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Beam diagnostics and transport magnet requirements for the ARC10 and Hall-D beamlines

Diagnostic and correction system upgrades for the proposed 12GeV upgrade will be required in the following regions: in the new Arc 10, in the modified 4th & 5th pass extraction regions, and in the new Hall D transport. Additionally the upgrades to the existing 6 GeV transport system are required due the increase in beam energy in the existing 6 GeV machine. This note lists the additional diagnostic and transport magnet requirements for the proposed 12 GeV upgrade in these regions. All the components listed come from the JLAB catalog of existing accelerator components. Hardware requirements for each of these regions are readily established using prior CEBAF operating experience.

Upgrades Required in Existing Transport System – Due to the increase ambient beam energy, a limited number of correctors in the existing transport system will require upgrade. Upper and lower bounds on the required numbers can be established by considering two scenarios.

Scenario 1 – upper bound: We observe that corrector strengths (apart from field integral correcting the (earth's field) ambient) will, with other magnets, scale with beam energy . The required correction field integral with therefore (save for the ambient correction offset) scale with cavity gradient, and, more importantly, correlate directly with quadrupole strength. Thus, the required corrector upgrade is well-characterized by the required quadrupole upgrade. The additional corrector strength can be supplied in most cases by running the correctors – as the associated quadrupole magnets are operated – at elevated current. Thus, each corrector associated with a quadrupole receiving a trim card upgrade will, similarly, require a trim card upgrade. If, however, the associated quadrupole requires a complete hardware upgrade, the corrector set will require similar replacement. The upper bound cost is therefore set by the number of upgrade trim cards required for quadrupole magnets (an equal number is required for correctors) plus the number of quadrupole magnets requiring a hardware rework (an equal number of corrector sets will require replacement).

From scaling up quads, the number which are over-range are as follows:

- 60 QAs (suggests MBC to MBD change)
- 17 QBs (suggests MBT to MBC change)
- 30 QCs (suggests MBT to MBC change)

for a total of 60 changes of MBC to MBD and 47 MBT to MBC.

Scenario 2 – lower bound: CEBAF operation at up to 6 GeV provides a datum on corrector excitation which may be scaled to 12 GeV. From this information, it is noted that the existing corrector set runs, on average, well below maximum excitation except in the spreader/recombiners. In these regions, the correctors are used to provide nonlocal correction to orbit errors induced by mis-set major dipoles. These set point errors have their source in the incomplete diagnostic set available for orbit management and limitations in dipole shunt range in the beam separation region. A minimal cost corrector upgrade could then be provided by: a) introducing a complete suite of diagnostics in each spreader and recombiner, b) upgrading shunt/adders system as required to provide local correction as dictated by new diagnostics, and c) allowing a small contingency to cover those corrector sets which are determined to be inadequate during commissioning. The total cost is then diagnostic costs + shunt/adder cost + minor upgrade contingency.

Scaling the 6 GeV operating data, under this scenario the following corrector upgrades are suggested:

- Double up all 20 MBD magnets; all but 6 OK if can run 30% higher field with new power supply (temperature of coil the issue)
- linac MAT magnets - replace with MBT magnets which are already on the girders, unpowered
- 2S/2R MBT magnets - change to BC, double up, run hot, or improve diagnostics and steer with shunts

We note that this is the basic philosophy used in the 10 kW IR FEL upgrade, wherein the fact that only a limited number of IR Demo correctors were run at moderate to high field motivated the use of hardware changes on only a case-by-case basis.

The upgrade requirements projected by both requirements are summarized in Table 2.

Table 2: Range of Requirements in Upgrade of Present Transport

Component	*#*
MBD	20 to 80 new
MBC	20 to 50 new

Upgrade Arc 10 Requirements – Arc 10 is optically similar to other high energy transport arcs (such as arc 8) and will therefore require a similar diagnostic and correction suite. Arc10 will only transport Hall-D beam. The proposed operating current range for Hall-D is nanoAmps to a few microAmps of beam current. This current range is best covered by the switched electrode BPM electronics [SEE] which has sensitivity down to 50nanoAmps of beam current. For this reason the Arc10 BPM electronics is proposed to be SEE style, which is different then the other Arcs where less sensitive style of electronics is used. The required hardware is summarized in Table 3.

Table 3: Arc 10 Corrector and Diagnostic Requirements

Component	*#*
Corrector (H + V) **all MBD magnets**	72
BPM(SEE style electronics)	45
SLM	1
Viewer	9
insertable dump	1

Requirements for Hall D Transport – The Hall D transport comprises numerous features present in other CEBAF recirculator and hall transport regions. Operational experience with these systems, together with input on Hall D operating parameters, suggests diagnostic and correction hardware components will be required as given in Table 4. This table includes requirements for the 6th pass Spreader as well.

*Table 4: Hall D (**Including 6th Pass Spreader**) Corrector and Diagnostic Requirements*

Component	*#*
H/V Corrector Pairs: MBD magnets	2 x 27 + 2 x 2 dump (58 total)
BPM(SEE style electronics)	28 + 1 dump
Cavity (low current) BPM	3
Viewers	6 + 1 dump

Profile monitors	4
SLM	3 + 1 dump
Active Collimator	1
Photon profiler	Position and profile, like hall B
BCM	1
insertable dump	1

Requirements for Modified 4th & 5th Extraction Regions – The new design for 4th & 5th pass extraction uses vertical separation into a lambertson, which bends the extracted beam along the same horizontal geometry as the lower passes. For the 4th pass no change in instrumentation is needed other than a possible viewer in front of the lambertson to ascertain correct beam separation. For the 5th pass the current AT04-AT06 is replaced by the AE01-AE03 extraction package following the lower pass configuration. There should be no changes in element count on these girders per se, except that the extraction channel (YB-BP-BQ) should be complemented by 2 BPMs as the lower passes. Furthermore we recommend 3 more girders complemented with quads, correctors and BPMs after the BQ, to allow transport matching in the spirit of the lower pass transport Recombiners. The required hardware is summarized in Table 5.

Table 5: 4th & 5th pass Extraction Regions

Component	*#*
H/V Corrector Pairs: MBD	2 x 3 (6 total)
BPM	5
Viewers	2

Note that, although not part of the instrumentation list, in addition it is recommended that 3 quadrupole magnets (QR) be added after BQ in the 5th pass to allow transport matching. Also note that the three 5th pass extraction quads (AE01-AE03) need to be double QC quadrupole magnets.