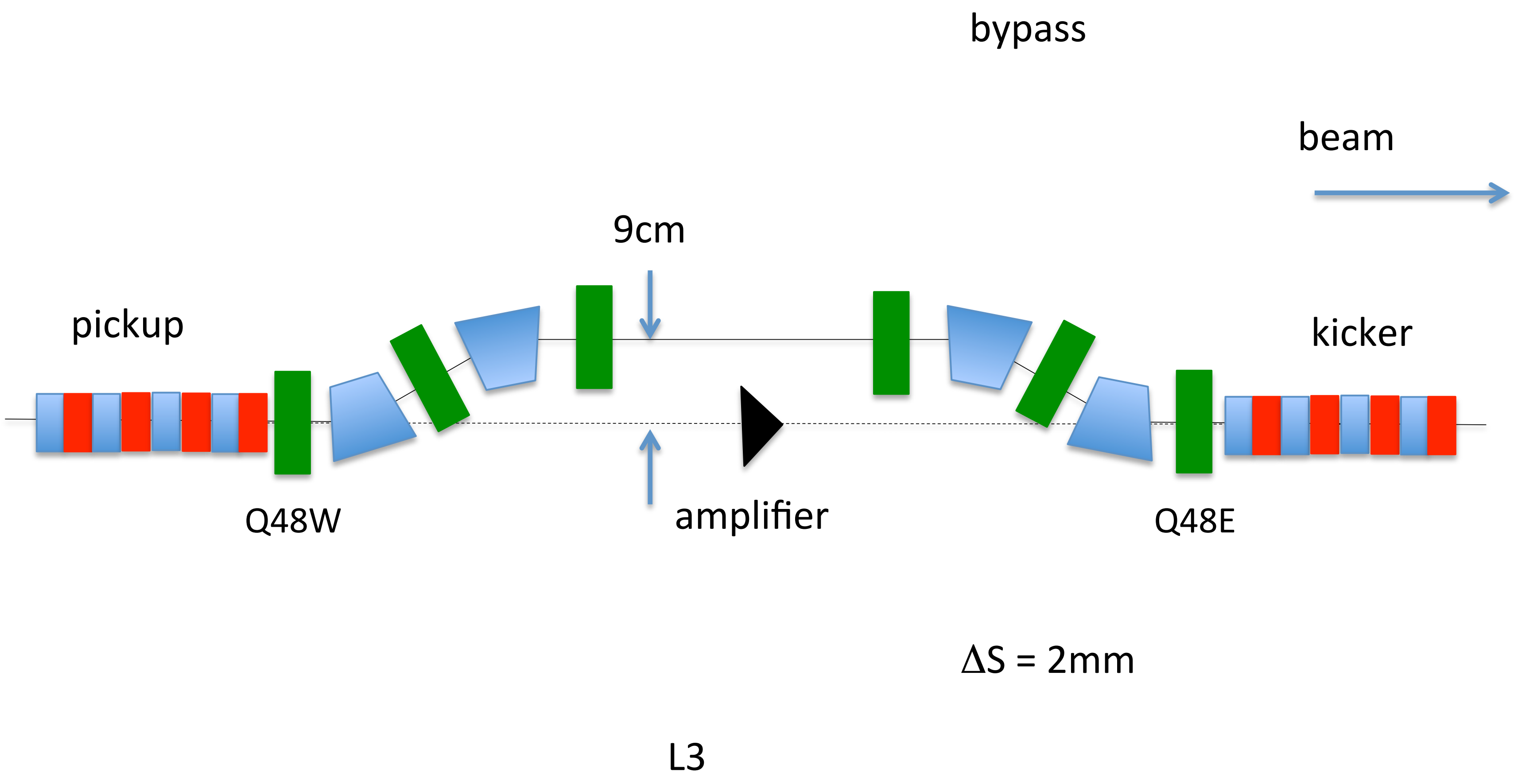
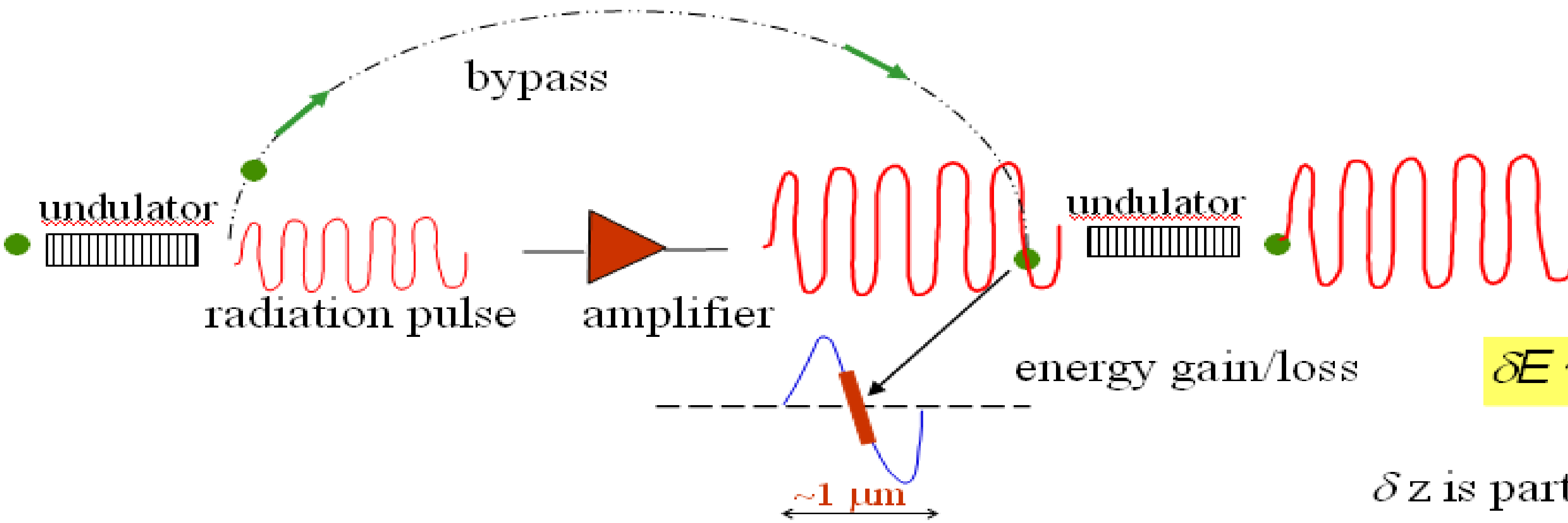
Test of Optical Stochastic Cooling in CESR

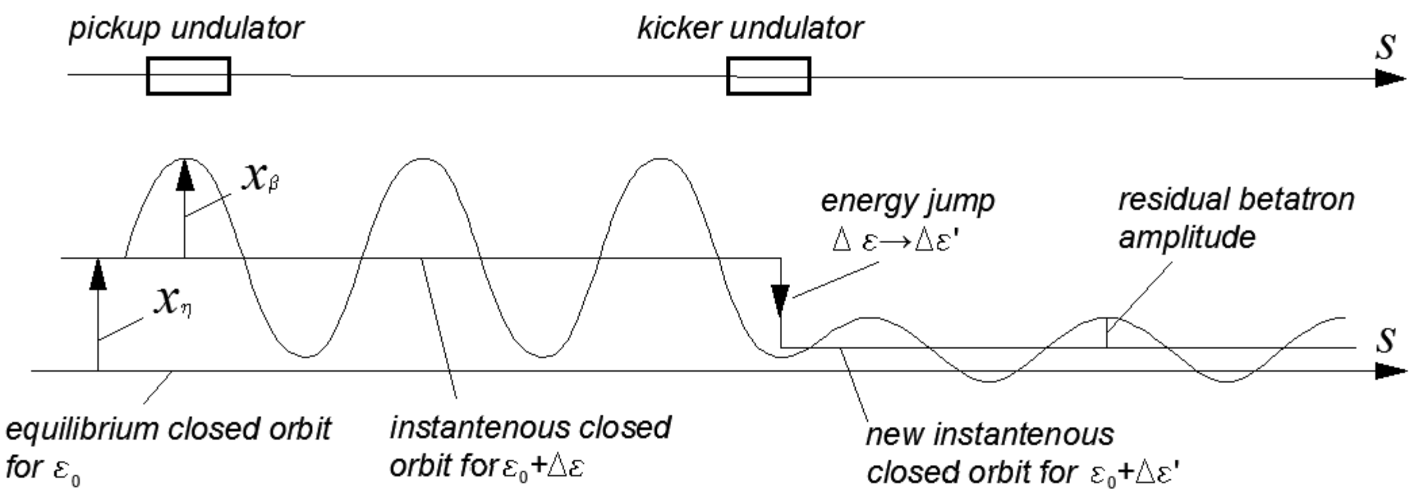
September 1, 2017

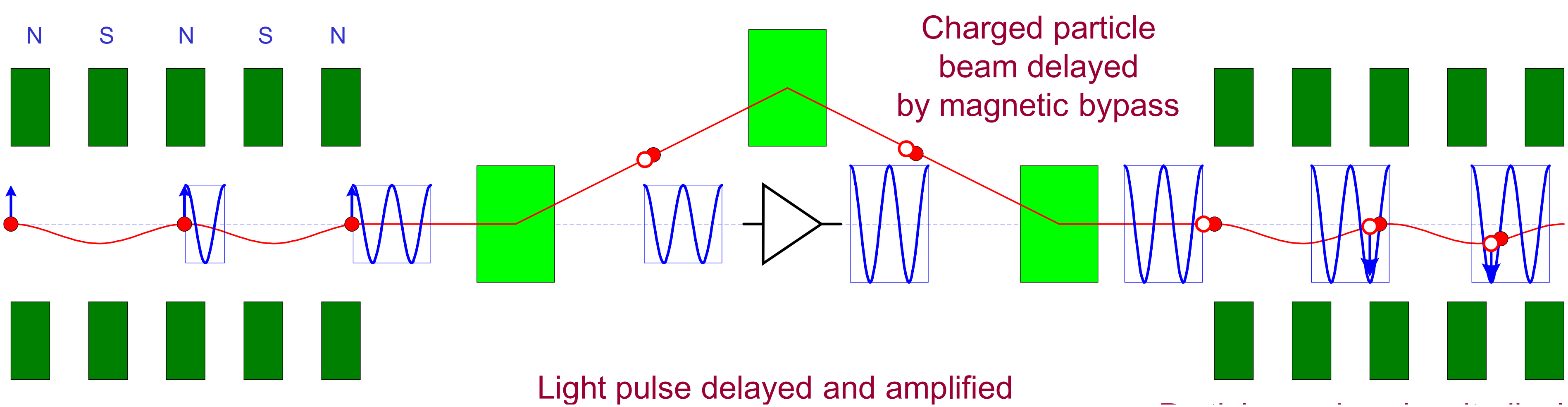

bypass
beam
9cm
pickup
kicker
Q48W
amplifier
Q48E
ΔS = 2mm
L3



$\delta E \sim \sin(k\,\delta z)$

δ z is particle delay


pickup undulator
kicker undulator
s
x_β
x_η
energy jump
$\Delta\varepsilon \rightarrow \Delta\varepsilon'$
residual betatron
amplitude
s
equilibrium closed orbit
for ε_0
instantenous closed
orbit for $\varepsilon_0+\Delta\varepsilon$
new instantenous
closed orbit for $\varepsilon_0+\Delta\varepsilon'$


N S N S N
Charged particle
beam delayed
by magnetic bypass
Light pulse delayed and amplified

Undulator

$$K = \frac{B_0 e}{m_0 c} \frac{\lambda_u}{2\pi} = 93.36\ B_0 \lambda_u$$ (B_0 in T, λ_u in m)

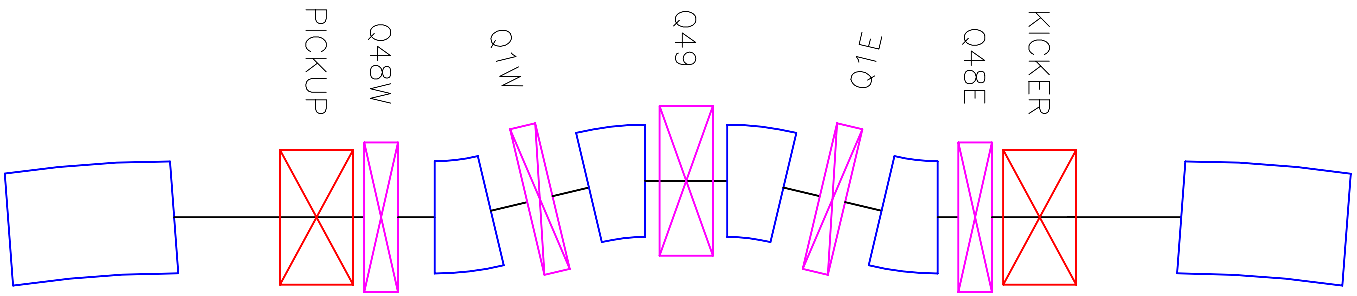
$$\lambda = \frac{\lambda_u}{2n\gamma^2} \left(1 + \frac{K^2}{2} + \theta^2 \gamma^2 \right)$$

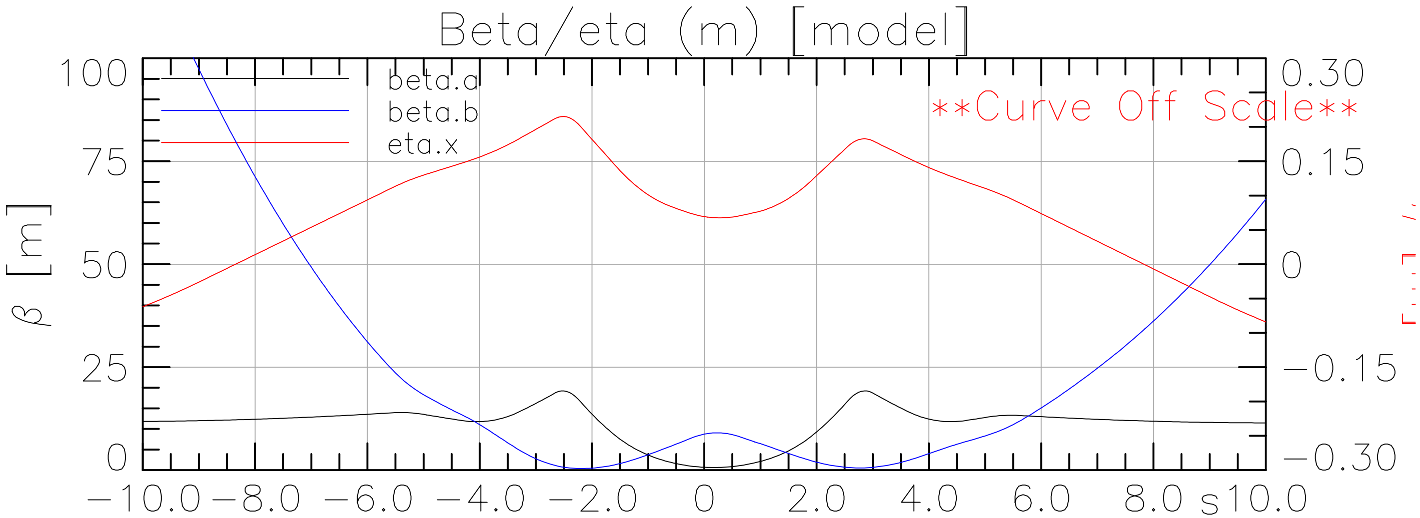
Example

B_0 = 750 G
λ_u = 0.4 m
K = 2.8

E = 0.5 GeV => γ = 1000 => λ = 1 μm

L3 bypass


PICKUP
Q48W
Q1W
Q49
Q1E
Q48E
KICKER


Beta/eta (m) [model]
beta.a
beta.b
eta.x
Curve Off Scale
β [m]
100
75
50
25
0
0.30
0.15
0
−0.15
−0.30
−10.0
−8.0
−6.0
−4.0
−2.0
0
2.0
4.0
6.0
8.0
s
10.0

Components of OSC experiment

- Delay bypass beam line
  - Delay electron beam by about 2mm/c to compensate for time delay of optical amplifier and
  - Couple transverse phase space to longitudinal position to enable cooling
  - Tolerances consistent with optical wavelength (~1 micron)
- Low energy (<0.5 GeV) operation of CESR
  - Lattice design
  - Injection
  - Power supply stability, quads and dipole
  - Undulators
  - IBS
- Demonstration of interaction of radiation from pickup undulator with radiation in kicker as a function of delay
  - Detector?
- Optics and optical amplifier amplifier
- Demonstration of cooling

Some questions that require new modeling tools

- What is the optical error tolerance of the delay bypass?
- What are the alignment tolerances?
- What is the intensity of the radiation for the relatively low bunch charge that we expect to circulate?
- What is the optimal wavelength for the optical radiation?
- What is the optimal undulator magnetic field?
- What kind of signal do we expect to see?
- Is there sufficient mixing?
- What is the optimal emittance, energy spread, bunch length?
- Gradient undulator or dipole undulator?

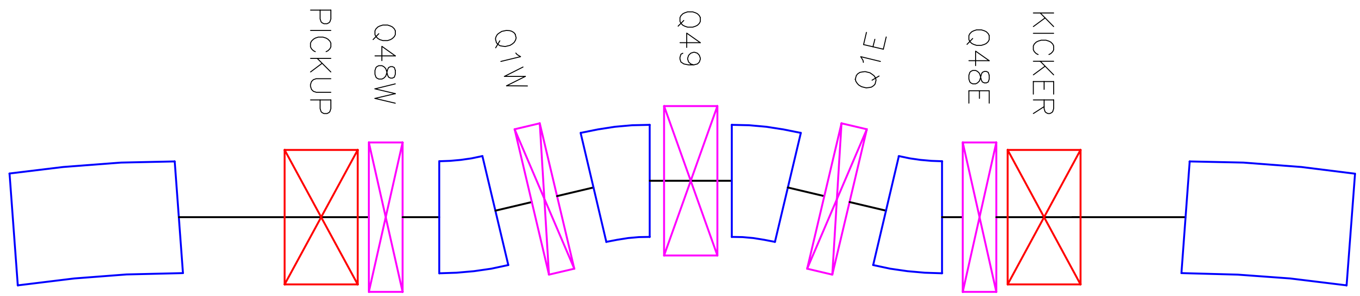
It is essential that we demonstrate the efficacy and tolerances of our design in simulation

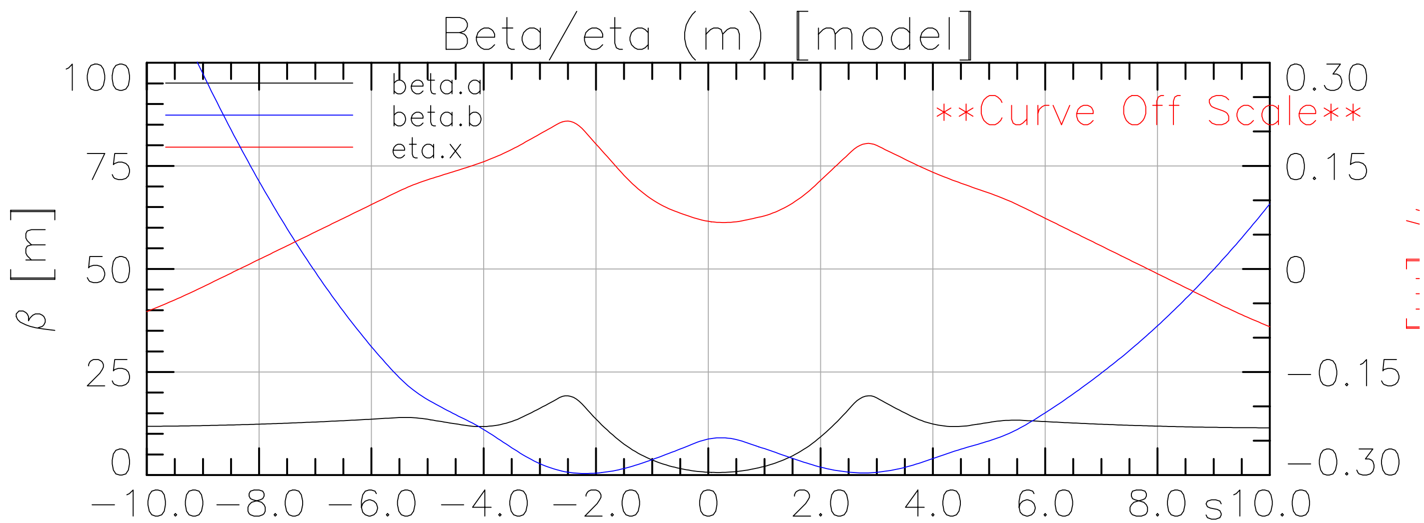
=> Code for modeling radiation and absorption by electrons

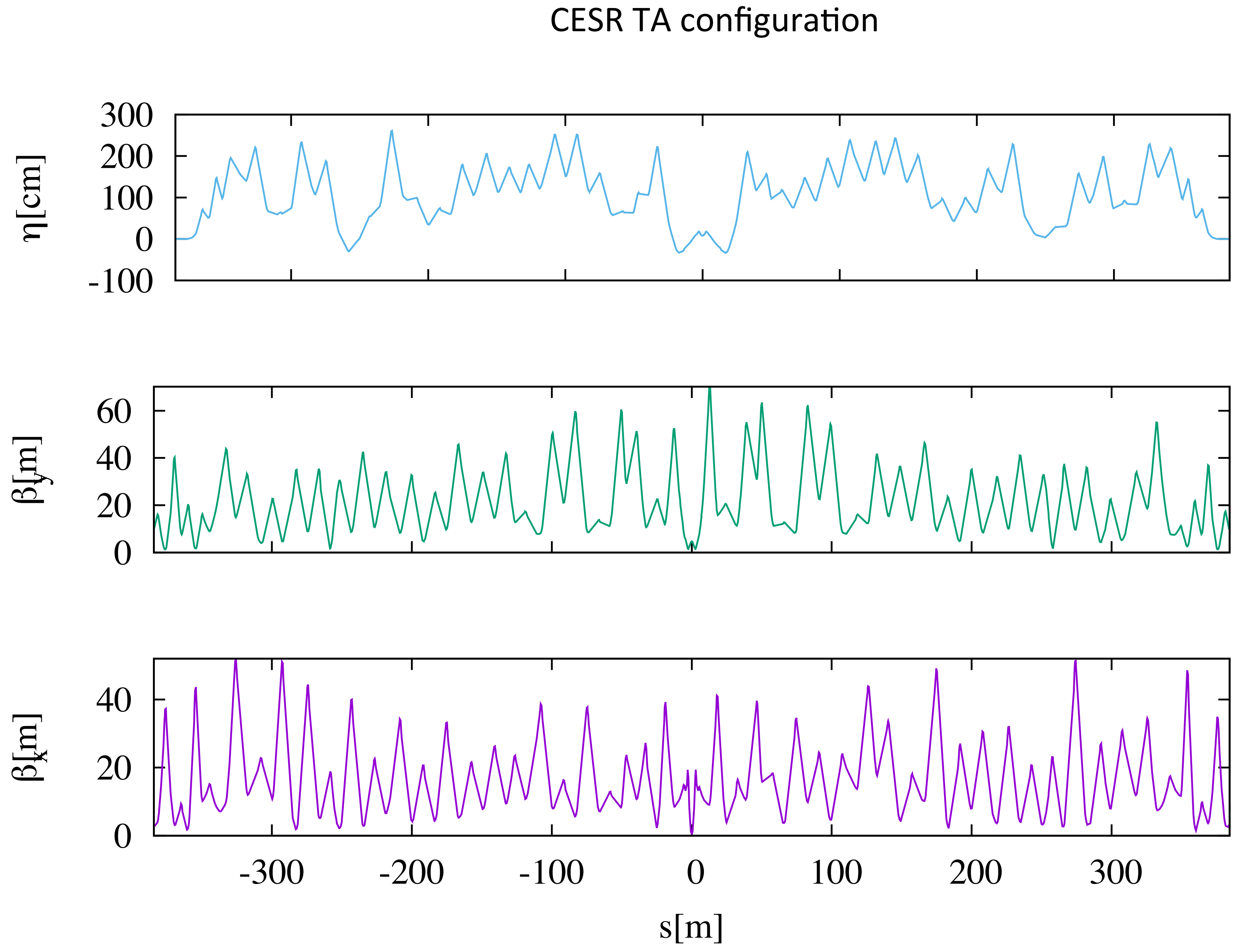
CESR TA configuration

Beam Energy [GeV]	0.5	$(\Delta p/p)_{max}$ X 10^{-4}	3.7 (n_s= 1.85)
ε [nm-rad] (radiation)	0.5	Wiggler period [m]	0.43
$(\Delta p/p)$ X 10^{-4}	2.01	Wiggler peak field [T]	0.07
Radiation damping times [s]	2.9/1.4	OSC Undulator parameter [K]	2.8
B_{max} (Damping Wigglers) [T]	0.5	Radiation wavelength λ [nm]	1130
Chicane delay [mm]	2.0	Particles/bunch	2 X 10^9
$R_{51}/R_{52}/R_{56}$ X 10^{-4}	3.7/-7.2/24.4	Bunch length [mm]	10
ε_{max} [nm-rad]	16 (n_x = 32)	OSC cooling time τ_x/τ_z [sec]	3.5/0.5

L3 bypass


PICKUP
Q48W
Q1W
Q49
Q1E
Q48E
KICKER

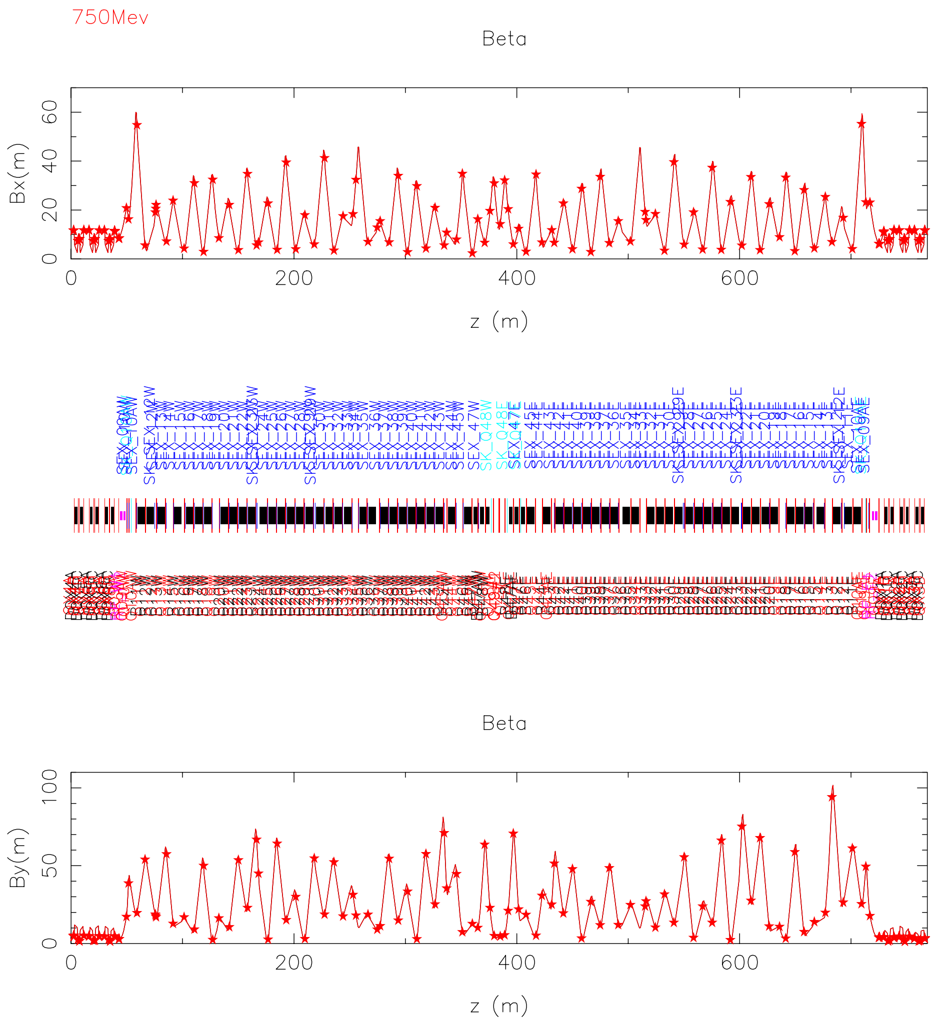

Beta/eta (m) [model]
beta.a
beta.b
eta.x
Curve Off Scale
β [m]
100
75
50
25
0
0.30
0.15
0
−0.15
−0.30
−10.0
−8.0
−6.0
−4.0
−2.0
0
2.0
4.0
6.0
8.0
s
10.0


CESR TA configuration
η[cm]
300
200
100
0
-100
β_y[m]
60
40
20
0
β_x[m]
40
20
0
-300
-200
-100
0
100
200
300
s[m]

Schedule

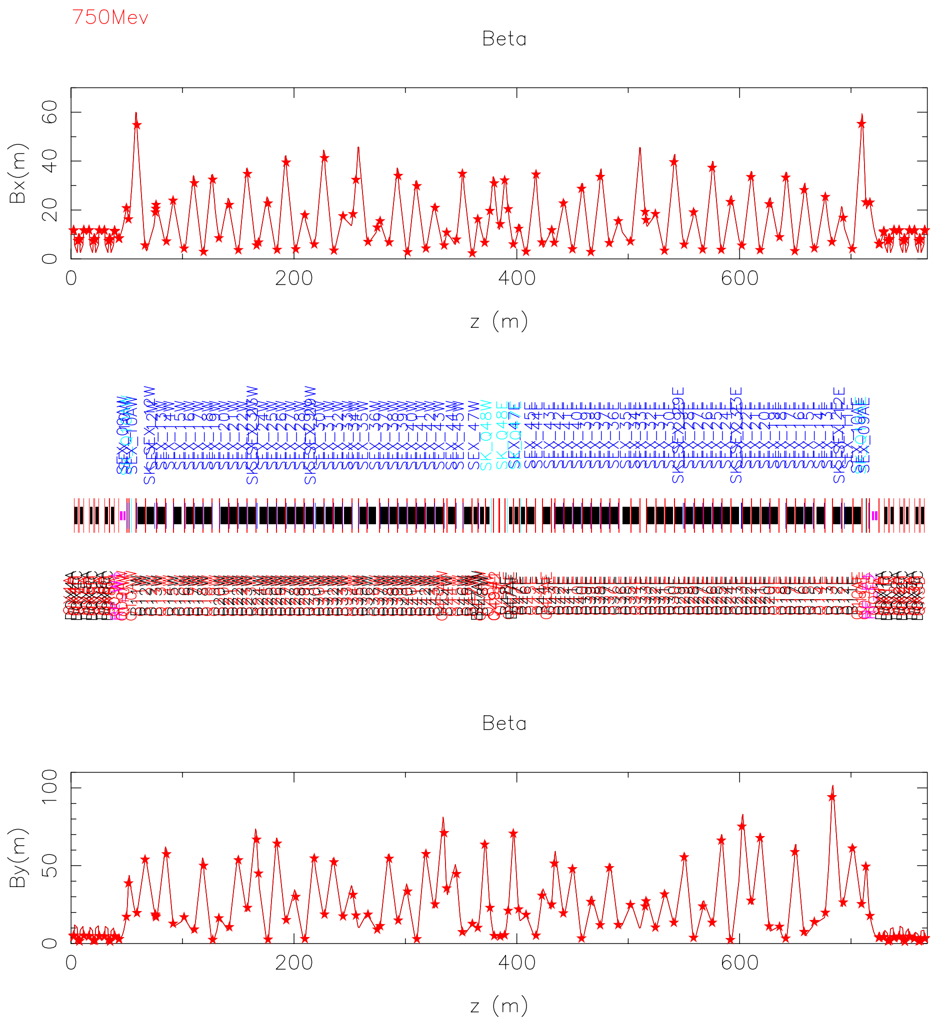
Activity	Start date
1. Lattice design	9/17
2. Bypass optics design -	10/17
3. Develop code and simulate cooling 60 days	10/17
4. Test of low energy operation of CESR	12/17
5. Bypass line magnet design -	1/18
6. Pickup/kicker undulator design	1/18
7. Bypass line vacuum component design	4/18
8. Second test of low energy operation	4/18
9. Bypass line engineering design -	6/18
10. Undulator engineering design	6/18
11. Undulator fabrication	10/18
12. Bypass line magnet fabrication	10/18
13. Bypass line vacuum fab	11/18
14. Fabricate support stands for bypass	1/19
15. Design optical amplifier	1/19
16. Test low energy optics in CHESS-U configuration	4/19
17. Design optical detector to measure interference	5/19
18. Installation of delay bypass	7/19
19. Commission bypass and demonstrate interference	12/19
20. Install optical amplifier and laser and detector	1/20
21. Demonstrate cooling (machine studies)	4/20

CHESS U 750 MeV

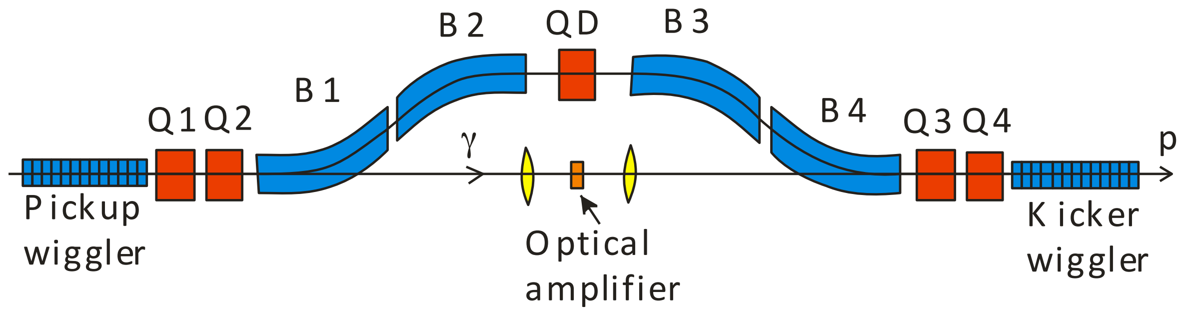


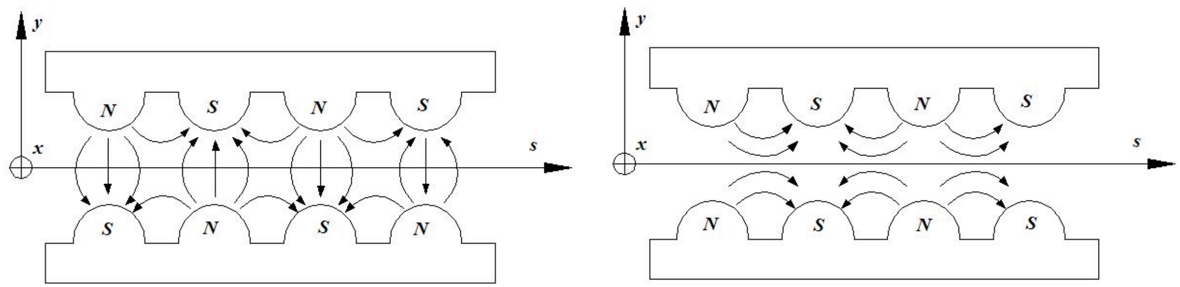
10 chess U undulators at 0.95T
750 MeV
Damping time 0.72 sec
Emittance 52 pm
V_RF=0.6MV => sigma_l=8.1mm

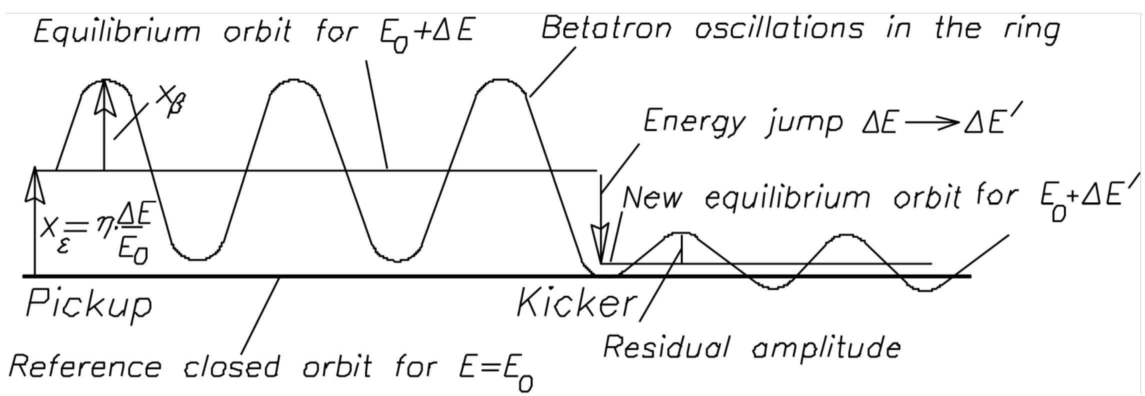
CHESS U 750 MeV

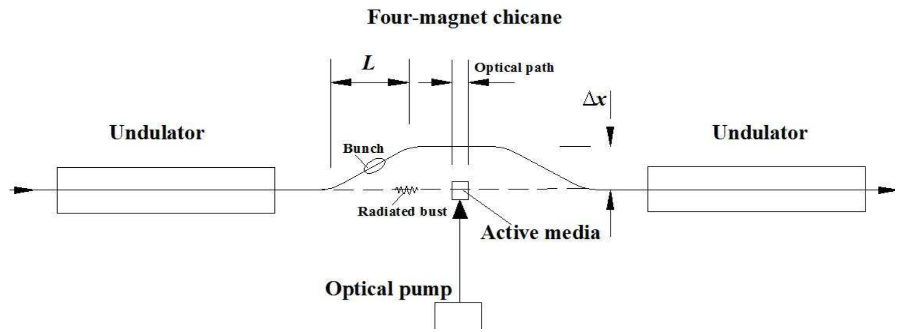


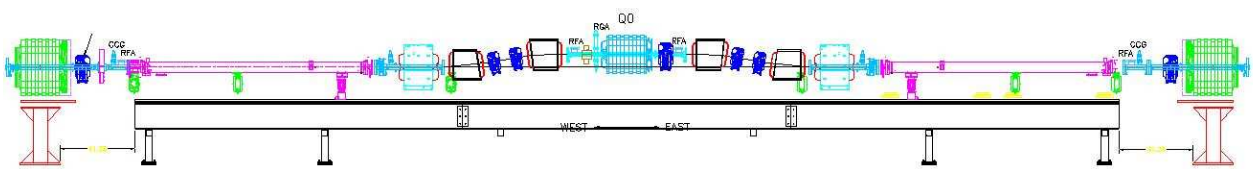
10 chess U undulators at 0.45T
300 MeV
Damping time 8.3 sec
Emittance 6.5 pm
V_RF=0.6MV => sigma_l=2.2mm

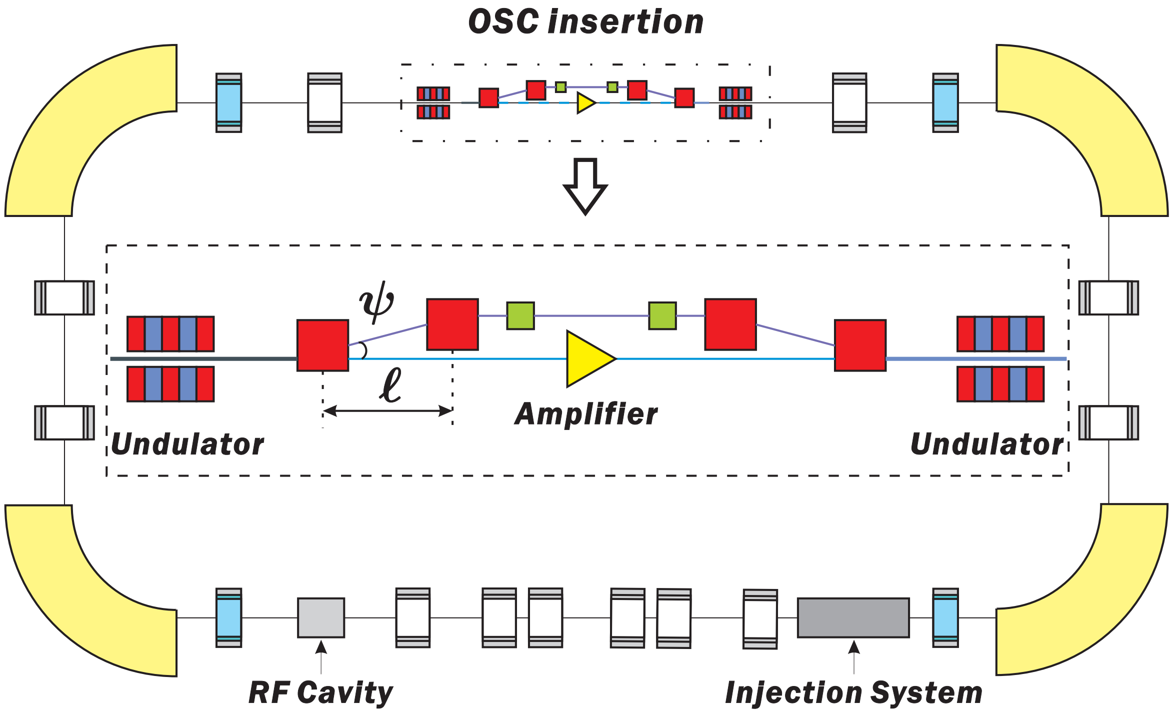

B 2
QD
B 3
B 1
B 4
Q1 Q2
Q3 Q4
γ
p
Pickup wiggler
Optical amplifier
Kicker wiggler


y
x
s
N
S
N
S
S
N
S
N
y
x
s
N
S
N
S
N
S
N
S

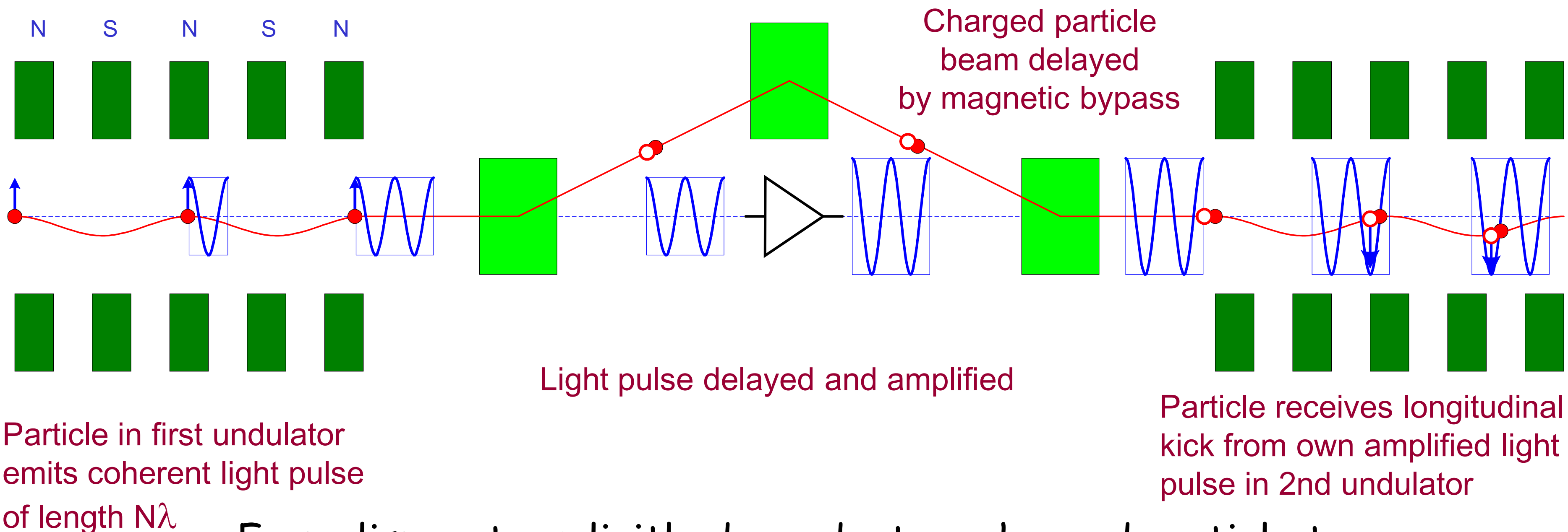

Equilibrium orbit for $E_0+\Delta E$
Betatron oscillations in the ring
x_β
Energy jump $\Delta E \longrightarrow \Delta E'$
New equilibrium orbit for $E_0+\Delta E'$
$x_\varepsilon = \eta \cdot \frac{\Delta E}{E_0}$
Pickup
Kicker
Residual amplitude
Reference closed orbit for $E=E_0$


Four-magnet chicane
L
Optical path
Δx
Undulator
Undulator
Bunch
Radiated bust
Active media
Optical pump


QO
RGA
RFA
RFA
CCG
RFA
CCG
RFA
WEST
EAST



OSC insertion
ψ
ℓ
Amplifier
Undulator
Undulator
RF Cavity
Injection System



Formalism not explicitly dependent on charged particle type