Harmonic Analysis of Selected Recycler ring Locations

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The study

- Objective
  - Use closed 3-bump orbit data.
  - Look for signs of local field errors.

- Selected locations
  - Only locations implicated from previous study.
    - ✓ Lambertson: 402, 328, & 214.
    - ✓ RR620.
- Use circulating proton beam
  - Closed orbit data with 64 turns averaging.
  - Sample orbit with MI at 8-GeV.

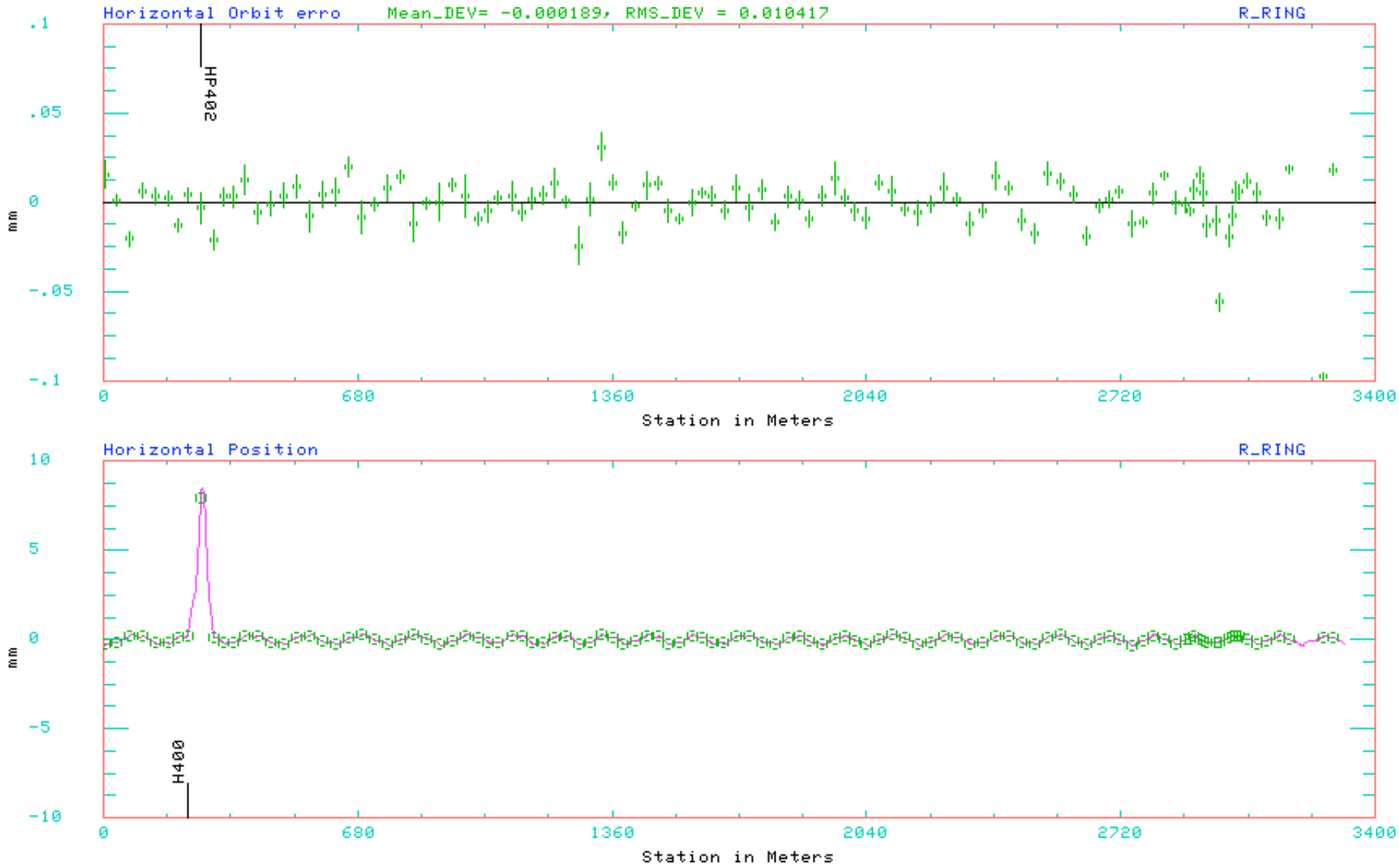
Data sets

- LAM402
  - ✓ H402:3
  - – V401:3, & V403:3 (not conclusive)
- LAM328
  - ✓ H328:3
  - – V327:3, & V329:3 (not analyzed)
- LAM214
  - ✓ H214:3
  - – V213:3, & V215:3 (not analyzed)
- RR620
  - ✓ H620:3
  - – V619:3, & V621:3 (not analyzed)

3-bump orbit analysis

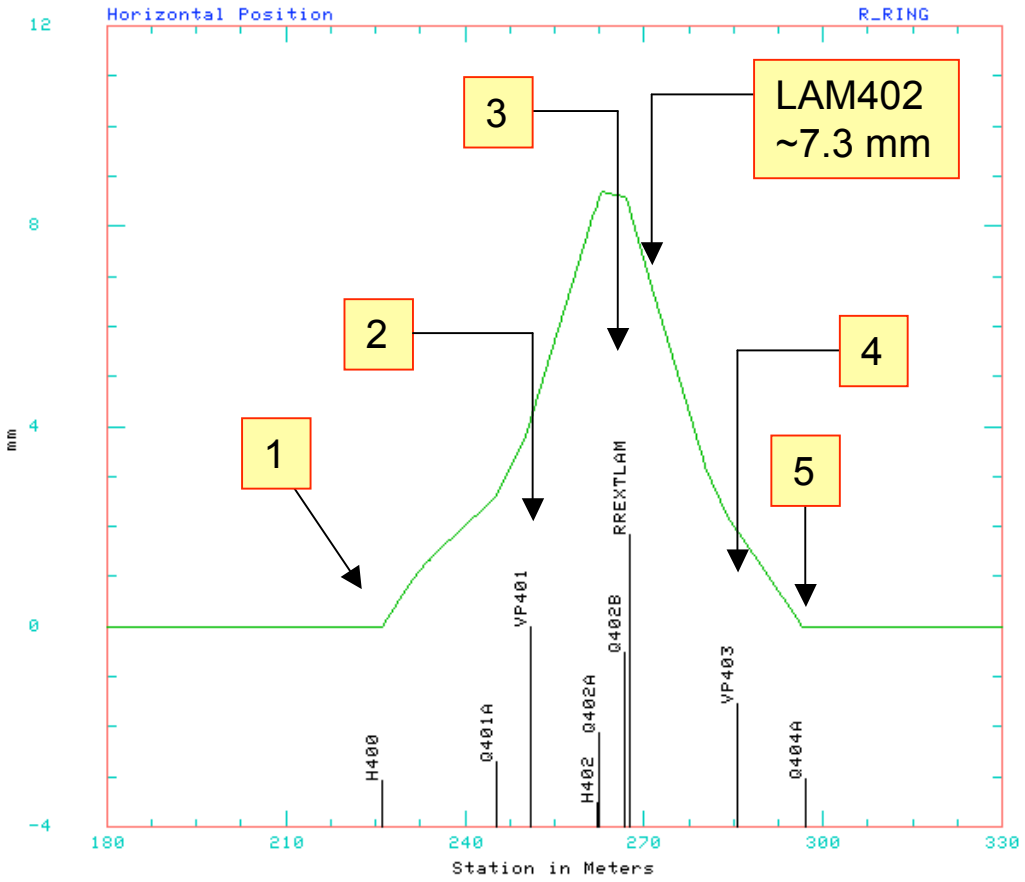
- I90
  - 3rd order polynomial fit to position data
    - ✓ w.r.t. kick from leading trim dipole in the bump.
  - Use polynomial coefficient as orbit, of a chosen order
    - ✓ And save into R39 BPM file.
  - Calculate and match the measured 3-bump orbit.
    - ✓ Get estimated displacement at the trouble location.
- R49, using "Magnet Move" option
  - Read coefficient orbit from R39 BPM file.
  - Send data to MICADO for fitting.
- Convert kick error into multipole strengths
  - Get integrated field from kick amplitudes.
- Both horizontal and vertical plane responses.
  - For normal and skew components.

H402 3-bump first order orbit, in mm/amp



What we get with closed 3-bump data

Using H402:3 bump as an example



Vertical kick sources implies:

Location 1 & 5:

- Rolled trim dipoles

Location 3:

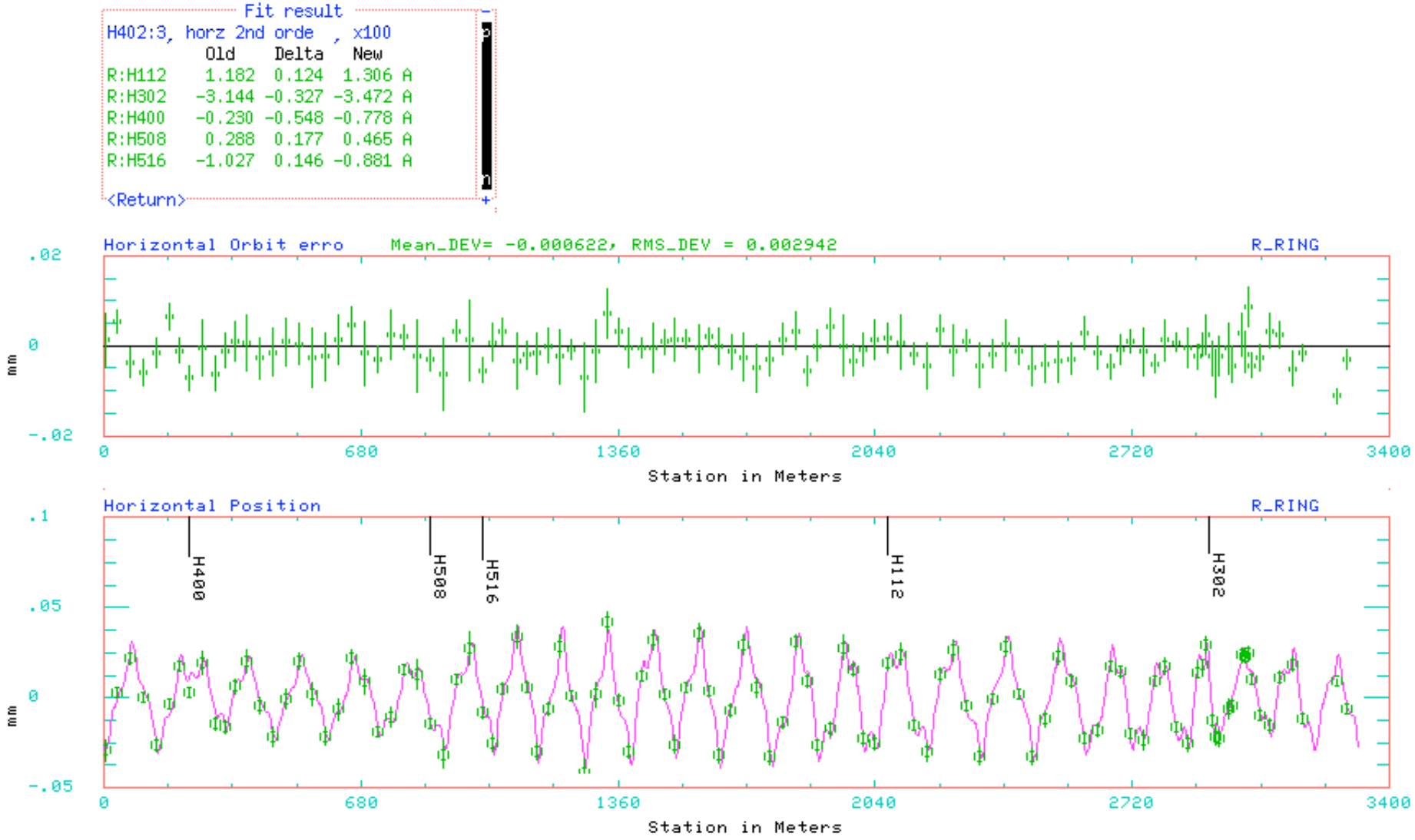
- Skew quad
- Rolled trim dipole

Excessive vertical BPM position readings

Location 2 & 4

- Rolled BPMs.

H402 3-bump 2nd order, horizontal



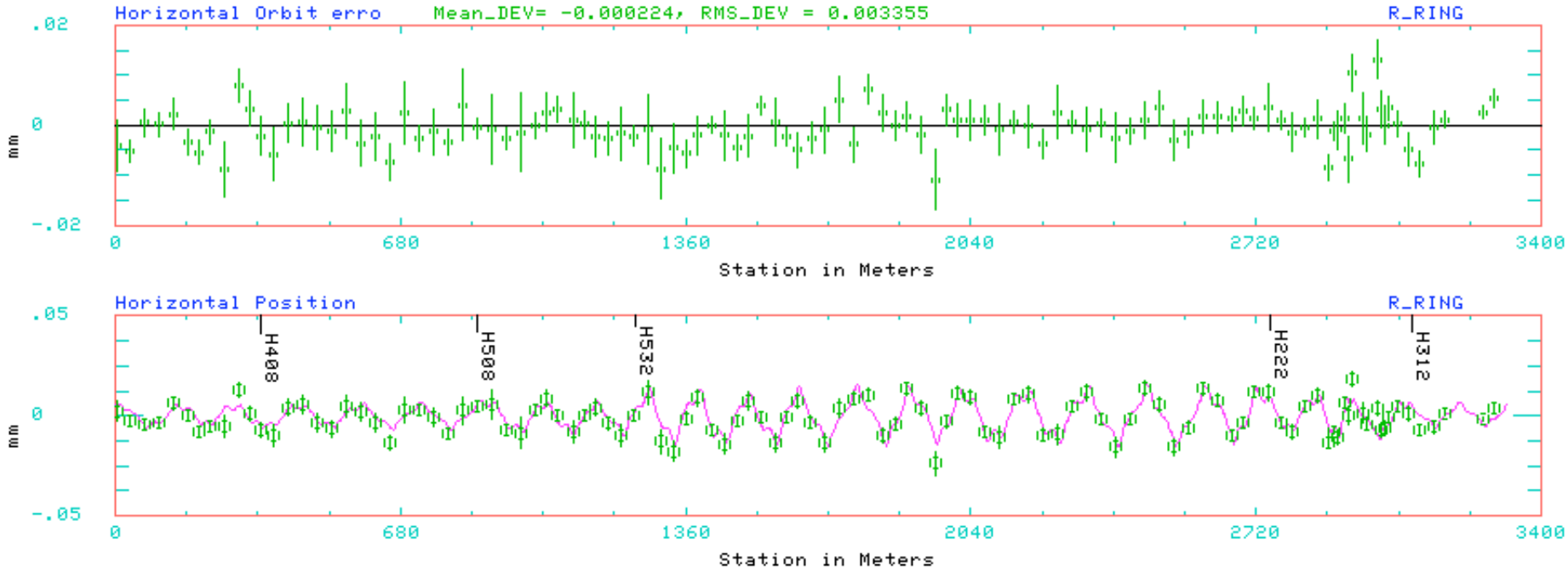
H402 3-bump 3rd order, horizontal

Fit result

H402:3, horz 3rd , x100

	Old	Delta	New	
R:H222	0.595	-0.072	0.523	A
R:H312	-0.598	-0.156	-0.755	A
R:H408	-0.137	0.146	0.009	A
R:H508	0.288	-0.094	0.194	A
R:H532	-0.038	-0.110	-0.148	A

<Return>



H402 3-bump 1st order, vertical

Magnet Movement

H402:3, vert 1st , x10

	mrad	mm	mils
G127A	-0.00404	-0.0822	-3.2
G336A	0.01426	-0.2802	-11.0
Q402B	-0.11452	2.5443	100.2
G507B	0.00204	0.0417	1.6
Q621B	0.00376	0.0866	3.4

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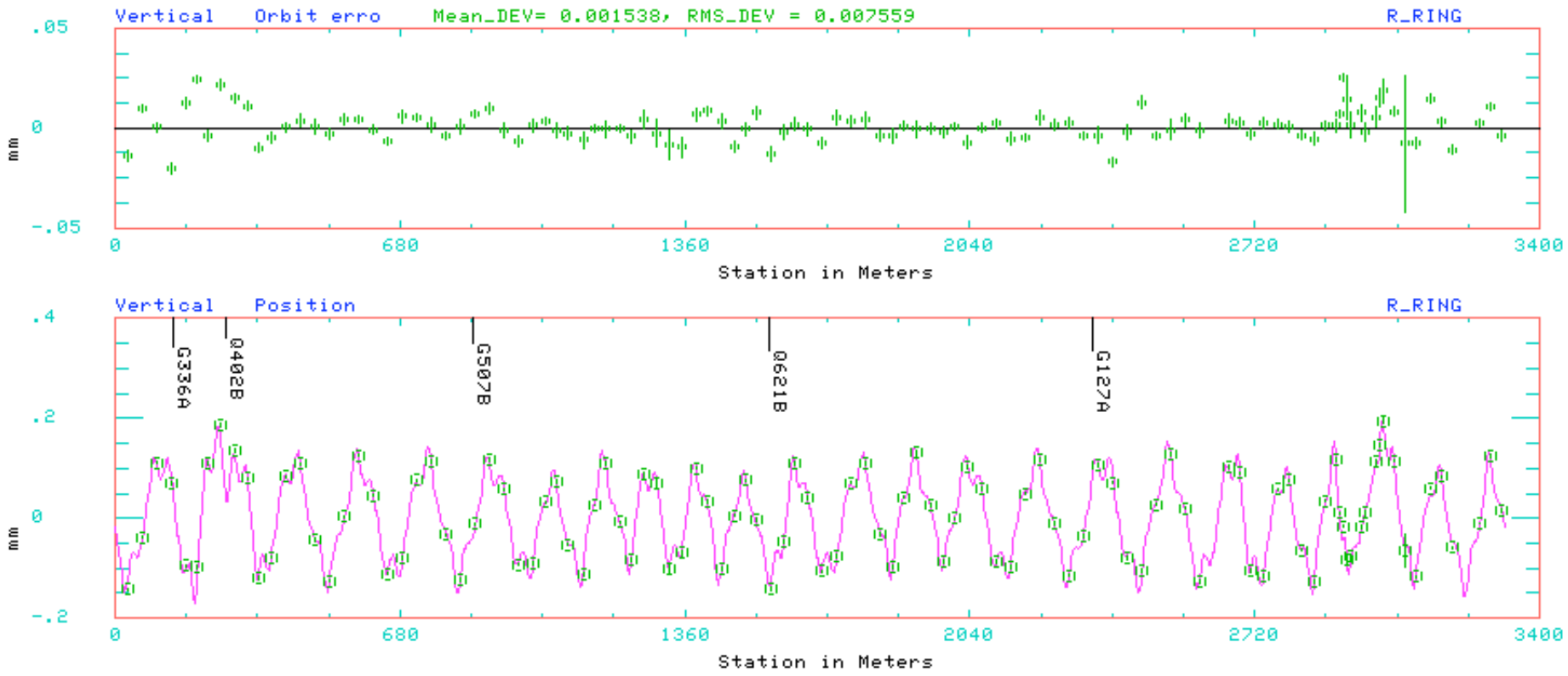
Orbit sent to MICADO was magnified 10 times for better accuracy.

Attributing kick error to skew quadrupole in LAM402



H402 3-bump 2nd order, vertical orbit

Magnet Movement

H402:3, vert 2nd , x100

	mrad	mm	mils
G204B	-0.01007	0.1980	7.8
G341B	-0.01516	-0.2125	-8.4
Q402B	0.19340	-4.2969	-169.2
G419B	0.00552	0.1124	4.4
G636A	-0.01290	0.2536	10.0

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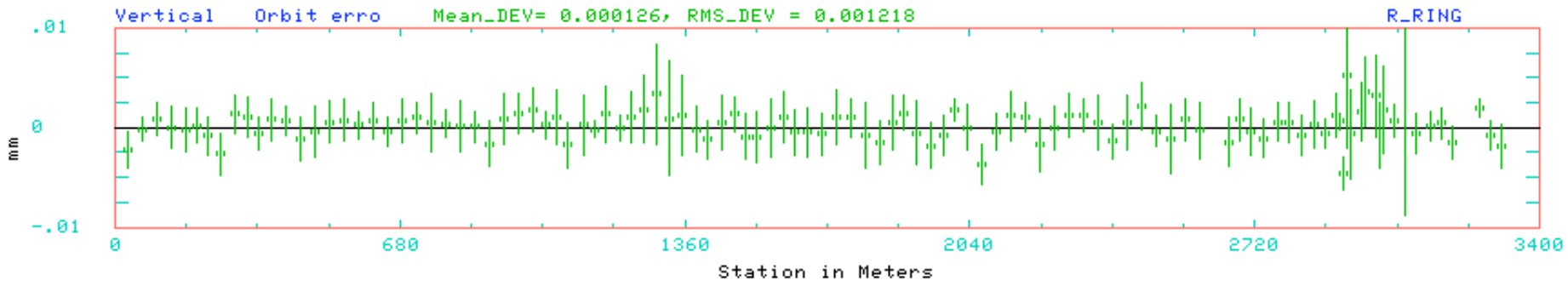
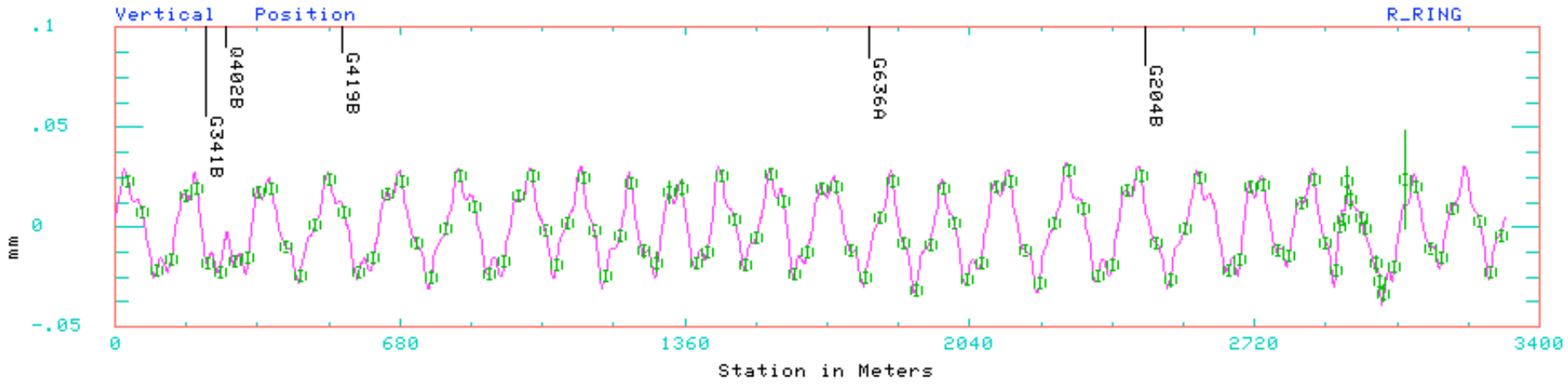
Orbit sent to MICADO was magnified 100 times for better accuracy.

Attributing 2nd order kick error to skew sextupole in LAM402

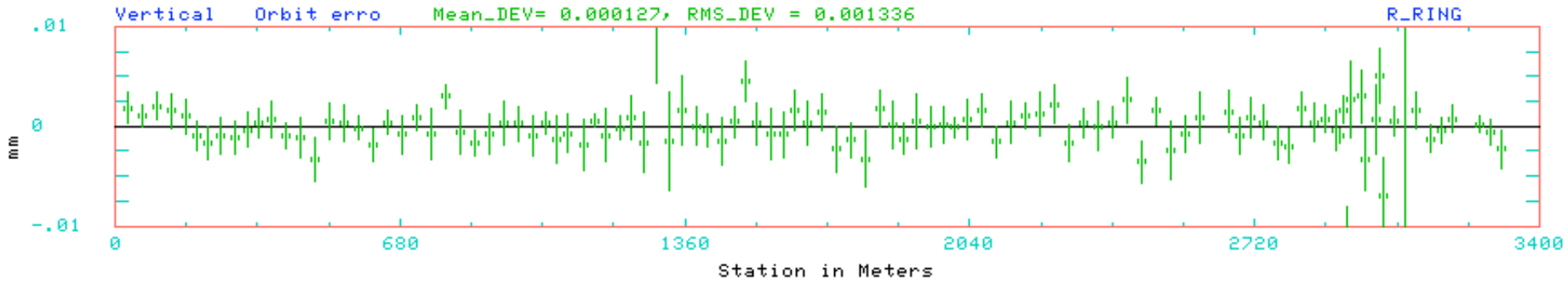


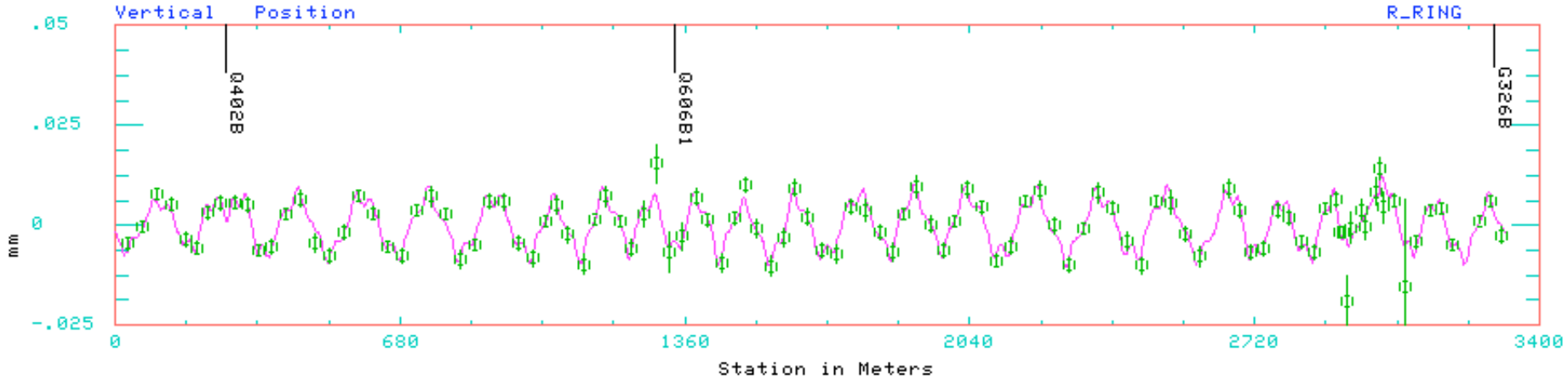


H402 3-bump 3rd order vertical orbit

Orbit magnified 100 times.

Attributing 3rd order kick error to skew octupole in LAM402.





Implicated multipole fields at Lam402

Fitted kick error from MICADO

Effective integrated field

H402	Δmr	ΔBL, G-M	B(n)L	B(n)			MTF units
Horz 1st	-0.0112	-3.3258	-0.4548	-0.1119	KG/M	Norm. quad	-18.685
Horz 2nd	0.0000	0.0000	0.0000	0.0000	KG/M^2	Norm. sext.	0.000
Horz 3rd	0.0000	0.0000	0.0000	0.0000	KG/M^3	Norm. Oct.	0.000
Vert 1st	-0.0115	-3.3956	-0.4643	-0.1143	KG/M	skew quad	-19.077
Vert 2nd	0.0019	0.5734	21.3581	5.2554	KG/M^2	skew sext.	11.144
Vert 3rd	-0.0006	-0.1819	-2756.8000	-678.3464	KG/M^3	skew oct.	-12.179

Integrated multipole strength, Factoring in bump displacement at LAM402

Multipole field strength

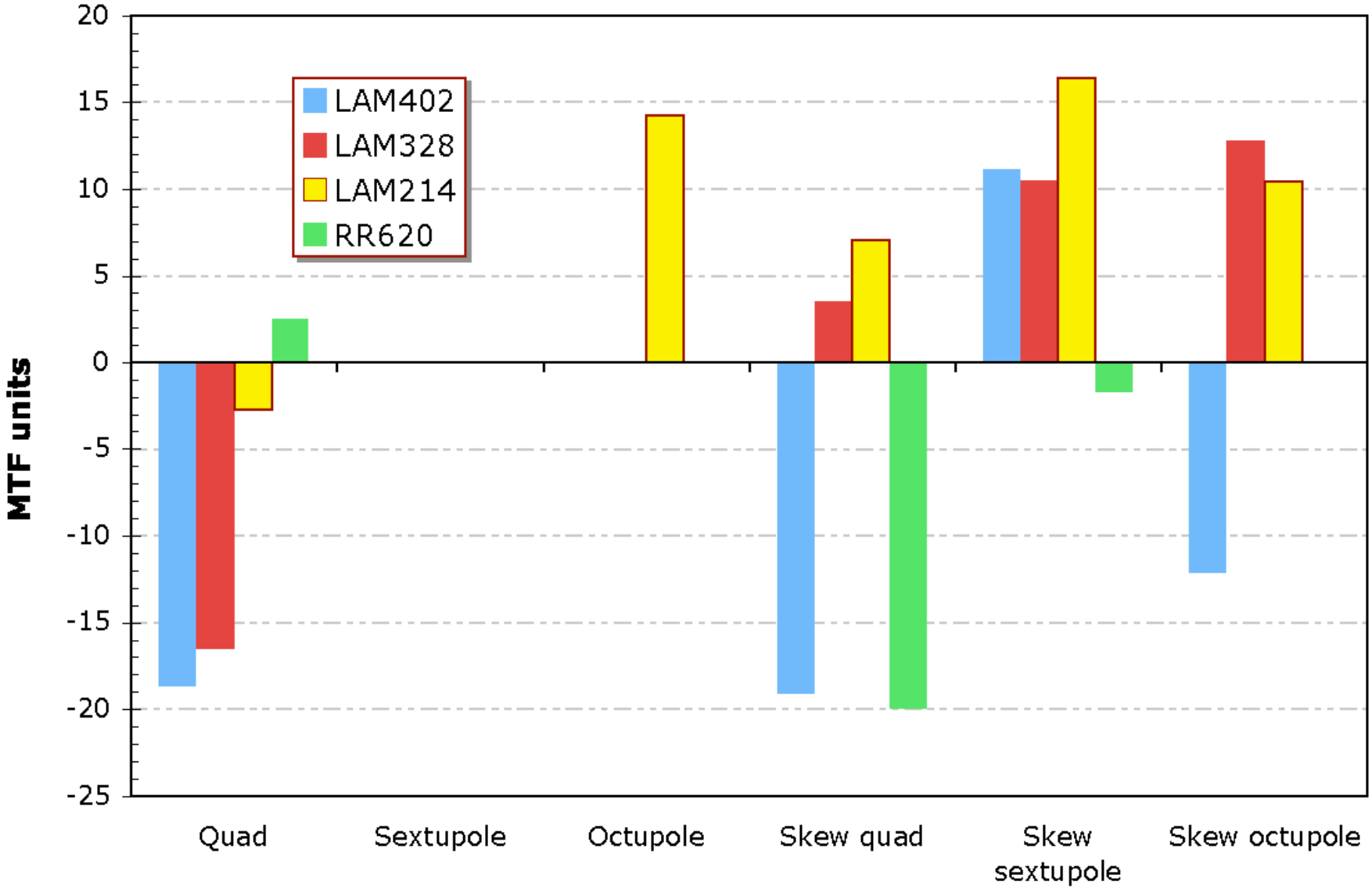
Implied multipole fields for other locations

H328	Δmr	ΔBL, G-M	B(n)L	B(n)			MTF units
Horz 1st	-0.0050	-1.4702	-0.4023	-0.0990	KG/M	Norm. quad	-16.527
Horz 2nd	0.0000	0.0000	0.0000	0.0000	KG/M^2	Norm. sext.	0.000
Horz 3rd	0.0000	0.0000	0.0000	0.0000	KG/M^3	Norm. Oct.	0.000
Vert 1st	0.0011	0.3154	0.0863	0.0212	KG/M	skew quad	3.545
Vert 2nd	0.0005	0.1355	20.1407	4.9559	KG/M^2	skew sext.	10.509
Vert 3rd	0.0001	0.0241	2898.1153	713.1189	KG/M^3	skew oct.	12.803

H214	Δmr	ΔBL, G-M	B(n)L	B(n)			MTF units
Horz 1st	-0.0010	-0.2892	-0.0659	-0.0162	KG/M	Norm. quad	-2.707
Horz 2nd	0.0000	0.0000	0.0000	0.0000	KG/M^2	Norm. sext.	0.000
Horz 3rd	0.0002	0.0464	3222.5157	792.9419	KG/M^3	Norm. Oct.	14.236
Vert 1st	0.0025	0.7540	0.1718	0.0423	KG/M	skew quad	7.057
Vert 2nd	0.0010	0.3049	31.4339	7.7347	KG/M^2	skew sext.	16.401
Vert 3rd	0.0001	0.0340	2362.4914	581.3217	KG/M^3	skew oct.	10.437

H620	Δmr	ΔBL, G-M	B(n)L	B(n)			MTF units
Horz 1st	0.0009	0.2809	0.0613	0.1207	KG/M	Norm. quad	2.519
Horz 2nd	0.0000	0.0000	0.0000	0.0000	KG/M^2	Norm. sext.	0.000
Horz 3rd	0.0000	0.0000	0.0000	0.0000	KG/M^3	Norm. Oct.	0.000
Vert 1st	-0.0075	-2.2270	-0.4861	-0.9570	KG/M	skew quad	-19.973
Vert 2nd	-0.0001	-0.0353	-3.3607	-6.6156	KG/M^2	skew sext.	-1.754
Vert 3rd	0.0000	0.0000	0.0000	0.0000	KG/M^3	skew oct.	0.000

Multi-pole fields



Summary

- Analysis
  - Data is limited by the corrector stability.
  - Not all data sets are analyzed.
- Result
  - Consistent with result from previous study.
  - Found evidence of multipole field errors
    - ✓ skew quadrupole, skew sextupole and octupole fields.
  - RR620 is consistent with rolled quads.
- Misc
  - Of the 3 Lambertson locations 214 has the smallest horizontal aperture.