Debuncher Stochastic Cooling Upgrade for Run II and Beyond

** DRAFT **

Pbar Note #573

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Assumptions

The basic beam parameters are shown in Table I. The beam size is assumed to be 25π mm–mrad (consistent with current estimates) although we hope to have 30π mm-mrad beams in Run II. The pickup apertures are assumed to be 40π mm-mrad—rather large for a 25π mm-mrad beam. The momentum changes as momentum cooling proceeds. The calculations are done with a fixed momentum spread corresponding roughly to that obtained at the end of momentum cooling.

Table I. Common Parameters

Energy spread (full)	18	MeV
Beam Energy	8938	MeV
Initial Beam Emittance	25	π mm-mrad
Accumulator Acceptance	5	π mm-mrad
$\eta = 1/\gamma_t^2 - 1/\gamma^2$	0.006	
Number of particles (Run II)	1×10^8	
Number of particles (TeV33)	4×10^8	

Originally we planned to simply upgrade the 2-4 GHz system. The parameters of a possible 2-4 GHz system are shown in Table II. The recently measured sensitivity of the planar loops is less than the theoretical numbers used in the Tev I design and shown in Table II. The impedance given should therefore be considered to be "optimistic." The horizontal and vertical systems have slightly different sensitivites. The differences are ignored in this report. In addition to the losses listed in Table II, we have assumed a 3 dB loss on both the pickup and kicker. The measured cooling rate is consistent with such a loss, but we do not know the nature of the loss. In fact, the perceived loss may not be real; it may just be a "fudge factor" to get the right cooling rate.

Table II. 2-4 GHz system parameters

PU/Kicker Impedance (peak)	57	Ω /loop
Number of pickup loops	128	
Number of kicker loops	128	
Number of Bands	1	
PU Combiner Loss	2.3 to 3.1	dB
Kicker Splitter Loss	2.5 to 3.7	dB
Amplifier Noise Temperature	10	°K
Resistor Temperature	10	°K
Pickup/Kicker Aperture	40	π mm-mrad
Gain (typical)	157	dB
Power	1600	W

We currently plan to use an entirely new 4-8 GHz system using 4 relatively narrow bands. This approach was used at the CERN AC. The parameters of the proposed 4-8 GHz Horizontal system are shown in Table III. The Vertical system is identical except the pickup and kicker impedances are slightly different because of small differences in the lattice functions. The impedances were calculated by Dave McGinnis and are consistent with the recently measured sensitivity.[i] The simulations include a more conservative 3 dB loss at the pickup and kicker, not the 1 dB loss listed in Table III.

Table III. 4-8 GHz Horizontal system parameters

PU/Kicker Impedance (peak)	3620	Ω
PU's/Kickers per band	8	
Number of Bands	4	
Combiner Loss	1	dB
Splitter Loss	1	dB
Amplifier Noise Temperature	25	°K
Resistor Temperature	10	°K
PU/Kicker Aperture	40	π mm-mrad
Gain (typical)	147	dB
Power	400	W/band

System Gain

A plot of the 2-4 GHz system gain versus frequency is shown in Figure 1. The variation in gain is due to the variation in pickup and kicker sensitivity. The definition of the system gain G per Schottky band is

$$\frac{dA^2}{dt} = 2 f_0 G A^2 \qquad [1]$$

where *A* is the betatron amplitude and 2*G* is the cooling rate for a particlular Schottky band.

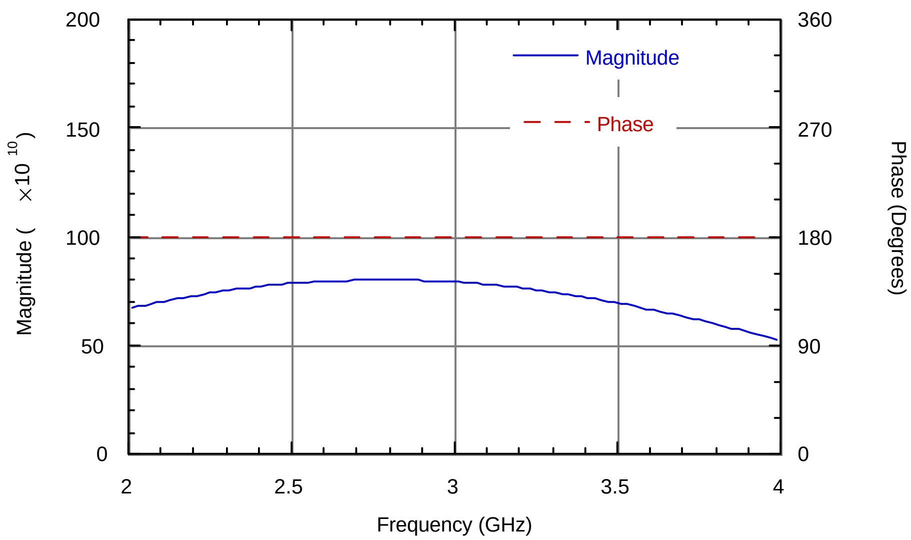

Figure 1. Calculated gain of the 2-4 GHz System.

A plot of system gain versus frequency is shown in Figure 2. The variations in gain are large and are entirely due to the variations in pickup and kicker sensitivity.

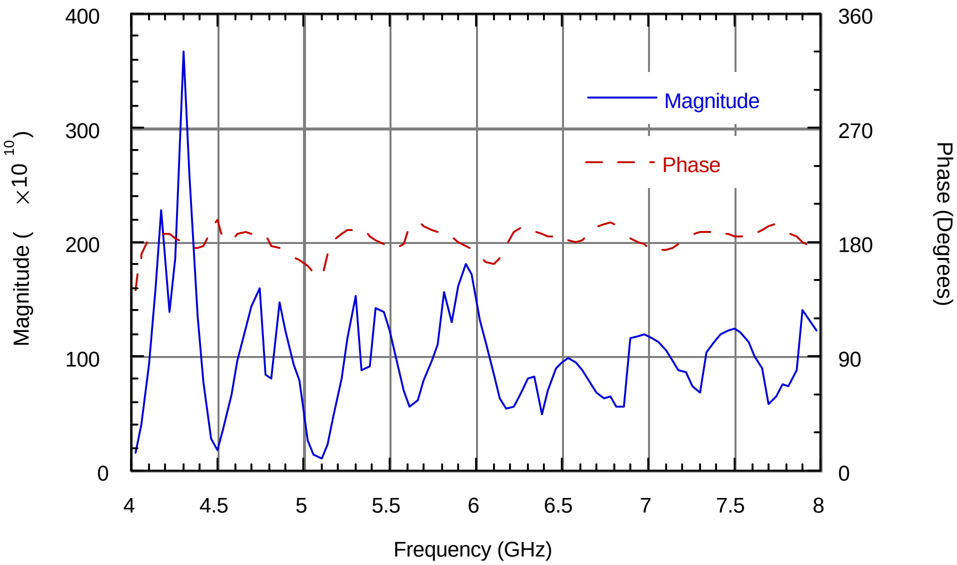

Figure 2. Gain of the 4-8 GHz system. The gain response is dominated by the pickup and kicker response.

Mixing Factor

The mixing factor for the 4-8 GHz system is shown in Figure 3. The mixing factor depends only on the lattice parameters and the frequency. The mixing factor follows a 1/*f* frequency dependence, so the mixing factor for the 2-4 GHz system is easily scaled from Figure 3.

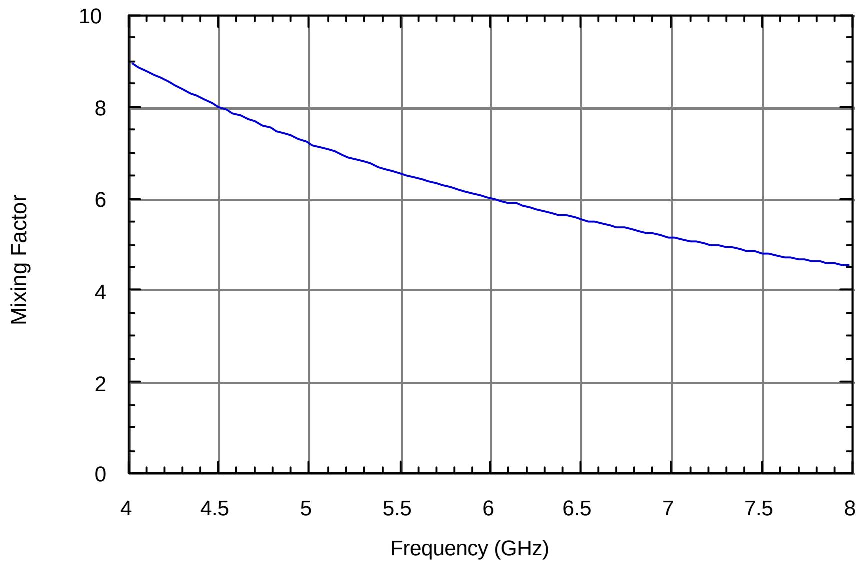

Figure 3. Mixing Factor for the 4-8 GHz transverse systems.

Signal to Noise Ratio

The signal to noise ratio is shown in Figure 4 for the 4-8 GHz Horizontal system and, for comparison, in Figure 5 for the 2-4 GHz system. The large variations in the 4-8 GHz systems come from variations in the pickup sensitivity. It has been assumed that sharp transversal filters are used in the 4-8 GHz system to filter unwanted broad-band noise outside the pickup bandwidth.[ii]

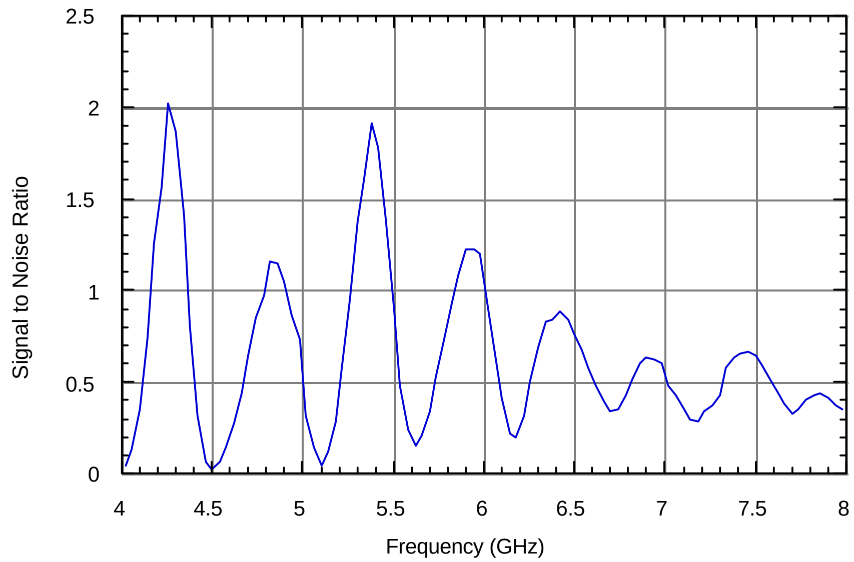

Figure 4. Signal to noise ratio for the 4-8 GHz system.

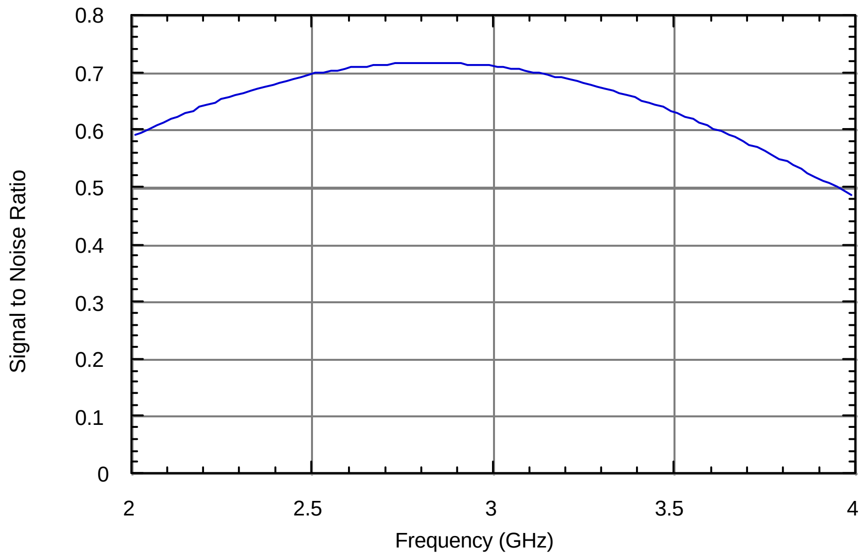

Figure 5. Signal to noise ratio for the 2-4 GHz system.

Signal Suppression

Signal suppression is a measure of the stength of the feedback. The signal suppression factor is (1-*GF*), and is equal to 2 at the optimum gain. The factor *GF* is plotted in Figure 6 for the 4-8 GHz Horizontal system and, for comparison, for the 2-4 GHz system in Figure 7.

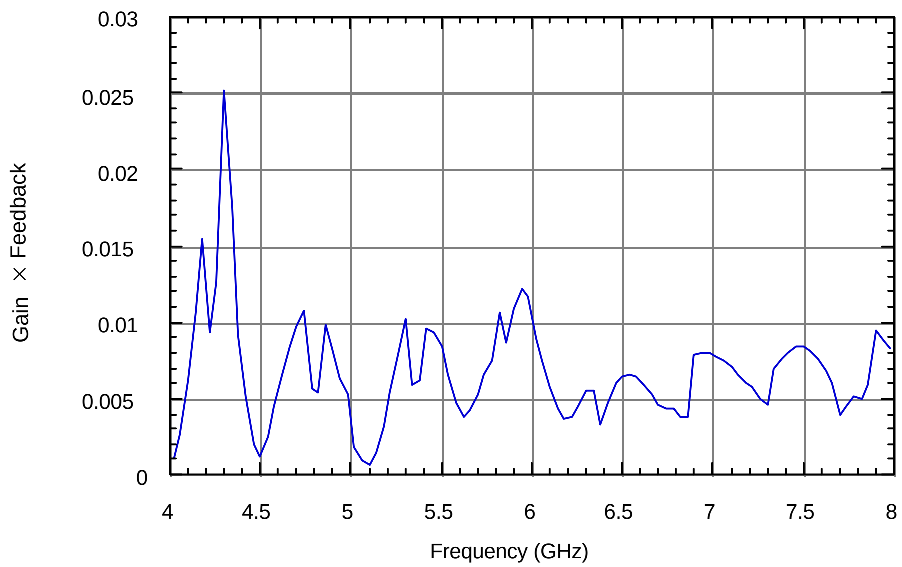

Figure 6. Signal supression factor for 4-8 GHz.

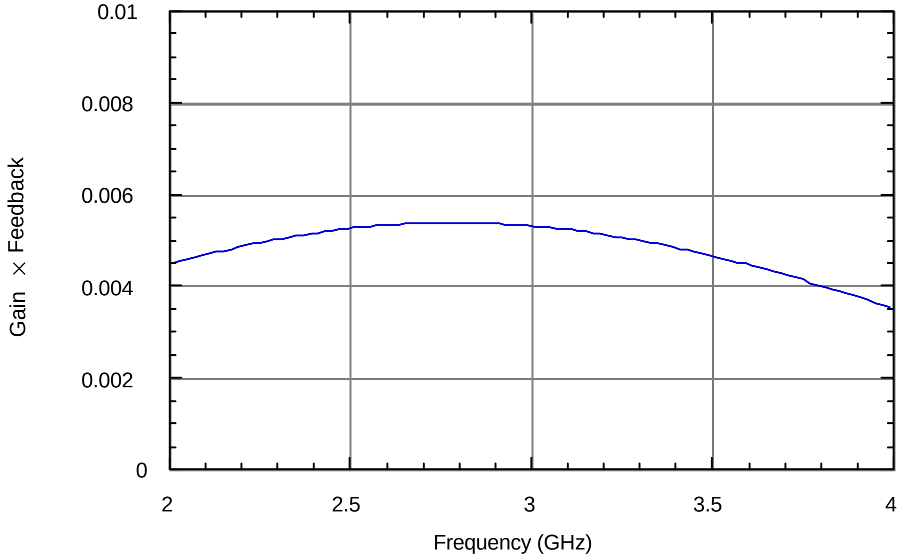

Figure 7. Signal suppression factor for the 2-4 GHz system.

Performance in Run II

The performance predicted in Run II under the previously stated assumptions is shown in Figure 8, which shows the horizontal emittance versus time. Similarly, Figure 9 shows the vertical emittance versus time. The system bandwidths and sensitivites are not finalized, but at this point the vertical cooling system performs noticably better.. The nominal cycle time is 1.5 sec. The four-band 4-8 GHz system outperforms the 2-4 GHz system. The 2-4 GHz system performs somewhere between 2 and 3 bands of the 4-8 GHz system.

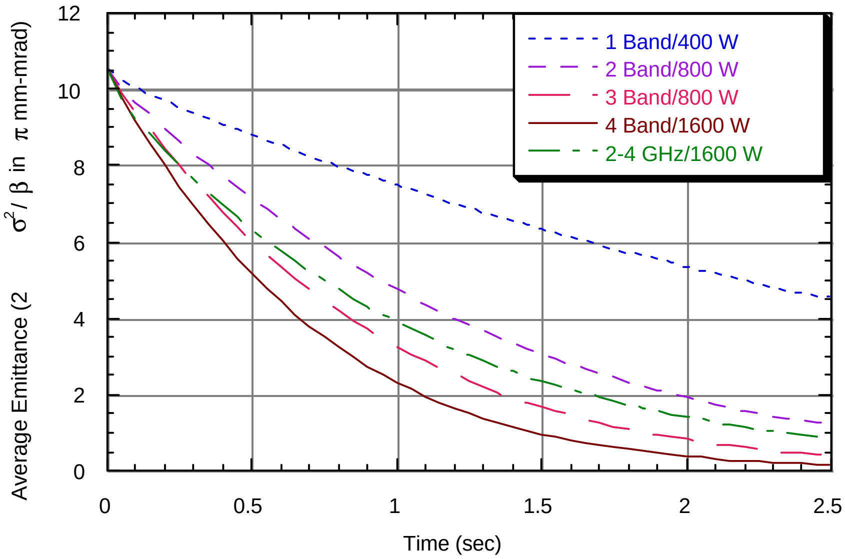

Figure 8. The horizontal emittance versus time for the various scenarios.

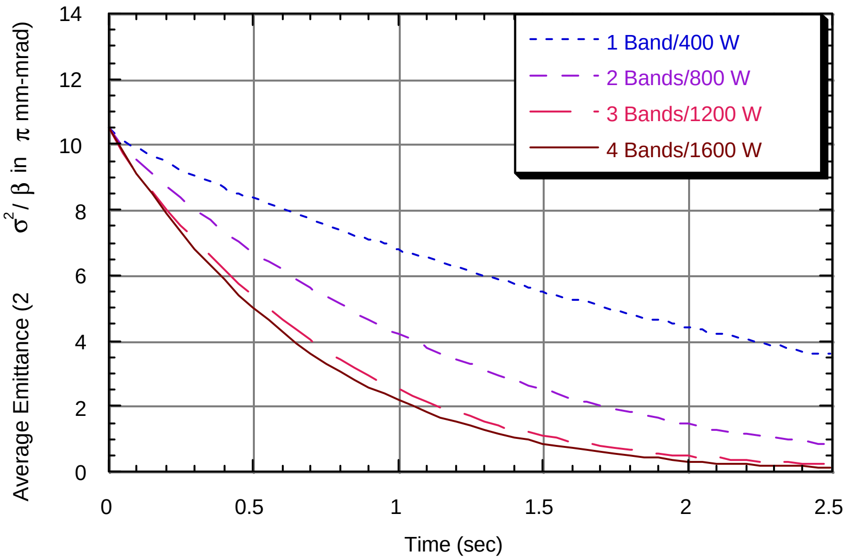

Figure 9. The vertical emittance versus time for the various scenarios.

The transfer efficiency is computed as the fraction of beam less than 5π mm-mrad horizontally times the fraction of beam less than 5π mm-mrad vertically. The combination of the data from Figure 8 and Figure 9 (assuming the 2-4 GHz cooling to be the same in each plane) is shown in Figure 10.

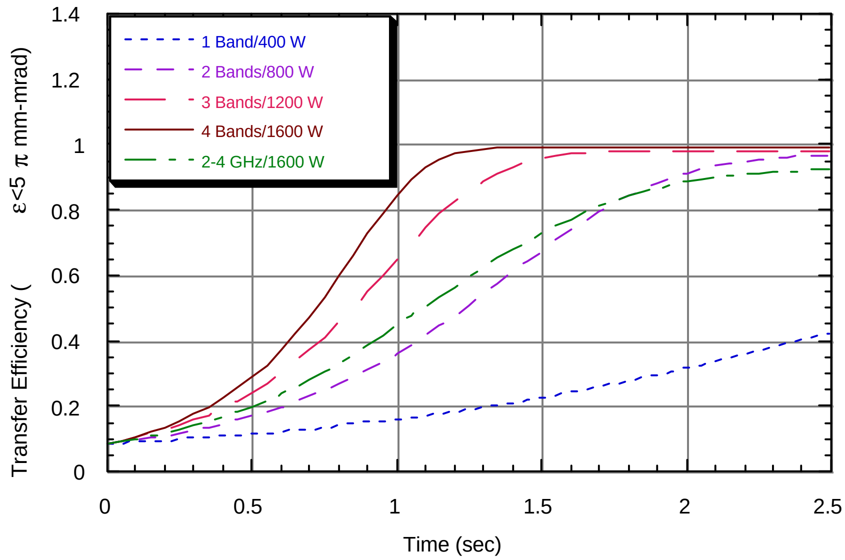

Figure 10. Transfer efficiency as a function of time for the various scenarios.

The original plan called for plunging pickups and kickers to be used in the 2-4 GHz band. The effect of using plunging pickups is shown in Figure 11 and Figure 12. Plunging PU's require some trade-off between obtaining the highest sensitivity (smallest PU gap) and the particle loss associated with the reduced aperture. This trade-off is apparent in Figure 12. It is assumed that the plunging PU's and kickers can start with a 26.2π mm-mrad aperture and that they define the aperture thereafter. This assumption is probably somewhat unrealistic - it assumes that all the electrodes exactly track each other, are optimally tuned, and have no mechanical imperfections. Much of the improvement of the plunging electodes comes from the smaller initial gap rather than the plunging. A mechanical design that allowed precise allignment of the top and bottom electrodes without plunging could probably achieve a similar effect.

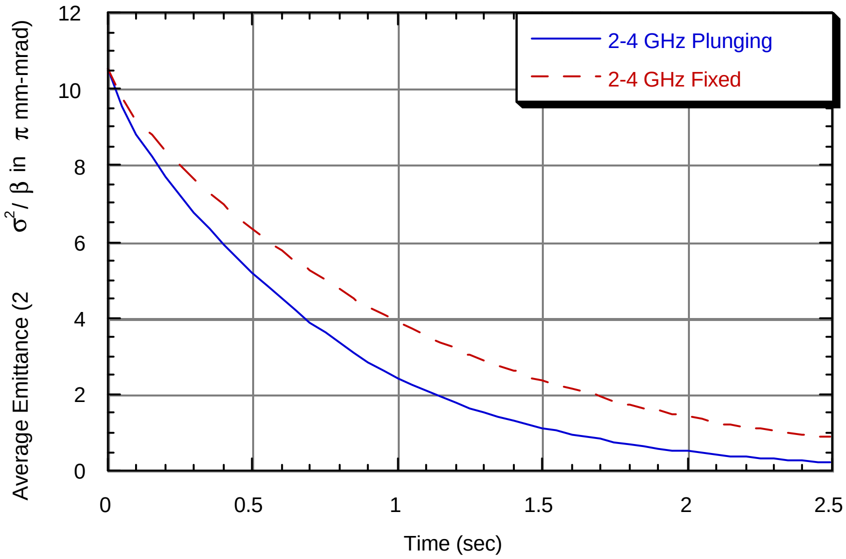

Figure 11. Comparison of emittance versus time for a 2-4 GHz system with plunging electrodes and one with fixed electrodes.

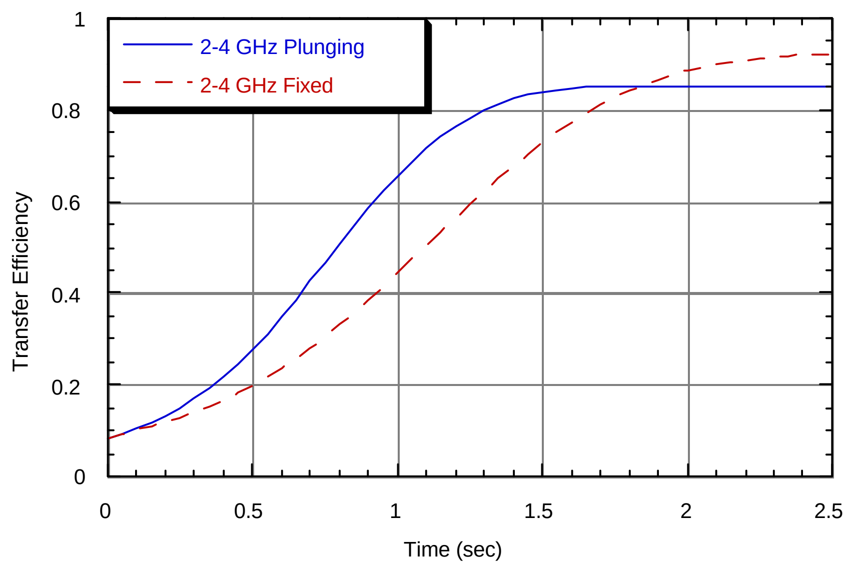

Figure 12. Comparison of emittance versus time for a 2-4 GHz system with plunging electrodes and one with fixed electrodes.

Performance with TeV33 parameters

We have also examined the system performance at higher intensity (TeV33 parameters). The results are shown in Figure 13 and Figure 14. The transfer efficiencies are obtained from the square of the fraction of the beam with a horizontal emittance less than 5π mm-mrad. Since the cooling is less effective in the horizontal plane, the transfer efficiency is probably underestimated. The 2-4 GHz system performance is limited primarily because of its lower bandwidth. The larger particle losses incurred with this system and shown in Figure 15 are indicative of the need for more bandwidth.

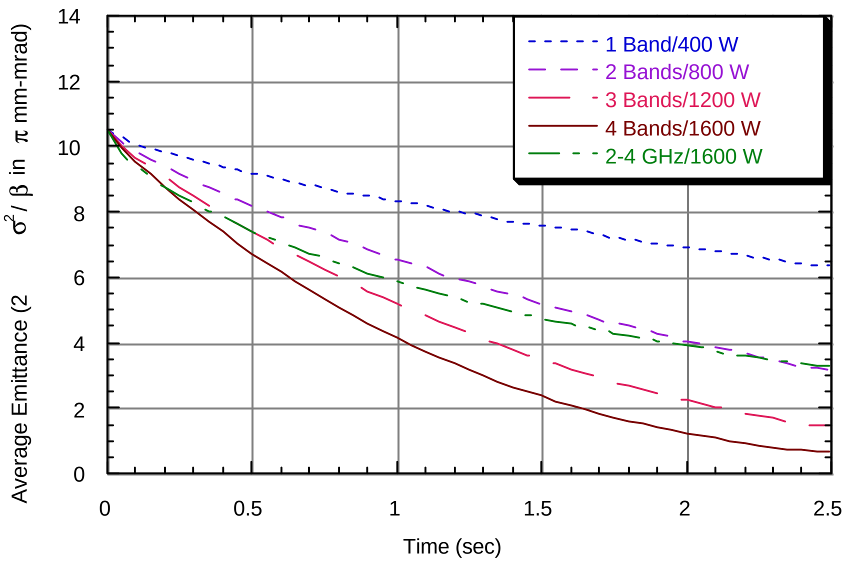

Figure 13. Horizontal emittance versus time for Tev33 intensities.

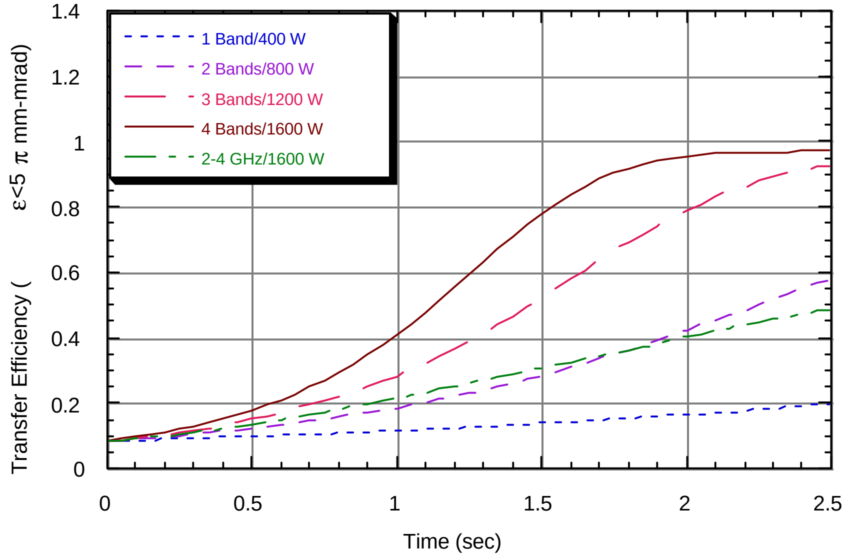

Figure 14. Transfer efficiency versus cooling time for TeV33 intensities. The transfer efficiencies are obtained from the square of the fraction of the beam with a horizontal emittance less than 5π mm-mrad.

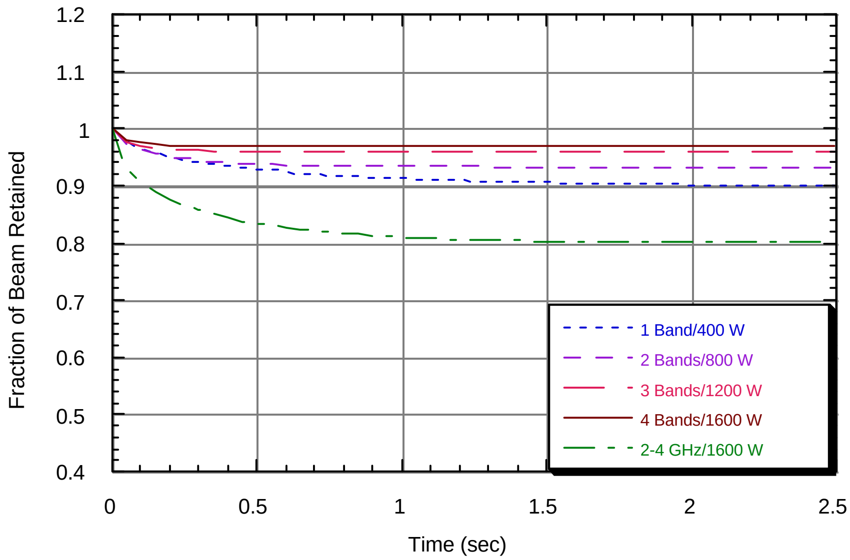

Figure 15. Fraction of beam retained as a function of cooling time. The limited bandwidth and relatively high gain of the 2-4 GHz system result in significant particle losses at the beginning of the cycle.

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[i] Dave McGinnis, pbar note xxx.
[ii] Do we have a reference?