Proposal for a CESR Damping Ring Test Facility

M. Palmer & D.Rubin

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CESR Status

Electron-positron collider for study of QCD and
weak interactions near the charmed quark threshold
~1.51 -> 2.2 GeV/beam (2/3) CLEO collaboration

Synchrotron radiation source operating at 5GeV/beam
3 permanent magnet wiggler lines
4 hard bend radiation lines (1/3) CHESS

Operation of CESR for CLEO is scheduled to end in March 2008

CESR parameters/hardware

- Circumference[m] - 768.4
- Energy reach[GeV] $1.5 < E_{beam} < 5.5$
- Single beam current[mA]
  - 1.9GeV -> 180mA
  - 5.0GeV -> 350mA
- Arc bend radius[m] 87
- Hard bend radius[m] 30
- RF, 4 single cell superconducting cavities
  - Frequency [MHz] 500
  - Max accelerating voltage[MV] 12

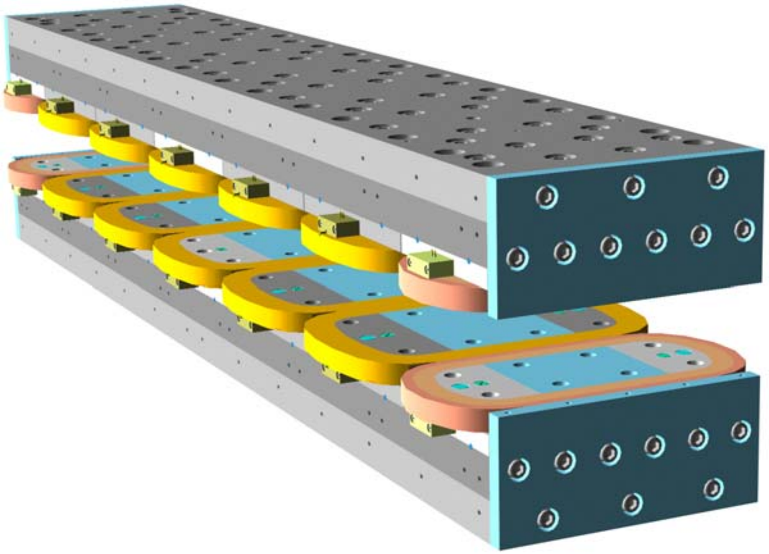
- Injector - full energy, electrons and positrons, 45 bunches at 60Hz
- Bunch by bunch transverse & longitudinal feedback
- 100 bunch by bunch beam position monitors

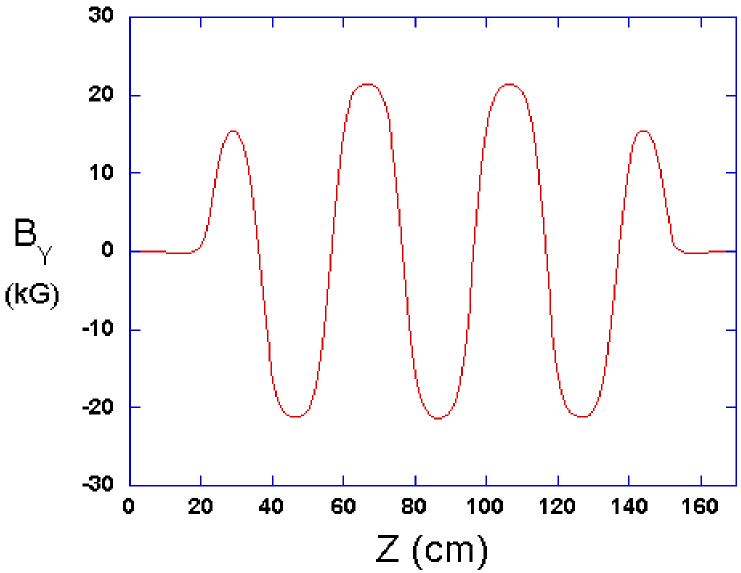
CESR parameters/hardware

- 100 quadrupoles on independent power supplies
- 78 sextupoles on independent supplies
- 18 skew quad correctors
- 6 skew sextupole correctors
- 4 octupole correctors
- Superconducting/ permanent magnet final focus quadrupoles
- Wigglers
  - 12 Superconducting
    - Period[m] 0.4
    - Gap[cm] 7
    - Peak field[T] $1.4<B<2.1$
    - Length[m] 1.6
  - 2 permanent magnet
    - Peak field[T] 0.78 & 1.2

CESR-c

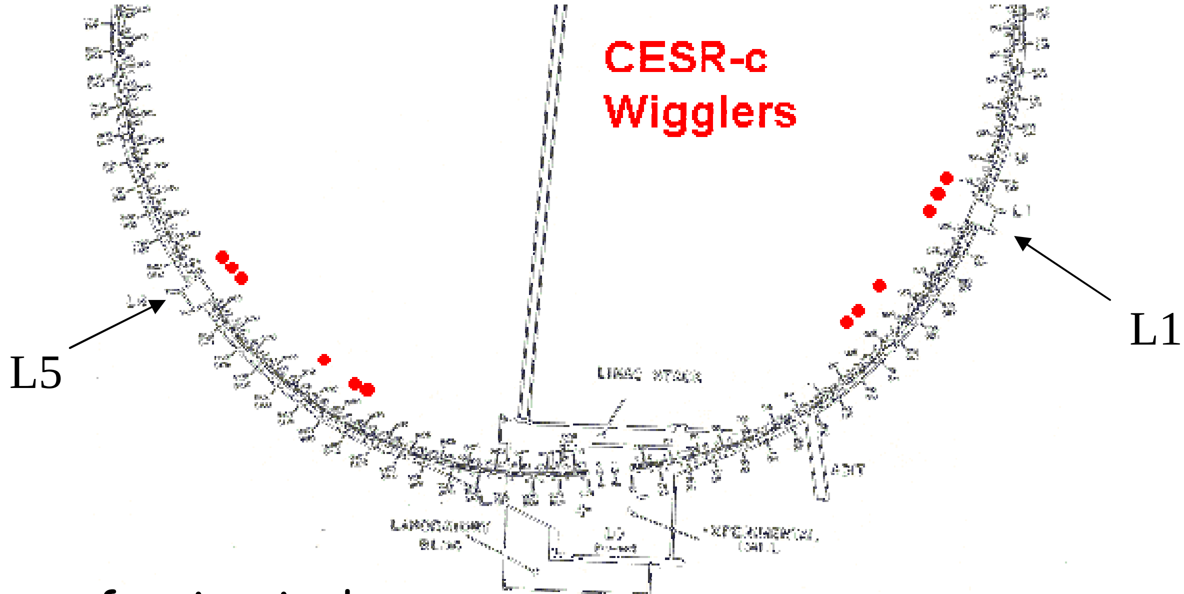
Damping and emittance control with wigglers





Superconducting wiggler prototype installed fall 2002

7-pole, 1.3m
40cm period,
161A, B=2.1T



Installed:

12 8-pole superferric wigglers

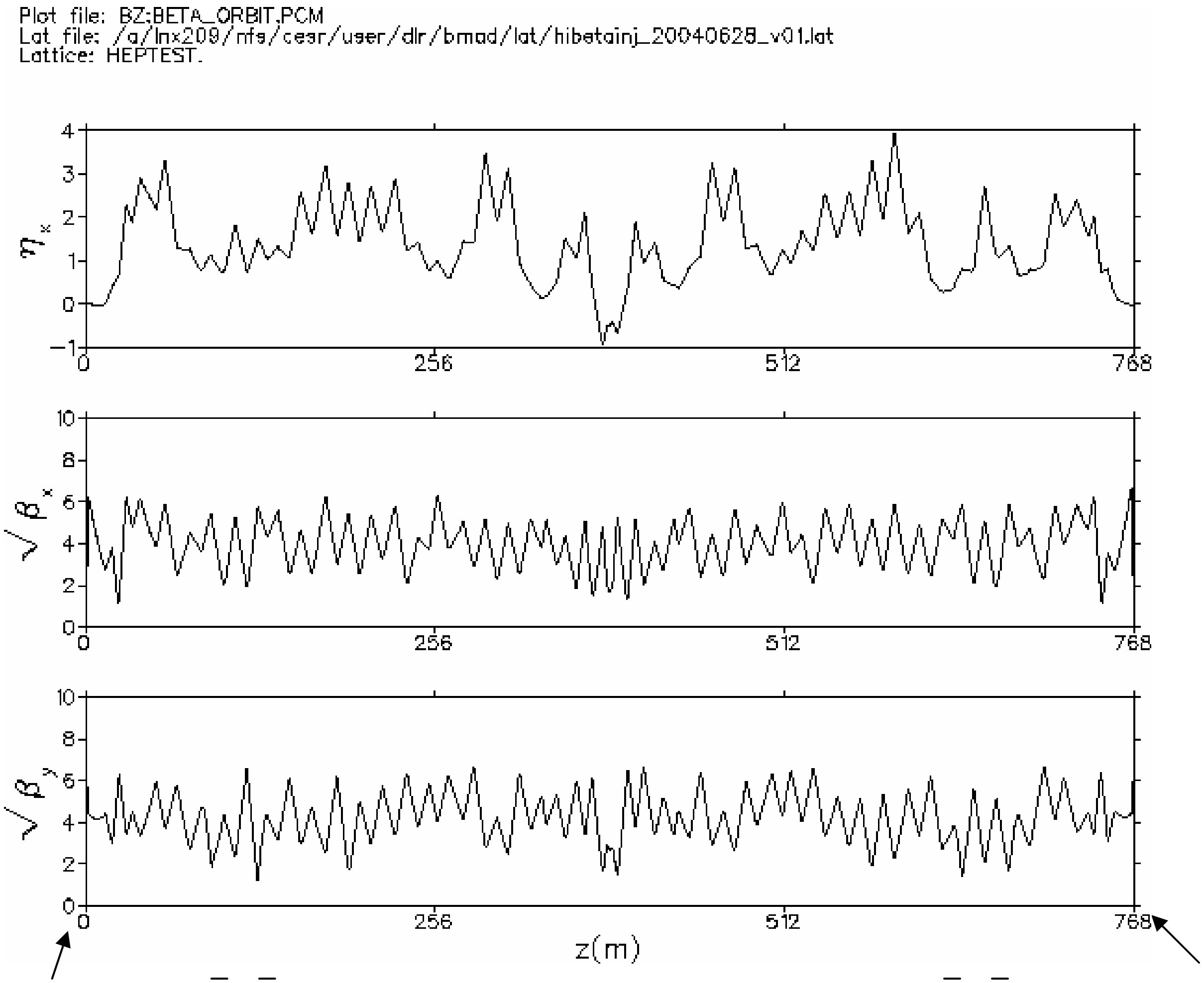
$1.4 < B_{peak}[T] < 2.1$

2 spare

Beam based measurements of wiggler nonlinearity in good agreement with modeled field

- Finite element code => 3-d field table
- Analytic fit => taylor map

Configuration for HEP
(wigglers reduce damping time and increase emittance)



IP

wigglers

wigglers

IP

2.1 T wigglers(#)	0	12
ε_h(nm)	30	130
τ_h(ms)	500	50

1.9 GeV/beam

$Q_h = 10.52$

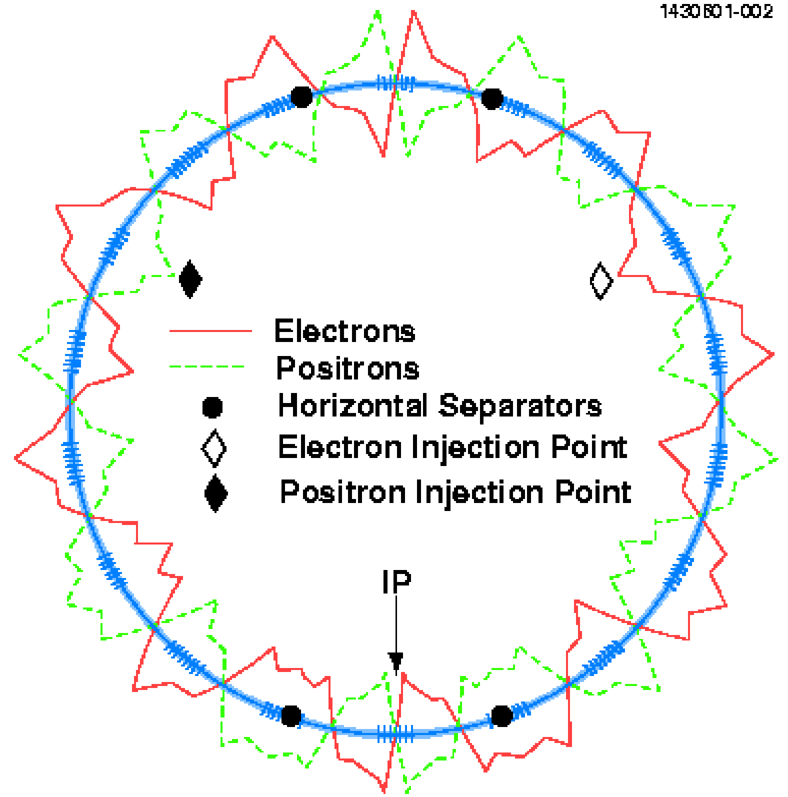
CESR-c

Energy reach 1.5-6GeV/beam

Electrostatically separated electron-positron orbits accomodate counterrotating trains

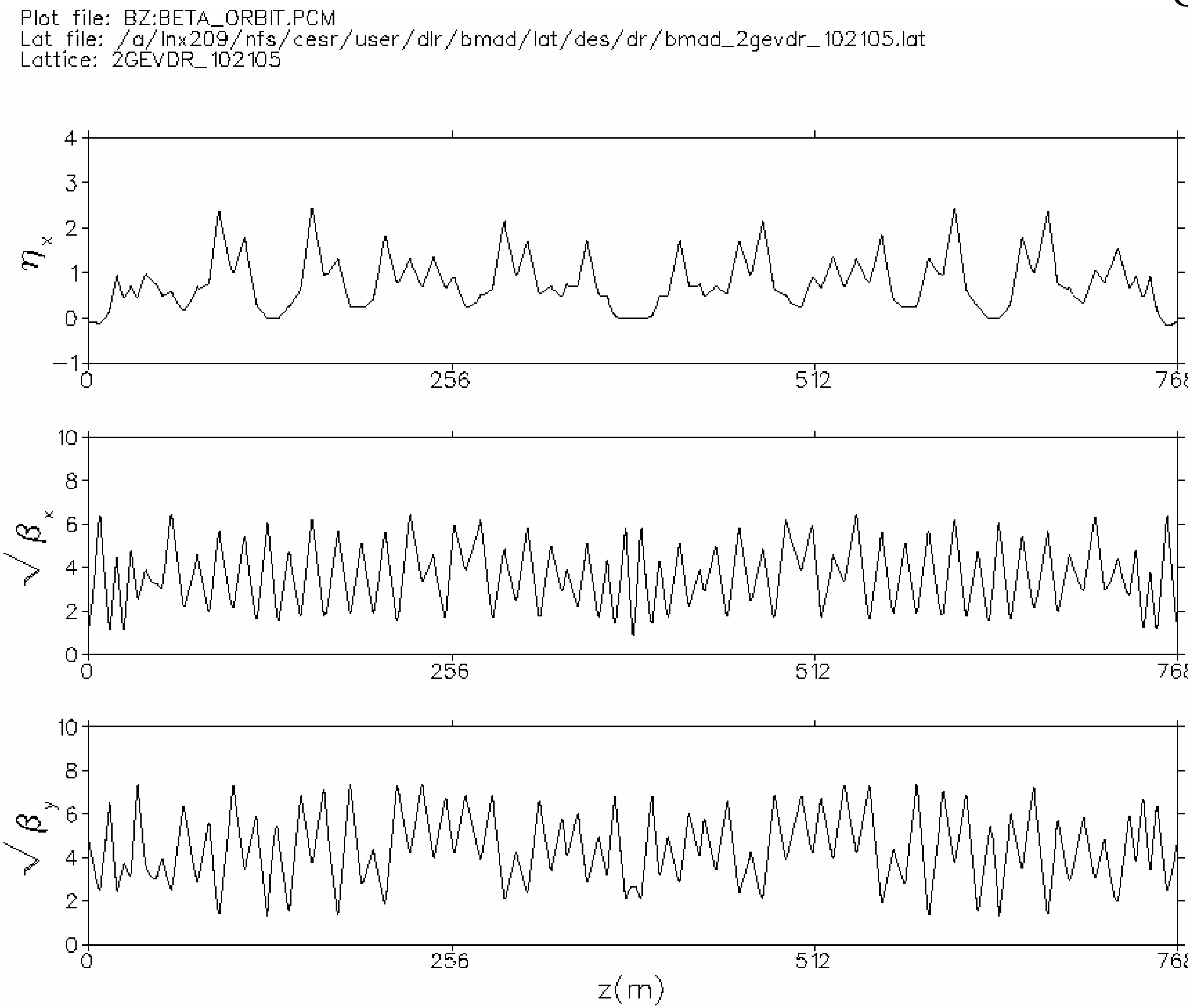
Electrons and positrons collide with ±~3.5 mrad horizontal crossing angle

9 5-bunch trains in each beam (768m circumference)



Damping ring configuration
High tune - low emittance optics

Q_h=14.52



Emittance scaling with energy and tune

$\varepsilon \sim E^2/Q_h^3$ -> 8 (nm) at Q_h=14.52, E=2GeV

Emittance scaling with wigglers

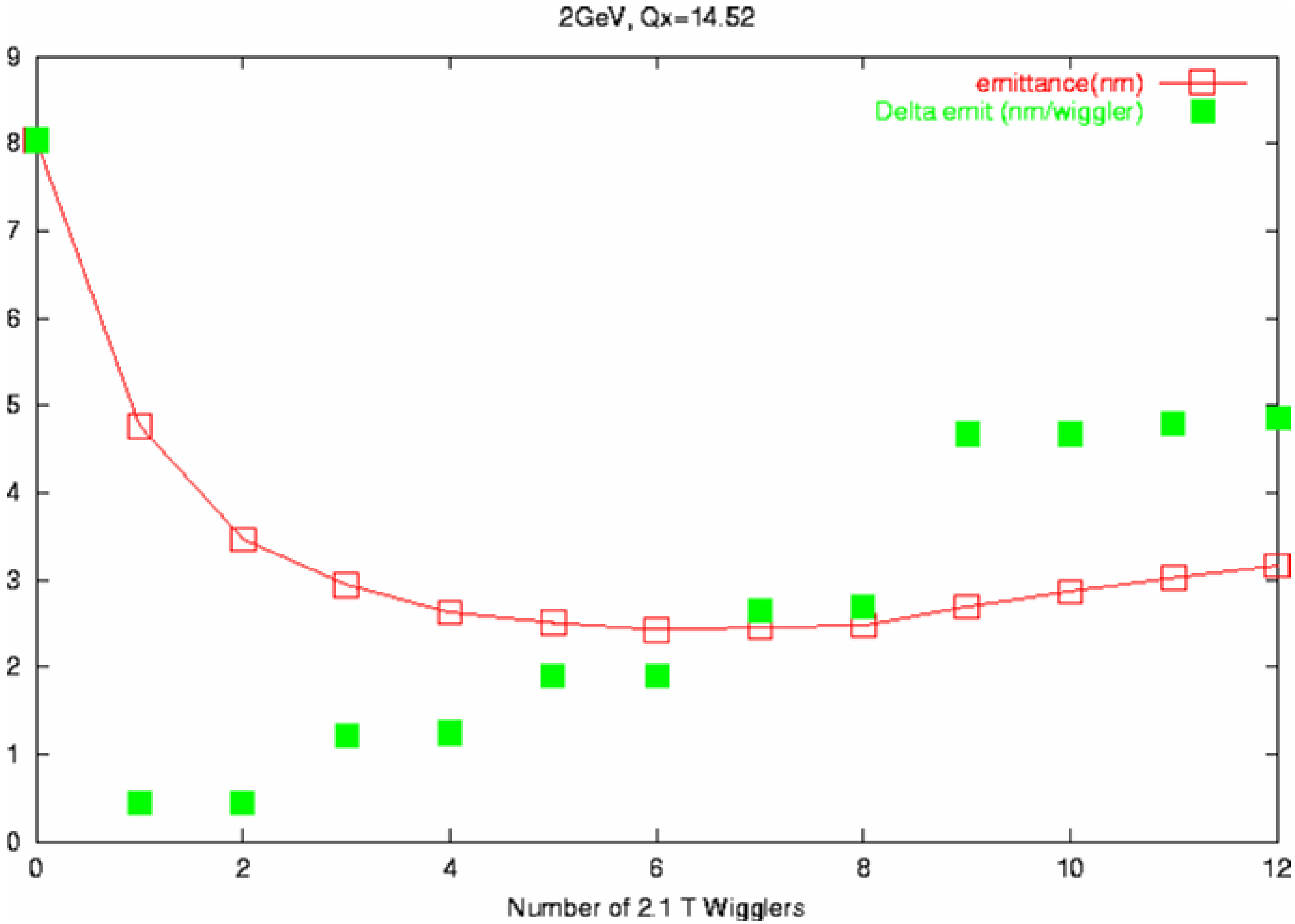
$$\varepsilon_x = C_q \frac{\gamma^2 I_5}{J_x I_2}, \qquad I_2 = \oint \rho^{-2} ds, \qquad I_5 = \oint \frac{H}{|\rho|^3} ds$$

<u>HEP configuration</u> - taylor *H* in wigglers to increase emittance
<u>Damping ring configuration</u> - minimize *H* in wigglers

12, 2.1T wigglers in CESR at 2GeV/beam increases I_2 X 10

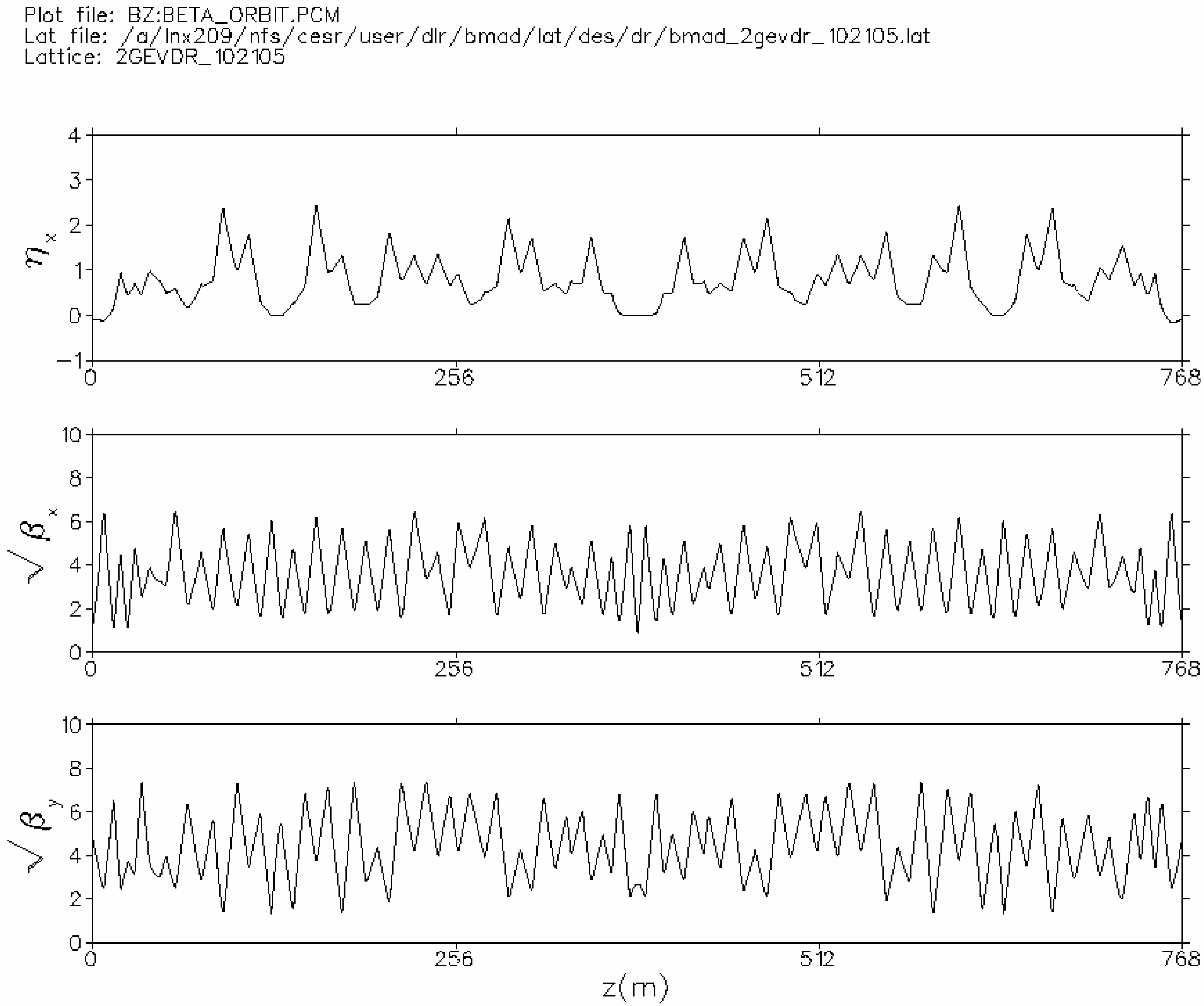
In the limit where I_2(arc)<<I_2(wiggler), and $I_5(\text{arc}) \to 0$, and $\eta=\eta'=0$ at start and end of wigglers,
The contribution of a single wiggler period is:

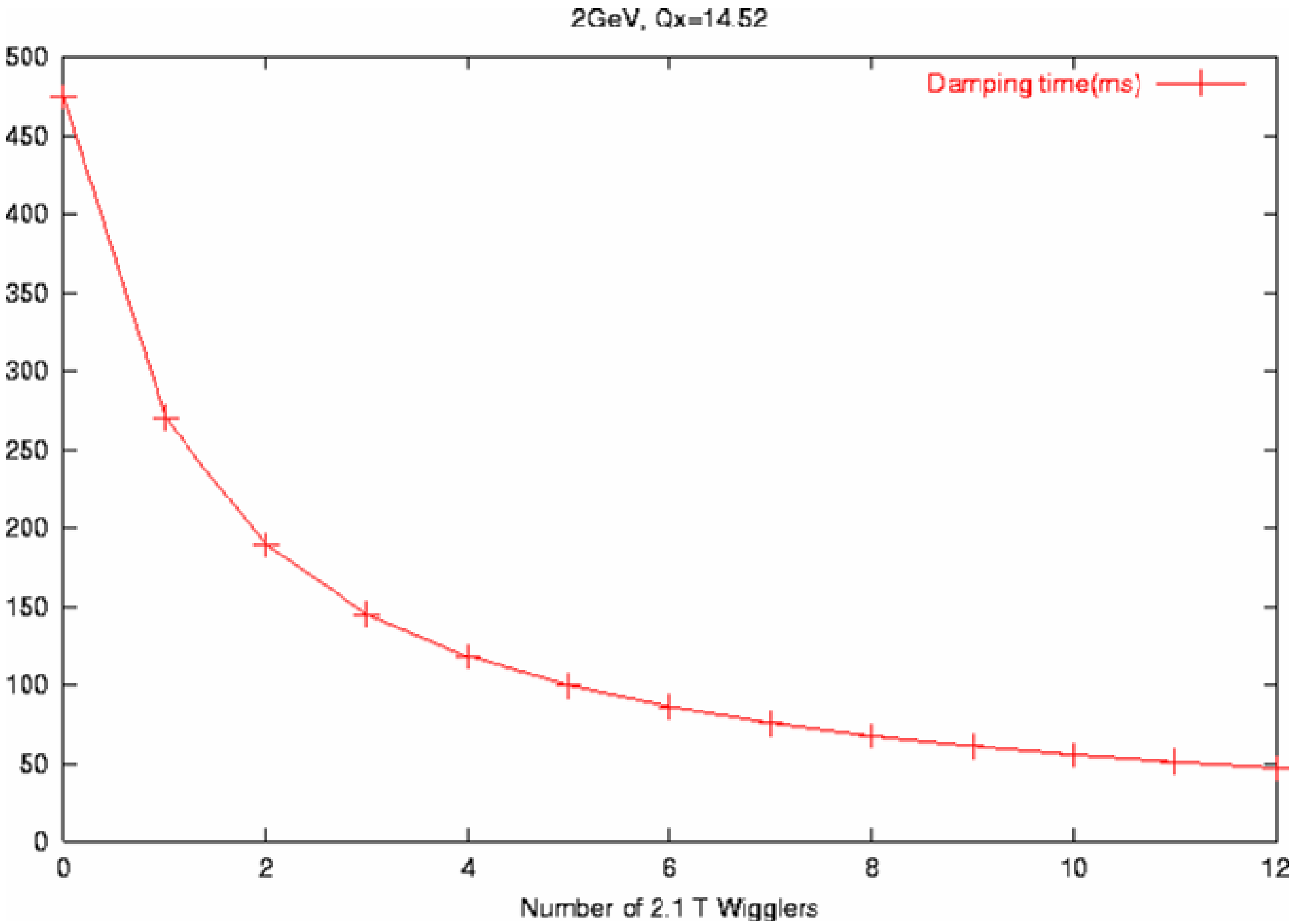
$$\Delta I_5 \approx \frac{4\beta_x}{15 k_p^3 \rho_w^5}, \qquad \Delta I_2 = \frac{\pi}{2 k_p \rho_w^2}, \qquad \varepsilon_x \approx C_q \frac{\gamma^2}{J_x} \frac{8\beta_x}{15\pi k_p^2 \rho_w^3}$$



Wigglers deployed in lattice where $\eta=\eta' =0$

ε_{min} ~ 2.5nm (6 wigglers)


Plot file: BZ:BETA_ORBIT.PCM
Lat file: /a/lnx209/nfs/cesr/user/dlr/bmad/lat/des/dr/bmad_2gevdr_102105.lat
Lattice: 2GEVDR_102105
η_x
$\sqrt{\beta_x}$
$\sqrt{\beta_y}$
0
256
512
768
z(m)


2GeV, Qx=14.52
Damping time(ms)
500
450
400
350
300
250
200
150
100
50
0
0
2
4
6
8
10
12
Number of 2.1 T Wigglers

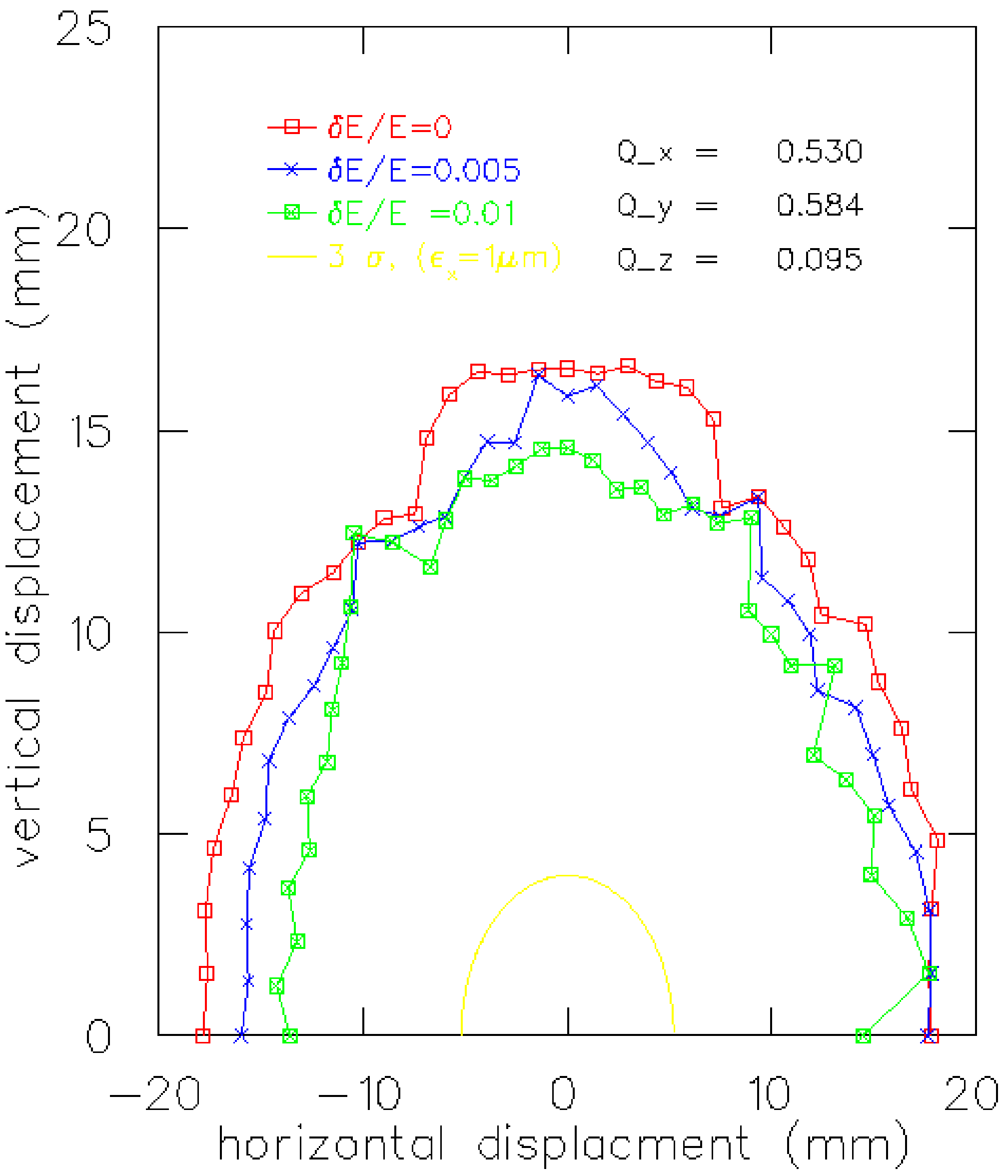
~1/I_2

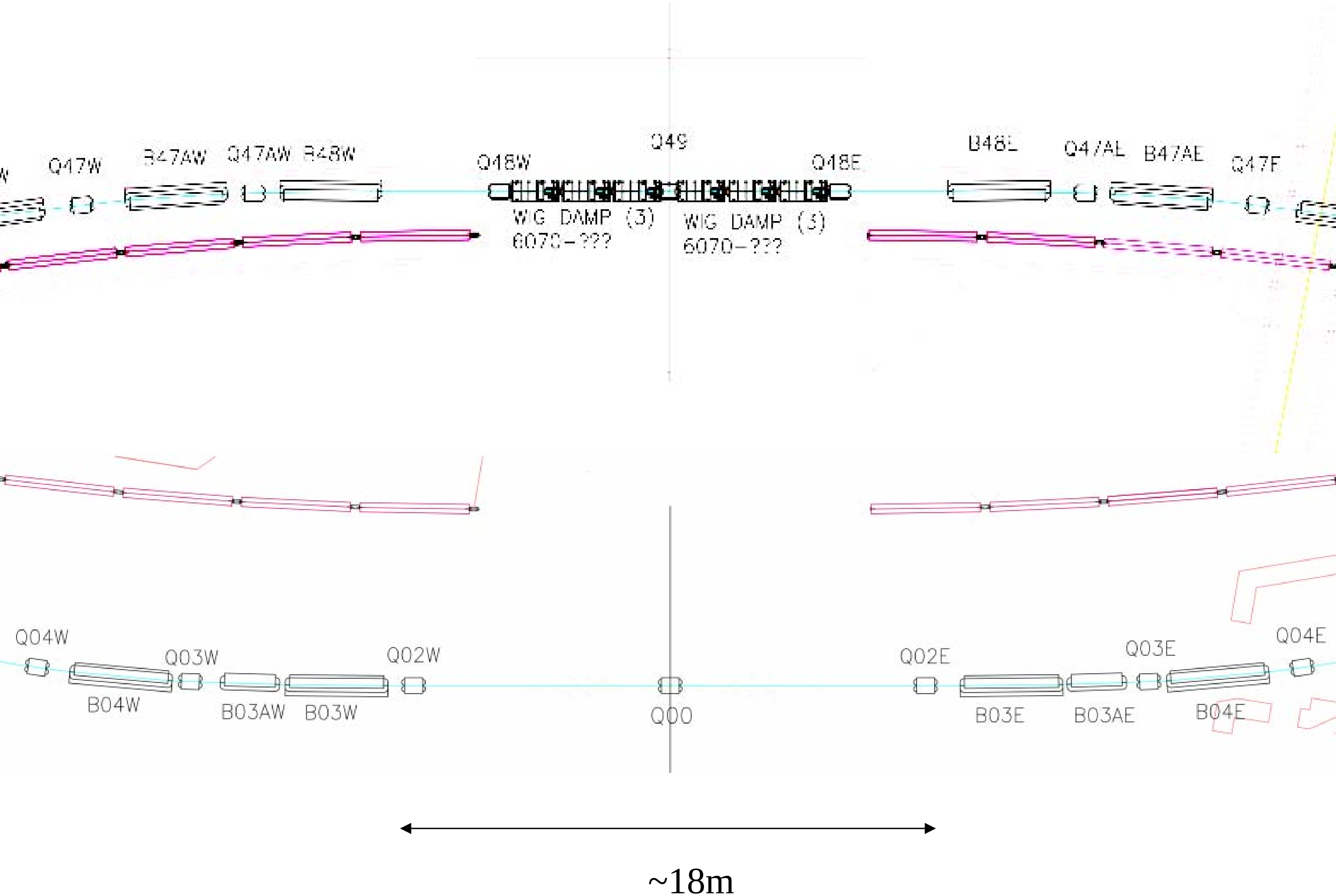
Emittance scaling with energy & wiggler field

Energy[GeV]	#Wigglers	B_{peak}[T]	ε_x [nm]	τ_x[ms]
1.5	6	1.575	1.4	203
2.0	0	0	8	437
2.0	12	2.1	3.1	47
2.0	6	2.1	2.4	86
5.0	6	2.1	34	16
5.0	0	0	54	28

6 2.1 T wigglers, 2GeV/beam

ε_{min} ~ 2.5nm
τ_x = 86ms
$\tau_{Touschek}$ ~ 3 minutes (N=2E10, $\varepsilon_y/\varepsilon_x$=0.1%)
σ_E/E = 0.084%
σ_l = 8.3mm @ 10MV accelerating field


δE/E=0
δE/E=0.005
δE/E =0.01
3 σ, (ε_x=1μm)
Q_x = 0.530
Q_y = 0.584
Q_z = 0.095
25
20
15
10
5
0
vertical displacement (mm)
−20
−10
0
10
20
horizontal displacment (mm)


Q47W
B47AW
Q47AW
B48W
Q48W
Q49
Q48E
B48E
Q47AE
B47AE
Q47E
WIG DAMP (3)
6070-???
WIG DAMP (3)
6070-???
Q04W
Q03W
Q02W
B04W
B03AW
B03W
Q00
Q02E
Q03E
Q04E
B03E
B03AE
B04E
~18m

Damping ring R&D

- Test coupling correction algorithms
  (in CESR we routinely achieve $\varepsilon_y/\varepsilon_x < 0.5\%$)
- Establish properties of ring with wiggler dominated emittance
- Measure electron cloud density in wigglers/dipoles vs
  - Bunch current
  - Bunch pattern
  - Emittance
  - Chamber radius
- Measure e-cloud instability threshold vs beam parameters (positrons)
- Fast ion instability (electrons)
- Test
  - Injection/ extraction kicker (extraction line)
  - Prototype wiggler
  - Feedback
  - Clearing electrodes
  - Deflecting cavity
  - Instrumentation …

Summary

- CESR can be configured for low emittance operation after CLEO detector removal
  - Changes are relatively straightforward
  - Will want to eliminate CLEO for CHESS ops anyways
- Significant insertion space can be made available for DR hardware studies
- The most interesting (and straightforward) setup is to study positrons
- Significant amount of further evaluation is needed
- We welcome input and participation from all interested parties!!!