Report from the 3rd Meeting of the Accelerator Technical Advisory Committee for the Japan Proton Accelerator Research Complex (J-PARC)

March 5-6, 2004
JAERI
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EXECUTIVE SUMMARY

The Accelerator Technical Advisory Committee (ATAC) of the Japan Proton Accelerator Research Complex (J-PARC) held its third meeting over the period March 5-6, 2004 at the JAERI laboratory in Tokai, Japan.

The J-PARC Project was initiated in 2001 as a joint project carried out by KEK and JAERI. When complete the facility will support research into the areas of Neutron, Nuclear, and Elementary Particle Physics. The Project is approved with a budget of 151.4 billion yen for Phase 1, which now includes funds for construction of the neutrino facility originally scheduled for Phase 2. To accommodate funding for the neutrino facility the linac energy in Phase 1 has been formally lowered to 181 MeV (as contemplated a year ago) and the construction schedule has been delayed a year. Phase 1 is now scheduled for completion at the end of JFY2007, with the neutrino facility completed one year later. Recovery of the linac energy to the originally planned 400 MeV will cost about 8.5 billion yen and will be completed following Phase 1, over the period JFY2008-2010. Phase 2 includes extension of the linac energy to 600 MeV, construction of the waste transmutation facility, and upgrade of the Main Ring to 50 GeV, but is not yet approved for construction. The committee notes that when complete J-PARC will provide Japan with the preeminent facility for hadron sciences in the world.

The ATAC heard presentations covering the technical design and fabrication of the accelerator facilities supporting the J-PARC Project. These presentations were well prepared and informative, as well as being responsive to most recommendations from the March 2003 ATAC meeting. In addition the committee toured the construction site and observed many initial production components undergoing testing as well as significantly advanced civil construction activities. Presentations and committee discussion concentrated on the Phase 1 project goals and the linac energy recovery plan. The committee was very impressed with the degree of progress since the last meeting, in particular the achievement of 30 mA of beam accelerated to 20 MeV in the first drift tube linac tank. This performance meets the design goal of the upstream end of the accelerator complex and portends well for the future. The ATAC congratulates the project team on its very excellent progress.

Subsequent to this meeting the ATAC Report was presented to the International Advisory Committee and discussed as part of their deliberations at their meeting on March 8-9, 2004.

General Comments

When completed J-PARC will be a state-of-the-art proton accelerator complex with associated experimental facilities. The accelerator facility, which was the subject of this review, consists of a 181 MeV linac, a 3 GeV rapid cycling synchrotron (RCS), and a 50 GeV synchrotron denoted the Main Ring (MR), and operating with a maximum energy of 40 GeV in Phase 1. The two synchrotrons are designed to provide extremely high average beam power: 0.6 MW from the RCS and 0.72 MW from the MR. This performance is beyond that of any other facility operational in the world today. Notable components of the project currently delayed beyond Phase 1 include restoration of the full linac energy to 400 MeV, an additional 200 MeV of superconducting linac and associated waste transmutation area, and realization of the full 50 GeV performance of the Main Ring. The neutrino beamline and target previously incorporated into Phase 2 has now been funded in parallel with Phase 1.

Performance criteria have been established for all the accelerators, all major components have been prototyped, and nearly all are currently on order.

Since the last ATAC meeting, the reduction of the linac energy in Phase 1 to 181 MeV (from 400 MeV), as first proposed a year ago, has been formalized. As such the meeting of the ATAC concentrated on issues related to facility performance based on the 181 MeV linac and plans for recovering the energy to 400 MeV once funds become available. However, such funds are not yet committed.

The accelerator design and construction present a large number of challenges, most of which are associated with the very high average beam power required from the facility. The design, construction, installation, and (ultimately) commissioning are being under taken by a staff numbering approximately 130 people. While this staff is extremely dedicated and skilled, the committee feels, as it did last year, that the overall staffing level is modest for such an ambitious and complex facility, constructed over a seven-year time frame. The committee is gratified to hear that increased staff have been pledged by laboratory management and suggests that the appropriate balance be maintained between new hires and reassignment of existing experienced accelerator staff as other activities wind down at KEK and JAERI.

The committee heard for the first time presentations on beam diagnostics and strategies for commissioning of the accelerator complex. The ATAC report provides several comments and suggestions in these areas.

400 MeV Recovery Plan

The plan for recovering the full 400 MeV linac energy has been modified from the preliminary plan presented to the ATAC in its last meeting. The revised plan is to fabricate and power test Annular Coupled Structure (ACS) units offline, over the period JFY2008-2010. ACS units are then installed on the beam line and commissioned over the second half of JFY2010. Operations with the full 400 MeV linac energy are then initiated in early JFY 2011 with full 1 MW achieved in the RCS at the end of JFY 2012. The ATAC has the following comments relative to the recovery plan presented at this meeting:

- The strategy of installing the ACS structures in a single shutdown, followed by immediate commissioning and transition to operations, eliminates concerns expressed by the ATAC last year relative to transmission of beam through idle ACS cavities in the prior recovery scheme. The ATAC is confident that 3 months are sufficient, with adequate preparation and personnel, to install and commission the ACS equipment. Setting-up with beam of the linac and RCS are likely to take a similar duration.
- Momentum collimation has been removed from the linac to RCS transfer line. While the performance of the linac appears to be acceptable in terms of beam capture in the RCS, the committee retains some concern with regard to this removal in terms of off-normal

linac pulses.

Recommendation: The presence of a momentum collimation device in the linac to RCS transfer line should be reconsidered.

- Achievement of the stated 3 month schedule to install the ACS followed by 3 months of commissioning appears aggressive and so will require detailed planning and assignment of adequate personnel. The committee did not hear details of the plan. J-PARC management will have to establish a plan, in consultation with users, several years in advance of the actual upgrade.
- The committee endorses the new strategy as minimizing risk associated with the energy recovery, and maximizing delivered beam power to users in the interim.
- The committee feels there is a high probability that linac performance goals for Phase 1 of the project will be met.
- However, as reflected in the discussion below the ATAC continues to believe that restoration of the linac energy to 400 MeV is essential for realization of the original J-PARC goals of 1 MW beam power from the Rapid Cycling Synchrotron and 0.75 MW from the 50 GeV Main Ring.

Recommendation: Recover the linac energy to 400 MeV as soon as possible.

<u>Performance expectations with the 181 MeV linac</u>

An energy of 181 MeV for injection into the RCS has now been formalized as the J-PARC Phase 1 goal. Installation of the ACS linac, and realization of the full 400 MeV originally proposed, are now delayed beyond Phase 1. Within this plan performance goals for the J-PARC accelerator complex in Phase 1 have been established as:

3 GeV Rapid Cycling Synchrotron:	0.60 MW
50 GeV Main Ring (40 GeV, fast spill)	0.72 MW

The ATAC meeting featured multiple presentations and subsequent discussion relative to the measures being taken to maximize performance of the J-PARC accelerator complex based on the lowered linac energy, and the degree of confidence that can be assigned to projected performance levels. With regard to RCS performance the ATAC has the following comments, conclusions, and recommendations:

- The RCS performance goal is consistent with the 30 mA achieved in DTL tank 1.
- Scaling the beam intensity to constant space charge results in a projection of 0.33 MW delivered from the RCS with a 181 MeV injection energy. The committee believes 0.33 MW represents a lower limit on what will be achieved with the RCS in Phase 1.
- Simulations presented to the ATAC indicate that a higher space charge tune shift should be achievable at 181 MeV than at 400 MeV because identical beam loss, in percent,

translates to lower lost beam power.

- The committee believes 0.6 MW beam power with 181 MeV injection into the RCS is plausible, but requires more developed simulations and loss analysis to provide confidence.

  Recommendation: Incorporate closed orbit errors and correction , magnet errors, resonance correction, and bunching factor variations into the RCS simulation.

  Recommendation: Improve the injection simulation by identifying where the lost particles go. Establish a budget for particles lost other than on the collimators and demonstrate that the collimation system meets this budget.

In order to recover the maximum beam power the injection scheme into the Main Ring has been modified from the original Phase 1 design. The Main Ring harmonic number has been doubled to enable operations with 15 bunches, rather than the originally planned 8. With expected bunch intensities delivered from the RCS the resultant beam power is 0.72 MW, essentially the same as the original Phase 1 goal of 0.75 MW. However, this mode of operation requires single bunch operation of the RCS and 15 individual injections into the MR. (The old scheme had four transfers of two bunches each.) With regard to MR performance the ATAC has the following comments, conclusions, and recommendations:

- RCS beamloading compensation is a greater challenge with a single bunch than with two. Nonetheless, the committee believes it is achievable.

  Recommendation: Consider the possibility of providing beam loading compensation via feedback in addition to or instead of feedforward.

- The MR injection time is extended from 0.12 seconds to 0.56 seconds with the new injection scheme. The ATAC expressed concern at its last meeting with respect to performance with an extended dwell time at the 3 GeV MR injection energy.
- Simulations to date provide a good start on understanding the issues associated with the extended dwell time and offer encouragement that MR performance goals can be achieved. This work is going in the right direction, however the situation is complex and an integrated simulation does not yet exist.
- If the MR were operated in the originally envisioned mode of four transfers of two bunches each from the RCS, the achievable beam power based on the current RCS performance goal would be 0.44 MW. The committee believes 0.44 MW represents the likely lower limit on what will be achieved with the Main Ring in Phase 1 (40 GeV, fast spill).
- The committee cannot yet establish a high degree of confidence in the 0.72 MW goal for the MR given current uncertainties in the simulations. (However, nothing has been presented that would preclude this.)
- Simulation of the full 0.56 second injection process is very difficult, thus some method of

extrapolation will be required.

Recommendation: The committee recommends an approach to establishing likely performance in the MR incorporating the following elements:

- Establish a loss budget, both for particles ending up on the collimators and particles ending up elsewhere.
- Incorporate all possible effects into the injection simulation: magnet errors, machine apertures, closed orbit distortion and correction, resonance correction, and the impact of increased bunching factor.
- Benchmark the simulation against an existing machine (BNL/AGS, KEK/PS, or Fermilab/MI).
- If indicated by the simulation, explore methods for increasing the bunching factor at injection into the MR.
- Estimate any longitudinal emittance growth that could lead to loss of beam from the MR at the start of acceleration (beam outside the buckets).
- We suggest linear extrapolation of simulated loss to 0.3 seconds (average time which a particle stays at 3 GeV). This should be conservative as simulations show slower than linear dependence of beam loss on time at 3 GeV.

Commissioning and Instrumentation

Preliminary strategies and planning for commissioning of the J-PARC accelerator facilities were presented at the meeting. These presentations were augmented by descriptions of instrumentation being prepared for the accelerators. The ATAC has the following comments and recommendations with regard to the commissioning strategy and instrumentation:

- The strategy and plans for commissioning appear to be very comprehensive for this stage of the project.
- Plans for providing instrumentation are well integrated and support the commissioning plan.
- The committee endorses the overall strategic approach to commissioning, but feels a few aspects of the plan deserve reconsideration: First, the plan to establish first turn orbits in the RCS and MR by utilizing low intensity beam at 1 Hz repetition rate requires the installation of pre-amplifiers on the BPMs in order to observe beam positions. The plan is to utilize a small number (4-5) of pre-amps which are physically moved around as the first turn beam progresses. Second, the role of the high energy abort in the MR seems to the committee to be unnecessarily restricted to a machine protection role.

Recommendation: Consider a strategy that utilizes high intensity beam (high enough to be visible on the BPMs) run at a relatively low (~1/minute) rate for commissioning. This will require that appropriate data is both saved and logged on individual pulses so that it can be analyzed and guide adjustments made on a subsequent pulse. Such a data logging capability could also serve for post-mortem analyses once the J-PARC facility is in operation. (By "post-mortem" we mean analysis of what happened after something goes wrong. For example, following a magnet quench in the Tevatron or in RHIC a collection of relevant data (orbits, loss monitors, voltage sensors) is frozen so that the conditions in the accelerator over the previous several hundred milliseconds can be used to reconstruct what happened.)

Recommendation: Consider utilization of the MR high energy abort for beam disposal during the commissioning period.

- The ATAC was not presented with plans for the high level applications programs that will be required to support commissioning. We would suggest a presentation at next year's meeting.

Machine Protection Systems

The committee was presented concepts for the machine protection system (MPS) and offers the following comments and recommendations:

- The overall design of the linac MPS is convincing although we suspect that the reaction time specified for beam loss below 50 MeV is unnecessarily small.
- The machine protection strategy for the RCS and MR does not appear to be fully developed at this time. It is unclear what damage can be done in the RCS or MR in a single pulse accident. This is a critical question and must form the basis of the machine protection strategy.

  Recommendation: Establish the potential impact of a single pulse accident in the RCS and MR, and reflect this information in the machine protection strategy.

- As noted above the role of the full energy abort in the MR is not well defined and requires further thought.

General Comments Relative to Accelerator Performance

Excellent progress has been made both on the DTL beam commissioning and on fabrication of all linac components (DTL and SDTL) required for 181 MeV operations. The full design current of 30 mA has been transmitted through DTL tank 1 with 100% efficiency and little tuning. Congratulations are due to the staff on this achievement. The ATAC has several comments relative to the linac beyond those given in the previous discussions.

- The ATAC was presented with the end-to-end simulations recommended last year. In general these appear comprehensive and support linac performance goals. However, we would further suggest assembling the data in a manner that allows one to see directly apertures vs. beam envelope over the length of the linac and transfer line to the RCS (although we saw nothing to give us any real concern).

- The RFQ runs with constant water temperature that is achieved about 60 minutes after turn-on. Stablization could probably be achieved in a shorter period with active control.

Within regard to the RCS the ATAC has several comments and recommendations beyond those discussed above:

- The committee is worried about the disposition of three monitors for radial position feedback to the rf system. Care must be taken to desensitize the arrangement to closed orbit distortions.

  Recommendation: Reexamine the disposition of radial position BPMs. As an alternative (or addition) consider utilization of a reference magnet.

- The committee believes foil lifetime is a potential issue. We suggest this be examined closely.
- The committee suggests that a description/simulation of the longitudinal painting scheme be presented at next year's meeting.
- The impedance estimates for the RCS seem high, but were presented as being consistent with the Keil-Schnell stability criterion.

  Recommendation: Undertake a beam simulation with measured and modeled impedances to assure stability.

- A preliminary study of the electron cloud effect in the RCS was presented. This work needs to be continued.

  Recommendation: Apply TiN coating on as many elements as possible, not just the ceramic beam tubes.

- The field quality of the main dipoles and quadrupoles is very important particularly at the injection energy.

  Recommendation: Measurements of the field multi-poles should be performed at fields corresponding to 400 MeV and 181 MeV injection energy under standard ramping conditions.

- The committee suggests that extended testing of an RCS dipole and quadrupole be undertaken with the full 25 Hz excitation profiles.

With regard to the Main Ring the ATAC has the following comments and recommendations:

- The committee heard a very interesting idea of using a pre-scatterer to limit losses on the electrostatic septum. The committee did not hear enough to judge whether this will work, but we encourage pursuit of this idea to establish viability.
- There was no presentation on impedances and instabilities in the MR. The committee remains concerned on this topic given the unprecedented beam intensities.

Recommendation: Prepare an impedance budget and instability analysis for the MR including both single and multi-bunch effects. Use results of the analysis to establish the requirements for beam dampers. Results should be presented at next year's ATAC meeting.

- The committee continues to be concerned relative to beam instability during the resonant extraction process featuring zero chromaticity and low momentum spread.

  Recommendations: 1)Complete the simulation demonstrating the 1% loss criteria during the slow extraction process.; 2)Simulate the debunching process of the beam in the presence of the cavity impedances; and 3)Consider measures to ameliorate beam stability issues during this process, for example through implementation of a higher frequency rf cavity.

Finally there are a few global issues that were raised at last year's meeting that remain unresolved:

- The committee wonders if electromagnetic compatibility (EMC) is a potential issue within the complex. Very large currents with high frequency modulation are being transported within the accelerators, which are not all 100% shielded. We suggest giving some thought to potential issues.

  Recommendation: Electromagnetic compatibility needs to be addressed at the project level. The strategy in this respect should be presented at the next ATAC meeting.

- The committee retains some concerns related to coordination across the the interfaces between the various accelerators in the J-PARC complex.

  Recommendation: Appoint a "accelerator physics coordinator" to globally oversee accelerator physics design, track changes in machine configurations, and oversee interface issues especially between the linac and RCS, between RCS and MR, and between RCS and the neutron target.

1 INTRODUCTION

The Accelerator Technical Advisory Committee (ATAC) for the J-PARC Project held its third meeting over the period March 5-6, 2004 at the JAERI laboratory in Tokai, Japan. The committee heard presentations from project staff on the 5th, held several closed sessions to discuss reactions and opinions, and presented a verbal report to project management on the 6th. The meeting agenda is attached as Appendix 3.1.

Committee members in attendance at this meeting included: R. Garoby/CERN, S. Holmes/Fermilab (chair), A. Noda/Kyoto, T. Roser/BNL, L. Young/LANL (retired), and J. Wei/BNL.

Committee members absent from this meeting included: K. Bongardt/Juelich, I. Gardner/RAL (deputy chair), and D. Gurd/ORNL.

The ATAC wishes to express it appreciation to JAERI and KEK management and support staff for their hospitality during this meeting, and to both the management and staff for their comprehensive presentations.

2 FINDINGS & RECOMMENDATION

2.1 Linac

Since the last ATAC meeting in March 2003, the management of the J-PARC project had both to ensure construction at the foreseen pace with a reduced budget in FY2003, to analyze the consequence of the decision to limit the linac energy to 181 MeV in a first stage and to negotiate correction of that decision. The Committee is pleased to report that convincing progress has been obtained on all these fronts and that our past recommendations concerning the linac have been properly taken into account.

In agreement with the project management, the Committee had asked in advance that the focus of the present session should be on specific issues and the subjects of the talks have carefully reflected that request.

The linac being both the first accelerator to be built and the one most affected by the energy change, a linac specialist in the Committee (L. Young) has been invited to a pre-meeting that took place one day before the ATAC.

Comments

Linac design issues (from pre-meeting)

The induction cavity for the pre-chopper in the LEBT produces a very large background noise on the beam diagnostic devices. Beam tests, up to now, have not used it. However, for longer macro pulse lengths (500 μs), the LEBT induction cavity pre-chopper will be needed to reduce the beam power deposited on the MEBT beam scraper. The Committee suggests some effort should be expended to reduce noise from LEBT chopper. (EMC measures like better grounding of the pre-chopper system and common mode rejection on the beam diagnostics have to be applied)

Two SDTL cavities are powered by a single klystron by splitting the RF power by a waveguide splitter. The two SDTL cavities have been designed to have nearly equal beam loading. The relative phase of these two cavities will be controlled by the movement of tuners in these cavities. The tuners are slow and can only be used to control the time-averaged relative phase. The relative amplitude will be adjusted by a variable RF power splitter. The Committee believes that in principle this system should operate satisfactorily.

Progress in linac construction

The revised schedule now foresees 6 months of beam tests on the linac in the period from September 2006 to February 2007. Visiting the site, the Committee could indeed observe that civil engineering advanced rapidly and approximately according to schedule, as reported by the project management. All DTL structures and 22 out of 32 SDTL structures are built.

30 mA of peak beam current were successfully accelerated up to 20 MeV on the DTL test set-up, at KEK. The Committee congratulates the J-PARC linac team for this important achievement that gives confidence in the future performance of the full linac.

Performance projections at 181 MeV

The ATAC appreciated the study made of the consequences of the presence of idle ACS cavities in the beam path and is convinced by the conclusions drawn. The Committee considers as highly justified and fully supports the decision to avoid installing ACS structures in the beam path while operating at 181 MeV.

End to end beam simulations have been made, in agreement with last year's ATAC recommendations. The effect of errors has been observed, with the consequence that transverse collimation is needed to meet the RCS emittance requirement. However, for an easier interpretation of the results, we would like future analysis to systematically indicate the ratio of beam size to aperture. In the longitudinal phase plane the fluctuations of the mean beam energy at the end of the SDTL (assuming 1 % in amplitude and 1 degree in phase) are of the order of 1 MeV peak to peak. However, the debuncher brings the energy spread and fluctuation within the requirement of the RCS. To reduce beam loss in the RCS, the Committee recommends momentum collimation to eliminate energy tails and possible abnormal pulses with energy outside the acceptance of the RCS.

The magnet configuration in the beam transport line at the place of the future ACS structures has been changed putting the doublets between SDTL pairs at their final location. The Committee is convinced of the interest of this change and approves it.

<u>400 MeV energy recovery plan</u>

The ACS structures will be installed during an extended shutdown followed by setting-up at 400 MeV . The ATAC is confident that 3 months are sufficient, with adequate preparation and personnel, to install and commission the ACS equipment. Setting-up with beam of the linac and RCS are likely to take a similar duration.

<u>Commissioning strategy</u>

The successive operating modes to progressively set-up the accelerator have been defined and scheduled. The thermal analysis of RFQ performance after cold turn-on has been made. The Committee is satisfied with this study and expects that practical means will be devised in due time to minimize the estimated 1 hour delay before beam can be accelerated.

Detailed procedures have been elaborated for linac tuning. The study has been remarkably well done and the ATAC is perfectly satisfied with the proposed procedure.

The development of beam diagnostics for the linac has been thoroughly described and progress looks adequate.

The machine protection system is at an advanced design stage. The overall design is convincing although we suspect that the reaction time specified for beam loss at low energy (below 50 MeV) is unnecessarily small.

Moreover, we feel concerned that electromagnetic interference represents a risk for the correct operation of the personnel and machine protection systems. We re-iterate our request that electromagnetic compatibility (EMC) should be addressed at the design and implementation stages.

Recommendations

1. The presence of a momentum collimation device in the linac to RCS transfer line should be

reconsidered.

2. Electromagnetic compatibility needs to be addressed at the project level. The corresponding strategy should be presented at the next ATAC meeting.
3. End to end linac simulations showing the ratio of beam size to aperture are requested for the next ATAC meeting.

2.2 3 GeV Rapid Cycling Synchrotron

The 3 GeV RCS is a state-of-the-art, high power synchrotron. It is designed to provide a 3 GeV proton beam with 8.3×10^{13} protons per pulse at 25 Hz repetition rate with a total delivered beam power of 1 MW. As discussed above the beam power is estimated to be at 40-60% of the design intensity while operating with a 181 MeV injection energy instead of the design value of 400 MeV.

Multi-turn charge-exchange injection of H- beam from the linac is utilized in the RCS. Phase space painting and a second harmonic rf system are used to minimize space-charge forces within the beam. The RCS includes two technical innovations not seen in comparable machines. Low Q cavities using FINEMET obviate the need for fast resonant frequency tuning and also support first and second harmonic frequencies at the same time. A "flexible momentum compaction" lattice produces a higher transition energy than would be achievable with a more traditional FODO type lattice and allows for adjusting the momentum compaction at extraction to the Main Ring.

The committee was given presentations that covered many issues of the design of the RCS, in particular including responses to the comments and recommendations that were raised by the previous ATAC meeting.

Comments

The construction of the RCS is proceeding well. Civil construction is about at its halfway point and procurement of most of the equipment has started. In particular the first production dipole and quadrupole will be completed by April 2004 and all magnets are scheduled for completion by March 2005. Proper slotting of the endplates of the dipole and quadrupole magnets reduced the eddy-current heating to less than 100 degrees Celsius. Beam commissioning of the RCS is scheduled to start in May 2007.

The rf beam loading is quite significant in the RCS and the committee was presented with a feed-forward compensation scheme. It includes harmonic amplitude and phase corrections at three (h= 2,4,6) or six (h=1,2,3,4,5,6) frequencies depending whether two or one bunch is circulating. Although feasible this scheme is quite complicated and will have to be adjusted carefully throughout the acceleration ramp. A feedback scheme might be more practical and should be explored.

The scheme to replace activated components in the RCS consists of using either a 10 T crane or air-pallets to move the components through the tunnel. To minimize radiation dose to personnel in case of equipment failure the component replacement procedure, in particular in high radiation areas such as the collimation, injection and extraction areas, has to be carefully planned and equipment that facilitates the operation should be installed during construction. A plan presently being developed by the project needs to be completed urgently as it may impact construction activities.

The allowable beam losses at the collimation system are 3% with 400 MeV injection energy and 6 % with 181 MeV injection energy assuming the majority of the losses occur at injection. No allowable loss levels at any other areas were given to the committee. It is essential for the development of injection and acceleration schemes to have such allowable levels of controlled and uncontrolled losses in all areas of the RCS.

The injection region is typically an area with high losses. The committee was presented with calculations that showed the sensitivity of the charge-exchange injection to the distributions and errors of the injected 400 MeV H- beam. These calculations should be extended to include 181 MeV injection, space charge of the circulating proton beam, and realistic foil deformations. All possible losses should be identified, both controlled and uncontrolled.

Foil deformation could be a serious problem for stable operation of the RCS. More stable foil configurations should be explored. Corner foils as planned for SNS would be more stable. This would require vertical bump magnets or operating with a “smoke ring” in the vertical phase space. It may also be possible to use a tubular structure of the stripping foil to increase the stability.

A machine protection system (MPS) is being developed that can quickly stop the beam at low energy if a failure occurs. In the case of the RCS such a system will protect the ring components provided that the already circulating protons in the RCS cannot cause any damage. It should therefore be verified that a single pulse of beam cannot damage any equipment in the RCS.

The planned beam instrumentation in the RCS consists mainly of a system of Beam Loss Monitors (BLM) and Beam Position Monitors (BPM). Both systems are well designed allowing for multiple readings during the 20 ms ramp time. The intensity dynamic range of the BPMs is 100, which covers the possible operating scenarios well. The analog output of three equally spaced BPMs will be used for the radial feedback loop. Equal spacing with a tune of 6.72 does not guarantee the suppression of the effect of horizontal closed orbit distortions. The placement of these BPMs should be reevaluated. It may also be possible to operate the rf system of the RCS without a radial loop as long as the average dipole field is reproducible and known well enough. The average dipole field would best be obtained from a reference dipole magnet.

No final plan exists for a circulating beam profile monitor. A possible profile monitor would look at luminescence from a sheet of nitrogen gas. Such a device would be non-destructive and not be affected by the beam space charge. However, the increased residual gas pressure could cause problems with electron clouds. An alternative would be an Ionization Profile Monitor (IPM) that detects electrons that are guided to the detector with a magnetic dipole field. The magnetic guide field makes this profile monitor also insensitive to space charge. Such a profile monitor was successfully tested at RHIC and is planned for SNS. An accurate beam profile monitor will help to reduce losses from beam tails.

A very thorough plan to commission the whole complex was presented. The driving consideration for the commissioning plan is to minimize activation during this period when beam losses are unavoidable. To this effect all activities will be performed with low bunch intensity and a low 1 Hz repetition rate. In addition it should be explored whether it would be possible to commission the complex with individually requested beam pulses instead of repetitive operation. This would further reduce the dose to the equipment but would require that the data acquisition can store all relevant diagnostic information for subsequent review and correction. Such a flexible data acquisition system would also be very useful for post-mortem investigation of failures during regular operation. By “post-mortem” we mean analysis of what happened after something goes wrong. Fore example, following a magnet quench in the Tevatron or in RHIC a collection of relevant data (orbits, loss monitors, voltage sensors) is frozen so that the conditions in the accelerator over the previous several hundred milliseconds can be used to reconstruct what happened.

A first list of impedance calculations of the RCS beam line components was presented. Some of the impedances seem large. This effort should be continued. In particular, the transverse impedance of the extraction kicker should be measured or calculated as soon as possible. The heating of the kicker ferrite by the beam image currents should also be evaluated.

All ceramic beam pipes are being coated with TiN to reduce the secondary electron emission yield. This should also be extended to all other surfaces including titanium sections.

The field quality of the main dipoles and quadrupoles is very important particularly at the injection energy. Measurements of the field multi-poles should be performed at fields corresponding to 400 MeV and 181 MeV injection energy under standard ramping conditions. Based in these measurements non-linear correction magnets should be specified and included in the RCS lattice. It would be prudent to have such non-linear correctors programmable.

Recommendations

1. Consider implementing RF feedback to compensate for the beam loading of the FINEMET cavities.

2. Ensure that there is enough crane coverage to support efficient replacement of activated ring components, in particular in the collimation, extraction and injection area.

3. Develop a complete budget of the allowable levels of controlled losses in the collimators and the injection area dumps and uncontrolled losses everywhere else.

4. Complete detailed simulations of the charge-exchange injection that includes realistic distributions and errors of the injected H- beam, space-charge effects of the circulating proton beam, and foil distortions. Consider using more stable foil configurations

5. Verify that a single lost beam pulse cannot damage any equipment in the RCS.

6. Evaluate the placement of the beam position monitors used for the radial feedback loop with regard to the suppression of the effect of closed orbit distortions. Alternatively the radial feedback loop could be replaced with the combination of a frequency loop and the average dipole field obtained from a reference magnet.

7. Evaluate beam profile instrumentation for the RCS. For example, consider installing an Ionization Profile Monitor with electron detection.

2.3 50 GeV Main Ring

The Main Ring injection scheme has been modified to recover the maximum performance in the face of reduced RCS bunch intensities based on its 181 MeV injection energy. The scheme now requires 15 single bunch injections from the RCS rather than four 2 bunch injections in the original plan. The result is an increase in the dwell time at the 3 GeV injection energy from 0.12 to 0.56 seconds. If successful this approach would preserve nearly all of the originally established performance goal of 0.75MW.

Comments

The ATAC expressed concern at its last meeting with respect to MR performance with an extended dwell time at the 3 GeV injection energy. Simulations presented at this meeting, based on a frozen model of space charge, provide a good start on understanding the issues and offer encouragement that MR performance goals can be achieved. This work is going in the right direction, however the situation is complex and an integrated simulation does not yet exist. This line of simulation should be pursued with consideration give to benchmarking against existing high intensity proton synchrotrons.

The idea of utilizing an upstream foil to minimize losses on the electrostatic septum for slow extraction seems quite interesting. The concept needs further study to clarify the real situation of the scattered beam. The committee also remains concerned about beam stability during the slow extraction process based on the low chromaticity coupled with the low momentum spread.

More generally, there was no presentation on impedances and instabilities in the MR at this year’s meeting. We suggest that this topic be addressed at next year’s meeting.

BPM pre-amplifiers are used at the commissioning stage to view the beam at low intensity. However, pre-amps are not required during full current operation. We suggest a reconsideration of this strategy.

Due to very heavy weight of the magnets, the floor levels of the RCS and MR tunnel are anticipated to vary after installation of the magnets. A strategic plan to attain needed precision of the alignment of the magnets should be developed. The possibility to check the precision even after running is preferred.

Machine availability (which we define as the ratio of actual/scheduled running time) has not been discussed at the ATAC meetings, nor has the strategy to make the beam down time as short as possible. However, the users will have certain expectations with regard to availability. We suggest a dialog with the users to establish expectations followed by development of planning to achieve agreed upon availability goals.

In the design of the beam lines to neutrino and neutron, close collaboration between the accelerator specialist and scientists from each research subject is required.

Recommendations

1. Prepare an impedance budget and instability analysis for the MR including both single and multi-bunch effects. Use results of the analysis to establish the requirements for beam dampers. Results should be presented at next year's ATAC meeting.
2. Complete the simulation demonstrating the 1% loss criteria during the slow extraction process. The simulation should include the debunching process of the beam in the presence of the cavity impedances. Consider measures to ameliorate beam stability issues during this process, for example through implementation of a higher frequency rf.
3. The committee recommends an approach to establishing likely performance in the MR, with the currently envisioned Phase 1 configuration, incorporating the following elements:
   - Establish a loss budget, both for particles ending up on the collimators and particles ending up elsewhere.
   - Incorporate all possible effects into the injection simulation: magnet errors, machine apertures, closed orbit distortion and correction, resonance correction, and the impact of increased bunching factor.
   - Benchmark the simulation against an existing machine (BNL/AGS, KEK/PS, or Fermilab/MI).
   - If indicated by the simulation, explore methods for increasing the bunching factor at injection into the MR.
   - Estimate any longitudinal emittance growth that could lead to loss of beam from the MR at the start of acceleration (beam outside the buckets).

2.4 Summary of Performance Projections with 181 MeV Linac

With the revised Phase 1 baseline for the accelerator complex, the Linac output energy is reduced from 400 MeV to 181 MeV. The design goal of beam power is reduced from 1 MW to 0.6 MW for the Rapid-Cycling-Synchrotron (RCS). The beam power for the Main Ring is reduced from 0.75 MW to 0.72 MW with the increased number of bunches from 8 to 15.

On the Linac, a study was performed on the impact of idle ACS on the output energy spread, and concluded that the design specification of 0.1% can not be met. Based on this study, a decision was made that no idle ACS modules will be present during on-line operation. The ACS section of the Linac will be populated with approximately 50% of doublet quadrupole magnets, resulting in increased beam envelopes in all dimensions. After the completion of the Phase 1 project, the ACS modules and the remaining 50% of doublet quadrupole magnets will be inserted. An end-to-end simulation was performed with PARMILA for the beam at 30 mA peak current from the RFQ exit to RCS injection assuming RF amplitude error of 1%, phase error of 1 degree, and various quadrupole magnet gradient errors, misalignments, and rolls.

On the RCS, the goal beam intensity is 5.0×10^{13} per pulse. The injection kinetic energy is 181 MeV. The injection/acceleration time is increased. The tolerable beam loss at injection is increased from 3% to 6% based on a collimation efficiency of 97%. The RF frequencies are lowered to 0.94 MHz for the fundamental harmonic (h=2), and 1.88 MHz for the second harmonic (h=4). The maximum peak current is reduced from 11.1 A to 6.7 A. The number of RF cavities and their power supplies are reduced from 11 to 10. Specification for the power supplies of the injection septum and bump magnets are reduced. A study on RF multi-harmonic beam loading compensation concluded that both 2-bunch and 1-bunch operations are possible based on system feed-forward. A study on beam injection indicates that the reduction in stripping efficiency is negligible if the injection straight has an acceptance of 30 mm mr. On the other hand, deformation of the stripping foil remains a serious problem even at the reduced beam power, especially due to reduced stopping distance and enhanced local energy deposit at 181 MeV injection energy. Considering the effect of space charge and vacuum chamber aperture but assuming a low field error (10^{-4}) and no closed-orbit error, computer simulation indicates that the expected beam loss at injection is about 5%. With increased closed orbit error, the beam loss increases dramatically. The expected beam power is 0.3 MW in order to retain the same space-charge tune shift as the original 400-MeV operation, and less than 0.6 MW in order to keep the beam loss below 4 kW.

On the Main Ring, the injection time is increased from 120 ms to 540 ms to populate 15 bunches in the MR with one-bunch operation in the RCS. The RF frequency is increased from 1.67-1.72 MHz to 3.34-3.44 MHz. The needed injection rise time is reduced from 300 ns to 170 ns. Computer simulation adopting a frozen space-charge model indicates a beam loss of more than 2% in about 200 ms. An estimate on loss distribution is presented.

Comments

At last year's review, we recommended evaluation of beam loss and radio-activation at the reduced linac output energy, considering effects like linac resonance induced beam emittance and halo growth, degradation due to idle ACS, enhanced magnet and power-supply errors at a reduced injection field in the RCS, enhanced RCS stripping loss when the injection field is not optimized, and enhanced loss in the MR when the injection time is extended. We also recommend that such a beam-loss model to be benchmarked with existing accelerator facilities for a “reality check”. At this review, we were presented with many simulation results including linac end-to-end simulation, idle ACS impact, RCS simulation including space charge, painting, and some field errors, and MR simulation with an estimate in loss distribution. In particular, we are pleased that the study on idle ACS has helped finalizing the 400 MeV recovery plan, and simulation on RCS ad MR has resulted in consideration of implementation of ramped resonance corrections.

At last year’s review, we recommended to appoint a coordinator to globally oversee accelerator-physics design and interface issues, to evaluate overall fault conditions, and to monitor across the entire acceleration cycle the evolution of key, expected beam and machine parameters including the controlled and uncontrolled beam loss, the transverse and longitudinal acceptances, beam emittances and pulse-to-pulse centroid jitters, to ensure adequate machine protection, tolerable radio-activation, and adequate acceptance-to-emittance ratios. We renew this recommendation with emphasis on tracking configuration changes in an actively evolving project, and on the integration of interface areas between various accelerator components (Linac to RCS, RCS to MR), and between accelerator system, neutron target system, and experimental systems especially regarding level of radio-activation, maintenance considerations, and parameter matching.

It would be important to base theoretical predictions not only on sophisticated computer simulations but also on the understanding of the performance of existing accelerator facilities. For example, the Linac performance could be benchmarked with that at proton linacs at LANL, CERN, FNAL, and BNL regarding energy tail, emittance growth, beam loss, and failure conditions. Calculation on the collimation efficiency in the RCS and MR could be benchmarked with the performance of existing facilities like ISIS. Beam loss estimates in RCS and MR could be benchmarked with those in existing machines like ISIS, KEK PS, BNL AGS, and FNAL Booster.

Recommendations

1. Evaluate beam loss and radio-activation distribution across the entire accelerator complex under the condition of reduced linac energy, taking into account realistic beam and machine configuration including injection loss (foil scattering, H- and H0 loss), static and dynamic, systematic and random errors in magnets and power supplies, optics perturbation across the injection chicane, and system malfunction (e.g. ion source malfunction, noise, kicker misfire), etc.
2. Bench-mark computer simulation / theoretical prediction with machine measurements / experience at existing linacs, rapid-cycling synchrotrons, and high-intensity rings to identify possible performance degradation mechanisms (e.g. linac energy tail, injection efficiency, collimation efficiency, ring injection and ramping loss).
3. Appoint an “accelerator physics coordinator” to globally oversee accelerator-physics design, to track changes in machine configuration, and to oversee interface issues especially between linac and RCS, between RCS and MR, and between RCS and the

neutron target.

3.1 Appendix: Agenda for the 3rd ATAC Meeting

Agenda of the 3rd ATAC Meeting for J-PARC Project (Tentative, 2/18 version, supplanted by 3/2 version)			
5 March 2004			
8:15 - 8:30		Welcome address and Project Status	S. Nagamiya
8:30 - 10:00		**Overview.**	
		Progress of design	
		Status of construction	
		Performance in the reduced energy operation	
		Energy recovery plan	
		Status of the neutrino facility	
	8:30	LINAC	K. Hasegawa
	9:00	RCS	H.Suzuki
	9:30	50GeV	M. Tomisawa
10:00-10:15		*Coffee break*	
10:15-11:15		**Commissioning strategy**	
	10:15	LINAC	A.Ueno
	10:45	Ring	S.Machida
11:15-12:15		**Beam diagnostics**	
	11:15	LINAC	S. Lee
	11:35	RCS	N.Hayashi
	11:55	MR	T.Toyama
12:15-13:20		*Lunch*	
13:20-14:00		**Machine/Personnel protection**	
	13:20	Personnel protection	Y. Takeuchi
	13:40	Machine protection	H. Yoshikawa
14:00-16:45		**Performances in 181MeV operation**	
	14:00	Beam degradation passing through idle ACS	Y. Shobuda
	14:30	Beam loading issues on number of bunches	F. Tamura
15:00-15:15		*Coffee break*	
	15:15	Reduction of the foil efficiency	Y. Irie
	15:45	RCS space-charge effect in injection porch	F.Noda
	16:15	Issues related to MR dwell time	S.Machida
16:45-17:15		**Study on the impedance**	
	16:45	Impedance budgets.	T.Toyama

17:15-19:00	**Executive Session**
6 March 2004	
9:00 - 11:50	**Executive Session**
11:50-13:30	*Lunch*
13:30-14:30	**Report to management**
14:30-16:30	*Site tour*
16:30-18:00	**Executive Session**