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Intrabeam Scattering Results for a High Frequency RF System

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One RF system that was proposed has the harmonic number $h = 8 \times 342 = 2736$, corresponding to a frequency of about $f = 214$ MHz. It was found that this RF system requires a voltage larger than 32 MV in order for the RF bucket to be large enough to contain the energy spread for a beam of Gold ions, after 10 hours, at $\gamma = 100$ with $N_b = 1.1 \times 10^9$ ions/buch, and an initial bunch area $A = 1$ ev-sec/AMU

Intra beam scattering causes the beam to grow as shown in the following table for Au ions after 10 hrs, and an initial bunch area of $A = 1$ ev-sec/AMU at $\gamma = 100$.

Table 1 – $\gamma = 100$

		initial		final, after 10 hrs					
h	V MV	$\sigma_{p_0}/10^{-3}$	σ_{ℓ_0} cm	$\sigma_p/10^{-3}$	σ_ℓ cm	σ_x mm	ϵ_x mm·mrad	$2.5\sigma_p/10^{-3}$	$\Delta p/p/10^{-3}$ bucket
2736	32	1.33	12.8	2.00	19.2	2.2	58	5.0	4.7
342	1.2	.36	48	1.07	142	1.61	28	2.67	2.6

For comparison, the results for the old RF system with $h = 342$, $V = 1.2$ MV are also shown.

There is a considerable improvement in the bunch length which grows to only $\sigma_\ell = 19$ cms after 10 hrs. However, the other dimensions have grown ~~[illegible]~~ larger, $\epsilon_x = 58$, $2.5\,\sigma_p = 5 \times 10^{-3}$ instead of the old results $\epsilon_x = 28$, $2.5\,\sigma_p = 2.6 \times 10^{-3}$.

The 6σ rule requires a stability limit of $A_{SL} = 9.3$ mm for $\sigma_x = 2.2$ mm. ~~The tracking resu~~ and for a ~~[illegible]~~ particle with $\epsilon_x = \epsilon_y$. The tracking result for a $\beta^* = 3$ m lattice gives $A_{SL} = 9$ mm at $\Delta p/p = 5 \times 10^{-3}$.

The larger energy spread will also cause a larger ν-spread in the beam due to the iron saturation generated by and due ~~to~~ random field errors.

The beam growth at $\gamma = 30$ is shown in the following table

Table 2, $\gamma = 30$

		initial		final after 10 hrs					
h	V (MV)	$\sigma_{p0}/10^{-3}$	$\sigma_{\ell 0}$ (cm)	$\sigma_p/10^{-3}$	σ_ℓ (cm)	σ_x (mm)	ε_x (mm.mrad)	$2.5\sigma_p/10^{-3}$	$\Delta p/p/10^{-3}$ bucket
2736	32	4.45	12.9	4.42	12.8	4.0	57	11	15
342	1.2	1.26	45	1.99	71	3.0	32	5.0	10.0

The bunch length is again considerably improved; the bunch length grows to only $\sigma_\ell = 12.8$ cm after 10 hours. The other dimensions have grown larger, $\varepsilon_x = 57$, $2.5\sigma_p = 11 \times 10^{-3}$ instead of the old results $\varepsilon_x = 32$, $2.5\sigma_p = 5 \times 10^{-3}$

The 6σ rule requires a stability limit of $A_{SL} = 17$ mm for $\sigma_x = 4$ mm and for a particle with $\varepsilon_x = \varepsilon_y$. The tracking results for a $\beta^* = 6$ m lattice give $A_{SL} = 7$ mm at $\Delta p/p = 11 \times 10^{-3}$ and $A_{SL} = 17$ mm at $\Delta p/p = 0$. This situation can be somewhat improved by reducing the voltage at $\gamma = 30$.

If the RF Voltage available is reduced the energy spread in the beam will grow to the boundary of the bucket in less than 10 hrs.
The following table shows the time it takes for the beam to reach the edge of the bucket as a function of the rf Voltage for a beam of Au ions at $\gamma = 100$

V MV	Time to reach bucket (hrs)	$\Delta p/p$ bucket $/10^{-3}$	Final σ_x mm	Initial A eV-sec/AMU	Final $\sigma_p/10^{-3}$	Final σ_e (cm)	Final $\frac{1}{\sigma_p}\frac{d\sigma_p}{dt}/10^{-2}$ (hr^{-1})
32	5.76	4.7	1.99	1	1.88	18	1.87
20	1.4	3.7	1.5	1	1.48	18	6.50
15	.56	3.2	1.28	1	1.28	18	13.0
10	.10	2.62	1.02	1	1.05	18	36.0

Possible Conclusions

The high frequency rf system h = 2736, f = 214 mhz might be consider acceptable. It has less margin for error. It ~~will probably~~ may lead to shorter beam lifetimes (less than 10 hrs), and to smaller luminosities.

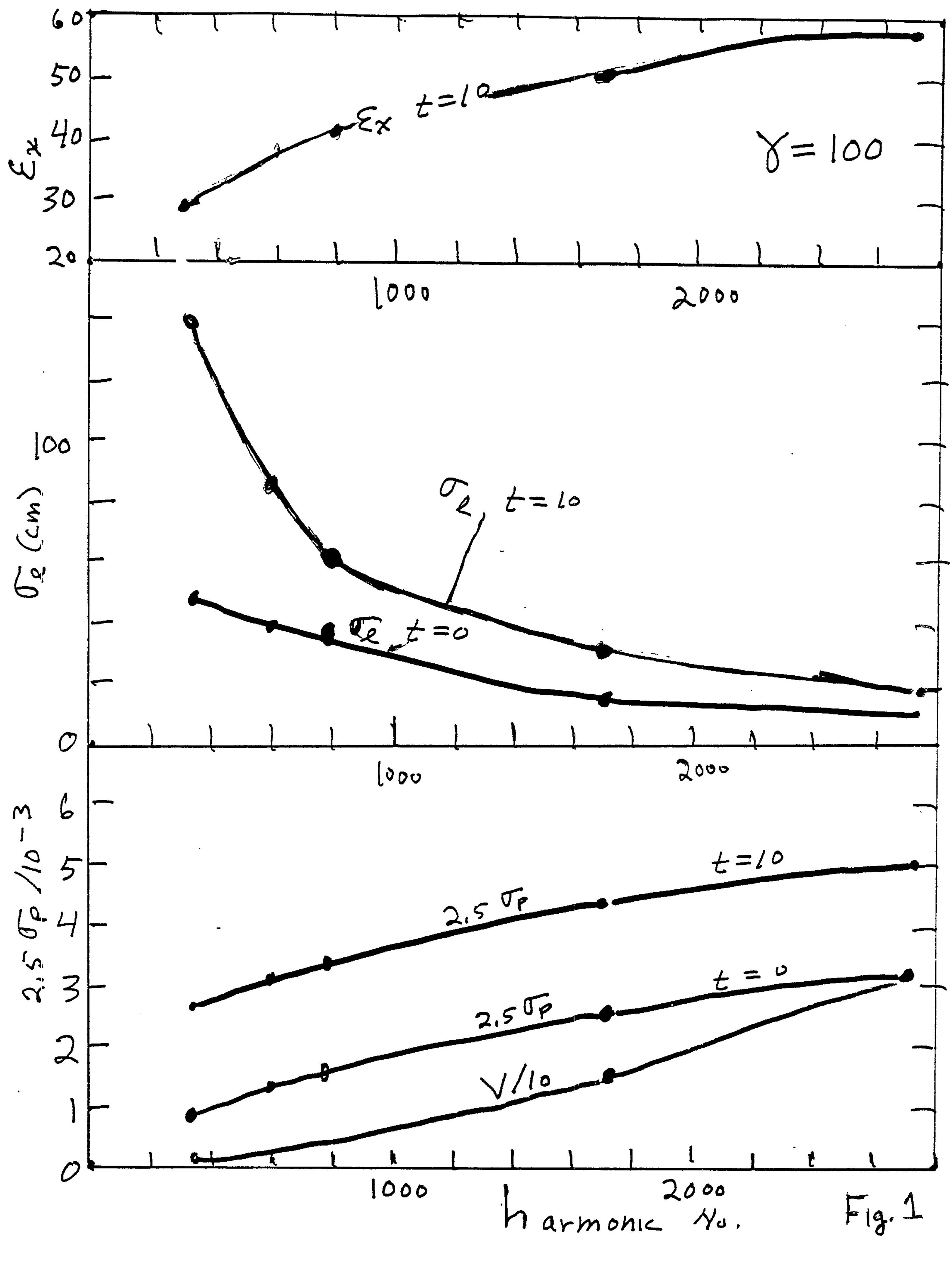
The high frequency 214 MHz RF system has the advantage of a shorter bunch length. In other ~~reports~~ respects, it appears to give less favorable results then the present 27 MHz RF system.

Frequency Dependence and Other Solutions

Figures 1 and 2 show how the intra beam scattering results depend on the harmonic number h or the frequency.

For each harmonic number, the voltage V has been adjusted so that the beam energy spread will just fit inside the rf bucket at $\gamma=100$ after 10 hours

Figs. 1 and 2 show σ_p, σ_ℓ and ϵ_x ~~after~~ after 10 hours as a function of the harmonic number h.
Fig 1. shows results at $\gamma=100$, Fig 2 shows results at $\gamma=30$



ε_x
60
50
40
30
20
ε_x t=10
$\gamma = 100$
1000
2000
σ_ℓ (cm)
100
0
σ_ℓ, t=10
σ_ℓ t=0
1000
2000
$2.5\,\sigma_p / 10^{-3}$
6
5
4
3
2
1
0
t=10
$2.5\,\sigma_p$
t = 0
$2.5\,\sigma_p$
V/10
1000
2000
harmonic No.

Fig. 1

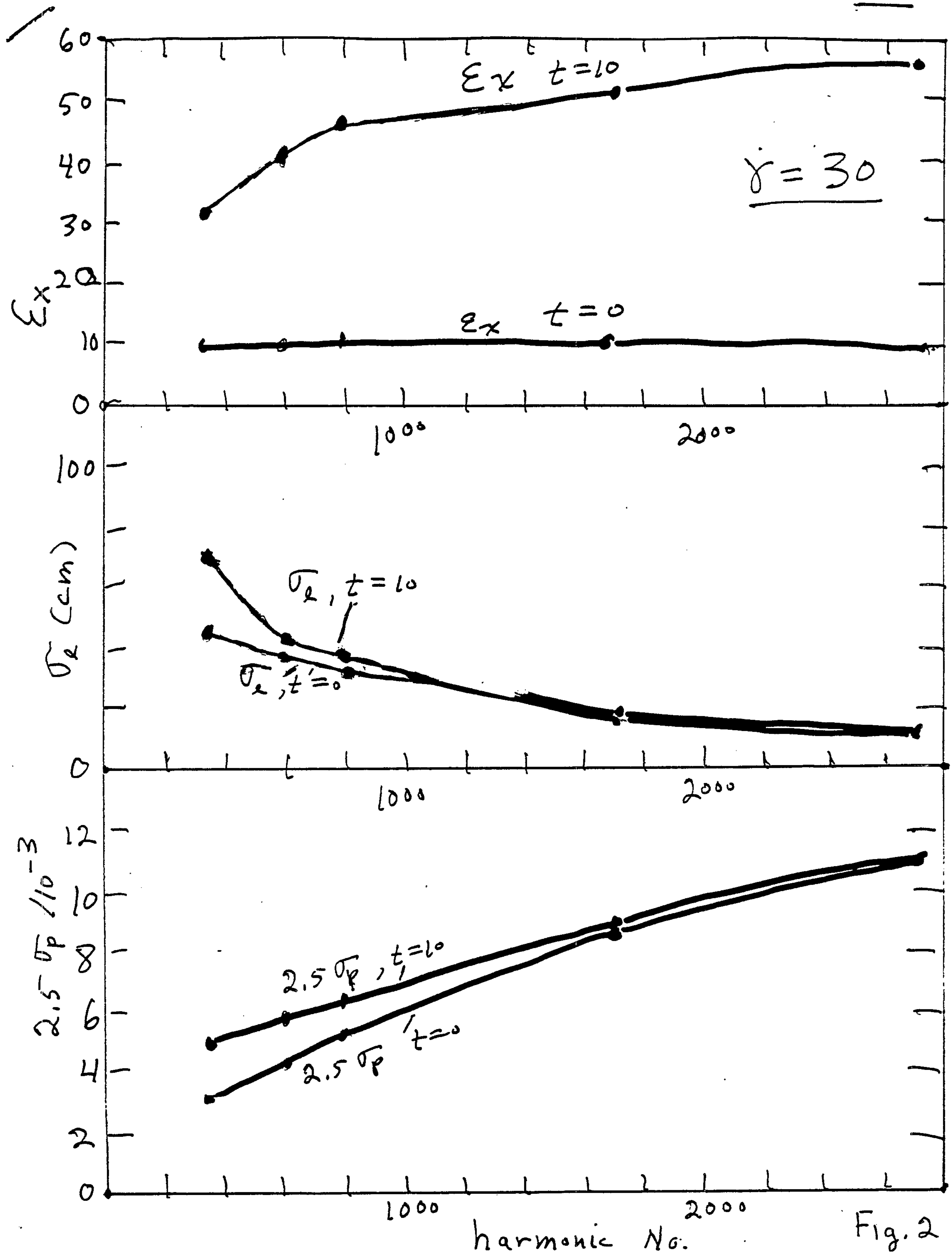

60
50
40
30
20
10
0
εx t=10
γ = 30
εx t=0
εx
1000
2000
100
0
σℓ (cm)
σℓ, t=10
σℓ, t=0
1000
2000
12
10
8
6
4
2
0
2.5 σp /10^-3
2.5 σp, t=10
2.5 σp, t=0
1000
2000
harmonic No.

Fig. 2

Figs 1 and 2 show that, except for the growth in σ_ℓ, the performance generally improves at the lower frequencies, which give smaller values for the final σ_p and ε_x.

other solutions, at lower frequencies, that may deserve consideration are the following:

<u>Solution A.</u> $h = 785$, $f = 61$ MHz, $V = 4.7$ MV

γ	30	100
$\sigma_\ell\ (t=0)$ cm	26	28
$\sigma_\ell\ (t=10)$ cm	31	61
$\varepsilon_x\ (t=10)$	45	41
$2.5\,\sigma_p\,(t=10)/10^{-3}$	6.4	3.4

This solution has $\sigma_\ell = 28$ at $t=0$ at $\gamma=100$. The addition of Stochastic cooling would be required to keep σ_ℓ from growing.

Solution B. $h = 1700$, $f = 130$ MHz $V = 16.5$ MV

γ	30	100
σ_ℓ ($t=10$) cm	18	28
ε_x ($t=10$)	52	52
$2.5\sigma_p$ ($t=10$) $/10^3$	9	4.5

This solution has $\sigma_\ell \leq 28$ cms for $t = 10$ hours, and $V = 16.5$ MV

Solution C $h = 2052$, $f = 160$ MHz, $V = 20$ MV

γ	30	100
σ_ℓ ($t=10$)	18	26
ε_x ($t=10$)	55	55
$2.5\sigma_p$ ($t=10$) $/10^{-3}$	10	4.6