CERN

MD4224 High Brightness

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Motivation

- **Motivation:** Investigate possible effects of space charge for injection setup in the PS.
- **MD4224:** Static tune scan investigating integer resonance in each plane separately.
- **Beam:** MD4224_LHC_BCMS25_2018_PSB_PN2 MD4224_48b_BCMS
- **Tune Spread:** dQx = 0.2, dQy = 0.24

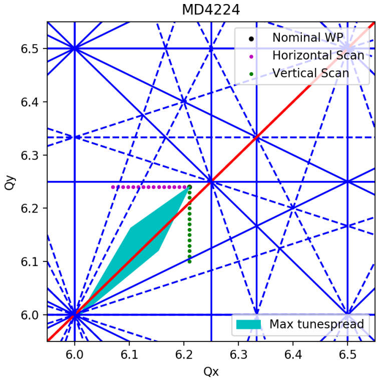
MD4224 Parameters

Parameter	Value
Intensity N_p $[10^{10}]$	$\approx$72.5
Normalised horizontal RMS emittance ϵ_x^n [mm mrad]	1.2
Normalised vertical RMS emittance ϵ_y^n [mm mrad]	1
Bunch length σ_t[ns]	140
Momentum spread $\frac{\Delta p}{p}$ $[10^{-3}]$	0.87
Horizontal maximum tune spread $\Delta Q_{x,\max}$	0.2
Vertical maximum tune spread $\Delta Q_{y,\max}$	0.24
Harmonic number h	9
RF voltage V_{rf} $[\mathrm{kV}]$	21.2
Horizontal chromaticity Q'_x	0.77
Vertical chromaticity Q'_y	-2.85
Kinetic energy of the stored beam $[\mathrm{GeV}]$	1.4
Relativistic β	0.916
Relativistic γ	2.4921
Synchrotron Frequency [Hz]	634

Tune Scan

Working Points: Operational (6.21, 6.24)

Horizontal scan (6.07-6.21, 6.24). Vertical scan (6.21, 6.10-6.24).



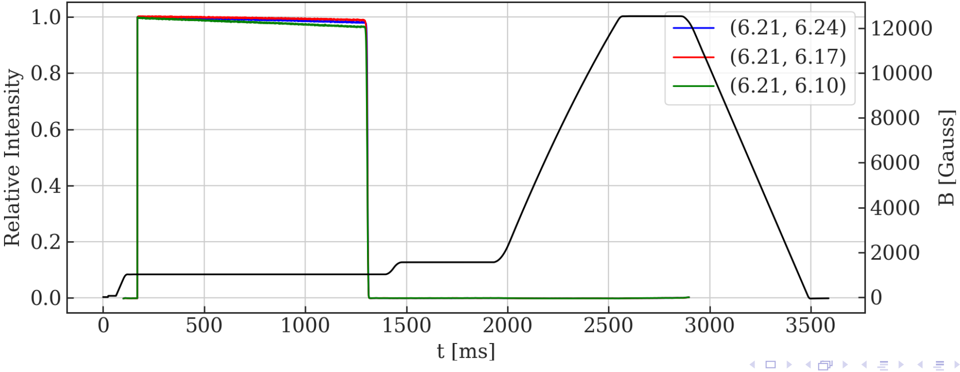
MD4224: High Brightness

- Clone of operational low-chroma BCMS cycle, with pole face windings (PFW) and skew quadrupoles used for chromaticity and coupling correction respectively.
- Orbit near injection corrected @ nominal WP, no degradation at lower Qx (orbit variation due to incorrect setting of PR.DHZ01 - details later).
- Transverse feedback used in the horizontal plane (set to individual shot tune).
- Accessible tune limits restricted by RMS current of low energy quadrupoles (LEQs) which must be monitored to stay under the limit of 6 Amps (current depends on whole super cycle).
- WS only available for same plane as scan (wire stuck in other plane).
- Tune measurement chirp active at 190 ms for all measurements: gives losses at flat bottom and coupling resonance.
- Only the first $\approx$ 20 ms (c170 - c190) was important for these measurements.

Cycle

3 Basic Periods, 1.4 GeV injection flat-top.

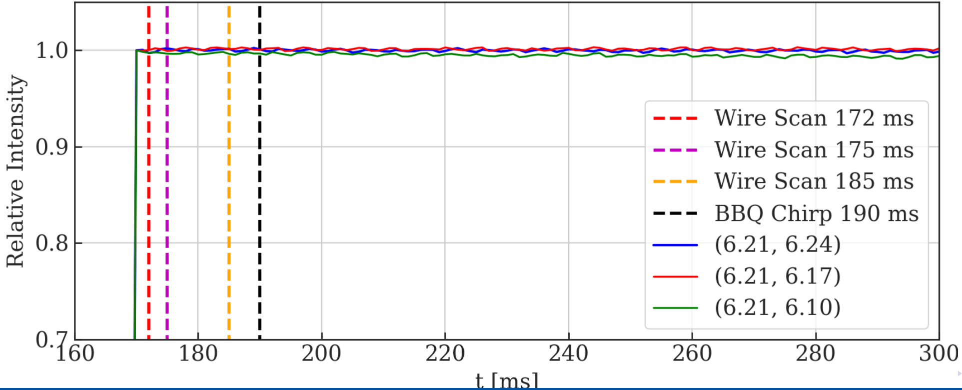
Injection @ 170 ms. Internal dump @ 1300 ms.



Cycle

Wirescanner Measurements

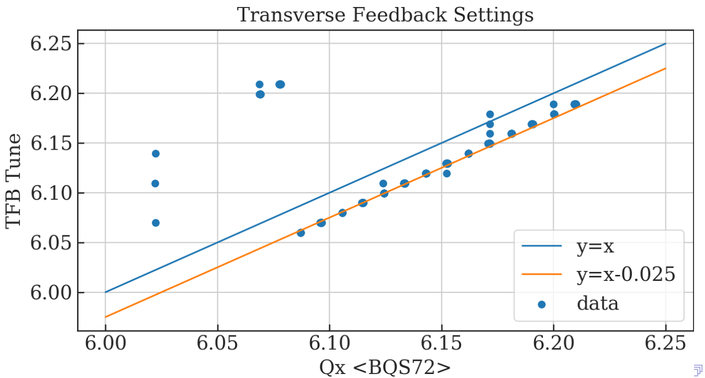
@ 172, 175, or 185 ms



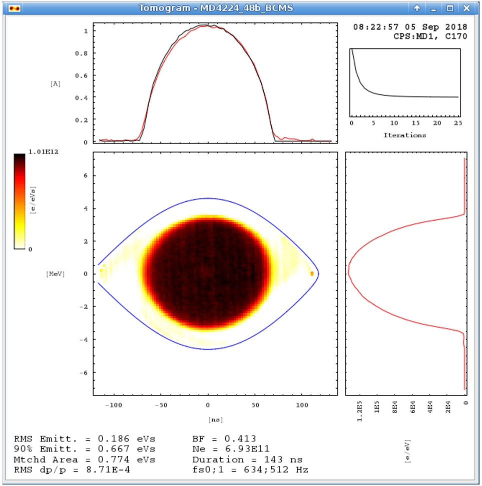
Transverse Feedback

H Scan: Set in Matlab script - small constant offset

Negligible as losses are a few %.



Tomo



Tomogram - MD4224_48b_BCMS
08:22:57 05 Sep 2018
CPS:MD1, C170
Iterations
[A]
1.01E12
[e/eVs]
[MeV]
[ns]
[e/eV]
RMS Emitt. = 0.186 eVs
90% Emitt. = 0.667 eVs
Mtchd Area = 0.774 eVs
RMS dp/p = 8.71E-4
BF = 0.413
Ne = 6.93E11
Duration = 143 ns
fs0;1 = 634;512 Hz

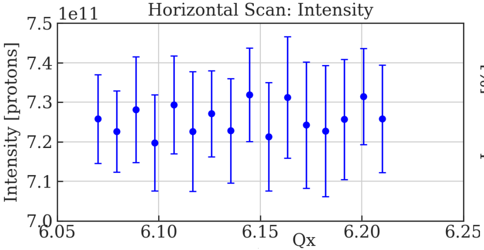
Analysis

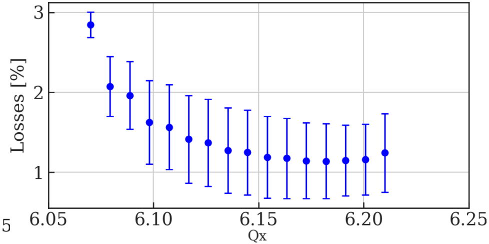
- Classical formula and single $\frac{dp}{p}$ value used for $\epsilon_{x,y}$ calculation.
- Emittance calculated with σ and second moment: $\epsilon_{x,y} \propto \frac{\sigma^2_{x,y}}{\beta_{x,y}(s)}$ and $\epsilon_{x,y} \propto \frac{\mu'^2_{x,y}}{\beta_{x,y}(s)}$
  .
- Optics changes taken into account at different tunes.
- Losses calculated between 170 - 1285 ms, but only 170 - 190 ms is important for measurements.

Intensity

Horizontal Scan

Losses calculated between 170 - 1285 ms

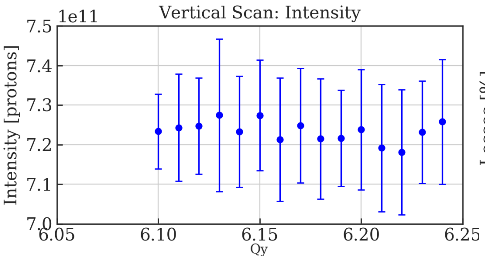


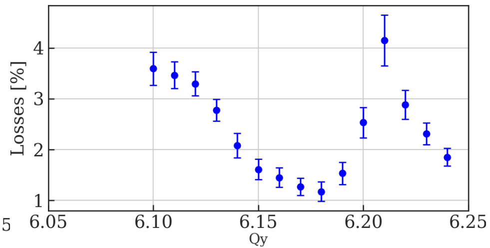


Intensity

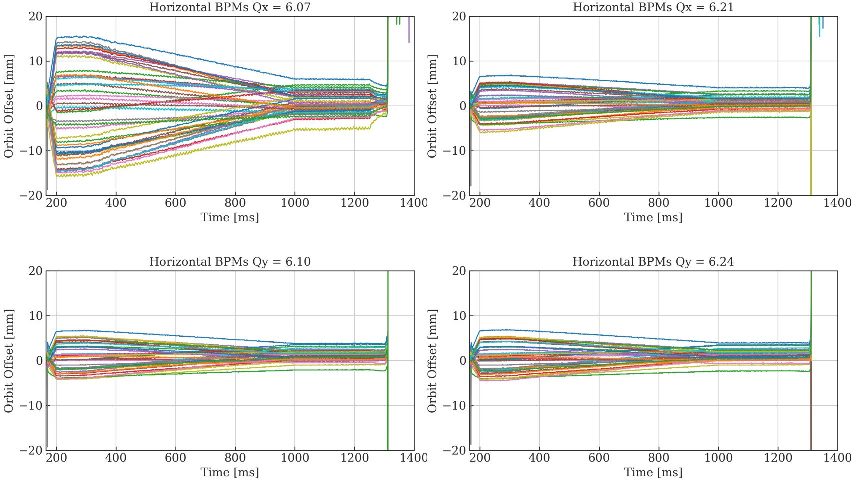
Vertical Scan

Losses calculated between 170 - 1285 ms





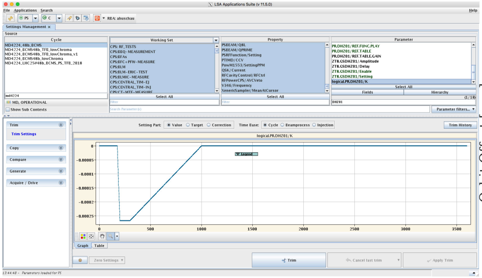
Orbit Deviation

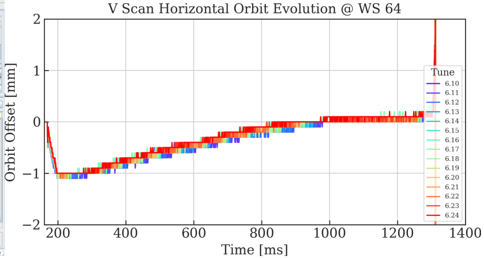


Orbit Deviation

Source of orbit offset

Function on orbit corrector PR.DHZ01

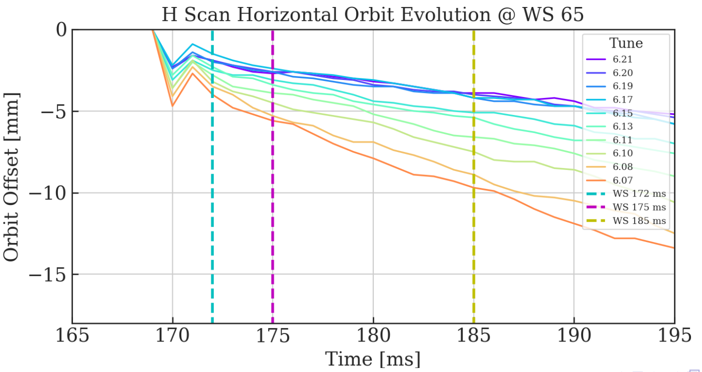




Orbit

Horizontal Scan: Horizontal Orbit

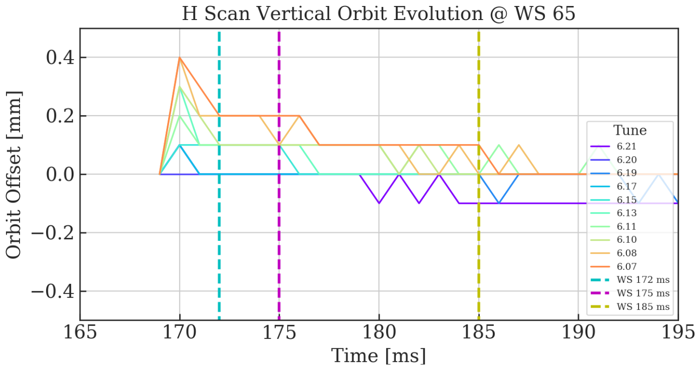
Large orbit deviation ≈ 10 mm in 15 ms



Orbit

Horizontal Scan: Vertical Orbit

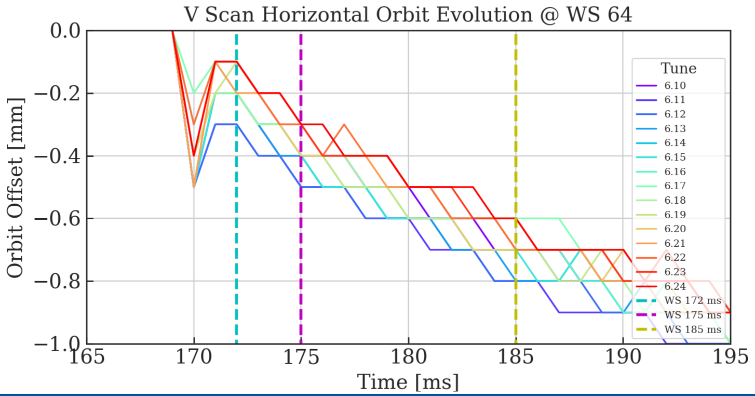
Small orbit deviation < 1 mm



Orbit

Vertical Scan: Horizontal Orbit

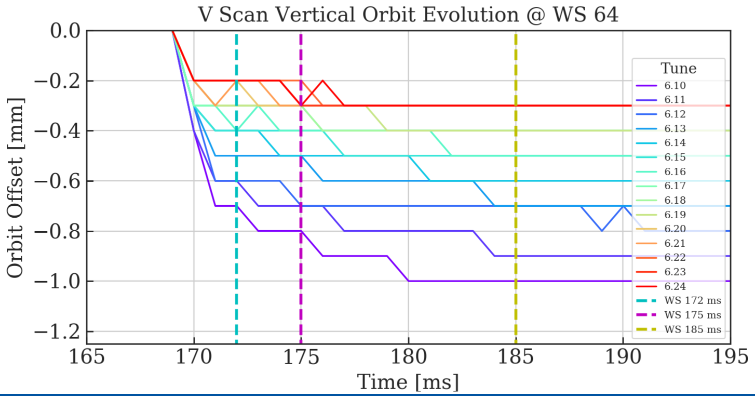
Small orbit deviation < 1 mm



Orbit

Vertical Scan: Vertical Orbit

Small orbit deviation < 1 mm



Optics for Analysis: Generated with MAD-X

Horizontal scan: WS 65.H Q_y = 6.24
Vertical scan: WS 64.V Q_x = 6.21

Q_x	β_x [m]	β_x [m]	D_x [m]
6.07	18.25	12.32	4.34
6.08	18.86	12.29	4.17
6.09	19.35	12.27	4.02
6.10	19.75	12.24	3.90
6.11	20.09	12.21	3.80
6.12	20.39	12.18	3.71
6.13	20.64	12.15	3.64
6.14	20.86	12.12	3.59
6.15	21.05	12.09	3.51
6.16	21.22	12.07	3.45
6.17	21.37	12.04	3.40
6.18	21.51	12.01	3.35
6.19	21.64	11.98	3.31
6.20	21.75	11.96	3.27
6.21	21.86	11.93	3.23

Q_y	β_x [m]	β_x [m]	D_x [m]
6.10	11.66	25.14	2.63
6.11	11.70	24.63	2.62
6.12	11.74	24.22	2.61
6.13	11.79	23.89	2.59
6.14	11.83	23.61	2.58
6.15	11.87	23.38	2.57
6.16	11.91	23.19	2.55
6.17	11.95	23.02	2.30
6.18	11.99	22.88	2.53
6.19	12.03	22.76	2.51
6.20	12.07	22.65	2.50
6.21	12.12	22.55	2.49
6.22	12.17	22.47	2.47
6.23	12.20	22.39	2.46
6.24	12.24	22.32	2.45

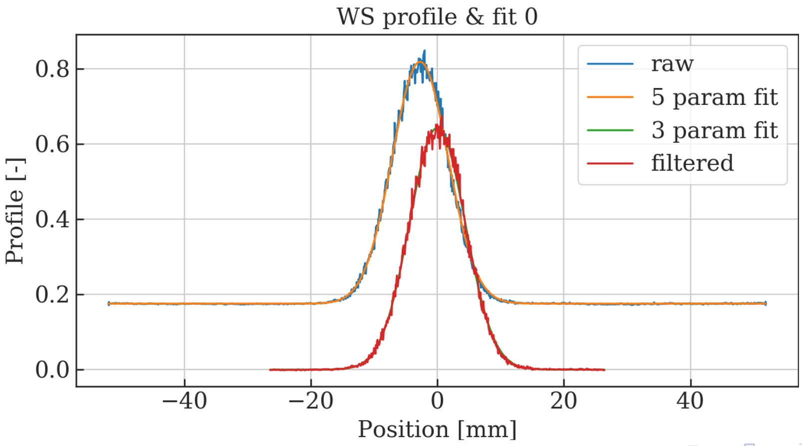
Wire Scanner Fitting

Procedure similar to that found in Appendix B of:
https://journals.aps.org/prab/abstract/10.1103/PhysRevAccelBeams.20.081006

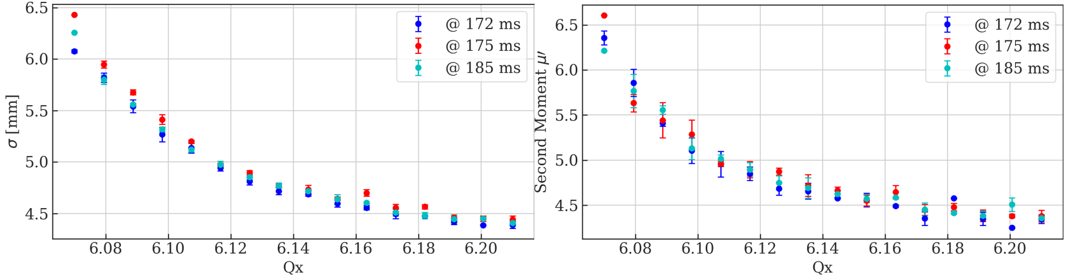
- 5 parameter Gaussian fit to find mean and σ.
- $\pm$ 6 σ cut to find slope.
- Remove slope.
- 3 parameter Gaussian fit to find centre.
- 2nd moment calculation.

Wire Scanner Fitting

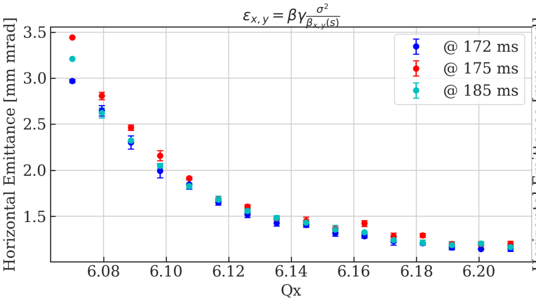
Example of fitting procedure and end result:

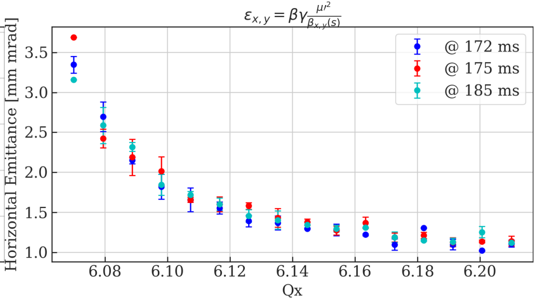


Horizontal Scan

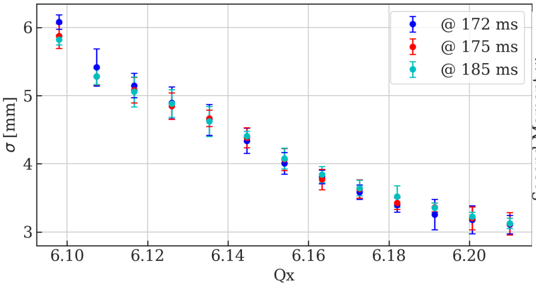


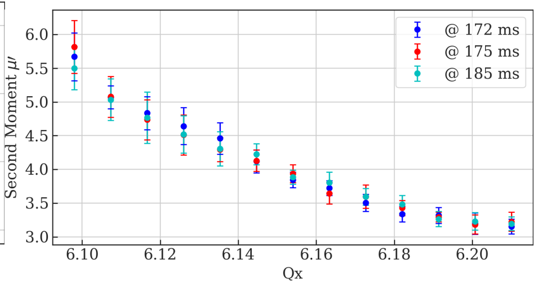
Horizontal Scan Emittance



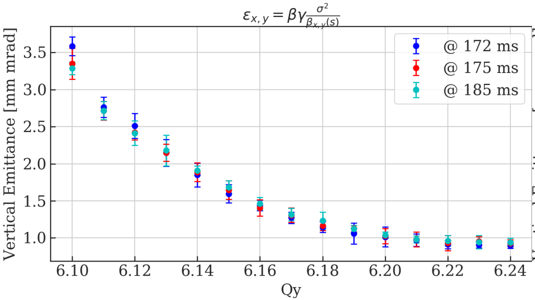


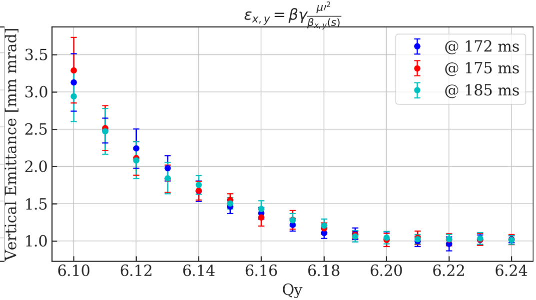
Vertical Scan





Vertical Scan Emittance





Summary

- Clear emittance blowup close to the integer in both planes.
- Due to core crossing the integer, and corresponding tune spread reduction.
- No obvious dependency on WS measurement time - implies very fast blowup.
- Simulations to come.

Conclusions

What did we do?

Took a high brightness PS beam close to the integer tune 6 in each plane respectively.

Why did we do it?

To see the impact of the integer resonance on the beam behaviour. These measurements provide a useful benchmarking tool to ascertain the reliability of our simulation models.

Conclusions

Why should you care?

This helps us understand limitations of the high brightness PS beam, provides an opportunity to investigate space charge mechanisms close to the integer, allows us to use simulations to better understand the real machine. By investigating the agreement between simulations and measurements we can improve our tools and models.

Acknowledgements

- **MD Facilitation**: PSB & PS Operators.

MD4224: High Brightness Logbook Entries

- 23.08.18 @ 14:58
- 31.08.18 @ 13:51
- 03.09.18 @ 10:21
- 04.09.18 @ 08:02
- 05.09.18 @ 08:21

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