Investigation of coupling in the SPS

Androula Alekou

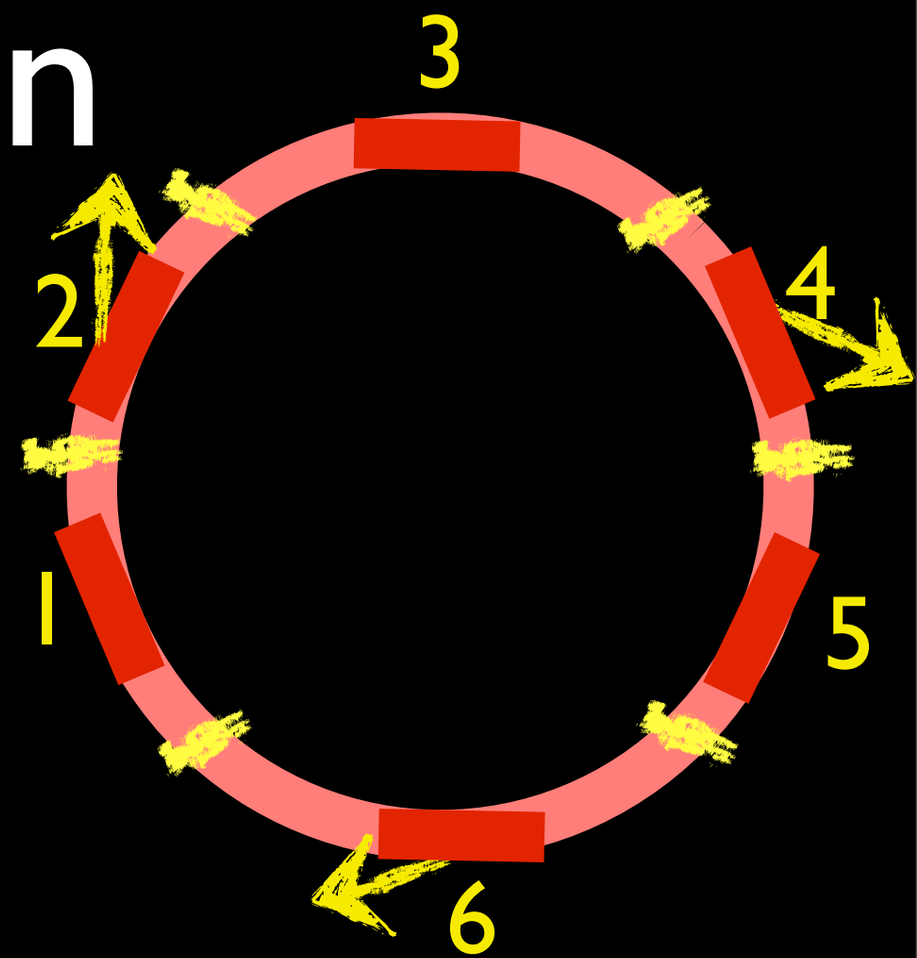
Many thanks to Y. Papaphilippou and H. Bartosik

Outline

- Introduction
  - need for non-local fast extraction from LSS2
  - ‘coupling’ observed during MD
- Steps towards reproducing that ‘coupling’
- Conclusion

Introduction

- SPS has 6 long straight sections (LSS): LSS1-LSS6



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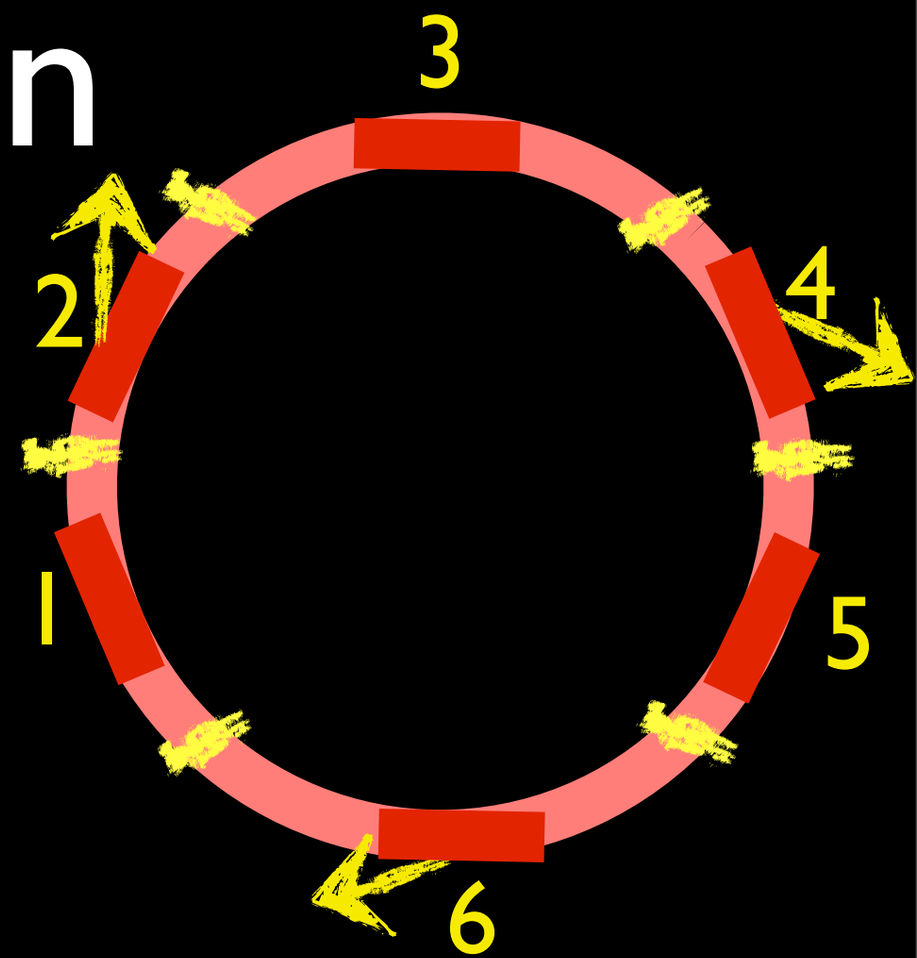
- LSS2, LSS4 and LSS6 are the three extraction channels



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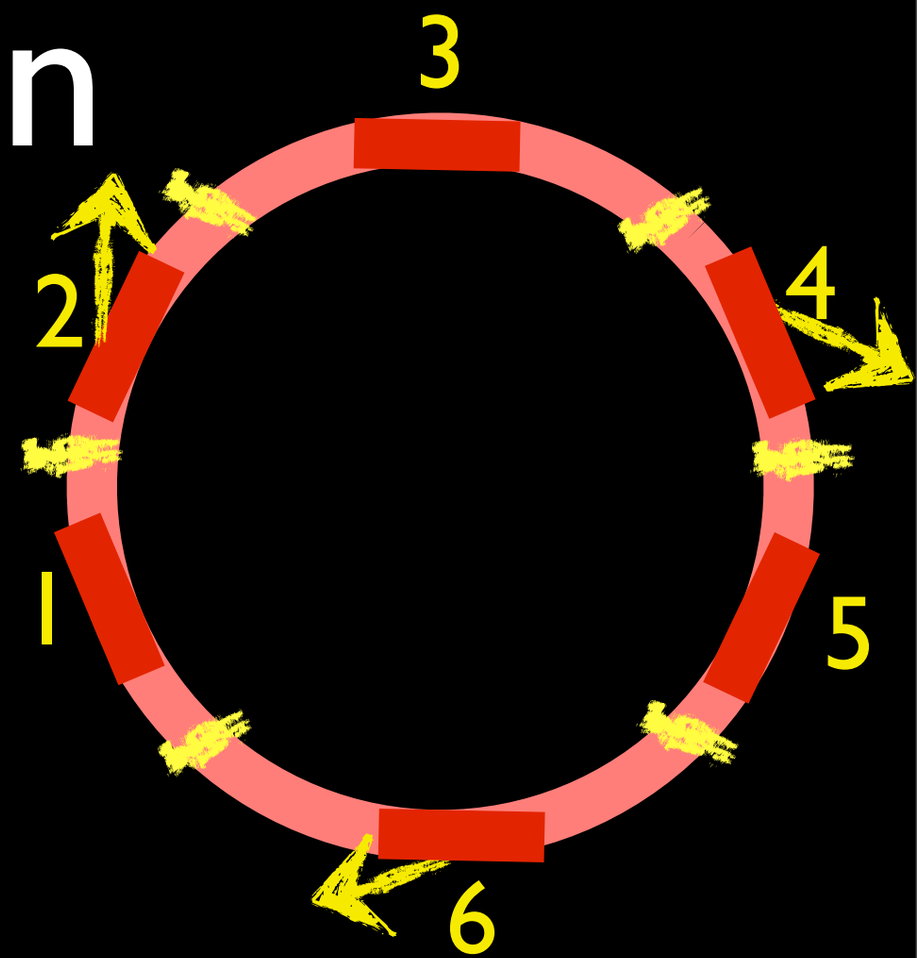

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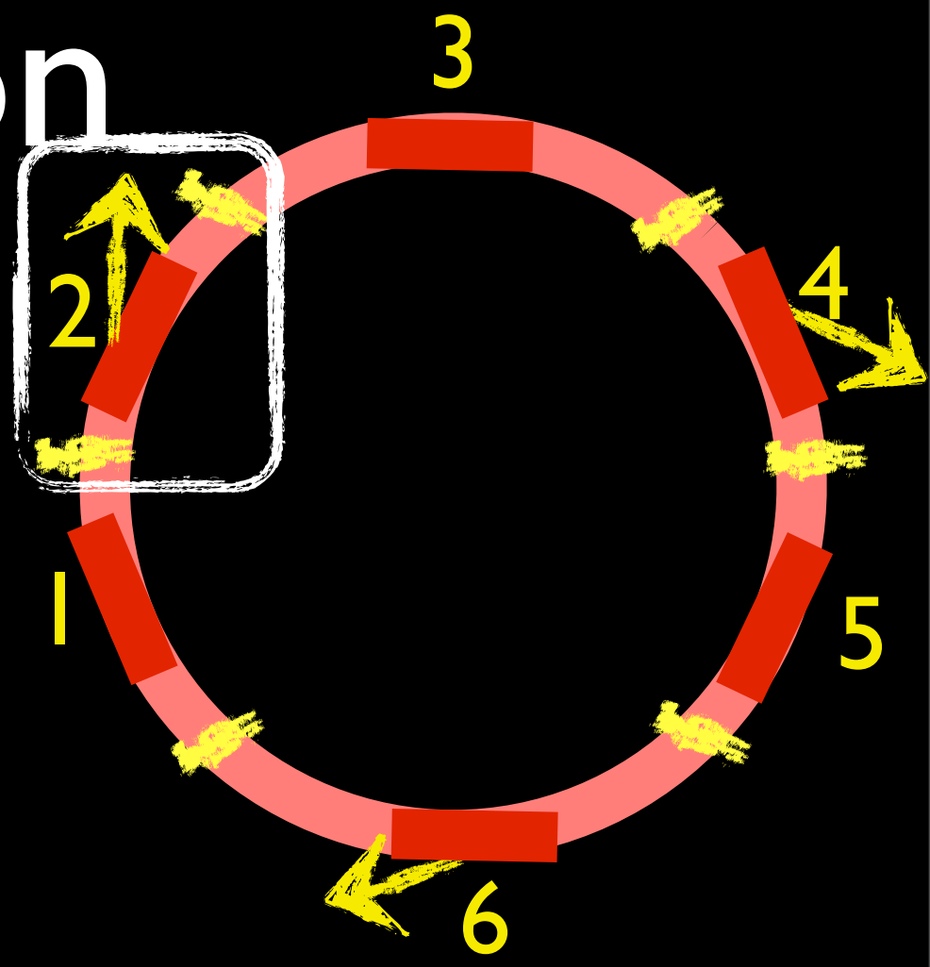
- CENF and LAGUNA require high-intensity and high-energy beam (100 and 400 GeV respectively) to be extracted in **one** machine revolution from LSS2

Introduction



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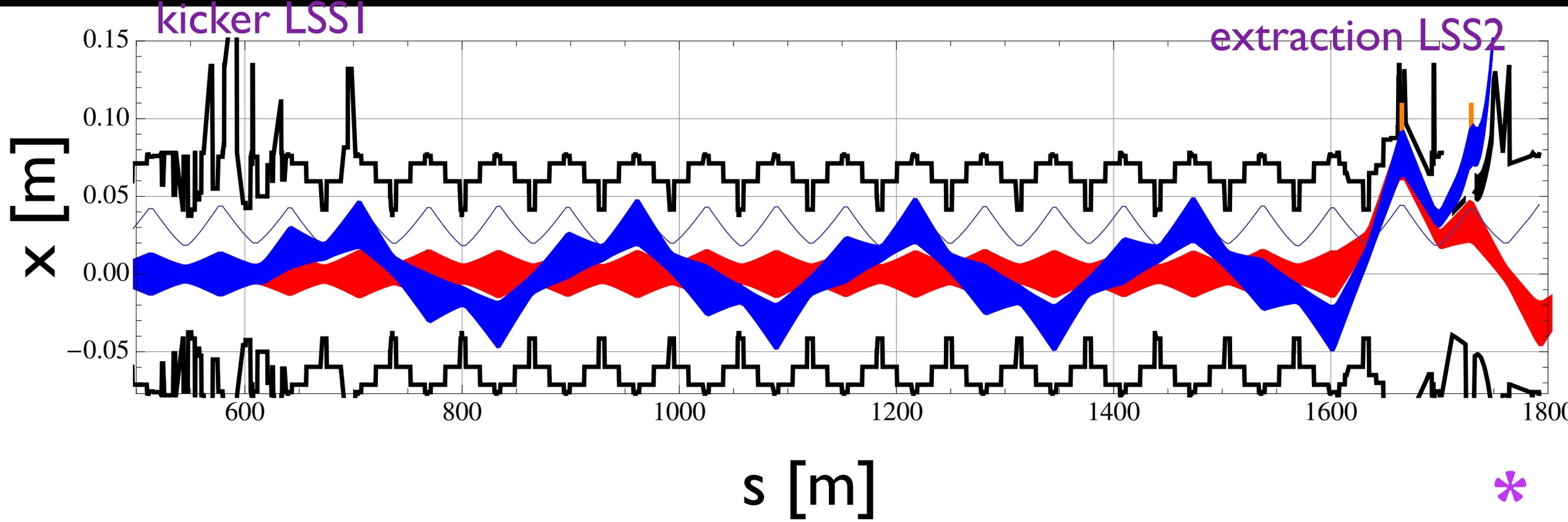
Introduction

- LSS2 always used for slow extraction; no kickers installed in it
- Very difficult to integrate kickers in LSS2; how to extract beam from this LSS?

- New approach for SPS: *non-local fast extraction*: use one of the already installed kickers in another LSS to perform a single-turn extraction from LSS2
- For the 100 GeV study, the injection kicker in LSS1 (MKP) has been chosen

- Simulations completed



circulating beam envelope (bumpers ON, kickers OFF)
extracted beam envelope (bumpers ON, kickers ON)

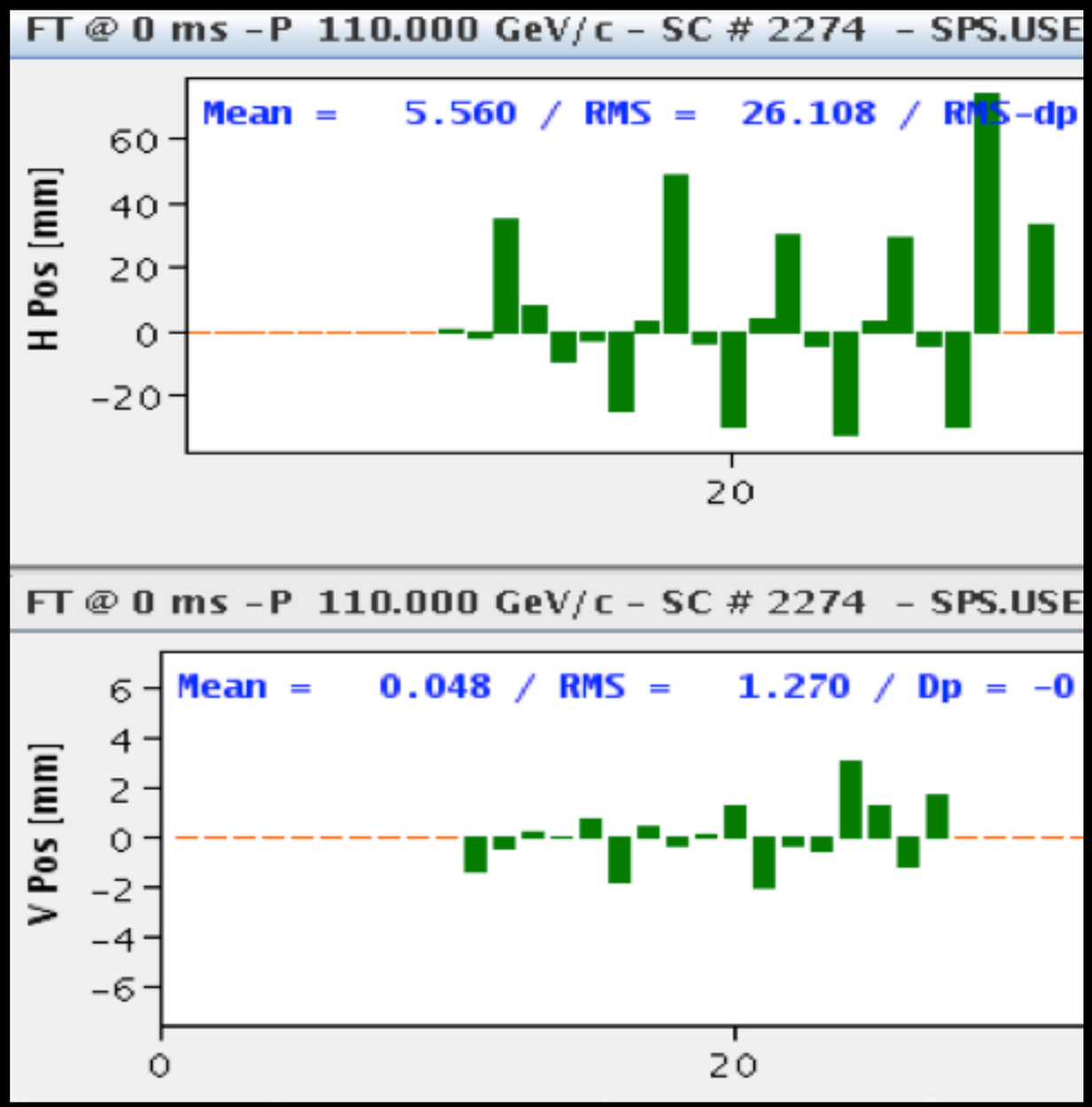
- Machine Development tests (MD) of fast extraction from LSS2 (using kickers of LSS1) done (Sept/Oct2012)**

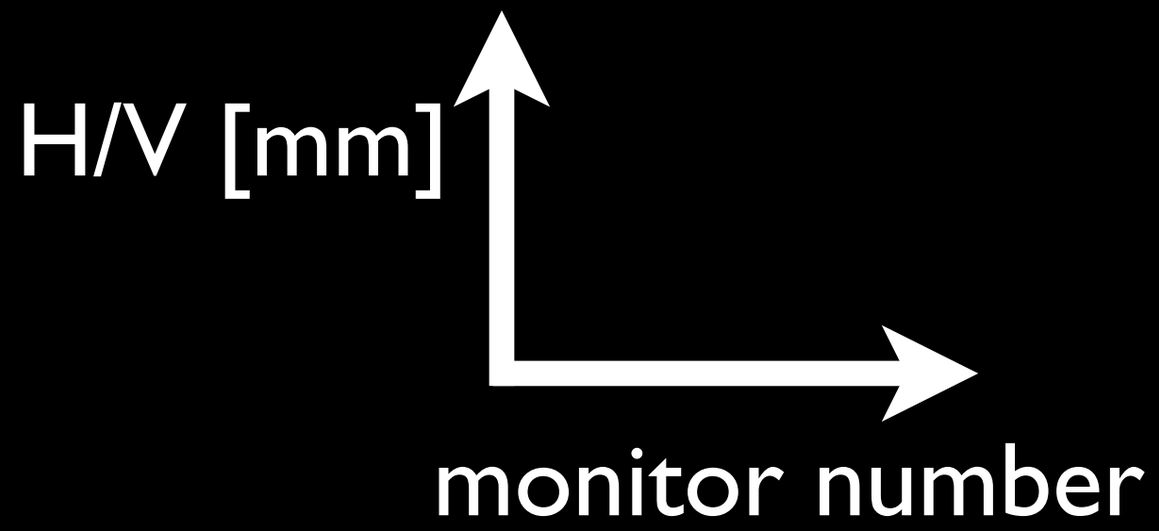
* Simulations from F.Velotti; IPAC13 http://accelconf.web.cern.ch/accelconf/IPAC2013/papers/mopfi050.pdf
** https://espace.cern.ch/be-dep/MSWG/Meetings%202012.aspx; SPS LSS2 fast extraction for neutrino beams

Introduction

- Since the kickers are H the behaviour of the beam in the V-direction should remain unchanged after the kickers were switched ON. So:
  - Subtraction of **H** trajectory_whenKickersON minus trajectory_whenKickersOFF should be **non-zero**
  - Subtraction of **V** trajectory_whenKickersON minus trajectory_whenKickersOFF should be **zero**

- Snapshot during MD (18Sept2012) given by BT team





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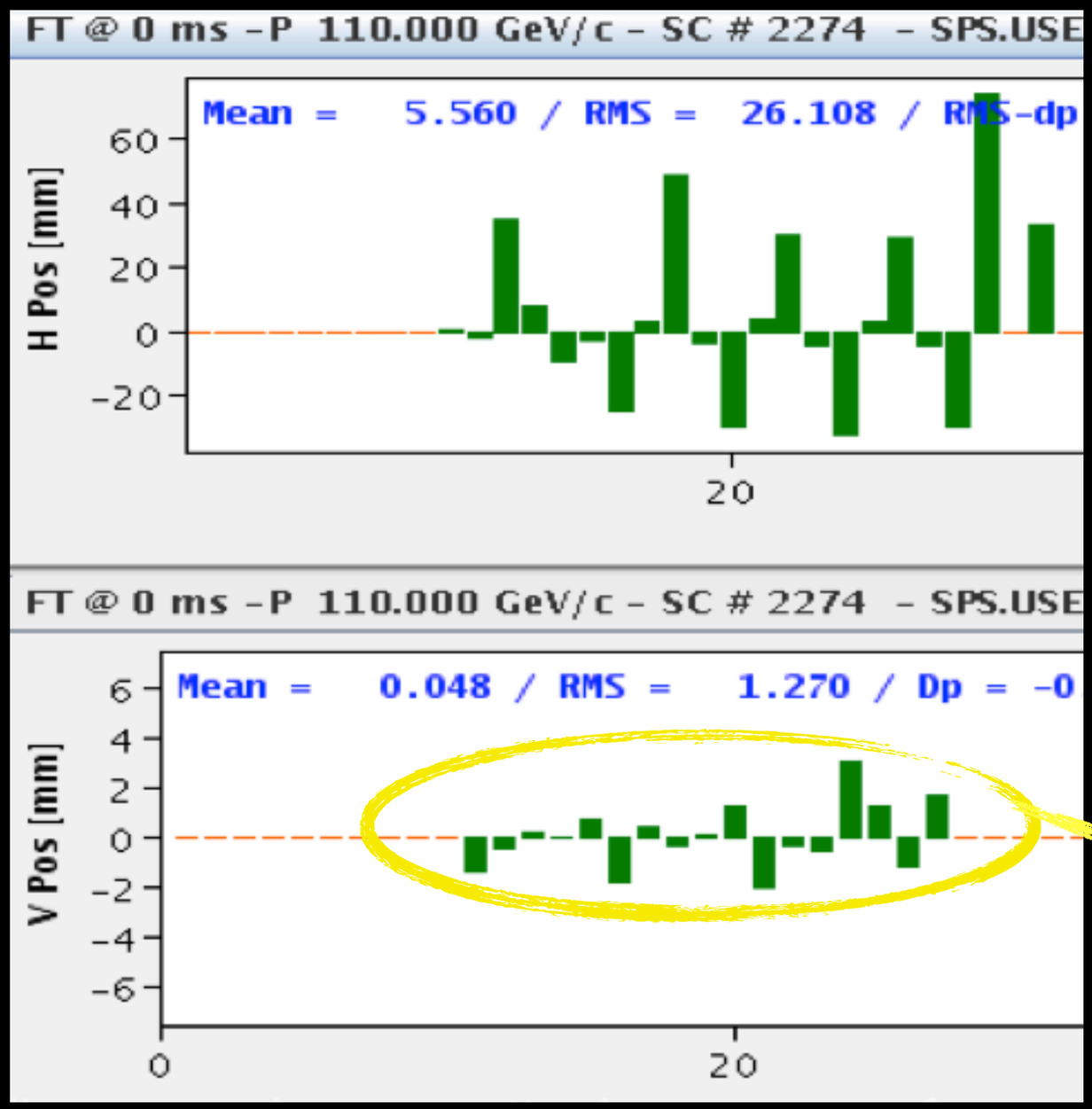

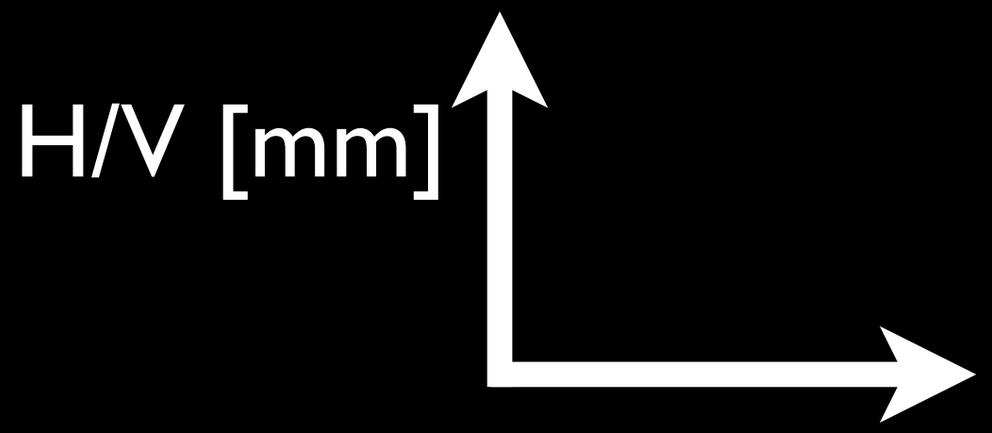

this should be zero. Since it's not coupling is implied between the H and V direction

"subtraction of trajectory when kickers were ON minus trajectory when kickers were OFF"

Coupling?

- Is there coupling between the H and V direction?
- What can create this coupling?
  - Quadrupole tilts
  - Shifted sextupoles in y (gives skewed quadrupole magnetic field component)

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- What can create this coupling?
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Reproduce the coupling using MAD-X and PTC. Understand what creates it

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Need trajectories from LSS1 to LSS2 when kickers are ON and OFF to get the subtraction plot

How can coupling be reproduced?

Same closed orbit as the one obtained during MD can be reproduced using MAD-X and the CORRECT method

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Need trajectories from LSS1 to LSS2 when kickers are ON and OFF to get the subtraction plot

How can coupling be reproduced?

CORRECT method finds necessary correctors that reproduce closed orbit of MD. When applied they should also reproduce trajectory when PTC_Trackline is used

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We don't have trajectory data. We have closed orbit data

Trajectories can be obtained with PTC_Trackline

Need trajectories from LSS1 to LSS2 when kickers are ON and OFF to get the subtraction plot

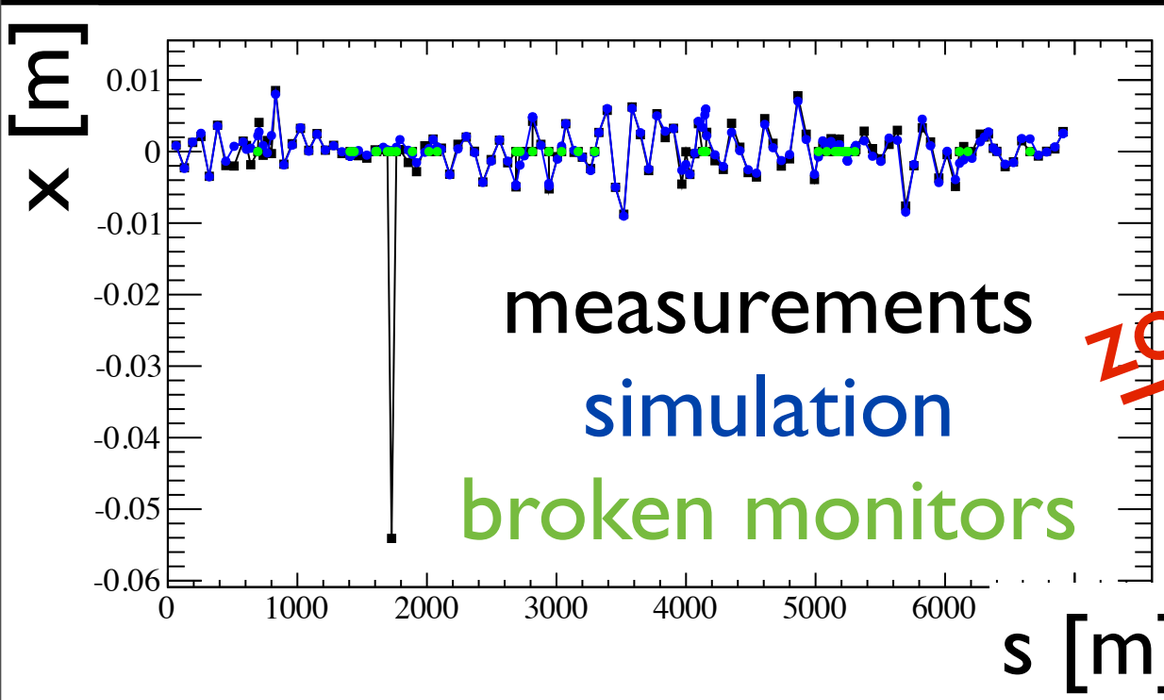
Steps followed in order to reproduce the coupling snapshot

a. **Using MAD-X:**

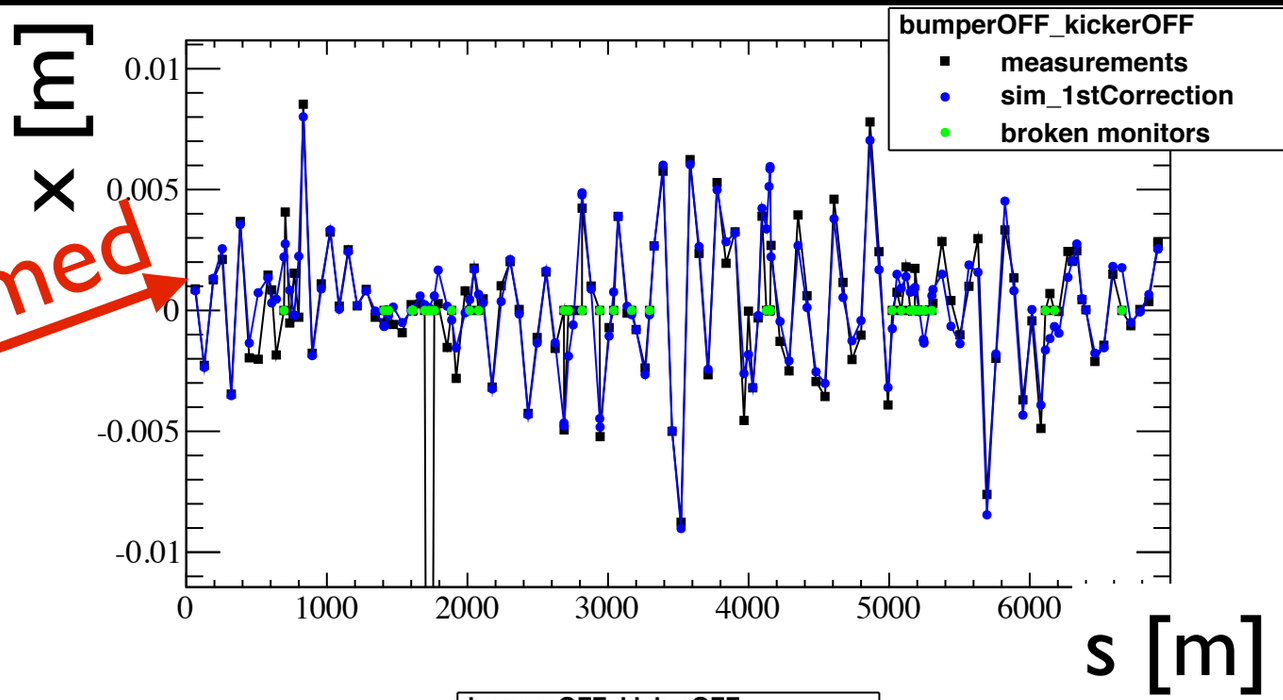
a.a. find what correctors are needed in order to match/reproduce the CO measurement when bumpers and kickers are OFF; apply these corrections

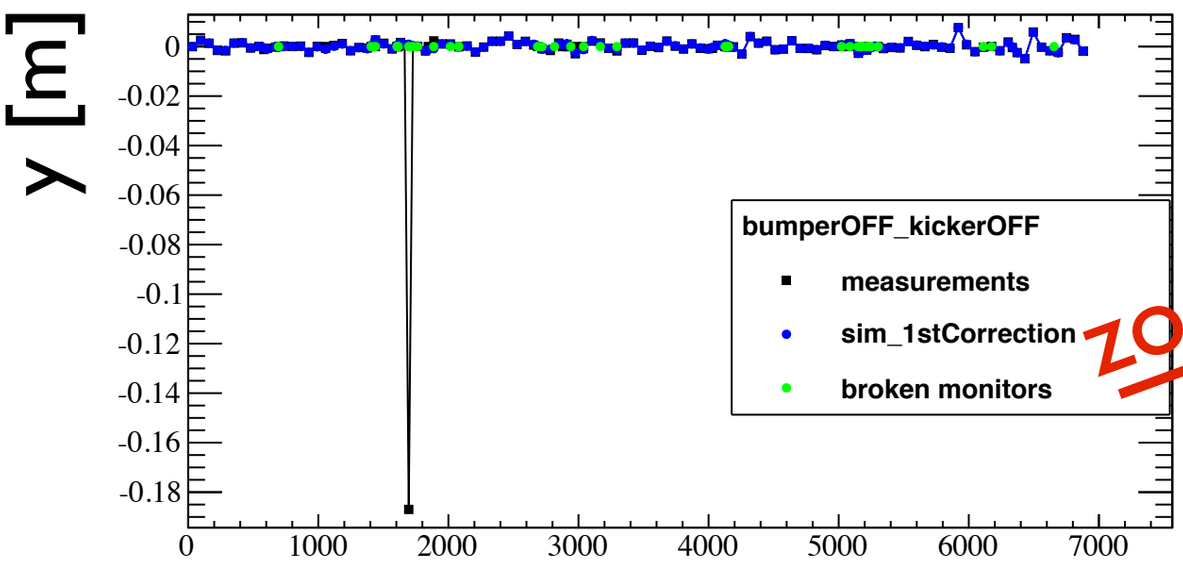
bumpers OFF
kickers OFF

70* correctors are used
Δrms(measurements-madx)=O(-5 m) in H and V



zoomed





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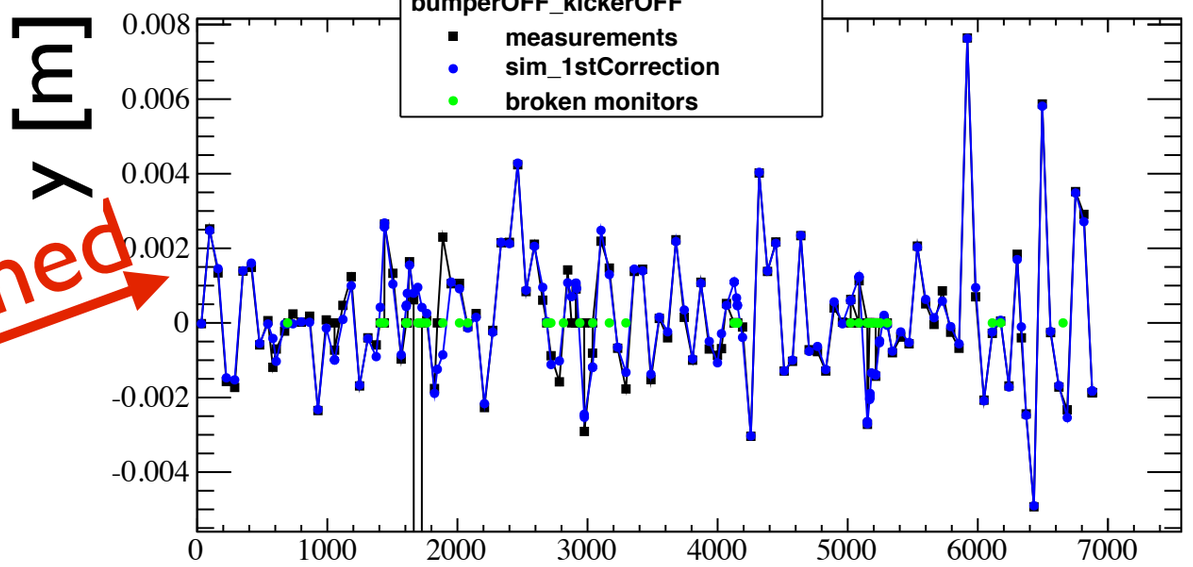


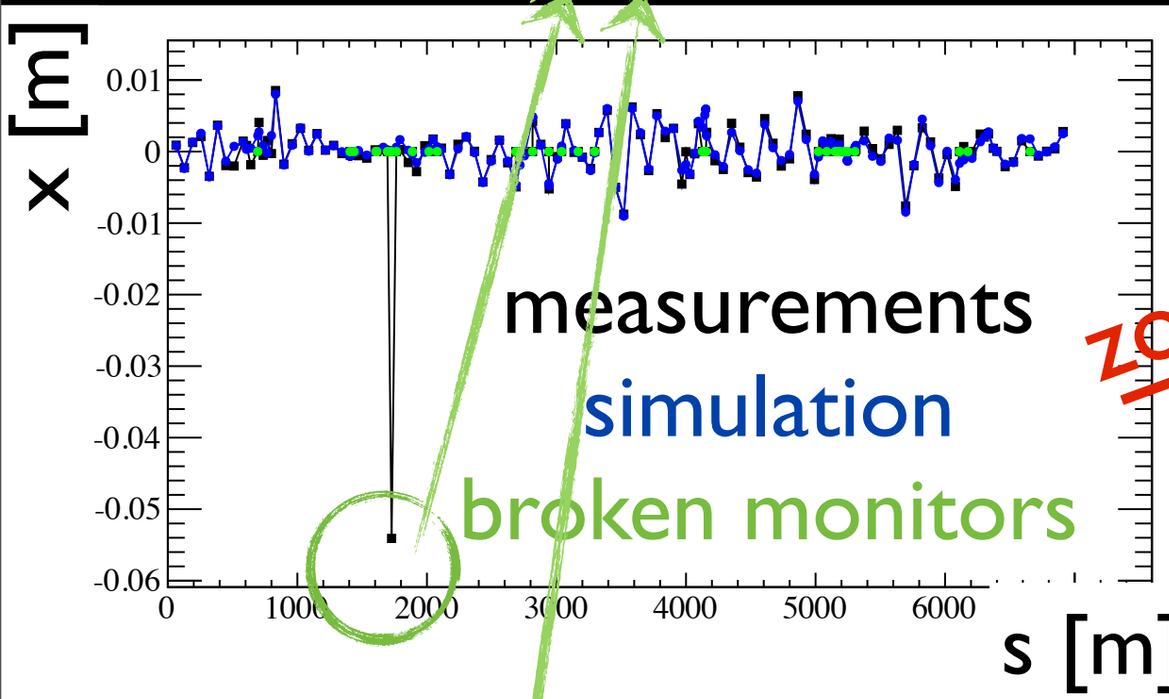
very good agreement between madx and measurements

bumpers OFF
kickers OFF

70* correctors are used

Δrms(measurements-madx)=O(-5 m) in H and V

no worries, broken monitor



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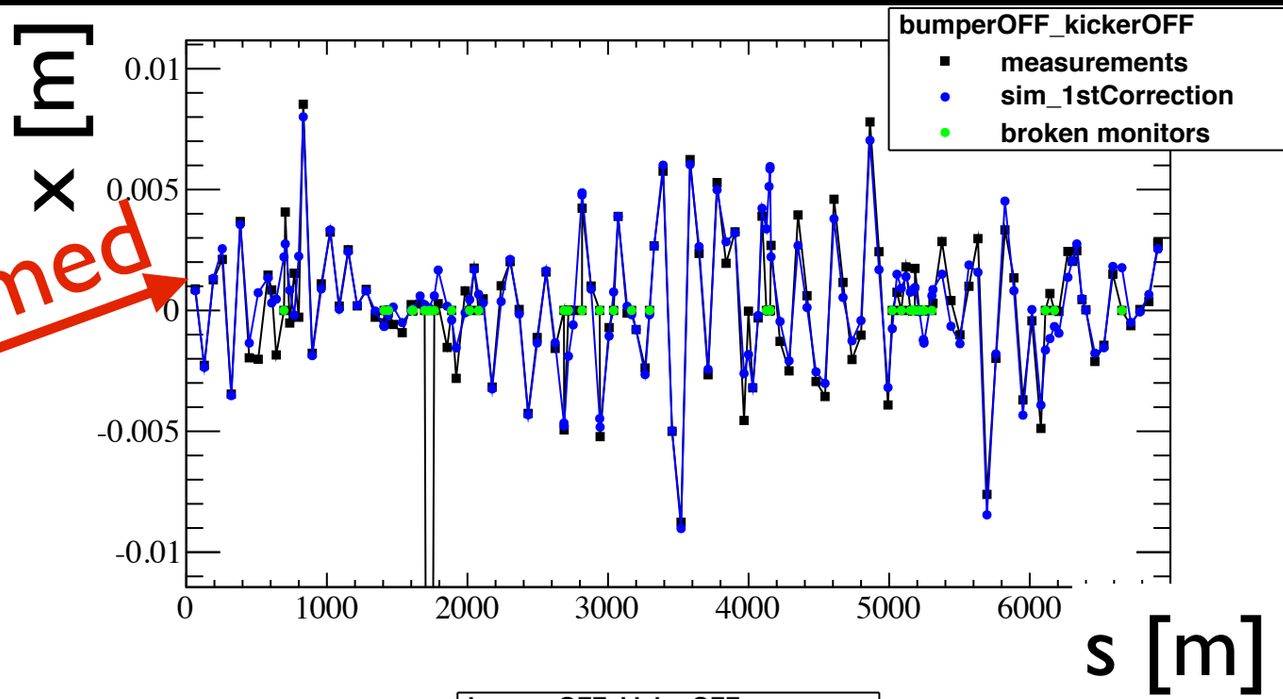

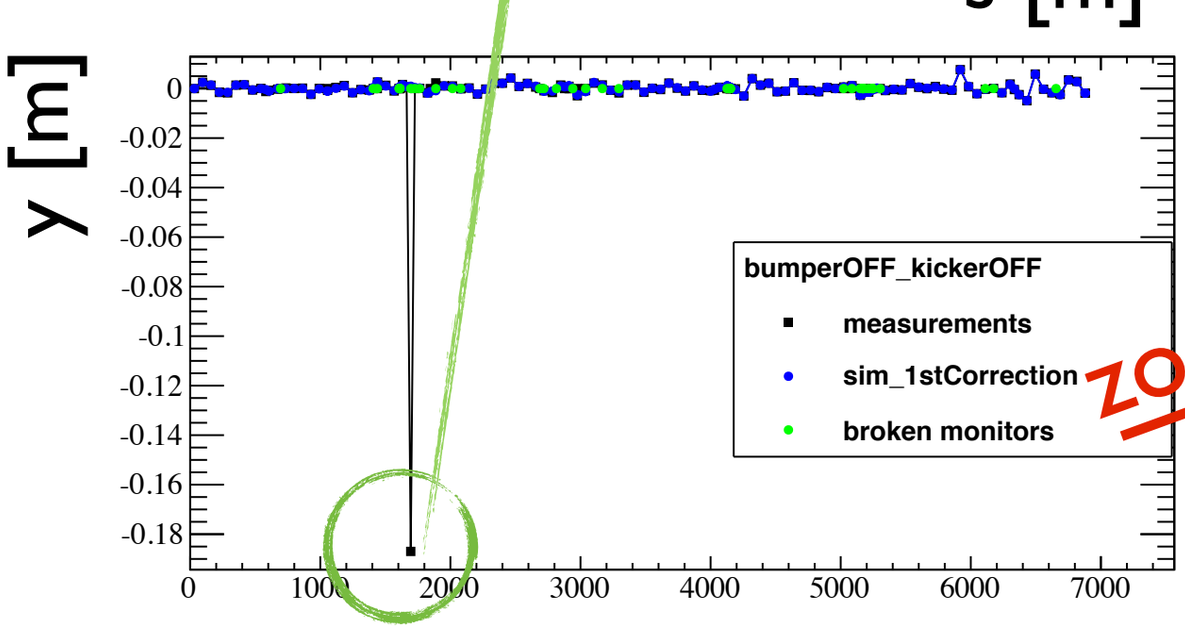

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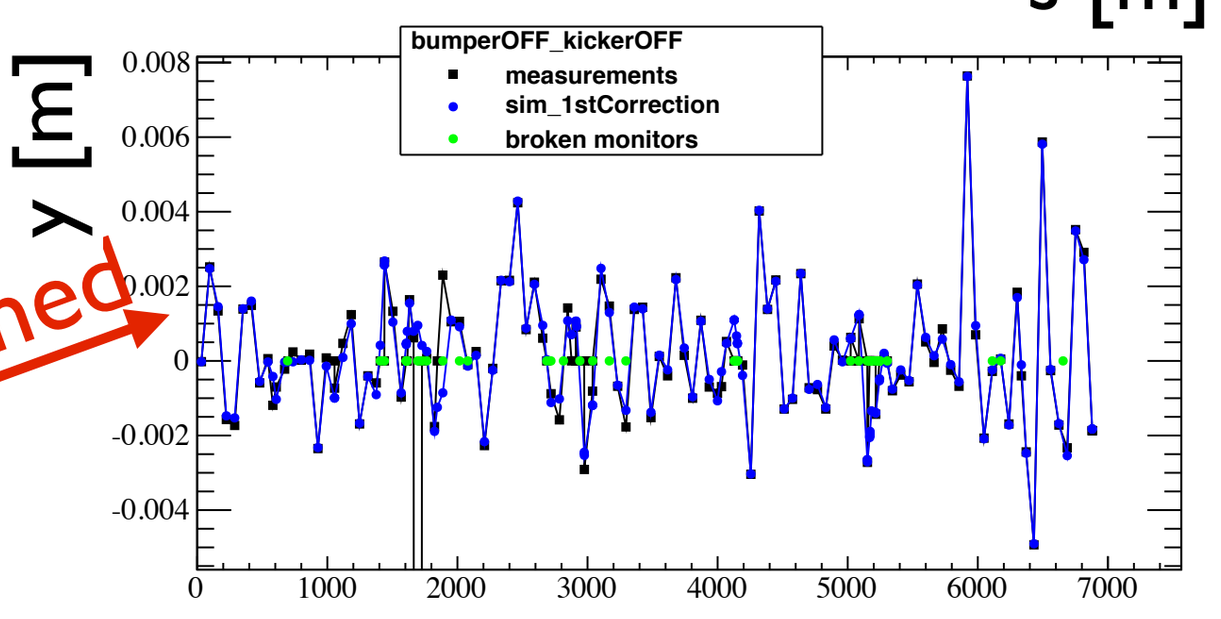

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IMPORTANT NOTE

- YASP (Yet Another Steering Application) has fewer BPMs than MAD-X. Only those in common were used. The others were set to zero in the target file*
- From the monitors in common, some are broken and were not taken into account during the correction (i.e. those monitors were switched OFF in MAD-X)**

*all BPMs need to be included in the target file otherwise the correction does not work properly. They should be included in s-increasing order (as outputted by MAD-X)

**They were not set to zero in the target file though. To set monitors OFF use command:
USEMONITOR, STATUS=OFF, RANGE="BPA.<numberOfMonitor>";

Number of Correctors

- Number of correctors has not been optimised
- empirical trials: Δrms70 correctors slightly better than 97*

rms target	rms 70	rms 97
0.00248235	0.00256536	0.00264184
|Δrms|	8.30E-05	1.59E-04

*for >97 correctors the twiss file returns back with error (I cannot explain this as nBPM's is >97; interesting to look into).

Steps followed in order to reproduce the coupling snapshot

a. **Using MAD-X:**

a.a. find what correctors are needed in order to match/reproduce the CO measurement when bumpers and kickers are OFF; apply these corrections

a.b. switch ON bumpers. Confirm the same CO as the measurements when bumpers are ON is obtained (i.e. verify the corrections applied in previous step are correct)

Bumpers

Bumper	Strength [rads]	s-position [m]
MPSH.21202	1.63E-06	1534.205
MPLH.21431	3.08E-04	1604.4681
MPNH.21732	3.75E-04	1701.1133
MPLH.21995	1.51E-04	1787.5547
MPLH.22195	-1.56E-04	1851.4998

When these bumpers are switched ON they give 27 mm bump at the entrance of the TPST (extraction channel of LSS2)

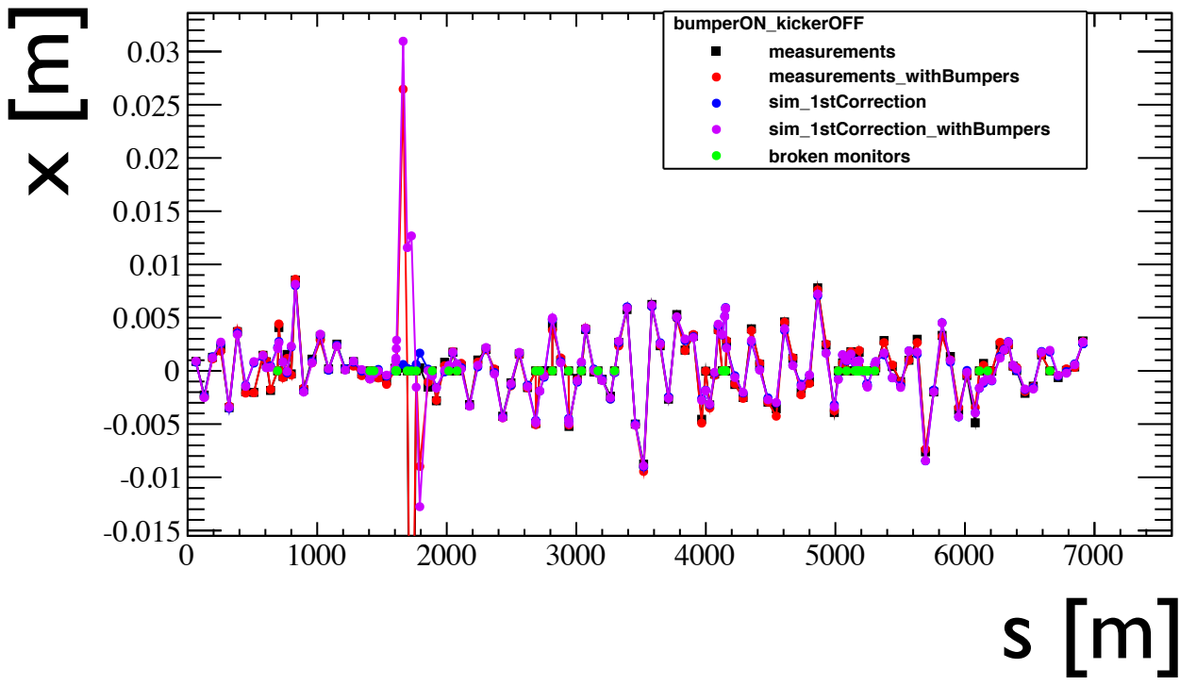
measurements; bumpers OFF

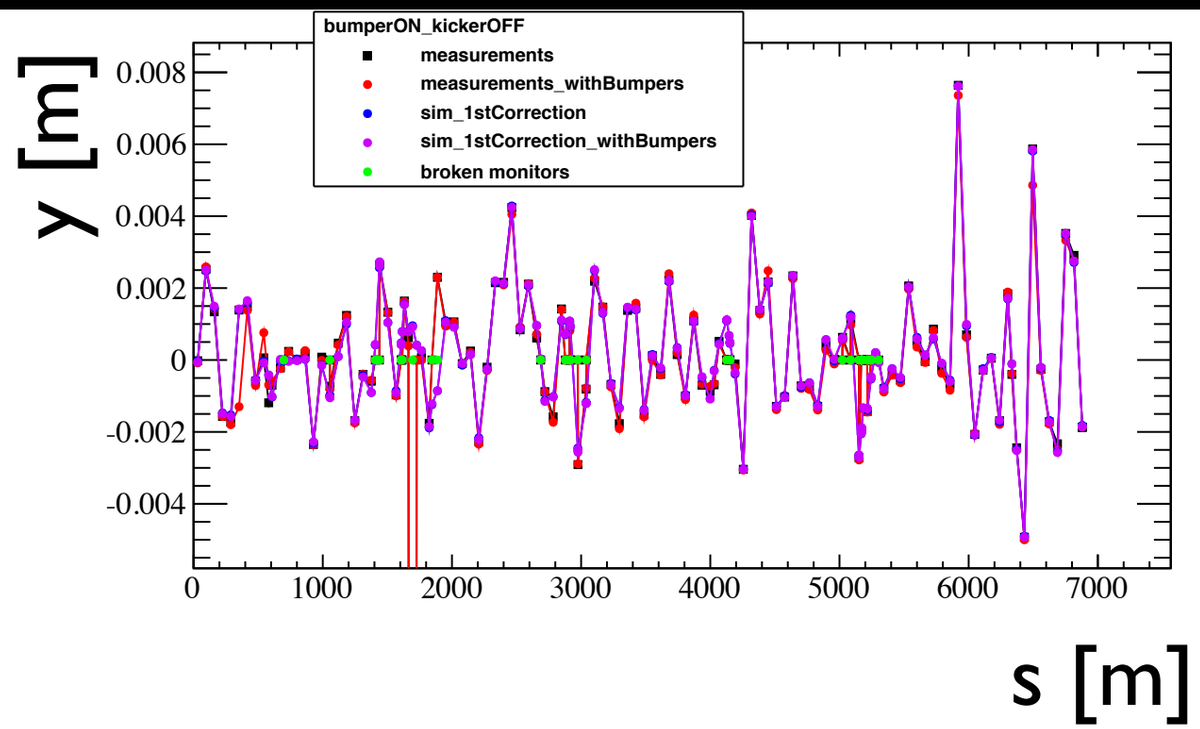
measurements; bumpers ON

simulation; bumpers OFF

simulation; bumpers ON

broken monitors





- very good agreement between MAD-X and measurements (CORRECT command works well); Δrms=O(-5) in H and O(-4) in V*
- before and after bumpers area: CO when bumpers are OFF same as when the bumpers are ON

*when measurements of s=1727.329 m and s= 1695.1633 m are excluded in H and V respectively

Steps followed in order to reproduce the coupling snapshot

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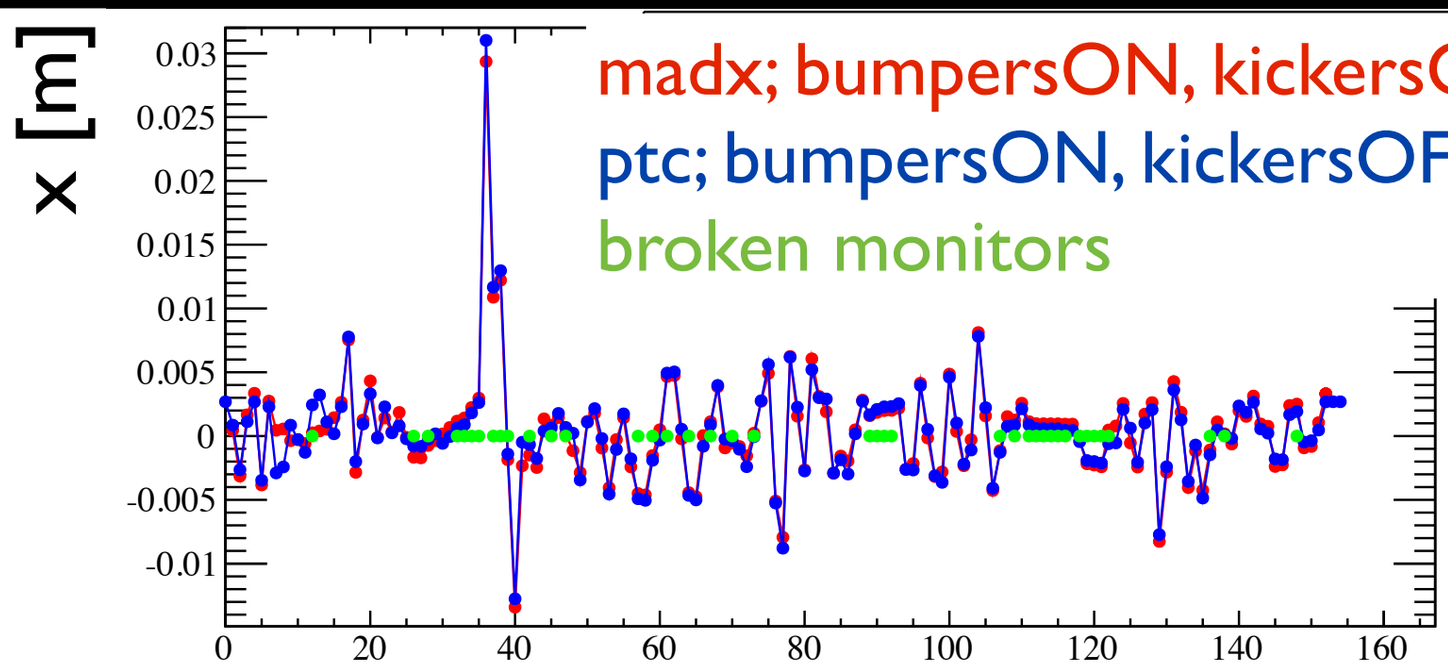
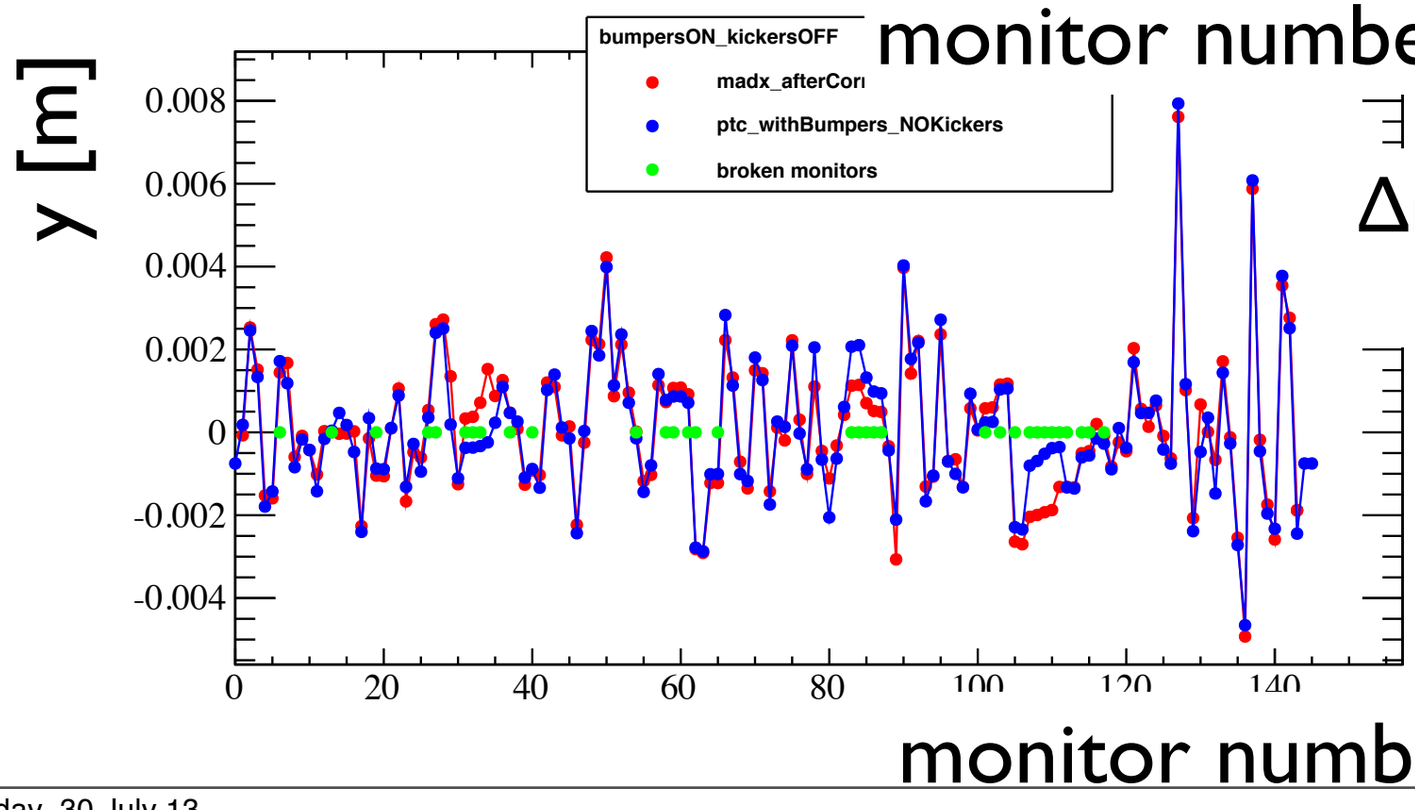
b. **Using PTC_Trackline:**

b.a. get the trajectories when the bumpers are ON and kickers are OFF; confirm they agree with MAD-X

MAD-X vs PTC_Trackline

bumpers ON
kickers OFF





Δrms (MAD-X and PTC_Trackline)
O(-3) in H and O(-6) in V

Steps followed in order to reproduce the coupling snapshot

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b. **Using PTC_Trackline:**

b.a. get the trajectories when the bumpers are ON and kickers are OFF; confirm they agree with MAD-X

b.b. get the trajectories when the bumpers and kickers are ON

c. plot the H/V subtraction (PTC_TRACKLINE_bumpersON_kickersON minus PTC_TRACKLINE_bumpersON_kickersOFF)

d. try to reproduce order of magnitude of coupling by rotating the quadrupoles (starting from the ones after the kickers)

Switching ON the LSS1 kickers

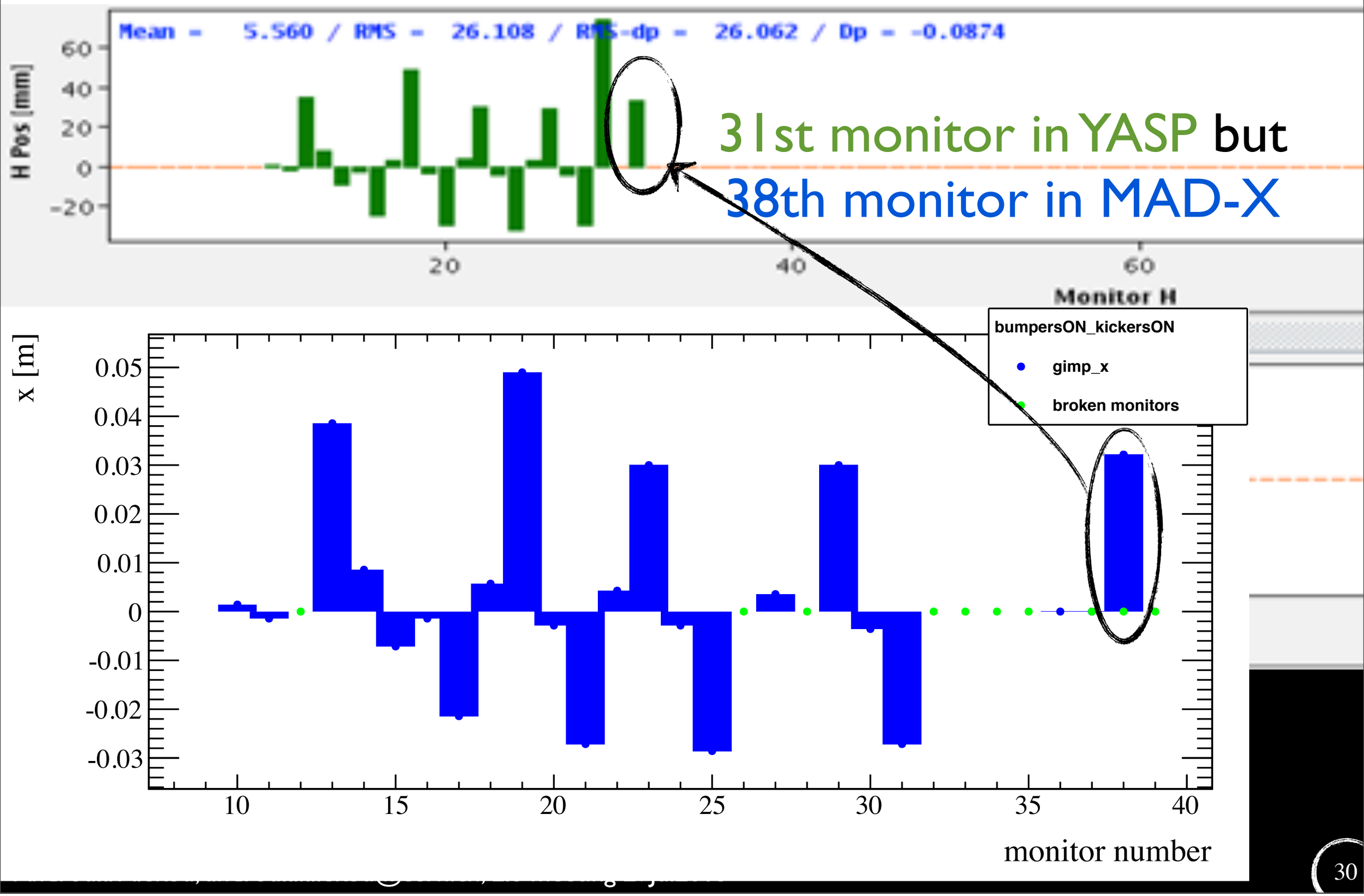
Kicker	Strength [rads]	s-position [m]
MKPA.11931	0.000255417	613.3839
MKPA.11936	0.000255417	617.0059
MKPC.11952	0.000102167	619.8064

Using GIMP

- There were no data saved for when the kickers were turned ON
- All we have is a snapshot that "shows the V-trajectory subtraction" (kickers ON minus kickers OFF)
- Using GIMP I found the snapshot's coordinates
- **Important**: the monitors of MAD-X and YASP are not 1-to-1 (MAD-X has more monitors)
- A "translation" is needed

example of “translated” monitors

subtraction of H trajectories (kickers ON minus kickers OFF)



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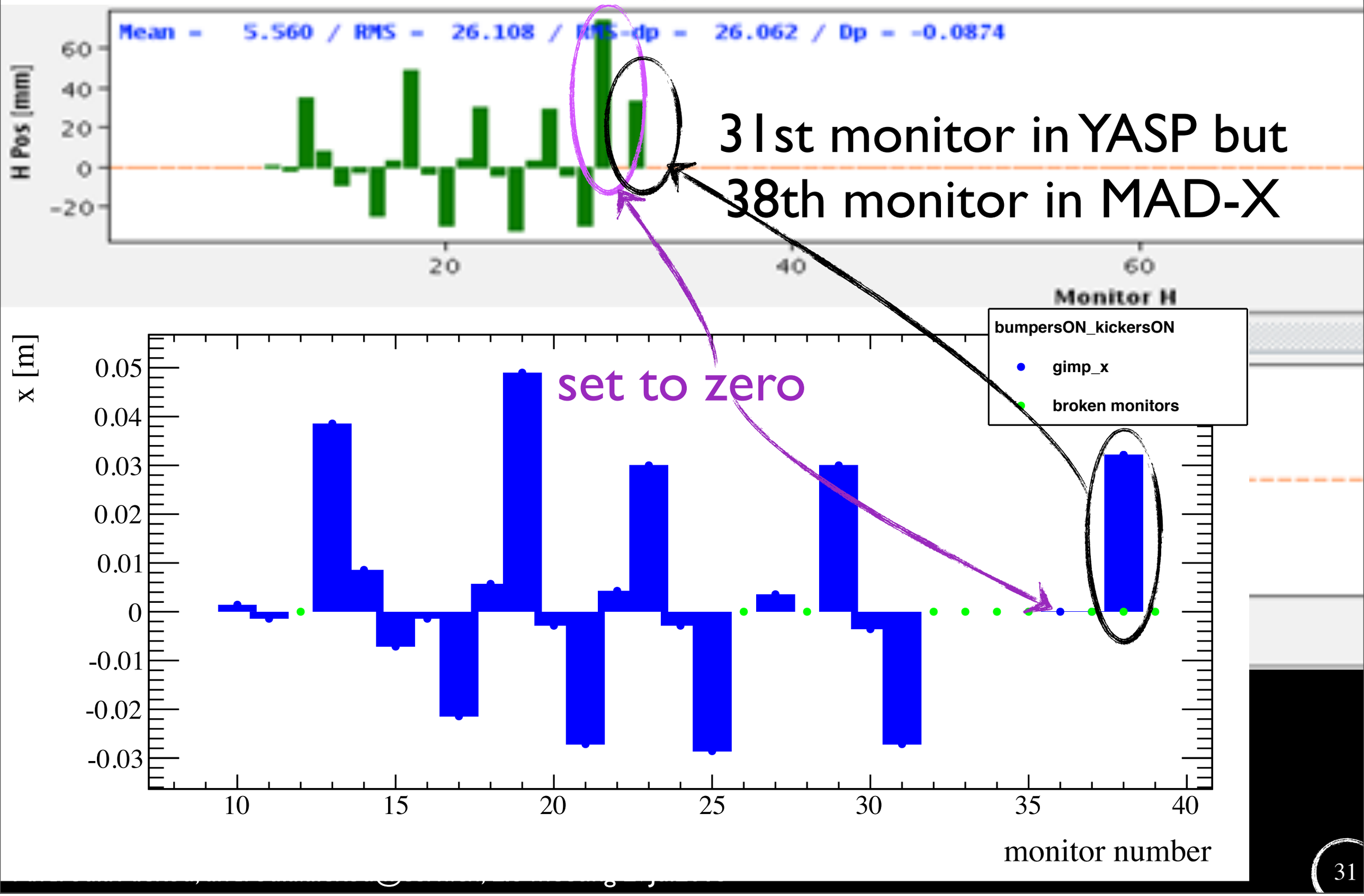
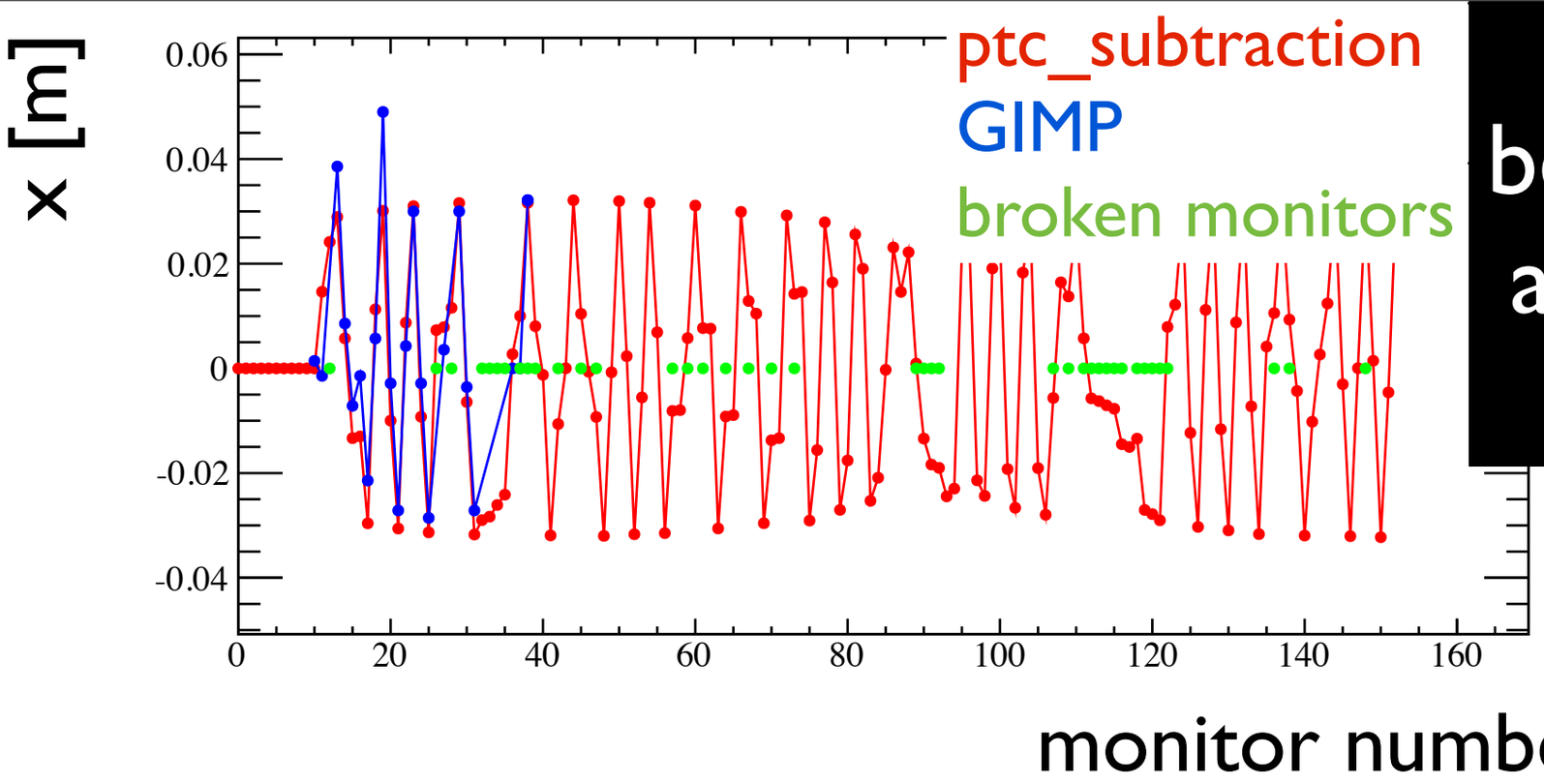
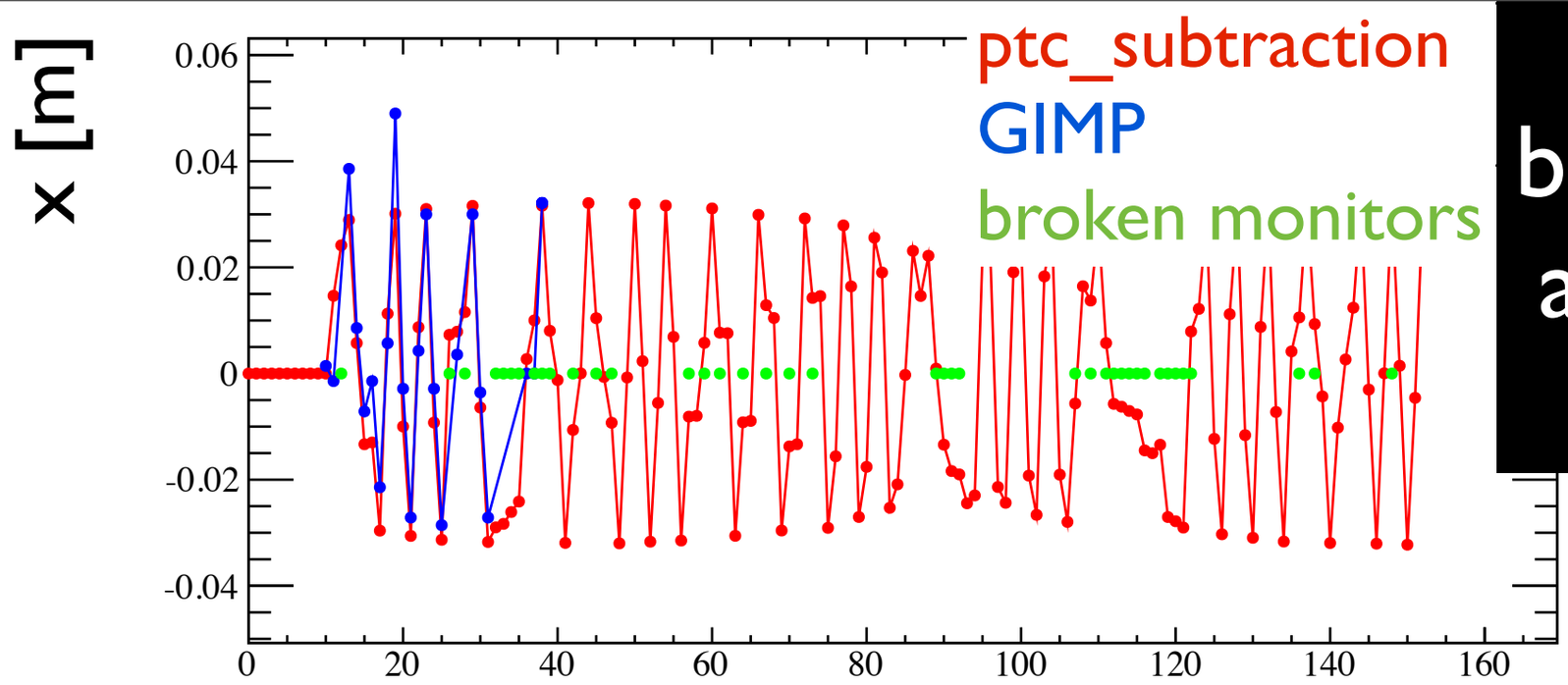




Good agreement between GIMP (data approximation) and PTC_subtraction



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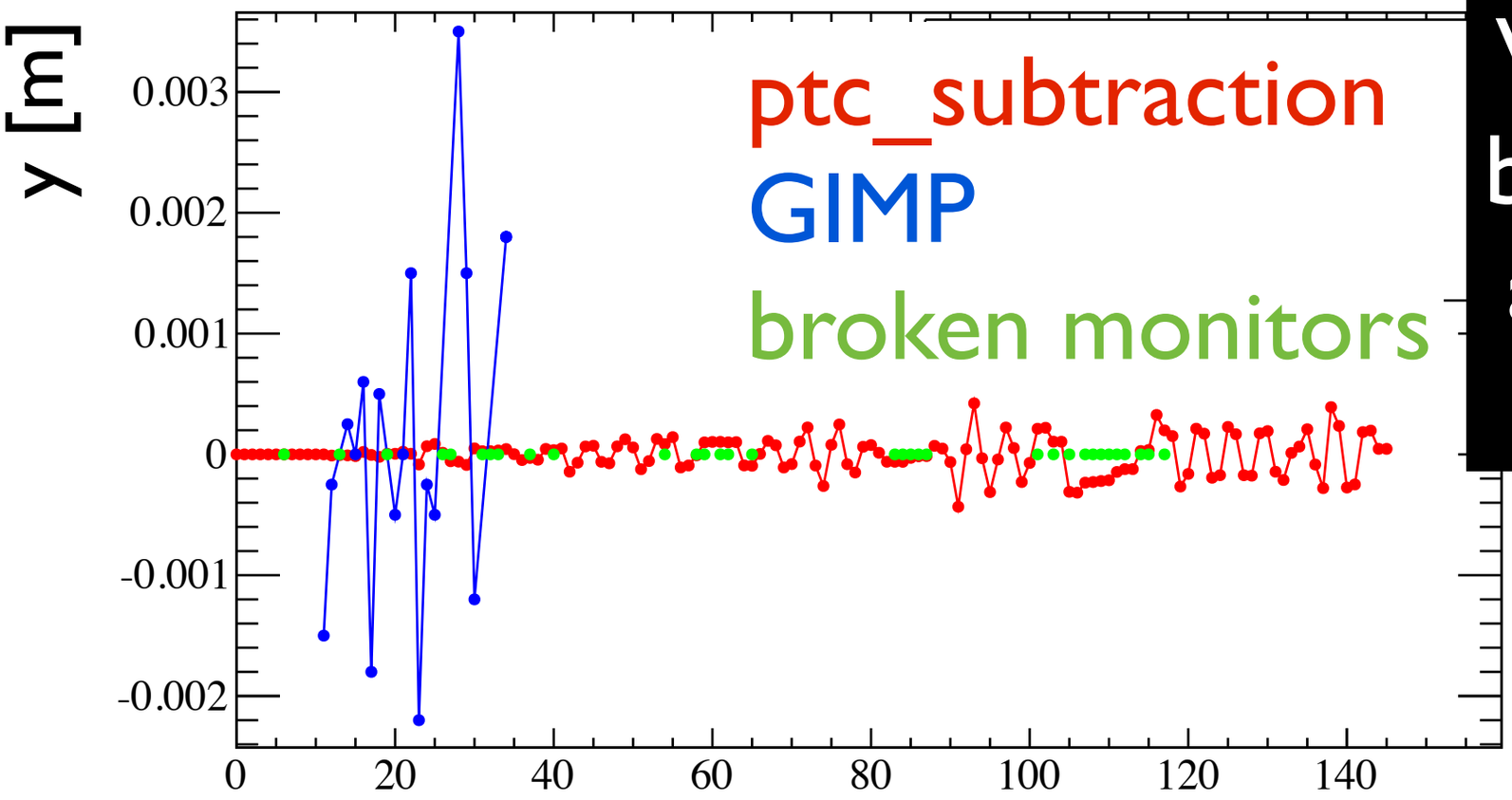
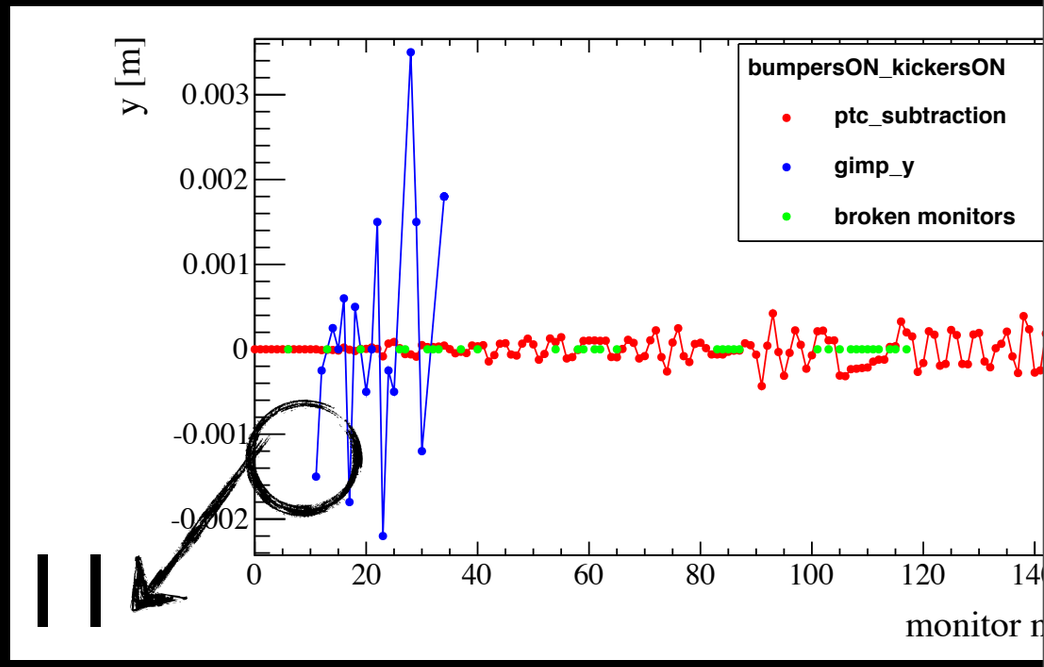


Very bad agreement between GIMP (data approximation) and PTC_subtraction

...Why?

Realising something goes wrong

- "Coupling" starts from monitor 11
- This means the "coupling" is due to a rotation of quadrupole QFA.11810 (closest element (quadrupole/sextupole) to monitor 11 from the left)



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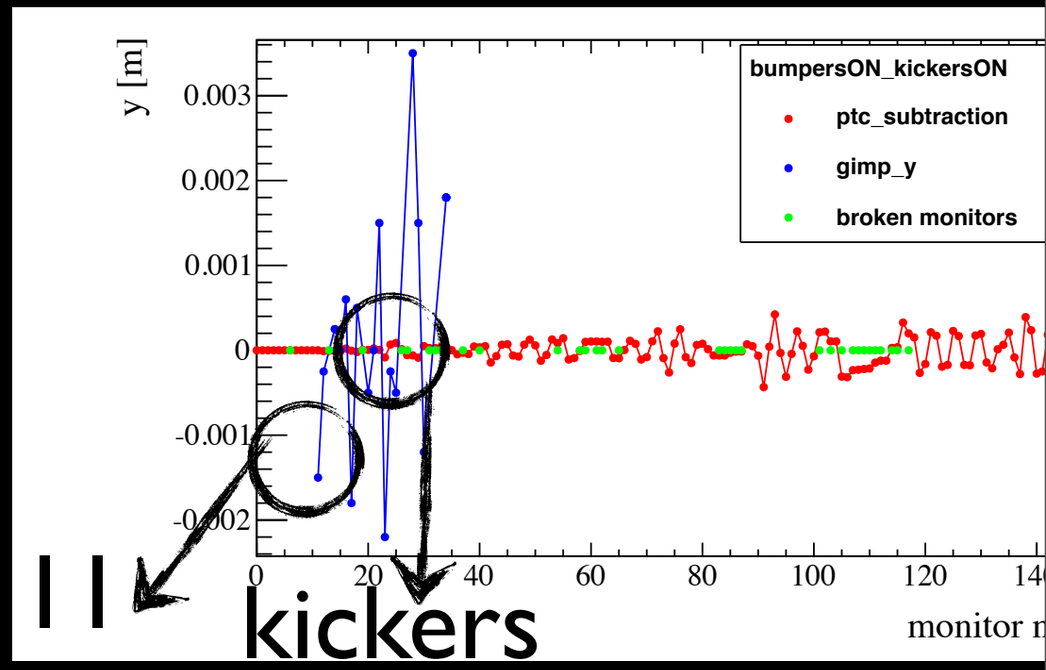

- ...But QFA.11810 is at s=577.5012 m, i.e. **before** the first kicker (MKPA.11931, s@613.3839 m)
- ...And in order to see coupling, the rotated quadrupole or shifted sextupole should be after the kicker

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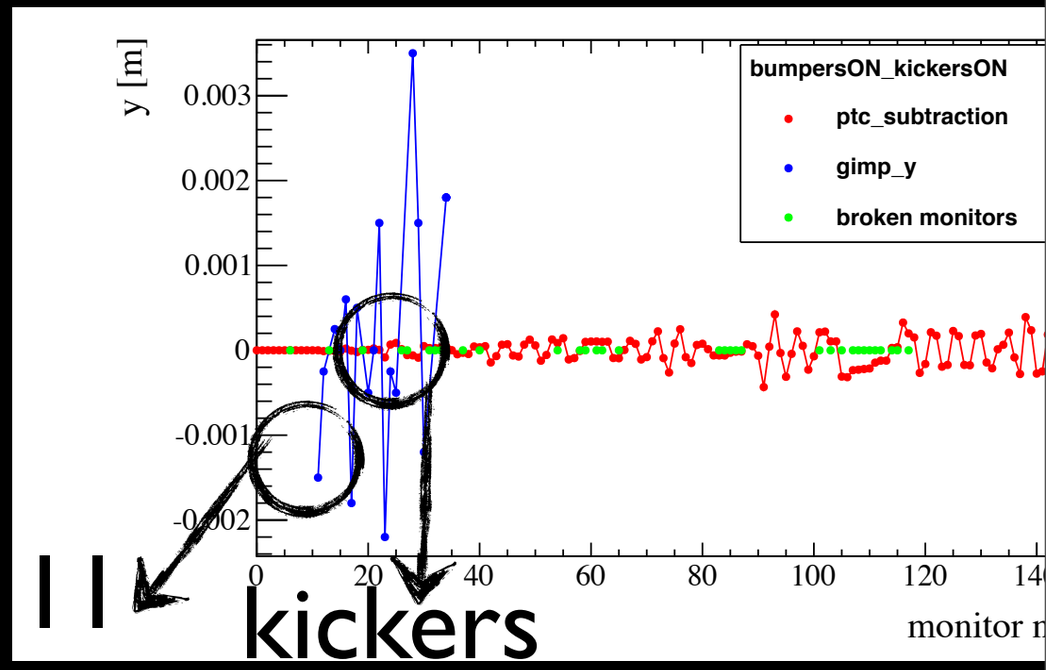

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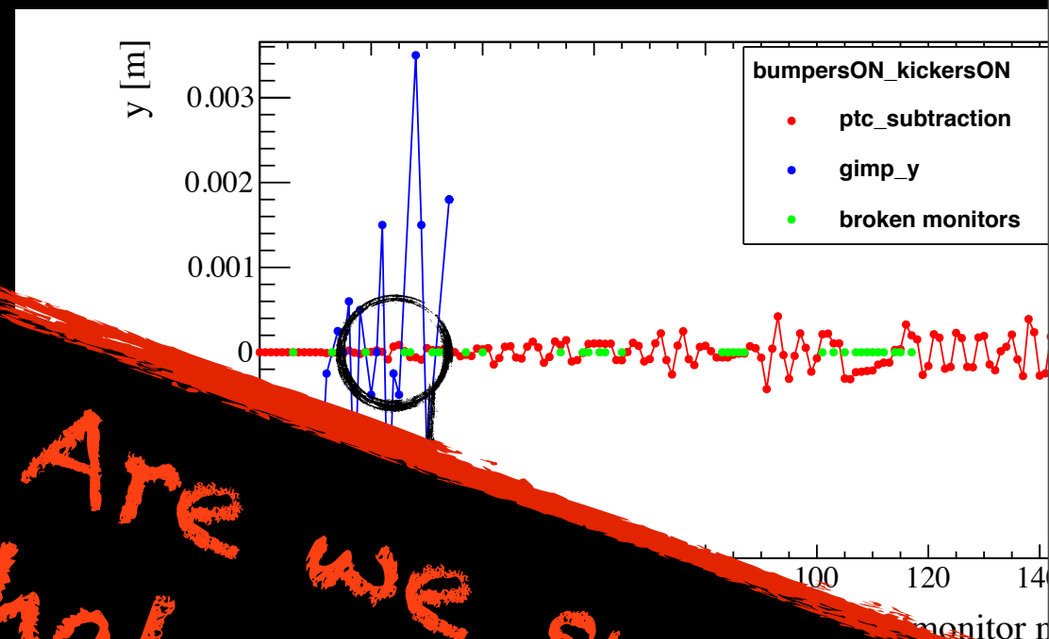
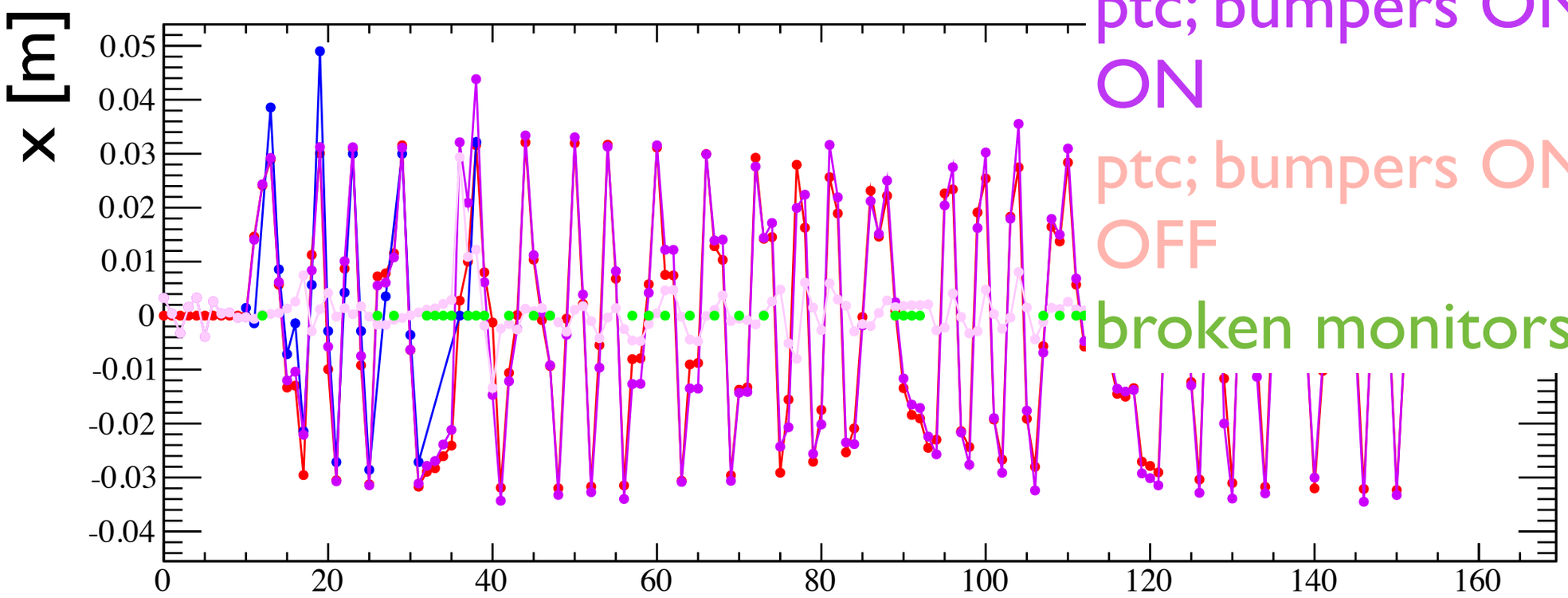
- This means the "coupling" is due to a rotation of quadrupole QFA.11810 (closest element (quadrupole/sextupole) to monitor 11 from the left)
- ...But QFA.11810 is at s=57
  i.e. **before** the first kicke
  11931, s@613.3839 m)
- ...And in order to see coupling, the rotated quadrupole or shifted sextupole should be after the kicker





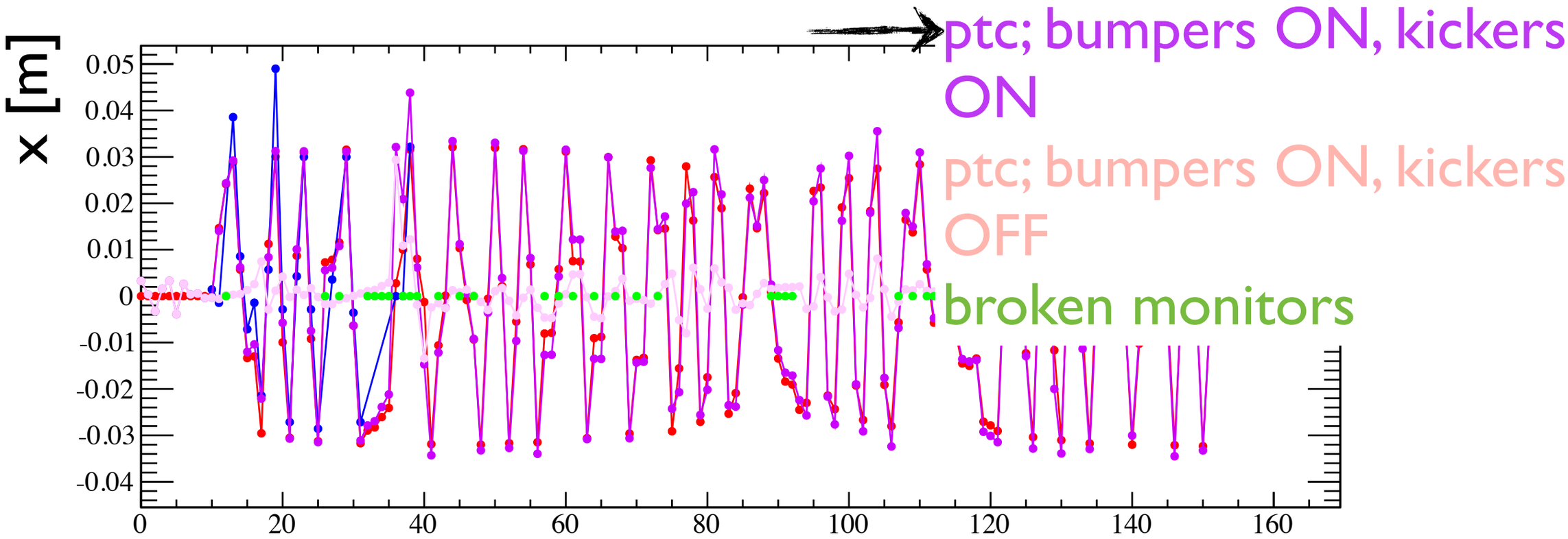
ptc_subtraction

GIMP

ptc; bumpers ON, kickers ON

ptc; bumpers ON, kickers OFF

broken monitors



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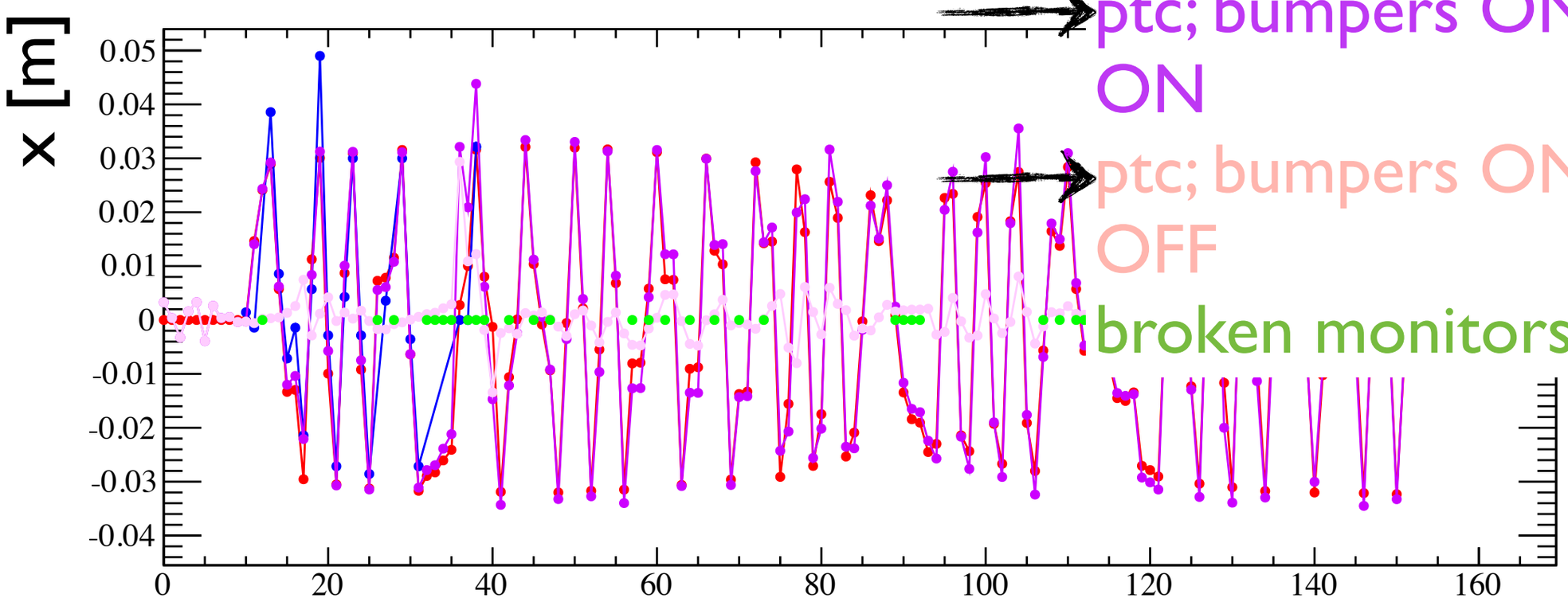

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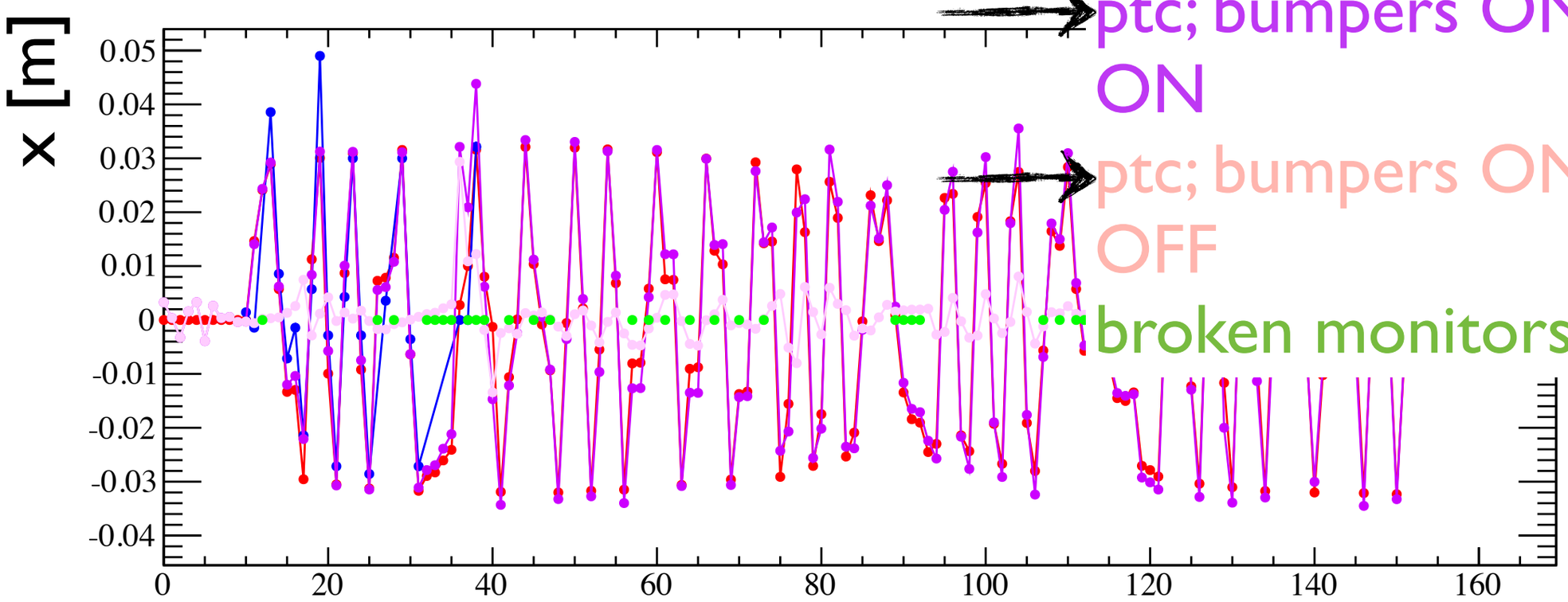

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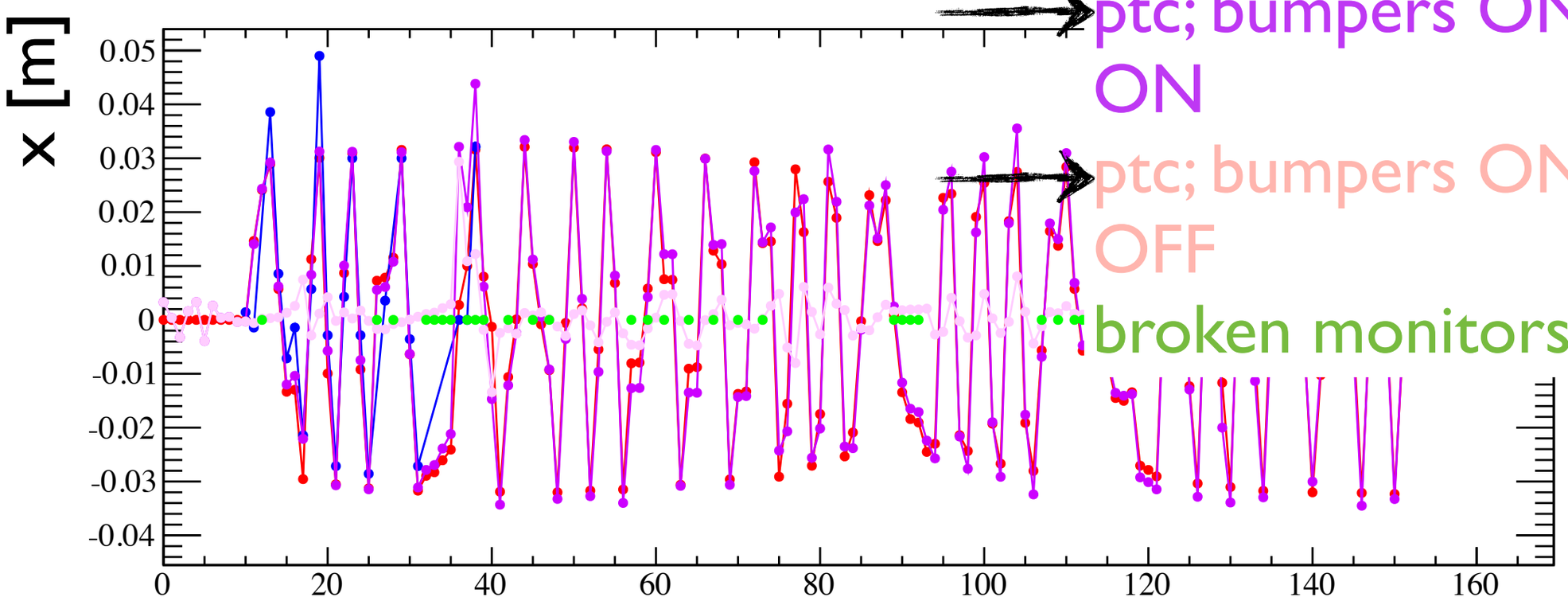

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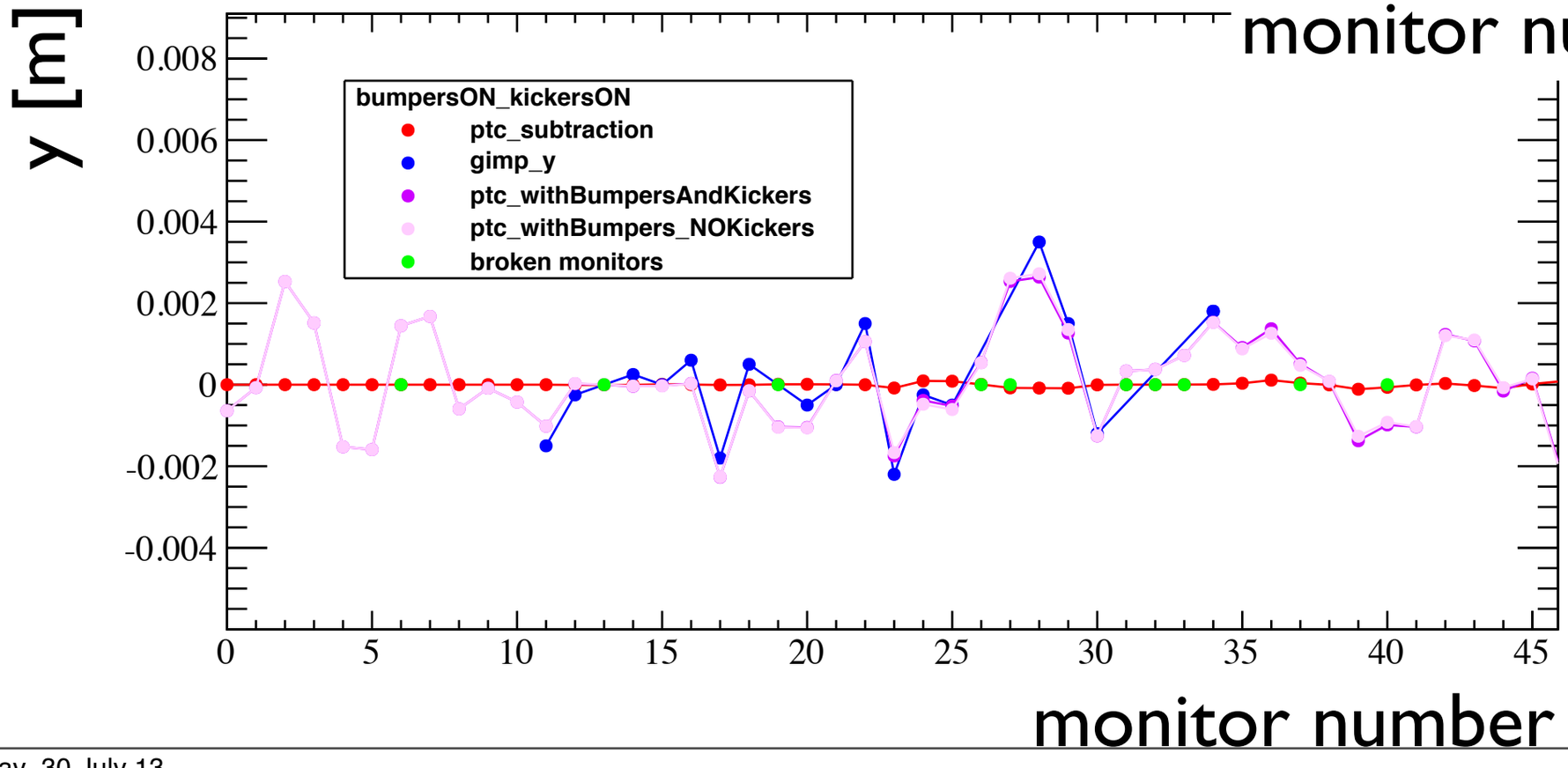
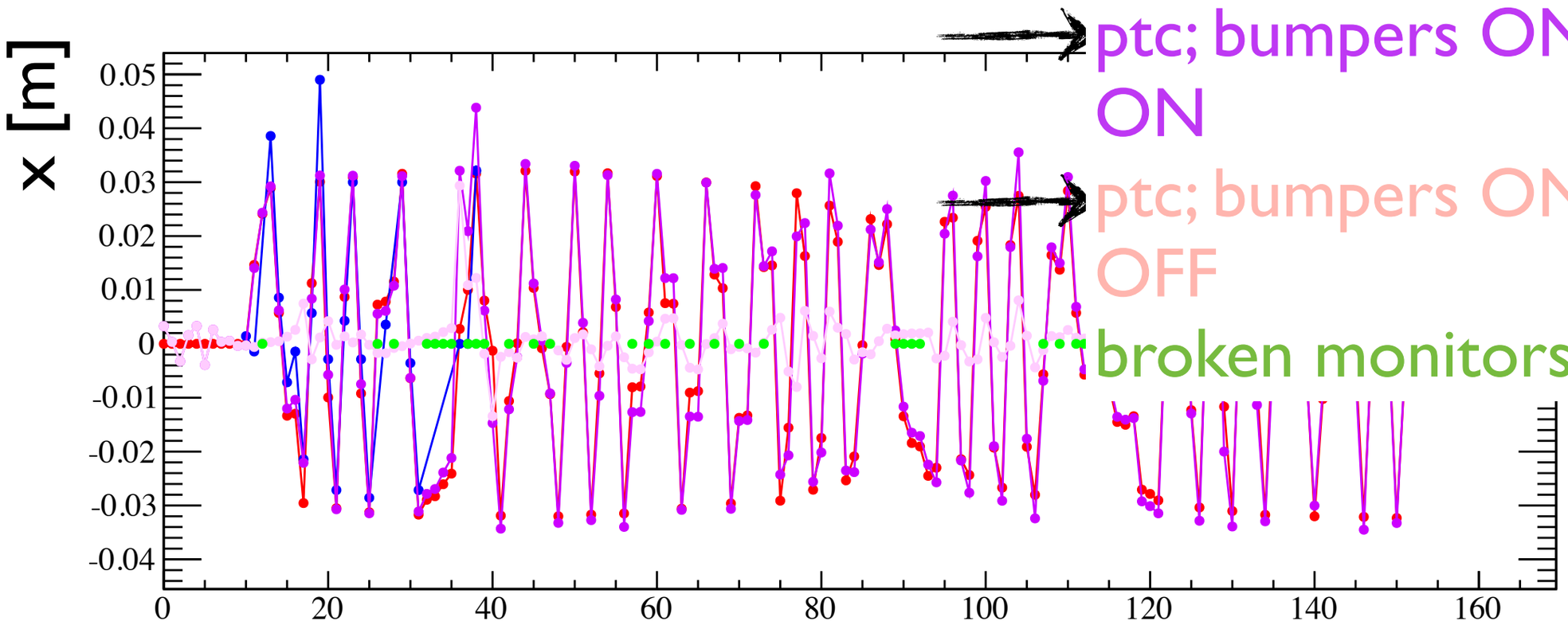
ptc; bumpers ON, kickers OFF

broken monitors





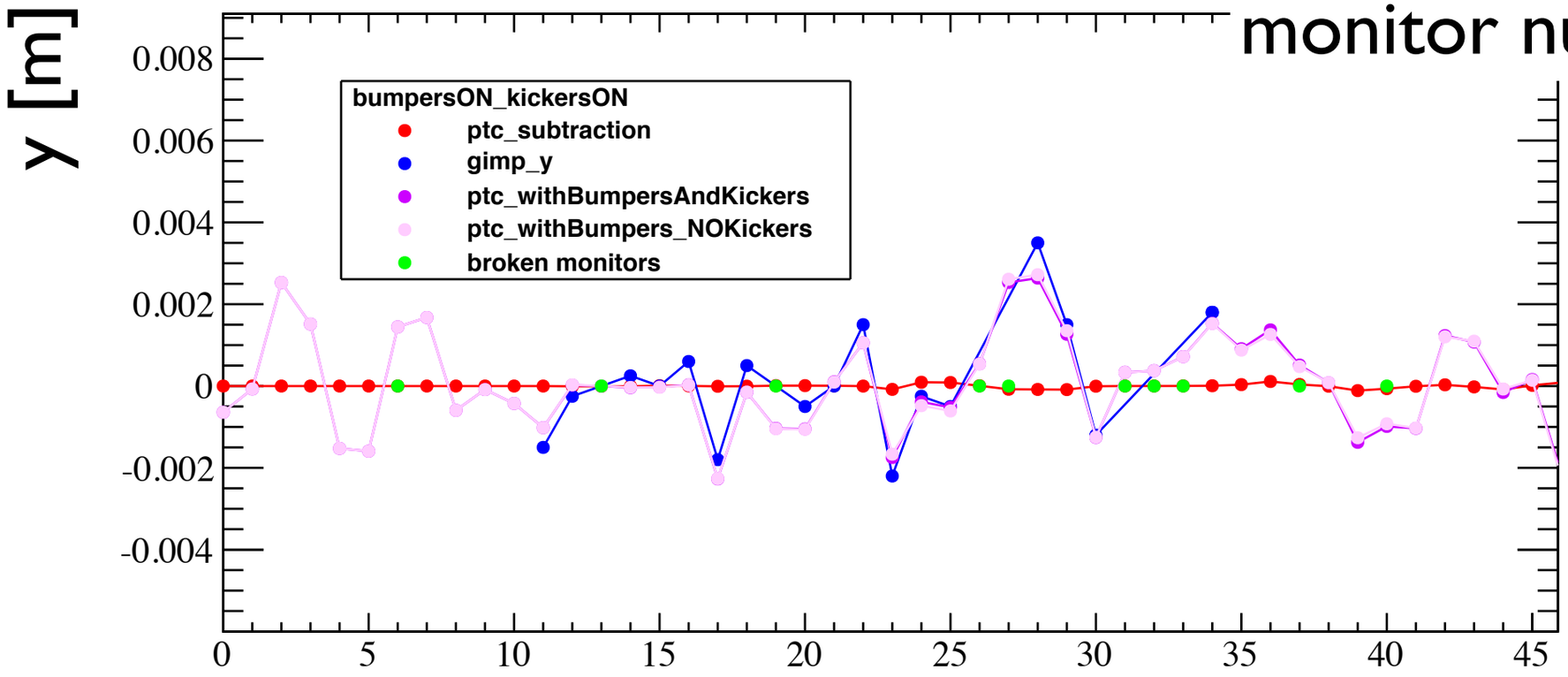
ptc_subtraction

GIMP

ptc; bumpers ON, kickers ON

ptc; bumpers ON, kickers OFF

broken monitors



tor number

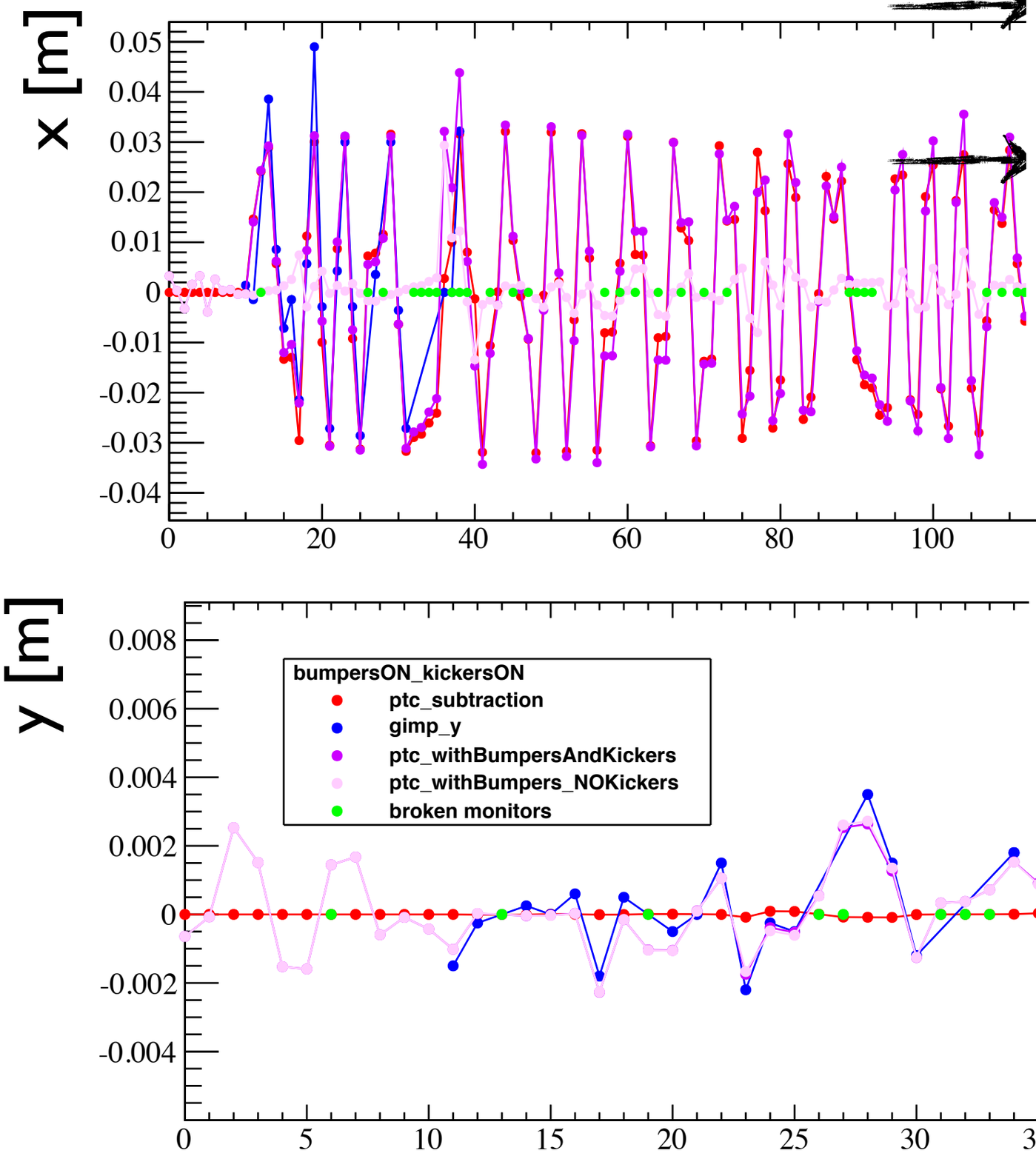
ptc_subtraction

GIMP

ptc; bumpers ON, kickers ON

ptc; bumpers ON, kickers OFF

broke

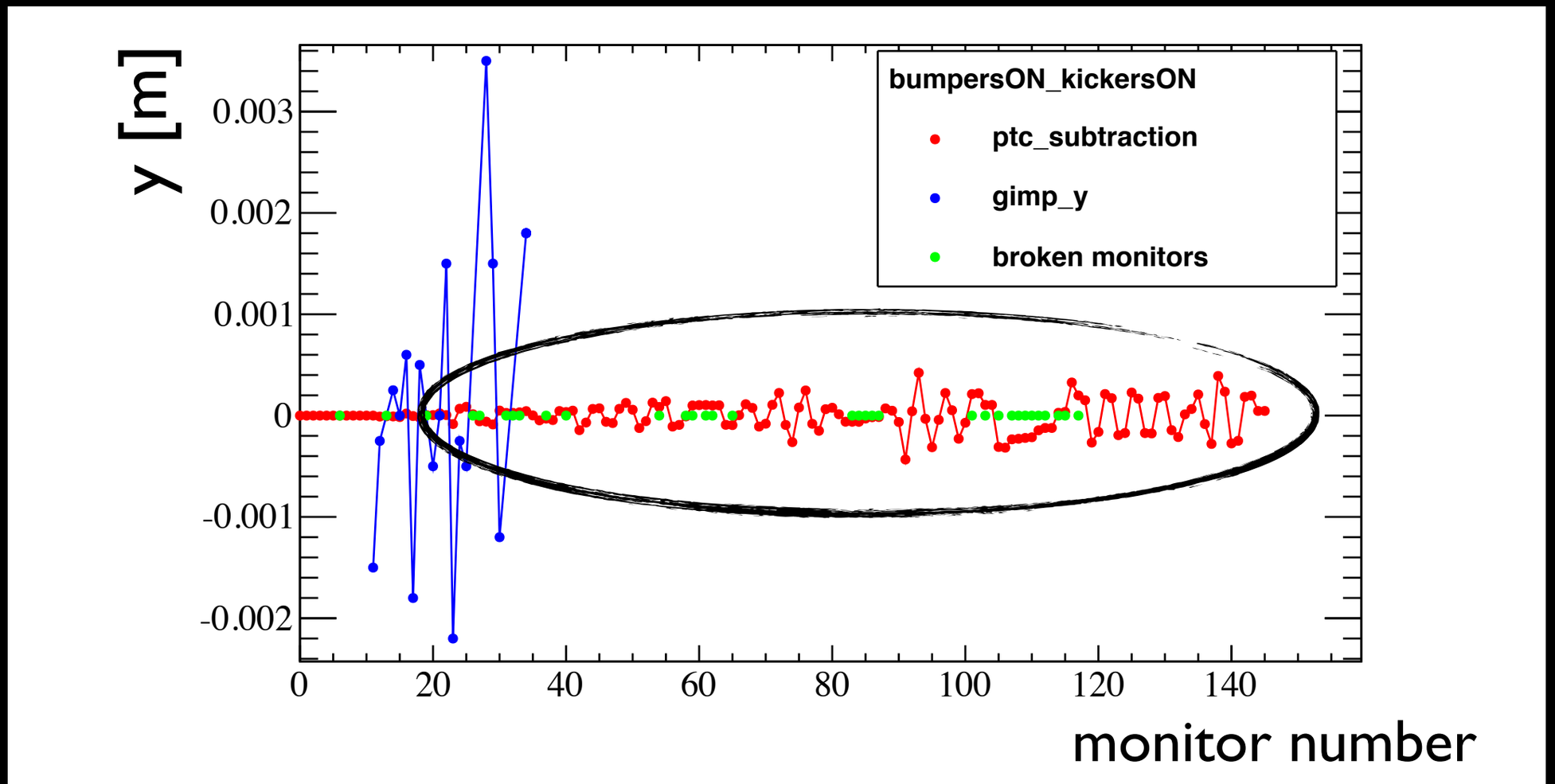


mon

tor number

So what that snapshot shows is the absolute trajectories when the kickers were switched ON, **not** a subtraction...

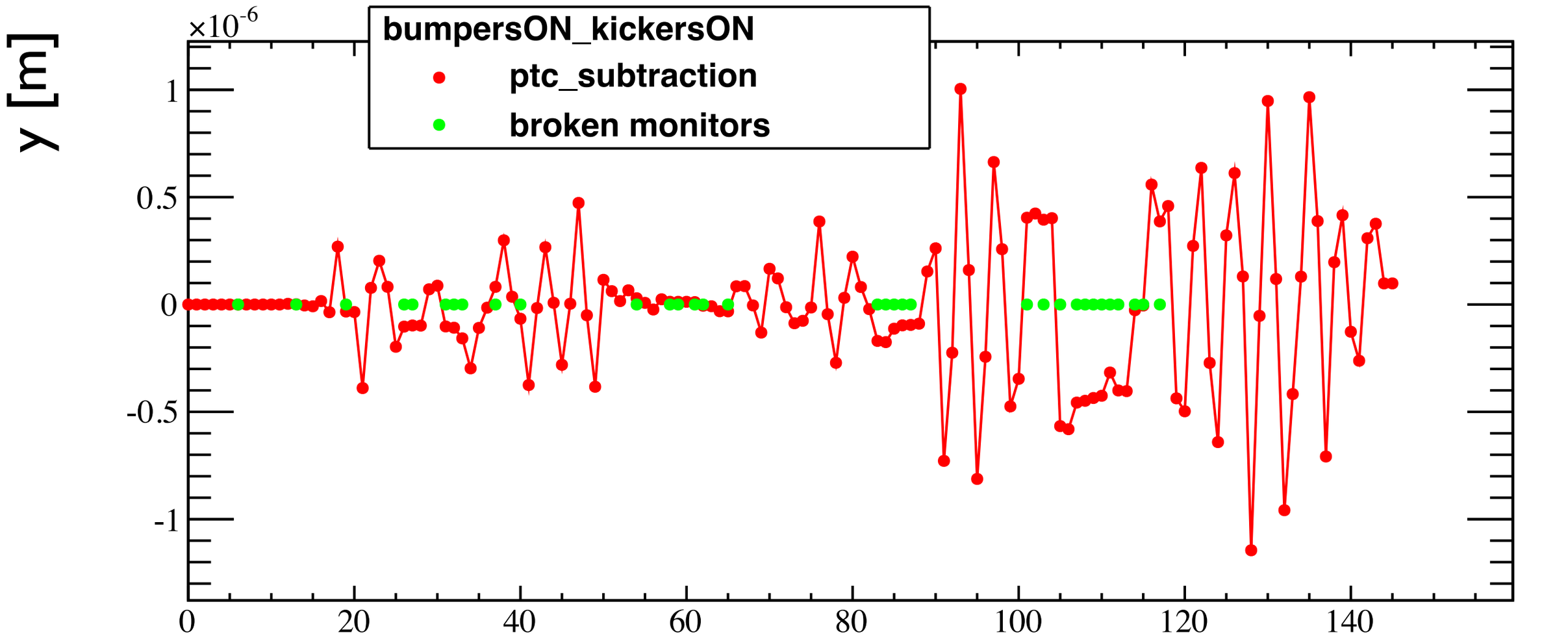
Still, there is some coupling (smaller, O(-4) and starts later)



Can that come from sextupoles?

Switch off sextupoles and check if V-subtraction gives zero

Switching OFF the sextupoles

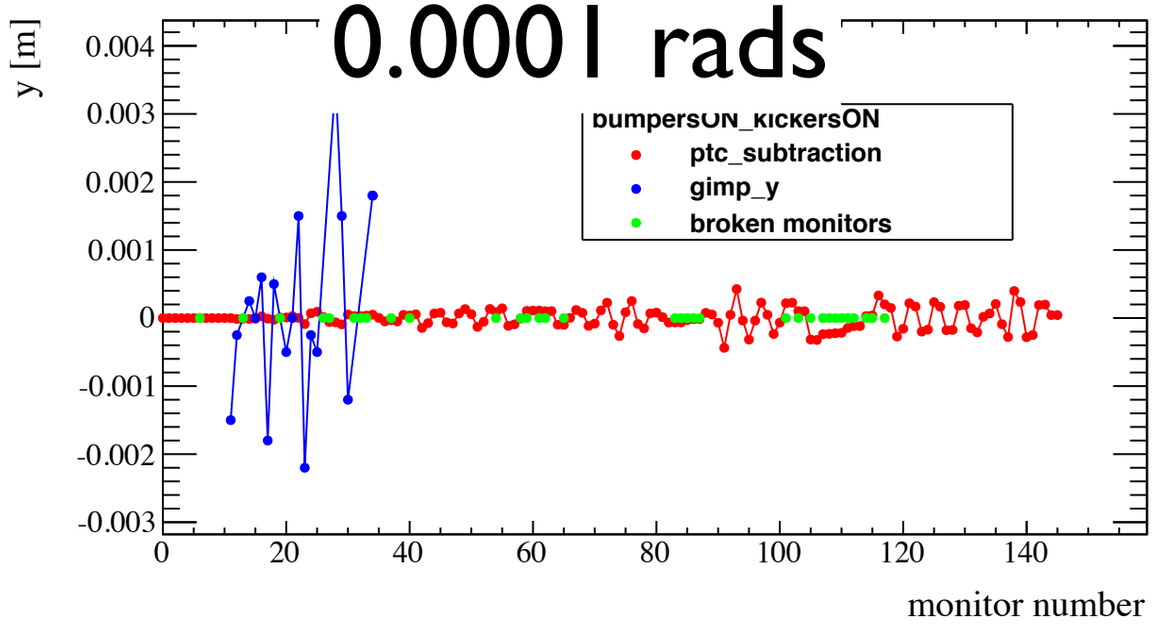


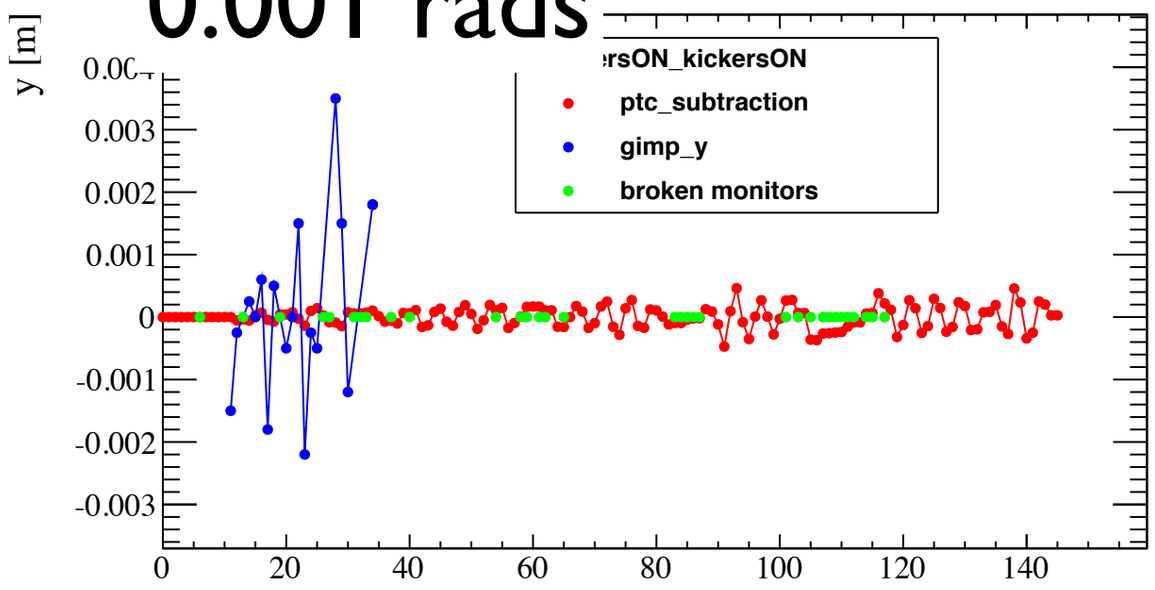
O(-6) m (from O(-4) m when sextupoles were ON)

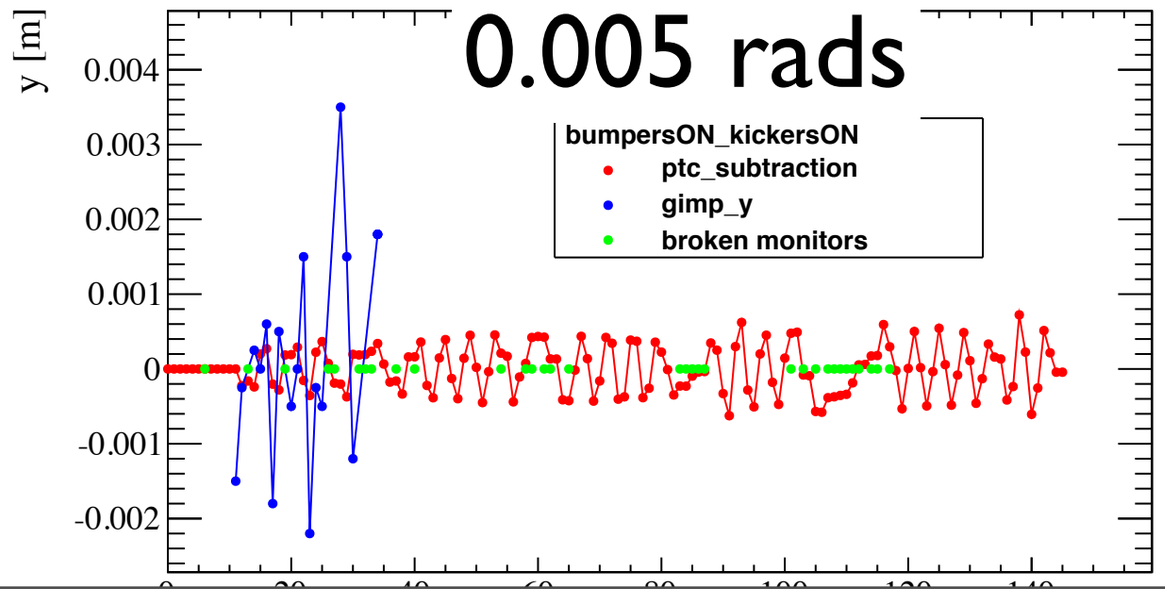
If that snapshot was showing a real coupling, how could we eliminate it?

If that snapshot was showing a real coupling, how could we eliminate it?

apply quadrupole rotation on QF.12010, i.e. the quadrupole just after the kickers (s=641.4966 m)



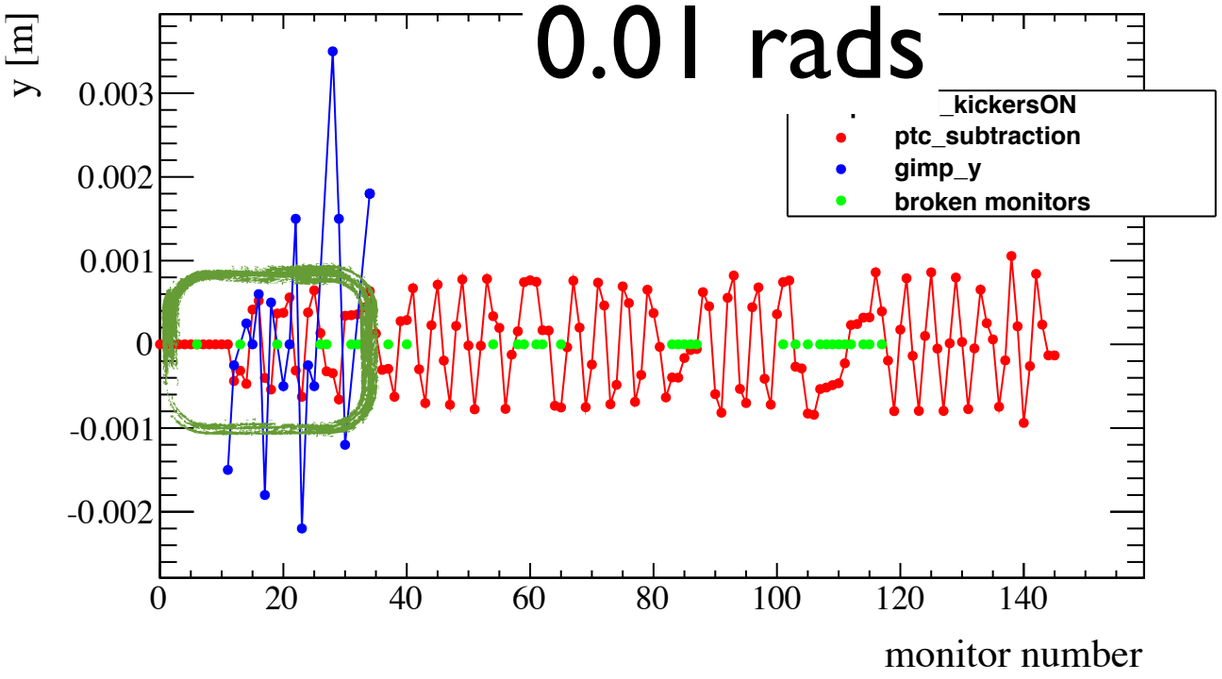


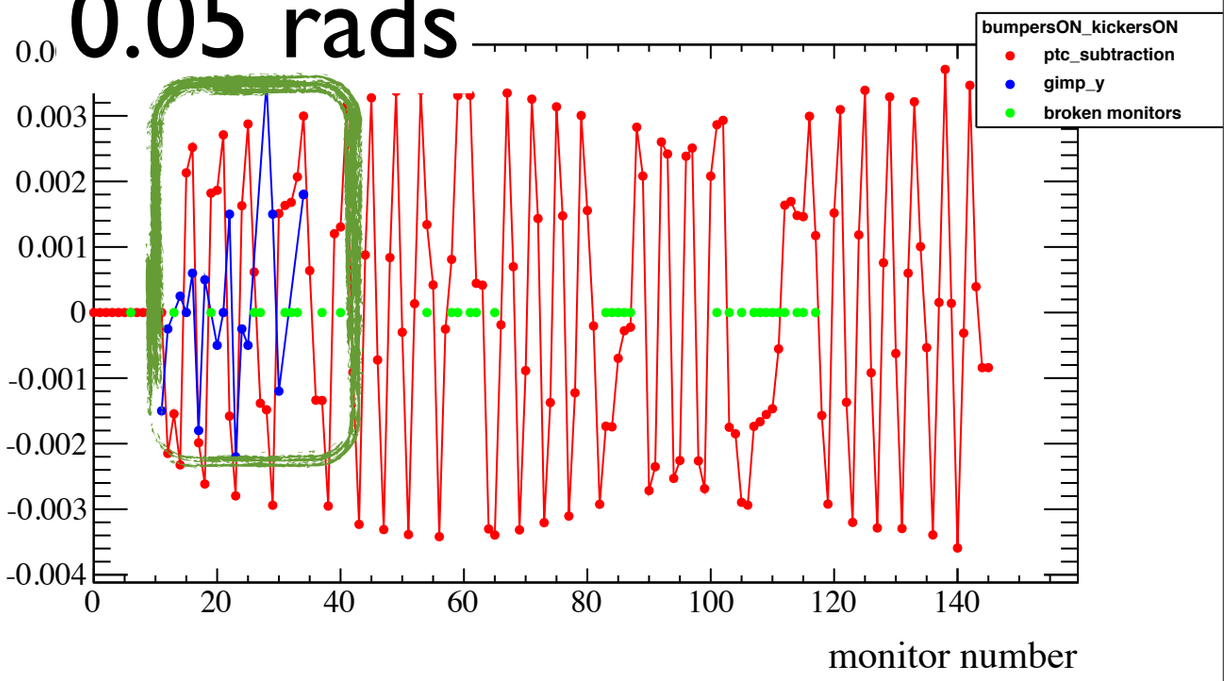


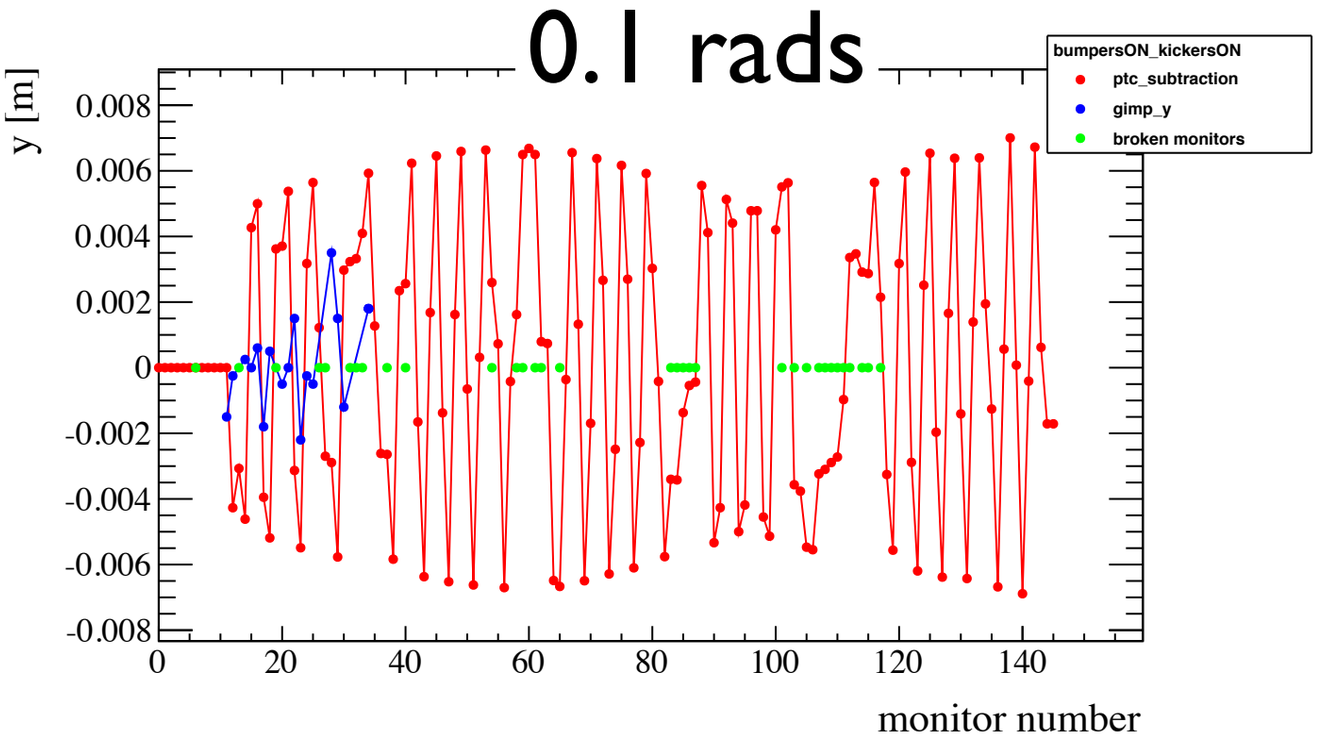
ptc_subtraction

GIMP

broken monitors







A combination of quadrupole rotation of 0.01 and 0.05 radians could reproduce the order of magnitude of “coupling”

Steps followed in order to reproduce the coupling snapshot

a. Using MAD-X:

a.a. find what correctors are needed in order to match/reproduce the CO measurement when bumpers and kickers are OFF; apply these corrections

a.b. switch ON bumpers. Confirm the same CO as the measurements when bumpers are ON is obtained (i.e. verify the corrections applied in previous step are correct)

b. Using PTC_Trackline:

b.a. get the trajectories when the bumpers are ON and kickers are OFF; confirm they agree with MAD-X

b.b. get the trajectories when the bumpers and kickers are ON

c. plot the H/V subtraction (PTC_TRACKLINE_bumpersON_kickersON minus PTC_TRACKLINE_bumpersON_kickersOFF)

d. try to reproduce order of magnitude of coupling by rotating the quadrupoles (starting from the ones after the kickers)

Bug found

MAD-X markers have a bug:
As soon as markers are installed the values of the twiss parameters change. The change is only significant when the CORRECT command is used.

This observation was sent to the madx group and was confirmed to be a bug
(by Andrea Latina and Ghislain Roy, 12June2013).

Summary & Conclusion

- CENF and LAGUNA require high-intensity and high-energy beam (100 and 400 GeV respectively) to be extracted in **one** machine revolution from LSS2
- Non-local fast extraction uses installed kickers in another LSS to perform single-turn extraction from LSS2
- "Coupling" was observed when switching ON the H-kickers in the LSS1 section
- MADX and PTC were used to reproduce the observed "coupling"
- **Conclusion**: there is no coupling of significant order of magnitude . The snapshot was the absolute trajectory in H and V when the kickers were ON
- There was a small coupling coming from the sextupoles (was minimised as soon as the sextupoles were switched OFF)
- If the snapshot was indeed representing coupling then a combination of QF. 12010 rotation by 0.01 and 0.05 radians could reproduce the same order of magnitude of that "coupling"
- Finishing up a note with all details

Thank you!

Any questions?

Backup slides

- No kicker installation at LSS2 due to the difficult integration with the electrostatic septum and to avoid increasing the overall machine impedance

Table 1: Phase advance between kickers and TPST (protection device of the MST in LSS2) obtained with MAD-X.

Kicker	$\Delta\mu$	$\Delta\psi$ [deg]	Q_x
MKQH.11653	4.63	226.51	26.62
MKQH.11653	4.54	195.52	26.13
MKP.11955	4.19	68.22	26.62
MKP.11955	4.11	40.45	26.13
MKE.41637	17.95	340.18	26.62
MKE.41637	17.61	220.95	26.13
MKE.61634	9.07	24.29	26.62
MKE.61634	8.90	323.94	26.13

Table 2: Simulation parameters.

Parameters	**Units**	**Values**
Q_x		26.62
Q_y		26.58
ε_{Nx}	$\pi.mm.mrad$	8.0
$\Delta p/p$	10^{-3}	0.4
MKP voltage	kV	52
MKP def. angle at 100 GeV	mrad	0.674
MKP generators		3

- LSS1: QFA.11610-QF. 12010 (513.5057-641.4966)
- LSS2: QF.21610-QF.22010 (1665.4231-1793.4139)
- LSS3: QF.31610-QF. 32010 (2817.3404-2945.3312)
- LSS4: QF.41610-QF.42010 (3969.2577-4097.2485)
- LSS5: QF.51610-QF.52010 (5121.175-5249.1658)
- LSS6: QF.61610-QF.62010 (6273.0923-6401.0831)

NOTE

- if there were monitors that were clearly giving wrong measurement of CO they were not taken into account but the measurement was NOT set to zero in the target file

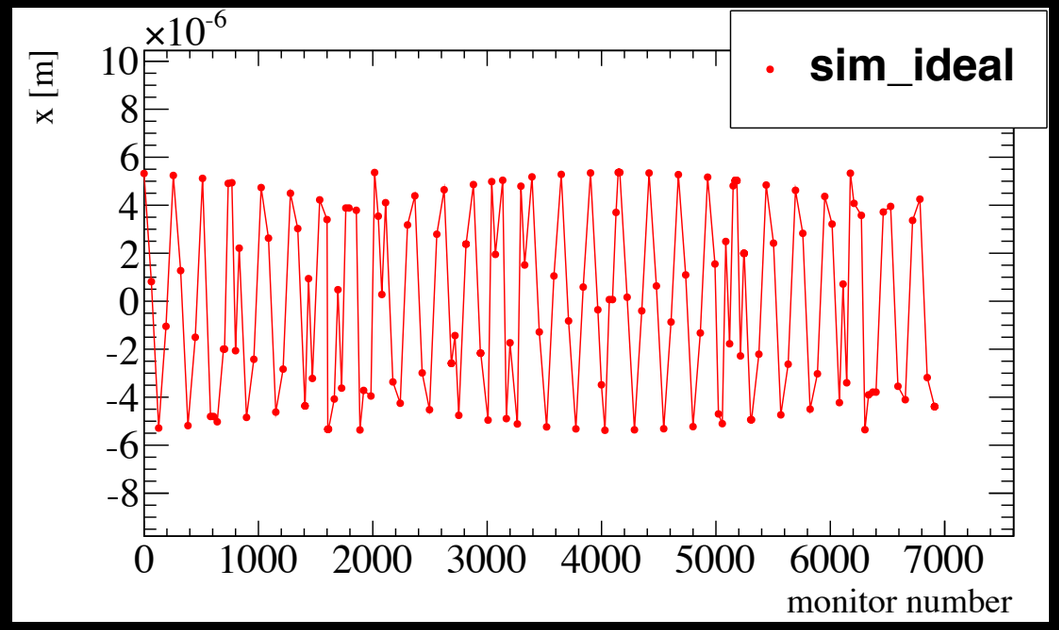
monitor “translation”

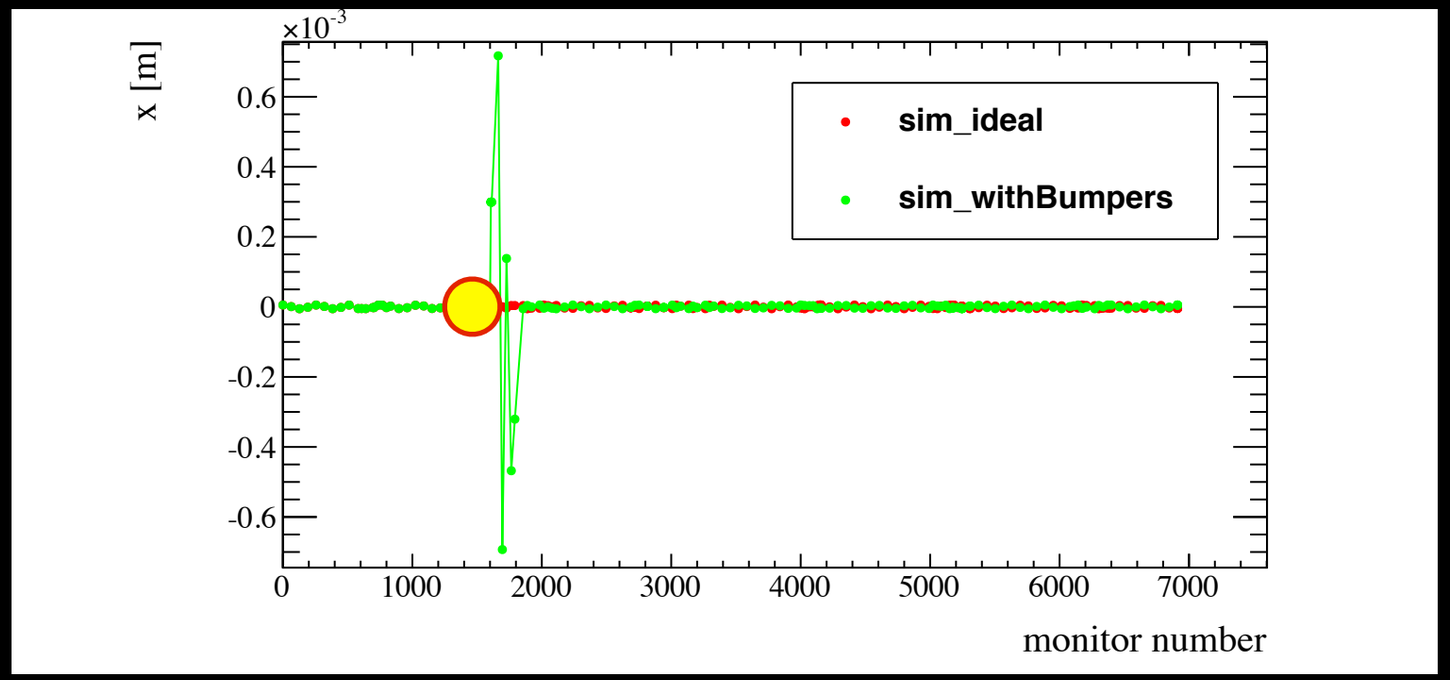
H

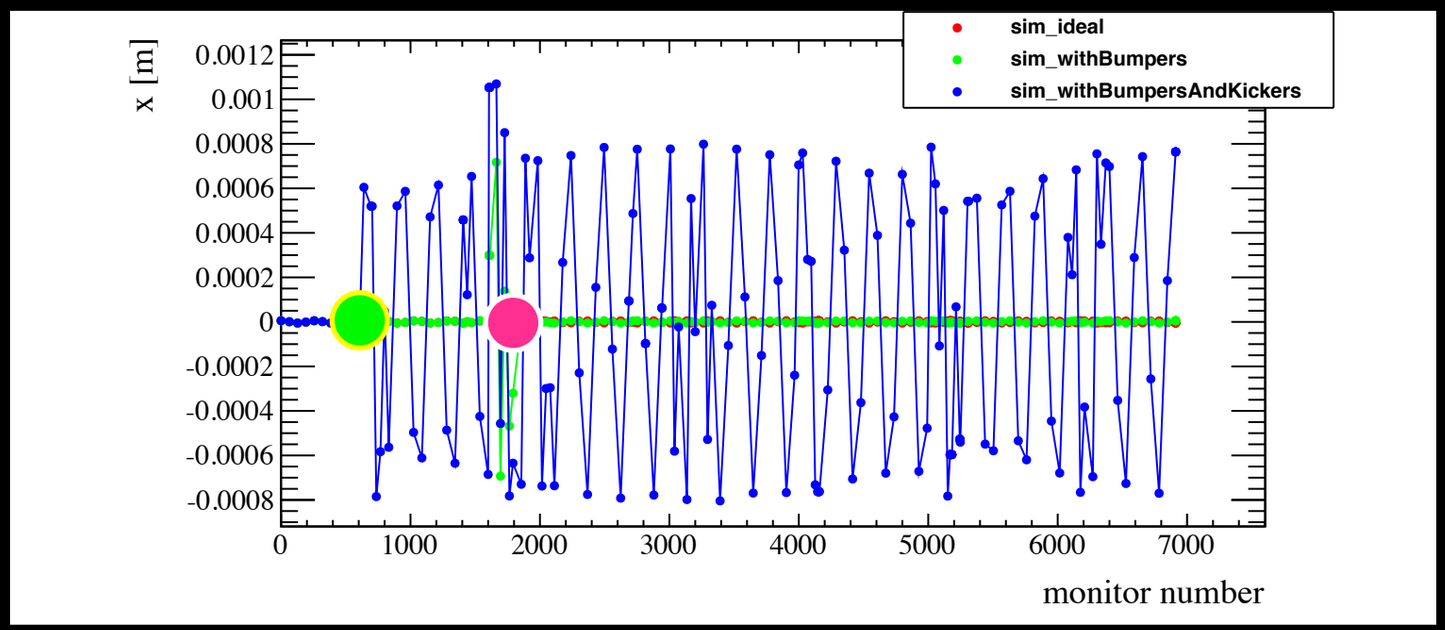
monitor YASP	monitor MADX
10	10
11	11
12	13
13	14
14	15
15	16
16	17
17	18
18	19
19	20
20	21
21	22
22	23
23	24
24	25
25	27
26	29
27	30
28	31
29	36
30	37
31	38

V

monitor YASP	monitor MADX
11	11
12	12
13	14
14	15
15	16
16	17
17	18
18	20
19	21
20	22
21	23
22	24
23	25
24	28
25	29
26	30
27	34



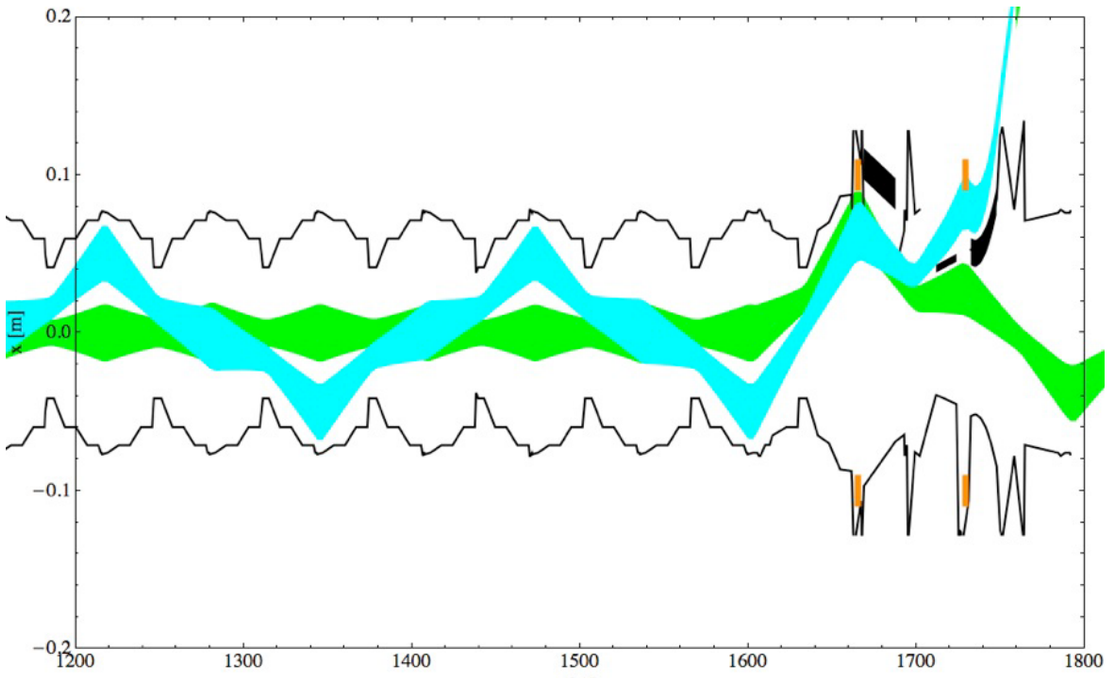




- _1stBumper=1534.205 m
- s_1stKicker=613.3839 m
- s_1stSeptum=1733.806 m

Simulations for LSS1-LSS2 extraction (F. Velotti)

Extraction region



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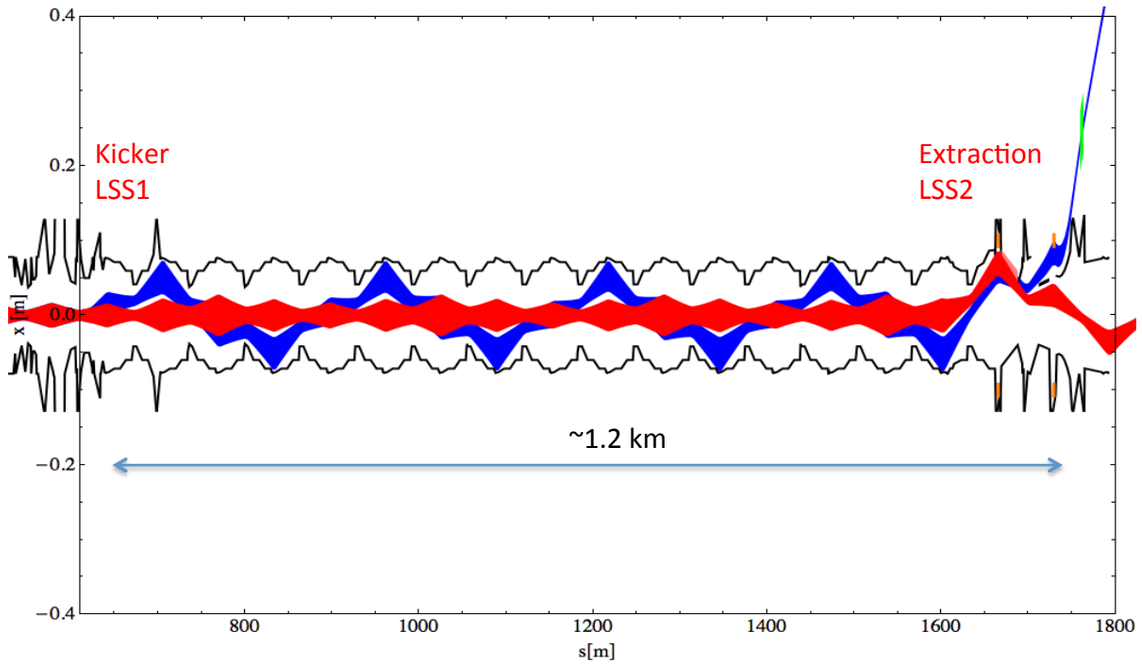
Extraction bump and trajectory

110 GeV, 8 um, ±5 σ envelopes



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