Users' Manual for tuning the DRAGON Separator

Revision history

Version	Author	Description	Date
1.0	D.A. Hutcheon	Initial document	14 January 2003

Contents

1 Introduction and Warning

By following the instructions in this document, a user can ensure that the beam has been properly centred on the target and that the elements of the electromagnetic mass separator have been tuned for optimum transmission of the desired recoil ions and rejection of the unwanted beam particles.

It is assumed that the user has some familiarity with the EPICS control system and the general properites of magnets, electrostatic dipoles, slits and Faraday cups. Detailed description of these devices and of the separator vacuum system are provided in other documents.

Warning: When the End Detector of recoil ions is a solid state device (e.g. double-sided silicon strip detector, DSSSD), care must be taken to avoid transmitting beam through the separator and onto the detector. At typical beam intensities, transmission of as little as 1% of the beam for a fraction of 1 second will be enough to damage a DSSSD. *Insert the final Faraday cup, FCF, before doing any tuning of beam through the separator. Check that there is no measurable beam current on FCF before pulling it Out.*

2 Scaling

2.1 Recovering a previous tune

To use Tune Scaling, it is essential to read from file a tune which is known to be "good" — to have the desired focus properties. Unfortunately, the Scaling program in its 2002 version encouraged the saving of many files which differ from each other by nothing more than scaling to a different rigidity or different strengths of Steering magnets. Even more unfortunately, the files saved in 2002 included many which are inappropriate because of changes in power supply current calibrations or because of errors made by the DRAGON users, who often assigned incorrect parameters to the tune.

Saved tunes are named according to date and time of their creation. If you do not know the date/time of a "good" tune (either from memory or a previous logbook entry), consult someone who does. If this is not possible, use the settings in Tables 1 and and 2 multiplied by the MD1 field or current (obtained by measuring the post-target beam energy as described below — for the energy measure to have been valid, Q1 and Q2 fields must have been set in the correct ratio to MD1 field).

Table 1: Magnet field ratios for a standard DRAGON tune.

Magnet	Field ratio
Q1	0.709
Q2	0.677
MD1	1.000
Q3	0.553
Q4	0.735
Q5	0.381
Q6	0.366
Q7	0.512
MD2	1.230
Q8	0.387
Q9	0.238
Q10	0.266

2.2 Saving the tune

To best use the Scaling feature, it is necessary to save the current Scaled tune and make it the new Reference tune.

- Check that NMR units are locked (blue numbers for field) for MD1 and MD2.

Table 2: Setpoint current ratios for a standard DRAGON tune.

Magnet	Setpoint ratio
SX1	0.0528
SX2	0.0112
MD1	1.000
SX3	0.0100
SX4	0.0974

- in the Scaled tunes page, click on "Modify reference parameters" and enter the current (Scaled) parameters. Click on "Save current tune as reference". The "Last saved file" box should show a filename with the current date/time. This will include the settings of steering magnets specific to the the present beam.
- "Select reference tune" and get the tune just saved.

3 Centring the beam through the target

The beam should be centred in the horizontal (x) and vertical (y), in both position and direction, at the middle ("z=0") of the target. This is important for 3 reasons: it optimizes transmission of the desired recoil ions; it minimizes aberrations, which reduces beam spotsize at the rejection slits; x-position of the beam at the target affects the apparent beam energy when it is measured using MD1.

When quadrupoles Q1 and Q2 are On at normal strength (according to the ratios of Table 1, they produce at the Charge slits following MD1 (XSLITC, YSLITC) an image of the beamspot at the middle ot the target. The linear magnification is -0.44 in x and -3.5 in y. When Q1 and Q2 are Off, the beam position at the Charge slits depends on the initial direction of the beam as well: to a fair approximation, the beam behaves as though it has travelled through a 3-m drift space between target and Charge slits (assuming MD1 field has been set to the magnetic rigidity of the beam). Thus, by alternating between "quads On" and "quads Off" it is possible to measure beam position and direction at the target.

If Tune Scaling is used to set Q1, Q2 and MD2, use the "Apply scaled tune (up to MD1)" option.

3.1 Beam position and angle at the windowless gas target

- Locate the 6-mm gas cell aperture in the CCD (if not already known)
  - gas target pumps must be running, so ion gauge IGU3 can be turned on
  - valve HEB2:IV8 must be closed, DRA:IV11 open
  - run a 10-second exposure on the CCD, use the Normal Stretch contrast control to make the displayed image sensitive to faint objects. A light circle should be visible: this is light from IGU3 that has reflected off valve IV8 and come through the 6-mm aperture of the gas cell.
  - use the View—Photometry feature to find the pixel coordinates of the 6-mm aperture. Record them.
- Allow Operations to tune beam through to FC1 in their traditional fashion, with gas cell pressure reduced by having both BYP1 and OVTR1 valves closed. (Remember to open IV8.)
- Put gas in the target, withdraw FC1 and adjust MD1 to centre beam at XSLITC. (Q1 and Q2 on.)

- Check horizontal position of the beam: have the Operator note the setting of HEBT2:XCB6, then change it until the beam transmission to FCCH (with XSLITC and YSLITC open) drops to 50% of the peak value. Note setting, then change XCB6 in the opposite direction until 50% transmission is reached at the opposite edge of the aperture. The difference between the "50%" currents corresponds to a shift of 6 mm. Compare the average of the "50%" currents vs the initial XCB6 setting: if they disagree by more than 0.5mm, set XCB6 to the average, otherwise use the initial setting.

- Turn off Q1 and Q2, set YSLITC for width=4mm, XSLITC for W=15mm. Adjust YSLITC Position until equal currents are measured on the Top and Bottom slits. Close XSLITC to W=4mm, open YSLITC to W=15mm and adjust XSLITC Position for equal Left and Right slit currents. If beam Position at XSLITC comes within 3 mm of zero and Position on YSLITC cmme within 3 mm of +3mm, beam is on-axis to within 1 mrad.

- If the beamspot is more than 0.5 mm away from the centre of the gas cell or the direction was >1 mrad off, have the Operator adjust the beam using HEB2 steering magnets:
  - in the Y direction, play YCB6 against YCB2. For a +1 amp change in YCB6 the change in YBC2 should be of order -0.03 amp.
  - in the X direction, play XCB6 against one of the 22.5-degree bending magnets.
  - observe the XSLITC/YSLITC asymmetries to get both the position and angle of beam within desired limits.

- When beam is centred in position and angle at the gas target, turn Q1 and Q2 back on and measure beam energy (Gas In or No-Gas, as desired). Make sure XSLITC is returned to Position=0, YSLITC to Position = +3mm. Adjust MD1 for equal Left and Right XSLITC currents at Width = 2mm.

- Document beam properties. A saved .fit file of the CCD image may substitute for "XCB6 values for 50% transmission" data, provided the filename is entered on the Beam Properties sheet. Take a picture on the CCD, adjust Normal Stretch to make the beamspot visible, then use Photometry to measure the beam position and width. If the beam is not circular and focussed, have the Operator try to improve it.

3.2 Troubleshooting

- beam disappears before the YBC2/6 adjustments have put the beam on centre: may be due to severe "porpoising" of the beam through HEB2. Suggest to the Operator to check the YCB's after the DTL and before HEB2 to see if any is on hard. If so, a tune may be improved by reducing early vertical steering and re-centring on the beamline harp monitors.

- beam disappears when doing the horizontal adjustments (XCB6 et al.). This is even more complicated than in the vertical because the "slaloming" can involve the 22.5 degree benders as well as the XCB's. No magic formula here, though it's probably a good idea to start with XCB's off or low.

- RIB spills high. Check again that beam is on-axis and small spotsize at our target. If so, our experience is that the problem most likely lies in the beam tune through the accelerators. If there has just been a switch from OLIS to the

Target/Ion Source, it may be a problem with r.f. phases to match OLIS vs those for the TIS.

4 Tuning beam through the separator

After the beam has been centred at the target and its post-target energy has been measured, the rest of the separator elements may be set to a "tune": dipoles and steerers set to transport ions of a certain mass, charge and energy down the ion-optic axis; quadrupoles set to confine the desired ions and to focus the beam and recoils at selection slits; sextupoles set to reduce higher-order aberrations. The EPICS page for DRAGON Optics has a "Tune scaling" utility which calculates and sets the elements for a certain mass, charge and energy of ion, scaled from a "Reference Tune".

4.1 Tuning from Charge slits to Mass slits

- On the Tune Scaling page, "Select reference tune" (provided you know the name of a "good" tune). With options "Scale E-dipoles" and "Scale Energy", set the "Scaled parameters" to match the beam mass, post-target energy and the selected charge state. Observe the calculated high voltages on the electrostatic dipoles ED1 and ED2: if they are higher than the voltages to which the ED's have been conditioned, it will be necessary first to do voltage conditioning (see Users' Manual for Separator Hardware). "Apply scaled tune" and watch for Operations box to change from "..." to "done". With XSLITC at Position=0, Width=2mm check that the beam is centred on XSLITC. If there is more beam on the Left slit than the Right, increase the "Energy" scaled parameter and "Apply scaled tune" again. If the Right slit has more beam than the Left, Energy parameter must be decreased. Iterate until the beam is centred on XSLITC.

- Check that all electromagnetic elements are On: scan through each of the EPICS Optics pages (1 through 4) to see that the icons are green, that MD1 and MD2 NMR units have locked on the resonance (readings are blue, not white) and that quadrupole Hall probe readings are reasonable (look for status buttons to be green, not yellow, and for readings to be reasonably close to the ratios of Table 1).

- Check again that final Faraday cup FCF is In. Put FCM In (page Optics (2)) and take FCCH Out.

- Put BCM2 In, set the range to the most sensitive one which doesn't saturate (reading below 0.98 on all of the quadrant currents). Use steering magnet SM1X (immediately downstream of FCCH) to centre the beam horizontally on BCM2. Use SM1Y for vertical centring. Provided the beam was properly centred at the target, very little current should be required to centre on BCM2 (compared to full-scale current of 5 amps).

- Pull BCM2 Out, open the Mass slits XSLITM, YSLITM to Width 25 mm each and look for beam current on cup FCM. If current is seen on one of the slits but not FCM, adjust ED1: increase ED1 if current is on the Left slit, decrease ED1 if current is on the Right slit. (If ED1 high-voltage readback does not stabilize on the new setting, check for signs of conditioning.)

- When current is seen on FCM, progressively reduce the Width of XSLITM and adjust ED1 to centre the beam, until Width = 2mm is reached.

- Open XSLITM to Width = 15 mm. Close YSLITM to Width = 3 mm and adjust SM1Y to centre the beam. Open YSLITM to Width = 25 mm.

4.2 Tuning from Mass slits to Final slits

- From DRAGON Optics (3), pull FCM Out, put In BCM3 and set to an appropriate current range. Adjust SM2X and SM2Y to centre the beam on BCM3. (Full scale on SM2 is 5 amp.) Pull Out BCM3.

- If necessary, adjust the MD2 current so that the ratio of magnetic fields B(MD1)/B(MD2) measured by the NMR's is 0.813.

- Put In BCM4 and adjust SM2Y for vertical centring. The beam will be shown as right of centre, but do not adjust SM2X. Pull Out BCM4.

- From Optics (4) put In BCM5 and adjust SM3Y for vertical centring. Use SM3X for horizontal centring, provided its setting is small compared to full scale (100 amp). If more than ≈15 amps is needed on SM3X, make a small adjustment to MD2 to centre on BCM5, instead. Pull Out BCM5.

- Put In BCM6 and use SM3Y to centre the beam vertically. Pull Out BCM6.

- Turn SM4X to 0 and use ED2 to centre beam as slit XSLITF is closed progressively to Width 2mm. Open XSLITF to 45 mm. Use SM4Y to centre beam as YSLITF is closed to Width 2mm. Open YSLITF to 45mm.

- Compare beam currents at FCCH, FCM and FCF to confirm that beam transmission is ≈100%.

Save the tune, as described in the section on Scaling.

5 Tuning the separator for Recoil ions

Provided the beam tune has been saved and made the new reference tune, in the Tune Scaling page change "Scale Energy" to "Fix momentum", change the Scaled Parameter to the mass of the Recoil and "Apply scaled tune". The voltages on the ED's should change by the ratio of masses of Beam/Recoils. The magnet settings should not change.

Beam current on FCF should drop below a measurable level. If so, it should be safe to pull Out FCF while watching the End detector count-rate monitor. **Do not pull Out FCF if measurable current remains after tuning for Recoils.**

6 Change of selected charge state

On the Tune Scaling page, enter the new value for the Reference Parameter Charge. Look at the new ED1 and ED2 settings listed below the Reference Parameters, to confirm that they are within the range for which the ED's have been conditioned. If so, "Apply scaled tune". If not, the selected charge state cannot be used.

7 General Troubleshooting

- Beam doesn't pass through an ED. Most often, this is because one or both of the isolation valves ("IV" on the Vacuum pages) of the ED tank is closed. If this is not the problem, the next likeliest cause is that the HV of one of the electrodes has tripped off. If the HV is on both electrodes, check that the setting is reasonable: the ED1 voltage V (in kV) is related to the MD1 field B (in kG) by

  $$V \approx 24.1 \frac{q}{A} B^2$$

  and the ED2 voltage is ≈80% of the ED1 voltage.

- Beam currents on Faraday cups indicate transmission <<100% or >>100%. Most probable cause is that bias voltage on the electron suppressor ring of one of the Faraday cups has tripped off. Bias should be On with Reverse polarity. If transmission is still low, check slit widths and currents on slits.

- Beam doesn't focus down so >50% passes through an X-slit set to 2–3 mm width. (with the possible exception of XSLITF if the tune is meant to focus at the end detector). Check that none of the quads has tripped off. If none tripped, check that the quad/MD1 field ratios match Table 1. If quads are all OK, check beamspot size at the target using the CCD: a large spot may indicate a quad is off in the HEBT line.