Beam Physics Note
TRI-BN-24-17
July 9, 2024

DTL Tune Without Bunchers-2 and -3

Olivier Shelbaya
TRIUMF

Abstract: This report records an ISAC-I linac tune with fewer RF cavities, achieving acceleration to 1.53Mev/u for a stripped beam in MEBT, without use of the bunch rotator[1] or DTL bunchers-2 and -3. This utilizes 70% of cavities downstream of RFQ and is ideal for cases where ISAC-I injects into ISAC-II.

4004 Wesbrook Mall, Vancouver, B.C. Canada V6T 2A3 · Tel: 604 222-1047 · www.triumf.ca

1 Overview

This note records an operational DTL configuration with the feature of reduced RF cavity use; of the 10 post-RFQ rf cavities, three are left unpowered for beam acceleration to 1.53 MeV/u. This has the desirable advantage of utilizing 70% of the resonant cavities.

While there have been instances in the past of *skipping* bunchers in the DTL for full energy acceleration, these have been considered somehow undesirable, as they deviate from the then usual manner[2] of tuning the DTL, which uses all available rf cavities and bunchers[3].

However, analysis of the DTL buncher's drift tube geometry reveals something puzzling: Analysis of the cell length for each DTL buncher:

$$L_C = \frac{\beta\lambda}{2} \tag{1}$$

reveals that Buncher-1 has a design E/A of 0.250 MeV/u, to match Tank-1's full E/A=0.254 MeV/u value. On the other hand, Bunchers -2 and -3 are designed for 0.346 MeV/u and 0.518 MeV/u[4], well below the E/A=0.461 MeV/u and 0.803 MeV/u for which they are utilized.

Finding-1: The cell length in DTL Bunchers-2 and -3 suggest they should be used when Tanks-2 or -3 are used for intermediate acceleration, below their respective operational output E/A values.

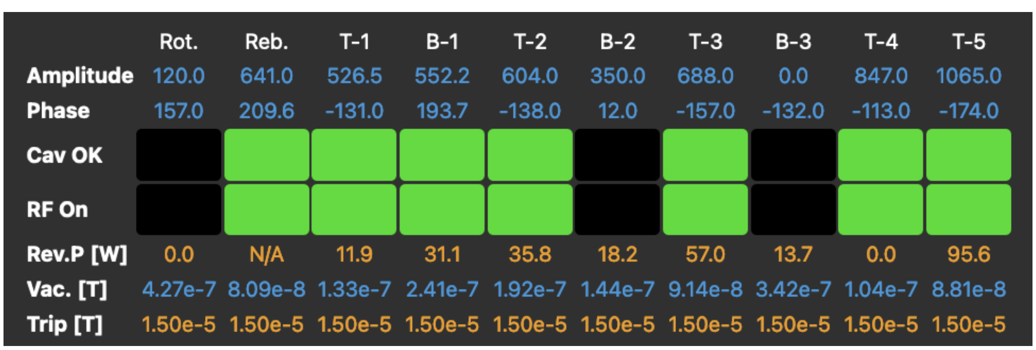
Inference: The designers of the DTL's drift tube structure likely intended for these cavities only to be operated in intermediate acceleration cases, not for full acceleration.

Supposition: Full operational DTL acceleration to 1.53 MeV/u should therefore omit Bunchers-2 and -3, as their longitudinal effect upon the beam will be minimal[4].

This note records a DTL tune which was established by RIB Operations during a machine development (MDEV) shift[5] using a ^{7}Li^{2+} beam through the DTL.

2 Reduced RF Tune

Figure 1 shows the RF status and amplitudes for the tune, while Figure 2 shows `TRANSOPTR` envelope simulations results computed by MCAT's autofocus[6] associated with operational snapshot 7022, in which a DTL transmission of 92.5% was recorded by RIB Operations. Operators optimized the RF amplitudes and phases to adjust trasn-mission and the E/A spectrum.



	Rot.	Reb.	T-1	B-1	T-2	B-2	T-3	B-3	T-4	T-5
Amplitude	120.0	641.0	526.5	552.2	604.0	350.0	688.0	0.0	847.0	1065.0
Phase	157.0	209.6	-131.0	193.7	-138.0	12.0	-157.0	-132.0	-113.0	-174.0
Cav OK										
RF On										
Rev.P [W]	0.0	N/A	11.9	31.1	35.8	18.2	57.0	13.7	0.0	95.6
Vac. [T]	4.27e-7	8.09e-8	1.33e-7	2.41e-7	1.92e-7	1.44e-7	9.14e-8	3.42e-7	1.04e-7	8.81e-8
Trip [T]	1.50e-5	1.50e-5	1.50e-5	1.50e-5	1.50e-5	1.50e-5	1.50e-5	1.50e-5	1.50e-5	1.50e-5

Figure 1: MCAT RF overview of reduced buncher tune, using ^{7}Li^{2+}.

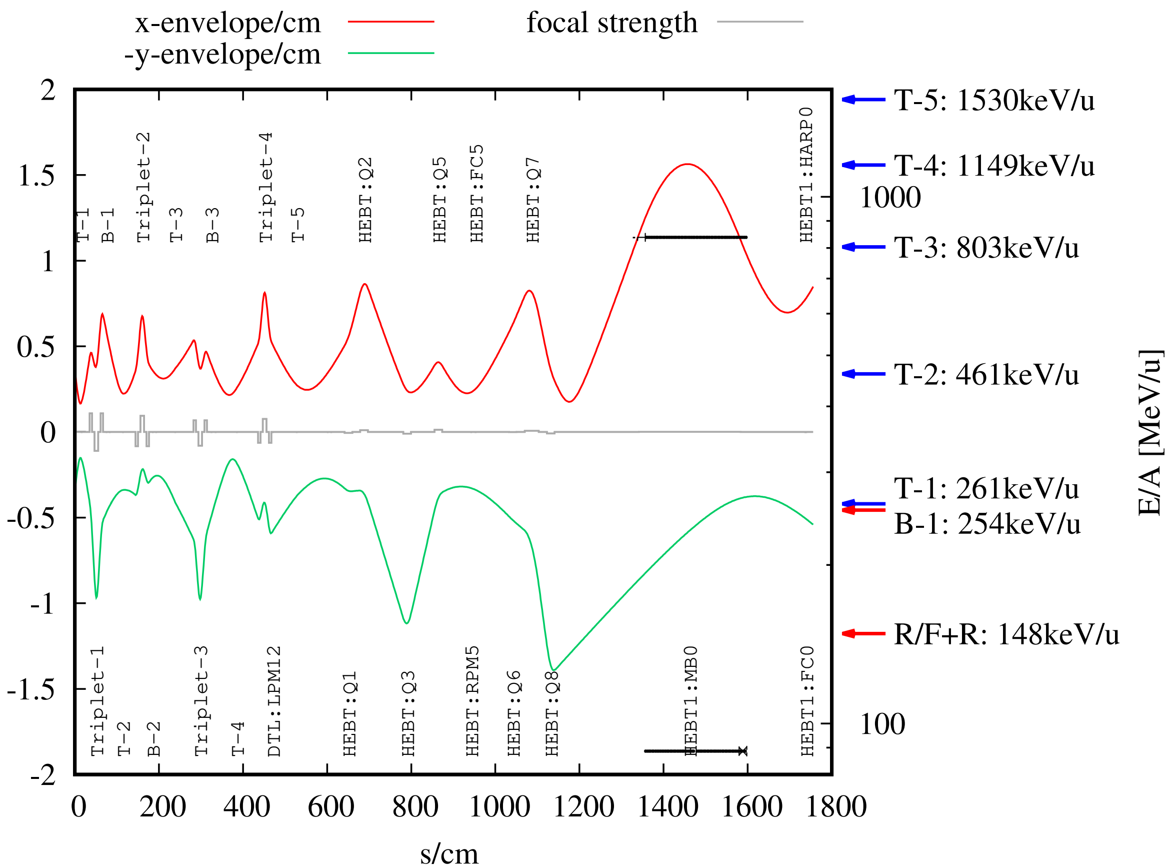


Figure 2: TRANSOPTR envelopes showing MCAT's autofocus solution used for this tune. Measured cavity output E/A values shown to the right.

Beam for this tune was $^{7}Li^{+}$ from the OLIS surface source, injected to RFQ and stripped to charge state 2+ in MEBT. The bunch rotator, along with bunchers-2 and -3 are unpowered. RF utilization downstream of RFQ is thus 7 cavities out of 10. The advantage of this tune for DTL operation at 1.53 MeV/u is the reduced dependence on actively powered RF cavities in the linac.

3 A/q and RF Limits

The RF amplitude settings from the tune are presented in Figure 3. The red bars show the $^{7}Li^{2+}$ values while green shows posted RF limits for each cavity. The limiting factor is Tank-1's maximum amplitude setpoint. In blue, the RF has been normalized to this limit: This allows up to A/q=4.9. **An A/q=5 could be used if Tank-1 can operate at an amplitude of 763.** Transmissions and E/A spectrum at HEBT1 are shown in Figure 4, with effective voltages in Figure 5.

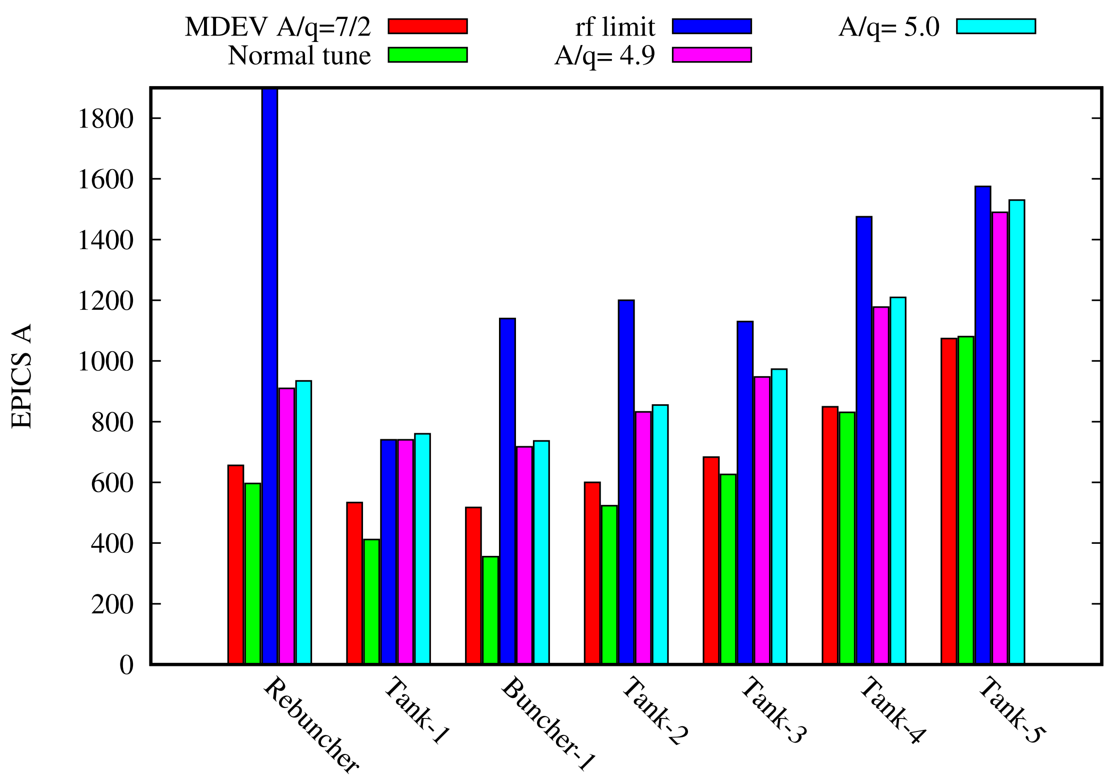


Figure 3: Amplitudes the no-buncher tune (red) compared to normal settings (green), RF limits (dark blue) and scaling to maximum RF operating amplitudes (pink). Pushing Tank-1 to amplitude 760 allows for A/q=5 (light blue).

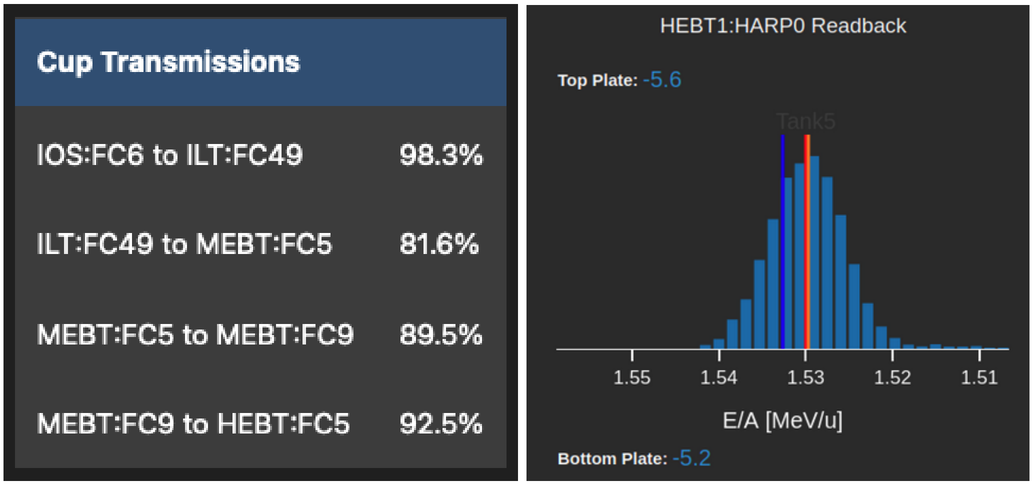


Figure 4: RIB Operations snapshot 7022, showcasing attained transmissions for the reduced RF tune, together with measured E/A spectrum at HEBT1.

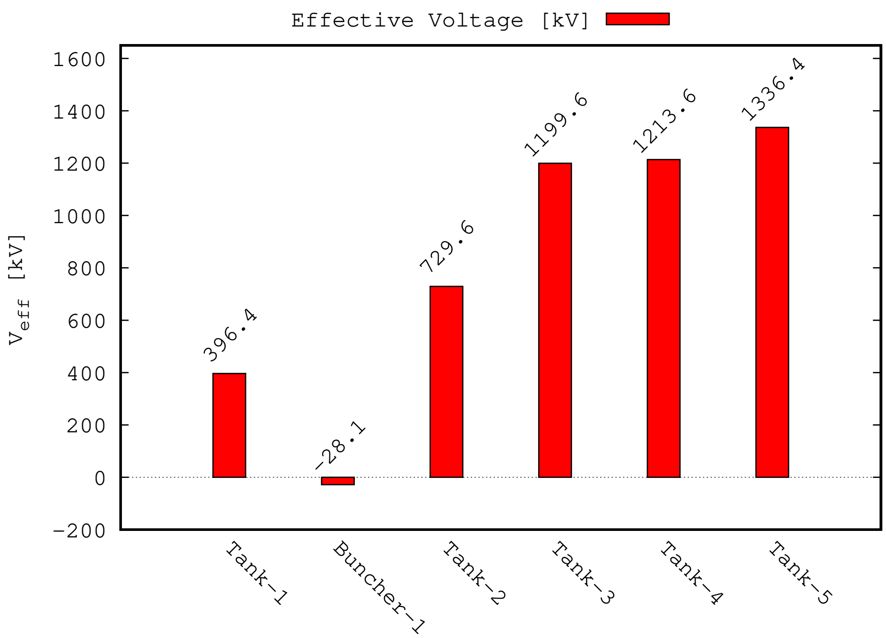


Figure 5: Effective voltages for each powered RF cavity in the DTL.

4 Summary

Finding-2: DTL Tank-1 amplitude limit of 740 limits the applicable use to A/q=4.9.

Finding-3: Raising DTL Tank-1 amplitude limit to 760 would allow for up to A/q=5.0 operation with reduced RF dependence.

5 Acknowledgements

Thanks to RIB operators for tuning efforts, essential to these results.

References

[1] Olivier Shelbaya. Time-Spread Manipulation Using Longitudinal RFQ Mismatch. Technical Report TRI-BN-24-13, TRIUMF, 2024. https://beamphys.triumf.ca/~oshelb/physnotes/notator/notator.pdf.

[2] M Marchetto, J Berring, and RE Laxdal. Upgrade of the ISAC DTL Tuning Procedure at TRIUMF. *EPAC08, Genoa*, page 3440, 2008.

[3] Olivier Shelbaya. The TRANSOPTR Model of the ISAC Drift Tube Linear Accelerator - Part I: Longitudinal Verification. Technical Report TRI-BN-20-08, TRIUMF, 2020.

[4] Olivier Shelbaya. Model Coupled Accelerator Tuning (PhD thesis). Technical Report TRI-BN-23-04, TRIUMF, UVic Dept. of Physics & Astronomy, 2023.

[5] Olivier Shelbaya. ISAC-I Machine Development Shift Overview. Technical Report TRI-BN-23-02, TRIUMF, 2023. https://beamphys.triumf.ca/~oshelb/physnotes/devShift/devShift.pdf.

[6] Olivier Shelbaya. On-Line Validation of DTL Autofocus. Technical Report TRI-BN-22-31, TRIUMF, 2022. https://beamphys.triumf.ca/~oshelb/physnotes/autofocus/autofocus.pdf.