

Stochastic Cooling

2010 Results and 2011 Plans

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Beam Components, Controls, RF,
Operations, etc.

RHIC Retreat
July 1, 2010

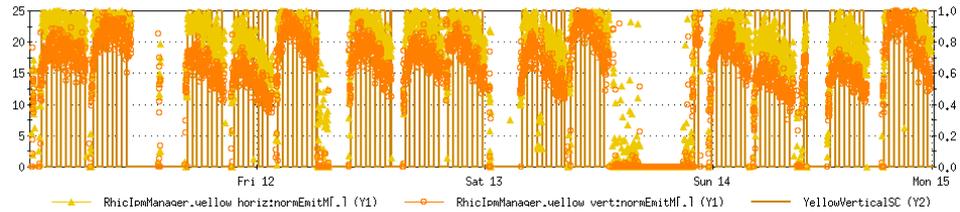
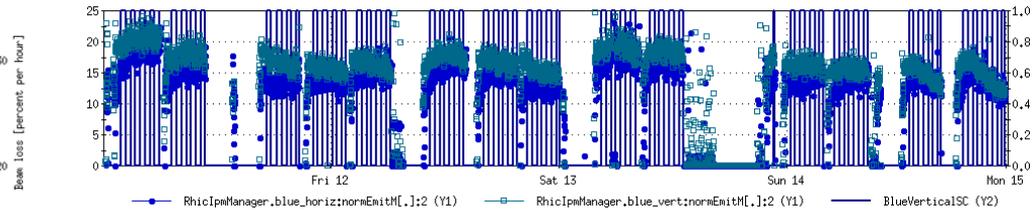
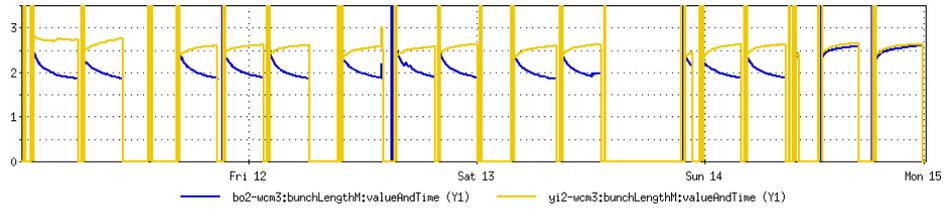
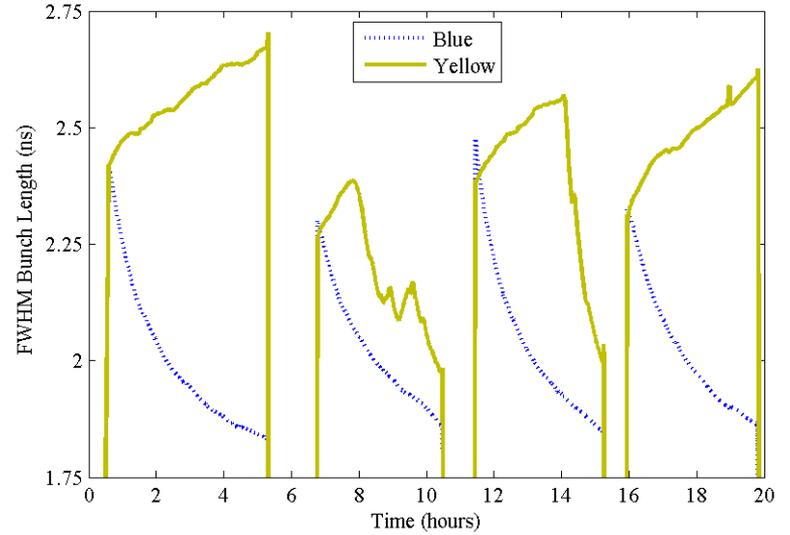
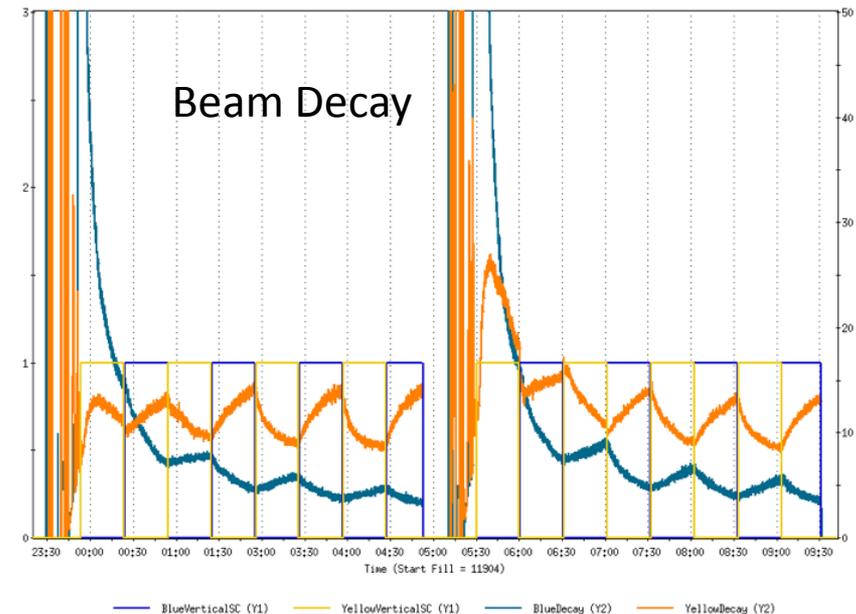
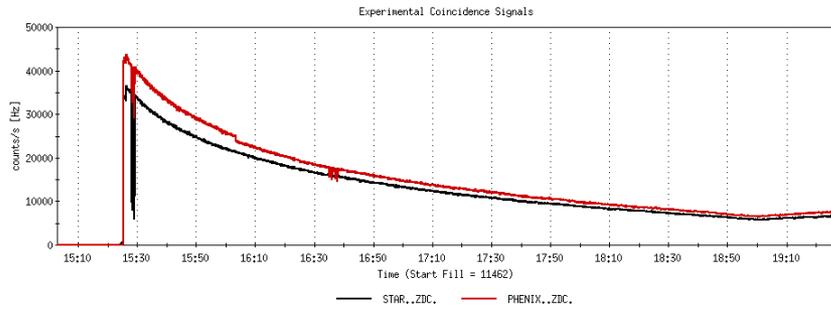
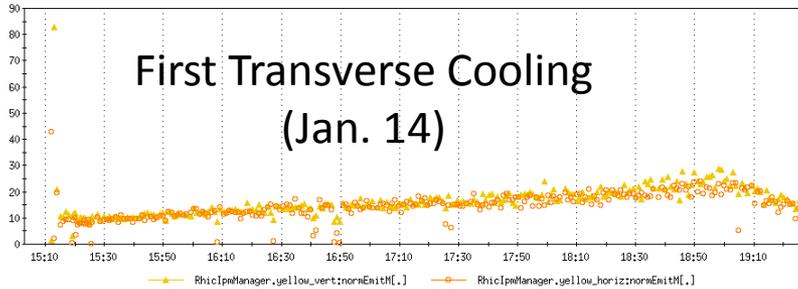


2010 Results

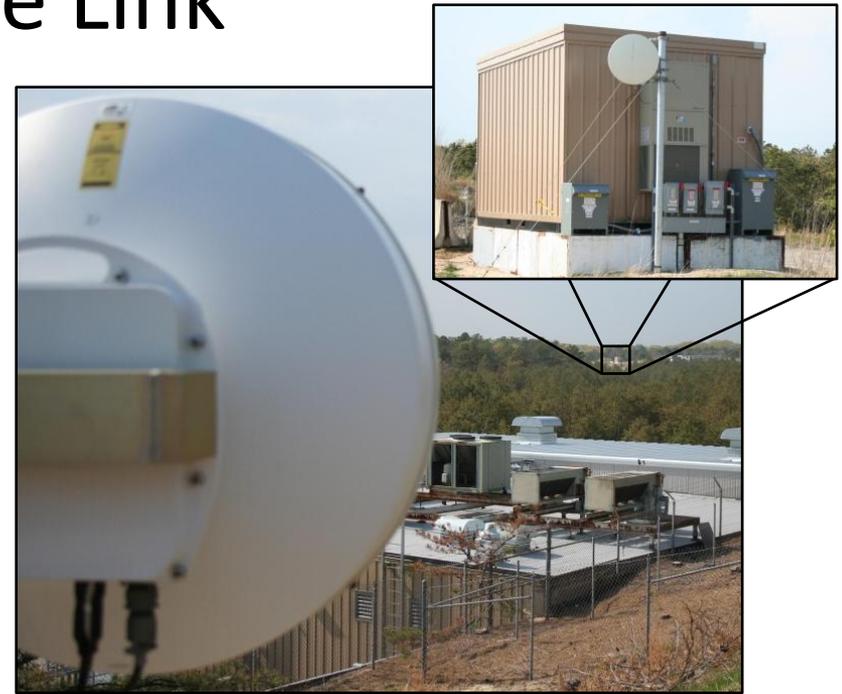
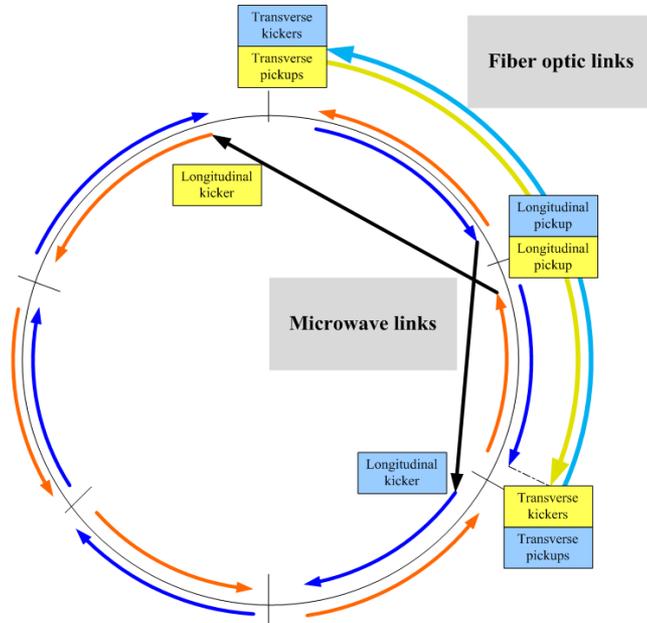
What worked	What didn't	What could be better
Stochastic cooling	Vacuum leaks	Common mode rejection of transverse pickups
Cooling of horizontal with coupling to vertical	Motion stuck in vacuum	Longitudinal cooling phase stability (dual pilot tone)
Microwave link	Cross talk between rings (transverse cooling)	Procedure and tools for setting up cooling
Notch filter feedback		Alarms, status messages, detecting problems before they get worse
Automatic gain/phase adjustments (BTFs)		Longitudinal pickups (*)
Longitudinal pickups		

Cooling Results

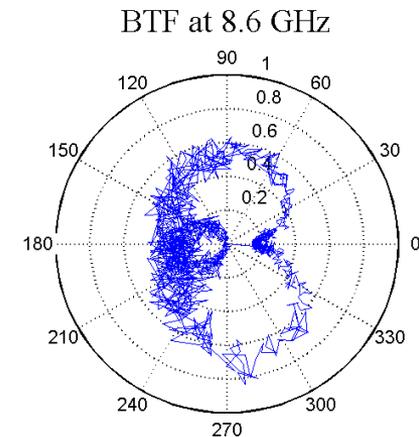
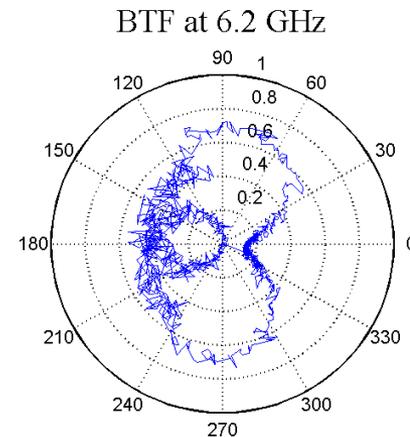
First Transverse Cooling
(Jan. 14)



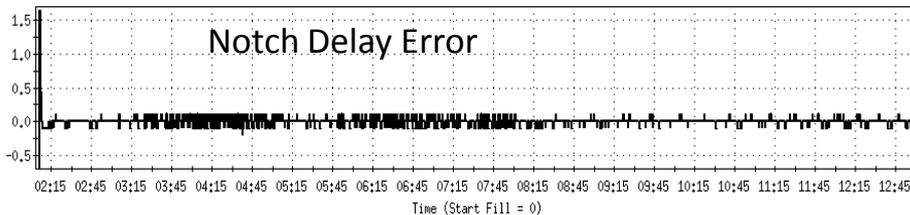
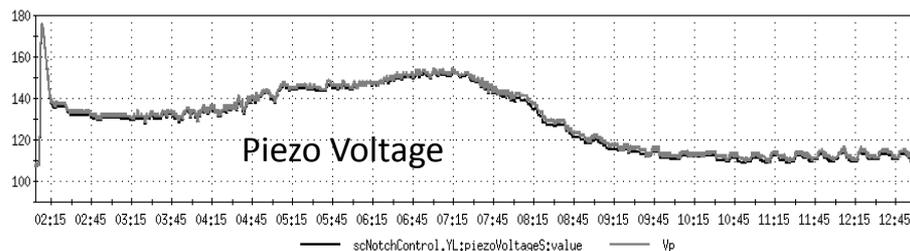
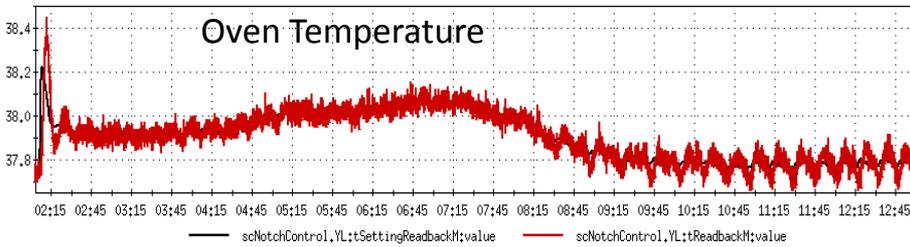
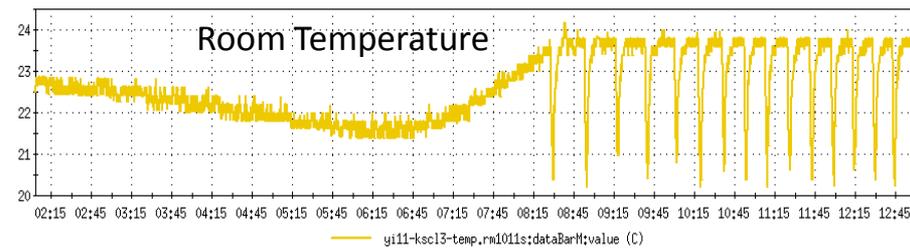
Microwave Link



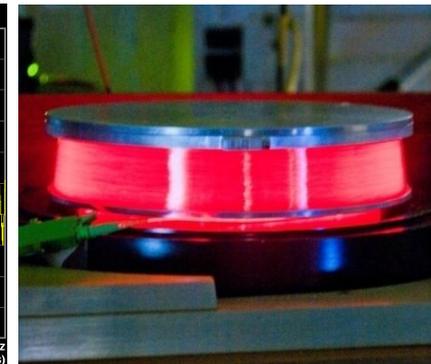
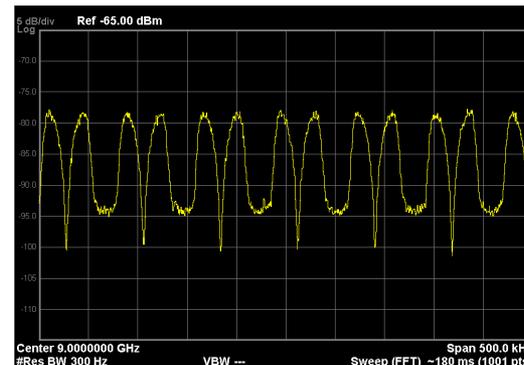
- This run was the first to cool with the microwave link. Previously, it had only been tested with deuterons and protons.
- The pilot tone compensates phase variations in the link to keep the cooling stable.
- It works, but only compensates one of the two sources of phase modulation. A new dual tone scheme is being developed currently.



Notch Filter Feedback

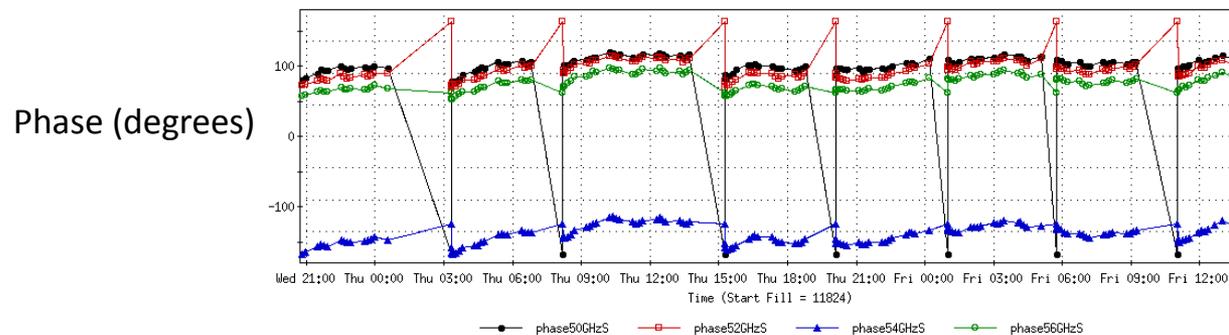
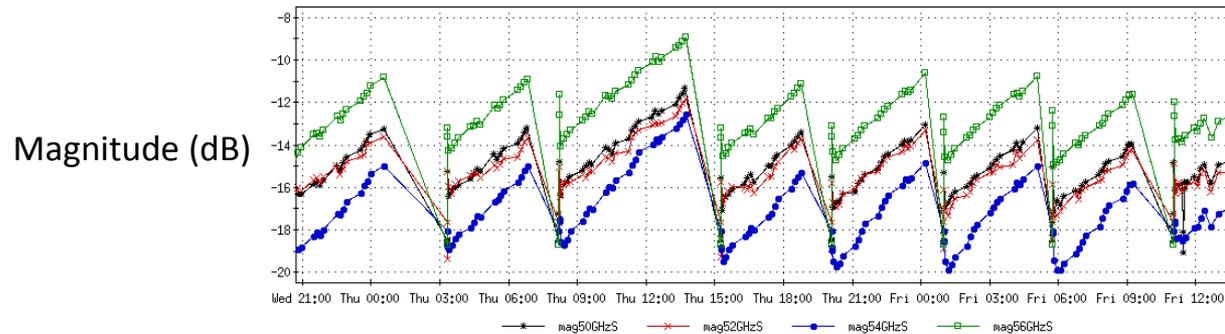


- The one-turn delay notch filter provides the proper direction of the kick and filters out much of the coherent beam signal for the longitudinal cooling.
- It relies on a fiber optic delay equal to the RHIC revolution period. The feedback stabilizes the length of the fiber with a piezoelectric stretcher and thermal chamber.
- The development was an excellent team effort with Ian Blackler, Ben Johnson, Roger Lee, Kevin Mernick, and Mike Brennan all contributing valuable pieces.
- The length of the $12.79 \mu\text{s}$ fiber is stabilized to better than 0.5 ps.



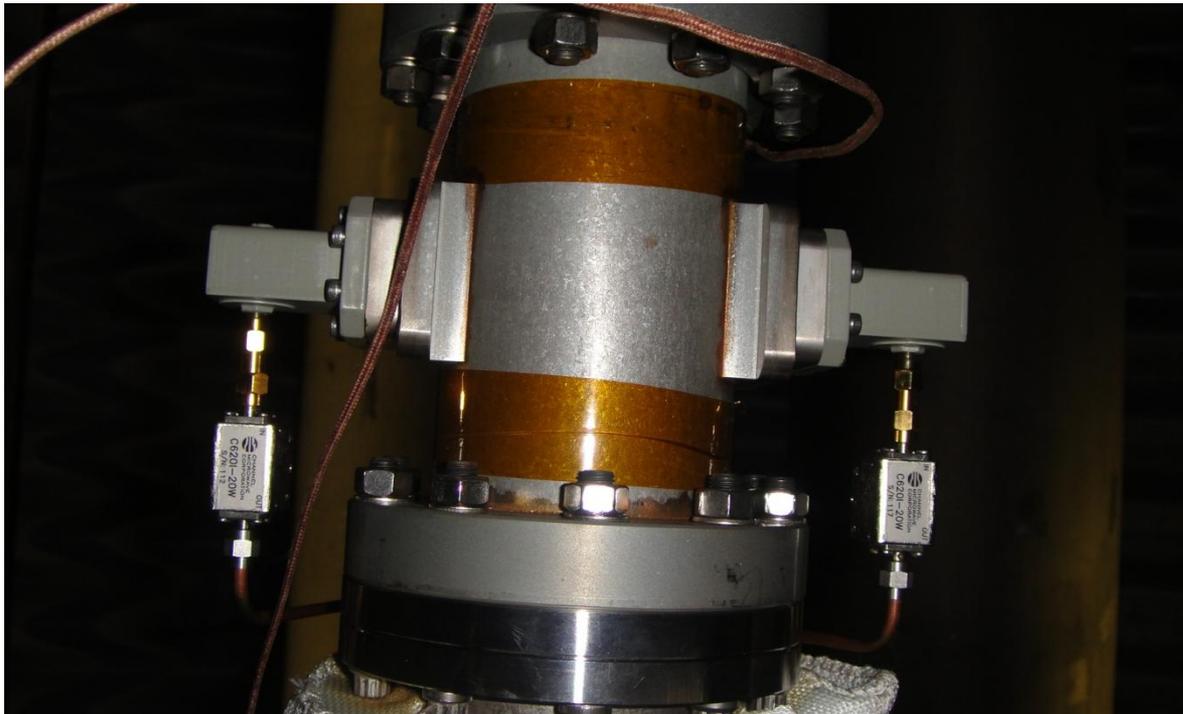
Automatic Gain/Phase Adjustments (BTFs)

- The system periodically measures the open loop response including the beam (the beam transfer function)
- The measured response is compared to a reference BTF to calculate new magnitude and phase settings for the IQ modulators
- This is a fairly complicated dance involving the network analyzer, switch matrices, and IQ modulators that Roger made work
- We are working on lookup tables to linearize the IQ modulator responses to further improve performance



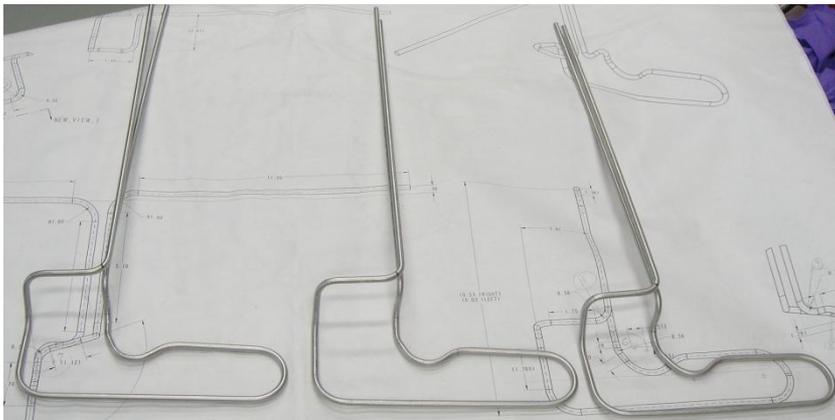
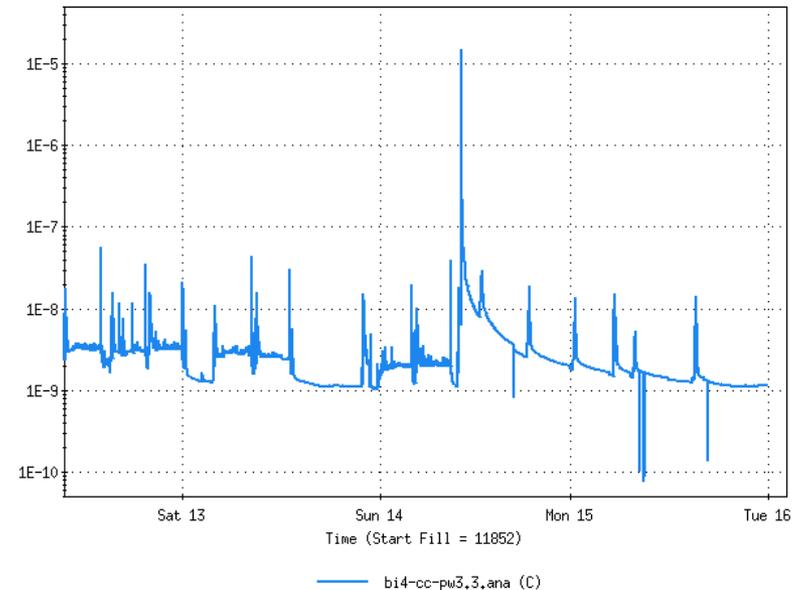
Longitudinal Pickups

- Waveguide to coax adapters are located outside the vacuum
- They couple to the beam through ceramic windows in the pipe
- The pickups worked this run, but we hope to improve performance in the future
- Due to the busy schedule this summer, any changes will be put off until next shutdown at the earliest



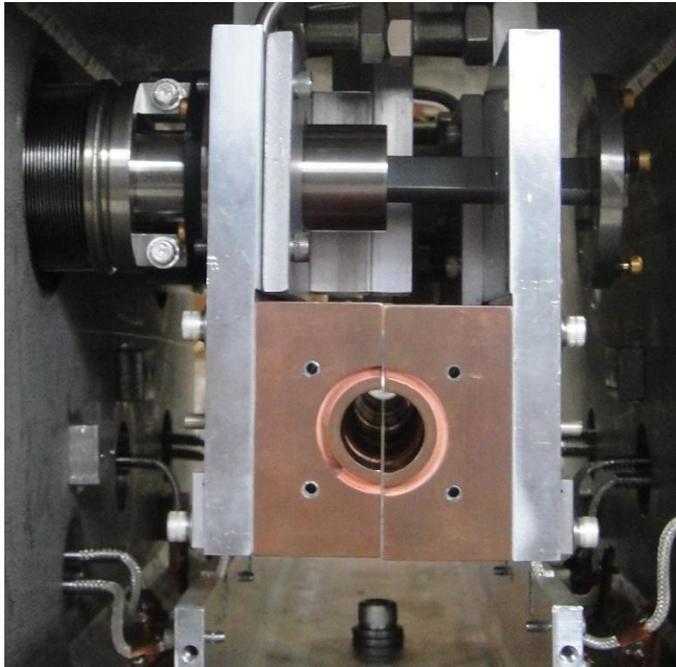
Vacuum Leaks

- The yellow longitudinal and blue vertical kickers both developed vacuum leaks in the aluminum tubing used to provide cooling water to the cavities
- The aluminum tubing was poor quality and failed almost immediately
- The yellow longitudinal kicker was rebuilt with stainless steel tubing and had no more leaks
- The blue longitudinal kicker had a few vacuum spikes from leaky RF feedthrus
- The top plate will be welded on the new transverse kickers to avoid previous problems of failures after bakeouts



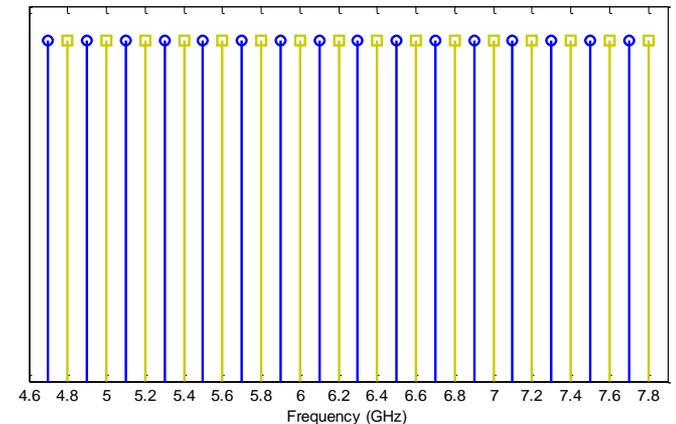
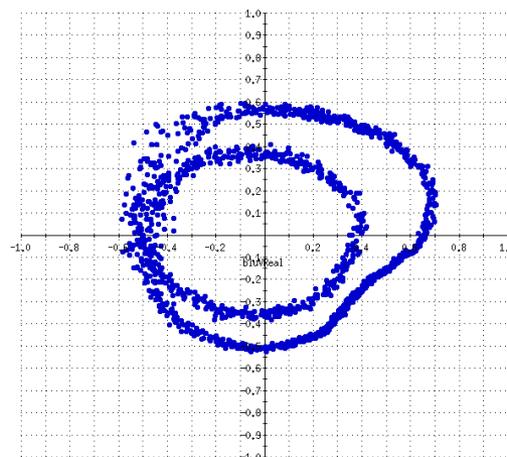
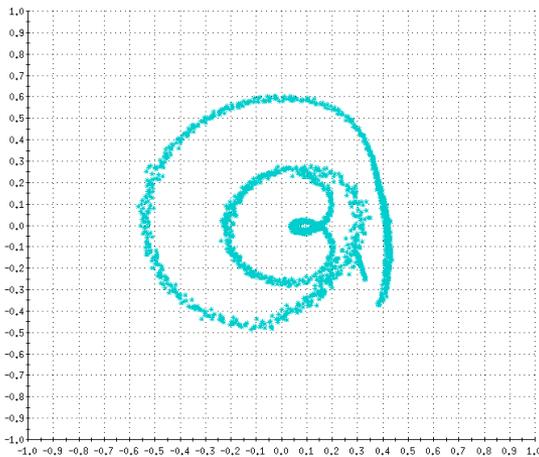
Stuck Motion in Vacuum

- The blue vertical pickup and yellow longitudinal kicker (both of which use Fermilab tanks) suffered failures due to stuck linear bearings in the vacuum
- The original Fermilab parts were coated with Teflon, both of the failed parts were coated with Dicronite
- The yellow longitudinal kicker was rebuilt with Teflon coated parts and one of the three tanks failed a “torture test” due to misalignment
- We are currently evaluating replacement bearings for the longitudinal kickers
- The blue vertical pickup will be replaced with the new design that does not have bearings in the vacuum



Crosstalk between Rings

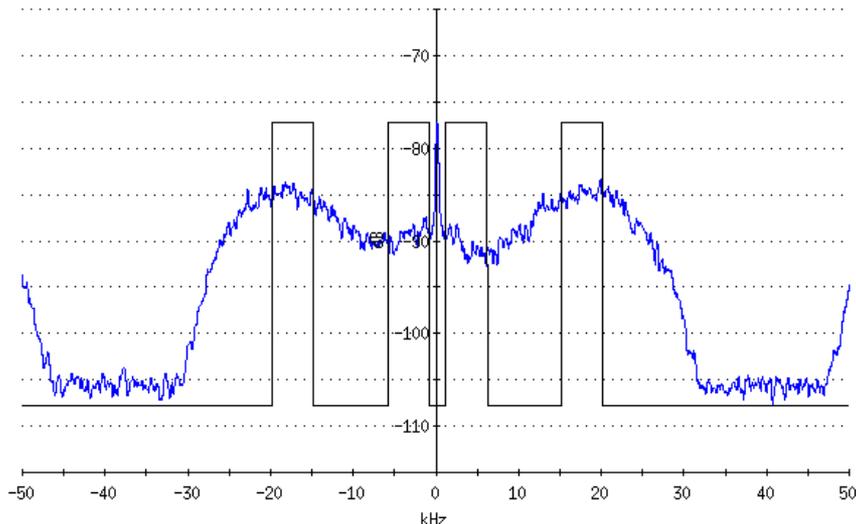
- The vertical cooling systems could not be operated simultaneously due to crosstalk between the rings
- The yellow kicker creates microwaves that propagate down the yellow pipe to the common section, where they reflect back up the blue pipe to the blue pickup
- The signal induced at the opposite ring pickup is small, but the cooling loop needs very high gain because the beam signal is also small
- We will offset the cavity frequencies in the blue ring to avoid interference



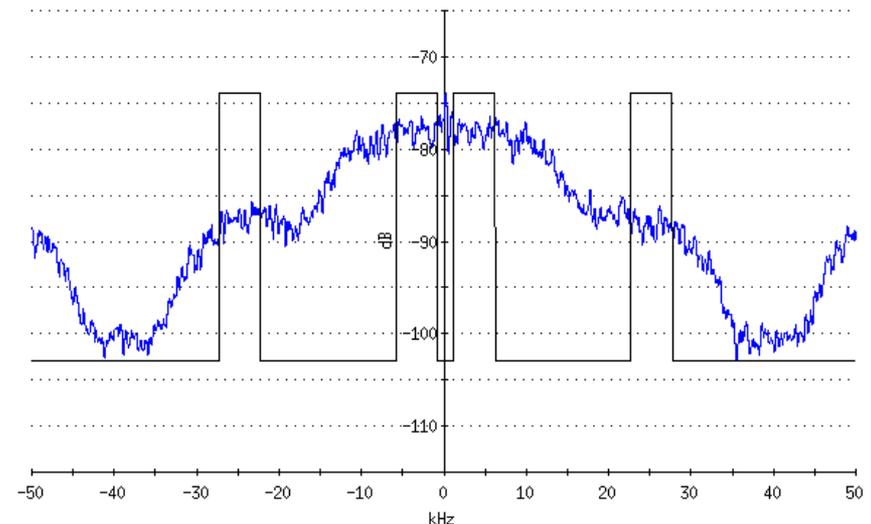
Common Mode Rejection of Transverse Pickups

- Common mode rejection (CMR) is important to reduce the power of the coherent signal from the pickup, which does not help with cooling but can saturate the electronics
- We can achieve good CMR at one cavity frequency, but not across the whole band
- CMR is limited by misalignment of the pickup plates relative to the beam and by the RF hybrid performance
- The new pickup design should improve pickup plate alignment
- Mike is working on custom hybrid design to improve performance

OK CMR



Bad CMR



2011 Plans

System	Kicker	Pickup
Blue Longitudinal	RF feedthru replacement, new stand for tanks, power supplies and amplifiers	No change
Yellow Longitudinal	Currently being rebuilt to repair stuck bearings in vacuum	No change
Blue Vertical	Replace with new tank, offset frequencies, fixed water cooling	Replace Fermilab tank with new design
Yellow Vertical	No change	Replace Fermilab tank with new design
Blue Horizontal	New	New
Yellow Horizontal	New	New

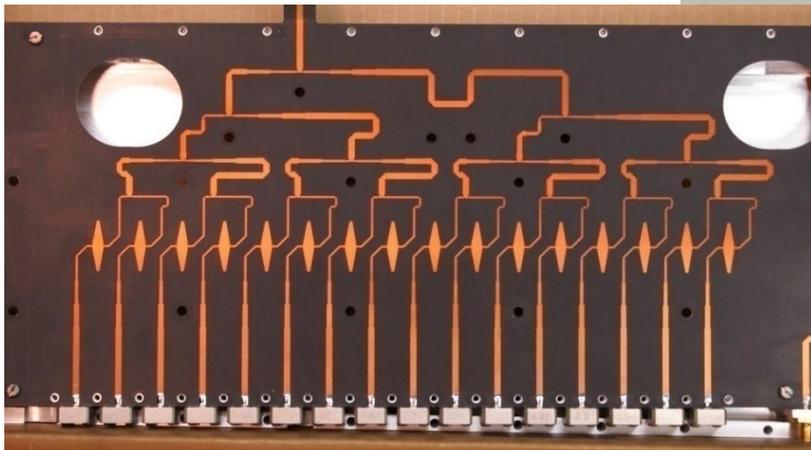
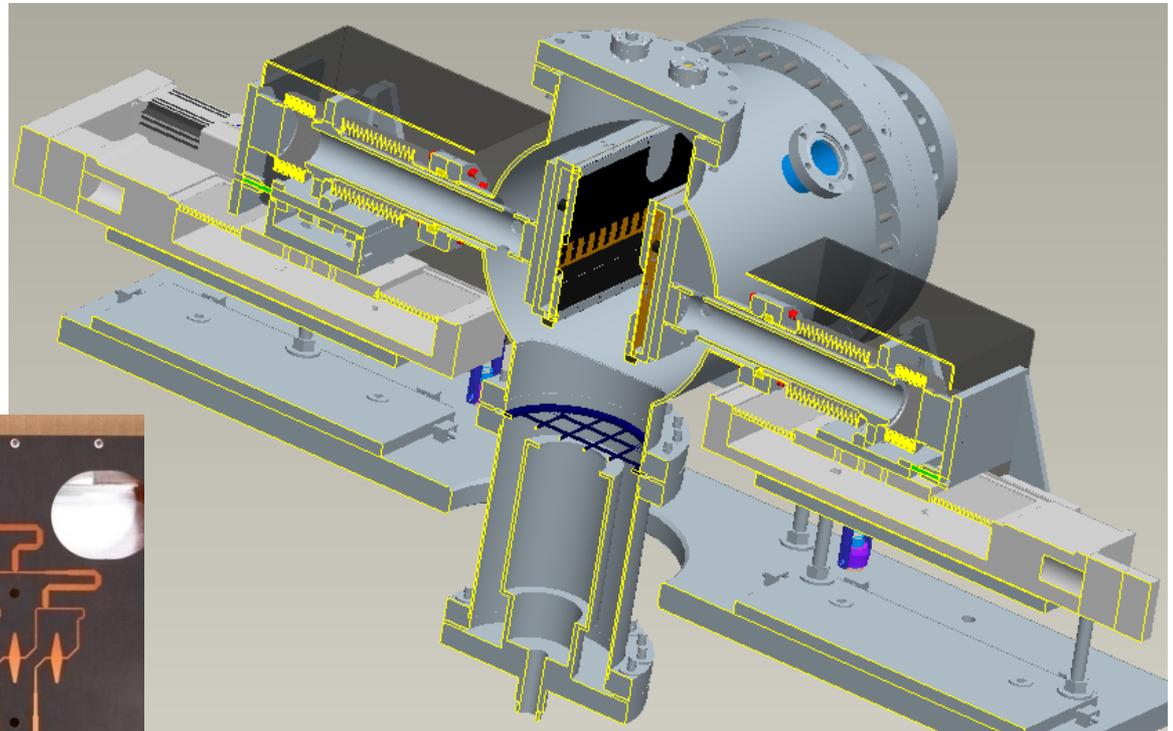
2011 Plans

Other major items for the shutdown:

- Build two new sets of electronics for the new systems
 - IQ modulators
 - Fanout amplifiers and filters
 - Switch matrices
 - Kicker amplifiers and power supplies
- Upgrade software to support running two systems (vertical and horizontal) from one network analyzer
- Develop lookup tables to correct amplitude and phase errors in IQ modulators
- Upgrade the pilot tone compensation to use two frequencies to correct both slope and offset of phase error
- Replace chillers on kicker cooling water circuit with water heater to allow better tuning of cavity resonant frequencies
- Upgrade notch filter to include automatic gain control for balancing prompt and delayed signals and improved biasing of Mach-Zehnder optical modulator
- Add PIN diode loss monitors at all kickers and transverse pickups (already installed at 3 of the kickers)
- Develop ADO interface to the Aerotech motor stages for the new pickups and modify manager to talk to it
- Other software enhancements

New Transverse Pickups

- The new pickups use precision stages for transverse motion of both parallel plates and longitudinal motion of one of the plates
- This should allow better cancellation of the common mode signal from the pickup
- There are no bearings inside the vacuum



Horizontal Kickers

- The horizontal kickers will use the vertical kicker design mounted on its side
- The tank will be modified to replace the hanging weight that closes the cavities with a spring mechanism
- The existing stand design can be used to mount the kickers, but a new mount for the microwave amplifiers needs to be developed

