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 $\sigma_E = 53\ MeV$ at $E = 80\ GeV$ (for pilot bunches)
  2) relative $\sigma_\delta = \sigma_E / E = 0.00066$
- Synchrotron modulation index:

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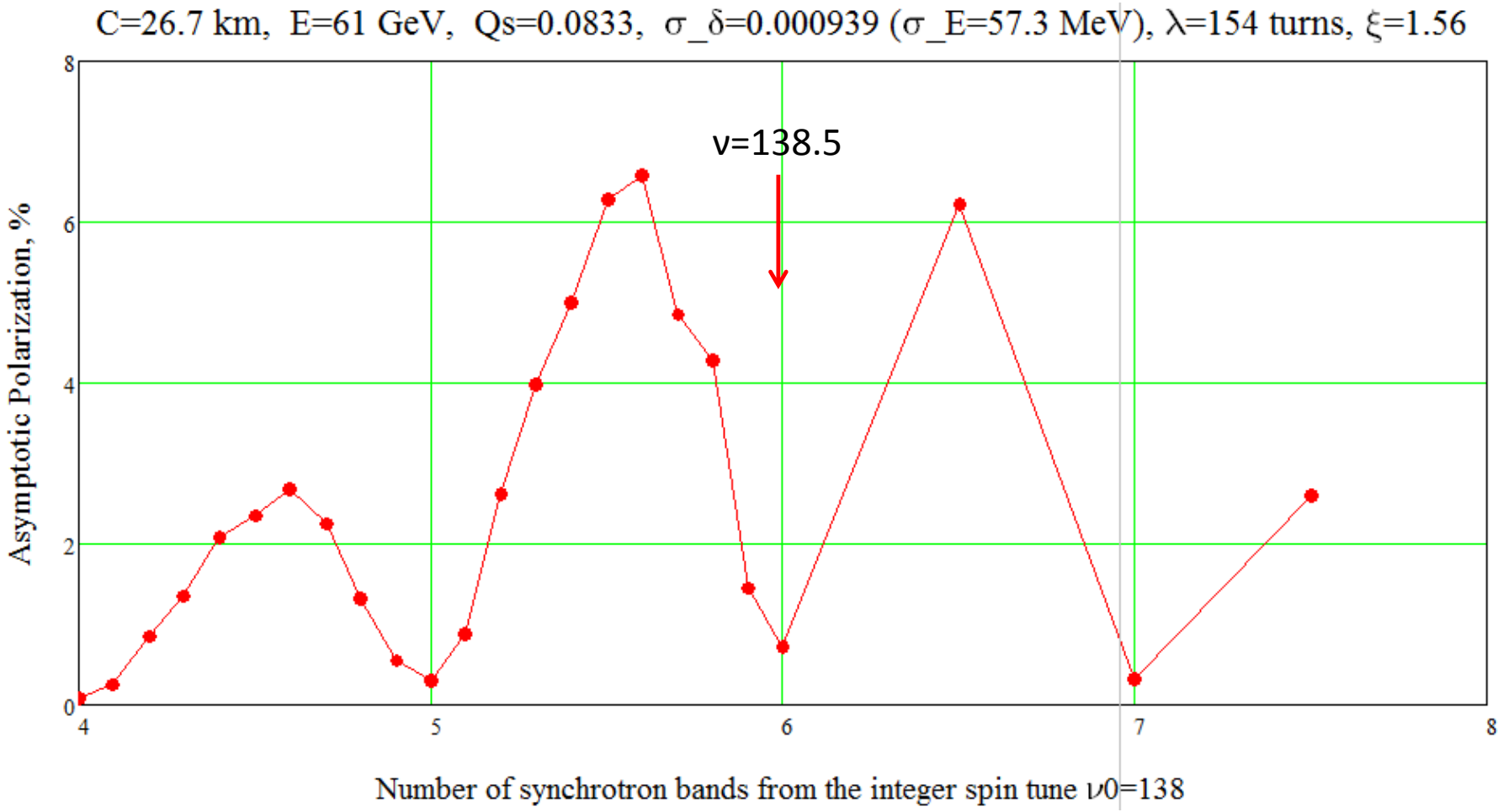
- Synchrotron modulation index: $x = \sigma_\delta \frac{\nu_0}{Q_s} = 0.00066 \frac{182.5}{0.025} = 4.8$, if $Q_s = 0.025$.

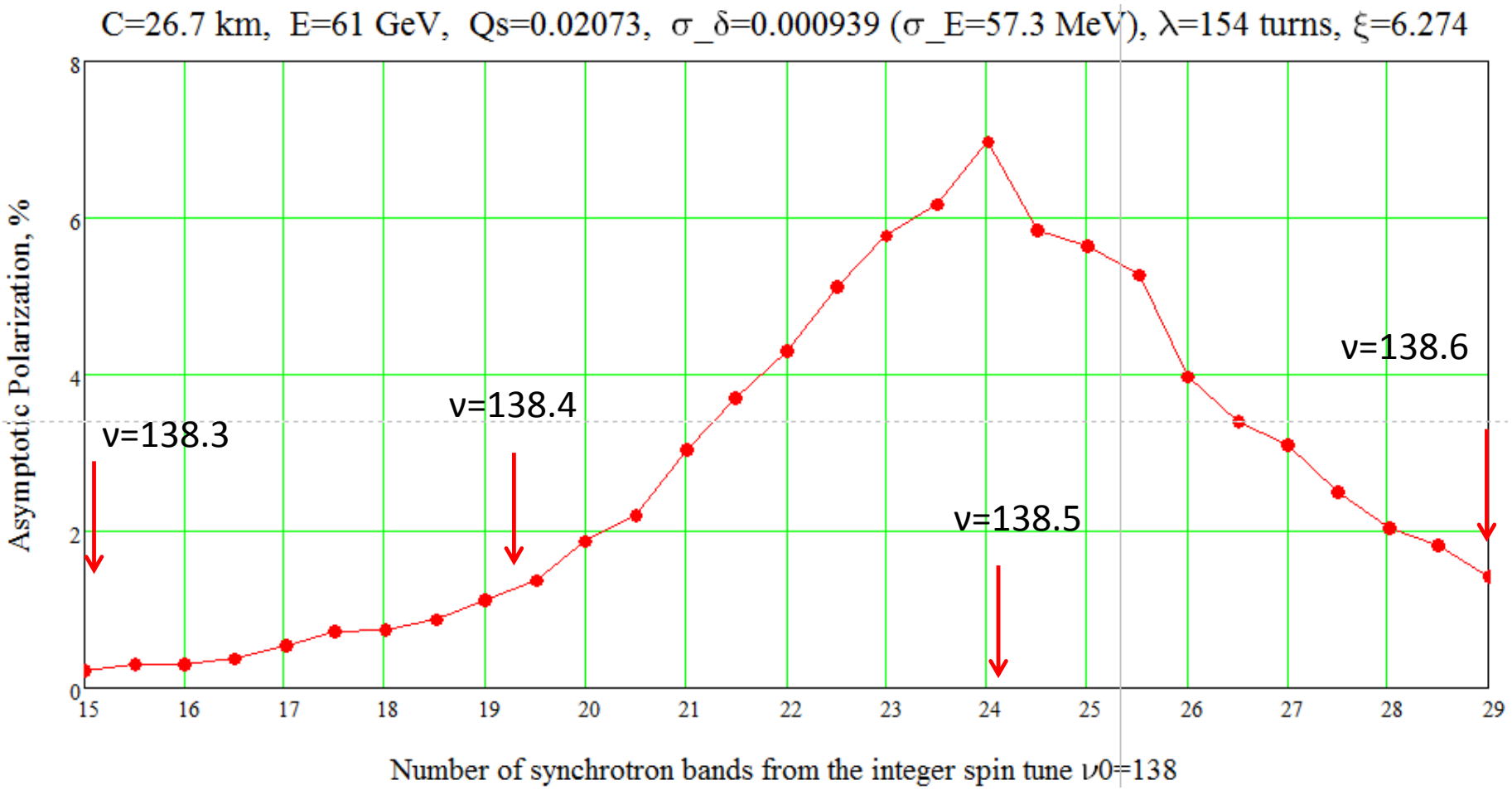
Equilibrium polarization for LEP at 61 GeV, Qs=0.0833

The parent and side band resonances are induced by the local spin rotation around the longitudinal axis by the angle $\varphi = w \cdot 2\pi$. Here $w = 0.0015$ 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.

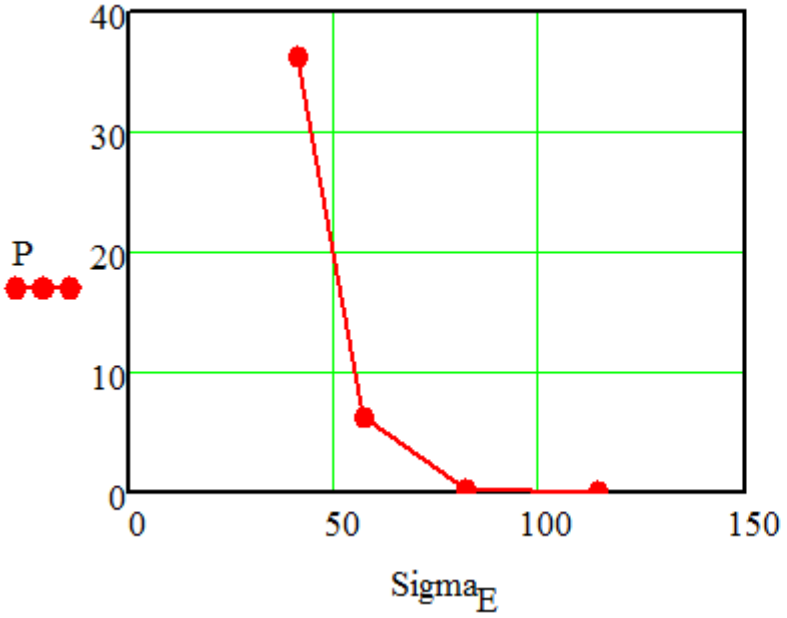


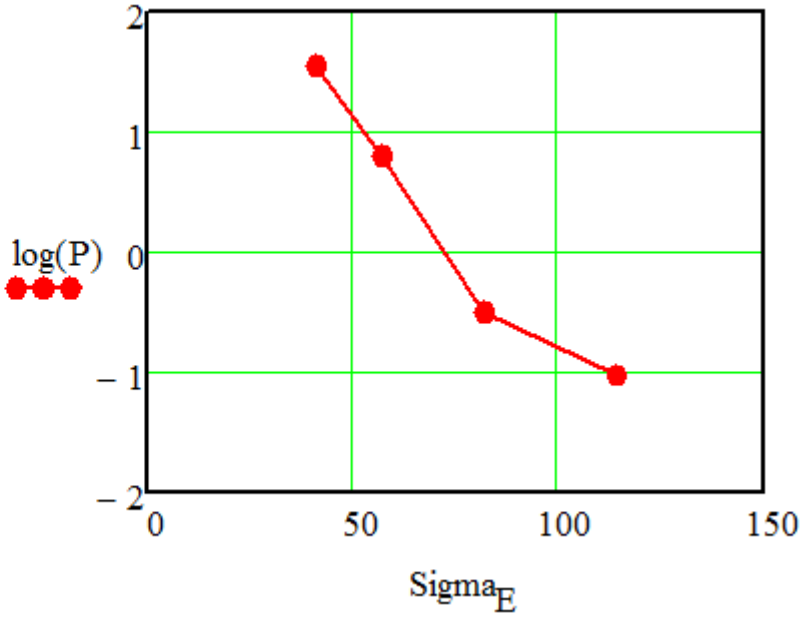
Equilibrium polarization for LEP at 61 GeV, Qs=0.02073

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, $\xi = 6$.



Polarization with increased/decreased energy diffusion rate





Conclusions:

1) No strong influence of Qs 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