Space Charge Resonance Analysis at the Horizontal Integer Tune for the CERN PS

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We report here about a study of a 2nd order resonance at the horizontal tune $Q_x = 6$ for a simulation model of the CERN PS including Space Charge (SC). At a horizontal base tune without SC of $Q_x = 6.039$ we find that in the simulation the SC force drags the horizontal tune onto $Q_x = 6$. In the PS there are two matching tune systems: a) Pole Phase Windings (PFW) and b) Low Energy Quadrupoles (LEQ) where the latter leads to very strong optics distortions at the integer. One of the authors, Foteini Asvesta et al, has developed a tool to determine Resonance Driving Terms (RDT) from the SC potential which confirms the appearance of the 2nd order resonance at the $Q_x = 6$. On the other hand, using only the PFW system there should be a RDT consistent with zero. The simulations using the PFW matching system confirm the absence of this resonance.

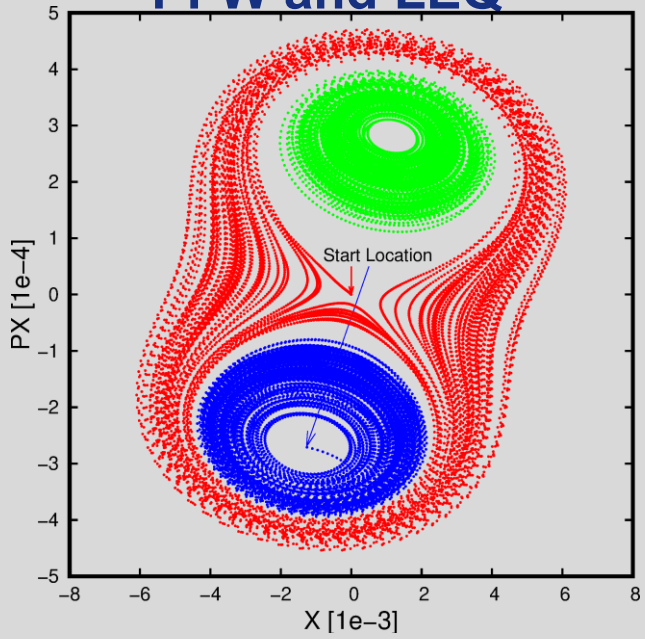
Simulations with MADX-SC: Horizontal Phase Space

Table of PS SC Experiment Parameters

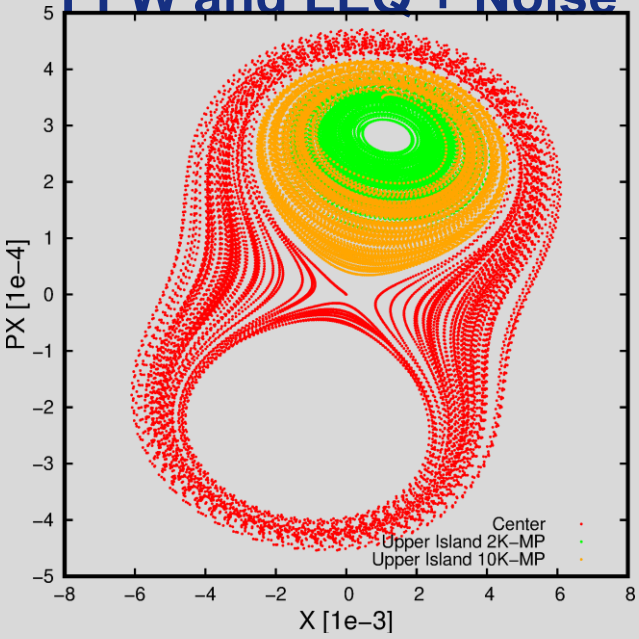
Kinetic energy	2 GeV
Intensity [10^{10} ppb]	55
Bunch length (rms) [m]	9.59
Momentum spread $\Delta p/p$ (rms) [10^{-3}]	0.95
Hor. normalized emittance, ε_x^n (1σ) [μm]	3.5
Ver. normalized emittance, ε_y^n (1σ) [μm]	2.2
Horizontal tune shift, ΔQ_x	−0.05
Vertical tune shift, ΔQ_y	−0.07

Simulations done with MADX-SC with SC in adaptive mode ➔ Paper this conference.

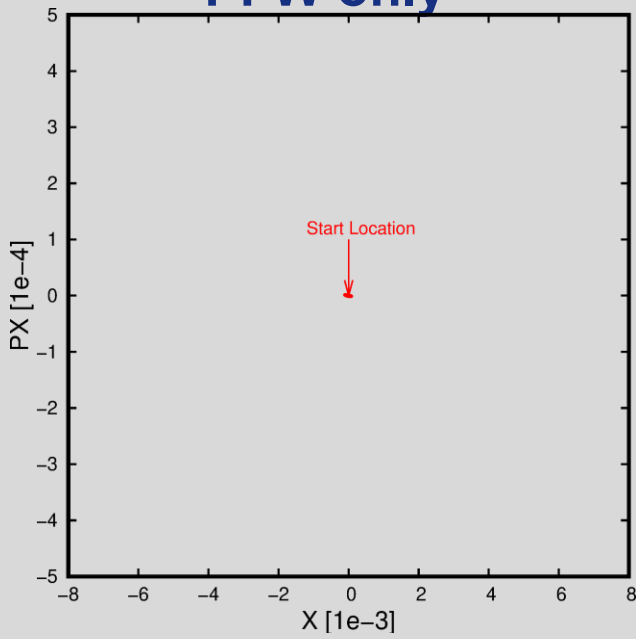
PFW and LEQ



PFW and LEQ + Noise



PFW only



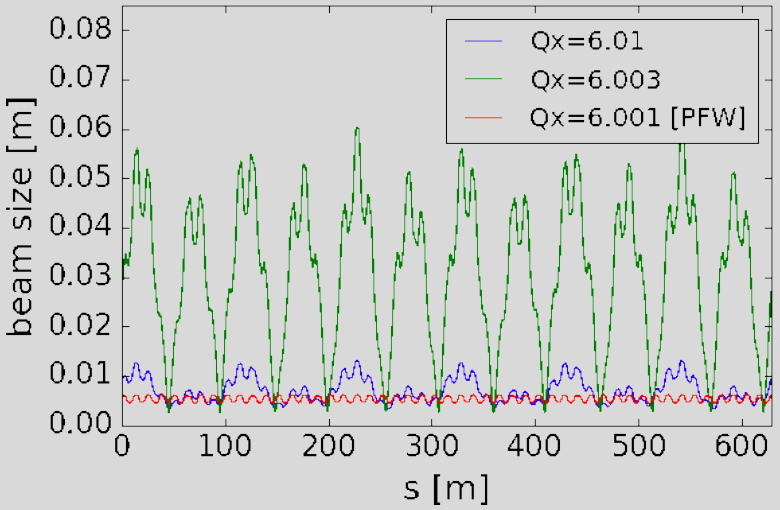
Driving-Term Analysis

RDT Amplitude

$$G_{2,0} = -\frac{K_{sc}}{2\pi}\int_0^C \frac{\beta_x}{\sigma_x \cdot (\sigma_x + \sigma_y)} \cdot e^{j(2\phi_x)} ds \qquad (1)$$

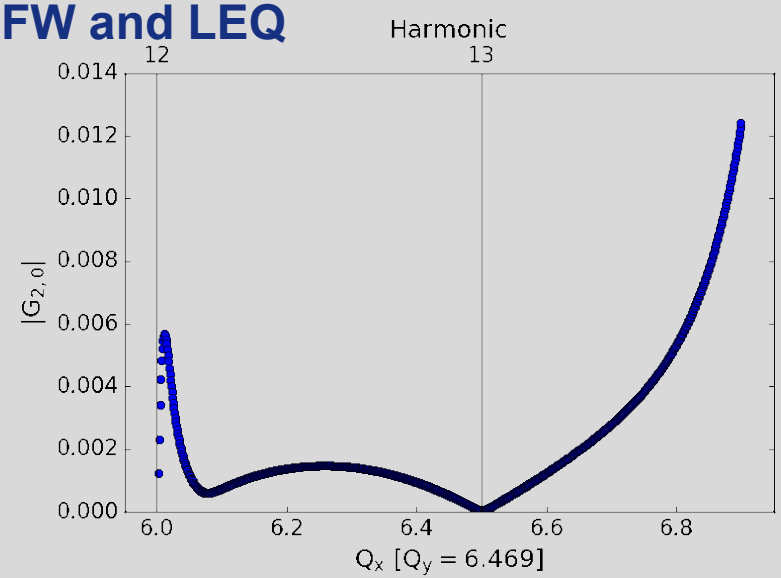
where, $K_{sc} = \frac{r_0 N_b}{\beta^2\gamma^3\sqrt{2\pi}\sigma_s}$, r_0 is the classical particle radius, N_b the. bunch intensity, β, γ, the relativistic factors, $\sigma_{s,x,y}$ the longitudinal and transverse beam sizes accordingly and ϕ_x the horizontal phase advance.

Beam Size

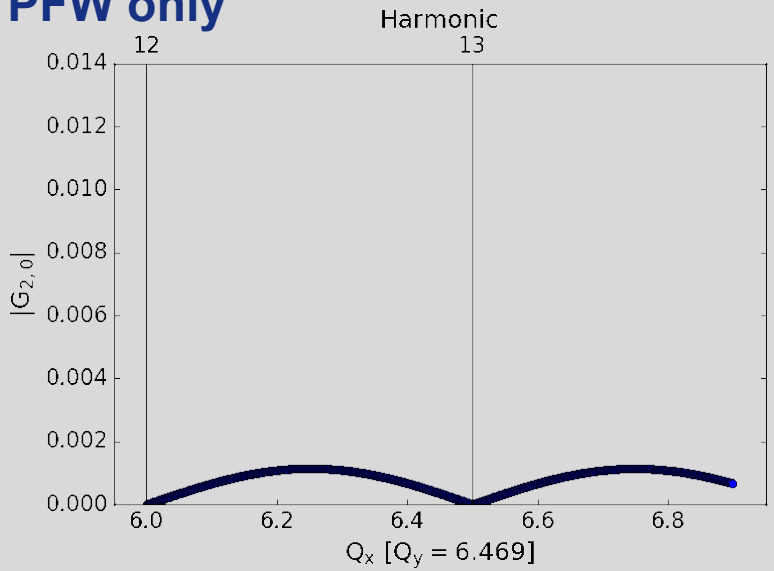


RDT Evolution

PFW and LEQ



PFW only



Outlook

Further studies may complement what has been described in this report: it would be interesting to analyze the 2nd order SC resonance with simulations using self-consistent PIC codes; equally important would be an experimental attempt to approach the PS integer tune without using the LEQs. Moreover, further analysis of the quadrupole RDTs could improve the understanding of the nature of the excitation and quantify the SC contribution.