Code Bench-Marking for Long-Term Tracking and Adaptive Algorithms

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Program

1. GSI BENCH-MARKING SUITE
2. VARIANTS OF SPACE CHARGE FROZEN MODELS
3. CODES IN COMPARISON WITH MACHINE EXPERIMENTS
   - PS
   - SPS
4. THE NOISE ISSUE OF PIC CODES
5. *Special request: ROUNDING ERROS IN CODES (time permits)*
6. CONCLUSIONS

GSI BENCH-MARKING SUITE

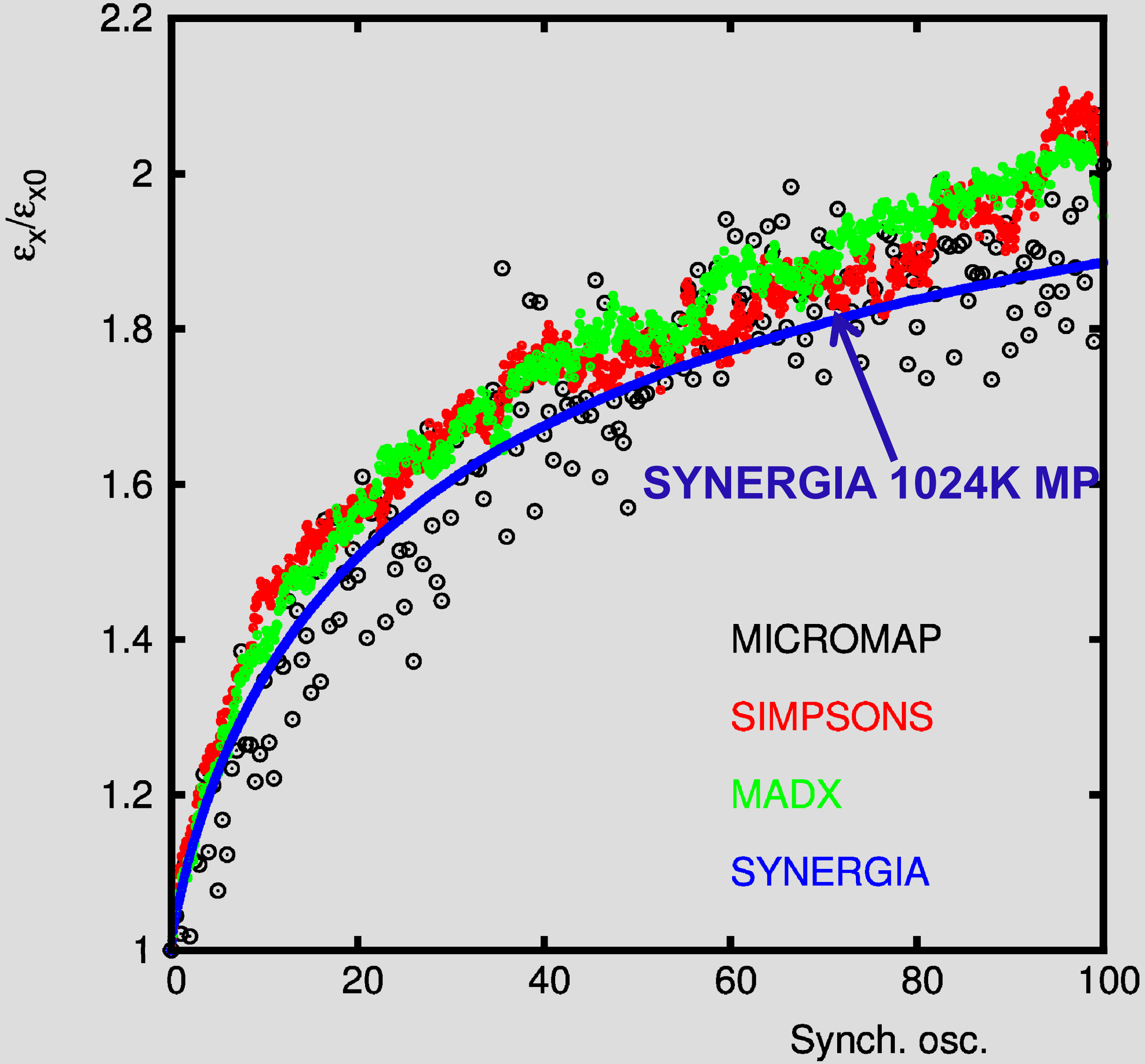
- Giuliano Franchetti has set-up the elaborate GSI bench-marking suite at:
web-docs.gsi.de/~giuliano/research_activity/trapping_benchmarking/main.html

- As a simple example the SIS18 is used with one sextupole and a synchrotron period of 1000 turns.

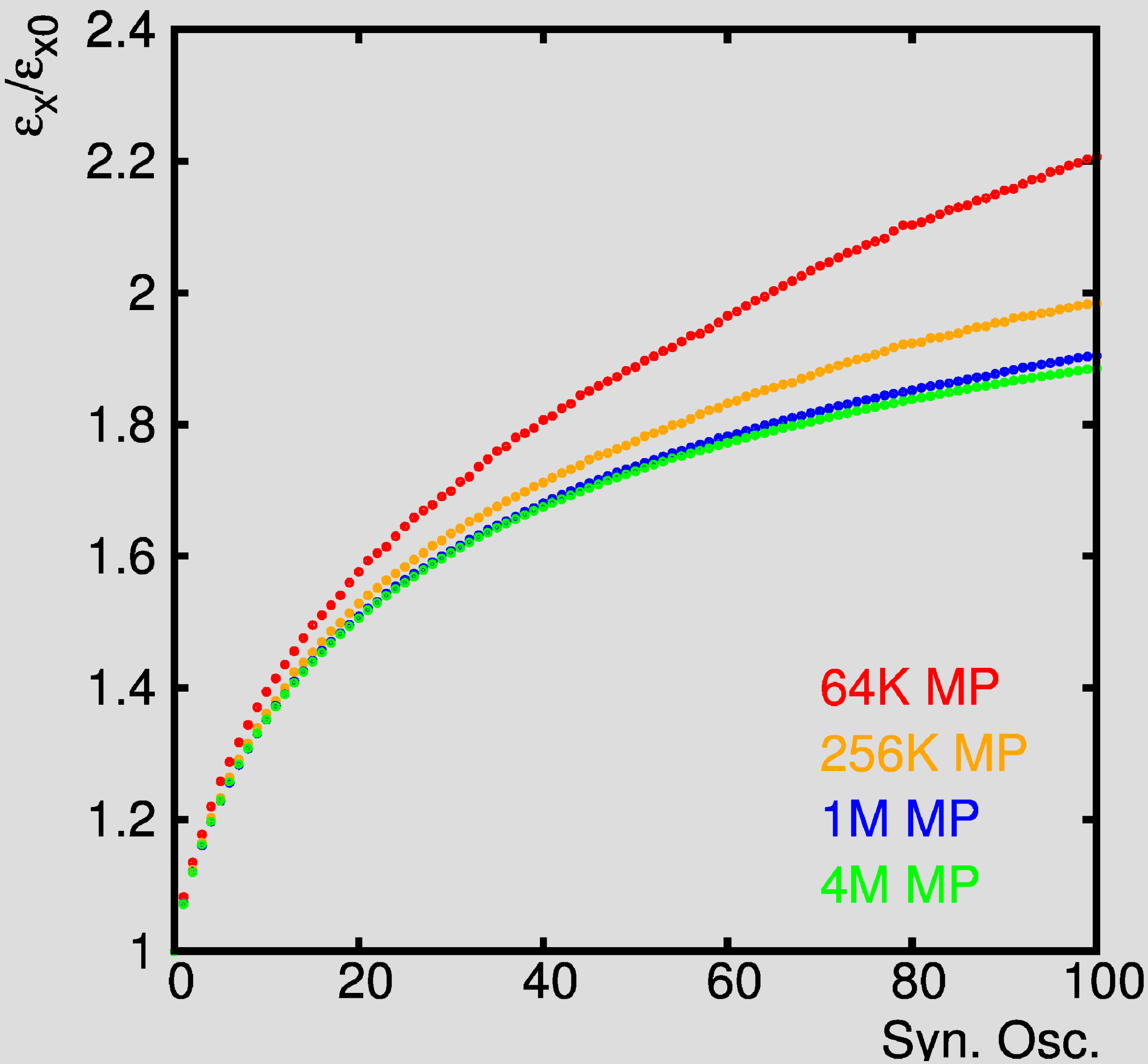
- It consist of 9 steps including:
  a. phase space plots
  b. SC amplitude dependent tune-shifts
  c. trapping related phenomena
  d. long-term evolution of emittance blow-up

- The SYNERGIA & ORBIT team have worked on all steps and their results will be added to the web-site after this conference.

Long-Term Bench-Marking



Long-Term Convergence Test



SYNERGIA

VARIANTS OF SPACE CHARGE FROZEN MODELS

Adaptive versus Purely Frozen Mode I

1. Frozen Mode looks at first sight like a flawed approach since it does not take into account the ever changing beam distribution due to SC and the lattice non-linearities.
2. However its very fast compared to the self-consistent PIC calculations and the calculation are symplectic.
3. Yuri Alexahin suggest a “hybrid” or “adaptive” solution that remains frozen at core but renormalizes the emittances once a turn.
4. To this end he has devised a fast iterative process to determine a good fit of Gaussians to the core of the beam distribution and ignoring tails.

Adaptive versus Purely Frozen Mode II

1. **PROS: Introduce at least partially (the Gaussian part) of a changing distribution. Speed-up via OPENMP (BNL contribution).**

2. **Cons: Implementation nightmare due to re-entry into the run module and intermittent TWISS runs. Like in the self-consistent approach the information of all particles are needed. Therefore a serialization is not possible ➔ very heavy speed penalty! Question: Does this renormalization of the emittance create noise? Needs study!**

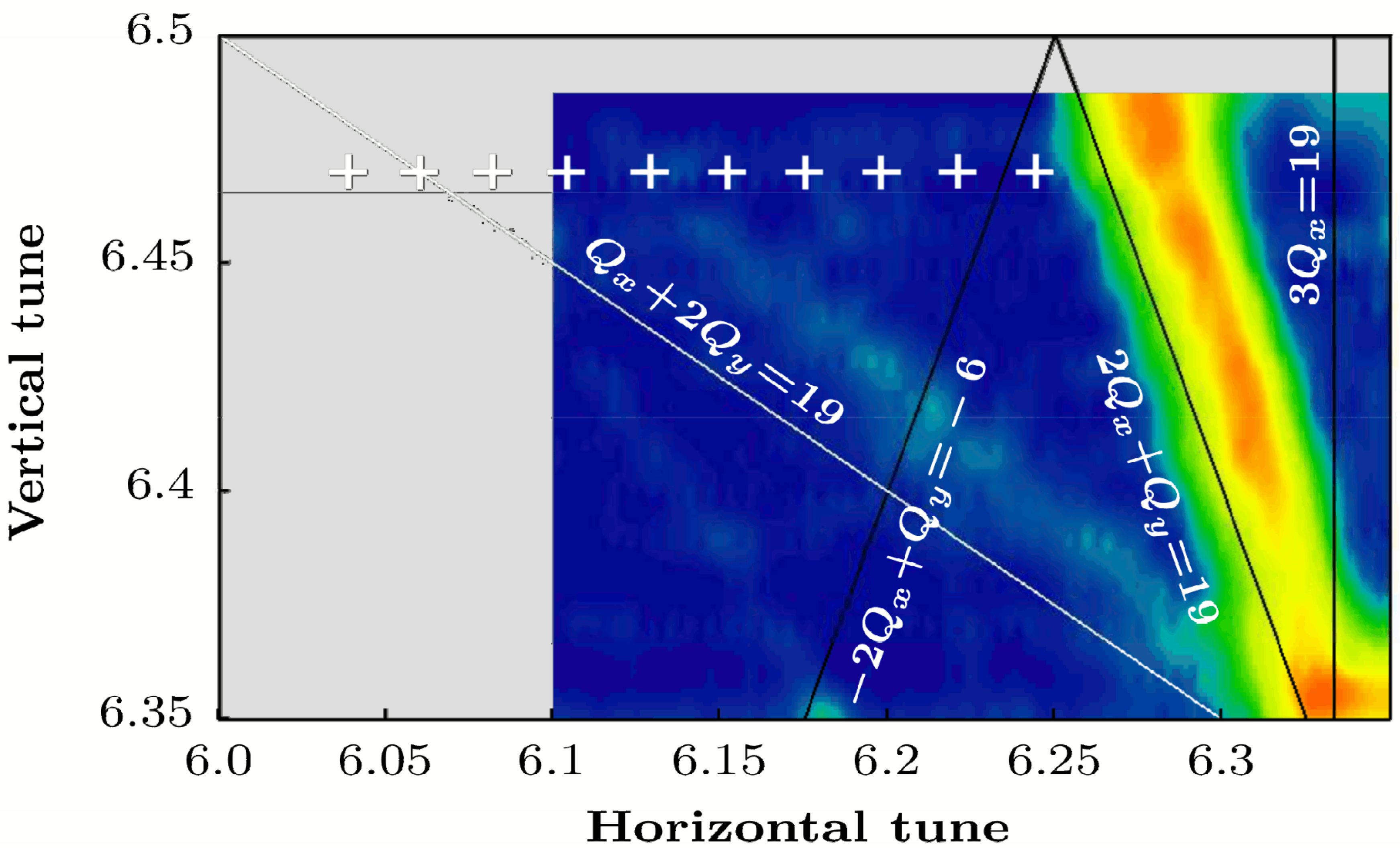
A) CODES IN COMPARISON WITH MACHINE EXPERIMENTS
PS

Machine Parameters

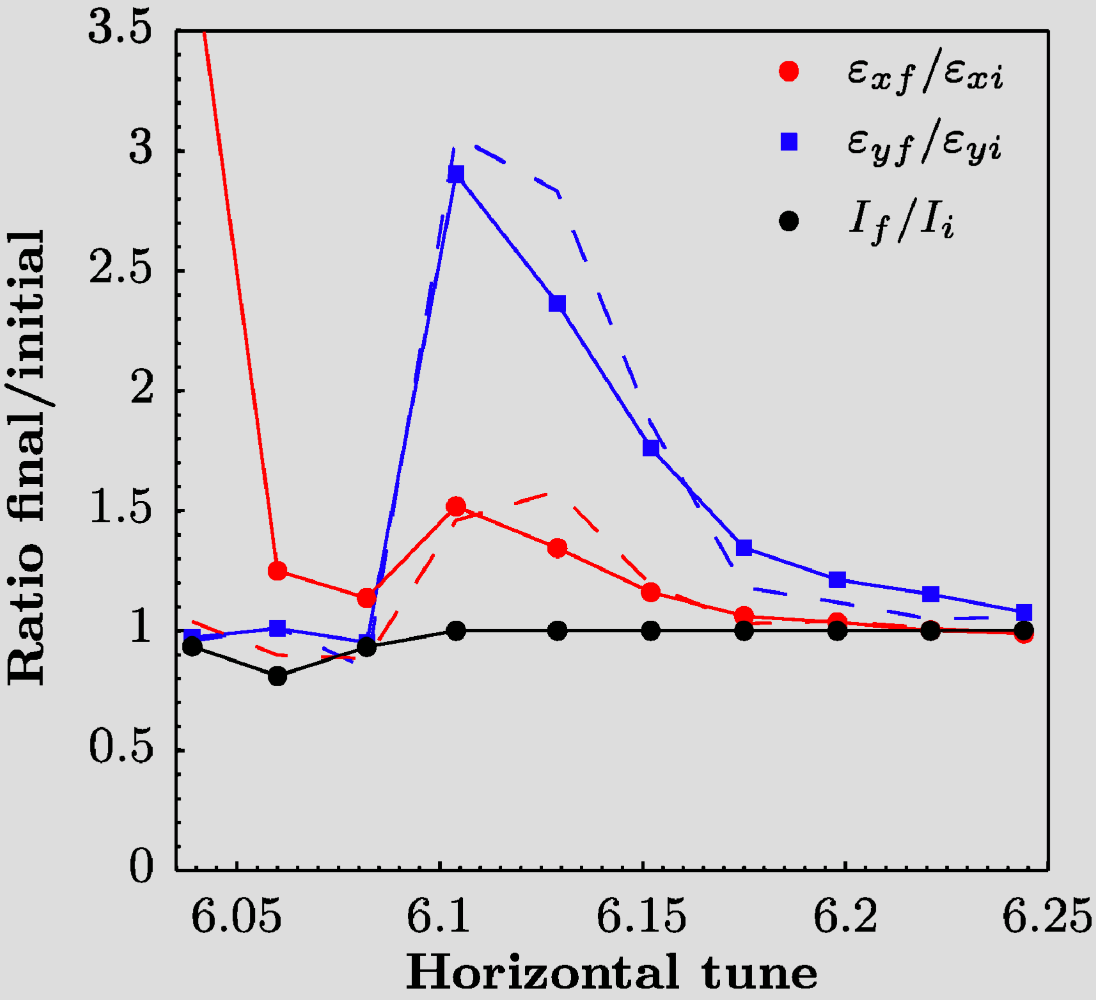
Table 1: Machine Parameters

Parameter	SIS18	PS	SPS
Length [m]	216.71	628.32	6911.5
Kin. E. [GeV]	0.0114	2	25.079
Tuneshift	-0.1/-0.1	-0.05/-0.07	-0.1/-0.19
Special Features	Sextupole	Sextupole	Optimal adjusted
	Uncorr. Chromaticity		

PS-Experiment I

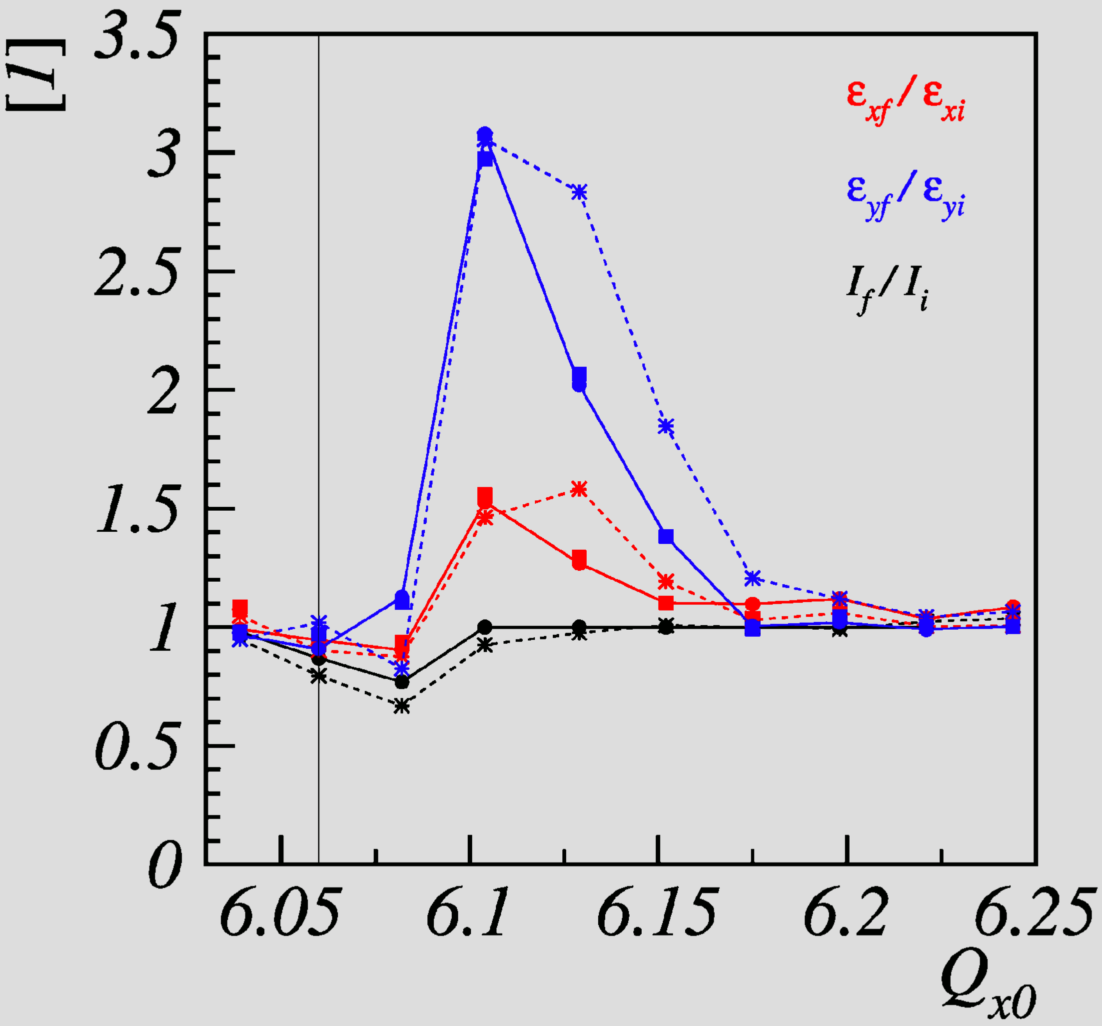


PS-Experiment II



ADAPTIVE

PS-Experiment III



FROZEN

PS Detailed MAD-X Simulations I

Given the differences found in this first round of simulations, a more refined study has been repeated under the following conditions:

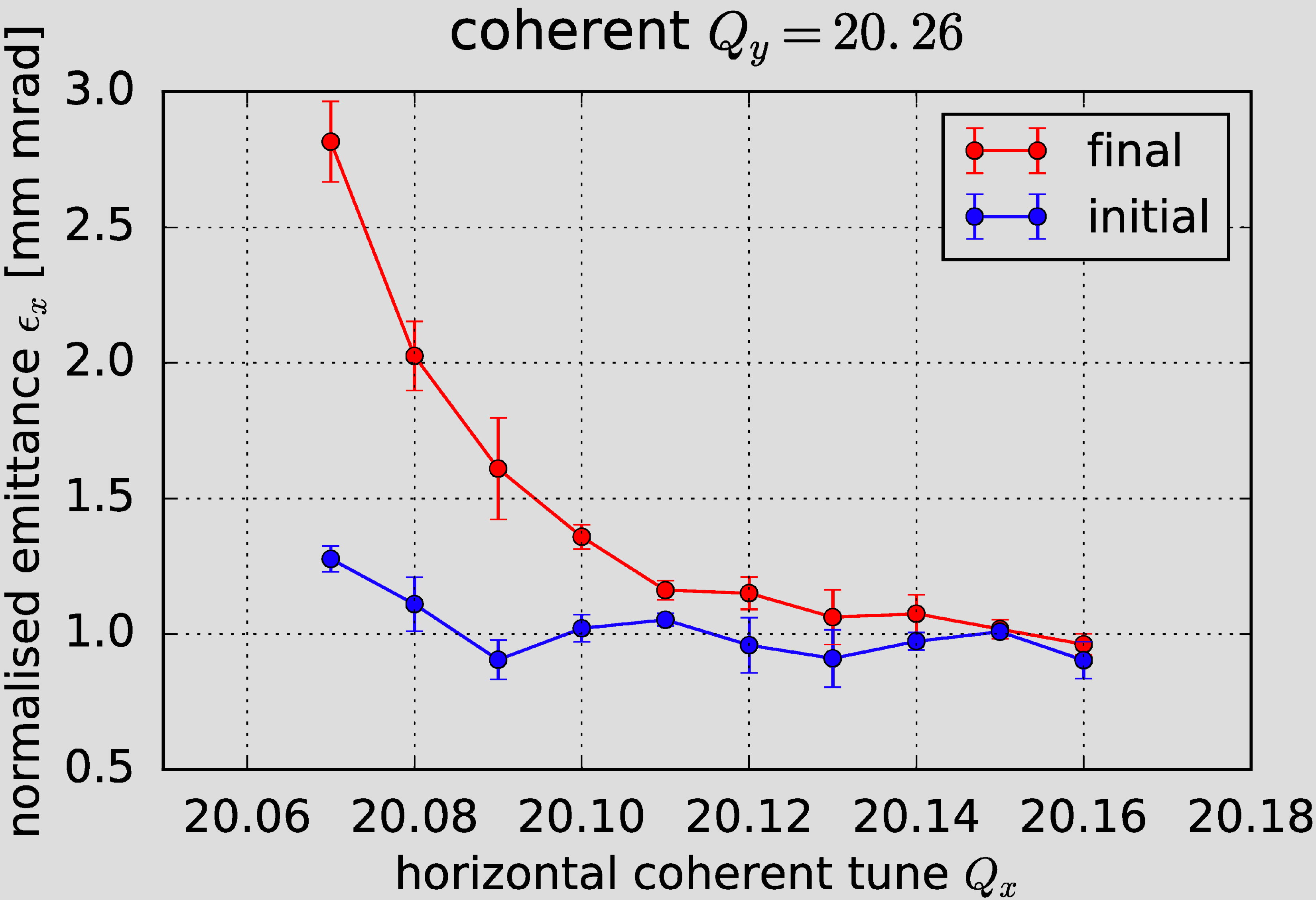
1. Re-study at Q_x = 6.039 and Q_x = 6.104
2. Use 2D polar Gaussian via Box-Muller transform and 6D transformation for fully matched 6D distributions and keep them for both WPs ➔ should be similar to the experimental set-up.
3. First trial of the new combined function magnet as derived and implemented by M. Titze, i.e. change of the horizontal chromaticity is about 16%.
4. Try out various sub-variants: adaptive/frozen with/without Twiss, combined function.

PS Detailed MAD-X Simulations II

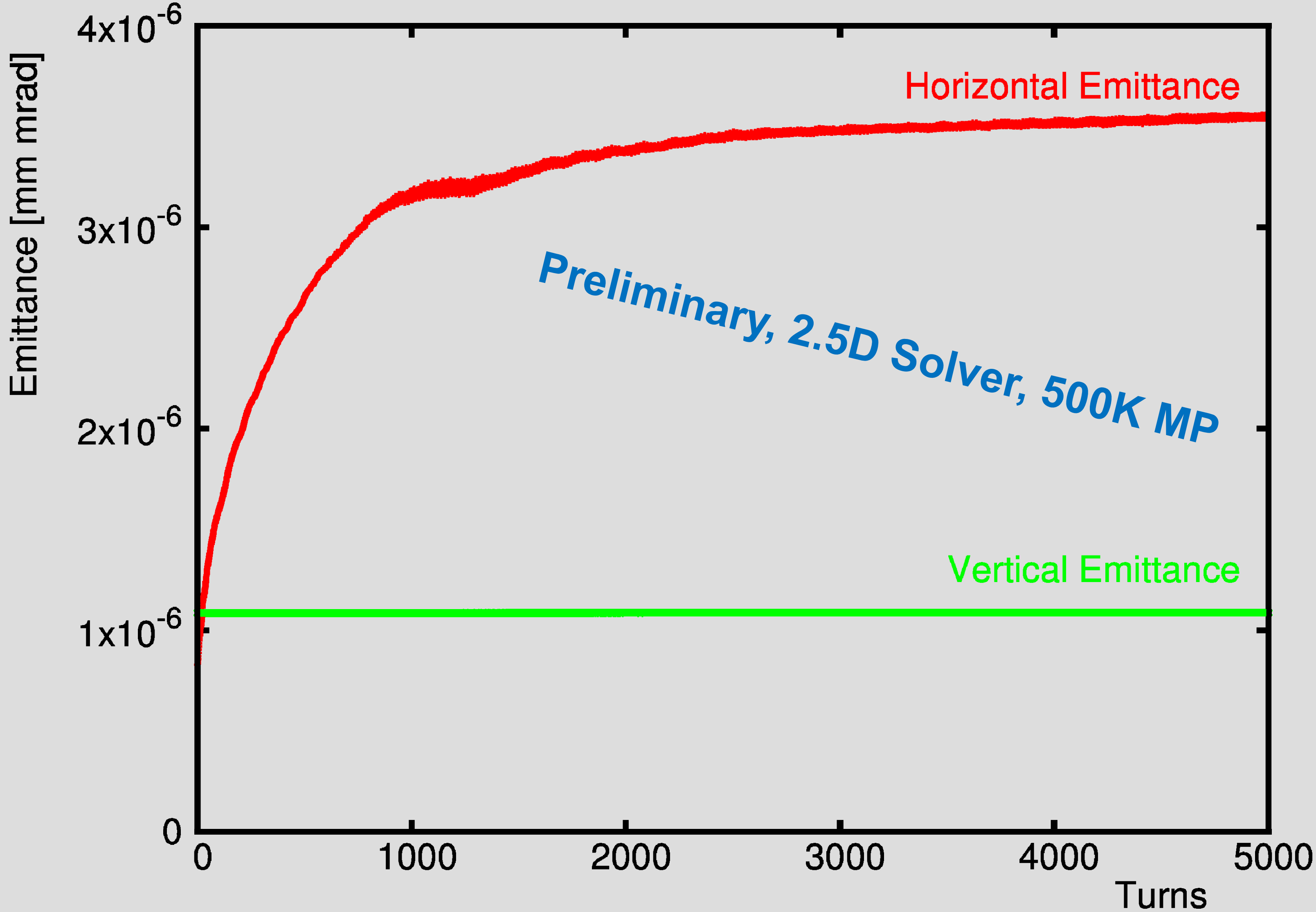
Q_x	Mode	Experiment
6.039	Frozen	0.97/1.077
	$1.07 \pm 0.06/0.99$	
	Adaptive	
	$1.73 \pm 0.03/0.97 \pm 0.02$	
6.104	Frozen	1.553/2.974
	$1.54 \pm 0.08/2.47$	
	Adaptive	
	$1.78 \pm 0.03/3.18 \pm 0.012$	

B) CODES IN COMPARISON WITH MACHINE EXPERIMENTS SPS

SPS-Experiment

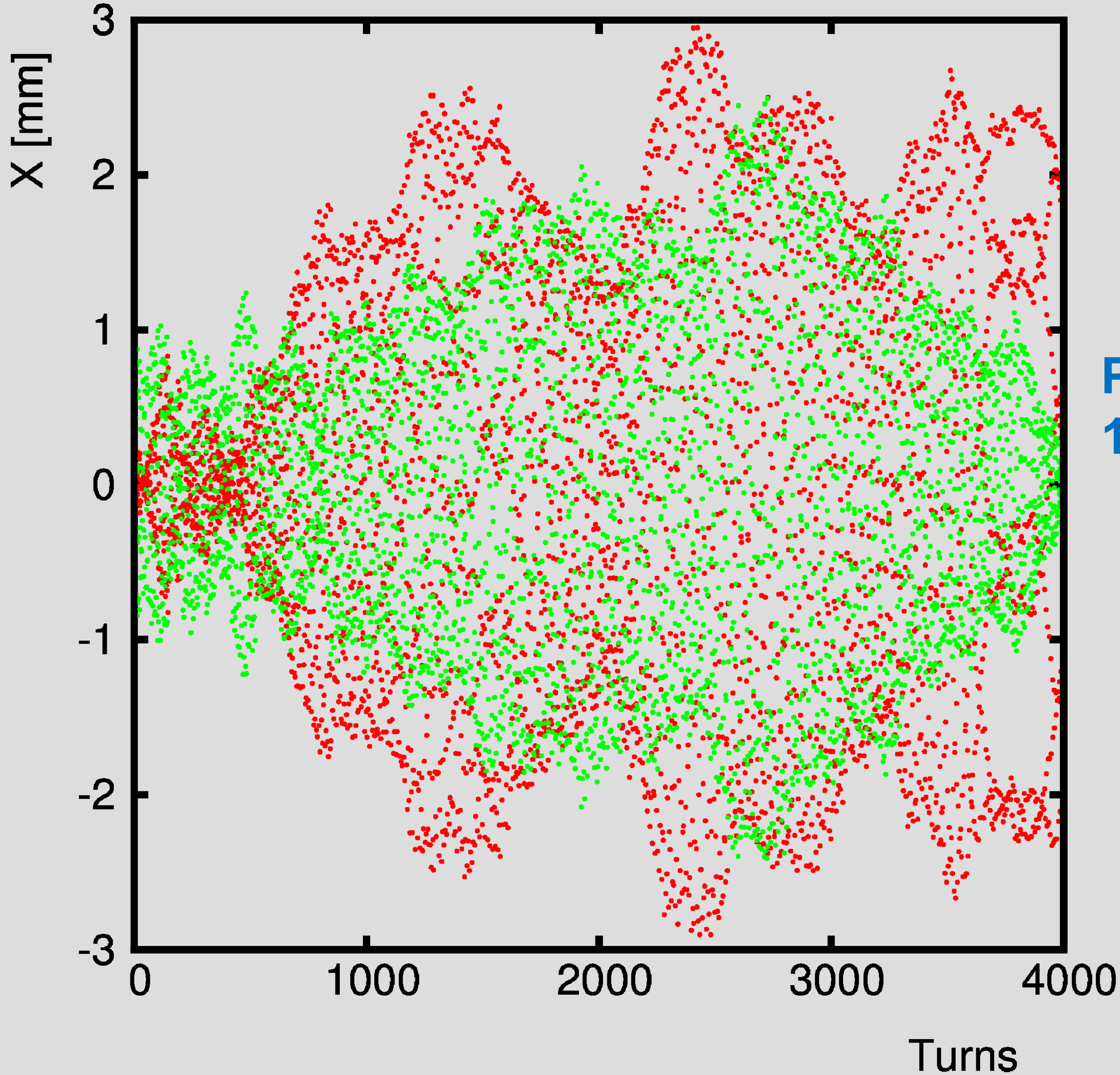


SPS PyORBIT Simulations



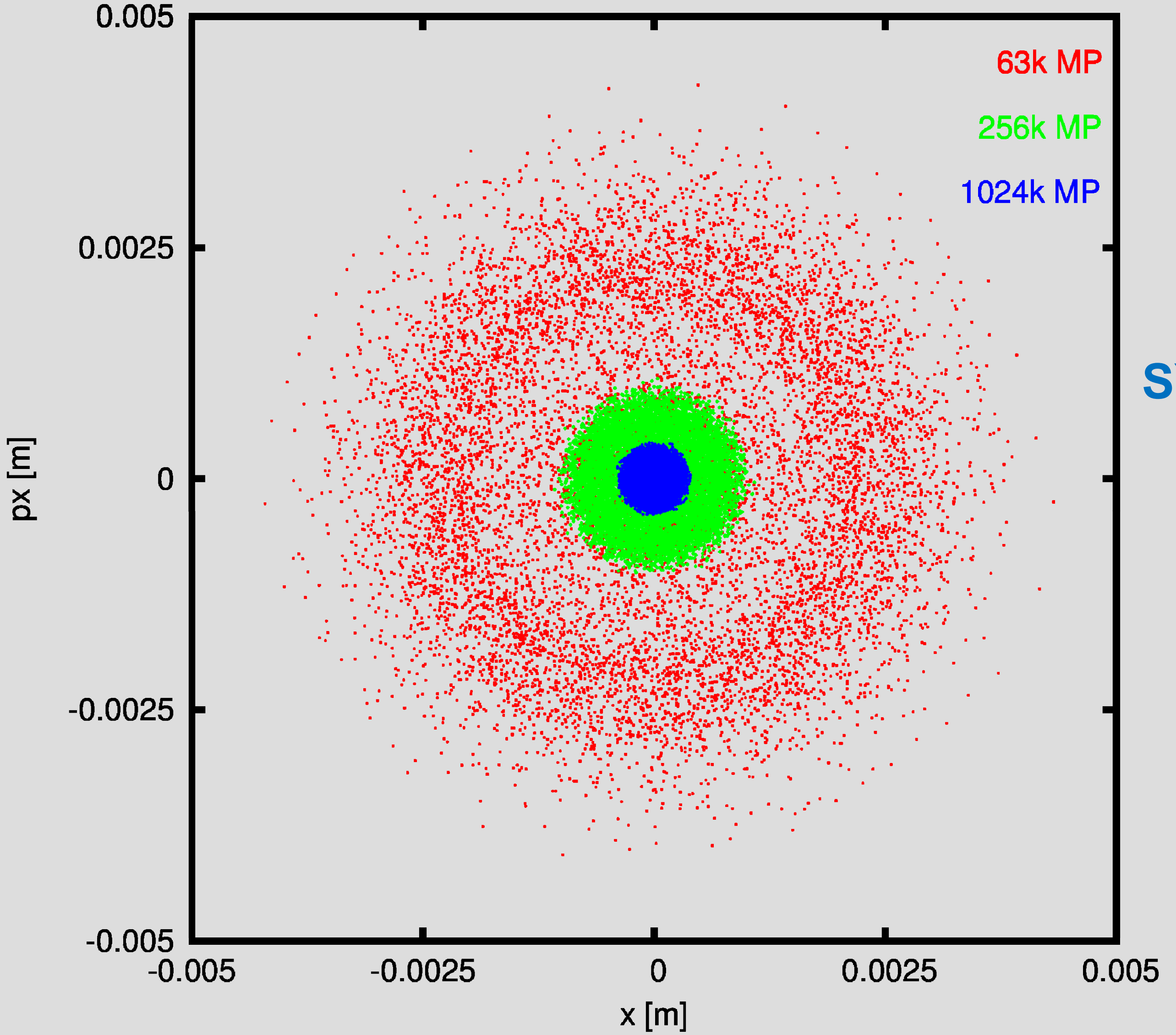
THE NOISE ISSUE OF PIC CODES

Effect of Grid Noise on Amplitude



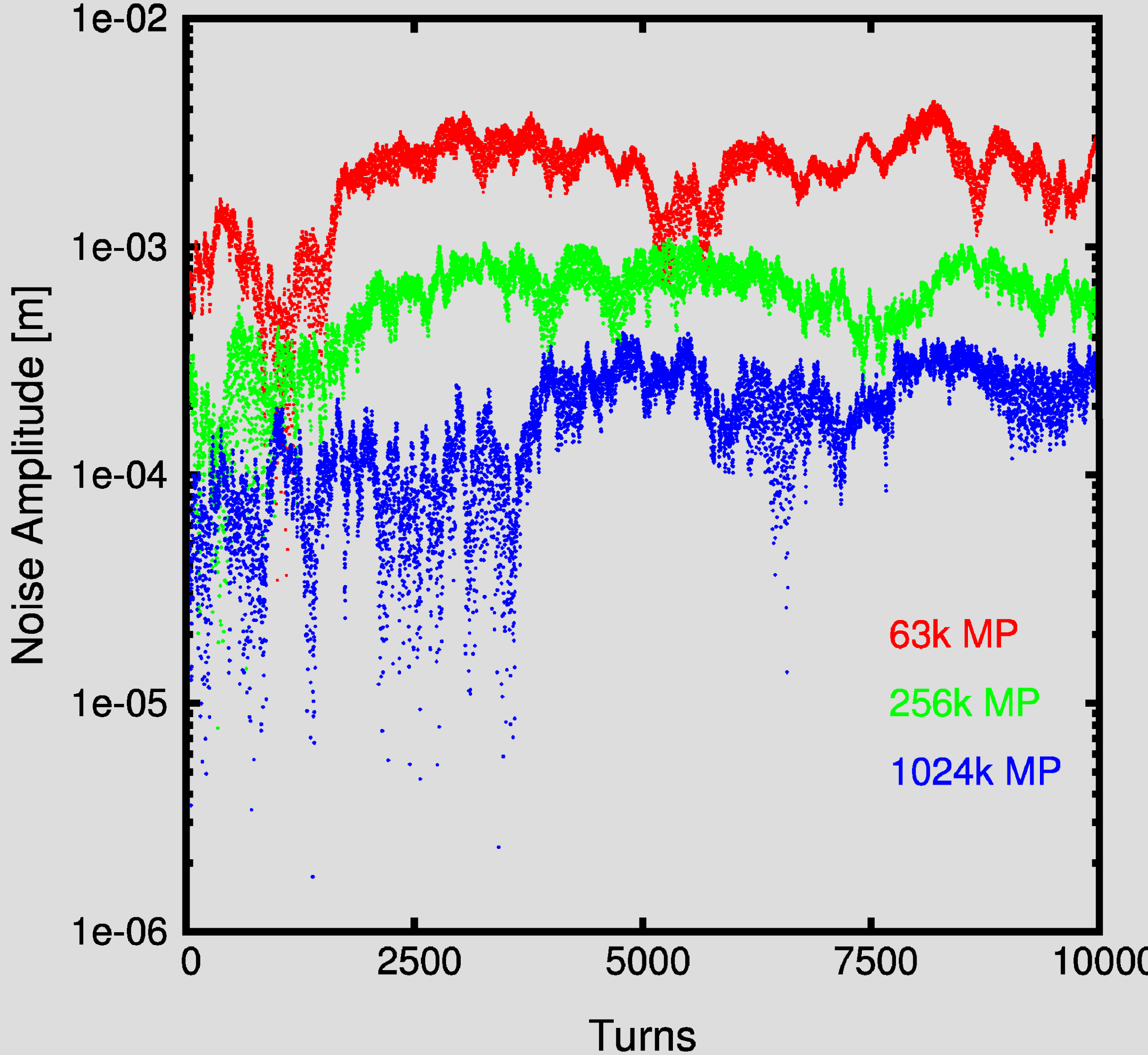
PTC-ORBIT
100K MP

Effect of Grid Noise on Phase Space



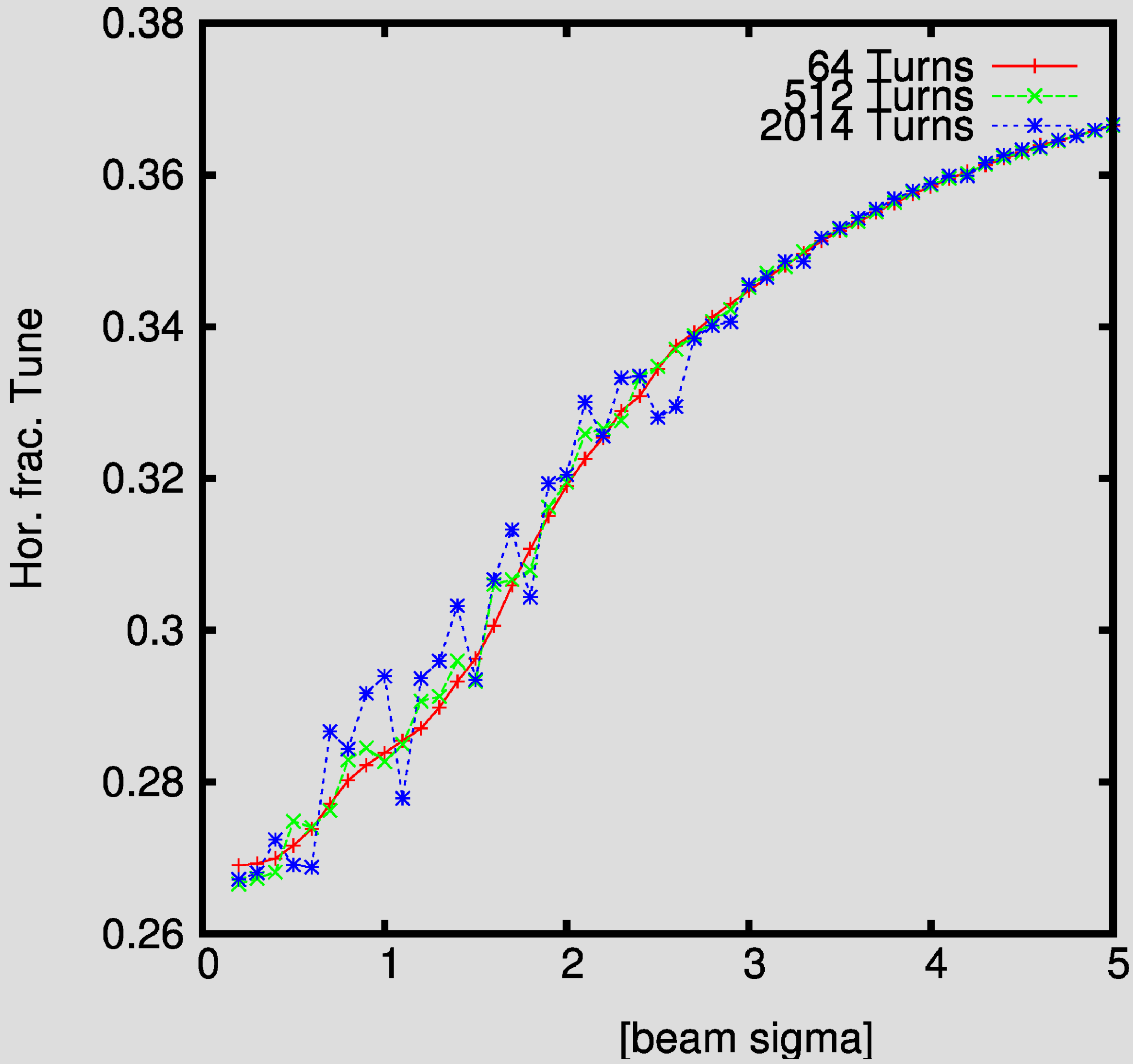
SYNERGIA

Effect of Grid Noise on Amplitude



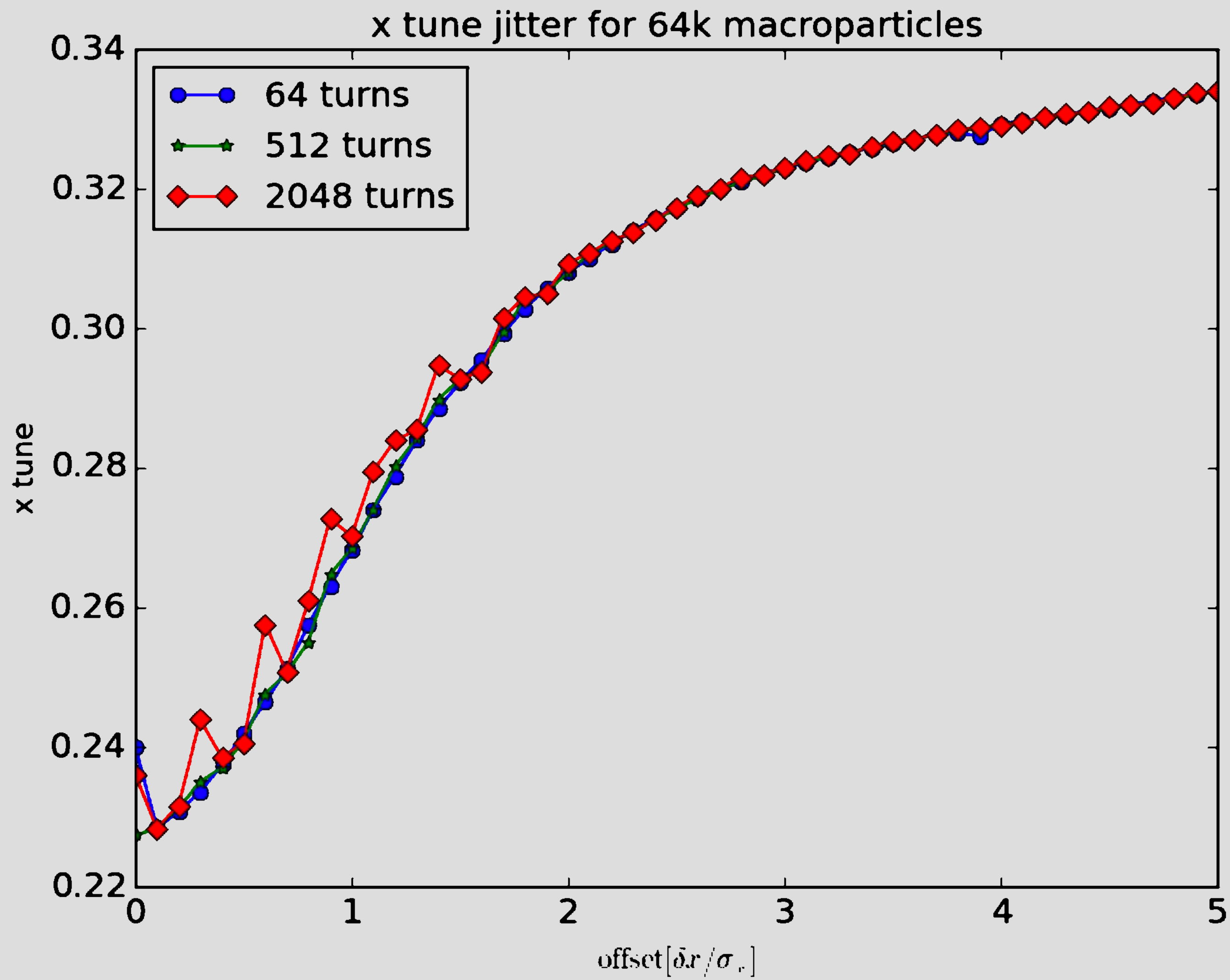
SYNERGIA

Effect of Grid Noise on Tunes



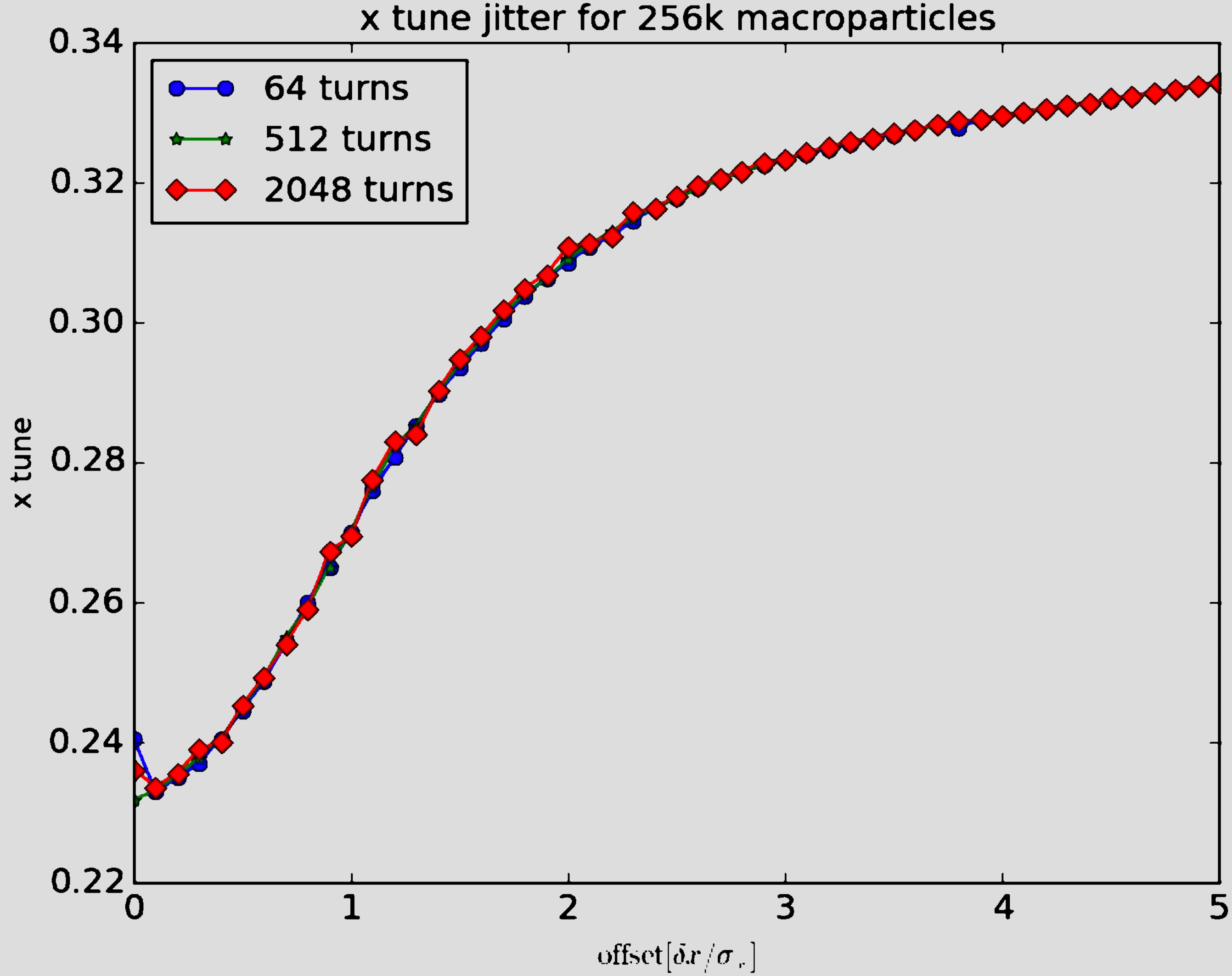
PTC-ORBIT
100K MP

Effect of Grid Noise on Tunes



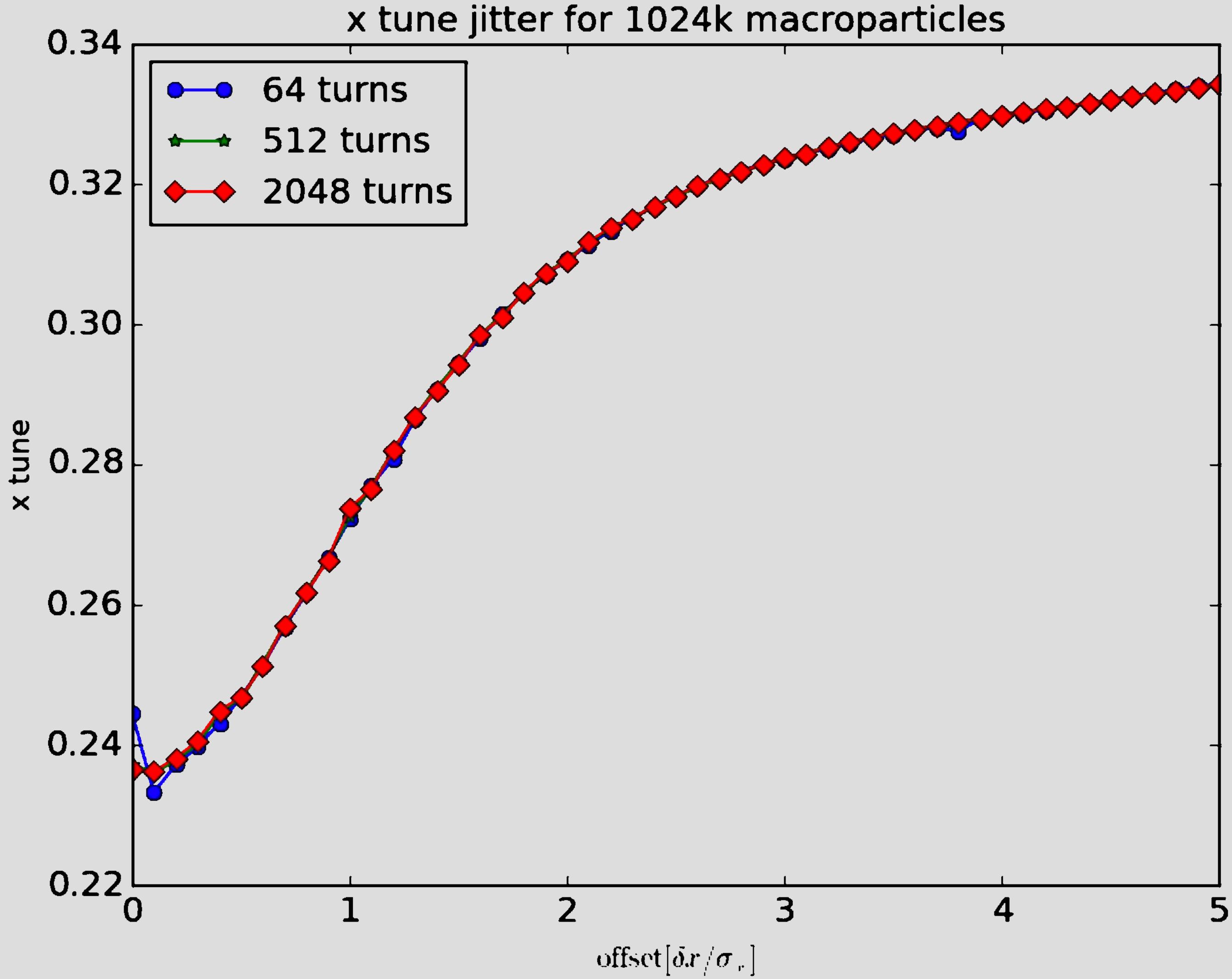
SYNERGIA 64K MP

Effect of Grid Noise on Tunes



SYNERGIA 256K MP

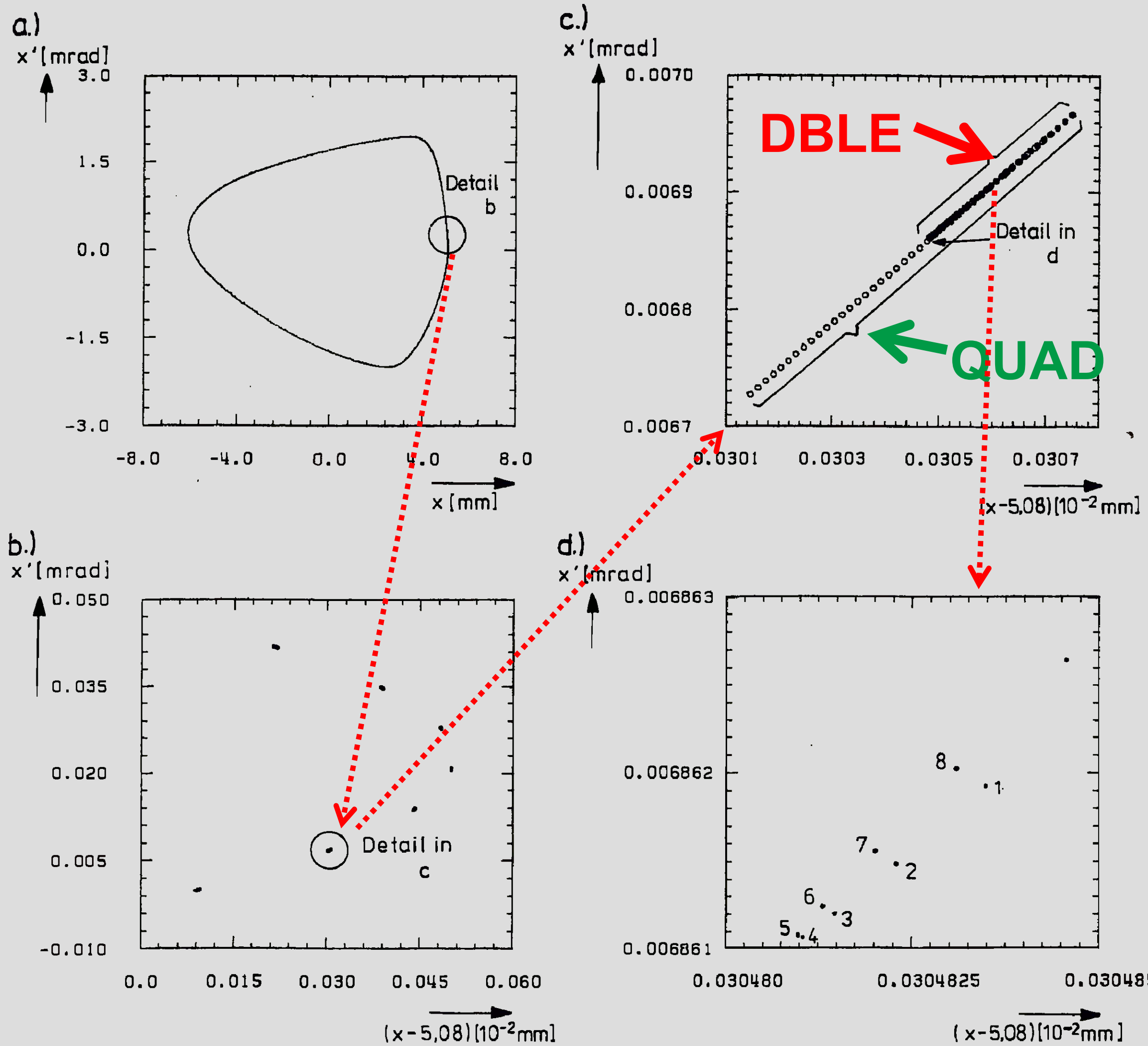
Effect of Grid Noise on Tunes



SYNERGIA
1M MP

ROUNDING ERROS IN CODES

Rounding Errors in Phase Space



Conclusions

1. The world-wide collaboration on the on the GSI Bench-Marking Suite is now completed for the 2 PIC codes SYNERGIA and PyORBIT.
2. Long-term PIC Simulations seem feasible despite the fact that the noise remains measurably relevant.
3. Several bench-marking experiment have been compared with simulation results.
4. The agreement is quite impressive. However, in the frozen model the plain frozen might be better suited than the adaptive mode ➔ more studies needed.
5. Super-fast frozen mode planned with SixTrack ~100 times faster!
6. Simulations at the integer will be completed for both frozen and self-consistent codes ➔ M. Titze's PhD.
7. Noise issues remain interesting and we are investigation apparent non-symplecticity of PIC codes (other main part of M. Titze's PhD).
8. Eventually CERN will invest into its own symplectic self-consistent SC module.