Measurements' Analysis

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Introduction : Goals of the study, measurement technique, scans performed

Trajectories stability :

- Constant tune
- Variable tune
- Special cycles
- Summary

Non-linear chromaticity measurements

Study of decoherence/recoherence

Closure of the Slow bump

- Bump for core
- Bump for islands
- Correlation with observed SPS fluctuations

Work to be done, conclusion

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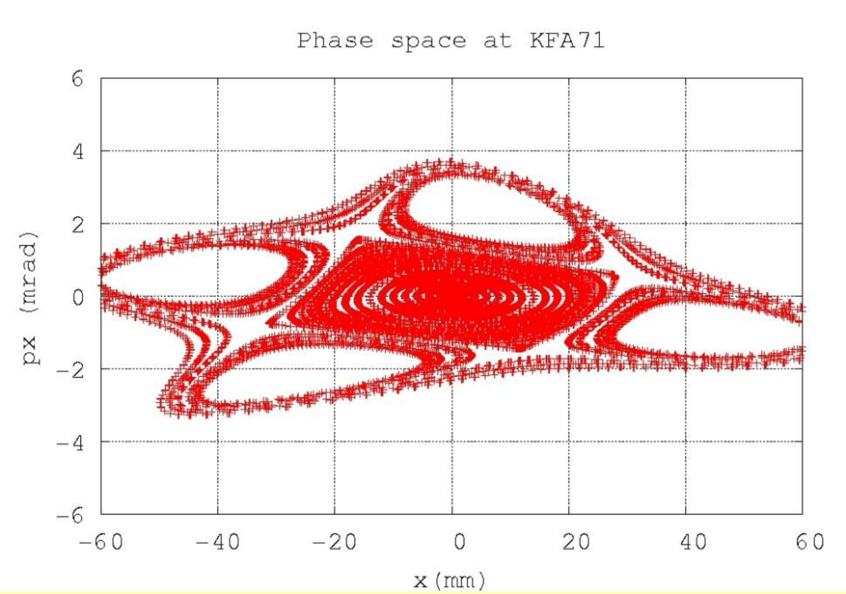
Introduction

Measurements have been done to study the stability of the trajectories from cycle to cycle and to identify possible sources of fluctuations for different cases.

As PS Pickups provide center of gravity of the charges distribution, they do not allow to distinguish trajectories of different beamlets for an “operational” MTE beam.



Introduction : measurement technique

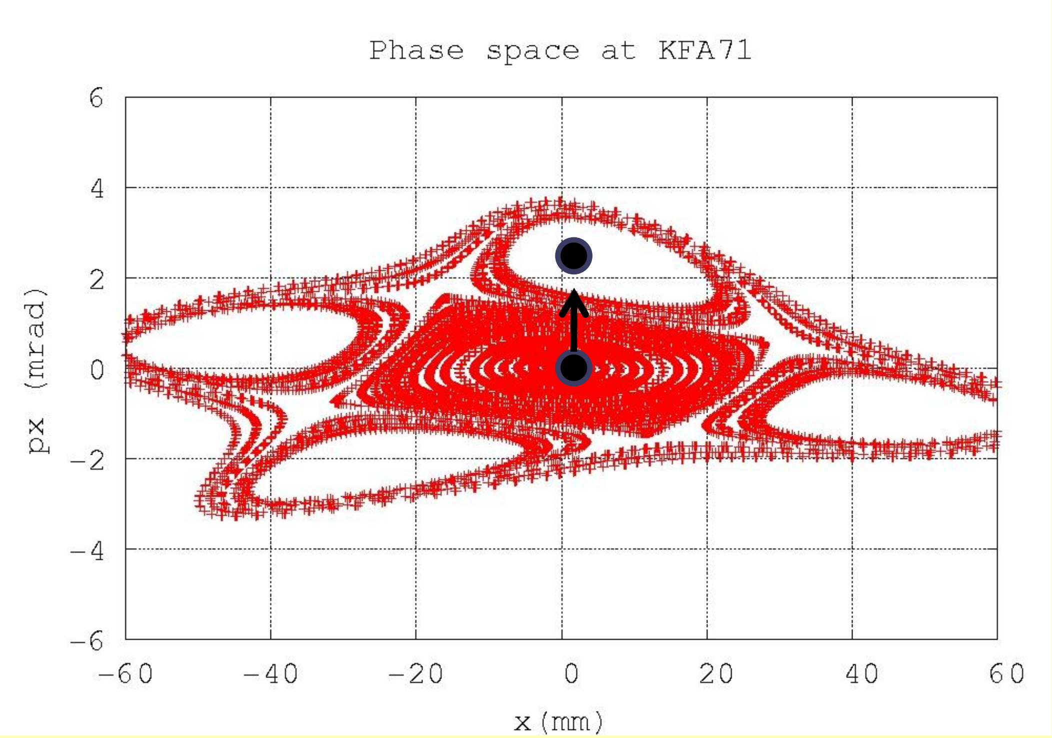
The extraction kicker (KFA71) is used to kick a pencil beam inside one island.

- Pencil beam allows good visualization of beam dynamics inside island

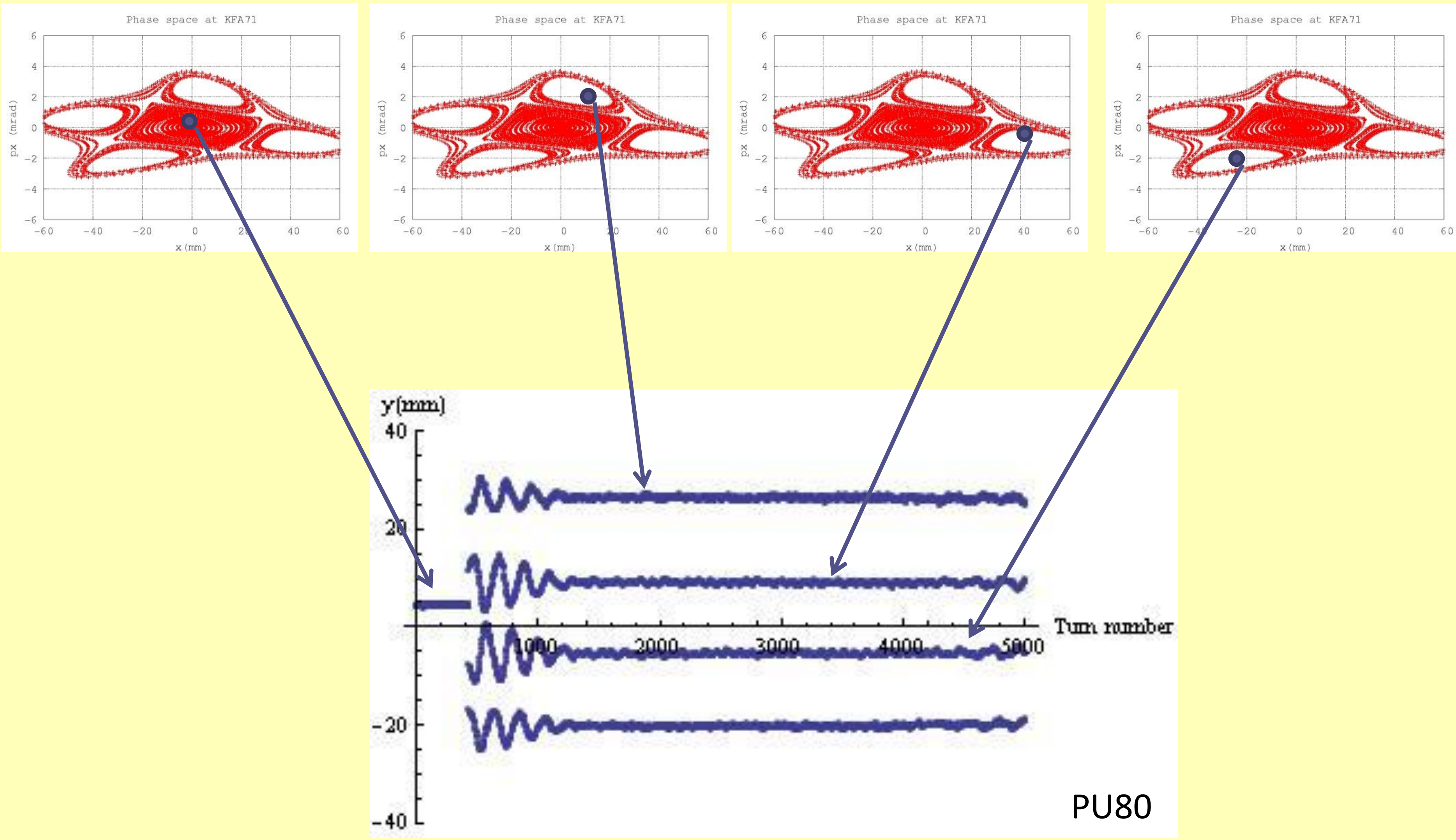
- Static situation after filamentation

- Orbit measurement system can be used to measure turn-by-turn islands trajectories

Beam energy	14 Gev
Intensity	1.10^{10} p
Transverse normalized emittance (H/V) RMS	1 mm.mrad
RMS Longitudinal emittance	0.29 eV.s
RMS Dp/p	$0.31.10^{-3}$
RMS Bunch length	21.2 ns



Introduction : measurement technique, what we obtain



Introduction : scans performed

All measurements have been done for a bare machine, only MTE sextupoles are turned on.
Octupolar component created by PFW's is enough to create islands in phase space for pencil beam

First measurements have been done for a "constant" machine : fixed tune, fixed gradients for non-linear elements.
Only previous user in super cycle has been changed : EASTB, TOF,ZERO (but for non-constant super cycle composition) and also PS main supply (POPS or rotating machine).

Second measurements have been done during a parameterized tune ramp applied with figure-of-eight loop to study the step between capture and extraction when island are moving far away from the core.
Various ramp parameters have been tested (length, speed, time start), also for different previous users, all done with POPS.

Finally trajectories have been measured using dedicated MTE super cycle. Scan performed on super cycle length and number of MTE cycle inside, done with POPS as PS main supply.

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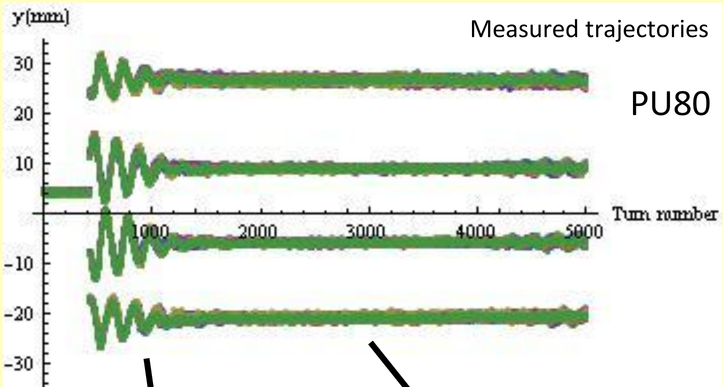
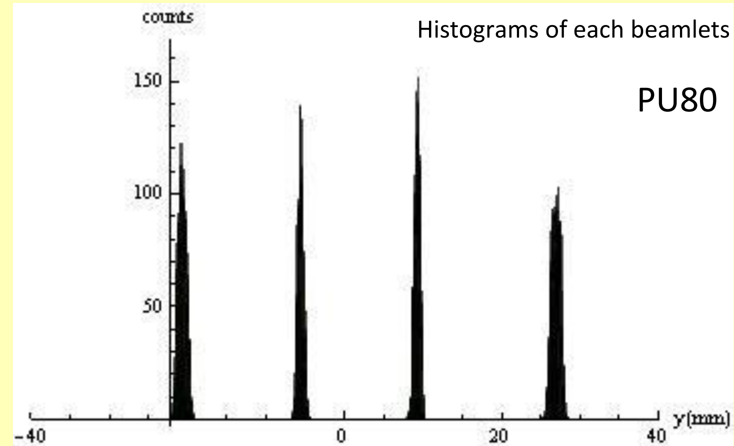
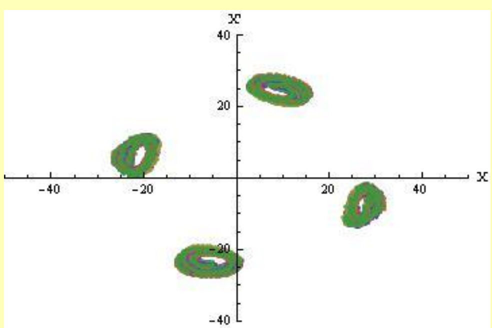
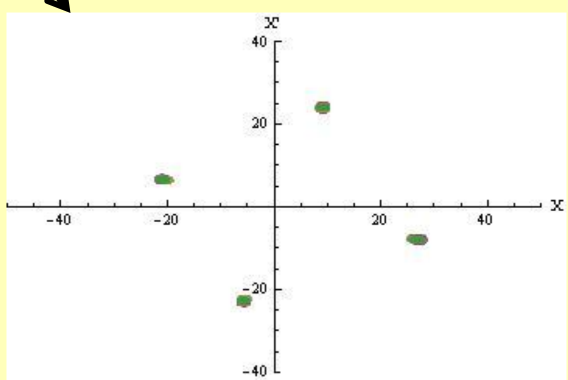
Trajectories stability : fixed tune

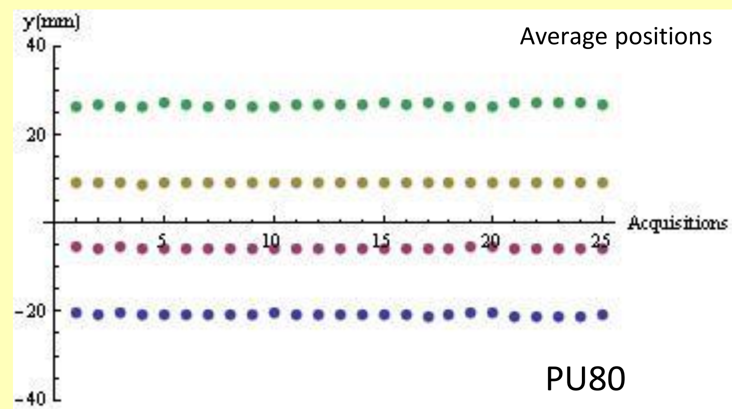
Typical plots of measured trajectories for a “constant” machine, here after a TOF cycle.
25 acquisitions are superimposed. Pickup80











PU80

Trajectories stability : fixed tune

	SLICE 1	SLICE 2	SLICE 3	SLICE 4
Pickup 80	S.deviation	S.deviation	S.deviation	S.deviation
After ZERO cycle (POPS)	0.612	0.309	0.336	0.658
After EASTB cycle (rotating machine)	0.740	0.329	0.379	0.838
After TOF cycle (rotating machine)	0.329	0.293	0.291	0.422
After TOF cycle (POPS)	0.747	0.324	0.365	0.859

	SLICE 1	SLICE 2	SLICE 3	SLICE 4
Pickup 80	Peak to peak (mm)	Peak to peak (mm)	Peak to peak (mm)	Peak to peak (mm)
After ZERO cycle (POPS)	1.89	0.75	1.01	2.12
After EASTB cycle (rotating machine)	2.71	0.83	1.3	3.27
After TOF cycle (rotating machine)	0.97	0.42	0.46	1.03
After TOF cycle (POPS)	3.37	1.15	1.13	3.72

		SLICE 1	SLICE 2	SLICE 3	SLICE 4
Pickup 80	Closed orbit before kick (mm)	Average position (mm)	Average position (mm)	Average position (mm)	Average position (mm)
After ZERO cycle (POPS)	4.12	-15.34	-3.59	7.79	21.37
After EASTB cycle (rotating machine)	4.24	-13.64	-2.23	8.79	22.16
After TOF cycle (rotating machine)	4.32	-20.75	-5.67	9.17	26.83
After TOF cycle (POPS)	3.92	-5.98	-0.29	4.98	11.48

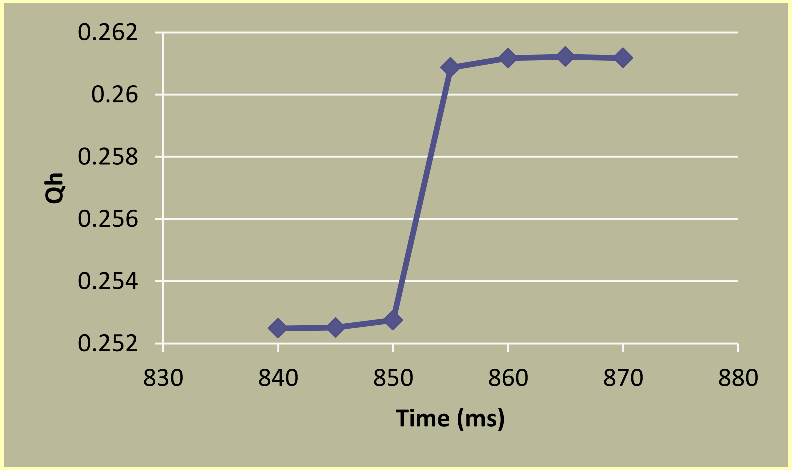
Trajectories stability : tune ramp

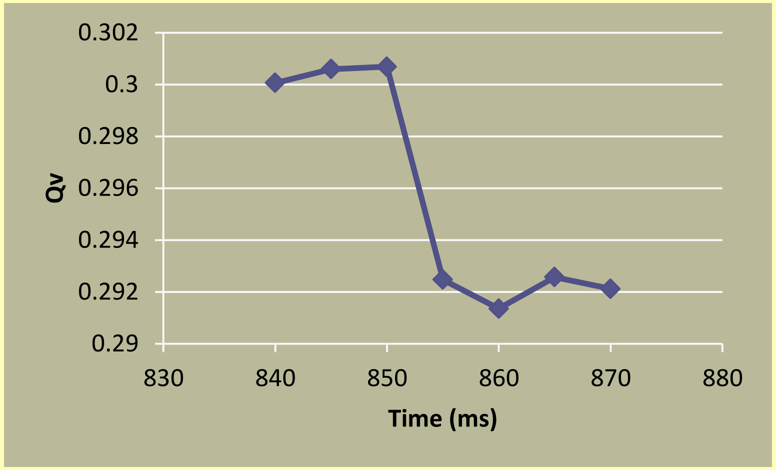
For these measurements a tune ramp is applied to the beam using the figure-of eight loop.

A deviation is applied to the figure-of eight loop value on the 14GeV flat-top (594.84A).
The Delta current is 8A.

The horizontal tune ramps from .253 to .261

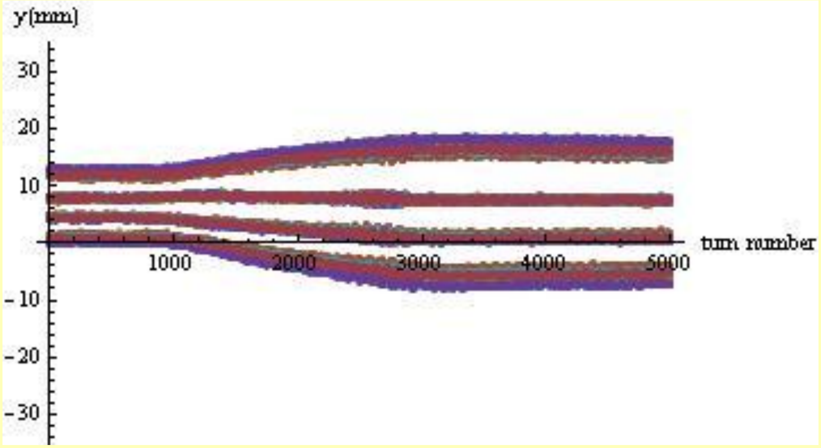
Different values for the slope of that deviation have been tested (5ms, 10ms and 20ms).

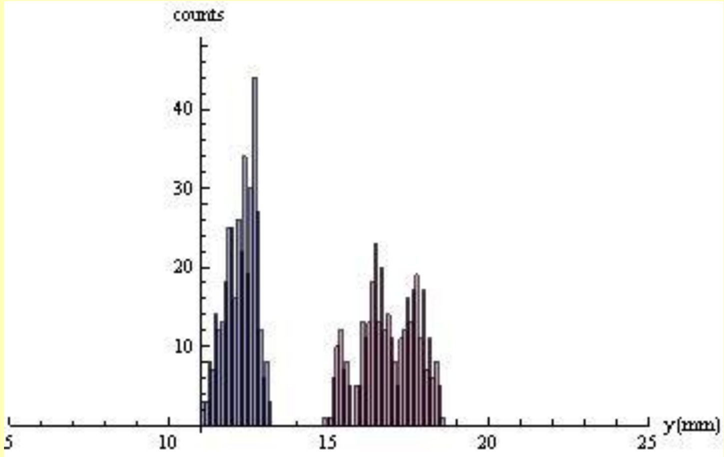


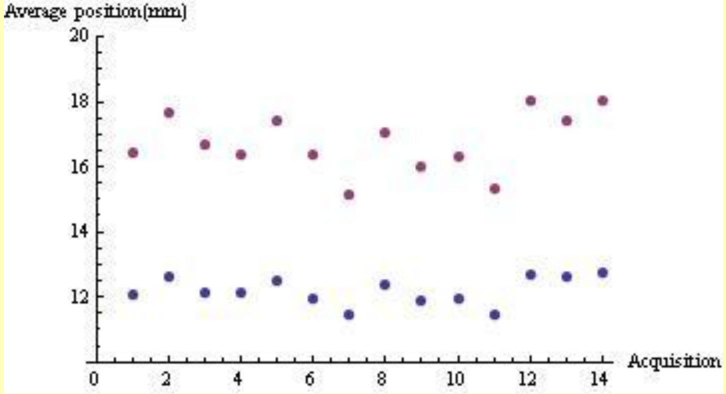


Trajectories stability : tune ramp

Trajectories plots obtained after a TOF cycle, 15 acquisitions super-imposed. Pkup 80







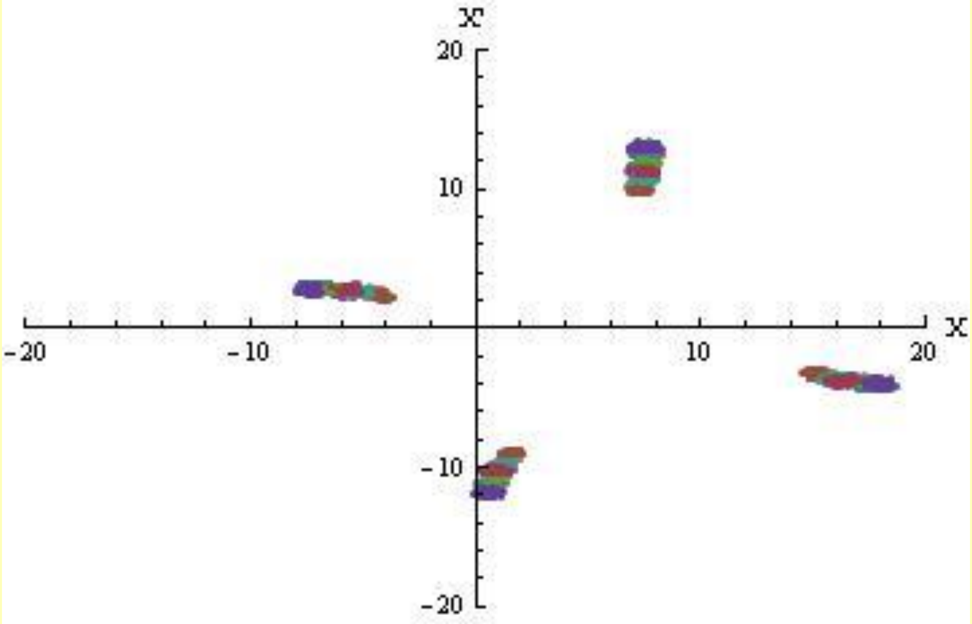
Top island, pkup80	Before ramp	After ramp
Standard Deviation	0.476	0.894
Peak to peak (mm)	1.31	2.9

Found : There is an increase of the fluctuations from cycle to cycle during the tune ramp.

Trajectories stability : tune ramp

Is that increase due to an effect of projection ? An island phase change during the ramp could explain that spread increase by projection on axis.

Phase space plot obtained by reconstruction from measured orbits : (courtesy Y.Papaphilippou)



PU 80

No island phase change has been observed during the ramp, so the spread increase is not due to projection on axis.

Trajectories stability : special cycles

During a PS restart after technical stop, dedicated super cycles for MTE have been programmed to allow us to measure trajectories to study the influence of the super cycle length and composition on the MTE beamlets trajectories.

Several configurations have been tested :

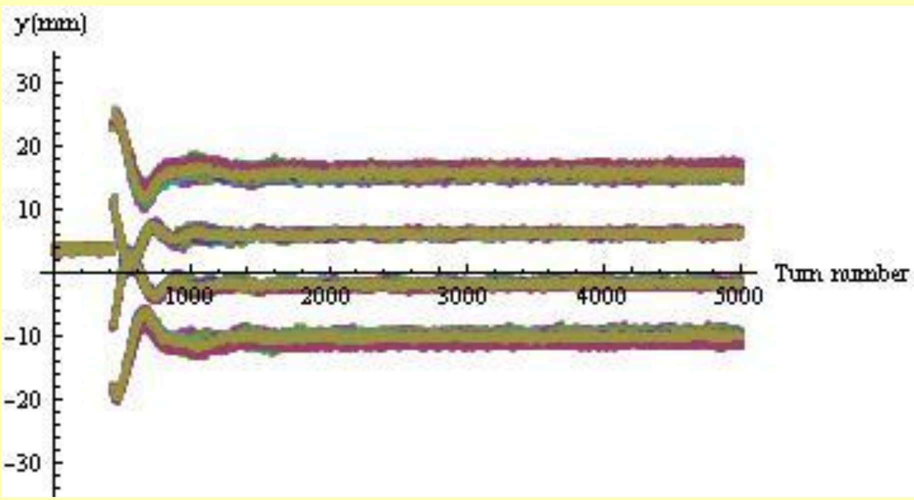
- 13 Basic period super cycle with one MTE cycle inside (and ZEROs to fill the supercycle)
- 26 Basic period super cycle with two MTE cycles inside (and ZEROs to fill the supercycle)
- 13 Basic period super cycle with two consecutives MTE cycles (and ZEROs to fill the supercycle)
- 26 Basic period super cycle full of MTE cycles (13MD1)

Trajectories for constant tune and tune ramp (from the kick to the top of the ramp) have been measured for each configuration.

Trajectories stability : special cycles

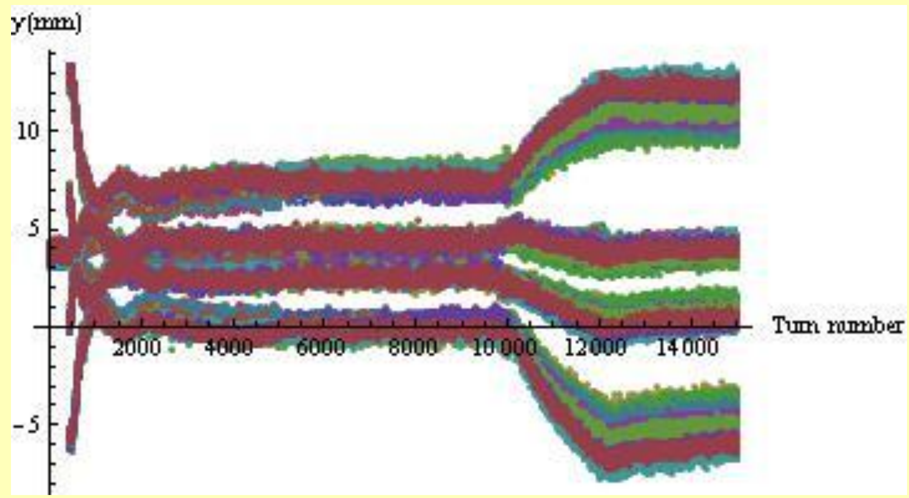
Configuration with 13Basic period super cycle and 1 MTE cycle inside. Pickup80.

Trajectories for constant tune



PU 80

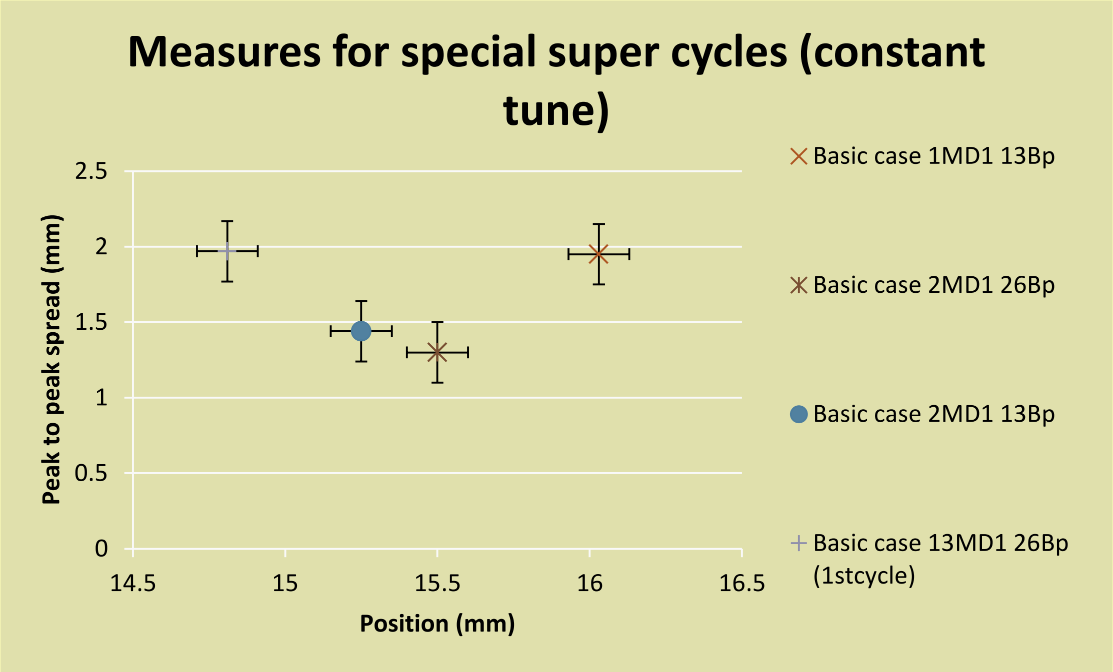
Trajectories from the kick to the top of the ramp



PU 80

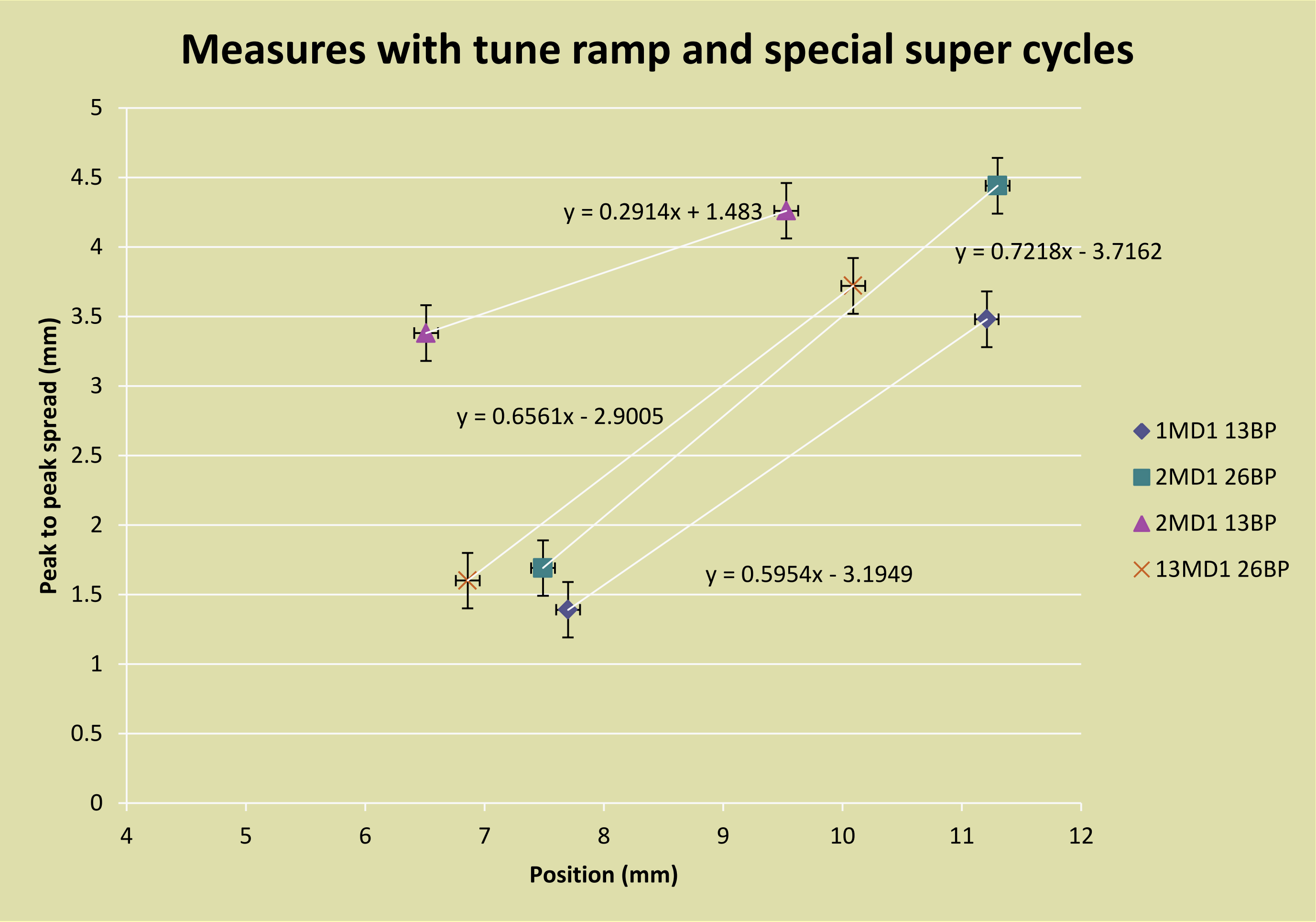
Trajectories stability : special cycles

Comparison of results for special super cycles and constant tune



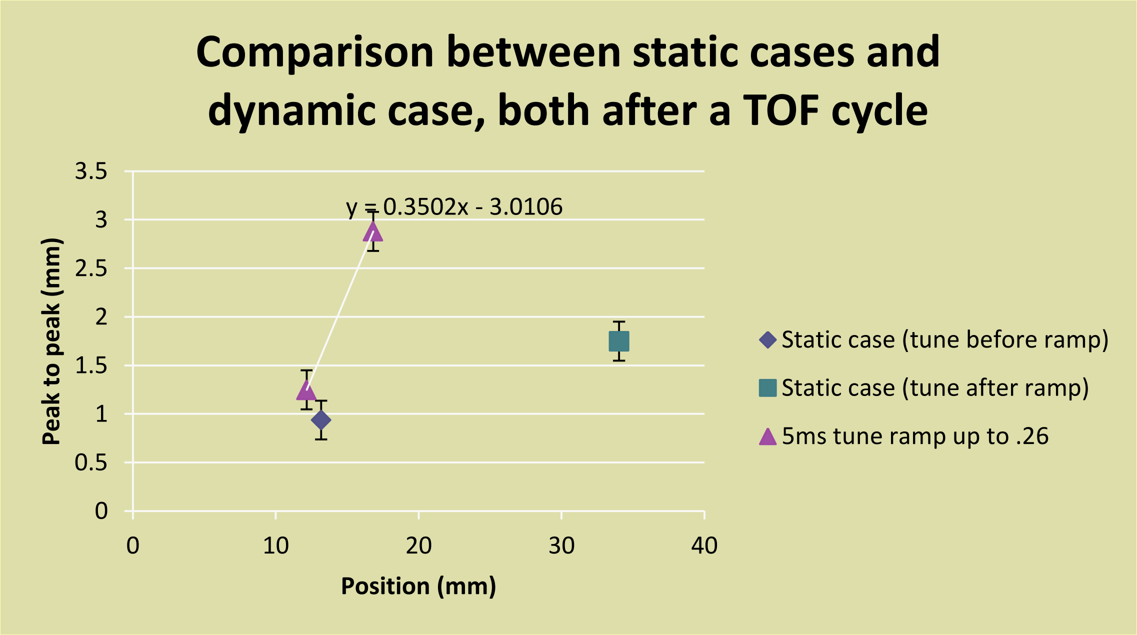
Trajectories stability : special cycles

Comparison of results for special super cycles and tune ramp (5ms ramp)



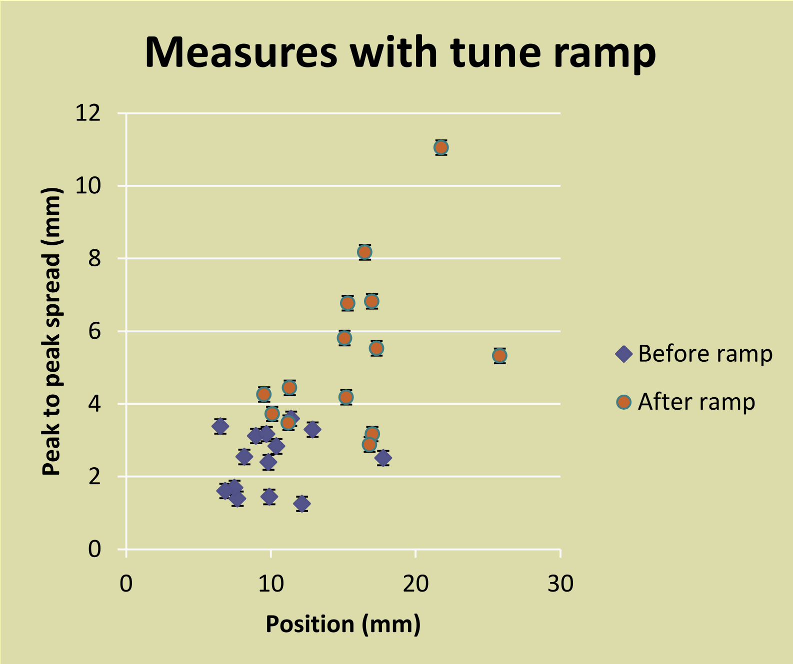
Trajectories stability : Summary

In order to determine if the tune ramp has a direct influence on the spread augmentation, the peak to peak spread before and after tune ramp has been compared to the peak to peak spread for a beam in "static " case (constant tune corresponding to value before and after tune ramp).



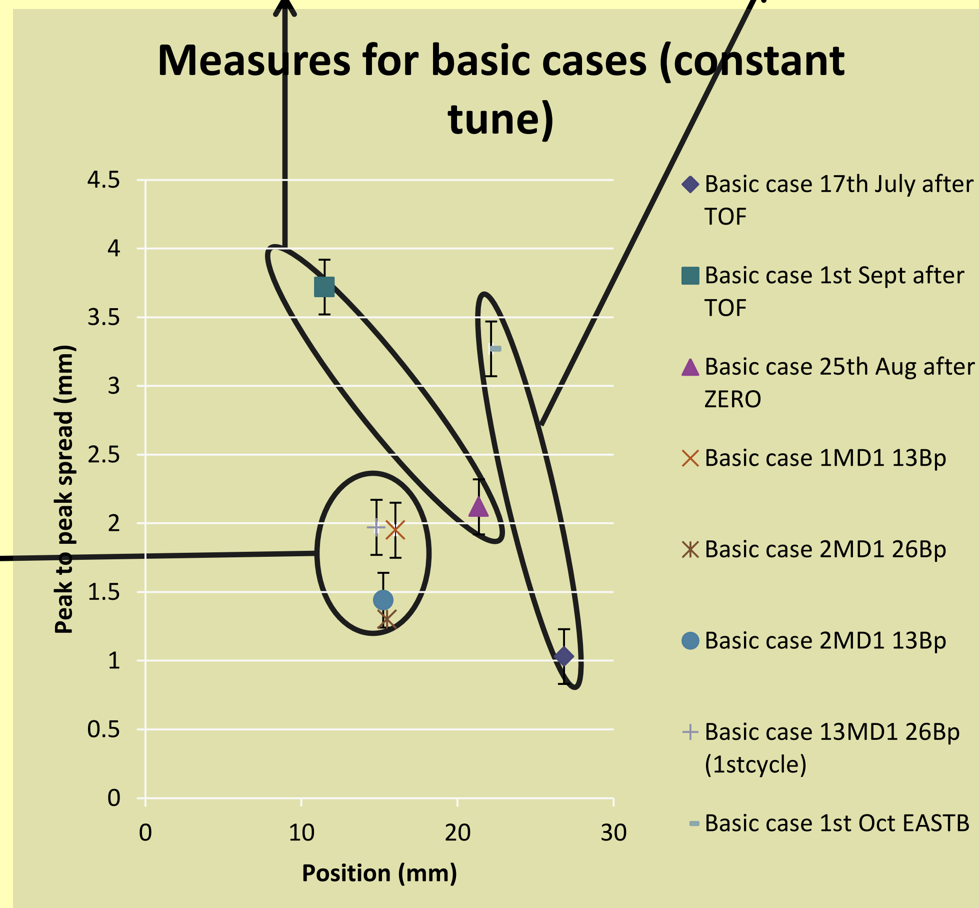
It clearly appears that the peak to peak spread has 2 components : one induced by the island amplitude augmentation, and the second one due to the tune ramp.

Trajectories stability : Summary



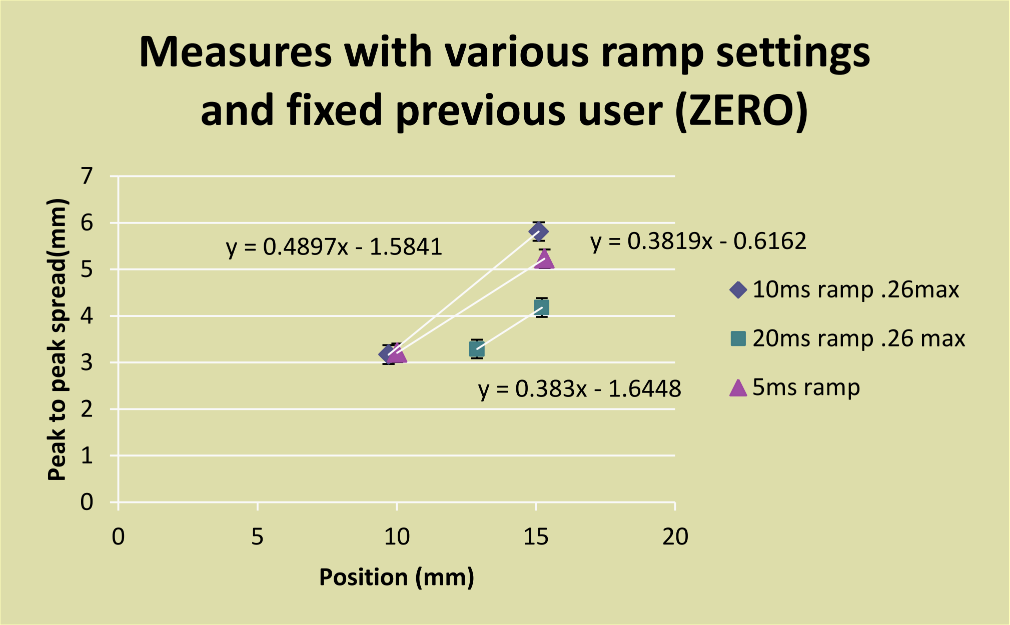
Measures with POPS

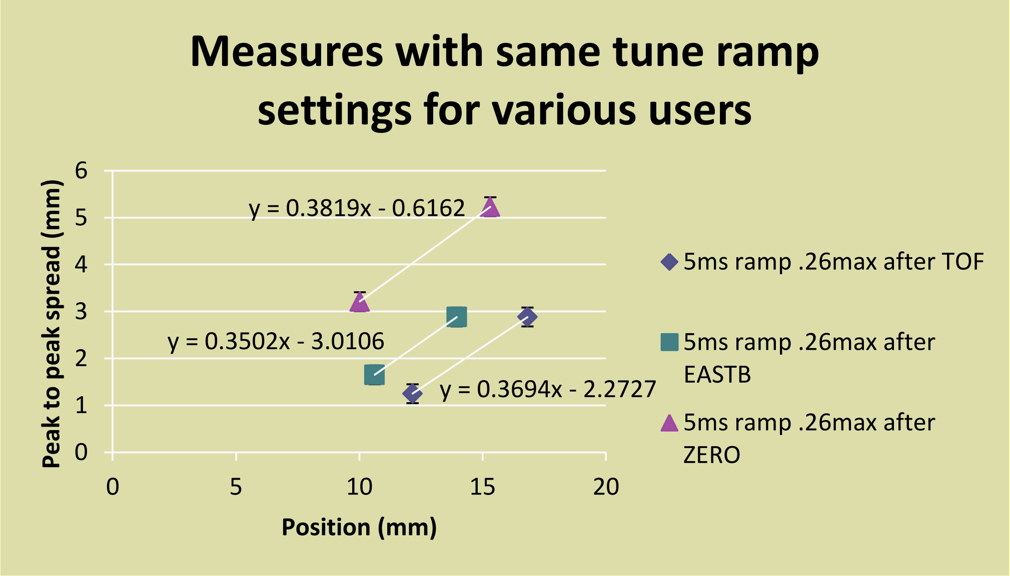
Measures with rotating machine



Measures with dedicated super cycles

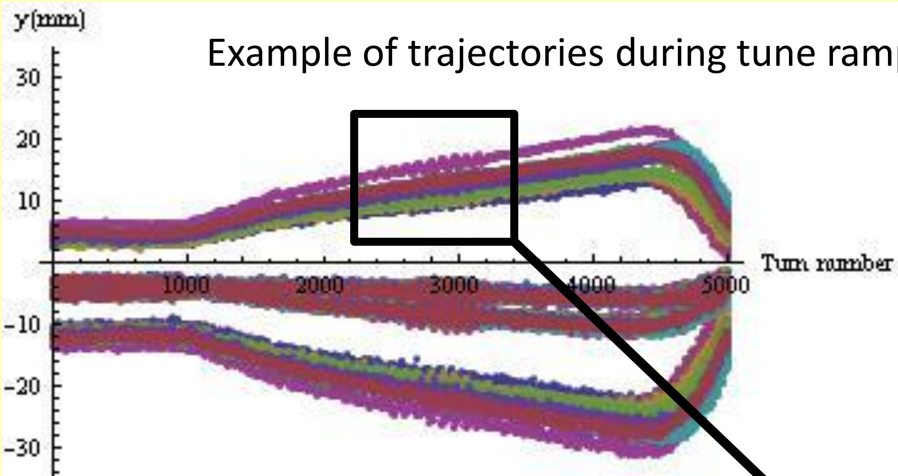
Trajectories stability : Summary

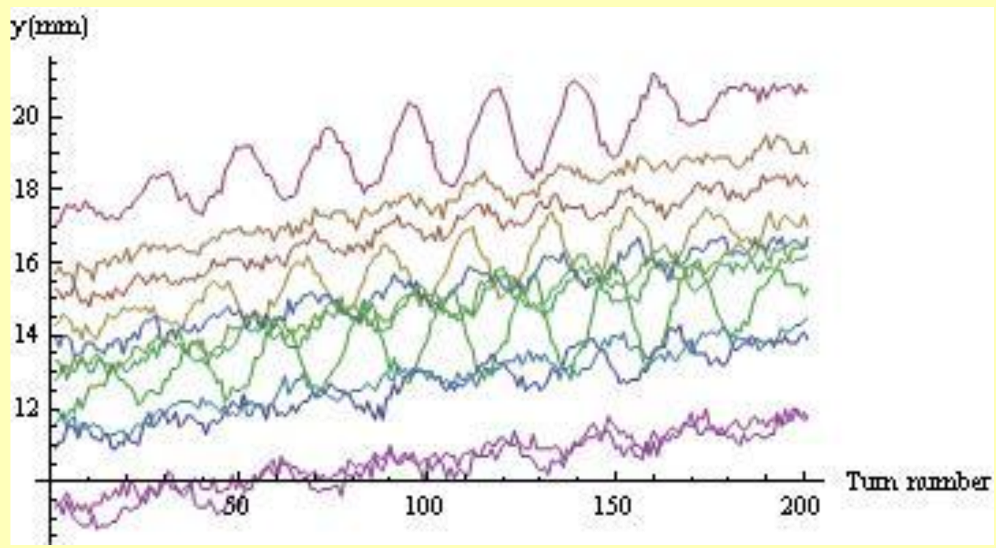




Trajectories stability : observed trajectories oscillations during tune ramp

Trajectories oscillations during tune ramp have been observed during the tune ramp. These oscillations are not reproducible.





FFT of these fluctuations gives a frequency of ~ 24KHz

Trajectories stability : observed trajectories oscillations during tune ramp

Several configurations have been tested to study these fluctuations : slope of the ramp, beam kicked at different time…

Is it decoherence ?

Fluctuations apparition fully independent of kick time : Not a decoherence

Is it an echo ?

No quadrupolar excitation observed between kick time and fluctuations :

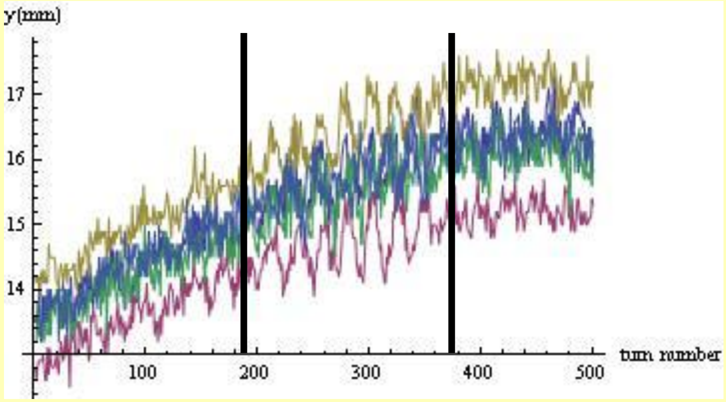
Probably not an echo

Frequency is always the same

Trajectories stability : observed trajectories oscillations during tune ramp

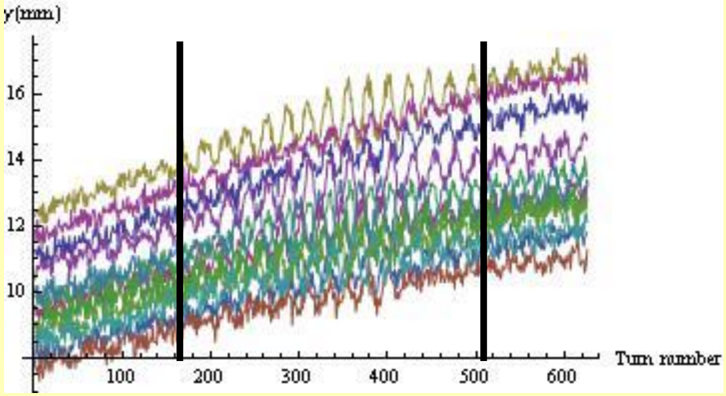
Length of fluctuations depends on tune ramp slope :

5ms ramp



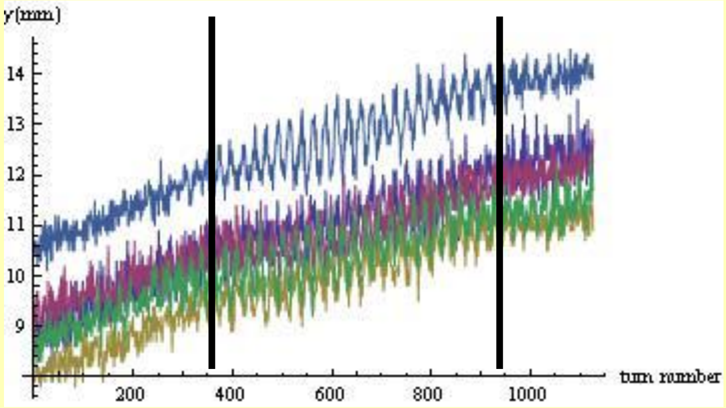
~150 turns

10ms ramp



~300 turns

20ms ramp



~600 turns

Amplitude of fluctuations varies a lot with time : to be measured during a long time in order to find some possible correlations.

Fluctuations seems to appear always around he same tune : (Qh,Qv) ~ (.26, .294)

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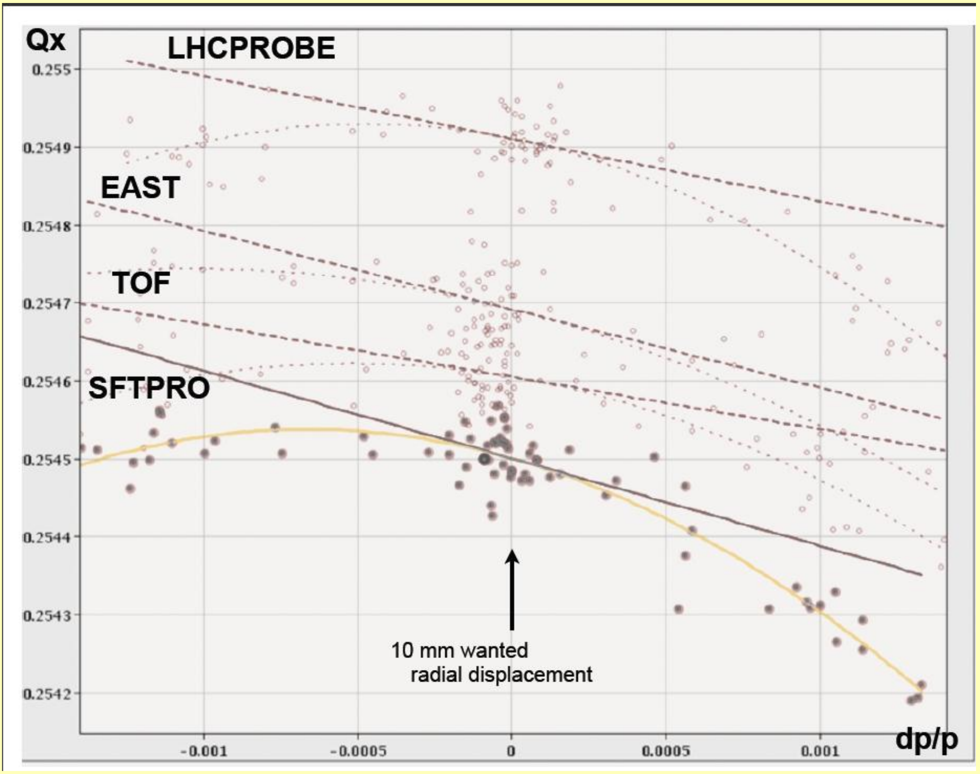
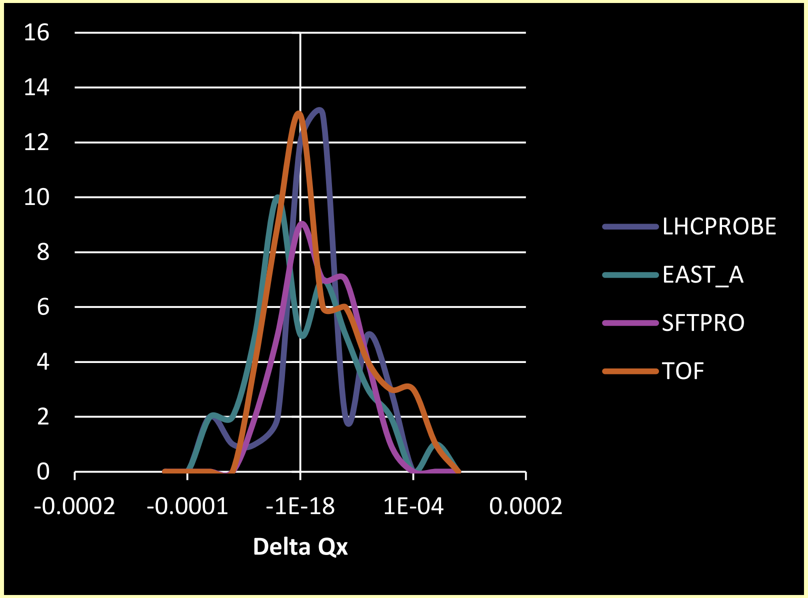
Trajectories stability : Tune and chromaticity measurements

Tune and chromaticity have been measured for various previous users in the super cycle



	Q_x	Q'_x	Q''_x
EAST_A	0.2547 ± 6.10^{-6}	-0.101 ± 8.10^{-3}	-97± 18
LHCPROBE	0.2549 ± 4.10^{-6}	-0.08 ± 6.10^{-3}	-168± 13
TOF	0.2546 ± 5.10^{-6}	-0.067 ± 7.10^{-3}	-130± 16
SFTPRO	0.2545 ± 4.10^{-6}	-0.112 ± 5.10^{-3}	-169± 12

Found: there is a systematic Q and Q'' shift, depending on the preceding user, with a ΔQx up to 5 10-4.



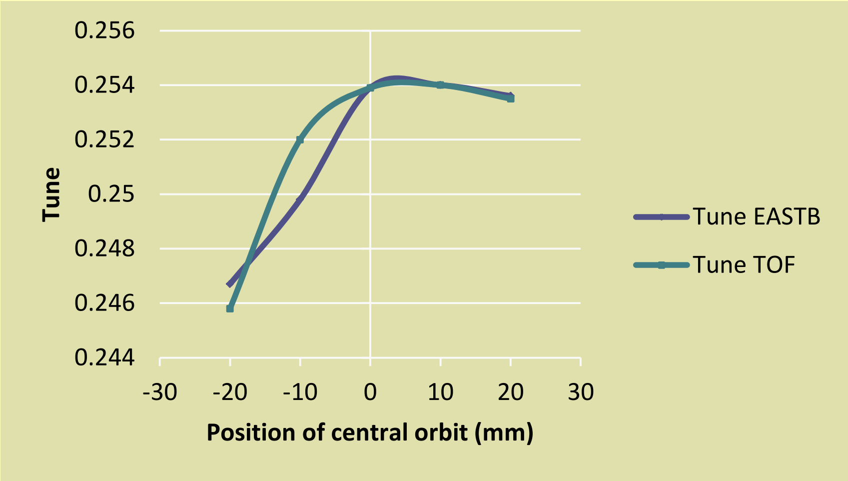
Trajectories stability : Tune and chromaticity measurements

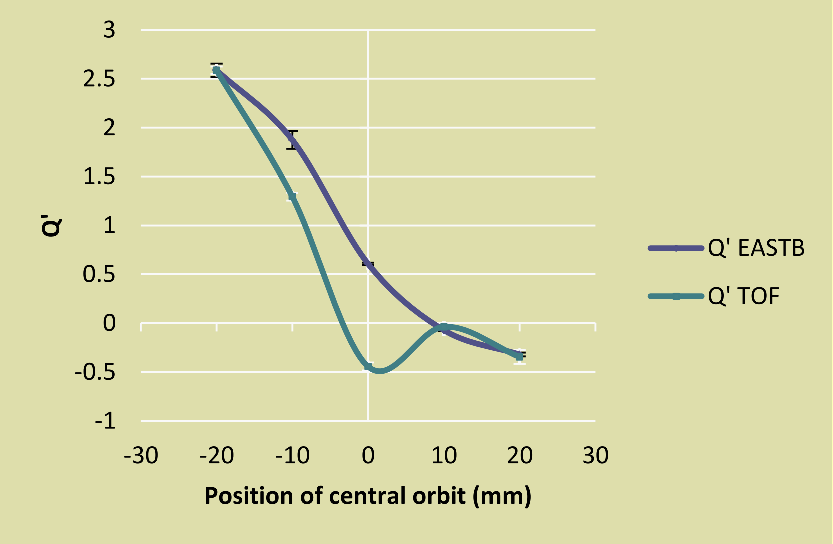
Chromaticity measurements have been done for different values of central orbits to check the stability.

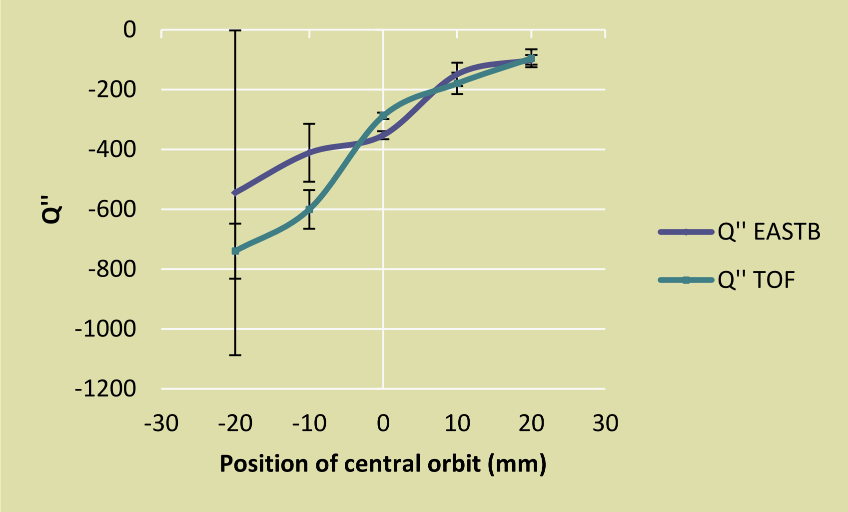
	Q_x	Q'_x	Q''_x
EAST_A 0mm	0.2539 ± 5.10^{-5}	0.61 ± 1.10^{-2}	-352 ± 11
EAST_A 10mm	0.2540 ± 1.10^{-5}	-0.07 ± 1.10^{-2}	-149 ± 36
EAST_A 20mm	0.2536 ± 8.10^{-6}	-0.32 ± 2.10^{-2}	-101 ± 30
EAST_A -10mm	0.2498 ± 5.10^{-5}	1.87 ± 9.10^{-2}	-411 ± 65
EAST_A -20mm	0.2467 ± 1.10^{-5}	2.59 ± 7.10^{-2}	-545± 92

	Q_x	Q'_x	Q''_x
TOF 0mm	0.2539 ± 6.10^{-5}	-0.44 ± 4.10^{-2}	-288± 13
TOF 10mm	0.2540 ± 1.10^{-5}	-0.04 ± 1.10^{-2}	-179 ± 39
TOF 20mm	0.2535 ± 8.10^{-6}	-0.34 ± 7.10^{-2}	-96 ± 16
TOF -10mm	0.2520 ± 3.10^{-5}	1.29 ± 4.10^{-2}	-600± 97
TOF -20mm	0.2458 ± 6.10^{-5}	$+2.56 \pm 4.10^{-1}$	-740± 543

Trajectories stability : Tune and chromaticity measurements







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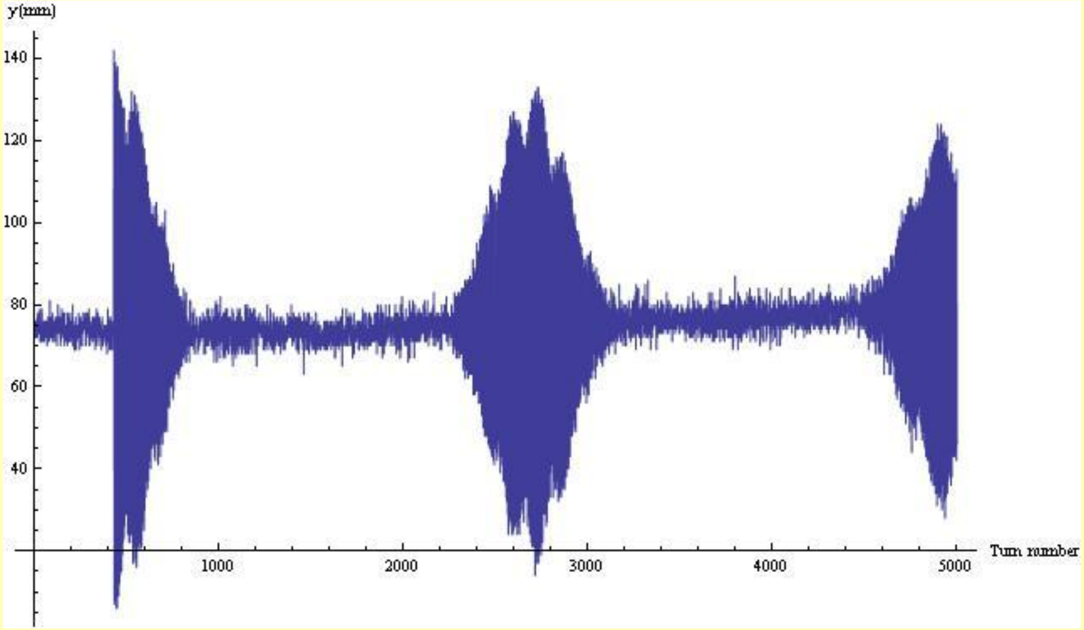
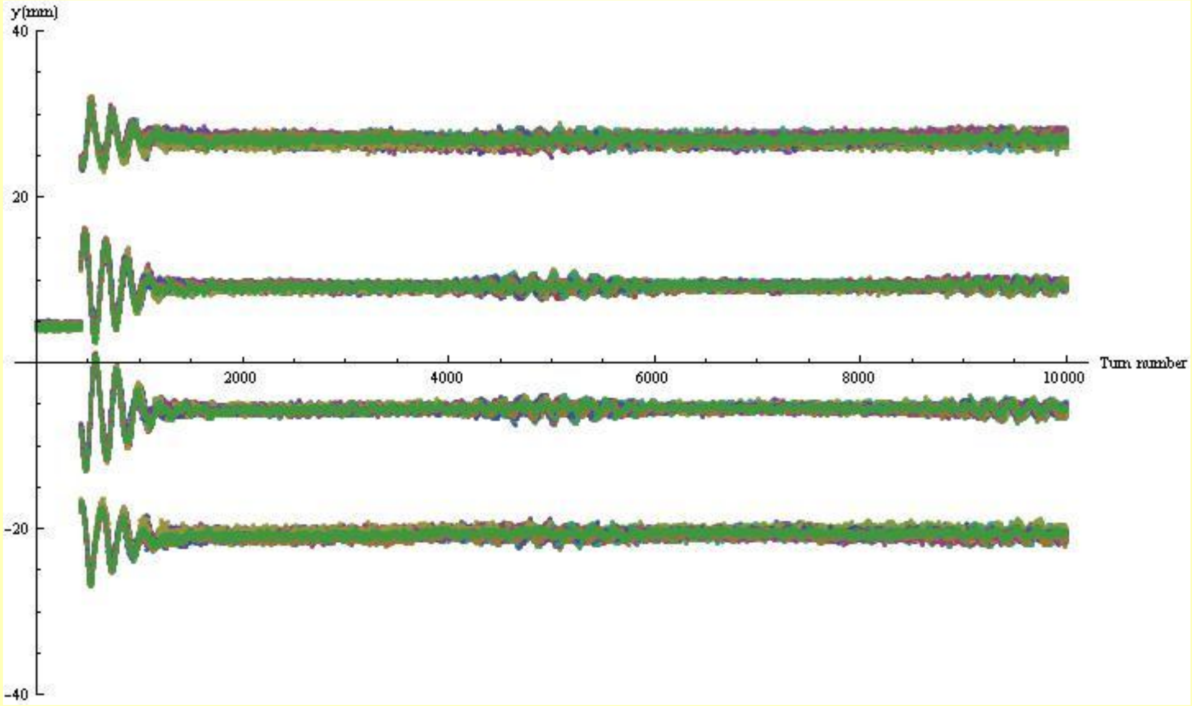
Decoherence / Recoherence : Core

After the kick, and due to the chromaticity, the phase space of the beam spreads from a localized bunch to a annulus and the observed beam centroid will show a decaying oscillation.
Then ,after a synchrotron period, a recoherence occurs when the phase distribution goes back to a delta function before going back to an annulus.
These decoherence/recoherence cycles have been observed on MTE beamlets.



FFT of transverse oscillations gives a frequency of 0.248 which correspond to the measured tune.
The calculated synchrotron period is 215Hz, which corresponds to the measured period with RF (214Hz).

Decoherence / Recoherence : Islands



The calculated decoherence period is 106Hz. (4500 turns) (215Hz for core (2200turns))

The decoherence frequency is 0.023 for all beamlets.

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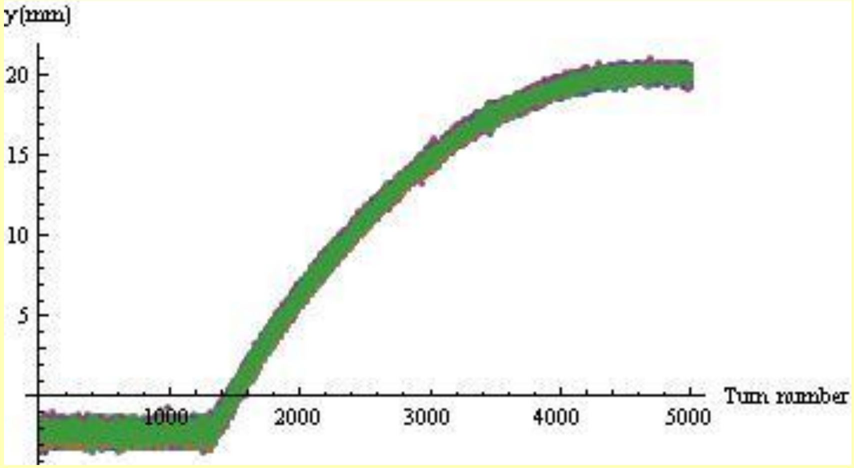
Slow bump closure

A combination of bumps is used to extract island and core up to transfer line. First a slow bump shifts the whole beam to the extraction septum. Then, two fats bumps extract the island and the core.

The slow bump closure has been optimized for the core. Due to different trajectories and non-linearities in the PS, the slow bump is probably not close for the islands.

Slow bump closure : bump for core

Analysis is done at pickup 15 (closest to the extraction septum).

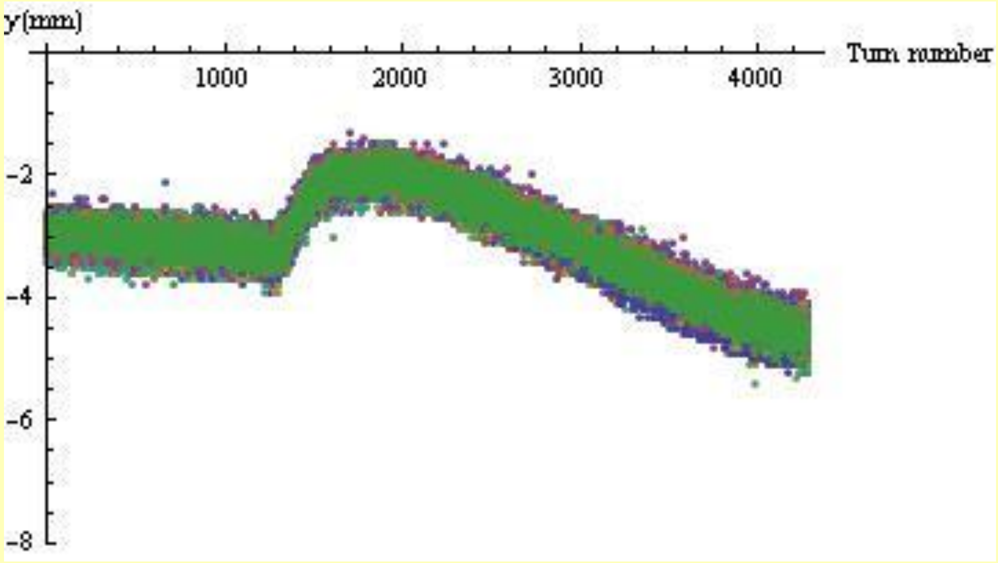


PU15

	Peak to peak Spread before bump (mm)	Peak to peak Spread after bump (mm)
Pickup 15	0.451	0.513

Slow bump closure : bump for core

The closure of the bump is checked by looking at trajectories for a pickup outside bump.



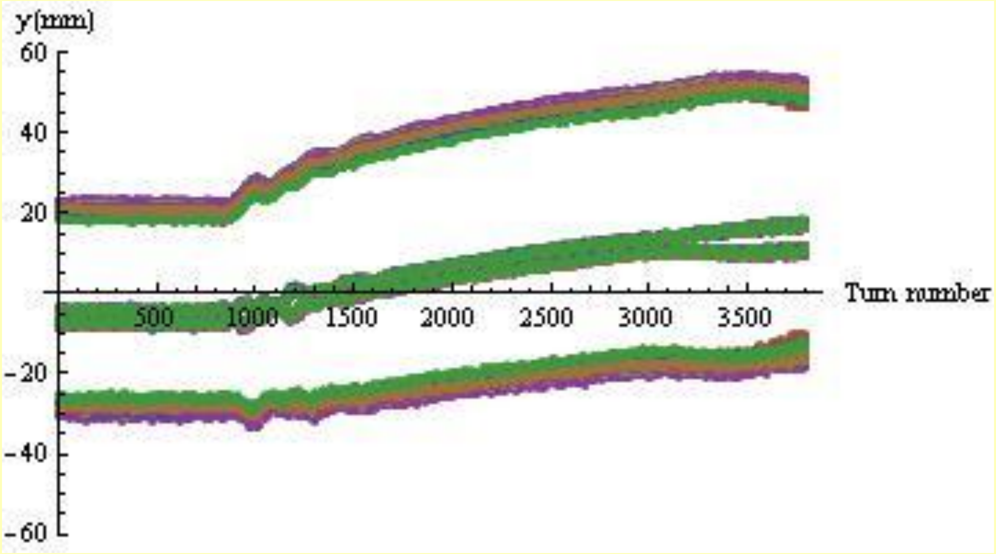
PU 47

The trajectory modification at the beginning of the bump can be explained by a non-perfect synchronization of the extraction kickers at their start.

However the position of the core is not the same at the top of the bump than before bump (about 1.4mm difference), so the bump is not perfectly close for the core.

Slow bump closure : bump for islands

Analysis is done at pickup 15 (closest to the extraction septum).

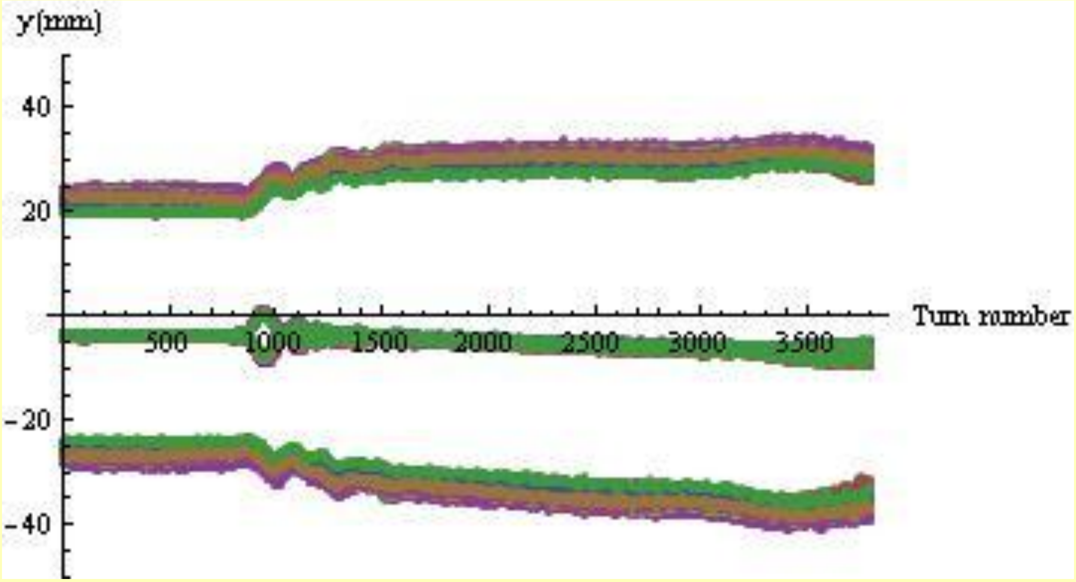


PU15

	Peak to peak Spread before bump (mm)	Peak to peak Spread at the top of the bump (mm)
Pickup 15	4.88	5.36

Slow bump closure : bump for islands

The closure of the bump is checked by looking at trajectories for a pickup outside bump. (pkup47)



PU 47

	Average beam position before bump (mm)	Average beam position at the top of the bump (mm)
Pickup 47	22.35	29.9

With a beam average position difference of around 7mm between bump start and flat top, it is obvious that the bump is not closed for islands.

Slow bump closure : outside bump

In order to probe the non closure of the bump, the beam has been kicked inside island at different time during the rise of the bump. The kfa71 used to kick the beam being outside the bump, if the voltage needed to kick the beam with minimized decoherence oscillations changes with the kick time, the bump is not closed.

The bump starts at 874ms and rises during around 6ms.

the beam has been kicked at 872ms, 874ms, 876ms and 878ms.

Kick time (ms)	Optimized kfa71 voltage (kV)
872	400
874	460
876	520
878	500

Slow bump closure : SPS measurements

Some trajectories measurements of the MTE beamlets in the SPS have been done last year.
They show some fluctuations from cycle to cycle.
With these measurements it is possible to deduce by simulation the distribution of the beamlet positions at the exit of the PS.

This distribution has been compared with fluctuations observed at the top of the bump in the PS from cycle to cycle.

The spread around center is the same in both cases (~ 5mm).

Introduction : Goals of the study, measurement technique, scans performed

Trajectories stability :

Constant tune
Variable tune
Special cycles
Summary

Non-linear chromaticity measurements

Study of decoherence/recoherence

Closure of the Slow bump

Analysis for a pickup inside bump
Analysis for a pickup outside bump
Correlation with observed SPS fluctuations

Work to be done, conclusion

Work to be done

Trajectories stability

The tune ramp has been applied with Figure-of-eight loop. To be done also using Qlow to compare with.

The chromaticity measurements show that octupolar component significantly vary. Measurements to be done with PFW's turned off and replaced by MTE non-linear magnets to create islands in order to minimize the machine octupolar component.

Repeat measurements at 2GeV, ie without PFW's and figure-of-eight loop to compare with 14GeV measurements.

Bump closure

Code development to close bump for core and islands in the same time.