RTML for SB2009

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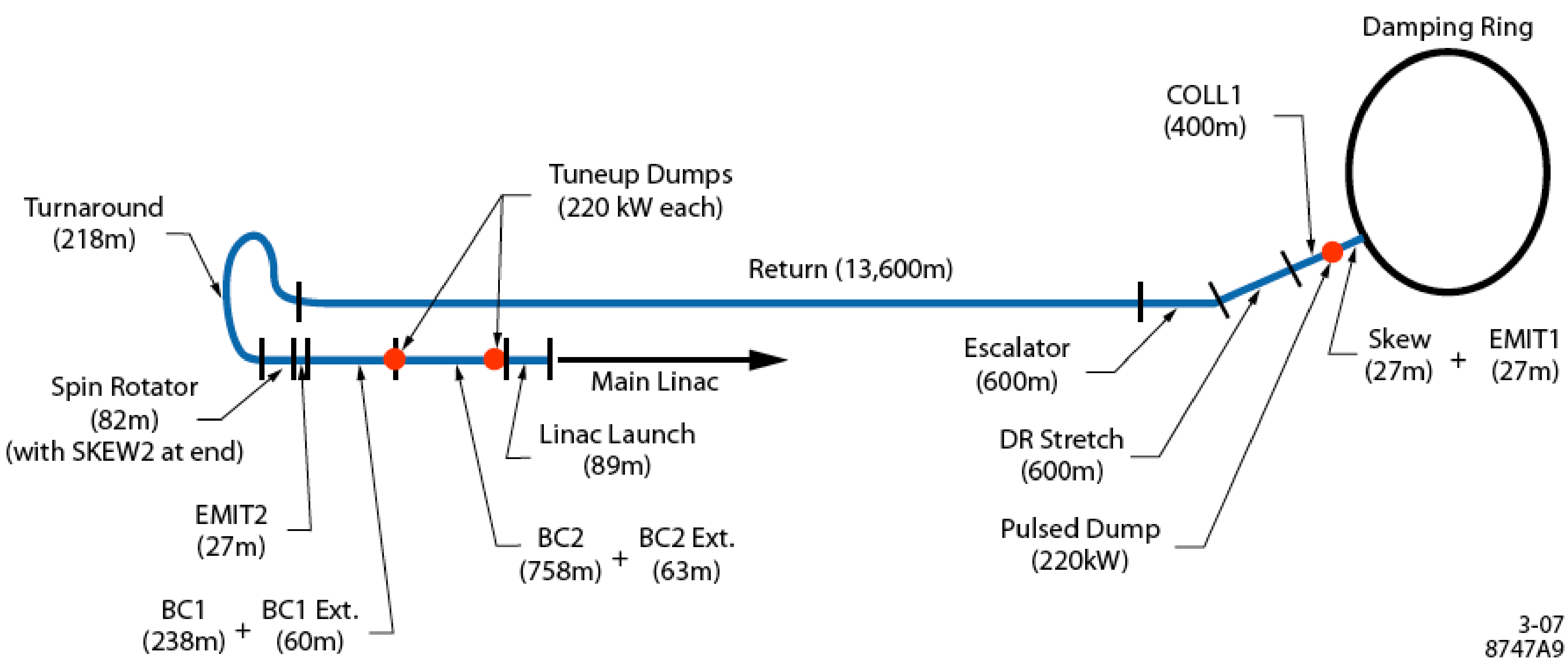


RDR Scheme

RTML for SB2009

Major modifications to the RTML lattice are:

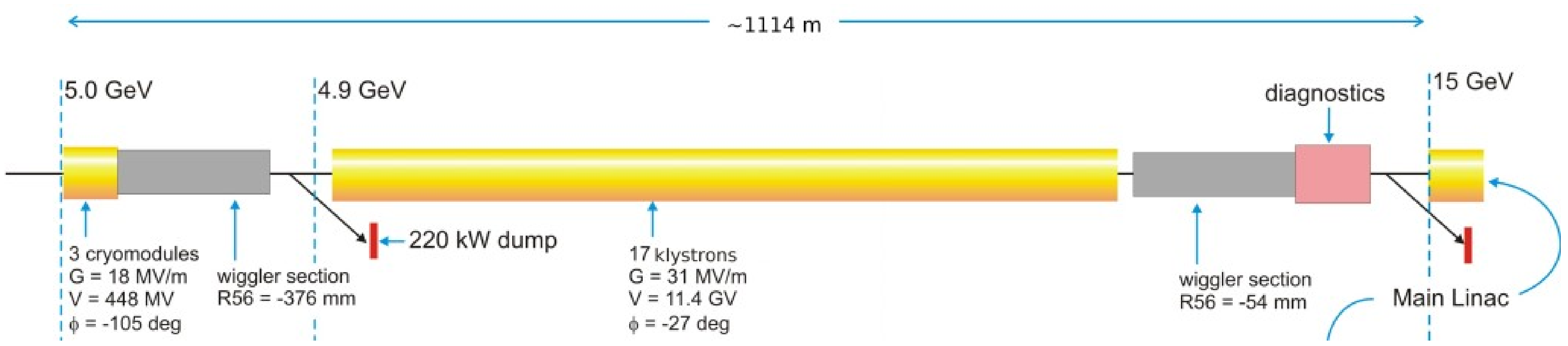
1) Single-stage bunch compressor

2) Re-design of the second extraction line, after bunch compressor, to accommodate larger energy spread (4% vs. 2.5%)

3) Re-design of the RTML lattice in central integration area, associated with new layouts of the DR, electron and positron sources and BDS

- *S-shape curved DR-to-Linac transition (in horizontal plane)*
- *Vertical dogleg*
- *Extraction line*
- *Correction, Diagnostics and Collimation sections*

RDR Baseline: Two-Stage Bunch Compressor



- Compression from **6/9 mm** at DR exit to **0.2/0.3 mm** at ML entrance

  Stage 1: at 5 GeV, bunch length down to about 1 mm

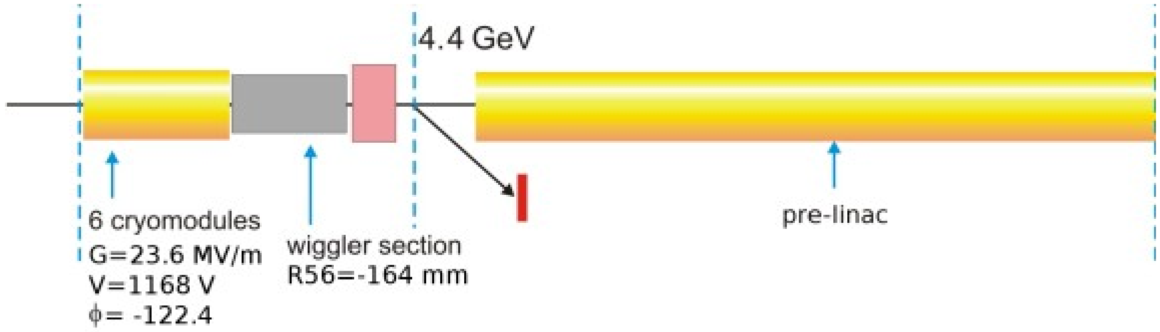
  Stage 2: from 5 to 15 GeV, bunch length down to 200/300 um

- Compression ratio: up to ~45

- Two diagnostics stations

- Two extraction lines

SB2009: Single-Stage Bunch Compressor



- New design of the Damping Rings allows **6 mm** bunch length
- Final bunch length fixed to **0.3 mm**
- Compression factor can be reduced to **~20**

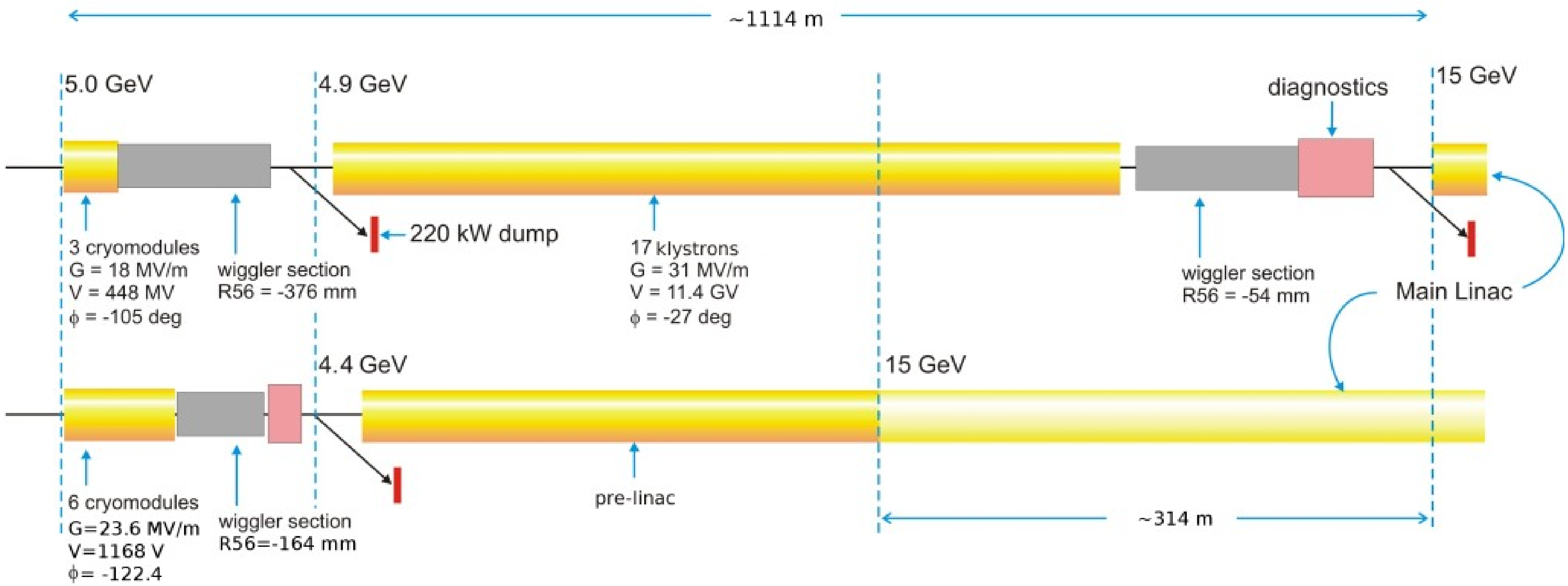
Design:

- **BC1S**: **6 crymodules** RF section from 5 to 4.37 GeV; **Wiggler**; **Diagnostics**; **Extraction**

- **Pre-linac**: from 4.37 to 15 GeV, configuration and parameters are identical to those of main linac

- now it is considered as an extension of the ML

BC1S: what we gain / loose



What we gain:

- Reduction in beamline and associated tunnel length (~314 meters)
- Removal of the second 220 kW/15 GeV beam dump and extraction line components
- Removal of one section of the beam diagnostics

What we loose:

- Less flexibility (not support for 200 um bunch length)
- Larger energy spread at BC exit: 3.5% @ 4.4 GeV
- Emittance preservation and additional tuning issues (e.g. DFS in the main linac)

(BC1+BC2) vs. (BC1S+preLinac)

	BC1+BC2	BC1S+preLinac
Length [m]	1114	800
RF units/klystrons	16/17	14(*)
Cryomodules	48	42
Cavities	414	360
Quadrupoles	88	61
BPMs	84	59

(*) No spares in BC1S (Klystrons and CM) so far

BC1 Instrumentation	BC2 Instrumentation (BC1S)
phase monitor, bunch length minitor, LOLA profile monitor	phase monitor, bunch length minitor, LOLA profile monitor
	4 laser wires

Beam Parameters

- **BC1**
- Initial bunch length = 6/9 mm
- Final Bunch length = 1 mm
- Initial energy = 5 GeV
- Final energy = less than 5 GeV
- Initial energy spread = 0.15%
- Final energy spread = 2.5%

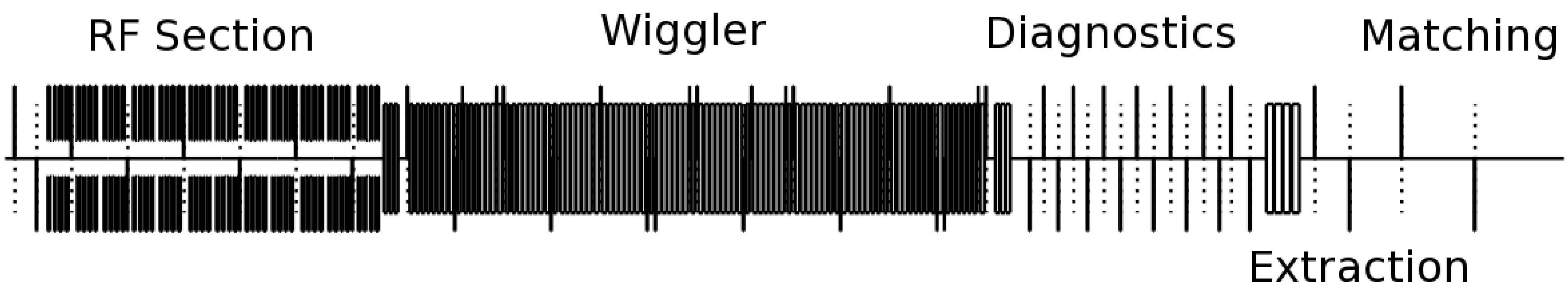
- **BC2**
- Initial bunch length = 1 mm
- Final Bunch length = 0.3/0.15 mm
- Initial energy = less than GeV
- Final energy = 15 GeV
- Initial energy spread = 2.5%
- Final energy spread = 1.07%

- **BC1S**
- Initial bunch length = 6 mm
- Final Bunch length = 0.3 mm (0.265 mm)
- Initial energy = 5 GeV
- Final energy = 4.37 GeV
- Initial energy spread = 0.15%
- Final energy spread = 3.5% (4.13%)

- **Pre-Linac**
- Bunch length = 0.3 mm
- Initial energy = 4.37 GeV
- Final energy = 15 GeV
- Initial energy spread = 3.5%
- Final energy spread = 1.08% (1.18%)

BC1S New Lattice

Starting point was Peter Tenembaum's lattice, dated 2005.



Single-Stage BC is structured as follows:

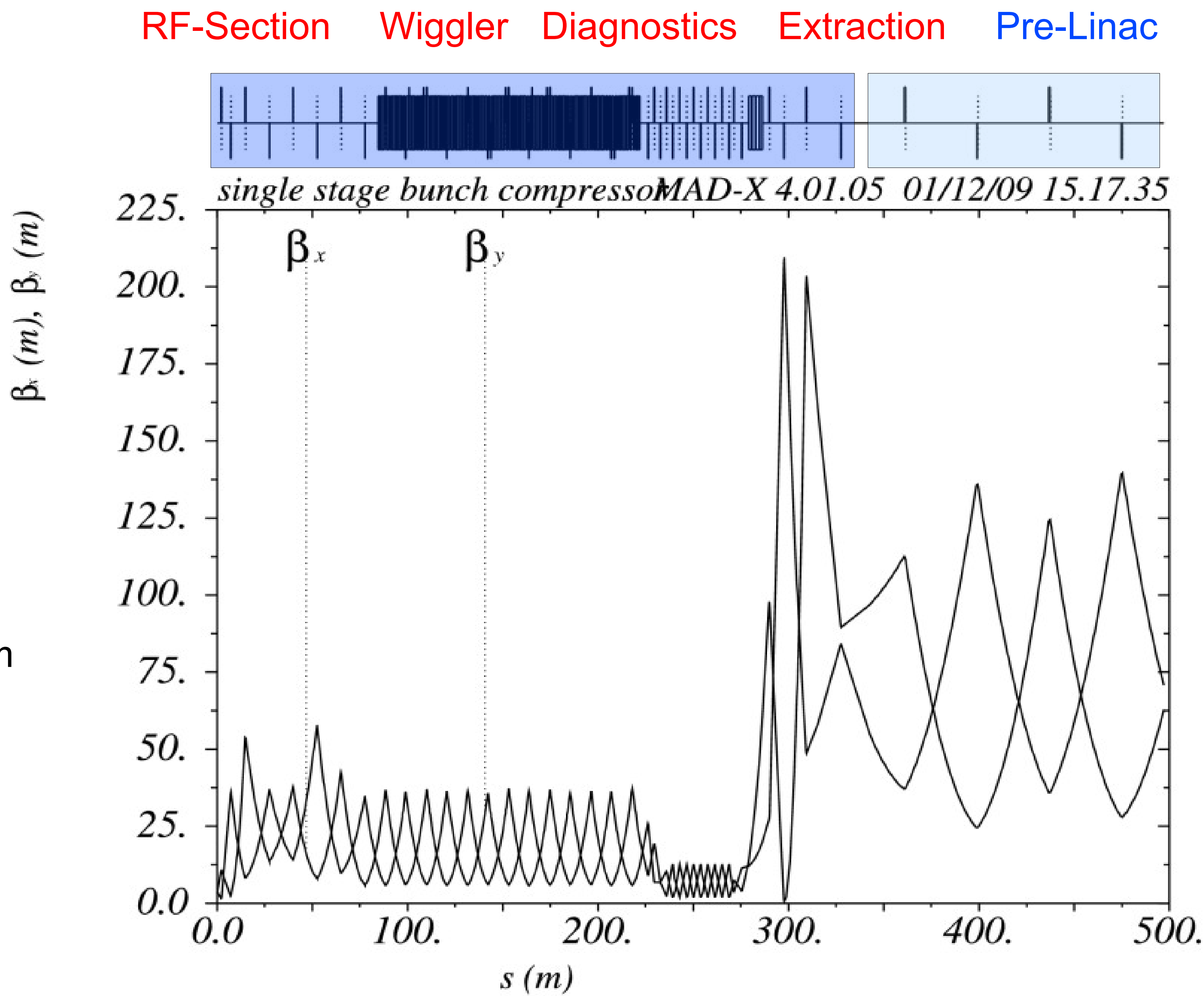
- **Matching**: from spin rotator (2 quads)
- **RF Section**: 6 cryomodules; 48 accelerating structures; Gradient=23.8 MV/m;

  RF phase=-122.38 deg; energy loss = 627.9 MeV
- **Wiggler:** PT and Seletszkiy's type (PAC07): 6 FODO cells with 90° phase advance;

  R56 = -164.8 mm; 2 dispersion matching sections
- **Diagnostics:** adapted from BC2: 4 LW, LOLA cavity for bunch length monitoring, phase monitor
- **Extraction line:** must accommodate beams with dE/E = 0.15% – 4% (Seletszkiy)
- **Matching:** to the main linac, with injection at 4.4 GeV (2 quads)

Total Length is 337 (342) meters (after matching)

BC1S Optics



Beam Parameters

Bunch at **entrance**:
- Energy = 5 GeV
- dE/E = 0.15%
- Bunch length = 6 mm

Bunch at **exit**:
- Energy = 4.37 GeV
- dE/E = 3.5%
- Bunch length = 0.3 mm

BC1S Wiggler and Optimization

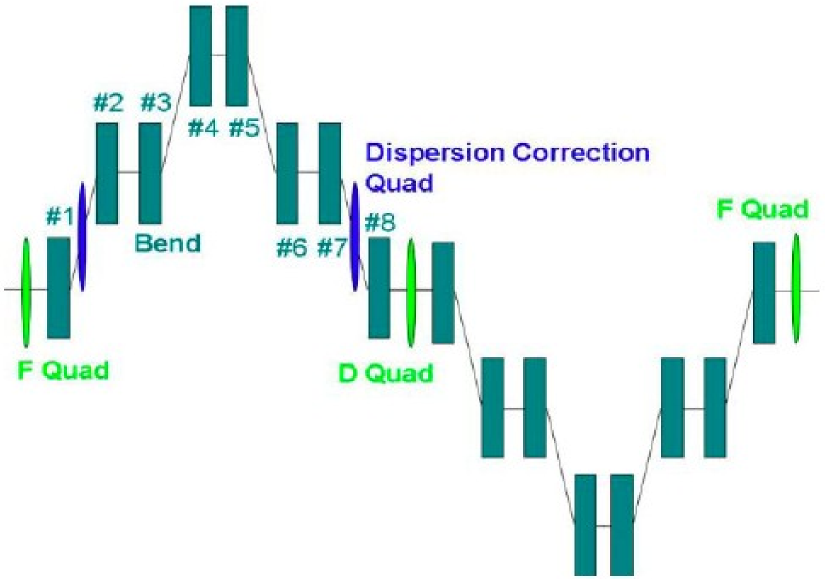
Wiggler consists of 6 identical cells

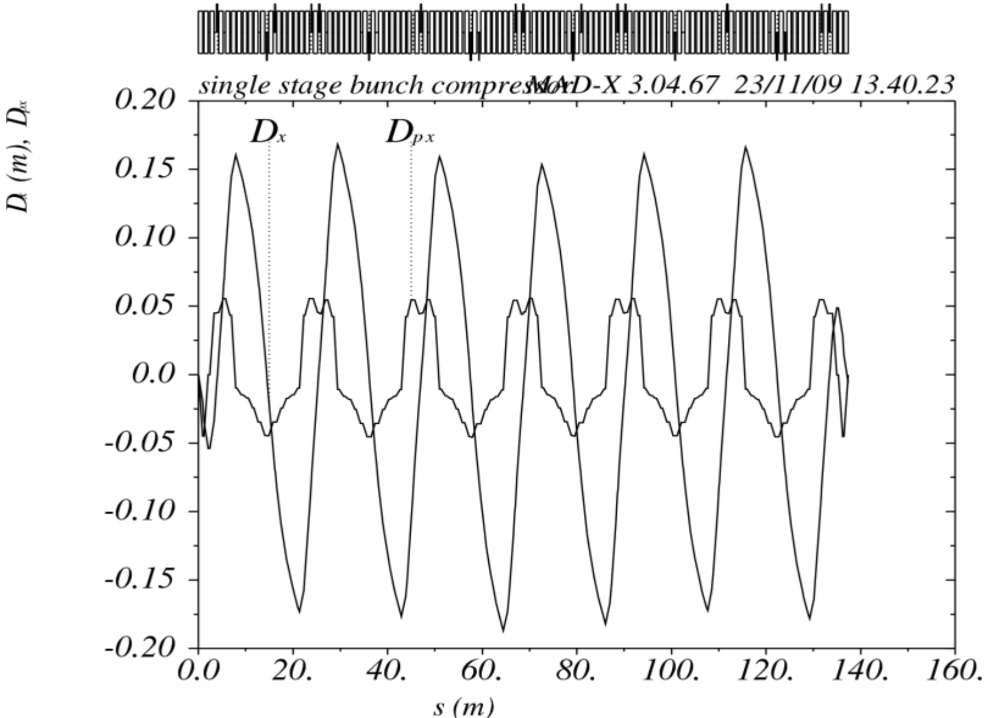
- Cells are contained in FODO structure with 90 deg phase advance per cell

- Focusing and defocusing quads are placed in the zero dispersion regions

- There are 4 additional normal quads and 4 skew quads (in cells 1,3,4 and 6) that are used for possible dispersion correction without introducing betatron coupling or mismatches

- Sixteen bends allow tuning R56 while preserving beam's trajectory in quads

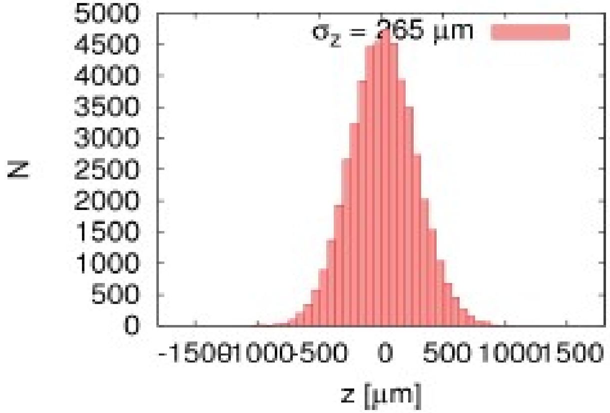


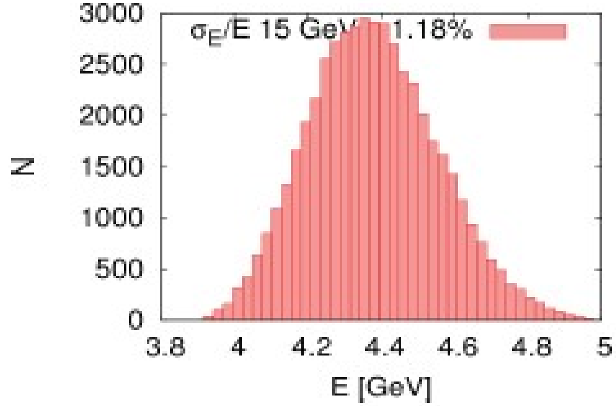


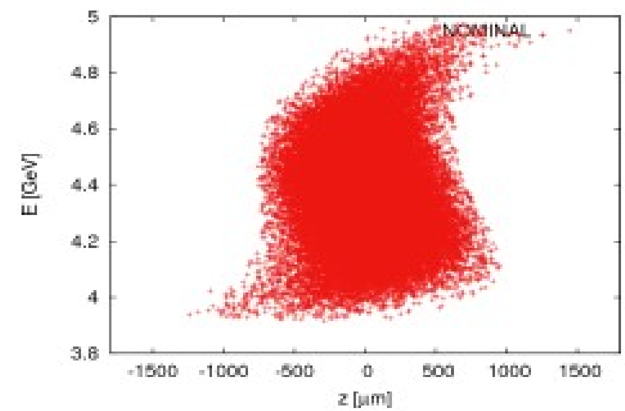
BC1S Beam Dynamics

- Before optimization
  - Bunch length = 265 μm
  - energy spread = 4.13 %
  - energy spread @ 15 GeV = 1.18 %
- After optimization
  - Bunch length = 300 μm
  - energy spread = 3.54 %
  - energy spread @ 15 GeV = 1.07 %

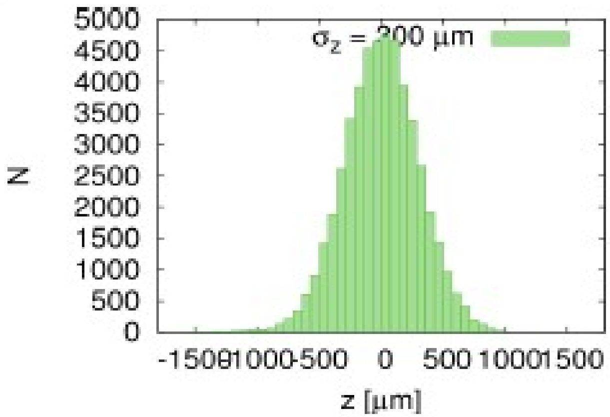
$\Rightarrow$ Before

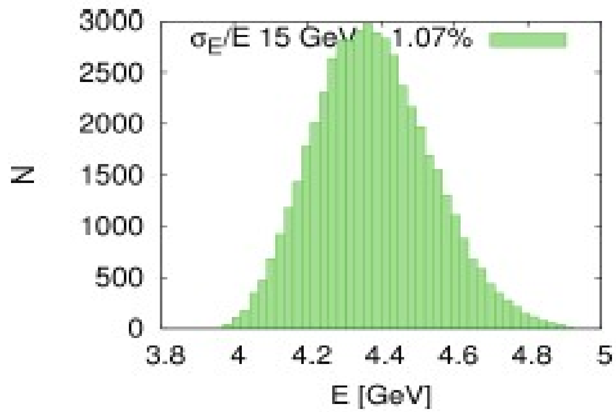


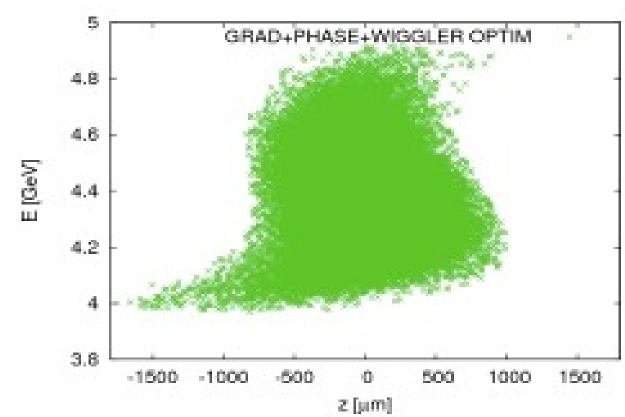




$\Rightarrow$ After







BC1S Beam Dynamics Studies

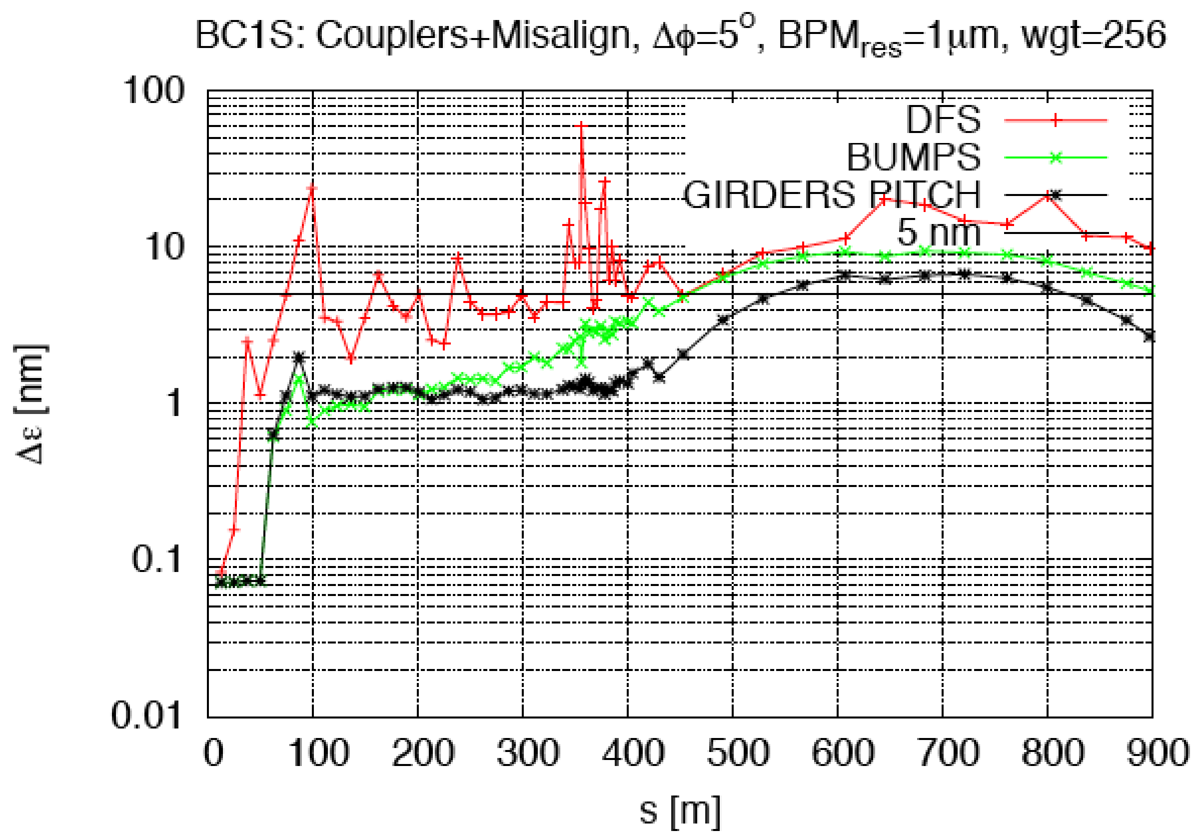
To be updated!

Emittance Preservation:

- Alignment Studies
- Coupler Kicks: RF + Wakefield

- Dynamic Effects

- Failure modes



$\Rightarrow$ Final vertical emittance growth is $\boxed{\Delta\epsilon = 2.6 \text{ nm}}$

Simulations must include the main linac to test Didspersion Free Steering (DFS).

BC1S Beam Dynamics

Previous studies showed similar performances between BC1S+Prelinac and BC1+BC2

- Two-stage bunch compressor

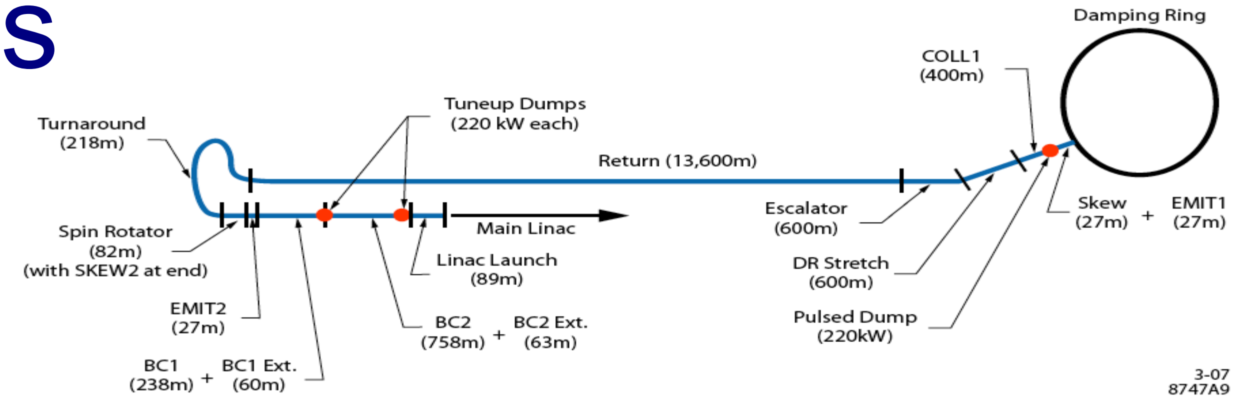
Technique	Misalignments	Couplers[1]	Misalign+Couplers
DFS	91.2 nm	7.7 nm	371.0 nm
BUMPS	2.1 nm	4.3 nm	6.9 nm
GIRDER	-	0.5 nm	2.0 nm

- Single-stage bunch compressor

Technique	Misalignments	Couplers[1]	Misalign+Couplers
DFS	14.8 nm	4.8 nm	27.0 nm
BUMPS	1.47 nm	3.4 nm	4.6 nm
GIRDER	0.8 [*] nm	2.5 nm	2.6[*] nm

(1) 1 machine
(*) 40 machines

Extraction Lines



RDR baseline's RTML contains three 220 kW extraction lines per linac for beam tune-up and emergency abort:

after DR (5GeV, dE/E=0.15%);

after BC1 (5GeV, dE/E=0.15% and 2.5%) and

after BC2 (15GeV, dE/E=1.5%).

In case of single-stage compressor there are no needs for 15 GeV extraction line

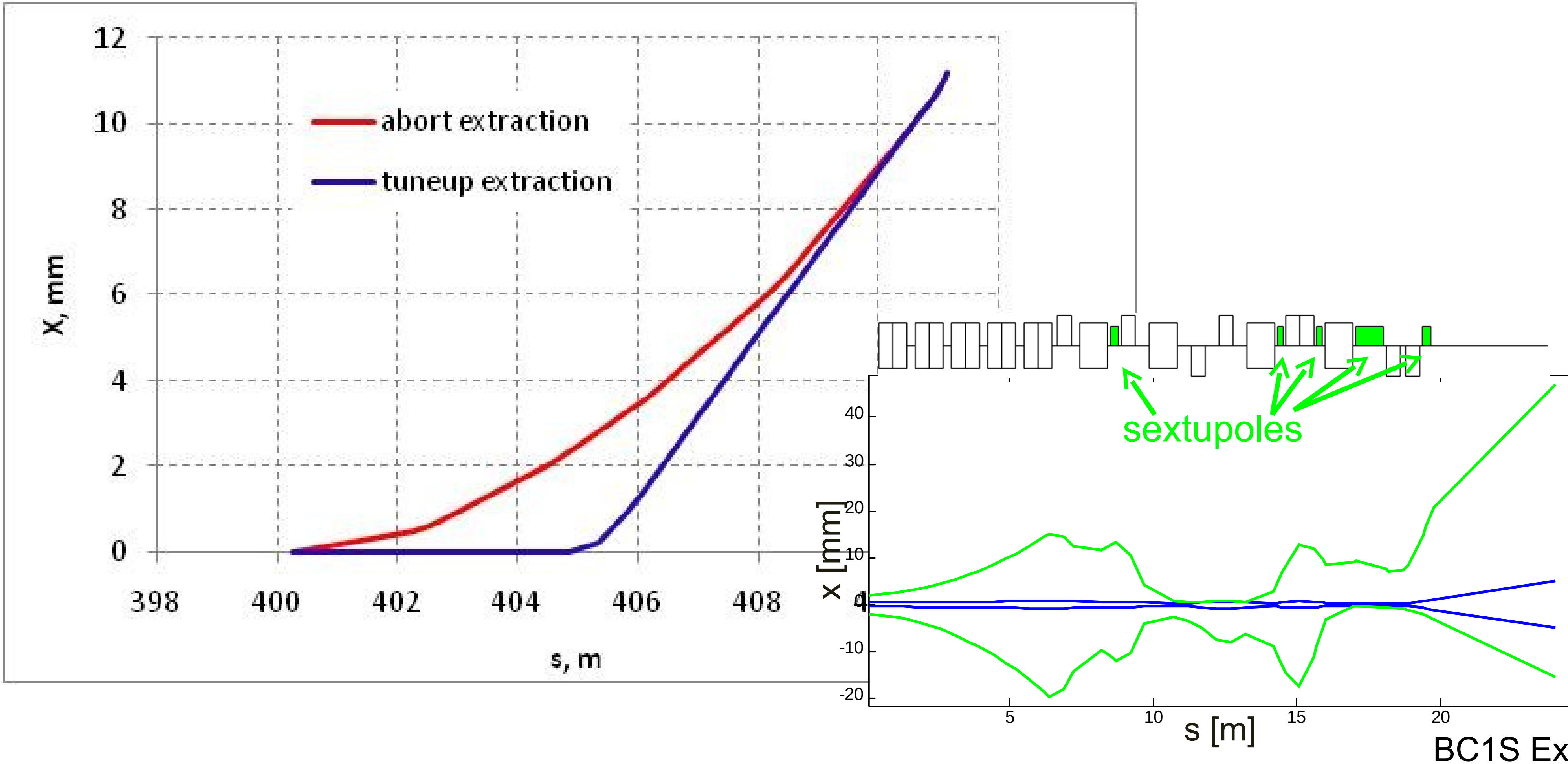
But second extraction line has to be redesigned to accommodate larger energy spread in the beam coming from BC1S (5GeV, dE/E=4%)

Few possible designs were proposed and studied in FY2009

The best of them was accepted as base for further studies and cost estimations

Extraction System Design

S. Seletskiy



- 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.
- When energy spread is high 3.5%, there is a significant beam size blowup due to chromaticity and non-linear dispersion. Sextupoles need to be used.

Extraction line for BC1S

S. Seletskiy

Class	*# of magnets*	*Length [m]*	*Maximum pole tip field [kG]*	*Aperutre [cm]*	*Comments*
Abort kickers	4	2	0.035		charged to 35G each in 100nS
Tune-up bend	1	1	0.28		
Septum bends	5	1	0.5	5	
Bends	4	1	15	5	
Quadrupoles	1	0.5	10	5	figure-8
	8	0.5			
	1	1			
Sextupoles	1	0.3	5	5	
	2	0.2	10		
	1	1	10		
	1	0.3	10		
Aluminum Ball Beam Dump: maximum acceptable power is 220MeV/train; beam dump window diameter is 12.5cm					

The Extraction Line is 24m long.

Beam size on the dump window is 17mm^2 in low energy spread case and less then 70mmx40mm in high energy spread case.

Dump is separated from the main beamline by 5.1m.

BC1S Extraction Line Summary

S. Seletskiy

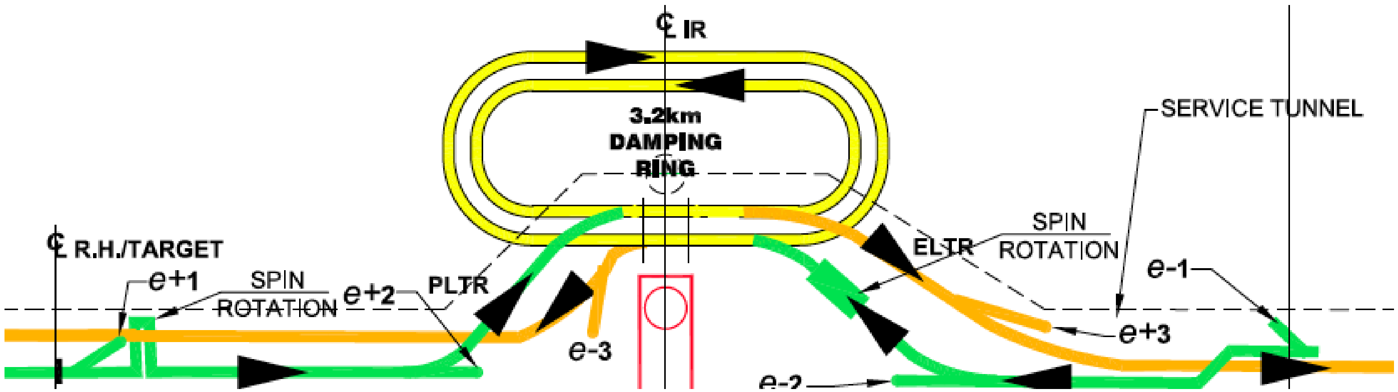
ILC RTML extraction line located downstream a single-stage bunch compressor was finalized.

- The extraction line is capable of accepting and transmitting up to 220kW of beam power.

- The EL can be used for both fast intra-train and continual extraction, and is capable of accepting both 0.15% and 3.54% energy spread beams at 5MeV and 4.37MeV respectively.

This design can be tweaked. For instance one can reduce strength of the sextupoles sacrificing size of the beam dump window.

Central Area



In SB2009, damping rings circumference has been reduced to 3.2 km

RDR DR extraction was at about 1 km from the central plane, in the direction of the turnaround, now the DR ext is located at about 100 meters from the central plane

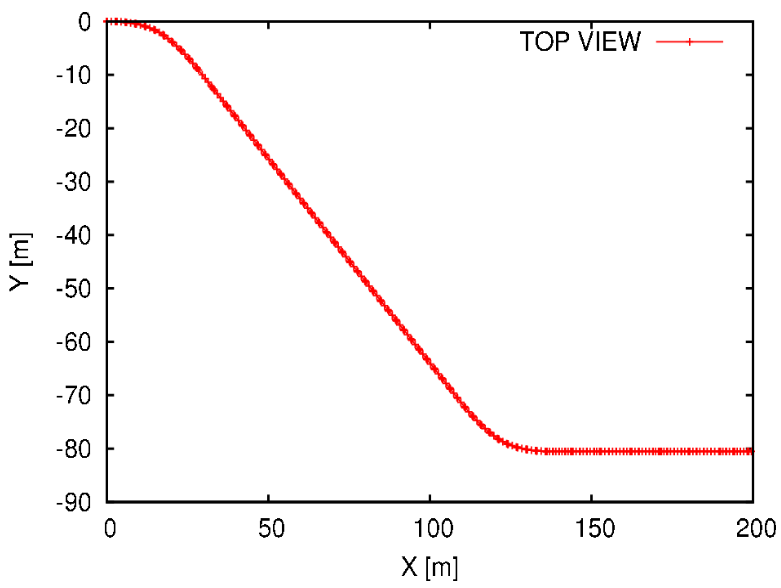
This change required a redesign of the beamlines. This resulted in a simplification of their geometries in terms of number of horizontal and vertical doglegs

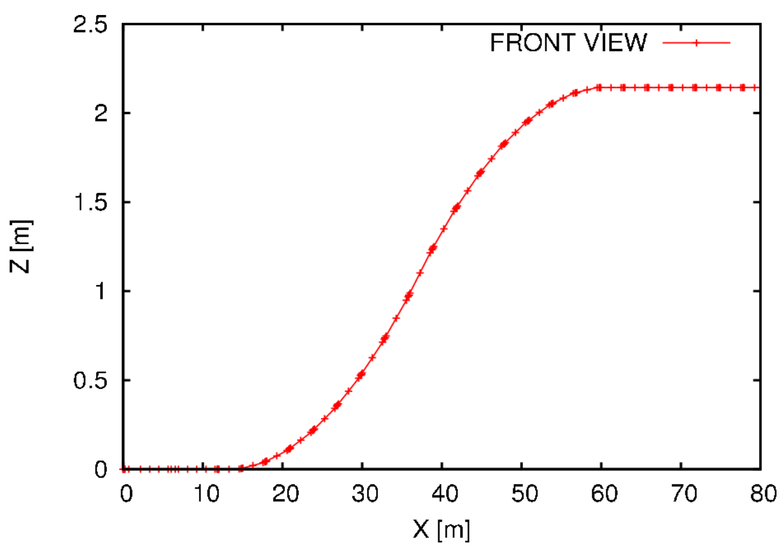
Main advantage of this change is the simplification in the overall layout

Possible risks might arise from the performances of the new system from the point of view of the low emittance transport

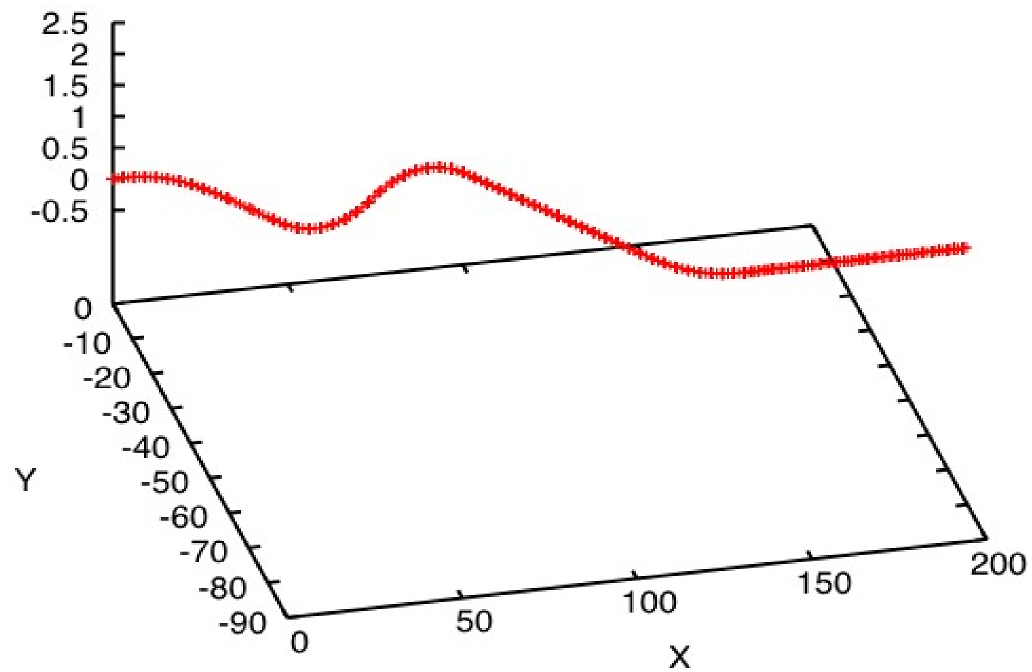
Central Area Layout

e+ damping Rings extraction





- Geometry depends on the DR Injection layout
- Simpler than RDR: less doglegs, straightforward layout
- Lattice files exist (needs some adjustment)
- Sequence: H-arc, Extraction, V-dogleg, H-arc, Skew-Correction, Diagnostics (LW+Chicane), Collimation, match to Return Line FODO



Proposed Relevant Studies

Lattice design of a single-stage bunch compressor, diagnostics section and matching section

Beam physics simulation to study effect of coupler RF kick, alignment and phase/amplitude stability of the RF system and provide requirements. The goal to demonstrate that RTML emittance budget can be achieved and beam parameters at the exit of RTML system provide acceptable emittance budget in Main Linac

Developing CAD models and cost estimations for single-stage bunch compressor components

Experimental studies of amplitude and phase stability, required for single-stage bunch compressor at FLASH/DESY facility (9 mA studies). This study is required to both RDR and SB2009 configurations

Re-design RTML section from DR tunnel to ML tunnel. It requires close coordination with other AS involved: DR and electron/positron sources.