
CERN

Pole Face Winding Scan

Simulation Updates

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Motivation

MD4224: Approaching the integer tune

High brightness beam static tune scan in Proton Synchrotron using Low Energy Quads (LEQs).

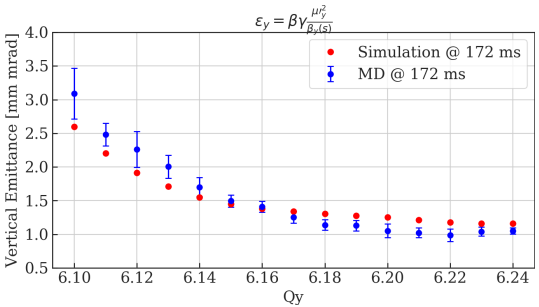


Figure: Result of MD4224 Vertical tune scan.

Motivation

Found emittance growth as tune is brought closer to the integer. Believe this to be due to quadrupolar stop-band, which is exacurbated by the use of the LEQs to modify the tune.

- If we switch off the LEQs and modify the tune with the Pole Face Windings (PFWs), do we excite the quadrupolar stop-band?
- Can we stimulate similar emittance growth with a single quadrupolar error in the lattice?

Optics Comparison

Tune (6.21, 6.10) - most extreme in vertical scan.
PLOT: Beta$_y$*LEQvsPFW*

Vertical Scan: Vertical Beta Function

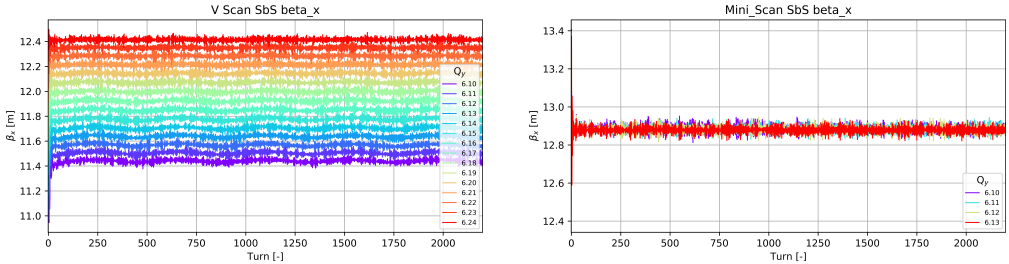


Figure: Comparison of vertical beta function at the position of the vertical wire scanner (BWSV64) when using LEQs (left) or PFWs (right) to modify the vertical tune.

Vertical Scan: Vertical Beam Size

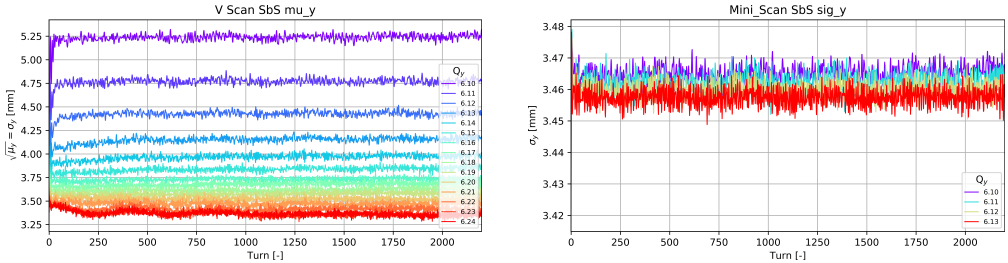


Figure: Comparison of vertical beam size at the position of the vertical wire scanner (BWSV64) when using LEQs (left) or PFWs (right) to modify the vertical tune.

Vertical Scan: Vertical Emittance

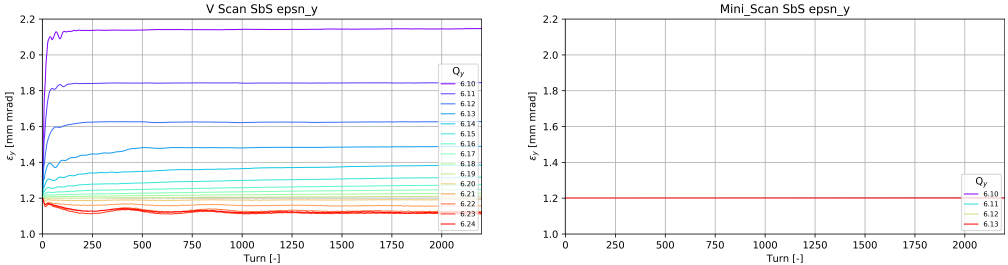


Figure: Comparison of vertical emittance at the position of the vertical wire scanner (BWSV64) when using LEQs (left) or PFWs (right) to modify the vertical tune.

Conclusion: PFWs do not excite the quadrupolar stop-band.

Vertical Scan: Longitudinal Motion

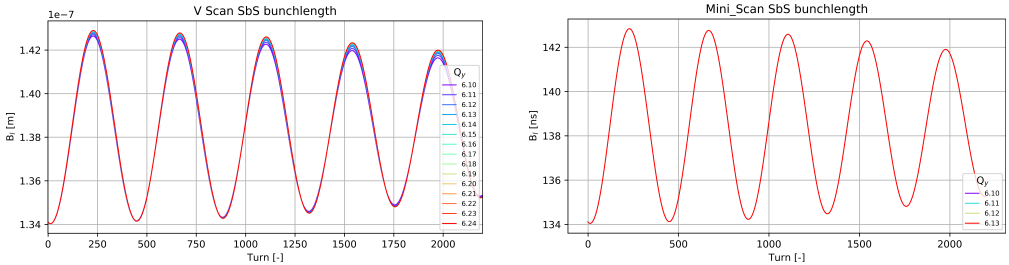


Figure: Comparison of bunch length at the position of the vertical wire scanner (BWSV64) when using LEQs (left) or PFWs (right) to modify the vertical tune.

Vertical Scan: Longitudinal Motion

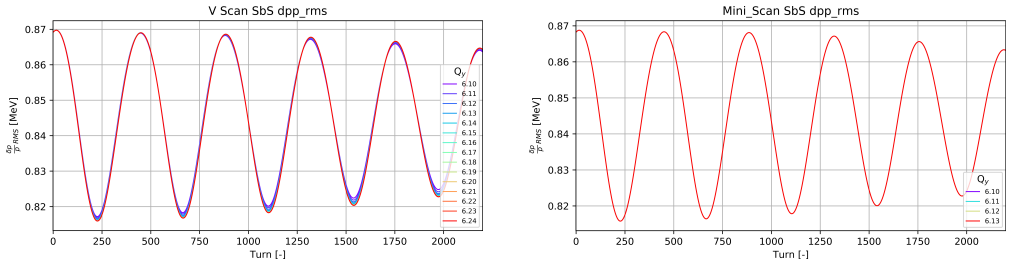


Figure: Comparison of momentum offset $\frac{\delta p}{p}_{RMS}$ at the position of the vertical wire scanner (BWSV64) when using LEQs (left) or PFWs (right) to modify the vertical tune.

PFW With Quadrupolar Error

Add quadrupolar error to single LEQ (QDN72)

Perform scan in beta-beating. All LEQs off except single error.

Beta Beating

Equation for beta-beating taken from H. Bartosik's JUAS 2019 lecture on linear imperfections and correction:

$$\frac{\delta\beta}{\beta_0} = -\frac{1}{2\sin(2\pi Q)} \int_{s_1}^{s_1+l} \beta(s)\delta K(s) \cos(2\psi - 2\pi Q)\, ds \tag{1}$$

Single quadrupole error ΔK, normalised quadrupole strength.

$$\Delta K = \frac{2\sin(2\pi Q)}{\beta_{max}} \left(\frac{\delta\beta}{\beta_0}\right) \tag{2}$$

Scan in Beta-Beating

$Q_y = 6.10$, $\beta_{max} = 23.01757$, $\beta_0 = 23.0095$

$$\Delta K = 0.0510425 \left(\frac{\delta\beta}{\beta_0} \right) \tag{3}$$

$\frac{\delta\beta}{\beta}_{estimated}$[%]	ΔK	β_{max}	$\delta\beta$	$\frac{\delta\beta}{\beta}_{out}$[%]
1	0.000510425	23.24475	0.22718	0.987
10	0.00510425	23.3844	2.36683	10.283
20	0.0102085	27.9566	4.93903	21.46
25	0.0127606	29.3158	6.29823	27.4

Table: Quadrupole error ΔK and corresponding $\frac{\delta\beta}{\beta}_{out}$.

PFW with Quadrupolar Error: Longitudinal Motion

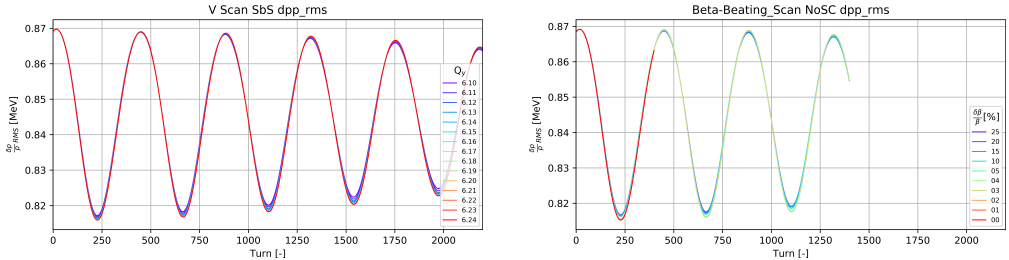


Figure: Comparison of momentum offset $\frac{\delta p}{p}_{RMS}$ at the position of the vertical wire scanner (BWSV64). The left plot shows a static tune scan using LEQs to modify the tune. The right plot shows a fixed tune of (6.21, 6.10) with a beta-beating error (indicated in legend) applied via a single quadrupolar error on the LEQ QND72.

PFW with Quadrupolar Error: Horizontal Beam Size

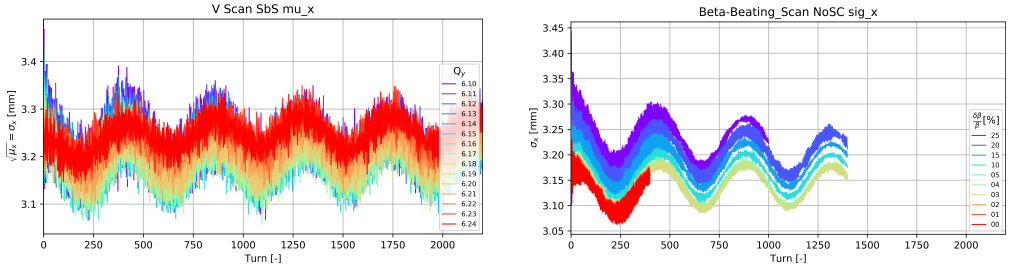


Figure: Comparison of vertical beam size at the position of the vertical wire scanner (BWSV64). The left plot shows a static tune scan using LEQs to modify the tune. The right plot shows a fixed tune of (6.21, 6.10) with a beta-beating error (indicated in legend) applied via a single quadrupolar error on the LEQ QND72.

PFW with Quadrupolar Error: Vertical Beam Size

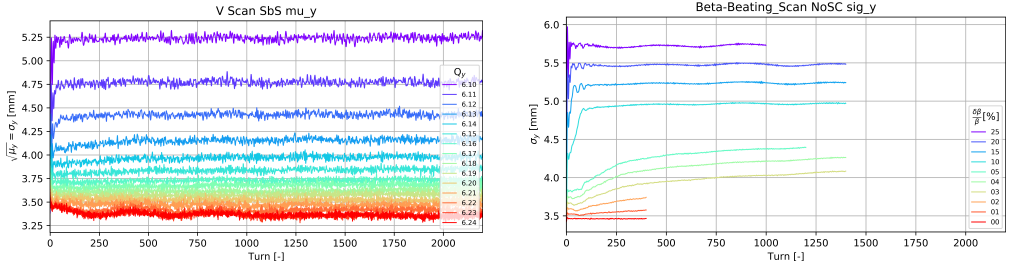
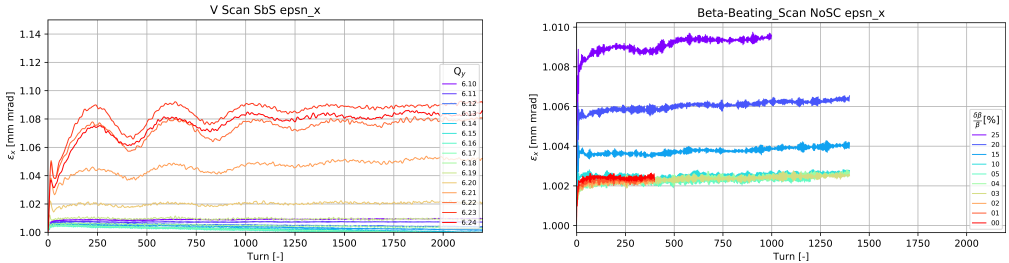


Figure: Comparison of horizontal beam size at the position of the vertical wire scanner (BWSV64). The left plot shows a static tune scan using LEQs to modify the tune. The right plot shows a fixed tune of (6.21, 6.10) with a beta-beating error (indicated in legend) applied via a single quadrupolar error on the LEQ QND72.

PFW with Quadrupolar Error: Horizontal Emittance



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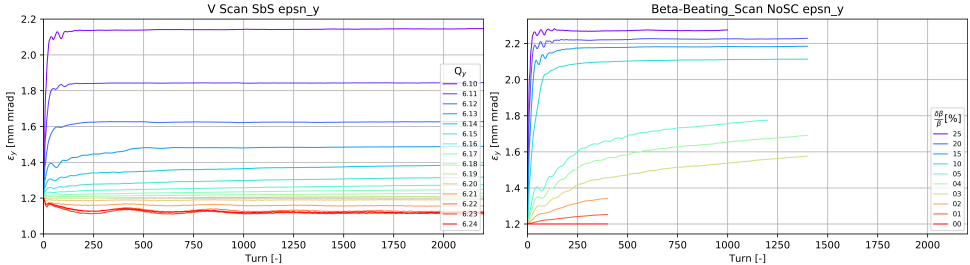
PFW with Quadrupolar Error: Vertical Emittance



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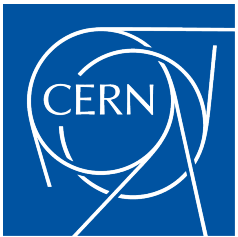
Conclusions

- PFW static tune scan shows no emittance growth with tune change - PFWs don't excite the quadrupolar stop-band at the (half) integer.
- Single quadrupolar error on QDN72 gives beta-beating - defined a scan in beta-beating from 1 - 25%.
- $\approx$ 15% beta-beating on top of PFW scan gives similar emittance growth as LEQ scan.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