Spectrometer Specifications
Rev1.0

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October 25, 2003

Abstract

A spectrometer has been designed to chararcterize the longitudinal beam properties at the exit of the gun. It will be used to measure the absolute energy and the correlated energy spread out of the gun. With this diagnostic, we should also be able to characterize the current uniformity along the bunch, any variation of thermal emittance along the bunch and the uncorrelated energy spread for low charges

1 Description of parameters

The first design was unsatisfactory as we could not resolve the energy spread by better than 11keV. It appears that the R16 could not only be of the order of R11. Even the addition of a quadrupole at the exit of the spectrometer could not dramatically change that ratio.

The quadrupole had been added to give the flexibility to reduce the dispersion. However, this could only be done at the expense of a loss of the point-to-point imaging in both planes.

We looked for a solution which gives the possibilities of

1- the ratio R16 / R11 close to 3

2- reducing the dispersion without losing the point-to-point imaging

1.1 Standard tuning

The new geometry is described in Table 1. It is also explicitely shown in figure 3 from the MAD output.

The two quadrupoles are off. We still want to have point-to-point imaging in both planes.

L0 [m]	Lq1 [m] , k	L1 [m]	L_{dipole} [m]	L2 [m]	Lq2 [m], k	L3 [m]	Lq3 [m], k	L4[m]	θ [°]	β
0.20	0.05 , 0	0.162	0.2991	0.10	0.05 , 0	0.18	0.05 , 0	0.2	84.46	26

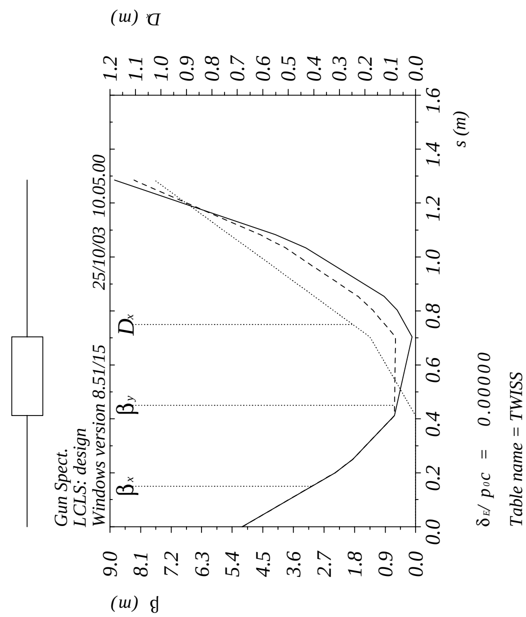


Figure 1:

Table1- Parameters for nominal tuning- The lengths of components are given in order of apparition

R_{11}	R_{12}	R_{33}	R_{34}	R_{16}
-1.311	$-1.2.10^{-3}$	-1.268	$-1.7.10^{-3}$	1.018

Table 2- Twiss parameters

A perfect point-to-point imaging is obtained with L4 = 0.2019 m. R_{12} and R_{34} are then in the 10^{-4} range. Tolerances on parameters are studied in paragraph 2.

1.1.1 Simulations

In figure2, the beam spot on YAG_spec1 is shown for the nominal LCLS parameters of 1nC run at the standard 27 degrees injection phase. The total horizontal beam size is close to 3.3 cm. A 1.5 " pipe will be required from spectrometer to screen. The spectrometer screen YAG_spec1 will occupy the 1.5" diameter.

In Figure3, we show that the resolution is as good as 10 keV but that 3 keV is not resolved. If the beam is overfocused at YAG1 by using a stronger solenoid field a better resolution will be obtained. The resolution is here computed for

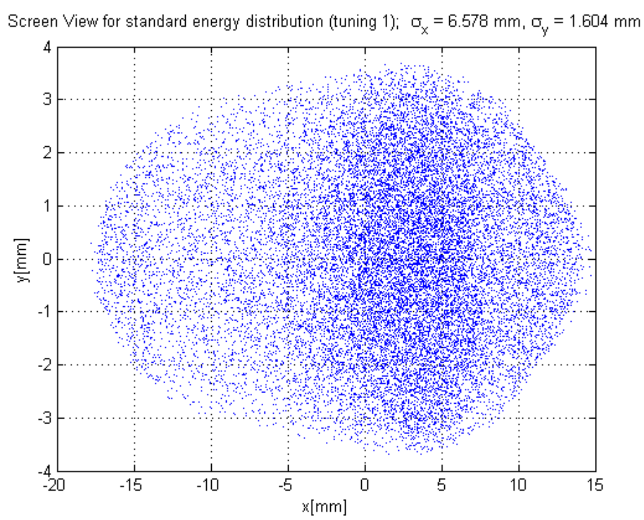


Figure 2:

an initial rms beam size of 1.29 mm at YAG1 which is the expected beam size for the nominal tuning with 1nC.

1.2 Tuning for good energy spread resolution

An optimization on the quadrupole strengths was then performed for finding a high ratio of R_{16} over R_{11}. In this case we don't constraint the imaging in the vertical plane (R_{34} is non zero). A ratio of up to a factor of R_{16} / R_{11} of 3 can be obtained but then the image gets blown up vertically.

R_{11}	R_{12}	R_{33}	R_{34}	R_{16}
-.076	0.00076	1.92	0.12	0.20

Table 3-Twiss parameters for the high energy resolution case

The quadrupole strengths are described in Table 4.

$k_{Q1}[m^{-2}]$	$k_{Q2}[m^{-2}]$	$k_{Q3}[m^{-2}]$
-318.12	-79.19	134.48

Table 4-Quadrupole strengths for second tuning

Unfortunately, this tuning is not satisfying since the first quadrupole is too strong. The betatron function attains 150 m. The beam dimensions in the bending magnet gets too large.

The only viable solution could be obtained for a longer drift L4 of 55 cm instead of 20 cm.

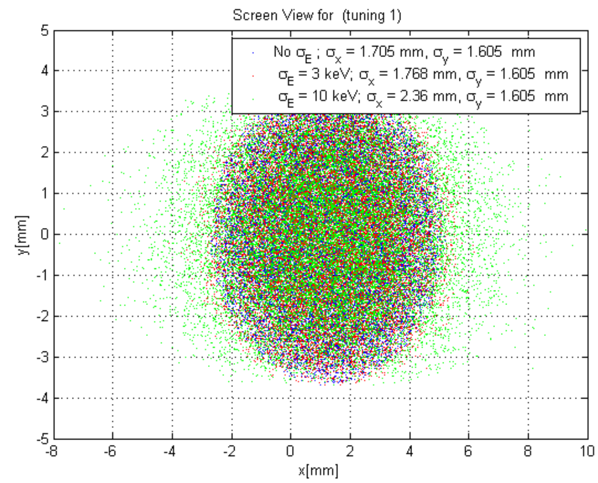


Figure 3:

R_{11}	R_{12}	R_{33}	R_{34}	R_{16}
-.012	-0.14	0.6	0.5	0.39

Table 4-Twiss parameters for the high energy resolution case

The quadrupole strengths are described in Table 4.

$k_{Q1}[m^{-2}]$	$k_{Q2}[m^{-2}]$	$k_{Q3}[m^{-2}]$	L4 [m]
202.0	-22.25	65.83	0.55

Table 5-Quadrupole strengths for second tuning

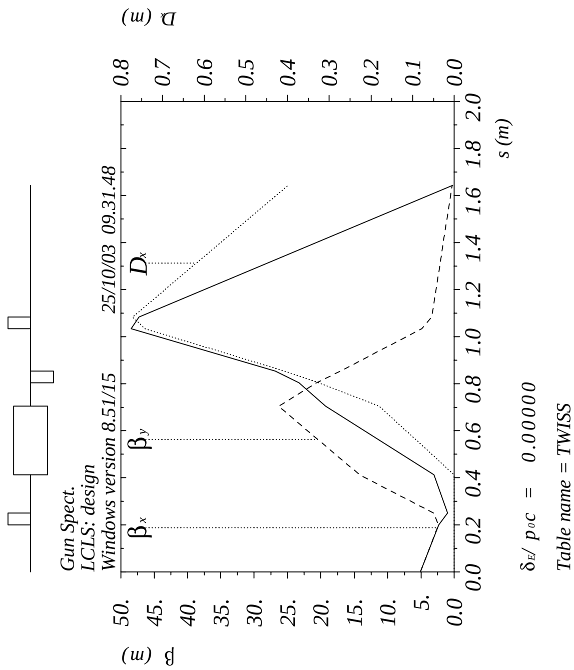
Figure 4 shows the betatron and dispersion functions for this tuning. The longitudinal axis extends up to screen YAG2_Spec1.

1.2.1 Simulations

We checked the betatron function with PARMELA by using a distribution with no energy spread. It was noticed that the tuning of the Ψparameter made the vertical betatron function vary quite rapidly. It was not the case for the standard tuning with no quadrupoles on. I don't have any explanation

Ψ has been computed using the definition given in Transport P39 , which should be the same as that used in PARMELA

$$\Psi = K_1 \frac{g}{\rho} \left(\frac{1 + \sin^2 \beta}{\cos \beta} \right) \left(1 - K_1 K_2 \frac{g}{\rho} \tan \beta \right)$$



Gun Spect.
LCLS: design
Windows version 8.51/15
25/10/03 09.31.48
βx
βy
Dx
β (m)
Dx (m)
s (m)
δE/ p0c = 0.00000
Table name = TWISS

Figure 4:

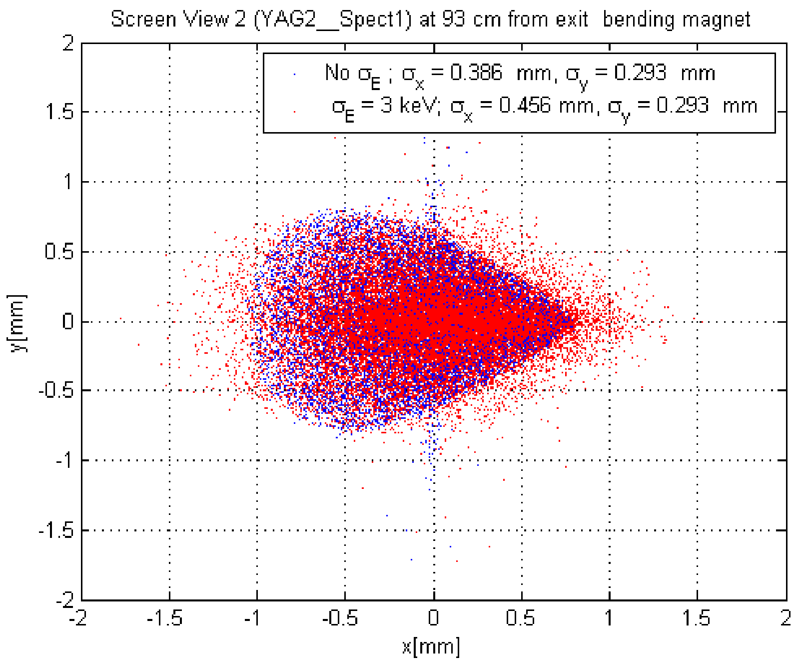


Figure 5:

with the parameters

$$
\begin{aligned}
g &= 2.5.10^{-2} \\
\rho &= \frac{0.3}{84.46^\circ} = 0.20\ m \\
\beta &= 26.56^\circ \\
K_1 &= 0.4 \text{ for a square-edged magnet} \\
K_2 &= 2.8
\end{aligned}
$$

Figure x shows that a resolution of 3keV is achieved in this configuration. One will notice that the presence of second order effects (sextupolar terms) is very visible on this graph.

This tuning will be of particular interest for checking the line density uniformity.

1.3 Tuning for small horizontal beam size on screen 1

An optimization on the quadrupole strengths was performed for finding a very small R_{16}, while maintaining the point-to-point imaging. The Twiss parameters obtained are summarized in Table 5.

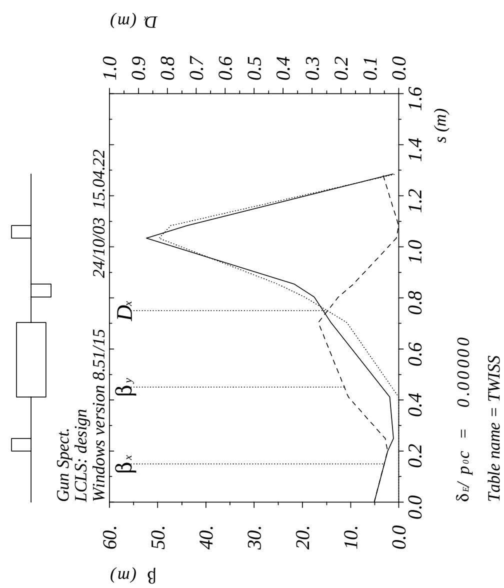


Figure 6:

R_{11}	R_{12}	R_{33}	R_{34}	R_{16}
0.49	0.000	-0.809	0.000	0.01

Table 6-Twiss parameters for small dispersion case

$k_{Q1}[m^{-2}]$	$k_{Q2}[m^{-2}]$	$k_{Q3}[m^{-2}]$
168.3	-45.356	147.2

Table 7-Quadrupole strengths for the third tuning

This tuning is not very useful. We prefer the next one which gives the 10keV resolution while keeping the image with decent dimensions.

1.4 Tuning with small horizontal and vertical beam sizes on screen 1

We finally checked that it will be possible to keep the point-to-point imaging in both planes and have a small beam size on the screen. This tuning would for instance be required for lower charge operation.

R_{11}	R_{12}	R_{33}	R_{34}	R_{16}
-0.17	-0.07	-0.67	1.10^{-4}	0.162

Table 8-Twiss parameters for small dispersion case

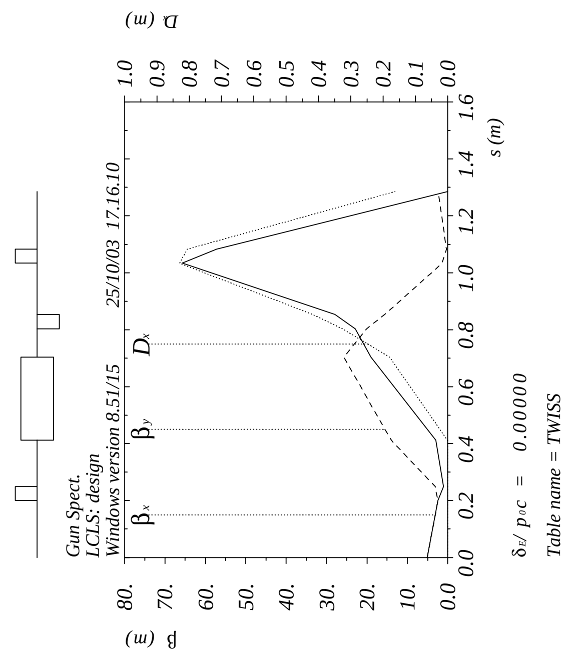


Figure 7:

$k_{Q1}[m^{-2}]$	$k_{Q2}[m^{-2}]$	$k_{Q3}[m^{-2}]$
225	-46.38	130

Table 9-Quadrupole strengths for the third tuning

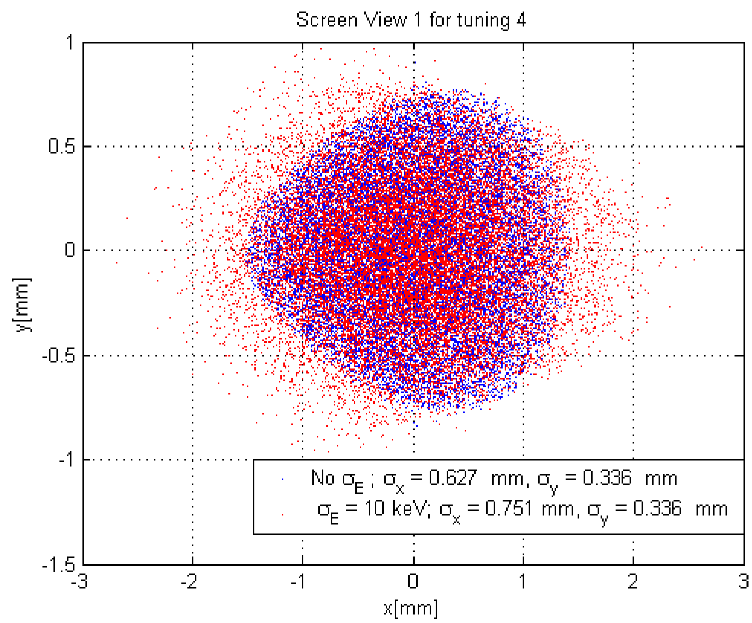
We limited the strength of Q1 to 225 m^{-2} as for larger currents the beam gets too large. This is equivalent to a maximum horizontal betatron function of 60 m as shown in figure xx.

1.4.1 Simulations

With this tuning, we can resolve 10keV and have small beam sizes on the first screen. Also the beam pipe diameter of 1.5" will be large enough to accomodate the large horizontal beam at the quadrupole 3 location.

1.5 Conclusion

We have now finalized the design. It will include three quadrupoles. The beam tube exiting the spectrometer should be at least of 1.5" diameter. Two screens



Screen View 1 for tuning 4
1
0.5
0
-0.5
-1
-1.5
-3
-2
-1
0
1
2
3
y[mm]
x[mm]
No σE ; σx = 0.627 mm, σy = 0.336 mm
σE = 10 keV; σx = 0.751 mm, σy = 0.336 mm

Figure 8:

will be used for the imaging, respectively at 53 cm and 88 cm from the exit of the bending magnet. The dump will be positioned after the second screen.

We have proven the wide potential of the spectrometer. The additional quadrupole added upstream of the spcectrometer gives a much better flexibility. The presence of the three quadrupoles will also help compensating for the defocusing effects induced by the space charge which have been ignored in those preliminary simulations. Future simulations will include spce charge effects for high and medium charges and will exhibit the high variety of measurements to be performed with this spectrometer.