Commissioning of the Beam Collimation System at the Fermilab Booster.

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1 Abstract

The Booster beam collimation system simulation results are presented.

References

[1] A. Drozhdin, P. Kasper, O. Krivosheev, J. Lackey, N. Mokhov, M. Popovic, R. Webber, FNAL, Batavia, IL 60510, USA, ”Beam Loss, Residual Radiation, and Collimation and Shielding in the Fermilab Booster”, Presented to PAC2001.

[2] N.V.Mokhov, A.I.Drozhdin, J.R.Lackey, E.J.Prebys, R.C.Webber, FNAL, Batavia, IL 60510, USA, ”Fermilab Booster Beam Collimation and Shielding”, FERMILAB-CONF-03-087, Presented to PAC2003.

[3] I. S. Baishev, A. I. Drozhdin and N. V. Mokhov, “STRUCT Program User’s Reference Manual”, SSCL–MAN–0034 (1994); http://www-ap.fnal.gov/∼drozhdin/.

Table 1: β-functions, dispersion and phase advances between collimators. Real location of collimators.

element	β-functions, m	dispersion, m	Phase advance between primary and secondary collimators, degree	
	hor. / ver.		horizontal	vertical
injection				
horiz. prim. PrH.	15.8/10.7	2.60	0	-
vert. prima. PrV.	16.2/14.8	2.90	-	0
secondary SH1	6.5/24.1	2.38	53	-
secondary SV1	7.9/23.3	2.54	-	21
secondary SH2	6.0/18.3	2.15	143	124
top energy				
horiz. prim. PrH.	19.0/11.9	2.49	0	-
vert. prima. PrV.	19.0/11.9	2.50	-	0
secondary SH1	6.3/20.0	1.85	47	-
secondary SV1	6.8/20.2	1.85	-	25
secondary SH2	6.3/20.1	1.84	148	118

Table 2: Horizontal and vertical position of collimators. Real location of collimators.

element	envelope of circulating beam, mm				collimator position, mm	
	horizontal		vertical		horizontal	vertical
	injection	top energy	injection	top energy		
horiz. prim. PrH.	16.85	16.85	13.42	16.49	-16.85	-
vert. prima. PrV.	16.96	16.86	16.63	16.63	-	-16.63
secondary SH1	10.83	10.27	21.40	21.51	-12.83	+23.51
secondary SV1	11.73	10.06	20.95	21.45	+13.73	-23.45
secondary SH2	11.28	10.23	17.55	21.54	+13.28	+23.54

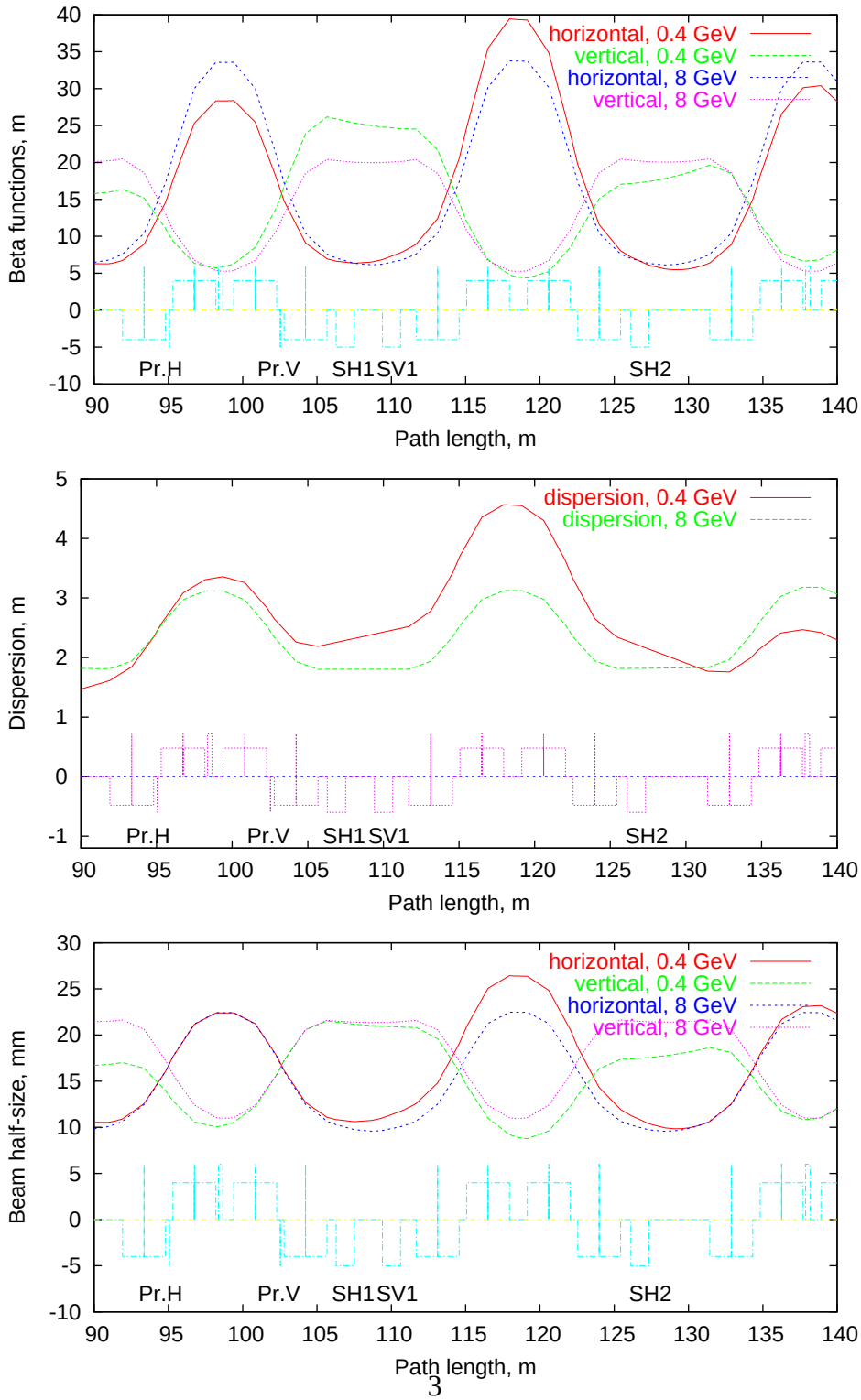


Figure 1: Beta functions, dispersion and beam size at injection and at the top energy in the collimation region for the real location of collimators. 95% normalized emittance is 12 mm.mrad. Beam size is defined by the position of primary collimator.

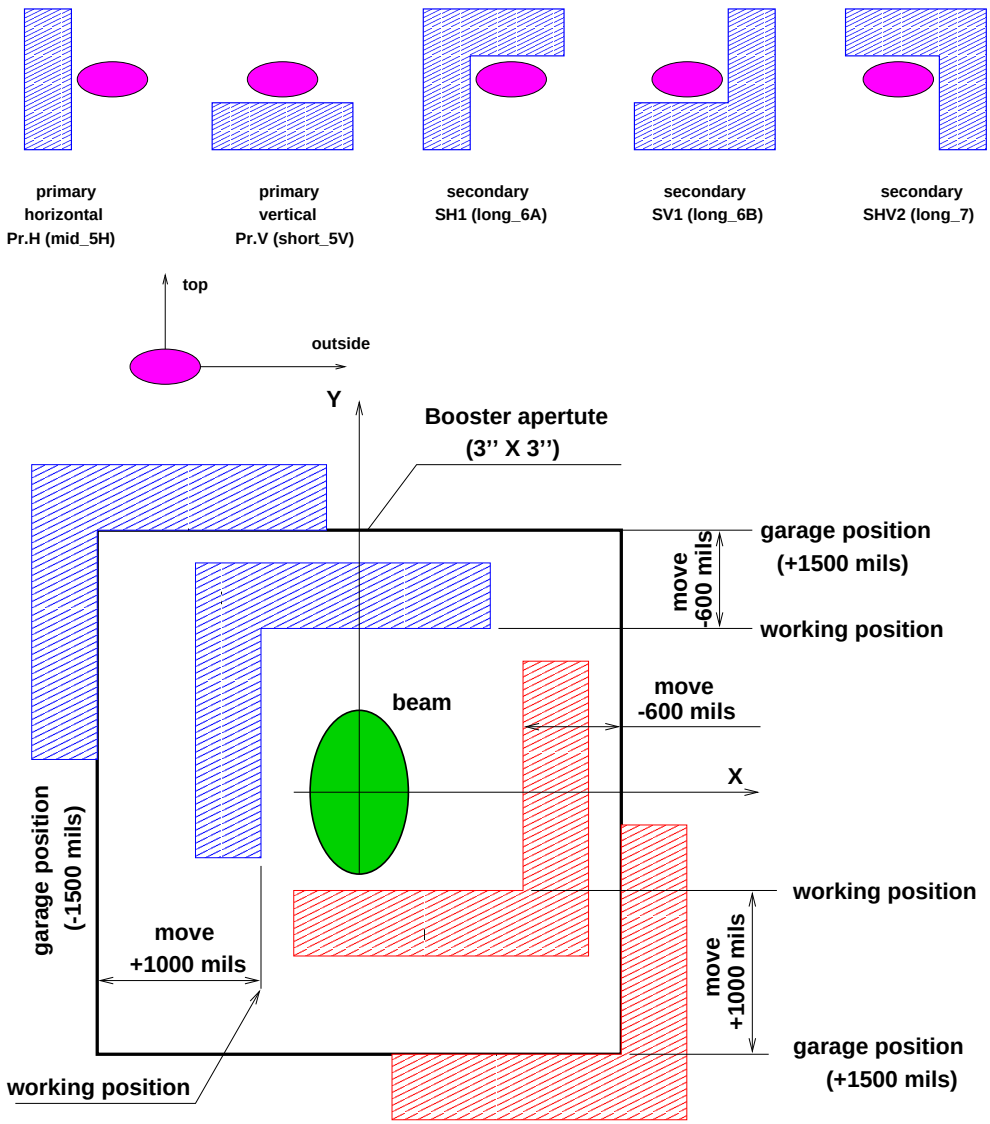


Figure 2: Booster collimator jaws position with respect to the circulating beam.

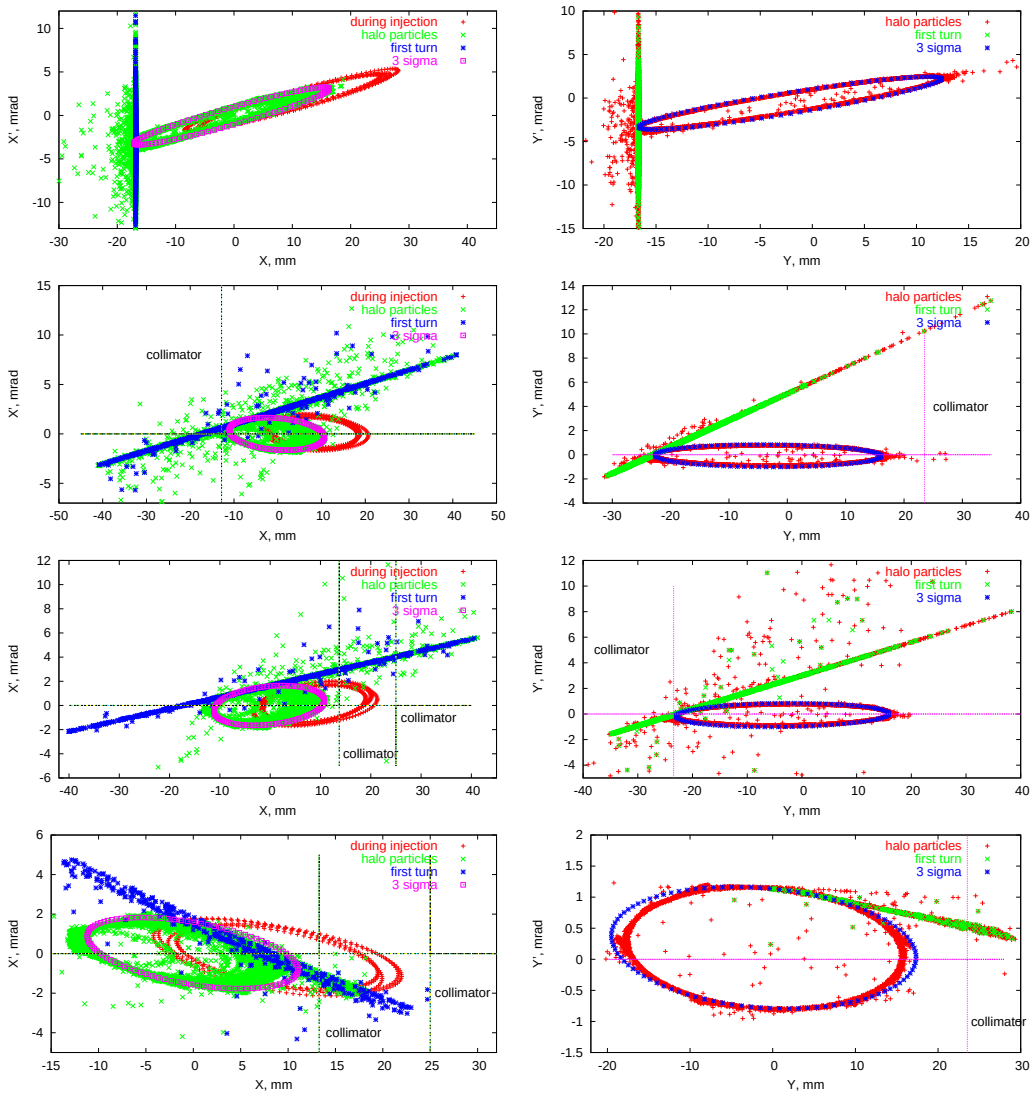


Figure 3: Horizontal (left) and vertical (right) phase space at injection in the primary collimators (top), secondary collimators SH1 (second line), SV1 (third line), and collimators SHV2 (bottom) for real location of collimators. Copper primary collimator thickness is 0.4 mm. Primary collimators are located at $3\sigma_{x,y}$ of the beam at injection (95% normalized emittance is 12 mm.mrad). Red line represents position of particles during injection, blue line - the first turn after interaction with the primary collimators without secondary collimators, green - secondary halo and pink - $3\sigma_{x,y}$ beam envelope. Average number of each particle interaction with horizontal and vertical primary collimator is ~ 1.

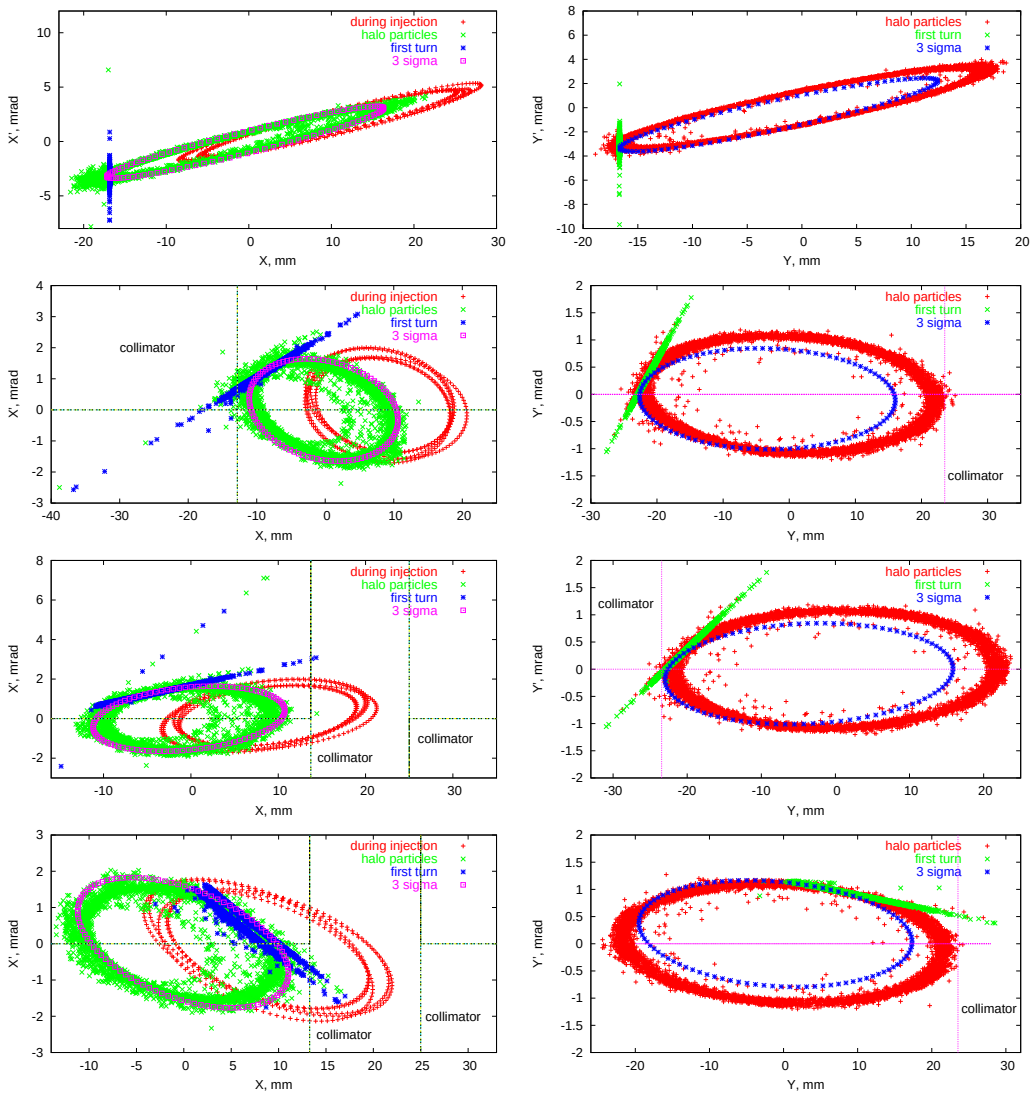


Figure 4: Horizontal (left) and vertical (right) phase space at 4 GeV in the primary collimators (top), secondary collimators SH1 (second line), SV1 (third line), and collimators SHV2 (bottom) for real location of collimators. Copper primary collimator thickness is 0.4 mm. Primary collimators are located at $3\sigma_{x,y}$ of the beam at injection (95% normalized emittance is 12 mm.mrad). Red line represents position of particles during injection, blue line - the first turn after interaction with the primary collimators without secondary collimators, green - secondary halo and pink - $3\sigma_{x,y}$ beam envelope. Average number of each particle interaction with horizontal primary collimator is 4.81, with vertical one is 2.91.

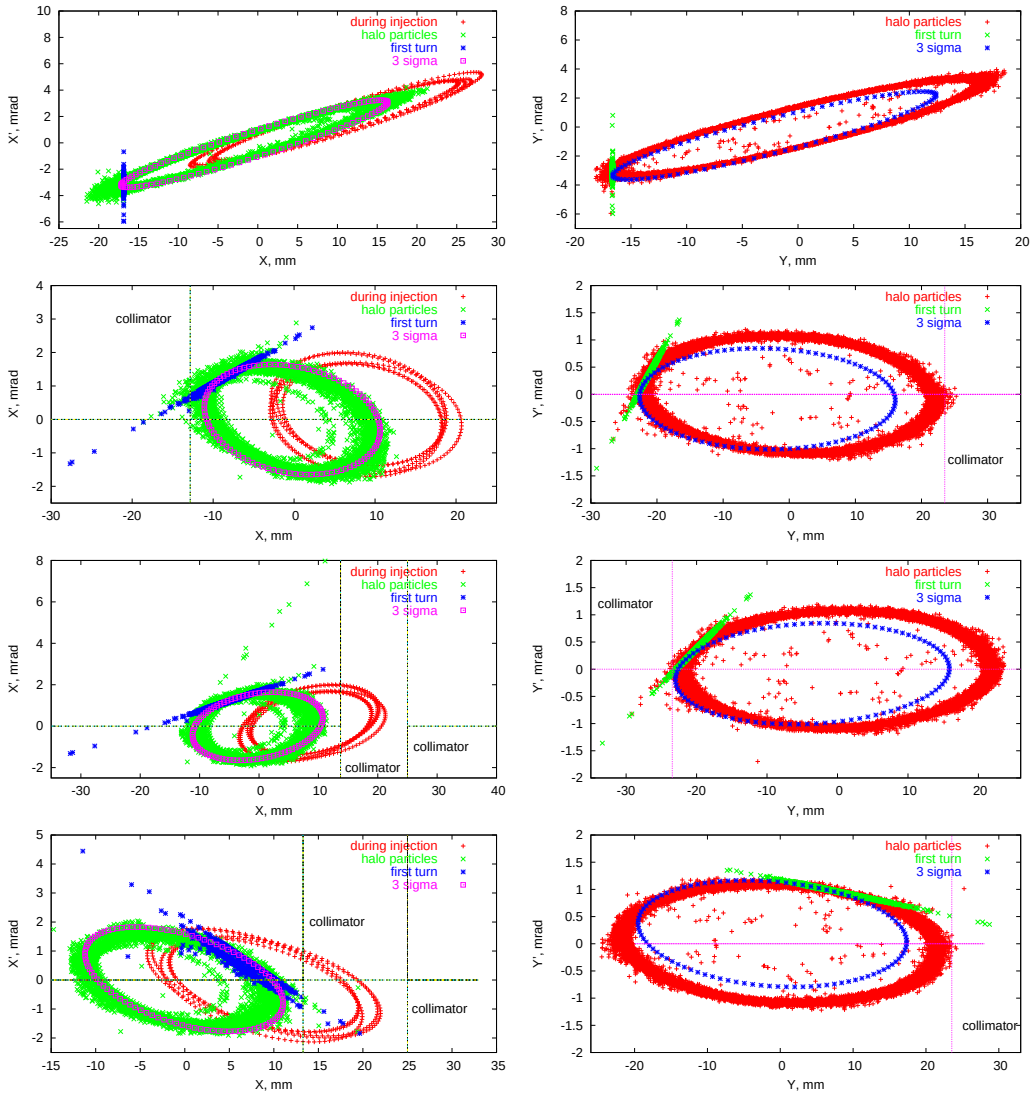


Figure 5: Horizontal (left) and vertical (right) phase space at 8 GeV in the primary collimators (top), secondary collimators SH1 (second line), SV1 (third line), and collimators SHV2 (bottom) for real location of collimators. Copper primary collimator thickness is 0.4 mm. Primary collimators are located at $3\sigma_{x,y}$ of the beam at injection (95% normalized emittance is 12 mm.mrad). Red line represents position of particles during injection, blue line - the first turn after interaction with the primary collimators without secondary collimators, green - secondary halo and pink - $3\sigma_{x,y}$ beam envelope. Average number of each particle interaction with horizontal primary collimator is 8.24, with vertical one is 4.56.

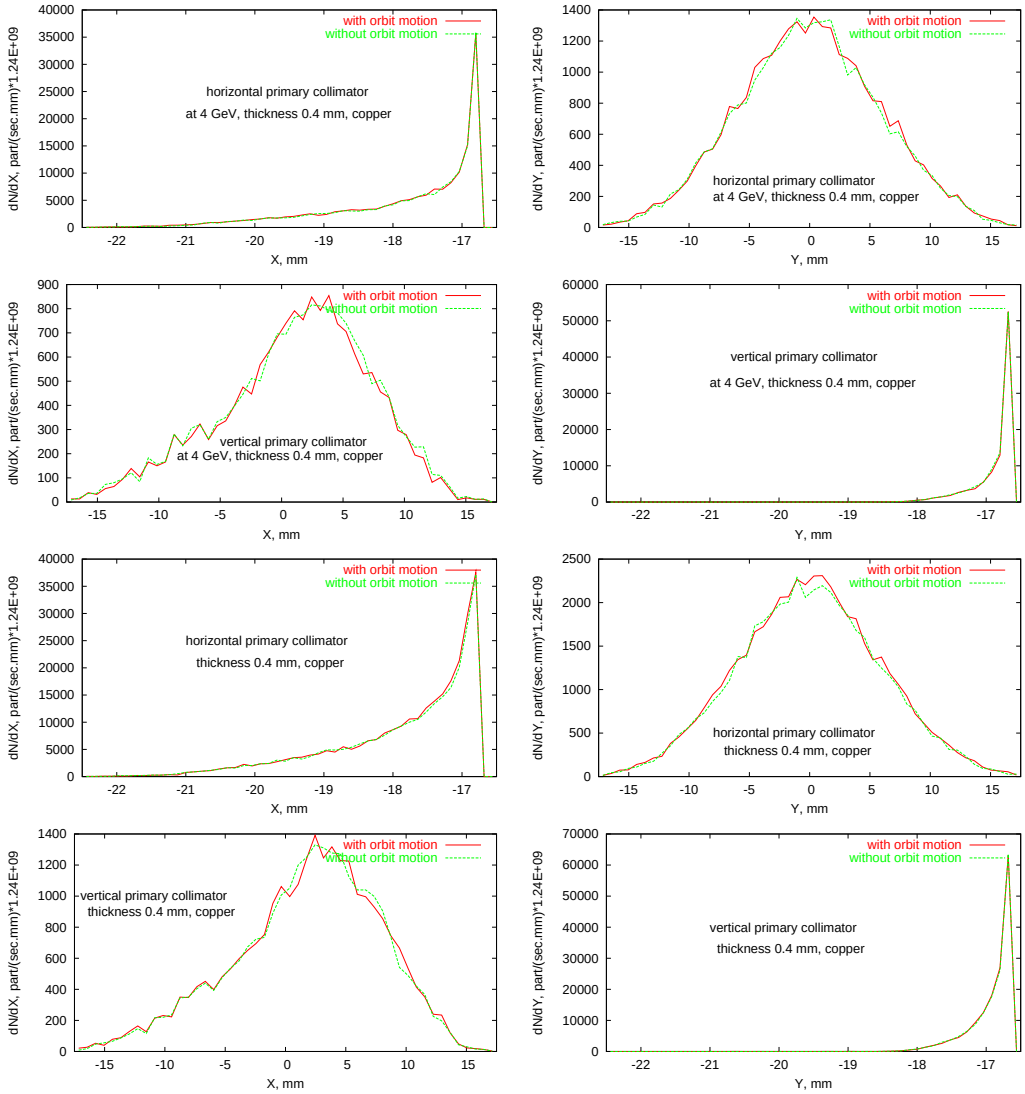


Figure 6: Proton hits distribution in the horizontal (top) and vertical (second line) primary collimators at 4 GeV and in the horizontal (third line) and vertical (4-th line) primary collimators at 8 GeV. Copper primary collimator thickness is 0.4 mm. Average number of each particle interaction with horizontal primary collimator is 8.24, with vertical one is 4.56 for 8 GeV, and 4.81 and 2.91 for 4 GeV. Estimated particle hits rate at the horizontal primary collimator is $4.12 \times 10^{13} hits/sec$, at the vertical one - $2.28 \times 10^{13} hits/sec$ if all particles are lost at 8 GeV, and $2.40 \times 10^{13} hits/sec$ and $1.45 \times 10^{13} hits/sec$ correspondingly if all particles are lost at 4 GeV. For these numbers estimation we assumed design parameters of accelerator for MiniBooNE operation at 5 Hz with intensity of $5 \cdot 10^{12} ppp$ and 20% of particle loss during the cycle. At these parameters of the beam the region of maximum hit density ($0.01\ mm \times 0.1\ mm$) is heated by the beam up to $5000^o\ C$. At existing intensity and repetition rate this number should be equal to $200^o\ C$.

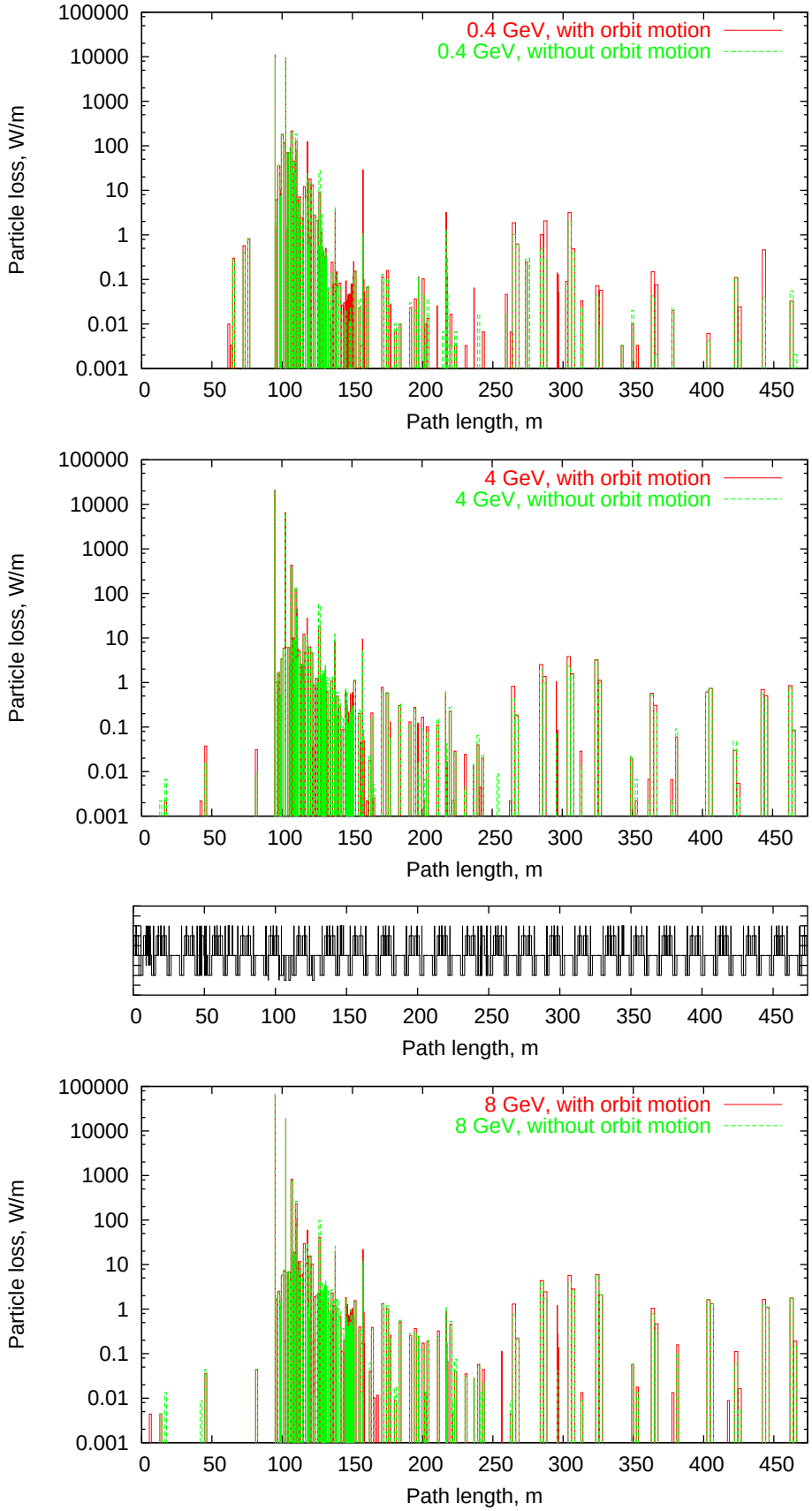


Figure 7: Beam loss distribution along the accelerator for 30% beam loss at injection (top), 2% beam loss at 4 GeV (middle) and 2% beam loss at the top energy (bottom) for real location of collimators with and without horizontal orbit motion. Intensity is $5 \cdot 10^{12} ppp$. Repetition rate is 15 Hz. Copper primary collimator thickness is 0.4 mm.

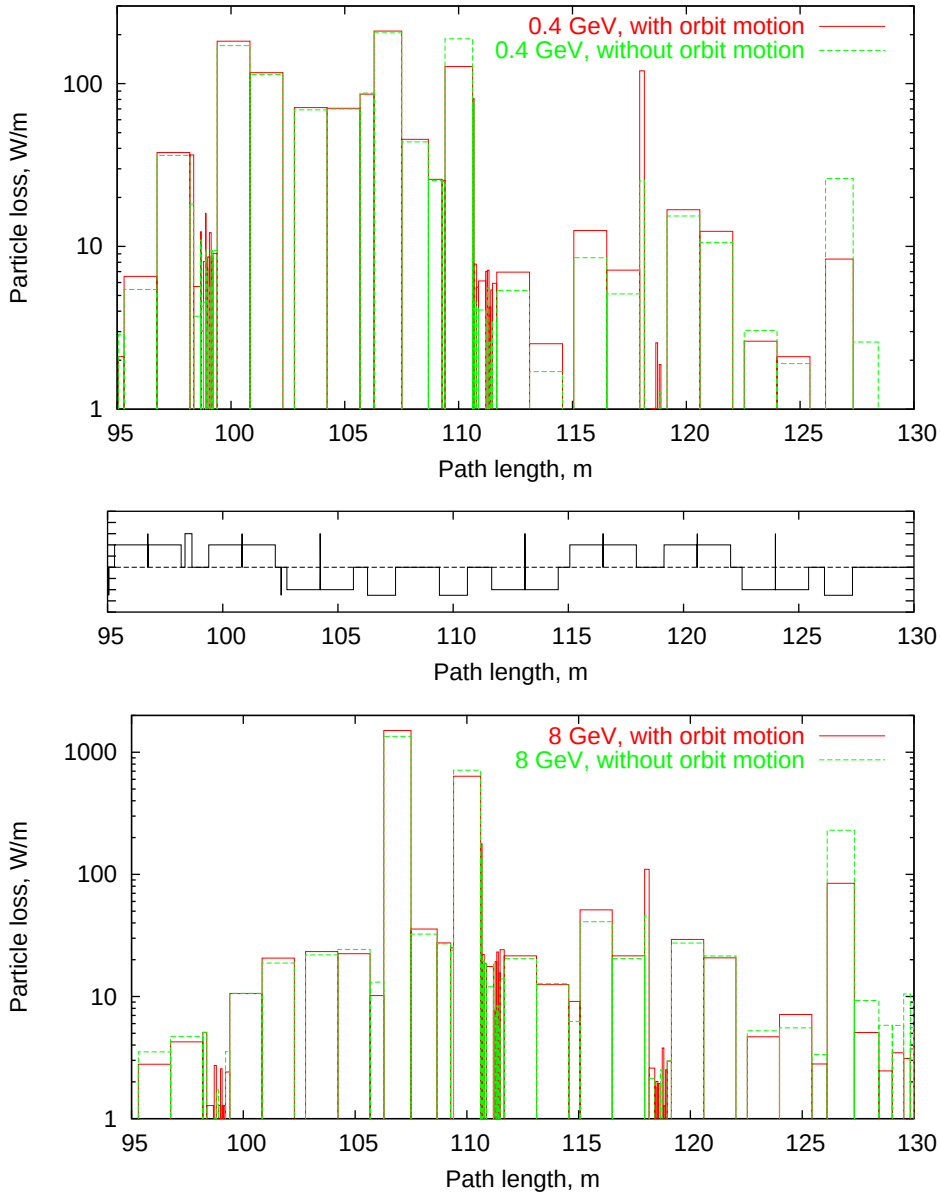


Figure 8: Comparison of beam loss distribution in the collimation region at injection (top) and at the top energy (bottom) with and without orbit motion. Intensity is $5 \cdot 10^{12} ppp$. Repetition rate is 15 Hz. Copper primary collimator thickness is 0.4 mm.

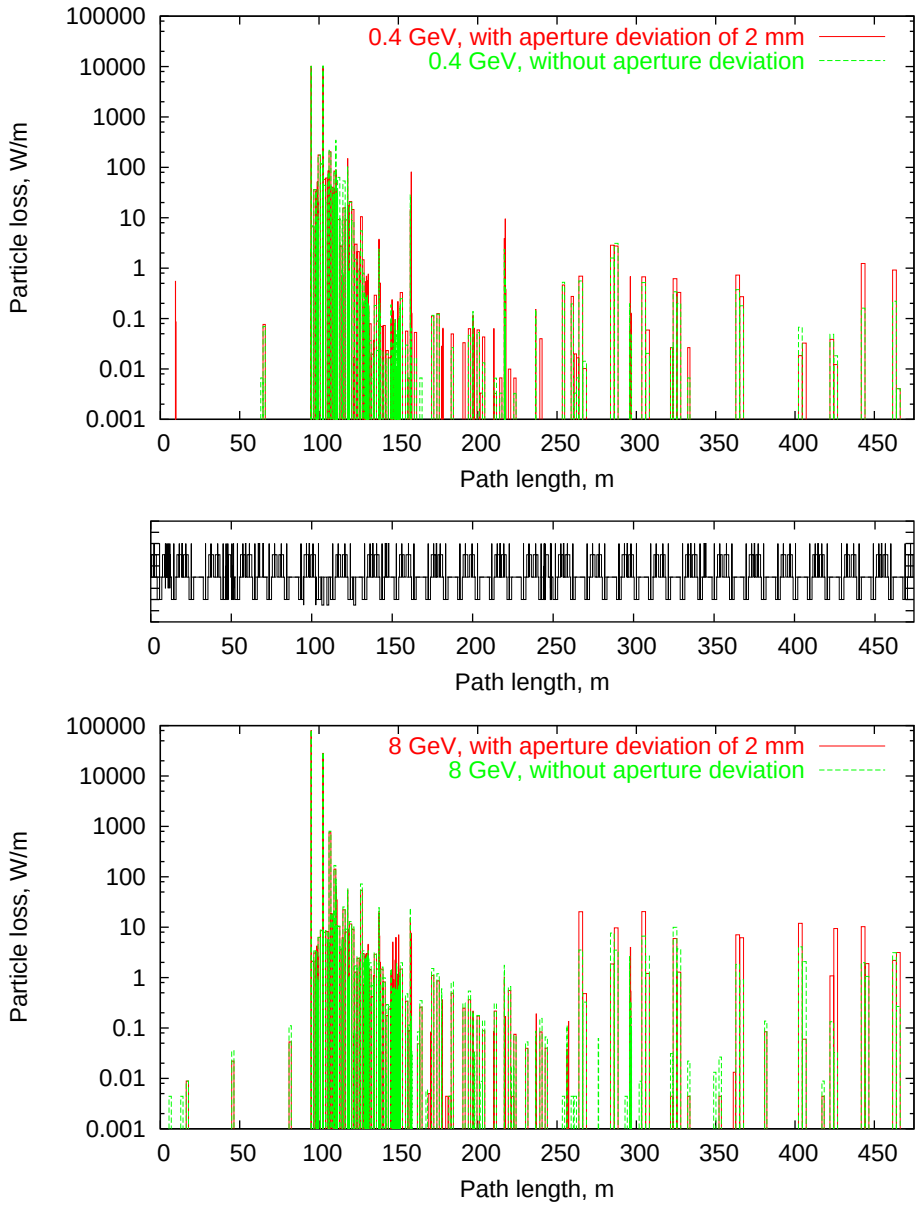


Figure 9: Beam loss distribution along the accelerator for 30% beam loss at injection (top) and 2% beam loss at the top energy (bottom) without and with random displacement of aperture along the ring by $\pm 2\ mm$. Intensity is $5 \cdot 10^{12} ppp$. Repetition rate is 15 Hz. Copper primary collimator thickness is 0.4 mm.

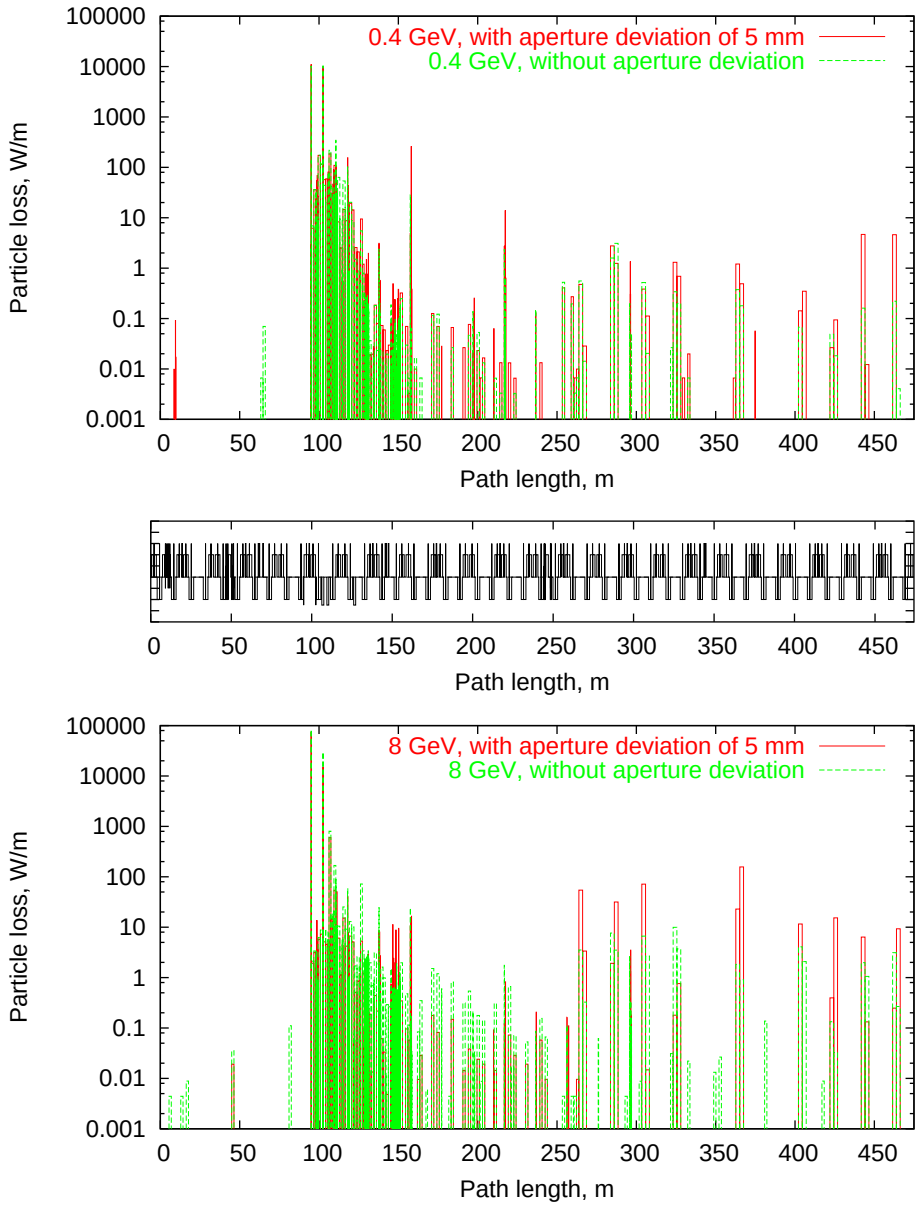


Figure 10: Beam loss distribution along the accelerator for 30% beam loss at injection (top) and 2% beam loss at the top energy (bottom) without and with random displacement of aperture along the ring by $\pm 5\ mm$. Intensity is $5{\cdot}10^{12} ppp$. Repetition rate is 15 Hz. Copper primary collimator thickness is 0.4 mm.

Table 3: Beam loss in the accelerator at random displacement of elements aperture along the ring with $\sigma_{x,y}$ of $2\ mm$ and $5\ mm$. (See Figs. 9 and 10).

kinetic energy	aperture displacement ($\sigma_{x,y}$)	beam loss		
		total in the ring	in the collimation region (92-152 m)	outside the collimation region
GeV	mm	W	W	W
0.4	0	1438.54	1412.41	26.14
0.4	2	1372.16	1335.41	36.76
0.4	5	1388.43	1332.87	55.56
8	0	1729.42	1586.38	143.03
8	2	1725.13	1442.95	282.17
8	5	1914.44	998.65	915.79

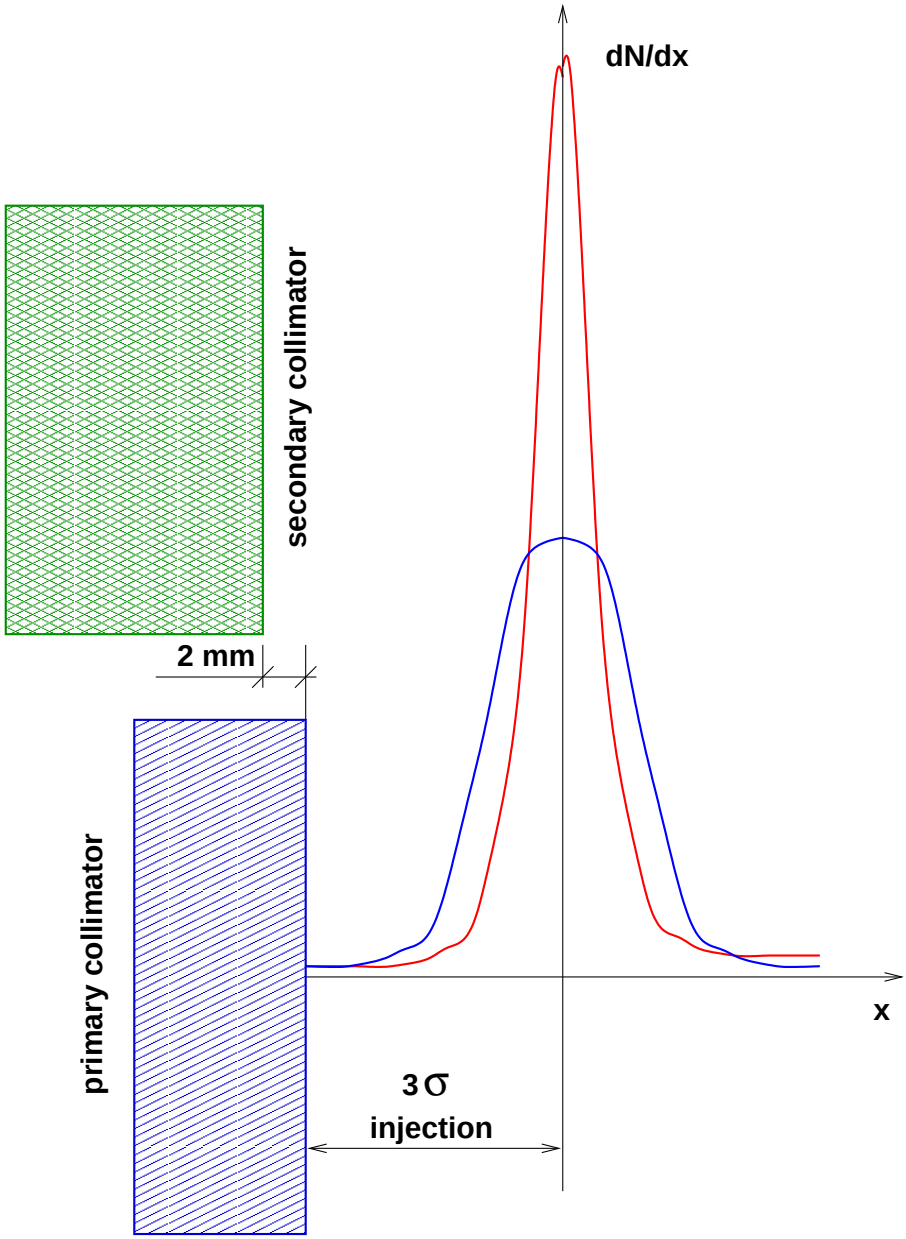
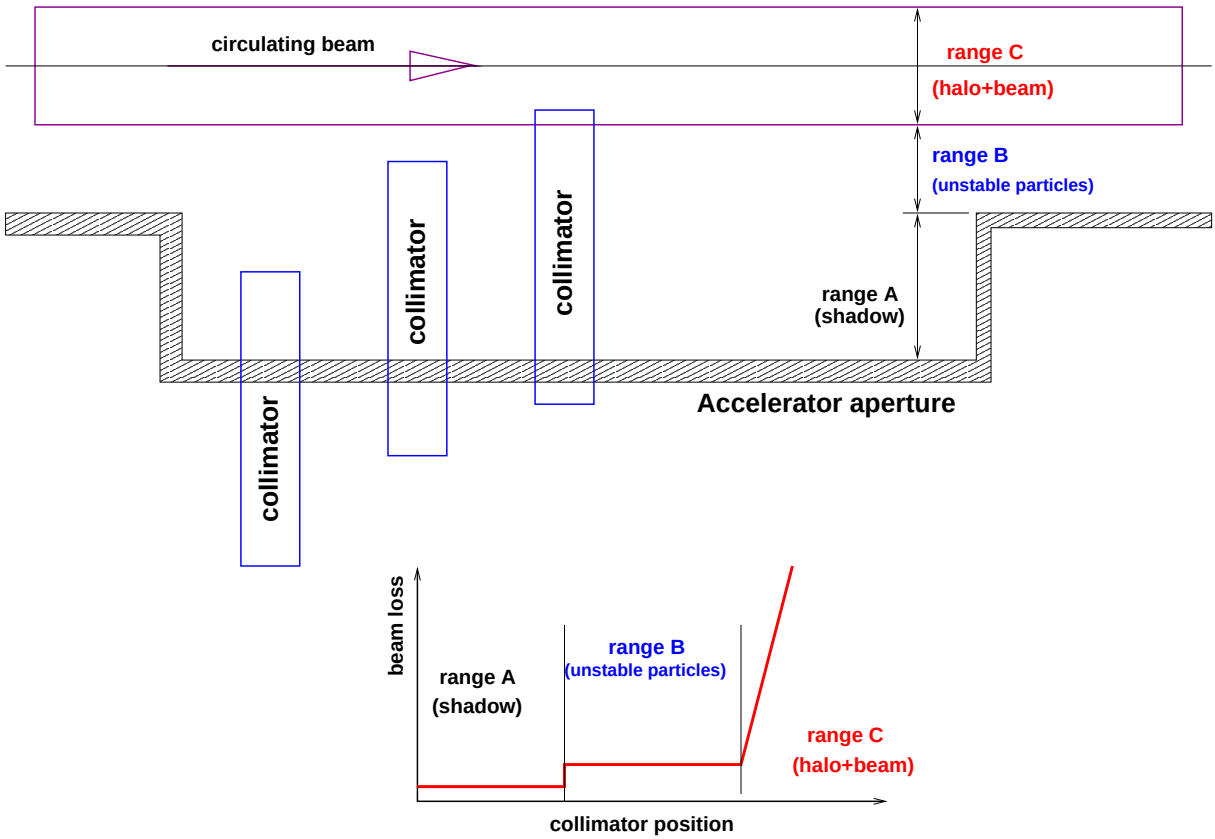


Figure 11: Collimators location with respect to the circulating beam.



Collimator jaws adjustment with respect to the beam

1. **The selected jaw is moved in small steps towards the beam center until it touches the beam halo.**

2. **After the detection of the beam edge the jaw is retracted by a few mm, but the found edge position is stored.**

3. **The procedure is repeated for all primary and secondary collimators.**

4. **Finally all jaws are moved to the found position plus an additional offset value, which is zero for the primary collimators and 2 mm for the secondary ones.**

Figure 12: Collimation system commissioning.