CICL RTML Beam-based Alignment

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Introduction

Previous Results

Integrate the RTML

Beam-based Alignment

Conclusion & Plan

CLIC RTML

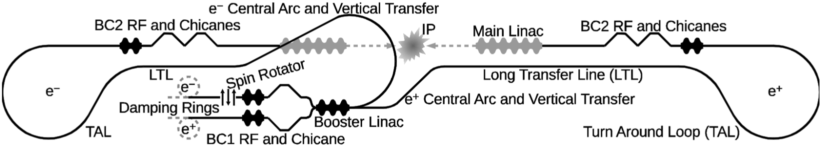


Figure: Sketch of RTML

- RTML connects the damping rings and the main linac
- Match beam properties, like bunch length and energy
- Two RTMLs with total length of approximately 27 km for each

Table: Beam properties at the start and end of the RTML for 3 TeV machine

Properties [unites]		Start	End
Particle energy [GeV]	E_0	2.86	9
r.m.s. bunch length [μm]	σ_{s}	1800	44
r.m.s energy spread [%]	σ_{E}	0.12	1.7
Normalized emittance [nm rad]	$\epsilon_{\mathrm{n,x}}$	500	600
	$\epsilon_{\mathrm{n,y}}$	5	10

We focus on the electron part.

Static Misalignment

Table: The effect of mis-alignment on different magnets

	position offset	angle offset	roll
Dipole	ok	Coupling	Coupling
Quarupole	Dispersion	Dispersion	Coupling
Sextupole	Quadrupole, Coupling	Coupling	Couling ...

The effect of BPM

- Position offset: Wrong position measurement. We need DFS
- Resolution: Make DFS worse

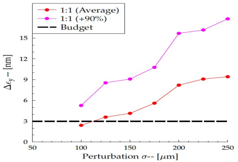
The vertical emittance budget for static misalignment is $\epsilon_y < 8\ \mathrm{nm} \cdot \mathrm{rad}$

- $5\ \mathrm{nm} \cdot \mathrm{rad}$ - the initial emittance
- $1\ \mathrm{nm} \cdot \mathrm{rad}$ - lattice design emittance growth
- $2\ \mathrm{nm} \cdot \mathrm{rad}$ - static alignment emittance growth

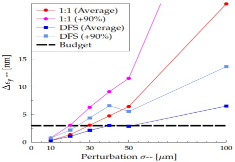
We focus on the quadrupole position offset

Previous Result - Vertical Emittance

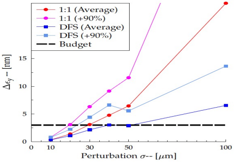
SR



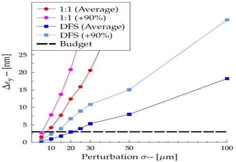
BC1



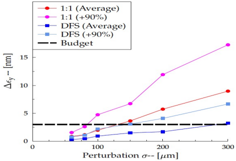
BOO



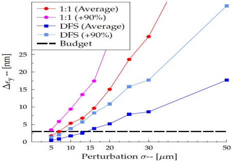
CA



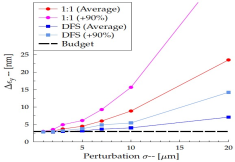
LTL



TAL



BC2



- Ideal beam
- Quadrupoles and BPMs are misaligned

From Thibaut Lienart

Previous Result - Vertical Emittance

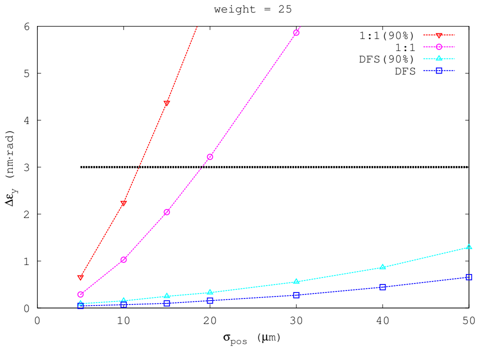


Figure: Dedicated BBA study on TAL

- Ideal beam
- Quadrupoles and BPMs are misaligned
- Use test beam with different energy

These results allow us to the whole RTML BBA.

Four parts RTML setup

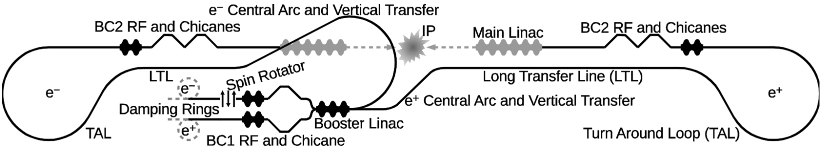


Figure: Sketch of RTML

Before, RTML are divided into four parts due to RF wakefield setup. Each part begin with RF cavity: SR → BC1 → Booster, CA, VT, LTL, TAL → BC2.

It is difficult to use this setup to do the DFS.

So we need to integrate the RTML to one beamline.

Integrate RTML to one beamline

Difficulities:

- In the four part setup, beam can be injected four times. Wakefields are setup dynamically when inject the beam.
- Now we can only inject beam once, the wakefield must be setup statically.

Solution: Use Spline method to setup the wakefield.

- Calculated the wakefield and save them to disk file
- Create the Spline for transverse and longitudinal plane respectively
- Create the short range wakefield
- Assign the short range wakefield to RF cavity.

BBA on the whole RTML

Table: Misalignment level (μm)

	Quadrupole offset σ_{pos}	BPM offset σ_{pos}	BPM resolution σ_{res}
SR	10	10	0.1
BC1	30	30	1
BOO	30	30	1
CA	30	30	1
VT	30	30	1
TAL	30	30	1
BC2	10	10	0.1

Dipole correctors are added to each quadrupoles.

One to one and DFS corrections are applied.

For the DFS, we need to know the dispersion response property.

- Scale the lattice - equivalent to use test beam with different energy
- Modify the gradient

Spin Rotator

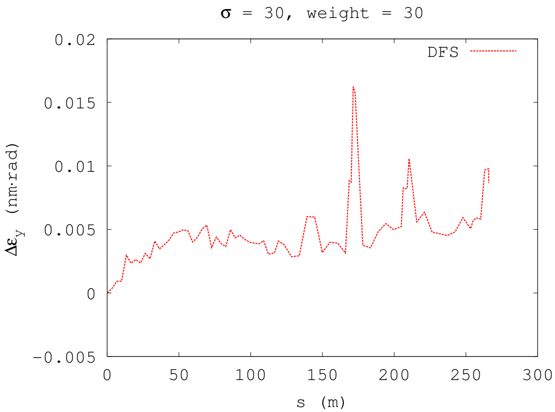


Figure: Vertical emittance growth along lattice

The emittance growth is very small. Actually even when $\sigma_{\rm pos} = 200\mu{\rm m}$, DFS still works well.

But a problem is hidden by the small emittance growth.

Spin Rotator - z corrleation

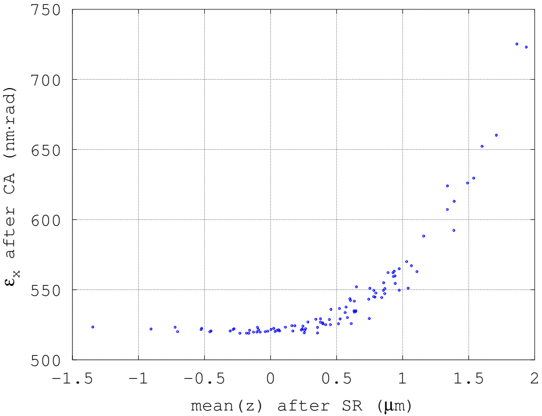


Figure: Average Z vs. emittance for 100 machines

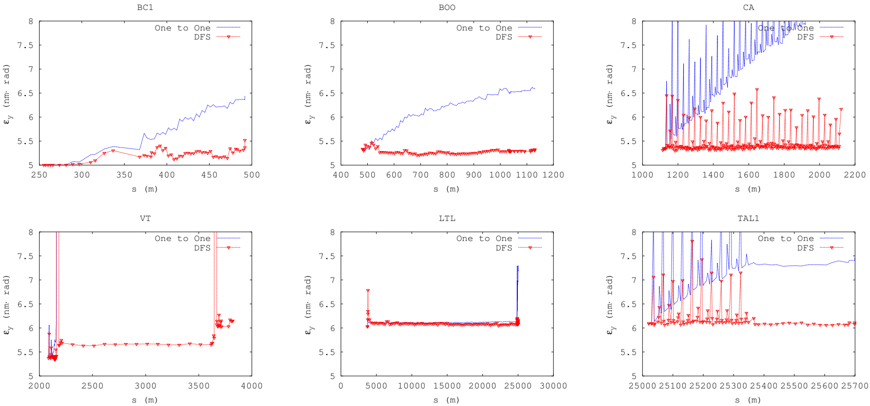
The average Z in perfect lattice is very close to 0.

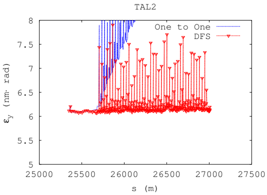
After BBA, average Z become not 0.

There is strong correlation between the average Z after SR and the emittance after CA.

We can not correct the Z now. So we use $\sigma_{\mathrm{pos}} = 10\mu\mathrm{m}$ and $\sigma_{\mathrm{res}} = 0.1\mu\mathrm{m}$ for SR.

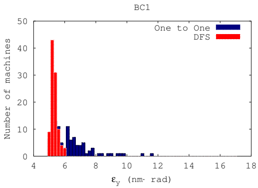
BC1, BOO, CA, VT, LTL and TAL - Emittance along lattice

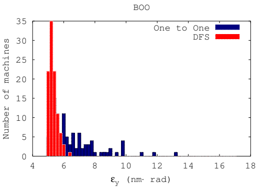


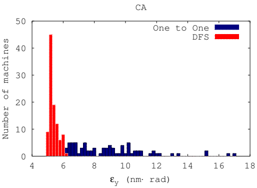


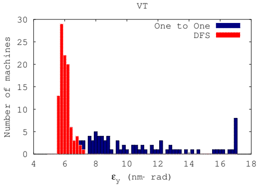
- The vertical emittance growth is almost from BC1 and Vertical Transfer Line.
- Average emittance is $\epsilon_x = 550$ and $\epsilon_y = 6.1 \text{ nm} \cdot \text{rad}$

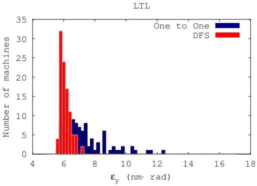
BC1, BOO, CA, VT, LTL and TAL - Emittance distribution

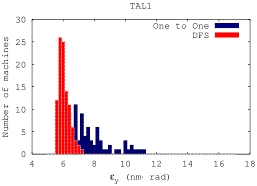


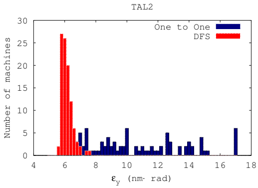












- After TAL, the vertical emittance for all 100 machine are below the budget.

BC2

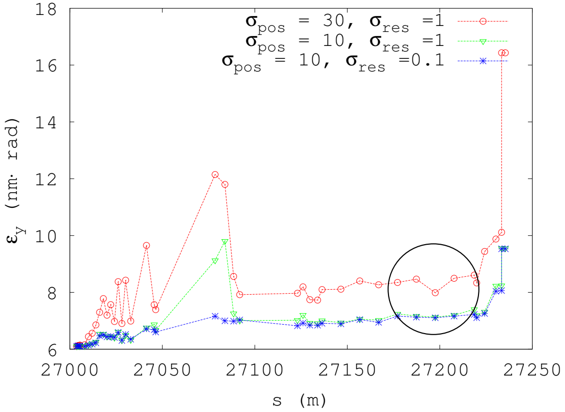


Figure: Average vertical emittance along lattice

- BC2 is very sensitive to the quadrupole mis-alignment
  - SR → TAL, 5.0 → 6.1
  - BC2, 6.1 → 8.4
- The RF cavities are 12 GHz cavities, which introduce strong wakefield.
  - The prealignment must be similar to the main linac's one
  - $\sigma_{\rm pos} = 10$ and $\sigma_{\rm res} = 0.1\ \mu$m is used

BC2 - Parameters optimize

Parameter in OTO, DFS are scanned.

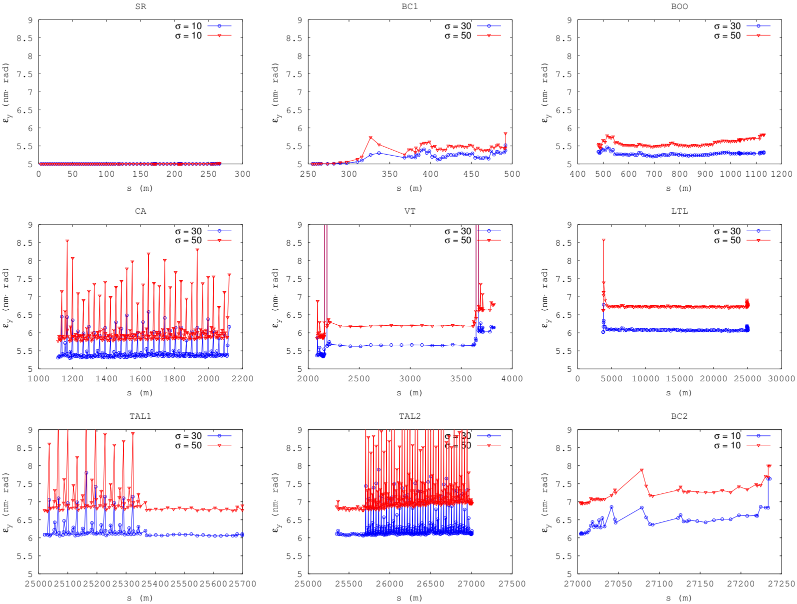
- β_0, control the fluctuation of corrector strength in OTO
- β_1, control the fluctuation of corrector strength in DFS
- ω, the weight of DFS

β_0 and β_1 are scanned in 2D region $[1:7] \times [1:7]$ with integer values.

ω is scanned in the region [20:140] with step 10.

The quality of BBA in BC2 also rely on how to split the correction bins.

Final Result - $\sigma = 30$ and 50 μm



Angle offset

Horizontal and vertical offset in angle are added. σ is 10 $\mu\mathrm{rad}$ for SR and BC2, σ is 30 $\mu\mathrm{rad}$ for other sectors.

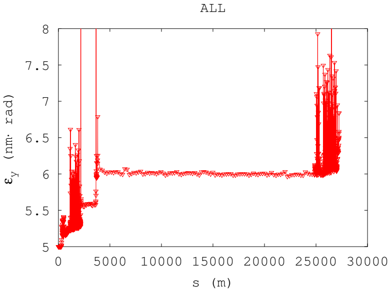


Figure: Average Vertical emittance along the lattice

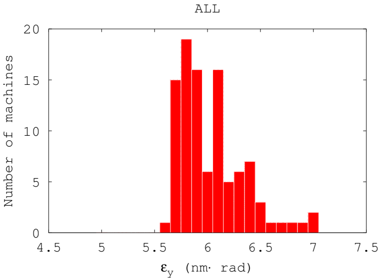


Figure: Vertical emittance distribution

Quadrupole Roll

The roll errors are added to quadrupoles.. σ is 10 μrad for SR and BC2, σ is 30 μrad for other sectors.

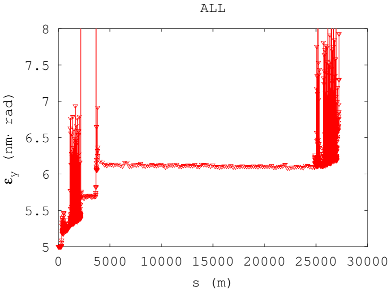


Figure: Average Vertical emittance along the lattice

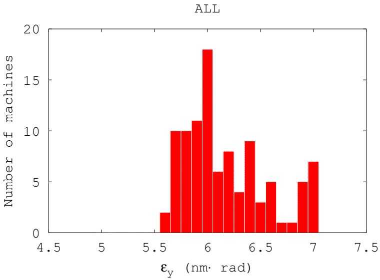


Figure: Vertical emittance distribution

Dipole Roll

The roll errors are added to dipoles.. σ is 10 $\mu\mathrm{rad}$ for SR and BC2, σ is 30 $\mu\mathrm{rad}$ for other sectors.

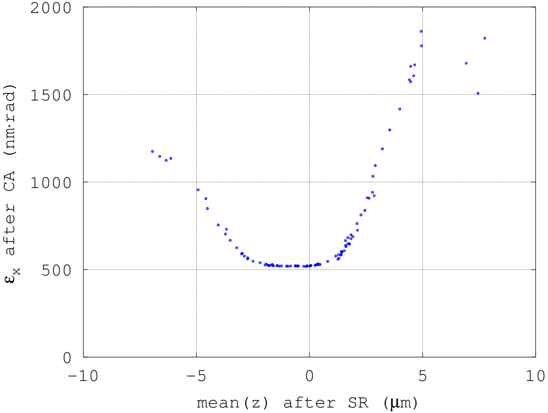


Figure: Average Z vs. emittance for 100 machines

The average Z offset after SR become more severe considering the dipole roll error.

The emittance growth is good without SR mis-alignment.

Sextupole offset

We try to add position offset to sextupoles. This make the beam become worse.

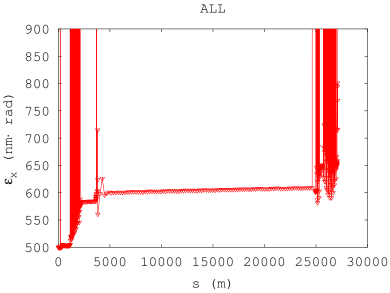


Figure: Average Horizontal emittance

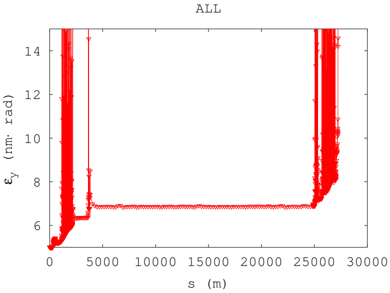


Figure: Average Vertical emittance

Both the horizontal and vertical emittance exceed the budget.

Conclusion & Plan

- We successfully applied the BBA on the whole CLIC RTML.

Table: The effect of mis-alignment on different magnets

	position offset	angle offset	roll
Dipole	OK	Coupling	Coupling
Quarupole	OK	OK	ok
Sextupole	Quadrupole, Coupling	Coupling	Couling ...

This shows that we need study to coupling correction next step.

- Correct the SR z offset (We tried this several days, but there is no solution now.)
- Rotate the beam at some locations.
- Add skew quadrupole sections.