Beam Transfer (Waldo MacKay)

- Description of the ATR beam line (AGS to RHIC)
- Status
  - Magnets
  - Other components
  - AGS
- Flag measurements
- Beam steering
- Commissioning strategy for next fall
- Conclusions
ATR Injection Line Description

I U-line:
   A. Match beam from AGS into W-line
   B. Stripping foil: \( \text{Au}^{+77} \Rightarrow \text{Au}^{+79} \)

II W-line:
   A. Vertical drop of 1.7m
   B. 20° bend to reach 6–12 o’clock symmetry line
      (Requires zero dispersion upstream and downstream of the 20° arc.)
   C. 6 Quads at end of W-line match into the 90° arcs.

III Y-line:
   A. Bend almost 90° into the Yellow (ccw) ring.
   B. 6 Quads at end of Y-line match into RHIC.
   C. Vertical injection into RHIC with lambertson.

IV X-line:
   A. Bend almost 90° into the Blue (cw) ring.
   B. 6 Quads at end of X-line match into RHIC.
   C. Vertical injection into RHIC with lambertson.

V Injection kickers inside each ring.
- Quads
- Dipoles
- Vert. Dipole

160 m

20° arc

8° arc

4° arc
$U$-line

YTransfer

$\beta [m]$

$\eta [m]$

$s [m]$
Y-line

\[ Y_{\text{Transfer}} \]

\[ H \quad V \]

\[ \beta [m] \]

\[ \eta [m] \]

\[ \text{583.2} \]

\[ \text{385.9} \]
Changes since 1993 Review

- Dipoles UD1 and UD2 changed to longer magnets with smaller gaps.

\[ B \sim 2\text{T} \rightarrow 1.28\text{T} \]
\[ |\Delta B/B| \sim 1/800 \rightarrow 1/4000 \text{ at } x = \pm 0.025 \text{ m.} \]

- 9 new planes of BPM’s for better steering.

- Moved 2 flags and added 2 new ones.
  (Better emittance measurements.)

- BLM’s allocated.

- AGS extraction and transfer to RHIC to be line-locked (30 Hz).
  - BPM electronics.
  - Frame grabbers for flags.

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Field Quality

- Quads OK.
  - All on separate power supplies.

- Dipoles OK.
  - Random errors $\left| \frac{\Delta B}{B} \right| < 0.002$ can be corrected.
    Measured $\sigma \simeq 0.1\%$
  - Random errors $\left| \frac{\Delta k_1}{k_1} \right| < 0.005$ can be corrected.
    Measured $\sigma \simeq 0.1\%$
  - 8 type-C dipoles have been measured and sorted for the $20^\circ$ arc.
  - The 7 type-B dipoles with old steel are being placed on either side of horizontal trims in the X- and Y-lines. Additionally, these trims are $180^\circ$ degrees apart in phase.
<table>
<thead>
<tr>
<th>Type of magnet</th>
<th>Number</th>
<th>Location</th>
<th>Constructed</th>
<th>Measurements</th>
<th>In Tunnel</th>
<th>Left to install</th>
</tr>
</thead>
<tbody>
<tr>
<td>Type-A dipoles thin</td>
<td>2</td>
<td>End of X and Y arcs</td>
<td>yes</td>
<td>no</td>
<td>0</td>
<td>2</td>
</tr>
<tr>
<td>Type-A dipoles fat</td>
<td>2</td>
<td>4° arc in U line</td>
<td>no</td>
<td>no</td>
<td>0</td>
<td>2</td>
</tr>
<tr>
<td>Type-B dipoles long</td>
<td>50</td>
<td>Large X and Y arcs</td>
<td>almost</td>
<td>1 left</td>
<td>24</td>
<td>26</td>
</tr>
<tr>
<td>Type-B dipoles short</td>
<td>10</td>
<td>Large X and Y arcs</td>
<td>none</td>
<td>1 to do</td>
<td>0</td>
<td>10</td>
</tr>
<tr>
<td>Type-C dipoles</td>
<td>12</td>
<td>8° and 20° bends</td>
<td>done</td>
<td>done</td>
<td>1</td>
<td>11</td>
</tr>
<tr>
<td>Quads of 4 types</td>
<td>31</td>
<td>all lines</td>
<td>done</td>
<td>done</td>
<td>20</td>
<td>11</td>
</tr>
<tr>
<td>Old trims</td>
<td>7</td>
<td>U line</td>
<td>done</td>
<td>no</td>
<td>4</td>
<td>3</td>
</tr>
<tr>
<td>New trims</td>
<td>26</td>
<td>W, X, and Y lines</td>
<td>done</td>
<td>no</td>
<td>0</td>
<td>26</td>
</tr>
<tr>
<td>W-line pitch</td>
<td>2</td>
<td>W line</td>
<td>done</td>
<td>no</td>
<td>0</td>
<td>2</td>
</tr>
<tr>
<td>Lambertson pitch</td>
<td>2</td>
<td>Ends of X and Y lines</td>
<td>done</td>
<td>no</td>
<td>0</td>
<td>2</td>
</tr>
<tr>
<td>Lambertsons</td>
<td>2</td>
<td>Ends of X and Y lines</td>
<td>done</td>
<td>soon</td>
<td>0</td>
<td>2</td>
</tr>
<tr>
<td>Switch magnet</td>
<td>1</td>
<td>begining of X and Y arcs</td>
<td>done</td>
<td>no</td>
<td>0</td>
<td>1</td>
</tr>
</tbody>
</table>
Status of other components

I Flags (12 total)
   A. Working prototype in BTA line between Booster and AGS
   B. Construction proceeding.
   C. Cameras have been ordered.
   D. Frame grabbers (4 channels) should be ordered soon.
   E. Working software application.

II BPM’s
   A. Type 1 and 2 assembled.
   B. Type 3 should be finished by November. (Upstream U-line)
   C. Electronics – 1 working module by November.

III Collimators being constructed.

IV Current transformers ordered (4 to 8 weeks).

V Beam loss monitors
   A. First ion chamber being received this week.
   B. Circuit boards are being stuffed.

VI Stripping foil
   A. Drive will be a duplicate of the Flag drives.
AGS and Extraction

I Bump windings should be completed in Nov.
   A. Should do machine studies with bumps during next proton run.

II G10 kicker is ready (install in Nov.)
   A. Kicker will be used to extract beam into the B2 test beam line in December.

III H10 septum should be finished by Feb. 1995.
   A. Installation will be next summer.

IV Upstream U-line inside AGS tunnel.
   A. Hopefully, most of this will be completed in Nov.
      1. UD1 and UD2 dipoles should be ready by Nov.
      2. The last bit UQ3 onward will be installed next summer, since shielding must be removed.

V At present, AGS BPM’s can’t see ion beams!
   A. The upgrade of electronics was scheduled for 1996.
   B. We will identify a minimum set of electrodes to instrument with more sensitive electronics for the 1995 test.
Flags

I Locations
   A. 1 at beginning of U-line near AGS.
   B. 1 near stripping foil.
   C. 3 upstream of 20° arc.
   D. 3 downstream of 20° arc near switch magnet.
   E. 2 at end of X-line.
   F. 2 at end of Y-line.

II Emittance measurement
   A. UF3, UF4, UF5, WF1, WF2, and WF3.
   B. Zero dispersion.
   C. Resolution: ~ 0.1 mm.
   D. Estimated accuracy of emittance with 6 flags: ~ 5%.
Double click MB1 on a variable or graphics object to change attributes.
Horizontal closed orbit sigma, 76 single errors, after correction

0.5 mm displaced errors of quadrupoles, radial roll, errors of dipoles

Vertical closed orbit sigma, 76 single errors, after correction

Note: "This print still has uncorrected data at this point."
Vertical Aperture at Injection

I. Aperture limits
   A. injected beam
      1. Lambertson: $\sim \pm 3.5\sigma$ at $30\pi$
      2. 24.5 mm vertical height
   B. Circulating beam
      1. Kicker: $\sim \pm 5\sigma$ at $30\pi$
      2. 41.2 mm ID
   C. Warm-to-cold transition after lambertson
      1. Constricts ID 8 mm more than quadrupole.
      2. Length subtracts another 2 mm.
      3. Net result: clip top of aperture by 6 mm.
      4. $\Rightarrow$ We need to hone the design.
Kick ≤ 1.86 mrad
Commissioning Strategy for Fall 1995

I Things to do before beam tests

II With beam

   1. Two weeks dedicated running.
   2. Two months of parasitic running.


I Things to do before beam tests

A. check cooling water on magnets
B. ramp magnets
C. check polarities of magnets
D. pump down line and check vacuum
E. check interlocks
F. check other hardware
   1. BPM's: cables and electronics
   2. BLM's (with a radioactive source)
   3. Flags: read back pictures with calibration lights
   5. Current transformers and electronics
   6. Timing system: check signals
      a. to transformers
      b. to BPM's
      c. eventually to injection kicker system

G. Test connection to RHIC abort system

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II With beam (∼ $10^{10}$ charges of some species, hourly average 1 pulse/30 sec)

A. Thread beam down the U- and W-lines.
   1. Steer the beam onto the flags.
   2. Measure the location with the BPM's.
   3. Verify magnet and BPM polarities with beam.
   4. After reaching a flag with a reasonable trajectory, remove the flag and go on to the next one.

B. Measure the pulse stability from the AGS.
   1. Current
   2. Position
   3. Profile on flags

C. Do fault studies.
   1. Check for radiation leaks when the beam hits certain key elements. Of particular interest are:
      a. Access doors, particularly in the split region.
      b. Penetrations for ventilation shafts and cables.
      c. Thin shielding areas.
      d. The top of the berm where Thompson road crosses the beam line.
D. Measure the transverse matrix elements \((C, S, C', S')\) for both \(x\) and \(y\).
   1. Measure the beam location at all BPM's.
   2. Change UTV1 by a small amount and remeasure the trajectory.
   3. Reset UTV1 to previous value and remeasure the trajectory.
   4. Change UTH2 by a small amount and remeasure the trajectory.
   5. Calculate the expected deviations and compare with data.

E. Measure the dispersion elements of the beam line \((D, D')\).
   1. Measure the trajectory.
   2. Simulate a \(-0.1\%\) momentum change by ramping all magnets up by \(0.1\%\).
   3. Remeasure the trajectory.
   4. Calculate the values of \(D\) and \(D'\) at the BPM locations.
   5. Compare with the expected values.
F. Measure the beam shape (hyperellipsoid)
   1. Measure the profile at flags UF3, UF4, and UF5
   2. Measure the profile at flags WF1, WF2, and WF3
   3. Attempt to measure momentum spread with collimator UC1.
   4. Calculate emittances, betas, and alphas (horiz and vert) at the flag locations.
   5. Measure dispersion of the beam.
      a. Change the momentum of the AGS extracted beam.
      b. Remeasure the trajectory.
      c. Calculate the values of $\eta$ and $\eta'$ at the BPM locations.
   6. Compare with the expected values.

G. Tune the U-line quads to best match the desired values going into the W-line.
   1. Note that the dispersion should be zero at the entrance to the W-line (20° arc).

H. Tune the W-line quads to best match the desired values just upstream of SWM (switch magnet).

I. Scan aperture
Conclusions

I Design and Construction

A. Magnets:
   1. Magnet construction almost complete.
   2. At least 50 (as of 23 Sept.) are already installed in tunnel.
   3. Field quality is good.

B. Minor changes to beam line (more flags and BPM’s)

C. BLM’s laid out.

D. Installation progressing well.

II Applications

A. Two major application codes well under development:
   1. Beam threading
   2. Emittance measurement: flag data has been read from BTA line.

III Sticky points

A. Design of warm-to-cold transitions near lambertsons need work.

B. Upgrade AGS BPM’s to see ions.

IV Beam test in 1995

A. Strategy fairly well planned.
\[ 10^{-7} \times 10^{-6} \text{ Au} \]

\[ 95\% \]

\[ \frac{\bar{\rho}}{\rho} \sim 10^{-3} \]