

General information

The Fermilab Booster is a circular proton accelerator which was built 50 years ago and still is the cornerstone of the Fermilab accelerator complex. The original considerations that lead to its construction are outlined at

http://www.fnal.gov/pub/news04/update_archive/update_10-15.html

During its lifetime the Booster went through a number of important upgrades like increase in injection energy from 200MeV to 400MeV, increase in the number of RF cavities from original 16 to 22, installation of transverse feedback systems and many more. These upgrades allowed to achieve the beam intensity $4.5e12$ /pulse with acceptable losses at 15Hz operation.

The purpose of the on-going projects PIP+ and PIP2 is to increase the beam intensity first to $5.5e12$ and finally to $6.3e12$ ppp without increase in total losses. The major Booster parameters for present operation and future upgrade are given in Table 1.

Table 1. Present and tentative future Booster parameters

Parameter	Present	Future
Circumference (m)	474.2	
Injection kinetic energy (GeV)	0.4	0.8
Extraction kinetic energy (GeV)	8.0	
Repetition rate (Hz)	15	20
Beam intensity (ppp)	$4.5e12$	$6.3e12$
Normalized 95% transverse emittance (pi.mm.mrad)	7 (injected beam)	
Momentum spread at extraction (%)	0.1	
Bunch length at extraction (ns)	1	
RF harmonic number	84	
Transition gamma	5.45	
RF voltage (MV)	1.15	
Bare lattice betatron tunes	6.75 / 6.85	
Space charge transverse tuneshift @ injection energy	-0.25 / -0.31	

Booster layout

Useful and rather detailed description of the Booster can be found in the so-called Rookie Book via a link on page

http://operations.fnal.gov/rookie_books/rbooks.html

It gives a good general idea, about 90% of the information in it is correct, while the other 10% is already outdated.

The Booster ring is divided in 24 periods. Each period includes 4 combined function magnets: two defocusing magnets separated by a 6 m “long” straight section and two focusing magnets separated by a 1.2 m “short” straight section. Numbering of the lattice periods begins at the injection long straight, designated as “L1”. The long straights precede the correspondingly numbered short straights, the one downstream of L1 being labeled as “S1”. The straight sections contain correction magnets up to the octupole and other elements.

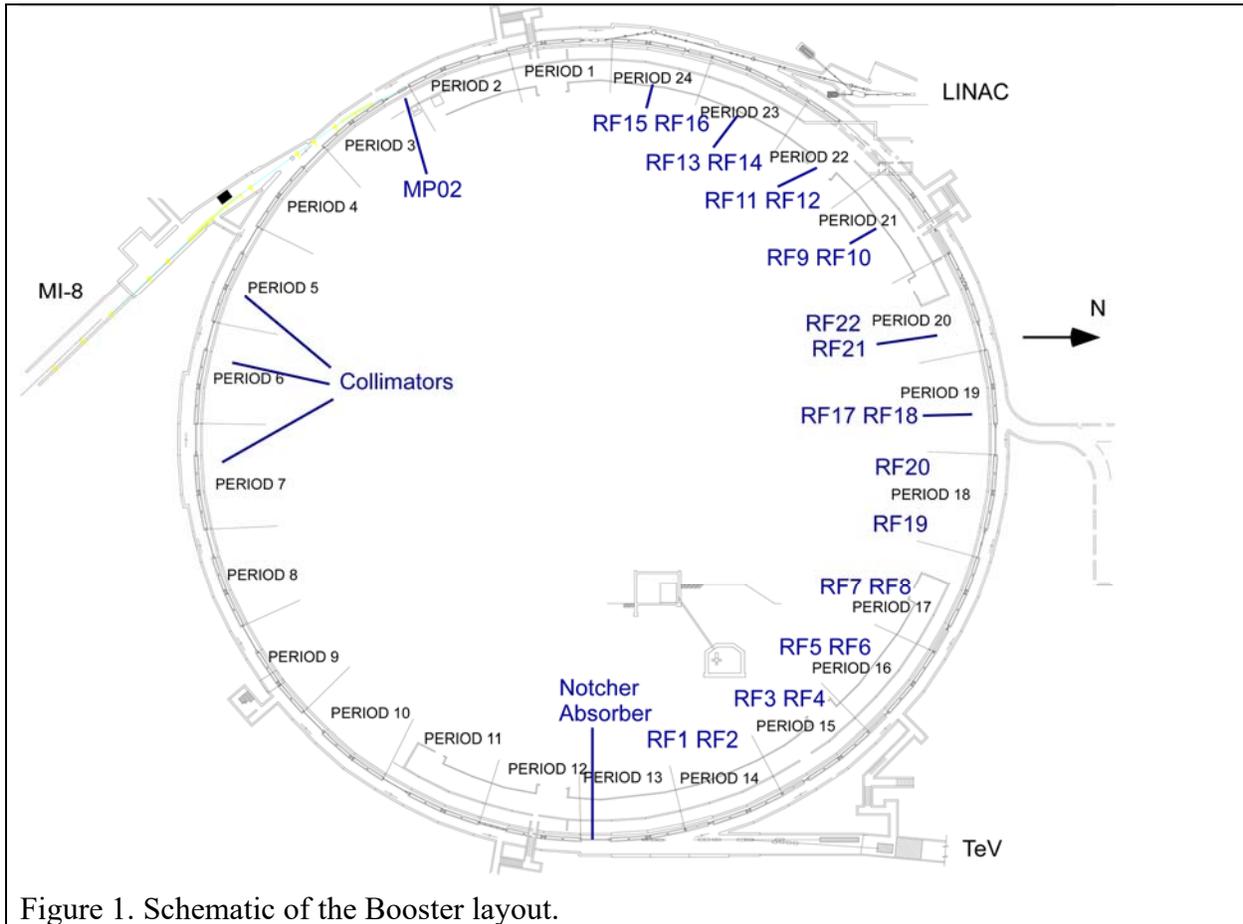


Figure 1. Schematic of the Booster layout.

Figure 1 shows the Booster layout with location of some devices indicated. The stripping foil for injection is located in L1 (close to 12 o’clock). During injection a horizontal “orbit bump” is turned on which shifts the closed orbit onto the foil.

The injection orbit bump – which is on for only about 30 turns – makes it necessary to displace the L1 corrector package upstream by about 1 m creating irregularity in the defocusing sextupole distribution. Even larger irregularity is associated with the extraction bump in L3 where the corrector package is displaced upstream by almost 5 m.

Beam Extraction

Extraction to the Main Injector MI-8 line takes place vertically with the help of constant field “dogleg” magnets and pulsed kicker and septum magnets as explained in detail in the Rookie

Book. It starts with vertical kicks exerted by four kickers in L2 and one in L12. These kicks put the beam in the field of pulsed septum magnet (MP02) in L3 which provides sufficient deflection for the beam to miss the downstream magnets.

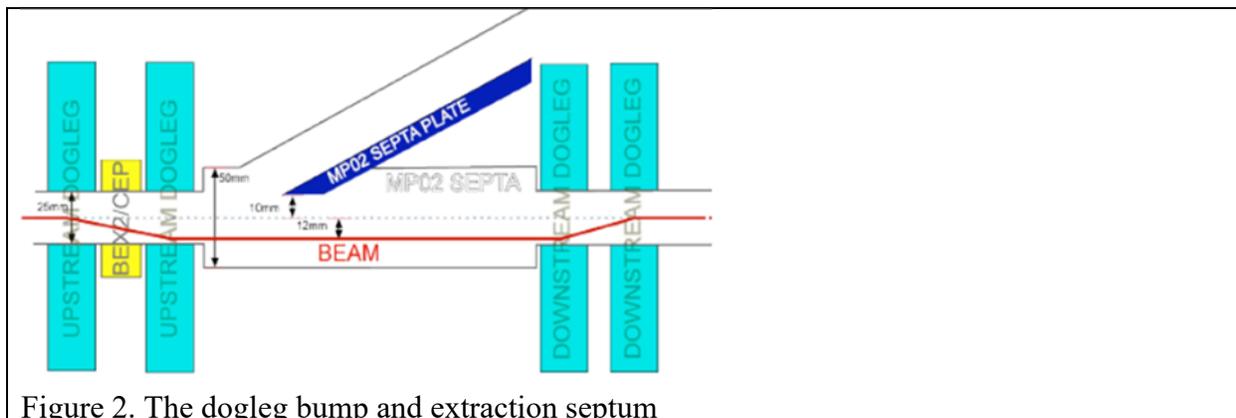


Figure 2. The dogleg bump and extraction septum

The losses at the septum at injection and acceleration are moderated with DC “dogleg” magnets which produce initially a 12mm vertical 4-bump (see Fig. 2). During the ramp the dogleg bump is diminishing so that the help from pulsed “BEX” magnets is needed which produce a 3-bump reaching its maximum 3 msec prior to extraction and then quickly ramping down. The dogleg magnets are strong enough to create optics perturbations at injection so there were suggestions to use pulsed magnets instead which would require the vertical displacement of the septum as well.

Booster optics

An official Booster Lattice repository is in the process of creation on the FNAL “redmine” server https://cdcvns.fnal.gov/redmine/projects/booster_madx_lattice_files/repository

It contains the MADX master file booster.madx and files booster.ele and booster.seq with the element definitions and the lattice description as a line. A number of axillary files contain the magnet current settings and focusing errors determined from measurements.

This complex of files constitute “the Booster model” which gives a close description of the real optics. Figure 3 presents the model optics functions at 1ms after injection (solid lines) and the values obtained through independent turn-by-turn measurements (dots). The agreement appears quite satisfactory, though the errors were not included in the model. This means that the dogleg is the main source of optics perturbation.

Finding actual Booster settings

The Booster is constantly tuned during operations. Using the model it is possible to see the effect of such tuning on the optics by replacing the axillary files. Those who have an account on FNAL Unix/Linux machines can read the actual settings using C.-Y. Tan’s script on the CLX cluster.

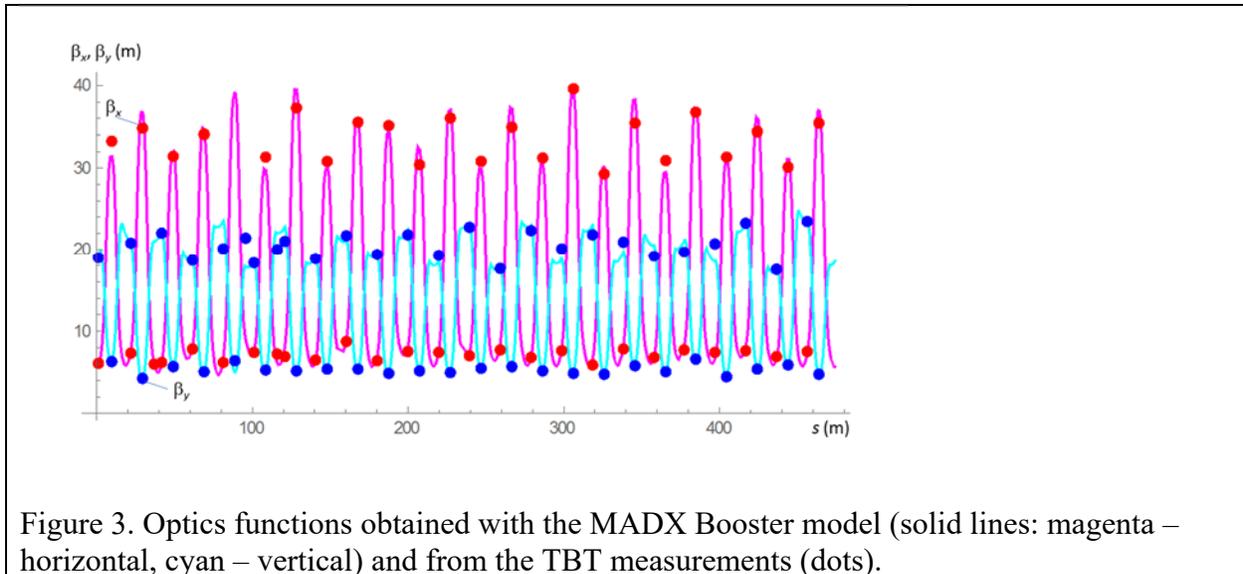
For that log into the machine you normally use, then ssh into outland.fnal.gov and from there ssh to a clx* machine where * can be 10, 11, etc. Then `cd ../cytan/ac1` and run command

`acl ReadAllSettings.acl`

when prompted, enter the output file name, e.g. `magnet_settings_now.txt`, it will be stored in directory

`/usr/local/cbs_files/cns_write/booster/LOCO/machineSettings`

on the same cluster. C.-Y. Tan also has MAC shell scripts to extract magnet currents from this file in a “standard” MADX format used for the FNAL Booster model.



ACNET

If you want to see the current parameter settings or even to change them you have to use the Accelerator Control NETWORK (ACNET) which is a system of computers that monitors and controls the accelerator complex. It can be accessed through consoles in the MCR and through PCs on the Fermi network around the lab.

A short and clear introduction can be found at:

<https://ftbf.fnal.gov/acnet-guide/>

while more general information can be found at

<https://www-bd.fnal.gov/controls/consoles/userguide.html>

Figure 4 lists the Booster application used for tuning and diagnostics. The Booster PS are on the Main Injector page I18 subpages 63-68.

