Focussing Lattices of Compton Gamma Rings

CERN, KEK, LAL, DESY, KIPT, …

POSIPOL – 2006, P.Gladkikh, KIPT

Required intensities

$N_{e+} \sim 10^{14}$ /s $\rightarrow$ $N_\gamma \sim 10^{16}$ /s $\rightarrow$ $n_\gamma \sim 0.3 - 0.4$ / (e^- turn)

Large energy spread

$$\delta_{tot} = \sqrt{\frac{\Delta E_{SR}}{\Delta E_{tot}}\delta_{SR}^2 + \frac{\Delta E_{CS}}{\Delta E_{tot}}\delta_{CS}^2} \approx \delta_{CS}\sqrt{\frac{\Delta E_{CS}}{\Delta E_{tot}}} \approx \begin{cases} 3.0\% \ \ for\ CO_2\ ring \\ 6.2\% \ \ for\ YAG\ ring \end{cases}$$

$$\Delta E_{tot} = \Delta E_{SR} + \Delta E_{CS}; \quad \delta_{SR}, \delta_{CS} - partial\ energy\ spreads$$

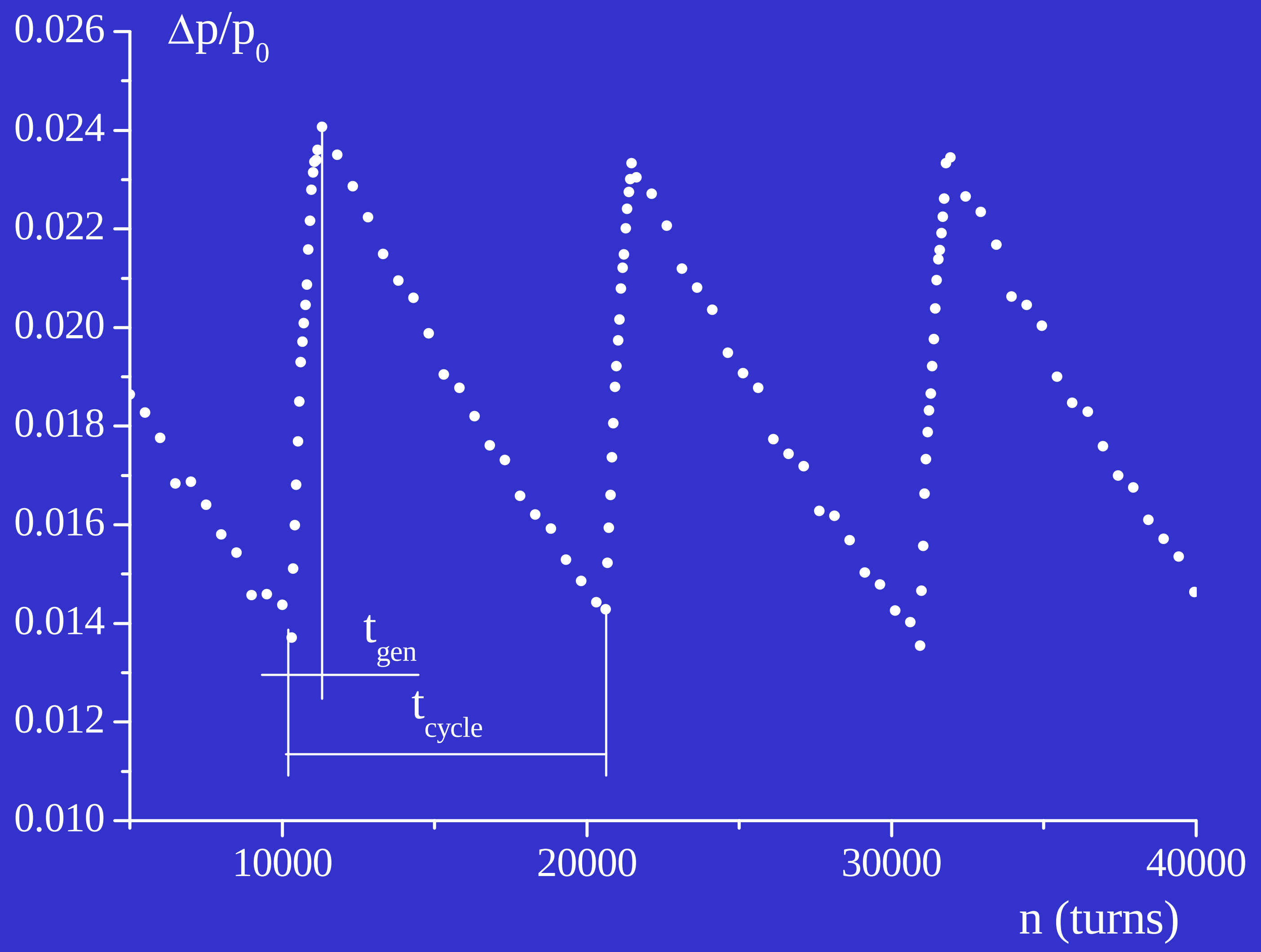
Large energy acceptance $\sigma_{RF} > 4 \div 5\delta_{tot}$

Correction of high order chromaticity

$$\Delta Q = \frac{\partial Q}{\partial \delta}\delta + \frac{\partial^2 Q}{\partial \delta^2}\delta^2 + \frac{\partial^3 Q}{\partial \delta^3}\delta^3 + \ldots$$

Suppression of high order dispersion functions at IP's

$$\Delta x = \eta_1\delta + \eta_2\delta^2 + \eta_3\delta^3 + \ldots$$



Energy spread during several cycles

Photon number per electron and per turn

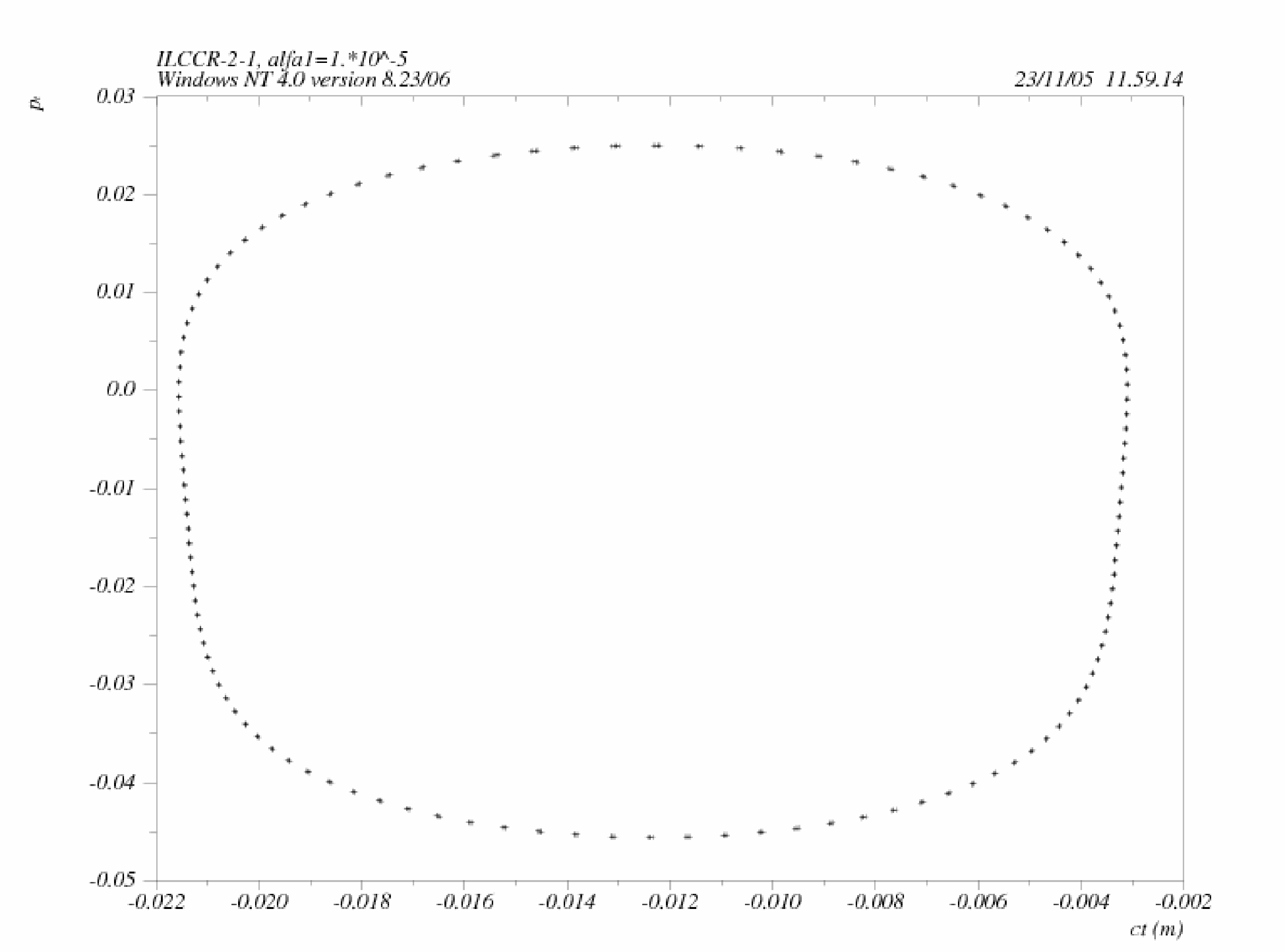
$$n_\gamma \approx \frac{n_{ph}\sigma_C}{\sqrt{z_e^2 + z_{ph}^2}\sqrt{x_e^2 + x_{ph}^2 + (s_e^2 + s_{ph}^2)\varphi_{col}^2 / 4}}$$

Longitudinal size of electron beam $s_e = (\alpha_1 c / \Omega_S)\, \delta$

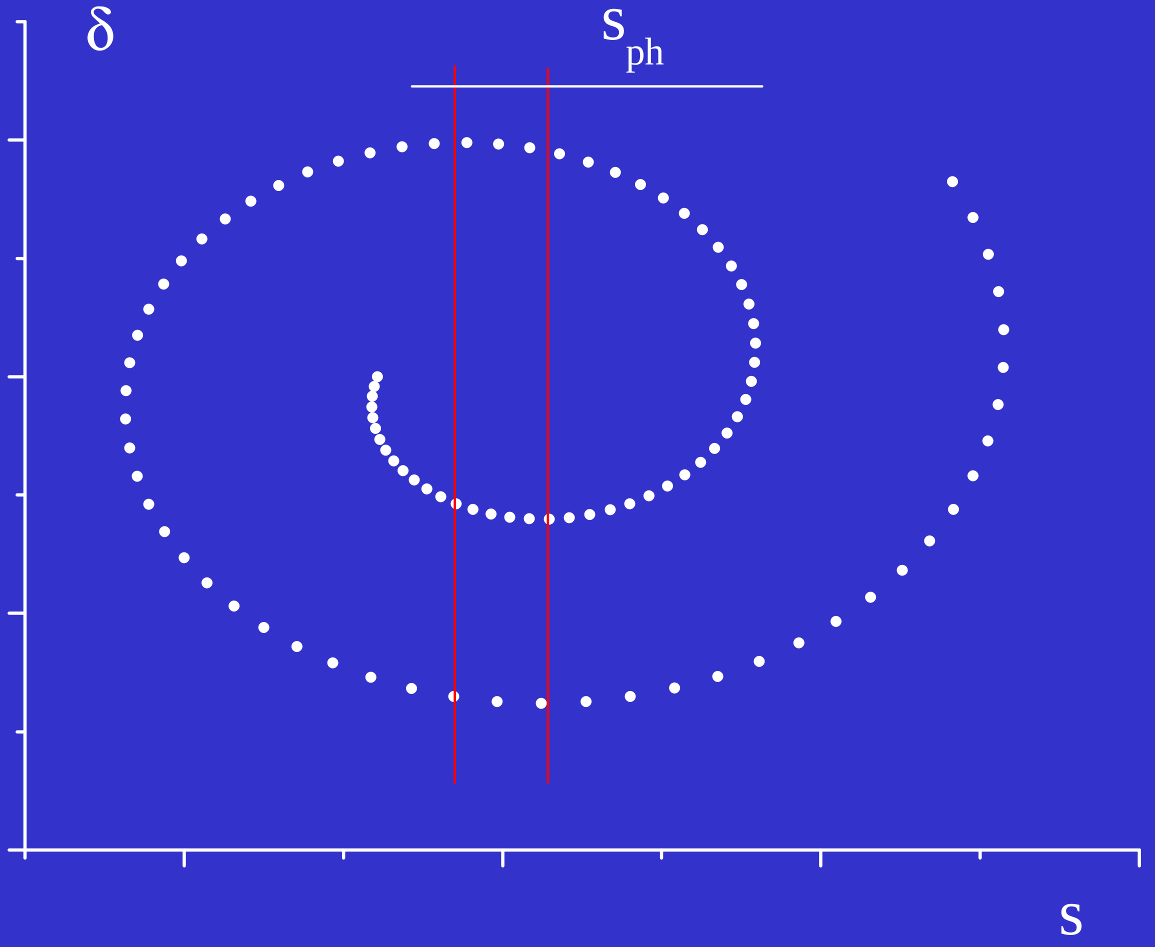
$s_e < 1$ mm in storage ring with $\Omega_S = 5$ kHz ($Q_S = 0.01$ for storage ring with circumference $C = 600$ m)

$\alpha_1 < 1.66 \cdot 10^{-6}$ at energy spread equal to 1 %.

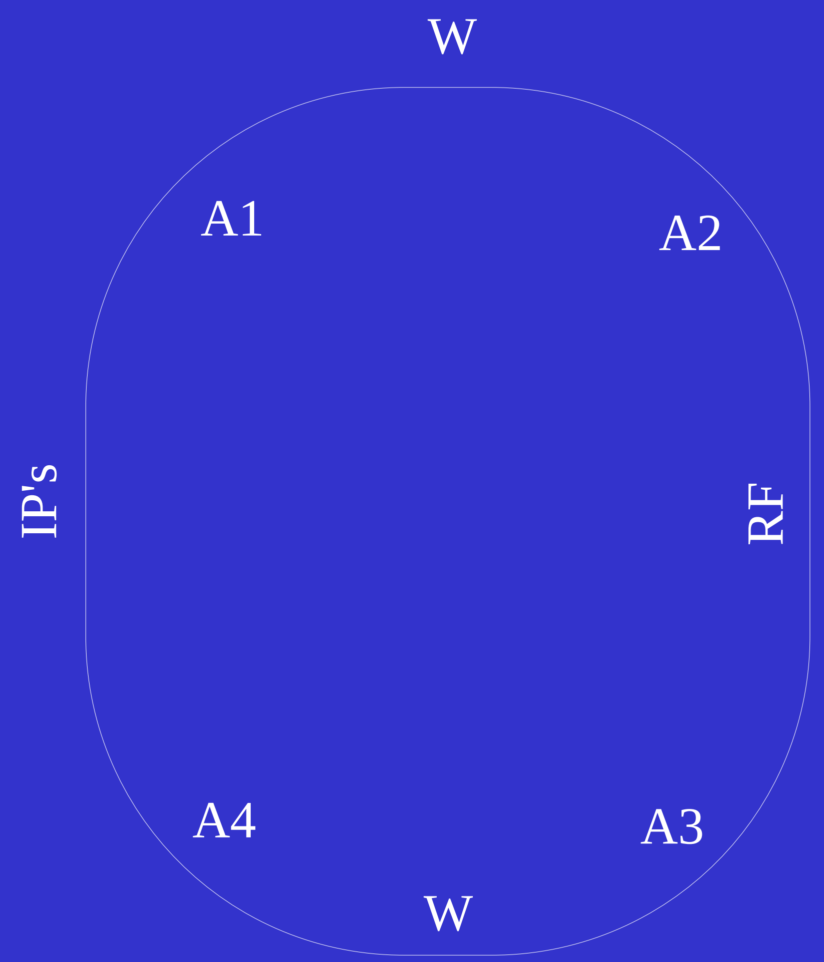
Orbit lengthening $$\frac{\Delta C}{C_0} = \alpha_1\delta + \alpha_2\delta^2 + \alpha_3\delta^3 + \ldots$$



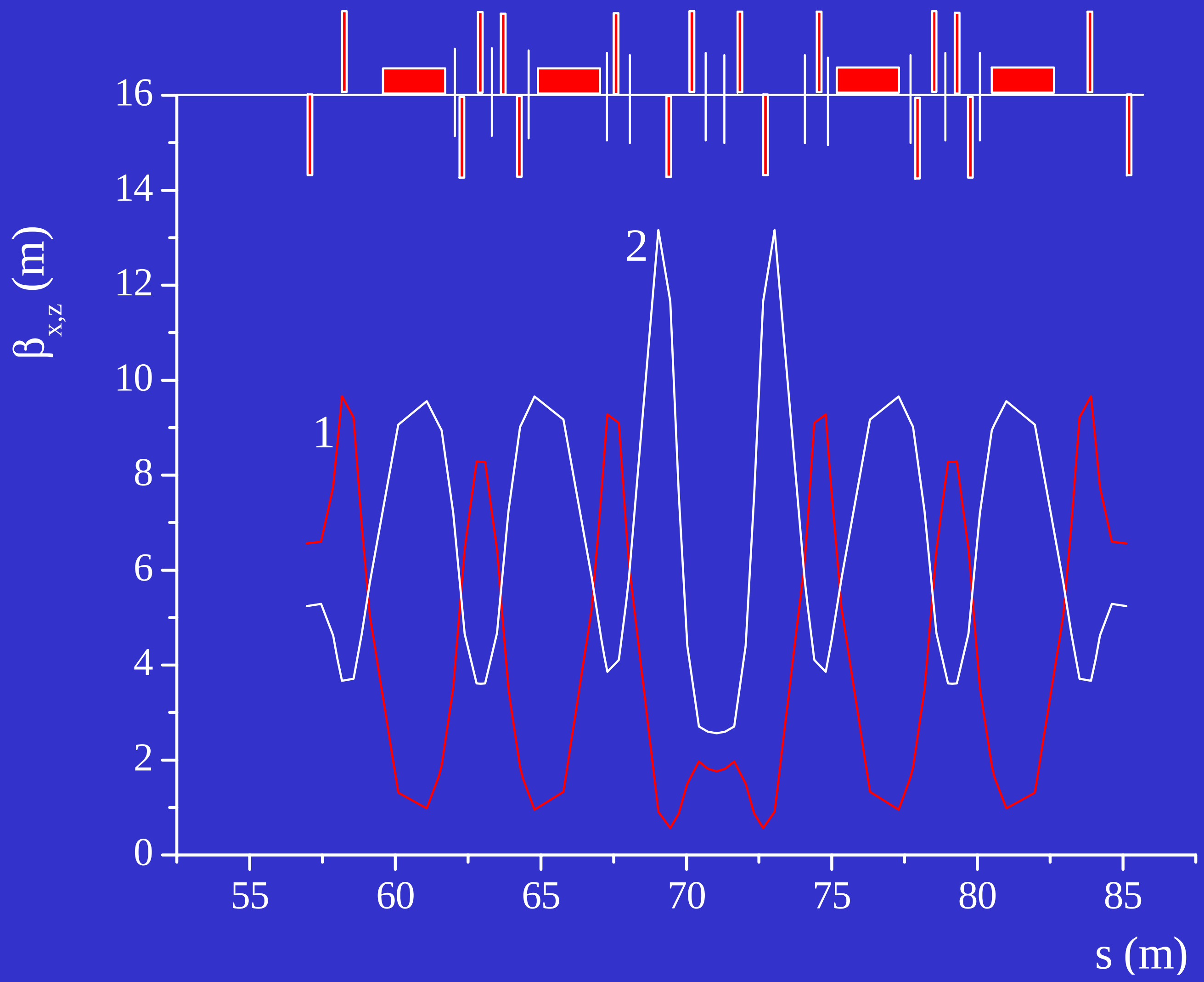
Phase trajectory of synchrotron motion. E_0 = 4.1 GeV, $\alpha_1 = 1*10^{-5}$ (MAD simulation)



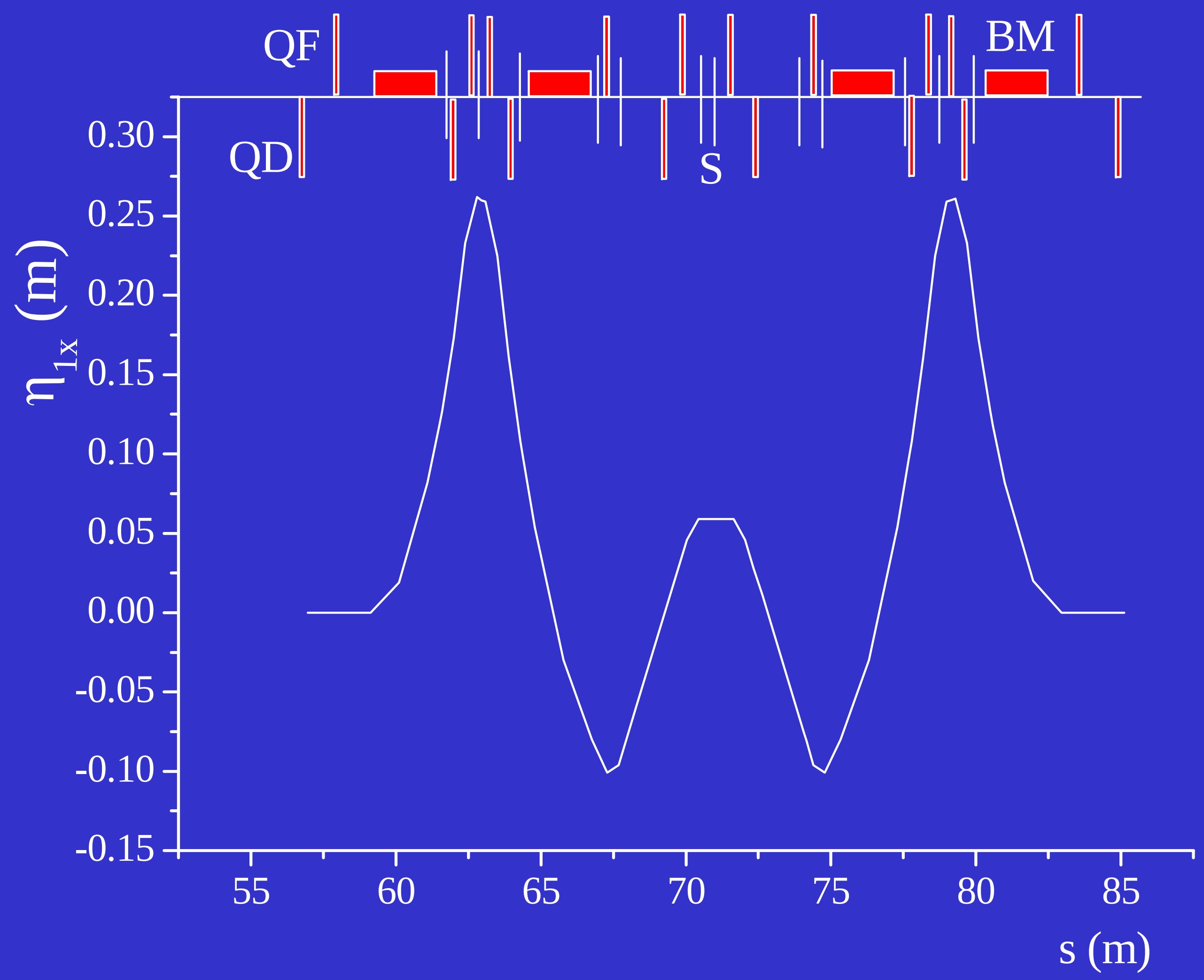
“Averaged” synchrotron motion at intense Compton scattering



Layout of Compton ring. A1-A4 – ring arcs; IP’s, RF, W – long straight sections of interaction points, RF and wigglers



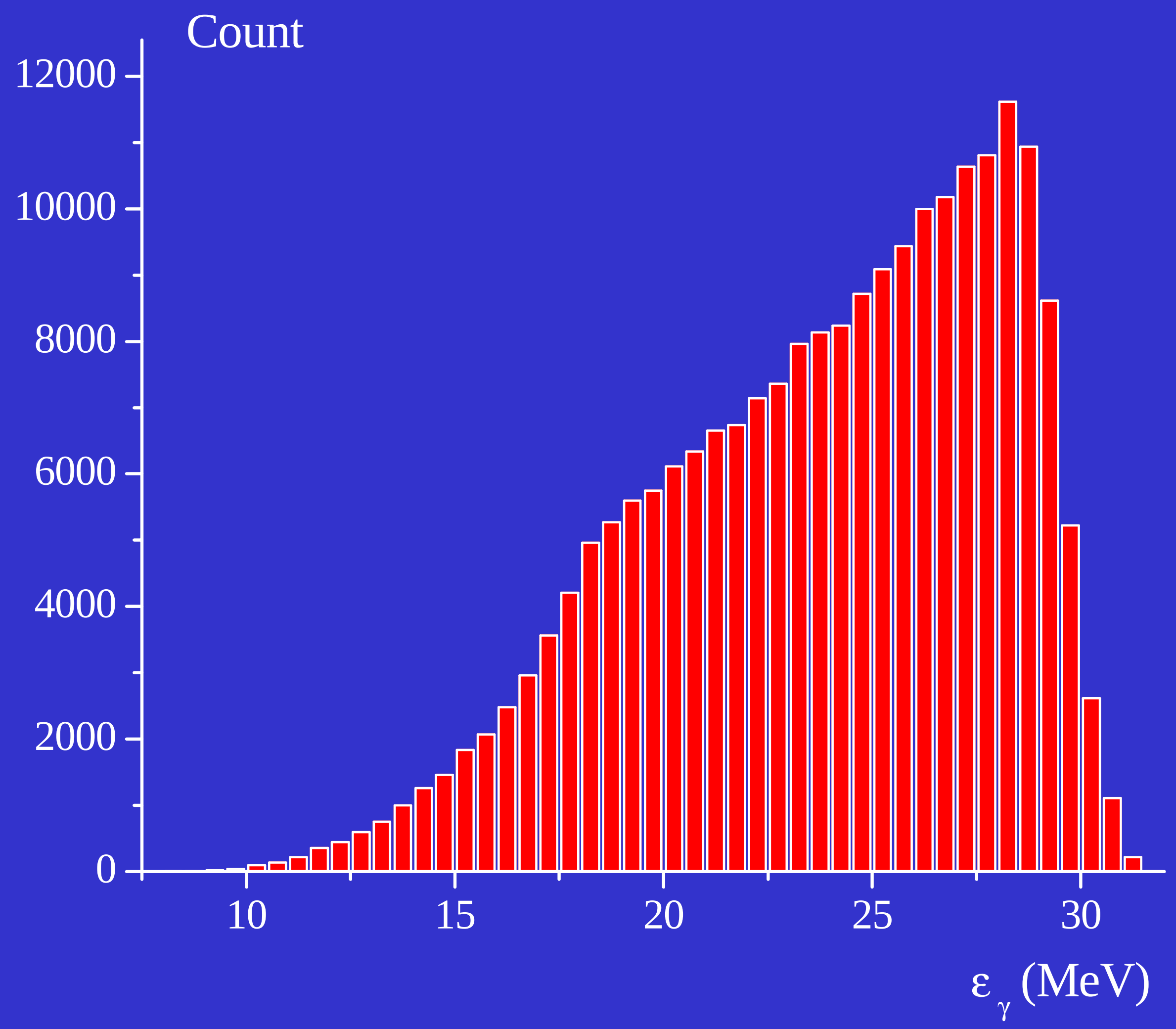
Horizontal (1) and vertical (2) amplitude functions of four – bending section



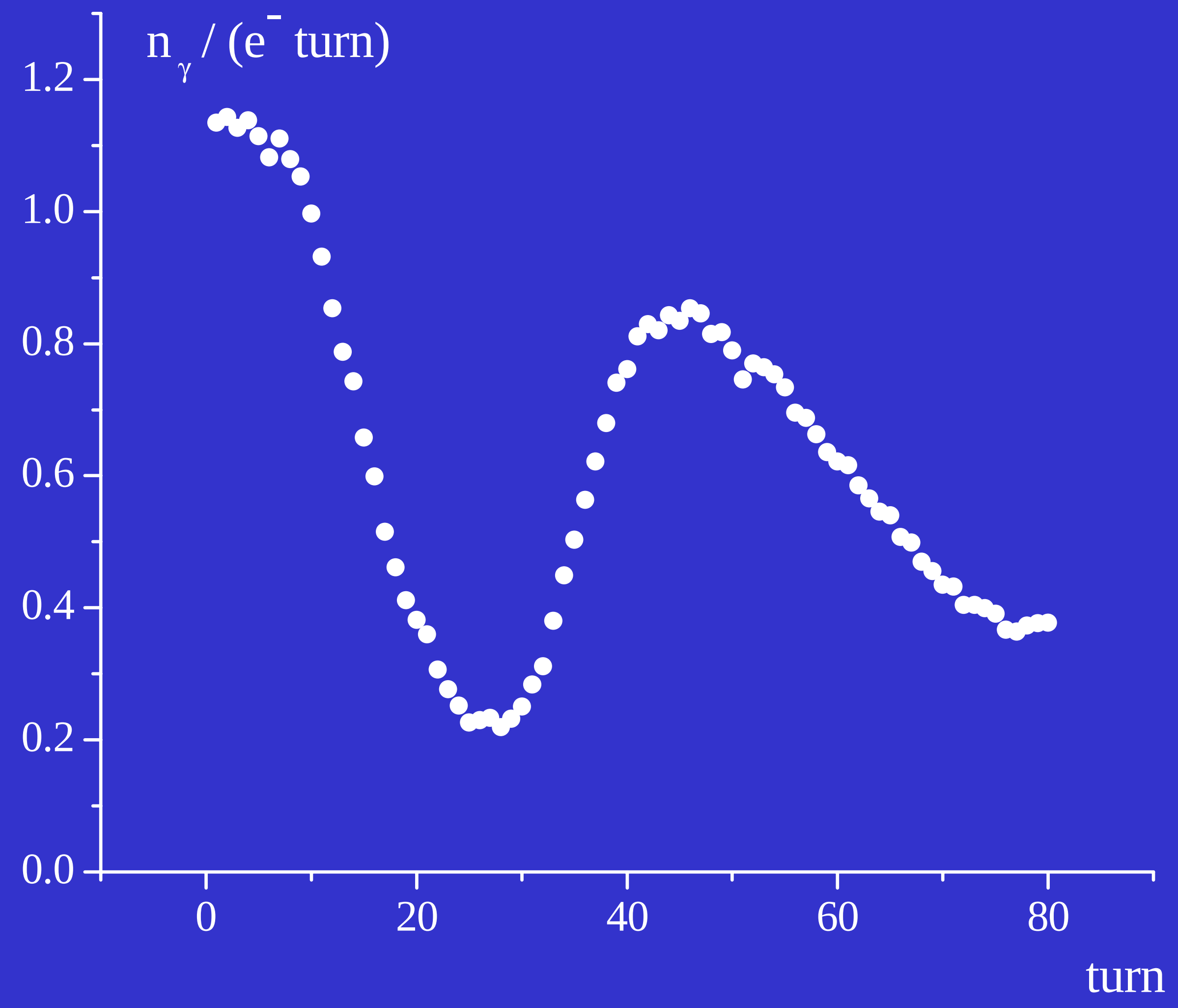
First order dispersion function of four – bending section.
BM are bending magnets, QF,QD - quadrupoles, S - sextupoles

Main parameters of CO_2 Compton ring:

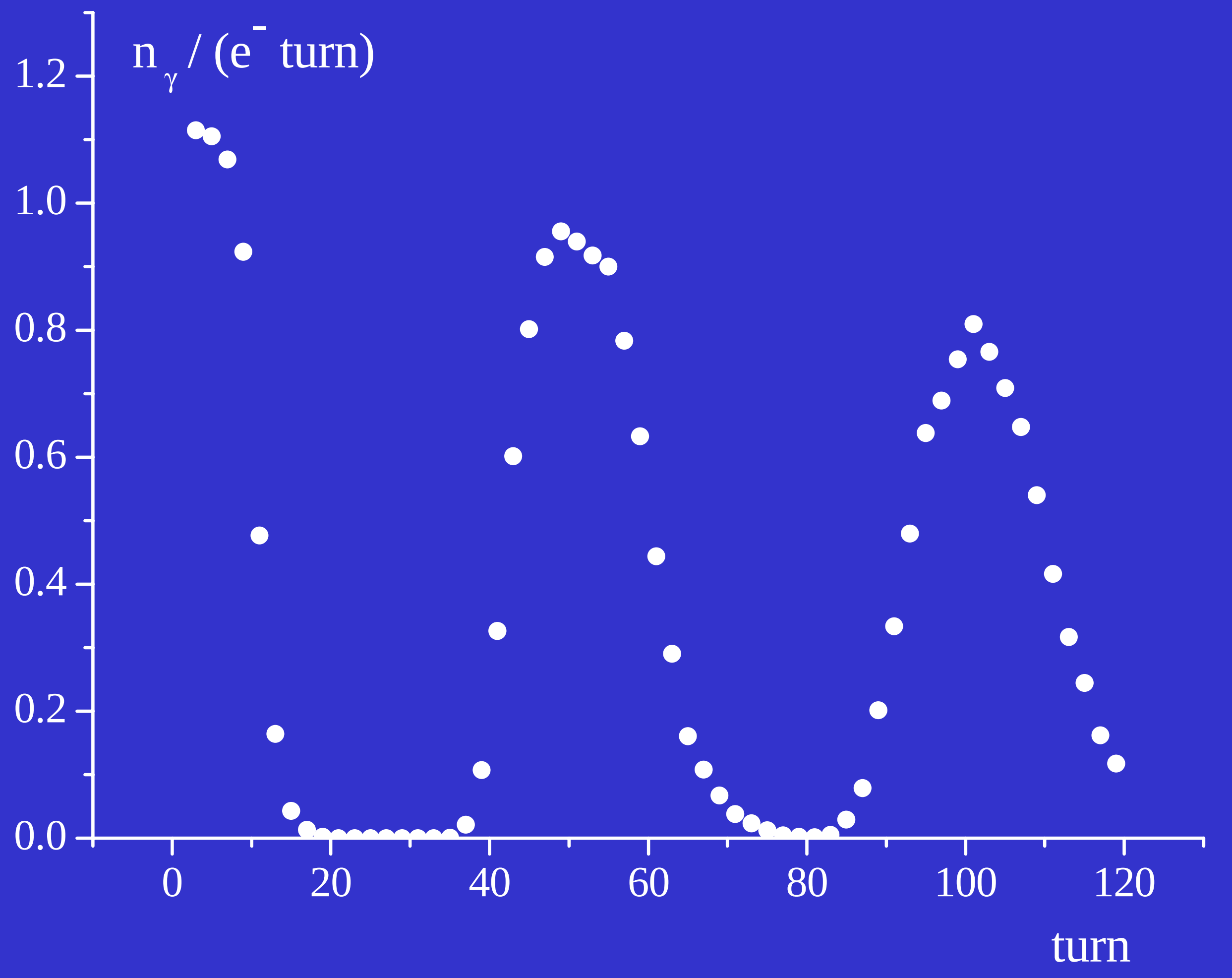
- Electron energy up to E_0 = 5 GeV;
- circumference C = 719.5 m;
- number of IP's N_{IP} = 30;
- harmonics number h = 1560;
- RF frequency f_{RF} = 650 MHz;
- number of bending magnets N_{BM} = 80;
- horizontal betatron number Q_X = 53.17;
- vertical betatron number Q_Z = 22.24;
- chromaticity $\chi_X = -73.9$, $\chi_Z = -49.4$;
- natural emittance at the maximal electron energy $\varepsilon_X = 2.8*10^{-9}$;
- RF – voltage V_{RF} = 60 MV;
- linear momentum compaction factor $0 \odot \alpha_1 \odot 2*10^{-4}$.



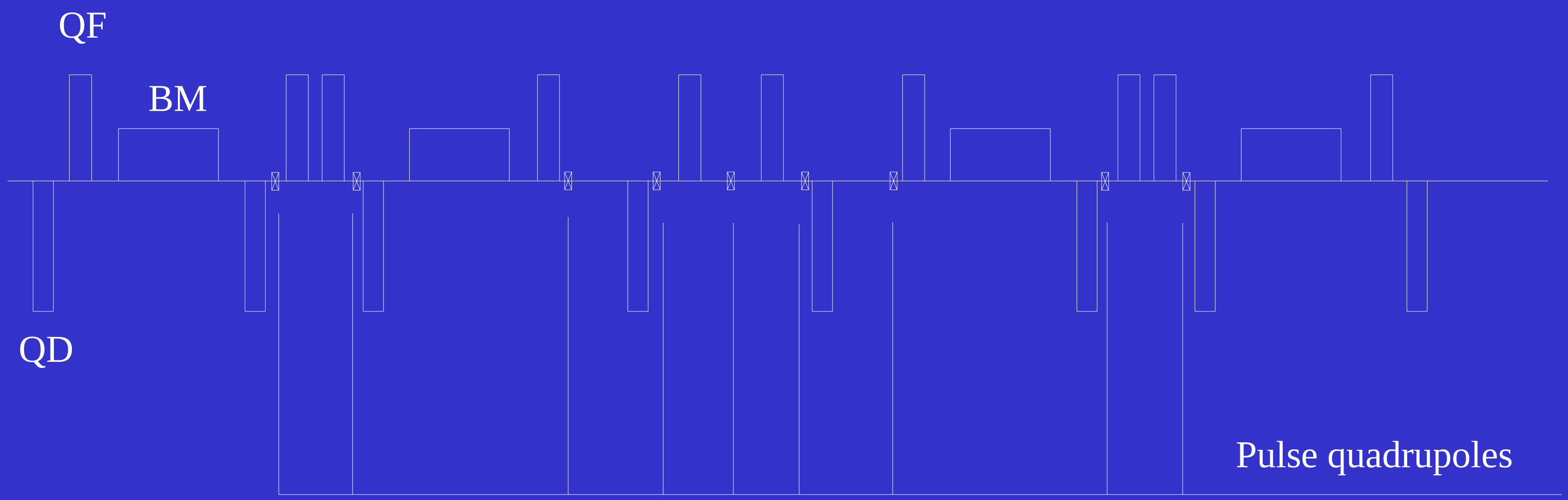
Collimated spectrum within collimation angle 0.1 mrad.
Electron energy is 4.1 GeV, number of electrons 10000.



Gamma beam intensity in train vs. turn number at RF phase manipulation.
RF frequency f_{RF} = 650 MHz, initial electron beam coordinates
s = 0.012 m (10 degrees), $\delta = 0$



Gamma beam intensity in train vs. turn number at f_{RF} = 1950 MHz.
Initial electron beam coordinates s = 0., δ = 0.



Distribution of pulse quadrupoles over arc cell

Preliminary evaluated parameters of CLIC Compton ring:

- electron beam energy E_0 = 1.3 GeV;
- circumference C = 191.8 m (h = 1200 at RF frequency 1875 MHz);
- number of interaction points N_{IP} = 2-3;
- RF voltage V_{RF} = 10 MV;
- momentum compaction factor at low α_1 mode ~ $1\text{-}5 \cdot 10^{-5}$;
- number of four – bending arc cells N_C = 8;
- required RF acceptance σ_{RF} ~ 10 %;
- natural emittance $\varepsilon_X \approx 3\text{-}5 \cdot 10^{-9}$ …

What are priority measures for further design?

- analytical treatment and simulation of electron beam instabilities in quasi-stationary operation mode;
- developing of the code for minimization of the second order momentum compaction factor (it would be most preferable to develop the HARMON module in MAD code);
- extension of the circle of participants in lattice design.