Status of Compton Experiment with 2-Mirror Cavity at KEK-ATF

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Collaboration

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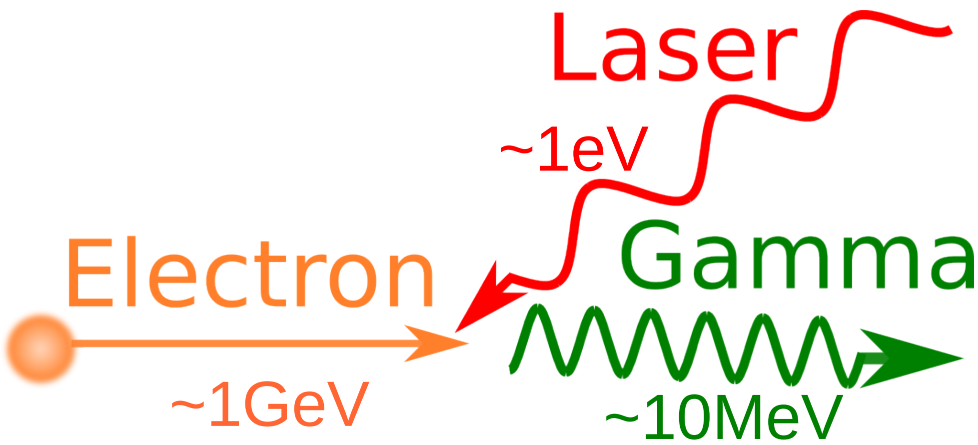
Introduction

- **Laser Compton Scattering**



Polarized **gamma-ray** generated by scattering **electron** and circularly polarized **laser beam**.

Electron energy : ~1GeV for 10MeV gamma
Polarization : easy to control (~kHz flip)

proof of principle experiment
T.Omori *et* al., Physical Review Letters 96, 114801(2006)

Next step for ILC ➡ **increase gamma yield**

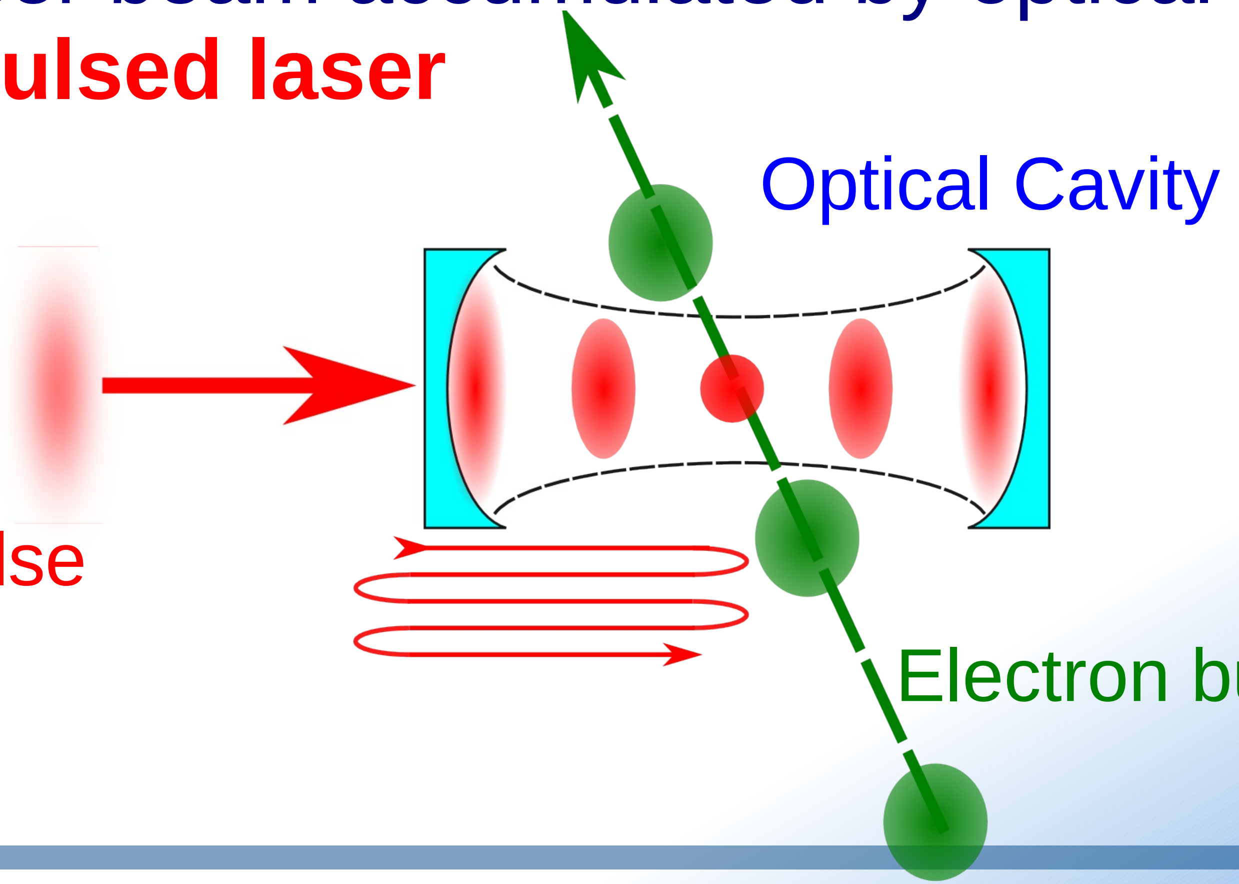
Staking Laser Pulses in Optical Cavity

Increase power of laser beam at interaction point for increasing gamma yield.

➡ **enhancement with optical cavity**

Laser beam accumulated by optical cavity

➡ **use pulsed laser**



Requirement of Optical Cavity

For increasing power of laser.

- **Stacking laser pulses in optical cavity**
  --> keeping resonance of cavity

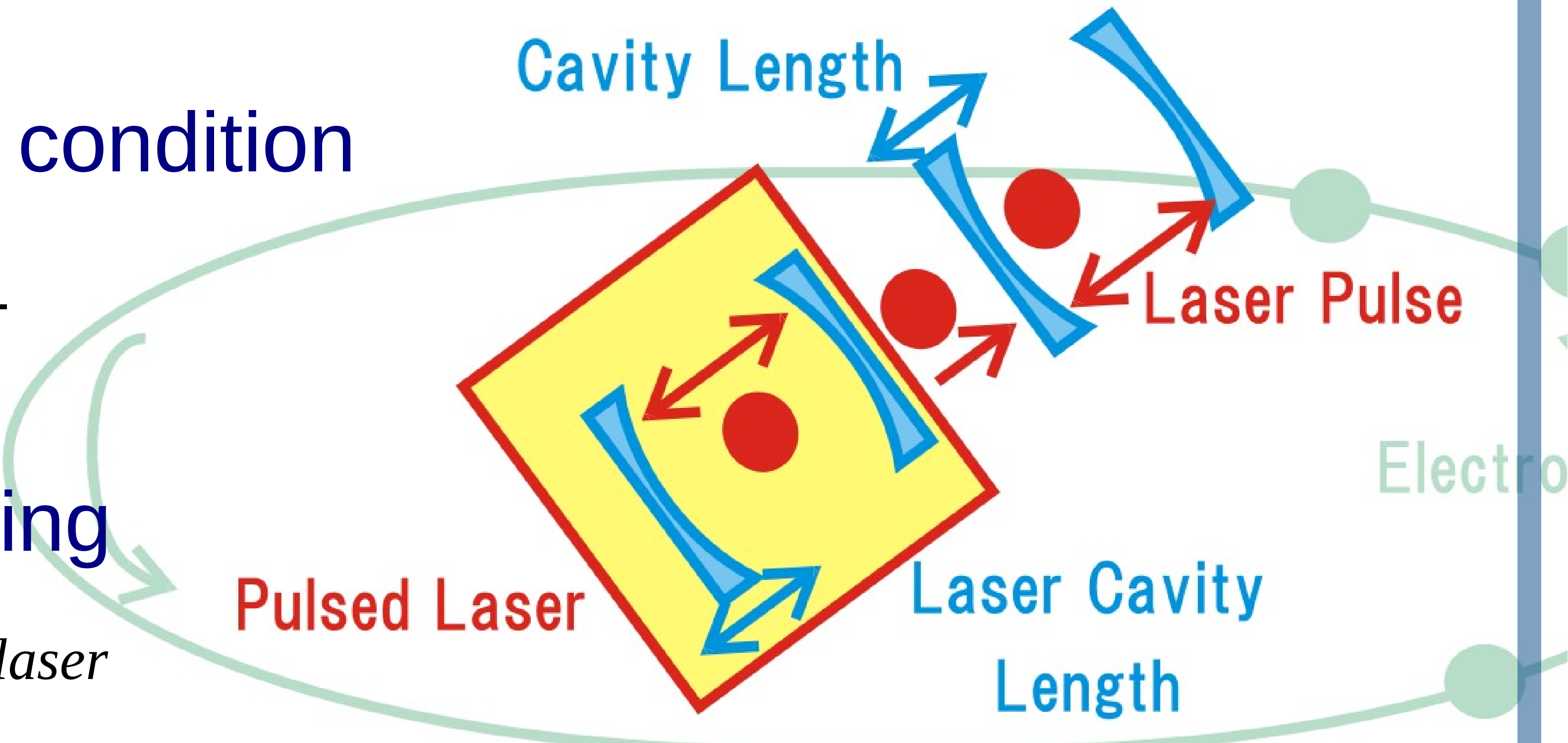
Resonance condition

$$L_{cav} = m\frac{\lambda}{2}$$

Pulse stacking

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

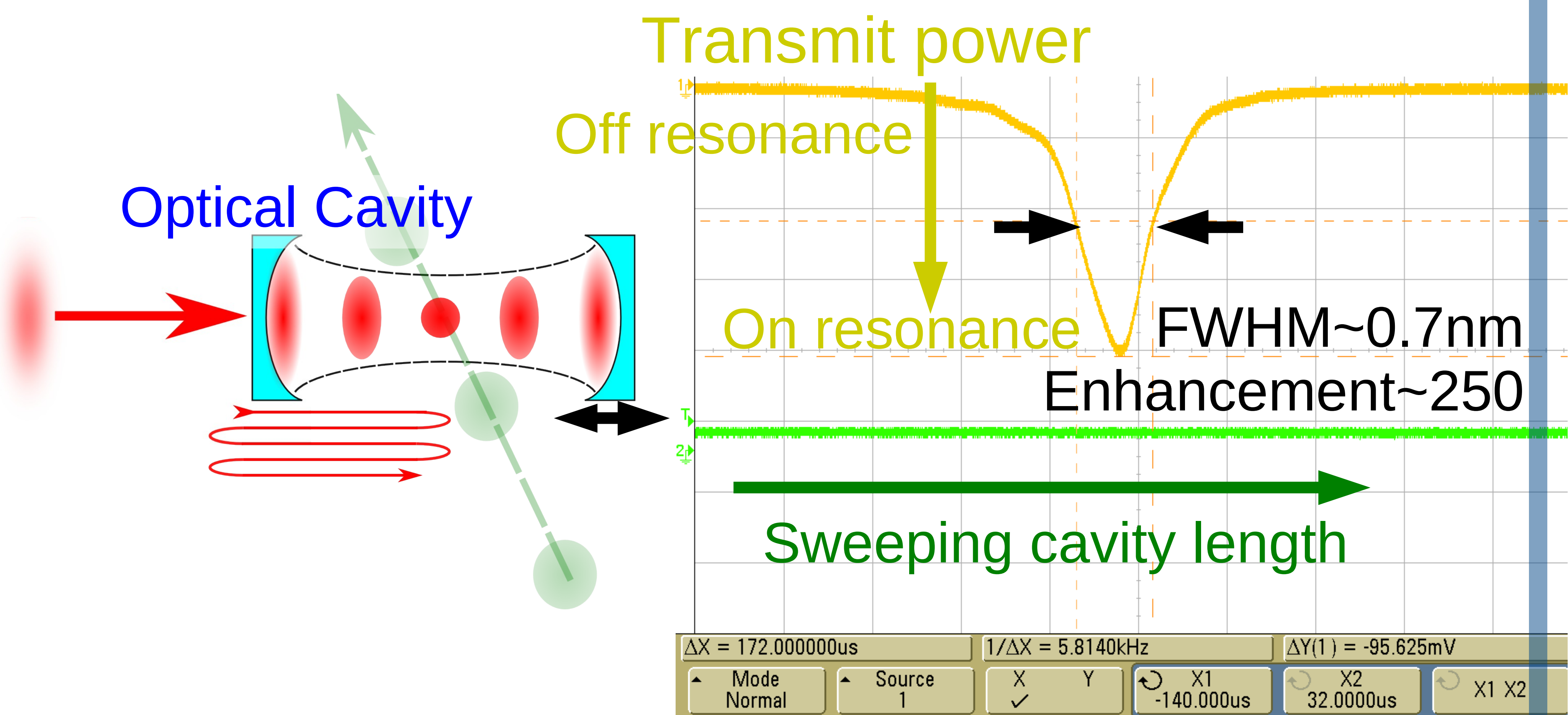
n,m: integer



In our setup, n = 1.

Sweeping Cavity Length

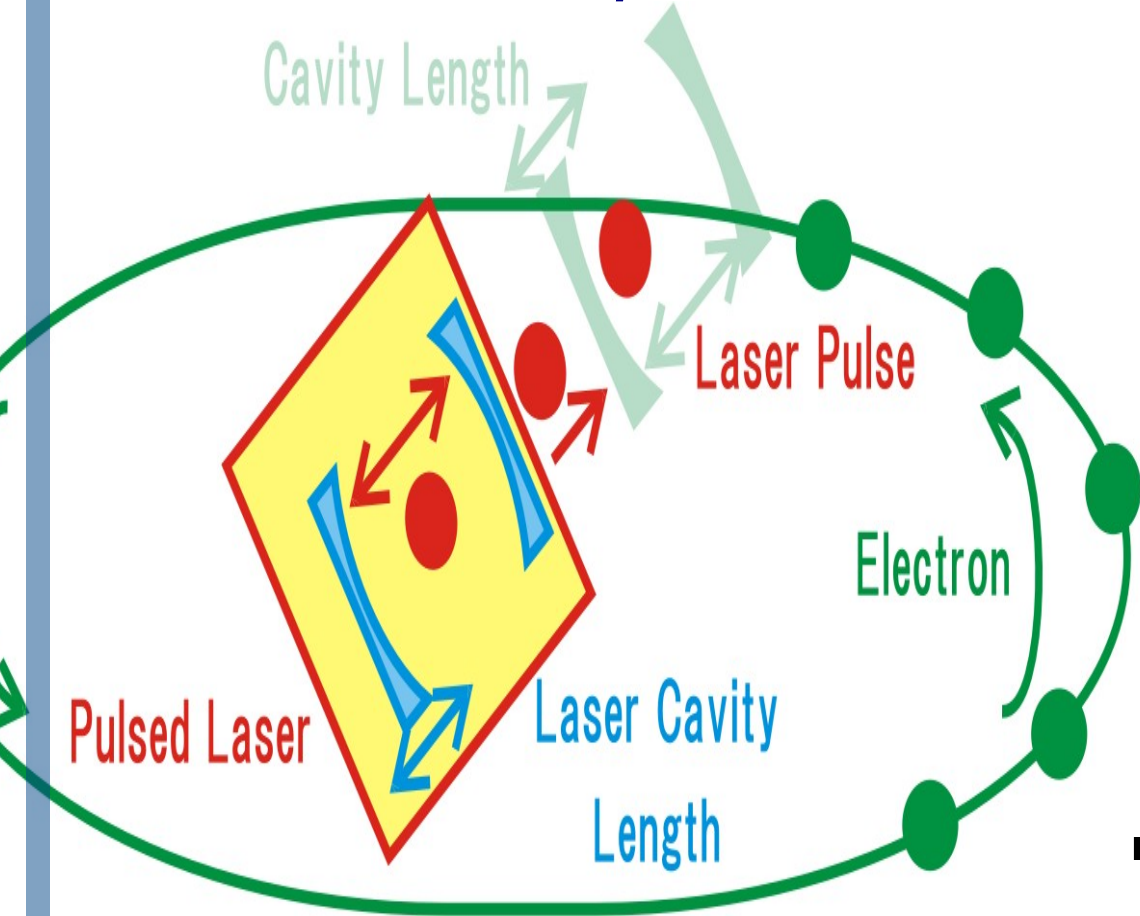
- **Stacking laser pulses in optical cavity**
  Transmitted power peaks on resonance

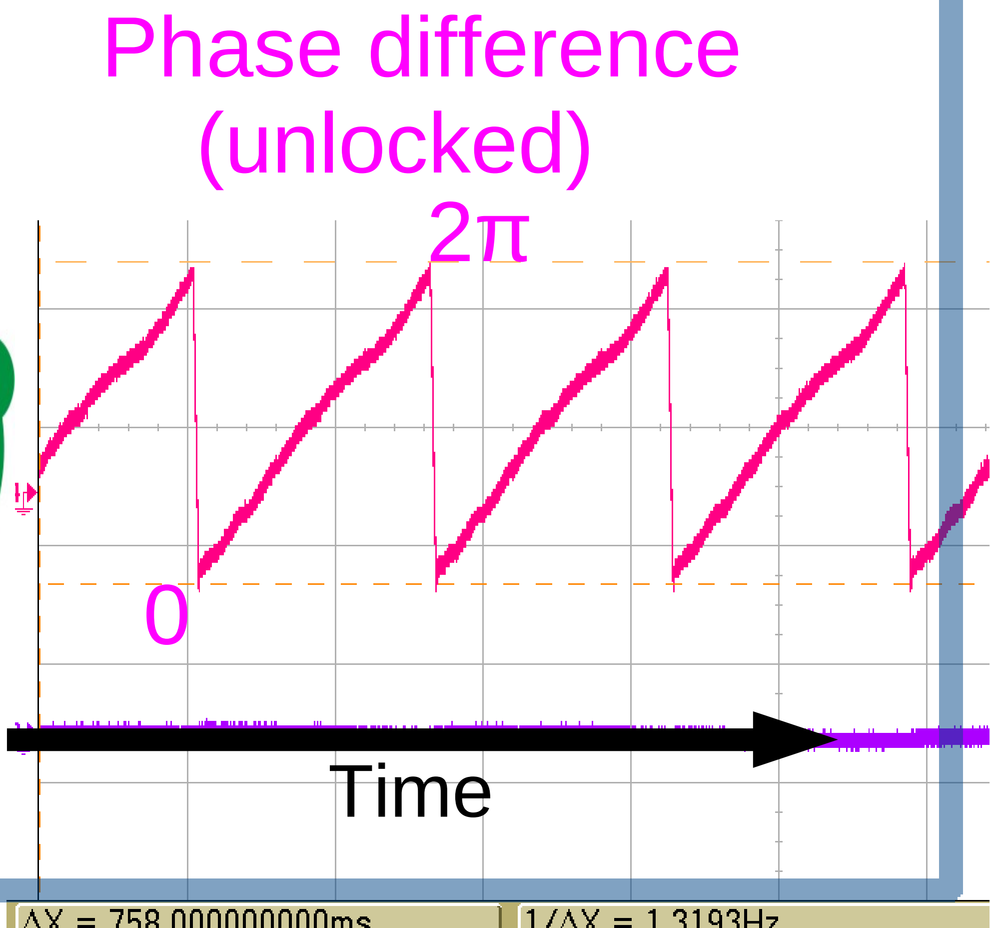


Timing Control electron and Laser

- **Locking electron and laser timing**

Acc. RF osc. phase **-** *Laser osc. phase* **=** *Const.*





Status before Summer 2008

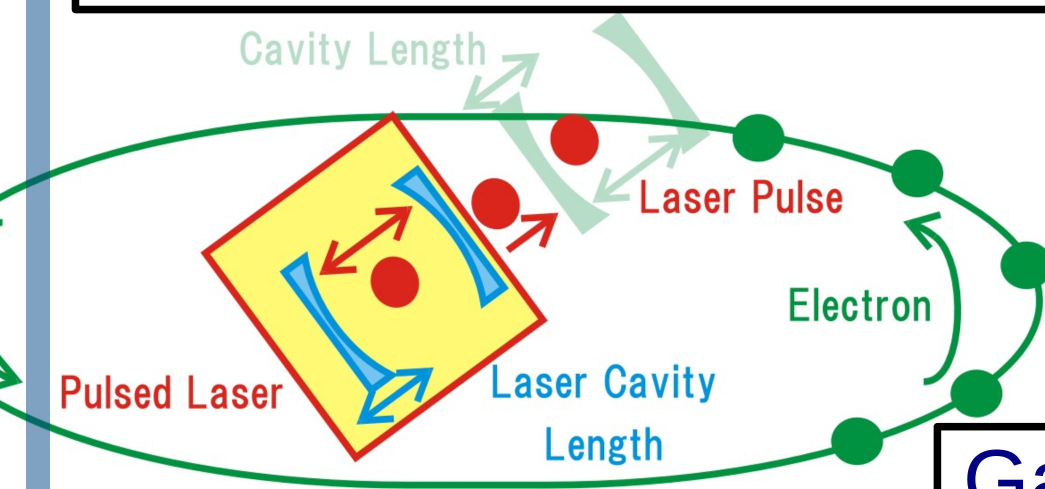
Dr. Shimizu & Mr. Ushio & Miyoshi reported status of experiment at PosiPol2008 June.

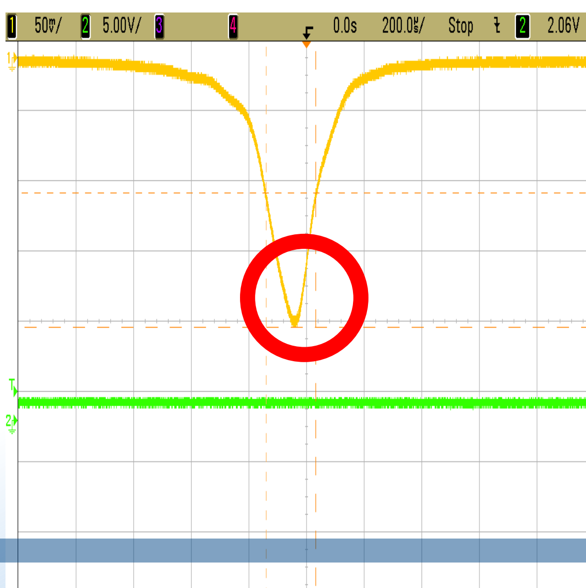
We were not able to keep cavity on resonance.
➡ We swept cavity length.
Only picked up data when cavity resonate.

Revolution of electron beam

Resonance of cavity

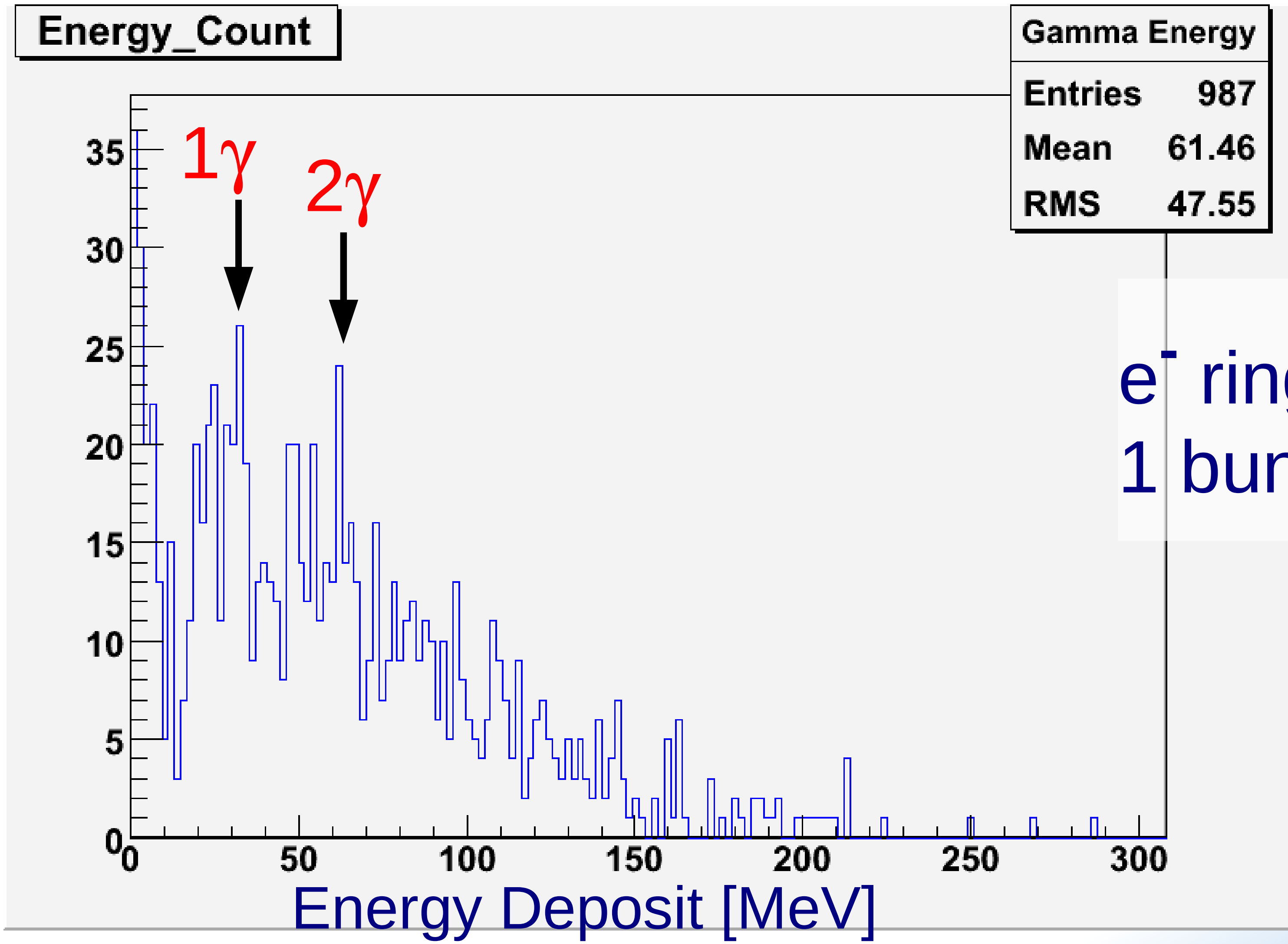
Gate Open





Data Presented at PosiPol 2008

We detected 3.3 gamma-rays / train.

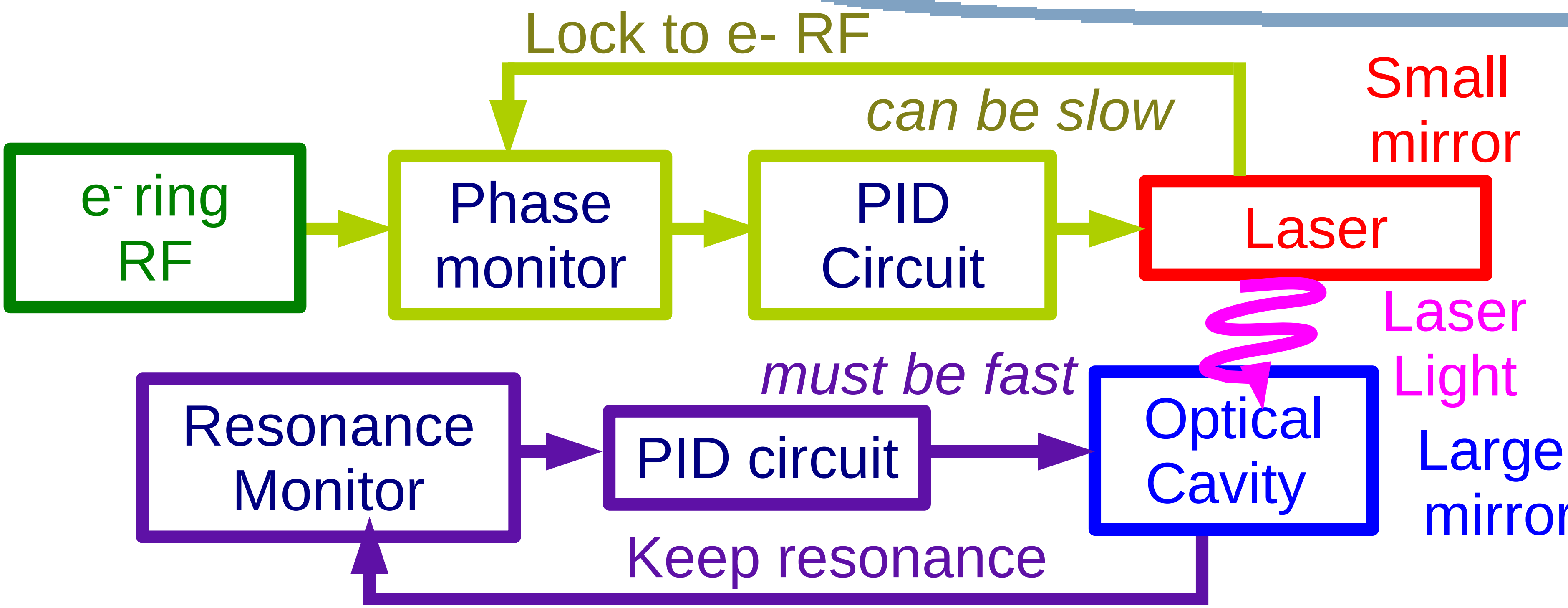


e⁻ ring opr. mode
1 bunch / train

After PosiPol 2008

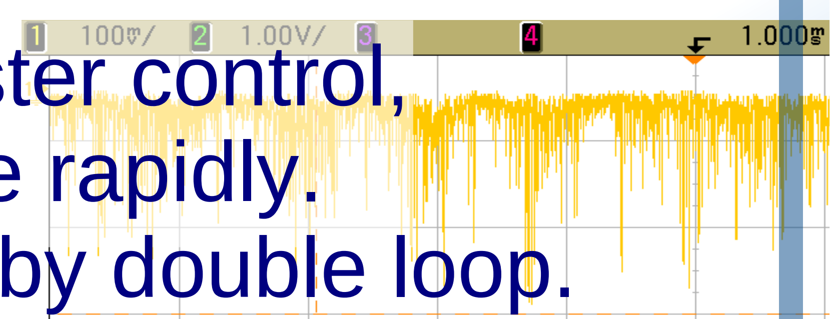
After PosiPol 2008,
we improved control system
for keeping resonance of cavity & locking timing.

Control Sys. before Summer 2008

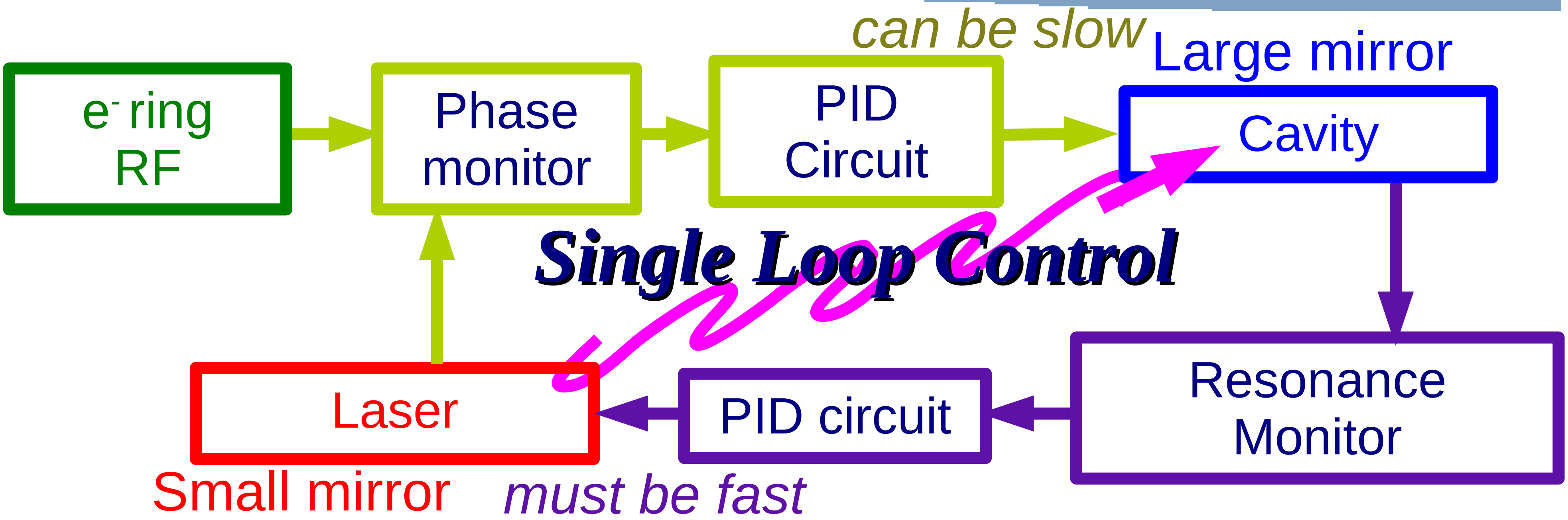


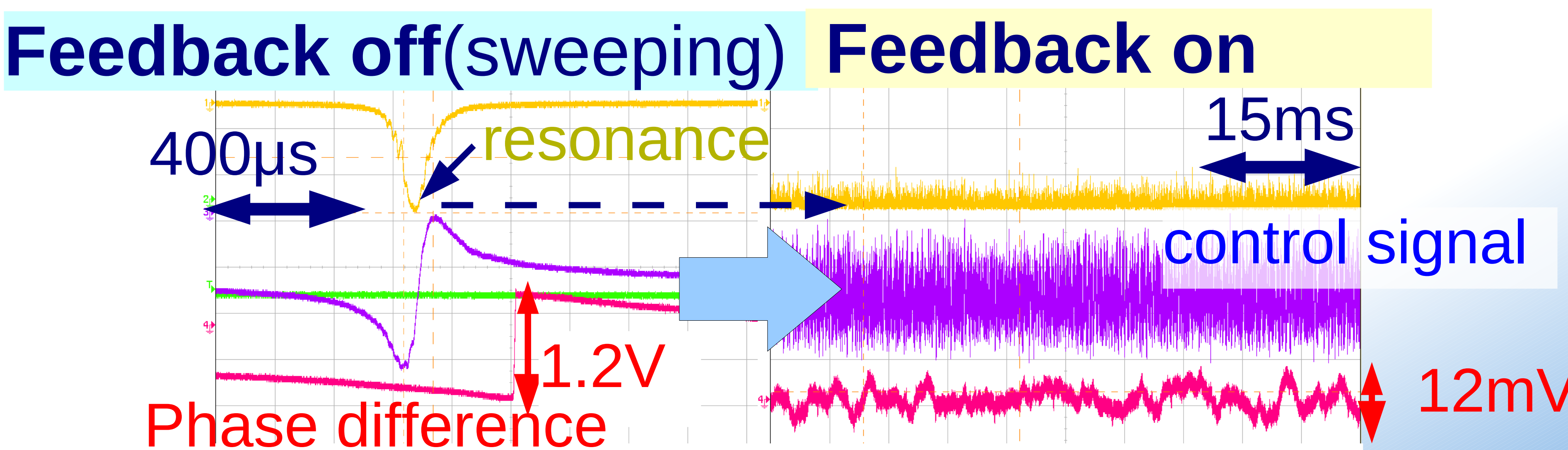
- Keeping resonance needs faster control, but cavity length don't change rapidly.
- 2 component were controlled by double loop.

  ⇨ We can not keep resonance.

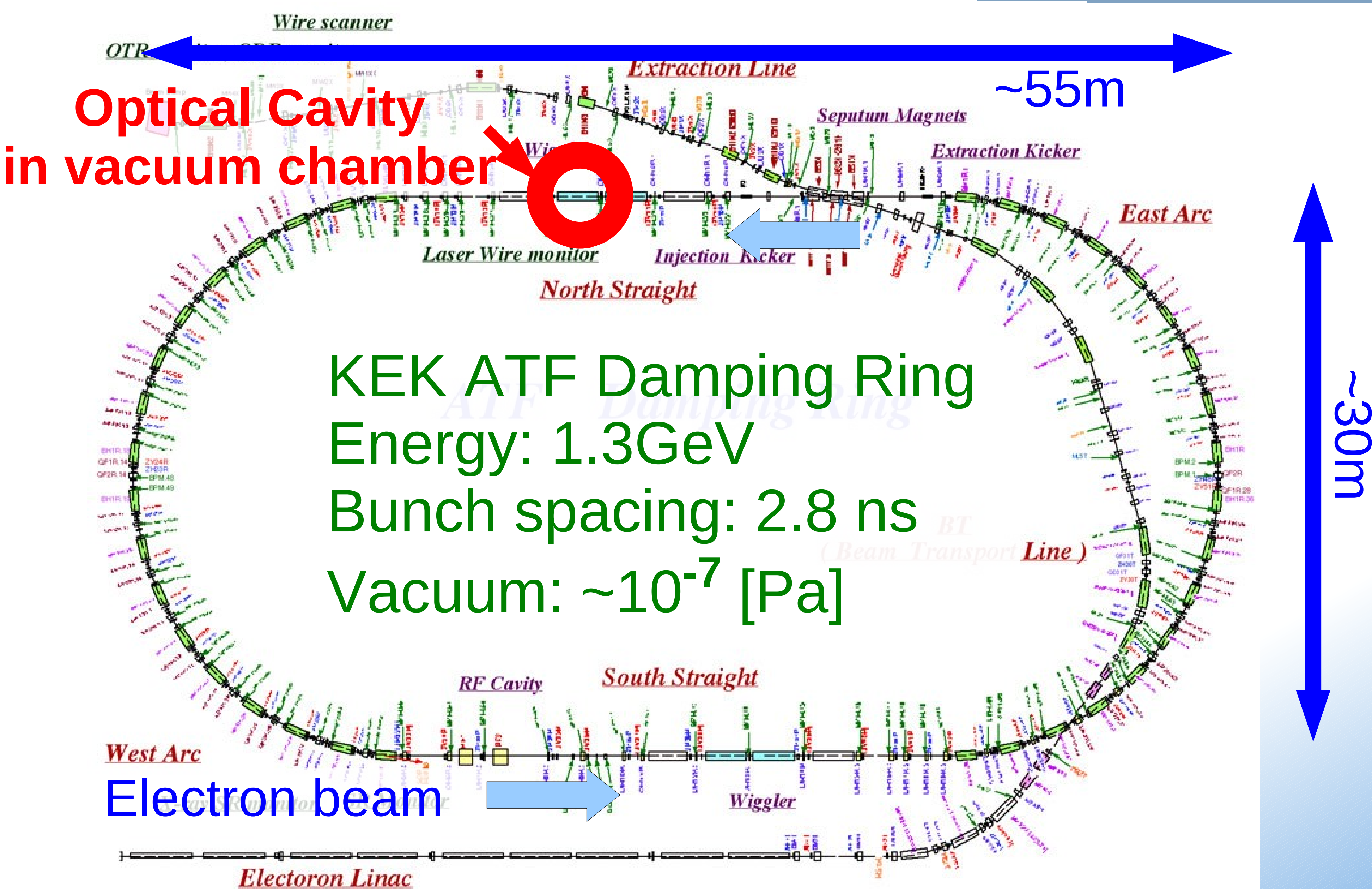


Improved Control System





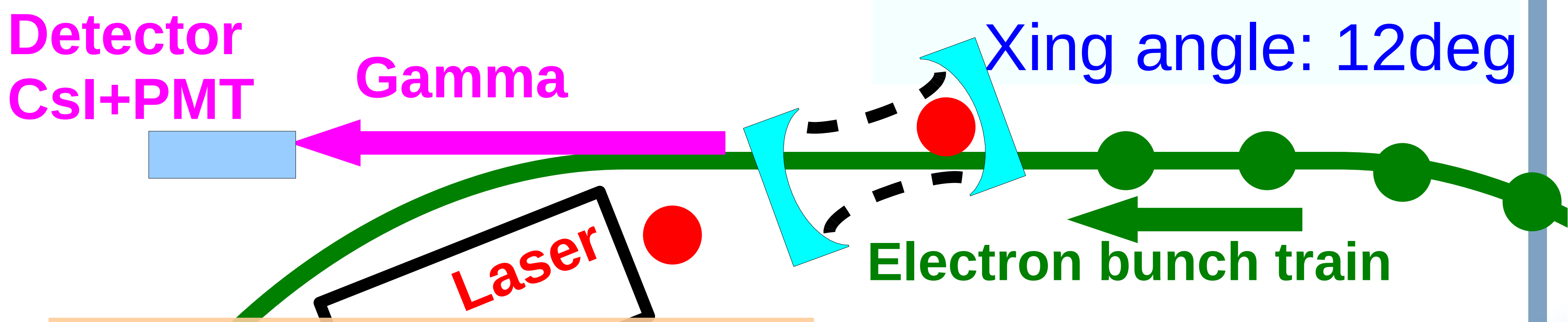
Experiment at KEK-ATF



Experimental Setup

Gamma Ray **in 0.26mrad**
Energy: 19~28MeV
Average: 24MeV

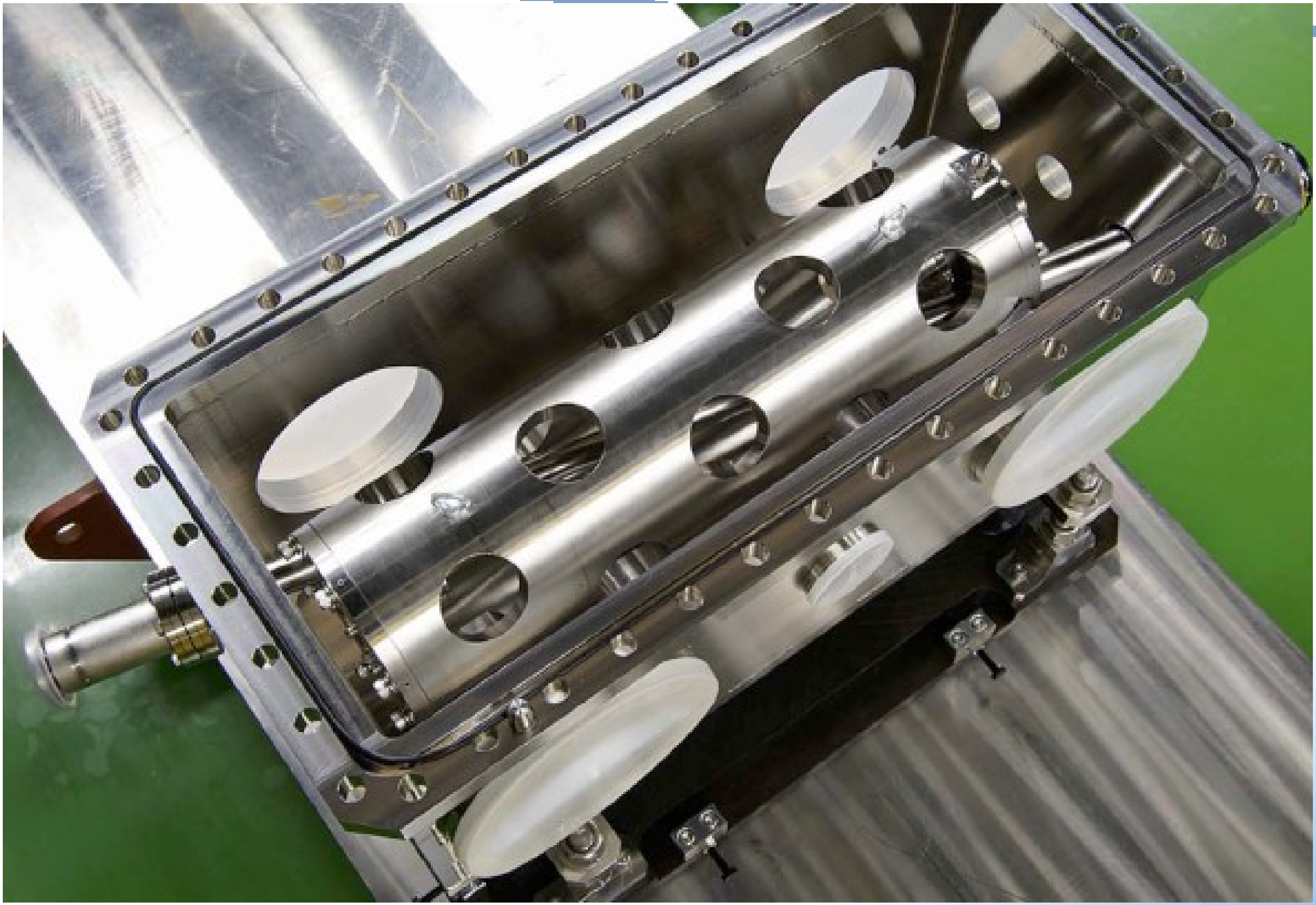
Optical Cavity
Cavity length: 420mm
Waist size(σ): 30μm
Enhancement: 250
Xing angle: 12deg



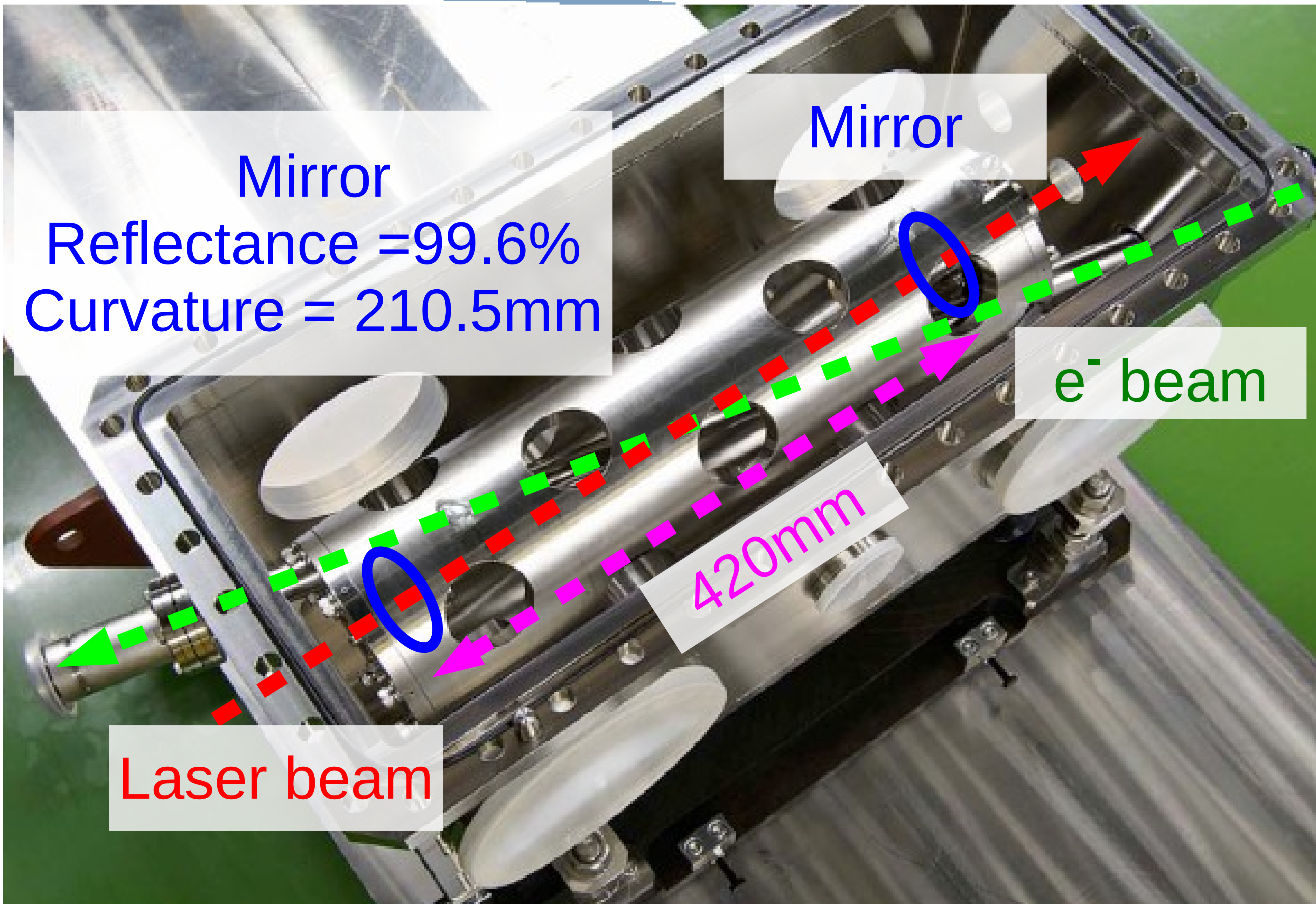
Laser Pulse
Wave Length: 1064nm
Pulse Spacing: 2.8ns
Power: 10W (28nJ/pulse)
Pulse Width(σ): 5ps

Electron **at Interaction Point**
Bunch length(σ): 25ps
Beam size H×V(σ):
170μm×12μm

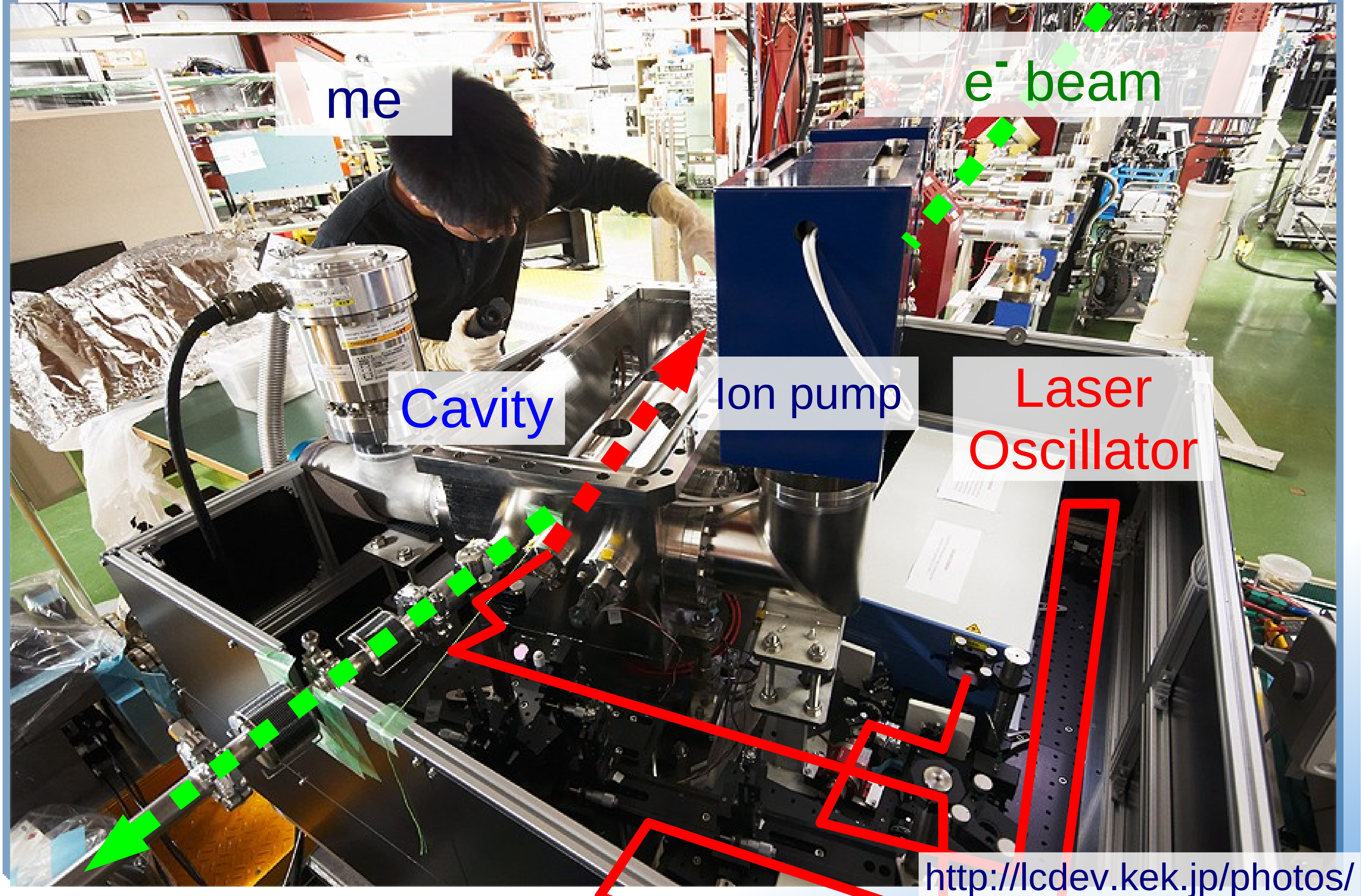
Optical Cavity



Optical Cavity

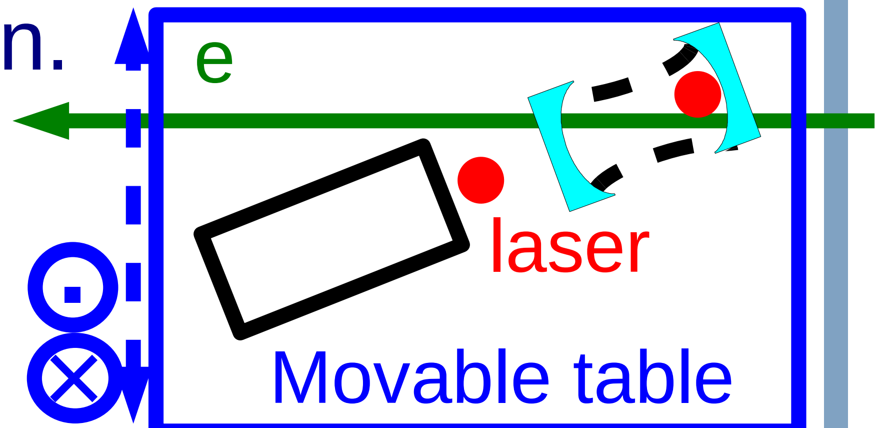


Experimental Apparatus

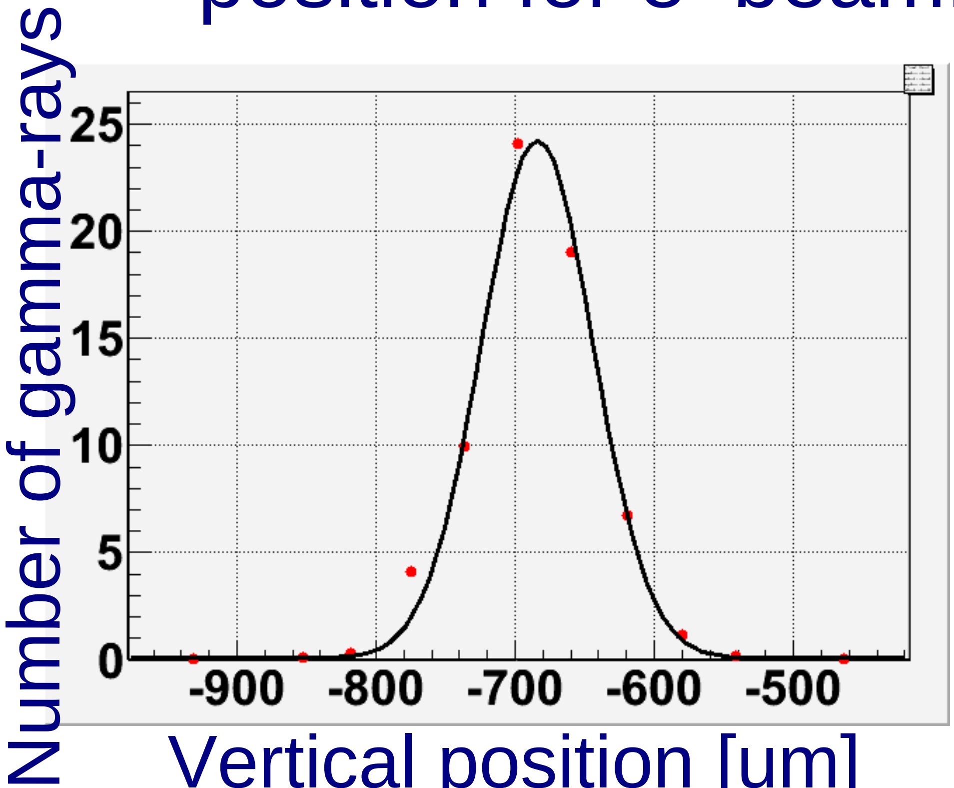


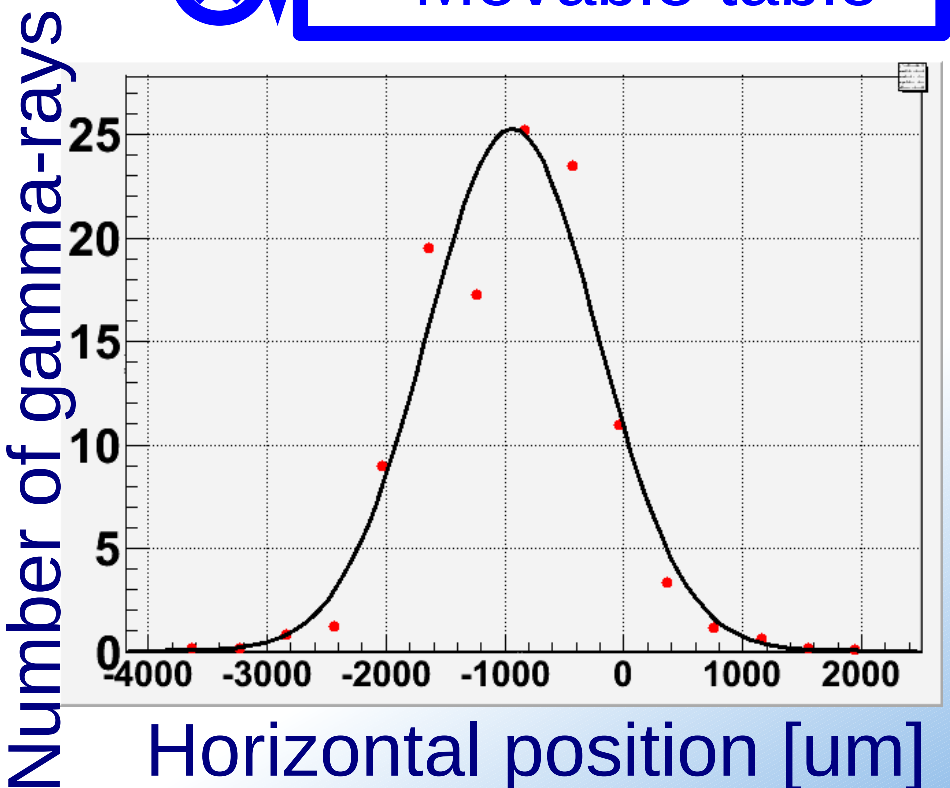
Find Optimum Position

First, scanning cavity position.



➡ Find optimum transverse position for e⁻ beam.

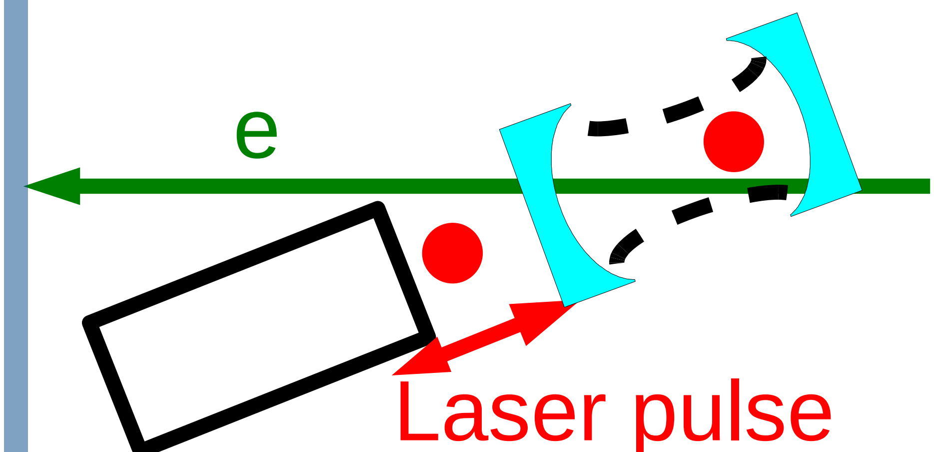


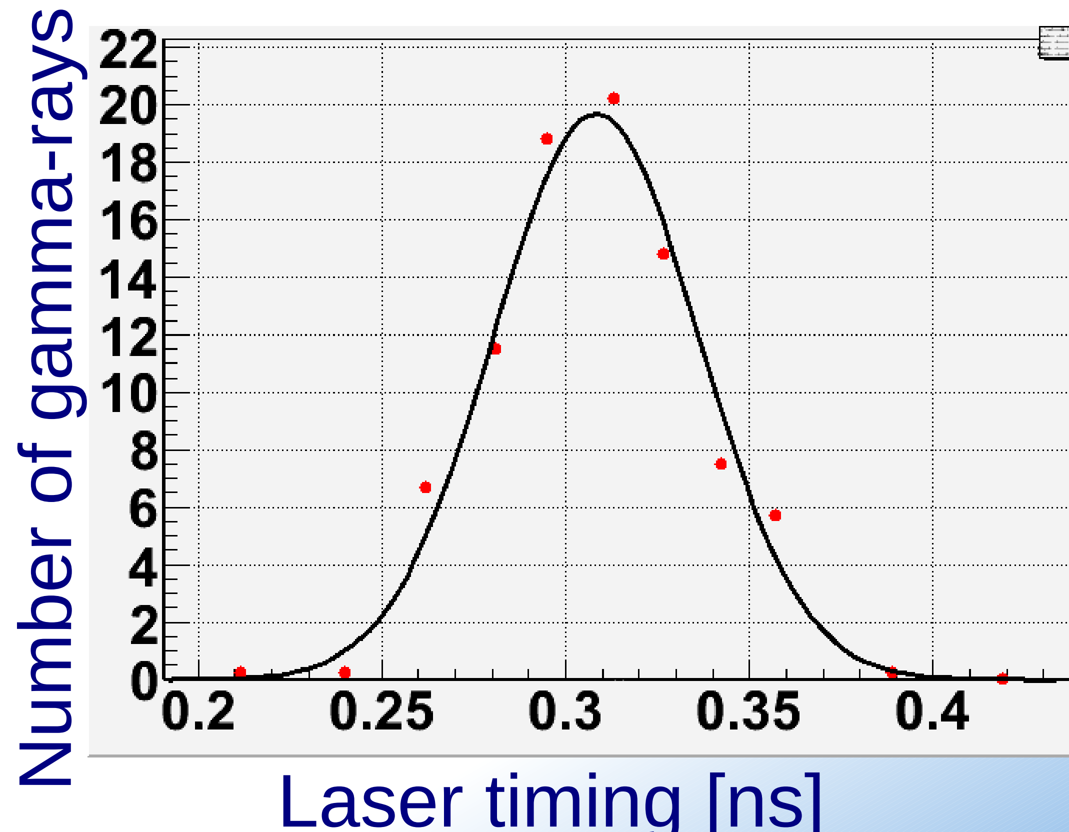


Find Optimum Timing

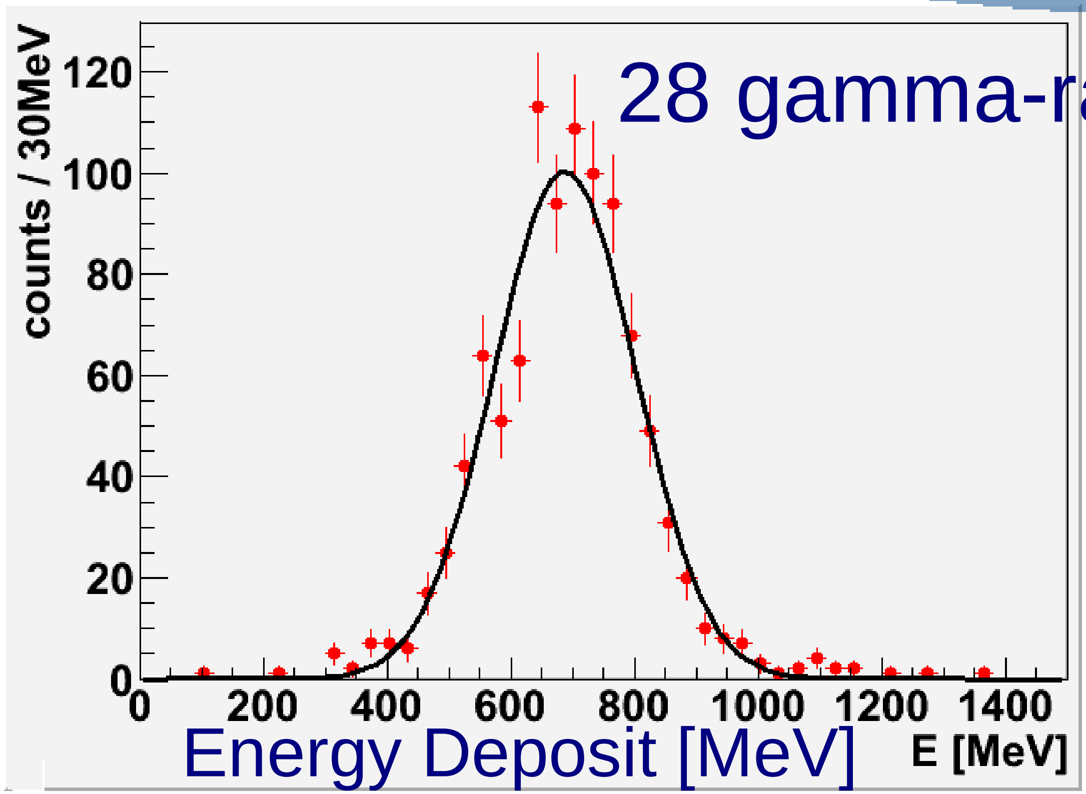
Next, scanning laser pulse timing.

→ find optimum timing position for e⁻ beam





Observed Gamma-ray Spectrum



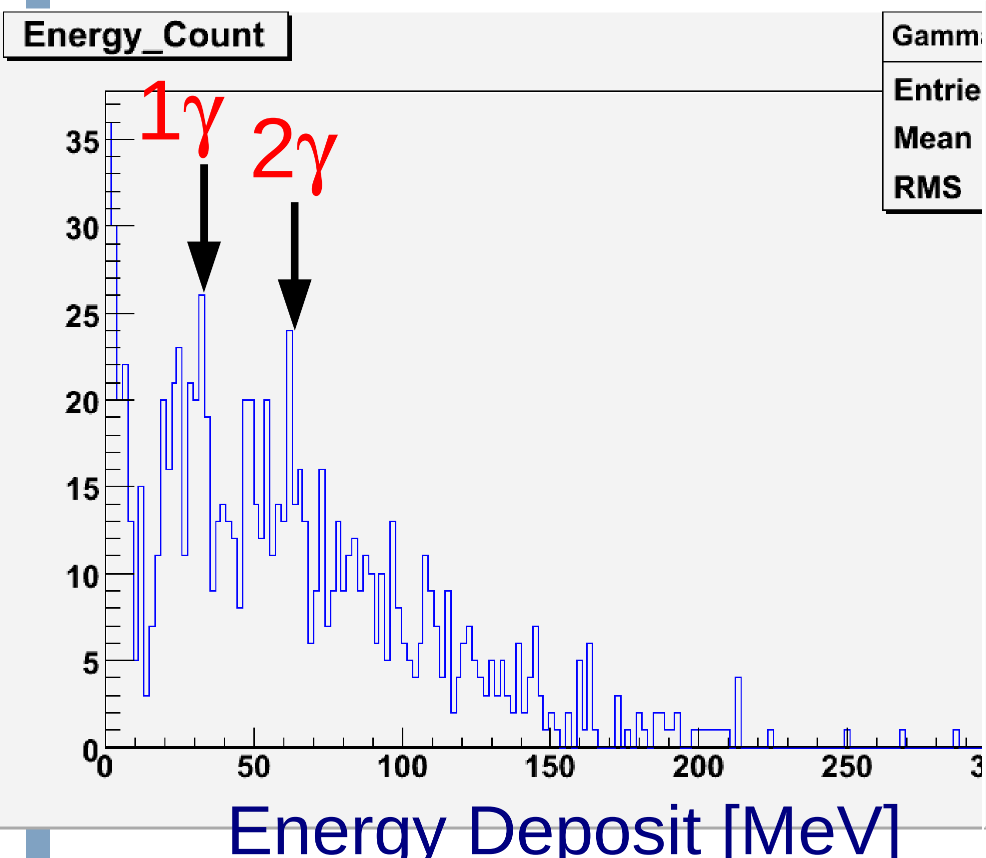
e- ring opr. mode
20 bunches / train

We observed 28.1±0.1 gamma-rays / train.
All solid angle → 60 gamma-rays / train

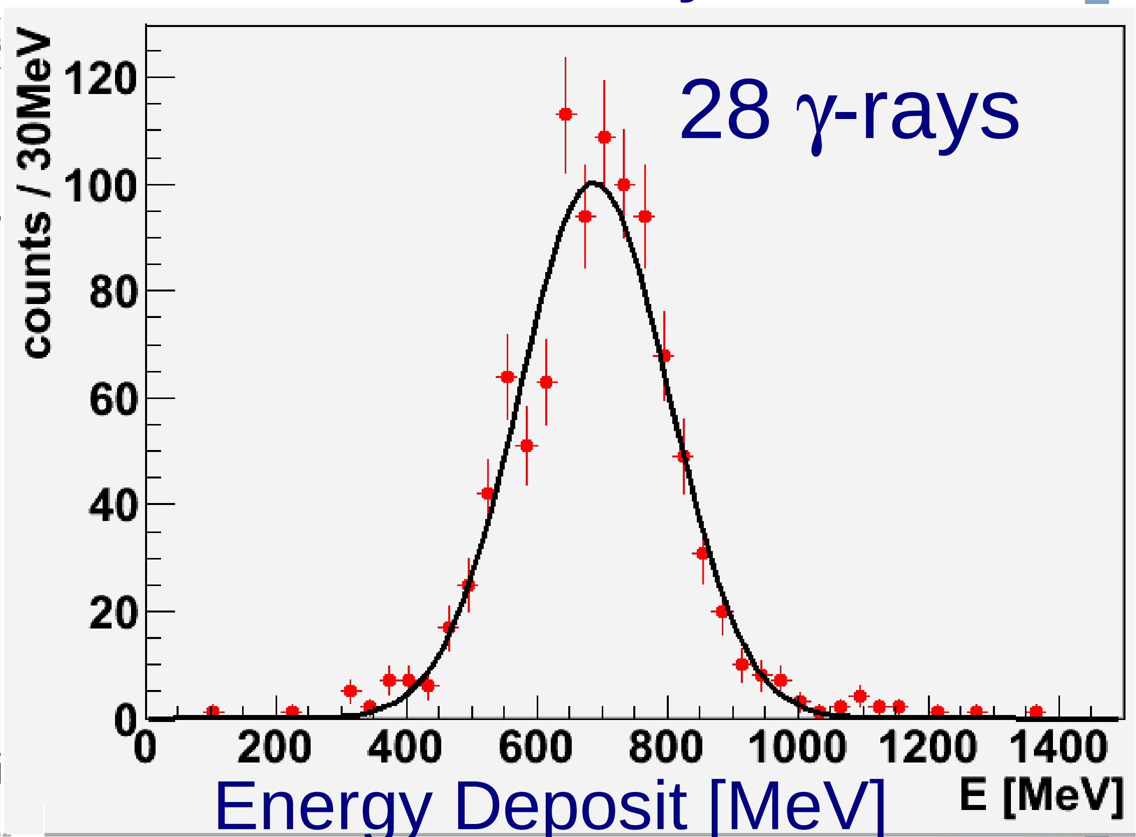
→ 60×2.16MHz ~ 1.2 × 10^8 [gamma / second]
Revolution

Comparison of Last Year & Today

PosiPol **2008**



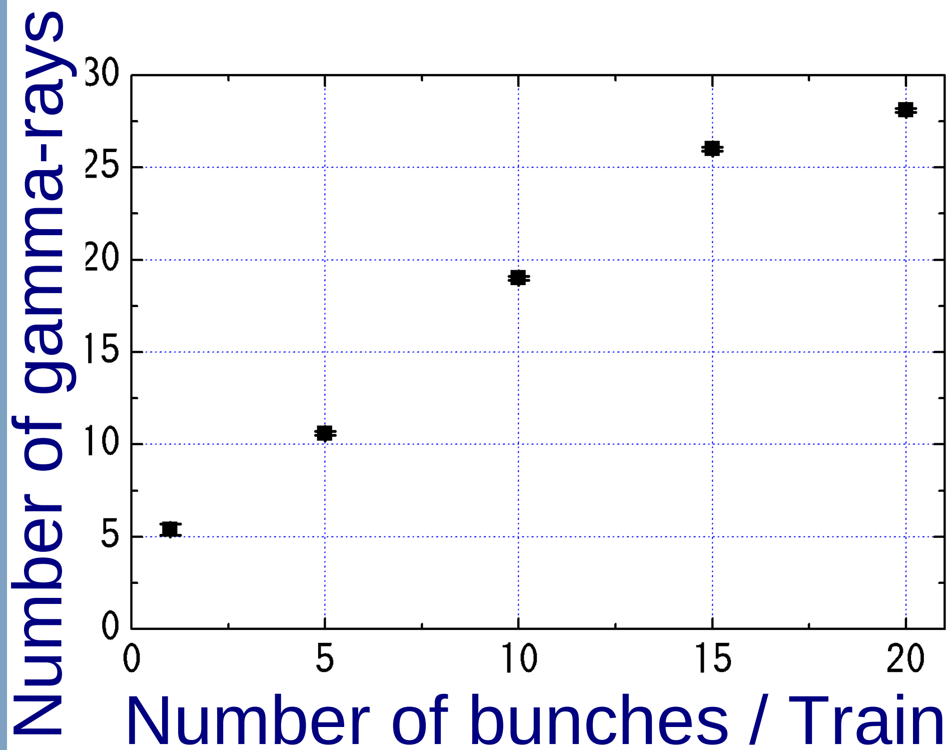
Today

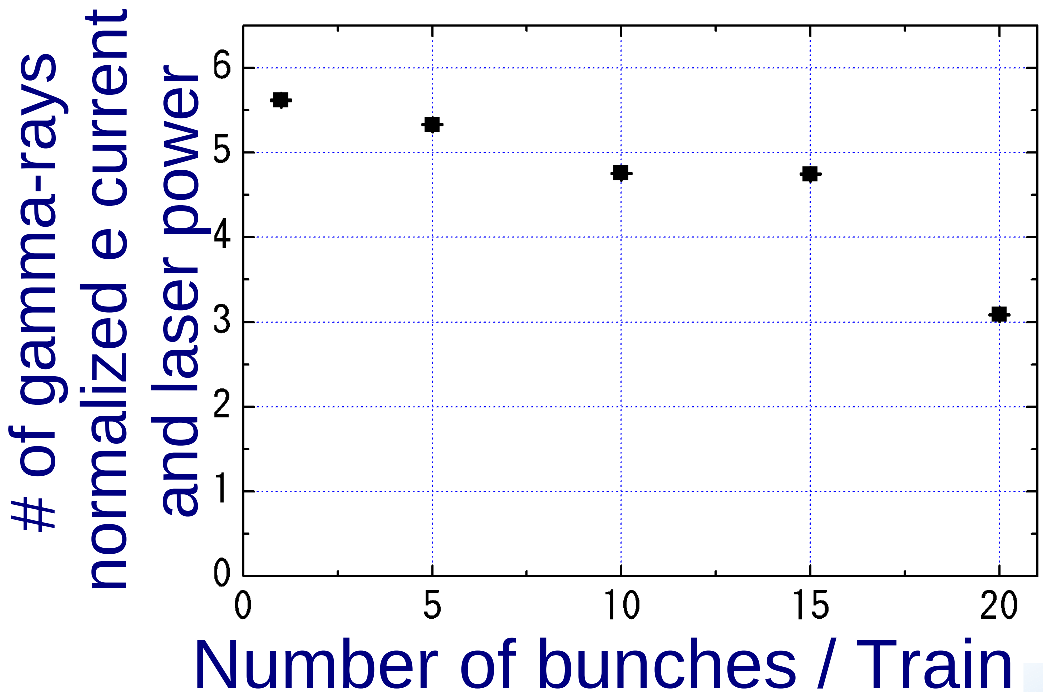


The number of gamma-rays increased by a factor of seven.

Gamma-ray Yield *vs* # of Bunches

We take data with 1, 5, 10, 15, 20 bunch operation.





Number of gamma-rays

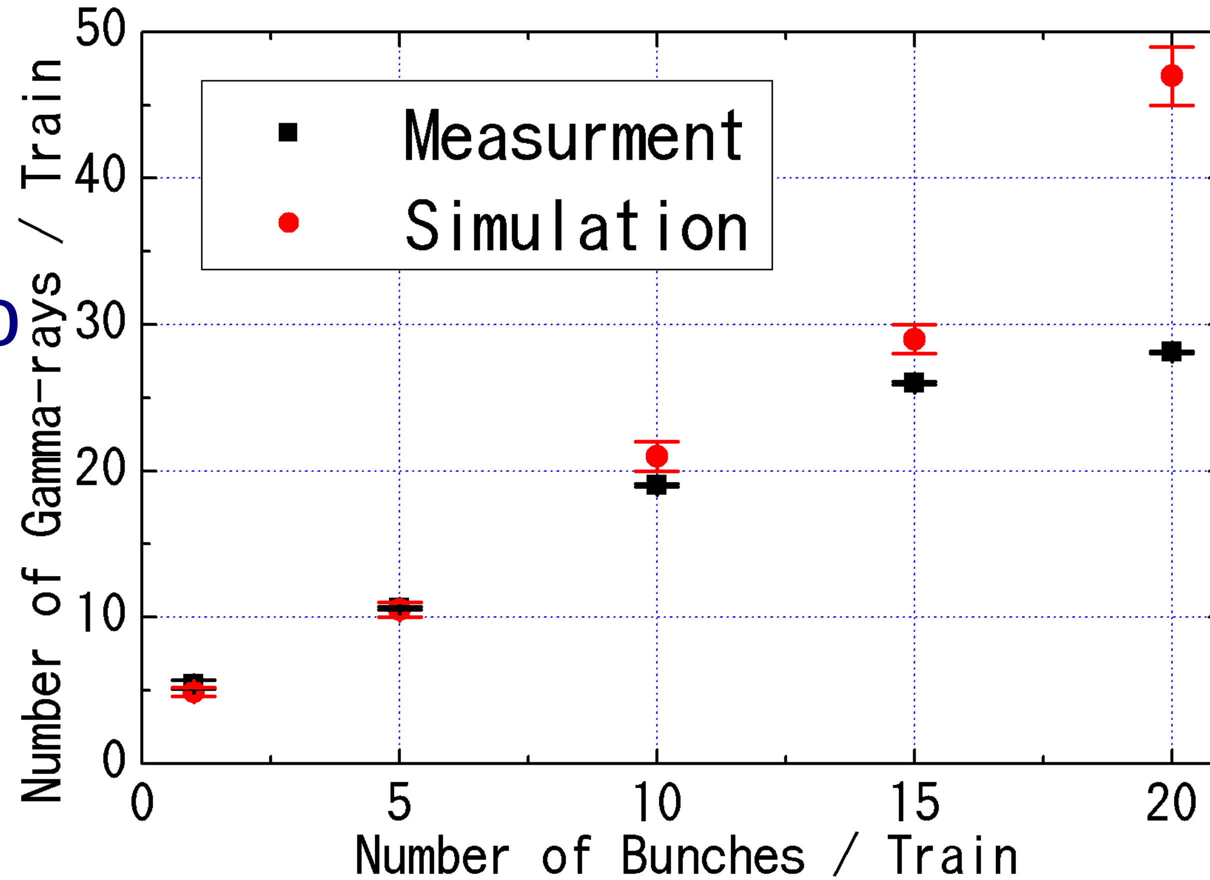
NOT proportional

Normalized number of gamma-rays

NOT constant

Compare with Simulation

Simulation taken into account beam size and current.



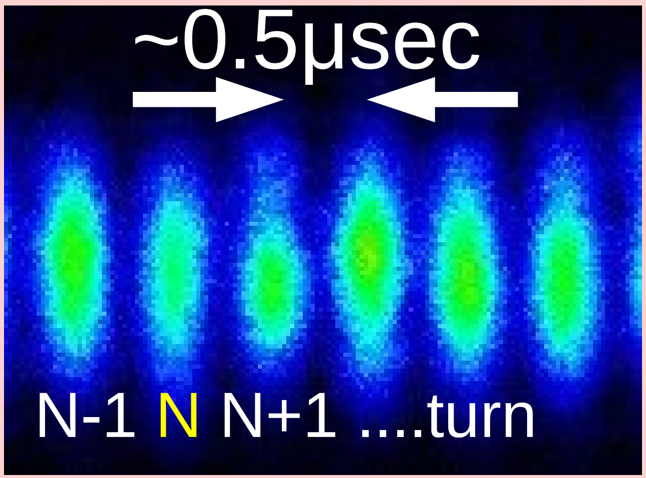
Comparison

small bunches / train → consistent

large bunches / train → deviation

Bunch Oscillation

Revolution



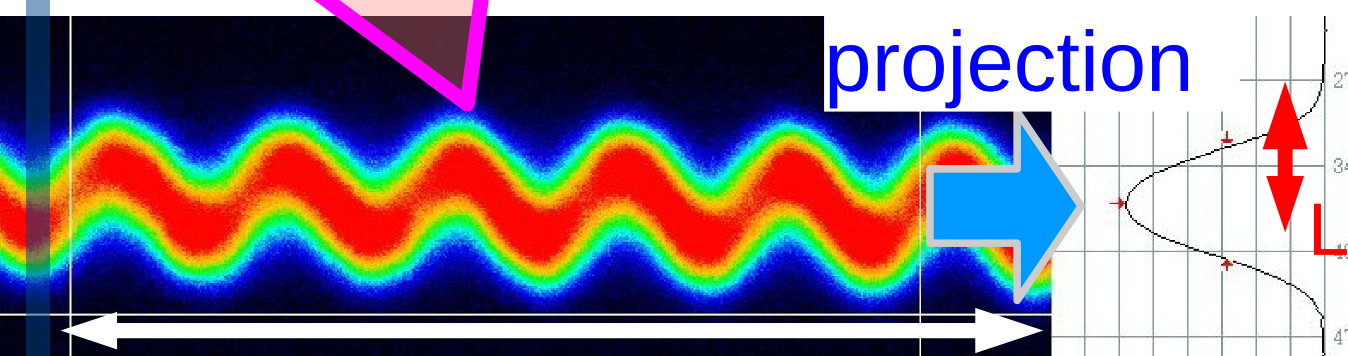
Bunch length

turn

We suspected the deviation may be due to synchrotron oscillation.

We measured convoluted bunch length by streak camera.

projection



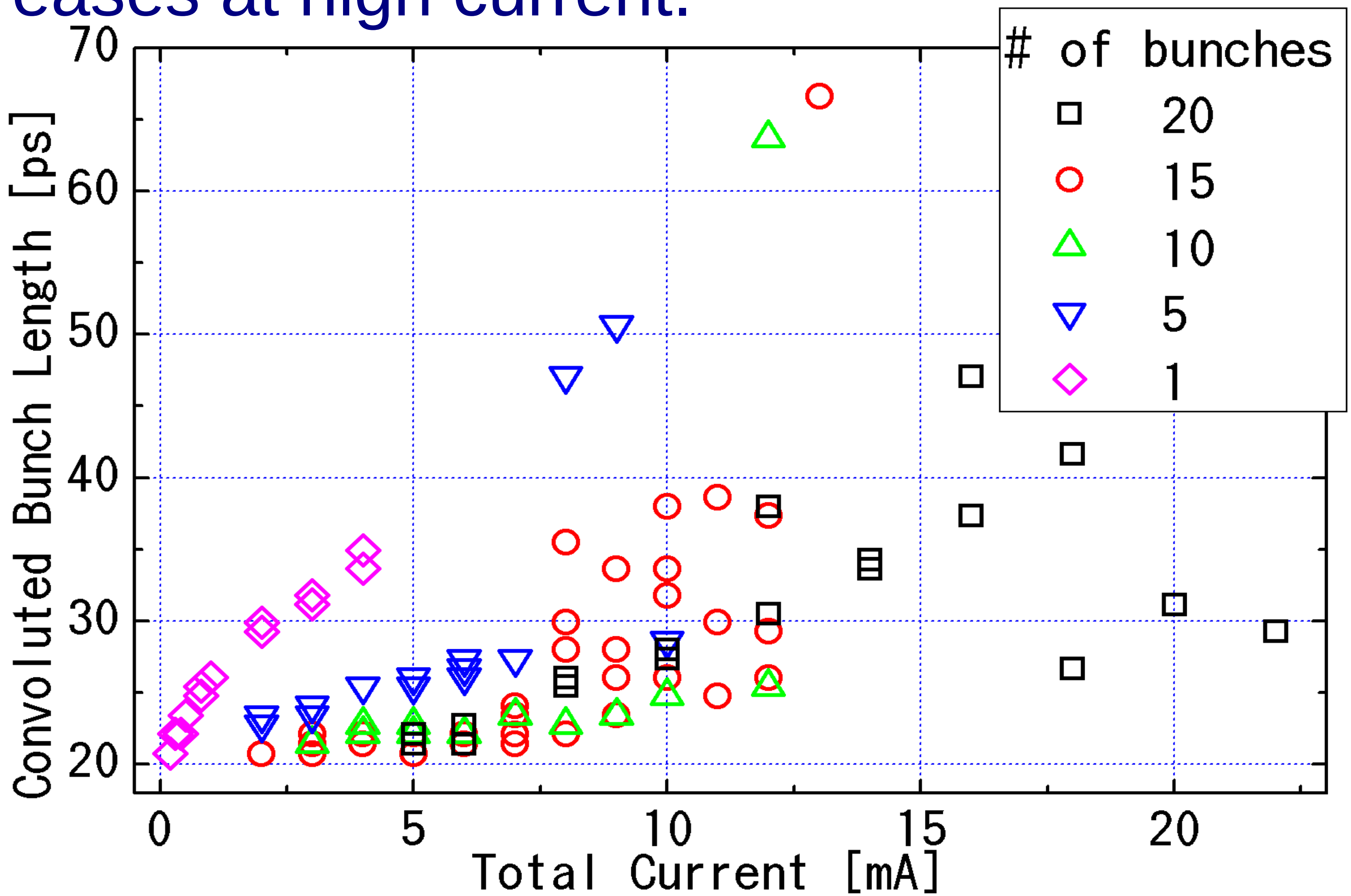
~500μsec

Bunch length
+
Longitudinal oscillation

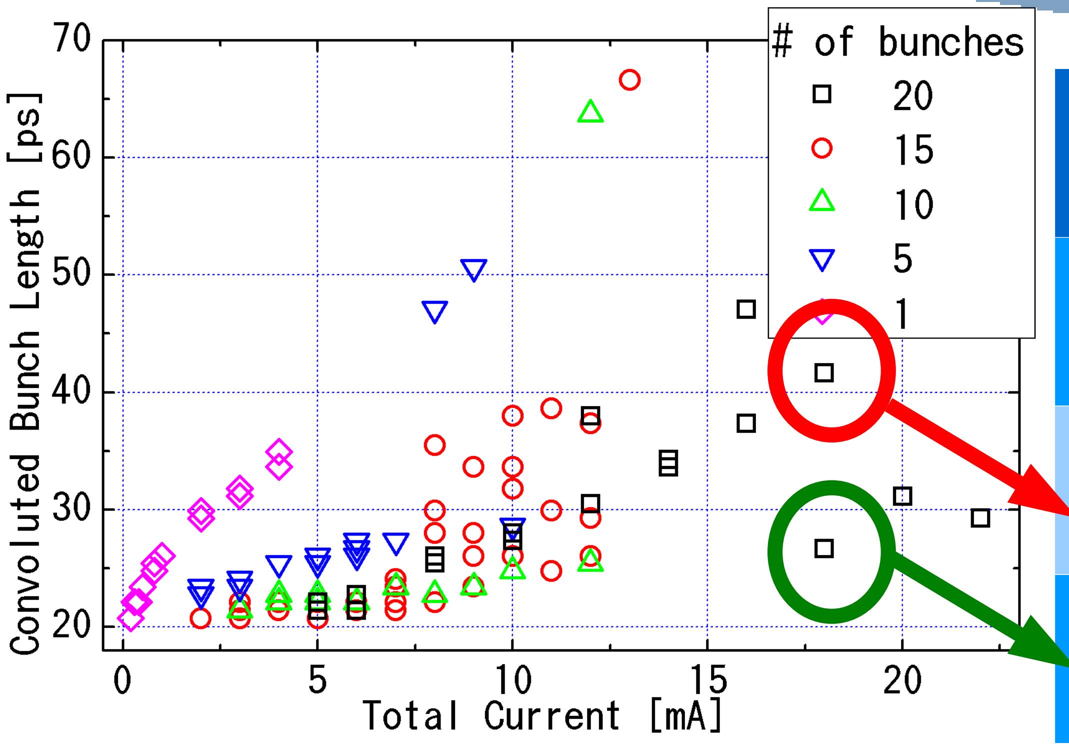
"Convoluted bunch length"

Convoluted Bunch Length *vs* Current

We observe convoluted bunch length increases at high current.



Simulation by Measurement Length



	Number of gamma-rays
Measurement	28.1±0.1
Simulate with 43.3ps	29±1
Simulate with 25ps	47±2

Measurement number of gamma-rays might be in the range of the observed convoluted bunch length.

⇒ But condition of convoluted bunch length changes at each injection and revolution.

Summary

- Laser power was enhanced up to 250.
- We achieved to keep cavity on resonance & timing synchronization.
- We observed 28.1±0.1 gamma-rays / 20 bunches.

  All solid angle ⇨ 60 gamma-rays / 20 bunches

  ⇨ 1.2×10^{8} gamma-rays / **sec**

Next Plan:

★Enhancement factor of optical cavity: 250 ⇨ 1000

Gamma yield will quadruple.

It needs more precise control: 0.7nm ⇨ 0.1nm

That's it

Thank you for your attention.

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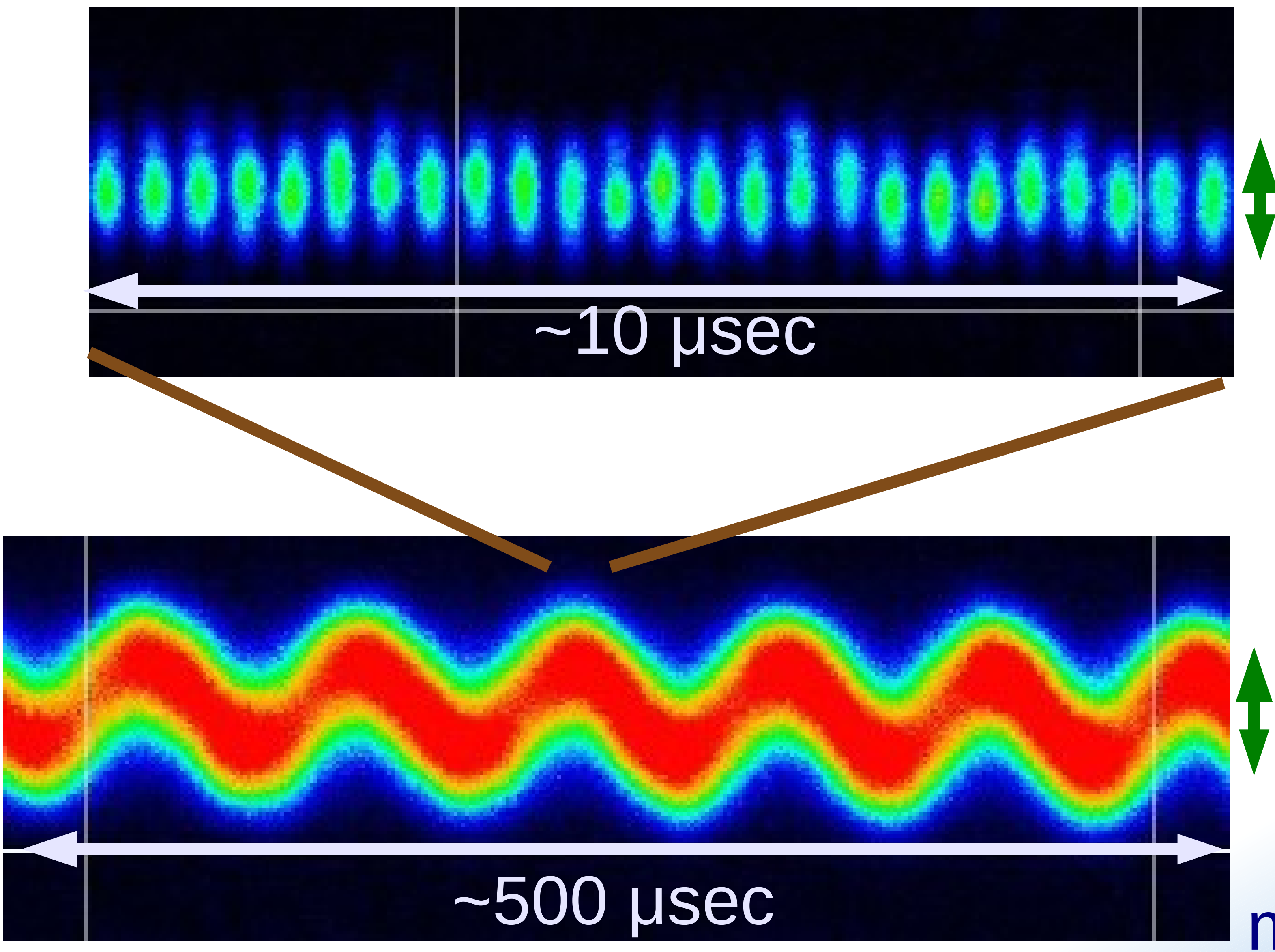
Table

# of bunches	e^- current [mA]	staking laser power [W]	detected gamma [1/train]	simulation [1/train]
1	2.2	437±2	5.4±0.3	4.9±0.3
5	4.7	423±2	10.6±0.1	10.5±0.5
10	8.5	470±2	19.0±0.1	21±1
15	11	498±2	26.0±0.1	29±1
20	18.5	492±2	28.1±0.1	47±2

Bunch Oscillation



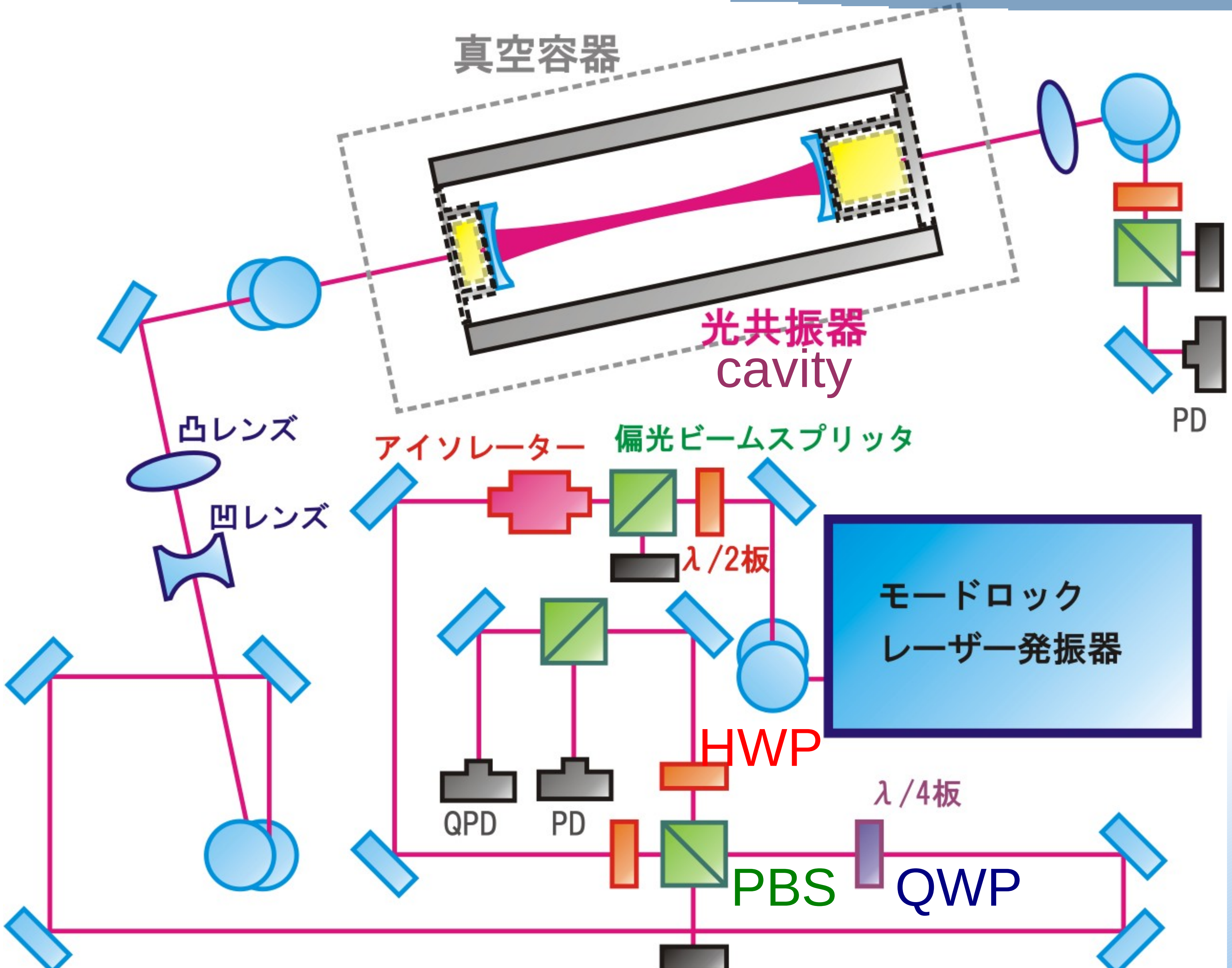
60 psec

100 psec

V axis means time

H axis means space

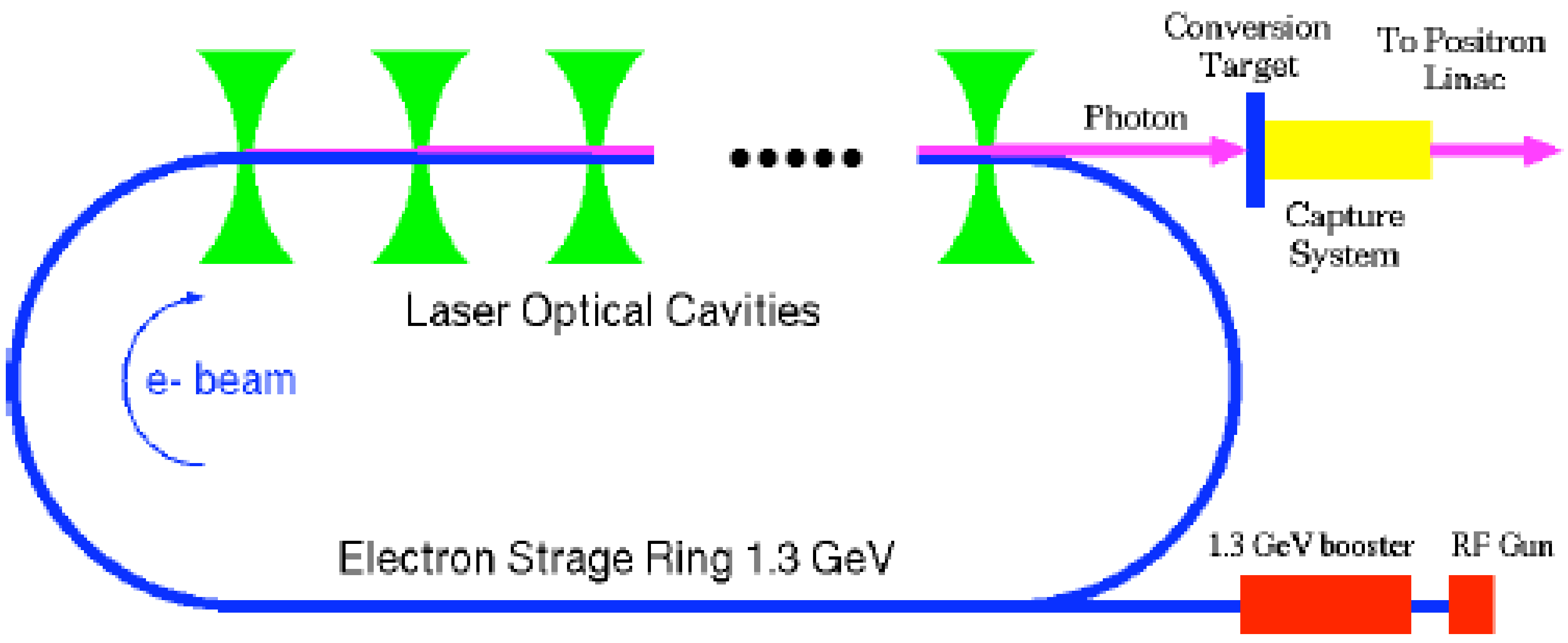
Optics



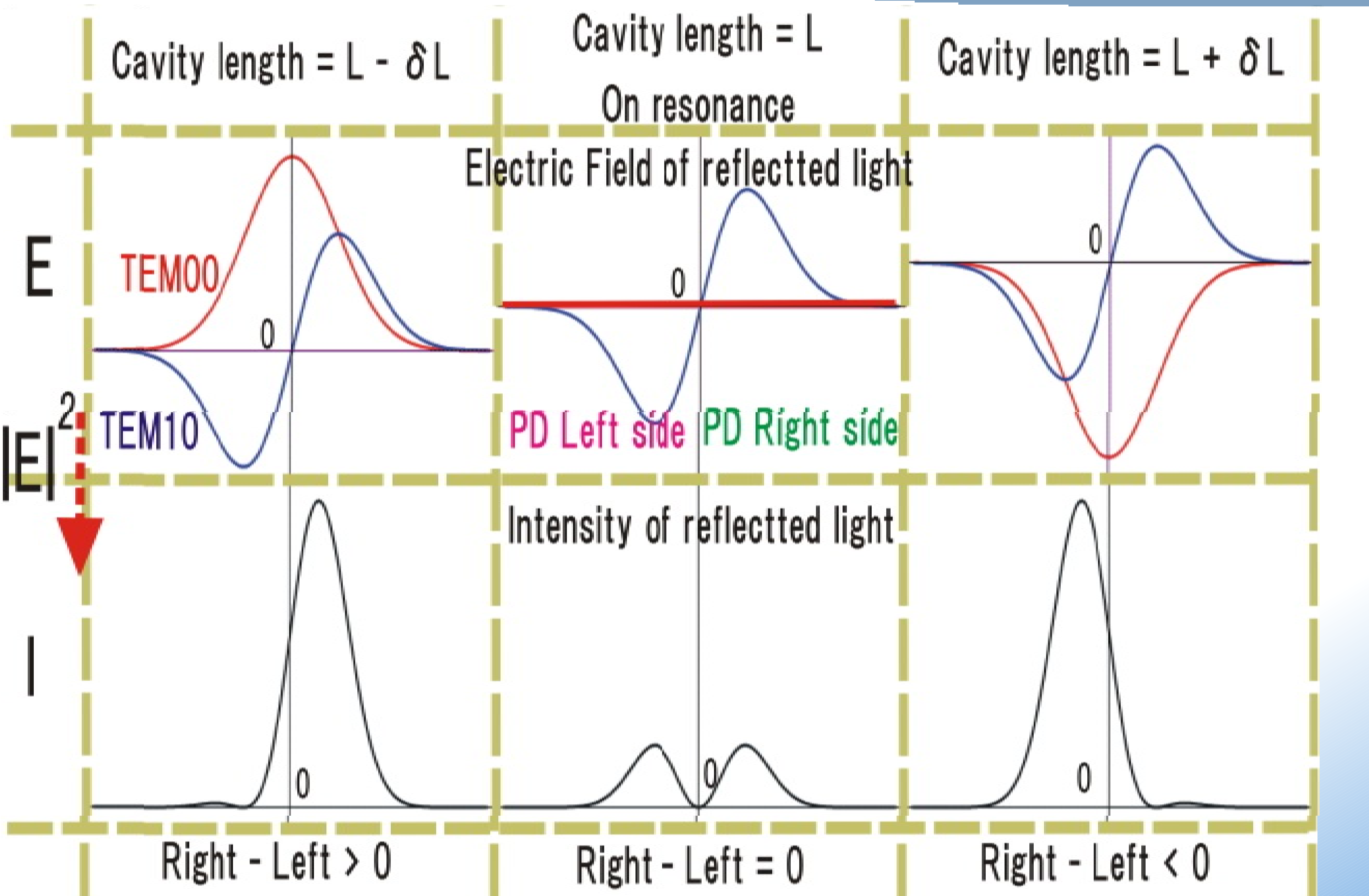
真空容器
光共振器
cavity
PD
凸レンズ
凹レンズ
アイソレーター
偏光ビームスプリッタ
λ/2板
モードロック
レーザー発振器
HWP
λ/4板
QPD
PD
PBS
QWP

For ILC

Compton ring scheme for ILC



Keeping Resonance

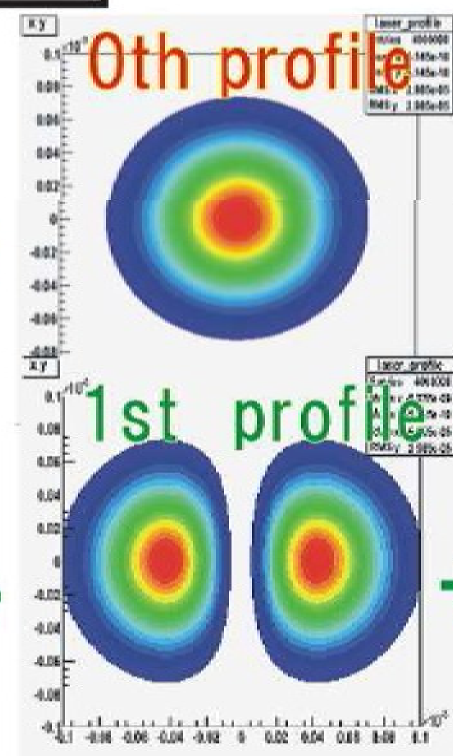


Keeping Resonance

Laser beam axis

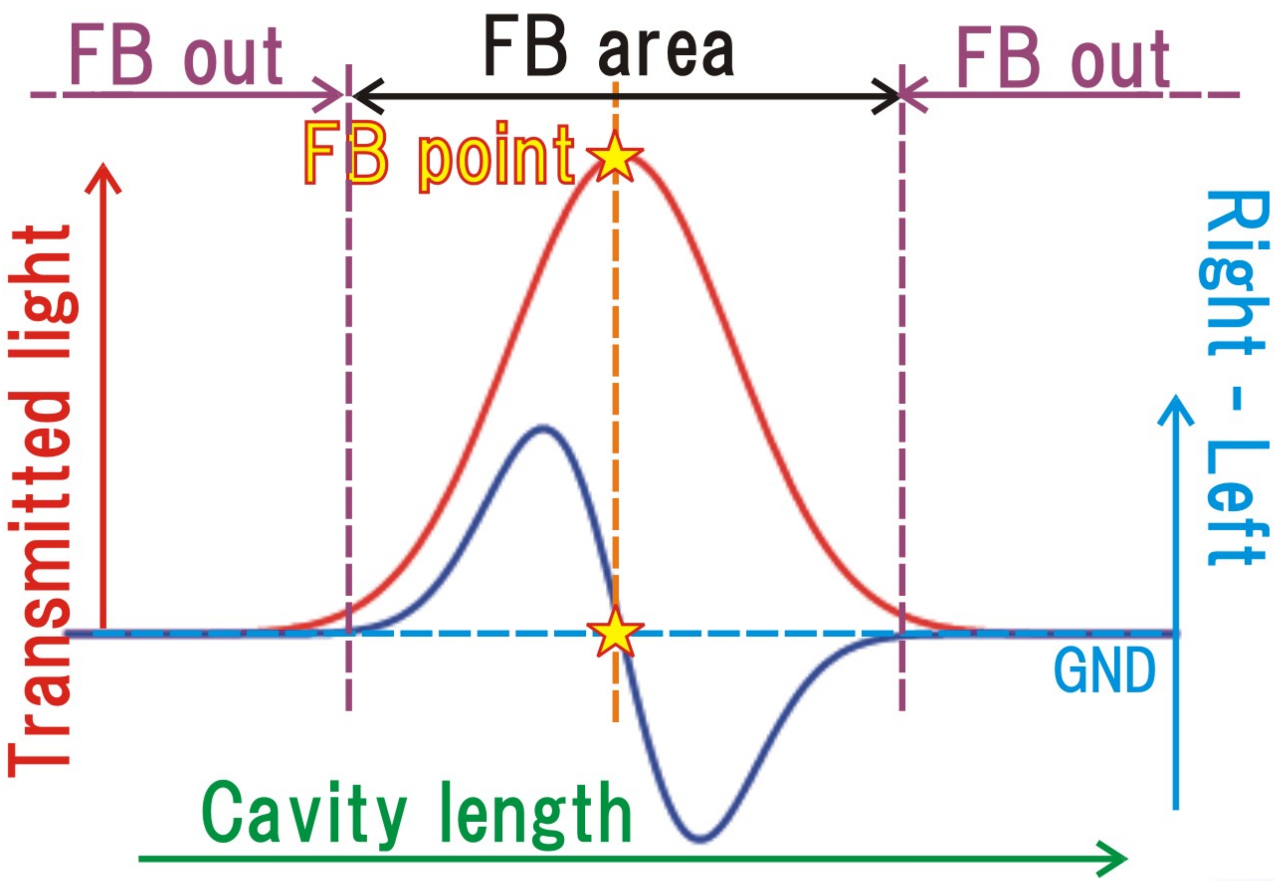
= Cavity axis → Only

Laser beam axis

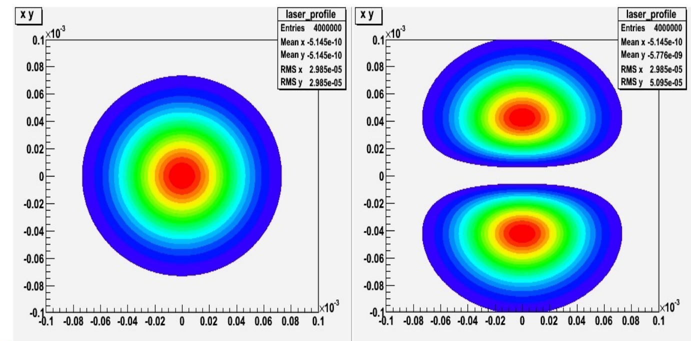
≃ Cavity axis → 0th +  +···

Keeping Resonance

Error signal is made by 0^{th} mode & 1^{st} mode of reflected laser.



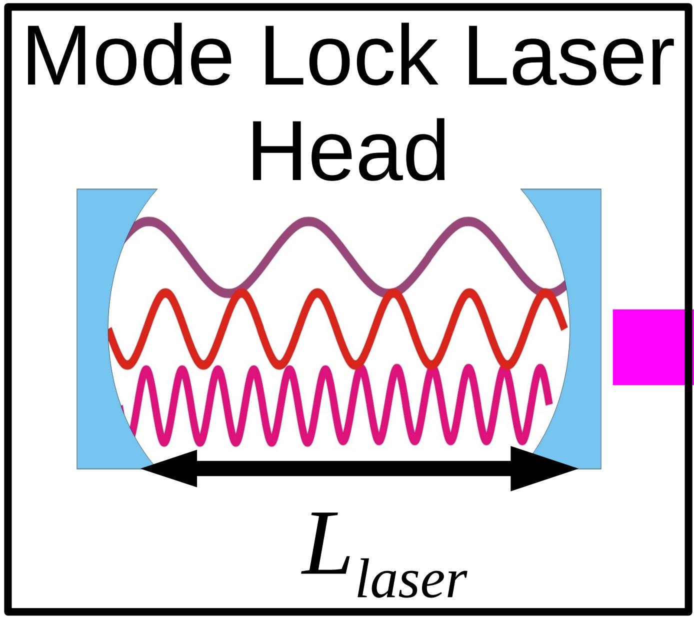
Profile mode



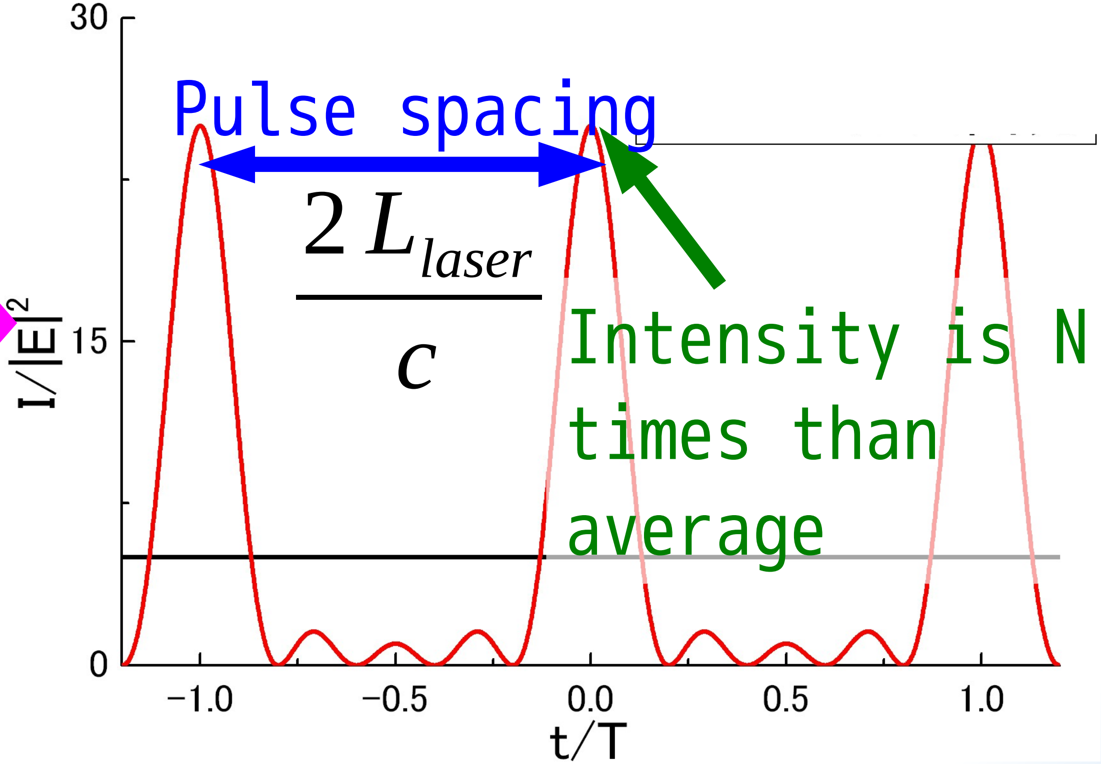
0^{th} 1^{st}

We can lock resonance of stacking cavity with this system.

Mode Lock Laser



Multiple Mode



We can control length of laser inner cavity by actuator.

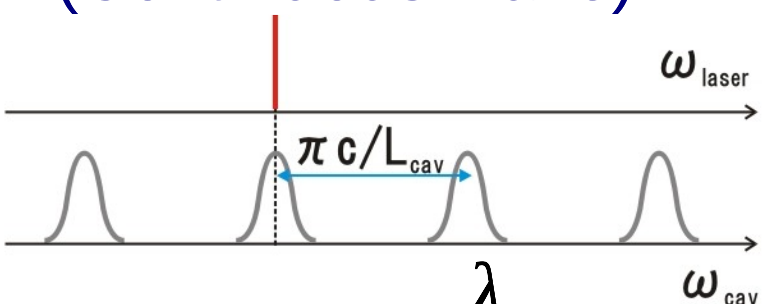
--> scattering laser pulse with electron each bunch

Pulse Laser Stacking

Stacking single mode laser w/ boundary condition.

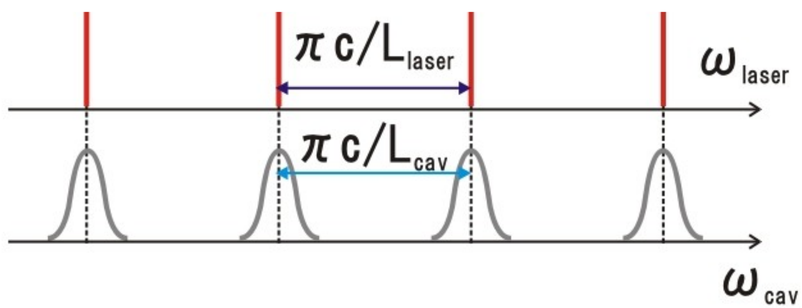
Mode lock laser emit multiple mode of light.
stacking all mode to cavity
--> request $L_{cav} = m' L_{laser}$

single mode laser
(Continuous wave)



$$L_{cav} = m \frac{\lambda}{2}$$

mode locked laser



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

Title

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