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Diagnostic Specifications for the 12 GeV Upgrade

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Abstract

Specifications for the beam diagnostic equipment required for the 12 GeV design are presented. The specifications presented make use of design studies of the 4 GeV CEBAF, operational experience with 6 GeV CEBAF and simulations of the 12 GeV design. The scope of this paper is to verify that the present diagnostic designs meet all specifications for 12 GeV design; specifically the to be built ArcA and Hall-D transport.

	Linac Style	Transport Style
Operating Current Range	700 nA - 2 mA	70nA - 200 μA
Nominal Measuring rate	$\geq$1 Hz	$\geq$ 1 Hz
Beam position range	$\|x\|, \|y\| \leq 5$ mm	$\|x\|, \|y\| \leq 5$ mm
Resolution	100 μm	100 μm
Maximum Measurement rate	$\geq$114 kS/s	$\geq$7.1 kS/s

Table 1: Specifications for BPM SEE style electronics.

	nA Cavity
Operating Current Range	1 nA - 1 μA
Nominal Measuring rate	$\geq$1 Hz
Beam position range	$\|x\|, \|y\| \leq 5$ mm
Resolution	100 μm @ 1nA CW
Maximum Measurement rate	$\geq$ 1 Hz

Table 2: Specifications for nA BPM cavities.

1 Beam Position Monitors (BPM)

There are two types of BPMs (antenna and cavity) in the CEBAF machine. For the antenna BPMS there are several types of electronics, linac and transport switched electrode electronics (SEE) and four channel (4CHAN) electronics. The SEE and 4CHAN electronics are used on antenna pick-ups and represent the majority of the BPMs in the 12 GeV machine. The nA BPM electronics are used for the cavity BPMs that will be located in the Hall-D line. These nA BPM, as the name suggest, measure beam position at very low beam currents.

1.1 SEE style BPM electronics

In the 12 GeV machine, all antenna electronics except non-lock antenna BPMs in the east Arcs shall meet or exceed the SEE specifications. The new ArcA and Hall-D transport lines will be SEE transport style electronics. The SEE specifications are in Table 1.

1.2 nA BPM cavities

Hall-D will at times require beam currents that are below the sensitivity of the SEE BPM electronics. This is a similar situation to the present 6 GEV Hall-B experiment. For Hall-B special cavity style BPMs were developed and installed at three locations near the end of the transport line for final control of the beam trajectory on the experimental target. For Hall-D two cavity style BPMs will be installed upstream of the Hall-D radiator target. These cavity BPMs shall meet or exceed the nA BPM specifications (Table 2).

	Nominal Harp	PMT Harp
Operating Current Range	5-20 μA (pulsed)	1 nA - 5 μA (CW)
Spatial Resolution	25 μm	25 μm
Relative position accuracy	50 μm	50 μm
Transverse width range	25 μm $< \sigma_{x,y} <$ 2.5 mm	25 μm $< \sigma_{x,y} <$ 2.5 mm

Table 3: Specifications for wire scanners.

2 Beam Profile Monitors

Measurement of the beam profile provides information on the transverse phase space of the electron beam. In addition to verifying that the beam size meets the users requirements, beam profiles are also used to measure the beam emittance, energy spread and for beam matching. The measurement of the transverse beam profile in 6 GeV CEBAF is done with wire scanners (called harps), optical transition monitors (OTR), synchrotron light monitors (SLM) and synchrotron light interferometers (SLI). The range of devices is a result of a range of operating conditions, beam current, invasive vs non-invasive, and beam size.

2.1 Wire Scanners (harps)

The wire scanners are instrumented in two styles, measurement of the secondary electron emission current induced on the wire (nominal Harp) and measurement of the scattered electrons with photomultiplier tubes (PMT harp). The two styles of harps cover different current ranges, with the PMT harp being best suited for Hall-D. For measurement of beam size on target, emittance measurements and beam matching the requirements (satisfied by the wire scanners) in Table 3 are needed:

2.2 Synchrotron Light Monitors (SLM)

When the electron beam is bent by magnetic field it radiates energy. Some of this energy is in the optical portion of the spectrum and this makes for a convenient diagnostic. If the location of observation happens to be a dispersive location, the width of the imaged light provides a measurement of the energy spread. There are additional SLM locations in the 12 GeV design, ArcA and Hall-D. In these locations $dp/p \geq 2 \times 10^{-4}$ and dispersion will be $\geq$1 m. This implies that a beam size of $\geq$200 μm and to measure dp/p to 10% require resolution of $\geq$ 20 μm, easily obtainable with standard CCD cameras and optics.

3 Beam Viewer Monitors

Beam viewers are mainly used for qualitative information. The viewer system provides a robust last resort check of the beam location and beam size (full width at base). The requirements for the

	Viewer
Operating Current Range	1 - 10 μA, 1 - 10 μsec pulse, @ 60Hz
Resolution	50 μm
Transverse width range	Full width at base $<$ 20 mm

Table 4: Specifications for beam viewers.

viewer system are listed in Table 4.

3.1 Beam Dump Viewers

In addition to the pulsed beam viewers, each beam dump must have viewer upstream to the entrance of the dump. This viewer is to be permanently located on the beam and capable of withstanding the CW beam current at the maximum allowed. The purpose of this final viewer is to provide a visual confirmation that the beam is incident on the beam dump. For Hall-D, the maximum beam current is 5 μA and a thin (100 μm) ceramic viewer is adequate.

4 Pathlength Monitors

The purpose of the pathlength monitors is to assure that the co-propagating beams in the linacs all have the same arrival time. For 12 GeV beam delivery the energy spread will be an order of magnitude larger then presently delivered with 6 GeV CEBAF. However there are 12 GeV experiments that require $dp/p \leq 3\times10^{-5}$ for beam energies less than 3 GeV. For these experiments, the 12 GeV pathlength monitor system must maintain the same capability as 6 GeV system. The requirement is a pathlength resolution of 0.25° of phase at 1497 GHz. This is accomplished by measuring the phase difference, with pulsed beam, between the beam signal and a reference. The beam signal is sourced from cavities at the end of each linac.

5 Summary

Beam diagnostic requirements for the 12 GeV upgrade have been specified. The core difference between 6 GeV and 12 GeV CEBAF are the effects of synchrotron radiation in the higher arcs. This will result in larger beam sizes and energy spread on the upper passes. These changes are not significant enough to alter the diagnostic requirements. The diagnostics locations can be found in the DIMAD decks [2].

6 Appendix I: ArcA Diagnostics

Table 5 updates the diagnostic requirement list for the tenth spreader, arc and recombiner line. In addition to those items in the table, the line also includes an insert-able dump at the R02 location of the recombiner. This table supersedes the information contained in [1].

BPM	Viewers	Profile Monitors
IPMAS02	ITVAS02	
IPMAS03		
IPMAS04	ITVAS04	
IPMAS05		
IPMAS06		
IPMAS07		
IPMAS08		
IPMAS09		
IPMAS10		
IPMAE01		IHAAE01
IPMAE02	ITVAE02	
IPMAE03		
IPMAA01		
IPMAA02	ITVAA02	
IPMAA03		
IPMAA04		
IPMAA05		
IPMAA06		
IPMAA07		
IPMAA08		
IPMAA09	ITVAA09	
IPMAA10		
IPMAA11		
IPMAA13		
IPMAA15		
IPMAA16		
IPMAA17	ITVAA17	
IPMAA18		
IPMAA19		
IPMAA21		
IPMAA23		
IPMAA24		
IPMAA25	ITVAA25	

BPM	Viewers	Profile Monitors
IPMAA26		
IPMAA27		
IPMAA29	ISRAA29	
IPMAA31		
IPMAA32		
IPMAR01	ITVAR01	
IPMAR02		
IPMAR03		
IPMAR04		
	ITVAR05	
IPMAR06		
IPMAR08		
IPMAR09		
totals: 46	9(ITV)/1(ISR)	1

Table 5: Diagnostics location (using accepted CEBAF nomenclature) for ArcA.

7 Appendix II: Hall-D Diagnostics

Table 6 updates the diagnostic requirement list for the Hall-D extraction, transfer and Hall-D line. In addition to the those items in the table, the line will also include a beam current monitor (BCM) and low power insert-able dump. This table supersedes the information contained in [1].

References

[1] J.F. Benesch, A. Bogacz, A. Freyberger, Y. Chao, M. Spata, M. Tiefenback, "Beam diagnostics and transport magnet requirements for the ARC10 and Hall-D beamlines", JLAB-TN-05-053.

[2] J. Benesch, A. Bogacz, Y. Chao, A. Freyberger, Y. Roblin, C. Tennant, "12 GeV DIMAD Decks" JLAB-TN-07-032.

BPM	Viewers	Profile Monitors
IPMBS01		
IPMBS02		
IPMBS03		
IPMBE01	ITVBE01	IHABE01
IPMBE02		
IPMBE03		
IPMBE04		
IPMBT01		
IPMBT02		
IPMBT03		
IPMBT04		
IPM5C00	ITV5C00	
	ISR5C00	
IPM5C01		
IPM5C02	ITV5C02	IHA5C02
IPM5C03		
IPM5C04		
IPM5C05		
IPM5C06	ITV5C06	IHA5C06
IPM5C07		
IPM5C08		
IPM5C09		
IPM5C10		
	ISR5C00	
IPM5C11	ITV5C11	
IPM5C12		
IPM5C13		
IPM5C14		
IPM5C14A		
IPM5C14B(cavity)		
IPM5C14C	ITV5C14	IHA5C14
IPM5C14D(cavity)		
IPMD100	ITVD100	
totals: 29(antenna)/2(cavity)	7(ITV)/2(ISR)	4(IHA)

Table 6: Diagnostics location (using accepted CEBAF nomenclature) for Hall-D.