ERL Lattice and Layout
Coherent Synchrotron Radiation

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Energy Recovery Linear Accelerator at Cornell

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Optimization of ERL Optics
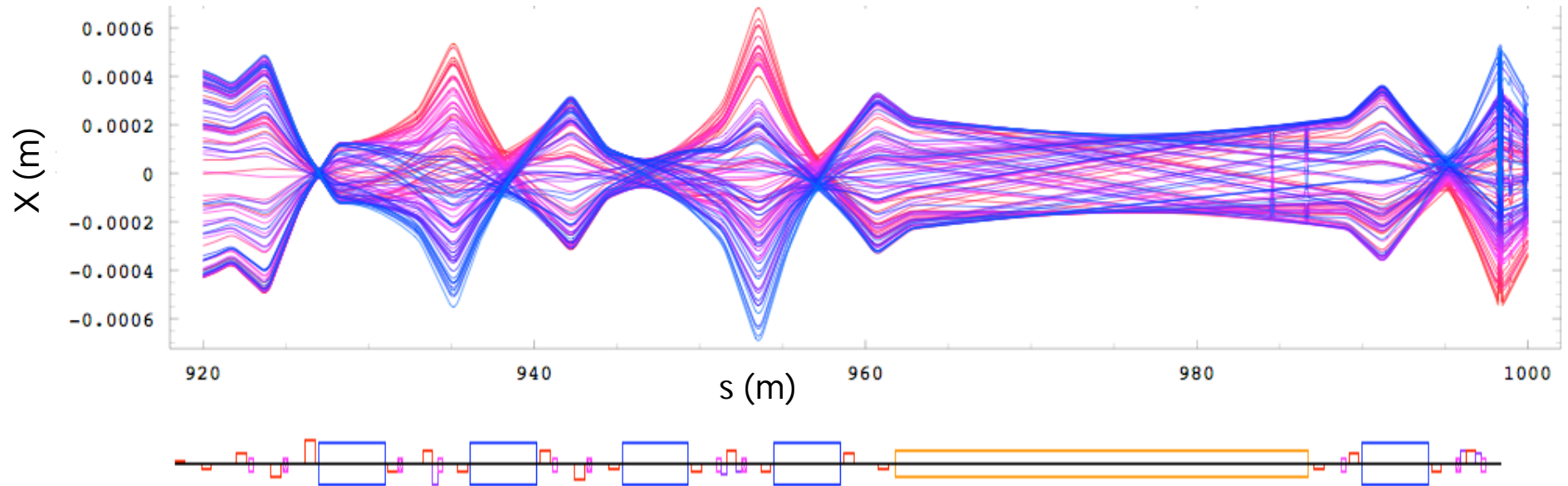
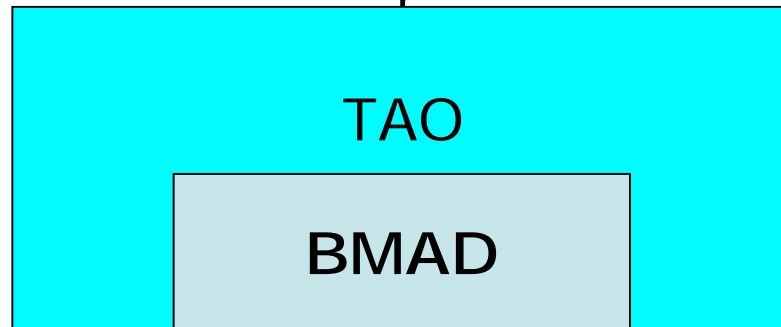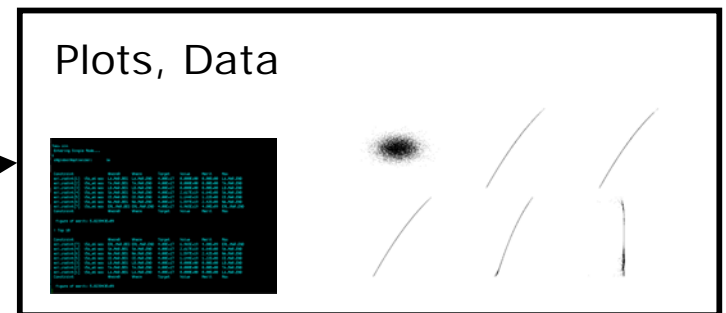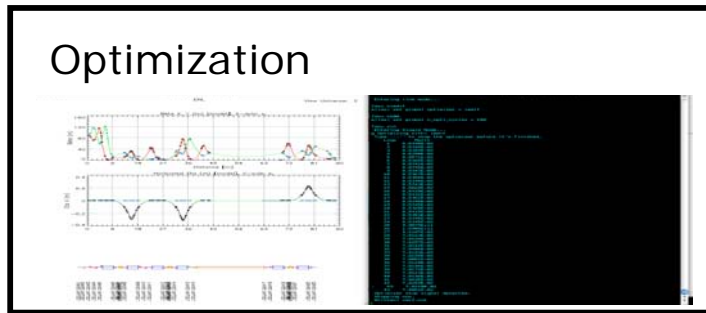## Variables

- 18 Undulators
- 535 Quadrupole Magnets
- 172 Dipole Magnets
- 64 Sextupole Magnets
- 400 Accelerating Cavities
- ~1300 Drifts

Constraints
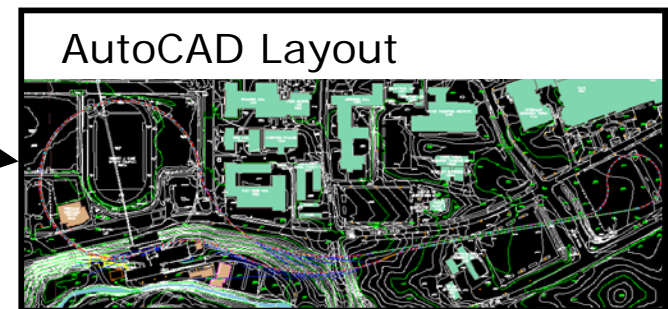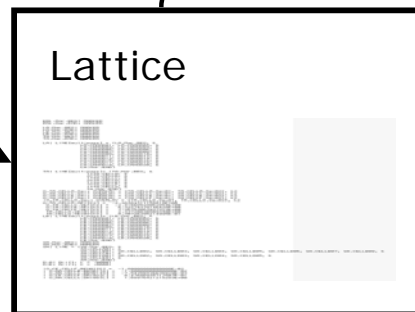
- Beta Functions
- Dispersion (1st and 2nd order)
- Time of Flight (1st and 2nd order)
- Physical Placement
- Number of Elements
- Space for additional elements
- Emittance Growth

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Tools. . .

Optimization

Plots, Data

TAO

BMAD

User Input

Lattice

AutoCAD Layout

SVN

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ERL Wiki

Sections and Subsections

6 Sections: Linac A, Turn Around, Linac B, South Arc, CEsr, North Arc
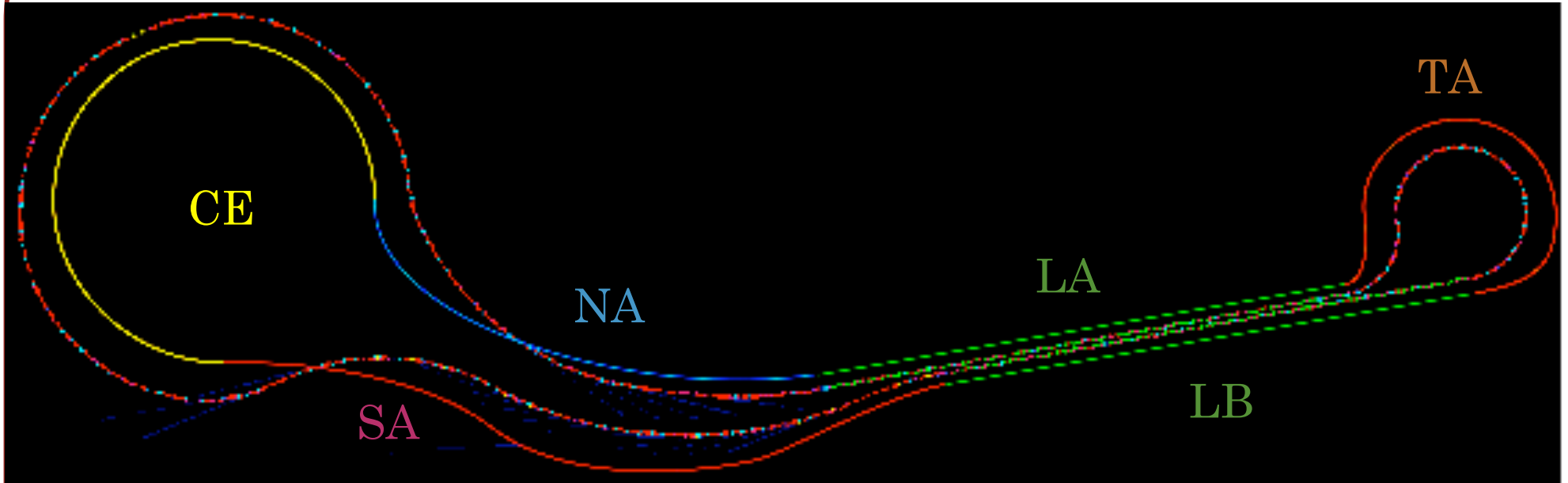
Subsections: SA = SA.CELLA01 + SA.CELLB01 + SA.CELLB02 + . . .
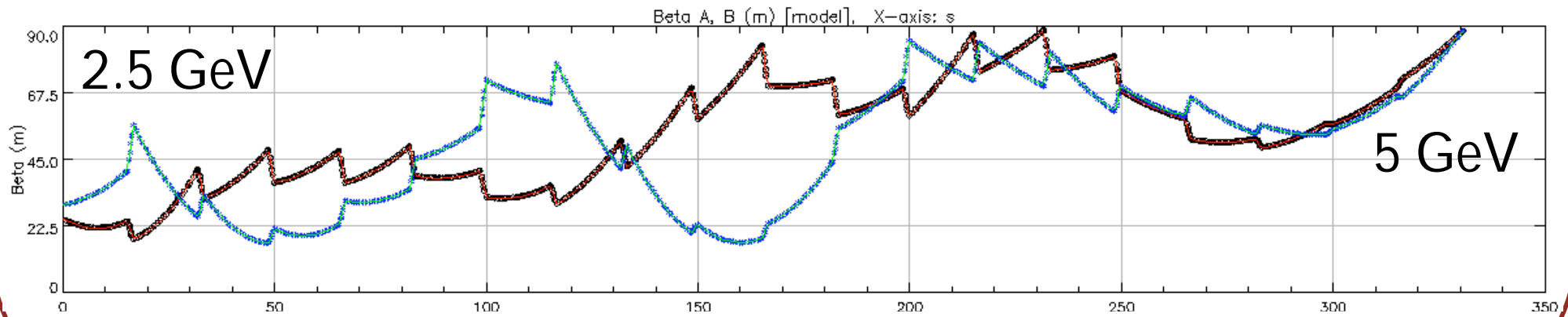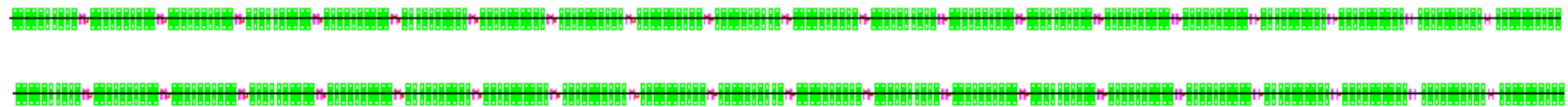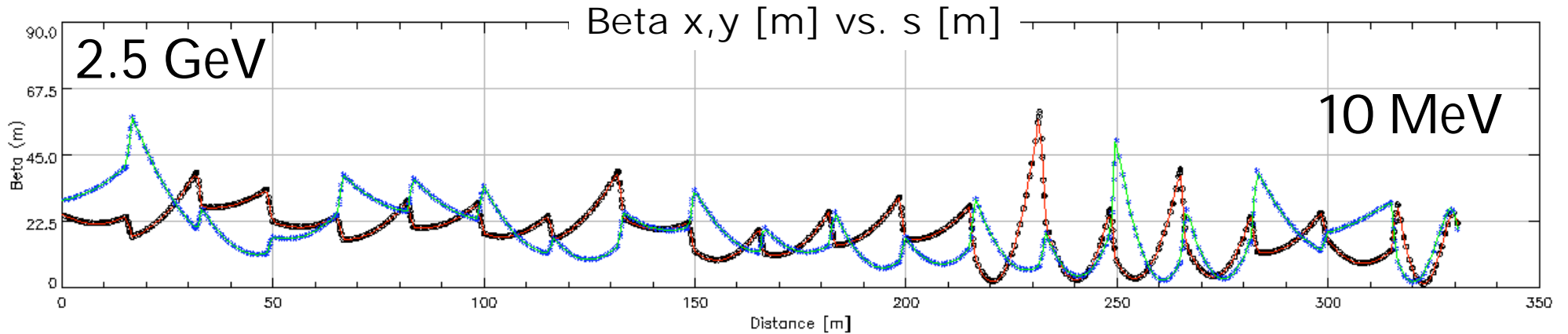
matching

~periodic

Full Naming Convention: TS.SE.SSNAM#S.DDD#DC
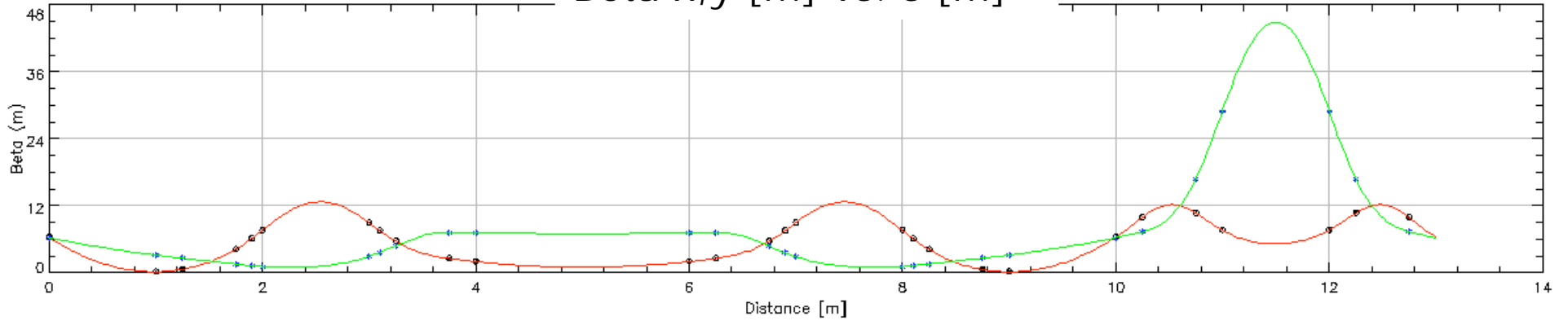Example: MA.SA.CELLB05.Qua03a

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Acceleration and Deceleration

Beta x,y [m] vs. s [m]

2.5 GeV

10 MeV

Beta A, B (m) [model], X-axis: s

2.5 GeV

5 GeV

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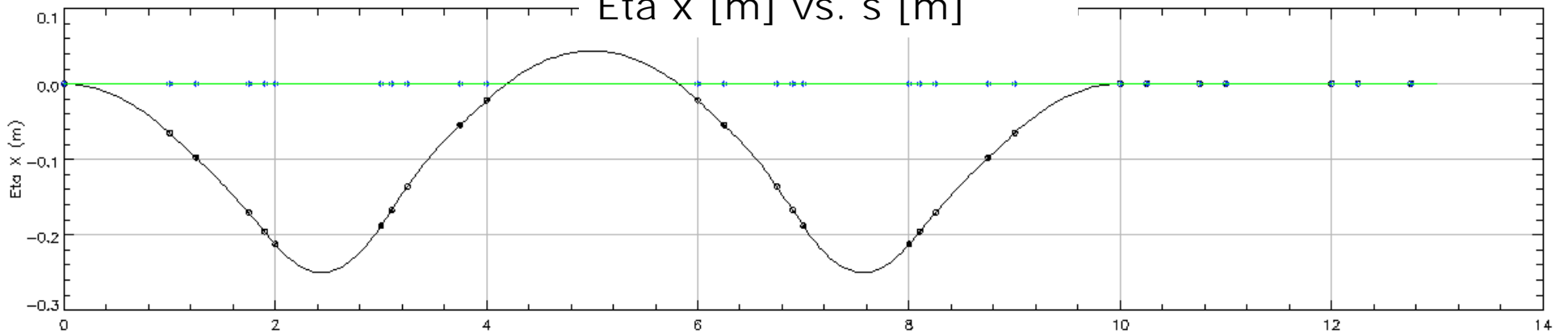# TA_CELLB

Beta x,y [m] vs. s [m]

Eta x [m] vs. s [m]

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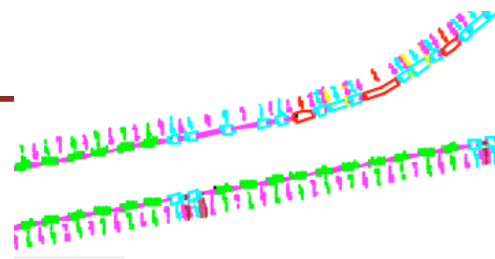
Full Turnaround
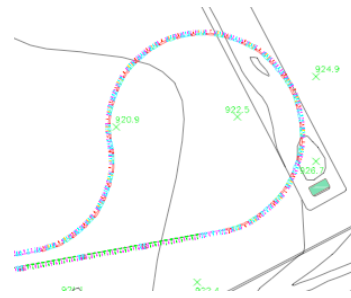
Beta x,y [m] vs. s [m]

t566 [m] vs. s [m]

South Arc

Beta x,y [m] vs. s [m]

Horizontal Eta (m) [model], X-axis: s

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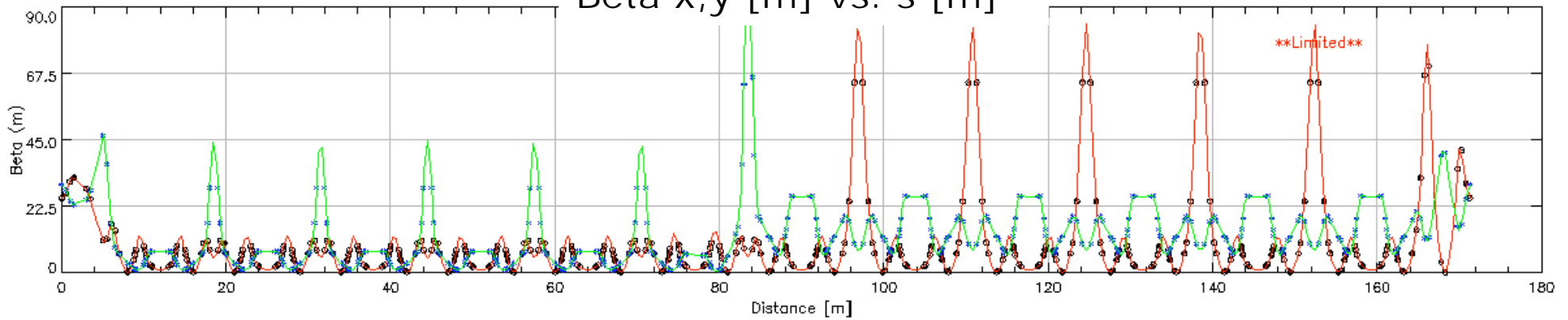
Beginning of the South Arc

Eta x [m] vs. s [m]

$$\beta_x = \beta_y = 12m$$
$$\alpha_x = \alpha_y = \eta_x = \eta'_x = 0$$

$$\beta_x = \beta_y = 2.5m$$

$$\beta_x = \beta_y = 1.25m$$

$$\beta_x = \beta_y = 0.5m$$

LB.CRMOD20
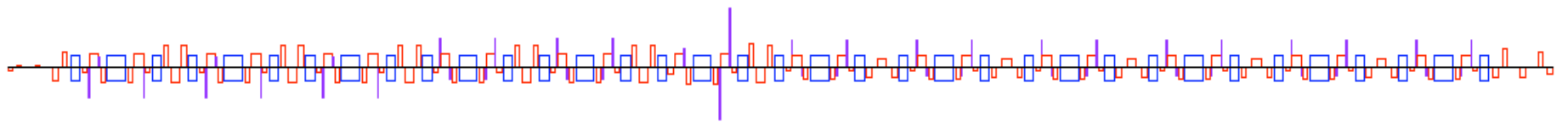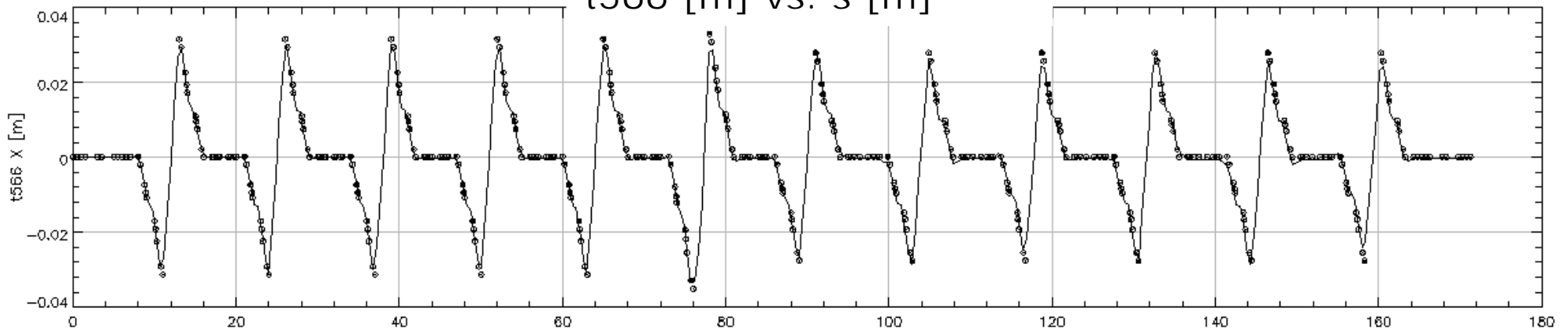
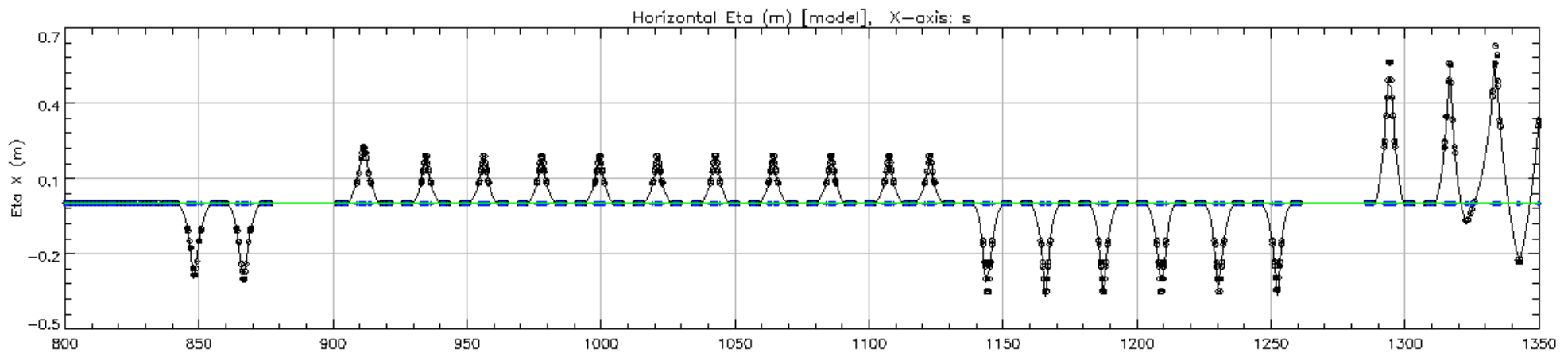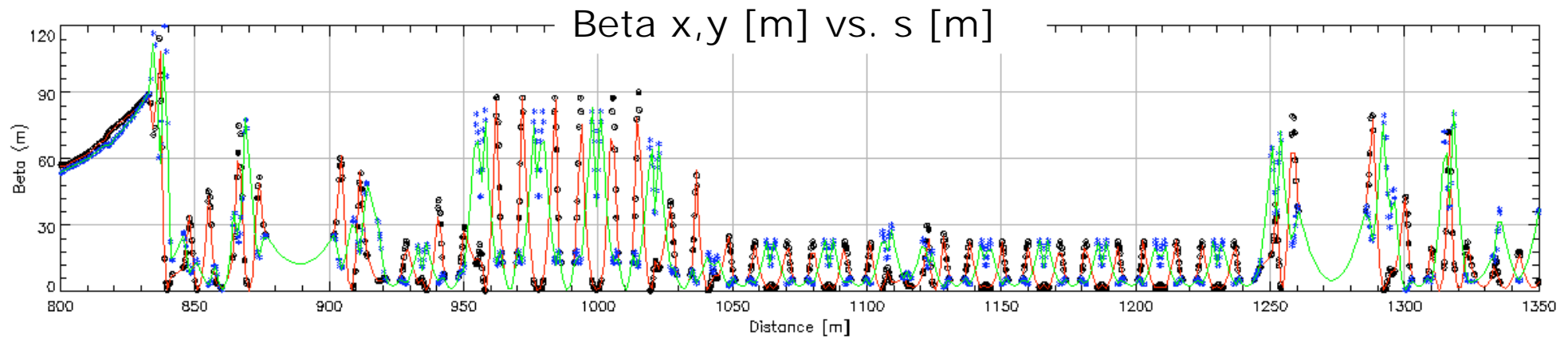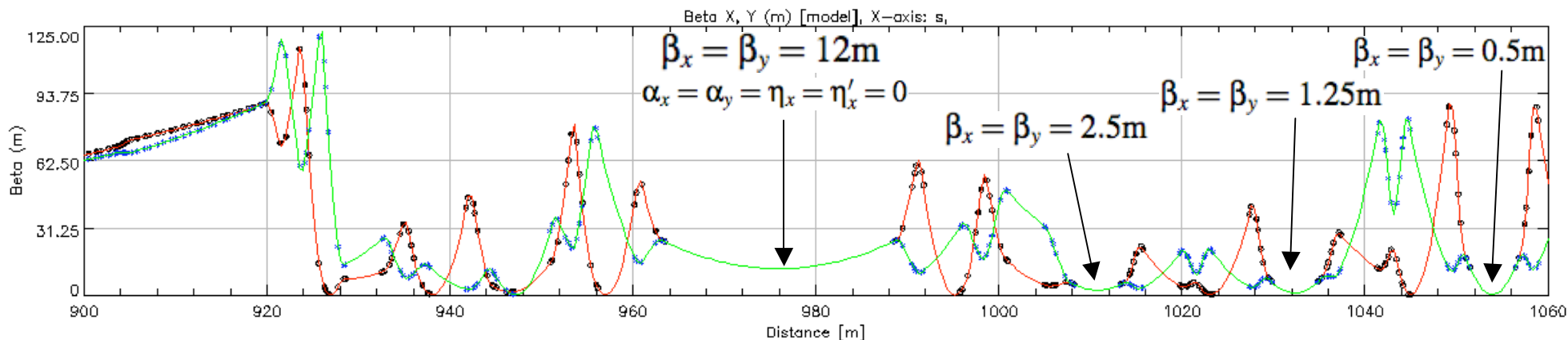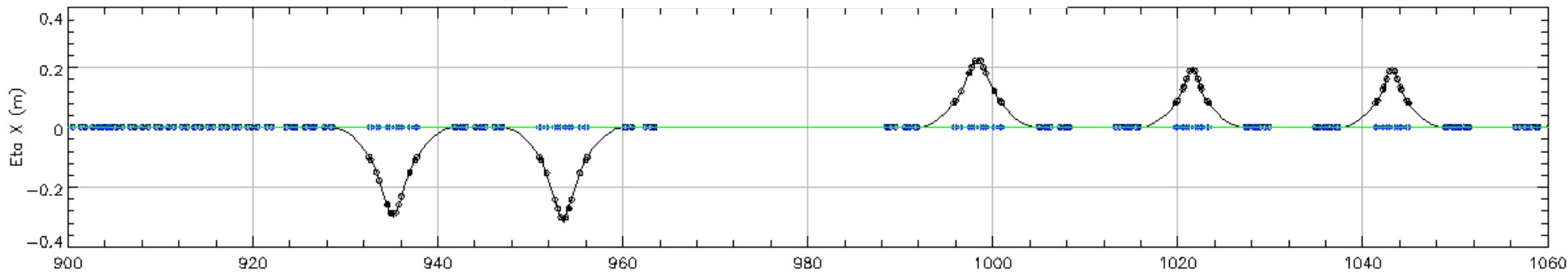SA.CELLA01

SA.CELLB01

SA.CELLB02

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CESR Arc Cell

Beta x,y [m] vs. s [m]

Eta x [m] vs. s [m]

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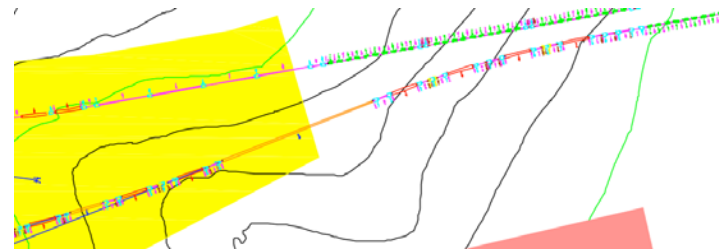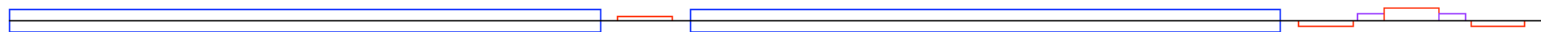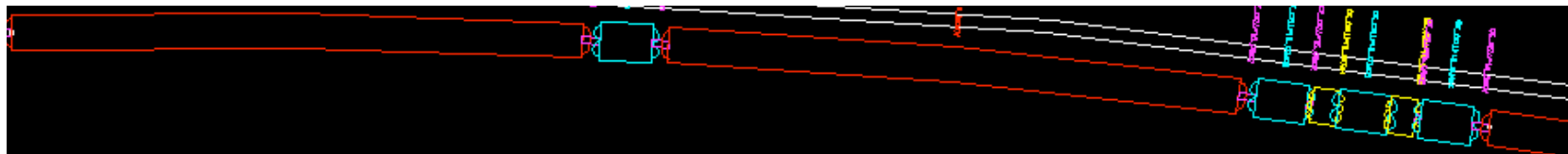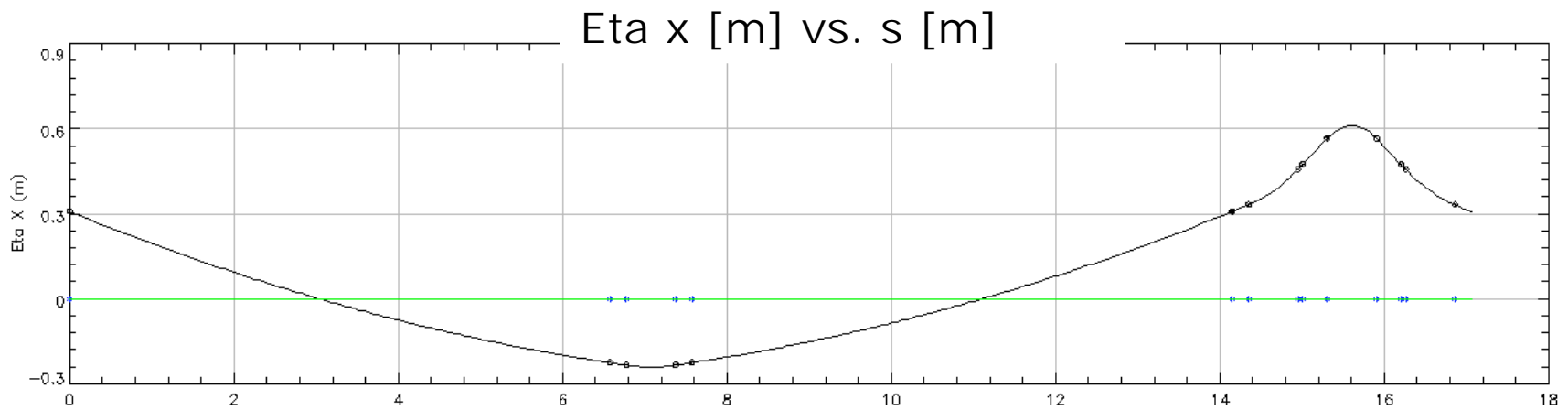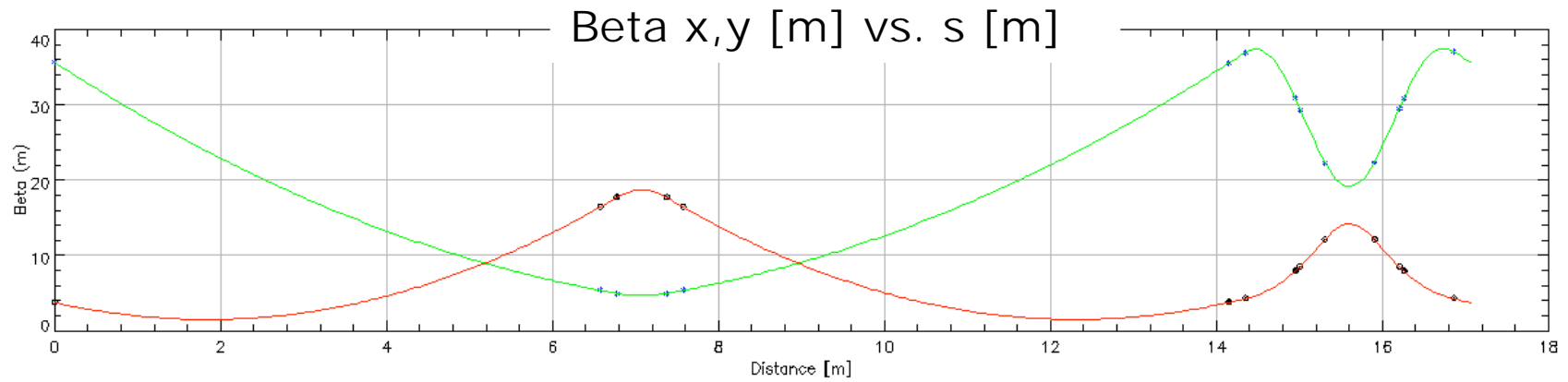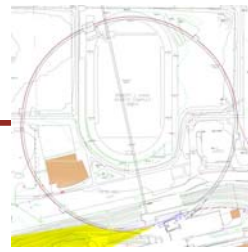
South Arc - CESR - North Arc Time of Flight

Beta x,y [m] vs. s [m]

r56 [m] vs. s [m]
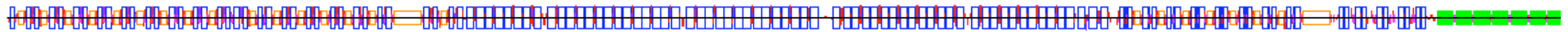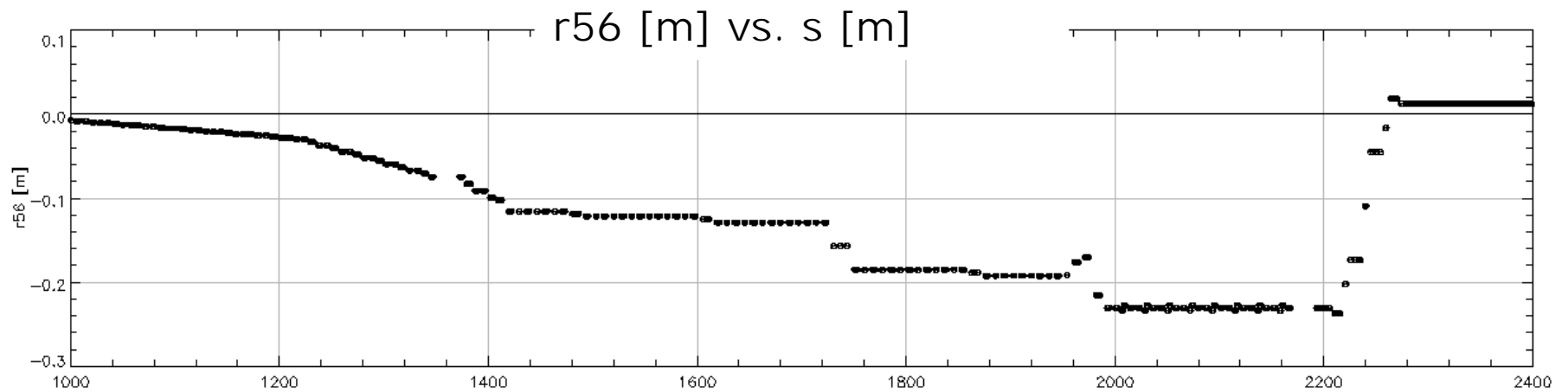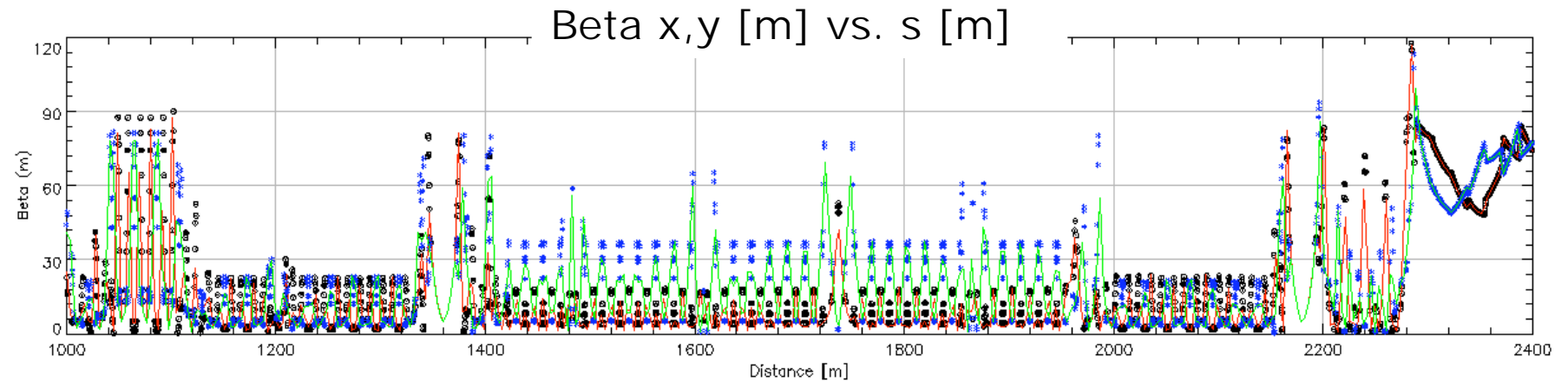
Mode C Bunch Compression

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Bunch Length

Mode C

Bunch Length [fs] vs. s [m]

Mode A

Bunch Length [fs] vs. s [m]

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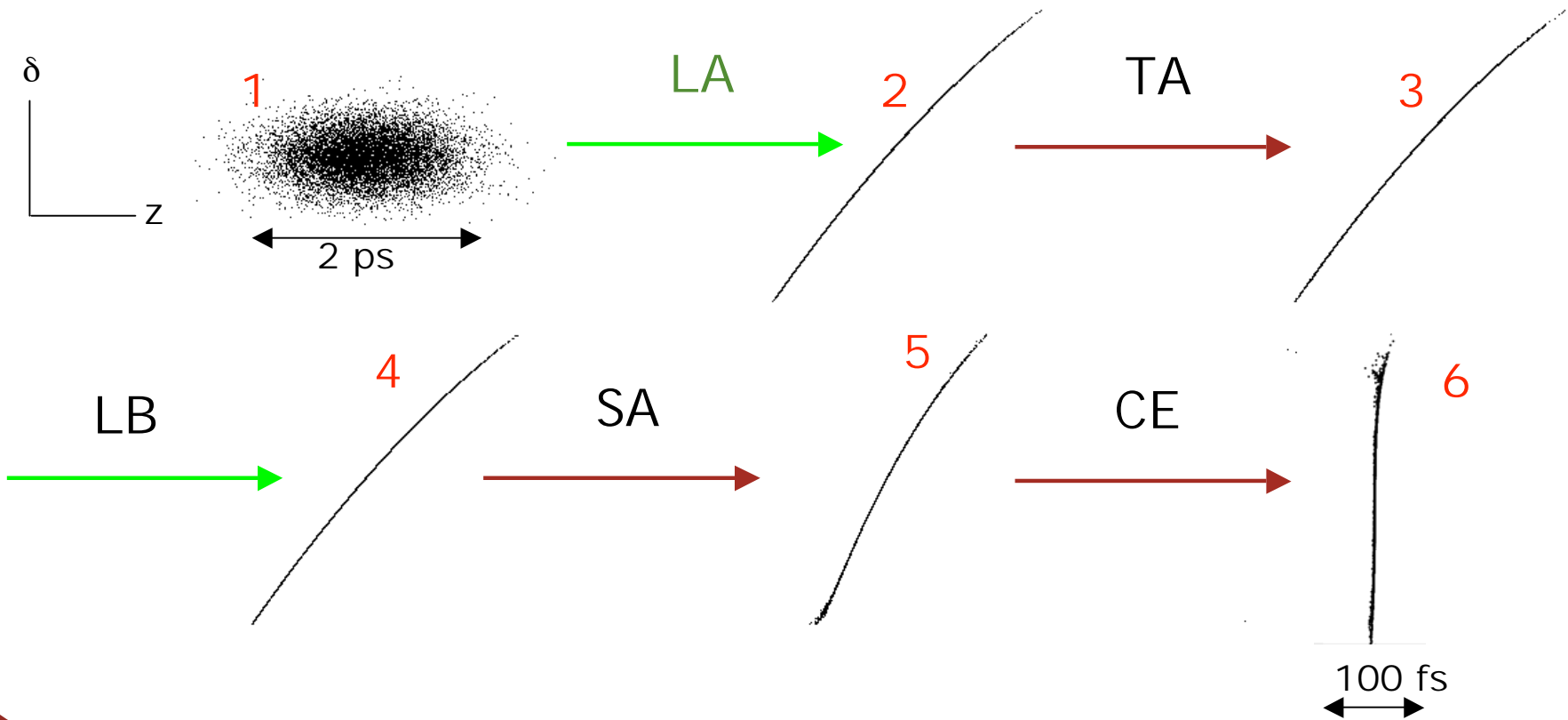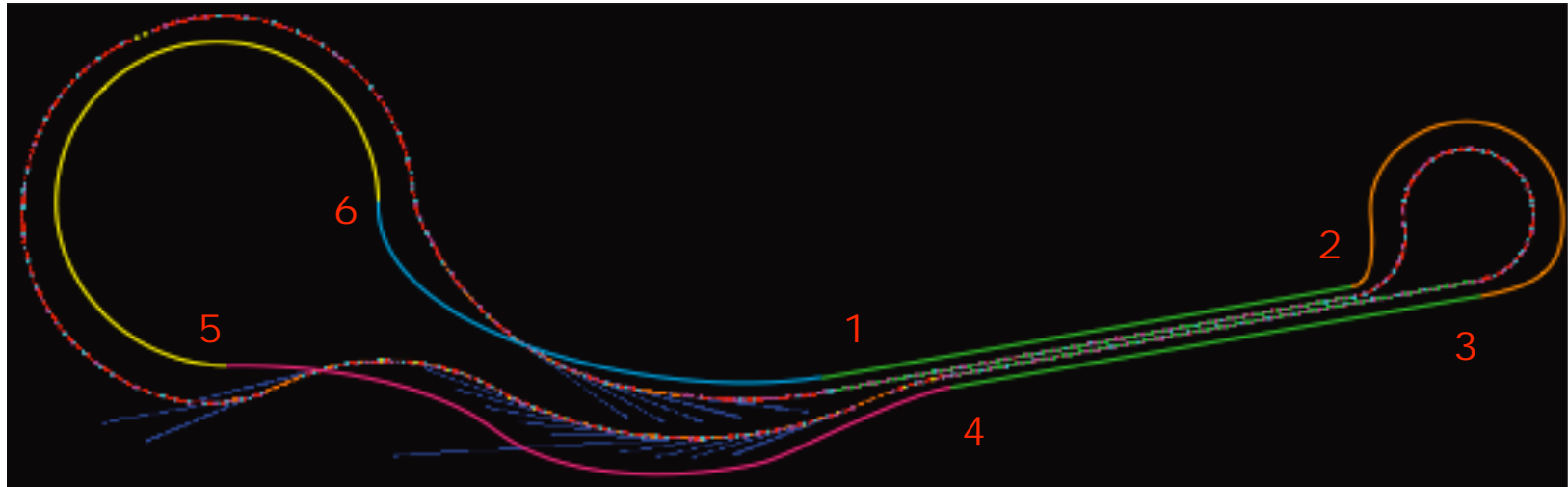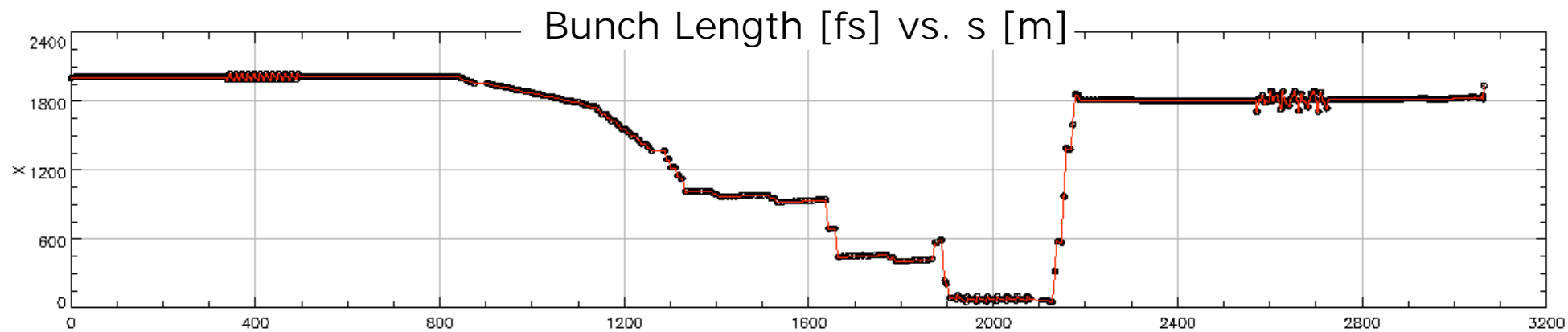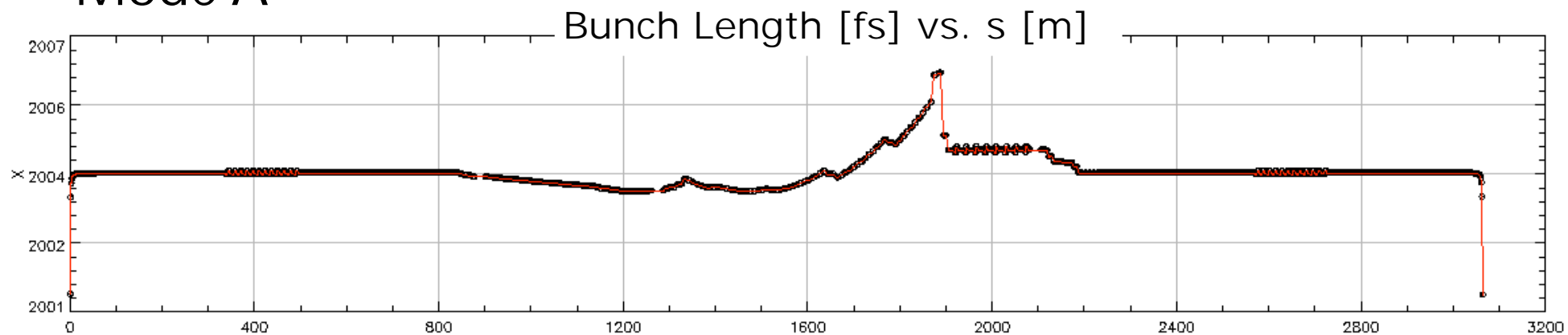
Emittance Growth in Complete ERL

Beta x,y [m] vs. s [m]
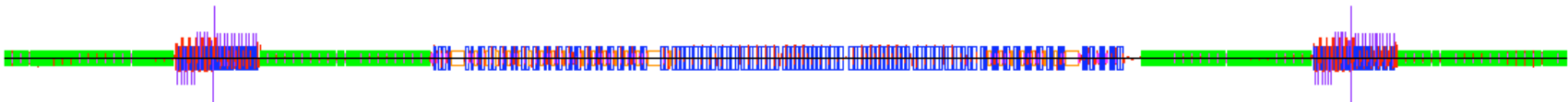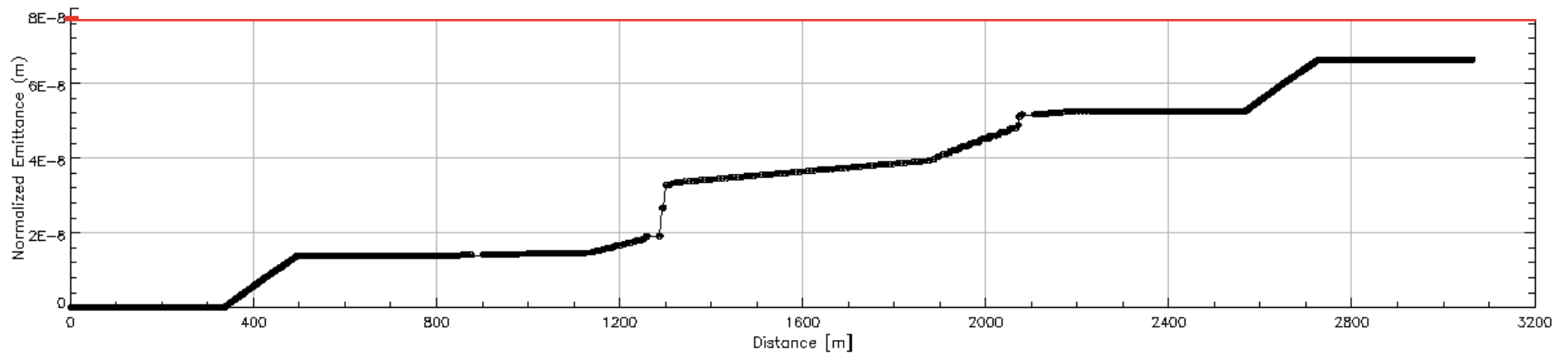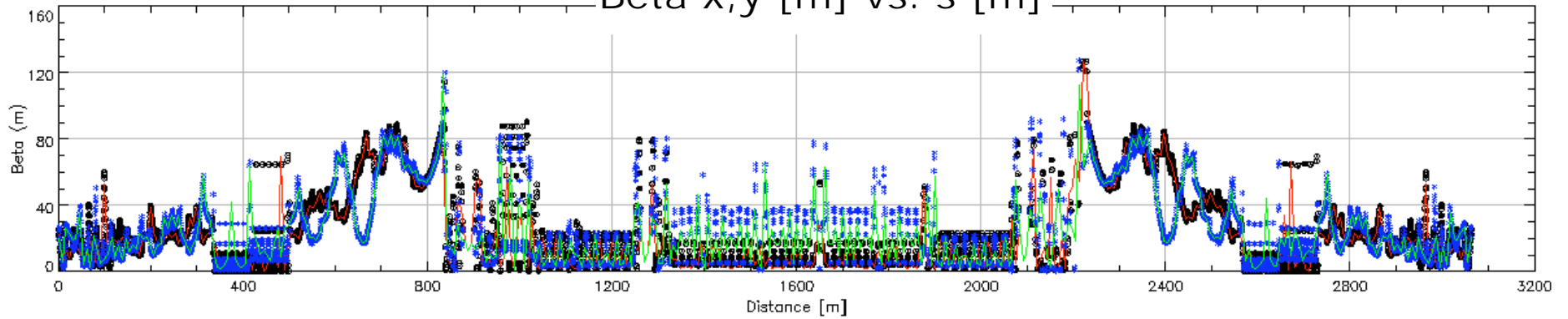
Coherent Synchrotron Radiation
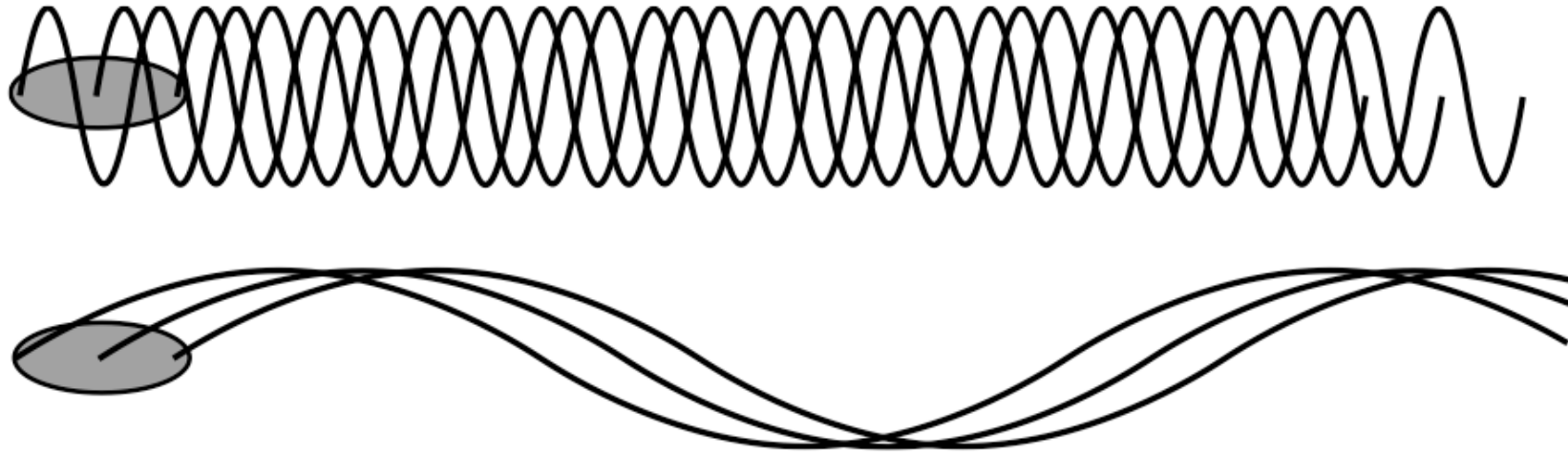
$$\frac{dP^{(N)}}{d\omega} = \left| \sum_{j=1}^{N} e^{i\phi_j} \right|^2 \frac{dP^{(1)}}{d\omega}$$

$$= \left(N + \sum_{j \neq k} e^{i(\phi_j - \phi_k)} \right) \frac{dP^{(1)}}{d\omega}$$

$$= N \left(1 + (N-1) \left| \int \lambda(z) e^{i\omega z/c} \, dz \right|^2 \right) \frac{dP^{(1)}}{d\omega}$$

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Power Spectrum per particle

Saldin et. al. 1-D Kick (1997)

- Tail influences Head (Lienard-Wiechert)
- No Transverse Size (1-D Distribution)

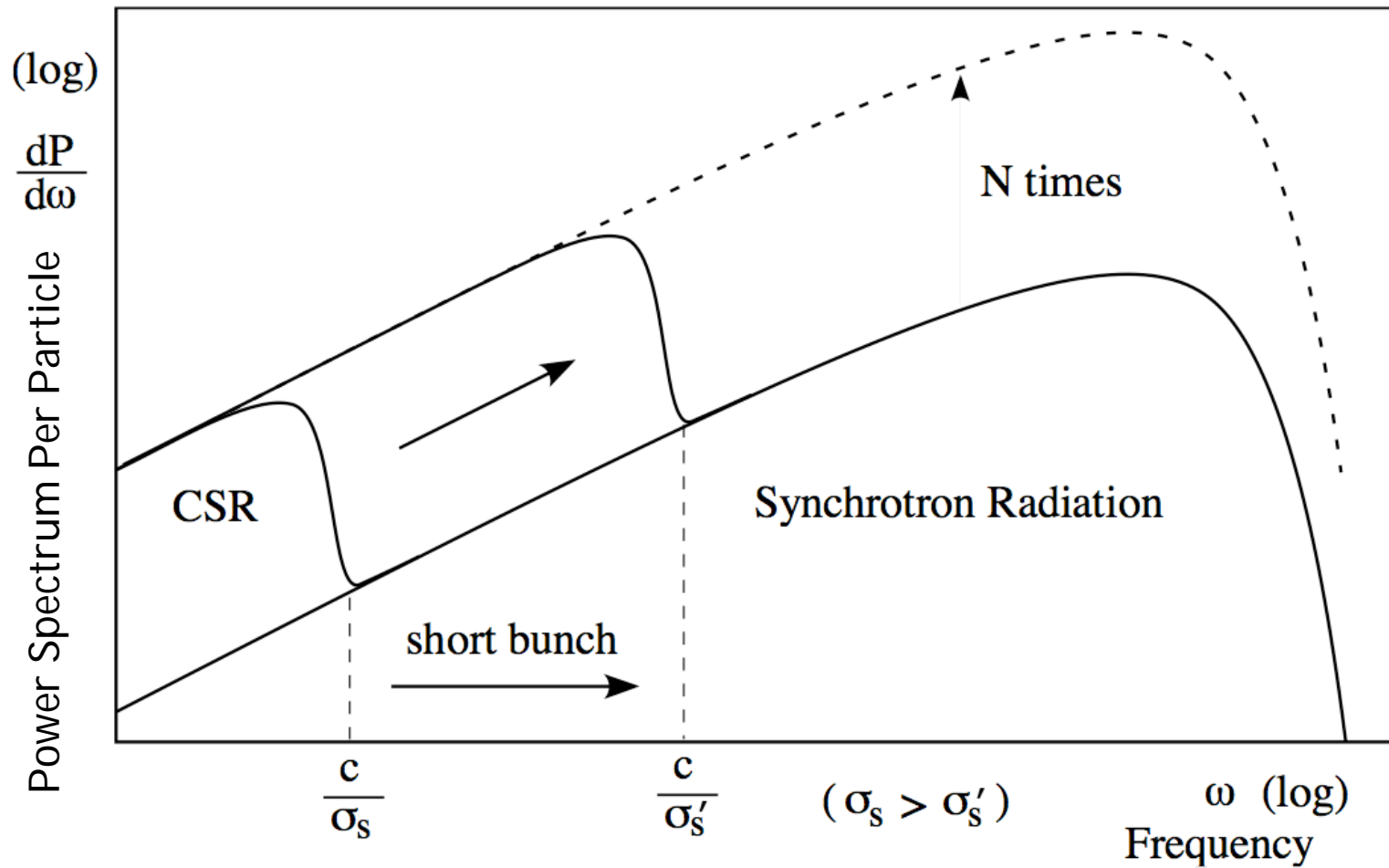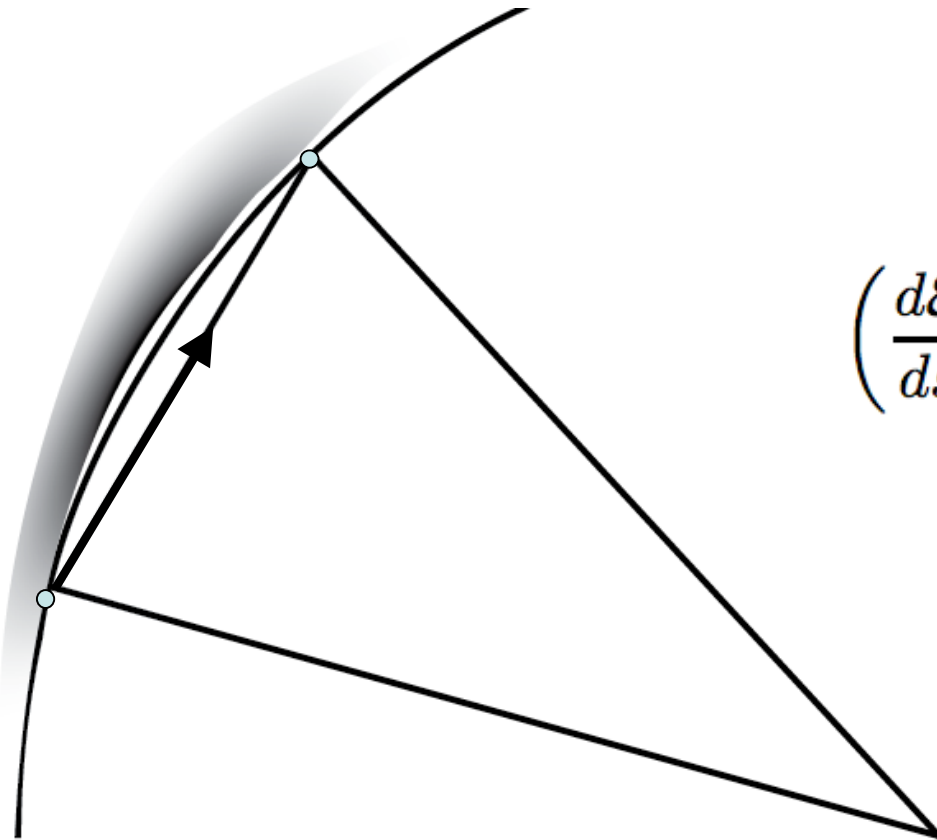$$\left(\frac{d\mathcal{E}}{ds}\right)_{\mathrm{CSR}} = \int_{-\infty}^{\infty} ds' \, \lambda(s') \, K_{\mathrm{CSR}}(s - s')$$

CSR in Mode C

Longitudinal Phase Space at Maximum Compression
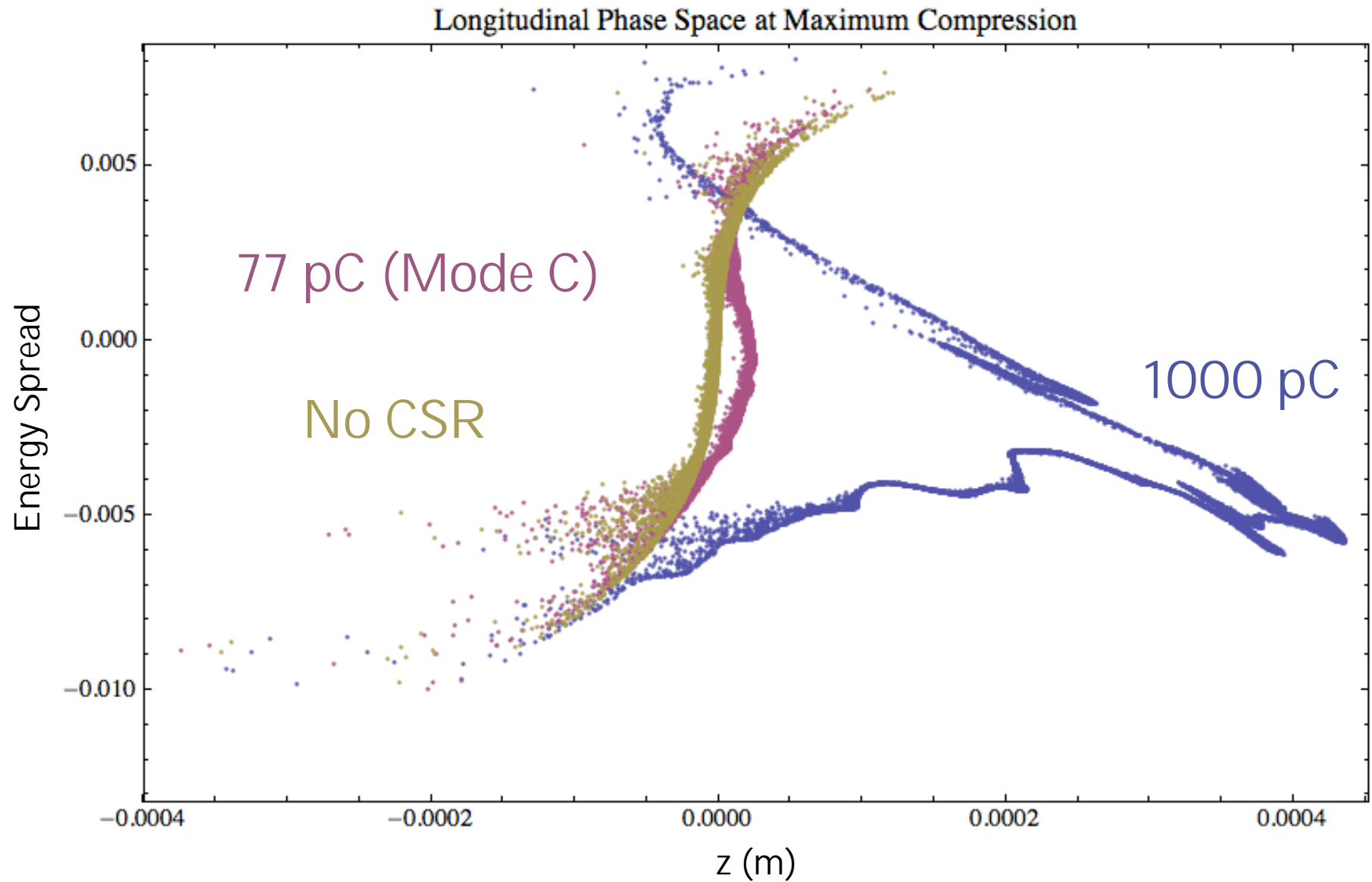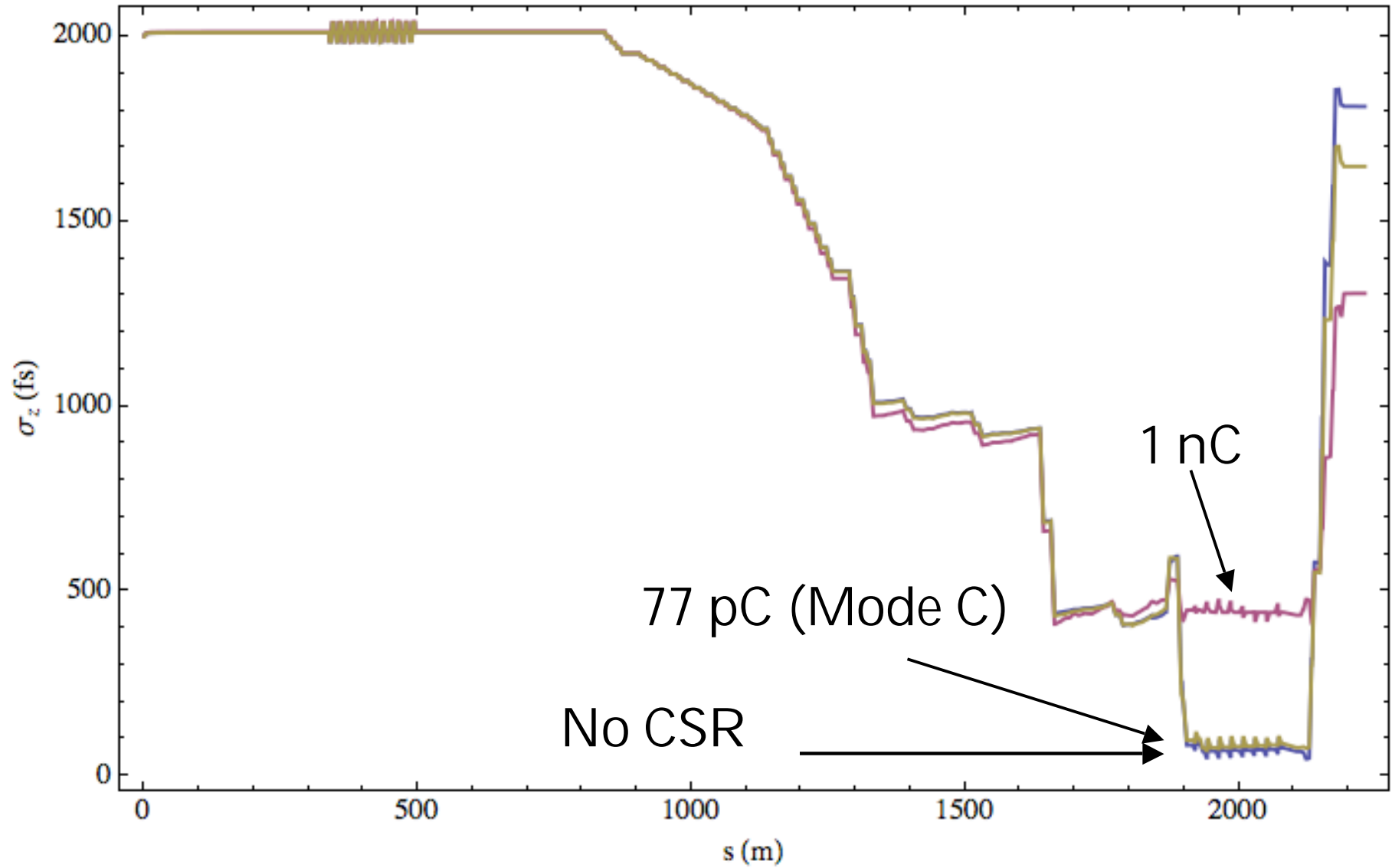
77 pC (Mode C)

No CSR

1000 pC

Energy Spread

z (m)

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CSR in Mode C

Bunch Length

1 nC

77 pC (Mode C)

No CSR

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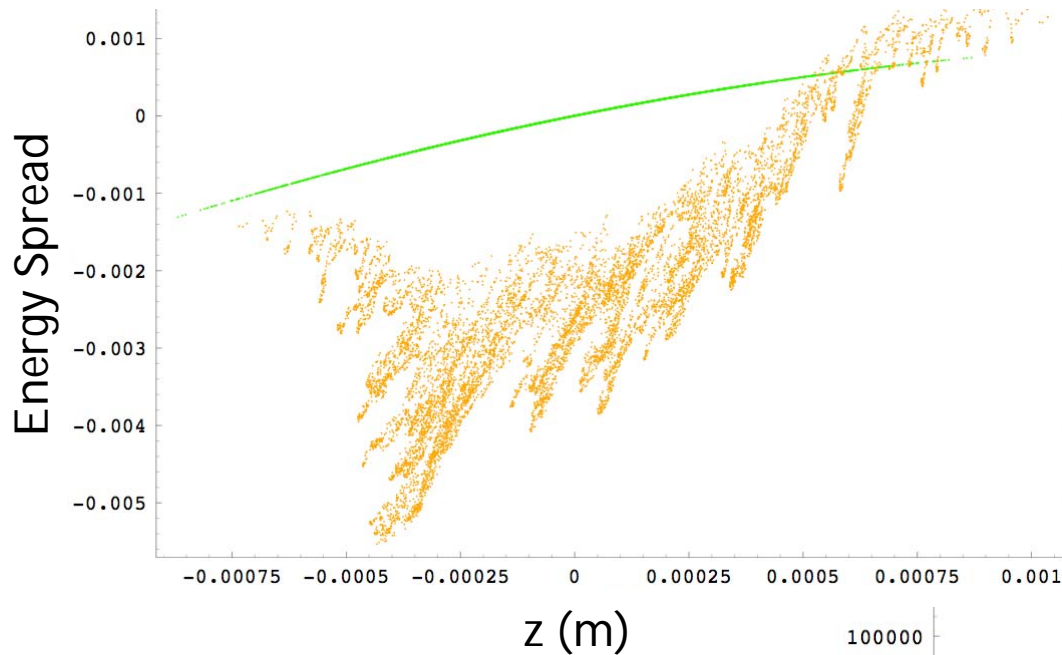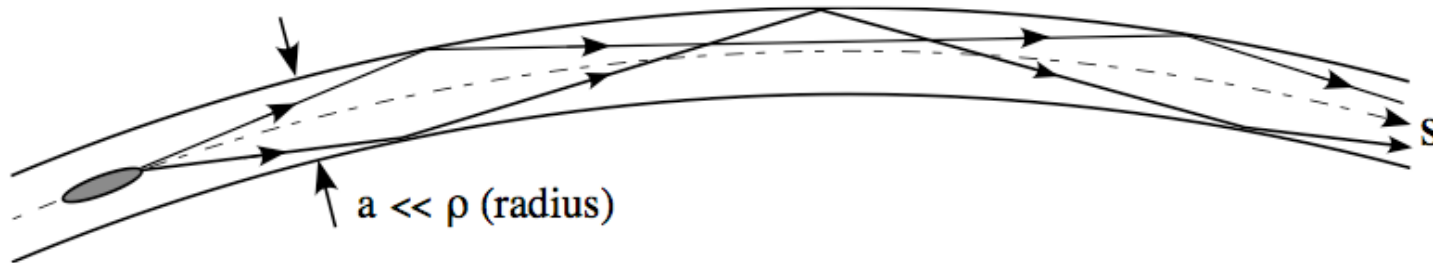
Short Pulses in the Turnaround

ERL Turnaround

- 1ps long bunch
- 1nC charge
- 0.3 mm-mrad normalized emittance
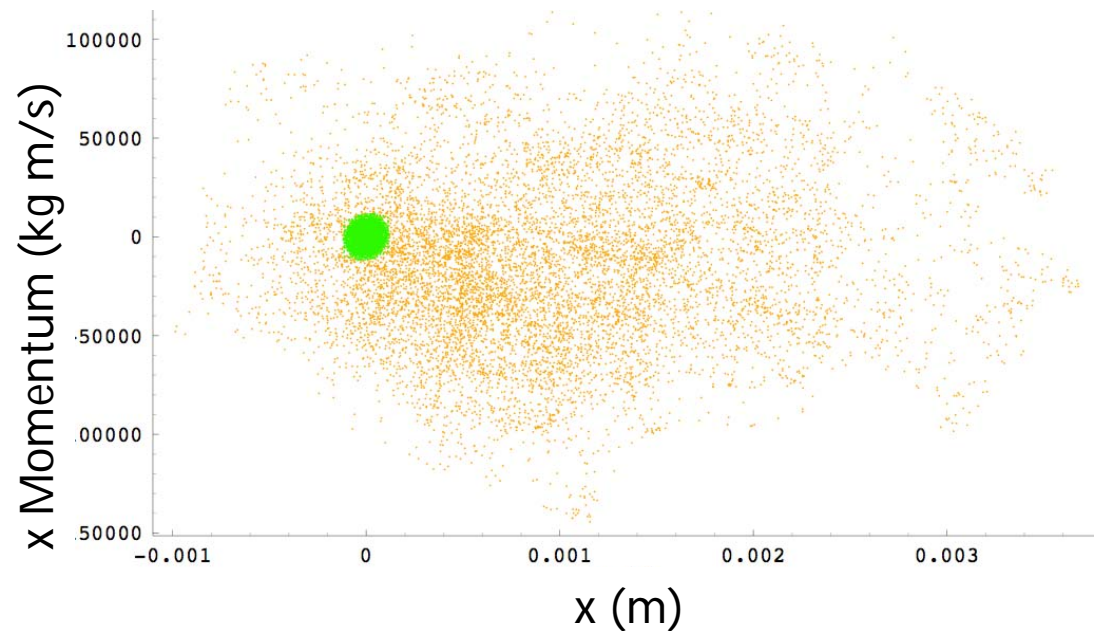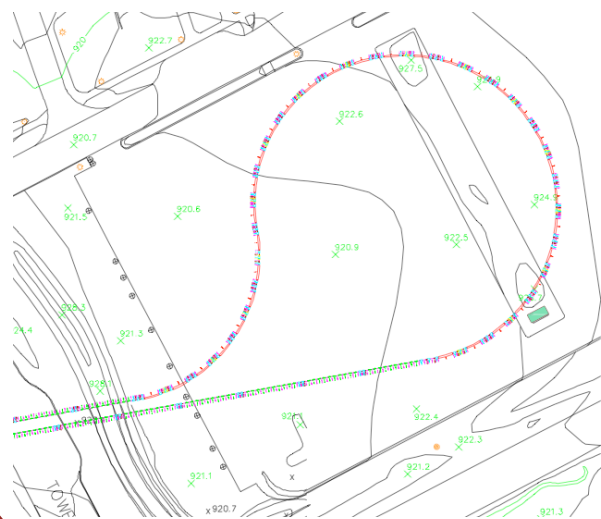
Agoh/Yakoya Mesh (2004)
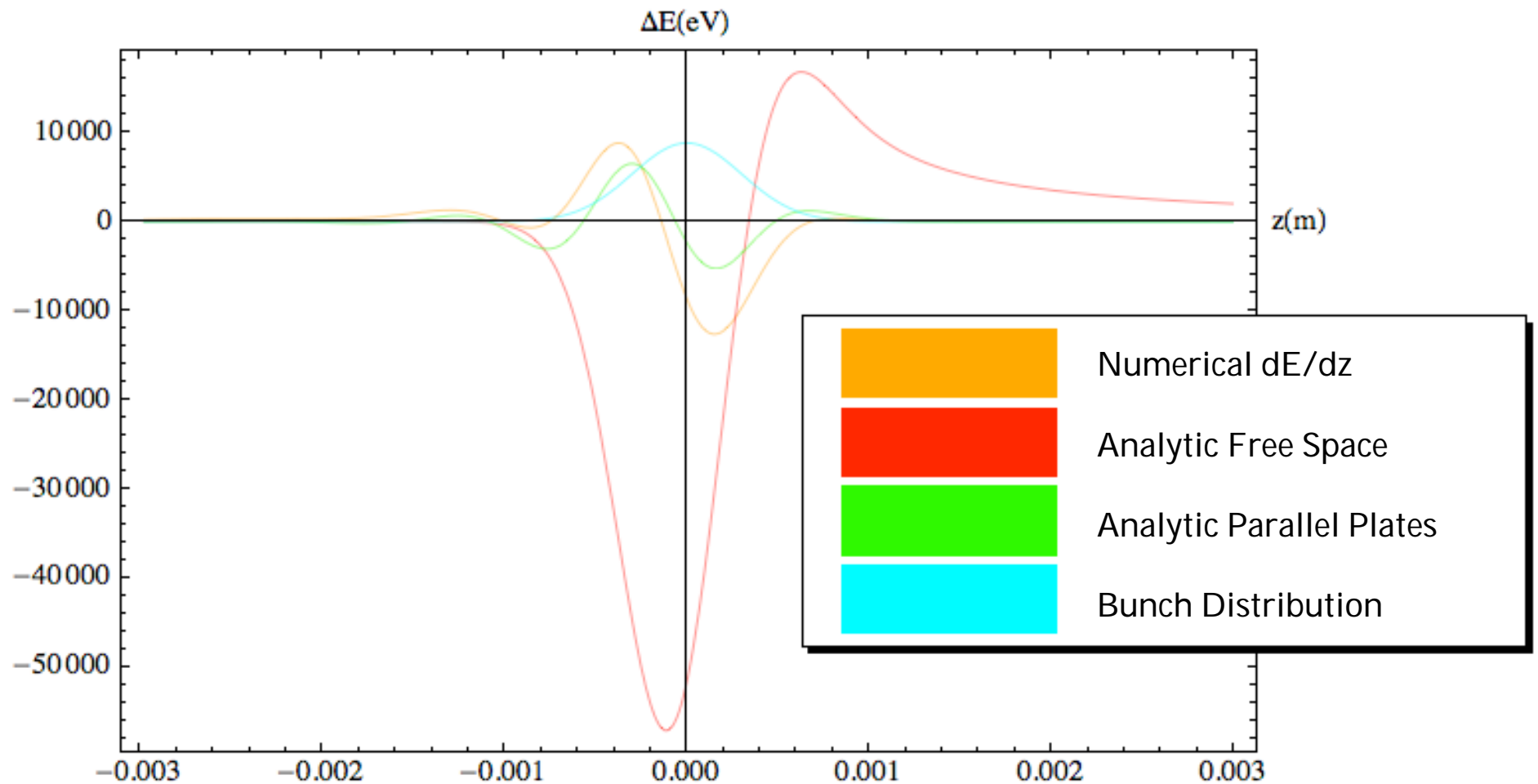

$a \ll \rho$ (radius)

- Approximate Maxwell's Equations
- Discretize Space, Fourier Transform Time
- Propagate Fields, Construct CSR Wake

Initial condition

Evolution

Δs Δs Δs Δs Δs

S_{-1} S_0 S_1 S_2 S_3 S_4 S_5
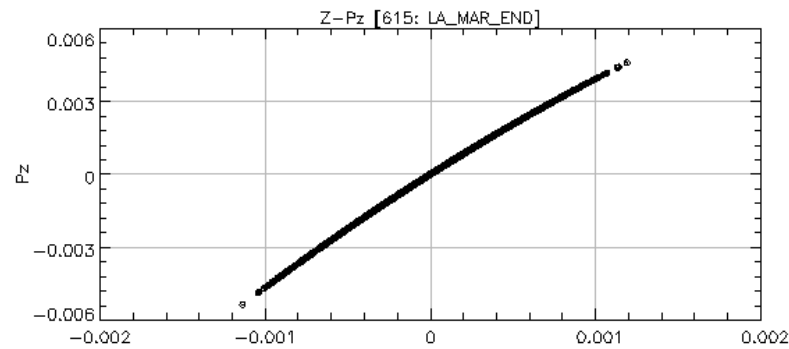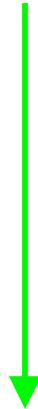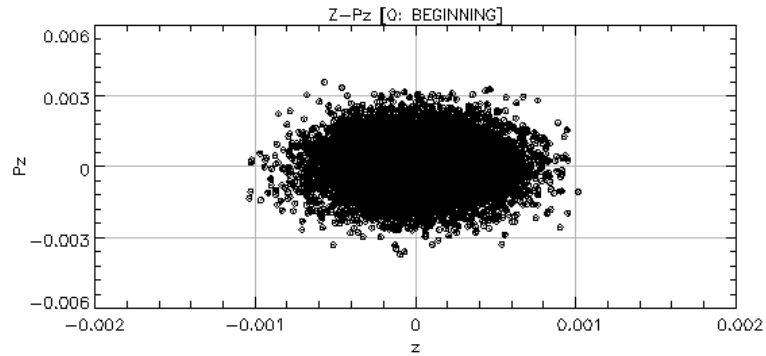
S

y

Δx

Δy

h

0

x

w
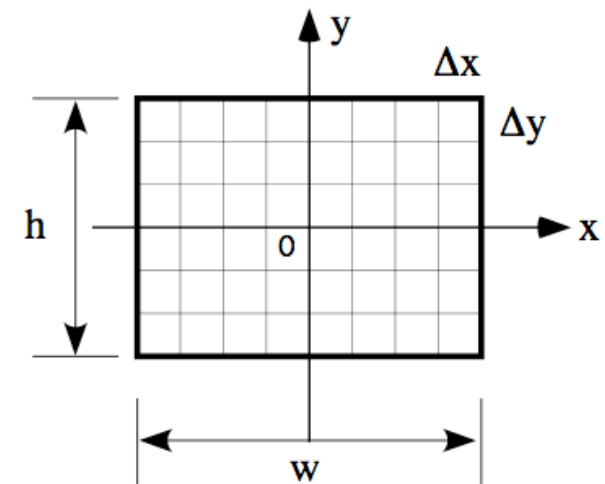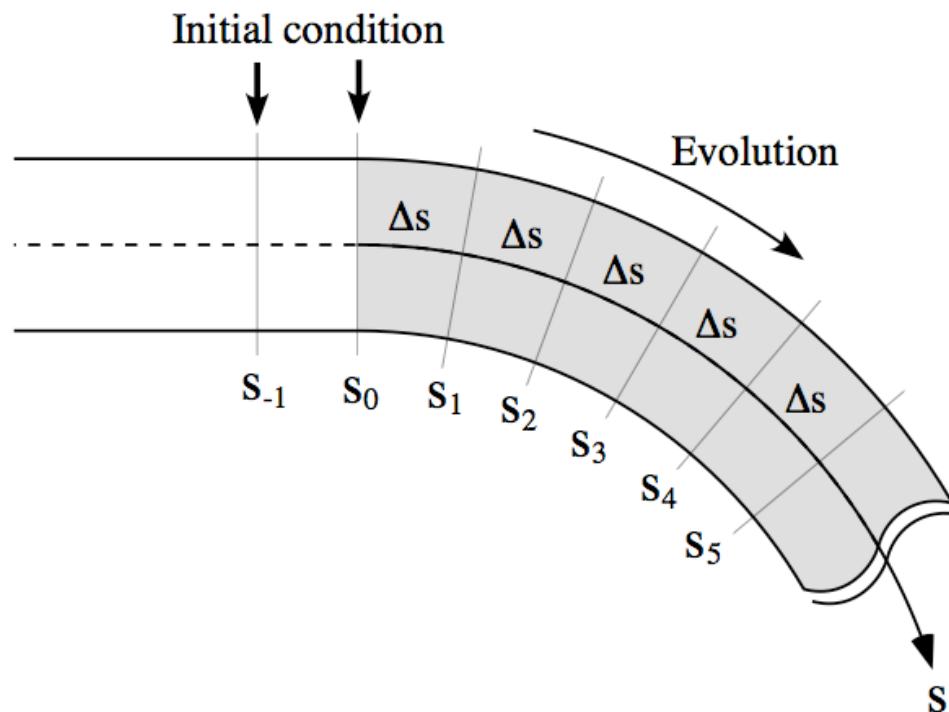
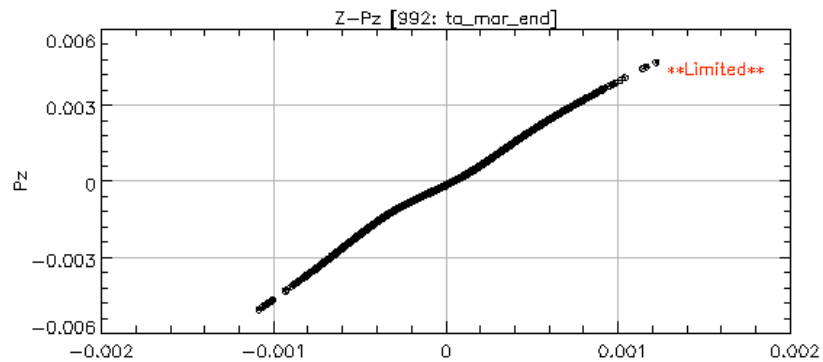rectangular cross section
(boundary condition)

Shielding Wake Fields

800 pC
1 ps
5cm x 1cm beam chamber
Magnet L = 1m, rho ~ 7m

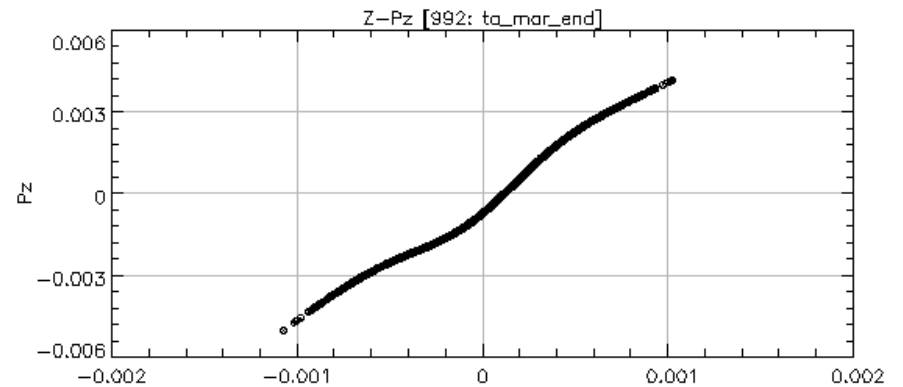# Shielding in the Turnaround

h = 1cm

h = 5cm

Some Conclusions

- CSR is not a problem for our current operating modes

- 5 GeV high charge short pulses have problems

- The CSR shielding effect may alleviate these issues

End

Energy Spread after Energy Recovery with CSR

1 MeV

Sigma Z (nm) [model], X-axis: s