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# Re-design of extraction line for single stage BC

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ILC-CLIC LET Beam Dynamics Workshop

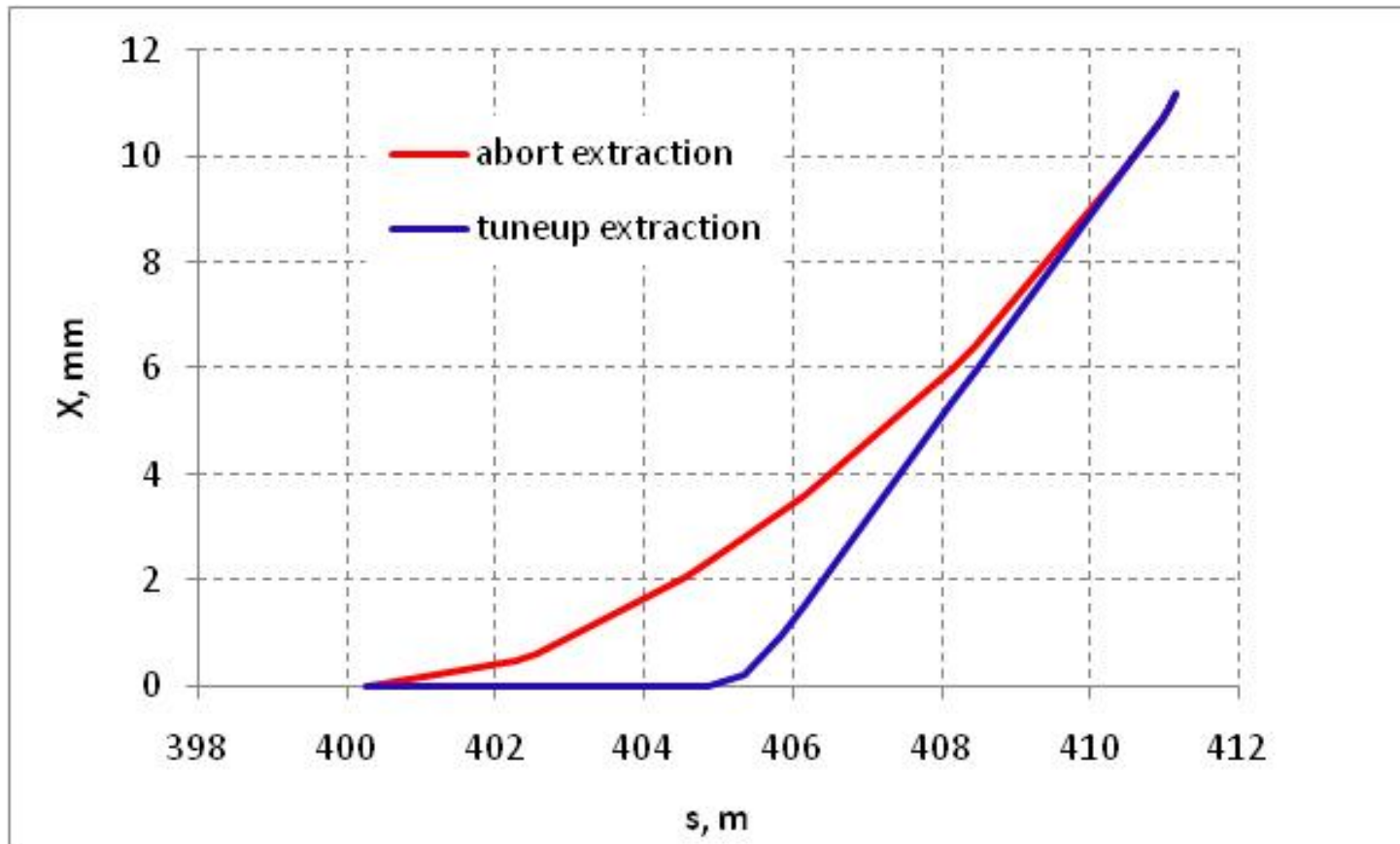
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# Requirements to the EL

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- 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  $12 \text{ mm}^2$ .
  - 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 4.38 GeV.
  - 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.
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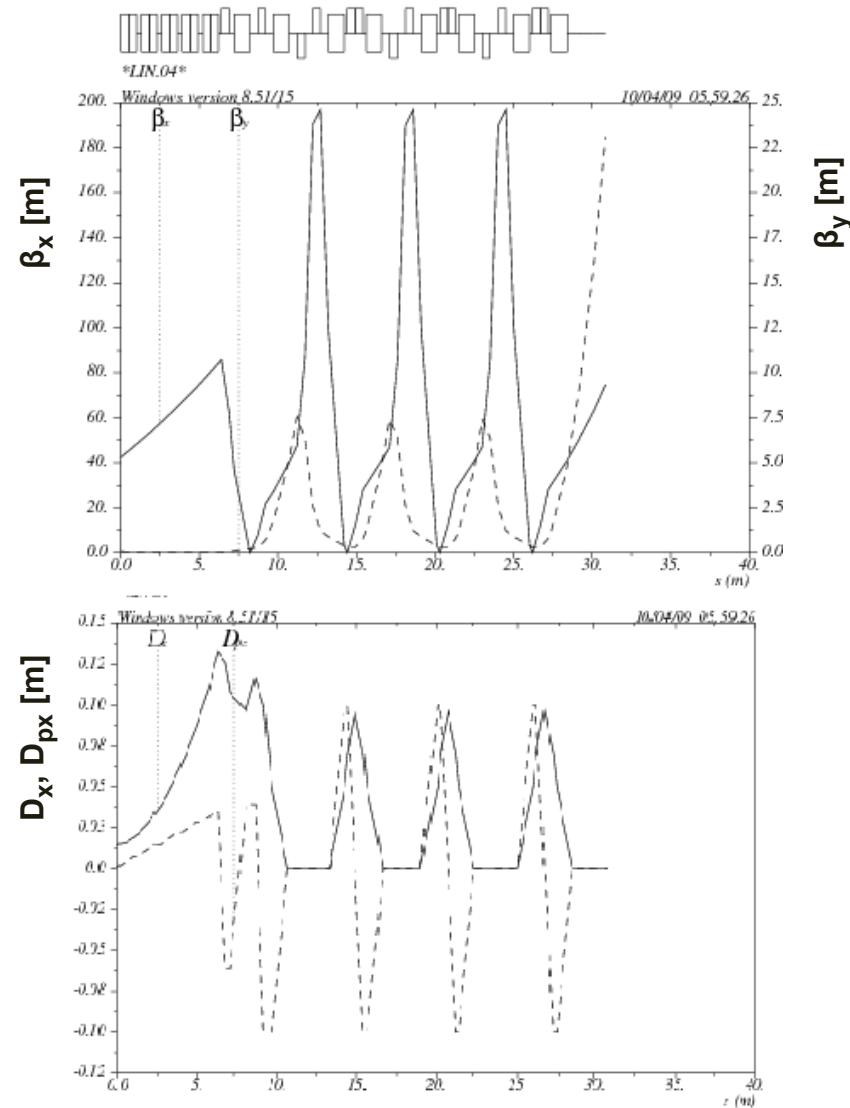
# Extraction system design



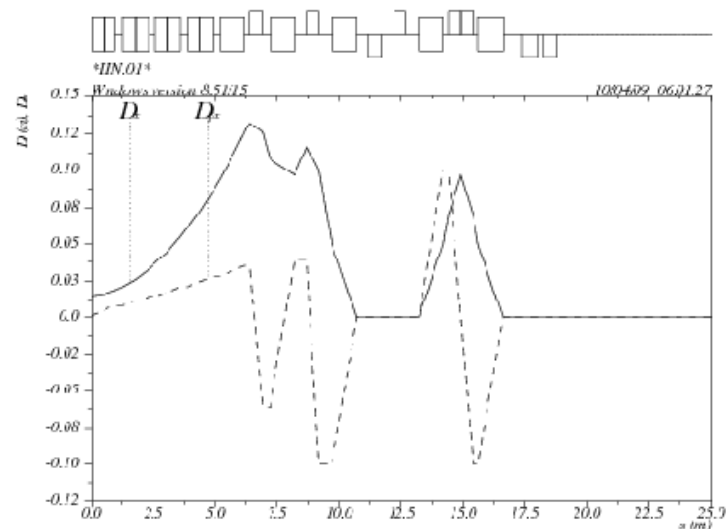
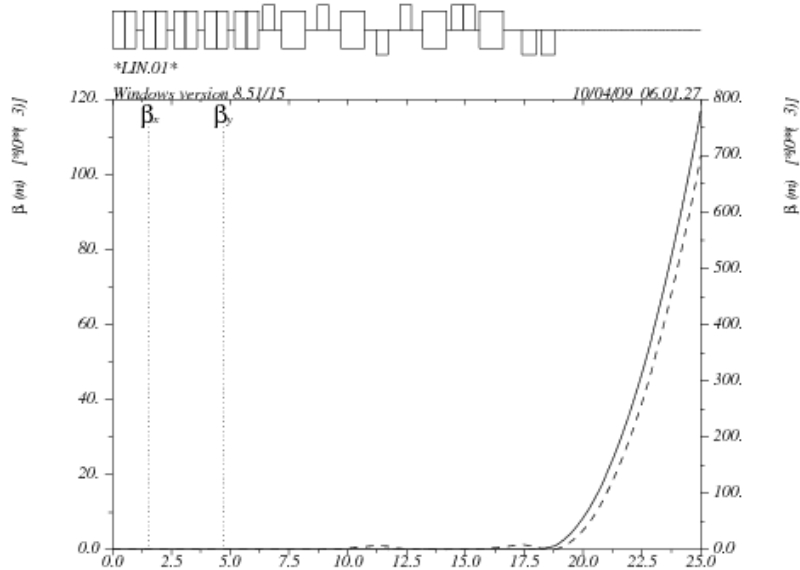
- Extraction system consists of four 2m long fast abort kickers, and a single 1m long tune-up extraction bend placed in between two central kickers.
- The abort kickers can be charged to 35G each in 100ns. The tune-up bend is powered to 280G.

# EL Design Concept

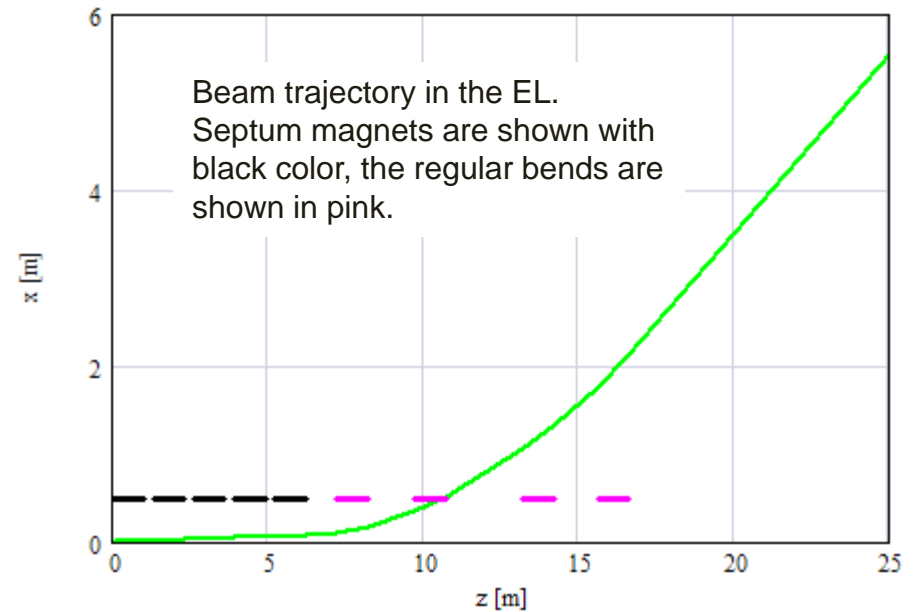
- We would like to make EL as short as possible. So we need as much bending as possible, as early as possible.
- On the other hand, horizontal dispersion and requirements to the strength of bends set their limits.
- Therefore, we suggest to use double bend achromats (DBA) as our bending blocks.
- Since 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  $12\text{mm}^2$  beam size on the dump window. Dump is separated from the main beamline by 5.5m.



# Beam dump

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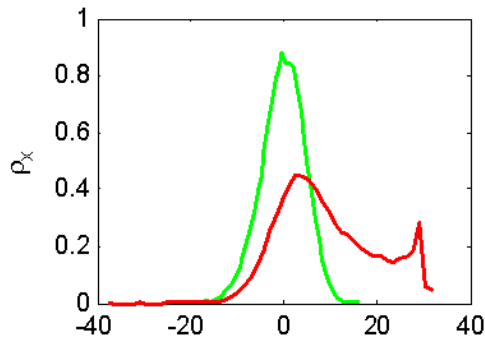
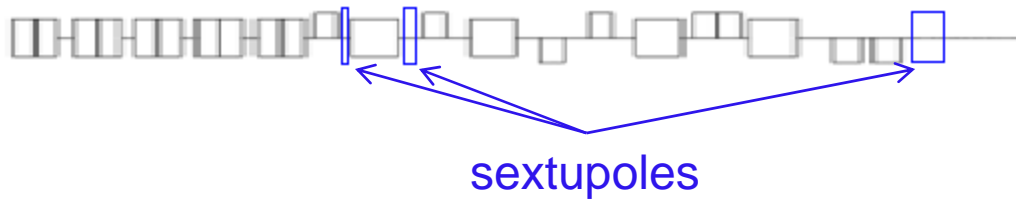
- We are utilizing 220kW aluminum ball dump. For 4.37GeV beam energy the total power/train is just 184kW.
- A dump window diameter of 12.5cm is considered to be a basic choice.
- An aluminum window using a 1mm thick hemispherical design is feasible for a suggested aluminum sphere dump.
- It has the promise 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 12mm<sup>2</sup>.
- 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

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- 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.

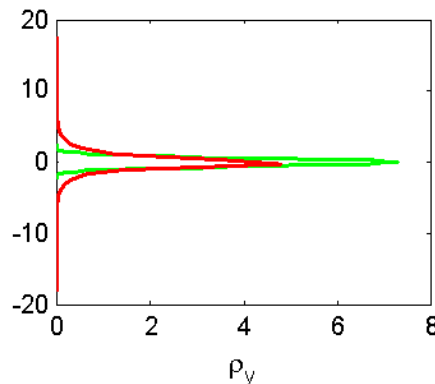
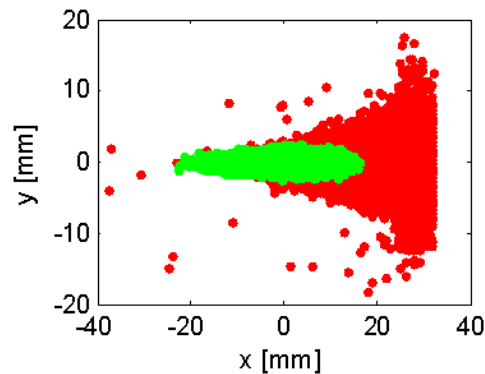
# Not Collimated I



**Dump window:**

- **0.15% energy spread beam**

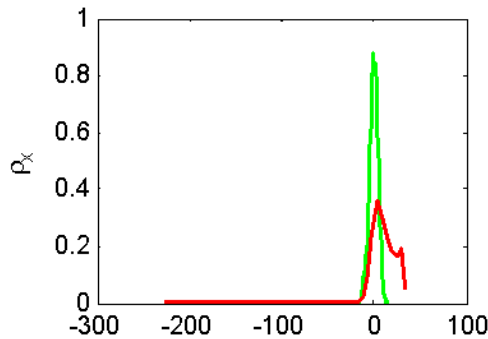
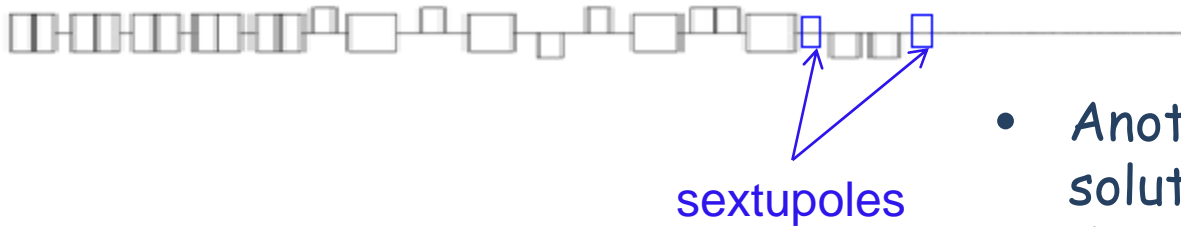
- **3.54% energy spread beam**



- We found solution, which doesn't require any collimation for high  $\delta$  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.



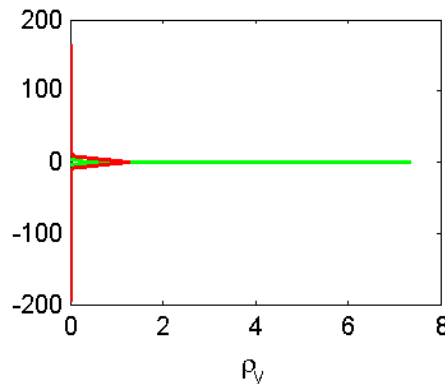
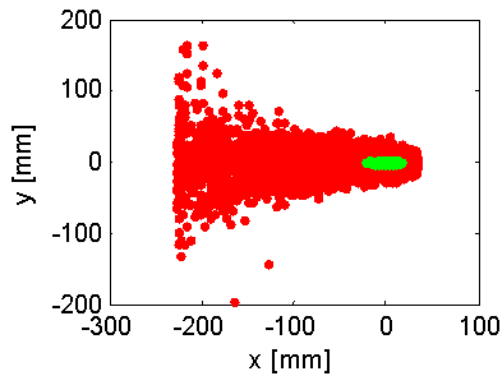
# Not Collimated II



**Dump window:**

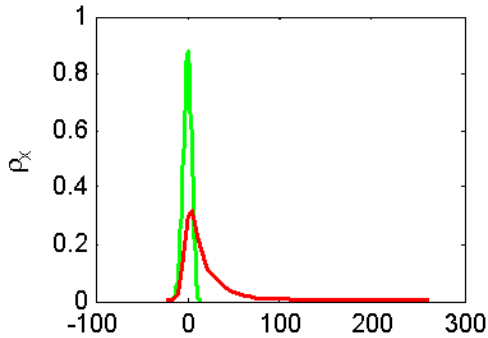
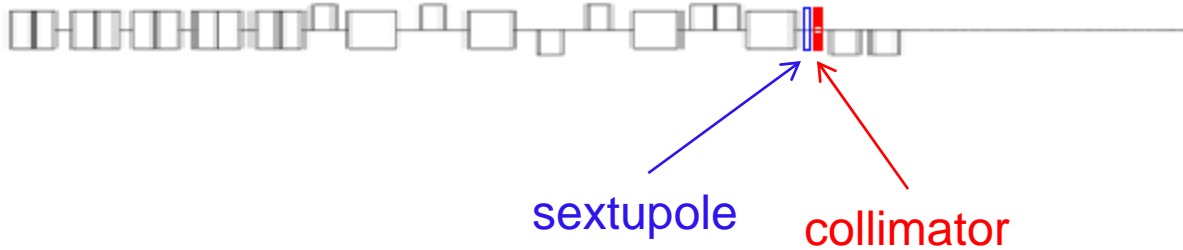
- **0.15% energy spread beam**

- **3.54% energy spread beam**



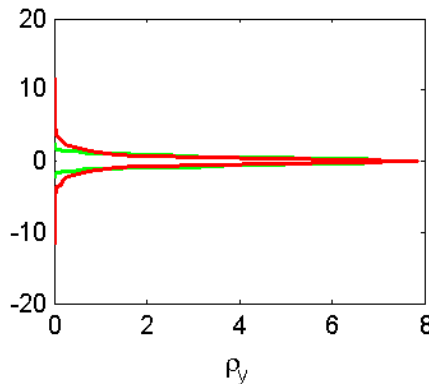
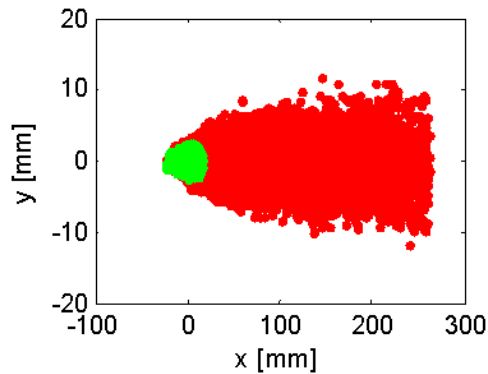
- Another non-collimated solution requires the final doublet quads and two tail-folding sextupoles of 12cm aperture and pole tip field up to 6T.
- The dump window radius must be 60cm in diameter.
- An obvious disadvantage of this scheme in addition to large dump window is SC magnets in the extraction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

# Weak Collimation

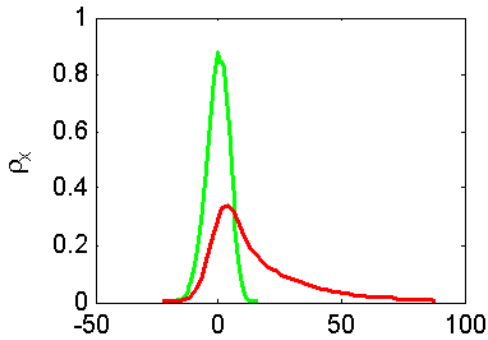
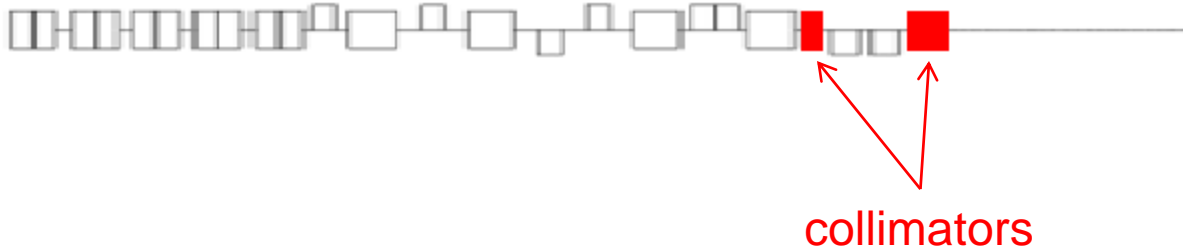


**Dump window:**  
- 0.15% energy spread beam  
- 3.54% energy spread beam

- 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.

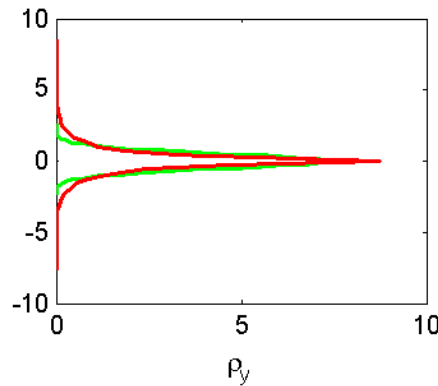
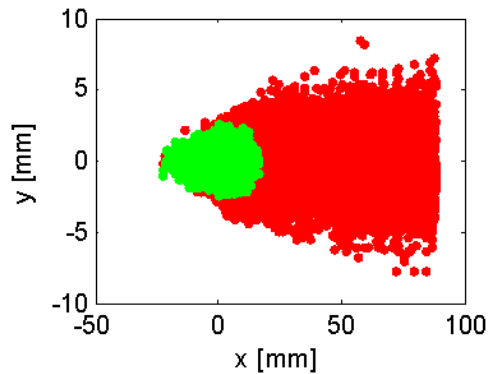


# Strong Collimation



**Dump window:**

- **0.15% energy spread beam**
- **3.54% energy spread beam**

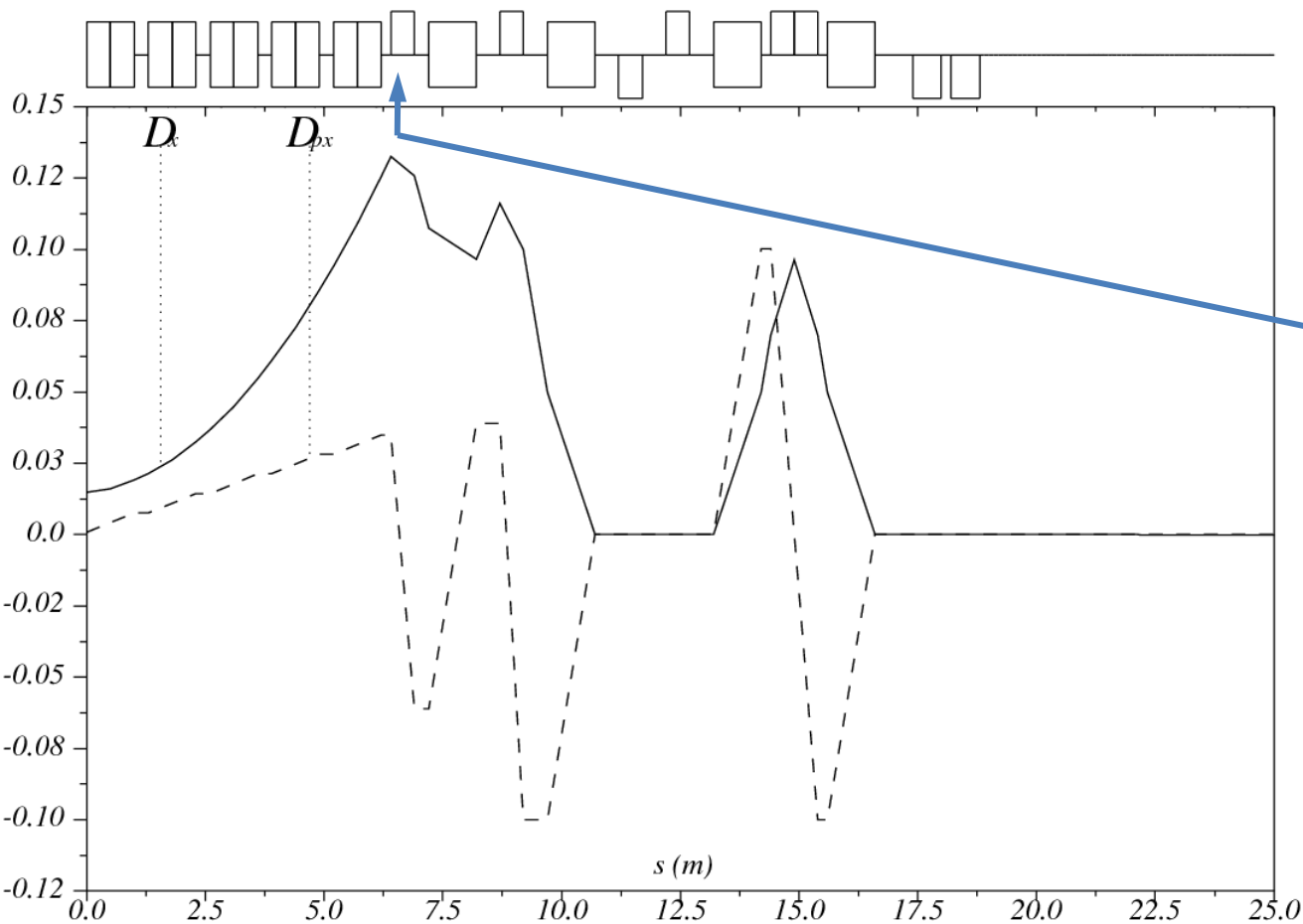


- Using two collimators to protect the doublet (2.2kW/train, 7.2mm horizontal aperture) and to collimate the beam on the dump window (11.7kW/train, 5cm horizontal aperture ) one can accommodate beam with 20cm diameter dump window.

# Collimation summary

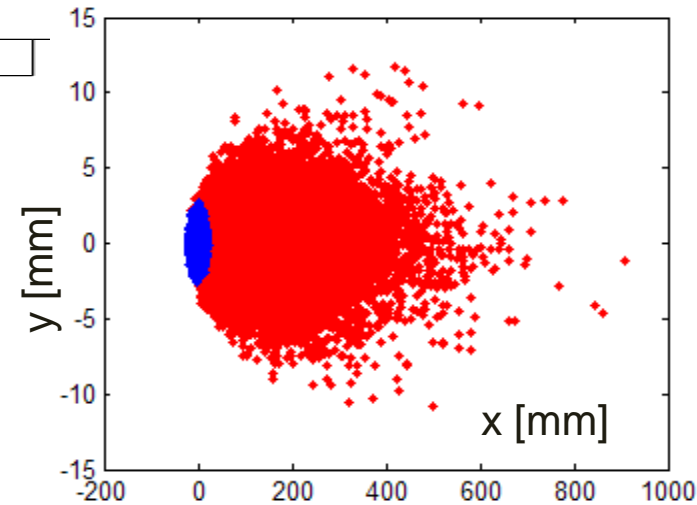
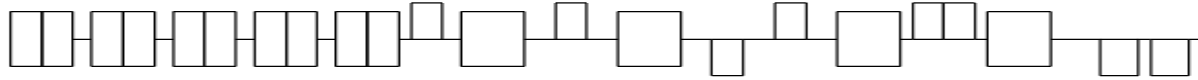
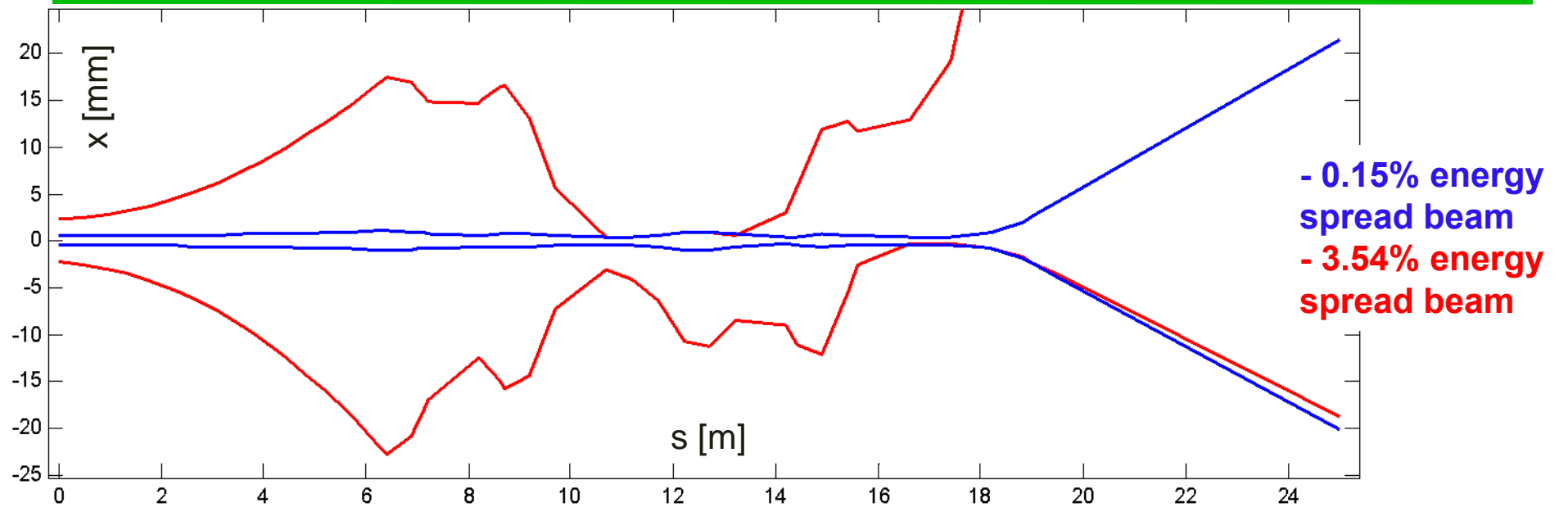
	No collimation	No collimation SC magnets	1 collimator (weak collimation)	2 collimators (strong collimation)
<b>Collimators</b>			1.9kW/train; 7.4mm horizontal aperture;	2.2kW/train; 7.2mm horizontal aperture;
				11.7kW/train; 5cm horizontal aperture;
<b>Sextupoles</b>	1T pole tip field; exotic shape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

# Where do troubles come from?



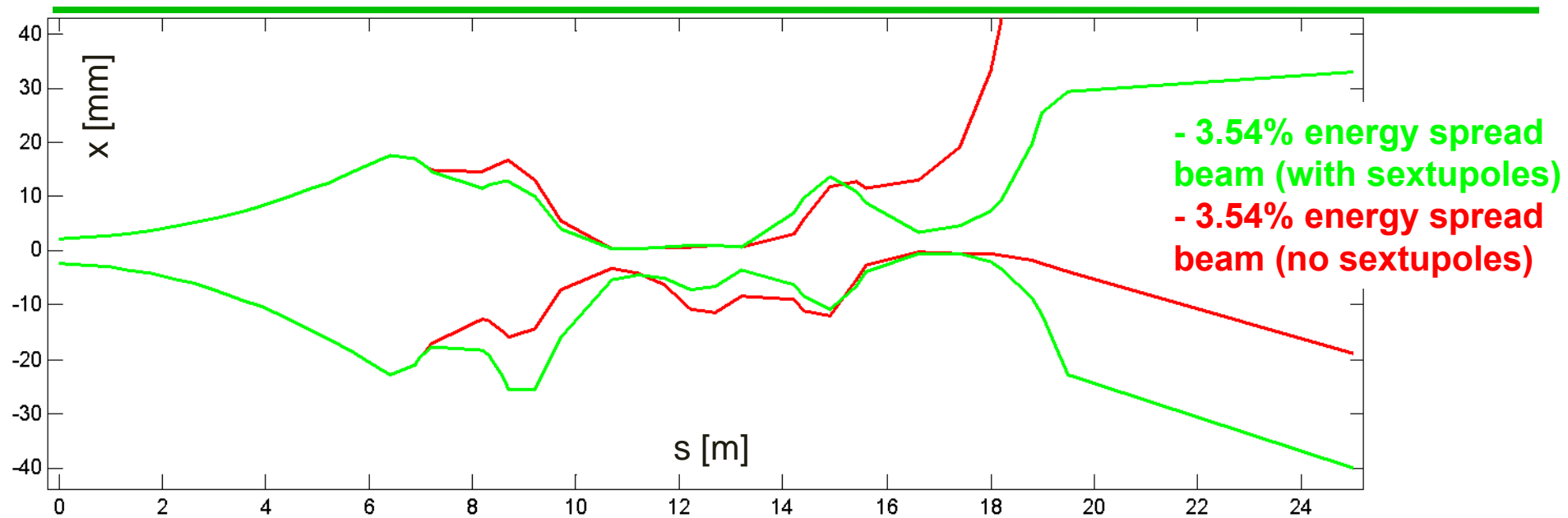
- The main source of high-energy halo is nonlinear dispersion.
- Therefore, one must reduce dispersion as soon as possible. Otherwise, the beams size becomes intolerably large at the very beginning of the extraction line.

# Where do troubles come from?

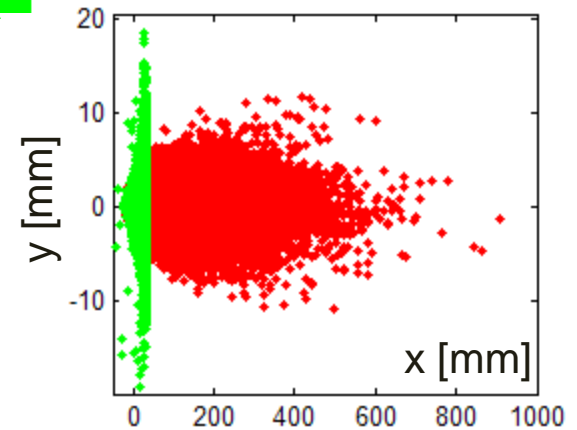
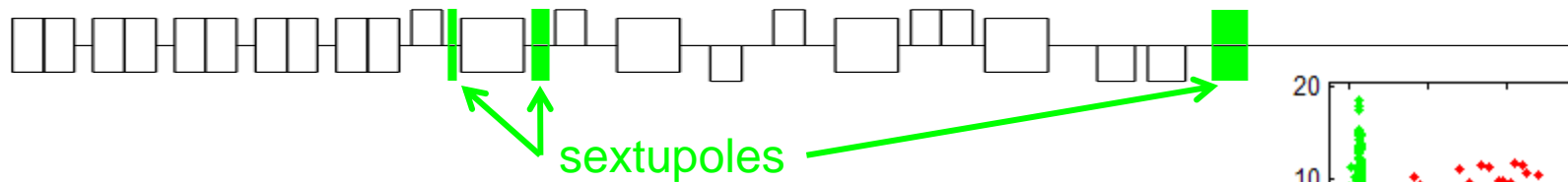


- It seems that it is inevitable having the quad at the location of small (10cm center-to-center) separation between EL and ML.
- It shouldn't be so for the sextupole.

# No collimation I (old scenario)

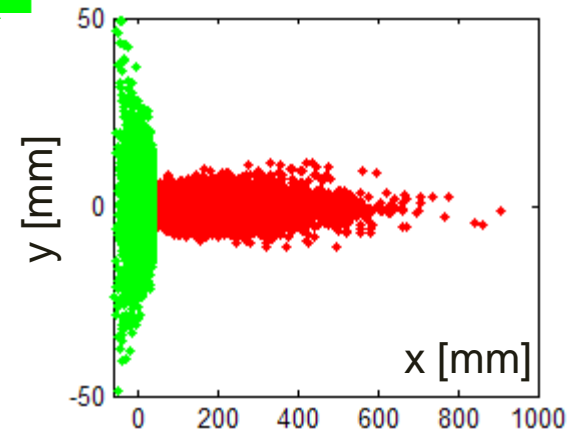
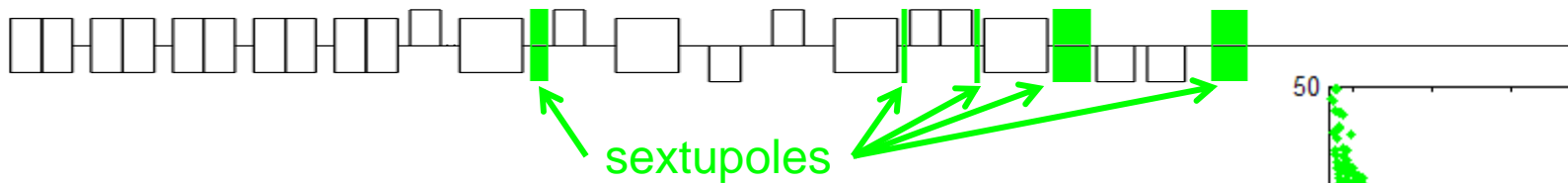
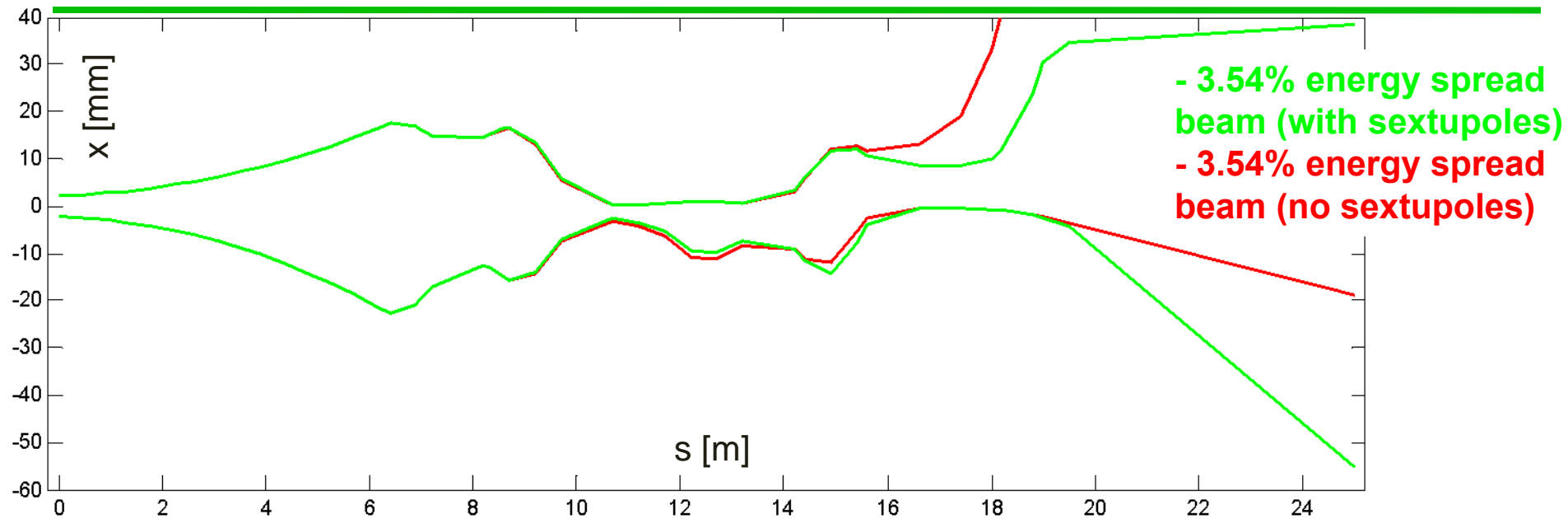


- 3.54% energy spread beam (with sextupoles)  
- 3.54% energy spread beam (no sextupoles)



- The reason for placing sextupole right after 5th septum was to compensate the nonlinear halo locally.

# No collimation (new scenario)



- One can utilize the compensation scheme with sextupoles distributed throughout the whole extraction line.
- In distinction from the old scenario, here we are not space-limited and sextupoles can be made weaker.
- I work on improving this design. I expect to have probably 1m longer EL when design is finalized.



# Summary

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- 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 made through cost optimization process.
- The most appealing of the 4 old designs was optimized. At that point it doesn't require neither collimation, nor "exotic" sextupoles or SC magnets.
- The work is in progress. We expect ~4% increase in the EL length in final design.