Re-design of extraction line for single stage BC

Sergei Seletskiy

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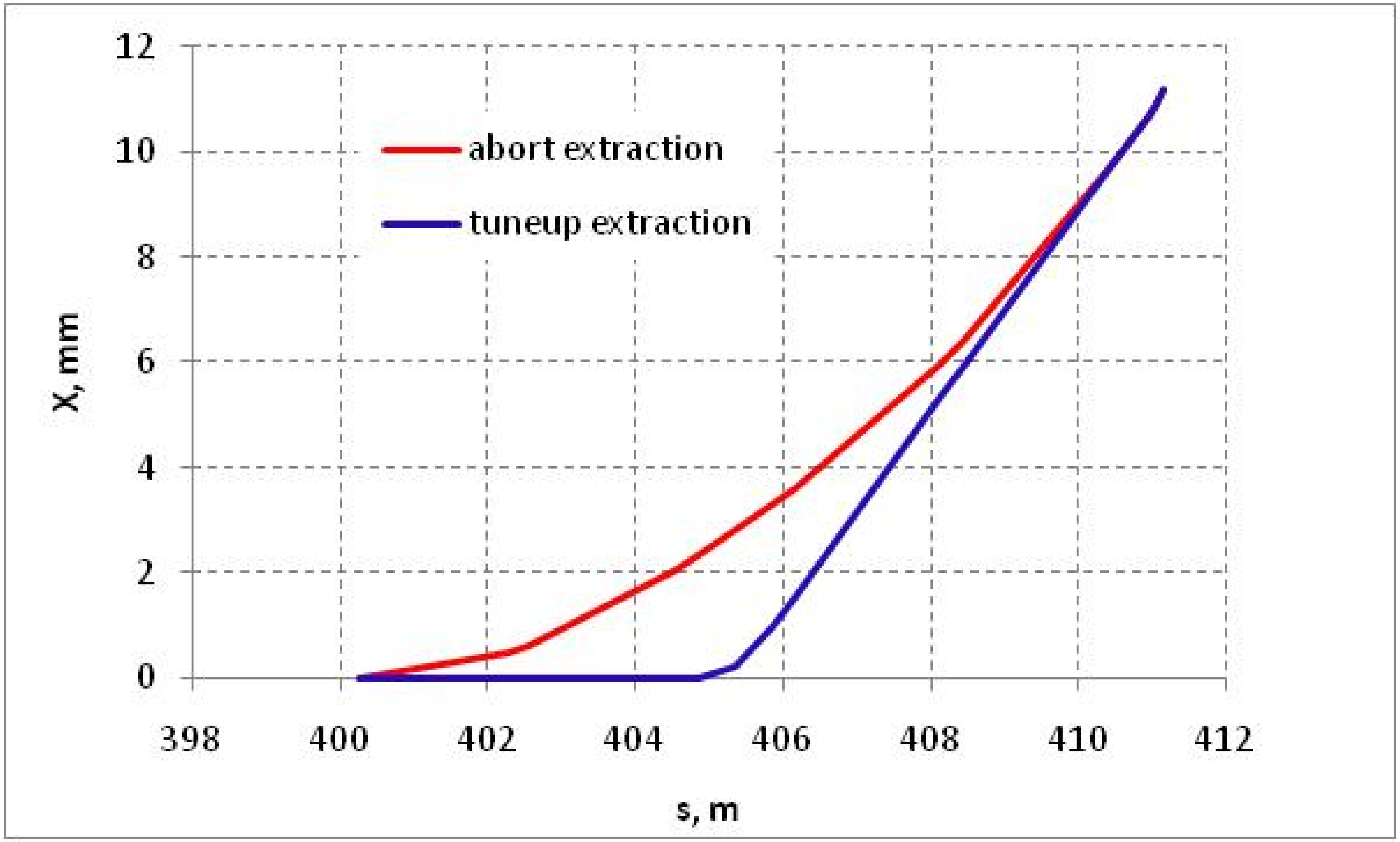
Requirements to the EL

- Horizontal offset of the dump from the main beamline is 5 m center-to-center.
- The beam size on the dump window is at least 12 mm^2.
- The EL has to accommodate both the beam with RMS energy spread of 3.54% and the uncompressed beam, i.e. the beam with the energy spread of 0.15%.
- Beam energy is 4.38GeV.
- The elements of the straight-ahead beamline and the extraction beamline must have enough transverse clearance so that they do not occupy the same physical space.
- One has to arrange for both the train-by-train extraction and emergency abort of the beam.
- The magnets must be physical. Here we limit ourselves to 1 T pole-tip fields for the quads, 1.5 T fields for the bends, and 0.05 T fields in septum magnets.
- The extraction line must be made as short as possible.

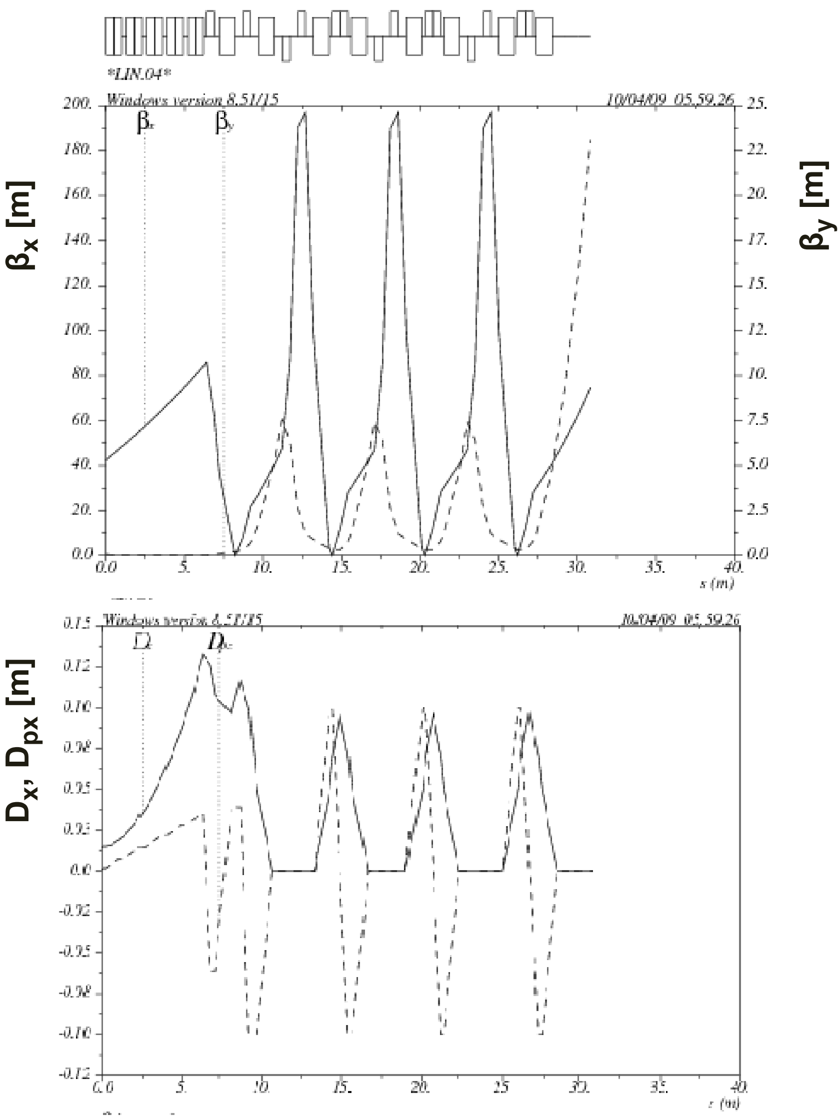
Extraction system design



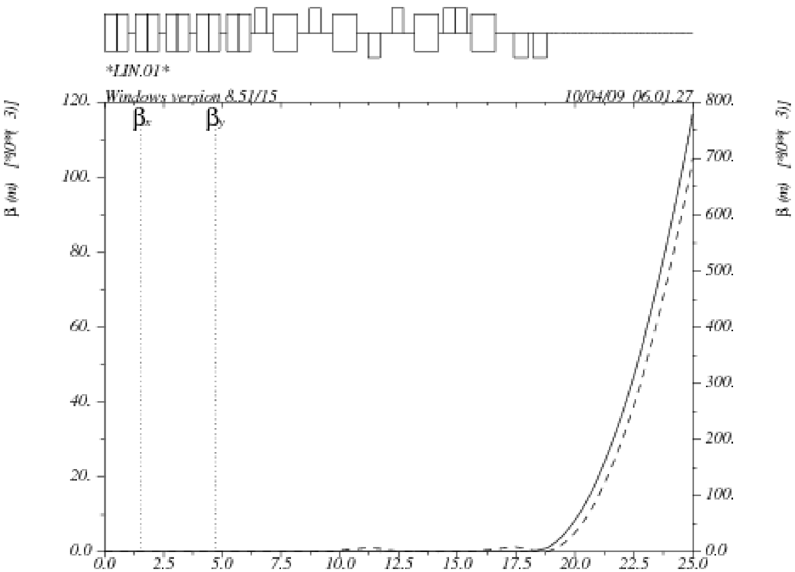
- Extraction system consists of four 2m long fast abort kickers, and a single 1m long tune-up extraction bend placed in between two central kickers.
- The abort kickers can be charged to 35G each in 100ns. The tune-up bend is powered to 280G.

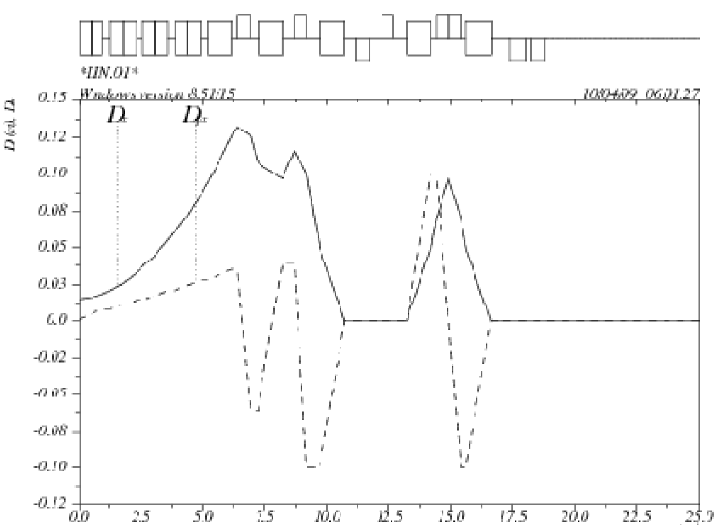
EL Design Concept

- We would like to make EL as short as possible. So we need as much bending as possible, as early as possible.
- On the other hand, horizontal dispersion and requirements to the strength of bends set their limits.
- Therefore, we suggest to use double bend achromats (DBA) as our bending blocks.
- Since we are confining the beam within 4.7 cm aperture we can not make bends too long. We must balance a wish for stronger bending at the beginning of the EL with allocating enough space for focusing quads.
- We build the EL of periodic cells consisting of DBA and focusing quads.

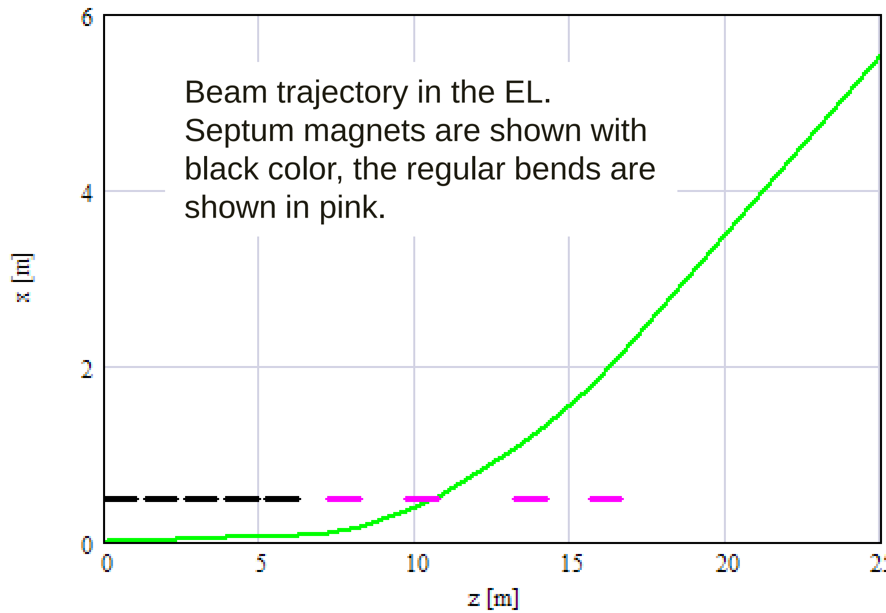


Extraction Line design





- Taking the described approach to EL design, we obtain (in "linear"/"low energy spread" approximation): 25m long beamline with 12mm² beam size on the dump window. Dump is separated from the main beamline by 5.5m.



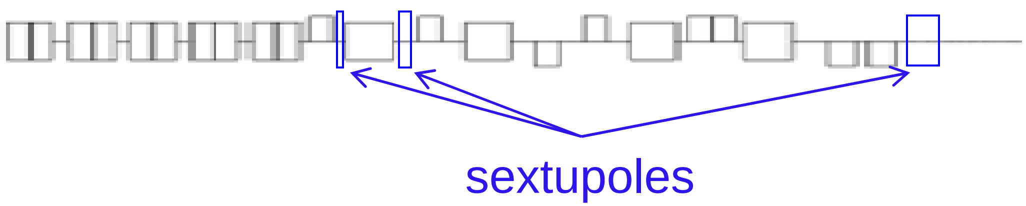
Beam dump

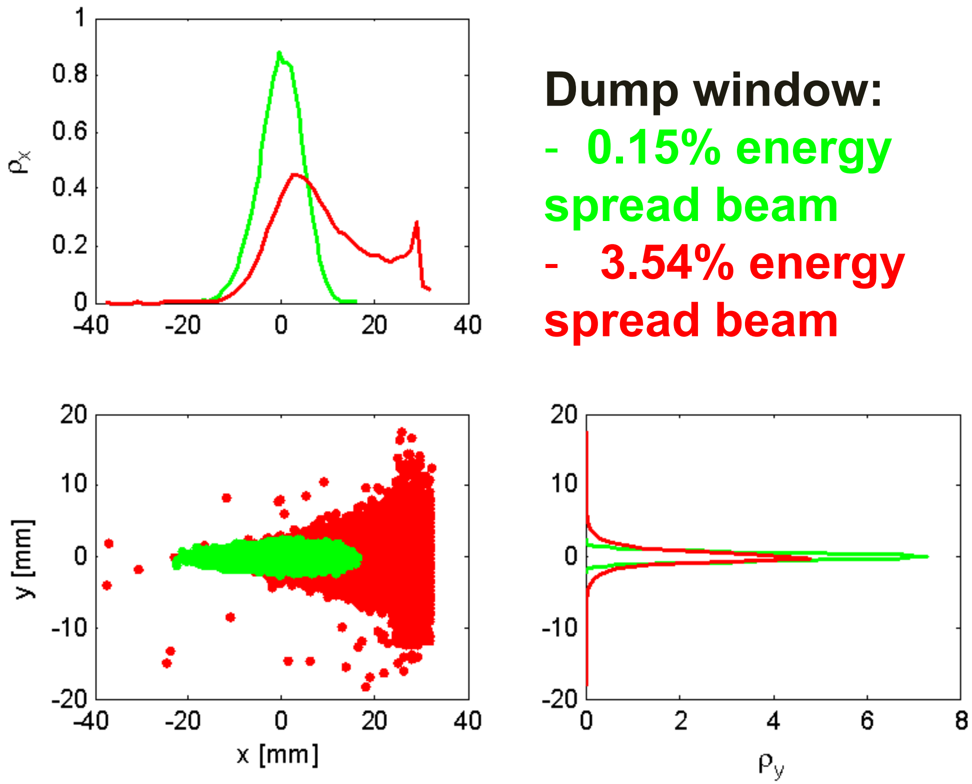
- We are utilizing 220kW aluminum ball dump. For 4.37GeV beam energy the total power/train is just 184kW.
- A dump window diameter of 12.5cm is considered to be a basic choice.
- An aluminum window using a 1mm thick hemispherical design is feasible for a suggested aluminum sphere dump.
- It has the promise of long term safe operation, even for the 0.15% $\Delta p/p$ optics with beam spot area on the dump window equal to or larger than $12 mm^2$.
- There are no steady state heat transfer issues to reject the energy deposited by the beam to the cooling water.
- Larger diameter (up to 1m) dump window can be made.

Nonlinear effects

- For the beam with high energy spread, there is a substantial blowup in the beam size from chromaticity and nonlinear dispersion at the end of the beamline.
- There are several possibilities to mitigate this problem.
- In next slides we are reviewing and summarizing the found solutions.

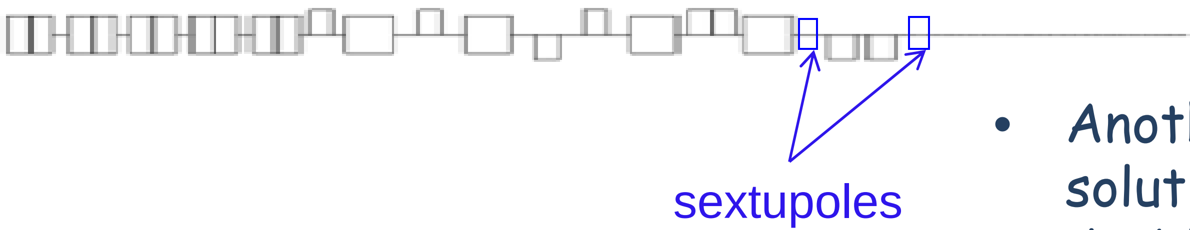
Not Collimated I

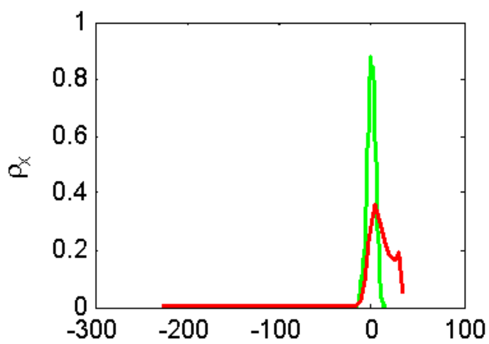




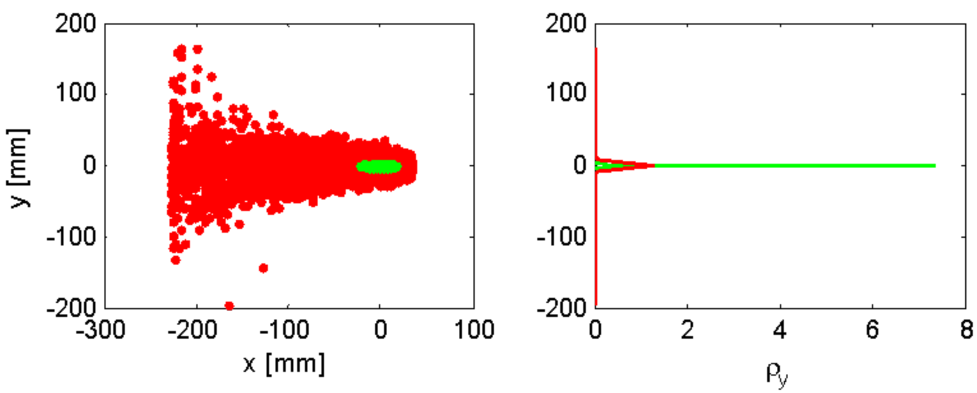
- We found solution, which doesn't require any collimation for high δ beam.
- Three strong (1T pole tip) sextupoles must be used to counteract the nonlinear dispersion and to fold beam tails.
- A "standard" dump window of 5inch diameter can accommodate the beam.
- The drawback of this solution is that the first sextupole is located in the region where separation between main and extraction beamlines is small, so we may need to build a sextupole of exotic shape.

Not Collimated II



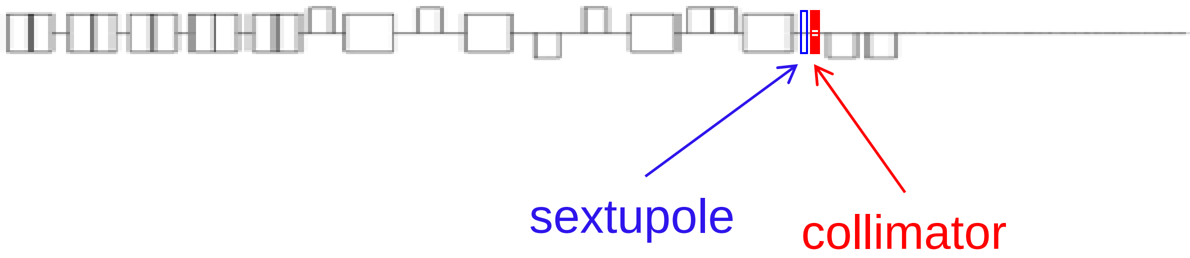


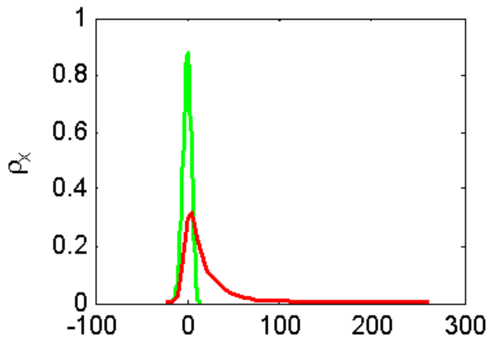
Dump window:
- **0.15% energy spread beam**
- **3.54% energy spread beam**



- Another non-collimated solution requires the final doublet quads and two tail-folding sextupoles of 12cm aperture and pole tip field up to 6T.
- The dump window radius must be 60cm in diameter.
- An obvious disadvantage of this scheme in addition to large dump window is SC magnets in the extraction line.

Weak Collimation

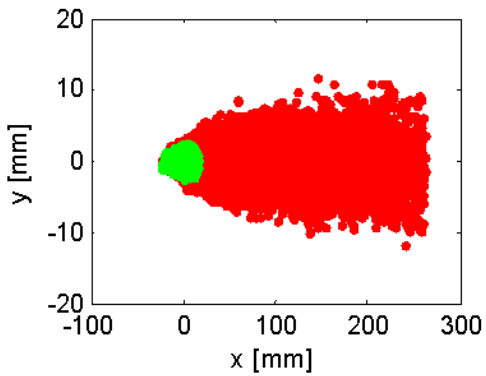


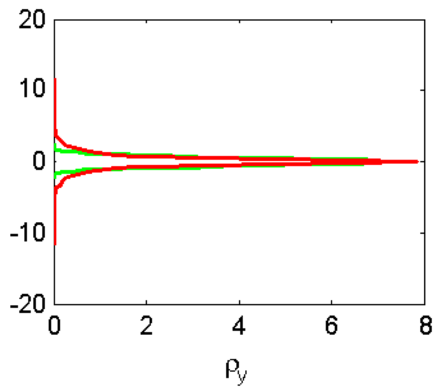


Dump window:

- 0.15% energy spread beam

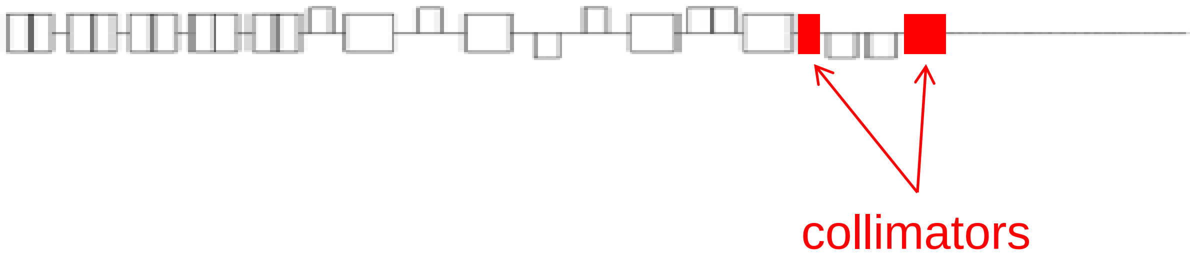
- 3.54% energy spread beam

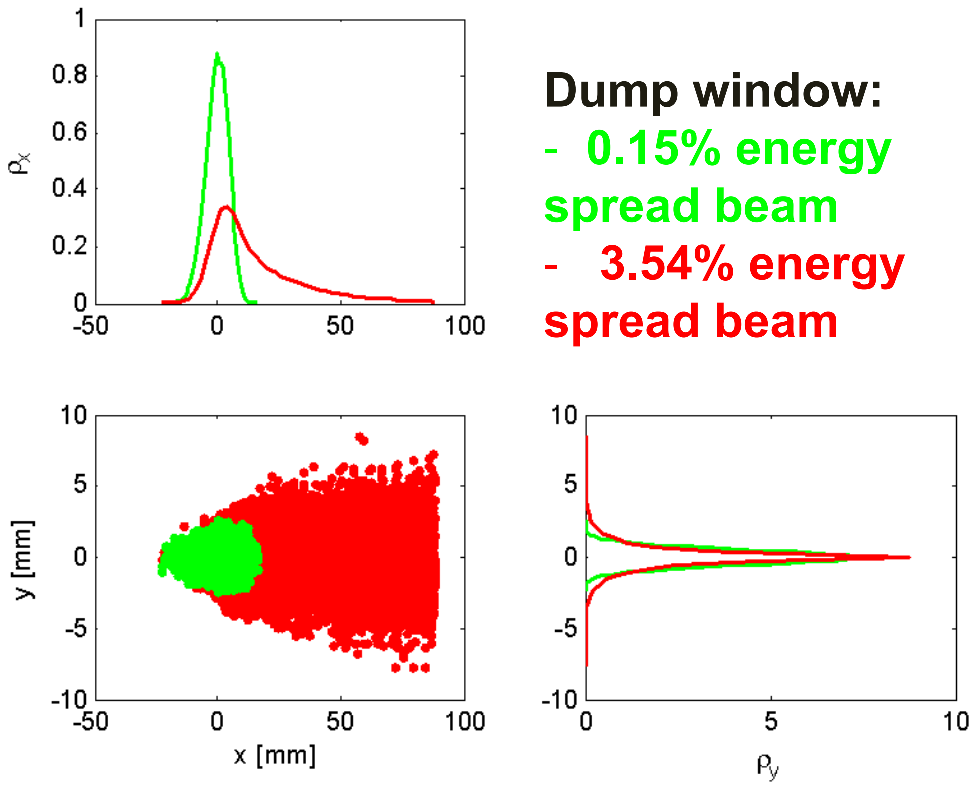




- Weak collimator (1.9kW/train) will be able to protect final doublet. Collimator's horizontal aperture is 7.4mm.
- The dump window radius must be 60cm in diameter.

Strong Collimation





Dump window:
- **0.15% energy spread beam**
- **3.54% energy spread beam**

- Using two collimators to protect the doublet (2.2kW/train, 7.2mm horizontal aperture) and to collimate the beam on the dump window (11.7kW/train, 5cm horizontal aperture) one can accommodate beam with 20cm diameter dump window.

Collimation summary

	No collimation	No collimation SC magnets	1 collimator (weak collimation)	2 collimators (strong collimation)
Collimators			1.9kW/train; 7.4mm horizontal aperture;	2.2kW/train; 7.2mm horizontal aperture;
				11.7kW/train; 5cm horizontal aperture;
Sextupoles	1T pole tip field; exotic shape	Two sextupoles with 12cm aperture and pole tip filed <6T	1T pole tip field	
	Two <1T pole tip field			
Dump window	12.5cm diameter	60cm diameter	60cm diameter	20cm diameter
Final doublet	5cm aperture; 1T pole tip field;	12cm aperture; Pole tip field<2.4T	5cm aperture; 1T pole tip field	5cm aperture; 1T pole tip field

Summary

- ILC RTML extraction line was redesigned for the case of single stage BC.
- The EL is designed to be used for both fast intra-train extraction, and for continual extraction.
- The extraction line is capable to accept the full beam power.
- The extraction line is capable of accepting both low energy spread and high energy spread beams, which is required for different scenarios of machine tune-up.
- Different scenarios of beam collimation are considered. Decision for the final design must be taken through cost optimization process.
- There is possibility for variations of the baseline design.