ILC RTML Lattice Design

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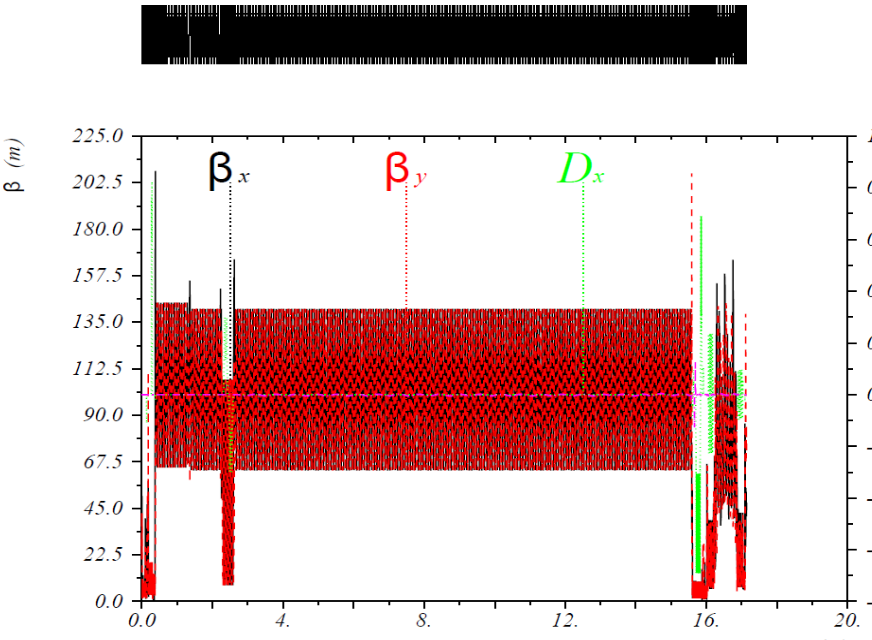
Fermilab

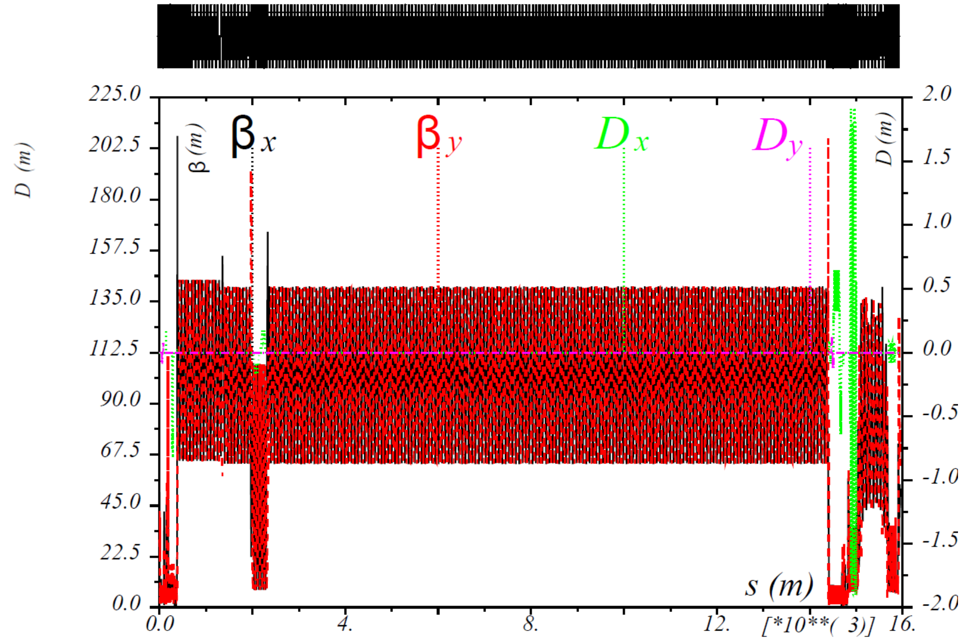
OUTLINE

- RTML Layout
- Latest changes in central region (ERTL/PRTL)
- Return Line Dog-Legs design (ELTL/PLTL)
- ML Treaty point definition and matching
- Earth curvature in Return Lines (ELTL/PLTL)
- Bunch Compressor design requirements
- Other sections of RTML
- Magnet count and Heat Load/Cost estimation
- Summary

RTML Functions



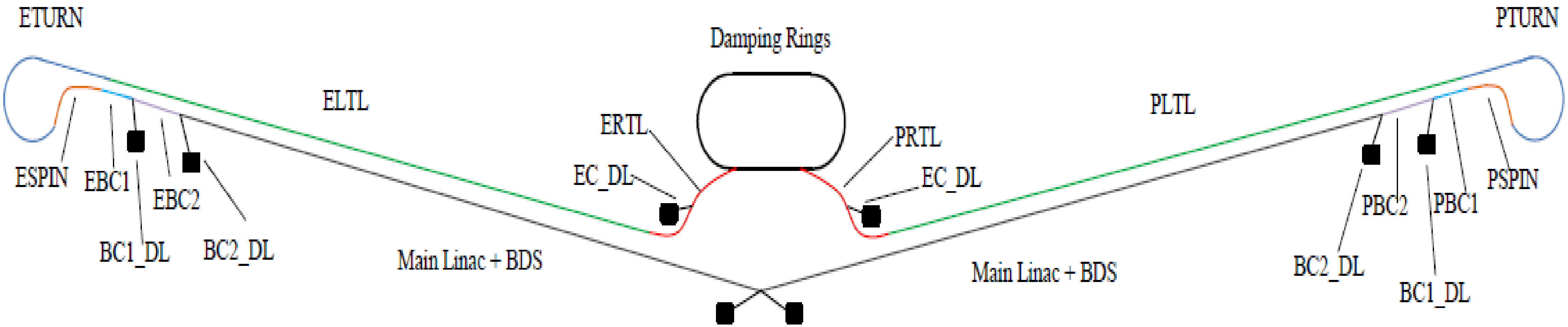
ERTML



PRTML

- Transport the beams from DRs to start of Main Linacs
- Collimation of Beam halo
- Polarization control
- Bunch Compression and acceleration
- Avoid emittance dilution
- Beam diagnostic, coupling correction, dump, etc…

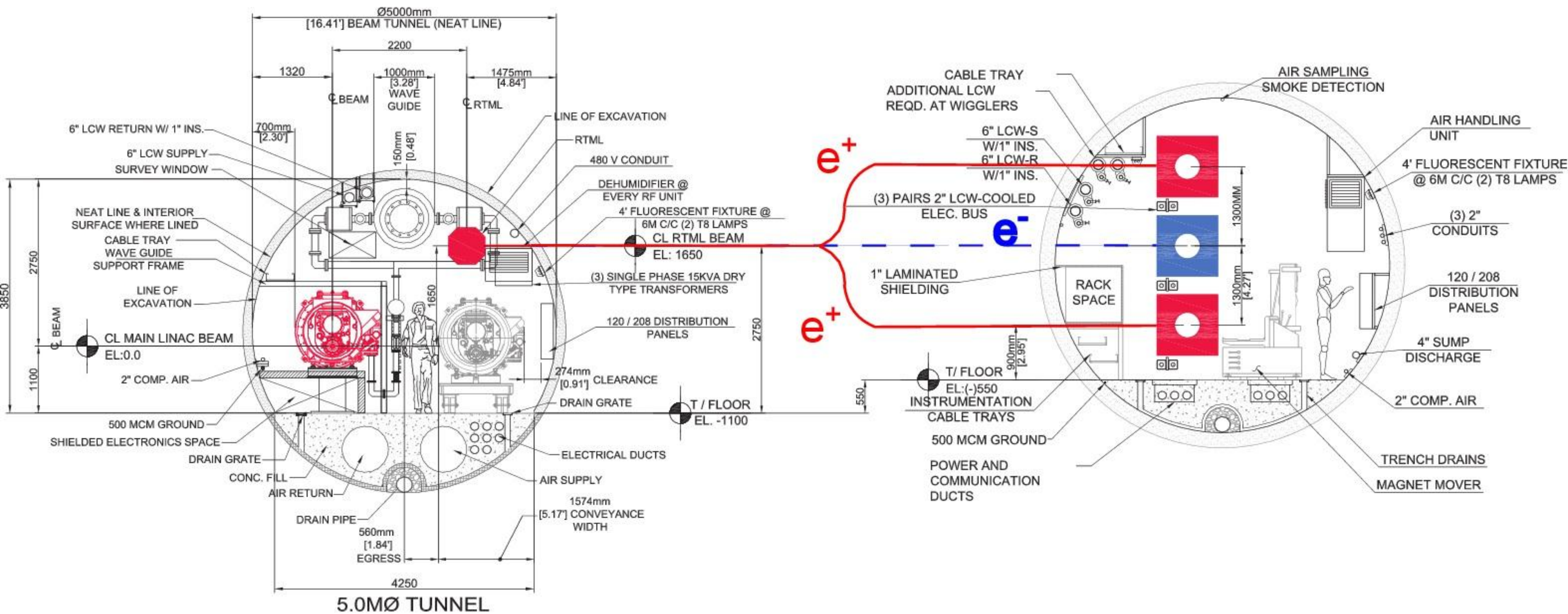
RTML Beamlines



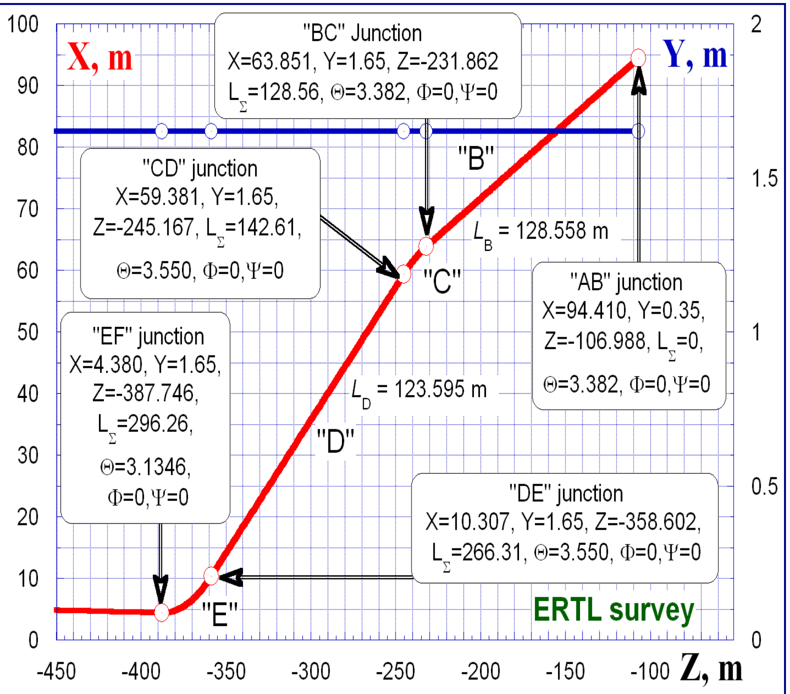
- ERTL/PRTL: Electron/Positron Ring-to-Line from DR to Main Tunnel (+ Dump Line)
- ELTL/PLTL: (E/P) Long-Transfer-Line
- ETURN/PTURN: (E/P) Turn-Around
- ESPIN/PSPIN: (E/P) Spin rotator
- EBC1/PBC1: (E/P) 1st stage of Bunch Compressor (+ Dump Line)
- EBC2/PBC2: (E/P) 2nd stage of Bunch Compressor (+ Dump Line)

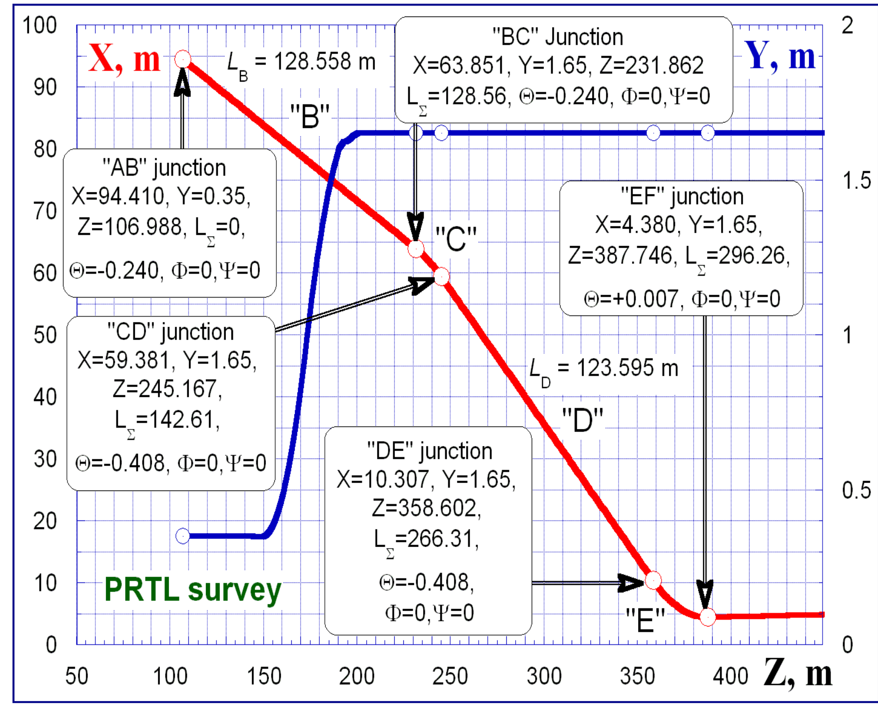
ERTL/PRTL (Central Region)

- Increased distance between DR and Main Tunnel.
- For first stages only bottom Positron Damping Ring built and vertical dogleg to reach PRTML in Main Tunnel.
- For luminosity upgrade 2 positron Damping rings and 2 doglegs.
- Replace last 2 bends in vertical dogleg with 2 septum magnets and merger.



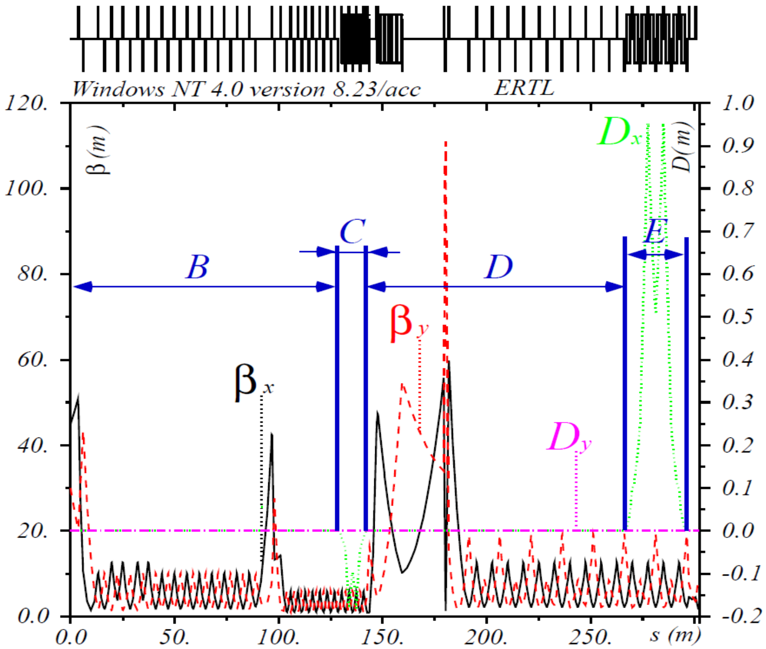
RTML Central Region Design

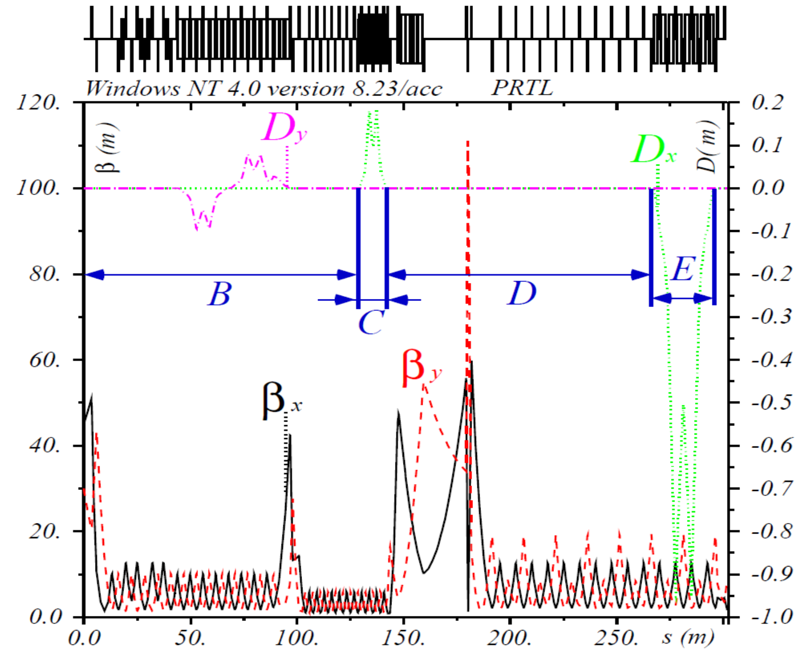




- Origin at IP.
- Main beam trajectory Θ = 7mrad.
- Extraction line from DR, A.
- Straight sections B,D.
- Horizontal arcs C,E.
- Extraction Line for early beam dump in section D.
- Vertical dogleg in Section B of PRTL, plane geometry for ERTL.
- Geometry of beamlines imposed by other areas (sources, DR injection lines, BDS Tunnel).

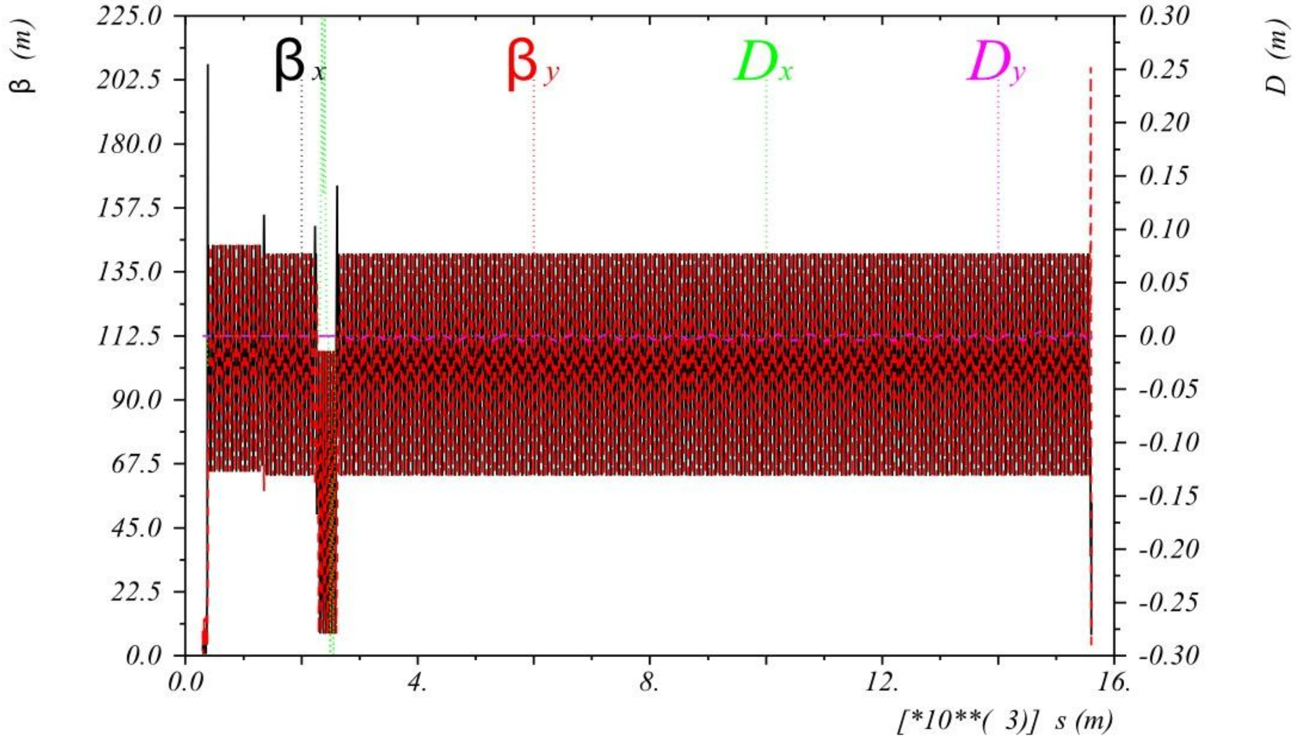
RTML Central Region Lattice





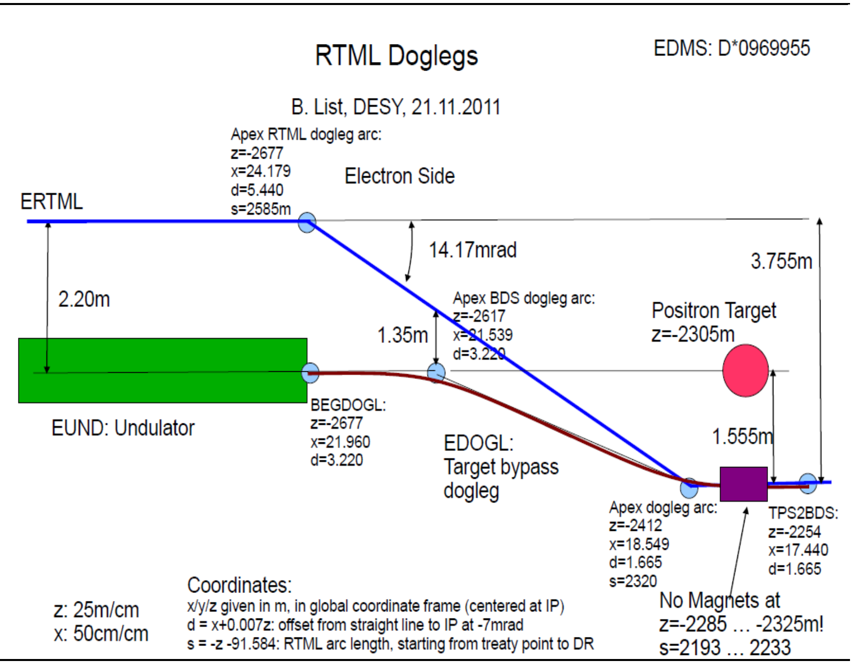
- Section A is extraction line from DR.
- Straight sections B,D (FODO lattice).
- Horizontal arcs C,E (FODO + BENDs lattice).
- Arc E shares tunnel with spin rotator.
- Vertical dogleg in Section B of PRTL.
- Extraction line in section D.
- Skew quadrupole correction, beam diagnostic and collimation moved to ELTL/PLTL.

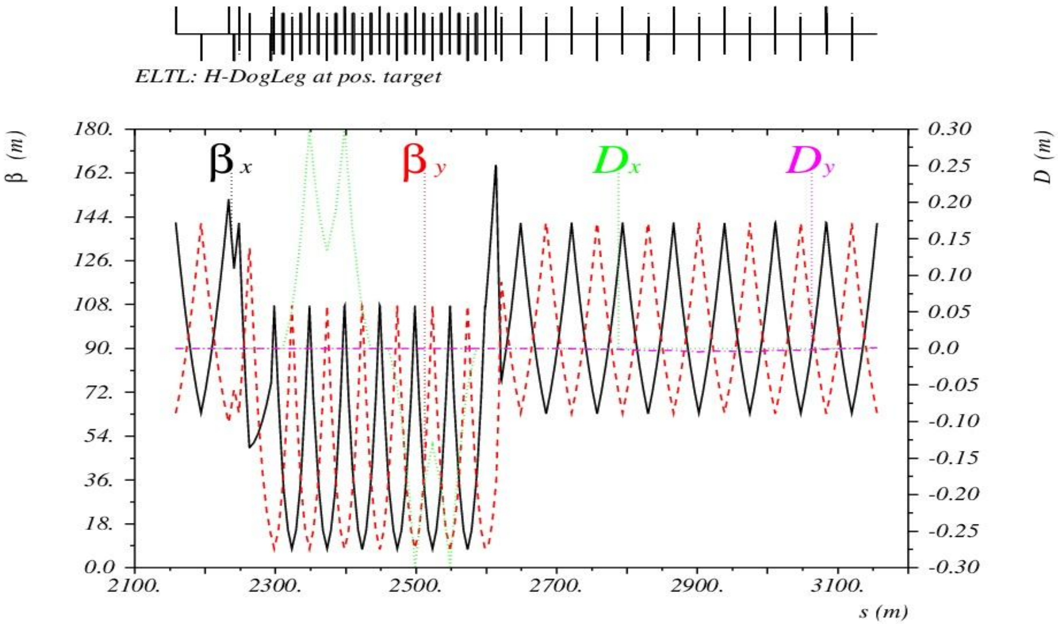
RTML Long Transfer line



- Coupling correction, diagnostic and collimator section in first part.
- Mainly FODO lattice (45°/45°) with vertical curvature.
- Horizontal dogleg at positron target location.

ELTL/PLTL Dogleg design



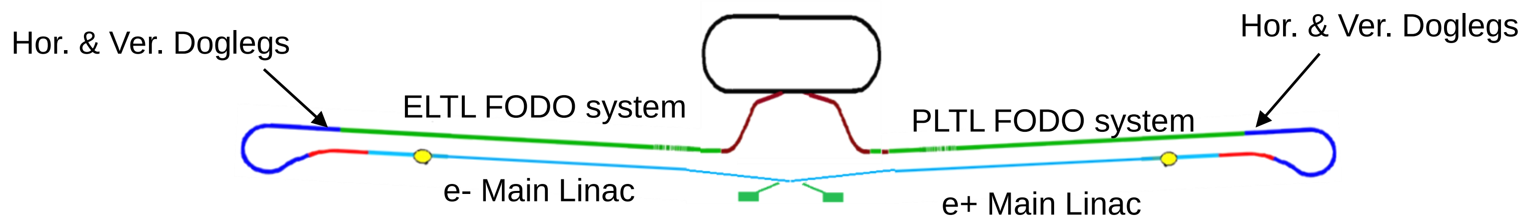


- Dogleg of positron source to by-pass positron target.
- ERTML follows geometry of positron source/BDS systems.
- Radiation from positron target requires magnet free zone.
- FODO+BEND lattice used.

ML/DR treaty points matching

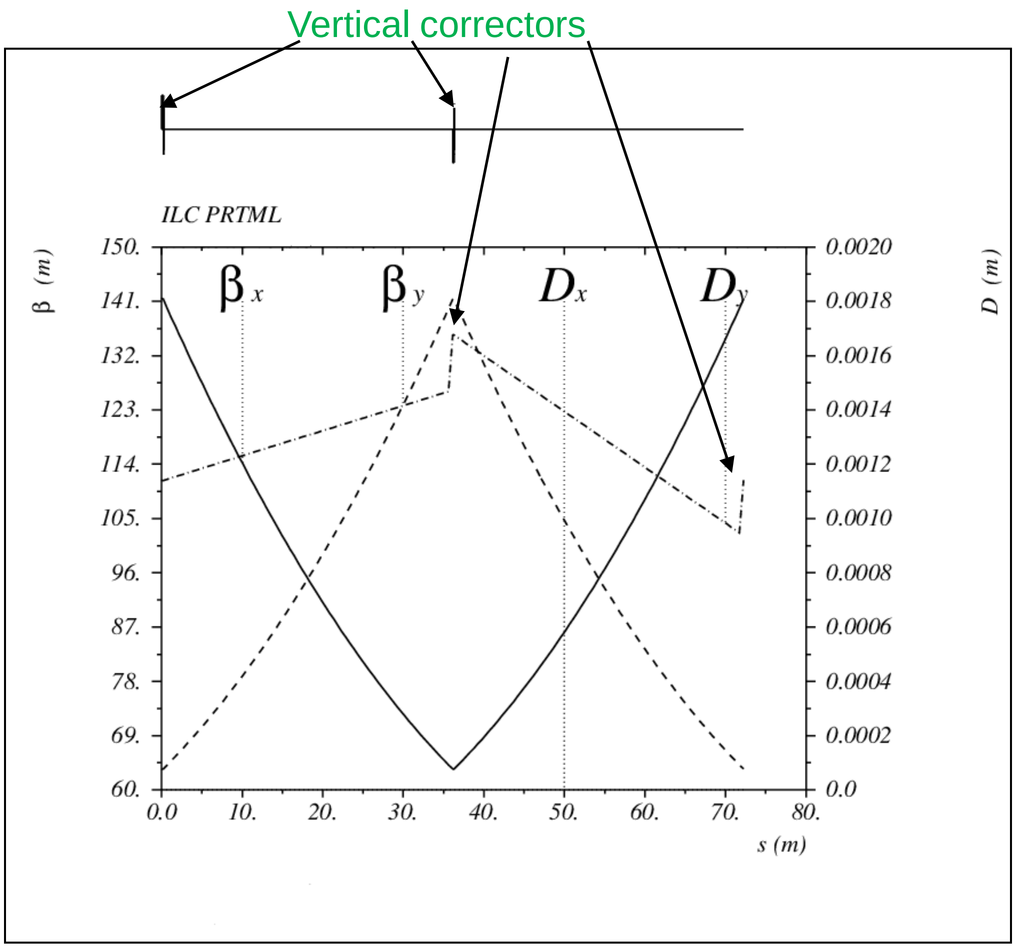
Treaty Point	TERTML2ML Electron RTML to Main Linac	TEML2PS Electron Main Linac to Positron Source (Undulator Section)	TPS2EBDS Positron Source (Undulator Section) to Electron BDS	TPRTML2ML Positron RTML to Main Linac	TPML2BDS Positron Main Linac to BDS
Geometry					
x [m]	104.5245011	26.540	17.440	94.62043163	17.433
y [m]	0	0	0	0	0
z [m]	-14471.78005	-3331.319	-2253.464	13279.10984	2252.514
θ [rad]	-0.0070	-0.0070	-0.0070	-3.1346	-3.1346
φ [rad]	0	0	0	0	0
ψ [rad]	0	0	0	0	0
d [m]	3.220	3.220	1.665	1.665	1.665
Optics Functions					
α_x [1]	-1.142	-2.402	-2.402	-1.142	-2.402
β_x [m]	52.67	51.33	51.33	52.67	51.33
η_x [m]	0	0	0	0	0
η'_x [1]	0	0	0	0	0
α_y [1]	1.279	0.4888	0.4888	1.279	0.4888
β_y [m]	70.74	9.395	9.395	70.74	9.395
η_y [m]	0	0	0	0	0
η'_y [1]	0	0	0	0	0
Input:		ELIN		PLIN	
Main Linac Length	[m]	11140.734		11026.866	
Reference:	ILC SCRF Cryogenics parameters D00000000975575				

Geometrical matching of the 2 RTML beam lines is made by tuning the cell length of the Long Transfer Line FODO lattice and the bending angles in the horizontal and vertical doglegs upstream the Turn Around.



Earth curvature in ELTL/PLTL

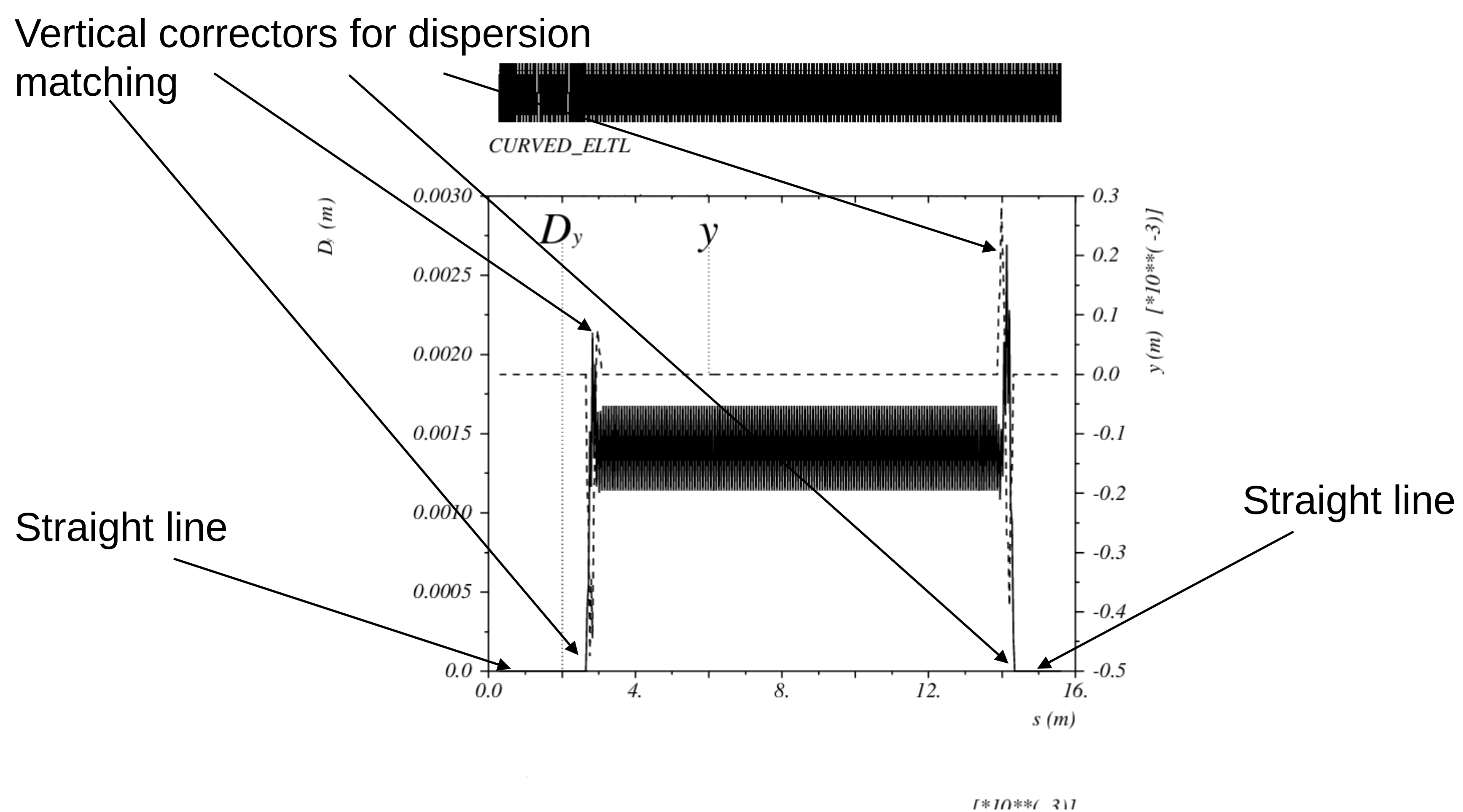
For Cryogenic requirements main linacs need to follow the curvature of the Earth.
Long Trasnsfer Lines are located in the same tunnel with ML's, then they need to be curved.



Geometric curvature of the beamlines is realized in the vacuum chamber and the beam orbit is curved by means of vertical dipole correctors at each quadrupole of the FODO lattice. A small vertical dispersion is then created and propagated along the line. The first 4 correctors and the last 4 correctors are used to match the curved section to the straight lines.

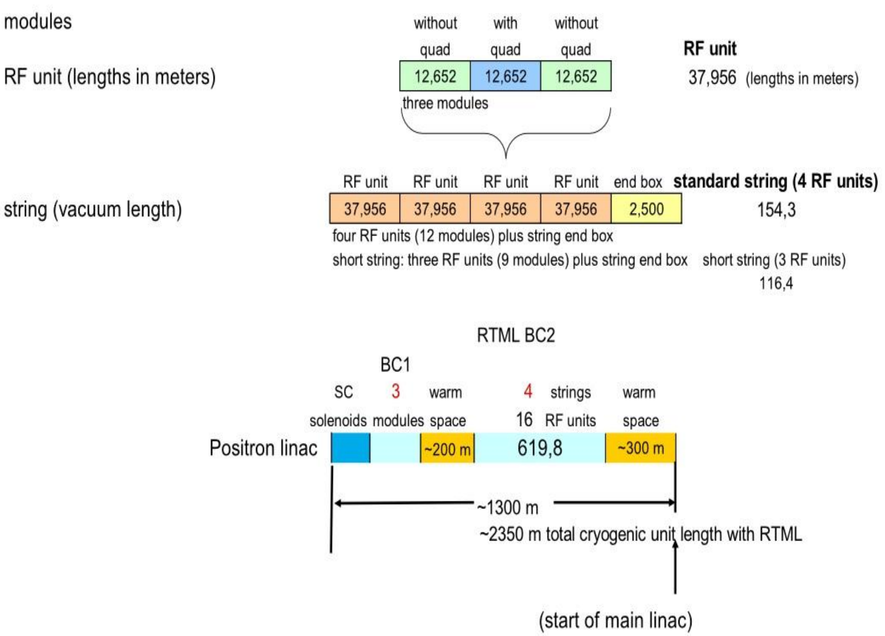
Earth curvature in ELTL/PLTL

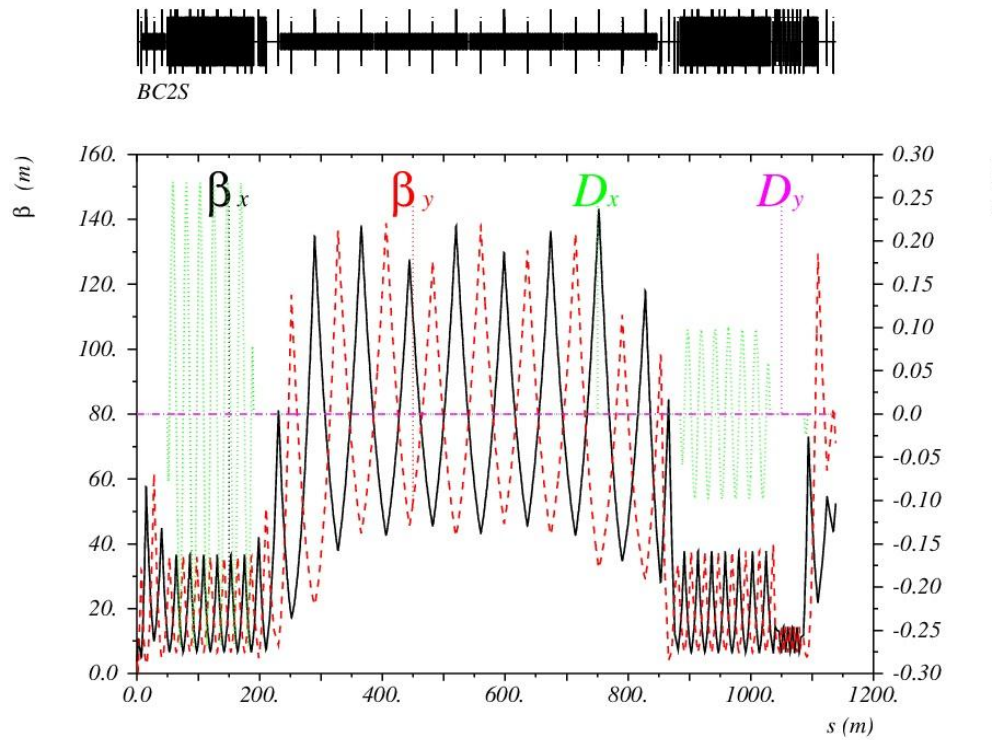
Vertical offset and dispersion of beams in curved ELTL/PLTL



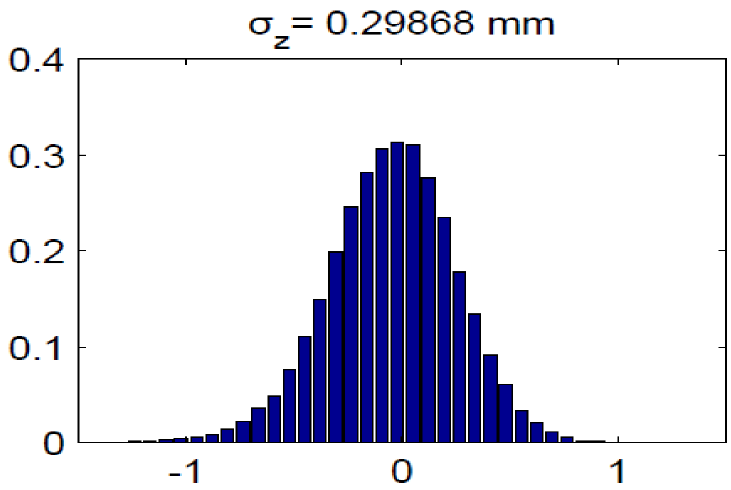
Bunch Compressor

- 2 stage BC design selected (more tunability, possibility of $\sigma_z < 220\mu m$).
- Use of 16 RF units in BC2 RF (416 RF cavities) to reduce gradient.
- Use 3 cryo-modules with quad (24 RF cavities) for BC1.
- New output parameters from DR.



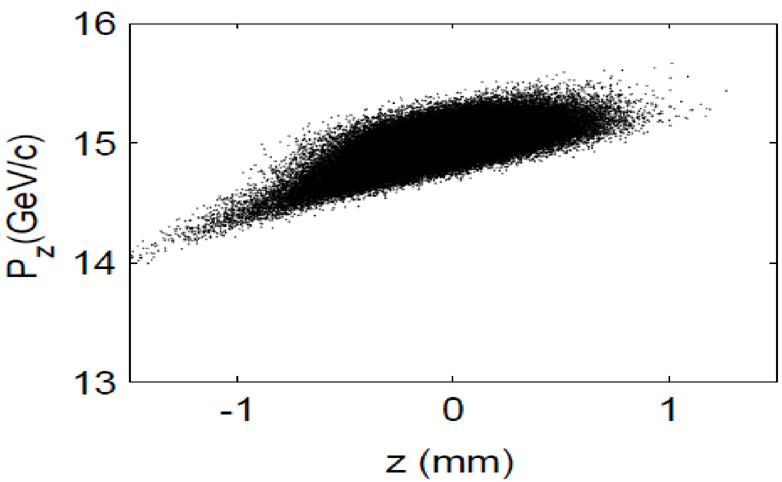


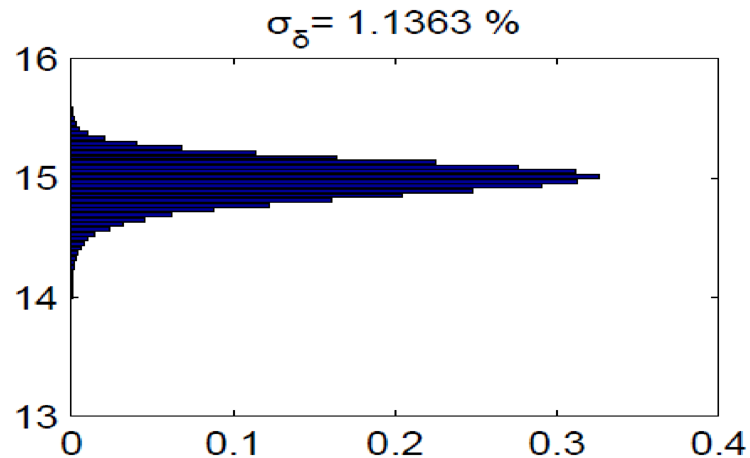
Bunch Compressor



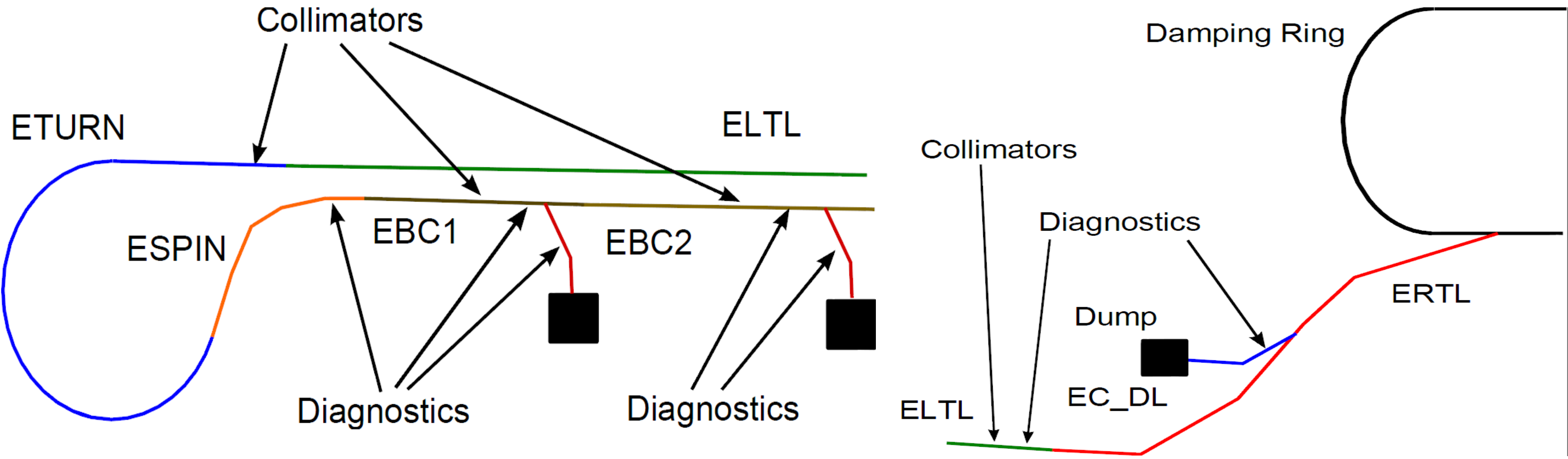
Final longitudinal phase space for bunch compression at nominal operation mode (5 Hz, E_{cm} = 500 GeV).

- New parameter optimization of BC wigglers done by S. Seletskiy (more details in his talk).





Collimators+Diagnostic+Extraction lines



- 3 Extraction lines in each side of RTML: DR exit, BC1 end, BC2 end.
- 4 Collimation sections: beginning of LTL, Turn-around dogleg, BC wigglers.
- 7 Diagnostic sections: beginning of LTL, end of Spin rotator, end of BC1 and BC2 and in each extraction line.
- Skew quadrupole sections at beginning of LTL and at end of Spin Rotator.

Extraction lines

• Extraction System can extract full beam for tune up or make fast bunch extraction.

• Extraction lines in RTL and BC1 can dump entire beam (220 Kw, @ 5GeV). Extraction line in BC2 can only dump 1/3 of beam power (@ 15 GeV).

• Extraction line at BC1 can dump compressed and uncompressed beam (E=4.8-5 Gev, σ_E = 0.11-1.42%), while the one at BC2 needs large energy acceptance.

• New design of extraction lines by S. Seletskiy (more details in his talk).

Collimator sections

Type	Aperture X×Y mm^2	Budget W	Cooling	Location	Number
Rectangular	3.43×10	$\ll$ 220	—	ELTL/PLTL	4
Rectangular	10×1	$\ll$ 220	—	ELTL/PLTL	4
Circular	6.5	200 (CW)	water	ELTL/PLTL	16
Rectangular	1×10	$\ll$ 220	—	ETURN/PTURN	4
Circular	6.5	200 (CW)	water	ETURN/PTURN	4
Rectangular	18×20	$\ll$ 220	—	EBC1/PBC1	4
Circular	30	200 (CW)	water	EBC1/PBC1	4
Rectangular	4×10	$\ll$ 220	—	EBC2/PBC2	4
Circular	5	200 (CW)	water	EBC2/PBC2	4

• Collimation is performed by adjustable-aperture rectangular (spoiler) and fixed-aperture circular (absorber) collimators.

• Spoilers are 0.6 RL titanium, with budget << 10^{-3} beam power (estimated halo), very small portion of energy deposited.

• Absorbers are ~20 RL, with budget ~200 W (estimated halo), full halo absorption.

• System in LTL for betatron collimation, other 3 for energy collimation.

Collimator sections

- Betatron collimation with couple of horizontal spoilers (@ focusing quad) and vertical spoilers (@ defocusing quad) separated by 90° fase advance. Absorbers are after each spoiler.
- Betatron collimation is performed @ 10 σ_x and 60 σ_y.
- Request to change collimation to 6 σ_x and 34 σ_y like in BDS. Wakefield effects from such collimators to be evaluated (maybe possible using tapered collimators).

- Energy collimation is performed @ 10 σ_δ in Turn-Around and 6 σ_δ in the wigglers.

- In Turn-Around spoilers are at opposite dispersion position separated by I matrix in betatron phase. In wigglers they are at same dispersion and separated by -I in betatron phase.

Magnet count and Heat Load/Cost estimation

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Magnet count and Heat & Power Load for RTML estimated with RDR parameters.

RTML (Ring-To-Main-Linac) DESIGN CRITERIA FOR CFS

MAR 14 2012

RTML Heat and Power Load (Totals RTML shown) 5HZ FULL POWER UPGRADE [CFS FACILITIES BASELINE]

HEAT LOAD to CFS	Total KW	rough location	Qty	Load to water-LCW				Load to Air	Beam tunnel Temperature	Notes
				KW heat load	LCW supply temperature (F)	Delta T (F)	or Flow (gpm)	KW heat load		
RTML components										
Magnets	** **931**	beam	**4651**	**838**	90	20	**286**	93		Qty and KW from P.Bellomo 5/9/2007. [SEP 3 2010, scale qty by ratio of 4000/4334). File/Email N. Solyak Aug 2011. **[MAR 8 2012 meeting w Alessandro & Nikolay]**
Cables	**158**	beam		106	90	N/A	N/A	52		P.Bellomo 5/9/2007. Aug 2011 CFS & NSolyak **[MAR 8 2012 meeting w Alessandro & Nikolay]**
Power supplies	**168**	caverns, Alcoves & Svc Tnl	TBD	156	90	N/A	N/A	12		P.Bellomo 5/9/2007. Aug 2011 CFS & NSolyak **[MAR 8 2012 meeting w Alessandro & Nikolay]**
RF for BC1	**300**	Alcove		270	90	45	41	30	104F (40C)	Jul 14 2009 Nikolai & Marc (50% from RDR). Aug 2011 CFS&NSolyak + assume % to air + used RDR. **[MAR 14 2012 Update from Alessandro]**
RF for BC2 (32 RF)	**3911**	75% in svc tunl		3168	90	45	481	743.1		**[MAR 8 2012 meeting w Alessandro & Nikolay]**
Racks (32RF)	320	Servc Tunl		320	90	N/A	N/A	0		
Dumps *	0	beam		0	90	56	0	0		{RDR showed 250 KW each AL ball dump with 30 gpm] Jul 14 2009 Nikolai & Marc (50% from RDR)
	0	beam		0	90	56	0	0		from dump list 2009 - not used?
Total heat load for CFS	**5788**			**4858**				**930**		* (6) 220 KW dump are not used all the time

** *=Magnet power calculated for nominal paramaters of lattice*

POWER		
Beam Power (from N.S.)	1427	KW
Numbers from Table above	5788	KW
TOTAL POWER operating	**7.21**	MW

LOAD DISTRIBUTION

4% of rtml are located in LTR area (central region to DR)

96% are in the rtml ends

Yellow highlighted numbers are changes compared to the last version

RTML (Ring-To-Main-Linac) DESIGN CRITERIA FOR CFS

MAR 14 2012

RTML Heat and Power Load (Totals RTML shown) 5HZ LOW POWER [ILC BASELINE]

HEAT LOAD to CFS	Total KW	rough location	Qty	Load to water-LCW				Load to Air	Beam tunnel Temperature	Notes
				KW heat load	LCW supply temperature (F)	Delta T (F)	or Flow (gpm)	KW heat load		
RTML components										
Magnets	** **931**	beam	**4651**	**838**	90	20	**286**	93		Qty and KW from P.Bellomo 5/9/2007. [SEP 3 2010, scale qty by ratio of 4000/4334). File/Email N. Solyak Aug 2011. **[MAR 8 2012 meeting w Alessandro & Nikolay]**
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Power supplies	**168**	caverns, Alcoves & Svc Tnl	TBD	156	90	N/A	N/A	12		P.Bellomo 5/9/2007. Aug 2011 CFS & NSolyak **[MAR 8 2012 meeting w Alessandro & Nikolay]**
RF for BC1	**250**	Alcove		225	90	45	34	25	104F (40C)	Jul 14 2009 Nikolai & Marc (50% from RDR). Aug 2011 CFS&NSolyak + assume % to air + used RDR. **[MAR 14 2012 Update from Alessandro]**
RF for BC2 (32 RF)	**2585**	75% in svc tunl		2094	90	45	318	491		**[MAR 8 2012 meeting w Alessandro & Nikolay]**
Racks (32RF)	320	Servc Tunl		320	90	N/A	N/A	0		
Dumps *	0	beam		0	90	56	0	0		{RDR showed 250 KW each AL ball dump with 30 gpm] Jul 14 2009 Nikolai & Marc (50% from RDR)
	0	beam		0	90	56	0	0		from dump list 2009 - not used?
Total heat load for CFS	**4412**			**3739**				**673**		* (6) 220 KW dump are not used all the time

** *=Magnet power calculated for nominal paramaters of lattice*

POWER		
Beam Power (from N.S.)	941	KW
Numbers from Table above	4412	KW
TOTAL POWER operating	**5.4**	MW

LOAD DISTRIBUTION

4% of rtml are located in LTR area (central region to DR)

96% are in the rtml ends

Magnet count and Heat Load/Cost estimation

Cost for RTML magnets & PS estimated using RDR data.

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X	Y	Z	AA	
1					Magnet Parameters, April 13, 2012																							
2																												
3	Name	Count 2 RTML	Type	Int.Str. T,Tn	MaxG,B	Lefm,m	Xgap	YGap	Bpole, T	Iw/pole,A	I,A	Wc	Lcu,m	qcu,mm^2	Vcu,m3	mcu/mag,to	Mcu,tons	Rw,Ohm	U,V	P,W	Ctool,k$	Cmag, $	Cstand,$	Cmts,k$	Cmt,k$	Cn,k$	Comments	Mag
4	DC Quadrupoles																											
5	QRTML1	8	Q20L100	0,400	4,000	0,1	0,02	0,02	0,040	1,67E+02	2	84	96	1	9,631E-05	0,0008571	0,006857	1,93	3,9	8	25	3000	3000	31,0	28,0	73	The same dye	
6	QRTML2	1526	Q20L200	17,520	87,600	0,2	0,02	0,02	0,876	3,66E+03	20	183	387	10	0,0038667	0,0344134	52,514862	0,77	15,5	309	40	5000	3000	48,0	45,0	12248	The same dye	
7	QRTML3	0	Q20L400	6,650	16,625	0,4	0,02	0,02	0,166	6,95E+02	20	35	140	10	0,0014009	0,0124684	0	0,28	5,6	112	40	8000	3000	51,0	48,0	40	The same dye	
8	QRTML4	0	Q20L800	13,300	16,625	0,8	0,02	0,02	0,166	6,95E+02	20	35	276	10	0,0027552	0,0245213	0	0,55	11,0	220	40	12000	3000	55,0	52,0	40	The same dye	
9	QRTML5	36	Q60L200	3,714	18,570	0,2	0,06	0,06	0,557	6,99E+03	200	35	87	50	0,0043592	0,038797	1,3966937	0,03	7,0	1395	40	15000	3000	58,0	55,0	688		
10	SC Quadrupoles																											
11	QRTML6	38	QSC80L200	2,430	12,150	0,2	0,08	0,08	0,486	8,13E+03	50	163	SC	SC	SC	SC	SC	SC	SC	SC	200	50000	3000	253,0	250,0	2214		
12	DC Dipoles																											
13	DRTML1	0	D25L400	0,028	0,070	0,4	0,025	0,025	0,070	7,31E+02	50	15	16	12,5	0,0001975	0,0017578	0	0,03	1,3	63	40	5000	3000	48,0	45,0	40		
14	DRTML2	55	D25L900V1	1,060	1,178	0,9	0,025	0,025	1,178	1,23E+04	50	246	561	12,5	0,0070153	0,0624364	3,4340023	0,90	44,9	2245	40	10000	4000	54,0	50,0	810	FNAL Cost at 5(	
15	DRTML3	192	D25L900V2	0,904	1,004	0,9	0,4	0,025	1,004	1,05E+04	50	210	668	12,5	0,0083445	0,0742665	14,259161	1,07	53,4	2670	40	40000	4000	84,0	80,0	8488		
16	DRTML4	192	D25L900V3	0,650	0,722	0,9	0,1	0,025	0,722	7,55E+03	50	151	371	12,5	0,0046415	0,0413091	7,9313455	0,59	29,7	1485	40	30000	4000	74,0	70,0	6568		
17	DRTML5	20	D25L1600	0,625	0,391	1,6	0,025	0,025	0,391	4,08E+03	50	82	323	12,5	0,0040411	0,0359662	0,7193246	0,52	25,9	1293	60	30000	4000	94,0	90,0	740	The same dye	
18	DRTML6	0	D25L1800	1,400	0,778	1,8	0,025	0,025	0,778	8,13E+03	50	163	722	12,5	0,0090217	0,0802931	0	1,15	57,7	2887	60	40000	4000	104,0	100,0	60	The same dye	
19	DRTML7	16	D25L1900	1,795	0,945	1,9	0,025	0,025	0,945	9,87E+03	50	271	1528	12,5	0,0190946	0,1699422	2,7190747	2,44	122,2	6110	60	45000	4000	109,0	105,0	844	The same dye	
20	DRTML8	219	D25L2300	1,823	0,793	2,3	0,025	0,025	0,793	8,28E+03	50	271	1267	12,5	0,0158406	0,1409815	30,874946	2,03	101,4	5069	60	50000	4000	114,0	110,0	11886	The same dye	
21																												
22	DC RT Correctors																											
23	DCRTML1	2283	D20L50	0,053	1,050	0,05	0,02	0,02	1,050	8,78E+03	5	1756	379	2,5	0,000948	0,0084373	19,262322	3,03	15,2	76	25	3000	3000	31,0	28,0	13723		
24																												
25	DC SC Correctors																											
26	DCRTML2	58	DSC80L200	0,0073	0,037	0,2	0,08	0,08	0,037	1,22E+03	100	12	11	SC	SC	SC	SC	SC	SC	SC	40	20000	3000	63,0	60,0	1374		
27																												
28	SC Solenoids																											
29	SLRTML1	8	SLSC20L2600	13,099	4,999	2,62	0,02	0,02	4,999	4,02E+06	4000	1005	221	SC	SC	SC	SC	SC	SC	SC	200	200000	5000	405,0	400,0	1840		
30																												
31	Total	4651														Total Cu,tor	133,1				Total cost, k$					61676		
32																												

Summary and outlook

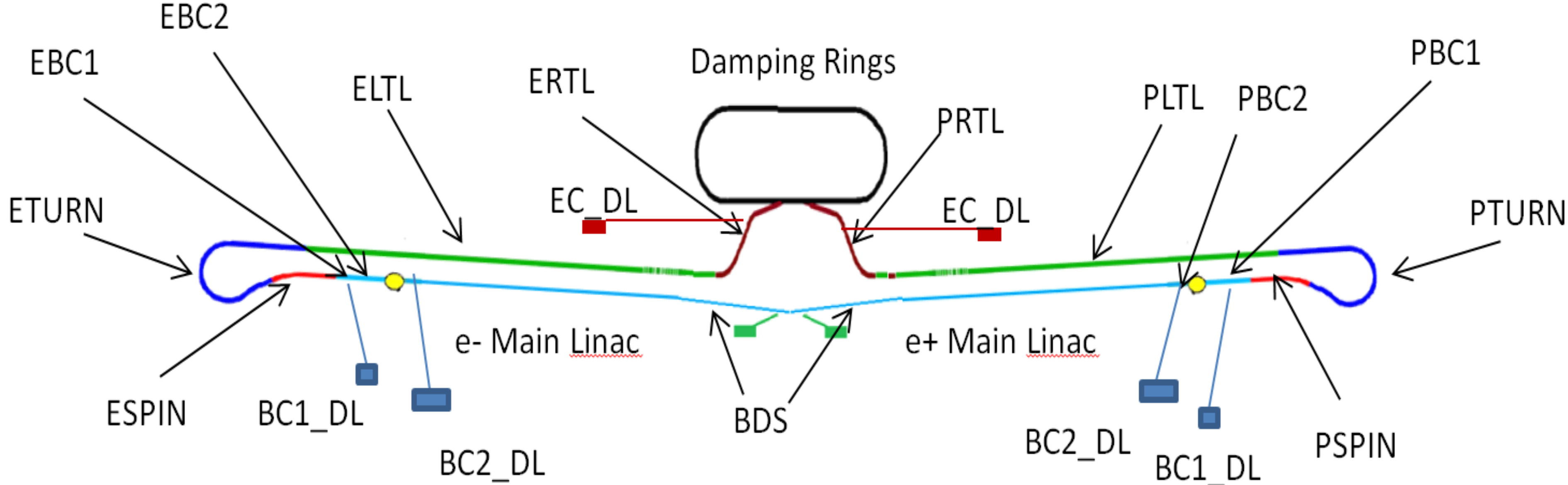
- The RTML lattice is almost in the TDR configuration.
- Earth curvature in return lines have been designed.
- Geometrical matching of DR/ML Treaty points have been performed, optics matching almost done.
- Renovated design and simulation of BC have been performed.
- Design of extraction lines has been renovated.
- Magnet count and Heat Load/Cost estimations completed.

Thanks for your attention.

BACK UP SLIDES

Layout

RTML LAYOUT



	Length in TDR (m)	Length in RDR (m)	Δs (m)
ERTML	17 140.844	16 171.529	919.315
PRTML	15 948.136	14 791.983	1 156.153

- Lines EC_DL and BC1_DL have same lattice design.