The electron lens: simulations for the SPS case

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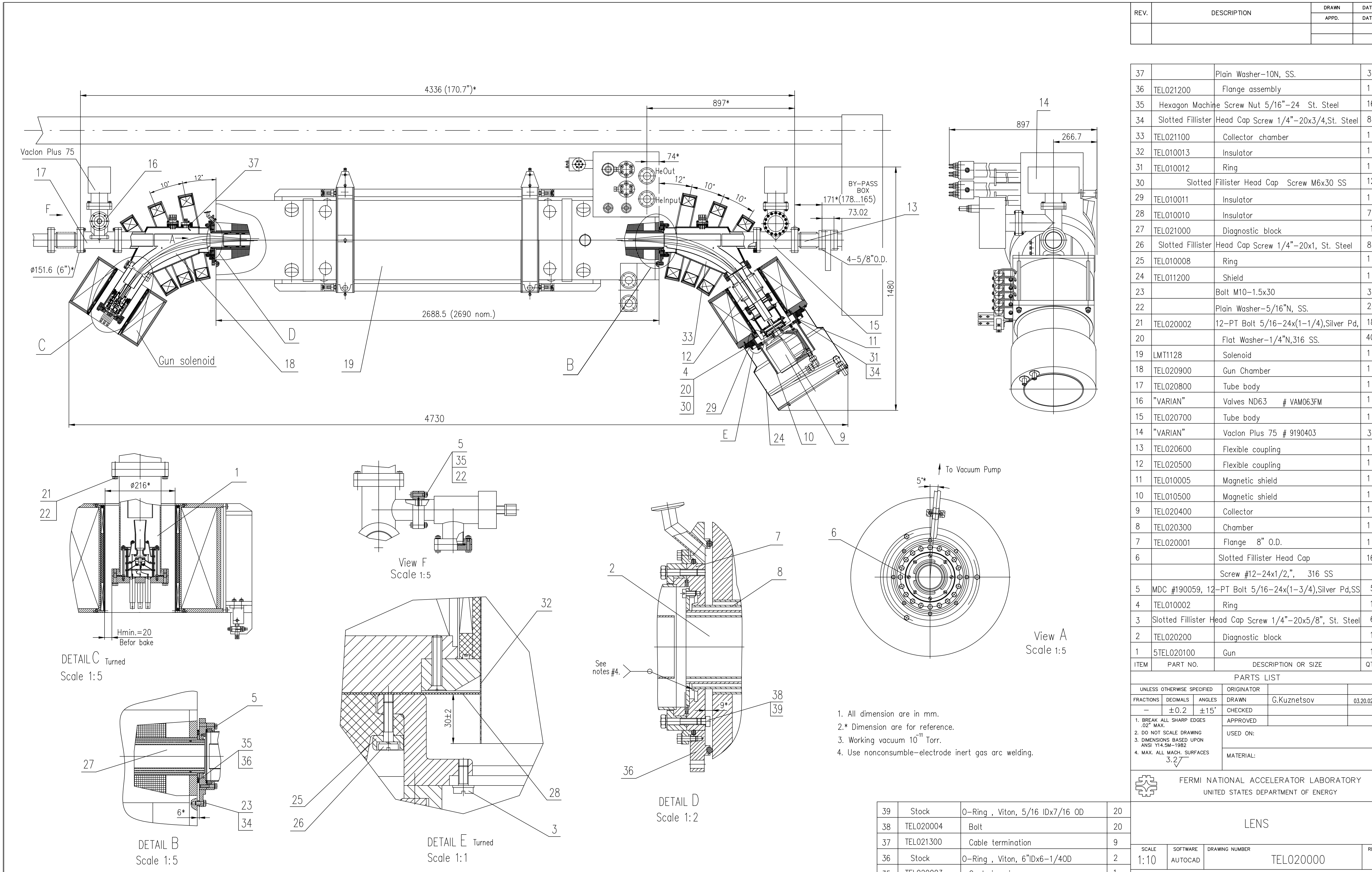
what happened in previous episodes...

- Introducing the hollow electron lens: what it is and its possible usage as a halo cleaning system

what is the electron lens?

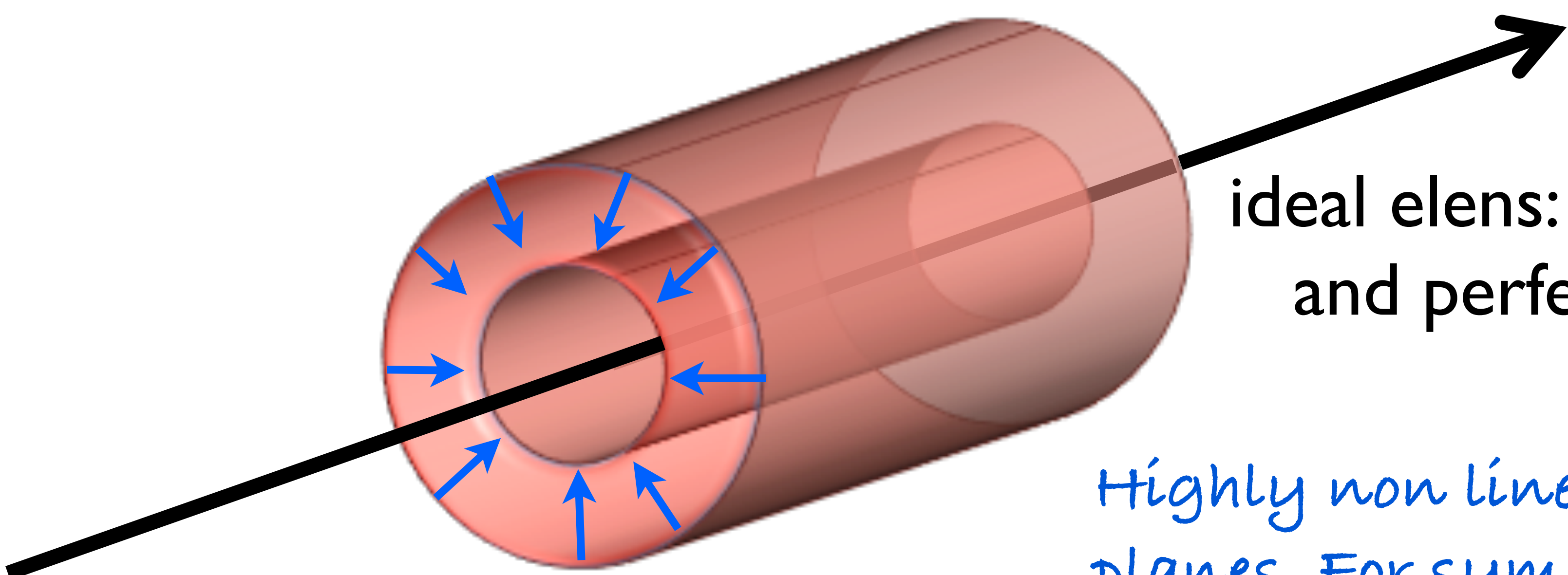


... better to ask an accelerator physicist...

what happened in previous episodes...

- Introducing the hollow electron lens: what it is and its possible usage as a halo cleaning system

electron lens: cylindrical distribution of electron around the proton beam



ideal elens: the electron density is uniform and perfectly symmetric and centered

Highly non linear field, focusing in both planes. For symmetry reasons, F=0 within the electron lens inner radius.

what happened in previous episodes...

- Introducing the hollow electron lens: what it is and its possible usage as a halo cleaning system
- Detected 3 possible operational modes:

1. DC mode: elens constantly ON
2. AC mode: elens activated in resonance with the betatron tune
3. diffusive mode: elens driven by a white noise signal

mild amplitude oscillation + tune shift

greatly enhancing amplitude oscillation

slowly diffusing particles

new material: studying the SPS case

- why?

  Because installation in LHC is very tight for LS1- maybe the SPS is more feasible.

- where?

  COLDEX location. Space available and maybe cryogenics.

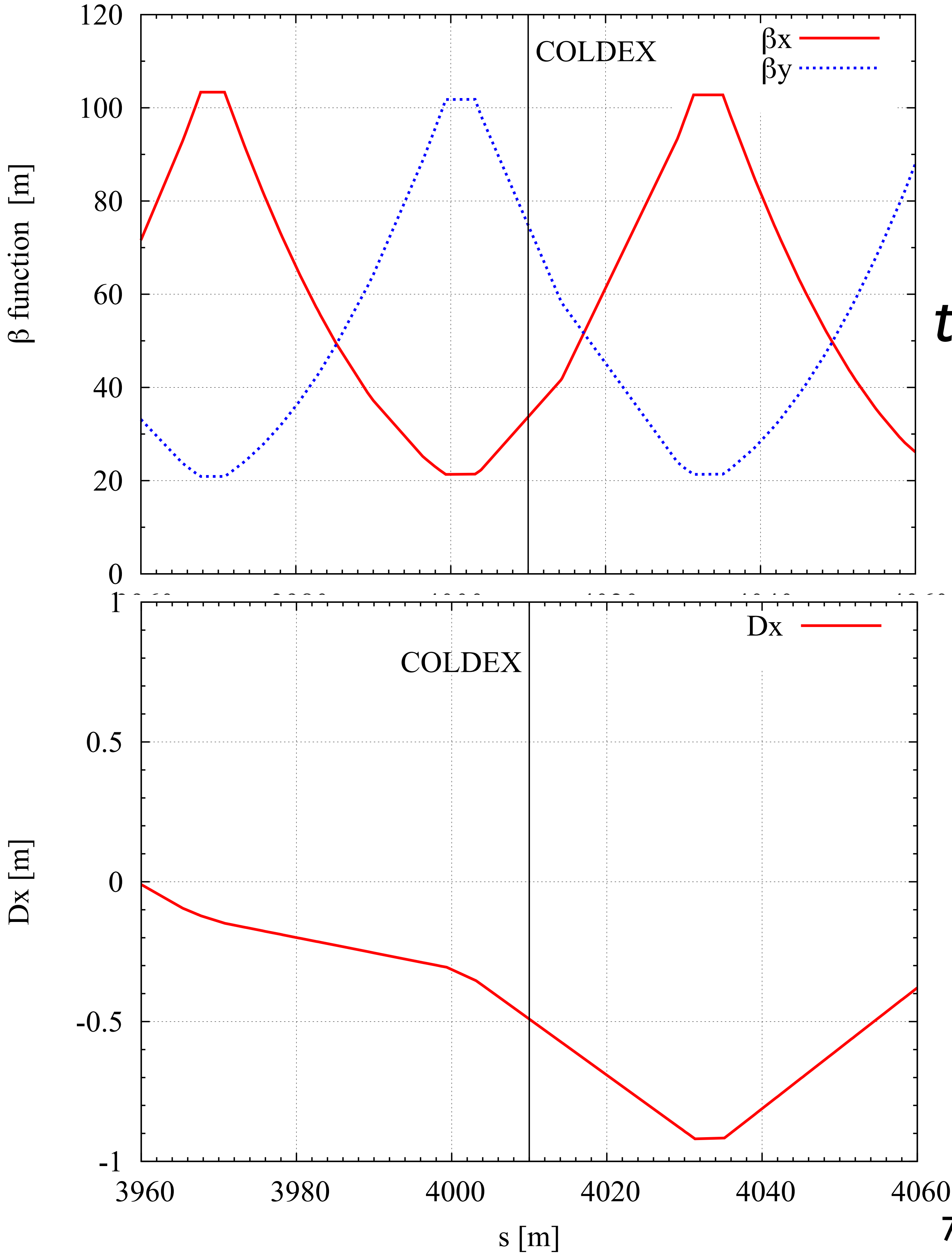
- when?

  as soon as possible/feasible.

- what?

  our goal is to study the efficiency of the device as an LHC scraper.

the elens in SPS



beta functions at the COLDEX location are very different -> this means we scrape at different sigma the horizontal and the vertical halo. For the moment only the vertical HALO has been simulated (larger beta)

the dispersion is small but not negligible; meaning we need to consider the impact on off momentum particles (for the H halo, still to be done)

which kind of kick do we expect?

SPS, 120 GeV, coldex location, R1=4sigma

vertical case (larger beta), primary coll @6.2 sigmay

particles generated between 4 and 6 sigmay

$$\theta(r) = \frac{2L\ f(r)\ I_T\ (1 \pm \beta_e \beta_p)}{4\pi\varepsilon_0\ r\ (B\rho)_p \beta_e \beta_p\ c^2} \qquad f(r) = \begin{cases} 0 & r < R_1 \\ \frac{r^2 - R_1^2}{R_2^2 - R_1^2} & R_1 < r < R_2 \\ 1 & r > R2 \end{cases}$$

- kick prop 1/pc (through the magnetic rigidity)
  - w.r.t 7 TeV, we expect a kick ~50x larger
- max kick is also proportional to 1/r
  - 1sigma is a factor 5 larger, so we expect a factor 5 smaller kicks
- **maximum kick for SPS case ~ 1urad (10x the LHC case)**

the electron lens effect

1. DC mode: elens constantly ON
2. AC mode: elens activated in resonance with the betatron tune
3. diffusive mode: elens driven by a white noise signal

effect on the tune

+

effect on the amplitude

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efficiency as a scraper

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+

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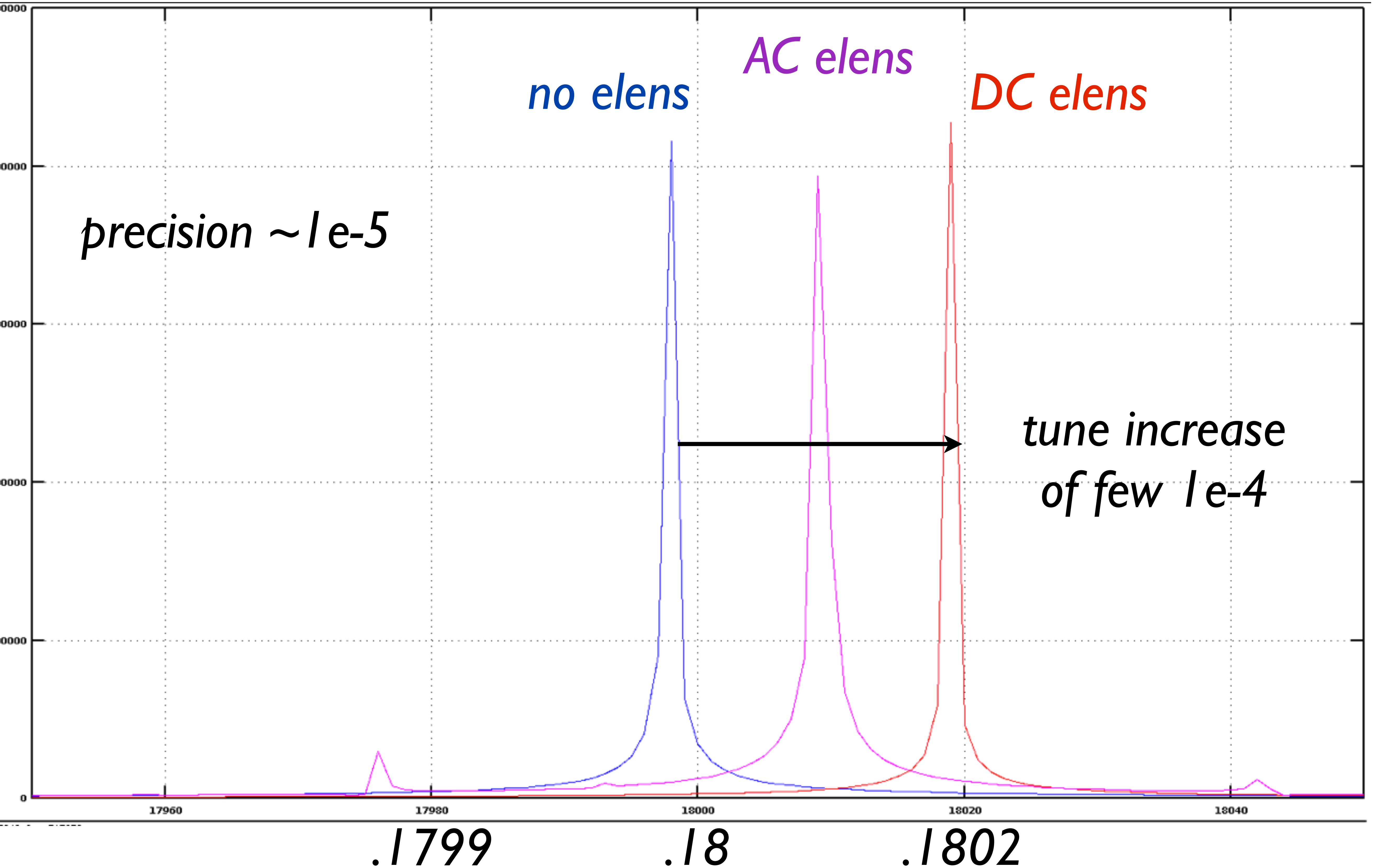
efficiency as a scraper

outline of the talk!

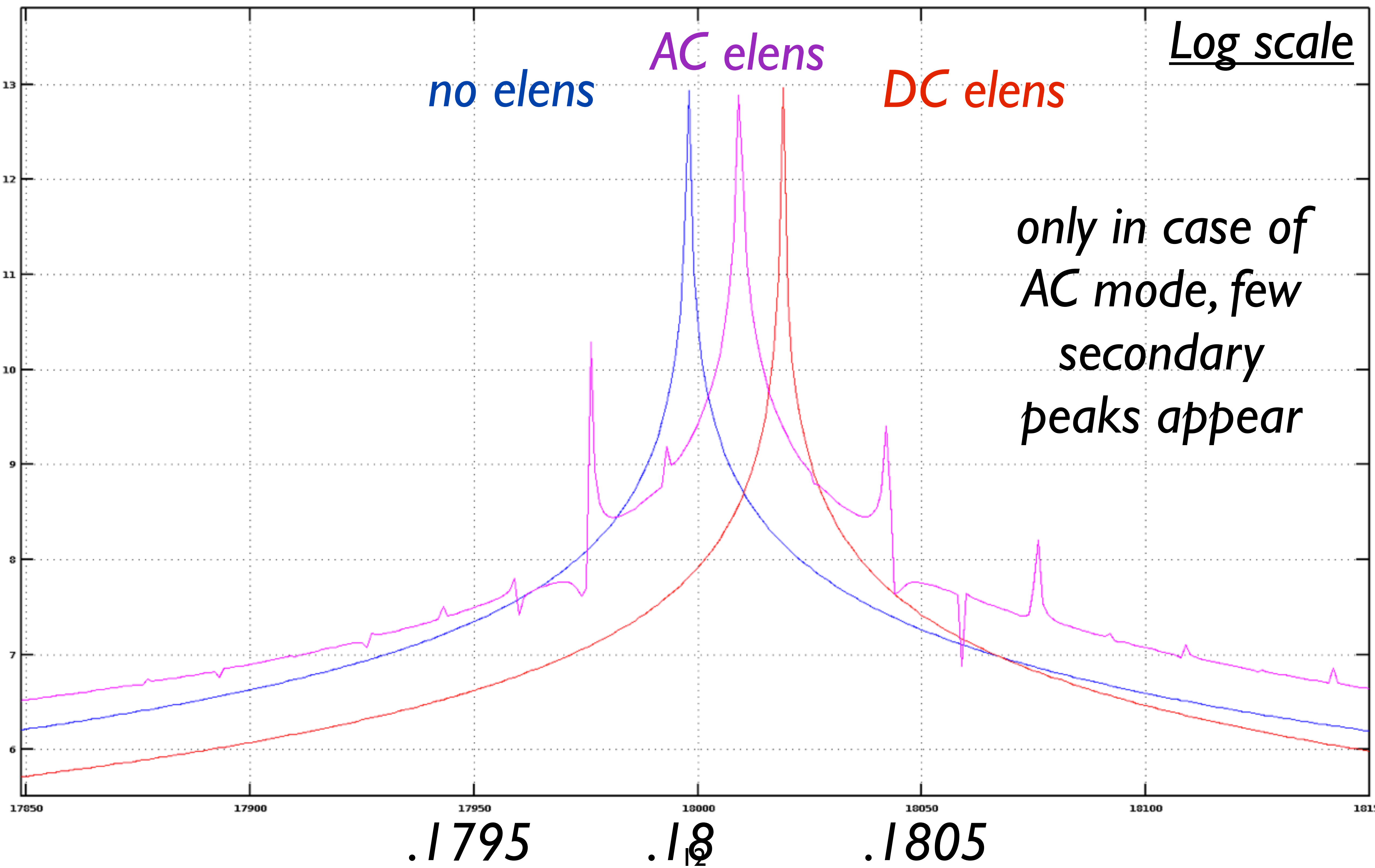
effect on the tune

main tune peak

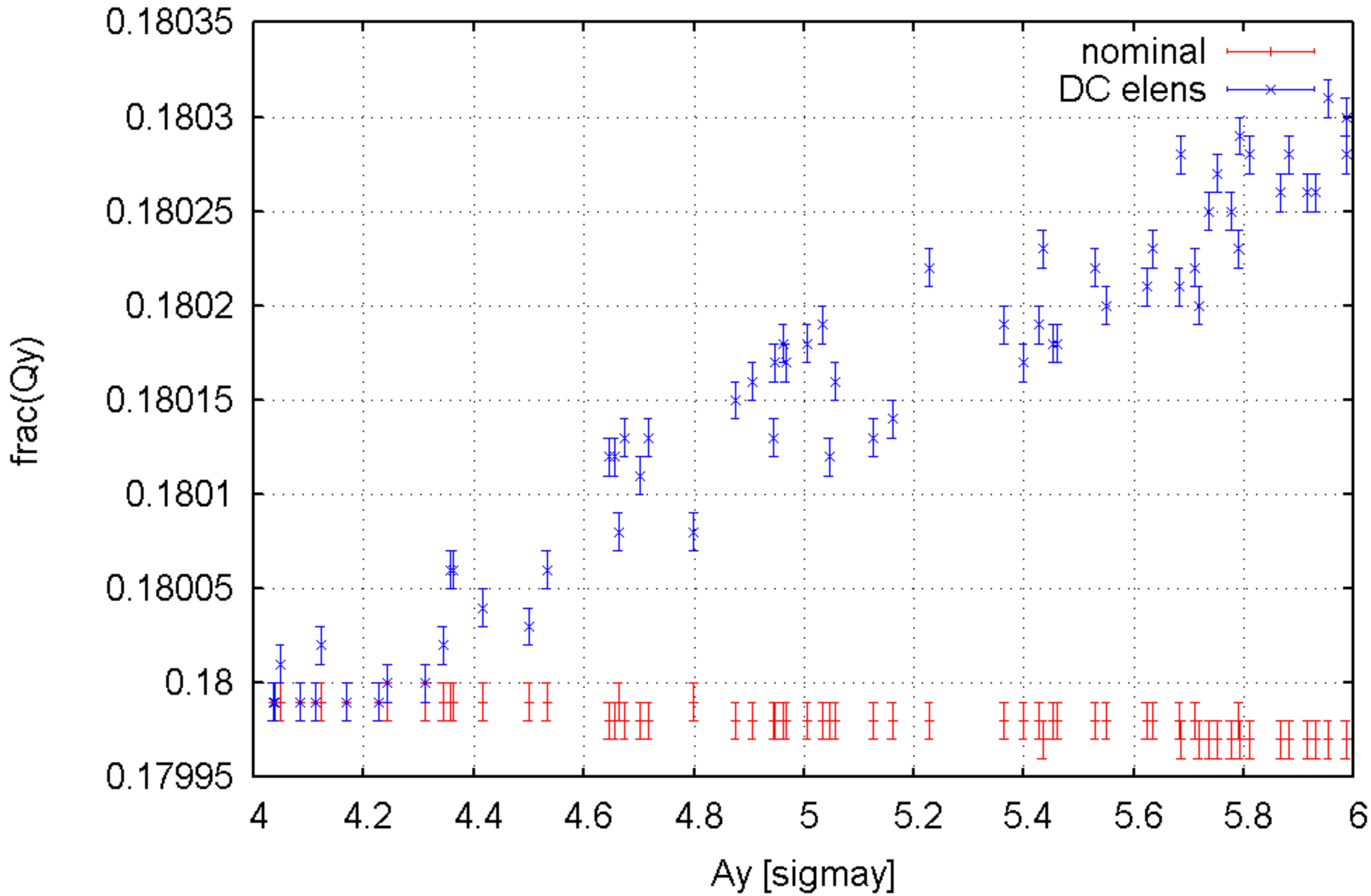


effect on the tune

main tune peak



tune variation vs initial amplitude

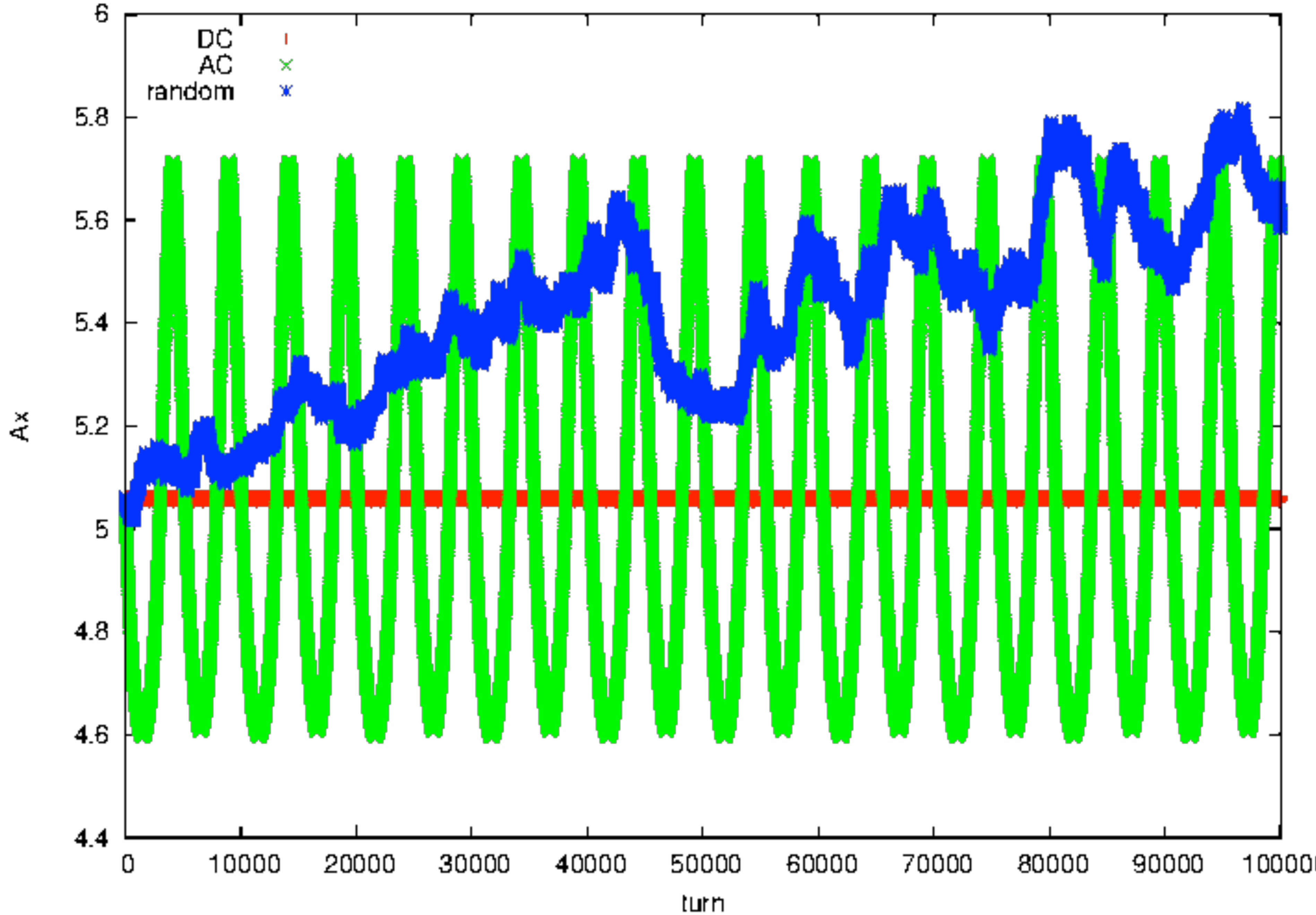


for each particle, the tune value is stable within 1e-4.
However, it depends on the particle initial conditions

effect on the tune : summary

1. The electron lens in DC mode introduce a tune shift of few 10-4 (depending on initial particle phase)
2. within 1e-4 there is no tune jitter for the DC mode (not presented here), higher precision measurements on the tune jitter should be performed with more advanced tools (e.g. fma plots with lifetrack)
3. only in case of AC mode, few secondary peaks appear
4. the tune shift depends (almost linearly) on initial amplitude of the particle.

effect on the amplitude



AC mode

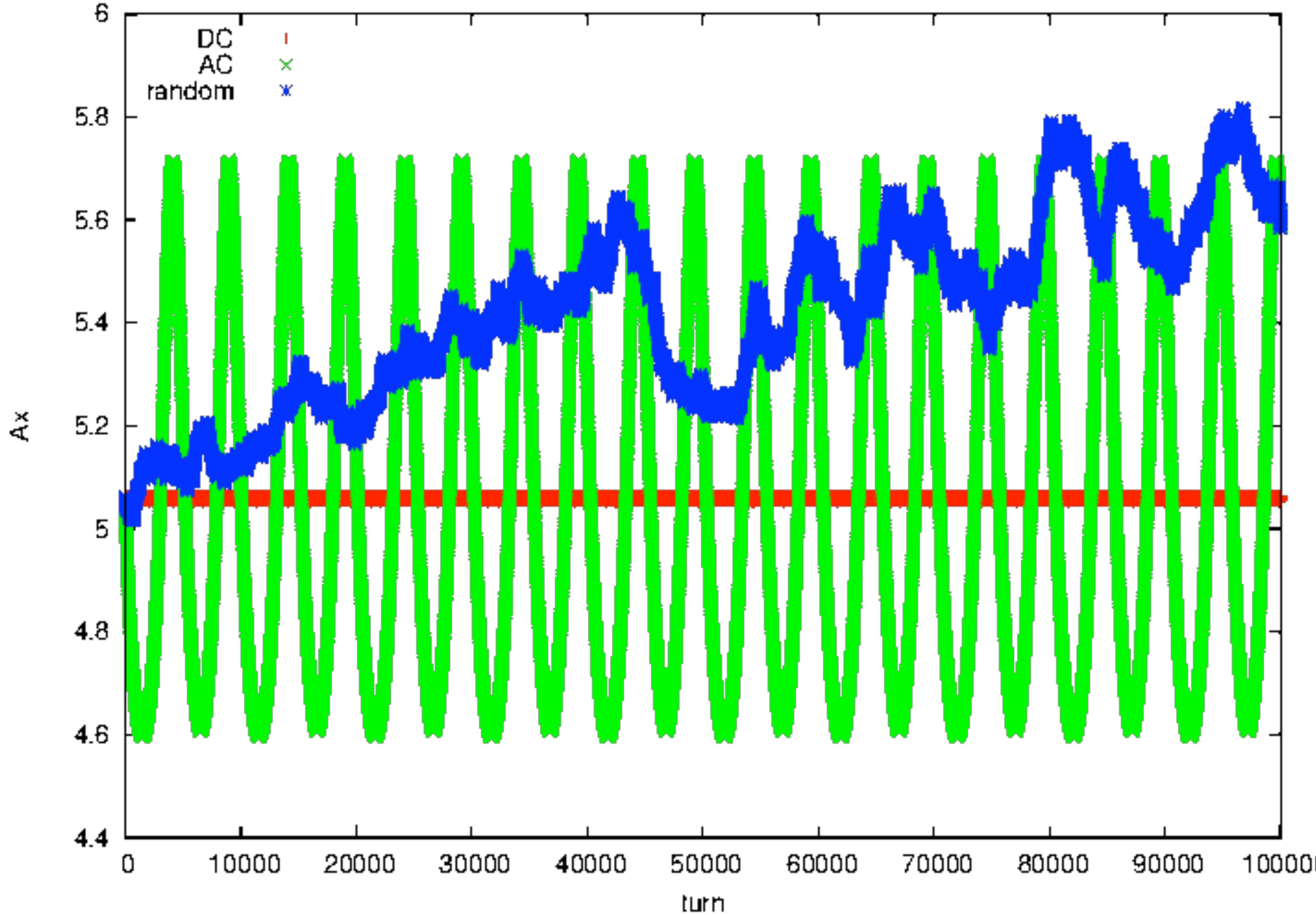
synced with nominal tune

DC mode

random mode

DC mode	does not produce any appreciable amplitude change
AC mode	large amplitude oscillations (enough?)
random mode	"slow" particle diffusion

effect on the amplitude



AC mode

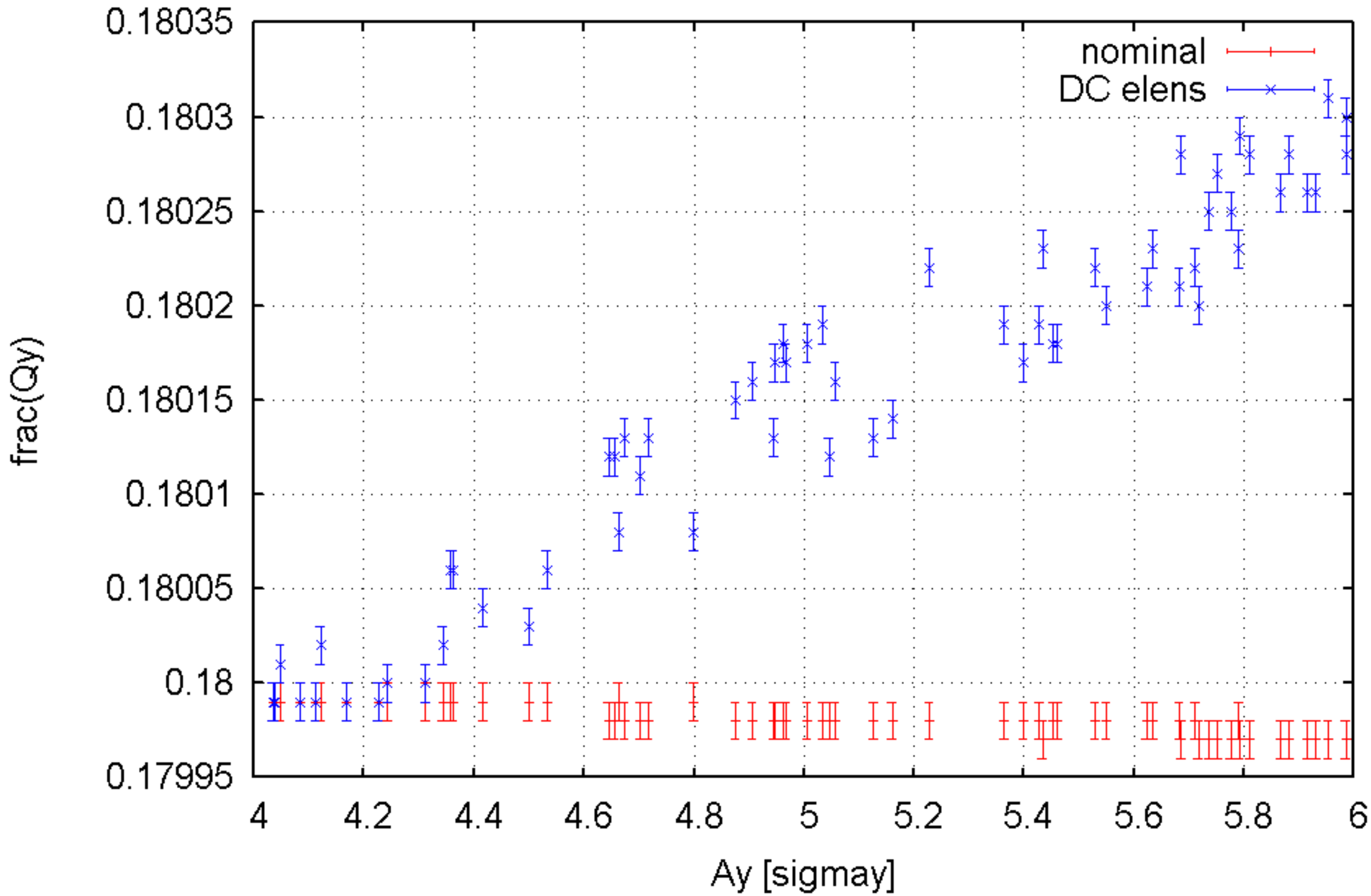
synced with nominal tune

DC mode

random mode

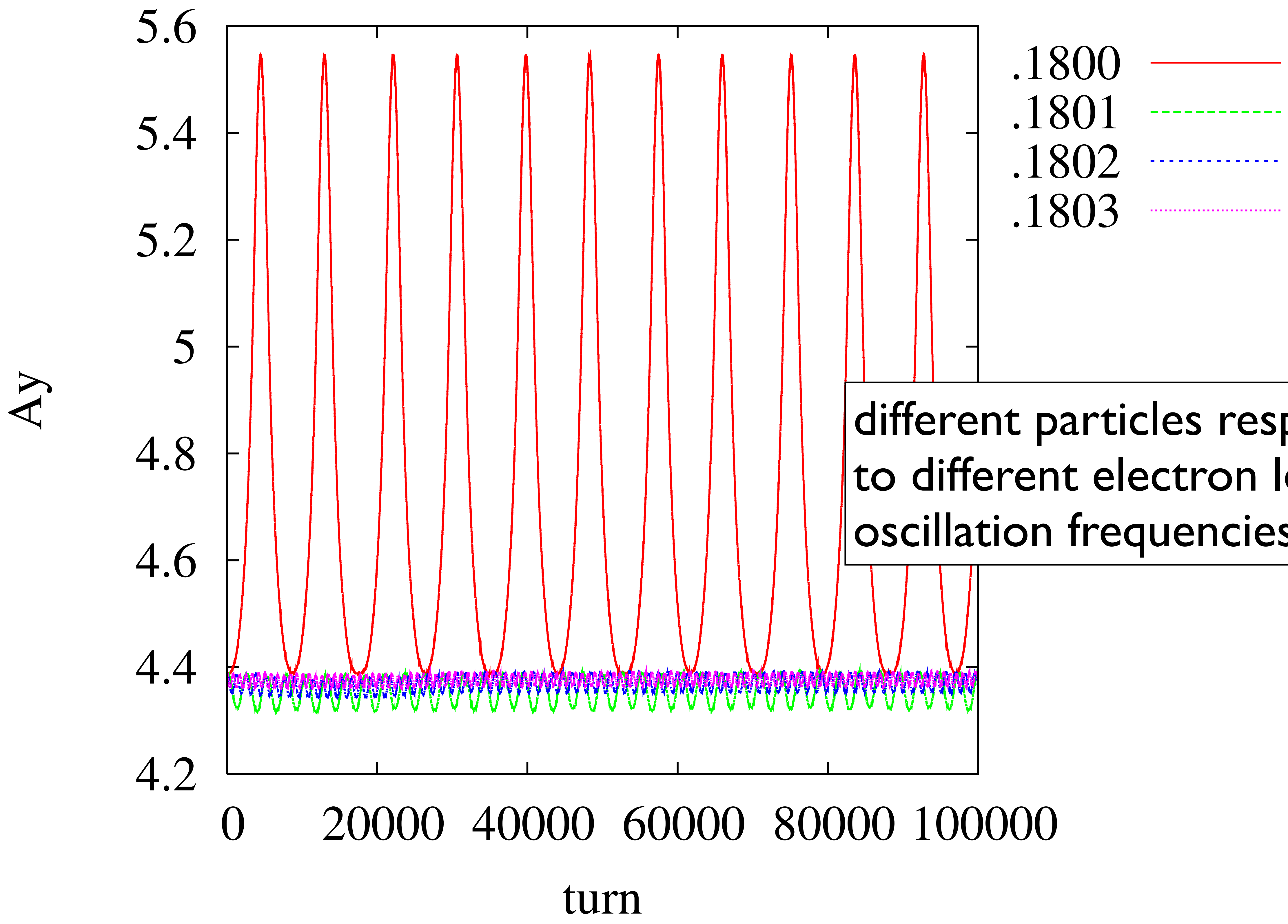
AC mode is the nominal tune the correct choice?

remember... (few slides ago)



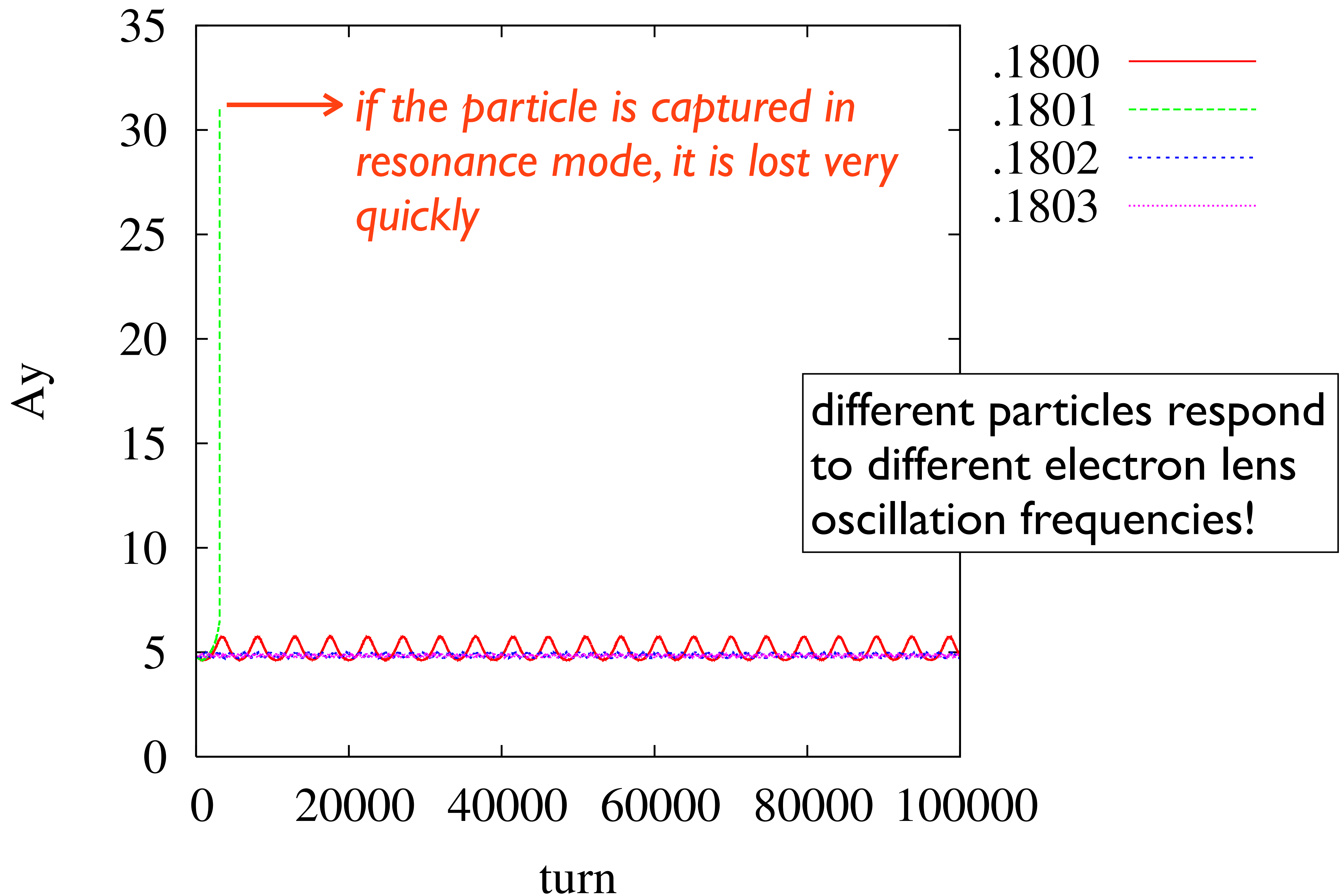
Different particles have different tunes, therefore...

effect on the amplitude



different particles respond to different electron lens oscillation frequencies!

effect on the amplitude



effect on the amplitude : summary

1. The electron lens in DC mode does not produce appreciable amplitude oscillations
2. Different particles have different tunes, therefore they will respond to different electron lens oscillation frequencies.
3. If a particle is captured in resonance mode, it can be lost extremely quickly (1000 turns ~ 10 ms)
4. The random mode works as a slow diffuser

how many particles do we scrape?

- for the AC mode: 200K turns, 3200 particles. Tunes between .18 and .18035, step of 0.0005
- for the DC mode: 1e6 turns, 640 particles
- for the random mode: 1e6 turns, 640 particles
- once a particle has an inelastic interaction with the primary collimator (at 6.2 sigma) is removed from tracking. The number of survival particles is observed.

efficiency as a scraper

survival particles

Long simulations (1e6 turns)

CASE	no el.	DC	random
survival %	1.0	1.0	0.32

AC mode, Fast simulations, 200K turns

TUNE	0.18	0.1805	0.1801	0.18015	0.1802	0.1803
survival%	0.71	0.19	0.3	0.46	0.65	0.88

efficiency as a scraper

survival particles

Long simulations (1e6 turns)

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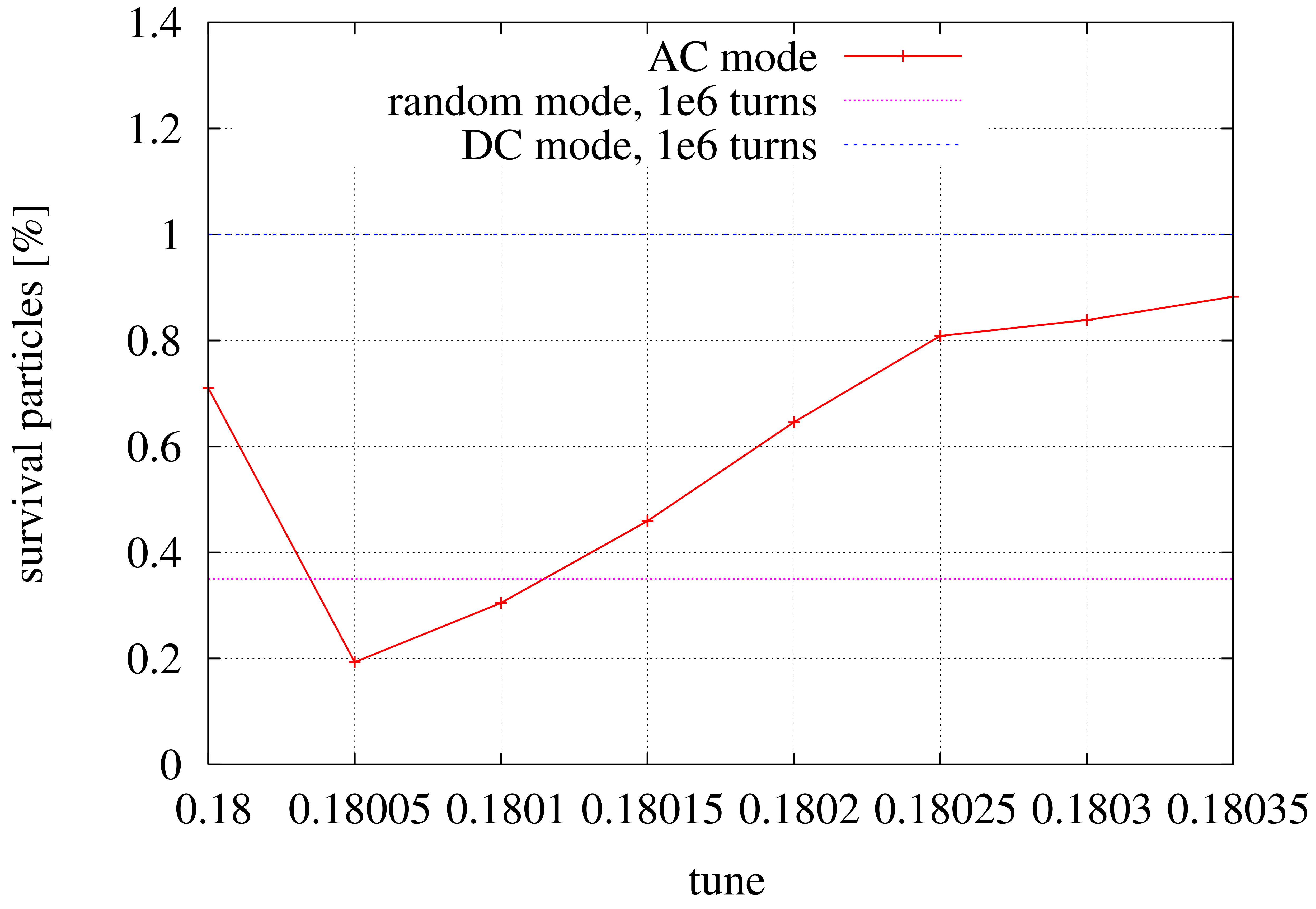
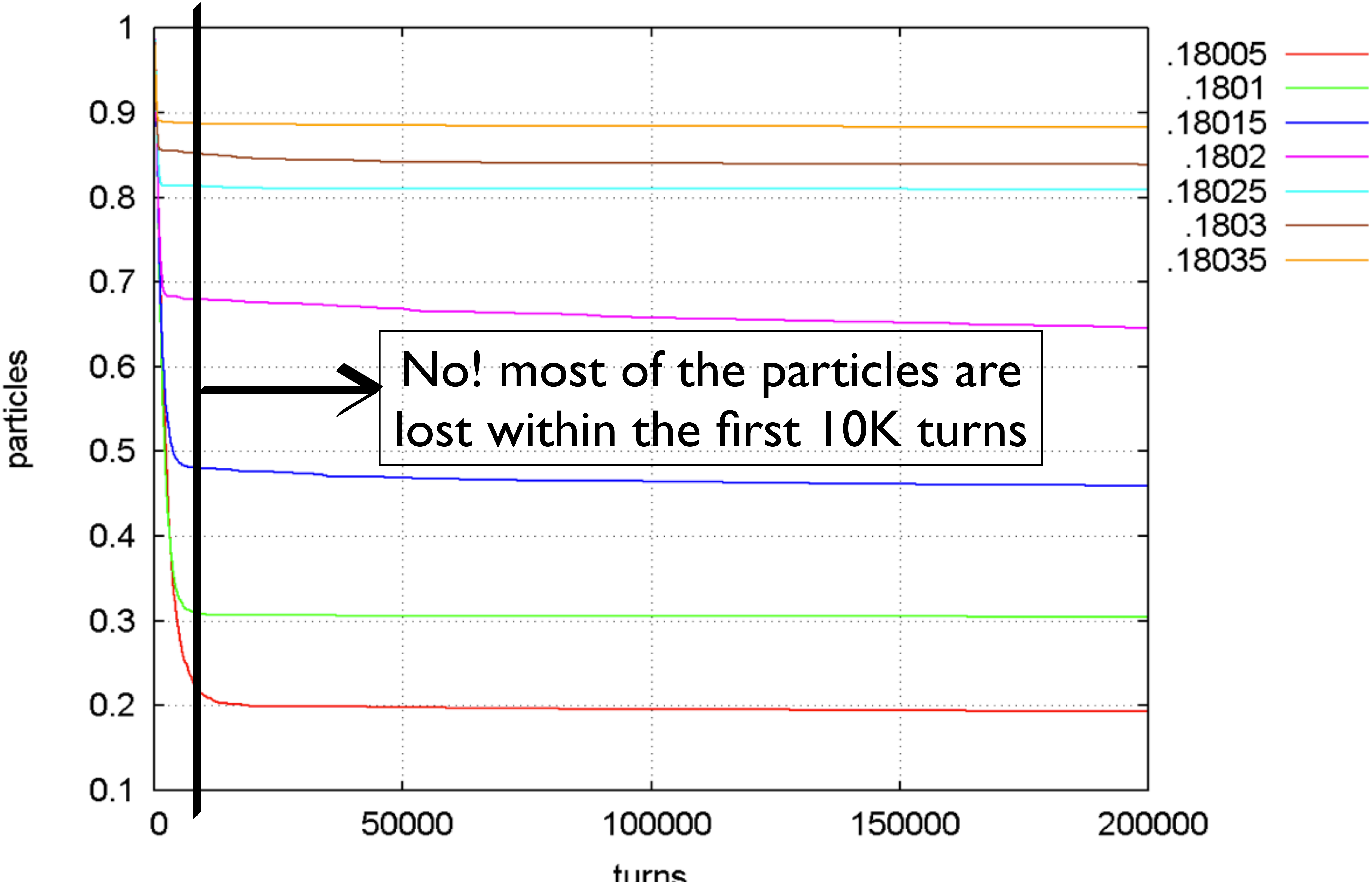
survival%	0.71	0.19	0.3	0.46	0.65	0.88


AC mode
random mode, 1e6 turns
DC mode, 1e6 turns
survival particles [%]
tune
1.4
1.2
1
0.8
0.6
0.4
0.2
0
0.18
0.18005
0.1801
0.18015
0.1802
0.18025
0.1803
0.18035

efficiency as a scraper

Are 200K turns necessary?

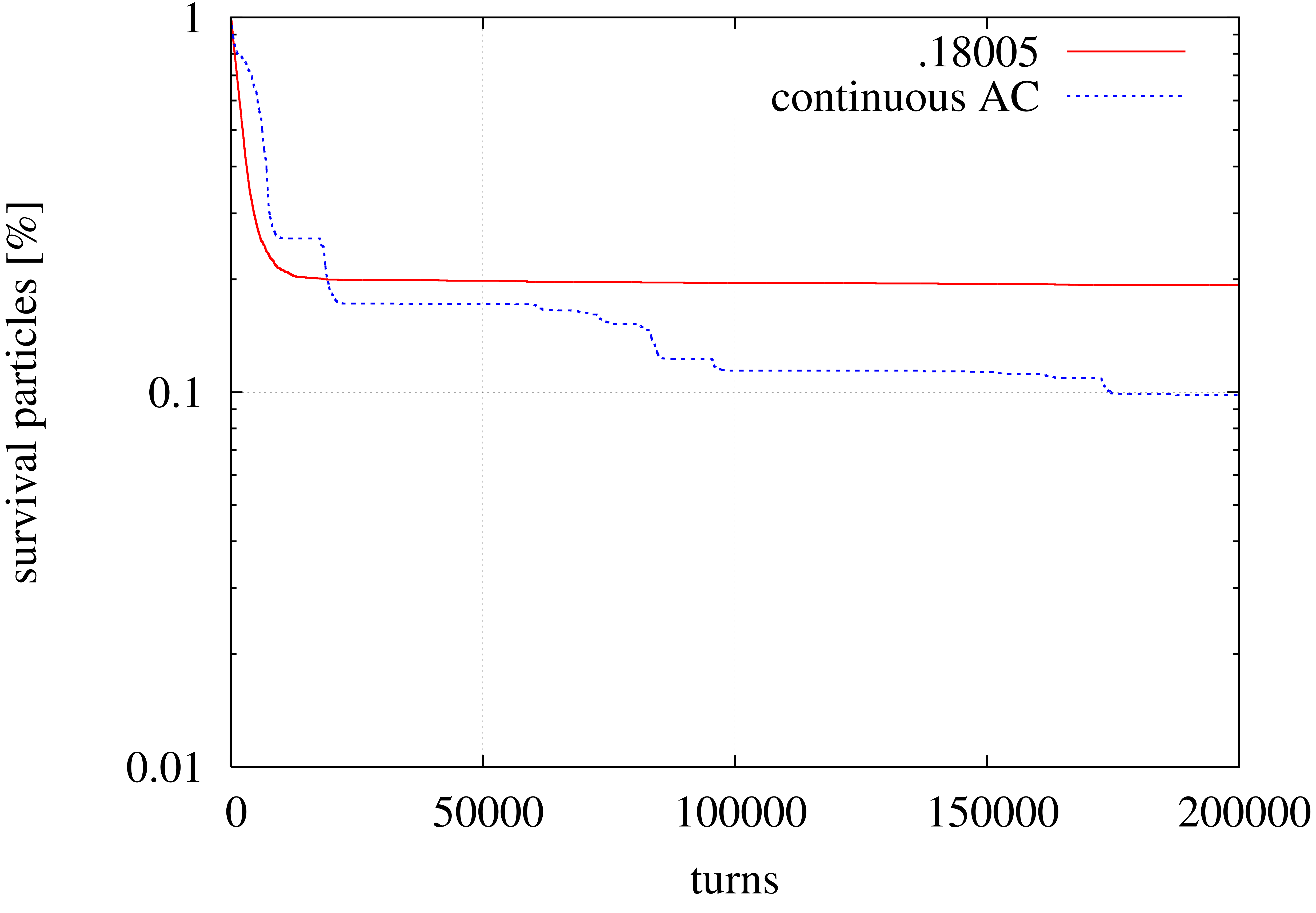


efficiency as a scraper

the continuous AC mode

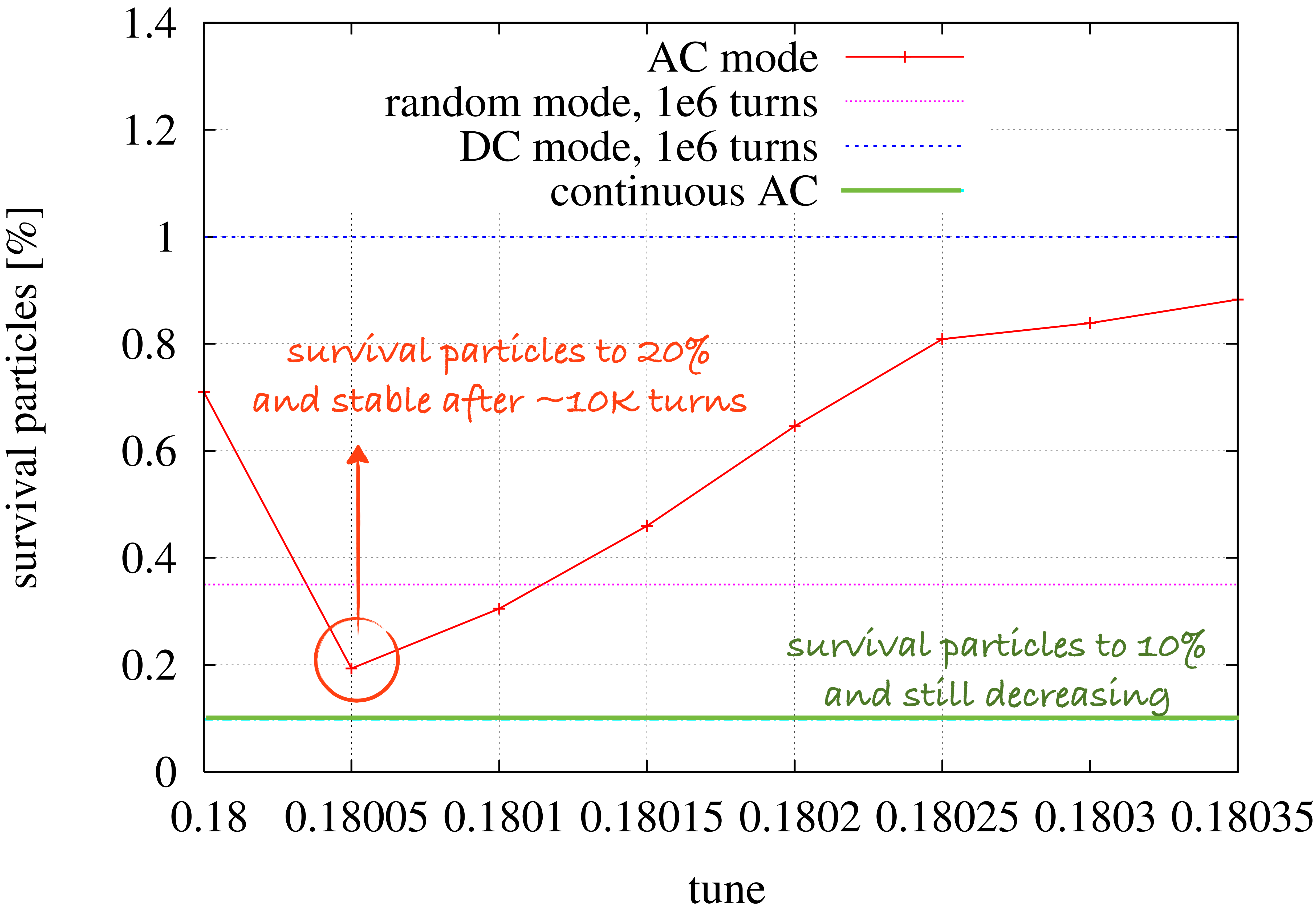
- sweep the AC modulation across the whole range of interesting tunes
- in simulations:
  - AC frequency varied between 17.995 and 18.035 (40 steps of 1e-5), back and forward
  - Change of frequency every 1000 steps

reasonable parameters, to be optimized with further simulations



1
0.1
0.01
0
50000
100000
150000
200000
turns
survival particles [%]
.18005
continuous AC

efficiency as a scraper

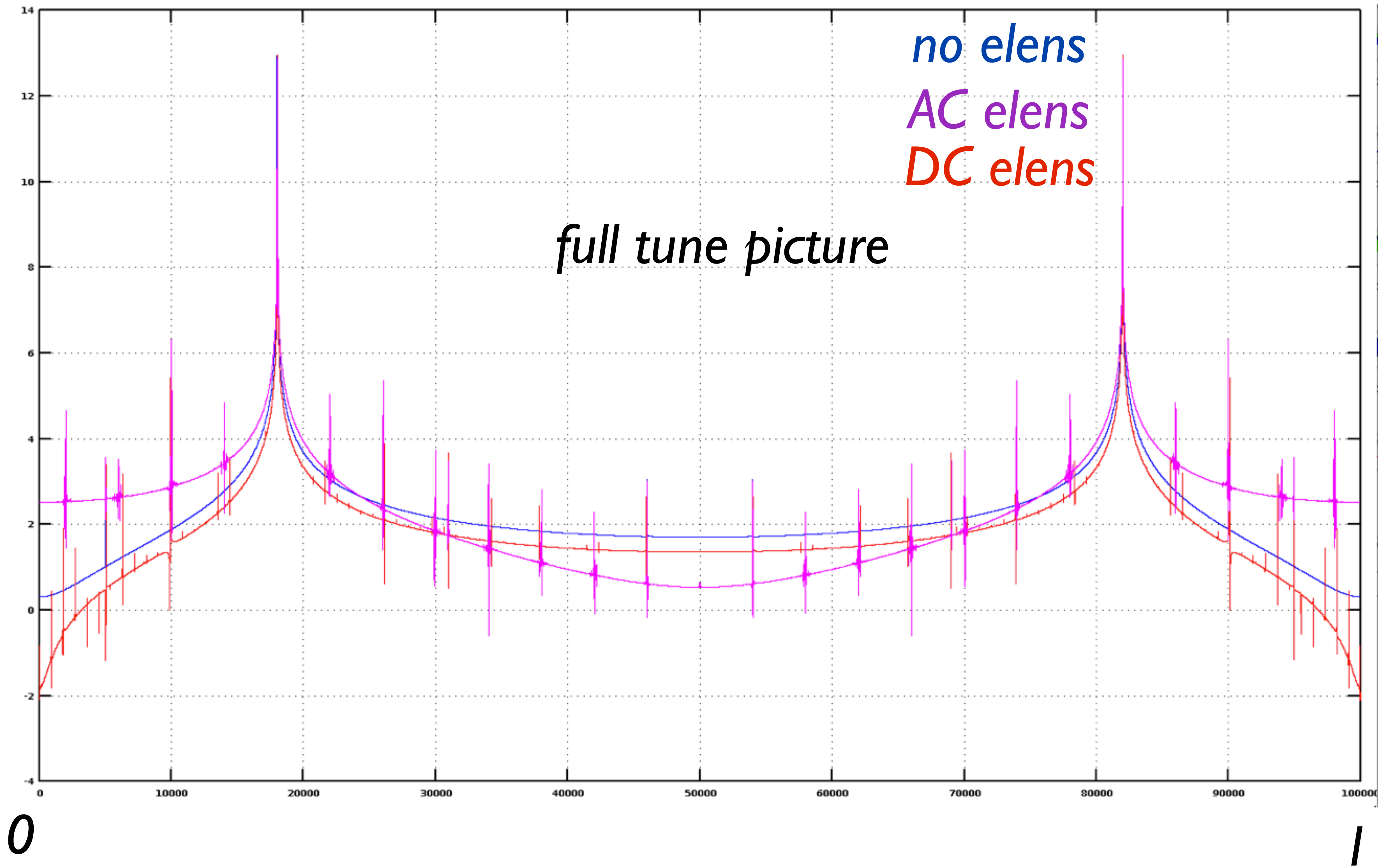


efficiency as a scraper

conclusions for SPS

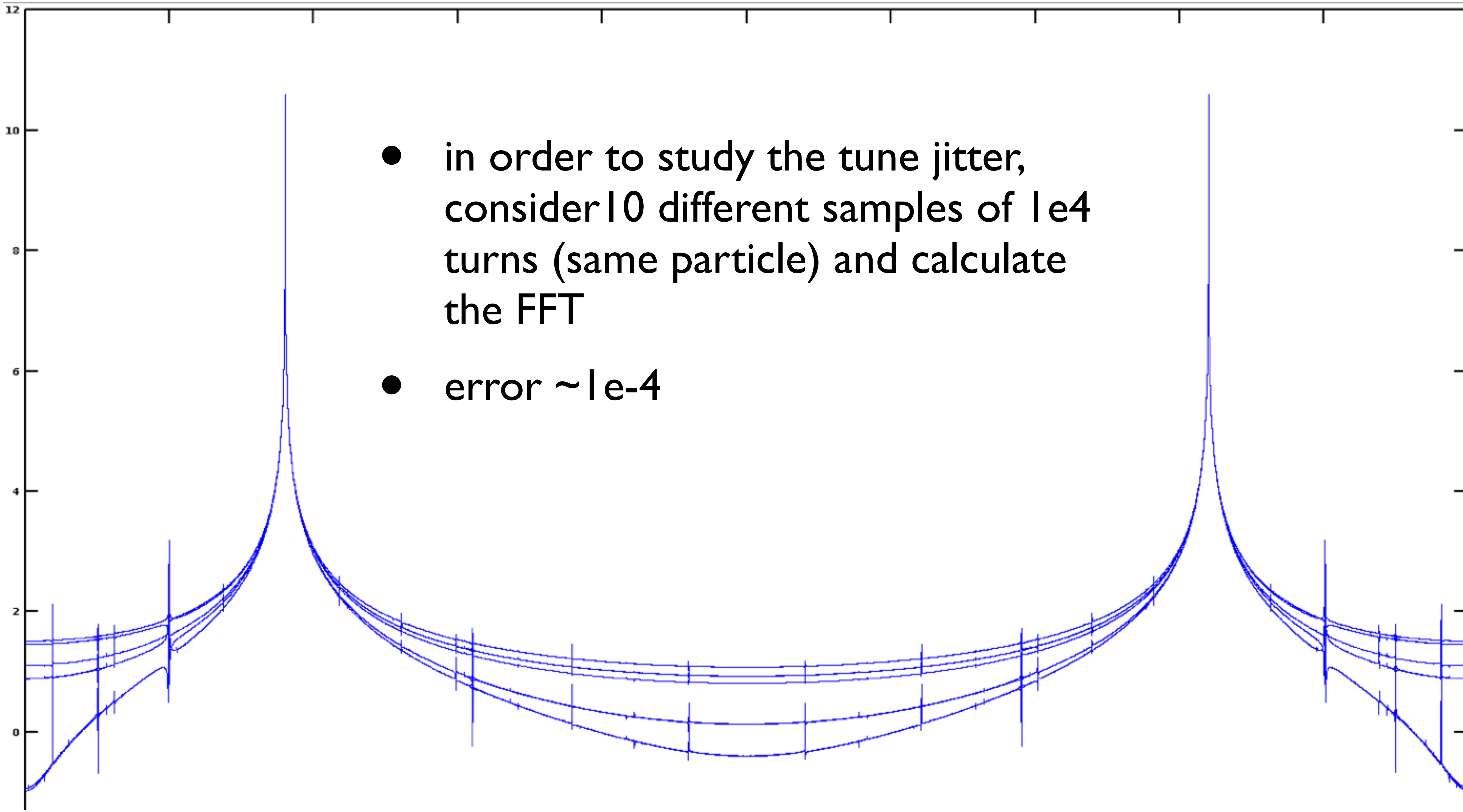
- Similar conclusions as for the LHC:
  - identified different operation modes of the electron lens
  - the DC is not effective (as for the LHC)
  - the AC mode is effective only if the resonance frequency is optimized
  - the random mode is effective over longer periods:
    - cleaning 70% of the particles in 1e6 turns (20 sec)
  - with the continuous AC mode, it is possible to clean:
    - 80% of the particles between 4 and 6 sigma 0.2 seconds.
    - 90% of the particles between 4 and 6 sigma 5 seconds.

Log scale


no elens
AC elens
DC elens
full tune picture
14
12
10
8
6
4
2
0
-2
-4
0
10000
20000
30000
40000
50000
60000
70000
80000
90000
100000
0
1

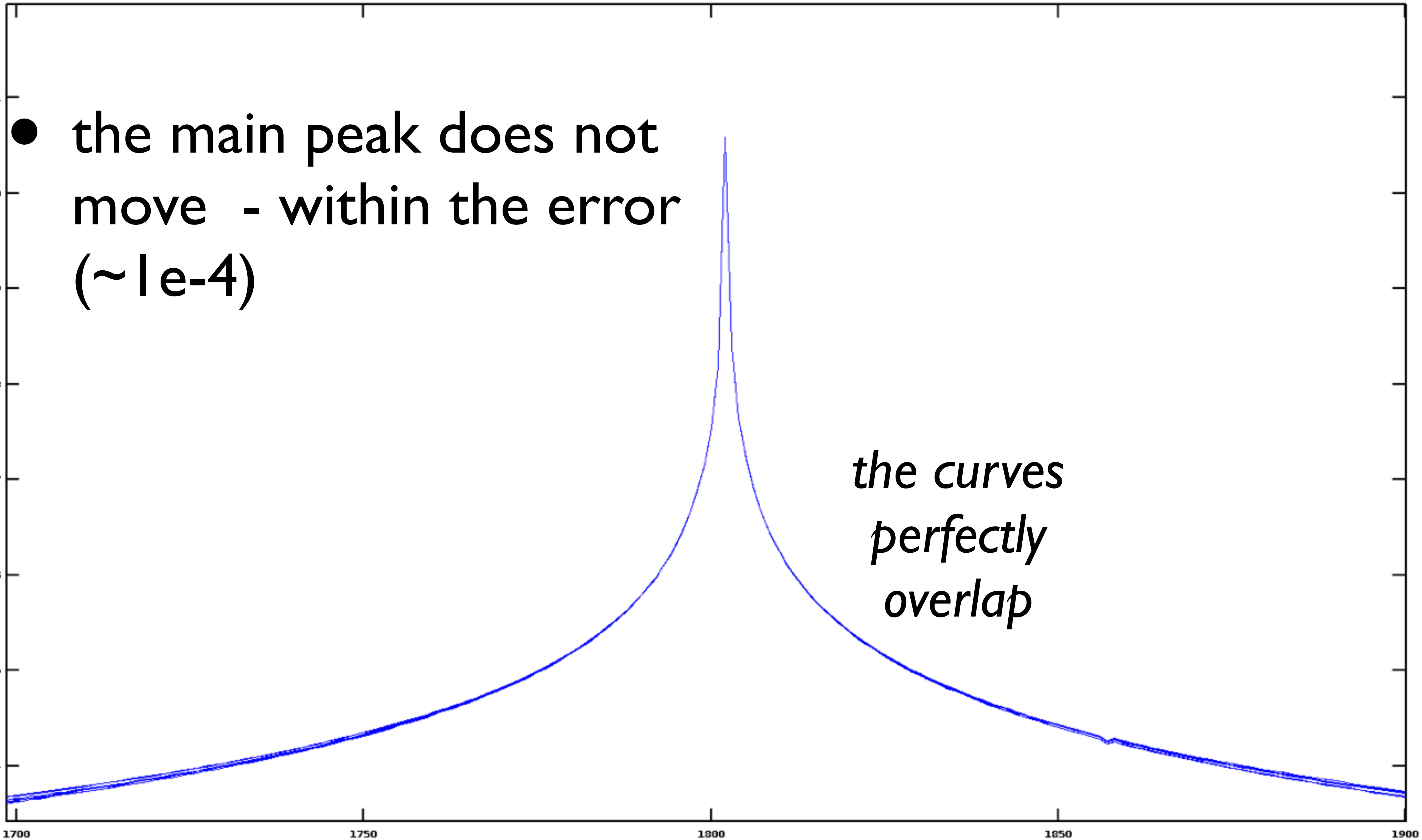
DC elens: tune jitter?

<u>Log scale</u>



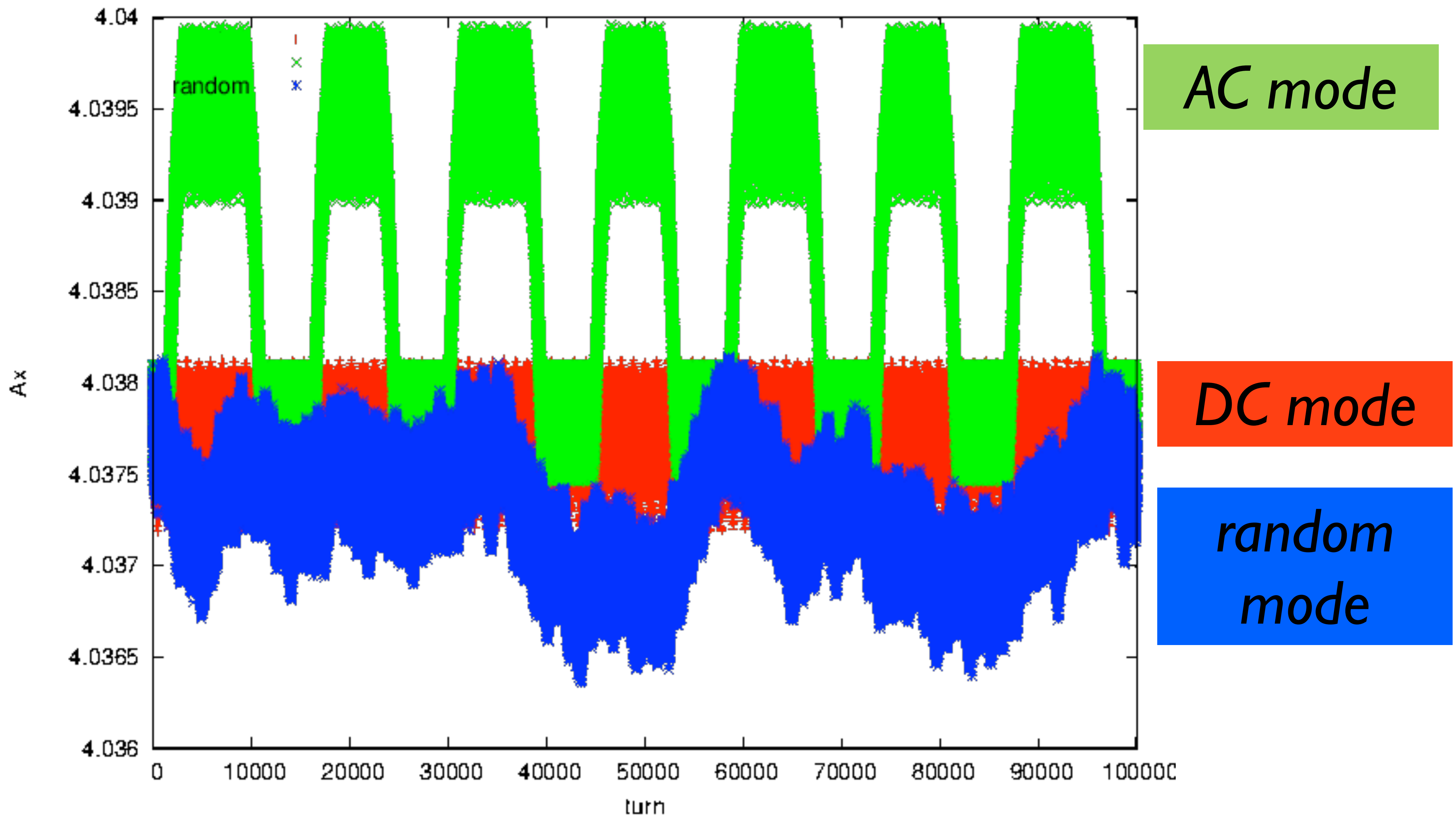
- in order to study the tune jitter, consider10 different samples of 1e4 turns (same particle) and calculate the FFT
- error ~1e-4

- the main peak does not move - within the error (~1e-4)



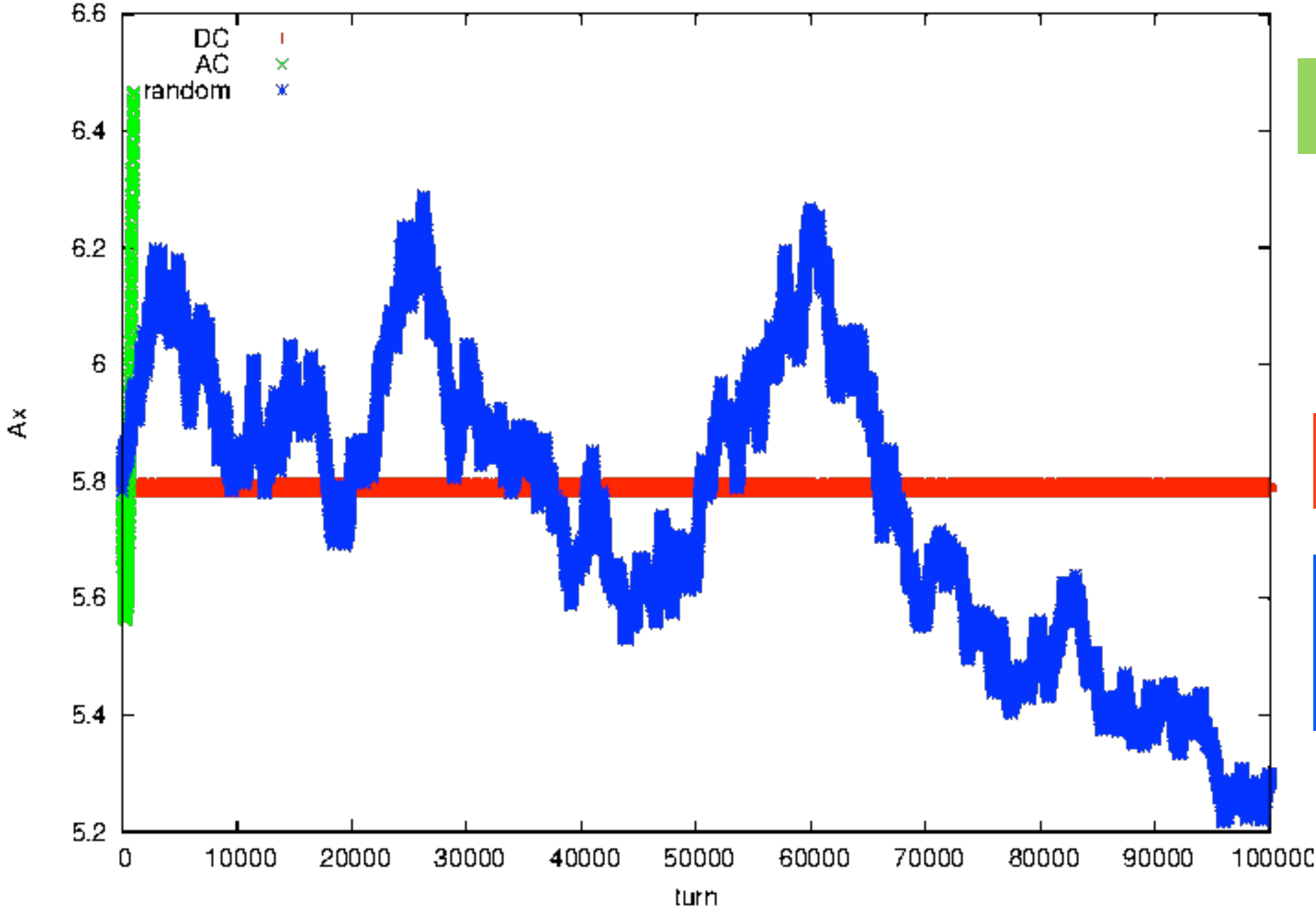
effect on the amplitude

comparison between AC, DC and random mode



effect on the amplitude

**IF* you lose a particle in AC mode, you lose it extremely fast*



AC mode

DC mode

random mode