Extension and Consolidation of Mathematical Packages for LHC Beam Optics and Geometry Calculations

A. M. DeMaio

BE-ABP-HSS

Steps...

1. Database

2. Web availability

3. Automation

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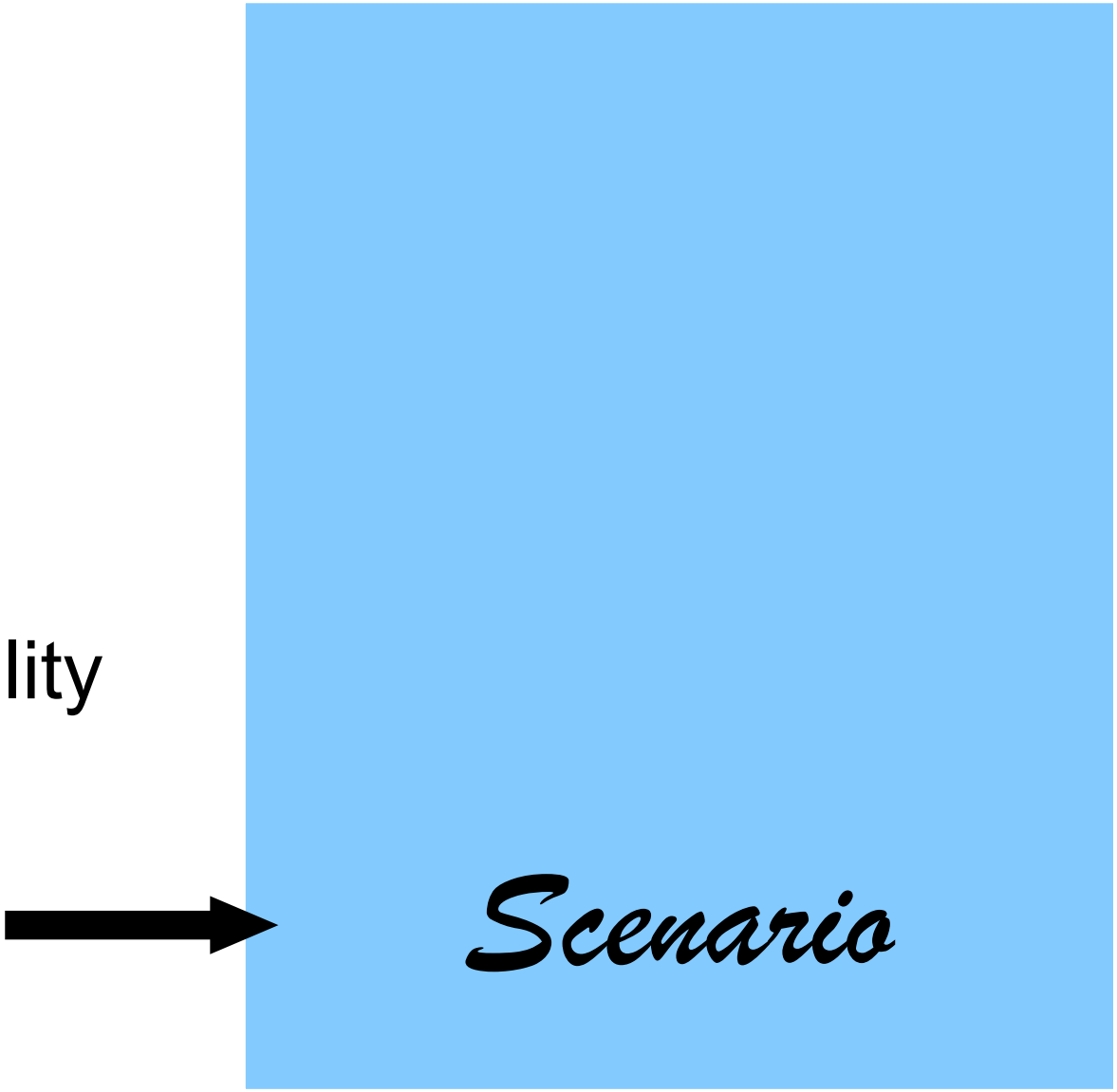

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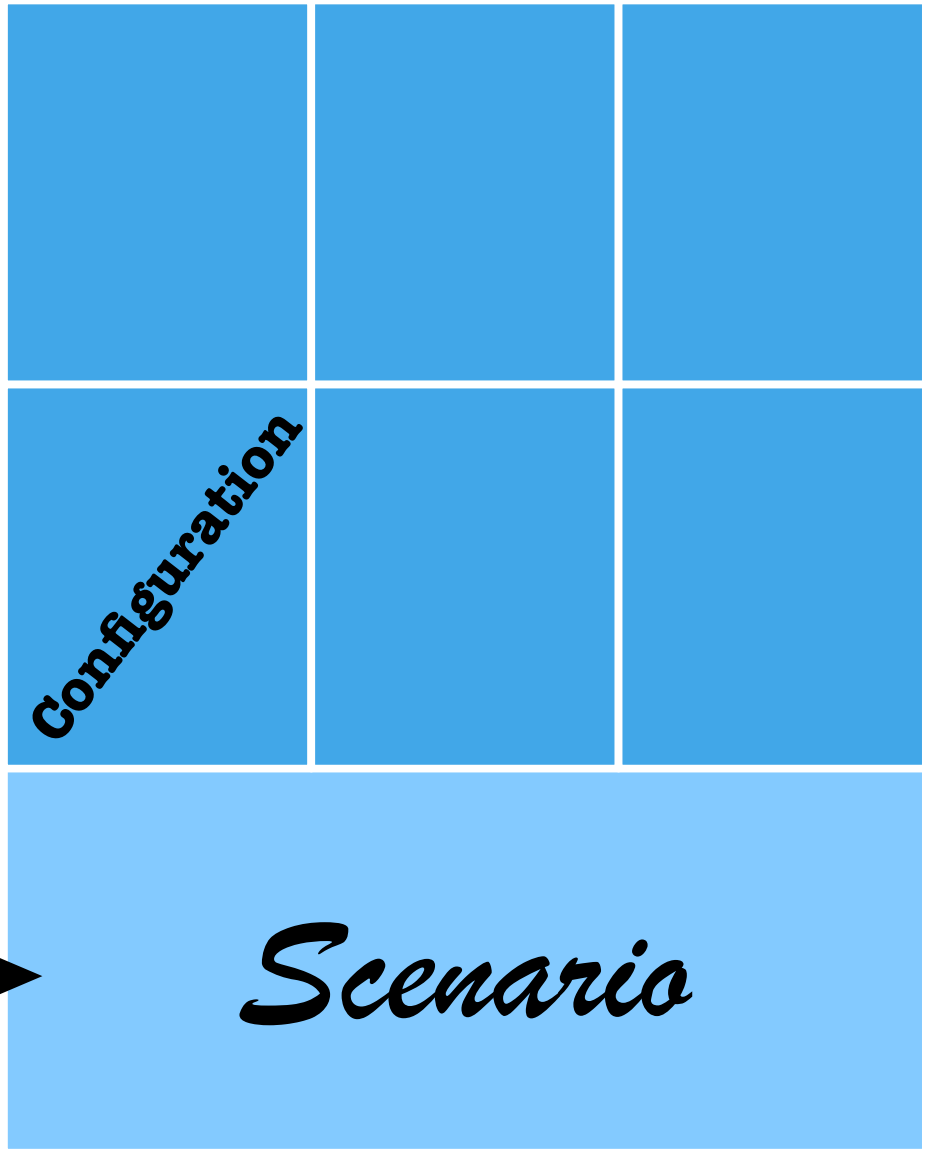

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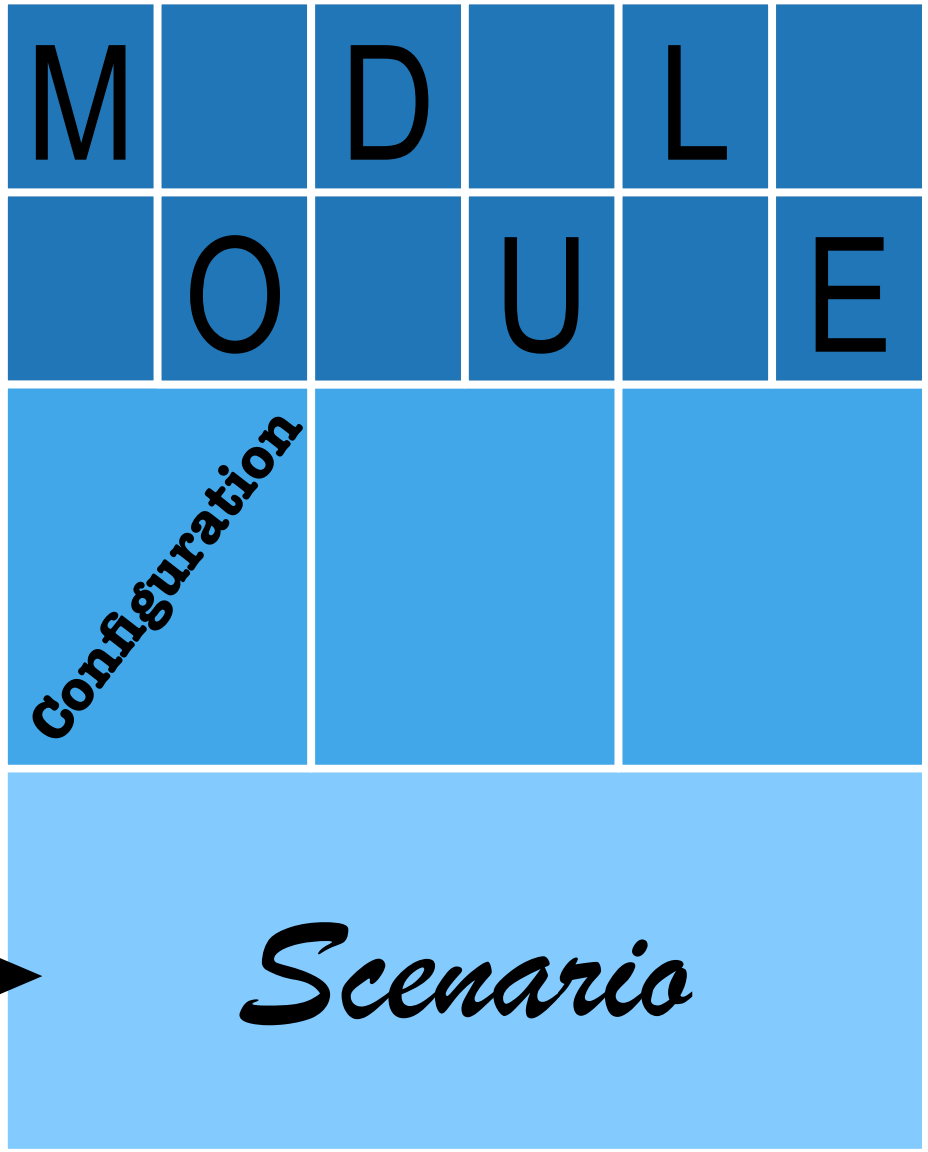
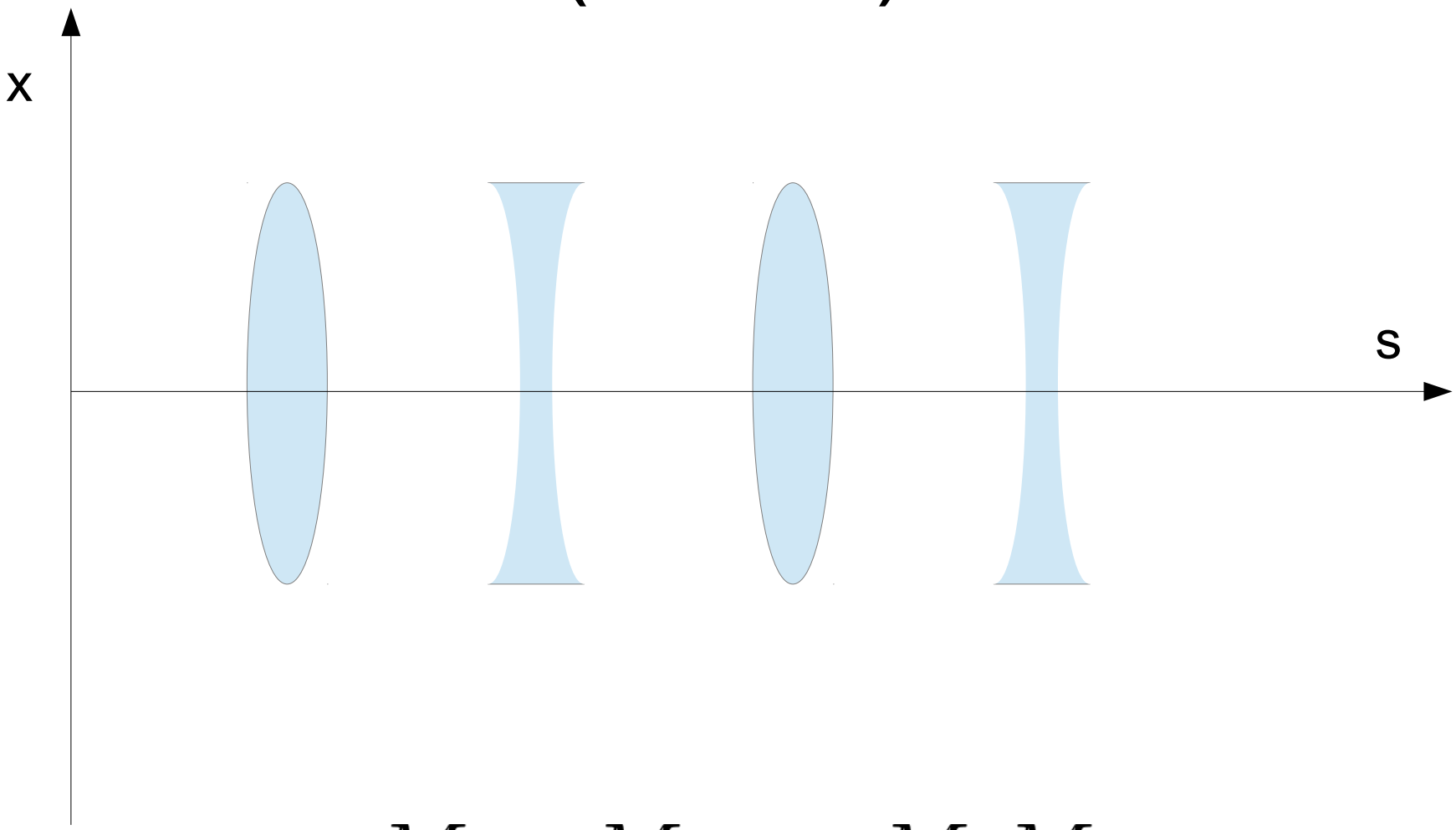


Beam optics: the study of particle paths

Lenses!

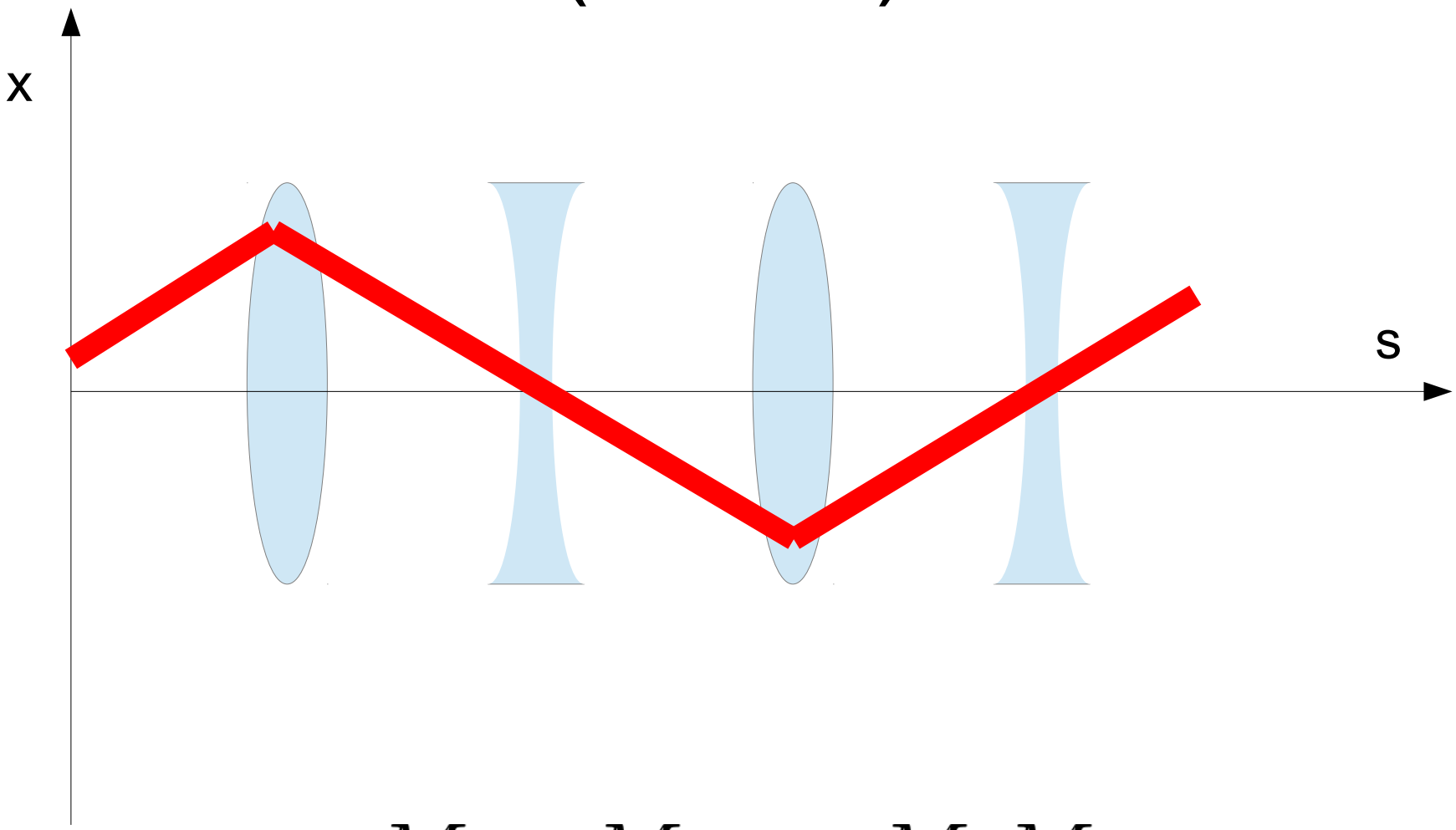
(quadrupole magnets)

Strong Focusing (FODO)



$$M = M_n \cdots M_2 M_1$$

Strong Focusing (FODO)



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Why Strong Focusing?

$$M^n \binom{x}{x'}_{in} \rightarrow \quad \textbf{\textit{stable}}$$

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$$-1 \leq \frac{1}{2}\mathrm{Tr} M \leq 1$$

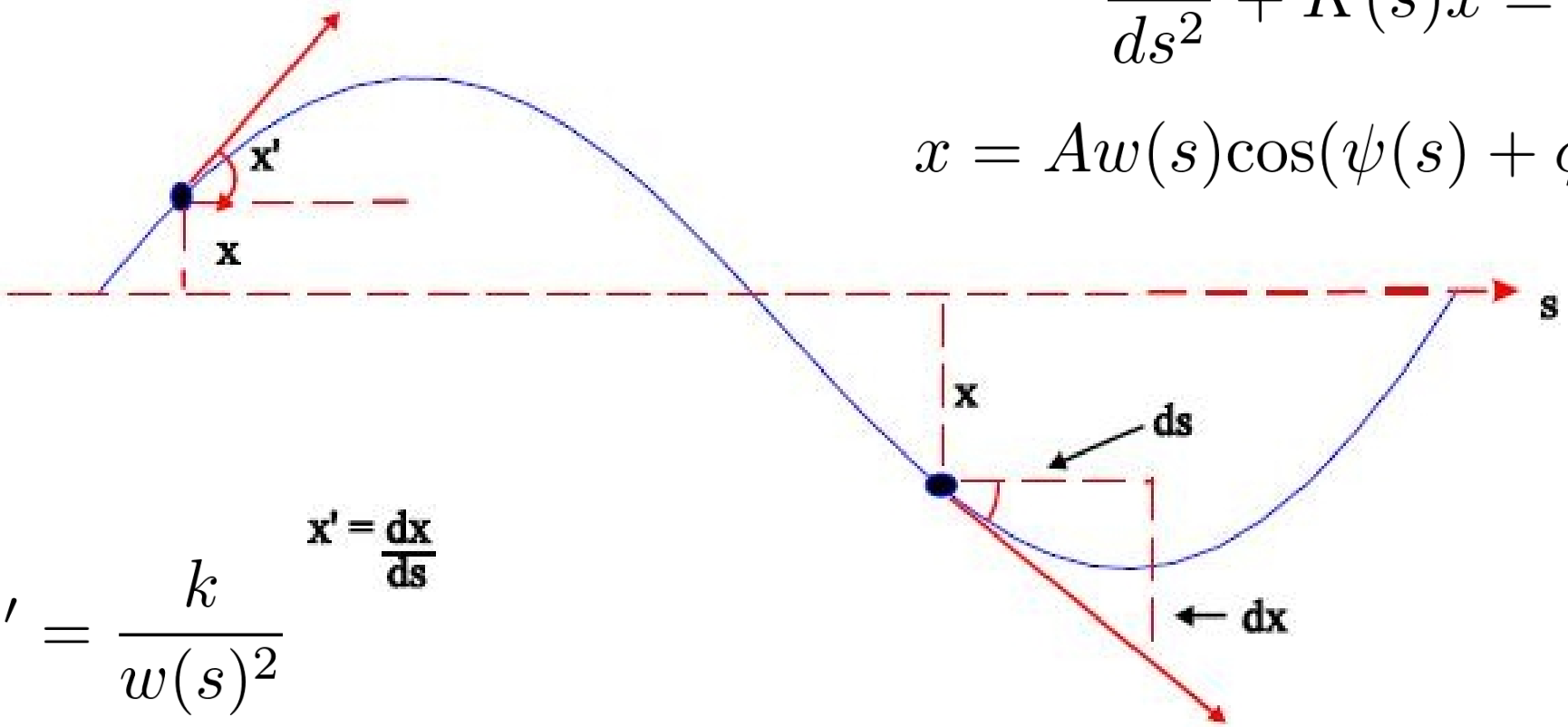
$$M = \begin{pmatrix} 1 - \frac{L}{f} - \left(\frac{L}{f}\right)^2 & 2L + \frac{L^2}{f} \\ -\frac{L}{f^2} & 1 + \frac{L}{f} \end{pmatrix} \qquad \left|\frac{L}{2f}\right| \leq 1$$

Equations of Motion

$$\frac{d^2x}{ds^2} + Kx = 0$$

$$\frac{d^2x}{ds^2} + K(s)x = 0$$

$$x = Aw(s)\cos(\psi(s) + \phi)$$



$$x' = \frac{dx}{ds}$$

$$\psi' = \frac{k}{w(s)^2}$$

$$\beta(s) \equiv \frac{w^2(s)}{k} \;\rightarrow\; \Delta\psi_C = \int_{s_0}^{s_0+C} \frac{ds}{\beta(s)}$$

$$x = A\sqrt{\beta(s)}\cos(\psi(s) + \phi) \;\rightarrow\; x = \sqrt{\epsilon \cdot \beta(s)}\cos(\psi(s) + \phi)$$

[2]

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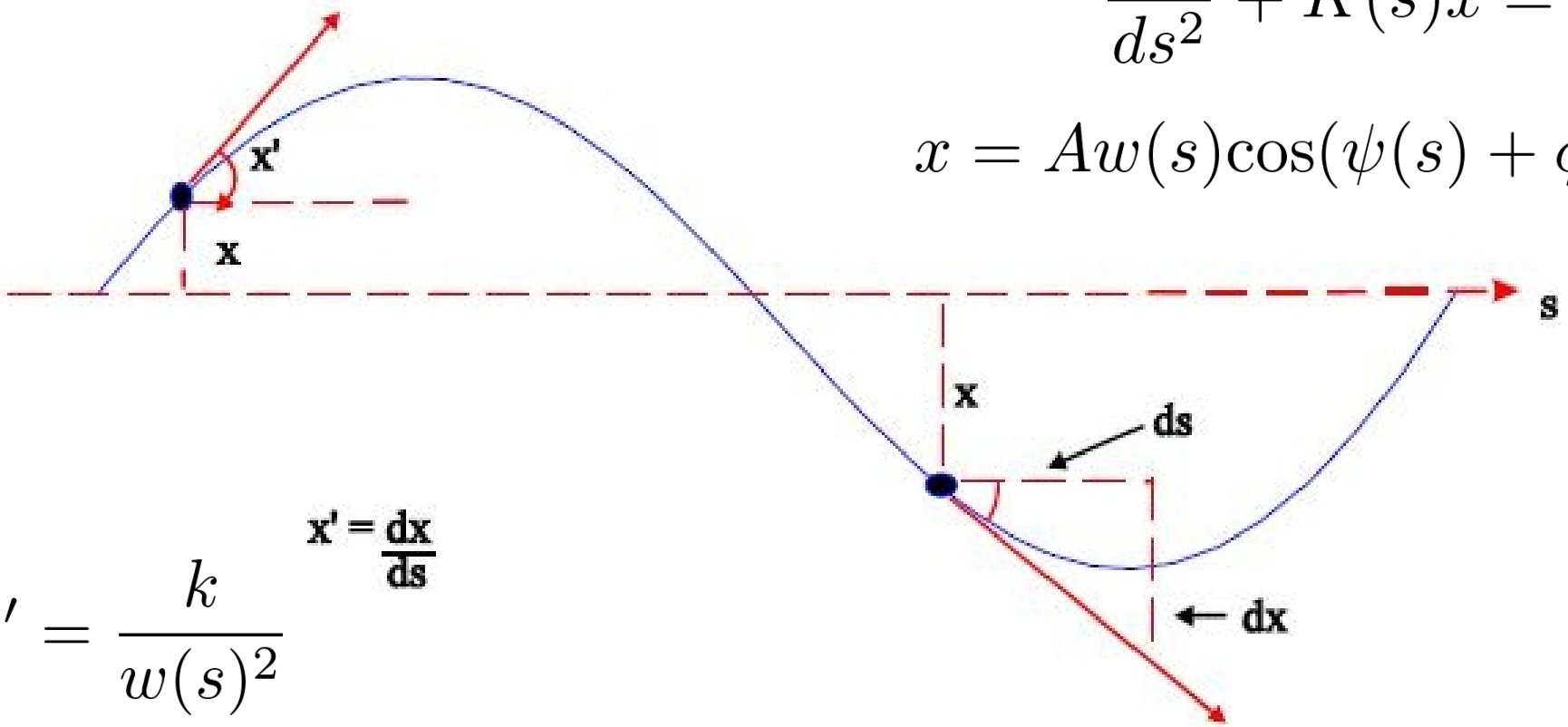

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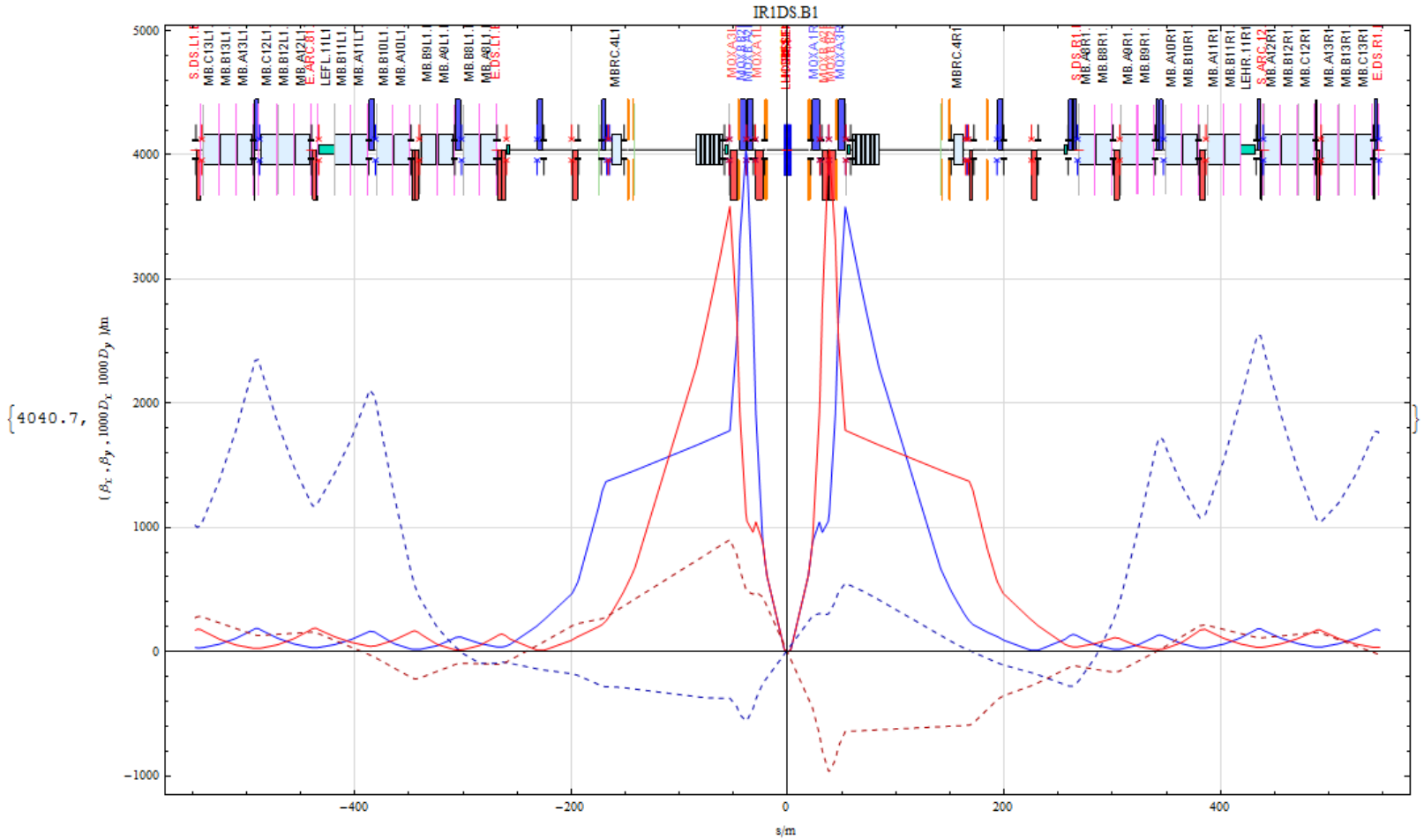
[2]

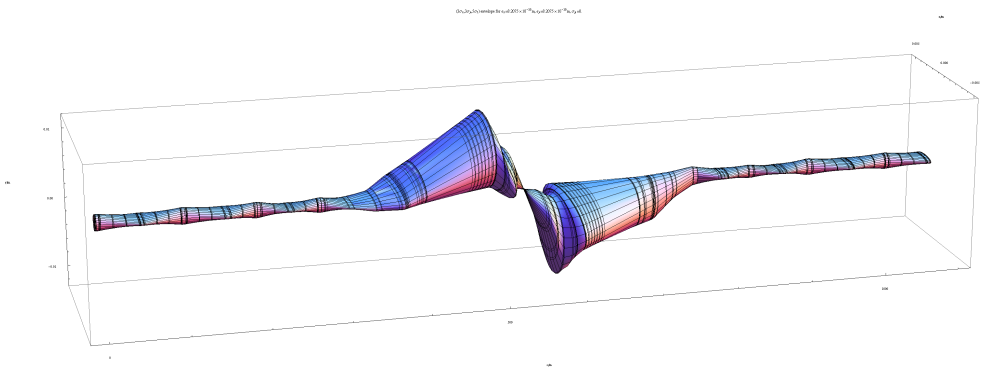
Momentum Dispersion

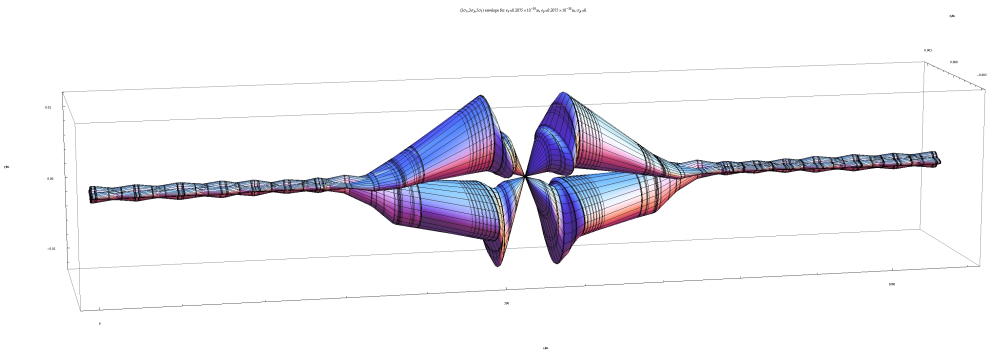
Chromatic aberration!

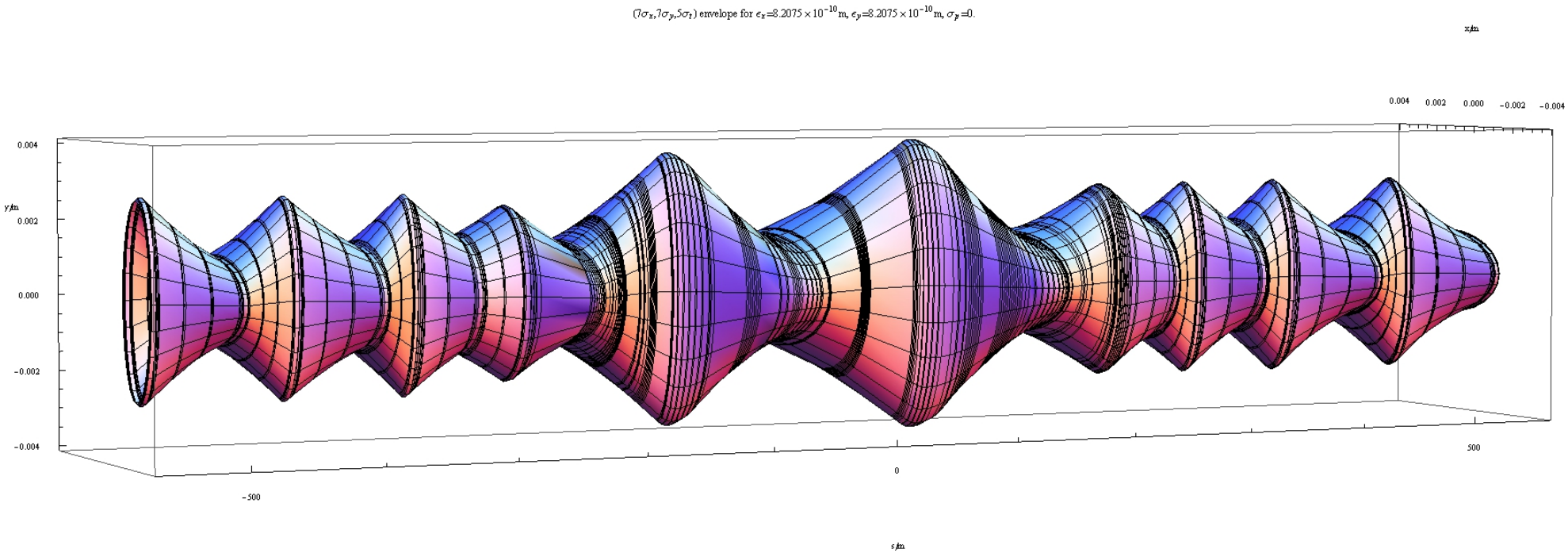
$$x = D(p, s)\frac{\Delta p}{p_0}$$

$$D'' + \frac{1}{\rho^2}\frac{2p_0 - p}{p} + \frac{B'}{B\rho}\frac{p_0}{p}D = \frac{1}{\rho}\frac{p_0}{p}$$


IR1DS.B1
5000
4000
3000
2000
1000
0
−1000
−400
−200
0
200
400
s/m
$(\beta_x, \beta_y, 1000 D_x, 1000 D_y)$/m
{4040.7,
}
S.DS.L1.
MB.C13L1.
MB.B13L1.
MB.A13L1.
MB.C12L1.
MB.B12L1.
MB.A12L1.
E.ARC.81
LEF.L11L1
MB.B11L1.
MB.A11L1.
MB.B10L1.
MB.A10L1.
MB.B9L1.
MB.A9L1.
MB.B8L1.
MB.A8L1.
E.DS.L1.1
MBRC.4L1
MQXA3L
MQXB.B2L
MQXB.A2L
MQXA1L
MQXA1R
MQXB.B2R
MQXB.A2R
MQXA3R
MBRC.4R1
S.DS.R1.1
MB.A8R1.
MB.B8R1.
MB.A9R1.
MB.B9R1.
MB.A10R1.
MB.B10R1.
MB.A11R1.
MB.B11R1.
LEHR.11R1
S.ARC.12
MB.A12R1.
MB.B12R1.
MB.C12R1.
MB.A13R1.
MB.B13R1.
MB.C13R1.
E.DS.R1.1

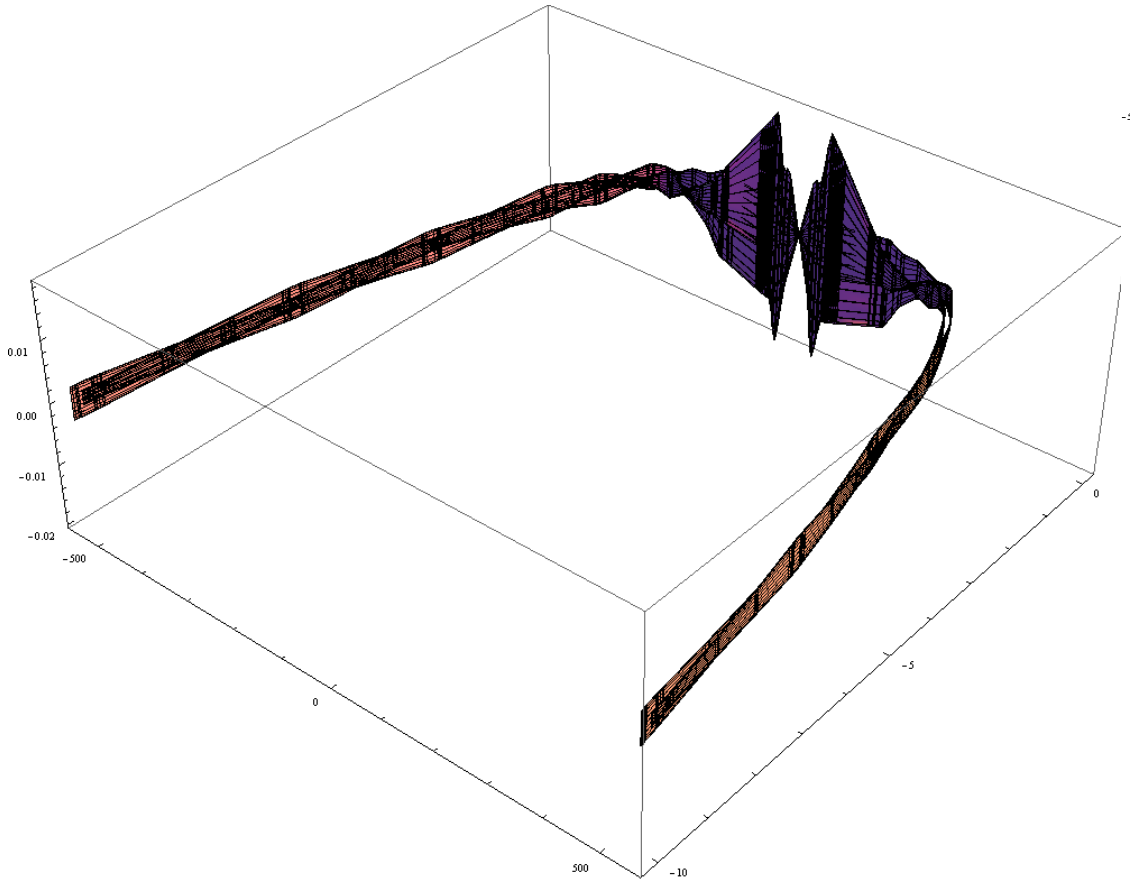


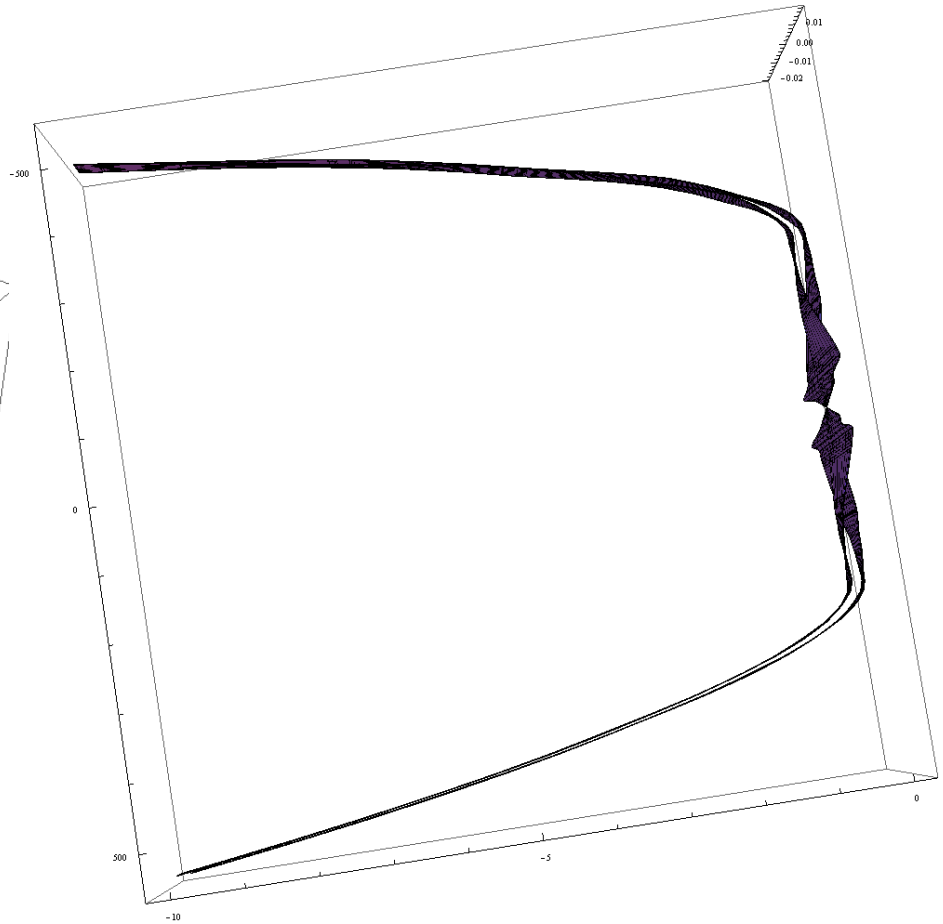


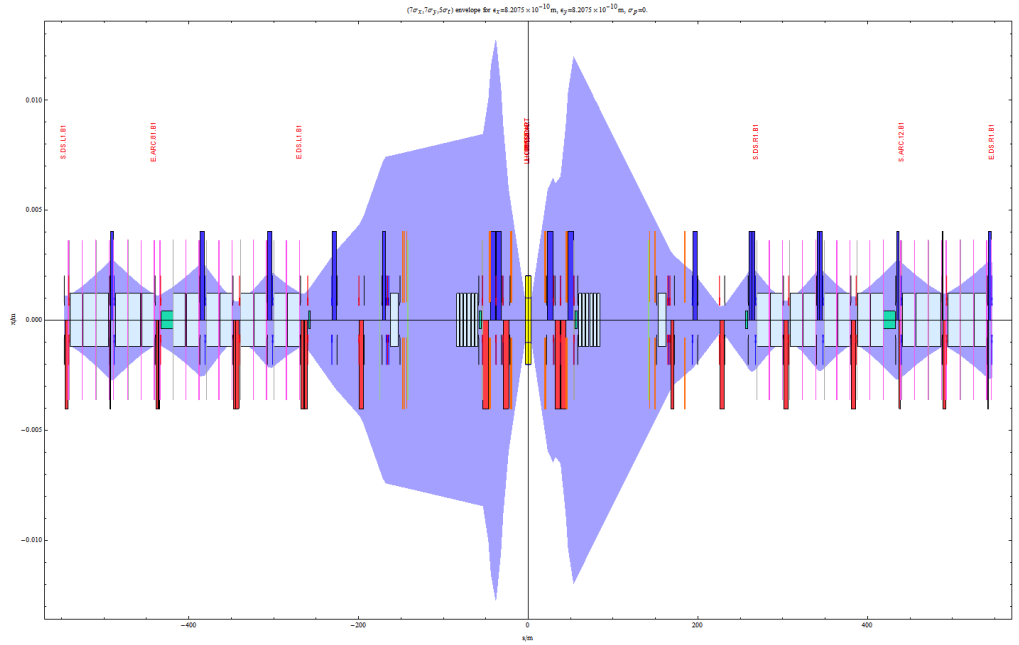


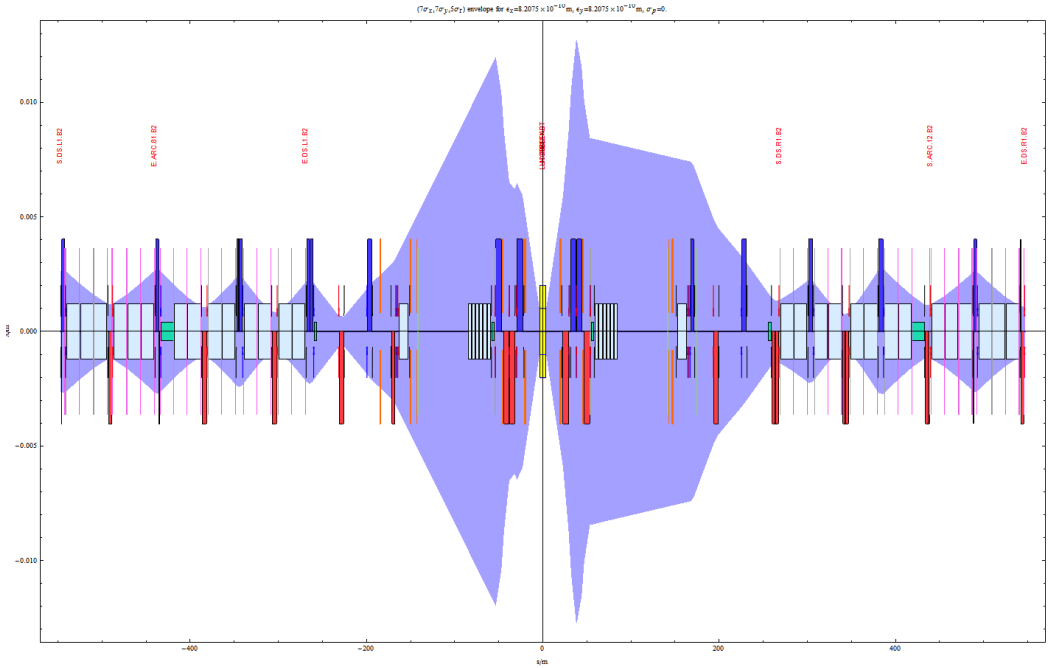
$$\sigma_x^2 = \frac{\beta_x \epsilon_x}{\pi} + D_x^2 \sigma_\epsilon^2$$

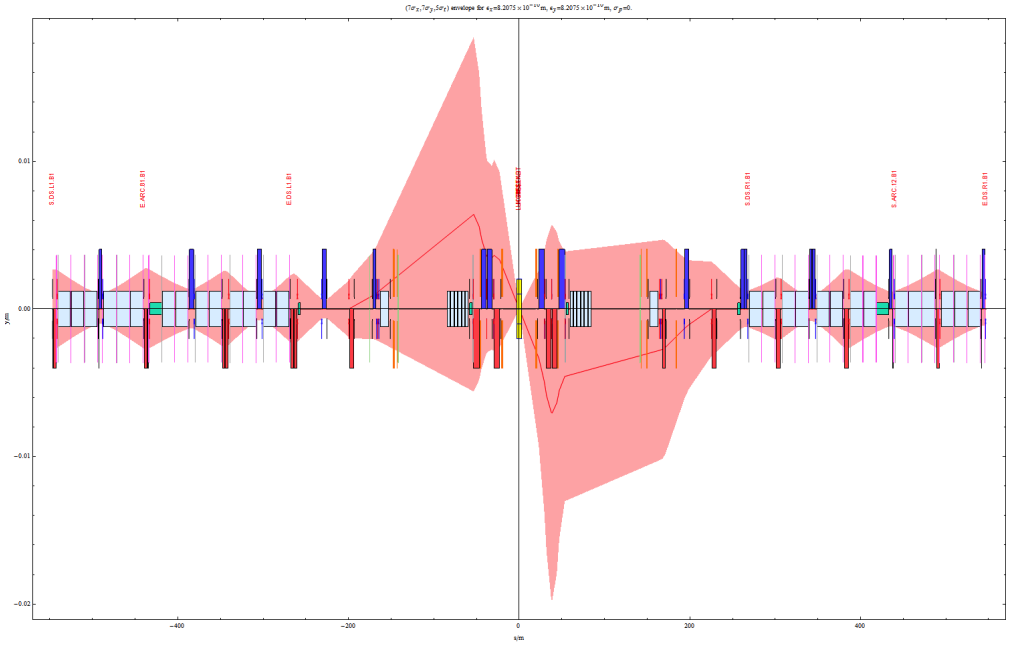
Global Cartesian Envelope Plots

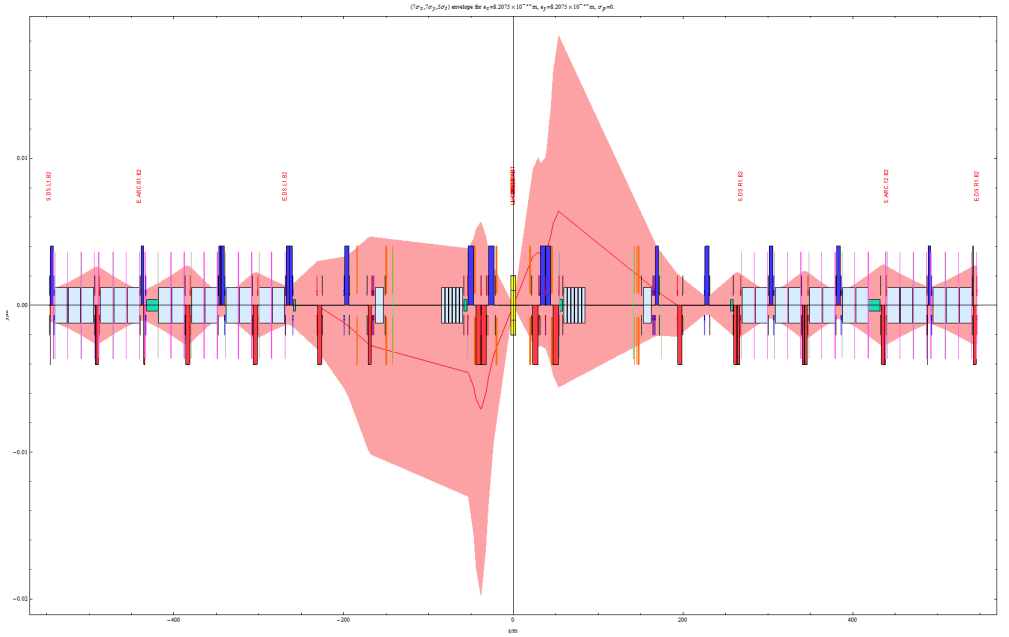


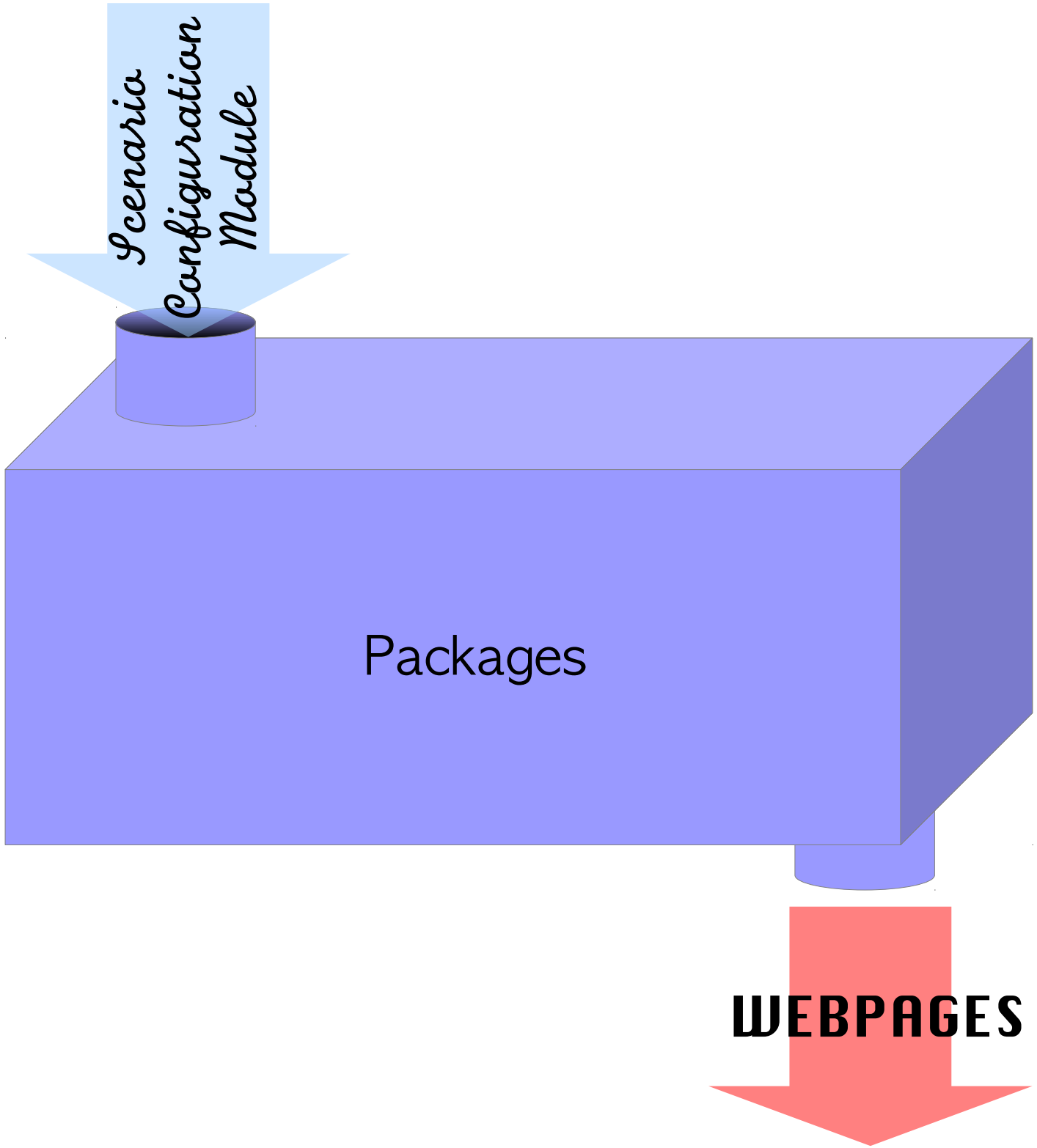


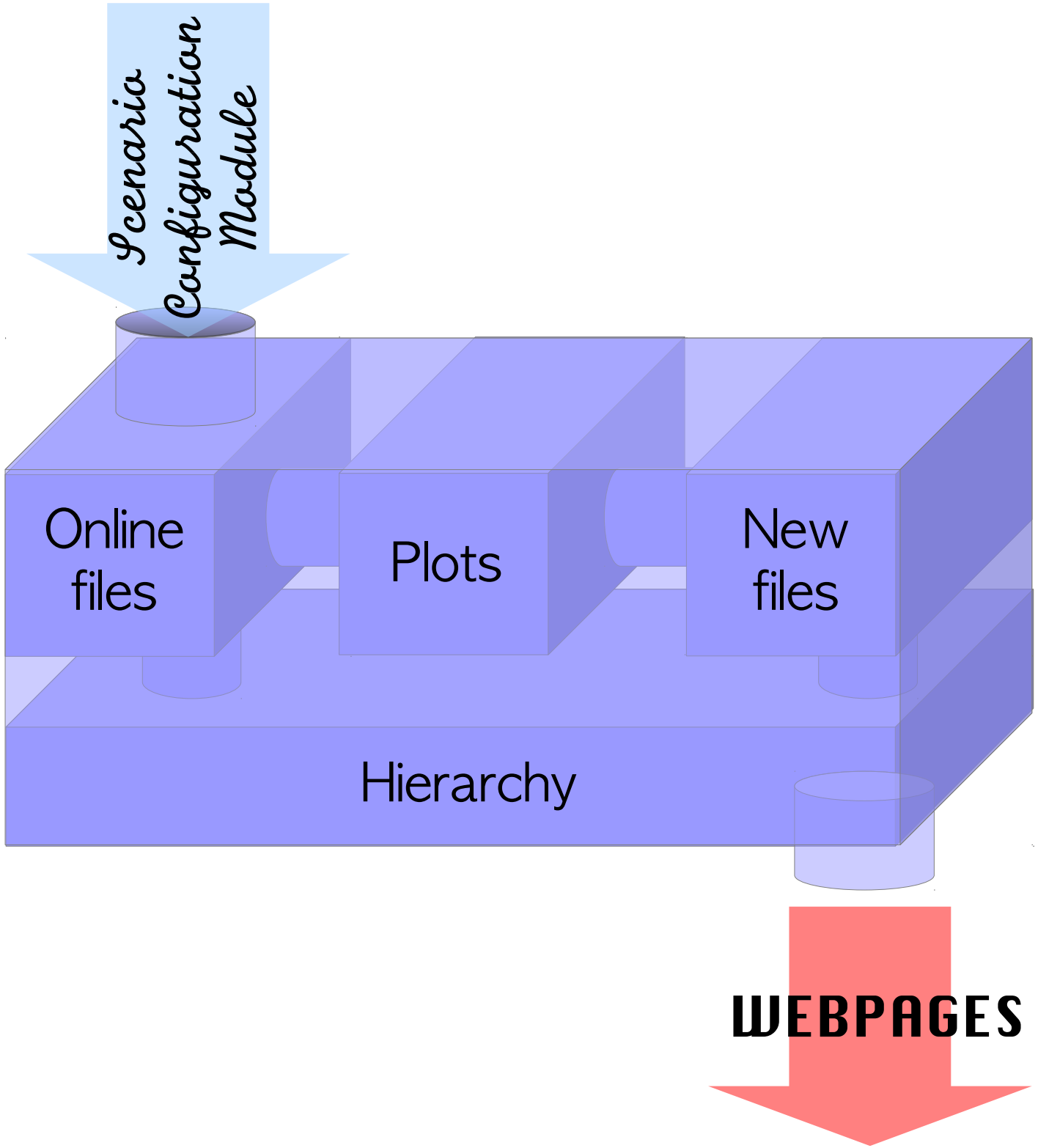

S.DS.L1.B1
E.ARC.B1.B1
E.DS.L1.B1
S.DS.R1.B1
S.ARC.12.B1
E.DS.R1.B1
0.010
0.005
0.000
−0.005
−0.010
−400
−200
0
200
400
s/m


S.DS.L1.B2
E.ARC.B1.B2
E.DS.L1.B2
S.DS.R1.B2
S.ARC.12.B2
E.DS.R1.B2
0.010
0.005
0.000
−0.005
−0.010
−400
−200
0
200
400
s/m


S.DS.L1.B1
E.ARC.B1.B1
E.DS.L1.B1
S.DS.R1.B1
S.ARC.12.B1
E.DS.R1.B1
0.01
0.00
−0.01
−0.02
−400
−200
0
200
400
s/m


S.DS.L1.B2
E.ARC.B1.B2
E.DS.L1.B2
S.DS.R1.B2
S.ARC.12.B2
E.DS.R1.B2
0.01
0.00
−0.01
−0.02
−400
−200
0
200
400
s/m


Scenario Configuration Module
Packages
WEBPAGES


Scenario Configuration Module
Online files
Plots
New files
Hierarchy
WEBPAGES

Webpages

pprun1, coll_4tev, IR1DS

Download B1 data as .csv

Download B2 data as .csv

Beamline Plots

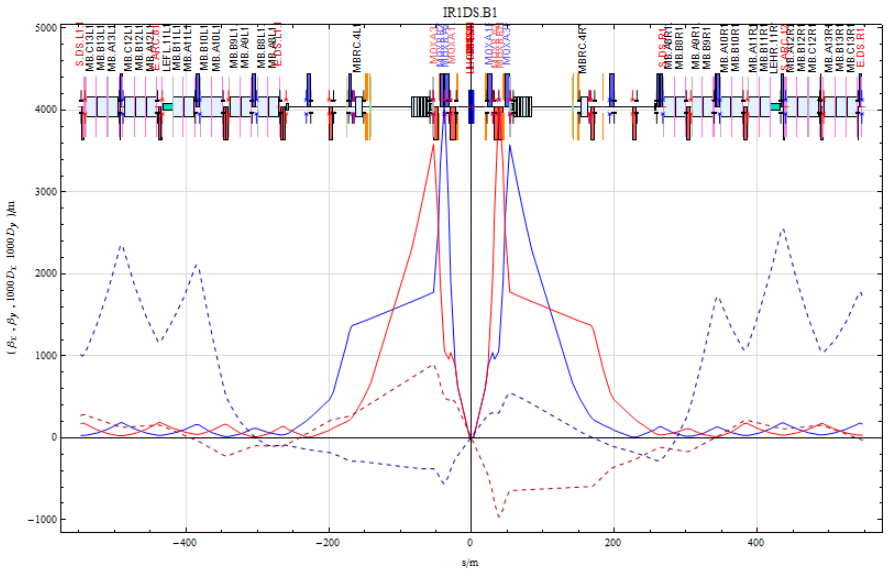
2D Envelope Plots

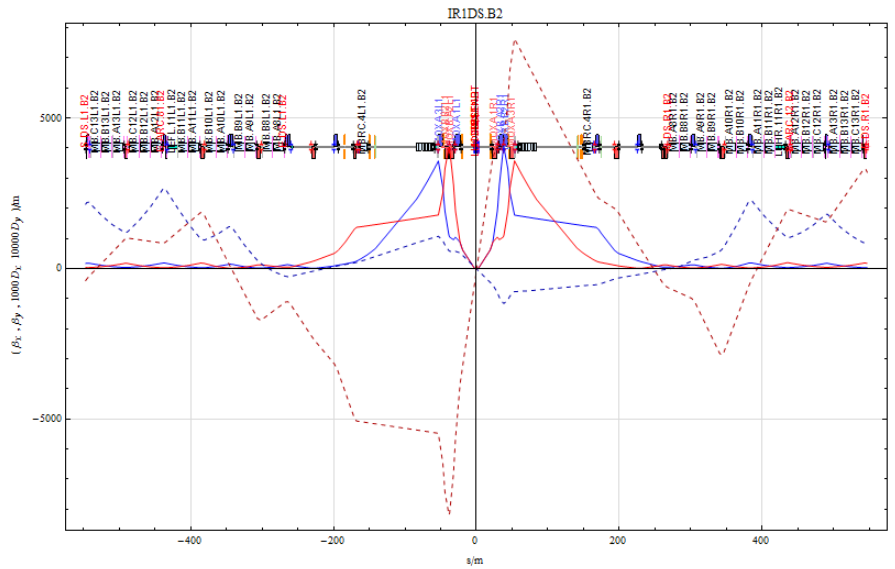
3D Envelope Plots (CS Coordinates)

3D Global Envelope Plots

Beamline Plots

β_x shown in red solid line, β_y shown in blue solid line, DispersionX shown in red dotted line, DispersionY shown in blue dotted line



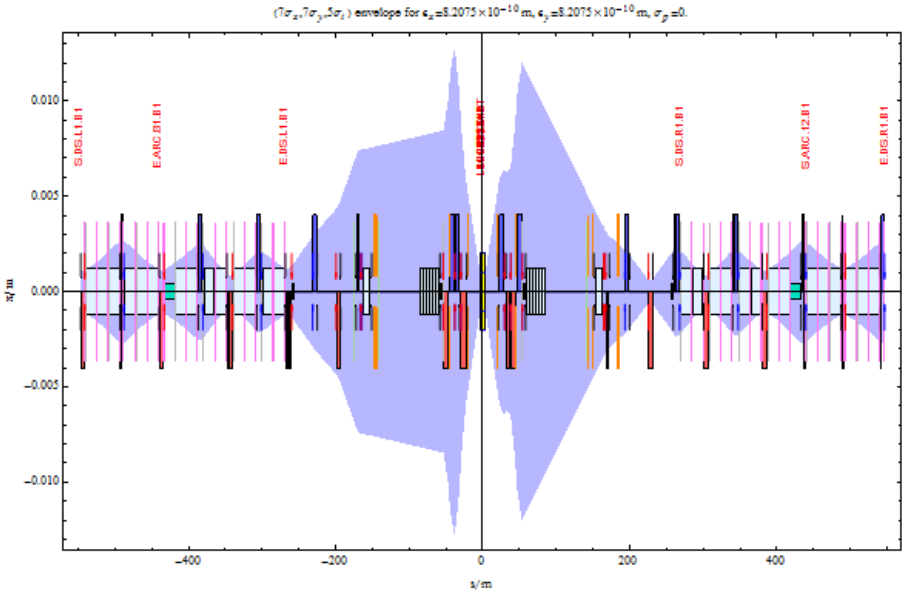


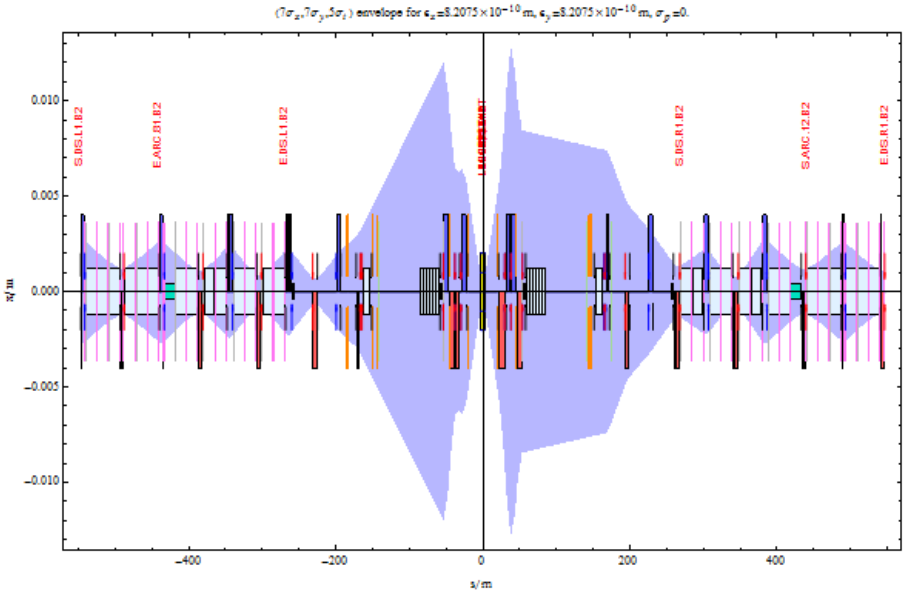
Download B1 plot as .m

Download B2 plot as .m

2D Envelope Plots

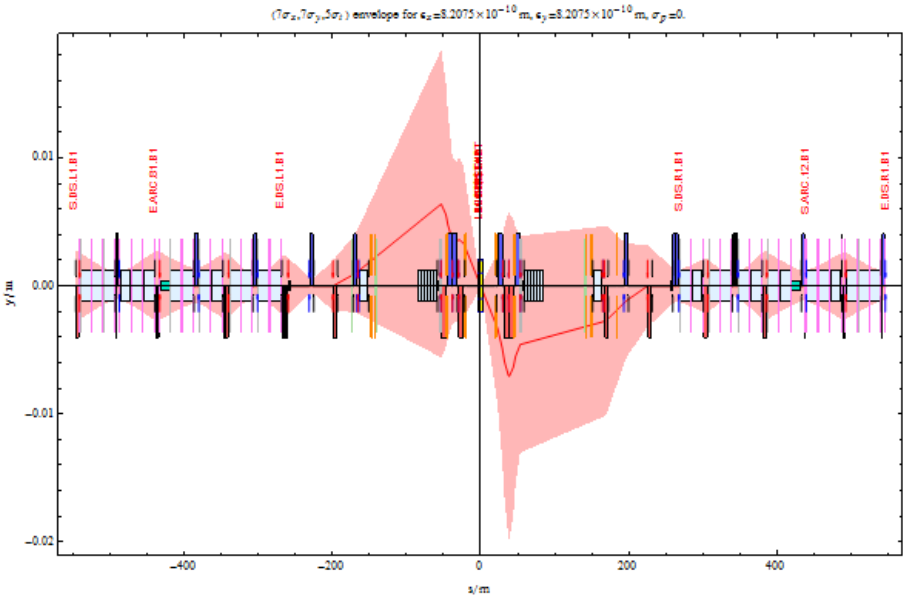
X shown in blue, Y shown in red

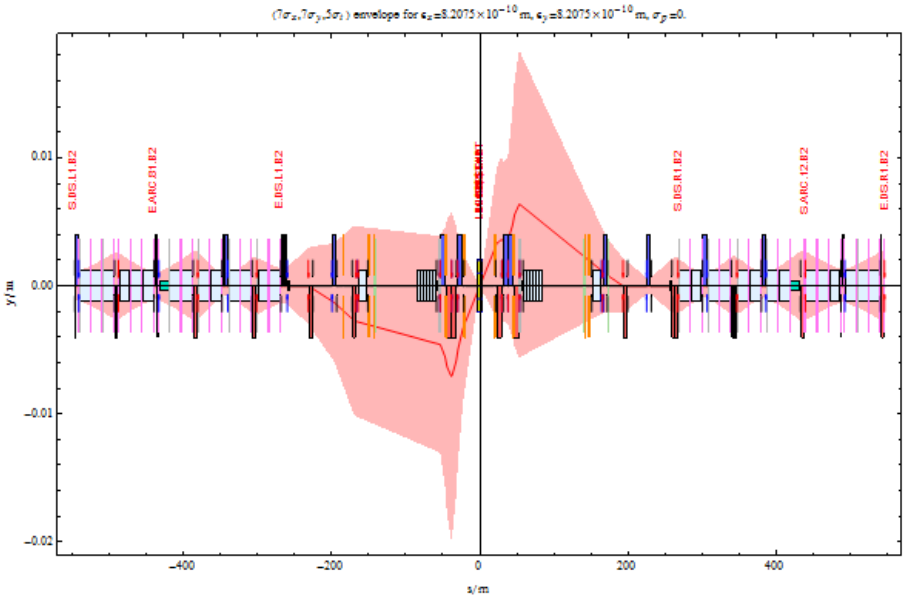




Download B1 plot as .m

Download B2 plot as .m

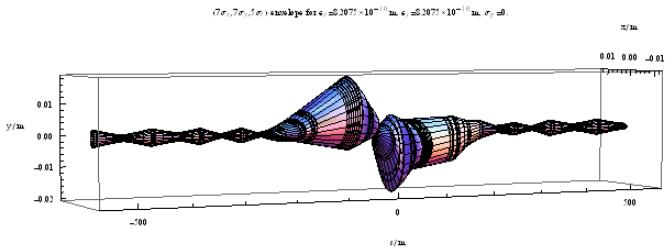


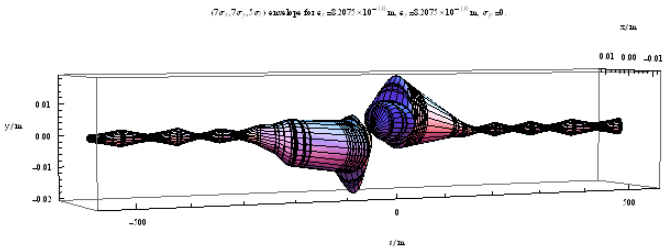


Download B1 plot as .m

Download B2 plot as .m

3D Envelope Plots (CS Coordinates)



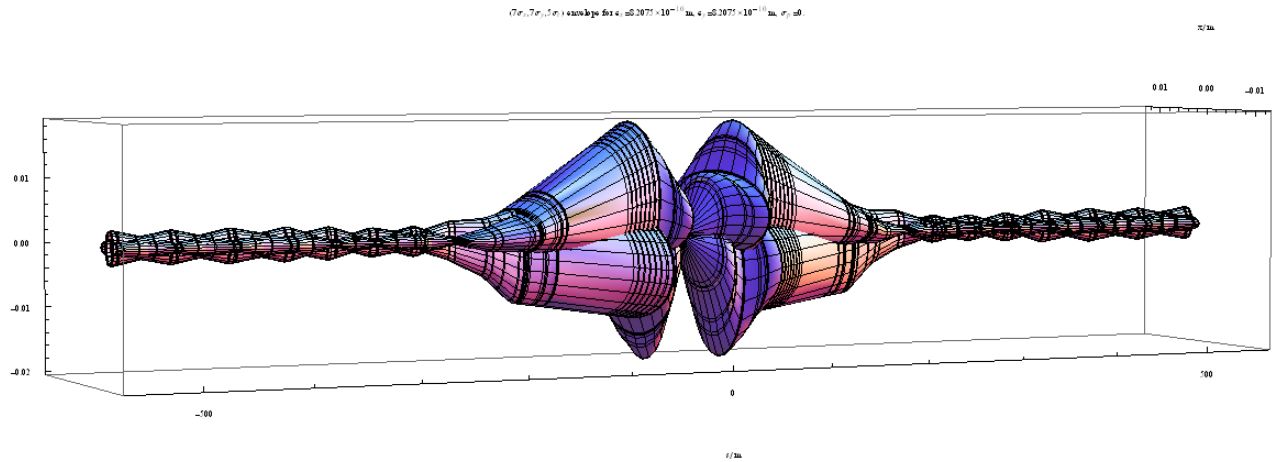


$Plot9$

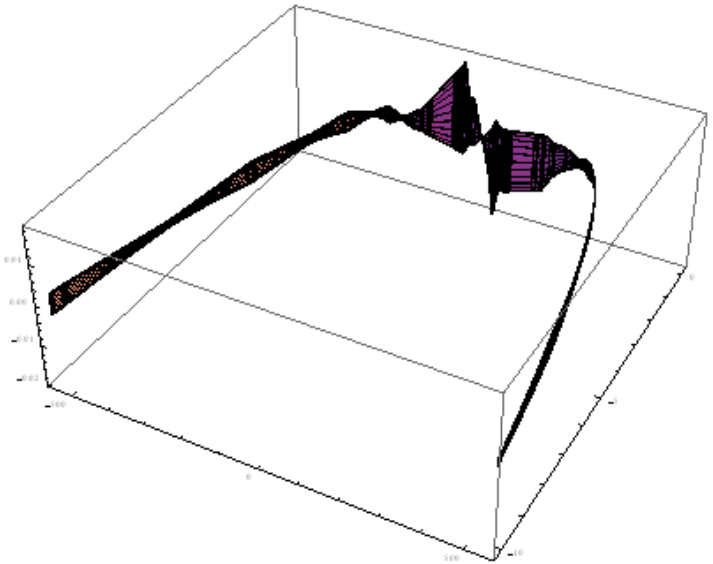
Download B1 plot as .m

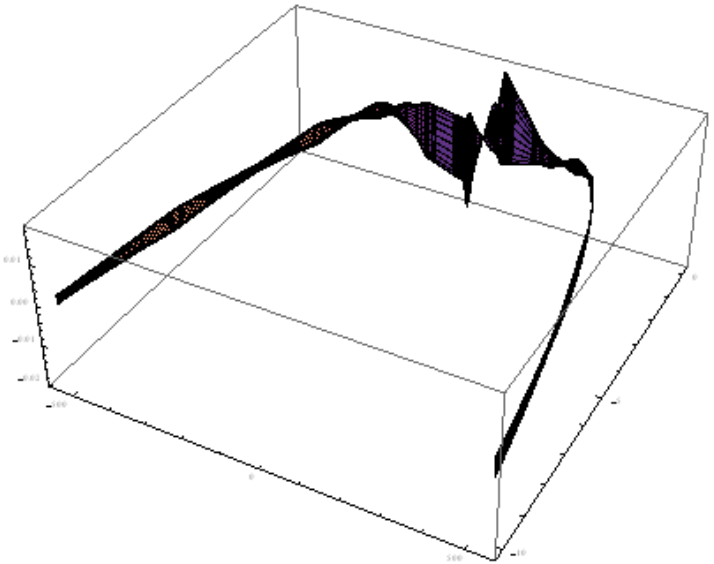
Download B2 plot as .m

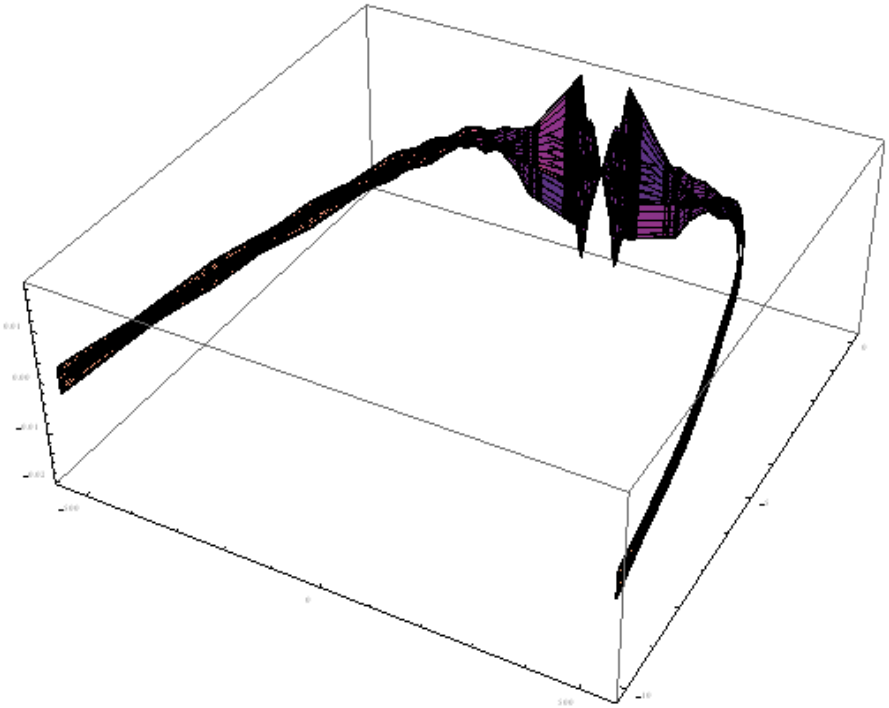
Download superposition plot as .m



3D Global Envelope Plots







Download B1 plot as .m

Download B2 plot as .m

Download superposition plot as .m

Future Work

Additional plots/simulations
(squeeze, aperture, etc.)

LHC upgrades = new scenarios

Thank you

Dr. John Jowett

University of Michigan

National Science Foundation

References

1. Edwards D A and Syphers M J 1993 An Introduction to the Physics of High Energy Accelerators (New York: Wiley)
2. [Web image] Retrieved from http://www.lhc-closer.es/1/4/1/1

Questions?