Comparison between CEBAF and neutrino factory recurculating linacs

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Table 1:

Parameter	CEBAF	Neutrino Factory
gamma	90-8000	20-200
dp/p	1.e-3 at injection	6.e-2 at injection
	2.e-5 at full energy	2.e-2 at full energy
dispersion	6 m peaks in arcs 1/2	~ 1 m peaks
	2.5 m peaks in arcs 3-9	
peak current	peak 200 uA	~ 1 A
avg current	(;^)	~ 5 uA
beam size	1 mm to 0.2 mm	700 mm to 200 mm
$\eta \cdot \frac{dp}{p}$	0.6 mm to 0.2 mm	40 mm to 20 mm

Common issues (what we all have to do):

- Setup
- Operation
- Diagnostics and performance monitoring

Linac “features”:

- Static magnets (drift susceptibility for optics)
- Open-ended system (beam envelope hard to gauge with bpms)

Systems:

Hardware monitoring

- Magnet stability (static magnetic field hard to verify)
- AC grid transients (can silently foul up magnets)
- magnetic and optics shifts (droop in B field)
- RF troubleshooting phase and gradient monitoring

Beam-related signals

BPM’s

- in arcs (beam positions and energies)
- multipass beam in linacs (setup)

Modulate beam steering or linac energy gain

- measure transfer functions for transverse tuning
- measure transfer functions for dispersion tuning

Modulate linac phase and measure multipass beam energies

- measure beam-RF phase
- measure multipass RF/beam phase shifts
- measure bunch length (extension of CEBAF tool)

OTR or viewers

- Distinguish between linacs for RF or other problems

Tuning modes:

Initial setup

- orbit control
- energy gain
- RF phase checkout
- bunch length and energy spread
- dispersion
- optics transfer functions
- M_56 tuning
- Aperture verification
- beam spot on target (wire scanner, aka “harp”)

Normal running

- current balance & loss monitoring
- beam energy monitoring
- feedback stabilization
- beam orbit monitoring

Tools for special purposes:

Difficulties in most of the bpm-based measurements are caused by unanticipated beam scraping/loss

Injector beam envelope matching to linacs

Multiple wire scanners along beamline section
Fit envelope moments to measured profiles

Envelope Control in main accelerator

Differential orbit measurement of transfer functions
Tune selected quadrupoles to “fix” transfer functions
Pulsed mode only, interrupts beam delivery to users
Cross-plane (x-y) coupling
    Complicates interpretation of measurements
    Better at CEBAF after nulling coupling

Global beam transfer function monitor

Being developed for global optics at CEBAF
Probably good to have for neutrino factory

Envelope Control at destination

- Wire Scanner (“harp”) measurement of beam envelope
- High-resolution viewers being implemented to speed tuning

Global linac RF phase

- Phase modulation coupled with bpm measurements
- Resolution at micron level with lock-in amplifier
- detection of 0.05 degree phase drifts of RF/beam

Path length

- Beam-excited RF cavity phase detection for multiple pass arrival phase
- Provides reliable relative timing monitoring

Higher arc detection as for global RF phase

- Expect 0.1 degree practical resolution
- practical in CW and for on-line tuning

M_56 control (path vs. energy)

- Sense beam timing vs. RF reference with diagnostic cavity
- Mix to DC and use as phase sensor
- Tune longitudinal transfer functions with selected quads
- At CEBAF this has never been fingered as a problem

Dispersion

- Currently checked only in pulsed mode
- Interrupts beam delivery to users

Aperture verification

- steer to scraping thresholds to verify clearances

Beam loss measurements

- Local loss monitors at vulnerable points (PMT-based)
- Global current balance monitors at injection/extraction
    - Detection reliability 1-2 uA

Beam energy fluctuations (RF trouble detection)

- Synchrotron light monitors
- Optical Transition Radiation viewers
- BPM fluctuations (RMS of discrete samples)

Aspects for neutrino factory

- Large beam size
- Beam scraping is guaranteed
- Beam envelope control is critical to maximizing throughput

Muons

- Synch light not readily available as low-energy diagnostic
- electron background may be troublesome
- OTR viewers should work throughout recirculating linacs

Hardware monitoring:

Magnets

- Magnets are set to static values for many days (weeks?)
- Monitoring is done digitally and misses transients
- AC grid transients cause fluctuations
- Troubles can be missed because of
  - CPU overload on monitoring computers
  - intermittent monitoring (1 Hz)

Recommendations

- analog latching current monitoring
- AC grid monitoring at all substations

RF

- RF modules at CEBAF keep no data history
  - next generation will do this
- Beam loading transients occur when beam trips off
- Transients obscure diagnosis of which system faulted
- Beam-based monitor can show which linac is flickering