TUNE MODULATION SIMULATIONS (UPDATED)

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SETUP OF THE SIMULATIONS

- included a TM (tune modulation) element in SixTrack+collimation
- The element can be either a quadrupole or a dipole. The element type is recognized by its name (TM_QUAD or TM_DIP)
- New format for the collimator DB entry

```
#new format for TM_QUAD entries in the collimator database

1: STRING                                   NAME UPPERCASE
2: STRING                                   name (lowercase)
3: DOUBLE                                   lenght [m]
4: DOUBLE                                   (quadrupole) angle of the focusing  plane [rad] 0=HOR
                                            (dipole) angle of the active plane [rad] 0=HOR
5: DOUBLE DOUBLE                            center_x[m] center_y[m]
6: DOUBLE                                   (quadrupole) gradient kick per length unit (rad/m^2)
                                            (dipole) kick per length unit (rad/m^2)
7: DOUBLE DOUBLE    DOUBLE      DOUBLE  INT operation tune, multiplication factor
                                            Delta tune, tune increment per step
8: LOGIC                                    if true, the quad polarity can be inverted
8: DOUBLE                                   database beta x
9: DOUBLE                                   database beta y
```

ELEMENT DEFITION

Dipole: the kick is given by strength*length
Quadrupole: the gradient is given by strength*length

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strength

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Quadrupole: the gradient is given by strength*length

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multiplication factor

The frequency of the element is the mult. factor * tune
Dipole: =1 , Quadrupole: =2

Dipole: the kick is given by strength*length
Quadrupole: the gradient is given by strength*length

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tune sweeping

The frequency sweep has the same parameters as for the e-lens

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```

polarity switch

The frequency sweep has the same parameters as for the e-lens

The frequency of the element is the mult. factor * tune
Dipole: =1 , Quadrupole: =2

polarity switch: if true the polarity of the element can be inverted (i.e. invert the current verse)
Dipole: true , Quadrupole: false

ADDITIONAL OUTPUTS

```
# change in fort.3 to activate detailed output for tune modulation quadrupole
line 10: LOGICAL    LOGICAL      INT        LOGICAL        STRING     LOGICAL    LOGICAL         LOGICAL           LOGICAL           LOGICAL          LOGICAL
        do_select   do_nominal   rnd_seed   dowrite_dist   name_sel   do_oneside dowrite_impact dowrite_secondary dowrite_amplitude write_elens_out write_TM_quad_out
```

new flag in the code to activate additional outputs for the TM elements. In case the flag is true the coordinates of the particles (both physical and normalized) are saved at each passage from the TM element. Files are saved in binary.

file tm.dat

```
# 1=coll 2=npart 3=nturn 4=x0 5=xp0 6=y0 7=yp0 8=kx &  9=ky 10=kr
3 1000001 1 1.446560051675370E-03 -4.347980565365830E-06 -1.214675826314091E-13 -1.181131138521943E-16 -5.451666212732319E-10 0.000000000000000E+00 5.451666212732319E-10
3 1000002 1 8.625902604751890E-04 -8.272520787922501E-06 -8.984670275718348E-16 7.350804138903585E-16 -3.250853065539972E-10 0.000000000000000E+00 3.250853065539972E-10
3 1000003 1 1.137171145699256E-03 1.576872089313577E-06 -1.182048908466069E-13 -5.985978214931910E-16 -4.285668960597410E-10 0.000000000000000E+00 4.285668960597410E-10
3 1000004 1 -1.716312414568961E-03 4.386249147475881E-07 1.244809140555632E-13 7.759083715939969E-16 6.468284804469118E-10 0.000000000000000E+00 6.468284804469118E-10
3 1000005 1 7.134117014072529E-05 8.797142848403944E-06 -6.726458640282975E-14 -1.377463562752518E-15 -2.688642247410783E-11 0.000000000000000E+00 2.688642247410783E-11
```

file tm.norm.dat

```
# 1=coll 2=npart 3=nturn 4=x0 5=xp0 6=y0 7=yp0 8=kx &  9=ky 10=Ax 11=Ay
3 1000001 1 4.785129304133292 -1.094343876964293 -4.039291297020937E-10 3.179323666998057E-10 7.310688054218417E-05 0.000000000000000E+00 4.908744106074153 5.140425387234315E-10
3 1000002 1 2.853394111139255 -4.068503199956440 -2.987768395905123E-12 4.426432946034697E-10 1.600707358617726E-04 0.000000000000000E+00 4.969523837008157 4.426533779577442E-10
3 1000003 1 3.761690340334034 2.143748527813281 -3.930793521353458E-10 2.003986840553822E-11 -1.276133349552566E-04 0.000000000000000E+00 4.329534263424474 3.935898542910557E-10
3 1000004 1 -5.677453086368497 -1.540379706983245 4.139496826207766E-10 6.595985391979054E-11 -1.018511412125278E-04 0.000000000000000E+00 5.882605279899815 4.191718526701927E-10
3 1000005 1 0.2359920858011872 5.365764008278396 -2.236821154819018E-10 -6.088904488763941E-10 -1.615439416191577E-05 0.000000000000000E+00 5.370934939881100 6.486765507703787E-10
3 1000006 1 1.858928918242967 4.930788887046460 -2.971335687493536E-10 -4.090364389927210E-10 -1.191836683194225E-04 0.000000000000000E+00 5.269443964420983 5.055681616771104E-10
3 1000007 1 5.039481318863747 0.7101365828858383 -4.901552592786400E-10 2.191308877330911E-10 -4.817054760763995E-05 0.000000000000000E+00 5.089221514734306 5.369083014418787E-10
3 1000008 1 -4.195479817460943 -1.224447246422060 3.301107349474714E-10 3.386058083200071E-11 -8.052966407134932E-05 0.000000000000000E+00 4.370425385901388 3.318427884734580E-10
3 1000009 1 -2.260624069873336 4.490443938817386 -1.164474582227075E-10 -6.941402272079055E-10 1.383536603718483E-04 0.000000000000000E+00 5.027514205230701 7.038399431367703E-10
```

CASES SIMULATED

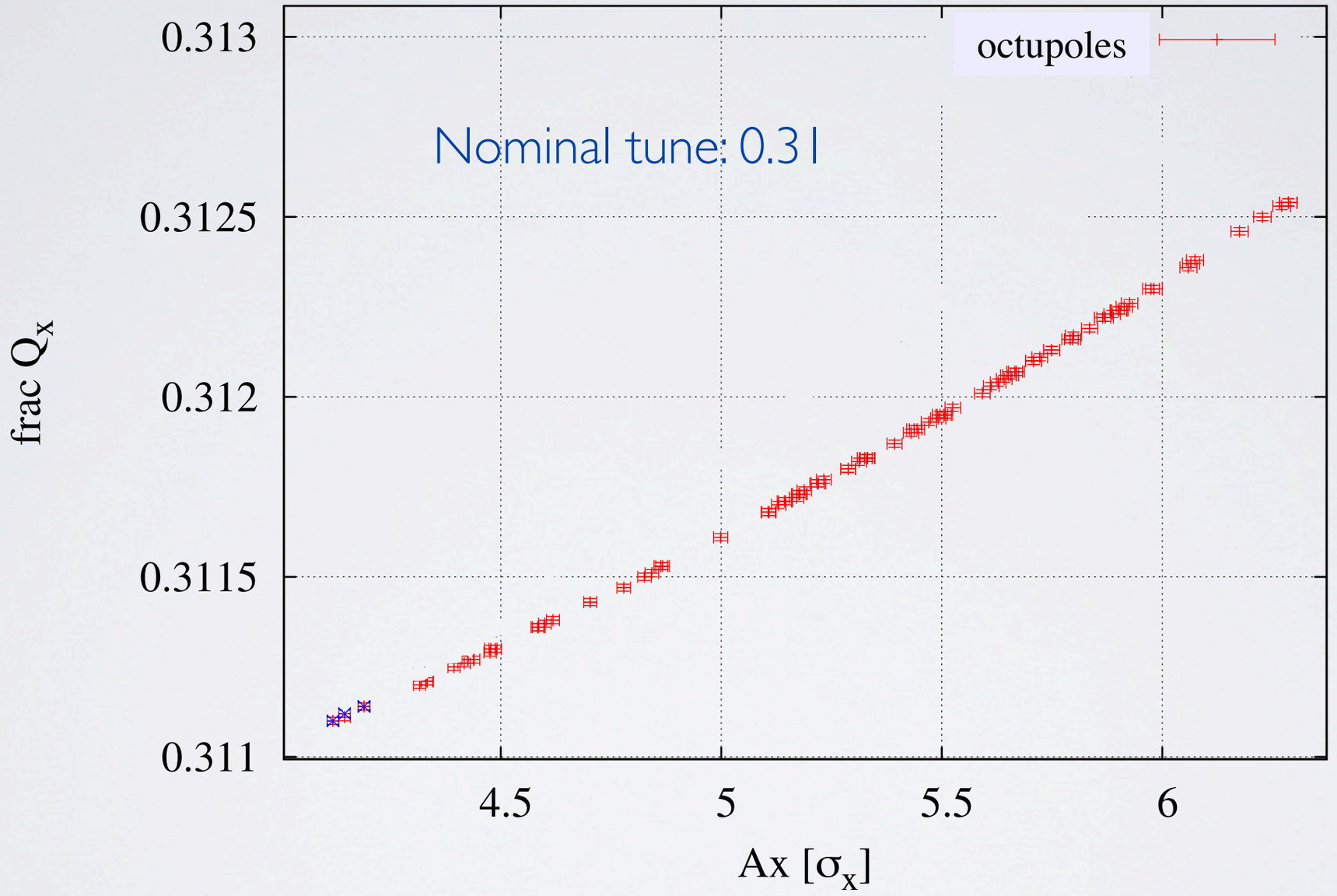
- inputs are as much as possible similar to the electron lens simulations (n. particles, distribution, n. turns)

- the quadrupole gradient has been chosen so that the tune spread is of the order of 10^{-4}

- the dipole strength has been chosen to match the ADT capabilities

- dipole can invert its polarity, for quadrupole both cases have been tested

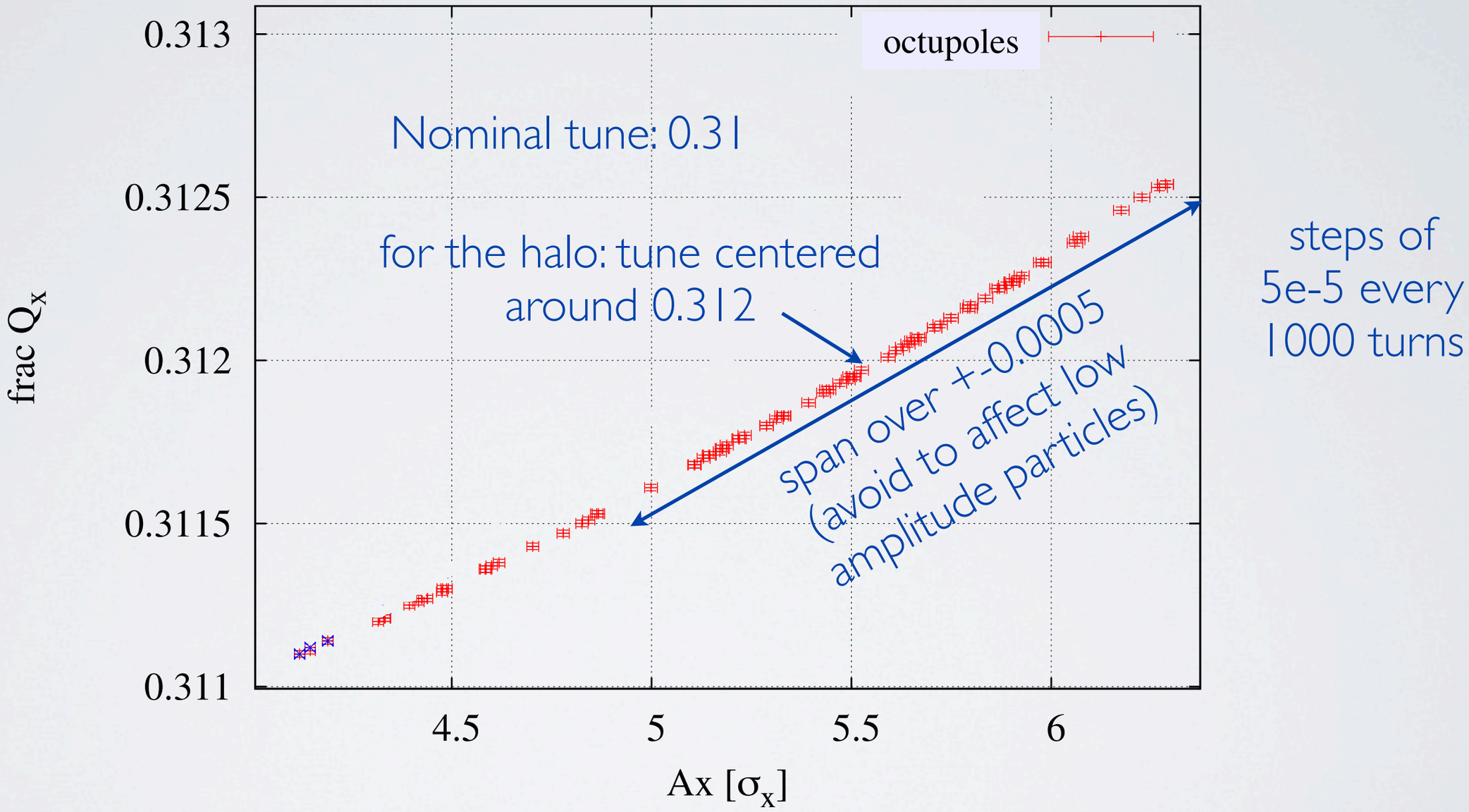
TUNE MODULATION



Selecting particles using the tune spread given by octupoles

TUNE MODULATION

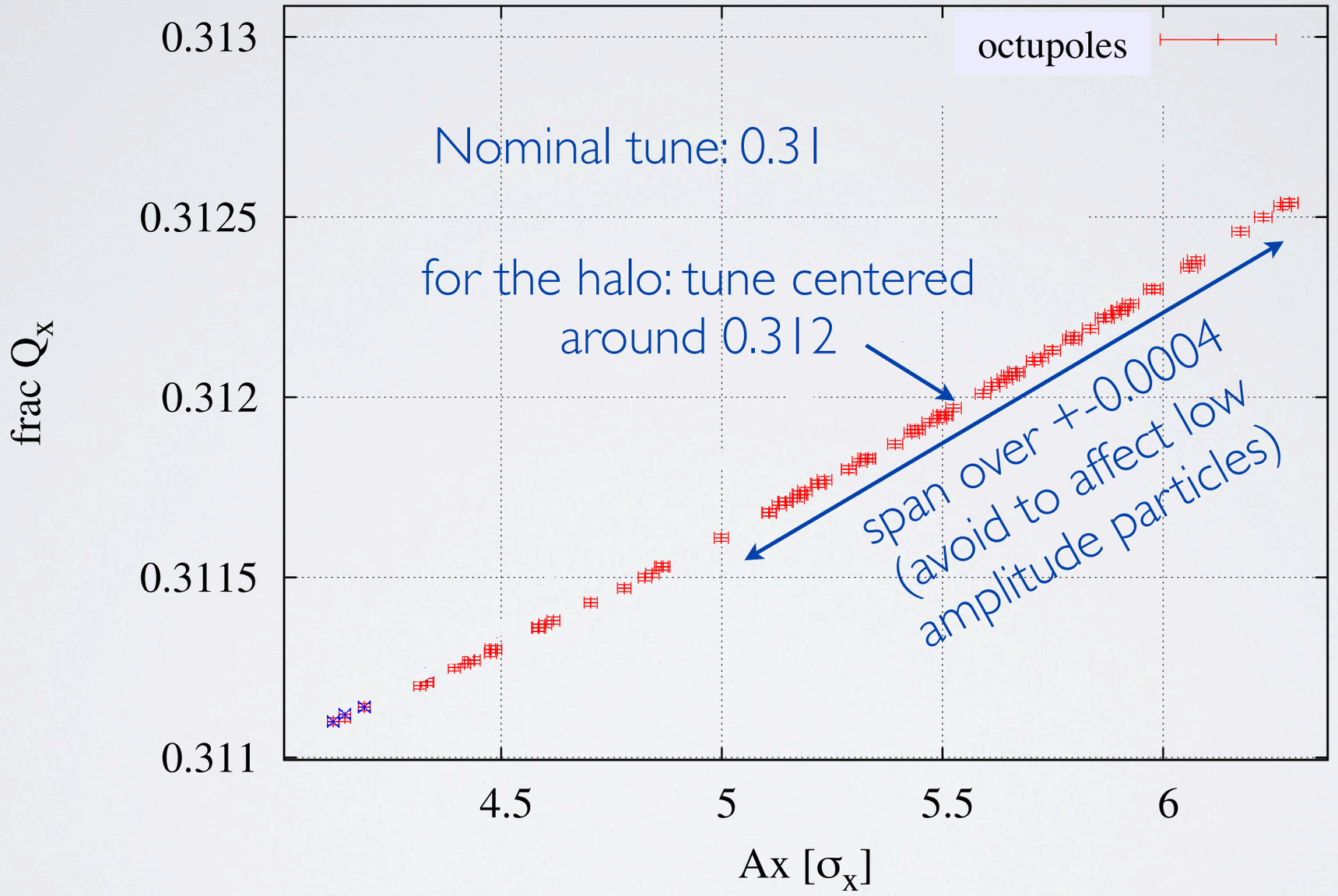
modulation 1: H10



Selecting particles using the tune spread given by octupoles

TUNE MODULATION

modulation 2: L8



steps of 2e-5 every 1000 turns

results are very similar (as in e-lens case)

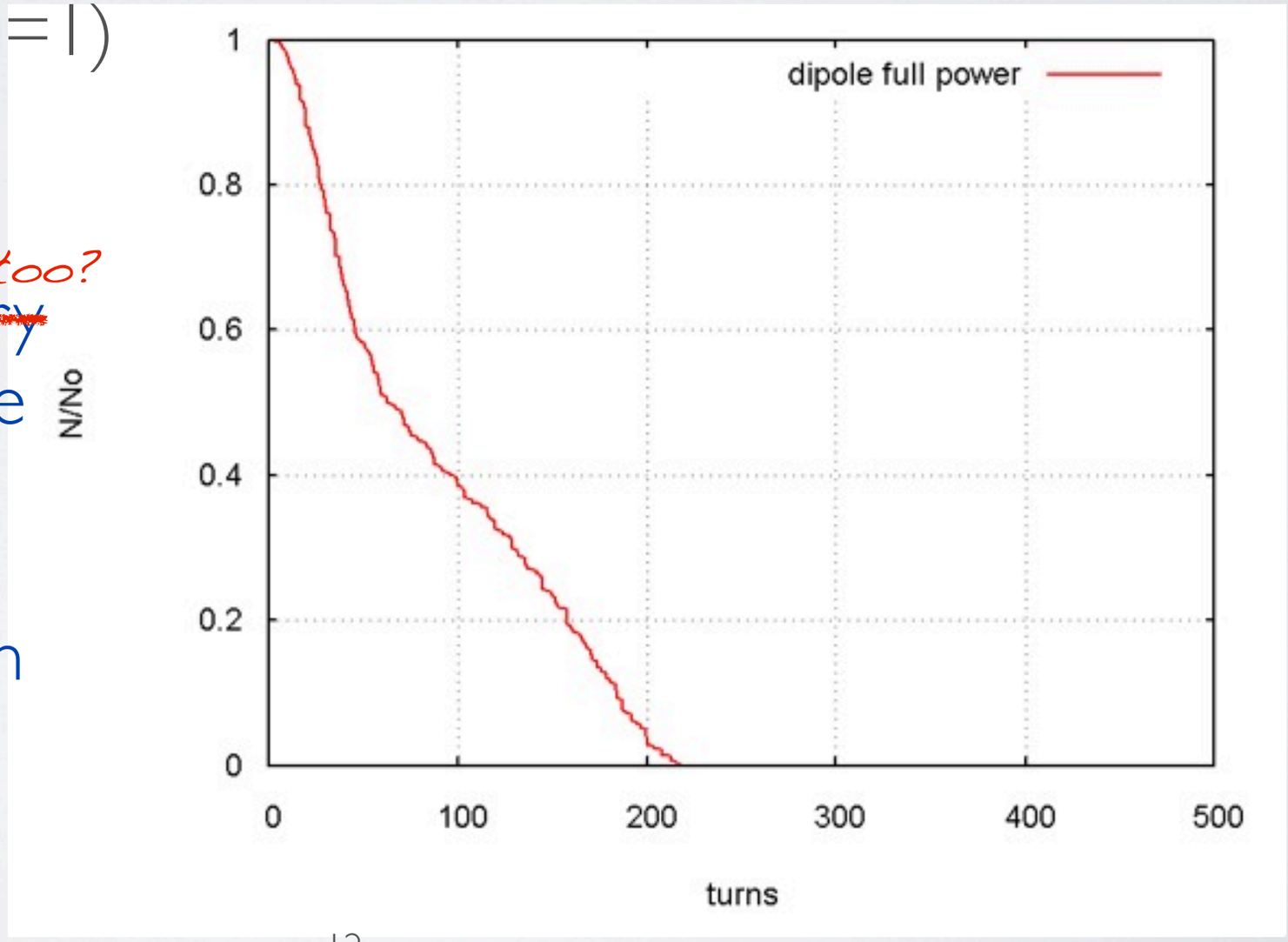
Selecting particles using the tune spread given by octupoles

THE DIPOLE

- First trial: full power ADT capabilities @ 7 TeV: 0.2 urad/turn

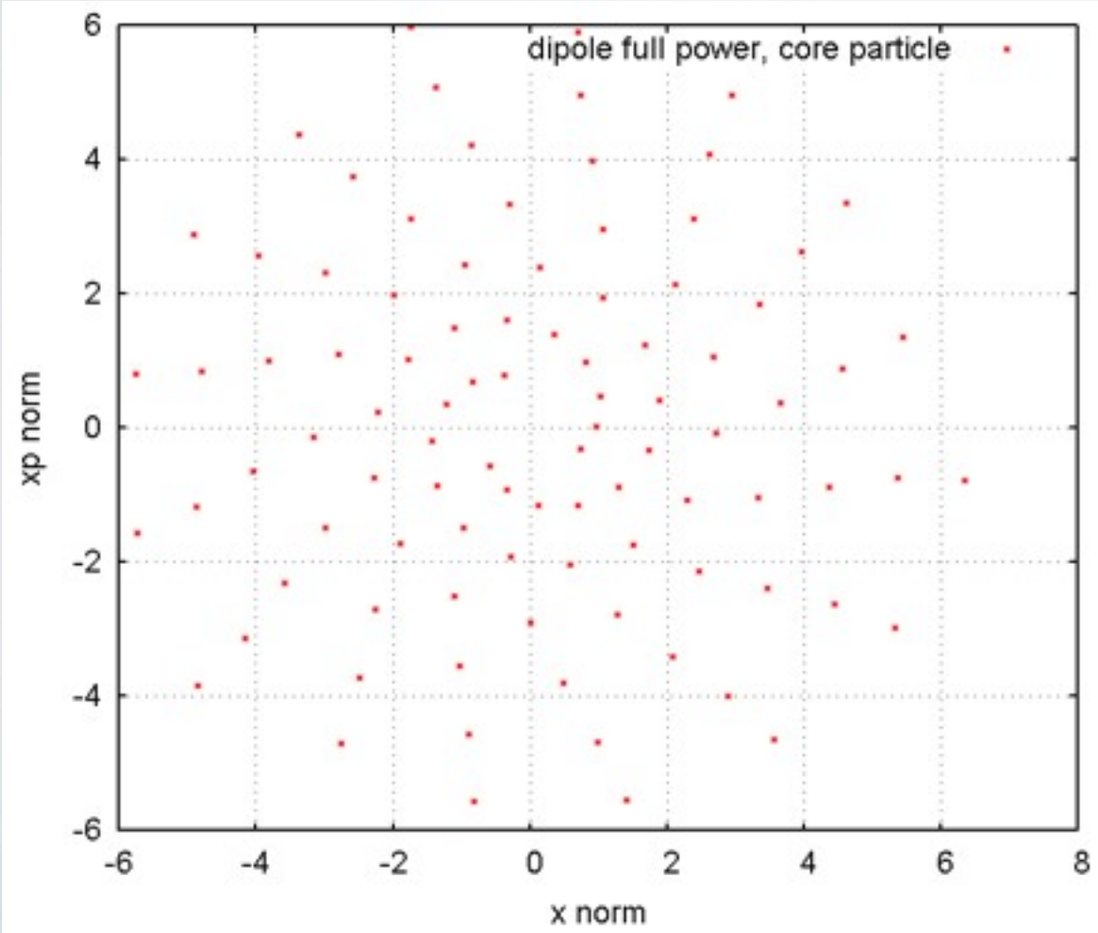
- Dipole excitation frequency $n\omega_0$ in resonance with the tune (multiplication factor n=1)

the excitation is ~~very~~ too? effective! lost all the particles in about 200 turns. (for both excitation patterns)

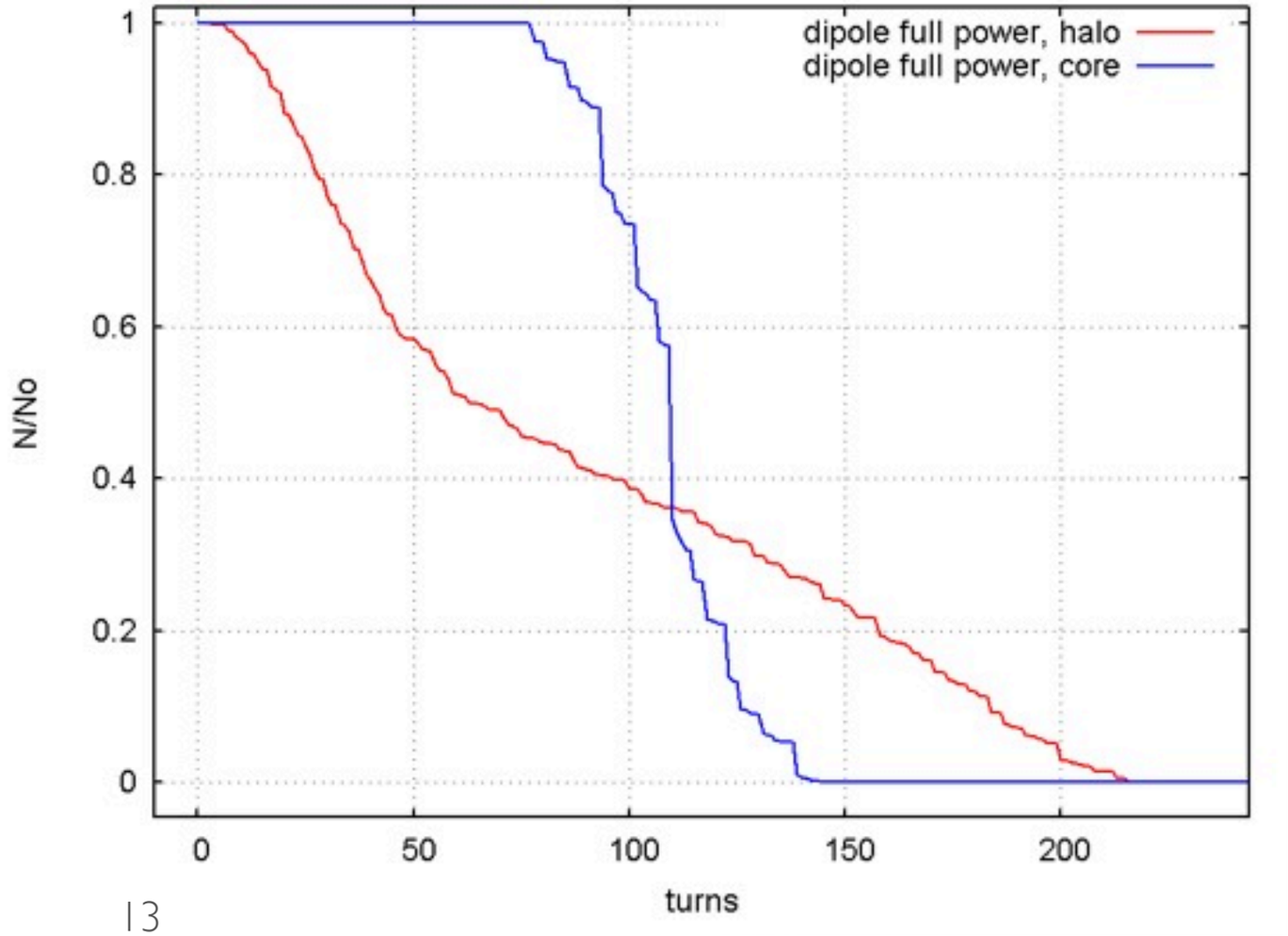


HOW ABOUT THE CORE?

- Tried to simulate the core (between 0 and 2 σx) of the beam in the same conditions.
- The tune does not perfectly match the beam tune, but still induces large oscillation amplitudes in the core (up to 10-15 σx).
- All the particles are lost in about 200 turns.



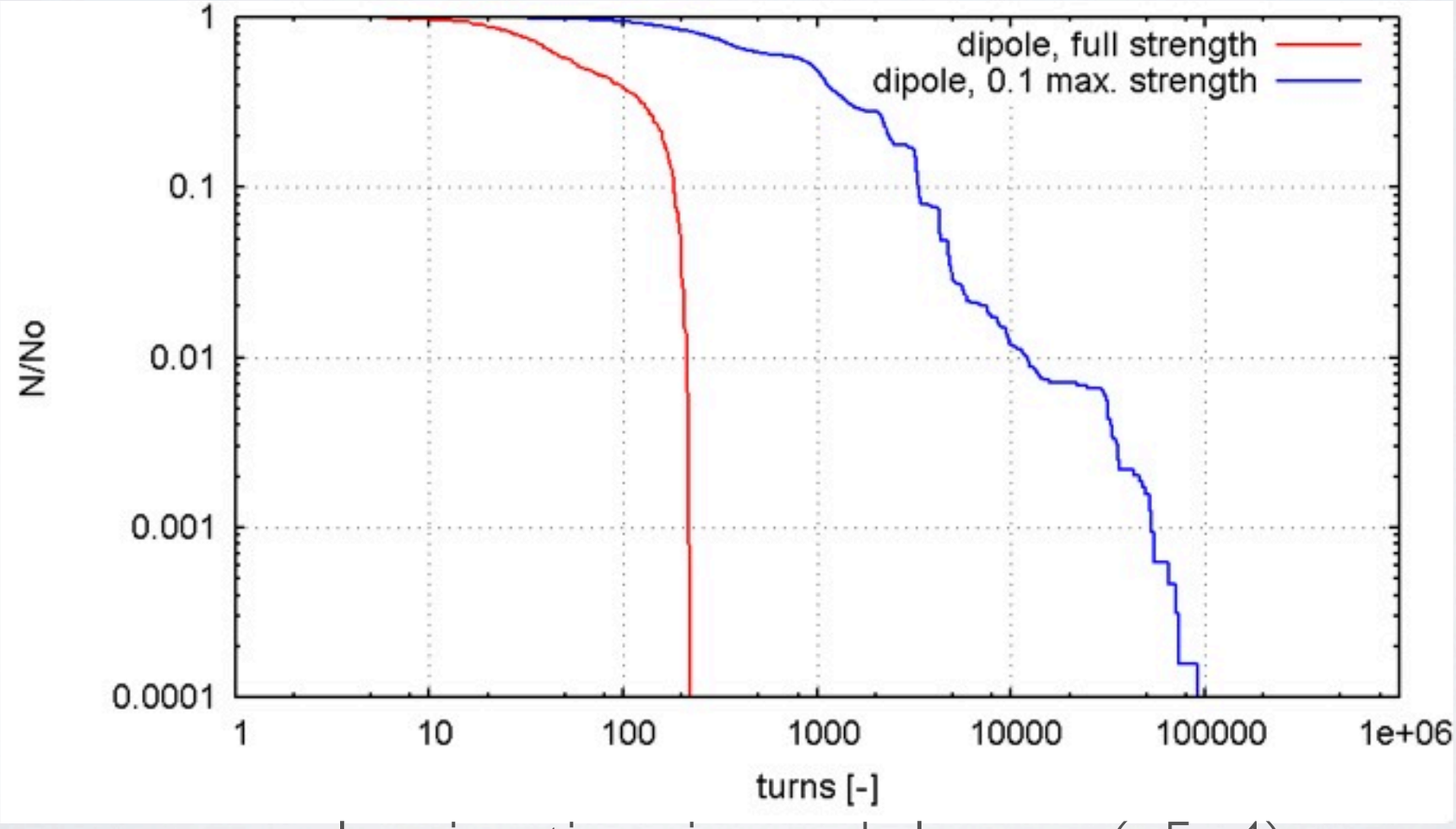
from 0.5 to 6 sigma in about 200 turns



DECREASING THE STRENGTH?

- since the core particle are not in perfect resonance condition, decreasing the dipole strength could decrease their oscillation amplitude

effect on the halo

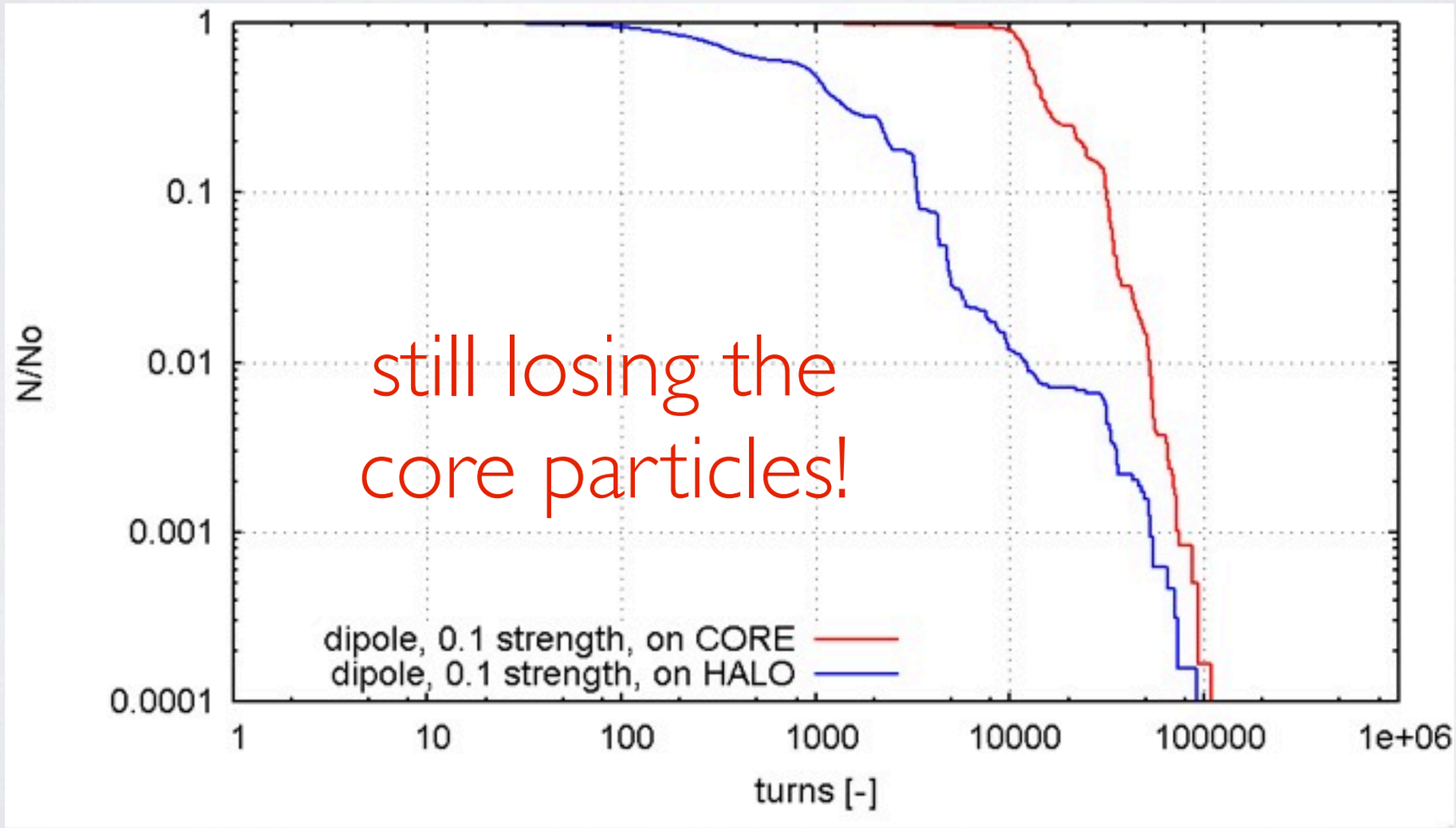


cleaning time is much longer (x5e4)

DECREASING THE STRENGTH?

- since the core particle are not in perfect resonance condition, decreasing the dipole strength could decrease their oscillation amplitude

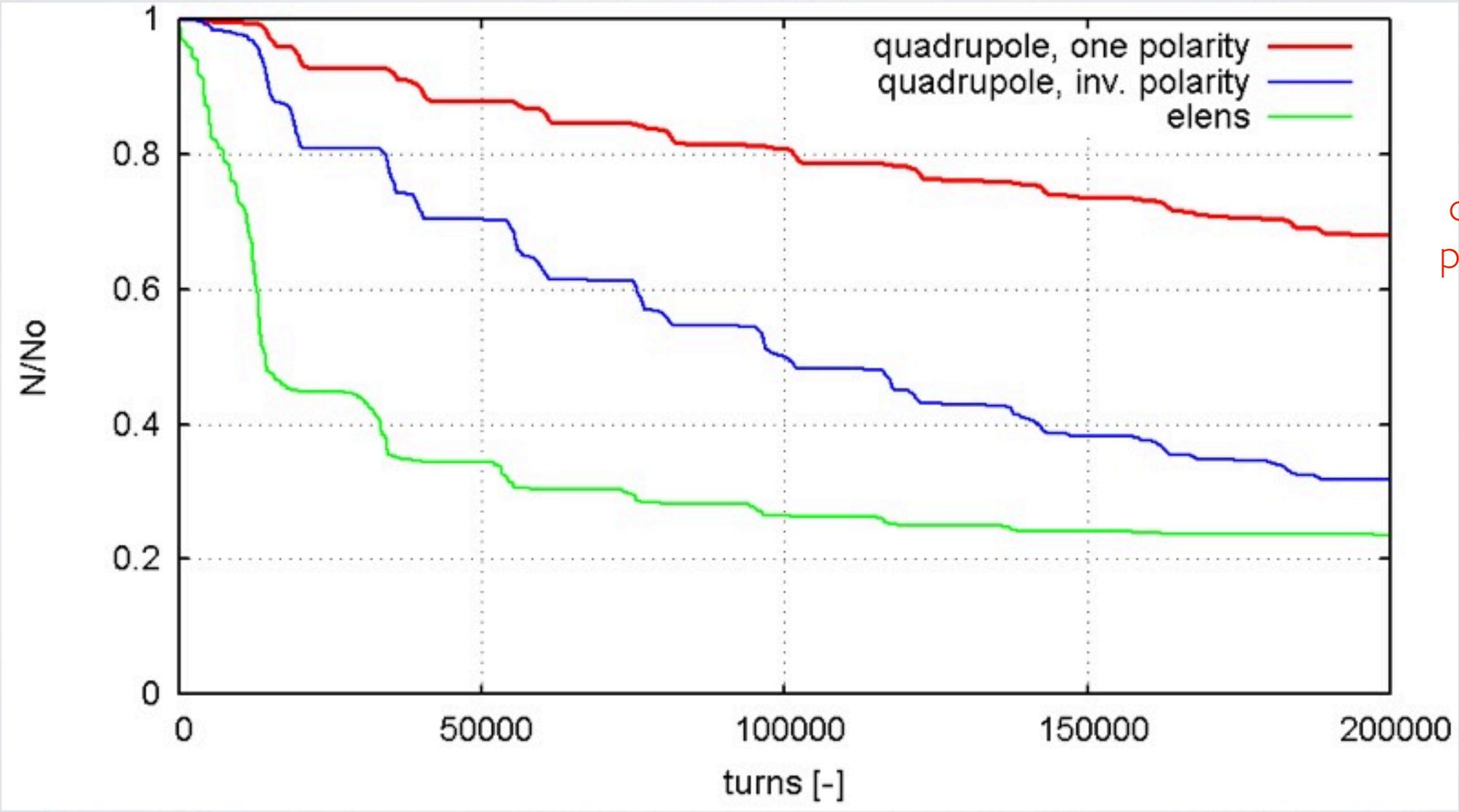
effect on the core



DIPOLE DOES NOT SEEM TO BE A VIABLE OPTION

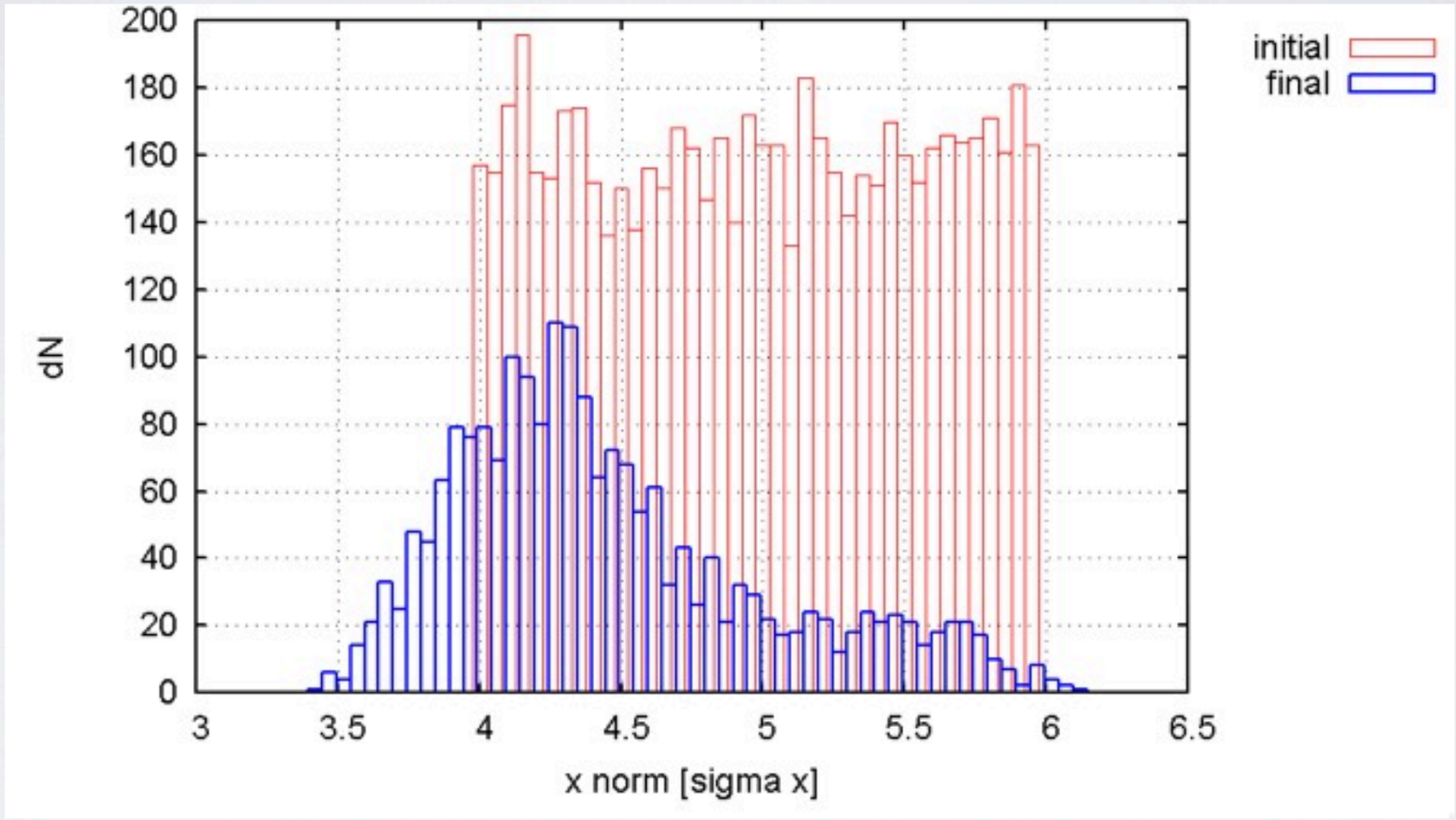
QUADRUPOLE

- quadrupole have been tested with and without inversion of polarity
- scraping efficiencies are lower than e-lens in both cases



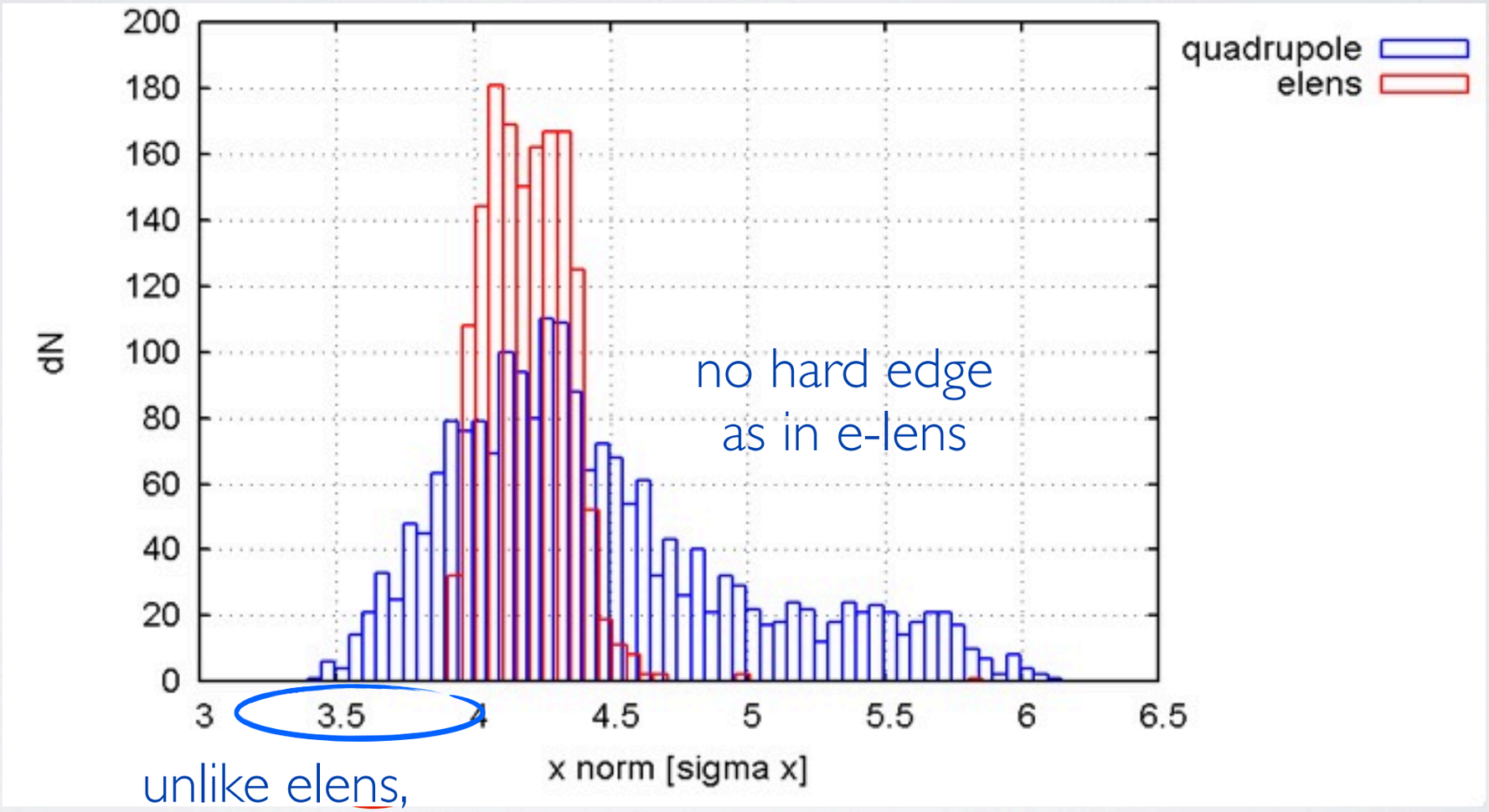
maybe a different tune pattern should be used

INITIAL VS FINAL DISTRIBUTION



no hard edge as in e-lens

FINAL DISTRIBUTIONS: E-LENS VS QUAD



unlike elens,
low amplitude particles
are also heavily affected

effect on the core emittance must be checked!

Quadrupole modulation results are comparable with electron lens results (even if a factor 2-3 less efficient)

STILL TO EVALUATE: EXPECTED EMITTANCE INCREASE OF THE CORE

Quadrupole modulation results are comparable with electron lens results (even if a factor 2-3 less efficient)