Aspects of eRHIC Longitudinal Dynamics

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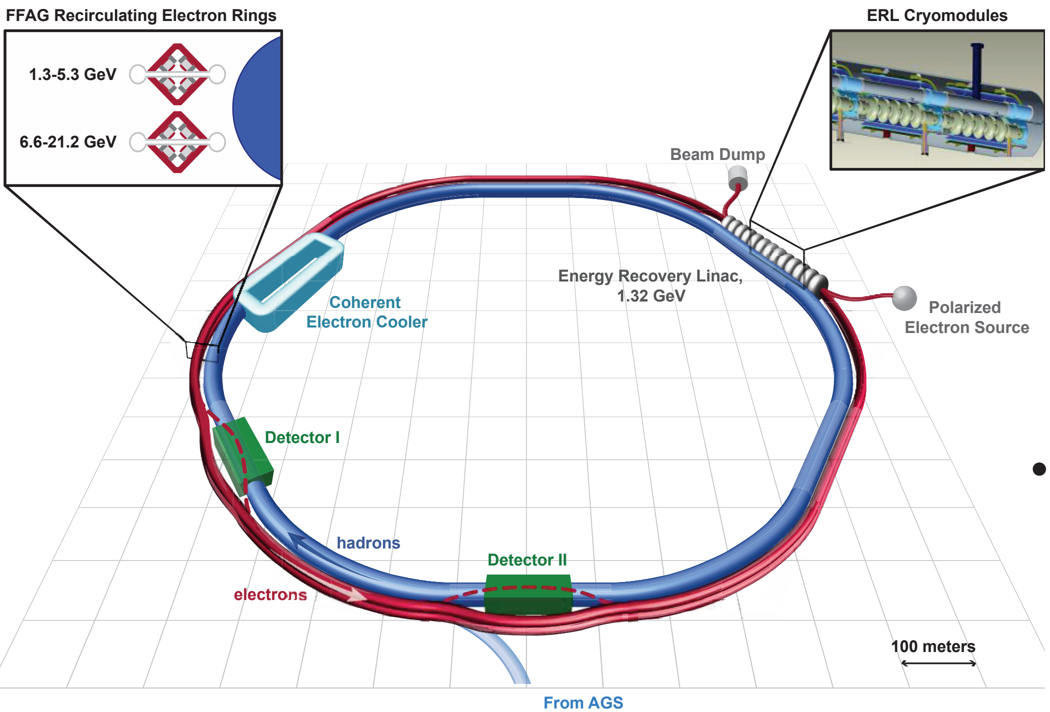
On behalf of eRHIC design team

ERL in eRHIC



- eRHIC ERL features
  - Multipass ERL
    - 1.322 GeV linac
    - 16 passes to 21.2 GeV
    - 12 passes to 15.9 GeV
  - FFAG recirculation pass
    - Cost saving
    - 16 sep lines -> 2 FFAG lines
    - Up to 4x energy range
- Challenges
  - Longitudinal dynamics
    - Energy spread
    - Energy recovery efficiency
  - Transverses dynamics
    - BBU, orbit control

ERL parameters

Parameters	Values
Injection energy	12-20 MeV
Energy gain per pass	1.322 GeV
Number of passes	16/12
Top energy	21.2GeV/15.9GeV
Bunch charge	1-5 nC
Number of recirculation FFAG passes	2
FFAG 1 energy range	1.3 GeV to 5.3 GeV
FFAG 2 energy range	6.6 GeV to 21.2 GeV
Rms bunch length (m)	0.004

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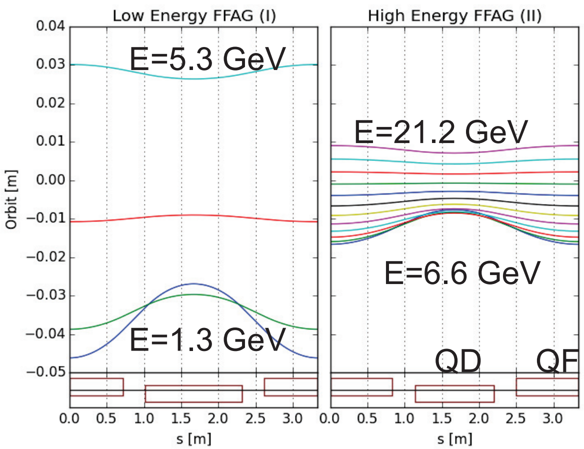
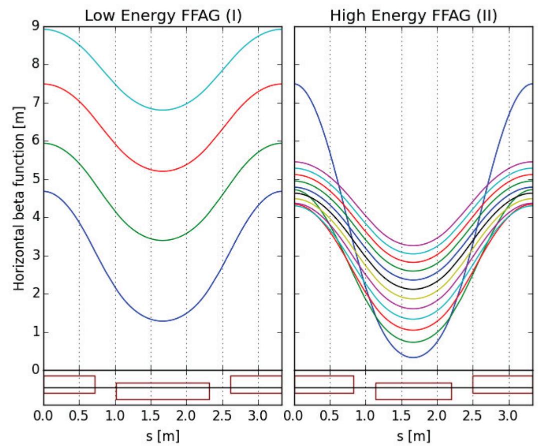
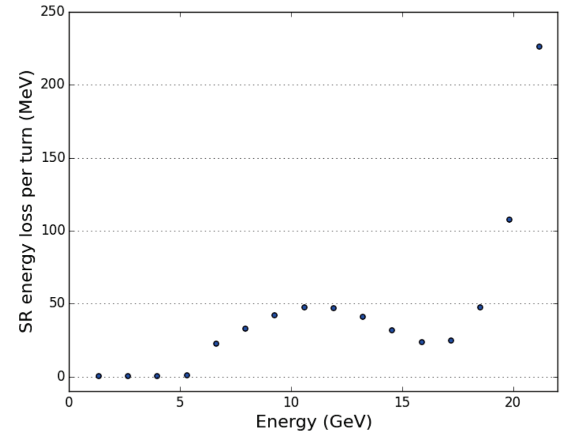
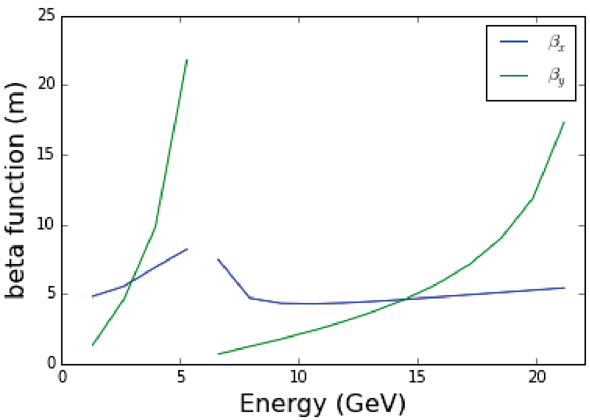
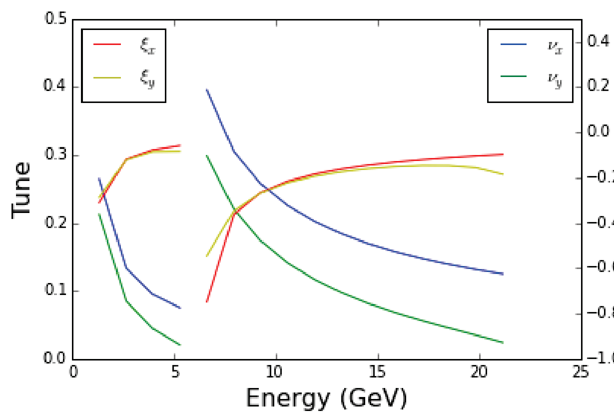
FFAG facts

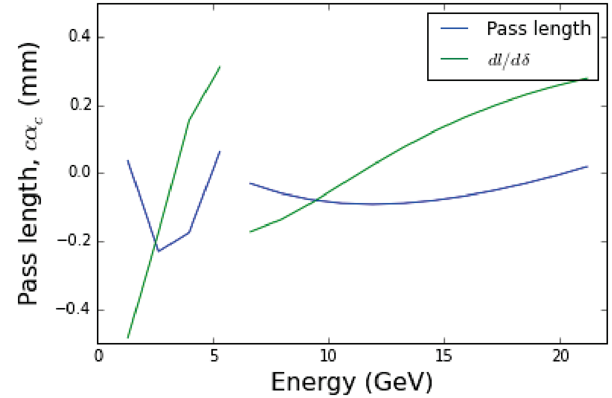












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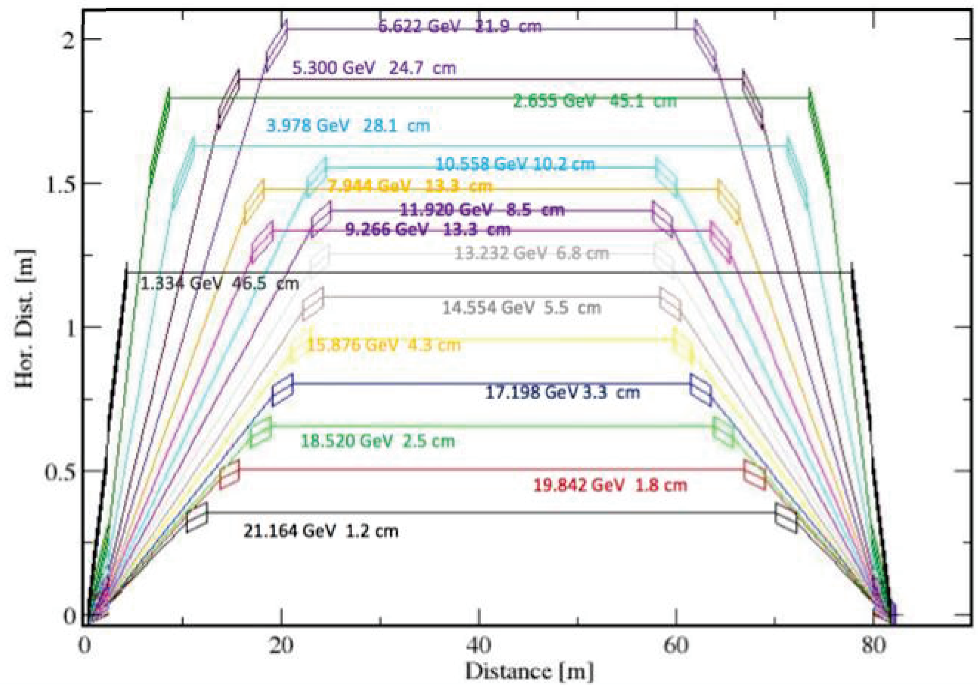
FFAG+ERL

- To make the FFAG be suitable for ERL application, a glue is needed—spreader/combiner

Goal of Spreader/Combiner (Longitudinal)

- Cancel the time-of-flight variance
- Make the recirculating pass isochronous, eliminate R_{51},R_{52} and R_{56}.
- Make small adjustments



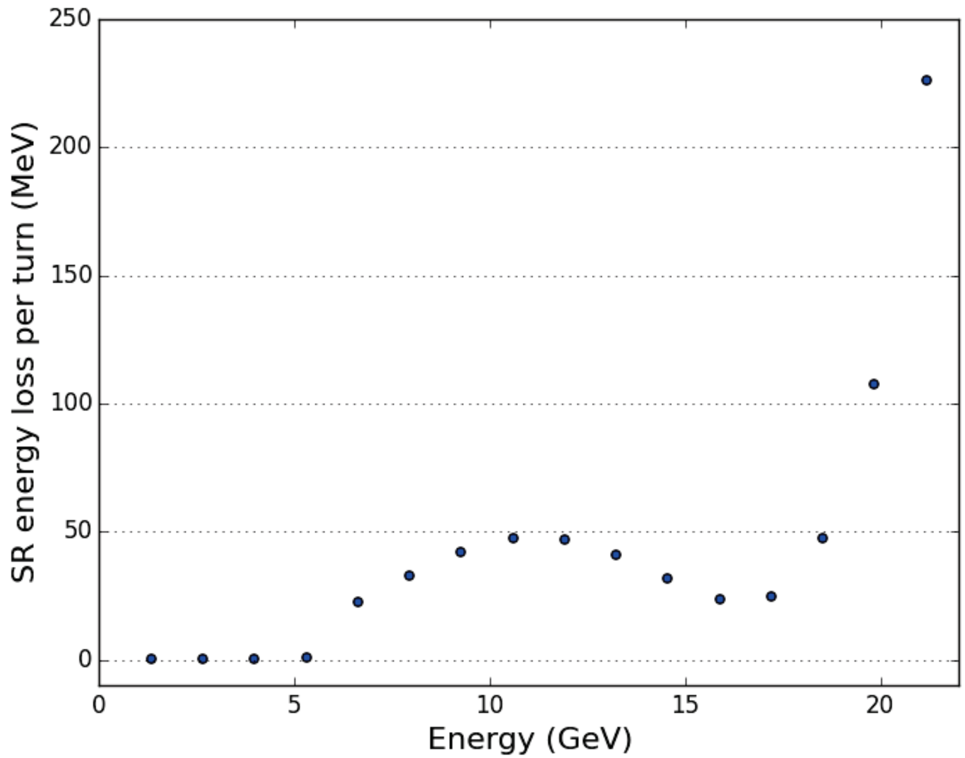
@ N. Tsoupas

Energy loss/spread

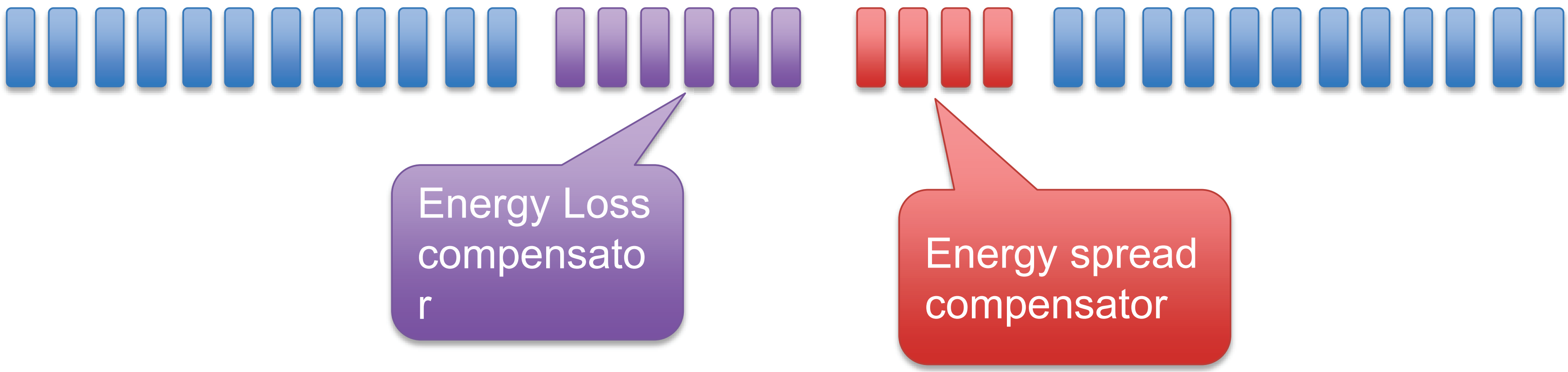
	Energy Loss (MeV)		rms Energy spread (MeV)	
	15.9 GeV	21.2 GeV	15.9 GeV	21.2 GeV
Machine Impedance	2.4	1.2	3.8	2.0
Synchrotron Radiation	221	540	2.8	6.7
Total	223	541	~5	~7

Energy loss/spread

	spread
	1.2 GeV
Machine Ir	2.0
Synchrotron	6.7
Tot	~7



Linac



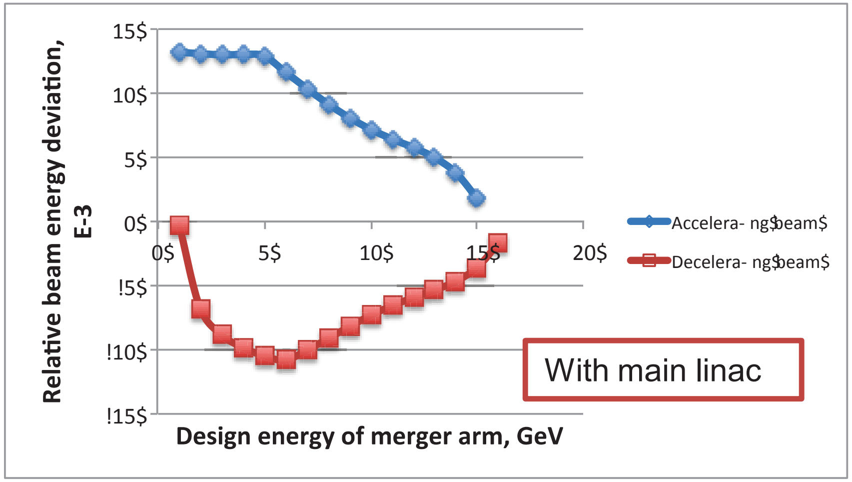
second harmonic cavities for energy loss compensation.

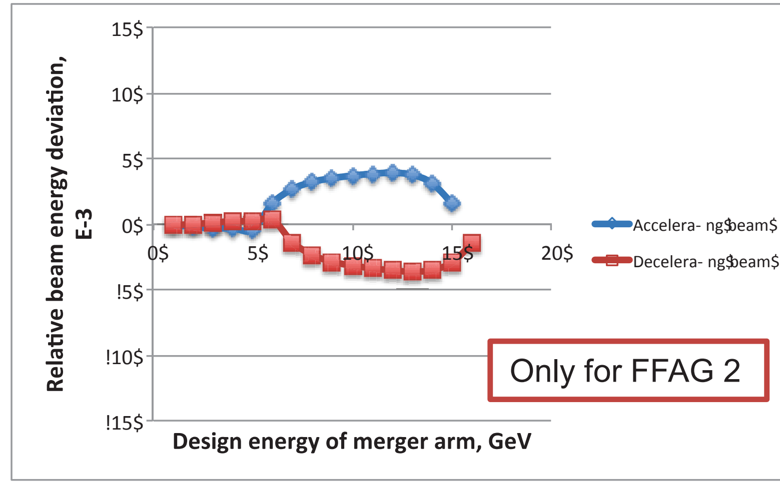
Energy loss due to synchrotron radiation, wake fields.

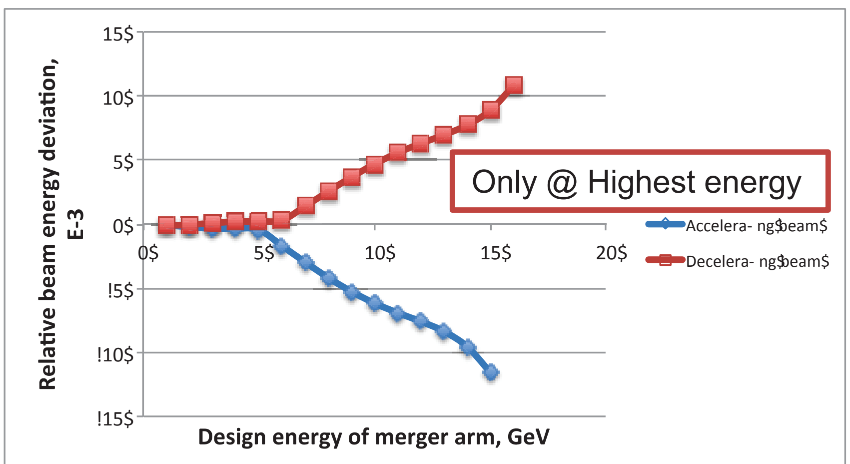
5th order harmonic cavities for energy spread due to the RF curvature.

The strength depends on the bunch length.

E-loss compensation schemes







	With main linac	FFAG 2	Highest energy
Effect	With drawbacks	Better	With drawbacks
Cost	Lowest	Add another Stripper	More cavities

@ V. Ptitsyn

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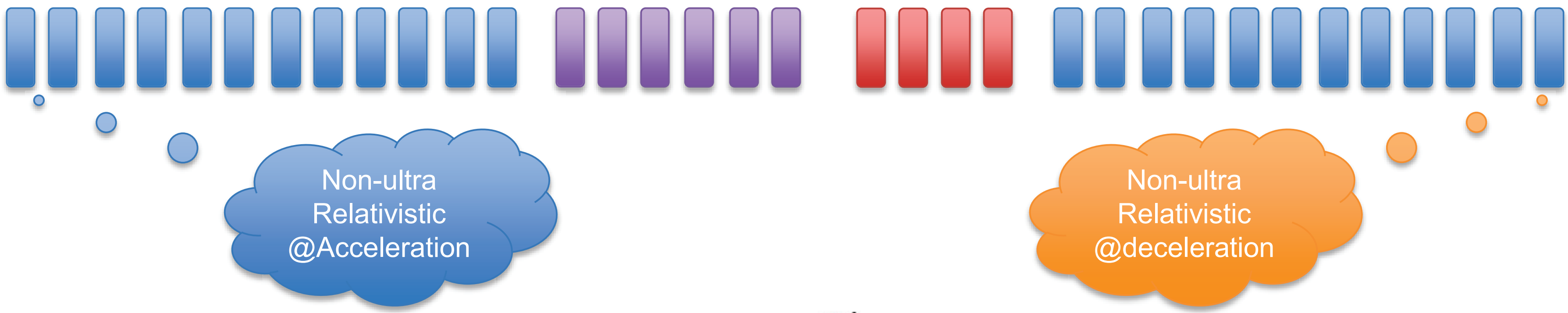
Challenges facts

- Curvature of RF wave (relative long bunch) → addressed locally by 5th harmonic cavity
- Injection energy is not ultra relativistic.
- Energy losses (ISR, wake fields)
- Energy compensation separates evenly to all passes, mismatch to the loss pattern.

Simulation tools

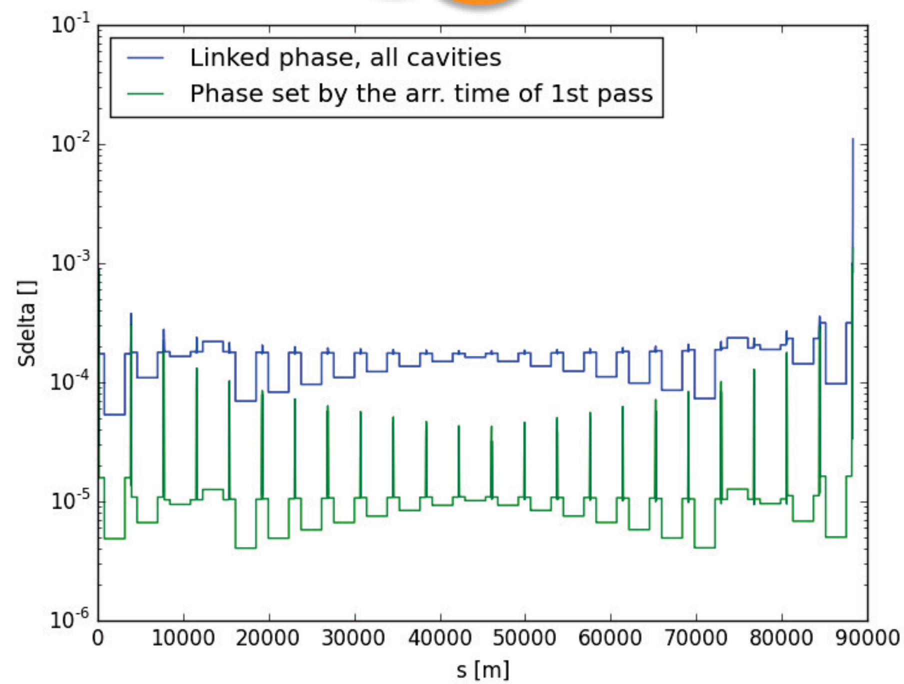
- A home-made glue code + Elegant for the 120 km line.
- Spreader/combiner is represented by the 6-D symplectic matrix.
- End-to-End simulation is done by stretch the ERL pass. Same element is guaranteed to have same errors.

A plain case



Options for cavity timing in the linac

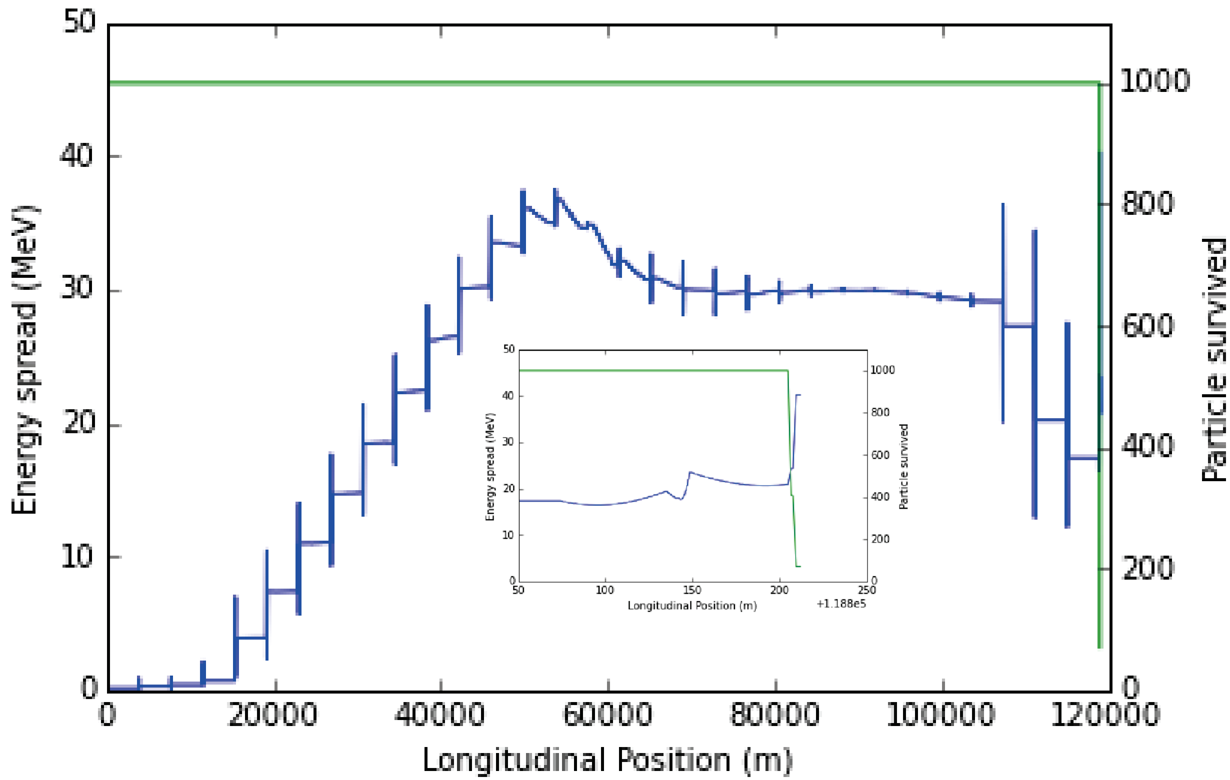
- The timing is optimized for particle with certain velocity (c or βc, constant)
- The timing is optimized for the low energy e-beam.



Energy spread

Energy spread becomes a problem when:

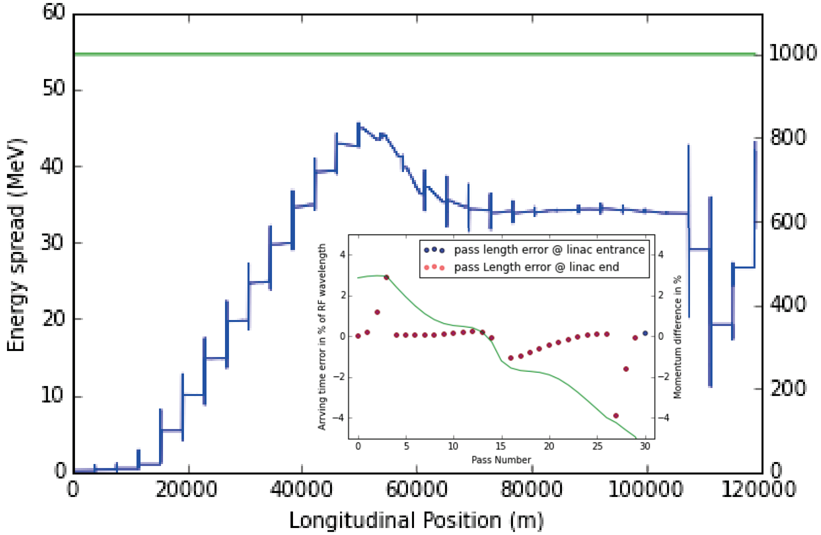
- Synchrotron Radiation is engaged and energy loss compensator is located with the main cavity
- Negative velocity @ last cavity. Must avoid!

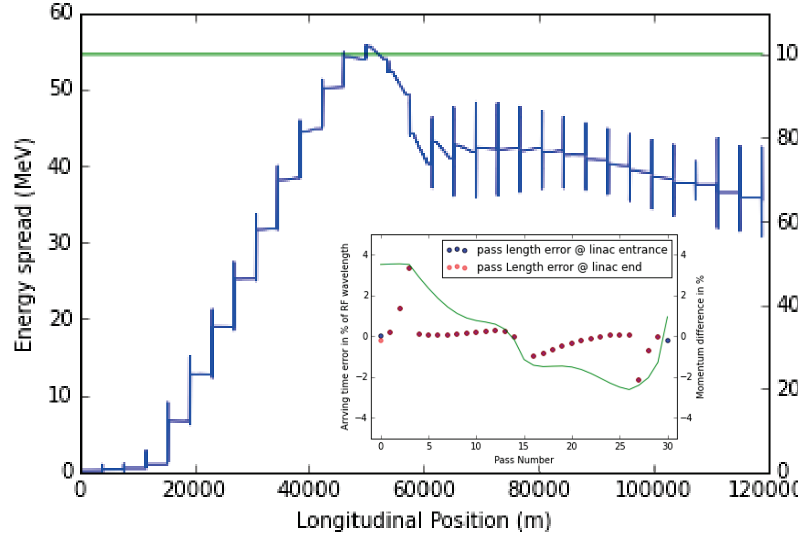


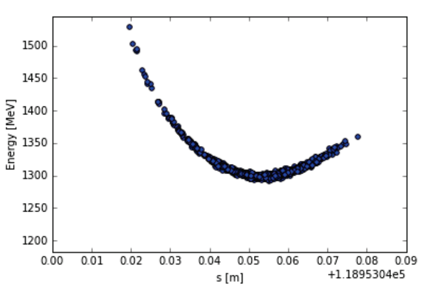
Undesired solutions

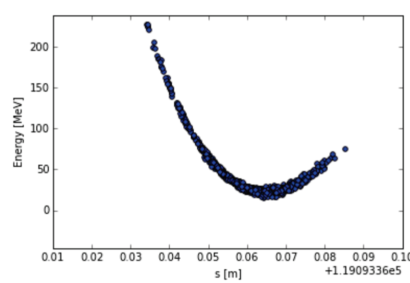
Increase the injection energy to 80 MeV to guarantee no beam loss.

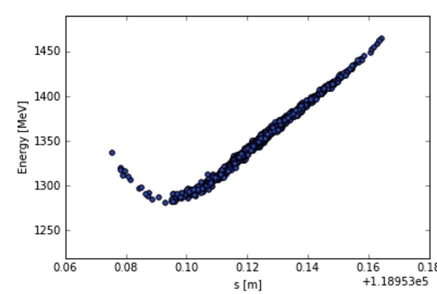
Over compensation, Injection @20MeV, but extraction @80 MeV

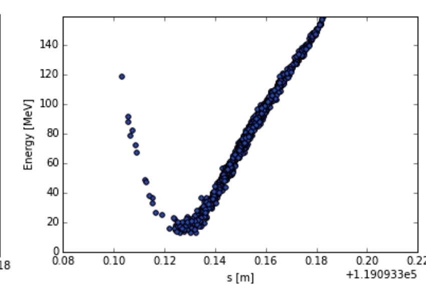








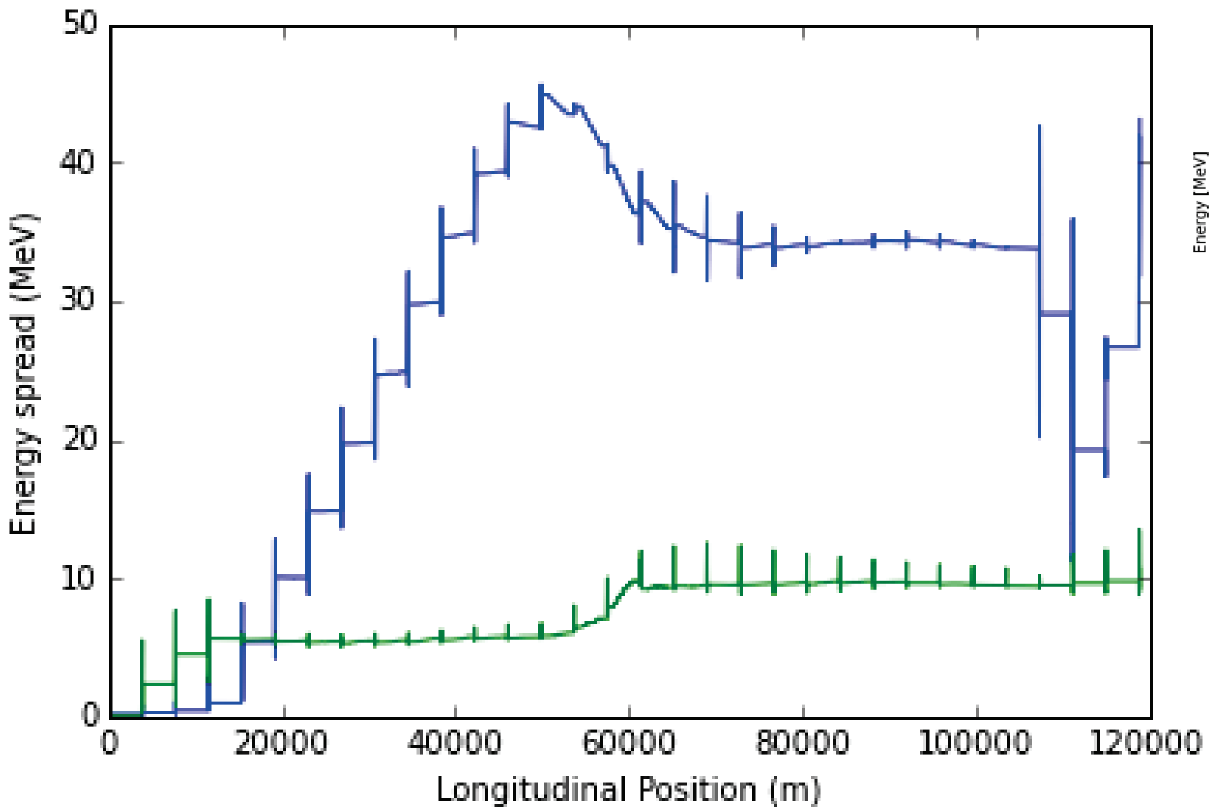


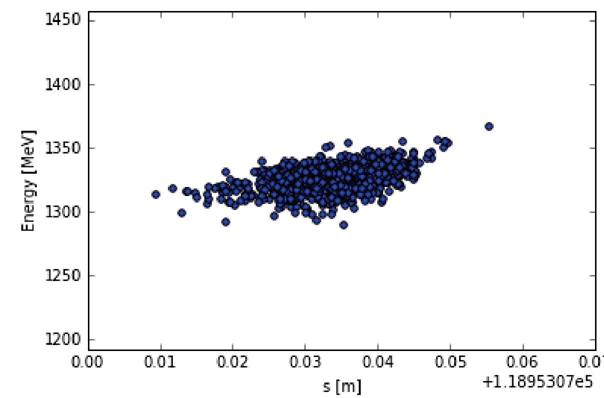


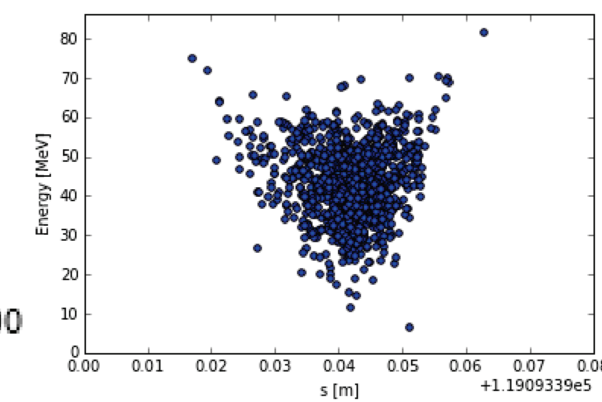
New practice I

- Adjust the arriving time of the second pass through the cavity (by changing pass length of the lowest energy spreader/combiner) -> optimize the energy spread in the accelerating stage/@IP.
- Adjust the arriving time of the first decelerating pass through the cavity (by changing the pass length of the top energy spreader/combiner) -> optimize the energy spread @dump.

Outcome

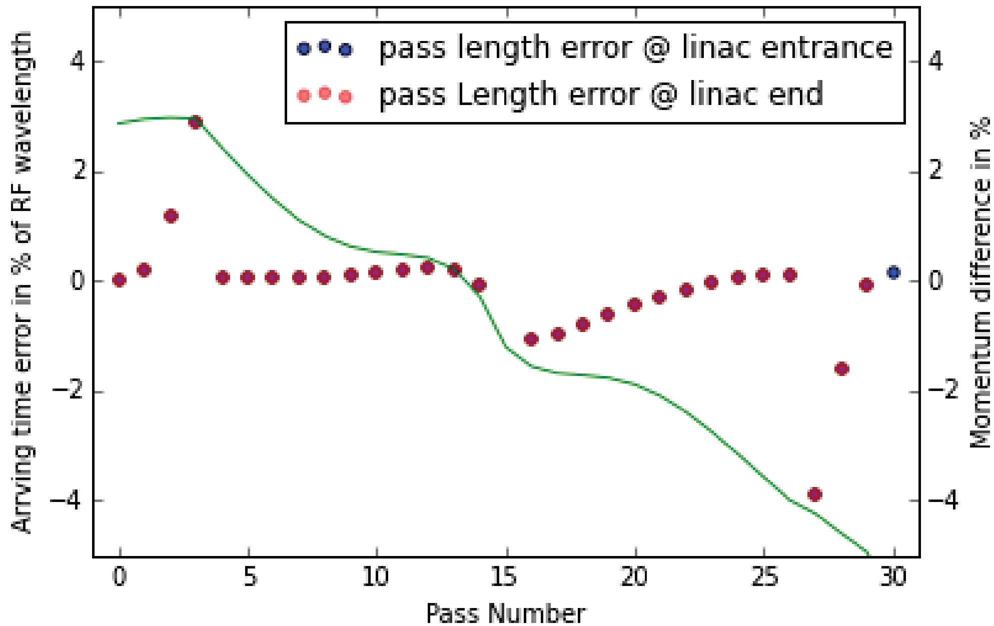

Energy spread (MeV)
50
40
30
20
10
0
0
20000
40000
60000
80000
100000
120000
Longitudinal Position (m)


Energy [MeV]
1450
1400
1350
1300
1250
1200
0.00
0.01
0.02
0.03
0.04
0.05
0.06
0.07
s [m]
+1.1895307e5

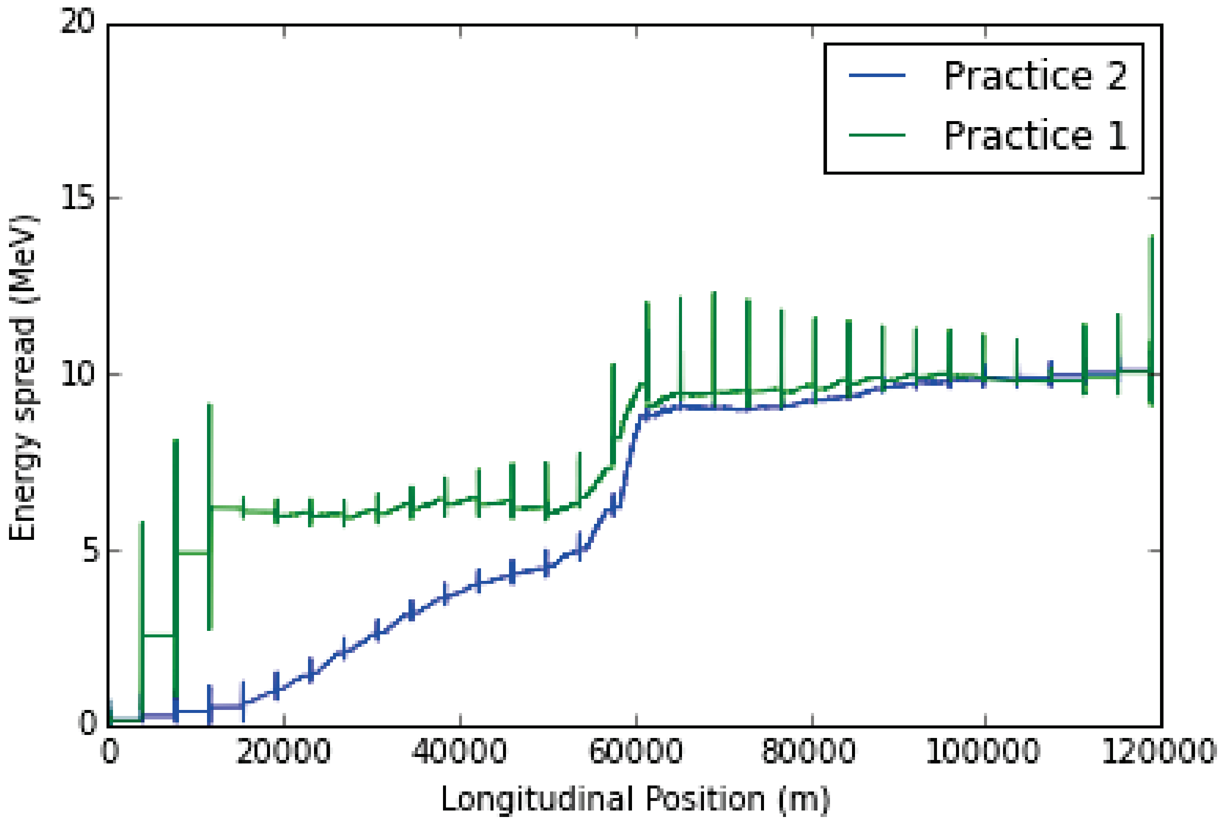

Energy [MeV]
80
70
60
50
40
30
20
10
0
0.00
0.01
0.02
0.03
0.04
0.05
0.06
0.07
0.08
s [m]
+1.1909339e5

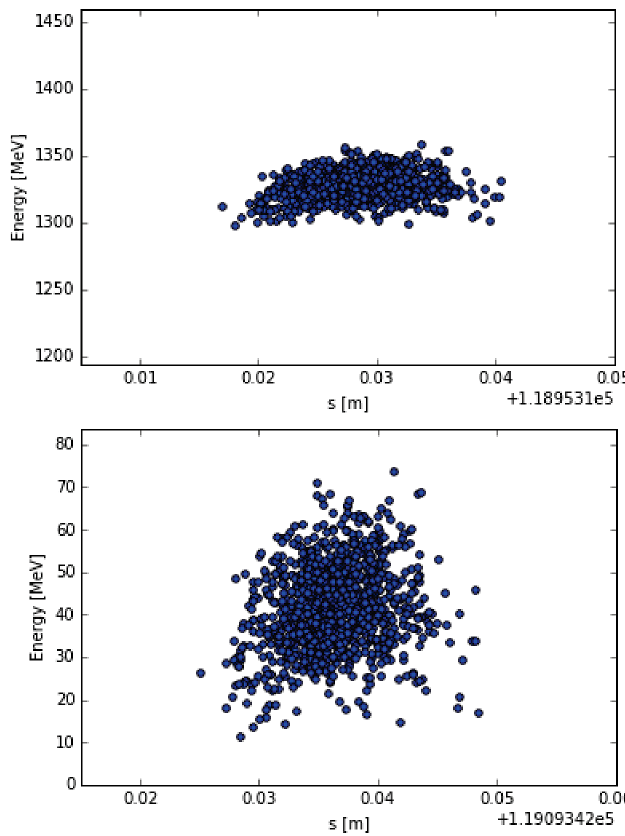
New practice II

- Due to the energy error and synchrotron radiation, the spreader/combiner can be re-adjusted to achieve isochronous condition.
- Introduce extra R56 based on 'measurement'



Outcome

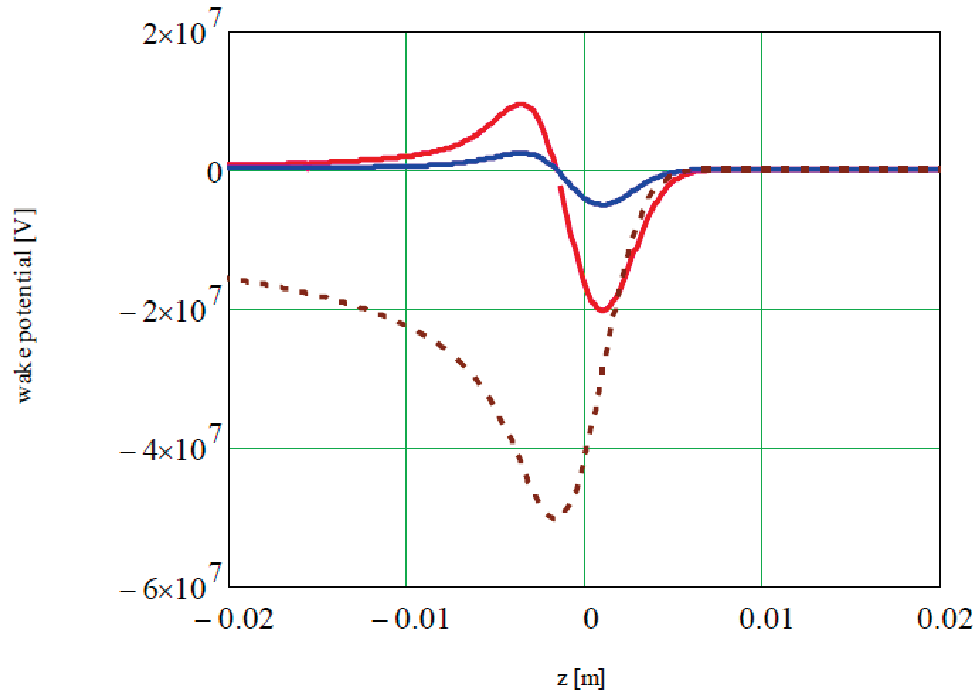




Still in working progress to further optimize. Especially the energy recovery efficiency is needed to be guaranteed.

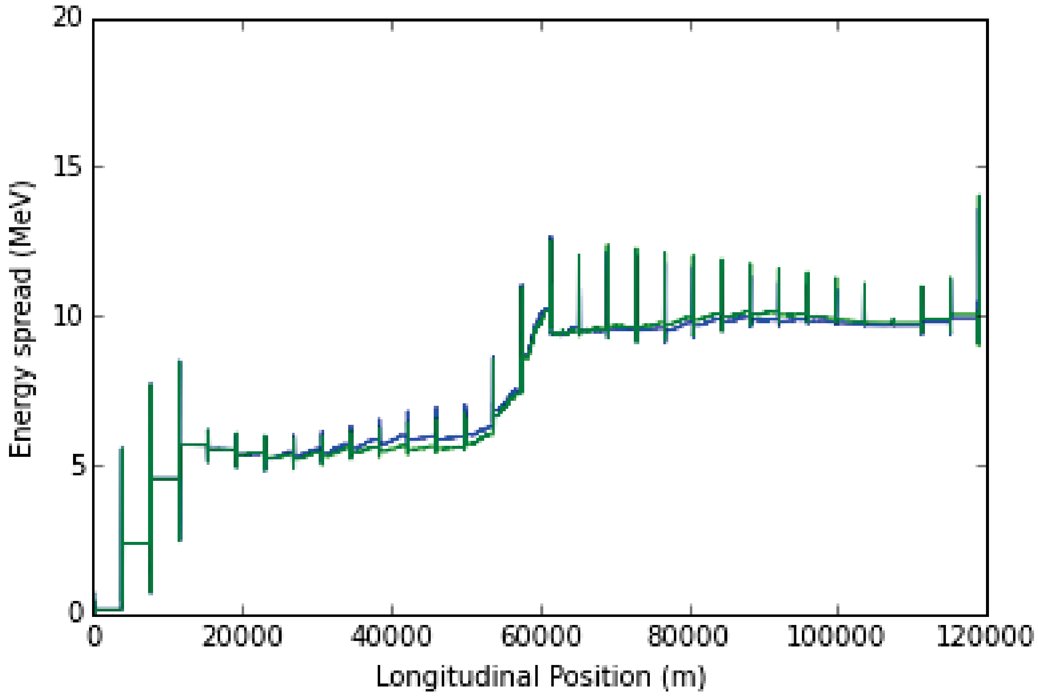
Effect of wake field

- Currently two wake field types are considered
  - Cavity and resistive wall
  - To be modeled, BPM wakes



@ A. Fedotov

Effect of wake field



Due to the low charge per bunch (1.1 nC) in 21.2 GeV eRHIC case, the effect of wake field is negligible.

Summary

- The synchrotron radiation introduces the largest challenges when cost-effective energy loss compensation scheme is adopted.
- Preliminary pass-length adjustment and R56 adjustment scheme are found to overcome this.
- More optimization is needed to ensure the energy recovery efficiency.

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Thank you for your attention!