E-LENS SIMULATIONS AT BNL

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- Introduction
- Multi-particle Simulation
- What to Simulate Next
- Summary

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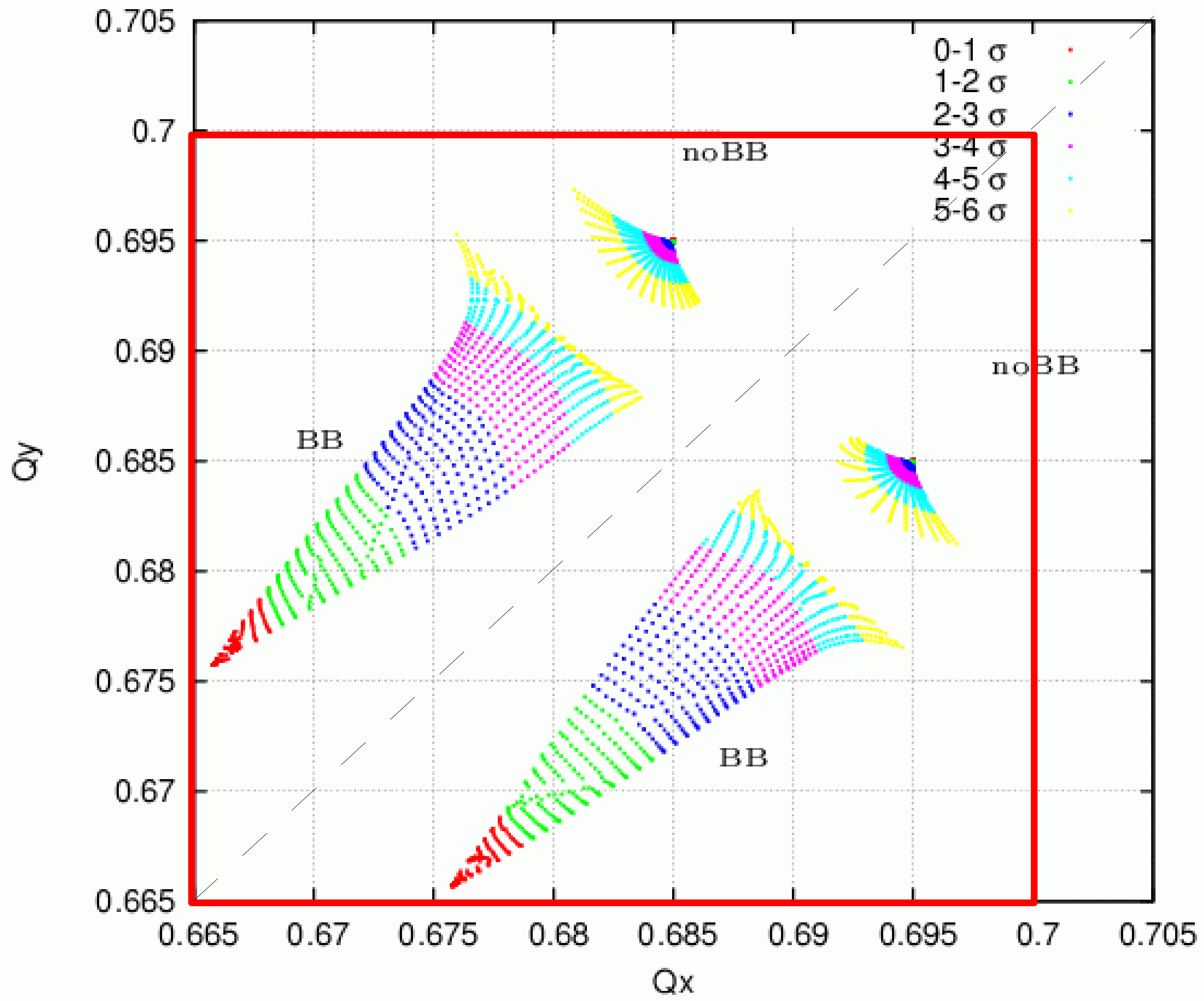
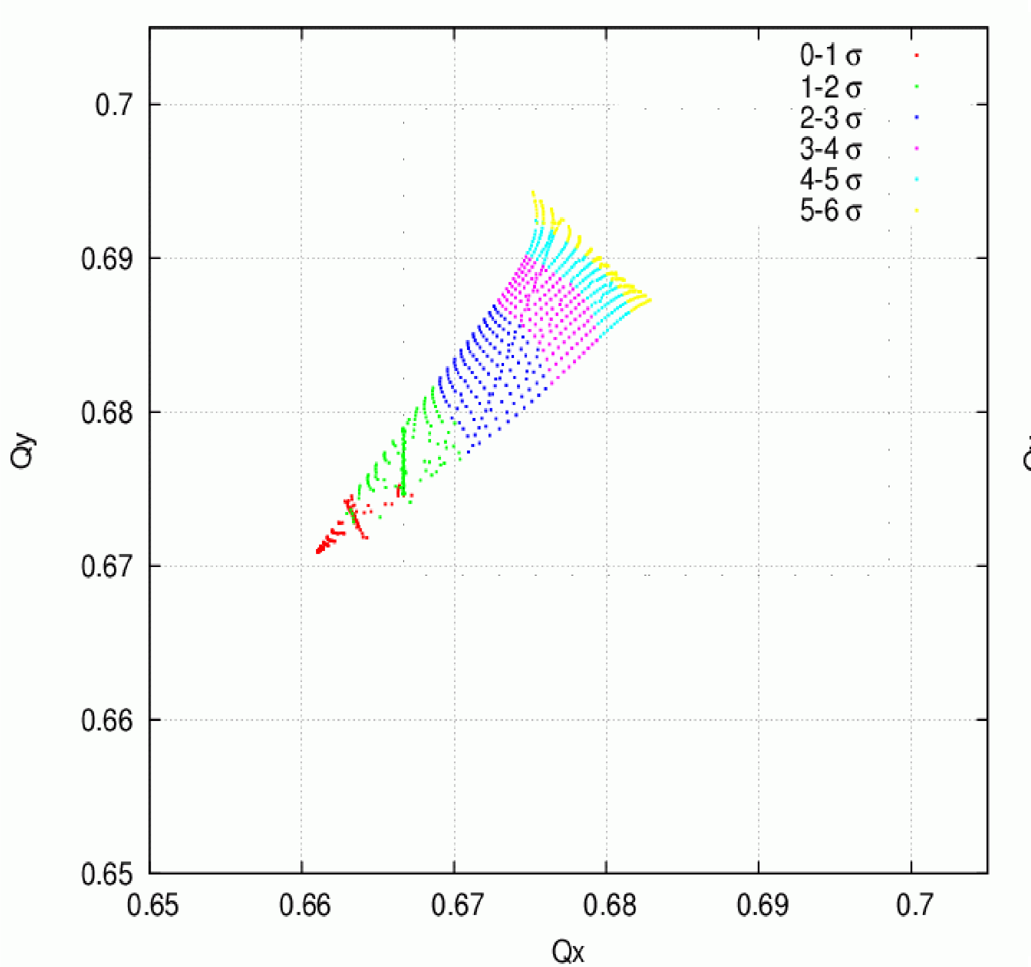
Why RHIC Head-on beam-beam compensation

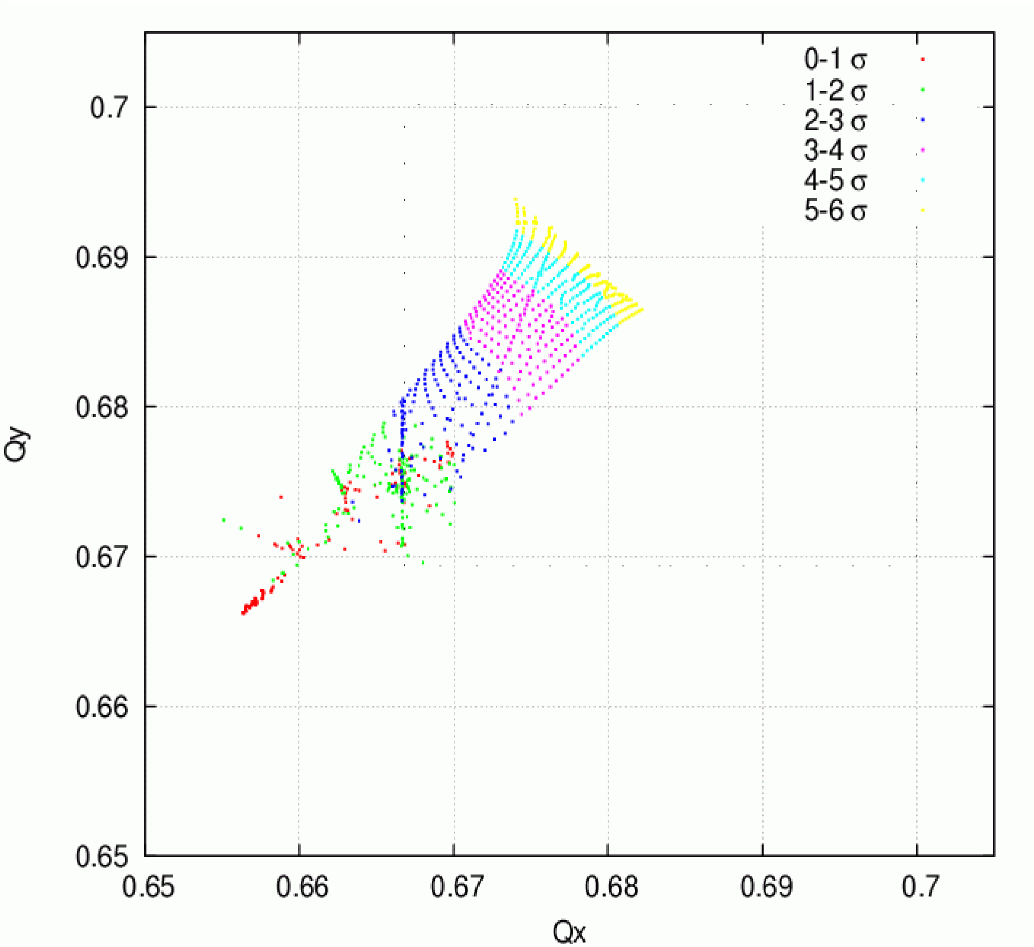


Np=2e11, Enorm=15pi mm.mrad

To increase bunch intensity beyond 2.0e11, or decrease proton emittance below 15 pi, head-on beam-beam compensation is needed due to limited tune space.

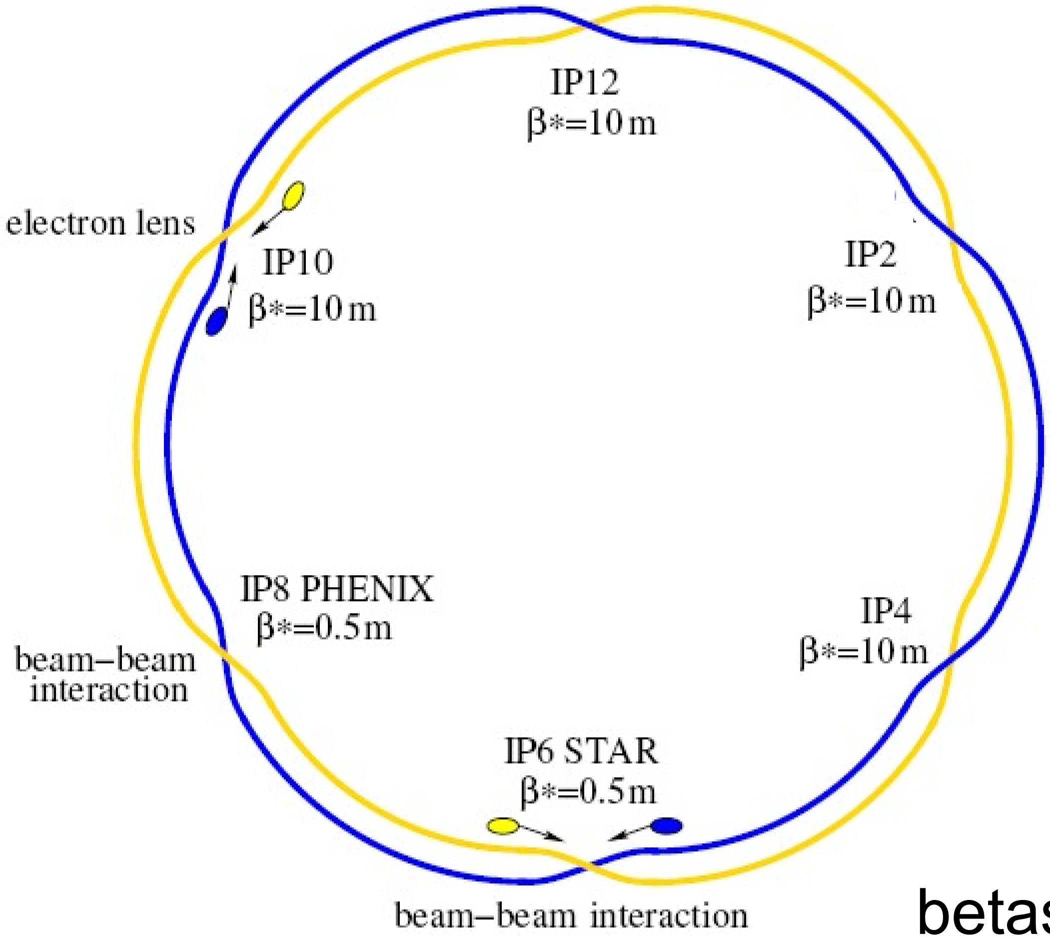


Np=2.5e11, En=15pi, BB only



Np=3.0e11, En=15pi, BB only

Layout of RHIC Head-on beam-beam compensation



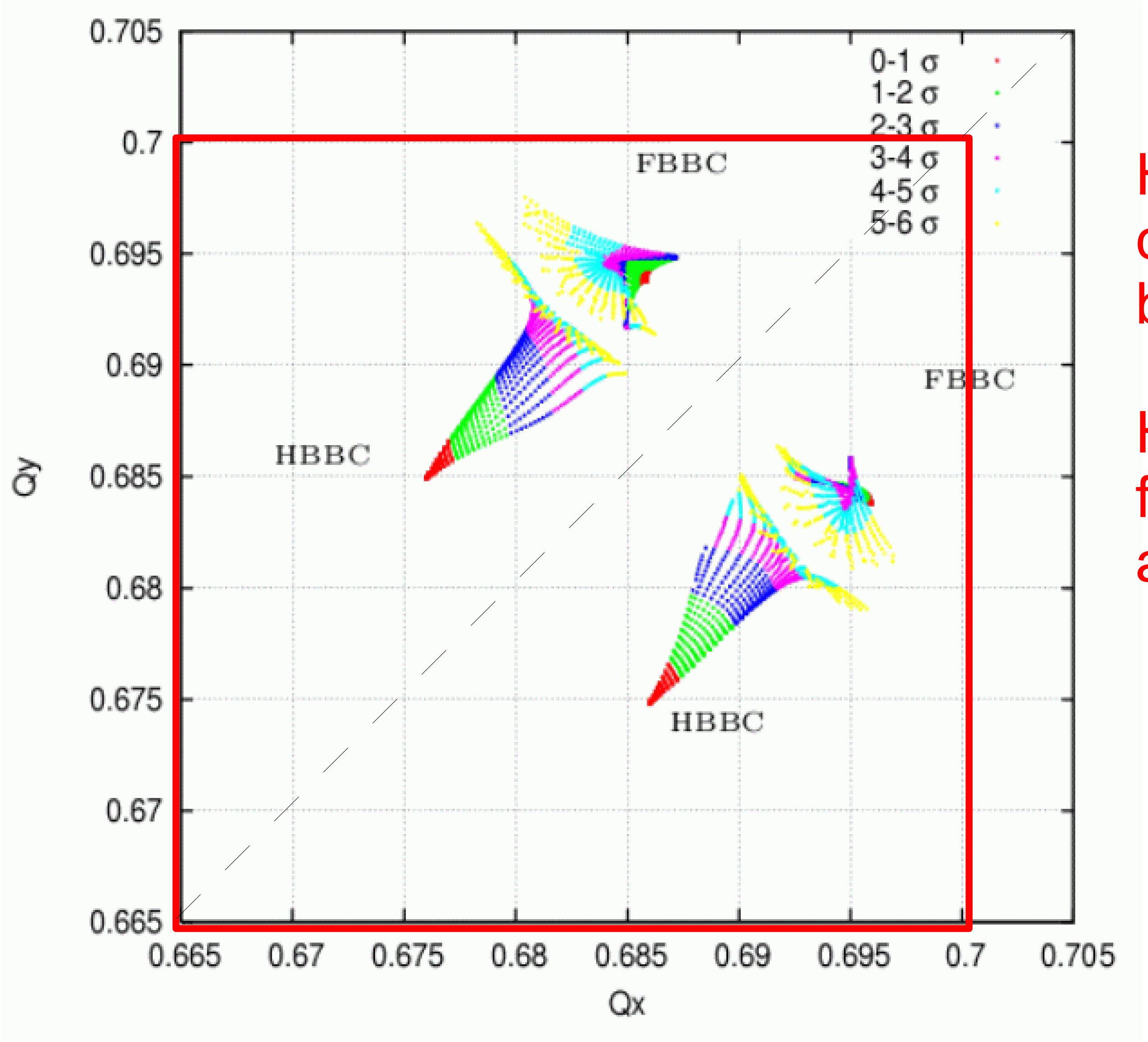
Proton bunches collide at IP6 and IP8 with beta*=0.5m.

Electron-lenses (e-lens) are to be installed at IP10 where beta*=10m.

betas and phase advances at IPs

* NAME	BETX	BETY	MUX (in 2 Pi)	MUY
"CLOCK6"	0.5187613667	0.5196453489	0	0
"CLOCK8"	0.5187613667	0.5196453488	5.304811589	4.294930232
"CLOCK10"	10.71138784	9.785402809	9.517622644	9.779139376

Beam-beam tune spread with compensation



Head-on beam-beam compensation compresses beam-beam tune footprint.

However full compensation folds tun footprint at low amplitude.

HBBC: compensate half p-p beam-beam parameter
FBBC: compensate all p-p beam-beam parameter

What we would like to learn from the simulation

Does head-on beam-beam compensation

Increase **beam-beam parameters** ?
Effect on **beam-beam lifetime** ?
Effect on **emittance growth** ?
==>
Effect on peak Luminosity ?
Effect on integrated Luminosity ?

Parameters of proton beam in simulation

quantity	unit	value
lattice		
ring circumference	m	3833.8451
energy	GeV	250
relativistic γ	-	266
beam-beam collision points	-	IP6, IP8
beam-beam compensation point	-	IP10
$\beta^*_{x,y}$ at IP6 and IP8	m	0.5
$\beta^e_{x,y}$ at IP10	m	10
$\beta^*_{x,y}$ at all other IPs	m	10
proton beam		
particles per bunch N_p	-	2×10^{11}
normalized transverse rms emittance $\epsilon_{x,y}$	mm·mrad	2.5
transverse rms beam size at collision points $\sigma^*_{x,y}$	mm	0.068
transverse rms beam size at e-lens $\sigma^e_{x,y}$	mm	0.40
transverse tunes (Q_x, Q_y)	-	$(28.695, 29.685)$ and $(28.685, 29.695)$
chromaticities (ξ_x, ξ_y)	-	$(1, 1)$
beam-beam parameter per IP $\xi_{p \to p}$	-	-0.01
longitudinal parameters		
		Acceleration rf system
harmonic number	-	360
rf cavity voltage	kV	300
rms longitudinal bunch area	eV·s	0.17
rms momentum spread	-	0.14×10^{-3}
rms bunch length	m	0.44

Simulation code and beam-beam modeling

SixTrack:

Simplectic / Fast

Two major modifications:

Multi-particle tracking

modify beam-beam parameters turn by turn

Optical tracking (between IPs):

Element-by-element

best RHIC lattice model used

Beam-beam model:

Currently 4-D transverse kick

Will upgrade to 6-D treatment

Computation Facilities and Environment:

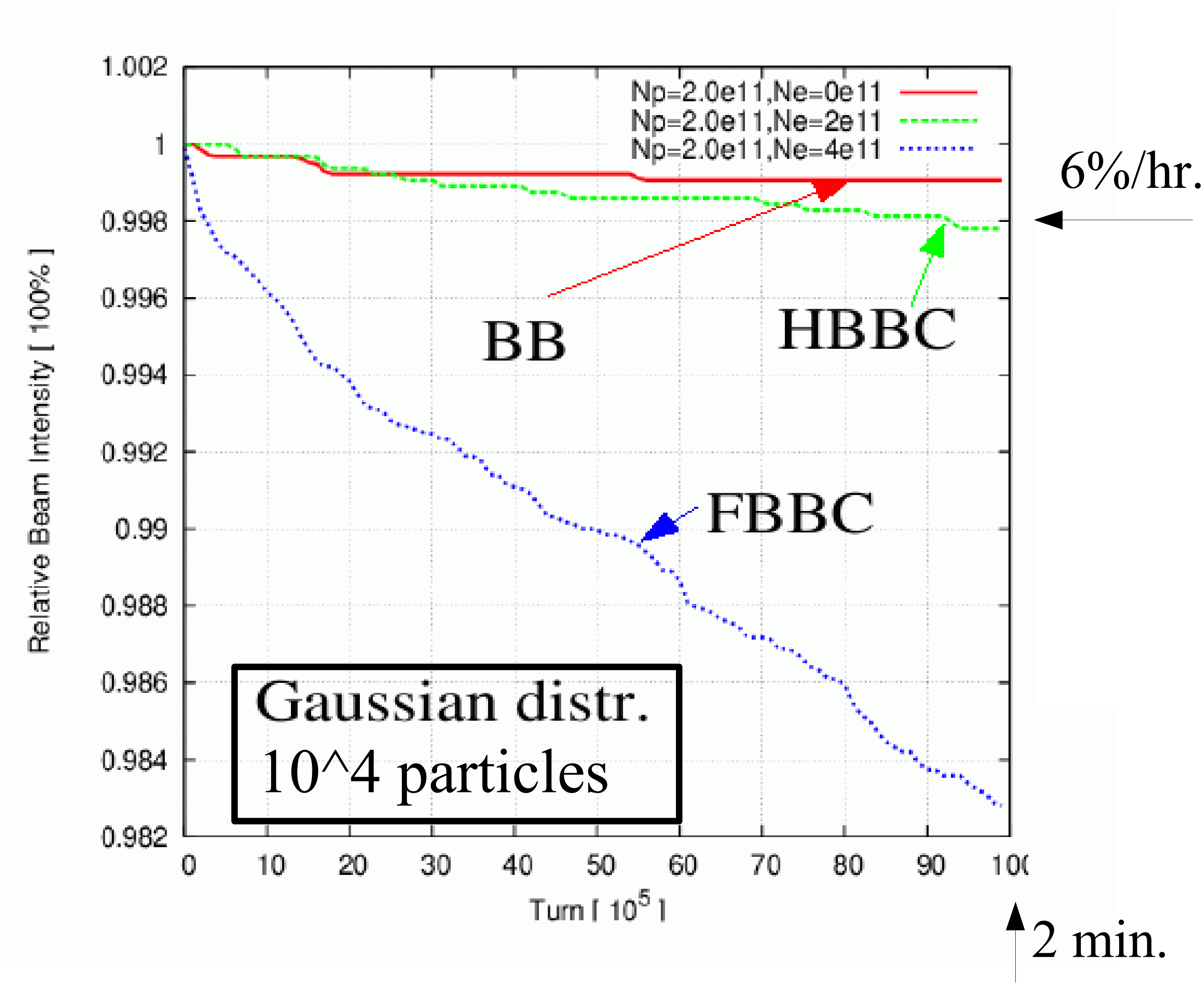
We developed an MPI version of sixtrack that makes an efficient use of the supercomputer facilities without overloading the queue management system as compared with the pc farm approach.

We run 5M turns for 1600 particles using 400 processes for 16 particles each in one single job.

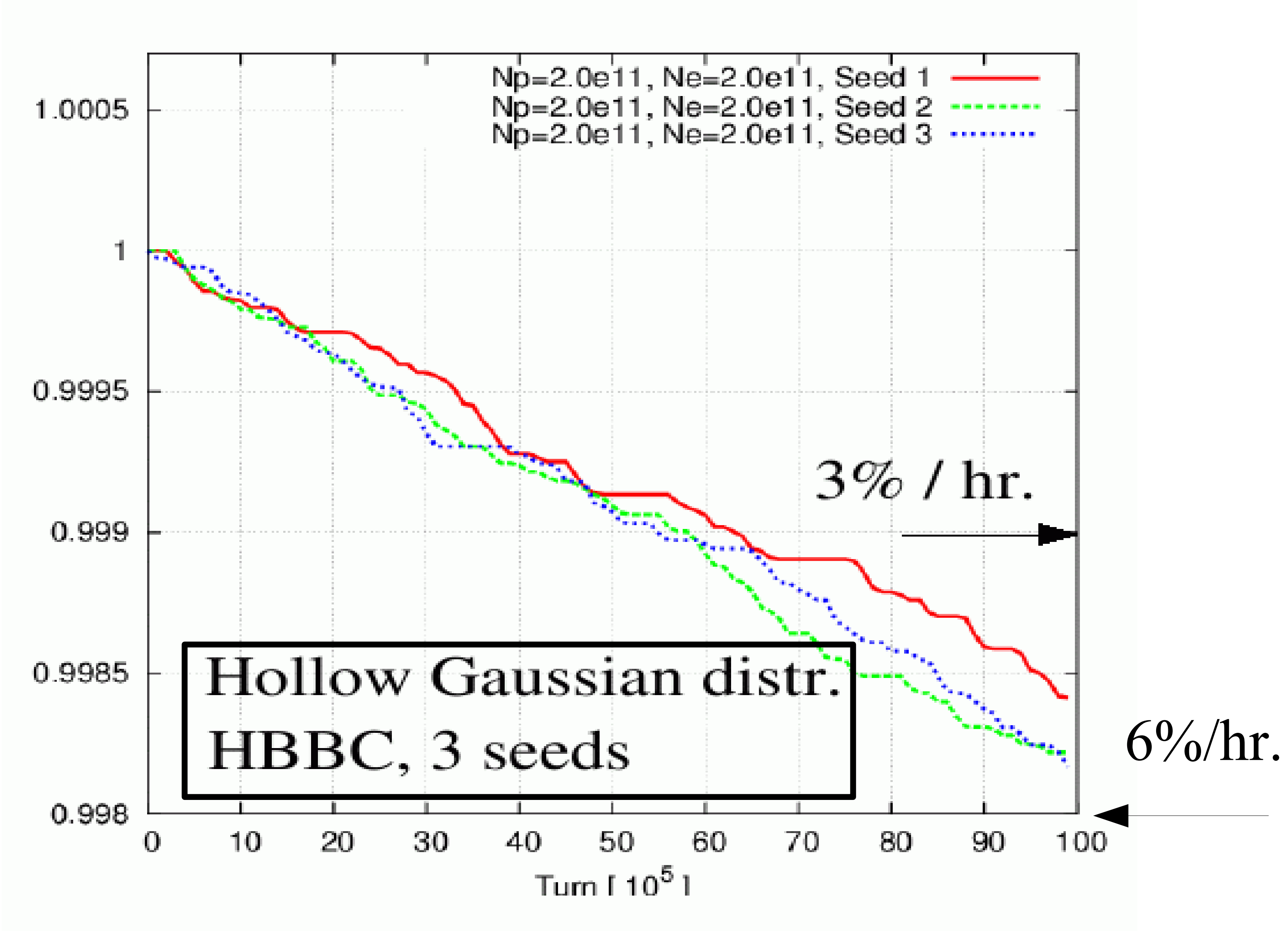
On Franklin the average time is 2.5h for completing a job.

A remaining sixtrack limitation for large scale problem is the usage of too many small files (100 per process) resulting in an unnecessary overload of the file system. Mitigation solution are under study.

Particle Loss can be used as a measure for comparison

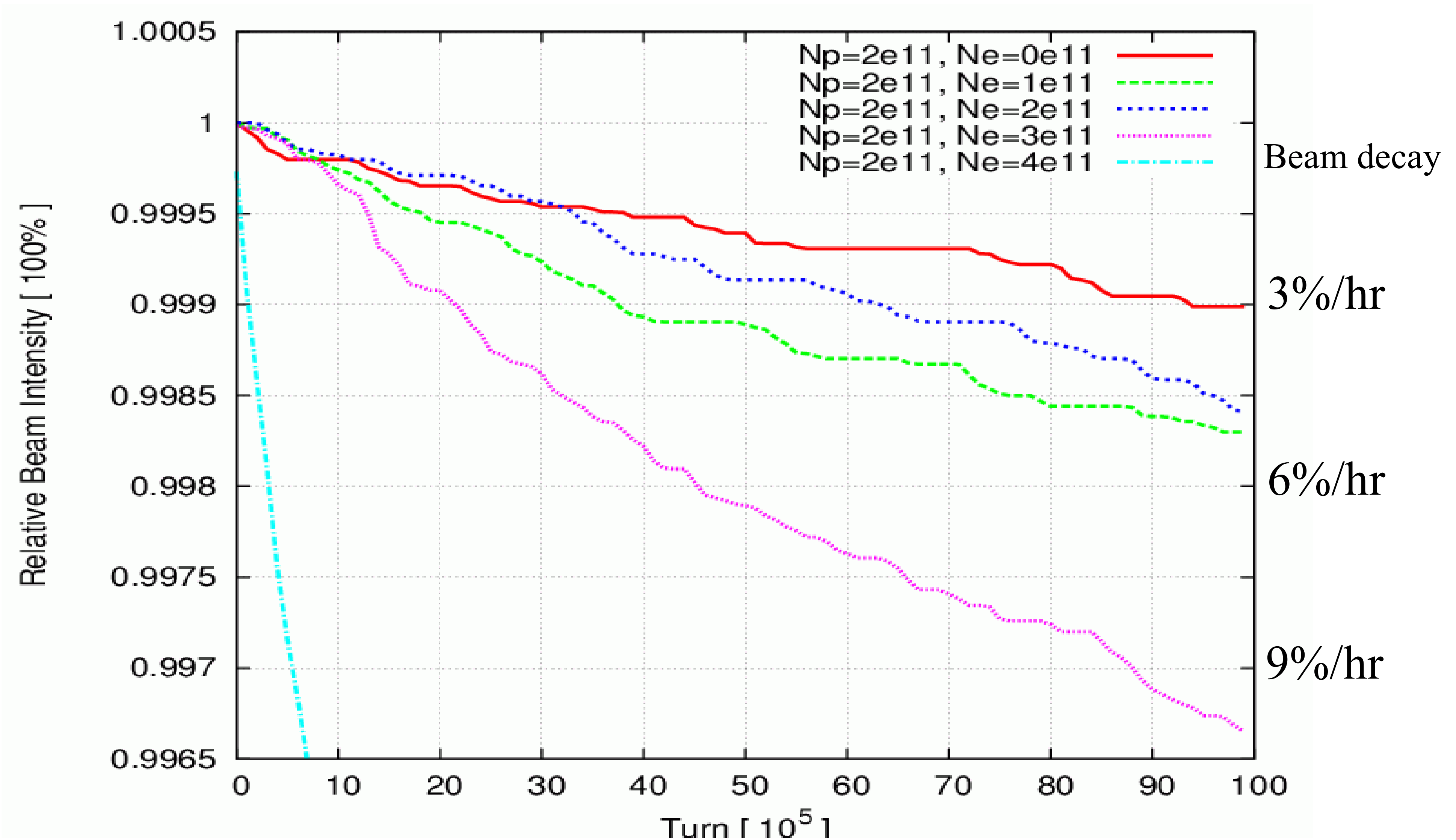


For bunch intensity Np=2e11, simulation shows head-on BBC is not needed. The full beam-beam compensation gives worst beam lifetime.



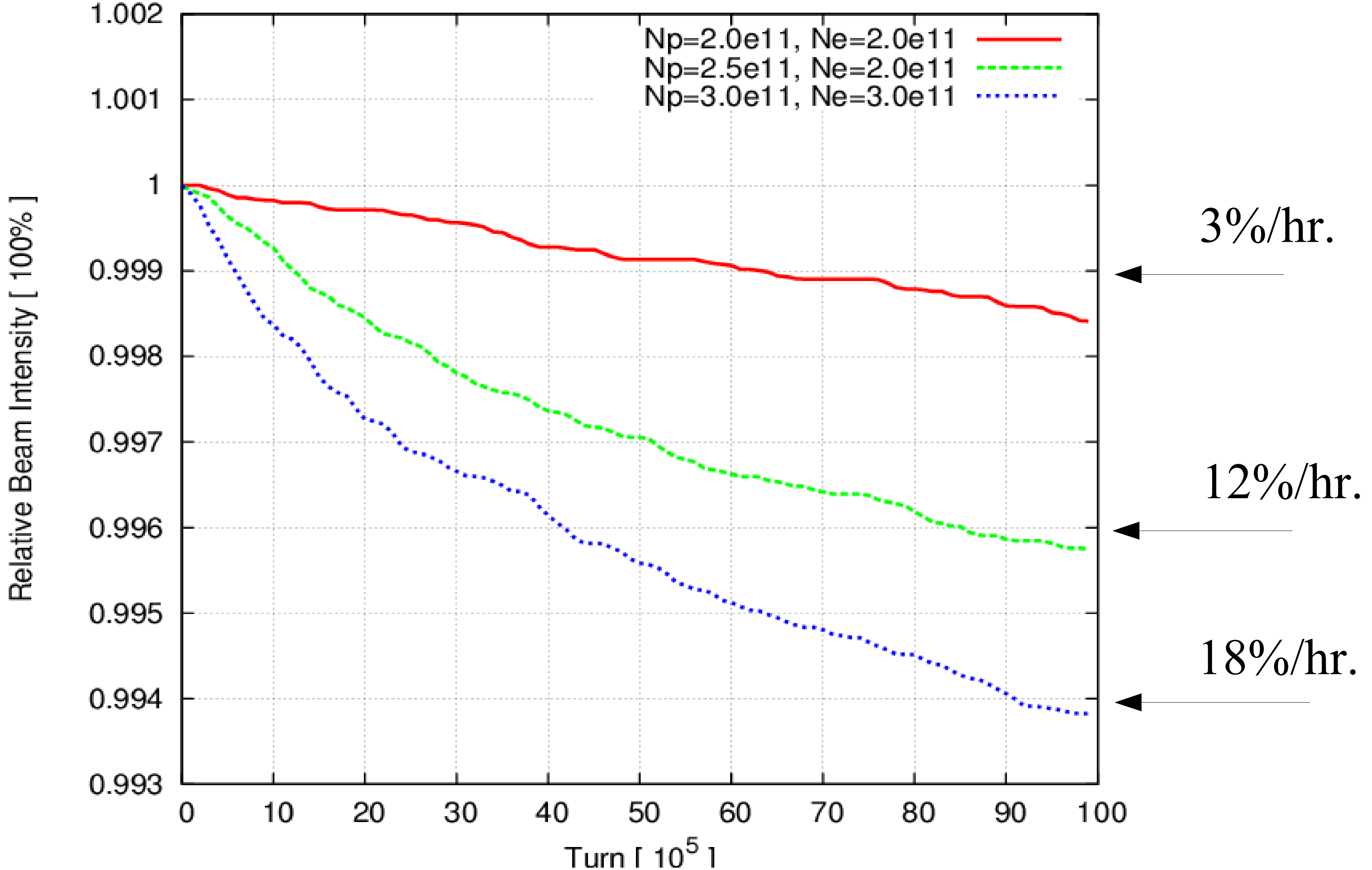
To save computation time a hollow Gaussian initial distribution is used.

Beam decay versus compensation strength

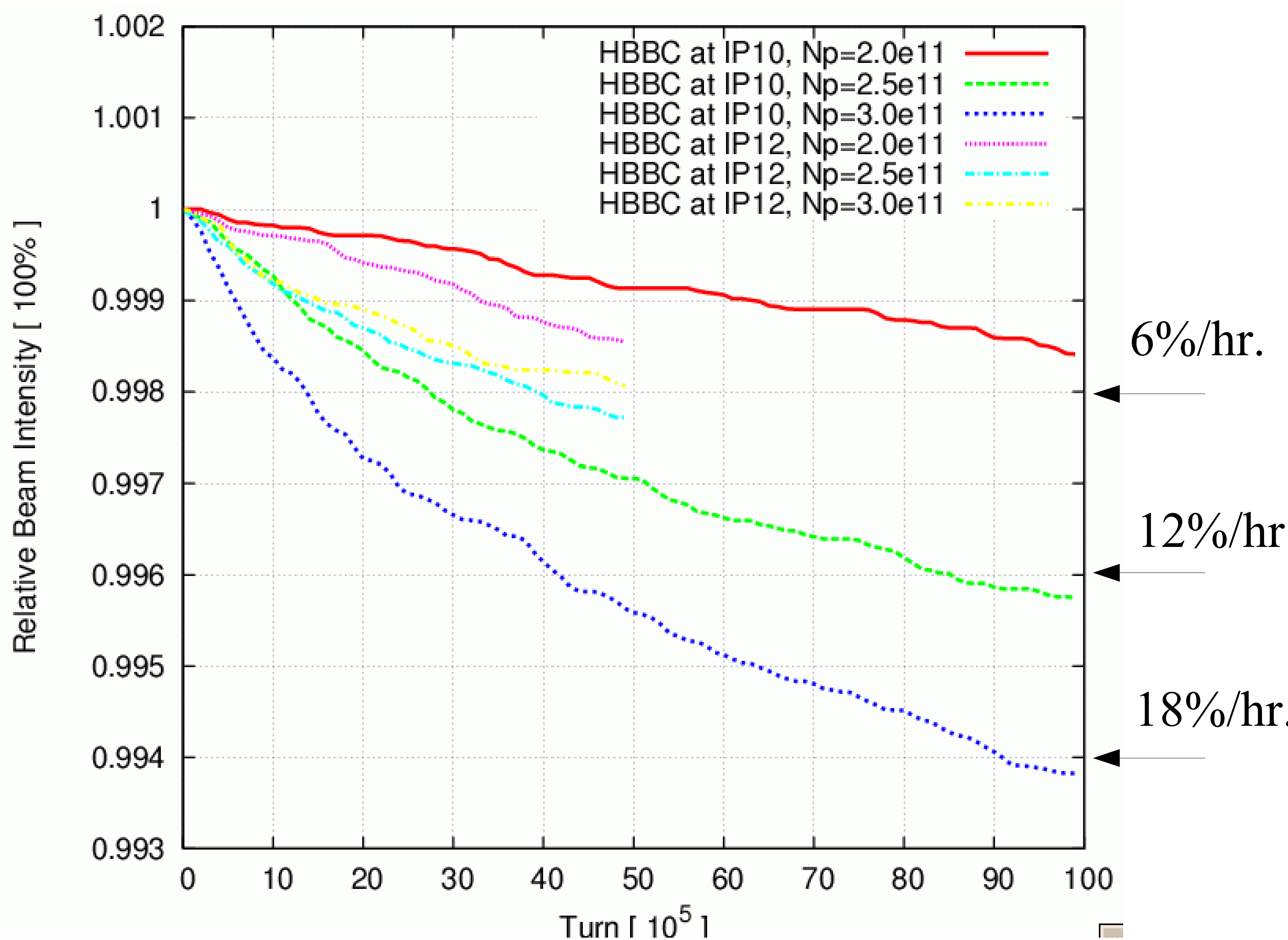


From simulation, stronger than HBBC has negative effect on beam lifetime.

With increased bunch intensity Np=2.5e11, 3.0e11

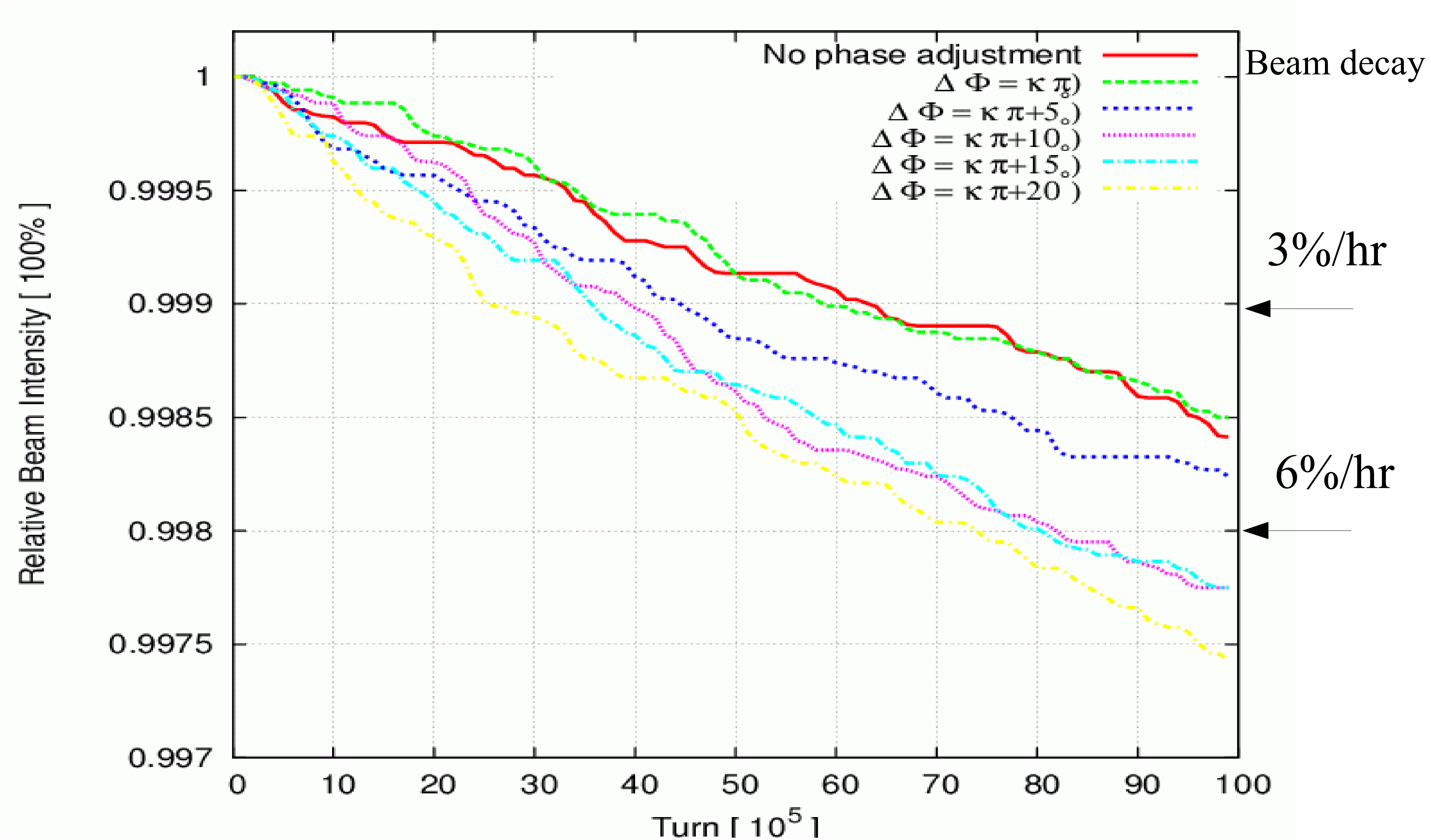


Beam decays if e-lenses at IP12



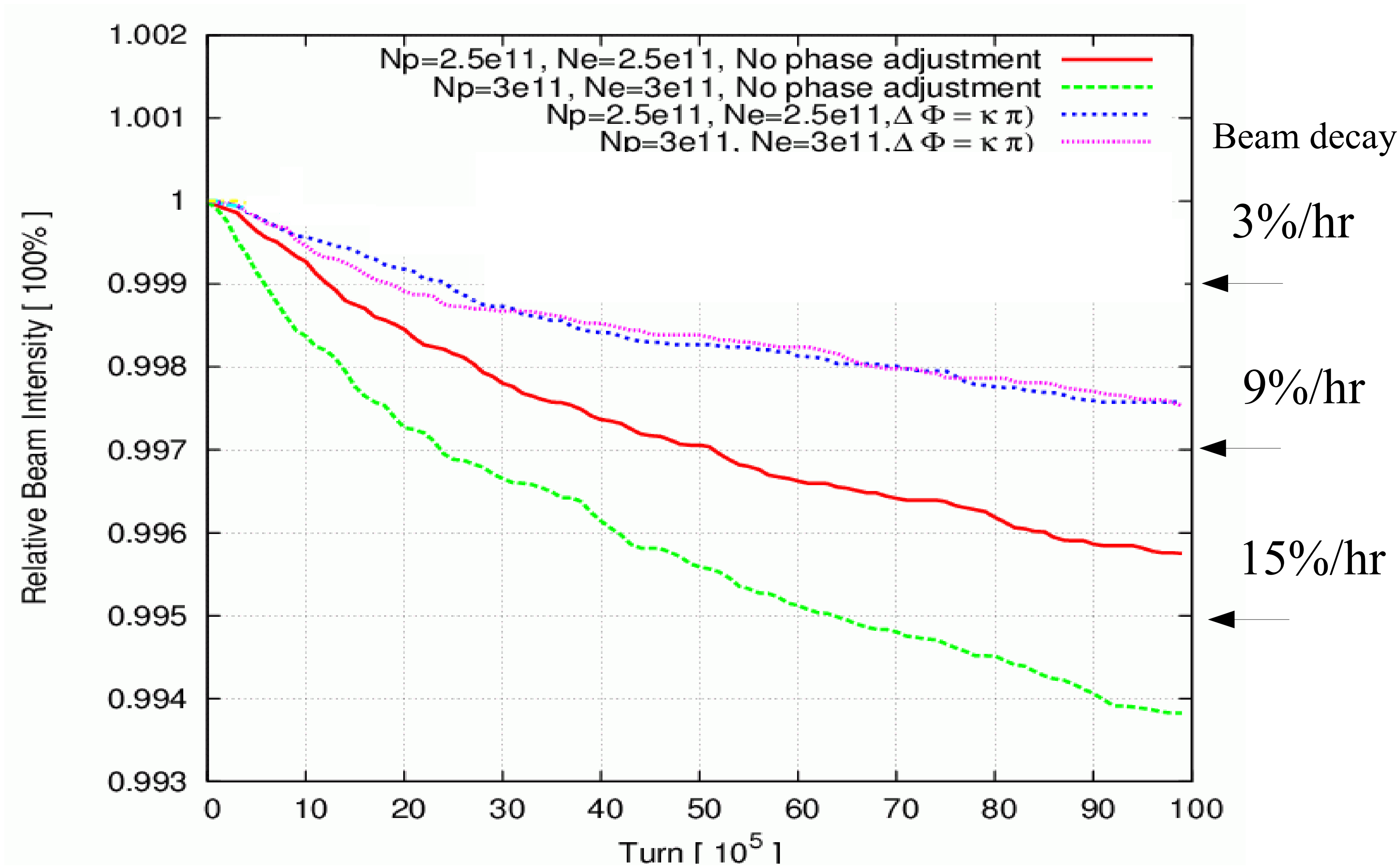
For Np=2.5e11, Np=3.0e11, e-lens at IP12 gives better beam-beam lifetime.

Beam decay versus phase advances between IP8 and IP10



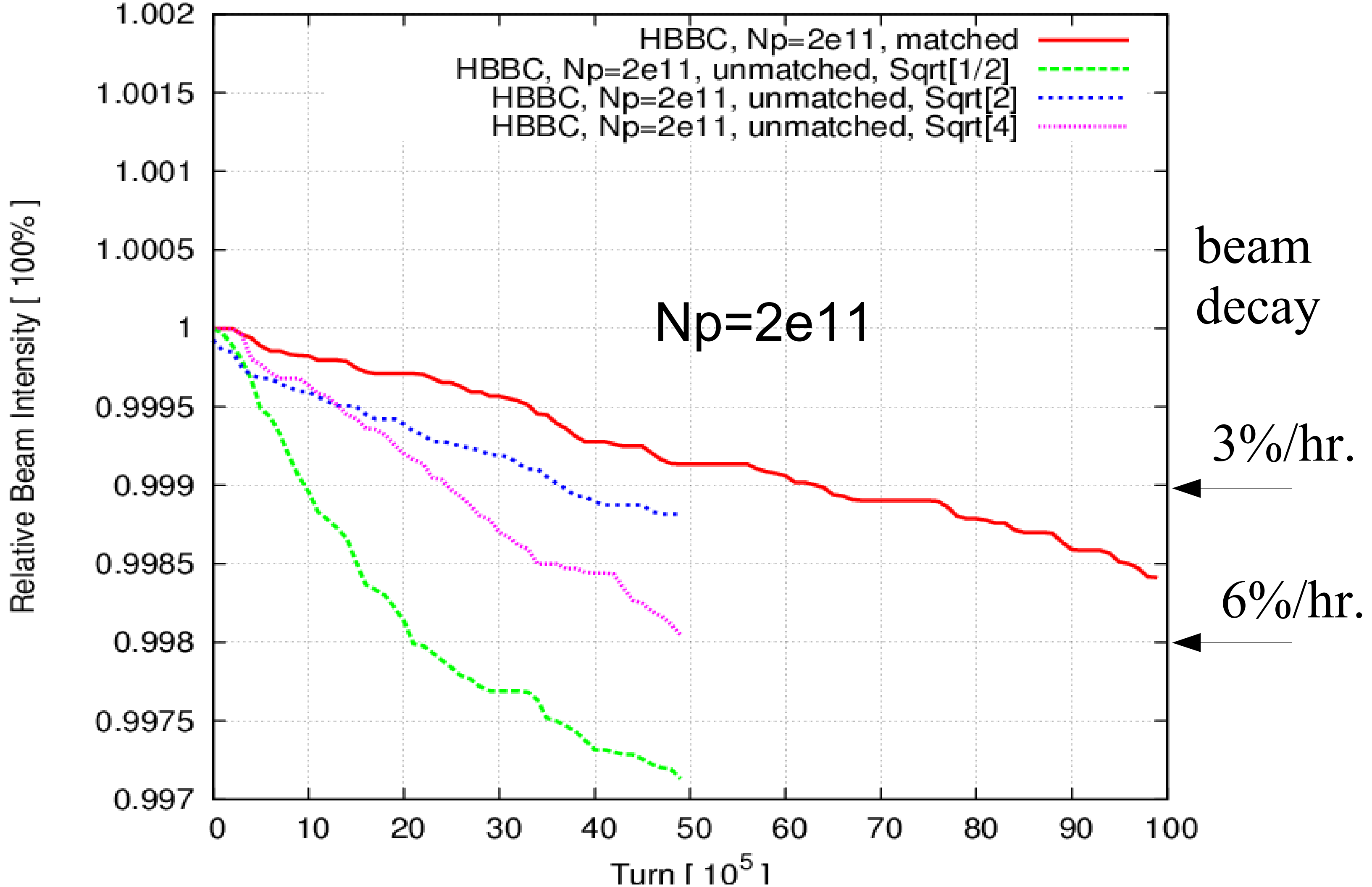
For Np=2e11, default phase advance is likely OK for e-lenses at IP10

Beam decay with phase adjustment for cases Np=2.5e11, 3.0e11

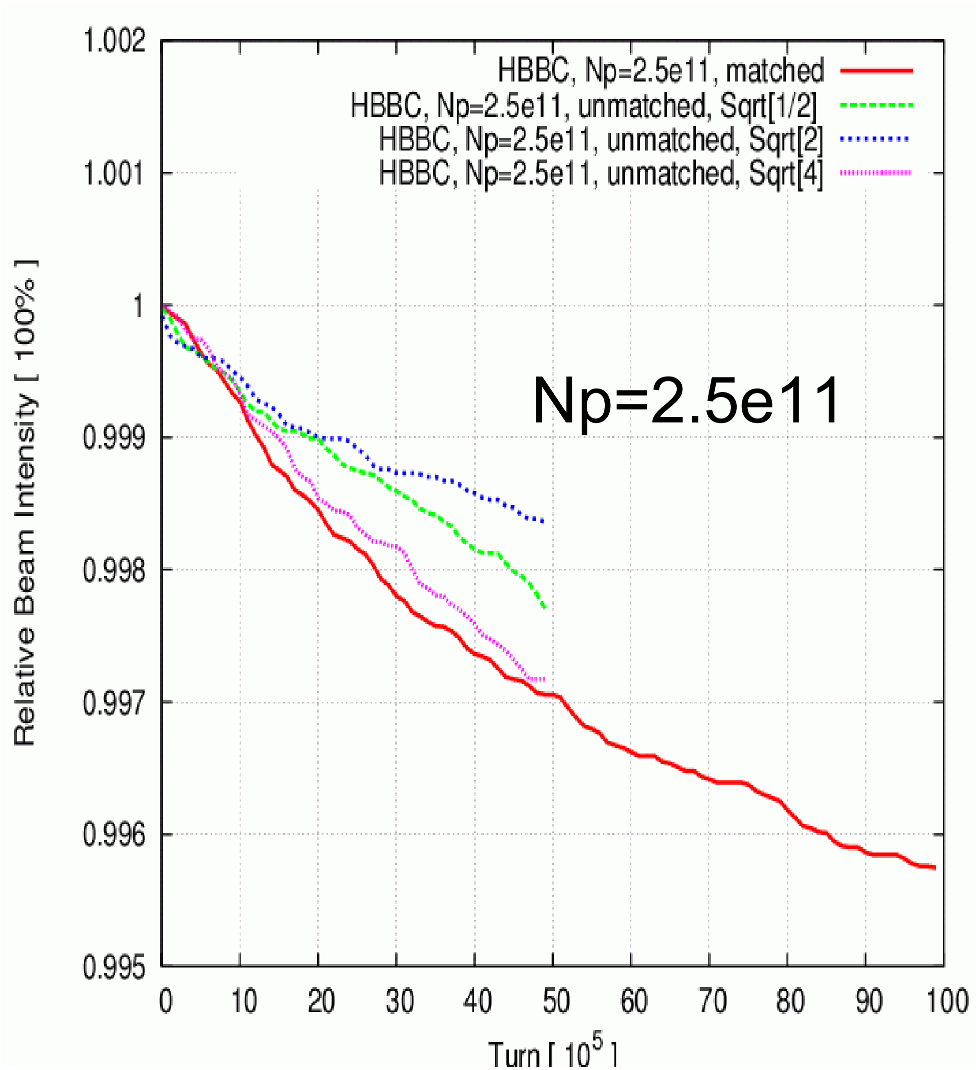


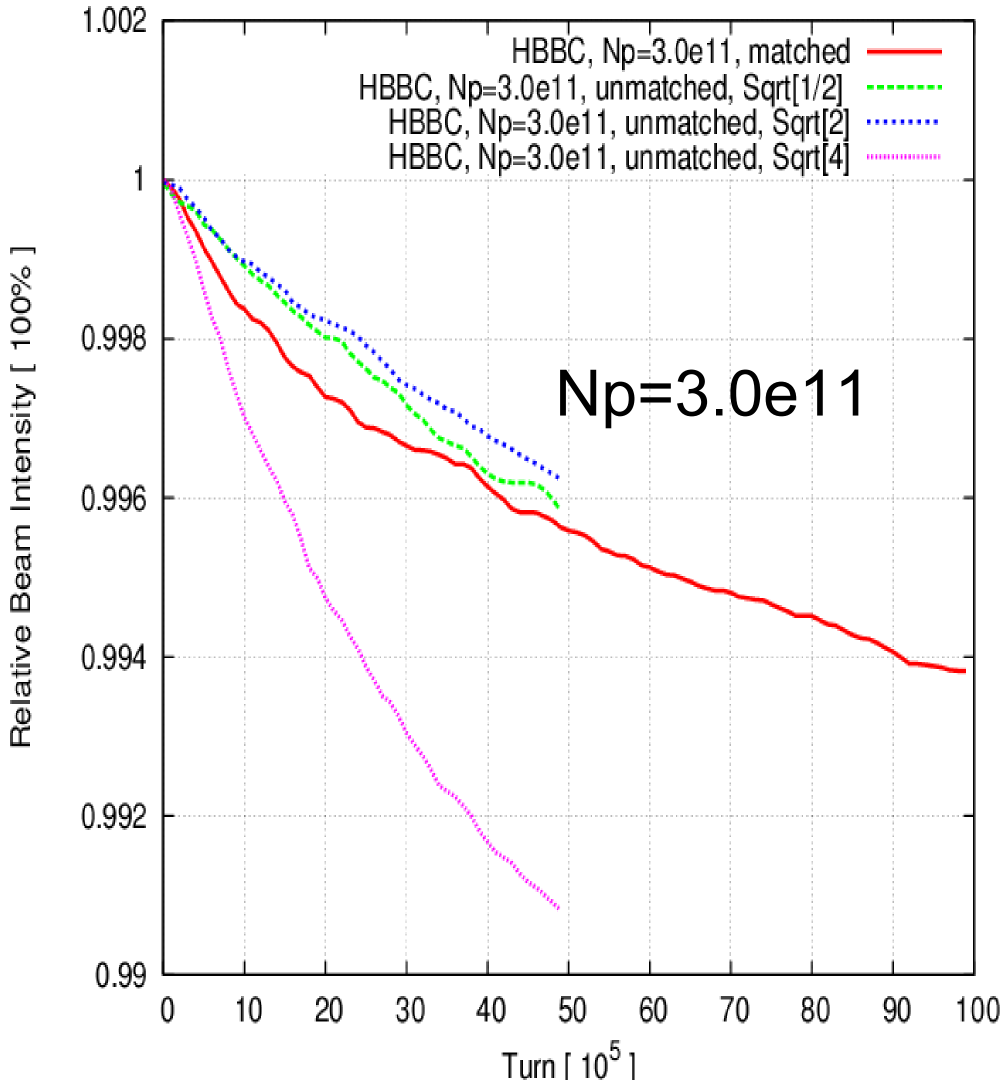
Some improvement in beam lifetime with phase adjustment and Np>2e11

Beam lifetime with unmatched electron beam sizes



For Np=2e11, unmatched electron beam size gives worse lifetime





Electron size enlarged by Sqrt[2] gives better lifetime for Np=2.5e11 and 3.0e11.

What to simulate next

- Effect of errors and noises in p-e interaction

  E-beam intensity Ne
  E-beam transverse emittances
  Alignments of p-e beams

- 6-D beam-beam interaction

  Re-do selected studies

  6-D BB treatment will give less beam decay compared to 4-D BB treatment

Summary

1. Head-on beam-beam compensation can efficiently reduce the beam-beam tune spread and gives possibility to increase beam-beam parameter. Head-on beam-beam with Np > 2.0e11 needs head-on beam-beam compensation. To avoid strong nonlinearities introduced by the compensation, only partial compensation should be considered.

2. Effect of betatron phases advances between IP8 and the head-on compensation point (IP10) was studied. Simulation shows that phase advances close to K*Pi improve the beam-beam lifetimes for bunch intensity Np=2.5e11 and 3.0e11. Simulation shows a slight enlarged electron transverse beam sizes also improve the beam-beam lifetimes for Np=2.5e11 and 3.0e11 cases.

3.The effects of the fluctuations in the electron beam parameters are being studied. The 6-D beam-beam treatment will be included in the simulation code.