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Automatic Optimization of Final Focus Systems with Local Chromaticity Correction

Jacques PAYET
CEA/DAPNIA/SACM

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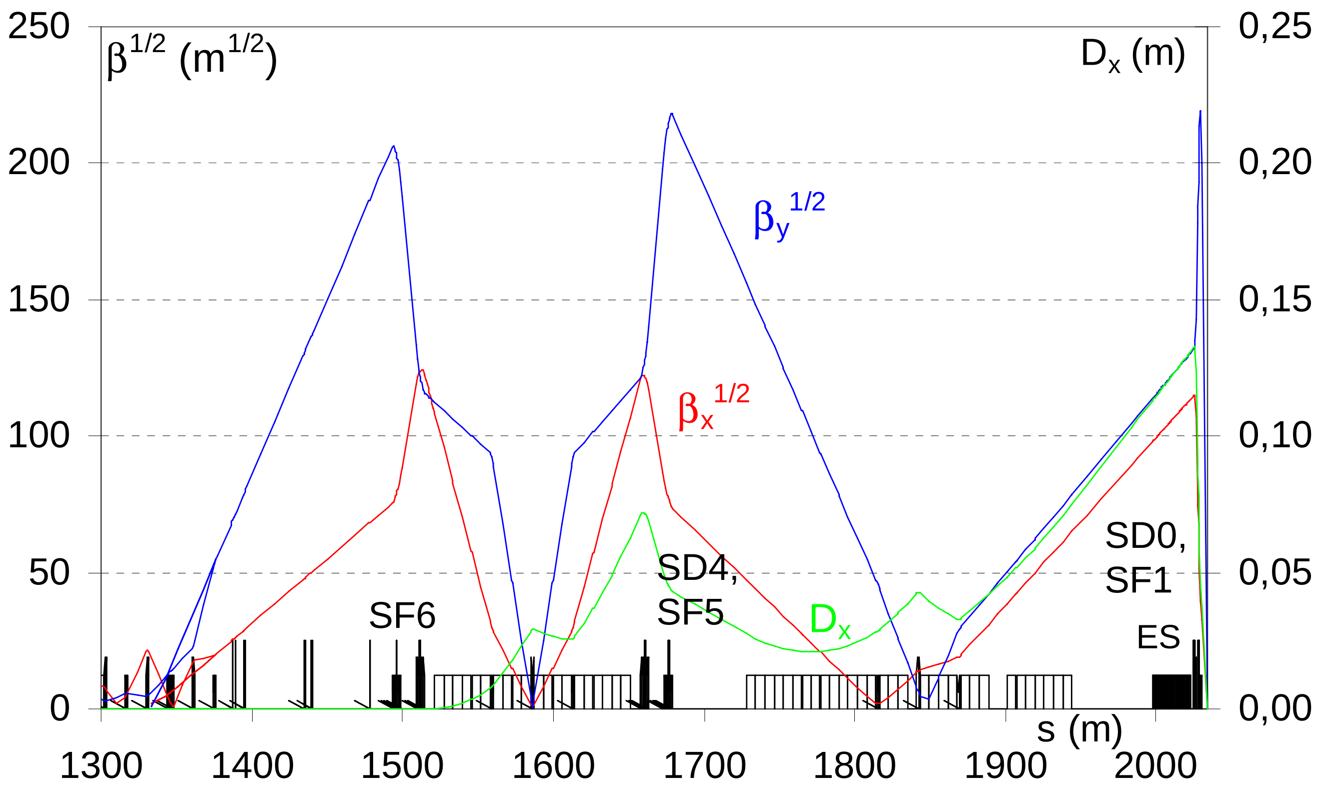
Outline

- Final Focus System
- Final Focus Optimization
  - Final Focus Matching
  - Luminosity Optimization
- Conclusions

Final Focus System



- Combine the Final Focalization and the Chromatic Correction functions

Final Focus Matching

- A recipe for the FFS matching was presented by A. Seryi and al. [1], and we adapted it to the luminosity optimization procedure.
- The Final Focus Matching is performed by 6 stages :
  - From the IP to the FFS entry
    - Tuning of the Twiss functions, α_x, α_y, at the FD entrance
    - Tuning of the phase advances between paired sextupoles and double waist at QF7 adjustment
    - Virtual waist near the FFS entry fitting
    - Dispersion and BDS deviation matching
    - Twiss functions matching at FFS entrance
  - From the BDS entrance to the IP
    - 2^{nd} order terms minimization with the sextupoles
- All these steps are automatically launched
- At the end, we get a first FFS tuning and we have to perform the Luminosity Optimization.

[1] A. Seryi, M. Woodley, P. Raimondi, A RECIPE FOR LINEAR COLLIDER FINAL FOCUS SYSTEM DESIGN, PAC 2003

Luminosity Optimization

- Once the 1st order matching and the 2nd order minimization was realized one have to perform the Luminosity Optimization

- This is done by varying the quadrupoles, in order to adjust the sextupole phase advances, and by varying the sextupole strengths

- As shown by R. Thomas [2], one can use an optimization algorithm that takes as figure of merit the rms beam sizes at the end of the beam line to increase the luminosity

- We adopt this strategy and we use two tools for the luminosity optimization:
  - The LUMOPT code (S. Auclair) which calculates analytically the rms beam sizes expressed as function of the transfer matrix high order terms
  - The TRACEWIN code (D. Uriot) which tracks a particle cloud

[2] R. Tomas, NON-LINEAR OPTIMIZATION OF BEAM LINES, CERN-AB Division CLIC Note 659

Luminosity Optimization : analytic

- We want to minimize the rms beam size product at IP : $\overline{\left(x_1-\overline{x_1}\right)^2}\ \overline{\left(x_3-\overline{x_3}\right)^2}$
- We express the particle coordinates as function of the initial coordinates and the high order transfer matrix terms :

$$x_i=\sum_j R_{ij}x_j^{(0)}+\sum_{jk}T_{ijk}x_j^{(0)}x_k^{(0)}+\sum_{jkl}U_{ijkl}x_j^{(0)}x_k^{(0)}x_l^{(0)}+\sum_{jklm}V_{ijklm}x_j^{(0)}x_k^{(0)}x_l^{(0)}x_m^{(0)}+..$$

- For the initial beam, we assume that :
  - All the odd moments are null : $\overline{x_j^{(0)}}=0,\ \overline{x_j^{(0)}x_k^{(0)}x_l^{(0)}}=0,..$
  - We can express the high even moments with the 2nd order moments :

$$\overline{x_j^{(0)}x_k^{(0)}x_{j'}^{(0)}x_{k'}^{(0)}}=\overline{x_j^{(0)}x_k^{(0)}}\ \overline{x_{j'}^{(0)}x_{k'}^{(0)}}+\overline{x_j^{(0)}x_{j'}^{(0)}}\ \overline{x_k^{(0)}x_{k'}^{(0)}}+\overline{x_j^{(0)}x_{k'}^{(0)}}\ \overline{x_k^{(0)}x_{j'}^{(0)}}$$

- With these assumptions we write the mean values as :

$$\overline{x_i}=\sum_{jk}T_{ijk}\overline{x_j^{(0)}x_k^{(0)}}+\sum_{jklm}V_{ijklm}\overline{x_j^{(0)}x_k^{(0)}x_l^{(0)}x_m^{(0)}}+..$$

- And then we write the rms beam size as :

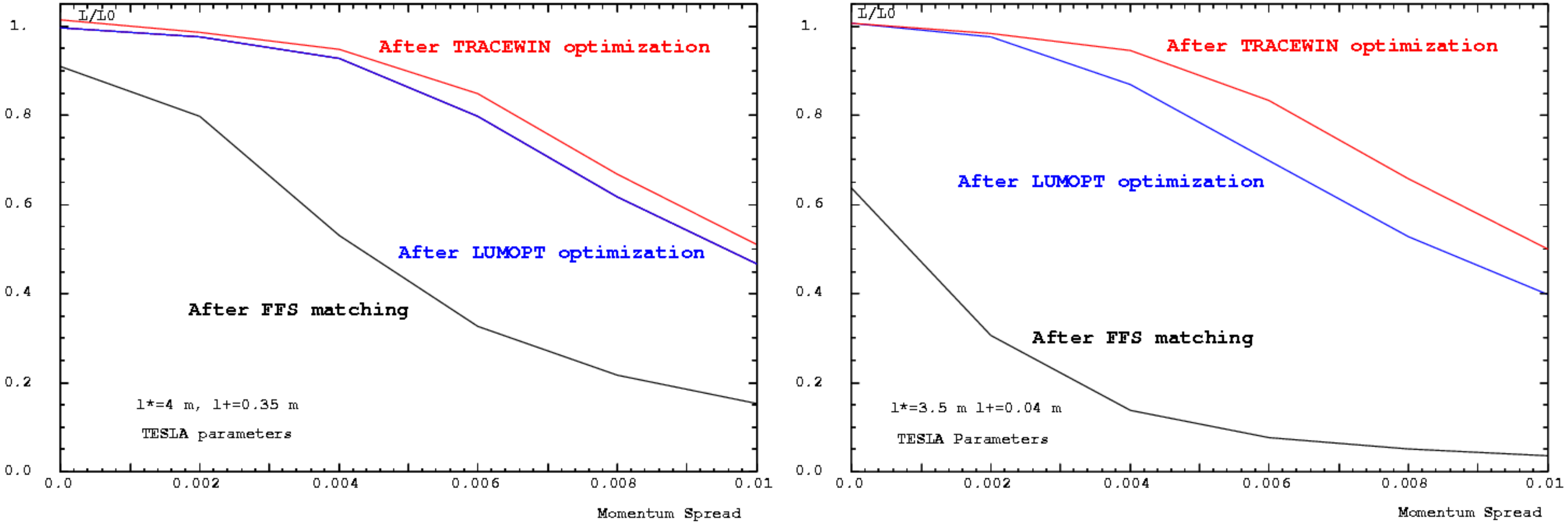
$$\overline{\left(x_i-\overline{x_i}\right)^2}=\sum_{jj'}R_{ij}R_{ij'}\overline{x_j^{(0)}x_{j'}^{(0)}}+\sum_{jkj'k'}T_{ijk}T_{ij'k'}\left(\overline{x_j^{(0)}x_k^{(0)}x_{j'}^{(0)}x_{k'}^{(0)}}-\overline{x_j^{(0)}x_k^{(0)}}\ \overline{x_{j'}^{(0)}x_{k'}^{(0)}}\right)$$
$$+2\sum_{jklj'}U_{ijkl}R_{ij'}\overline{x_j^{(0)}x_k^{(0)}x_l^{(0)}x_{j'}^{(0)}}+\sum_{jklj'k'l'}U_{ijkl}U_{ij'k'l'}\overline{x_j^{(0)}x_k^{(0)}x_l^{(0)}x_{j'}^{(0)}x_{k'}^{(0)}x_{l'}^{(0)}}$$
$$+2\sum_{jklmj'k'}V_{ijklm}T_{ij'k'}\left(\overline{x_{j'}^{(0)}x_{k'}^{(0)}x_j^{(0)}x_k^{(0)}x_l^{(0)}x_m^{(0)}}-\overline{x_{j'}^{(0)}x_{k'}^{(0)}}\ \overline{x_j^{(0)}x_k^{(0)}x_l^{(0)}x_m^{(0)}}\right)+..$$

Luminosity Optimization (2)

- To perform a quick luminosity optimization we have developed the code LUMOPT (S. Auclair) :
  - the variables are the FFS magnetic elements
  - minimize the beam sizes (applying the previous formulae)
    - to obtain the high order matrix terms it launch :
      - TRANSPORT (SLAC) which gives the matrix terms up to 3^{rd} order
      - or MADX with PTC extension (CERN), up to 7^{th} order and more
  - or maximize the luminosity (particle cloud analysis)
    - to transport the particle cloud it launch DIMAD
    - and use LUMTRAK (Saclay) to compute the luminosity
  - different minimization algorithms are available (“classic”, simplex, least square)
- A final optimization (if needed) is performed with TRACEWIN code (D. Uriot)
  - transport a particle cloud through the beam line and maximize the luminosity at IP by varying the magnetic elements.

Luminosity Optimization (3) : Luminosity result

BDS Normalized Luminosity v.s Momentum Spread



- LUMOPT with TRANSPORT and a classic minimization algorithm gives quickly (15mn) a good starting point, and some time it is sufficient.

- The TRACEWIN optimization time is decreased (~3 h compare to 1 night)

$\Rightarrow$ To perform a full optimization we need about 1/2 -1 day dapnia SACM

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Conclusions

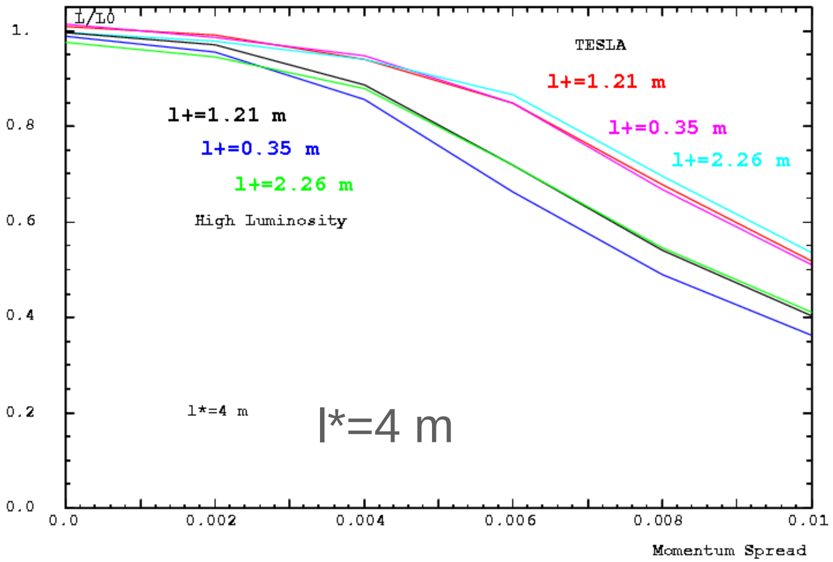
- The BDS optimization are now automatic for a large part
- The time needed to optimize a line is strongly reduced
- The obtained luminosity curves are quite flat in the useful area

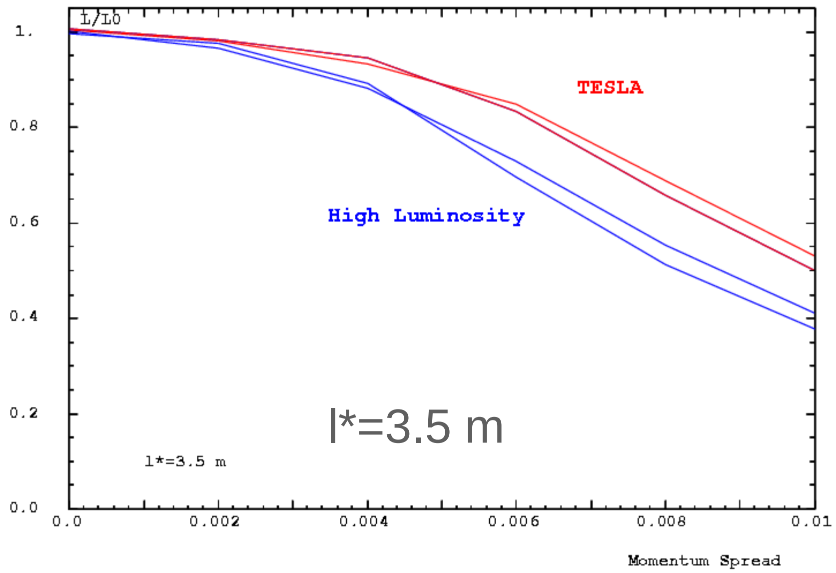
Parameter Space for E=250 GeV L=2 10^{34} $cm^{-2}s^{-1}$

		Nominal	Large Y	Low P	High L	TESLA	Med Q P
N	x 10^{10}	2	2	2	2	2	1.3
n_b		2820	2820	1330	2820	2820	2820
$\varepsilon_{x,y}$	µm,nm	9.6, 40	12, 80	10, 35	10, 30	10, 30	9.6, 30
$\beta_{x,y}$	cm,mm	2, 0.4	1, 0.4	1, 0.2	1, 0.2	1.5, 0.4	1, 0.2
$\sigma_{x,y}$	nm	626.5, 5.7	495.3, 8.1	452.1, 3.8	452.1, 3.5	553.7, 5	443, 3.5
σ_z	µm	300	500	200	150	300	200
Bunch space	ns	308.5	308.5	462.4	308.5	308.5	308.5
D_y		19.12	28.30	26.72	21.66	24.98	19.16
δ_{BS}	%	2.2	2.2	5.1	6.2	2.7	2.5
P	MW	11.3	11.3	5.3	11.3	11.3	7.3

BDS : Luminosity

Luminosity vs. Momentum spread





- Full optimization for the TESLA case.
- Matching with QM15-QM11 and luminosity optimization for High Lum. case.
- The "best" luminosity curves are obtained for the largest free drift.
- The luminosity curves are very similar for l*=4 m and l*=3.5 m.