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«Quasi-Frozen Spin»

T-BMT Equations

$$\frac{d\vec{S}}{dt} = \vec{S}\times\left(\vec{\Omega}_{MDM} + \vec{\Omega}_{EDM}\right),$$

$$\vec{\Omega}_{MDM} = \frac{q}{m\gamma}\left\{(\gamma G + 1)\vec{B}_{\perp} + (G+1)\vec{B}_{\parallel} - \left(\gamma G + \frac{\gamma}{\gamma+1}\right)\frac{\vec{\beta}\times\vec{E}}{c}\right\},$$

$$\vec{\Omega}_{EDM} = \frac{q\eta}{2m}\left(\vec{\beta}\times\vec{B} + \frac{\vec{E}}{c}\right), G = \frac{g-2}{2},$$

Spin-tunes in E, B fields

$$v_s^B = \gamma G$$

$$v_s^E = \frac{G+1}{\gamma} - G\gamma$$

Optimization in ByPass NICA Storage Ring

Spin Tune Decoherence Effects

Equilibrium Level Energy Shift

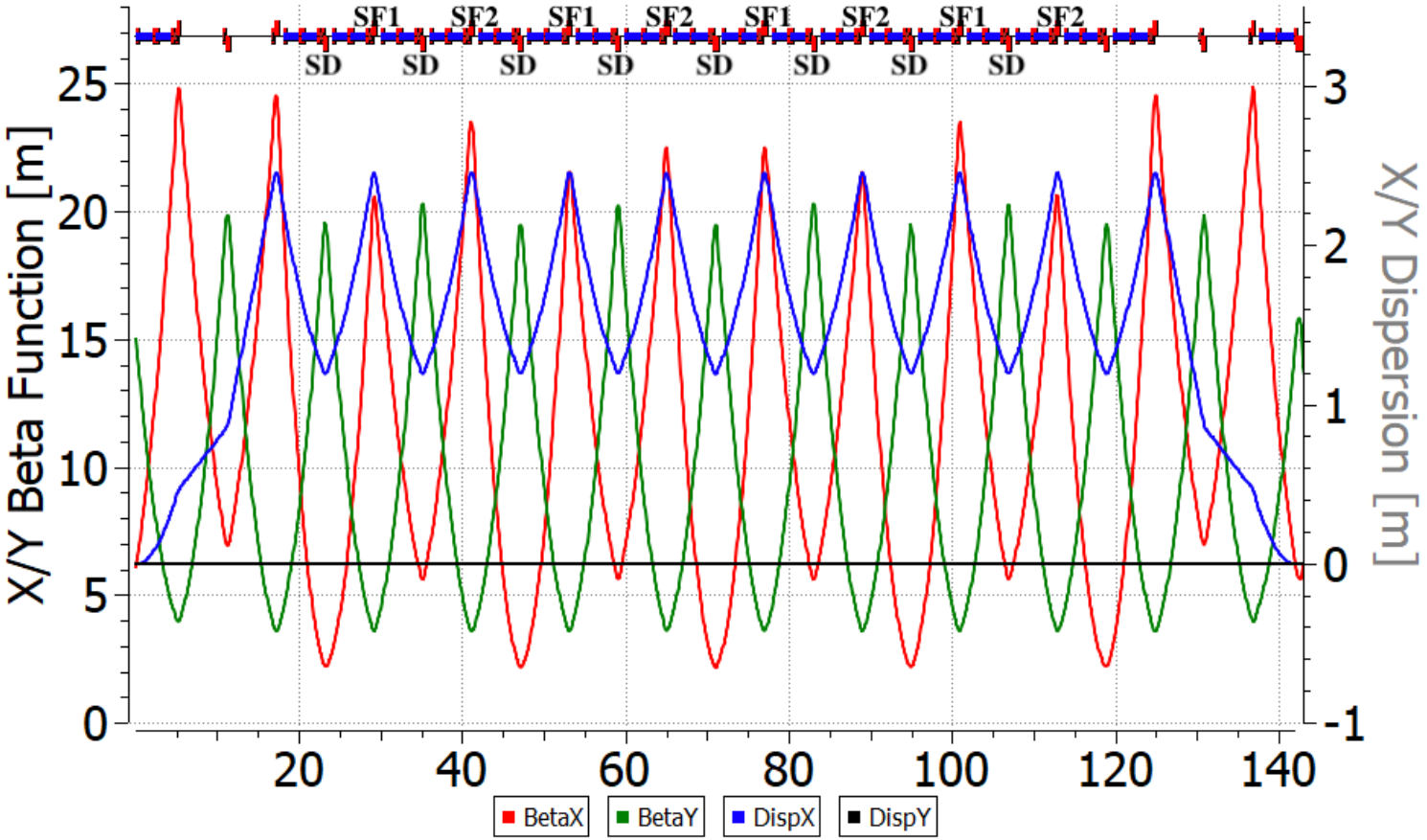
$$\gamma_{eff} = \gamma_s + \beta_s^2 \gamma_s \Delta\delta_{eq}$$

$$\Delta\delta_{eq} = \frac{\gamma_s^2}{\gamma_s^2 \alpha_0 - 1}\left[\frac{\delta_0^2}{2}\left(\alpha_1 + \frac{3}{2}\frac{\beta_s^2}{\gamma_s^2} - \frac{\alpha_0}{\gamma_s^2} + \frac{1}{\gamma_s^4}\right) + \left(\frac{\Delta L}{L}\right)_\beta\right], \qquad \left(\frac{\Delta L}{L}\right)_\beta = -\frac{\pi}{L_0}\left[\varepsilon_x \nu_x + \varepsilon_y \nu_y\right]$$

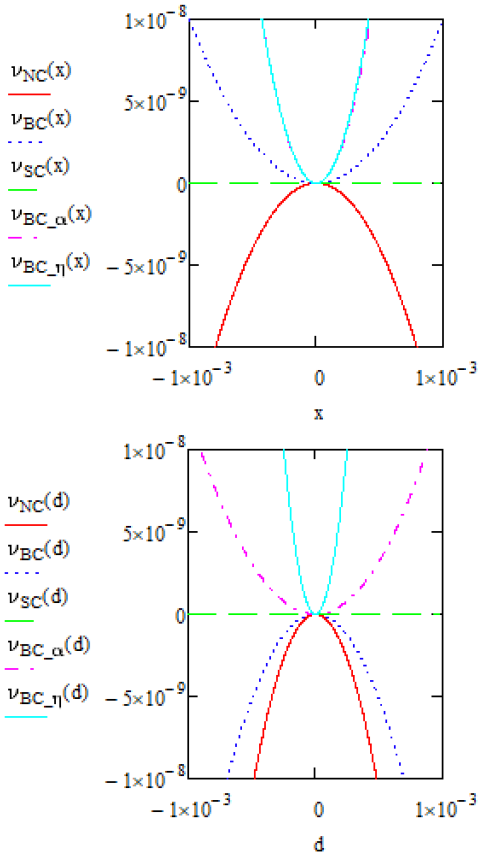
Orbit Lengthening and Betatron Chromaticity

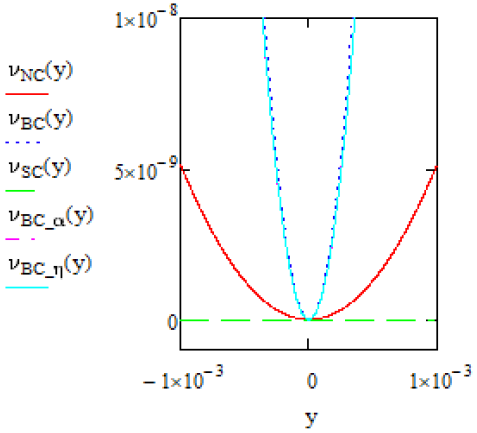
$$\Delta C_\Sigma = -\pi\left(\varepsilon_x \xi_x + \varepsilon_y \xi_y\right) + \delta_0(\alpha_0 + \alpha_1 \delta_0 + \cdots)$$

Sextupole Correction

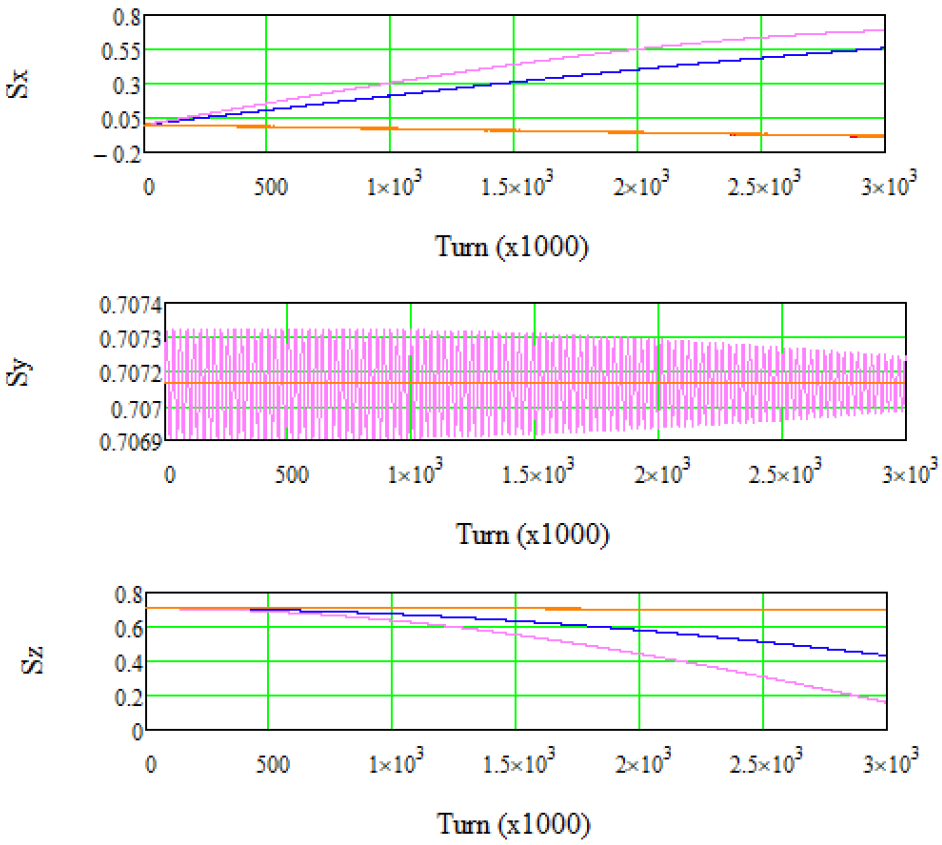


Betatron Chromaticity

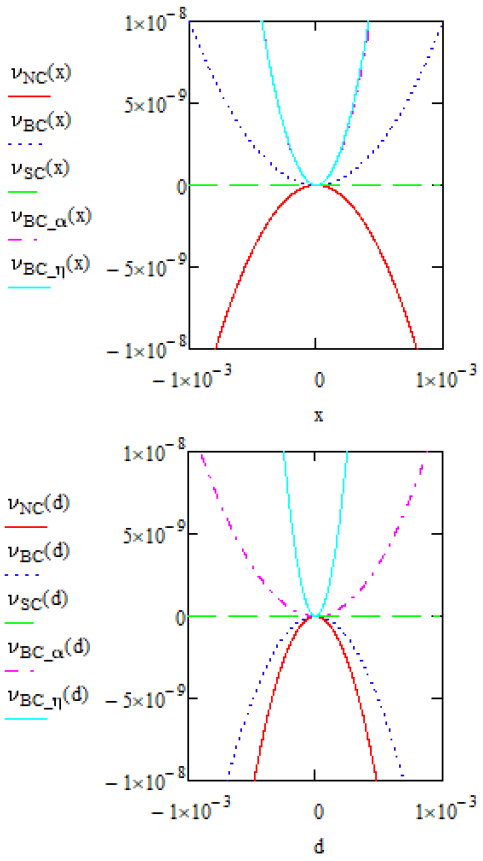


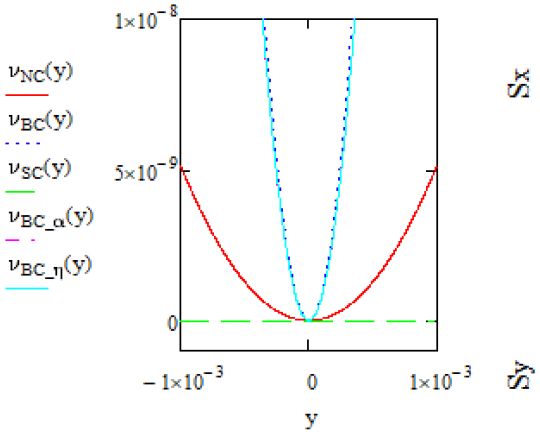


- 2 sextupole families
- Zero betatron chromaticity
- No spin coherence

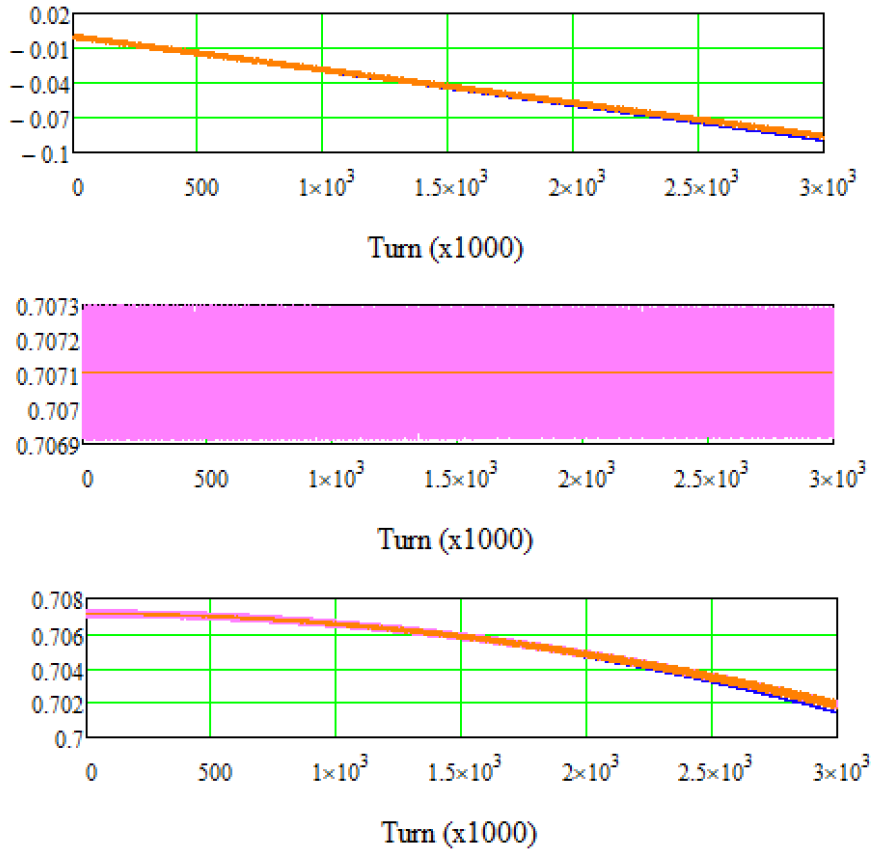


Spin Coherence

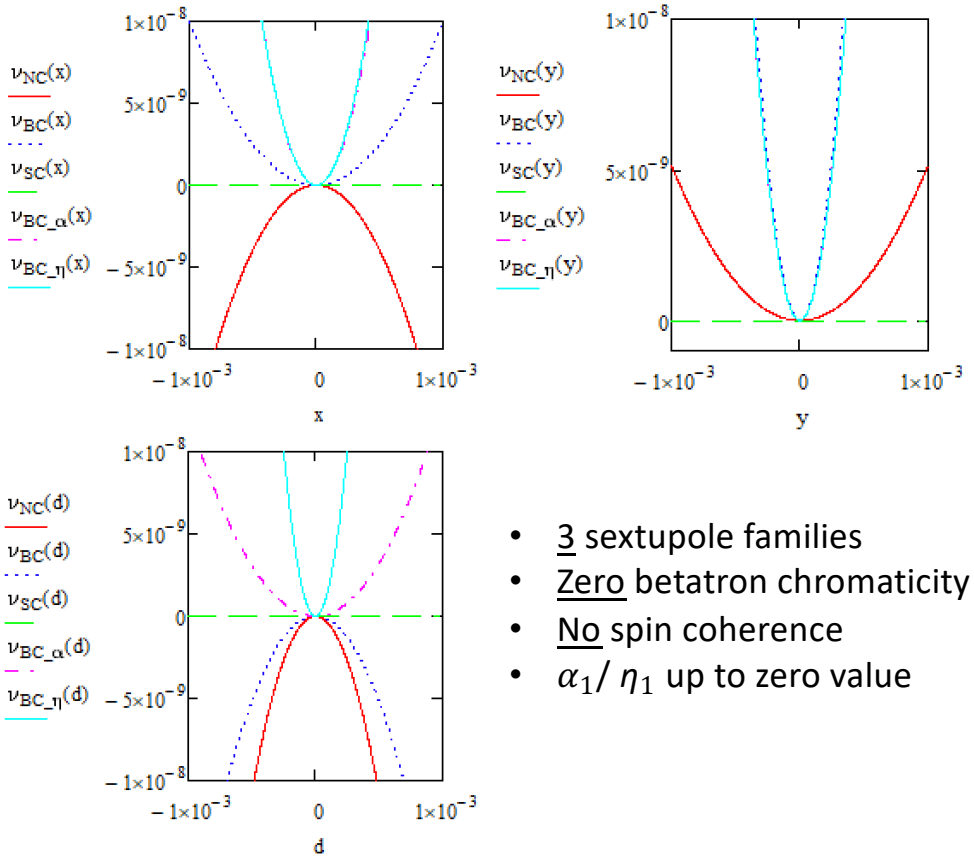




- 3 sextupole families
- Non-zero betatron chromaticity
- Spin coherence achieved



α_1/η_1 Correction



- 3 sextupole families
- Zero betatron chromaticity
- No spin coherence
- α_1/η_1 up to zero value

$$\gamma_{eff} = \gamma_s + \beta_s^2 \gamma_s \Delta\delta_{eq}$$

$$\Delta\delta_{eq} = \frac{\gamma_s^2}{\gamma_s^2\alpha_0 - 1}\left[\frac{\delta_0^2}{2}\left(\alpha_1 + \frac{3}{2}\frac{\beta_s^2}{\gamma_s^2} - \frac{\alpha_0}{\gamma_s^2} + \frac{1}{\gamma_s^4}\right) + \left(\frac{\Delta L}{L}\right)_\beta\right],$$

$$\left(\frac{\Delta L}{L}\right)_\beta = -\frac{\pi}{L_0}\left[\varepsilon_x\nu_x + \varepsilon_y\nu_y\right]$$

$$\Delta C_\Sigma = -\pi\left(\varepsilon_x\xi_x + \varepsilon_y\xi_y\right) + \delta_0(\alpha_0 + \alpha_1\delta_0 + \cdots)$$

Optimization Summary Table

Optimization	No optimization	Chromaticity	Spin Coherence	Chromaticity + α_1	Chromaticity + η_1
Tunes	$-17/-17$	$0/0$	$-13/-18$	$0/0$	$0/0$
α_1	0.2	-0.4	$-0.37 \cdot 10^{-2}$	$\sim -10^{-12}$	-0.85
quadK$_x$	$-0.16 \cdot 10^{-1}$	$0.55 \cdot 10^{-1}$	$0.27 \cdot 10^{-13}$	$0.55 \cdot 10^{-1}$	$0.56 \cdot 10^{-1}$
quadK$_y$	$0.51 \cdot 10^{-2}$	$0.76 \cdot 10^{-1}$	$-0.12 \cdot 10^{-12}$	$0.78 \cdot 10^{-1}$	$0.78 \cdot 10^{-1}$
quadK$_z$	$-0.43 \cdot 10^{-1}$	$0.20 \cdot 10^{-1}$	$0.13 \cdot 10^{-12}$	$0.13 \cdot 10^{-1}$	$1.6 \cdot 10^{-1}$
Sextupole families	No sextupoles	2	3	3	3
Max. sextupole coefficient, m^{-3}	–	2.7	19.4	4.9	104.2

Conclusions

- Considered the phenomenon of spin decoherence simultaneously with betatron chromaticity in ByPass NICA Storage Ring.
- Different cases of sextupole optimizations.
- 3 sextupole families in regular structure can't compensate both betatron chromaticities and get spin coherence.
- It can be possible to modulate dispersion function in such way to get now 3 linear independent sextupole families.
- One of the possible problem decisions is using cooled beam at the level of $dp/p \sim 10^{-5}$. This can help to minimize γ-effective.
- Maximum value of sextupole coefficient not satisfactory and can cause non-linear instabilities.