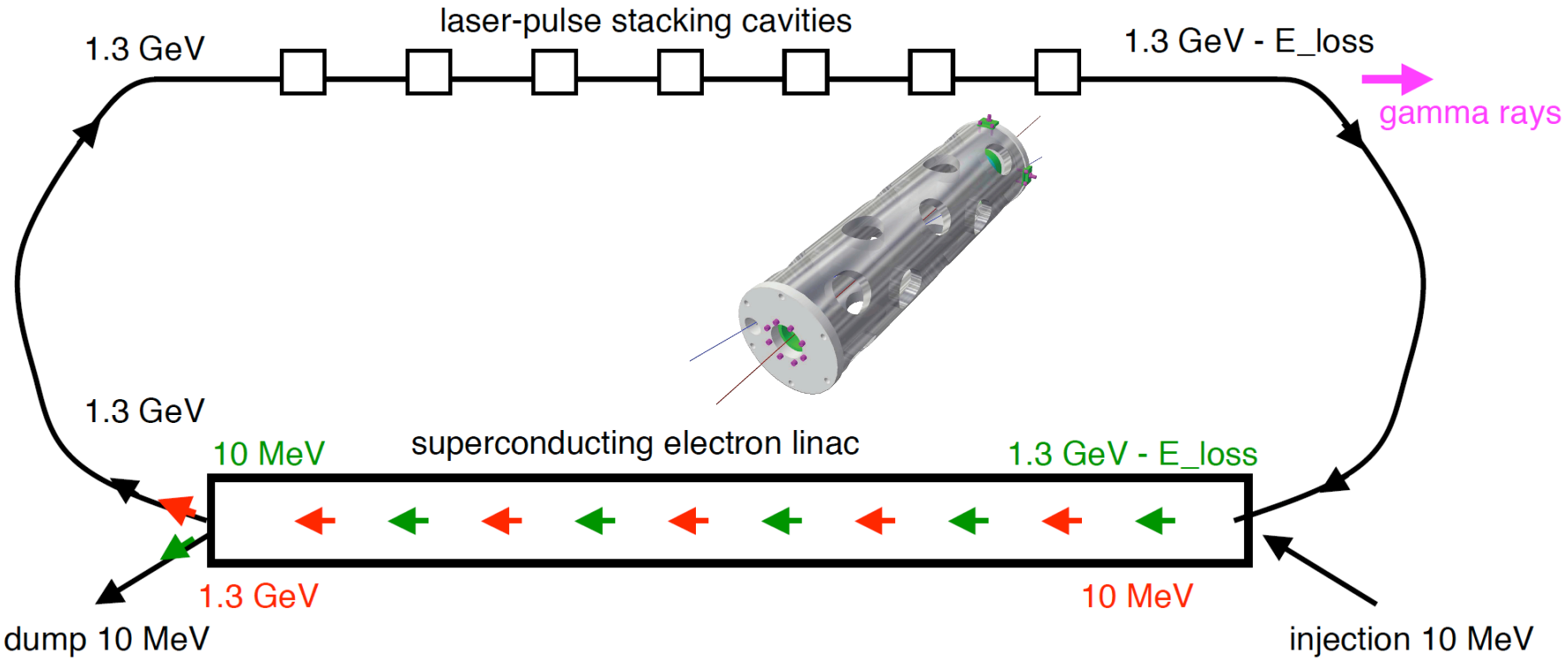
ERL based Compton e^+ source for ILC



Tsunehiko OMORI (KEK)

ILCWS 2007@DESY

31/May/2007

World-Wide Compton Collaboration

Collaborating Institutes:
BINP, CERN, DESY, Hiroshima, IHEP, IPN, KEK,
Kyoto, LAL, NIRS, NSC-KIPT, SHI, Waseda,
BNL, JAEA, and ANL

Sakae Araki, Yasuo Higashi, Yousuke Honda, Masao Kuriki, Toshiyuki Okugi, Tsunehiko Omori, Takashi Taniguchi, Nobuhiro Terunuma, Junji Urakawa, X. Artru, M. Chevallier, V. Strakhovenko, Eugene Bulyak, Peter Gladkikh, Klaus Meonig, Robert Chehab, Alessandro Variola, Fabian Zomer, Alessandro Vivoli, Richard Cizeron, V. Soskov, M. Jacquet, R. Chiche, Y. Fedala, D. Jehanno, C. Sylvia, Frank Zimmermann, Kazuyuki Sakaue, Tachishige Hirose, Masakazu Washio, Noboru Sasao, Hirokazu Yokoyama, Masafumi Fukuda, Koichiro Hirano, Mikio Takano, Tohru Takahashi, Hirotaka Shimizu, Shuhei Miyoshi, Akira Tsunemi, Ryoichi Hajima, Li XaioPing, Pei Guoxi, Jie Gao, V. Yakinenko, Igo Pogorelsky, Wai Gai, and Wanming Liu

3 of Compton schemes

1. Ring-based Compton.

2. ERL-based Compton.

3. liniac-based Compton.

3 of Compton schemes

similar : re-use

1. Ring-based Compton.

2. ERL-based Compton.

3. liniac-based Compton.

throw-away e- beam

3 of Compton schemes

similar : re-use

1. Ring-based Compton.

different

2. ERL-based Compton.

3. liniac-based Compton.

throw-away e- beam

3 of Compton schemes

1. Ring-based Compton.

2. ERL-based Compton.
   new comer: no parameter-set yet

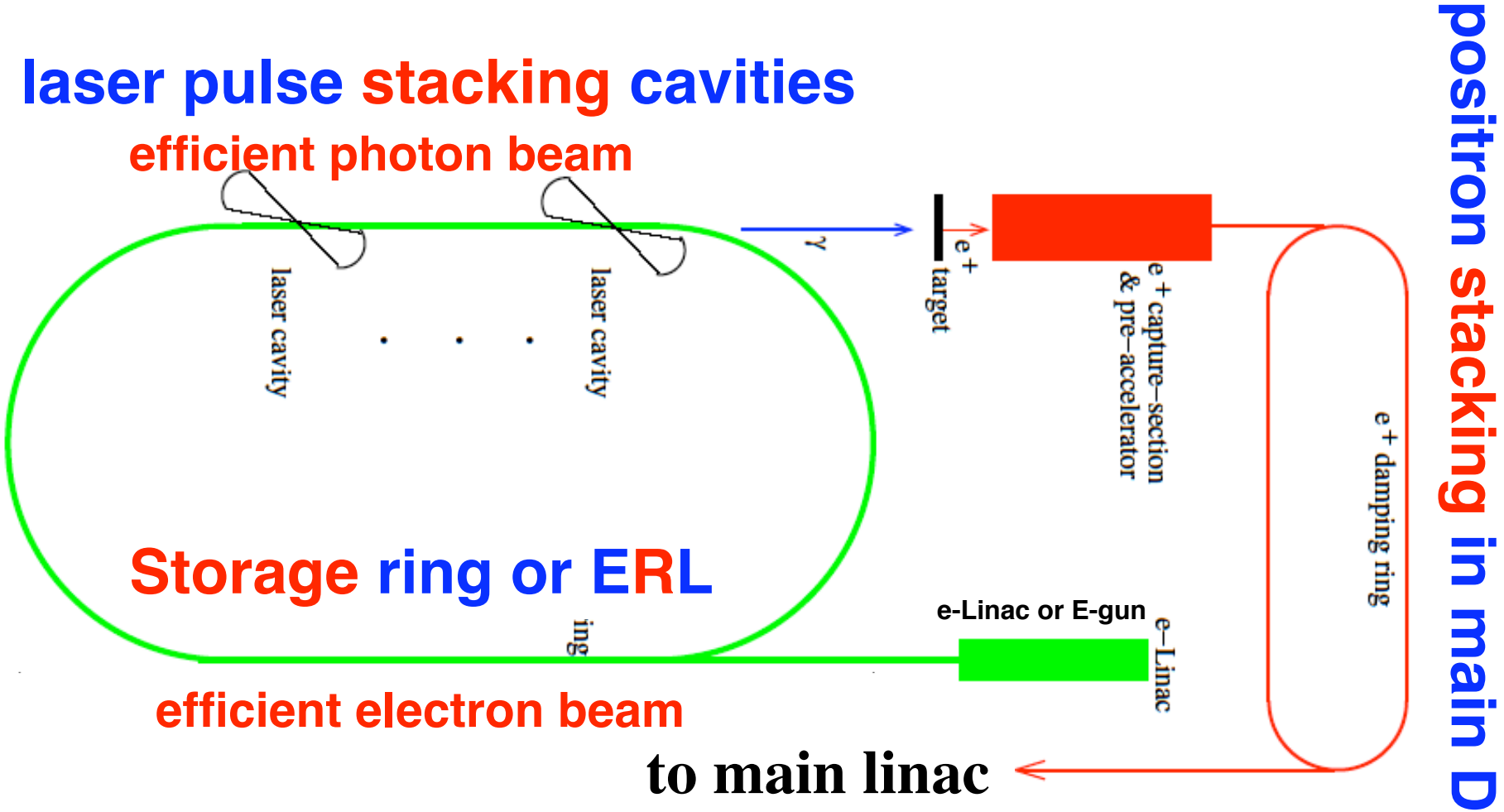
3. liniac-based Compton.

Today's Talk

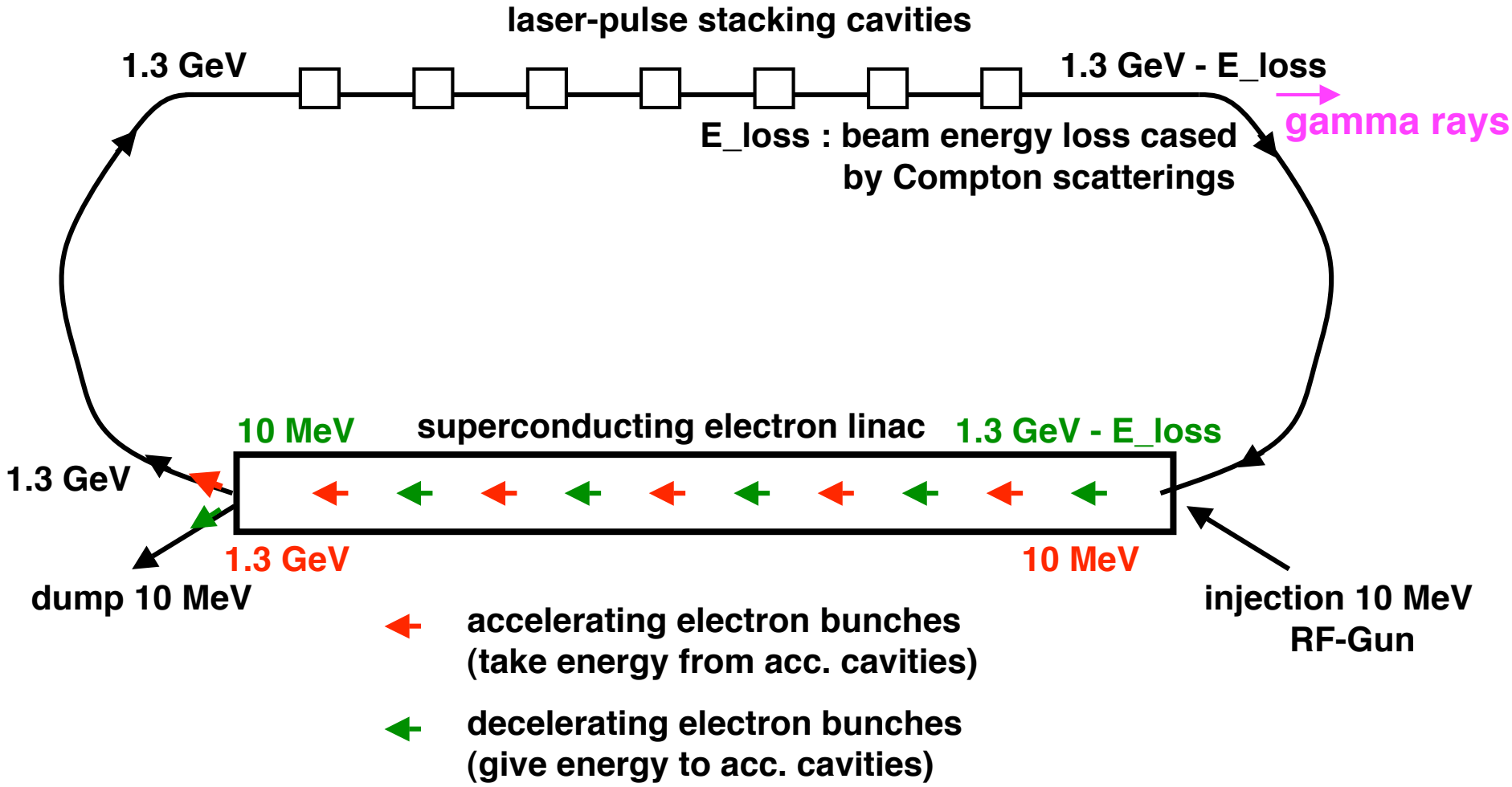
Aim : to get working-assumption-models of ERL scheme

I will consider many constraints and show two models.

Ring/ERL Compton Re-use Concept

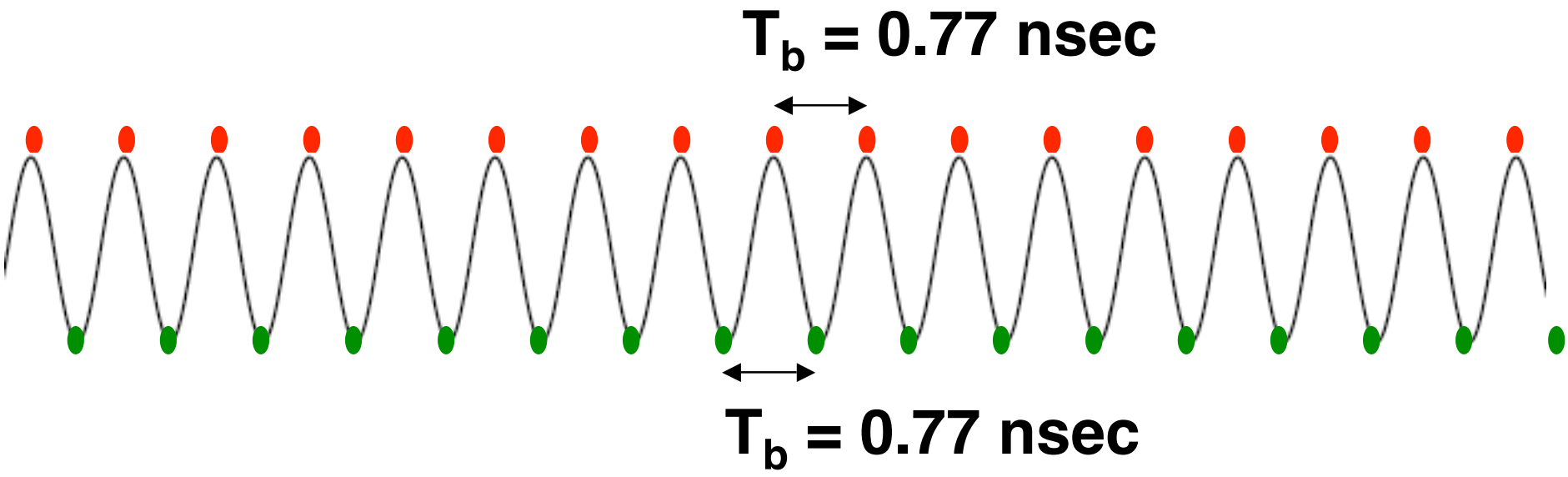


What is ERL?
What is ERL based Compton source?



What is ERL?

e^- bunches in ERL (f_{RF} = 1.3 GHz)



- Accelerating bunches
- Decelerating bunches

T_b : bunch to bunch separation

Points of ERL 1

- Re use: Energy of electron beam.
- Throw away: electron beam.

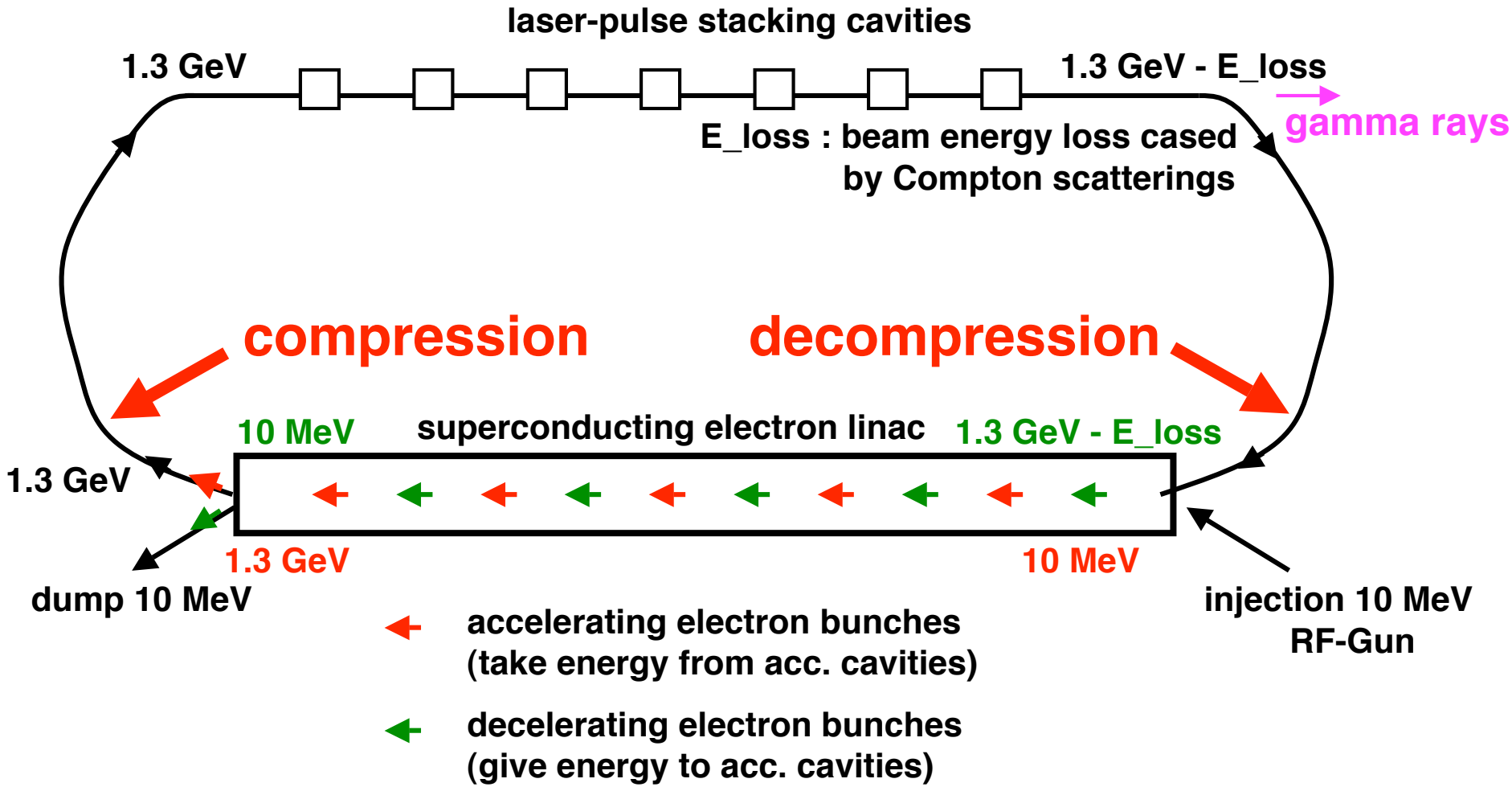
Points of ERL 1

- Re use: Energy of electron beam
- Throw away: electron beam.

Points of ERL 2

- Fresh, high quality beam.
- Easy beam compression.

What is ERL?
What is ERL based Compton source?



Points of ERL 1

- Re use: Energy of electron beam
- Throw away: electron beam.

Points of ERL 2

- Fresh, high quality beam
- Easy beam compression

Points of ERL 3

- Need steady exchange of energy:
  - Acc-Bunches, Decl-Bunches, Klystrons
- Need CW operation

Points of ERL 1

- Re use: Energy of electron beam
- Throw away: electron beam.

Points of ERL 2

- Fresh, high quality beam
- Easy beam compression

Points of ERL 3

- Need steady exchange of energy:
  - Acc-Bunches, Decl-Bunches, Klystrons
- Need CW operation

Injection : ERL --> DR

Constraint 1 : ERL needs CW operation

choice: quasi-CW operation

1) first 100 msec

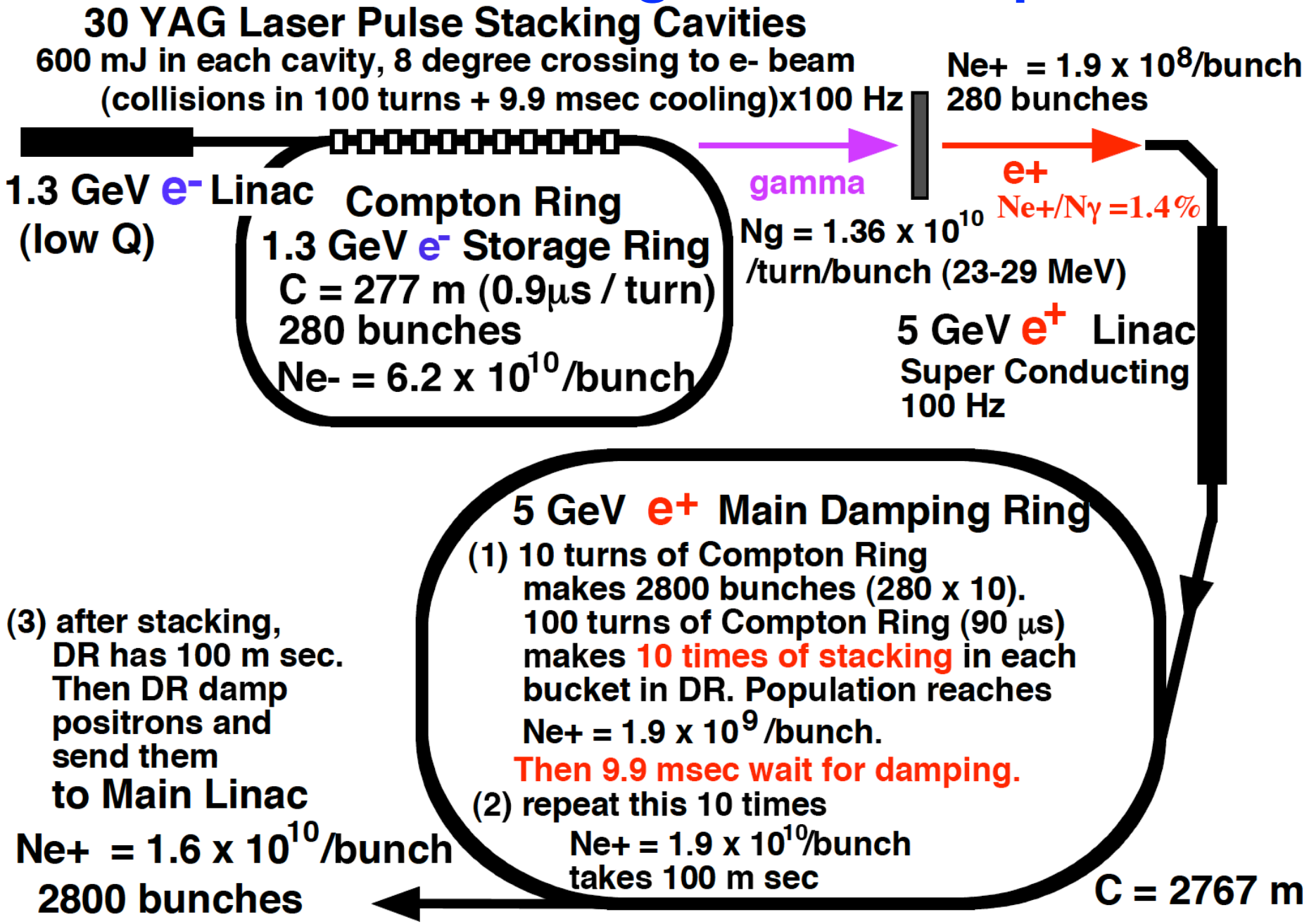
   ERL operation + top-up injection to DR

   very different from storage ring scheme

2) 2nd 100 msec

   damping in DR

Snowmass 2005 Ring based Compton



Snowmass 2005 Ring based Compton

Burst injection

1) first 100 m sec

10 x (injection 0.1 ms + damping 9.9 ms)

required by both DR and Compton ring

--->

total : injection 1 ms + damping 99 ms

2) second 100 m sec

damping in DR

Snowmass 2005 Ring based Compton

Burst injection

1) first 100 m sec

10 x (injection 0.1 ms + damping 9.9 ms)

required by both DR and Compton ring

--->

total : injection 1 ms + damping 99 ms

2) second 100 m sec

damping in DR

ERL scheme --> top-up injection

injection 100 ms

top-up injection

possible? working assumption

Snowmass 2005 Ring based Compton

Burst injection

1) first 100 m sec

10 x (injection 0.1 ms + damping 9.9 ms)

required by both DR and Compton ring

--->

total : injection 1 ms + damping 99 ms

2) second 100 m sec

damping in DR

x 100 gain

ERL scheme --> top-up injection

injection 100 ms

top-up injection

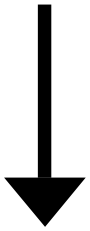
possible? working assumption

ERL scheme has "x100 gain" in time

Tight e^+ selection in the Capture system

Get better emittance of e^+ in Capture

typical capture: N_{e+} (Captured) / $N\gamma$ ~ 2 %



intentional reduction to get better ε

Proposal: N_{e+} (Captured) / $N\gamma$ ~ 0.3 %

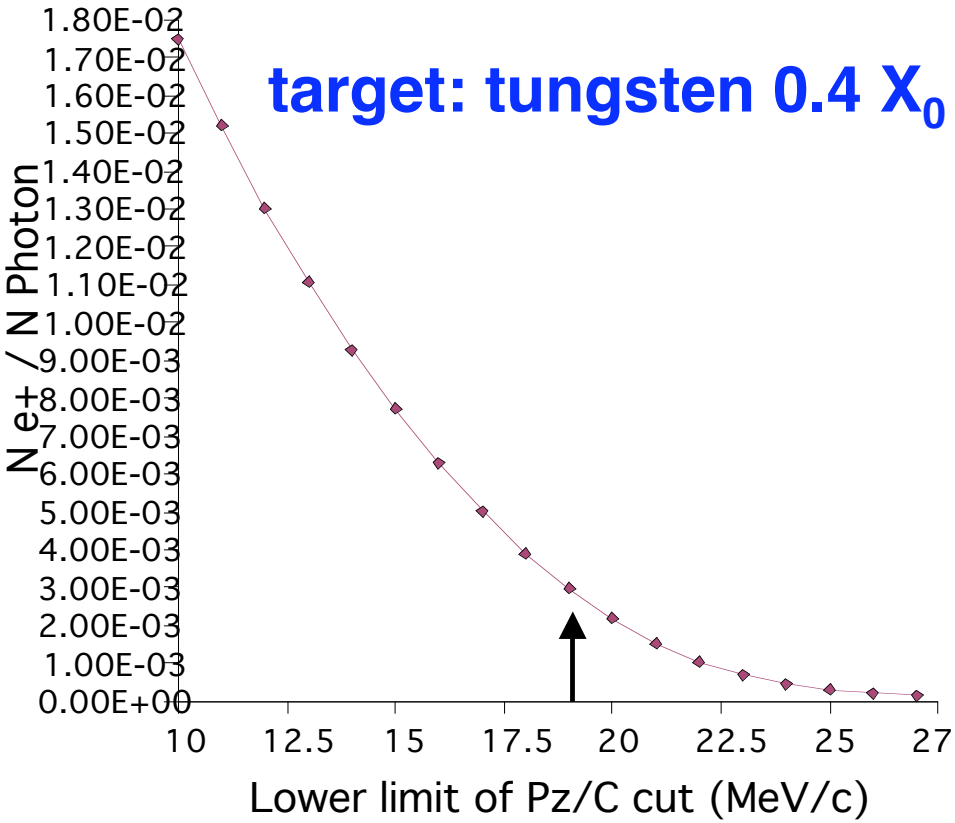
How to reduce N_{e+} ?

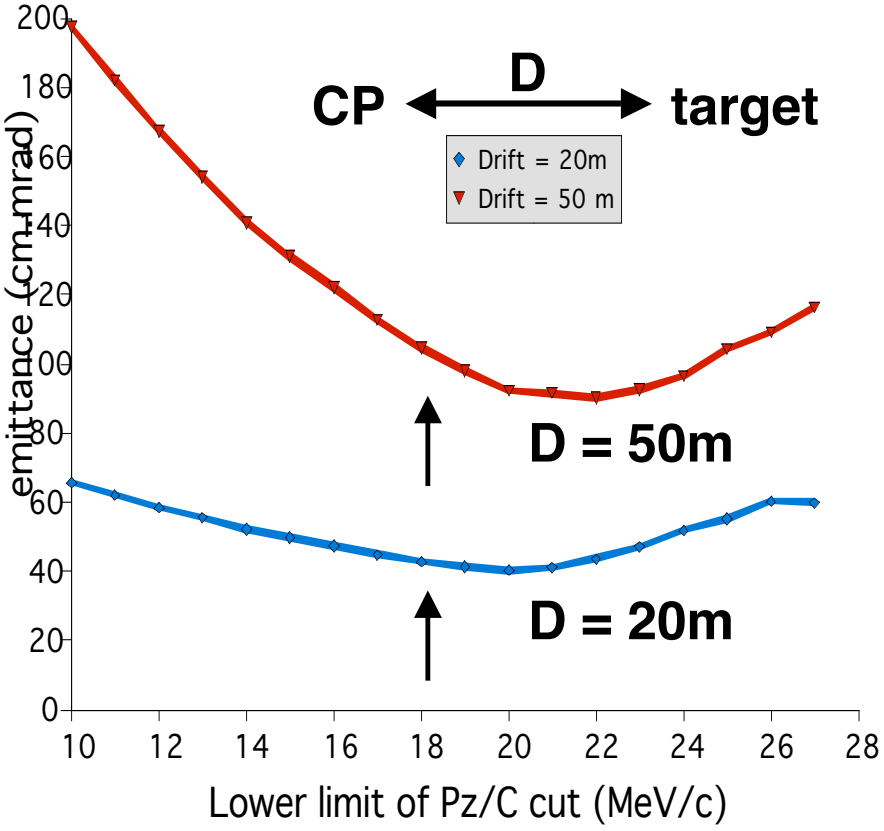
(1) Pz selection

(2) reduce target thickness

(3) combination of (1) and (2)

Preliminary study by Wanming & Wei (ANL)





if Pz > 18 MeV/c --> $Ne^+/N\gamma$ ~ 0.3% Pol ~ 80%

ε(geo) at target exit ~ 100 cm-mrad (D=50m)

~ 50 cm-mrad (D=20m)

Injection : ERL --> DR

Constraint 1 : ERL needs CW operation

choice: quasi-CW operation

1) first 100 msec

   ERL operation + top-up injection to DR

   very different from storage ring scheme

2) 2nd 100 msec

   damping in DR

Constraint 2 : $T_{b\_ERL} = nT_{b\_DR}$

Injection : ERL --> DR

Constraint 1 : ERL needs CW operation

choice: quasi-CW operation

1) first 100 msec

   ERL operation + top-up injection to DR

   very different from storage ring scheme

2) 2nd 100 msec

   damping in DR

Constraint 2 : $T_{b\_ERL} = nT_{b\_DR}$

Constraint : T_b in ERL <---> T_b in DR

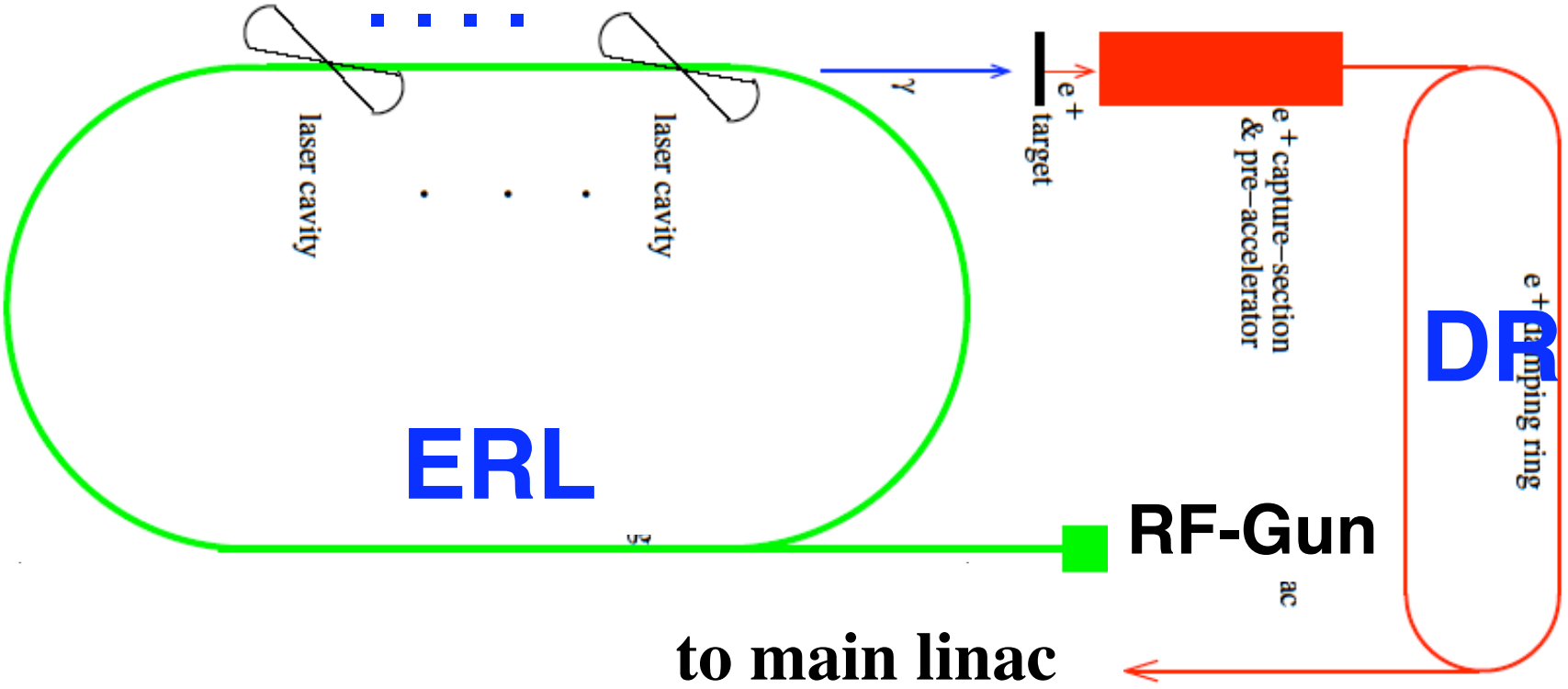
$$T_{b\_ERL} = nT_{b\_DR} \quad (n=1, 2, 3, ,)$$

T_{b_ERL} = 6.15 nsec $\qquad$ T_{b_DR} = 6.15 nsec

12.3 nsec

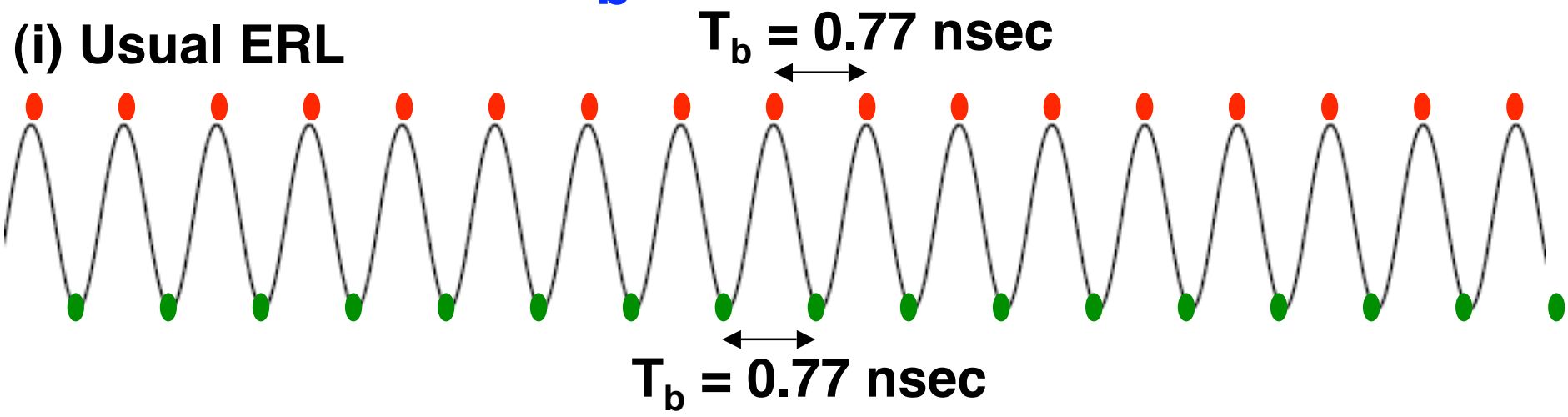
18.5 nsec

. . . .

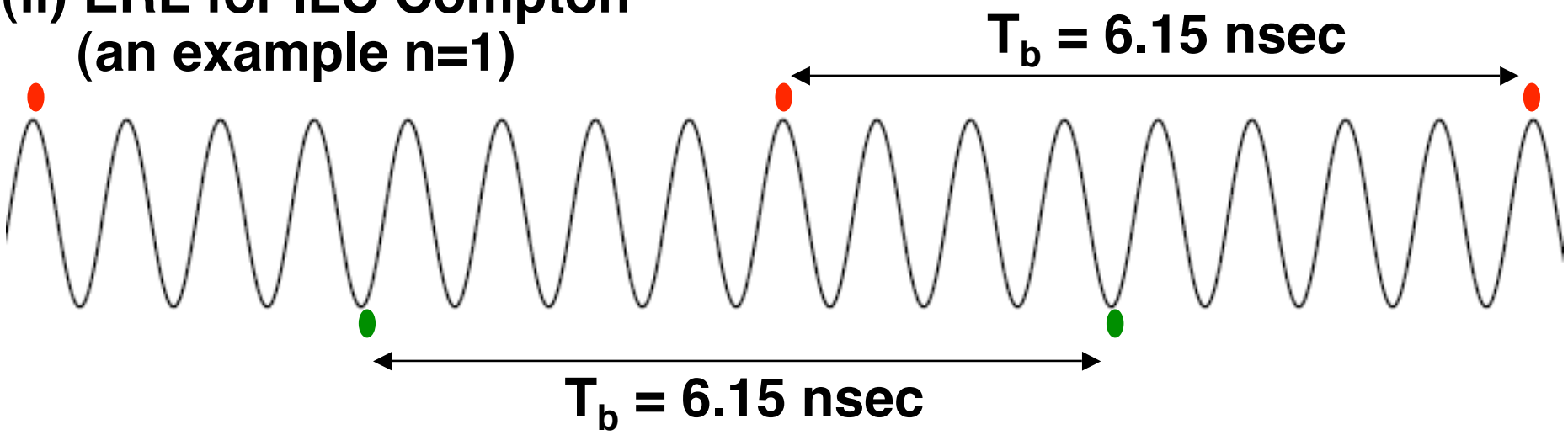


Constraint : T_b in ERL

(i) Usual ERL



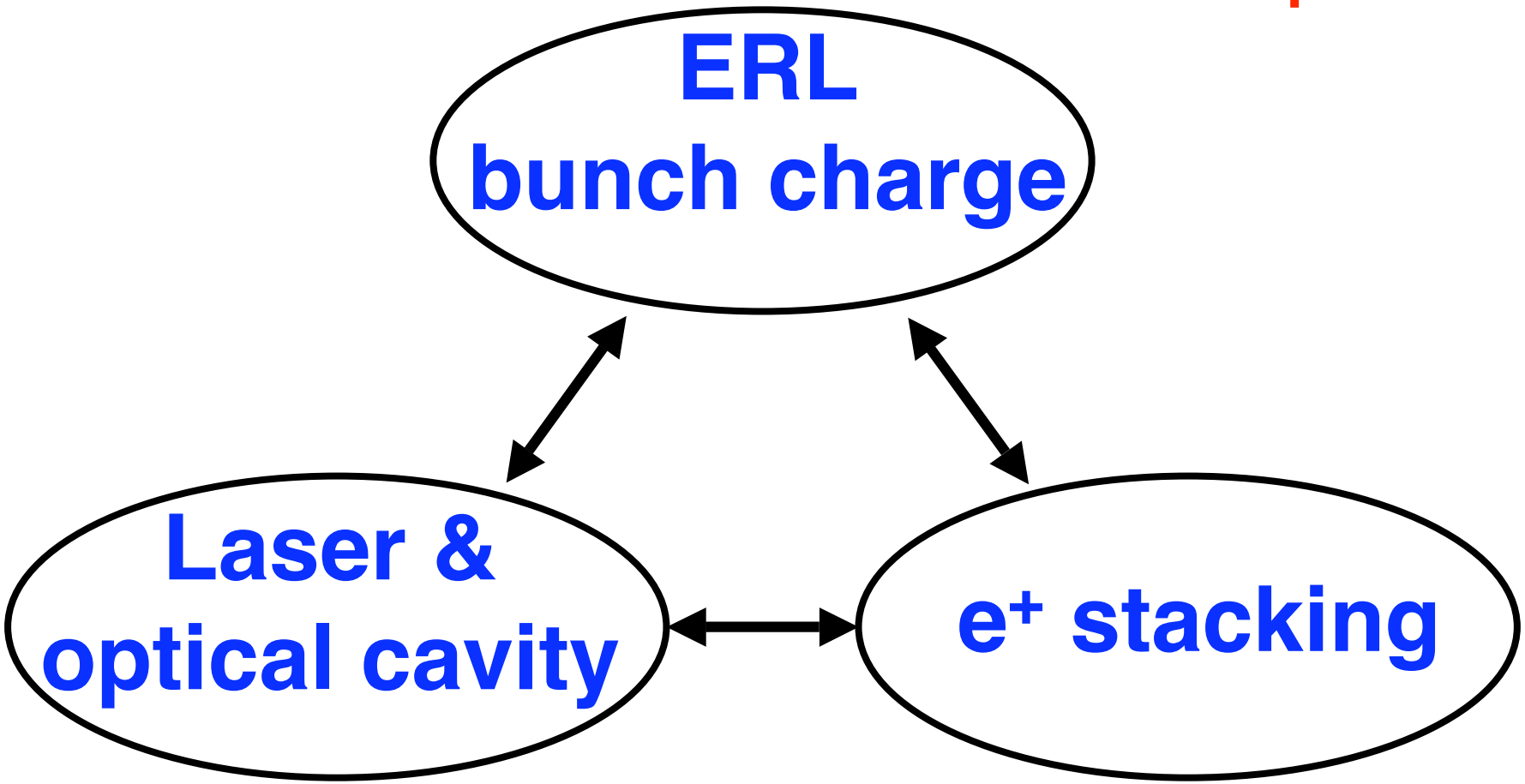
(ii) ERL for ILC Compton
(an example n=1)



- Accelerating bunches
- Decelerating bunches

Selection of bunch repetition: f_{rep}

3 factors to determine f_{rep}



Compare two choices

(a) f_{rep} = 163 MHz

$T_{b\_ERL} = T_{b\_DR}$ = 6.15 nsec

(b) f_{rep} = 40.8 MHz

$T_{b\_ERL} = 4T_{b\_DR}$ = 24.6 nsec

Common parameters

ERL: f_{RF} = 1.3 GHz ($T_{bucket\text{-}to\text{-}bucket}$ = 0.77 ns)

$E_{e\text{- beam}}$ = 1.3 GeV

σ_z = 0.7 ps at CP

σ_z = 2 - 3 ps in Liniac

DR: T_{b_DR} = 6.15 ns

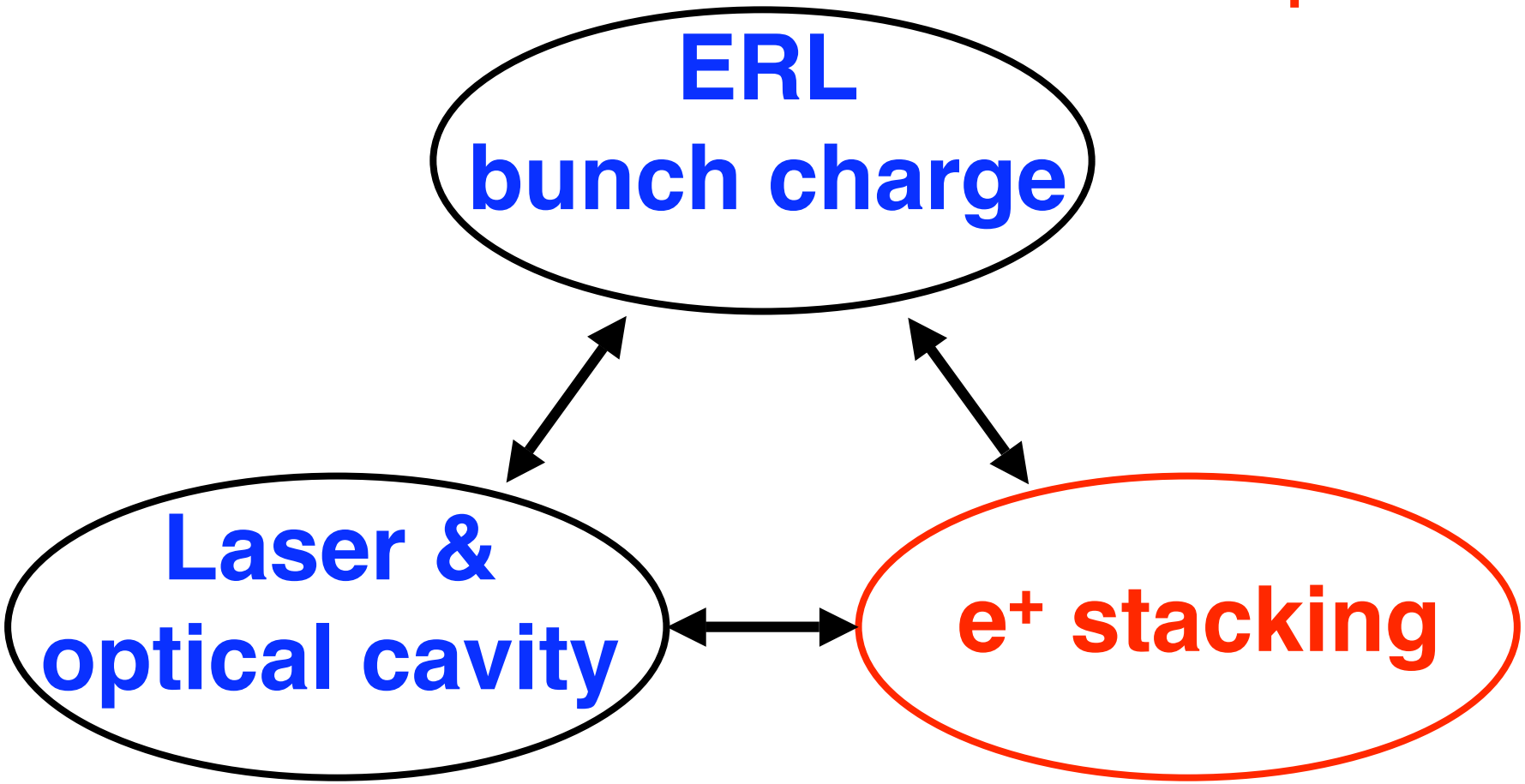
Laser: λ_{Laser} = 1064 nm

σ_z = 0.8 ps at CP (after compression)

σ_z = ~500 psec in Amp.

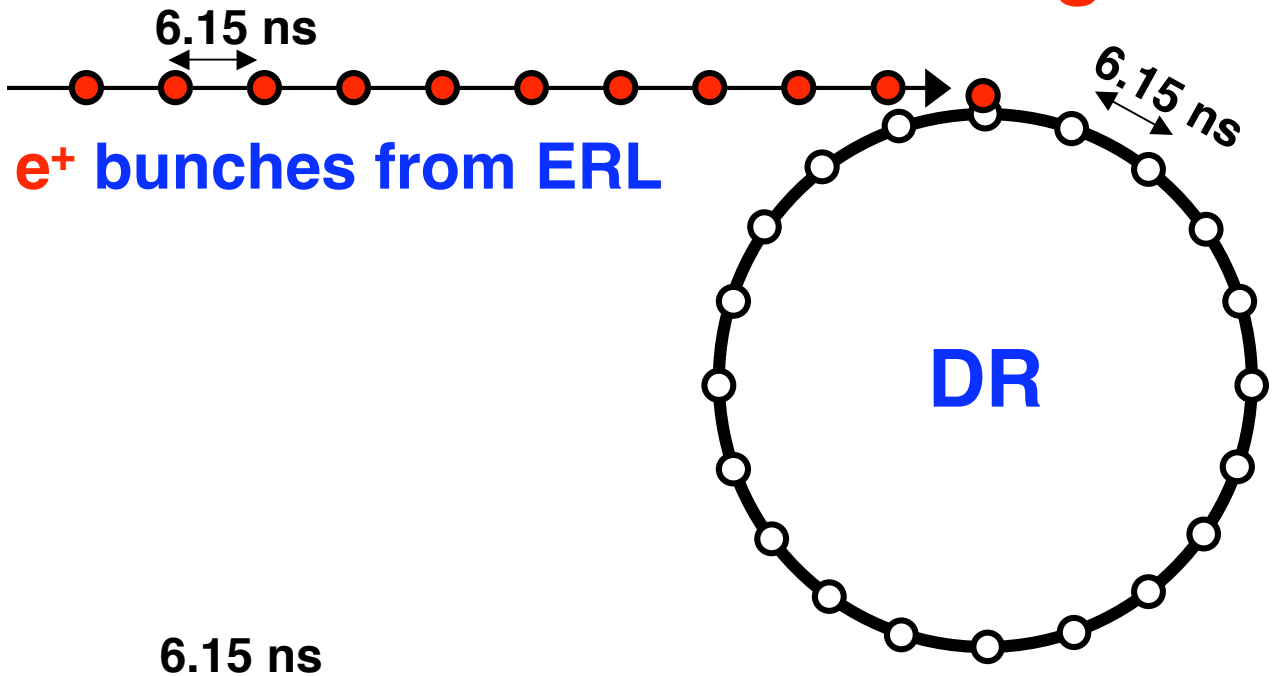
Selection of bunch repetition: f_{rep}

3 factors to determine f_{rep}



(a) f_{rep} = 163 MHz : 1st turn of DR stacking

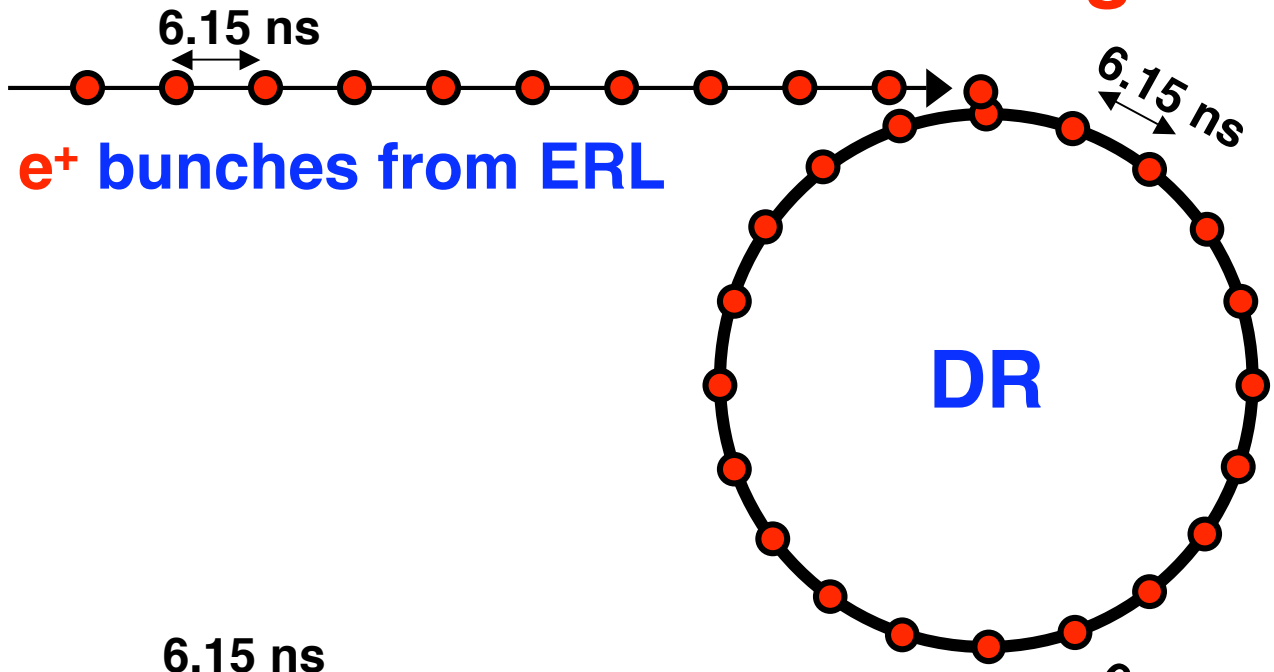
(1) 1st turn begin



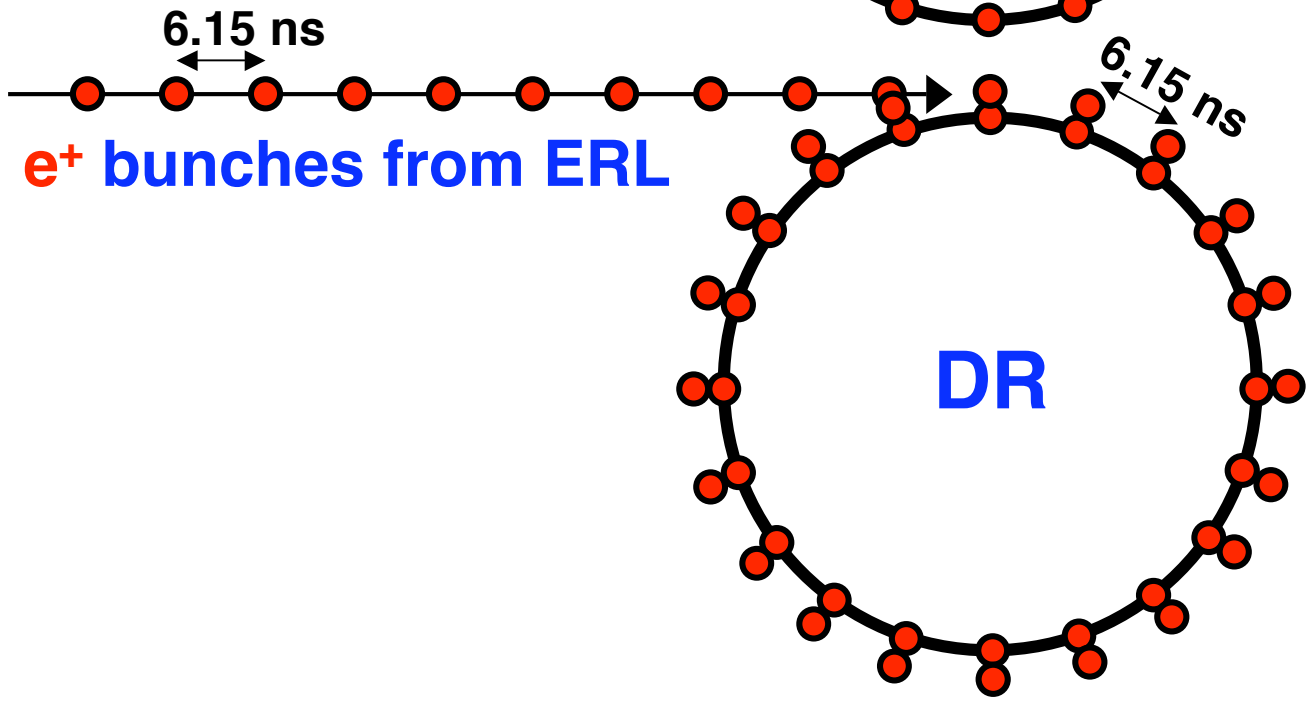
(2) 1st turn end

(a) f_{rep} = 163 MHz : 2nd turn of DR stacking

(3) 2nd turn begin

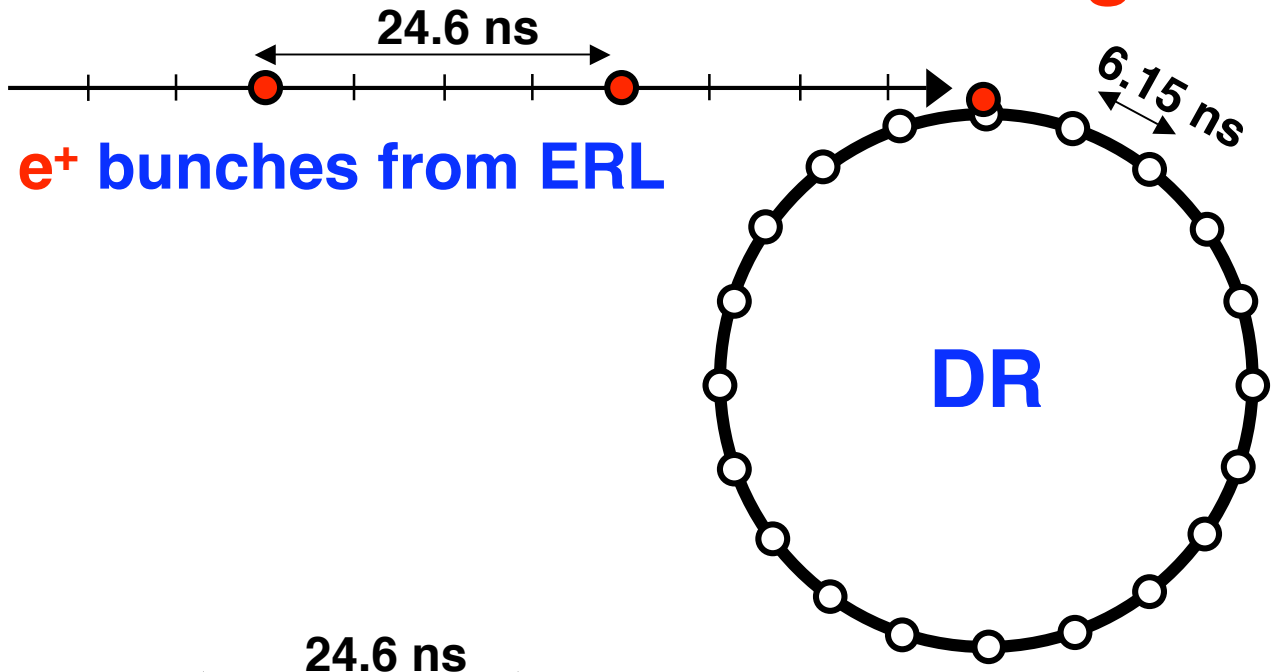


(4) 2nd turn end

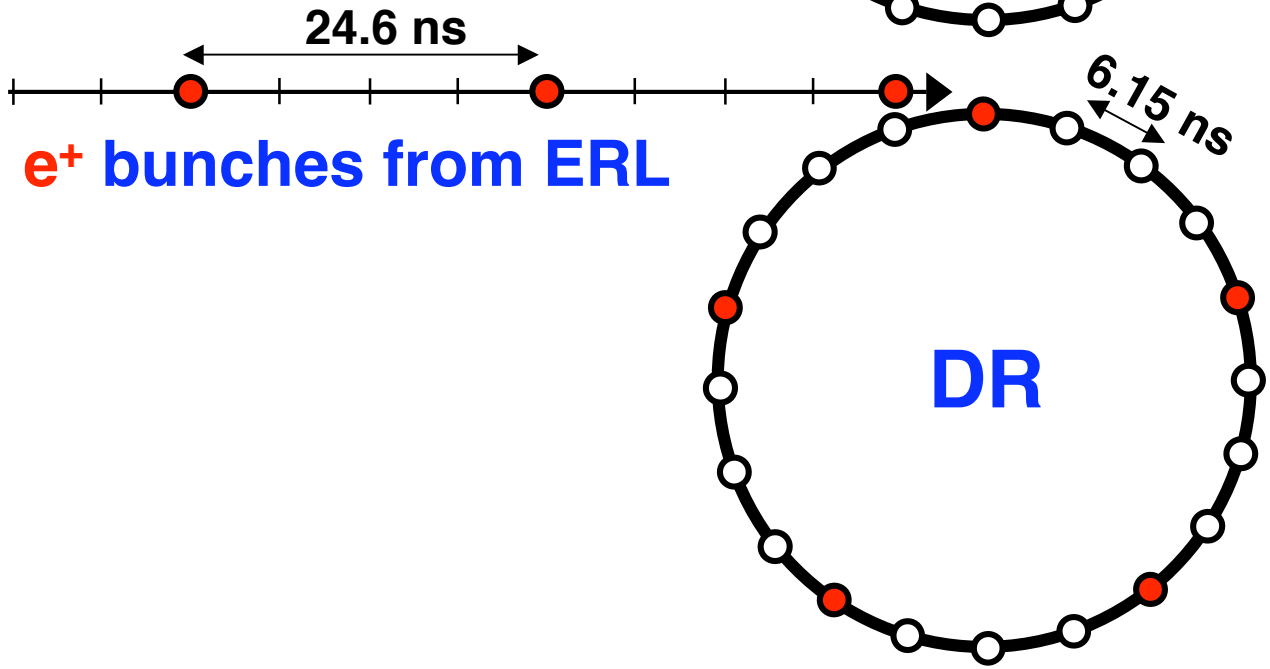


(b) f_{rep} = 40.8 MHz : 1st turn of DR stacking

(1) 1st turn begin

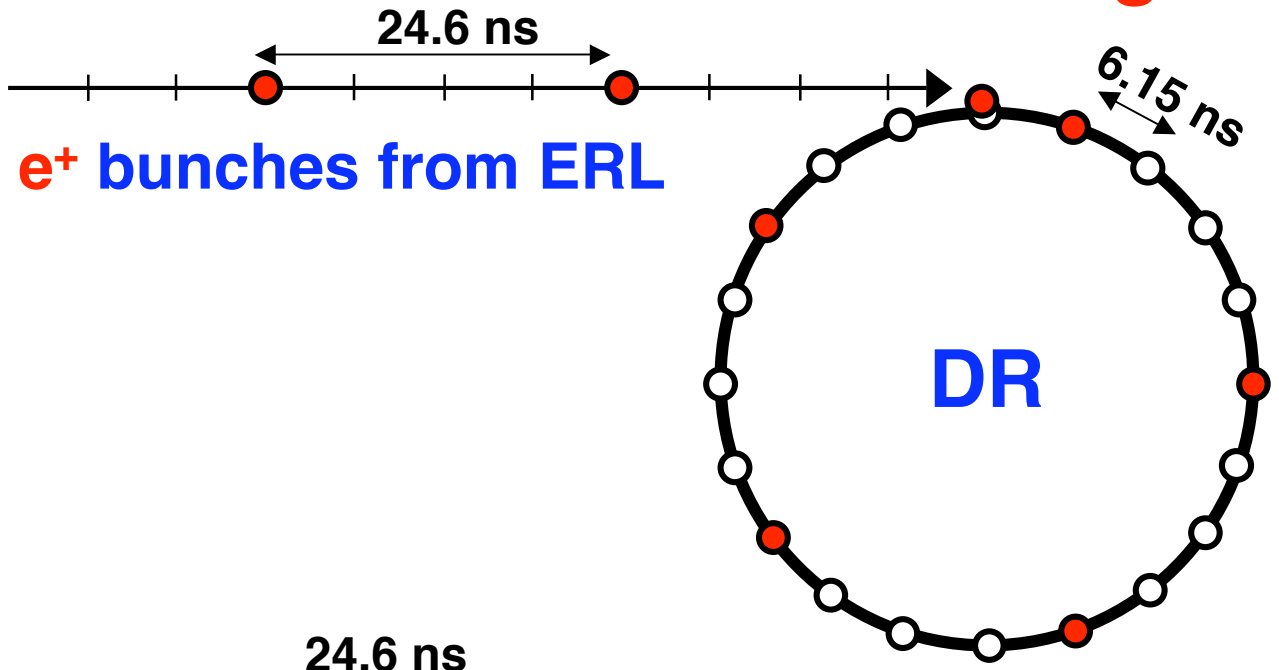


(2) 1st turn end

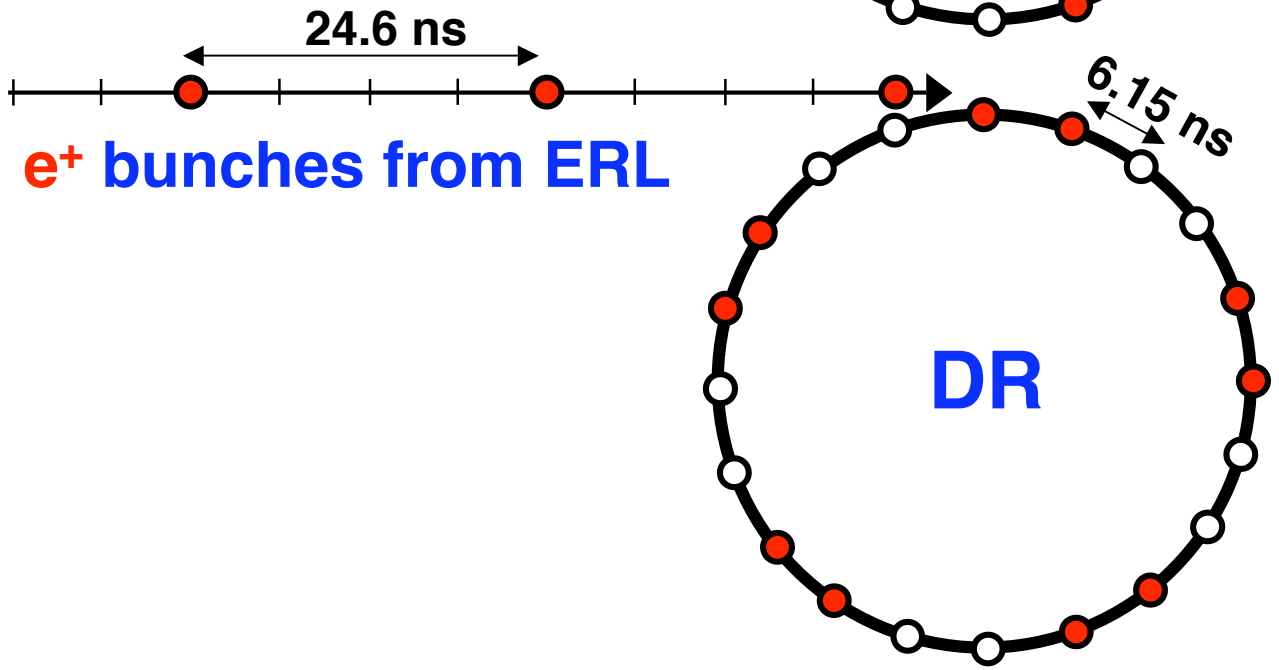


(b) f_{rep} = 40.8 MHz : 2nd turn of DR stacking

(1) 2nd turn begin

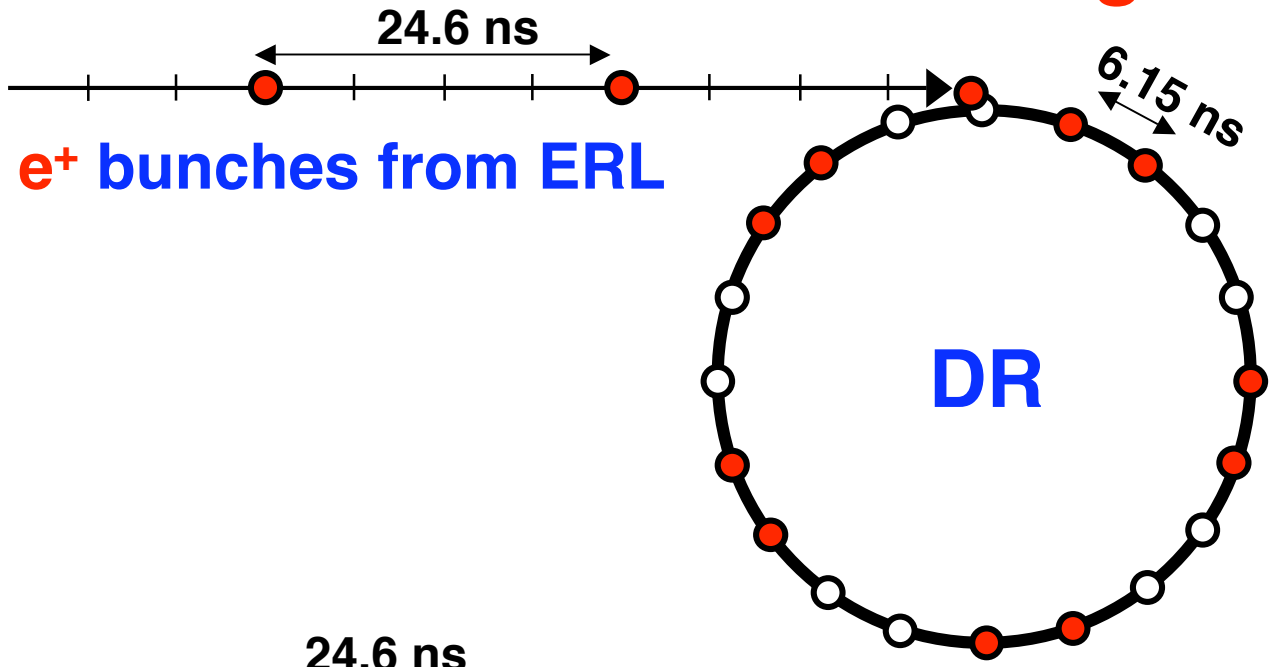


(2) 2nd turn end

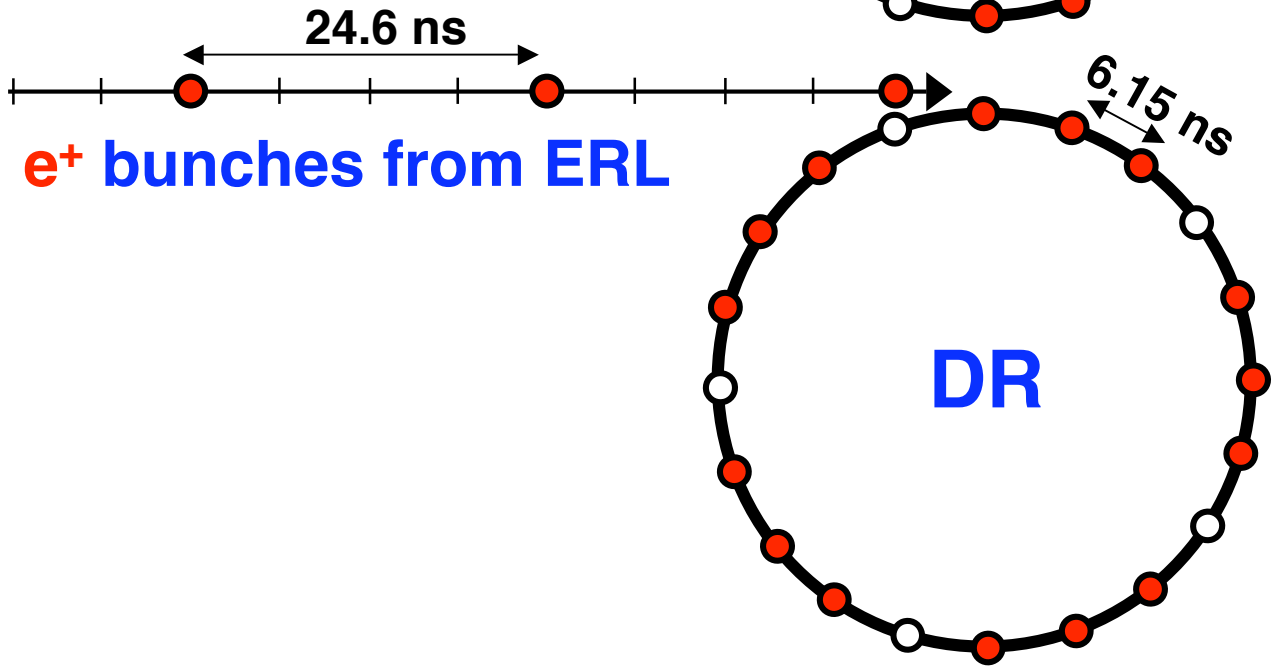


(b) f_{rep} = 40.8 MHz : 3rd turn of DR stacking

(1) 3rd turn begin

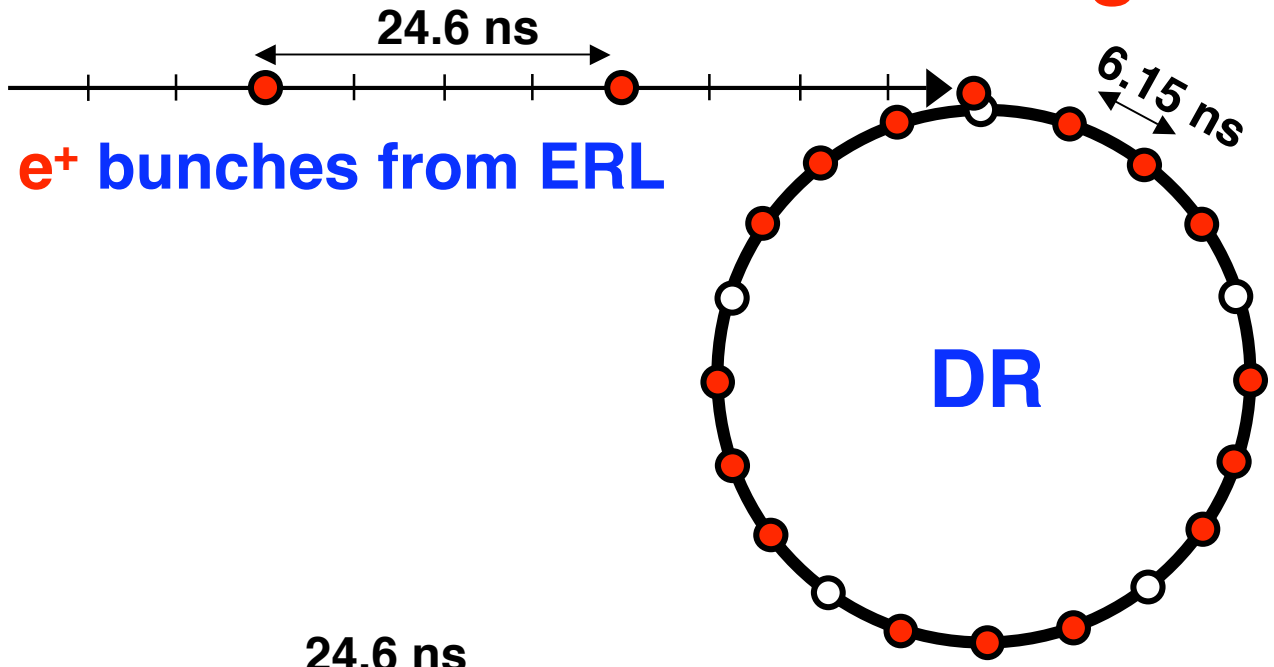


(2) 3rd turn end

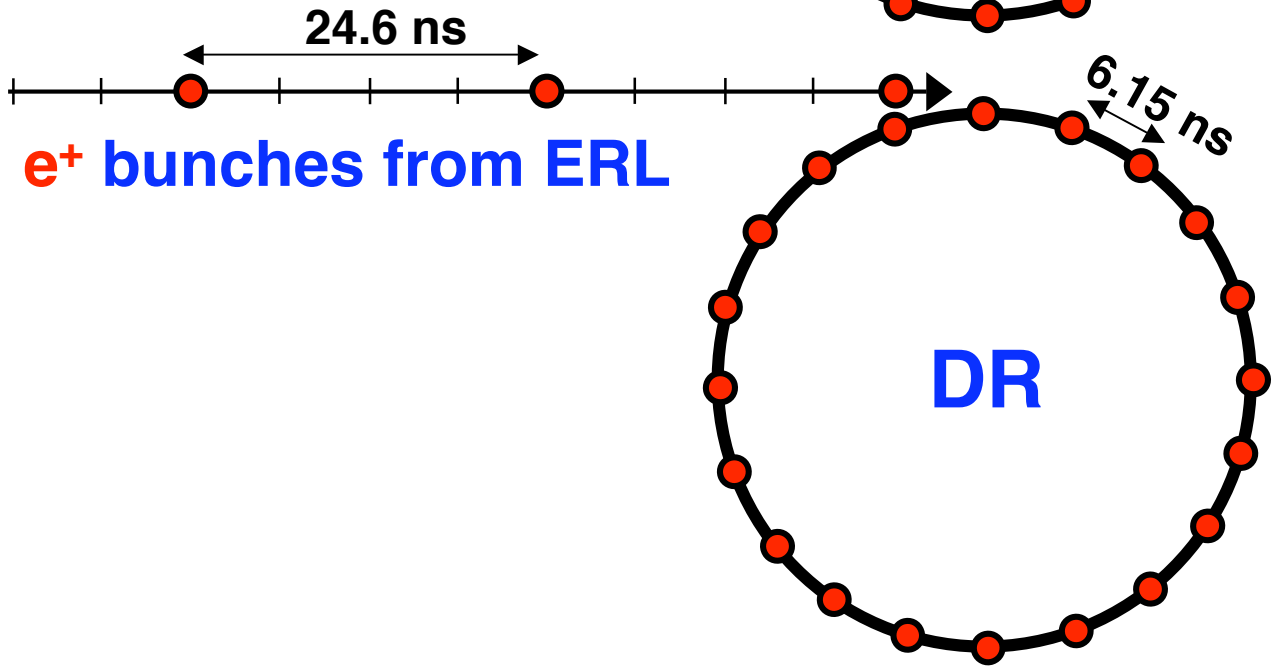


(b) f_{rep} = 40.8 MHz : 4th turn of DR stacking

(1) 4th turn begin

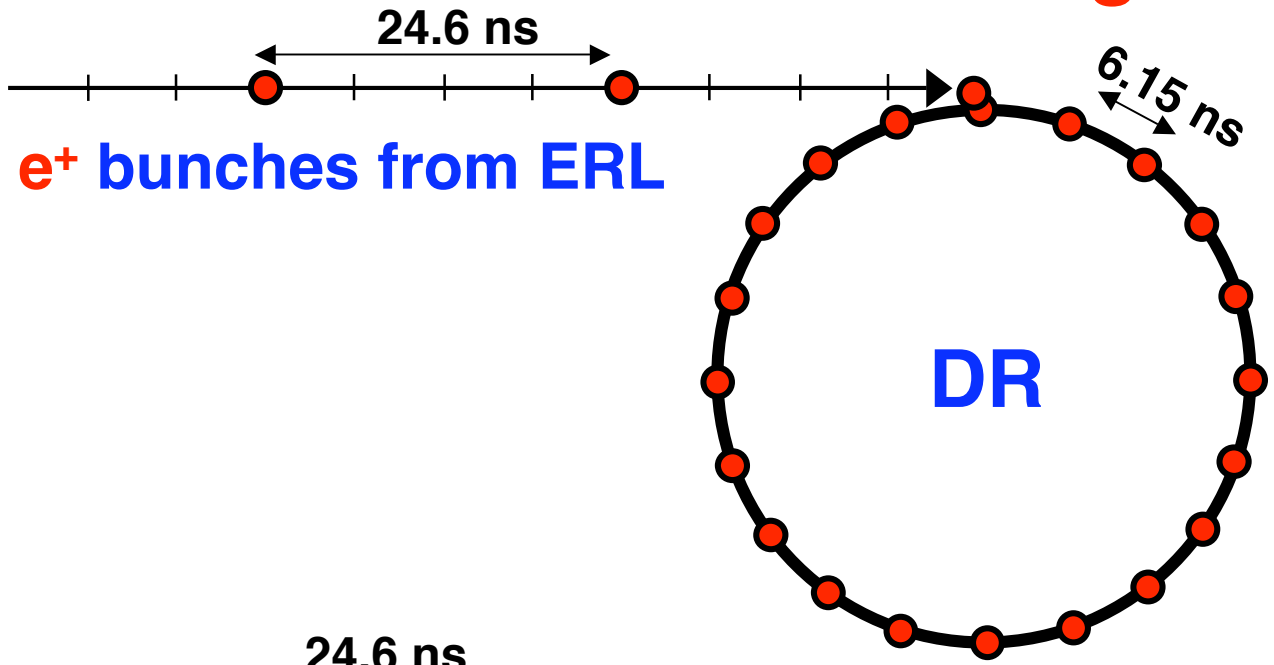


(2) 4th turn end

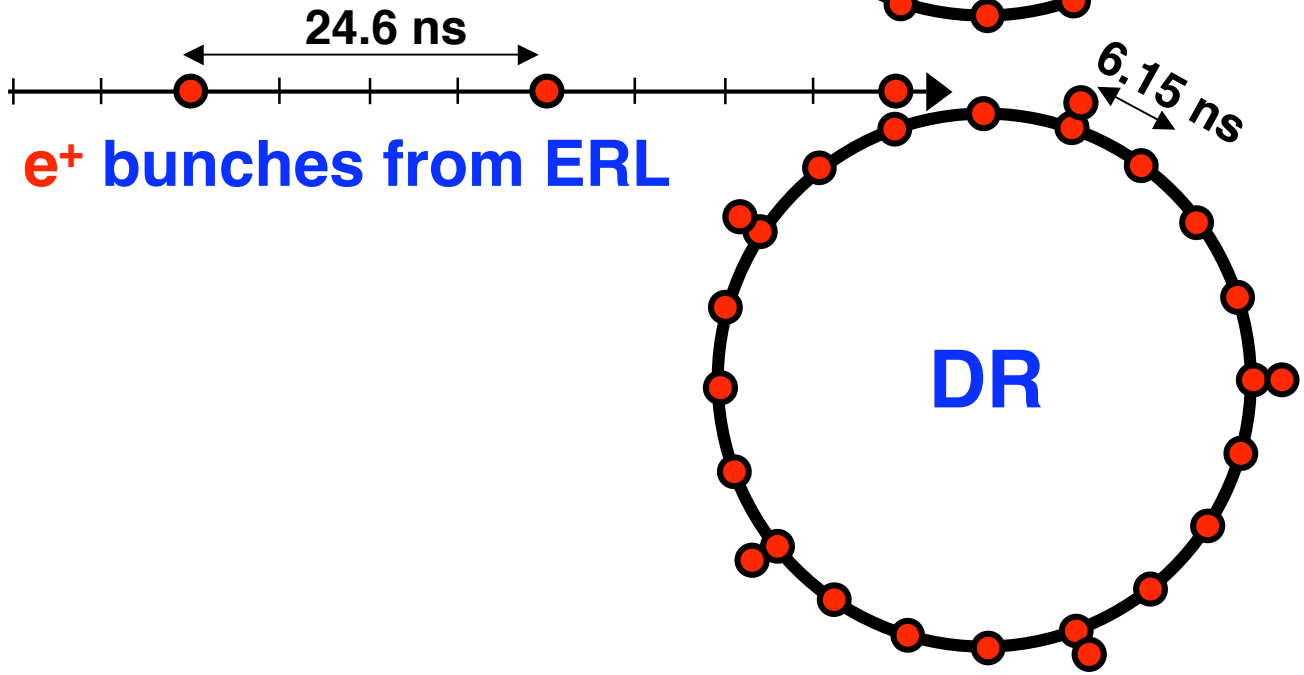


(b) f_{rep} = 40.8 MHz : 5th turn of DR stacking

(1) 5th turn begin



(2) 5th turn end



(b) f_{rep} = 40.8 MHz : 6th-7th turn of DR stacking

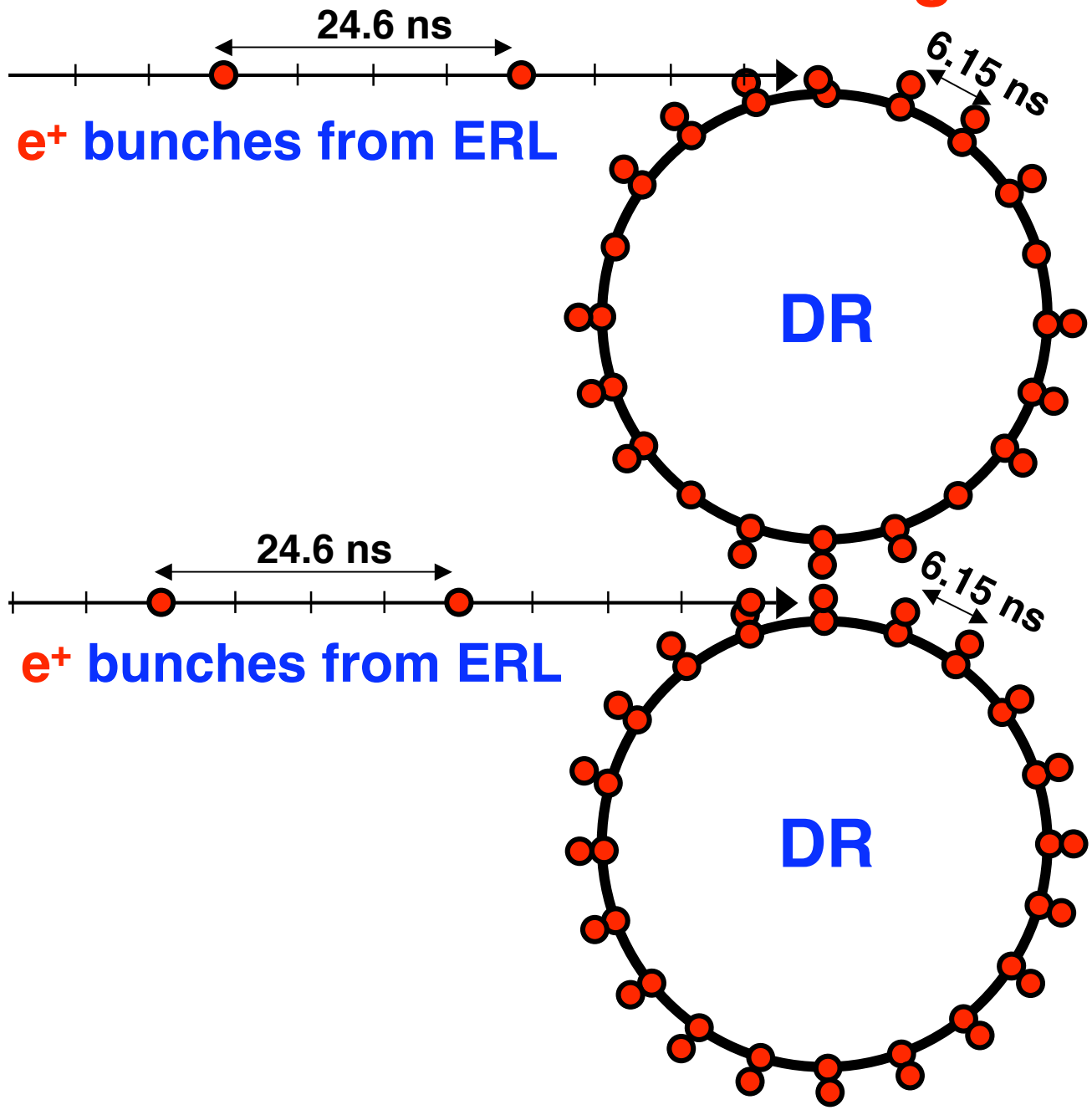
stacking goes on.

6 th turn of DR stacking

7 th turn of DR stacking

then,

(b) f_{rep} = 40.8 MHz : 8th turn of DR stacking



From View point of e^+ stacking

(a) f_{rep} = 163 MHz

$T_{b\_ERL} = T_{b\_DR}$ = 6.15 nsec

(b) f_{rep} = 40.8 MHz

$T_{b\_ERL} = 4T_{b\_DR}$ = 24.6 nsec

From View point of e^+ stacking

(a) f_{rep} = 163 MHz

$T_{b\_ERL} = T_{b\_DR}$ = 6.15 nsec

Hard: we have to do stacking in every DR turn

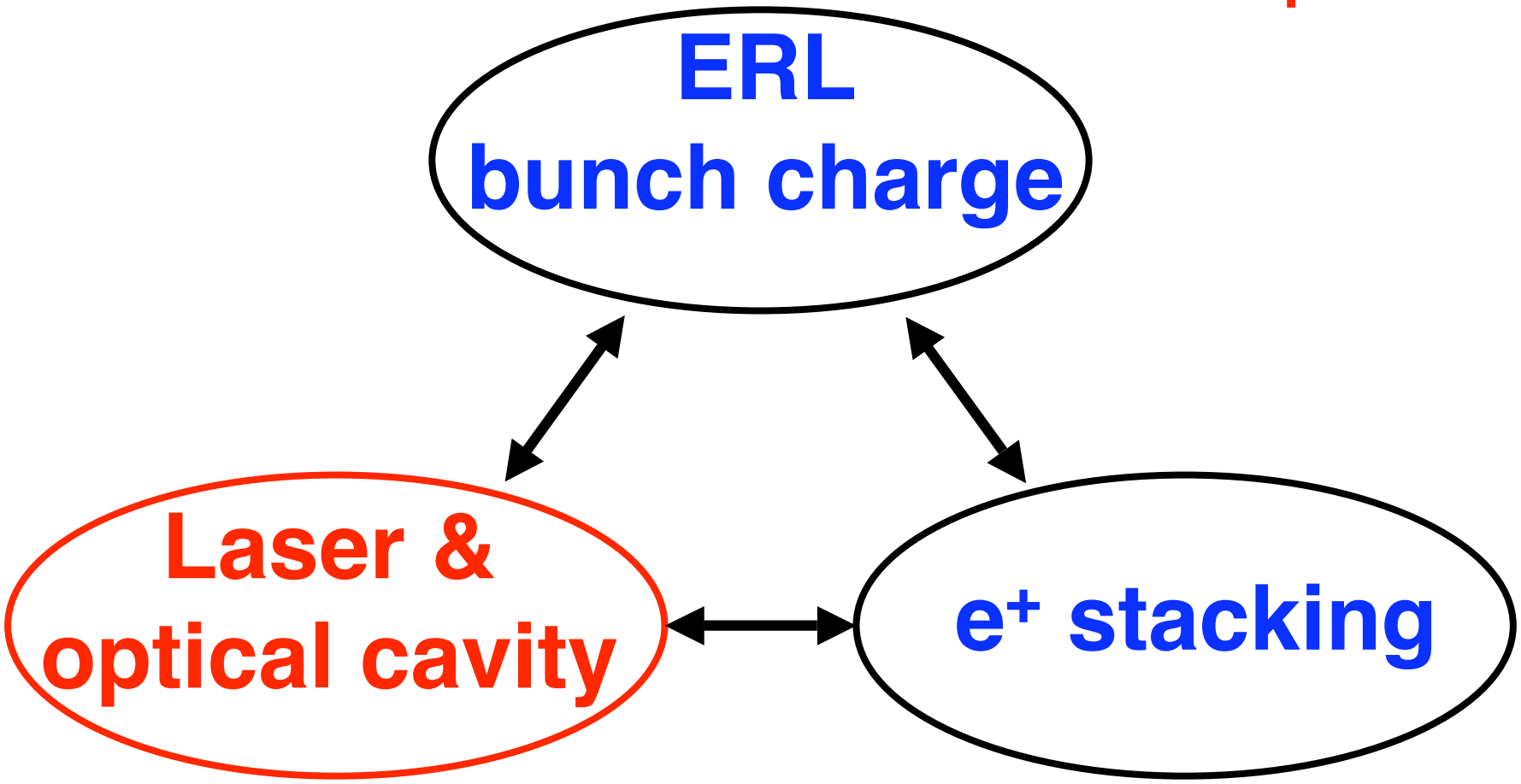
(b) f_{rep} = 40.8 MHz

$T_{b\_ERL} = 4T_{b\_DR}$ = 24.6 nsec

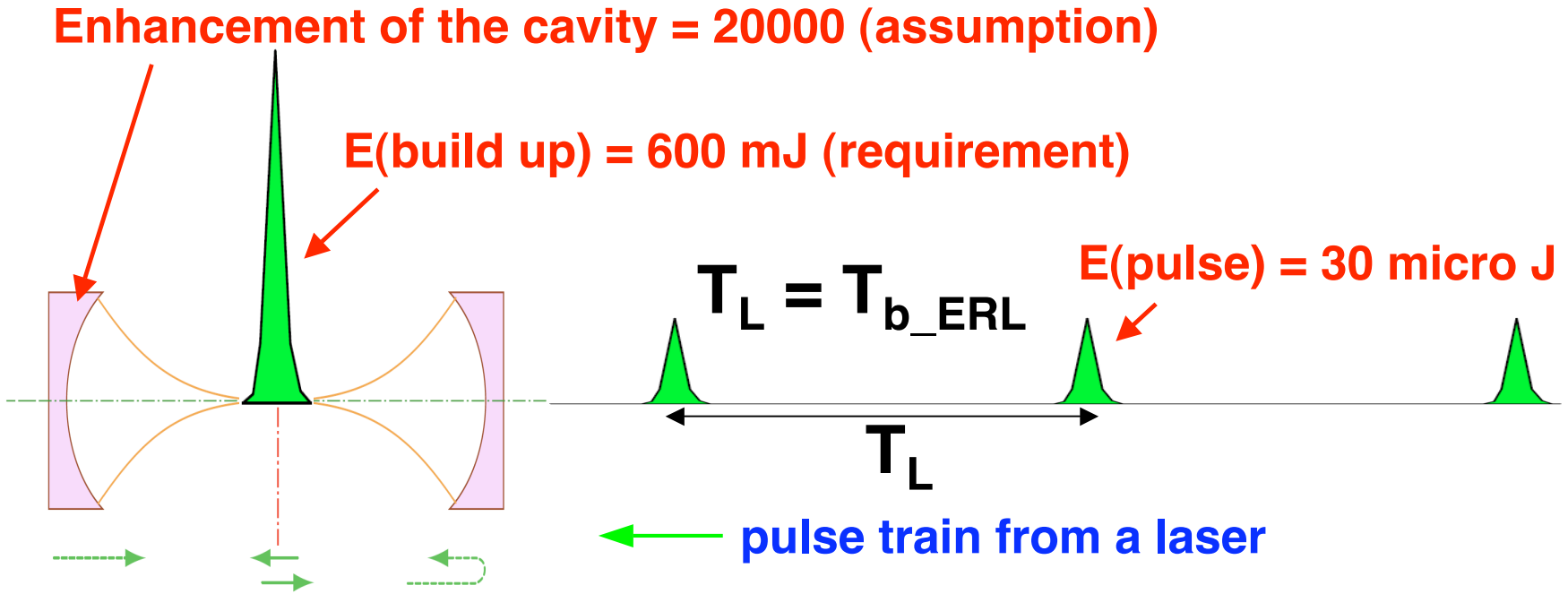
Easier: there are 4 DR turns of damping (bunch position moving in a phase space) before the next stacking.

Selection of bunch repetition: f_{rep}

3 factors to determine f_{rep}



Requirement to a laser



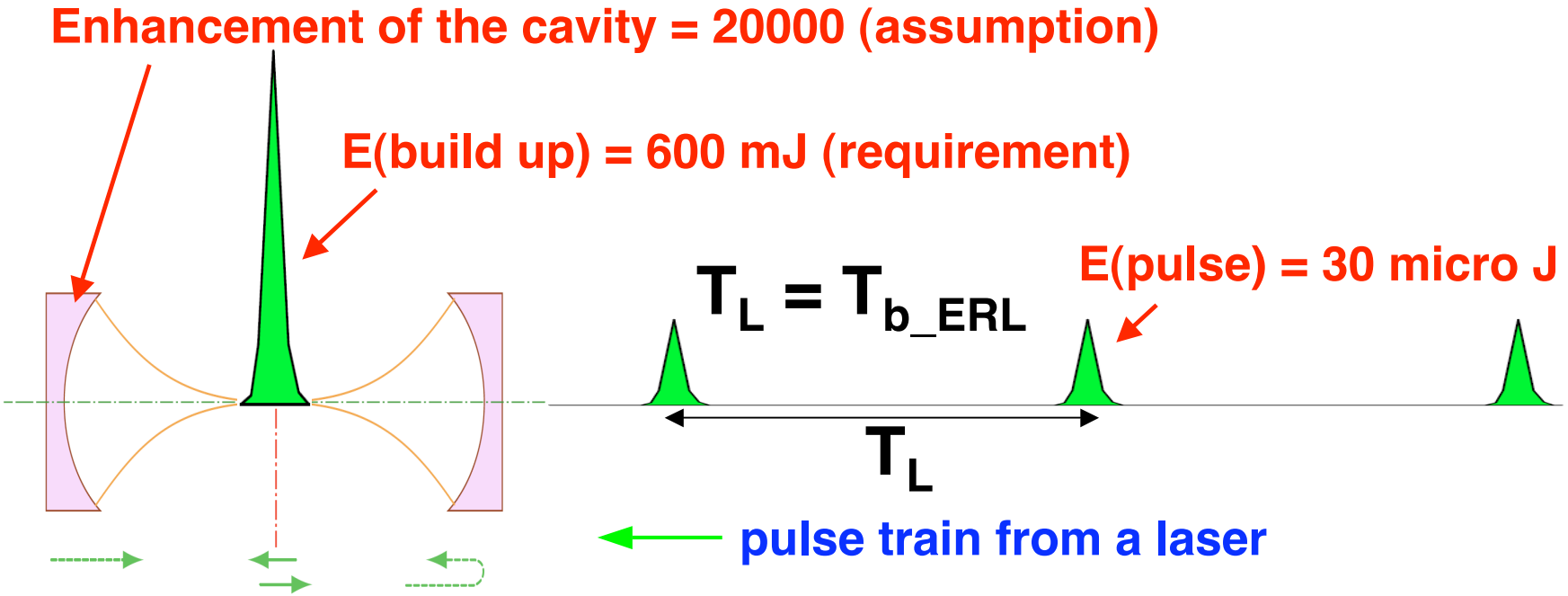
(a) f_{rep} = 163 MHz ($T_{b\_ERL} = T_L$ = 6.15 ns)

Laser beam power (average) = 4.8 kW

(b) f_{rep} = 40.8 MHz ($T_{b\_ERL} = T_L$ = 24.6 ns)

Laser beam power (average) = 1.2 kW

Requirement to a laser



(a) f_{rep} = 163 MHz ($T_{b\_ERL} = T_L$ = 6.15 ns)

Laser beam power (average) = 4.8 kW

Difficult, but seems in extension of current technology

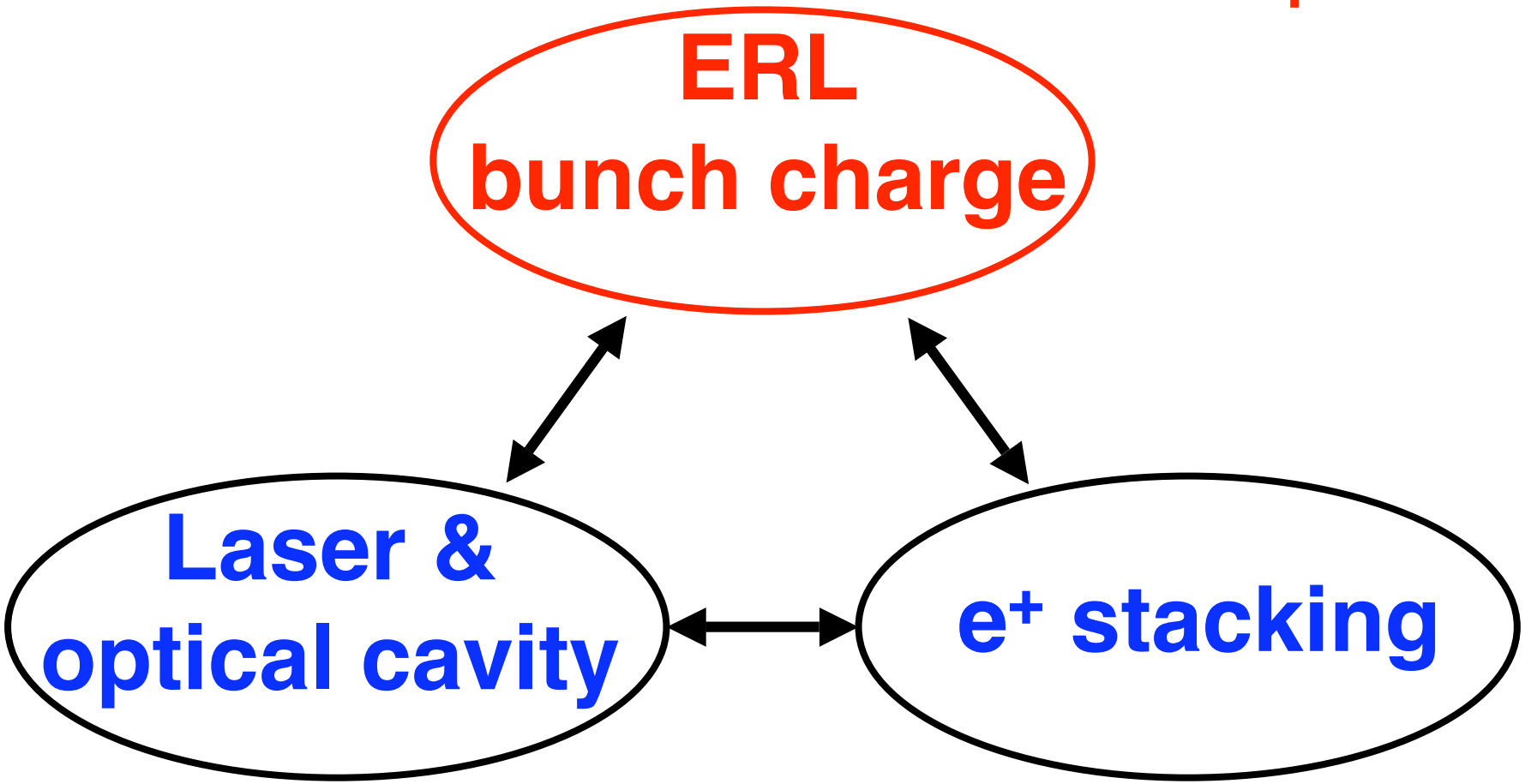
(b) f_{rep} = 40.8 MHz ($T_{b\_ERL} = T_L$ = 24.6 ns)

Laser beam power (average) = 1.2 kW

Easier, But, Difference exists only in average power.

Selection of bunch repetition: f_{rep}

3 factors to determine f_{rep}

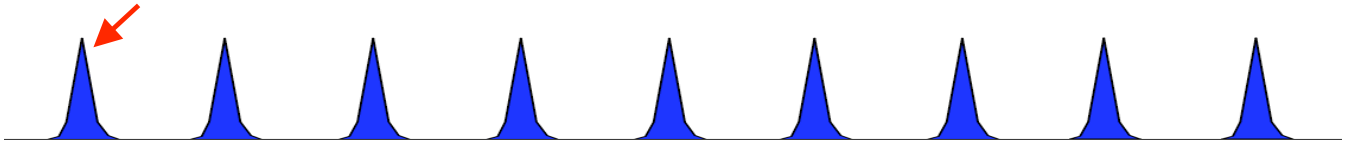


Requirement to an ERL

I (average) = 26 mA (assumption)

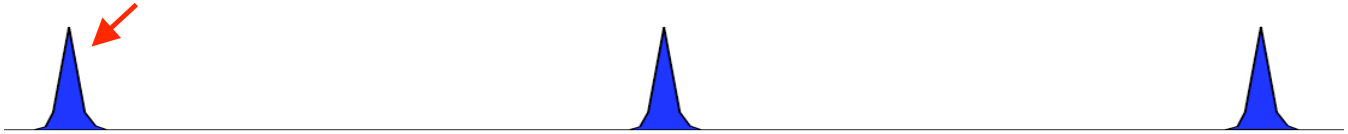
(a) f_{rep} = 163 MHz (T_{b_ERL} = 6.15 ns)

N_e = 1 x 10^9 (160pC) /bunch



(b) f_{rep} = 40.8 MHz (T_{b_ERL} = 24.6 ns)

N_e = 4 x 10^9 (640pC) /bunch

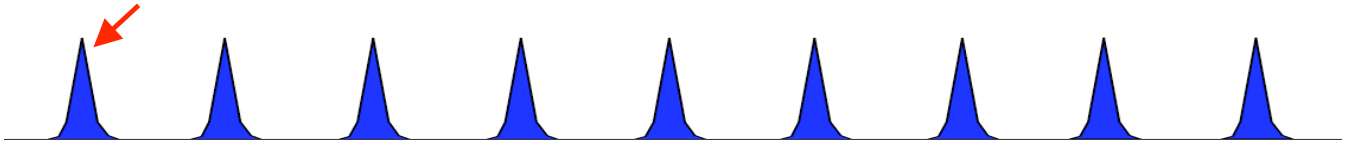


Requirement to an ERL

I (average) = 26 mA (assumption)

(a) f_{rep} = 163 MHz (T_{b_ERL} = 6.15 ns)

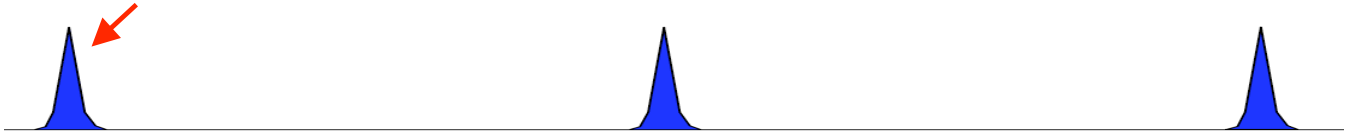
$N_e = 1 \times 10^9$ (160pC) /bunch



Easier, No significant difficulty.

(b) f_{rep} = 40.8 MHz (T_{b_ERL} = 24.6 ns)

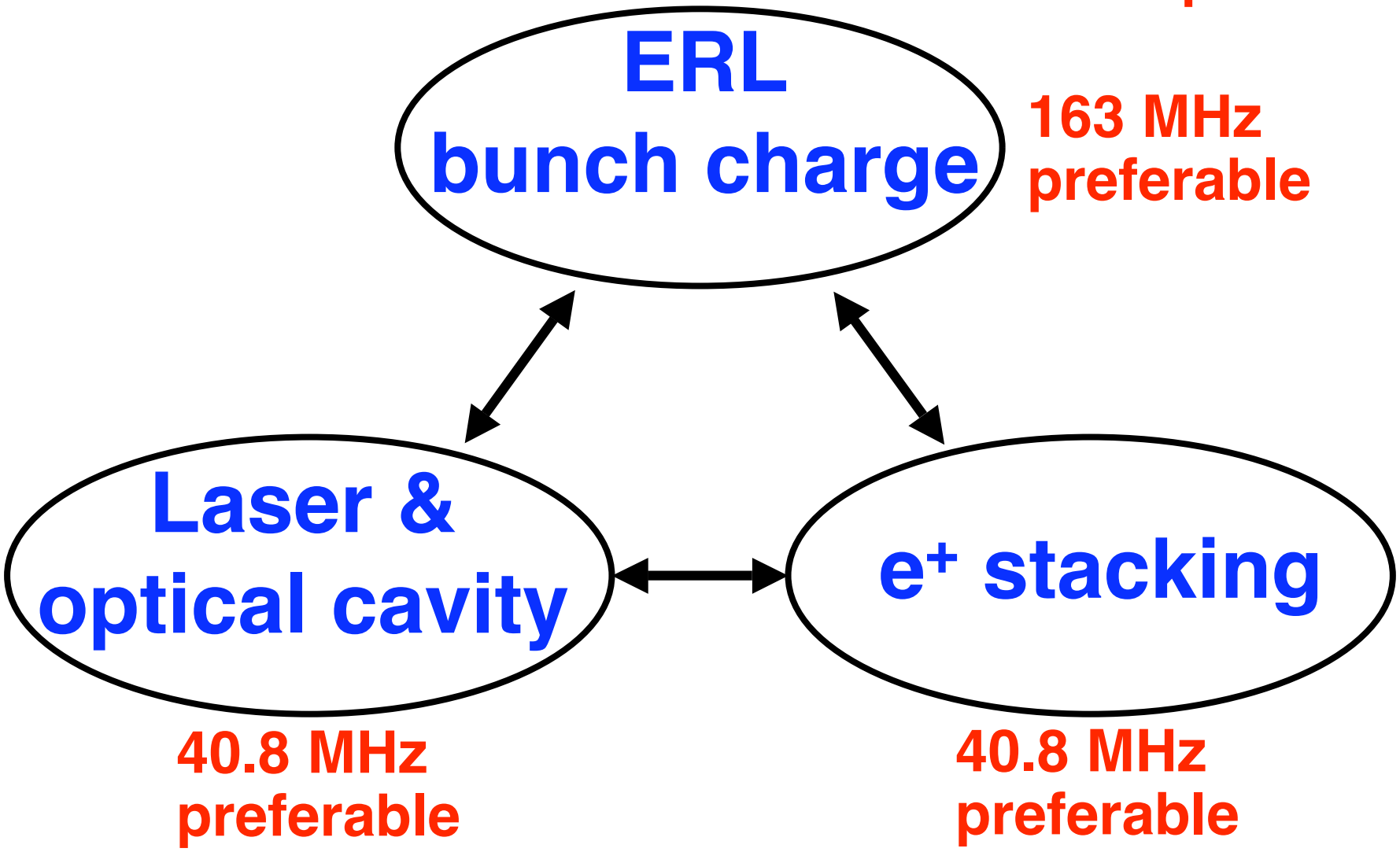
$N_e = 4 \times 10^9$ (640pC) /bunch



More difficult, wake-field, charge limit at GUN, CSR,,,
But it seems manageble .

Selection of bunch repetition: f_{rep}

3 factors to determine f_{rep}



$N\gamma$ and Ne^+ in single turn of ERL

Laser beam at CP

E_{pulse} = 600 mJ / cavity

$\sigma_x = \sigma_y$ = 5 micron

σ_z = 0.7 psec

Electron beam at CP

$\sigma_x = \sigma_y$ = 5 micron

σ_z = 0.8 psec

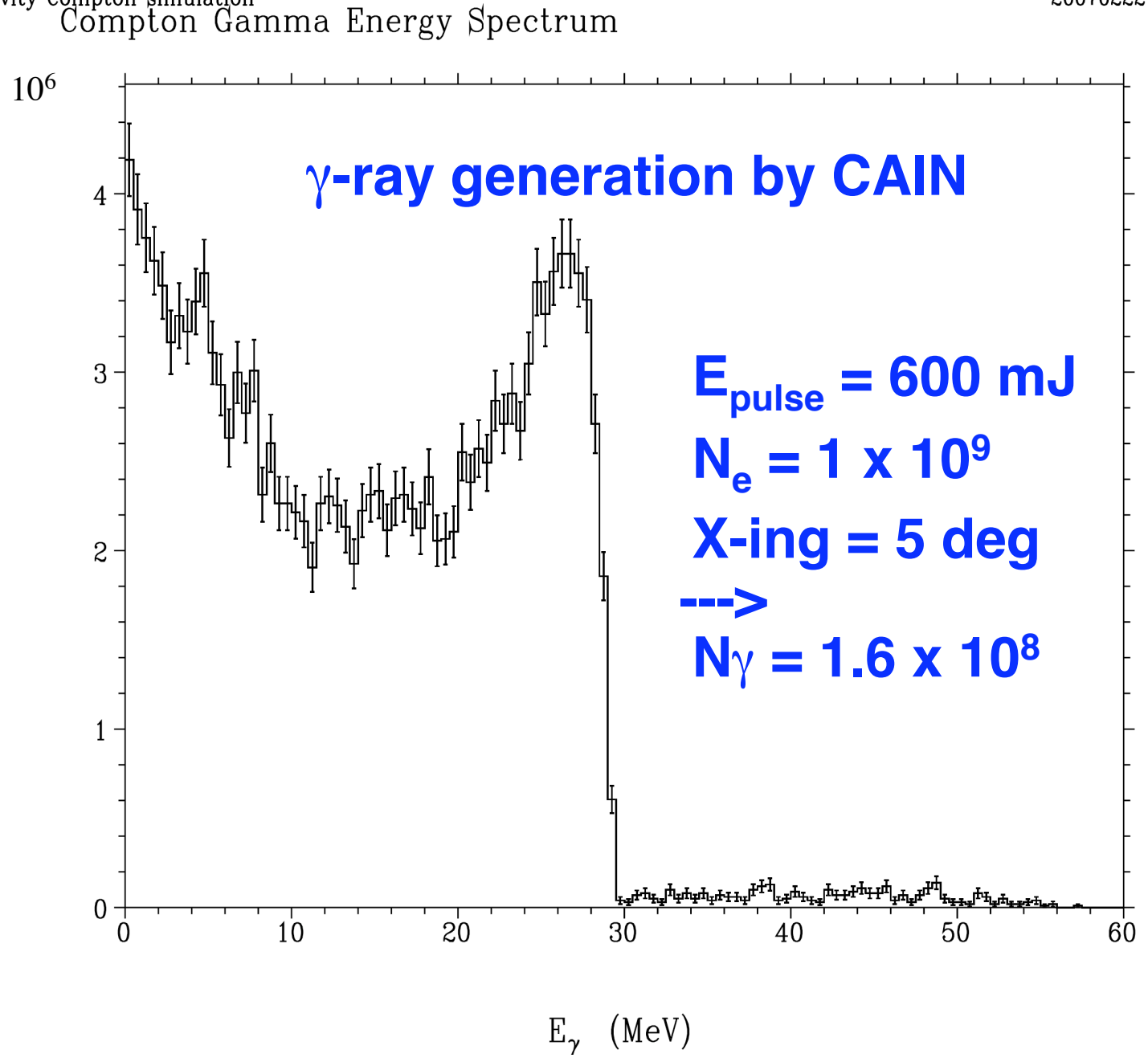
(a) $N_e = 1 \times 10^9$ (160pC) (163 MHz) --> $N\gamma = 1.6 \times 10^8$ /cavity

(b) $N_e = 4 \times 10^9$ (640pC) (40.8 MHz)--> $N\gamma = 6.4 \times 10^8$ /cavity

$N\gamma$ total (10 optical cavities, 600 mJ x 10 = 6J)

(a) $N\gamma = 1.6 \times 10^9$ in total ---> Ne+(captured) = 5×10^6

(b) $N\gamma = 6.4 \times 10^9$ in total ---> Ne+(captured) = 20×10^6


Compton Gamma Energy Spectrum
10^6
4
3
2
1
0
0
10
20
30
40
50
60
E_γ (MeV)
γ-ray generation by CAIN
E_pulse = 600 mJ
N_e = 1 x 10^9
X-ing = 5 deg
--->
Nγ = 1.6 x 10^8

Number of stacking in 100 ms

(a) 163MH: Ne+(captured) = 5 x 10^6 /ERL turn

Ne+(ILC reqirement) = 2 x 10^{10}

--> $N_{stacking}$ = 4000 required

One turn of DR = 25 micro sec

stacking in every DR turn --> 4000 DR turns

--> 100 msec

(b) 40.8 MHz: Ne+(captured) = 20 x 10^6/ ERL turn

Ne+(ILC reqirement) = 2 x 10^{10}

--> $N_{stacking}$ = 1000 required

One turn of DR = 25 micro sec

stacking in every 4 DR turns --> 4000 DR turns

--> 100 msec

Achieve Ne+ = 2 x 10^{10} in both (a) and (b)

Summary

1. ERL -> easy beam compression at CPs
2. ERL -> quasi CW operation:
   top-up injection, possibility Pol.~80%
3. Two models:
   f_{rep} = (a) 163MHz and (b) 40.8MHz

Summary

1. ERL -> easy beam compression at CPs
2. ERL -> quasi CW operation:
   top-up injection, possibility Pol.~80%
3. Two models:
   f_{rep} = (a) 163MHz and (b) 40.8MHz
4. Both of two are working assumptions.

Summary

1. ERL -> easy beam compression at CPs
2. ERL -> quasi CW operation:
   top-up injection, possibility Pol.~80%
3. Two models:
   f_{rep} = (a) 163MHz and (b) 40.8MHz
4. Both of two are working assumptions.
5. Need stacking simulation

Summary

1. ERL -> easy beam compression at CPs
2. ERL -> quasi CW operation:
   top-up injection, possibility Pol.~80%
3. Two models:
   f_{rep} = (a) 163MHz and (b) 40.8MHz
4. Both of two are working assumptions.
5. Need stacking simulation, Need ERL study

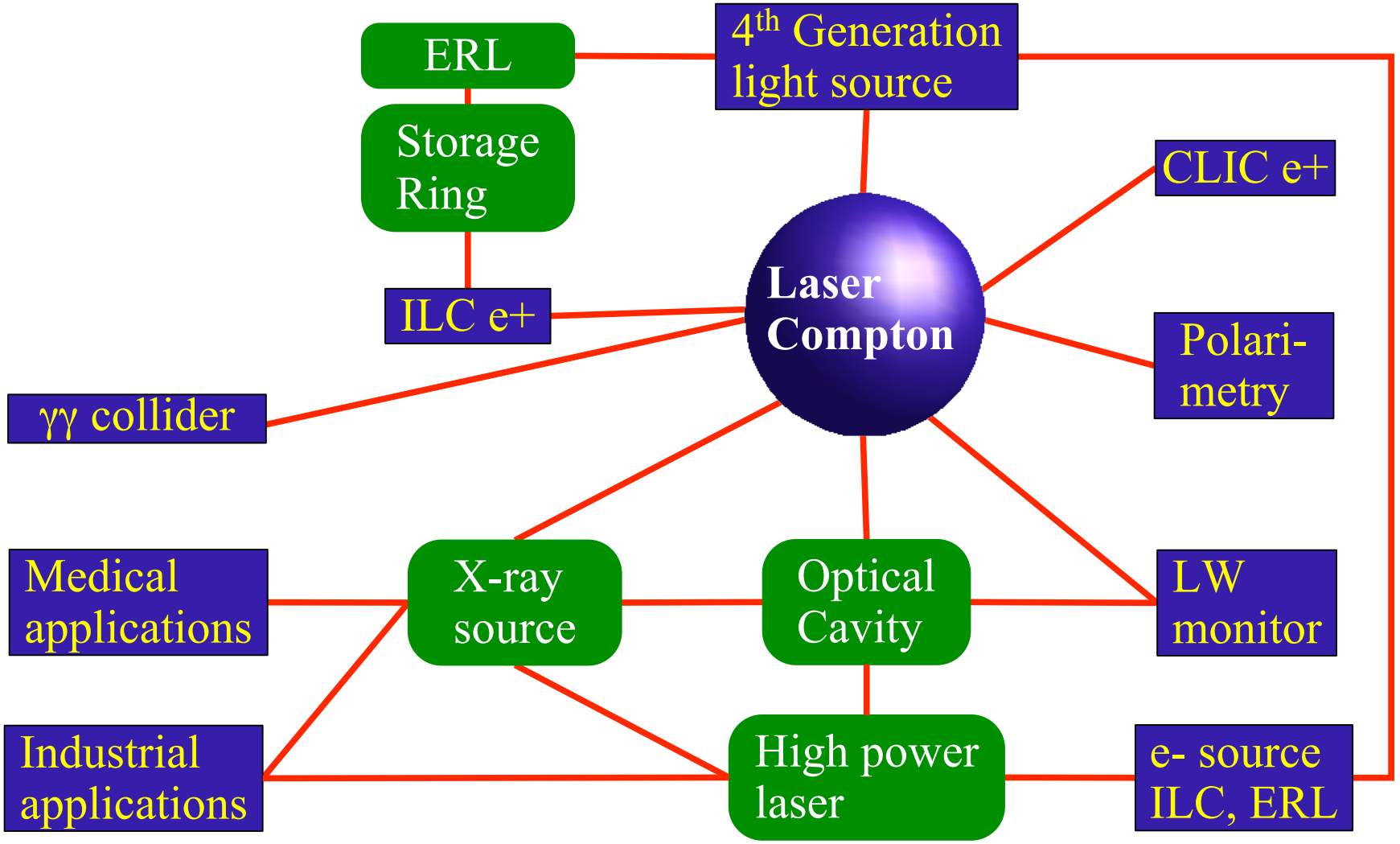
Summary

1. ERL -> easy beam compression at CPs
2. ERL -> quasi CW operation:
   top-up injection, possibility Pol.~80%
3. Two models:
   f_{rep} = (a) 163MHz and (b) 40.8MHz
4. Both of two are working assumptions.
5. Need stacking simulation, Need ERL study,
   Need Laser study

Summary

1. ERL -> easy beam compression at CPs
2. ERL -> quasi CW operation:
   top-up injection, possibility Pol.~80%
3. Two models:
   f_{rep} = (a) 163MHz and (b) 40.8MHz
4. Both of two are working assumptions.
5. Need stacking simulation, Need ERL study,
   Need Laser study, Need capture study

World-Wide-Web of Laser Compton



Kuriki at Beijing e+ meeting 2007

Summary

1. ERL -> easy beam compression at CPs
2. ERL -> quasi CW operation:
   top-up injection, possibility Pol.~80%
3. Two models:
   f_{rep} = (a) 163MHz and (b) 40.8MHz
4. Both of two are working assumptions.
5. Need stacking simulation, Need ERL study,
   Need Laser study, Need capture study
6. We have a world-wide collab of Compton.
   Not only for ILC e^+ source.
   Also for many other applications.

Summary

1. ERL -> easy beam compression at CPs
2. ERL -> quasi CW operation:
   top-up injection, possibility Pol.~80%
3. Two models:
   f_{rep} = (a) 163MHz and (b) 40.8MHz
4. Both of two are working assumptions.
5. Need stacking simulation, Need ERL study,
   Need Laser study, Need capture study
6. We have a world-wide collab of Compton.
   Not only for ILC e^+ source.
   Also for many other applications.

The END

Thank you for your attention

3 of Compton schemes

similar : re-use

1. Ring-based Compton.

different

2. ERL-based Compton.

new comer: no parameter set yet

3. liniac-based Compton.

throw-away