Beam Beam parameters optimization

Mathematica to Guinea Pig inerface

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Super B factory meeting

Outline

1. Main strategy
   - Tools and interfaces
2. Round case with $N = 7 \cdot 10^{10}$ electrons per bunch
   - Phase space sampling and optimization
   - Scans around optimum point
   - Stability
3. Flat case
   - Scan around the best point found so far by hand

Dramatis Personae (Main characters of the Drama)

Guinea Pig

- Author: Daniel Schulte
- Beam beam effects simulator
- Read from a card the accelerator specifications
- Write to an ascii file the spent bunches, luminosities, log informations

Mathematica^{TM}

- Author: Steve Wolfram
- General purposes environment
- Powerful mathematical algorithms

Lack of communication among them

Solution: write a set of scripts to

- preprocess the Guinea configuration files
- postprocess the Guinea output file

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Goal of the first exercise

Boundary conditions

- 10^4 bunches
- damping time $\tau_{\text{damp}} = 10\,\text{ms}$
- Round geometry
- Collision rate:

$$f = \frac{1}{\tau_{\text{damp}} \log \frac{\epsilon'}{\epsilon}}$$

Goal

Maximize:

$$\mathcal{L} = f \cdot \mathcal{L}_{\text{single cross.}} \propto \frac{\mathcal{L}_{\text{single cross.}}}{\log \frac{\epsilon'}{\epsilon}}$$

or even better:

$$\int d\sqrt{s}\, \mathcal{L}(s) \cdot \sigma\left(e^+e^- \rightarrow \Upsilon(4S)\right)$$

Phase space

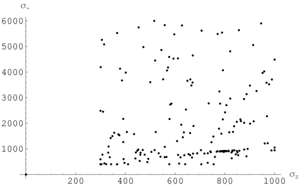
Constraints:

- $400\,\mathrm{nm} < \sigma_\mathrm{x} < 6\,\mu\mathrm{m}$ ($\sigma_x = \sigma_y$)
- $.4\,\mathrm{mm} < \beta_\mathrm{x} < 7\mathrm{mm}$ ($\beta_x = \beta_y$)
- $300\,\mu\mathrm{m} < \sigma_\mathrm{z} < 1\,\mathrm{mm}$
- Waist shift W in $[-2\sigma_z, 2\sigma_z]$
- Traveling focus correlation ϑ in $[-1.5, 1.5]$
- Blow up:

$$\mathcal{B} = \max \log \frac{\epsilon_i'}{\epsilon_i} < 100\%$$

Sampling and optimization

“Random” sampling



Floated parameters

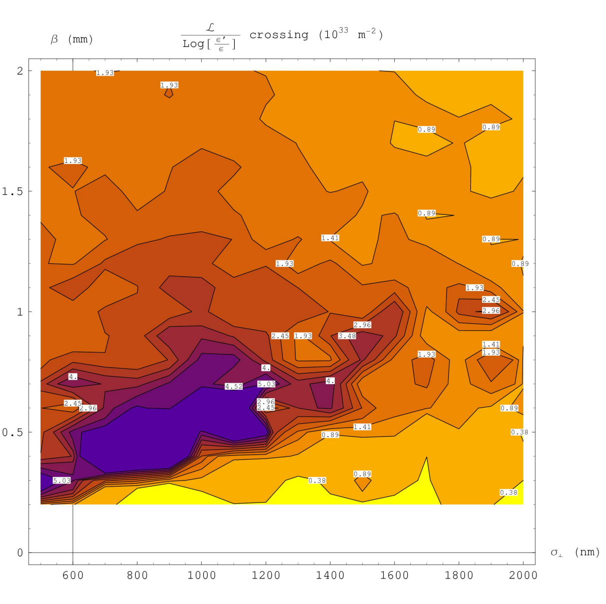
- $\sigma_x = \sigma_y$
- $\beta_x = \beta_y$
- σ_z
- Waist shift and traveling focus correlations

Optimum

☺ Optimum!!
$\sigma_\perp$ = 915.699 nm
β = 0.55203 mm
σ_z = 800.54 μm
N = 7 10^{10} part.
w = -0.49707 (mm)
θ = -0.588194
$\mathcal{N}$ = 1.37395 10^{-4} Υ(4S) / cross.
$\mathcal{L}$ = 1.14347×10^{33} m^{-2} / cross.
$h_\mathcal{L}$ = 2.45892
Log[ϵ'/ϵ] = 0.0974953
$\mathcal{L}$ / Log[ϵ'/ϵ] = 1.17285×10^{34} m^{-2} / cross.

L=10^36

Scans around optimum point: $\mathcal{L}/\mathcal{B}$

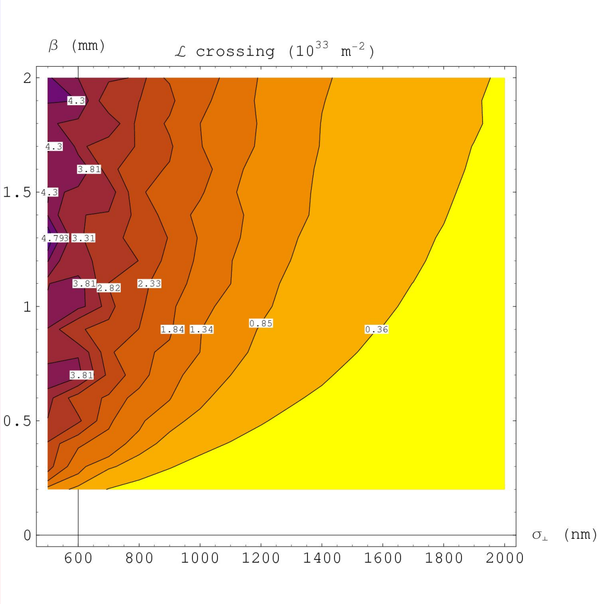


Scan over the $\beta_x \sigma_x$ plane of the figure of merit:

$$\frac{\mathcal{L}}{\log \frac{\epsilon'}{\epsilon}}$$

The optimum seats in the blue lake

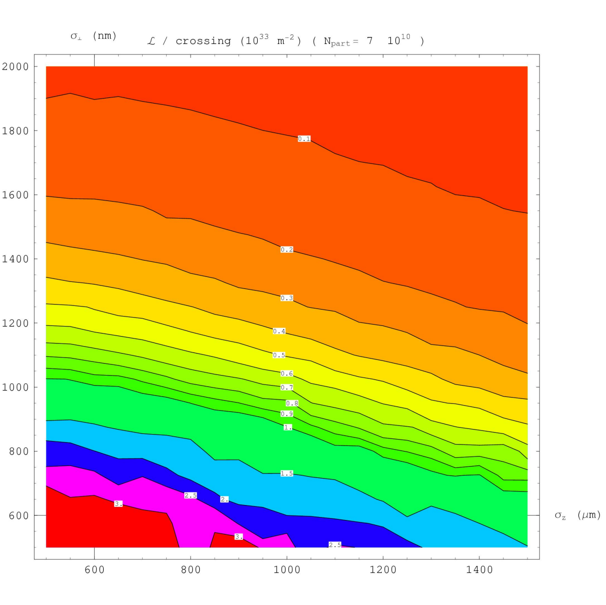
Scans around optimum point: $\mathcal{L}$



Scan over the $\beta_X \sigma_X$ plane of the luminosity per crossing.
As expected

- Hour glass effect decreases with increasing β: luminosity increase with β
- Luminosity decreases with increasing σ

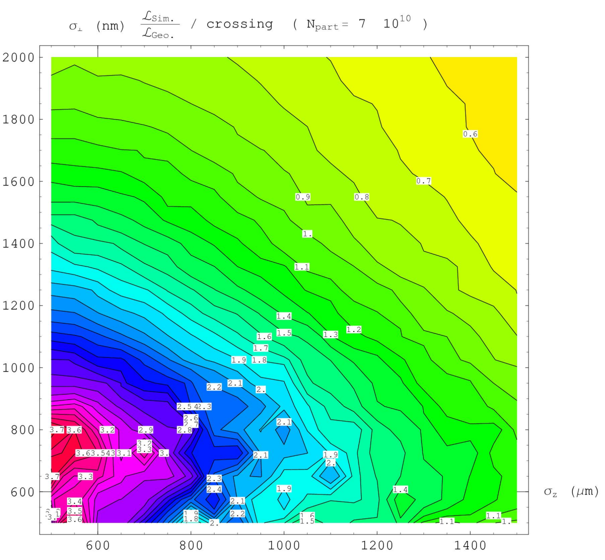
Scans around optimum point: $\mathcal{L}$



Scan over the $\sigma_z \sigma_x$ plane of the luminosity per crossing.
As expected

- Hour glass effect increases with σ_z: Luminosity decreases with increasing σ_z
- Luminosity decreases with increasing σ_x

Scans around optimum point: $\mathcal{L}/\mathcal{L}_{\text{geo.}}$



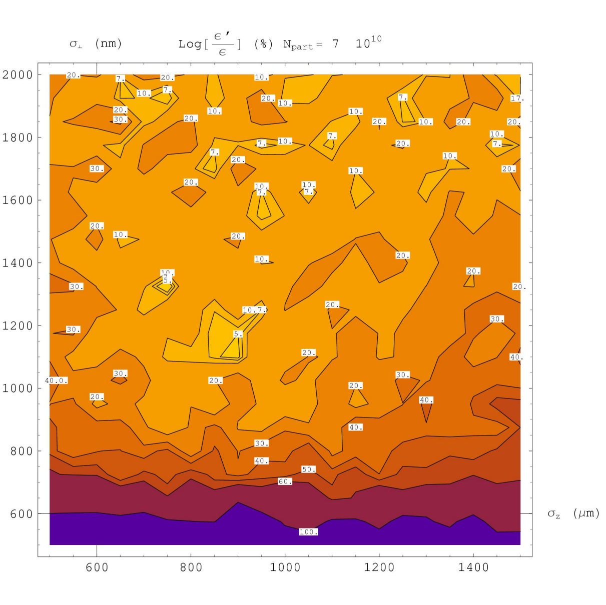
Luminosity without hour glass effect nor self focusing

$$\mathcal{L}_{\text{geo.}} = \frac{N_e^2}{4\pi\sigma_x^2}$$

Another figure of merit:

$$\frac{\mathcal{L}_{\text{sim.}}}{\mathcal{L}_{\text{geo.}}}$$

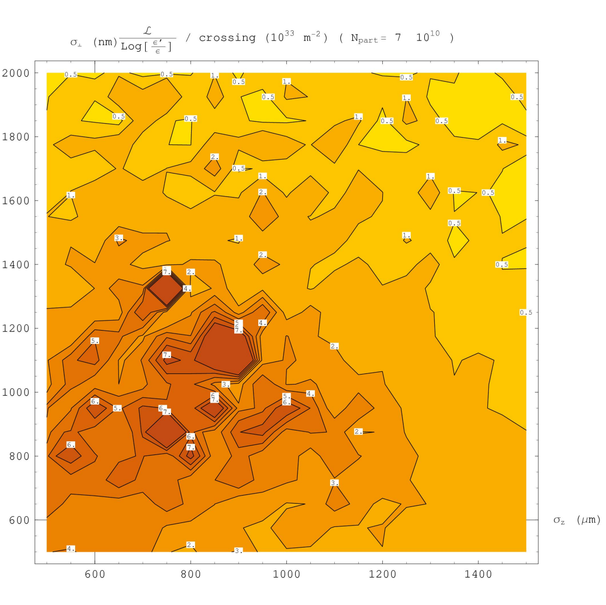
Scans around optimum point: $\mathcal{B} = \log \epsilon'/\epsilon$



$$\mathcal{B} = \max \log \frac{\epsilon'}{\epsilon}$$

is directly proportional to the time spent by the bunch in the damping ring.

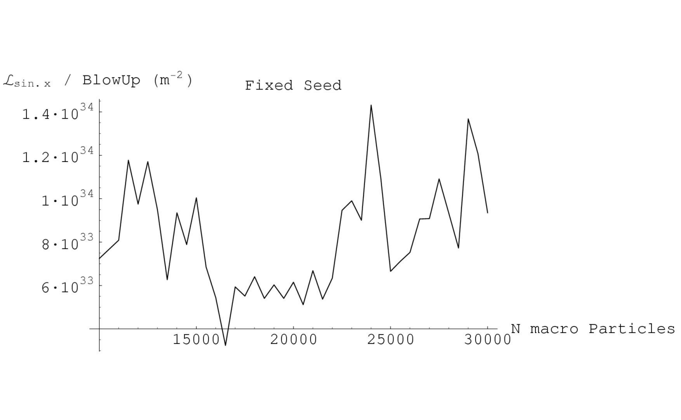
Scans around optimum point: $Q = \mathcal{L}/\mathcal{B}$



Simulation accuracy and stability

Unphysical parameters in the simulation:

- Number of macro particles in the bunch: $N = 10000$
- Real Physics = $\lim_{N\to\infty}$ simulation



Extrapolation plagued by instabilities...

Conclusions for the round case

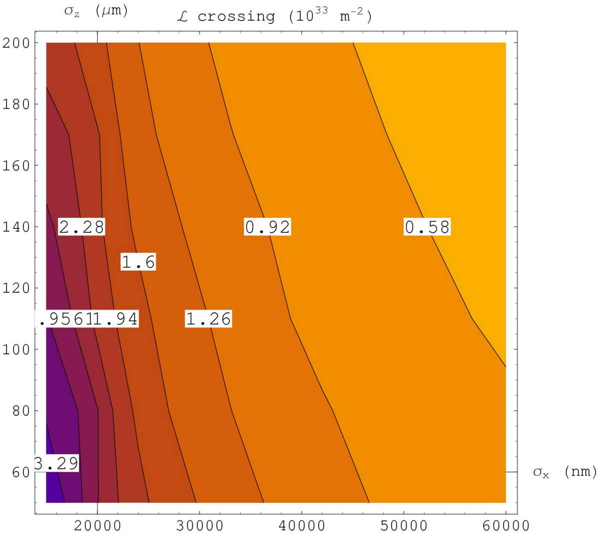
- Useful tools at hand to find the best point in multi dimensional parameters space
- Optimum point affected by instabilities
- How to distinguish real Physical instabilities from artefacted Simulated instabilities?
- Never the less Mathematica found a promising land in the parameters phase space

Flat case

Work started just yesterday afternoon...
Working hypothesis

- $\sigma_y = 12.6\,\mathrm{nm}$
- $\sigma_x = 30,000\,\mathrm{nm} = 30\,\mu\mathrm{m}$
- $\beta_x = 2.5\,\mathrm{mm}$
- $\beta_y = 0.08\,\mathrm{mm} = 80\,\mu\mathrm{m}$
- $N_e = 7 \cdot 10^{10}$
- Blow up $\sim 7\%$
- Collision rate $\sim 10^4 \mathrm{bunches}/1\,\mathrm{ms}$

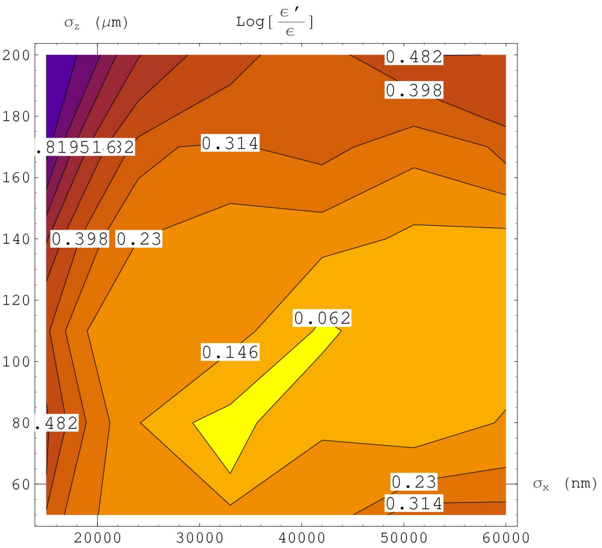
Flat case: scan around the unoptimized best point



$\mathcal{L} = 10^{36} / \mathrm{cm}^2\mathrm{s}$ can be achieved with:

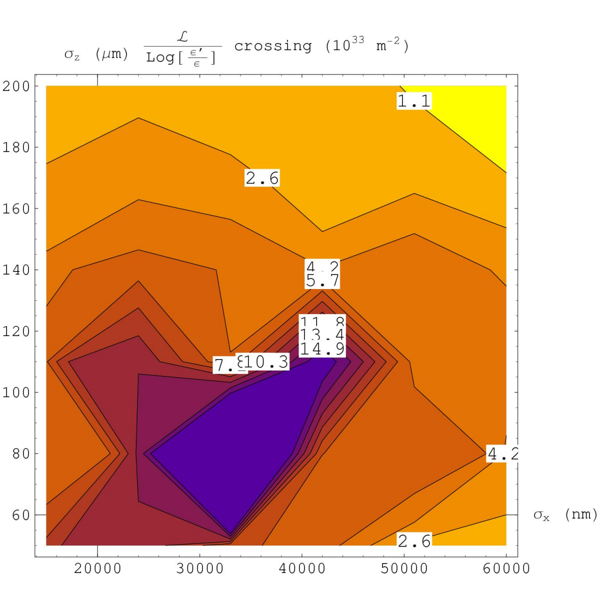
- $\mathcal{L} = 10^{33} / \mathrm{m}^2$ cross
- $\mathcal{B} = \log \frac{\epsilon'}{\epsilon} < 10\%$

Flat case: scan around the unoptimized best point



The blowup requirements met!

Flat case: scan around the unoptimized best point



Lot of space for improvements

Beginnings...

Preliminaries for the Crab waist

- The Mathematica $\leftrightarrow$ Guinea Pig interface design is able to handle the flat case also
- Work just started: stay tuned

Preliminaries for the Crab waist

- Is Guinea Pig (Strong - Strong) the right tools?
- Strong-Weak (faster) simulation more useful?
- Just started thinking about it