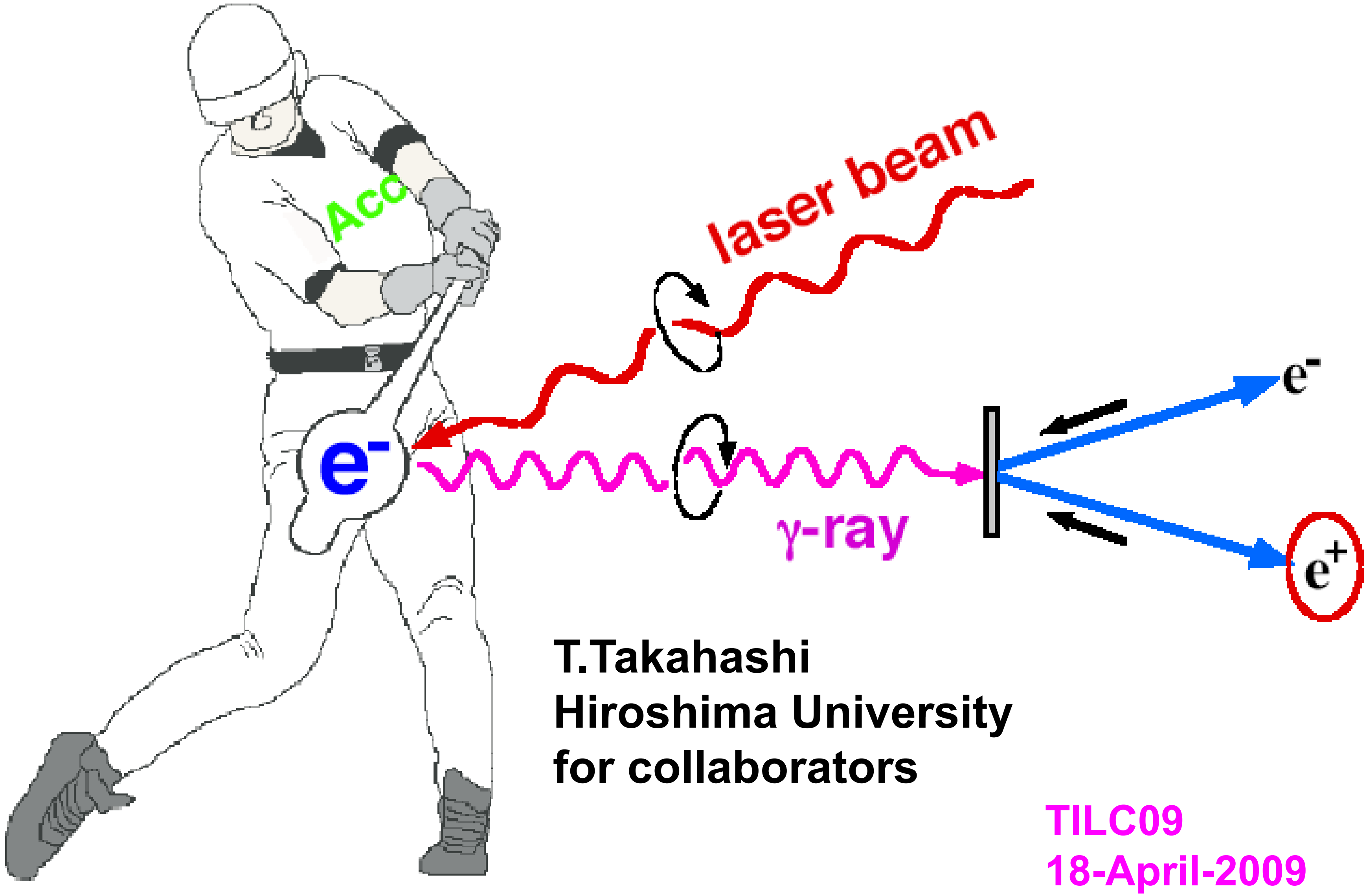
Status of the Compton Experiment at the ATF



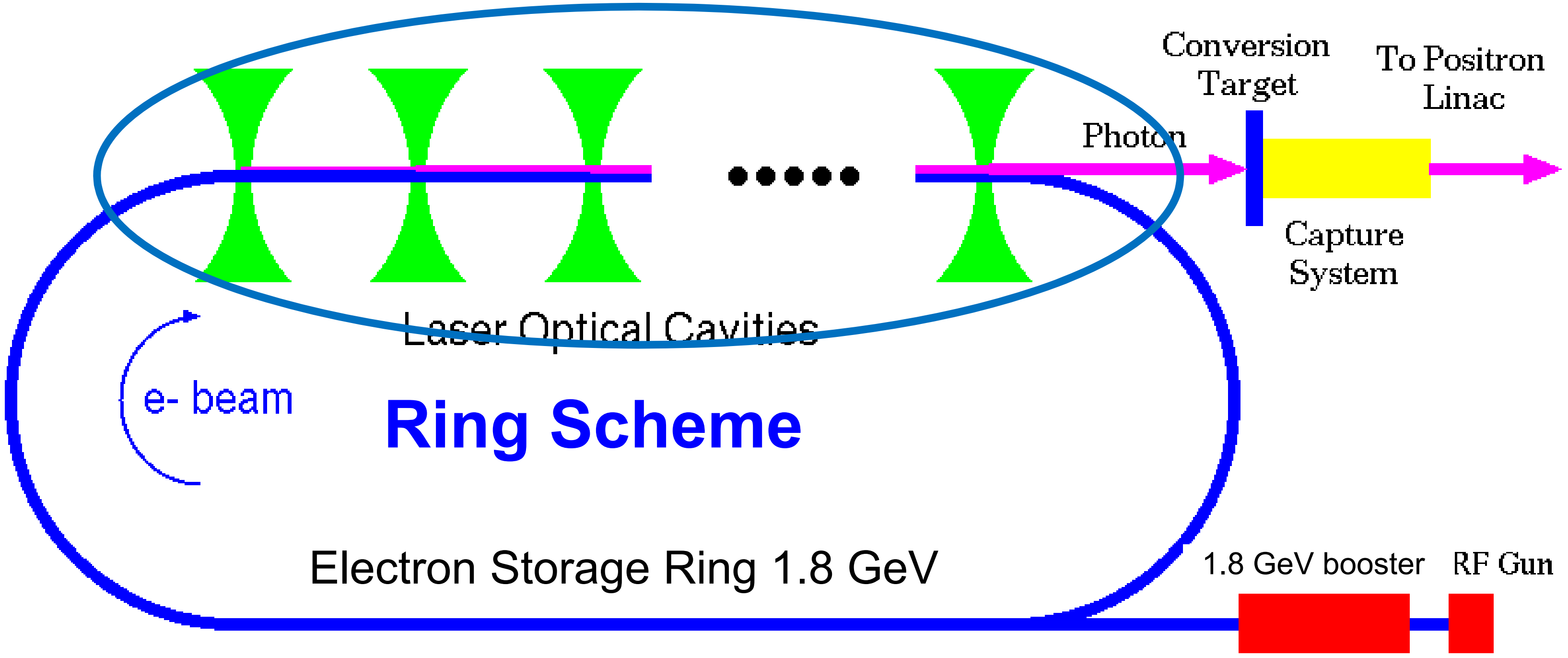
T.Takahashi
Hiroshima University
for collaborators

TILC09
18-April-2009

The Ring/ERL Compton Scheme

Pulse Stacking Cavity

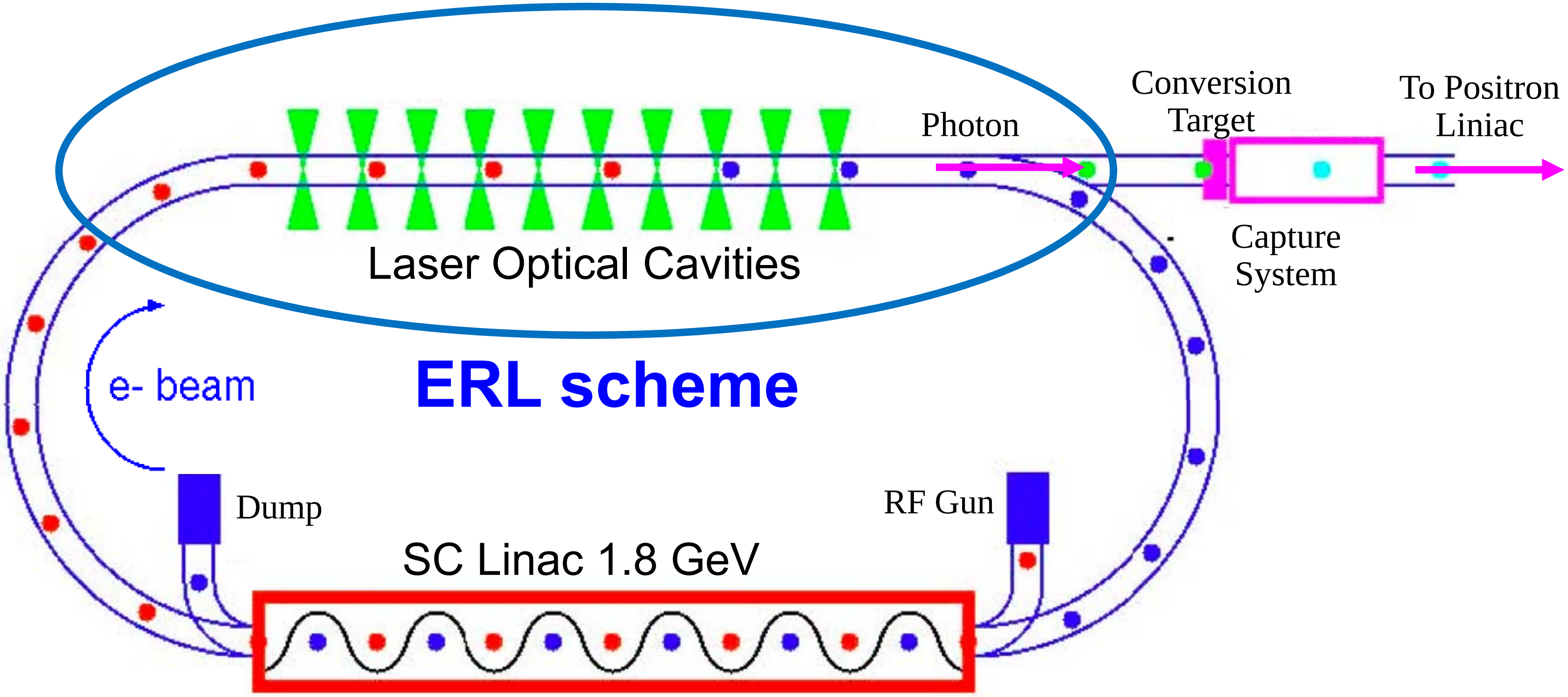
Each has 600mJ/pulse



The Ring/ERL Compton Scheme

Pulse Stacking Cavity

Each has 600mJ/pulse



Ring / ERL scheme R&D List

e+ stacking in DR
- **simulation studies**

Compton Ring simulation studies

ERL simulation studies

e+ capture (common in all e+ sources)
- **Simulation study**
- **Collaboration with KEKB upgrade**

e+ production target

Laser
- **Fiber laser / Mode-lock laser**

Laser Stacking Cavity
- **experimental and theoretical studies**

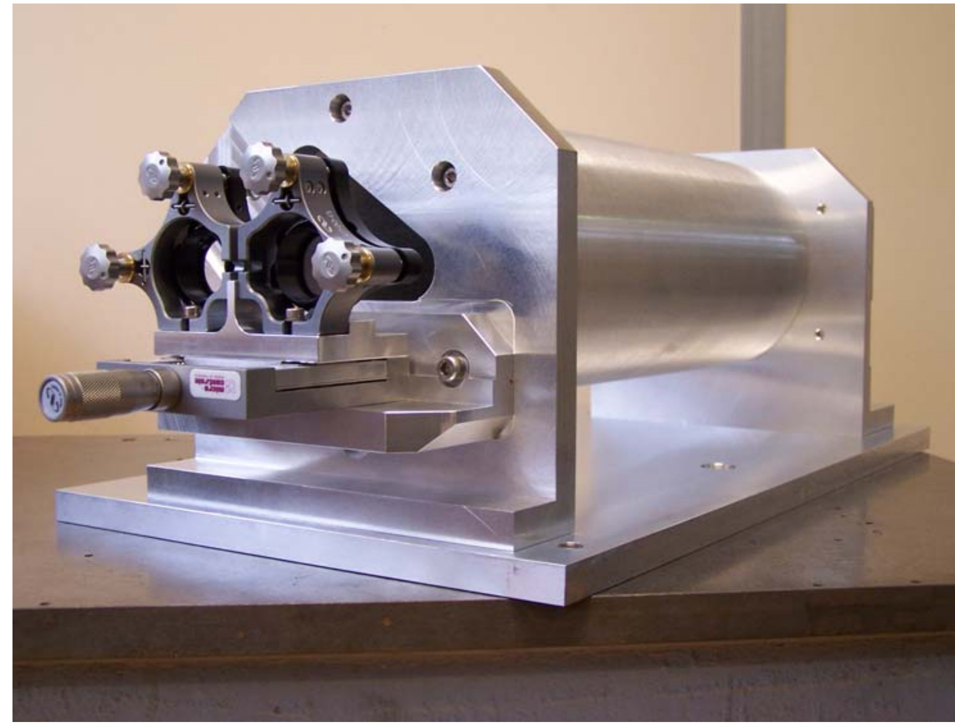
reduction of laser power by 0.6/enhasement

Prototype Cavities

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

moderate enhancement
moderate spot size
simple control

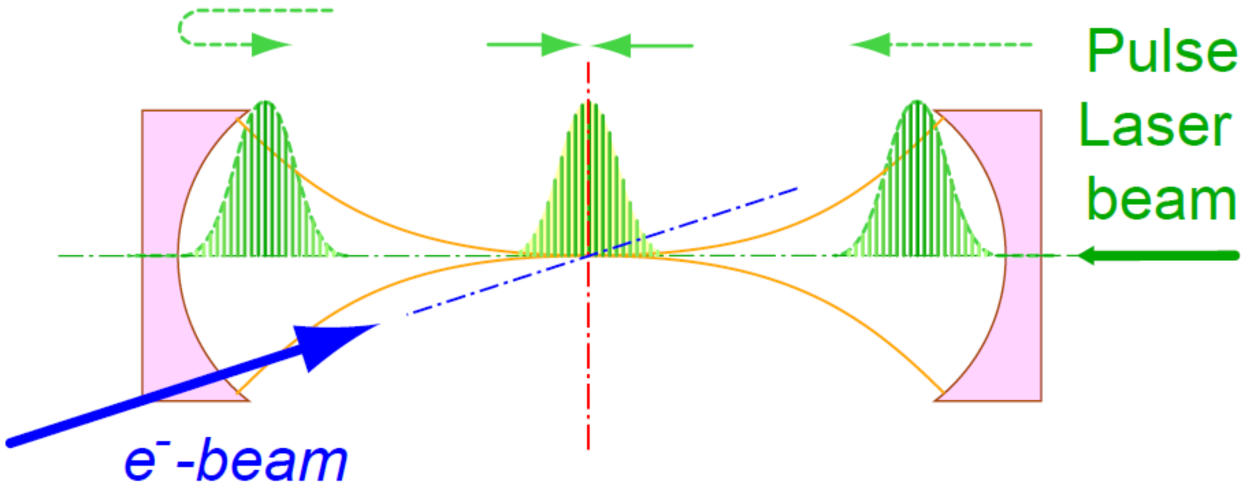
4-mirror cavity (LAL)



high enhancement
small spot size
complicated control

Experimental R/D in ATF

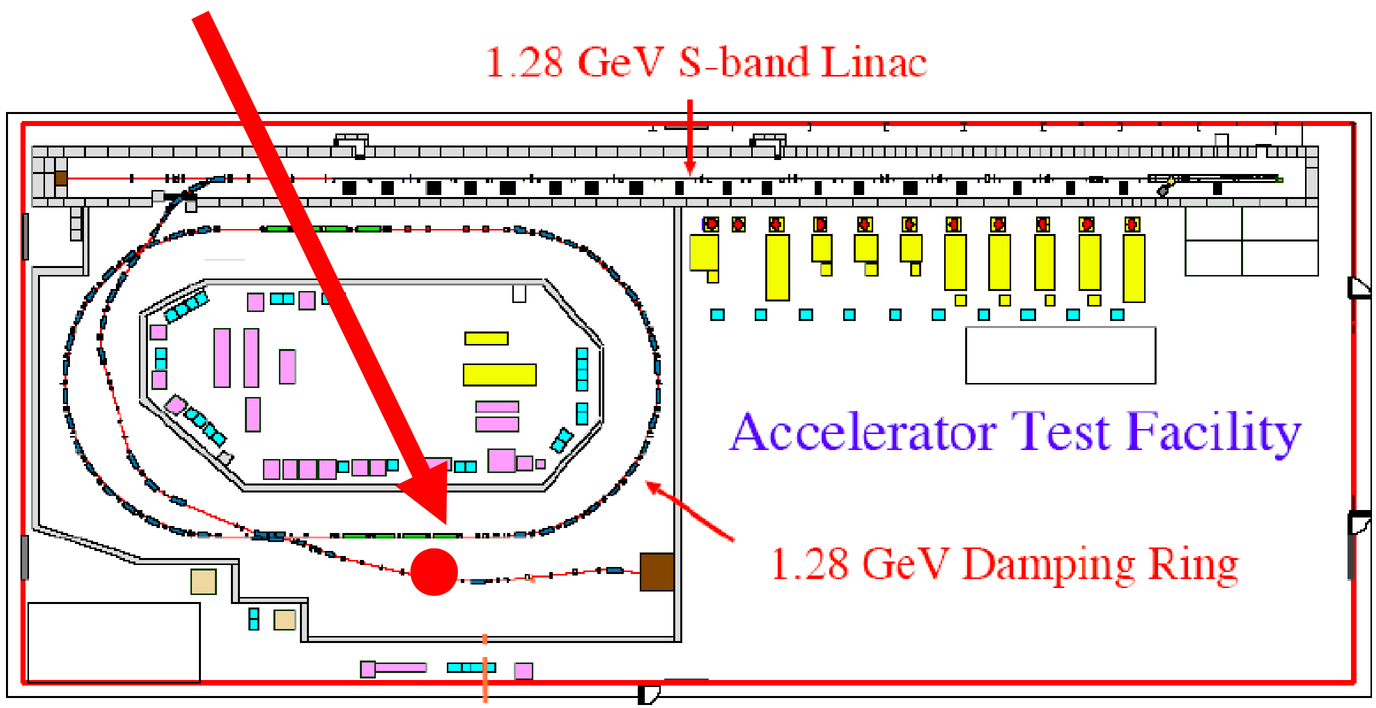
Hiroshima-Waseda-Kyoto-IHEP-KEK



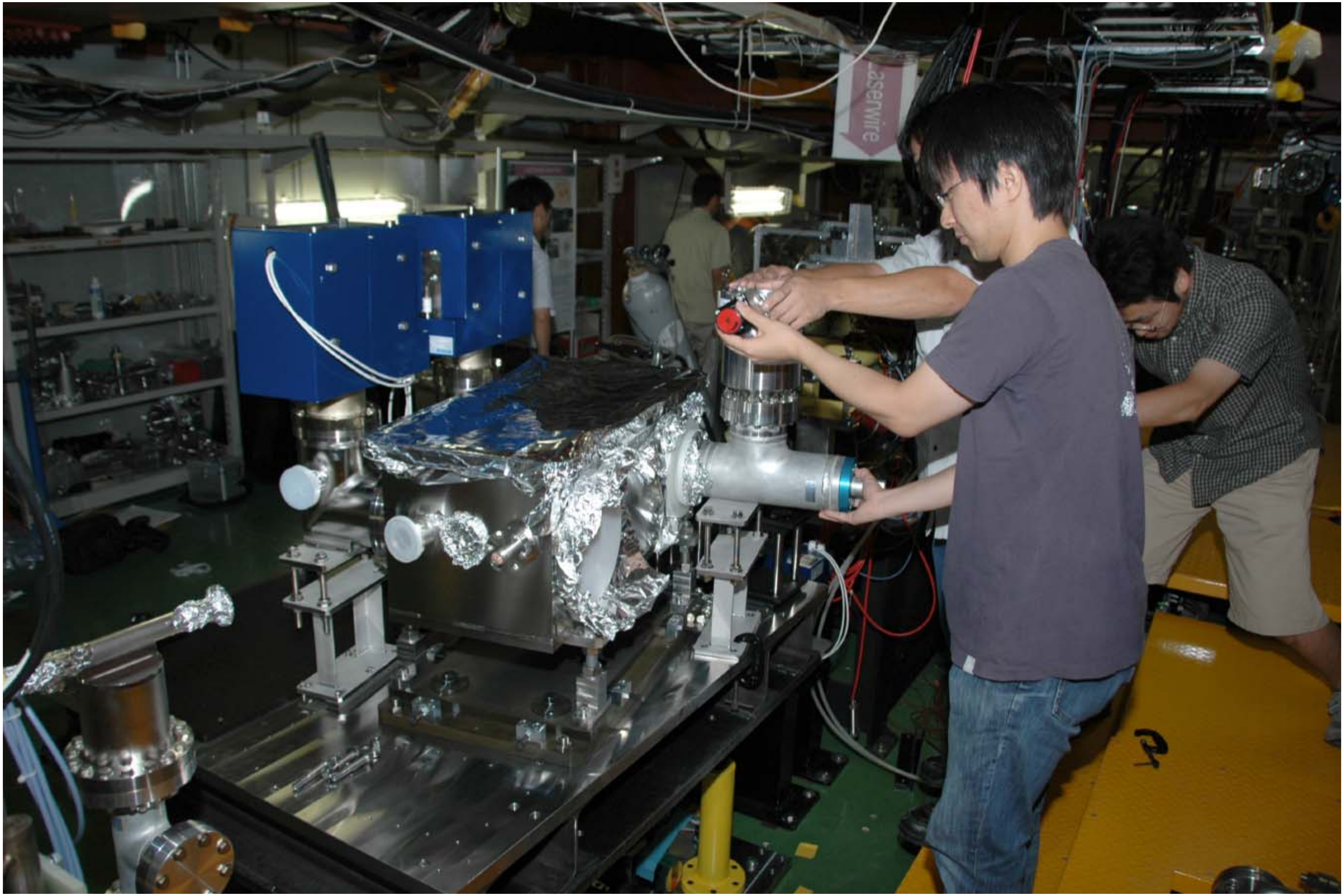
Make a fist prototype 2-mirror cavity

L_{cav} = 420 mm

Put it in ATF ring



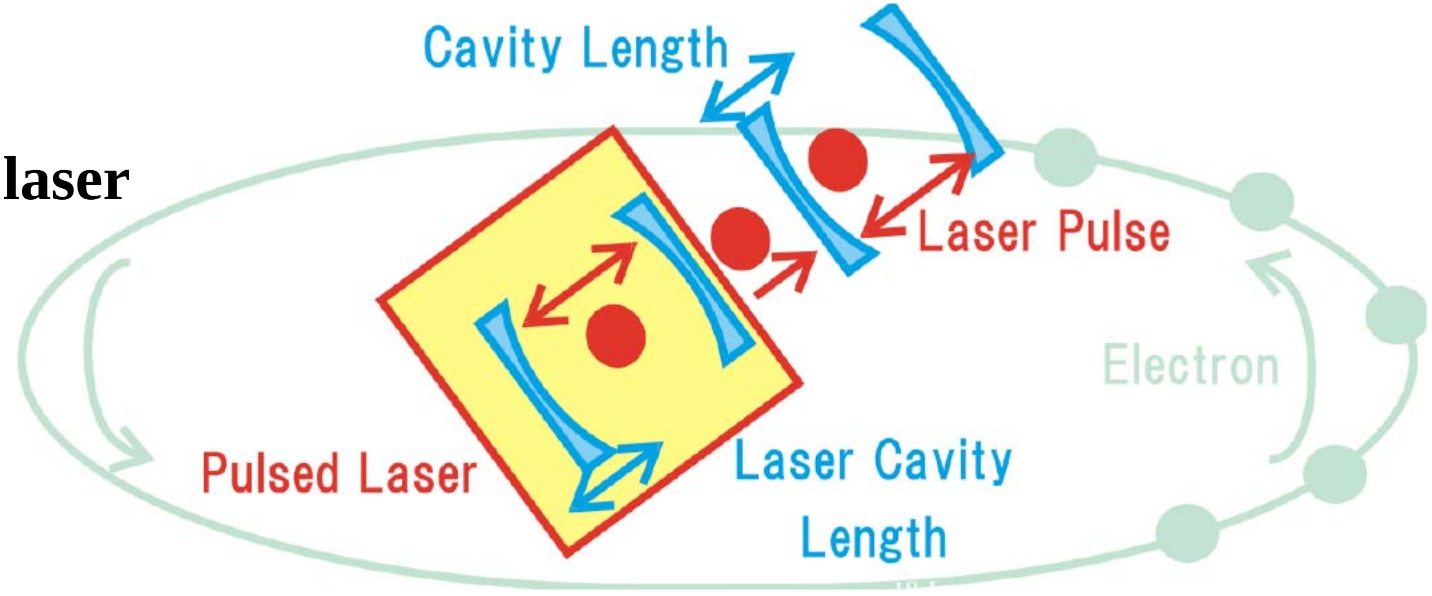
October 2007: Install the 2-mirror cavity into ATF-DR



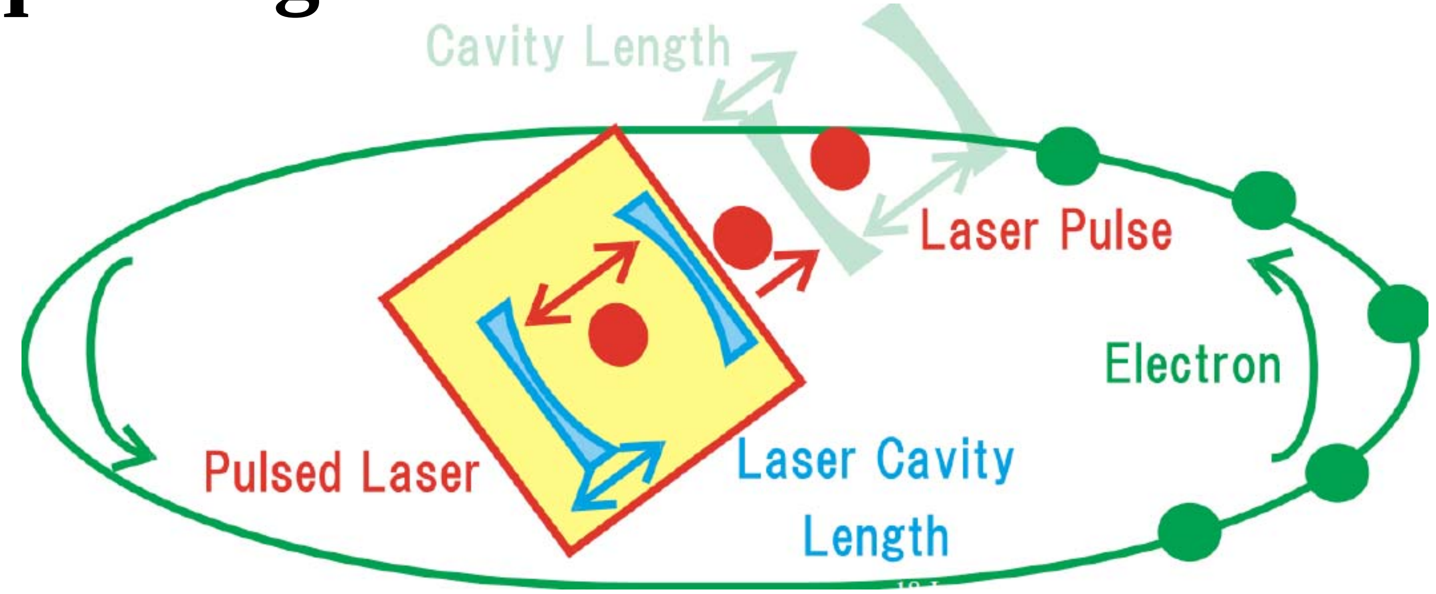
Feedback to Achieve 3 Conditions

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

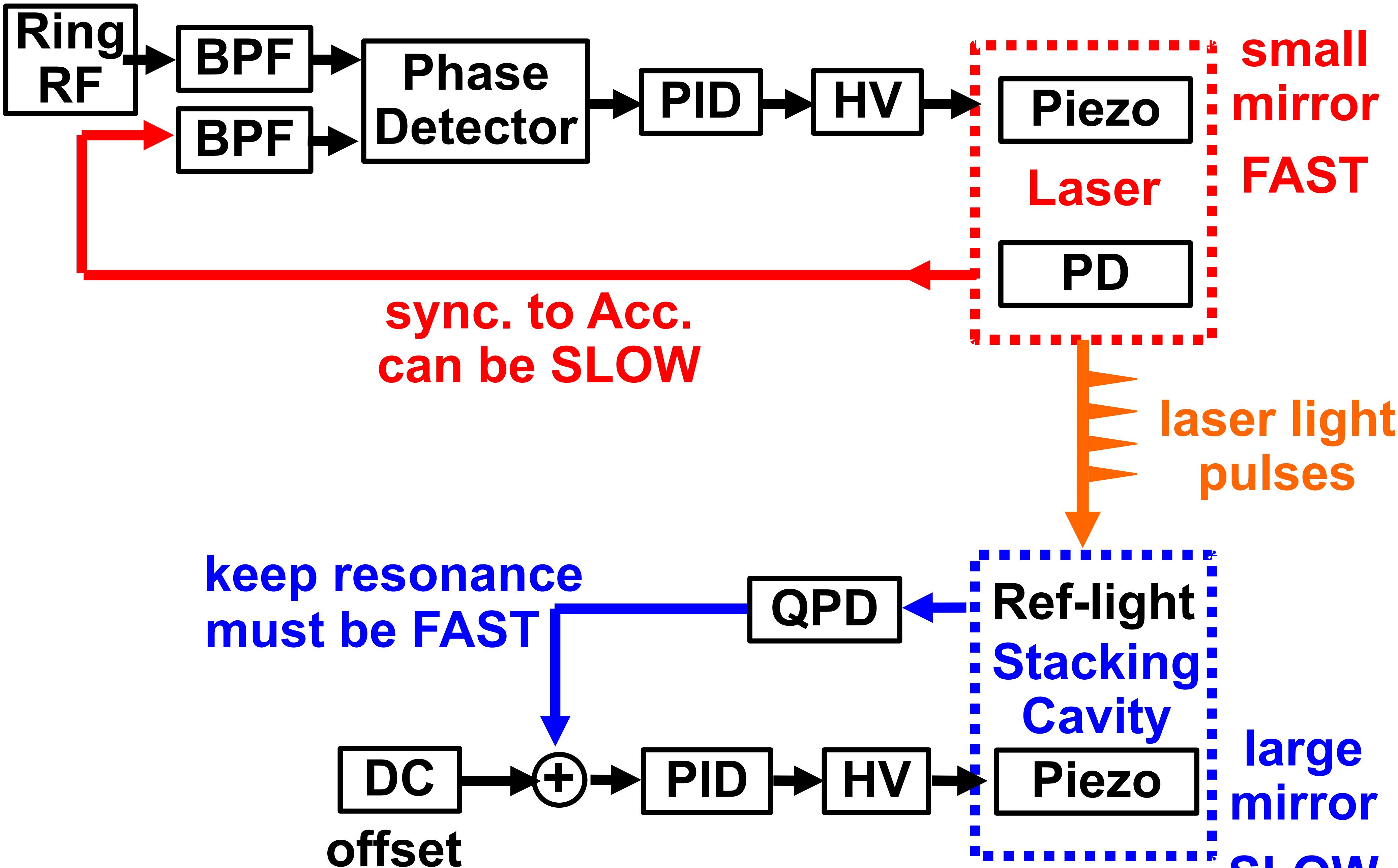
$$L_{cav} = m\,L_{laser}$$



Laser freq = Ring RF

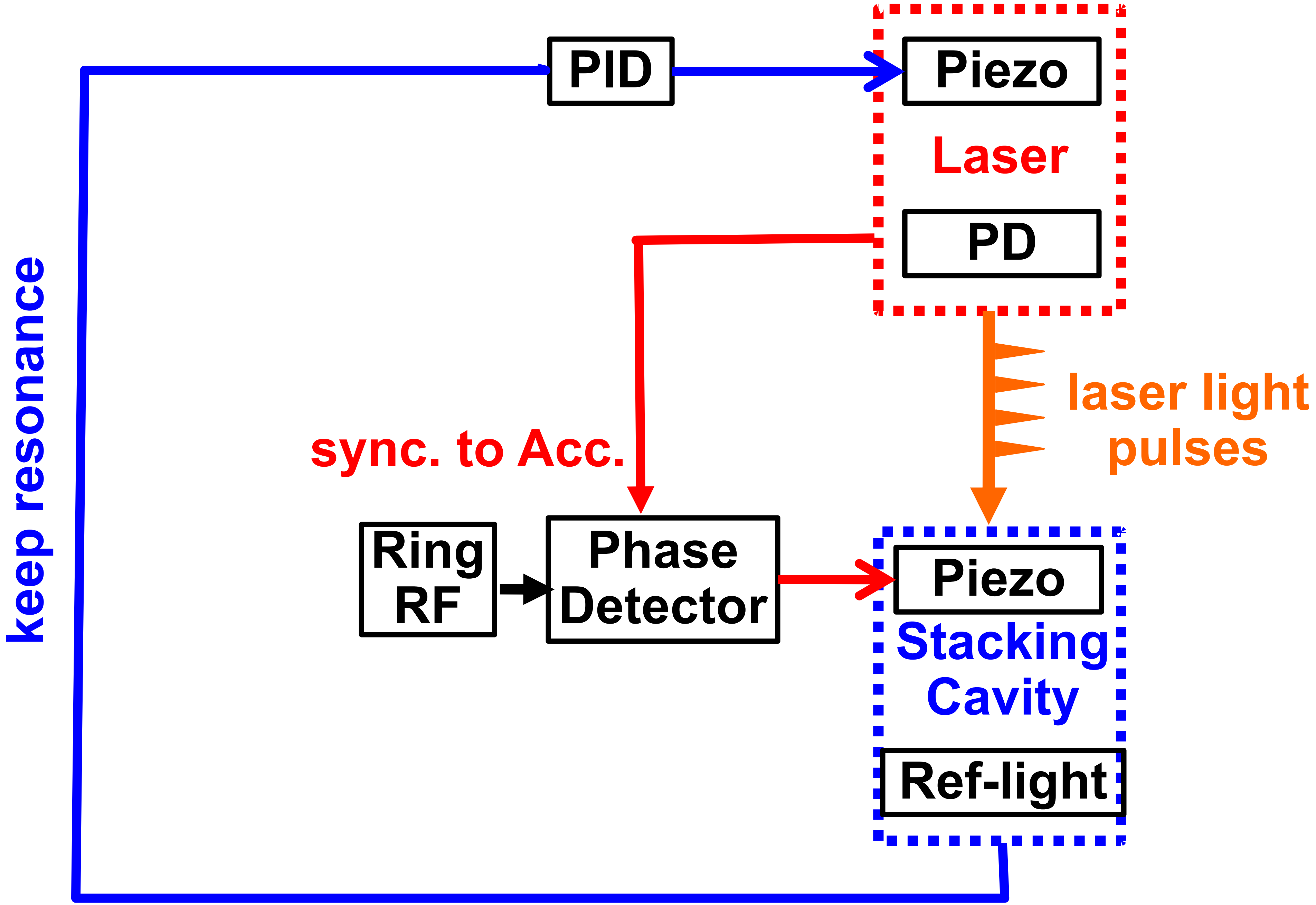


Normal Solution



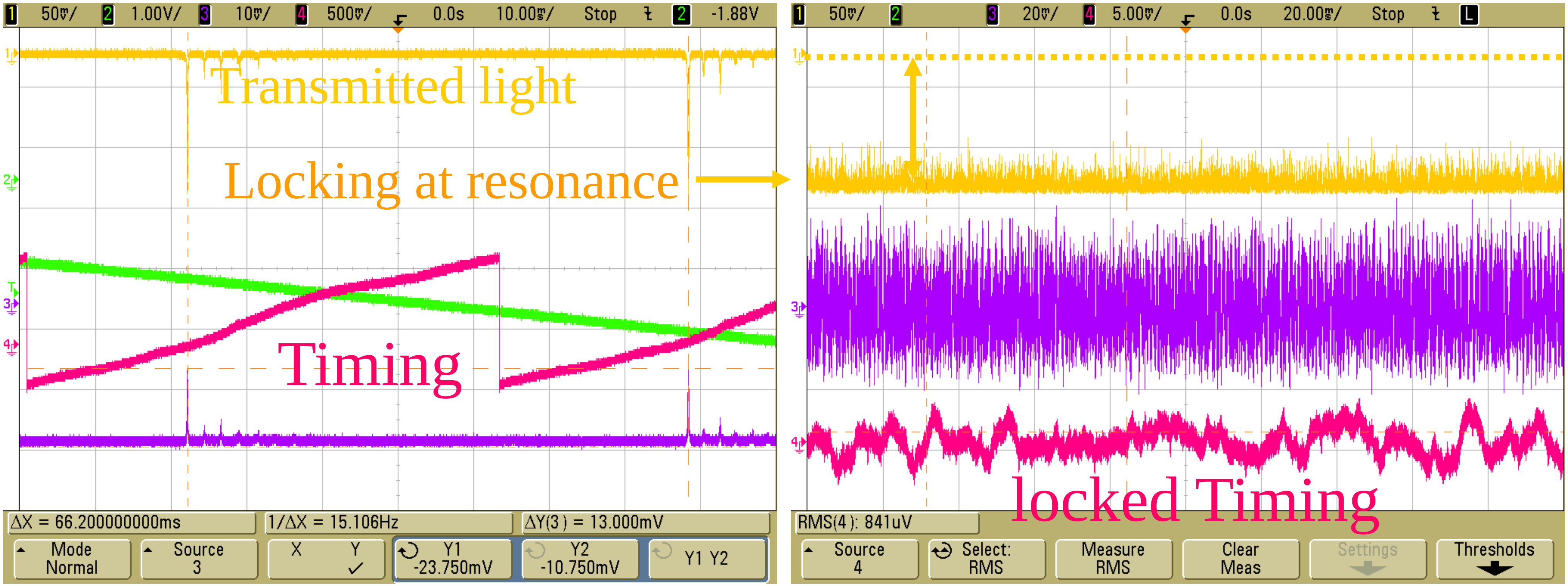
Cross-feedback=Closed loop

(Sakaue)

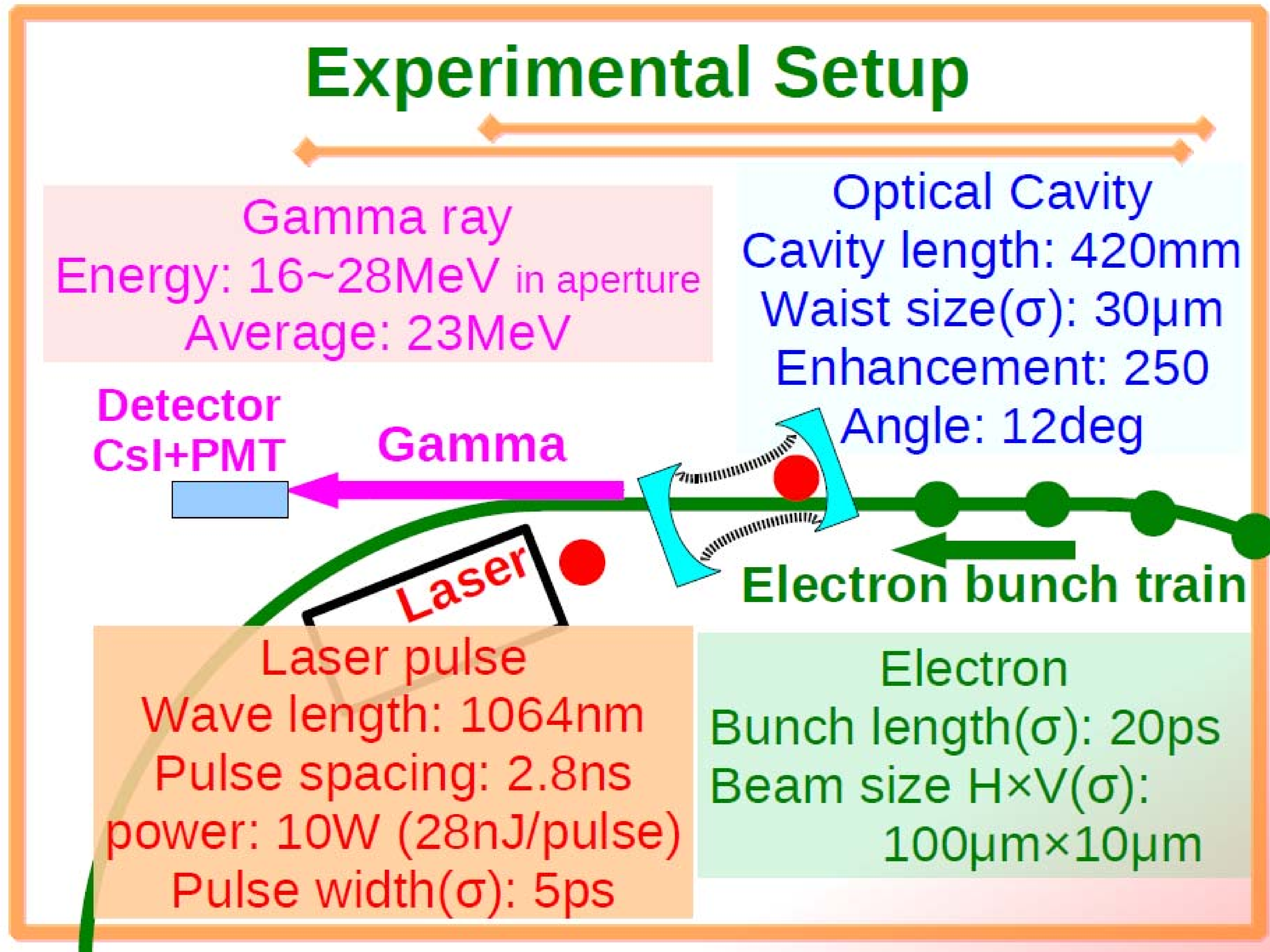


Optical cavity condition

In summer time, we succeeded to keep condition of optical cavity timing lock and locking at resonance point.



Last week beam time, Optical cavity was to keep condition timing lock and locking at resonance point.

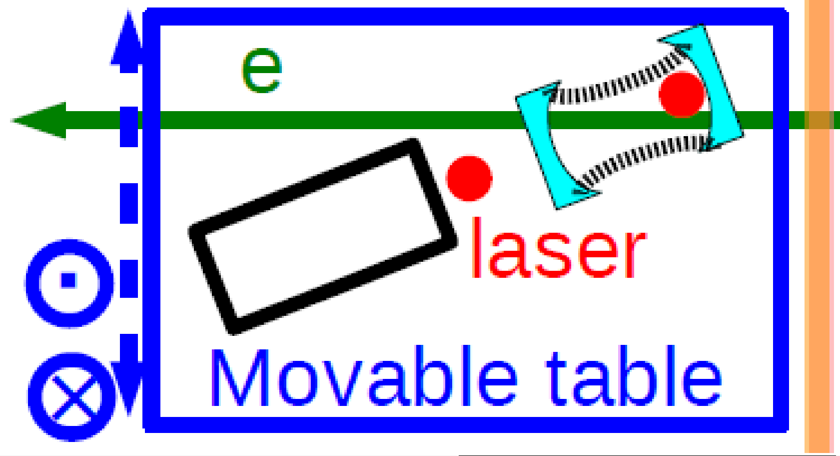


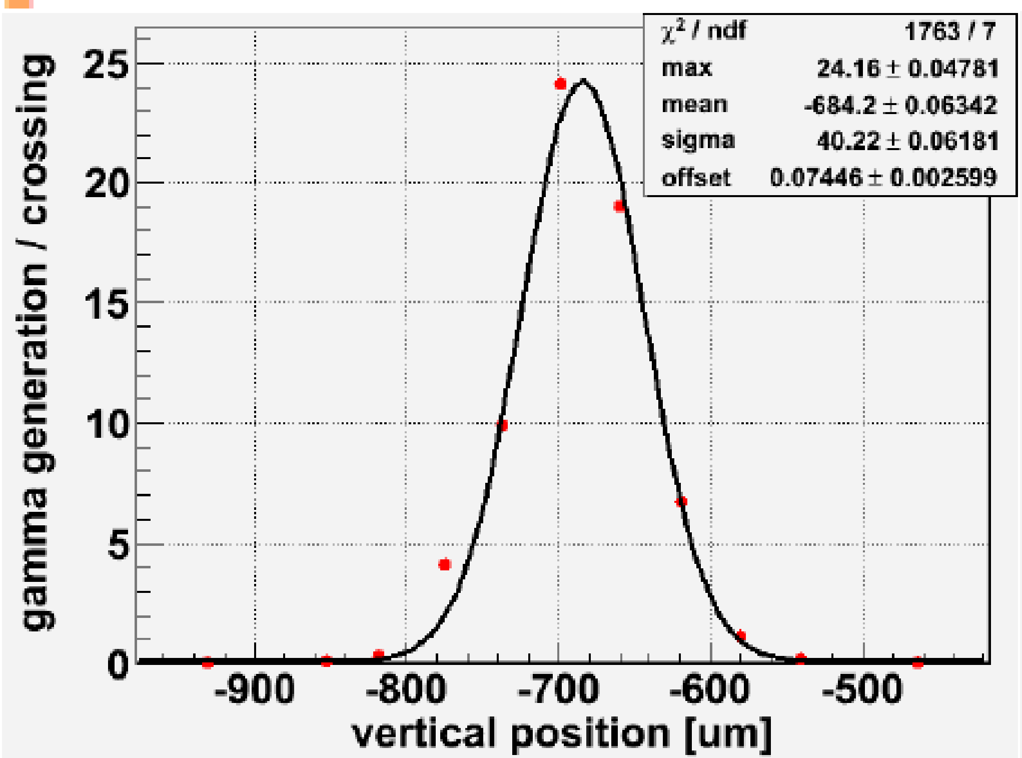
Experimental Setup
Gamma ray
Energy: 16~28MeV in aperture
Average: 23MeV
Optical Cavity
Cavity length: 420mm
Waist size(σ): 30μm
Enhancement: 250
Angle: 12deg
Detector
CsI+PMT
Gamma
Laser
Electron bunch train
Laser pulse
Wave length: 1064nm
Pulse spacing: 2.8ns
power: 10W (28nJ/pulse)
Pulse width(σ): 5ps
Electron
Bunch length(σ): 20ps
Beam size H×V(σ):
100μm×10μm

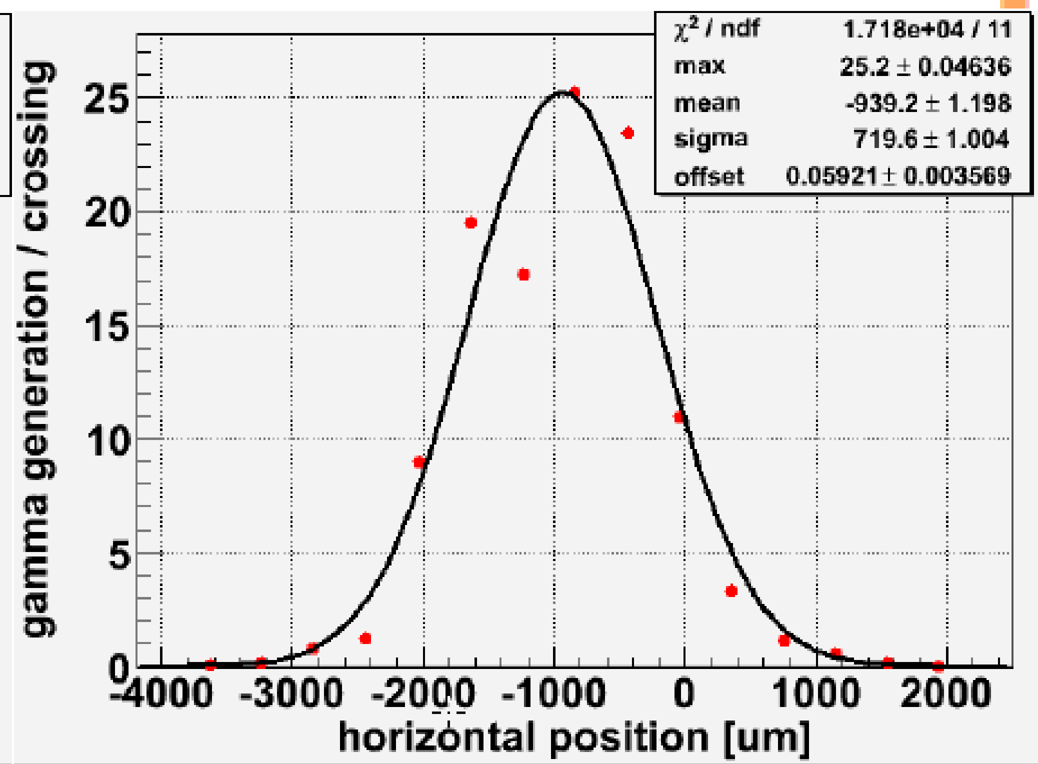
Find Optimum Position

First, scanning cavity position.

find optimum transverse position for e beam



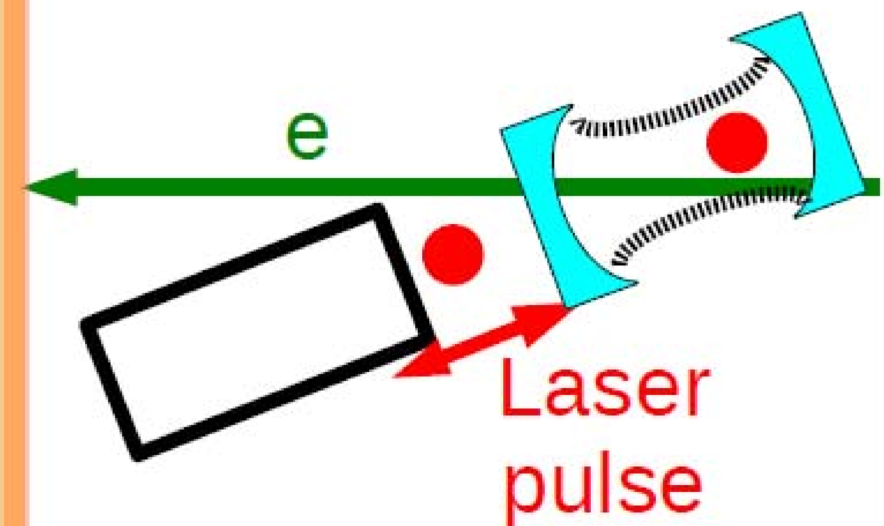


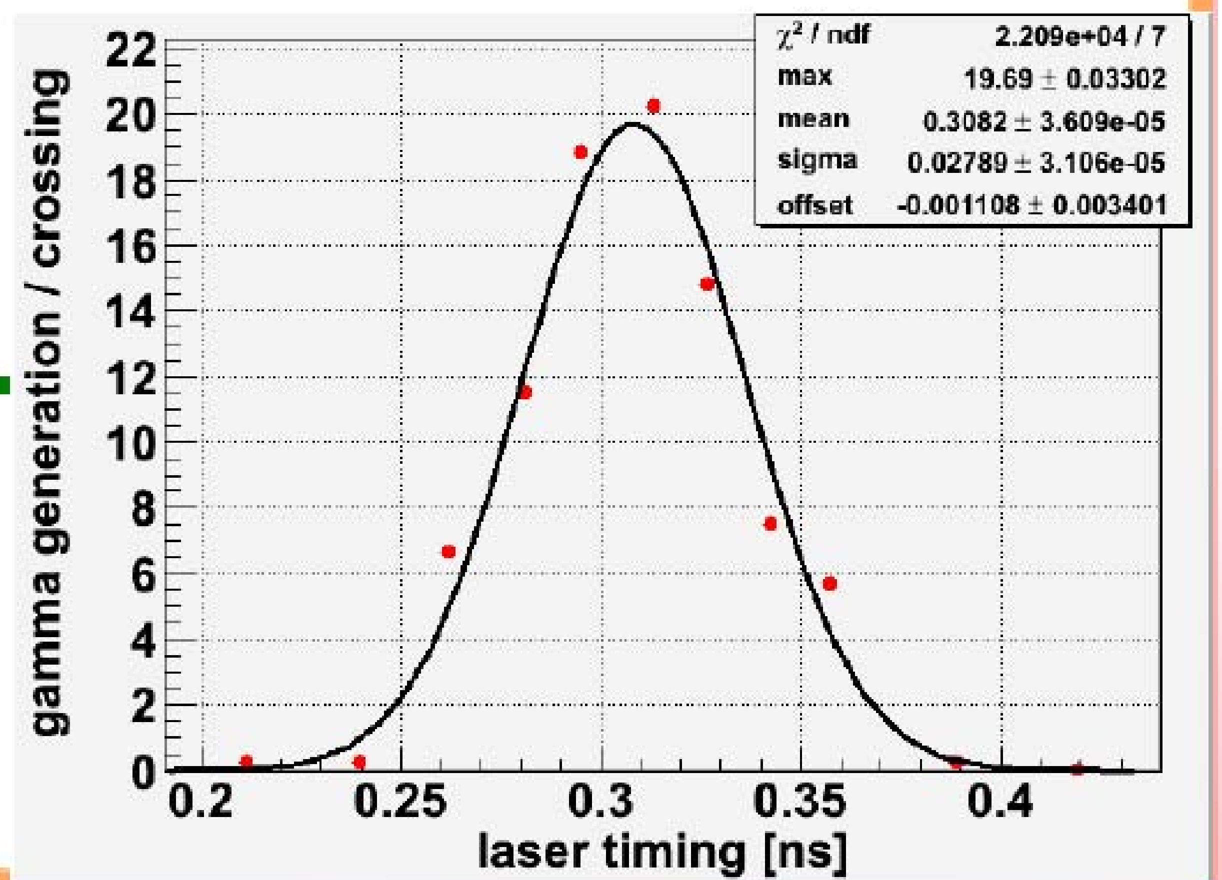


Find Optimum Position

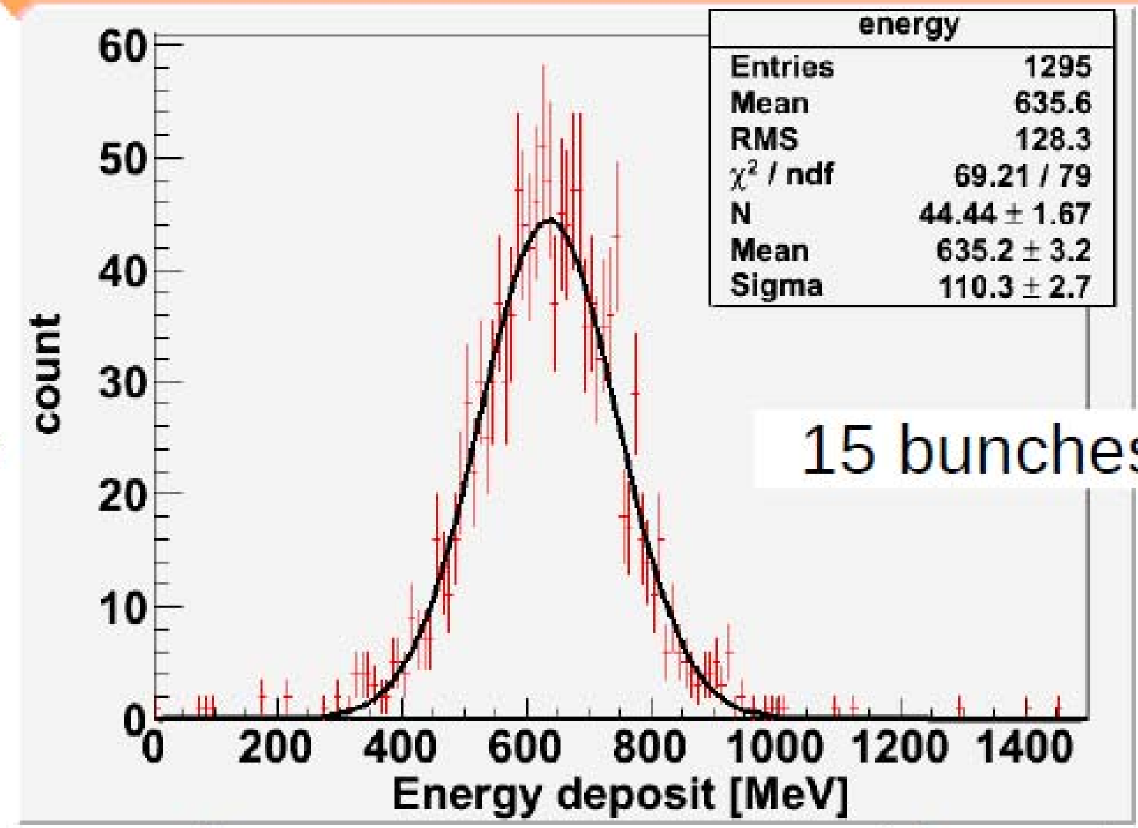
scanning laser pulse timing

--> find optimum 3D (transverse & timing) position for e beam





Result



15 bunches / train

We detected 27 gamma-rays / bunch train.
generation 60 gamma-rays / train to all angle.

→ $60 \times 2.16\text{MHz} \sim 1.2 \times 10^{8}$ [gamma / second]

Revolution

data summary

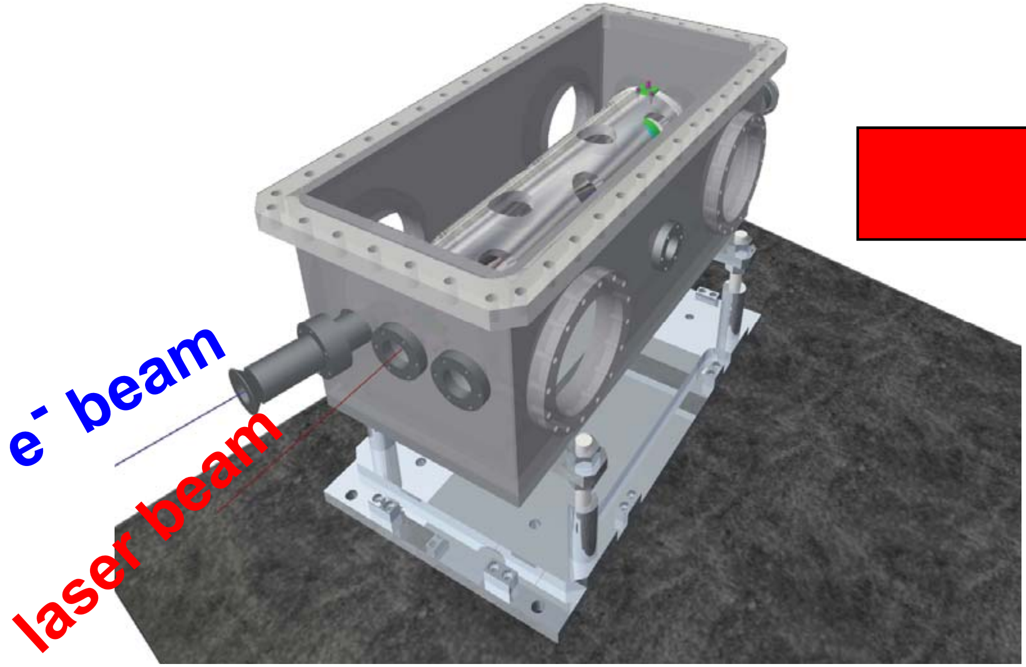
bunch /train	current [mA]	Stacked Laser power[W]	γs/train	expectation	normarized γs/A/W
1	2.2	437 ± 2	5.4 ± 0.3	4.9 ± 0.3	5.6 ± 0.3
5	4.7	432 ± 2	10.6 ± 0.1	10.5 ± 0.5	5.3 ± 0.1
10	8.5	470 ± 2	19.0 ± 0.1	21 ± 1	4.8 ± 0.1
15	11	498 ± 2	26.9 ± 0.1	29 ± 1	4.8 ± 0.1

Normalized γ yield seems to decrease as # bunches/train goes up

⇒ Bunch (size, timing) fluctuation in the ATF suspected

2-mirror-cav to 4-mirror-cav.

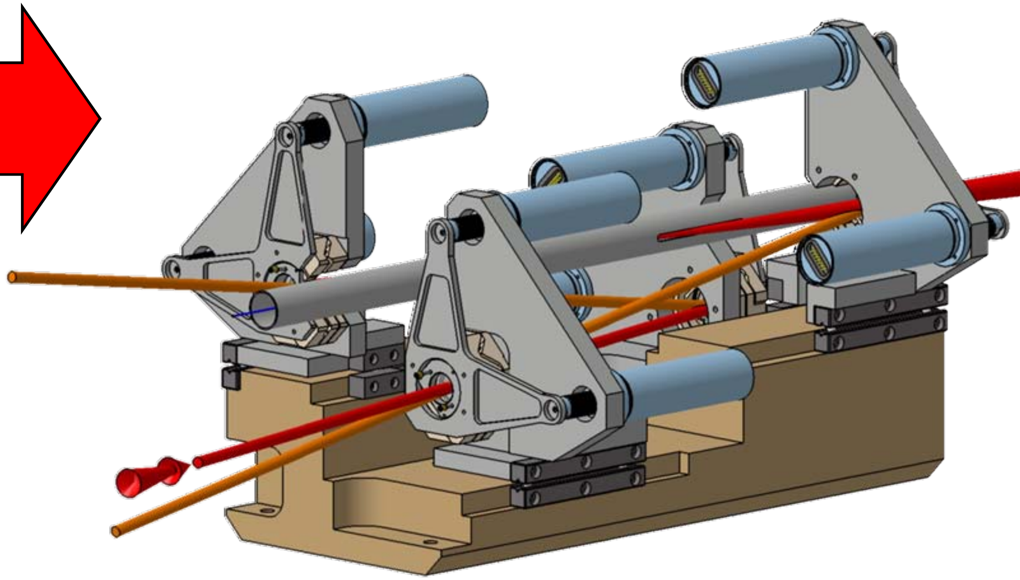
2-mirror cavity



Spot size = 30 um
Enhance = 1000

difficult to achieve both high enhancement and small spot

4-mirror cavity

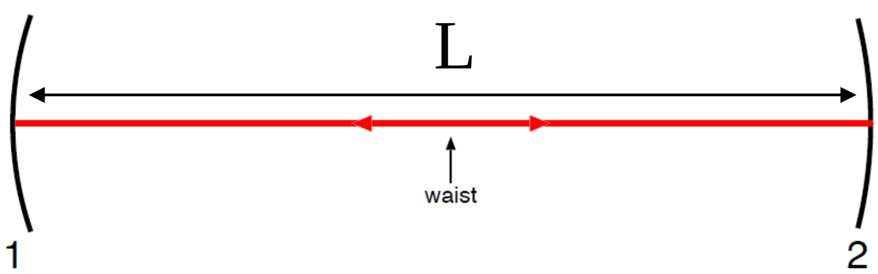


R. Cizeron

Spot size = 10 um
Enhance = 10000

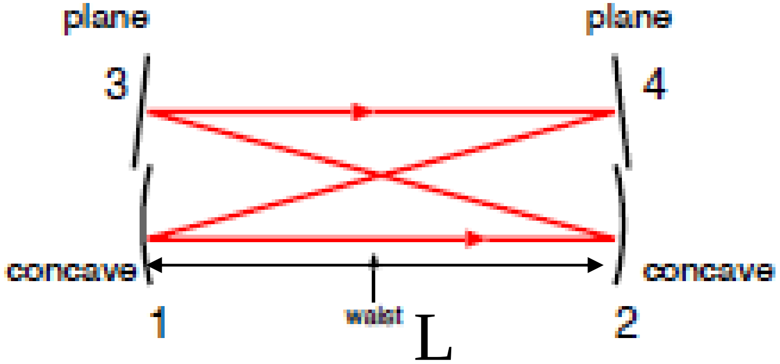
2-mirror cavity

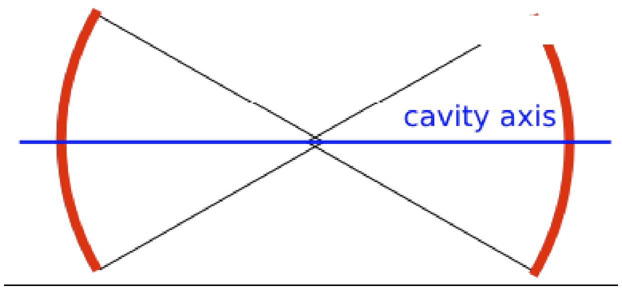
R1=R2=L/2



4-mirror cavity

R1=R2=L

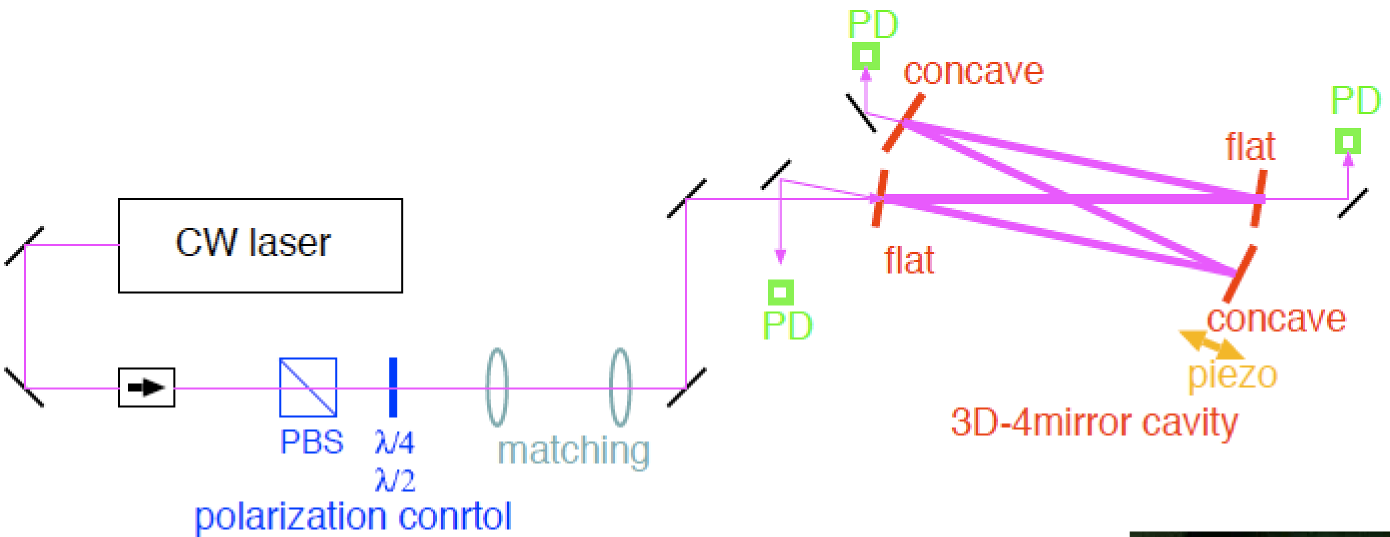


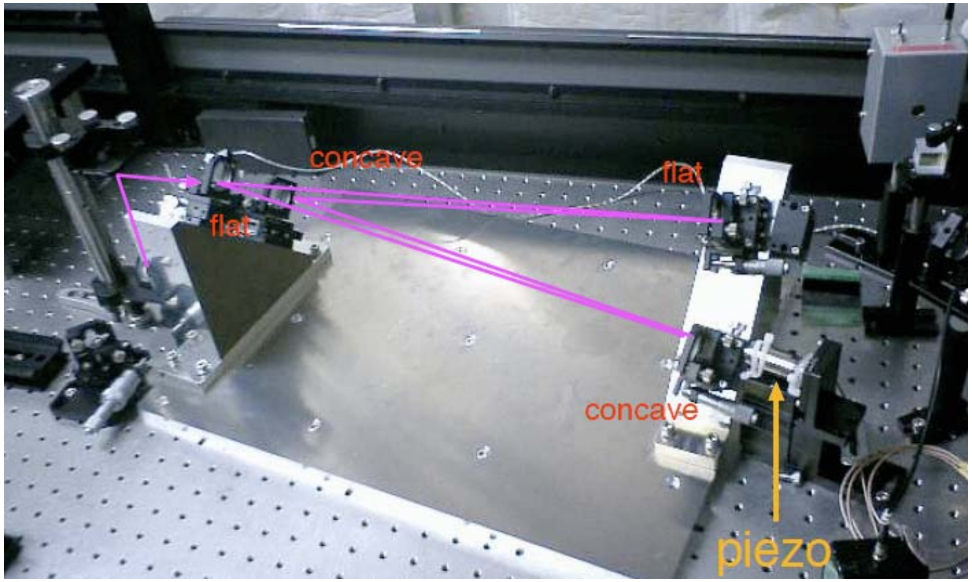


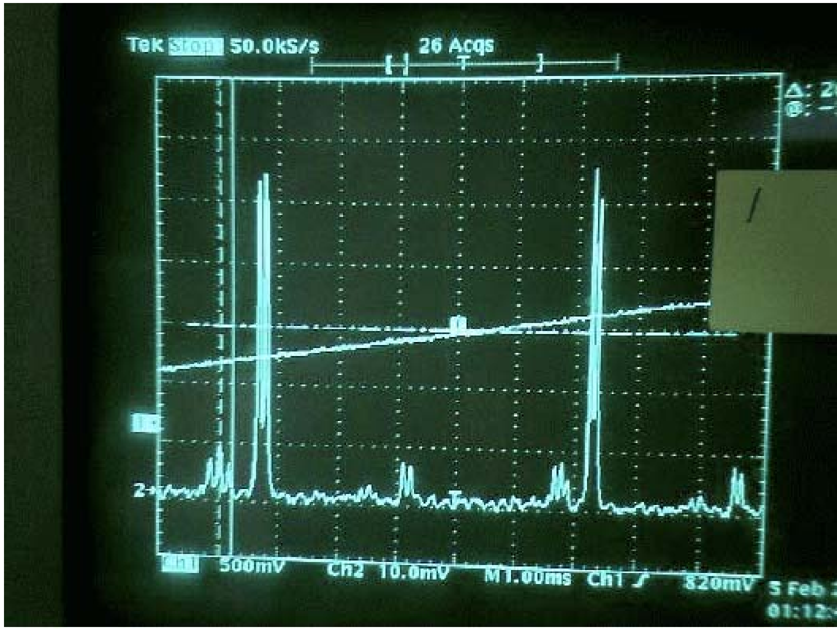
focus laser and maintain resonance by L

focus laser by L
maintain resonance by circumference

R&D of 4 mirrors cavity started



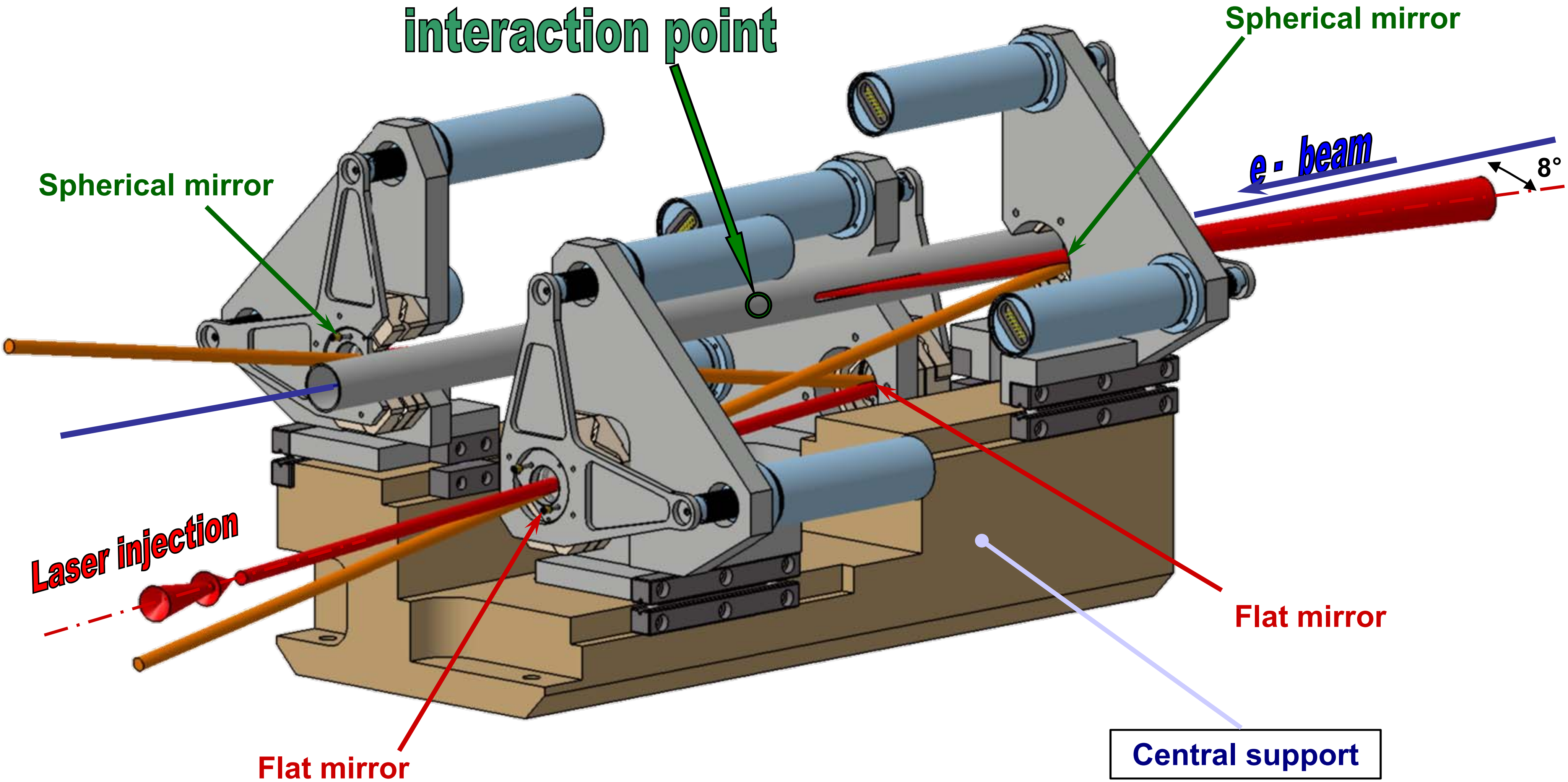




Summary

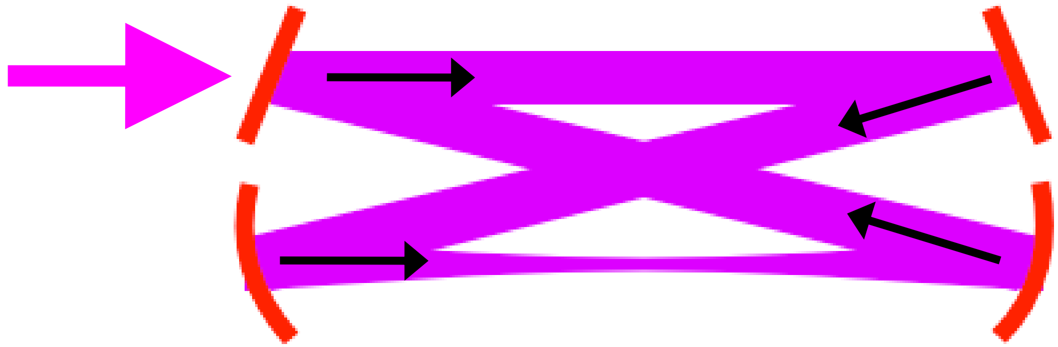
- Optical Cavity at the ATF is in progress
  - Successful to generate gamma rays with
    - stable operation of the Cavity in the ATF
    - no disturbance for the ATF beams
    - enhancement of 250
    - 27 gammas / crossing
- Short term plan is to get 1000 enhancement by high reflection mirror (99.6% -> 99.9%)
- R&D of 4 mirror ring cavity has been started
  - aming 10000 enhansement and 5mm sport size

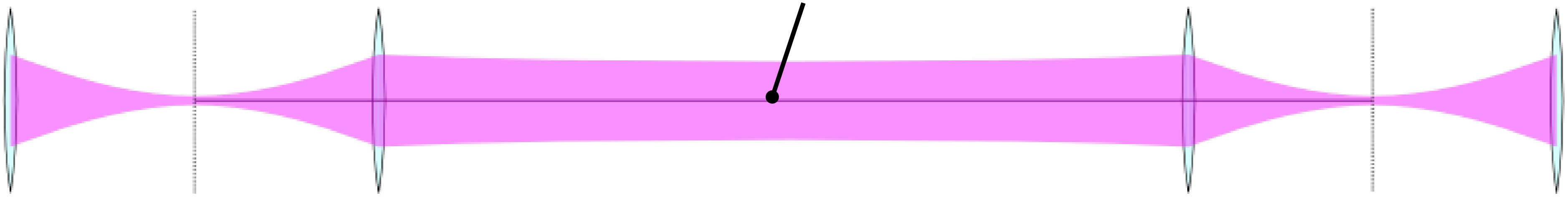
e^- beam compatible 4-mirror cavity



R. Cizeron
LAL 30/01/2008

4-mirror ring cavity

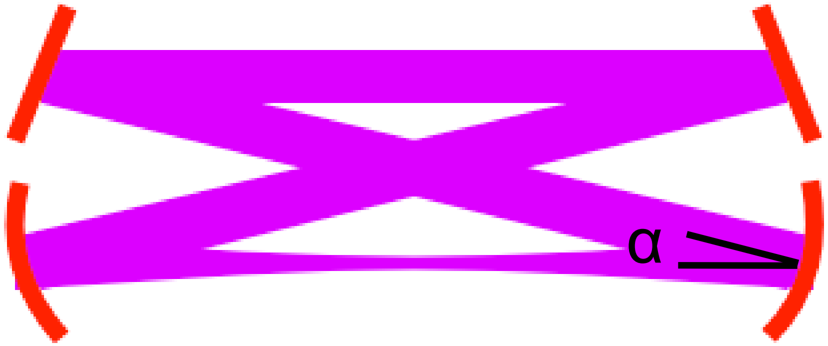




Equivalent Optics of the 4-mirror Cavity

tolerance : 4-mirror = 100 x 2-mirror

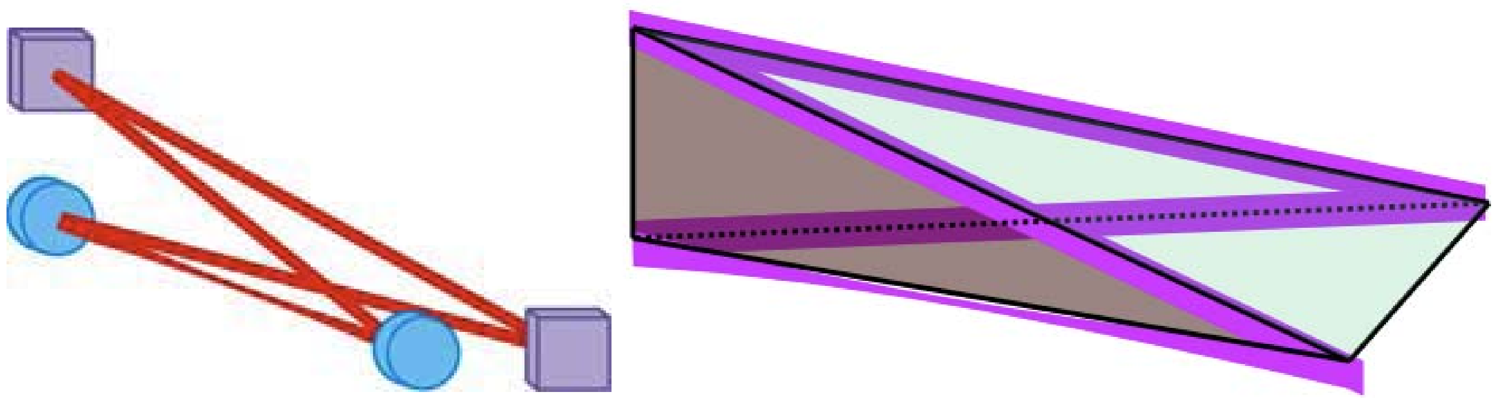
2D configuration



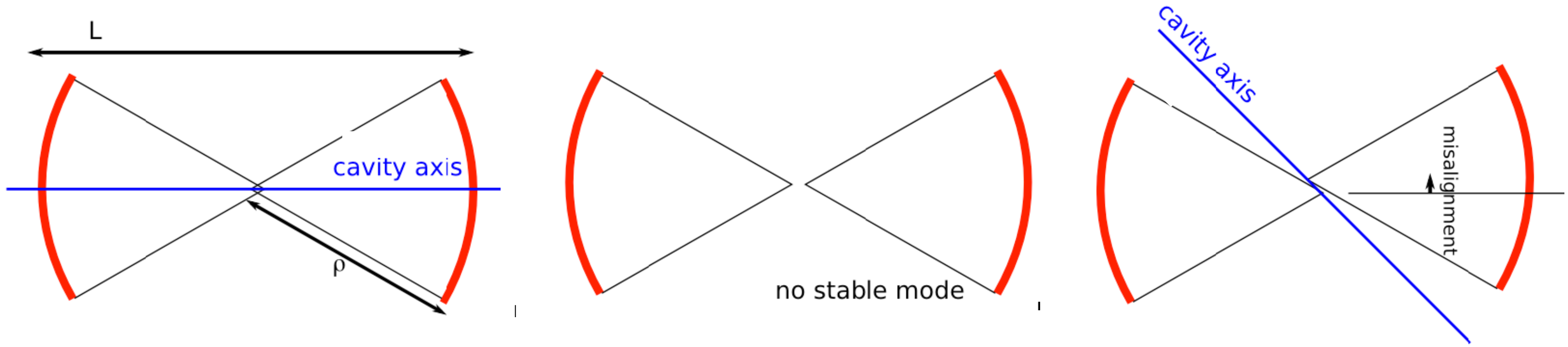
$$f_t = \frac{\rho}{2} \cos(\alpha/2)$$

$$f_s = \frac{\rho}{2 \cos(\alpha/2)}$$

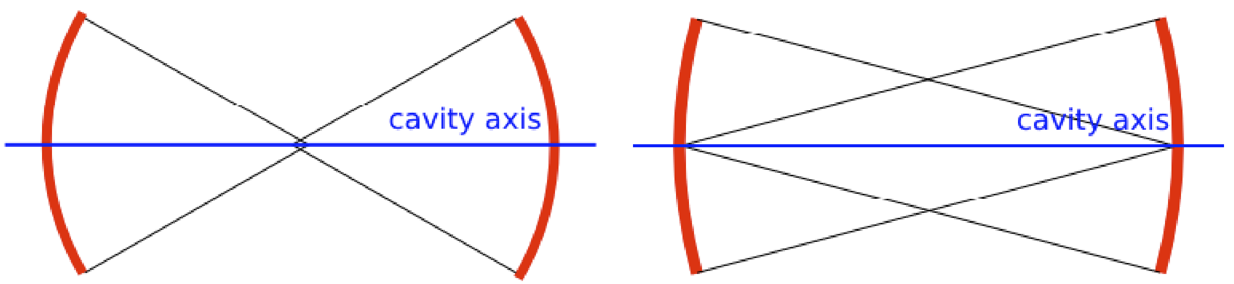
3D configuration



Tolerance of 2-mirror cavity



Concentric Configuration and Confocal Configuration

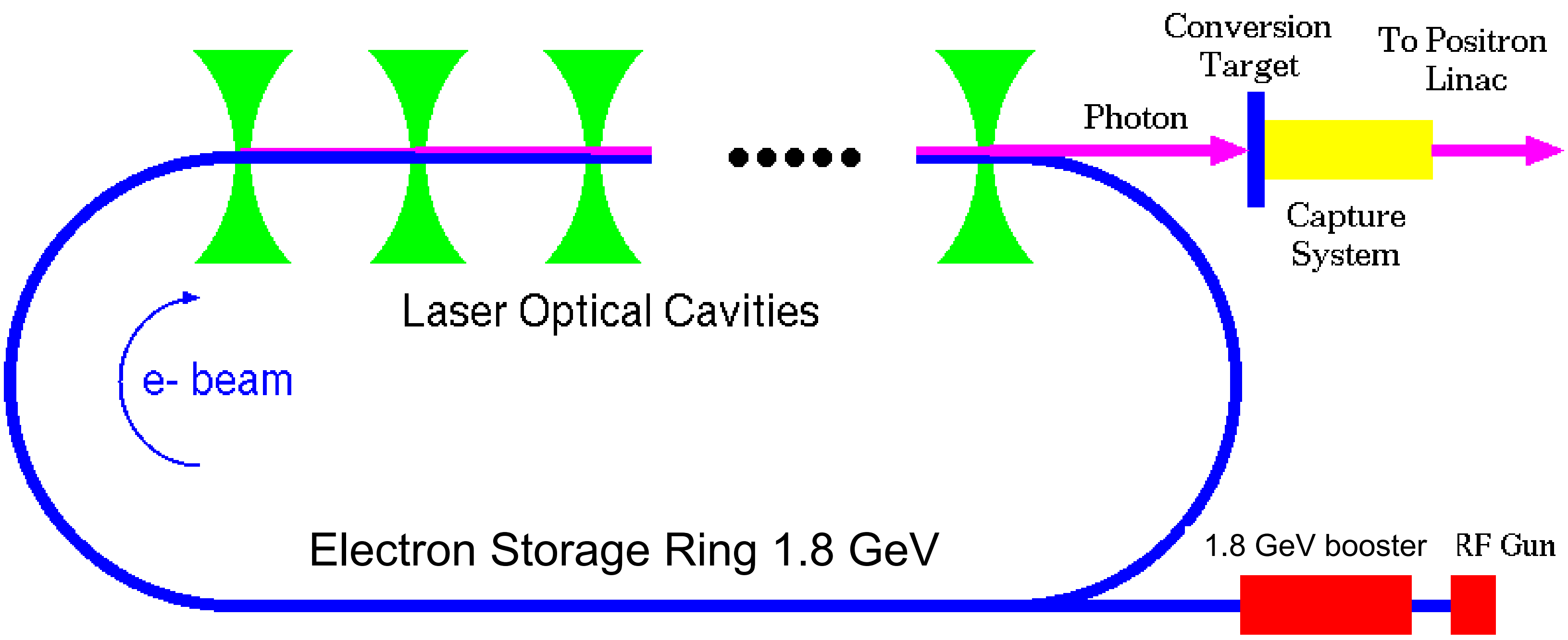


concentric

confocal

Compton Ring Scheme for ILC

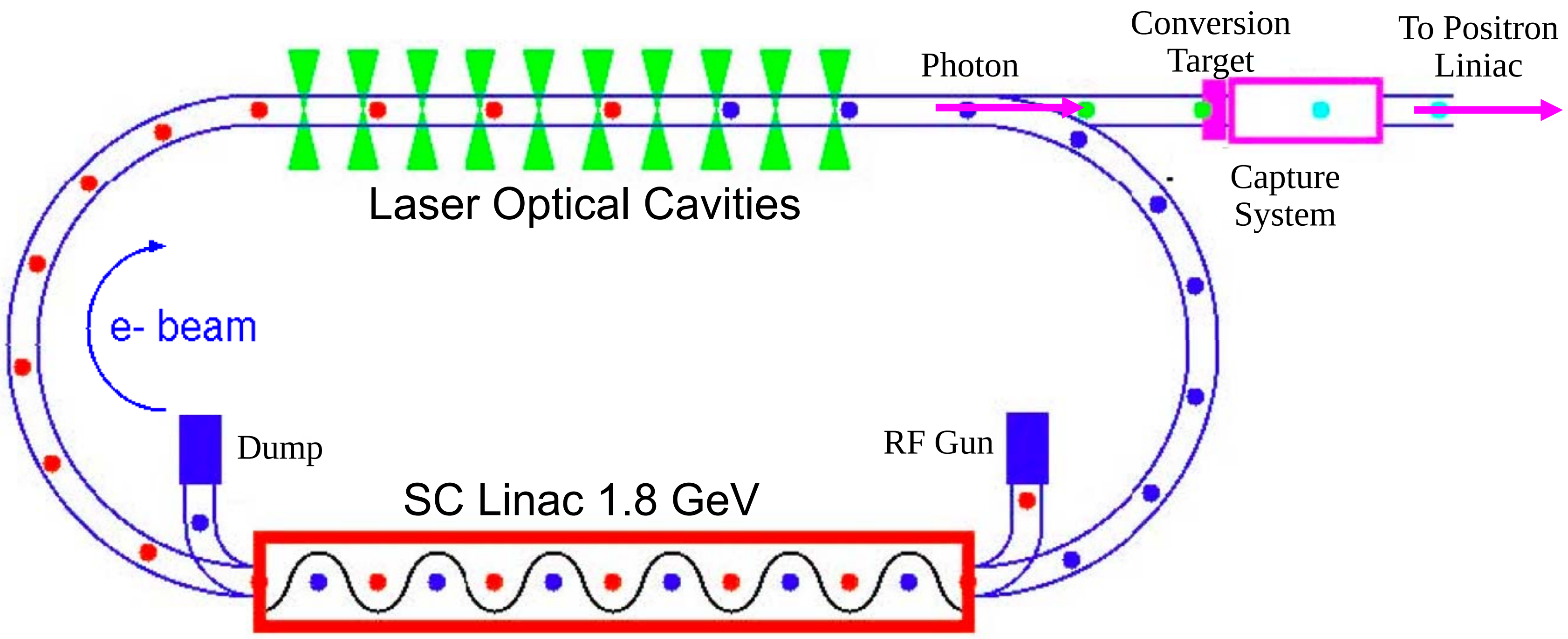
- Compton scattering of e- beam stored in storage ring off laser stored in Optical Cavity.
- 5.3 nC 1.8 GeV electron bunches x 5 of 600mJ stored laser -> 2.3E+10 γ rays -> 2.0E+8 e+.
- By stacking 100 bunches on a same bucket in DR, 2.0E+10 e+/bunch is obtained.



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



Why Laser-Compton ?

i) Positron Polarization.

ii) Independence

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

Laser-base e^+ : independent

iii) Polarization flip @ 5Hz (for CLIC @ 50 Hz)

iv) High polarization (potentially <-- 1st harmonic)

v) Low energy operation

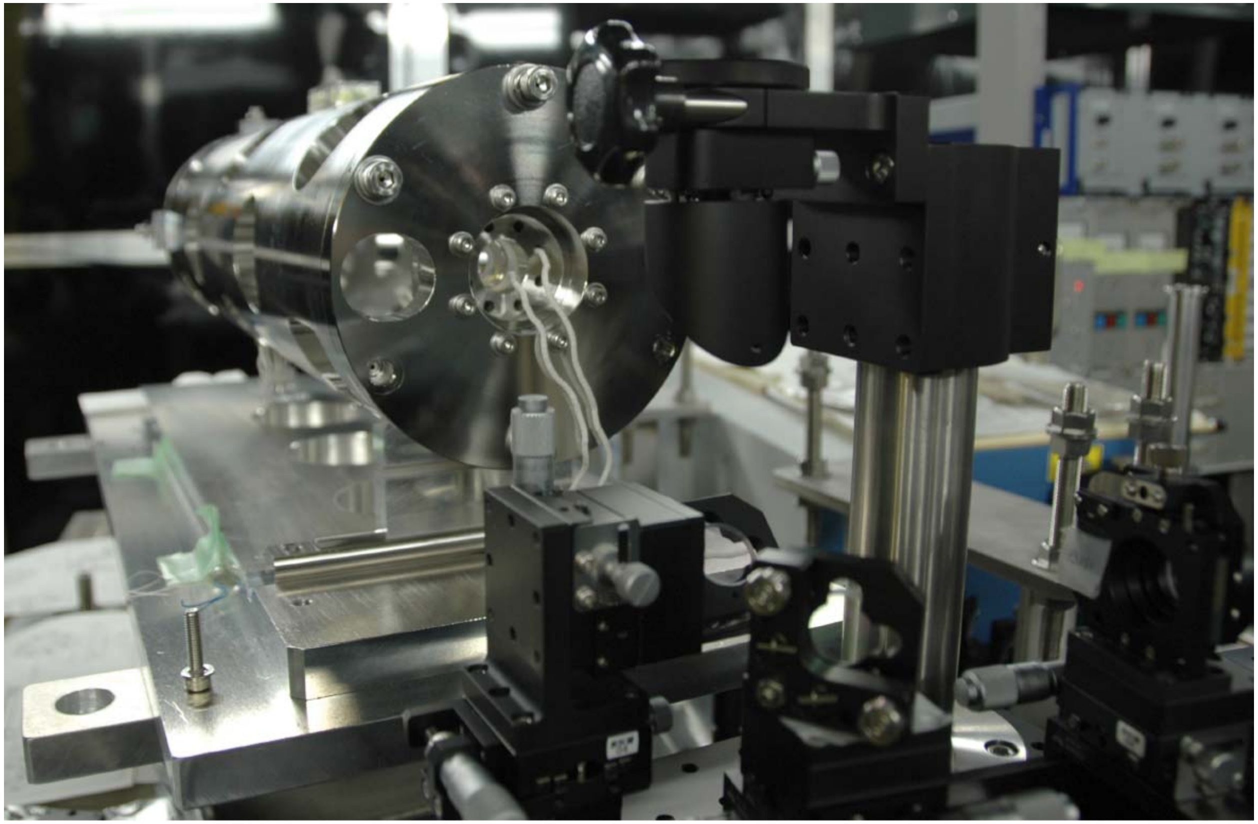
Undulator-base e^+ : need deceleration

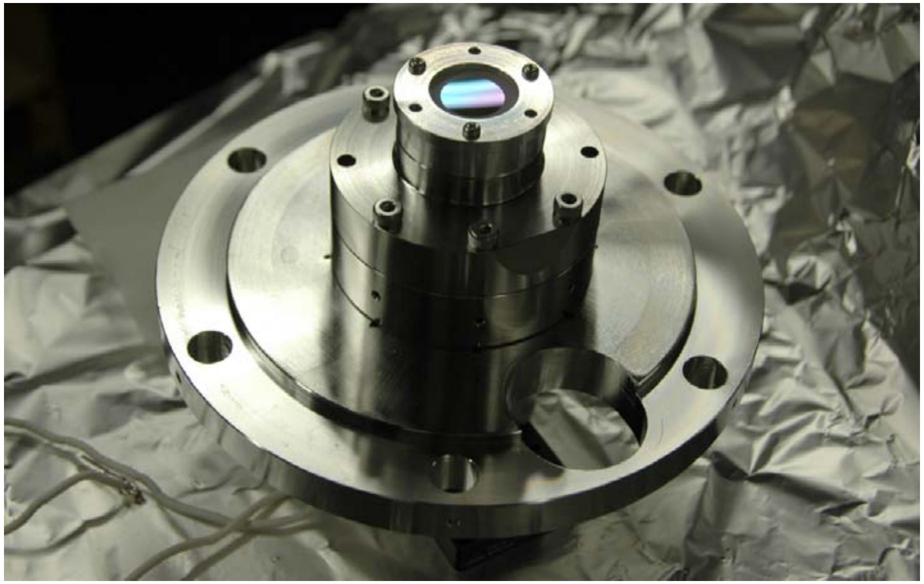
Laser-base e^+ : no problem

vi) Synergy in wide area of fields/applications

Laser Stacking Optical Cavity in Vacuum Chamber

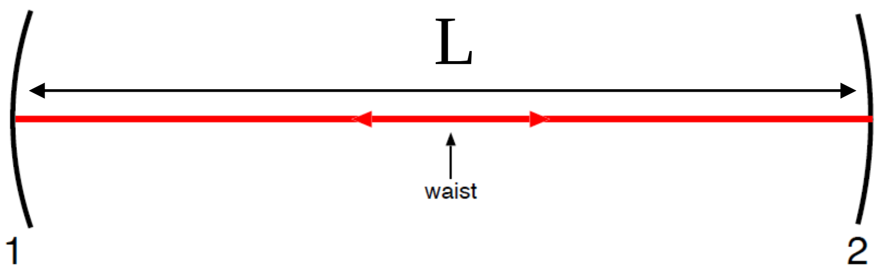
Summer 2007: Assembling the Optical Cavity

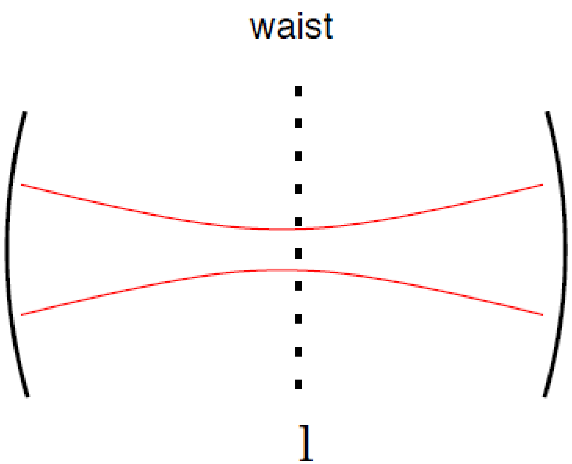


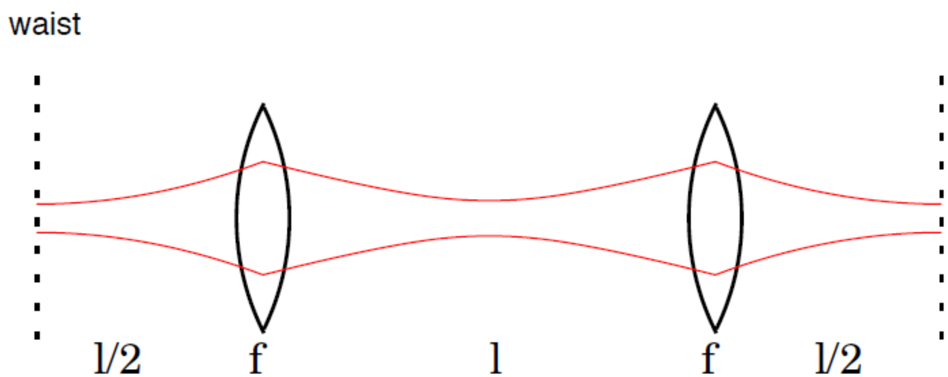


2-mirror cavity

R1=R2=L/2



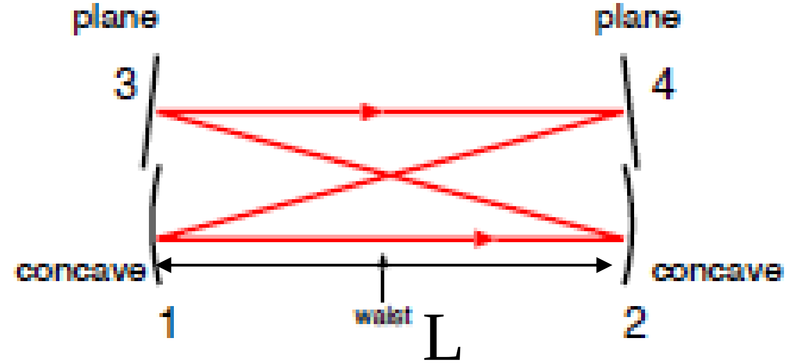


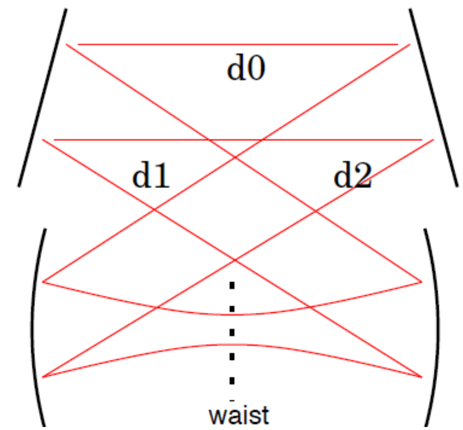


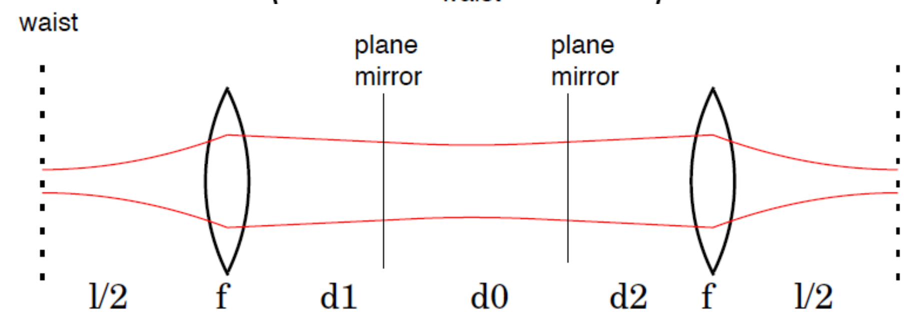
concentric

4-mirror cavity

R1=R2=L







confocal

data summary

bunch /train	current [mA]	Stacked Laser power[W]	γs/crossing	exectation	normarized γs/A/W
15	11	498.2±0.4	27.6±0.1	30~45	5.04±0.02
10	8.5	469.8±0.4	20.2±0.1	22~33	5.06±0.03
5	4.7	423.4±0.8	11.3±0.1	11~17	5.68±0.05
1	2.2	436.8±0.4	5.4±0.3	5~8	5.6±0.3

Normalized γ yield seems to decrease as # bunches/train goes up

➡ Bunch (size, timing) fluctuation in the ATF suspected

data summary

bunch /train	current [mA]	Stacked Laser power[W]	γs/train	expectation	normarized γs/A/W
1	2.2	437 ± 6	5.4 ± 0.3	4.9 ± 0.8	5.6 ± 0.8
5	4.7	432 ± 6	10.6 ± 0.1	10.5 ± 1.5	5.3 ± 0.7
10	8.5	470 ± 7	19.0 ± 0.1	21 ± 3	4.8 ± 0.7
15	11	498 ± 7	26.9 ± 0.1	29 ± 4	4.8 ± 0.7

Normalized γ yield seems to decrease as # bunches/train goes up

⇒ Bunch (size, timing) fluctuation in the ATF suspected