ZDR e-ring Progress and Plan

1. ZDR1.0 reference lattice release and machine parameters.
   - Main Features
   - Round and flat beam collisions
   - Polarized round beam test
   - Machine parameter table
2. Work plan and status
   - Linear Lattice
   - Interactions with others
   - Dynamic aperture
   - Collective effects, Beam-beam effects

1. ZDR1.0 reference lattice release and machine parameters

1.1 Main features (Changes, Clarification):

Aug. 1: 10 GeV(Low emittance) (D.Wang)

Aug. 13: 5 GeV(High emittance) with HERA type IR.

- Circumference 1/3 of RHIC (emittance, radiation)
- FODO structure (Dynamic Aperture)
- Emittance Range (Round-flat beam, protons/bunch)

Work pushed forward from both BNL and Bates sides.

- Electron Ring Beam Emittance requirement

	Low Emittance 100 (GeV)Au/10(GeV)e Au/bunch = $1x10^9$	High Emittance 50 (GeV) p/5(GeV)e p/bunch=$1x10^{11}$
Required Round Beam Emittance (nm)	18	46
Lattice Horizontal Emittance (nm) (no coupling)	36	92

1.2 What about flat beam collision?

- Ring beam emittance required for flat beam collision is usually larger than round beam collisions

  Linear beam-beam tune shift (equal beam size):

$$\xi_x^e = \frac{r_e Z N_i}{2\pi\gamma_e \varepsilon_x^e} \frac{1}{(1+k_\sigma)}, \qquad \xi_y^e = \frac{r_e Z N_i}{2\pi\gamma_e \varepsilon_y^e} \frac{1}{(1+\frac{1}{k_\sigma})}$$

$$\xi_x^i = \frac{r_i N_e (v/c)_i}{2\pi Z \varepsilon_{in}} \frac{1}{(1+k_\sigma)}, \qquad \xi_y^i = \frac{r_i N_e (v/c)_i}{2\pi Z \varepsilon_{in}} \frac{1}{(1+\frac{1}{k_\sigma})}$$

$$k = \frac{\varepsilon_y^e}{\varepsilon_x^e}, \qquad k_\sigma = \frac{\sigma_y^i}{\sigma_x^i} = \frac{\sigma_y^e}{\sigma_x^e} < 1 \qquad \text{(flat beam, equal size condition)}$$

Usually $k_\sigma \geq k$ (Don't want very small k_σ)

Then ξ_x^i and ξ_y^e will be more critical.

Using ξ_y^e for beam-beam tune shift limit, desired emittance:

$$\varepsilon_{of} = \frac{(1+k)}{k\left(\frac{1}{k_\sigma}+1\right)}\varepsilon_0$$

ε_0 : H - emittance, nocoupling, round beam.

ε_{of} : H - emittance, nocoupling, flat beam.

HERA parameter (upgrade operation): k_σ =30/112, k~0.17, k_σ/k=1.58

$$\varepsilon_{0f} = 2.2\varepsilon_0$$

.

- Luminosity compare to round beam (beam-beam tune shift limits, equal beam size).

$$L = \pi f_c \frac{\xi_x^i \xi_y^e}{(\nu / c)_i} \frac{\gamma_e}{r_e r_i} \frac{\varepsilon_{in}}{\sigma_y} \frac{\varepsilon_x^e}{\sigma_x} k(1+k_\sigma)(1+\frac{1}{k_\sigma})$$

If tune shift limits and "aperture limits" are the same

for round and flat beam collisions?

$$L_{flatbeam} = L_{roundbeam} \frac{k}{4}(1+k_\sigma)(1+\frac{1}{k_\sigma}) = K_{f-r} L_{roundbeam}$$

Example: $k_\sigma/k=1$ (Maximum K_{f-r})

k	0.1	0.2	0.5	1
K_{f-r}	0.30	0.39	0.56	1

This comparison is illusory. ($\beta*$, chromaticity, σ' …)

1.3 Polarized Round Beam Test at Bates

Purpose: highly polarized, round electron beam.

Key: Separate beam x-y coupling and spin rotation.

Bates South Hall Ring environment:

Spin direction in horizontal plan, pure longitudinal at IR straight with 180^0 spin rotator at opposite straight of the ring.

Method: Adjust solenoid ~1kgm at IR straight to couple X-Y motion for round beam.

Check effects on beam polarization.

1.4 Machine Parameters

	ZDR1.0-10GeV 2003	ZDR1.0-5GeV 2003	e-RHIC 02(sup. B)	SLAC HER	KEKB HER
Circumference(m)	1277.91	1277.91	958.65	2200.00	3016.26
Energy (GeV)	10	5	10	9	8
Bending radius(m)	81.0162	81.0162	58	165	88.95
Bunch Spacing (ns)	35.52	35.52	35.71	16.8/8.4/4.2	1.97
Bunch spacing(m)	10.65	10.65	10.71	1.26	0.59
Number of bunches	120.00	120.00	90.00	415/831/1658	5000
Bunch population	1.00E+11	1.00E+11	1.00E+11		1.40E+10
Beam current(A)	0.45	0.45	0.45	3.00	1.1
Arc Cell	FODO	FODO	FODO	FODO	2.5π Cell noninterlea
Harmonic Number	2028	2028	1169	3492	5120
RF frequency MHz	475.8	475.8	365.7	476	508.9
Energy loss/turn (MeV)	11.44	0.72	15.26	3.52	3.5
			(+supper B) 21.26		
Accelarting voltage(MV)	30	10	30	14	20
Synchrotron tune	0.04	0.034		0.0449	0.011
Total rad. Power(MW)	5.13	0.32	9.57(with S.B)	10.56	3.85
Syn. Rad. Power/m (KW) in Arc	9.63	0.60	18.78	10.19	6.89
from normal bend					
Self-pola. Time at 10GeV(minutes)	22.03	704.85	8.47		
Emittance-x, no coupling (n m.rad)	30.7	93.8	65	49	25
Beta function at IP (cm) y/x	10./10	10./10	10./10	1.5/50	1./33
Round Beam size at IP(um)	38.73	67.08	57.01		
Momentum compaction α	1.79E-03	9.12E-03			2.00E-04
Momentum spread	9.53E-04	4.76E-04	1.60E-03	6.00E-04	6.70E-04
Bunch length (cm)	1.72	3.2	2	1.1	0.4
S.R. damping time(x) (mS)	7.4	58.6	4.2	37.7	23
Beta tune Ux	30.579	17.808	27.48	24.62	44.51
Beta tune Uy	28.649	15.722	21.9	23.64	42.29
Natural chromaticity x,y	30nm: x=-61.80, y=-56.38	90nm: x=-44.86, y=-35.89	x=-76, y=-53		

2. Plan of Work (August-September)

2.1 Linear Lattice Design continue:

- **Path length adjustment (C. Tschalaer)**
- Injection
- Phase(tune) adjustment
- RF location
- Wigglers for very large emittance? : Probably not
- Arc ⇔ Dynamic aperture and other requirements

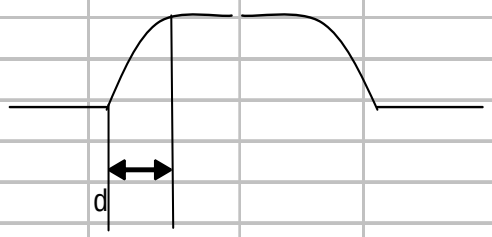
=> Final "ZDR layout" and

Lattice parameter sets vs. emittance

vs. path length…

Difficulties with electron ring path length adjustment of 0.9m!

E0(GeV)	0.93826	C=	2.99793E+08				bunch spacing l=		or for v=c, τ(ns)		
C(m)	3833.73264						10.64926	(m)	35.52		
E(GeV)	γ	β=v/c	T=C/v =3833/v	Tb=T/360	ΔT=(T-T25) r	D(length) m	RF (MHz)	e-RF(MHz	L-ebunch	L eRING	ΔL
25.00	26.64507	0.99930	1.27970E-05	3.55471E-08	8.92558	2.67582	28.1317	478.238	10.6568	1278.81182	0.89194
50.00	53.29013	0.99982	1.27902E-05	3.55283E-08	2.16206	0.64817	28.1465	478.491	10.6511	1278.13594	0.216057
100.00	106.58027	0.99996	1.27885E-05	3.55237E-08	0.47286	0.14176	28.1503	478.554	10.6497	1277.96713	0.047253
200.00	213.16053	0.99999	1.27881E-05	3.55225E-08	0.05066	0.01519	28.1512	478.570	10.6494	1277.92494	0.005063
250.00	266.45066	0.99999	1.27880E-05	3.55223E-08	0.00000	**0.00000**	28.1513	478.572	10.6493	1277.91988	0
1000.00	1065.80266	1.00000	1.27880E-05	3.55221E-08	-0.08443	-0.02531	28.1515	478.575	10.6493	1277.91144	-0.00844
Path length adjustment of electron ring to match proton beam bunches respect to different proton energies 03/21/2003											
Straight Chican or wigglers											
angle(degr	Angle(rad)	R	Rα	P(KW/m)	sin(a)R	h	d	Δ length *	N(4 mag.)		Total L (m)
5.00	0.08727	40.000	3.491	3.96141E+01	3.48623	0.56939625	10	0.040845	22	0.89858124	440



2.2 Interactions with …

- Detector design, RHIC IR, Second e-p ring crossing…(…)
- Polarization analysis (D. Barber)

  (More details in ref. file proposed: RF, orbit kick, thin lens skew Q etc. for simulation.)

Future release: Basic version for general purposes, special for …)

- Polarimeter Requirements (T.Zwart)
- Other system and Engineering:

  Injector (inj. rate, optics, timing…,acceptance)

  RF: location, minimizing chromatic β function changes…

  Vaccum:Syn. Radiation, section move?

2.3 Dynamic Aperture

Criteria: Injection and stored beam lifetime.

Off energy: $\Delta p/p \sim \pm 10\ \sigma_E$, at 10 GeV ~ ±0.01

$\geq 10\sigma_{x,y}$ with errors

On energy : $\geq 20\ \sigma_{x,y}$

Design parameters form :

KEKB $\Delta p/p \sim \pm 0.005(8\sigma_E)$, $\sigma_E \sim 0.00067$ (8 GeV).

PEP-II HER $\Delta p/p \sim \pm 10\ \sigma_{E,,}$ $\sigma_E \sim 0.0006$ (9 GeV).

- Tracking Codes and Method Verification
- DYNA with errors
- DYNA for different emittance (sextupole groups)

  (FODO phase/cell: ~40^0 => 90^0)
- DYNA Improvement update

- Tracking Codes and Method Verification

Tests are going on at both Bates and BNL(J.Cardona) sites.

Codes: MAD, SIXTRACK, MaryLie…

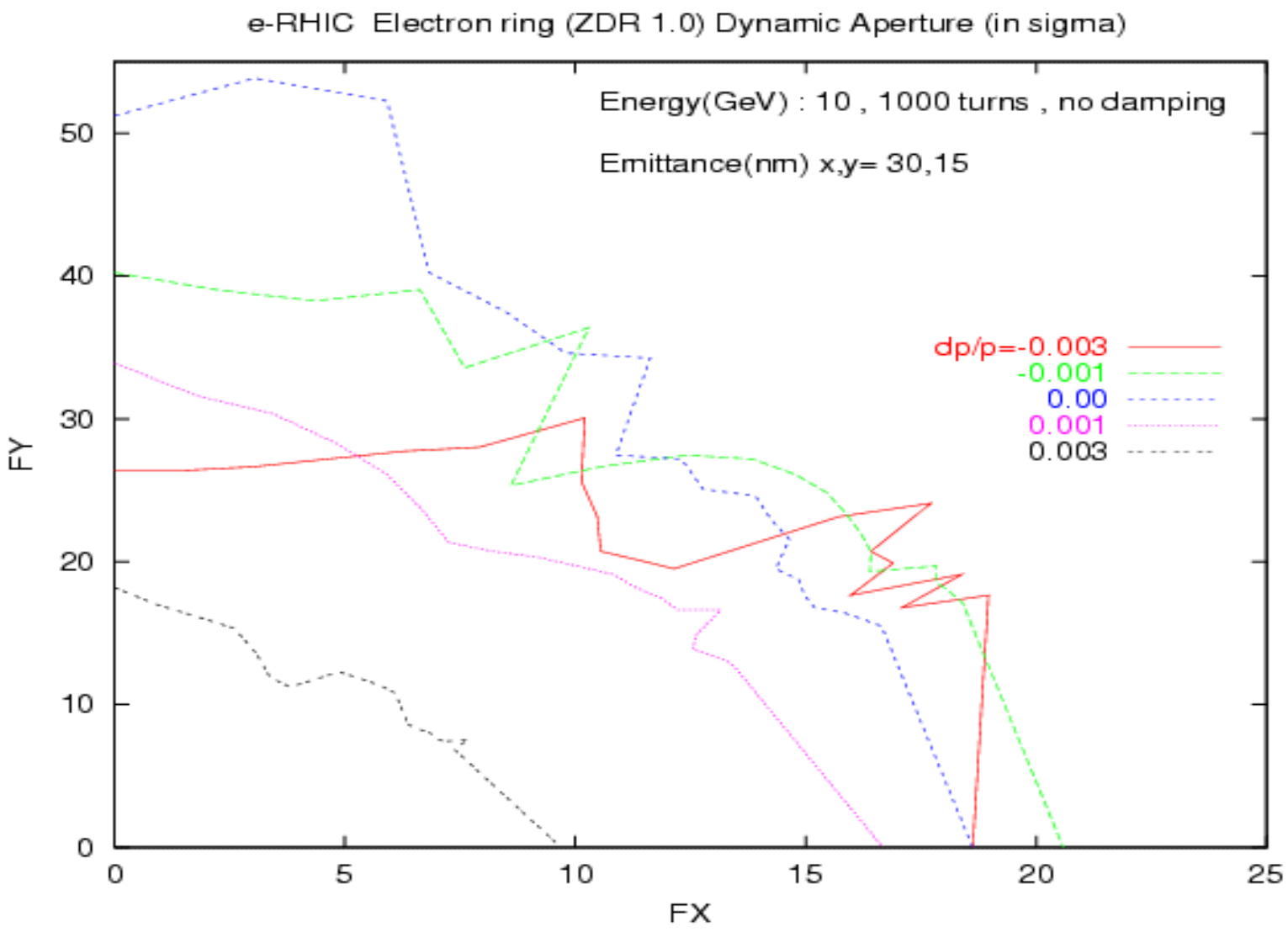
MAD DYNA Tracking:

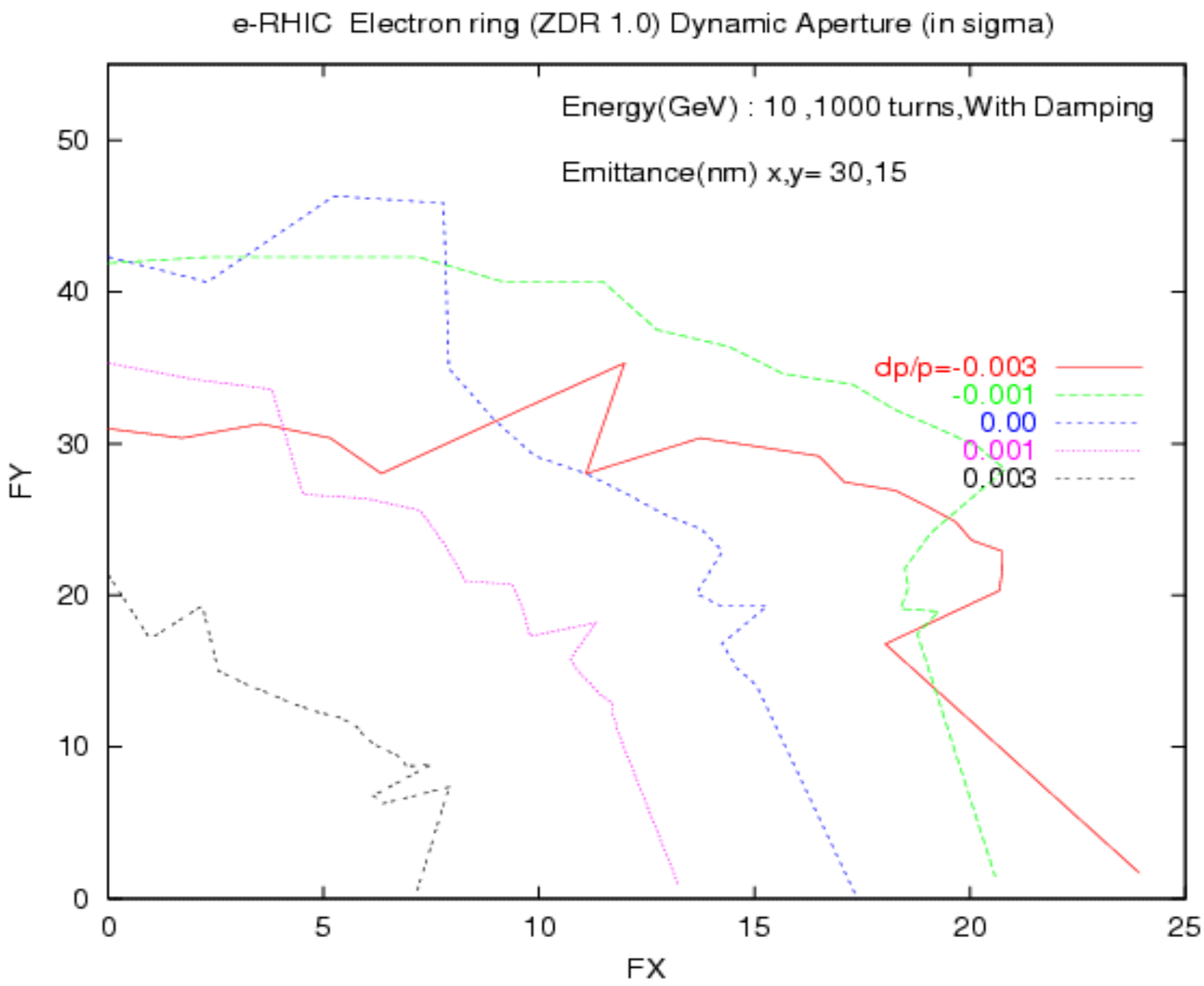
1000 turns (~4 ms) no damping,

1000 turns (~ 0.5 x-damping time at 10 GeV) with damping,

4000 turns (~2 x-damping time at 10 GeV) with damping

? 5 GeV tracking of > 1damping ting(59 ms) requires long computation time and MAD will not be used .


e-RHIC Electron ring (ZDR 1.0) Dynamic Aperture (in sigma)
Energy(GeV) : 10 , 1000 turns , no damping
Emittance(nm) x,y= 30,15
dp/p=-0.003
-0.001
0.00
0.001
0.003
FY
FX
0
10
20
30
40
50
0
5
10
15
20
25


e-RHIC Electron ring (ZDR 1.0) Dynamic Aperture (in sigma)
Energy(GeV) : 10 ,1000 turns,With Damping
Emittance(nm) x,y= 30,15
dp/p=-0.003
-0.001
0.00
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0.003
FY
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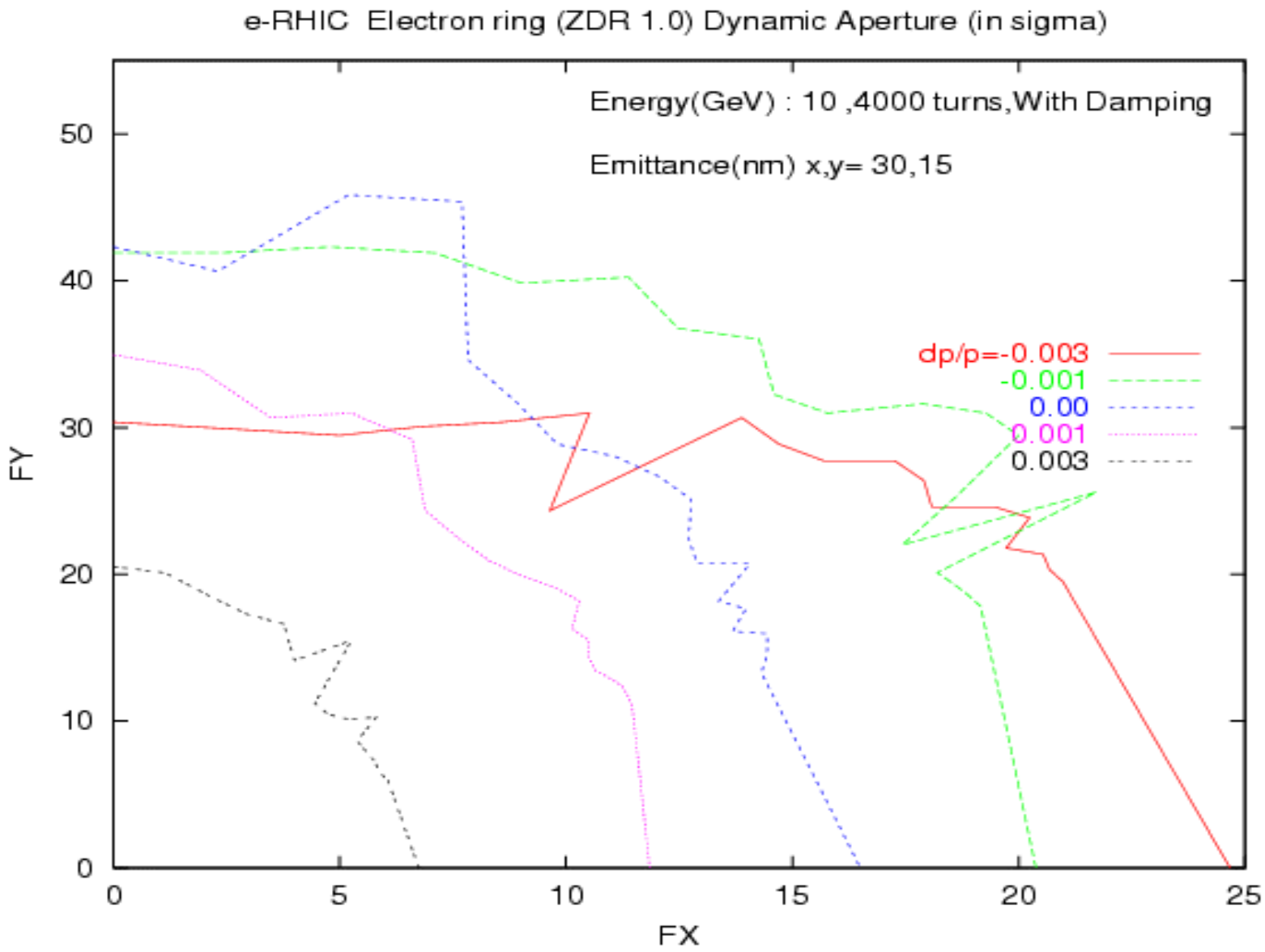
e-RHIC Electron ring (ZDR 1.0) Dynamic Aperture (in sigma)
Energy(GeV) : 10 ,4000 turns,With Damping
Emittance(nm) x,y= 30,15
dp/p=-0.003
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0.001
0.003
FY
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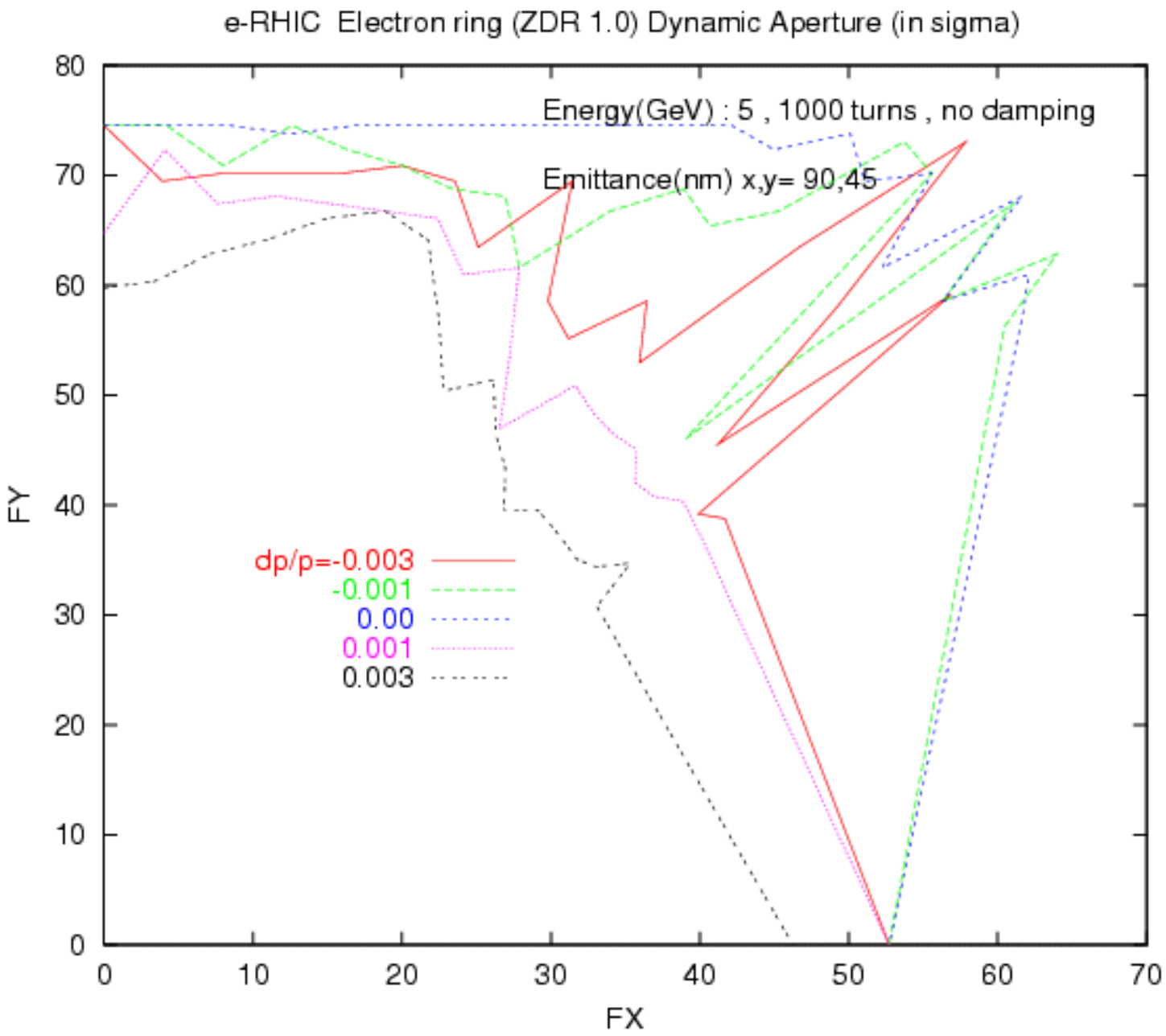
e-RHIC Electron ring (ZDR 1.0) Dynamic Aperture (in sigma)
Energy(GeV) : 5 , 1000 turns , no damping
Emittance(nm) x,y= 90,45
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0.00
0.001
0.003
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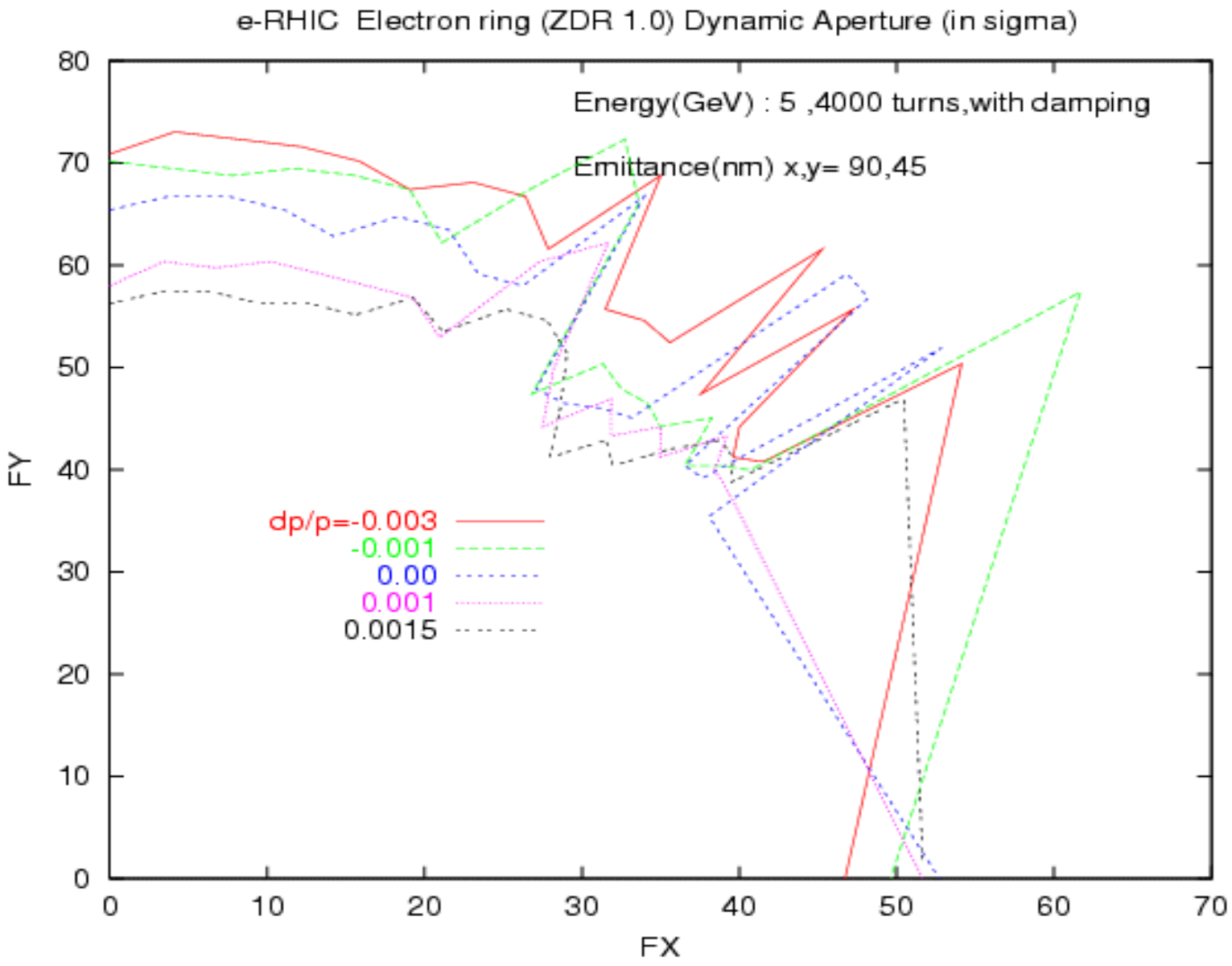
80


e-RHIC Electron ring (ZDR 1.0) Dynamic Aperture (in sigma)
Energy(GeV) : 5 ,4000 turns,with damping
Emittance(nm) x,y= 90,45
dp/p=-0.003
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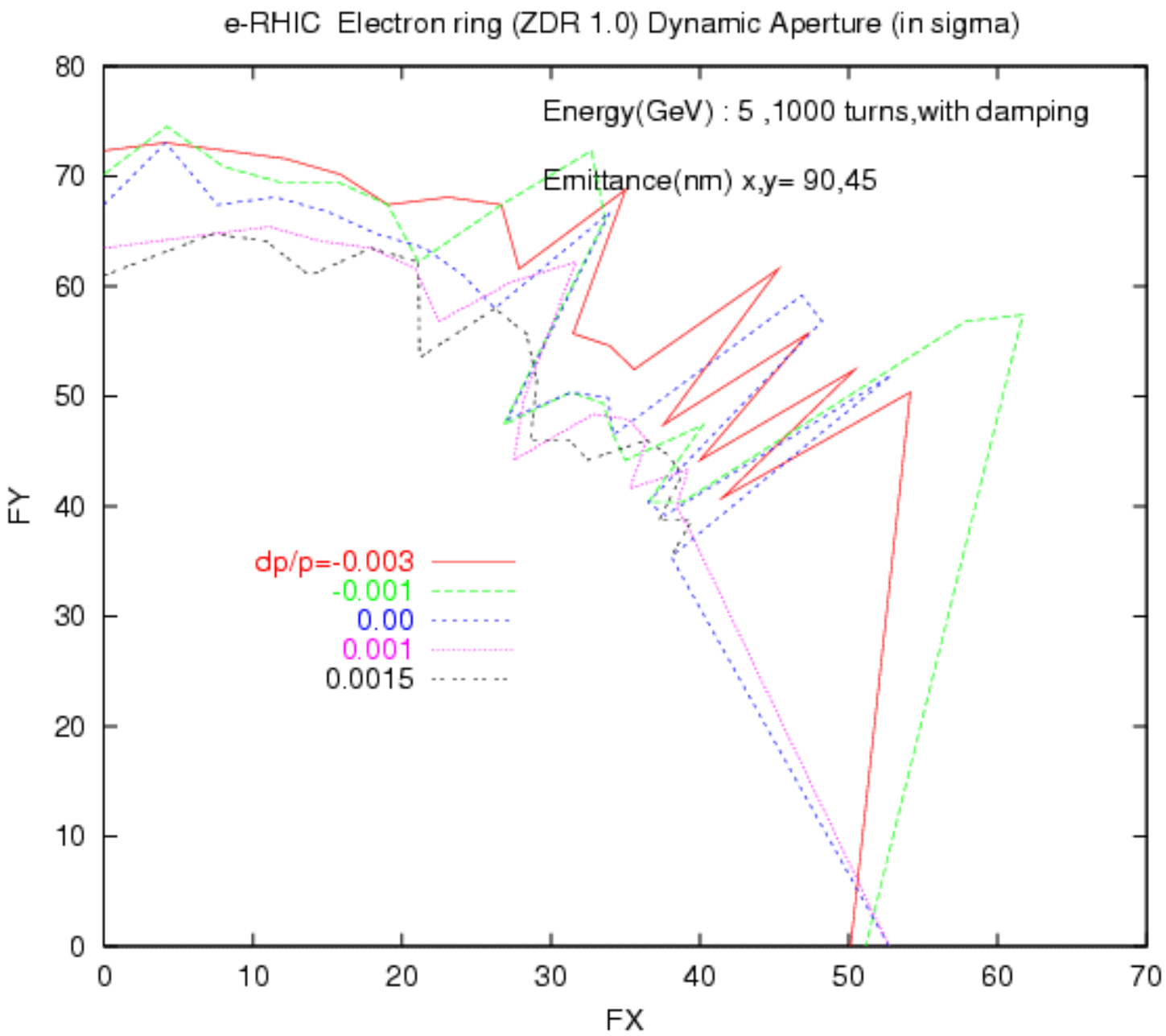
e-RHIC Electron ring (ZDR 1.0) Dynamic Aperture (in sigma)
Energy(GeV) : 5 ,1000 turns,with damping
Emittance(nm) x,y= 90,45
dp/p=-0.003
-0.001
0.00
0.001
0.0015
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70
80

- Dynamic Aperture Improvement Update

o Multi-family sextupoles for minimizing chromatic betatron tune changes and partial geometrical aberration cancellation.

Still working on…

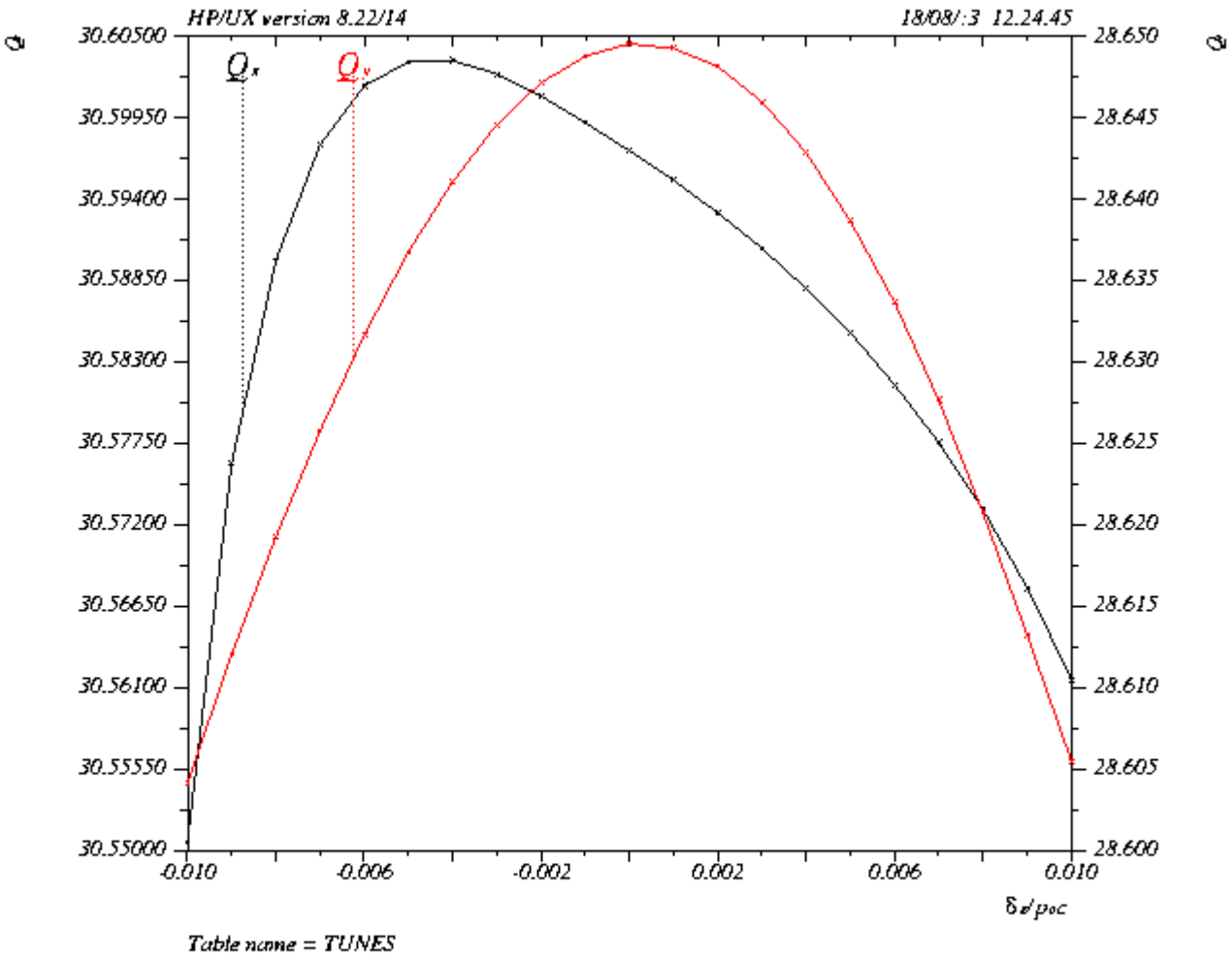
o Longitudinal Aperture Improvement (10 GeV, Low emittance):

For DYNA>10 $\sigma_{x,y}$

$\Delta p/p$ range : -0.01(-10 σ_E) to 0.005 (+5 σ_E)

Compare to ZDR1.0 two sextupole family:

$\Delta p/p$ range : ~ -0.004(-4 σ_E) to 0.002 (-2 σ_E)


HP/UX version 8.22/14
18/08/:3 12.24.45
Qx
Qy
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30.59950
30.59400
30.58850
30.58300
30.57750
30.57200
30.56650
30.56100
30.55550
30.55000
28.650
28.645
28.640
28.635
28.630
28.625
28.620
28.615
28.610
28.605
28.600
-0.010
-0.006
-0.002
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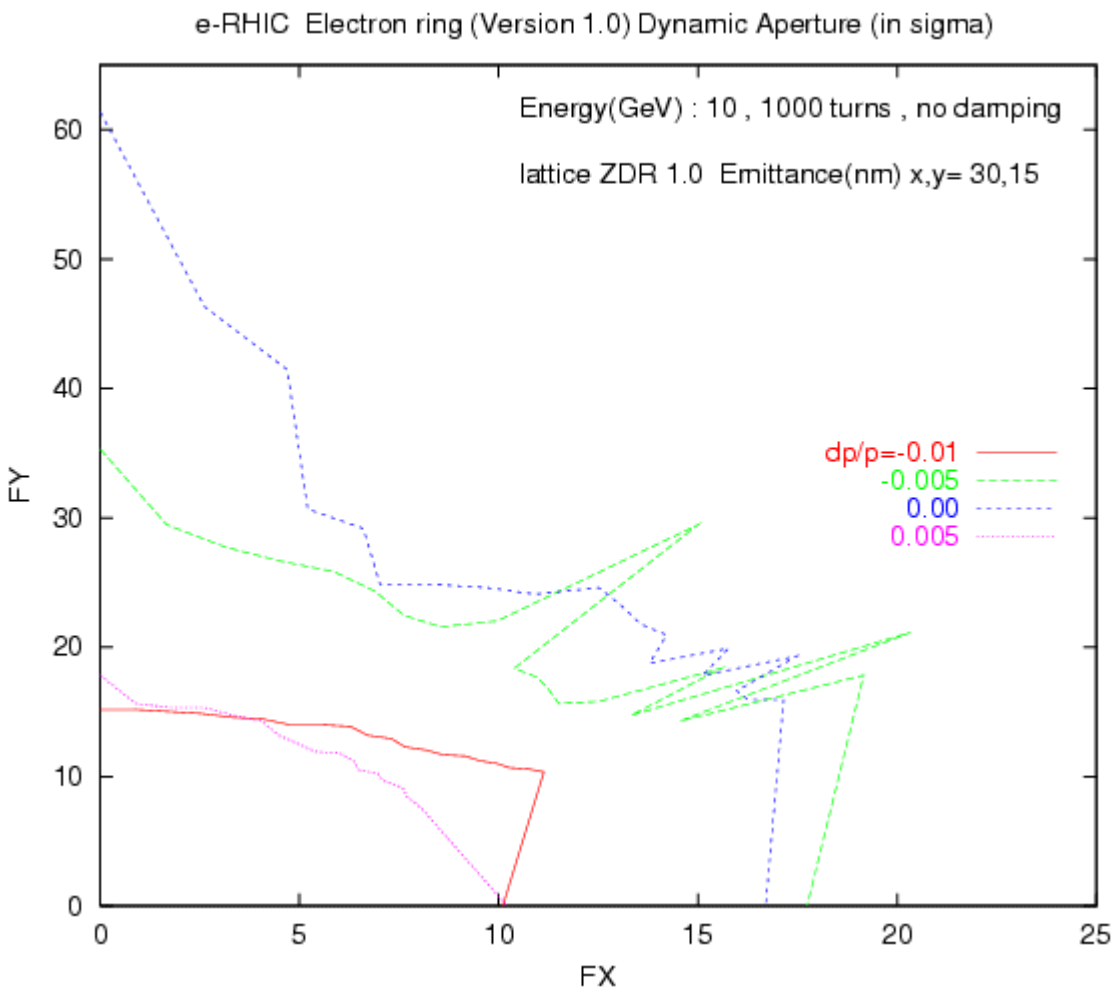
0.006
0.010
δe/pc
Table name = TUNES


e-RHIC Electron ring (Version 1.0) Dynamic Aperture (in sigma)
Energy(GeV) : 10 , 1000 turns , no damping
lattice ZDR 1.0 Emittance(nm) x,y= 30,15
dp/p=-0.01
-0.005
0.00
0.005
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FX
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25

2.4 Collective effects and Beam-beam effects