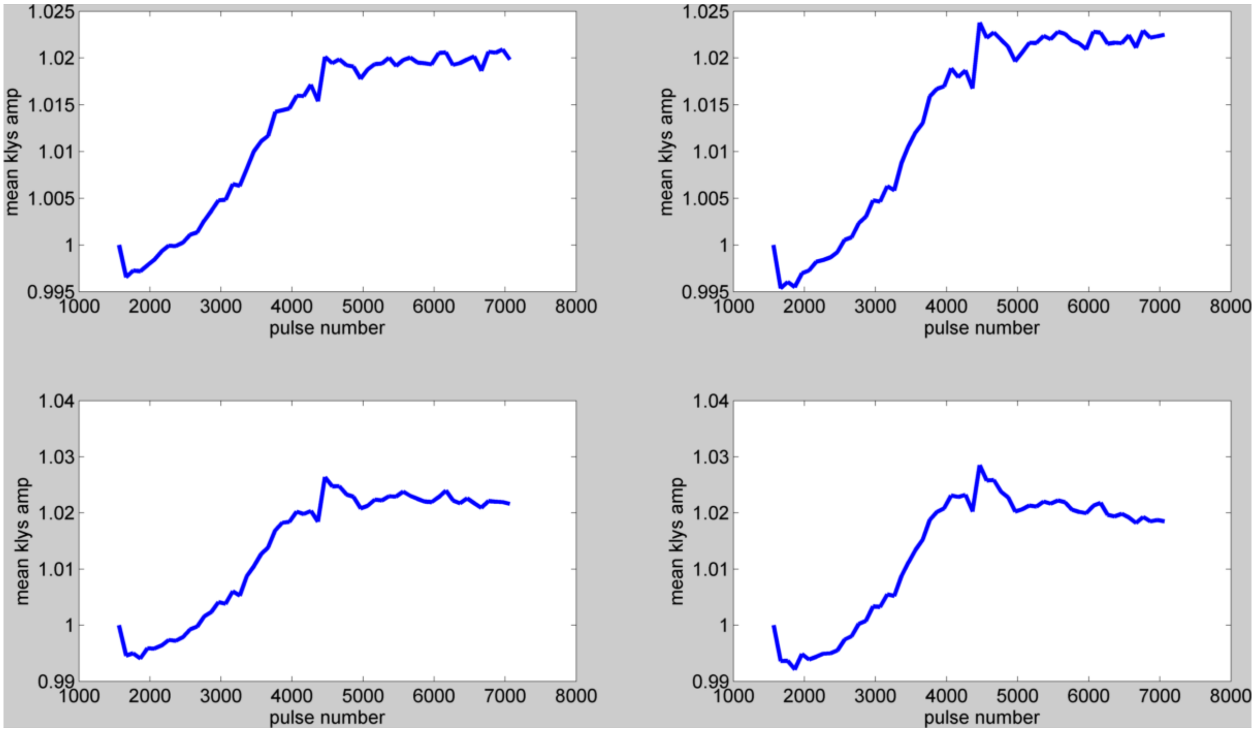

Figure 13 Klystron amplitude mean; similar to figure 8.

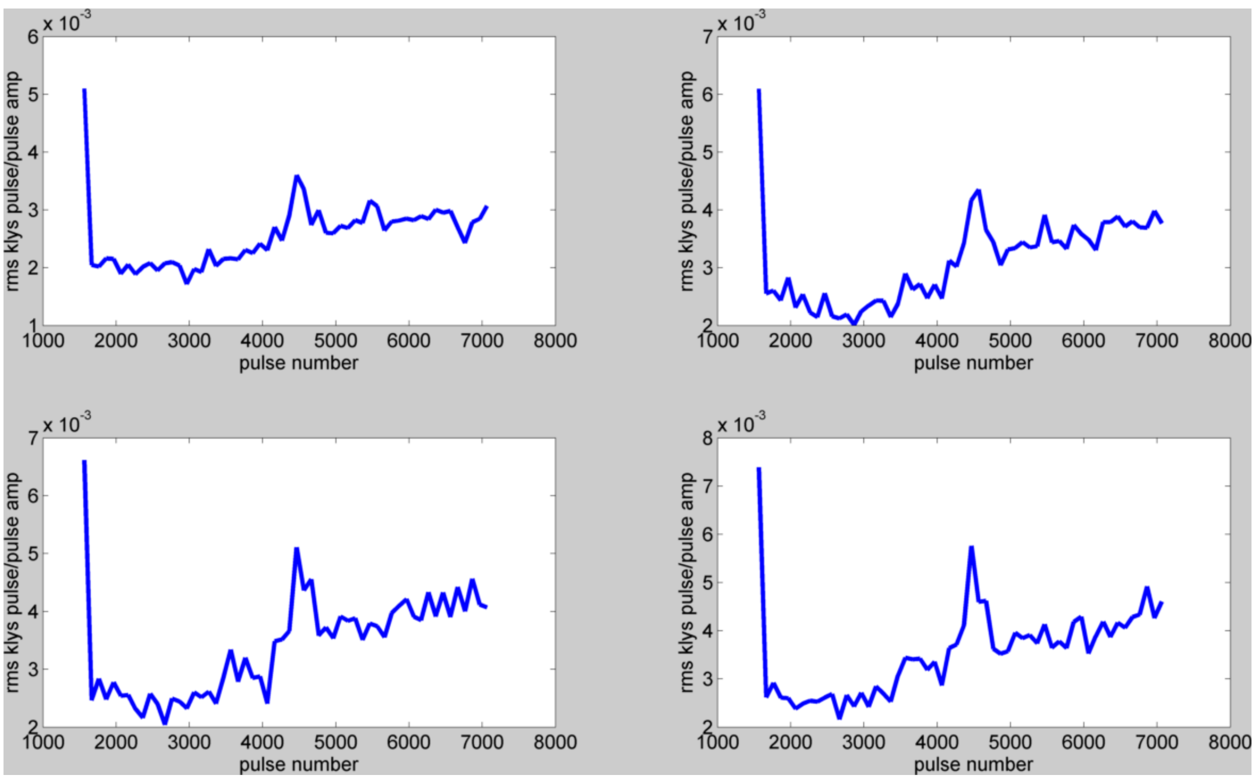

Figure 14. Klystron amplitude rms; similar to figure 9.

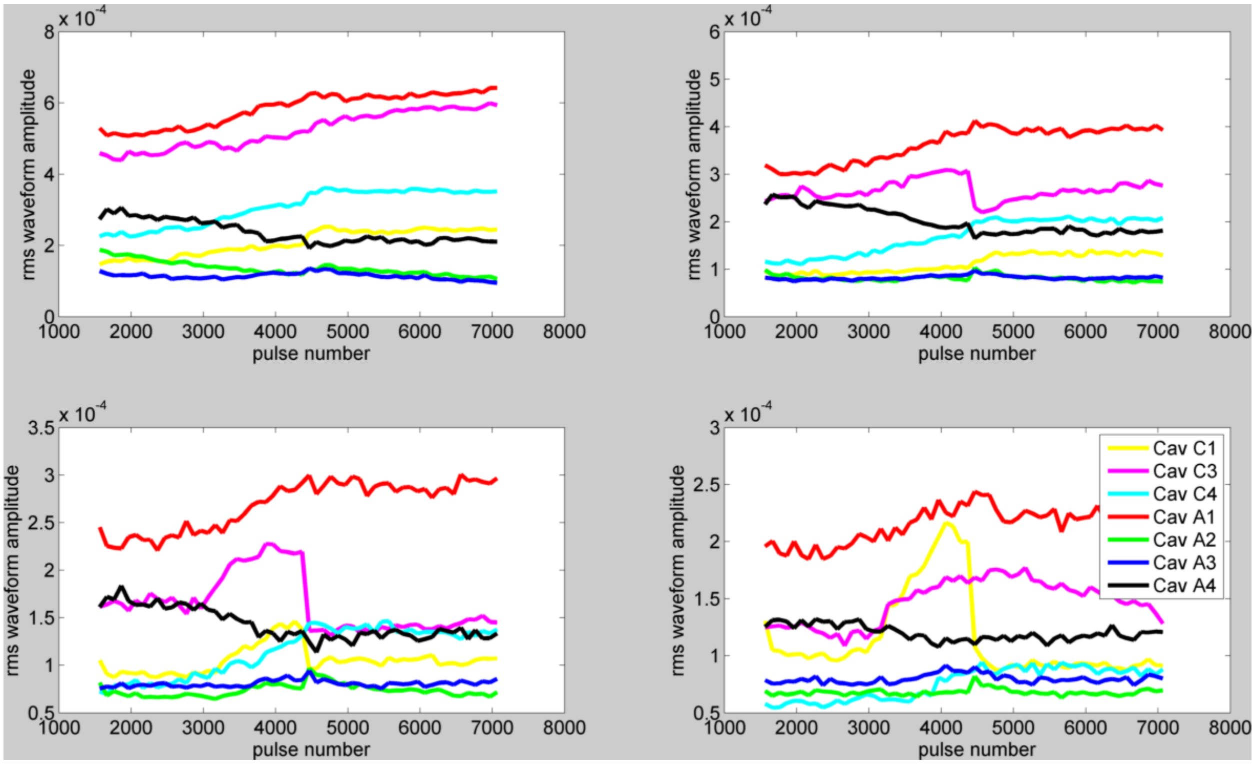

Figure 15: Waveform digitization error and noise. The figure shows the history of the rms of the 20 sample segments for the two hour interval. The rms is quite small, but instability similar to that in figure 8 can also been seen.

Observations :

1) General stability is excellent, almost to the level required for linac operation.
2) Long term drifts (~15 minutes) can be seen during the two hours. This can impact cavity tuning (see slide 10 of the 25 January presentation). The cryogenic system pressure fluctuations should be plotted.
3) Cavity – to – cavity fluctuations are highly correlated (or anti-correlated). This suggests that microphonics is not a cause; instead RF power fluctuations appear to be important. This may be the most important observation from this data and appears to be inconsistent with slide 10 of the presentation noted above).
4) Klystron and cavity fluctuations appear to be inconsistent. The klystron amplitude rms is larger than the cavity rms. (4 e-3 vs 2 e-3; figure 14 and figure 9).
5) Klystron and cavity amplitude behavior do not appear to track each other. This may be caused by detuning or feedback and is yet to be understood.