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Head On Interaction Region -Final Focus Optimization-

Jacques PAYET
CEA/DAPNIA/SACM

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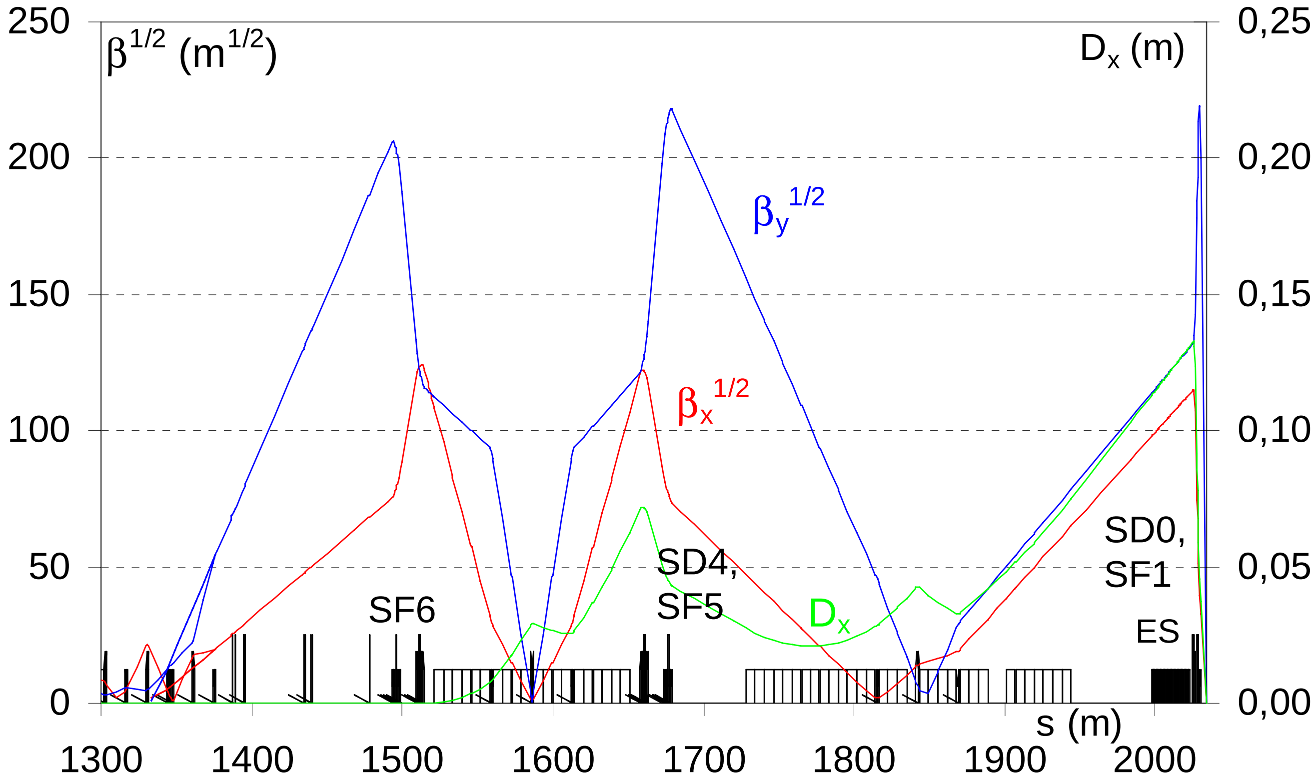
Outline

- Final Focus System
- Final Focus Optimization
  - Final Focus Matching
  - Luminosity Optimization
- BDS luminosity(ILC parameter set) vs. Final Focus geometry
- Conclusions

Final Focus System

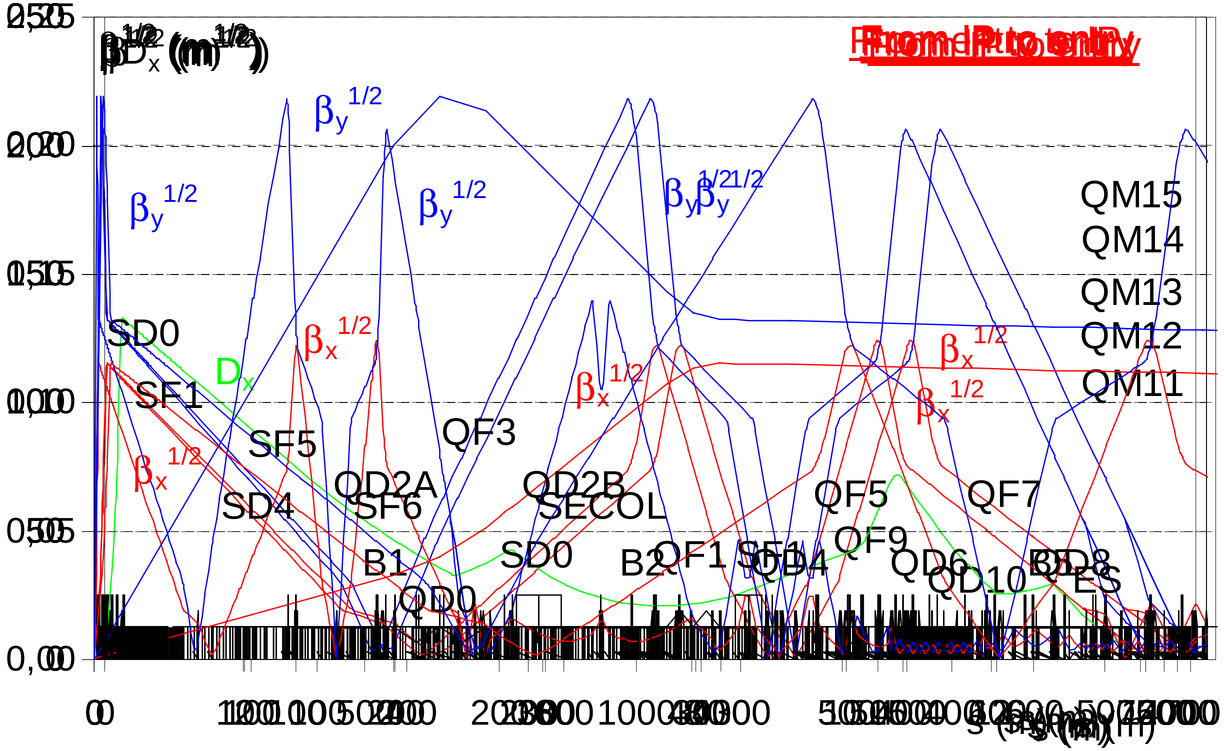


- FFS length is about 734 m.
- Combine the Final Focalization and the Chromatic Correction functions
- Have to provide an easy spent beam extraction

Final Focus Matching (1)

- The Final Focus Matching is performed during 6 stages :
  - From the IP to the FFS entry
    - Matching of the Twiss functions, α_x, α_y, at the FD entry
      - If needed, we change the FD quadripole length, in order to have the desired gradient, and we repeat the matching
    - Phase advances between paired sextupoles and double waist at QF7
    - Virtual waist near the FFS entry
    - Dispersion and BDS deviation matching
      - We check the B1 field, and if needed, we change α_x and we restart at the 1st step until the B1 field is in the correct range
    - FFS entry Twiss functions matching
  - From the BDS entry to the IP
    - 2nd order terms minimization with the sextupoles
      - If needed, we change the FD sextupole length, in order to have the desired strength, and we repeat the matching
- At the end we have a first FFS tuning and we have to perform a Luminosity Optimization

Final Focus Matching (2) : in pictures



Luminosity Optimization (1)

- We use two tools to perform the luminosity optimization :

  - Quick optimization with LUMOPT code (S. Auclair)
    - minimize the beam sizes or maximize the luminosity, at IP
      - the variables are the magnetic elements
      - launch external codes to compute :
        - » the beam sizes : TRANSPORT, MADX-PTC
        - » or the luminosity : DIMAD, LUMTRAK (O.Napoly)
      - different optimization algorithms are available ("classic", simplex, least square)

  - Final optimization (if needed) 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 (2) : LUMOPT

- We want to minimize at IP : $\overline{\left(x_1-\overline{x_1}\right)^2}\;\overline{\left(x_3-\overline{x_3}\right)^2}$
- We start with the particle coordinates :

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

- For the initial beam, we assume that :
  - 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 :

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

- Then the mean values are :

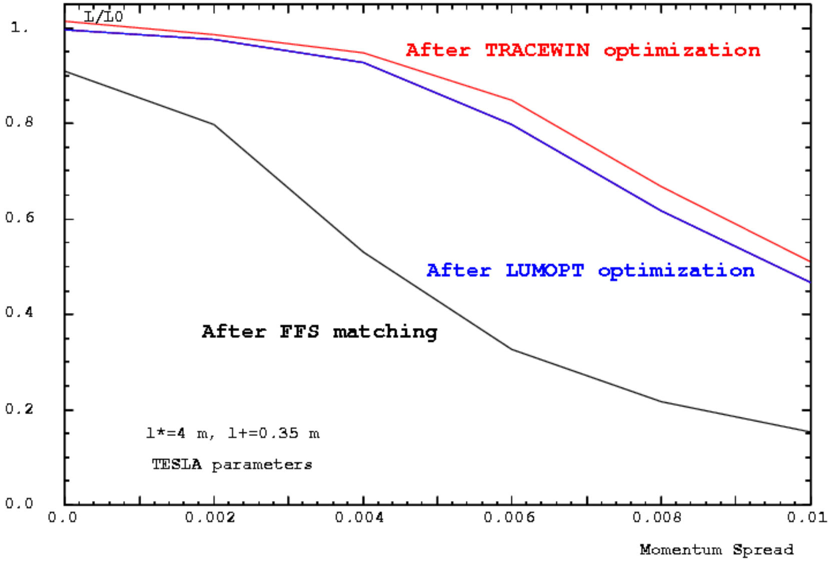
$$\overline{x_i} = \sum_{jk} T_{ijk} \overline{x_j^{(0)} x_k^{(0)}} + \sum_{jklm} V_{ijklm} \overline{x_j^{(0)} x_k^{(0)} x_l^{(0)} x_m^{(0)}} + ..$$

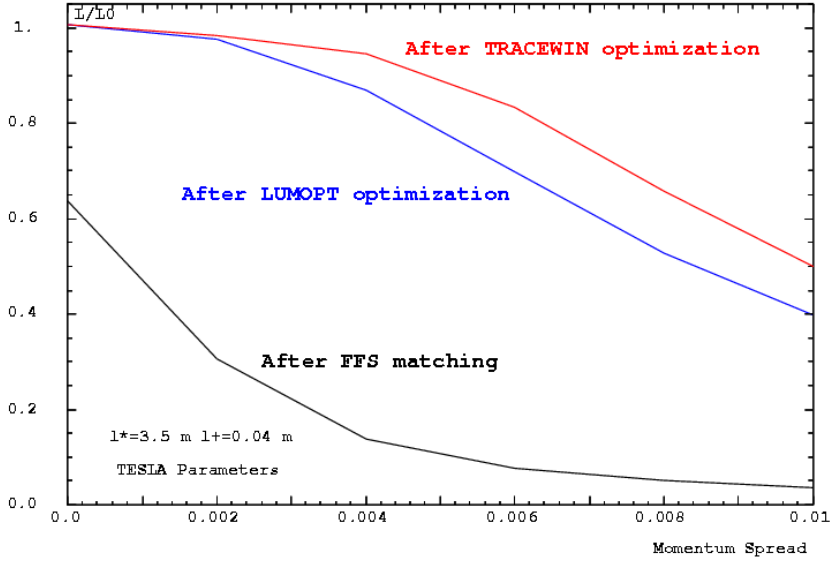
- And the rms values are :

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

Luminosity Optimization (3) : Luminosity result

BDS Normalized Luminosity v.s Momentum Spread





- LUMOPT gives a good starting point, and some time it is sufficient.
- The TRACEWIN optimization time is decreased (~3 h compare to 1 night)

⇒To perform a full optimization we need about 1/2 -1 day

BDS Luminosity vs. Final Focus geometry

The goal is to compare the obtained luminosity curves for various parameter sets when we vary l_{QD-QF} and l*

Constraints and variables :

- Varying l*
- Varying l_{QD-QF} between FD quadripoles
- FD quadripoles with maximum gradient (~ 250 T/m).
- FD sextupoles with maximum strength (~ 3 T at ϕ 56 mm).

  $\Rightarrow$The element lengths are minimum

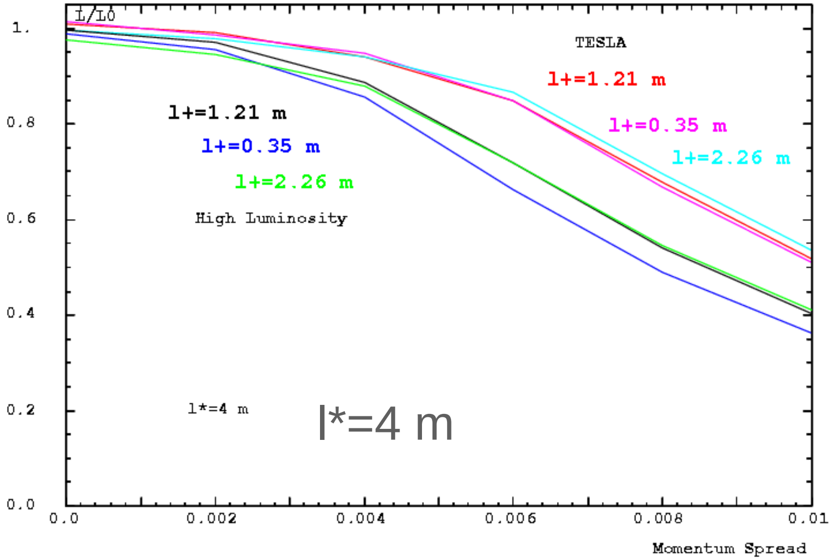
- 2 m long drift between the last sextupole and the separator.
- B1 deviation is about 2.6 10^{-5} rad.
- The distance IP$\rightarrow$B1 is kept identical.

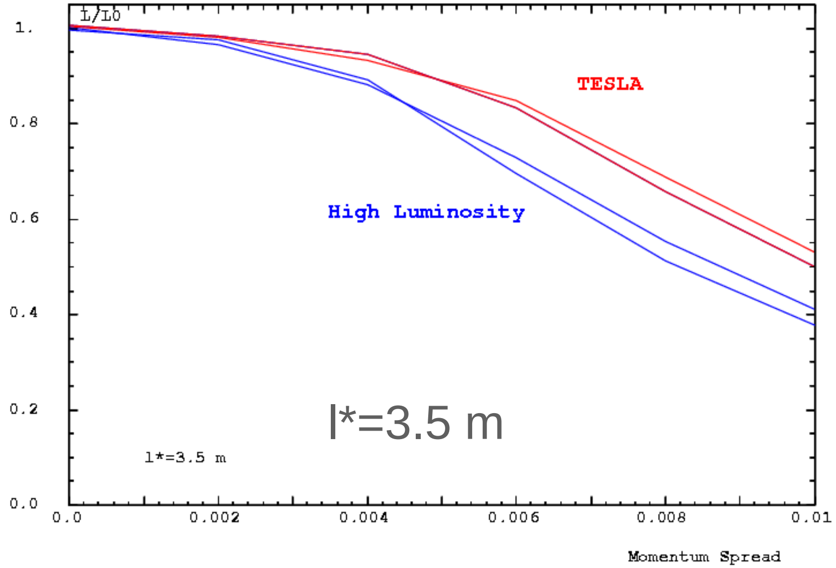
Parameter Space for E=250 GeV L=2 10^{34} $cm^{-2}s^{-1}$

		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

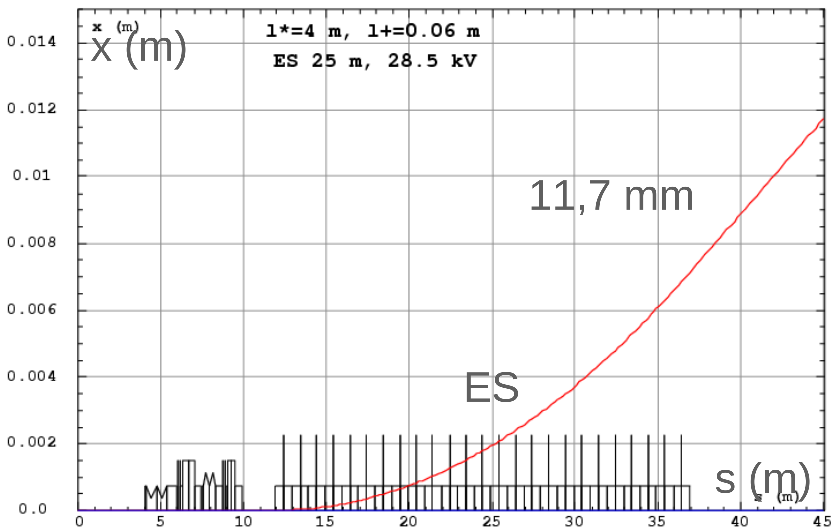




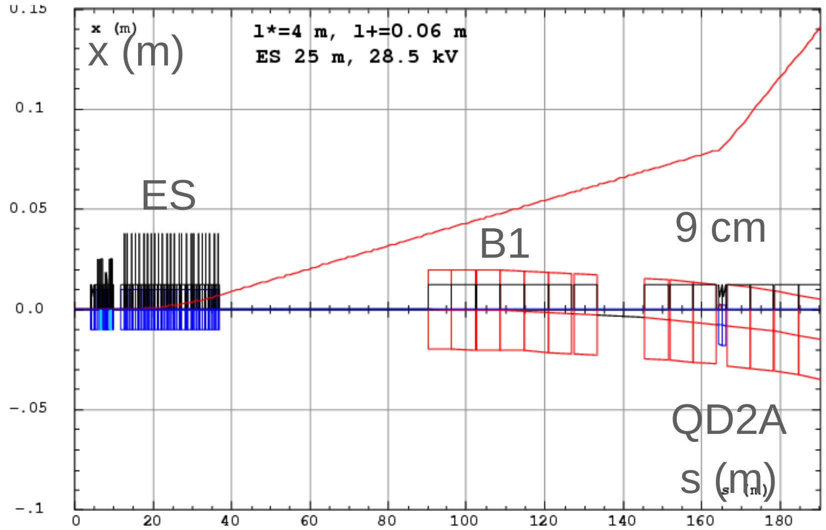
- Full optimization for the TESLA case.
- Matching with QM15-QM11 and luminosity optimization for High Lum. case.
- The "best" luminosity curves are obtained for the largest free drift.
- The luminosity curves are very similar for l*=4 m and l*=3.5 m.

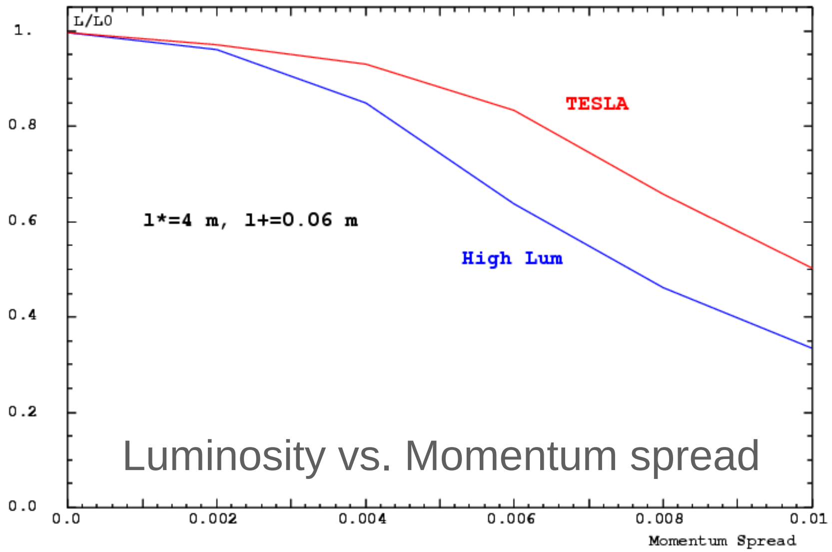
Final Focus with l*=4.0 m

Spent beam at parasitic crossing



Spent beam at QD2A

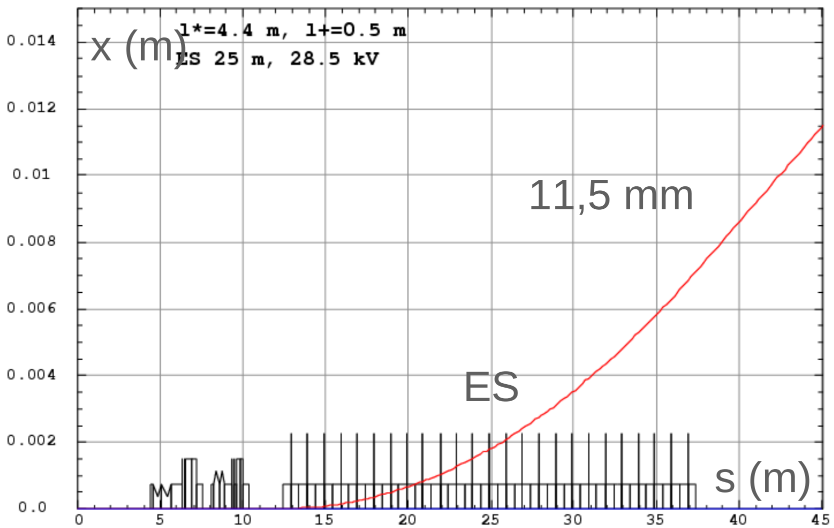




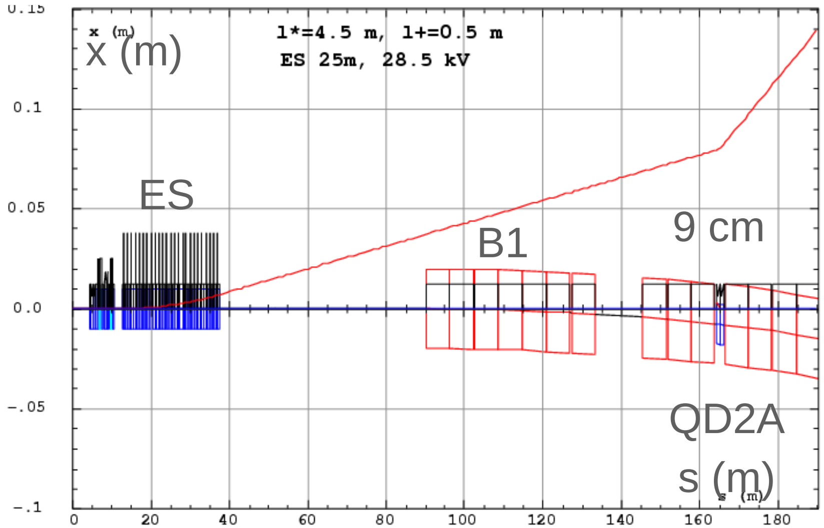
- QD0 + 0.7 m, QF1 + 0.5 m
- SD0 + 0.5 m, SF1 + 0.5 m
- B1 deviation 1.9 10^{-5} rad
- ES 25 m, 0.00057 rad
- IP->ES 11.8834 m

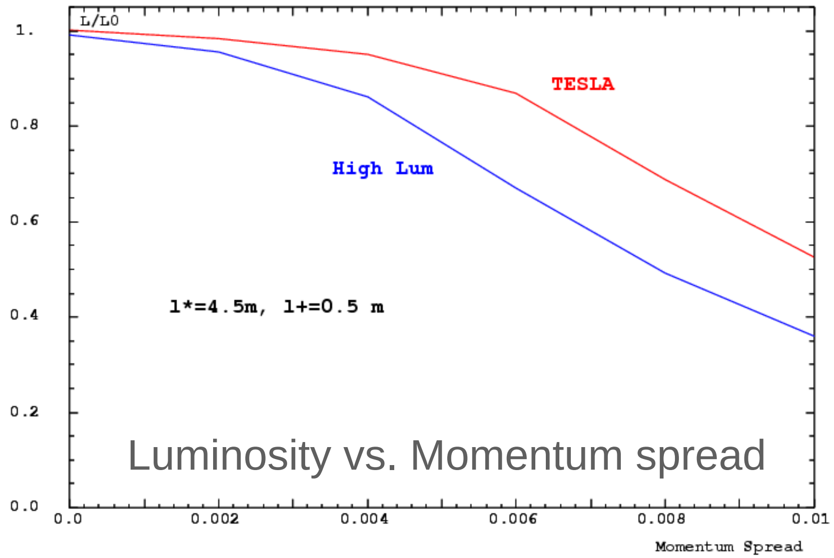
Final Focus with l*=4.4 m

Spent beam at parasitic crossing



Spent beam at QD2A





- QD0 + 0.7 m, QF1 + 0.5 m
- SD0 + 0.5 m, SF1 + 0.5 m
- B1 deviation 1.9 10^{-5} rad
- ES 25 m, 0.00057 rad
- IP->ES 12.3644 m

Conclusions

- The tools for the BDS optimization allow quick optimizations.

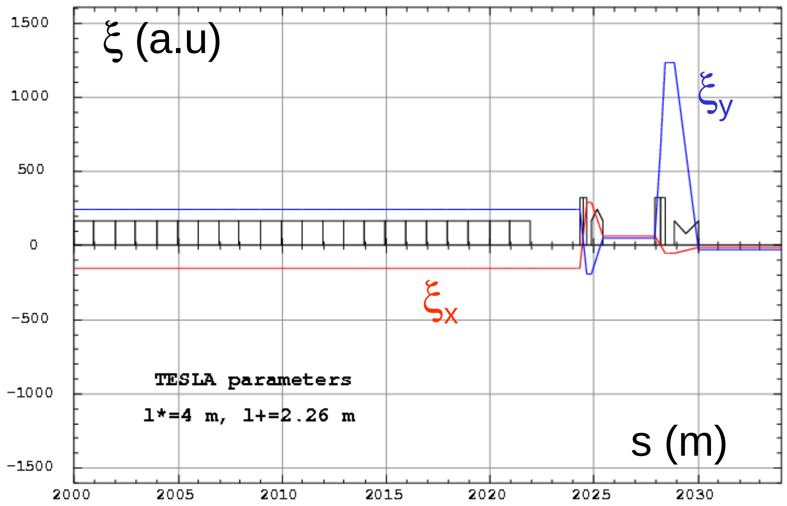
- For various Final Focus geometry we have obtained comparable BDS Luminosity curves for two ILC parameter sets.

- The extraction and the experimentation needs are strong guides for the Head On Final Focus geometry :
  - enlarge l* in order to minimize the solenoid field in QD0.
  - shorten the distance between the IP and the ES to improve the extraction
    - $\Rightarrow$ maximize the quadripole gradient (250 T/m)
    - $\Rightarrow$ maximize the sextupole strength (3 T at ϕ 56 mm)
    - $\Rightarrow$ with a 25 m long 28.5 kV field ES, the beam separation at the parasitic crossing is sufficient to avoid mkink instabilities.
  - decrease the B1 field to keep reasonable QD2A aperture.

Length of Elements

l* (m)	QD0 (m)	SD0 (m)	QF1 (m)	SF1 (m)	IP To ES (m)
4.4	1.142	0.628	0.682	0.410	12.3644
4	1.242	0.744	0.732	0.504	11.8834

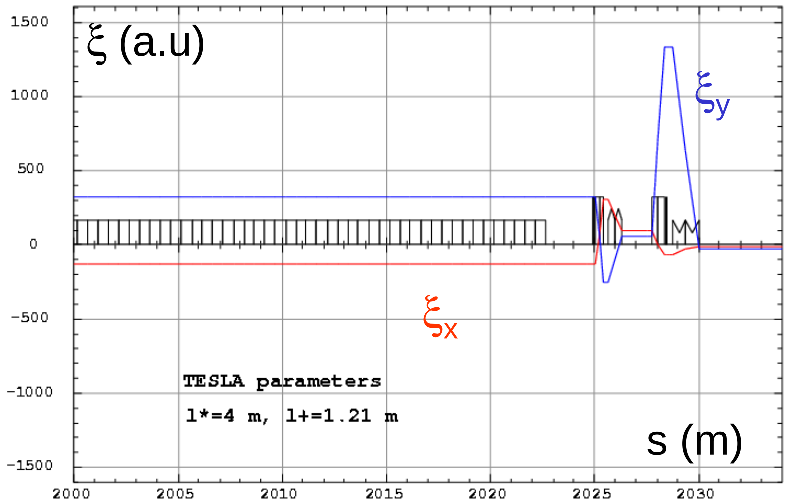
BDS Chromaticities for l*=4m

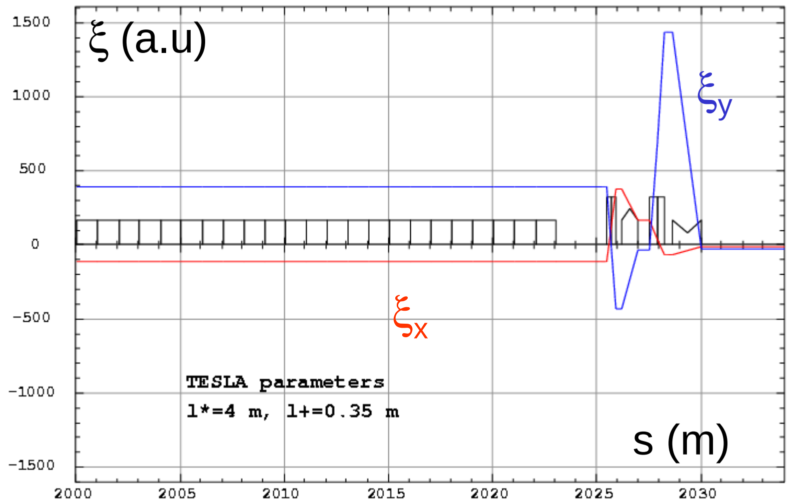


When the distance decrease :

- The QP chromaticities increase
- The SF1 coupling increase and it counteracts the SD0 contribution
- The SX correction increase

⇒Are the luminosities similar ?





Length of Elements for l*=4m

Free Drift (m)	QD0 (m)	SD0 (m)	QF1 (m)	SF1 (m)	IP To ES (m)
2.2574	1.142	0.566	0.586	0.286	12.0374
1.2104	1.242	0.602	0.718	0.354	11.3264
0.3554	1.334	0.718	0.832	0.500	10.9294

Relative change 14 % (QD0)

Relative change 21 % (SD0)

Relative change 30 % (QF1)

Relative change 43 % (SF1)

Relative change 10 % (IP To ES)