Development of Computational Tools for Halo Analysis and Study of Halo Growth in the SNS

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Spallation Neutron Source

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Spallation Neutron Source (SNS)

H⁻ ions are created and bunched.

Ions are accelerated to 1GeV.

Delivers 1micro-second pulses.

Liquid mercury target produces neutrons.
Minimize Beam Losses

- SNS design beam power is 1.44 MW
- SNS beam specification for beam loss is < 1W/m
- Beam halo has been identified as a contributing factor to beam loss as can be seen in the beam profiles.
- Halo production is attributed to mismatch.

Wirescanner beam profiles for two quadrupole settings.
Medium Energy Beam Transport (MEBT)

- The MEBT is responsible for matching into the DTL.
- The DTL has permanent magnet quadrupoles.
- Quadrupoles 11, 12, 13, and 14 are main matching quads.
- Wirescanners are used to measure beam profiles.
Quantifying Halo

- Qualitatively halo are large amplitude particles outside a central beam core.

- Kurtosis method [Wangler, XX International Linac Conference, 2000] was difficult to use on experimental data due to low signal to noise ratio.

- Area Ratio method was used.

- Gaussian is fitted to the top 90% of the profile.

- Using only data outside 1 sigma.

- Dividing the total area by the Gaussian area gives a ratio of halo.

\[
    f(x) = Ae^{-\frac{(x-\mu)^2}{2\sigma^2}}
\]
Matching

- Purpose of this study was to control halo development by matching from MEBT to DTL.
- Pictorial representation of a mismatched particle.
- Quadrupoles 11-14 were used.
- Varying each quad 10% from the nominal value.
Simulations

- Parmila using the 3DPicnic routine was used.
- Run for nine quadrupole settings.
- Cases are named by the amount each quadrupole was varied from nominal.
- Using three input distributions
  - Reference Distribution (measured)
  - Gaussian Distribution
  - Waterbag Distribution
- Tracked from the beginning of the MEBT through the DTL to the end of the CCL.
Results: Measured vs. Simulation

- Halo plots for all quadrupole cases at different positions in the horizontal transverse direction.
- Halo decreases at the end of the CCL in both simulation and experimental data.
- Difference between simulated and experimental halo data in the DTL.
- Certain quadrupoles appear to be more sensitive to halo production with the Nominal case having the least halo.
Results: Measured vs. Simulation

- Measured halo trends show little similarity with simulation in the vertical direction.
- Vertical results show similar quadrupoles produce more halo.
- Simulations for both horizontal and vertical show a decrease in halo in the CCL
Simulated Halo Growth

- Simulation profile data shows a decrease in halo at the end of the CCL.
Results: Emittance Analysis

- Simulated emittance data showing core growth.
- Simulations conclude that the core grows and consumes the halo particles.
- Phase space orientation could explain disappearance of halo in experimental data.
Initial Distribution Dependence

- Gaussian and Waterbag distributions were used to study sensitivity to initial halo.
- Halo is produced regardless of initial distribution.
- Halo production is primarily dependent on mismatch, not initial distribution.
Simulation vs. Experimental Data

- Partial success of simulating profiles.
Conclusions

• Gaussian Area Ratio method is useful for quantifying halo.

• Partial success of simulations to model halo profiles.

• Simulations show a decrease in halo with an increase in emittance. This has not yet been experimentally confirmed.

• Phase advance may be a reason for the apparent disappearance of halo in experimental data.

• Finding an initial distribution, matched to measured Twiss parameters, that accurately represents the beam is currently being sought.