

Progress Report

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<http://www-bd.fnal.gov/pdriver/booster/>

General

- A Booster parameter list has been compiled.
- A web site has been set up.
- All the talks, references, measurements, simulations, etc. are or will be on the web.

1. Space Charge Simulation Using ORBIT

- Can do now:
 - Tune footprint as a function of beam intensity, working point, orbit bump, etc.
 - Emittance growth as a function of beam intensity, working point, orbit bump, etc.
 - Turn-by-turn emittance growth
 - Multi-turn injection
 - Stationary RF
- Need make to work:
 - 2nd order transfer matrices (sextupoles)
 - RF acceleration
 - Impedance
 - Magnet errors
- Will do comparison with **SYNERGIA** in simple cases

2. Machine Modeling Using MAD

- Almost all the optical elements are in the model (main magnets, steering magnets, correction quads and skew quads, chromaticity and harmonic sextupoles, octupoles, orbit bump, dogleg, etc.), with the exception of the septum.
- Jim (L.) has provided the dogleg field data.
- Jim has provided the orbit bump magnet field data and current waveform.
- Jim (L.) has provided the current-strength conversion data of all the correction elements (dipoles, quads, sextupoles, octupoles).
- Ray (T.) has provided the chromaticity measurement data, with and without chromaticity sextupoles.
- Need:
 - Alignment error
 - Body and field sextupole data (E4R)
- E4R work is waiting for power connection

3. Beam Measurements

- A list of required measurements has been drafted and posted on the web.
- Booster Dept. has designated a liason (Milorad) and a machine coordinator (Eric) for this study.
- Lots of data are available. Ray will give a summary.
- New measurements (machine acceptance, lattice function, stop band, quadrupole moment, etc.) are being planned or carried out.

4. Hardware Development

- Ready to go:
 - Inductive inserts:
 - 7 modules have been made (D. Wildman)
 - Impedance has been measured (Chris Beltran, LANL)
 - Stands will be improved
- Can be done if get blessing from the division:
 - IPM conversion (J. Zagel)
 - Quadrupole pickup (A. Jansson)
- In conceptual stage:
 - Laser profile monitor (LPM, X. Yang)

Fermilab Booster Parameters (December 5, 2002)

Circumference (m)	474.2
Average machine radius (m)	75.47
Injection/Extraction kinetic energy (GeV)	0.4, 8
Repetition rate (Hz)	15
RF frequency (MHz)	37.87 – 52.81
Harmonic number	84
Protons per bunch	6×10^{10}
Protons per cycle	5×10^{12}
Protons per second*	2.5×10^{13}
Protons per hour*	9×10^{16}
Average beam current* (μA)	4
Average beam power* (kW)	32
Lattice	FOFODODO
Super-periodicity	24
Cell length (m)	19.758
Length of combined function magnet (m)	2.889612
Magnet per cell	4
Magnet total	96
Number of straight sections	24 Long, 24 Short, 48 Mini
Length of each straight section (m)	6(Long), 1.2(Short), .5 (Mini)
Max/Min β_x (m)	33.67 (Short)/6.12 (Long)
Max/Min β_y (m)	20.46 (Long)/5.27 (Short)
Max/Min D_x (m)	3.19 (Long)/1.84 (Short)
Phase advance per cell φ_x, φ_y (degree)	100.5, 102
Horizontal, vertical tune ν_x, ν_y	6.7, 6.8
Natural chromaticity ξ_x, ξ_y	-9.2, -7.0
Transition γ_t	5.45
Transition momentum (GeV/c)	5.03
Transition crossing moment (ms)	17
β at injection, extraction	0.713, 0.994
γ at injection, extraction	1.426, 9.526
$ \eta $ at injection, extraction	0.458, 0.0227
Revolution frequency at injection, extraction (kHz)	450.8, 628.7
Revolution time at injection, extraction (μs)	2.22, 1.59
Injection turns (typical)	11
Injection time (typical, μs)	24.4
Injection linac peak current (typical, mA)	40
Maximum Laslett tune shift	0.4
Normalized transverse emittance ε_N (95%, mm-mrad)	12π
Longitudinal emittance (95%, eV-s)	0.1

* MiniBooNE continuous operation at 5 Hz.

Booster Beam Study Plan

(Revised, 12/09/02)

Schedule: A and B to be implemented in the next 6 months; C to be determined.

Simulations: ORBIT – Francois, Leo, Weiren
SYNERGIA – Panagiotis, Jim (A.)
MAD – Sasha, Norm, Weiren

Beam study: (see names in each item)

A. Measurements:

a) Parasitic measurements:

1. Longitudinal emittance and profile:

- At injection:
 - Panagiotis and Jim (A.) measured the first 8 turns using the 6-GHz wall current monitor in L18. Data are posted on the web.
 - In the 400 MeV line upstream from the Debuncher, there is a "Griffin" pickup (made of striplines) that can be used for this measurement. But one may need to add 3 more cables to it. Ray will do it.
- At top energy:
 - In the ring: Ray, Bill (P.), Francois, Weiren.
 - In the MI-8 line: There is also a 6-GHz pickup. Need help from Bill (P.) to use it.
- Turn-by-turn:
 - To be planned when simulation results (ORBIT and/or SYNERGIA) are available.

2. Transverse emittance and profile:

- At injection:

- Panagiotis and Jim (A.) measured the first 30 turns using the flying beam method. (The injection orbit bump pulse length limits the measurable number of turns.)
 - This is for horizontal plane only.
 - They also have the data of the 400 MeV line using multi-wire.
 - Ray has tried to use the collimator to measure the vertical plane.
 - Data will be available on the web.
 - At top energy:
 - Panagiotis and Jim (A.) are measuring it using IPM.
 - They also have the data of the MI-8 line using multi-wire.
 - Data will be available on the web.
 - IPM calibration:
 - By comparing the IPM raw data with the multi-wire data, Panagiotis and Jim (A.) found the IPM data is about 30% larger at both injection and top energy.
 - Turn-by-turn:
 - To be planned when simulation results (ORBIT and/or SYNERGIA) are available.
3. Beam position:
- At injection:
 - The regular BPM cannot take data until after about 50 turns.
 - One can try the IPM in the first 50 turns.
 - Three BPMs - S24, DSL1 and S1 - can measure the orbit in the first 50 turns, provided that only 1-turn injection is used. (They have the 200 MHz electronics.)
 - Jim (L.), Ray, Francois, Weiren.

- Turn-by-turn
 - Data to be compared with simulation (MAD), which includes alignment and field errors.
- 4. Tune during ramp:
 - Ray did it using a vertical pinger fired at 2 kHz, i.e., every 0.5 ms. (The horizontal tune is also measurable due to coupling.)
 - Data will be posted on the web and compared with simulation (ORBIT), which includes space charge tune shift.
- 5. Chromaticity during ramp:
 - Ray did it also with the vertical pinger.
 - Data will be posted on the web and compared with simulation (MAD), which includes magnet sextupoles (measured by the TD) and correction sextupoles.
- 6. Quadrupole moment:
 - Jim (L.) used the BPM in L4 and S4 for this measurement, because the cables of the two BPM were measured to the nanosecond accuracy.
 - Measurement will be redone and data need to be understood.
 - Jim (L.), Francois, Weiren, Andreas.
- 7. Emittance dilution due to foil scattering:
 - Carol did it for the 200 MeV linac and 200 $\mu\text{g}/\text{cm}^2$ foil and found 0.5% emittance dilution per hit.
 - Will redo it for the 400 MeV linac and 540 $\mu\text{g}/\text{cm}^2$ foil.
 - Jim (L.), Carol, Francois, Weiren.

b) Dedicated measurements:

Requests will be submitted to Eric, coordinator of the Booster study. There are two possibilities: one is during shot setup when the pbar production is on hold; another is when some

machine is down. But one may also request specific Booster study time when necessary.

1. Dependence of the above measurements on beam intensity and working point.
2. Varying tune ramp curve:
 - To be planned when simulation results (ORBIT) are available.
3. Varying chromaticity ramp curve:
 - To be planned when simulation results (MAD) are available.
4. Machine acceptance:
 - Longitudinal:
 - Linac beam energy can be varied and measured (by an energy meter) for this measurement.
 - 400 MeV line needs to be retuned.
 - Milorad, Elliott, Francois, Weiren.
 - Transverse:
 - There is an aperture scan program available based on 3-bump method.
 - Prefer to use "pencil beam" (in physical space by scraping) for this measurement, which can be obtained by scraping the beam in the 400 MeV line.
 - Jim (L.), Francois, Weiren.
5. Lattice function:
 - Shekhar (S.) did this but data got lost.
 - Milorad will try to find the program and redo it.
6. Stopband using "pencil beam" (in tune space):
 - Chuck (A.) did this in the '80s and also last year. It needs to be redone.
 - Eric has a program for coupling correction.
 - Chuck (A.), Ray, Eric, Francois, Weiren.

B. Experiments:

a) Inductive inserts:

- Dave (W.) has made 7 modules, 1-m long each.
- Installation location and date to be decided.
- Before installation: To measure the module impedance (Re and Im) as a function of frequency up to 200 MHz.
- After installation: To measure bunch spectrum and longitudinal quadrupole oscillation frequency.
- Dave (W.), Ray, Weiren.

b) Tune split:

- To be planned when simulation results (ORBIT) are available.

c) Injection orbit bump waveform:

- To be planned when simulation results (MAD) are available.
- Jim (L.) will provide current waveform and magnet field data.

C. Hardware development:

a) IPM modification:

- First step will be to relocate MI IPM clearing field power supply (30 kV) to the Booster.
- In the meantime, to start the design of converting IPM to electron collecting. The key element is permanent magnets, of which we probably need six (two large aperture ones for the IPMs, four small aperture ones for correction).
- Jim (Z.), Stephen (P.), Weiren.

b) Transverse quadrupole mode pickup :

- First we will use the L4/S4 BPMs (see item A a) 6).
- In the meantime, to have a feasibility study of fabricating an inductive pickup similar to the one at the CERN PS (to investigate the purpose, requirement, manpower, budget and schedule).
- Andreas, Jim (L.), Francois, Weiren.