Report from the 2nd Meeting of the Accelerator Technical Advisory Committee for the Japan Proton Accelerator Research Complex (J-PARC)

March 7-8, 2003
KEK
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EXECUTIVE SUMMARY

The Accelerator Technical Advisory Committee (A-TAC) of the Japan Proton Accelerator Research Complex (J-PARC) held its second meeting over the period March 7-8, 2003 at the KEK laboratory in Tsukuba, 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 Science, Nuclear, and Elementary Particle Physics. The Project is approved with a budget of 133.5 billion yen for Phase 1, and a construction schedule leading to completion in 2006. Phase 2 of the project requires an additional 55.5 billion yen in funding and 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 A-TAC heard presentations concerned with 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 extremely responsive to recommendations from the May 2002 meeting. In addition the committee toured the construction site and observed many prototype components undergoing testing as well as significant civil construction activities underway. The committee did not specifically review the cost of the facility nor the construction, installation, and commissioning schedule. Presentations and committee discussion concentrated on the Phase 1 project. The committee was very impressed at the degree of progress since the last meeting and congratulates the project team on its very excellent progress in further developing the design and initiating construction of the accelerator complex.

Subsequent to this meeting the A-TAC Report was presented to the International Advisory Committee and discussed as part of their deliberations at their meeting on March 10-11, 2003.

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 400 MeV linac, a 3 GeV rapid cycling synchrotron, and a 50 GeV synchrotron. The two synchrotrons are designed to provide extremely high average beam power: 1 MW from the 3 GeV ring and 0.75 MW from the 50 GeV ring. This performance is beyond that of any other facility operational in the world today. Notable pieces of the project that are currently delayed into Phase 2 include an additional 200 MeV of superconducting linac and associated waste transmutation area, realization of the full 50 GeV performance of the Main Ring (phase 1 provides 40 GeV), and a neutrino beam line supporting long baseline neutrino experiments.

Performance criteria have been established for all the accelerators and advanced conceptual designs are complete. All major components have been prototyped, and approximately 50% (by cost) are now on order.

The committee heard of a significant scope modification during this meeting—the reduction of the linac energy in its initial implementation to 181 MeV (from 400 MeV). This de-scoping is in response to cost growth that must be accommodated in other areas of the project, most notably through an increase in the aperture and circumference of the RCS and improvements to the injection system. Performance implications were discussed, along with the strategy for recovering the full 400 MeV operation once funding becomes available.

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—an increase of 19 over the last year. While this staff is extremely dedicated and skilled, the committee feels, as it did last year, that the overall staffing is modest for such an ambitious and complex facility, constructed over a six-year time frame.

The committee heard very little on beam diagnostics and strategies for commissioning of the accelerator complex. This is largely because of the limited available time to cover everything. However, the committee feels that it would be appropriate to delve into these areas at the 2004 A-TAC meeting.

Issues Associated with the Lower Linac Energy

The most significant issue discussed at the meeting concerned the decision by J-PARC management to defer implementation of the annular coupled structure (ACS) linac section as a result of a budget shortfall of roughly 8.5 billion yen. As a result, in its initial implementation the linac is proposed to have a capability of 181 MeV rather than the 400 MeV in the original project scope. The Project Director has assembled an ad-hoc committee to identify a strategy for recovery of the full 400 MeV performance once funding is secured, consistent with projected operational demands for the facility. J-PARC management specifically asked the A-TAC for comment on the projected performance of the facility in the lower energy configuration and on the strategy for recovery.

Lowering the linac energy has the most direct impact on performance and configuration of the RCS. It has secondary, but still significant, impact on the performance and configuration of the 50 GeV Main Ring. The primary elements of the complex that have to be addressed in this configuration are:

- Space-charge forces at RCS injection. The space-charge tune shift scales as $1/(\beta^2\gamma^3)$ for a fixed physical beam emittance (as is created by the RCS injection scheme). Scaling from 400 MeV to 181 MeV would lead to a 66% reduction in beam intensity, and hence beam power, if one maintained the same space-charge tune shift.
- The RCS rf system. The frequency swing in the RCS rf system is increased because of the lower injection energy. This is not deemed a significant obstacle. In addition, the RCS will be asked to operate in single bunch mode when filling the 50 GeV Main Ring (see discussion below). Beam loading issues are significantly different with single, as compared to the normal two, bunch operations.
- The RCS magnet/power supply system. With 181 MeV injection the magnetic fields in the RCS will be about 64% of their values at 400 MeV. Field quality and power supply regulation at these values need to be understood.

- The 50 GeV MR rf system. In order to maintain as much beam intensity as possible in the MR it is proposed to double the harmonic number of the MR rf system and inject single bunches over 15 cycles from the RCS. Implications that must be addressed in the RCS include beam loading compensation with single bunch operations and the duty cycle which can be maintained in the RCS for 3 GeV beam users. Within the MR it is noted that the injection dwell time is increased from 0.16 to 0.60 seconds.

The J-PARC staff argued, and supported with simulations, the idea that one can operate at a higher space-charge tune shift at the injection energy because a greater fractional beam loss on the collimator can be tolerated. It was estimated that in practice the achievable RCS beam power would be in the range 0.4-0.6 MW when operating in this configuration. It is noted that these numbers would be further downgraded by 15-18%, i.e. to 0.33-0.51 MW, when running in the single bunch mode for simultaneous 50 GeV MR operations. It should be noted that a 5% average power reduction in the RCS due to simultaneous 50 GeV MR operations accompanies the original accelerator configuration incorporating the 400 MeV linac.

The recovery scenario developed involves installing the downstream 219 MeV of ACS during 3 month periods executed over three consecutive summer shutdowns, followed by a 3 month commissioning period immediately subsequent to the final installation. The A-TAC finds the recovery strategy to be credible.

We also find the strategy for reconfiguring the accelerator complex to accommodate the lower linac energy to be fundamentally sound. However, the committee believes that there is significant uncertainty associated with the performance projections in the interim period in which the linac is operating at 181 MeV and hence makes the following recommendations:

- Before endorsing completely the proposed scenario for energy recovery, we strongly recommend detailed computation of the performance degradation of the 181 MeV beam when passing through idle detuned ACS structures including the debunching process up to the L3BT achromat.
- The committee strongly endorses the strategy of completing all civil construction and associated utilities installations to support retrofitting of the full 400 MeV linac energy at a future time.
- The committee does not believe the original project goals (1 MW RCS, 0.75 MW MR) can be achieved with the lower energy linac. Hence, the committee strongly encourages management to secure funding to complete the 400 MeV linac at the earliest possible date.
- The committee recommends that continued simulations and measurement effort be invested in understanding performance with the 181 MeV linac. In particular we recommend that magnetic fields of RCS magnets be measured at the 181 MeV excitation fields and that consideration be given to non-linear correction elements.
- The committee is concerned about the ability of the 50 GeV Main Ring to store beam at flat-bottom over the required 0.6 sec injection time in the presence of strong space charge forces. The committee feels this is a potential vulnerability that requires further investigation.

- The committee suggests that commissioning and early operations schedules for J-PARC include realistic assumptions of performance with the 181 MeV linac and the 400 MeV recovery plan.

Immediately following the ATAC meeting these assessments and recommendations were transmitted to the International Advisory Committee as input to their discussion of the impact on the J-PARC science program. Based on this input the IAC concluded that the risk to the science output of J-PARC was too great to accept and so recommended developing a plan that provided the full 400 MeV linac operations at the time of RCS startup.

Linac

The linac consists of an (H^-) ion source (IS), drift tube (DTL), separated drift tube (SDTL), and annular coupled structure (ACS) linacs. As described above, the ACS construction and implementation is currently delayed. The final energy in Phase 1 (including the ACS linac) is 400 MeV, with a peak current of 50 mA, and a repetition rate of 50 Hz. For 181 MeV operations the peak current is limited to 30 mA due to RCS considerations. The committee notes that this gives the J-PARC staff some additional time to explore options for implementation of the final ion source/RFQ.

The linac design is well advanced and procurement of the DTL and SDTL has begun. An ion source that nearly meets specified requirements also exists and studies of the source and associated low energy beam transport (LEBT) and medium energy transport (MEBT) lines are underway. DTL tanks have been measured and will soon be tested with beam. All recommendations from the May 2002 review have been considered, and some accepted. The committee is happy with the responses. The committee offers the following specific comments and recommendations with respect to the linac, in addition to those listed above relative to the lower injection energy:

- The design and hardware assembled to date are basically sound and likely to deliver the specified performance.
- The end-to-end simulations of the linac are absolutely necessary. We recommend that these be adapted to utilize the observed particle distributions coming out of the ion source and MEBT, and to carry through the entire linac up to the RCS.

Rapid Cycling Synchrotron (RCS)

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

Multi-turn charge-exchange injection from the linac is utilized in the RCS. Transverse and longitudinal painting, plus a second harmonic cavity, are employed to minimize the impact of space-charge forces within the beam. Acceleration utilizes a novel RF system. The lattice is of the “flexible momentum compaction” type producing a higher transition energy than would be achievable with a more traditional FODO type lattice.

The design lattice for the RCS has been finalized over the last year. The aperture and circumference of the machine have both been increased in order to assure desired performance. Recommendations relative to the design from the May 2002 review have been considered and some adapted. Procurements have been initiated and prototype dipoles and quadrupoles have been fabricated. A prototype rf cavity has been produced and operated at full power and 50% duty factor. The committee commends the project team on an improved injection system relative to that described at the May 2002 meeting. The committee is very favorably impressed by all these developments and offers the following specific comments and recommendations, in addition to those listed above relative to the lower injection energy:

- The design and hardware assembled to date are basically sound and likely to deliver the specified performance (at the 400 MeV injection energy).
- The committee was not presented with detailed impedance and tune-shift budgets for the RCS. The committee recommends that these budgets be developed and requests a presentation at next year’s meeting. In addition the committee recommends measurement of impedances of critical components of the RCS, especially the ceramic vacuum chamber.
- We recommend a realistic simulation of injection painting and initial ramping incorporating magnetic field errors, space-charge, and collimation.

50 GeV Main Ring

The 50 GeV Main Ring is the second state-of-the-art, high power, synchrotron in the project. It is specified as providing 50 GeV proton beam with 3.3×10^{14} protons per pulse with a 0.3 Hz repetition rate. The total delivered beam power is 0.75 MW. As discussed above the average beam power is estimated to be at 54-96% of the design intensity while operating with a 181 MeV injection energy into the RCS.

Injection utilizes 15 beam transfers from the RCS (for 181 MeV linac operations). The original design utilized four transfers. Thus, the injection time has been lengthened from 0.16 sec to 0.60 sec. Beam is either fast or slow extracted from the 50 GeV ring in support of a variety of high energy and nuclear physics experiments. The lattice is of the “flexible momentum compaction” type that allows acceleration of the beam without crossing transition. In phase 1 the energy of the Main Ring is limited to approximately 40 GeV.

A complete design for the 50 GeV Main Ring exists and procurements of magnets and power supply systems are well advanced. R&D continues in parallel on RF systems. The committee is very favorably impressed by these developments and offers the following specific comments and recommendations, in addition to those listed above relative to the lower RCS injection energy:

- The design and hardware assembled to date are basically sound and likely to deliver the specified performance (once the 400 MeV linac is operational).

- The committee heard a presentation of a proposed design modification that would lower the vertical tune (relative to the horizontal tune) of the MR by 2 units. This change appears well motivated and the committee is happy to add its endorsement.
- The discussion provided to the committee on impedances and instabilities represents a good start at understanding these issues within the MR. This effort is in the early stages of development and needs to be continued. The committee recommends that the design team considers the introduction of new elements (for example active dampers or octupoles) or new strategies (increased longitudinal emittance) to combat beam instabilities, especially during the slow extraction process.
- The committee is concerned with the performance of the slow extraction from the MR. The scheme presented relies on zero chromaticity and a debunched beam. We believe that beam stability is going to be a serious issue when operating in this mode and thus make the following 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.

Control System

The J-PARC Control System provides integrated control of the entire complex. The Control System is based on EPICS and the basic infrastructure is already in place. The network architecture has been quite fully worked out and includes a fiber backbone to many distributed edge switches with copper to the IOCs and other network devices. This system will operate in a noisy, high pulsed power environment. A small and versatile suite of instruments have been selected that can be interfaced to the control system via Ethernet or the VME backplane. Drivers for these devices have been written and tested.

Specific discussions were held at this meeting concerning the timing, personal protection, and machine protection systems. The committee is favorably impressed with progress to date and offers the following comments and recommendations:

- The controls team is very small (~9 people) and much of the work will have to be out-sourced. Very tight communication between the two sites will be essential to success.
- Based on experience at other laboratories the committee has some concerns relative to the strategy of not locking the timing system to the AC line. The committee recommends the project team consider the impact on non-line-locking on performance of the complex.

1 INTRODUCTION

The Accelerator Technical Advisory Committee (A-TAC) for the J-PARC Project held its second meeting over the period March 7-8, 2003 at the KEK laboratory in Tsukuba, Japan. The committee heard presentations from project staff on the 7th, held several closed sessions to discussion reactions and opinions, and presented a verbal report to project management on the 8th. The meeting agenda is attached as Appendix 3.1.

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

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

Committee members absent from this meeting included: K. Bongardt/Juelich, I. Gardner/RAL (deputy chair), and L. Young/LANL. All absent members were invited to view review presentations as posted on the internet and to provide input to the committee

This report summarizes the March 7-8 meeting. The body of this report consists of the committee's findings and recommendations related to the major accelerator components of the J-PARC Project. Also included are discussions of the control system and beam dynamics topics that span the individual accelerators and allow the complex to operate efficiently as a whole.

2 FINDINGS & RECOMMENDATION

2.1 Linac

The Committee has been informed in detail about the status of the J-PARC project and the events that took place since its previous meeting, in May 2002. The main concern is a shortfall in resources, attributed to improvements decided after the official approval of the project and its budget, which imposes a revision of the goals and performance (Y. Yamazaki). To give satisfaction to the highest priorities of the user communities and preserve the schedule for the start of physics, the proposal of the management is to begin with a linac whose energy is reduced from 400 to 181 MeV. The plan for handling the situation and the performance that could be achieved in these conditions have been presented (S. Machida) and debated with the committee. A scenario of recovery to nominal performance has been sketched (Y. Yamazaki), which minimizes the consequences for the users.

Apart from this, the progress in the realisation of the various accelerator components has been described, and answers have been given to the previous recommendations of the Committee (T. Kato, M. Ikeagami, A. Ueno).

Comments

<u>Ion source development (A. Ueno)</u>

The status and performance of the three different types of ion sources that are considered have been described. For the RF plasma source, information has been obtained from the SNS device. *The Committee approves this tight collaboration which addresses the worry mentioned in the first A-TAC report of compatibility with the presence of a close-by RFQ.*

In the case of the filament sources, recent KEK experimental results have been quoted. The existing DC arc source with LaB6 filament will be used for the test of the accelerator component: a beam current of 33 mA has already been achieved which is sufficient for the 181 MeV linac, and the absence of Cesium is a clear advantage. If life time proves to be adequate (>500h), this could be used in the J-PARC linac until the upgrade to 400 MeV. In parallel, development is planned of another DC source with Ta filament and plasma electrode, as well as of a 13 MHz RF plasma source using Cesium.

<u>MEBT plans and commissioning results (T. Kato & M. Ikeagami)</u>

Experimental results have been obtained on the low energy part of the linac. Operating at 30 mA beam current, the set-up includes the filament ion source, a 3 MeV RFQ (first version, designed for 30 mA) and a fully equipped MEBT line with bunchers, choppers and beam instrumentation. Transition times of ~ 10 ns have been measured on the beam for the chopper. *Although this performance seems adequate, an anti-chopper scheme has nevertheless been designed to answer the request of the A-TAC in its previous report*. Preliminary comparison between measurement and simulations on the 3 MeV / 30 mA test set-up are satisfying

Extensive work has been done on the effect of hardware imperfection, and pulse to pulse energy variations due to vibrations and errors in the regulation of the field in the accelerating structures. A remarkable stability of +- 0.3 % in amplitude and +- 0.3 degree in phase over a one hour period has been demonstrated with a digital feedback system. *Based on this data, multi-particle tracking results lead to the conclusion that the fluctuation in beam momentum can then be kept below 0.1 %, and longitudinal collimation can be avoided the L3BT.*

Arguments were presented concerning the previous A-TAC proposal that a tapered gradient should be considered in the ACS. *The committee took note of the advantage in flexibility represented by the variable matching section in MEBT2.*

Because of the lack of time, the results of the MEBT simulations could not be discussed sufficiently. A proper effort of preparation and due time for presentation has to be foreseen at the next A-TAC meeting for a complete understanding of beam dynamics along the full linac. *Moreover, the Committee strongly encourages the ongoing effort to introduce measured emittances and profiles in the end to end multiparticle simulations.*

<u>Linac energy reduction and recovery procedure (Y. Yamazaki)</u>

To reduce the project cost by 85 oku-yen, while preserving the schedule for beam availability to the users, the proposal is being made to begin operation with a linac energy reduced from 400 to 181 MeV. Moreover, any later energy recovery procedure should also not influence the accelerator schedule as foreseen by the physicists. In a first step, the low energy part of the linac will be installed and operated in its final position in the accelerator tunnel. Beyond 181 MeV, a line will be built with all magnetic elements foreseen for beam transport along the ACS. The RCS will then be set-up and operate for physics at this injection energy. *The Committee is convinced that such an operating mode is acceptable.*

As soon as the necessary resources become available, the components needed in the ACS part of the linac will be built and the accelerating structures will be installed during the summer shut-downs. A total of four years are needed for completion. Accelerating structures will be progressively installed during the first three shut-downs. Beam commissioning at the full energy will take place during the start-up after the fourth shut-down. *Although this scheme seems feasible, the Committee members underline that detailed analysis and simulations are necessary to demonstrate that negligible performance degradation will be encountered by the 181 MeV beam passing through the idle detuned ACS structures.*

Recommendations

The Committee has been very favorably impressed by the progress in the development of the accelerator component. *We take note that our first set of recommendations have been taken into account by the project team.*

Ion source developments take place in close collaboration with SNS. The results achieved so far are very satisfying and we agree with the plans for the future.

The excellent results achieved in the regulation of the field in accelerating structures give a convincing basis to the analysis of energy stability of the linac.

The experimental measurements made on the 3 MeV/30 mA set-up at KEK demonstrate the validity of the designs of the components and represents a remarkable opportunity to obtain realistic beam characteristics. *We strongly encourage the ongoing effort to fully characterize the beam dynamics along the full linac and to introduce measured beam characteristics in the end to end multiparticle simulations.*

We regret for the development team that only a partial realization of the linac can be considered in a first stage, but we agree with the logic of the proposal to begin with a reduced energy linac. *However, before endorsing completely the proposed scenario for energy recovery,* *we strongly recommend detailed computation of the performance degradation of the 181 MeV beam when passing through idle detuned ACS structures, including the debunching process up to the L3BT achromat.*

2.2 Rapid Cycling Synchrotron

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 A-TAC meeting. Several presentations also addressed the impact of lowering the injection energy from 400 MeV to 181 MeV.

The first recommendation from the last committee meeting was to examine a FODO lattice instead of the missing dipole lattice with a higher transition energy. The present layout of the RCS cannot easily be changed at this point and without changing the number of cells and the straight section lengths a FODO lattice doesn't offer many advantages. The high gamma-t lattice also eases synchronization and longitudinal matching with the Main Ring.

The second recommendation to implement dynamic tune control was addressed by studying the replacement of four dipole correctors with trim quadrupoles in each arc. The plan is to implement this if it is necessary.

A dipole and a quadrupole prototype for the RCS have been constructed using the stranded aluminum cable and tests of the dipole magnet have been performed with excellent results. The stranded cable offers significant advantages with regard to eddy current heating. The fabrication issues of intra-strand isolation and the connection to the conductor ends have been solved. It was also shown that proper slotting of the magnet end plates substantially reduces the fringe field and heating from eddy currents.

The design of the injection region allows for both correlated and anti-correlated phase space painting and collects both H0 and H- after the stripping foil in a beam dump.

<u>Reduction of injection energy from 400 to 181 MeV</u>

With the same physical size of the beam at injection the incoherent tune shift at injection can be maintained at –0.16 by reducing the beam intensity by about a factor of 3. This can be partially compensated since at the lower injection energy about a factor of three more proton losses can be tolerated allowing the intensity to be increased again. However, losses are non-linear function of the incoherent tune shift (or intensity) and simulations were presented that indicate that the tune shift (and intensity) can be doubled giving a prediction of about 0.6 MW for operation with 181 MeV injection energy.

The required extended frequency range for rf system can be accommodated by the low Q cavities. Operation of the RSC for filling the MR would be modified to accelerate only a single bunch per cycle and using 15 cycles to fill 15 out of 18 buckets in the MR. Accelerating with one bucket empty in the RSC requires careful beam loading compensation.

Comments / Recommendations

Further studies are required to support the plan to operate the RCS at a tune shift of about –0.3 with 10% beam losses. At this tune shift level the AGS Booster has about 20 % beam losses even after careful tuning of the closed orbit and betatron tunes and compensation of all third order resonances.

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. Based in these measurements non-linear correction magnets should be specified and included in the RCS lattice. If necessary such non-linear correctors could be run at fixed field.

Beam loading is quite severe in the RCS with the low Q rf cavities. The studies of the feed-forward beam loading compensation should be continued and a commissioning strategy to effectively implement feed-forward should be developed.

2.3 50 GeV Main Ring

Construction of 50 GeV Main Ring is at the mass production stage for main magnet and RF cavity after completion of the evaluation of the component development. Present status of such developments is presented together with the some new idea of equipment for injection/extraction and investigations on the effect of the nonlinear field in connection with slow beam extraction and instabilities. Efforts on these works are greatly appreciated at first.

Findings/Comments

Bunch Filling Scheme

In order to cope with the reduction of the beam intensity in a single bunch in 3 GeV synchrotron due to the decrease of the injection energy from 400 MeV to 181 MeV, new idea to inject 15 bunches instead of 8 bunches is presented. This idea is very interesting, but it needs careful consideration about the beam dynamical point of view to keep the injection beam as long as 0.6 sec with the tune shift as large as -0.16. The possibility of occupying 15 cycles of 3GeV synchrotron every 3.5sec should also be carefully investigated compromising the requirement from the users of 3 GeV synchrotron.

Operation Tune

Proposal to shift the bare vertical tune from ~22 to 20.78 in order to avoid the effect of the coupling resonance Q_H-Q_V=0 is presented, which is very interesting and beam simulation including space charge effect with this operating point is strongly required. The scheme driving the tune to the third order resonance by ramping the quadrupole magnet is required to be carefully compared with the scheme which increases the horizontal betatron amplitude by application of transverse RF electric field keeping the separatrix size constant especially in connection with the temporal structure of the extracted beam.

Main Magnet

Results of field measurements of dipole and quadrupole magnet are presented which , in general, seems quite satisfactory although further careful studies are required about higher multi-pole components and saturation effect for all the magnets. Even if the routine measurement for all the quadrupoles are made by rotating coils, efforts to evaluate the higher multi-pole components at larger radius should be continued although field distribution of the quadrupole magnet outside of the bore radius has been measured with use of a Hall probe. Harmonic correction system should be studied in addition to closed orbit distortion.

MA Loaded RF cavity

Magnetic alloy loaded cavity with high field gradient has successfully developed. Direct water cooling by coating the magnetic alloy with epoxy vacuum molding has also been succeeded. Development of the hardware of the RF cavity seems quite satisfactory, although further investigation to compensate the beam loading effect such as feed forward or feed back will be needed from now on.

Equipment for Injection/Extraction

Opposite field septum magnet is designed and fabricated in order to realize effective separation between the deflected and main beams. With this scheme, the length of the septum magnet for injection/extraction is reduced almost factor 2, although the dipole magnet to compensate the effect to the circulating beam becomes necessary. This idea seems interesting and careful study about the perfect compensation of the kicking effect on the circulating beam for the present wide aperture case is needed. Possible experimental test with use of the real beam in connection with beam keeping time might back up this scheme more thoroughly. The idea installing the central septum coil in the vacuum should be paid attention concerning the possible vacuum deterioration due to temperature rise caused by heat dissipation.

In order to realize the 1 % beam loss, first septum with septum thickness of the order of 0.1 mm is needed assuming the turn separation of ~10 mm. Hardware development usable at the present intensity will be needed.

Beam Instability

Investigation on the impedance caused by various equipments is presented together with the measured impedance of some equipments. Consideration on various beam instabilities both in transverse and longitudinal is also presented, which should be extended in combination with the simulation taking the space charge effect into account In order to cure the beam instability, installation of a scheme to damp such an instability is recommended. Study on the vacuum instability is also presented, which indicated this instability is not so dangerous, although further careful investigation will be preferable. Possibility of coating the surface of the vacuum chambers by some materials such as TiN should be further investigated.

Slow Beam Extraction

Zero chromaticity correction at the stage of extraction should be carefully studied in connection with instability during debunching. Possibility of application of higher frequency (a few hundreds MHz), which is acceptable from the users of counter experiments, without making a coasting beam should also be considered. Simulation study throughout whole slow beam extraction process, which enables the 1 % beam loss at the new operating point, is strongly needed.

Collaboration with Fermilab on slow beam extraction scheduled in coming spring is to be reflected on the further study of slow extractions.

2.4 Control Systems

Findings/Comments

A separate, parallel session was held to discuss the control system. More than a dozen people attended to hear the presentation by H. Yoshikawa of JAERI, who described the overall control system architecture, as well as progress on the Personnel Protection System, Machine Protection System, Timing System and with software development.

The network architecture has been quite fully worked out, and includes a fiber backbone to many distributed edge switches with copper to the IOCs and other network devices. This system will operate in a noisy, pulsed-power environment. Consideration might be given to the cost/benefit of extending the fiber even closer to the IOCs. A plan for the mitigation of Electromagnetic Interference should be developed early in the project, and followed by all technical groups.

A small and versatile suite of instruments have been selected that can be interfaced to the control system via Ethernet or the VME backplane. Drivers for these devices have been written and tested. Every effort should be made to complete this work by defining the interface between the control system and the low-level RF system and the beam instrumentation. The low-level RF system on the linac test stand visited by the committee is interfaced using VME, but a PCI-based system is apparently also under development.

The timing system consists of three separate distribution infrastructures (12 MHz clock, 50 Hz Master Trigger and Pulse Type). The machine is not synchronized with the AC line. Removal of this constraint greatly simplifies synchronization with neutron choppers; however the committee noted that most accelerator projects find it necessary to operate in a "line-synched" mode. Thought should be given to the possible impacts of not synchronizing to the line. The timing system modules, including distributed gate generators, have been built and tested.

The personnel Protection System (PPS) is based upon redundant PLCs with redundant sensors and signal paths for critical inputs. All mode transitions for this system have been modeled, although it appears only geographic modes and not beam-intensity modes are considered. The Machine Protection System is a hard-wired link in a star configuration that derives its mode and consequent mode masks from the PPS. The required shut-off time at the low energy end of the machine is a very demanding 2usecs, however the modules have been built and tested with a 145m cable delay and found to meet the requirement. Sensor response times must also be considered, however. There was no discussion of beam shut-off mechanisms or required redundancies.

The software development strategy is based upon a model-driven approach from the lowest (devices) to the highest (Physics) levels. The basic EPICS infrastructure is already in place. The application of formal system identification methods and physics models has not yet started. This approach should in principle front load the software development effort, but reduce the total effort required. It will be interesting to track its success.

The controls team is very small (9 people?) and much of the work will have to be out-sourced. This approach requires very careful documentation of requirements and design. Very tight communication between the two sites and with vendors or contractors will be essential to success.

Recommendations

1. At the next A-TAC meeting present a description of the planned beam instrumentation including bandwidth requirements and the strategy for interfacing these instruments to EPICS. These instruments should be related to a commissioning plan and a description of the high-level application programs that will be required to support that plan.
2. Work with the RF team to complete the development of the interface definition to EPICS for the low-level and high-power RF systems.
3. At the next A-TAC meeting present a strategy for control of Electromagnetic Interference (EMI) including grounding strategy and source control.
4. Identify any requirements for beam-based feedback with required bandwidths. Make sure the control system infrastructure can support these requirements.
5. At the next A-TAC present the approach for beam shut-off for Personnel Protection.

2.5 Beam Dynamics

Findings

Beam dynamics works are presented largely to address comments and recommendations raised during the 2002 A-TAC review, and to address issues associated with reduced linac output energy from 400 MeV to 181 MeV.

With the baseline design, structural transitions occur at kinetic energies of 50 keV (Ion source to RFQ), 3 MeV (RFQ to DTL), 50 MeV (DTL to SDTL), 191 MeV (SDTL to ACS), 400 MeV (ACS to RCS), and 3 GeV (RCS to MR). Major changes of transverse focusing type occur at energies of 50 MeV (singlet to doublet) and 400 MeV (doublet to singlet). Major changes of acceleration frequency occur at 191 MeV (324 to 972 MHz) and 400 MeV (972 to 1.23 MHz). The linac contains a transport section (3-meter MEBT1 at 3 MeV) for chopping and matching, and a section (15.9-meter MEBT2 at 191 MeV) for matching upon frequency transition. The Rapid-cycling-synchrotron (RCS) lattice is designed with arc achromats containing missing dipoles (six FODO-cells per arc including two missing-dipole cells) to increase the transition energy and synchrotron frequency. The Main Ring lattice is designed with arc achromats containing missing-dipoles to avoid crossing transition during acceleration. The linac is designed for H- operation at high peak intensity (50 mA). The RCS is designed for a fast ramping (25 Hz) with high intensity (8.3×10^{13} proton per pulse). The Main Ring is designed for a high intensity (3.3×10^{14} proton per pulse) and high brightness (about 10^{13} per eV-s at tens of GeV).

With the reduced-energy scenario, the ACS section is populated only with lattice quadrupoles. The linac peak current is reduced from 50 mA to 30 mA. The RCS multi-turn injection number is reduced from 300 to 230 turns, holding the injection time constant at about 0.5 ms. The amount of space-charge tune shift at RCS injection is increased from 0.16 to 0.28. The injection time for the Main Ring is increased by a factor of 4 to about 0.6 sec. To justify an estimated beam power of 0.6 MW in the RCS, computer simulations were presented. With the effects of space charge, closed-orbit deviation (3 mm rms), and chromatic sextupoles considered, the simulated beam loss is increased by about a factor of 10 from 0.5 to 5%, still within the 10% (4 kW) loss tolerance.

For Linac and connecting transport lines, a new end-to-end simulation results with program LINSAC were presented, incorporating RF cavity field errors of +/-1% in amplitude and +/- 1 degree in phase, and quadrupole position error of up to +/-0.1 mm with 3200 macro-particles. The simulation assumed computer-generated initial distribution after RFQ. Pulse-to-pulse field stability was measured to be within +/- 0.3% in amplitude and +/- 0.3 degree in phase. The transverse rms emittances were increased by a factor of 2.5, and 99% emittance increased by a factor of 5. Noticeable increases were at transition areas from DTL to SDTL, and at MEBT2 from SDTL to ACS. Earlier simulation with PARMILA based on a different set of errors gave larger emittance growths. Such large-emittance halo particles were to be intercepted by transverse collimators located in L3BT line. Longitudinal collimation in L3BT was concluded to be unnecessary in the presence of functioning debunchers.

Based on measured chopper performance with a rise time of 10 ns, the estimated beam power from partially chopped beam is about 0.4kW. An optional anti-chopper scheme required an additional buncher and two choppers.

A new L3BT lattice was presented with double-bend achromat for the 90-degree arc. Longitudinal collimation was eliminated. The 90-degree arc was found to be insensitive to the peak beam current. The lattice functions, however, vary significantly in the rest of L3BT especially before RCS injection.

For the Rapid-cycling-synchrotron, a comparison was presented between the high-transition lattice and a normal FODO lattice. The high-transition lattice was adopted. The normal FODO lattice used for comparison, however, does not seem to be optically matched and optimized.

A tune-shift budget was presented including space charge, chromaticity, magnet errors, and tracking errors. Option for dynamic tune adjustment was presented as an option with 12 trim quadrupoles replacing 12 existing correction dipoles. Nonlinear and resonance corrections were not presented, neither addressed were earlier findings of a significant reduction in dynamic aperture and a large off-momentum beta-beating in the two-family sextupole chromatic correction. The ATAC suggests continued attention to this issue.

A new injection scheme was presented eliminating lattice quadrupole from the injecting beam trajectory. Earlier found large optical perturbation from the injection chicane and painting bumps was greatly reduced.

Longitudinal beam-coupling impedance was measured for the RCS extraction kicker. Detailed impedance budget and collective effect studies were not reported based on latest design configurations.

For the Main Ring, a split-tune lattice was reported, effectively suppress transverse beam coupling. Longitudinal beam-coupling impedance was measured for the Main Ring BPM and RF cavity. A detailed evaluation of beam-coupling impedance and their impacts on beam collective motion has been started. Chromaticity is expected to play an essential role especially since the momentum compaction factor is small.

Comments

Beam loss and radio-activation pattern need to be established with the reduced linac energy scenario. For the linac, resonance analysis needs to be performed to evaluate possible beam emittance and halo growth. For the RCS, impact from various kinds of magnet errors and power-supply tracking errors, usually significantly enhanced at a much-reduced excitation, must be fully accounted for. Evaluation is also needed on possibly reduced foil stripping efficiency when the injection field is not optimized. For the MR, main impact is from staying at injection for an extended amount of time in the presence of a large space-charge force. Such a beam-loss model needs to be benchmarked with similar, existing accelerator facilities for a “reality check”.

It would be useful to appoint a “beam-dynamics coordinator” to globally oversee accelerator-physics design and interface issues, 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.

The linac end-to-end simulation should be extended to incorporate both measured (at 30 mA peak current) and simulated (50 mA peak current) initial distribution, extended, realistic field errors and magnet errors (e.g., quadrupole roll), and realistic scraping geometry from RFQ to the end of L3BT. Since both beam rms emittance and beam halo are matters of issue, an increased number of macro-particles should be used. Results should be benchmarked among computer codes (e.g., LINSAC, PARMELA, IMPACT) with 3D space charge capabilities. Close cooperation with the institutes that develop these codes is strongly suggested.

Beam collimation is intended not only for normal operation, but also equally important for fault conditions. For such purposes, existing-machine experience should be seriously considered in addition to computer simulations. Even with the present L3BT lattice, efforts should be made to utilize the beam dump in the L3BT arc for longitudinal collimation of low-energy tail particles. A sensitivity study should be made and back-pocket plan developed for the case of increased beam emittance at the end of L3BT.

Vertical beam painting in the RCS relies on the optics of the L3BT. Sensitivity on varying machine and beam conditions need to be studied for the transverse phase advance between the vertical kickers.

For the RCS and Main Ring, the development of “tune-shift budget” and dynamic aperture tracking should incorporate realistic factors like magnetic errors (geometrical, saturation, ramp-dependent, and magnet-to-magnet tracking, remnant fields from septa) at various energies, magnetic fringe field, chicane and bump orbit perturbation, and magnet misalignments, based on actual magnet measurement and survey, and power-supply tracking. End-to-end, 3D simulation should be pursued for the RCS to incorporate the actual injection painting, injection momentum offset, and initial ramping in the presence of realistic machine errors.

For both RCS and MR, the resonance structure near the working points needs to be fully investigated. Possible driving sources need to be identified, impact evaluated, and correction strategies developed. Since chromaticity control plays an essential role, sextupole correction scheme should be refined along with dynamic-aperture assessments.

A relatively large momentum spread is likely to be needed for the control of collective phenomena. Combined with the relatively large dispersion, momentum aperture can be a limitation. A detailed study of the longitudinal space is needed, evaluating the effectiveness of momentum collimation and extraction cleanness.

We applaud efforts made to the re-design of RCS injection. Injection sensitivity study is recommended on varying linac conditions and injecting beam conditions.

The choice of split-tune working point for the MR is likely to suppress transverse coupling due to systematic sources.

For both the RCS and Main Ring, it is necessary to continue develop the “impedance budget” based on both impedance bench measurements and simulations. Impedance quality assurance should be integrated into the engineering design to avoid accidental introduction of unnecessary impedances. Collective effects need to be fully evaluated, and machine design refined accordingly possibly including measures to reduce impedance and to enhance Landau damping. Effects of electron cloud need to be fully evaluated, and remedies formulated including possible treatment of vacuum-chamber surfaces, effective suppression and clearing, and diagnostics.

Recommendations

1. Evaluate beam loss and radio-activation distribution under the condition of reduced linac energy, taking into account realistic magnet and power supply errors.
2. Refine end-to-end simulation from RFQ to the end of L3BT, incorporating measured beam distribution, field errors, and scraping conditions. Develop end-to-end simulation for RCS incorporating injection painting, initial ramping, and collimation.
3. Continue and extend beam-dynamics studies, especially on collective effects, instabilities, and electron-cloud effects.
4. Appoint a "beam dynamics coordinator" to globally oversee accelerator-physics design and interface issues.

3.1 Appendix: Agenda for the 2nd A-TAC Meeting

Agenda of the 2nd A-TAC Meeting for J-PARC Project (2/25 version)

March 7th(Fri), 2003

8:00 - 8:15	Welcome Address	S. Nagamiya
8:15 - 8:30	Executive Session	
8:30 - 9:10	Overview (30'+10')	Y. Yamazaki
	Progress of Design	
	Status of Construction	
	Linac Energy Recovery Scenario	
9:10 – 9:35	Beam Powers of the RCS and MR in the case of the 181-MeV Linac Operation (15'+10')	S. Machida
9:35 – 10:55	Linac	
9:35	Answer to the 1st A-TAC Report (18'+7')	T. Kato
	Including Vibration and Error Analysis	
10:00 - 10:15	*Coffee Break*	
10:15	MEBT Commissioning Result (18'+7')	M. Ikeagami
10:40	Ion Source Development Strategy including Cesium Issue (10'+5')	A. Ueno
10:55 - 14:30	RCS	
10:55	Beam Optics and Dynamics(25'+10')	K. Yamamoto
	Feasibility Study of FODO Cell Structure	
	Trim-Q and Dynamic Correction Magnets	
	Beam Halo and the Collimator Configuration	
11:30	Rapid-Cycling Magnet System (including experimental results on the stranded cables) (18'+7')	N. Tani
11:55 - 13:15	*Lunch*	
13:15	Longitudinal Bucket Manipulation (18'+7')	M. Yamamoto
13:40	New Design of the Injection System (18'+7')	I. Sakai
14:05 - 16:15	MR	
14:05	Study of the Non-Linearity Effect in 50-GeV MR(18'+7')	A. Molodojentsev
14:30	Design of the Opposite Field Septum Magnet(18'+7')	I. Sakai
14:55	Progress of the MA-loaded Cavity System (15'+5')	C. Ohmori
15:15	Fabrication and Field Measurement of the Magnet (15'+5')	M. Muto
15:35 – 15:50	*Coffee Break*	
15:50 – 16:35	Impedance and Instability	
15:50	Impedance Budget (15'+5')	T. Toyama
16:10	Beam Instability Issues (18'+7')	S. Koscielniak
16:35 – 17:00	Accelerator Computer Control (18'+7')	H. Yoshikawa
17:00 - 19:00	Executive Session	

March 8th(Sat), 2003

8:30 - 11:00	Executive Session, Report Write-Up
11:00	A-TAC Report to Management (Open to Everybody)
12:00	Move to JAERI with Lunch Boxes
13:30	JAERI Site Tour