Report from the RIKEN RIBF TAC meeting of November 17-19, 2005

February 12, 2006

Summary

A Technical Advisory Committee was appointed to review the status of the construction and commissioning plans for the RIKEN Radioactive Ion Beam Factory Project, and to also review the technical aspects of the plans for experimental apparatus proposed for Phase II of the project. The TAC met on November 17-19, 2005, and three members also attended a SHARAQ Spectrograph Workshop on November 20.

The members of the TAC want to express their thanks to Dr. Yano and his team for their hospitality during our visit. We are also very happy with the quality and detail of the presentations and the written materials provided during and in advance of the meeting. We appreciate the large amount of work that went into the preparations for this meeting. In our report below we could not review all aspects of what was covered at the review.

The team is also to be congratulated on the overall progress with the Phase I of the Project, as well as, the current status of the plans for the proposed Phase II apparatus. A major milestone was reached recently with the successful operation at full field of all six of the superconducting sector magnets of the SRC, the world's first superconducting ring cyclotron. It is well on its way to becoming the largest cyclotron in the world.

The strong and effective interaction between the RIKEN team and the industrial teams is leading towards an excellent final product with the associated high degree of technology transfer between the RIKEN science center and industry.

The final combination of the accelerator complex completed under the Phase I Project and the complement of experimental instruments proposed for construction under the Phase II Project will produce a truly world-leading radioactive beam research facility.

In the following section there are general comments and observations, as well as, some recommendations for your consideration. The next two sections consist of specific comments, observations, and recommendations for the Phase I and Phase II Projects.

General comments

2006 will be a very busy year with most major sub-systems scheduled for commissioning. It would be helpful to have a more detailed plan of the coordination or sequence of the commissioning process. For example, in some cases RF conditioning interferes with the commissioning of other systems such as the electrostatic inflectors and deflectors.

The type of event experienced recently with the SRC cryogenic system is not so unusual in such large systems in the early stages. Similarly, it would not be unusual to experience more such delays during the commissioning process.

A more detailed plan of the beam loss diagnostics and radioprotection systems will be essential as the commissioning proceeds towards higher intensities. For example, beam losses due to residual gas stripping should be monitored carefully during commissioning at low intensities to avoid machine activation.

The RF systems, including the flat-topping capabilities, for all 3 new cyclotrons are very well done. The addition of flat-topping to the RRC is also a good idea.

The parameters of the electrostatic inflectors and deflectors are within the region of existing experience and hence should not be a major source of trouble during the commissioning process.

The present performance of the 18 GHz ECR source for uranium and other beams is already at the levels required for the commissioning process.

The beam intensity tables for beams lighter than Kr could be updated to higher intensities considering the lower radiation created by these beams per particle microampere. Simulations of the shielding requirements for the lighter beams relative to the heavier ones can be used to generate such tables.

The instruments currently being planned and designed for Phase II are essential to enable a broad-based experimental program at the frontiers of nuclear science, and will provide a very large incremental return on the investments in the Phase I capabilities.

The TAC was not charged with assessing cost and schedule or detailed manpower needs for the projects. Hence, we do not comment of these issues below. However, we did get the sense that there is a need for a larger in-house permanent staff for the upcoming commissioning and operations stages of the Project.

Comments on Specific Components of Phase I

fRC

Final magnetic maps to check the fields of the fRC are in progress. Commissioning is likely to proceed smoothly.

IRC

We are happy to see that the IRC is essentially complete and ready for commissioning.

SRC

We congratulate the team on the successful operation of all 6 magnetic sectors of the SRC. The overall design of these sectors and the magnetic circuits is very innovative and appropriate.

There will be some time necessary to analyze and repair the leak that developed in the cryogenics control dewar. As commissioning of other subsystems can proceed during this time, the overall delay should be tolerable.

The first excitation of the main coils and superconducting trim coils of the SRC sector magnets up to the maximum field is a major achievement. It also demonstrates that the initial alignment of the coils with respect to the iron is already satisfactory. Analysis of the forces in the various coil supports will allow the fine tuning of the coil alignment. Good vertical alignment of the coils with respect to the iron will be a critical parameter for successful acceleration of the highest energy beam. Since measurement of the radial field components with the required accuracy is not feasible the vertical beam motion will have to be used as the tool to determine the corrections to be applied.

The mapping hardware of the SRC sectors is being prepared.

The presence of significant magnet fringe fields in the RF cavities of this machine may influence the conditioning and conditioning process.

Cryogenics

The choices made for the cooling systems of the BigRIPS quadrupole triplets are appropriate. The refrigerator based cooling system for the triplets STQ1 – STQ5 has a demonstrated reserve of 300 W to compensate radiation heating, which should be sufficient given the intensity of the primary beam.

The successful cool-down of the SRC sector magnets is an important milestone in the project. The reported refrigeration capacity and heat load shows a satisfactory reserve of cooling power. The incident that caused the loss of insulating vacuum in the SRC cryogenic system is of a scale that is not uncommon for such large systems during commissioning.

Beam loss monitoring and interlocking

At high intensity localized loss of even a small fraction of the beam will lead to damage to components. Therefore, beam loss monitoring throughout the system is an essential diagnostic tool for reliable operation of the facility. At high energy such a system can be based on detection of the ionizing radiation outside the beam pipe, as used e.g. at PSI and elsewhere. At low energy it will be necessary to determine beam loss from non-destructive current measurements at several locations, such as developed at GSI. In cases of excessive beam losses the monitoring system should be combined with a fast interlocking system reducing the beam intensity by means of reducing the beam duty factor rather than completely interrupting it. In this way beam tuning at low intensity will always be possible.

Vacuum

Beam losses due to charge exchange in the cyclotrons and beam lines may give rise to degradation of the vacuum, which then may lead to an avalanche effect on the vacuum, which severely limits the transmission. In the cyclotrons the presence of parasite beams with a Q/A-value close to that of the beam to be accelerated may give rise to similar effects. This applies in particular to the RRC, which has a smaller q/A-acceptance than the RILAC and acts as a filter for the subsequent machines. For the IRC and fRC the beam injection systems should have a q/A selectivity of better than 1 % in order to reject neighboring charge states, generated in the stripping process, for the heaviest beam particles.

Charge-state stripper R&D

We are happy that the stripper problem is recognized as high priority for R&D. We encourage active work and testing of the various strippers required for the various modes of operation. Beam-based evaluation of uniformity of various candidate foils and plates is recommended. The use of foils/degraders to match the required energies into the fRC and IRC need to be considered in terms of straggling and emittance growth as well. The TAC encourages investigation of the robustness of the stripping scheme (including energy losses) in view of the uncertainties of charge state yields as a function of stripper thickness. One of the challenges is to develop stripper foil mechanisms that give both the realistic charge states as needed at the assumed foil thicknesses and also have the ability to dissipate the heat deposited in the foils by the intense, ~1 pμA, heavy ion beams (such as uranium).

28 GHz ECR R&D

We were impressed by the detailed plans for the development of the advanced 28 GHz ECR ion source. This advanced source is absolutely essential to obtain the full intensity operation of the facility, especially for the heaviest beams. Close communication with related projects in other countries is encouraged to ensure the maximum rate of progress and to avoid duplication of efforts.

New linac injector system

We recognize that the proposed new linac injector system is essential to enable continued R&D for heavy elements with the GARIS apparatus. Consideration should be given to an approach that integrates the requirements of the 28 GHz ion source from the beginning. Recent international developments in room temperature accelerating structures for RFQ's and drift-tube linacs should be considered before final design selection. We also feel that a thorough analysis of the 3-D fields of the compact quadrupole triplets should be done to assure optimal beam matching to the entrance of the linac.

BigRips

The committee is convinced that the in-flight separator BigRips, presently under construction and assembly, is indeed a world-class, next generation facility for physics and applications with rare isotopes. It is based on the most advanced separation scheme with multiple degrader stages (and/or event-by-event identification) to handle the highest intensities of exotic nuclei which have ever been achieved in the magnetic rigidity range up to 9 Tm. The large-acceptance device will enable optimal use of projectile fragmentation and fission of ^{238}U. Hexapole magnets are included and the committee would like to see them applied in simulations to find out how the degrader shape has to be optimized under the residual influence of focal plane tilt due to higher-order aberrations.

Many technical challenges have been successfully solved and the simulation of the performance clearly reflects the unique research potential. The high radiation area has been equipped with a radiation hard dipole magnet and the target and beam dumps have been prepared based on careful computer simulations and test experiments on the present facility. The committee would like to suggest in addition the consideration of high-density shielding blocks to reduce the light particle and neutron flux which would impinge on the superconducting coils of the subsequent magnets after interaction in matter (target or beam dump). The instrumentation in the highest radiation fields should be kept as simple as possible to have easy maintenance and replacement. For example, as an alternative to water-cooled target, a radiation-cooled carbon target could be considered as a backup. Such a target has been used at PSI where 10 times more beam power is deposited. It will be important to develop a more detailed scenario for the handling of major maintenance in the pre-separator stage and to perform tests with smaller equipment before the activation is a serious issue. Early tests will be important since what is learned may require design modifications.

The committee recommends that the full installation of the diagnostic and particle identification at the focal planes of BigRips should have the highest priority because they are needed to commission the complex device and will be required for the first experiments with RI beams. The proposed high-rate detectors fulfill the resolution requirements and also the modern data acquisition with optical fiber is an excellent solution.

Collaboration with the fragment separator groups of RIA and FAIR is recommended. The meeting of fragment separator experts that is being organized by RIKEN for May, 2006 for discussion of many aspects and issues related to next-generation separators is an excellent step towards such collaboration.

Comments on Phase II experimental instruments

RI Spin Laboratory

The RI Spin Laboratory is considered to be a very logical step towards maximizing the productivity of the RIBF and the diverse and interesting research program is backed by a strong collaboration.

Once beam-sharing is implemented, the RI Spin Laboratory will introduce true multi-user capability at the RIBF and help to increase its scientific output.

With costs being moderate and realization and operation expected to not be problematic an early implementation could help to establish a broad science program already at the start of phase 2. We note that a large user community has indicated strong interest in this capability.

Development of a method to independently adjust intensity for the two users is recommended for the future.

Samurai

The committee is convinced that the Samurai spectrometer is an essential part of the exotic nuclei research where different types of reactions are employed to investigate nuclear matter. Presently, a HISS type of spectrometer is planned with a large gap and a maximum magnetic rigidity of 7 T-m. Tracking detectors for charged particles and a large neutron detector will be used in combination with magnetic rigidity analysis. Since the final magnetic design for the spectrometer has not been completed, collaboration with the corresponding groups at MSU and GSI is recommended. For example, a workshop bringing together the groups from all three laboratories and some of the potential users of this apparatus is likely to be beneficial for all.

The design of the R3B dipole at GSI is optimized for low fringe-field components and high momentum resolution. Some aspects of the R3B design might be a useful if scaled to RIKEN energies. The TAC recognizes that Samurai requires larger angular acceptance and a larger bend angle than the R3B dipole, so the design can not be applied directly, but may have some features that may apply at Samurai. Interaction with the Sweeper Magnet group at MSU, led by Michael Thoenessen, could also be useful.

The proposed tracking is certainly well suited to achieve the required resolution. The committee suggests reserving enough space directly behind the spectrometer to have the option for higher-resolution experiments either by simply changing the distance of auxiliary detectors or even to install a high resolution spectrometer as it is planned at the high-energy branch of the Super-FRS.

The Sharaq Spectrometer

The Sharaq spectrometer is designed for the high-resolution physics program at the RIBF. The main characteristics of the spectrometer and of the matching line are well adapted to fulfill the needs for this program. The main difficulty to achieve the high resolution is related to the fact the incoming beam is a secondary beam of quite big emittance. With this large emittance an image size of 1mm for a monochromatic beam must be achieved. This is probably difficult to obtain with a secondary beam the size of which is often increased by the use of degraders in the preceding BigRips. Therefore, mainly two solutions could be used: either use the ray-tracing detectors already projected for BigRips, or construct specific detectors in the matching line. Careful trajectory calculations, starting in BigRips, should be done to optimize the final solution.

A useful workshop to review details of the Sharaq project was held and hosted by the CNS group on November 20 following the TAC meeting. Three TAC members attended this workshop (Geissel, Mittig, and Nolen). Many issues were discussed, such as, the details of the optical designs of the spectrograph itself and the dispersion-matching beam line that delivers properly prepared secondary beams from BigRips. The issues of coordination and respective responsibilities of the CNS and RIKEN groups were discussed and clarified.

SLOWRI

Pioneering work has been done at RIKEN with respect to gas stopping and related techniques, recently rewarded by a first successful laser spectroscopy experiment of trapped Be ions from fast beam fragmentation.

The SLOWRI facility and the proposed experimental equipment will enhance the RIBF science program by providing the opportunity for low-energy beam experiments like mass measurements, laser spectroscopy or decay studies, and eventually for experiments with post-accelerated beams. While not reaching as far from stability as the proposed ring mass measurement, the mass measurements with an electrostatic time-of-flight spectrometer are considered to be a very cost-effective and less risky approach.

The committee appreciates that the realization of SLOWRI, related R&D work, and preparation of experiments involves national and international collaborations.

The proposed R&D work towards higher intensities and faster gas cell extraction should be given high priority. With respect to next-generation systems the cyclotron ion guide appears to be the most promising option. We recommend consideration of the relative effort/performance merits of a small-scale system based on an existing magnet versus immediate development of a full-scale system.

Rare RI ring project

The TAC committee is convinced that the project on mass measurements of short-lived exotic nuclei in the isochronous rare-RI ring has a large discovery potential due to the high primary beam intensity of the RIBF. The aimed uncertainty of 10^{-6} is sufficient to contribute to nuclear structure and astrophysics particularly for the r-process path. The method provides access to nuclei with lifetimes down to the sub-millisecond range which cannot be measured with other devices with the same accuracy. The TAC committee sees no principal technical difficulties with the proposed set-up since similar measurements have been carried out successfully at the FRS-ESR facility at GSI. Also, the reuse of the TARN-II ring in the transfer line is a cost-effective approach for this project.

The injection of single particles identified in-flight and the emittance measurements allow for corrections to effectively use the small range of ideal isochronicity in the ring. The transverse cooling of the fragments before they enter the storage ring improves the accuracy and also the transport efficiency. The time-of-flight measurements with accuracy of 10-4 are required to correct the non-isochronicity. Thin (in the microgram range) TOF detector foils have to be used to avoid that the influence of energy-loss straggling. The presented simulations are realistic and manifest the feasibility. The isochronicity will be improved and optimized by trim coils (multi-pole component) and verified with stable beams at different momenta.

There are some significant challenges associated with some of the components such as the fast kickers and the tuning of isochronicity to better than 10-6.

SCRIT project

The number of ions stored in SCRIT in the feasibility test was $\sim 10^4$. It indicates the reality of the electron scattering experiment in the SCRIT system. However, the achieved number of stored ions is a little bit low with respect to the required luminosity of higher than 10^{27} /cm^2-s. When the available electron intensity is 500 mA, the required number is higher than 10^7 ions. Further improvement is needed to reach this level. However, even if the full desired luminosity is not achieved useful measurements can be done at luminosities as low as 10^{24}.

As for the RI-generator, the intensity of 10^8 pps of ^{132}Sn is easily obtained by uranium fission irradiated by electrons as well as protons or deuterons. However, the effort to build, implement and operate an intense ISOL beam source should not be underestimated.

We endorse the idea of bringing one of the two existing electron storage rings to RIKEN for the further development of this method as long as there is a future plan to couple beams from the SLOWRI system to this apparatus. Without this connection there is no special reason for location of the SCRIT project in the RIB factory experimental area.

We also recommend that a full demonstration of the method be carried out with stable ions as soon as possible.

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