
The Overview of the ILC RTML Bunch Compressor Design

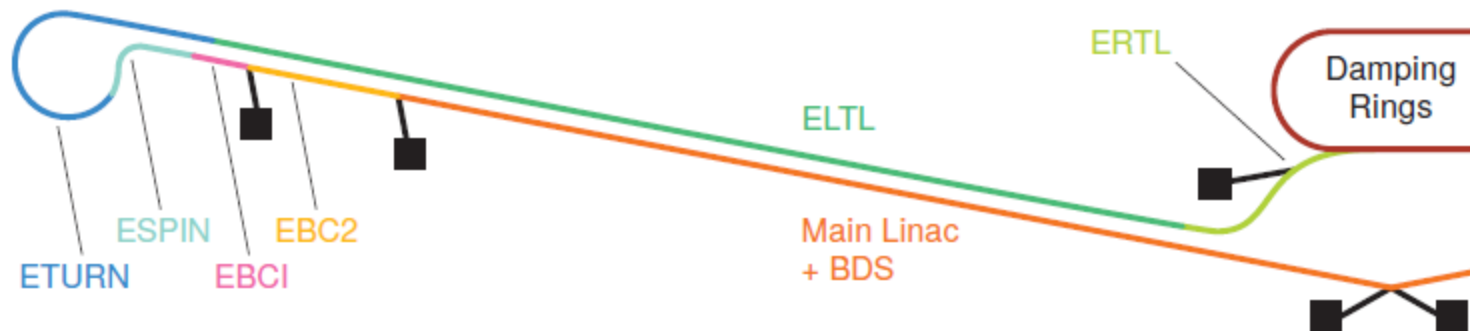
Sergei Seletskiy

LCWS 13

November, 2012

The bunch compressor overview

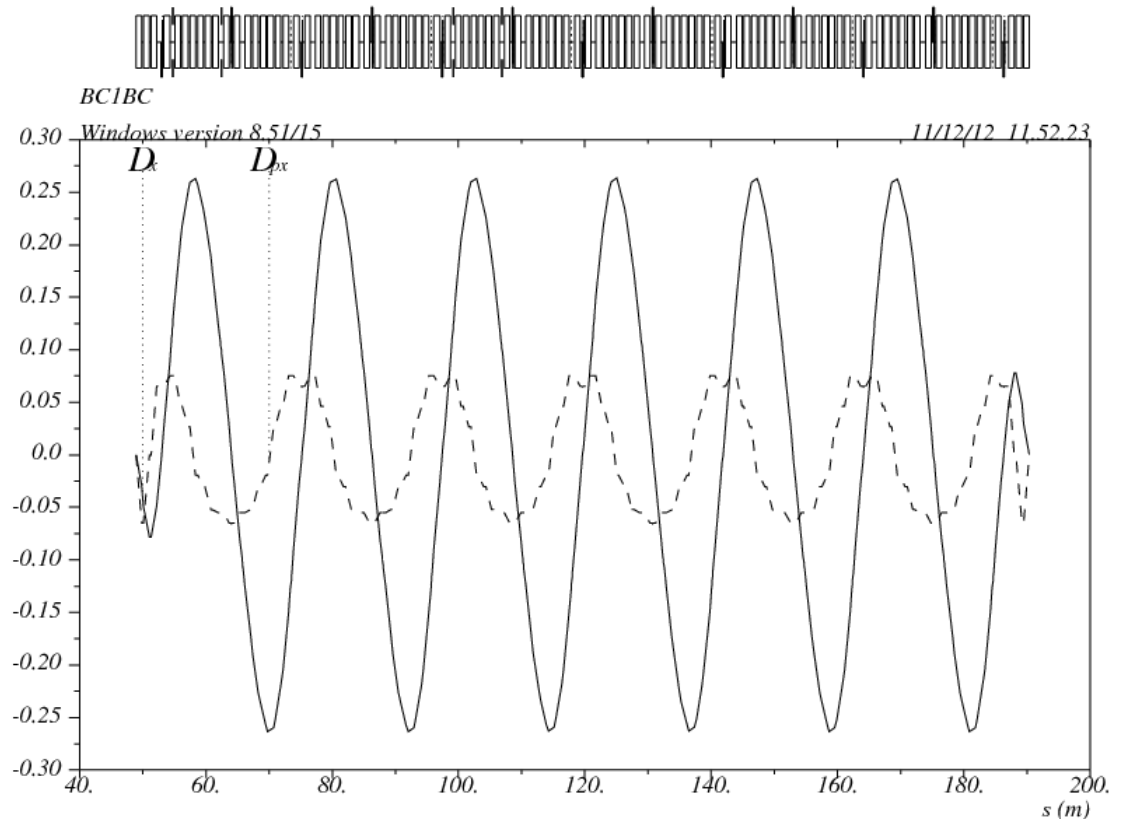
- Both the electron and the positron damping ring to main linac transfer lines include identical two-stage bunch compressors.
- In the baseline design the BC compresses 6 mm 5 GeV to 0.3 mm at 15 GeV beam. It can also compress beam to the final length of 150 μm .
- There are dump lines after each stage of the bunch compressor, which can be used for both fast intra-train and continual extraction.



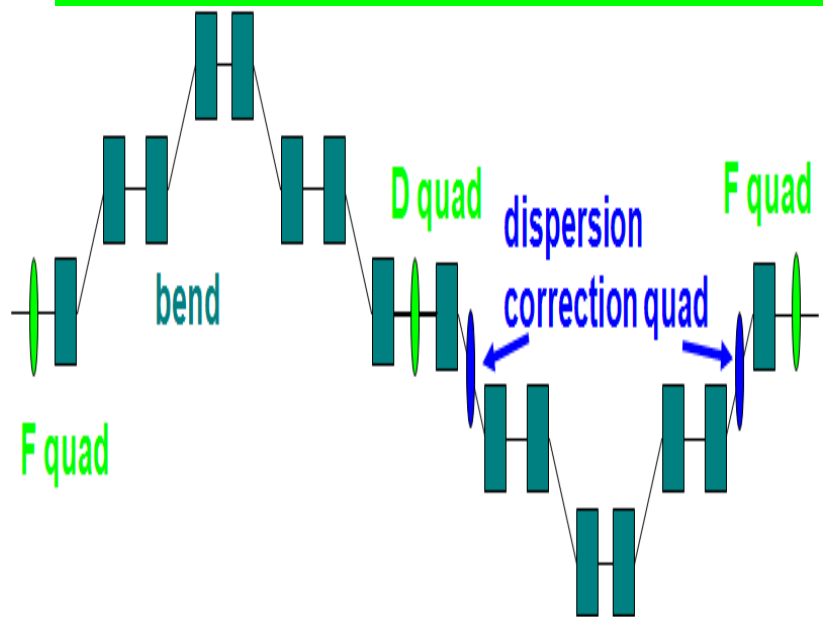
- The good references for the TDR BC design are:
 - S. Seletskiy, N. Solyak, Renovated 2-stage bunch compressor for the International Linear Collider, Proceedings of IPAC12. (Please note, some BC parameters have been updated since then.)
 - S. Seletskiy, N. Solyak, Design of the ILC RTML extraction lines for the renovated two-stage bunch compressor, Proceedings of NAPAC13.

Design of the Wiggler

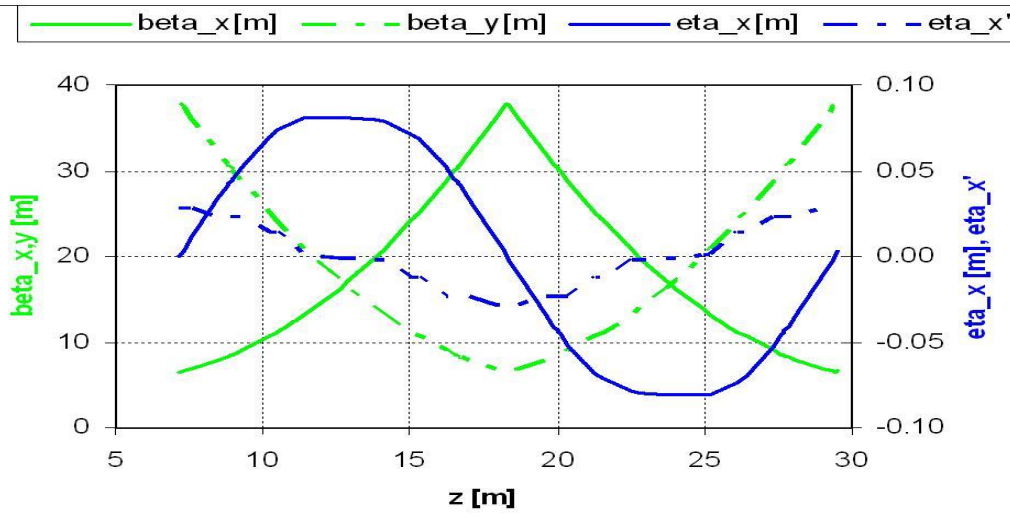
- Each stage of the bunch compressor uses a wiggler to provide required momentum compaction.
- The wiggler consists of 6 identical cells.
- Each cell is contained in FODO structure with 90° phase advance per cell.
- The length of the wiggler is minimized by introducing nonzero η' at the entrance of each cell. This allows to obtain required R56 with reasonably low bending angles (and thus limited possible horizontal emittance growth caused by synchrotron radiation).



Design of the Wiggler

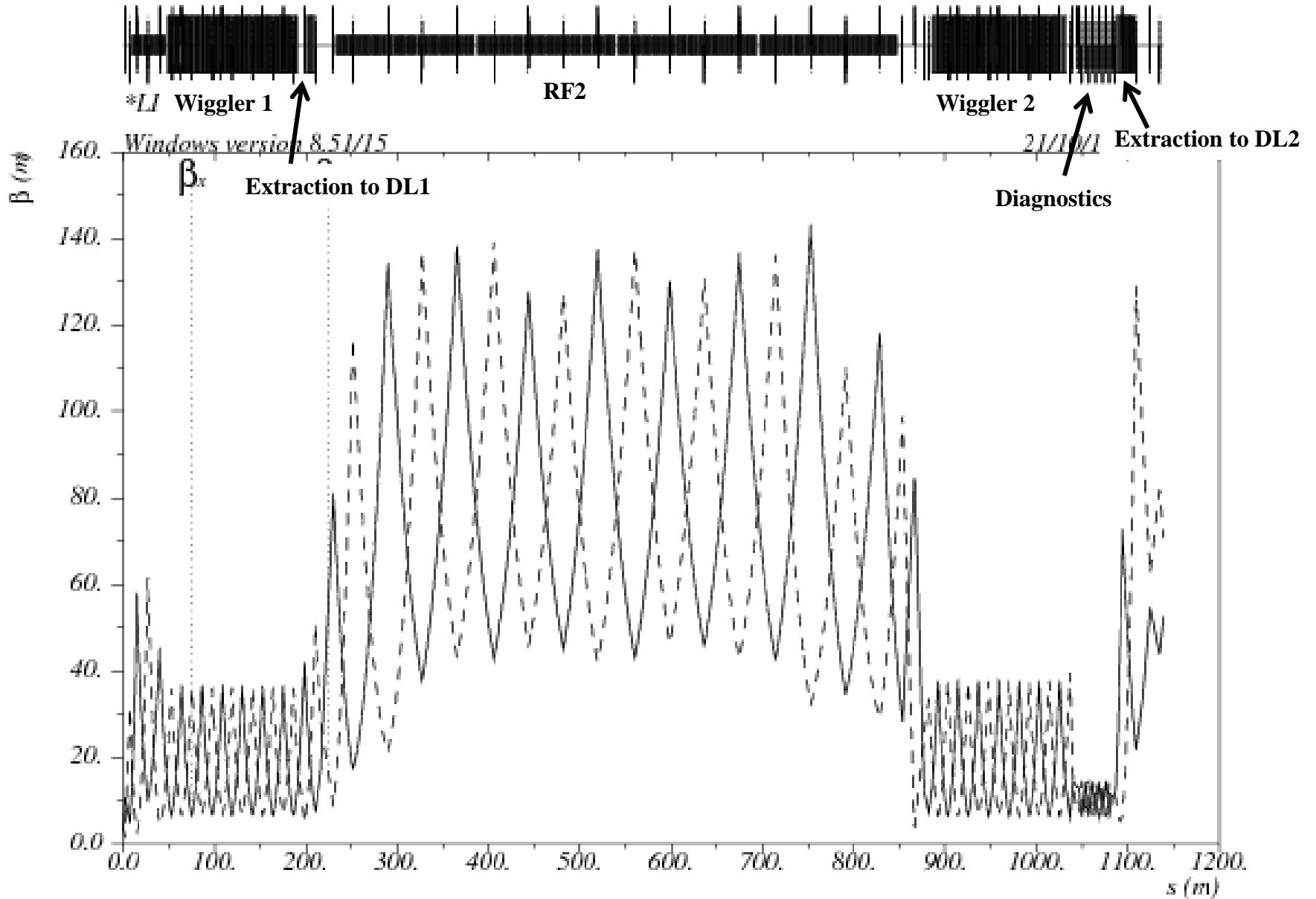


- Focusing and defocusing quads are placed in the zero dispersion regions.
- There are 4 additional normal quads and 4 skew quads per wiggler (in cells 1,3,4 and 6) that are used for possible dispersion correction without introducing betatron coupling or mismatches.
- The wiggler is tunable: sixteen bends allow changing R56 while preserving beam's trajectory in quads.
- The mirror symmetry of the first and second halves of the cell together with the requirement to the sum of 8 bending angles in each half of the cell to be equal to $-2\eta'$ forces η' at the exit of each cell to be equal to its entrance value.



matching
and RF1

Bunch compressor lattice



S. Seletskiy

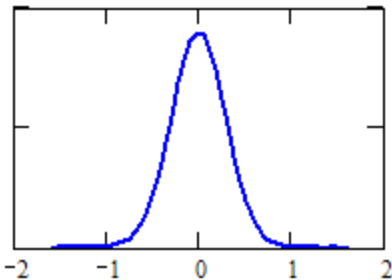
Two stage BC parameters

Initial beam			BC1 parameters		Beam after BC1			BC2 parameters		Final beam		
dp/p, %	σ_z , mm	E, GeV	Grd/- ϕ , MeV/deg	R ₅₆ , mm	dp/p, %	σ_z , mm	E, GeV	Grd/- ϕ , MeV/deg	R ₅₆ , mm	dp/p, %	σ_z , mm	E, GeV
0.11	6	5	18.67/115	372	1.42	0.9	4.8	25.8/23.9	55	1.13	0.3	15
0.12	6	5	18.67/115	372	1.42	0.9	4.8	26.1/25.2	55	1.19	0.3	15
0.137	6	5	18.67/115	372	1.42	0.9	4.8	26.5/26.9	55	1.26	0.3	15

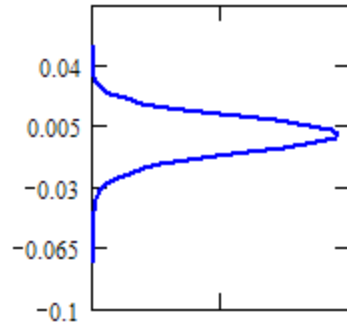
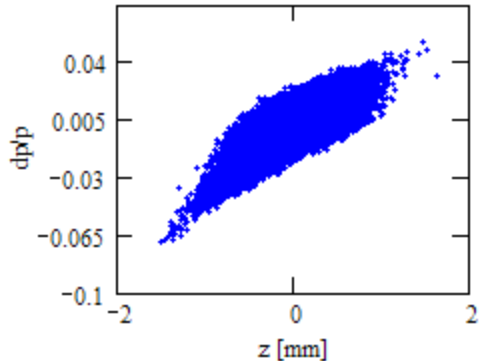
- The three initial energy spreads upstream of the BC correspond to:
 - dp/p = 0.11% 5Hz mode for both electrons and positrons
 - dp/p = 0.12% 10Hz mode for electrons
 - dp/p = 0.137% 10Hz mode for positrons

Final 0.3mm long beam

- The plot shows final 0.3mm long beam with 1.13% energy spread at 15GeV for the case of initial $dp/p=0.11\%$.
- The beam is not sensitive to 10% drop in RF2 gradient.



Initial beam dp/p , %	Final beam length change (%) for 10% drop in BC2RF gradient
0.11	1.3
0.12	2.3
0.137	3.0

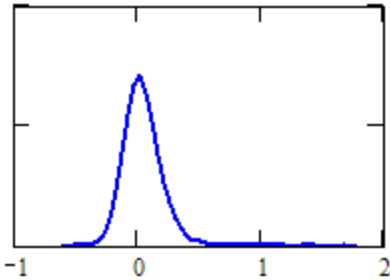


BC parameters for 150 um long final beam

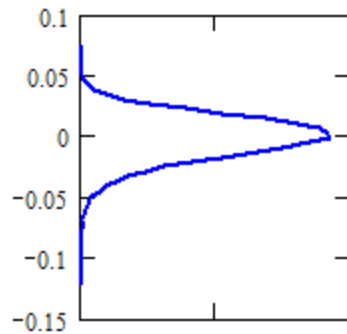
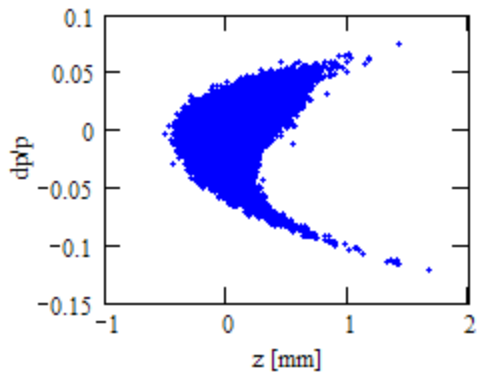
Initial beam			BC1 parameters		Beam after BC1			BC2 parameters		Final beam		
dp/p, %	σ_z , mm	E, GeV	Grd/- ϕ , MeV/deg	R ₅₆ , mm	dp/p, %	σ_z , mm	E, GeV	Grd/- ϕ , MeV/deg	R ₅₆ , mm	dp/p, %	σ_z , mm	E, GeV
0.11	6	5	18.67/120	348	1.37	1.36	4.77	27.2/29.2	69	1.85	0.15	15
0.12	6	5	18.67/120	348	1.37	1.37	4.77	27.5/30.4	69	1.93	0.15	15
0.137	6	5	18.67/120	348	1.37	1.4	4.77	30.5/39	52.4	2.52	0.15	15

- The 150um final length is achievable for all three cases of initial energy spread.
- It requires higher RF2 gradient.
- The maximum final energy spread is 2.5%.

Final 0.15mm long beam



Initial beam dp/p , %	Final beam length change (%) for 10% drop in BC2RF gradient
0.11	7.1
0.12	5.3
0.137	9.0

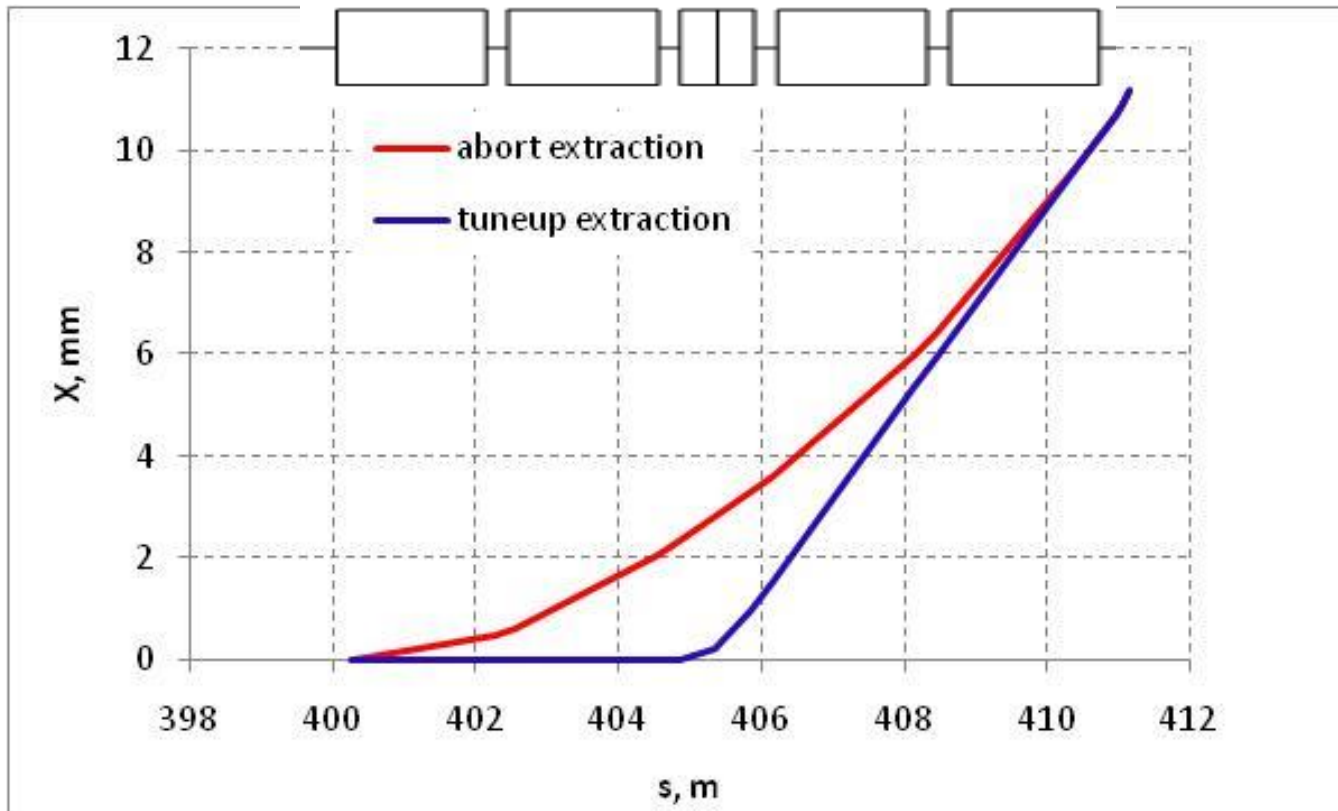


- The plot shows the final 150um long beam for the case of initial $dp/p=0.11\%$.
- The 10% drop in RF2 gradient noticeably affects the final beam length.

Extraction lines

- The extraction lines are capable of accepting and transmitting up to 220kW of beam power.
- The ELs can be used for both fast intra-train and continuous extraction, and are capable of accepting both low and high energy spread beams.
- The beam size on the dump window must be at least $\pi\sigma_x\sigma_y=12 \text{ mm}^2$. Since the energy spread of the beam can be both large and small the beam size due to dispersion is no help in maintaining the required beam size on the dump window. Indeed, the beamline apertures have to be large enough to accommodate the high energy spread beam, but on the other hand, aperture size is limited by the requirements to the field of the non-SC magnets.
- The design of the compact extraction line is based on the bending blocks built of double bend achromats. This allows decoupling (in the linear approximation) the dispersion and the beam size.
- Due to the requirements of acceptable radiation levels in the service tunnel, horizontal offset of the dump from the main beamline must be at least 5 m center-to-center.

Extraction System Design

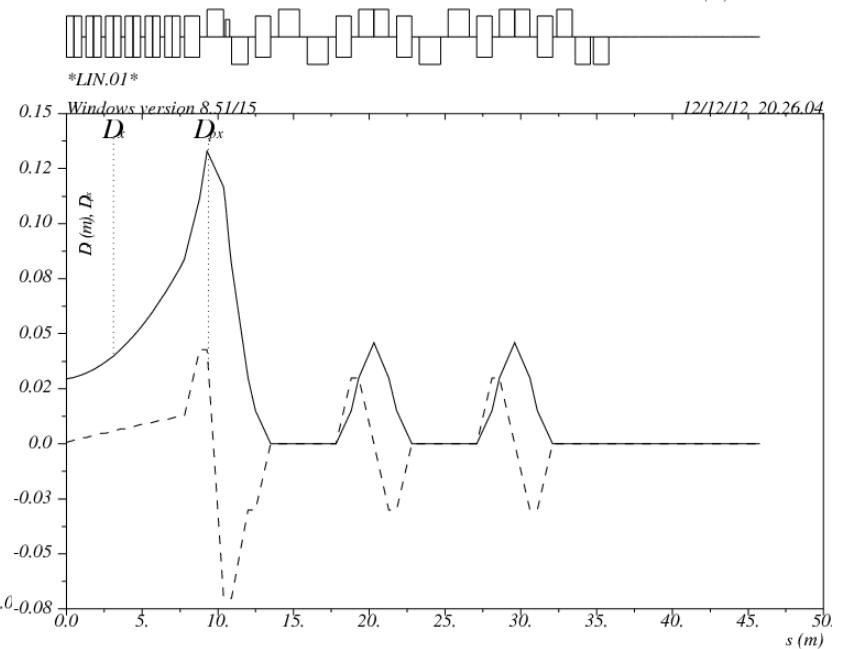
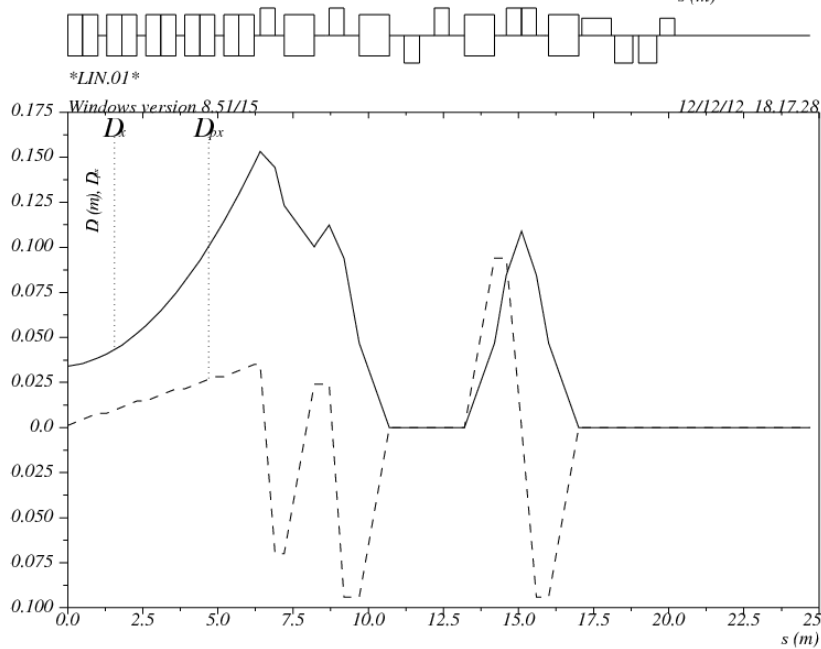
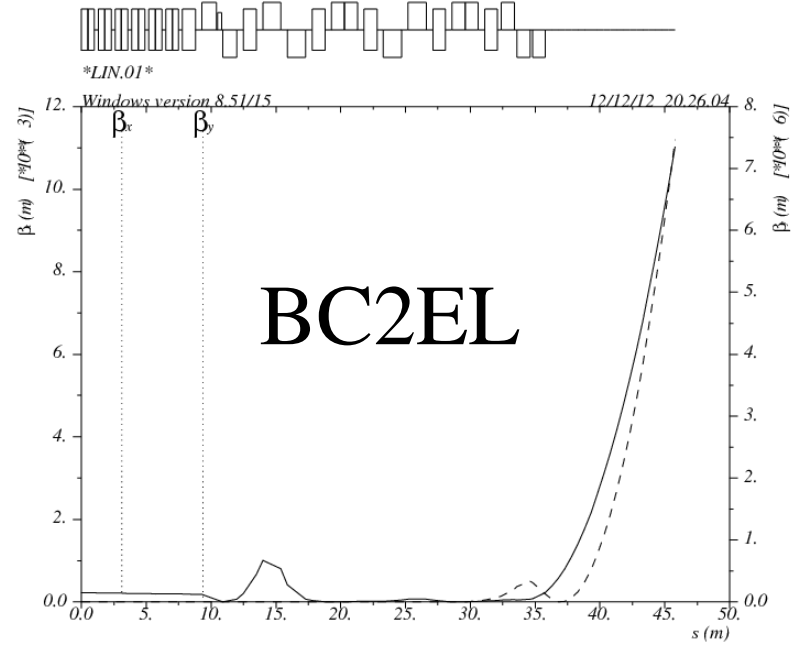
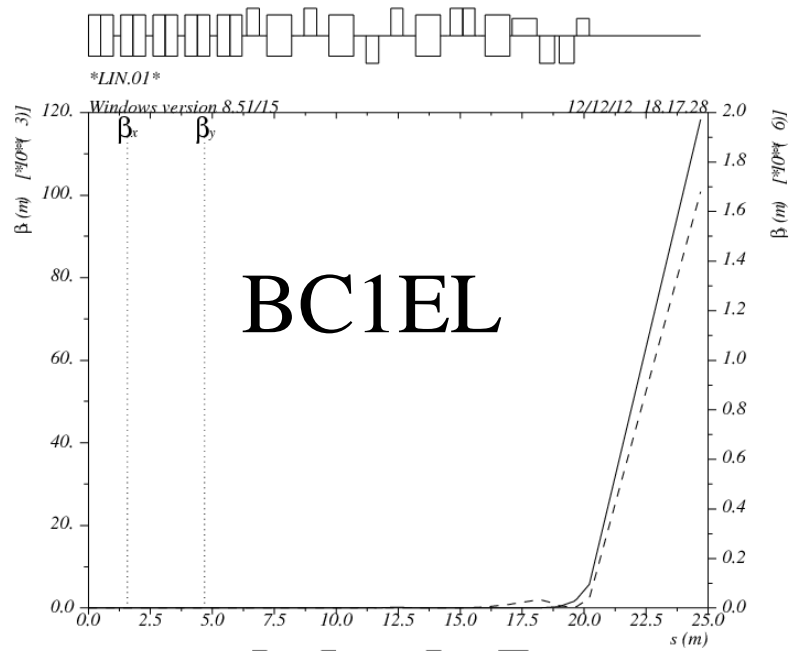


- Extraction system is common for all dump-lines and consists of four 2m long fast abort kickers, and a single 1m long tune-up extraction bend placed in between two central kickers.
- The abort kickers can be charged to 35G each in 100ns. The tune-up bend is powered to 280G.

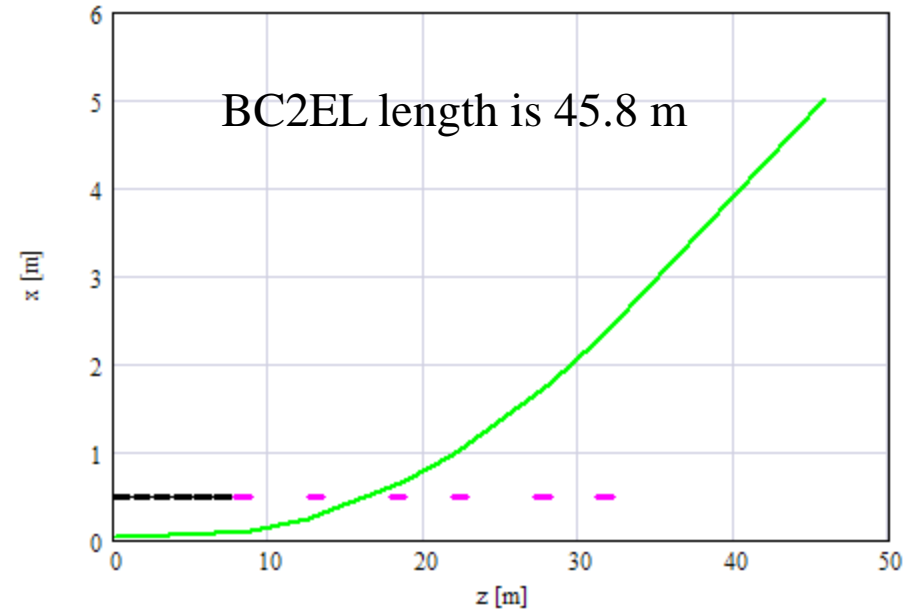
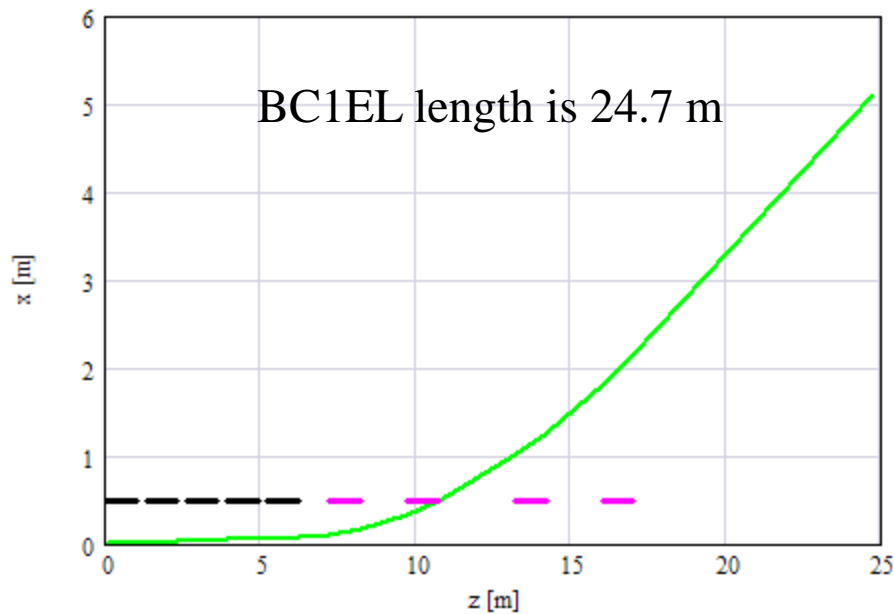
Beam Dump

- Another common feature of all dump lines is the 220kW aluminum ball dump. It is capable of absorbing the full beam power at 5 GeV, while at 15 GeV it can absorb only about 1/3 of the nominal beam power. Full trains can be run to ELBC2 dump at reduced repetition rate.
- A dump window diameter of 12.5 cm is considered to be a basic choice.
- An aluminum window using a 1 mm thick hemispherical design is feasible for a suggested aluminum sphere dump.
- It has the promise of long term safe operation even for the 0.11% $\Delta p/p$ optics with beam spot area on the dump window equal to or larger than 12mm².
- There are no steady state heat transfer issues to reject the energy deposited by the beam to the cooling water.
- The dumps can be used at 10 Hz pulse repetition rate in case the number of bunches is <1400.

EL lattice



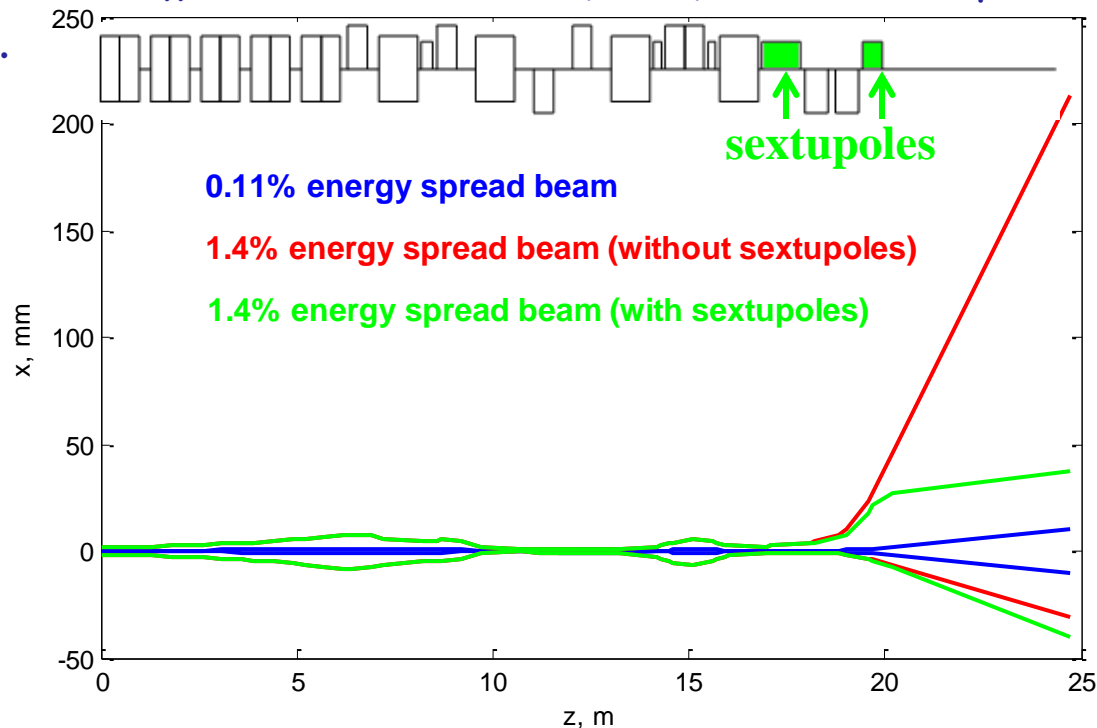
EL lattice



- The length of both ELs was minimized.
- Separation of the dump from the main beamline is ≥ 5 m for each of the ELs.

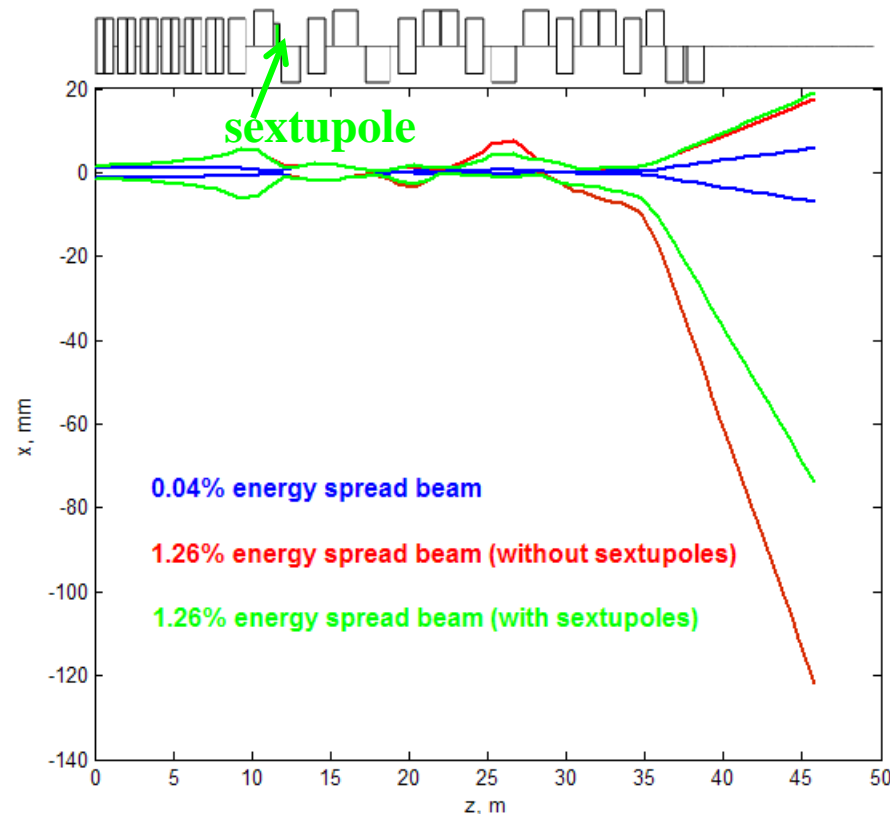
Nonlinear dynamics

- For a beam with a high energy spread there is a substantial blow-up of beam size at the end of the EIs because of chromatic aberrations and nonlinear dispersion.
- We found that relatively weak sextupoles can contain the nonlinear halo and such solution doesn't require any additional beam collimation.
- For BC1EL the final beam size is 19.5 mm^2 in low energy spread case and the high energy spread beam is contained within the borders of a dump window of 12.5 cm diameter.



Nonlinear dynamics

- In case of ELBC2 we found that the high energy spread beam can be contained with the help of only one sextupole strategically placed at the location of highest dispersion.
- Beam size on the dump window is 12.3 mm^2 in low energy spread case and the high energy spread beam is contained within the borders of a dump window of 12.5 cm diameter.



Conclusion

- The ILC RTML two stage bunch compressor under nominal conditions compresses 6 mm long 5 GeV bunches to 300 um long bunches at 15 GeV. The maximum final energy spread of the compressed beam is 1.26% (10 Hz positrons).
- The bunch compressor can be tuned to compress bunches to 150 um. The maximum energy spread of the compressed bunches for this case is 2.52%.
- Each stage of bunch compressor is followed by extraction to the dump line which can be used for both fast intra-train and continual extraction, and is capable of accepting both low and high energy spread beams.
- The extraction lines are capable of accepting and transmitting up to 220 kW of beam power.