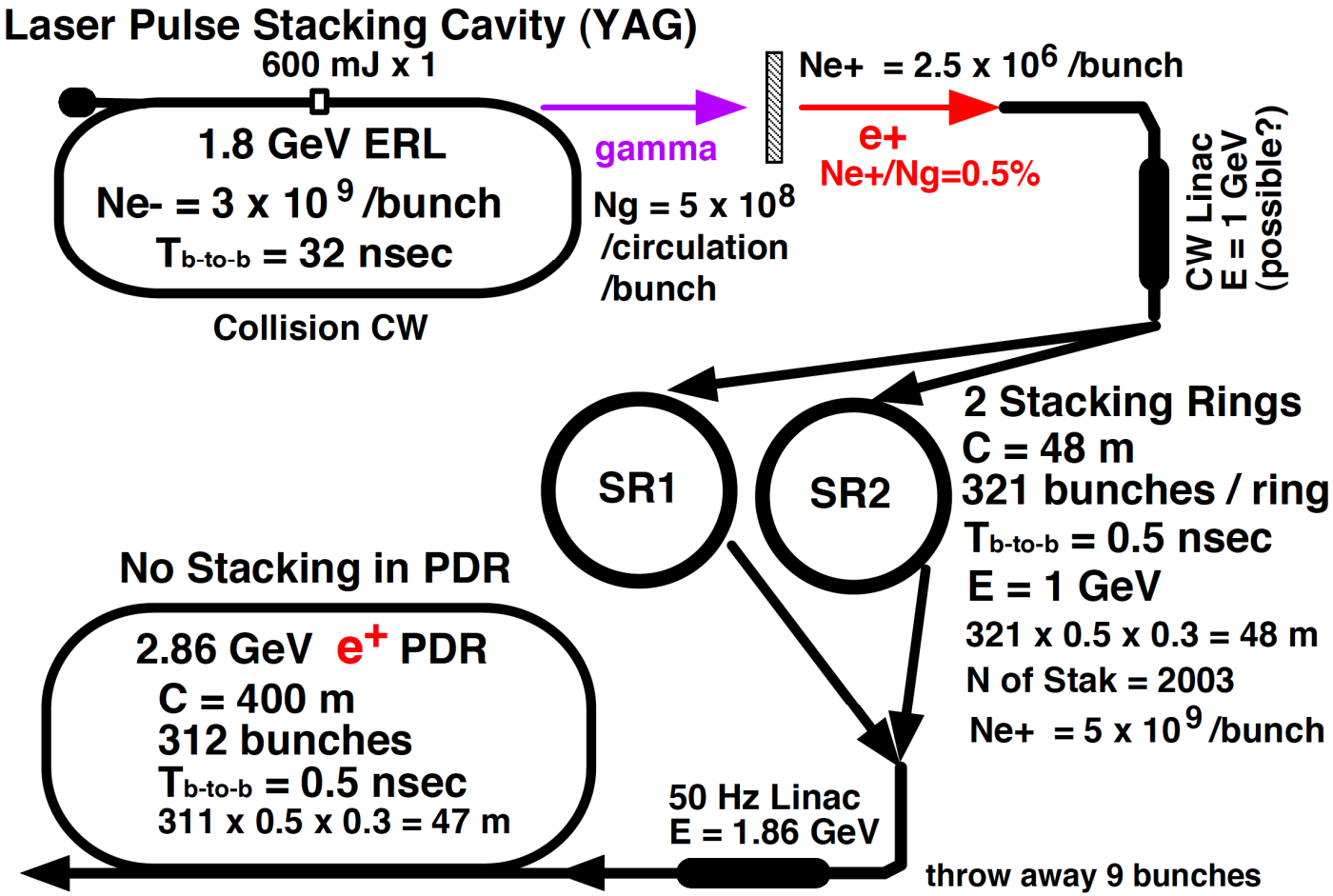
ERL Compton scheme for CLIC



L. Rinolfi (CERN) and T. Omori (KEK)

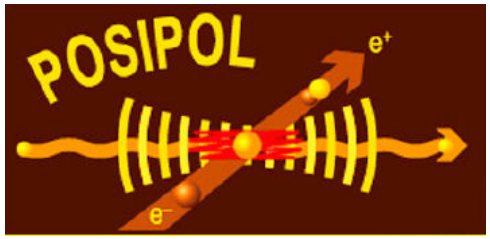
many thanks to all Posipol collaboraters

CLIC WS 15-Oct-2009 CERN

World-wide PosiPol Collaboration

Collaborating Institutes:
BINP, CERN, DESY, Hiroshima, IHEP, IPN, KEK, Kyoto, LAL, CELIA/Bordeaux, 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, Yoshimasa Kurihara, Kazuyuki Sakaue, Masafumu Fukuda, Takuya Kamitani, X. Artru, M. Chevallier, V. Strakhovenko, Eugene Bulyak, Peter Gladkikh, Klaus Meonig, Robert Chehab, Alessandro Variola, Fabian Zomer, Alessandro Vivoli, Richard Cizeron, Viktor Soskov, Didier Jehanno, M. Jacquet, R. Chiche, Yasmina Federa, Eric Cormier, Louis Rinolfi, Frank Zimmermann, Kazuyuki Sakaue, Tachishige Hirose, Masakazu Washio, Noboru Sasao, Hirokazu Yokoyama, Masafumi Fukuda, Koichiro Hirano, Mikio Takano, Tohru Takahashi, Hirotaka Shimizu, Shuhei Miyoshi, Yasuaki Ushio, Tomoya Akagi, Akira Tsunemi, Ryoichi Hajima, Li XaioPing, Pei Guoxi, Jie Gao, V. Yakinenko, Igo Pogorelsky, Wai Gai, and Wanming Liu



POSIPOL 2006
CERN Geneve
26-27 April
http://posipol2006.web.cern.ch/Posipol2006/

POSIPOL 2007
LAL Orsay
23-25 May
http://events.lal.in2p3.fr/conferences/Posipol07/

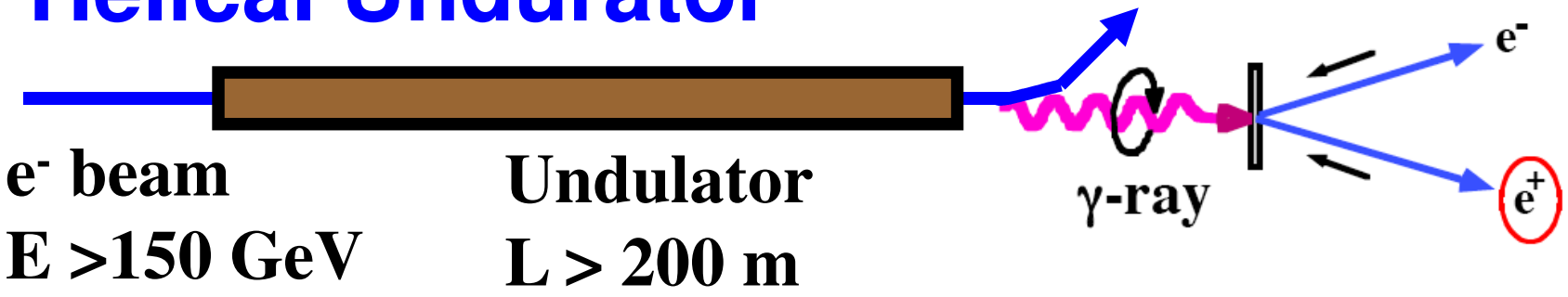
POSIPOL 2008
Hiroshima
16-18 June
http://home.hiroshima-u.ac.jp/posipol/

POSIPOL 2009
Lyon
23-26 June
http://indico.cern.ch/internalPage.py?pageId=1&confId=53079

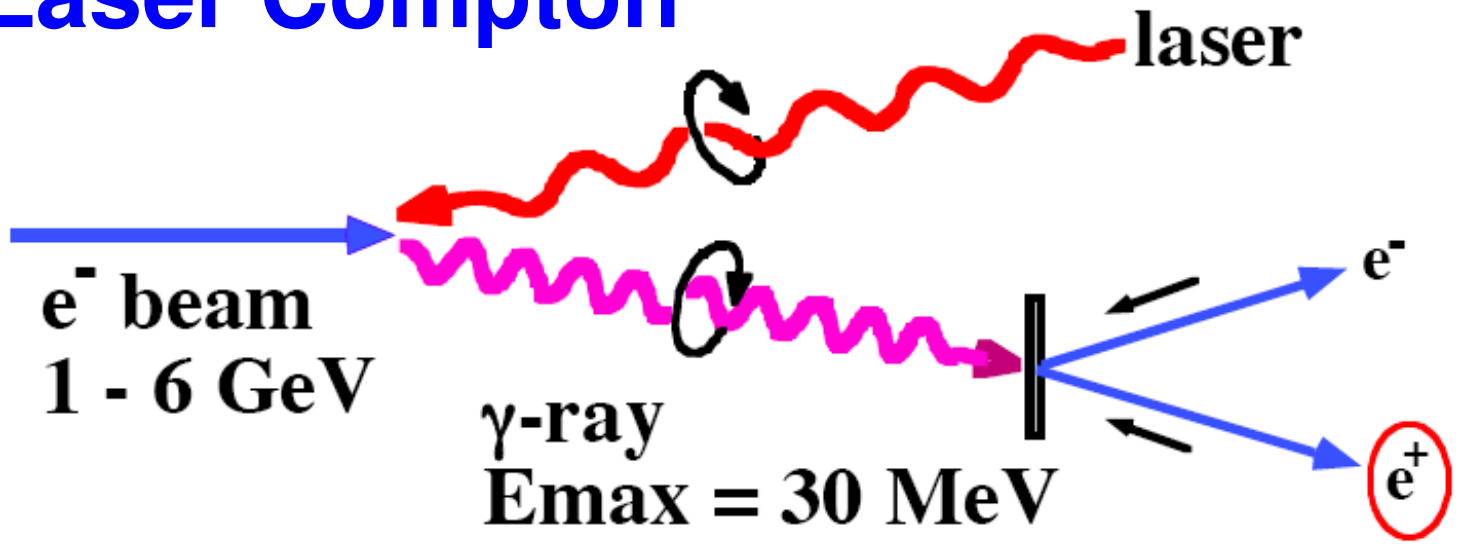
POSIPOL 2010
Tsukuba

Two ways to get pol. e^+

(1) Helical Undurator

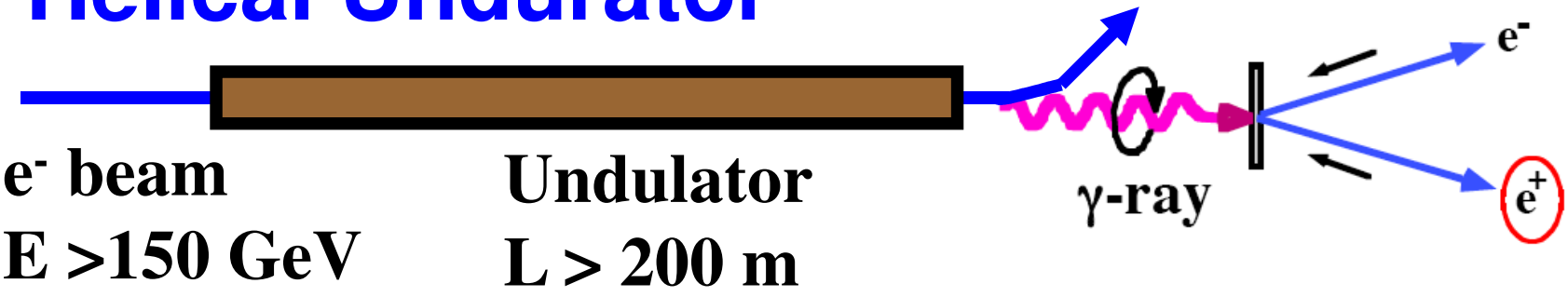


(2) Laser Compton



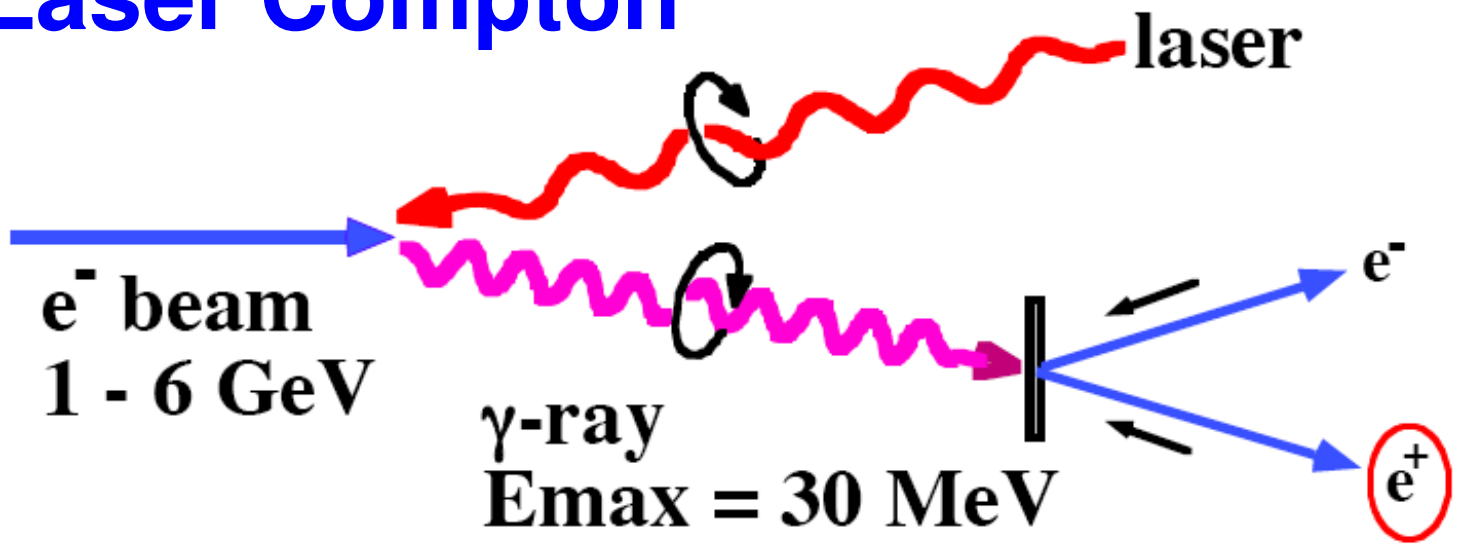
Two ways to get pol. e^+

(1) Helical Undurator



Our Proposal

(2) Laser Compton



Why Laser-Compton ?

i) Positron Polarization.

ii) Independence

Undulator-base e^+ : use e^- main linac

Problem on design, construction, commissioning, maintenance,

Laser-base e^+ : independent

Easier construction, operation, commissioning, maintenance

iii) Polarization flip @ 50 Hz

iv) High polarization

v) Low energy operation (exsmpl: E_{cm} = 230 GeV)

Undulator-base e^+ : not suitable

Laser-base e^+ : no problem

Three of Compton schemes for CLIC and ILC

1. Ring-based Compton.

2. ERL-based Compton.

3. Linac-based Compton.

Three of Compton schemes for CLIC and ILC

1. Ring-based Compton.

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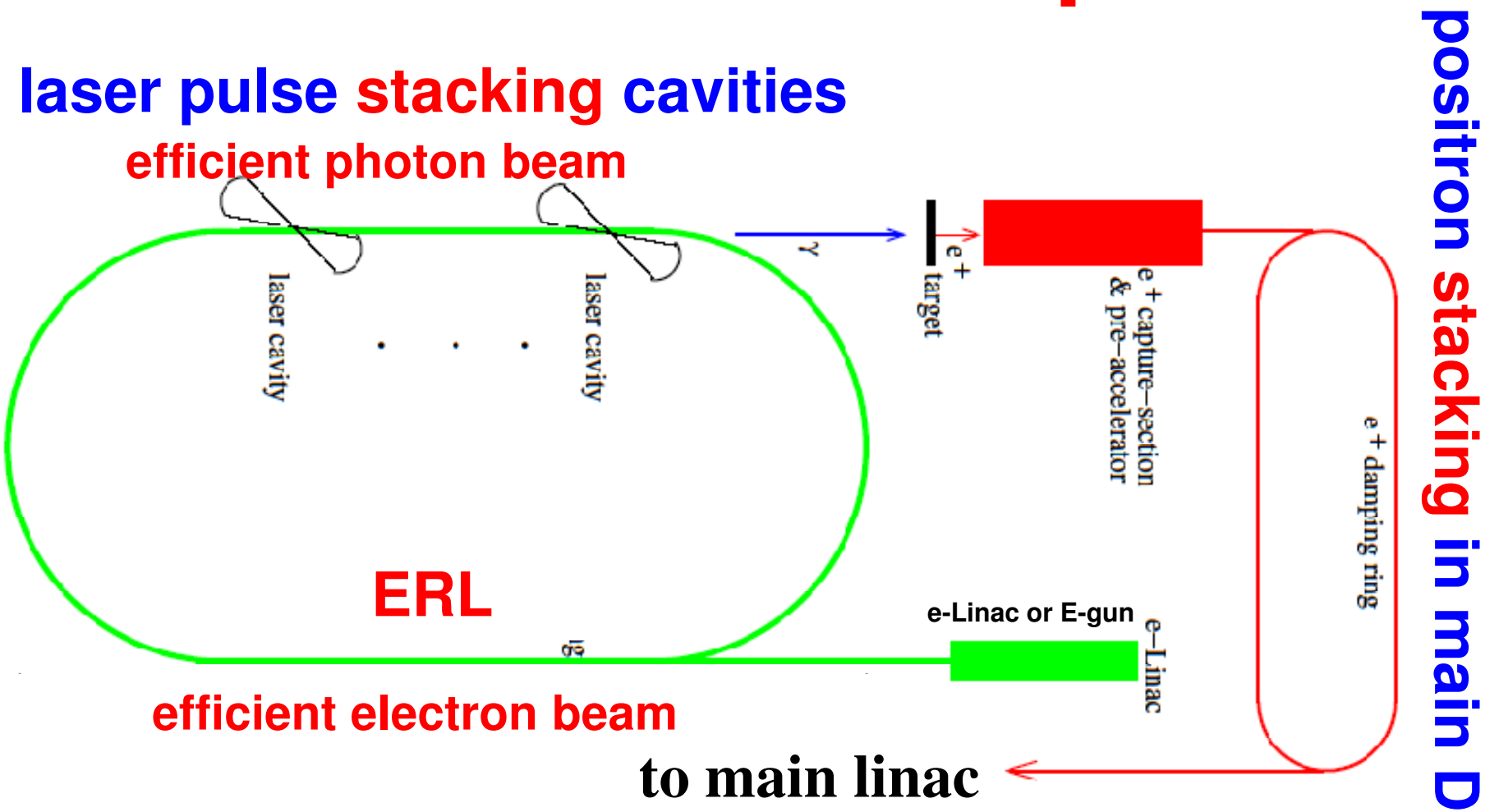
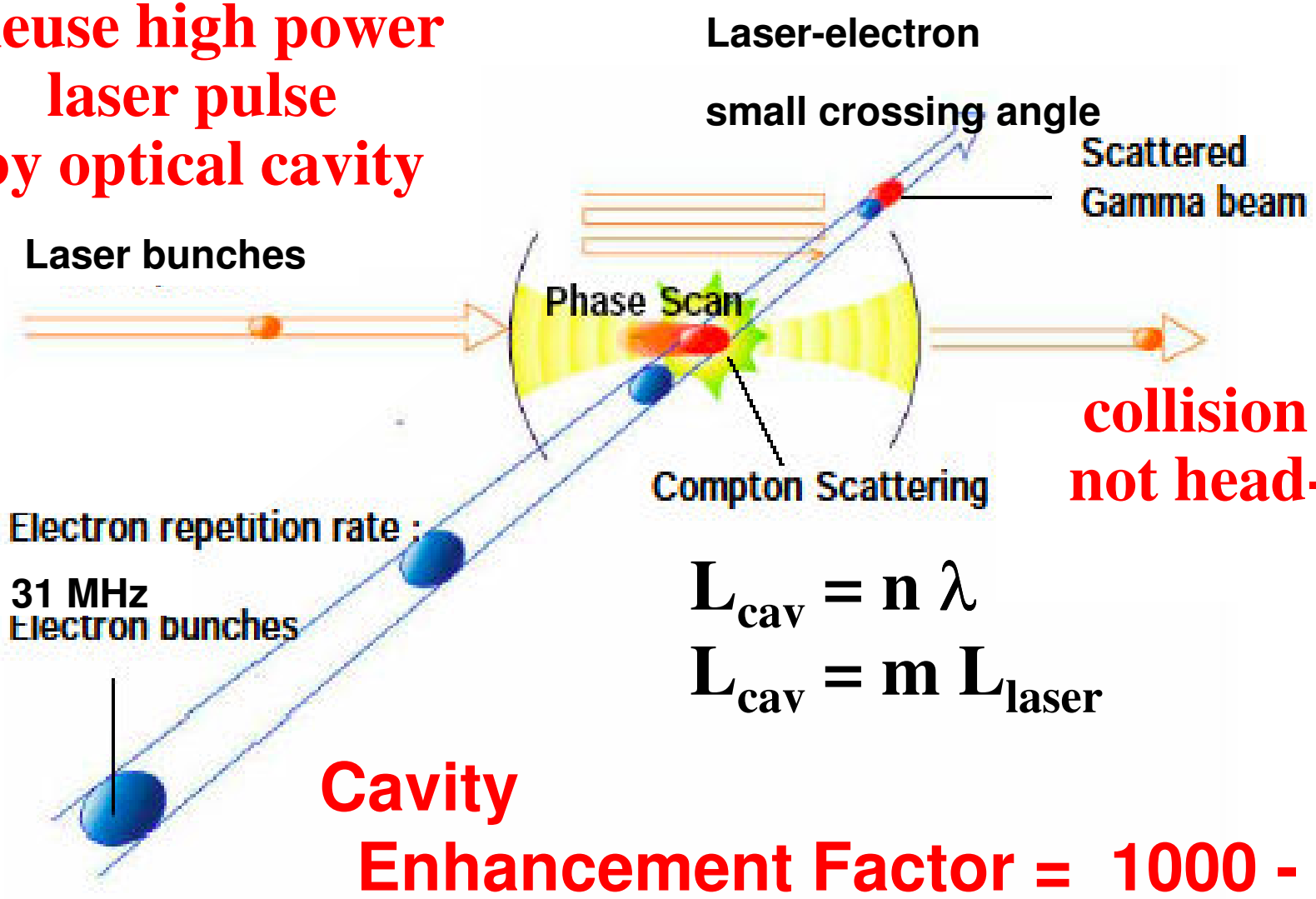
My talk today

ERL Compton Re-use Concept



Optical Cavity for Pulse Laser Beam Stacking

Reuse high power laser pulse by optical cavity



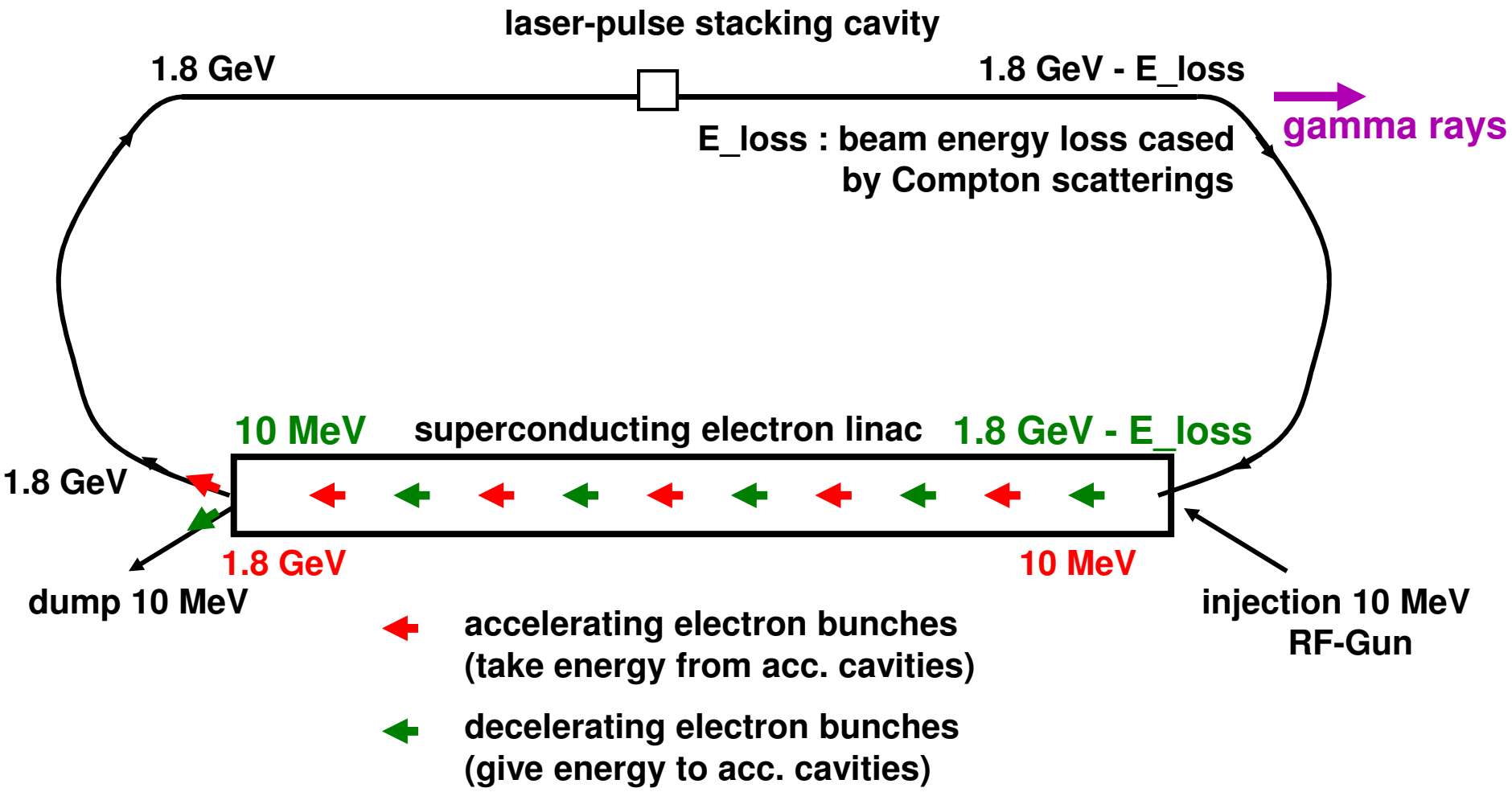
collision is not head-on

$$L_{cav} = n \lambda$$

$$L_{cav} = m L_{laser}$$

Cavity Enhancement Factor = 1000 - 10^5

ERL based Compton source



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
- Small spot size (10 micron) at CP.

Points of ERL: 1

Re use: Energy of electron beam

Throw away: electron beam.

Points of ERL: 2

Fresh, high quality beam

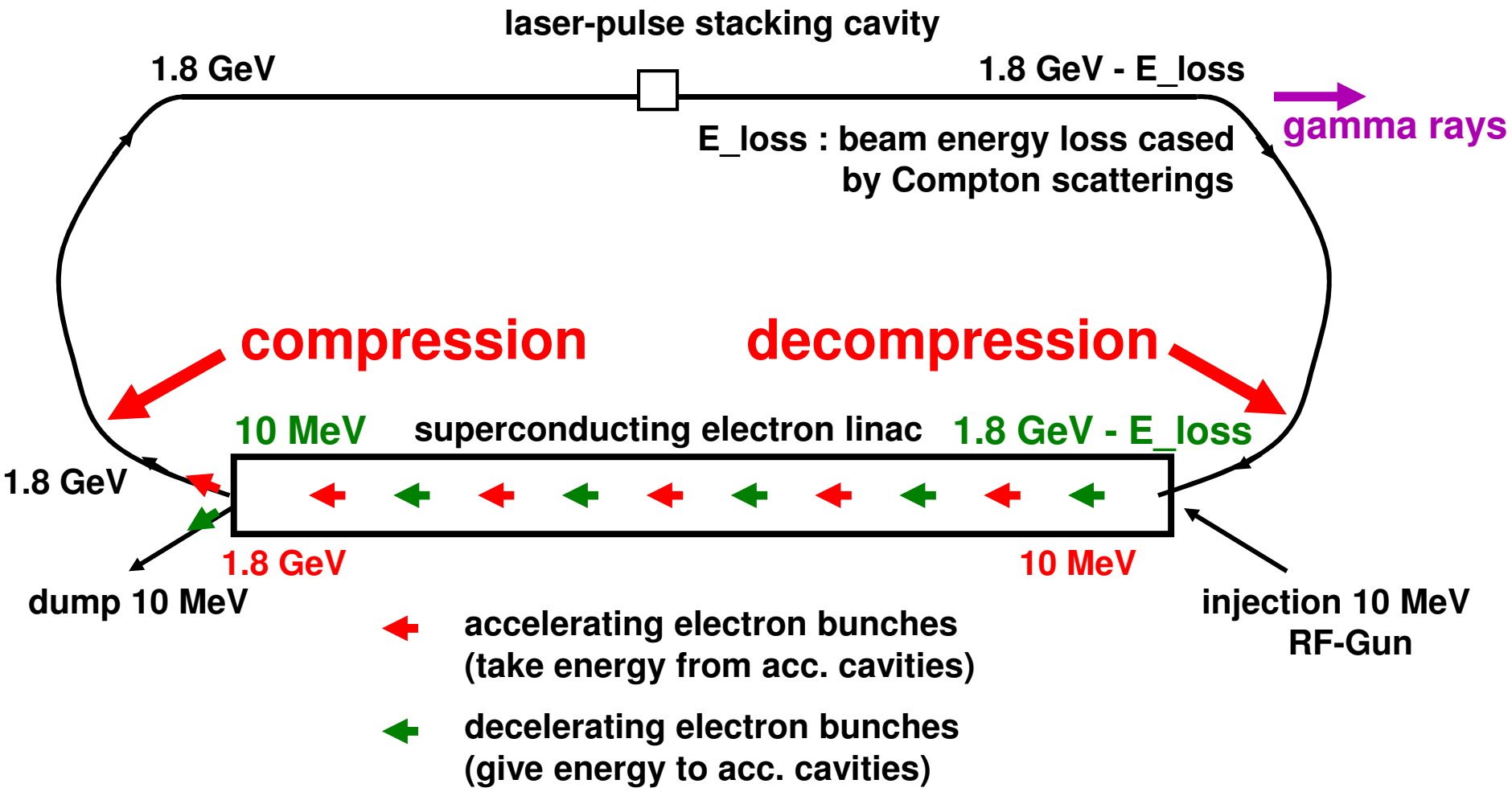
Small spot size (10 micron) at CP.

Points of ERL: 3

Short bunch (< 1 ps) at CP. (non head-on)

Beam compression (3 ps to < 1 ps)

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

Small spot size (10 micron) at CP.

Points of ERL: 3

Short bunch (< 1 ps) at CP.

Beam compression (3 ps to < 1 ps)

Points of ERL: 4

Need steady exchange of energy:

Accel-Bunches, Decel-Bunches, Klystrons

Need CW operation

CLIC e^+ source parameters

- 4.2 x 10^9 e^+/bunch (exit of Pre Damping Ring:PDR)
- E (PDR and DR) = 2.86 GeV
- $T_{b\text{-}to\text{-}b}$ = 0.5 ns
- $C_{DR} = C_{PDR}$ ~ 400 m
- N_{bunch} = 312 / trian
- F_{rep} = 50 Hz (N_{train} = 50/sec)

Compare ERL and CLIC

ERL : CW device

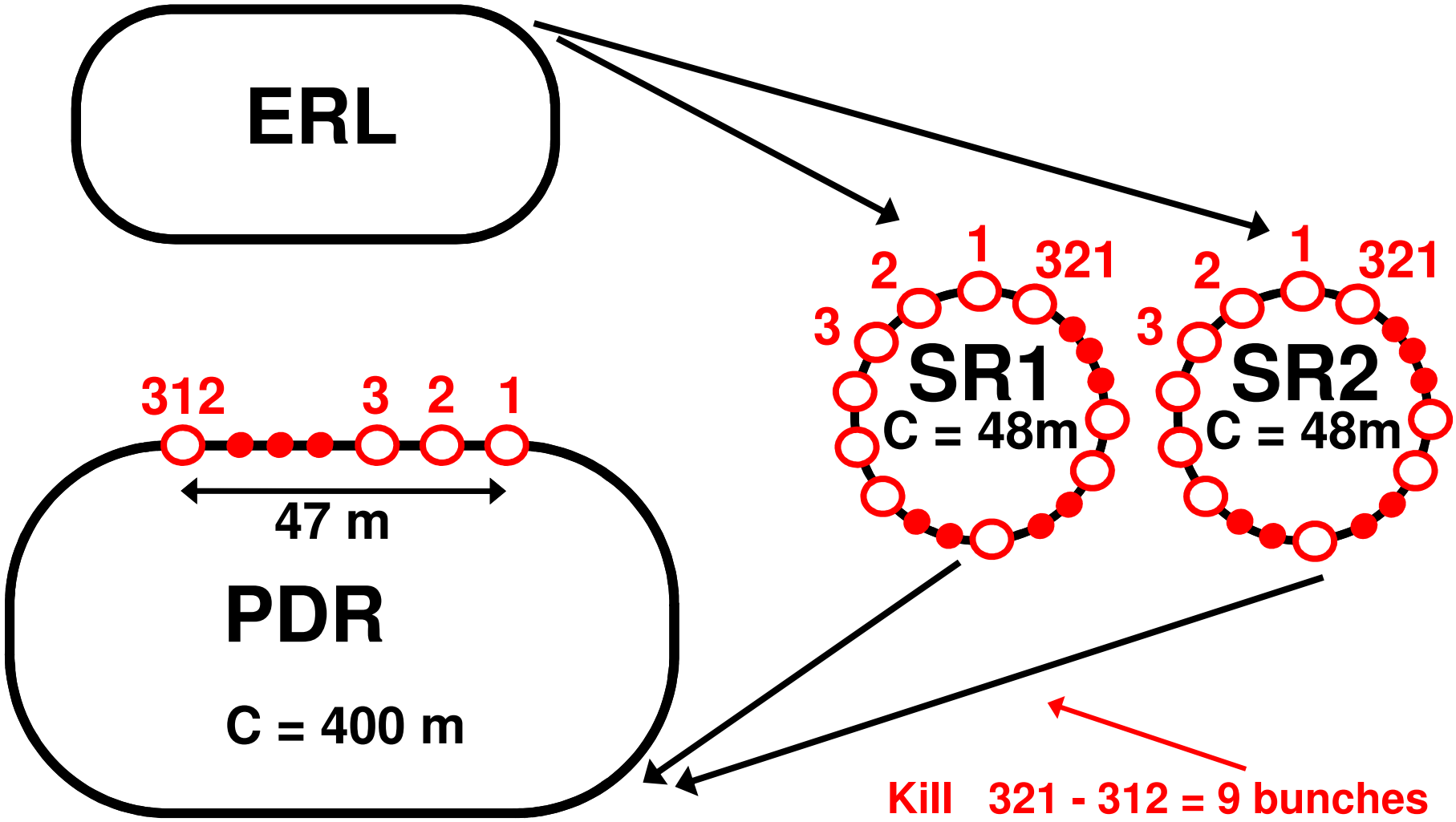
CLIC : short pulse 150 ns & high rep. 50 Hz

(312 bunches w/ 0.5 ns spacing)

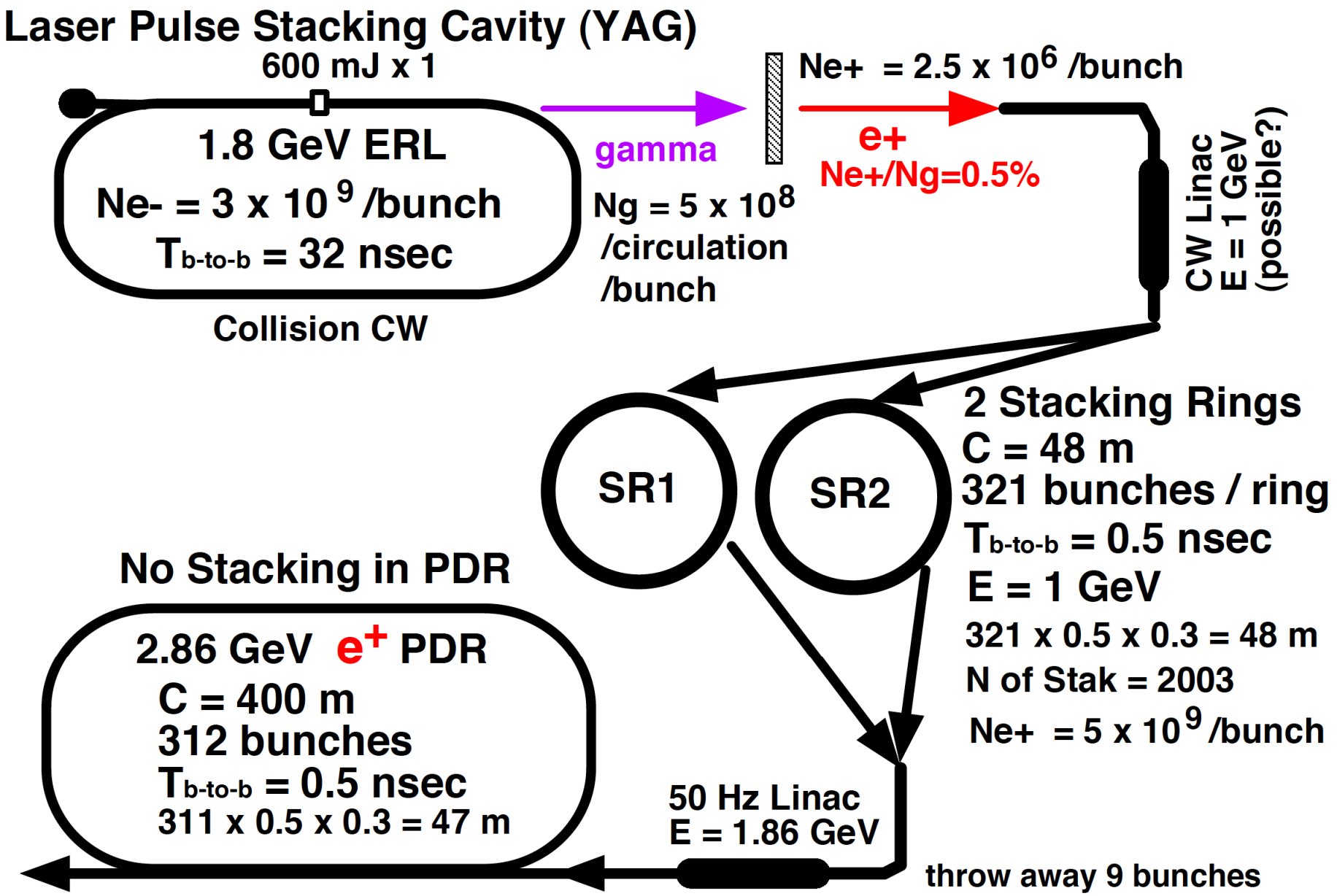
How to adapt ERL to CLIC?

Solution

Put 2 stacking rings (SRs) between ERL and PDR to separate stacking and damping functions.



Configuration



Stacking Ring (SR)

SR makes stacking and pre^2 damping

- C = 48.15 m
- 0.156 μs / turn
- 321 bunches in a ring

  321 x 0.5 ns x 0.3 m/ns = 48.15 m

match

- stack in the same bucket every 64th turn

  (injected beam: $T_{b\text{-}to\text{-}b}$ = 32 ns --> explain later)
- N of stacking in the same bucket = 2003

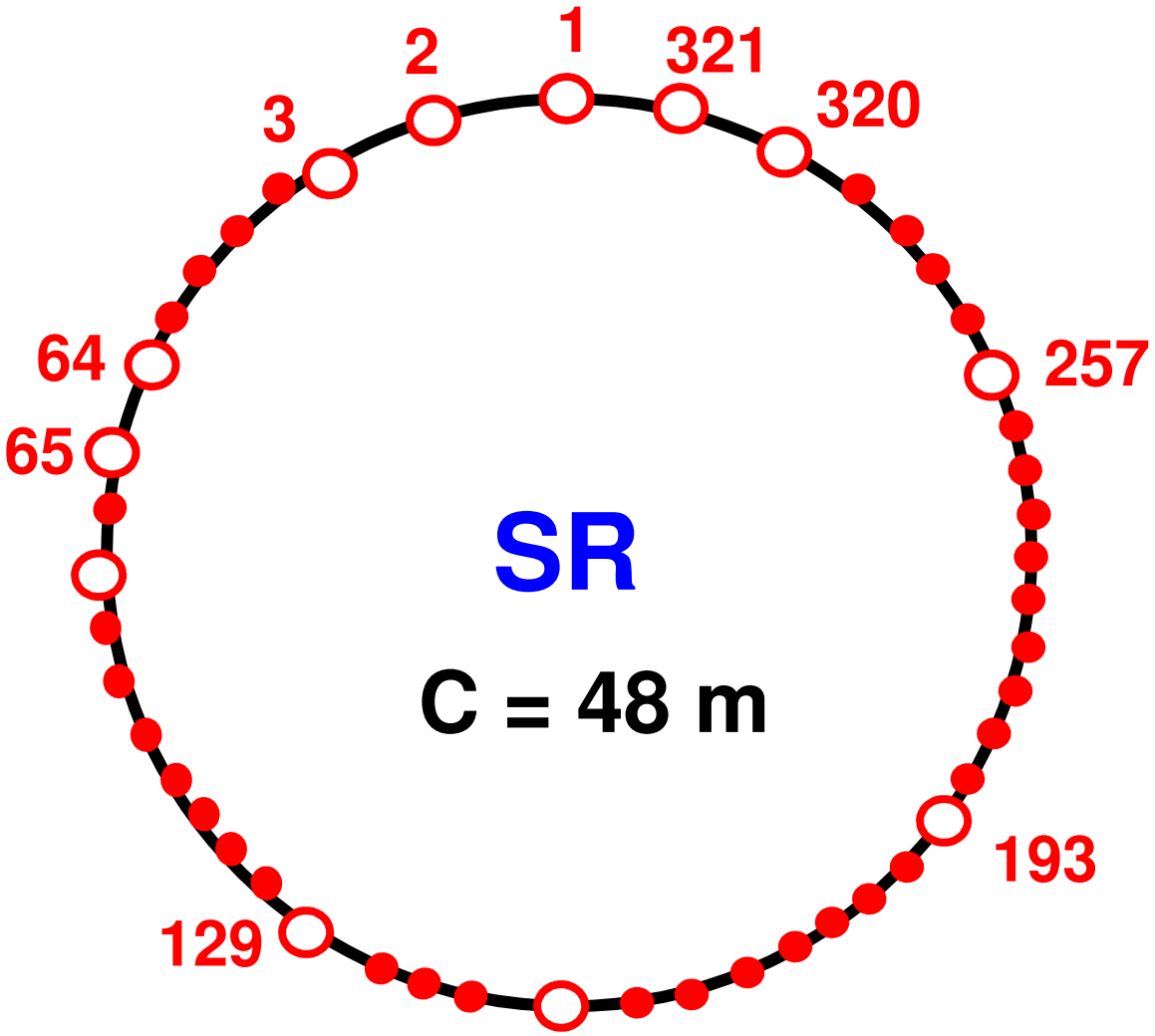
  64 x 2003 = 128 192 turns = 1.2 x 10^5 turns

  0.156 μs x 1.2 x 10^5 = 19.9979 ms ≅ 20 ms
- "Stacking = 20 ms" + "Damping in SR = 20 ms"

  --> total 40 ms /cycle (25 Hz)

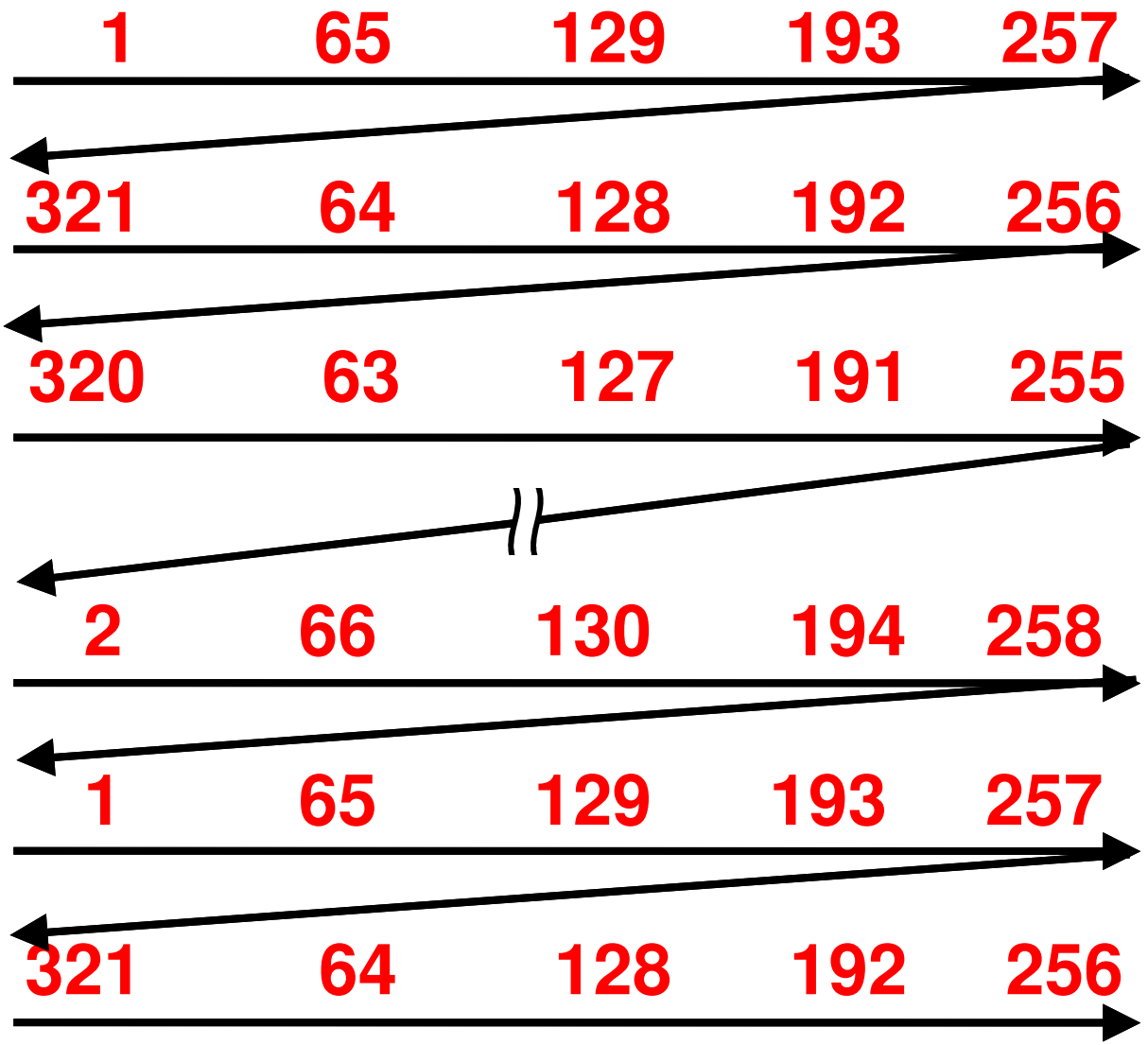
Stacking in a SR : part 1

We give labels "1" to "321" to the buckets in the SR.

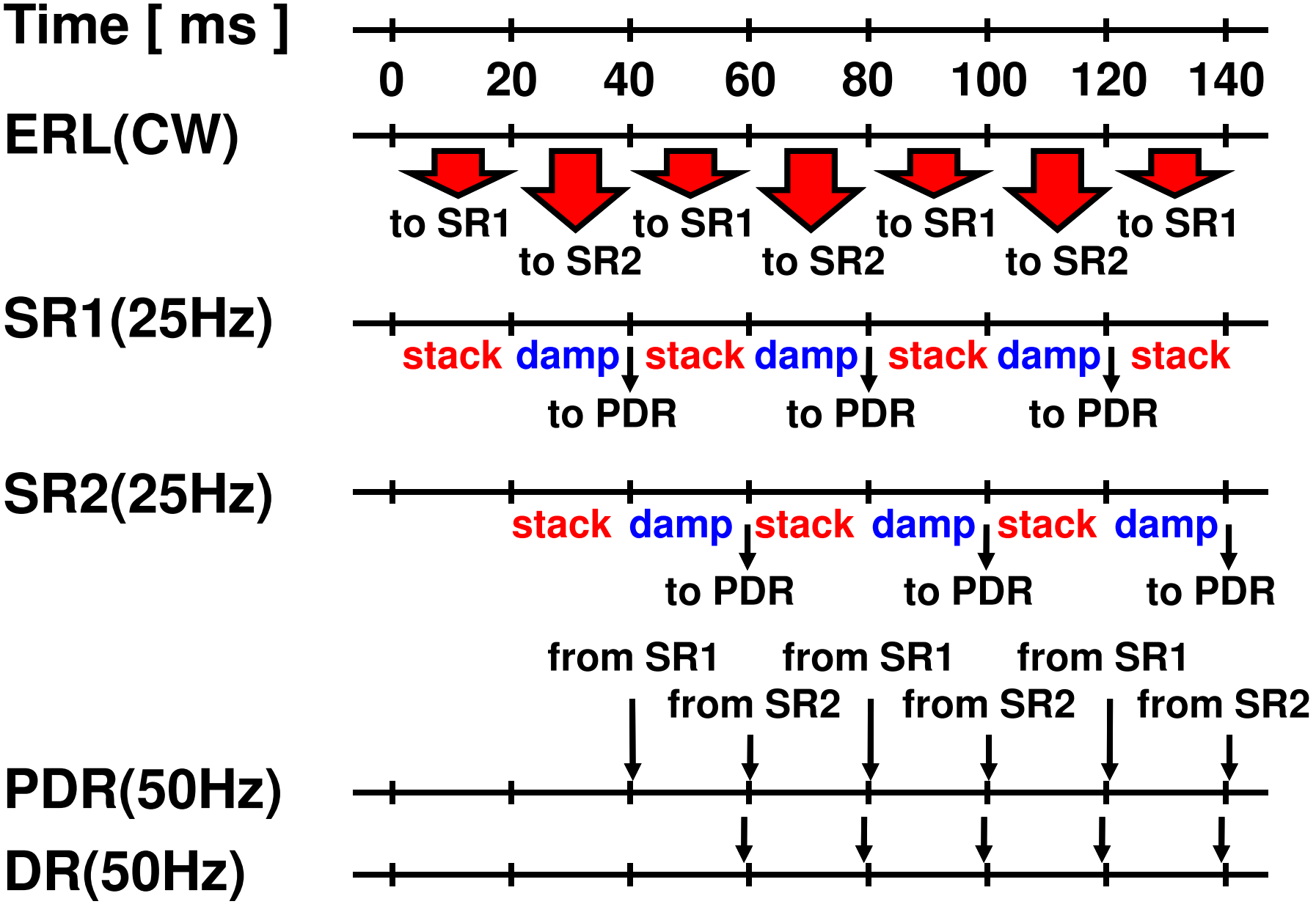


Stacking in a SR : part 2

- 1st turn
- 2nd turn
- 3rd turn
-
-
- 64th turn
- 65th turn
- 66th turn
-



Timing Chart



Number of γ-rays/ e^+s

collision

- e^- beam (ERL)
  - 3 x 10^9 e^-/bunch
  - E = 1.8 GeV
- Laser
  - 600 mJ / cavity
  - 1 cavity in ERL

→ • 5 x 10^8 γ-rays/bunch

↓ thin conversion target: yield 0.5 %

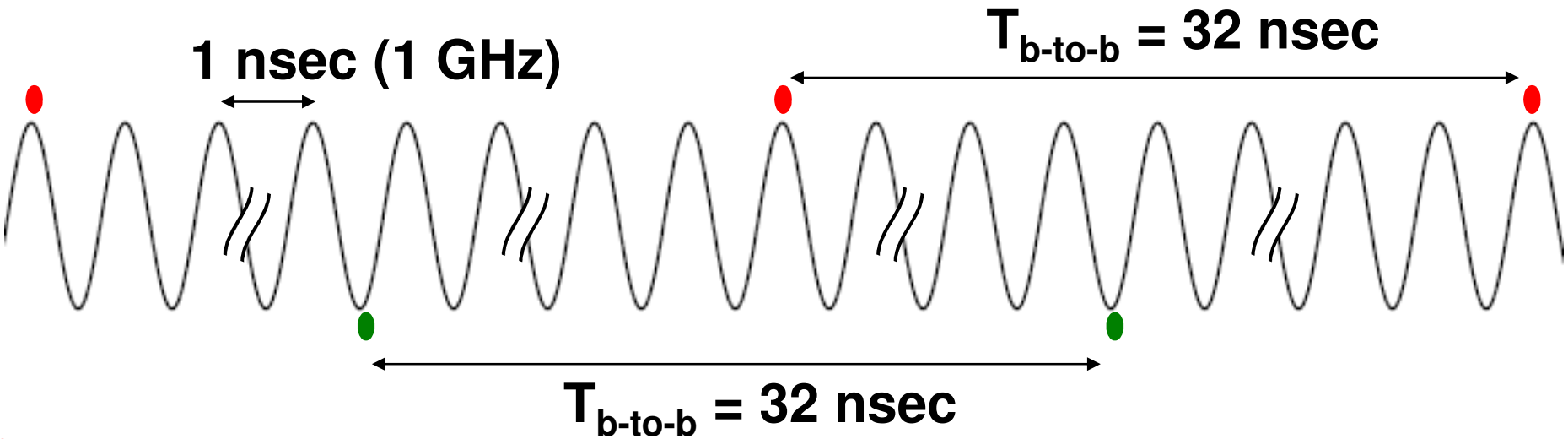
• 2.5 x 10^6 e^+/bunch

↓ 2003 stacking in the same bucket

• 5 x 10^9 e^+/bunch (CLIC requires 4.2 x 10^9)

ERL

- 3 x 10^9 e^-/bunch
- E = 1.8 GeV
- $T_{b\text{-}to\text{-}b}$ = 32 ns
- F_{ref} = 31.25 MHz
- F_{RF} = 1 GHz (for example)



Accelerating bunches

Decelerating bunches

Summary

- ERL scheme can provide small spot size and short pulse at the laser-electron collision point.
  Especially short pulse (< 1ps) is big advantage.
- A solution where stacking and damping are decoupled seems possible to fulfill CLIC requirements with an ERL scheme
- Challenge remains to be demonstrated in order to make 2000 stacking in a same bucket.
  There was a simulation for ILC-ERL-Compton by F. Zimmerman. The result was encouraging.
- Stacking ring with 48 m circumference and 1 GeV is also a challenge.
- The cost increase with 2 storage rings is not an issue compared to the rest of the complex.

Backup slides

Status of Compton Source

Proof-of-Principle demonstration was done.

ATF-Compton Collaboration

Polarized γ-ray generation: M. Fukuda et al., PRL 91(2003)164801

Polarized e+ generation: T. Omori et al., PRL 96 (2006) 114801

We still need many R/Ds and simulations.

We have 3 schemes.

Choice 1 : How to provide e- beam

Storage Ring, ERL Linac

Choice 2 : How to provide laser beam

Wave length (λ=1μm or λ=10μm)

staking cavity or non stacking cavity

Choice 3 : e+ stacking in DR or Not