Magnet sorting for the XFEL hybrid Undulator—Comparing study

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Abstract

Current permanent magnet material quality is insufficient to obtain field qualities in undulators, which satisfy FEL requirements. Therefore position and orientation of magnets have to be carefully chosen in order to obtain mutual cancellation of field errors. In this paper we compare two different sorting schemes, simulated annealing and a straight forward paring method. They are applied to a 5 m prototype structure built for the European XFEL facility. The algorithms of these two methods are described in detail and the sorting results and the expected field qualities are carefully compared.
Key words: undulator, sorting, annealing, pairing

1 Introduction

The European XFEL will be a user facility in the wavelength range from 0.1 to 1.6 nm [1]. It will use the so-called Self Amplified Spontaneous Emission (SASE) scheme to reach saturation in a single pass [2, 3]. The XFEL will use a technology similar to FLASH [4]. The electron beam is generated in an RF photo cathode gun, accelerated and compressed twice before it reaches its final nominal energy of 17.5 GeV. After acceleration and collimation, the beam will be distributed among several SASE undulators and wigglers for spontaneous emission. The radiation is distributed among 10 user stations. The wavelength can be changed by changing the electron beam energy or by changing the undulator gap.

In its initial stage, SASE undulators are foreseen for the short wavelength range between 0.1 and 0.4 nm and for the longer wavelengths between 0.4 and 1.6 nm, the latter using the beam after it has radiated at the short wavelengths. The short-wavelength undulator will be planar hybrid devices using NdFeB. The long-wavelength undulator will probably be a variable-gap APPLE-type device in order to supply users with radiation of variable polarization. All devices will have an undulator segment length of about 5 m separated by approximately 1.1 m intersections to allow space for phase shifters, quadrupoles in order to focus the beam, and some diagnostics. The overall undulator length for the short wavelengths will exceed 100 to 200 m.

Studies for FLASH have shown that the transverse overlap between radiation and electron beam has to be better than 20% of the beam size in order not to have a too large reduction in gain and therefore a too large increase in needed undulator length [5, 6]. A similar criterion holds for keeping the resonance condition, i.e. keeping the phase shake within reasonable values. A typical rms deviation here is a few degrees. The undulator magnet quality needed to provide this overlap and phase shake without additional effort does not exist. Therefore, additional methods have to be used in order to guarantee a sufficiently good undulator quality.

Given the quality of the individual magnets, several methods can be used to obtain the appropriate undulator quality. Standard methods are magnet sorting, i.e. measuring the magnetic properties of the individual magnets and putting them into the structure such that errors in the magnet blocks cancel each other [7]. A second method is the use of shims in order to correct the magnetic field after the magnets have been built into the structure [8, 9]. Both methods are time-consuming. The result of magnet sorting depends on the method and on the model for the resulting magnetic field. Afterwards it is still necessary to measure the magnetic field. Ideally, shimming afterwards is no longer needed. For shimming, one only has to measure the magnetic field structure and compensate errors in field and field integrals by adding small magnets to correct the field locally. The better the sorting in advance or the magnet quality, the smaller the number of shims needed. A last method which can be applied to correct the main field component of the structures that are discussed in this paper is pole-height adjustment [10]. This procedure, which has to take place in any case, is outside of the scope of this report and can only be applied to the main field. Therefore, our main aim is to correct the transverse field components that cannot be corrected by this method.

The structure for which the magnets are sorted is shown in Fig. 1. It consists of magnets separated by iron poles that focus the flux lines resulting in the main magnetic field. Of each magnet, several parameters have been measured: the magnetization in all three directions (M_x, M_y, M_z) and the main magnetic field at a given distance $(B_z^{(n)}, B_z^{(s)})$, thus giving the north-south inhomogeneous field. For a perfect magnet, $M_x = M_y = 0$ and $B_z^{(n)} = B_z^{(s)}$. In order to uniquely identify the orientation of the magnet, each of them is marked as in Fig. 1. Therefore, the direction of the field components is known independent of the orientation of the magnet.

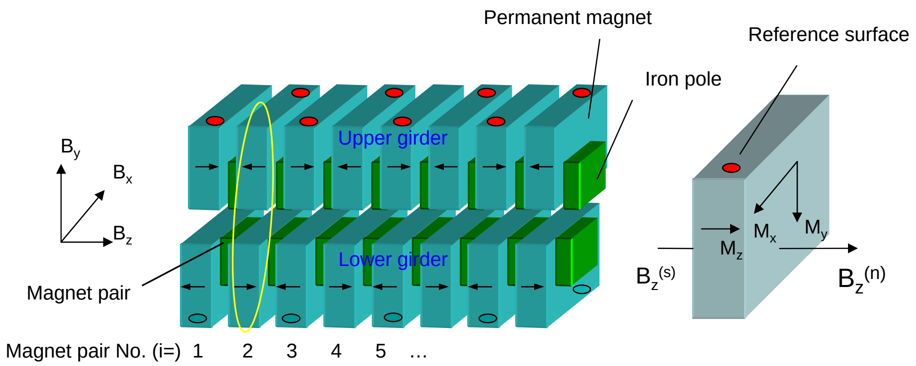

Figure 1: *Coordinate system for the undulator and the magnet blocks. The red dot is used to determine the orientation of the magnet under any transformation that may be applied inside the magnetic structure. The arrangement shown here is referred to as the normal state.*

The undulator main field on each pole is determined by the north and south field of each magnet $\left(B_z^{(n)}, B_z^{(s)}\right)$:

$$B_z^{(s)} \propto M_z^{(s)} = \frac{2M_z}{1+\alpha}, \qquad B_z^{(n)} \propto M_z^{(n)} = \frac{2\alpha M_z}{1+\alpha} \tag{1}$$

with $\alpha = B_z^{(s)}/B_z^{(n)}$.

With the magnet transverse flux M_x, M_y and main field components $B_z^{(s)}$ and $B_z^{(n)}$, the undulator field can be evaluated by:

$$B_{x,i} \propto (F_{l,i}M_{x,l,i} + F_{u,i}M_{x,u,i})(-1)^i \quad B_{y,i} \propto F_{l,i}M_{y,l,i} - F_{u,i}M_{x,u,i}$$
$$B_{und,i}^{(1)} \propto (M_{z,l,i}^{(n)} + M_{z,u,i}^{(s)})(-1)^{i-1} \quad B_{und,i}^{(2)} \propto (M_{z,l,i}^{(s)} + M_{z,u,i}^{(n)})(-1)^i \tag{2}$$

The subscript l refers to magnets on the lower girder, u to magnets on the upper girder,i means pole position, F stands for a possible flip of magnet at a certain position, with $F = 1$ the magnet in its normal state and $F = -1$ in its flipped state. $B_{x,i}$ and $B_{y,i}$ are undulator transverse field on each magnet pair (although $B_{y,i}$ in fact is the same direction as the main undulator field, but because it is relatively small and generated by the magnet transverse field, we still call it transverse field to distinguish it from the main undulator field). Two opposite magnets construct one magnet pair, one is on the upper girder, another is on the lower girder (see Fig. 1). $B_{und,i}^{(1)}$ and $B_{und,i}^{(2)}$ are the main undulator field produced by one magnet pair, the superscripts (1) and (2) refer to the field on each side (left and right) of the magnet pair.

In this report, we will sort the magnets using two different methods, namely simulated annealing and pairing of magnets based on the magnetic measurements. The field measurements for these structures will be compared to a structure in which the magnets have been inserted randomly. Because the real, measured magnets can be used only once, it is difficult to compare the results of the different methods since it cannot be excluded that a different result is due to a difference in the original magnet quality. Therefore, the comparison in this report is performed on the 5 m structure. In appendix B, the magnets with their actual measured magnetization will be added for comparison. In a future paper we hope to compare the real measured magnetic fields of the structures with the results simulated here.

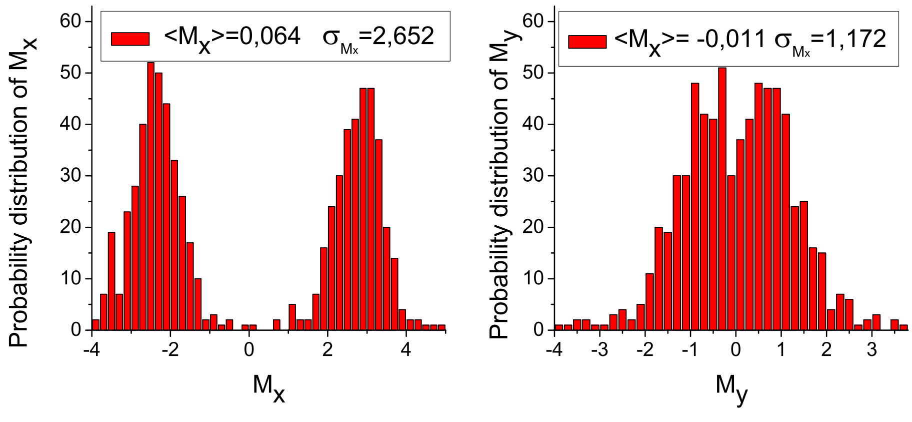

Figure 2: *Magnet transverse field distribution in the x- (left) and y-direction (right). Note that both show a double Gaussian distribution, indicating either an angle of the magnet during the measurement or of the external magnetic field while the magnets were produced.*

The transverse magnetization of the magnets used for the 5 m structure is shown in Fig. 2. As can be seen, it shows a double Gaussian structure.

For the present design, the height of undulator poles can be adjusted easily which means the main undulator field can be corrected after assembling magnets onto the undulator. Therefore, in this report the magnets are sorted taking into account their transverse field only. In Sect. 4, we discuss how to sort by undulator main field with the pairing method.

2 Algorithms description of simulated annealing and pairing method

Of all possible methods to sort magnets, two methods have been used here: simulated annealing and pairing. A program has been developed optimizing the magnet position and orientation using either one of these two methods. In this section they are described in detail.

2.1 Algorithm of simulated annealing

The method of simulated annealing [11, 12, 13] is a technique that has been used for optimization problems. Its main purpose is to avoid getting trapped in a local optimum. In the case of sorting magnets, the magnet position and orientations are changed and the magnetic field for this magnet distribution is calculated. It is quite possible that any single change makes the field quality worse, whereas a combination of changes improves the quality. In this sense the method is similar to a slow cooldown of liquids, allowing the formation of a crystalline state as compared to an amorphous state during a sudden cooldown. Also materials such as glass are cooled down slowly to avoid stress and solid state surface layers doted with semiconductor material are heated after the deposition to allow a redistribution of the atoms in the structure.

So the essence of the process is slow cooling, allowing enough time for redistribution of the atoms as they lose mobility. This is the technical definition of annealing, and it is essential for ensuring that a low energy state will be achieved. The energy state can be described by so-called Boltzman probability distribution:

$$Prob(E) \sim exp(-E/kT)$$

This expresses the idea that a system in thermal equilibrium at temperature T has its energy probabilistically distributed among all different energy states E. Even at low temperature, there is a chance, although very small, of the system being in a high energy state. So the system has a chance to go out of a local energy minimum in favor of finding a better, more global one.

The simulated annealing algorithm can be divided into several steps:

1. Find a description for the possible system configuration
2. Find a generator of random changes in this configuration
3. Define a cost function E (analog of energy) whose minimization is the goal of the procedure.
4. Change the system configuration randomly; depending on the values of the cost function before and after changing (E_1, E_2) , calculate the value p :

$$p = exp[-(E_2 - E_1)/T = exp[-\Delta E/T]$$

If $E_2 < E_1$, then $p > 1$, this means the changing be accept; if $E_2 > E_1$, then $p < 1$, randomly generate a number m in the range of $[0, 1]$, if $m < p$, then this change will still be accepted, if $m > p$, this change will be refused.

5. Control the parameter T (analog of temperature) decreasing during the process. This annealing schedule tells how the T value is lowered from the high to low, e.g., after how many times of accepted or refused changes the value T should be decreased and how large is that step.

A simulated annealing program used for sorting undulator magnet has been developed which satisfied the five points above. This program stores all of the magnets' *field flux* in x, y, z directions (M_x, M_y, M_z) and their positions within the undulator in some arrays respectively.

The program controls the main annealing progress: first the undulator's configuration is randomly rearranged for 20000 times to determine the range of values of ΔE that will be encountered from move to move, by this the average value $\langle \Delta E \rangle$ can be obtained. Depending on $\langle \Delta E \rangle$ a starting value for the parameter T is chosen which is considerably larger than the largest ΔE which is normally encountered. Then after I_1 times accepted changes or I_2 times refused changes (I_2 is normally larger than I_1), the parameter T is reduced by a certain amount. If three attempts in a row T decreases because of refused change, the program will be terminated by a last 'quenched' sorting, in which only the changes of $\Delta E < 0$ are accepted.

- $TFAK$ — help to determine the initial parameter T, $T_{initial} = \langle \Delta E \cdot TFAK \rangle$
- $TEMPR$ — help to determine how large the parameter T decrease for each step, $\Delta T = T \cdot TEMPR$
- $NTRIED$ — help to determine the value of I_1, $I_1 = N_{magnet} \cdot NTRIED$, N_{magnet} is the total number of magnets for the undulator
- $NGUP$ — help to determine the value of I_2 ,$I_2 = I_1 \cdot NGUP$

In this program there are some key subroutines:

- Subroutine $FIELD$ can be used to calculate out the undulator field on each pole
- Subroutine $ZUFALL$ can randomly change the undulator configuration. There are two kinds of change, one is to change position of two magnets; another is to flip one magnet.
- Subroutine $COST$ is used to calculate the cost value (corresponds to the E value mentioned above).

Because the height of a pole can be adjusted by at least ±3 mm [1], the errors in the main field direction are easily to be compensated. This means the cost function need not take into account the main undulator field $B_{und,i}$. On the other hand, if the undulator is ideal, the field $B_{x,i}$ and $B_{y,i}$ should be zero, so the cost function includes these two elements. From Fig. 1 one can see that $B_{x,i}$ and $B_{y,i}$ is the transverse field of each magnet pair, they should of course be included in the cost function. Two neighbouring magnet pairs construct one undulator period, so $B_{x,2i-1} + B_{x,2i},\ B_{y,2i-1} + B_{y,2i},\ i = 1, 2, 3...$ represents the transverse field in $i-$th period and these two elements are also included in the cost function. What is more the first and second magnetic field integral of the transverse field $B_{x,i}$ and $B_{y,i}$ determines the electron beam angle and distance from axis, so the first integral of the transverse field is included too. Consequently six elements are included in the cost function:

- Rms value of transverse field of each magnet pair:

$$A = \sqrt{\frac{1}{N}\sum_{i=1}^{N} B_{x,i}^2}\ , \quad B = \sqrt{\frac{1}{N}\sum_{i=1}^{N} B_{y,i}^2} \tag{3}$$

- Rms value of transverse field of each undulator period:

$$C = \sqrt{\frac{1}{N/2}\sum_{i=1}^{N/2} (B_{x,2i-1} + B_{x,2i})^2}\ , \quad D = \sqrt{\frac{1}{N/2}\sum_{i=1}^{N/2} (B_{y,2i-1} + B_{y,2i})^2} \tag{4}$$

- Rms value of first integral transverse field on each magnet pair along undulator:

$$E = \sqrt{\frac{1}{N}\sum_{i=1}^{N} \left(\sum_{j=1}^{i} B_{x,j}\right)^2}\ , \quad F = \sqrt{\frac{1}{N}\sum_{i=1}^{N} \left(\sum_{j=1}^{i} B_{y,j}\right)^2} \tag{5}$$

N represents the number of magnet pairs in one undulator. So the value of cost function E is:

$$E = w_1 A + w_2 B + w_3 C + w_4 D + w_5 E + w_6 F\ , \tag{6}$$

where $w_1, w_2, w_3, \ldots$ are the weights for these six elements. They are input parameters for the annealing program. In section 3.1 we will discuss how to suitably set these weights.

Fig. 3 illustrates how the value of the cost function decreasis during the simulated annealing process. In this plot as the iteration number increases, the controlled 'temperature' goes down. One can see that in the beginning region of process where the 'temperature' is still high, the value of cost function changes in a large range and many of accepted tries give even larger cost function values. As the sorting process progresses, the 'temperature' decreases so the variation range of cost function value becomes smaller. In general the cost function value decreases and a small one can be found finally.

2.2 Algorithm of pairing magnets

From Eq. 2, one can see that the undulator transverse field is proportional to the sum of two magnets' flux in x- or y-direction instead of the magnet's flux it self. From the flux distribution shown in Fig. 2, it can be seen that it follows a double peak Gaussian distribution, whereas the average value is around zero. So we can choose two magnets whose transverse field deviates significantly from zero for but their sum flux is close to zero.

Following this idea the sorting work can be done by another so-called pairing method. It is divided into two steps: first list all magnets in increasing order of their flux, secondly pairing the magnet with smallest flux to the one with largest flux one by one. The algorithm is:

1. Calculate the absolute transverse field value $|M_x|$ and $|M_y|$ for each magnet, then store them as ascending order in two arrays;

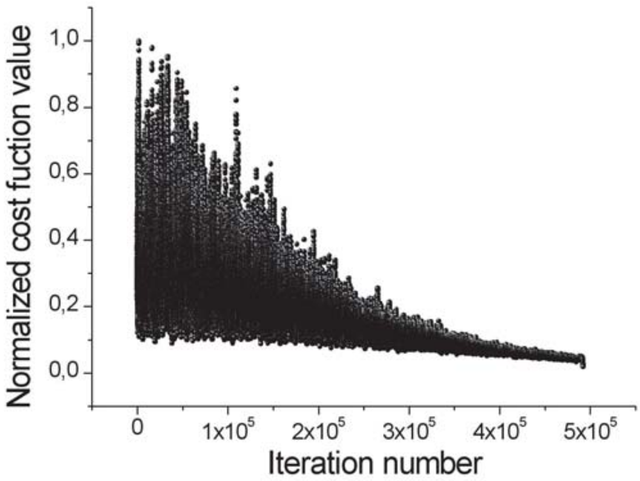

Figure 3: *The cost function variation during the annealing process. In the initial part of the process, the variation range of the cost function value is large for the "temperature" is high. As the process continues the "temperature" cools down so that the cost function value varies in a small range and decreases.*

2. Choose another magnet to match the magnet whose absolute value is largest. First step we choose the magnet whose $|M_x|$ and $|M_y|$ is closest to the one that has to be matched. This includes the possibility that by flipping the magnet the sign of M_x and M_y changes at the same time. If matching both cannot be satisfied, then flipping the magnet to make the sign of M_x different has priority. This means that the x-direction has preference during this step because the x-direction can only be corrected by shimming, which is much more difficult than adjusting pole vertical position.

3. After pairing the magnets, we pair the pairs. Because the x-direction of the field had higher priority during the previous step, the y-direction is considered first during this step. After this treatment, as shown in Fig. 7, the spikes appear by couples and the sign is different, so the integral field can be decreased.

4. After pairing the pairs, we pair double pairs. This time it considers the x-direction field more (the result of this step is shown in Fig. 8). Then we pair four pairs by y-direction, and then eight pairs by x-direction, and so on.

From the algorithm described above, one can see that the pairing method, unlike to the annealing method, does not randomly rearrange of the undulator magnet configuration and is therefore less computer intensive. The result of the pairing method and the annealing method will be compared in next section.

3 Sorting the 5 m long undulator by simulated annealing method and pairing method

Three undulator prototypes have been manufactured, one is 5 m long and two are 2 m long. In reality the 5 m long undulator is sorted by simulated annealing method, one 2 m long undulator is sorted by pairing and for another 2 m long undulator the magnets are put in randomly. So after measuring these three undulator magnet field, the sorting efficiency can be checked and compared.

To directly compare the sorting efficiency of annealing and pairing, in this section we sorted the 5 m long undulator not only by annealing method but also by pairing, and then compare the two sorting results.

3.1 Magnet sorting by simulated annealing

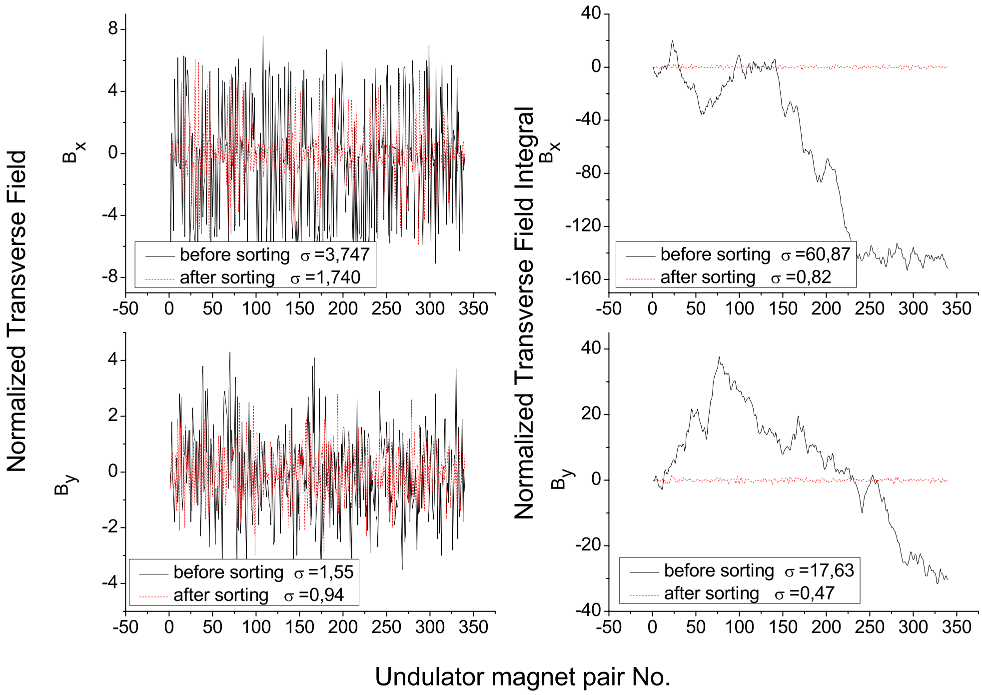

Figure 4: *Sorting result by annealing with same element weights for the cost function (given in Sec. 2.1). Both transverse fields in x- and y-direction show a moderate improvement, while the main improvement is observed in the first field integral.*

Since introducing annealing in last section, it is known that suitable weight of the elements included in the cost function must be set before running the program. Before any information is given, the most direct way is to equally set every element weight. Fig. 4 compares the transverse magnet field and its first integral before and after sorting by annealing with the same element weight for the cost function. One can see that after sorting, both of the transverse fields in x- and y-direction at each magnet pair show only a moderate decrease, while the first integral decreases by more than an order of magnitude. In order to improve also the transverse fields, the weight of elements for the cost function have to be set to different values.

One reasonable method to determine the weight is that first randomly setting the undulator configuration for many times and then observing how much the deviation of each element's contribution to the cost function is. Then each of element weight is set depending on this deviation [14]. The random setting time is 20000.

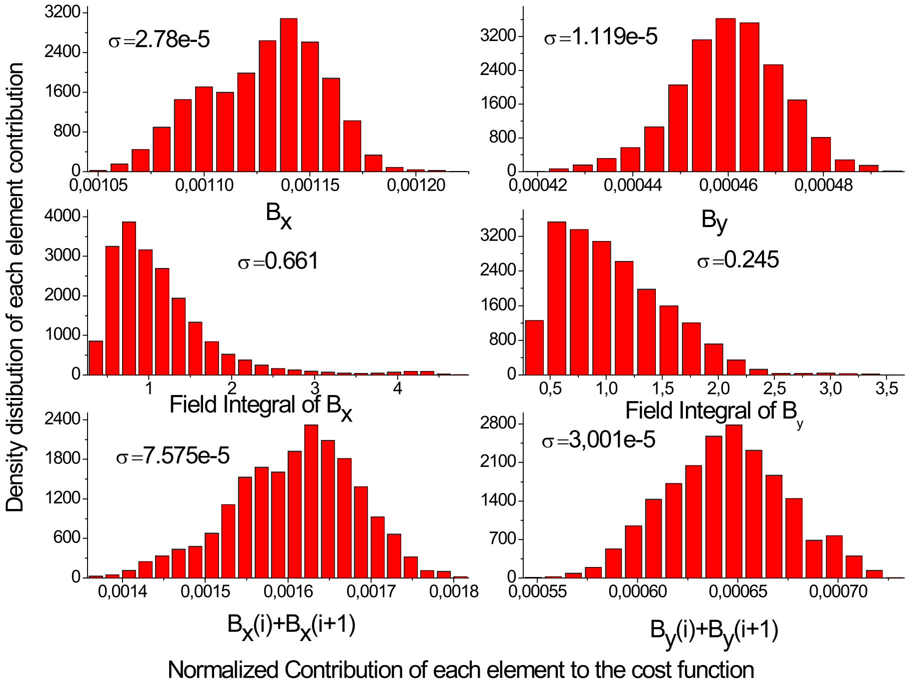

Figure 5: *The six elements' contribution to the cost function in Eqs. (3) to (5) obtained from 20000 random configurations. The contribution of first field integral to the cost function is much larger than the others.*

Fig. 5 gives the result. One can see that the contribution of the field integral to the cost function is much larger than the others. We set as weight of each element the inverse of the deviation of its contribution to the cost function as obtained in Fig. 5. Table 1 illustrates the different weights. As can be seen, the weight of the field integral is much smaller than the others and in fact can be nearly neglected in the cost function. If the field integral is not neglected, the value of cost function is mainly determined by it. This explains why in Fig. 4 the transverse field improvement is not dramatic.

The 5 m long undulator is sorted again with element weights listed in Table 1. Fig. 6 illustrates the result. One can see that by resetting the element weight, both of the deviation of transverse field and the deviation of their integral decreases by more than an order of magnitude. Although the weight of the field integral is nearly zero compared to the other elements, we get an even better result than before. This is because the field itself is decreased and this directly decreases the field integral.

Table 1: *Weight for the rms value of each element for cost function*

Elements for the cost function	**weight**
field B_x on each magnet pair	35971
field B_y on each magnet pair	89365
First field integral of B_x on each magnet pair	1.513
First field integral of B_y on each magnet pair	4.0816
field $B_x(i) + B_x(i+1)$ on each undulator period	13210
field $B_y(i) + B_y(i+1)$ on each undulator period	33333

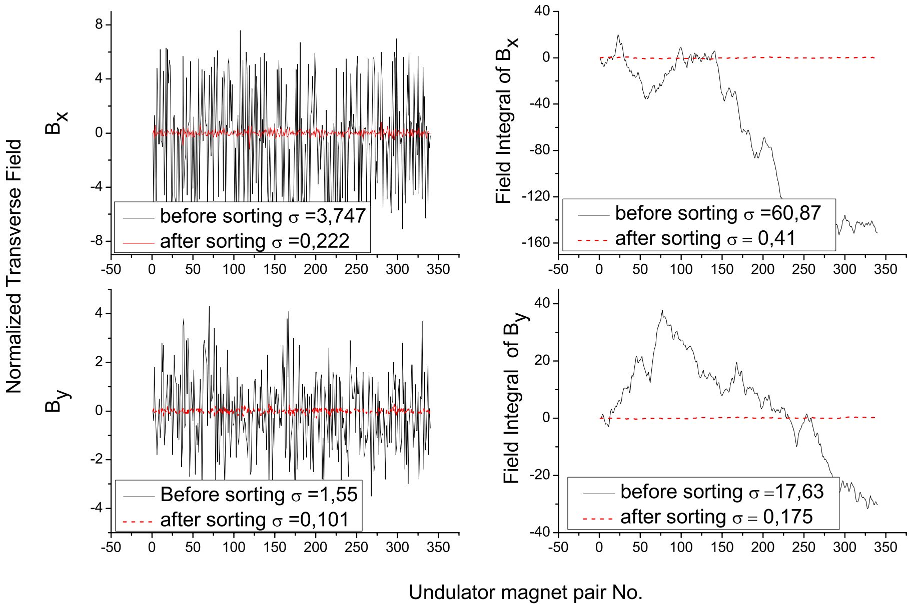

Figure 6: *Sorting result by annealing with different element weight listed in Table 1. Both of transverse field in x- and y-direction and their field integrals are decreased by one to two orders of magnitude.*

3.2 Sorting for the 5 m long undulator by pairing

Although in reality the 5 m long undulator is sorted by annealing, in order to evaluate the efficiency of the pairing method, we sorted the 5 m long undulator again by the pairing method described in section 2.2. By this mean the two sorting methods can be compared in the same context.

As described in section 2.2, the pairing method is divided into many steps: pairing magnets, pairing magnet pairs, paring double magnet pairs and so on. The result of the different steps on the field at different length scales is shown in Figs. 7 to 9.

Fig. 7 illustrates how the field on each magnet pair (B_x, B_y), i.e. for each half undulator period, depends on the subsequent sorting steps. Because in the first step the magnets are paired, attempting to improve both B_x and B_y, both of these fields improve by close to an order of magnitude. Pairing of magnet pairs results in a correlation for B_y shown in the 3rd graph. In this case the magnets are organized such that on the scale of an undulator period, the errors in B_y compensate each other. Because in this step B_x is

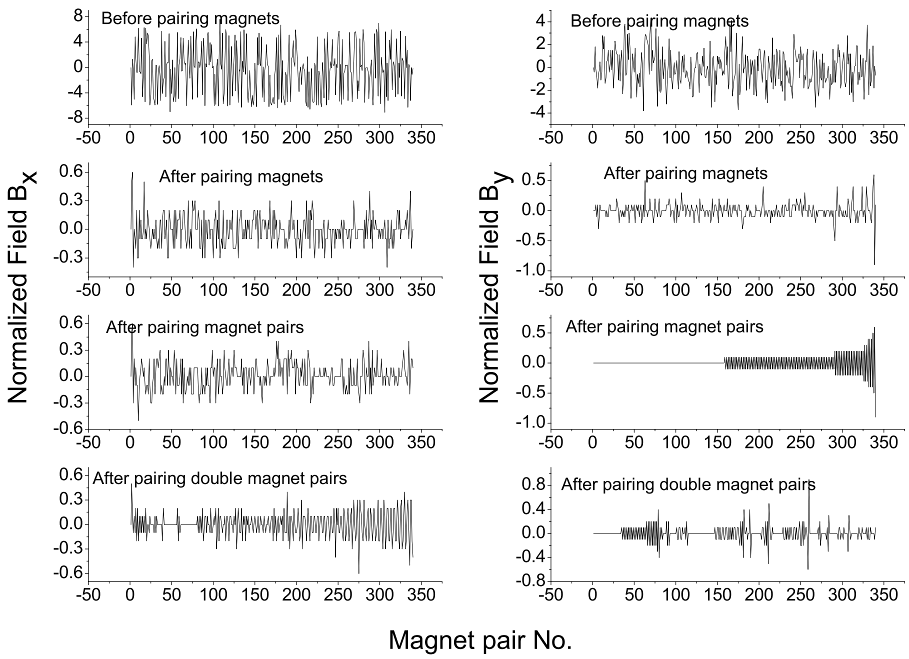

Figure 7: *Transverse field on each magnet pair (B_x ,B_y) development before pairing, after pairing of magnets, after pairing magnet pairs, after pairing double magnet pairs, respectively. At the first step to pair magnets, it is tried to minimize both of B_x and B_y, if this can not be possible, then B_x has priority over B_y.*

not considered, this field component is reorganized but not improved. The last step in Fig. 7 shows how sorting magnets on a scale of two undulator periods results in further correlations, now also on B_x which was taken into account in this (final) sorting step.

Fig. 8 shows for the same order of magnet positions as in Fig. 7 the magnetic field per undulator period. Where pairing of pairs is visible as spikes in Fig. 7, here it shows a large reduction of the normalized field B_y. Similarly, pairing of double pairs shows correlations on the scale of an undulator period in B_x. At the same time B_y is almost identical to zero (on this scale) with the exception of two spikes.

Fig. 9 shows for the same magnet configuration the transverse fields over a length of two undulator periods. As can be seen, the B_x-field, which showed spikes after pairing the double pairs (which is equivalent to two undulator periods), now shows a small remaining field error. All other components are not further reduced. Further reduction of field integrals is in principle possible when continuing pairing over an even longer length scale.

Finally, Fig. 10 shows the field integral in x and y after each of the pairing steps shown in Figs. 7 to 9. Because in each of the steps mainly one of the planes x or y is considered, only the integral in that plane is considerably better, whereas the integral in the other plane actally gets slightly worse.

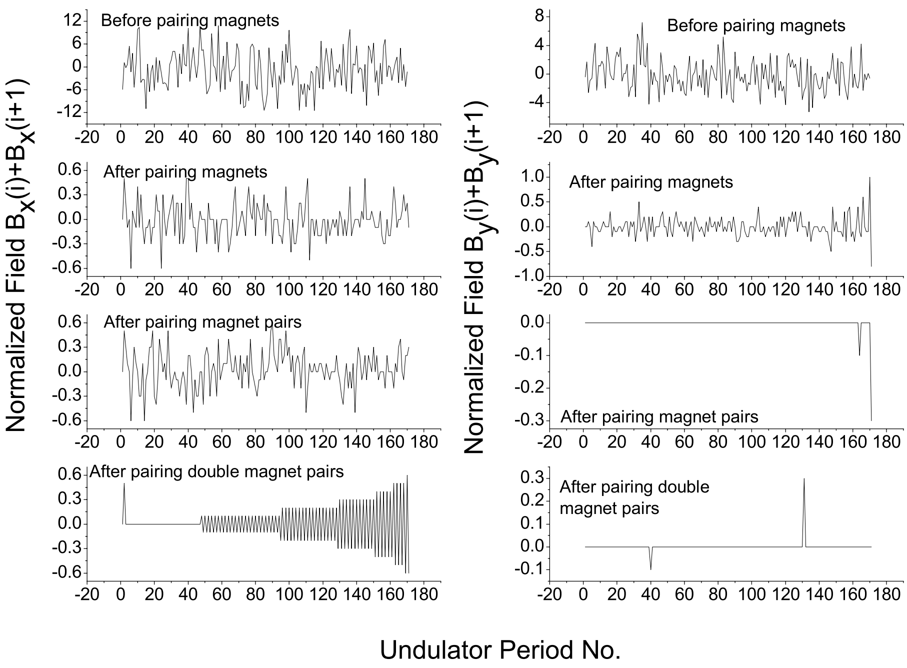

Figure 8: *Similar to Fig. 7, but now per undulator period* $(B_x(i) + B_x(i + 1), B_y(i) + B_y(i + 1))$.

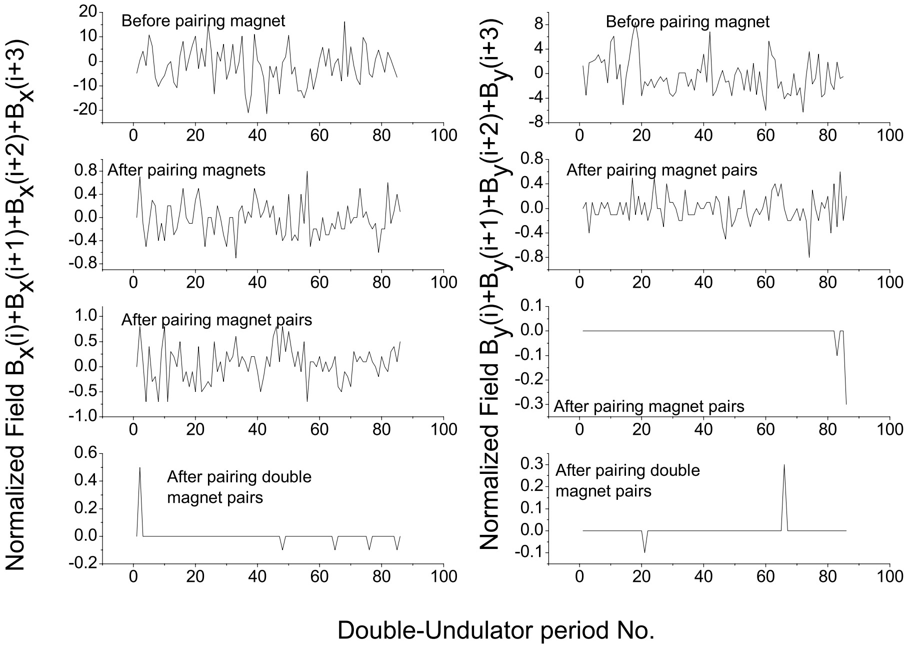

Figure 9: *Similar to Figs. 7 and 8, but now per double-undulator period* $(B_x(i) + B_x(i + 1) + B_x(i + 2) + B_x(i + 3), B_y(i) + B_y(i + 1) + B_y(i + 2) + B_y(i + 3))$.

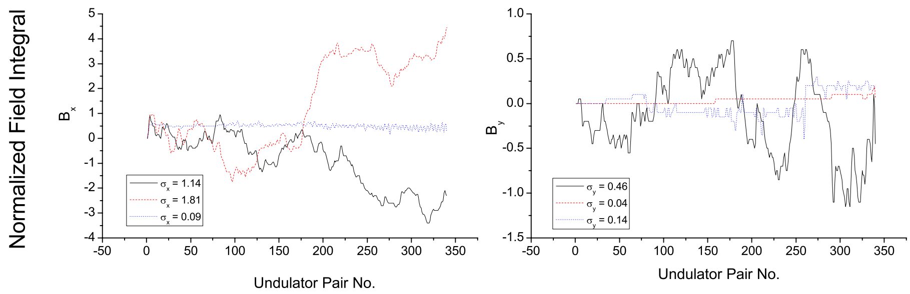

Figure 10: *Improvement of the field integral after each step of optimization, pairing of magnets (black curve), pairing of pairs (red curve) and pairing of double pairs (blue curve). The field integral before pairing is the same as in Fig. 4 and therefore not shown.*

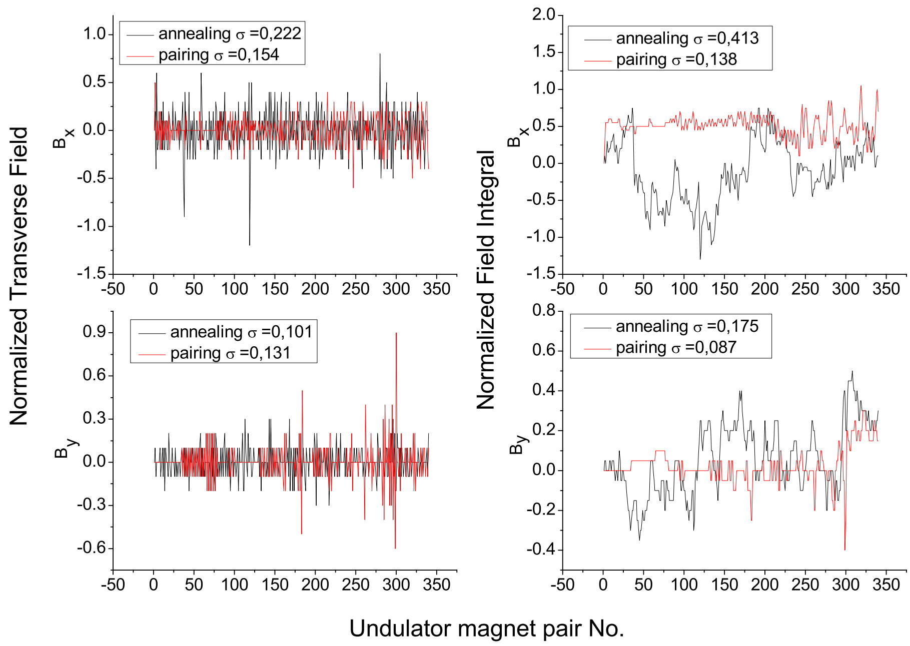

Figure 11: *Comparing the transverse field after sorting by annealing and pairing. One can see that for both of transverse field the results are similar, whereas for the field integrals the pairing method gives a factor of 2 smaller errors.*

3.3 Comparison of Annealing and Pairing

The comparison of pairing and annealing for the 5 m long undulator is illustrated in Fig. 11. One can see that for both transverse fields the results are similar. The field integrals are clearly smaller in case of the pairing method. The reason for this is that errors are corrected locally. The results so far show that magnet pairing is much less computer intensive and gives slightly better results. As a consequence, one might say that there is no reason to use simulated annealing. As will be shown in the next section, however, it also has some drawbacks.

3.4 Treatment for the case of unavailable magnets during assembling by annealing and pairing method

Some magnets may be unfortunately broken or lost when they are assembled onto the undulator girder. When this happens, others may already be fixed on the girder. It is too much trouble to take them out and resort all of the magnets, so the only two ways can be used to treat this case. One is fixing the magnets already assembled on the girder and then re-sorting the others, another method is simply replacing the broken magnets directly by some others whose field is most close to the broken ones'. Annealing method is easy to adopt the first re-sorting method while the pairing method can only adopt the second way.

For the 5 m undulator structure, two magnets whose numbers are 1554 and 1664 were broken.

3.4.1 Treatment by annealing method

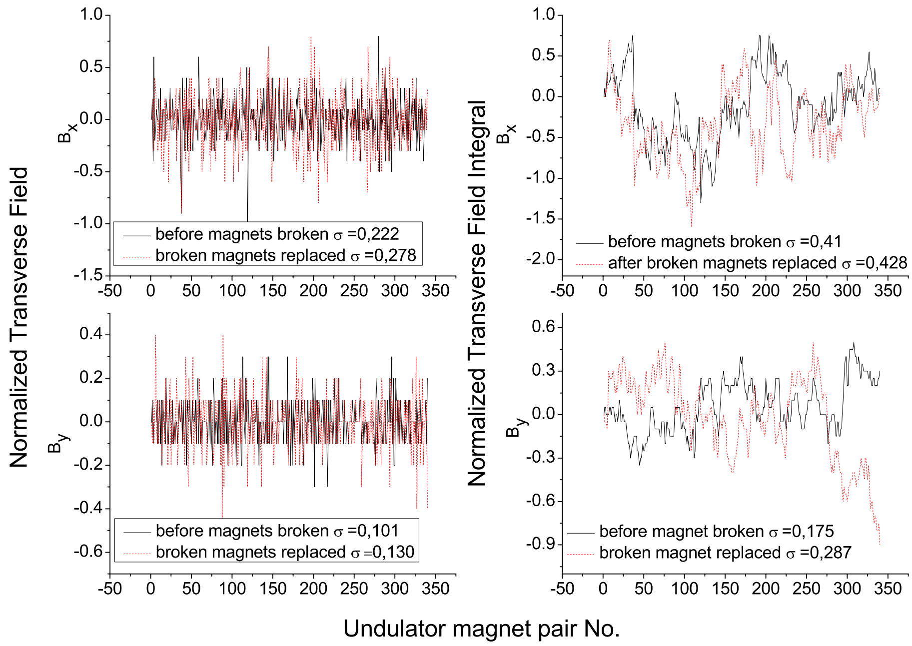

Figure 12: *Re-sorting results by annealing method. After the resorting, the field has the similar quality as the original sorting result. Because the magnets are assembled first onto the upper or lower girder and then onto the other girder, so the construction of magnet pair and its field is totally different after re-sorting*

Fig. 12 illustrates the result using annealing to re-sort the unassembled magnets. One can see that after resorting, the field has the similar quality as the original sorting result, while the field distribution is totally different. This is because the magnets are assembled not in the order of pair after pair but they are first assembled onto either the lower or upper girder then onto the other girder. So after re-sorting, the field on each magnet pair changes.

3.4.2 Treatment by pairing method

Table 2: *Transverse field of broken magnets and their replaced ones. The magnetic flux in x is almost the same. The different sign is has as consequence that the magnet has to be flipped. Because the field in y is different, kicks at the position wqhere these magnets are inserted are expected in this plane.*

Old **Magnet No.**	Old M_x	Old M_y	New **Magnet No.**	New M_x	New M_y
1554	2.9	-0.5	369	2.8	-2.7
1664	3.7	0.2	465	-3.6	-2.6

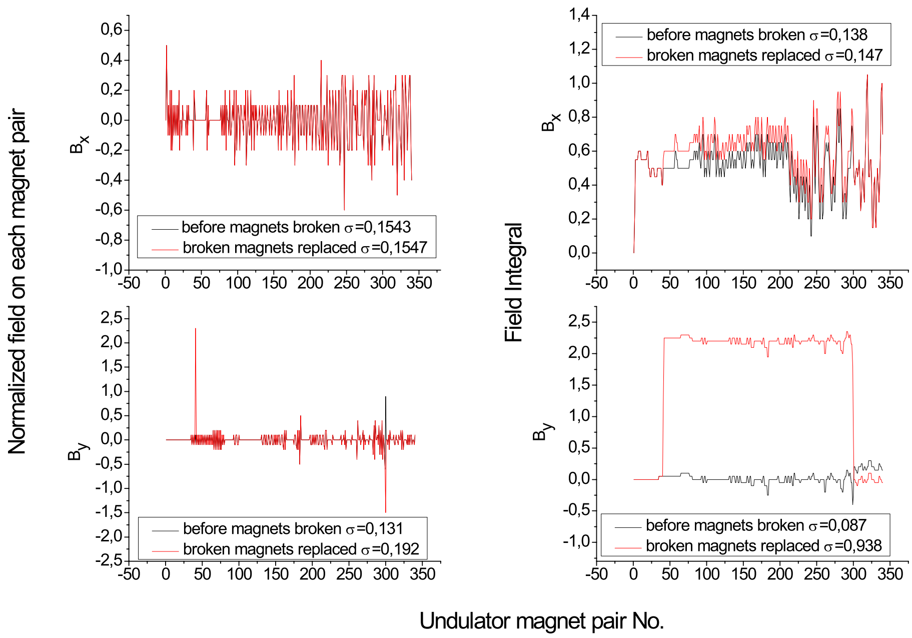

Figure 13: *Similar results as shown in Fig. 12 but now for the pairing method. Because no pairs with the same fields are available, magnets with the same field in the x-direction are used (see Table 2). As a consequence, a large deviation of the field integral in the y-direction occurs due to the two exchanged magnets.*

Because the magnets are assembled not in the order of pair after pair, when some magnets are broken, it is difficult to resort the unassembled magnets using the pairing method. One treatment is to find two other magnets to replace the broken magnets. From the remaining magnets selected by pairing, No. 369 is the best to replace No. 1554 and No. 465 is the best to replace No. 1664. Table 2 gives the data of broken magnets and their replaced ones.

From Table 2 one can see that the x-direction field of the broken and replaced magnets is close, while there is relatively large difference in the y-direction. So it can be foreseen that there would be little impact to x-direction field and in the y-direction there will be two peaks at the broken magnets position. The field on the other magnet pairs should be exactly same. We can see this phenomenon in Fig. 13. Because the field in the y-direction is different, two kicks occur at these positions and therefore a large field integral which has to be corrected by shimms at these positions. If there are more broken magnets, to find replacements is more difficult and there will be more peaks appearing in the field. The annealing method is preferable over pairing method in this respect.

4 Pairing magnets to decrease the main field component

In section 2.2 we discussed using pairing to sort magnets. The algorithm only considers how to compensate the transverse field error. However, in some cases, the main field component maybe more important. Therefore in this section we discuss how to use the pairing method to compensate the main field error.

Pairing by M_z

First we set the magnets in descending order of M_z . By this magnet list, we pair two magnets that one's M_z is large and another is small, i.e. both with large deviation from the average value. Thus the sum field M_z of each pair is more constant.

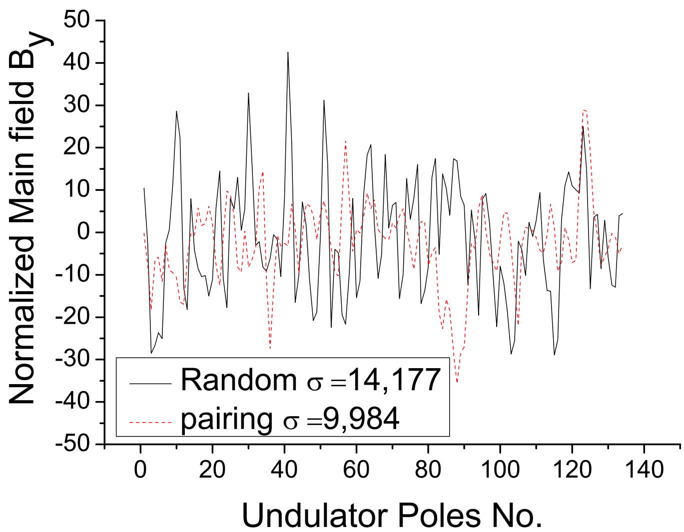

Figure 14: *Compare of main field distributions sorted by pairing method and random setting. The field quality improvement is moderate.*

Fig. 14 illustrates the sorting result for the main field. The improvement of the field quality by this method is moderate. This is because the main magnet field is not homogeneous: the field on the north side and south side is not same. And the undulator main field is determined by two magnet pairs: it is the sum of the two fields, one is produced by the left side of one pair and another is produced by the right side of the second pair (see Fig. 1). Therefore, the value of the field on the north and south side is more important than M_z.

Pairing by $M_z^{(s)}$ and $M_z^{(n)}$

Because the main field quality improves little by sorting depend on M_z, we correct the algorithm to take into account the case of inhomogenous field on north and south sides of the magnet. The algorithm is:

1. Exclude superfluous magnets: making the number of magnets being sorted exactly equal to the number needed. The magnets whose are most far from the mean value are excluded.

2. Pairing magnets: getting a magnet A as the one to be paired, and then choosing another B to compose a pair. B is so chosen such that the sum of south field of A and north field of B has smallest difference with the sum of the north field of A and south field of B.

3. For each pair, fix one magnet and flip another one to ensure the signs of these two magnet field are different. By this mean one can decrease the transverse field.

4. Pairing pairs: calculating for every pair. If the sign of for one pair is different to the sign for the pair next to it, then flip the two magnets belonging to the second pair. By this way one can make them smaller. From the algorithm described above, one can see it also to some extent takes into account the optimizing of the transverse field.

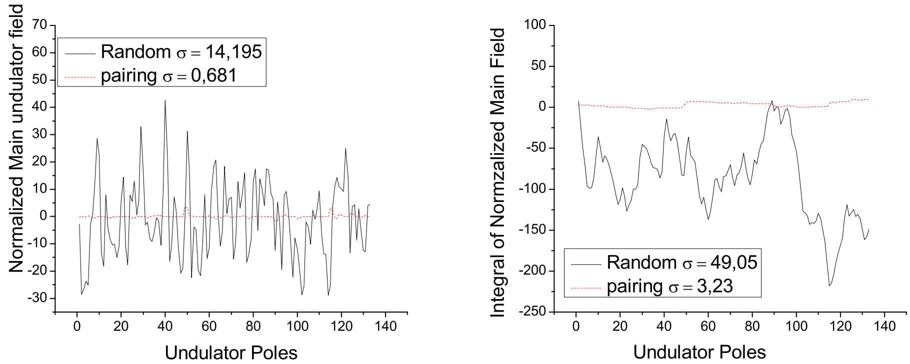

Figure 15: *Sorting result for main field component by pairing method. Its quality is improved over an order of magnitude.*

Figs. 15 and 16 show the result. One can see that the main field component has a large improvement after sorting. The transverse field in x-direction also has some improvement. But the transverse field in y-direction is improved little. In should be noted here that a similar procedure of optimization of the main field can be applied to the annealing method with similar results.

5 Summary

In order to reach saturation in an FEL the overlap between electron and photon beam has to be guaranteed. Because the quality of the individual magnets is at the moment not good enough to achieve this, additional methods have to be used to reach this goal.

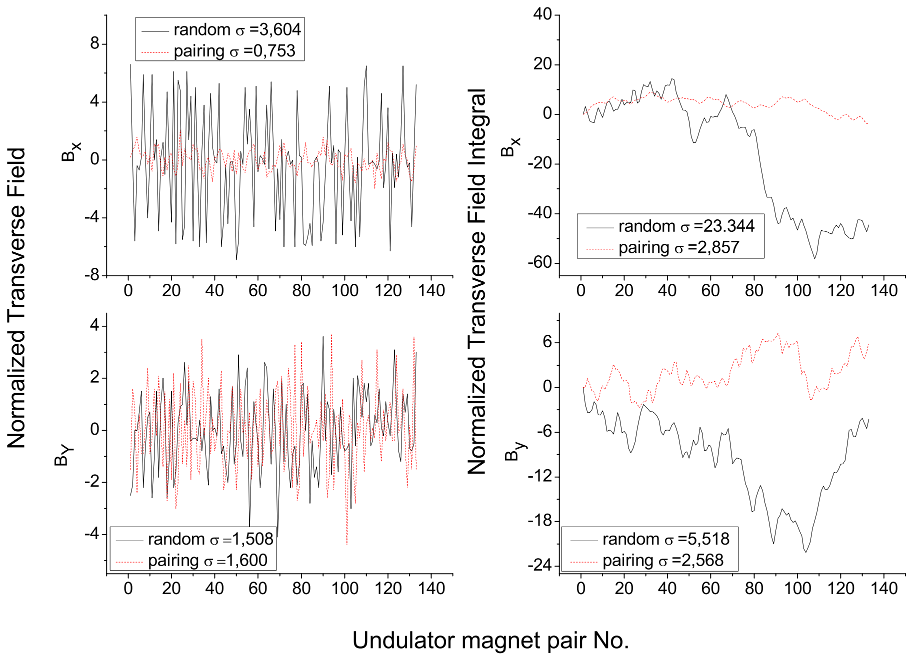

Figure 16: *Sorting result for transverse field (B_x and B_y) by pairing method (mainly consider the main undulator field). The quality of B_x improves, while there is no significant improvement for B_y.*

One of these methods is the use of sorting schemes. To this aim individual magnets are measured and put into the undulator structure in a special order. The two methods discussed in this report are simulated annealing and generating pairs of magnets. Because the main undulator field can be corrected with pole-height adjustment, no attempt has been made to correct this field component, e.g. only the transverse field components have been corrected.

As has been shown, both methods can greatly improve the transverse undulator field. The pairing method is more straightforward and gives a better field than the annealing method. The field integral is about a factor of 2 better for pairing, which would result in a better overlap. However, both methods meet and even exceed the required field accuracy. On the other hand, if some magnets have to be exchanged during assembling, using annealing method can easily re-sort the unfixed magnet, while the pairing method faces some difficulty keeping the field quality with the remaining magnets.

For the undulators for which the sorting was performed, the main undulator field can be perfected by pole-height adjustement. Therefore this field component has not been part of the actual optimization procedure. In case that this is not possible, also this component can be included in either sorting method. As has been shown, the inhomogeneity of the magnetic field plays an important role here (with the flux lines through the iron poles being the sum of the field of left and right magnet) and has to be included in the sorting procedure. Without taking this effect into account, the improvement in field quality is only moderate.

Appendix A. 2 m long undulator for pairing result

The magnets for the 5 m long undulator have been sorted using the annealing and pairing method. For the actual structure, the annealing data have been used. Also for the 2 m long undulator prototype both methods have been used. In this case, the pairing method is used for the actual structure. The result is shown in Fig. 17. Once more it can be seen that pairing can give slightly smaller field errors than annealing method.

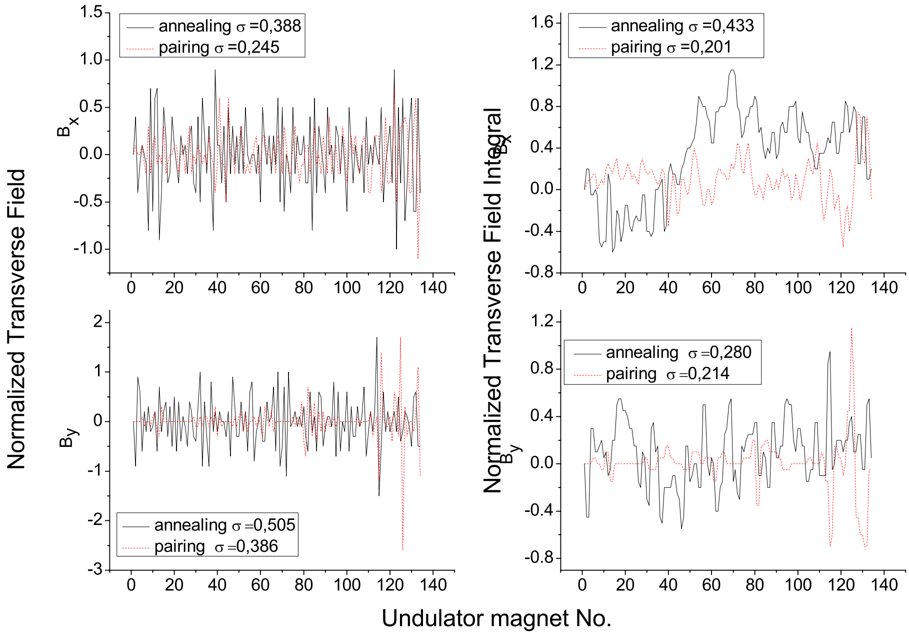

Figure 17: *Sorting result for the 2 m long undulator by annealing and pairing. One can see that for both of transverse field and their field integral, the pairing method gives smaller deviations.*

Appendix B. structures for the three undulator prototypes

Three undulator prototypes have been constructed. The 5 m long undulator named "NoellU29" is sorted using the annealing method, a 2 m long undulator "Danfysik" is sorted using the pairing method and in another 2 m long undulator "HelmhotzACCEL" the magnets have been put in without sorting. During assembling, some magnets have been broken. In this section we list the magnet position and orientation for the structures as they have been delivered at DESY.

The columns in the Table have the follwing meaning

- `1U/O` stands for undulator `1` in the Lower (`Unten`) or Upper (`Oben`) girder.
- `0...6` refers to the module within an undulator. Depending on the undulator length, there are 2 or 5 modules of 65 periods and at the entrance and exit a matching section referred to as '0' and '6'.
- `1...65` stands for the position of the magnet within an undulator module.
- `567N/V` refers to the magnet number and the orientation Normal (`Normal`) or Flipped (`Verdreht`).
- `609.00` Tis the main magnetic field flux.
- `3.20` is the flux in x.
- `-0.60` is the flux in y.
- `309.07` is the field measured at the north pole of the magnet.
- `299.93` is the field measured at the south pole of the magnet.

1. Magnet structure for 5 m long undulator NoellU29

Upstream compensation:

Und.	Mod.	Pos.	Magn.	Mz	Mx	My	North	South
1U	0	1	567N	609.00	3.20	-0.60	309.07	299.93
1O	0	1	1587V	613.00	3.20	0.50	302.21	310.79
1U	0	2	566N	608.00	1.80	-0.70	309.17	298.83
1O	0	2	573N	613.00	-1.60	-0.80	318.15	294.85
1U	0	3	1417V	610.00	2.90	-0.30	298.60	311.40
1O	0	3	1467N	611.00	3.20	0.40	300.61	310.39
1U	0	4	1680N	607.00	3.40	-1.20	300.77	306.23
1O	0	4	507V	612.00	3.00	1.20	317.02	294.98

Module number 1:

Und.	Mod.	Pos.	Magn.	Mz	Mx	My	North	South
1U	1	1	621N	611.00	-1.30	-1.30	311.00	300.00
1O	1	1	1449V	612.00	-1.00	1.70	297.13	314.87
1U	1	2	1465V	612.00	-1.40	1.30	299.57	312.43
1O	1	2	591N	611.00	-1.30	-1.30	307.94	303.06
1U	1	3	1483N	611.00	3.00	0.90	297.86	313.14
1O	1	3	1736V	611.00	3.00	-1.00	294.50	316.50
1U	1	4	1744V	613.00	2.90	0.40	298.84	314.16
1O	1	4	455V	610.00	-2.60	0.50	314.76	295.24

1U	1	5	1688N	608.00	2.80	0.30	300.05	307.95
10	1	5	344V	611.00	2.80	-0.40	305.50	305.50
1U	1	6	1556V	609.00	2.00	-0.10	295.37	313.63
10	1	6	522V	611.00	-1.80	0.00	308.86	302.14
1U	1	7	343N	612.00	3.60	-1.00	313.04	298.96
10	1	7	645N	613.00	-3.80	-1.00	312.94	300.06
1U	1	8	527V	610.00	-3.10	0.90	309.57	300.43
10	1	8	1485N	613.00	-3.50	-0.90	307.42	305.58
1U	1	9	1694V	608.00	-2.20	1.70	297.92	310.08
10	1	9	557V	612.00	2.30	1.50	314.57	297.43
1U	1	10	1540V	613.00	-2.10	1.30	303.44	309.56
10	1	10	1711V	611.00	2.00	1.40	297.86	313.14
1U	1	11	1696V	607.00	-2.30	0.30	301.98	305.02
10	1	11	431N	612.00	-1.80	-0.30	309.98	302.02
1U	1	12	1427V	612.00	-2.00	0.70	303.25	308.75
10	1	12	1502N	612.00	-1.80	-0.60	301.10	310.90
1U	1	13	503V	610.00	-2.20	0.10	308.36	301.64
10	1	13	560N	610.00	-2.40	-0.30	310.80	299.21
1U	1	14	1395N	610.00	-1.30	-0.70	301.34	308.66
10	1	14	644N	612.00	1.10	-0.70	309.37	302.63
1U	1	15	1391N	611.00	2.70	0.30	296.34	314.67
10	1	15	384N	612.00	-2.80	0.20	310.59	301.41
1U	1	16	1524V	613.00	2.40	-1.20	300.06	312.94
10	1	16	693V	612.00	-2.40	-1.40	306.92	305.08
1U	1	17	1623V	611.00	-3.10	-0.50	299.08	311.92
10	1	17	534N	610.00	-2.50	0.50	308.96	301.03
1U	1	18	1497N	612.00	-2.90	-0.20	302.33	309.67
10	1	18	310N	612.00	3.10	-0.30	309.37	302.63
1U	1	19	1739N	613.00	-3.10	-0.80	305.58	307.42
10	1	19	336V	613.00	-3.10	1.00	315.08	297.92
1U	1	20	651V	611.00	-2.50	0.60	309.78	301.22
10	1	20	545N	610.00	-2.40	-0.40	305.31	304.69
1U	1	21	1655N	610.00	-2.50	-1.60	301.34	308.66
10	1	21	1566V	609.00	-2.50	1.70	299.02	309.98
1U	1	22	506V	611.00	3.00	0.50	308.56	302.45
10	1	22	1463N	612.00	3.10	-0.40	311.81	300.19
1U	1	23	1699N	611.00	2.50	0.20	299.08	311.92
10	1	23	615N	609.00	-2.40	0.30	312.42	296.58
1U	1	24	420N	614.00	2.80	1.80	313.14	300.86
10	1	24	466N	612.00	-2.80	1.80	313.34	298.66
1U	1	25	1621V	611.00	-2.30	0.90	302.14	308.86
10	1	25	393N	611.00	-2.20	-0.80	310.08	300.92
1U	1	26	1434N	613.00	2.70	1.20	301.29	311.71
10	1	26	1470N	611.00	-2.40	1.10	298.78	312.22
1U	1	27	1562N	610.00	3.20	-0.10	296.76	313.23
10	1	27	1608N	611.00	-2.80	-0.30	300.31	310.69
1U	1	28	1631N	611.00	1.80	0.60	299.08	311.92
10	1	28	311N	612.00	-1.70	0.80	312.73	299.27
1U	1	29	689N	612.00	2.50	0.80	310.28	301.72
10	1	29	1431V	613.00	2.50	-0.90	299.76	313.24

1U	1	30	1706V	612.00	3.40	-0.20	301.72	310.28
10	1	30	359N	613.00	3.70	0.10	312.32	300.68
1U	1	31	1488N	611.00	2.90	0.20	303.06	307.94
10	1	31	537V	612.00	3.20	-0.20	312.73	299.27
1U	1	32	504N	613.00	1.00	-1.70	312.94	300.06
10	1	32	337N	614.00	-1.50	-1.70	315.29	298.71
1U	1	33	663N	609.00	3.10	2.40	312.42	296.58
10	1	33	434N	612.00	-2.20	2.30	310.59	301.41
1U	1	34	319N	612.00	-2.80	0.40	309.67	302.33
10	1	34	1398N	611.00	3.00	0.50	298.78	312.22
1U	1	35	1511N	613.00	-1.70	0.50	304.66	308.34
10	1	35	624V	612.00	-1.50	-0.60	311.20	300.80
1U	1	36	1605V	612.00	2.50	-0.80	298.96	313.04
10	1	36	1393N	610.00	2.50	0.80	298.90	311.10
1U	1	37	500N	610.00	-2.10	0.20	308.96	301.03
10	1	37	523V	612.00	-1.80	-0.40	311.51	300.49
1U	1	38	1430N	613.00	-2.80	1.80	301.60	311.40
10	1	38	510N	611.00	2.40	1.50	308.56	302.45
1U	1	39	575V	613.00	-1.40	-0.90	313.86	299.14
10	1	39	1700V	608.00	1.70	-0.90	299.14	308.86
1U	1	40	602N	612.00	3.20	-0.80	311.20	300.80
10	1	40	612V	609.00	3.30	0.80	314.55	294.45
1U	1	41	1441V	611.00	-1.70	0.30	298.78	312.22
10	1	41	329V	613.00	2.00	0.00	314.78	298.22
1U	1	42	1477V	611.00	2.70	0.80	300.00	311.00
10	1	42	394V	613.00	-2.20	1.00	314.78	298.22
1U	1	43	581V	612.00	-1.30	-0.70	308.45	303.55
10	1	43	1527N	612.00	-1.70	0.70	302.02	309.98
1U	1	44	491N	612.00	-3.50	1.90	314.87	297.13
10	1	44	674N	610.00	3.20	1.90	312.32	297.68
1U	1	45	627V	612.00	-1.90	0.70	308.75	303.25
10	1	45	492N	613.00	-2.30	-0.60	315.08	297.92
1U	1	46	1547N	612.00	-2.10	-0.60	300.19	311.81
10	1	46	1484V	609.00	-1.90	0.70	297.50	311.50
1U	1	47	470V	614.00	3.80	0.60	312.53	301.47
10	1	47	542V	613.00	-4.00	0.90	311.71	301.29
1U	1	48	1722N	612.00	2.30	-1.20	302.63	309.37
10	1	48	350V	612.00	2.10	1.00	311.81	300.19
1U	1	49	1478V	611.00	-2.50	-0.30	300.31	310.69
10	1	49	1715V	610.00	2.80	-0.30	297.38	312.62
1U	1	50	688N	612.00	-2.70	-0.10	312.12	299.88
10	1	50	1734V	612.00	-2.60	0.10	302.02	309.98
1U	1	51	1469N	612.00	1.70	-0.20	301.41	310.59
10	1	51	1594N	612.00	-1.60	-0.10	298.04	313.96
1U	1	52	1719V	611.00	2.80	-1.50	299.08	311.92
10	1	52	648N	609.00	2.80	1.40	307.55	301.46
1U	1	53	1510N	610.00	-2.30	0.80	298.60	311.40
10	1	53	382N	612.00	2.40	0.80	315.49	296.51
1U	1	54	1438V	613.00	-1.70	0.70	300.06	312.94
10	1	54	348N	613.00	-1.50	-0.70	312.63	300.37

1U	1	55	1504V	610.00	3.30	-1.50	297.68	312.32
1O	1	55	1591N	614.00	3.30	1.30	299.94	314.06
1U	1	56	673V	610.00	-2.00	-0.40	309.88	300.12
1O	1	56	1641V	611.00	2.00	-0.50	300.61	310.39
1U	1	57	614V	610.00	2.20	0.40	310.19	299.81
1O	1	57	1749N	613.00	2.10	-0.50	304.97	308.03
1U	1	58	1549V	611.00	3.50	-1.70	296.95	314.05
1O	1	58	414V	613.00	-3.00	-1.90	317.53	295.47
1U	1	59	352V	611.00	-2.60	-1.30	315.58	295.42
1O	1	59	1572V	613.00	2.80	-1.30	302.82	310.18
1U	1	60	1695V	611.00	-2.20	-0.10	300.92	310.08
1O	1	60	516V	612.00	2.60	0.00	311.51	300.49
1U	1	61	1580N	613.00	3.20	0.70	300.68	312.32
1O	1	61	599V	611.00	3.20	-0.70	311.92	299.08
1U	1	62	312N	611.00	3.00	-1.00	313.44	297.56
1O	1	62	1682N	609.00	-2.90	-1.10	303.59	305.41
1U	1	63	445V	610.00	2.20	0.40	311.71	298.29
1O	1	63	558N	611.00	2.30	-0.50	307.94	303.06
1U	1	64	324N	612.00	-2.20	-1.40	310.59	301.41
1O	1	64	530V	611.00	-2.40	1.20	310.69	300.31
1U	1	65	1443V	612.00	-2.20	0.10	299.57	312.43
1O	1	65	1632N	611.00	-2.10	0.00	300.31	310.69
1U	1	66	1515V	611.00	3.40	0.20	301.83	309.17
1O	1	66	570V	613.00	-3.80	0.30	308.34	304.66

Module number 2:

Und.	Mod.	Pos.	Magn.	Mz	Mx	My	North	South
1U	2	1	1595V	610.00	-3.30	-0.80	302.25	307.75
1O	2	1	1429V	614.00	3.70	-0.70	301.17	312.83
1U	2	2	400V	611.00	-3.20	1.40	310.08	300.92
1O	2	2	417N	612.00	-3.70	-1.40	310.59	301.41
1U	2	3	608N	613.00	-1.80	-0.90	313.55	299.45
1O	2	3	1684V	610.00	-1.50	0.90	301.03	308.96
1U	2	4	487N	612.00	-3.50	0.40	317.93	294.07
1O	2	4	664V	612.00	-3.20	-0.30	309.67	302.33
1U	2	5	697N	612.00	-2.40	1.20	313.34	298.66
1O	2	5	1445V	612.00	-2.20	-1.20	299.57	312.43
1U	2	6	678V	611.00	-2.90	1.50	309.17	301.83
1O	2	6	385V	612.00	3.20	1.30	308.14	303.86
1U	2	7	1448V	613.00	2.80	0.00	297.92	315.08
1O	2	7	1387V	610.00	-2.70	-0.10	297.38	312.62
1U	2	8	1589V	613.00	-2.70	1.00	299.45	313.55
1O	2	8	1517V	610.00	2.90	0.90	294.02	315.98
1U	2	9	446V	612.00	-3.60	0.40	313.96	298.04
1O	2	9	1613V	610.00	3.20	0.50	299.81	310.19
1U	2	10	554N	612.00	-1.70	0.60	312.43	299.57
1O	2	10	642N	612.00	2.10	0.60	311.20	300.80
1U	2	11	559V	611.00	3.70	0.60	309.78	301.22
1O	2	11	700V	614.00	-3.60	0.70	311.61	302.40
1U	2	12	1611N	608.00	2.60	1.40	297.31	310.69

1O	2	12	1723V	611.00	2.60	-1.30	296.64	314.36
1U	2	13	469N	612.00	-2.80	1.30	311.51	300.49
1O	2	13	1746N	612.00	2.40	1.30	297.43	314.57
1U	2	14	1442V	611.00	3.10	-0.60	298.17	312.83
1O	2	14	423N	611.00	2.90	0.60	311.61	299.39
1U	2	15	511N	611.00	-2.50	-1.00	312.83	298.17
1O	2	15	1730N	608.00	2.40	-0.80	293.06	314.94
1U	2	16	1575N	611.00	-2.00	0.00	299.39	311.61
1O	2	16	1599V	612.00	-1.90	0.20	298.96	313.04
1U	2	17	1640N	611.00	-3.70	1.50	300.00	311.00
1O	2	17	692V	612.00	-3.70	-2.10	307.84	304.16
1U	2	18	1489V	610.00	-3.10	0.40	295.85	314.15
1O	2	18	440V	612.00	3.10	0.80	312.43	299.57
1U	2	19	402N	611.00	-2.50	-2.10	306.42	304.58
1O	2	19	1658N	608.00	2.20	-1.80	292.14	315.86
1U	2	20	1597V	614.00	-1.50	1.40	301.17	312.83
1O	2	20	489N	610.00	-2.10	-1.60	312.01	297.99
1U	2	21	1614V	610.00	-2.10	0.90	298.60	311.40
1O	2	21	471N	613.00	-2.10	-0.90	309.87	303.13
1U	2	22	1666V	608.00	3.40	-0.30	299.74	308.26
1O	2	22	603N	613.00	3.30	0.10	314.78	298.22
1U	2	23	650N	612.00	2.10	1.30	311.20	300.80
1O	2	23	1574V	612.00	2.40	-1.20	305.39	306.61
1U	2	24	668N	613.00	-3.60	-2.40	315.08	297.92
1O	2	24	1473N	612.00	3.40	-2.20	303.25	308.75
1U	2	25	430N	611.00	2.30	0.30	307.33	303.67
1O	2	25	1678N	607.00	-2.10	0.50	297.43	309.57
1U	2	26	412V	613.00	-2.10	-0.30	315.08	297.92
1O	2	26	1731N	609.00	-1.90	0.30	300.24	308.76
1U	2	27	1546N	613.00	-2.70	1.20	304.05	308.95
1O	2	27	683V	611.00	-2.90	-1.10	316.80	294.20
1U	2	28	1692V	608.00	1.90	-0.80	298.83	309.17
1O	2	28	1615N	610.00	2.00	0.80	299.81	310.19
1U	2	29	1403N	614.00	3.00	-1.30	303.01	310.99
1O	2	29	1486V	613.00	2.90	1.10	301.29	311.71
1U	2	30	1573V	612.00	2.40	0.00	300.19	311.81
1O	2	30	1509V	610.00	-2.50	0.10	296.15	313.85
1U	2	31	328V	612.00	-3.50	-0.50	309.06	302.94
1O	2	31	1410N	607.00	-2.90	0.60	296.52	310.48
1U	2	32	1446V	613.00	3.20	0.10	302.21	310.79
1O	2	32	383N	612.00	3.50	-0.30	313.04	298.96
1U	2	33	349V	609.00	-2.20	-0.30	314.24	294.76
1O	2	33	1416N	611.00	-2.00	0.30	298.17	312.83
1U	2	34	447N	610.00	2.20	-2.70	311.10	298.90
1O	2	34	484V	612.00	2.00	2.60	314.26	297.74
1U	2	35	539N	610.00	3.50	2.00	308.96	301.03
1O	2	35	456V	612.00	3.60	-2.00	317.02	294.98
1U	2	36	1390N	612.00	2.70	-1.90	297.74	314.26
1O	2	36	513V	614.00	2.80	1.70	306.08	307.92
1U	2	37	526N	611.00	2.90	0.40	311.61	299.39

1O	2	37	1704N	608.00	-2.40	0.50	297.31	310.69
1U	2	38	699N	611.00	-2.80	-1.70	311.61	299.39
1O	2	38	363V	611.00	-3.00	1.90	310.39	300.61
1U	2	39	686V	607.00	3.30	2.40	309.87	297.13
1O	2	39	316V	612.00	-2.80	2.30	316.40	295.60
1U	2	40	1571N	612.00	-2.20	1.30	298.35	313.65
1O	2	40	448N	612.00	2.50	1.10	308.75	303.25
1U	2	41	1624V	609.00	-1.80	1.00	295.37	313.63
1O	2	41	365V	613.00	1.90	0.90	311.10	301.90
1U	2	42	1618V	609.00	2.00	-2.10	300.54	308.46
1O	2	42	672V	614.00	-1.60	-1.90	315.90	298.10
1U	2	43	1450N	612.00	3.70	0.40	296.82	315.18
1O	2	43	533N	610.00	-3.50	0.40	310.80	299.21
1U	2	44	1598N	613.00	-1.80	-0.90	304.05	308.95
1O	2	44	1560N	610.00	1.80	-0.90	298.60	311.40
1U	2	45	395N	612.00	2.50	-0.50	312.73	299.27
1O	2	45	1674V	608.00	2.70	0.50	298.53	309.47
1U	2	46	358V	611.00	2.20	1.60	309.17	301.83
1O	2	46	1544V	611.00	-1.90	1.60	302.14	308.86
1U	2	47	437V	611.00	3.30	0.10	309.47	301.53
1O	2	47	1402N	612.00	2.90	-0.30	299.88	312.12
1U	2	48	1436V	612.00	-2.20	2.20	303.25	308.75
1O	2	48	618N	609.00	-2.50	-1.90	309.98	299.02
1U	2	49	694V	614.00	3.60	1.00	308.53	305.47
1O	2	49	1609V	607.00	-3.20	1.00	297.73	309.27
1U	2	50	467N	611.00	-1.50	-2.50	303.06	307.94
1O	2	50	636V	609.00	-2.00	2.50	307.24	301.76
1U	2	51	1444V	609.00	-1.60	0.30	295.97	313.03
1O	2	51	416N	613.00	-1.70	-0.20	316.31	296.69
1U	2	52	659N	612.00	-3.00	0.50	306.31	305.69
1O	2	52	1451N	613.00	2.80	0.50	300.37	312.63
1U	2	53	1649V	609.00	2.90	0.10	299.93	309.07
1O	2	53	1564N	612.00	2.90	-0.20	307.22	304.78
1U	2	54	356N	611.00	-1.80	-0.80	315.28	295.72
1O	2	54	665V	610.00	-1.90	0.70	311.71	298.29
1U	2	55	1659N	610.00	-2.40	-0.50	298.60	311.40
1O	2	55	1396N	612.00	2.40	-0.70	302.02	309.98
1U	2	56	1493N	611.00	2.00	-0.90	300.00	311.00
1O	2	56	373V	612.00	2.10	0.70	307.53	304.47
1U	2	57	413N	613.00	2.50	1.10	317.53	295.47
1O	2	57	1490V	612.00	2.60	-1.00	303.55	308.45
1U	2	58	1538V	612.00	2.30	-0.90	301.41	310.59
1O	2	58	681V	612.00	-2.10	-0.90	308.45	303.55
1U	2	59	346N	611.00	3.10	0.70	313.44	297.56
1O	2	59	1550V	612.00	3.00	-0.70	302.63	309.37
1U	2	60	635V	609.00	-2.40	-0.50	315.16	293.84
1O	2	60	481N	608.00	-2.10	0.50	315.25	292.75
1U	2	61	649N	610.00	1.90	1.50	314.45	295.54
1O	2	61	1698N	611.00	-1.90	1.40	300.61	310.39
1U	2	62	589N	611.00	-2.00	-1.20	309.17	301.83

1O	2	62	588V	614.00	-1.90	1.10	309.15	304.85
1U	2	63	1673V	610.00	3.10	1.00	297.38	312.62
1O	2	63	396N	612.00	3.40	-1.00	315.79	296.21
1U	2	64	640V	612.00	-2.60	-1.00	311.81	300.19
1O	2	64	1748N	611.00	-2.30	1.10	299.39	311.61
1U	2	65	444N	610.00	-2.30	-0.40	311.10	298.90
1O	2	65	1412N	607.00	2.10	-0.10	294.09	312.91
1U	2	66	1533V	614.00	-3.10	-0.90	299.33	314.68
1O	2	66	1743V	608.00	3.20	-0.60	296.70	311.30

Module number 3:

Und.	Mod.	Pos.	Magn.	Mz	Mx	My	North	South
1U	3	1	1596N	613.00	3.60	0.60	305.27	307.73
1O	3	1	563N	611.00	-3.60	0.60	311.30	299.70
1U	3	2	586N	610.00	-2.80	-1.40	309.57	300.43
1O	3	2	549N	612.00	2.60	-1.30	312.43	299.57
1U	3	3	472N	611.00	2.60	-0.40	317.41	293.59
1O	3	3	451V	611.00	2.70	0.30	307.64	303.36
1U	3	4	690V	611.00	2.20	0.80	312.22	298.78
1O	3	4	1685V	608.00	-2.00	0.80	304.00	304.00
1U	3	5	517V	610.00	-2.20	1.00	312.62	297.38
1O	3	5	662N	611.00	-1.90	-1.30	309.78	301.22
1U	3	6	361N	613.00	-1.30	0.10	313.86	299.14
1O	3	6	474N	609.00	1.90	0.20	306.02	302.98
1U	3	7	1505V	613.00	2.20	-1.60	295.47	317.53
1O	3	7	669V	611.00	-2.20	-1.50	308.86	302.14
1U	3	8	355V	611.00	-2.40	-2.80	311.92	299.08
1O	3	8	625N	611.00	-1.70	2.90	310.39	300.61
1U	3	9	562N	612.00	-2.50	-1.30	311.20	300.80
1O	3	9	1647N	607.00	2.50	-1.30	293.48	313.52
1U	3	10	1578V	612.00	-3.00	0.60	298.04	313.96
1O	3	10	1654N	609.00	-3.20	-0.70	301.15	307.85
1U	3	11	509N	611.00	-2.50	-1.10	309.17	301.83
1O	3	11	1687N	608.00	2.10	-1.10	301.57	306.43
1U	3	12	331V	610.00	3.20	1.10	314.15	295.85
1O	3	12	555V	612.00	-2.60	1.00	314.26	297.74
1U	3	13	525N	612.00	2.30	-0.50	308.45	303.55
1O	3	13	497V	611.00	2.50	0.60	308.56	302.44
1U	3	14	1447N	611.00	-2.70	0.00	300.31	310.69
1O	3	14	1637V	608.00	-2.50	-0.20	299.74	308.26
1U	3	15	1401N	611.00	-1.90	1.00	300.92	310.08
1O	3	15	518V	612.00	-2.10	-1.10	311.51	300.49
1U	3	16	1577N	610.00	-3.00	1.60	295.85	314.15
1O	3	16	682N	610.00	3.30	1.60	311.40	298.60
1U	3	17	1526N	610.00	2.60	0.20	301.03	308.96
1O	3	17	601N	611.00	-2.60	0.20	314.67	296.34
1U	3	18	1557N	612.00	2.40	0.60	299.27	312.73
1O	3	18	1675V	609.00	2.50	-0.70	299.02	309.98
1U	3	19	326V	613.00	1.30	-1.80	312.94	300.06
1O	3	19	410V	610.00	-1.60	-1.70	310.19	299.81

1U	3	20	441V	610.00	2.80	-0.70	310.19	299.81
1O	3	20	1745N	613.00	2.90	0.80	303.13	309.87
1U	3	21	1500V	612.00	-3.50	0.80	304.16	307.84
1O	3	21	341V	611.00	3.90	0.80	310.39	300.61
1U	3	22	1415N	613.00	2.60	1.20	300.37	312.63
1O	3	22	483N	612.00	-2.60	1.20	316.71	295.29
1U	3	23	1579N	612.00	2.30	-0.90	302.33	309.67
1O	3	23	386N	613.00	-2.20	-0.90	314.16	298.84
1U	3	24	1462V	613.00	-3.00	0.40	300.37	312.63
1O	3	24	1683N	608.00	-3.00	-0.50	299.74	308.26
1U	3	25	1648V	611.00	1.60	-1.70	299.08	311.92
1O	3	25	1475V	614.00	-1.60	-1.70	298.40	315.60
1U	3	26	631V	611.00	-2.20	-0.40	309.17	301.83
1O	3	26	1612V	609.00	2.30	-0.40	297.80	311.20
1U	3	27	436V	613.00	-2.70	0.90	311.40	301.60
1O	3	27	1454N	614.00	-3.10	-1.00	305.77	308.23
1U	3	28	1725V	611.00	-2.60	1.10	307.33	303.67
1O	3	28	398N	611.00	-2.90	-1.10	314.05	296.95
1U	3	29	1468N	612.00	3.10	1.00	297.43	314.57
1O	3	29	1464V	612.00	2.90	-0.90	303.86	308.14
1U	3	30	1651V	609.00	3.50	0.50	301.15	307.85
1O	3	30	616V	610.00	-3.60	0.60	310.80	299.21
1U	3	31	496N	610.00	-1.50	-0.40	311.40	298.60
1O	3	31	1657N	612.00	1.10	-0.50	299.27	312.73
1U	3	32	1409V	612.00	-2.80	1.30	299.57	312.43
1O	3	32	1418N	613.00	-2.90	-1.10	298.22	314.78
1U	3	33	600V	611.00	-3.60	0.00	309.17	301.83
1O	3	33	1747N	613.00	-3.50	-0.10	303.74	309.26
1U	3	34	419V	613.00	2.50	0.70	311.40	301.60
1O	3	34	633N	612.00	2.60	-0.70	306.31	305.69
1U	3	35	1525V	612.00	-1.70	1.50	302.02	309.98
1O	3	35	318N	613.00	-2.00	-1.40	312.32	300.68
1U	3	36	408V	613.00	-3.20	1.00	311.10	301.90
1O	3	36	1508V	612.00	3.30	1.00	299.88	312.12
1U	3	37	597N	610.00	2.10	0.30	308.96	301.03
1O	3	37	399N	611.00	-2.30	0.30	310.39	300.61
1U	3	38	330V	612.00	-2.60	0.40	310.59	301.41
1O	3	38	1553V	612.00	3.00	0.40	302.02	309.98
1U	3	39	1459V	612.00	3.00	-1.70	297.43	314.57
1O	3	39	529V	612.00	-2.90	-1.70	312.12	299.88
1U	3	40	1693N	608.00	-2.40	0.20	297.92	310.08
1O	3	40	1479V	613.00	-2.40	-0.30	298.22	314.78
1U	3	41	514V	610.00	-3.00	0.30	313.24	296.76
1O	3	41	1741V	611.00	3.00	0.10	302.14	308.86
1U	3	42	1586N	613.00	-2.30	1.90	305.27	307.73
1O	3	42	333N	608.00	1.80	1.60	309.17	298.83
1U	3	43	1616N	612.00	2.70	0.00	303.86	308.14
1O	3	43	611N	611.00	-2.60	0.10	312.22	298.78
1U	3	44	1432V	614.00	-2.70	-1.90	302.09	311.91
1O	3	44	568V	614.00	2.90	-1.70	310.68	303.32

1U	3	45	387V	611.00	1.90	-2.00	307.33	303.67
1O	3	45	320V	612.00	-2.30	-1.80	311.20	300.80
1U	3	46	1721V	610.00	3.10	-1.60	300.12	309.88
1O	3	46	531N	607.00	3.50	1.80	312.61	294.40
1U	3	47	564N	611.00	3.00	-0.90	305.81	305.19
1O	3	47	1686N	608.00	-3.00	-0.90	300.05	307.95
1U	3	48	1386V	609.00	-2.40	1.00	303.89	305.11
1O	3	48	1419N	609.00	-2.50	-1.10	292.62	316.38
1U	3	49	583V	613.00	2.60	-0.80	308.34	304.66
1O	3	49	677V	612.00	-2.60	-0.60	313.96	298.04
1U	3	50	1738N	611.00	2.00	-0.70	299.39	311.61
1O	3	50	552V	612.00	2.20	0.50	312.43	299.57
1U	3	51	1639V	610.00	-2.00	-0.50	295.85	314.15
1O	3	51	1399V	613.00	1.40	-0.60	299.14	313.86
1U	3	52	1691N	610.00	-1.50	1.10	302.56	307.44
1O	3	52	520V	607.00	-1.90	-1.00	308.96	298.04
1U	3	53	1709N	607.00	3.30	0.30	294.40	312.61
1O	3	53	405V	610.00	3.40	-0.30	313.54	296.46
1U	3	54	443N	612.00	2.70	0.90	309.37	302.63
1O	3	54	1576N	611.00	-2.50	1.00	303.67	307.33
1U	3	55	543N	611.00	-3.60	-0.10	309.47	301.53
1O	3	55	424V	615.00	-3.20	0.10	314.27	300.74
1U	3	56	1650N	610.00	3.50	-0.90	297.07	312.93
1O	3	56	1392V	611.00	4.00	0.80	299.08	311.92
1U	3	57	327N	612.00	-2.70	-1.60	309.98	302.02
1O	3	57	1552V	612.00	-2.50	1.60	298.66	313.34
1U	3	58	315N	613.00	-2.20	1.50	308.95	304.05
1O	3	58	1422N	614.00	2.00	1.50	301.47	312.53
1U	3	59	1638V	610.00	-3.30	-0.10	300.43	309.57
1O	3	59	335N	612.00	-2.80	0.00	313.65	298.35
1U	3	60	1406N	609.00	-1.10	-0.30	298.11	310.89
1O	3	60	1457N	613.00	1.90	-0.20	297.61	315.39
1U	3	61	590N	613.00	-2.20	1.00	312.32	300.68
1O	3	61	499V	607.00	-2.40	-1.10	305.02	301.98
1U	3	62	442V	612.00	2.10	-0.70	311.51	300.49
1O	3	62	1414N	610.00	2.50	0.60	295.24	314.76
1U	3	63	1568N	612.00	-2.30	0.70	303.86	308.14
1O	3	63	538N	612.00	2.60	0.60	316.40	295.60
1U	3	64	478N	613.00	-2.90	2.50	311.71	301.29
1O	3	64	465V	609.00	-3.60	-2.60	309.37	299.63
1U	3	65	1530V	611.00	2.00	0.40	299.39	311.61
1O	3	65	540V	609.00	-2.10	0.50	310.29	298.71
1U	3	66	604N	613.00	2.30	0.00	312.94	300.06
1O	3	66	1627N	608.00	-2.30	0.00	295.18	312.82

Module number 4:

Und.	Mod.	Pos.	Magn.	Mz	Mx	My	North	South
1U	4	1	574N	611.00	-3.10	-0.90	314.36	296.64
1O	4	1	620V	611.00	-3.00	1.00	307.94	303.06
1U	4	2	584N	613.00	-2.30	-0.10	311.10	301.90

1O	4	2	1581V	611.00	-2.30	0.10	303.36	307.64
1U	4	3	1720V	611.00	1.80	2.10	296.03	314.97
1O	4	3	482N	613.00	2.60	-2.20	309.56	303.44
1U	4	4	698N	611.00	-2.30	0.90	314.05	296.95
1O	4	4	495V	611.00	-2.80	-1.00	311.92	299.08
1U	4	5	479N	608.00	-2.70	-0.90	309.78	298.22
1O	4	5	439N	612.00	2.40	-0.90	311.20	300.80
1U	4	6	652V	613.00	2.90	1.60	311.71	301.29
1O	4	6	428N	611.00	2.90	-1.50	308.56	302.45
1U	4	7	1697N	606.00	2.50	0.30	299.36	306.64
1O	4	7	490V	606.00	2.60	-0.30	309.67	296.33
1U	4	8	425N	612.00	2.30	0.60	313.65	298.35
1O	4	8	473V	611.00	2.30	-0.80	311.00	300.00
1U	4	9	639N	613.00	2.90	-0.30	309.87	303.13
1O	4	9	541V	611.00	3.20	0.30	309.47	301.53
1U	4	10	459N	612.00	-2.40	-1.10	308.45	303.55
1O	4	10	1523V	611.00	-1.90	1.10	297.86	313.14
1U	4	11	524V	611.00	-2.40	-1.10	311.61	299.39
1O	4	11	1548V	613.00	2.20	-1.00	297.00	316.00
1U	4	12	1487V	611.00	-3.60	-0.20	302.14	308.86
1O	4	12	634V	612.00	3.60	-0.30	309.98	302.02
1U	4	13	1588N	611.00	-2.80	0.70	298.78	312.22
1O	4	13	435V	611.00	-2.70	-0.50	311.61	299.39
1U	4	14	321V	614.00	3.70	-1.10	310.68	303.32
1O	4	14	450N	613.00	3.10	1.20	306.81	306.19
1U	4	15	701V	613.00	-2.70	-0.60	310.48	302.52
1O	4	15	438N	613.00	-2.50	0.60	310.48	302.52
1U	4	16	561V	610.00	-2.40	1.00	311.40	298.60
1O	4	16	1592N	610.00	-2.20	-1.00	294.32	315.67
1U	4	17	623N	609.00	2.70	1.40	308.15	300.85
1O	4	17	1514N	613.00	-2.60	1.50	297.92	315.08
1U	4	18	426N	612.00	1.80	1.00	311.51	300.49
1O	4	18	1558V	611.00	1.70	-1.00	295.72	315.28
1U	4	19	461N	613.00	-2.50	-0.10	312.02	300.98
1O	4	19	609N	608.00	2.80	-0.10	310.08	297.92
1U	4	20	1512N	613.00	-2.80	0.80	300.06	312.94
1O	4	20	1394N	608.00	3.00	0.90	294.58	313.42
1U	4	21	1496V	612.00	2.30	-1.40	298.35	313.65
1O	4	21	546N	613.00	2.60	1.40	314.47	298.53
1U	4	22	480V	612.00	2.30	-0.30	305.39	306.61
1O	4	22	630N	610.00	2.40	0.10	311.40	298.60
1U	4	23	1424N	610.00	-1.40	0.70	298.60	311.40
1O	4	23	407N	614.00	1.60	0.50	308.23	305.77
1U	4	24	1724V	612.00	2.60	-1.30	298.04	313.96
1O	4	24	1555N	611.00	2.90	1.30	299.39	311.61
1U	4	25	351V	608.00	3.30	0.70	308.56	299.44
1O	4	25	357N	612.00	3.60	-0.60	309.06	302.94
1U	4	26	647V	613.00	3.10	-1.30	309.87	303.13
1O	4	26	1645V	611.00	-3.30	-1.10	299.70	311.30
1U	4	27	1646N	610.00	3.00	0.20	297.99	312.01

1O	4	27	655N	614.00	-3.00	0.30	310.99	303.01
1U	4	28	1437N	612.00	-1.50	0.60	306.31	305.69
1O	4	28	1610N	609.00	1.30	0.40	297.50	311.50
1U	4	29	1439V	613.00	2.70	-0.90	304.35	308.65
1O	4	29	488V	609.00	-2.60	-0.90	309.07	299.93
1U	4	30	1735V	612.00	-2.60	-1.80	295.90	316.10
1O	4	30	1677N	608.00	-2.40	1.90	297.62	310.38
1U	4	31	657V	611.00	3.40	0.70	309.17	301.83
1O	4	31	364V	614.00	-3.00	0.70	313.14	300.86
1U	4	32	661V	609.00	-2.80	0.10	313.94	295.06
1O	4	32	390N	613.00	-3.10	-0.10	312.63	300.37
1U	4	33	569V	614.00	3.00	0.90	308.23	305.77
1O	4	33	380V	612.00	-2.70	0.90	309.37	302.63
1U	4	34	1460N	613.00	-2.40	1.40	300.37	312.63
1O	4	34	653N	610.00	2.50	1.40	309.27	300.73
1U	4	35	512V	610.00	2.30	0.80	306.52	303.48
1O	4	35	691V	612.00	-2.00	0.90	315.79	296.21
1U	4	36	1733V	610.00	3.10	-0.30	297.99	312.01
1O	4	36	1620N	612.00	3.00	0.30	300.80	311.20
1U	4	37	409V	612.00	-2.50	1.20	310.90	301.10
1O	4	37	515N	612.00	-2.50	-1.20	312.43	299.57
1U	4	38	1529N	611.00	2.50	-1.10	298.47	312.53
1O	4	38	1405N	613.00	-2.60	-1.10	304.97	308.03
1U	4	39	598V	612.00	3.40	0.80	309.37	302.63
1O	4	39	610N	613.00	3.30	-0.80	310.48	302.52
1U	4	40	544V	613.00	3.10	-0.80	312.32	300.68
1O	4	40	1433N	613.00	3.20	0.90	300.68	312.32
1U	4	41	1425N	609.00	3.10	0.00	297.50	311.50
1O	4	41	429V	612.00	3.10	0.00	310.90	301.10
1U	4	42	1663V	609.00	-2.60	1.80	298.41	310.59
1O	4	42	565N	611.00	-2.60	-1.80	309.17	301.83
1U	4	43	1670N	609.00	2.70	0.50	293.84	315.16
1O	4	43	521V	611.00	2.80	-0.40	311.00	300.00
1U	4	44	1389V	614.00	-2.40	0.80	303.93	310.07
1O	4	44	314N	609.00	-2.60	-0.70	313.33	295.67
1U	4	45	1420N	611.00	-3.30	-0.90	299.39	311.61
1O	4	45	535N	612.00	2.90	-0.90	309.67	302.33
1U	4	46	1494V	609.00	3.10	-1.90	301.46	307.55
1O	4	46	675V	611.00	-2.70	-1.90	315.89	295.11
1U	4	47	1407N	614.00	2.60	0.60	298.71	315.29
1O	4	47	308V	611.00	2.80	-0.70	311.92	299.08
1U	4	48	505N	612.00	2.20	1.50	309.06	302.94
1O	4	48	1710V	609.00	2.50	-1.40	298.11	310.89
1U	4	49	1458N	610.00	-2.10	0.90	293.11	316.89
1O	4	49	676N	611.00	2.40	0.80	306.72	304.28
1U	4	50	641V	608.00	-2.60	0.50	307.34	300.66
1O	4	50	454N	612.00	-2.60	-0.50	308.75	303.25
1U	4	51	1400V	612.00	-3.20	-1.00	295.29	316.71
1O	4	51	658N	611.00	-3.10	1.00	314.97	296.03
1U	4	52	1644V	609.00	-2.70	-0.20	300.24	308.76

1O	4	52	1480N	611.00	-2.60	0.20	297.56	313.44
1U	4	53	553V	611.00	-2.40	0.30	312.22	298.78
1O	4	53	1569V	612.00	2.60	0.30	302.63	309.37
1U	4	54	1492V	612.00	2.80	0.60	298.96	313.04
1O	4	54	1521V	610.00	-2.40	0.70	300.12	309.88
1U	4	55	1404V	610.00	1.80	-0.60	296.46	313.54
1O	4	55	339V	612.00	-1.90	-0.40	314.87	297.13
1U	4	56	502V	611.00	-2.40	-1.70	311.30	299.70
1O	4	56	1626N	611.00	-2.00	2.00	303.67	307.33
1U	4	57	1472N	612.00	3.20	0.40	300.80	311.20
1O	4	57	666N	611.00	-3.50	0.50	306.11	304.89
1U	4	58	1701N	607.00	3.10	-0.30	297.43	309.57
1O	4	58	605V	611.00	3.20	0.40	314.05	296.95
1U	4	59	376V	613.00	2.60	-0.80	312.32	300.68
1O	4	59	687V	611.00	-2.50	-0.80	309.17	301.83
1U	4	60	1531N	611.00	2.40	-1.20	300.31	310.69
1O	4	60	388N	613.00	-2.70	-1.30	310.79	302.21
1U	4	61	418N	614.00	2.90	1.30	314.98	299.02
1O	4	61	1634V	610.00	3.00	-1.30	302.56	307.44
1U	4	62	345N	609.00	2.60	-1.10	313.33	295.67
1O	4	62	468V	610.00	2.70	1.00	311.10	298.90
1U	4	63	1672N	607.00	-2.40	-1.40	298.64	308.36
1O	4	63	1712N	609.00	3.10	-1.40	299.63	309.37
1U	4	64	493N	609.00	3.10	1.00	308.15	300.85
1O	4	64	1661N	610.00	-2.40	1.10	300.43	309.57
1U	4	65	1498N	610.00	2.20	-1.10	300.73	309.27
1O	4	65	613V	612.00	2.60	1.10	308.45	303.55
1U	4	66	347V	609.00	3.10	-0.80	313.33	295.67
1O	4	66	1535N	610.00	3.00	0.90	299.51	310.49

Module number 5:

Und.	Mod.	Pos.	Magn.	Mz	Mx	My	North	South
1U	5	1	1625V	609.00	3.60	0.60	302.06	306.94
1O	5	1	667N	614.00	4.10	-0.60	316.52	297.48
1U	5	2	643V	612.00	-2.80	-0.40	315.49	296.51
1O	5	2	1600N	611.00	-2.50	0.30	304.58	306.42
1U	5	3	1629N	610.00	-3.00	-0.70	297.38	312.62
1O	5	3	1603V	613.00	-2.70	0.60	300.37	312.63
1U	5	4	1708V	607.00	2.40	1.10	294.09	312.91
1O	5	4	1593V	612.00	-2.00	1.20	301.41	310.59
1U	5	5	458V	612.00	1.90	1.10	312.73	299.27
1O	5	5	1567N	611.00	2.00	-1.00	300.61	310.39
1U	5	6	1476V	612.00	-2.60	0.20	297.74	314.26
1O	5	6	1636V	611.00	2.70	0.10	303.36	307.64
1U	5	7	1516N	609.00	2.50	1.60	296.58	312.42
1O	5	7	403N	612.00	-2.10	1.80	309.67	302.33
1U	5	8	519N	612.00	-1.80	0.80	308.45	303.55
1O	5	8	1662N	611.00	2.20	0.70	300.61	310.39
1U	5	9	1582N	612.00	-3.70	-0.20	300.19	311.81
1O	5	9	1742V	610.00	-3.60	0.00	294.02	315.98

1U	5	10	338V	610.00	-2.70	-1.80	309.88	300.12
1O	5	10	449N	610.00	-2.50	1.80	310.49	299.51
1U	5	11	369V	610.00	2.80	-2.70	311.40	298.60
1O	5	11	571N	612.00	3.30	2.80	311.20	300.80
1U	5	12	1532N	612.00	2.60	0.40	298.04	313.96
1O	5	12	654V	613.00	2.40	-0.40	310.48	302.52
1U	5	13	464V	611.00	2.70	0.30	312.22	298.78
1O	5	13	411V	613.00	-2.50	0.40	310.18	302.82
1U	5	14	477V	611.00	-2.00	-1.60	315.28	295.72
1O	5	14	1681N	609.00	-2.10	1.80	302.67	306.33
1U	5	15	486V	613.00	-2.60	-1.70	310.79	302.21
1O	5	15	695V	610.00	2.10	-1.50	313.85	296.16
1U	5	16	433N	613.00	2.20	1.70	313.55	299.45
1O	5	16	1628V	610.00	1.70	-1.60	303.78	306.22
1U	5	17	415N	611.00	2.50	1.50	309.47	301.53
1O	5	17	1606V	610.00	2.60	-1.60	294.94	315.06
1U	5	18	1653N	611.00	3.40	-0.40	301.22	309.78
1O	5	18	1536N	611.00	-3.70	-0.40	302.14	308.86
1U	5	19	432V	612.00	-2.70	2.30	312.43	299.57
1O	5	19	452N	610.00	-3.20	-2.40	308.36	301.64
1U	5	20	1481N	611.00	2.50	-0.70	296.34	314.67
1O	5	20	1740N	612.00	-2.80	-0.60	295.29	316.71
1U	5	21	532V	608.00	-2.30	-1.50	304.00	304.00
1O	5	21	1585N	610.00	-2.30	1.60	298.29	311.71
1U	5	22	494N	610.00	2.80	0.80	310.49	299.51
1O	5	22	684N	613.00	-2.60	0.80	307.73	305.27
1U	5	23	1534N	611.00	-2.70	1.40	297.86	313.14
1O	5	23	1466N	610.00	3.10	1.40	297.07	312.93
1U	5	24	1541N	612.00	-2.20	0.50	305.39	306.61
1O	5	24	1729N	612.00	2.50	0.50	302.33	309.67
1U	5	25	572N	611.00	-1.70	-1.30	311.92	299.08
1O	5	25	1520N	612.00	1.10	-1.00	293.76	318.24
1U	5	26	593N	612.00	2.90	-1.60	315.18	296.82
1O	5	26	460V	614.00	3.20	1.80	315.29	298.71
1U	5	27	679V	611.00	-3.30	-2.60	311.00	300.00
1O	5	27	1665V	609.00	3.40	-2.60	302.06	306.94
1U	5	28	670N	612.00	3.00	0.40	313.65	298.35
1O	5	28	1617N	606.00	-2.60	0.50	302.39	303.61
1U	5	29	1559N	610.00	3.30	0.10	300.43	309.57
1O	5	29	1491V	610.00	3.30	0.00	299.51	310.49
1U	5	30	463N	610.00	2.90	0.50	312.62	297.38
1O	5	30	638V	612.00	3.00	-0.60	313.04	298.96
1U	5	31	1561N	612.00	-2.70	-1.60	301.72	310.28
1O	5	31	323N	612.00	3.00	-1.60	310.28	301.72
1U	5	32	1668V	607.00	2.20	-0.60	295.61	311.39
1O	5	32	1388V	613.00	-2.30	-0.50	300.68	312.32
1U	5	33	1461V	611.00	-2.40	1.40	299.39	311.61
1O	5	33	632N	610.00	-2.30	-1.40	309.88	300.12
1U	5	34	1689V	607.00	-2.10	-1.60	295.61	311.39
1O	5	34	1583N	612.00	-1.70	1.60	296.51	315.49

1U	5	35	392N	611.00	2.90	-0.30	308.25	302.75
1O	5	35	1604N	610.00	-2.90	-0.40	297.38	312.62
1U	5	36	313V	611.00	2.80	-0.80	314.67	296.34
1O	5	36	1519N	611.00	2.60	0.90	296.34	314.67
1U	5	37	646N	613.00	3.10	-0.40	316.00	297.00
1O	5	37	1513V	612.00	3.00	0.50	302.63	309.37
1U	5	38	1727V	611.00	1.60	-1.00	300.61	310.39
1O	5	38	498V	612.00	-1.70	-1.00	304.16	307.84
1U	5	39	1679N	608.00	-2.20	0.90	300.05	307.95
1O	5	39	617N	608.00	2.50	0.90	309.47	298.53
1U	5	40	1590N	614.00	2.30	-1.20	299.33	314.68
1O	5	40	1426N	612.00	-2.20	-1.20	297.43	314.57
1U	5	41	578N	612.00	2.70	-0.70	312.12	299.88
1O	5	41	1408N	611.00	-2.60	-0.60	299.39	311.61
1U	5	42	397N	613.00	-2.00	1.30	317.23	295.77
1O	5	42	325V	612.00	-2.10	-1.30	312.43	299.57
1U	5	43	342N	613.00	2.70	-0.50	313.24	299.76
1O	5	43	1542V	611.00	2.50	0.60	299.08	311.92
1U	5	44	1522V	612.00	-3.20	-0.50	303.25	308.75
1O	5	44	1660V	610.00	3.20	-0.60	302.56	307.44
1U	5	45	476N	611.00	-3.00	-0.70	310.08	300.92
1O	5	45	1656V	609.00	-2.70	0.80	301.46	307.55
1U	5	46	1633N	608.00	-2.10	-0.60	299.74	308.26
1O	5	46	1707V	607.00	-1.80	0.60	296.82	310.18
1U	5	47	587V	611.00	-1.80	0.90	310.39	300.61
1O	5	47	1717N	610.00	-2.10	-1.00	300.12	309.88
1U	5	48	1607N	611.00	-3.10	-0.80	299.08	311.92
1O	5	48	550N	610.00	2.80	-0.80	312.01	297.98
1U	5	49	475N	610.00	-2.90	-0.40	308.05	301.95
1O	5	49	1503N	610.00	2.90	-0.30	296.15	313.85
1U	5	50	1455V	611.00	-2.10	-1.50	302.44	308.56
1O	5	50	1551V	612.00	2.30	-1.40	303.25	308.75
1U	5	51	528V	611.00	-3.10	-1.10	307.03	303.97
1O	5	51	606V	613.00	3.10	-1.30	312.63	300.37
1U	5	52	462V	611.00	3.10	-0.10	312.22	298.78
1O	5	52	1635N	610.00	2.90	0.00	301.03	308.96
1U	5	53	1713N	610.00	-1.60	-0.20	300.43	309.57
1O	5	53	582V	611.00	-1.20	0.40	314.67	296.34
1U	5	54	685N	610.00	2.60	1.40	308.36	301.64
1O	5	54	1507N	613.00	-2.60	1.60	300.98	312.02
1U	5	55	1495V	612.00	2.80	-0.30	298.04	313.96
1O	5	55	619V	612.00	-2.80	-0.30	308.14	303.86
1U	5	56	1602N	612.00	2.80	-1.20	304.16	307.84
1O	5	56	622V	610.00	2.80	1.10	311.71	298.29
1U	5	57	485V	613.00	2.00	-0.10	316.00	297.00
1O	5	57	427V	613.00	-1.70	0.20	318.76	294.24
1U	5	58	1499V	612.00	-1.00	1.00	297.43	314.57
1O	5	58	1726V	609.00	1.10	0.60	298.71	310.29
1U	5	59	381V	611.00	-2.40	-0.30	305.81	305.19
1O	5	59	547N	611.00	-2.30	0.30	312.22	298.78

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    1U      5    60   332V   612.00     -2.50     -1.70    305.39   306.61
    1O      5    60  1528N   610.00     -2.40      1.80    300.12   309.88
    1U      5    61   501N   610.00     -2.20     -0.50    309.57   300.43
    1O      5    61  1619V   606.00     -2.00      0.70    300.88   305.12
    1U      5    62   696V   611.00     -1.80      2.20    312.22   298.78
    1O      5    62   404N   616.00     -2.00     -2.00    313.24   302.76
    1U      5    63  1728N   611.00      3.80     -1.10    302.14   308.86
    1O      5    63   422V   613.00      3.60      1.10    313.55   299.45
    1U      5    64   340N   609.00     -3.20     -0.10    311.20   297.80
    1O      5    64  1732V   611.00     -3.20      0.00    298.78   312.22
    1U      5    65   660V   613.00     -1.80      1.10    309.87   303.13
    1O      5    65   536N   610.00     -1.90     -1.30    307.44   302.56
    1U      5    66  1601N   610.00     -2.00     -0.90    300.73   309.27
    1O      5    66  1671N   608.00      1.90     -0.70    296.70   311.30

Downstream compensation:
   Und.   Mod. Pos. Magn.   Mz       Mx        My    North   South
    1U      6     1 1456V   615.00      1.50      1.30    301.66   313.34
    1O      6     1 1506V   615.00     -1.40      1.30    301.35   313.65
    1U      6     2 1543V   611.00     -3.00     -0.60    299.70   311.30
    1O      6     2  508V   613.00      3.10     -0.60    315.69   297.31
    1U      6     3  366N   613.00     -1.50     -0.40    309.26   303.74
    1O      6     3  406V   613.00     -1.30      0.40    312.63   300.37
    1U      6     4 1545N   612.00      1.90      2.50    300.80   311.20
    1O      6     4  453N   611.00     -2.00      2.40    311.61   299.39
    1U      6     5 1652V   610.00     -2.70     -0.40    300.12   309.88
    1O      6     5 1737N   608.00     -3.00      0.80    305.52   302.48

Magnets not used:
 1676
 1716
  551
  421
 1584
 1563
 1664
 1554

  317
  322
  353
  360
  362
  389
  391
  401
  457
  556
  585
  607
```

637
656
680
1411
1421
1435
1452
1471
1474
1482
1565
1667
1669
1718

Magnet structure for 2 m long undulator Danfysik

Module number 1:

Und.	Mod.	Pos.	Magn.	Mz	Mx	My	North	South
1U	1	1	1167N	608.00	1.70	-0.50	293.06	314.94
1O	1	1	1332N	612.00	-1.80	-0.50	296.51	315.49
1U	1	2	160N	611.00	-2.40	-0.90	308.56	302.45
1O	1	2	164N	609.00	2.40	-0.90	307.85	301.15
1U	1	3	181N	612.00	2.40	-0.20	311.51	300.49
1O	1	3	184N	610.00	-2.40	-0.20	307.13	302.87
1U	1	4	1170N	613.00	-2.30	-0.40	299.45	313.55
1O	1	4	264V	611.00	-2.40	0.50	310.39	300.61
1U	1	5	1369N	613.00	-2.40	0.20	300.06	312.94
1O	1	5	1178V	610.00	-2.50	-0.30	298.60	311.40
1U	1	6	187N	612.00	3.50	0.00	309.37	302.63
1O	1	6	1336N	612.00	-3.70	0.00	302.63	309.37
1U	1	7	299N	615.00	3.50	1.70	315.80	299.20
1O	1	7	1220V	610.00	3.80	-1.70	300.12	309.88
1U	1	8	1195V	611.00	-2.20	0.00	301.83	309.17
1O	1	8	301N	612.00	-2.40	0.10	314.57	297.43
1U	1	9	260V	612.00	-2.60	0.10	314.57	297.43
1O	1	9	1211N	610.00	-2.70	-0.20	296.46	313.54
1U	1	10	1351V	611.00	3.20	1.50	296.95	314.05
1O	1	10	1339N	611.00	3.40	-1.70	297.25	313.75
1U	1	11	1325V	611.00	2.50	-0.10	300.61	310.39
1O	1	11	1379V	611.00	-2.60	-0.30	303.67	307.33
1U	1	12	169V	612.00	3.20	-1.00	314.87	297.13
1O	1	12	1183N	611.00	3.20	1.30	302.14	308.86
1U	1	13	1184N	610.00	-3.20	0.40	295.24	314.76
1O	1	13	272N	611.00	3.30	0.10	313.75	297.25
1U	1	14	1243N	609.00	-2.20	0.70	302.67	306.33
1O	1	14	225V	610.00	-2.50	-0.70	311.10	298.90
1U	1	15	1385N	612.00	-2.20	-1.00	299.27	312.73
1O	1	15	1350V	611.00	-2.40	1.00	296.95	314.05
1U	1	16	297V	615.00	-2.40	1.10	315.19	299.81

1O	1	16	221N	612.00	-2.50	-1.10	314.26	297.74
1U	1	17	1354V	609.00	-2.40	0.30	302.06	306.94
1O	1	17	1367V	612.00	2.40	0.30	300.19	311.81
1U	1	18	304V	613.00	-2.50	0.90	313.55	299.45
1O	1	18	1228V	611.00	2.50	0.90	298.47	312.53
1U	1	19	1234V	613.00	-2.50	-1.10	299.14	313.86
1O	1	19	1182V	612.00	2.60	-1.10	297.43	314.57
1U	1	20	1371N	611.00	-2.50	-0.50	297.56	313.44
1O	1	20	245V	610.00	-2.60	0.50	308.96	301.03
1U	1	21	1384N	613.00	-2.50	-1.00	302.82	310.18
1O	1	21	191V	611.00	-2.70	1.00	314.05	296.95
1U	1	22	197V	612.00	-2.60	-0.60	311.51	300.49
1O	1	22	220V	609.00	2.60	-0.60	311.20	297.80
1U	1	23	256V	613.00	-2.60	-0.60	310.18	302.82
1O	1	23	1246N	614.00	-2.70	0.60	304.85	309.15
1U	1	24	258V	612.00	-2.60	-1.20	311.81	300.19
1O	1	24	217N	611.00	-2.80	1.20	311.61	299.39
1U	1	25	274V	608.00	-2.70	0.40	306.43	301.57
1O	1	25	1370V	614.00	2.80	0.40	300.86	313.14
1U	1	26	1366N	612.00	-2.80	0.20	300.80	311.20
1O	1	26	302N	611.00	3.10	0.20	314.05	296.95
1U	1	27	230N	611.00	-2.90	0.50	310.08	300.92
1O	1	27	277V	611.00	-3.10	-0.50	313.75	297.25
1U	1	28	157V	612.00	-2.40	1.10	312.73	299.27
1O	1	28	202N	611.00	-2.40	-1.20	313.14	297.86
1U	1	29	158N	610.00	-2.50	-1.40	310.19	299.81
1O	1	29	1185N	609.00	2.60	-1.30	298.11	310.89
1U	1	30	1327N	612.00	-1.90	0.90	305.69	306.31
1O	1	30	206V	612.00	-2.00	-1.00	316.10	295.90
1U	1	31	226V	611.00	-2.10	-0.70	311.61	299.39
1O	1	31	1216N	613.00	-2.10	0.60	299.45	313.55
1U	1	32	1347V	613.00	-2.10	-0.60	301.29	311.71
1O	1	32	1187V	610.00	2.20	-0.70	294.02	315.98
1U	1	33	166N	609.00	2.20	-0.80	309.98	299.02
1O	1	33	219V	611.00	2.20	0.90	314.05	296.95
1U	1	34	286V	613.00	-2.20	0.80	316.92	296.08
1O	1	34	232N	610.00	-2.30	-0.90	312.01	297.99
1U	1	35	1208V	612.00	-2.20	-0.40	306.31	305.69
1O	1	35	201V	611.00	2.40	-0.50	310.69	300.31
1U	1	36	255N	613.00	-2.60	-0.60	308.65	304.35
1O	1	36	1253V	613.00	-2.60	0.70	301.29	311.71
1U	1	37	285N	611.00	-2.60	0.20	311.61	299.39
1O	1	37	1248V	612.00	-2.70	-0.30	298.35	313.65
1U	1	38	211N	612.00	1.60	1.50	309.06	302.94
1O	1	38	1226N	612.00	-2.00	1.20	299.88	312.12
1U	1	39	263V	615.00	2.20	1.30	311.81	303.19
1O	1	39	231N	613.00	2.30	-1.00	315.08	297.92
1U	1	40	1252N	612.00	-1.30	-0.10	298.04	313.96
1O	1	40	1247V	613.00	-1.90	0.20	296.69	316.31
1U	1	41	1174N	609.00	-2.10	0.10	298.11	310.89

1O	1	41	307V	612.00	-2.20	-0.20	313.96	298.04
1U	1	42	1204N	611.00	2.80	0.60	303.36	307.64
1O	1	42	1207V	609.00	2.90	-0.60	300.85	308.15
1U	1	43	1333N	611.00	-2.80	-0.90	301.53	309.47
1O	1	43	241V	610.00	-3.30	0.90	313.24	296.76
1U	1	44	1344V	610.00	3.30	-0.50	296.15	313.85
1O	1	44	1188N	609.00	3.90	0.50	296.89	312.11
1U	1	45	228V	609.00	-3.40	0.00	311.81	297.19
1O	1	45	1341V	613.00	3.40	0.00	299.14	313.86
1U	1	46	188V	614.00	-2.70	-0.90	316.21	297.79
1O	1	46	1331V	612.00	2.70	-1.00	300.49	311.51
1U	1	47	1215N	612.00	-2.70	-0.80	299.27	312.73
1O	1	47	179N	612.00	2.90	-0.90	309.67	302.33
1U	1	48	193N	610.00	-3.20	0.00	314.15	295.85
1O	1	48	190V	609.00	-3.30	-0.10	310.29	298.71
1U	1	49	1361V	613.00	-2.00	-0.40	298.22	314.78
1O	1	49	1212V	609.00	2.10	-0.30	299.32	309.68
1U	1	50	1209V	611.00	3.50	-0.30	301.53	309.47
1O	1	50	198V	614.00	-3.80	-0.10	313.14	300.86
1U	1	51	218V	608.00	2.50	0.40	304.91	303.09
1O	1	51	271V	614.00	-2.50	0.20	309.76	304.24
1U	1	52	1200V	612.00	-1.20	-1.00	295.29	316.71
1O	1	52	276N	612.00	-1.40	0.80	312.12	299.88
1U	1	53	248V	611.00	2.50	1.40	311.61	299.39
1O	1	53	1191V	612.00	-2.60	1.20	299.88	312.12
1U	1	54	156V	610.00	-3.00	0.60	315.37	294.63
1O	1	54	163V	610.00	3.20	0.60	309.27	300.73
1U	1	55	222V	611.00	3.00	-0.30	305.19	305.81
1O	1	55	1374N	613.00	3.10	0.30	296.39	316.61
1U	1	56	249V	611.00	2.60	1.10	306.72	304.28
1O	1	56	189V	610.00	-2.70	1.20	306.22	303.78
1U	1	57	289N	612.00	2.80	1.10	311.51	300.49
1O	1	57	305V	612.00	3.00	-1.20	308.75	303.25
1U	1	58	194V	612.00	-2.80	-1.00	312.73	299.27
1O	1	58	235V	612.00	3.00	-0.90	310.90	301.10
1U	1	59	1224V	613.00	2.80	-0.40	297.00	316.00
1O	1	59	185N	610.00	2.90	0.50	311.10	298.90
1U	1	60	1231N	610.00	-2.60	0.10	301.03	308.96
1O	1	60	1214V	611.00	-2.80	-0.40	303.67	307.33
1U	1	61	165V	610.00	-3.20	0.70	316.89	293.11
1O	1	61	1328V	613.00	3.40	1.00	302.82	310.18
1U	1	62	186N	613.00	-2.50	-0.40	316.31	296.69
1O	1	62	1190V	611.00	-2.50	0.50	299.39	311.61
1U	1	63	1241V	614.00	-2.50	-0.80	306.08	307.92
1O	1	63	1330V	612.00	2.50	-0.90	299.88	312.12
1U	1	64	300N	612.00	2.80	1.80	307.53	304.47
1O	1	64	257V	610.00	2.90	-1.60	309.88	300.12
1U	1	65	254V	610.00	-3.10	-1.60	313.54	296.46
1O	1	65	227V	609.00	3.20	-1.80	303.59	305.41
1U	1	66	1360V	613.00	-1.80	0.50	300.06	312.94

1O	1	66	1353V	612.00	2.00	0.50	299.57	312.43

Module number 2:

Und.	Mod.	Pos.	Magn.	Mz	Mx	My	North	South
1U	2	1	1323V	613.00	-1.90	0.60	301.60	311.40
1O	2	1	268V	612.00	2.10	0.60	313.34	298.66
1U	2	2	240N	610.00	-2.00	-0.80	314.76	295.24
1O	2	2	1181V	612.00	-2.10	0.80	296.51	315.49
1U	2	3	173N	610.00	-2.10	0.10	311.10	298.90
1O	2	3	1173V	612.00	-2.30	-0.10	299.88	312.12
1U	2	4	1382N	612.00	-2.70	-1.00	302.63	309.37
1O	2	4	1213V	610.00	-3.00	1.00	296.46	313.54
1U	2	5	216N	609.00	2.80	1.30	307.24	301.76
1O	2	5	295V	613.00	2.90	-1.30	312.63	300.37
1U	2	6	1376V	613.00	-3.00	0.10	297.61	315.39
1O	2	6	1165V	613.00	3.20	0.10	302.52	310.48
1U	2	7	200V	610.00	3.10	-0.50	309.27	300.73
1O	2	7	1372N	614.00	3.30	0.50	295.95	318.05
1U	2	8	208V	611.00	3.20	-0.30	309.78	301.22
1O	2	8	1250N	610.00	3.30	0.20	302.87	307.13
1U	2	9	1362N	613.00	3.40	-0.30	298.22	314.78
1O	2	9	1355V	611.00	3.70	0.20	298.78	312.22
1U	2	10	1358V	611.00	-2.10	-1.10	300.92	310.08
1O	2	10	1380N	611.00	-2.20	1.00	300.00	311.00
1U	2	11	290N	612.00	-2.20	-2.20	308.14	303.86
1O	2	11	1238N	609.00	2.50	-2.10	297.80	311.20
1U	2	12	292V	612.00	-1.90	-1.50	311.20	300.80
1O	2	12	250V	610.00	2.00	-1.10	313.54	296.46
1U	2	13	176N	611.00	-2.50	-2.00	309.47	301.53
1O	2	13	294N	610.00	2.60	-1.60	307.74	302.25
1U	2	14	1222V	610.00	3.50	-1.00	297.38	312.62
1O	2	14	282V	611.00	-3.60	-1.70	311.30	299.70
1U	2	15	1210V	610.00	-3.50	0.90	302.25	307.74
1O	2	15	174V	610.00	3.60	1.60	312.93	297.07
1U	2	16	180N	612.00	2.10	1.40	310.59	301.41
1O	2	16	159N	610.00	-2.30	1.10	308.96	301.03
1U	2	17	236N	610.00	1.50	0.90	308.05	301.95
1O	2	17	1171N	610.00	-1.50	1.20	297.07	312.93
1U	2	18	251V	610.00	3.50	-0.60	311.71	298.29
1O	2	18	1206N	612.00	3.80	0.20	299.27	312.73
1U	2	19	1244N	613.00	-1.20	-0.80	301.29	311.71
1O	2	19	1377V	612.00	-1.30	0.40	297.43	314.57
1U	2	20	204V	611.00	-2.70	-1.20	311.30	299.70
1O	2	20	1381N	612.00	-2.70	1.00	297.43	314.57
1U	2	21	224N	609.00	-2.80	-1.00	313.63	295.37
1O	2	21	283V	611.00	-3.00	0.80	312.83	298.17
1U	2	22	298N	614.00	-3.30	0.40	314.68	299.33
1O	2	22	1179N	611.00	3.50	0.20	300.00	311.00
1U	2	23	253N	610.00	-1.70	-0.80	309.57	300.43
1O	2	23	1175N	611.00	1.70	-0.60	298.17	312.83

1U	2	24	303V	613.00	-1.80	-1.20	309.87	303.13
10	2	24	172V	611.00	2.00	-1.10	316.50	294.50
1U	2	25	1233V	612.00	-1.90	-1.60	297.13	314.87
10	2	25	1232N	612.00	-2.30	1.70	302.63	309.37
1U	2	26	171V	612.00	-3.00	-1.60	311.20	300.80
10	2	26	1240V	609.00	3.20	-1.70	300.54	308.46
1U	2	27	1196V	612.00	-1.90	-0.70	301.10	310.90
10	2	27	1199V	610.00	1.90	-0.60	303.48	306.52
1U	2	28	1337V	610.00	2.30	0.40	297.68	312.32
10	2	28	261N	614.00	2.40	-0.30	317.44	296.56
1U	2	29	275V	613.00	3.00	-0.40	315.39	297.61
10	2	29	1322N	613.00	3.20	0.30	301.90	311.10
1U	2	30	1251N	610.00	3.20	-1.80	296.46	313.54
10	2	30	209N	610.00	-3.40	-1.80	311.10	298.90
1U	2	31	161N	612.00	3.30	-0.40	313.96	298.04
10	2	31	1166V	611.00	3.60	0.40	300.92	310.08
1U	2	32	265N	614.00	-2.10	0.20	316.21	297.79
10	2	32	280V	611.00	-2.20	-0.20	317.11	293.89
1U	2	33	267N	611.00	-2.10	1.90	312.83	298.17
10	2	33	1239V	610.00	-2.40	-1.90	298.60	311.40
1U	2	34	1221V	608.00	-2.10	0.00	300.35	307.65
10	2	34	1340N	612.00	-2.10	0.00	298.96	313.04
1U	2	35	1346V	611.00	-2.10	0.80	300.61	310.39
10	2	35	195N	612.00	-2.30	-0.80	310.28	301.72
1U	2	36	233N	611.00	-2.20	-0.90	313.14	297.86
10	2	36	284N	613.00	2.20	-0.90	313.24	299.76
1U	2	37	1229N	612.00	2.20	-0.80	295.60	316.40
10	2	37	266V	613.00	2.40	0.80	312.32	300.68
1U	2	38	1180N	609.00	-2.10	0.90	296.58	312.42
10	2	38	1359V	614.00	-2.10	-0.80	301.78	312.22
1U	2	39	1342N	611.00	-2.10	0.20	300.92	310.08
10	2	39	270N	612.00	2.30	0.30	307.84	304.16
1U	2	40	1193N	611.00	-2.70	-0.70	300.61	310.39
10	2	40	196V	611.00	-2.80	0.70	312.83	298.17
1U	2	41	1378N	611.00	2.70	0.00	294.50	316.50
10	2	41	167V	610.00	2.90	0.00	310.49	299.51
1U	2	42	234V	608.00	2.90	0.00	309.47	298.53
10	2	42	1176N	610.00	3.00	0.00	293.11	316.89
1U	2	43	1219V	614.00	2.90	1.20	303.32	310.68
10	2	43	243N	610.00	3.30	-1.20	312.01	297.98
1U	2	44	238V	612.00	-2.70	-2.20	308.14	303.86
10	2	44	1349V	613.00	3.10	-2.00	303.13	309.87
1U	2	45	252V	612.00	-1.30	1.40	313.04	298.96
10	2	45	1164N	608.00	-1.30	-1.10	297.01	310.99
1U	2	46	1249N	613.00	-2.80	0.20	298.84	314.16
10	2	46	1218V	613.00	-3.00	-0.30	302.82	310.18
1U	2	47	1352N	611.00	2.90	-0.20	301.53	309.47
10	2	47	1202V	612.00	3.10	0.30	297.43	314.57
1U	2	48	1343N	613.00	-3.50	0.70	303.13	309.87
10	2	48	1186N	611.00	3.70	1.90	302.75	308.25

1U	2	49	1235N	610.00	-3.80	0.90	298.29	311.71
1O	2	49	239N	613.00	4.20	-0.50	306.81	306.19
1U	2	50	296V	612.00	-3.10	-1.30	309.67	302.33
1O	2	50	1205V	610.00	3.30	-1.20	298.29	311.71
1U	2	51	288N	614.00	3.30	-1.10	311.91	302.09
1O	2	51	1356N	614.00	-3.70	-1.00	300.25	313.75
1U	2	52	1329V	615.00	-2.20	1.80	302.27	312.73
1O	2	52	175V	611.00	2.50	1.70	317.72	293.28
1U	2	53	1227V	613.00	2.90	1.40	303.44	309.56
1O	2	53	287N	613.00	3.20	-1.50	310.18	302.82
1U	2	54	269N	613.00	3.20	-0.50	307.73	305.27
1O	2	54	246N	614.00	-3.30	-0.10	315.60	298.40
1U	2	55	1326N	614.00	3.50	-0.50	302.09	311.91
1O	2	55	1169N	610.00	-4.20	-1.10	303.48	306.52
1U	2	56	281V	613.00	-0.60	0.50	313.86	299.14
1O	2	56	259N	614.00	-1.10	-0.80	317.75	296.26
1U	2	57	1225N	608.00	1.40	1.00	294.88	313.12
1O	2	57	1338N	610.00	-1.40	1.30	298.60	311.40
1U	2	58	207N	611.00	-3.70	1.50	307.03	303.97
1O	2	58	1324N	614.00	4.00	-0.20	299.02	314.98
1U	2	59	1236N	610.00	4.00	-1.30	298.29	311.71
1O	2	59	1194V	612.00	4.30	-1.30	294.37	317.63
1U	2	60	223N	614.00	-1.40	0.00	313.75	300.25
1O	2	60	273V	613.00	-1.80	0.30	311.40	301.60
1U	2	61	244N	609.00	3.60	-0.30	311.20	297.80
1O	2	61	278V	611.00	3.90	0.00	303.97	307.03
1U	2	62	1242N	610.00	3.10	-0.50	301.64	308.36
1O	2	62	229V	611.00	3.50	0.50	311.92	299.08
1U	2	63	192N	610.00	-3.20	0.80	308.36	301.64
1O	2	63	199V	613.00	-3.60	-0.80	311.71	301.29
1U	2	64	203N	612.00	-3.10	0.60	309.37	302.63
1O	2	64	1373N	612.00	3.40	0.80	304.78	307.22
1U	2	65	1245N	612.00	3.30	-0.90	296.51	315.49
1O	2	65	279V	611.00	3.90	1.10	309.17	301.83
1U	2	66	170N	610.00	3.60	-0.40	314.15	295.85
1O	2	66	1335V	612.00	4.70	1.50	299.88	312.12

Downstream compensation:

Und.	Mod.	Pos.	Magn.	Mz	Mx	My	North	South
1U	6	1	1203N	609.00	3.60	-0.70	295.67	313.33
1O	6	1	1363N	613.00	-3.60	0.40	302.82	310.18

Magnets not used:

1321
162
306
1364
1334

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 205
 210
 293
 178
1223
1345
1375
 183
 247
1172
1357
1365
 262
1217
 237
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Magnet structure for 2 m long undulator HelmhotzACCEL

Module number 1:

Und.	Mod.	Pos.	Magn.	Mz	Mx	My	North	South
1U	1	1	1129V	609.00	-3.40	0.50	302.06	306.94
1O	1	1	82V	611.00	3.10	-0.10	311.00	300.00
1U	1	2	1033V	612.00	-2.90	0.00	302.94	309.06
1O	1	2	67V	613.00	-2.30	-0.80	317.84	295.16
1U	1	3	104V	613.00	-3.00	-0.10	311.71	301.29
1O	1	3	1111N	610.00	3.10	0.30	299.51	310.49
1U	1	4	54N	615.00	-2.90	-0.80	316.73	298.28
1O	1	4	1069N	612.00	-3.10	-0.40	299.88	312.12
1U	1	5	1125N	614.00	3.80	-0.60	305.77	308.23
1O	1	5	88N	615.00	-2.70	0.80	311.19	303.81
1U	1	6	65V	613.00	-3.10	0.60	311.10	301.90
1O	1	6	36N	612.00	-3.20	-2.30	308.14	303.86
1U	1	7	105V	610.00	-2.20	-0.80	316.89	293.11
1O	1	7	1095V	613.00	-2.20	-0.90	297.00	316.00
1U	1	8	63V	610.00	-2.90	-0.40	308.05	301.95
1O	1	8	94V	612.00	-2.40	0.40	311.20	300.80
1U	1	9	38V	611.00	-2.80	0.10	317.41	293.59
1O	1	9	149N	611.00	3.90	1.40	311.92	299.08
1O	1	10	1063N	611.00	2.50	-0.80	299.08	311.92
1O	1	10	27N	614.00	3.10	0.30	312.83	301.17
1U	1	11	1139N	613.00	1.90	-0.30	299.76	313.24
1O	1	11	1001N	611.00	-1.40	0.90	300.00	311.00
1U	1	12	1004V	611.00	-2.90	-1.10	301.83	309.17
1O	1	12	89V	613.00	-2.30	-0.80	313.86	299.14
1U	1	13	122V	610.00	-2.80	0.50	315.37	294.63
1O	1	13	1019N	608.00	1.80	-0.40	298.83	309.17
1U	1	14	1157V	614.00	2.90	-2.10	301.17	312.83
1O	1	14	71V	612.00	-2.40	-1.50	312.43	299.57
1U	1	15	31V	613.00	2.10	1.20	311.71	301.29
1O	1	15	1119V	609.00	2.70	-0.40	301.15	307.85

1U	1	16	1047N	610.00	3.60	-1.40	295.85	314.15
10	1	16	1133N	613.00	-2.70	0.00	302.82	310.18
1U	1	17	95N	614.00	2.60	-0.30	315.90	298.10
10	1	17	1088N	611.00	2.50	-1.70	294.50	316.50
1U	1	18	4V	611.00	-2.10	-2.00	309.78	301.22
10	1	18	143V	611.00	2.40	2.00	314.36	296.64
1U	1	19	1051V	611.00	2.80	1.70	296.95	314.05
10	1	19	132N	612.00	3.40	0.50	309.98	302.02
1U	1	20	10V	611.00	3.20	0.40	311.30	299.70
10	1	20	2N	614.00	2.80	-0.80	309.46	304.54
1U	1	21	152N	610.00	2.20	1.80	316.89	293.11
10	1	21	1102N	608.00	-2.30	-0.30	300.05	307.95
1U	1	22	1009N	611.00	1.40	-1.00	293.89	317.11
10	1	22	41V	613.00	2.30	0.80	316.00	297.00
1U	1	23	1093N	610.00	2.30	-1.10	302.56	307.44
10	1	23	1101N	611.00	2.50	-0.10	298.78	312.22
1U	1	24	1144N	611.00	-2.30	1.60	295.11	315.89
10	1	24	61N	613.00	3.30	-0.60	313.55	299.45
1U	1	25	1074N	611.00	-1.70	-0.70	296.34	314.67
10	1	25	154N	610.00	-3.00	0.70	311.10	298.90
1U	1	26	1159N	610.00	3.50	1.10	296.46	313.54
10	1	26	117V	613.00	3.50	1.50	311.40	301.60
1U	1	27	1031N	611.00	-1.60	0.90	300.92	310.08
10	1	27	1127V	612.00	2.70	-1.70	302.33	309.67
1U	1	28	1005N	611.00	-3.20	0.40	300.31	310.69
10	1	28	1037N	614.00	3.00	1.40	300.25	313.75
1U	1	29	1064N	611.00	3.50	0.10	298.47	312.53
10	1	29	18V	611.00	1.70	-1.70	312.22	298.78
1U	1	30	75N	613.00	-2.40	-0.70	308.65	304.35
10	1	30	1136N	611.00	2.50	0.70	299.39	311.61
1U	1	31	1146N	614.00	2.90	-0.60	301.78	312.22
10	1	31	64V	610.00	-2.80	-0.10	305.91	304.09
1U	1	32	44N	614.00	-2.10	-1.70	313.45	300.55
10	1	32	7N	613.00	2.20	1.30	310.79	302.21
1U	1	33	24N	609.00	2.40	0.50	310.89	298.11
10	1	33	1V	612.00	2.80	0.40	311.51	300.49
1U	1	34	1147V	612.00	2.50	0.50	295.60	316.40
10	1	34	1134V	611.00	-2.90	0.50	296.95	314.05
1U	1	35	151V	613.00	-2.60	-0.90	312.32	300.68
10	1	35	1056V	610.00	-1.80	1.90	300.12	309.88
1U	1	36	9N	612.00	2.60	-1.50	313.34	298.66
10	1	36	22N	613.00	-2.40	0.60	316.00	297.00
1U	1	37	1108V	610.00	-3.80	0.20	299.81	310.19
10	1	37	115N	613.00	2.40	0.70	310.79	302.21
1U	1	38	73N	614.00	2.30	-0.60	312.83	301.17
10	1	38	1048V	611.00	3.10	-0.40	300.31	310.69
1U	1	39	8V	613.00	3.30	-0.50	312.02	300.98
10	1	39	1065V	610.00	-2.50	0.00	298.60	311.40
1U	1	40	19V	615.00	2.20	-0.60	313.34	301.66
10	1	40	1060V	612.00	2.70	-1.10	301.72	310.28

1U	1	41	70N	610.00	2.70	1.50	315.98	294.02
1O	1	41	1097N	613.00	-3.60	1.00	300.98	312.02
1U	1	42	1045V	613.00	-2.30	0.70	297.61	315.39
1O	1	42	39N	613.00	-2.40	-0.60	317.53	295.47
1U	1	43	1073N	609.00	1.50	-1.00	297.19	311.81
1O	1	43	1117V	610.00	-2.50	0.80	300.12	309.88
1U	1	44	1083N	612.00	3.10	0.90	297.13	314.87
1O	1	44	1123N	613.00	-2.70	1.70	298.53	314.47
1U	1	45	80V	613.00	-2.30	0.60	306.81	306.19
1O	1	45	1128N	611.00	2.20	0.60	301.53	309.47
1U	1	46	11V	611.00	2.10	-1.70	307.33	303.67
1O	1	46	52N	615.00	2.60	1.50	319.80	295.20
1U	1	47	1057V	609.00	3.40	0.40	302.67	306.33
1O	1	47	1012N	612.00	-2.50	-1.00	304.47	307.53
1U	1	48	42N	615.00	3.20	1.40	313.34	301.66
1O	1	48	1086V	611.00	3.60	0.00	298.17	312.83
1U	1	49	121N	613.00	2.40	0.00	311.10	301.90
1O	1	49	46V	613.00	-2.30	0.50	317.53	295.47
1U	1	50	1078V	612.00	3.40	0.60	300.49	311.51
1O	1	50	47N	613.00	2.00	-0.60	309.87	303.13
1U	1	51	1071N	608.00	3.80	0.40	300.05	307.95
1O	1	51	130V	610.00	-2.60	0.70	312.93	297.07
1U	1	52	138V	610.00	-2.10	-0.20	310.80	299.21
1O	1	52	1017N	612.00	-2.90	0.20	302.63	309.37
1U	1	53	1154N	611.00	2.70	0.80	299.08	311.92
1O	1	53	45N	613.00	3.10	-1.00	315.08	297.92
1U	1	54	87N	614.00	2.90	-0.70	314.06	299.94
1O	1	54	1032V	611.00	-3.20	-0.70	297.86	313.14
1U	1	55	139N	611.00	3.10	0.00	313.14	297.86
1O	1	55	1104V	611.00	2.00	-1.20	301.53	309.47
1U	1	56	1090N	611.00	-2.30	1.90	303.06	307.94
1O	1	56	14N	612.00	-2.30	1.90	312.73	299.27
1U	1	57	84V	612.00	-2.10	0.90	308.45	303.55
1O	1	57	1149N	610.00	-2.50	0.90	297.07	312.93
1U	1	58	62N	611.00	-2.30	0.00	314.97	296.03
1O	1	58	107V	610.00	-2.50	-1.00	315.98	294.02
1U	1	59	148V	611.00	-3.20	-1.00	311.92	299.08
1O	1	59	1153V	612.00	-2.40	-0.30	299.57	312.43
1U	1	60	1091N	612.00	2.20	0.50	305.08	306.92
1O	1	60	1162N	611.00	2.70	1.00	296.03	314.97
1U	1	61	55V	613.00	-1.80	-1.00	312.02	300.98
1O	1	61	1099V	610.00	2.40	-1.30	297.98	312.01
1U	1	62	150V	610.00	-1.50	-2.10	309.57	300.43
1O	1	62	1082N	611.00	-2.40	-0.50	301.22	309.78
1U	1	63	48N	614.00	2.60	-0.80	316.82	297.18
1O	1	63	1121V	612.00	2.90	-0.60	296.51	315.49
1U	1	64	1049N	613.00	2.40	-0.50	297.61	315.39
1O	1	64	108N	611.00	-2.40	1.70	314.36	296.64
1U	1	65	1038N	611.00	2.60	-1.40	297.56	313.44
1O	1	65	16V	614.00	-2.50	0.60	306.39	307.61

1U	1	66	5N	614.00	-3.20	1.80	310.68	303.32
1O	1	66	1041N	611.00	-2.90	-0.40	301.83	309.17

Module number 2:

Und.	Mod.	Pos.	Magn.	Mz	Mx	My	North	South
1U	2	1	15V	611.00	-2.50	-1.70	309.78	301.22
1O	2	1	77V	614.00	-2.40	0.90	313.75	300.25
1U	2	2	1034N	612.00	-2.90	-0.60	300.80	311.20
1O	2	2	1152N	611.00	3.50	-0.10	296.64	314.36
1U	2	3	1141V	612.00	2.30	-0.80	300.19	311.81
1O	2	3	83N	613.00	2.50	-0.50	311.71	301.29
1U	2	4	1036V	613.00	-2.80	1.20	304.05	308.95
1O	2	4	1103V	609.00	2.90	-0.50	301.46	307.55
1U	2	5	1010N	612.00	-2.40	0.70	298.04	313.96
1O	2	5	23N	612.00	2.50	-0.40	313.96	298.04
1U	2	6	131N	611.00	3.40	0.10	305.19	305.81
1O	2	6	1094V	611.00	2.20	1.90	295.42	315.58
1U	2	7	1072N	609.00	2.70	-2.10	299.93	309.07
1O	2	7	1137N	614.00	-3.10	-0.20	302.09	311.91
1U	2	8	28V	614.00	2.10	0.40	318.36	295.64
1O	2	8	1138N	610.00	3.20	0.70	298.90	311.10
1U	2	9	1150V	610.00	-2.20	0.40	301.64	308.36
1O	2	9	102N	611.00	2.80	1.00	308.86	302.14
1U	2	10	29V	610.00	2.60	-0.20	309.57	300.43
1O	2	10	50V	614.00	2.80	-1.00	315.60	298.40
1U	2	11	145N	610.00	3.20	-0.90	310.19	299.81
1O	2	11	1155N	609.00	-2.80	-0.10	301.76	307.24
1U	2	12	1130V	609.00	2.90	2.20	304.50	304.50
1O	2	12	146N	608.00	-1.70	-0.70	313.73	294.27
1U	2	13	1024V	613.00	3.70	-1.60	302.21	310.79
1O	2	13	1151N	608.00	3.80	-0.60	298.53	309.47
1U	2	14	85V	615.00	2.60	1.20	311.19	303.81
1O	2	14	59N	611.00	3.30	-1.10	311.61	299.39
1U	2	15	1006N	611.00	3.00	2.30	301.83	309.17
1O	2	15	110V	611.00	2.80	-0.10	315.28	295.72
1U	2	16	142V	610.00	2.70	0.10	310.19	299.81
1O	2	16	26V	614.00	2.50	1.30	314.06	299.94
1U	2	17	43N	613.00	2.70	0.50	312.94	300.06
1O	2	17	99N	616.00	-2.10	0.80	318.78	297.22
1U	2	18	114V	614.00	-2.90	-0.80	313.75	300.25
1O	2	18	1120N	610.00	-3.30	0.10	295.85	314.15
1U	2	19	1114N	611.00	-1.90	1.70	294.50	316.50
1O	2	19	1070V	612.00	-2.70	1.10	303.25	308.75
1U	2	20	1007N	612.00	-2.50	0.50	298.35	313.65
1O	2	20	1135V	611.00	-2.30	-1.00	303.97	307.03
1U	2	21	1054V	613.00	2.50	0.40	299.14	313.86
1O	2	21	1113V	612.00	3.20	0.80	296.82	315.18
1U	2	22	1050V	613.00	-2.90	0.10	299.76	313.24
1O	2	22	1156N	612.00	2.30	-1.40	300.19	311.81
1U	2	23	1067V	611.00	-3.40	0.10	299.08	311.92

1O	2	23	76V	613.00	-2.70	-2.30	314.47	298.53
1U	2	24	40N	614.00	2.40	1.70	314.37	299.63
1O	2	24	1043V	615.00	2.40	0.80	301.35	313.65
1U	2	25	1011N	610.00	-3.70	-0.90	298.60	311.40
1O	2	25	30V	613.00	-3.40	2.10	310.48	302.52
1U	2	26	141N	609.00	2.10	-1.20	309.37	299.63
1O	2	26	90N	612.00	3.10	0.20	307.53	304.47
1U	2	27	1029V	611.00	2.60	-0.80	295.11	315.89
1O	2	27	1058V	612.00	-3.00	-0.40	297.74	314.26
1U	2	28	98V	611.00	3.10	1.70	310.39	300.61
1O	2	28	81V	611.00	2.80	-0.50	309.47	301.53
1U	2	29	1160N	611.00	-2.70	0.20	299.39	311.61
1O	2	29	1044N	613.00	2.80	-0.90	300.98	312.02
1U	2	30	60N	612.00	-2.00	-0.30	311.51	300.49
1O	2	30	134N	613.00	2.30	1.40	311.71	301.29
1U	2	31	1081V	608.00	-1.60	-1.70	297.92	310.08
1O	2	31	100V	613.00	-2.00	-1.10	314.47	298.53
1U	2	32	1098N	611.00	-1.70	2.00	301.83	309.17
1O	2	32	1122N	613.00	3.00	-0.40	303.44	309.56
1U	2	33	6V	613.00	-1.80	-0.80	314.16	298.84
1O	2	33	129N	609.00	2.30	-1.00	309.37	299.63
1U	2	34	106V	611.00	3.10	-1.70	311.00	300.00
1O	2	34	1055N	613.00	-2.10	1.50	296.39	316.61
1U	2	35	1027V	610.00	-1.60	-0.90	298.60	311.40
1O	2	35	1132N	614.00	-3.20	-0.10	300.25	313.75
1U	2	36	69N	611.00	-1.80	-0.50	314.67	296.34
1O	2	36	1158N	612.00	3.50	-0.40	302.63	309.37
1U	2	37	119N	613.00	3.10	-0.60	314.16	298.84
1O	2	37	113N	612.00	2.90	0.80	317.32	294.68
1U	2	38	1131N	612.00	-3.00	-1.00	304.78	307.22
1O	2	38	1052V	614.00	-2.50	0.50	304.24	309.76
1U	2	39	1022N	612.00	-2.70	1.00	295.29	316.71
1O	2	39	133N	615.00	-2.60	-1.10	312.11	302.89
1U	2	40	1068V	609.00	3.60	0.10	302.98	306.02
1O	2	40	111V	609.00	-2.30	0.40	311.50	297.50
1U	2	41	153N	609.00	-1.90	-1.50	312.42	296.58
1O	2	41	1030V	611.00	-2.90	-0.80	301.22	309.78
1U	2	42	1142V	612.00	-3.00	-0.70	298.04	313.96
1O	2	42	140V	612.00	-2.50	-2.20	309.67	302.33
1U	2	43	51V	615.00	-2.30	0.80	317.95	297.05
1O	2	43	1079N	613.00	-2.40	1.30	305.27	307.73
1U	2	44	78N	615.00	-2.70	-0.70	316.73	298.28
1O	2	44	137V	611.00	-3.00	0.00	309.47	301.53
1U	2	45	91V	613.00	3.20	0.20	309.56	303.44
1O	2	45	1148N	610.00	-2.30	-0.10	300.73	309.27
1U	2	46	1107V	612.00	2.40	-1.70	300.49	311.51
1O	2	46	1013V	610.00	2.60	-0.70	294.02	315.98
1U	2	47	1145V	611.00	-2.70	1.90	301.22	309.78
1O	2	47	96N	612.00	-3.30	-1.10	310.28	301.72
1U	2	48	1163V	610.00	-2.00	1.80	300.12	309.88

1O	2	48	128N	610.00	3.90	-0.60	304.39	305.61
1U	2	49	1075N	612.00	3.40	1.10	297.43	314.57
1O	2	49	1140V	612.00	-2.60	0.50	301.41	310.59
1U	2	50	1089V	611.00	2.10	0.70	294.50	316.50
1O	2	50	1020N	613.00	3.50	0.50	302.21	310.79
1U	2	51	1062N	613.00	-2.80	0.60	296.69	316.31
1O	2	51	79V	609.00	2.20	0.60	304.80	304.20
1U	2	52	1018V	611.00	-3.10	-0.50	296.95	314.05
1O	2	52	1053N	612.00	-1.70	-0.50	298.04	313.96
1U	2	53	1100N	610.00	3.10	-0.50	295.85	314.15
1O	2	53	93N	612.00	-1.70	-1.70	310.28	301.72
1U	2	54	1008N	612.00	2.80	0.40	298.04	313.96
1O	2	54	3N	614.00	-2.80	0.40	314.06	299.94
1U	2	55	1077V	613.00	2.30	1.60	301.90	311.10
1O	2	55	1003V	612.00	3.80	0.40	298.66	313.34
1U	2	56	1040N	612.00	-2.40	-0.60	304.47	307.53
1O	2	56	72N	611.00	-2.70	-0.40	311.61	299.39
1U	2	57	53N	615.00	1.70	-1.10	313.34	301.66
1O	2	57	20V	615.00	-3.10	0.30	311.50	303.50
1U	2	58	1112V	612.00	2.90	0.00	299.88	312.12
1O	2	58	1105V	612.00	2.80	0.20	306.31	305.69
1U	2	59	97N	612.00	3.00	2.10	308.75	303.25
1O	2	59	1061V	613.00	2.90	1.00	299.45	313.55
1U	2	60	1066N	612.00	2.90	-0.70	300.80	311.20
1O	2	60	33V	613.00	-1.90	-1.10	308.65	304.35
1U	2	61	1028N	610.00	-2.40	1.30	299.81	310.19
1O	2	61	1035N	613.00	-3.00	0.00	307.11	305.89
1U	2	62	1002N	613.00	-2.40	-0.20	299.76	313.24
1O	2	62	127V	611.00	2.70	0.40	313.14	297.86
1U	2	63	135V	611.00	3.30	0.30	310.08	300.92
1O	2	63	68N	612.00	2.00	-1.80	306.00	306.00
1U	2	64	57N	612.00	-1.40	-1.10	311.81	300.19
1O	2	64	25N	612.00	2.30	0.20	311.51	300.49
1U	2	65	136N	612.00	-2.60	-0.80	310.59	301.41
1O	2	65	1143V	610.00	-3.20	1.00	299.51	310.49
1U	2	66	1085N	611.00	2.90	-2.20	298.47	312.53
1U	2	66	49N	613.00	2.80	1.10	311.71	301.29

Downstream compensation:

Und.	Mod.	Pos.	Magn.	Mz	Mx	My	North	South
1U	6	1	147V	611.00	3.20	-0.10	308.86	302.14
1O	6	1	101V	613.00	-2.00	0.10	312.63	300.37

Magnets not used:

112
1059
34
56
12

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  13
  17
  21
  32
  35
  37
  66
  74
  92
 103
 109
 116
 118
 120
 123
 144
 155
1023
1025
1046
1076
1084
1087
1092
1106
1115
1124
1126
1161
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