Injection Studies on the ISIS Synchrotron

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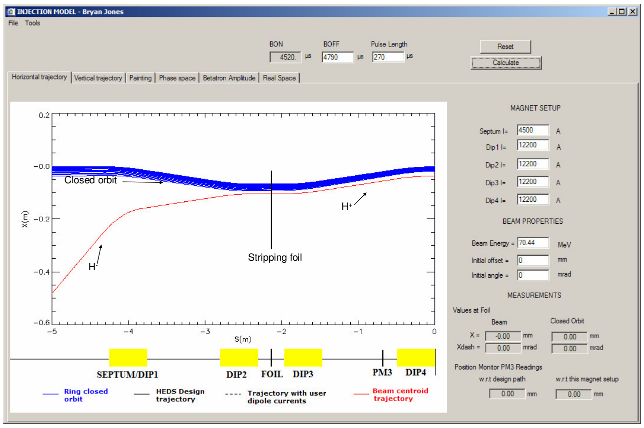
The ISIS Facility at the Rutherford Appleton Laboratory in the UK produces intense neutron and muon beams for condensed matter research. It is based on a 50 Hz proton synchrotron which, once the commissioning of a new dual harmonic RF system is complete, will accelerate about 3.5×10^{13} protons per pulse from 70 to 800 MeV, corresponding to mean beam powers of 0.24 MW. The multi-turn charge-exchange injection process strongly affects transverse beam distributions, space charge forces, beam loss and therefore operational intensity. The evolution of longitudinal distributions and subsequent trapping efficiency is also intimately linked with injection.

Optimising injection is therefore a key consideration for present and future upgrades. Work is now under way looking at this process in more detail, and relates closely to other transverse space charge studies on the ring.

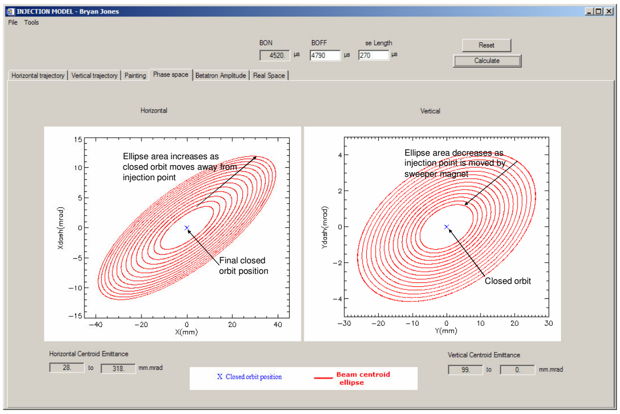
Presented here is an IDL application which simulates various aspects of the injection process. This application is a tool for use in machine physics sessions, to help understand and optimise injection configuration.

Beam centroid trajectory

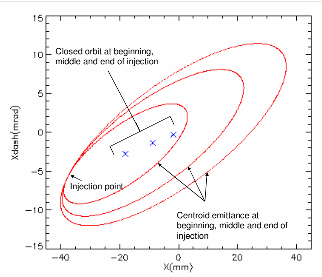


The application allows the user to specify currents for each of the injection dipoles and offsets in position and angle of the injected beam. Trajectories are displayed for the design path and perturbed beam path as well as the closed orbit of the ring. Position and angle of the beam is displayed at the foil and at a position monitor for comparison with experimental data.

Centroid phase space



The closed orbit position and the particle injection point at the foil are plotted in phase space. The vertical emittance decreases over injection due to a falling current in the sweeper magnet. In the horizontal plane the injection point is stationary and the closed orbit moves with the falling main magnet field. The emittance of the beam increases since the ellipse is centred on the closed orbit point. In both planes the result is a painted beam usually with a hollow distribution as shown in the plots above.



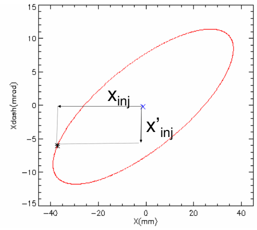
The plots display to the user the status of the accumulated beam at the end of the injection period. It is also possible to veiw snapshots of the beam at different times of the injection period. The plot left shows three different horizontal closed orbit positions and the beam ellipse associated with each positon.

The ellipses are calculated from the injection point and synchrotron Twiss parameters.

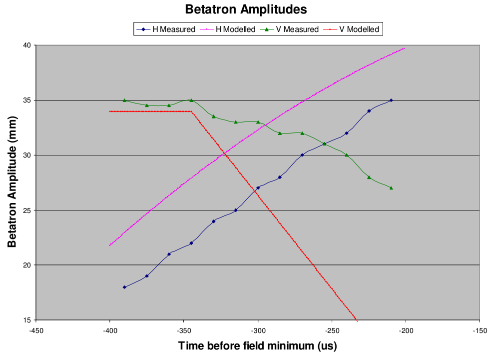
$$\varepsilon\cdot\beta = x_{inj}^{2} + \left(\alpha\cdot x_{inj} + \beta\cdot x'_{inj}\right)^{2}$$

$$x = \sqrt{\varepsilon\cdot\beta}\cdot Cos\phi$$

$$x' = \alpha\cdot\sqrt{\frac{\varepsilon}{\beta}}\cdot Cos\phi - \sqrt{\frac{\varepsilon}{\beta}}\cdot Sin\phi$$

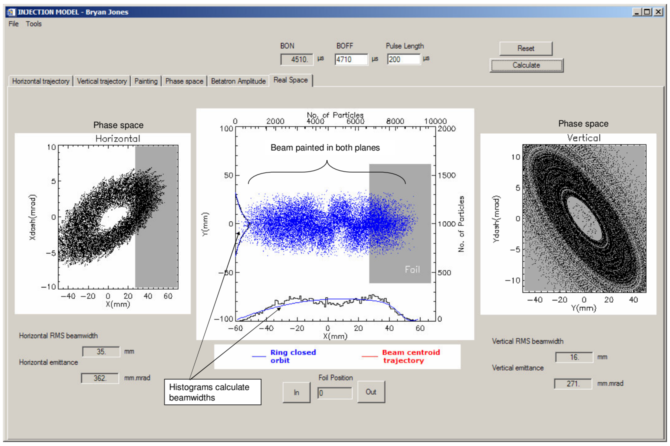


Betatron amplitudes are plotted for comparison with experimental data. Although numerically different, the trend of the betatron amplitude in both planes shows good agreement with measured values.



Beam distribution model

In order to understand the final beam distributions resulting from the above centroid painting, a multi-particle (low intensity) model is being developed. This generates representative injected distributions (4D waterbag) derived from injection line beam parameters. The centroid of this distribution is then calculated as above, and beam accumulated over multiple turns. This gives valuable predictions of low intensity painted distributions, which can be compared directly with suitable "chopped beam" measurements. This detailed modelling and checking of injection forms the basis for minimising losses at high intensity and minimising foil traversals



Further work

This application is a work-in-progress and further development is planned. Experimental measurements are required to validate the results presented here and will be made when machine time is availiable. It is intended to develop the beam distribution simulation to allow better optimisation of the injection process.

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