Spectrometer Specifications
Rev1.0

C. Limborg

October 15, 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

The gun spectrometer has been designed to characterize the longitudinal properties of the beam at the gun exit. In this note, we discuss the geometry and give the field requirements for the sector dipole magnet and the quadrupole. This follows the analytic study presented in note LCLS-INJ-01.

The dipole magnet alone gives a point-to-point imaging of the YAG1 screen onto the YAG2 screen in both the vertical and horizontal plane. The cancellation of the R_{12} and R_{34}terms is achieved by introducing 31.24 degrees pole face rotation for the entrance and exit dipole faces. A quadrupole magnet has been added to the original design to vary the dispersion at the YAG2 location. Accordingly, we will be able to control the value of the dispersion function over a wide range. A variety of measurements will be done using this station:

- absolute energy
- correlated energy spread
- uncorrelated energy spread (for low charges)
- current uniformity along the electron bunch
- slice thermal emittance

1 Geometry

1.1 Point-to-point imaging

1.1.1 Standard tuning

The dipole magnet alone will image on YAG2 the object plane corresponding toYAG1 located at 40cm from the cathode. This point-to-point imaging can be achieved in both planes by using the focusing introduced by the pole face rotation at the entrance and the exit of the sector dipole magnet. The choice of pole face angle, bending angle, dipole length and length of drift space was done using MAD for the system shown in figure 1. For this optimization, the quadrupole was turned off. The analytical description of this system has also been given in [C.Limborg, Spectrometer Specifications Discussion].

Parameters are described in table 1 for the nominal tuning. The corresponding Twiss paramaters are then given in table2.

L1 [m]	L_{dipole} [m]	L2 [m]	L3 [m]	Lq [m]	θ [°]	β [°]	k [m^{-2}]
0.4	0.2991	0.1185	0.1785	0.05	94.86	31.1689	0

Table1- Parameters for nominal tuning

The length of the dipole corresponds to the effective length

$$L_{eff} = \frac{L\theta}{2\sin(\theta/2)}$$

R_{11}	R_{12}	R_{33}	R_{34}	R_{16}
-.902380	-9.4.10^{-5}	-0.9217	-7.6.10^{-5}	0.7731

Table2 - Twiss parameters

We checked that the second order terms are negligeable.

T_{116}	T_{126}	T_{166}	T_{216}	T_{226}	T_{266}
2.04	0.86	-0.916	2.032	1.367	-0.826

Typically at YAG1, $\sigma_{xo} = 1.78$ mm and $\sigma'_{xo} = 2.1$ mrad.

In figure 1, we show the evolution of betatron functions and of the dispersion.

The standard tuning will allow to resolve 10.4keV. It corresponds to the case in which $R_{11}\sigma_{xo}$˜$R_{16}\sigma_{\delta}$ with σ_{δ}˜ 10.4keV/5MeV = 2.1.10^{-3}.

1.1.2 Controlling dispersion

In the standard tuning described here above, the quadrupole is off.

However, assuming $\sigma_{xo} = 1.78$ mm and $\sigma_{\delta} = 1\%$, the image size is $(R_{11}^2\sigma_{xo}^2 + R_{16}^2\sigma_{\delta}^2)^{1/2}$˜ 7.9 mm

Such a large image can not be observed on the screen.

The 5 cm long quadrupole at 12 cm from the exit of the spectrometer allows us to control the dispersion.

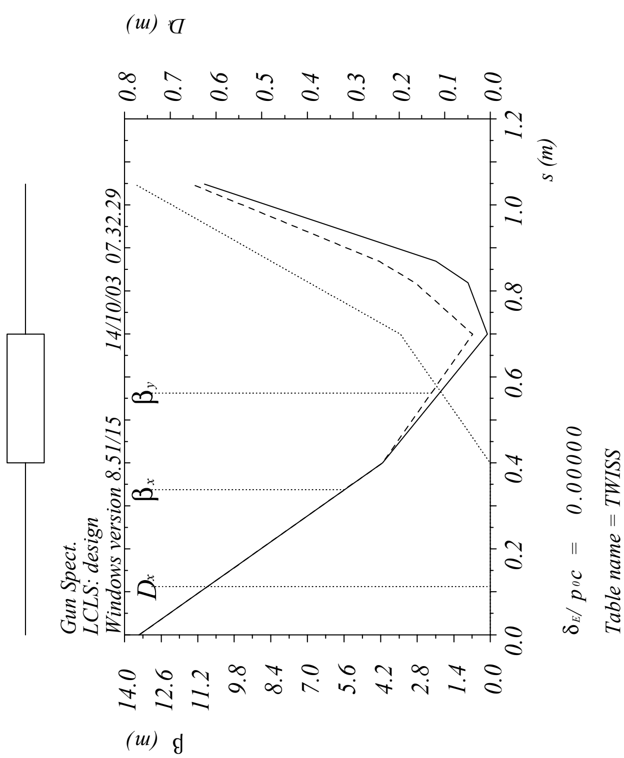

Figure 1: MAD Output showing betatron and dispersion functions for standard tuning

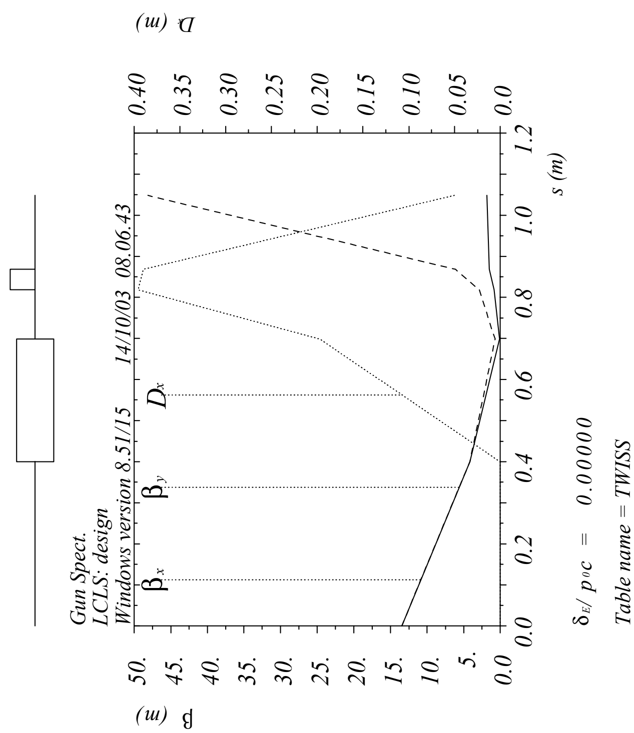

Figure 2: MAD Output for tuning to low dispersion

The dispersion can be reduced down to 0.05m at the screen location. The R_{11} term is then -0.787 and R_{12}= 0.377, the beam size is then $(R_{11}^2\sigma_{xo}^2 + R_{12}^2\sigma_{x'o}^2 + R_{16}^2\sigma_\delta^2)^{1/2}$~1.7mm

This solution is not entirely satisfying as it does not give the point-to-point imaging since R_{12} is non-zero. However, it still offers a wider range of tuning.

The quadrupole strength K1 is 174 m^{-2} corresponding to a gradient of 2.9 T/m (or a pole field of 0.58 kG for a pole of 2cm radius)

1.2 Tolerances on parameters

We studied the variations of the matrix parameters for the transport matrix and of the beam size for different errors on the bending magnet parameters (bending angle and pole face rotation) and errors on drift lengths. We assumed $\sigma_{xo} =$ 1.78 mm, $\sigma'_{xo} = 2.1$ mrad and $\sigma_\delta = 1\%$.

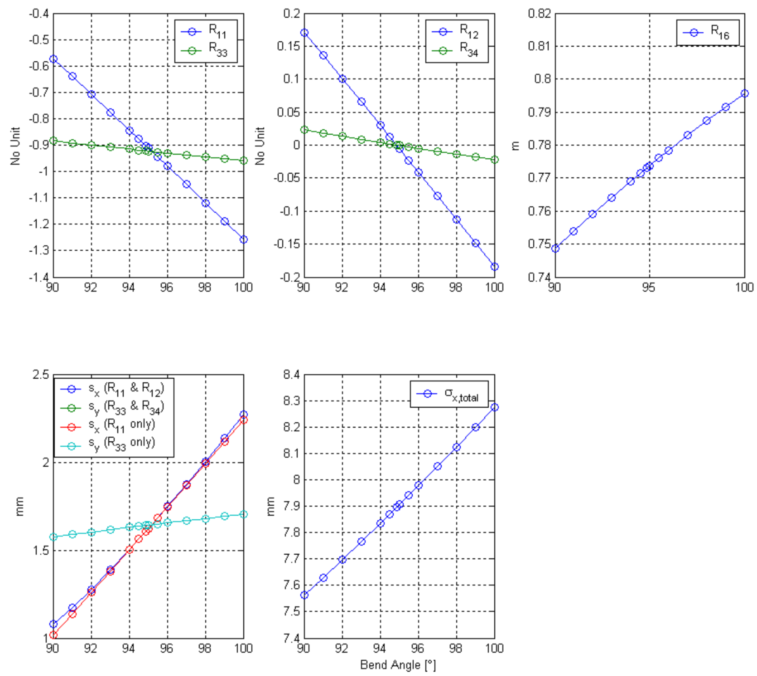

Figure 3: Variation of Twiss parameters and beam size as a function of an error in pole face rotation

1.2.1 Pole Face Rotation

A tolerance of +/- 0.2 degrees is largely enough for the pole face rotation nominal value of 31.16 degrees.

1.2.2 Bending Angle

A tolerance of +/- 0.2 degrees is largely enough for the pole face rotation nominal value of 94.86 degrees.

1.2.3 Drifts

An error of +/- 1 mm is tolerable on the position of the screen.

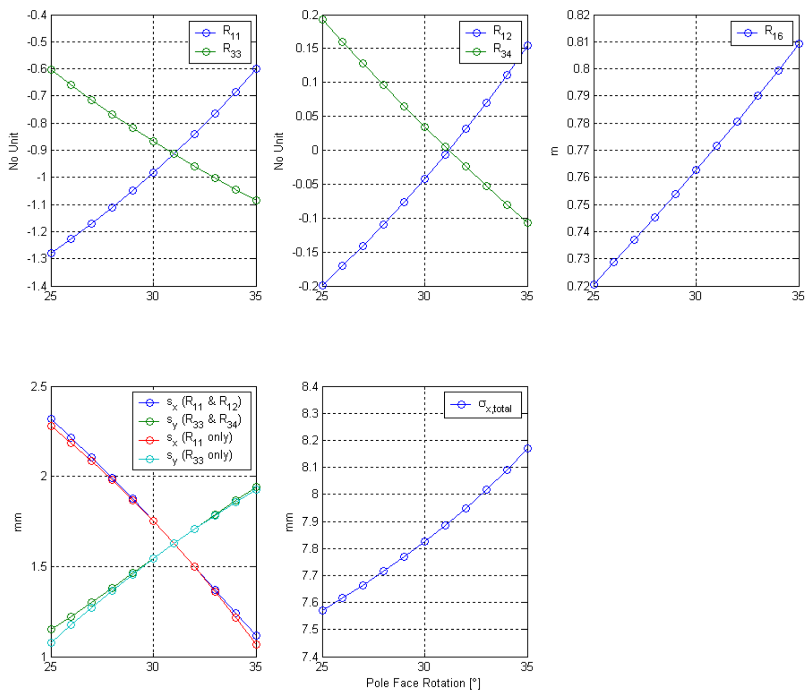

Figure 4: Variation of Twiss parameters and beam size as a function of an error in bending angle

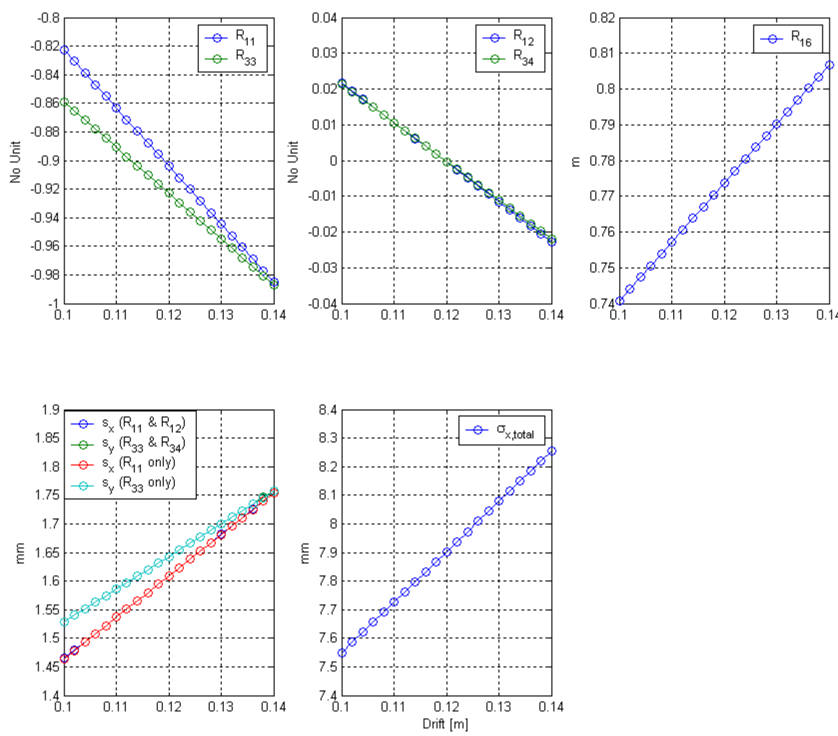

Figure 5: Variation of Twiss parameters and beam size as a function of an error position of the screen

2 Conclusion

The design proposed here meets the requirements to measure absolute energy and energy spread with a 11keV resolution. The use of the quadrupole offers the possibility to control the dispersion and thus measure the entire correlated energy spread on the screen. This design can still be improved as the point-to-point imaging is not obtained for the low dispersion tuning.

The calibration and alignment procedures will be discussed later. A description of all the types of measurements will also be given in a later note.