Proposed Pre-Cooling with 4-8GHz Momentum Aggregate

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It has been shown that pre-cooling the Accumulator core prior to shot setup with both the 2-4GHz and 4-8GHz momentum cooling systems significantly decreases the longitudinal cooling time necessary to sufficiently reduce the frequency width enough to ramp to the shot lattice. The datalogger plot shown in Figure 1 shows cooling the beam longitudinally after stacking has been halted in the beginning stages of shot setup. A:FRWDTH (green trace) is the momentum width of the Accumulator core, which decreases as the beam is cooled longitudinally. A:CPTW01 (cyan trace) is the 2-4GHz momentum power, A:CPTW01 (red trace) is the power in one of the 4-8GHz momentum TWTs, and A:EMT3HN (blue trace) is the horizontal emittance. Now we will examine the plot, to see how the 2-4GHz and 4-8GHz momentum cooling systems effect the longitudinal cooling. From 10:30 until 10:33, only the 2-4GHz momentum cooling is being used exclusively. In this configuration the longitudinal cooling is relatively slow. By 10:34, the 4-8GHz momentum cooling system is turned on and brought up to power, so that we are cooling with both the 4-8GHz and the 2-4GHz systems. The frequency width value starts decreasing faster, showing that the longitudinal cooling is more efficient in this configuration. Once a frequency width of 16Hz was reached, which was around 10:41 on this plot, the 4-8GHz momentum cooling was turned off so that the only longitudinal cooling was coming form the 2-4GHz momentum. Notice that the slop of the A:FRWDTH trace flattens out, showing that the 2-4GHz momentum system is not as efficient cooling the beam by itself. If the longitudinal cooling would have been completed with only the 2-4GHz momentum system, then it would have take much longer to reach a frequency width of 15Hz. If the 4-8GHz momentum cooling system was used during the entire cooling process, it would have taken much less time to get to 15Hz. It has been observed that it is common to save 30 minutes or more of cooling by using both the 2-4GHz and 4-8GHz momentum cooling systems to cool longitudinally.

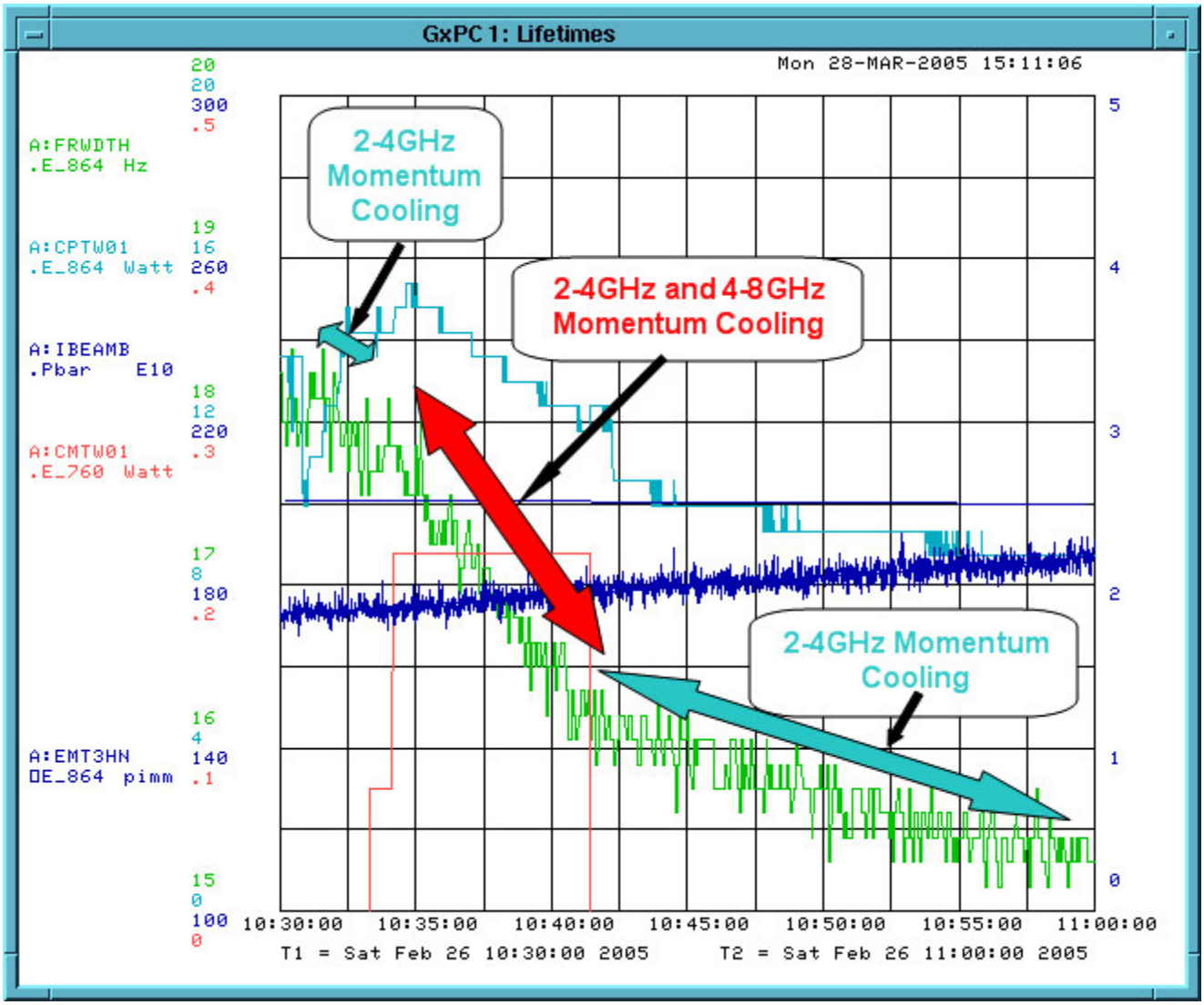


Figure 1: Example of using the 4-8GHz Momentum Cooling

As a result of the benefits of using both the 2-4GHz and 4-8GHz momentum systems, Dave Vander Meulen wrote a procedure that can be followed prior to shot setup. This document can be seen in the online Pbar Tuning Guide(http://www-bdnew.fnal.gov/pbar/organizationalchart/drendel/TuningGuide/tuning-guide.htm) at http://www-bdnew.fnal.gov/pbar/organizationalchart/drendel/TuningGuide/ShotsWith48/ShotsWith48.htm. The only problem with this procedure is some of the steps change depending on where the Pbar Sequencer Operator is in the shot setup process. It may be of benefit to create an aggregate that can be run prior to the normal shot setup that can take advantage of cooling with the 2-4GHz and 4-8GHz systems.

For the remainder of this document we will outline the steps required to create a pre-shot cooling aggregate in the Pbar sequencer. This aggregate would be **optionally** started before shot setup begins to get a jump on cooling the beam. The first portion of the aggregate would have the Pbar Sequencer Operators turn on the 4-8GHz momentum cooling at a very low level while still stacking. The second portion of the aggregate would have operators stop stacking to more aggressively cool the core. The last part of the aggregate would restore all settings needed to make this aggregate standalone. Upon completion of this aggregate, the **Run II Start Shot Setup** aggregate could be started, or the sequencer operator could return to stacking if the shot setup was cancelled. If this aggregate is well received over time, we could make it a permanent part of the shot setup process.

A great deal of redundancy is built into this aggregate to allow it to be an "optional" aggregate. Some commands are repeated again in the **Run II Start Shot Setup** aggregate, for example. One limitation with this procedure has to do with the VSA momentum thermostat. The VSA momentum thermostat was designed to use either the 2-4GHz or 4-8GHz momentum system, but not both at the same time. The reason for this is that the two system can fight each other, causing instabilities. However, we have seen that if we use 2-4GHz and 4-8GHz in a controlled manner, we have had repeated success in speeding up the longitudinal cooling of the core prior to shot setup. If the VSA thermostat could be changed to allow both the 2-4GHz and 4-8GHz to run at the same time, we can incorporate the second portion of this proposed aggregate into the existing **Run II Start Shot Setup** aggregate. That would also make this aggregate safer since the momentum thermostat would be able to turn off both the 2-4GHz and 4-8GHz when the desired frequency width is reached. The largest danger with using this procedure would be if the frequency width is allowed to get smaller than 15Hz. History shows when this happens the beam can become unstable and we can lose a significant portion of the Accumulator beam.

This document makes an attempt to show the layout of the sequencer commands needed to make this aggregate. The sequencer commands are shown in blue text in the following format.

::: Sequencer Command .

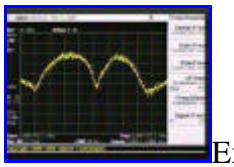
Below each command are explanations and commentary on that particular sequence. Text that would be incorporated into sequencer instructs is shown in green text.

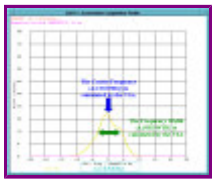
This is an example of text that would be used
inside of an instruct.

The actual aggregate instructs would be made in colors that maximize their readability. The instructs are all listed in green here simply for clarity.

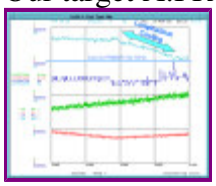
Pre-Cooling Aggregate (optional): Run this aggregate 15-60 minutes prior to the start of shot setup depending on stack size.

1. **Part 1:** This portion of the aggregate is run while we are still stacking to get a jump on the cooling with the 4-8GHz.
   - ::: INSTRUCT ###1 .
     - This instruct would contain at least the following comments.
       -This aggregate is used to pre-cool the core prior to starting shot setup.
       -This aggregate can be started 15-60 minutes prior to shot setup, depending on stack size.
       -This aggregate does not write to the shot scrapbook, so it can be started prior to any other shot setup sequence.
       -The first portion of this aggregate turns on the 4-8GHz momentum while stacking to get a jump on cooling the beam.
       -The goal is to start gently cooling our momentum width.
   - ::: SPECTRUM_LOAD 1 22 .
     - Sends P41 file 22 to Spectrum Analyzer #1 to allow the 4-8GHz momentum array to be aligned.

-  Example plot. Click on the thumbnail image for a full-sized version.
- ::: ACKNOWLEDGE .
  - Issues an acknowledge that says "Start FTP on GxSA."
- ::: AUTO_PLOT {Plot Name} .
  - Starts a Fast Time Plot named {Plot Name} that contains A:EMT3HN (0-4 pi-mm-mrad), A:EMT3VN (0-4 pi-mm-mrad), A:CENFRQ (62885-628890 Hz) and A:FRWDTH (0-40 Hz) over time (0-1200 sec).
  - Our target A:FRWDTH is 20Hz.
- **:::** INSTRUCT ###2 .
  - This instruct would contain at least the following comments.
    -The 4-8GHz momentum cooling array has been loaded to Spectrum Analyzer #1 and can be viewed at CATV Pbar #20.
    -Go to P36 CORE_M_&_B < 3>.
    -Adjust A:MARAYU or A:MARAYD to center the pickup over the beam. This means make the two humps on the CATV Pbar #20 trace equal height.
    -A negative knob makes the value of A:MARAYU or A:MARAYD more negative and moves the notch to the right.
- ::: SETIT_DEVICE A:VSAFWD =17 .
  - Sets the desired frequency width to 17 Hz.
  - 17Hz was chosen rather arbitrarily here. Our final goal is 15Hz. Since we are still stacking and the Stacktail is still on, I started with a value a little higher than our final goal. Two good indicators that can tell us if we are cooling too much longitudinally are to watch the transverse emittances and the CATV Pbar #16 display. I have outlined what to watch for on these two items in the next instruct.
  - If we can do most of the longitudinal cooling while stacking, it will minimize stacking downtime between shots. As this aggregate is run for different stack sizes, we can see if we have any instability problems that are a result of cooling to 17Hz while stacking. If so, we can increase this number to a larger value. If not, we may want to try cooling even further while stacking. If we can cool all the way to 15Hz while stacking, then part 2 of this aggregate would not be necessary.
  - As we will see below in the next command, given the current functionality of the VSA thermostat, this command is not fully functional. If the thermostat is changed to allow running both the 2-4GHz and 4-8GHz at the same time, this command would be valid. This command is in place for future functionality.
- ::: SETIT_DEVICE A:VSARST = 0 .
  - Sets the VSA to normal running. Eventually, we want to be able to set VSARST to 5, which is momentum thermostat mode.
  - Currently the VSA momentum thermostat works with either the 2-4GHz or the 4-8GHz momentum system, but not both. There is a threshold that can set what frequency width the VSA switches from using the 2-4GHz to the 4-8GHz, but it cannot use both systems. The bottom line is if VSARST is set to 5 (momentum thermostat), then either the 4-8GHz or the 2-4GHz system will be turned off by the VSA. The VSA thermostat would have to be modified to allow both momentum cooling systems on at the same time.
  - With the current VSA functionality we would have to set VSARST to 0 (no thermostat) in order to use both the 2-4GHz and the 4-8GHz. The danger of doing this, is that if the Pbar Sequencer operator is not attentive to this procedure, then the

cooling could drive the frequency width too narrow and lead to instabilities and lost beam.
    - It would be of utmost importance for the Pbar Sequencer Operator manually watch the frequency width and turn off the 4-8GHz, when we got to our desired frequency width.
    - Our target frequency width while we are still stacking would have to be more than our target frequency width after we turned off stacking. We may want to make a target table that showed our desired FRDWTH versus stack size while we were stacking? For now, I just set the target frequency width to 20Hz.
- ::: CHECK_DEVICE A:VSARST .
    - Checks A:VSARST and displays the value in the sequencer message box.
- ::: ACKNOWLEDGE .
    - Issues an acknowledge that says "Start VSA on GxSC."
- ::: START_PGM SA1136 .
    - This command starts the VSA on GxSC.
    - 
- ::: SETIT_DEVICE A:CMPA01 = 31.75 .
    - This command sets the 4-8GHz Momentum pin attenuator (A:CMPA01) to its maximum value of 31.75dB. This ensures that there is no power on the system when it is turned on.
- ::: CTLIT_DEVICE A:CMPS01 ON .
    - This command turns on the 4-8GHz.
    - We have two options with the momentum cooling. We can either adjust to cooling manually for both systems, or implement power leveling. At this point, I believe we should adjust the cooling by hand, especially since we are still stacking at this point. If this aggregate is shown to work well over time, we may want to switch to using power leveling. It would only add a couple of commands to the aggregate.
- **:::** INSTRUCT ###3 .
    - This instruct would contain at least the following comments.
      -Watch the VSA on GxSC. If it dies at anytime, it must be restarted.
      -Watch A:VSARST. If it goes to -1 at any point, the VSA SA must be restarted.
      -Lower the 4-8GHz momentum pin attenuator (P34 or A:CMPA01) until the power increases to 0.5W (P34 or A:CMTW01 + A:CMTW02).
      -Tune the 2-4GHz momentum pin attenuator (P34 or A:CPPA01) to keep a constant power level (P34 or A:CPTW01).
      -Watch the VSA display on GxSC (and CATV Pbar #16). If coherent spikes show up on the display, then lower the 2-4GHz momentum power until the spikes go away.
      -Carefully watch A:FRWDTH on the FTP. If the frequency width gets smaller than 17Hz, then continue to the next portion of the aggregate. If the frequency width gets to 15Hz, issue the remaining commands in this aggregate and continue on to **Run II Start Shot Setup** once the Tevatron sequencer has started the shot scrapbook.
      -Carefully watch the transverse emittances (A:EMT3HN and A:EMT3VN) on the FTP. If A:EMT3HN grows to greater than 2.5 pi-mm-mrad, then turn off the 4-8GHz momentum, turn down the 2-4GHz momentum and continue to the next portion of this aggregate. If A:EMT3HN grows to greater than 3 pi-mm-mrad, than turn off the 4-8GHz momentum, turn down the 2-4GHz momentum, finish the remaining commands in this aggregate to get back to a safe state, and contact a Pbar expert if the

emittance growth does not get under control. Note that it is normal to see some transverse emittance growth as we are cooling the beam longitudinally.
-If we are within 15 minutes of shot setup, then continue to the next portion of this aggregate.
-If for any reason the Pbar Sequencer operator can not dutifully watch the VSA and FRWDTH plot, finish all remaining commands in this aggregate to get back to a safe state.

2. **Part 2:** This portion of the aggregate turns off stacking to more aggressively cool with the 4-8GHz momentum. Note that once we can run the VSA thermostat with both the 2-4GHz and 4-8GHz momentum systems at the same time, the commands for this section of this aggregate should be moved to the **Run II Start Shot Setup** aggregate.
   - **:::** INSTRUCT ###4
     - This instruct would contain at least the following comments.
       -In this portion of the aggregate, we stop stacking to more aggressively cool the core with both the 2-4GHz and 4-8Ghz momentum systems.
       -Please take the Pbar beam switch.
       -A fast time plot will be started to monitor the frequency width. Overwrite the FTP started earlier in this sequencer since it is the same plot with different limits.
       -Do not start the FTP on GxSC, since the VSA SA should be running there.
       -If the VSA SA dies on GxSC, restart it form P142.
   - ::: BEAM_SWITCH PBAR_SOURCE OFF .
     - This command takes the software beam switch
   - ::: ACKNOWLEDGE .
     - Issues an acknowledge that says "Overwrite FTP on GxSA."
   - ::: AUTO_PLOT {Plot Name} .
     - Starts a Fast Time Plot named {Plot Name} that contains A:EMT3HN (0-4 pi-mm-mrad), A:EMT3VN (0-4 pi-mm-mrad), A:CENFRQ (62885-628890 Hz) and A:FRWDTH (0-20 Hz) over time (0-1200 sec).
     - This plot is similar to the one started in part 1 of this aggregate. The only difference is the limits on A:FRWDTH.
     - Our target A:FRWDTH will now be 15Hz.
     - 
   - ::: SETIT_DEVICE A:VSAFWD =16 .
     - Set the desired frequency width to some intermediate value while we are waiting for the Stacktail to be pulled over. This command is only used if we are able to run the VSA in momentum thermostat using both the 2-4GHz and 4-8GHz momentum cooling at the same time.
     - Again, the choice of 16Hz is completely arbitrary. If this does not create instability problems, then we may want to try to cool all the way to 15Hz at this point.
   - **:::** INSTRUCT ###5
     - This instruct would contain at least the following comments.
       -Continue when all of the beam in the Stacktail has been pulled over into the core.
       -The sequencer will now turn off the Stacktail.
   - ::: CTLIT_DEVICE A:SPPS01 OFF .
     - Turn off the Stacktail
   - **:::** INSTRUCT ###6
     - With the Stacktail moved over, do we want to re-adjust the array? If so, we would

have an instruct here that would contain at least the following comments.
-Look at CATV Pbar #20
-Verify that the array is still centered on the beam.
- If not go to P36 CORE_M_&_B < 3>.and adjust A:MARAYU or A:MARAYD to center it.

- ::: SETIT_DEVICE A:VSAFWD =15 .
  - This command sets our desired frequency width to 15Hz. This command is only used if we are able to run the VSA in momentum thermostat using both the 2-4GHz and 4-8GHz momentum cooling at the same time.
- Another note on cooling:
  - Again we have the choice of either adjusting the cooling by hand, or using Power Leveling.
  - I think it would be good for us to start this process adjusting the cooling by hand to see how well the aggregate works.
  - Once the aggregate is shown to work as written, we could add Power Leveling to the cooling systems to dial in on our target powers. This would only add a few commands to this aggregate.
- **:::** INSTRUCT ###7
  - This instruct would contain at least the following comments.
    -Lower the 4-8GHz momentum pin attenuator (P34 or A:CMPA01) to get the power between 1.3W and .8W (P34 or A:CMTW01 + A:CMTW02).
    -Adjust the 2-4GHz momentum pin attenuator (P34 or A:CPPA01) to get the power between 8W to 12W(P34 or A:CPTW01).
    -Watch the VSA display on GxSC (and CATV Pbar #16). If coherent spikes show up on the display, then lower the 2-4GHz momentum power (P34 or A:CPPA01) until the spikes go away.
    -Note that the 2-4GHz momentum power will fall fairly fast as the core cools, so watch the power and adjust the attenuator to keep the power in its desired range, or as close as you can without seeing coherent spikes on CATV Pbar #16.
    -Watch the VSA on GxSC. If it dies at anytime, it must be restarted.
    -Watch A:VSARST. If it goes to -1 at any point, the VSA SA must be restart.
    -Carefully watch the Frequency Width (A:FRWDTH) on your FTP. Once the frequency width drops to 15Hz, continue on to the next portion of the shot setup.
    -Carefully watch the transverse emittances (A:EMT3HN and A:EMT3VN) on the FTP. If A:EMT3HN grows to greater than 3 pi-mm-mrad, than turn off the 4-8GHz momentum, turn down the 2-4GHz momentum, finish the remaining commands in this aggregate to get back to a safe state, and contact a Pbar expert if the emittance growth does not get under control. Note that it is normal to see some transverse emittance growth as we are cooling the beam longitudinally.
    -Warning! If the beam gets much thinner than 15Hz, it may go unstable and a large portion of the stack could be lost. If for any reason the Pbar Sequencer operator can not dutifully watch the VSA and FRWDTH plot, finish all remaining commands in this aggregate to get back to a safe state.

3. **Part 3:** This portion of the aggregate cleans things up to allow the start of the **Run II Start Shot Setup** aggregate, or allow stacking to resume.
   - ::: CTLIT_DEVICE A:CMPS01 OFF .
     - Now that the beam has been cooled to 15Hz, the 4-8GHz momentum cooling must be turned off.
   - ::: COPY_SCREEN 0 SA .
     - This command copies the FTP showing emittance and frequency width to a D5 save file.

- The shot scrapbook is not necessarily opened at this point, so the D5 save might be our best option.
- ::: INSTRUCT ###8
  - This instruct would contain at least the following comments.
    - The 4-8GHz momentum system has been turned off and will remain off in the next two aggregates as you prepare to move to the shot lattice. If there is need to run the 4-8GHz in the next aggregate, then you can
      - Change A:VSARST from 5 to 0.
      - Set the pin attenuator
      - Turn on the 4-8GHz Momentum system
      - Carefully watch FRDWTH. When it reaches 15Hz again,
        - Turn off the 4-8GHz
        - Change A:VSARST back to 5.
    - At this point, you can either
      - Cancel out of this instruct and continue on to the **Run II Start Shot Setup** aggregate. Remember that the Tevatron sequencer starts the shot scrapbook chapter for the shot so don't start the next aggregate until this is done.
      - If you accidentally continued to this point before the frequency width reached 15Hz, go back to INSTRUCT ###4 and continue from there.
      - If the shot setup is cancelled, simply run the two commands after this aggregate and then flip the beam switch to return to stacking.
- ::: BEAM_SWITCH PBAR_SOURCE ON .
  - The software beam switch is turned back on just in case the Pbar Sequencer operator needs to go back to stacking.
- ::: CTLIT_DEVICE A:SPPS01 OFF .
  - The Stacktail is turned back on just in case the Pbar Sequencer operator needs to go back to stacking.
- Another note on cooling.
  - If we later implement power leveling in the aggregate, then we would put commands here to put the cooling back in case the Pbar Sequencer Operator is going back to stacking.

That summarizes all of the commands that would be required to make an optional standalone aggregate to pre-cool the core before shot setup. If this aggregate proves to be a success, then we could implement it operationally into the Pbar Collider Run II Shot Setup aggregates.