Energy calibration in FCC-ee based on polarization

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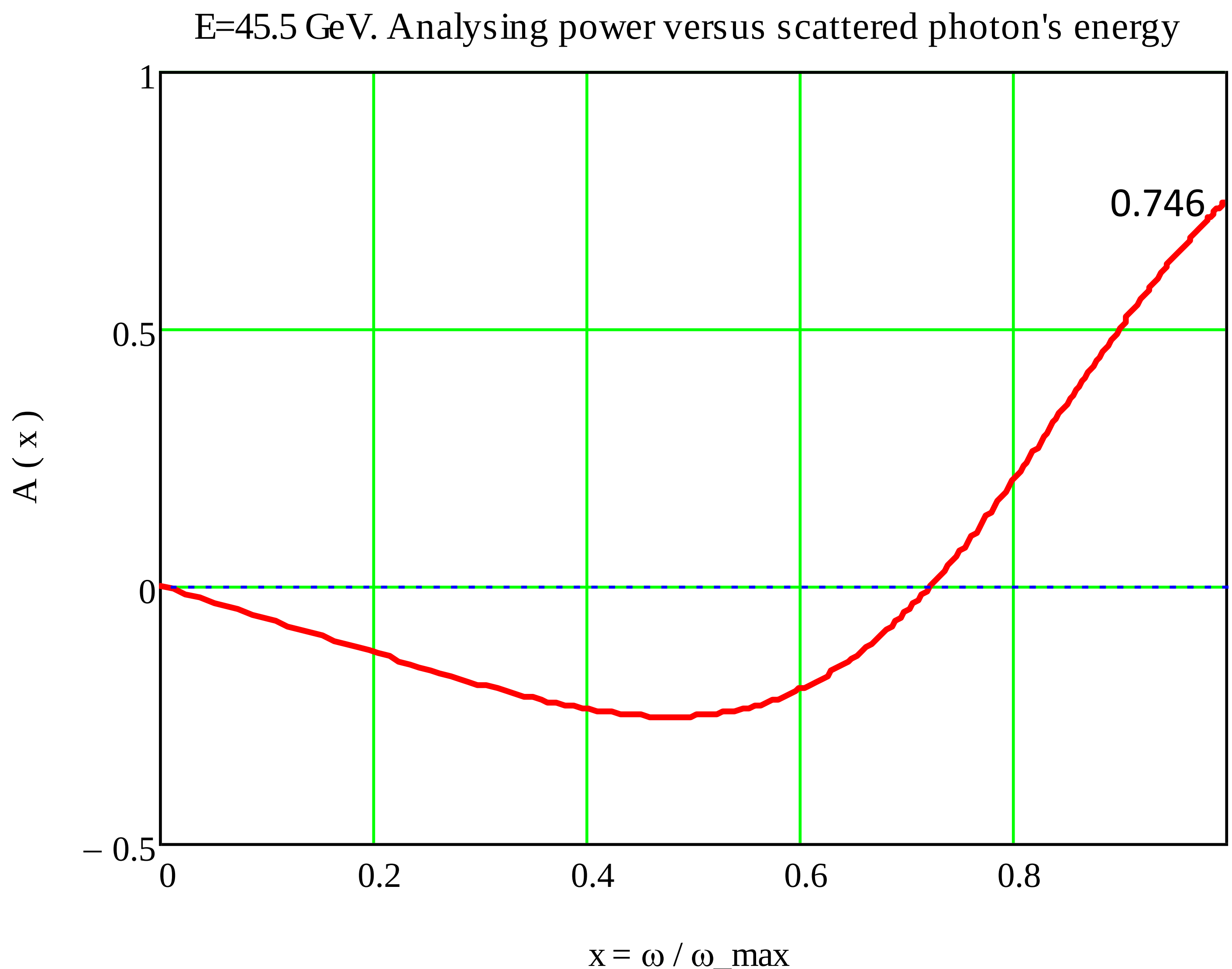
Outline

- Energy calibration concept
- Longitudinal Compton Backscattering Polarimeter
- Free precession frequency measurement approach
- Spin precession de-phasing rates
- Spin tracking results for various FCC-ee beam parameters
- Discussion
- Conclusion

Energy calibration concept

- Production of polarized electrons from a laser photocathode
- Production of polarized positrons in a small energy damping ring (1-2 GeV), with polarization time in the order of 10 min
- Acceleration of polarized beams via linac, SPS ? and finally in the fast ramping booster storage ring (100 km) using Siberian Snakes.
- Injection of polarized bunches into the collider rings with the horizontal spin orientation.
- Measuring turn by turn free precession frequency using the longitudinal Compton polarimeter.

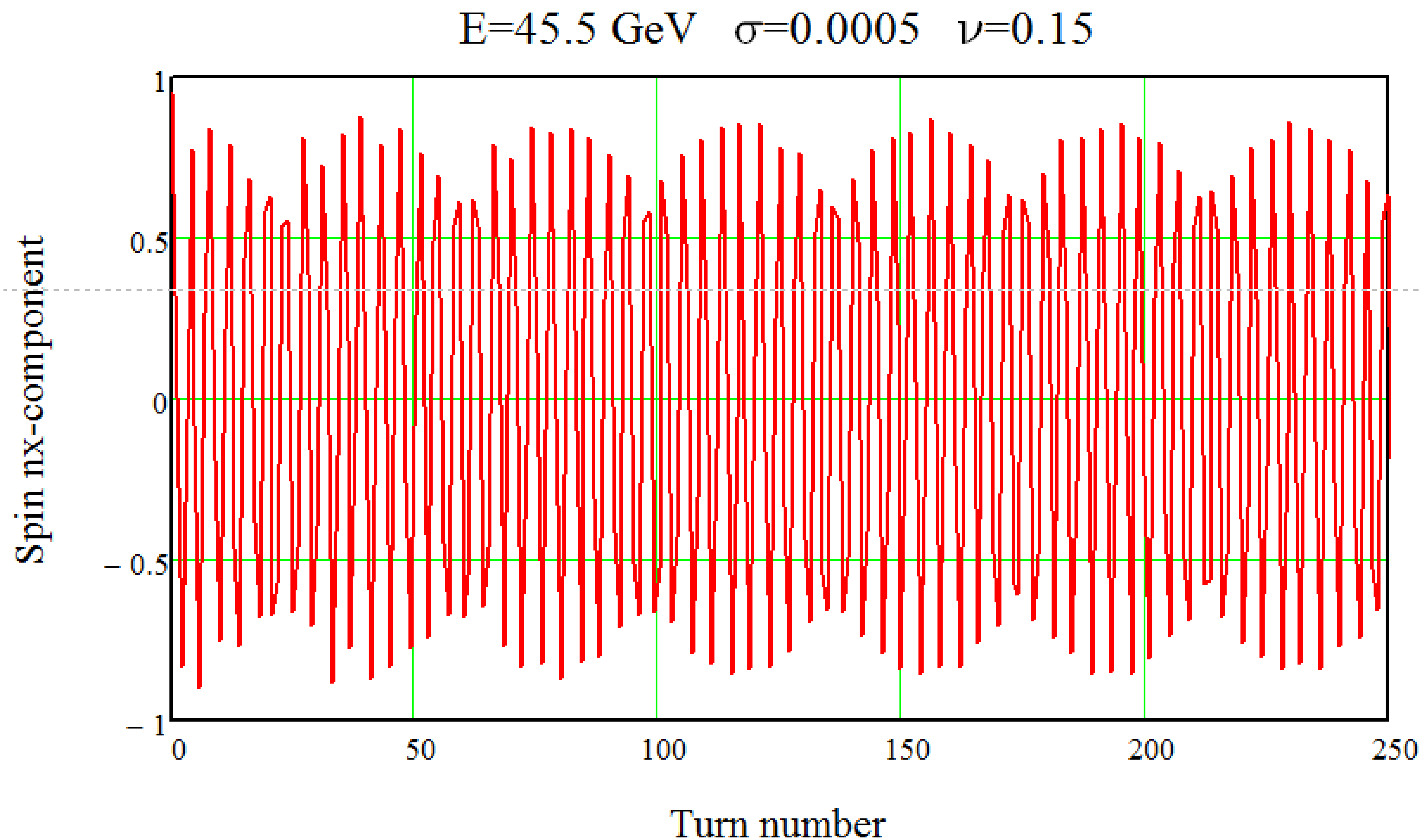
Compton scattering of a laser light



Detection of the scattered electrons instead of photons provides selection of events with maximal momentum loss!

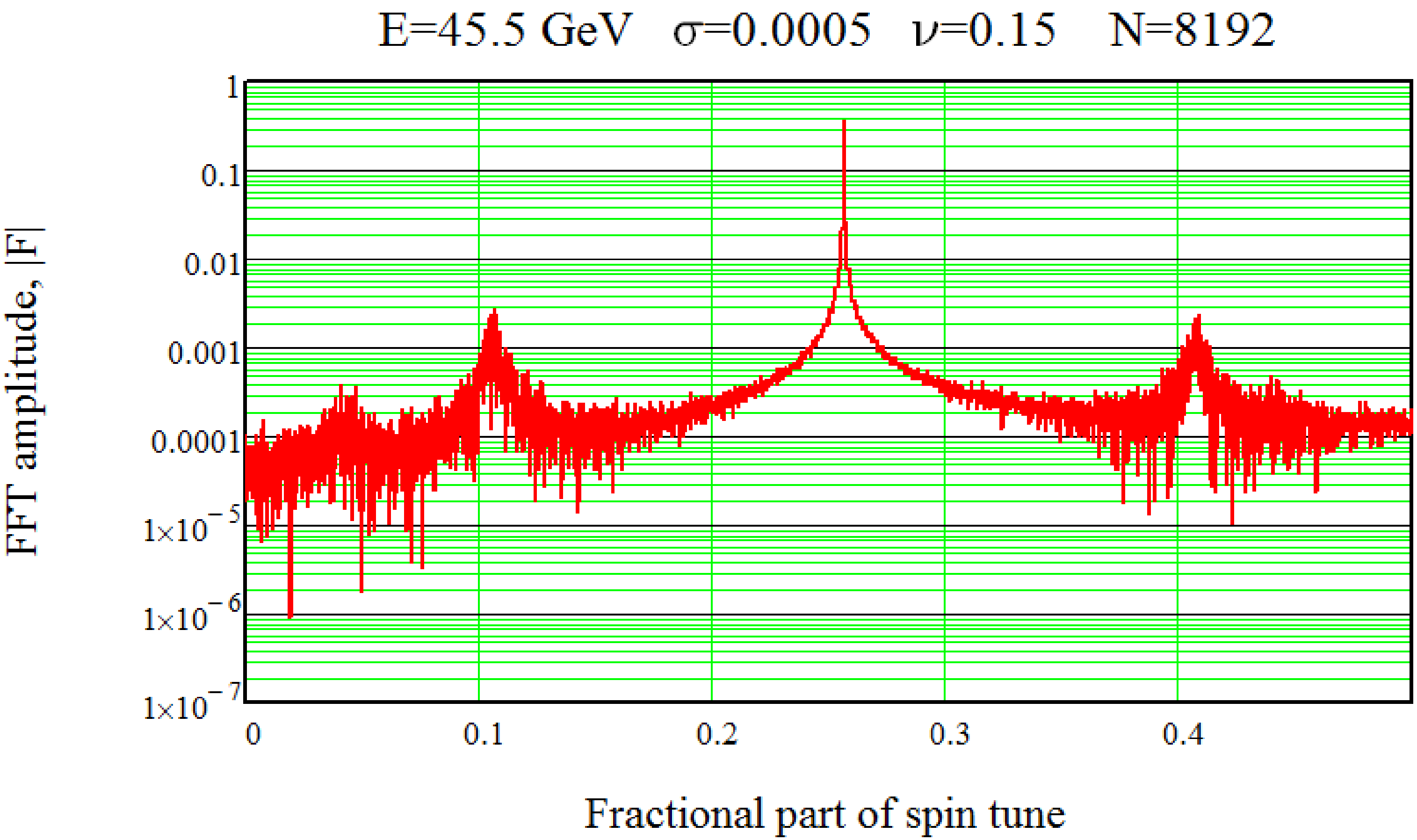
Let's utilize the highest value of the analysing power!

Spin tracking oscillogram. 125 macro-particles.
E=45.5 GeV, σ_E=0.0005, ν_E =0.15, τ_E =1320 turns



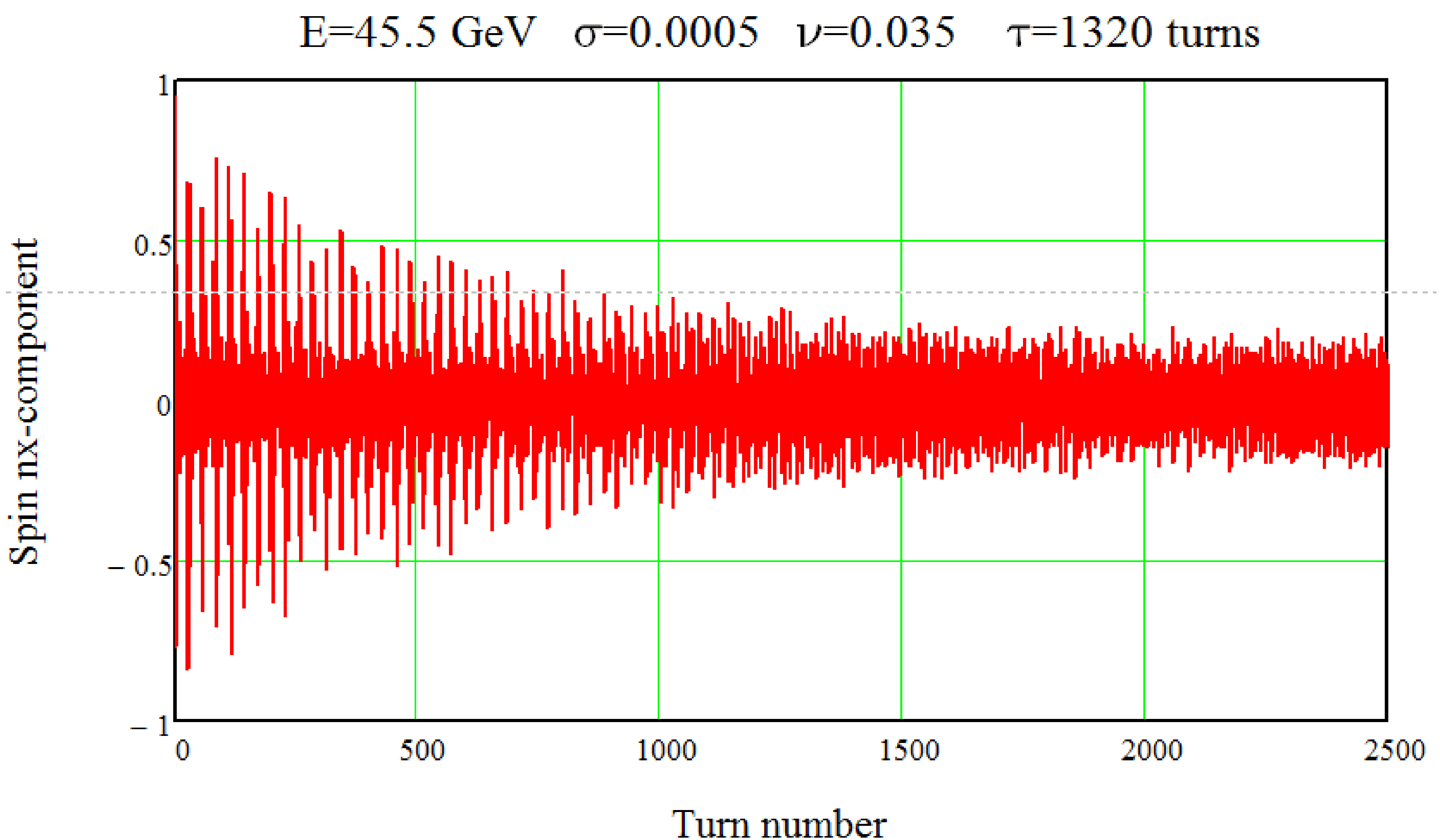
Loss of polarization value due to de-phasing is small thanks to high ν_E.

Spin precession spectrum. Number of turns 8192. $E=45.5$ GeV, $\nu_0=103.25$, $\sigma_E=0.0005$, $\nu_E=0.15$, $\chi=0.35$

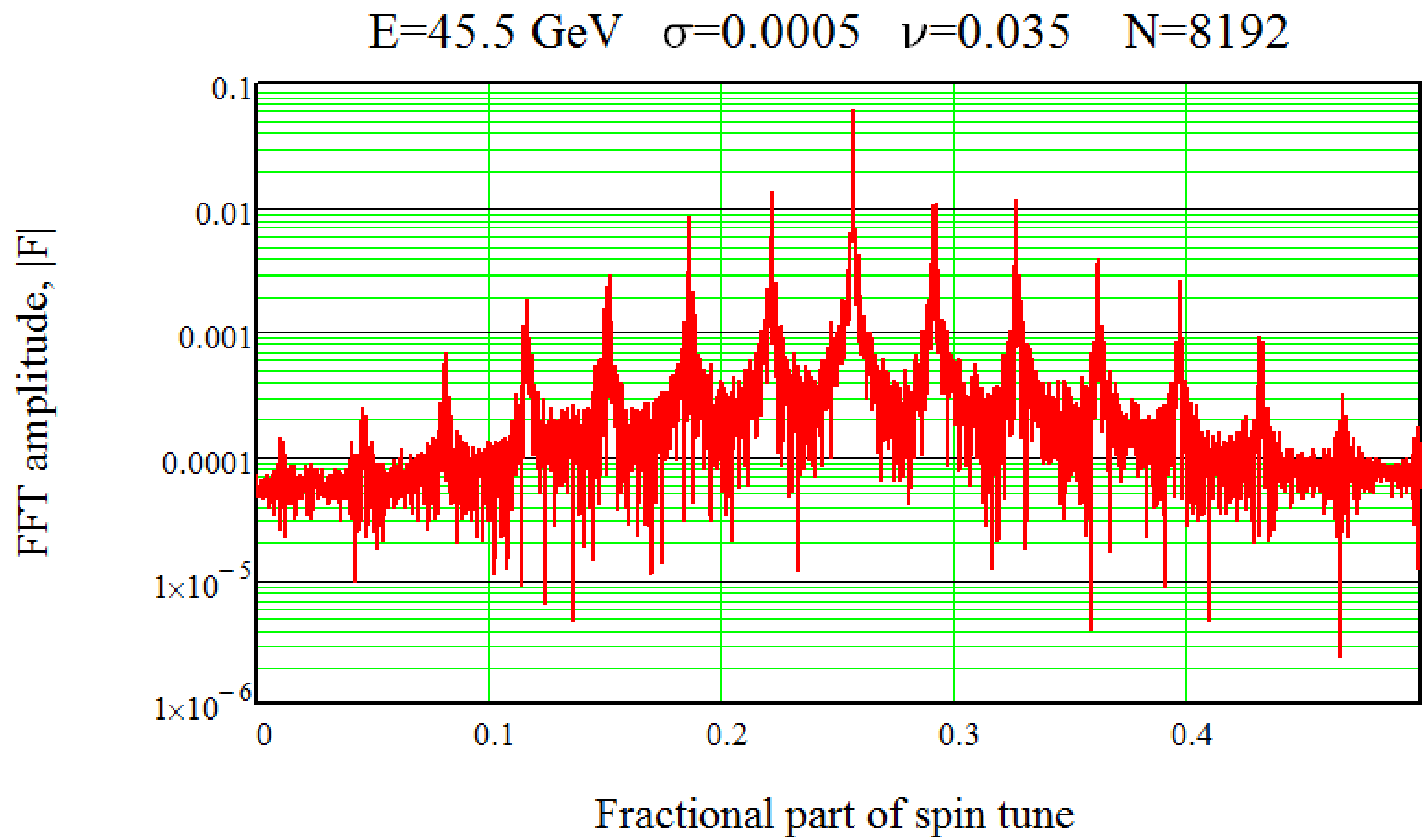


$\chi = \sigma_E \nu_0 / \nu_E = 0.35$ – synchrotron modulation index.

Spin tracking oscillogram. 125 macro-particles. E=80 GeV, σ_E=0.0005, ν_E =0.035, τ_E =1320 turns

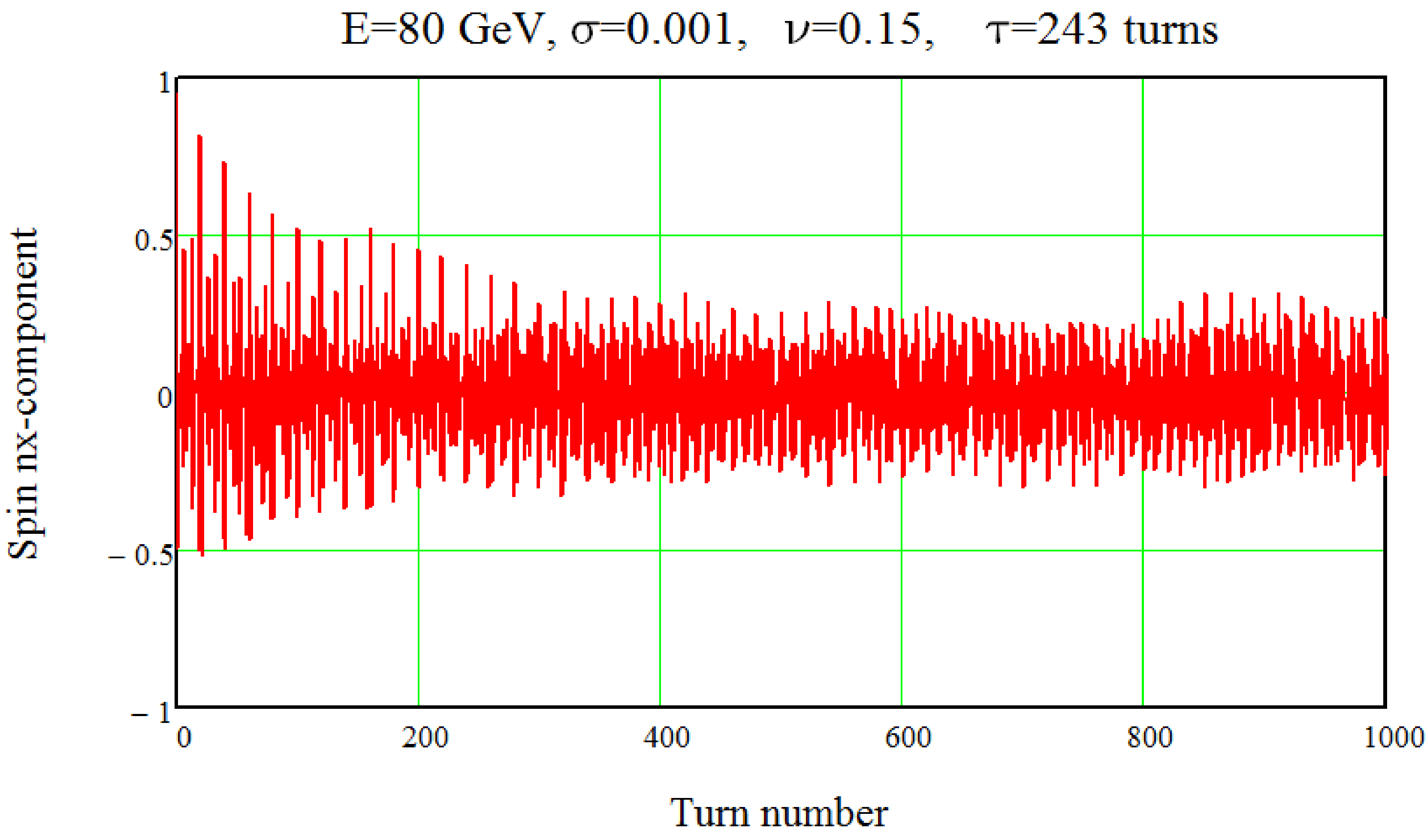


Spin precession spectrum. Number of turns 8192.
E=45.5 GeV, ν_0=103.25, σ_E=0.0005, ν_E =0.035, χ=1.48

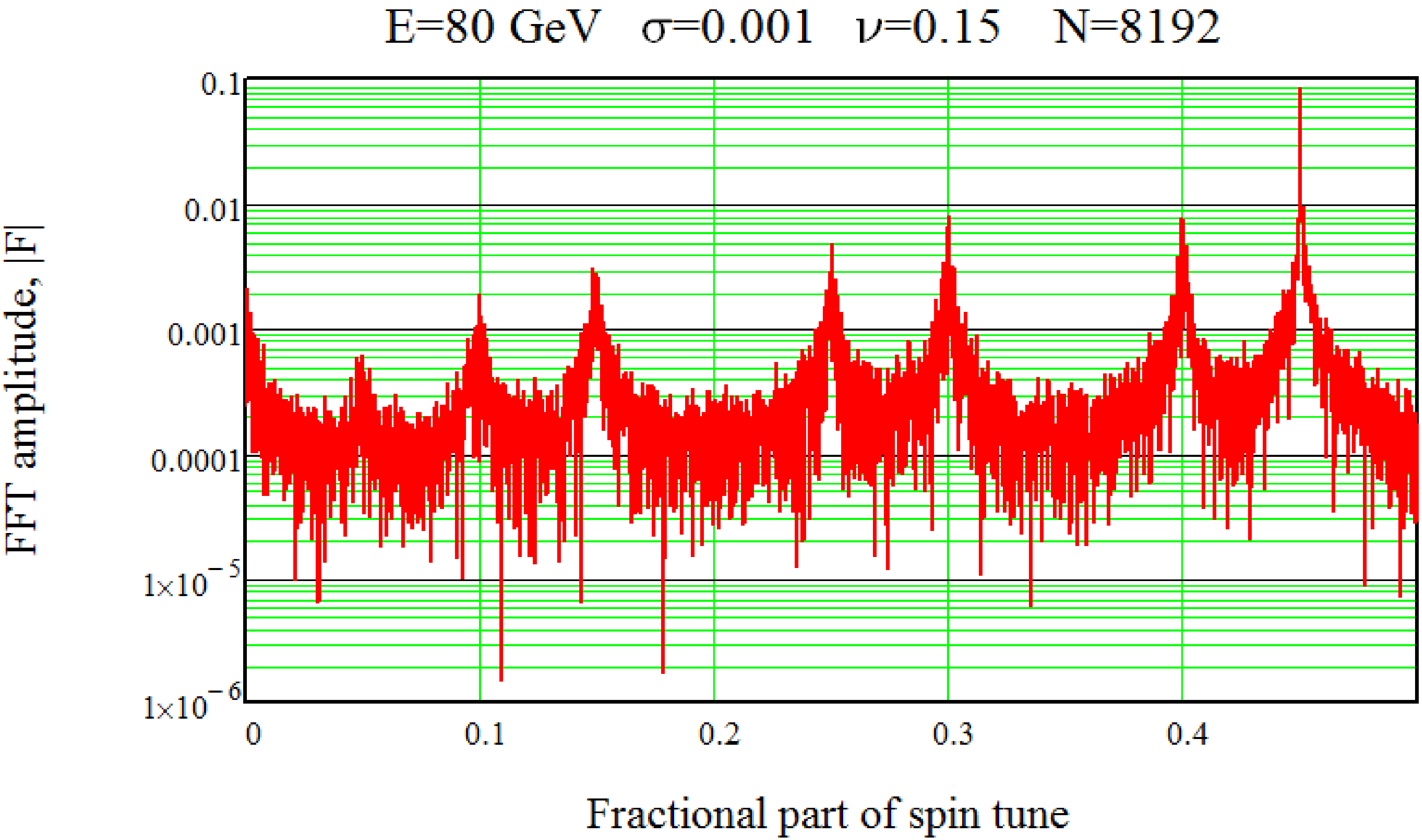


We want: $\chi < 1.7$. With $\chi > 1.7$ peaks will disappear!

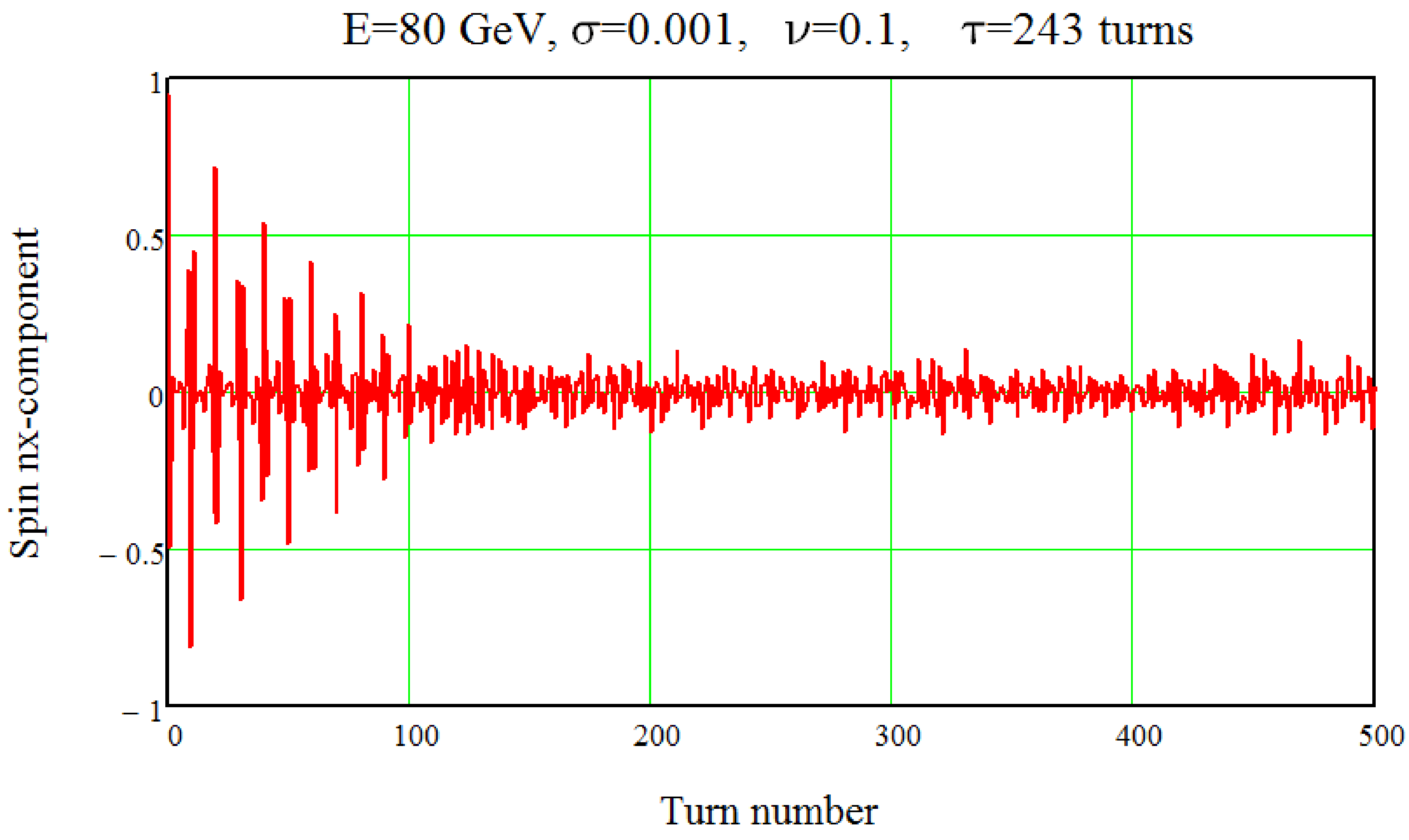
Spin tracking oscillogram. 125 macro-particles. $E=80$ GeV, $\sigma_E=0.001$, $\nu_E=0.15$, $\tau_E=243$ turns



Spin precession spectrum. Number of turns 8192. E=80 GeV, ν_0=181.55, σ_E=0.001, ν_E =0.15, χ=1.21

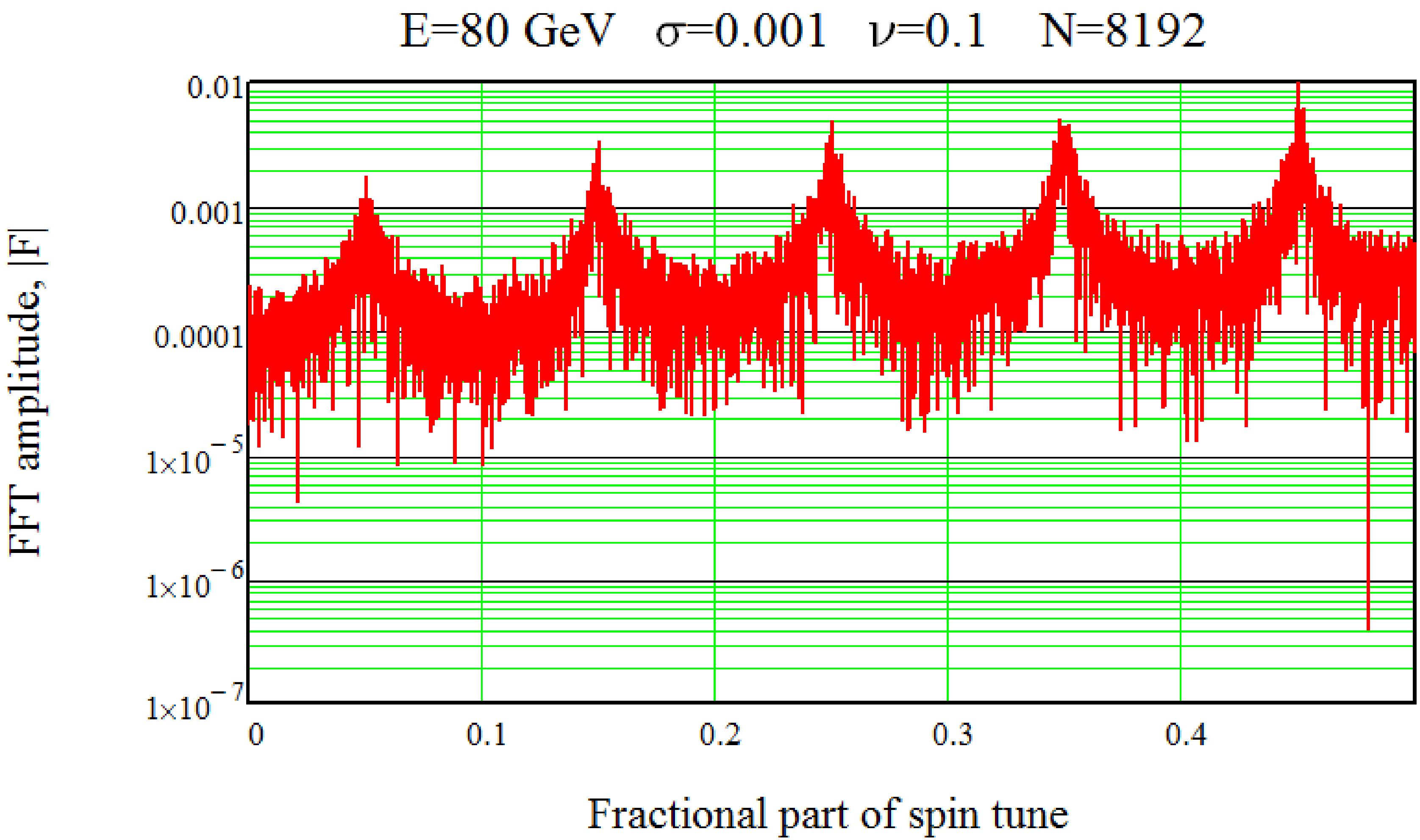


Spin tracking oscillogram. 125 macro-particles. E=80 GeV, σ_E=0.001, ν_E =0.10, τ_E =243 turns



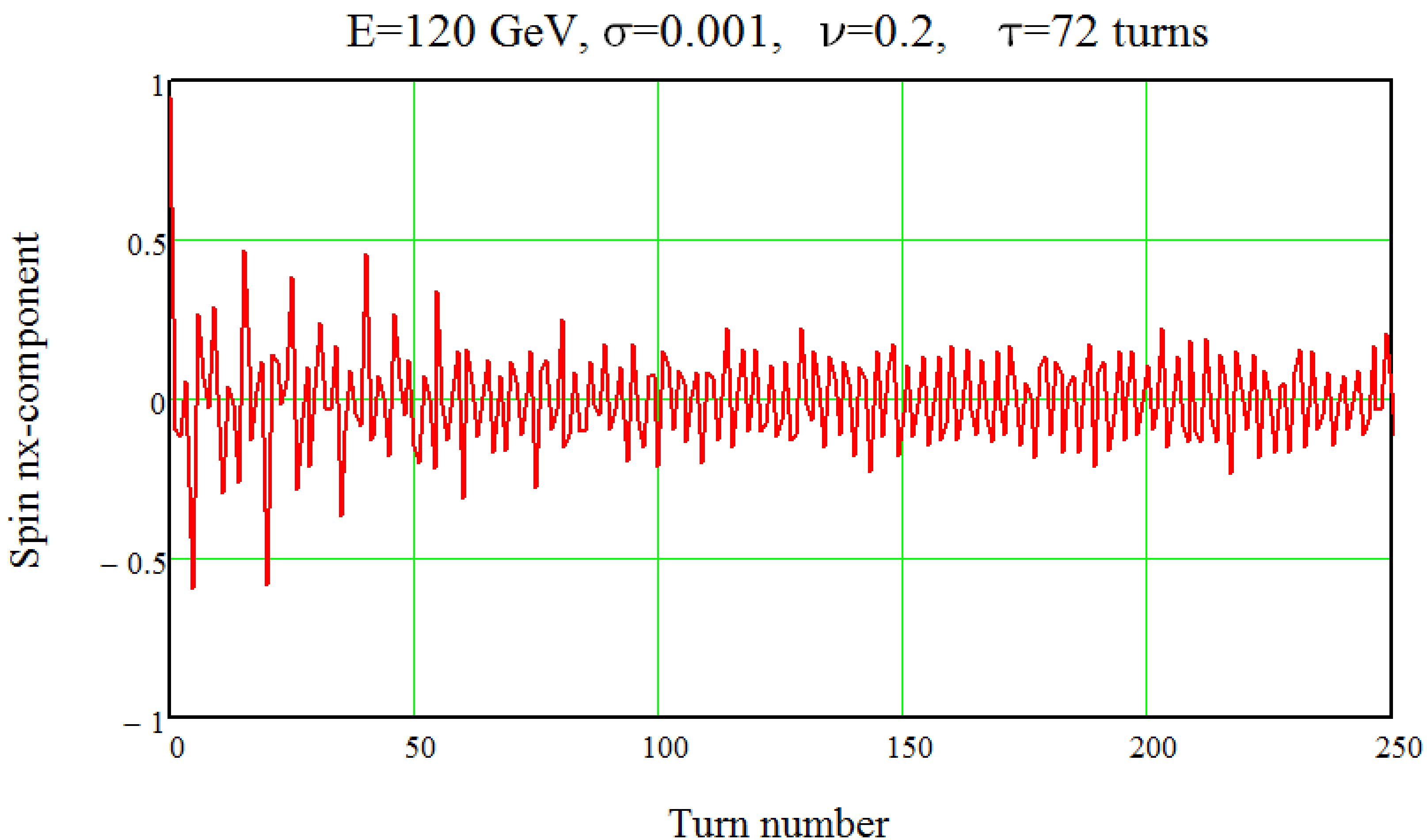
Fast de-phasing due to slow synchrotron motion!

Spin precession spectrum. Number of turns 8192.
E=80 GeV, ν_0=181.55, σ_E=0.001, ν_E =0.10, χ=1.82



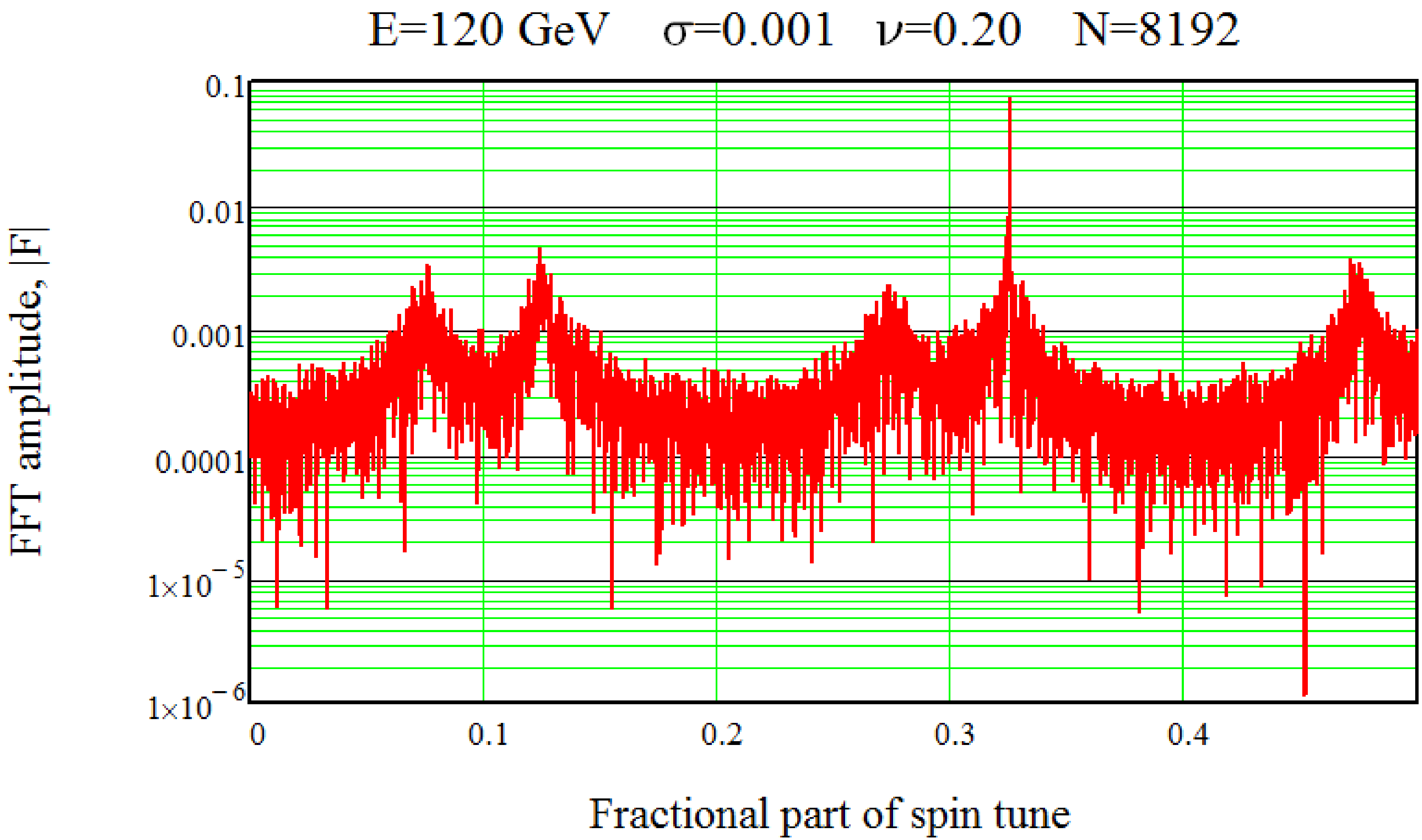
Same results one gets with doubled both: energy spread and synchrotron tune.

Spin tracking oscillogram. 125 macro-particles.
E=120 GeV, σ_E=0.001, ν_E =0.20, τ_E =72 turns



Fast de-phasing. Synchrotron modulation index too high: x=1.36

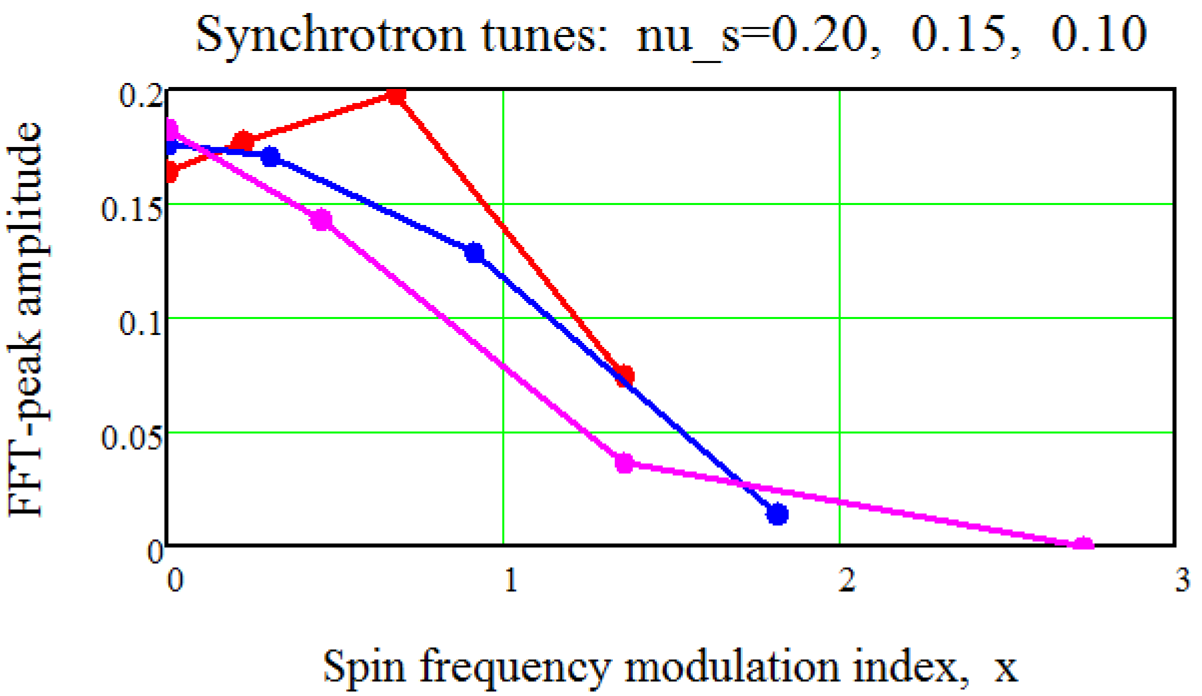
Spin precession spectrum. Number of turns 8192. E=120 GeV, ν_0=272.325, σ_E=0.001, ν_E =0.20, χ=1.36



Same results one gets with scaled both: energy spread and synchrotron tune.

Discussion

- Spin de-phasing rate is governed by the synchrotron frequency modulation index. It should be low enough, x < 1.7 at least.
- Collision with the half-intensity bunch will reduce σ_E .



Conclusion

- Free precession approach could provide extremely fast method of spin frequency measurement.

- It is limited only by the energy spread averaging rate, provided by the synchrotron oscillations. This is expressed via synchrotron modulation index. It should not exceed a factor $x < 1.7$ or lower. This, in general, leads to choice of high synchrotron tunes.

- FCC-ee beam parameters satisfy this requirement at energies below 120 GeV, assuming $\nu_E < 0.2$.