LCWS2024 International Workshop on Future Linear Colliders

Beam Dynamics Summary

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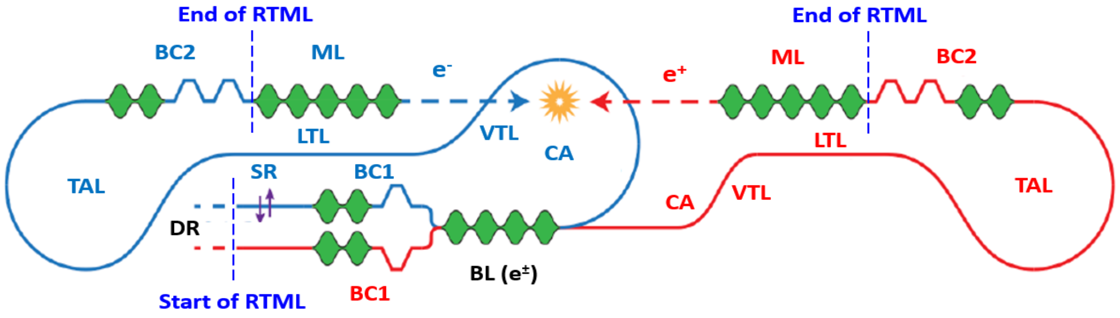
CLIC Updates /I

(Yongke Zhao, CERN)

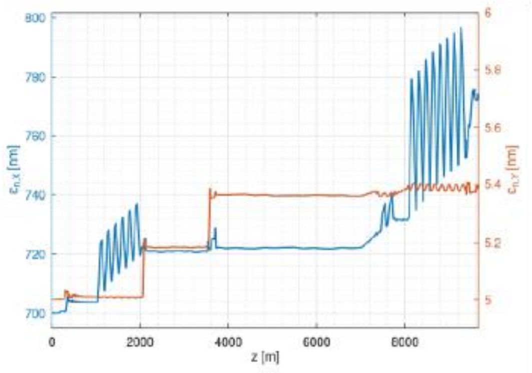


Rings to Main Linac:

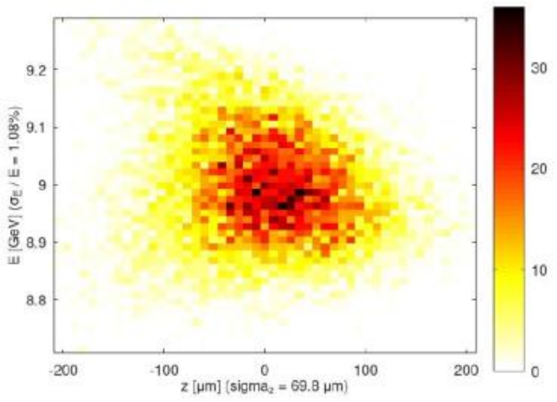
- **Optimization of BC2 for power consumption and cost**
- **Consolidation of the tuning procedures**

Normalized emittance budgets	$\epsilon_{n,x}$	$\epsilon_{n,y}$
Without imperfections	< 800	< 6
With static imperfections	< 820	< 8
With dynamic imperfections	< 850	< 10

- 99% good machines (required: ≥ 90%)

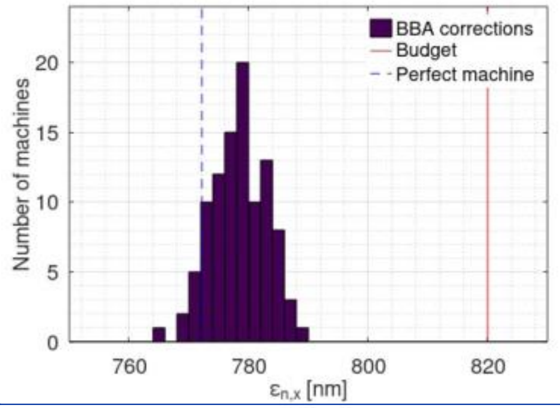


Emittance growth along RTML

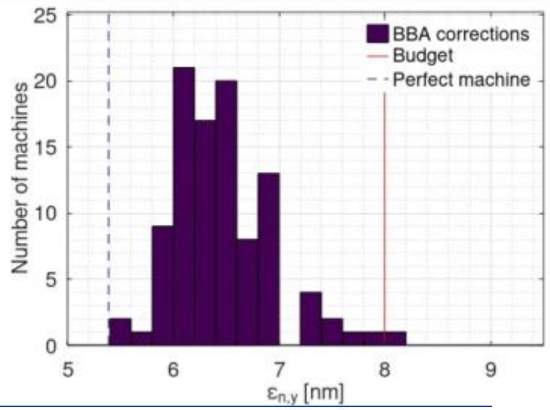


Longitudinal phase space at the end

100% good in X



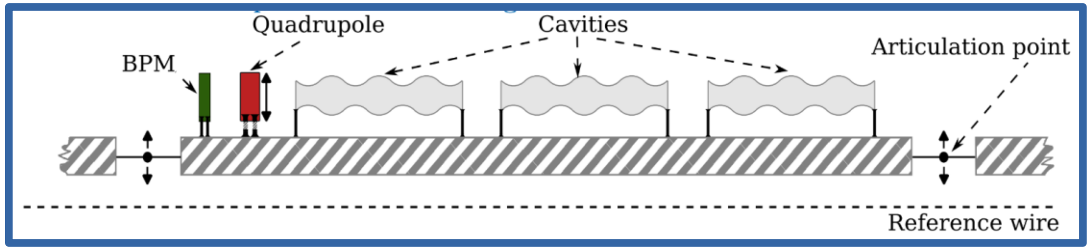
99% good in Y



Such an increase in performance allows for the redefinition of emittance growth budgets and, ultimately, the production of more integrated luminosity.

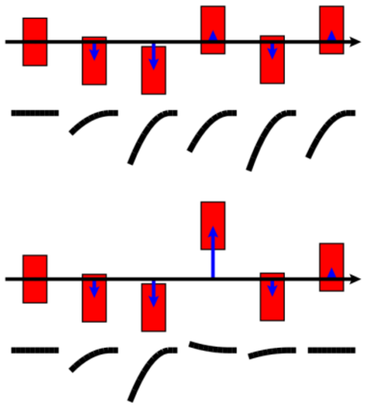
CLIC Updates /II

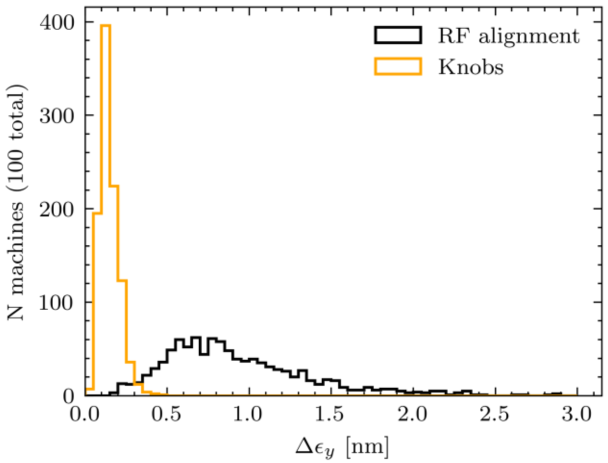
(Andrii Pastushenko, CERN)



Main Linac: tight emittance growth budget: **5 nm** for **static imperfections** and **5 nm** for **dynamic imperfections**

- New optimized **emittance tuning bumps**
- **Search for the optimal setup** of the quads/girders **using** Forward Feature Selection (FFS) in **Tensorflow**.

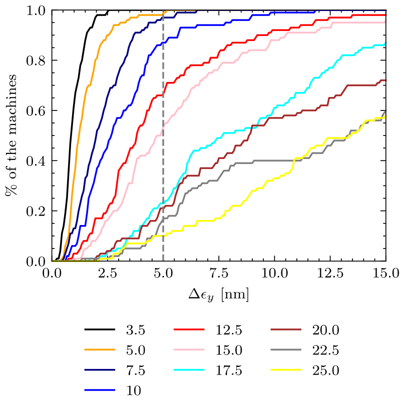




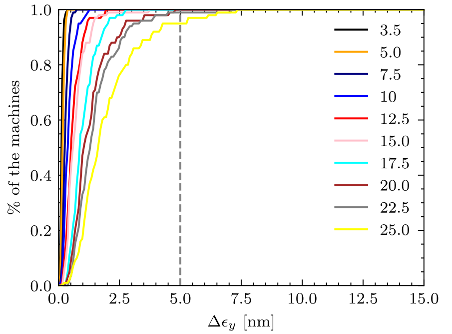
100% of the machines have emittance growth < 0.5 nm.

Wakefield monitors

Performance of the knobs when the RF alignment is not perfect (accuracy > 3.5 μm)



The budget is not respected for **> ~7 μm**



All the machines respect the budget for **up to 25 μm.**

CLIC Updates /III

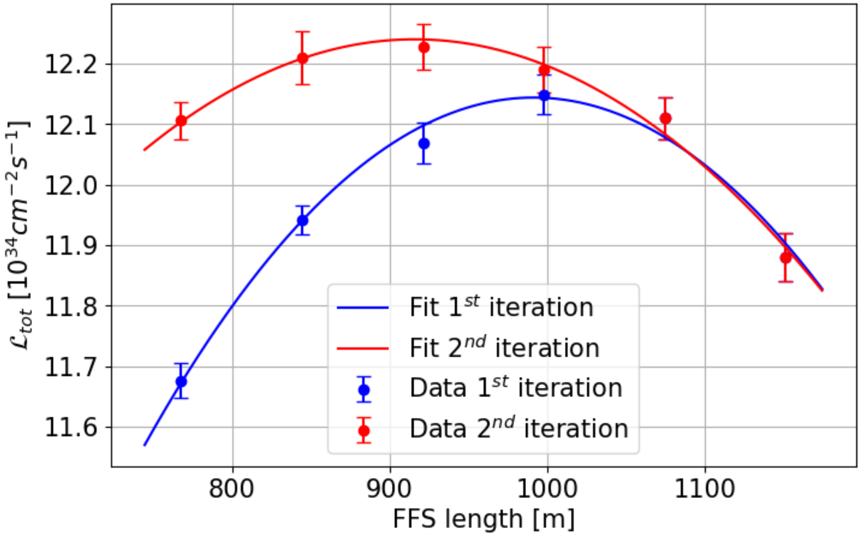
(Enrico Manosperti, CERN)

Exploring the possibility of going to even **higher energies than 3 TeV** in c.o.m.

Beam Delivery System at **7 TeV in the center of mass.**

Optimization in four successive steps:

- Scaling the BDS for 3 TeV, $\mathcal{L}_{\rm tot} = 0.76 \cdot 10^{34} \rm cm^{-2} s^{-1}$
- Beam size optimization
- β_y^* scan
- Dispersion optimization



$$\mathcal{L}_{tot} = (12.23 \pm 0.04) \cdot 10^{34} cm^{-2} s^{-1}$$

- **FFS final length = 921 m**

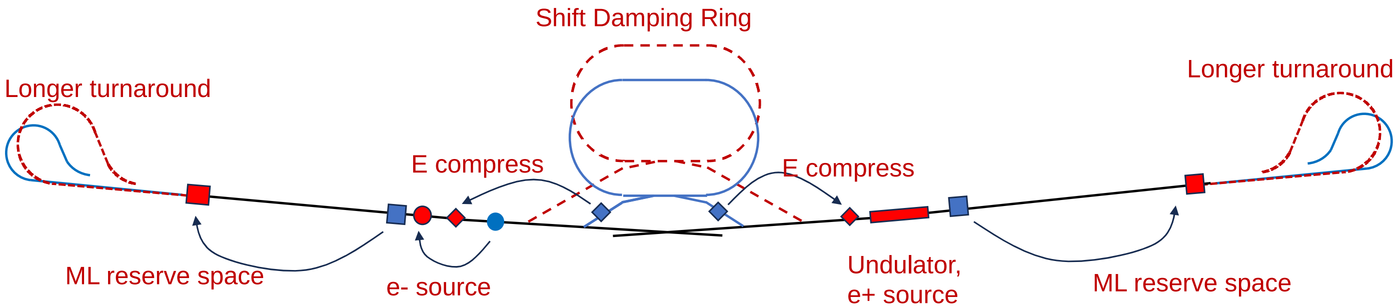
ILC Updates

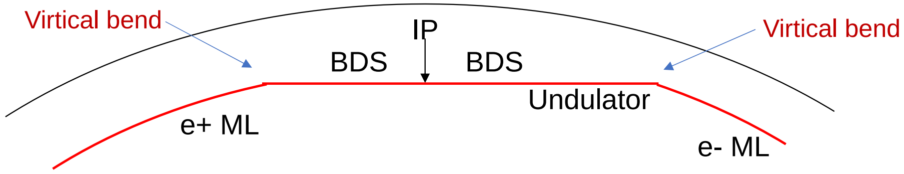
(Kiyoshi Kubo, KEK)

Consolidation of the TDR Lattices

- **Reporting the activities of the ILC Beamline Related to CFS (2019~)**
  - Y. Enomoto, H. Hayano, K. Kubo, T. Okugi, T. Sanuki, N. Terunuma, K. Yokoya

- Considerations of CFS & beam dynamics
- Main Linac reserved space moved
- Longer turnarounds optimized for 250 GeV
- Added “timing adjusting” chicanes
- Undulator region
- Positron source beamline
- Electron source beamline





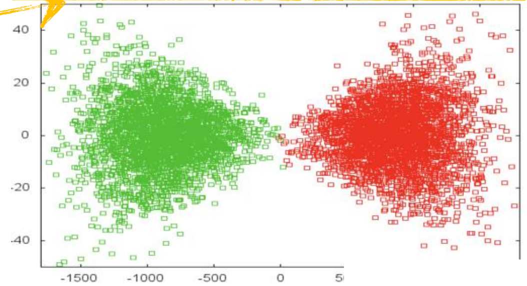
C^3 Luminosity optimization

(Dimitris Ntounis, Stanford University & SLAC)

Quantity	CLIC	ILC-250	ILC-500	C^3-250	C^3-550
$\frac{4\pi}{n_b f_r \gamma} L_{\text{literature}}$ ($\times 10^{29}$ m^{-2})	3.2069	10.572	7.0479	4.3453	4.4107
$\langle \Upsilon \rangle_{\text{literature}}$	0.17	0.028	0.062	0.065	0.21
$\frac{4\pi}{n_b f_r \gamma} L_{\text{GP}}$ ($\times 10^{29}$ m^{-2})	5.0557	12.65	9.993	5.9109	6.6508
$\langle \Upsilon \rangle_{\text{GP}}$	0.12266	0.02801	0.02961	0.06501	0.08825
$\frac{4\pi}{n_b f_r \gamma} L_{\text{simulations}}$ ($\times 10^{29}$ m^{-2})	4.9582	10.862	9.447	5.6218	5.7022
Overall gain (%)	35.3	2.7	25.4	22.7	22.6

- Instantaneous Luminosity*: $\mathcal{L}_{\text{inst}} = H_D \frac{N_e^2 n_b f_r}{4\pi \sigma_x^* \sigma_y^*} = H_D \mathcal{L}_{\text{geom}}$

Luminosity depends on strength of beam-beam interactions!

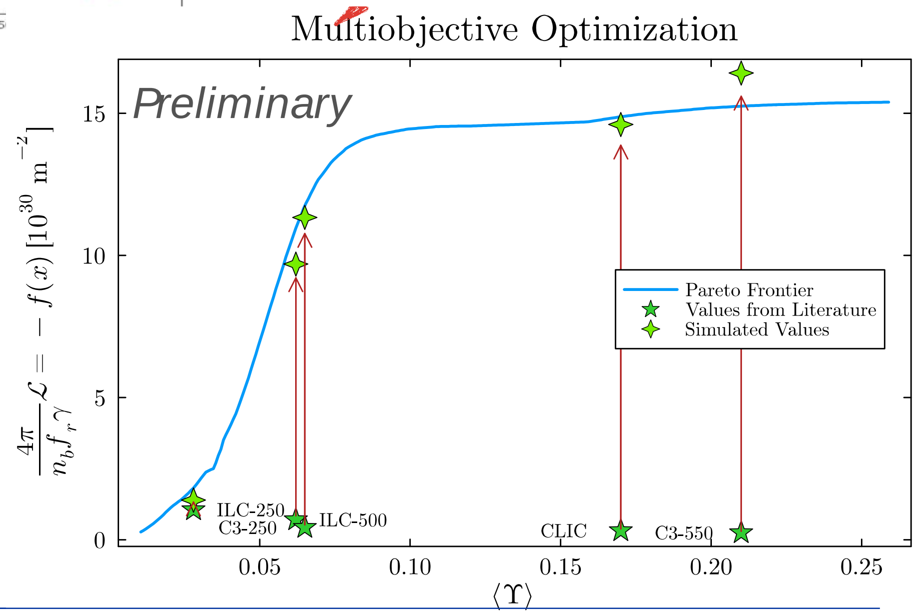


- N_e : # of particles/bunch
- n_b : # of bunches/bunch train
- f_r : train rep. rate
- $\sigma_{x,y}^*$:horizontal and vertical RMS beam sizes at the IP
- σ_z^*: bunch length
- H_D:enhancement factor that accounts for the effects of beam-beam interactions (~1.5-2.5).

$$\sigma_{x,y}^* = \sqrt{\frac{\epsilon_{x,y}^* \beta_{x,y}^*}{\gamma}}$$

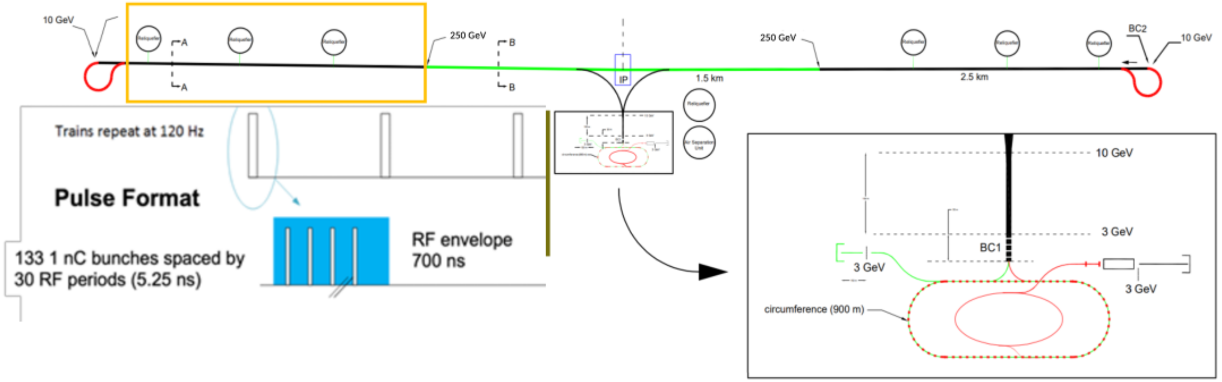
Surrogate model optimization

- We use a probabilistic surrogate model for $H_D = H_D(N_e, \epsilon_x^*, \epsilon_y^*, \beta_x^*, \beta_y^*, \sigma_z^*)$ trained on ~ $\mathcal{O}(10^4)$ GUINEA- PIG simulations, which we use for luminosity optimization leveraging:
  - efficient out-of-the-box optimizers,
  - no additional grid sampling
  - ability to impose constraints



C³ Main Linac

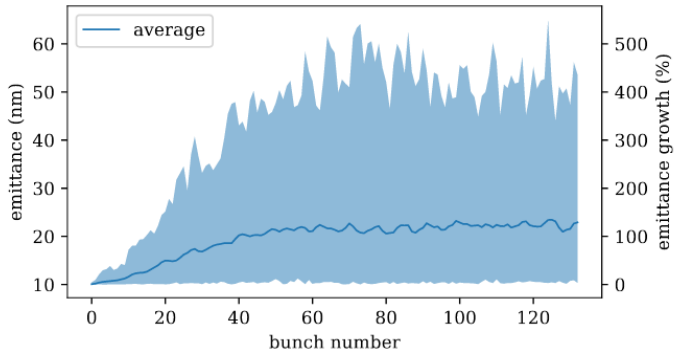
(Wei-Hou Tan, SLAC)

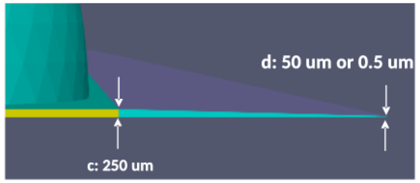


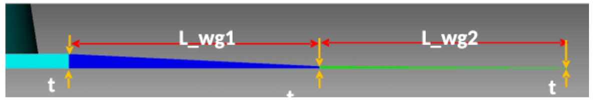
250 GeV beam dynamics studies

Studying the impact of long-range wakefields on the beam emittance due to bunch-to-bunch random jitter

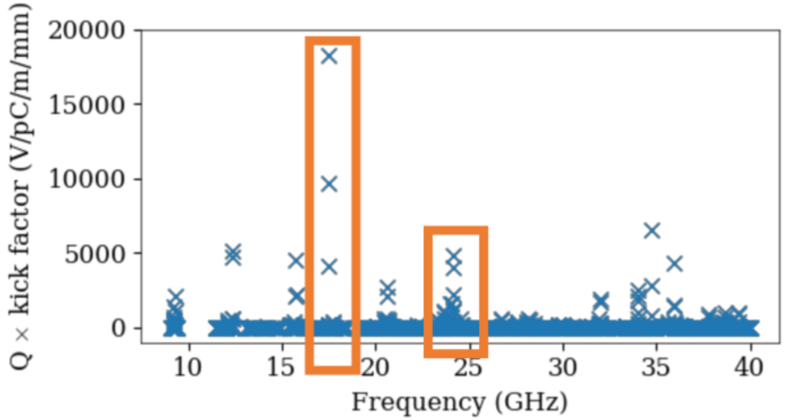
- Mitigation: damping
- Mitigation: detuning







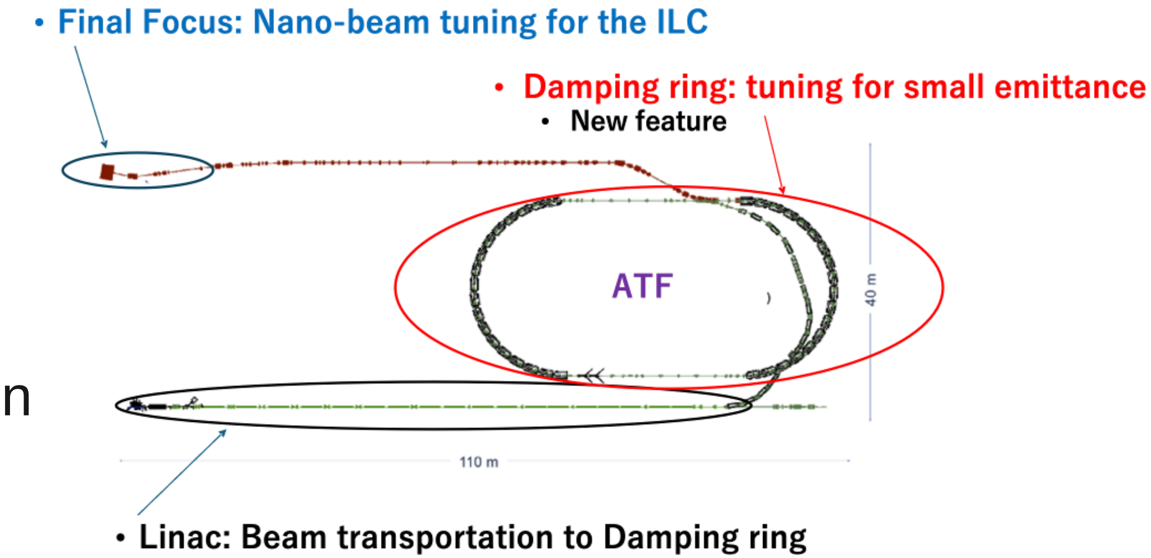
Parameter	Value
Cryocooled temperature	77 K
Length	8 km
Center of mass energy	250 GeV
Number of bunches	133
Charge per bunch	1 nC
Bunch spacing	5.25 ns (30 RF cycles)
Field gradient	70 MV/m



- **Identified frequency bands that need detuning**

Machine Learning at KEK

(Masakazu Kurata, KEK)



ATF2: Small beam

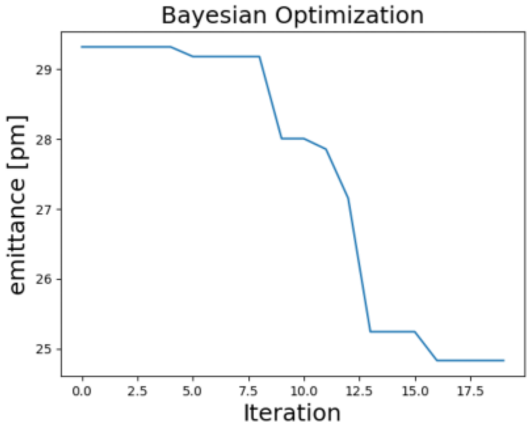
FFS: Chromaticity correction using 5 sextupole magn

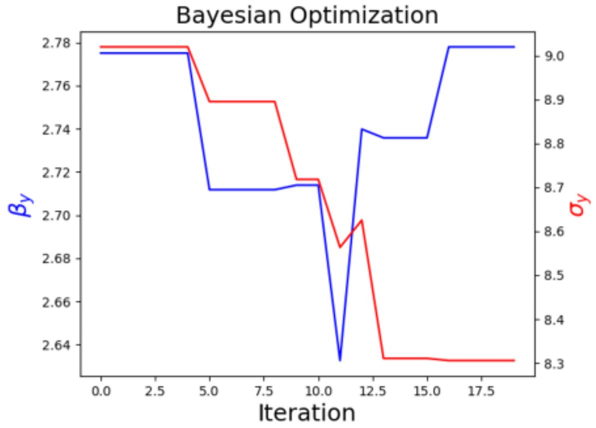
DR: optimization for smaller emittance

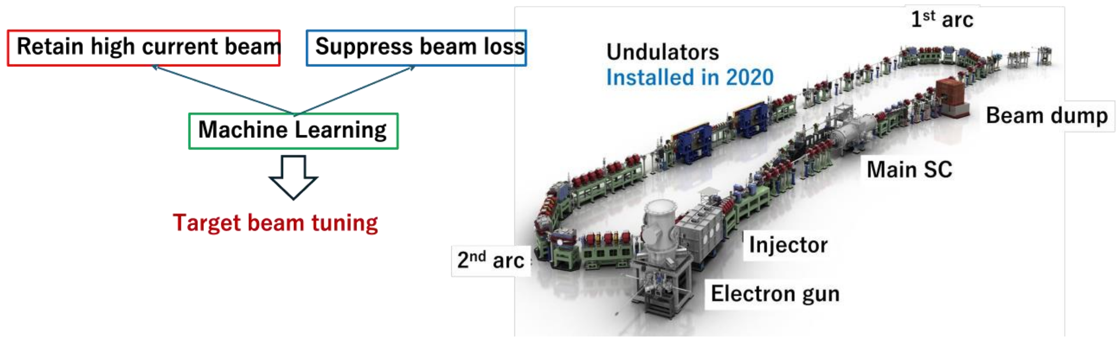
ML: small emittance

Measures in place for robust optimization

Main Linac







Compact ERL

Thank you for your attention.