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A NOTE ON DEUTERON ACCELERATION IN LINAC AND AGS

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E. Courant recently brought to my attention that deuterons accelerated in the new 200-MeV linac, perhaps do not reach its final relativistic energy of 80 MeV due to unfavorable energy gains across the accelerating gaps in the later linac tanks.

With the formula for the transit time factor[1]:

$$T \times R = \frac{\sin n\pi g/L}{ng/L} \times I_o \ (k_n a)$$

the energy gains of protons and deuterons were compared at the entrance and exit of each tank. Table I shows the results.

For proper acceleration of deuterons the (T x R) for deuterons should be half or more than (T x R) for protons. These ratios are summarized in Table I.

The following general conclusions seem to be valid.

a) Acceleration of deuterons up to 30 MeV will not impose a significant change from the procedures of proton acceleration.

b) Acceleration of deuterons from 30 to 80 MeV is limited by the available rf power in each tank; acceleration "off" stable phase is quite possible, but it might affect the final energy spread. The practical limit of deuteron acceleration in this energy range has to be measured. The quadrupole fields and bending magnets have to be reduced accordingly.

How will this lower final energy of the deuterons affect acceleration in the AGS? The maximum frequency range of the new rf cavities is 2.3 to 4.8 MHz.

In this frequency range the lower energy limit of the deuterons seems to be 67 MeV (β = 0.26, see Table I). Hereby we assume to accelerate deuterons using the 24th harmonic to 4.8 MHz and then the 12th harmonic to the final energy.[2,3] It is, however, unlikely that we can reach this energy!

What will happen if we can only accelerate up to 40 MeV deuterons? A possible procedure is to leave one "old" rf cavity in the ring (operational frequency range 1.4 to 4.5 Mc). The 24th harmonic of this cavity will accelerate deuterons of 40 MeV energy until they reach the lower frequency range of the new system. If the frequency range of the "old" cavity reaches indeed 4.6 or 4.8 Mc, the deuteron beam can be recaptured by the 12th harmonic (f = 2.3 Mc) of the new cavity.

Another possibility is to start with the 36th harmonic of the new cavities until the deuterons reach the frequency limit of f = 4.8 Mc (β_D = .364). Then it jumps back to the 24th harmonic until the deuterons reaches again the frequency limit of 4.8 Mc after which a third tuning back to the 12th harmonic will finally accelerate the deuterons to the energy of 30 BeV/c. Though this procedure seems to be more complicated compared with the first solution, it has the advantage that it needs only one tuning system.

1. E. Courant, Linear Accelerator Conf., 1962.
2. J.G. Cottingham, AGS Div. Tech. Note No. 86, 1971.
3. A.M. Baldin, et al., Dubna, p. 9-5442, 1971.

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TABLE I

(transit time factors for protons and deuterons)

Tank		g/ℓ	a (cm)	$T_{H^+} \times R_{H^+}$	$T_{D^+} \times R_{D^+}$	$\frac{T_{D^+} \times R_{D^+}}{T_{H^+} \times R_{H^+}}$	H^+ Energy (MeV)	D^+ Energy (MeV)	$\beta_{Deuteron}$	
T_1	in	.21	2.0	0.73	0.31	0.42	.75	.37		
	out	.31	2.5	0.83	0.42	0.50	10.42	5		
T_2	in	.20	3.0	0.87	0.62	0.70	10.42	5		
	out	.31		0.84	0.45	0.53	37.54	18		
T_3	in	.30	3.0	0.84	0.48	0.57	37.54	18		
	out	.36		0.79	0.33	0.41	66.18	30		
T_4	in	.37	3.0	0.78	0.30	0.38	66.18	30		
	out	.41		0.74	0.21	0.28	92.55	41.5	0.207	
T_5	in	.37	4.0	0.78	0.30	0.38	92.55	41.5		
	out	.40		0.75	0.23	0.31	116.54	50	0.227	
T_6	in	.40	4.0	0.75	0.23	0.30	116.54	50		
	out	.42		0.73	0.18	0.25	138.98	58	0.245	
T_7	in	.42	4.0	0.73	0.18	0.25	138.98	58		
	out	.44		0.70	0.13	0.18	160.53	66	0.259	(f=1.14Mc
T_8	in	.44	4.0	0.07	0.13	0.18	160.53	66		
	out	.46		0.68	0.084	0.12	181.01	73	0.271	
T_9	in	.46	4.0	0.68	0.084	0.12	181.01	73		
	out	.47		0.67	0.061	0.09	200.30	80	0.283	

$$T_{H^+} = \frac{\sin \pi g/L}{\pi g/L} \qquad T_{D^+} = \frac{\sin 2\pi g/L}{2\pi g/L}$$

$$R_{H^+} = \frac{1}{I_o(k_1 a)} \qquad R_{D^+} = \frac{1}{I_o(k_2 a)}$$