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TRIUMF Cyclotron Current Limit

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Beam Physics Group

TRIUMF Science Week, 2020

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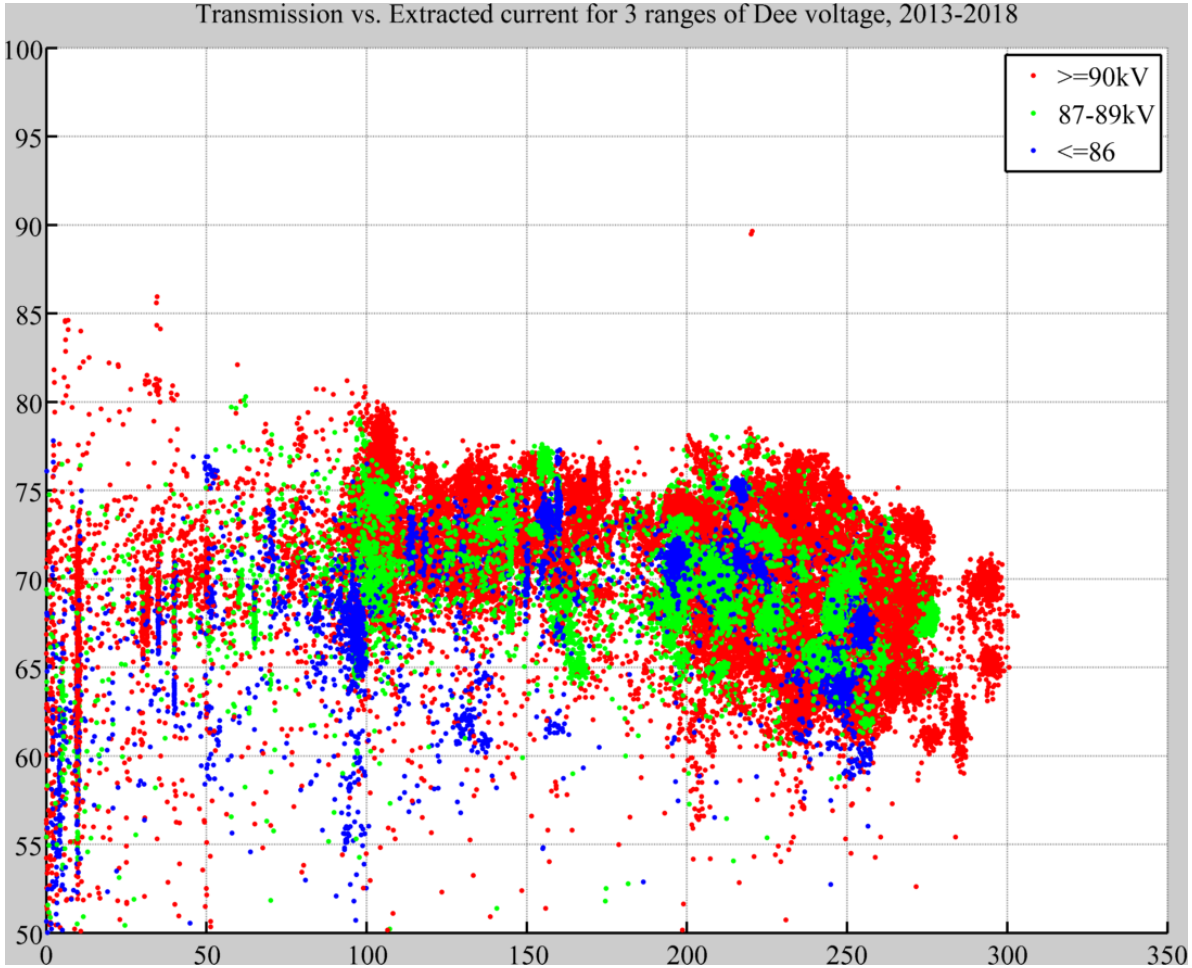
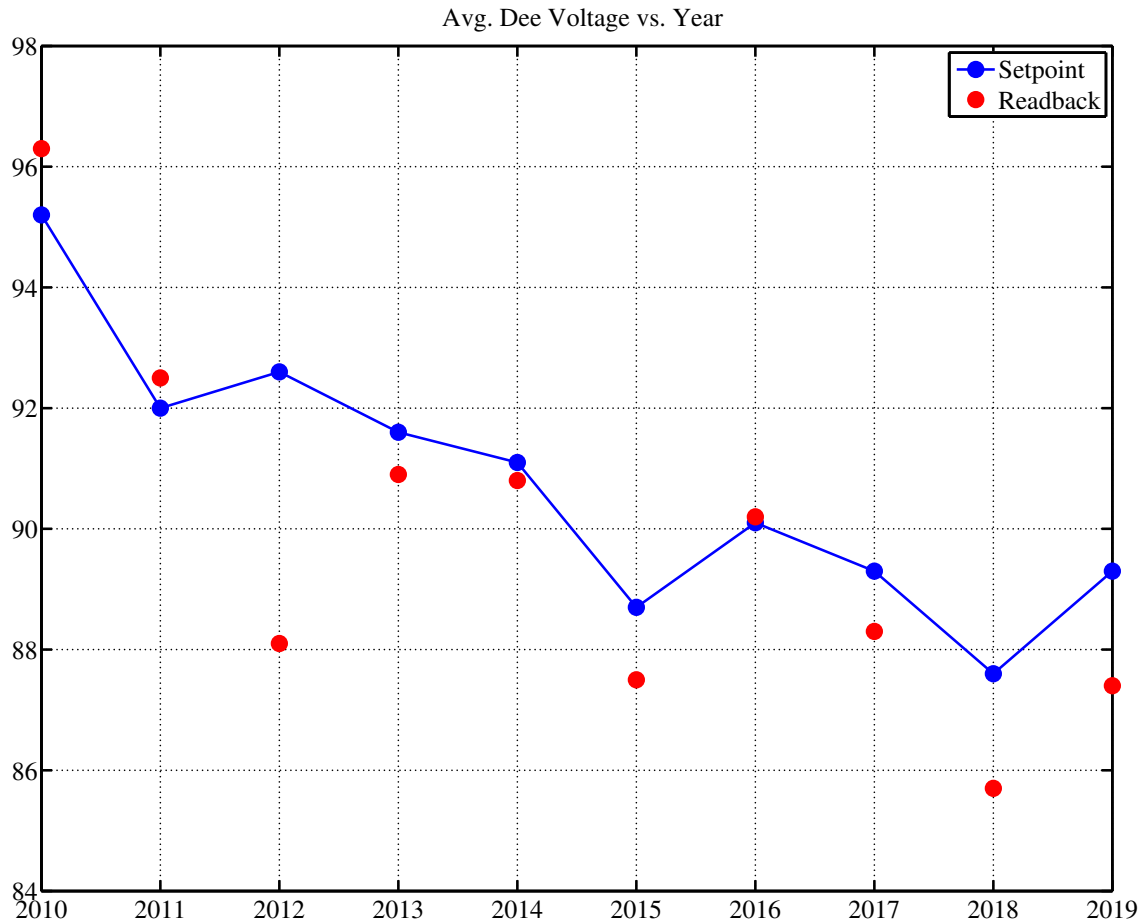
Recent Decade

Extracted current is higher for higher dee voltage:

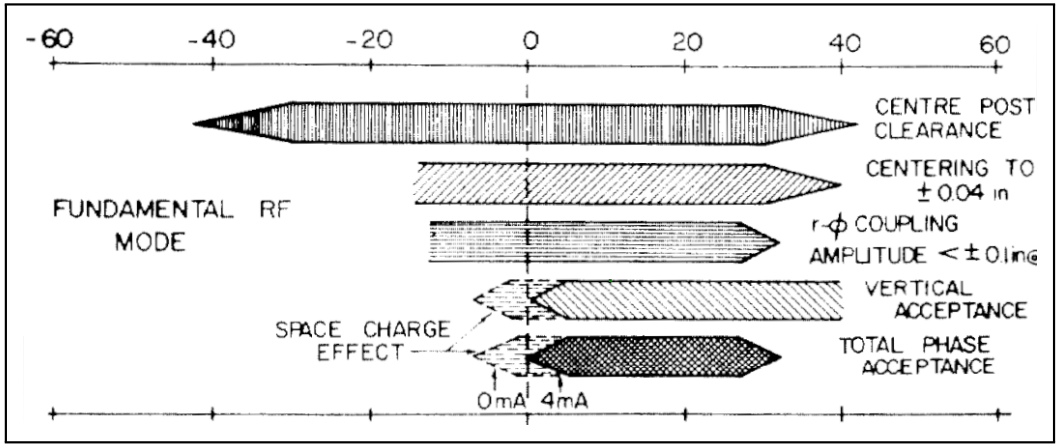


...but dee voltage has gone steadily down:

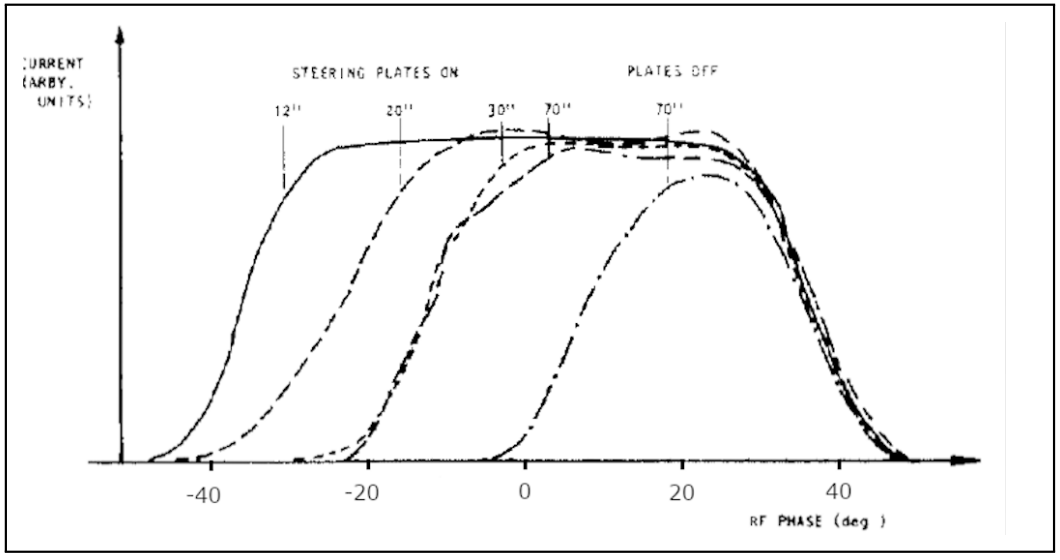


Phase Acceptance

Design $V_D = 100\,\text{kV}$, Richardson 1972. Later much improved and optimized by Dutto, Craddock, Kost, Mackenzie



Measurement (1975, zero space charge, $V_D = 85\,\text{kV}$)



Acceptance formula

- Right-hand edge is just $\cos^{-1}(66\,\mathrm{kV}/V_D)$, e.g. $V_D = 100\,\mathrm{kV} \implies 49°$, $V_D = 85\,\mathrm{kV} \implies 39°$.
- Left-hand edge depends on electric focusing of the dee gap: $\sim 20°$ at $V_D = 100\,\mathrm{kV}$ but $\propto V_D$ (recent `TRIWHEEL` study by Yi-Nong Rao, backed up by beam development studies.)
- but because of space charge, loses about $4°/\mathrm{mA}$ of local (peak) current.
- So phase acceptance at $V_D = 100\,\mathrm{kV}$ is

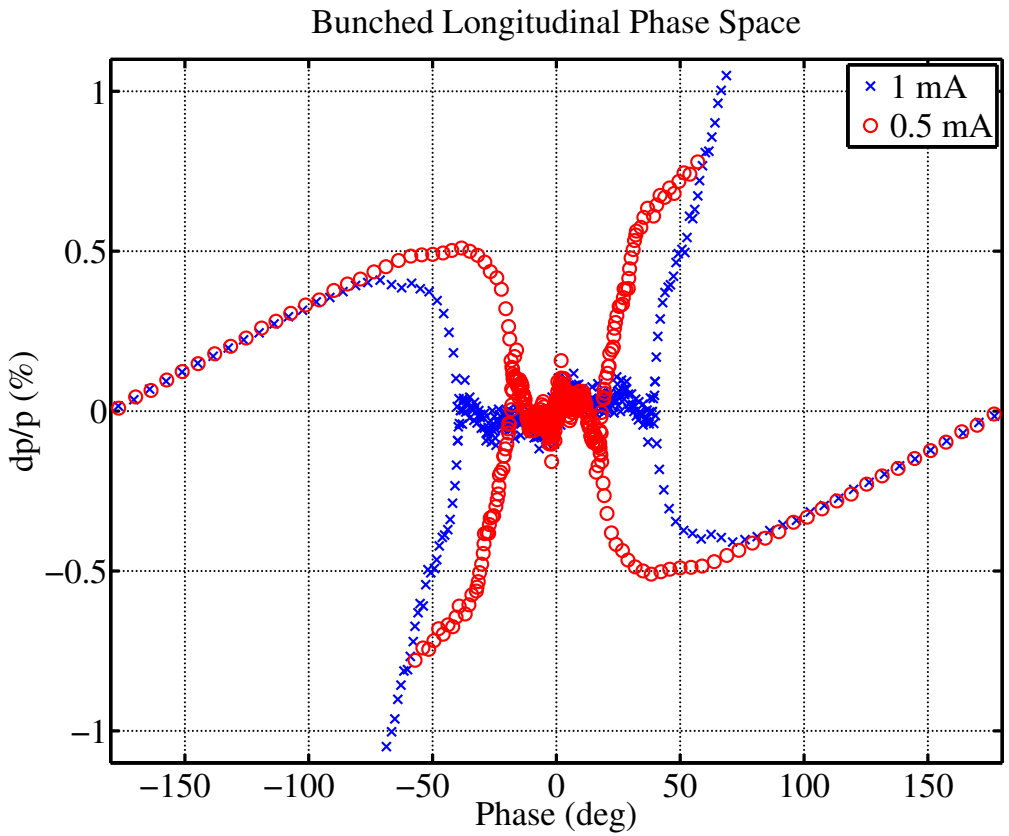
$$\Delta\phi = 49° + 20° - 4°(\hat{I}/\mathrm{mA}),$$

or more generally,

$$\Delta\phi = \cos^{-1}(66\,\mathrm{kV}/V_D) + 20°(V_D/100/\mathrm{kV}) - 4°(\hat{I}/\mathrm{mA})$$

Bunchers

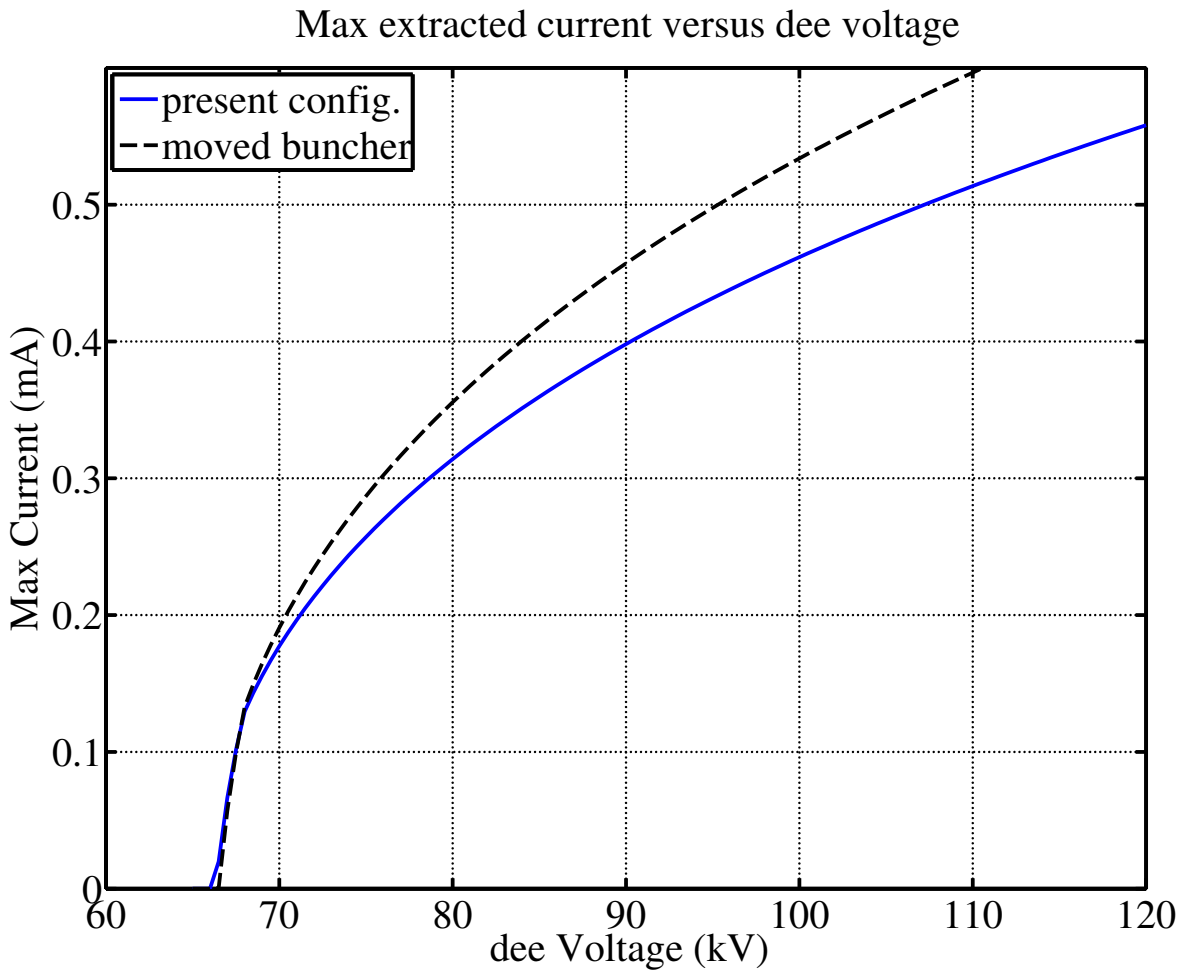
They compress source beam to $\sim 10\,\mu$A/degree, independent of source current $\implies \hat{I} \sim 3.6$ mA peak



...unless we move bunchers closer to injection.

Max current vs. V_D

$500\,\mu$A average at 90% pulser requires $550\,\mu$A in pulse and therefore at least $V_D \sim 110\,$kV



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Thank you
Merci

1988 result: $420\,\mu$A at $V_D = 95\,$kV

THE UPGRADING OF THE TRIUMF FACILITY TO 500 μA OPERATION

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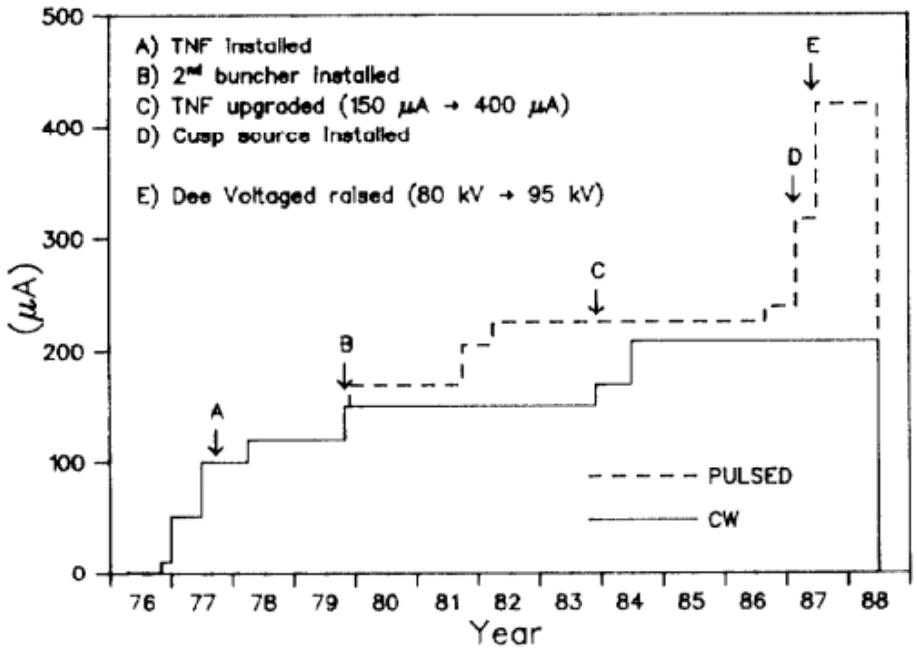

In the experiments with beam currents up to 420 μA at 50% duty cycle, the dee was conditioned at 97 kV, and was set to 95 kV for operation. No system problems were encountered during this test. Beam loading had no substantial effect on the operation of the rf system. The instantaneous beam power was 210 kW with the resonator power approximately 1250 kW.

Other reasons to increase V_D

Lowers loss/activation in two ways:

- Lower time of flight.
- Wider acceptance window allows to crowd beam into right-hand edge of phase acceptance window, so all particles are well-focused vertically. This would not be a consideration if we had a high power vertical scraper but we don't.