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Run II PMG  
Stacking Rapid Response Team Report

Dave McGinnis  
January 19, 2006

# December Antiproton Study Period Statistics

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- Length of Time: Tue Nov 22 to Thu Dec 15
- Number of Elog shift pages: 72
- Number of Recorded Debuncher Orbits: 857
- Number of Recorded AP2 Orbits: 775
- Number of Commissioned items: 12
- Number of Major Accomplishments:  $6 + \frac{1}{2} + \frac{1}{2}$
- Number of Confusions (at the time):  $\infty$
- Number of Other Things Done:  $8 + 1$
- Number of "Next Times" Known Items:  $7\frac{1}{2}$

# Instrumentation Commissioned

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- Debuncher Reverse Proton Turn-By-Turn system
- Debuncher Reverse Proton partial turn extraction up AP2
- Debuncher Component Centering
- Debuncher Orbit-Quad offset
- AP2 Orbit-Quad offset
- AP2 Beam Line Correction
- One-Shot TLG for getting Debuncher beam
- Admittance measurement from data-logger
- "Deb Heat Rev p's to AP2" aggregate
- AP2-Debuncher Injection region setup
- Auto-tune 120 GeV orbit of P1-P2-AP1

## Scheduled Studies Accomplishments

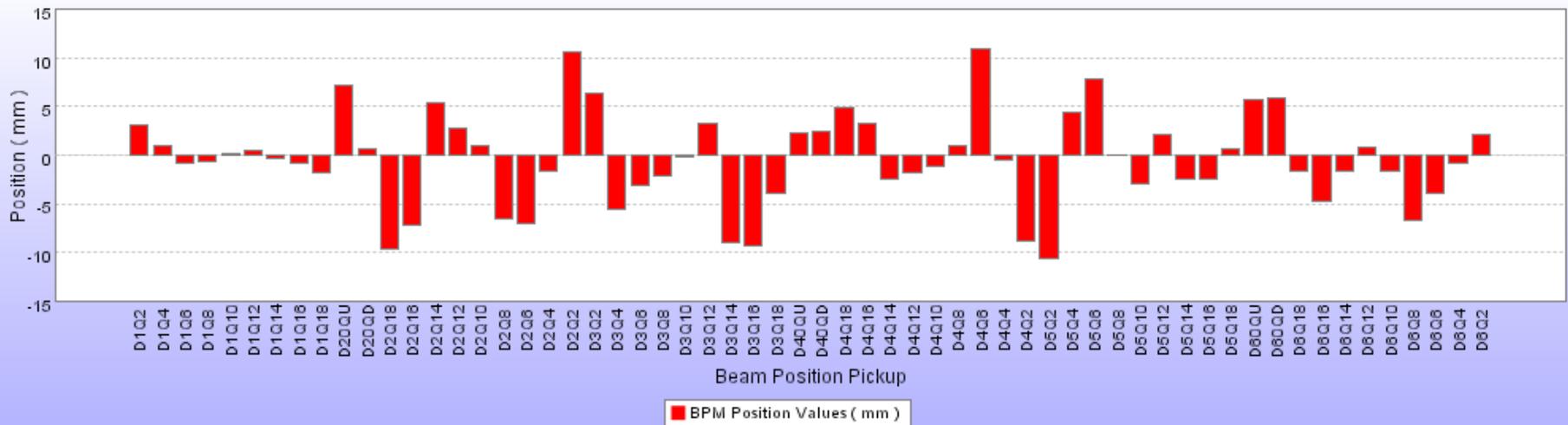
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- Lattice measurements for Debuncher and AP2
- Determine Debuncher Orbit/BPM-Quad offsets
- Corrected Debuncher Vertical Orbit to Quad Centers
- Centered Debuncher Components about orbit
- Determine AP2 Orbit/BPM-Quad offsets
- Set Orbit, Stands and Settings for AP2-Debuncher Injection Region
- Corrected AP2 Orbit to near Quad Centers
- Installed AP2 lattice that matches to current Debuncher Lattice

# Change in Debuncher Vertical Orbit

- Determined Orbit-Quad center offsets
- Steered to center of quads
- Center components about orbit using motorized stands

Debuncher Vertical Beam Positions: Recalled Record 1740 Minus 916

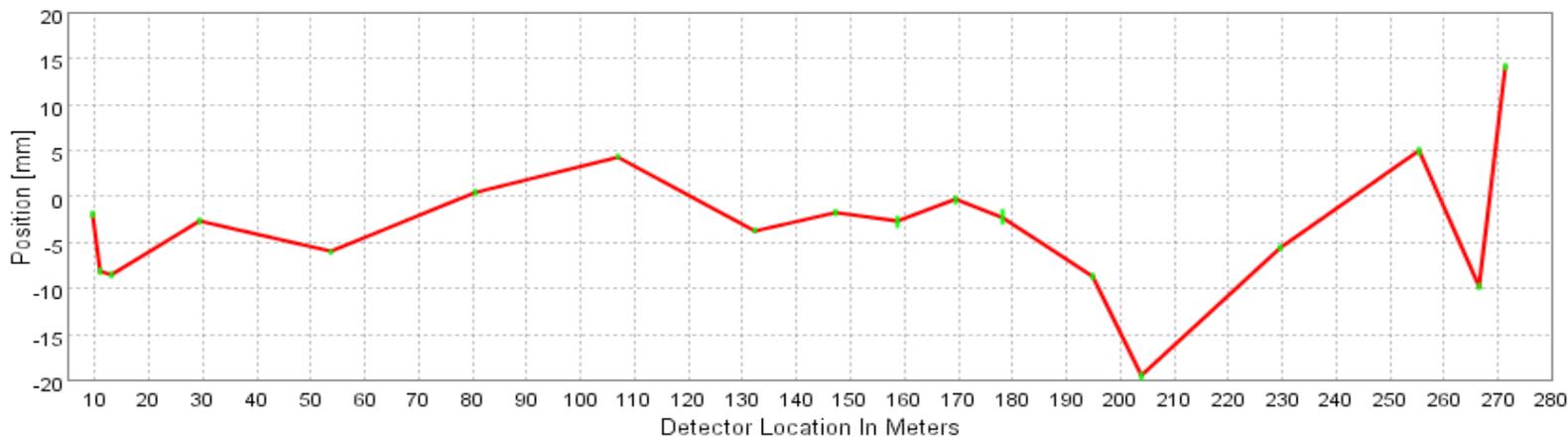


# Change in AP2 Stacking Orbit

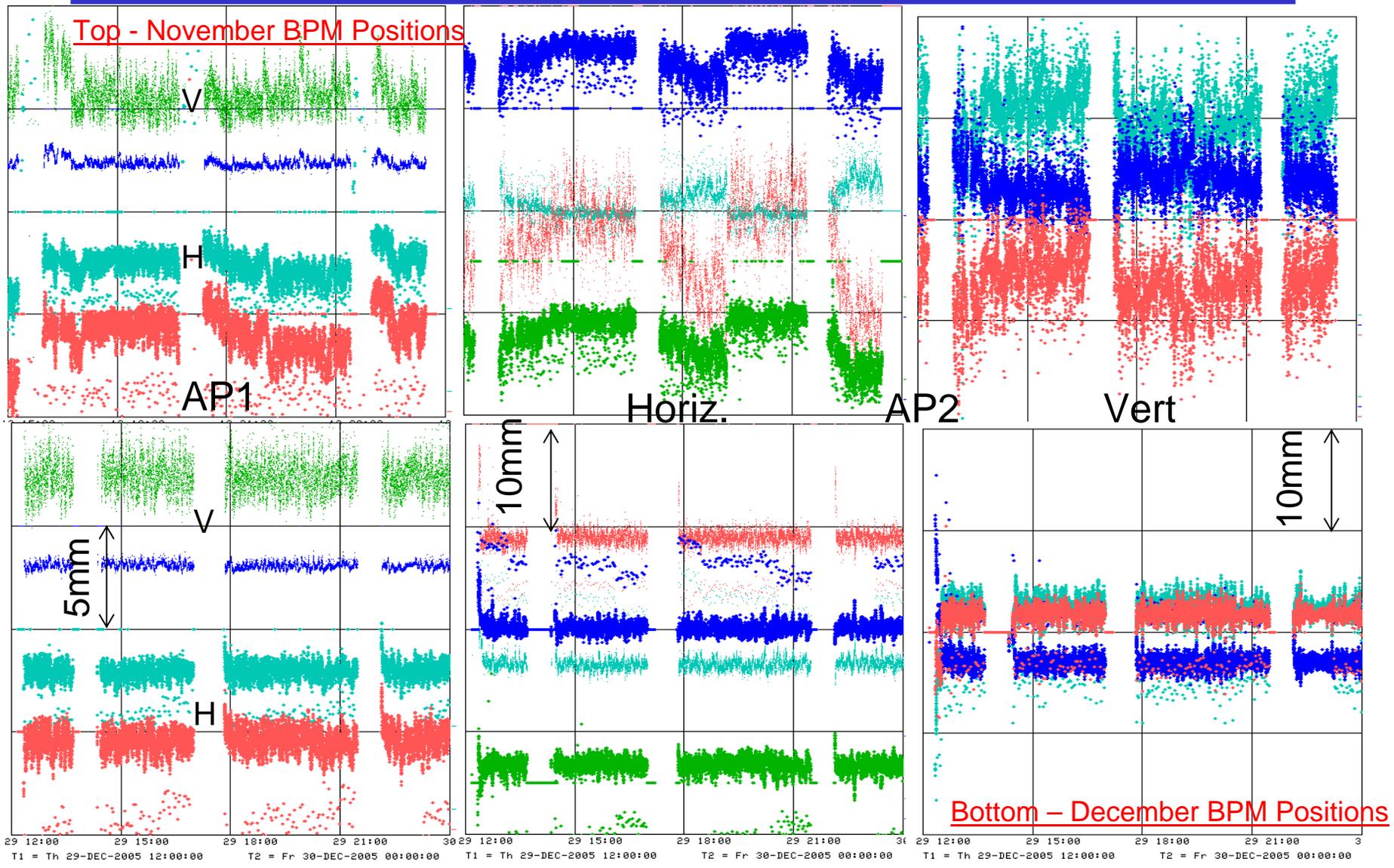
## AP2 Horizontal Beam Positions Record 995 - Record 228



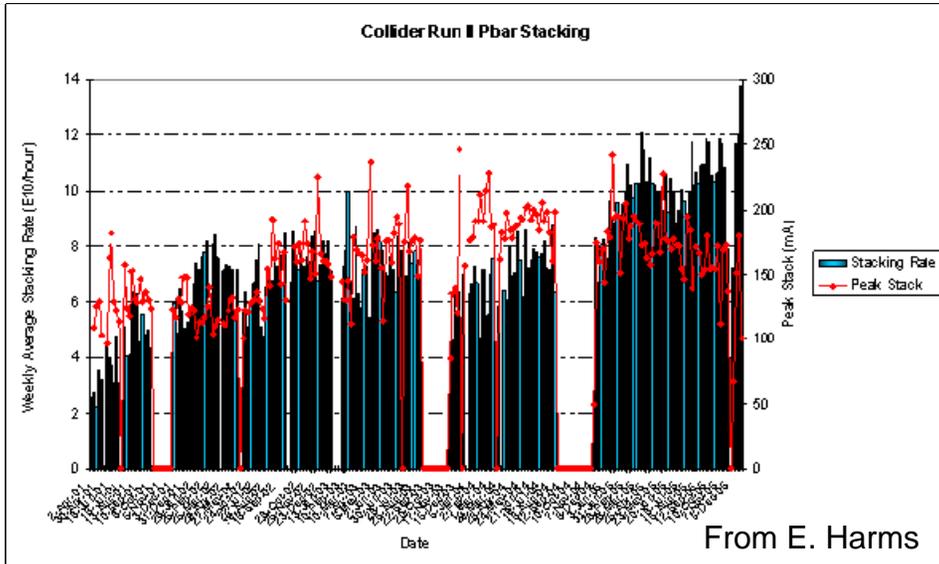
## AP2 Vertical Beam Positions Record 995 - Record 228



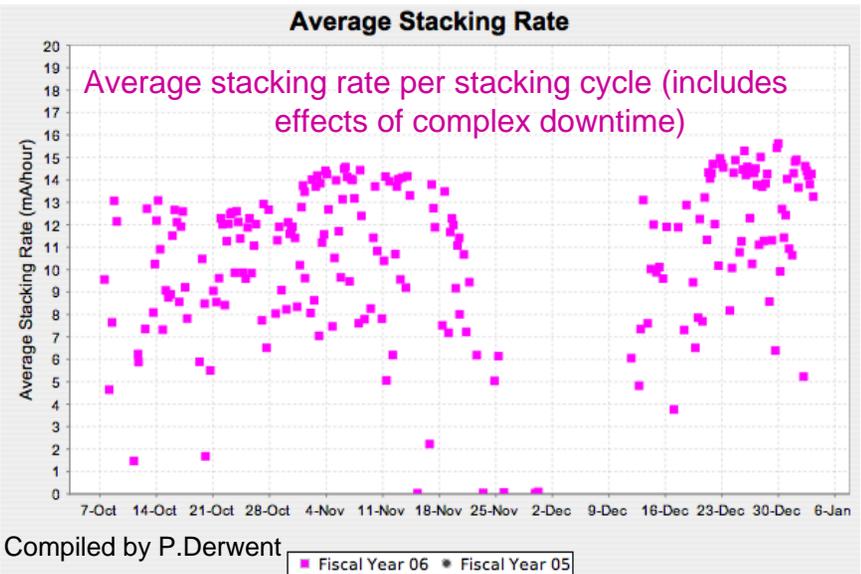
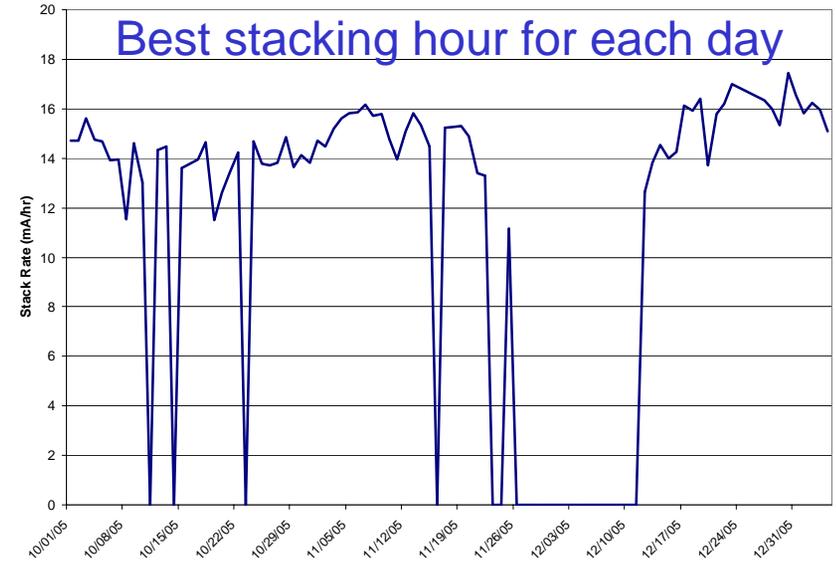
# Primary and Secondary Beamline Auto-Correction (Oscillation Overthruster)



# Stacking Rate



Stacking record  
**17.46mA.hr**  
 (Dec 29, 2005)



## Other Items Done

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- Replaced failed Li Lens
- Installed Collimator in Target Station
- Survey of AP2-Debuncher Injection Region
- Commissioned Ramped Devices in AP1
- 2.5MHz noise in AP30 found as problem for 2.5MHz mode of new AP3 BPMs
- D/A Beam Based Alignment
- Accumulator orbit/aperture
- Stacking tune-up

## January Antiproton Study Period

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- Quad Steering of the AP1 line
- Alignment of the Debuncher horizontal orbit and moveable devices.
- Installation and commissioning of Debuncher lattice modifications
- Removal of the Debuncher Schottkies
- Obstruction search of the AP2 line.
- Installation of 4 additional AP2 trims
- Accumulator orbit and aperture optimization

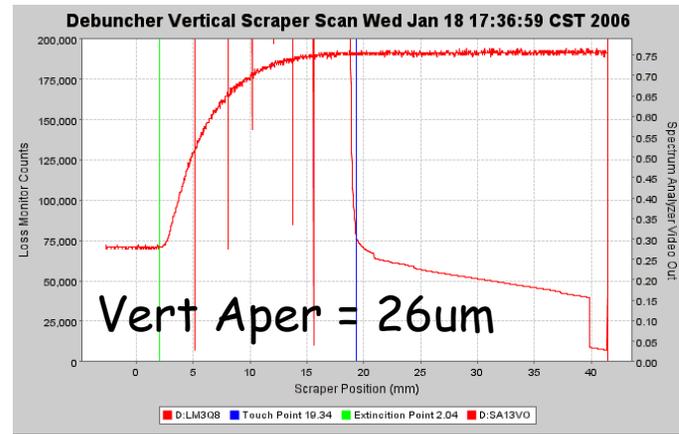
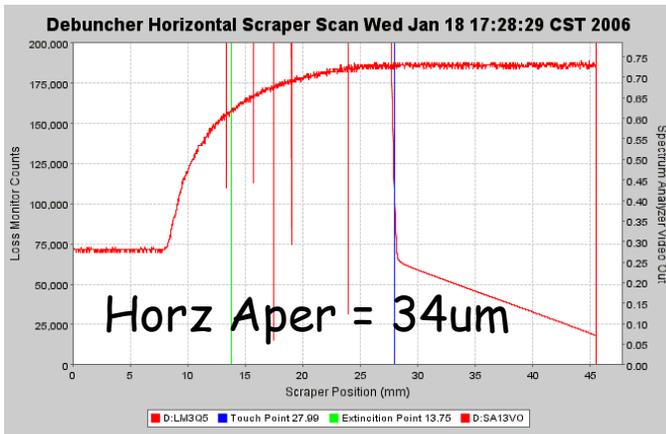
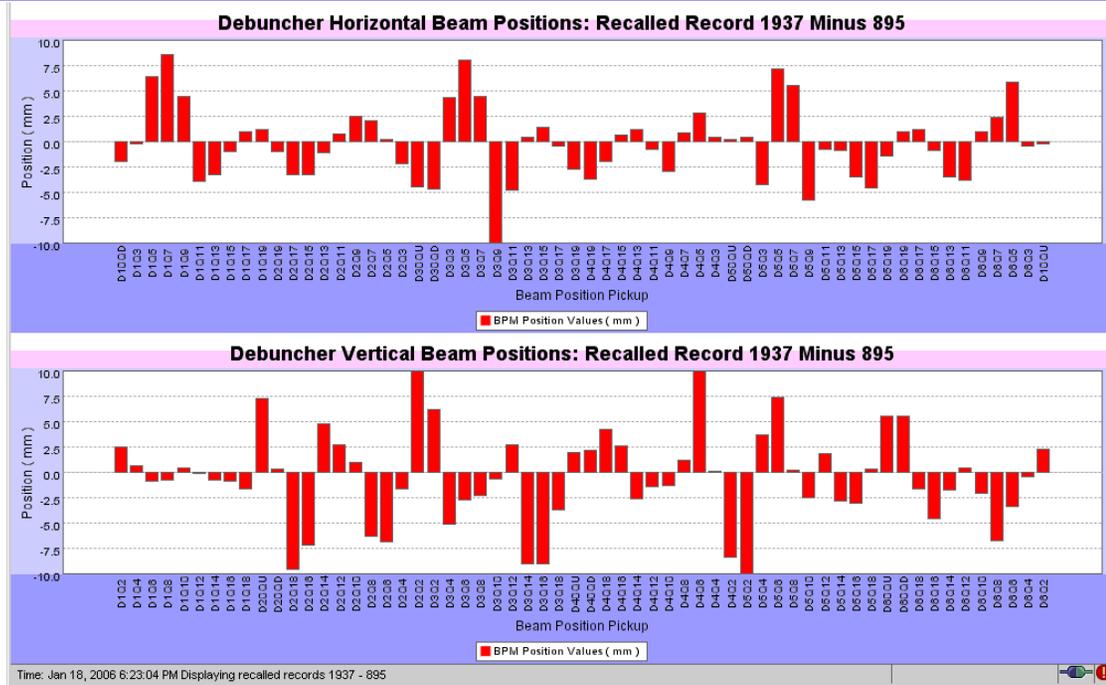
# January Antiproton Study Period

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- 1/15 Sun -- Upstream AP2 Steering
- 1/16 M -- Debuncher Horizontal Orbit
- 1/17 T -- Debuncher Horizontal Orbit
- 1/18 W -- Debuncher Horizontal Orbit & Component Centering
- 1/19 Th day -- If ready, access to Rings to remove Debuncher Schottkys  
and work on Debuncher quad shunt controls
- 1/19 Th day -- 120GeV beam to beam stop, convert AP1 components to ramp cards
- 1/19 Th eve -- 8GeV beam to accumulator while Debuncher pumps down, convert AP1 components to ramp cards
- 1/20 F -- Debuncher lattice and aperture work
- 1/21 S -- Accumulator aperture
- 1/22 S -- Accumulator aperture
- 1/23 M -- Accumulator aperture
- 1/24 Tu -- If AP2 trim installation is ready, Transport access to install AP2 trims
- 1/25 W -- If AP2 trim installation is ready, Rings access to install AP2 trims
- 1/25 Th -- Recover stacking
- 1/26 F -- Earliest TeV is back
  
- All will go according to plan!

# Horizontal And Vertical Orbit Changes

Difference  
between  
1/19/06  
and  
11/22/05



# Proposed Pbar Studies Review

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- **Operational Issues** (Drendel & Johnson)
  - Setup one-shots for circ beam in Deb
  - Setup Deb partial turn beam up AP2
  - Setup AP2 extraction of Deb circ beam
  - Setup for D/A orbit studies
- **Debuncher Orbit**
  - Deb Orbit/BPM-Quad offset determination (Gollwitzer)
  - Deb Orbit Correction (Gollwitzer)
  - Deb Component Centering (Werkema)
  - Deb Electrical Centering (Gollwitzer)
  - Deb Lattice Measurements (Nagaslaev)
- **AP2**
  - Setting of the AP2-Deb Injection Region (McGinnis)
  - AP2 and Deb survey (Harms)
  - Lattice Design (Lebedev)
  - AP2 Orbit/BPM-Quad offset determination (Gollwitzer)
  - AP2 Orbit Correction (Gollwitzer)
  - AP2 Lattice Measurements (Nagaslaev)

# Proposed Pbar Studies Review

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- **D/A Line**
  - Acc Injection region (kicker & septa) (Derwent)
  - D/A Beam Based Alignment (Derwent)
  - Acc Injection channel and orbit Apertures (Derwent)
  - Deb Reverse Proton TBT system (Vander Meulen)
  - D/A Kicker time during stacking (Ashmanskas)
  - DRF2 timing (Ashmanskas)
- **Accumulator Aperture**
  - Quad centers on the Accumulator (Werkema)
  - Orbit Correction in the Accumulator (McGinnis)
  - Moveable devices (Werkema)
- **Stacking**
  - P1-P2-AP1 drift and auto-tune (McGinnis)
  - AP2 Orbit drift and correction (McGinnis)
  - Stacking Losses in AP50 (Werkema)

## Pbar Re-Organization

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- Keith Gollwitzer will become Antiproton Source Department Head starting 2/6/06
- Paul Derwent will become Recycler Department Head starting 3/1/06
- Booster Longitudinal Emittance group in the stacking team will be phased out.
- Recycler group in the stacking team will be phased in.

# 2.5 MHz Coalescing Studies Review

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## ▪ Findings:

- The present operational coalescing technique
  - Can provide 87 - 90% coalescing efficiency with over 98% acceleration efficiency for (2.5 MHz) bunches with an initial emittance of 1.2 - 1.4 eV sec with an intensity up to at least  $8e10$  per (2.5 MHz) bunch.
  - The final emittance is on the order of 2.1 eV-sec which correlates to about a 60% emittance dilution.
- The new 2.5 MHz coalescing
  - Has seen a combined acceleration coalescing efficiency of 95% for 1.4 eV-sec  $5e10$  bunches with longitudinal emittance growth on the order of 5-10% for protons.
  - Has seen a combined acceleration coalescing efficiency of 85% for 1.0 eV-sec  $2e10$  bunches with longitudinal emittance growth on the order of 25% for pbars.
- The new scheme has somewhat more complicated RF states and has different acceleration ramps from the standard MI acceleration ramp but while these complications might require intensive effort initially to tune-up should not present difficult long-term maintenance issues.
- The new scheme has the possibility for a 5-10% improvement in integrated luminosity over the present operational coalescing scheme for the current Recycler stash size.
  - Most of this promise results from the possibility of better acceleration and coalescing efficiency.
  - The lower longitudinal emittance will probably not improve integrated luminosity at our present operating conditions.

# 2.5 MHz Coalescing Studies Review

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## ▪ Recommendations:

- The possible 5-10% increase in integrated luminosity at our present conditions is not a good enough reason to switch to this scheme at this time.
  - The headaches associated with implementing this scheme into operations would probably outweigh the benefits.
- However, our plan is to push the Recycler stash well in excess of  $400e10$ .
  - Due to cooling issues or stability issues, it might not be possible to cool the Recycler stash to 50 eV-sec at such large stash sizes. It is very probable that the emittance of the Recycler stash could be in the range of 80 eV-sec for stash sizes over  $400e10$ .
  - At this point, because of low emittance dilution, it might be very likely that the new 2.5 MHz scheme provides a sizeable advantage over the present coalescing scheme.
  - We should perform a side by side comparison of the coalescing schemes (using protons) with bunch intensities greater than  $10e10$  and an initial longitudinal emittance of 2.25eV-sec.
- When these studies are performed,
  - it is imperative that all the necessary instrumentation is working.
  - Also, prior to the studies, there should be an agreed upon convention for measuring coalescing and acceleration efficiencies.
  - Ioanis Kourbanis should decide on these definitions.
  - Finally, these studies on the different coalescing schemes should be performed during the same time period and the data used for comparisons should come only from the same time period.
- Brain Chase should be in charge of conducting these studies.
  - It is likely that he will designate Ioanis to perform the standard coalescing measurements while Chandra would probably be asked to do the new 2.5 MHz measurements.
  - It is understood that some advanced study time will be needed to tune-up both schemes.
  - The study time will be requested at the 9am meetings.

# Tevatron Failures

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- After two years of running without a major Tevatron component failure, we have suffered two incidents in the past two months.
- We expect the Collider complex to fail periodically.
  - In FY06 we planned for 105 store hours per week ON AVERAGE)
  - The reason for this expectation is that the collider is an extremely complex machine. (There are over 200,000 devices in the controls database.)
- Although we expect the collider to fail periodically, we are doing everything we believe prudent to protect the machine.

# Tevatron Failures

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- Because of the enormous size and complexity of the machine, we can never run the collider in "perfect" operating condition.
  - There is always some system or subsystem that is not operating in peak performance.
  - A good example of this is the vacuum in the Tevatron
- The Run Coordination team together with the Systems departments assesses these risks on a day-to-day basis and decides whether to repair the sub-system or run the collider.
- These decisions are made very formally and openly in the 9 am operations meeting and documented in the Run Coordinator Electronic logbook

# Tevatron Failures

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- Because of the complexity of the accelerator complex and because the state of the complex changes (i.e. different modes such as stacking, Recycler transfers, collider ramping, and the fact that a setting today might be a different setting tomorrow), we have many levels at which configuration control is checked.
  - Level 1. Compares - Software that compares settings against best known settings. C23 is a good example of this
  - Level 2. Machine Checkout - checks with low intensity beam. A "wet squeeze" is a good example of this.
  - Level 3. Control System Alarms - there are many different types of alarms
    - analog alarms (device out of tolerance),
    - digital alarms (device not on),
    - acknowledgeable alarms (you must do something).
    - Because the collider must go through many different configurations, there are tailored alarm lists for display that are associated with each configuration.
    - It is very important to keep the alarm display clean. A cluttered alarm display with unnecessary alarms could result in an important alarm overlooked.
  - Level 4. Machine Protection Hardware that removes the beam or dumps the electrical power. A good example of this is quench protection monitors or the Tev abort system.

# Tevatron Failures

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- Operationally, we have a very well-defined chain of command.
  - The first level is the operators in the control room. They report directly and **ONLY** to the crew chiefs.
  - The crew chiefs are administered by the Operations Department head but report directly to the Run coordinator.
  - The Run Coordinator takes input from the crew chiefs, operation specialists, and the machine coordinators for each system department. The Run Coordinator is responsible for the day-to-day operations of the complex.
  - The Run coordinator reports directly to Associate Division Head for Systems and Operations which has line responsibility for the systems departments and is concerned with the short term and long term operations of the systems departments.
- We maintain a disciplined attitude towards operations.
  - The 9am meetings follow a well defined format with our daily plans documented in the Run coordinator electronic logbook
  - No studies are done on any accelerator without the knowledge and approval of the Run Coordinator.
  - We have eliminated impromptu or poorly planned studies and require extensive documentation of study results
  - To maintain configuration control of work performed on the Accelerator, we have instituted electronic work-lists where submittal, approval, and completion of every job performed in the Accelerator complex can be tracked.

# Tevatron Failures

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- When we have a store lost in the Tevatron, a well defined procedure is activated.
  - The operations crew performs an immediate investigation of the event and call in the appropriate system department personnel to do a more thorough investigation.
  - The investigations are written up in the electronic logbook.
  - If required, the investigations are written up in a formal document as was the case in the CDF Roman Pot incident.
  - We do not turn the Tevatron back on until we have identified the cause of the lost store and the cause has been fixed.
    - Sometimes the remedies are as simple replacing a ramp card.
    - Other remedies require much more work as was the case for the CDF Roman Pots.
    - In cases where human error is to blame, either modifications or additions to collider software is made (such as the sequencer) or procedures and/or training is updated.
    - Communicating updates in training to the crews can be as simple as an email or involve more formal documented training.

# B-1 Component Failure

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- The root cause of the failure was a Kautzky (relief) valve that had a rare failure that prevented it from opening during a quench to relieve pressure.
  - Therefore, it would have likely caused a component failure from any quench (and this house quenches a lot because of the Tevatron optics).
- The quench that led to the component failure was due to a B11H separator spark.
  - Problems with that separator began on 11/16 when separator vacuum degraded following an access.
  - The leak was traced to an RGA head, which was blanked off that night after vacuum got as bad as 100 microns.
    - Since there had been a maintenance work on the hydrostatic level system in the vicinity, it was suspected (but not proven) that a worker had stepped on the RGA head and damaged it.
    - There was separator conditioning on the owl shift of 11/17, then a series of unrelated problems that prevented returning to Operations during the day.

# B-1 Component Failure

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- Late in the day vacuum techs observed that the vacuum in the B11H separator had begun to degrade again and theorized that air had leaked past the vacuum valve during the RGA repair and frozen on the beam pipe and was beginning to sublime.
  - Experts had differing opinions as to whether the vacuum was bad enough to increase the risk of sparking.
    - The vacuum began to slowly improve and was expected to continue.
- The Run Coordinator made the decision to proceed with putting another store in, which occurred late in the owl shift of 10/18.
  - This store lasted until 2200 that night, when it was terminated intentionally and followed with Tevatron studies.
- Another store was put in on the owl shift of 11/19.
  - The store only lasted six hours and ended with a quench when the B11H separator sparked.
    - Vacuum and separator experts then proposed to spend several days warming up the house to nitrogen temperature to improve the vacuum (which had actually improved by about an order of magnitude since the previous day).
    - Warming up presented some risk of component failure and the possibility that the sparking wasn't vacuum-related and would continue.

## B-1 Component Failure

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- The Run Coordinator elected to put another store and stated that another separator spark from B11H would trigger the vacuum work.
- There was a series of studies, accesses and squeezes leading up to the store, B11H sparked one more time during a dry squeeze.
- A store was put in at the beginning of the owl shift on 11/20 and continued for more than 24 hours, being intentionally terminated at 0512 on Monday 11/21.
- Another store was put in around 0800, this store lasted until 1615 when the B11H separator sparked and caused the quench that led to the B1 component failure.

# B-1 Component Failure

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- The B11H separator was baked out at the end of the B-1 repair period, returning vacuum to a normal operator range.
- Separators, including B11H, went through an extensive conditioning period following the repairs.
- Despite this, the second store after the repairs was lost to a B11H separator spark on 12/14.
  - The separator was conditioned overnight, then sparked again on 12/15.
  - At this point, experts were down to their last option, trying an alternative conditioning procedure where the separator polarity is reversed.
  - If this conditioning didn't work, the separator would have to be replaced (requiring another bake-out and conditioning period taking about a week).
  - The conditioning went well and another store was put in on 12/16. The B11H separator has not sparked since, a period of about a month.

# A44 Failure

- A large cryostat vacuum leak at A-44 developed after a quench that was caused by beam loss.
  - It is important to note that A-44 was not one of the cells that quenched as a result of beam loss.
  - The cell "antiquenched" in sympathy with adjacent quenching cells which caused the QPM to fire the heater firing units and caused a weak quench.
  - Since this cell usually doesn't experience beam loss, it had not had heaters fire at high field in more than a year.
  - So, there was likely a weak component that was vulnerable to the next quench.
  - The quench occurred on Saturday 1/14/06 while collisions were being initiated for store 4594.
  - The leak was large enough so that adding additional vacuum pumps didn't improve vacuum enough to operate.
  - At this time the leak is suspected to be internal to one of the magnets at A-44.
- There were multiple houses that quenched and quenches occurred at two distinct times.
  - First there was a quench at D-1, D0 low betas and B0 low betas as the result of a slow beam loss.
  - When the abort fired, part of the protons missed the abort block and caused a large fast loss that quenched A-1, A-2, A-4, C-3 and C-4.
  - This large loss also generated SVX aborts from CDF and D0, but the abort had already fired and the beam was gone.
  - It is believed that the transverse beam emittance had grown rapidly after initiating collisions.
    - The most plausible explanation for why beam missed the abort block is that the emittance was large enough so that they missed the block after being kicked by the abort kickers and continued clockwise around the ring with high amplitude. Because of the nature of the emittance growth and beam missing the abort block, loss monitors tied to the abort system would not have prevented the beam loss.

# A44 Failure

- Emittance blew up after initiating collisions because the T:SQD0 (small skew quad circuit) power supply was not running and putting out the program current of approximately 2 Amps.
  - This was enough to greatly increase coupling, driving the tunes apart.
  - The proton tunes went through a resonance causing beam loss and likely large emittance growth.
    - It's worth noting that T:SQD0 is one of several small skew quad circuits that are used in addition to the main circuits of T:SQF and T:SQD.
- The previous store had been intentionally terminated after one of the A48V separator power supplies failed, distorting the orbit but not causing significant beam loss or a quench.
  - After store termination, both experiments were given the opportunity to access their Collision Halls.
  - Power supplies for devices in the CDF and D0 Collision Hall were turned off and alarms bypassed (alarms are bypassed to prevent spurious alarms from masking real alarms).
- It appears that there were two operational errors made after the access ended.
  - The first was that the alarms were not enabled, which is standard protocol.
  - The second is that after the bulk supplies in the CDF and D0 Halls were turned on, individual reset and on commands were not sent to the individual regulators, one of which was T:SQD0.
    - The individual regulators often turn back on automatically when the bulk supply is powered without specific reset and on commands, and most of them did so in this case.

# A44 Failure

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- The Tevatron was turned on and run through a dry squeeze to reset fields and check devices with the compare program, C23.
  - Operators did identify two power supplies, C:S7D1A and T:SQA4, that had been left off after the access and turned them back on.
  - It appears T:SQDO was missed because it runs at 0 Amps through most of the low beta squeeze and only runs at 2 Amps after initiating collisions.
  - T:SQDO was not flagged during the ramp and most of the squeeze because it runs at 0 Amps. It did show up on the compare made at low beta, but it was mistaken for a change due to tuning because of the small amount it was out of tolerance (there were several feed-down sextupoles that were flagged, but were out of tolerance because of intentional tuning changes). To get a sense of scale, approximately 500 devices are compared through more than 25 break points during the ramp and squeeze.
- Nearly a shift of Tevatron studies followed the dry squeeze, one of them involved protons at low beta.
  - It was noticed that the coupling was stronger than usual during the studies, but wasn't recognized as a serious problem.
  - The effect of T:SQDO on the low intensity protons used during the study was not enough to cause beam loss or other obvious sign of trouble.
  - Collider shot setup followed the studies period and went routinely.
  - As mentioned above, the store was lost with a quench during initiate collisions and the rest of the day was spent attempting to overcome the cryostat vacuum leak at A44.