Drive Beam Status

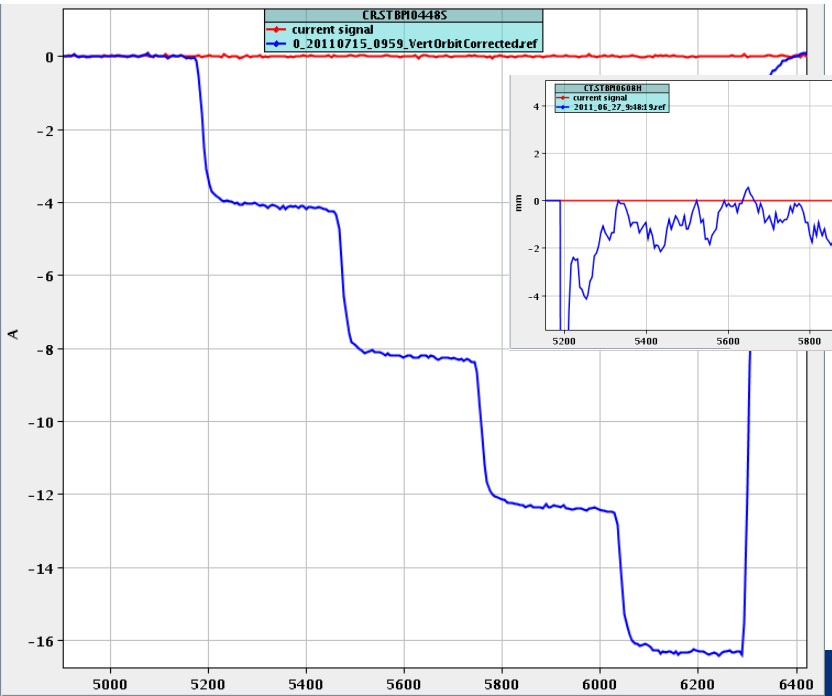
and Issues

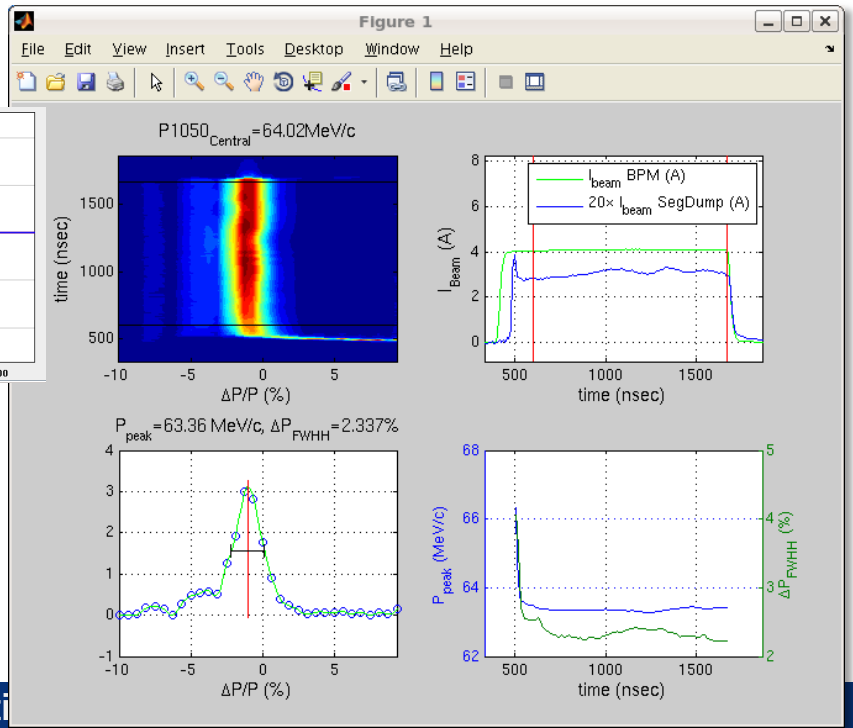
Drive beam quality
Dispersion tuning
Emittance
Combination issues

Piotr Skowroński

2011 Improvements

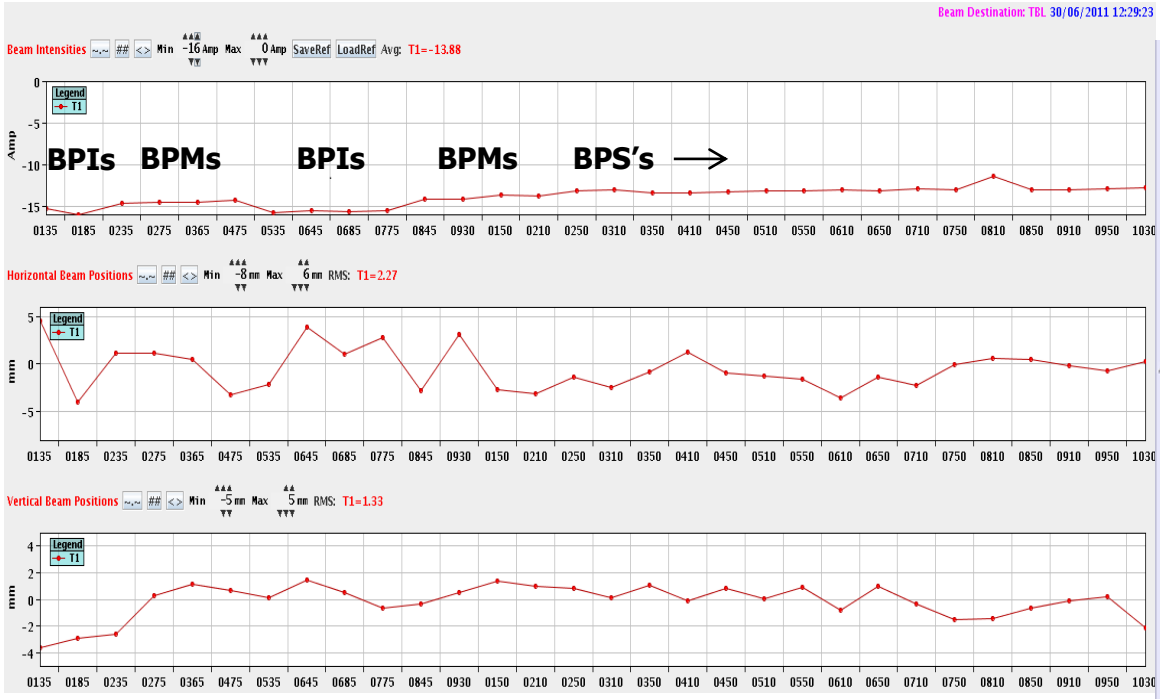
- Gun pulse flattening
- All RF phase sags made the same, including TWTs and MKS02
- Allowed for very quick setup of the factor 4 recombination
- CTF3 Monitor: watches all signals stability, complete references, …
- Feedbacks
- Increased recombined beam stability
- The recombination is now much less vulnerable to drifts and jitters
- 14A in CLEX, 13A routinely

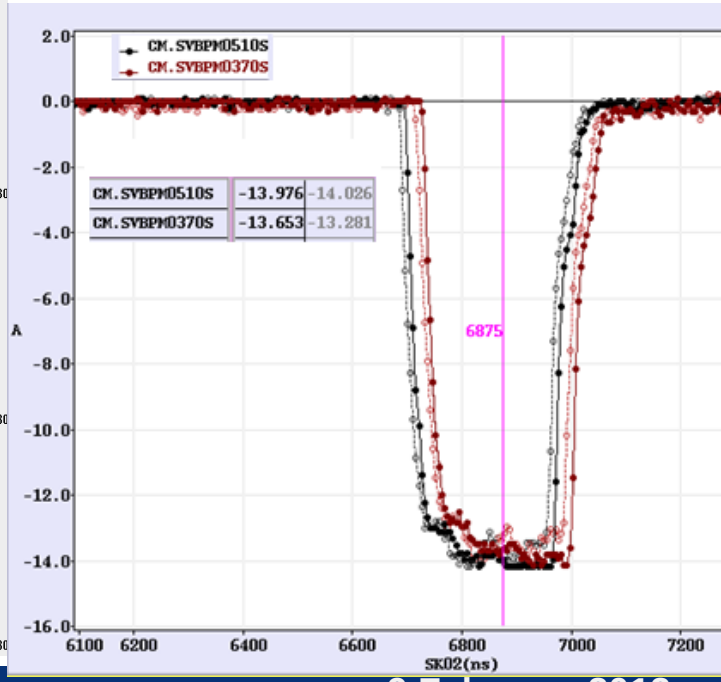




Drive Beam in CLEX

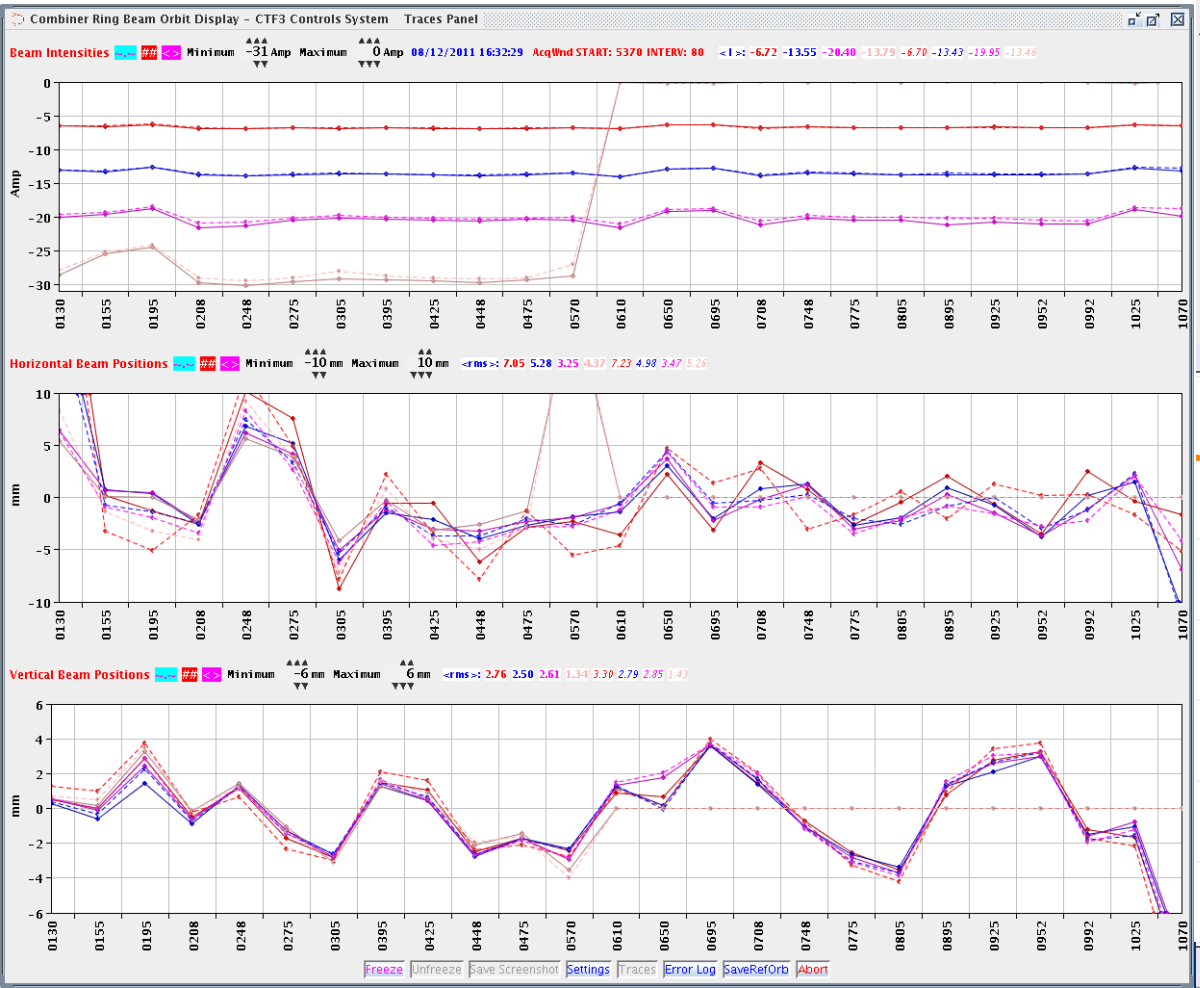
- Routinely delivered 13A, up to 14 A
- 10% losses at CR ejection
  - Difficult (very strong) optics given by the building geometry
- Minor differential losses along TL2
- Issue with BPIs calibration
  - They measure 10% more current then BPMs and BPS's

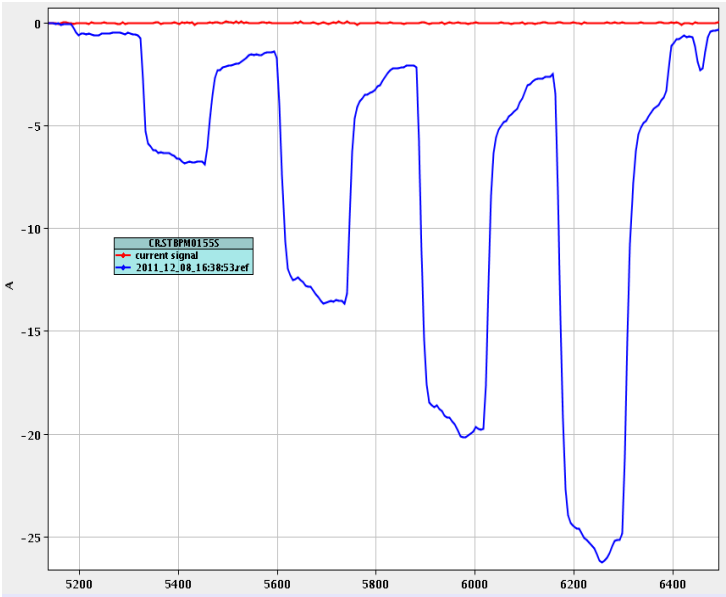


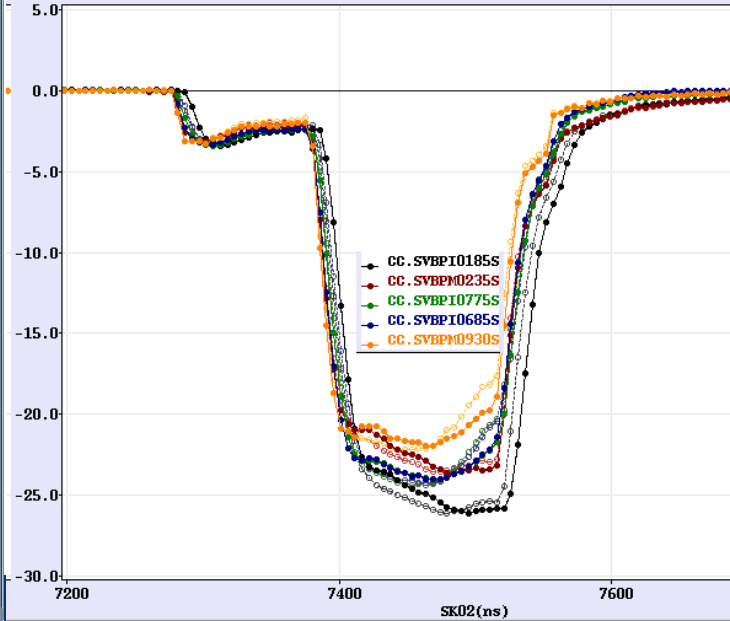


Factor 8

- 26A out of 6.5 injected
- 20A delivered to CLEX

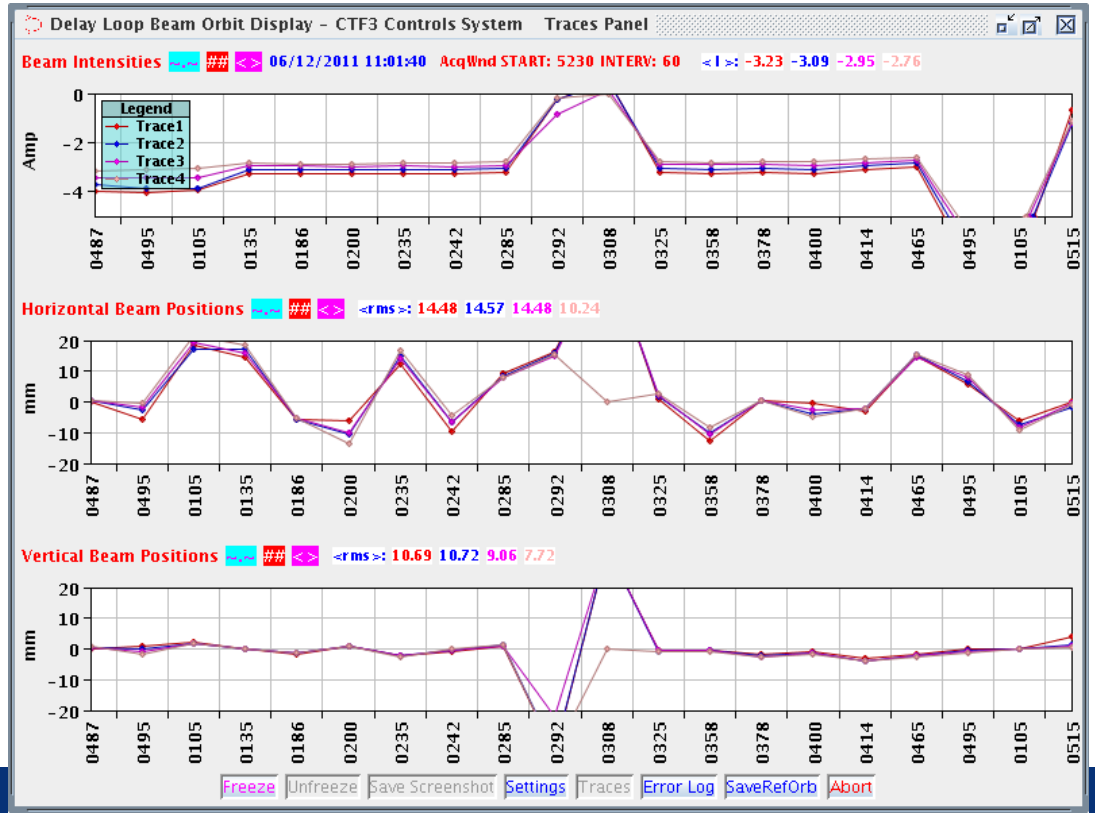






Issue with DL

- This year the setup of the DL was extremely difficult
- The orbit that gave good transmission has large amplitude
- Any losses on straight section induced alarm at the doors
  - After long fight we found a setting that gave good recombination and no losses, but it was extremely sensitive to any drift
- We suspect misalignment quad/BPM misalignment at the beginning of the Loop after leak repair in summer 2011

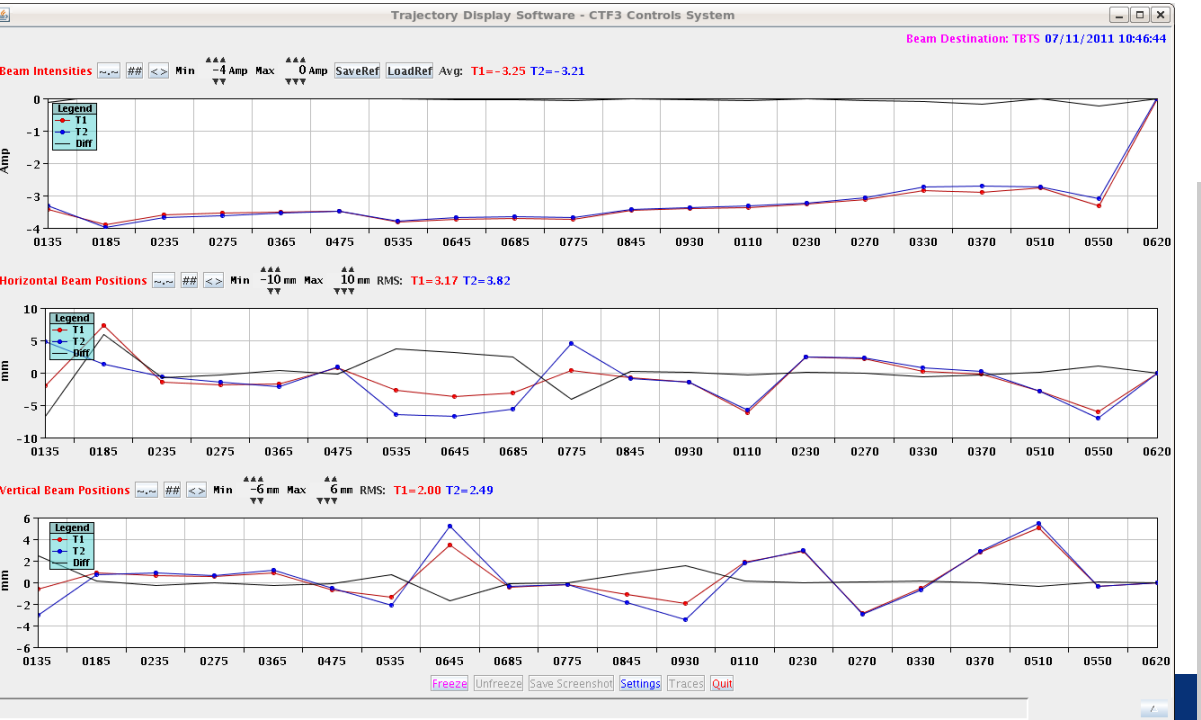


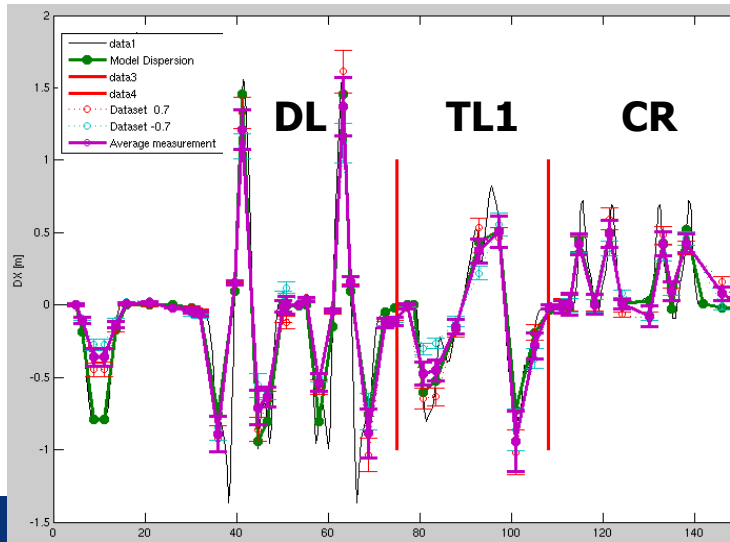
Control of the optics

- The optics was verified with help of Response Matrix and Dispersion measurements (up to CR)
  - Achieved satisfactory agreement with the Machine Model in the horizontal plane
  - The disagreement in vertical plane suggests that fringe fields of the bends are not sufficiently understood
- Ben performed more sophisticated measurements
  - To be summarized tomorrow
  - No issue found, see details tomorrow
- The checks in TL2 and TBTS were not completed
  - Simona tried very hard to get it in 2009 and 2010, but it was extremely difficult to do (experimental LAPP BPM electronics)
  - We did not find time to do it in 2011

Dispersion

- The most effective way to tune the dispersion is generation of a beam pulse with energy step within
  - By adjusting the RF compression for girder 15
  - There should be no step visible in position traces where dispersion should be null
  - Often, strong steerers introduce spurious dispersion
- Dispersion is also measured by
  - Scaling all the magnets
  - Changing beam energy by changing phase of klystron 15 or changing compressed power level for girder 15
- Dispersion is well controlled, no issue here



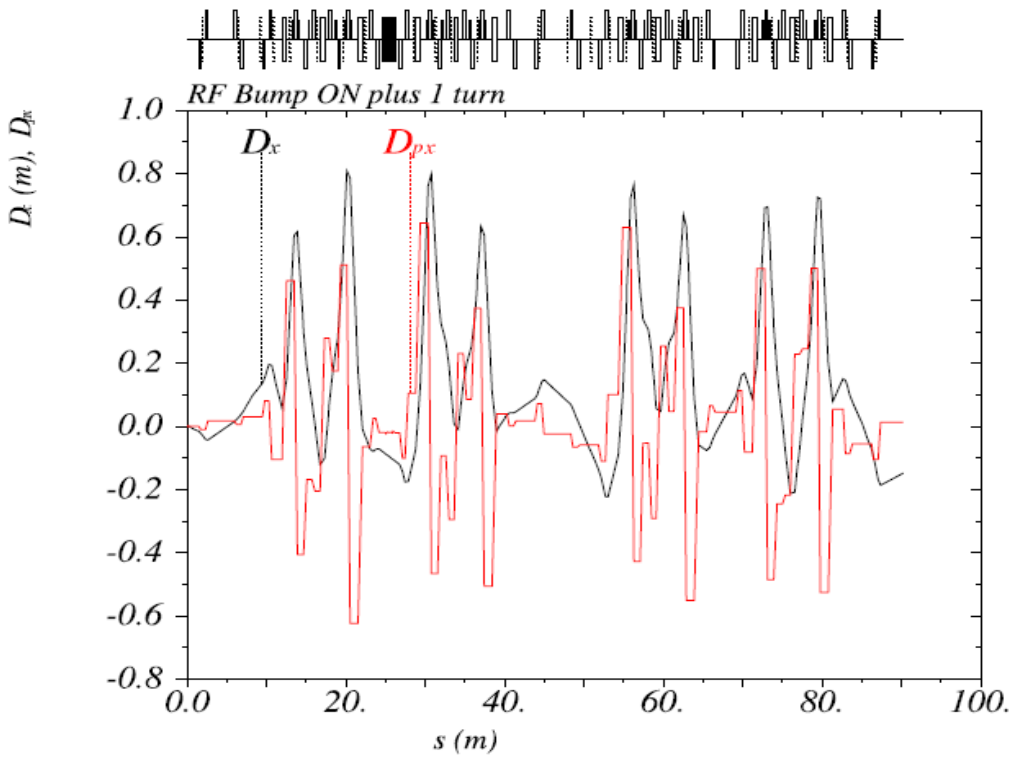


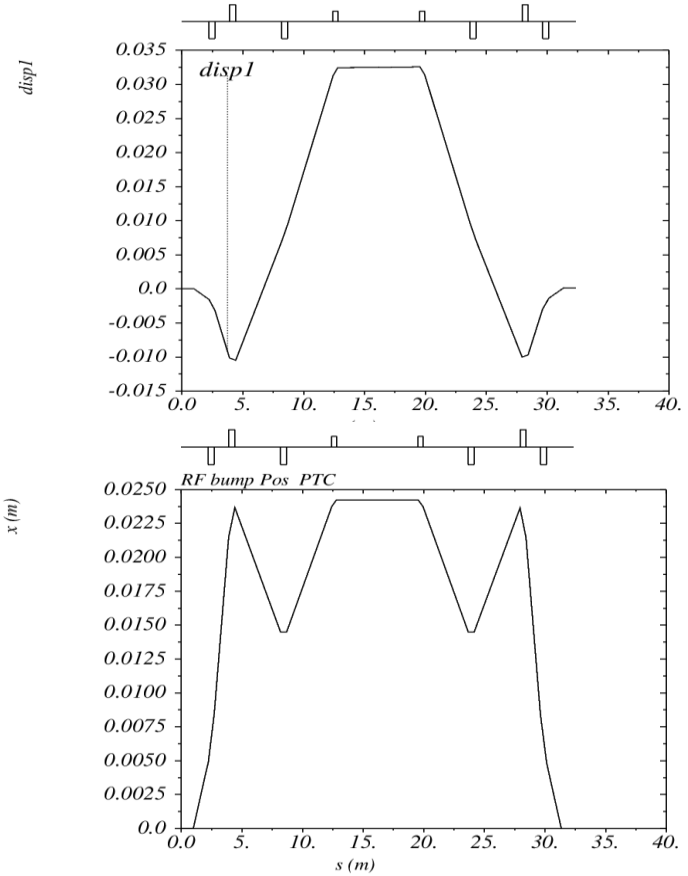
The Ring and the Loop Length

- Time of flight over the Delay Loop is measured with BPR, which is not very accurate, but good enough
  - It is fine tuned to maximize the 12GHz power production
- For Combiner Ring we use coasting beam, and we can get very accurate measurement with doing FFT of the BPR signal
- However, the orbit length is very sensitive to the beam energy
  - It is virtually impossible to keep it on the set point
  - Hopefully, the feed-back closed on the produced RF power will help

Flaw in RF bump design

- The RF bump in CTF3 is not achromatic
  - On 3rd turn it spoils the dispersion
    - inevitably giving rise to the emittance growth
- Only solution would be to install sextupoles in the bump

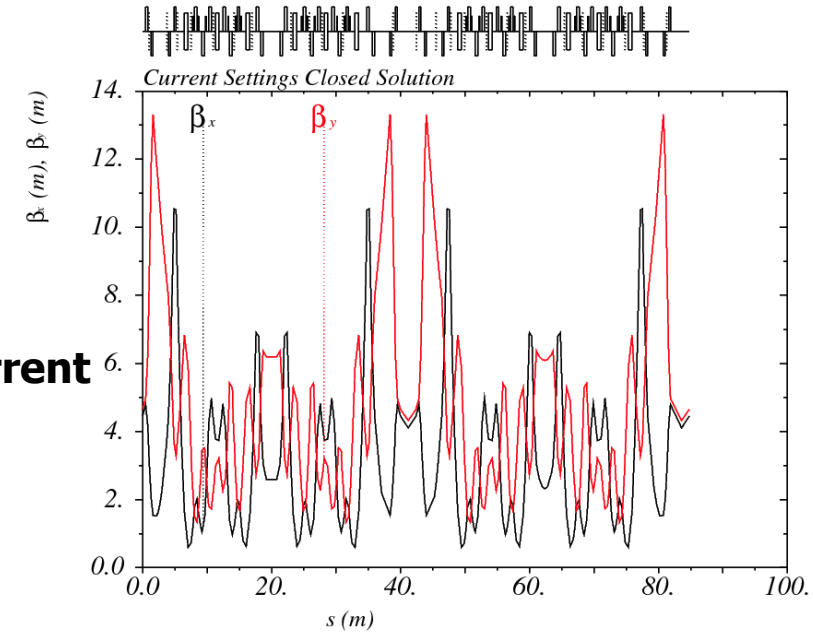


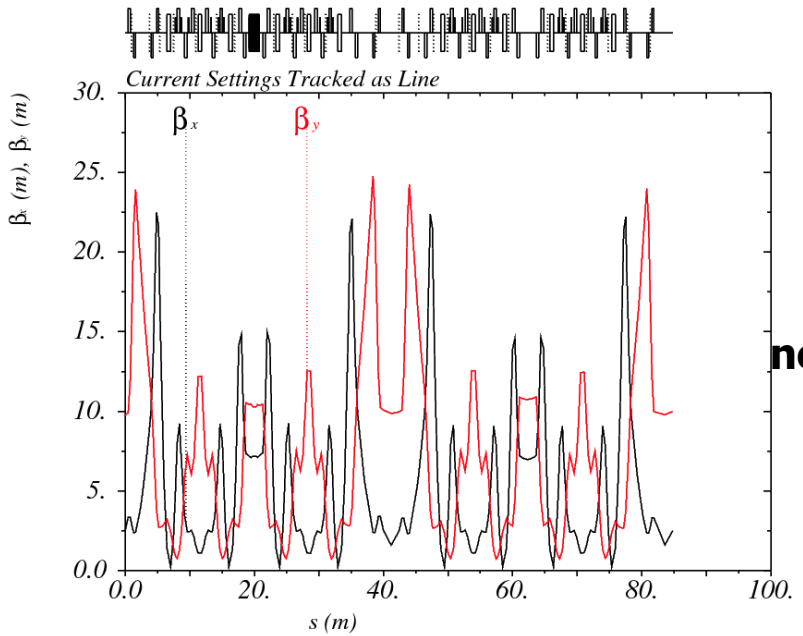


CR Optics

- The optics that is in use in the Combiner Ring is not suitable for 3rd order corrections because it is not symmetric along the cell
  - While sextupoles are placed and connected symmetrically
  - It was made to be as easy as possible in the times we were fighting with the instability from the RF deflectors
  - Appropriate optics is prepared (even more than one)
    - It was even quickly checked and it looks OK
    - However, due to very tight schedule there was never time to perform the switch and

current

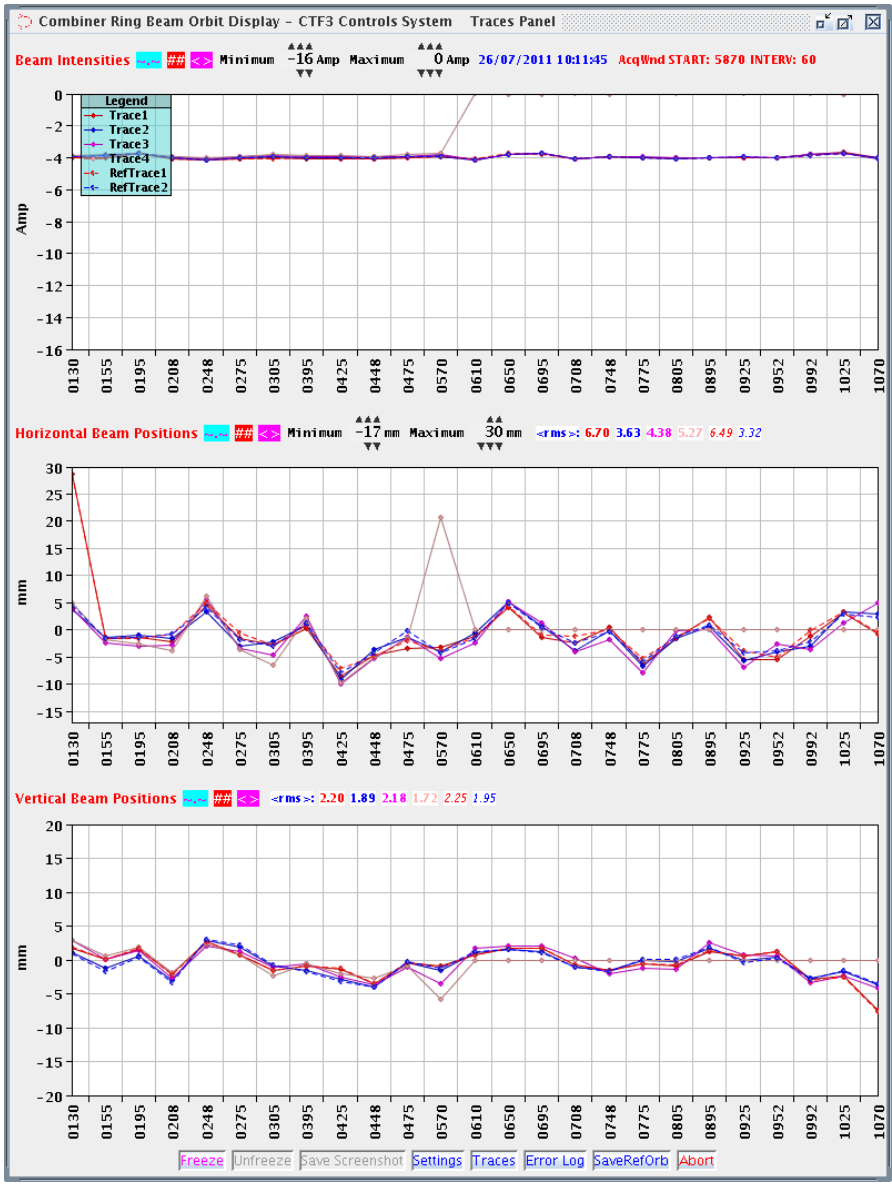




new

Orbit and Closure

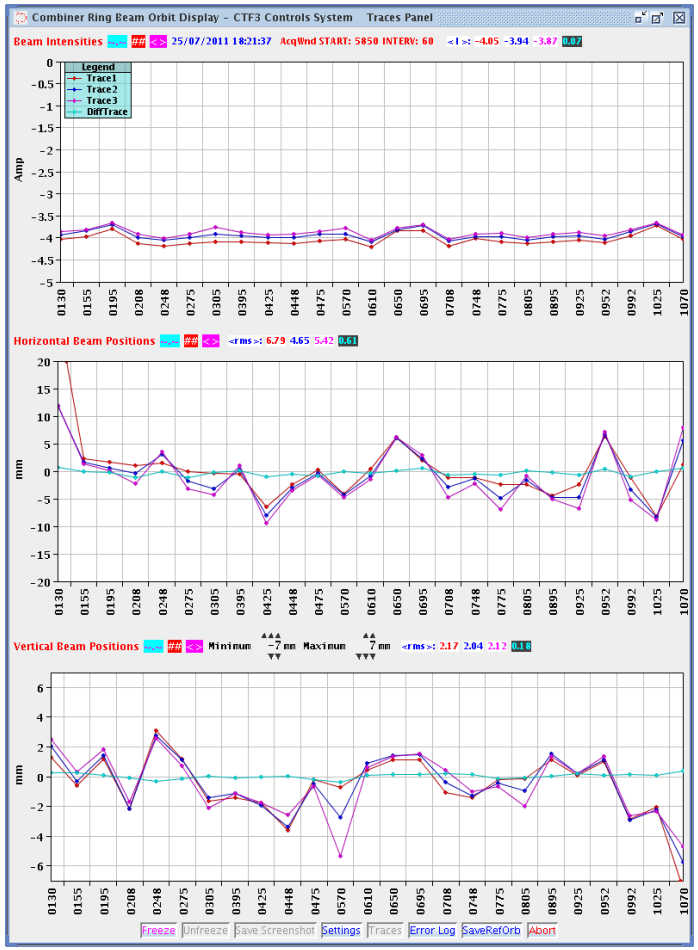
- Improvement of the orbit all over the machine: thanks to Guido
  - Summary tomorrow
- Some issues persists
  - Complication from droop in BPI's that are all over the arcs
    - BPM's are OK
  - A few problematic points
    - Steering after the first and before the last bend
    - At the beginning of the long straight section it seems we have iverted BPI/corrector or optics error
      - Must be investigated further
- Computer program to close the orbit out of DL is also in preparation by Davide



RF Deflectors in CR

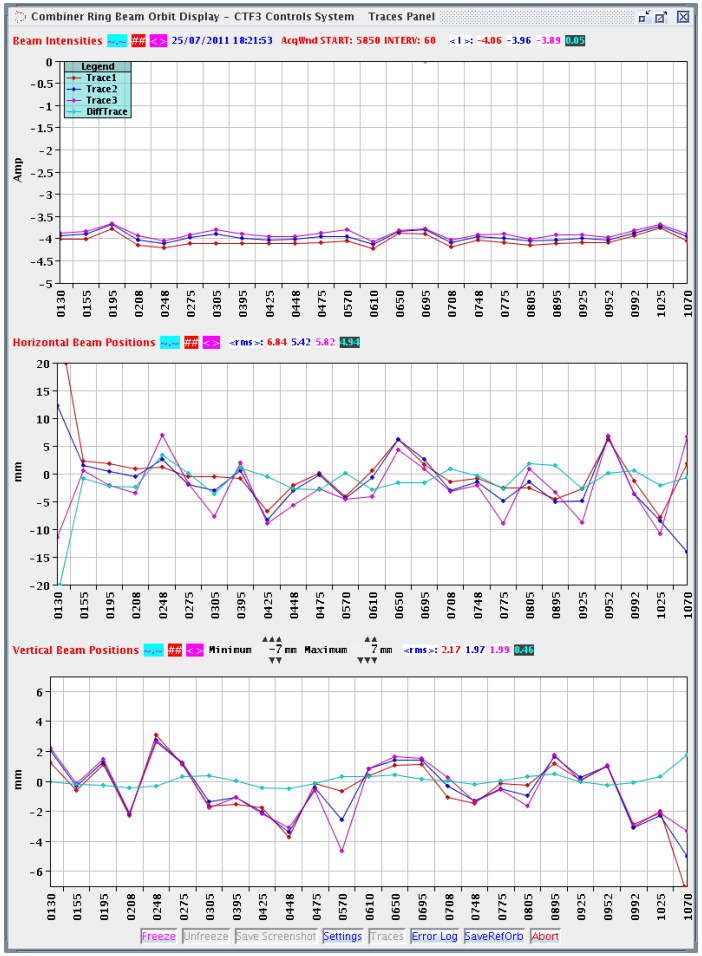
- Most probably the RF deflectors in CR are dis-balanced
- Ben measured optics to check if it is not phase advance problem (must be 180deg), but he found no problem

RF defl stopped on 2nd turn



Red: 1st turn
Blue: 2nd turn
Magenta: 3rd turn
Cyan: 3rd minus 2nd

RF defl on 3rd turn

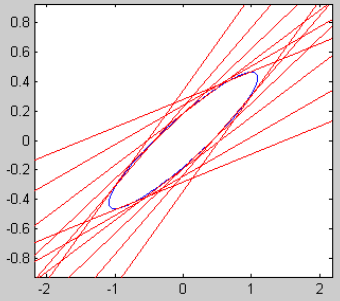


Emittance

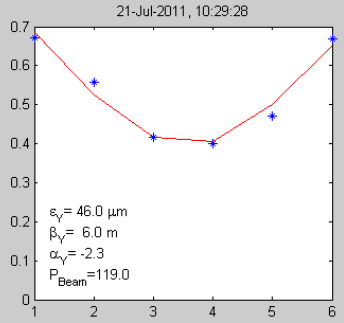
- The emittance in the linac is 40-50 mm mrad in both planes
- It increases in horizontal by 10-20% after Frascati Chicane
- We observe emittance growth in the Combiner Ring and TL2
  - Remark: Quad Scans just after ejection from the Combiner Ring are very difficult and of not the best quality because
    - The optics in the dog leg is very strong to get null dispersion
    - The beam is strongly diverging and it is very difficult to find a range

Vertical

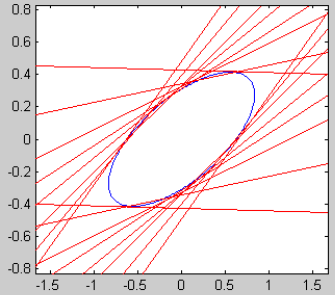
Turn 1



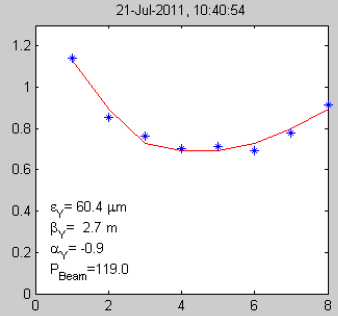
46 mm mrad



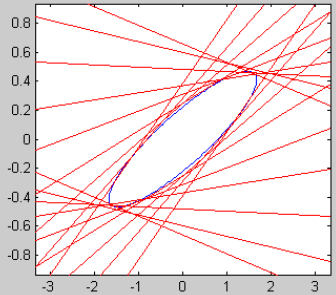
Turn 2



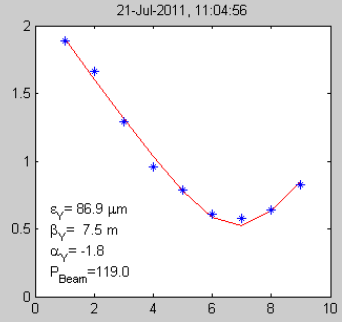
61 mm mrad



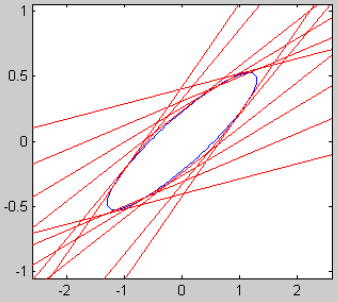
Turn 3



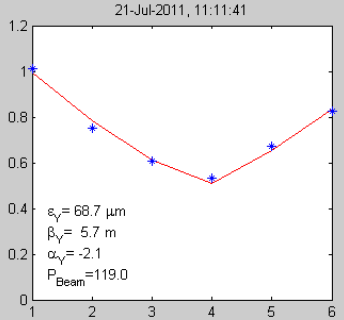
87 mm mrad



Turn 4



69 mm mrad



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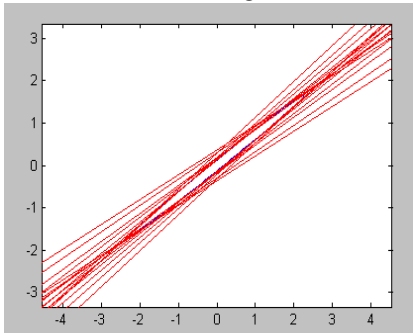
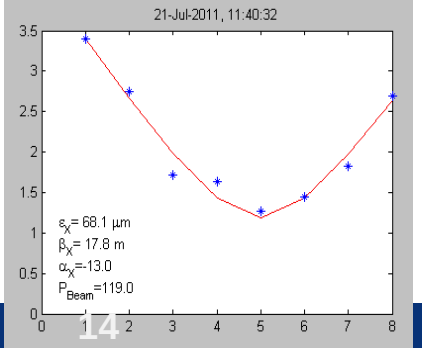
Horizontal

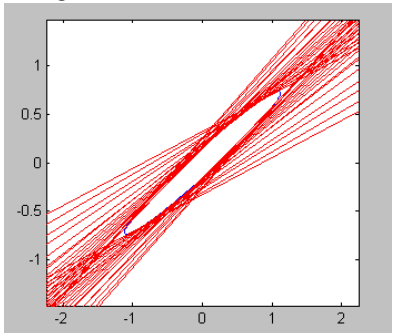
Turn 1



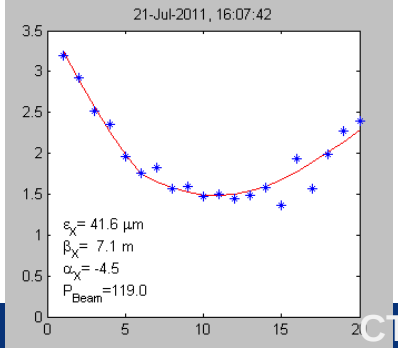
68 mm mrad



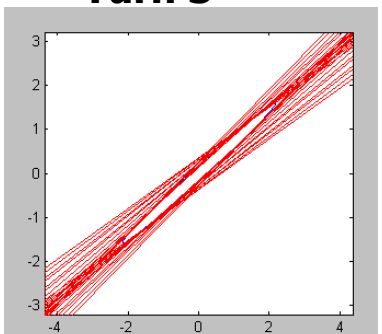
Turn 2



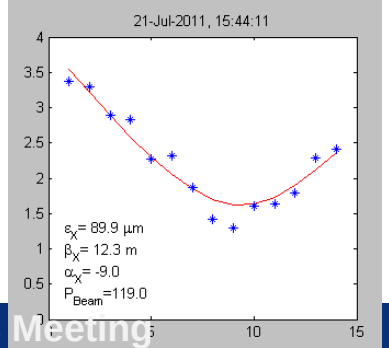
42 mm mrad



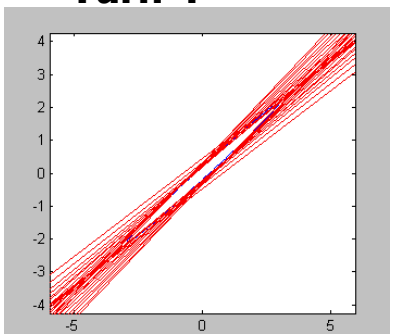
Turn 3



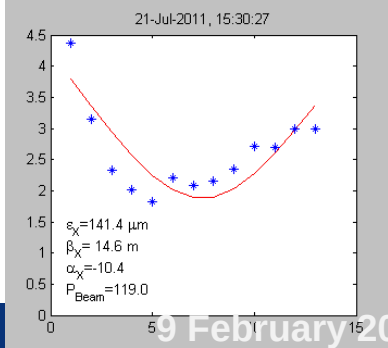
90 mm mrad



Turn 4

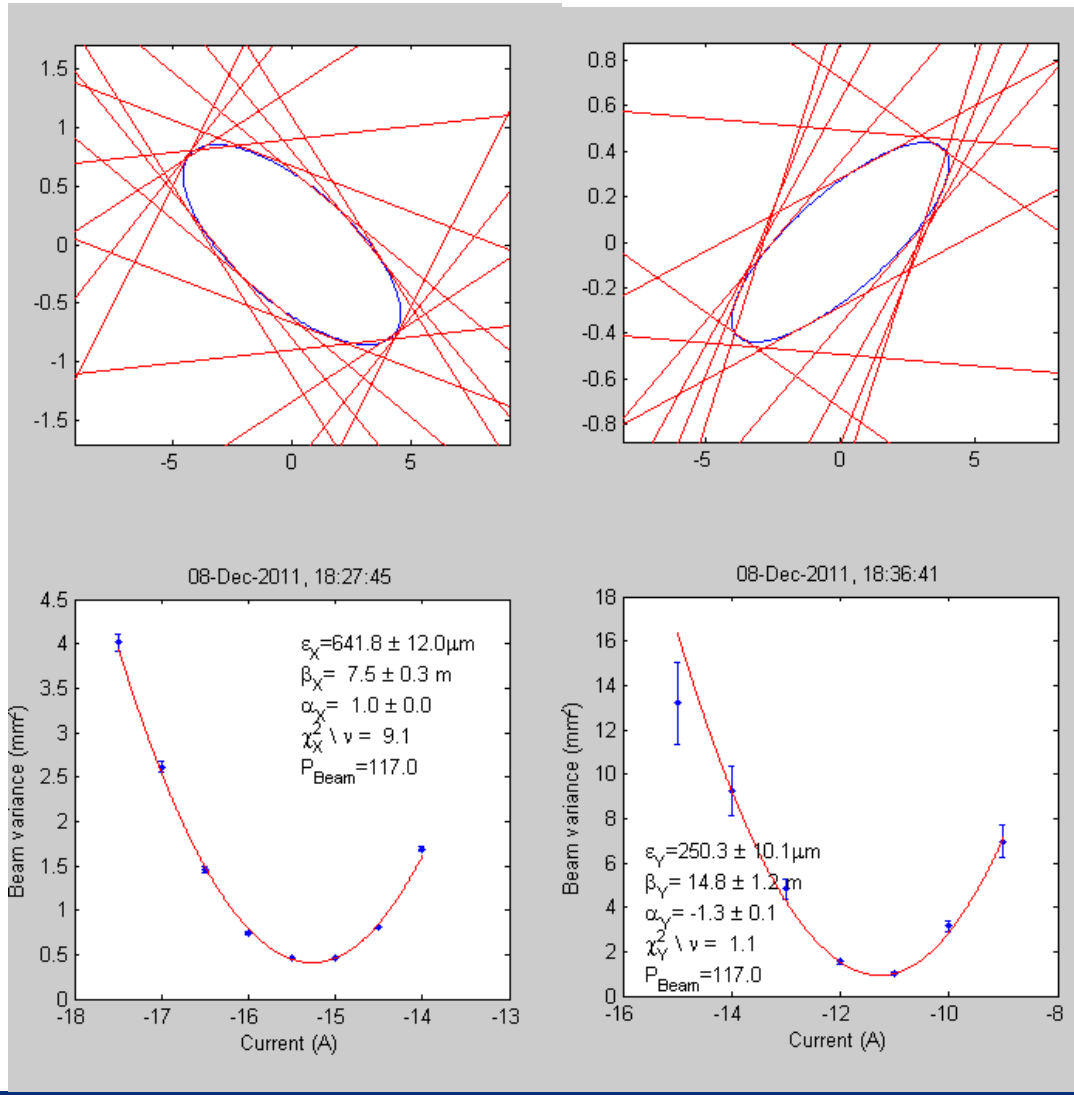


142 mm mrad



2011 Factor 8 Emittance

- Clearly, the biggest issue here is the orbit closure
  - We clearly see on the screens that the spot is made of few ones
- Not closed dispersion in the RF bump
- Bad orbit itself generates dispersion
- The large momentum spread combined with strong that we have (due to iso-chronicity requirement) also contributes
  - We should check if sextupoles can help here



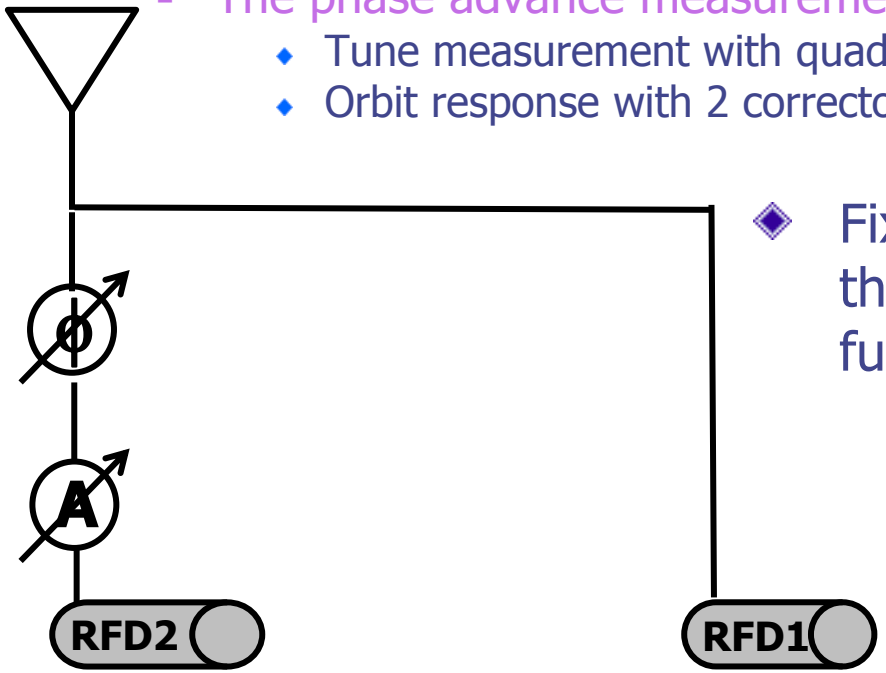
Summary: Issues and spaces calling for improvements

- Switches
- Misalignment in the Delay Loop
- R56 of Frascati Chicane; Spurious dispersion from Frascati that appeared in Aug 2010
  - spent already a lot effort to find the source -> no effect
  - Found a work-around by tuning a quad inside
  - Might be related to the difficulty of setting op smaller R56
- Optics check and control in TL2 and TBTS
- Orbit
- Closure in DL and CR => Emittance
  - Need additional attenuation for the 2nd RF deflector
- Chromatic corrections (need good orbit)
- Tune measurement and control in CR
- For both, DL and CR, beam trajectory is steered down when passing through or passing by the septa

ADDITIONAL SLIDES

RF deflector in CR

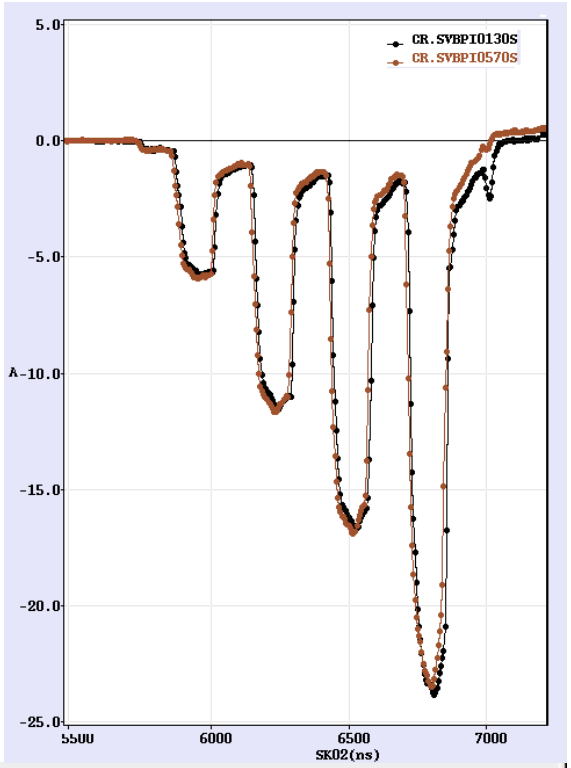
- We found that the RF deflectors in CR are disbalanced
  - It was inferred that longer waveguide to RFD1 has higher losses than than the short one with the variable attenuator and variable phase shifter to RFD2
  - However, with the minimal setting of the attenuator the kick from RFD1 is still bigger then from RFD2
- In principle, the phase advance in between the deflectors different from the nominal 180deg could also the reason
  - The phase advance measurements are in preparation
    - Tune measurement with quad strength modulation
    - Orbit response with 2 correctors (aka phase space painting)

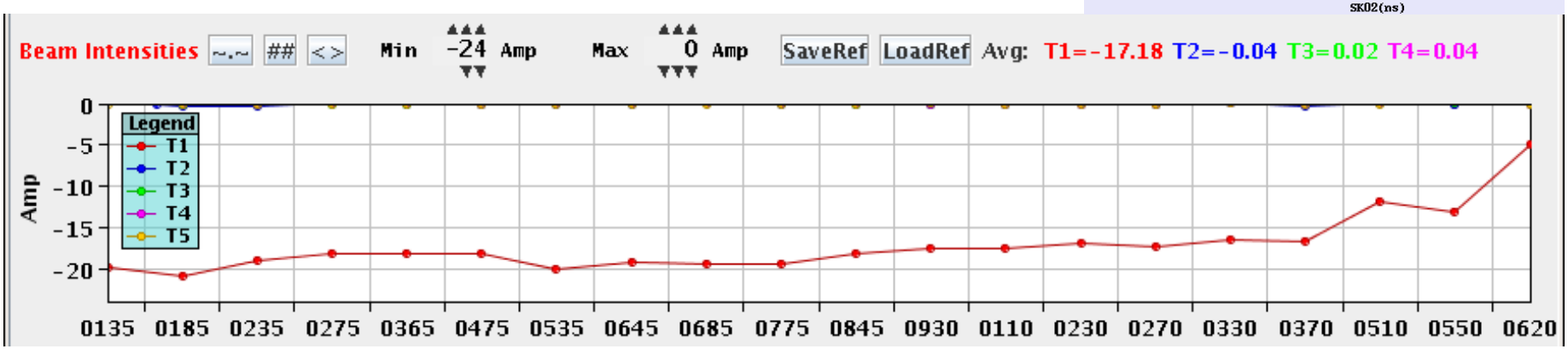


- Fixed 3dB attenuator will be installed in the waveguide to RFD1 what will give the full flexibility as it was designed

2010 Autumn Run

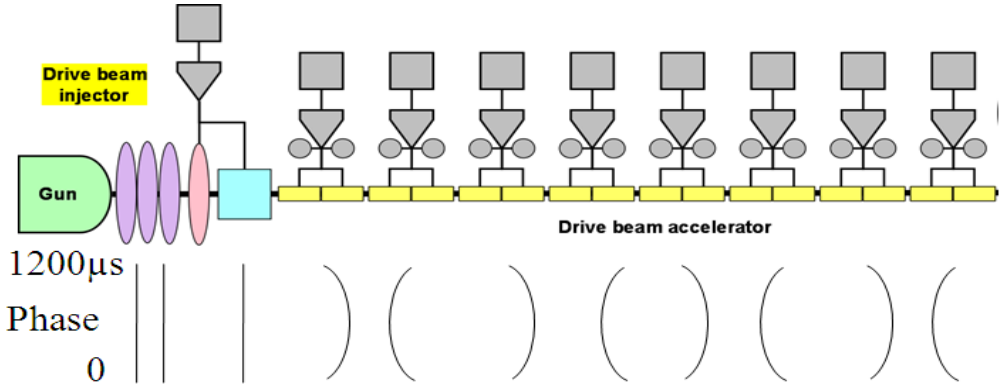
- Recombination factor 8
- Routinely delivered 15-16A
  - MKS13 was missing
    - Only 3.5A was accelerated in the Linac to keep energy 120MeV
  - One sub-harmonic buncher not powered due to failure of the power source (Travelling Wave Tube)
- The flatness of the pulse still not good
- Still losses in CR ejection and TL2
- Last week of 2010 run 2nd TWT fails
  - Came back from reparation in TMD only in July 2011
    - Most of 2011 run was with 3GHz, factor 4 recombined beam

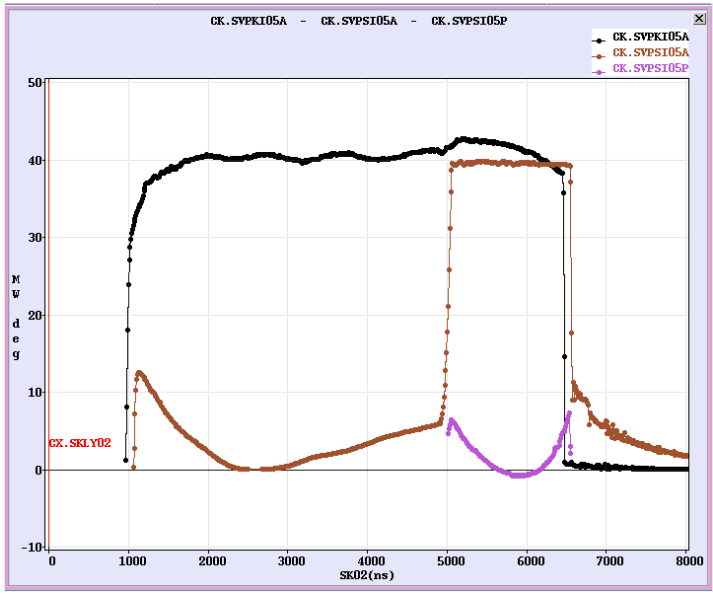


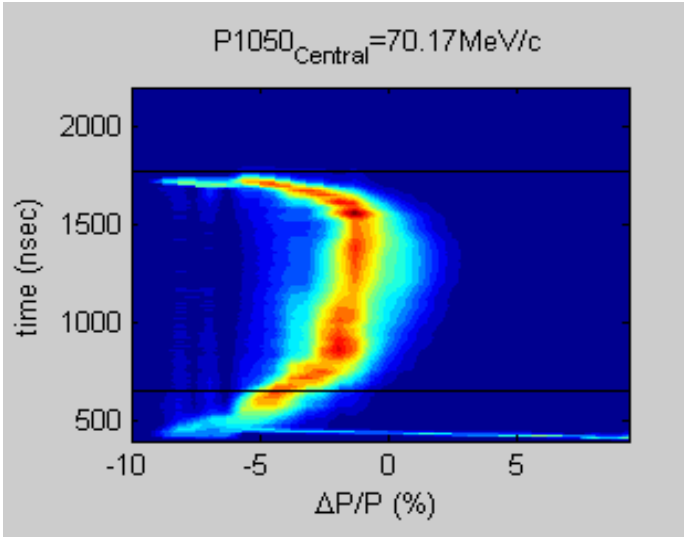


Acceleration RF phase sag

- The pulse compression introduces inevitable phase sag of 7-10 deg
- Phases are set inversely for consecutive klystrons
  - In order to minimize single bunch energy spread variation along the pulse



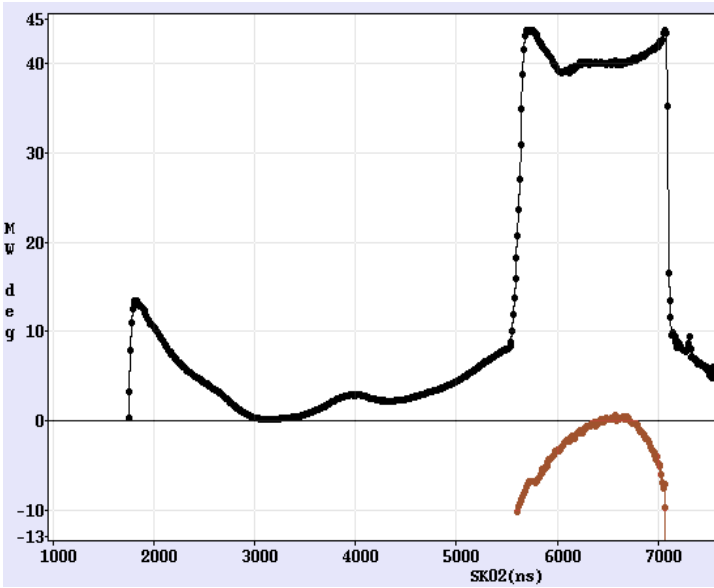


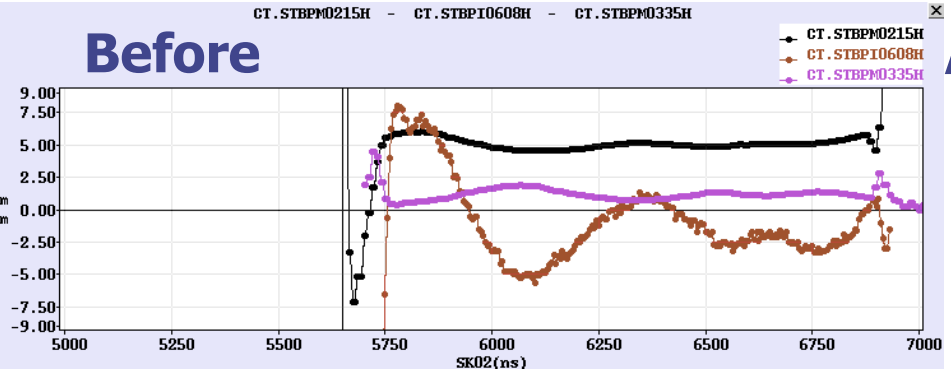


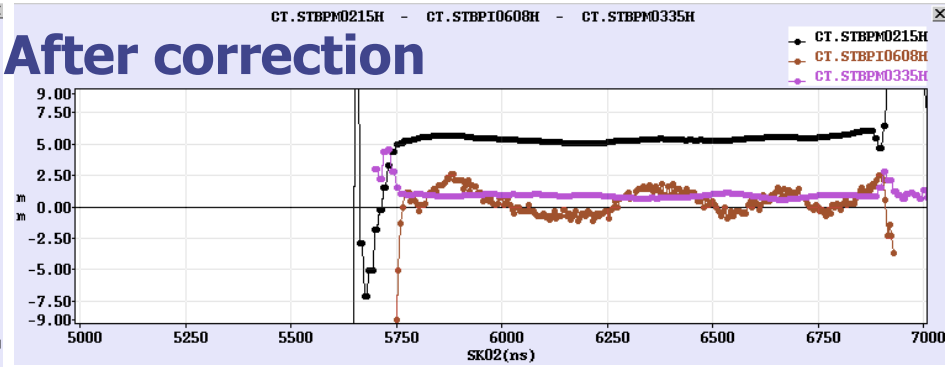
- This leads to **energy** and **bunch spacing** variation along the pulse

Acceleration RF phase sag

- The effects were eventually reduced by shaping power RF
- However, large bunch phase variation still present

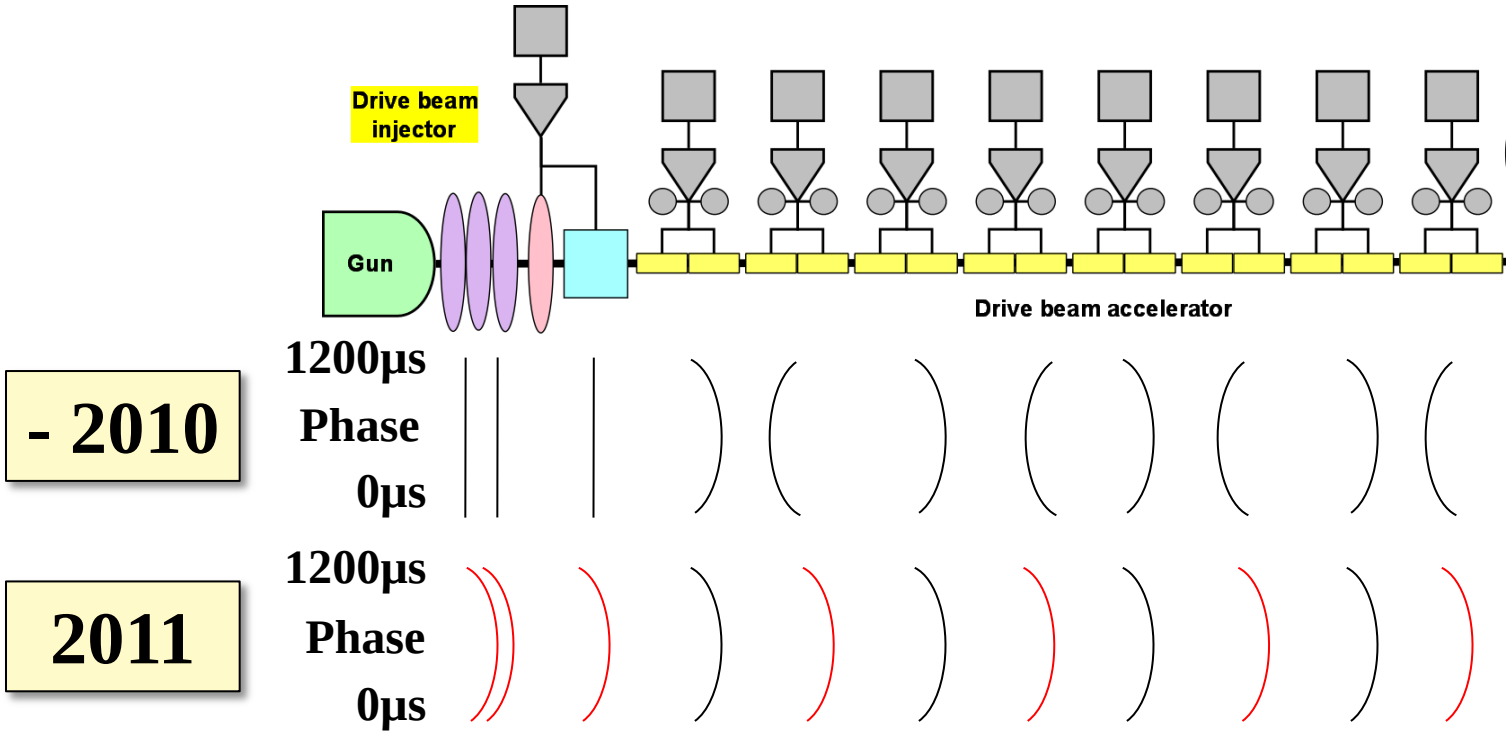






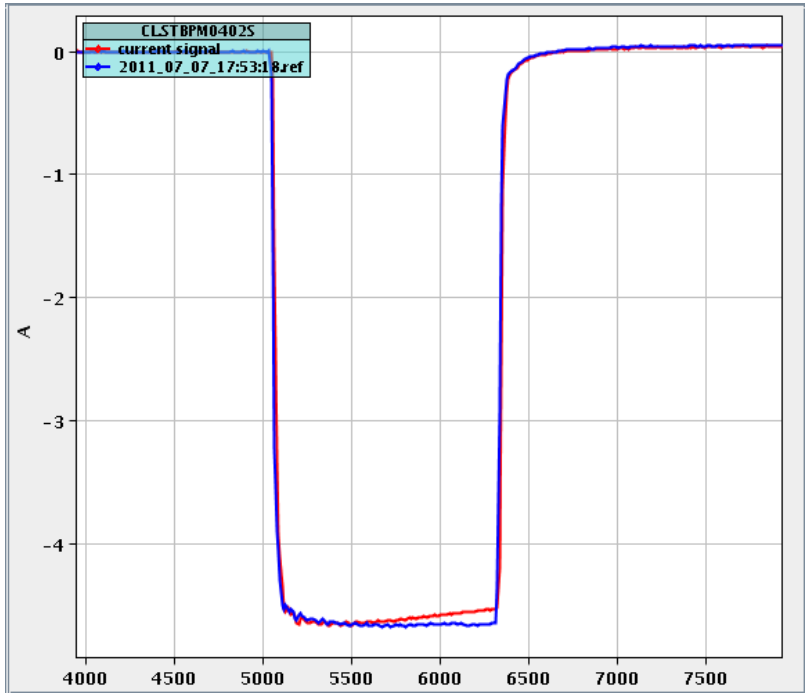
Improved RF setup scheme

- This year new scheme was introduced
  - All pulses are set the same way
  - The same sag is introduced the injector RF
    - The RF sources in the injector were equipped with programmable wave form generators to reproduce the sag



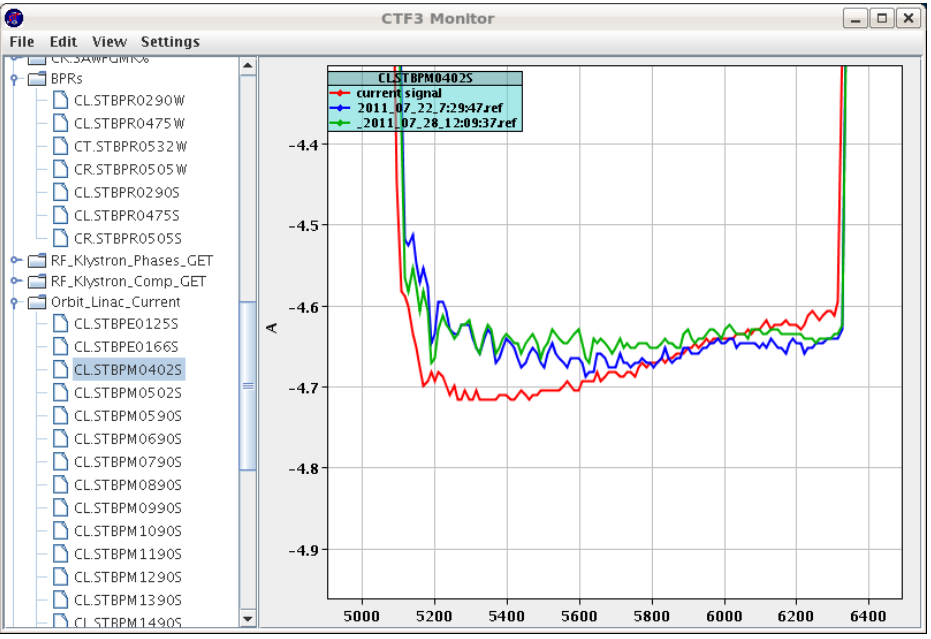
Gun current droop correction

- The current delivered from the gun was not constant along the pulse due to high voltage droop
- Correction implemented with programmable wave form generator with an amplifier "hooked" to the pulser



Machine stability and reproducibility

- Since autumn 2010 all devices are monitored
  - It allows to spot quickly sources of the beam jitter and the drifts
  - The same software stores reference for all signals of a given machine configuration
    - Permits to recover quickly the desired conditions

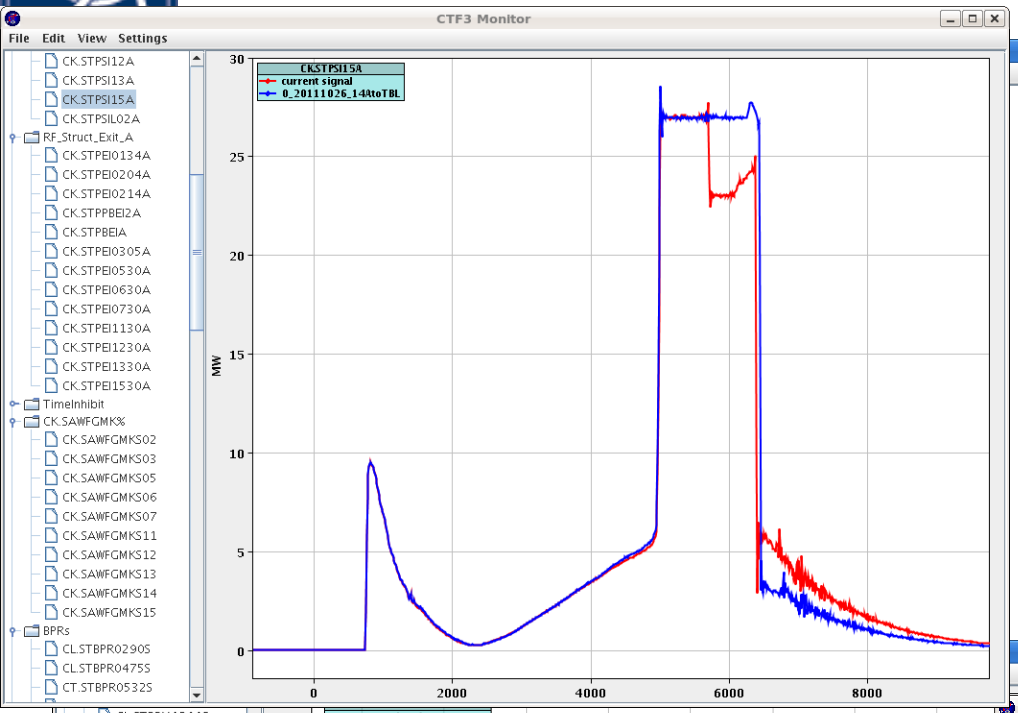


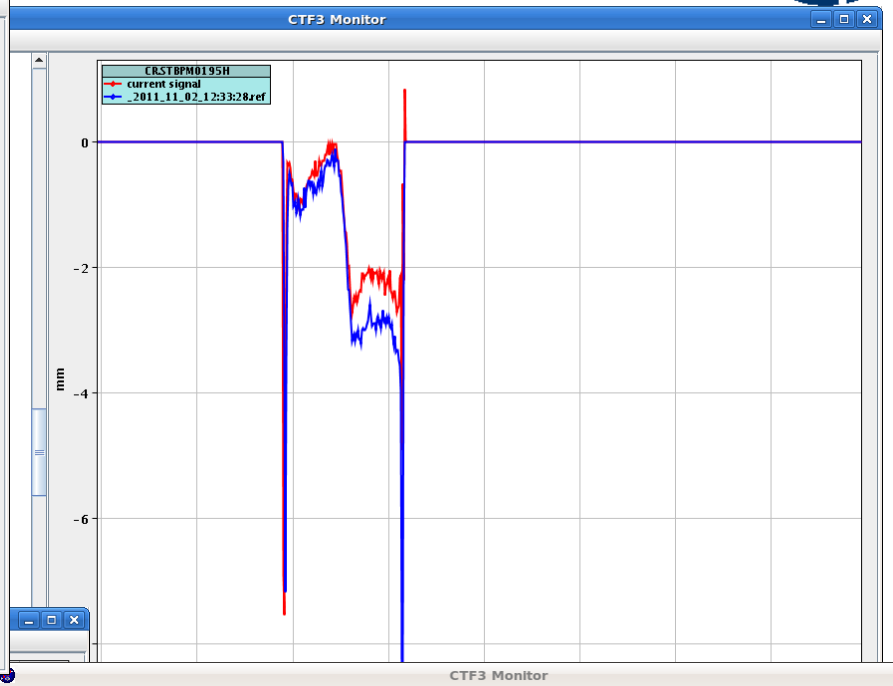
Example of CTFMonitor use:
The gun flattening got disabled

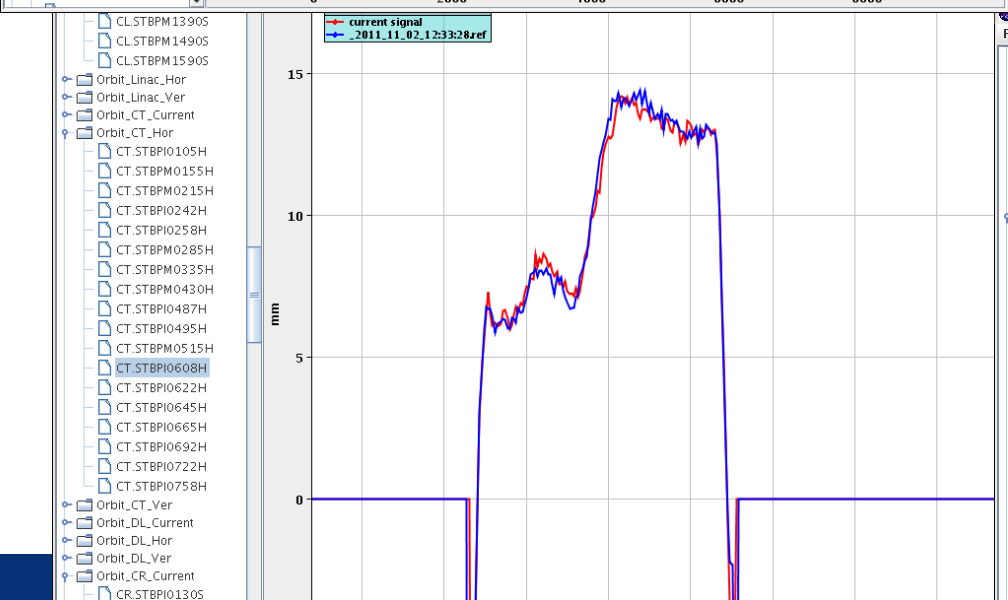
Feed-backs

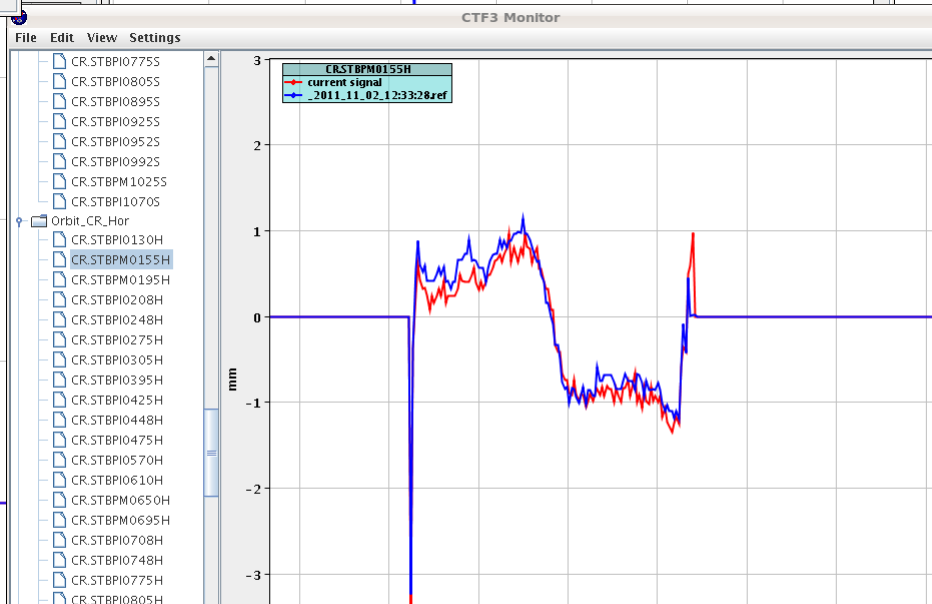
- Several drift/jitter sources were identified and feed-backs put in place, predominantly in RF
  - Klystron phase
  - Coolant temperature for the RF pulse compression cavities correcting the ambient temperature change in the klystron gallery
    - Beam was acting as a thermometer of klystron gallery
  - RF pulse flatness feedback
  - Few others in preparation and tests
    - Klystron phase correction to keep constant beam loading
    - Phase of injector RF to keep bunch length and the produced 12GHz RF power stable

Dispersion: energy step

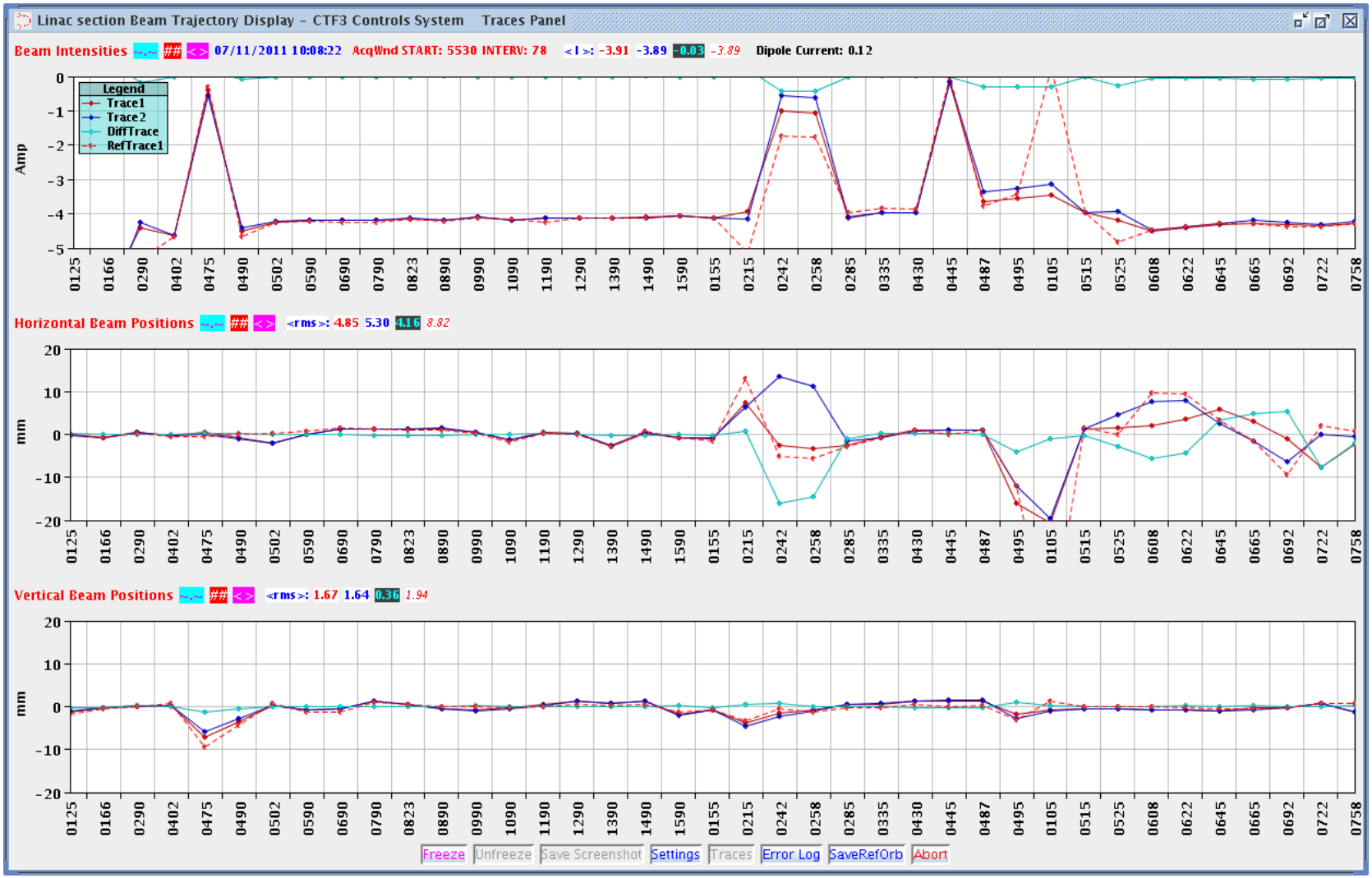




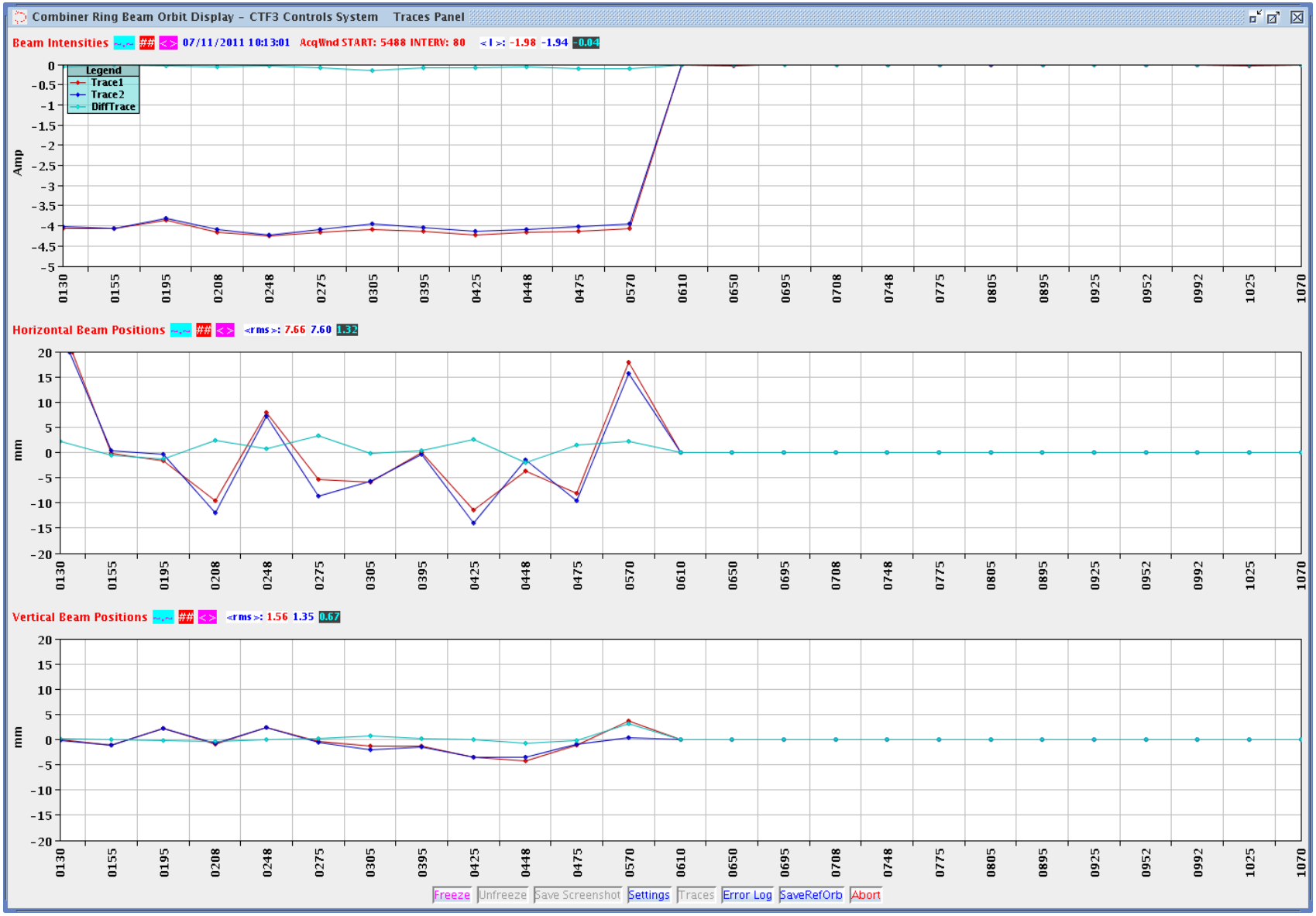




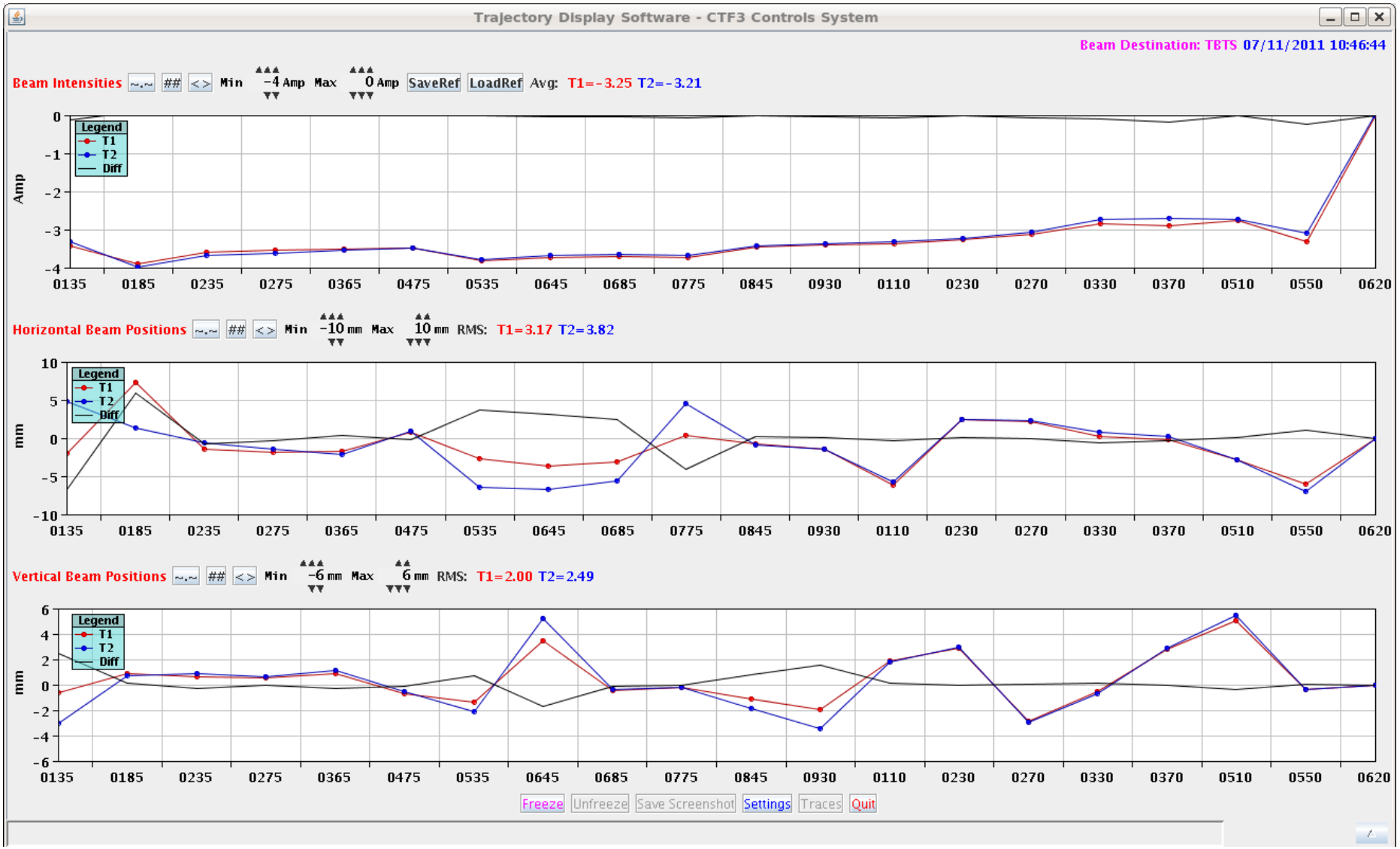
Dispersion with step TL1



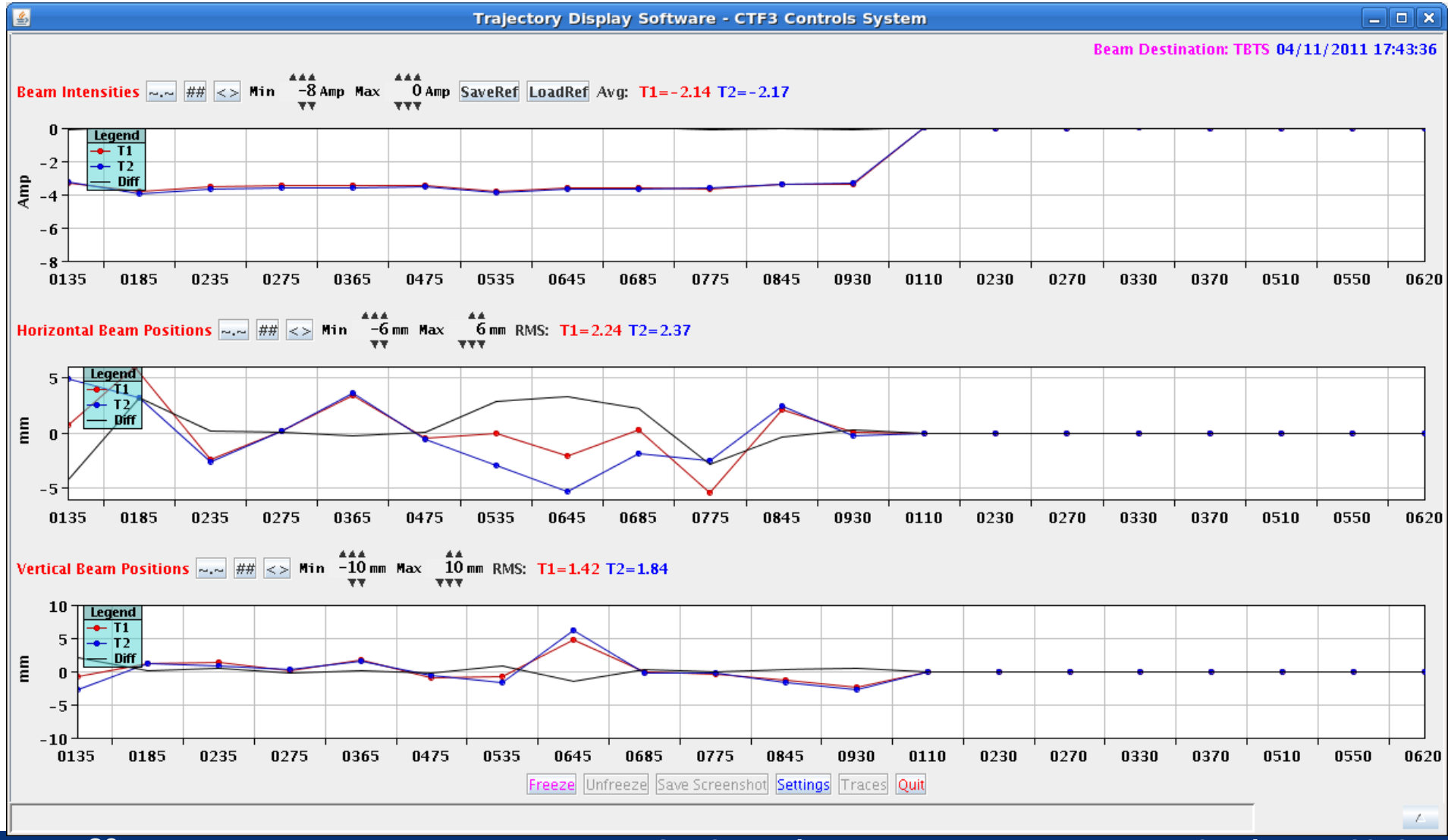
Dispersion with step CR



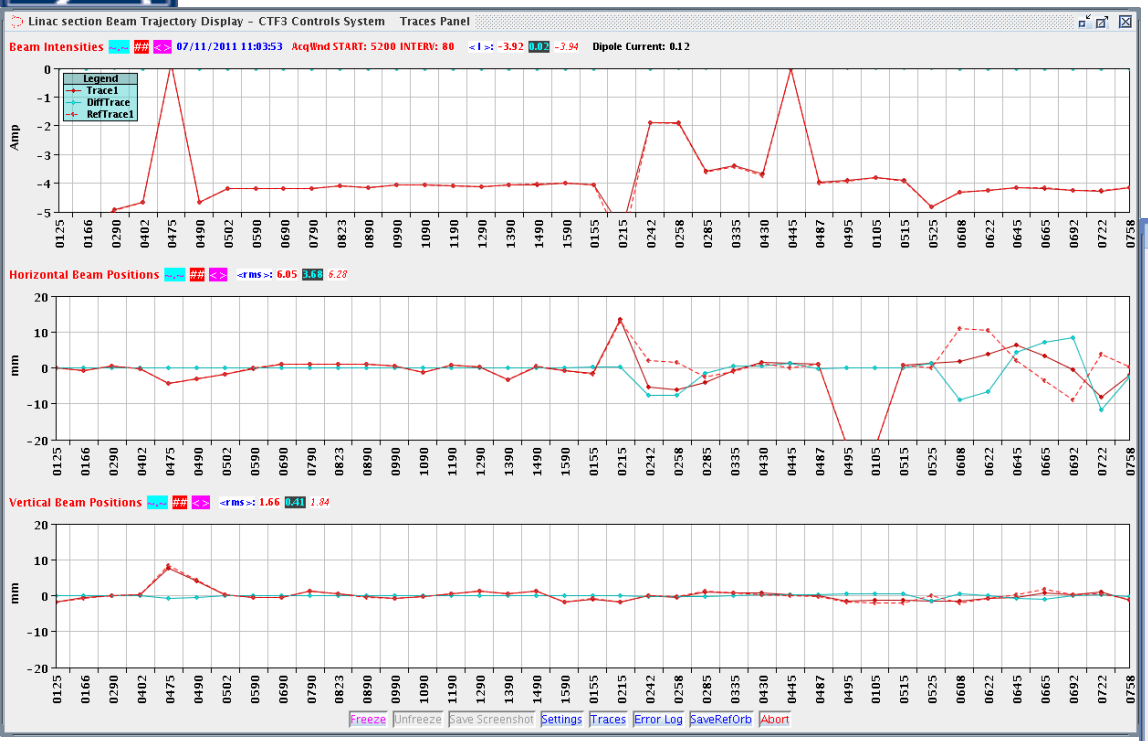
Dispersion with step TL2

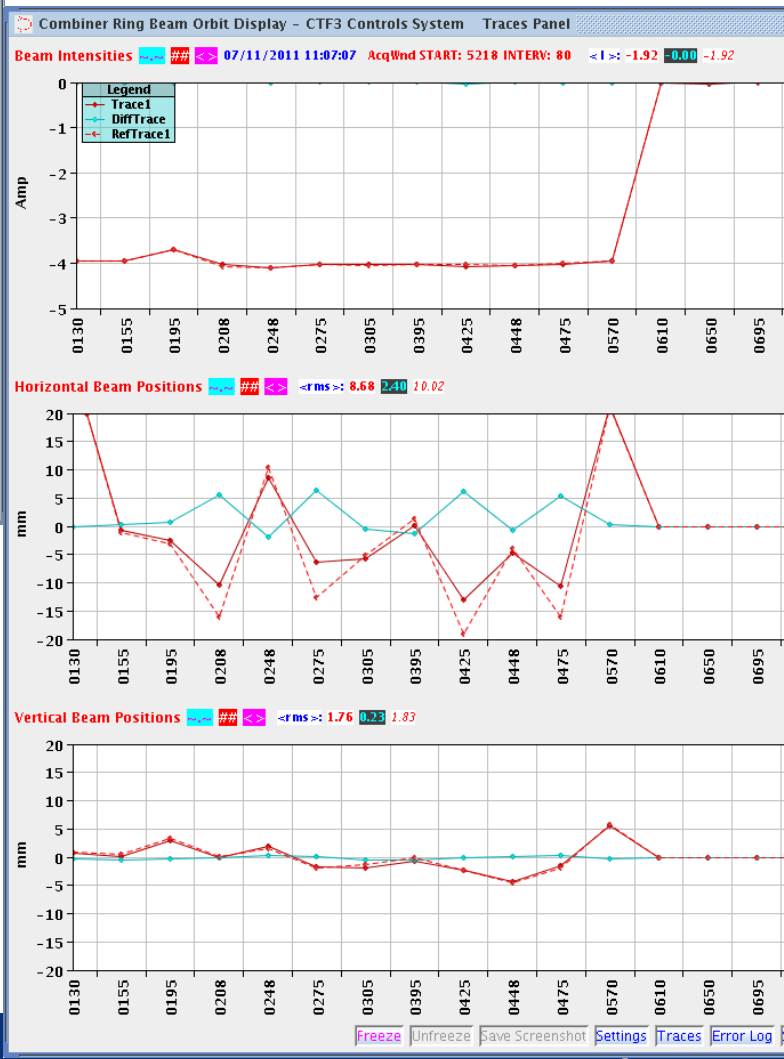


Dispersion with step TL2



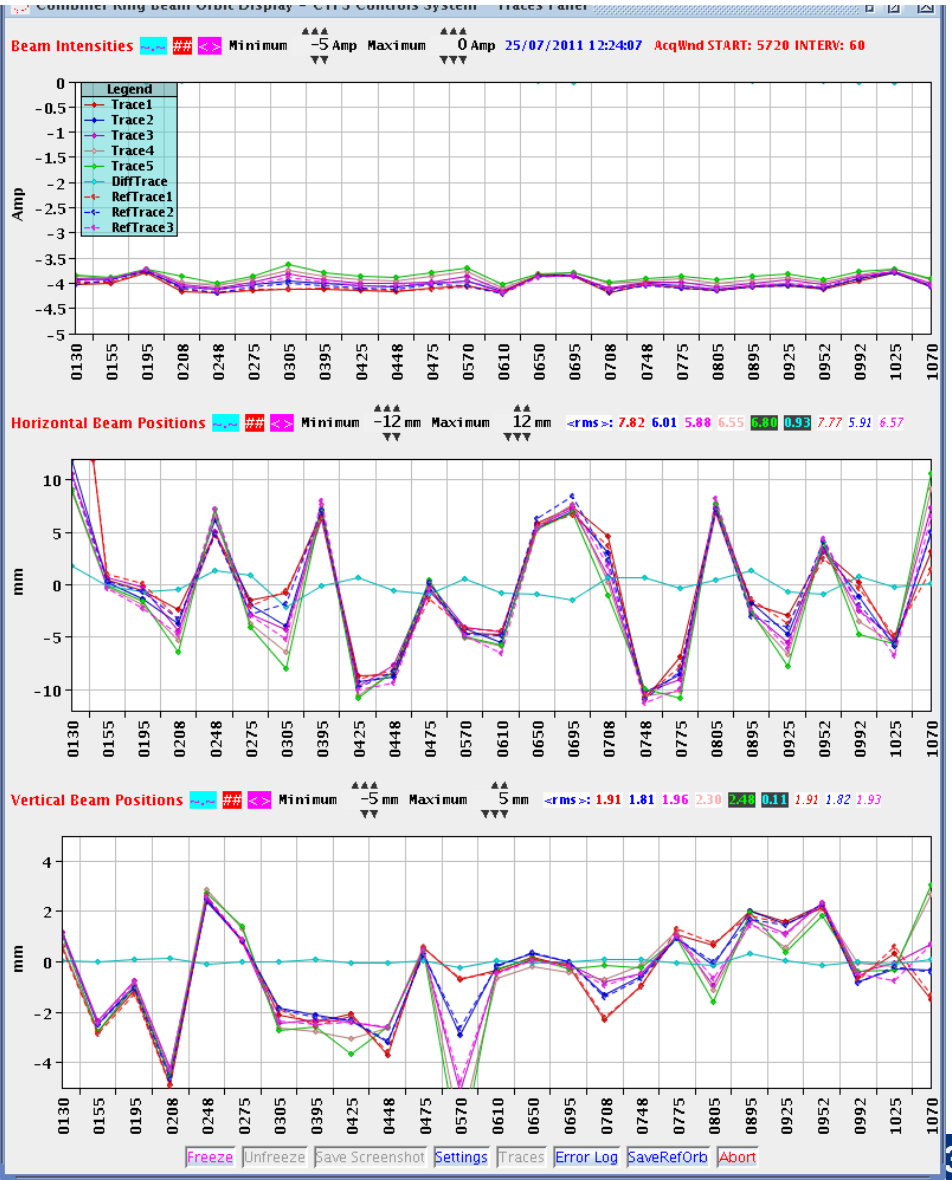
Dispersion girder 15 power change

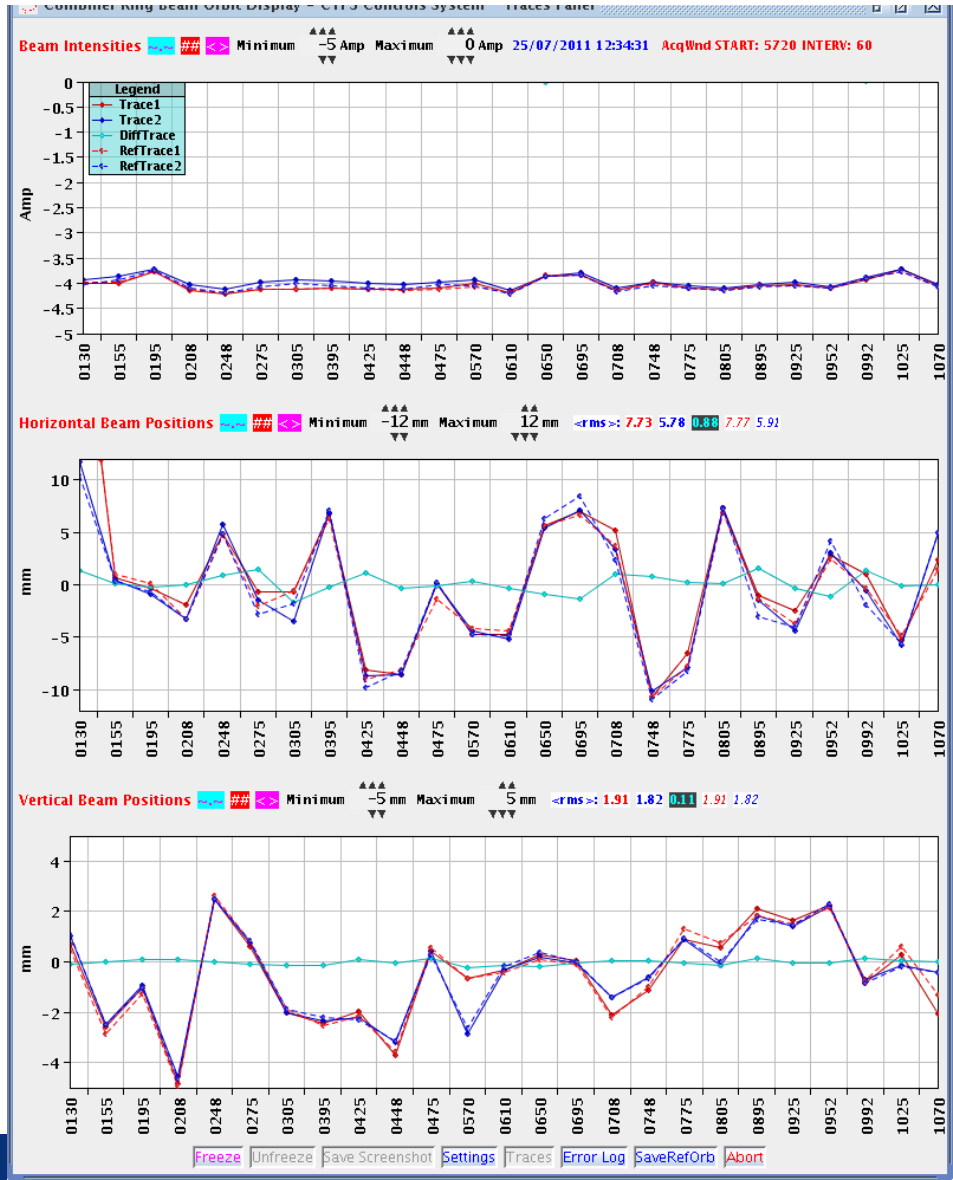




CR closure

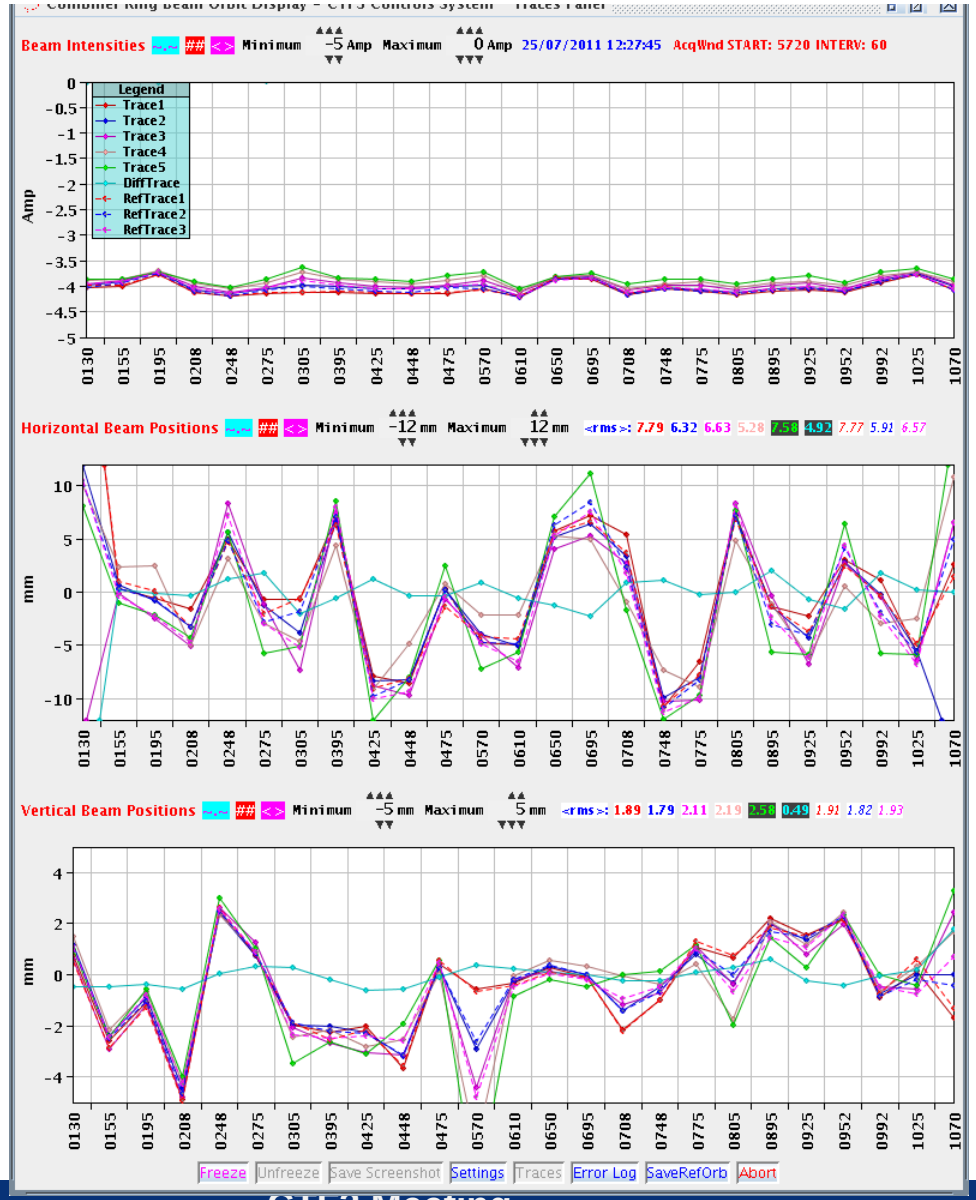
Moving RF defl to the 2nd turn does not change the orbit.
Difference is the reference with defl end after inj and the orbit with RF defl in the second turn,



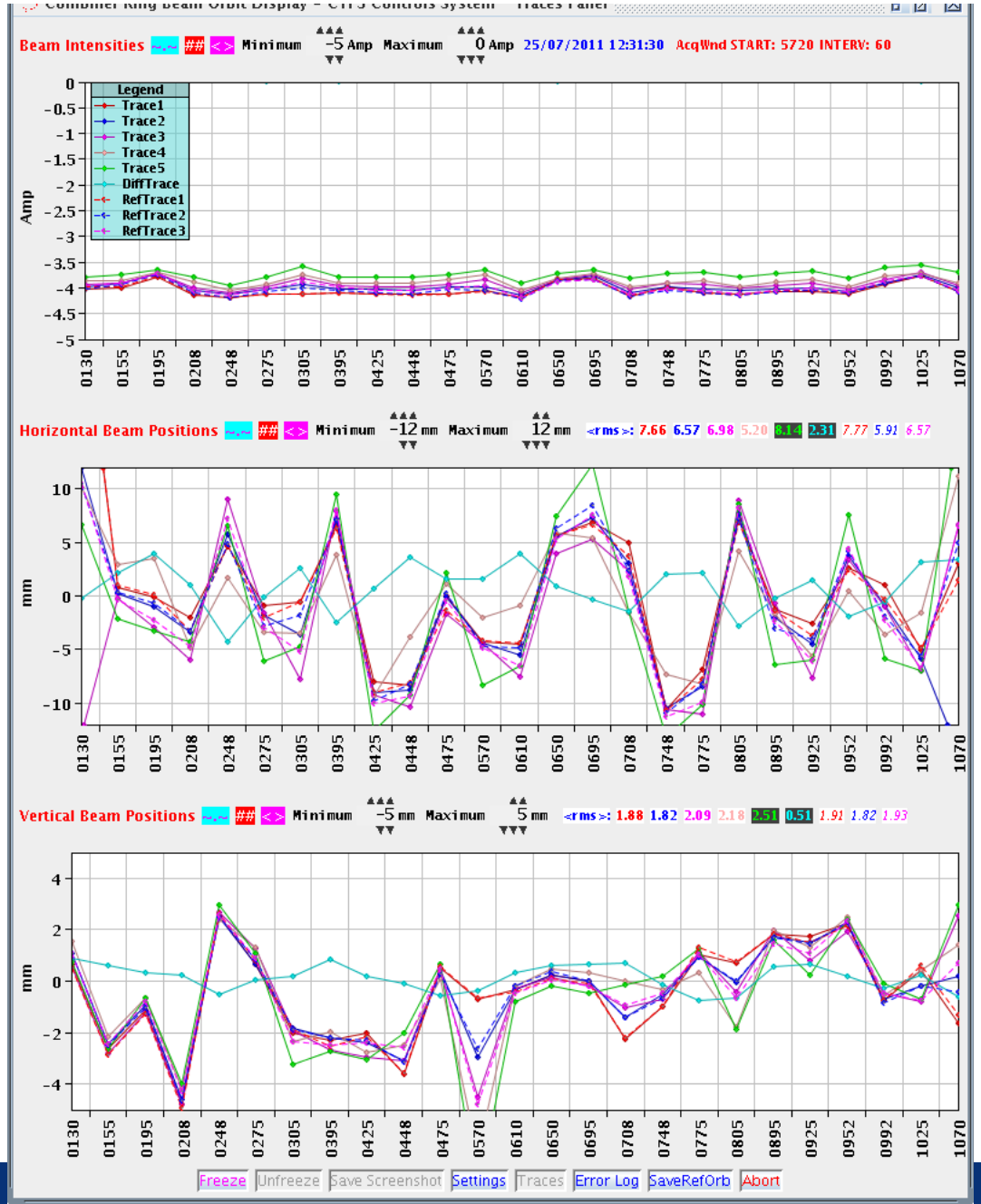


CR closure

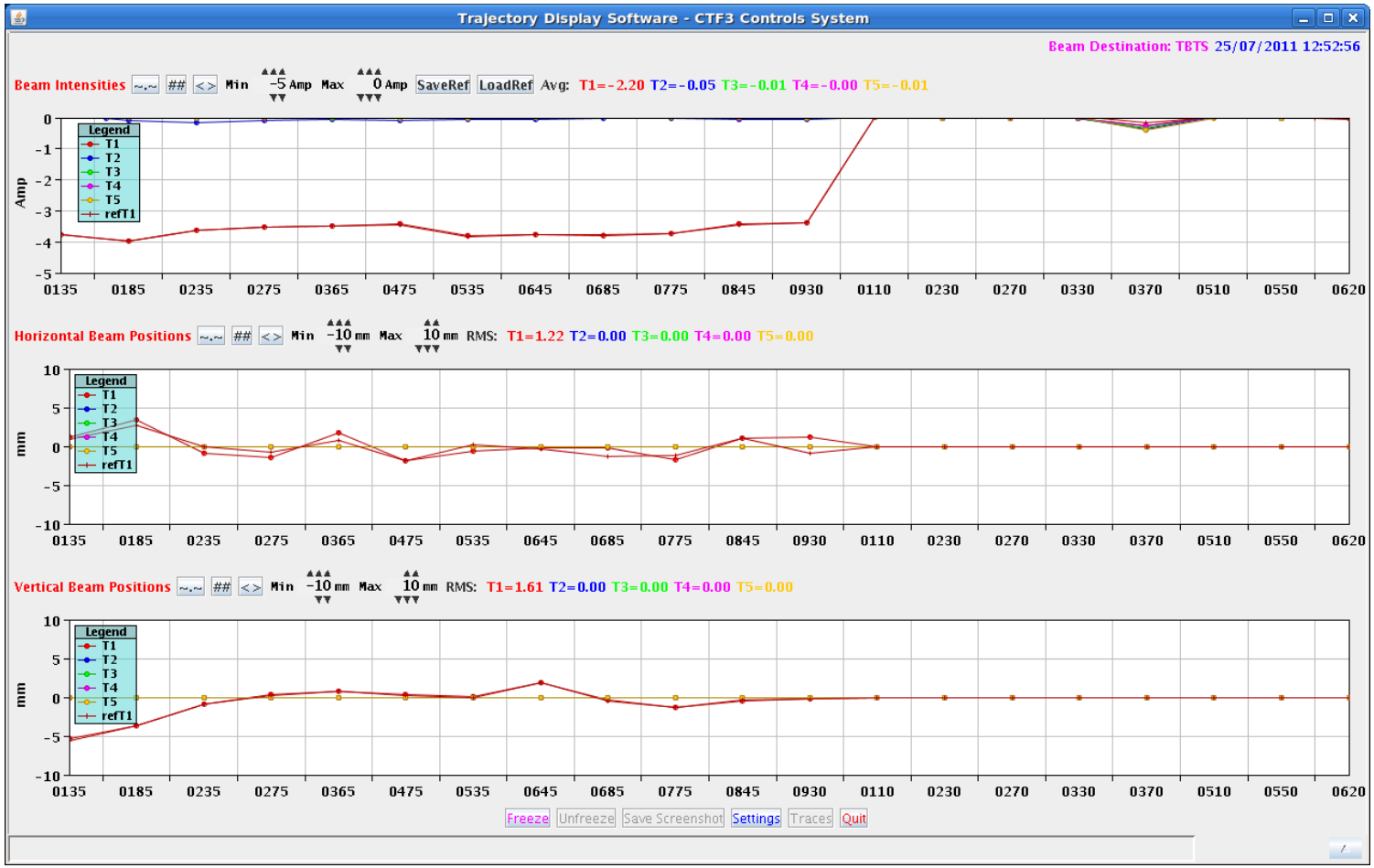
Moving RF defl on the 3rd turn. The orbit is clearly changed. Plotted diff of ref of orbit 3 and orbit 3. Min difference at 570 of MKS14-PHAS



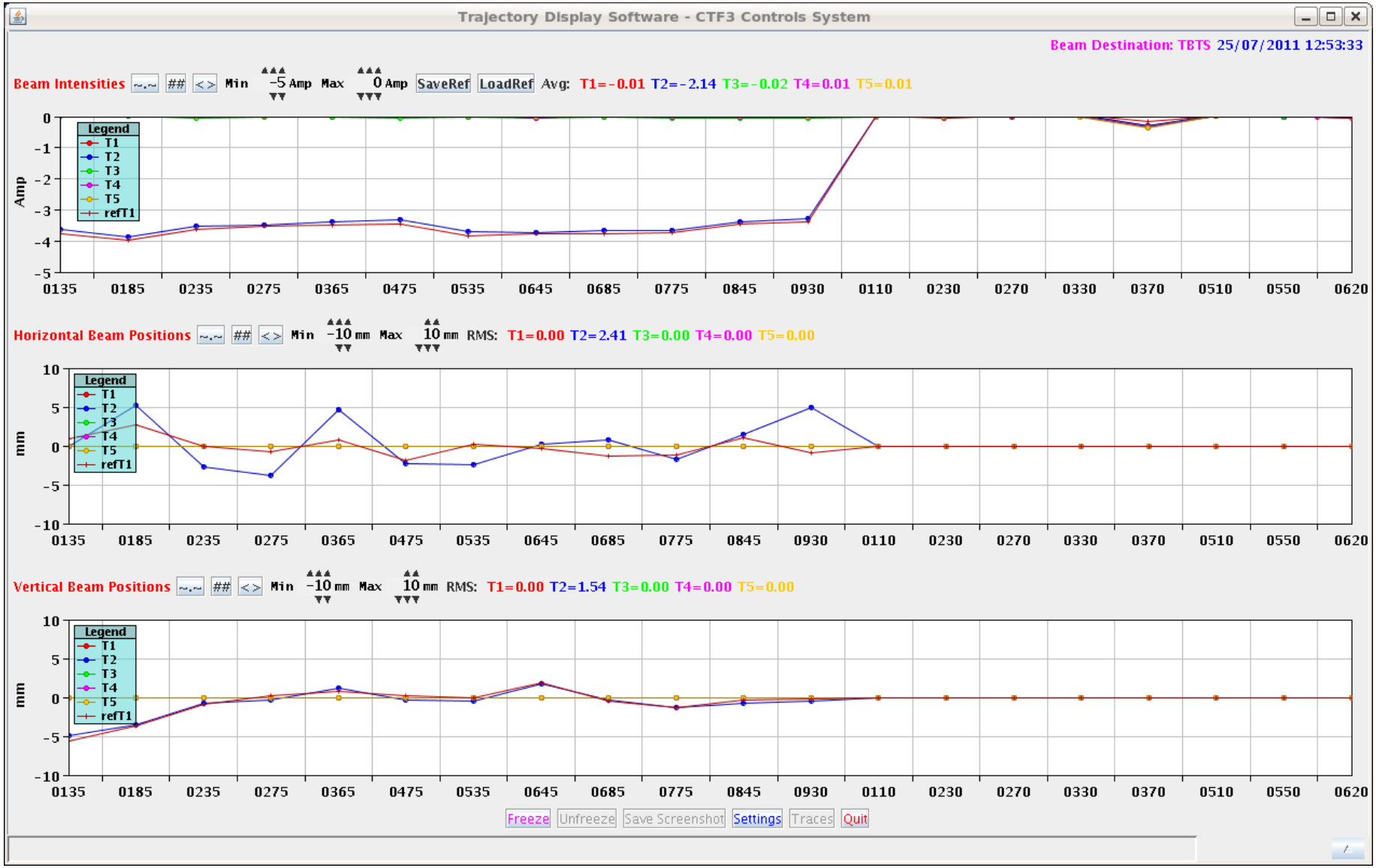
CR closure


Beam Intensities
Minimum -5 Amp Maximum 0 Amp 25/07/2011 12:31:30 AcqWnd START: 5720 INTERV: 60
Legend
Trace1
Trace2
Trace3
Trace4
Trace5
DiffTrace
RefTrace1
RefTrace2
RefTrace3
Amp
Horizontal Beam Positions
Minimum -12 mm Maximum 12 mm
<rms>: 7.66 6.57 6.98 5.20 3.14 2.31 7.77 5.91 6.57
mm
Vertical Beam Positions
Minimum -5 mm Maximum 5 mm
<rms>: 1.88 1.82 2.09 2.18 2.51 0.51 1.91 1.82 1.93
mm
0130 0155 0195 0208 0248 0275 0305 0395 0425 0448 0475 0570 0610 0650 0695 0708 0748 0775 0805 0895 0925 0952 0992 1025 1070
Freeze
Unfreeze
Save Screenshot
Settings
Traces
Error Log
SaveRefOrb
Abort

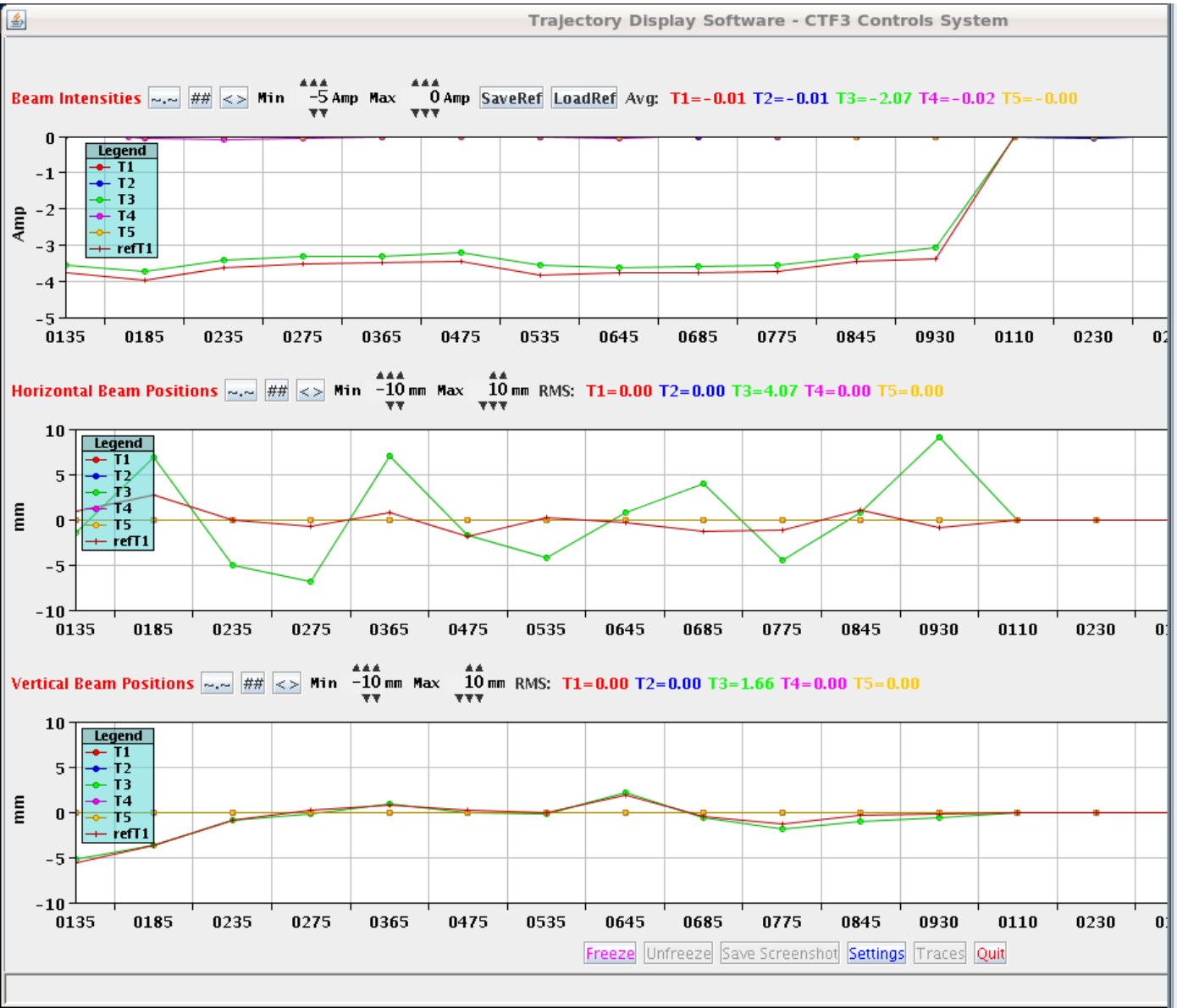
CR closure
TL2 orbit for different turns

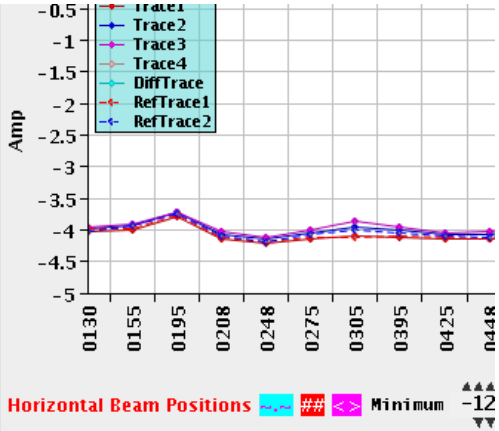


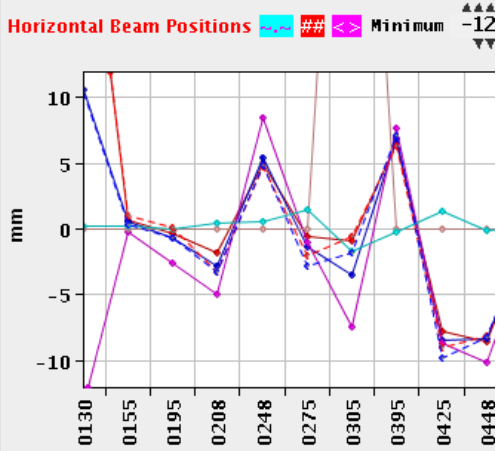
CR closure
TL2 orbit for different turns (2nd)

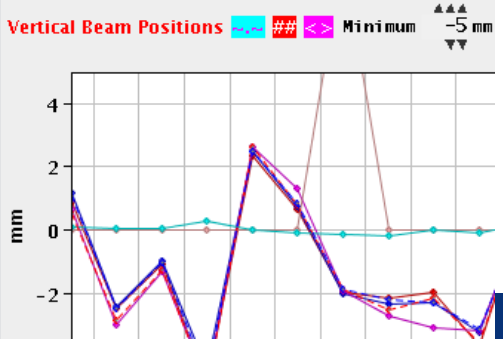


CR closure
TL2 orbit for different turns (3rd)

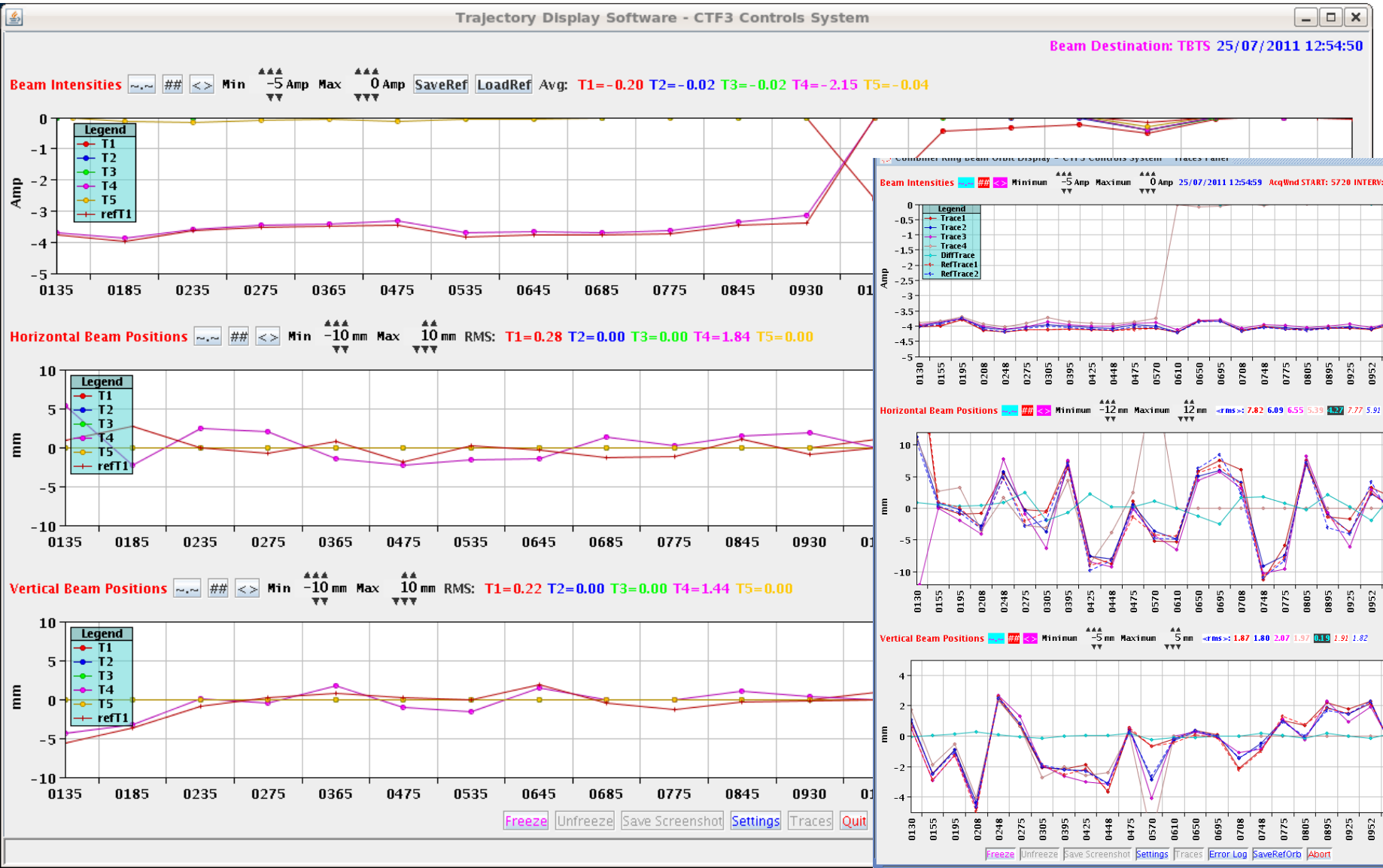




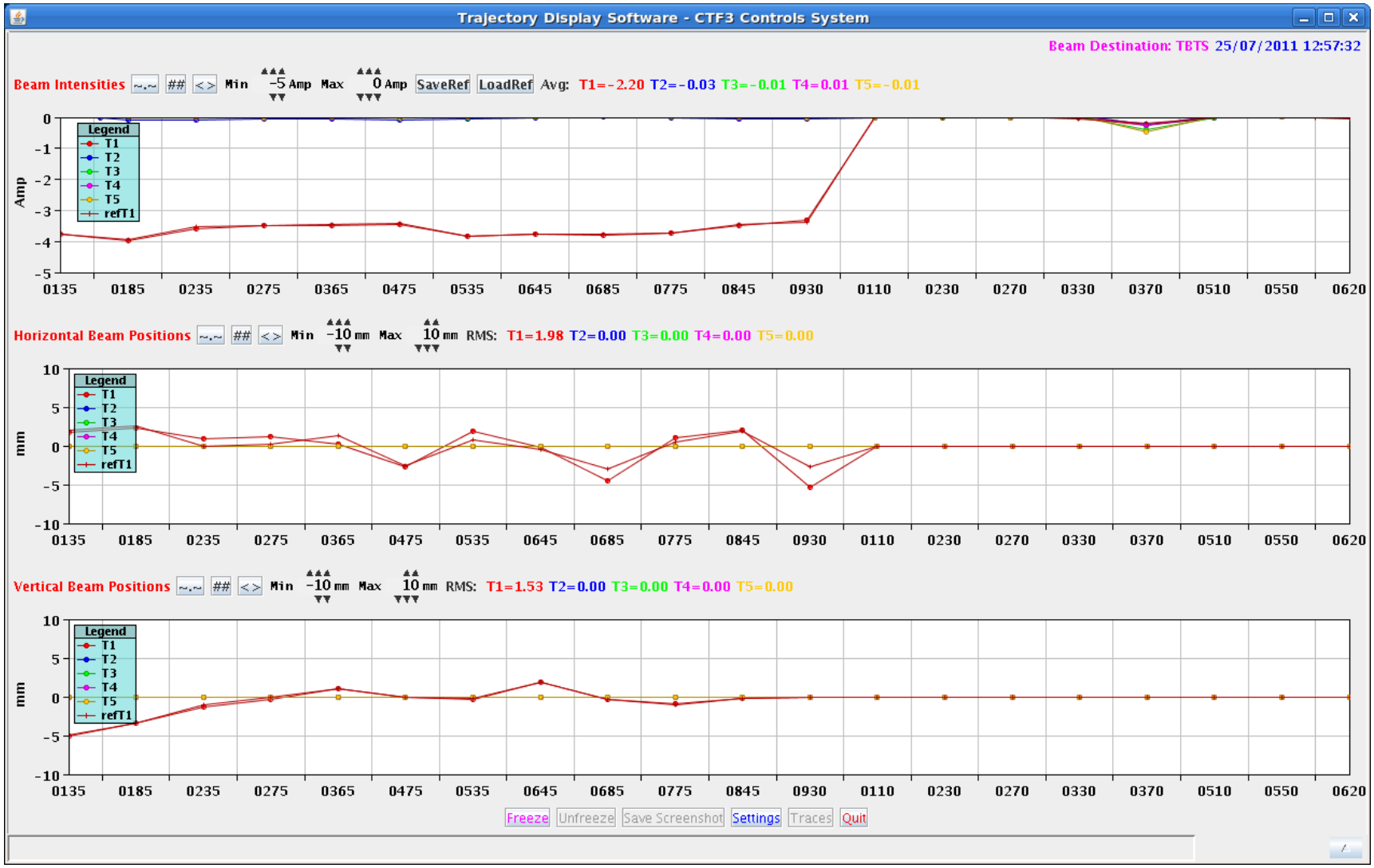




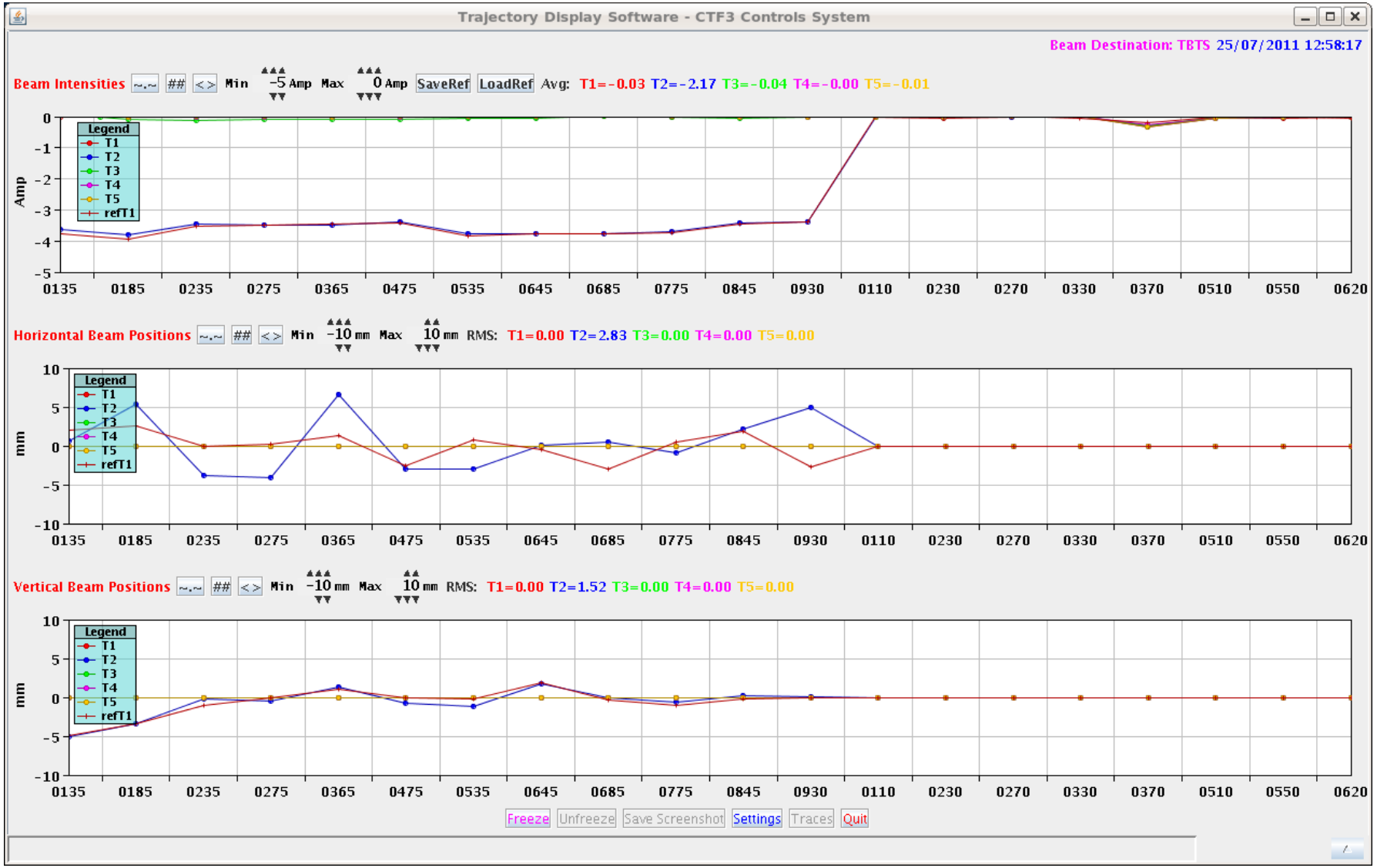
CR closure
TL2 orbit for different turns (4th)



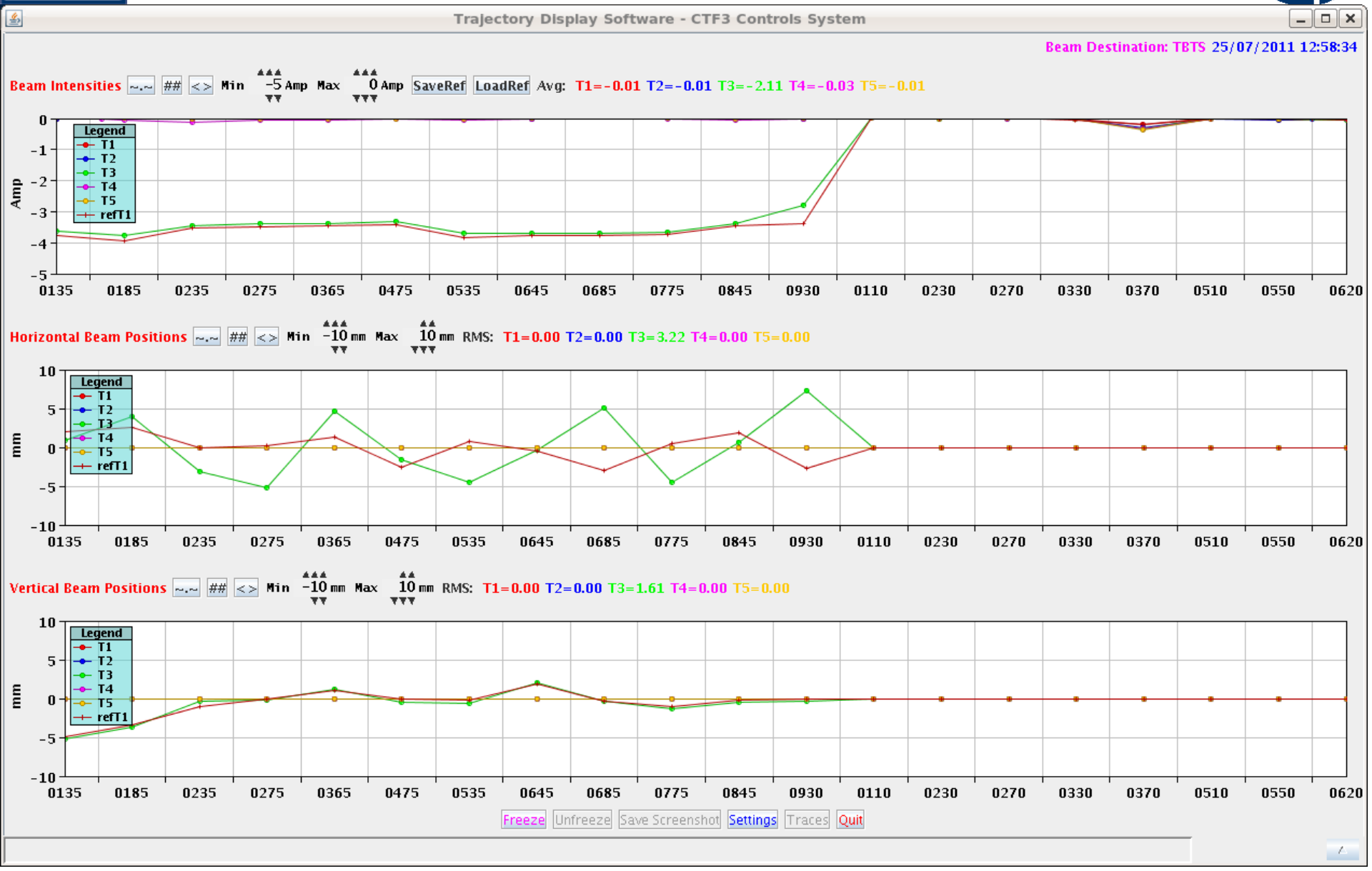
CR closure - improved TL2 orbit for different turns



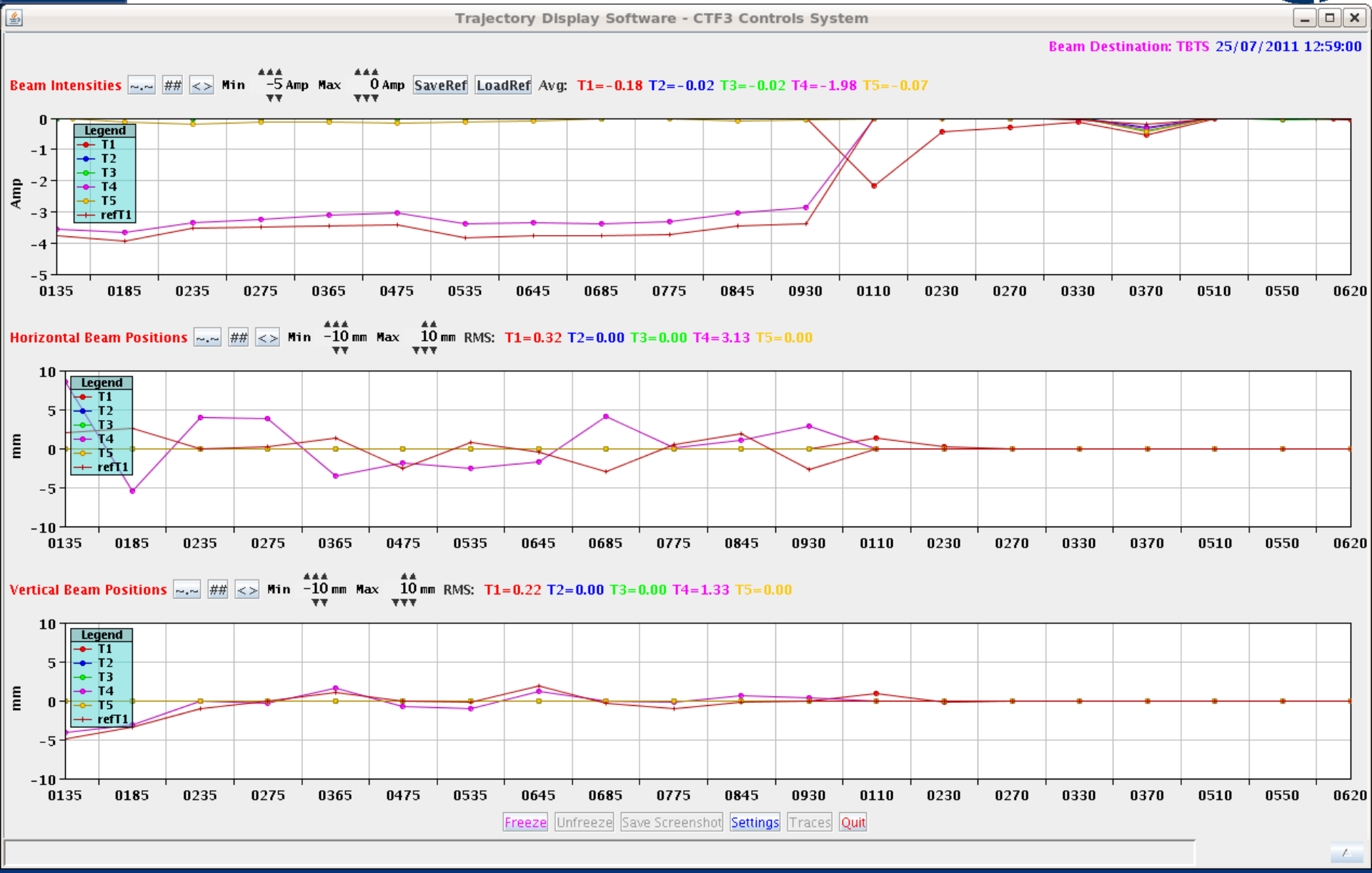
CR closure - improved TL2 orbit for different turns (2nd)



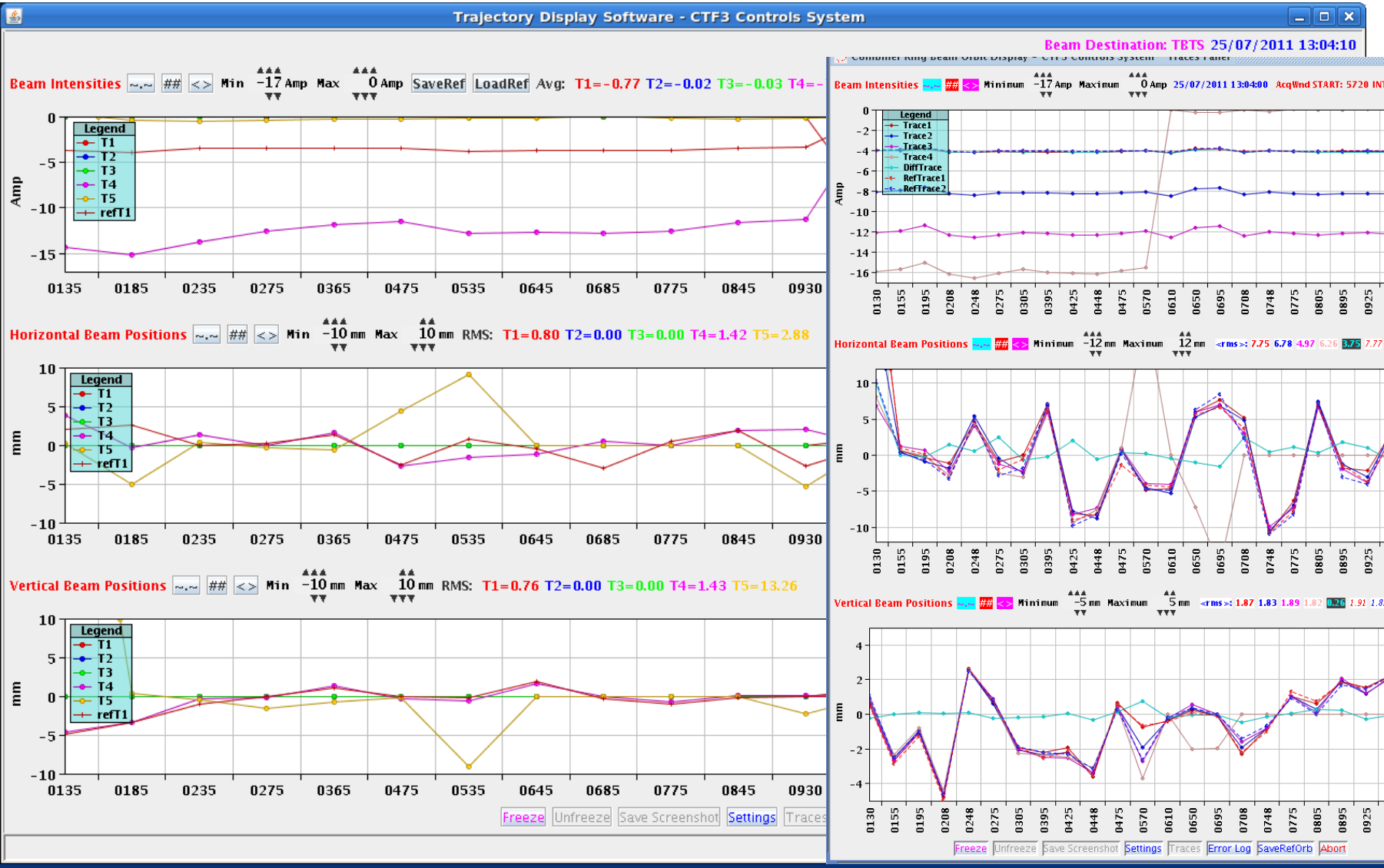
CR closure – improved avg TL2 orbit for different turns (3rd)



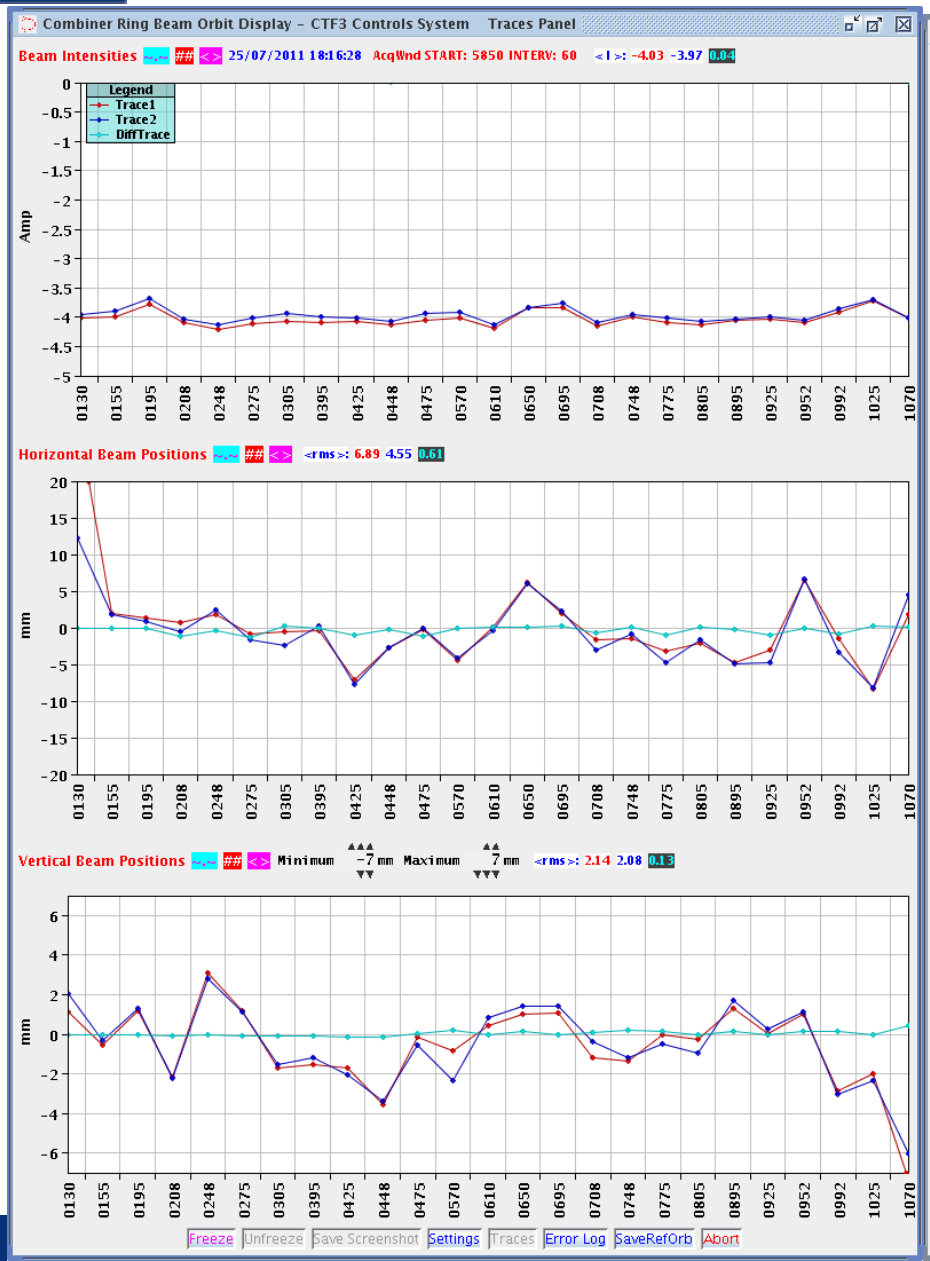
CR closure - improved TL2 orbit for different turns (4th)

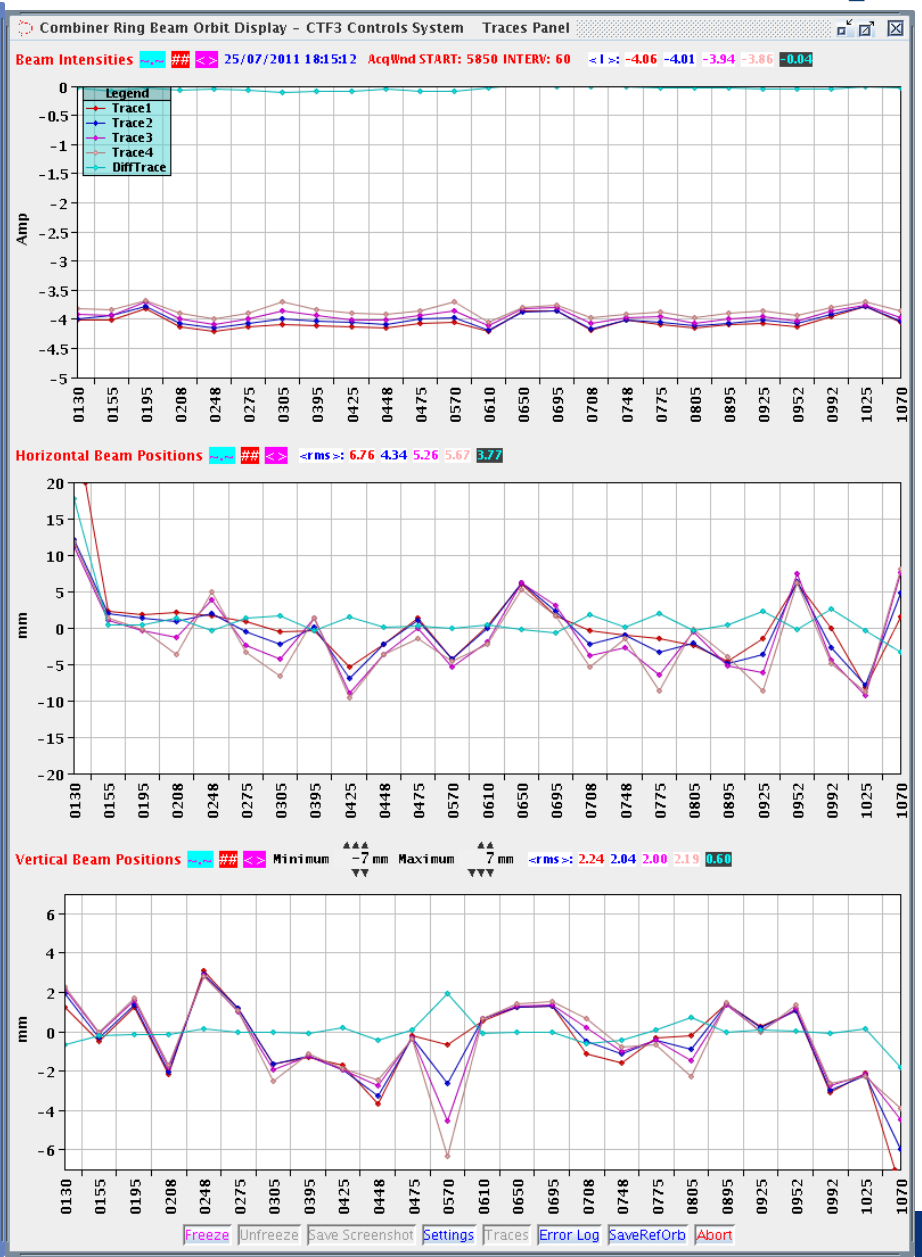


CR closure – improved avg Combined



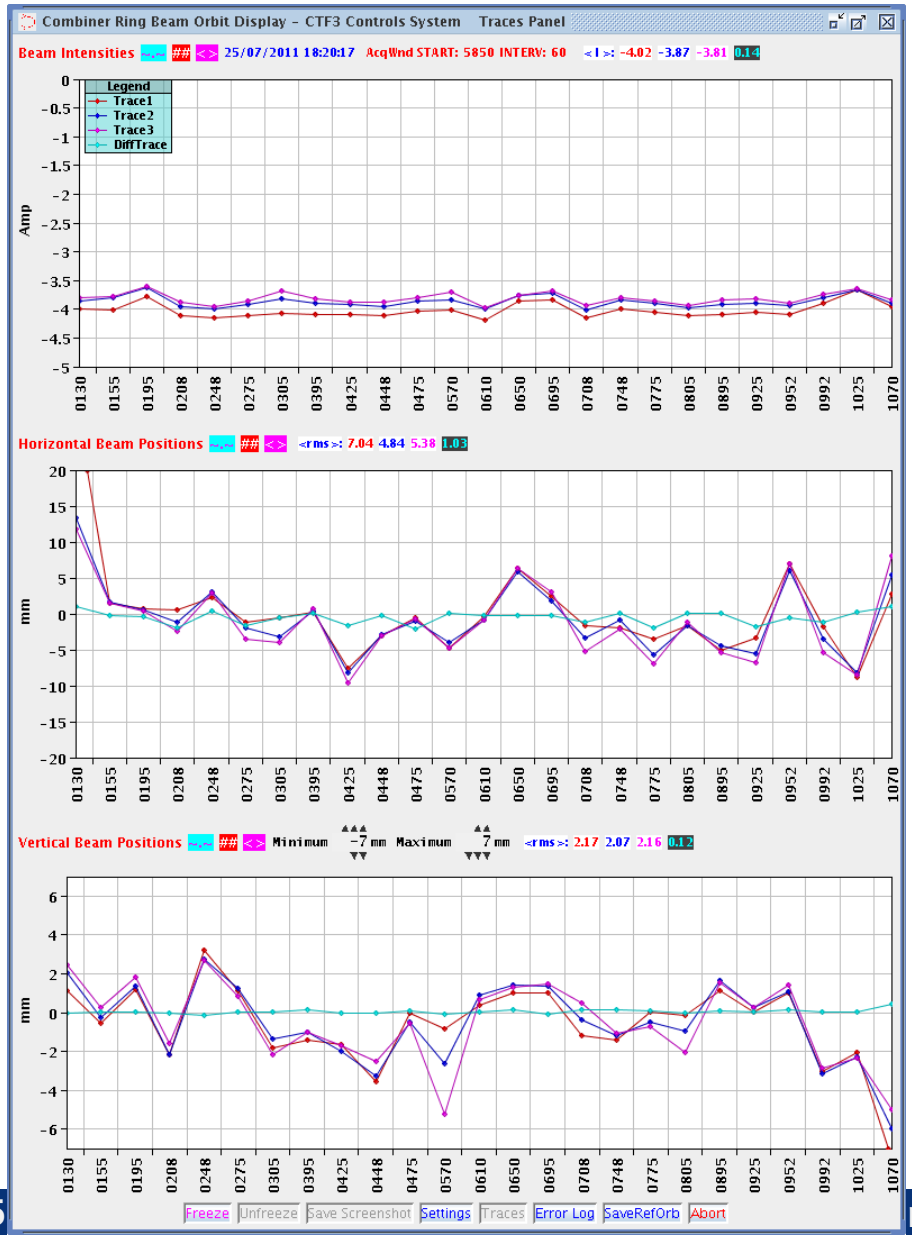
Closing CR attempt 2
RF defl stopped after injection



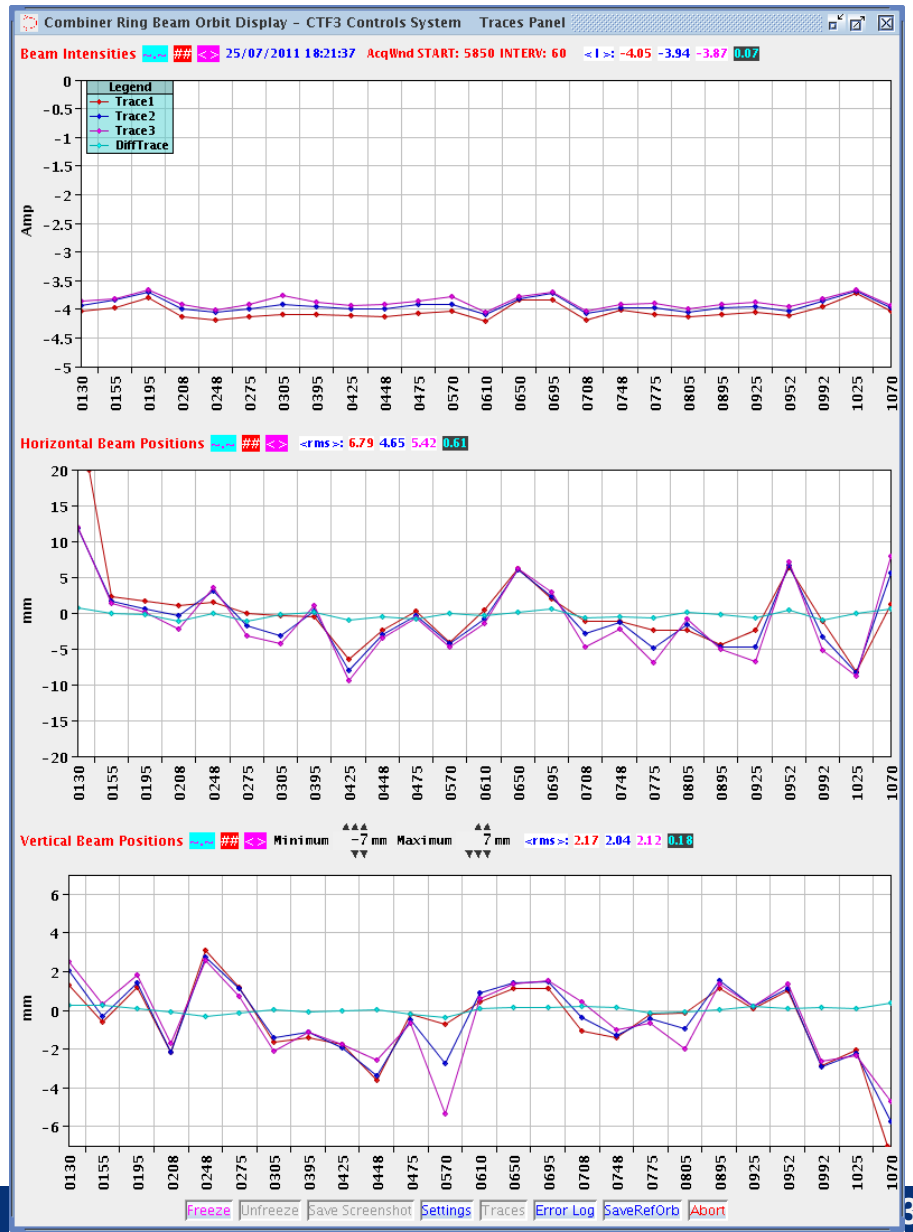


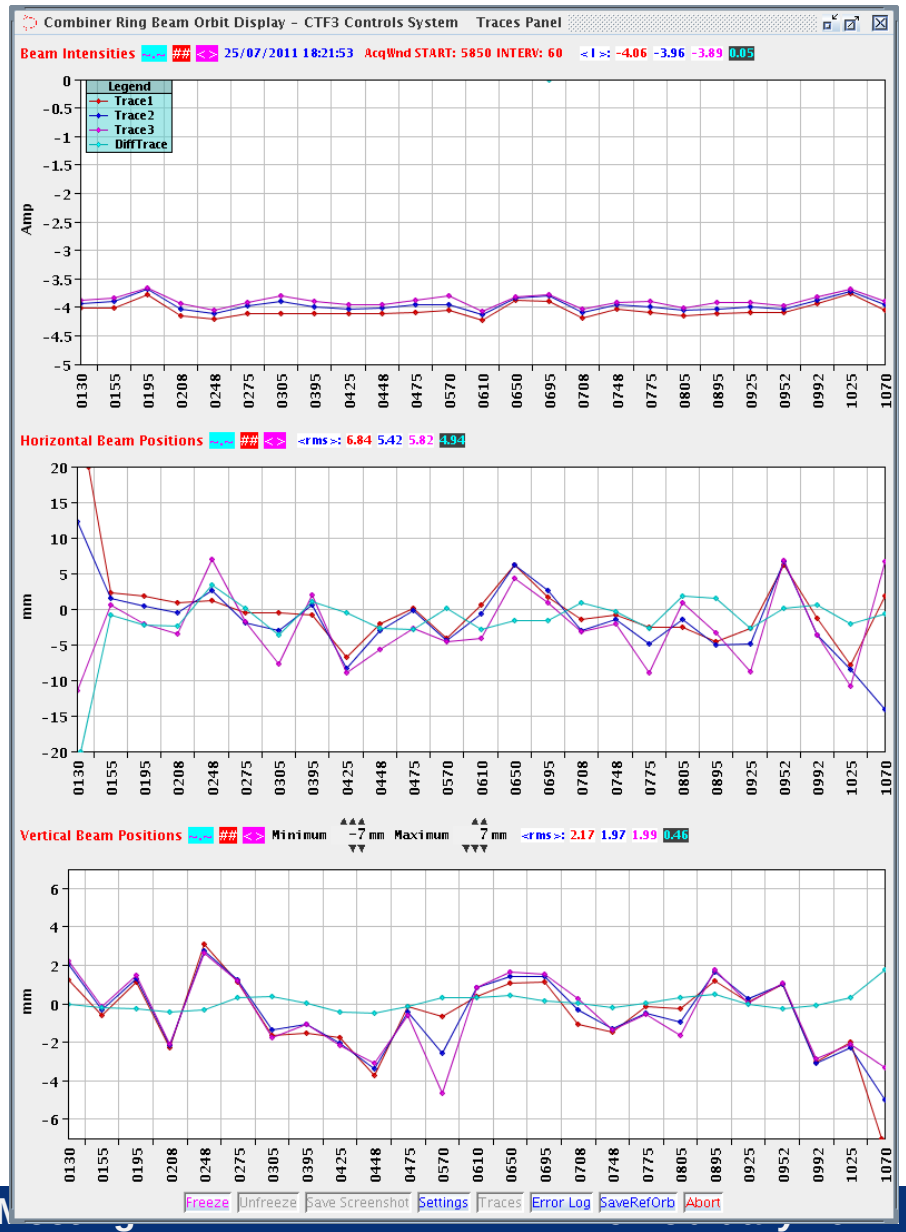
Closing CR attempt 2
RF defl on 2nd turn, adjusted phase of MKS14-PHAS.

Diff is Reference Turn 2 and Turn 2

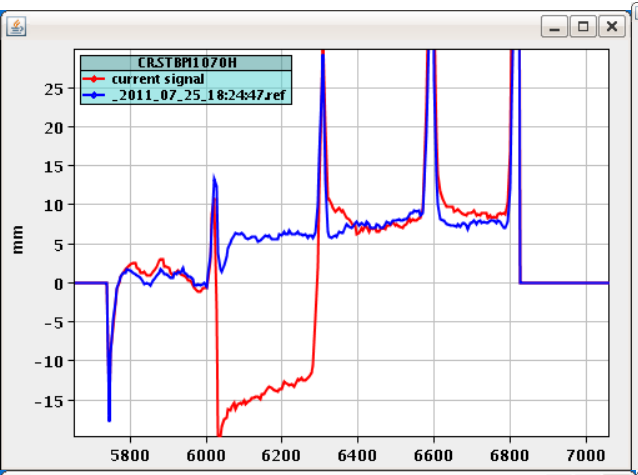


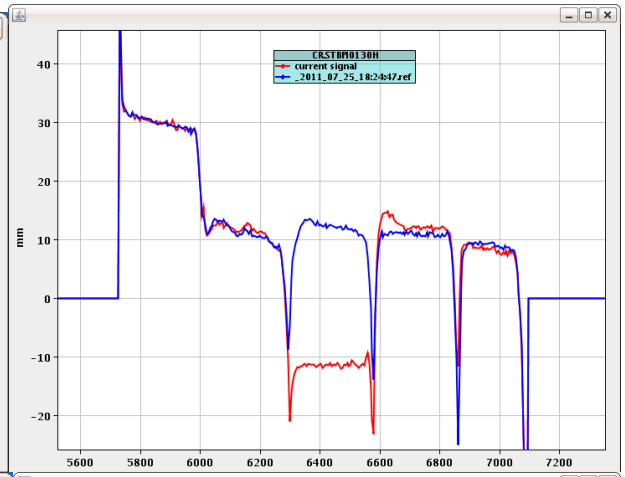
Closing CR attempt 2
Before and after Rf defl on turn 3
Diff is od Reference Turn 3 and Turn 3.

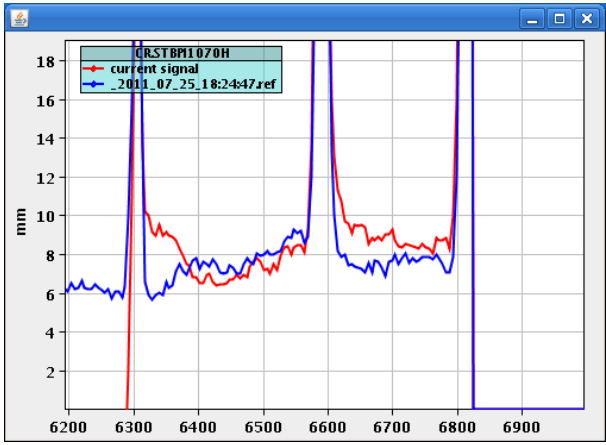


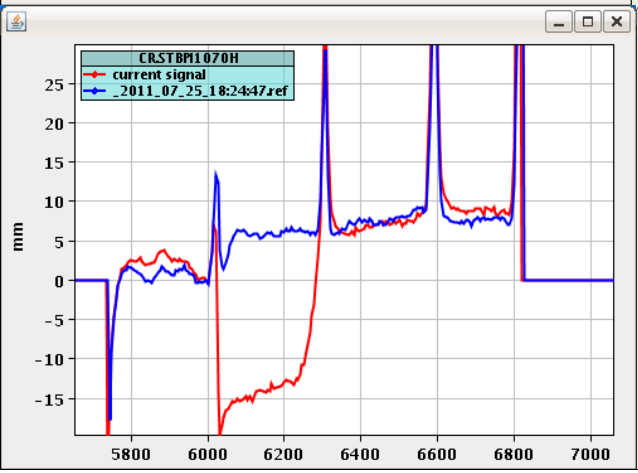


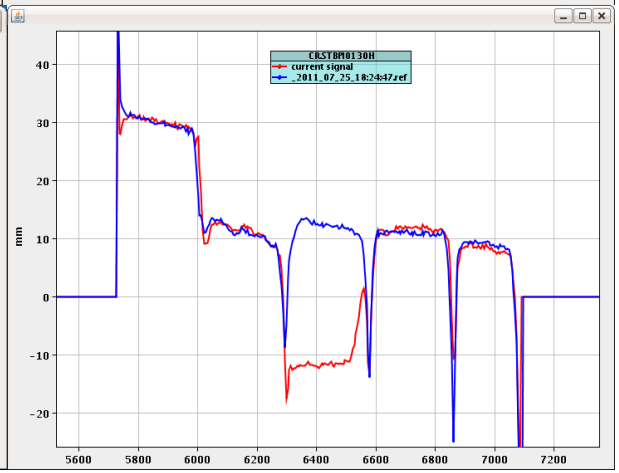
Traces for above

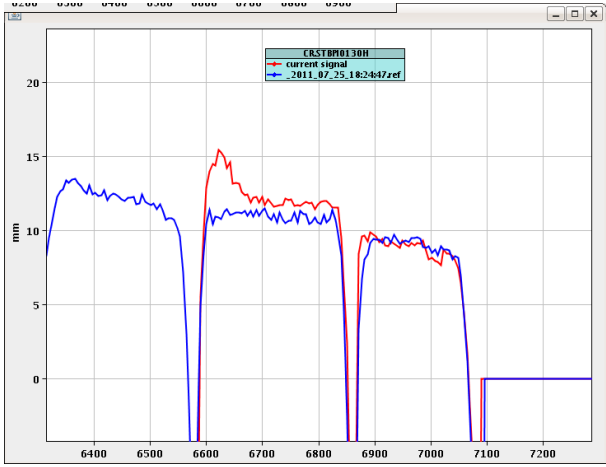




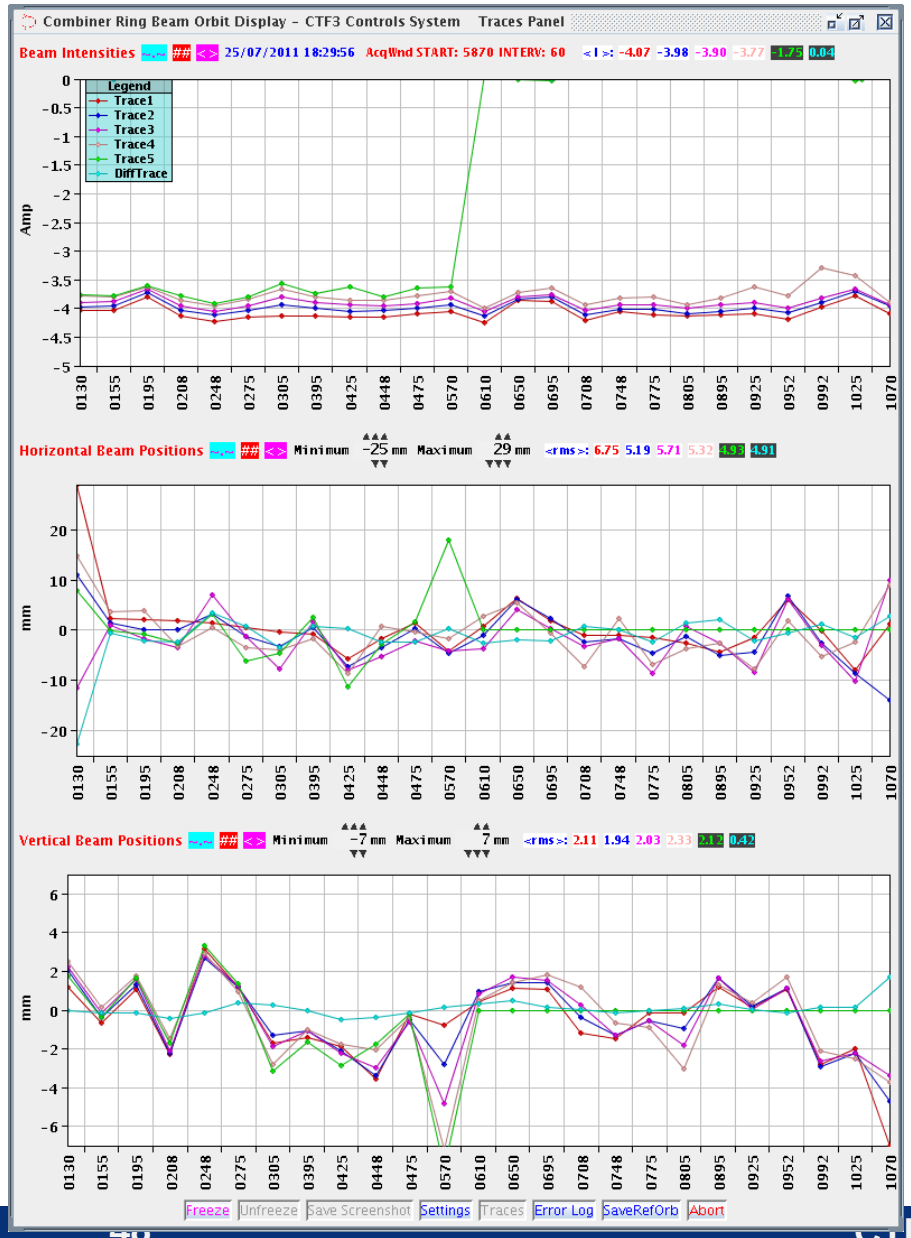


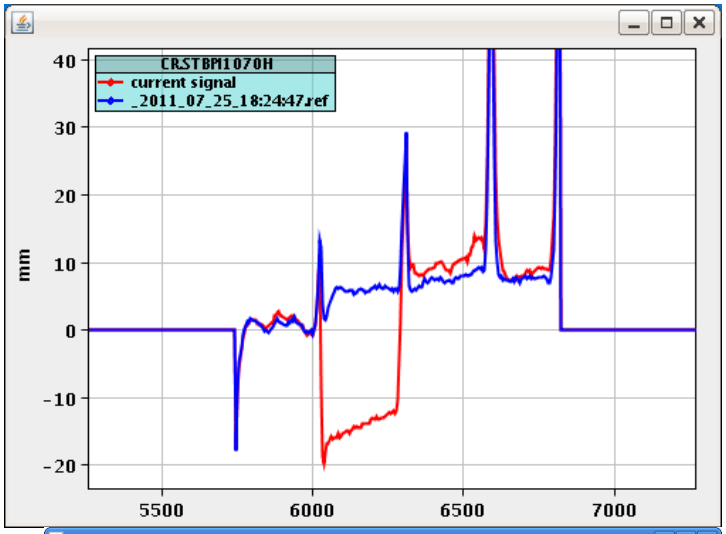


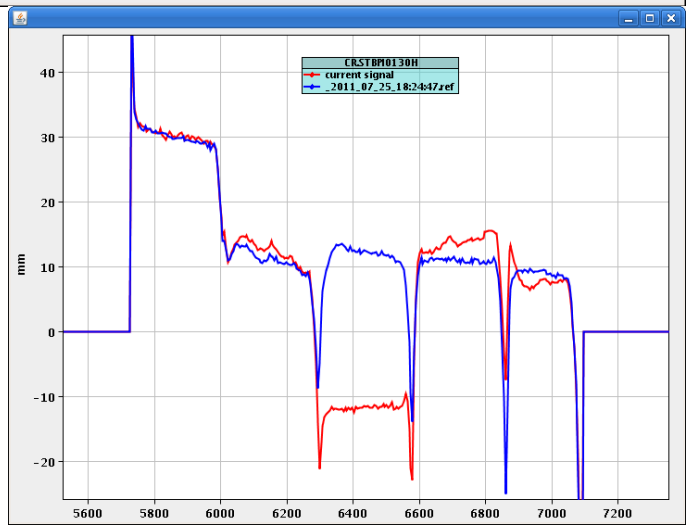




Closing CR attempt 2
Before and after Rf defl on turn 4

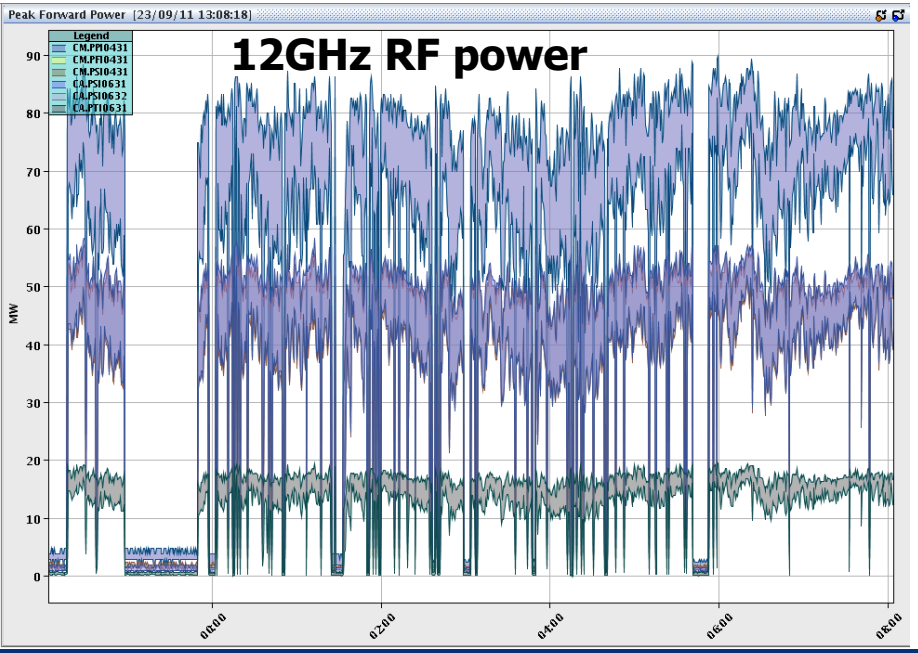




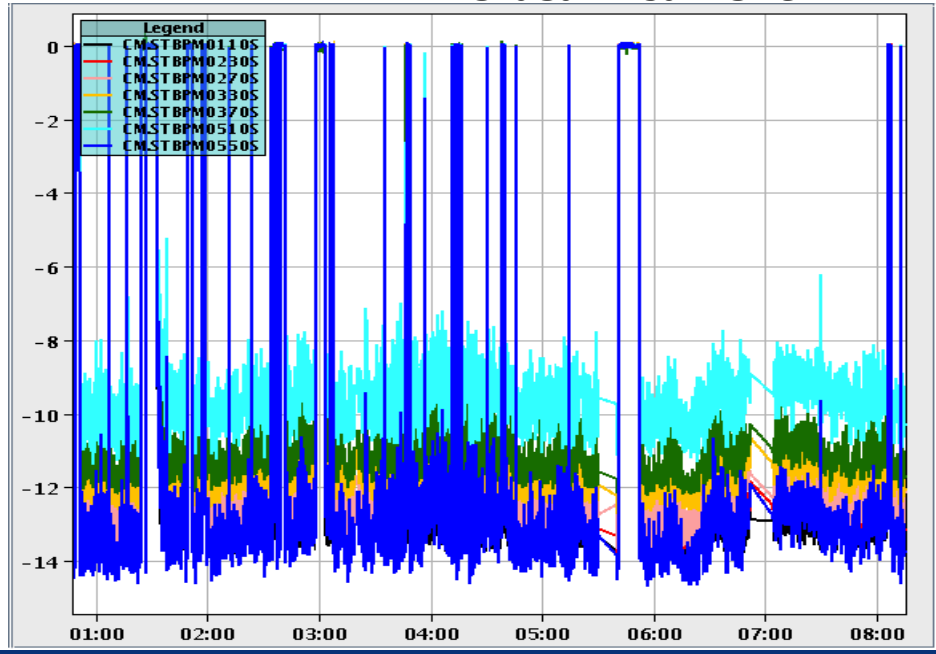


Night operation with remote supervision from CCC

- We have reached a sufficient stability to leave the machine operating during nights with remote supervision from the Cern Control Center
  - Required implementation of a beam loss interlock
    - If current lower than a threshold over more than 30 seconds the gun is disabled



Drive beam current



Night operation with remote supervision from CCC

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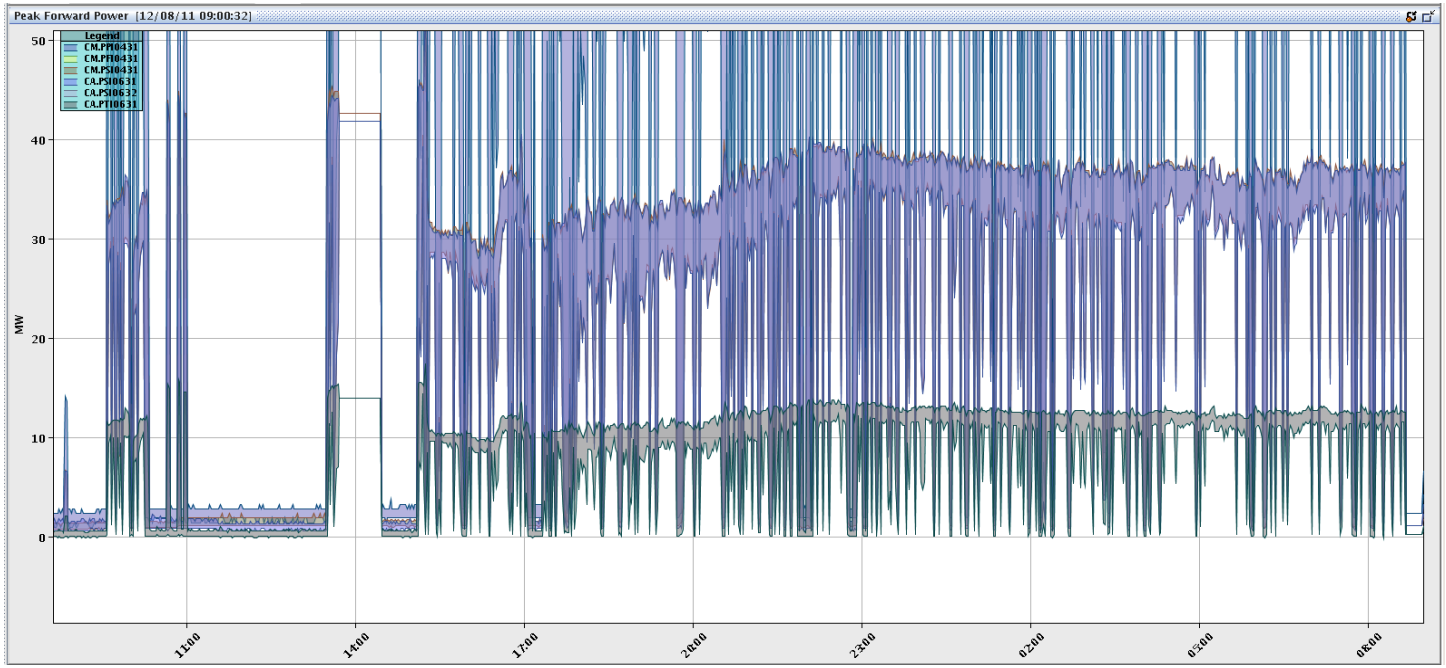
    - If current lower than a threshold over more than 30 seconds the gun is disabled



Night operation with remote supervision from CCC

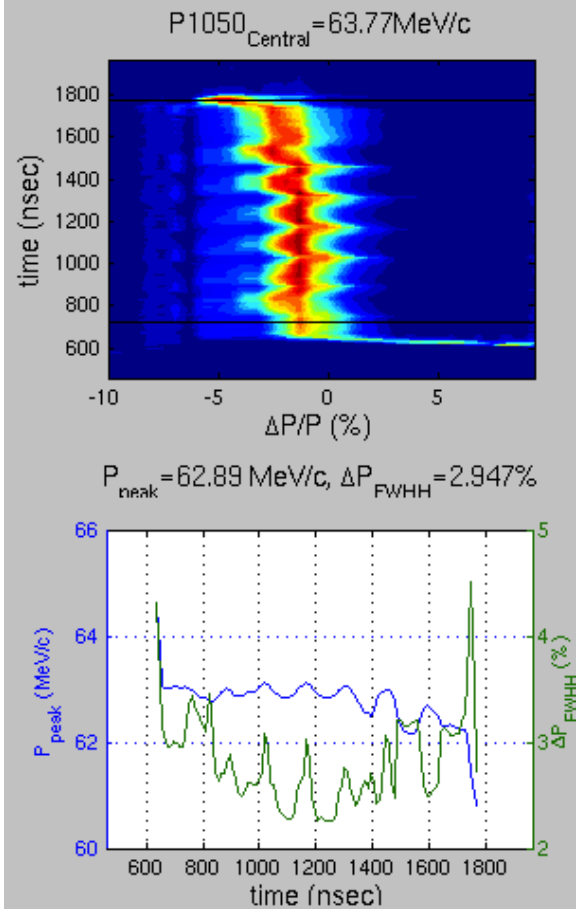
- We have reached sufficient stability to leave machine operating during night with remote supervision from the Cern Control Center
  - Required implementation of beam loss interlock
    - If current lower than a threshold over more than 30 seconds the gun is disabled
- It allowed for efficient conditioning of the accelerating structure in Two Beam Test Stand and break down rate measurements
  - The night operation performance was limited by stability of klystrons that very oftern trip
    - Automatic restart procedure was implemented in dedicated computer program
    - Still, often human intervention is needed and CCC crew is not always able to react promtly to restore the beam

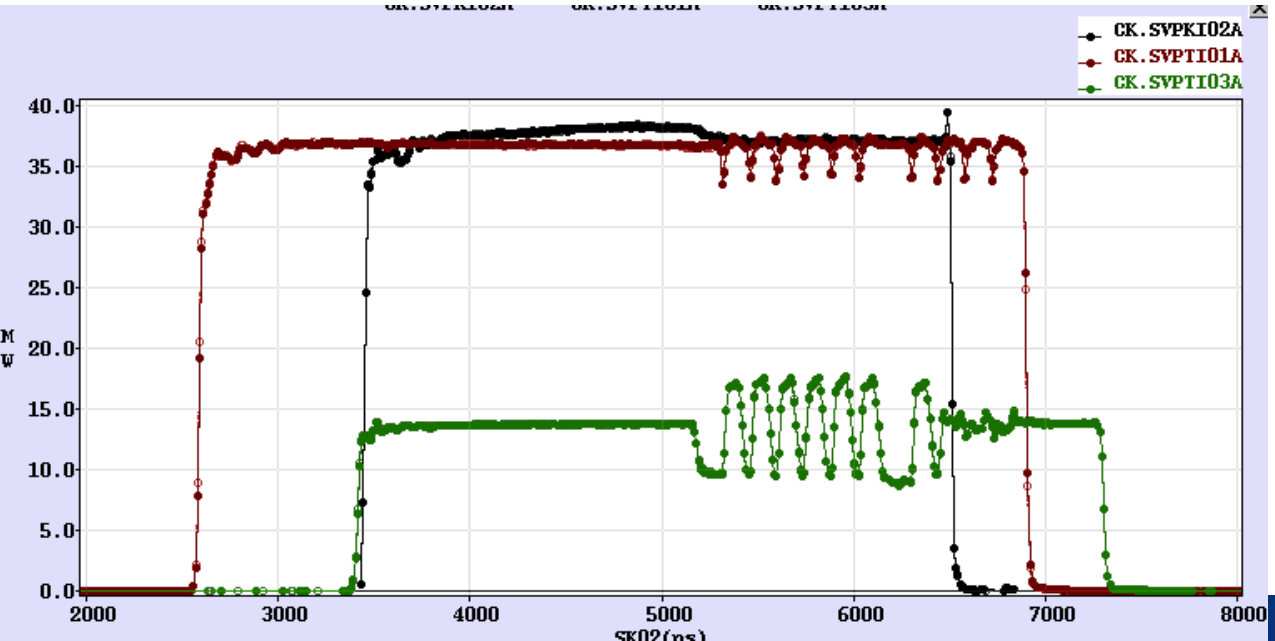
Bunch length and its control

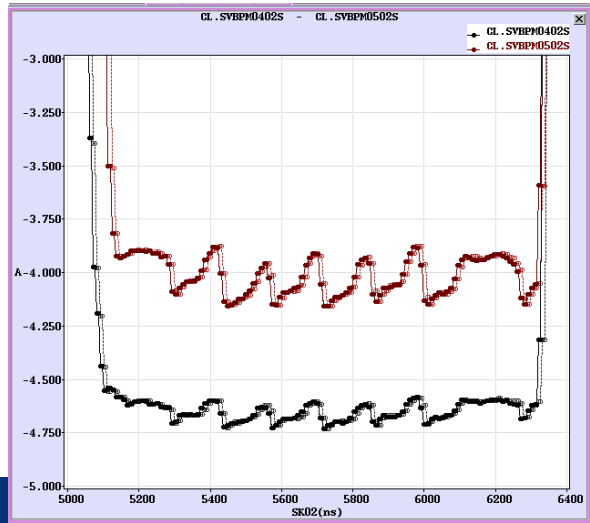
- We measure bunch length of 18ps FWHM using streak camera and rf deflectors + OTR screens
- Streak camera measurements shows that the length stays constant over several turns in the Combiner Ring
- Newly installed camera in CLEX measures XXX
- The level of the 12GHz power production gives form factor 0.85-0.95 that is in agreement with the direct bunch length measurements
- Lower R_{56} setting in the Stretcher Chicane still needs to be commissioned
  - We attempted to setup R_{56}=0 previous year but could not get quickly the lossless transmission

Fully Recombined Beam

- The quality of factor 8 recombined pulse is much worse than the factor 4
- Since 2010 the sub-harmonic bunching introduces a before unseen energy variation
  - In 2006-2009 we did not observe it to this level
    - Than it is not a fundament
  - Till now we do not have its explanation
- The phase itself is switched very quickly
  - Streak camera shows below 10ns
- Bunching is disturbed by this transient for over 100ns



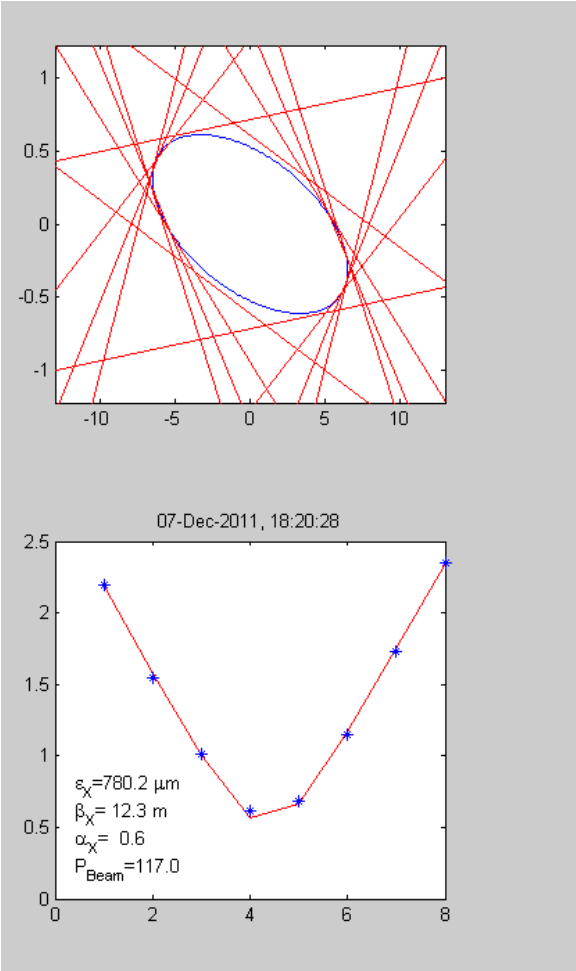




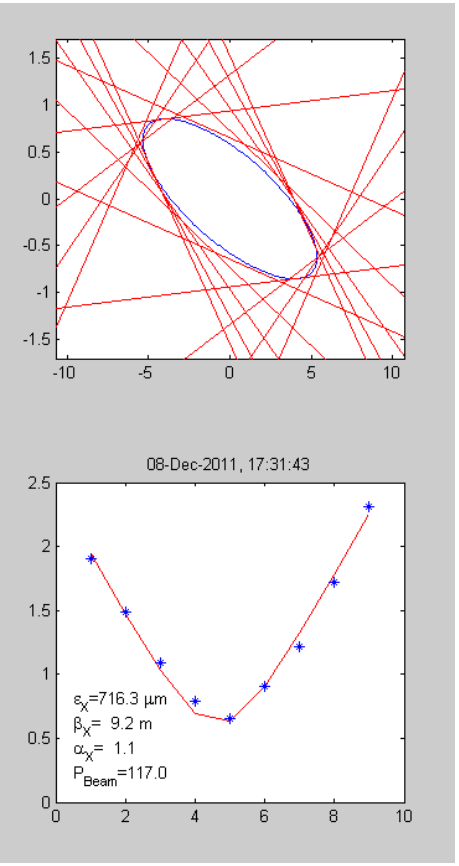
Tools in preparation

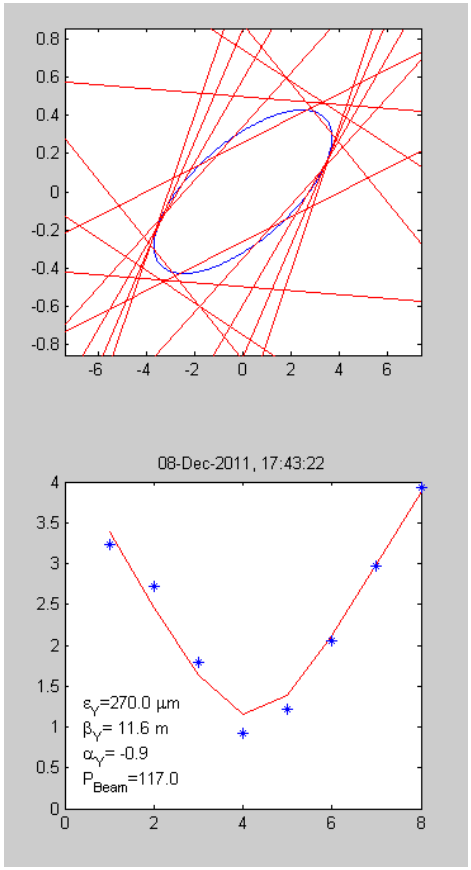
- Dispersion Free Steering for whole machine
- Orbit closure for DL and CR

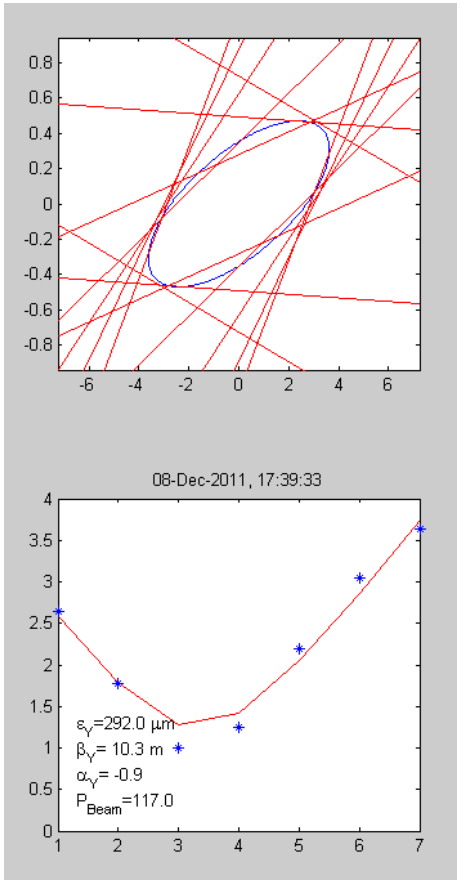
Emittance 2011 Factor 8



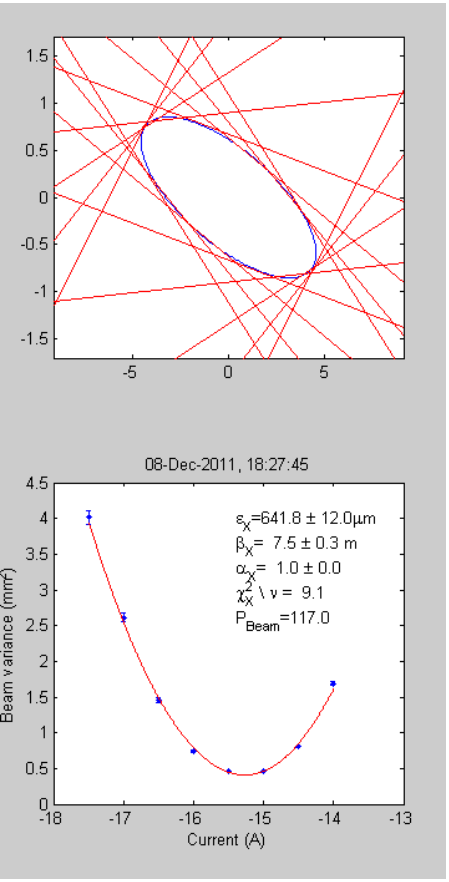
Emittance 2011 Factor 8

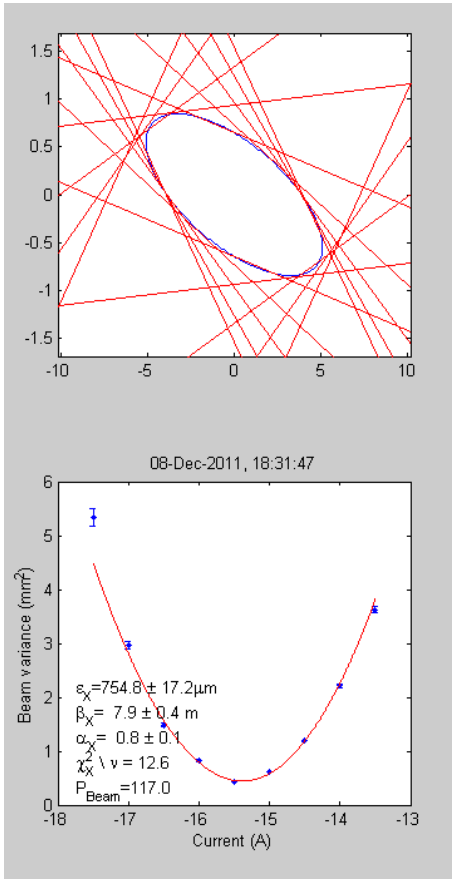


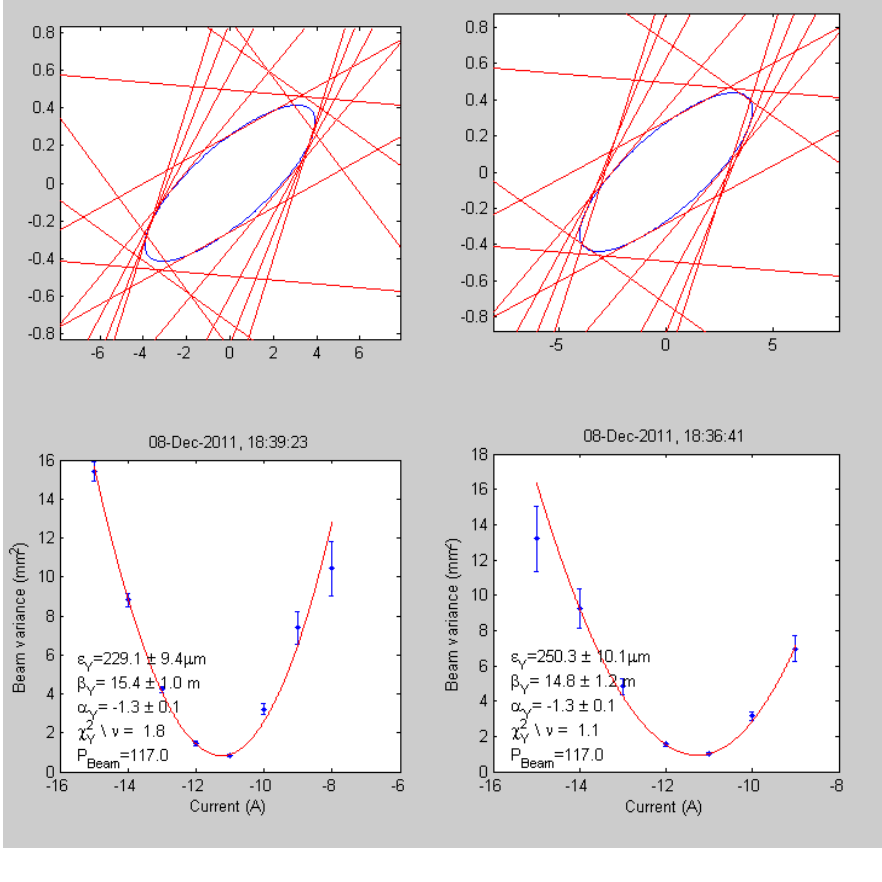




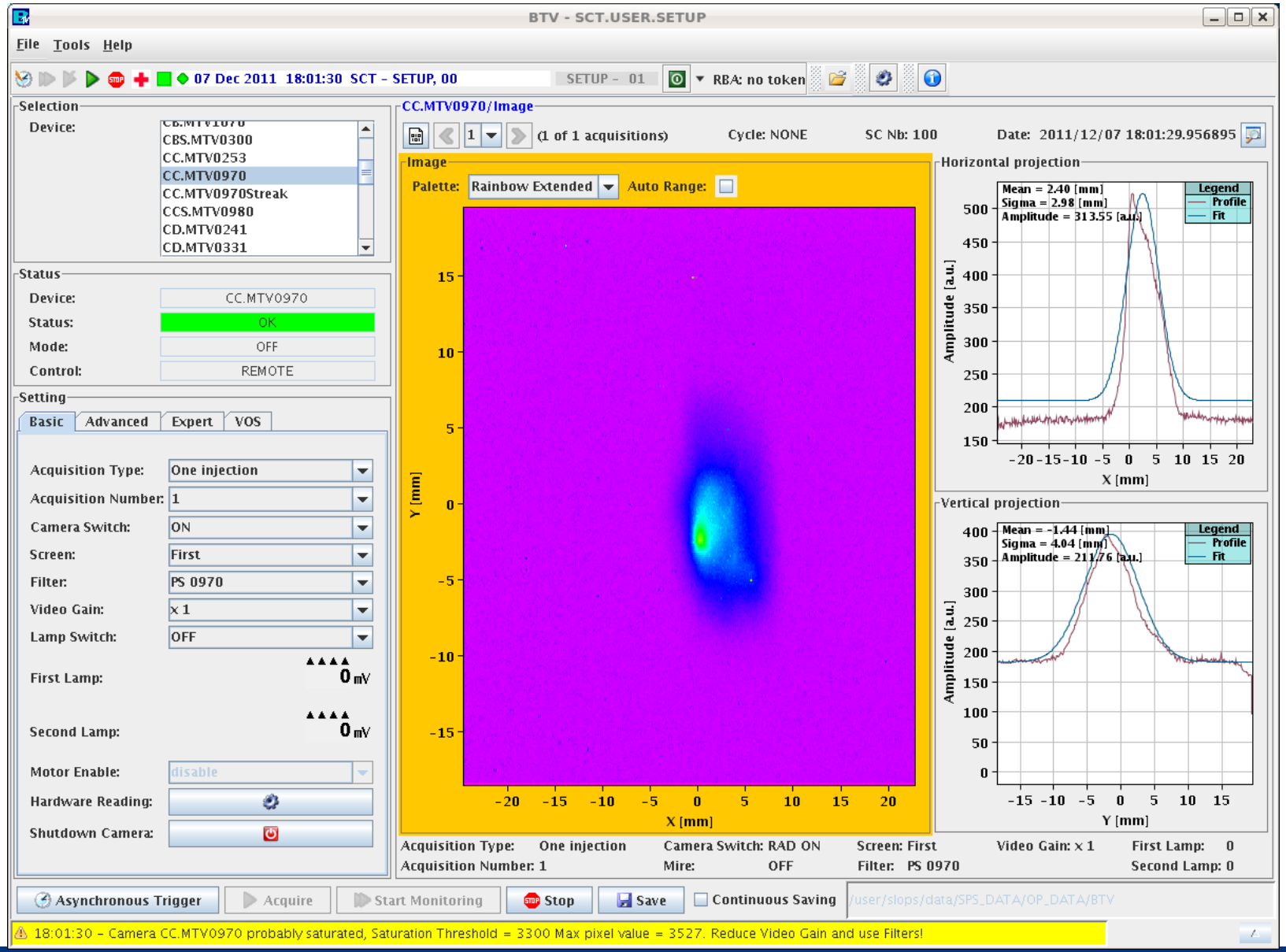
Emittance 2011 Factor 8
The same as above (Ben's fitting)



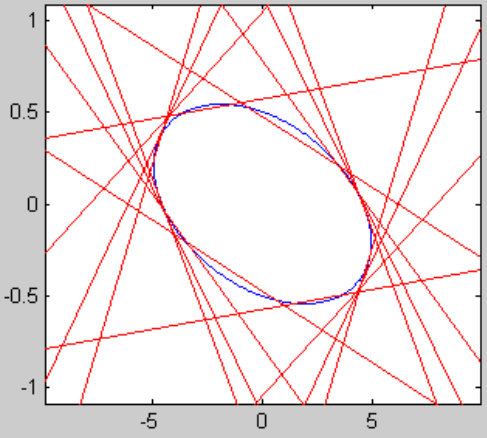


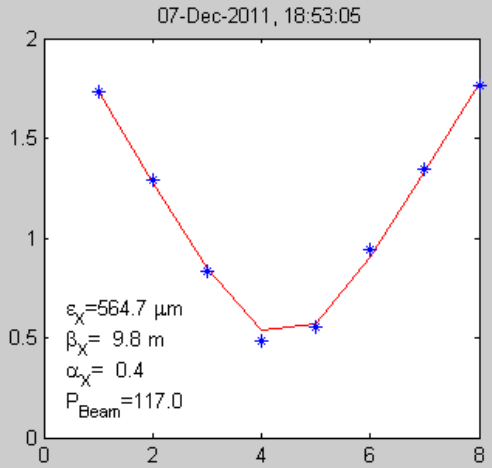


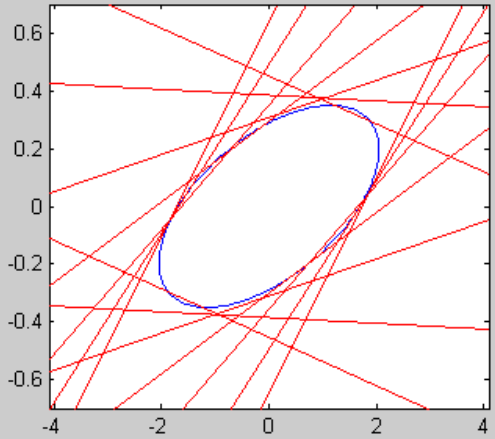
Factor 8 at CC0970

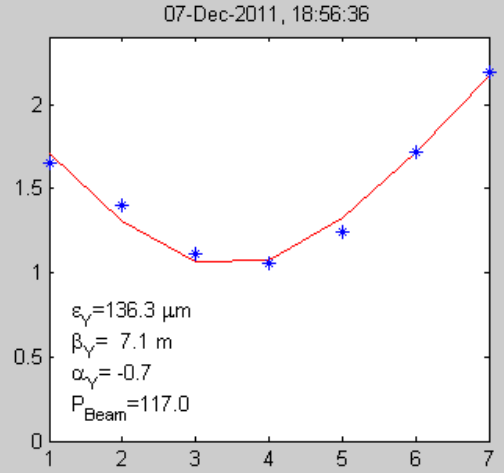


Emittance 2011 Factor 8
DL part killed

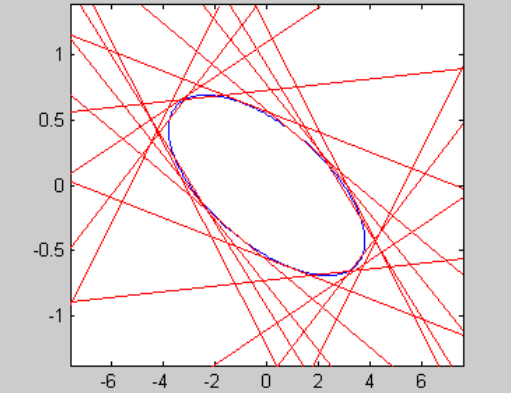


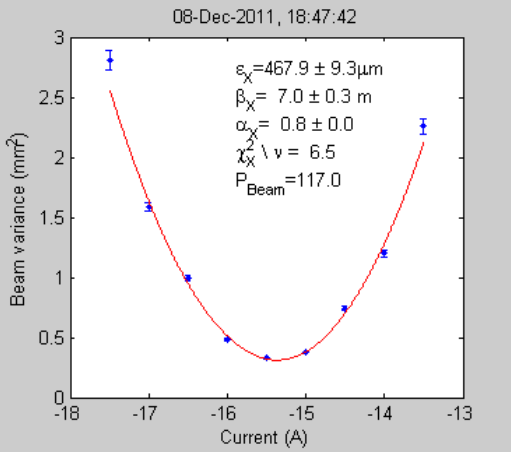


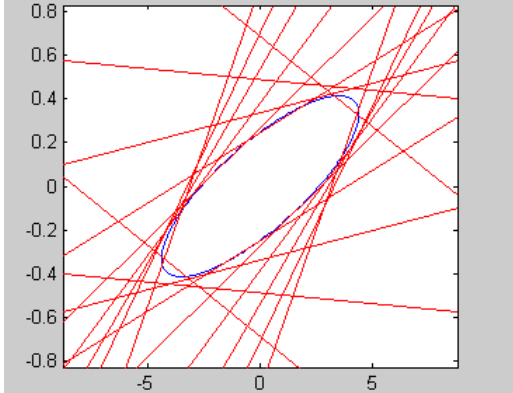


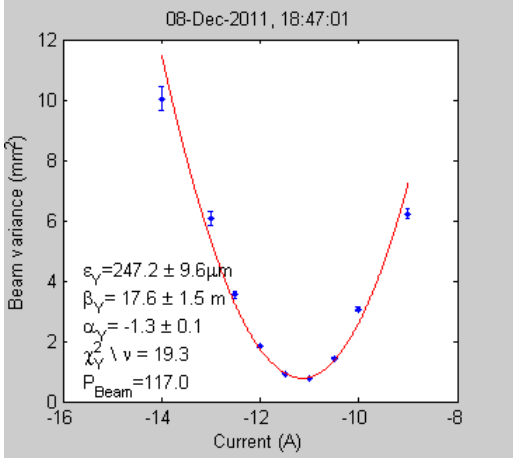


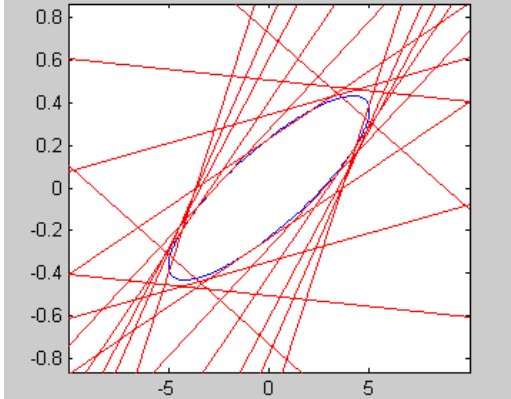
Emittance 2011 Factor 8
DL part killed

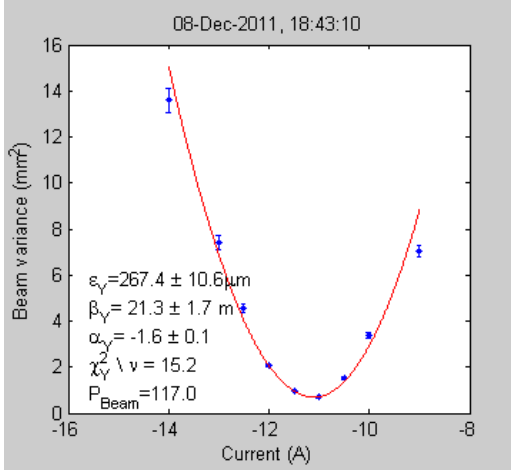




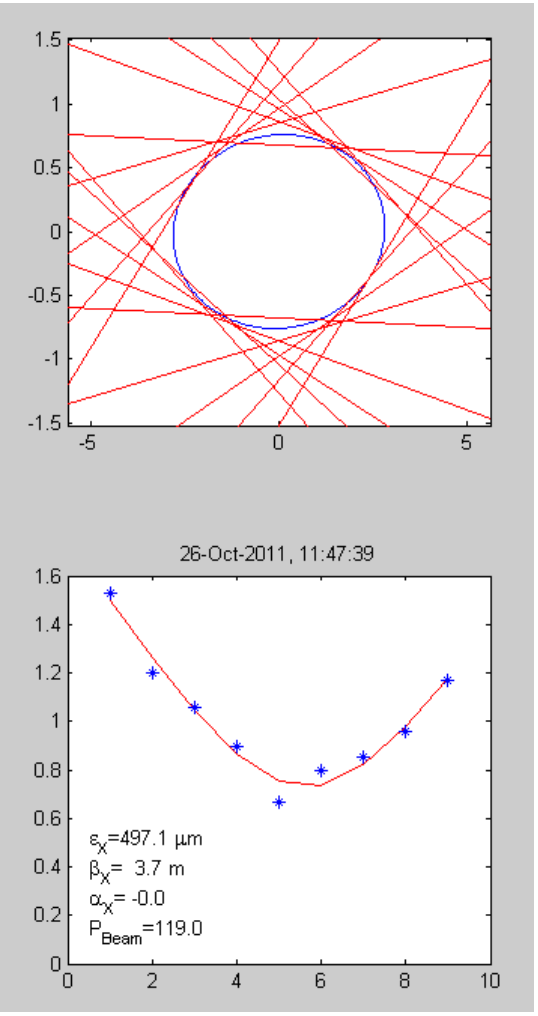


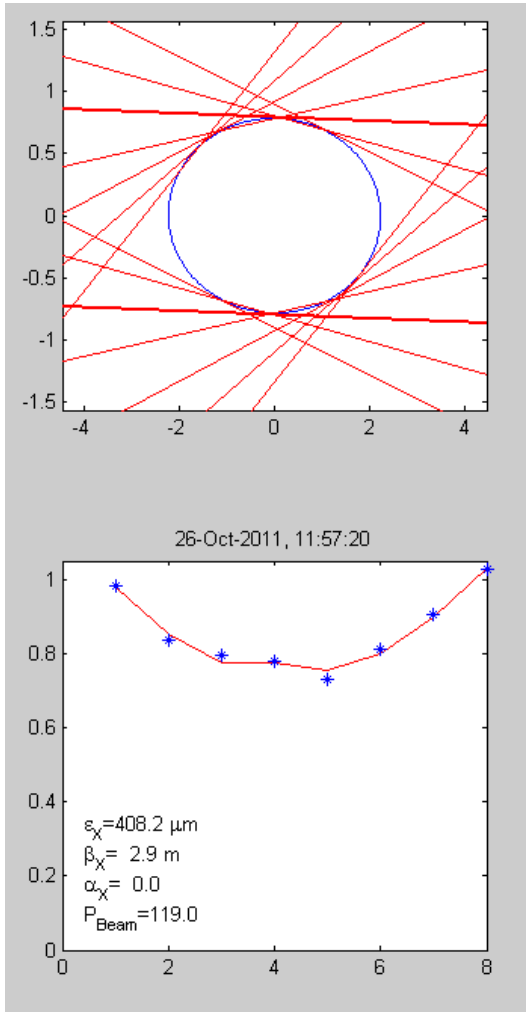


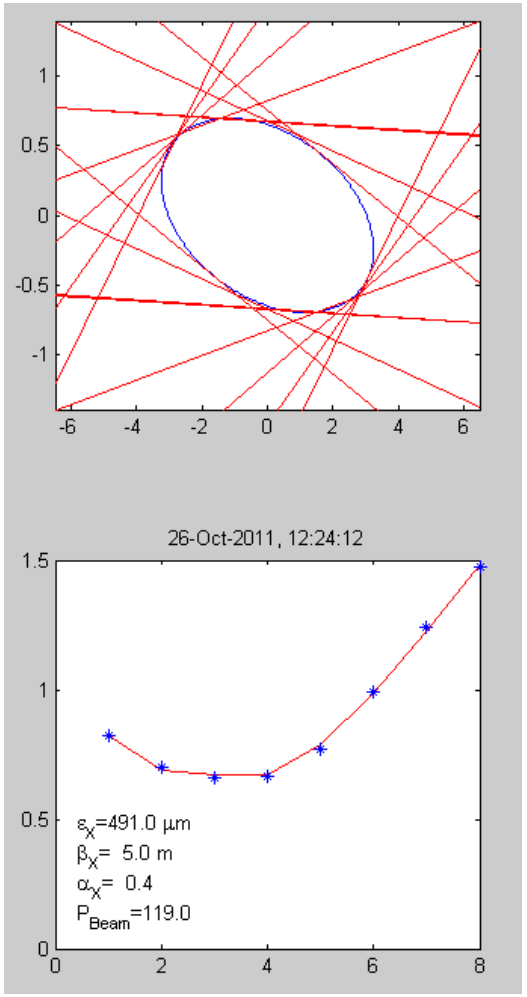




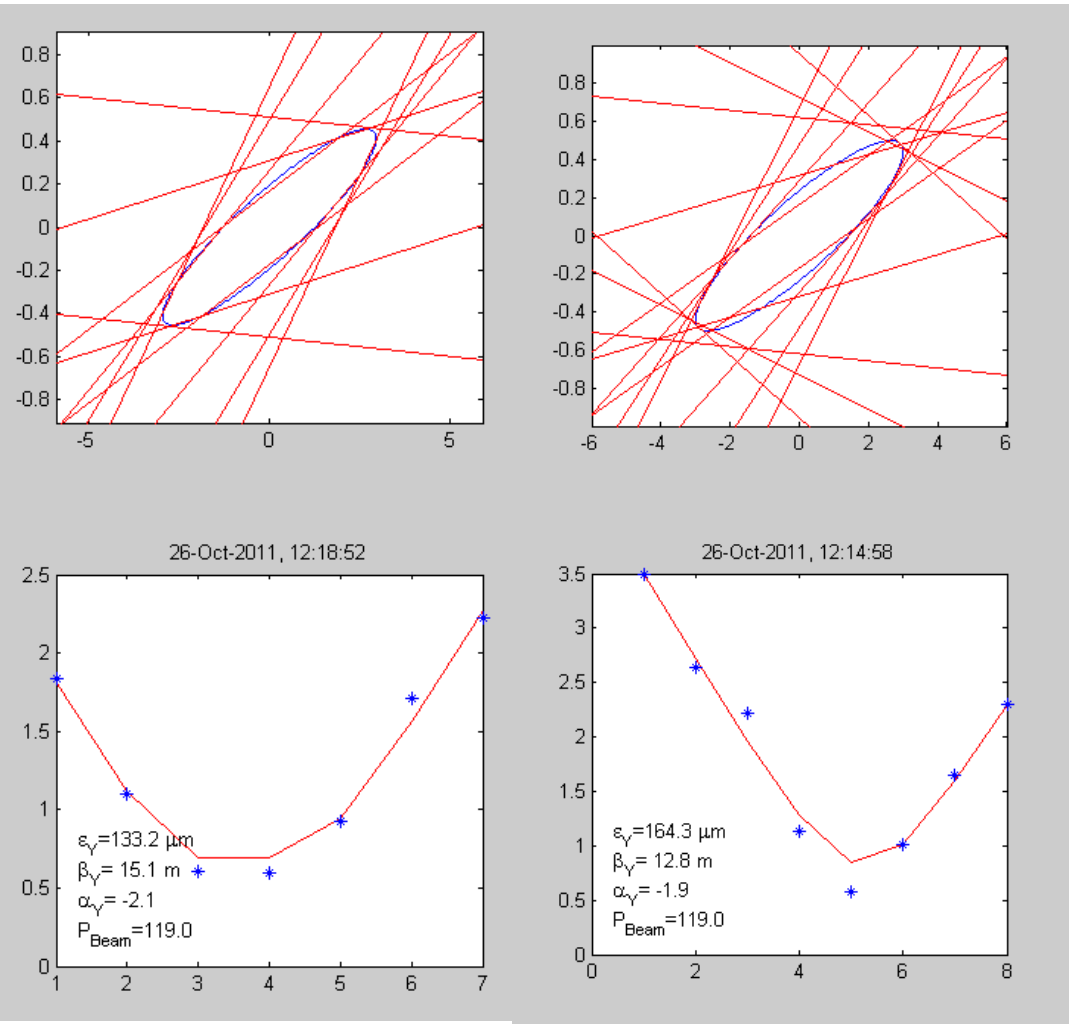
Emittance Factor 4 in CLEX

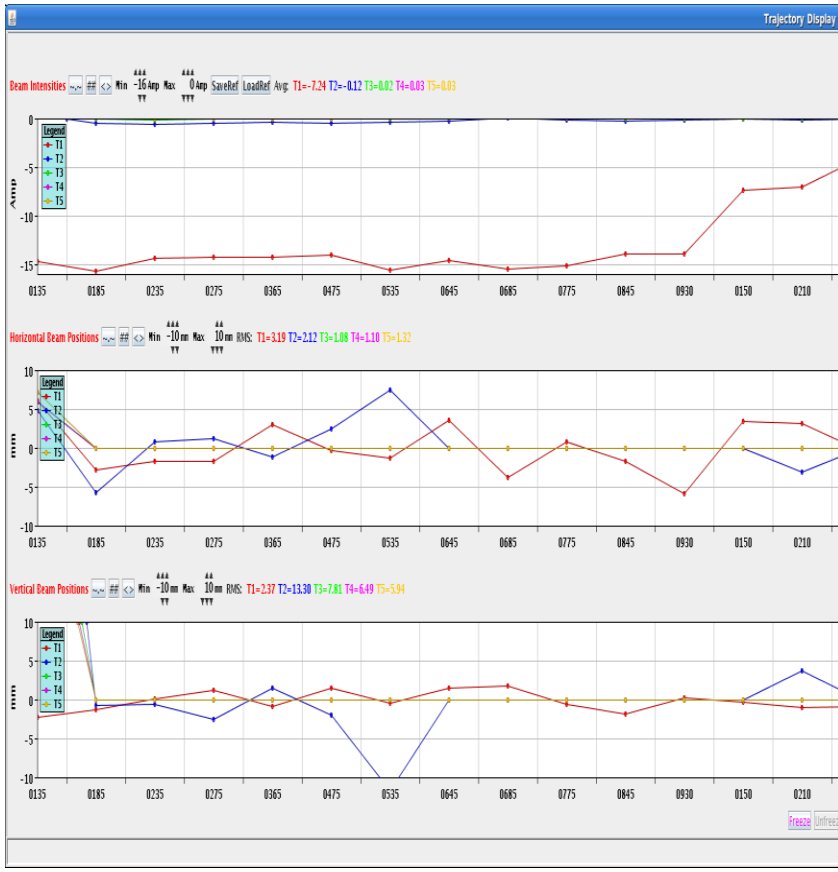




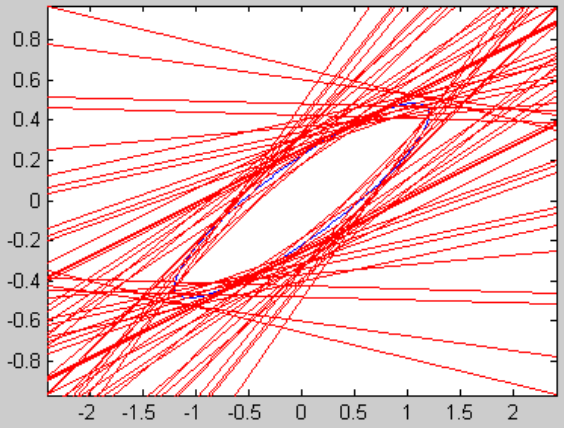


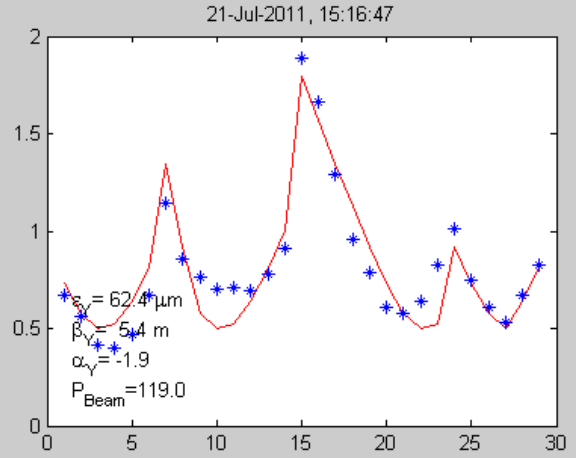
Emittance Factor 4 in CLEX





Quad Scans for single turn Combined 1,2,3,4





Conclusions

- The delivered drive beam allowed to perform the key experiments in TBTS and TBL in 2010 and 2011
- We demonstrated the recombination concept at the right current level
- However, the quality of the drive beam is still not fully satisfactory; many optimizations and studies are still to be done
  - The Drive Beam quality optimizations were often sacrificed in order to assure accomplishment of the key experiments
  - Therefore, suffered first when unexpected events stopped CTF3 for long periods in 2010 and 2011
  - CTF3 is limited by the need of reusing the existing hardware, and therefore has a design and a hardware that is not optimized for its purpose
  - We suffer from many operational issues, mainly in stability matters but also in instrumentation, which limit the machine performance
    - In the time span of emittance measurement the dispersion and orbit closure are sufficiently spoiled
    - We put effort to stabilize the beam by understanding the drift sources and implementing appropriate feed-back