Simulations of polarization dependence on Qs

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Simulation of Qs effects by simplified spin tracking

- Beam emittances in FCC-ee are so small that all intrinsic resonances are very weak.
- Therefore only the orbit distortions and nonzero integrals of the longitudinal magnetic field affects the spin motion.
- These distortions define the strength of parent resonances, which are sitting on integers of spin tune.
- Due to energy modulation by the synchrotron oscillations higher order side bands are created. They are spaced from the parent resonance $\nu = n$ by the integer number of synchrotron tune:
  \[ \nu = n + m \cdot Q_s \]

Questions to be answered:
- Which parameter or its combination defines the attainable polarization degree in FCC-ee?

The relevant beam parameters are:
- Beam energy spread: 1) absolute $\sigma_E = 53 \text{ MeV}$ at $E = 80 \text{ GeV}$ (for pilot bunches)
  2) relative $\sigma_\delta = \sigma_E / E = 0.00066$
- Synchrotron modulation index:
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- Synchrotron modulation index: $x = \sigma_\delta \frac{\nu_0}{Q_s} = 0.00066 \frac{182.5}{0.025} = 4.8$, if $Q_s = 0.025$. 
Equilibrium polarization for LEP at 61 GeV, $Q_s=0.0833$

The parent and side band resonances are induced by the local spin rotation around the longitudinal axis by the angle $\varphi = \omega \cdot 2\pi$. Here $\omega = 0.0015$ was chosen to explain the polarization level observed at LEP experimentally.

At such relatively high value of $Q_s = 0.0833$ dips at integer detunings from the parent resonance $\nu = n + m \cdot Q_s$ are quite pronounced.

$\nu = 138.5$
Here \( w = 0.0015, Q_s = 0.02073 \). Dips at integer detunings from the parent resonance \( \nu = n + m \cdot Q_s \) disappear because of high \( m \). \( J_m(\xi) \) is a rather small value for \( m=20, \xi = 6 \).
Conclusions:
1) No strong influence of $Q_s$ on the attainable polarization level. Synchrotron modulation not too much important!
2) Only the value of beam energy spread is really important. Recommendation from the LEP experience: $\sigma_E < 52\ MeV$ confirmed by these simulations