FINAL REPORT

Review of NSLS2 Preliminary shielding calculations

March 27-28, 2007

Table of Contents

Executive Summary 3
Introduction 4
Shielding Objectives 5
Bulk Shielding Calculation Methodology 5
Bulk Shielding for the Storage Ring 6
Penetrations to Roof, Mazes 6
Beam Loss Assumptions 7
Area Monitors 8
Critical Devices and Interlocks 8
Beamline Shielding: Design Criteria 10
Beamline Shielding: Contribution of Neutrons 11
Top-Off Operations 11
Appendices 12
Agenda 13
Review Committee Members 14
Charge to the Committee 15
List of Recommendations 16

Executive Summary

The National Synchrotron Light Facility NSLS-II Project is near CD-1 level approval. The project has stepped up its efforts on advanced conceptual design and preliminary design of the facility for the CD-2 review presently scheduled in November, 2007. Preliminary shielding design calculations for the shielding of 200 MeV Linac and 3.5 GeV, 500 mA Storage Ring have been completed and presented to the review committee.

It is evident to the committee that the NSLS2 Project has invested substantial efforts in considering radiation safety design and radiological impacts of the operation of the facility. Given the status of the project, the design of the bulk shielding of the accelerator complex is well developed and is based on sound principles and reasonable assumptions. The design of shielding for the beamlines is in early stages and should continue to develop.

Introduction

A peer Review of NSLS2 preliminary shielding calculations was held on March 27-28, 2007 at the Brookhaven National Laboratory. The primary purpose of this review was to confirm adequacy of methodology, and evaluate the assumptions and parameters used in the preliminary calculations for the bulk shielding of the proposed NSLS2 Light Source. Additionally, the committee members were asked to provide lessons learned from their experiences on other radiation protection issues such as Interlocks; Critical Devices and Area Radiation Monitoring plans.

The assessment of the Review Committee is documented in the body of this report. Each section in this report is generally organized by Comments and Recommendations. Comments are either statements of fact that are, or may be of significance to the project and summarize noteworthy information presented during the review, or are judgment statements about the facts presented during the review and are based on reviewers' experience and expertise. Recommendations are suggestions for considering a different approach, calculation method, parameter, requirement, or data to the project.

The review committee commends members of the NSLS2 design team for the large amount of high-quality work done on this project and the informative presentations and discussions at the Review.

Shielding Objectives

Comments

- Given the assumed beam loss scenarios, the shielding objectives presented are within the requirements of DOE (10CFR835.1002) and internal BNL shielding policy. The change in the shielding design goal from 0.25 mrem/hr on contact with the surface of the shield wall, to 0.25 mrem/hr at1 meter from the wall is within the above mentioned limits. The dose rate objectives should be expressed in terms of dose rate at 30 cm from the surface of the shield wall.

- The committee concurs with the project plans to use ordinary concrete in shielding of most areas of storage ring rather than heavy concrete since the increase in the calculated radiation levels is not significant.

- NSLS2 plan for not requiring short-term visitors to have dosimeters routinely is reasonable contingent upon verification by measurements.

Bulk Shielding Calculation Methodology

Comments

- Results of the preliminary calculations for bulk shielding are based on semi-empirical and analytical calculations (e.g. Swanson, Sullivan), augmented by limited EGS4 Monte Carlo simulations. These are similar to methods and formulae that are used widely in shielding of other synchrotron radiation facilities and electron accelerators.

- As the design of the facility develops further, additional MC and analytical calculations should be expected (e.g. design of critical devices, special arrangements for ducts, mazes).

- Preliminary Activation Analysis of Accelerator Components and Beam stops, Soil, Air, and Water near NSLS2 Accelerator Enclosures have been performed using standard empirical formulae. These calculations are mainly very conservative and need to be updated and reflect new designs and operating scenarios. Preliminary radiological environmental impact of the NSLS2 has been evaluated and is expected to be minimal.

Recommendations

- The review committee concurs that the methodology used for preliminary calculations of bulk shielding, is appropriate and encourages the project to continue to compare the adequacy of the shielding thickness for the NSLS2 with other facilities, accounting for proper beam loss normalization.

- The project should maintain their access to a proper and current suite of Monte Carlo and analytical shielding codes.

Bulk Shielding for the Storage Ring

Comments

- The design of the shielding of the storage ring ratchet walls as detailed in NSLS II Technical Note 21 (Sept 21, 2006) foresees the use of shadow shields to reduce the overall thickness of the perpendicular part of the front end ratchet wall. The proposed solution foresees a central part of the port end wall with 25 cm of lead and 70 cm of normal concrete, and 100 cm of heavy concrete elsewhere, together with shadow shields placed behind the bending magnets. While this approach is considered acceptable in reducing ratchet wall dose rates the presence of shadow shields in the storage ring tunnel may present an operational constraint that should be avoided in the design of a new facility.

- The shielding calculations to define the thickness of the front end safety shutters have been performed using the following design criteria: dose rate < 0.25 mrem/h at1meter with maximum beam parameters (3.5 GeV, 500 mA) and for a vacuum of 1×10^{-9} torr in the 16 m long straight section. Experience from other synchrotron radiation facilities shows that vacuum intervention on the storage ring are required at practically every maintenance shutdown.

Recommendations

- Project should consider making such shielding an integral part of the ratchet wall design. Additionally, project should consider placing the front end safety shutter(s) immediately upstream of the port end wall.

- The vacuum conditioning times should be included in the shielding evaluations. The thicknesses for various components, especially the front end safety shutters, should be designed to handle periodically higher pressures.

Penetrations to Roof, Mazes

Comments

- The storage ring roof will be used as a technical gallery. This implies that a large number of cable penetrations are expected in the roof.

Recommendations

- Design of the penetrations and mazes must keep radiation levels outside these penetrations within acceptable limits.

Beam Loss Assumptions

Comments

- Storage ring beam parameters presented during various talks included 3.0 GeV, 3.5 GeV, 3.6 GeV, 500 mA and 750 mA. However, the probability that the facility might remain operating at 3.0 GeV for the foreseeable future was presented as the most likely plan. These are fundamental and controlling parameters for the radiation shielding design. In particular, synchrotron beam critical energy is a strong function of stored beam energy. The scattered synchrotron beam dose rates through shielding can be an even stronger function of the stored beam energy.

- The two sets of beam loss assumptions were presented for the storage ring. These results were not yet documented in a technical note due to the non-finalized design of the magnet lattice and the current early stage of machine design. One set of assumptions was presented as the current thinking of the radiation protection group while the second set represented the current estimates by accelerator physics personnel. It was stated that using either set resulted in approximately the same bulk wall thicknesses.

- Due to the very short life time of the stored beam in the ring, the number of electrons that are lost in various locations is higher than most other light sources. The project plans to consider placing limiting apertures at well-shielded locations which represents good ALARA practice~~s~~. If the apertures work as designed, it could also be used for dumping of the stored beam.

Recommendations

- The committee recommends that the project perform parametric shielding studies exploring these parameters and be made fully aware of the impact of building into the design possible future upgrades.

- The committee suggests that the NSLS2 design team establish a single set of beam loss assumptions which represent the consensus of the groups involved at any time, and that this be summarized in a technical note or memo, then used as the basis for subsequent shielding analyses.

- Additionally, we suggest that consideration be given in these beam loss estimates to contributions from routine accelerator physics machine studies.

- The project should evaluate other schemes for placing beam loss points and apertures in well shielded areas, or provide local shielding for such components. Other concepts that reduce the radiation levels outside the shielding walls, such as ramping down beam energy in the booster synchrotron facility before dumping the beam should be explored.

Area Monitors

Comments

- Current area monitoring plans include the placement 42 gamma and neutron radiation monitors – 4 in the linac, 4 in the booster and 34 around the storage ring adjacent to straight section ID's.

Recommendations

- Given the high cost of gamma and neutron radiation monitors, project should consider establishing neutron/gamma dose rate ratio(s) analytically and experimentally, then measure dose rate from one radiation component in most similar locations.

- The committee recommends that the project consider placing interlocked radiation monitors (gamma or neutron) for each unit storage ring cell, and interlocked radiation monitors for each insertion device beamline FOE.

Critical Devices and Interlocks

Comments

- Results from a recent failure mode analysis of the interlock systems for the present NSLS facility by a subject matter expert from BNL were presented.

- The risk of this failure for the scenario that a person enters hutch using proper procedure and interlock logic is satisfied, but in fact shutter did not close, was calculated to be 1.12 E-7 for a 6 month interlock test interval and 4.5E-7 for a 12 month test interval.

- The study credits a 2nd critical device for reducing failure risk by approximately 1000. The project estimates that the hutch doors are opened about 1E5 times per year, therefore risk of an unsafe failure of a shutter at the NSLS is estimated to be 1 E-2 per year.

- Based on this study, project has tentatively concluded that redundant critical devices are appropriate for NSLS2 and asked for input on a potential policy for its Critical Device & Interlocks which requires two critical devices that was presented to the committee.

- It was also stated that plans are to use two critical devices isolating linac from booster (dipole & shutter), booster from storage ring (dipole & shutter).

- The committee noted that the issue of number of critical devices is not typically dealt with in a consistent manner in different accelerators and light sources. Some of the committee members agreed with the proposal to use

redundant critical devices for NSLS2 while other committee members favored use of a single critical device.

- At several facilities (e.g. APS, SSRL, TJLAB) two critical devices with redundant monitoring of system status are used. Other facilities (e.g. ALS, ESRF, NSLS) use a single critical device with redundant monitoring in their photon beam lines. DOE recommends that facilities consider use of two or more critical devices.

- It was noted that the estimated failure rates may not coincide with the actual failure rates that can be obtained by considering the number of hutches at each light source, the number of light sources and other accelerators using similar hardware, and the sum of all accelerator operating years.

- Also, it was noted that hutch access frequency of 1E5 per year for px beamlines may be overly conservative for a future light source given the trend toward reducing hutch access time by automating px exposures

- Results from Monte Carlo simulations for beam stoppers were presented; there were discussions regarding the choice of materials, longitudinal and transverse thicknesses for such devices; the committee noted that in one Light Source, use of beam shutter made of carbon has been considered. Being a relatively low–z material, such a target would generate lower number of high-energy neutrons.

- An alternative solution, implemented at the ESRF, was discussed. Here the PPS interlocks the RF system and drives a copper block (beam killer) in the beam path. It takes approximately 0.5 s to enter the beam killer. Its position is detected with redundant switches. If, 1 s after the PPS trip, the beam killer is not detected as being inserted the PPS trips the magnet power supplies. This alternative solution has the advantage that normally the power supplies will not be switched off, therefore not requiring recycling of the magnets and not causing problems of thermal instabilities.

- Design features of a dual chain interlocked Access Control System that uses one safety rated PLC was presented to the committee.

Recommendations

- The committee agrees that the means of stopping beam from entering an occupied area needs to be redundant. Furthermore, committee recommends that at least one method use a physical beam blocking device.

- The committee applauds the efforts made to quantify the failure rates of critical components. The project should then follow the results from the failure analysis studies after further investigation of the analysis in light of the above comments..

- The committee recommends more simulations be performed to optimize the design (thickness, material) of beam blocking critical devices.

- The design basis for the access control system should be reviewed by a committee of experts.

Beamline Shielding: Design Criteria

Comments

- The wall and roof thicknesses for the FOEs of insertion device beamlines are designed to yield dose rates behind the shield walls < 0.1 mrem/h for the following accelerator parameters: 3.5 GeV beam energy, 500 mA beam current, 16 m straight section length and 1×10^{-9} torr straight section pressure. The vacuum reconditioning time following a vacuum intervention in a straight section, necessary to bring the pressure in the straight down to values $<1\times10^{-9}$ torr, will not be negligible. During this period, the corresponding beamline will either not be allowed to operate or will have to operate with substantial increased dose rates outside the FOE.

Recommendations

- The committee recommends that estimations of the vacuum conditioning times are included in the shielding design reports to evaluate the impact on the dose rates outside the FOEs of insertion device beamlines.

- The committee recognizes that the design of shielding for the beam lines is in early stages. More communication between shielding designers and beam line staff is encouraged.

- Synchrotron beam loss assumptions should be established by the design team and compared with other facilities.

- The beam line synchrotron radiation shielding methodologies should be further developed and compared with methods used by other facilities. For example, effects such as Compton scattering from mirrors may impact shielding of downstream mono-chromatic hutches.

Beamline Shielding: Contribution of Neutrons

Comments

- The shielding design for the FOEs does not take into account the contribution of neutrons produced by the gas-bremsstrahlung interacting with optical components. Calculations and experience at other synchrotron radiation facilities show that for insertion device beamlines and for FOEs side wall and roof thicknesses more than 1 or 2 cm, the neutron dose becomes significant compared with the attenuated scattered bremsstrahlung dose, and eventually becomes the dominating radiation field outside the shield wall.

Recommendations

- The committee recommends that the shielding design for the FOEs of insertion device beamlines takes into account the contribution of neutrons.

Top-Off Operations

Comments

- Due to the short stored beam line time the top-off mode is crucial to the NSLS2 operation.

Recommendations

- Systematic electron beam tracking studies should be performed at an early in the design to support the case for top-off safe operations.

Appendices

Agenda

Tuesday, March 27

0830 – 8:45	Welcome and Introduction	*Casey*
8:45 – 9:15	Overview of NSLS-II	*TBD*
0915-1000	Review of Shielding Objectives for NSLS2	Casey
1000 - 1015	Coffee Break	
1015 - 1115	Bulk Shielding Calculation Methodology	Job
1115 – 1200	Beam Loss Assumptions, Source Terms and Attenuation Lengths	Job
1200 – 1000	Lunch	
0100 – 0200	Summary of Shielding Design	Job
0200 – 0300	Area Monitoring/Beam Loss Monitors	Casey
0300 – 0315	Coffee Break	
0315 - 0430	Critical Devices and Interlocks	Casey/Buda
0430 – 0530	Committee Discussion	
0600	Dinner	

Wednesday, March 28

0900 – 1000	Shielding design of beamlines	Job
1000 – 1015	Coffee Break	
1015 – 1100	Soil, Water and Air Activation	Casey
1100 – 1200	Committee Session	
12:00 – 1:00	Lunch	
0100 – 0200	Close Out	Casey/NSLS-II management

Review Committee Members

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Charge to the Committee

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February 6, 2007

Dr. Sayed Rokni
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RE: Peer Review of NSLS2 Shielding Calculations

Dear Sayed,

Thank you for agreeing to Chair the committee to review the shielding calculations for the NSLS2 on March 27- 28, 2007. As we discussed, the review committee is requested to evaluate the assumptions and parameters used in the preliminary shielding calculations for the proposed NSLS2 Light Source. In addition to the shielding, we also plan to discuss other radiation protection issues such as interlocks, critical devices, and area radiation monitoring. Richard Donahue (ALS), Paul Berkvens (ESRF), and Henry Kahnhauser (BNL) have agreed to assist you in this review.

The review should take approximately 1½ days and will consist of presentations to the committee with time for questions. On conclusion of the review, the committee is requested to produce a brief report of its findings and recommendations.

Enclosed is the committee membership.

Sincerely,

Bob

William Robert Casey
ESH Manager, NSLS2
Email casey@bnl.gov, (631) 344 4654

List of Recommendations

1. The review committee concurs that the methodology used for preliminary calculations of bulk shielding, is appropriate and encourages the project to continue to compare the adequacy of the shielding thickness for the NSLS2 with other facilities, accounting for proper beam loss normalization.

2. The project should maintain their access to a proper and current suite of Monte Carlo and analytical shielding codes.

3. Project should consider making such shielding an integral part of the ratchet wall design. Additionally, project should consider placing the front end safety shutter(s) immediately upstream of the port end wall.

4. The vacuum conditioning times should be included in the shielding evaluations. The thicknesses for various components, especially the front end safety shutters, should be designed to handle periodically higher pressures.

5. Design of the penetrations and mazes must keep radiation levels outside these penetrations within acceptable limits.

6. The committee recommends that the project perform parametric shielding studies exploring these parameters and be made fully aware of the impact of building into the design possible future upgrades.

7. The committee suggests that the NSLS-II design team establish a single set of beam loss assumptions which represent the consensus of the groups involved at any time, and that this be summarized in a technical note or memo, then used as the basis for subsequent shielding analyses.

8. Additionally, we suggest that consideration be given in these beam loss estimates to contributions from routine accelerator physics machine studies.

9. The project should evaluate other schemes for placing beam loss points and apertures in well shielded areas, or provide local shielding for such components. Other concepts that reduce the radiation levels outside the shielding walls, such as ramping down beam energy in the booster synchrotron facility before dumping the beam should be explored.

10. Given the high cost of gamma and neutron radiation monitors, project should consider establishing a neutron/gamma dose rate ratio analytically (for example Monte Carlo calculations) and experimentally, then measure dose rate from one radiation component in most similar locations.

11. The committee recommends that the project consider placing interlocked radiation monitors (gamma or neutron) for each unit storage ring cell, and interlocked radiation monitors for each insertion device beamline FOE.

12. The committee agrees that the means of stopping beam from entering an occupied area needs to be redundant. Furthermore, committee recommends that at least one method use a physical beam blocking device.

13. The committee applauds the efforts made to quantify the failure rates of critical components. The project should then follow the results from the failure analysis studies after further investigation of the analysis in light of the above comments.

14. The committee recommends more simulations be performed to optimize the design (thickness, material) of beam blocking critical devices.

15. The design basis for the access control system should be reviewed by a committee of experts.

16. The committee recommends that estimations of the vacuum conditioning times are included in the shielding design reports to evaluate the impact on the dose rates outside the FOEs of insertion device beamlines.

17. The committee recognizes that the design of shielding for the beam lines is in early stages. More communication between shielding designers and beam line staff is encouraged.

18. Synchrotron beam loss assumptions should be established by the design team and compared with other facilities.

19. The beam line synchrotron radiation shielding methodologies should be further developed and compared with methods used by other facilities. For example, effects such as Compton scattering from mirrors may impact shielding of downstream mono-chromatic hutches.

20. The committee recommends that the shielding design for the FOEs of insertion device beamlines takes into account the contribution of neutrons.

21. Systematic electron beam tracking studies should be performed at an early in the design to support the case for top-off safe operations.