Pbar Stacking Report

Dave McGinnis

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Outline

- Purpose
  - Investigate low pbar stacking rates in FY04
  - not including the AP2-Debuncher aperture work
- Investigation of sub-systems
  - Debuncher Momentum cooling
  - RF systems
  - Stacktail Momentum Cooling
  - Transfers between the Debuncher and Accumulator
    - Transverse Debuncher cooling
    - Transfer line between Debuncher to Accumulator
- Plan of Work
- Conclusions

FY04 Goals

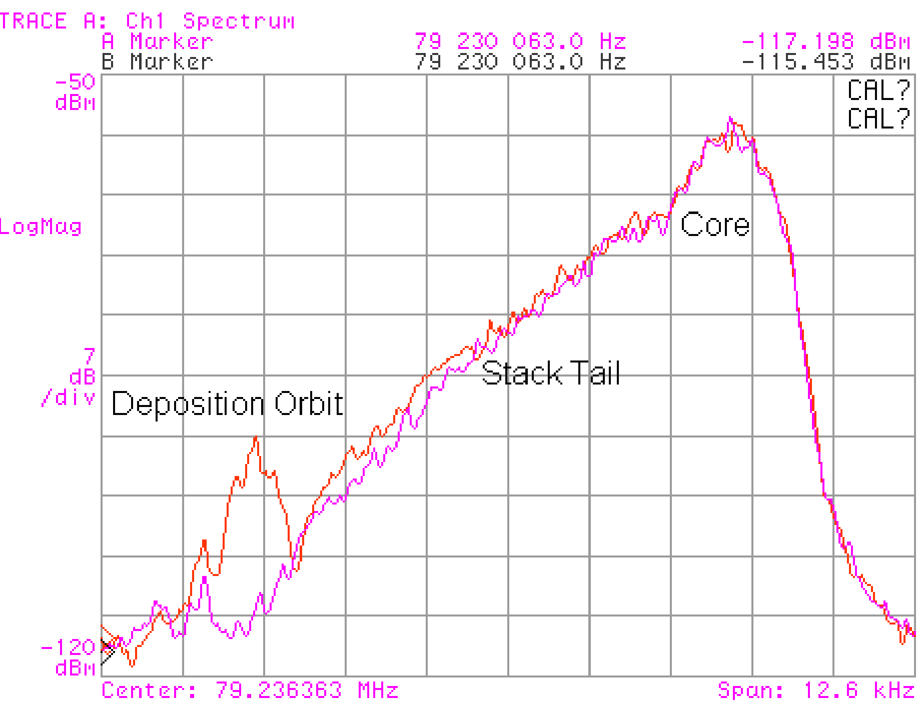
- Goal
  - Zero Stack Stacking Rate 18×10^{10} pbars/hr
    - Beam on target 5.0×10^{12} protons per cycle
    - Production 17×10^{-6} pbars/proton
    - Cycle time 1.7 sec
- Achieved
  - Zero Stack Stacking Rate 12.7×10^{10} pbars/hr*
    - Beam on target 5.2×10^{12} protons per cycle
    - Production 15×10^{-6} pbars/proton
    - Cycle time 2.2 sec
- Difference
  - Zero Stack Stacking Rate down 29%
    - Beam on target up 4%
    - Production down 12%
    - Cycle time up 29%

*Averaged over the 10 stores with the highest initial luminosity

Pbar Cycle Time

- Initial focus on reducing the cycle time was spent looking at the Stacktail deposition orbit
- Beam must be cleared off the Stacktail deposition orbit before next beam pulse.
  - The more gain the Stacktail has, the faster the pulse will move.

Accumulator Longitudinal Spectrum

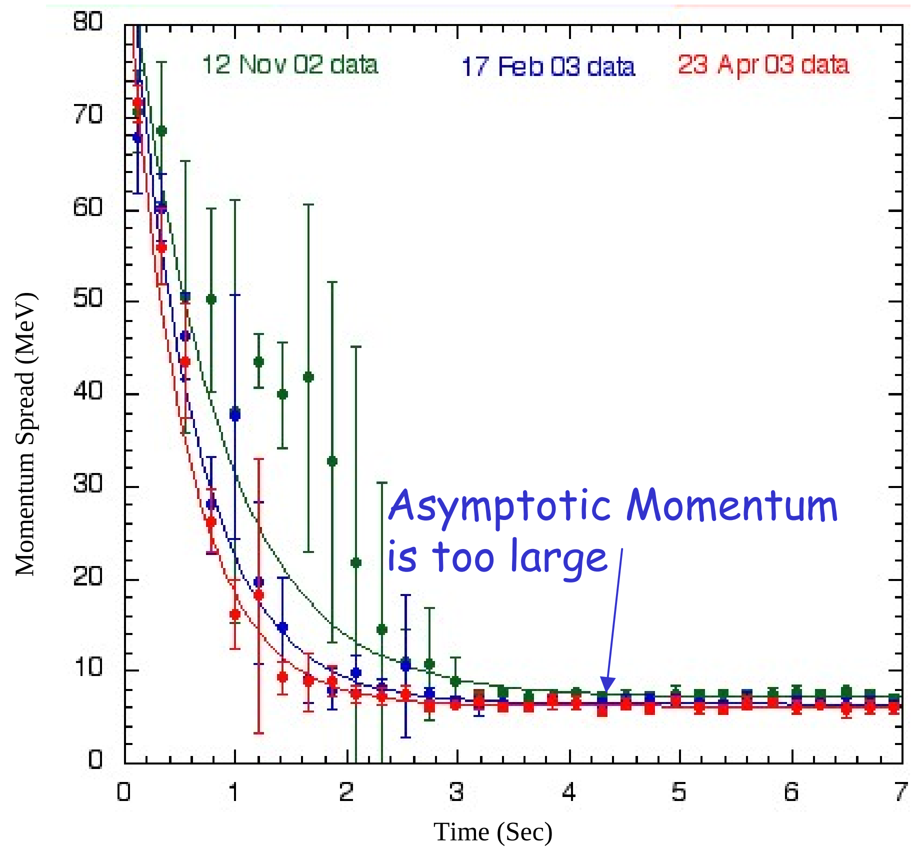


- The Stacktail gain is limited by
  - System instabilities between the core beam and the injected beam
  - Transverse heating of the Stacktail on the core
- As the stack gets larger
  - The instability feedback path grows stronger
  - The core transverse cooling gain is reduced
- The gain of the Stacktail must be turned down to compensate
- The cycle time must increase for the lower Stacktail gain

- For a given Stacktail gain, the larger the momentum spread of the injected pulse, the longer it takes to clear the pulse from the Stacktail Deposition orbit.
  - The momentum spread coming from the Debuncher is too large.
    - Bunch length on target
    - Debuncher Cooling rate
    - Debuncher asymptotic momentum

Debuncher Momentum Cooling

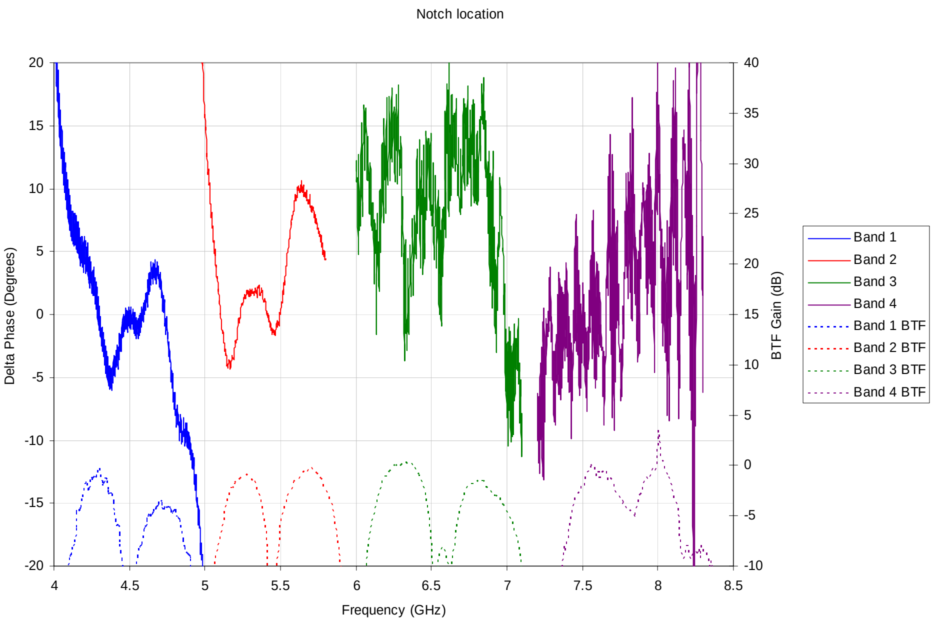
- The 4-8 GHz Debuncher momentum cooling systems have enough gain to bring the momentum spread down in 1.5-1.7 secs.
- The momentum spread exiting from the Debuncher is limited by the asymptotic momentum spread.
- A large contribution to the asymptotic momentum was thought to be the result of dispersion in the Debuncher Momentum cooling notch filters.
- By reducing the Debuncher Momentum Cooling Notch filter dispersion by 33%, it was thought that the Stacktail gain could be lowered by 33% and would permit the zero stack cycle time to be lowered from 2.4 sec to 1.7 sec



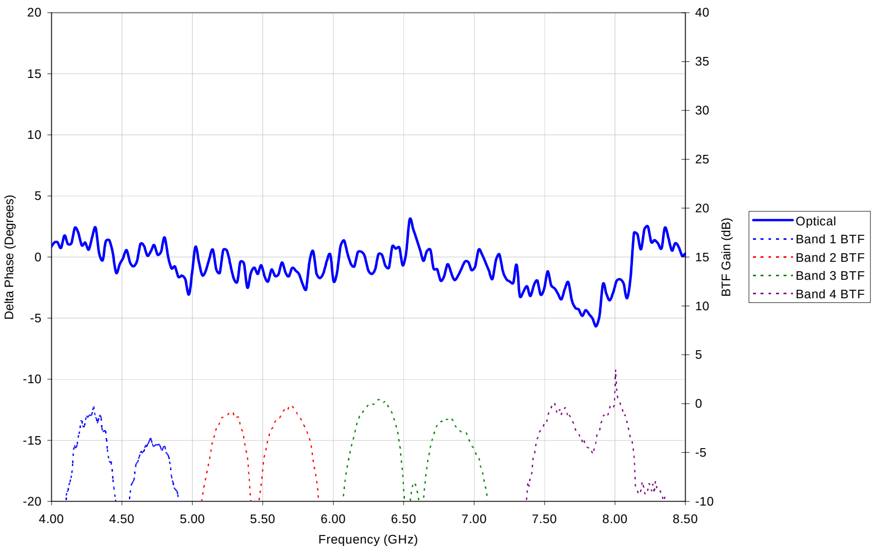
Debuncher Optical Notch Filters

- Initial pass on reducing dispersion in the Debuncher notch filters was attempted by building better equalizers for the BAW delay lines for each of the 4 bands
  - Tolerances in building microwave strip-line filters limited the amount of dispersion that could be equalized
- Next step was to build optical notch filters
  - Factor of 3-4 lower in dispersion than Bulk Acoustic Wave filters
  - More difficult to implement than BAW filters because all 4 bands have to be channeled into a single optical filter and then split out separately again after the filter.
  - Optical filter was installed during the March '04 short shutdown

Bulk Acoustic Wave filters

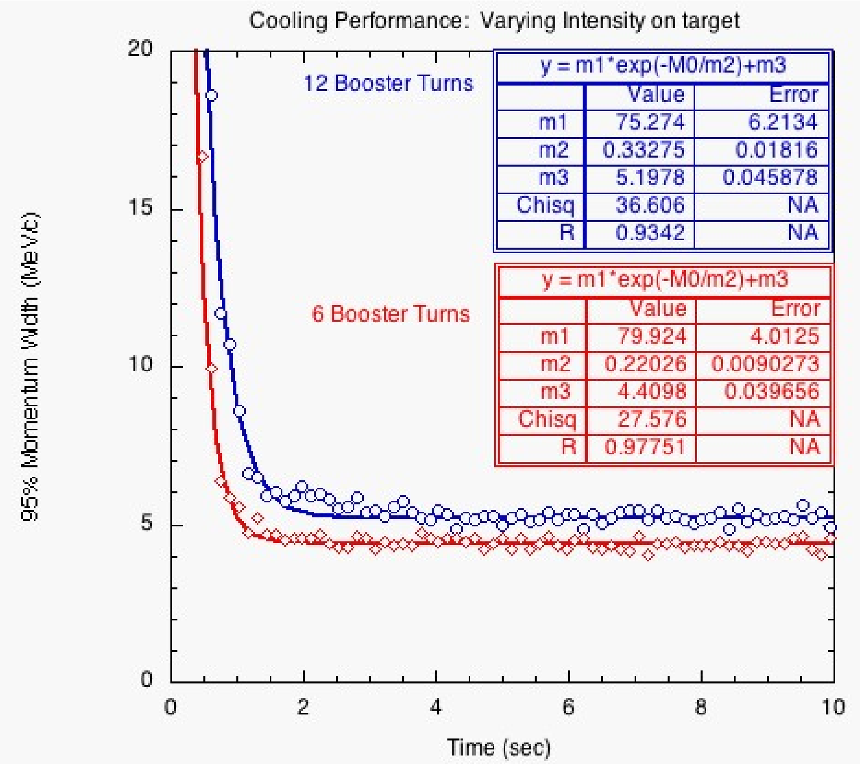


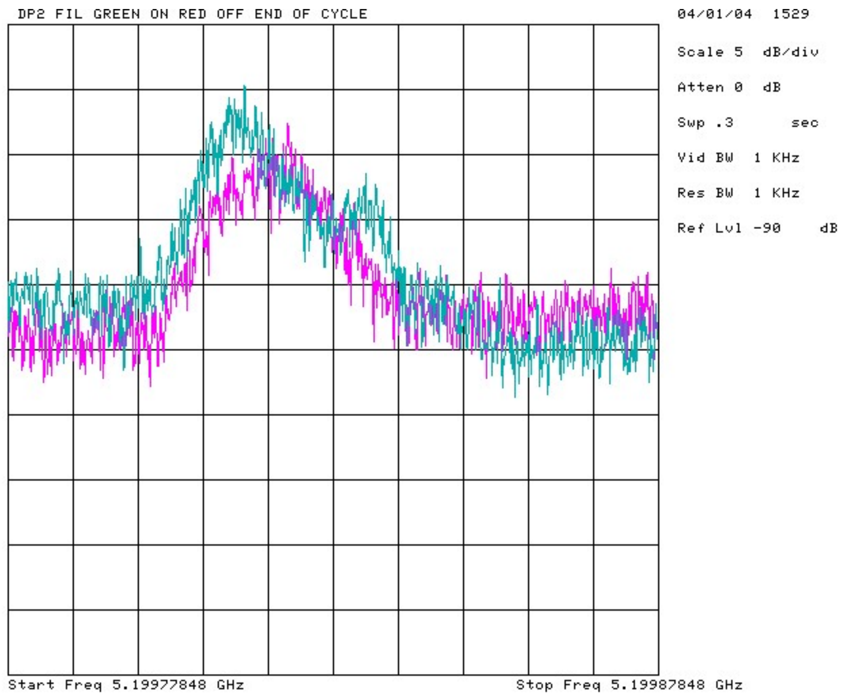
Optical filters



Optimum Gain in Debuncher Momentum Cooling

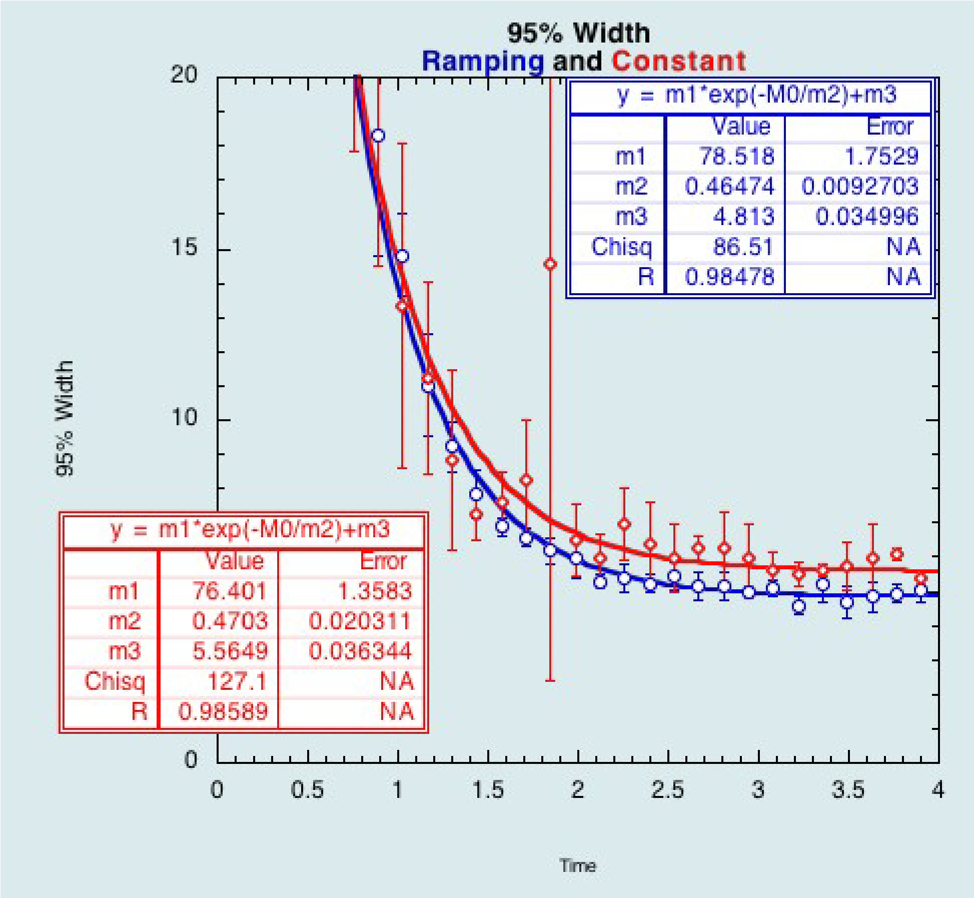
- Optical Filters reduced asymptotic momentum spread from above 8 MeV to about 6 MeV
- Subsequent measurements showed that the asymptotic momentum spread was a function of the amount of beam injected into the Debuncher
- Further measurements showed that the Debuncher Momentum cooling system was close to optimum gain





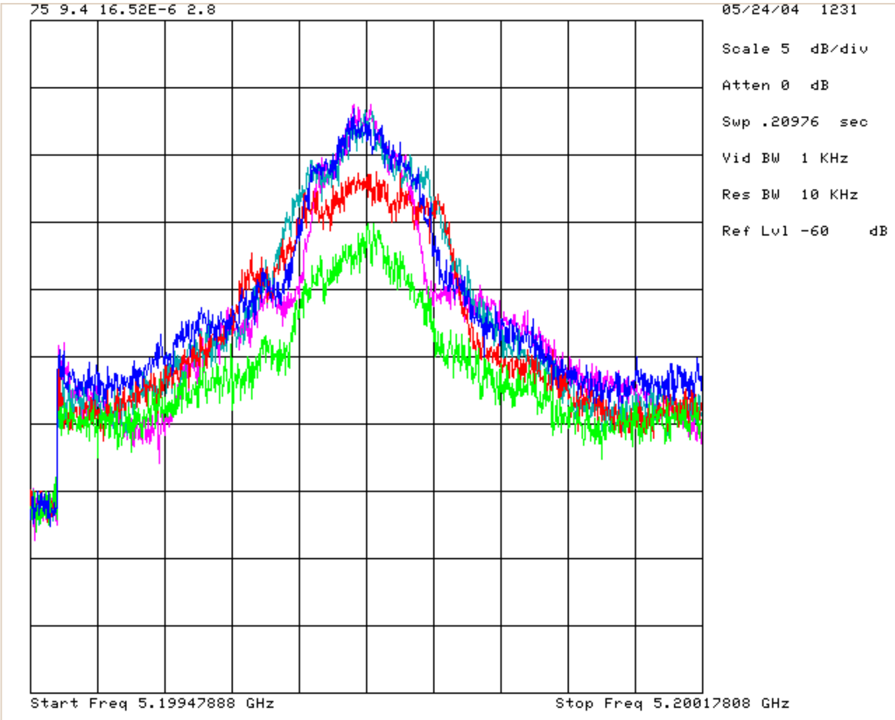
Momentum Cooling Gain Ramping in the Debuncher

- Gain ramps were introduced into the Debuncher Momentum Cooling system
  - Gain was reduced as momentum spread decreased (as particle density increased)
  - Gain ramping decreased the momentum spread to below 5 MeV



Static Decrease in γ_t in the Debuncher

- Bunch Rotation done during the first tens of milliseconds of the stacking cycle. Bucket height for bunch rotation is inversely proportional to $\eta^{1/2}$
- Stochastic cooling is done during the remaining 1.8 seconds of the stacking cycle. The error signal fed into the momentum cooling system is proportional to η.
- Ideal case would be to ramp γ_t down during cooling cycle
  - Under investigation
  - Power supply control, orbit control, tune control are issues
- Tried a static increase in η from 0.006 to 0.0075
  - Trade-off of bunch rotation bucket height vs large frequency spread for Debuncher Momentum cooling
  - Marginal results
  - Not fully explored



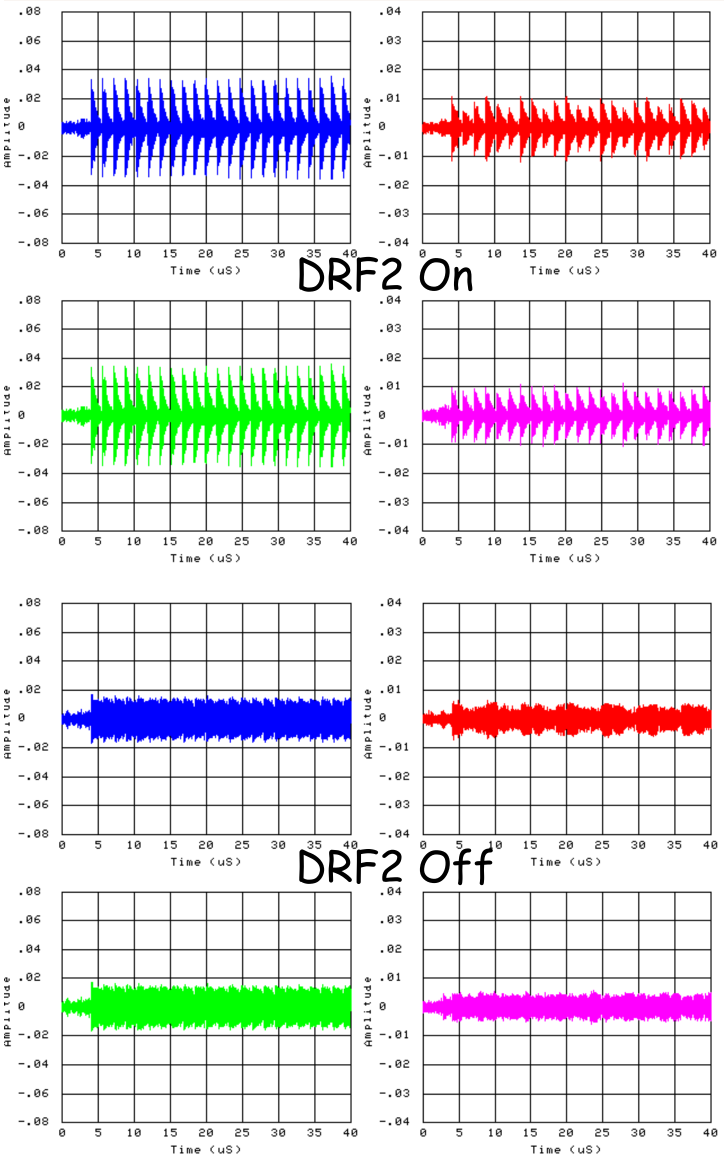
Debuncher Longitudinal Schottky after bunch rotation

Magenta Trace with small η

Blue Trace with increased η

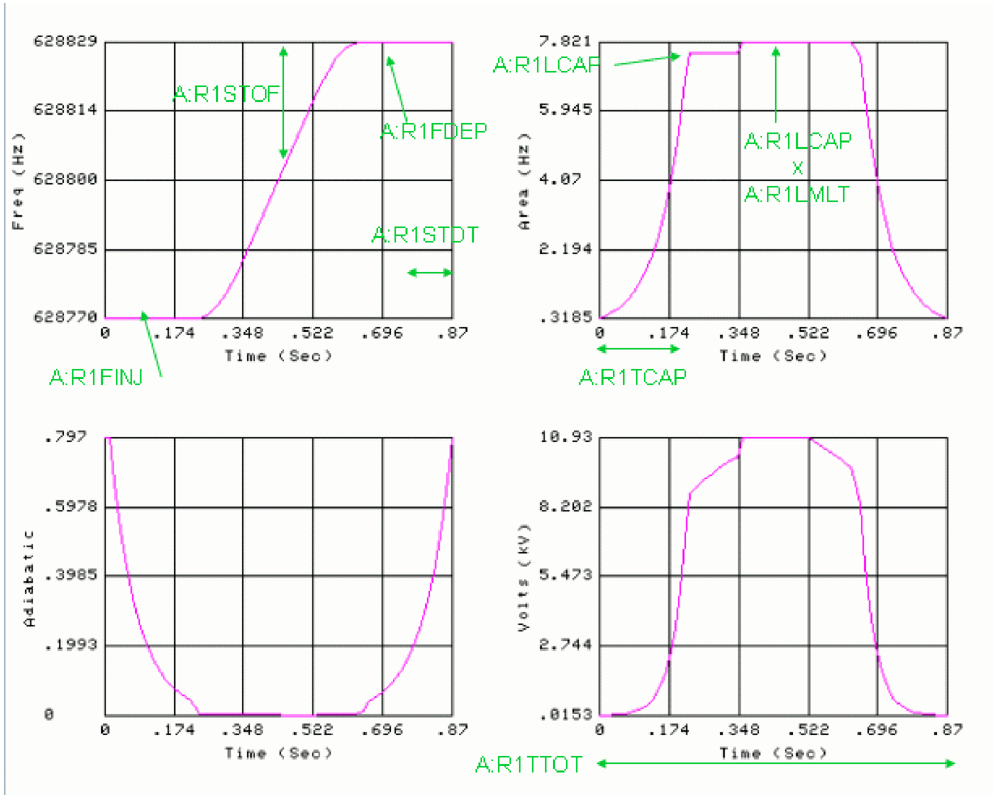
Gap Preserving RF in the Debuncher

- The Debuncher has a larger circumference than the Accumulator
- A 220 nS gap in the Debuncher beam is created with a barrier bucket (DRF2). This gap is large enough to accommodate the difference in circumference between the Debuncher and Accumulator and kicker rise and fall times.
- The voltage of DRF2 outside of the barrier bucket is supposed to be zero so that a rectangular phase space distribution will be transferred to the Accumulator.
- Recent measurements using the new TBT system for injecting pbars into the Accumulator has shown that there is a large bunching of the beam by DRF2 outside the barrier bucket.
- This bunching will result in a longitudinal emittance blowup when the beam is transferred to the Accumulator
- A new arbitrary waveform generator is being built for DRF2 and will be operational by the end of the shutdown.
  - This system can be tuned using the new Accumulator TBT



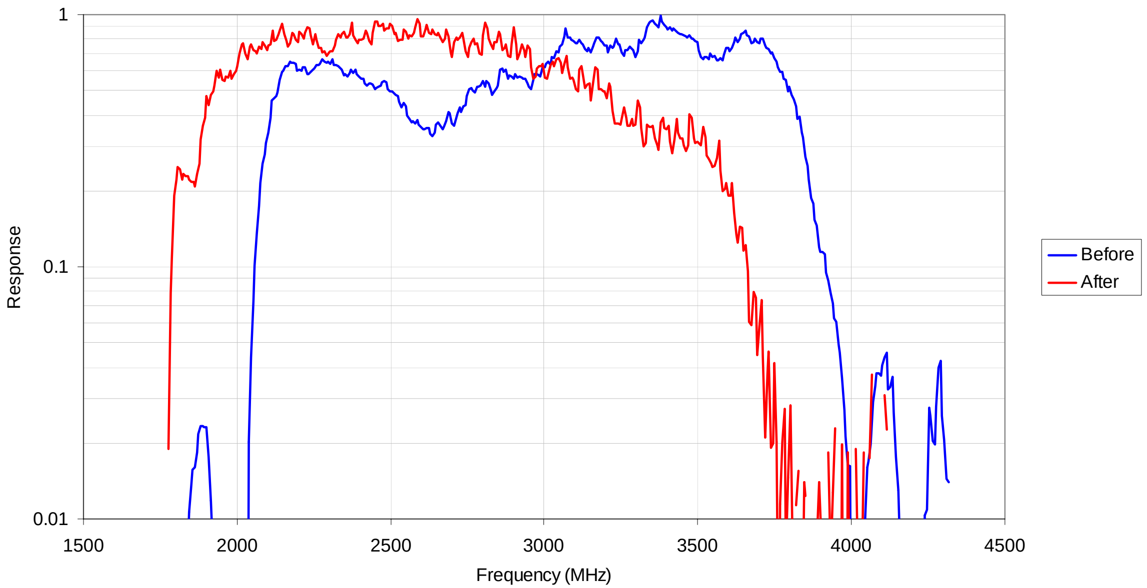
New ARF1 Curves Developed

- ARF1 is the RF system that decelerates beam from the injection orbit of the Accumulator to the deposition orbit of the Stacktail in the Accumulator.
- A new algorithm was developed for the ARF1 curve in which the low energy bucket edge of ARF1 is held at a constant energy when the bucket gets close to the Stacktail deposition orbit
- The curve is parameterized by 8 tunable ACNET parameters
- The curves can also be momentum selective which will be needed when NUMI comes into operation



Stacktail Bandwidth Adjusted

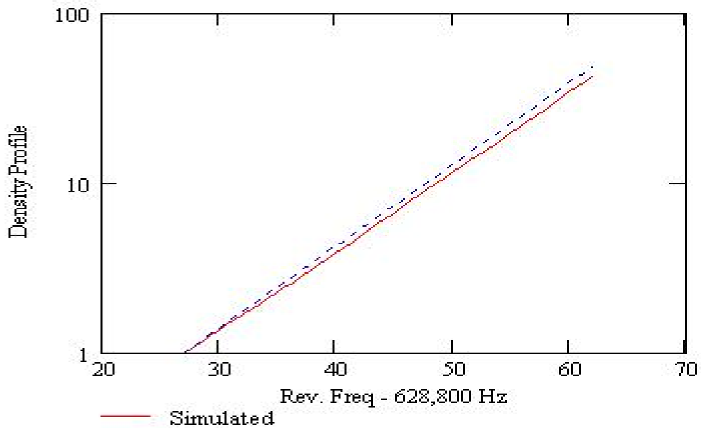
- The 2-4 GHz Stacktail pickups have sensitivity well below 2 GHz (to about 1.5 GHz)
- The initial BAW delay lines for the Stacktail notch filters cutoff sharply at 2 GHz
- An attempt was made to increase the Stacktail bandwidth by replacing the BAW delay lines with BAW delay lines that could reach lower frequency (1.5 GHz)
- Replacement yielded little or no gain because upper frequency band was lowered.

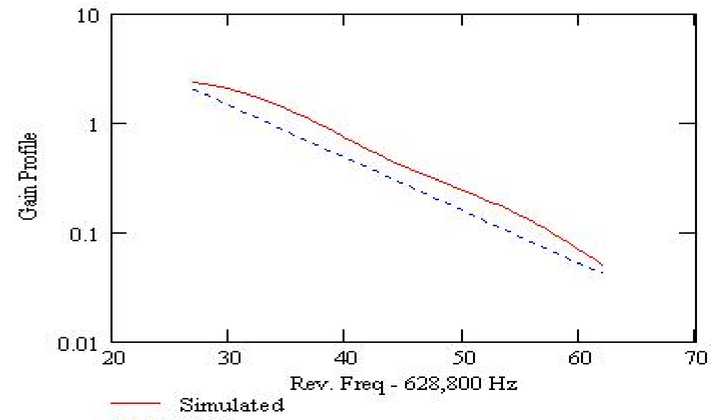


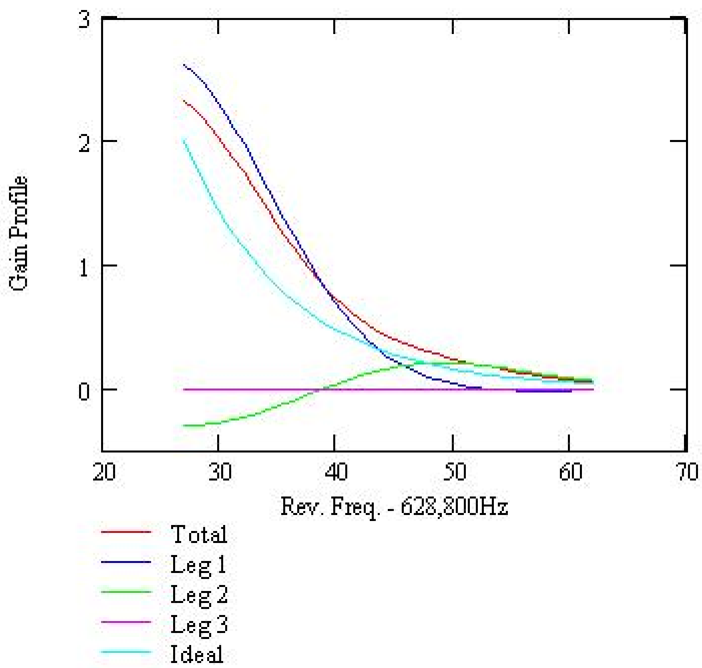
StackTail Phasing

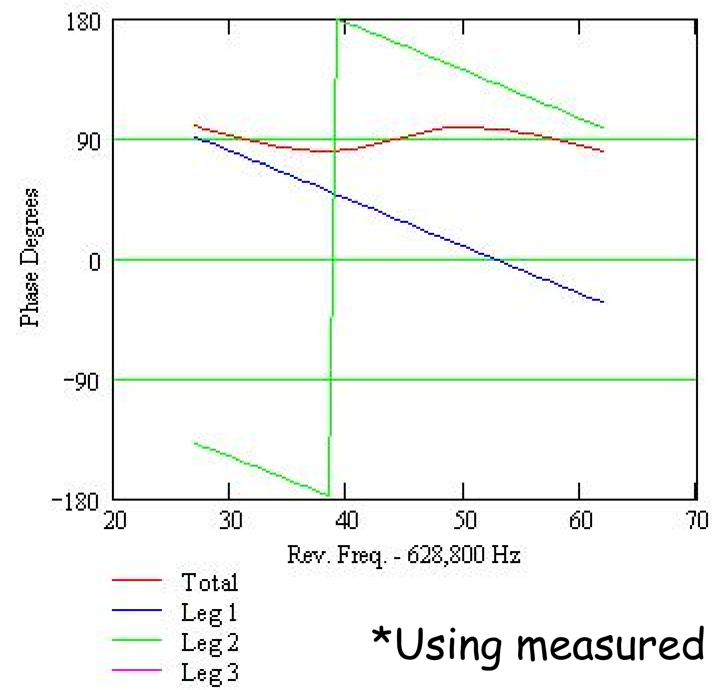
- Beam transfer function measurements were done with the beam placed on at revolution frequencies of 628,840 Hz (very close to the Leg 2 pickup) and 628,850 Hz
  - Beam was scraped to a width of 2Hz and scrapers were left in to ensure that beam width stayed at 2Hz
  - Fan-in and Fan-out were phased with very little changes made.
  - Trunk Beam transfer functions were made for all three legs independently.
    - Long leg of notch filters were left out for all legs
    - Saturation of amplifiers was checked by adjusting the network analyzer power and the trunk gain independently
- Using the actual beam transfer function measurements at 628,840 Hz, the theoretical Stacktail profile was determined by integrating the static Fokker-Plank equation.
  - with no phase shifter changes in the legs
  - With a gain slope of 9Hz
  - With notches at L1 = 628,873Hz, L2=628,887Hz, Trunk=628,887Hz
- The profile determined from the measured BTFs can support a static flux of 29.5 mA/hr

Fokker-Plank Integration Results*



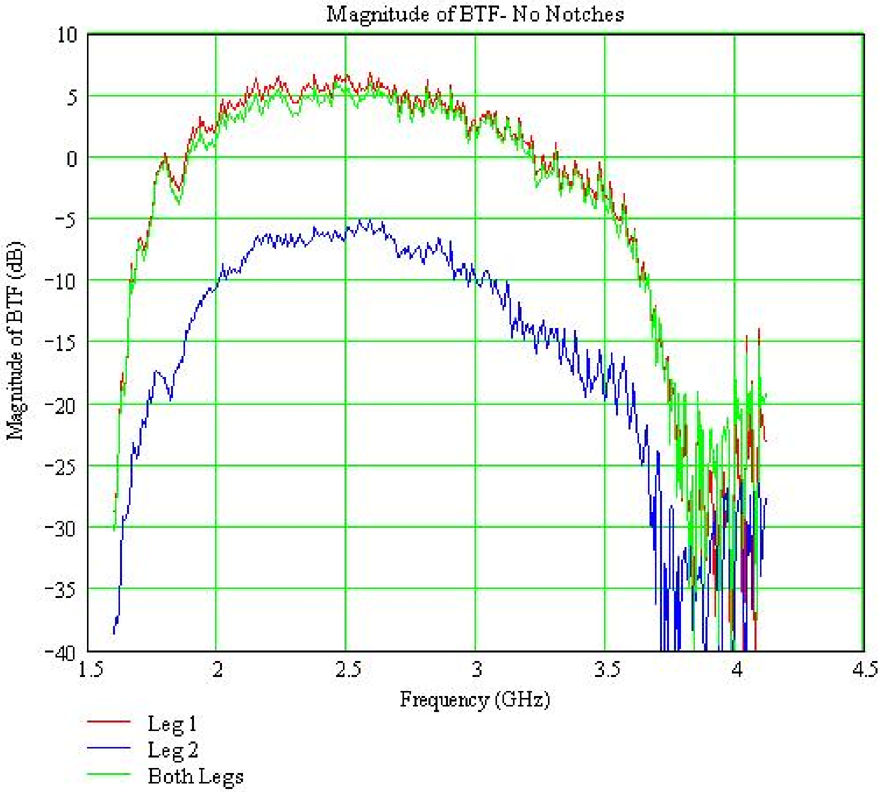


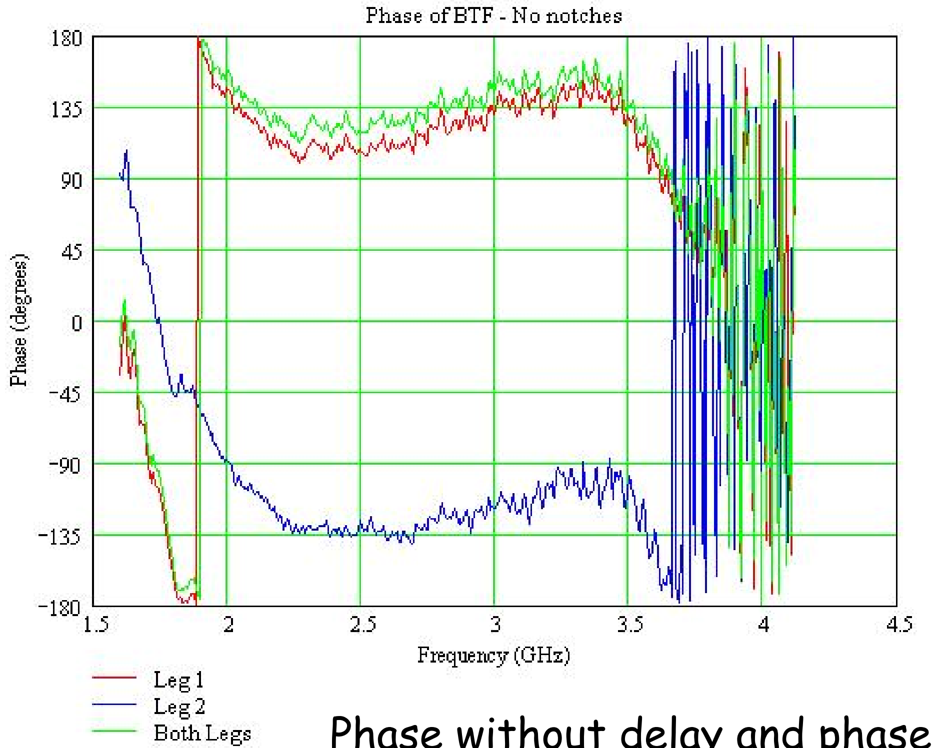




*Using measured BTFs

Magic Numbers at 628,840 Hz with No Notch Filters





Phase without delay and phase intercept removed

Leg1 at 628,840 Hz

Delay = -26 pS

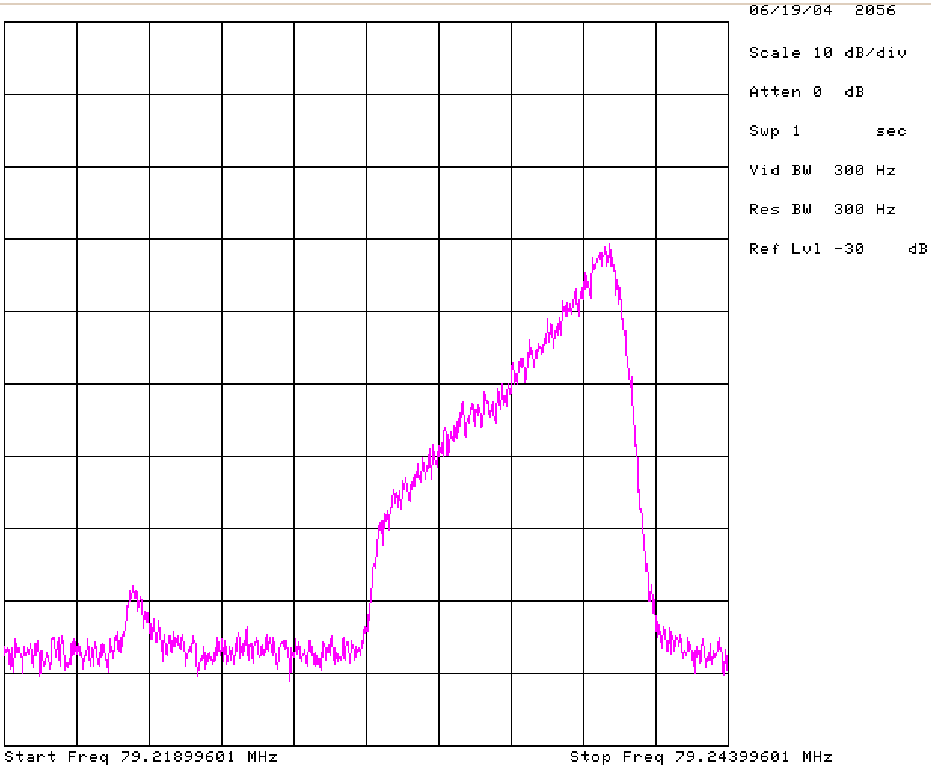
Phase = -149.5 degrees

Leg2 at 628,840 Hz

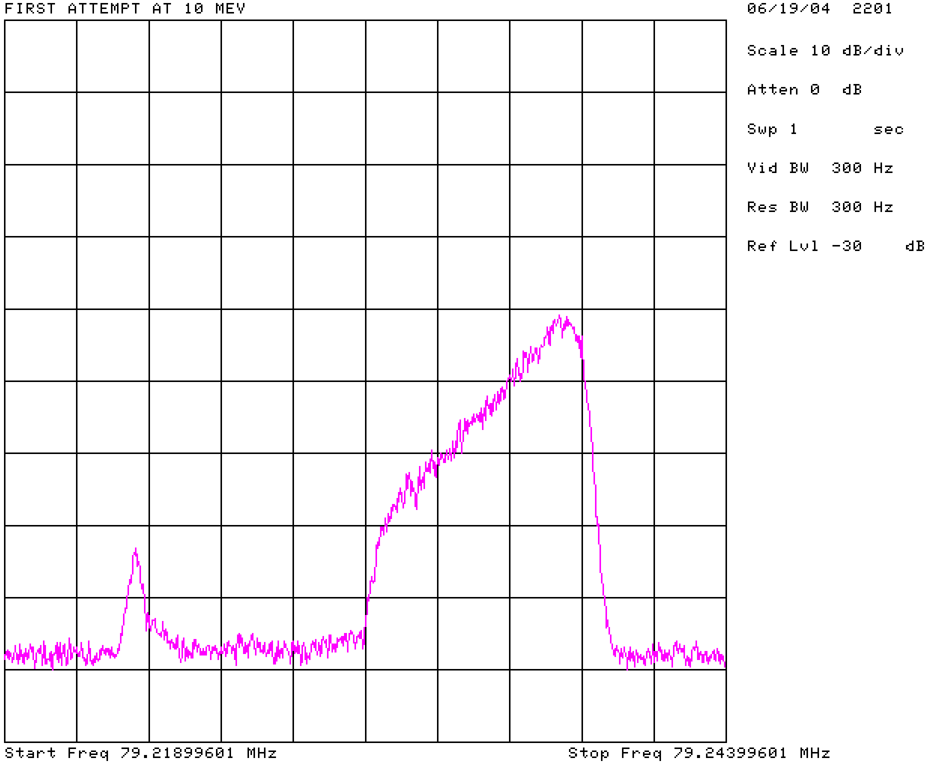
Delay = -47 pS

Phase = 75 degrees

Stacktail Profile with 9 Hz Slope

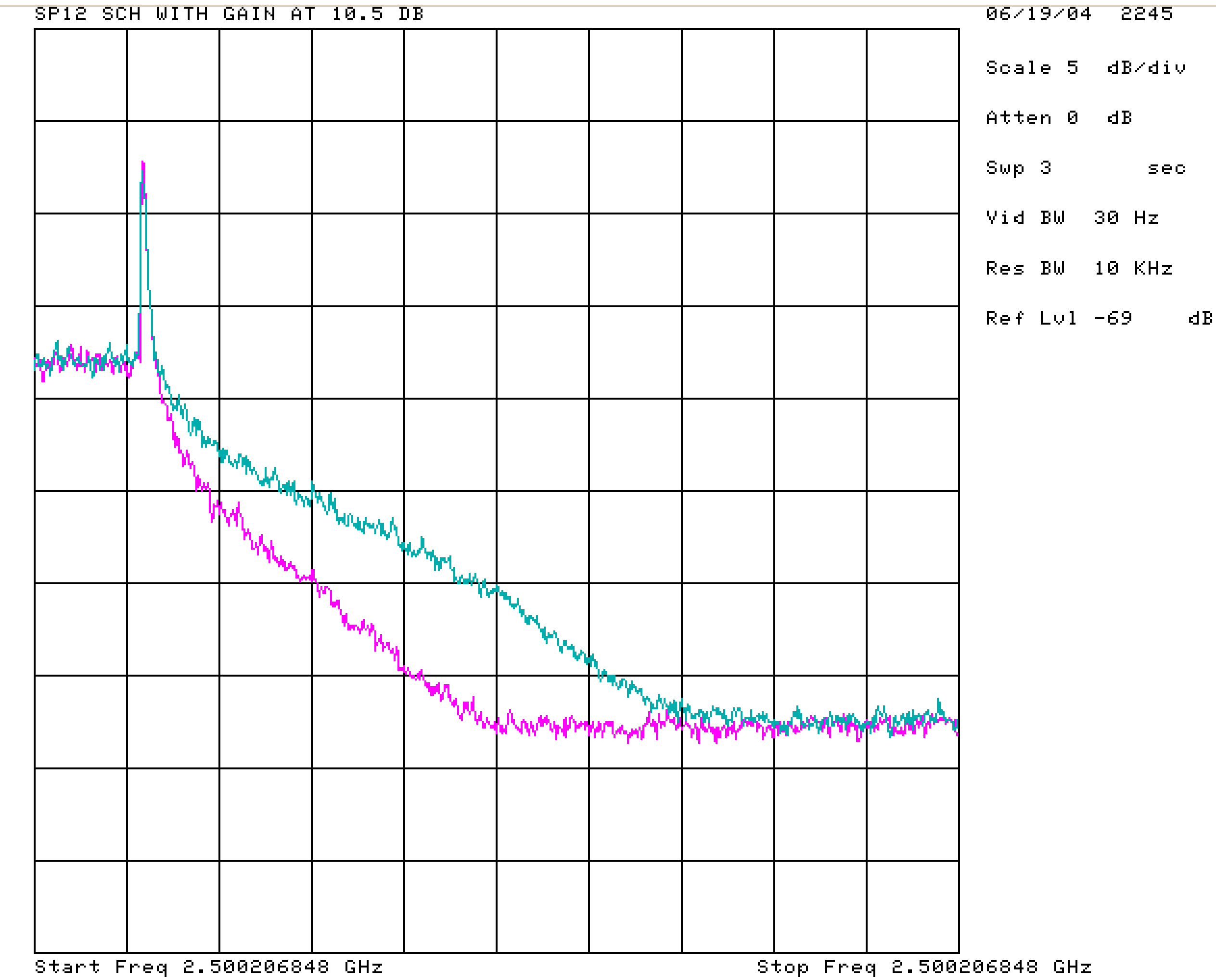


Profile Before Changes



Profile After Changes

Clearing Beam off the Stacktail Deposition Orbit



- With no core in the Accumulator, the rate at which the Stacktail moves beam off the deposition orbit was measured

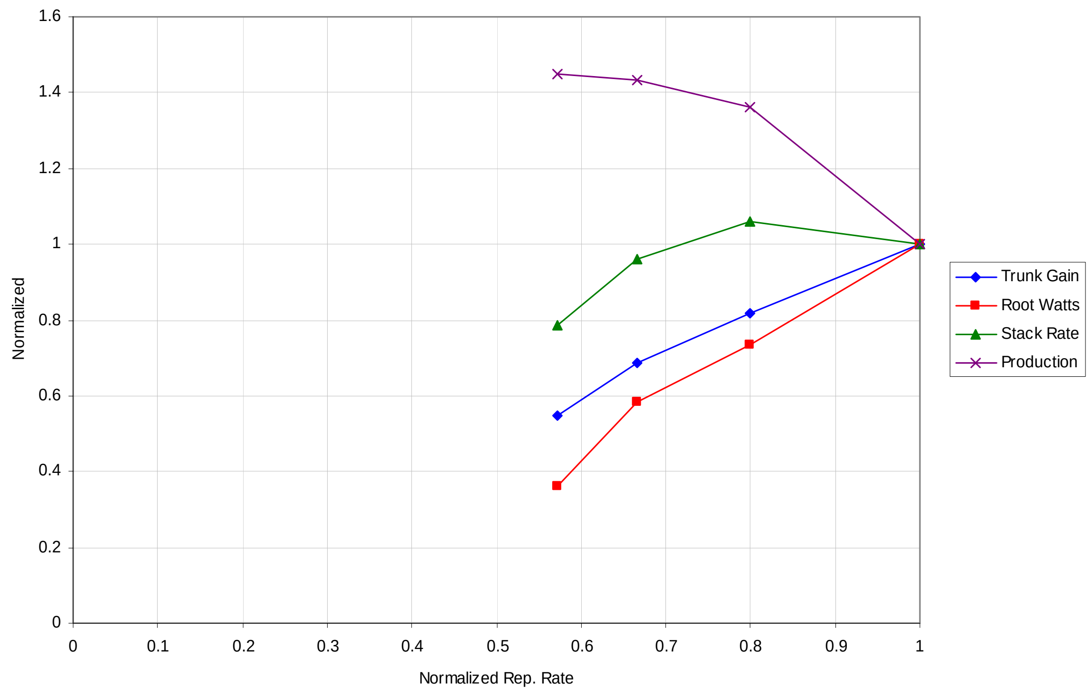
Cyan Trace with attenuator at 10.5 dB clears in 1.8 secs

Magenta Trace with attenuator at 4.5 dB clears in 1.2 secs

Variable Cycle Time While Varying Stacktail Gain

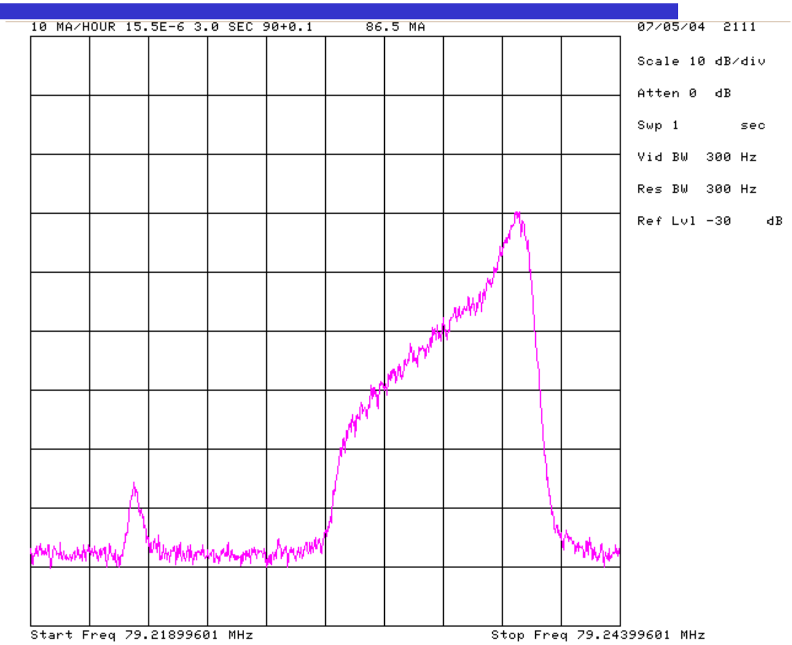
- With very small stacks, the cycle time was varied from 3.5 Secs. to 2.0 Secs. in steps of 0.5 Sec.
- At each step, the stacktail gain was adjusted so that the Stacktail profile exhibited a "hint" of back-streaming.
- Each data point was the average of ten 60 Sec. super-cycles
- The drop in production negates short cycle times.

Cycle time	StackTail Trunk Attenuator	Stacktail TWT Power	Stack Rate	Production
Secs.	dB	Watts	mA/hr	$x10^{-6}$
3.5	17.5	65	7.8	14.8
3	15.5	170	9.5	14.6
2.5	14	270	10.5	13.9
2	12.25	500	9.9	10.2



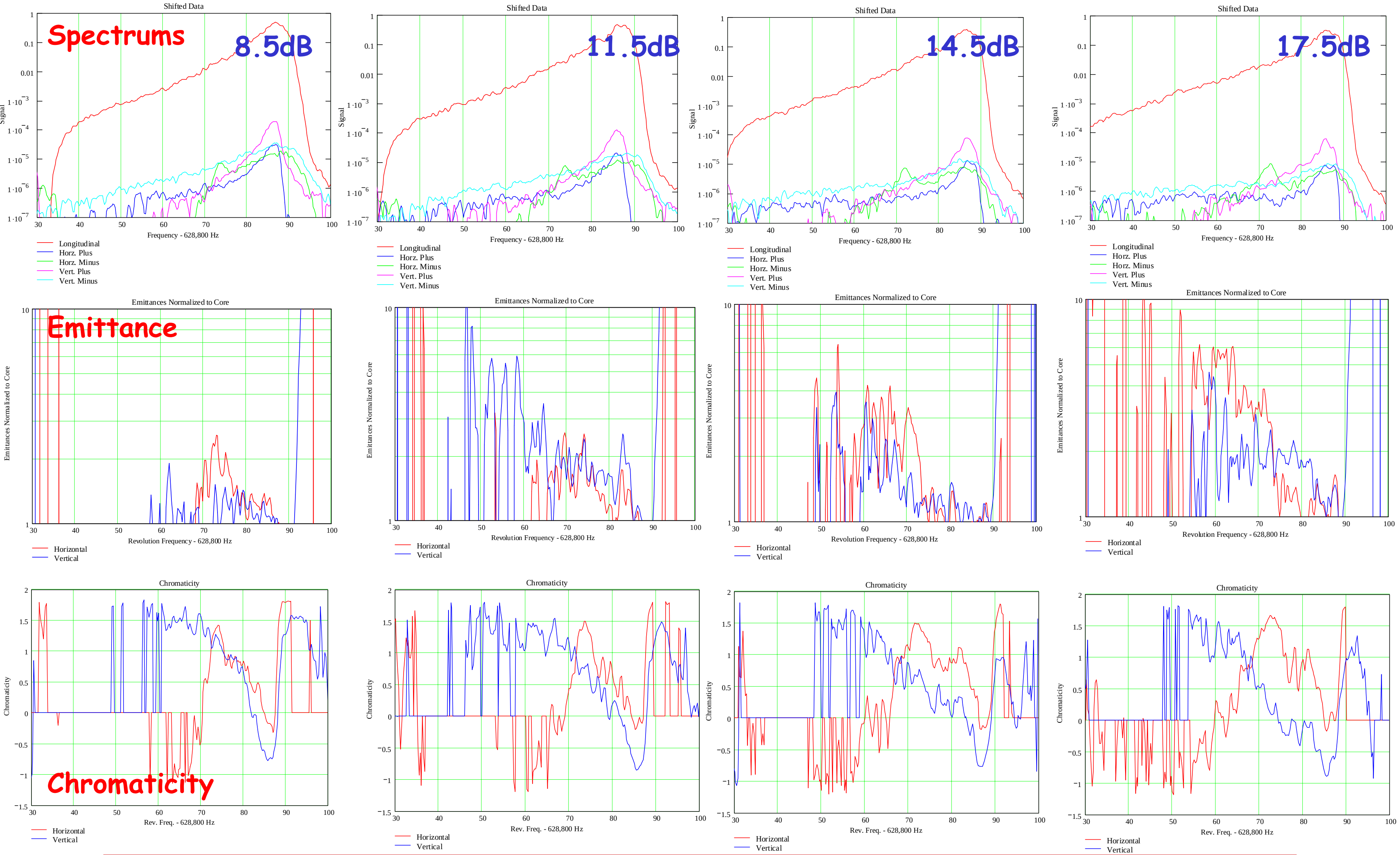
Constant Long Cycle Time While Varying Stacktail Gain

- Ran at a slow cycle time (3.5 secs)
- The lowest Stacktail gain was set for when the Stacktail profile had a "hint" of back-streaming
- Each data point was the average of ten 60 Sec. super-cycles
- Result: Small Stack Stack Rate does not seem to be a function of Stacktail Gain or Power
- Also measured transverse emittances through the Stacktail using Van der Meer's technique and found the emittances were fairly independent of Stacktail gain



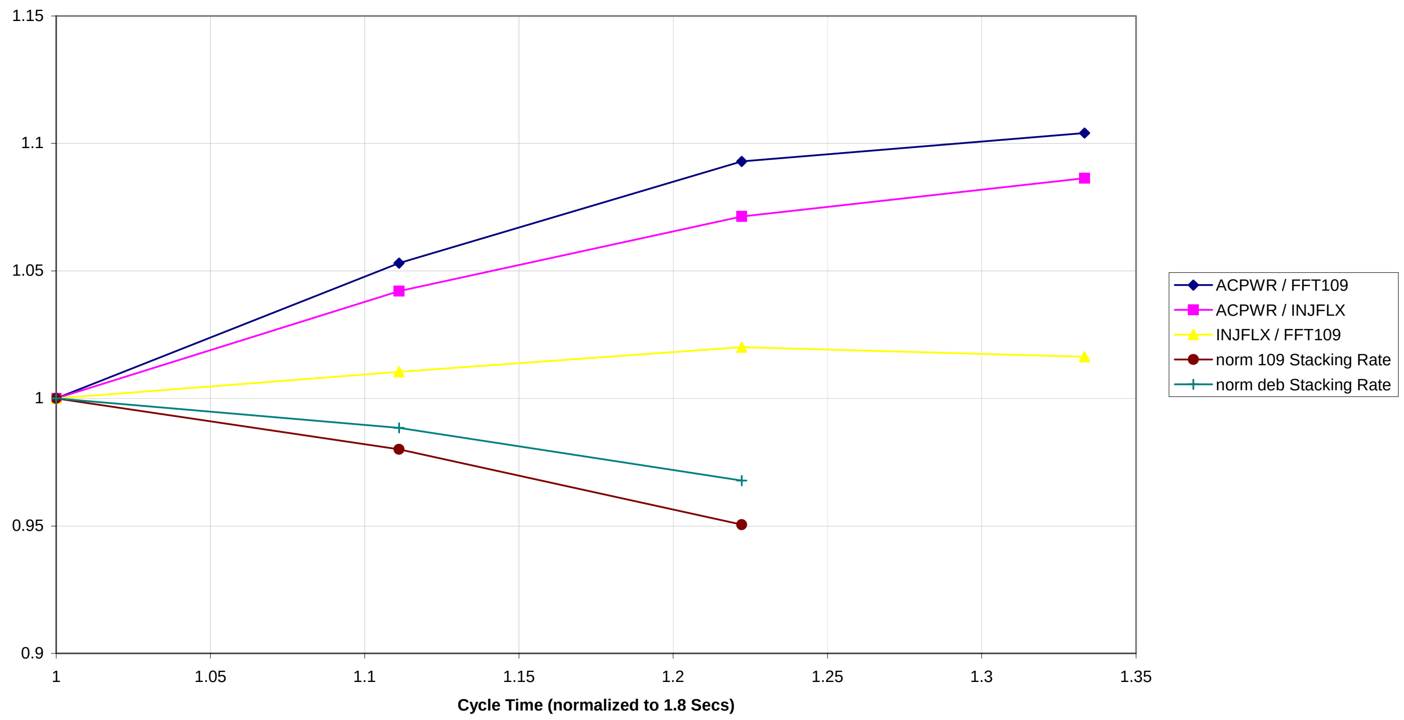
StackTail Trunk Attenuator	Stacktail TWT Power	Stack Rate	Production
dB	Watts	mA/hr	x10^{-6}
17.5	65	7.8	15
14.5	180	7.5	14.5
11.5	400	7.6	14.7
8.5	700	7.6	14.7

Measuring Stacktail Emittances with Constant Long Cycle Time While Varying Stacktail Gain



Zero Stack Measurements with Constant Stacktail Gain and Variable Cycle Time

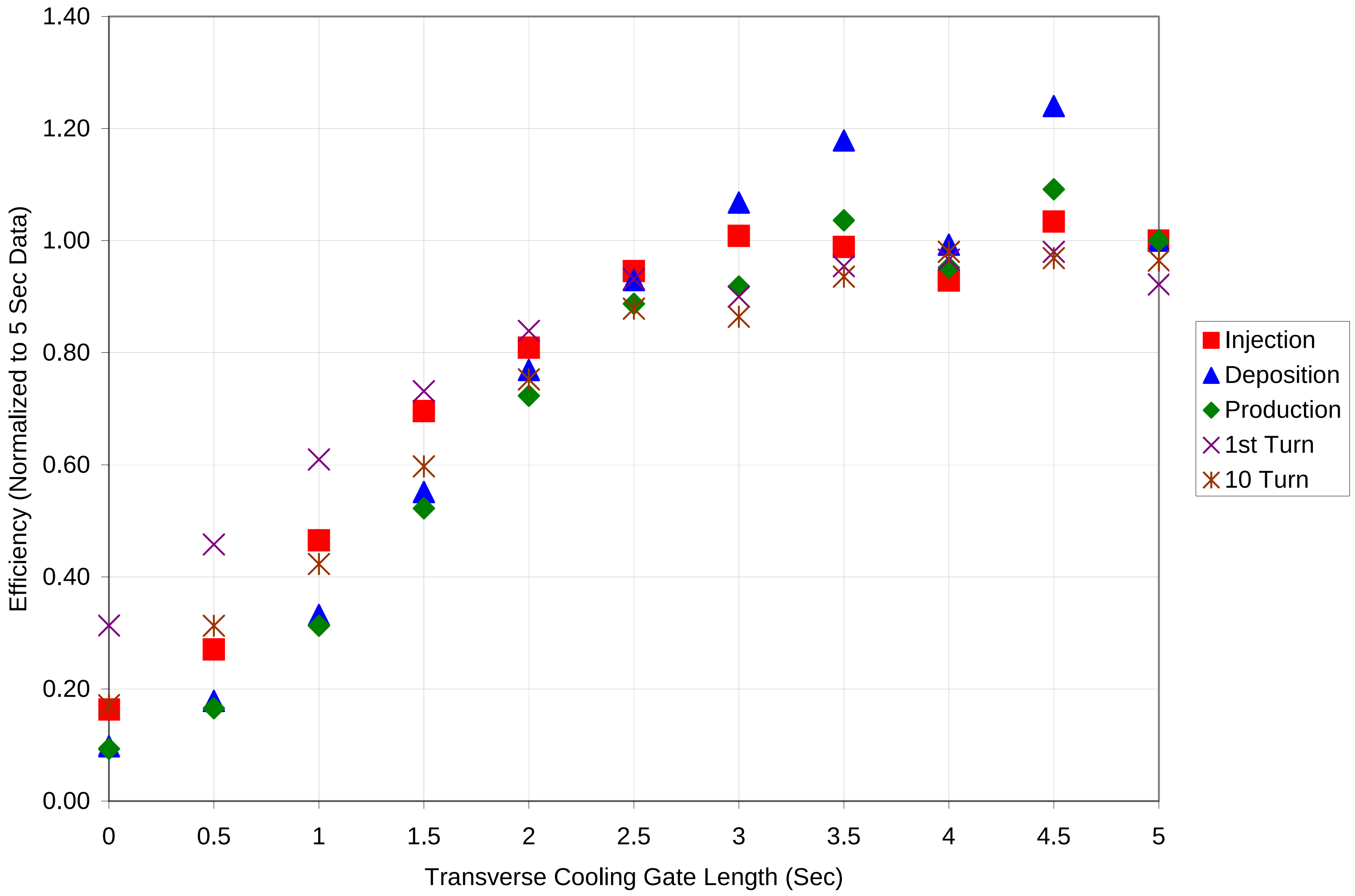
- Stacking measurements were taken with a fixed gain of 9 dB
- The stacking Rate falls 5% while the cycle time increases from 1.8 secs to 2.2 seconds
- If the amount of beam on the injection orbit was constant as a function of cycle time, the stacking rate should have fallen by 22% while the cycle time increases from 1.8 secs to 2.2 seconds
- Most of this discrepancy can be explained by the reduction in the fraction of beam making it into the Accumulator as a function of the cycle time



Pbar Production Efficiency vs Debuncher Cooling Time

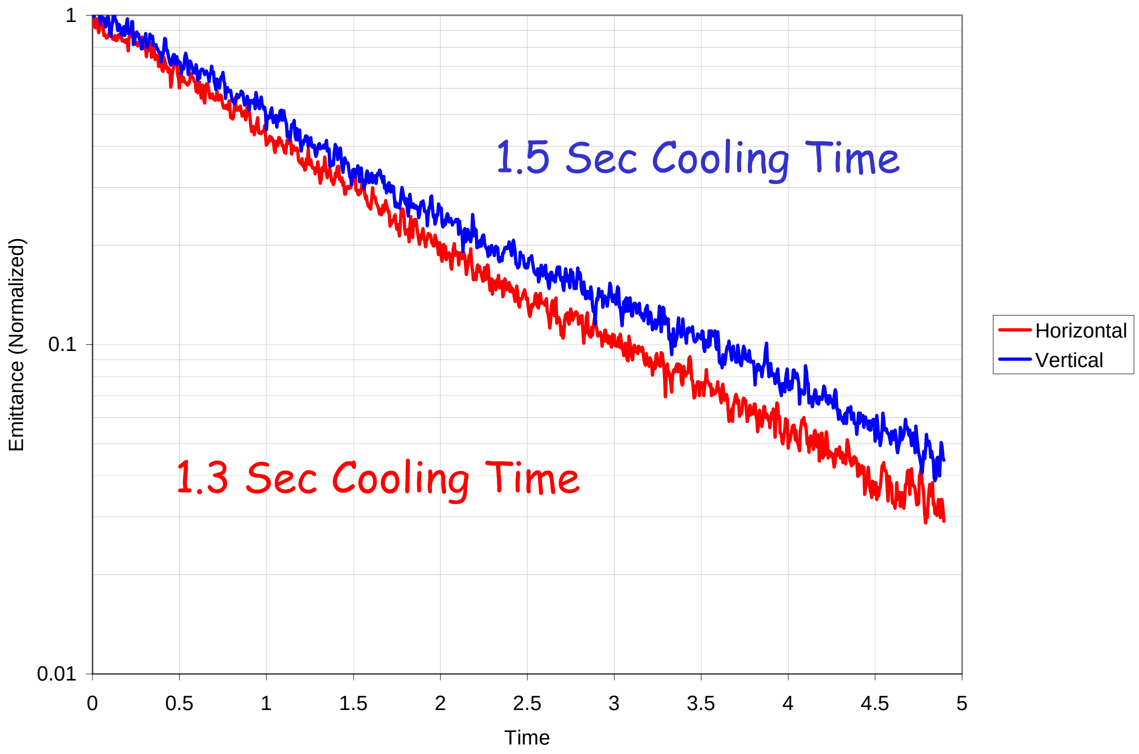
- To investigate if the reduction of beam injected into the Accumulator as a function of cycle time is due to Debuncher transverse cooling, beam transported to different stages of the Accumulator as a function of how long the Debuncher transverse cooling was left on was measured.
  - Done at small stacks
  - Done with a very long cycle time of 5 secs.
    - Low Stacktail and Debuncher Momentum cooling gain
  - Debuncher transverse cooling systems gate length was varied.
  - Injection and Deposition orbit efficiencies were measured using the Accumulator Longitudinal Schottky
    - Measurements were gated on only when Stacktail and ARF1 were gated off.
  - First and Tenth turn measurements were done by bunching the beam in the Debuncher at extraction from the Debuncher with DRF1 (53 MHz) and measuring the bunched beam intensity on the Accumulator Longitudinal Schottky
    - These measurements were done on different cycles than the measurements made with the longitudinal Schottky

Pbar Production Efficiency vs Debuncher Cooling Time



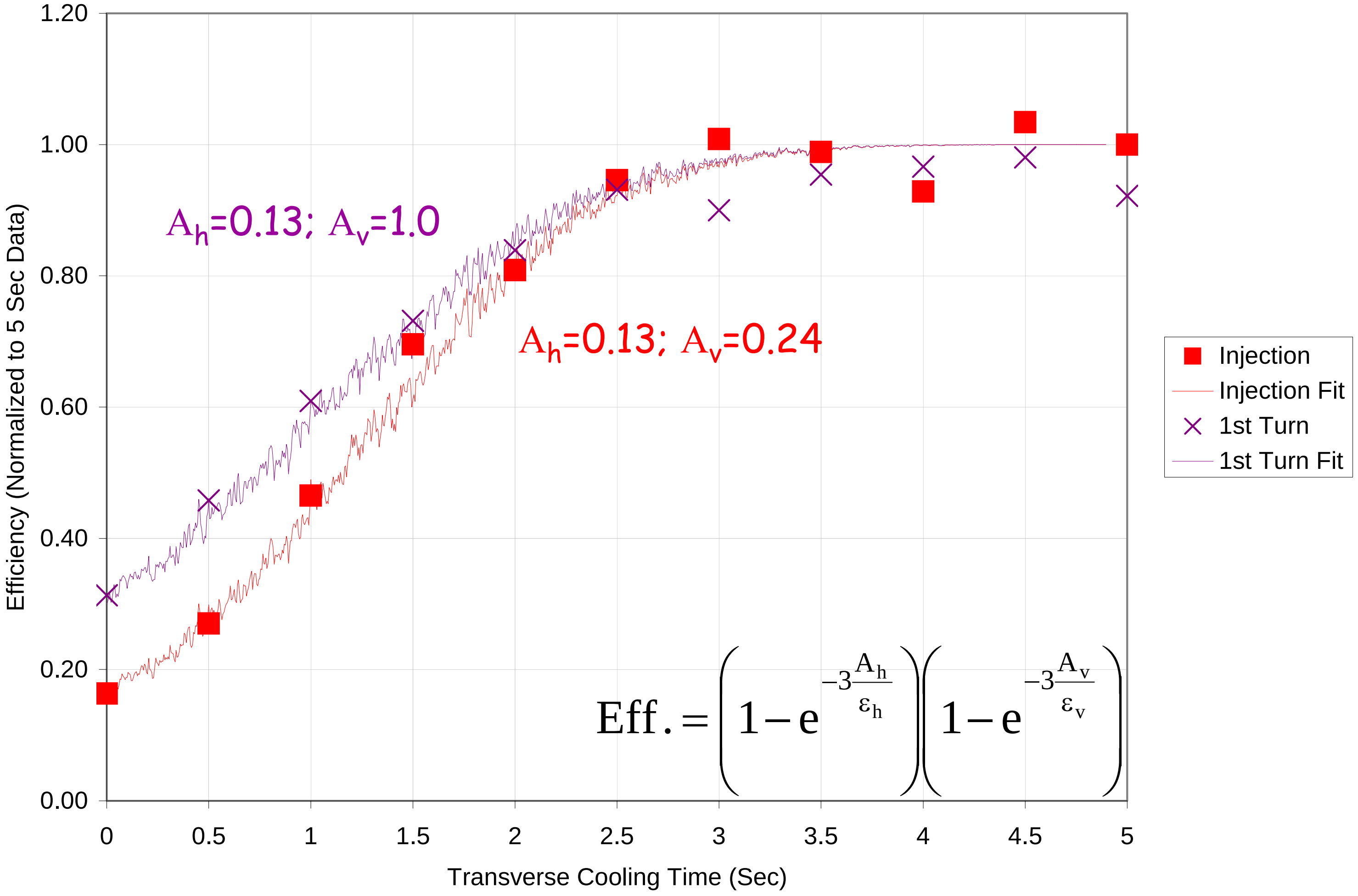
Debuncher Transverse Cooling

- Because of the low noise temperature and high impedance of the Debuncher transverse cooling pickups, the emittance as a function of time can be directly measured from the transverse cooling system schottky signals.
  - Measured over a single transverse sideband with a spectrum analyzer zero span mode.
  - Signal suppression is a small effect



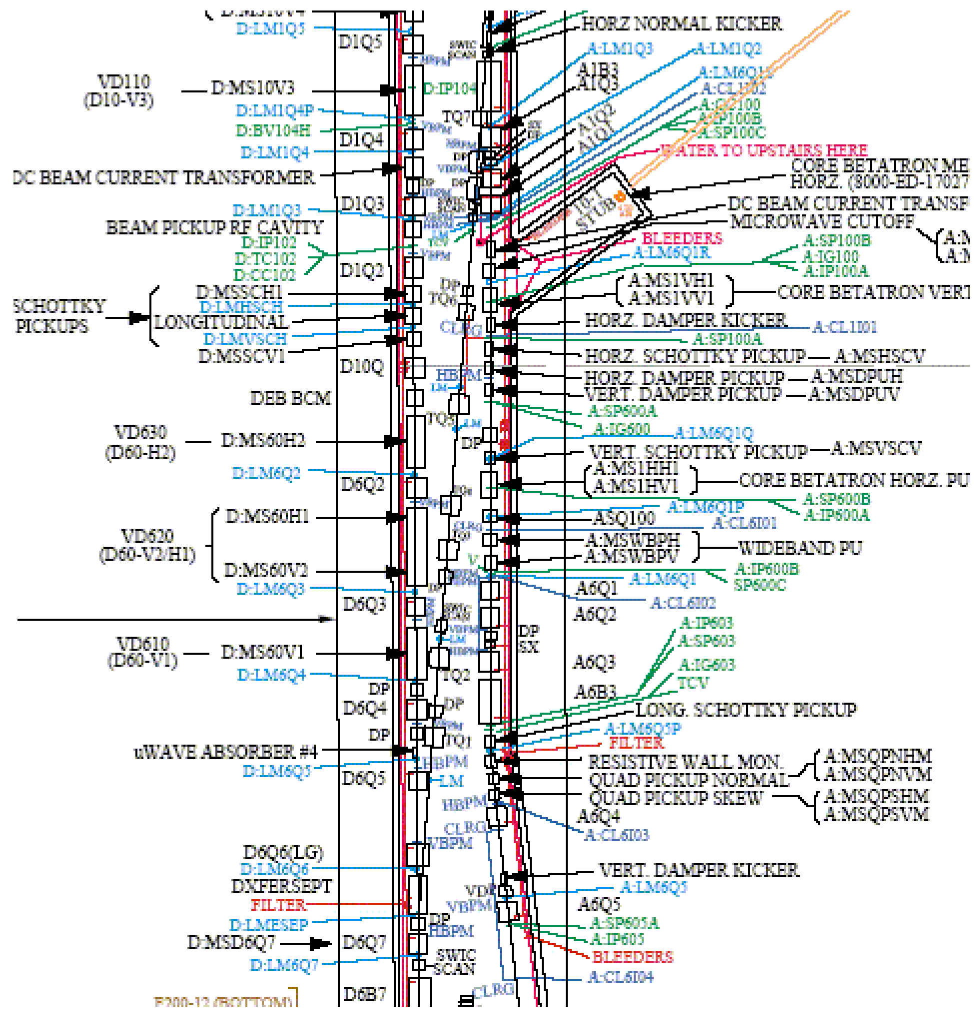
Debuncher Extraction - Accumulator Injection Aperture

- The production vs transverse cooling time measurements can be explained if there is an aperture restriction between Debuncher Extraction and Accumulator Injection

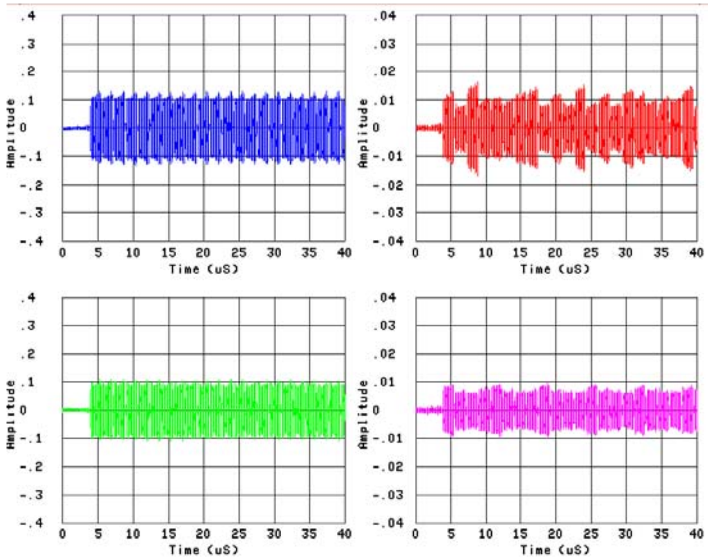


Reverse Proton Debuncher to Accumulator Transfer Line Instrumentation

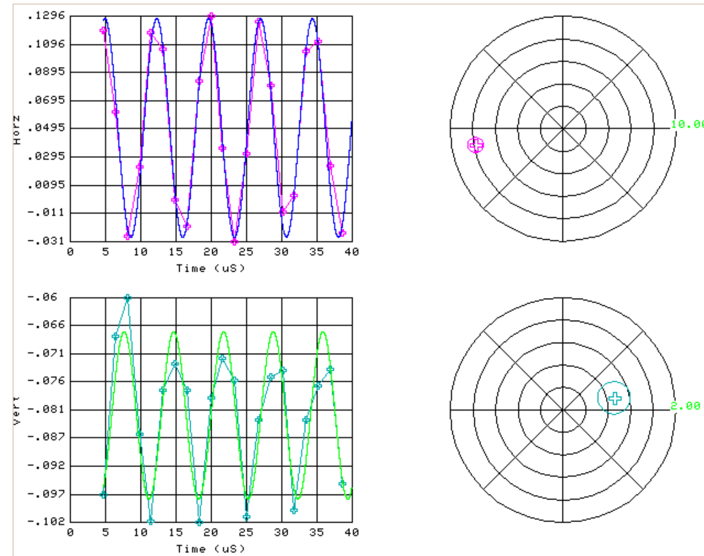
- To search for the the possible aperture restriction in the D-A Line we:
  - Developed a procedure for bunching reverse protons in the Accumulator with 53 MHz RF just before extraction from the Accumulator to the Debuncher
  - Instrumented 4 BPMs in the Accumulator, 7 BPMs in the D-A Line, and 1 BPM in the Debuncher to see the 53 MHz RF signal
    - Calibrated the cable loss for the above BPMs for an absolute intensity measurement
  - Developed a 53 MHz Reverse Proton TBT system in the Debuncher

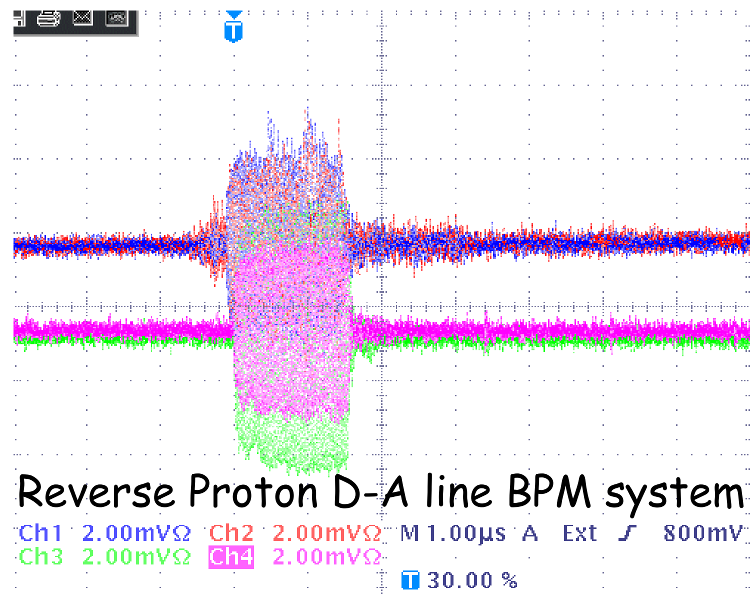


Reverse Proton Debuncher to Accumulator Transfer Line Instrumentation



Reverse Proton TBT System

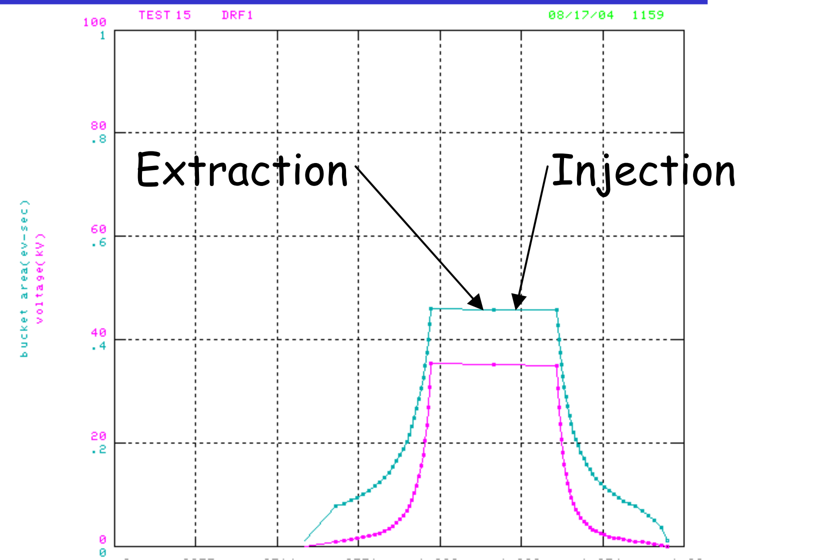


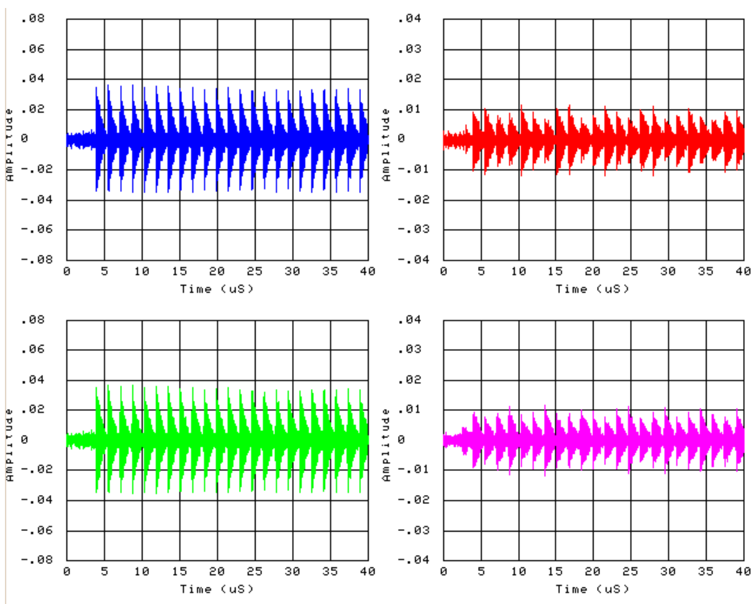


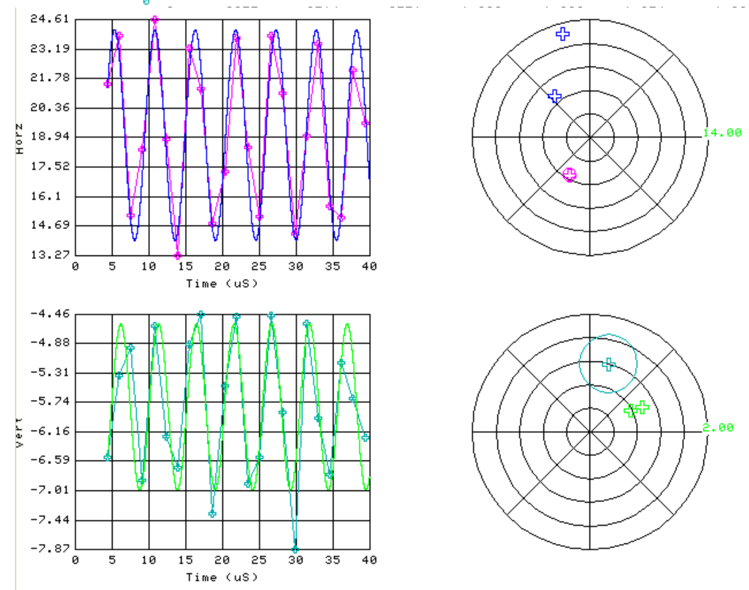
Reverse Proton D-A line BPM system

TBT System for Pbar Injection into the Accumulator

- Needed to develop bunched beam at injection into the Accumulator
  - Used DRF1 to bunch beam at end of cycle in Debuncher by extending bunch rotation curve backwards in time
- Used 79 MHz Schottky to see transverse and longitudinal motion of the beam in Accumulator at 53 MHz
  - Resonant effect probably does not help that much
  - Long pickup and good pre-amps reason for seeing good bunched signal





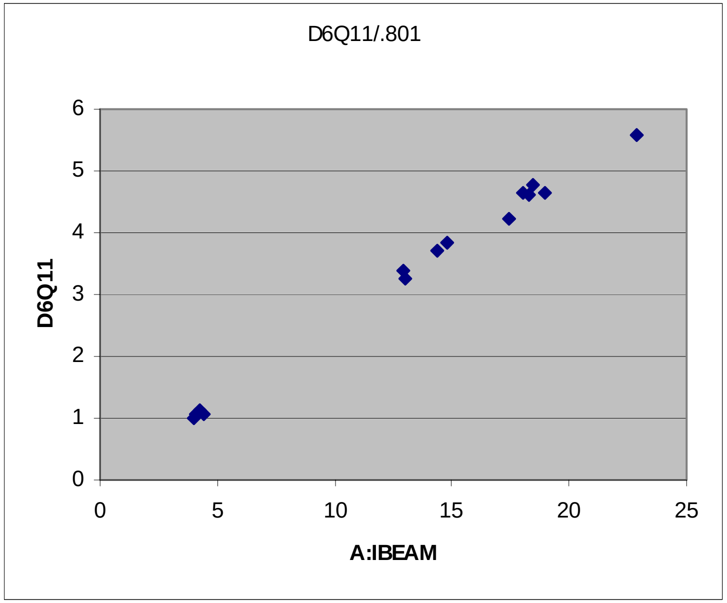


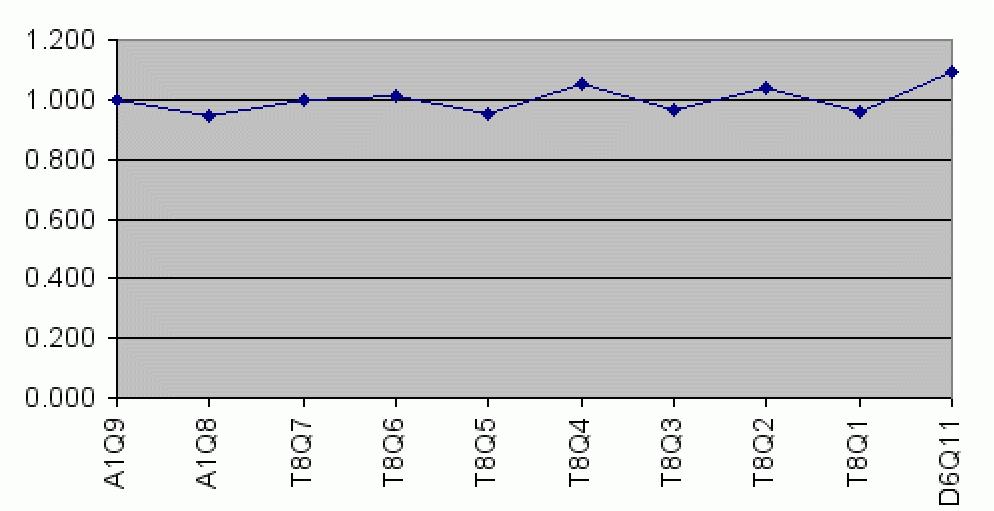
Uses of the TBT System for Pbar Injection into the Accumulator

- Close pbar trajectory into Accumulator
  - Done during the last day of studies
  - Did not seem to effect efficiency much
    - Did not do a transverse cooling time scan
- Measure Quad Steering in the D/A line
  - Each quad in the D/A line is independently controlled
  - Measured a significant amount of steering in the middle of the line
  - Will be used for beam-based alignment in the future
- Measure response matrix of D-A transfer line
  - Measure unperturbed trajectory by using quad shunts to measure steering in the D-A line
  - Place a trajectory perturbation at beginning of line and by using quad shunts to measure steering in the D-A line
  - Compare quad steering orbits
  - Initial data already taken
- Measure TBT injection intensity into Accumulator (see slide 23)
  - Can also be used to tune DRF2 voltage slope in between barrier bucket

Reverse Proton D-A Transfer Line Studies

- We were unable to see any large intensity drop in intensity for reverse protons in the D-A line
  - The beam was blown up to the Accumulator aperture of 6π-mm-mrad before extracting from the Accumulator to the Debuncher
  - BPM intensity signal tracks beam current in the Accumulator

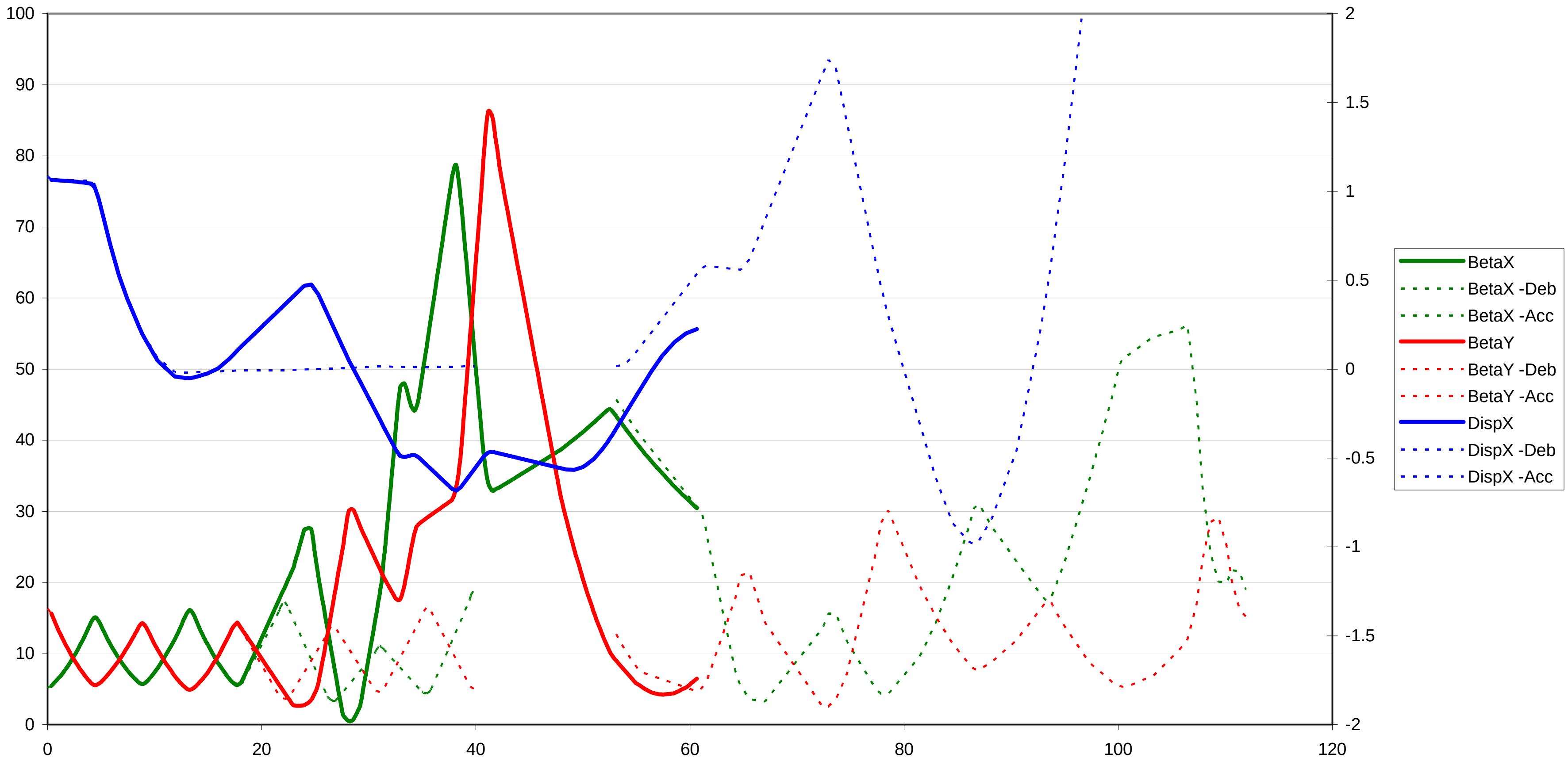




Possible Explanations for Reverse Proton BPM Studies and Forward Pbar Production Measurements

- The forward pbar trajectory is different from the reverse proton trajectory
  - Trajectories were not closed for either species
    - Reverse protons go from a small aperture to a big aperture – closure not as important
    - Forward pbars go from a larger aperture to small aperture – closure is much more important
  - Directional differences of kickers and timing
- The optics of the D-A line is not matched
  - The injection lattice of Accumulator is different than the lattice of the Accumulator on the central orbit
    - Need to measure Accumulator Injection lattice with differential orbits
    - Need to measure transfer matrix of the D-A Line

D-A Line Lattice Functions

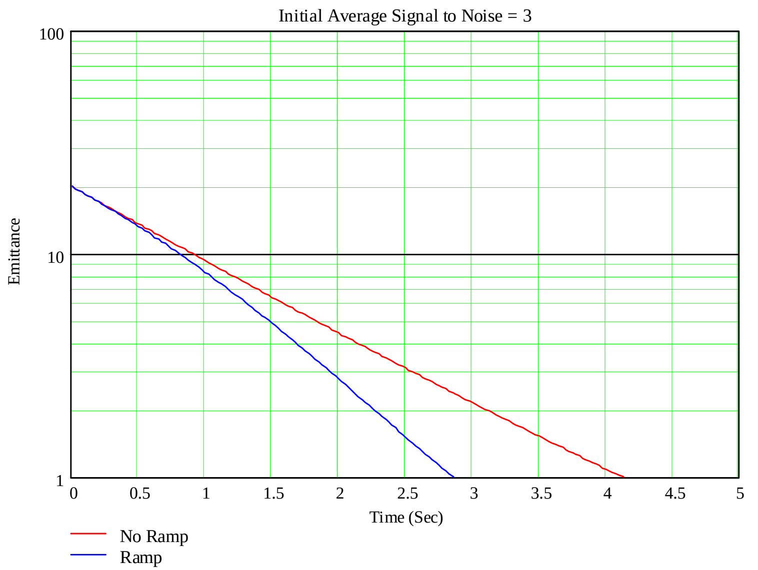


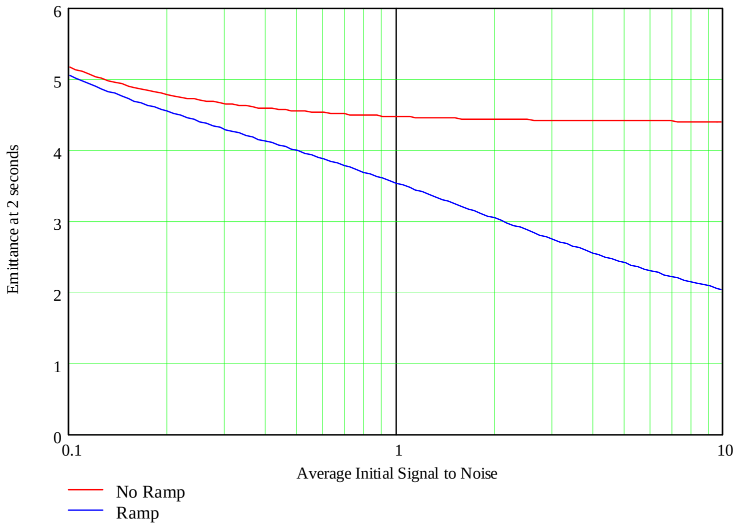
Plan of Work

- Make the beam smaller
  - Gain ramping of the transverse systems
  - Investigate slower than expected Debuncher transverse cooling rate
- Make the hole bigger
  - Alignment of the D-A line
  - Beam Based alignment of the beam through the line

Gain Ramping the Debuncher Transverse Stochastic Cooling Systems

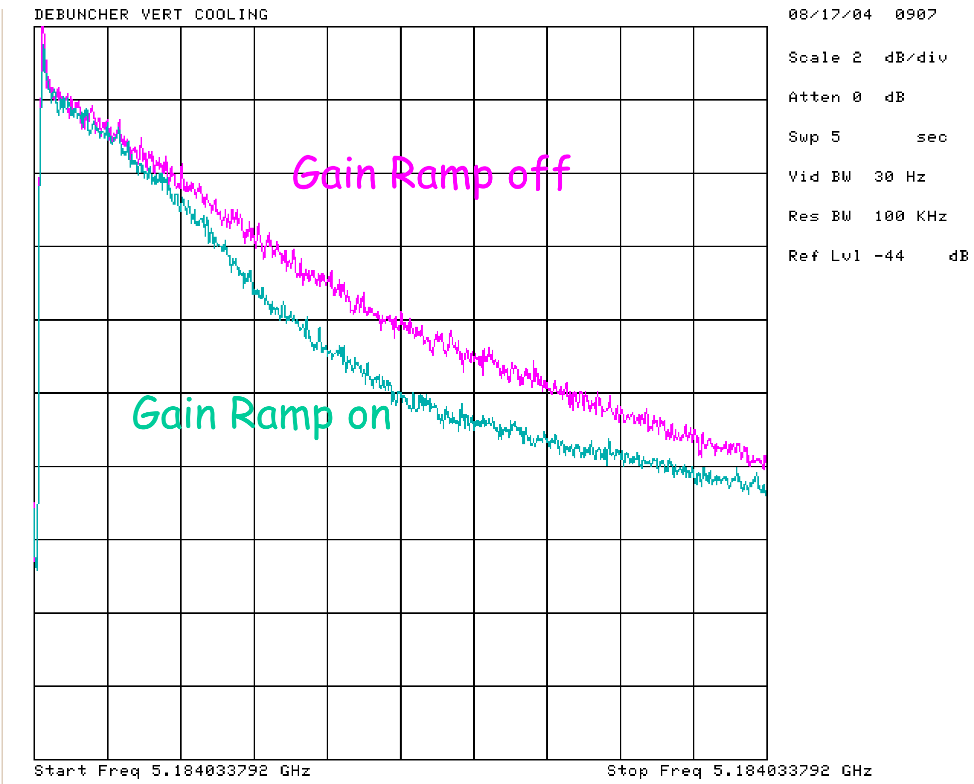
- Debuncher Transverse Stochastic Cooling systems:
  - Have reasonable signal to noise
  - Are power limited (don't have enough TWT power)
- As the beam cools in the Debuncher, TWT power shrinks as well.
- If the cooling system gain is ramped up to keep TWT power constant, than the emittance can be further reduced.



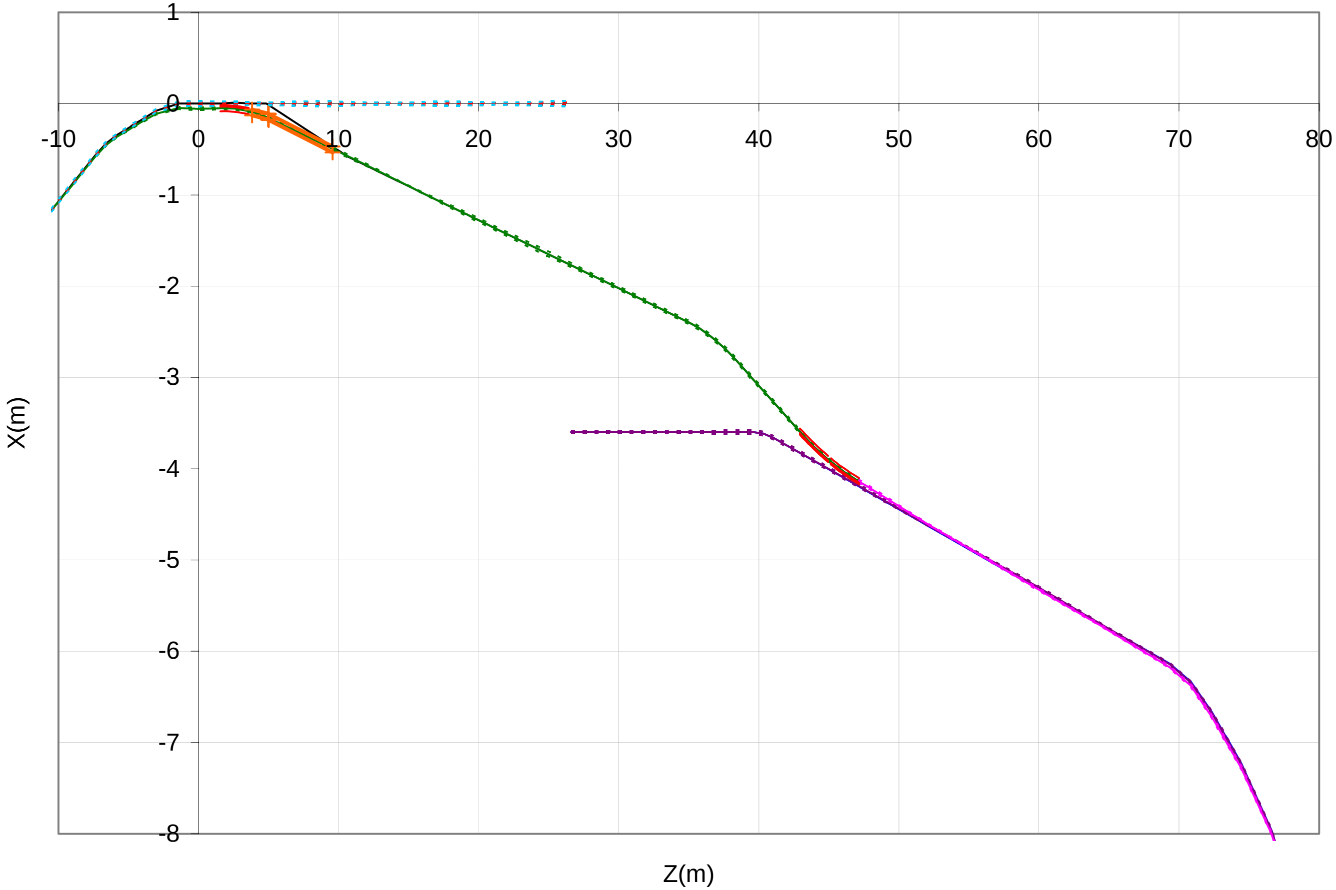


Debuncher Transverse Cooling Gain Ramping

- Transverse Schottky signal dominates the TWT power for Bands 1 & 2 of the Debuncher transverse cooling systems
  - Transverse Schottky signal is a noticeable component in Bands 3 & 4 as well
- Transverse gain ramping in which the transverse gain increases as the emittance decreases was implemented.
  - Systems well below optimum gain.
  - Gain ramps need more work

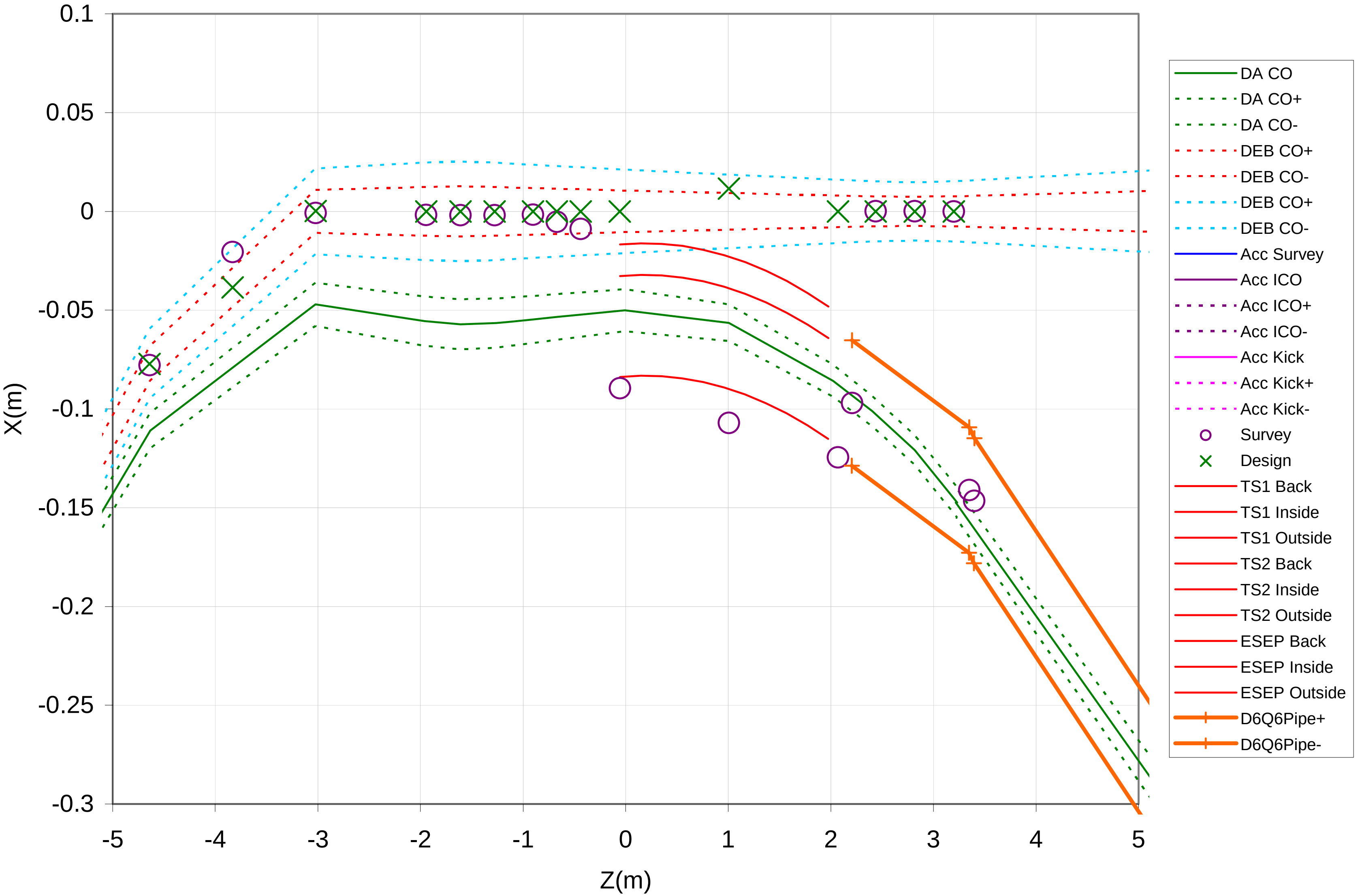


Debuncher to Accumulator Transfer Line



- Did a complete Laser Tracker survey of the entire D-A line from Debuncher Extraction Kicker to Accumulator A1Q5
- Built a lattice model (MAD) that matched survey coordinates to within 1-2 mm

Debuncher Extraction as Found



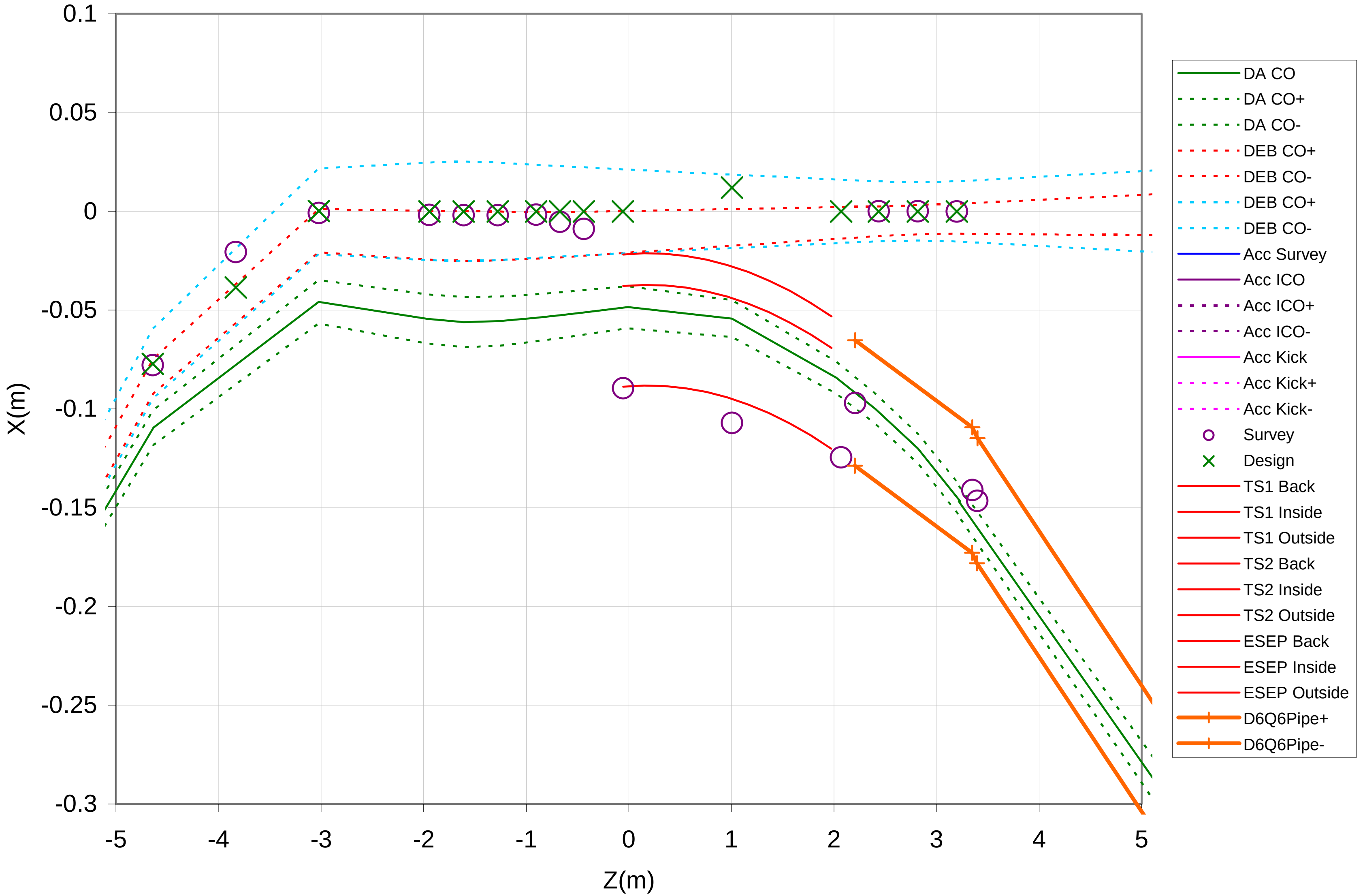
Debuncher Extraction (as found)

- Upstream end D:ESEP and "D-Pipe" need to move 5mm towards Accumulator
  - For a 40 π-mm-mrad aperture injection beam
  - For a 10 π-mm-mrad aperture extraction beam
  - A 48.4 mm separation between kicked beam and closed orbit at the Debuncher Extraction Septum
    - Need to confirm that D:EKIK can deliver at least 50mm of separation between circulating and extracted beam at D:ESEP
      - Debuncher needs 5.0 mrad kick for 48.4 mm
      - Accumulator needs 2.6 mrad for 50 mm.
      - Both kickers are running close to max voltage of 60 kV
- Installing DEX Bump (Ramped 3 bump at the Debuncher extraction septum) to compensate insufficient kicker voltage
  - Bump is off when injecting beam to maximize injection aperture
  - Bump is on when extracting beam to snug up closed orbit to the septum as close as possible for a 10 π-mm-mrad
  - Next injection immediately follows extraction so bump must ramp down fast.

Debuncher Extraction Bump

- Bump is composed of:
  - NDA trim just upstream of the Debuncher bend B608
  - NDB trim at H606
  - NDA trim just upstream of Q605
  - Ratio = 1: -1.151 : 0.886
- A Dex Bump with an amplitude of -12 mm at H606 will bring the inside edge of a 10 π-mm-mrad circulating beam for extraction to the inside edge of an injected 40 π-mm-mrad beam
- The kicker angle needed is now 3.87 mrad (reduction of 23%)
  - Requires a bend ratio of 1.2 : -1.38 : 1.06 mrad
  - Requires a current ratio of 19.9 : -19.45 : 17.57 A
- Power Supply Voltage
  - The inductance of an NDA is ~450mH and the resistance is ~750mΩ
  - An inductive voltage of 100V could ramp the 12 mm bump in 90mSec
    - Shortening the Debuncher cooling cycle time by 90mSec for a 2 second cycle time would increase the tranverse emittance by 7% for a 1.3 sec cooling time constant
    - If there is no DEX bump and the kicker voltage is 3.87 mrad.,
      - The center of the extracted beam will hit the septum edge
      - Therefore only 50% of the beam will make it through the Debuncher extraction septum.
  - The resistive voltage swing is 15V

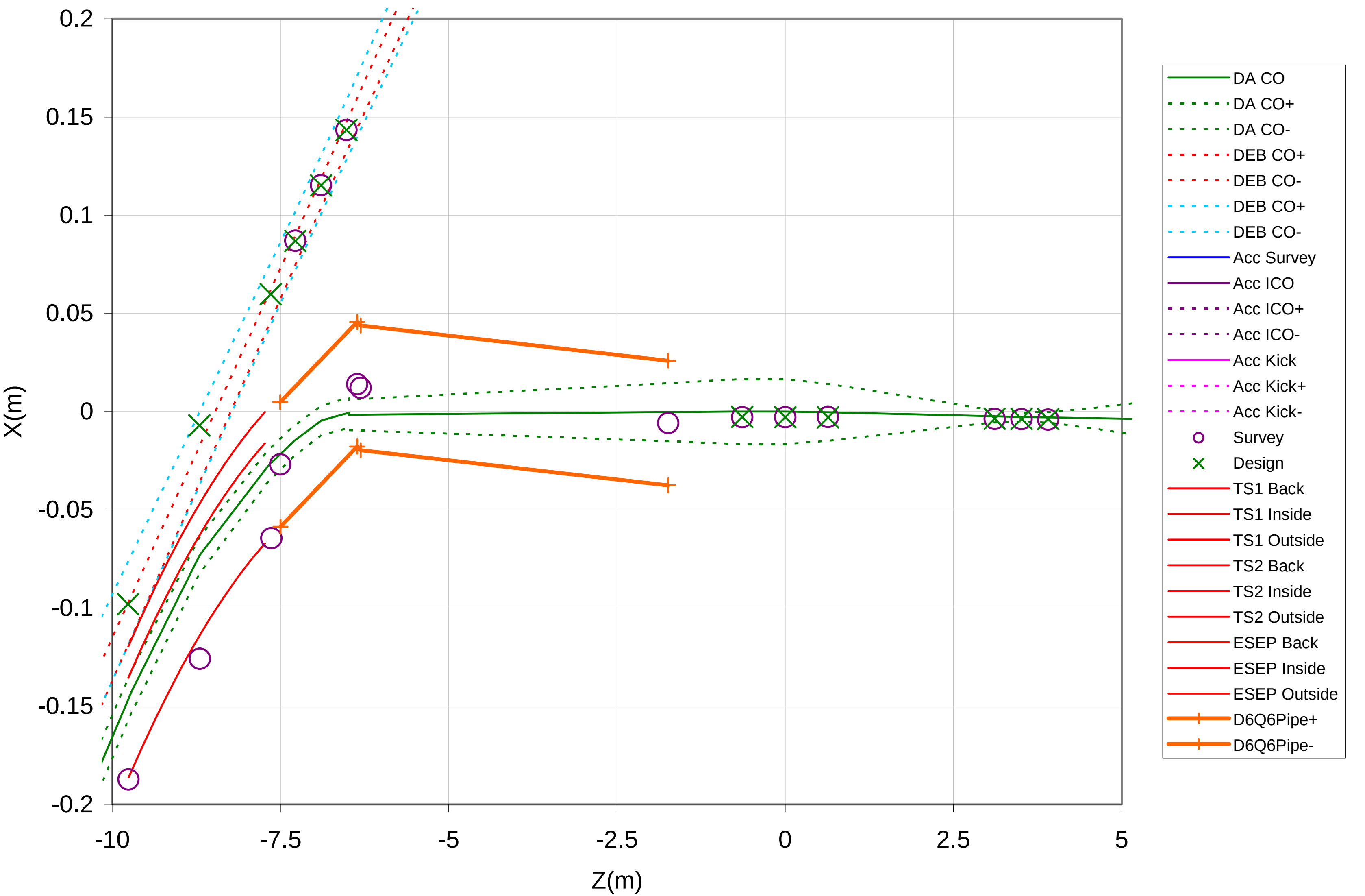
Debuncher Extraction with DEX Bump and Septum Move



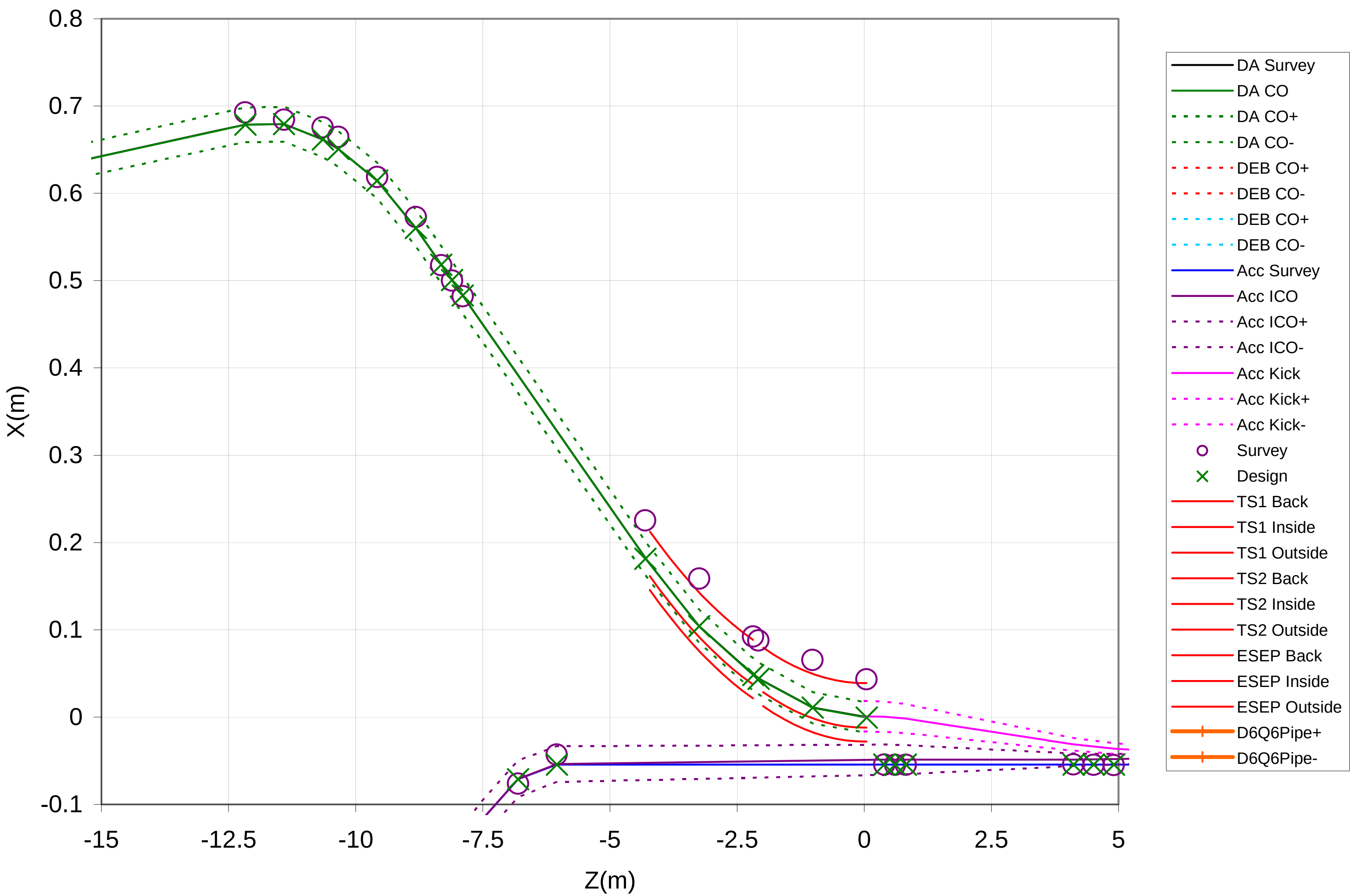
Injecting into the Transfer Line

- Injection into the transfer line must satisfy 3 constraints:
  - Beam Separation at the extraction septum
    - Set by the extraction Kicker voltage
  - Angle of the transfer line with respect to the Debuncher
    - Set by the location of the quads in the transfer line
  - Intercept of the transfer line with respect to the Debuncher
    - Set by the bend by going off-center through the Debuncher quad D6Q6
- There are only 2 knobs to control injection into the transfer line
  - Extraction kicker voltage
  - Extraction Septum bend angle
    - The gradient on D6Q6 is adjusted for Debuncher lattice properties
- According to the lattice model and magnetic field measurements of D6Q6 there is a 2-3 mrad error in the bend needed by D6Q6 to center beam in TQ1
  - An alternative is to correct the distortion at TQ3 by using a 0.7mrad kick at D:HT804.
  - The angle introduced by DEX bump would reduce the required kick to 0.4mrad at D:HT804
  - This requires beam based alignment techniques
    - Adjust Debuncher extraction septum bend so that beam is centered in TQ3
    - Adjust D:HT804 so that beam is centered in TQ6
    - Requires measuring trajectory perturbations WITH PBARS!!!
      - Installed a forward PBAR BPM system in the line
      - Built a forward PBAR TBT system in the accumulator
      - Developed a technique for bunching the forward PBAR beam
- A 2.5″ diameter beam pipe at D6Q6 is close to being an aperture restriction for a 10 π-mm-mrad beam.
- Quads and trims in the transfer line are within 1-2 mm of alignment
  - TB1&2 out of alignment horizontally, but aperture is still acceptable

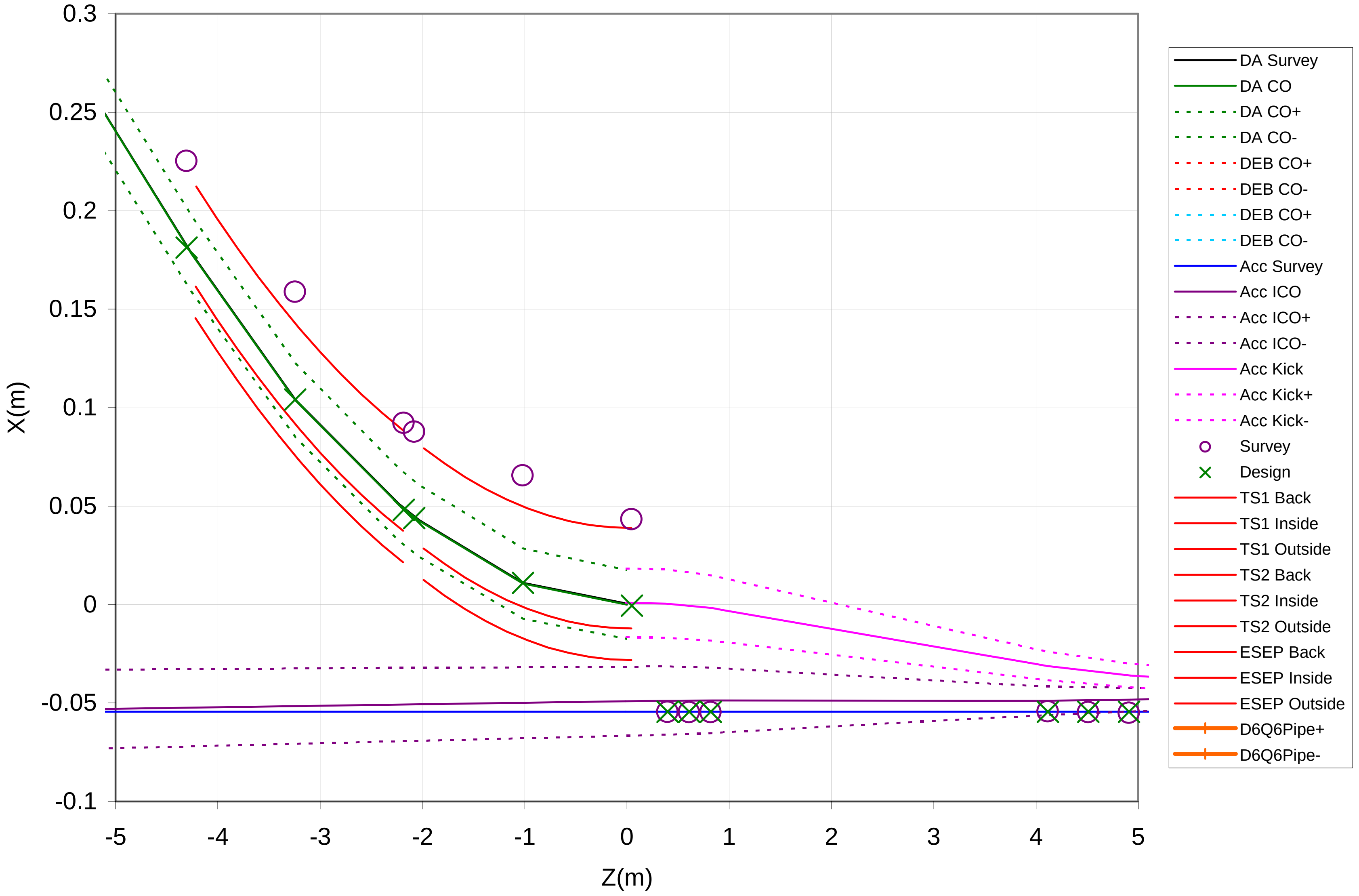
Injecting into the Transfer Line



Accumulator Injection (as found)



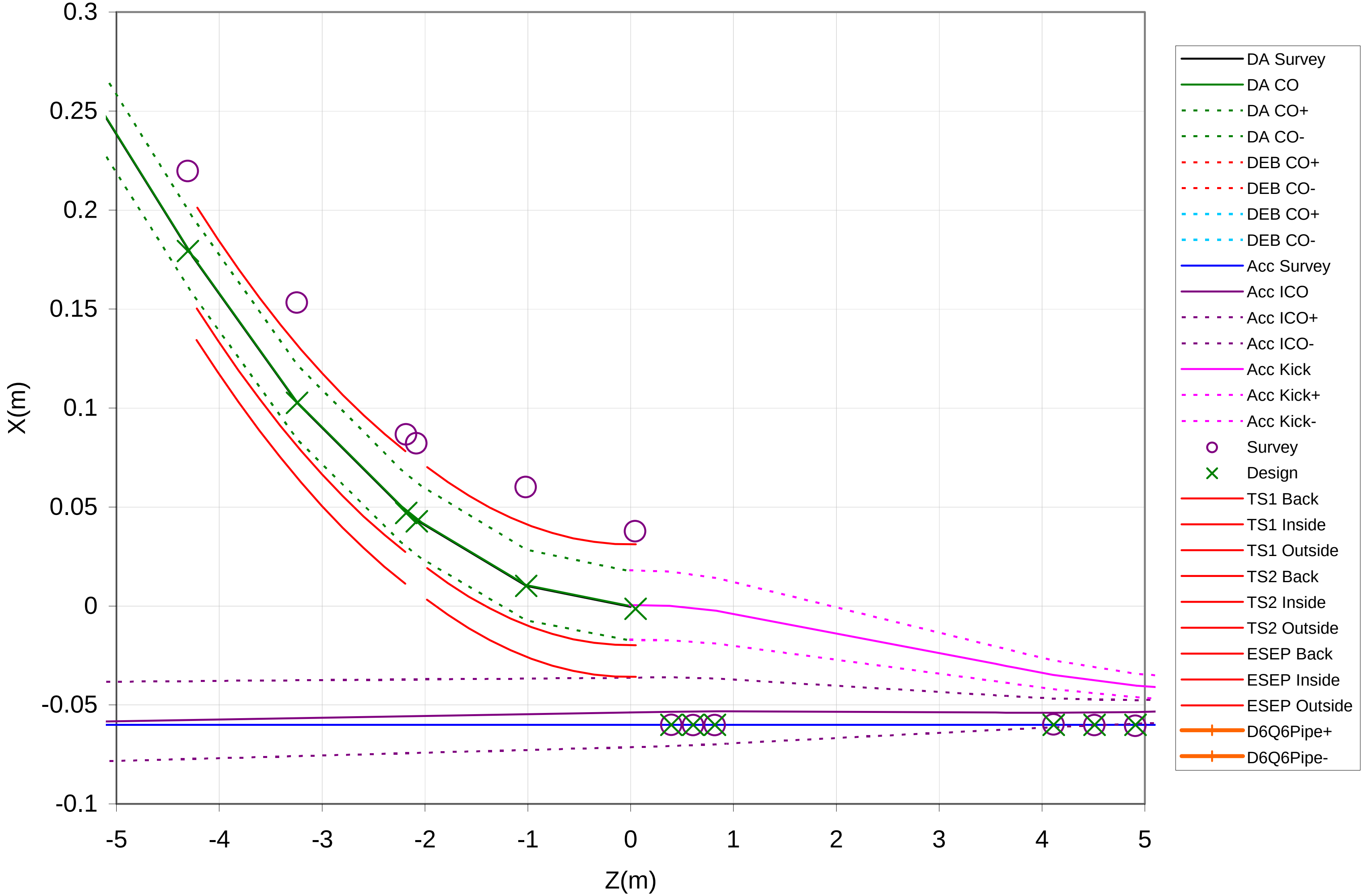
Accumulator Injection (as found)



Accumulator Injection

- A:ISEP1 was shunting current into the beam pipe and has been replaced
- The upstream ends of the Accumulator Injection Septa need to move closer to Accumulator by about 5mm
- Downstream end of A:ISEP1 constrained by Accumulator "D-pipe" and shouldn't be moved
  - For 50 mm kick amplitude at A:ISEP1
    - 10 π-mm-mrad beam clips by 4.5mm at downstream end
    - 5 π-mm-mrad beam just fits
  - Increasing Kicker Amplitude by 12% will clear 10 π-mm-mrad beam
    - Need a 2.6 mrad kick for 50mm
      - Debuncher needs 5.2 mrad kick for 50mm
    - Current running at 58kV out of a possible 65 kV
  - 10 π-mm-mrad circulating beam has 3.5 mm of elbow room
    - Install a three bump at Accumulator Injection
      - BS103,Q104,H105 (2.53 : 2.89 : 1)
        - 3.5 mm at Q104 would require 2.62 Amps on H105
        - The 3 bump would reduce the required kicker voltage increase to 5%
      - Do not have a trim at Q104 (6" beam pipe)
        - Modified and installed a 5.5" aperture NDB trim to have a 6.5" aperture

Accumulator Injection with Septa Move, Q104 bump, and Kicker Increase



D-A Line Initial Beam Studies

- Check-out instrumentation
  - Forward pbar and reverse proton timing for transfer line SEMs
  - Ring SEMs A104 and D607
  - Beam bunching procedures
    - Forward pbar extraction from the Debuncher using adiabatics.
    - Reverse proton extraction from the Accumulator using ARF1
  - TBT Systems
    - Forward pbar system in the Accumulator
    - Reverse proton system in the Debuncher
  - Forward pbar BPM system in the transfer line
- Debuncher Extraction and Accumulator Injection Beam separation versus kicker voltage using ring SEMs
- Transfer line transfer function matrix
  - Measure differential orbits of one-bumps with transfer line BPMs
    - Easy to do but coverage is limited by the number of BPMs
  - Measure effect of varying Quad currents on a one bump excitation with TBT system
    - Hard to do but transfer function of every quad can be measured.

D-A Line Tune-up Philosophy

- Because TQ1 -TQ6 are surveyed very close to an ideal line, the trajectories through the Debuncher and Accumulator septa can be established independent of each other as long as each trajectory goes through the centers of TQ3-TQ5
- The goal for the Debuncher is to scan the kicker voltage (D:EKIK) to find the minimum kicker voltage needed to pass 100% of a pbar beam that has been cooled for 2 seconds
- The goal for the Accumulator is to scan the kicker voltage (A:IKIK) to find the minimum kicker voltage needed to pass 100% of a reverse proton beam that has been heated to the aperture limit of the Accumulator injection orbit

D-A Line Tune-up Procedure

- Reverse Proton– Accumulator Injection tune-up
  - Use new injection three bump to snug beam against Accumulator Injection Septa but not limit the injection orbit aperture with this bump.
  - Develop position and angle bump for reverse protons forTQ6 through TQ4 using D:H807 and Accumulator Injection Septa current
  - Scan Accumulator Injection kicker voltage:
    - Adjust Accumulator Injection Septa to center beam on TQ7 using BBA instrumentation
    - Adjust position and angle bump to center on TQ6-TQ1 using BBA instrumentation
    - Heat beam in Accumulator to aperture and measure intensity of beam on 807 SEM or TQ7 BPM intensity signal
- Forward Pbars - Debuncher Extraction Tune up
  - Adjust DEX Bump
    - Maximum aperture at injection
    - For the minimum cooling cycle time, snug beam against extraction septum at the end of the cooling cycle.
      - Measure beam intensity in Debuncher at the end of the cycle with momentum cooling schottky signal.
  - Scan Debuncher Extraction kicker voltage:
    - Adjust Debuncher Extraction Septum current to center on TQ3 using BBA instrumentation.
    - Adjust D:HT804 to center on TQ5 and TQ6 using BBA instrumentation
    - For the minimum cooling cycle time, measure the intensity of beam on D-A Line SEMS or BPM intensity signal
  - Compensate for directionality of the Accumulator Injection Kicker
    - Adjust Accumulator Injection kicker voltage to close orbit using Pbar TBT

Conclusions

- The momentum spread extracted from the Debuncher into the Stacktail has been decreased by about 35% over the past year.
  - Future gains are possible but will be much smaller
    - Increase bandwidth of Debuncher momentum cooling system with equalizers
    - Optimize gain profile (each band at optimum gain) and gain ramping for Debuncher momentum cooling system.
    - Fix DRF2 voltage slope for rectangular phase space
    - Investigate feasibility of ramping γ_t in Debuncher

Conclusions

- The present Stacktail system with the bandwidth as measured should be capable of handling a static flux of 29mA/hr
  - The upper end of the bandwidth should be restored with a correction to the BAW equalizer design
  - At small stacks, the present Stacktail system can clear the deposition orbit as fast as 1.2 seconds
  - At small stacks, increasing the Stacktail gain or power does not affect stacking
  - It also does not seem to affect the emittances in the Stacktail
  - The curves for the deposition RF system (ARF1) have been optimized but should include bunch tumbling to match the Stacktail Profile
  - Note in the future, that the present 2-4 GHz Accumulator Core Momentum Cooling system will have to be replaced with either the present or modified 4-8 GHz Accumulator Core Momentum Cooling system if the Accumulator is going to have to continue support large stacks.

Conclusions

- In the range of cycle times of interest, the amount of beam reaching the injection orbit of the Accumulator is proportional to how long the transverse cooling is on in the Debuncher.
  - Indicates an aperture problem in the D-A line.
  - The transverse cooling can be increased marginally by optimizing transverse gain ramping

Improvements to the DA Line

- Laser Tracker survey of the D-A Line
- Developed Lattice Model for survey predictions
- Realignment of the septa
  - Debuncher extraction
  - Accumulator Injection
- Installation of the DEX bump
- Replacement of A:ISEP1
- Developed beam based procedure for aligning beam in transfer line
  - New BPMs and new TBT system
  - New bunching procedure
- Installation of an Accumulator injection 3 bump
- Installation and analysis of Debuncher Gain ramping