Comments to RD studies at KARA and ESRF

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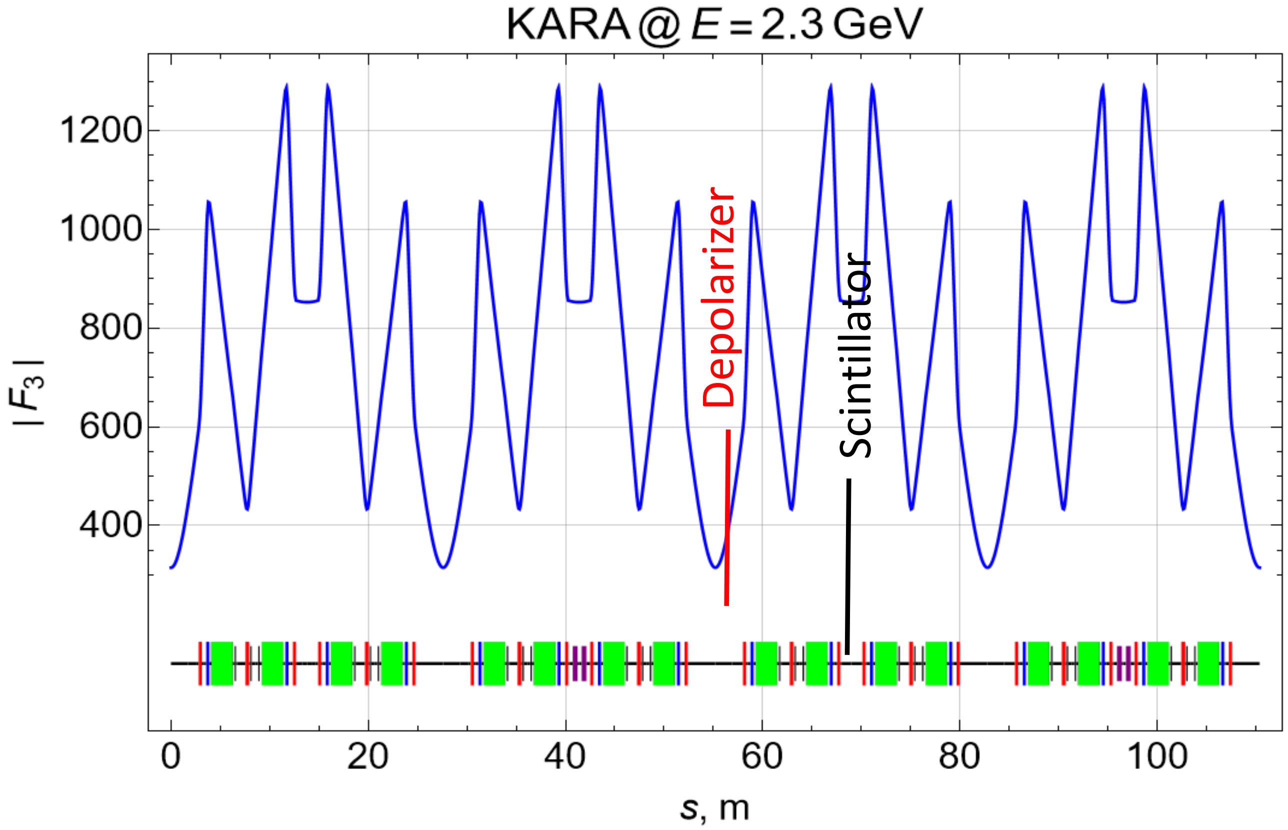
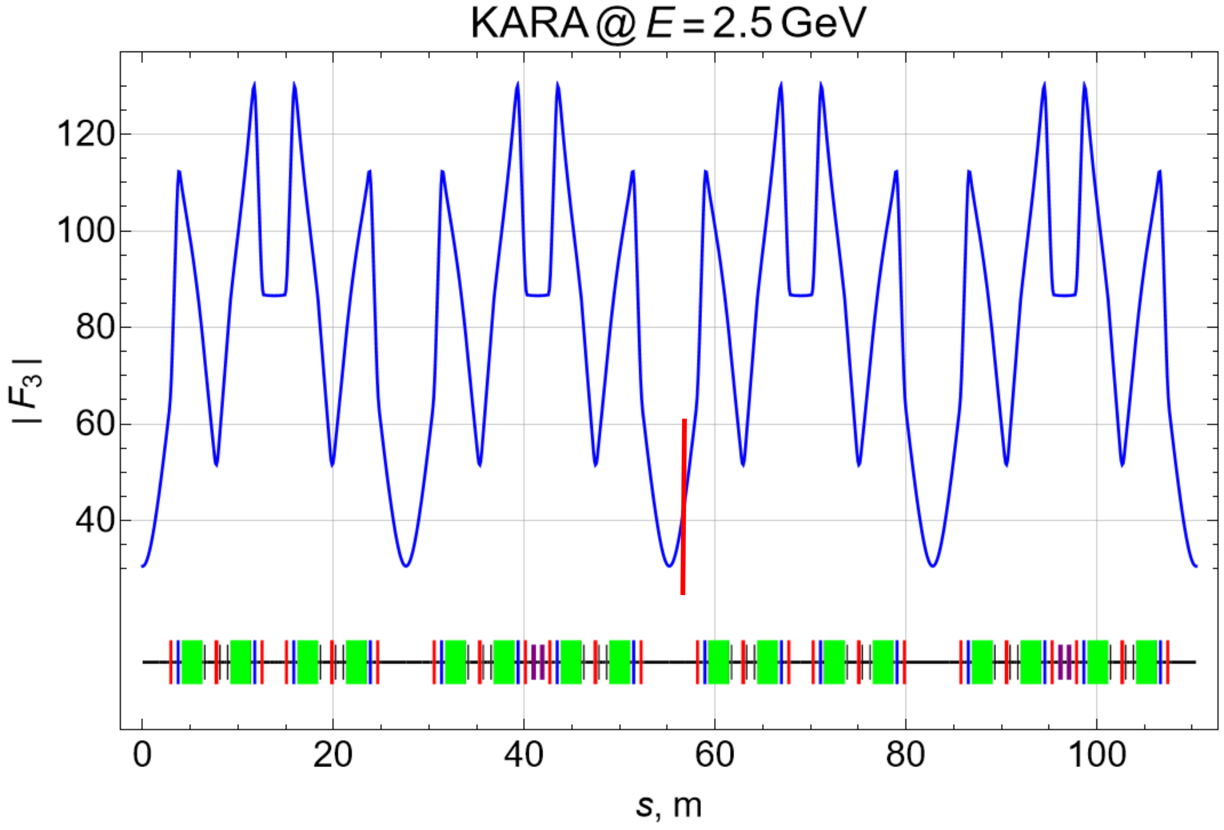
KARA spin-orbit response function F3





Depolarizer angle for P=160 W, Z=8 kOhm:

$$\Delta\theta = \frac{e\sqrt{2PZ}}{E} = \begin{cases} 7.0 \cdot 10^{-7} & \mathrm{E} = 2.3\ \mathrm{GeV} \\ 6.4 \cdot 10^{-7} & \mathrm{E} = 2.5\ \mathrm{GeV} \end{cases}$$

Depolarizer harmonic strength:

$$w = \frac{\Delta\theta}{2\pi}|\mathrm{F3}| = \begin{cases} 4.4 \cdot 10^{-5} & \mathrm{E} = 2.3\ \mathrm{GeV} \\ 4.0 \cdot 10^{-6} & \mathrm{E} = 2.5\ \mathrm{GeV} \end{cases}$$

Strong intrinsic resonance at $E = 2.3155$ GeV: $\nu_0 = 5.2543$, $\nu_y = 2.7457$, $\nu_0+\nu_y=8$, 8 KARA superperiods!

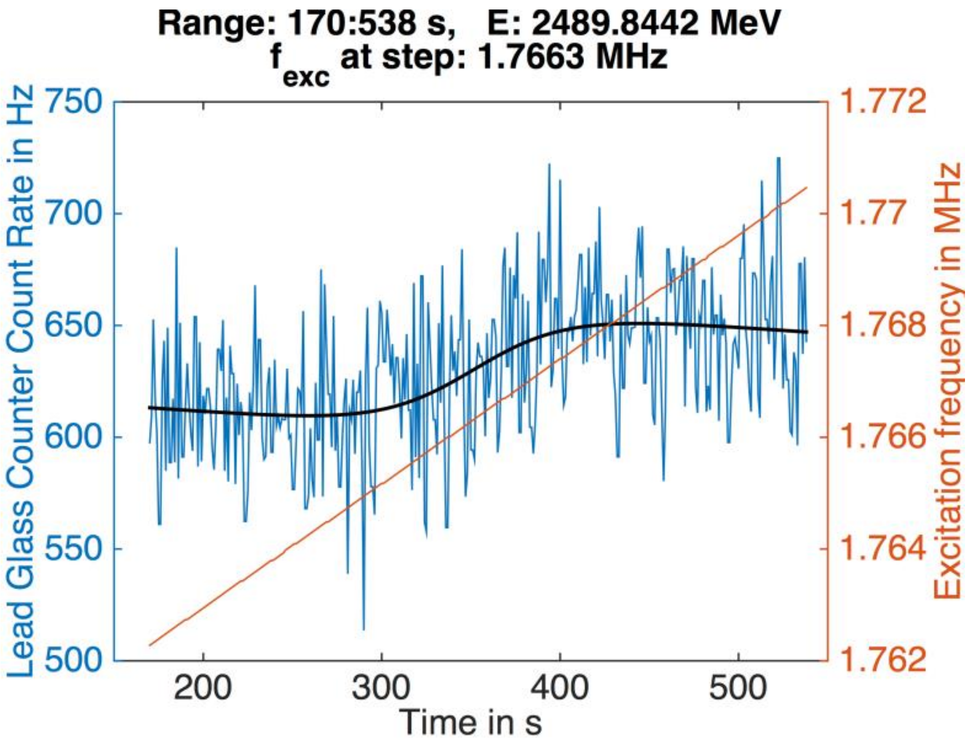
Its RMS harmonic value: $w_{k=8} = 1.68 \cdot 10^{-4}$, for betatron coupling $\varepsilon_y/\varepsilon_x=0.01$.

KARA RD at 2.5 GeV

Beam parameters at 2.5 GeV: $\sigma_E = 0.001,\ \nu_s = .01,\ \nu_0 = 5.674,\ B = \nu_0\sigma_E/\nu_s = 0.567,$
$J_0(B) = 0.92$ - relatively small reduction of the depolarizer strength!

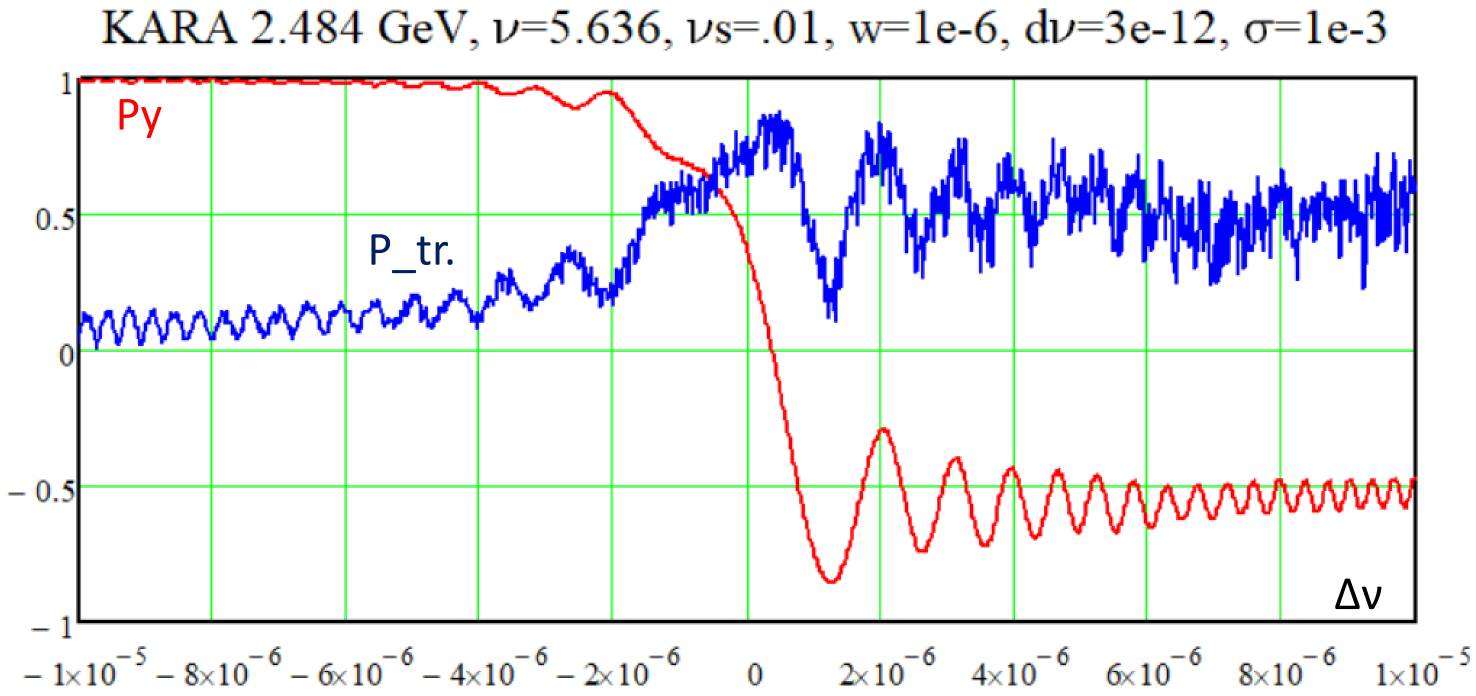
Sweep speed: $\mathrm{d}\varepsilon = \dot{f}/f_0^2 = 3 \cdot 10^{-12}$ per turn ($\dot{f}$=22.2 Hz/s, $f_0 = 2.715$ MHz)

B. Härer, E. Blomley – Possible beam tests at KARA:



-.0015 ← Δν → .0015

Simulation with the reduced 4 times depolarizer (P=10 W) w=1e-6:



-.00001 ← Δν → .00001

Polarization became flipped!

Comments and suggestions for experements at KARA:

- KARA is a normal ring with high enough synchrotron tune $\nu_s = .01$ and low RMS value of the modulation index $B = \nu_0 \sigma_E / \nu_s = 0.567,\ \ J_0(B) = 0.92$.

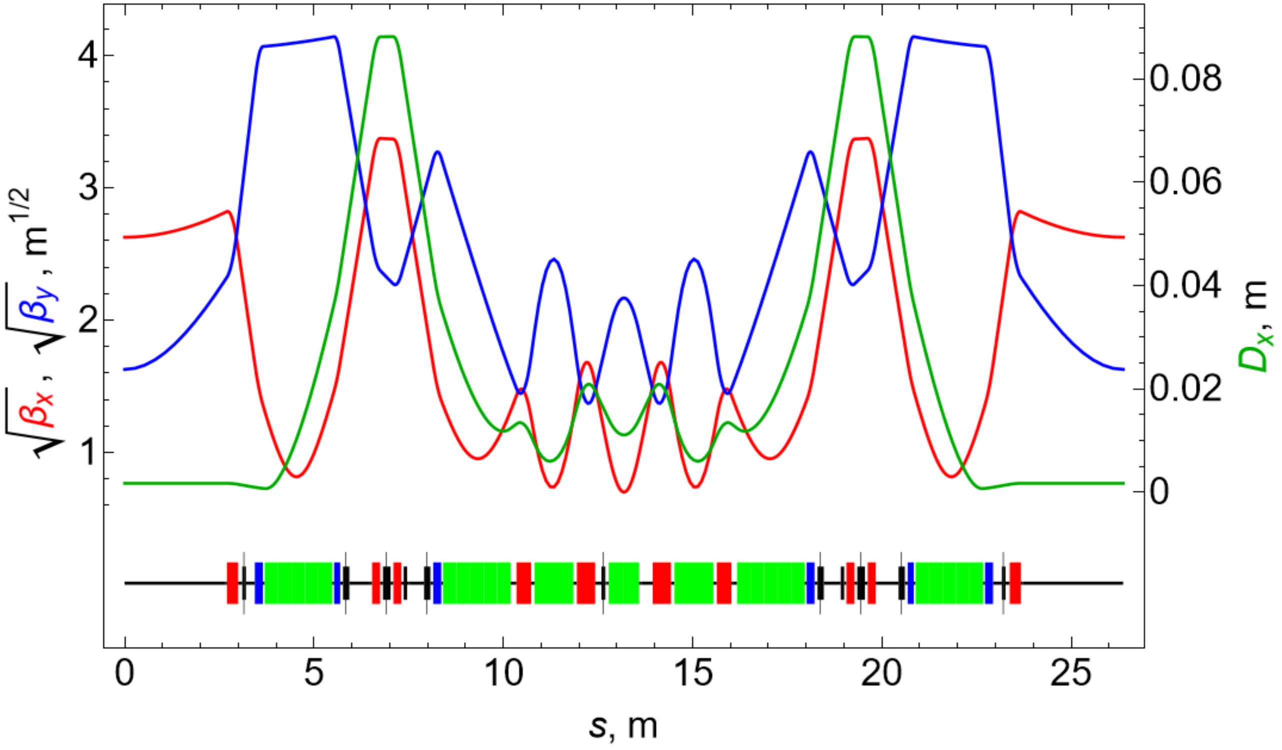
- No any problems with RD!

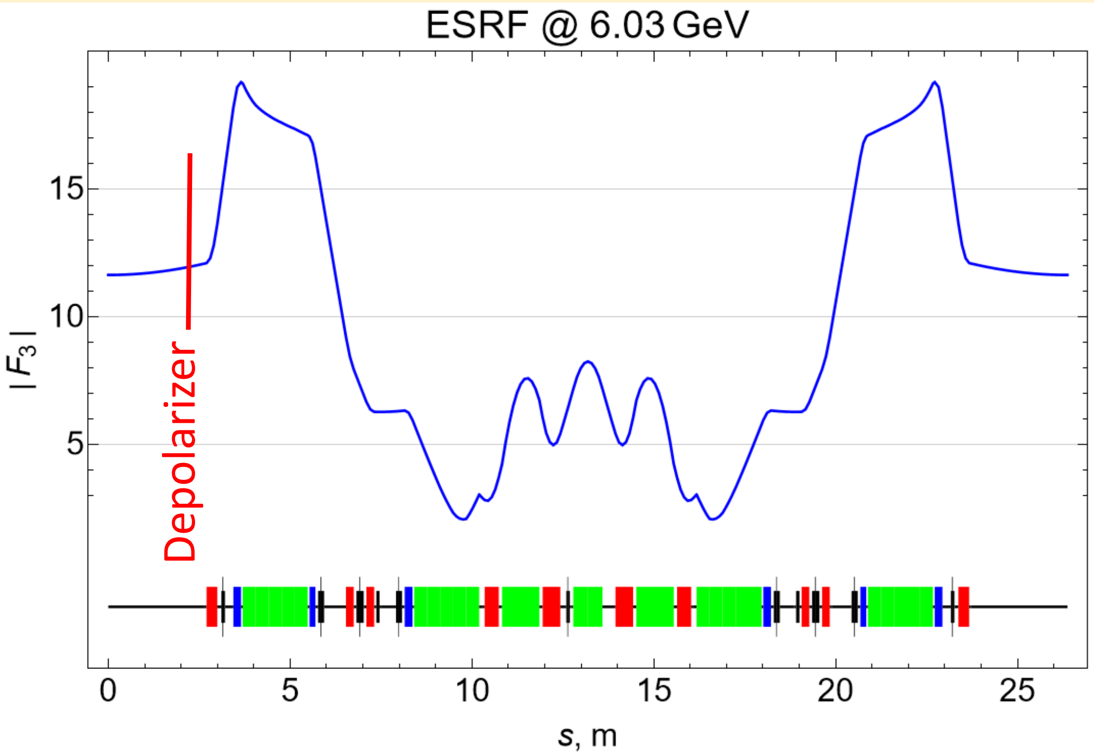
- Our idealized simulation show a potential to further squeeze the RD uncertainty in the resonance spin tune down to Δν=1e-6 or even better.

- We do not include noise from the power supply and from a RF station. Then depolarization could become not as sharp, as in our simulation.

- We recommend to work with the reduced value of the depolarizer's harmonic w, especially at 2.3 GeV, where F3 is 10 times higher compared with its value at 2.5 GeV. With strong depolarizer a beam will become not depolarized but spin flipped! There is some optimal value of w, when polarization vanishes completely after crossing a resonance - jump in Touschek counting rate is sensitive to $\Delta\langle P_y^2\rangle$, not to $\Delta\langle P_y\rangle$! It is better to fully depolarize a beam!

ESRF lattice functions and beam parameters





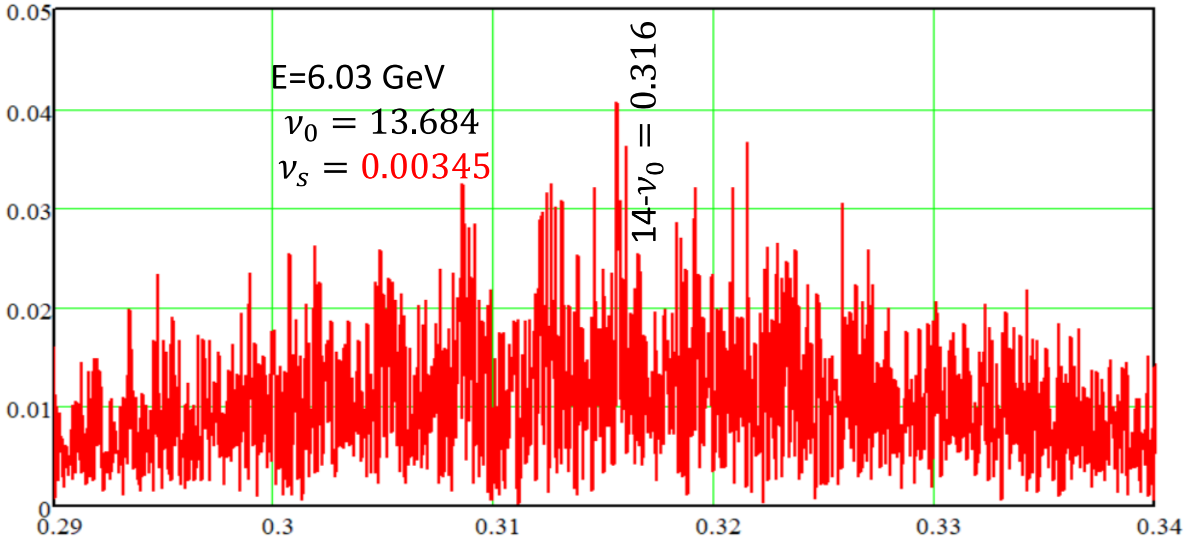
Beam and lattice parameters provided by Simone Liuzzo, Friederike Ewald:

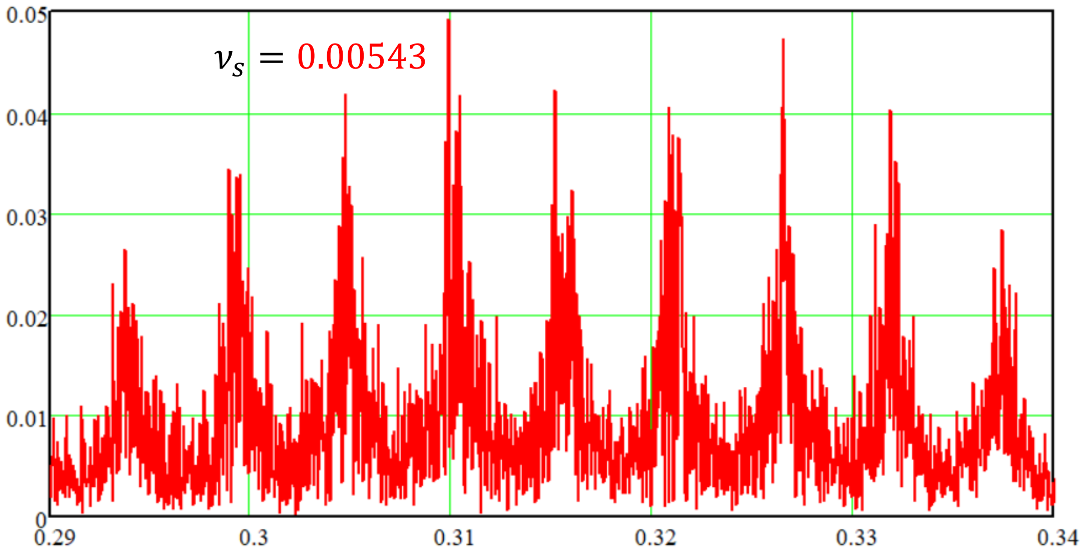
ESRF-EBS at 6.03 GeV: $\sigma_E = 0.001,\ \nu_s = 0.00345,\ \nu_0 = 13.684, \quad B = \nu_0 \sigma_E / \nu_s = 4.01$,

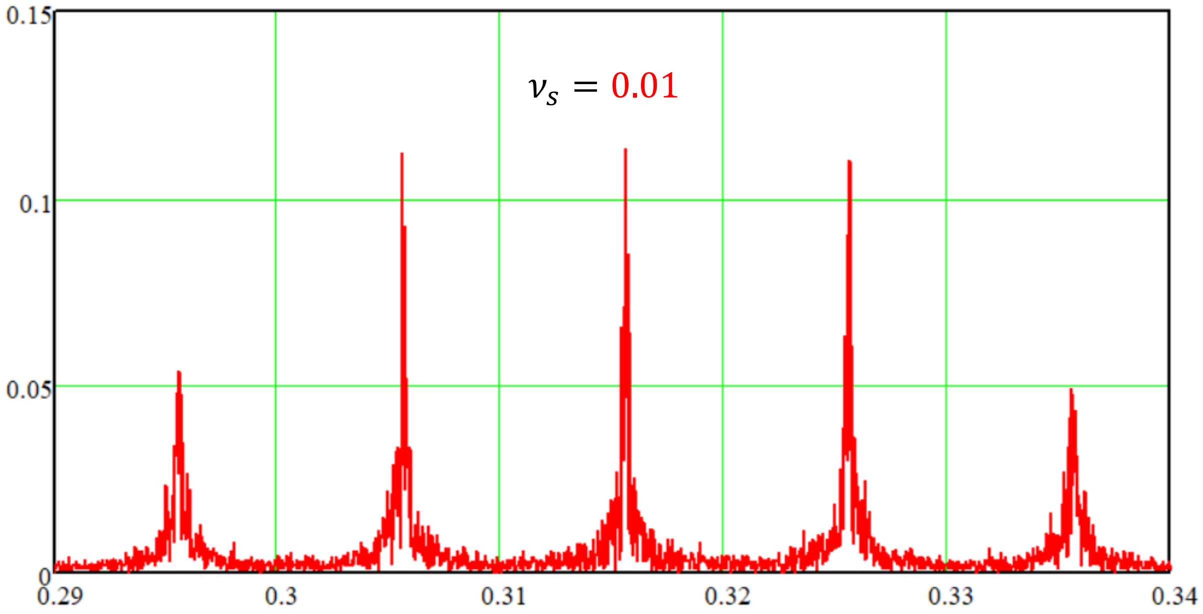
$J_0(B) = -0.4$ - the depolarizer strength becomes different for different synchrotron amplitudes! May even change a sign!

Sweep speed: $\mathrm{d}\varepsilon = \dot{f}/f_0^2 = 4 \cdot 10^{-10}$ per turn ($\dot{f}$=50 Hz/s, $f_0 = 0.3552$ MHz)

ESRF-EBS free spin precession spectrum in 32768 turns

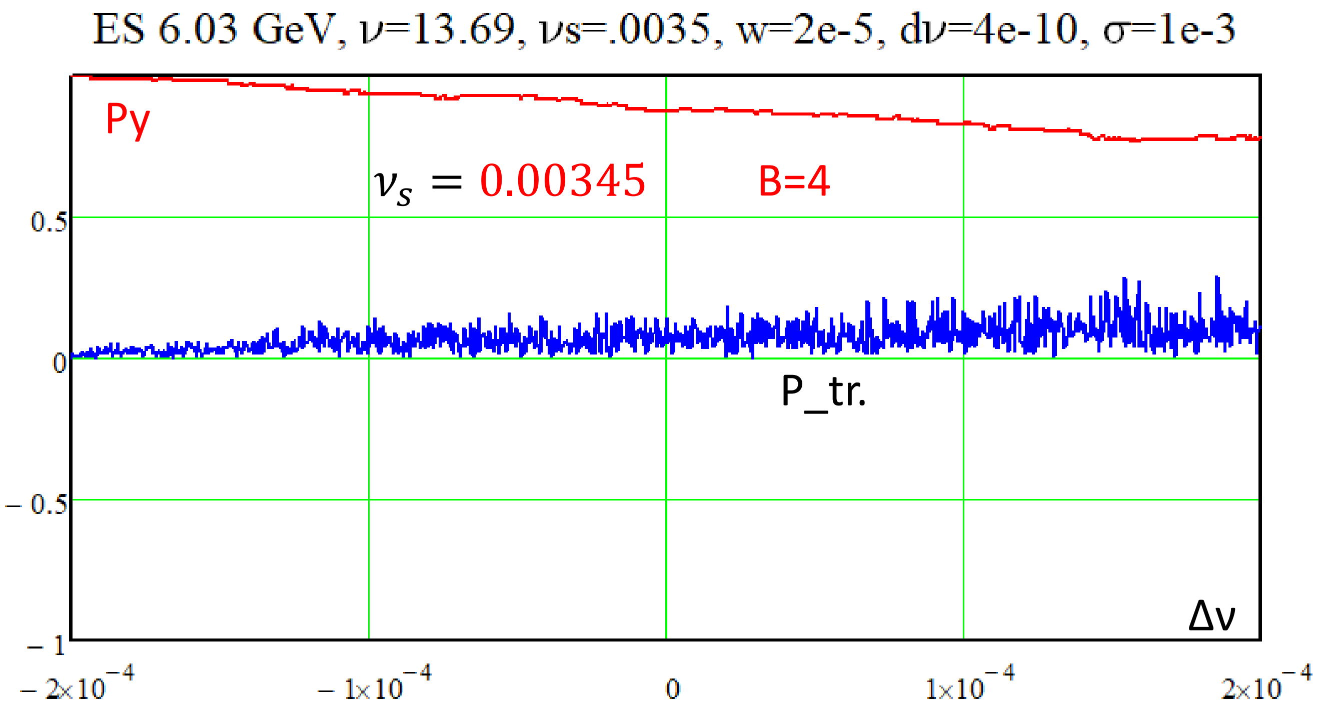


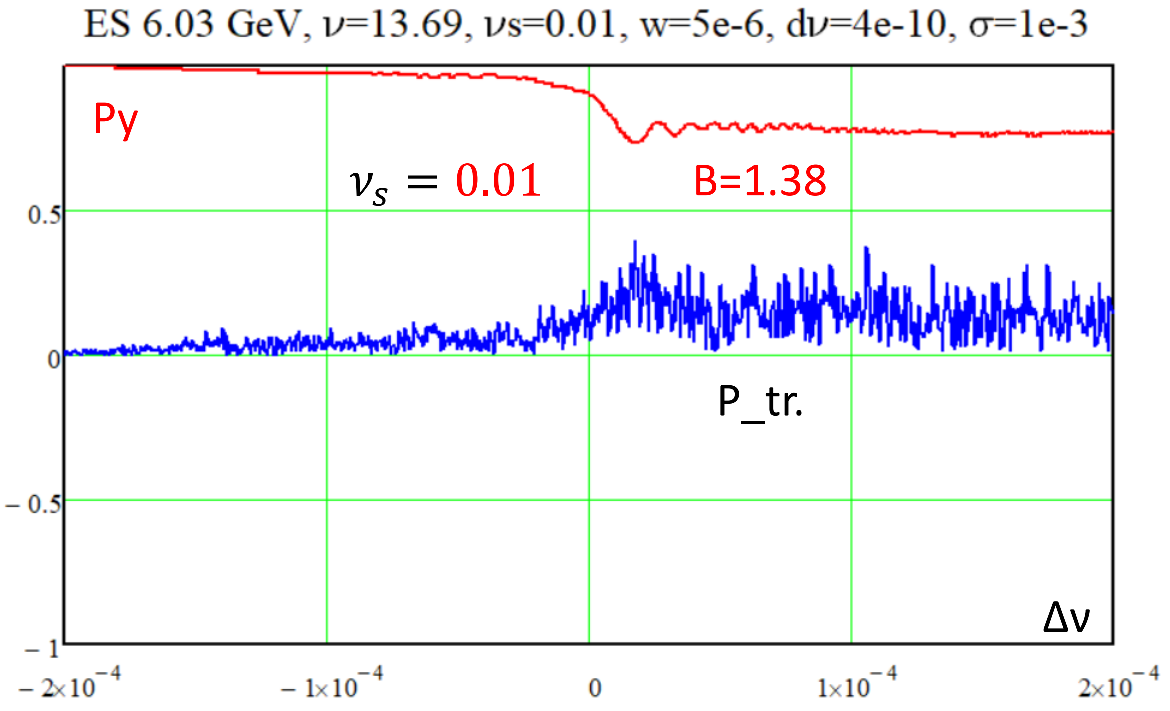


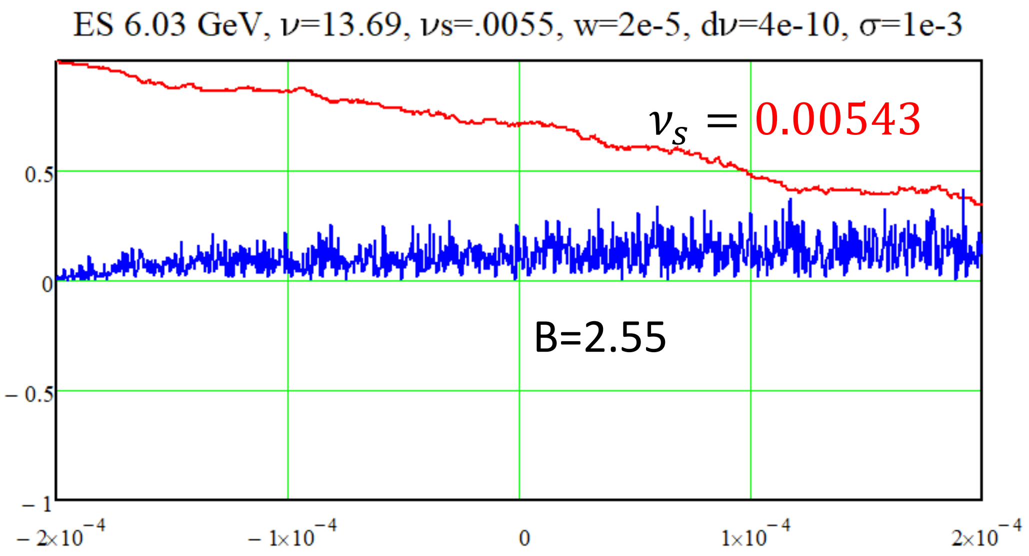


These 3 plots illustrate how the synchrotron side bands become fully overlapped at a nominal synchrotron tune $\nu_s = 0.00345$, while at 2-3 times higher tune the spectrum lines become visible.

Simulation of RD for ESRF-EBS beam parameters







These plots illustrate that only with the enhanced synchrotron tune $\nu_s = 0.01$ the Resonant Depolarization is possible.

Lessons learned for FCC-ee from these studies

- ESRF team had experimentally demonstrated that RD is almost impossible in a storage ring with a large synchrotron modulation index *B*. It should be kept less than *B*<1.5. Spin precession spectrum becomes flat in case of large *B*-index.

- Situation at W production threshold in FCC-ee looks very similar to ESRF_EBS case. With such low the synchrotron tune as $\nu_s = 0.05$ the synchrotron modulation index is too large *B*=2.45. And only with the increased $\nu_s = 0.08$ the situation becomes somewhat better: *B*=1.53.

- We should very seriously consider that situation and take significant efforts to find possible ways to increase the synchrotron tune at W energy range up to $\nu_s = 0.08$-0.09.