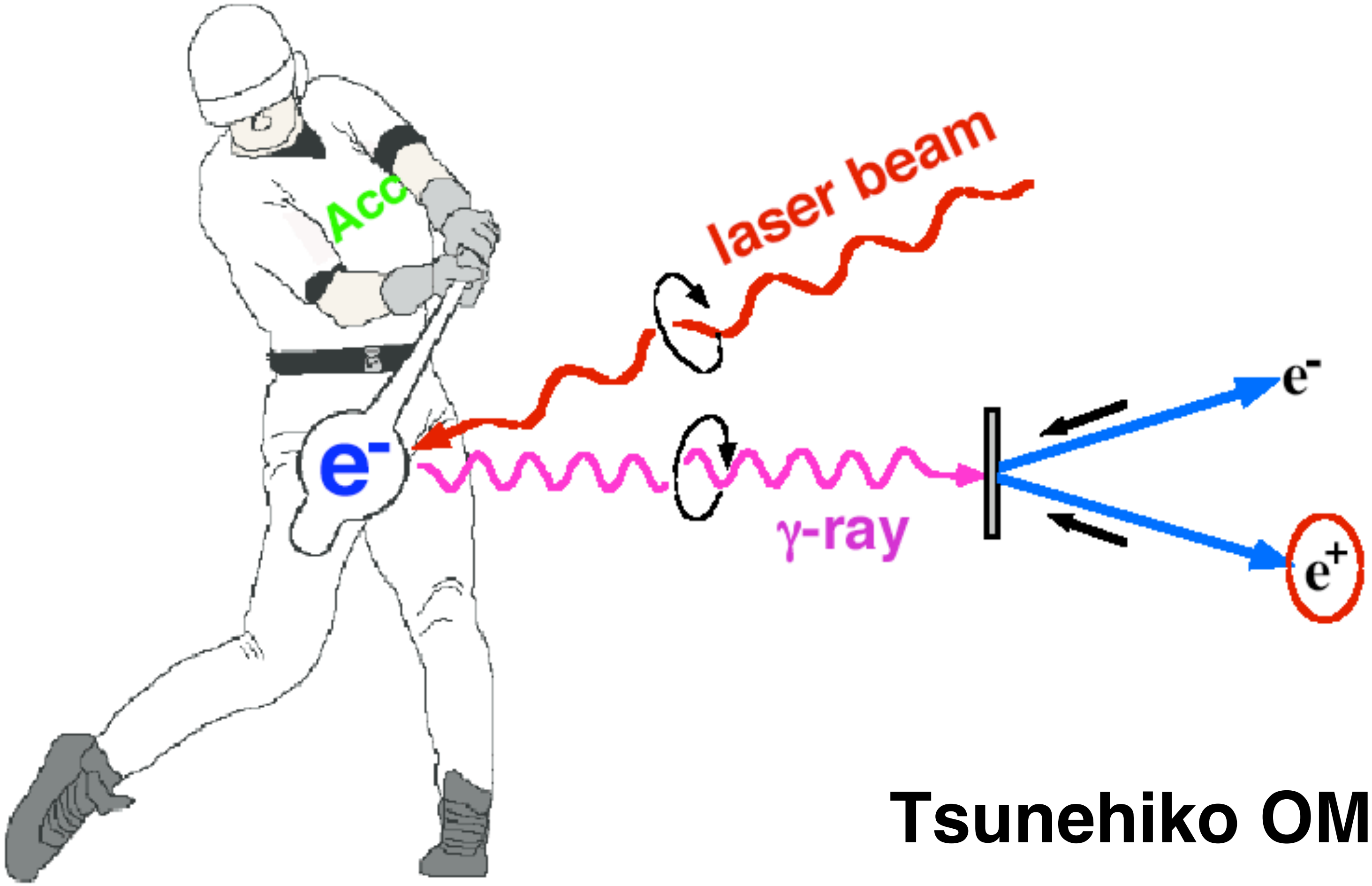
Compton Status Report



Tsunehiko OMORI (KEK)

e+ source meeting@ANL
17/Sep/2007

World-wide PosiPol 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, Yoshimasa Kurihara, Takuya Kamitani, X. Artru, M. Chevallier, V. Strakhovenko, Eugene Bulyak, Peter Gladkikh, Klaus Meonig, Robert Chehab, Alessandro Variola, Fabian Zomer, Alessandro Vivoli, Richard Cizeron, 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

POSIPOL 2006
CERN April 2006

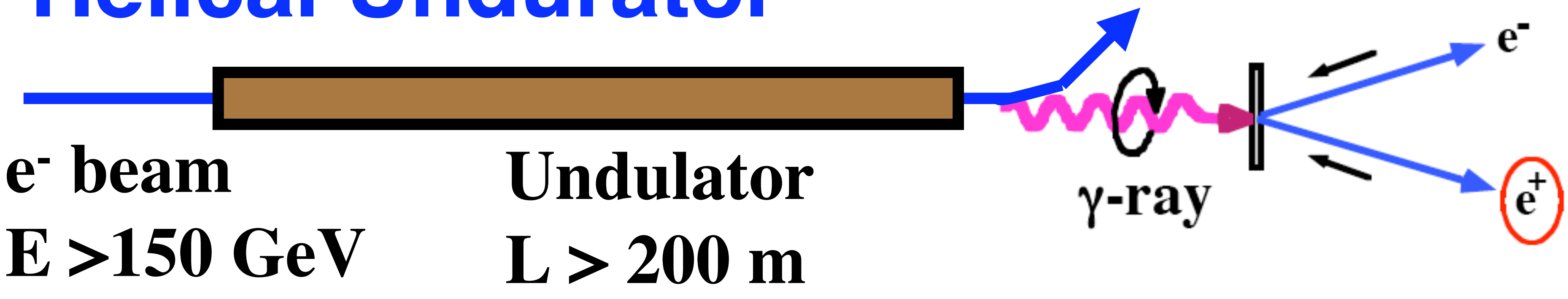
http://posipol2006.web.cern.ch/Posipol2006/

POSIPOL 2007
LAL-Orsay, France
23-25 May

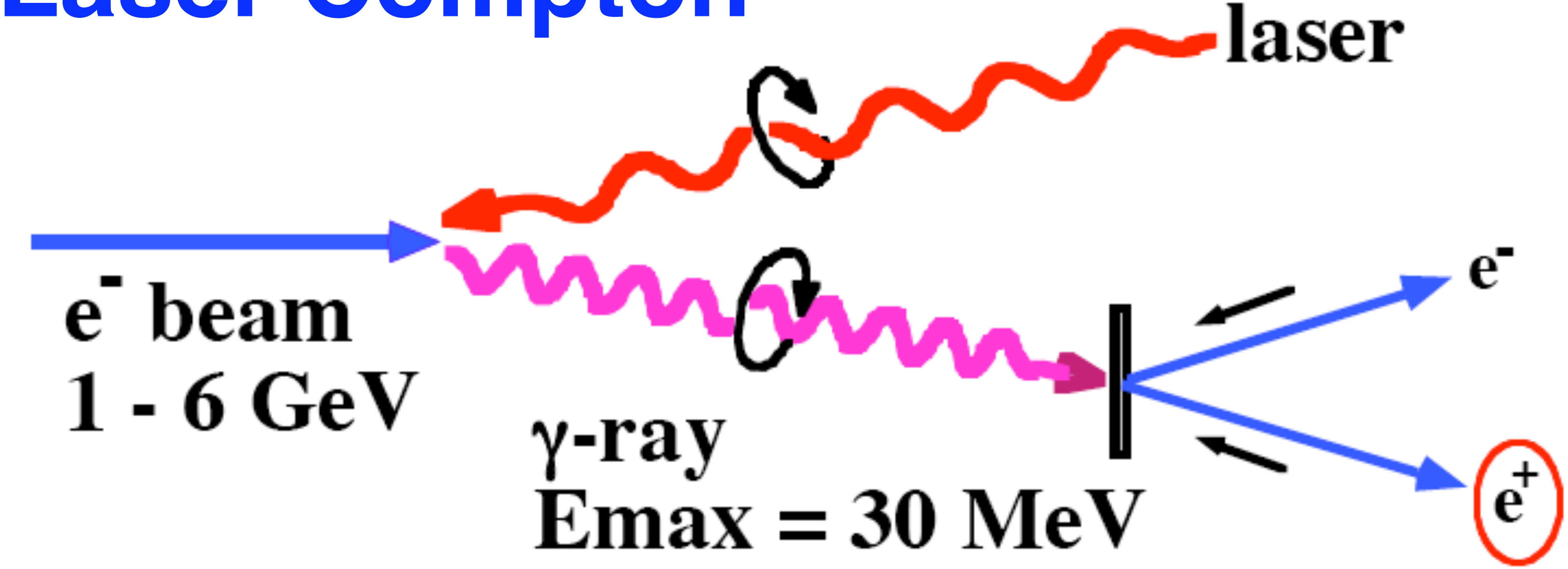
http://events.lal.in2p3.fr/conferences/Posipol07/

Two ways to get pol. e^+

(1) Helical Undurator



(2) Laser Compton



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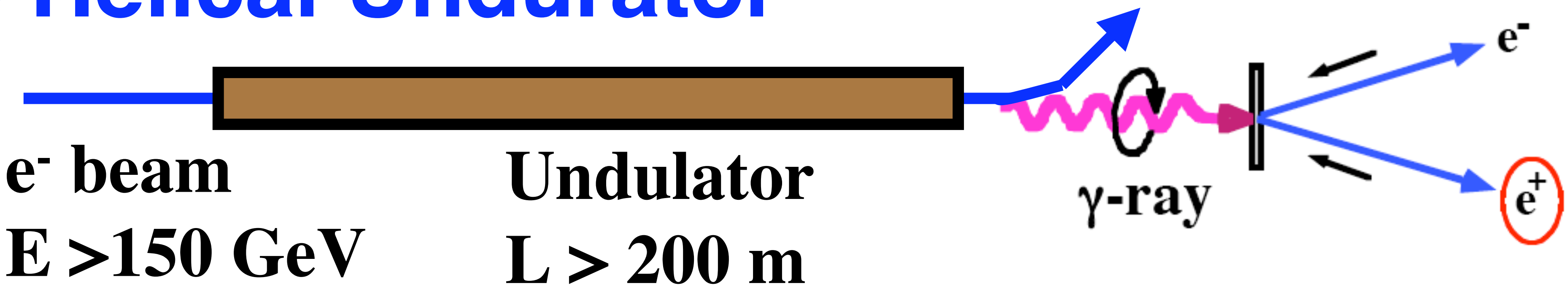
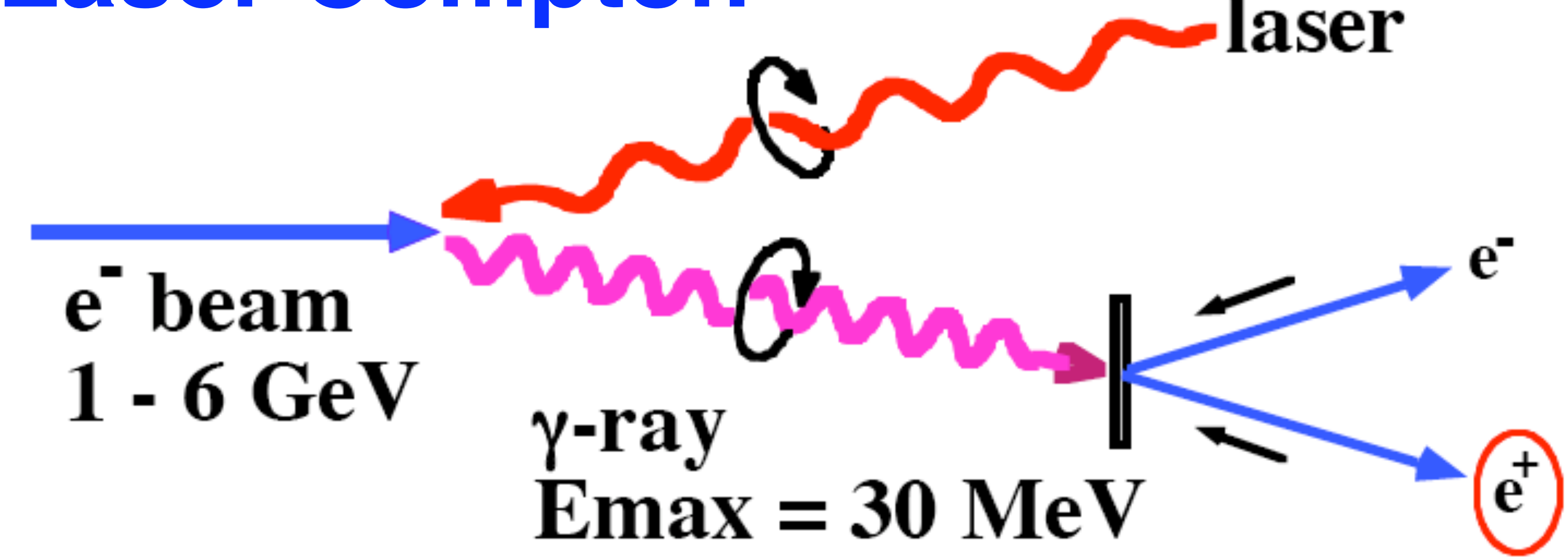


Our Proposal

(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

iv) High polarization

v) Low energy operation

Undulator-base e^+ : need deccelation

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

We still need many R/Ds and simulations.

We have 3 schemes.

Laser Compton e^+ Source for ILC

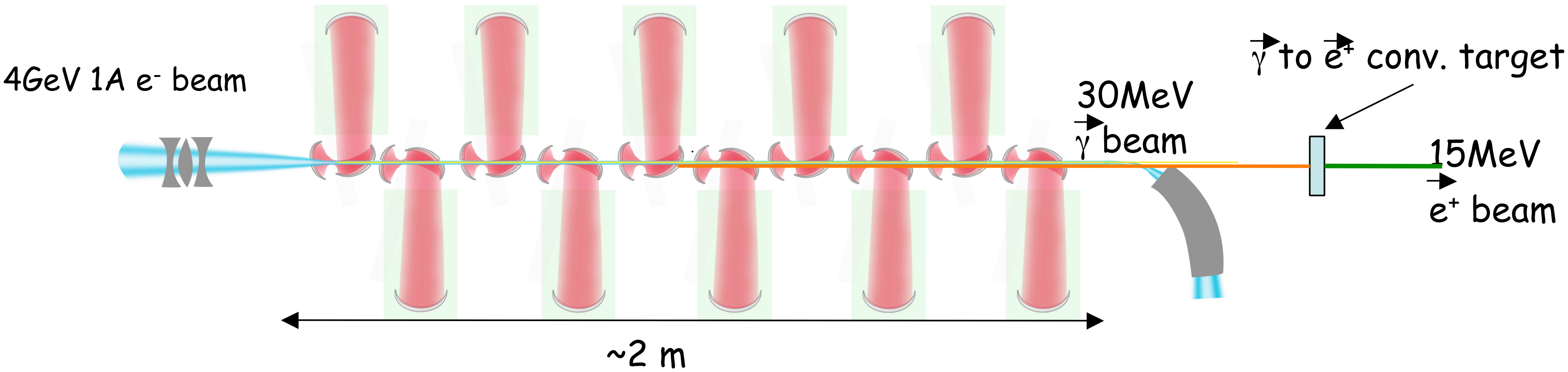
We have 3 schemes.

1. Linac Base Laser Compton
   Linac + External non-stacking Laser Cavity,
   and No stacking in DR
   T. Omori et al., Nucl. Instr. and Meth. in Phys. Res., A500 (2003) pp 232-252
   Proposal by V. Yakimenko and I. Pogorersky
2. Ring Base Laser Compton
   Storage Ring + Laser Stacking Cavity,
   and moderate stacking in DR (~100 times)
   S. Araki et al., physics/0509016
3. ERL Base Laser Compton
   ERL + Laser Stacking Cavity,
   and many stacking in DR (~1000 times)

Good! But we have to choose!

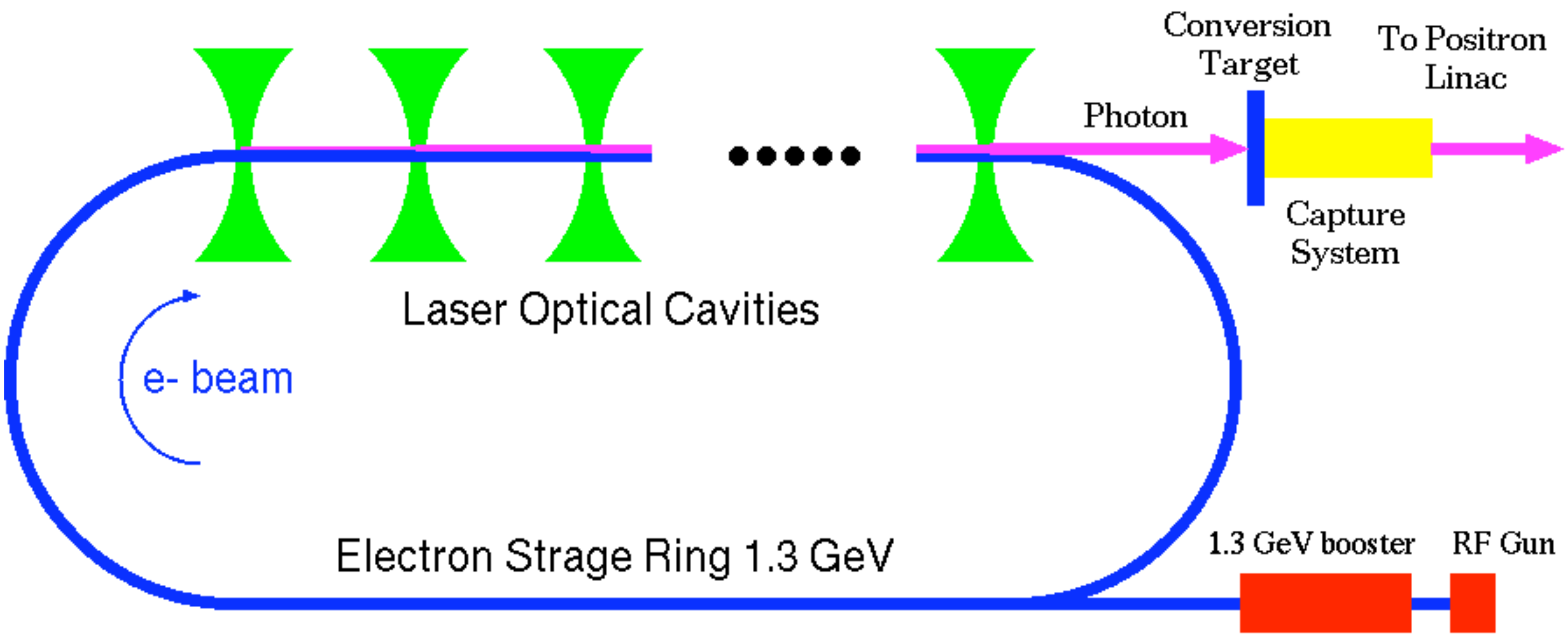
Linac Scheme

- Polarized γ-ray beam is generated in the Compton back scattering inside optical cavity of CO_2 laser beam and 4 GeV e-beam produced by linac.
  - **4GeV 15nC e- beam with 12 ns spacing.**
  - **10 CPs, which stores 10 J CO_2 laser pulse repeated by 83 Mhz cycle.**
- 5E+11 γ-ray -> 2E+10 e+ (2% conversion)
- 1.2μs pulse, which contains 100 bunches, are repeated by 150 Hz to generated 3000 bunches within 200ms.
- No stacking in DR

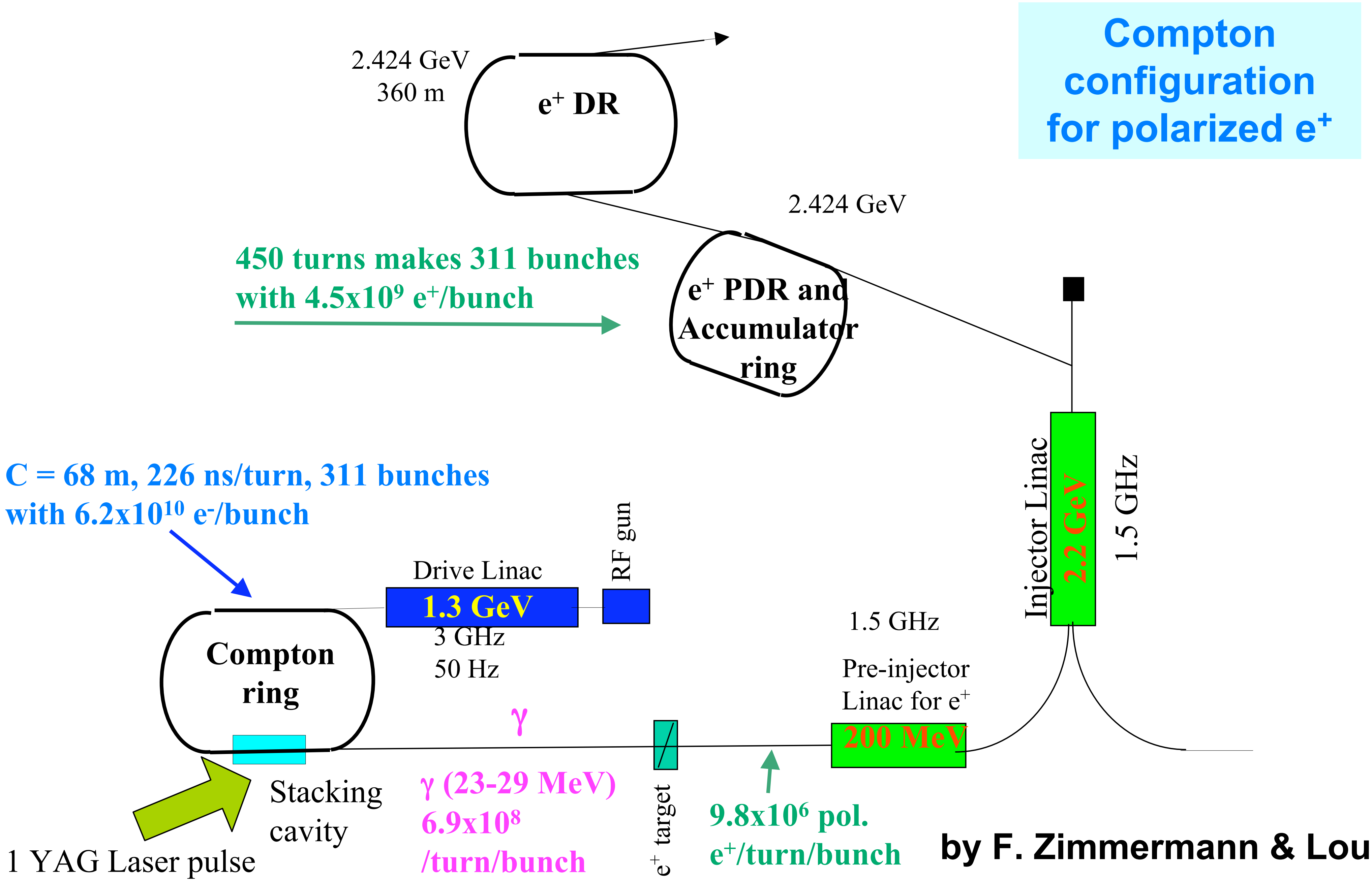


Compton Ring Scheme

- Compton scattering of e- beam stored in storage ring off laser stored in Optical Cavity.
- 15 nC 1.3 GeV electron bunches x 10 of 600mJ stored laser -> 1.7E+10 γ rays -> 2.4E+8 e+.
- By stacking 100 bunches on a same bucket in DR, 2.4E+10 e+/bunch is obtained.

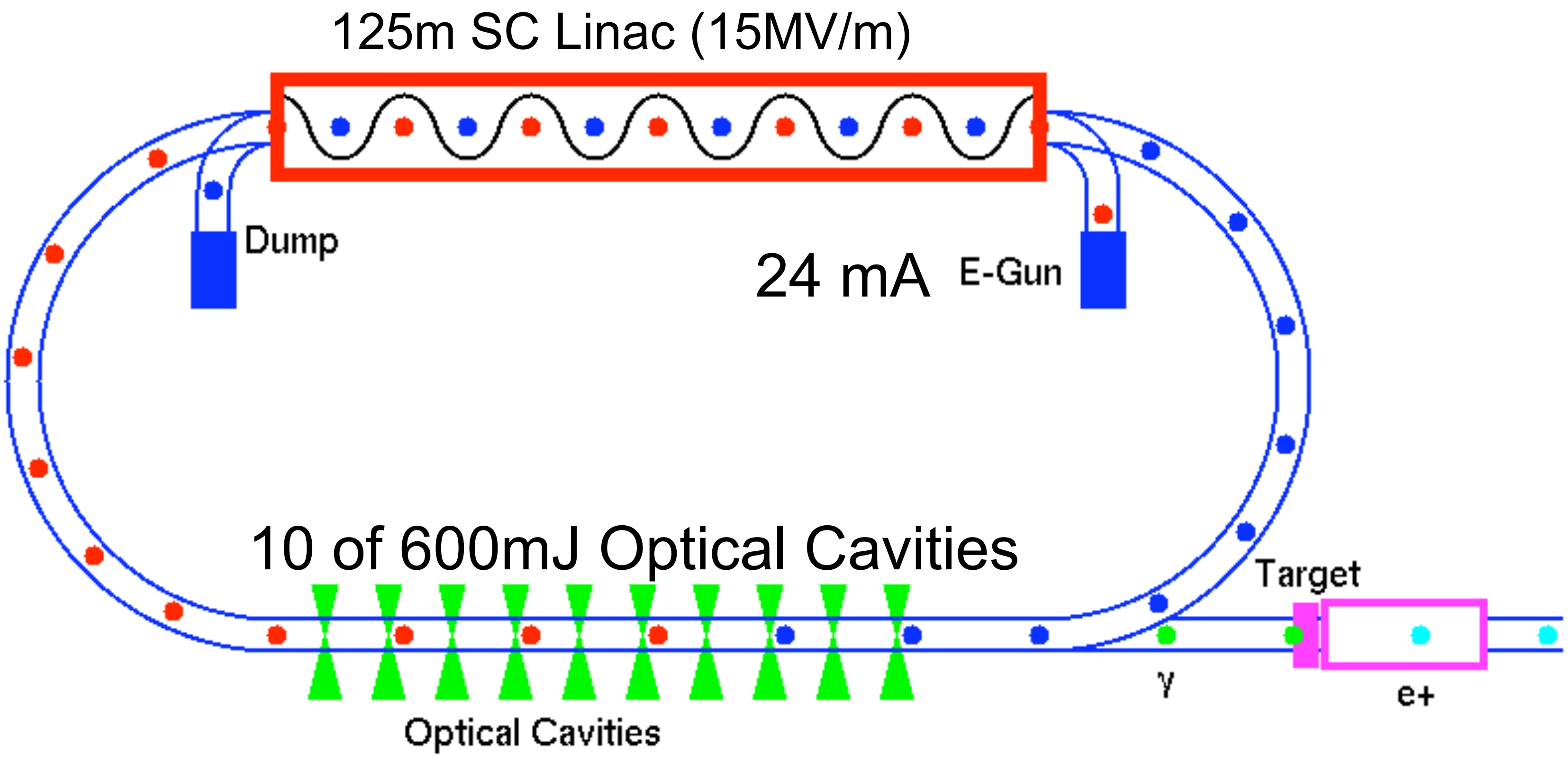


CLIC Scheme



by F. Zimmermann & Louis

ERL scheme = Linac scheme + Ring scheme



- Both advantages (high yield + high repetition) are compatible in ERL solution.
  - 0.64 nC 1.3 GeV bunches x 10 of 600 mJ laser, repeated by 40.8MHz -> 6.4E+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+.

R&D items

CR/ERL simulations studies (Kharkov, LAL, JAEA, KEK)

- design studies
- beam dynamics studies

Optical Cavity (LAL, Hiroshima, KEK)

- experimental R/D

e+ capture (LAL, ANL)

- We will start collaboration with KEKB upgrade study

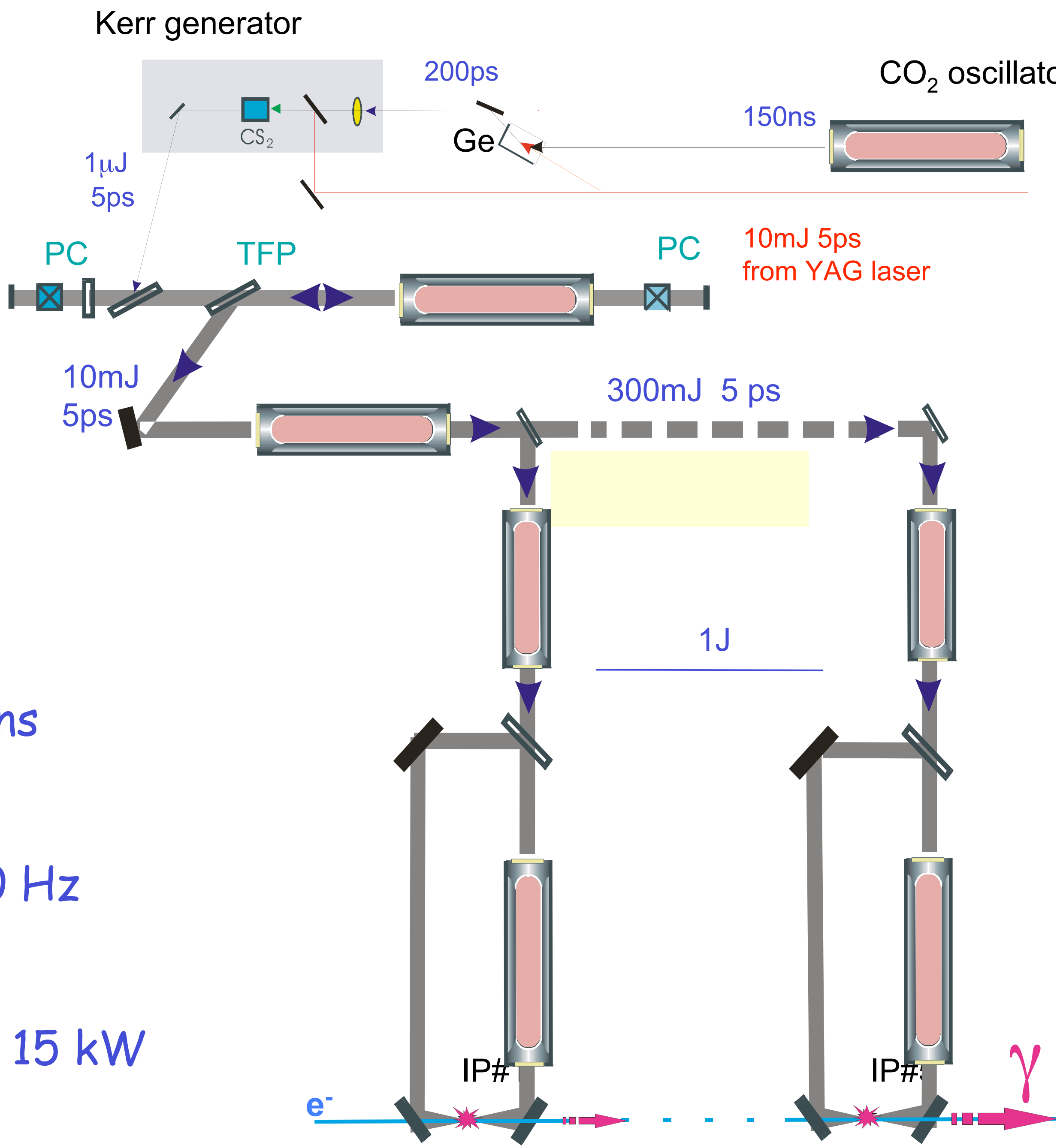
e+ stacking in DR (CERN)

- Basic beam dynamics studies

Laser

- Fiber laser / Mode-lock laser (cooperation with companies)
- CO_2 laser (BNL)

CO_2 Laser system for ILC



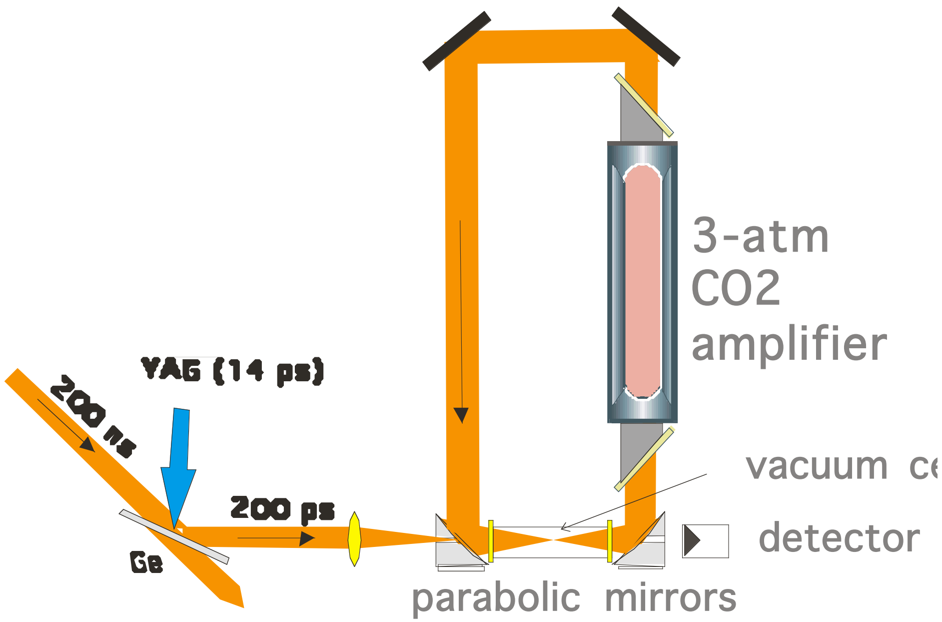
intra-cavity pulse circulation :

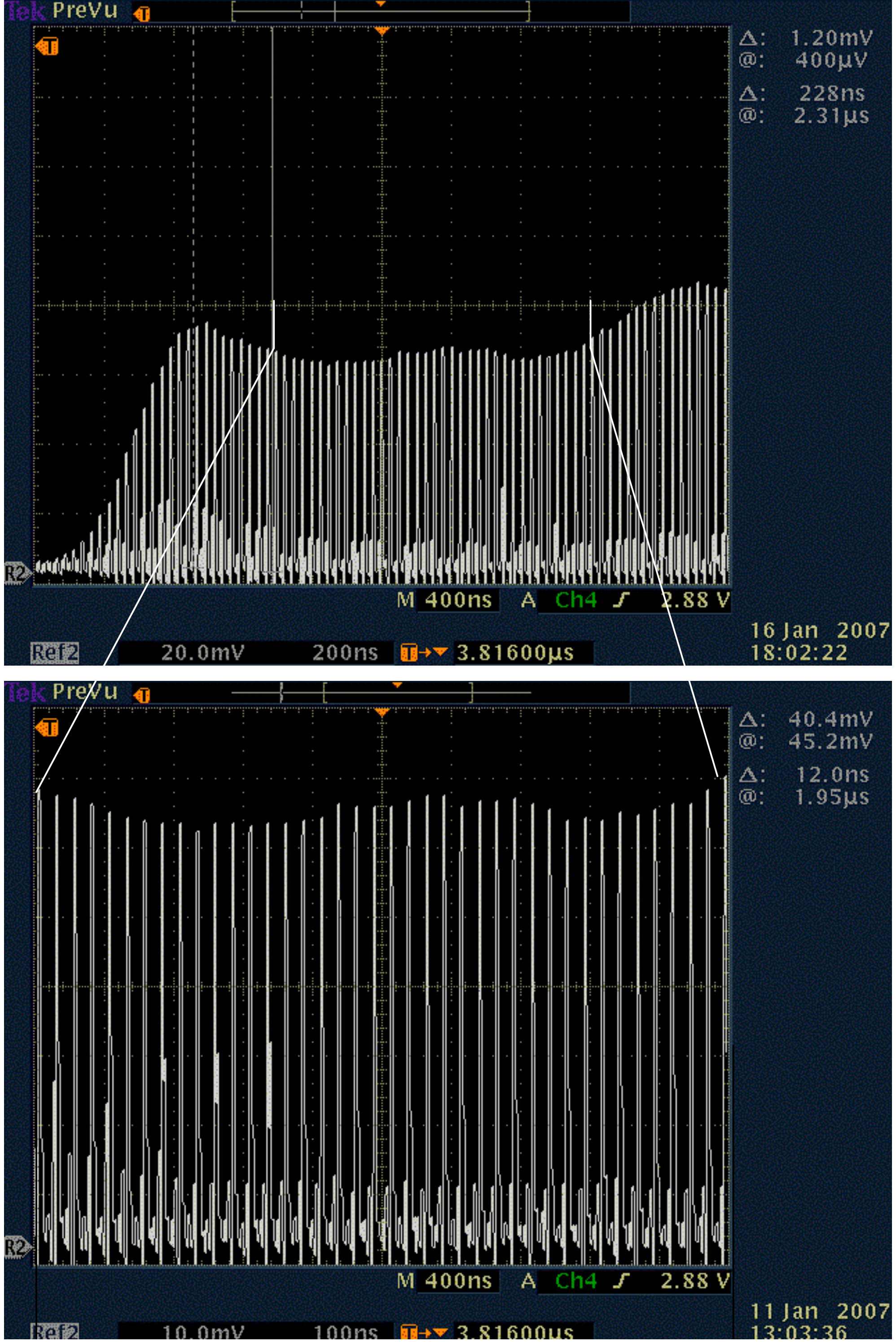
- pulse length 5 ps
- energy per pulse 1 J
- period inside pulse train 12 ns
- total train duration 1.2 μs
- pulses/train 100
- train repetition rate 150 Hz

- Cumulative rep. rate 15 kHz
- Cumulative average power 15 kW

See Yakimenko's talk tomorrow

Test setup



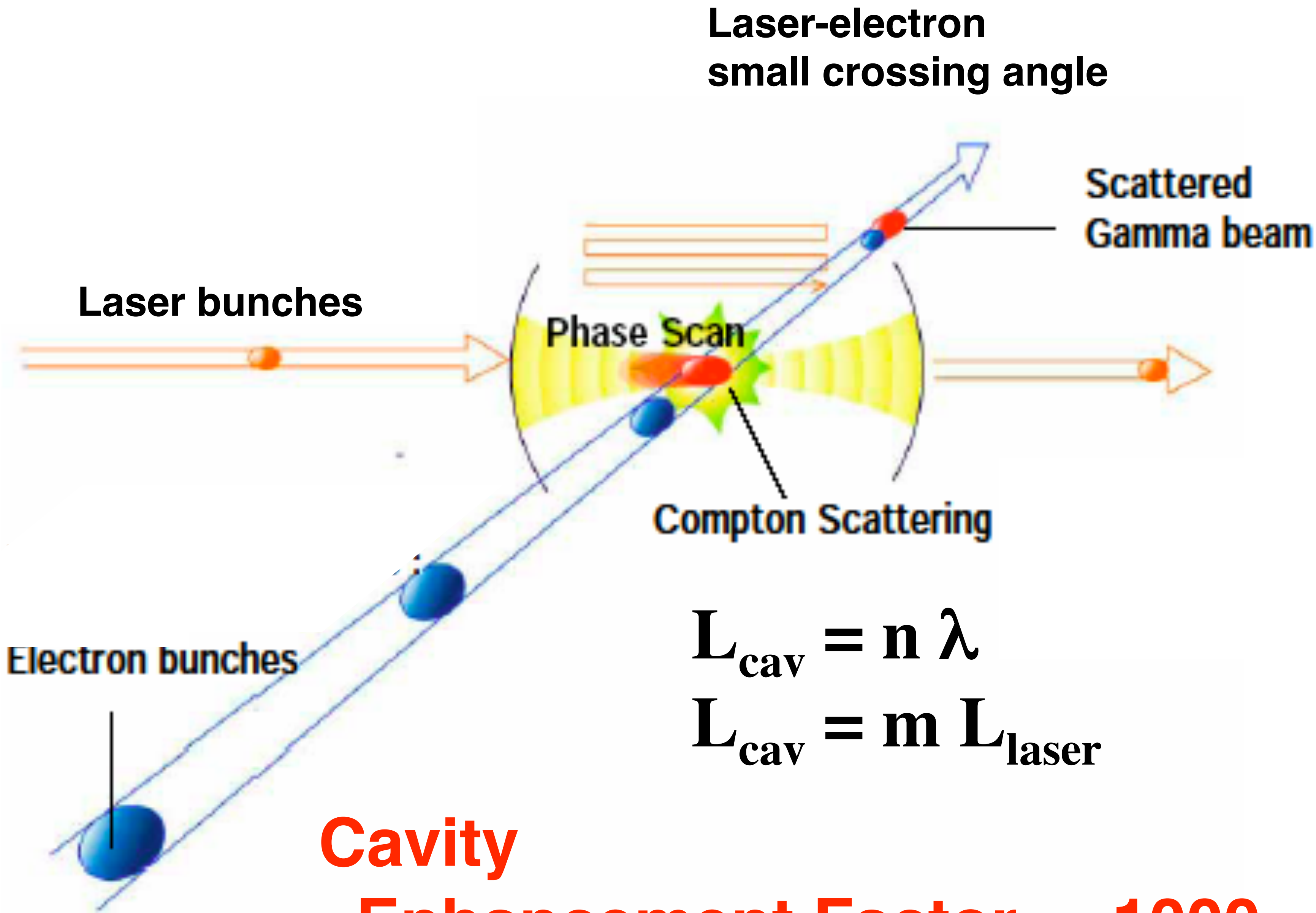


Observations:

- Optical gain over 4 μs
- Single seed pulse amplification continues to the end

See Yakimenko's talk tomorrow

Laser Pulse Stacking Cavity

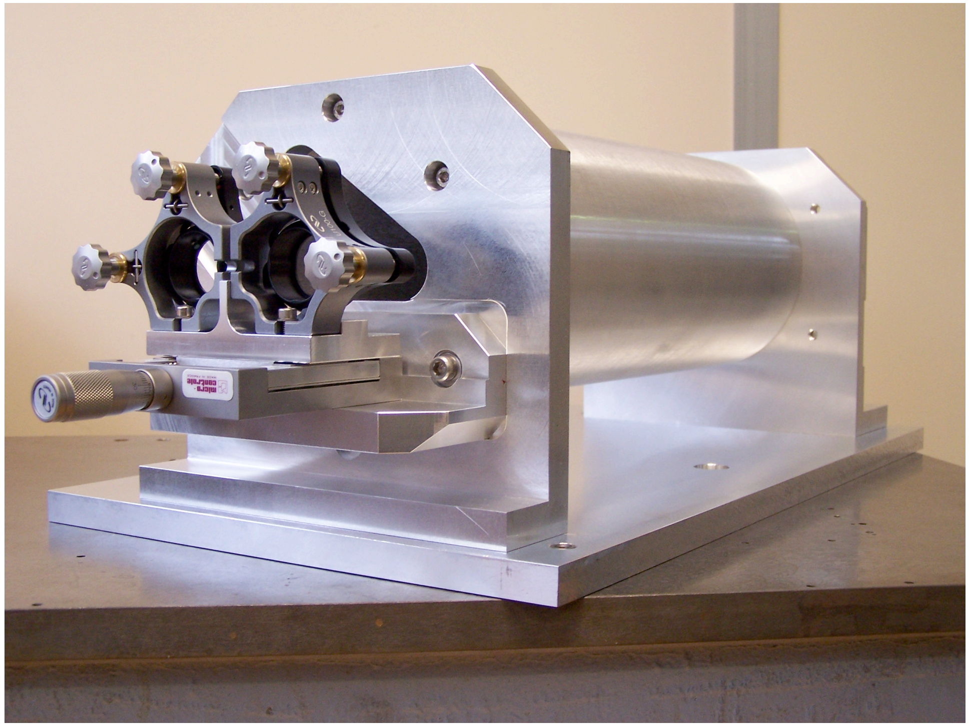


$$L_{cav} = n\,\lambda$$
$$L_{cav} = m\,L_{laser}$$

Cavity
Enhancement Factor = 1000 - 10^5

Prototype Cavities

4-mirror cavity (LAL)



high enhancement
very small spot size
complicated control

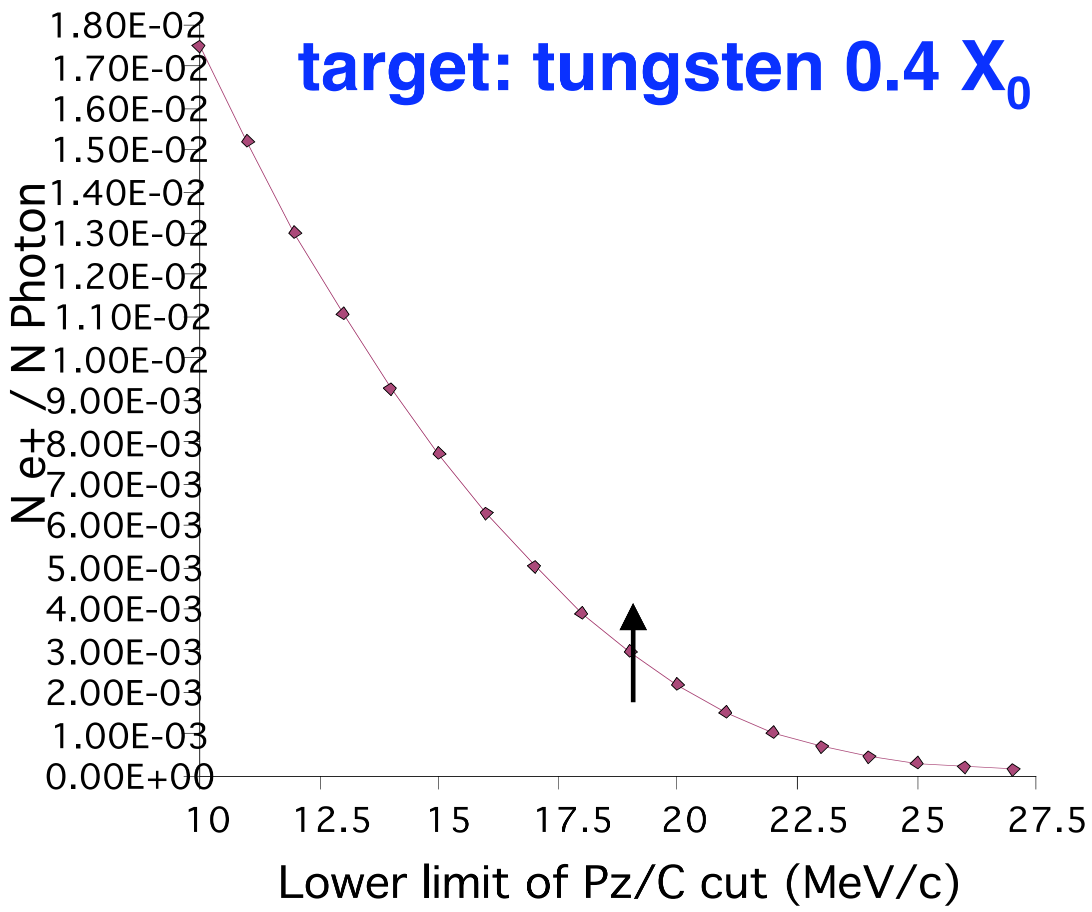
2-mirror cavity (Hiroshima/KEK)

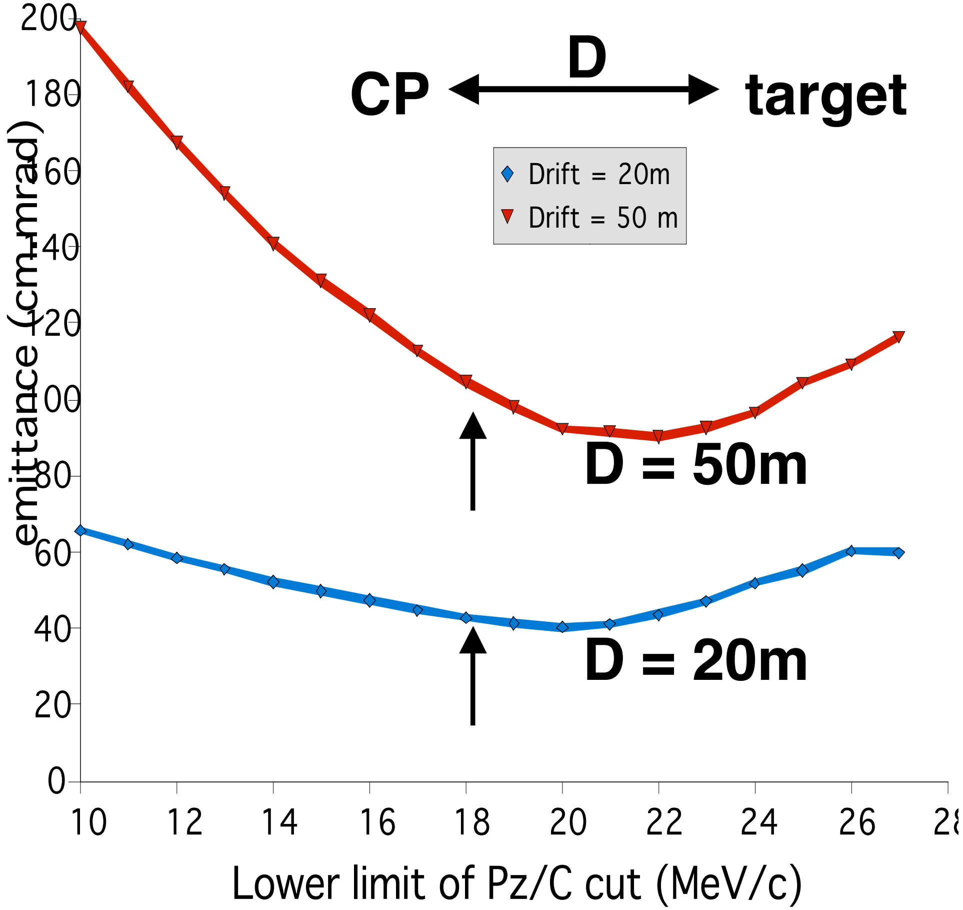
moderate enhancement
small spot size
simple control

See Omori's talk tomorrow

Capture simulation for ERL Compton

Preliminary study by Wanming & Wei (ANL)





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

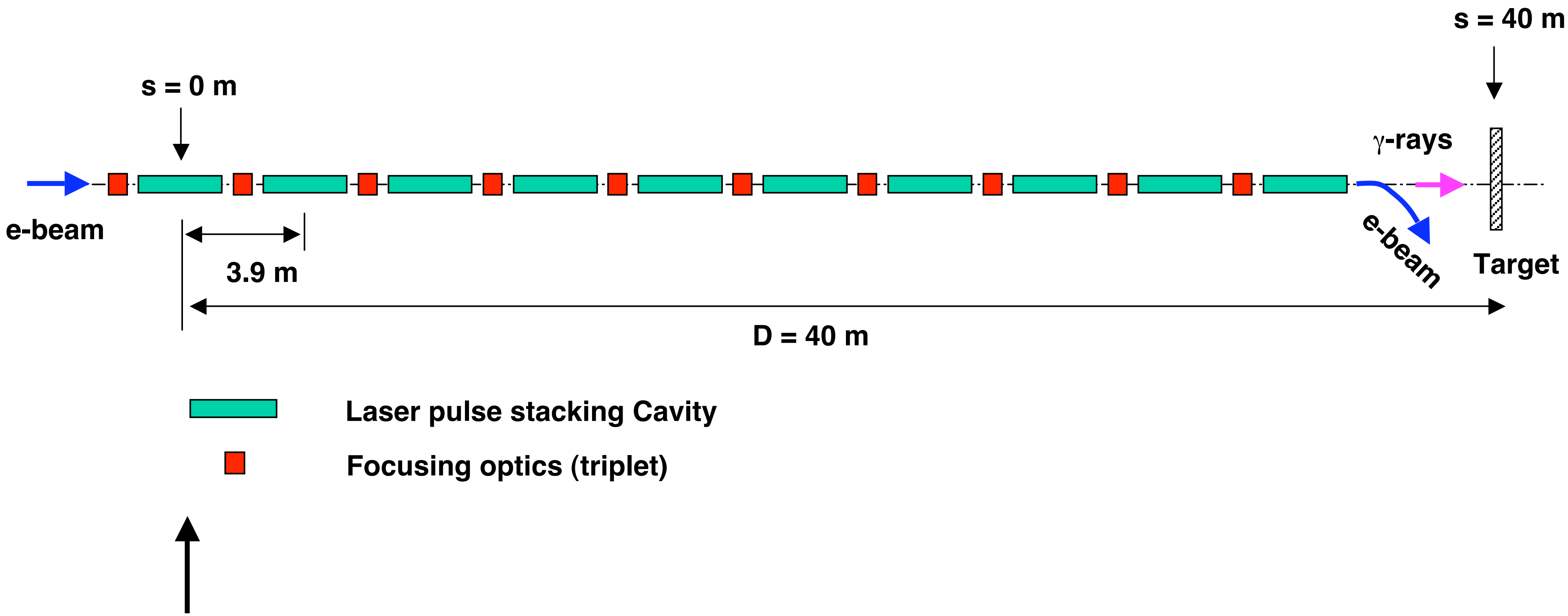
ε(geo) at target exit ~ 100 cm-mrad (D=50m)

~ 50 cm-mrad (D=20m)

Design Study of 10 collision points in ERL

Number of gamma-rays (relative)

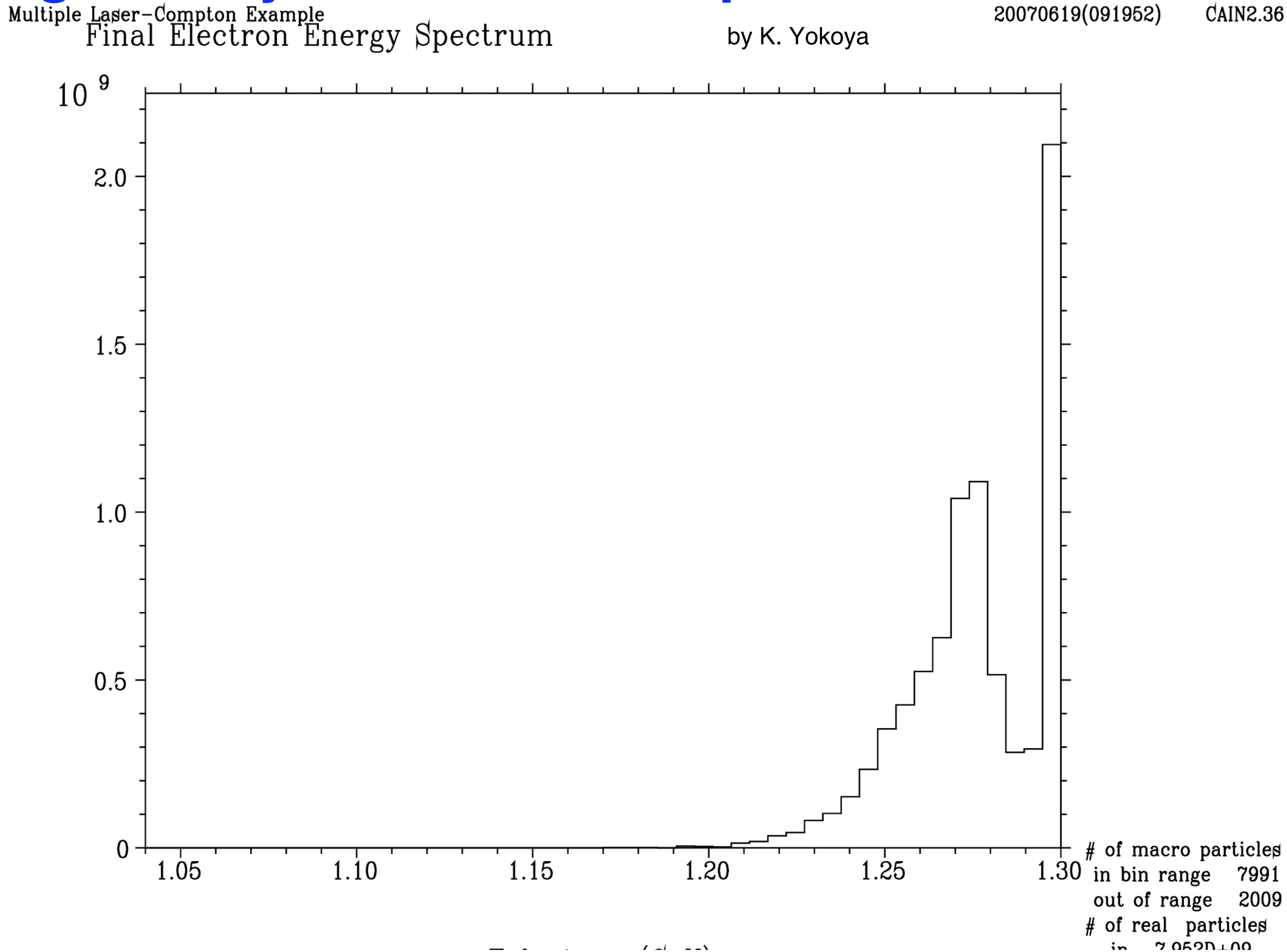
simulated using CAIN by T. Omori with help of K.Yokoya



Ng = 1 0.93 0.84 0.72 0.64 0.55 0.49 0.49 0.47 0.43

Ng sum of 10 Collision Points = 6.5 (10 was expected in naive assumption)

Design Study of 10 collision points in ERL



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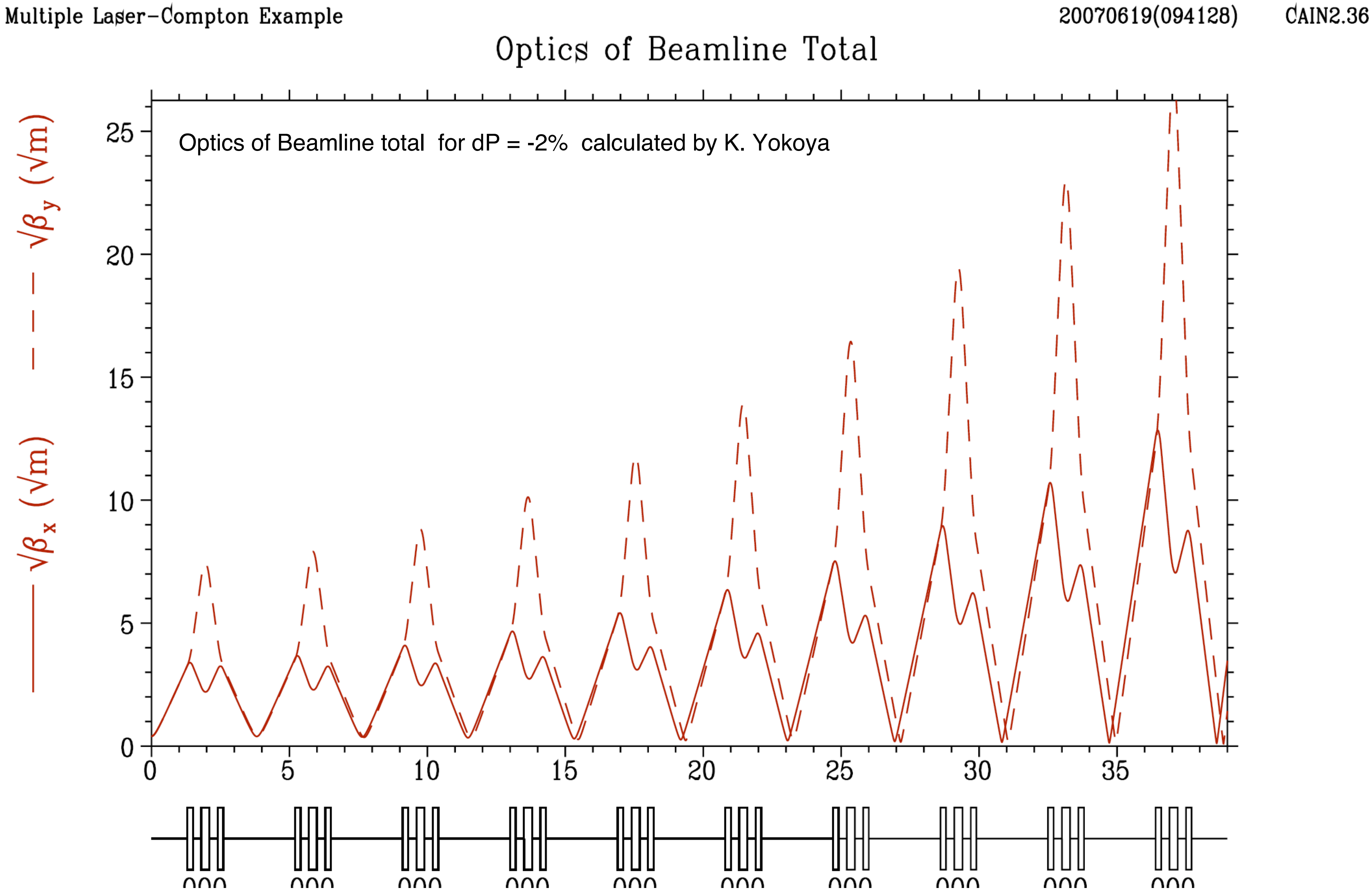
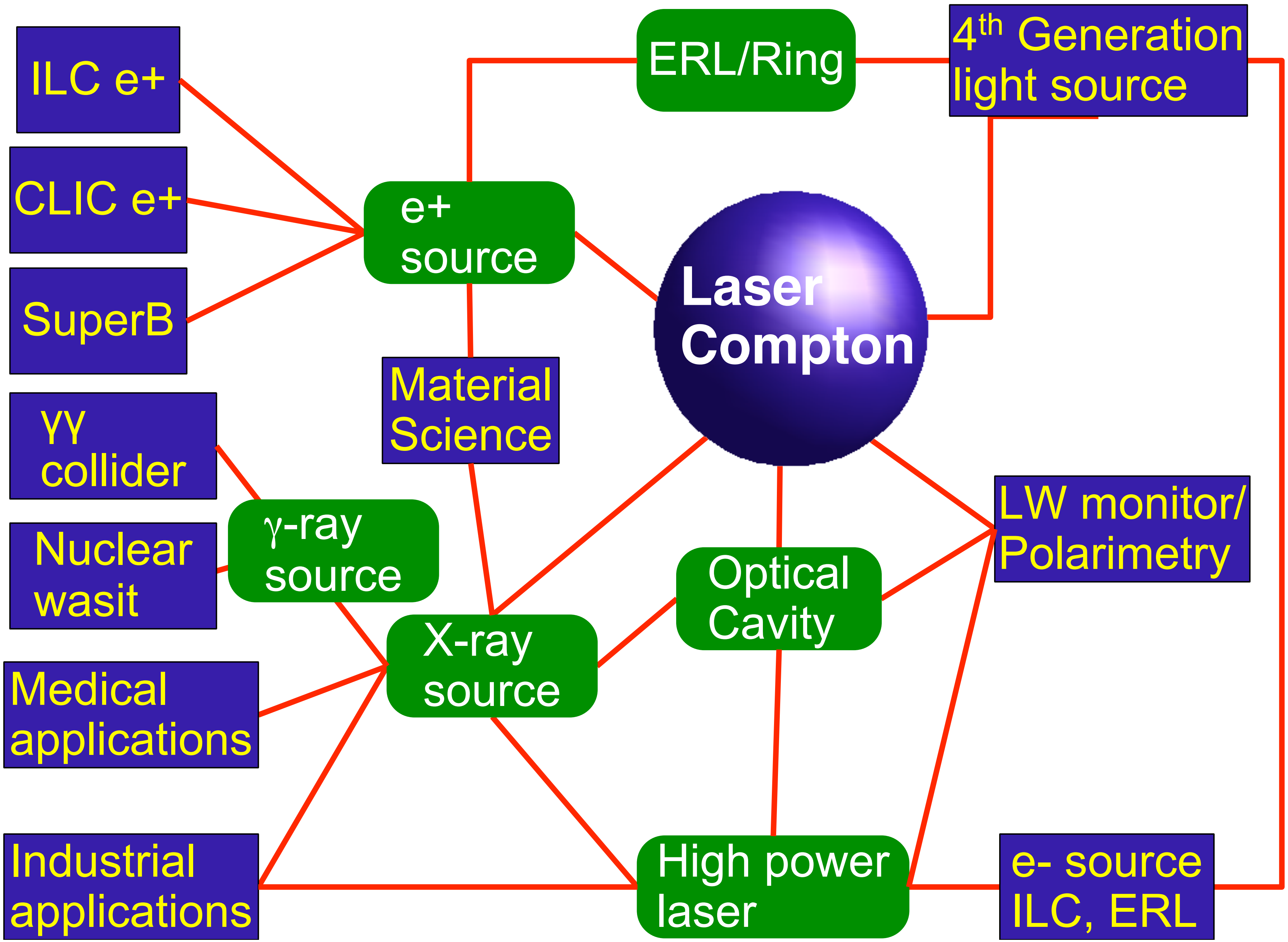


World-Wide-Web of Laser Compton



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 good quarity X-ray source for industrial and medical applications
   - γ-ray source for disposal of nuclear wastes
   - Beam diagnostics with Laser
   - Polarized Positron Generation for ILC and CLIC
   - $\gamma\gamma$ collider
3. State-of-the-art technologies are quickly evolved with world-wide synergy.
   - Optical Cavity,
   - Laser,
   - ERL

Summary

1. Laser Compton ILC e+ source is an attractive alternative

   Independent system

   high polarization

   5 Hz polarization flip

   Operability

   wide applications

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   - Many studies are on going (see tomorrows's talks)
   - Not only for ILC e^+ source.
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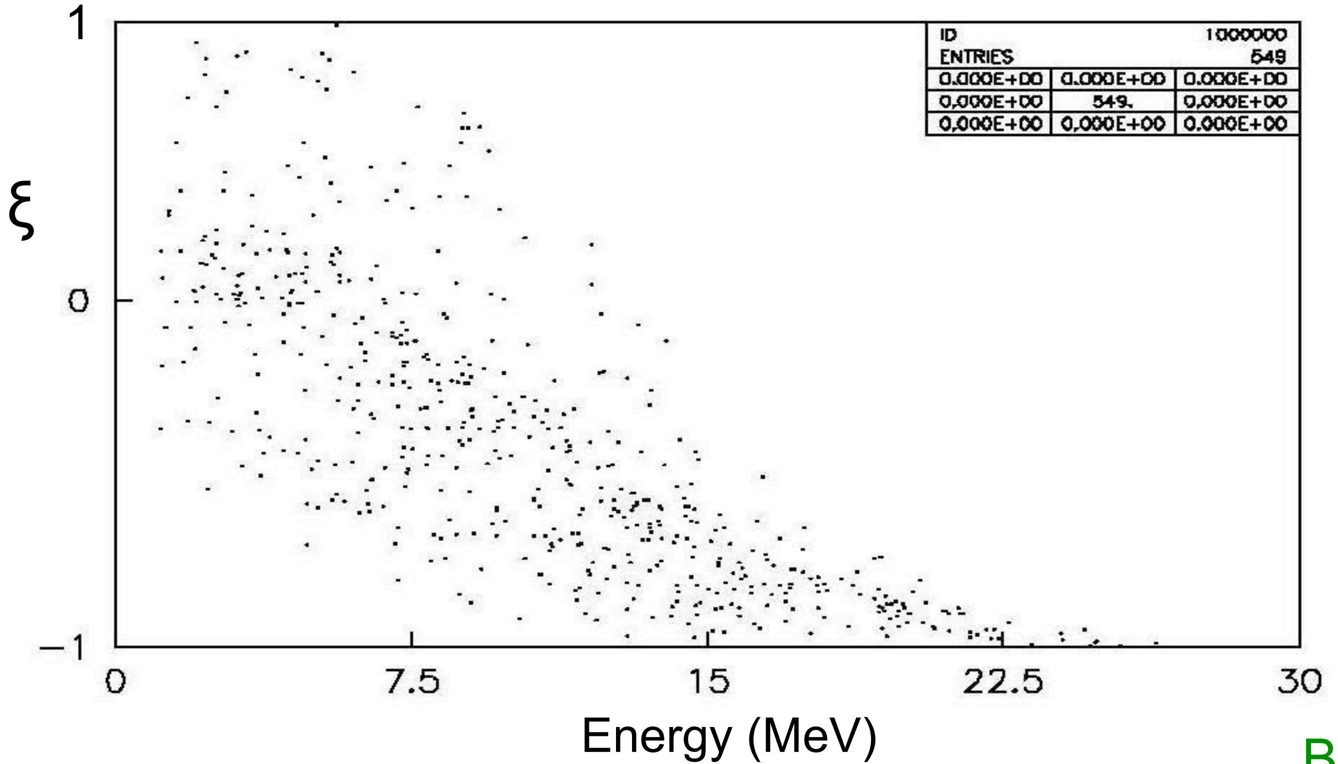
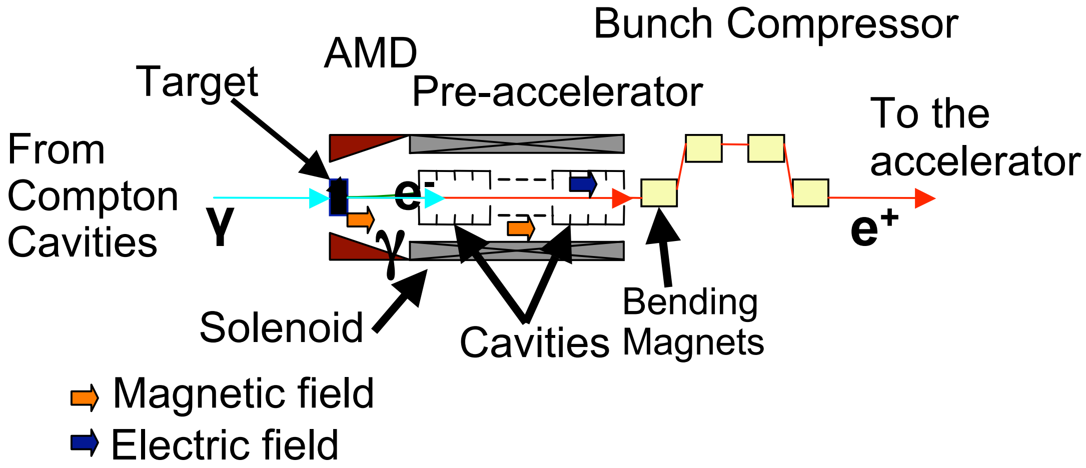
4. Compton-Undulator collaboration
   - in ILC e^+ source: capture section
   - in Attracting many researchers: X-ray source (for example)

Backup Slides

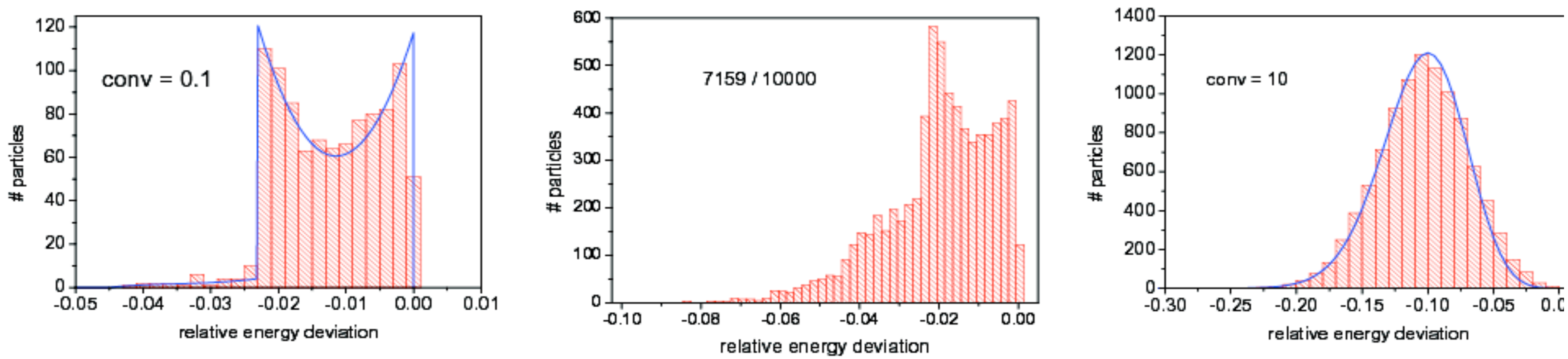
Capture and Transmission



By. A. Vivoli



Recoiled Spectra



Linac (undulator) Increase of the energy spread by
$\Delta E_e \approx \sqrt{x} \times \langle E_\gamma \rangle = 170\,\mathrm{MeV}$
(if scattered gammas are uncorrelated)

Ring The ring must comprise spread up to
$\frac{\Delta E_e}{E_e} \approx \sqrt{\frac{7E_{\mathrm{laser}}\gamma}{10E_0}} \approx 6\,\%$

ERL Recovery of the energy from
a beam with the large spread
should be a challenging problem.

By E. Bulyak (Kharkov)

Optical Cavity R&Ds

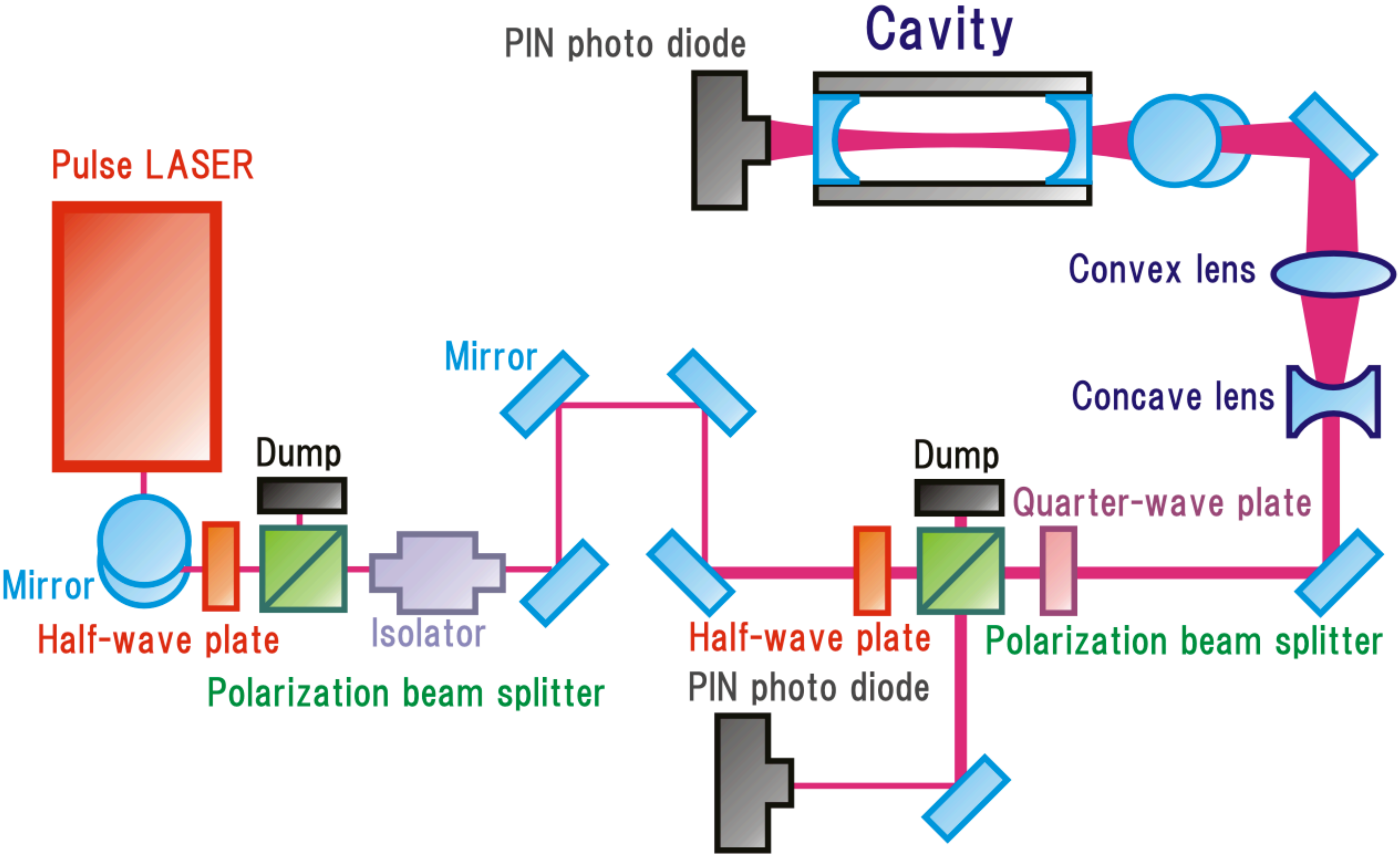
- KEK-ATF and LAL advance experiments with external cavity to stack laser beam.
- Goal is to achieve high enhancement & small laser spot size.
  - LAL cavity has theoretically high enhancement, but needs more complicated control.
  - KEK cavity has less enhancement, but its control is simpler.

Optical Cavity History at KEK-ATF

By H. Shimizu

	What we want ILC YAG laser case	What we will at KEK-ATF	What we did (Takezawa, 2004)
Electron Energy (GeV)	1.3	1.3	1.3
Ne/bunch	6.2E10	2.0E10	1.0E10
Electron repetition rate (MHz)	325	357	357
Hor. Beam size (rms,us)	25	79	79
Ver. Beam size (rms,us)	5	6	6
Bunch length (rms,mm)	5	9	9
Laser type (wavelength)	YAG(1064nm)	YAG(1064nm)	YAG(1064nm)
Laser frequency (MHz)	325	357	357
Laser radius (rms, um)	5	29	125
Laser pulse width (rms,mm)	0.9	0.9	0.9
Laser pulse power /cavity	750uJ x 1000	28nJ(10W) x 1000	1nJ(0.3W) x 65
Number of laser cavities	30	1	1
Crossing angle (degree)	8	10	90

Pulse Mode Setup



Yb Fibre Laser

- Double clad-core optical fiber.
- InGaAs LD (940nm) is for pumping.
- Typical core size is 6 - 40 μm.

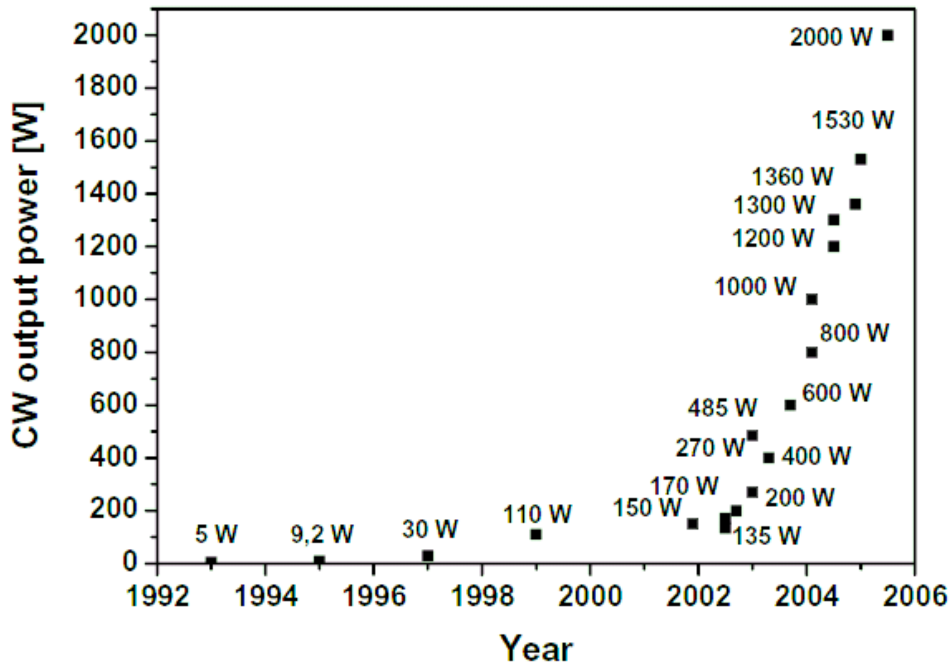
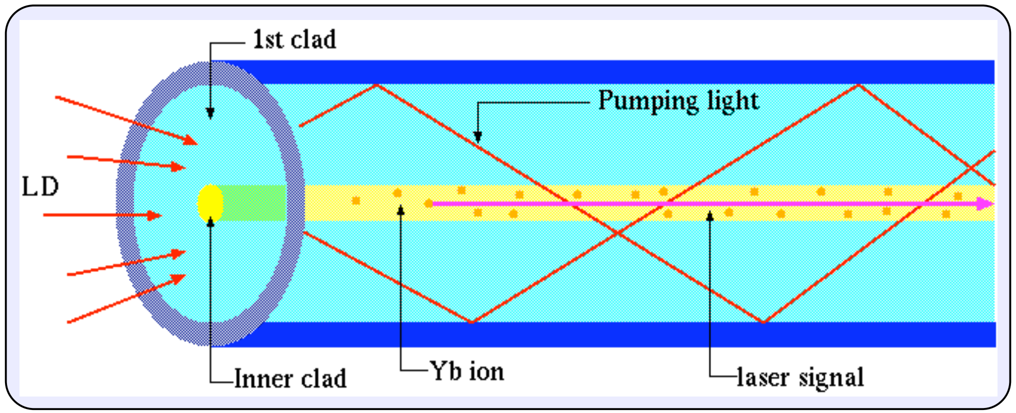
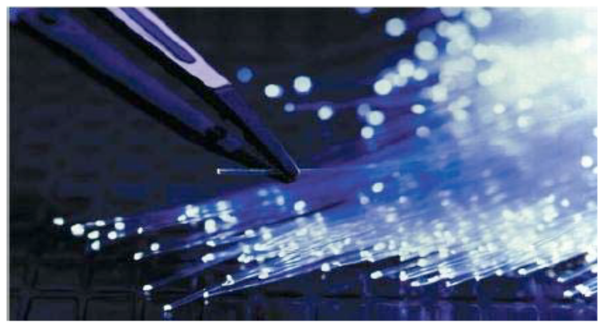


Fig. 4: Power evolution of cw double-clad fiber lasers with diffraction-limited beam quality over the last decade

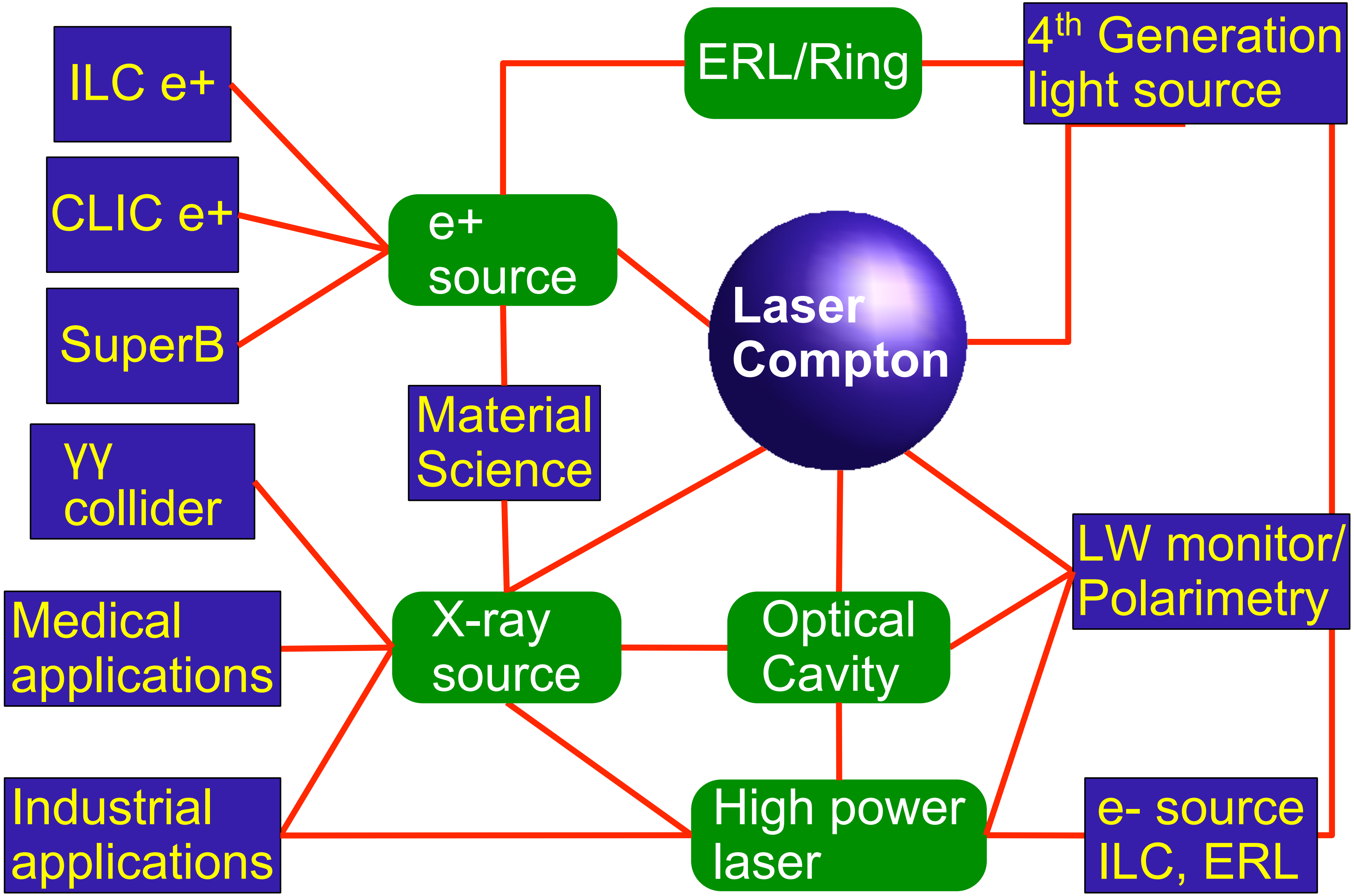
J. Limpert,T. Schreiber, and A. Tünnermann, " Fiber based high power laser systems"





By M. Hanna

World-Wide-Web of Laser Compton



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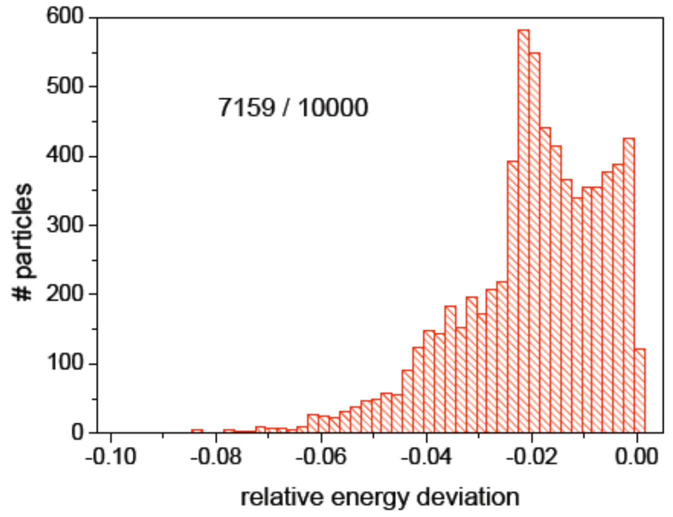
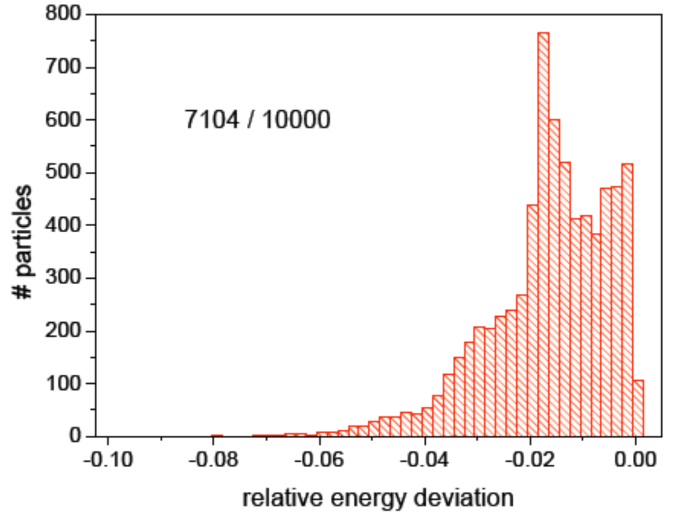
ERL Gammas' Energy 30 MeV vs. 20 MeV





ERL Recoil Spectra

30 1.30 GeV, Recoil 26 ± 18 MeV

20 1.06 GeV, Recoil 17 ± 12 MeV

Recoils shrink quadratically

Ring Gammas' Energy 30 MeV vs. 20 MeV

CLIC YAG Rings

Beam energy (GeV)	1.06	1.301
Max gammas energy (MeV)	20	30
Cycle (turns)	2546/14888	2546/14888
Max $C(e^- \to \gamma)$ /pass	0.1	0.1
Yield (gammas/cycle)	112	85
Particle losses /cycle	0	1.5 %

Provide more realistic gamma data --> 10 collision points

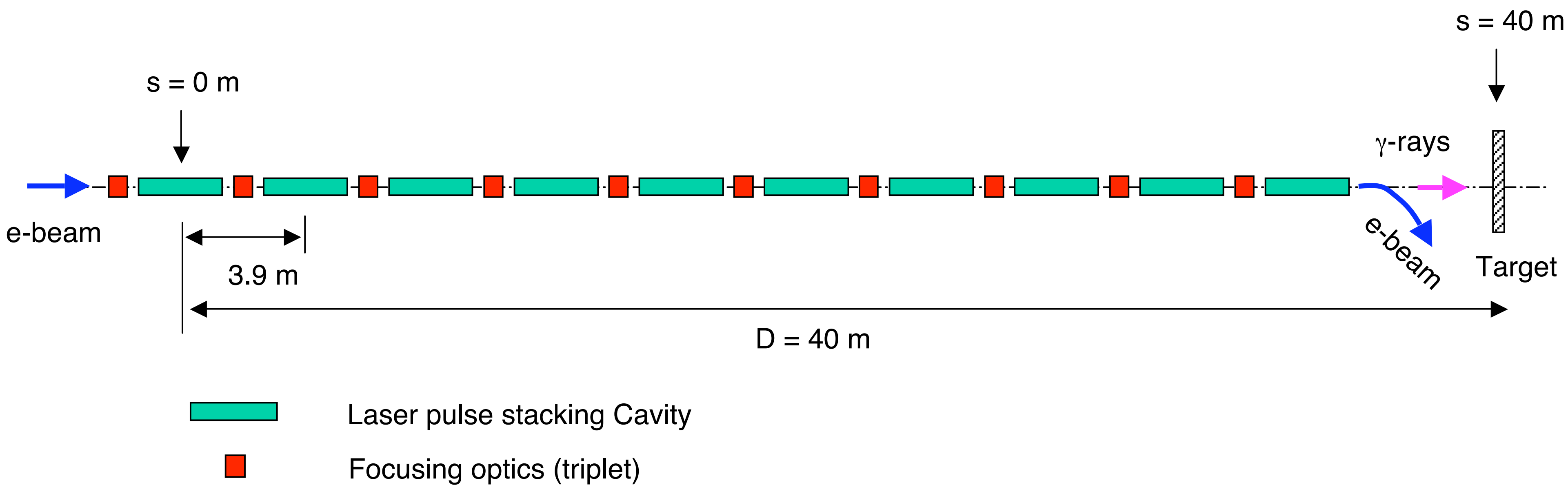
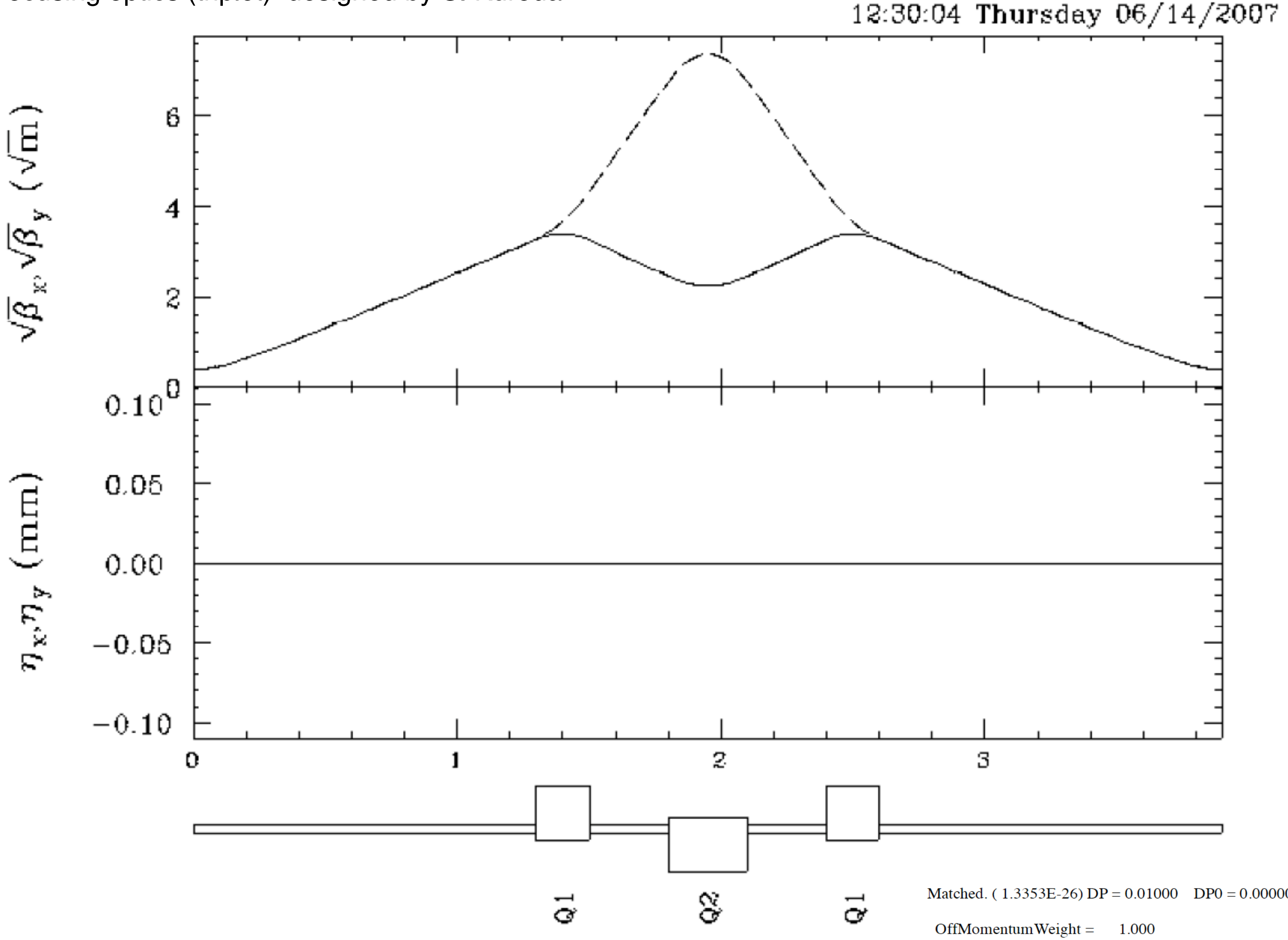


Table of the beam parameters.

```
  Electron beam
     Ne/bunch                =  1x10^{10}
     beta_horizontal         =  0.16 m
     beta_vertical           =  0.16 m
     emittance_horizontal =  6.25x10^{-10}
     emittance_vertical    =  6.25x10^{-10}
     sigma_horizontal       =  10 micron (in the first collision point)
     sigma_vertical          =  10 micron (in the first collision point)
     sigma_longitudinal    =  0.2 mm

  Laser beam (for each collision point)
     Energy in a pulse     = 0.6 J
     sigma_rateral           = 5 micron
     sigma_longitudinal    = 0.24 mm
```

Focusing optics (triplet) designed by S. Kuroda



;

QUAD Q1 =(L =.2 K1 =1.5395571461291)

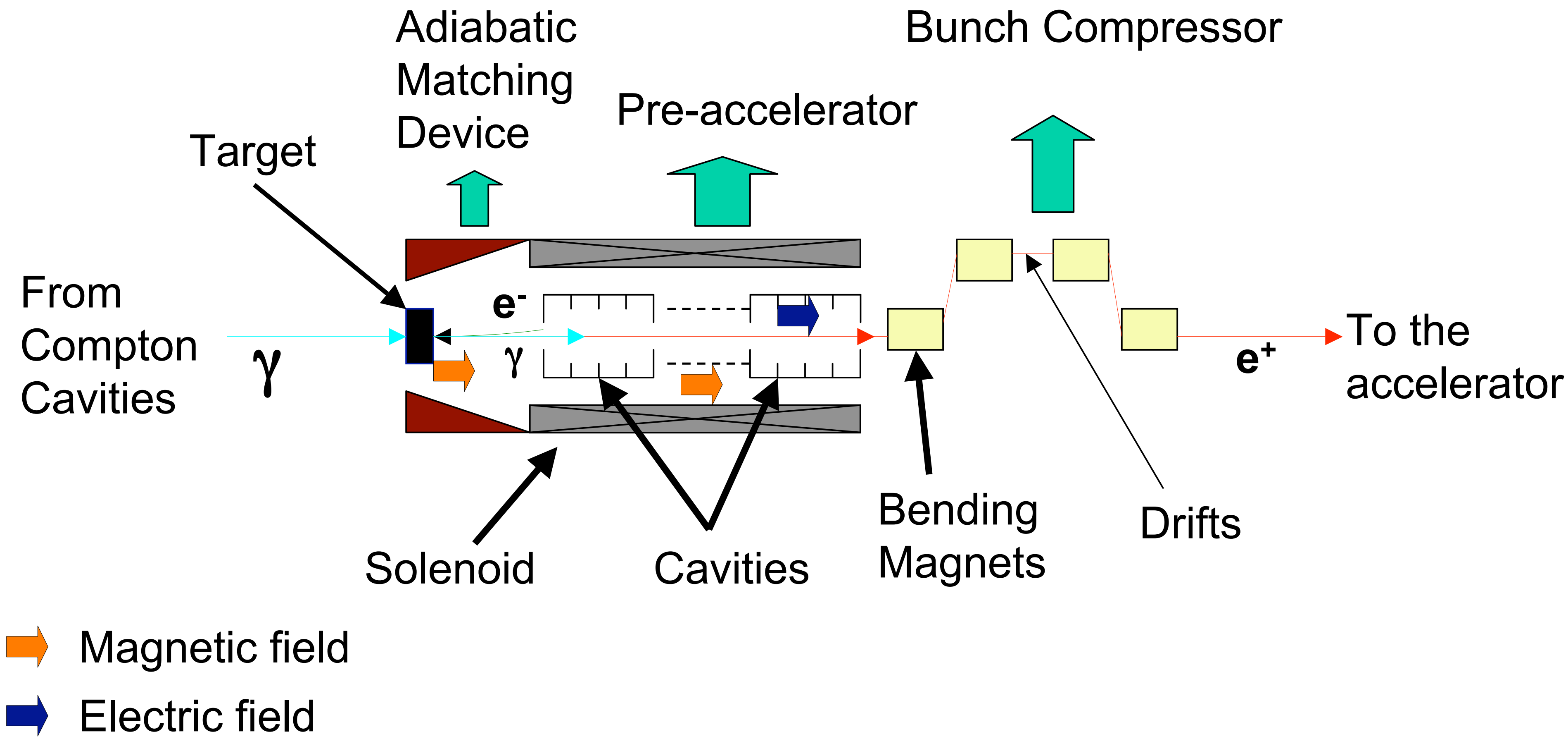
```
Matched. ( 1.3353E-26) DP = 0.01000    DP0 = 0.00000    ExponentOfResidual = 2.0
 OffMomentumWeight =      1.000
IP          f BX    .16         1      .160000 IP          f BY    .16         1      .160000
$$$          AX     #######   #   3.831E-15 $$$          BX     #######   #     .16000
$$$          NX     #######   #     .487506 $$$          AY     #######   #   2.872E-14
$$$          BY     #######   #     .160000 $$$          NY     #######   #     .46995
```

Gamma Data

Data was sent to Wanming-san (ANL)

Data will be sent to Vivoli-san (LAL)

Capture Section (+ B.C.)



Pre-accelerator

Solenoid

- Magnetic Field = 0.5 T
- Length = ~ 31 m

Accelerating Cavities:

- Length = 1.25 m
- Aperture = 2.3 cm
- Average accelerating Field = ~ 7 MV/m
- Number of cavities = 22

Drift length between cavities = 13 cm