End Spectrometer Specifications

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Abstract

Spectrometer2 (located at the end of the injector beamline) has been designed to provide a 3keV energy resolution. It will be used for a variety of measurements:

absolute energy, correlated energy spread, uncorrelated energy spread, longitudinal phase space , slice emittance... In this note, we show that with three quadrupoles, we will have enough flexibility to perform the measurements mentioned.

1 Standard tuning

The spectrometer will consists of a 66cm long bending magnet deflecting the beam at 35 degrees so that the spectrometer beamline is parallel of the main accelerator. This bending magnet is a sector magnet with no pole face rotation. It will then be followed by three standard 15.5 cm quadrupoles distributed as shown in Table 1. The distance D1 is calculated from the OTR5.

Having the flexibility to tune three quadrupoles, we get obtain a point-to-point imaging in both planes.

The ratio of $R_{16}/R_{11}$is constant but we can adjust the value of R_{16}. The position of the quadrupoles and screen were chosen such that this ratio would be of -3.

With a ratio of -3,

D1[m]	$L_{bend}[m]$	D_2[m]	$Q_1[m]$	$D_3[m]$	$Q_2[m]$	$D_4[m]$	$Q_3[m]$	$D_5[m]$
4.765	0.66	0.3	0.155	0.40	0.155	0.4	0.155	0.5

Table 1: Geometry of end-spectrometer beamline

R_{11}	R_{12}	R_{33}	R_{34}	R_{16}
-0.102	4.10^{-4}	-0.567	0.000	0.3000

Table 2: Twiss Parameters for 1st tuning

$k_{Q_1}[m^{-2}]$	$k_{Q_2}[m^{-2}]$	$k_{Q_3}[m^{-2}]$
-6.807	2.199	12.588

Table 3: Quadrupole settings for first tuning

$$\begin{aligned}
\frac{R_{16}\sigma_\delta}{R_{11}\sigma_{xo}} &> 1 \\
for\ \sigma_E &> 3.4\ keV \\
\sigma_\delta &= \sigma_E/E\ with\ E = 135MeV \\
\sigma_{xo} &= 75\mu m
\end{aligned}$$

This resolution can be improved by reducing the electron beam size at the waist below $75\mu m$.

1.1 First tuning parameters

The Twiss parameters are given in table

The quadrupole strengths are given in table .

1.2 Simulations

The output from Mad presented in figure 1 shows the betatron and dispersion functions for the first tuning.

The PARMELA simulations were done without space charge on. The space charge effects at 135MeV were studied (see note 135MeV) and proven to be negligeable. We checked that the same betatron functions were obtained as those obtained in figure1.

Figure 2 shows the screen image for a beam with no correlated energy spread and very small uncorrelated energy spread.

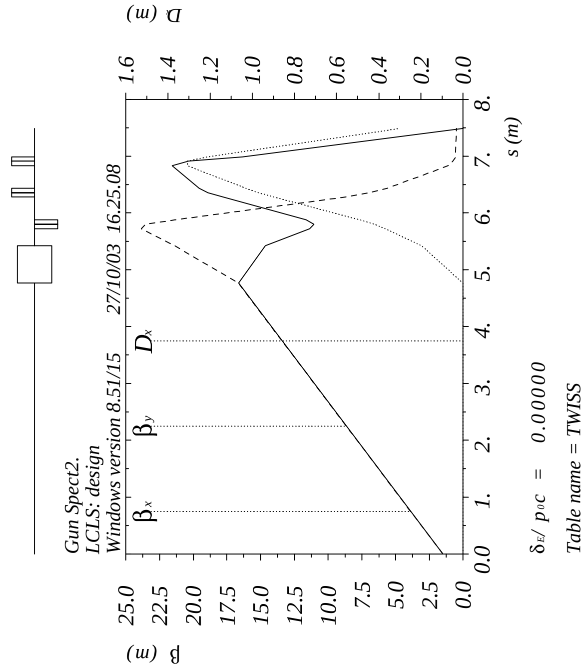

Figure 1:

R_{11}	R_{12}	R_{33}	R_{34}	R_{16}
-0.307	1.310^{-3}	-0.219	0.000	0.9000

Table 4: Twiss Parameters for second tuning

$k_{Q_1}[m^{-2}]$	$k_{Q_2}[m^{-2}]$	$k_{Q_3}[m^{-2}]$
-7.55	11.69	-10.97

Table 5: Quadrupole Settings for second tuning

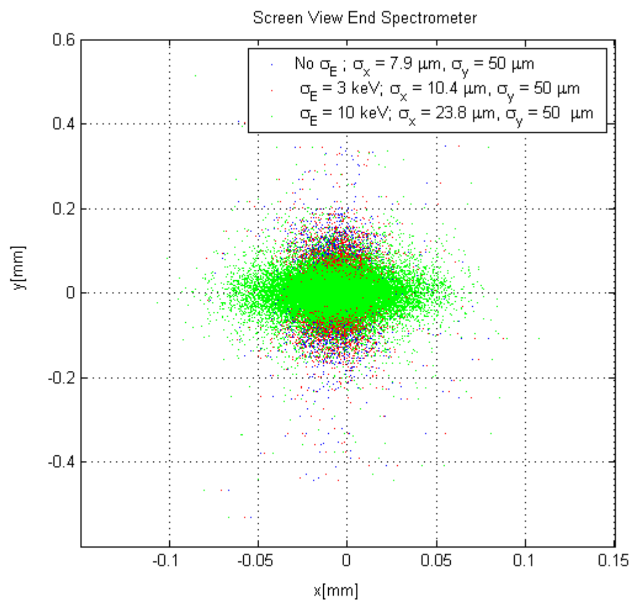

Figure 2:

R_{11}	R_{12}	R_{33}	R_{34}	R_{16}
-0.8188	$3.6.10^{-3}$	-0.103	0.000	2.400

Table 6: Twiss Parameters for tuning with largest R11

2 Second tuning

2.1 Simulations

Figure 3 shows the screen image for a beam with no correlated energy spread and very small uncorrelated energy spread.

The ratio of R_{16}/R_{11} is kept to -3 up to $R_{16} = 2.4$. No larger value R_{16} could be obtained while keeping the point-to-point imaging.

The evolution of Twiss Parameters and quadrupole strengths as a function of initial desired R11 is summarized in figure 4.

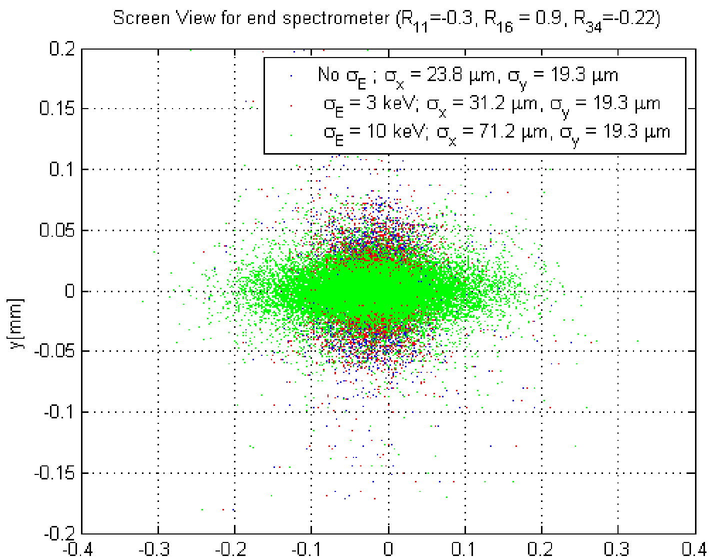

Figure 3:

$\mathrm{k}_{Q_1}[m^{-2}]$	$\mathrm{k}_{Q_2}[m^{-2}]$	$\mathrm{k}_{Q_3}[m^{-2}]$
3.709	-7.600	-5.4437

Table 7: Quadrupole settings

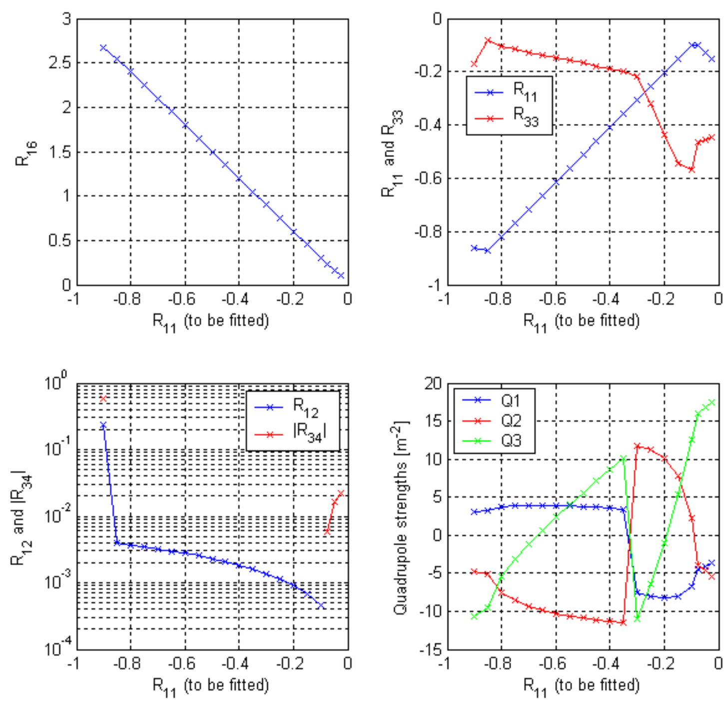
R16
R11 (to be fitted)
R11 and R33
R11
R33
R12 and |R34|
R12
|R34|
Quadrupole strengths [m-2]
Q1
Q2
Q3

Figure 4:

2.2 Limit on beam pipe radius

For an energy chirp larger than 0.635/1.9 MeV on the beam, the beam will be truncated by the one inch beam pipe at $3\sigma_x$,assuming $\mathrm{R}_{11} = 0.3/0.1$.

$$\sigma_\delta < \frac{1}{3}\sqrt{(\frac{2.54.10^{-2}}{6R_{11}})^2 - \sigma_{xo}^2}$$

The tuning with $\mathrm{R}_{11} = 0.1$ is better for studying the large correlated energy spread configuration.

We still need to compute what is the maximum beam size along the beamline. Simulations include an aperture.

3 Longitudinal Phase Space

When combined with the transverse deflecting cavity, we will obtain an image of the longitudinal phase space. The transverse deflecting cavity introduces a time/ vertical axis correlation. The spectrometer will give the energy / horizontal axis correlation.

In the simulations presented here below, we have introduced +/- 1 mrad linearly from head-to-tail at the OTR4 screen. This was done for conveniency, but more rigorously it should have been introduced at the transverse deflecting cavity location.

Figure 5 shows the reproduction of the longitudinal phase in the horizontal/vertical space.

We then checked the resolution of the system for six different rms values of the uncorrelated energy spread : 0 , 3keV, 6keV, 10 keV, 20keV, 30keV. We introduce a linear chirp at the location of OTR4 and added the uncorrelated enrgy spread as shown in figure 6.a. The screen image is shown in figure xx.b. It is difficult to see by eye the differences except for the energy spread larger than 10 keV.

From figure 6.b , we extracted a slice with $-5\mu m < y < 5\mu m$. The rms of the horizontal beam size is given in the legend of figure 7. This plot suffers from the very low statistic in particles (total number of particles is on;y 20000), but the evolution of the rms shows that we should be able to resolve 6 keV.

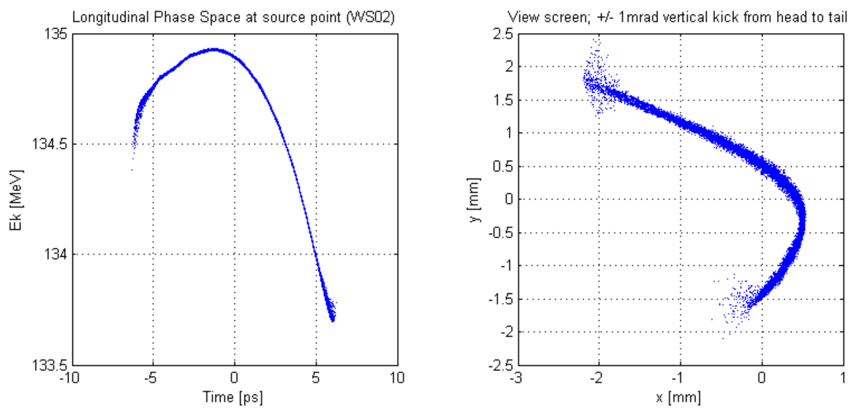

Figure 5:

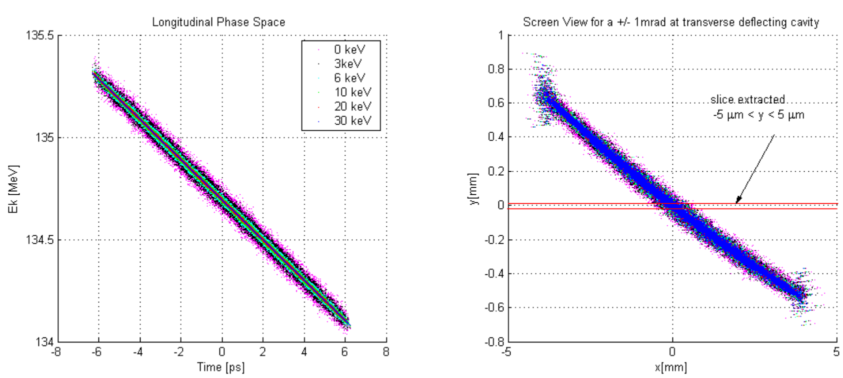

Figure 6:

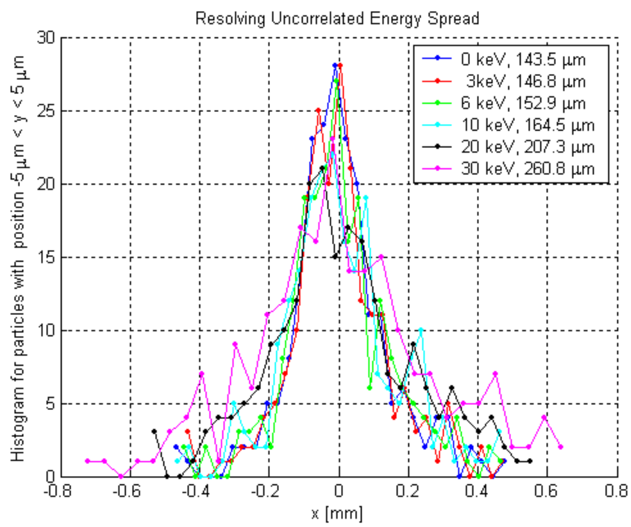
Resolving Uncorrelated Energy Spread
0 keV, 143.5 µm
3keV, 146.8 µm
6 keV, 152.9 µm
10 keV, 164.5 µm
20 keV, 207.3 µm
30 keV, 260.8 µm
Histogram for particles with position -5 µm < y < 5 µm
x [mm]

Figure 7: