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TESLA DAMPING RING: INJECTION/EXTRACTION SCHEMES WITH RF DEFLECTORS

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Abstract

In the paper we illustrate some possible injection/extraction schemes in the Damping Ring of TESLA using RF deflectors. We illustrate different possible solutions using 2 or 3 RF frequencies in 2, 4 or 6 RF deflector groups both considering the bunches modeled as macro-particles without a finite length and considering a finite bunch length. We discuss, finally, the effects of the errors in the Damping Ring parameters such as the phase advance between the deflectors and the RF amplitude and phase.

1. Introduction

Different possible injection/extraction (inj./extr.) schemes in the TESLA Damping Ring (DR) using high power kickers have been proposed [1]. These schemes foresee the use of a large number of kickers fed by high power.

A possible alternative inj./extr. scheme using RF deflectors seems to be very promising from the point of view of required power and number of kickers.

The idea is to adopt, for the DR, an injection scheme similar to that of the Combiner Ring (CR) of CTF3 [2] sketched in Figs. 1,2. The first calculations have been done by J.P. Delahaye [3]. In CTF3 the long bunch train coming from the Drive Beam accelerator with an intra-bunch distance of 20 cm is converted into a series of short bunch trains with an intra-bunch distance of 2 cm. This is done by properly recombining the bunches of the long train in two steps: first by a factor of 2 in the Delay Loop (DL) and, after, by a factor of 5 in the CR. In particular, Fig. 2 shows the recombination process in the CR. The bunches of the 1st train coming from the DL with an intra-bunch distance of 10 cm are injected in the CR with the 1st RF deflector. The length of the CR is properly chosen so that, after one turn, the bunches are $2\pi/5$ out of phase with respect to the RF voltage of the 2nd RF deflector. The residual transverse kick is completely compensated by the 1st RF deflector because the betatron phase advance between the two devices is $180°$. In this way the bunches are progressively recombined.

We will illustrate the extensions of this injection procedure to the DR.

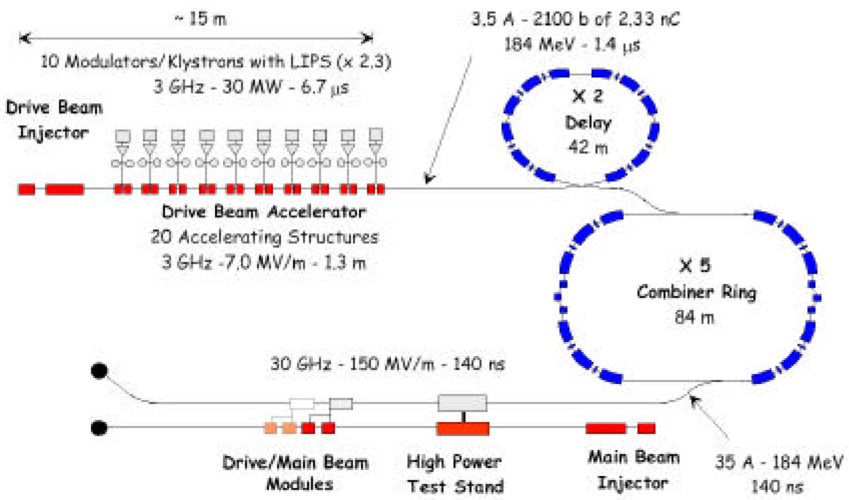

Figure 1 - CTF3 schematic layout

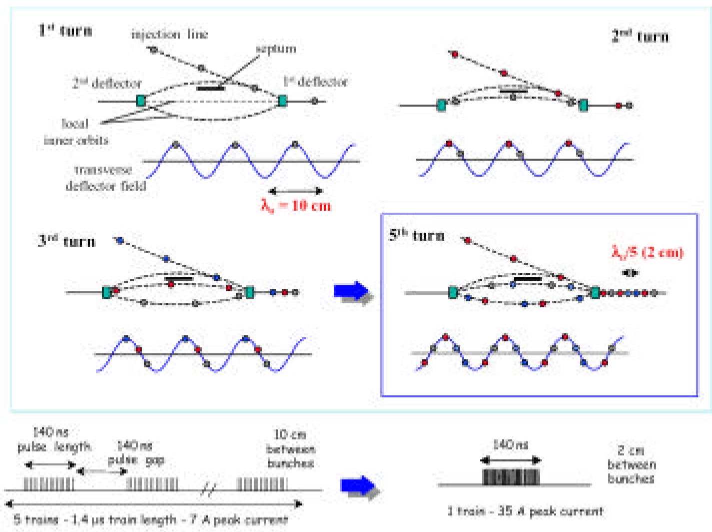

Figure 2 - CTF3 CR injection system

2. CTF3-like injection/extraction schemes for TESLA

The direct way to apply the CTF3 injection scheme to the DR is to consider the Damping Ring itself as a Combiner Ring and to use 2 RF deflectors for the injection process and 2 for the extraction, as illustrated in Figs. 3 and 4. Fig. 5 shows the bunches distribution over the RF voltage. In that figure ΔT_L is the time distance between bunches in the LINAC and ΔT_{DR} is the time distance in the DR after the complete injection. The recombination factor F indicates how much the bunches have been "compressed" in the DR with respect to their time distance in the LINAC.
Considering this simple scheme it has to be pointed out that:

a) the RF frequency has to be a multiple of the LINAC repetition frequency $f_L = 1/\Delta T_L$;
b) if the filling time (t_F) of the deflectors is less than ΔT_{DR}, it is possible to inject or to extract the bunches without any gap in the DR filling pattern;
c) Δf should be bigger than a certain Δf^*, depending on the optics and septum position, in order to close the bump without hitting the septum. Considering the most simple case of a single RF frequency it follows that $\Delta f / f_{MAX} = 1 - \cos(2p / F)$.

Using the TESLA parameters given in [1] the requirements for the RF deflectors have been derived. The injection requirements for this scheme are listed in Table I.
It is important to remark that:

a) the RF frequency of the deflectors can be chosen equal to the frequency of the LINAC in order to use the same type of klystrons;
b) considering a reasonable value for Δf^* equal to 0.6 mrad, the minimum deflecting angle to extract or inject the bunches is 12 mrad because $\Delta f / f_{MAX} = 5\%$. This angle of deflection cannot be achieved with RF deflectors [4] of a reasonable length (of the order of 1m). As we illustrate in the next paragraphs it is possible to overcome such problem using more frequencies in the inj./extr. processes;
c) assuming a recombination factor F=20 the time distance between the bunches in the DR is 16.85 ns. Since the filling time of the RF deflectors should be less than ΔT_{DR} it is necessary to use fast

TW RF deflectors (as those of CTF3 [5]). Even with this type of deflectors it is necessary to introduce a gap in the DR filling pattern. In fact, typical filling times for TW RF deflectors [4-6] are of the order of 100 ns. The gap in the DR filling pattern can be obtained with the method illustrated in Fig. 6. If the n_B bucket over N_B/F of the total train coming from the LINAC are empty, the total time gap is $T_G = \Delta T_L * n_B$. With the typical filling times of TW deflectors it is enough to choose n_B=1, it means an empty bucket over N_B/F.

Table I - TESLA parameters in the inj./extr. processes using RF deflectors

	QUANTITY	SYMBOL	VALUE
LINAC	Number of bunches in the Linac	N_B	2820
	Bunch time spacing in the Linac	ΔT_L	337 ns
	Bunch spacing	$\Delta L_L = \Delta T_L * c$	~101 m
	Total length of the bunch train	$L_B = N_B * \Delta L_L$	~285 km
	Energy at the injection of the DR	E	5 GeV
DR	Recombination factor	F	20
	Total length of the DR	$L_{DR} = L_B / F \pm \Delta L_L / F$	~14 km
	Bunch spacing in the DR	$\Delta L_{DR} = \Delta L_L / F$	~5 m
	Bunch time spacing in the DR	$\Delta T_{DR} = \Delta T_L / F$	16.85 ns
	Emittance at extraction	e	$8 \cdot 10^{-4}$ mm·mrad
	b at the RF deflectors	$b_{Defl.}$	50 m
	b at the septum	$b_{Sept..}$	50 m
	a at the RF deflectors	$a_{Defl.}$	0
	a at the septum	$a_{Sept..}$	0
RF DEFL.	Total number of RF deflectors	N_D	4 (2 for inj. and 2 for extr.)
	Freq. of the RF deflectors	f_{RF}= n*1/ ΔT_L	~1.3 GHz (= 438*1/ DTL)
	Deflection between the extr./inj. bunches and the stored ones	Δf^*	0.6 mrad
	Deflection of the extr./inj. Bunches	$f_{MAX} = \Delta f / 1 - \cos(2p / F)$	12 mrad!!

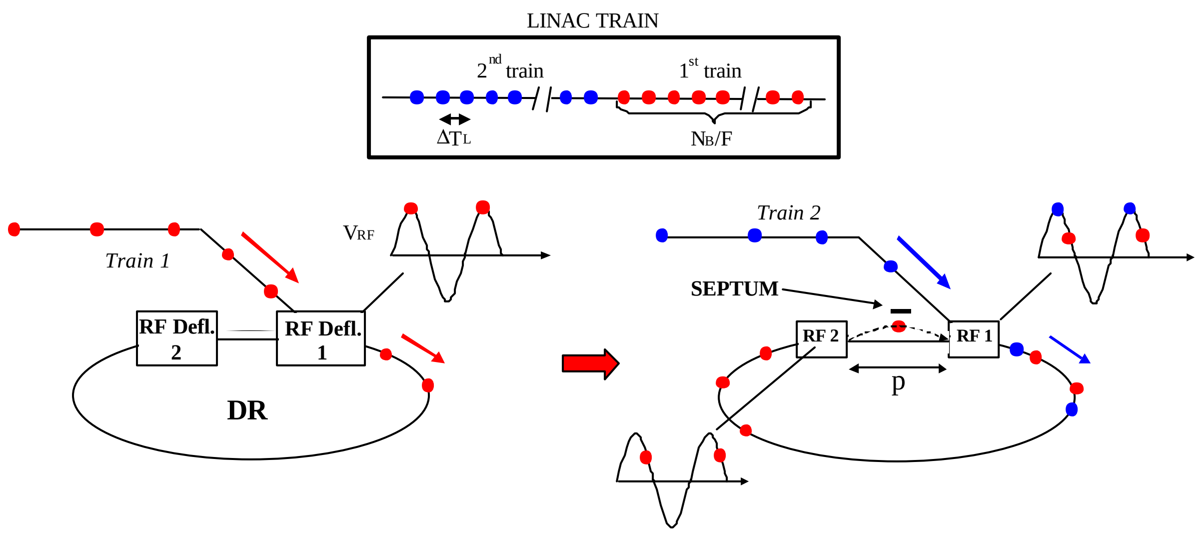

Figure 3 - CTF3-like injection scheme for the TESLA DR

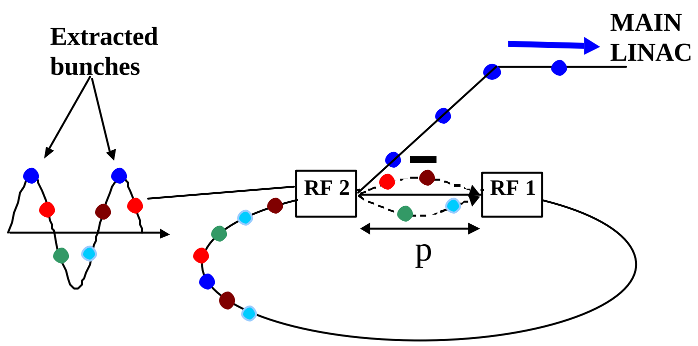

Figure 4 - CTF3-like extraction scheme for the TESLA DR

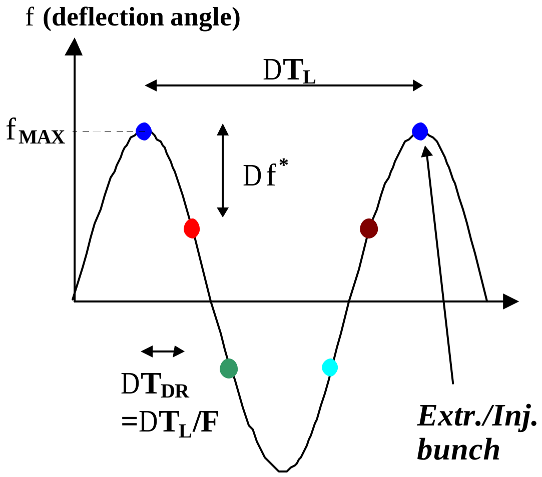

Figure 5 - Bunch distributions over the RF voltage in the CTF3-like inj./extr. scheme for DR

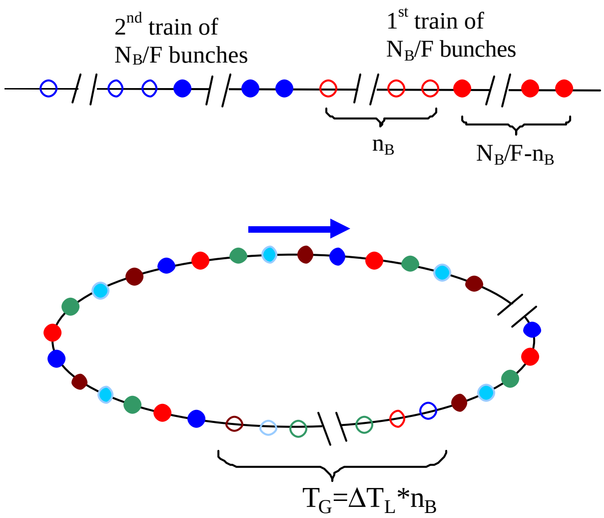

Figure 6 - Method to obtain a gap in the DR filling pattern

3 Inj./Extr. with 2 or more RF frequencies near 1.3 GHz

By using the combination of 2 or more frequencies it is possible to increase the ratio $\Delta f / f_{MAX}$ and, therefore, to reduce the maximum deflection.

3.1 2 frequencies case

To choose the 2 different frequencies the ratio $\Delta f / f_{MAX}$ has been calculated for all the combinations of $1/\Delta T_L$ in the range $[430 * 1/\Delta T_L \times 450 * 1/\Delta T_L] = [1.276 GHz \times 1.335 GHz]$. The maximum achievable $\Delta f / f_{MAX}$ is 44%. The deflection received by each bunch for a recombination factor F=20 is shown in Fig. 7. The optimization made considering 2 distant frequencies (i.e. every possible frequency in the considered range) gives the same result as the optimization with 2 close frequencies (i.e. two frequencies that differ by $1/\Delta T_L$).

The TW RF deflectors parameters, relative to this case, are reported in Table II. In this scheme it is necessary to use 4 RF deflectors for injection and 4 RF deflectors for the extraction. The total deflection is 1.36 mrad (0.68 mrad each deflector) to obtain $\Delta f = 0.6 mrad$. The calculated length and filling times are referred to two possible input powers of 9 or 5 MW.

The use of two close frequencies can be interesting to feed a single RF device with the two frequencies. Looking at the typical dispersion curve of a TW RF deflector (Fig. 8) we can excite the structure at a frequency (f_1) near f*. Doing this we loose synchronism with the bunch and, with the same input power, we obtain a reduction of the transverse kick given by the formula:

$$\frac{f_{f_1}}{f_{f^*}} = \frac{\sin\left(t_F p \Delta f\right)}{\left(t_F p \Delta f\right)} \tag{1}$$

As shown in (1) the reduction is less if the filling time of the structure is short. In the case of two frequencies it is possible to obtain a closed solution with the final parameters reported in Table III. The 2 deflectors used in the injection (extraction) process are, in this case, powered with two RF frequencies near the "classical" working point.

Table II - RF deflectors parameters in the 2 frequencies case

P_{RF} [MW]	Number of deflectors	fRF [GHz]	Length [m]	Filling time [ns]	Numb. Of cells	Deflection [mrad]	$\Delta f / f_{MAX}$
9	4 inj. +4 extr.	f_{RF1}=1281.90 f_{RF2}=1278.93	1.51	112	26	$f_{DEFL1} = 0.68$ $f_{DEFL2} = 0.68$	44%
5			2.03	150	35		

Table III - RF deflector parameters using 2 close frequencies to excite the same device

P_{RF} [MW]	Number of deflectors	fRF [GHz]	Length [m]	Filling time [ns]	Numb. Of cells	Deflection [mrad]	$\Delta f / f_{MAX}$
9	2 inj. +2 extr.	f_{RF1}=1281.90 f_{RF2}=1278.93	1.59	118	28	$f_{DEFL1} = 0.68$ $f_{DEFL2} = 0.68$	44%
5			2.25	167	39		

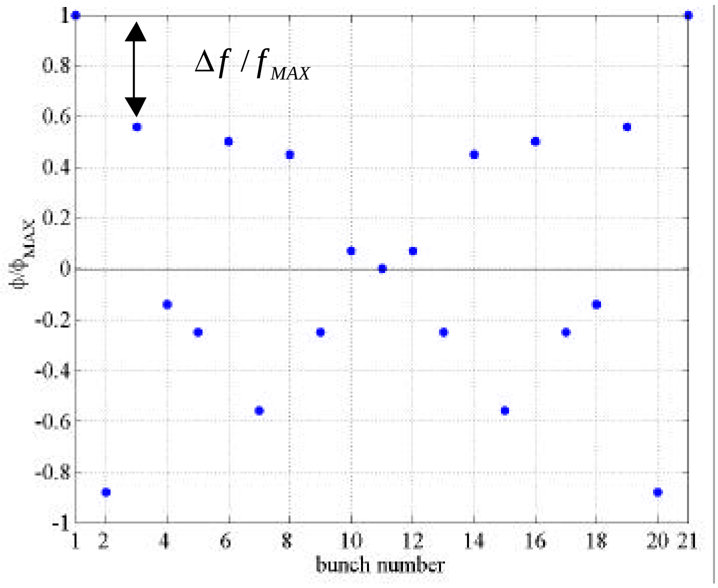

Figure 7 - Deflection of the bunches with 2 RF frequencies ($\Delta f / f_{MAX} = 44\%$)

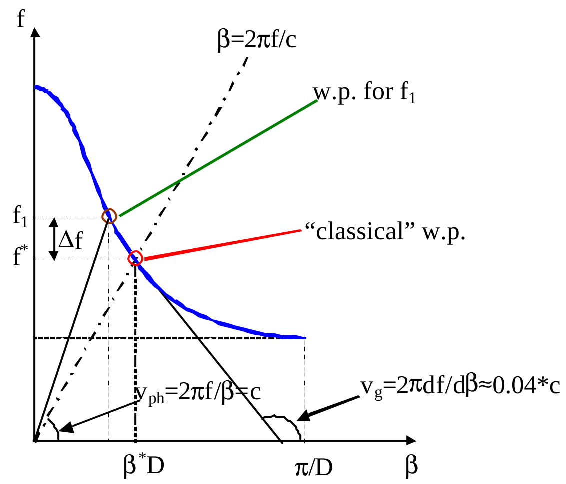

Figure 8 - Typical dispersion curve of a TW RF deflector

2.2 3 frequencies case

The same optimization can be done considering 3 different frequencies. In this case, as shown in Fig. 9, the $\Delta f / f_{MAX}$ is equal to 69% and is, obviously, better than the previous 2 frequencies case. The results obtained considering 3 close frequencies is shown in Fig. 10 and is slightly different from the 3 distant frequencies case. A possible choice of RF deflectors parameters is shown in Table IV for the 3 distant freq. case and in Table V for the 3 close frequencies case[1].

This kind of calculations can be performed considering different recombination factors F and comparing the various cases 2/3 distant/close frequencies as shown in Fig. 11. As predictable, the best results can be obtained considering 3 distant frequencies.

Table IV - RF deflectors parameters in the 3 distant frequencies case

<table>
<tr><th>P_{RF} [MW]</th><th>Number of deflectors</th><th>fRF [GHz]</th><th>Length [m]</th><th>Filling time [ns]</th><th>Numb. Of cells</th><th>Deflection [mrad]</th><th>$\Delta f / f_{MAX}$</th></tr>
<tr><td>9</td><td rowspan="2">6 inj.+6 extr.</td><td rowspan="2">f_{RF1}=1284.87
f_{RF2}=1299.70
f_{RF3}=1314.54</td><td>0.64</td><td>48</td><td>11</td><td rowspan="2">$f_{DEFL1} = 0.29$
$f_{DEFL2} = 0.29$
$f_{DEFL3} = 0.29$</td><td rowspan="2">69%</td></tr>
<tr><td>5</td><td>0.86</td><td>64</td><td>15</td></tr>
</table>

Table V - RF deflector parameters using 3 close frequencies to excite the same device

<table>
<tr><th>P_{RF} [MW]</th><th>Number of deflectors</th><th>fRF [GHz]</th><th>Length [m]</th><th>Filling time [ns]</th><th>Numb. Of cells</th><th>Deflection [mrad]</th><th>$\Delta f / f_{MAX}$</th></tr>
<tr><td>9</td><td rowspan="2">2 inj. +2 extr.</td><td rowspan="2">f_{RF1}=1293.77
f_{RF2}=1296.74
f_{RF3}=1290.80</td><td>0.69</td><td>51</td><td>12</td><td>$f_{DEFL1} = 0.31$
$f_{DEFL2} = 0.3$
$f_{DEFL3} = 0.3$</td><td>66%</td></tr>
<tr><td>5</td><td>0.96</td><td>71</td><td>17</td><td>$f_{DEFL1} = 0.32$
$f_{DEFL2} = 0.3$
$f_{DEFL3} = 0.3$</td><td>65%</td></tr>
</table>

[1] In this case, there is a slight variation in the ratio $\Delta f / f_{MAX}$ with respect to the ideal case shown in Fig. 10 because there is no perfect synchronism between the bunches and the electromagnetic waves in the RF deflectors powered with different frequencies.

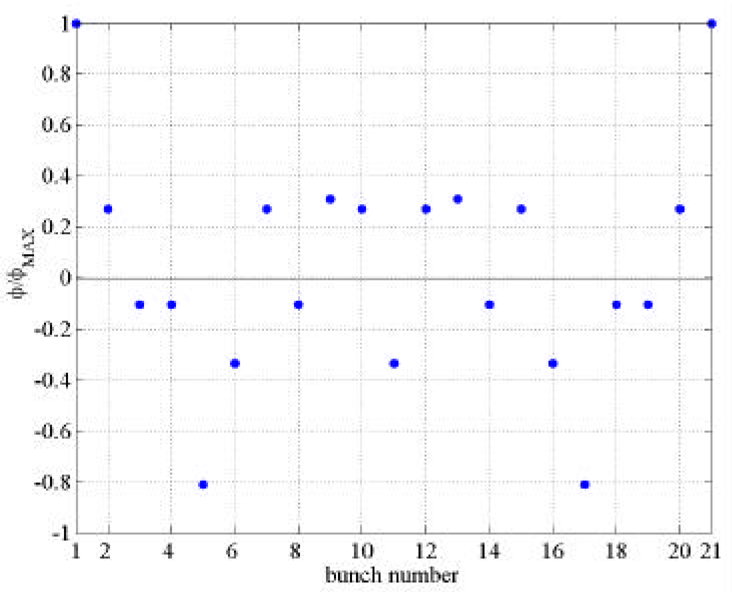

Figure 9 - Deflection of the bunches with 3 distant RF frequencies ($\Delta f / f_{MAX} = 69\%$)

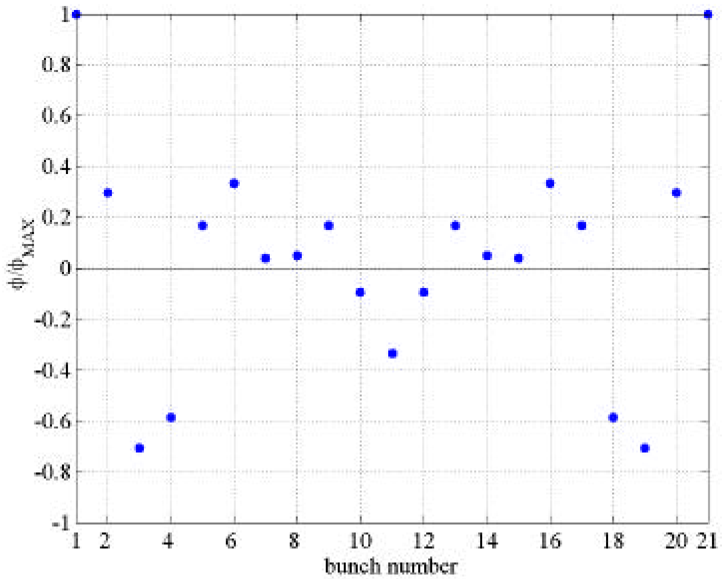

Figure 10 - Deflection of the bunches with 3 close RF frequencies and P_{RF}=9 MW

($\Delta f / f_{MAX} = 66\%$)

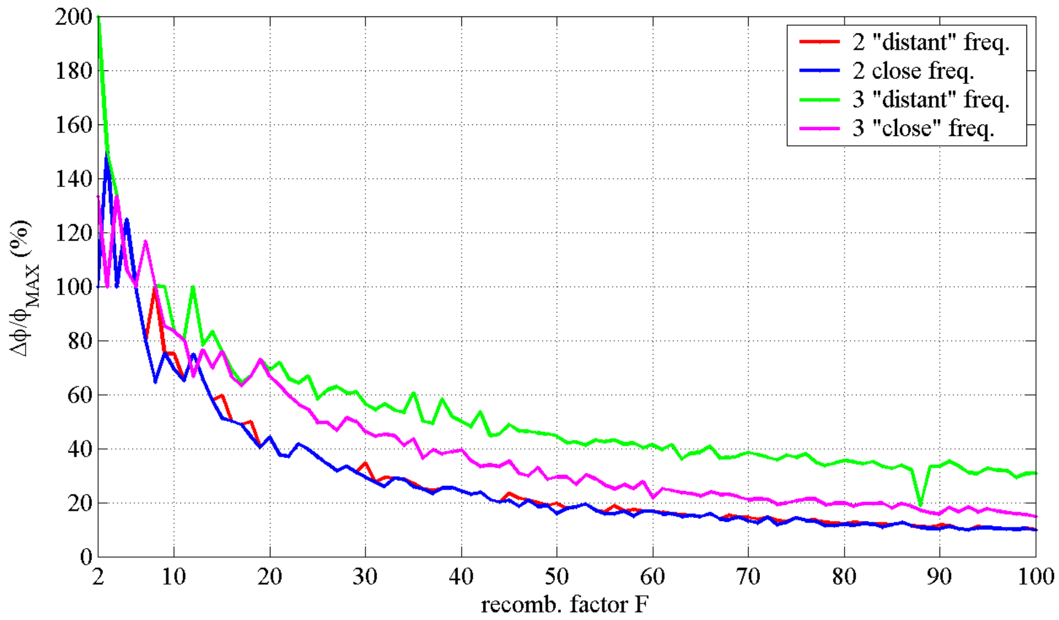

Figure 11 - $\Delta f / f_{MAX}$ considering different recombination factor F

4. Effect of a finite bunch length

If we consider the 2 frequencies case and we introduce a gaussian profile of the bunches (Fig. 12) with a $s_z = 6mm$ [1] we obtain the result plotted in Fig. 13. The new effective $\Delta f_{TAIL} / f_{MAX}$ relative to the tails of the bunches is considerably reduced ($\Delta f_{TAIL} / f_{MAX} = 9\%$). Moreover there are two effects that have to be taken into account:

a) the effect of the RF curvature that is especially harmful for the extracted bunches. In fact, for the injected ones, we expect a cancellation of this effect due to the damping mechanism;
b) the slope of the RF voltage over the stored bunches that is, in principle, canceled by the other deflector but that can cause problems if there are non linearities in the magnets between the two RF deflectors.

From these points of view it is therefore necessary:

a) a new optimization procedure to increase the ratio $\Delta f_{TAIL} / f_{MAX}$;
b) a compensation of the distortions due to the RF curvature over the extracted bunches;

c) a new optimization procedure to reduce the RF slope over the bunch length;

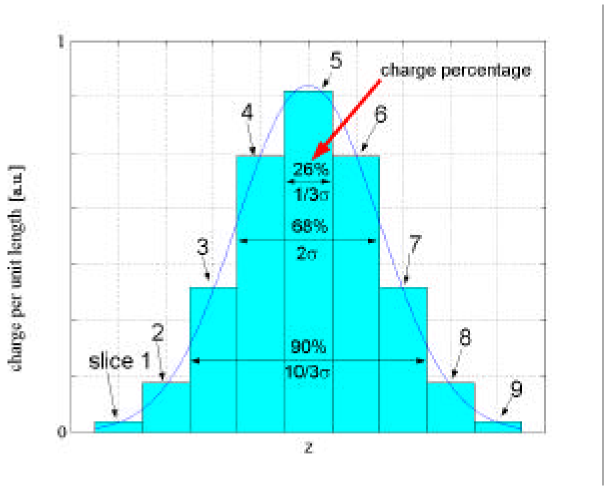

Figure 12 - Discretized gaussian bunch profile

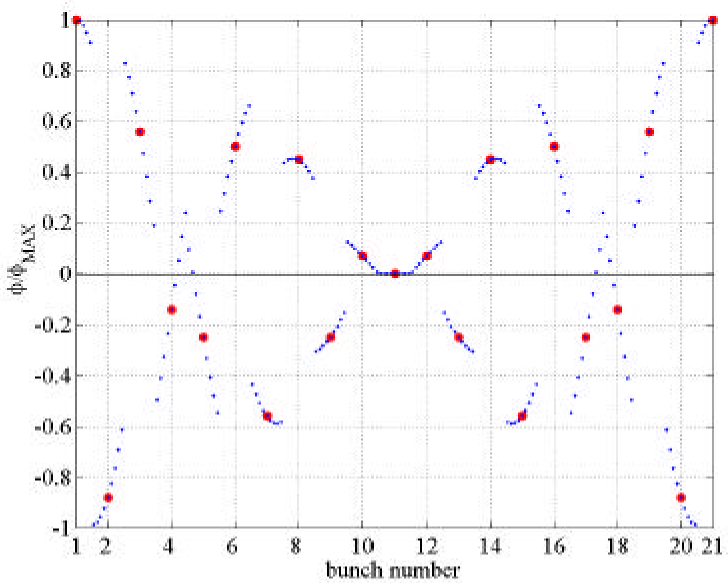

Figure 13 - Deflection of the bunches with 2 RF frequencies (optimized in the macroparticle case) for a gaussian bunch distribution ($s_z = 6mm$)

4.1 $\Delta f_{TAIL} / f_{MAX}$ maximization in the case of a gaussian bunch distrubution

The result of the optimization considering 2 distant frequencies is shown in Fig. 14. The maximum achievable $\Delta f_{TAIL} / f_{MAX}$ is equal to 22% and is obviously reduced with respect to the case without bunch length. A possible choice of RF deflector parameters is reported in Table VI.

The case of 2 close frequencies is shown in Fig. 15. Unfortunately in this case it is not possible to find a solution considering 2 RF deflectors for the injection (+2 for the extraction) powered with 2 RF frequencies (as done in the macroparticle case).

The 3 distant frequencies result is shown in Fig. 16 with a possible choice of RF deflector parameters of Table VII. The case of 3 close frequencies is shown in Fig. 17 with the RF deflector parameters of Table VIII (in this case we have considered P_{RF}=9 and 6 MW because the case P_{RF}=5 MW does not give solution with 2+2 RF deflectors).

Table VI - RF deflectors parameters in the 2 distant frequencies case assuming a gaussian bunch with $s_z = 6mm$

P_{RF} [MW]	Number of deflectors	fRF [GHz]	Length [m]	Filling time [ns]	Numb. Of cells	Deflection [mrad]	$\Delta f / f_{MAX}$
9	4 inj. +4 extr.	f_{RF1}=1326.41 f_{RF2}=1281.90	2.95	219	51	$f_{DEFL1} = 1.33$ $f_{DEFL2} = 1.33$	22%
5			3.96	294	68		

Table VII - RF deflectors parameters in the 3 distant frequencies case assuming a gaussian bunch with $s_z = 6mm$

P_{RF} [MW]	Number of deflectors	fRF [GHz]	Length [m]	Filling time [ns]	Numb. Of cells	Deflection [mrad]	$\Delta f / f_{MAX}$
9	6 inj.+6 extr.	f_{RF1}=1317.51 f_{RF2}=1296.74 f_{RF3}=1290.80	0.78	58	13	$f_{DEFL1} = 0.35$ $f_{DEFL2} = 0.35$ $f_{DEFL3} = 0.35$	57%
5			1.04	77	18		

Table VIII - RF deflector parameters in the 3 close frequencies case assuming a gaussian bunch with $s_z = 6mm$

P_{RF} [MW]	Number of deflectors	fRF [GHz]	Length [m]	Filling time [ns]	Numb. Of cells	Deflection [mrad]	$\Delta f / f_{MAX}$
9	2 inj. +2 extr.	f_{RF1}=1290.80 f_{RF2}=1293.77 f_{RF3}=1287.83	1.26	93	22	$f_{DEFL1} = 0.57$ $f_{DEFL2} = 0.5$ $f_{DEFL3} = 0.5$	38%
6			1.83	135	32	$f_{DEFL1} = 0.67$ $f_{DEFL2} = 0.51$ $f_{DEFL3} = 0.51$	36%

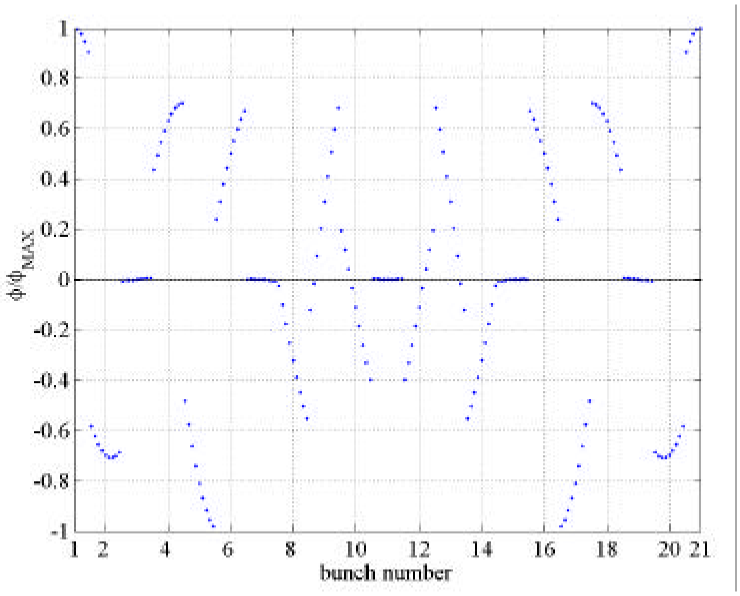

Figure 14 - Deflection of the bunches with 2 distant RF frequencies ($\Delta f_{TAIL} / f_{MAX} = 22\%$**) for a gaussian bunch distribution (**$s_z = 6mm$**)**

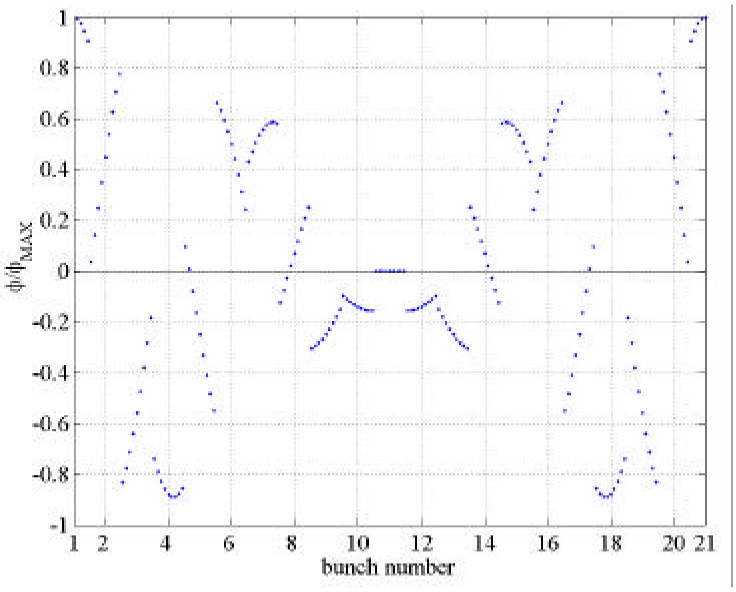

Figure 15 - Deflection of the bunches with 2 close RF frequencies ($\Delta f_{TAIL} / f_{MAX} = 14\%$) for a gaussian bunch distribution ($s_z = 6mm$)

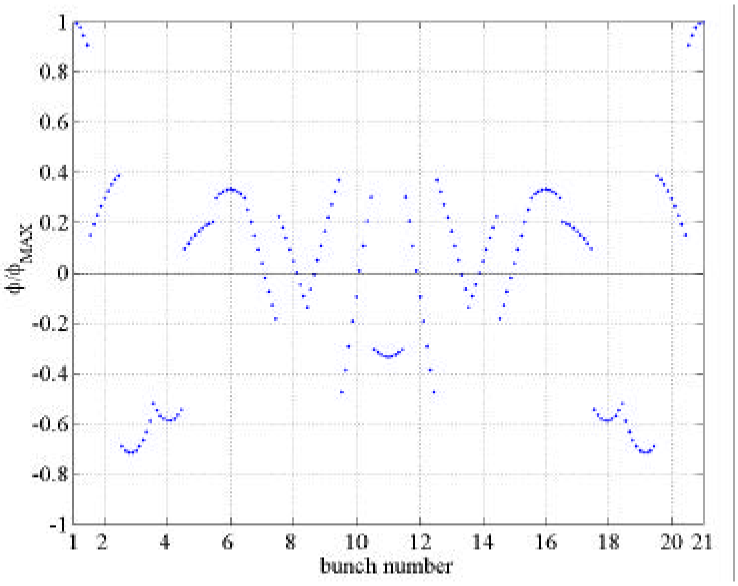

Figure 16 - Deflection of the bunches with 3 distant RF frequencies ($\Delta f_{TAIL} / f_{MAX} = 57\%$) for a gaussian bunch distribution ($s_z = 6mm$)

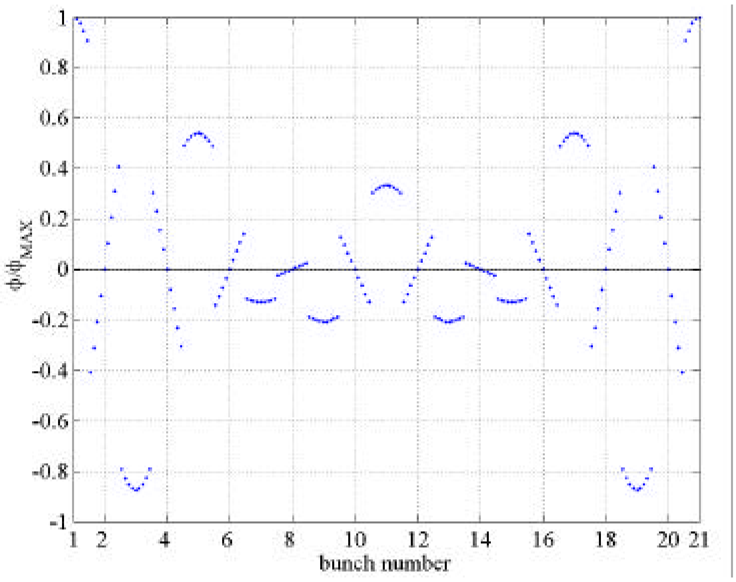

Figure 17 - Deflection of the bunches with 3 close RF frequencies ($\Delta f_{TAIL}/f_{MAX} = 38\%$) for a gaussian bunch distribution ($s_z = 6mm$)

4.2 Compensation of the RF curvature over the extracted bunches

A possible simple way to correct the distortion due to the RF curvature over the extracted bunches is shown in Fig. 18. It is enough to install a 3rd RF deflector with a 180° phase advance with respect to the deflector 2.

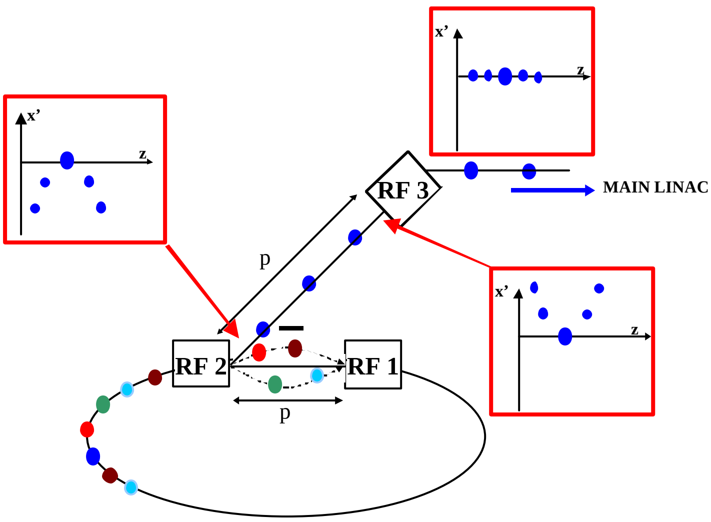

Figure 18 - Correction of the distortion due to the RF curvature over the extracted bunches

4.3 Reduction of the RF slope over the stored bunches

Starting from the 3 distant frequencies case we can find different frequencies to reduce the RF slope over the stored bunches in spite of a little loss of $\Delta f_{TAIL} / f_{MAX}$ with respect to the optimized case. The result is shown in Fig. 19 where the optimization has been taken considering the best case with $\Delta f_{TAIL} / f_{MAX} \geq 30\%$.

A possible choice of RF deflectors is shown in Table IX.

Table IX - RF deflector parameters in the 3 close frequencies case optimized to reduce the RF slope over the stored and assuming a gaussian bunch with $s_z = 6mm$

P_{RF} [MW]	Number of deflectors	fRF [GHz]	Length [m]	Filling time [ns]	Numb. Of cells	Deflection [mrad]	$\Delta f / f_{MAX}$
9	6 inj.+6 extr.	f_{RF1}=1311.57 f_{RF2}=1299.70 f_{RF3}=1290.80	1.48	110	26	$\Delta f_{DEFL1} = 0.67$ $\Delta f_{DEFL2} = 0.67$ $\Delta f_{DEFL3} = 0.67$	31%
5			1.99	147	34		

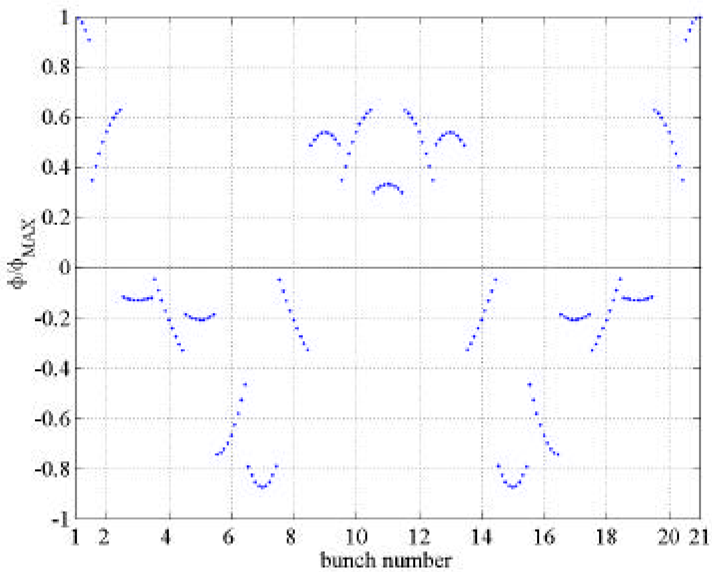

Figure 19 - Deflection of the bunches with 3 distant RF frequencies optimized to reduce the RF slope over the stored bunches and assuming a gaussian bunch distribution with $s_z = 6mm$ $(\Delta f_{TAIL} / f_{MAX} = 31\%)$

5. Recombination factor bigger than 20

In Fig. 20 are reported the optimized solutions considering recombination factors F=45 and F=100. Both are done considering the 3 distant frequencies case: the first case can be interesting considering recent calculations [7] to use the HERA Tunnel for the DR with a L_{DR}=6.3Km.

The second case can be interesting if we want to considerably reduce the length of the DR. In this last case it has been considered a $s_z = 2mm$. In Tables X, XI are reported the possible RF deflector parameters for the two cases.

Table X - RF deflector parameters in the 3 distant frequencies case assuming a gaussian bunch with $s_z = 6mm$ and F=45

P_{RF} [MW]	Number of deflectors	fRF [GHz]	Length [m]	Filling time [ns]	Numb. Of cells	Deflection [mrad]	$\Delta f / f_{MAX}$
9	6 inj.+6 extr.	f_{RF1}=1326.41 f_{RF2}=1305.64 f_{RF3}=1299.70	1.50	111	26	$f_{DEFL1} = 0.67$ $f_{DEFL2} = 0.67$ $f_{DEFL3} = 0.67$	30%
5			2.00	149	35		

Table XI - RF deflector parameters in the 3 distant frequencies case assuming a gaussian bunch with $s_z = 2mm$ and F=100

P_{RF} [MW]	Number of deflectors	fRF [GHz]	Length [m]	Filling time [ns]	Numb. Of cells	Deflection [mrad]	$\Delta f / f_{MAX}$
9	6 inj.+6 extr.	f_{RF1}=1326.41	1.6	119	28		28%

5	extr.	f_{RF2}=1305.64 f_{RF3}=1293.77	2.15	160	37	$f_{DEFL1} = 0.72$ $f_{DEFL2} = 0.72$ $f_{DEFL3} = 0.72$	

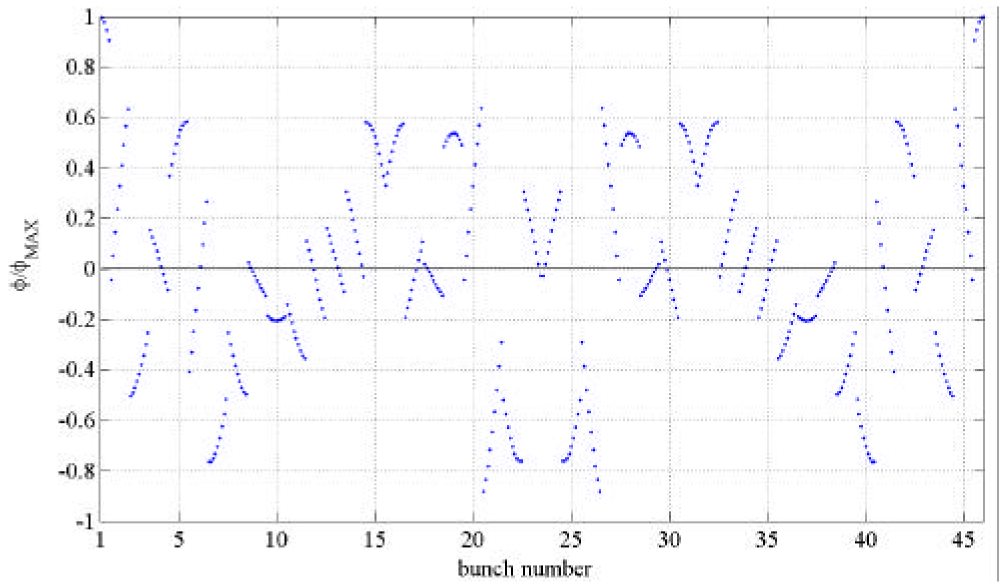

Figure 20 - Deflection of the bunches with 3 distant RF frequencies for a gaussian bunch distribution with $s_z = 6mm$ **and F=45** ($\Delta f_{TAIL} / f_{MAX} = 30\%$)

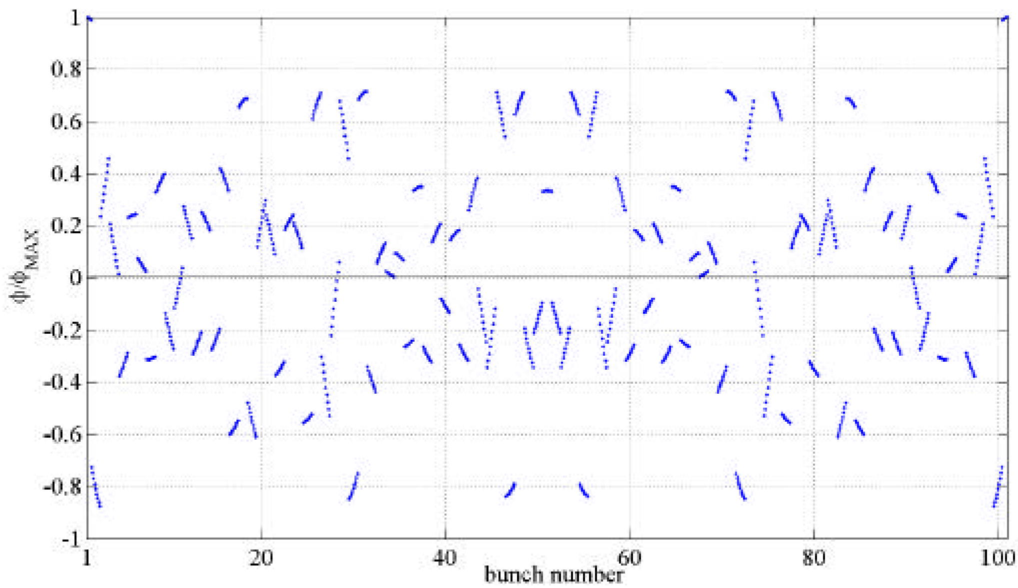

Figure 21 - Deflection of the bunches with 3 distant RF frequencies for a gaussian bunch distribution with $s_z = 2mm$ and F=100 ($\Delta f_{TAIL} / f_{MAX} = 28\%$)

6. Effects of errors

The possible main sources of errors in the inj./extr. processes are plotted in Fig. 22. They are:

a) the phase advance variation between the deflector 2 and 1 (Ph. Adv. 2-1) whose nominal value is $180°$;
b) the RF amplitude and phase jitter of one of the deflectors group with respect to the other.

The Ph. Adv. 1-2 or the values of the optical functions b, a in the deflectors can be considered as parameters that can magnify or reduce the effects of these errors.
All these errors are, obviously more critical in the extraction process since in the injection one they can be damped after some turns in the DR.

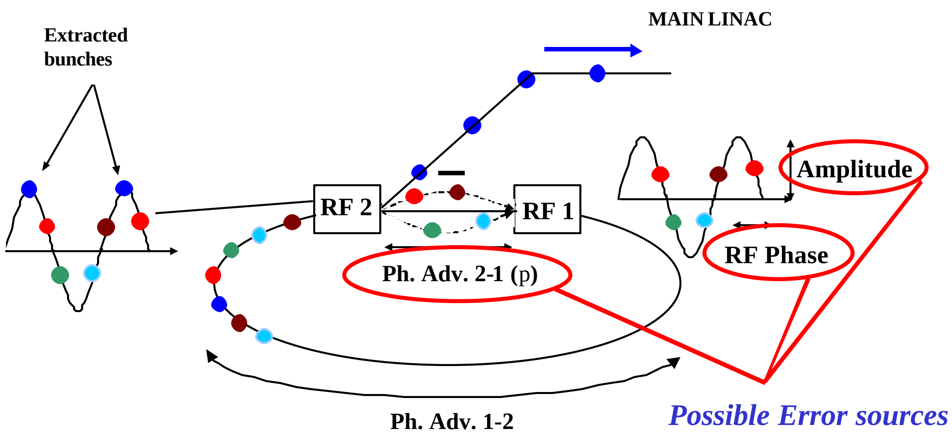

Figure 22 - Possible sources of errors in the extraction process

6.1 Errors in Ph. Adv. 2-1

Let us consider, as example, the phase advances Ph. Adv. 2-1=179° and Ph. Adv. 1-2=150° in the optimized cases of 2 and 3 distant frequencies disussed in par. 4.1 with F=20. The position and angle of the central slice of bunches at the septum after the extraction process are reported in Fig. 23 (a , b values at the septum are those of Table I and the phase advance between RF 2 and the septum is 90°). As shown in the figure, the position and angle of the first extracted bunches are the nominal ones. For the other extracted bunches the bump between the deflectors is not perfectly closed because Ph. Adv. 2-1=179° and the residual orbit gives the error in angle and position. This error is, obviously, periodic over F bunches. The ratio between the Courant-Snyder Invariants of the central slices (I_{out}) and the emittance of bunches (e) at the septum position are plotted in Fig. 24.

For a given value of Ph. Adv. 2-1 and Ph. Adv. 1-2, it is possible to calculate the average and the maximum values of the ratio I_{out}/e. Considering, as example, Ph. Adv. 2-1=179° and Ph. Adv. 1-2 between 0° and 360° we obtain the result plotted in Fig. 25.

From these results it is important to remark that:

a) the ratio I_{out}/e in the case of 3 distant frequency is less than in the 2 distant frequency case. This is because (see par. 4.1) the deflection angles are less in the first case.

b) with Ph. Adv. 1-2$\cong$180° the ratio I_{out}/e has a minimum. In particular with 3 frequencies there is a minimum also with Ph. Adv. 1-2$\cong$ 0°,360°.

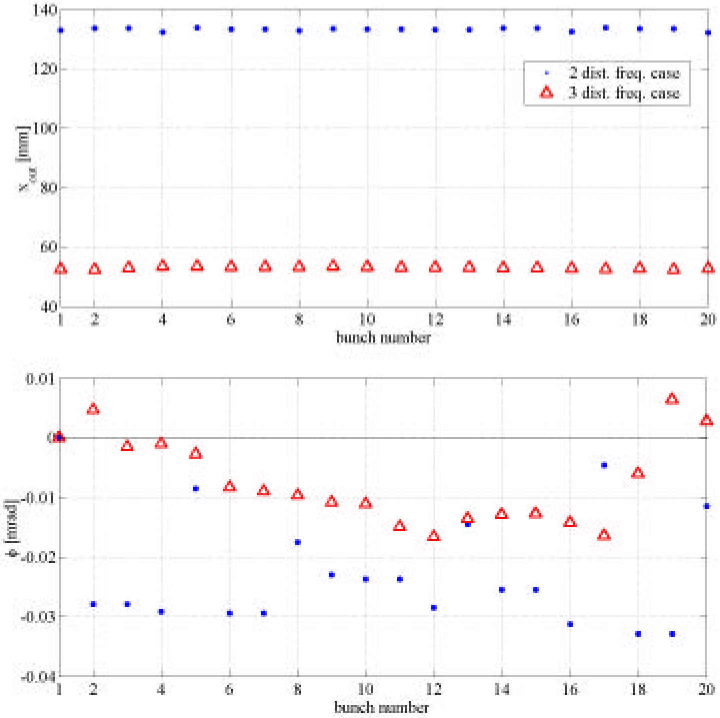

Figure 23 - position and angle of the central slice of the bunches after the extraction processes with Ph. Adv. 2-1=179° **and Ph. Adv. 1-2=**150°

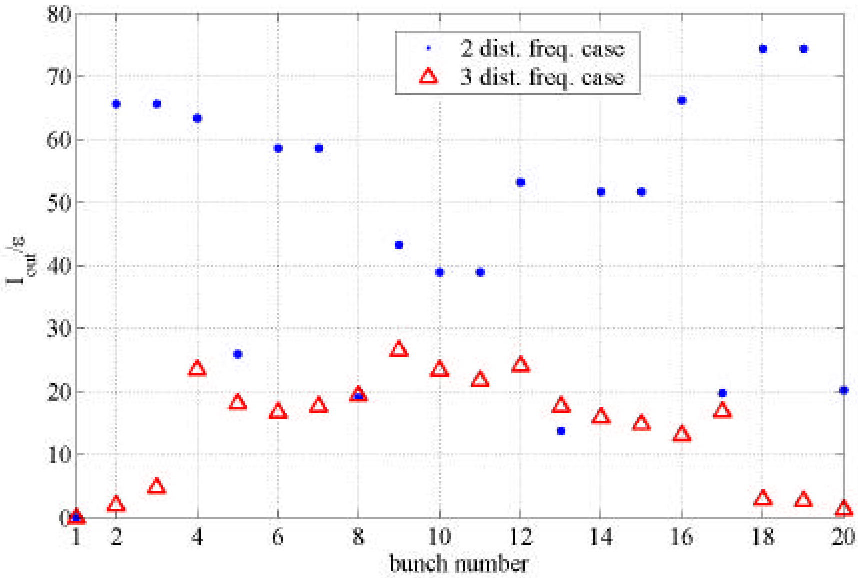

Figure 24 - Ratio between the Courant-Snyder Invariants of the central slices and the emittance of bunches at the septum position with Ph. Adv. 2-1=179° **and Ph. Adv. 1-2=**150°

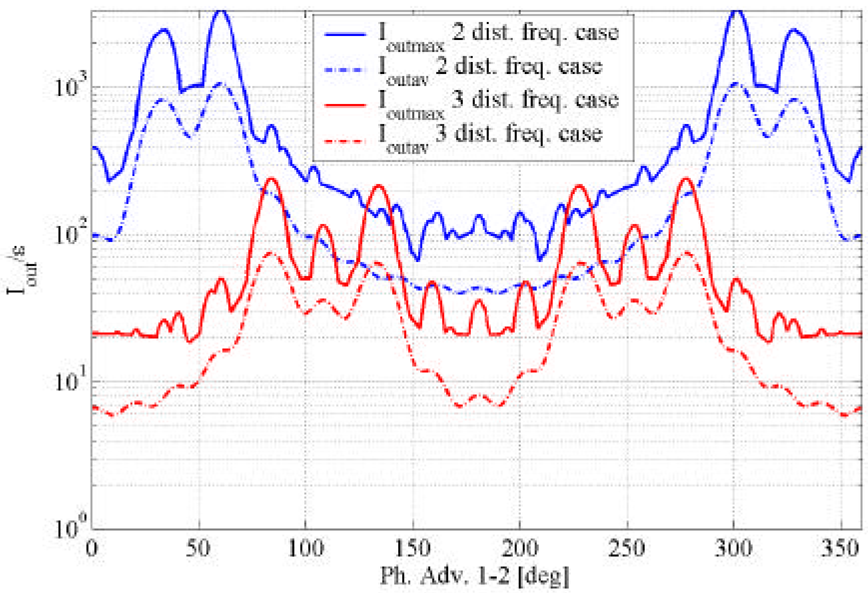

Figure 25 - Average and maximum values of the ratio I_{out}/e as a function of Ph. Adv. 1-2 and with Ph. Adv. 2-1=179°

6.2 Errors in the RF amplitude and phase

Similarly to what done in par. 6.1, we can consider an error in the amplitude of the RF voltage. Considering, as example, an amplitude variation of +1% of the deflecting voltage RF 1 related to f_{RF1}, we obtain the result plotted in Fig. 26-27. In the calculation Ph. Adv. 1-2=150° and Ph. Adv. 1-2=180°. Even in this case the bump between the deflectors is not perfectly closed and the residual orbit gives errors in the position and angle of the extracted bunches. The average and the maximum values of I_{out}/e with an amplitude variation of +1% of the deflecting voltage RF1 related to f_{RF1}, with Ph. Adv. 2-1=180° and Ph. Adv. 1-2 between 0° and 360°, are plotted in Fig. 28.
Finally, in Fig. 29, it has been considered a phase variation of +1% of the deflecting voltage RF1 related to f_{RF1} with Ph. Adv. 2-1=180° and Ph. Adv. 1-2 between 0° and 360°.

The previous results can give useful information about the stability requirements of the power amplifiers and related jitters. Moreover, to correct the residual errors it is possible to adopt feed-forward or feed-back systems acting on the extracted bunches.

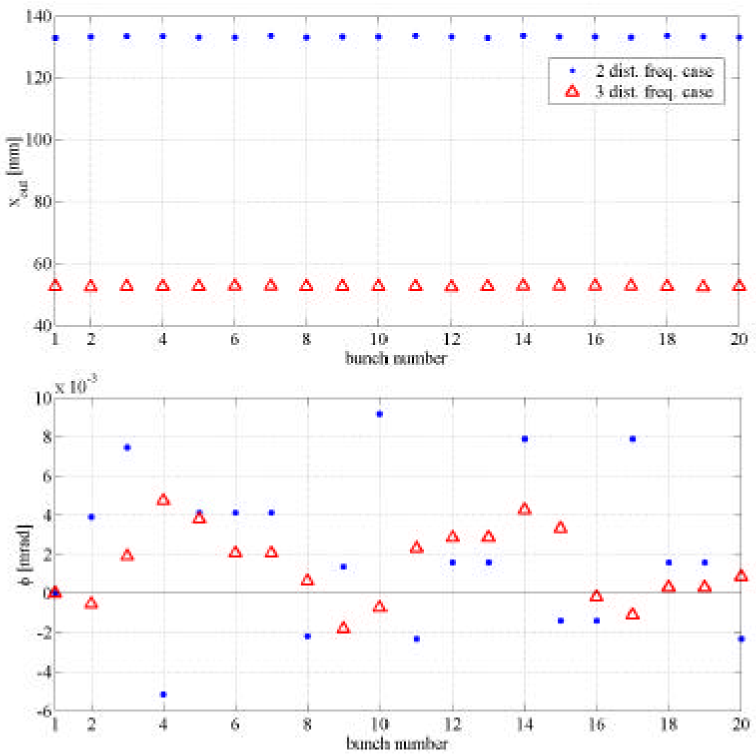

Figure 26 - position and angle of the central slice of the bunches after the extraction processes with an amplitude variation of +1% of the deflecting voltage RF1 related to f_{RF1} (Ph. Adv. 2-1=180° and Ph. Adv. 1-2=150°)

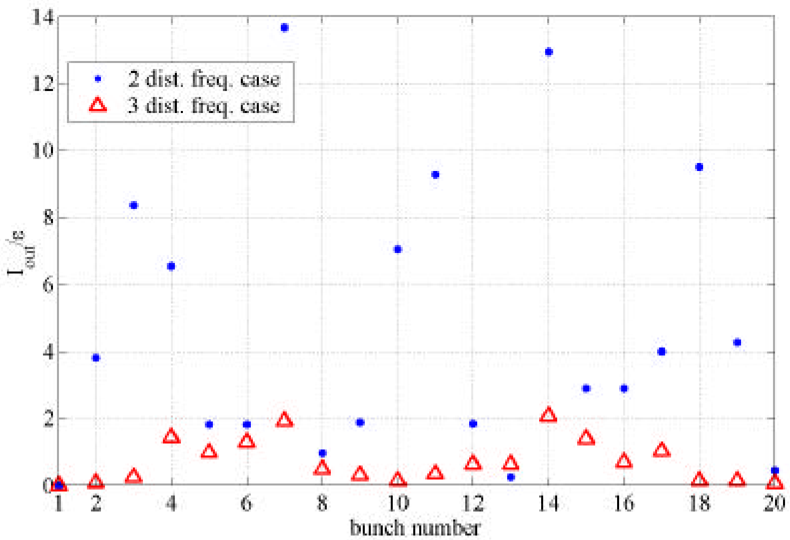

Figure 27 - Ratio between the Courant-Snyder Invariants of the central slices and the emittance of bunches at the septum position with an amplitude variation of +1% of the deflecting voltage RF1 related to f_{RF1}

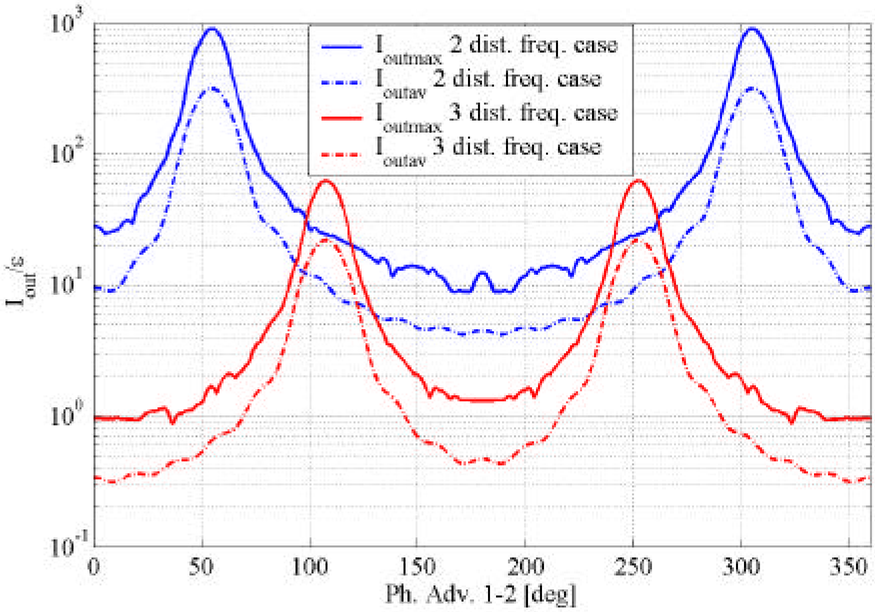

Figure 28 - Average and maximum values of the ratio I_{out}/e as a function of Ph. Adv. 1-2 with an amplitude variation of +1% of the deflecting voltage RF1 related to f_{RF1}

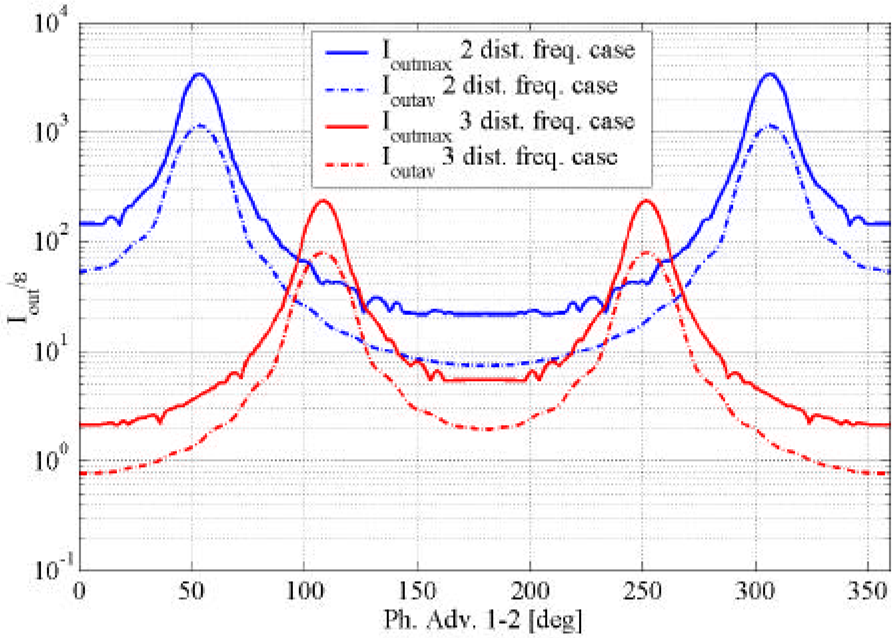

Figure 29 - Average and maximum values of the ratio I_{out}/e as a function of Ph. Adv. 1-2 with a phase variation of +1% of the deflecting voltage RF1 related to f_{RF1}

7. Conclusions

In the paper we have illustrated some possible injection/extraction schemes in the Damping Ring of TESLA using RF deflectors. The inj./extr. processes using TW RF deflectors is feasible and we have illustrated different possible solutions using 2 or 3 RF frequencies in 2, 4 or 6 RF deflector groups. In particular the cases of 2-3 RF frequencies and different recombination factors have been illustrated and discussed. The problem of the finite bunch length has been discussed showing that it is possible to optimize the frequencies to extract or inject without affecting the tails of bunches. The best results have been obtained using 3 RF frequencies. Finally the effects induced by errors has been analyzed. The study allows determining the tolerances of the power supplies of the magnets and in the RF jitter in amplitude and phase.

8. References

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