# DESIGN OF 200MeV ENERGY SPECTRUM ANALYTIC SYSTEM OF LINAC IN NSRL*

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*Abstract*

Energy Spectrum Analytic System of 200MeV Linear Accelerator in NSRL is used to detect the beam energy, guild the machine adjustment, and it supplies experimental evidence of the machine status. This paper showed the present status of the system, and analysed a few of its shortcomings. In the NSRL Project-II, we redesigned the system, and it will be installed soon. The details of physics computation are described.

## 1 INTRODUCTION

National Synchrotron Radiation Laboratory (NSRL) uses a 200MeV linear accelerator as the injector of HeFei Light Source (HLS). The Linac began to be constructed in 1984, and can send beam in 1987. The beam energy spectrum analytic system[1] was installed with the Linac, but as the building's construction wasn't in harmony with the analytic system design, this made the system installation didn't accord to the design, this leads the analytic system is not an imaging system and we can't precisely get the energy spectrum from the fluorescent image on the target sheet. The Linac's adjustment depends on experience from the fluorescent image, but it worked well in the past years, it satisfied the machine's operation and storage injection. With the NSRL Project II, our machine's performance will upgrade to a new level, this demands us to know the beam energy spectrum information accurately, so we plan to redesign the Linac's spectrum analytic system.

## 2 PRESENT STATUS

### 2.1 General Layout

Figure.1 is the general layout of the transport line

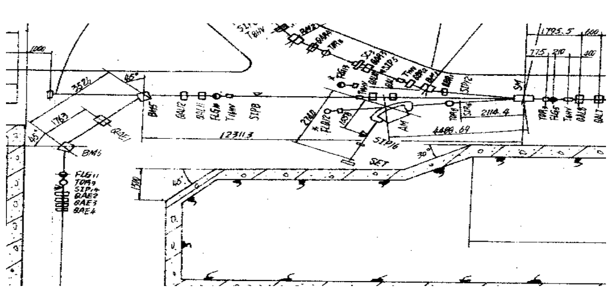

Figure 1: Layout of Linac crossing

switched to three bunches by a switch magnet. One channel leads to the storage ring, one to the garbage and nuclear hall, and another transported to an analytic magnet together composed the 200MeV energy spectrum analytic system. As the figure shows, the transport line downstream of the analytic magnet is immediate to the wall. In the original design of the system, the transport line would stretch inside the wall. As the building's construction completed, the line had to be shortened.

### 2.2 Spectrum Analytic Principle

In Accelerator Physics, the beam motion can be described by Beam Transformation Matrices[2]. When we have the original status of the beam and the transfer matrix between the site and the target, we can get the terminal information, take an example with the horizontal motion:

$$\begin{pmatrix} x_f \\ x'_f \\ \frac{\Delta p_f}{p} \end{pmatrix} = \begin{pmatrix} m_{x11} & m_{x12} & m_{x13} \\ m_{x21} & m_{x22} & m_{x23} \\ m_{x31} & m_{x32} & m_{x33} \end{pmatrix} \begin{pmatrix} x_i \\ x'_i \\ \frac{\Delta p_i}{p} \end{pmatrix}$$

Then we get:

$$x_f = m_{x11} x_i + m_{x12} x'_i + m_{x13} \frac{\Delta p_i}{p}$$

We usually use a CCD to get the fluorescent image on the target, the intensity distributing indicates the particle amount distributing. If we make $m_{x11}$ or $m_{x12}$ equal 0 and $x_i$ or $x'_i$ can be limited to a knowable range, then we can get the energy spectrum by analyzing the fluorescent image intensity distributing on the target.

### 2.3 Original Design

The sketch map of the beam lattice shows as Figure.2, Figure.3 is the sketch map of the switch magnet and the analytic magnet. The switch magnet has a $6^0$ fringe angle on the beam outside, and the analytic magnet has an $18^0$ fringe angle on both sides.

The transfer matrix of the horizontal motion from the

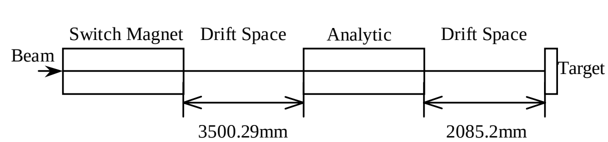


Figure 2: Lattice Sketch Map

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switch magnet entrance to the target is calculated as the following:

$$\begin{pmatrix} 0 & 2.683 & 0.9403 \\ -0.3727 & -0.7541 & 0.1506 \\ 0 & 0 & 1 \end{pmatrix}$$

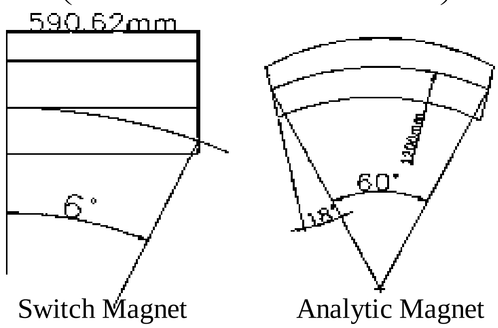


Figure 3: The sketch map of switch magnet and analytic magnet

In the computation, we use meter, radian as the units. The half width of the fluorescent target is 5cm, so we can get $\pm\frac{0.05\times 200}{0.9403}=10.635$ MeV's energy spectrum information on the target. In order to make the beam dispersion influence less than 1mm on the target, the aperture of the scraper should limit the dispersion angle in $\pm\frac{0.5\times 10^{-3}}{2.683}$ rad = ±0.186 mrad.

From the upper analytic, we have the following conclusion:

- The resolution of this system is very low. The fluorescent material granule and the CCD have a definite resolution, the detail spectrum will be blurred.
- The demand to the aperture of scraper is high, it will be a great influence to machine operation and storage injection.

### *2.4 Present Status*

As the building's construction wasn't in harmony with the design, the vacuum chamber had to be shorten so that it can be installed, now the real length of the drift space downstream the analytic magnet is 1.422m, using this length, we calculated the transfer matrix:

$$\begin{pmatrix} 0.2469 & 3.183 & 0.8405 \\ -0.3727 & -0.7541 & 0.1506 \\ 0 & 0 & 1 \end{pmatrix}$$

As the matrix shows, both $x_i$ and $x_i'$ will influence the target image.

## 3 SYSTEM REFORM

### *3.1 Final Redesign*

We have tried and computed many schemes, and determined the scheme eventually. Whereas the modulability is so limited as the target is adjacent to the wall, a rational idea is to push on the analytic magnet and the transfer line downstream of it to the spacious corner crooked to the nuclear hall. There is each quadrupole magnet respectively on the downstream and the upstream of the analytic magnet.

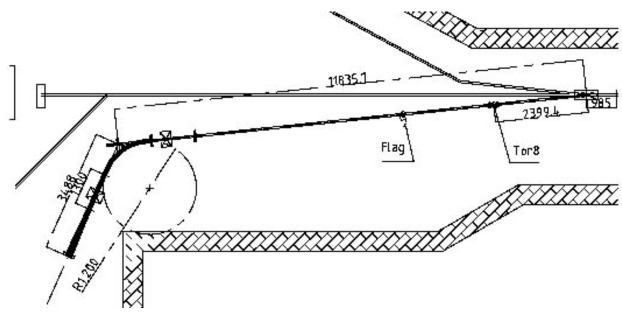


Figure 4: Final Redesign Layout

Figure 4 shows the redesigned layout, we appoint the site at the nearest flag detector as the object, and select appropriate length so that its image (Make the transfer matrix's element $m_{x12}$ equal zero from the object to the target) can be displayed on the target when no current supplies the two magnets. We can adjust the resolution of the spectrum analysis by setting corresponding current of the magnets. But we found a problem later, the $\beta_y$ function is too big to transfer the beam to the target. For solving it, we add a quadrupole magnet about in the middle of the transfer line between the switch magnet and the analytic magnet, set its K<0, we can depress the $\beta_y$, and the $\beta_x$ is limited in an acceptable range. Figure.5 shows the sketch map, Q1, Q2, Q3 are the quadrupole magnets, the dashed Q1 is supplemented, the effective lengths of Q1, Q2, Q3 are all 0.28m. In the following, we will give the calculated result of Twiss parameter.

### *3.2 Calculated Result of Twiss Parameter*

The initial Twiss Parameter at the entrance of the switch magnet is: $\beta_x$ = 48.32974 m, $\beta_y$ = 1.35255 m, $\alpha_x$ = - 2.56926, $\alpha_y$ = - 0.09582, $\eta$ = 0, $\eta'$ =0, the emittance is 0.5mm.mrad(the horizontal and the vertical are the same). We calculated the β function along the transport line of

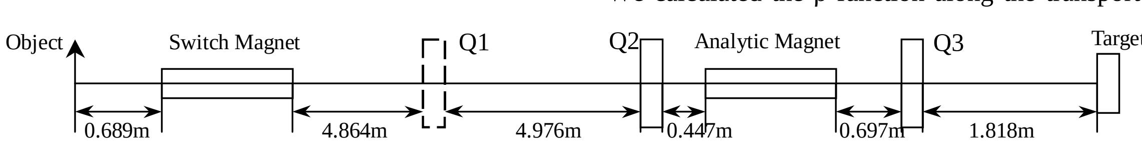


Figure 5: The Redesigned Lattice Sketch Map

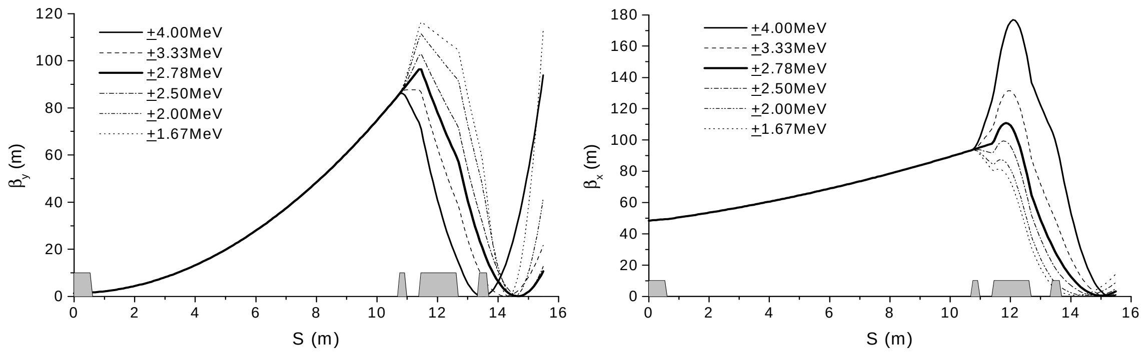


Figure 6: The β function curve when the Q1 is not added

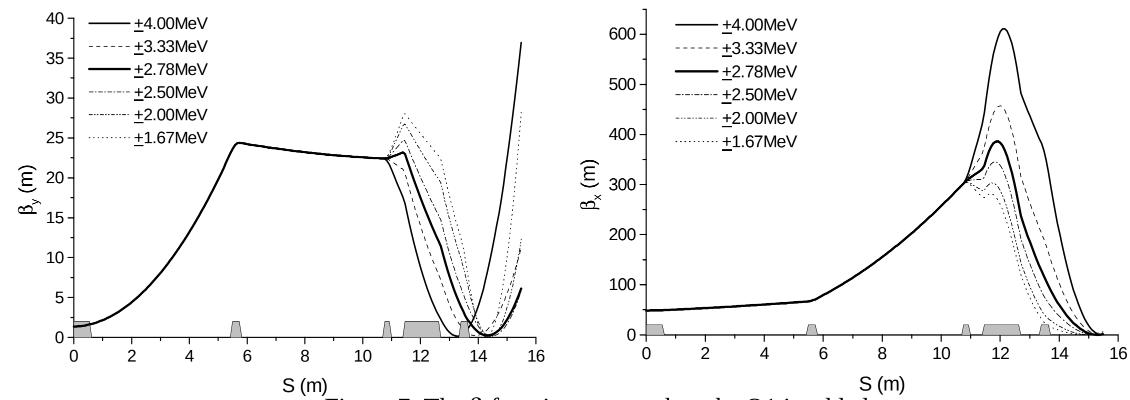


Figure 7: The β function curve when the Q1 is added

energy spectrum analytic system with or without Q1. Figure.6 shows the β function when Q1 is not added, the different curve present different resolution on the target, Figure.7 is one that Q1 is added ($K_{Q1}$=-0.65$m^{-2}$). Thus it is can be seen that the $\beta_y$ is depressed and the $\beta_x$ is limited in the acceptable range.

### *3.3 Related Parameter Table*

In the following, we will give out the numerical value of some important parameters, such as K value of Q1, Q2, Q3 for different resolution on the target, the matrix element $m_{x11}$ of the horizontal motion, and the element $m_{y11}$, $m_{y12}$ of the vertical motion from the object to the target, the concrete values are shown on Table.1.

From the table we can find a stirring advantage, the horizontal matrix element $m_{x11}$ is so small in the range about 0.1~0.36, we have observed the beam spot at that flag detector, the size is about 4mm, so the blurring effect by the beam size on the target is aproximately 1mm also, and in the future, the system will usually run at the ±2.78 MeV resolution(no current supplied to Q3), the beam size influence is so little that we need not to add a gap on the transfer line upstream the switch magnet, this is the reason why we use the site of the nearest flag detector as the object.

Table 1: Numerical Values

| **MeV** | **± 4.00** | **± 3.33** | **± 2.78** | **± 2.50** | **± 2.00** | **± 1.67** |
|---|---|---|---|---|---|---|
| $K_{Q1}$ ($m^{-2}$) | -0.65 | -0.65 | -0.65 | -0.65 | -0.65 | -0.65 |
| $K_{Q2}$ ($m^{-2}$) | -0.7512 | -0.1901 | 0.1275 | 0.3395 | 0.5939 | 0.7428 |
| $K_{Q3}$ ($m^{-2}$) | 1.2512 | 0.6163 | 0 | -0.6252 | -1.8310 | -3.0036 |
| $m_{x11}$ | -0.0984 | -0.1362 | -0.1735 | -0.2120 | -0.2877 | -0.3636 |
| $m_{y11}$ | -0.6875 | -0.5890 | -0.4759 | -0.3537 | -0.1107 | 0.1266 |
| $m_{y12}$ | -7.4102 | -4.1775 | -3.0890 | -2.9794 | -4.1372 | -6.0835 |

## 5 CONCLUSION

From the upper analysis, we can see the system have much flexibility because two independent parameters can be tuned, we will test its efficiency in the near future.

## REFERENCES


[1]. Baogen Sun, Zhigao Fang, et al. Beam Energy Spectrum Monitor for Hefei 200MeV Linac. Nuclear Techniques, Vol.21, No.1, 1998.1, P48-50

[2]. Zuping Liu, Beam Optics. University of Science and Technology of China