ILC RTML overview

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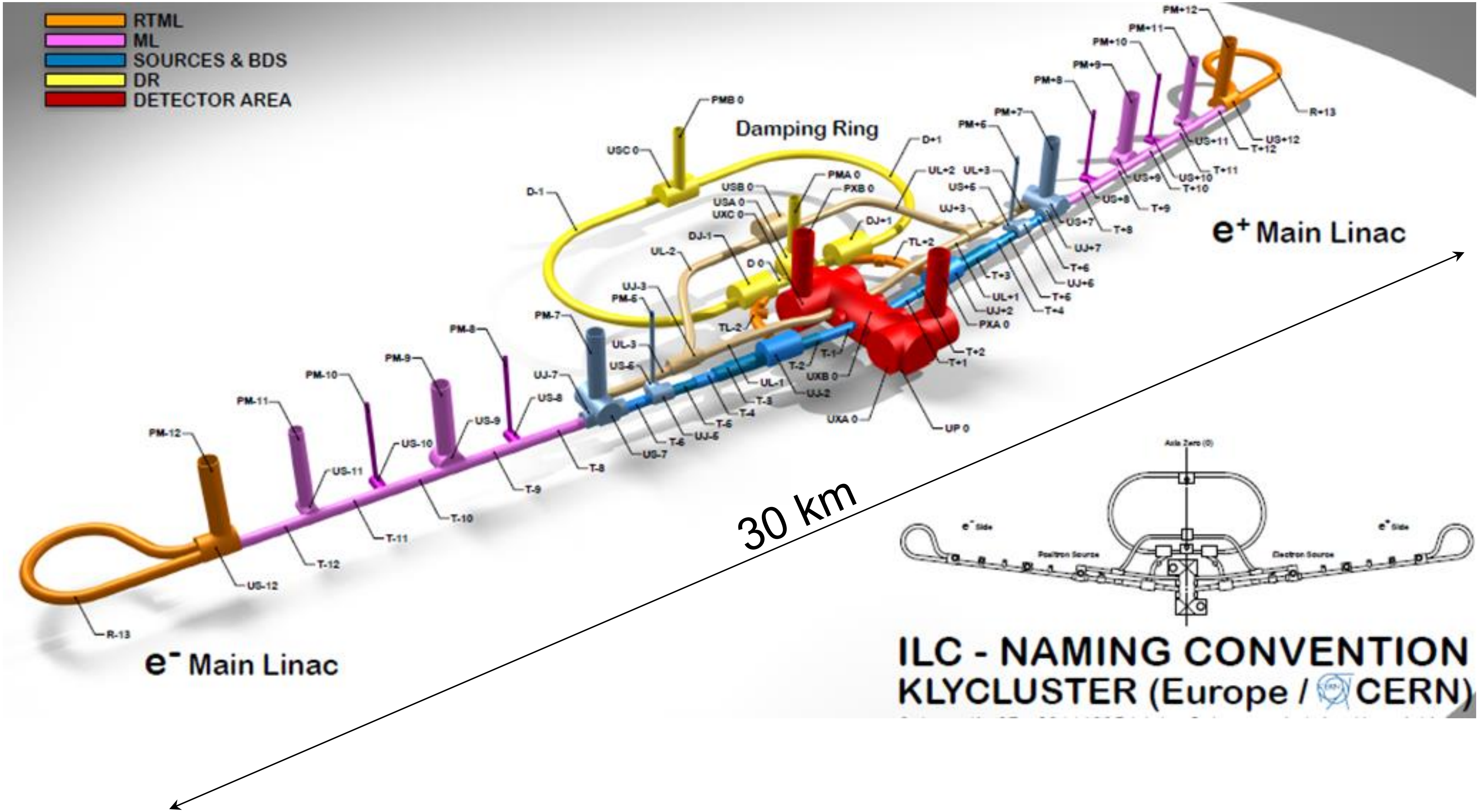
Fermilab

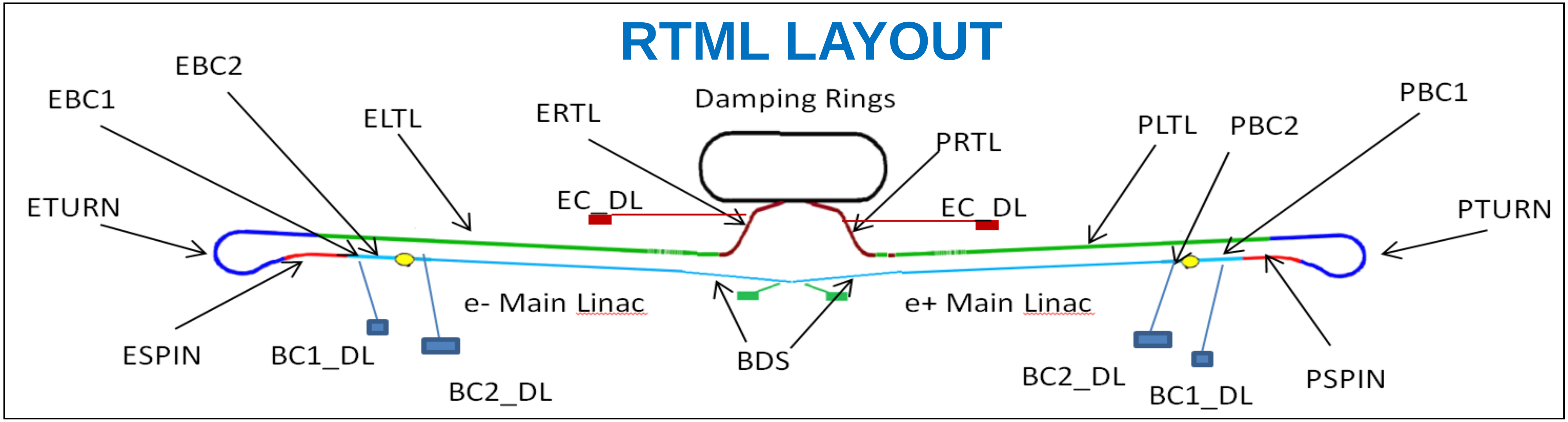
- RTML Lattice update in TDR
- Emittance preservation overview
- Other effects
- Conclusion

ECFA Linear Collider Workshop
DESY, May 27-31, 2013

ILC TDR Layout



RTML Beamlines in TDR lattice



- ERTL/PRTL: Electron/Positron Ring-to-Line from DR to Main Tunnel (EC_DL - Dump Line)
- ELTL/PLTL: (E/P) Long-Transfer-Line ← Return Line
- ETURN/PTURN:) ←Turn-Around
- ESPIN/PSPIN: ← Spin rotator
- EBC1/PBC1: (E/P) 1st stage of Bunch Compressor (BC1_DL - Dump Line)
- EBC2/PBC2: (E/P) 2nd stage of Bunch Compressor (BC2_DL - Dump Line)

	Length TDR, m	Length RDR, m	Δs, m
ERTML	17 140.844	16 171,5	919.315
PRTML	15 948.136	14 791.983	1 156.153

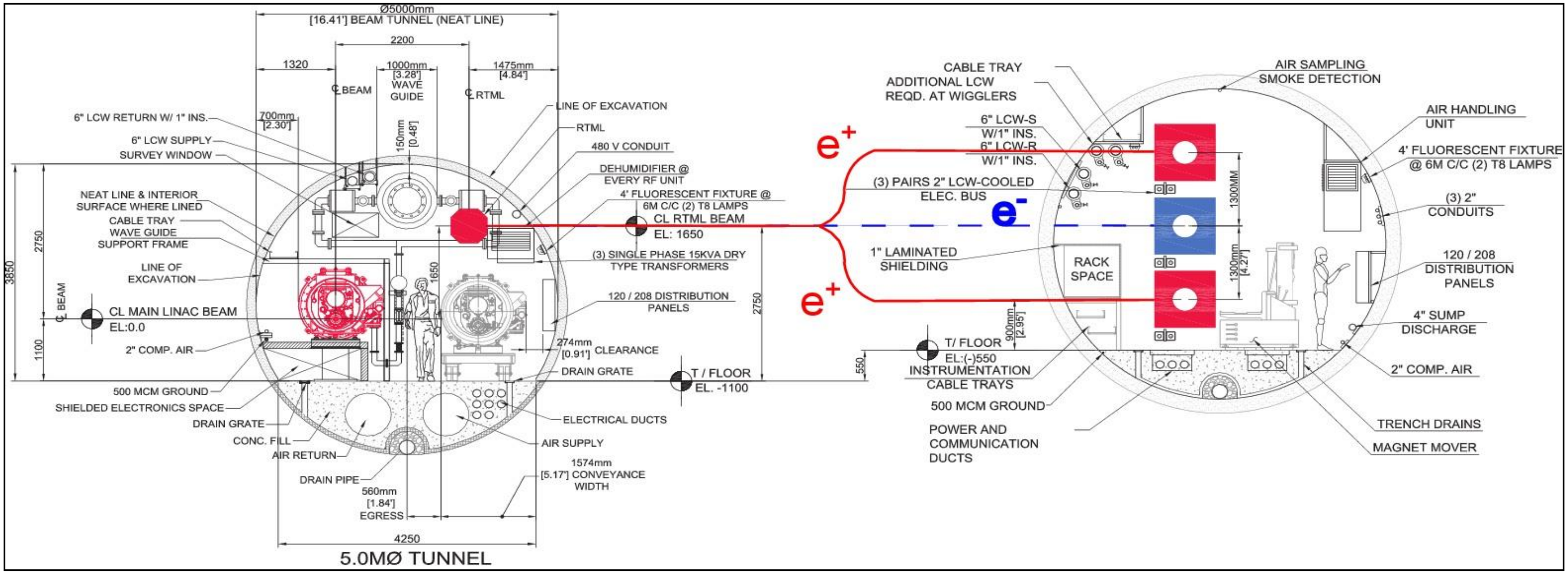
Note: Lines EC_DL and BC1_DL now have same lattice design.

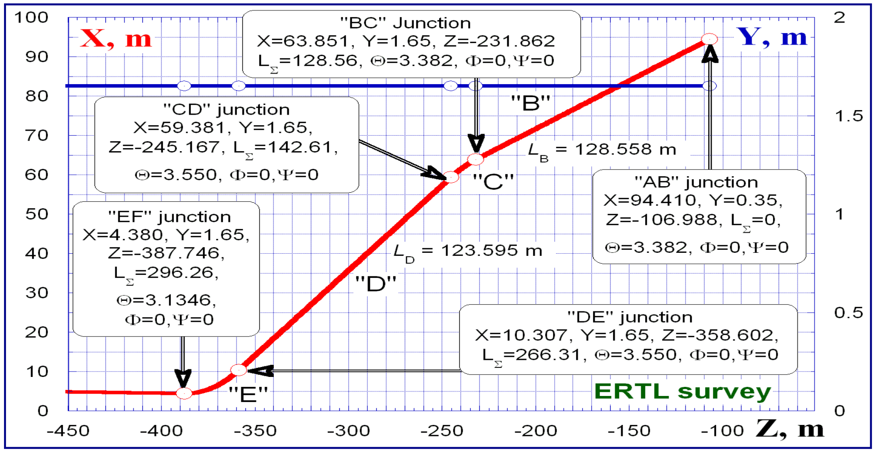
Changes in RTML configuration (TDR vs. RDR)

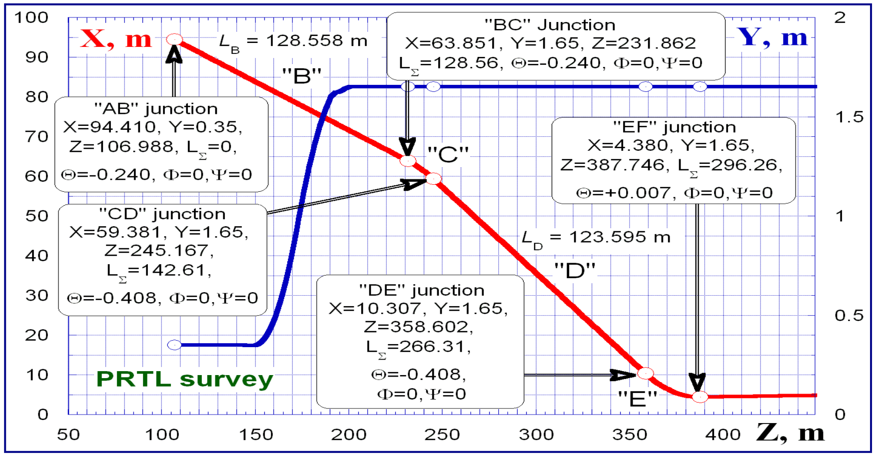
- Central area (DR extraction lines)
  - *RDR: DRX (200m)+Getaway(1100m)+Elevator (800m)*
  - *TDR: ERTL (~150m)*
    - ***No vertical elevation in electron line;***
    - ***Vertical merger in positron line to merge beams from 2 DR's,***
    - ***Extraction to dump moved closer to DR and modified (like BC1)***
- Skew Corr, Emittance Diagnostics and Collimation sections are moved to BDS tunnel as part of ELRL/PLRL, as well as Return Line.
- New H-dogleg in RTML in positron target area (tunnel geometry)
- Length of Return line increase to adjust TDR length in ML, curvature in Return line
- ETURN/PTURN ("Turnaround"): V and H-dogleg parameters are modified to fit new RTML-to-ML separation in tunnel
- BC1+BC2: minor modifications (BC1S – was declined)
- Beam dump design was modified

ERTL/PRTL (Central Region)

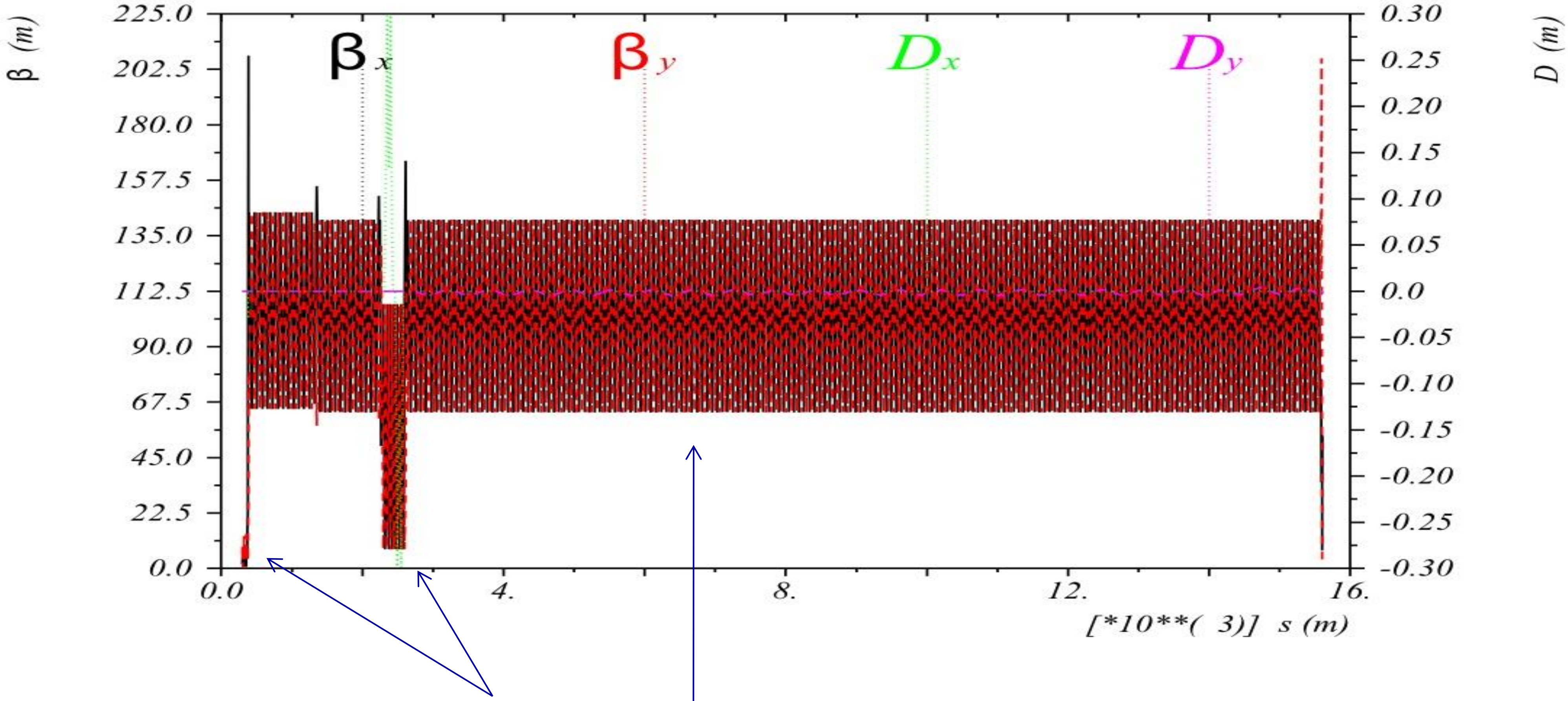
First stage only bottom Positron DR built and V-dogleg
For luminosity upgrade 2 positron DR's and 2 doglegs with merger







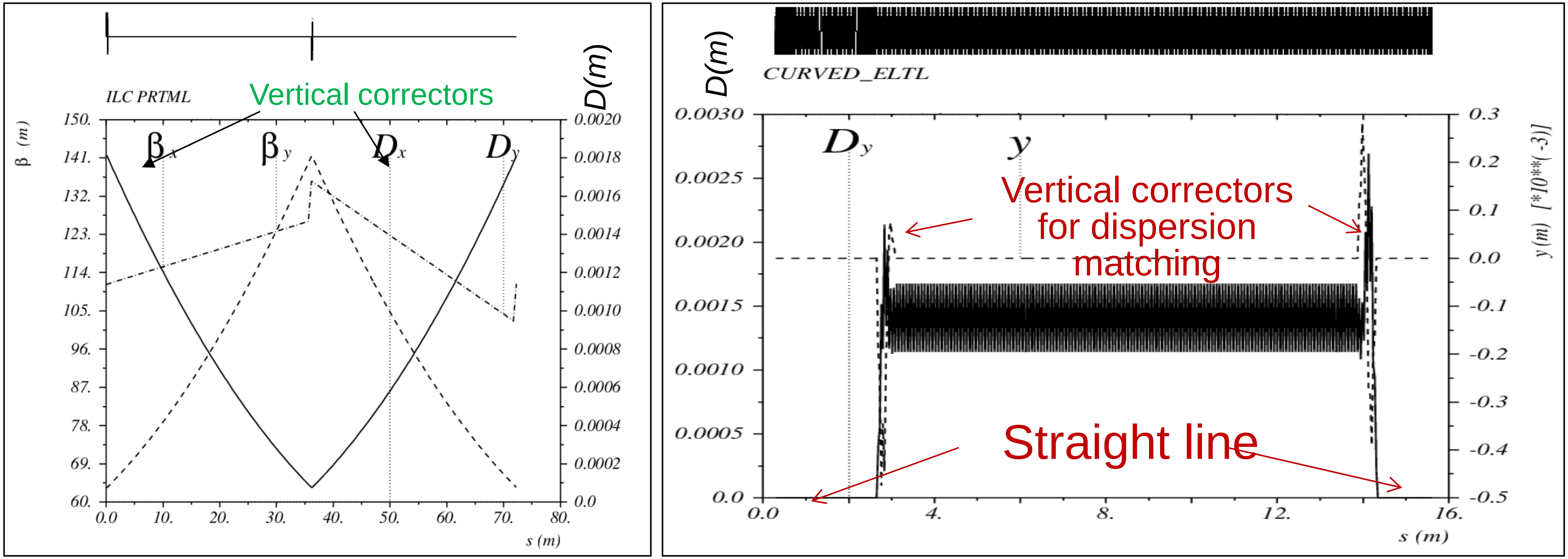
RTML Long Transfer line



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

Earth curvature in ELTL/PLTL

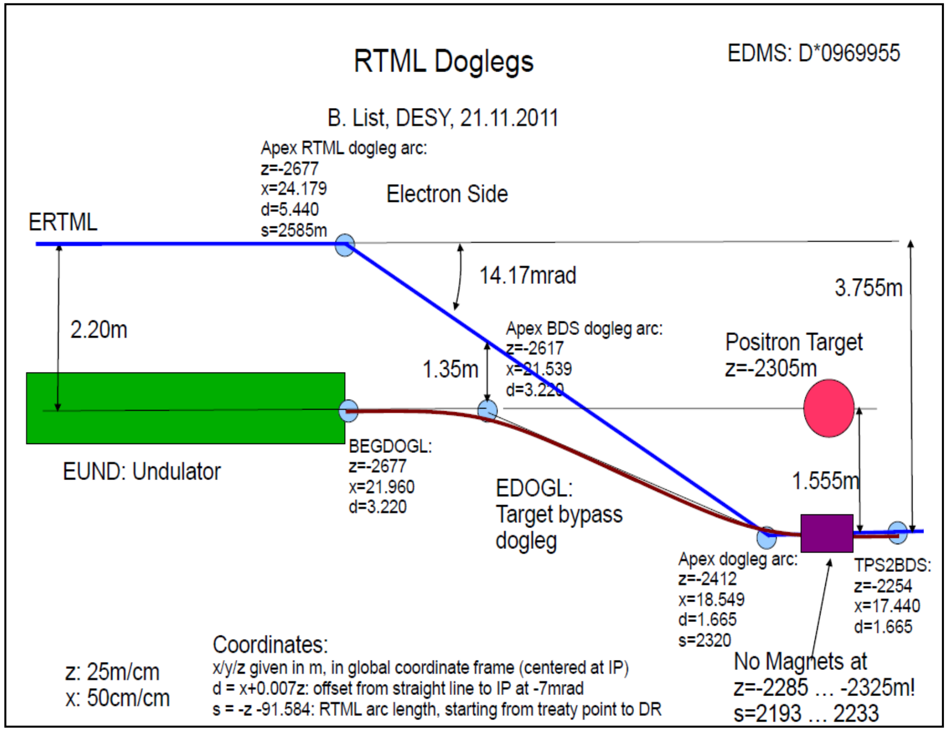
Cryogenic requirements in ML → Return Line need to be curved.

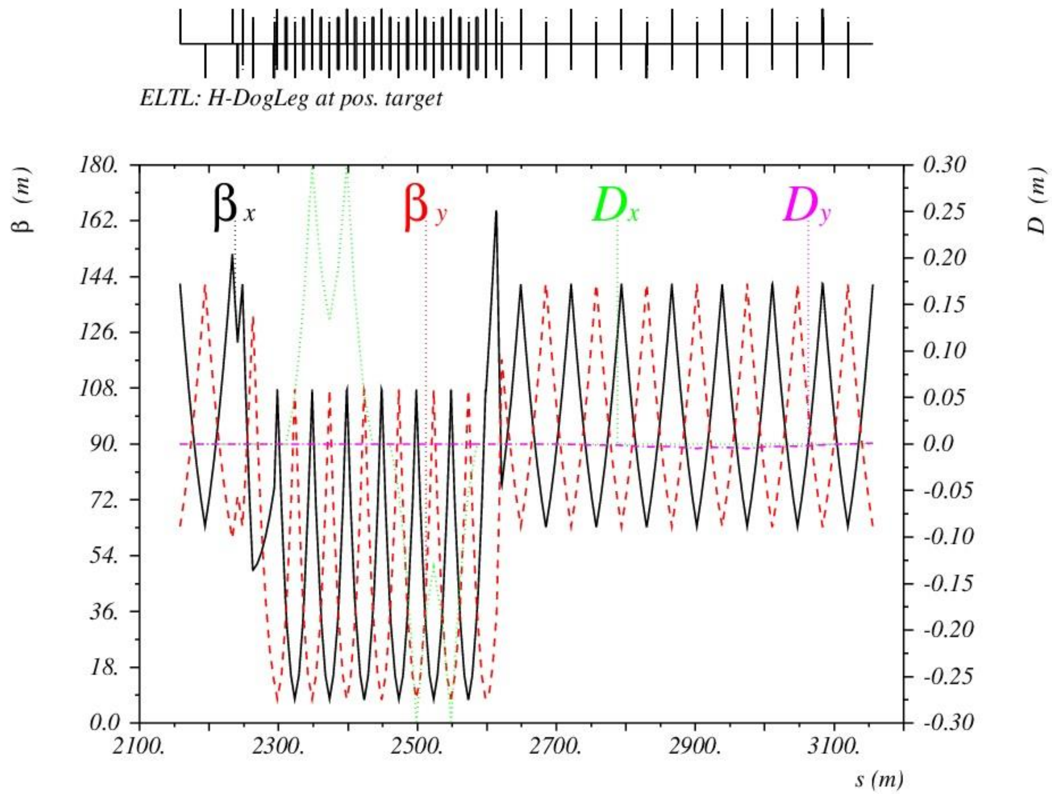


Geometric curvature of the beamlines is realized by means of vertical dipole correctors at each quad of the FODO lattice. A small vertical dispersion is then created and propagated along the line. The first 4 correctors and the last 4 correctors are used to match the curved section to the straight lines.

A.Vivoli

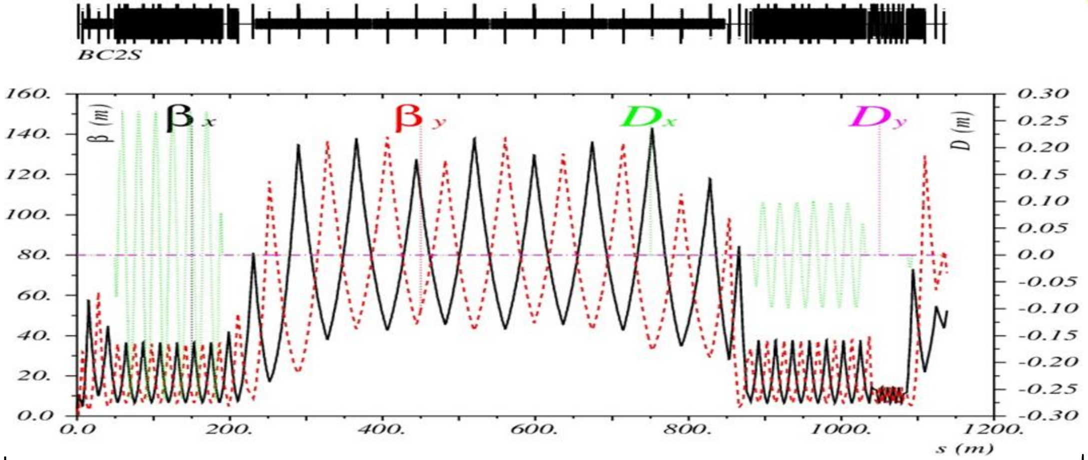
ELTL/PLTL Dogleg design



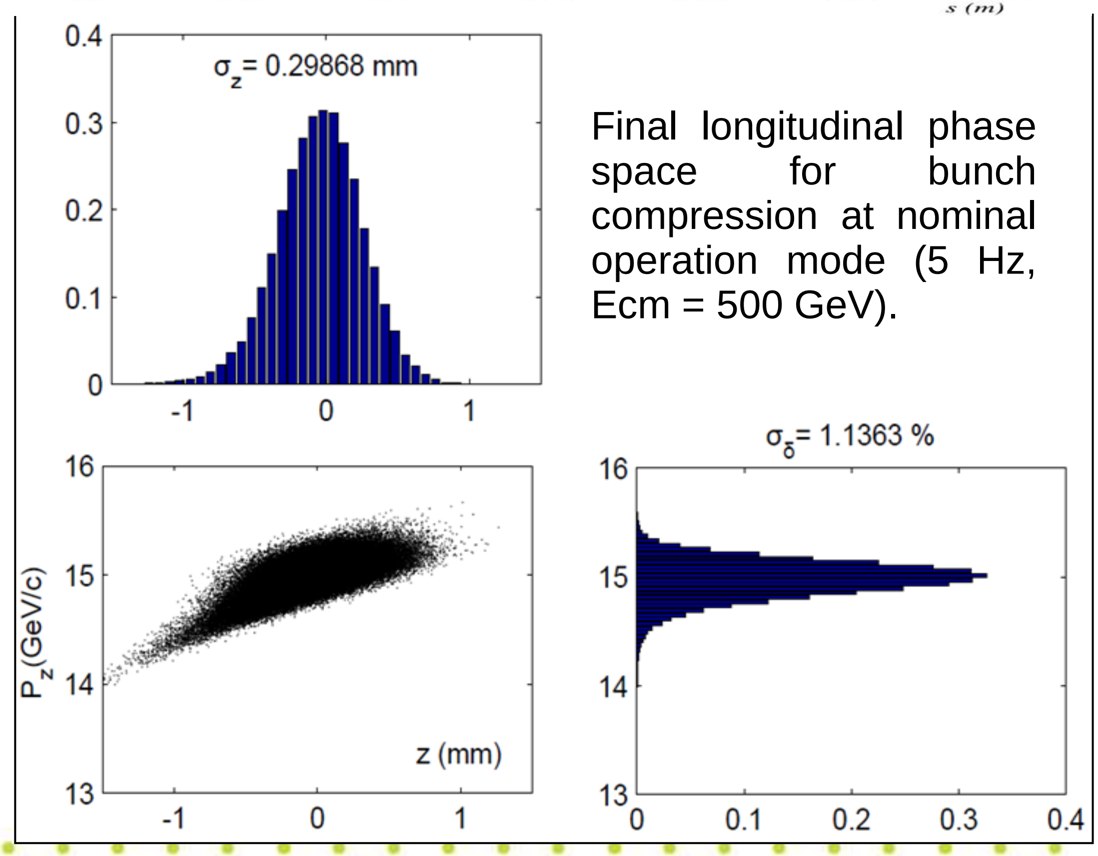


- Dogleg of positron source to by-pass positron target.
- ERTML follows geometry of positron source/BDS systems.
- Radiation from positron target requires magnet free zone.
- FODO+BEND lattice used.

2-stage Bunch Compressor (back to RDR design)



2 stage BC design was finally selected for TDR design (more tunability, shorter bunch ~ 150μm is possible).



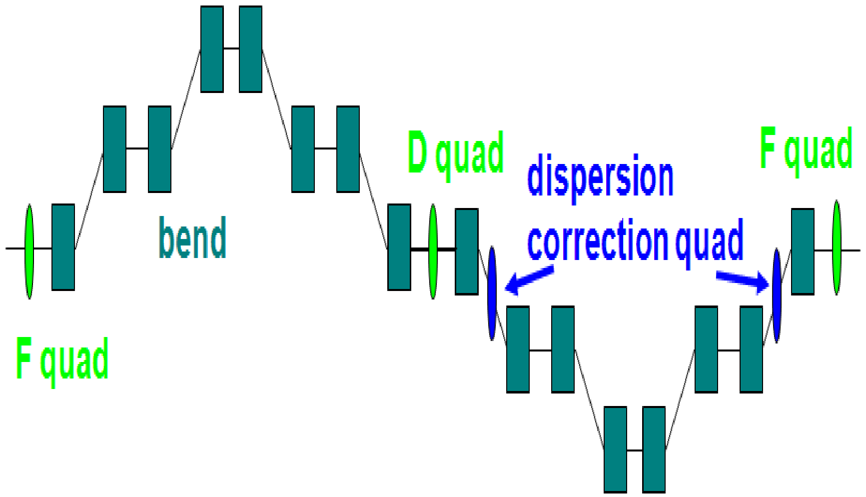
Final longitudinal phase space for bunch compression at nominal operation mode (5 Hz, Ecm = 500 GeV).

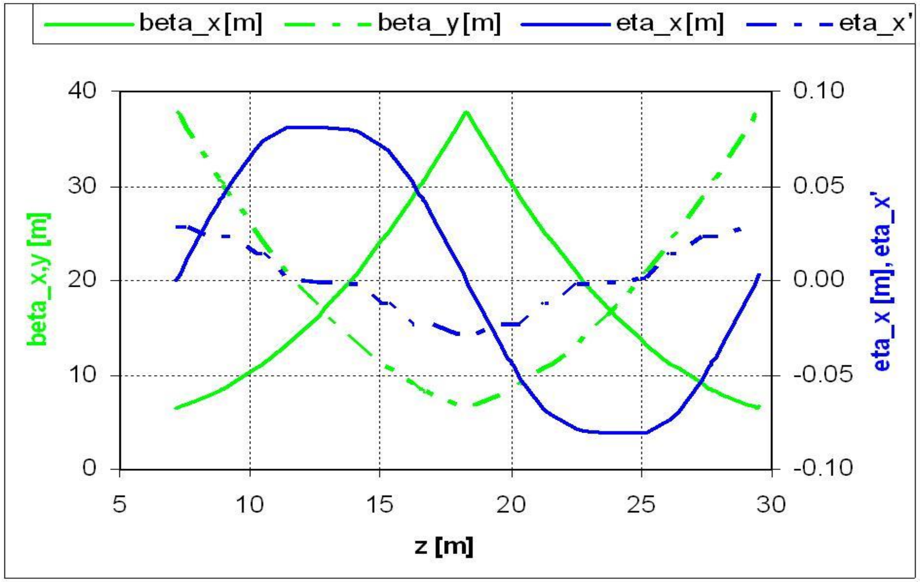
Modifications (for TDR):

- 3 CM's with quads for BC1 (ILC design instead of XFEL).
- 16 RF units in BC2 RF (48 CM's; 416 cavities) to reduce gradient.
- New parameter optimization of BC wigglers (S. Seletskiy)
- New output parameters from DR is used.
- New treaty point from RTML to ML

S. Seletskiy, A.Vivoli

Design of the Wiggler





- Each wiggler consists of 6 identical cells
- Nonzero dispersion slope (η') is introduced at the entrance of each cell
- Wiggler cells are contained in FODO structure with 90° phase adv./cell
- Focusing and defocusing quads are placed in the zero dispersion regions
- There are 4 additional normal quads and 4 skew quads per wiggler (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

Differences between the current TDR design and the RDR (ILC2007b) lattice are minimal.

- Now the tuning quads are located in the second half of the wiggler cell; (in old lattice the tuning quads are located in the first half).
- Also the new wiggler has collimators (adjustable energy spoilers at the SQ location and fixed absorbers at the CQ location) in cells #1 and #3.

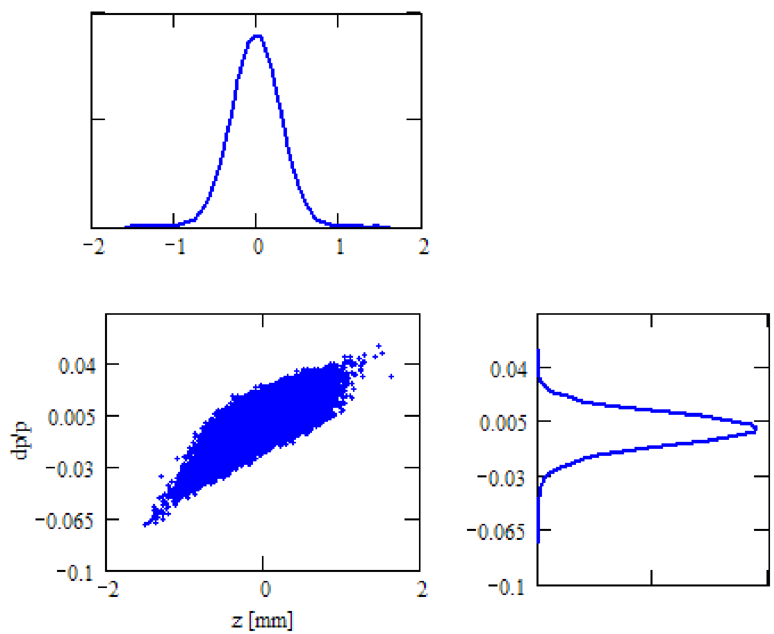
Final 0.3mm and 0.15 mm long beam

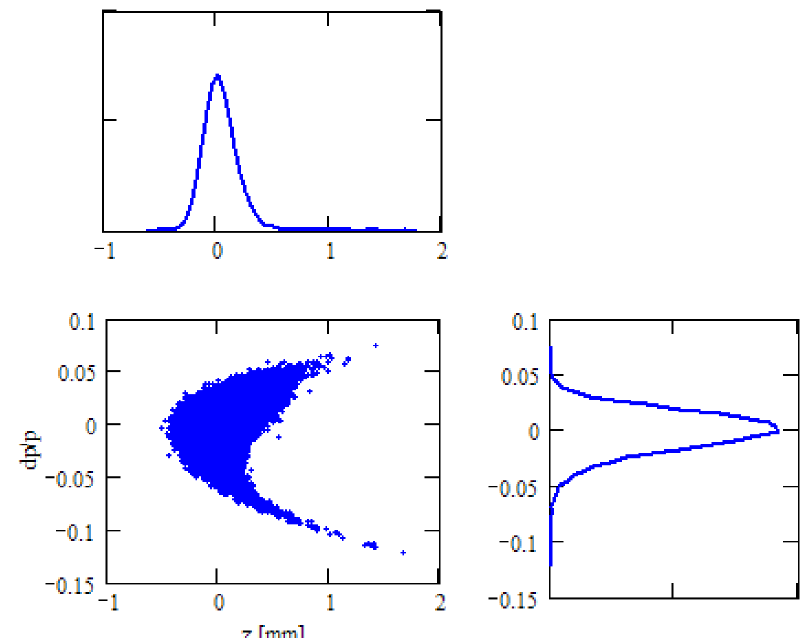
For the case of initial dp/p=0.11%, energy spread at 15 GeV:

- **1.13% for final 0.3mm long beam**
- **1.85% for final 0.15mm long beam**

Sensitivity to RF gradient is shown in table

Initial dp/p, %	Final beam length change (%) for 10% drop in BC2 RF gradient	
	bunch 300 um	Bunch 150 um
0.11	1.3	7.1
0.12	2.3	5.3
0.137	3.0	9.0





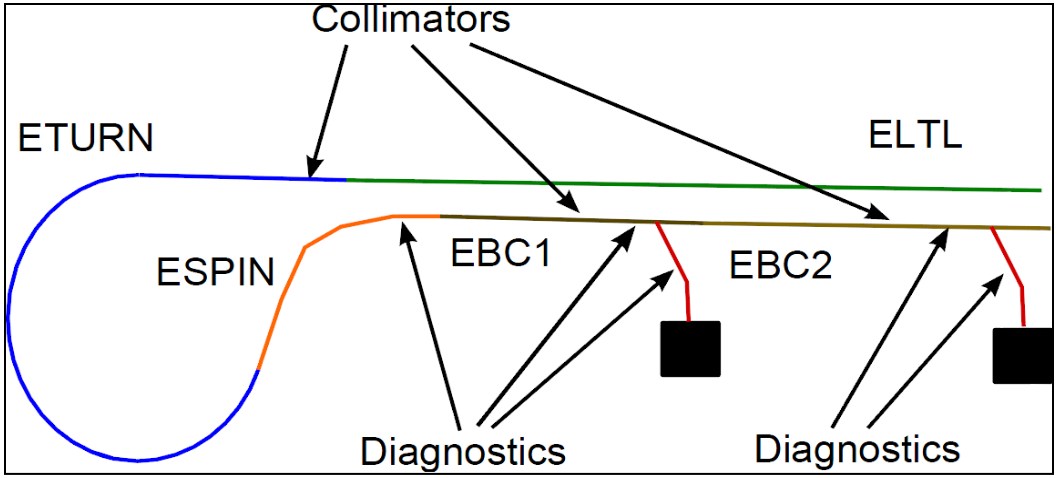
The plot shows the final 300um and 150um long beam for the case of initial dp/p=0.11%.

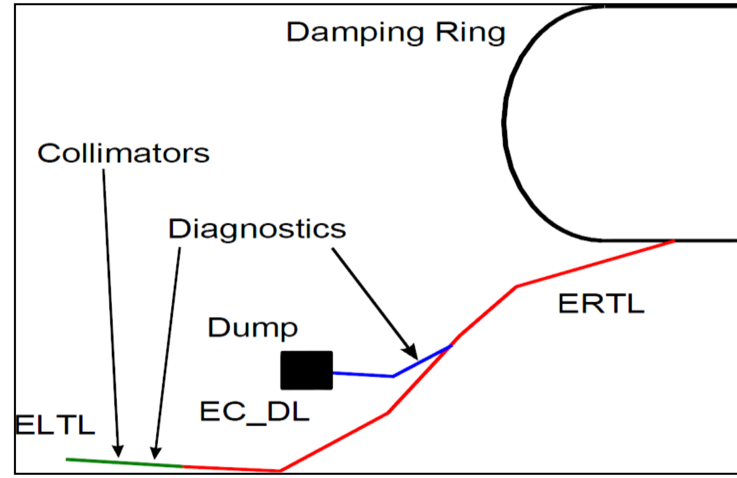
BC parameters for 150 um long final beam

Initial beam			BC1 parameters		Beam after BC1			BC2 parameters		Final beam		
dp/p, %	σ_z, mm	E, GeV	Grd/-φ, MeV/deg	R_{56}, mm	dp/p, %	σ_z, mm	E, GeV	Grd/-φ, MeV/deg	R_{56}, mm	dp/p, %	σ_z, mm	E, GeV
0.11	6	5	18.67 / 120	348	1.37	1.36	4.77	27.2 / 29.2	69	1.85	0.15	15
0.12	6	5	18.67 / 120	348	1.37	1.37	4.77	27.5/ 30.4	69	1.93	0.15	15
0.137	6	5	18.67 / 120	348	1.37	1.4	4.77	30.5 / 39	52.4	2.52	0.15	15

- The 150um final length is achievable for all three cases of initial energy spread.
- It requires higher RF2 gradient.
- The maximum final energy spread is 2.5%.

Collimators, Diagnostics, 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, BC1, BC2 wigglers.
  - *Betatron collimation ($10\sigma_x/60\sigma_y$) with 2 horizontal spoilers at F-quad and 2 vertical spoilers at D-quad separated by 90°. Absorbers after each spoiler.*
  - *Energy collimation @ $10\sigma_E$ in Turn-Around and $6\sigma_E$ 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 phase.*
- 4 Diagnostic sections: beginning of LTL, end of Spin rotator, end of BC1 and BC2
- Skew quadrupole sections at beginning of LTL and at end of Spin Rotator.

Extraction lines

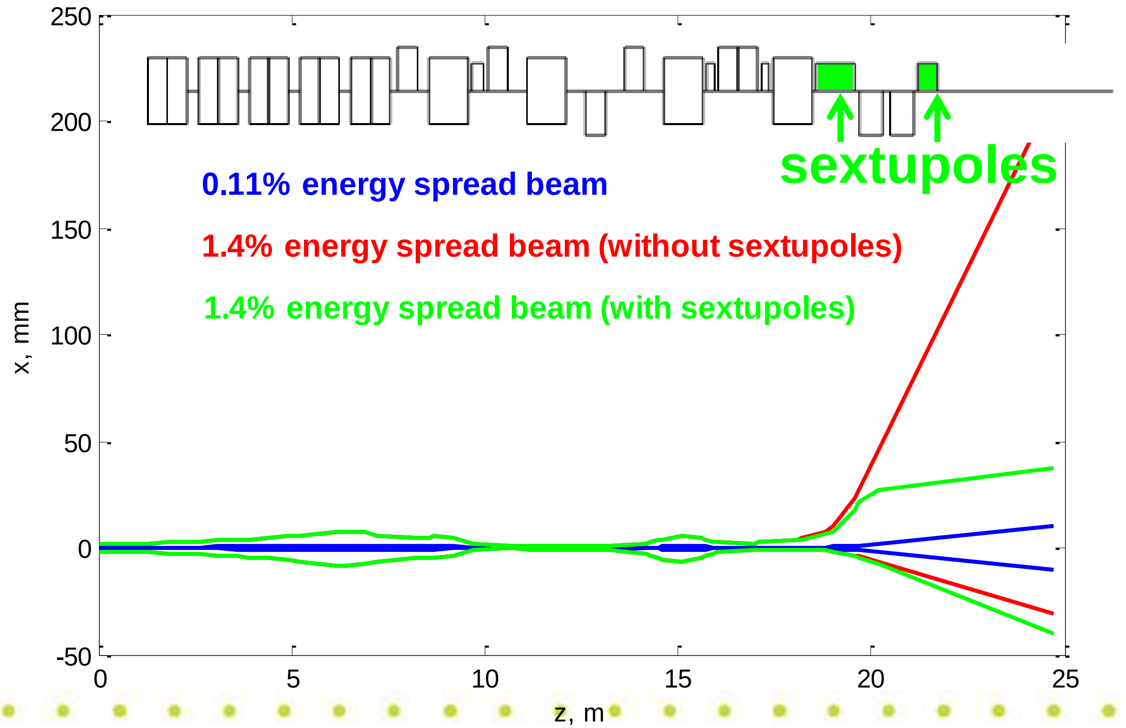
- Extraction System can extract full beam for tune up or make fast bunch extraction.
- Extraction lines in RTL and BC1 can dump entire beam (220 kW, @ 5GeV). Extraction line in BC2 can only dump 1/3 of beam power (@ 15 GeV).
- Extraction line at BC1 can dump compressed and uncompressed beam (E=4.8-5 GeV, s_E = 0.11-1.42%), while the one at BC2 needs large energy acceptance.
- *BC1 extraction lines was re-designed based on ideas developed for BC1S (single stage BC)* For the renovated extraction lines we are combining the best features of both designs. *(more details in S. Seletskiy talk, LCWS' 2012, Albuquerqe).*

Renovated BC1 extraction line (w/o collimators)

- After BC1 the energy spread of compressed beam is small the nonlinear effects are weak and the beam can be contained with only two sextupoles (no collimators). In BC1S we use 5 sextupoles.
- Beam size on the dump window is 19.5mm² for both low energy spread beam. High energy spread beam are in dump window of 12.5cm diameter.
- The Extraction Line is 24.7m long, Dump is separated from the main beamline by 5.1m.

Same line is used for central area (EC_DL and PC_DL)

The renovation of the BC2 extraction line is in progress.



LET studies overview

Survey Alignment

Our old canonical set, should consider more realistic misalignments...
Survey people would prefer we use cold specs for all components.

Error	Cold Sections	Warm Sections	With Respect To...
Quad Offset	300 μm	150 μm	Cryostat
Quad Tilt	300 μrad	300 μrad	Cryostat
Quad strength	0.25%	0.25%	Design Value
BPM Offset	300 μm	200 μm	Cryostat/Survey
BPM-Quad Shunting	20 μm?	7 μm	Quadrupole
BPM Resolution	1 μm	1 μm	True Orbit
Bend tilt	300 μm	300 μm	Survey Line
Bend Strength	0.5%	0.5%	
RF Cavity Offset	300 μm	n/a	Cryostat
RF Cavity Pitch	200 μrad	n/a	Cryostat
Cryostat Offset	200 μm	n/a	Survey Line
Cryostatic Pitch	20 μrad	n/a	Survey Line

Sources of emittance degradation

- **Synchrotron radiation**
  - From DRX arc, turnaround, BC wigglers
- **Beam-ion instabilities**
- **Beam jitter**
  - From DR
  - From stray fields
- **Dispersion**
  - DR extraction
  - Misaligned quads
  - Rolled bends
- **Coupling**
  - DR extraction septum
  - Rolled quads
  - Misaligned bends
  - Quad strength errors in spin rotator
- **Pitched RF cavities**
  - Produce time-varying vertical kick
- **RF phase jitter**
  - Varies IP arrival time of beams
- **Beam halo formation**
- **Collimator and cavity Wakefields**
- **Space charge**
- **Resistive wall wakes in vac. chamber**

BBA @ ILC RTML

Several BBA are used:

- Ballistic Alignment (BA)
- Kick minimization (KM)
- Dispersion Free Steering (DFS)
- Dispersion Bumps
- 4D Coupling Correction
- Girder pitch optizationj

- Try
  - Adaptive alignment
  - Wakefield Bumps

Feed-Back and

Feed Forward system

RTML

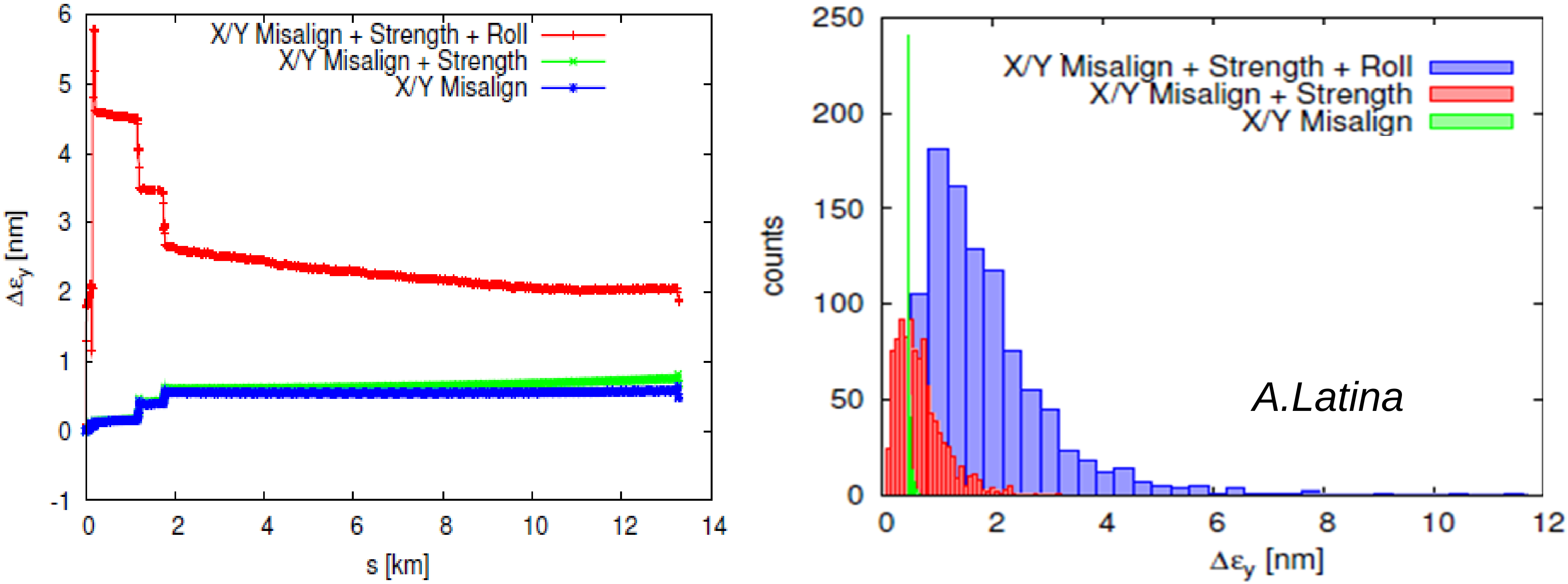
- Not there yet... Budget just 4 nm

Region	BBA method	Dispersive or Chromatic mean Emittance Growth	Coupling mean emittance Growth
Return Line	Kick Minimization and feed-forward to remove beam jitter	0.15 nm	2 nm (without correction)
Turnaround and spin rotator	Kick Minimization and Skew Coupling Correction	1.52 nm (mostly chromatic)	0.4 nm (after correction)
Bunch Compressor	KM or DFS and Dispersion bumps	greater than 4.9 nm (KM + bumps) 2.68 nm (DFS and bumps)	0.6 nm (without correction)
Total		~5 nm almost all from BC	3 nm (without complete correction)

Jeff Smith RTML overview, Dec. 2007,SLAC (lattice 2006)
Since that Lattice changed (2007, TDR)

Getaway + Escalator + Return Line (2007b)

Correction: 1-1 + Kick Minimization + Dispersion Bumps + Coupling Correction
Emittance growth along the line and Histogram of final emittance for 1000 seeds:

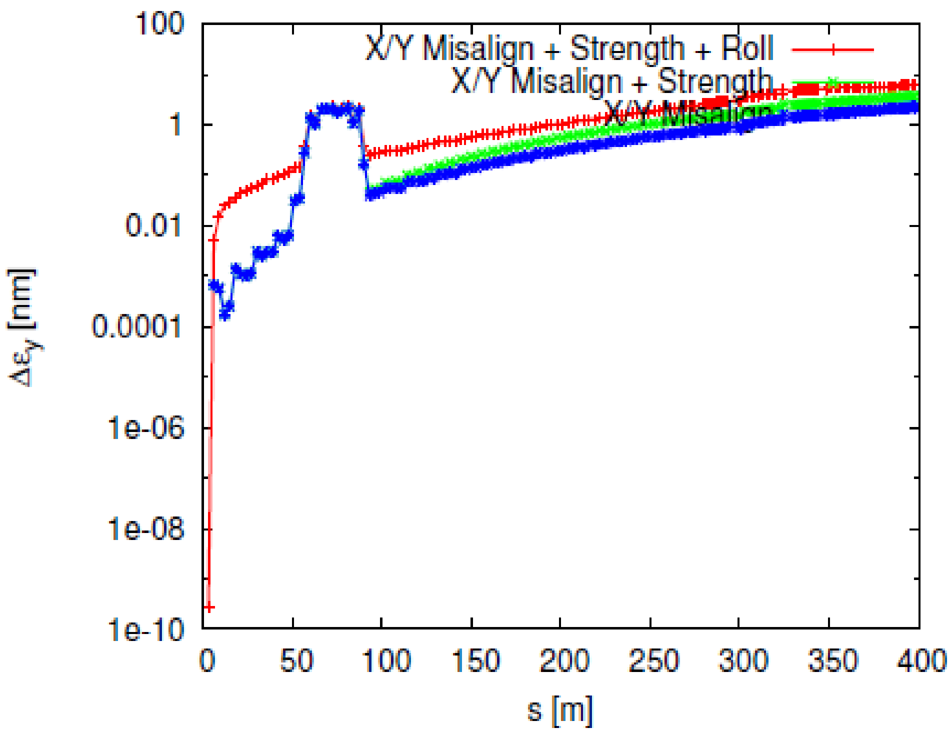


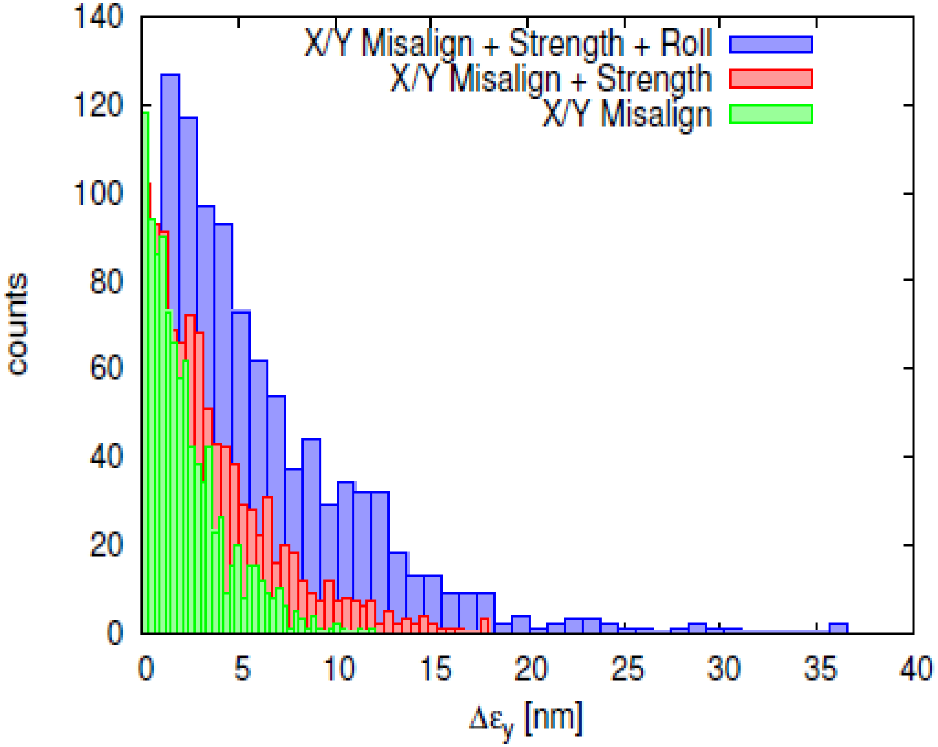
- ➔ X/Y Offsets: Final average emittance growth is 0.48 nm (0.52 nm 90% c.l.)
- ➔ Add Quad/Sbend Strength: Final average emittance growth is 0.68 nm (1.25 nm 90% c.l.)
- ➔ Add Quad/Sbend Roll: Final average emittance growth is 1.87 nm (3.23 nm 90% c.l.)

Turnaround + Spin Rotator (Solenoids OFF)

Correction: 1-TO-1 + Kick Minimization + Dispersion Bumps

Emittance growth along the line and Histogram of final emattance for 1000 seeds:



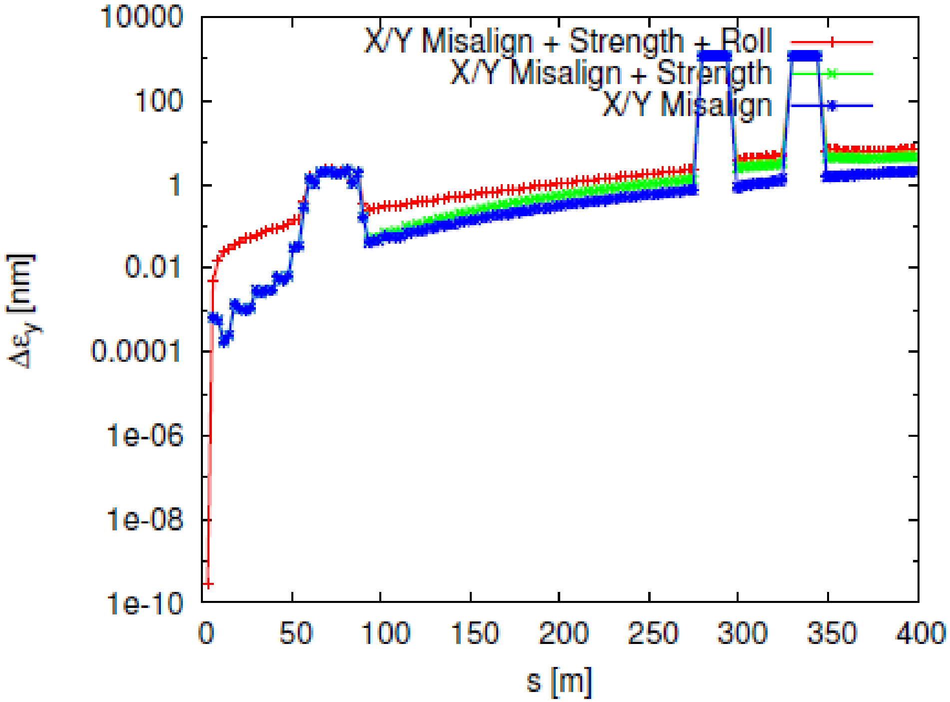


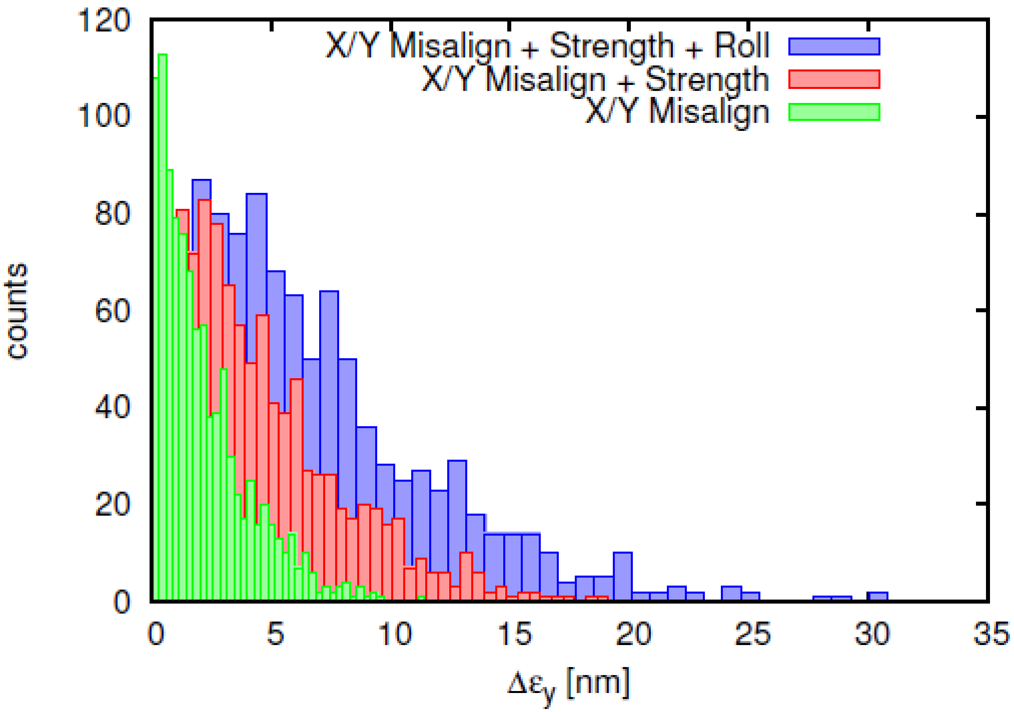
- ➔ X/Y Offsets: Final average emittance growth is 2.26 nm (5.33 nm 90% c.l.)
- ➔ Add Quad/Sbend Strength: Final average emittance growth is 3.69 nm (8.12 nm 90% c.l.)
- ➔ Add Quad/Sbend Roll: Final average emittance growth is 6.11 nm (12.73 nm 90% c.l.)

Turnaround + Spin Rotator (Solenoids ON)

Correction: 1-TO-1 + Kick Minimization + Dispersion Bumps

Emittance growth along the line and Histogram of final emittance for 1000 seeds:





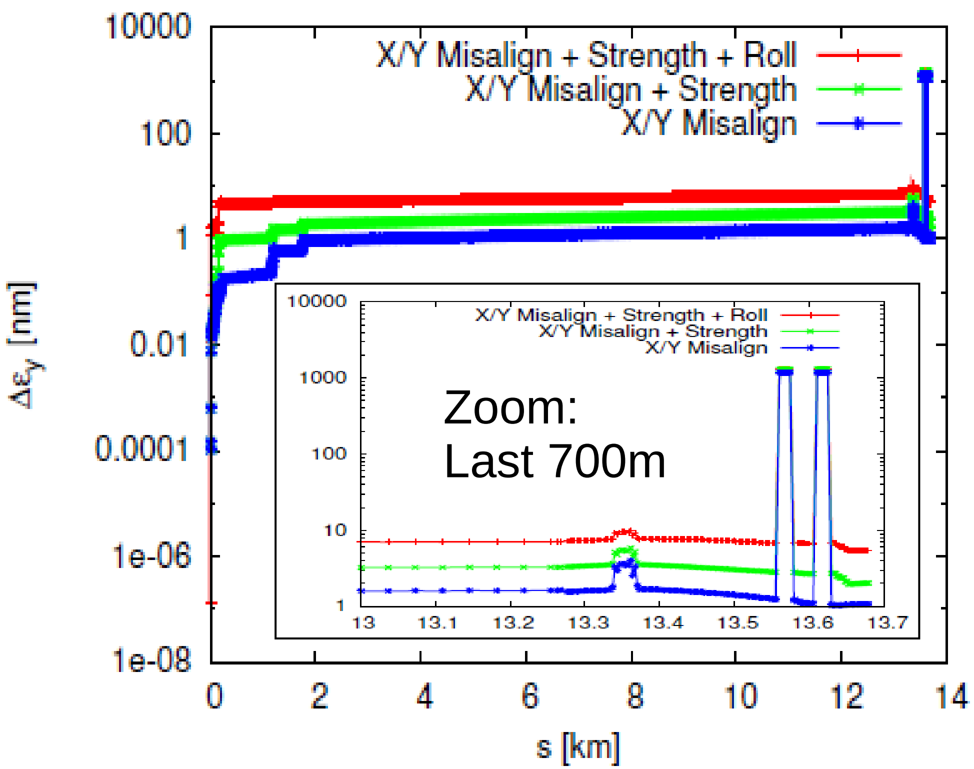
➔ X/Y Osets: Final average emittance growth is 2.14 nm (4.83 nm 90% c.l.)

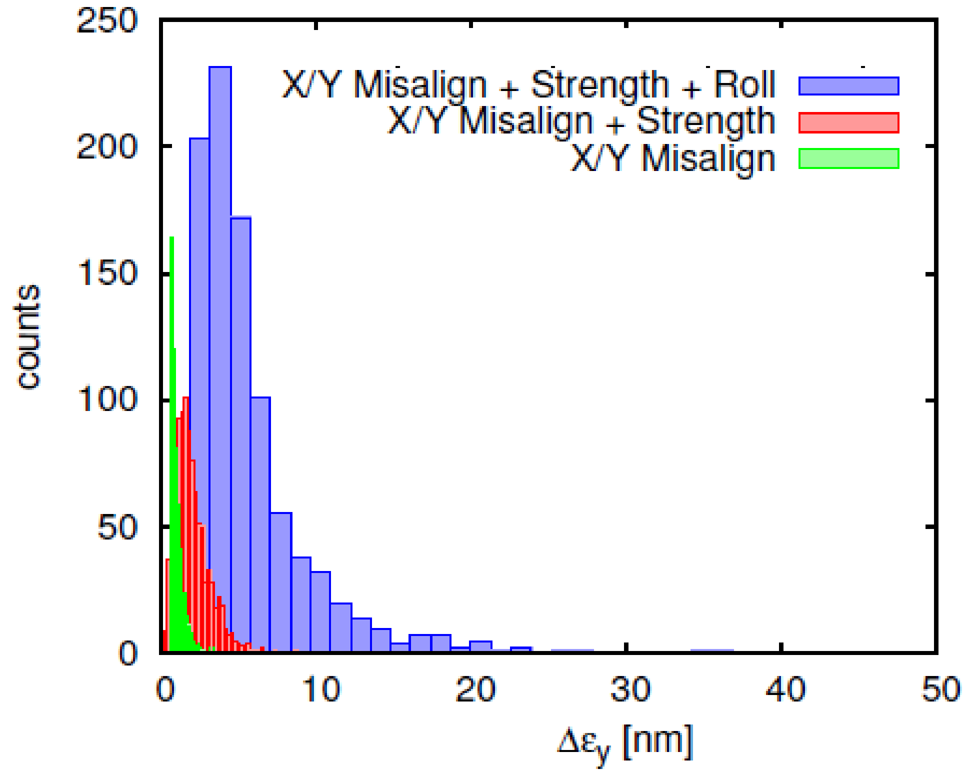
➔Add Quad/Sbend Strength: Final average emittance growth is 4.63 nm (9.42 nm 90% c.l.)

➔Add Quad/Sbend Roll: Final average emittance growth is 6.86 nm (13.66 nm 90% c.l.)

Entire Front-End

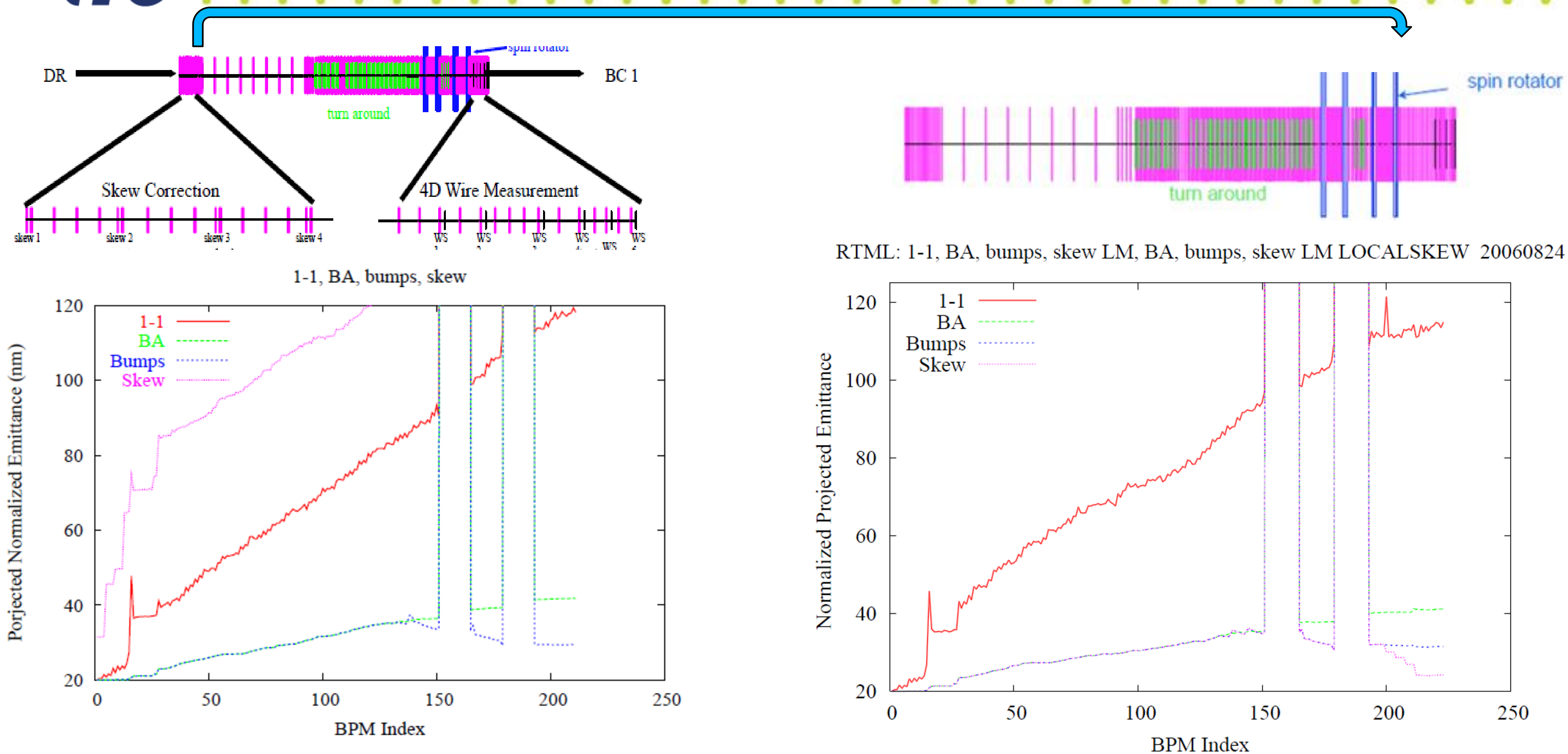
Correction: 1-TO-1 + Kick Minimization + Dispersion Bumps + Coupling Correction
Emittance growth along the line and Histogram of final emittance for 1000 seeds:





- → X/Y Osets: Final average emittance growth is 1.06 nm (1.58 nm 90% c.l.)
- → Add Quad/Sbend Strength: Final average emittance growth is 2.01 nm (3.51 nm 90% c.l.)
- → Add Quad/Sbend Roll: Final average emittance growth is 5.36 nm (9.94 nm 90% c.l.)

Coupling correction studies (J.Smith)



J.Smith, Coupling Correction in the ILC RTML, LEPP, Cornell Univ,Ithaca, NY, March 22, 2007

Tuning the skew quads when they are far from the wire scanners results in the introduction of both coupling and dispersion, which causes the optimization to get confused. However, the system was found to require the measurement of the coupling parameters <xy> at each wire scanner station. Optimizing of the vertical emittance is more effective then optimizing vertical beam size at each station (4D stations)

Summary Tables for the "Front End"

Region	Errors	Emittance Increase (nm)		Correction
		average	90% CL	
Escalator + Getaway + RL	X/Y Offsets	0.48	0.52	KM + knobs + CC
	+ Quad Strength	0.68	1.25	KM + knobs + CC
	+ Quad/Sbend Roll	1.87	3.23	KM + knobs + CC
Turnaround + Spin Rotator (OFF)	X/Y Offsets	2.26	5.33	KM + knobs
	+ Quad/Sbend Strength	3.69	8.12	KM + knobs
	+ Quad/Sbend Roll	6.11	12.73	KM + knobs
Turnaround + Spin Rotator (ON)	X/Y Offsets	2.14	4.83	KM + knobs
	+ Quad/Sbend Strength	4.63	9.42	KM + knobs
	+ Quad/Sbend Roll	6.86	13.66	KM + knobs
Entire "Front End"	X/Y Offsets	1.06	1.58	KM + knobs + CC
	+ Quad/Sbend Strength	2.01	3.51	KM + knobs + CC
	+ Quad/Sbend Roll	5.36	9.94	KM + knobs + CC

***Simulations done for 2007b RTML lattice (Placet, A.Latina, 2010)**

Older PT's summary table for *2006 lattice* *(average emittance growth)*
→SLAC-Tech-Note-07-002

Errors	All Aberrations	Chromaticity	Dispersion	Coupling
X/Y Offsets	0.37 nm	0.37 nm	0.00 nm	0.00 nm
Add Quad Strength	3.20 nm	0.82 nm	0.01 nm	2.39 nm
Add Bend Strength	3.25 nm	0.82 nm	0.06 nm	2.39 nm
Add Quad Rolls	7.60 nm	1.49 nm	0.00 nm	6.08 nm
Add Bend Rolls	7.61 nm	1.49 nm	0.02 nm	6.08 nm

Difference due to different lattices (2006 vs. 2007b), better coupling correction ???

Beam Based Alignment in the Bunch Compressor

- Misaligmments are 300μm, BPM resolution is 1 μm
- RF-Kick wakes
- Dispersion Free Steering
  - two test beams
    - Case A: no Couplers. $\Delta\phi = \pm 25^o$ phase offset in both the RF sections of BC1+BC2
    - Case B: Couplers

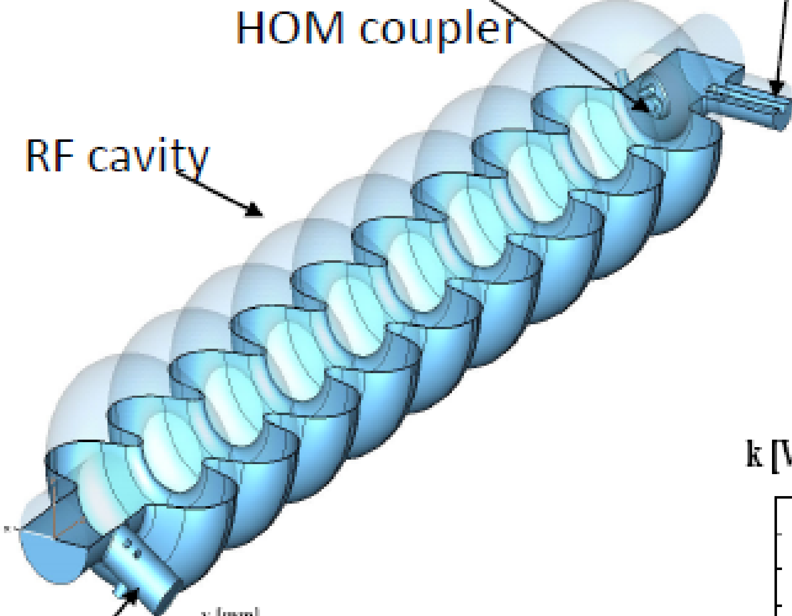
      $\Rightarrow$ $\Delta\phi = \pm 25^o$ phase offset in the RF section of BC1 (no phase offset in BC2)

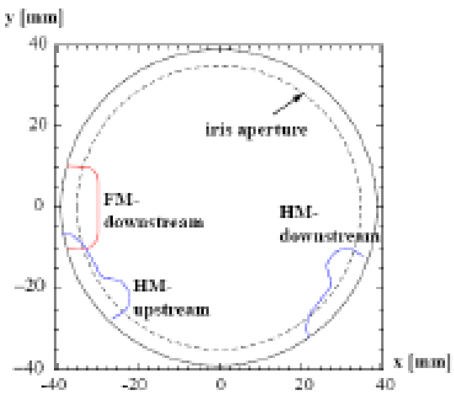
      $\Rightarrow$ phase synchronization at entrance of BC2 is necessary

      $\Rightarrow$ otherwise RF-Kicks completely spoils the test beams, due to the large phase difference (10 σ_z $\approx$ 1 cm)
- Dispersion bumps optimization
  - minimize the final dispersion-corrected emittance by changing the dispersion at entrance
- Girder Pitch optimization
  - *Compensation the effect of cavity pitches and coupler asymmetry*
  - *Using 3 CM in BC1 and 4 in BC2 (1 every 12)*

Input beam parameters:
- *6mm RMS length*
- *0.11% RMS energy spread*

Simulations of Coupler Kick and Wakes (2008)





The profiles of the 3 couplers, as seen from the downstream end.

. Simulations: DESY/FNAL/SLAC

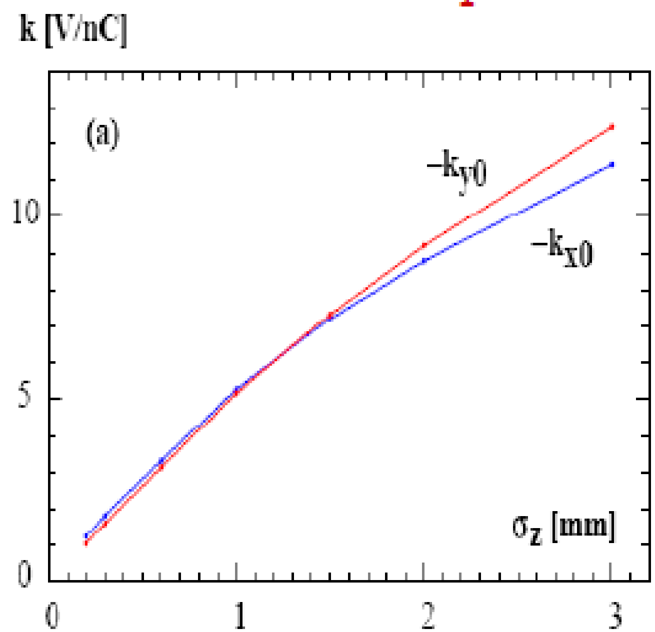
$Q_L \sim 3.10^6$

Total RF KICK (FNAL):

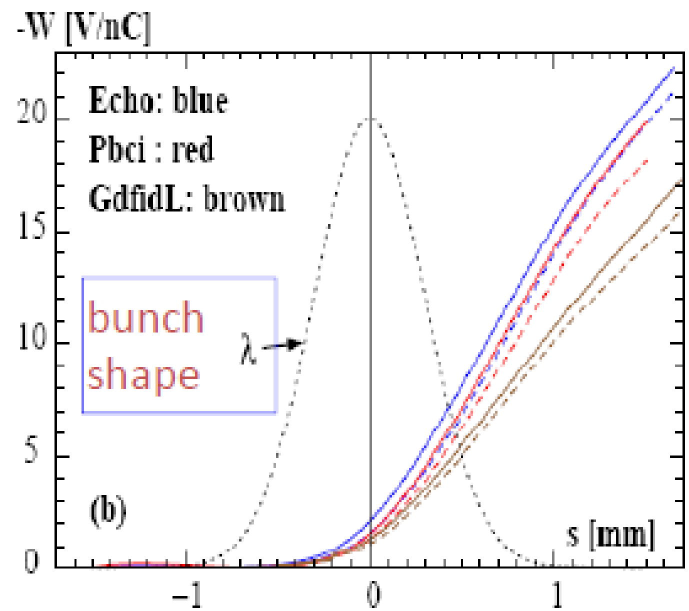
$V_y/V_z = (-5.9+19.6i)\times10^{-6}$;
$V_x/V_z \approx (-98.5+86.8i)\times10^{-6}$.

Errors < 10%

Coupler Transverse Wakefield



On-axis kick factor vs. σ_z



$W_x(s)$-solid,, $W_y(s)$-dashed for σ_z = 300 μm.

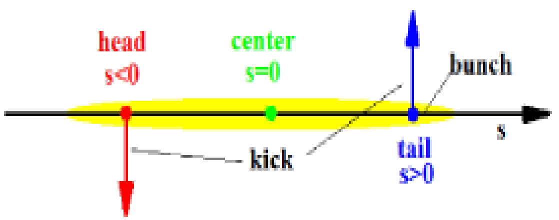
Coupler RF-kick

- Couplers' asymmetry induces a transverse RF-kick:

$$\Delta\vec{V}_{RF} = (k_{\rm real} + i k_{\rm imag})\, G L\, e^{-i(\phi_{RF} + ks)}$$

where $\vec{k} \simeq (-7.2 + 11\, i) \times 10^{-6}$ (HFSS calculations by A.Lunin).

- Kick has opposite sign at the head and the tail of the bunch



$$\Delta\vec{V}_{RF} = V_{\rm real}\cos(ks) \; - \; V_{\rm imag}\sin(ks)$$

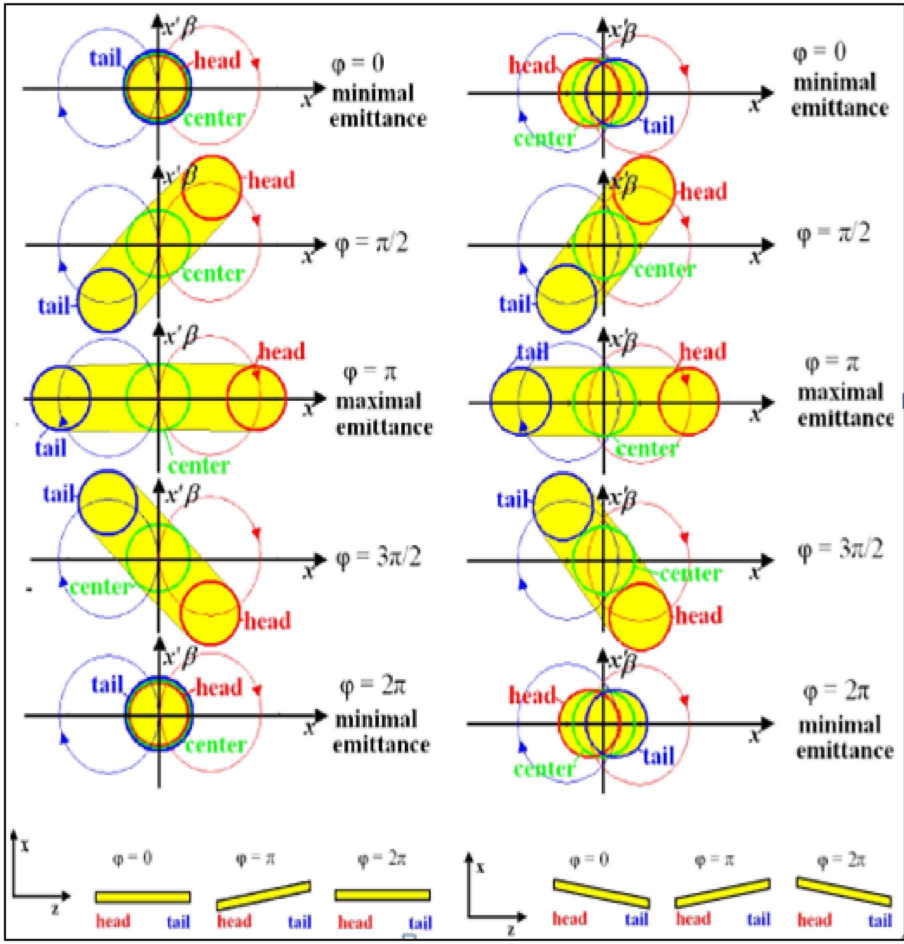
- **Emittance growth** due to RF-Kick (V. Yakovlev's analytical estimation) is

$$\Delta\epsilon \approx \frac{(F')^2\sigma^2\beta^3\gamma_0}{2U_0^2}\left(1 - 2\sqrt{\frac{\gamma_0}{\gamma(z)}}\cos(z/\beta) + \frac{\gamma_0}{\gamma(z)}\right)$$

where ϵ_0 is the initial emittance, F' is the first derivative of the kick for $z = 0$, σ is the bunch length, β is the betatron amplitude, U_0 is the initial energy and γ_0 the corresponding relativistic factor.

$\Rightarrow$ Note that: when $z/\beta = 2\pi n$ and there is no acceleration : $\Delta\epsilon = 0$

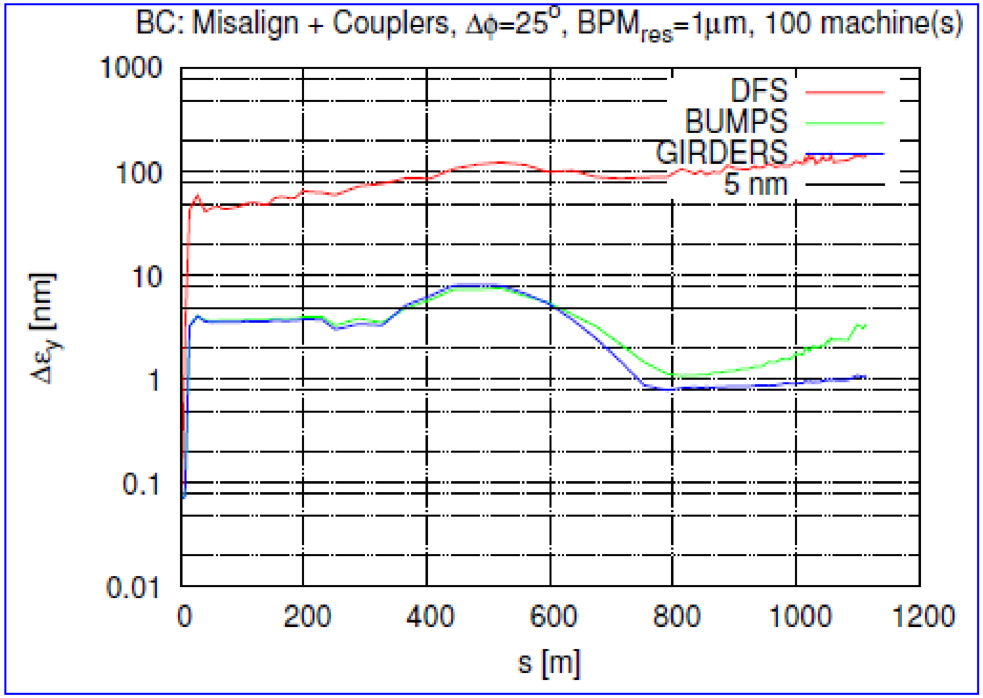
No acceleration Acceleration



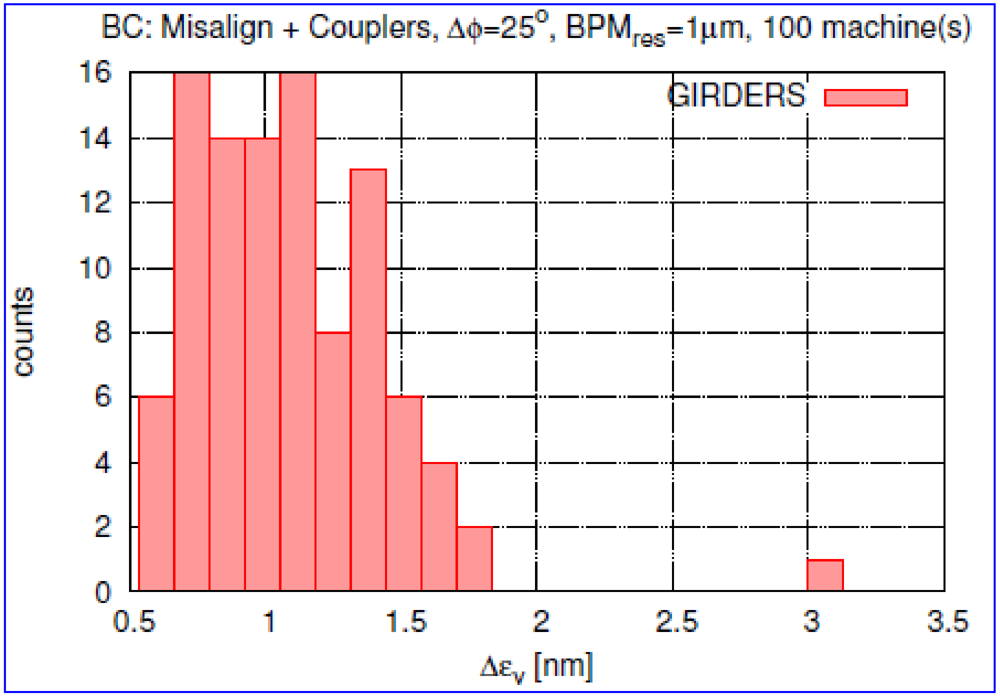
Emittance oscillations

2-stage Bunch Compressor

Correction: 1:1 + DFS + Dispersion Bumps + Girder Optimization



Emittance growth along the line.



Histogram of the final emittance for 1000 seeds

- ➔Minimum of the emittance is at ω= 2048 (weight in DFS)
- ➔Average of final vertical emittance growth is 1.09 nm (1.48 nm 90% c.l.)

Summary Tables for the Bunch Compressors

Region	Errors	Emittance Increase (nm)		Correction
		average	90% CL	
BC1+BC2	X/Y/X'/Y' Offsets	0.98	1.6	DFS + knobs + Girders
	+ Quad Strength	-	-	DFS + knobs + Girders
BC1+BC2 w/Couplers	X/Y/X'/Y' Offsets	1.09	1.48	DFS + knobs + Girders
	+ Quad Strength	-	-	DFS + knobs + Girders
BC1S w/Couplers	X/Y/X'/Y' Offsets	2.3	3.0	DFS + knobs + Girders
	+ Quad Strength	-	-	DFS + knobs + Girders

Previous studies

P. Tenenbaum
SLAC-TN-07-004
February 27, 2007

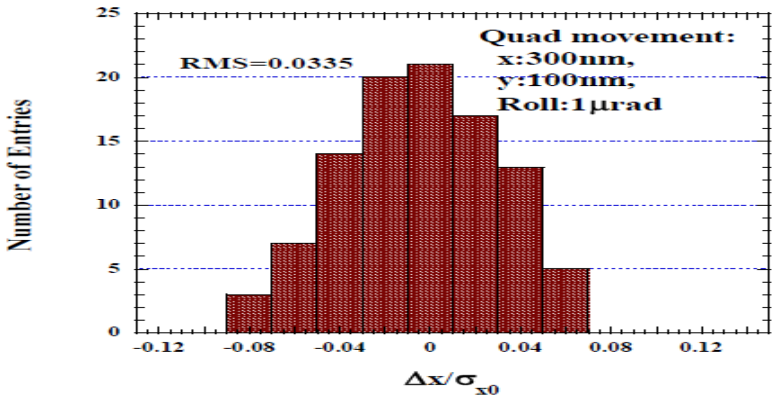
Table 5: Summary of results from [1] and this study. All studies use KM steering as a first step.

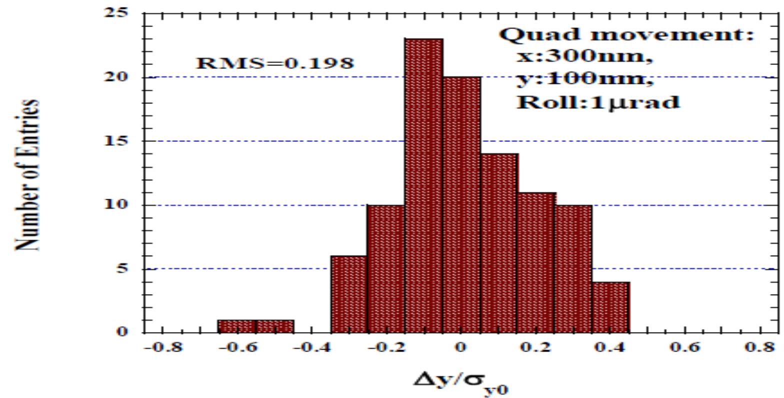
Quad Offset (μm)	BPM Offset (μm)	Cavity Pitch (μrad)	Knobs	Mean growth (nm)		90% CL Growth (nm)	
				Old	New	Old	New
150	7	0	None	6.8	3.6	15.1	7.1
150	7	0	BC1	2.1	1.5	4.7	3.3
150	7	0	All	–	1.2	–	2.4
150	7	300	BC1	9.2	4.9	17.6	9.5
150	7	300	All	–	3.9	–	7.5

[1] K. Kubo, "Bunch Compressor KM steering – dispersion bump simulation – Vertical emittance dilution," presented at the 2007 EuroTeV / LET Meeting, Daresbury, UK (2007).
[2] P. Tenenbaum, "Application of Kick Minimization to the RTML 'Front End'," SLAC-TN-07-002 (2007).

Dynamics effects in Return Line 12km (K.Kubo, 2006)

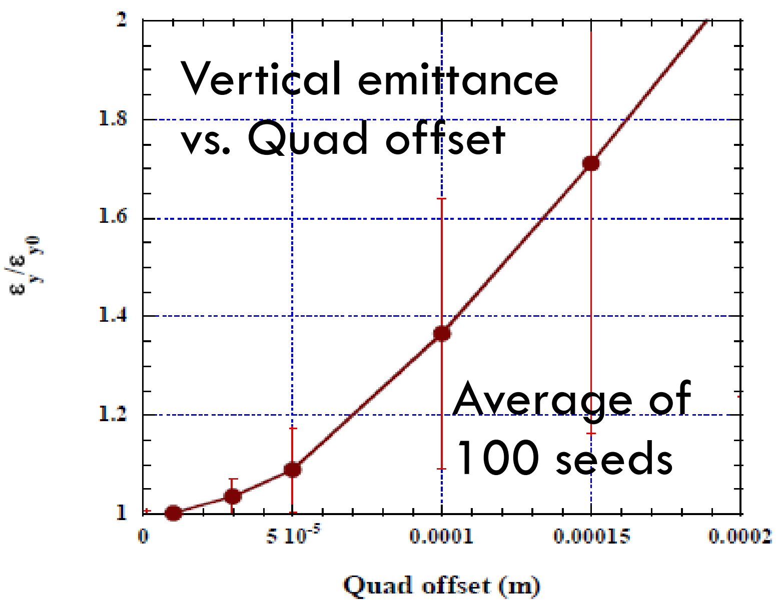
1. Fast Beam center position jitter due to quad motion (No corrections:))





- 100 nm RMS quad jitter will cause beam position jitter about 0.2 σ which will be tolerable
- Note that emittance increase due to this level of movements will not be signifcint.

2. Slow quad jitter (<0.1Hz) Emittance increase due to Quad misalignment with 1-to-1 corr.



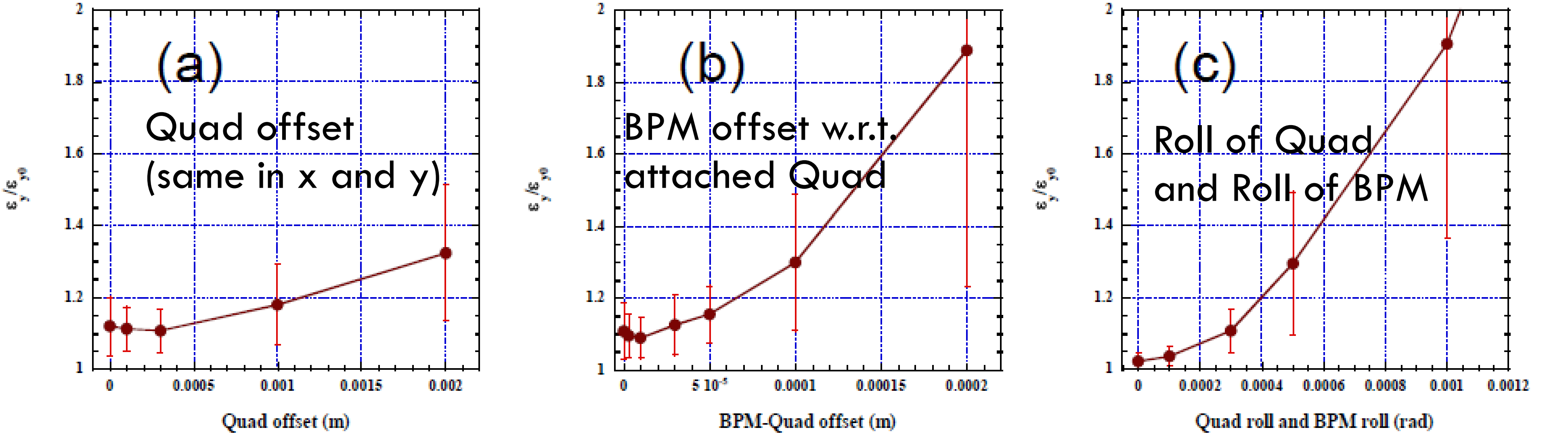
30 µm (σ_E=0.15%) quad offset increases emittance by 0.75%.

Simulated done for 0.3% beam energy spread. For nominal 0.15% increase is down by 4:

BPM is attached and perfectly aligned w.r.t. every quad.

Use Kick-minimization (KM)

standard” errors: Quad offset 300 µm, roll 300 µrad, BPM-Quad offset 30 µm)



- 300 µm RMS Quad offset and 30 µm RMS BPM-Quad relative offset error will be tolerable, using “Kick Minimization” → emittance increase less than 0.75%.
- 300 µrad Quad roll will increase emittance about 2.5%. (KM does not correct x-y coupling, need skew quads)

CONCLUSION

The long low emittance transport will not be a serious problem.

Summary of Emittance Growth in RTML

Region	Errors	Emittance Increase (nm) average	Emittance Increase (nm) 90% CL	Correction
Escalator + Getaway + RL	X/Y Offsets	0.48	0.52	KM + knobs + CC
	+ Quad Strength	0.68	1.25	KM + knobs + CC
	+ Quad/Sbend Roll	1.87	3.23	KM + knobs + CC
Turnaround + Spin Rotator (OFF)	X/Y Offsets	2.26	5.33	KM + knobs
	+ Quad/Sbend Strength	3.69	8.12	KM + knobs
	+ Quad/Sbend Roll	6.11	12.73	KM + knobs
Turnaround + Spin Rotator (ON)	X/Y Offsets	2.14	4.83	KM + knobs
	+ Quad/Sbend Strength	4.63	9.42	KM + knobs
	+ Quad/Sbend Roll	6.86	13.66	KM + knobs
Entire "Front End"	X/Y Offsets	1.06	1.58	KM + knobs + CC
	+ Quad/Sbend Strength	2.01	3.51	KM + knobs + CC
	+ Quad/Sbend Roll	5.36	9.94	KM + knobs + CC

BC1+BC2 w/Couplers	X/Y/X'/Y' Offsets	1.09	1.48	DFS + knobs + Girders
	+ Quad Strength	-	-	DFS + knobs + Girders

Total growth vertical emittance: ~6nm RMS (~11nm 90% c.l.)

- Emittance growth is a bit larger (RDR budget 4nm), need revision (≤10nm?)
- Need further studies to reach goal for emittance growth
- Cross-checking with different codes (important)
- Jitter in long Return line is not a serious problem.

Stray magnetic fields

RTML requirement for high frequency stray magnetic fields: B < 2 nT (studied by K.Kubo, 2006)

Magnetic field examples

– Commercial SC solenoid – 10 Tesla (1 e+1)
– Earth magnetic field – 50 micro-Tesla (5 e-5)
– Cell phone – 100 nano-Tesla (1 e-7)

Frequency dependence

– < 0.1 Hz (can be compensated by control system)
– > 100 kHz (attenuated in the structure)

Classification (following F.R.T.)

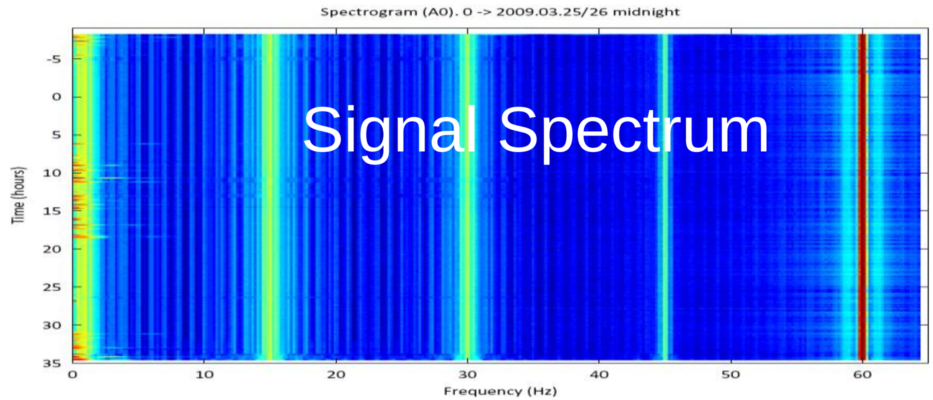
– 60 Hz and its harmonics (near-coherent with 5-Hz pulsing)
– Fields from RF systems (coherent with 5-Hz pulsing)
– Others (non-RF technical sources) (uncorrelated with pulses)

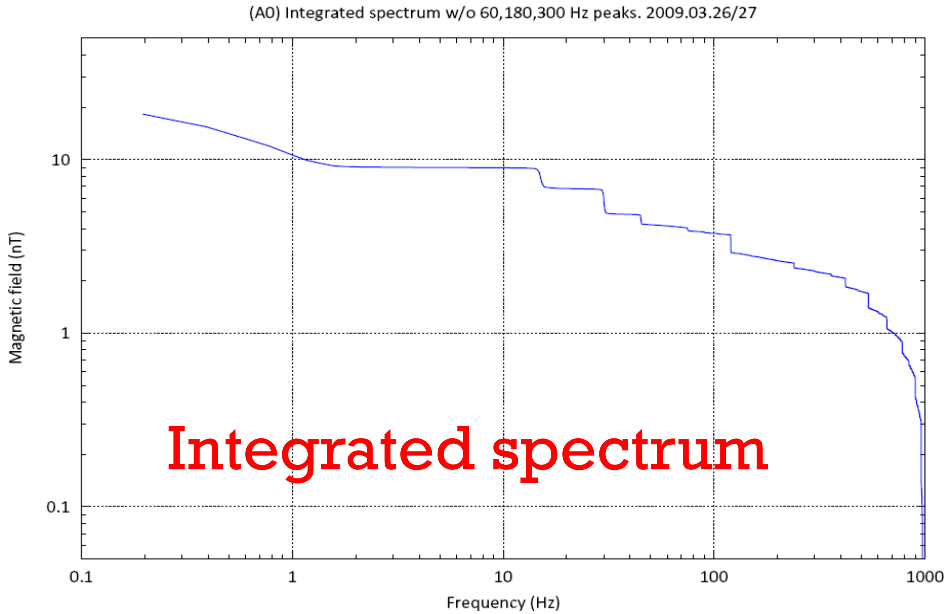
Previous work on Stray Field measurements (Conclusion : *we are mostly OK)*

- SLAC, "Sensitivity to Nano-Tesla Scale Stray Magnetic Fields", SLAC LCC Note-0140 (June 7, 2004) → Data from SLC End station B.
- Fermilab studies at A0 *(D.Sergatskov, 2006)*
- DESY and CERN

FNAL Magnetic Stray Fields Studies

- RTML requirement for stray fields in Return Line < 2nT (freq>1Hz)
- SLAC measurements (at Station A) are promising (~2nT)
- Need more studies for different sites. Stability of 60Hz is an issue





- Total integrated field ~9 nT (>1Hz)
- Only 60/180/300 Hz peaks are removed
- 15, 30 and 45 Hz (Linac & Booster) ~ 5nT
- Other harmonics 120/180 /240Hz) ~ 2nT
- All the rest ~ 2 nT

Other annoying effects

There are a number of collective effects which are important in the RTML, and a few which are utterly unimportant.

Ion Instability: The fast-ion instability is important in the electron Return line, and sets the limit on the tolerable vacuum in that system. 20 nTorr produce ~3% beam jitter.

Electron Cloud: this effect is completely irrelevant in the RTML. The electrons dissipate completely in ~100ns between bunches.

Collimator Wakefield: A modest longitudinal taper should reduce kick from wakes to tolerable level to reduce beam jitter. Effect estimated analiyically. Effect of resistive wake is also important.

Vacuum Chamber Resistive Wall Wakefields: kicks scale as the inverse-cube of the chamber size and inverse-square-root of the conductivity. Looks we are OK with RTML.

Space Charge: The vertical-plane incoherent space charge tune spread is about 0.15 for a beam with the parameters of the RTML in total beamline. it might be a problem for global emittance correction techniques, or for the dispersion matching and suppression in the Return line. Looks OK (P.Spentzouris studies, not reported publically)

Work still to be done

- We are way past the 4 nm budget!
  - **But we really haven't worked on it much yet and have more things to try.**
- Upstream of the Bunch compressor no serious problems apparent
  - **Well, provided stray fields in return line are no greater than 2 nTesla**
  - **...and we can measure coupling with the wire scanners.**
  - **Vertically displaced bends?**
- Need to address cavity pitches in Bunch Compressor.
  - **DFS may work if tweaked for BC #2 but BC #1 cannot be DF steered.**
  - **There's only three cryomodules in BC #1 perhaps we can treat these with extra care when aligning, or place them on movers.**
- **Phase errors/stability in BC**
- **Dynamic effects and Feedback??????**

Conclusion

- New TDR lattice for RTML beam-line is now available for LET studies (matched, Includes all features, etc.).
- Performances of the entire RTML have been evaluated, and resulted satisfactory. Budget for vertical emittance growth in RTML is ~8 nm. Goal is not achieved yet, but close
- Dynamics effects are studied (magnet strength and alignment jitter, magnetic stray fields, …). Effect of other was estimated..
- Start to end simulation are needed
- Problem is available resources. Hope a new breath in Japan ILC.

Thank you for your attention.