Transverse Instabilities in HALHF Acceleration Stages

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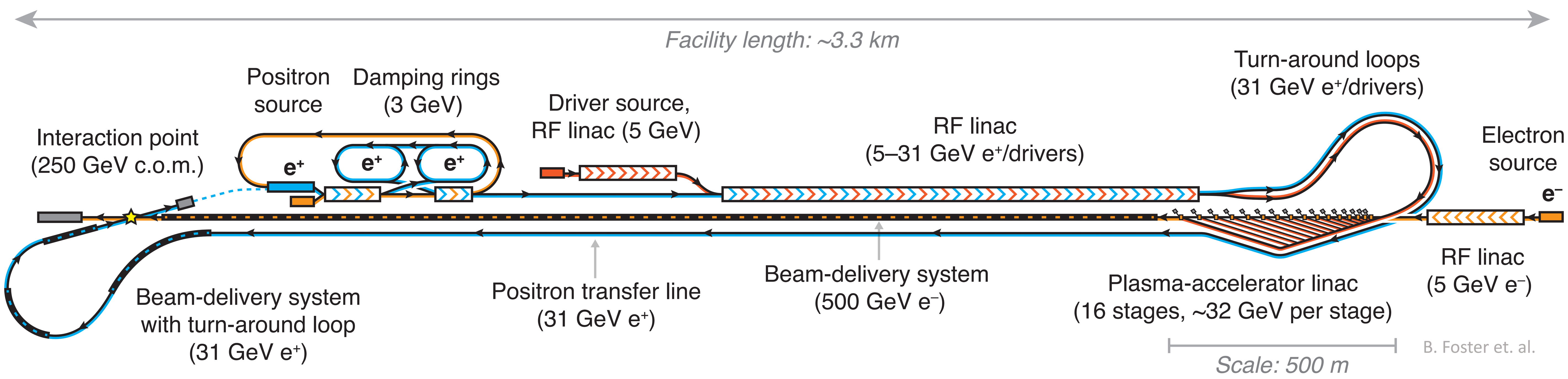


- Circumvent positron problem.
- Comparable luminosity and power to RF colliders.
- Significant cost savings.

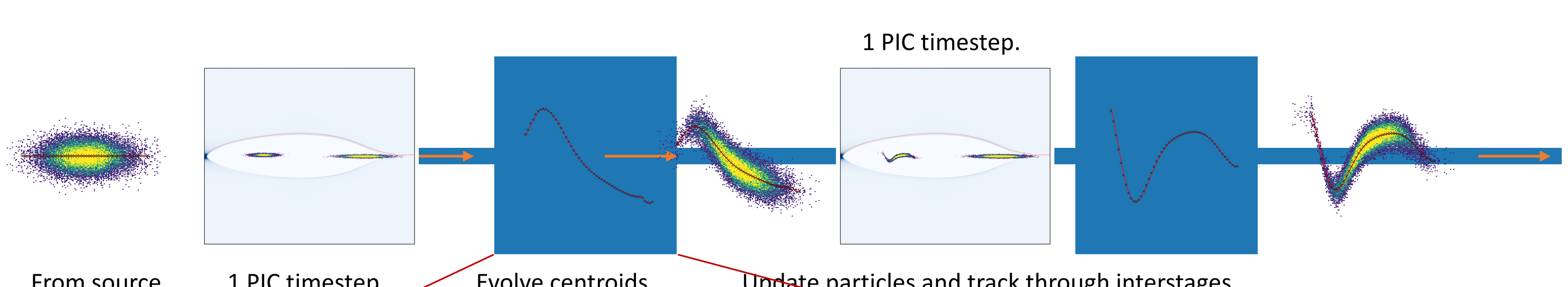
Introduction

A hybrid, asymmetric, linear Higgs factory based on plasma-wakefield and radio-frequency acceleration

B. Foster,[1,2,*] R. D'Arcy,[1,2] and C. A. Lindstrøm[3]

- High e^- and low e^+ energy to save cost on RF linac.
- Mitigate loss in efficiency of asymmetric energies by using large e^+ beam charge and low e^- beam charge.
- Asymmetric emittances (high e^- emittance).
- Need to include transverse instabilities.
- Currently studying effects of self-correction.

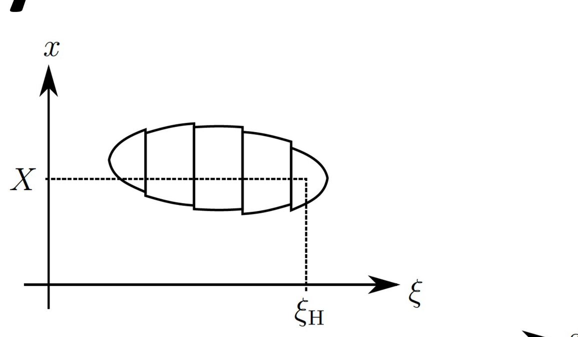
Methodology



Transverse wake instability model

$$W_\perp(\xi'-\xi) = \frac{2}{\pi\varepsilon_0}\frac{\xi'-\xi}{\left(r_b(\xi')+\alpha k_p^{-1}\right)^4}\Theta(\xi'-\xi)$$

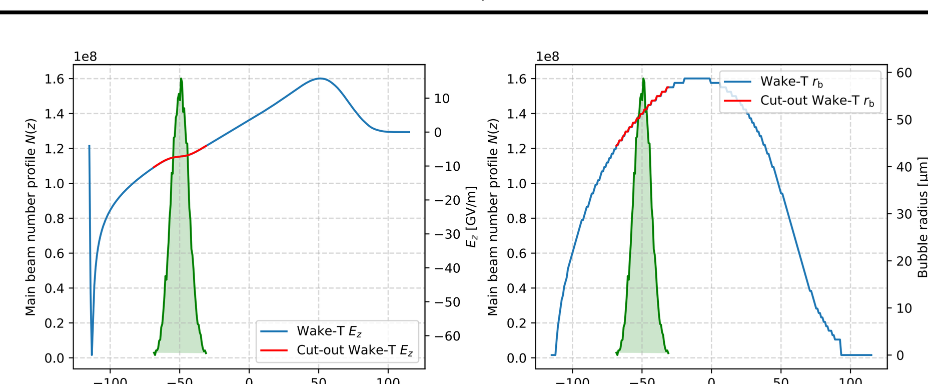
$$\mathcal{W}_\perp(\xi,s) = -e\int_{\xi_H}^{\xi} W_\perp(\xi'-\xi)\lambda(\xi')X(\xi',s)\mathrm{d}\xi'$$

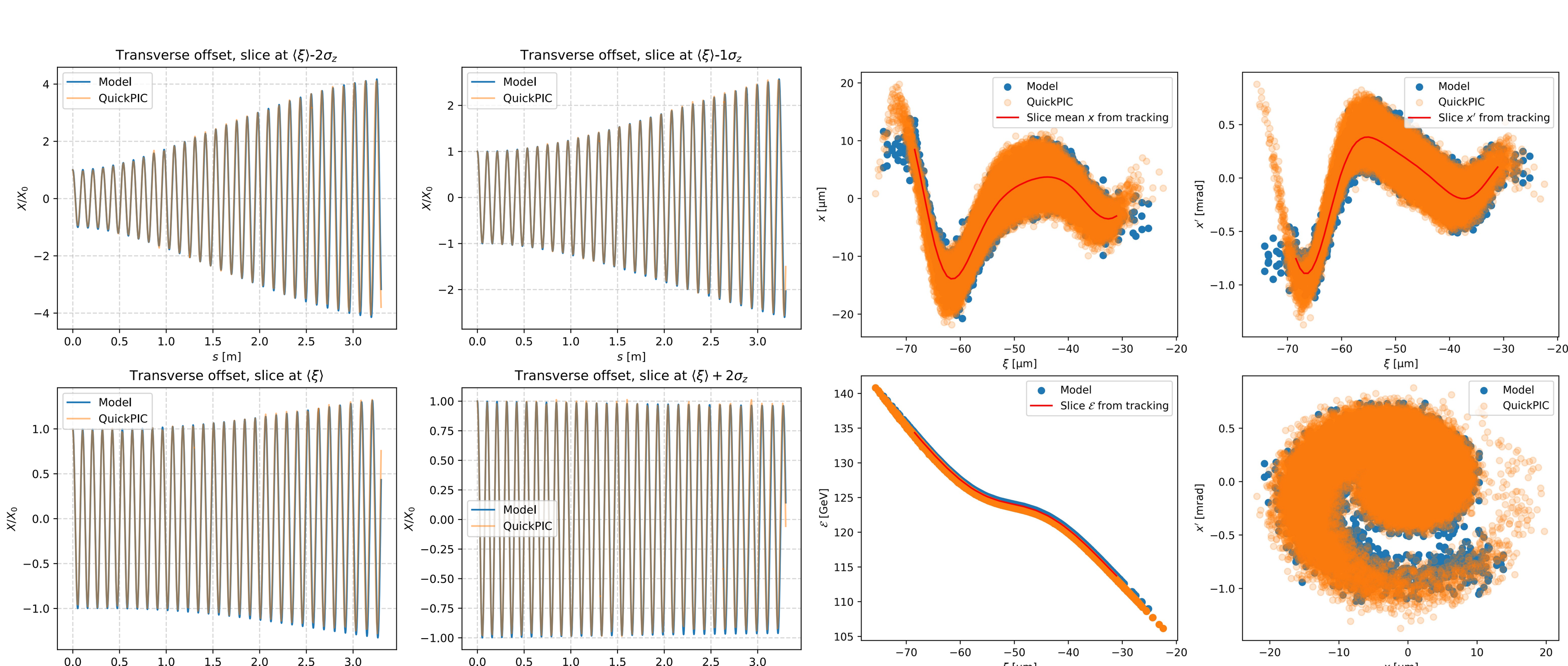


$$\frac{\partial^2}{\partial s^2}X(\xi,s) + \frac{1}{\gamma(\xi,s)}\frac{\partial\gamma(\xi,s)}{\partial s}\frac{\partial}{\partial s}X(\xi,s) + \frac{1}{\beta(\xi,s)^2}X(\xi,s) = -\frac{e}{\mathcal{E}(\xi,s)}\mathcal{W}_\perp(\xi,s)$$

- β : Beta function.
- $\mathcal{E}$: Electron energy of an electron in a beam slice at ξ.

Need initial $E_z(\xi)$ and $r_b(\xi)$ as inputs from e.g. a PIC code.

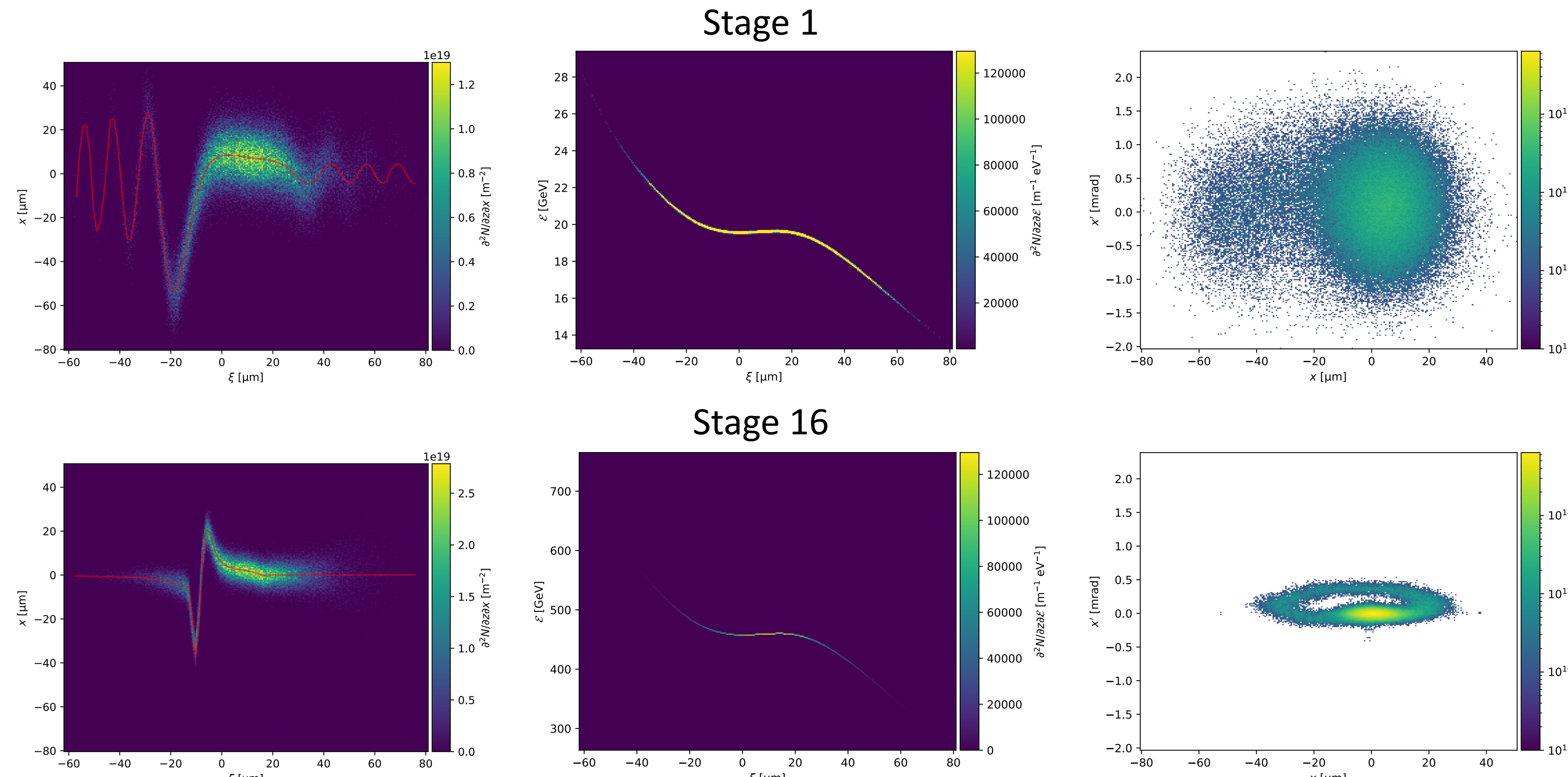


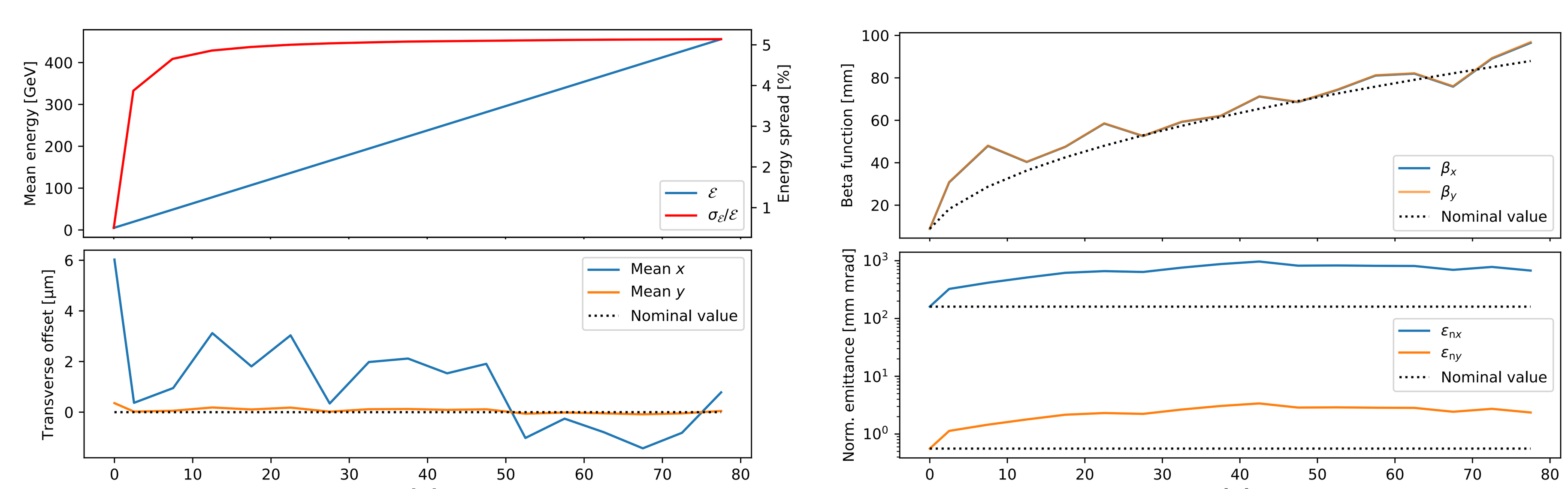


Results and outlook

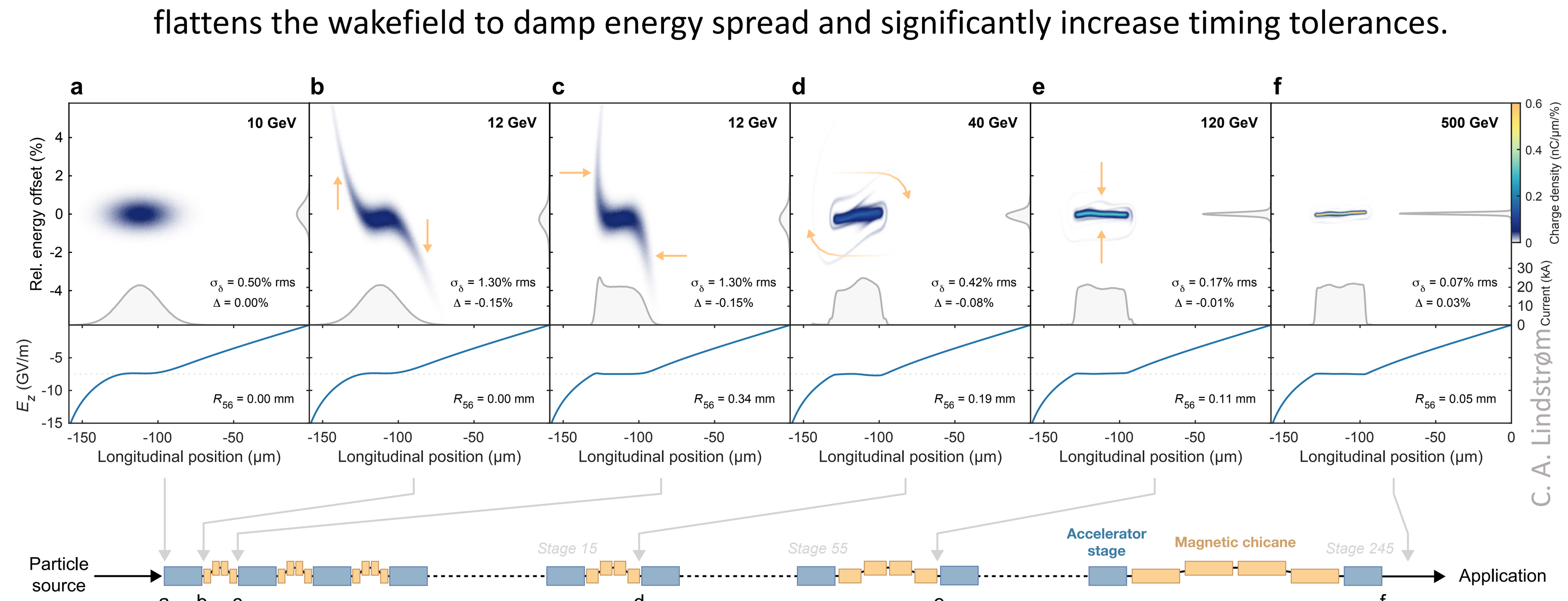
Parameter	Unit	HALHF		ILC	CLIC
		e^-	e^+	e^-/e^+	e^-/e^+
Center-of-mass energy	GeV	250		250	380
Center-of-mass boost		2.13		-	-
Bunches per train		100		1312	352
Train repetition rate	Hz	100		5	50
Average collision rate	kHz	10		6.6	17.6
Average linac gradient	MV/m	1200	25	16.9	51.7
Main linac length	km	0.41	1.25	7.4	3.5
Beam energy	GeV	500	31.25	125	190
Bunch population	10^{10}	1	4	2	0.52
Average beam current	μA	16	64	21	15
Horizontal emittance (norm.)	μm	160	10	5	0.9
Vertical emittance (norm.)	μm	0.56	0.035	0.035	0.02
IP horizontal beta function	mm	3.3		13	9.2
IP vertical beta function	mm	0.1		0.41	0.16
Bunch length	μm	75		300	70
Luminosity	$cm^{-2}\ s^{-1}$	0.81×10^{34}		1.35×10^{34}	2.3×10^{34}
Luminosity fraction in top 1%		57%		73%	57%
Estimated total power usage	MW	100		111	168
Site length	km	3.3		20.5	11.4

B. Foster et. al.





Self correction: Using magnetic chicanes to compress bunches to self-correct into a current profile that flattens the wakefield to damp energy spread and significantly increase timing tolerances.



Conclusion

- Study of 16 merged HALHF acceleration stages.
- Preliminary results indicate emittance growth, even though instabilities are likely damped by large energy spread.
- Model requires further upgrades and tests.
- Future work: apply this method to study self-correction using interstages.
- Also include jitter between stages

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