Outcome of Cyclotron Beam Development in 2015

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Contents

1 H$^-$ Ion Sources

1.1 I1 current limitation

In January 2015 we investigated why the beam current from I1 saturates around 4-6A of arc current instead of scaling linearly. We found that the amount of current going past the Einzel lens does scale linearly with current (see figure 2); a large fraction of the beam is lost on the pulser dump over 4A of arc. This phenomenon coincides with the presence of two peaks on the extraction electrode (EE) voltage scans. This phenomena could be affected by small voltages on skimmer plates (see Figure 4).

We also found that 30 kV on the Einzel lens does not provide sufficient focusing (at 8A of arc, see figure 5). This is totally inconsistent with our understanding of beam optics in the optics box (see link), where 25 kV should be about enough (keep in mind that the focal power scales with the square of the voltage). To refine our model of the Einzel lens I even modelled it with OPERA (see link), but this changed the focal power only very marginally.

From this study we conclude that the current limitation from I1 does not come from the ion source itself, but comes from something not understood about the optics in the optics box. To mitigate this issue we chose to ground skimmer#45 and ask operators to run the Einzel lens at 30 kV.

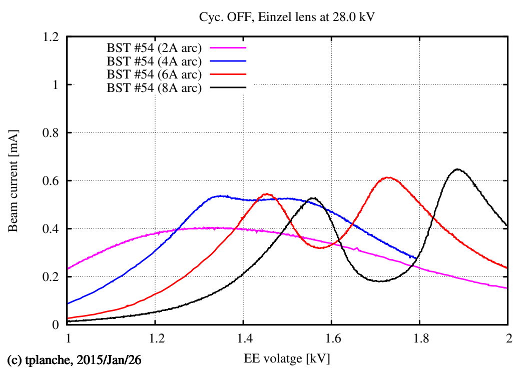

Figure 1: Scan of I1 extraction electrode (EE) voltage, while keeping pooler electrode voltage fixed, for various arc currents. Current is read on beam stop #54 (immediately downstream of the pulser dump).

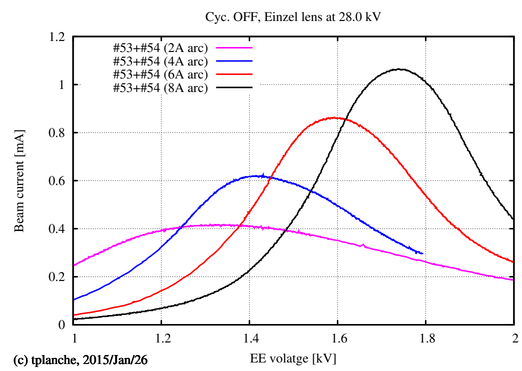

Figure 2: Same scans, but here showing beam current on beam stop #54 + on the pulser dump (#53). The amount of beam reaching #53+#54 for optimal EE setting does scale linearly with arc current.

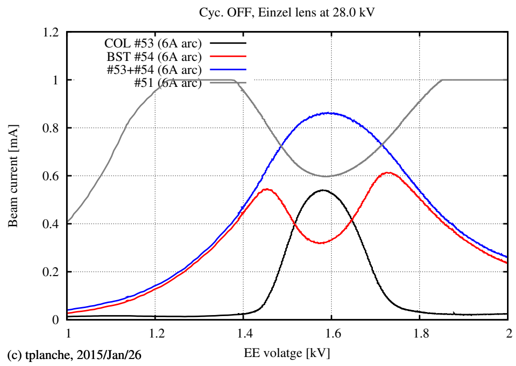

Figure 3: Same EE voltage scan at 6A as before; on this plot we also show the current read on the 'emittance-defining' grounded collimator (#51), and on the pulser dump (#53).

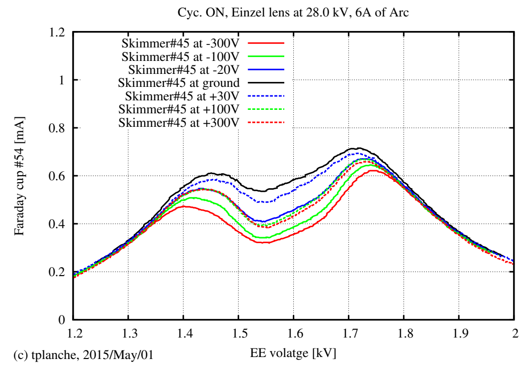

Figure 4: EE voltage scans at 6A of arc for various bias voltages on skimmer #45 (plates on both sized of the Einzel lens). After this test, we left the skimmer grounded.

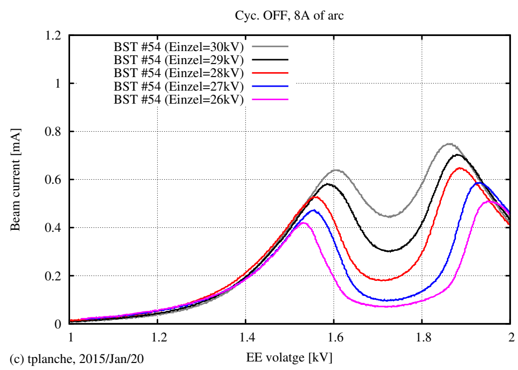

Figure 5: EE voltage scans at 8A of arc for various Einzel lens voltage.

1.2 ISIS slits scan

We took many ISIS slits scans all along the year. The first part of the curve (up to ∼150thou) was always identical to the reference data from Oct. 2014 (see for example fig. 6), except one time: when the quad. voltage in the periodic section was set too high. We conclude that the beam brightness from the source has not changed significantly since 2014, despite all the efforts to increase it.

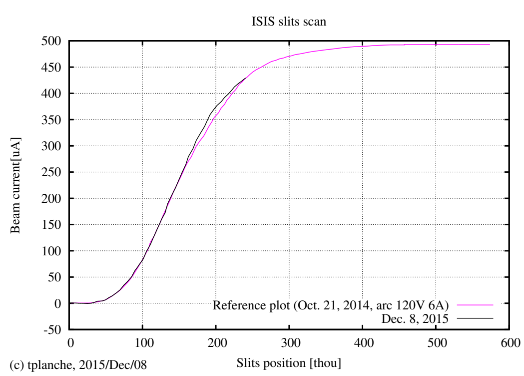

Figure 6: Typical result from ISIS slit scan.

1.3 I3 studies to understand I1

Our co-op student studied the relation between the partial pressure of contaminants and the filament life-time (see http://qr.triumf.ca/319).

He also found that beam current out of I3 was not scaling linearly with arc current, and was 'saturating' like in I1. This is in contradiction with what had been observed as the end of 2014 - beginning of 2015 where linear scaling had been observed up to at least 20A of arc (with almost no change in beam emittance). This requires further investigations.

2 Injection line

2.1 ISIS Optics Model

On June 19$^{\text{th}}$, for the first time in the history of the injection line, we achieved theoretical understanding of the optics along the entire beamline. Corresponding e-log entry:

After some source touching up (Keerthi), the wirescans were taken and used to fit quads 106 to 112 to calculate a match to the slits (Yi-Nong). This new tune worked well, but steering corrected (Thomas). Then new tune was calculated to re-match this to 5:1 slit (Rick). Thomas adjusted steering to get beam to vertical section. Discovered col155 not reading (Fault Reported #8202). By "dead reckoning", calculated beam from 5:1 slit to vertical periodic section and fitted quads 305,312,313,314 to match to periodic vertical section. Again, this worked very well, with wirescan profile widths matching closely to calculated. We stored all wirescans to "Master", and handed off to Jas and Robin.

This will allow the development of high-level application to help operators tuning the injection line.

2.2 Commissioning of ISIS Phase Monitors

A summary of our first attempt to commission those monitors ca be found here:
http://beamphys.triumf.ca/~tplanche/beamdev_shifts/2015/20151117/report/report.pdf

3 Cyclotron

3.1 Tests With Harmonic Coil #5

Harmonic coil #5 was successfully used to improve radial centring in the r=160" region, see detailed report from Yi-Nong:
http://beamphys.triumf.ca/~tplanche/beamdev_shifts/2015/20150619/YN_summary.pdf.

No significant improvement of beamline 2C4 current stability was observed after HC#5 had been left to the optimal setting.

3.2 Tests With Harmonic Coil #9

Our purpose was to use this harmonic coil in Br first harmonic mode to drive (and possibly correct) the $\nu_{\text{r}} - \nu_{\text{z}} = 1$ resonance. A detailed report can be found here:
http://beamphys.triumf.ca/*sim*tplanche/beamdev_shifts/2015/20151006/report/report.pdf In summary: we could affect vertical beam centring as expected, but we did not observe any effect on vertical emittance growth. This remains a mystery, and will have to be attempted again next year when the second HE probe will be available.

3.3 Beam current stability better that 4% for all beam lines in all operational modes

Not achieved this year for BL2C4, despite our attempts with harmonic coils #5 and #9. But we obtained the conviction that vertical beam size/position instability plays a more significant role than radial beam density fluctuations. So we propose to carry test with narrower foils that can fully be dipped into the beam.

3.4 Planned items not attempted/completed this year:

- Reach over 300 μA total extracted current from the cyclotron in operational conditions: no high-power run scheduled.
- Carry out detailed studies of space charge effects: the lack of brightness make this study hard to carry out.
- Design and replace Q1 and Q3 correction plates: beam based measurement were unsuccessful.
- Design and build a new full inflector assembly: failure of the new deflector electrode made us decide to build a test stand to test components prior to installation in the cyclotron.
- Measure the contribution of electromagnetic stripping to cyclotron spill.
- Develop advanced cyclotron performance metrics: work started during 2016 shutdown.

4 Secondary Beamlines

4.1 Re-commission BL1A & BL1B

- The beamline had to be tune to lower spill generated around the UCN septum magnet.
- T2 protect monitor re-aliment was successful, and resulted in increased yield to .

4.2 BL1A Optics Model

We invested a lot of effort in an attempt to get accurate profile measurements to benchmark our optics model, especially in the front-end. It was determined to be practically impossible to get accurate profile measurements from multi-wire harp monitors, even by scanning the beam and using signal from single wires. The best series of measurements (Dec. 8) is summarized in figure 7, keep in mind that error bars are of the order of a few mm.

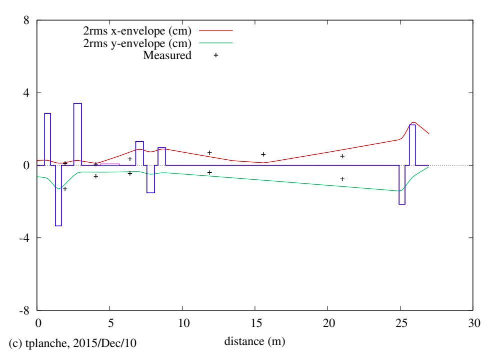

Figure 7: BL1A front-end modelled envelope vs measurements.

4.3 Localized Beam Loss Test (M11)

Following Anne Trudel's request, we generated a known localized beam loss around M11 area, and we recorded the reading from a Neutron monitor she had re-localized for this test. Data are available here: http://beamphys.triumf.ca/~tplanche/beamdev_shifts/2015/20150901/M11_beamLossTest/.

4.4 Commission of BL2A rastering

The most part of 3 development shift were dedicated to this work this year. Detailed report can be found here: add links to Yi-Nong and Aurelia's reports.

4.5 BL2A Optics Model and Proposed New Tunes

add link to Yi-Nong's report.

4.6 BL2C4: try to run with beam lower on target

Was attempted at the end of the year on a few targets. Seem to result in increased yields (for a give integrated charge). Need more statistics to draw a definite conclusion.

4.7 Planned item not attempted this year:

BL2C4: regular operation at 100μA extracted at $\sim$110 MeV