**12 GeV CEBAF Injector System Requirements Document**

**What are the performance parameters which the system must satisfy and what are the means of verification**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Parameter** | **Nominal value and range** | **Verification technique[[1]](#footnote-1)** | **Stability** | **Settability[[2]](#footnote-2)** | **Justification** |
| **Energy** | 123MeV (22.5 MeV to 130 MeV) | S: at 45 MeV spec­trometer and/or chi­cane | within limit | < 0.1% | Design |
| **E** | < 5.6 ⋅ 10-3 MeV | S: at 5 MeV spec­trometer and/or chi­cane and end of N. Linac, M: same | < 10% | < 10% | Budgeted to injec­tor to meet final energy requirement **\*** |
| **Maximum total current** | 85A CW  (0 – 380 A) | S: Faraday cup, M: BCM | < 0.2 A | <5% | PSS (900kW site limit) **\***  (Linac beam load­ing?) |
| **Current per bunch train** | 85A CW (1A) | S: Faraday cup, M: BCM after BSY; Feedback from halls for final set | < 0.2 A total  3% Long term  1% short term | <5% | Limitation is the beam dynamics and demand from the halls **\*** |
| **Pulse mode capa­bility** | < 1 A average,  200 A peak, (1-10sec for viewer, 250+4 sec for pulse) | S: Faraday cup, M: BCM | < 0.2 A | < 5% | Low average cur­rent is safe for set up. |
|  |  |  |  |  |  |
| **Current modula­tion capability** | TBD |  |  |  |  |
| **Phase stability w.r.t.**  **Master oscillator** | < 0.1 degree |  |  |  | Correlated error contributing to final energy spread |
| **trans (norm rms)** | 0.25 ⋅ 10-6 m⋅rad | S: Use QD0l06 and Harp at 0L10, M: assume unchanged if x, y constant | < 10% | < 20% | Emittance Budget |
| **Bunch length ()** | < 0.27 degree @ 1.497 GHz | S: Yao cavity in front of north linac, M: same | < 10% | < 10% | Budgeted to meet final energy spread req. **\***(keeps us honest) |
| **x @0L10** |  | S: Harp, M: period­ically measure with harp | < 5% | < 10% | Monitored parame­ter showing changes in beam parameters |
| **y @0L10** |  | same as x | < 5% | < 10% | “ “ “ |
| **x @ QD0L06** | 10m to 25m | same astrans | < 10% | < 10% | Match to the north linac, Emittance degradation < 10% |
| **y @ QD0L06** | 25m to 50m | same astrans | < 10% | < 10% | “ “ “ |
| **x @ QD0L06** | 0 to 2 | same astrans | < 0.1 | < 0.1 | “ “ “ |
| **y @ QD0L06** | -3 to 0 | same astrans | < 0.1 | < 0.1 | “ “ “ |
| **Dispersion (x, y)** | 0 | BPM after injec­tion chicane | < 10 cm | < 10 cm | “ “ “ |
| **Position (x, y)** | 0 mm | BPM at end of injector | < 10% of spot size | < 50% of spot size | 10% Emittance dilution, can be relaxed w/ feedback |
| **Angle (x’, y’)** | 0 mrad | 2 BPMs at end of injector | < 10% of beam divergence | < 50% of beam  divergence | 10% Emittance dilution |

**Injector subsystems requirements:**

**List of subsystems**

1. Gun
2. 15 degree bend, Wiens, and Emittance defining region
3. Pre-buncher
4. Chopper system
5. Buncher
6. Capture section
7. 1/4 cryo unit
8. Cryomodules
9. Beam transport
10. Control software applications
11. Vacuum
12. Diagnostics & beam instrumentation

**A. polarized Gun**

1. Purpose and scope of the system

Produce polarized electron beam for three halls each at 499 MHz and variable currents. The subsystem includes the Gun hardware and gun software

2. Input assumptions

Low level RF to drive the lasers

3. Output parameters

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Parameter | Nominal value and range | Verification tech­nique | Stability | Settability | Justification |
| Gun voltage | 200 keV | Measured with H.V. probe on cathode | < 10 eV | < 10 eV | phase jitter and bunch length change < 0.1 degree |
| Current | TBD (500 A) | Faraday cup | < 2 A | < 0.5% | Sufficient current to generate current req. |
| Current slew rate | < 6mA/sec, max step size 10 A | Faraday cup, time resolution 600 Hz |  |  | To limit the gradient change in RF cavities |
| Pulse mode capabil­ity | < 1 A avg for tuning and up to 300 A peak | Faraday cup | < 0.5% | < 0.5% | Set up  **\***present capability ok |
| Pulse structure for linac BPM’s | 1. 250sec followed by 4 sec @60hz 2. 0% to 100% duty factor |  |  |  | For pulse and diag.  For variable pulse mode  **\***present capability ok |
| Pulse Viewer limit | 0.05-1A avg, 1-10sec |  |  |  | **\*** |
| Beam Frequency | 3 beams each @499 | **\* ?** | **\*** | **\*** | To add up to 1497 MHz, main RF freq. |
| Beam phase for each Beam | 120 degree of 499M apart from the other beams | In the Choppers | < 0.16 degrees rms | < 0.16 degrees rms | bunch length  varia­tion<10% |
| Laser pulse width | 30ps(10-100ps) |  |  |  | Beam dynamics |
| Laser spot size, FWHM | 0.5mm (0.5-2.5mm) |  |  |  | Beam dynamics |

4. Other requirements

1. Limit the beam current in “low power mode” to1 A average and 200A peak after the chopper.
2. Limit the beam power delivered to the beam dump to dump’s capacity
3. Ability to change the cathode without contaminating the vac­uum

5. Interfaces to other systems

a) FSD system

b) Personnel safety system

c) Interlock

**\***Gun req. not complete

**B. 15 degree bend, Wiens, and Emittance defining region**

1. Purpose and scope of the system

Defines the dc electron beam emittance and bends the beam from the output of the gun to the direction of the main beam line. It includes elements between the gun and the chopper system plus software.

2. Input assumptions

Output of the gun subsystem

3. Output parameters

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Parameter | Nominal value and range | Verification tech­nique | Stability | Settability | Justification |
| Current | TBD to 500 A DC past A2 | Faraday cup | < 1%**\*** | < 0.5% | Sufficient current to produce post chop­per current req. |
| trans (norm rms) | <0.1 mm.mrad**\*** | Defined by apertures | NA | NA | Beam halo removed, emittance limit defined |
| Position (x,y) | 0 mm | Chopper aperture central hole. | < 10m | < 10m | 10% change in bunch length**\*** |

4. Other requirements

a) Fields of the 15 degree bend magnet and Wiens should be: stable to 1% (**\***beam loss and bunch length con­sideration needs simulation) resettable toTBD% able to be zeroed to within TBD gauss.

**C. Pre-buncher**

(**\***RF field strength needs to at most increase by 30% from present 130 keV. Need to finish simulations)

**D. Chopper System**

1. Purpose and scope of the system

The subharmonic chopper system provides rf structure to three interspersed bunch trains with independently controlled current. It includes two chopping cavities, solenoids, chopping apertures and viewer, electronics, and software

2. Input assumptions

Output of the emittance defining subsystem

3. Output parameters

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Parameter | Nominal value and range | Verification tech­nique | Stability | Settability | Justification |
| Beam Energy | 200 keV | Measured at 500 keV spectrometer |  |  |  |
| Maximum total cur­rent (3 beams) | 500A |  | < 0.2 A |  | RF power limit.. |
| Current per bunch train | 1 A CW or off to 200 A CW | Faraday cup | < 0.2 A | < 5% |  |
| Bunch length | 110ps |  |  |  | Beam dynamics after the choppers |
| Energy spread | < 3%, lower better |  |  |  | Beam transport through the choppers |
| Chopper 1 field amplitude | 0.15 MV/m (50% more than 100keV) | S: beam circle @ chop screen  M: Control module | < 2% | < 2 | phase jitter < 0.1 degree |
| Chopper 1 phase w.r.t. M. O. | will be the reference |  | 0.5 degree | 0.5 degree | bunch length varia­tion<10% |
| Chopper 1 phase x vs. y | setup value | S: beam circle @ chop screen  M: Control module | 0.7 degree | 0.7 degree |  function<0.1  function var.<10% |
| Chopper 2 x(y) field amplitude | 0.15 MV/m (50% more than 100keV) | S: screen after chop 2  M: control module | < 2 | < 2% |  function<0.1 |
| Chopper 2 x(y) phase w.r.t. M.O. | setup value | S: screen after chop 2  M: control module | 0.5 degree | 0.5 degree | bunch length varia­tion<10% |

**E. Buncher**

1. Purpose and scope of the system

Purpose is to prebunch the beam. It includes buncher cavity, rf controls, and software.

2. Input assumptions

Output of the chopper subsystem

3. Output parameters

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Parameter | Nominal value and range | Verification tech­nique | Stability | Settability | Justification |
| Beam Energy | 200 keV | Measured at 500 keV spectrometer | within limit | < 0.1% |  |
| Field amplitude (peak) | 0.21 MV/m  (15-30 MV/m)**\*** | S: 500 keV spectrom­eter  M: bunch length, Control module | < 6.25⋅ 10-3 | < 6.25⋅ 10-3 | Bunch length change <10%, energy spread <10% |
| Phase w.r.t. M. O. | Setup value (-87 deg.) | S: 500 keV spectrom­eter  M: bunch length cav­ity | 0.16 degree | 0.16 degree | phase jitter <0.1 degree |

**F. Capture**

**Capture is turned off in the new configuration only to be used in an alternative setup if needed!**

1. Purpose and scope of the system

To accelerate the beam to 0.5 MeV, and provide more bunching to the beam.

2. Input assumptions

Output of the buncher subsystem

3. Output parameters

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Parameter | Nominal value and range | Verification tech­nique | Stability | Settability | Justification |
| Beam Energy | 538 keV | Measured at 500 keV spectrometer | within limit | < 0.1% |  |
| Bunch length () | < 2.1 degrees | M: Bunch length cav­ity | < 10% | < 10% |  |
| Field amplitude | 1.24 MV/m | S: 500 keV spectrom­eter  M: bunch length, Control module | < 3.1⋅ 10-4 | < 3.1⋅ 10-4 | phase jitter <0.1 degree |
| Phase w.r.t. M. O. | setup value | S: 500 keV spectrom­eter  M: bunch length cav­ity | 0.15 degree | 0.15 degree | energy spread <10% |

4. Other requirements

a) The cavity temperature should be stable to 1oC at all times (even when rf is off).

**G. Cryounit**

1. Purpose and scope of the system

The purpose of the subsystem is to complete the longitudinal bunching and accelerate the beam to 5 MeV. It includes the cryounit, rf controls, and software.

2. Input assumptions

Output of the capture sectionsubsystem

3. Output parameters

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Parameter | Nominal value and range | Verification tech­nique | Stability | Settability | Justification |
| Beam Energy  (end of 2 cell cavity  and end of 7 cell cavity) | 0.553 MeV  and 4.812 MeV | S: Harp in 5MeV spect.  M: BPM @ same | within limit | < 0.1% |  |
| E | < 5.0 keV**\*** | S: Harp in 5MeV spect.  M: BPM @ same | < 10% | < 10% | Measurement for all of injector at this point |
| Bunch length () | < 0.27 degrees | Bunch length cavity | within the 0.27 degree limit | with in the limit | Energy spread req. |
| Field amplitude in the 2-cell cavity (peak) | 4.6 MV/m (2-8 MV/m) |  | < 7.8⋅ 10-4 | < 7.8⋅ 10-4 | phase jitter <0.1 degree |
| Q0 for 2-cell cavity | 8e9 |  |  |  |  |
| Qext for 2-cell cavity | 6 e6 |  |  |  | Design for 1 mA |
| QHOM for 2-cell cavity | < 1e8 |  |  |  |  |
| Phase w.r.t. M. O. the 2-cell cavity | Setup value (-17 deg.) |  | 0.25 degree | 0.5 degree | phase jitter <0.1 degree |
| Rf kick due to 2-cell cavity FPC | < 1e-3 radiant |  |  |  | To avoid x/y distortion, the beam should be less than 0.5 mm away from the axis at the entrance of the 7-cell cavity. |
| Field amplitude 7-cell cavity (peak) | 13.2 MV/m  (8-26 MV/m) |  | < 10-3 | <10-3 | phase jitter <0.1 degree |
| Phase w.r.t. M. O. the  7-cell cavity | Setup value (-15 deg.) |  | 0.625 degree | 0.625 degree | phase jitter <0.1 degree |
| Q0 for 7-cell cavity | 8e9 |  |  |  |  |
| Qext for 7-cell cavity | 9e6 |  |  |  | Design for 1 mA, add stub tuners for 380A |
| QHOM for 7-cell cavity | < 1e8 |  |  |  |  |
| Rf kick due to 7-cell cavity FPC | < 2e-3 radiant |  |  |  | To keep the beam displacement at less than 1 mm at the first corrector after the unit (~0.5m away). |

**H. Cryomodules**

1. Purpose and scope of the system:

To accelerate the beam to the final injection energy. It includes IN03 and IN04 modules, rf controls, and software

2. First module should maintain average accelerating gradient of at least 7.5 MV/m with accept­able rf heat load.

3. Second module (C100) should maintain average accelerating gradient of at least 20 MV/m with accept­able rf heat load (250 cavity, 50 shield).

**\* (Need to determine who goes on first and what goes on second, IN03 or IN04. Putting the old style cryomodule at higher energy may reduce the x/y coupling but putting the high gradient C100 at lower energy may increase the RF focusing in the module, needs more study)**

**I. Beam transport system**

1. purpose and scope of the system

Transports a well steered, well focused beam through the injector. It includes the steering magnets, focusing magnets, injector chicane, and the software.

2. Input assumptions

None

3. Output parameters: Deliver beam to different elements through the injec­tor as specified in the requirement.

4. Existing optical components satisfy requirements

5. Place the BPMs at different betatron phases.

**K. Control Software Applications**

a) Autosteering

b) Autophasing**\***this could help in 5 MeV

c) Beam parameter monitoring software

d)

**J. Vacuum**

**K. Diagnostics & Beam Instrumentation**

**L. Position of BPMs**

**The star (\*) shows the fields that I am not sure about or need more research to answer. (Reza 5/9/2011)**

1. “Verification” means both initial setup and periodic monitoring of the parameter where different. Include “destructive” and “nondestructive” in the description. Use abbreviations “S:” for set-up, “M:” for periodic monitoring, “F:” for the frequency of monitoring. [↑](#footnote-ref-1)
2. “Settability” means how well the parameter is reproduced at turn-on without adjustment to set points. Provide both short-term and long-term where dif­ferent. State if a feed-back system is used to obtain the parameter. [↑](#footnote-ref-2)