Experimental Verification of Halo Formation Mechanism of the SNS Front End

Dong-o Jeon

Spallation Neutron Source
Oak Ridge National Laboratory

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The Spallation Neutron Source

- The SNS began operation in 2006!
- At 1.4 MW it will be the world’s leading pulsed spallation source
- The peak neutron flux will be \( \sim 20-100 \times \) ILL
- It will be a short drive from HFIR, a reactor source with a flux comparable to the ILL
Overview of Spallation Neutron Source

LINAC (332 m) 1GeV
HEBT
RTBT
RING
Target
Sources of Front End halo generation

- MEBT is the largest contributor to FE halo generation

- Nonlinear space charge force stemming from a large transverse beam eccentricity generates halo in MEBT (D. Jeon et al, PRST-AB 5, 094201 (2002))

- As minor contributors, several FE components and physical effects may contribute to the generation of beam halo

Region with a large transverse beam eccentricity ~2:1
Fraction of core in x plane sees nonlinear space charge force, resulting in halo formation in x plane

Beam at the chopper target

Potential halo

Space charge force and real space distributions
Optics modification improves beam quality

Nominal Optics

Round Beam Optics
Optics modification alone reduces halo significantly in simulations (Simulation)

At 171MeV

Blue: baseline MEBT
Red: 2nd half of MEBT optics modified
Green: all MEBT optics modified

Number of particles vs. radius [cm]

Nominal Optics

Round Beam Optics

Half optics modified

CCL bore
Round Beam Optics improves X beam quality (Emittance Measurement)

- Round Beam Optics reduces halo and rms emittance in X significantly

### Nominal Optics
\[
\varepsilon_X = \begin{cases} 
0.349 \text{ mm-mrad (1\% threshold)} \\
0.454 \text{ mm-mrad (0\% threshold)} 
\end{cases}
\]

### Round Beam Optics
\[
\varepsilon_X = \begin{cases} 
0.231 \text{ mm-mrad (1\% threshold)} \\
0.289 \text{ mm-mrad (0\% threshold)} 
\end{cases}
\]
Tail is significantly reduced for Round Beam Optics

- Round Beam Optics reduces beam tail visibly
- This tail is the source of beam loss in downstream linac

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Round Beam Optics improves Y beam quality (Emittance Measurement)

Nominal Optics
\[ \varepsilon_Y = 0.353 \text{ mm-mrad (1\% threshold)} \]
\[ 0.472 \text{ mm-mrad (0\% threshold)} \]

Round Beam Optics
\[ \varepsilon_Y = 0.264 \text{ mm-mrad (1\% threshold)} \]
\[ 0.306 \text{ mm-mrad (0\% threshold)} \]

- Round Beam Optics reduces halo and rms emittance in Y significantly

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Tail is significantly reduced for Round Beam Optics

- Round Beam Optics reduces beam tail visibly
- This tail is the source of beam loss in downstream linac
Parmila simulation

- Consistent with the emittance measurement results

Nominal MEBT Optics

Round Beam MEBT Optics
Round Beam Optics reduces beam loss in the downstream linac

- Loss in CCL-SCL transition reduced by factor 4
- Loss also reduced in the downstream linac
- Consistent with the simulation predictions
Conclusion

- A new halo mechanism was experimentally verified through emittance measurements!
- The proposed “round beam optics” improves beam quality, reducing rms emittance and halo.
- The first emittance data showing practically no halo!
- Beam loss reduced in the downstream linac.
- Valuable benchmarking of space charge codes with measurements.
- For mismatched beam, simulations show some limitations.
Halo formation in Front End and its Mitigation

Beam loss along the linac with Nominal Optics

- Halo particles are lost primarily on the CCL bore.
- Beam loss along the linac with Nominal Optics.