Residual Does Rate Analyses for the SNS Accelerator Facility

I. Popova, J. Galambos

HB2008
August 25-29, 2008, Loew’s Vanderbilt Hotel, Nashville, TN, USA
Outline

• Introduction
• SNS layout
• Methods for neutronics analyses
• Instruments and uncertainties
• Results from comparison measurements vs. calculations
• Conclusions
Introduction

- SNS is an accelerator driven neutron scattering facility that recently started operations and in power ramp-up process during cycles of operation, maintenance, and tuning

- SNS accelerator is loss limited machine. In order to limit the activation level

- BLM are located along the beam line and measure prompt radiation and inhibit the beam when excessive losses occur

- In order to plan maintenance work after each operations period, residual dose measurements are taken at 30 cm and on contact
Scope of work

- Analyses of residual dose rates due to accelerator component activation in order to understand nature of the radiation fields behavior inside the accelerator tunnel
- Preliminary results, we started to perform these analyses recently
- Analyses performed for two last operation cycles, fall 2007 and spring 2008 and compared with measurements
SNS Layout and parameters

3 measurements location:
• After cryomodule 16
• After cryomodule 24
• After cryomodule 32
• After stripping foil
Methods

3 steps analyses

- Monte Carlo transport code MCNPX to calculate reaction rates
- Activation script to execute CINDER’90 to obtain the time dependence of the isotope buildup and decay including decay gamma spectra
- Residual dose calculation
Methods

Residual dose calculation

- For simple only beam tube model - by conversion gammas production spectra in the multi-group structure and gamma power for each time step to the dose rate
- For model with beam tube and tunnel walls - by feeding back to MCNPX decay gamma spectra and gamma power for each time step to calculate dose rates
Methods

• Simplifications in geometry
  – Outside the accelerator structures the highest source of residual gammas is the steel beam tube, analyses were performed for a very simple model of beam pipe without adjacent beam structures
  – For second round of analyses surrounding concrete accelerator tunnel walls were added
Methods

- **Sources for calculations**
  - Proton losses in beam pipe

<table>
<thead>
<tr>
<th>Location</th>
<th>After cryomodule 16</th>
<th>After cryomodule 24 and 32</th>
<th>After stripping foil</th>
</tr>
</thead>
<tbody>
<tr>
<td>Beam lost monitor</td>
<td>scl16b</td>
<td>scl32b</td>
<td>ring_A11c</td>
</tr>
<tr>
<td>Beam energy</td>
<td>660</td>
<td>845</td>
<td>845</td>
</tr>
</tbody>
</table>

- Losses modeled like continuous cylindrical proton source, forward directed inside the beam pipe
- Operational scenario for activation and decay calculation is provided from BLM readings taken during operation cycle for each location
Instruments and uncertainties

Instrument uncertainties

- Precision
- Location
- Timing
Instruments and uncertainties

Beam loss monitors - ionization chambers

- Precision is about 20%
- Locates about 10 cm from the beam line in SCL and 60 cm from the beam line in Ring Injection, which gives especially for the SCL section about 40%
- Data averaged over beam running period
Instruments and uncertainties

Hand-held ionization chambers

- Precision is about 15% - 20%

- Standard measurements are carried out by hand on 30 cm distance from the beam tube. This introduces at least 20% of geometry uncertainty in radial direction

- The location for each measurement is not precise in the axial direction and vary relative to the corresponding BLM location up to 0.5 m. Uncertainty is 10-50%

- Loss location relative to the BLM can vary during the run cycle. Measured residual dose rates could not exactly correspond to the loss recorded by BLM

- Difference in time of measuring and recording
Instruments and uncertainties

Calculation uncertainties

- Geometry representation in calculations
- Uncertainties in material composition
- Assumptions in source representations
- Accuracy in physics model and cross sections data
- Statistical errors in the code
- Calculation accuracy for these analyses could be about 30%.
Results, fall 2007

- Calculation performed for one operation cycle with five running periods
- Eight measurement campaigns during operational cycle
- Calculated dose rate are scaled to the measurements
Results, fall 2007

![Graph showing dose rates, mrem/h over time (11/14/07 to 03/13/08). The graph includes measurements, calculations, and power as indicated by different markers and colors.]
Results, fall 2007

![Graph showing dose rates, mrem/h over time from 11/14/07 to 03/13/08.]

- **Measurments**
- **Calculations**
- **Power**
Results, fall 2007

Carbon foil area

Dose rates, mrem/h

Measurements
Calculations
Power

11/14/07 12/04/07 12/24/07 01/13/08 02/02/08 02/22/08 03/13/08
Results, spring 2008

- BLM monitors were set to measure decay gamma radiation in small time increments in the end of the cycle
- Only decay calculations were compared vs. measurements
- Sensitivity analyses were performed to estimate influence of:
  - Different types of steel: S304 vs. S316
  - Energy of beam intercepting the pipe: 200MeV, 400MeV, 600MeV, 800MeV, 1000MeV
  - Influence of surrounding concrete walls
Comparison of residual radiation due from ss304 and ss316 for 800MeV and 1GeV beam

Date
10-Jul-08 11-Jul-08 12-Jul-08 13-Jul-08 14-Jul-08 15-Jul-08 16-Jul-08 17-Jul-08 18-Jul-08 19-Jul-08 20-Jul-08 21-Jul-08 22-Jul-08

Radiation
1.0E-10 1.1E-09 2.1E-09 3.1E-09 4.1E-09 5.1E-09 6.1E-09 7.1E-09 8.1E-09 9.1E-09

Calculated 800MeV, S316
Calculated 1 GeV, S316
Calculated 800MeV, ss304
Calculated 1 GeV, ss304
Measured 870MeV ND24
Comparison of dose rates due to beam with vary energies

- Measured 870MeV ND24
- Dose rate 1 GeV, ss304
- Dose rate 800MeV, ss304
- Dose rate 600MeV, ss304
- Dose rate 200MeV, ss304
- Dose rate, 400MeV, ss304

Results, spring 2008
Comparison of dose rates due to beam with 800MeV with concrete wall and without concrete walls

- Measured 870MeV ND24
- Dose rate, beam tube, 800MeV
- Dose rate, concrete and beam tube, 800MeV, at 10cm
- Dose rate, concrete and beam tube, at 800MeV, 30cm
Results, second running cycle

Additional contribution from gammas ray and positron emitters in the very first hours of decay are about the same like from photon dose


FIG. 7. Dose equivalent rate as a function of cooling time for the stainless steel sample and the three measurement positions.
Conclusions

- MCNPX in conjunction with a newly developed activation script with CINDER’90 was used for residual analyses
- Wide range of uncertainties
- Simulations data was compared to the performed measurements and it appears that measured decay is faster than calculated except for injection area
- After 2 days results are in a good agreement
- Steps to improve measurements precisions
- Steps to improve calculations