BNL's Booster Application Facility as pCT test bed.

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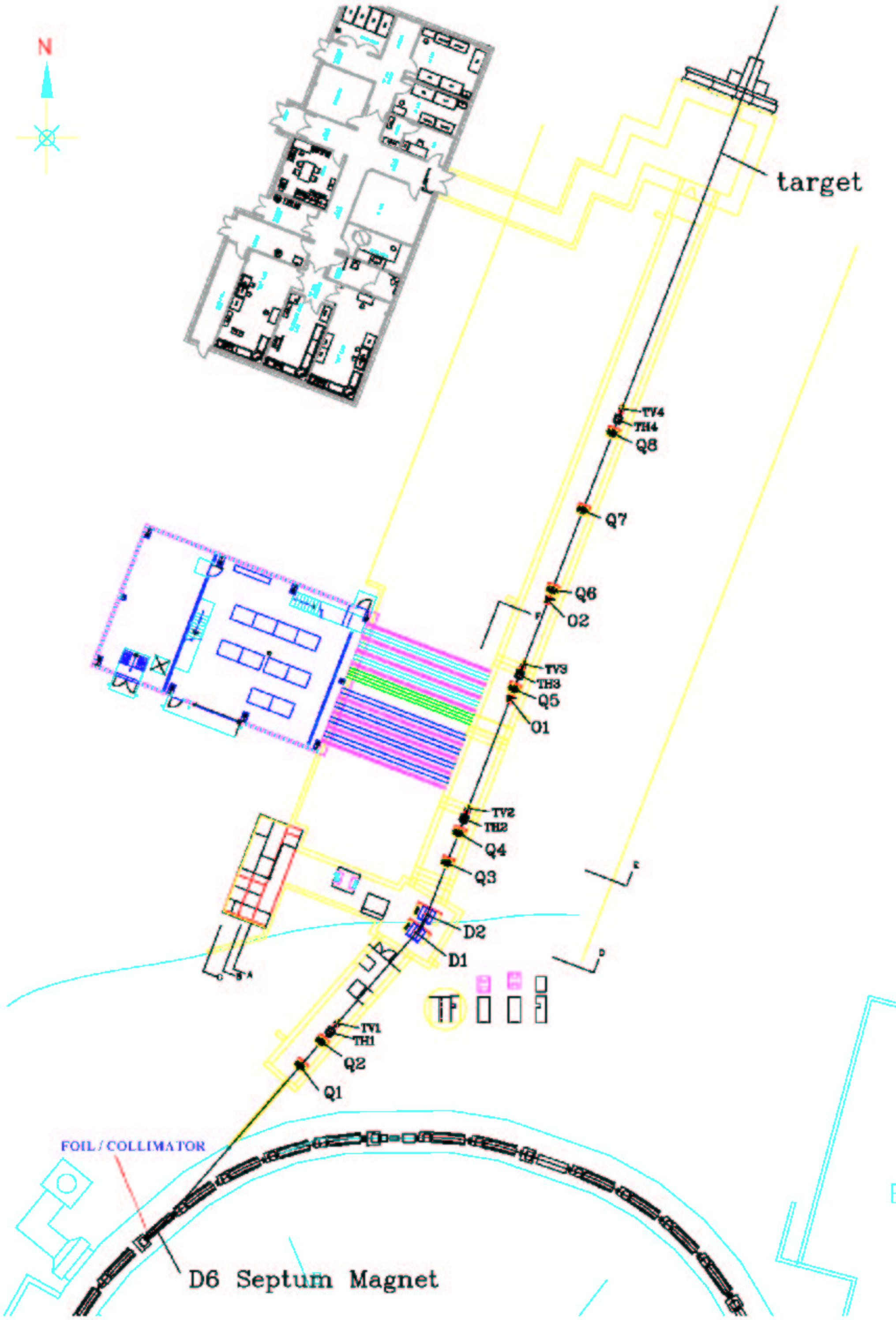
12:00 o'clock
Sextant 10/11
Sextant 12/1
PHOBOS
BRAHMS
2:00 o'clock
RHIC
Sextant 2/3
4:00 o'clock
Sextant 4/5
(First sextant to be tested)
Sextant 6/7
STAR
G-2
BOOSTER
LINAC
AGS
TANDEMS



N
target
TV4
TH4
Q8
Q7
Q6
O2
TV3
TH3
Q5
O1
TV2
TH2
Q4
Q3
D2
D1
TV1
TH1
Q2
Q1
FOIL / COLLIMATOR
D6 Septum Magnet

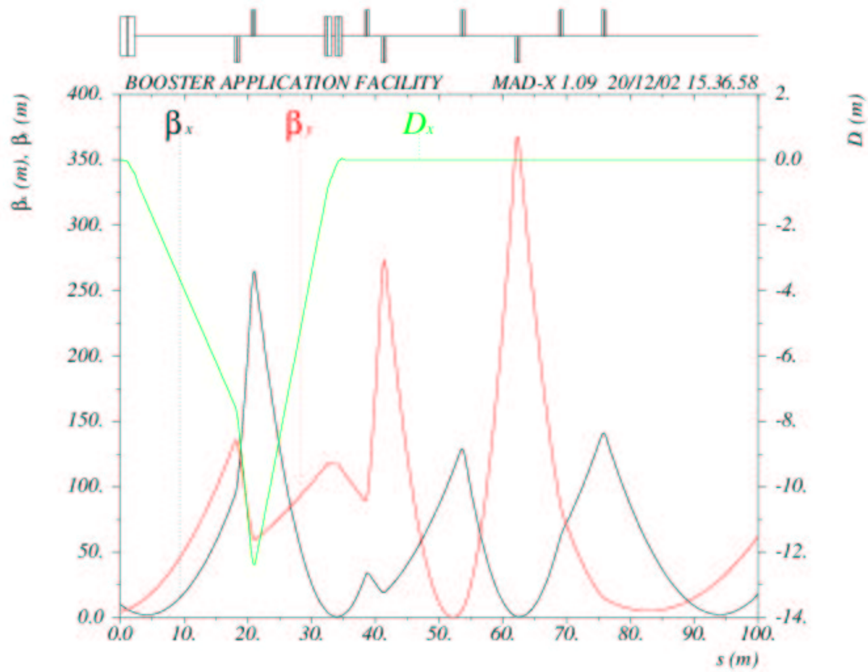
•Booster/BAF Capabilities:

Parameter	**Value**
Circumference	201.78 (1/4 AGS) m
Ave. Radius	32.114 m
Magnetic Bend R	13.75099 m
Lattice Type	Separated Function, FODO
No. Superperiods	6
No. of Cells	24
Betatron Tunes,X,Y	4.82, 4.83
Vacuum Chamber	70 x 152 mm Dipoles
	152 mm (circular) Quads
Max. Rigidity	17 Tm
Injection Rigidity	2.2 Tm (200 MeV protons)
	0.9 Tm (1 MeV/nuc Au(32+))
Acceleration Rate	8.9 T/s up to 7.5 Tm (7.5 Hz)
	1 T/s up to 17 Tm (0.7 Hz)

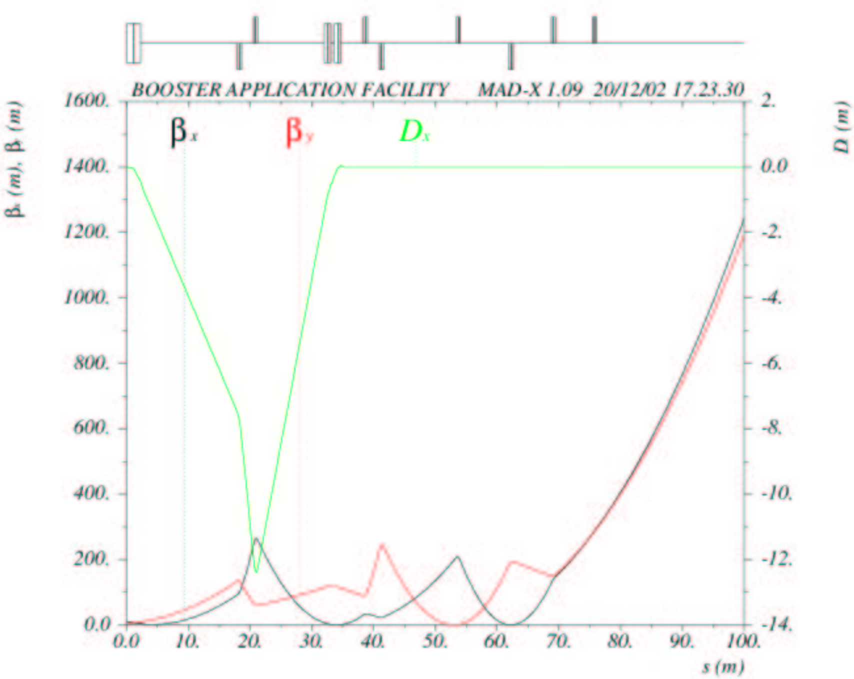
Ion	**Charge in Booster**	**K.E. Range (GeV/nucl.)**	**Intensity [10^9 Ions/pulse]**
p	1	0.1...3.07	100
28 Si	14	0.09...1.23	4
56 Fe	21	0.10...1.10	0.4
63 Cu	22	0.10...1.04	1
197 Au	32	0.04...0.30	2

• <u>BAF Capabilities</u>

1. Transverse and Longitudinal uniform beams.
2. Beam sizes from 1 cm to 20 cm
3. "Spills" up to 1 second (25 % duty factor).
4. Kinetic Energy ranges from 0.1 to 3.0 GeV (protons).
5. Dispersion free beam line,after 20 degree bend.
6. Particle fluences from 10^3 to $> 10^8$ ions/sec.
7. micro-planar beams ($\approx$100 μm wide, 1 cm high).
8. Dosimetry
9. Future improvement - microbeams



BOOSTER APPLICATION FACILITY
MAD-X 1.09 20/12/02 15.36.58
βx
βy
Dx
β (m), β (m)
D (m)
s (m)
400.
350.
300.
250.
200.
150.
100.
50.
0.0
2.
0.0
-2.
-4.
-6.
-8.
-10.
-12.
-14.
0.0
10.
20.
30.
40.
50.
60.
70.
80.
90.
100.



BOOSTER APPLICATION FACILITY
MAD-X 1.09 20/12/02 17.23.30
βx
βy
Dx
β (m), β (m)
D (m)
s (m)
1600.
1400.
1200.
1000.
800.
600.
400.
200.
0.0
2.
0.0
-2.
-4.
-6.
-8.
-10.
-12.
-14.
0.0
10.
20.
30.
40.
50.
60.
70.
80.
90.
100.


8X20 OC
SUPPLY
DO NOT ENTER

•<u>Microbeams</u>

Motivation:

Single ion exposures to cells.

DNA damage and mutagenesis from non-uniform dose resulting from high charge, high energy (HZE) particles.

single ion cell membrane, cytoplasm damage over multiple cells

neurotoxicity in human neural cells in single ion exposures

near neighbor damage from single ion irradiation

Definitions:

low flux: one particle per cell
time between particle arrivals determined by time to move a new cell into the targeting position

highly confined: all particles target onto an area of the order of the size of a cell or cell nucleus, or around 10 to 100 microns.

HZE: High charge, high energy particles (e.g., 1 GeV Fe)

high-LET: high linear energy transfer radiation.

To achieve a 10 micrometer beam in BAF

1. vertical wire stripping (0.02 mm wire)
2. vertical jaw collimator (0.03 mm opening)

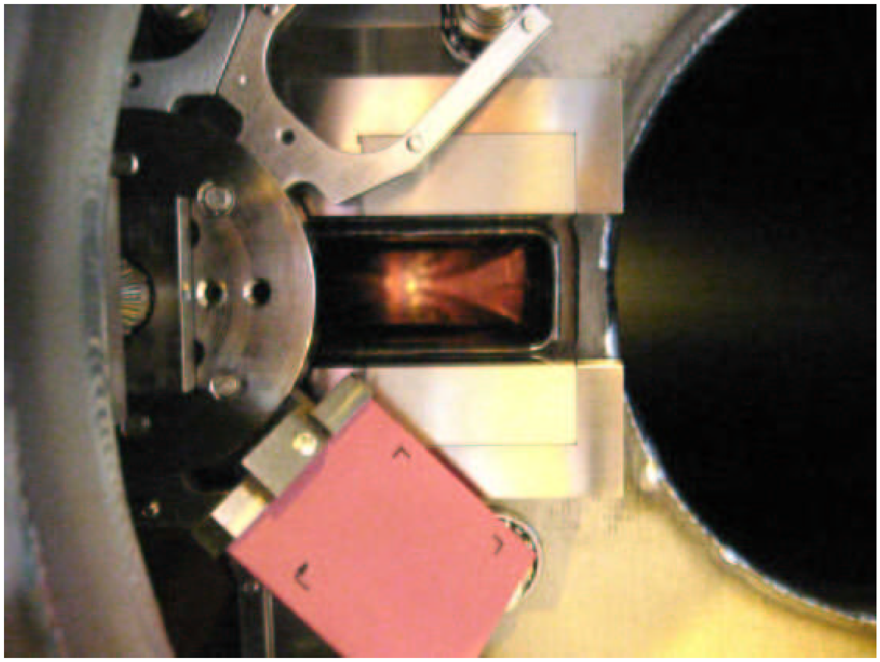
Emittance (99 % unnormalized) is then

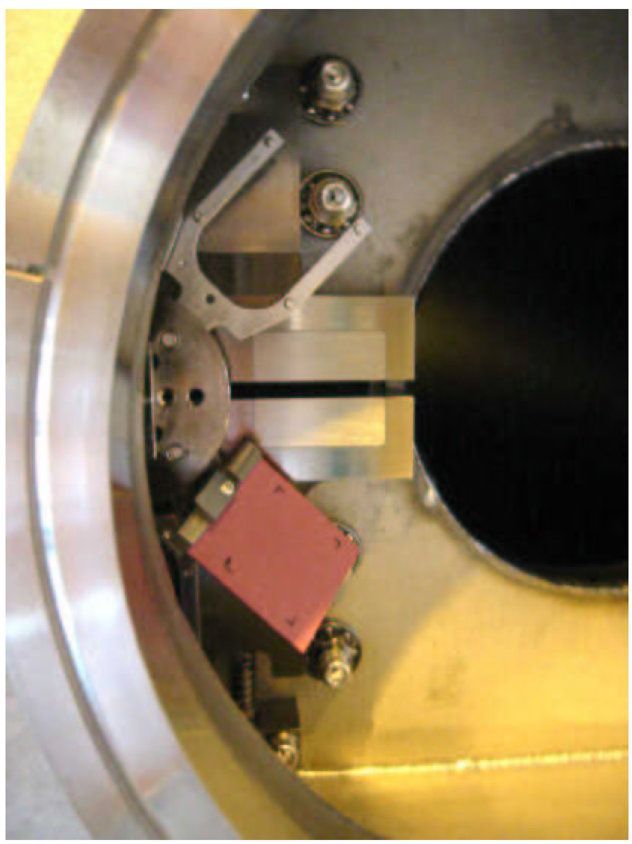
$$\epsilon_x \approx 2 \times 10^{-8} \ \pi\text{-m-rad}$$
$$\epsilon_y \approx 4 \times 10^{-8} \ \pi\text{-m-rad}$$

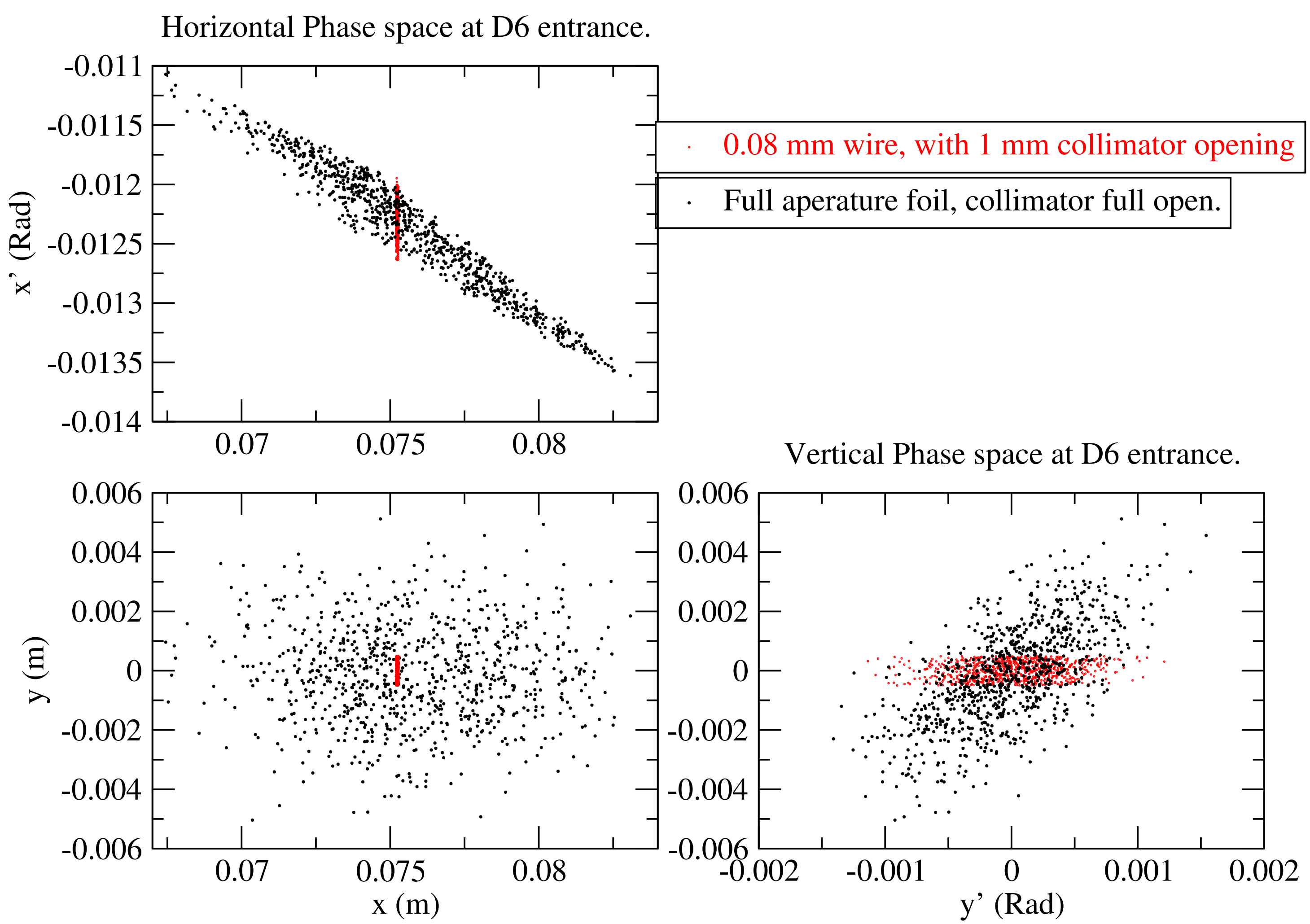
Which then requires (to reach 10 umeter, 1 sigma):

$$\beta_x \approx 0.030 \text{ m}$$
$$\beta_y \approx 0.015 \text{ m}$$

With 2×10^8 ions/sec exiting the Booster, the wire stripping/collimator combination will reduce the flux to about 2800 ions/sec. To keep to <u>one ion per cell</u> requires a beam "shutter", to allow only a single ion through at a time.







Horizontal Phase space at D6 entrance.
x' (Rad)
-0.011
-0.0115
-0.012
-0.0125
-0.013
-0.0135
-0.014
0.07
0.075
0.08
0.08 mm wire, with 1 mm collimator opening
Full aperature foil, collimator full open.
Vertical Phase space at D6 entrance.
y (m)
0.006
0.004
0.002
0
-0.002
-0.004
-0.006
x (m)
-0.002
-0.001
0.001
0.002
y' (Rad)

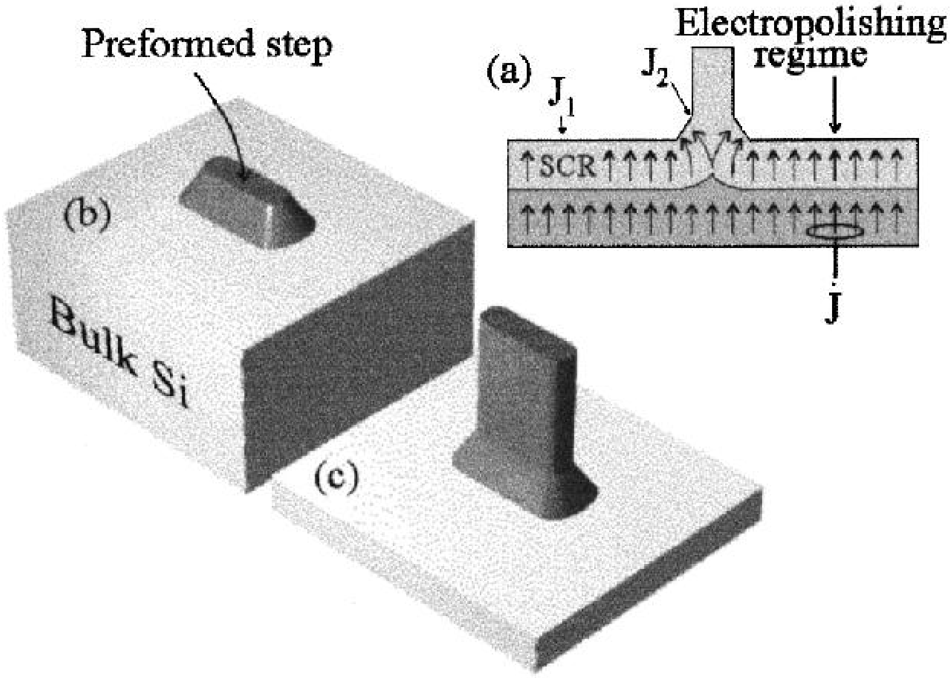
• Beam Line:

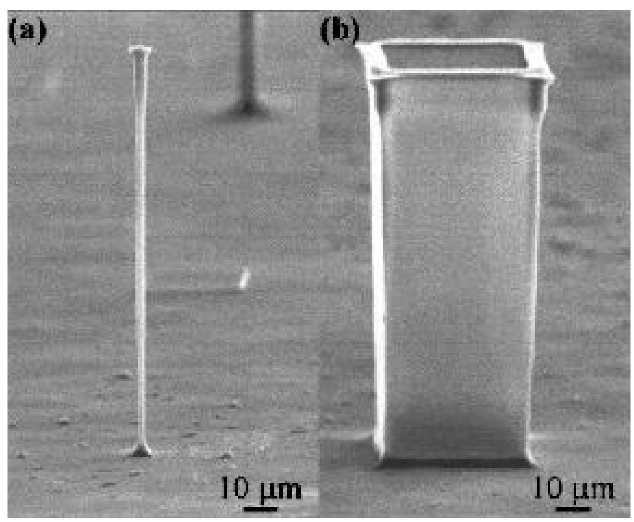
1. beam optics, how to get small β's ?

2. shutter;
   electrostatic choppers or fast kickers
   required kicks are small (small ϵ)
   (kickers off lets beam through, on stops beam)

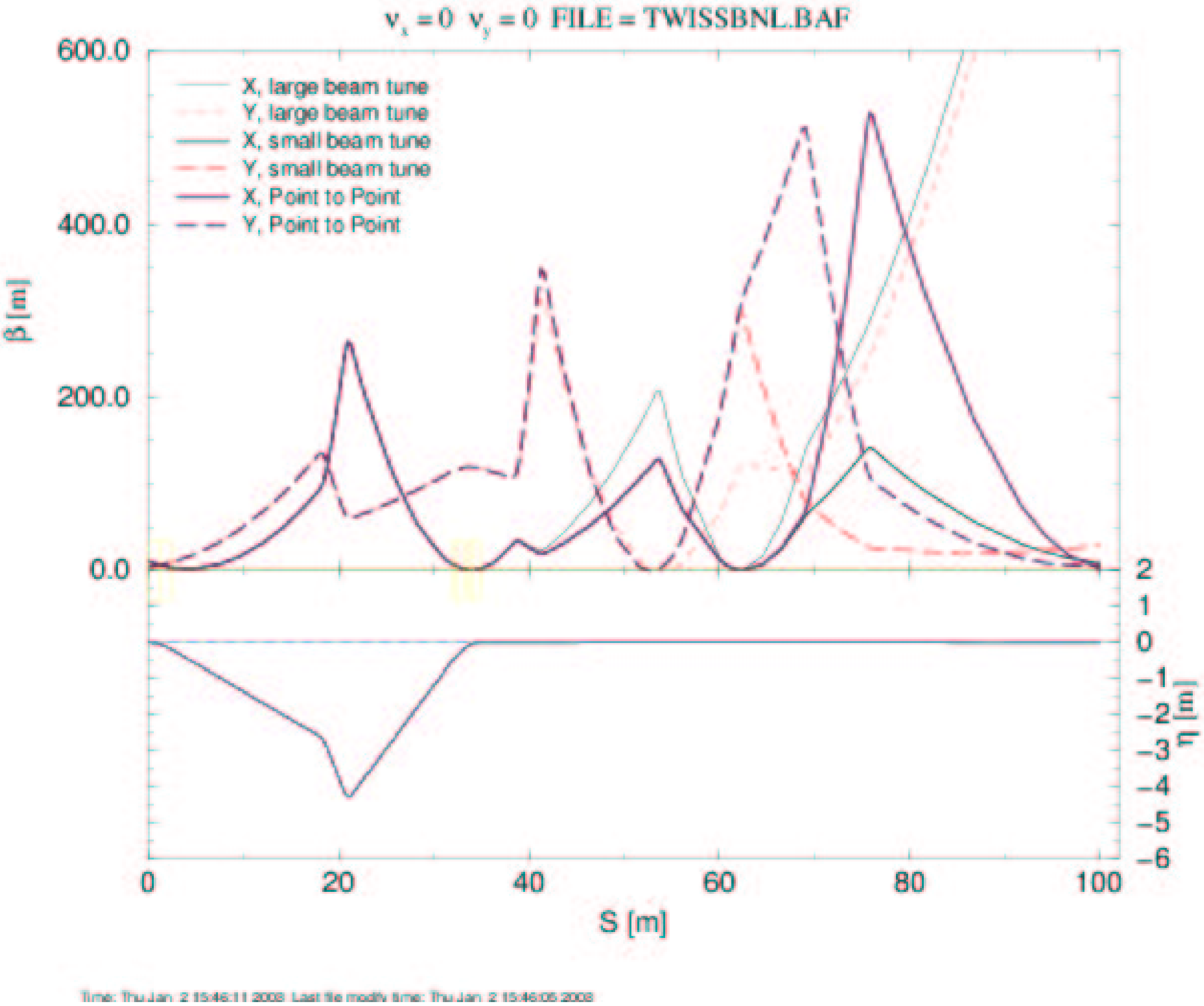
3. permanent magnet quadrupole for final focus (need to be insensitive to power supply ripple)

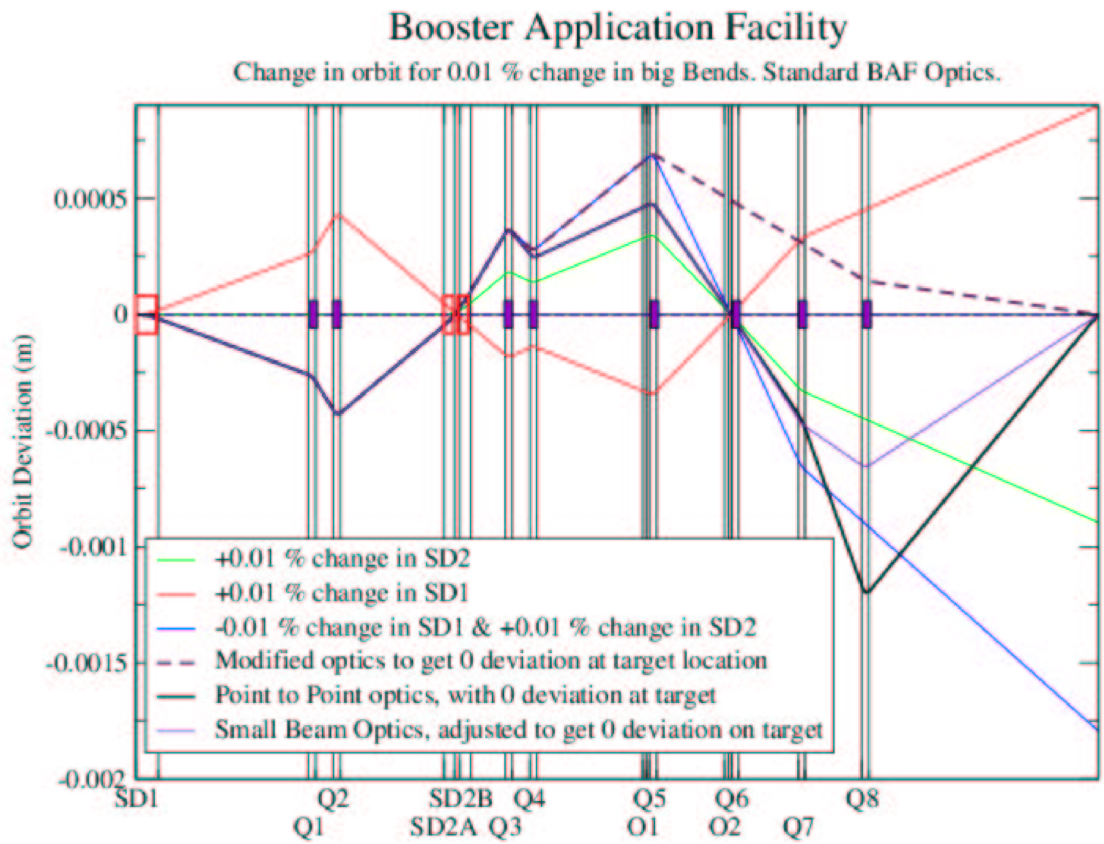
4. crystal channeling/collimation = provides a spatially fixed source of particles.


Preformed step
Electropolishing regime
(a)
J_1
J_2
SCR
J
(b)
Bulk Si
(c)


(a)
(b)
10 μm
10 μm

BOOSTER APPLICATION FACILITY




Booster Application Facility
Change in orbit for 0.01 % change in big Bends. Standard BAF Optics.
Orbit Deviation (m)
0.0005
0
-0.0005
-0.001
-0.0015
-0.002
+0.01 % change in SD2
+0.01 % change in SD1
-0.01 % change in SD1 & +0.01 % change in SD2
Modified optics to get 0 deviation at target location
Point to Point optics, with 0 deviation at target
Small Beam Optics, adjusted to get 0 deviation on target
SD1
Q1
Q2
SD2A
SD2B
Q3
Q4
Q5
O1
Q6
O2
Q7
Q8

Microbeam issues:

1. Final window: particles get scattered

2. Background radiation: stray neutral particles

3. Compatible with normal BAF operation

Summary:

1. BAF is a well designed, modern beam line, capable of delivering many types of beams.

2. BAF is designed for bio-medical research and has the infrastructure to support pCT developement and experiments.

3. In the future BAF will be capable of delivering high precision microbeams.