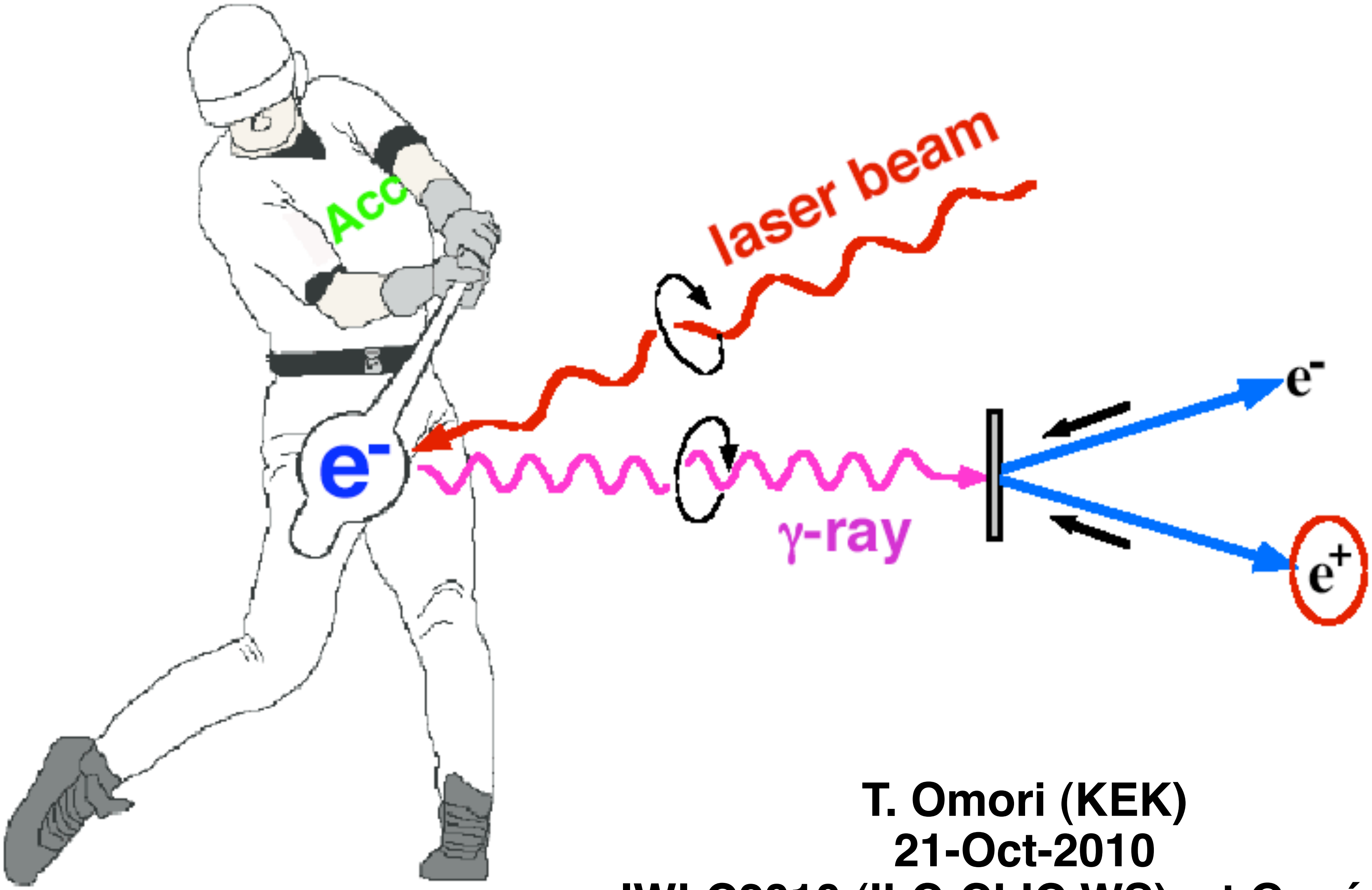
Ring/ERL Compton e^+ Source for ILC/CLIC



T. Omori (KEK)

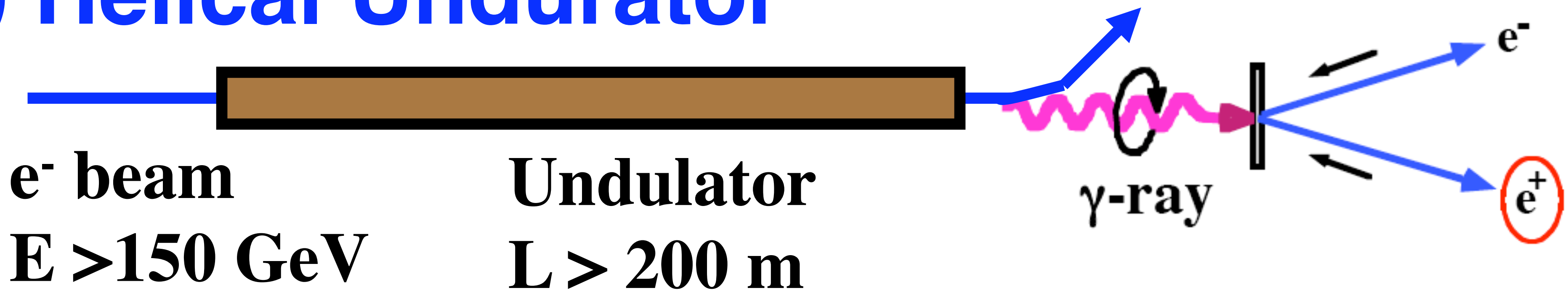
21-Oct-2010

IWLC2010 (ILC-CLIC WS) at Genéve

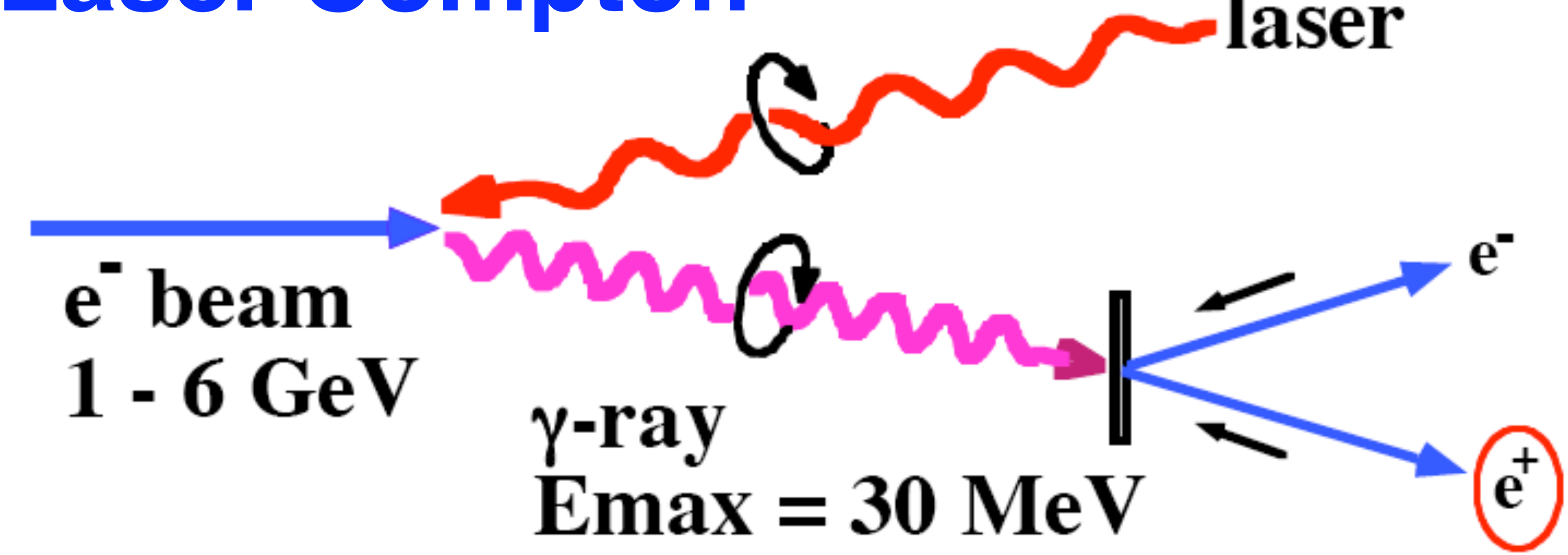
Laser-Compton e^+ source for ILC/CLIC

Two ways to get pol. e^+

(1) Helical Undurator

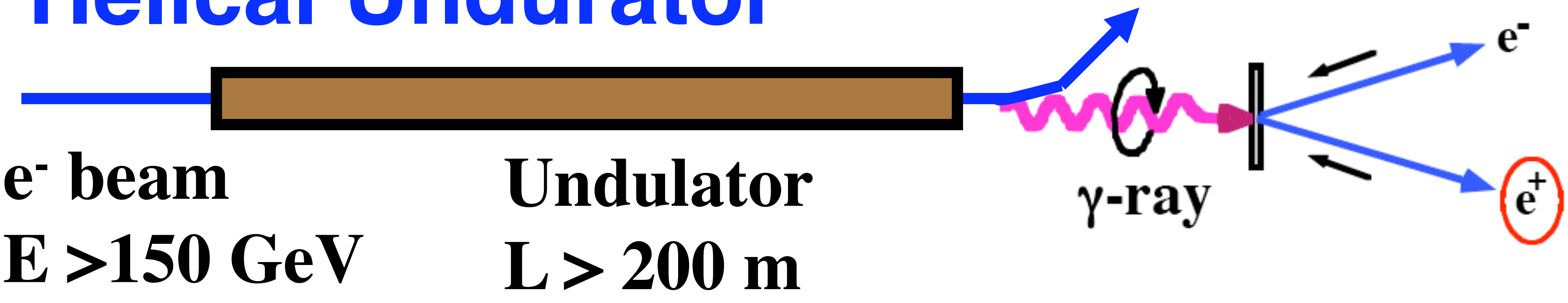


(2) Laser Compton



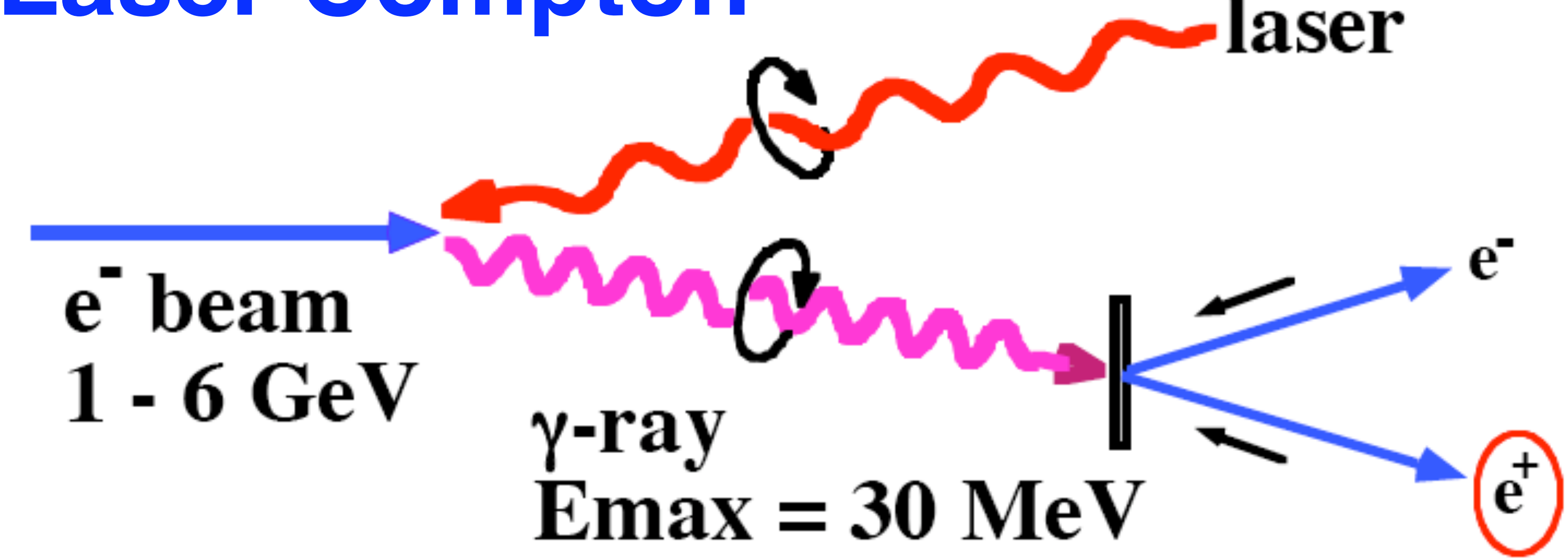
Two ways to get pol. e^+

(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 @ 5Hz (for CLIC @ 50 Hz)

iv) High polarization

v) Low energy operation

Undulator-base e^+ : need deceleration

Laser-base e^+ : no problem

Status of Compton scheme

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

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We still need many R/Ds and simulations.

Many Talks in this Workshop

Status of Compton Source

Proof-of-Principle demonstration was done.

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We still need many R/Ds and simulations.

Many Talks in this Workshop

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

Laser Compton e^+ Source for ILC/CLIC

We have 3 schemes.

1. Ring Base Laser Compton
   Storage Ring + Laser Stacking Cavity (λ=1μm),
   and e+ stacking in DR
   S. Araki et al., physics/0509016

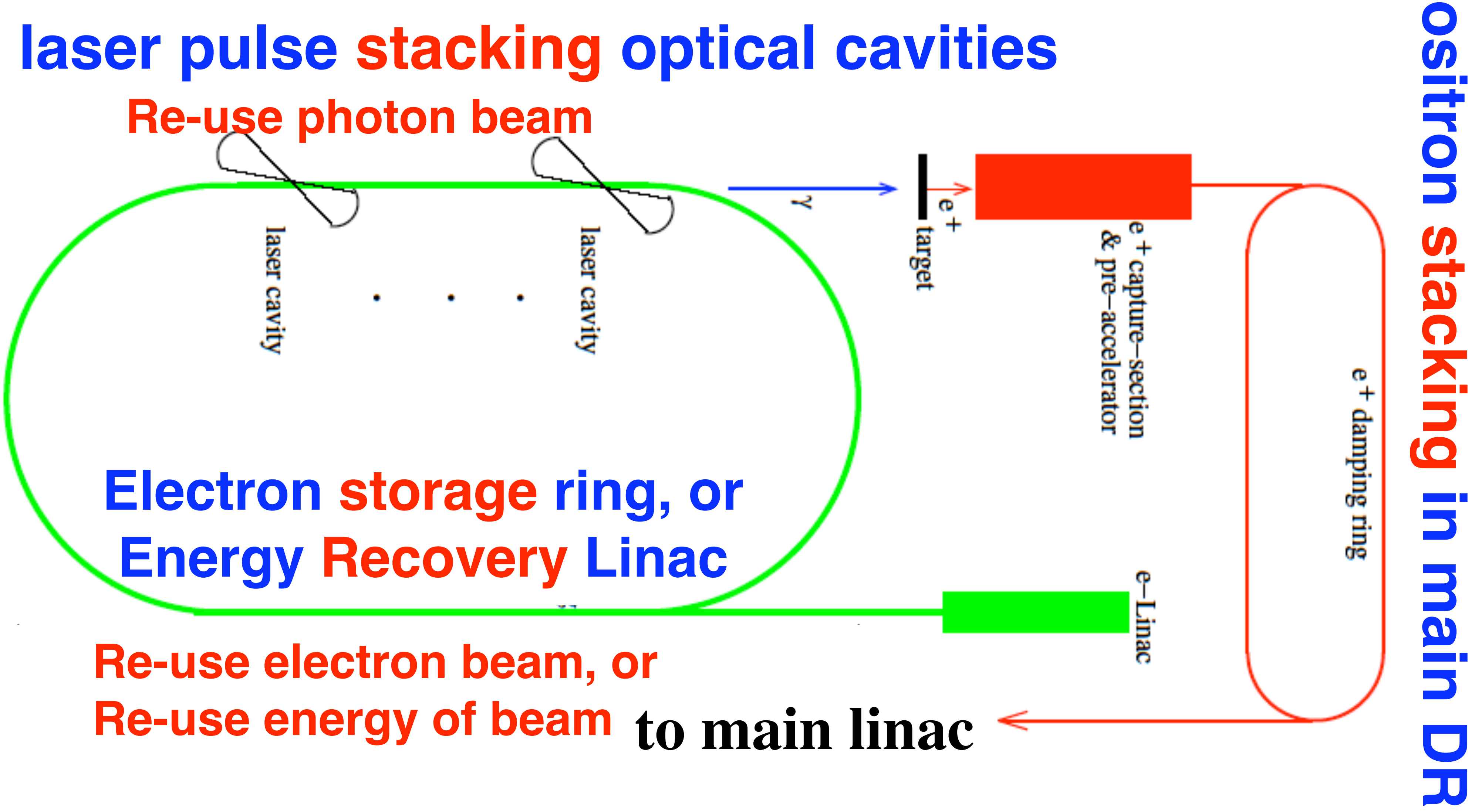
2. ERL Base Laser Compton
   ERL + Laser Stacking Cavity (λ=1μm),
   and e+ stacking in DR

3. Linac Base Laser Compton   talk: V. Yakimenko
   Linac + non-stacking Laser Cavity (λ=10μm),
   and No stacking in DR
   Proposal V. Yakimenko and I. Pogorersky
   T. Omori et al., Nucl. Instr. and Meth. in Phys. Res., A500 (2003) pp 232-252

Good!   But we have to choose!

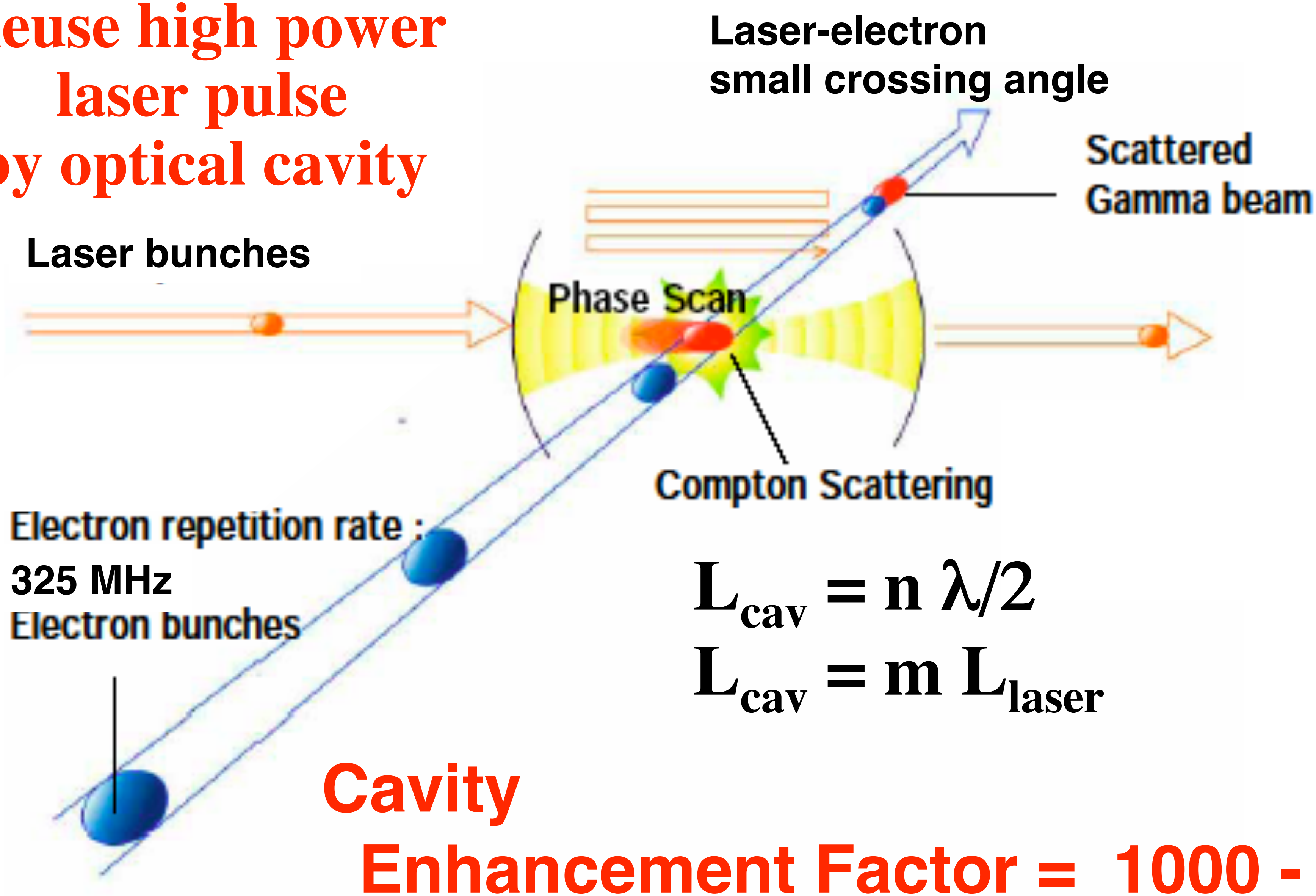
Ring/ERL Scheme

Ring/ERL Compton
Re-use Concept



Optical Cavity for Pulse Laser Beam Stacking

Reuse high power laser pulse by optical cavity



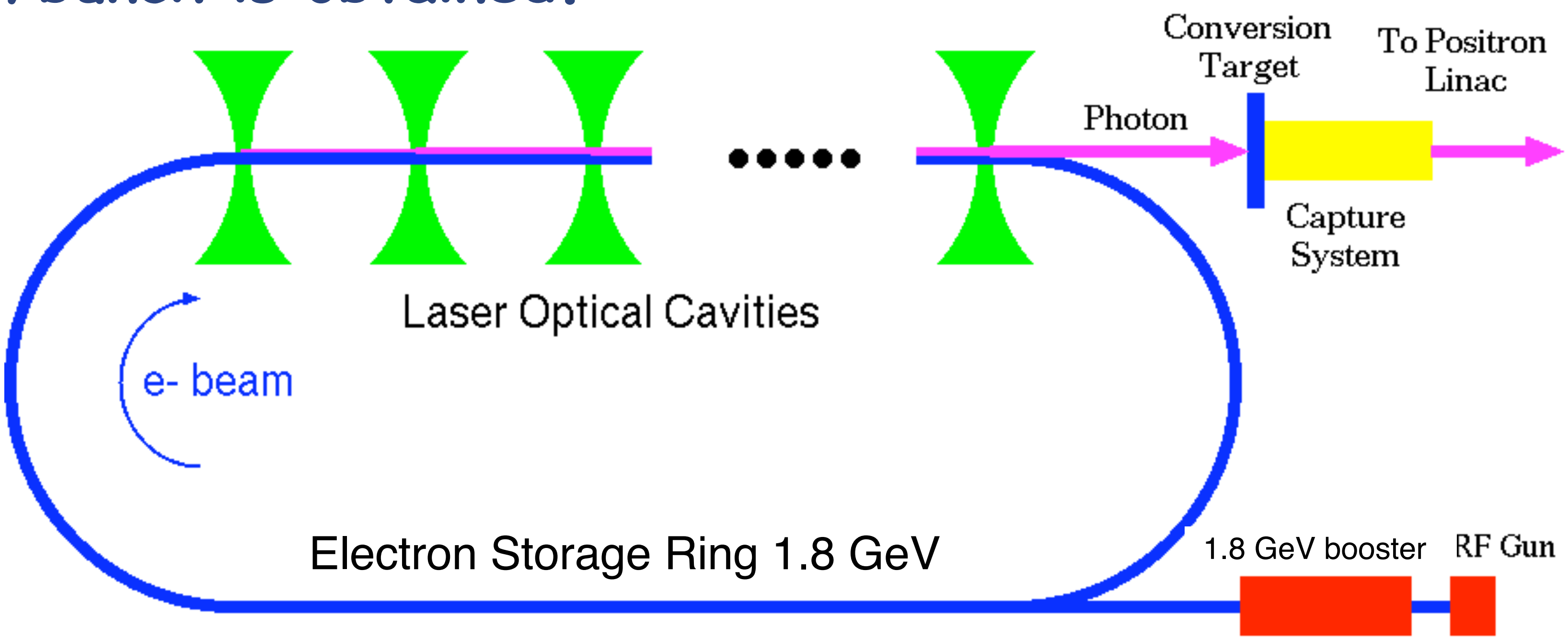
$$L_{cav} = n\,\lambda/2$$

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

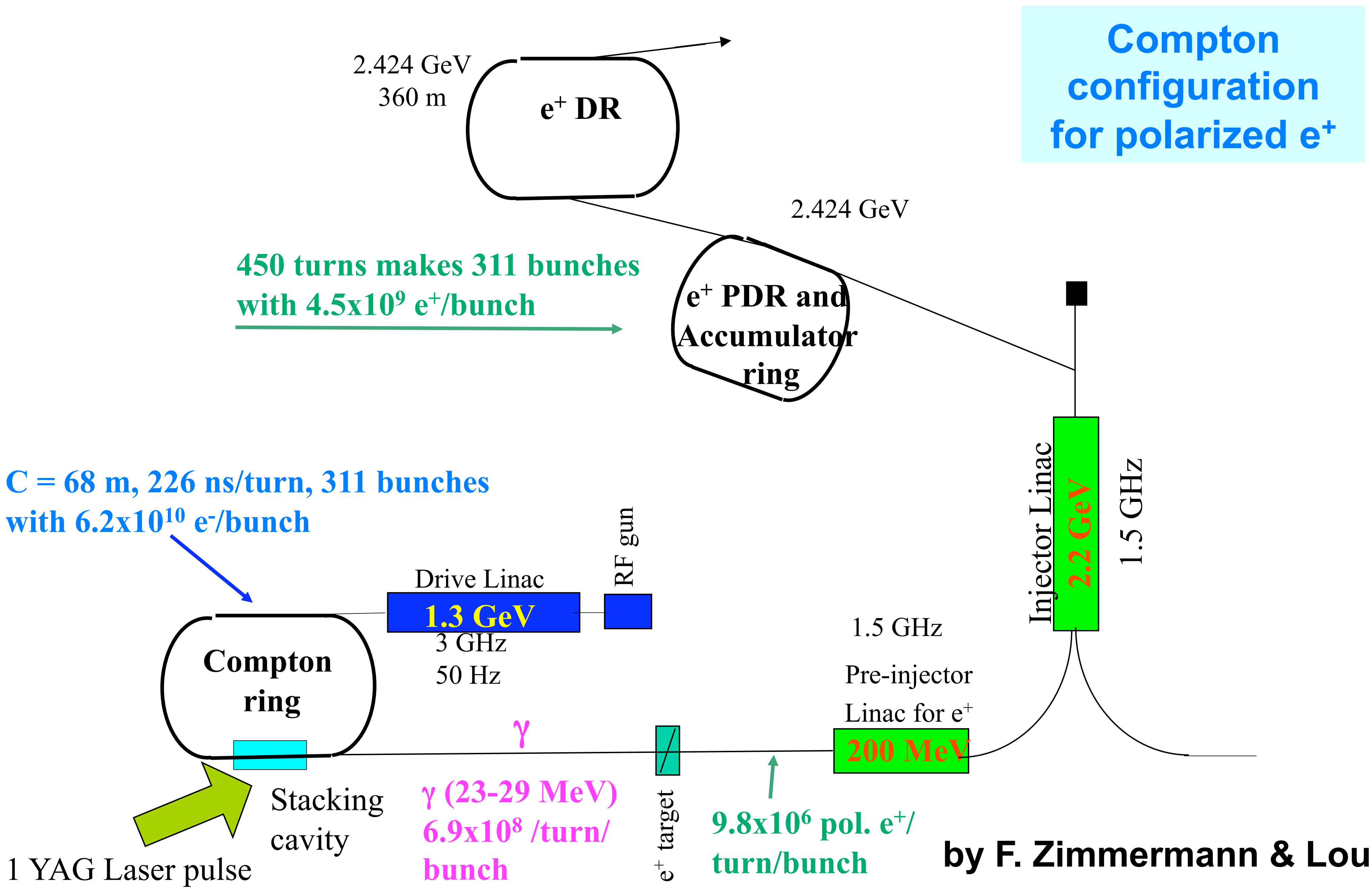
Cavity Enhancement Factor = 1000 - 10^5

Compton Ring Scheme for ILC

- Compton scattering of e- beam stored in storage ring off laser stored in Optical Cavity.
- 5.3 nC 1.8 GeV electron bunches x 5 of 600mJ stored laser -> 2.3E+10 γ rays/bunch -> 2.0E+8 e+/bunch.
- 10 bunches are stacked on a same bucket. This is repeated 10 times with 10 ms interval.
- By stacking 100 bunches on a same bucket in DR, 2.0E+10 e+/bunch is obtained.



Compton Ring Scheme for CLIC

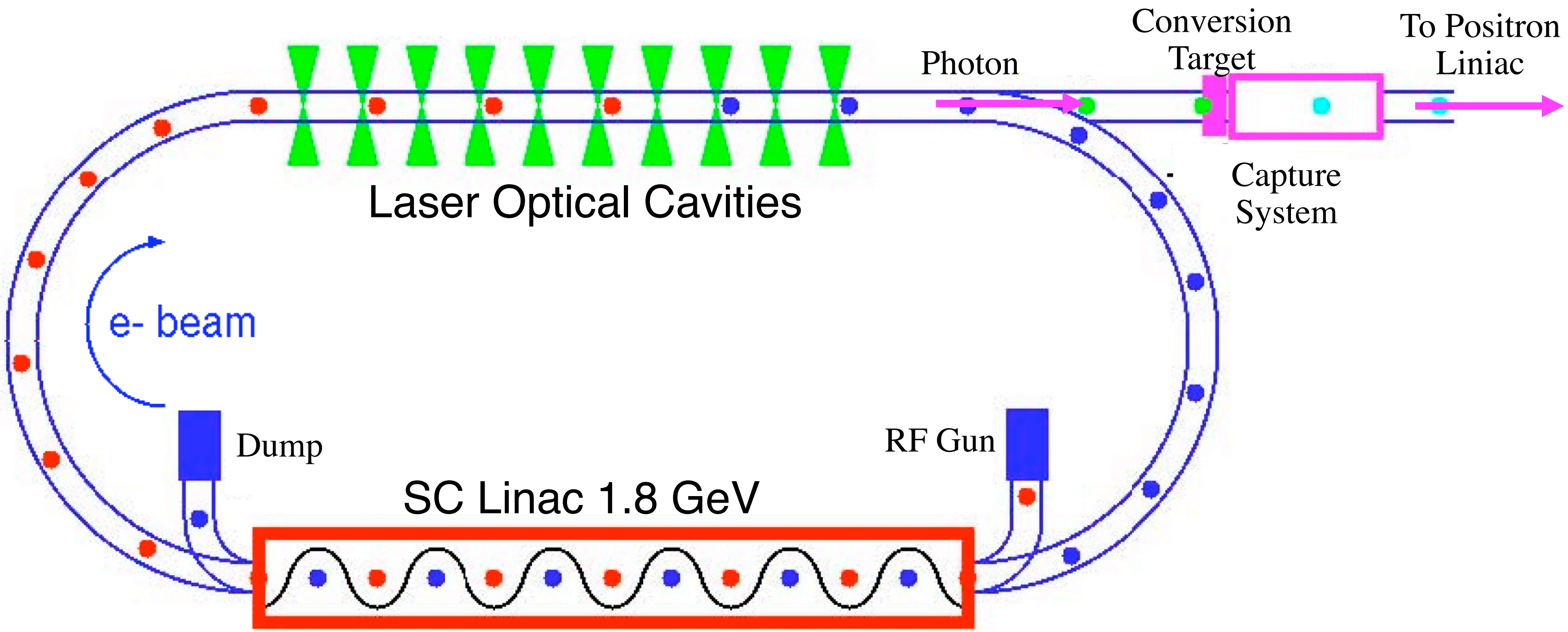


by F. Zimmermann & Louis

Compton ERL scheme for ILC

- High yield + high repetition in ERL solution.
  - 0.48 nC 1.8 GeV bunches x 5 of 600 mJ laser, repeated by 54 MHz -> 2.5E+9 γ-rays -> 2E+7 e+.
  - Continuous stacking the e+ bunches on a same bucket in DR during 100ms, the final intensity is 2E+10 e+.

1000 times of stacking in a same bunch



Choice of ERL parameters

I = 26 mA

(a) Ne/bunch = 1 x 10^9 $T_{b\_to\_b}$ = 6.15 ns (160 pC x 160 MHz)

prev. page → (b) Ne/bunch = 3 x 10^9 $T_{b\_to\_b}$ = 18.5 ns (480 pC x 54 MHz)

(c) Ne/bunch = 1 x 10^{10} $T_{b\_to\_b}$ = 61.5 ns (1.6 nC x 16 MHz)

(d) Ne/bunch = 3 x 10^{10} $T_{b\_to\_b}$ = 185 ns (4.8 nC x 5.4 MHz)

I = 80 mA (too ambitious !?)

(e) Ne/bunch = 3 x 10^9 $T_{b\_to\_b}$ = 6.15 ns (480 pC x 160 MHz)

(f) Ne/bunch = 1 x 10^{10} $T_{b\_to\_b}$ = 18.5 ns (1.5 nC x 54 MHz)

(g) Ne/bunch = 3 x 10^{10} $T_{b\_to\_b}$ = 61.5 ns (4.8 nC x 16 MHz)

Choice of ERL parameters

ERL

I = 26 mA

more difficult

(a)	Ne/bunch = 1×10^{9}	$T_{b\_to\_b}$ = [illegible] ns	(160 pC x 160 MHz)
(b)	Ne/bunch = 3×10^{9}	$T_{b\_to\_b}$ = 1[illegible]s	(480 pC x 54 MHz)
(c)	Ne/bunch = 1×10^{10}	$T_{b\_to\_b}$ = 6[illegible]s	(1.6 nC x 16 MHz)
(d)	Ne/bunch = 3×10^{10}	$T_{b\_to\_b}$ = 18[illegible]	(4.8 nC x 5.4 MHz)

I = 80 mA (too ambitious !?)

more difficult

(e)	Ne/bunch = 3×10^{9}	$T_{b\_to\_b}$ = [illegible] ns	(480 pC x 160 MHz)
(f)	Ne/bunch = 1×10^{10}	$T_{b\_to\_b}$ = 1[illegible]s	(1.5 nC x 54 MHz)
(g)	Ne/bunch = 3×10^{10}	$T_{b\_to\_b}$ = [illegible]	(4.8 nC x 16 MHz)

Choice of ERL parameters

ERL — more difficult

Laser & Stacking — Easier

I = 26 mA

(a) Ne/bunch = 1 x 10^9 $T_{b\_to\_b}$ = ... ns (160 p... 60 MHz)

(b) Ne/bunch = 3 x 10^9 $T_{b\_to\_b}$ = 1... s (480 p... 54 MHz)

(c) Ne/bunch = 1 x 10^{10} $T_{b\_to\_b}$ = 6... s (1.6 n... 16 MHz)

(d) Ne/bunch = 3 x 10^{10} $T_{b\_to\_b}$ = 18... (4.8 n... 5.4 MHz)

I = 80 mA (too ambitious !?)

(e) Ne/bunch = 3 x 10^9 $T_{b\_to\_b}$ = ... ns (480 p... 160 MHz)

(f) Ne/bunch = 1 x 10^{10} $T_{b\_to\_b}$ = 1... s (1.5 n... 54 MHz)

(g) Ne/bunch = 3 x 10^{10} $T_{b\_to\_b}$ = ... (4.8 ... 6 MHz)

Choice of ERL parameters

ERL — more difficult

Laser & Stacking — Easier

I = 26 mA

(a) Ne/bunch = 1 x 10^9 $T_{b\_to\_b}$ = ns (160 p 60 MHz)

(b) Ne/bunch = 3 x 10^9 $T_{b\_to\_b}$ = 1 s (480 p 54 MHz)

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(d) Ne/bunch = 3 x 10^{10} $T_{b\_to\_b}$ = 18 (4.8 n .4 MHz)

I = 80 mA (too ambitious !?)

(e) Ne/bunch = 3 x 10^9 $T_{b\_to\_b}$ = ns (480 p 160 MHz)

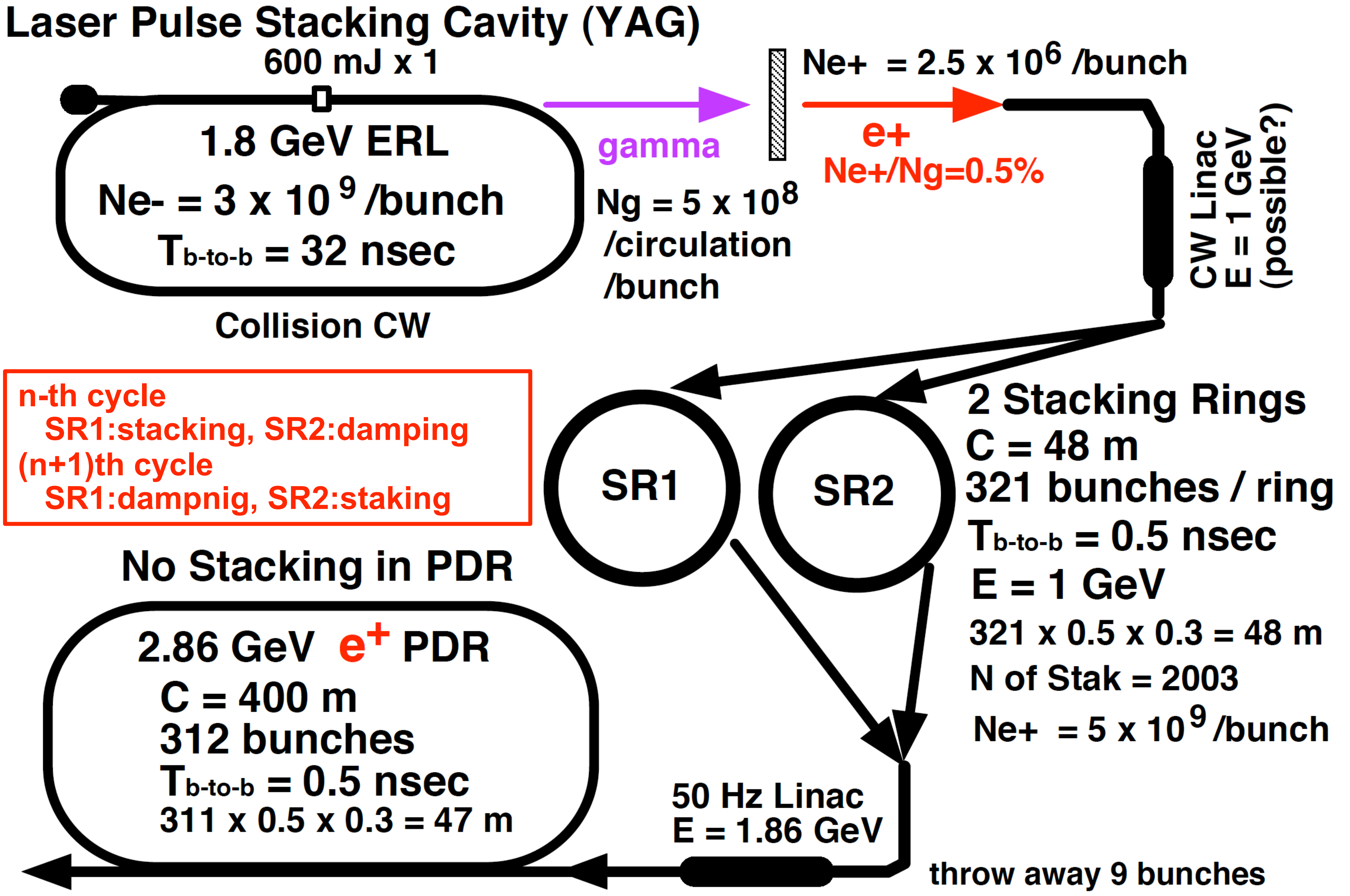
(f) Ne/bunch = 1 x 10^{10} $T_{b\_to\_b}$ = 1 s (1.5 n 54 MHz)

(g) Ne/bunch = 3 x 10^{10} $T_{b\_to\_b}$ = (4.8 6 MHz)

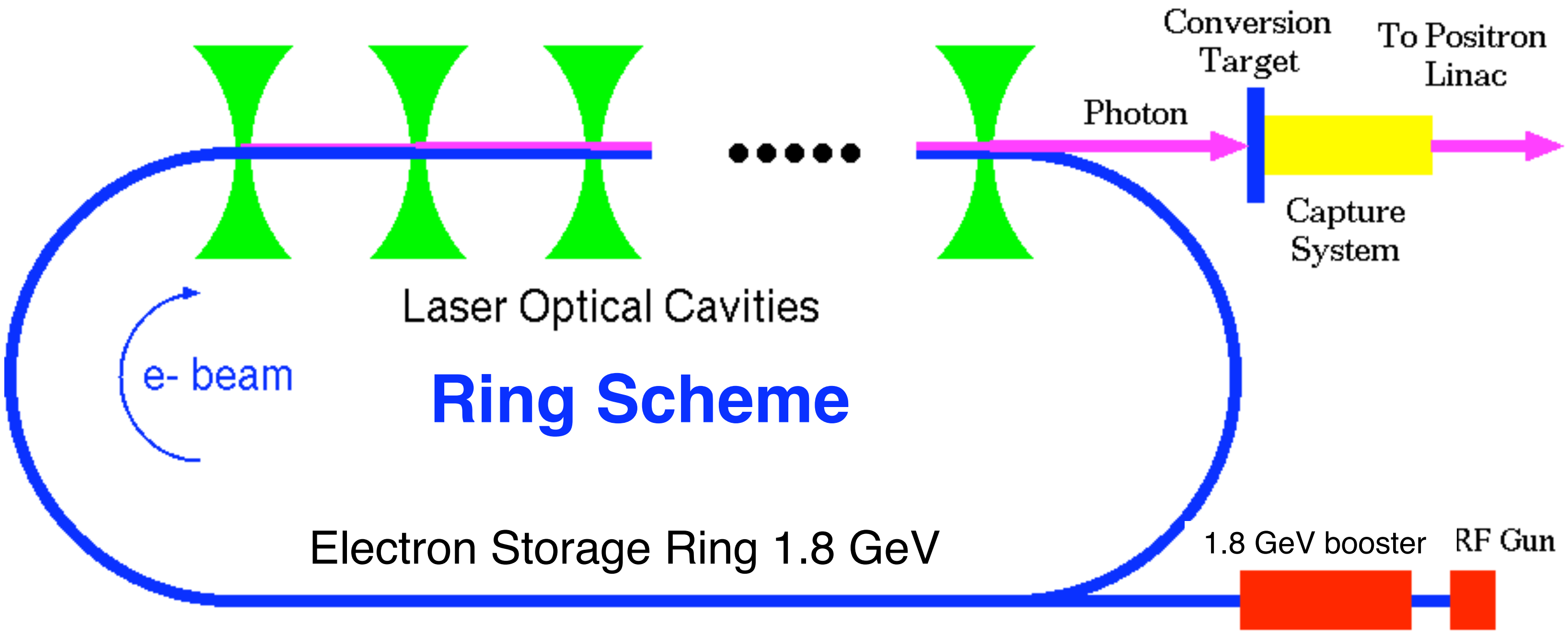
Note: Goal of KEK ERL project: E=5GeV, I=100 mA

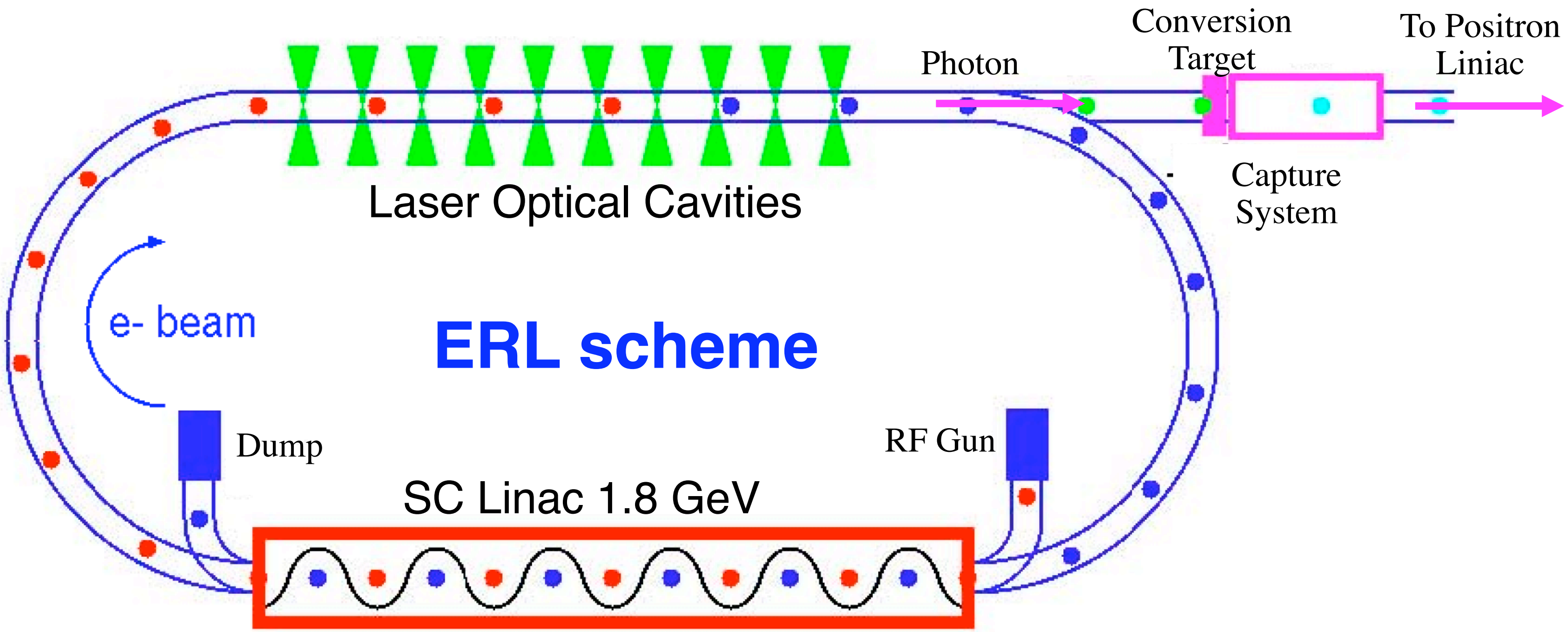
Compton ERL scheme for CLIC

Louis&TO



Ring scheme and ERL scheme are SIMILAR





What is the Difference? : Ring and ERL

What is Reused

Ring: Electron Beam

ERL: Energy of the electron beam

What is the Difference? : Ring and ERL

What is Reused

Ring: Electron Beam

ERL: Energy of the electron beam

Operation

Ring: Burst Operation (need cooling time)

ERL: as CW as possible

What is the Difference? : Ring and ERL

What is Reused

Ring: Electron Beam

ERL: Energy of the electron beam

Operation

Ring: Burst Operation (need cooling time)

ERL: as CW as possible

Bunch Length

Ring: Naturally Long (typically 30 psec)

ERL: Short (can be less than 1 p sec)

What is the Difference? : Ring and ERL

What is Reused

Ring: Electron Beam

ERL: Energy of the electron beam

Operation

Ring: Burst Operation (need cooling time)

ERL: as CW as possible

Bunch Length

Ring: Naturally Long (typically 30 psec)

ERL: Short (can be less than 1 p sec)

Bunch Charge

Ring: Larger

ERL: Smaller

Necessary R/Ds

for Ring/ERL scheme

Ring/ERL scheme R&D List

e+ stacking in DR

- simulation studies — talks F. Zimmermann, E. Bulyak

CR simulation studies — talk E. Bulyak

ERL simulation studies — talk I. Chaikovska

e+ capture (common in all e+ sources)

- Simulation study — talk A. Vivoli
- Collaboration with KEKB upgrade — talk T. Kamitani

e+ production target

Laser

- Fiber laser / Mode-lock laser — talks F. Zomer and J. Urakawa

Laser Stacking Cavity

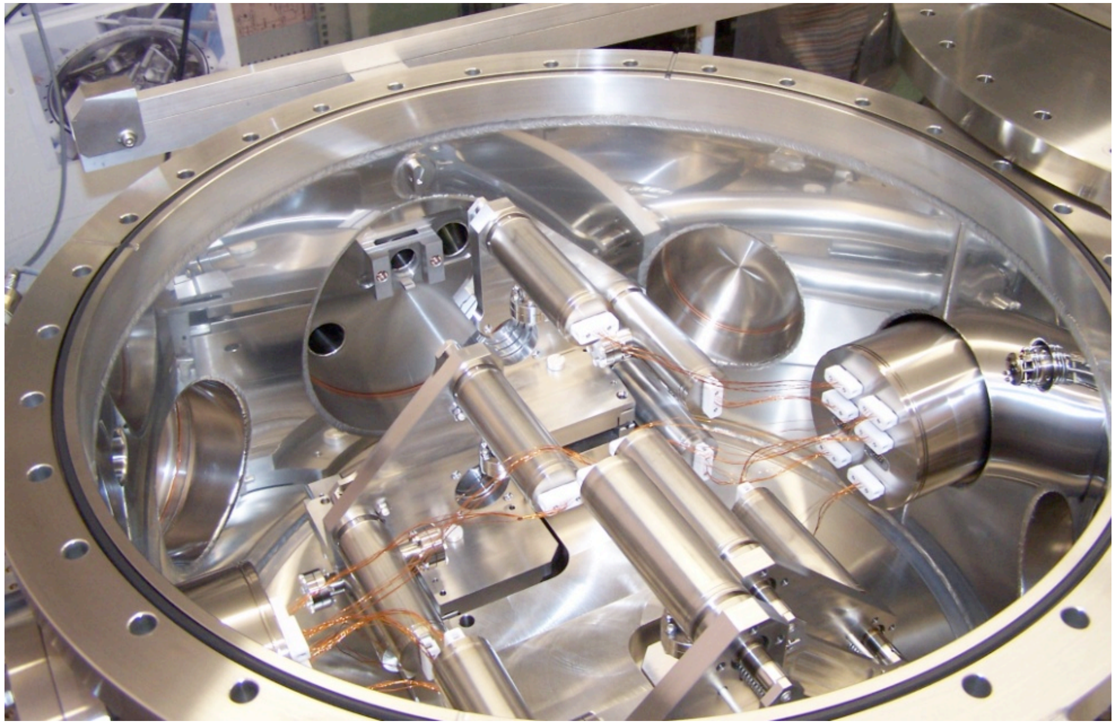
- experimental and theoretical studies — talks F. Zomer and myself

Just Example

Prototype Cavities

2-mirror cavity (Hiroshima / Weseda / Kyoto / IHEP / KEK)

4-mirror cavity (LAL)

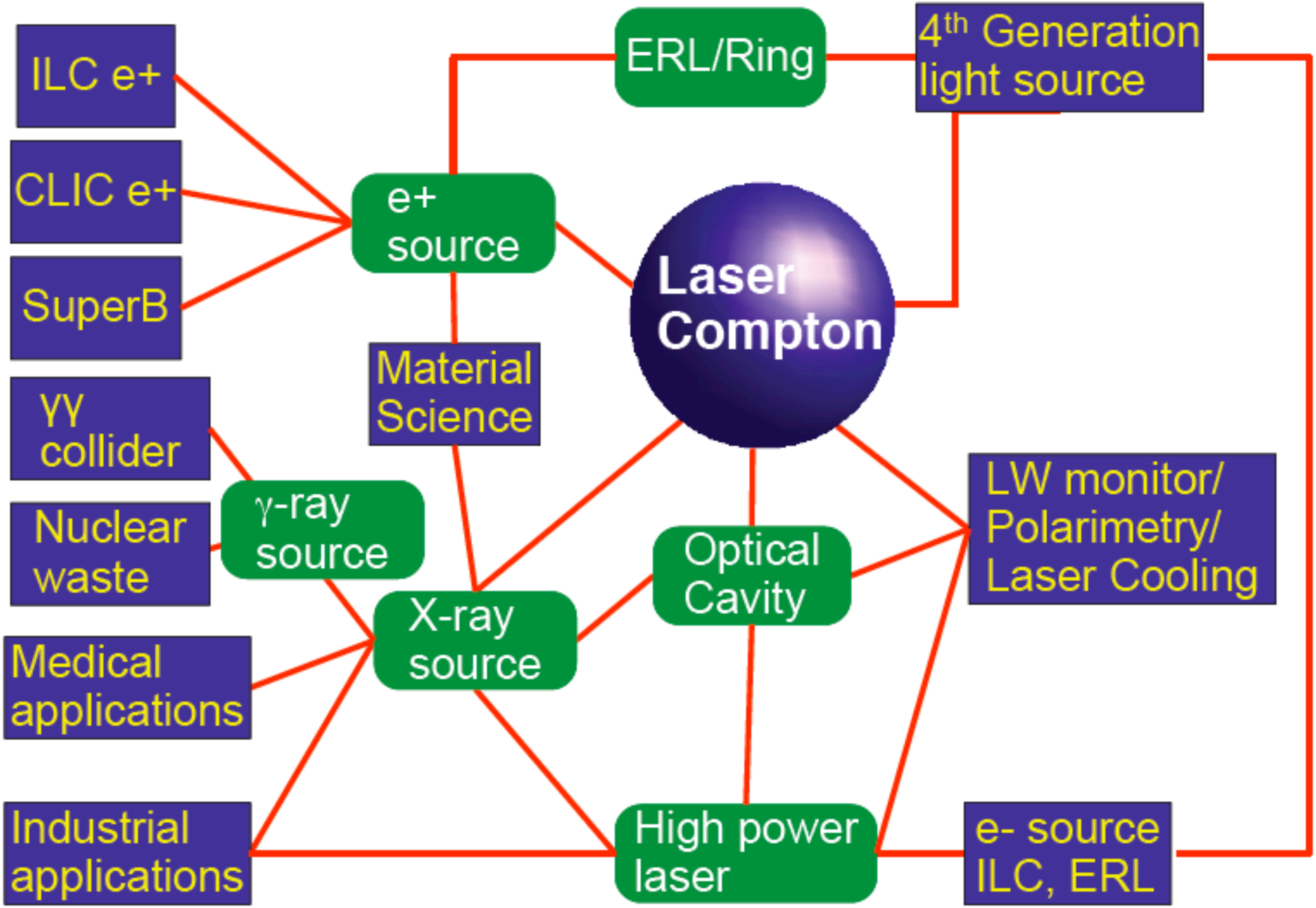


moderate enhancement
moderate spot size
simple control

high enhancement
small spot size
complicated control

Applications
and
PosiPol Collaboration

World-Wide-Web of Laser Compton



PosiPol-Collaboration

1. Laser-Compton has a large potential as a future technology.

2. Many common efforts can be shared in a context of various applications.
   - Compact and high quality X-ray source for industrial and medical applications
   - γ-ray source for disposal of nuclear wastes
   - Beam diagnostics with Laser
   - Laser Cooling
   - Polarized Positron Generation for ILC and CLIC
   - $\gamma\gamma$ collider

Q-Beam and cERL (1)

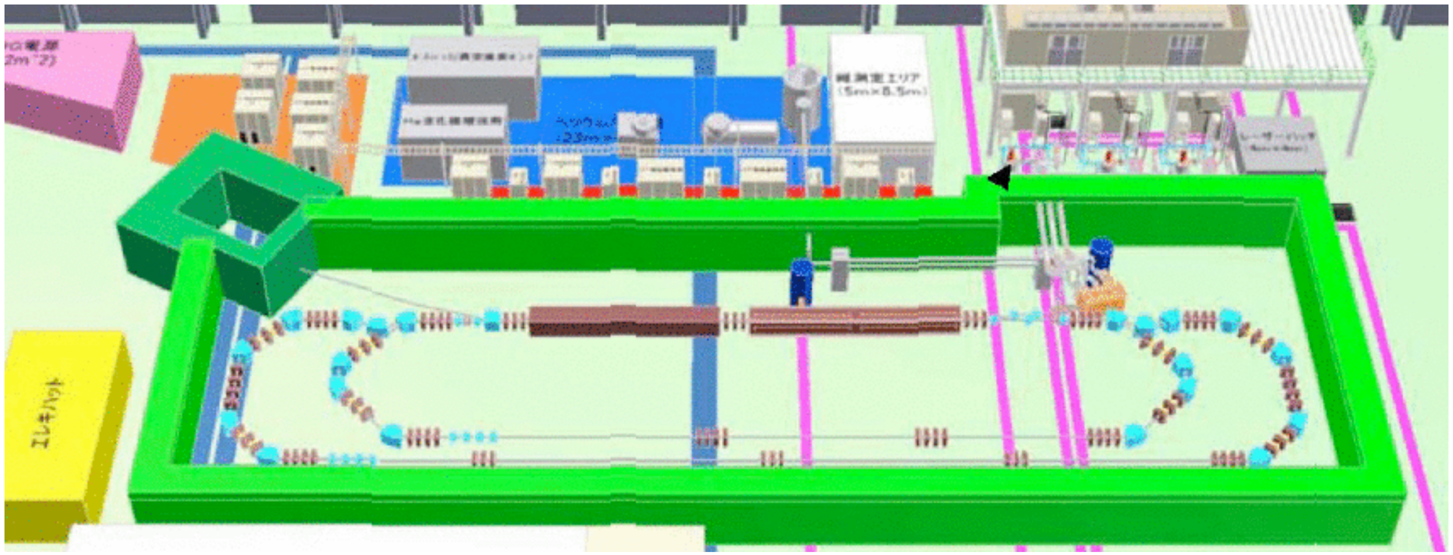
- ►Quantum-Beam project is a strategic R&D for X-ray source for various applications based on the SC linac.
- ►1st step: Pulsed X-ray generation with SC linac; It will be carried out at KEK-STF, 2010-2011.
- ►2nd step: CW X-ray generation with SC ERL; It will be carried out at cERL-KEK, 2012~.

Energy : 25-30 MeV
Micro pulse rep.:162.5MHz,
Current in macro pulse:16mA,
Macro pulse rep: 10Hz

http://kocbeam.kek.jp/project/index.html

Q-Beam and cERL (2)

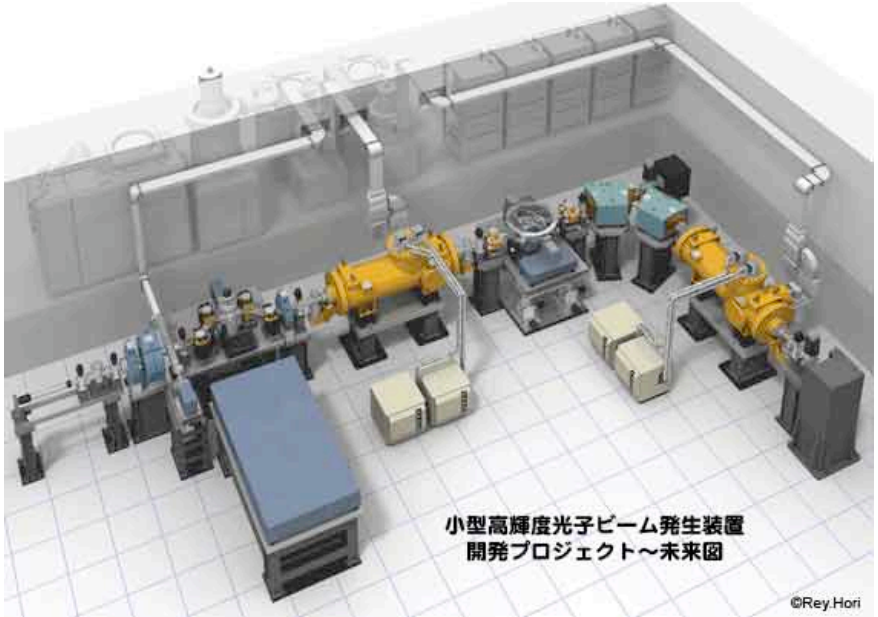
- cERL is a test machine to prove the technical feasibility of 5GeV class ERL machine for future light source.
- It will be constructed in the "east counter hall" of ex-KEK-PS.
- The operation will be started from 2012.
  - The energy 35-65 MeV.
  - Average current : 10mA
  - Emittance : 1.0 π mm.mrad

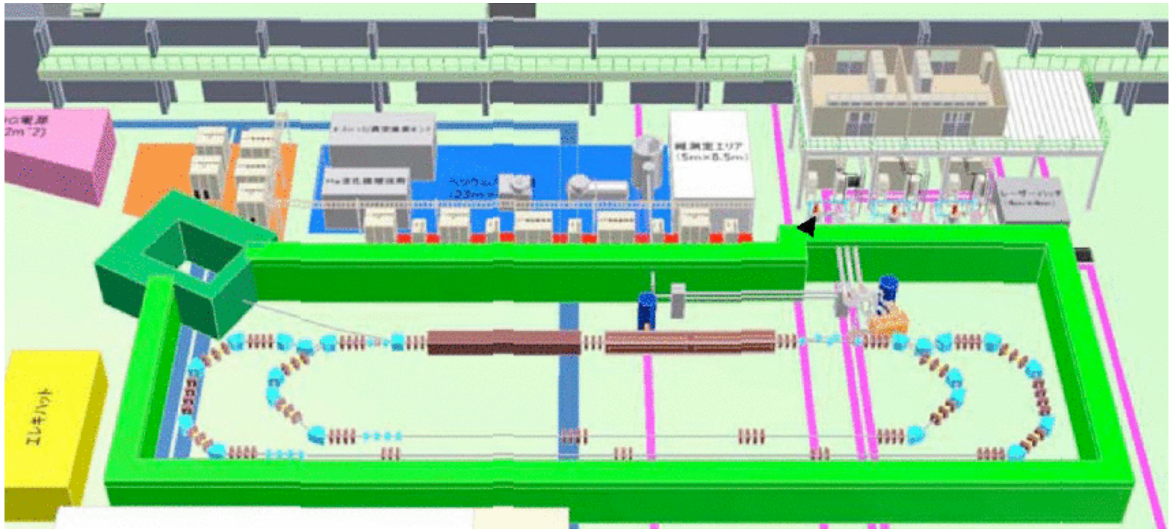


Q-Beam and cERL (3)

- Q-beam and cERL is technically very close to each other.
- X-ray generation and THz radiation are two major applications of cERL. It can be linked to the LC positron R&D.

Transition from Pulse to CW
x60 larger average current





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, Takuya Kamitani, Yoshisato Funahashi, 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, Iryna Chaikovska, 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
KEK Tsukuba
31 May - 2 June
http://atfweb.kek.jp/posipol/2010/

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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
KEK Tsukuba
31 May - 2 June
http://atfweb.kek.jp/posipol/2010/

POSIPOL 2011
IHEP Beijing
26-28 September

Summary

Summary 1

1. Laser Compton e+ source is attractive option for ILC/CLIC
   - Independent system
   - high polarization
   - 5 Hz polarization flip (for CLIC 50 Hz flip)
   - Operability
   - wide applications

2. Three schemes are proposed
   - Ring Laser Compton for ILC
   - ERL Laser Compton for ILC
   - Linac Laser Compton

   My talk Today

3. Ring & ERL Schemes

   Examples of parameter sets are presented for ILC and CLIC. However, those are only examples. We absolutely need more study to get conclusions.

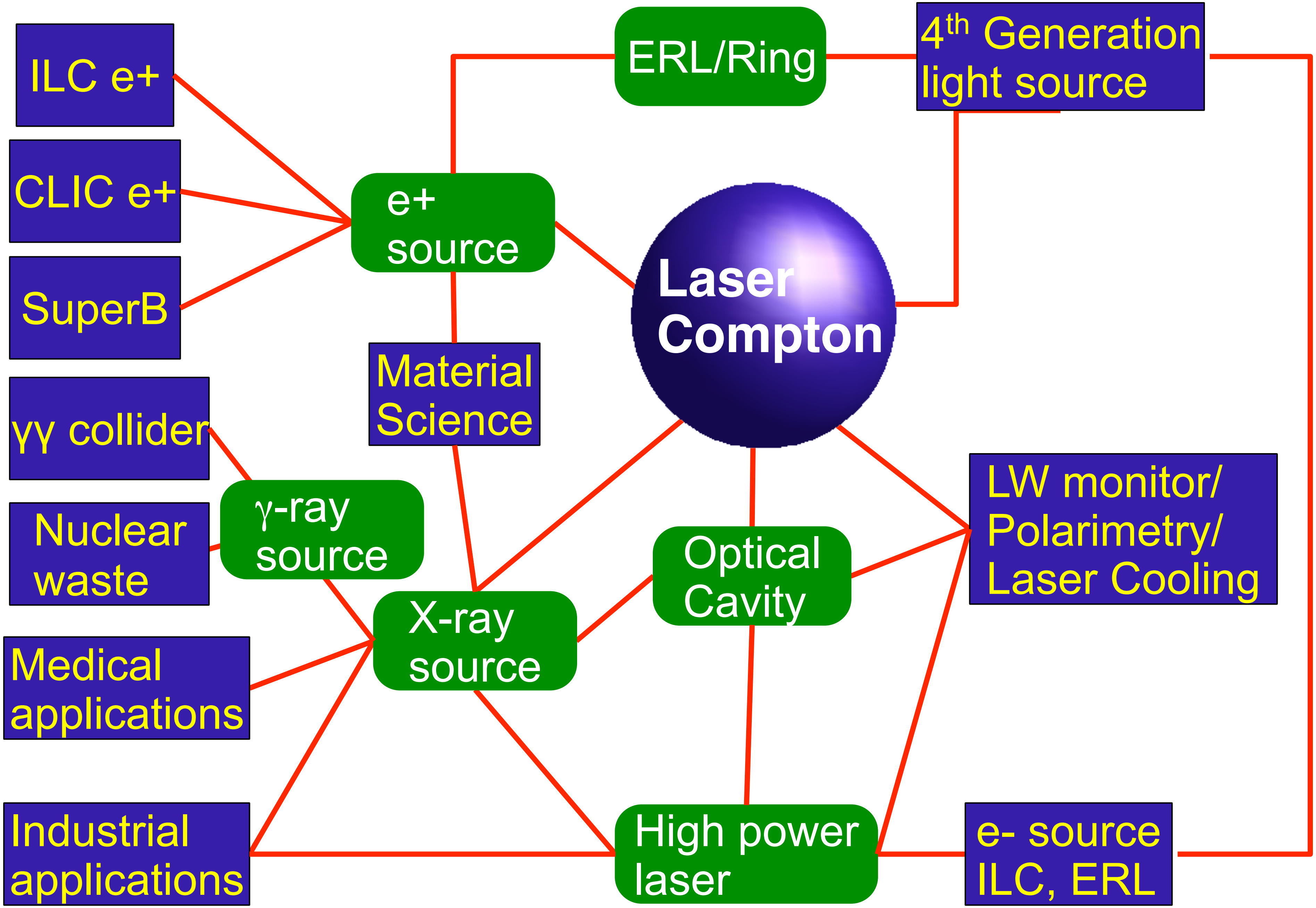
Summary 2

4. We need many R/Ds
   (a) e+ stacking, (b) Ring, (c) ERL, (d) e+ capture
   (e) e+ production target, (e) Laser
   (g) Laser stacking optical cavity
   All of R/Ds are very important and correlated.
   Choices are highly depends on the results of the R/Ds.

5. We have the world-wide collaboration for Compton.
   Not only for ILC/CLIC e^+ source.
   Also for many other applications.
   X-ray generation, treatment of nuclear waste, ERL,,,,
   In KEK, Quantum beam (SRF Linac + Compton) and
   cERL (Compact ERL + Compton) projects are on going.

Backup Slides

World-Wide-Web of Laser Compton



Parameters and Choices

of Ring/ERL scheme

Ring Scheme Parameters

Compton Scheme Parameters

Burst Operation of Laser

Need to cool Compton Ring

Good for stacking in DR

Cooling time ~ 10 m sec

Ng / bunch = 2.3×10^{10} CAIN

E=1.8 GeV, 0.6 J x 5 CP (assume)

Ne/ bunch = 3.3×10^{10} (5.3 nC / bunch) (assume)

Bunch length ~ 1 p sec (assume)

Ne+ / bunch = 2×10^{8}

Ne+(captured) / Ng = 0.8 % (assume)

We need 100 times of stacking in a same DR bunch.

{10 stacking (<<1 ms) + cooling (~10 ms) } x 10

Burst Operation of Laser --> Burst Amplifier ?

Compton Scheme Parameters

Bunch Length in the Compton Ring

Bunch Length 30 p sec --> Loose luminosity

Short Bunch ?

Bunch Compress --> CPs --> Decompress

too difficult ?

Very Small Momentum Compaction Factor

beam dynamics

Crab Crossing ?

Head on Collision?

We need mirrors with a hole.

--> Non Stacking Laser Cavity --> Linac Scheme

Ne / bunch

Ne / bunch = 3.3×10^{10} (5.3 nC/bunch)

Reasonable Feasibility?

ERL Scheme Parameters

ERL repetition ($R_{rep} = 1/T_{b\_to\_b}$)

ERL repetition and e+ Stacking

How many stacks do we need ?

Number of gamma-rays

Ng / bunch = 0.75×10^{10} CAIN

E=1.8 GeV, 0.6 J x 5 CP, Ne=1×10^{10}

Number of positrons

Ne+(captured) / Ng = 0.8 % (assume)

Ne+ / bunch = 0.6×10^{8}

I = 26 mA (assume)

R_{rep} (MHz)	160	54	16
Ne /bunch	1×10^{9}	3×10^{9}	1×10^{10}
Necessary N stack	3300	1000	330

ERL repetition ($R_{rep} = 1/T_{b\_to\_b}$) continued

ERL repetition and e+ Stacking (continued)

Max N stack is limited by time.

T stack < 100 m sec

T stack = 3000 bunches x N stack / R_{rep}

I = 26 mA (assume)

R_{rep} (MHz)	160	54	16
Ne /bunch	1×10^9	3×10^9	1×10^{10}
Necessary N stack	3300	1000	330
Max N stack	5000	1600	500

Max N stack is limited by DR.

How many stacks can we achieve ?

--> Need study

ERL repetition ($R_{rep} = 1/T_{b\_to\_b}$)   continued

ERL repetition and Laser

R_{rep} (MHz)	160	54	16
L cavity (round trip)	1.9	5.6	19
L cavity (4 mirror)	0.46	1.4	4.6

Reasonable size of stacking cavity?

Reasonable size of laser oscillator?