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Intrabeam Scattering Results with Constant Voltage RD Buckets for the 160 MHz RF System

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Some recent results of Jie Wei indicate that constant voltage RF buckets may have some advantages.

This appears to contradict some earlier results that indicated that better results were obtained using "tight buckets", where the voltage changes so as to keep $\Delta_B = 2\sigma_p$, where Δ_B is the bucket height in $\Delta p/p$.

At the RHIC Workshop (1988), constant voltage RF buckets were studied, and it was found that for Au, $V = 36$ MV was required to keep $\Delta_B \geq 2.5\ \sigma_p$, and the beam grew to $\epsilon_x = 58$ and $\Delta p/p = \pm 11 \times 10^{-3}$ at $\gamma = 30$.

Note the criteria used then for acceptable beam loss was $\Delta_B \geq 2.5\ \sigma_p$.

Later, tight buckets were studied. It was found that for Au, $V = 11.5$ MV was required to keep $\Delta_B = 2\ \sigma_p$, and the beam grew to $\epsilon_x = 34$, $\Delta p/p = \pm 5.5 \times 10^{-3}$ at $\gamma = 30$.

Note the criterion used for acceptable beam loss was reduced to $\Delta_B \geq 2\ \sigma_p$. Even taking this into account, tight buckets appeared better than constant voltage buckets.

Table 1 compares the intrabeam scattering results of tight buckets and constant voltage buckets with different voltages for the case where the beam is blown up to $\epsilon_{x,0} = 60$ and $\gamma = 100$.

Table 1: $\epsilon_{x,0} = 60$, $\gamma = 100$, Au, A = 0.3 ev-sec

		Tight Bucket $\Delta_B = 2\ \sigma_p$	V=constant				
t=0	V_0 (MV)	0.283	2	3	4.5	6	8
	$\sigma_{p,0}/10^{-3}$	0.248	0.404	0.447	0.503	0.540	0.581
	$\sigma_{\ell,0}$	31	19.0	17.2	15.3	14.2	13.2
	$\epsilon_{x,0}$	60	60	60	60	60	60
	Δ_B/σ_p	2.0	3.27	3.62	3.96	4.26	4.54
t=10	V (MV)	4.53	2	3	4.5	6	8
	$\sigma_p/10^{-3}$	0.993	0.989	1.05	1.123	1.17	1.22
	σ_ℓ	31	46.5	40.0	34.2	30.9	27.9
	ϵ_x	69	68	69	70	71	71.4
	Δ_B/σ_p	2.0	1.34	1.54	1.78	1.96	2.16
	$\Delta_B/10^{-3}$	1.986	1.32	1.62	1.99	2.30	2.64

Comments on Table 1, $\gamma = 100$, $\epsilon_{x,0} = 60$

Using the criterion of $\Delta_B \geq 2\ \sigma_p$ for acceptable beam loss, one would conclude from Table 1 that tight buckets require $V = 4.5$ MV to get $\Delta_B \geq 2\ \sigma_p$, while constant V buckets require $V = 6$ MV for $\Delta_B \geq 2\ \sigma_p$.

The Fokker–Planck calculation by J. Wei modifies the above calculations as follows[1]

1. The tight bucket leads to large beam loss, about 60% beam loss, probably because at $t = 0$, $\Delta_B = 2\ \sigma_p$ is not good enough – one needs something like $\Delta_B \simeq 4\ \sigma_p$ at $t = 0$.
2. $V = 4.5$ MV constant bucket has about a 23% beam loss. The bucket may be tighter, $\Delta_B \sim 2\ \sigma_p$ at $t = 10$ without causing large beam loss. Also the actual σ_p, with beam loss, is smaller than the σ_p from IBS theory (no beam loss), which improves the Δ_B, σ_p comparison.

[1] J. Wei, private communication.

Table 2: $\gamma = 100$, $\epsilon_0 = 10$, Au, A = 0.3 ev-sec

		Tight Bucket $\Delta_B = 2\ \sigma_p$	V=constant				
t=0	V_0	0.283	4.5	11.5	15	20	30
	$\sigma_{p,0}/10^{-3}$	0.248	0.503	0.636	0.680	0.719	0.796
	$\sigma_{\ell,0}$	31	15.3	12.1	11.3	10.7	9.66
	$\epsilon_{x,0}$	10	10	10	10	10	10
	Δ_B/σ_p	2	3.94	4.97	5.31	5.81	6.4
t=10	V	11.5	4.5	11.5	15	20	30
	$\sigma_p/10^{-3}$	1.58	1.55	1.71	1.76	1.80	1.84
	σ_ℓ	31	47	32.5	29.3	26.8	22.9
	ϵ_x	34	32	36	37	38	40
	Δ_B/σ_p	2	1.27	1.85	2.05	2.3	2.7
	$\Delta_B/10^{-3}$	3.16	1.98	3.16	3.61	4.17	5.1

Comments on Table 2, $\gamma = 100$, $\epsilon_{x,0} = 10$

Using the criterion of $\Delta_B \geq 2\ \sigma_p$ for acceptable beam loss, one would conclude from Table 2 that the tight bucket requires $V = 11.5$ MV to get $\Delta_B \geq 2\ \sigma_p$, while constant V buckets require $V = 15$ MV for $\Delta_B \geq 2\ \sigma_p$.

The Fokker–Planck, with beam loss, results indicate[1] large losses for the tight bucket (perhaps 60%). The constant V bucket with $V = 11.5$ MV gives a beam loss of about 13%.

Table 3: $\gamma = 30$, $\epsilon_{x,0} = 10$, Au, A = 0.3 ev-sec

		Tight Bucket $\Delta_B = 2\ \sigma_p$	V=constant				
t=0	V_0	0.321	2.5	3.5	4.5	6	1.5
	$\sigma_{p,0}/10^{-3}$	0.827	1.38	1.50	1.60	1.72	2.16
	$\sigma_{\ell,0}$	31	18.6	17.1	16.1	14.9	11.9
	$\epsilon_{x,0}$	10	10	10	10	10	10
	Δ_B/σ_p	2	3.35	3.64	3.80	4.16	5.24
t=10	V	2.43	2.5	3.5	4.5	6	15
	$\sigma_p/10^{-3}$	2.28	2.38	2.46	2.52	2.59	2.85
	σ_ℓ	31	32.1	28	25.3	22.5	15.7
	ϵ_x	33	36	38	39	41	47
	Δ_B/σ_p	2	1.94	2.22	2.46	2.76	3.98
	$\Delta_B/10^{-3}$	4.56	4.62	5.46	6.21	7.164	11.33

Comments on Table 3, $\gamma = 30$, $\epsilon_{x,0} = 10$

Running with constant V buckets, the lowest V that gives acceptable beam losses appears preferable to keep the final σ_p and ϵ_x as low as possible.

The Fokker–Planck, with beam loss, results indicate[1] large losses for the tight bucket. A constant V bucket with $V = 4.5$ MV gives about a 22% loss.

Some Conclusions

Because of the uncertainties in the beam loss results, there are uncertainties in the choice of the RF strategy.

It is likely that tight buckets are not acceptable because of large beam losses.

The beam losses with constant V buckets with $V \leq 4.5$ MV may be about 20%. It is possible they might be considerably larger. At present, the constant V RF scenario appears preferable.

At $\gamma = 30$, the choice of $V = 4.5$ MV for the constant V bucket, will lead to a somewhat larger beam size, $\epsilon_x = 39$, $\Delta p/p = 2.5\ \sigma_p = 6.3 \times 10^{-3}$ instead of the presently used $\epsilon_x = 33$, $\Delta p/p = 5.5 \times 10^{-3}$.