RTML Pulsed Extraction Beamlines

Sergei Seletskiy

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Thanks to:

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Introduction

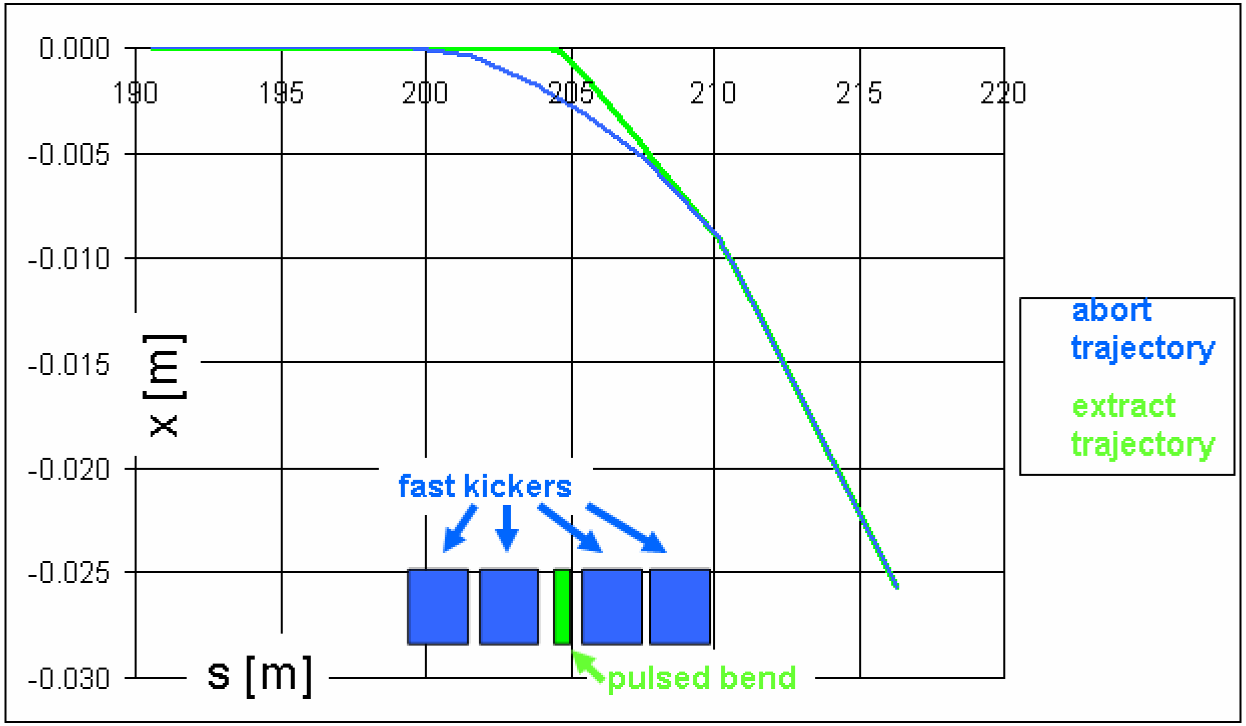
- The RTML incorporates three dump lines (DL): one downstream of the Damping Ring extraction arc (1st DL), and two in the Bunch Compressor (BC), downstream of each of both BC's stages (BC1DL and BC2DL).
- Since BC1DL happened to be a hardest one to build, we consider the design of all 3 DLs on its example.
- Final specs are given for the hardware required by all 3 DLs.

Requirements to the DL

- 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 9 mm^2.
- The DL has to accommodate both the beam with RMS energy spread of 2.5% and the uncompressed beam, i.e. the beam with the energy spread of 0.15% (for the DL located after the first stage of the BC).
- 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, 2 T fields for the bends, and 0.1 T fields in septum magnets.
- The dump line must be made as short as possible.

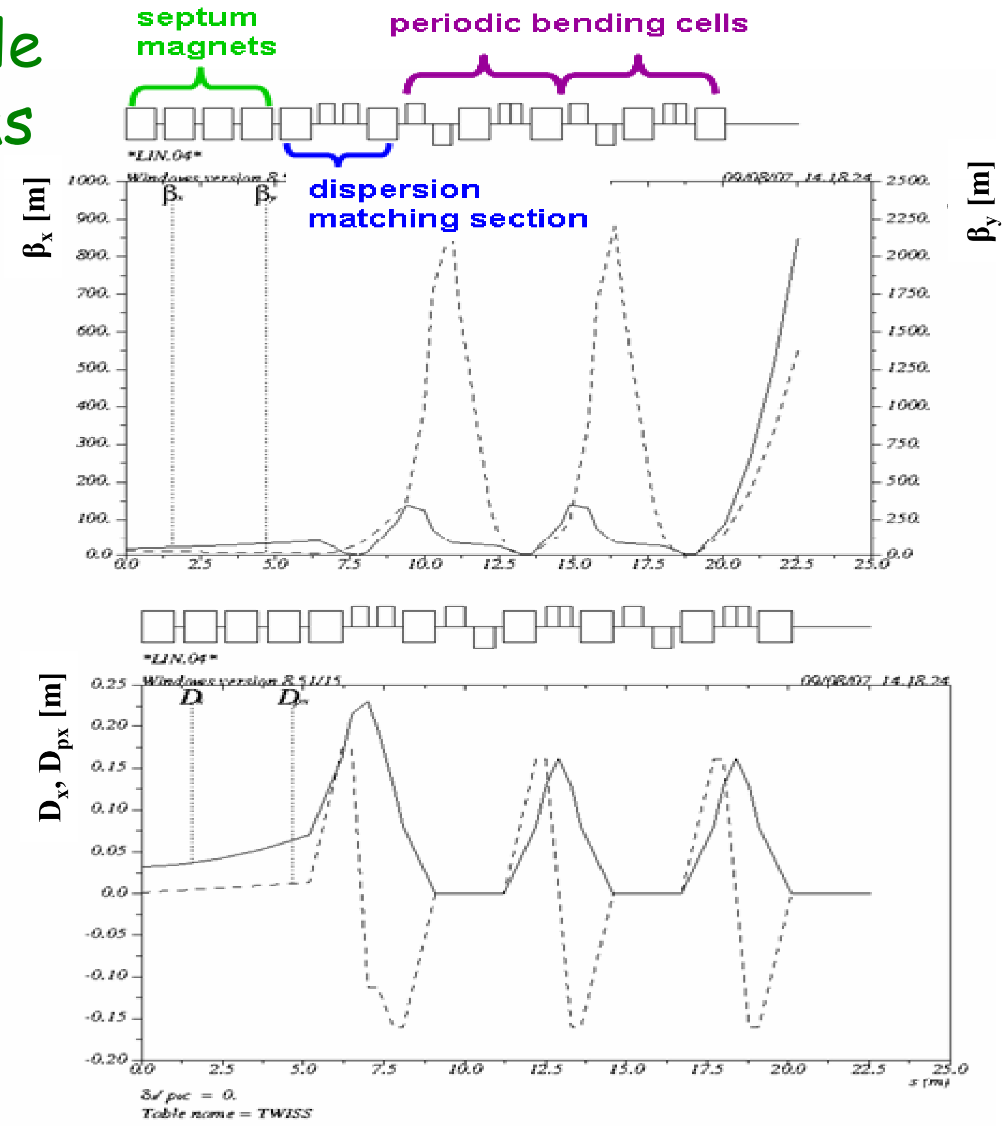
DL Design (Extraction)

- The train-by-train extraction of the beam is realized by the 1 m long pulsed bend with 280 G field. Four 2 m long fast kickers that are powered up to 70 G in 100 ns are used for the abort extraction of the beam.



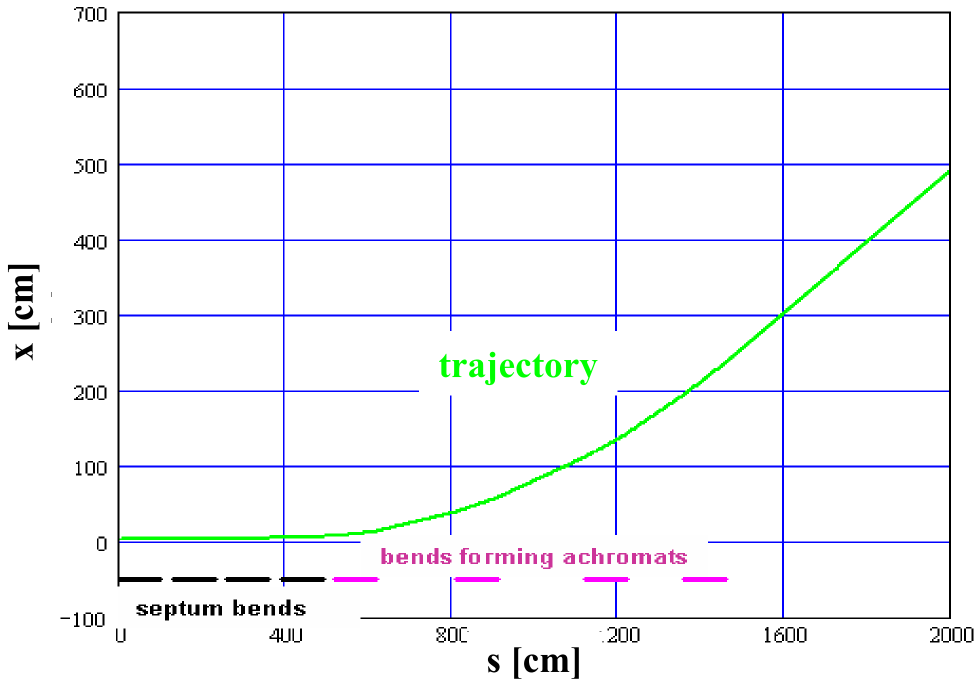
DL Design (Concept)

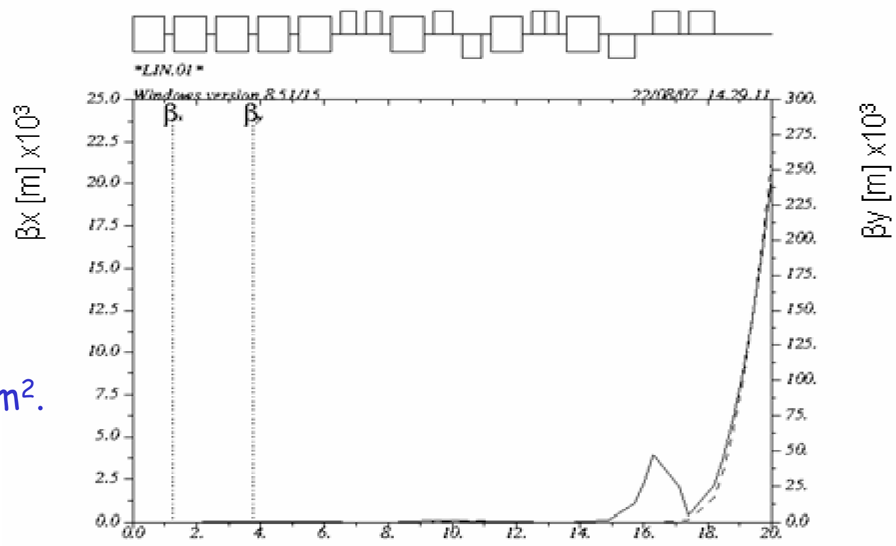
- We suggest to use double bend achromats (DBA) as our bending blocks.
- We build the DL of the cells consisting of DBA and focusing quads and having periodic solution for Twiss parameters.

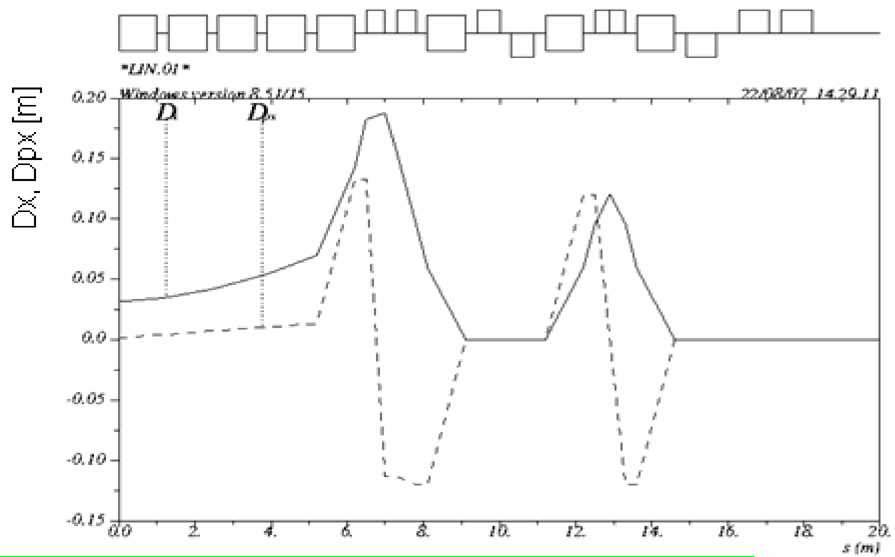


DL Design (Solution)

- Only one periodic cell is required in addition to the dispersion matching cell to separate the dump from the main line by required 5 meters.
- The three additional quads at the end of the dump line are used to blow up the beam size.
- Finally:
  - The separation of the two lines at cryomodule location is 2m;
  - Separation of the dump and the main line is 5 m;
  - The size of the beam on the dump window is 9 mm^2.



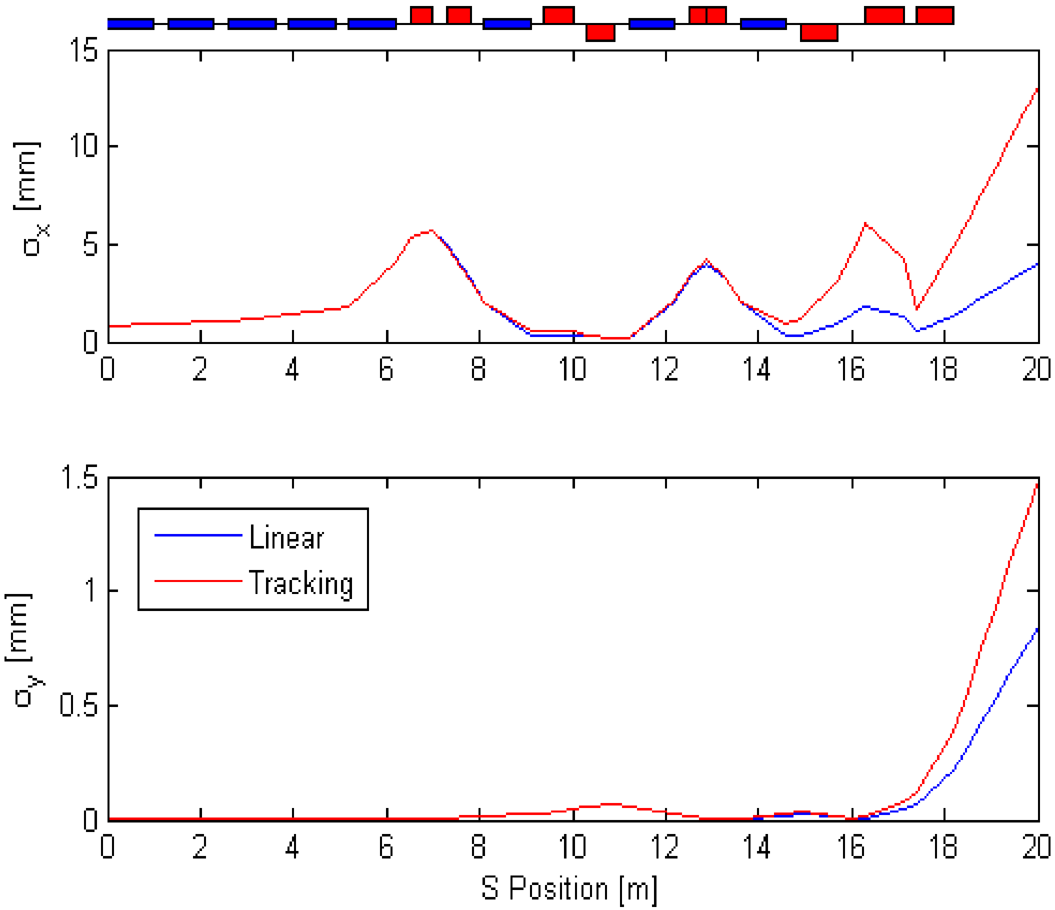




DL Design (Diagnostics)

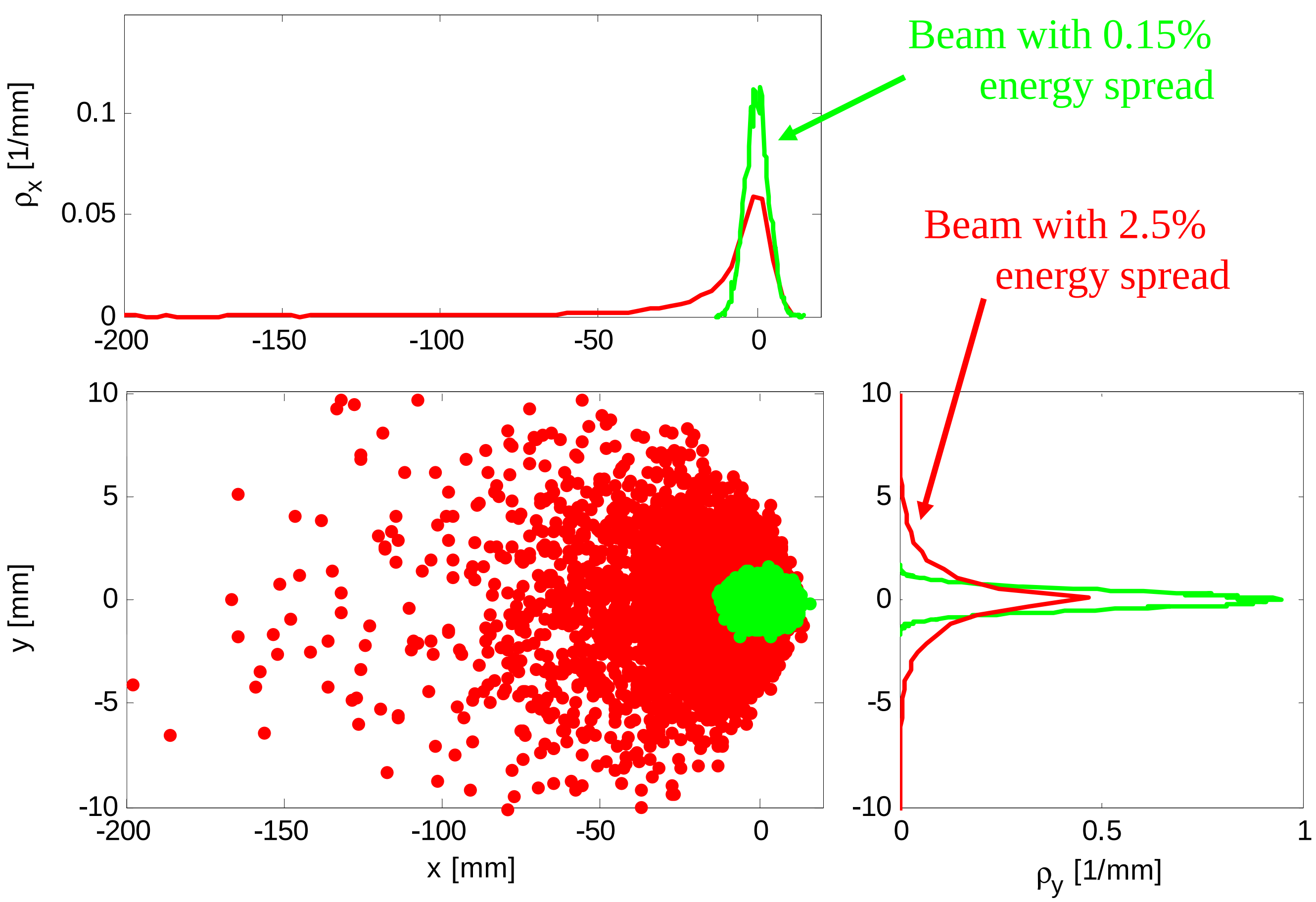
- We plan to use button-style BPM pickups, which need ~ 40 mm extra length. They will be part of the quad vacuum chamber and located on one side of the quad.
- The minimum inter-magnets space in the current design is 30 cm. => More than enough for the BPMs.

- There is a substantial blowup in the beam size from chromaticity and nonlinear dispersion at the end of the beamline.



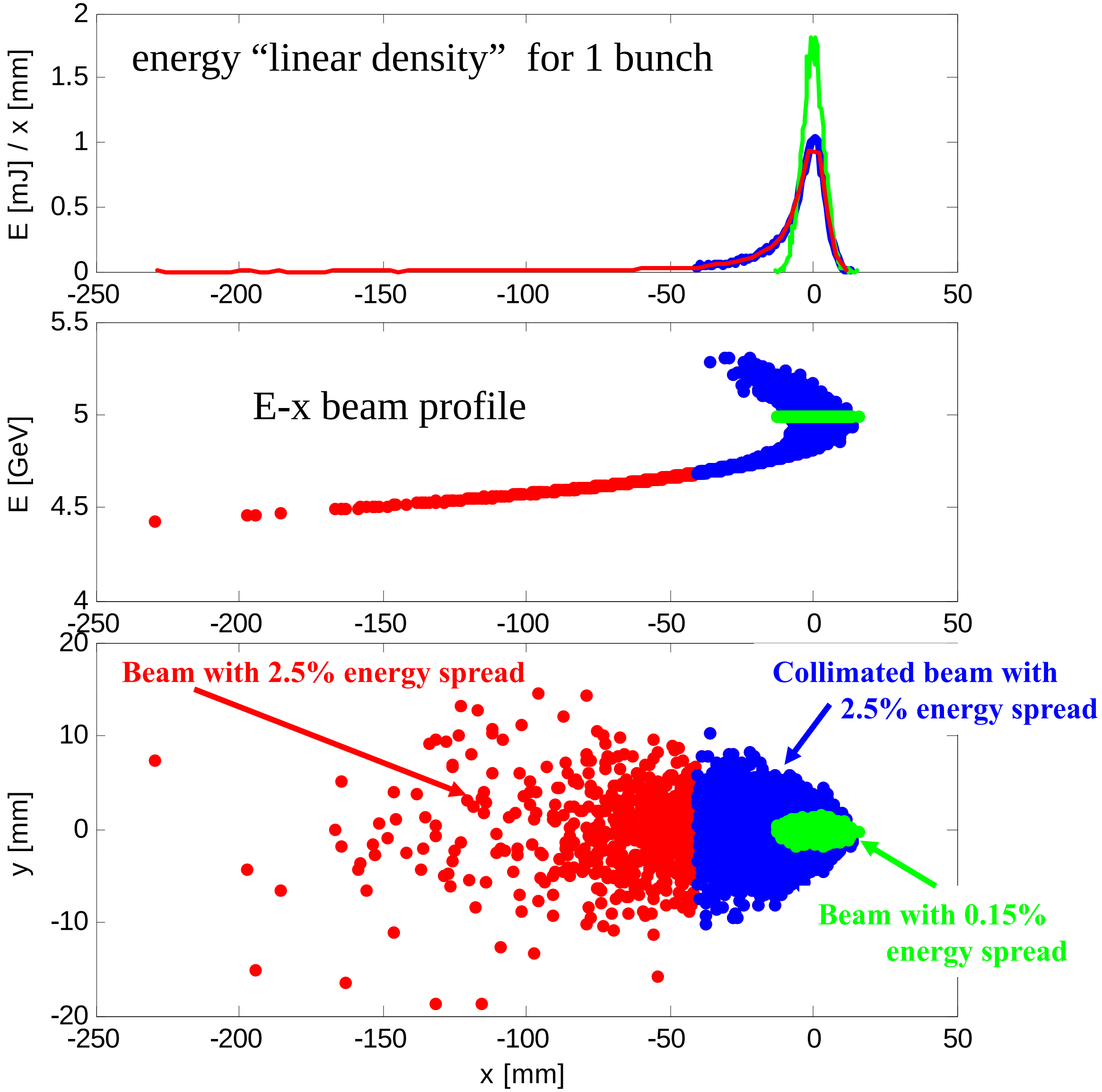
Beam's Nonlinear Halo

- While the beam with low energy spread has the designed size at the end of the dump line and on the dump window, the beam with 2.5 % energy spread is much larger.
- The main portion of the particles from the off-energy tails is deposited on the final quad triplet.



Beam Collimation

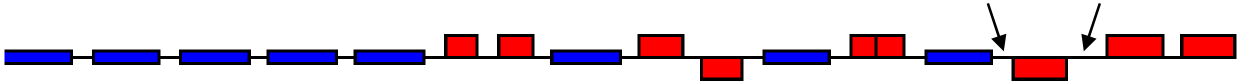
- One can see that energy distribution on the dump window is not of any concern for uncollimated high-energy spread beam.
- The window size of the aluminum ball dump can be customized. One can imagine having window sizes up to ~1m. The optimal window size will depend on 'value optimization' between the cost of a collimation system and the transverse size of the dump.
- Here we use collimators to protect the quads in the final triplet rather than to limit the beam size or peak energy deposit on the dump window.



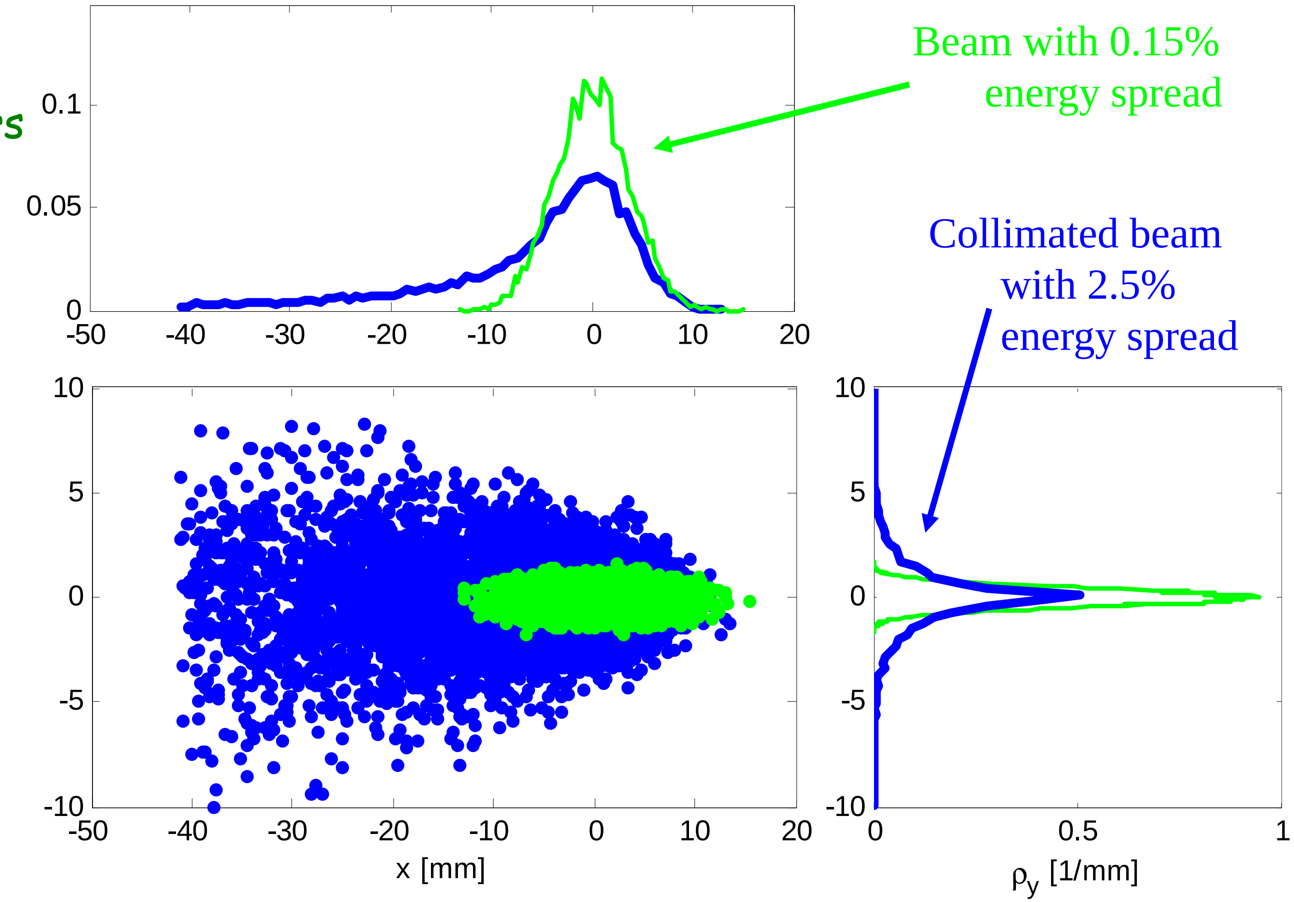
Beam Collimation

X-collimator with 12 mm aperture; it takes 3kW/train

X-collimator with 30 mm aperture; it takes 9.5kW/train



- We suggest to use a system of two collimators with 12mm and 30 mm fixed apertures, which take 3kW/train and 9.5kW/train of beam power respectively.



Options, options, options...

- Here we enter the land of endlessly diverging possibilities:
  - One can use suggested collimation system and increase the length of so far 20 m long beamline by additional ~ 4 m. On other hand one saves the effort of making large dump window and redesigning final quads.
  - One can imagine doing without any collimation at all. That leads to three 20 cm aperture quads with ~4T pole tip field (SC quads?) and huge aperture beam-pipe as well as large dump window. Is saving the beamline length worth the trouble?
  - One can try to cure the halo with sextupoles (this option has to be explored).
  - Finally, one can consider combination of the above options.
- As far as I understand, to choose proper solution we need to measure these possibilities in universal units ($$$).

Specifications

magnets					
type	N	L [m]	aperture [cm]	max B [G]	comments
emergency abort kickers1	8	2		70	ramped up to designed B in 100ns; peak power 0.5 MW
emergency abort kickers2	10	1		90	ramped up to designed B in 100ns; peak power 1 MW
pulsed bend	3	1		890	in 1st and 2nd lines Bmax=280G
septum bends	14	1		1000	in1st and 2nd lines Bmax=500G
bends	14	1	4	20000	
quads1	8	0.8	4	10000	
quads2	4	0.5	4	10000	
quads3	4	0.6	4	10000	
quads4	9	1	4	10000	
quads5	2	1.6	4	10000	

other	
BPM	button style BPMs they are part of the vacuum chamber
collimators	12mm and 30 mm fixed apertures; take 3kW/train and 9.5kW/train respectively
aluminum ball dump	2 dumps with window radius R=5 cm; one dump with window radius R=2cm

- Note: 1^{st} DL is identical to BC1DL; BC2DL was designed in accordance with the principles described in this presentation

- Aside of choosing proper cure for beam halo there is one other question: in current design the beam at the entrance to the first bend is separated from the center of the main line by just 8 cm (for 1st DL and BC1DL) and by 10cm (for BC2DL). I am not quite sure that the physical space there is enough for the bending magnet. Can we design the magnet of the small horizontal size that still provides 2 T field?
- Currently 1st DL and BC1DL are 20m long, and BC2DL is 42m long. I expect that some additional optimization of BC2DL can be done that will allow to reduce its length. Also, 1st DL doesn't have to be as fancy as BC1DL, so it might be made shorter, having smaller number of quads but probably larger number of bends.