March 26, 2013

(LHC simulation updates)

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~ new LHC results

- **no big surprises...**

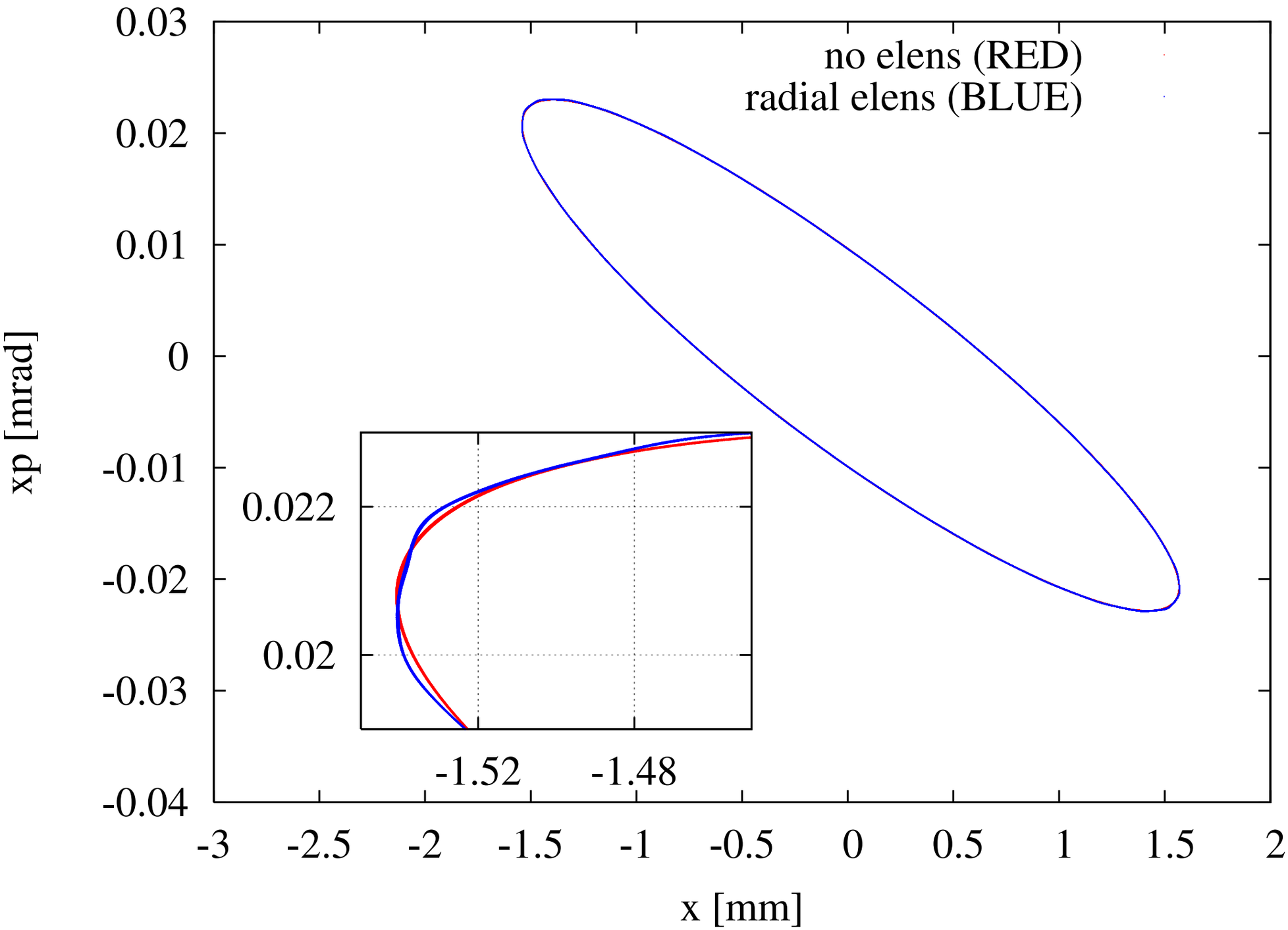
1. DC mode: full results with/without octupole, radial mode, jitter
2. AC mode: "new" solution acoording to parametric oscillation equations.
   - Different frequencies tested.
   - Optimization of frequency sweep
   - Distribution of survival particles studied
3. random mode:
   - New random mode tested
   - Distribution of survival particles studied

simulation settings

- LHC 7 Tev nominal optics with octupoles (unless specified)
- 200K turns
- 6400 particles (for survival particles evaluation)
- uniform halo between 4 and 6 sigma (horizontal halo mostly)
- when vertical halo has been simulated, no substantial difference
- electron lens 1.2 A
- 5 kV

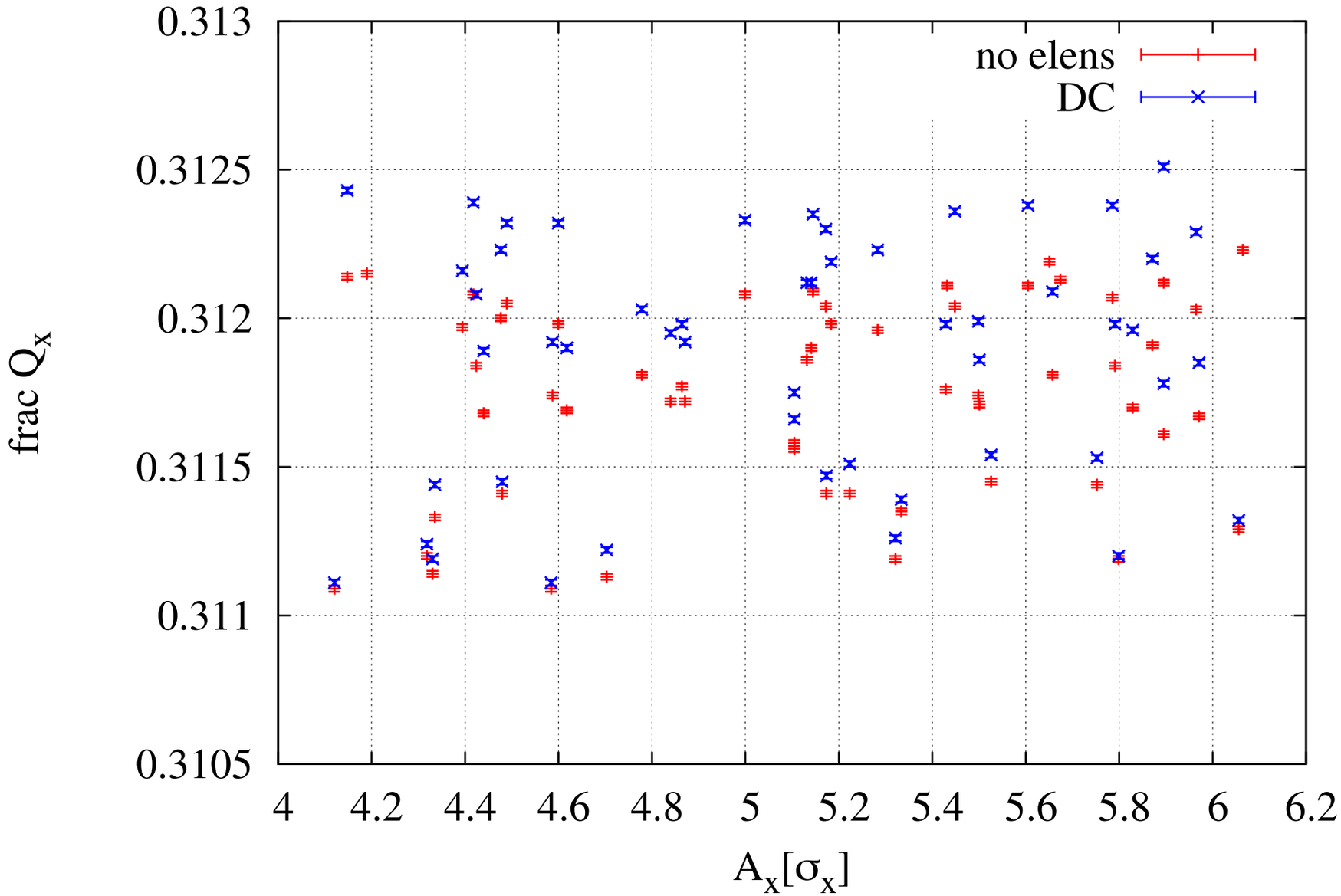
DC mode : quasi-linear machine

- Re- run the linear machine with the Radial model
- past results are confirmed: mild phase-space deformation


no elens (RED)
radial elens (BLUE)
xp [mrad]
x [mm]
0.03
0.02
0.01
0
-0.01
-0.02
-0.03
-0.04
-3
-2.5
-2
-1.5
-1
-0.5
0
0.5
1
1.5
2
0.022
0.02
-1.52
-1.48

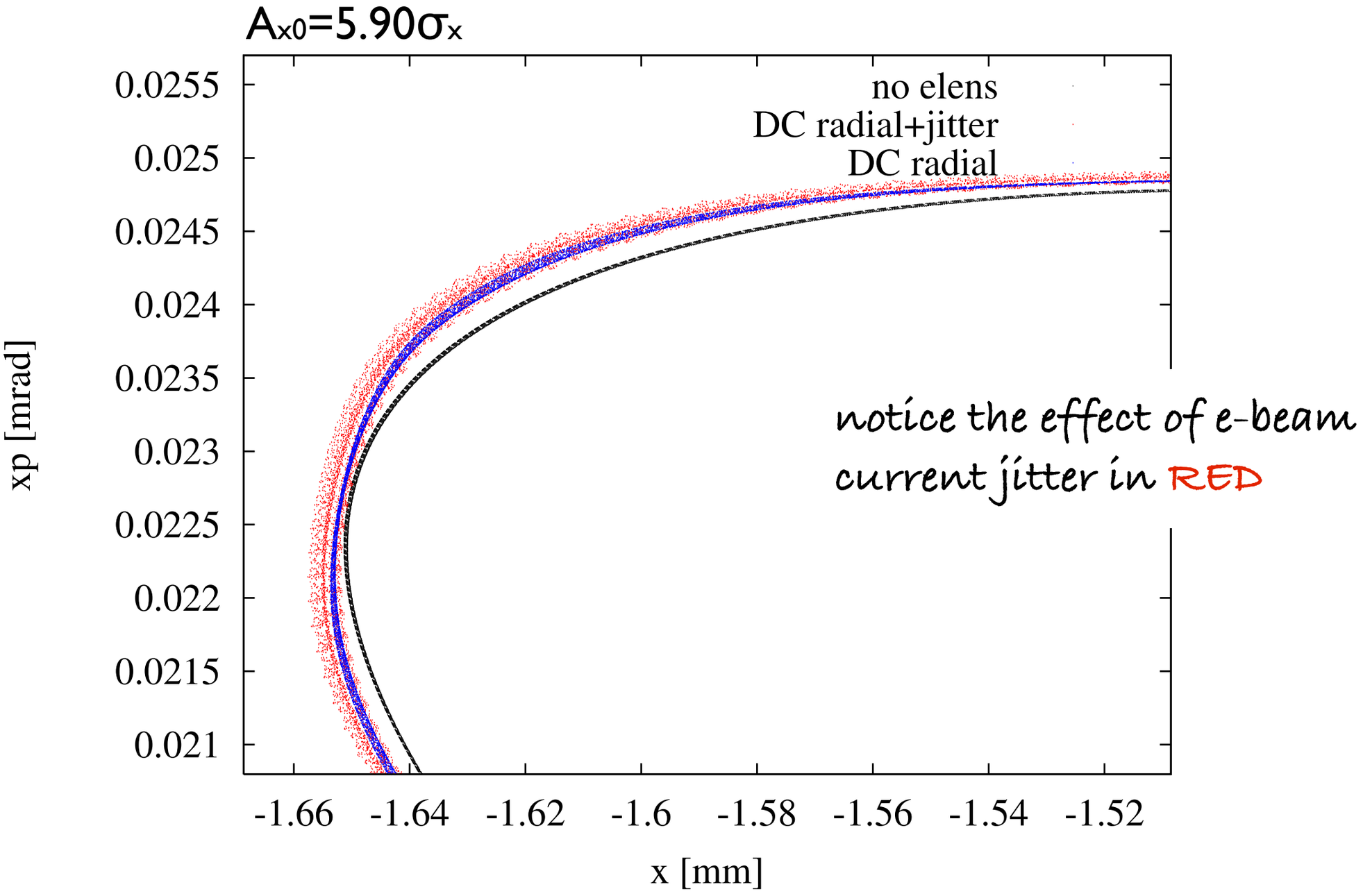
Including Octupoles

Tune values are scattered. Tune spread is much larger.



Δ tune =1.5 e-3
(to be compared
with 4e-5
without octupoles &
with elens)

Non-linearities begin to be important.



For *some* particles the elens-effect is still a mild one

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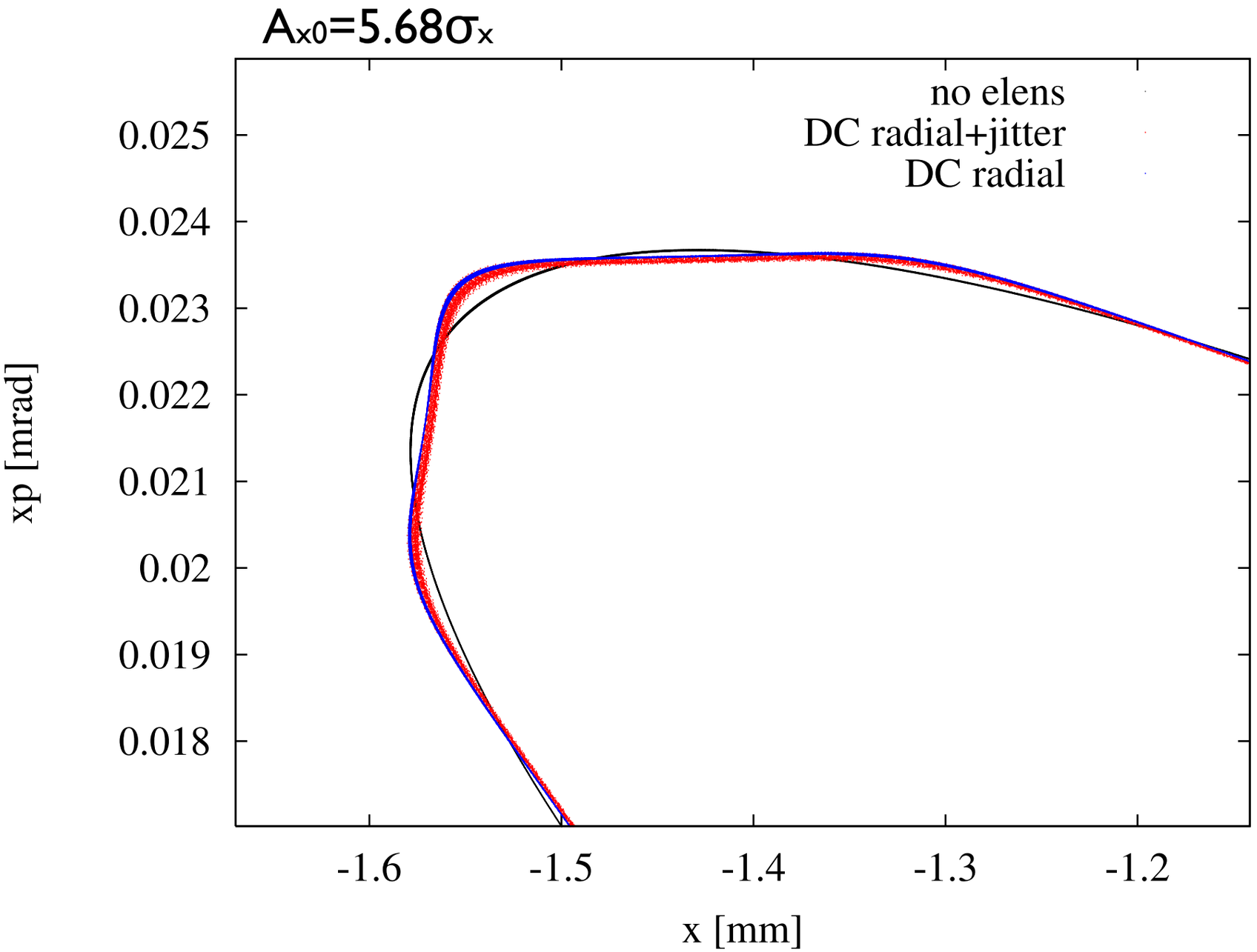

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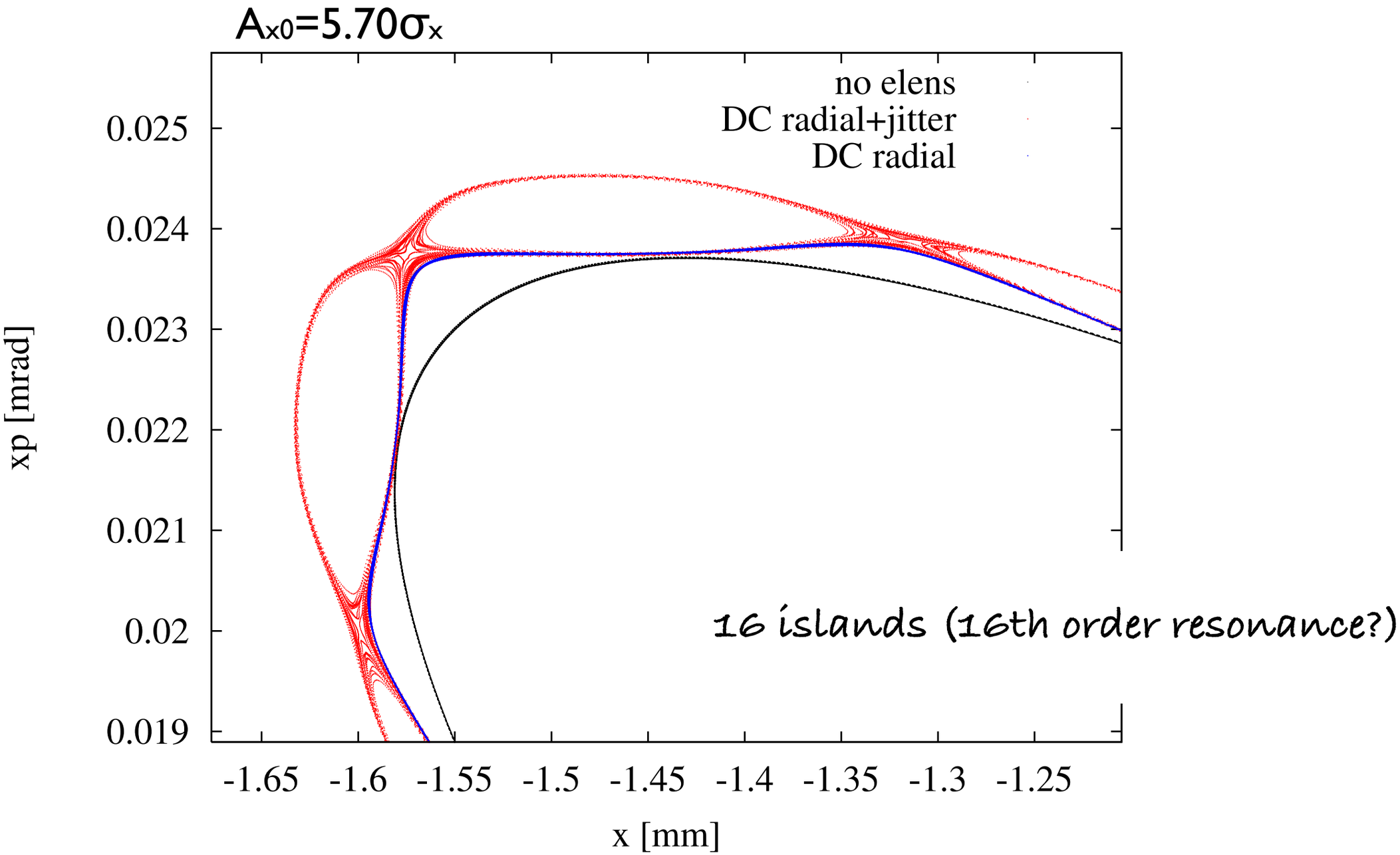

For *some* particles the phase space is heavily deformed by the e-lens.

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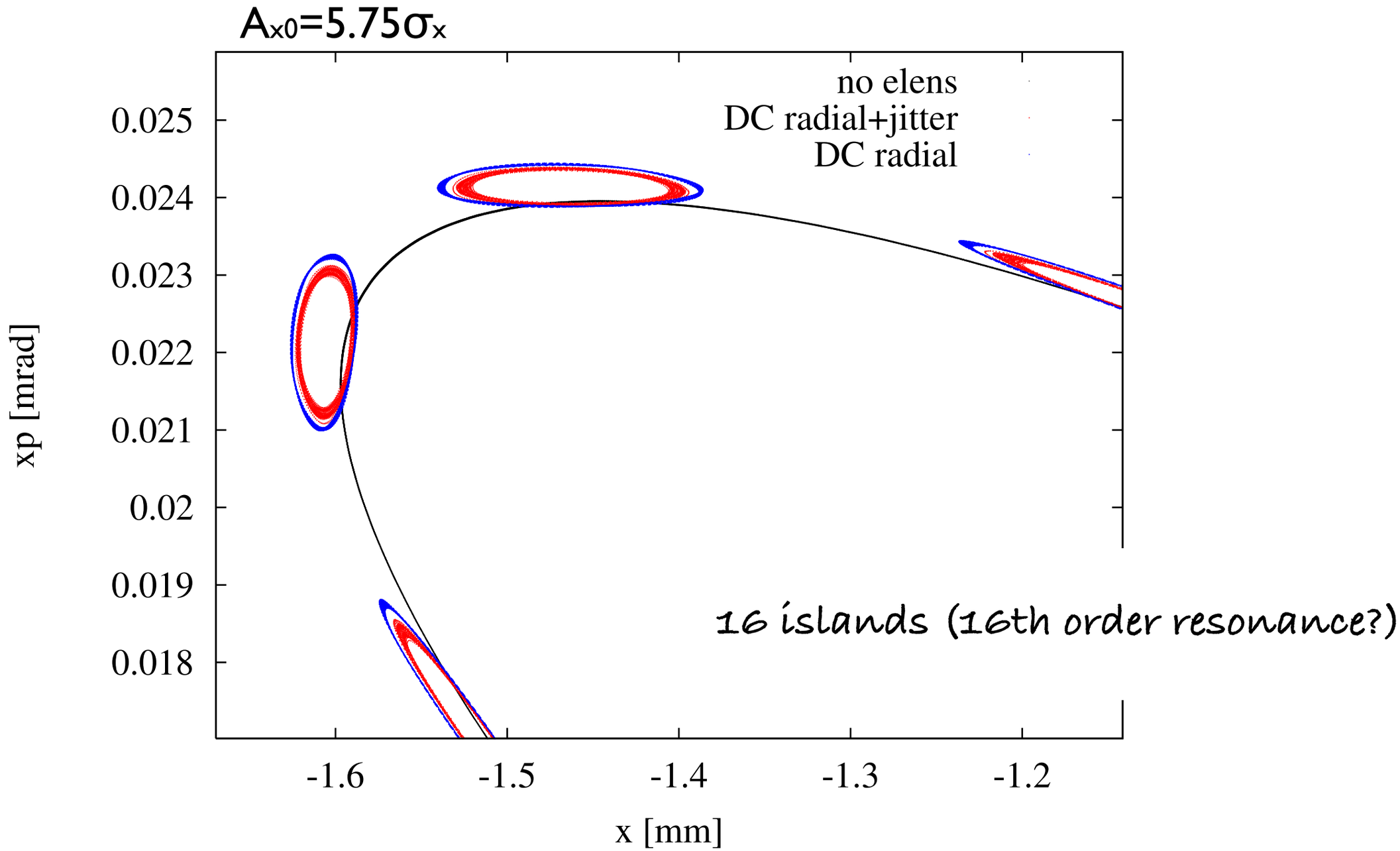


For *some* particles the phase space is heavily deformed by the e-lens

"parametric" AC mode

- If we consider the simple case of a non-hollow flat lens and to study the motion for a limited transverse range:

$$m\ddot{x} + kx = -k_{DC}\, x$$

- when the e-lens is modulated with a frequency ωe the equation becomes:

$$m\ddot{x} + [k + k_{DC}(1 + \sin\omega_e t)]\; x = 0$$

- i.e. parametric resonance (can be found in literature) with resonance condition:

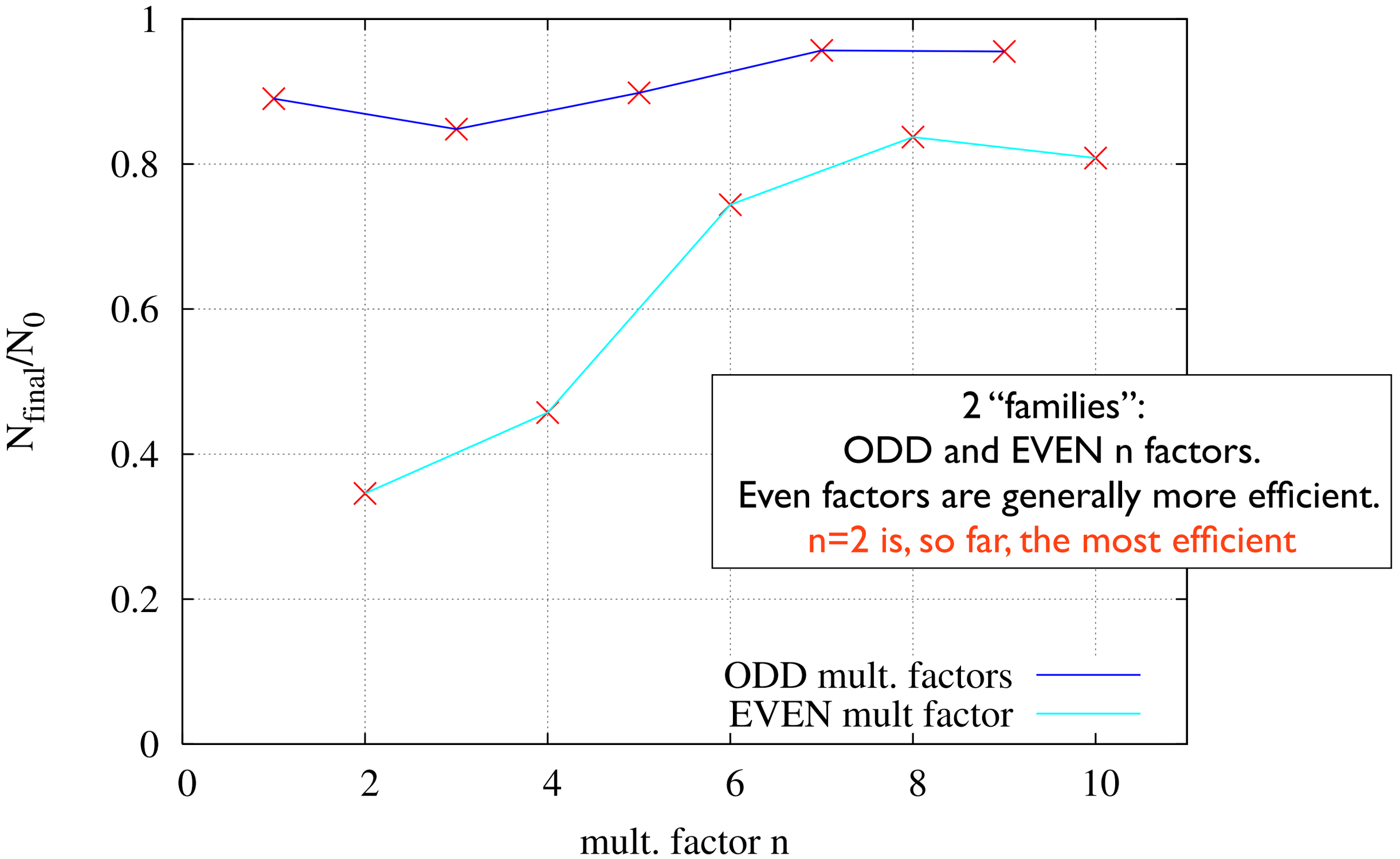
$$\omega_e = 2\omega + \epsilon$$

betatron oscillation frequency (tune)

- The transposition to the case of a force generated by an hollow electron lens is not easy.
- Even with a polynomial approximation, the solution of the differential equation is not straightforward. In order to identify the optimal excitation frequency, I simulated the scraping effect of an el-lens driven by different multiples of the natural frequency $n\omega_0$, with the multiplying factor n in the range {1, 2 ... 10}

covering the frequency range $\omega_e = n \cdot (.3120 \pm .0015)$

one steps of 5e-5 every 1000 turns



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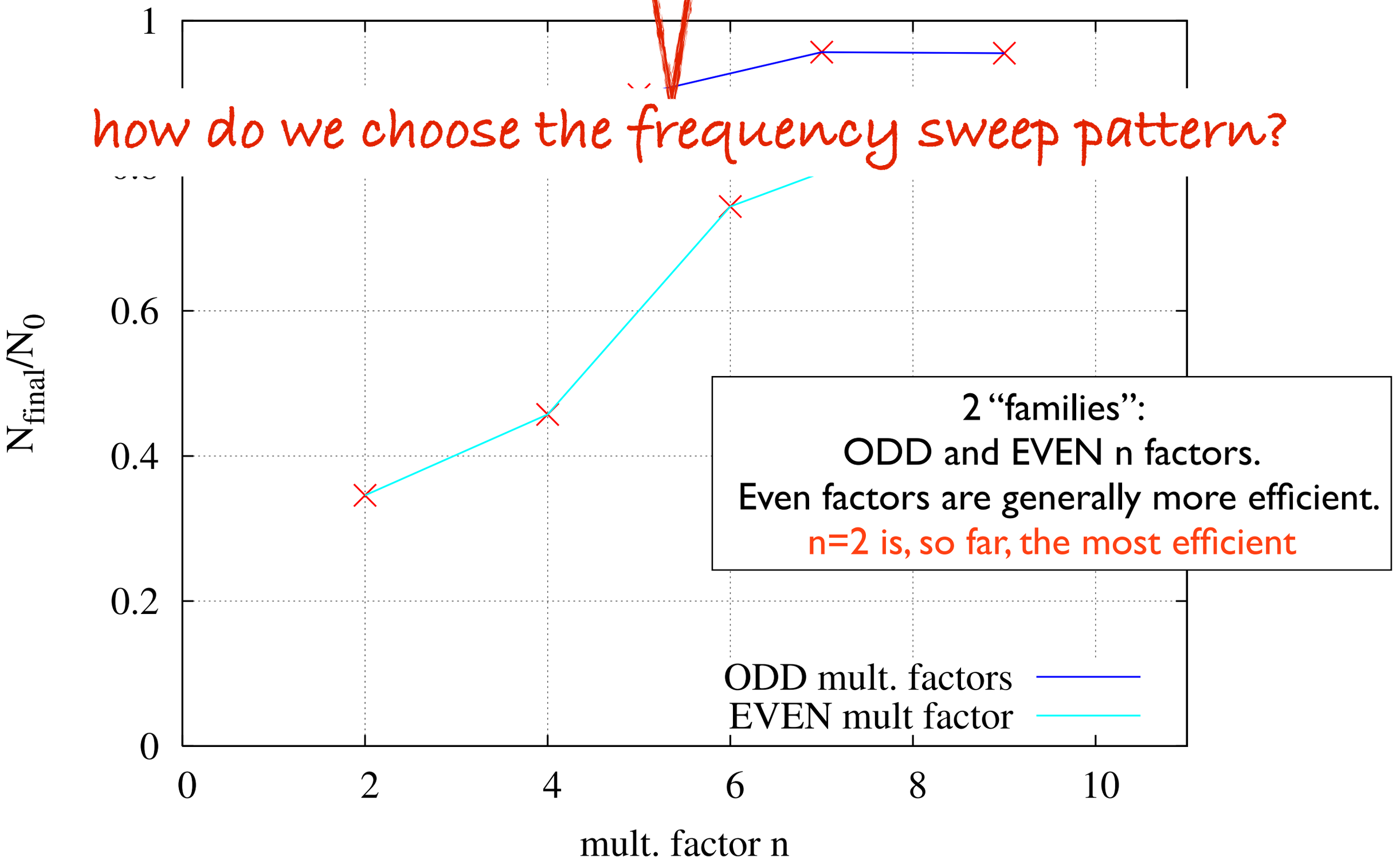
how do we choose the frequency sweep pattern?



optimization of frequency sweep range- speed

Label	f_{min}	f_{max}	F_{avg}	Δf	Frequency Step	Turns per step
L8	.3116	.3124	.3120	.0008	$2\,10^{-5}$	10^3
L10	.3115	.3125	.3120	.0010	$2\,10^{-5}$	10^3
L16	.3112	.3128	.3120	.0016	$2\,10^{-5}$	10^3
L20	.3110	.3130	.3120	.0020	$2\,10^{-5}$	10^3
L32	.3104	.3136	.3120	.0032	$2\,10^{-5}$	10^3
H5	.31175	.31225	.3120	.005	$5\,10^{-5}$	10^3
H10	.3115	.3125	.3120	.0010	$5\,10^{-5}$	10^3
H15	.31125	.31275	.3120	.0015	$5\,10^{-5}$	10^3
H20	.3110	.3130	.3120	.0020	$5\,10^{-5}$	10^3
H30	.3105	.3135	.3120	.0030	$5\,10^{-5}$	10^3

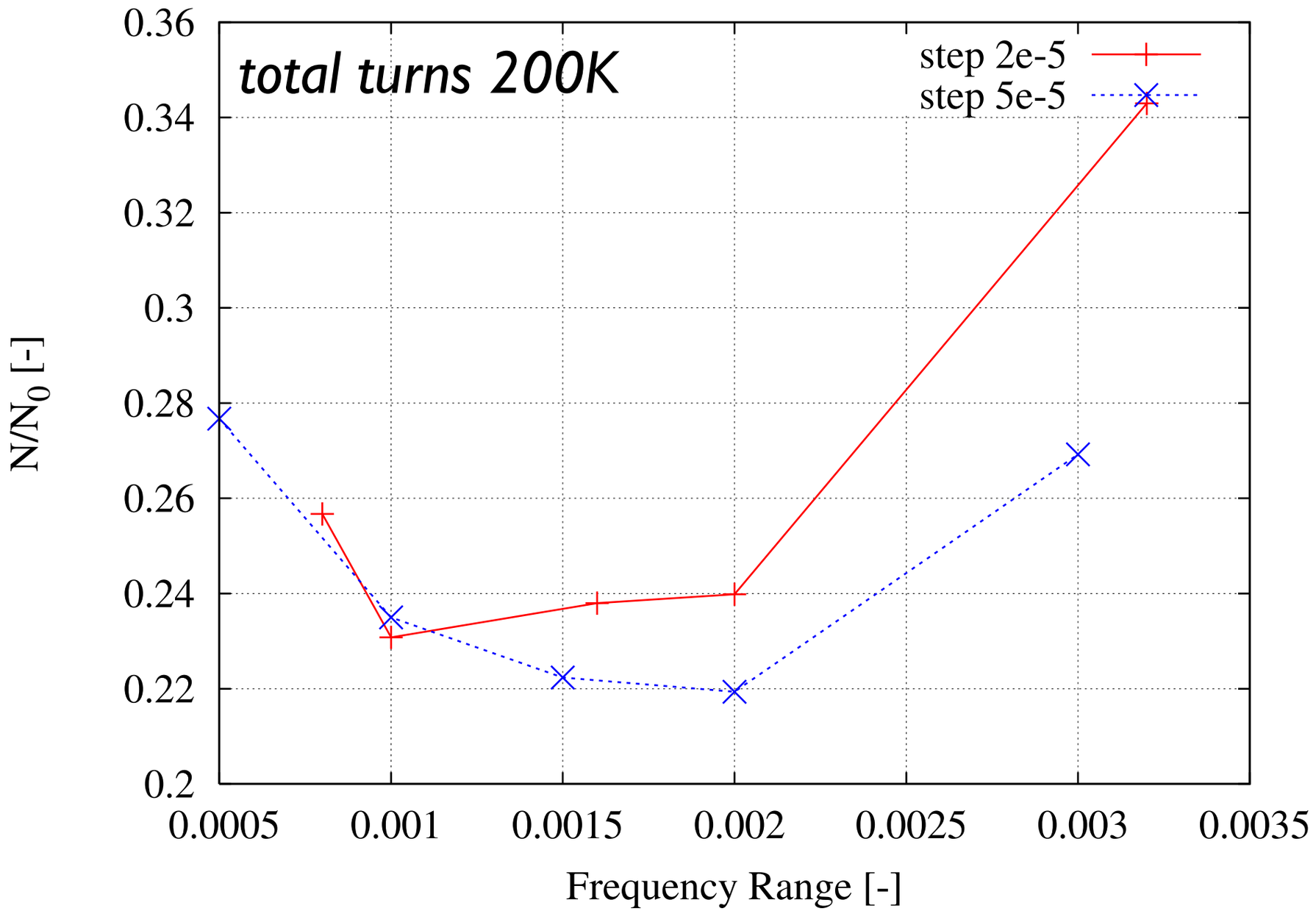
"small" step

"large" step

always the same central frequency

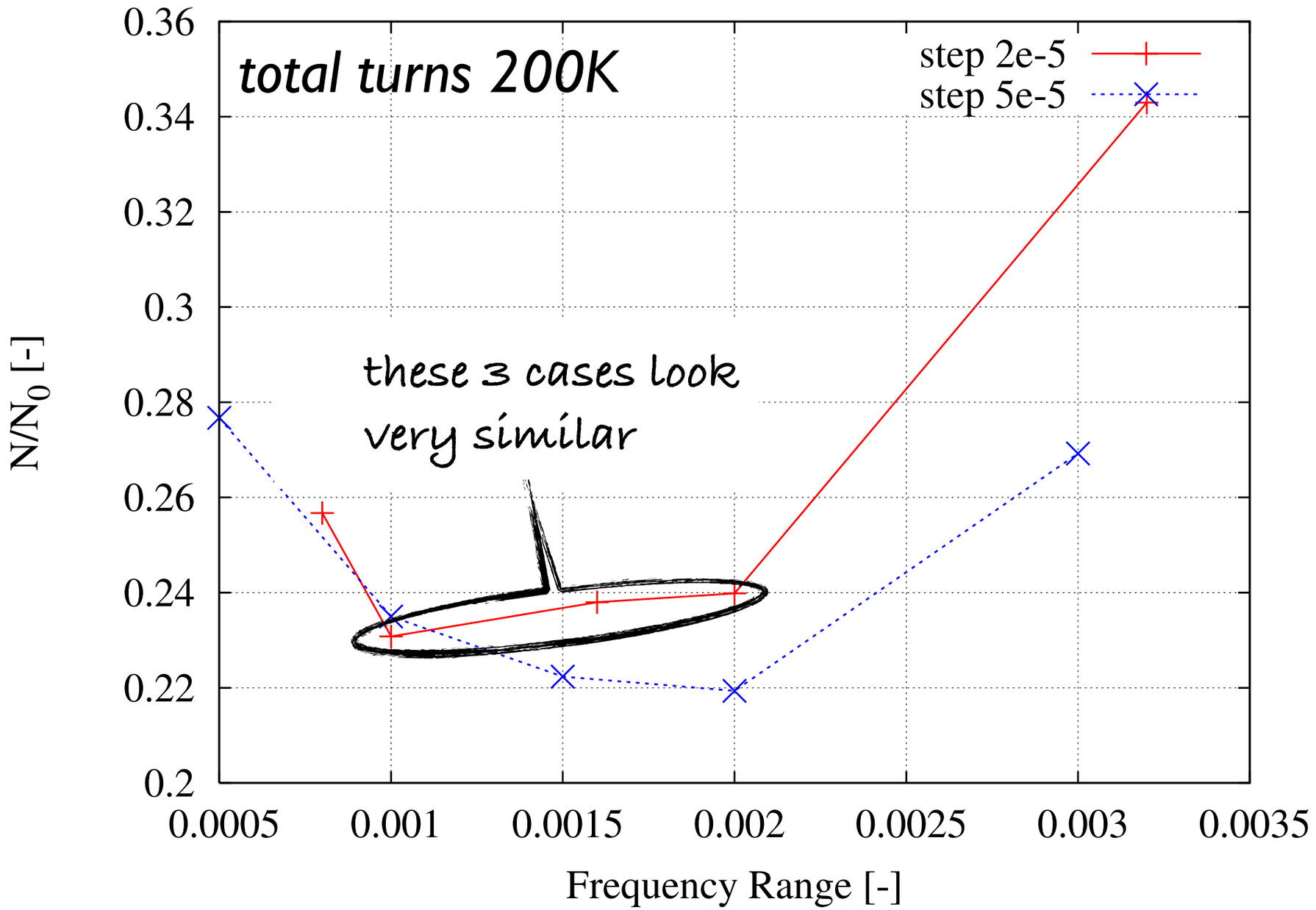
different total frequency ranges

survival vs range

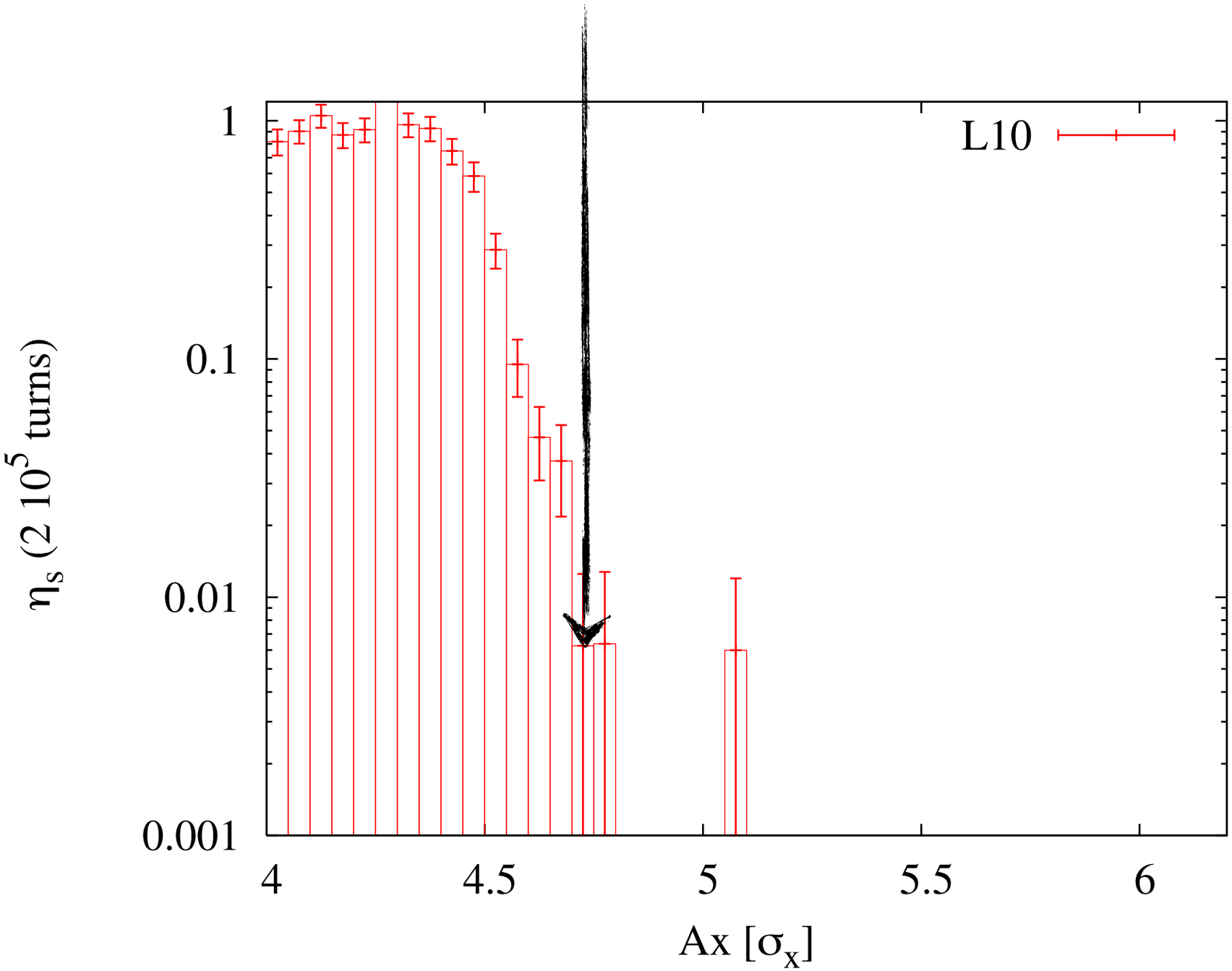


survival vs range

is survival rate enough?



L10: almost no particles over 4.7σx



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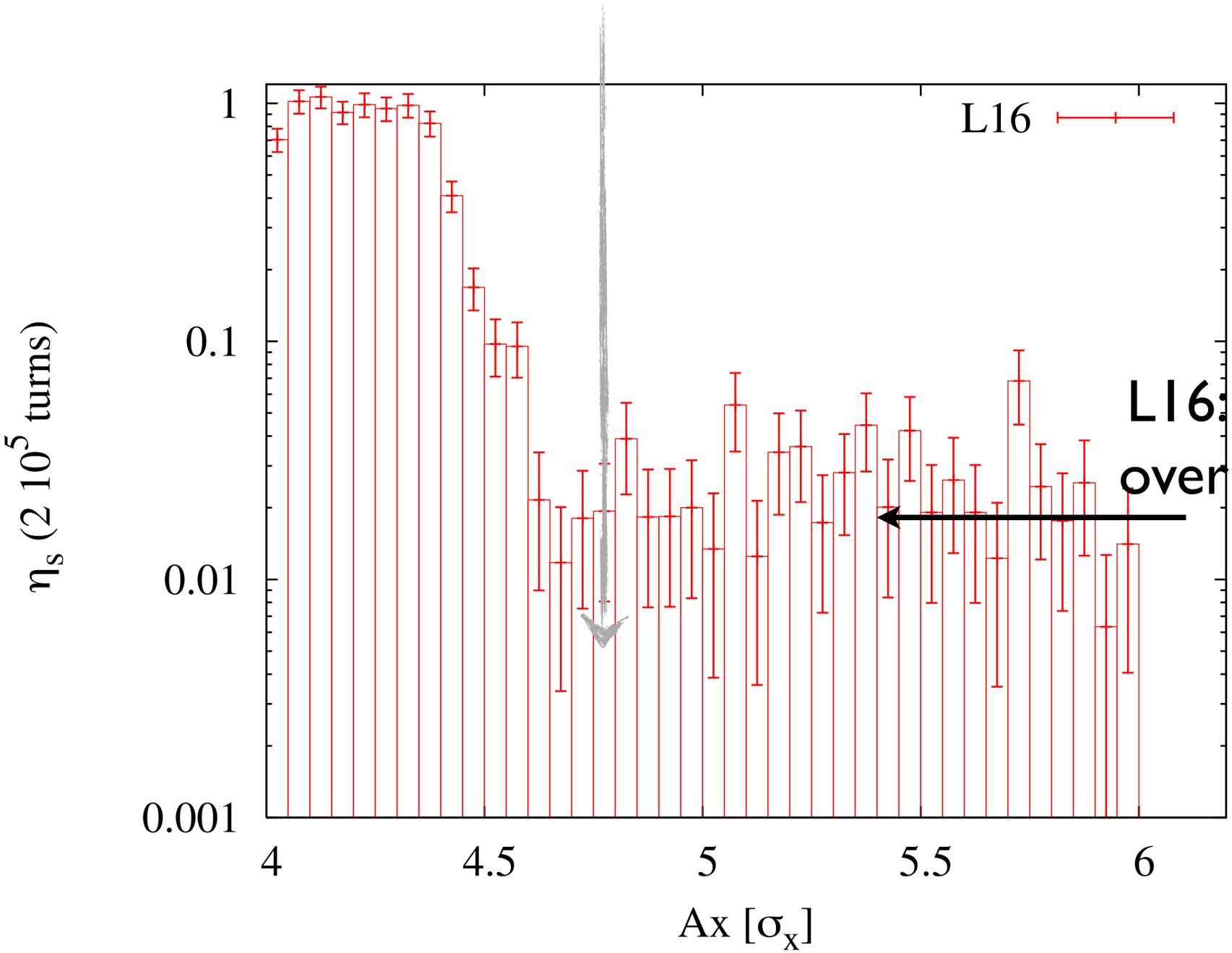

L16: particle level over 5σx is about 1-2%

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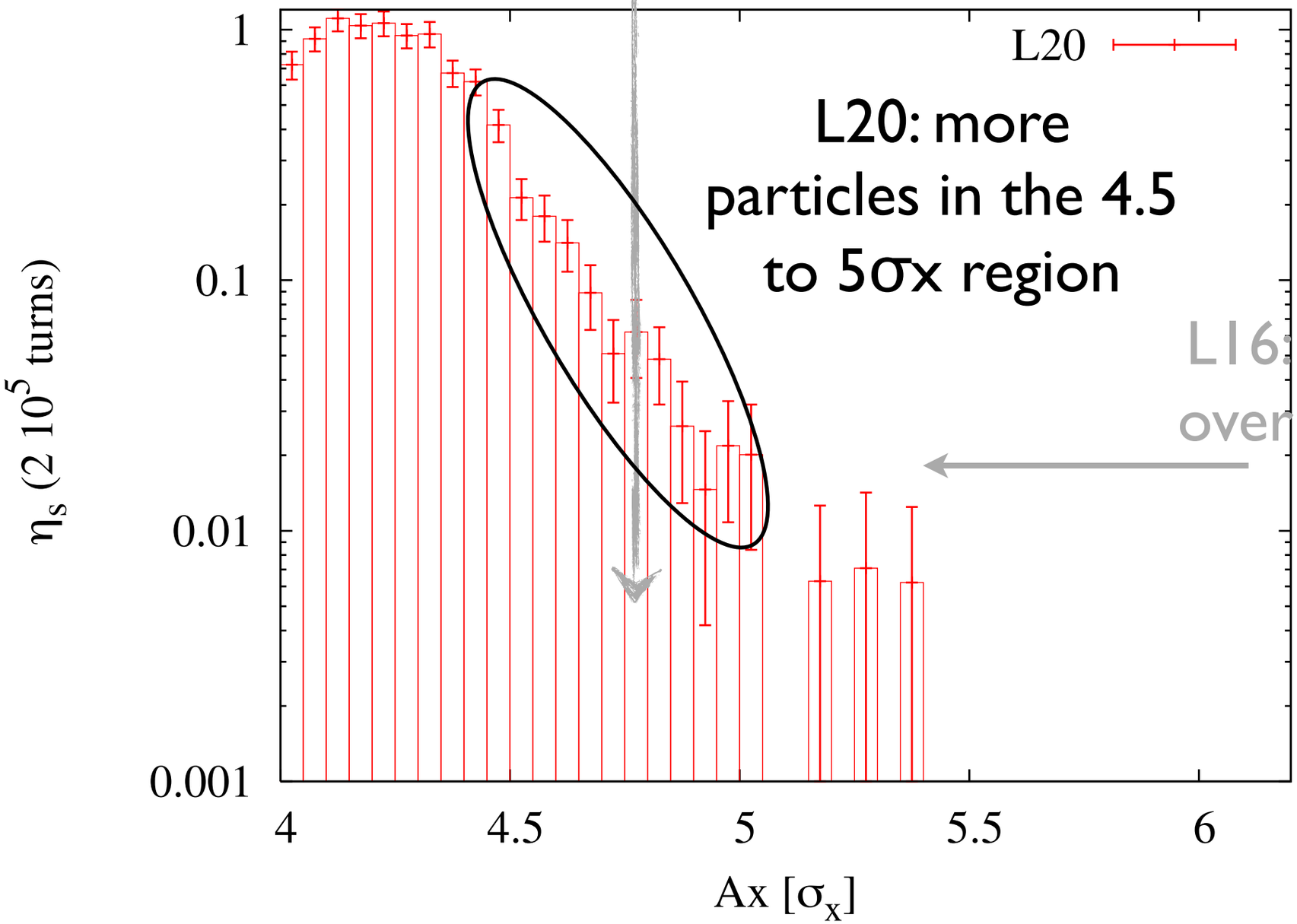

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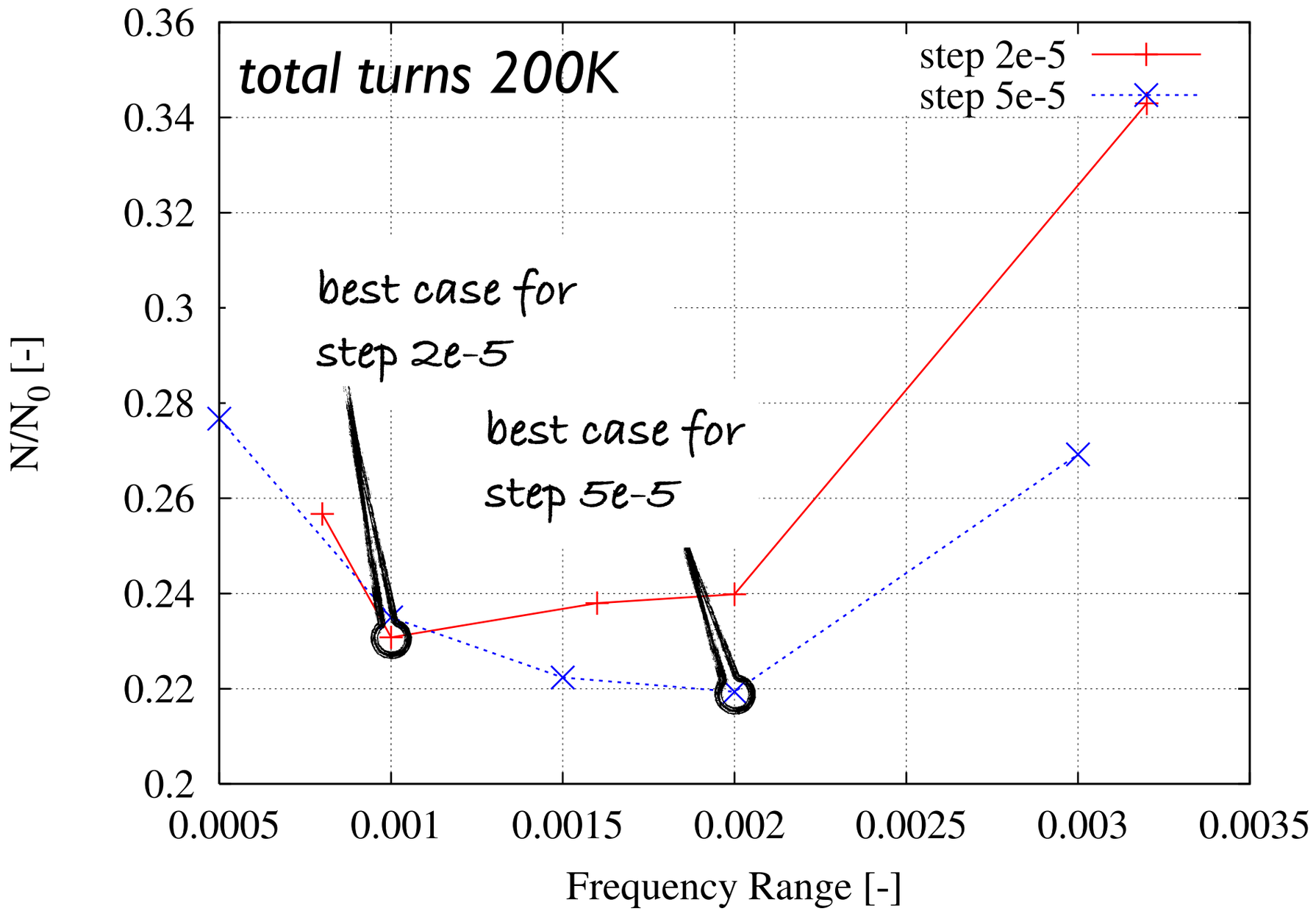
2 best cases: comparison



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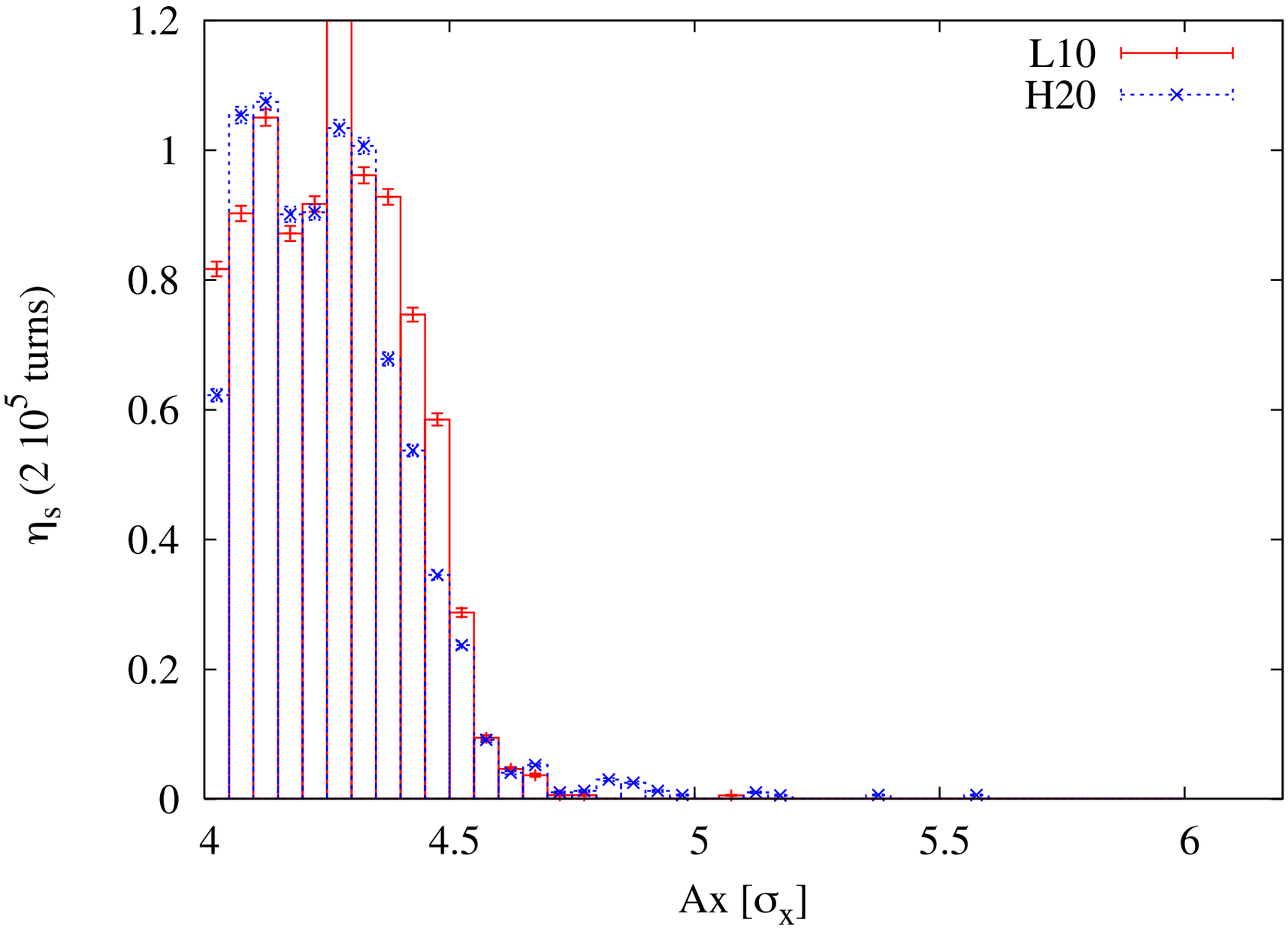

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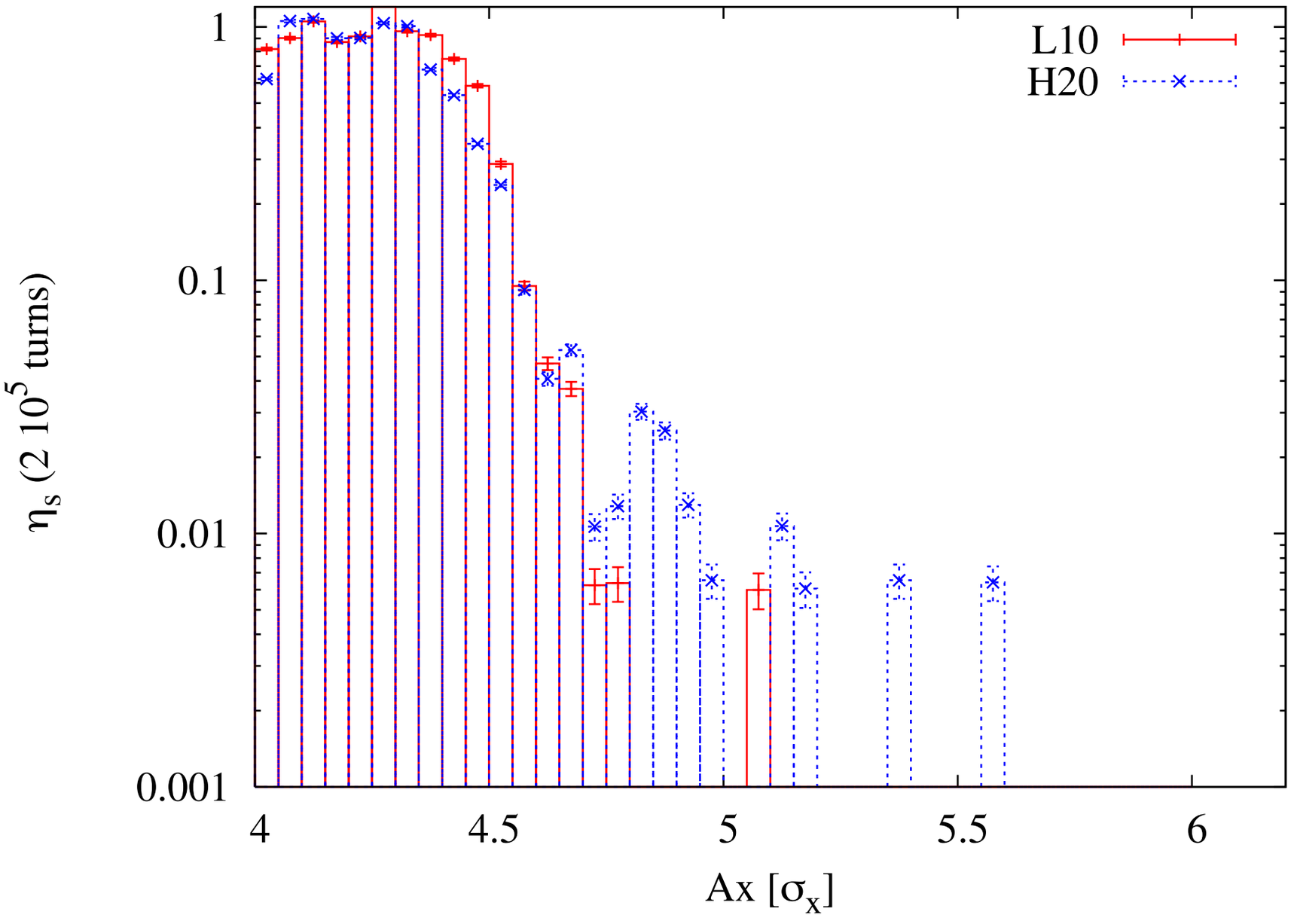
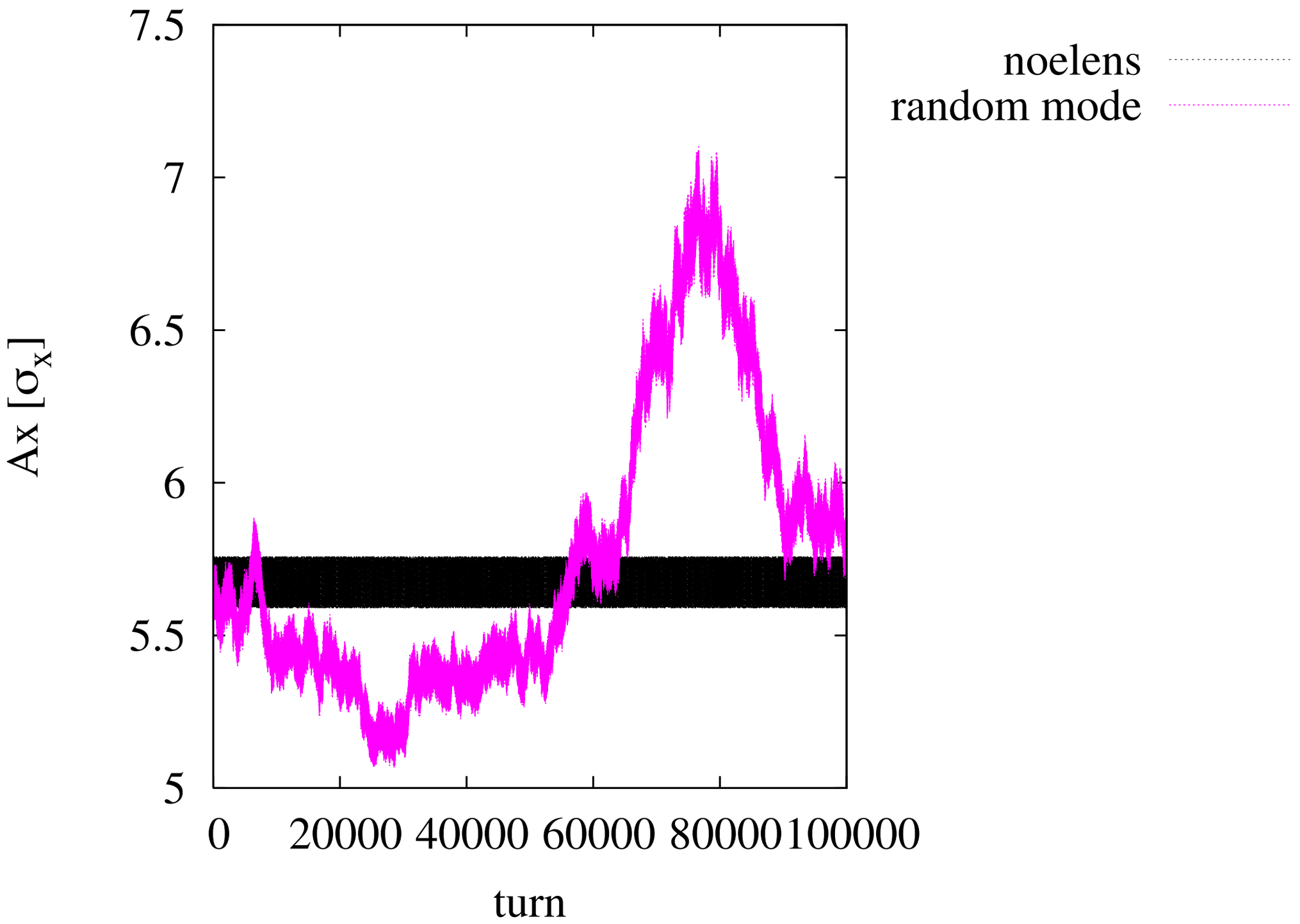
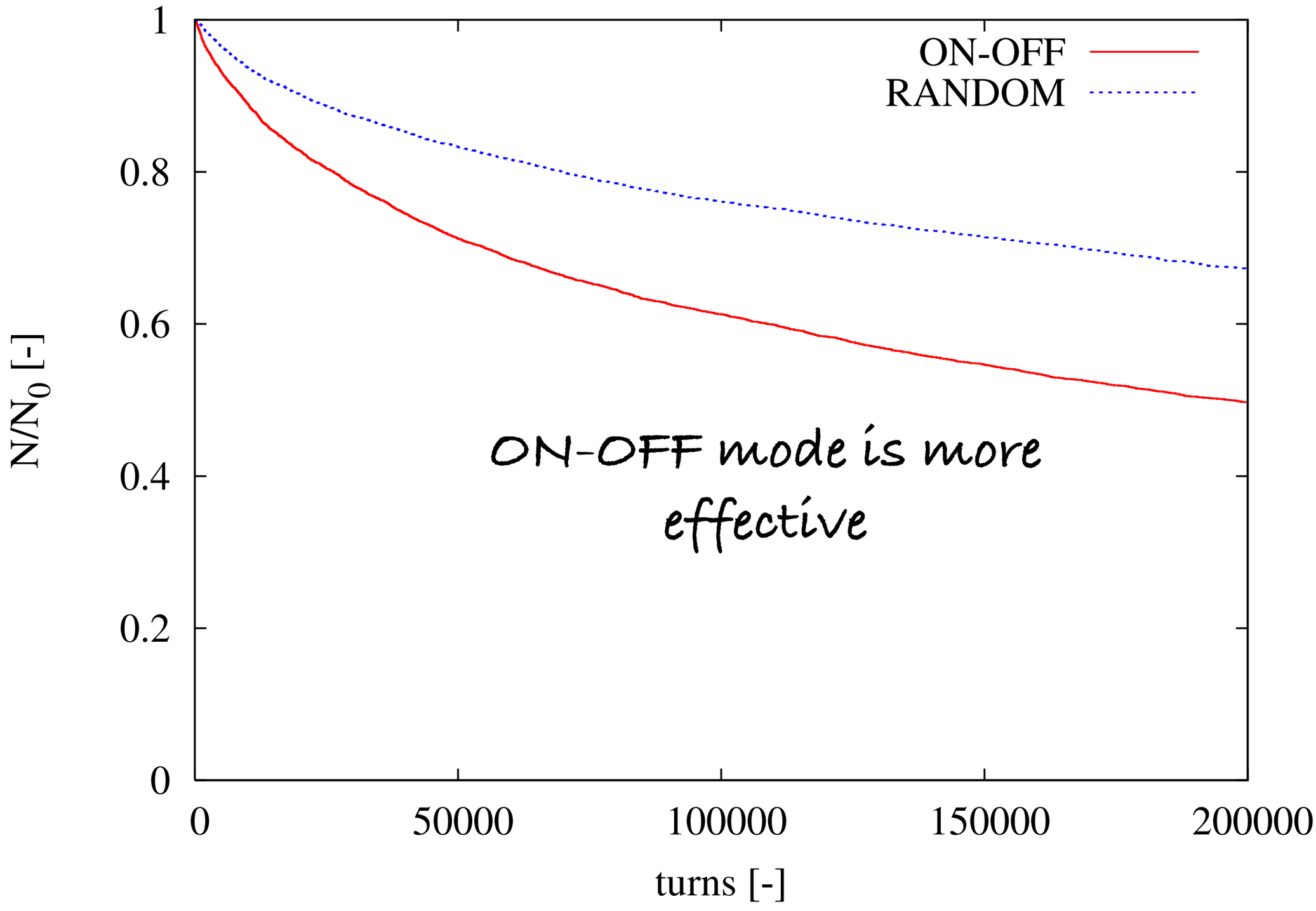


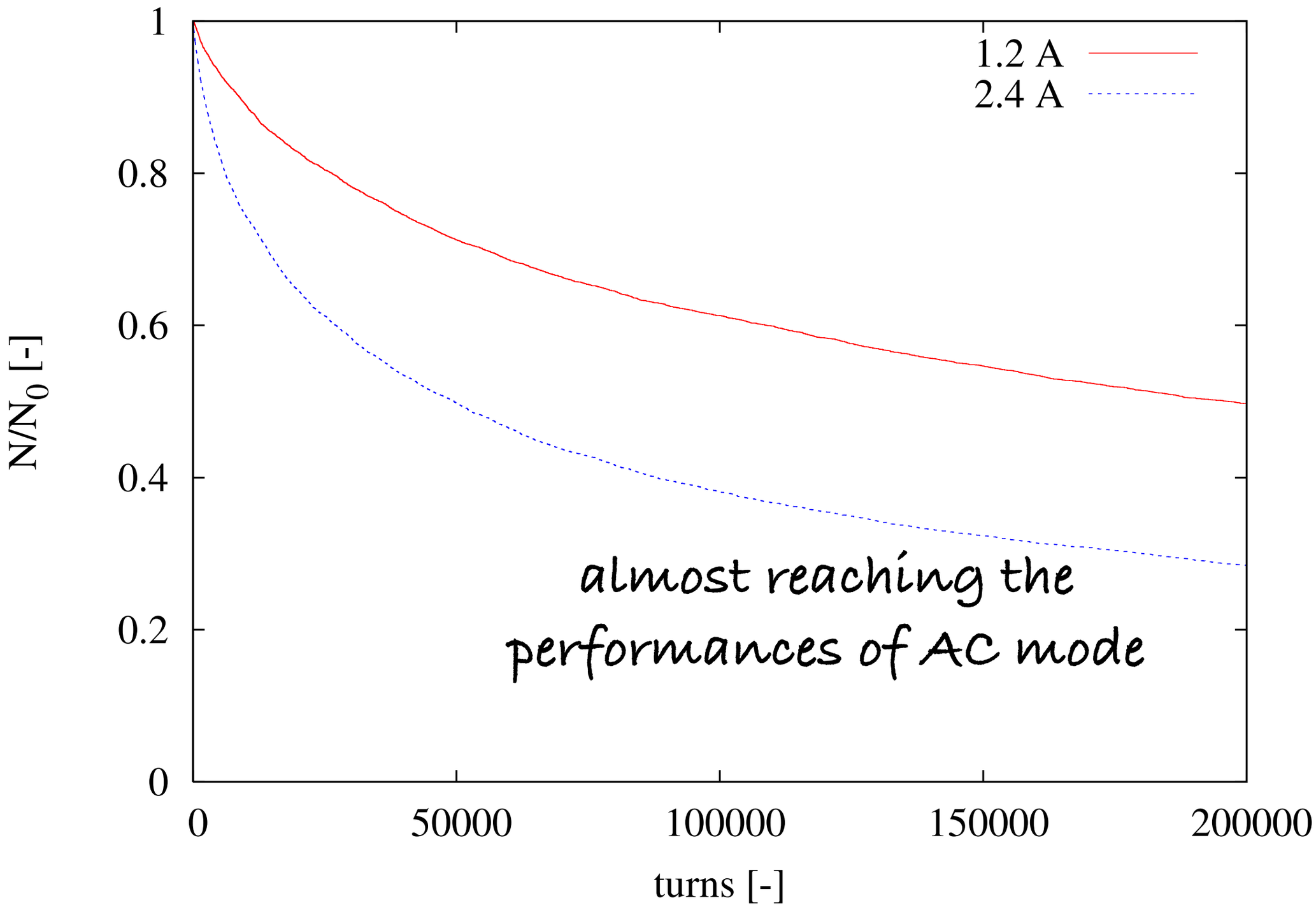
Random mode

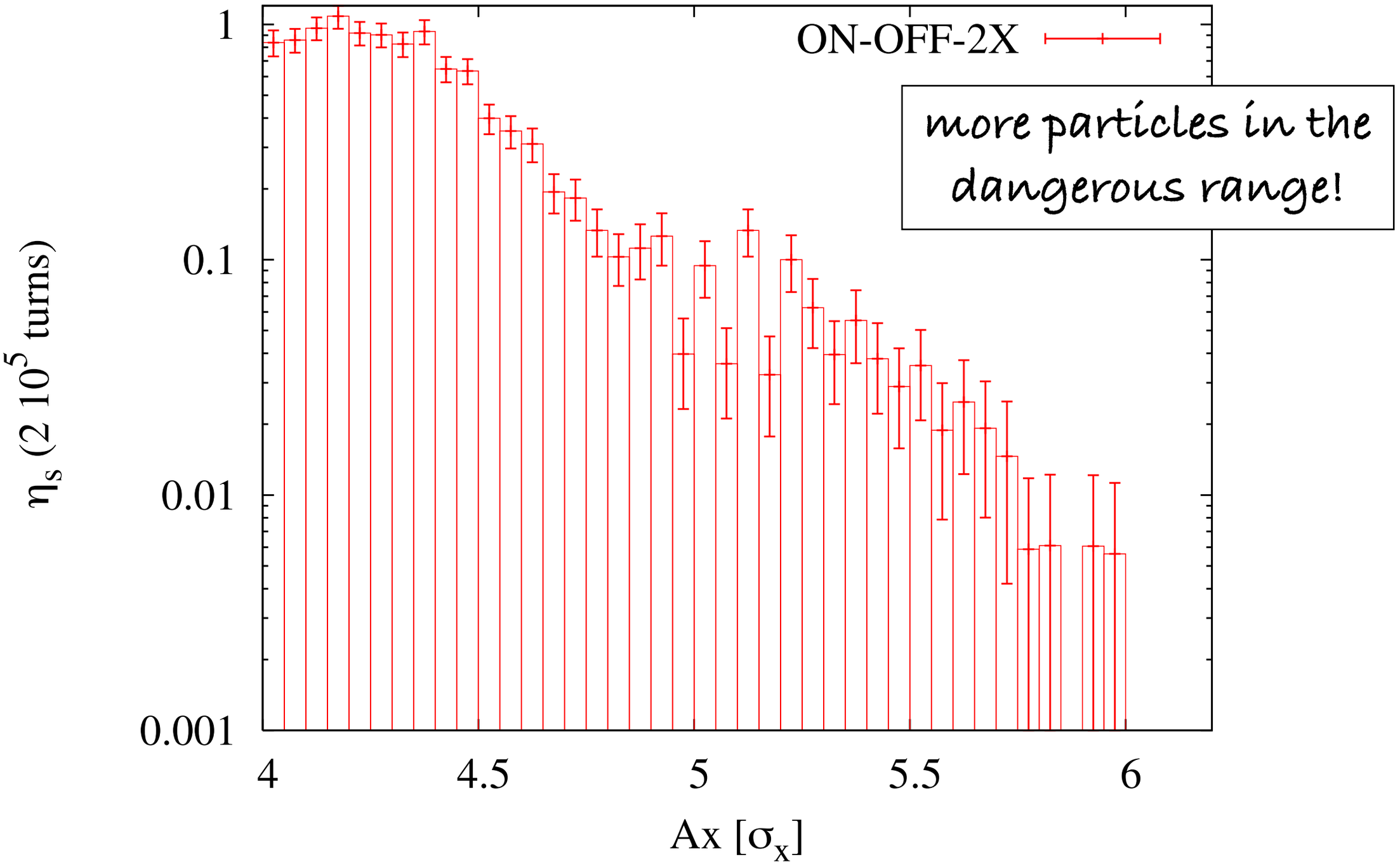
- 2 different random mode tested:
  1. ON-OFF mode: then electron beam was either reduced to zero (OFF) or at its full power (ON) randomly on a turn-by-turn basis.
  2. Random mode: the electron beam current was modulated on turn by turn basis by a random multiplier in the range [0,1];
- PROS
  - completely uncorrelated with the particle state (both amplitude and tune)
  - works simultaneously for Vertical and Horizontal plane
  - the scraping efficiency can be easily increased by in- creasing the beam current.
- CONS: slower (a factor 2x w.r.t. AC mode)


7.5
7
6.5
6
5.5
5
Ax [σx]
0
20000
40000
60000
80000
100000
turn
noelens
random mode


1
0.8
0.6
0.4
0.2
0
N/N0 [-]
0
50000
100000
150000
200000
turns [-]
ON-OFF
RANDOM
ON-OFF mode is more
effective

From 1.2 A to 2.4 A




ON-OFF-2X
more particles in the dangerous range!
1
0.1
0.01
0.001
4
4.5
5
5.5
6
Ax [σx]
ηs (2 10^5 turns)

comparison with AC "good" case