A Plan to Evolve the BNL C-AD Proton Accelerators Capability to Provide the Beams Required by the RSVP Experiments in Parallel with RHIC Operation

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Summary:

The following material gives a plan to provide the beams required by the RSVP experiments. This plan does not include the beam line development beyond getting a place to measure the bunch structure and a place to dump the beam. Nothing about experiment commissioning is included.

There are two broad areas where progress is required. The first is in the establishment of the extraction schemes, which are essential for the two experiments. Both extractions involve producing bunched beams in the "slow extraction" lines of the AGS complex albeit with rather different time distributions. Both require that extremely little beam exist out between the desired bunches. Considerable progress toward both extraction schemes have been made over the past five years, but meeting the requirements for both experiments will still be a great challenge. The plan starts with very low intensity beams.

The second area involves providing high intensity proton beams – in some ways considerably higher than beams provided from the AGS in the past. To satisfy the experimental needs, losses per produced proton will have to be reduced below levels achieved in the past while the protons per second and per bunch need to increase. Of course the behavior of the extraction will be strongly influenced by the beam intensity, so considerable time is spent working out the high intensity extraction issues.

The efforts toward intensity and the bunched extractions will be carried out "behind" the periodic filling of the RHIC. The machinery to rapidly and accurately shift the complex between modes is well established. But here too getting to peak performance for all the modes will be interesting - will require time – at low and then higher intensities.

In the following then the steps to be followed are outlined. The first year of work is given in fair detail – as provided by the lead accelerator physicists involved. Succeeding years' efforts are described more in terms of objectives than in detailed steps. Except for the first year, the plan assumes the beam work occurs during the RHIC running period. The first several weeks of each new RHIC running setup will be avoided given that working "behind RHIC" becomes inefficient. The RHIC experiments need for long smooth fills provides the RSVP effort the time required for progress. The shutdowns between RHIC runs allow for the few equipment installations needed by RSVP.

This plan intends to deliver beams adequate for the RSVP engineering runs in FY2008. To get there, beam work is assumed to occur every year, starting this spring. The work is largely sequential. If a run doesn't occur, the schedule slides. The basic tasks must be done.

RSVP Plan

This plan does not attempt to include experimental beam line development time beyond that needed to provide an external beam bump and extinction measurement capability for both experiments.

The first phase of the RSVP plan involves beam work to develop and demonstrate parts of the two extraction schemes. This is the new territory, as opposed to the other challenge namely improving on old high intensity limits. The extraction work is best done first a very low intensity. Beam behavior using low intensity beams is very relevant and simpler to understand than what will be seen at high intensity. The costs and difficulties from radiation and activation introduced by higher intensity beam work are avoided. To the extent that this work is not accomplished in FY04, it will have to be done in the next period. The detailed plans for this '04 work comes directly from the major players. Time estimates for work in the later years becomes increasingly less reliable as it moves into the future.

FY04:

During RHIC run: parasitic beam work (as resources permit and especially if motivated by RHIC gold performance) on measuring AGS impedance, towards understanding instability thresholds and associated momentum spread requirements.

Also during the RHIC running period: simulation work for both KOPIO and the MECO should be carrier out – to predict beam behavior in the setups to be created in the machine at the end of the run. Hard predictions up front will increase the usefulness of this year's work

After the RHIC running period, before summer shutdown: The general plan is to set up software lists - "Sequences" - to allow mode switching among the games on the table - at least between 8 GeV and 24 GeV extraction. This exercise is well used in the past, though in slightly different context. Set up these extractions first in normal SEB configurations - i.e. without the rf component. With that accomplished, work on both micro and mini bunching understanding. An AGS extraction channel for low (<3e12 protons = 3Tp) intensity proton beam is required. Expect to work with 0.2 - 0.5 Tp/bunch. Available time is limited - between the end of RHIC and the beginning of summer power savings - less than 6 weeks.

Summary of time requirements in '04: Run in dedicated mode for about one month calendar time. Switch between KOPIO and MECO configuration perhaps every four to five days. Specific estimates follow below.

The lead AGS players in both experiments (Brown and Glenn) have provided more details of how to spend the resources during this '04 dedicated period and how much time would be useful. I give my summaries of these plans next.

KOPIO

The time requirements are estimated to be three several-day blocks of time, separated by breaks of several days of thinking planning time, 13 sessions = 13 days of beam activity total.

The first block recommissions the KOPIO setup, starting with regular SEB to D line and with set up of the instrumentation in D required for microbunching measurements. Then microbunching using the 4.4 MHz rf system is setup and using the nominal settings for parameters other than the rf frequency, a scan of that frequency is made measuring bunch width, punch through, and extraction efficiency. "Punch through" is Glenn's term for describing extracted beam that occurs in time between the desired bunches. (5 sessions)

The second block repeats the frequency scan at several rf voltages. Then the extraction setup is modified to work with a smaller momentum spread in the beam, and the frequency scan is repeated. Then again the extraction setup is modified, now to work with as strong an extraction resonance as possible, and the rf frequency scan is repeated. (4 sessions)

The final block uses the optimal parameters learned from the previous work, and again carries out a frequency scan. This block also carries time for "other" measurements motivated by the earlier work. (4 sessions)

MECO

The time requirements are estimated to be two week long blocks, 17 sessions of work = 17 days of beam activity

1) Low energy, not mini-bunched, slow extraction setup and careful measurement: 9 sessions of work.

a) Measure extraction efficiency - vs vertical size in AGS. Measure emittance in AGS and in extraction line. Also measure horizontal extracted emittance vs internal emittance to get extraction parameters right. Fitting the beam into the existing vertical extraction acceptance could be a stopper already at modest intensity (not at 0.2 Tp) … if so what to do - larger aperture H20 and F10 septa surely not a quick thing, or "insist" on restricting the vertical beam size throughout the acceleration in Booster and AGS? – not consistent with going to higher intensities.

b) Measure spill structure, understand what we see, and work to minimize. This measurement provides the baseline for later work with rf present, and also provides MECO specifications for the Siemens active filter. The setup of this filter may impact mode-switching speed and hence our planning.

2) Add mini-bunching: 8 sessions of work.

a) Carry out an exploration of (extinction, extraction efficiency) parameter space. Optimize our position in this space. This needs simulation work - which is ongoing. In particular, explore control on the population of the beam between the two bunches. Extinction measurements of some sort are required and this is part of the parameter space to explore. Use the AGS (vertical damper and ac dipole to clean out the beam between the bunches. From this come specifications for new AGS extinction hardware.

b) Measure change in the spill structure relative to 1b. Minimize structure. There may be some specifications coming from this for hardware modifications to cope with any power frequency or rf-associated components found in the spill.

FY05:

RSVP base support required to accomplish the tasks specified below.

Occurs during the RHIC running: begin high-intensity-driven setup / studies. Exploration of Booster intensity potential towards a 20Tp bunch is the primary objective. In step with this it is required to develop efficient AGS extraction / transport to a beam dump at 8GeV, working toward (20+Tp/cycle) capability. This extraction work builds on the MECO studies in '04. Use of the internal beam dumps in the Booster and AGS is possible at low to intermediate intensities. The AGS dump can be used to remove 6Tp per 2.4 second cycle at any energy. If the internal dump must be used for higher intensity development, a "slow extraction into the dump" procedure will be developed and the machine repetition rate slowed as required.

3 sessions: Low intensity (1 Tp/cycle) beam work, acceleration in Booster. Set up Booster for high intensity commissioning. h=1. Commission / recommission 1st and 2nd harmonic setup as required. This machine configuration is now fully “PPM” switch able to/from the fully optimized RHIC setups.

1 session: Set up low intensity transfer of beam into AGS to AGS beam dump.

3 sessions: Intensity increase (Booster work) - to 5 Tp with single-transfer beam into AGS beam dump. Intensity studies at AGS injection. Accelerate to below transition - 8 GeV.

2 sessions: set up extraction and transport to external dump at 8 GeV, modest intensity. This follows on '04 MECO work.

9 sessions Work toward 20Tp in Booster and AGS. In synch with this maintain extraction efficiency. "Late" AGS intensity measure is a critical parameter for optimization. Booster injection longitudinal distribution optimization. Study AGS

injection loss patterns in time and space vs intensity. When we have made all the measurements we can think of, and the performance of all systems is understood, we are done. That is, we will not go into extended 'tuning' this year.

At this point we can draw some conclusions about where to go next on intensity issues. We may have hit a wall in Booster preventing progress without an extended entry.

Also during '05 follow-ups on the '04 studies for both KOPIO and MECO will provide essential information on intensity dependence of the extraction setups. Intensities 10 times higher than in '04 (i.e. 2-5 Tp/bunch) should be available. As configured the setup is ready for MECO. To work on KOPIO, extraction at 24 GeV needs to be set up.

2 sessions Set up KOPIO extraction and transport to the beam dump.
1 sessions Set up KOPIO / MECO "mode switch".

3 sessions KOPIO '04 follow up (micro bunching)

3 sessions MECO '04 follow up (mini bunching)

total 27 sessions.

FY06:

RSVP base support required to accomplish the tasks specified below.

Prior to the '06 RHIC running period:

Respond to what was learned in '05 in Booster to increase available intensity in terms of hardware modifications.

During the RHIC running: continue high intensity work, now with mini and micro bunch extraction. Again we will need high intensity external beam dumps for both extraction energies. The intensity parameter - how intensity affects mini and micro bunching - hopefully becomes the primary issue. Of course even this requires "baseline" work at low intensity and in addition some other issues will want low intensities and so can be handled using the internal beam dumps.

10 sessions Set up "basic" high intensity acceleration / extraction / transport / dump. MECO and KOPIO. Basic means this is a careful adjustment, with measurements of Linac, Booster injection, BtA transfer and both synchrotron machine set ups to agree with the present understanding of the "book". MECO and KOPIO are lumped together, though there will be a portion of the work which is unique to each.

10 sessions "Tune" this setup for MECO and KOPIO, to achieve an acceptable intensity. We need to exceed the '05 intensity level by a significant margin so looking for a factor of 1.5 here, to 7.5 Tp/bunch.

As we begin to push the machines toward their intensity limits, the way the machines are left during the 12 hours each night between RSVP study periods will start to affect the time estimates in a significant way. If the high intensity machine is turned off, a recovery period will be required each day to get back to where we left off. An estimate for the required time is 25% of the shift. Some of the recovery work could be done by Operations. The "session" time estimates here assume no penalty; the machine is assumed to be left running at high intensity.

3 sessions MECO mini bunching and intensity

3 sessions KOPIO micro bunching and intensity

total 26 sessions (same comments associated with this estimate as for '05)

FY07:

RSVP base support required to accomplish the tasks specified below.

Prior to the '07 RHIC running period:

Install A10 kicker modules (AGS injection)
Install the KOPIO 25 MHz cavity in the AGS
Respond to what was learned in '06 in Booster and AGS to increase available intensity in terms of hardware modifications.

During the RHIC running: The AGS injection kicker upgrade is done. Final high intensity development work begins, now with all the expected hardware. This activity will extend from Booster injection through AGS extraction, will involve low and high intensity studies, and will follow somewhat different paths for the two experimental requirements. KOPIO has the 25 MHz cavity and so the predictions from the simulations can be checked directly.

Tune mini and micro bunching setups with higher intensities. The KOPIO beam line is available.

10 sessions High intensity basic setups. This builds on the work of '06, but now adds in the availability of the A10 kicker at AGS injection. MECO and KOPIO extraction must be set up as before. Intensity during this period is not yet at the limit, but is significant from an ALARA perspective.

5 sessions High intensity tuning, for MECO.

5 sessions High intensity set up, for KOPIO.

5 sessions MECO micro-bunching, performance with intensity - working towards the spec.

5 sessions KOPIO mini-bunching, commission the 25 MHz cavity. This is the first opportunity to study the performance of the actual system. Low intensity studies will be required, mapping the space.

5 sessions KOPIO mini-bunching performance with intensity - working towards the spec.

total 35 sessions.

Still want to avoid high intensity "tuning" for significant periods - now the time scale is a month - of time to get the last 20 - 30 %.

FY08:

RSVP base support required to accomplish the tasks specified below.

During RHIC running:

Engineering runs for both MECO and KOPIO begin. High beam intensity tuning continues with existing hardware.

Session/Shift normalization:

What does a "session" mean? In the above, one session is thought of as one efficient working day of effort by a team of accelerator people - perhaps a long day but nevertheless an effort that could be sustained for many days. The "day" would about 12 hours of machine time (some set up by Operations on each end). To translate this into other definitions of time - for evaluating costs and availability for others some fudge factors are useful. The number of shifts does not include the “working behind RHIC” overhead. How large is that overhead? This depends on the details of the activity and on how the RHIC run is going. Assume we avoid the RHIC "ramp up" periods. Then we apply a factor of 2 to the required times. I think we did not do this well working with polarized protons behind RHIC in 2003, but recent RHIC experience suggests 2 might even be conservative (too large). This factor is certainly not appropriate, (i.e. too high) for steady state activity behind RHIC. It is the need to have the appropriate set of experts and machine conditions to make commissioning progress that makes the factor high.

Do we have the people to accomplish this work with RHIC running? That is one reason for the 1 session per day requirement. The most likely places where resources will get tight are with expert tuning resources - folks who can quickly recognize what is wrong with the machine - and with rf group resources given that RHIC will continue to evolve too. And with RHIC running and RSVP commissioning, there will be little beyond the most basic operations support available for additional tasks.

So within each of the fiscal years, the estimate is for sessions with a working machine and people resources available. To translate this into required calendar time, one needs to translate 1 session into 1 day and then multiply by 2. And for each of these days in this model AGS RSVP activity occurs for about half of the clock hours. Beam line and especially experimental commissioning activity are not covered in the activities described here. Some of this work, provided different experts are relevant, may make good use of the between-session periods.

Fiscal Year	'04 sessions	'05 sessions	'06 sessions	'07 sessions
basic setup		9	10	10
intensity		12	10	10
MECO, low intensity work	17	3	0	0
MECO, high intensity work	0	0	3	5
KOPIO, low intensity work	13	3	0	5
KOPIO, high intensity work	0	0	3	5
total sessions	30	27	26	35
	days	days	days	days
required calendar days	30	54	52	70
with high intensity penalty	30	54	60	80
	days	days	days	days
potential unused (between sessions) time	0	27	26	35