ALARA Analysis of NSLS-II Design

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Status of NSLS-II Project

- Construction has started
- Commissioning of accelerators and storage ring scheduled to begin December 2012
- Start of routine operations – June 2015
- Total Project Cost - 912 million dollars

Other Key Milestones

- Feb 2011 Begin Accelerator Installation
- Feb 2012 Beneficial Occupancy of Experimental Floor
- Jun 2014 Early Project Completion; Ring Available to Beamlines

Background

- There has been significant discussion since preliminary design regarding the shielding policy for NSLS-II

- Do we design the shield to:
  - 5 μSv/h
  - 2.5 μSv/h
  - 0.5 μSv/h

- An important issue - cost of shielding can be significant

- We adopted:
  - 5 μSv/h for the accelerator enclosures
  - 0.5 μSv/h for the hutches

U.S. DOE Shielding Requirements

- For areas with continuous occupancy
  - Design shielding to at least 5 μSv/h
  - and reduce to as low as reasonably achievable (ALARA)
- We need to demonstrate that design values are ALARA

How do we determine what is As Low as Reasonably Achievable?

1. Estimate total dose for shield designed at 5 μSv/h

2. Estimate total dose for shield designed for different dose rate (e.g. 0.5 μSv/h

3. Determine the total saved dose for the different criteria

4. Determine the additional cost of more shielding

5. If value of saved dose < cost of additional shielding, no need to add shield

6. If value of saved dose > cost of additional shielding, more conservative shield criteria should be adopted.

To calculate total dose

- We must estimate
  - Machine operating conditions
  - Occupancy of ring building when machine is operating
  - Location of personnel
  - Operating lifetime of facility
- Estimates should be conservative, but not wildly high

Estimates used in calculations

Operating conditions

- Energy – 3 GeV
- Stored Current – 500 mA
- Life-time – 2 hours
- 5000 hours per year for user program
- Top-off every 72 secs to keep current at or near 500 mA
- 200 complete fills per year
- Accelerator Physics – 1000 hours per year
  - 200 hours per year at 1 hz injection rate and maximum injection current (15 nC/s)
  - 800 hours per year for other studies at conditions similar to normal operation (i.e. 500 mA stored beam, top-off operation 1 pulse per minute top off

Occupancy Estimates

- Key to developing dose estimates
- Estimates were developed for:
  - Normal beam line operations
  - Study periods
- Nine worker groups were considered

Examples of Occupancy Estimates

1. **Beam line staff & users at mono-chromatic end-station and FOE while storage ring operating**

Assumptions:

- 3 personnel per beamline located at an average distance of 30 cm from an end station wall.
- 1 person per beam line located at an average distance of 30 cm from FOE wall
- 58 beamlines in operation located at an average distance of 10 meters to end station from the storage ring wall.
- 5000 hrs/y occupancy with storage ring operating.

Occupancy Estimates

2. Beam line personnel working in FOE while storage ring operates for user program

Assumptions:

- Periodically beam line personnel must enter the FOE to install, adjust or maintain equipment within the enclosure.
- We assume a 10% occupancy during the standard 5000 hour operating year.
- We assume 2 personnel per beamline, 58 beamlines, working 30 cm from the storage ring wall

Occupancy Estimates

3. Staff at infrared beam lines

Assumptions:

- 3 Infra-Red scientists per beamline
- 6 beamlines with occupancy at 1 m from wall
- 4 beamlines at 10 meters from the storage ring wall.
- 5000 hrs/y occupancy with storage ring operating

Occupancy Estimates

4. Beam line personnel working on top of hutch while beam line is in operations

Assumptions:

- There will be need intermittently during beam line operations for personnel to place or retrieve equipment from the hutch top.
- We assume a total of 5% of the operating cycle. (250 hours)
- 1 person per beamline, 58 beamlines, 30 cm from the hutch top.
- 25 hours per year on mezzanine traveling to hutch top – 1 m from mezzanine floor

Occupancy Estimates

5. **Floor Coordinators, health physics staff, ESH personnel and other non beam line staff**

Assumptions

- 5 people for 100 hours each working at a distance of 30 cm from end station and also from FOE per 5000 hour operating year.

Dose estimate from radiation through accelerator enclosure

- Total dose over 30 years for 5 μSv/h criterion for concrete shield

~ 1.8 Sv

- Total dose over 30 years for 2.5 μSv/h criterion for concrete shield

~ 0.9 Sv

Value of Saved Dose over 30 years

- .9 Sv x $1,100,000/person Sv = $990,000
- Cost of additional shielding to reduce radiation levels to 2.5 μSv/h = $1,800,000
- Therefore, no ALARA driver to increase shield thickness and accelerator shield design can be considered optimized at 5 μSv/h

Dose estimates to beam line staff from beam line operations

- Total dose over 30 years for 5 μSv/h criterion for hutch shields

~ 108 Sv

- Total dose over 30 years for 0.5 μSv/h criterion for hutch shields

~ 10.8 Sv

Saved Dose = ~ 97 person Sv

Value of Saved Dose over 30 years

- 97 person Sv x $1,100,000/person rem = ~$103,000,000
- Cost of additional shielding to reduce radiation levels to 0.5 μSv/h = ~ $1,160,000
- Therefore, strong ALARA driver to shield to 0.5 μSv/h before hutch shielding can be considered optimized.
- Mono station may not be optimized at 0.5 μSv/h – 0.1μSv/h may be cost effective.
- FOE is optimized at 0.5 μSv/h. Additional shielding is not warranted.

Impact of Commissioning and other Accelerator Studies

- Prolonged injection at 1 hz can raise radiation levels significantly.
- Radiation monitors located around ring will be interlocked with machine and will prevent continued injection.
- Planning and controls will be required during all commissioning and study periods. Limits on occupancy near accelerator walls may be needed.

Conclusion

- The concrete bulk shield for the storage ring designed to 5 μSv/h complies with the U.S DOE requirements and is ALARA.
- Supplemental lead shields provided in the injection region which reduce radiation levels to 5 μSv/h complies with the U.S DOE requirements and is ALARA.
- The lead shielding in the beam line hutches designed to 0. 5 μSv/h complies with the U.S DOE requirements and is ALARA. (Mono hutches should be considered for additional shielding to 0.1 μSv/h)
- The estimated total annual dose for the facility designed to these criteria is ~0.4 person-Sv with an average dose per worker/user assuming 3500 workers of ~ 110 μSv.