

*Master*



CEBAF-TN-0067  
 Geoffrey Krafft  
 10/22/87

### Note on the Energy Spread

This note summarizes the results on energy spread discussed yesterday morning. In **Table 1** I give tolerances on the RF system necessary to obtain  $10^{-4}$  full width energy spread in a typical case. An effective bunch length of  $\Delta\ell = 1.2^\circ$  is assumed (somewhat smaller than in the design handbook yielding relaxed tolerances on the RF system). This choice means that an energy spread of approximately  $6 \times 10^{-5}$  comes from the effective bunch length, the other 40% of the energy spread being split equally between the phase error and amplitude error. INJECTOR PHASE is the permissible injector phase error, V is the permissible voltage fluctuation,  $\Delta\phi_f$  is the permissible fast phase fluctuation, and  $\Delta\phi_s^*$  is the permissible slow phase fluctuation, fast and slow being determined by the response time of the energy vernier system. In the W VERNIER case, two examples are given to illustrate possible tradeoffs.

**Table 1 RF Tolerances Yielding  $10^{-4}$  Energy Spread**

	W VERNIER		WO VERNIER
INJECTOR PHASE	$\pm .32^\circ$		$\pm .45^\circ$
UNCORRELATED ERRORS			
V	$\pm 4.5 \times 10^{-4}$		$\pm 4.5 \times 10^{-4}$
	Case 1	Case 2	
$\Delta\phi_f$	$\pm 0.5^\circ$	$\pm 1.5^\circ$	$\pm 1.9^\circ$
$\Delta\phi_s^*$	$\pm 5.8^\circ$	$\pm 1.5^\circ$	...
CORRELATED ERRORS			
V	$\pm 2.2 \times 10^{-5}$		$\pm 2.2 \times 10^{-5}$
$\Delta\phi_f$	$\pm 0.24^\circ$		$\pm 0.24^\circ$
$\Delta\phi_s$	$\infty$		...

\*  $\Delta\phi_s \doteq \sqrt{\frac{4}{3}} \Theta_T$  where  $\Theta_T$  is the total phase error down the linac

Since there is no wobble in the WO VERNIER case, a greater tolerance to injector phase errors is possible. However, a thermal expansion of the phase line must be treated as a correlated error yielding a tolerance more stringent than that with the vernier. Consequently the W VERNIER case is preferable.

For aid in understanding the possible tradeoffs, I record the result in CEBAF-TN-0050 in terms of the full width spread ( $\Delta E = 4\sigma_E$ ):

$$\Delta E/E \approx 0.25 \sqrt{\Delta \ell^4/2 + (\Delta \phi_f^2)(\Delta \phi_s^2)/N + \Delta \phi_f^2(\Delta \phi_f^2/2 + \Delta \ell^2)/N + 16(\Delta A)^2/N}$$

for uncorrelated errors and

$$\Delta E/E \approx 0.25 \sqrt{(\Delta \ell^2 + \Delta \phi_f^2)^2/2 + 16(\Delta A)^2}$$

for correlated errors where

$$\Delta \ell^2 = (\text{bunch length})^2 + (\text{fast injector error})^2 + (\text{wobble})^2$$

in radians. Note that  $\Delta \phi_f = 0.4^\circ$  implies that the error listed in **Table 1** is  $\pm 0.2^\circ$ .

This calculation assumes  $E = 4 \text{ GeV}$ . When  $E < 2 \text{ GeV}$  the energy spread of the injected bunch becomes relatively large causing slightly more stringent tolerances. A more important effect arises if klystrons are turned off for low energy operation. For uncorrelated errors  $N$  is reduced. Thus more energy spread is generated for the same error levels. Conversely, if the same energy spread is to be obtained, the tolerances on the RF system must be made more stringent.