Status and Plan of Compton γ-ray Generation at KEK-ATF

Tsunehiko OMORI (KEK)

for

French Labs. : LAL (Orsay) in Collaboration with
CELIA (Laser lab., Bordeaux) and
LMA (mirror coatings Lab., Lyon)
Japanese Labs. : KEK, ATF group,
Hiroshima University

24 January 2013
ATF Project Meeting at KEK

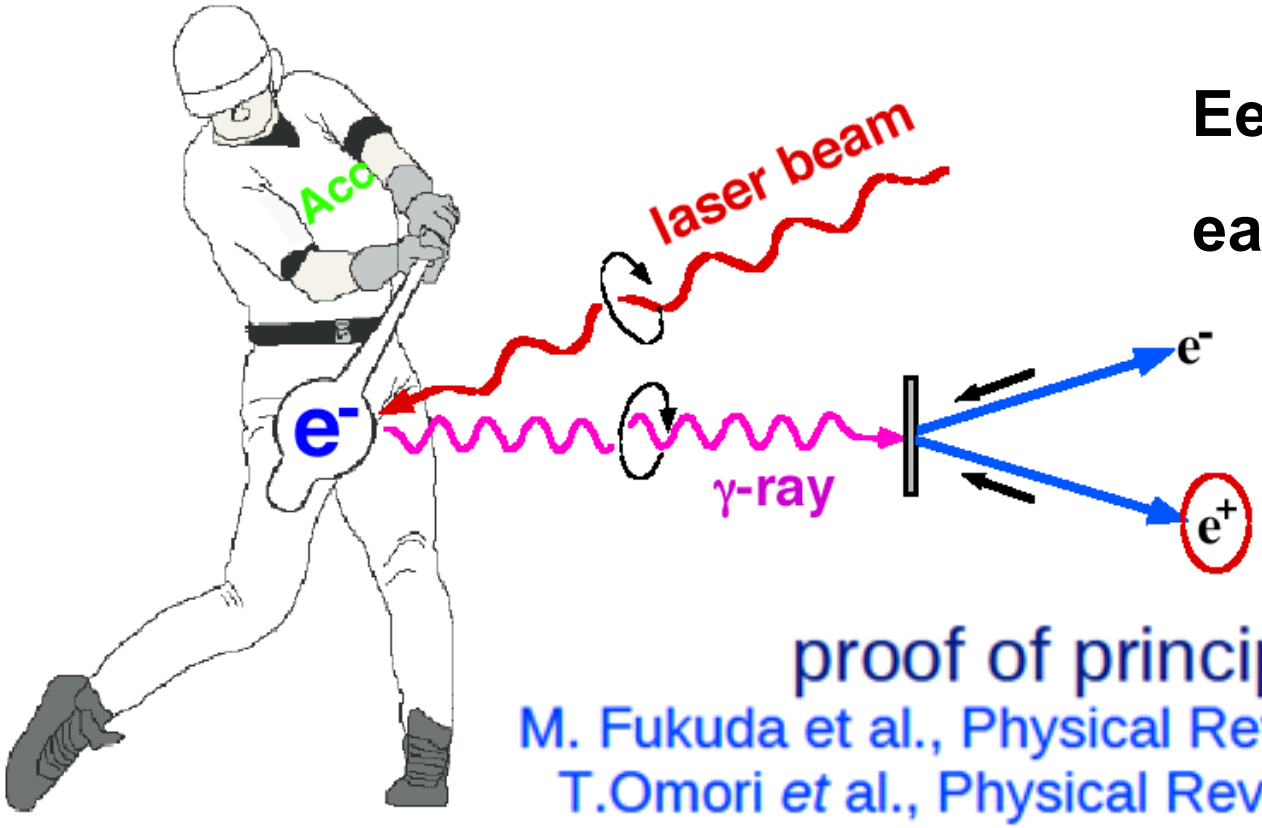
Today's Talk

1. Laser-Compton-Scheme and laser pulse stacking
2. Brief History at ATF
3. Why we move from 2-mirror cavity to 4-mirror cavity?
4. French 4-mirror cavity
5. KEK-Hiroshima 4-mirror cavity
6. Statuses and Plans
7. Summary

Laser-Compton-Scheme and Laser Pulse Stacking

Introduction

▶Polarized e+ by laser Compton Scheme



Ee~1GeV for 10MeV gammas

easy to control polarization

proof of principle experiment

M. Fukuda et al., Physical Review Letters 91, 164801 (2003)

T.Omori *et* al., Physical Review Letters 96, 114801(2006)

Toward the positron sources

-> increase intensity of gamma rays

Staking Laser Pulses in Optical Cavity

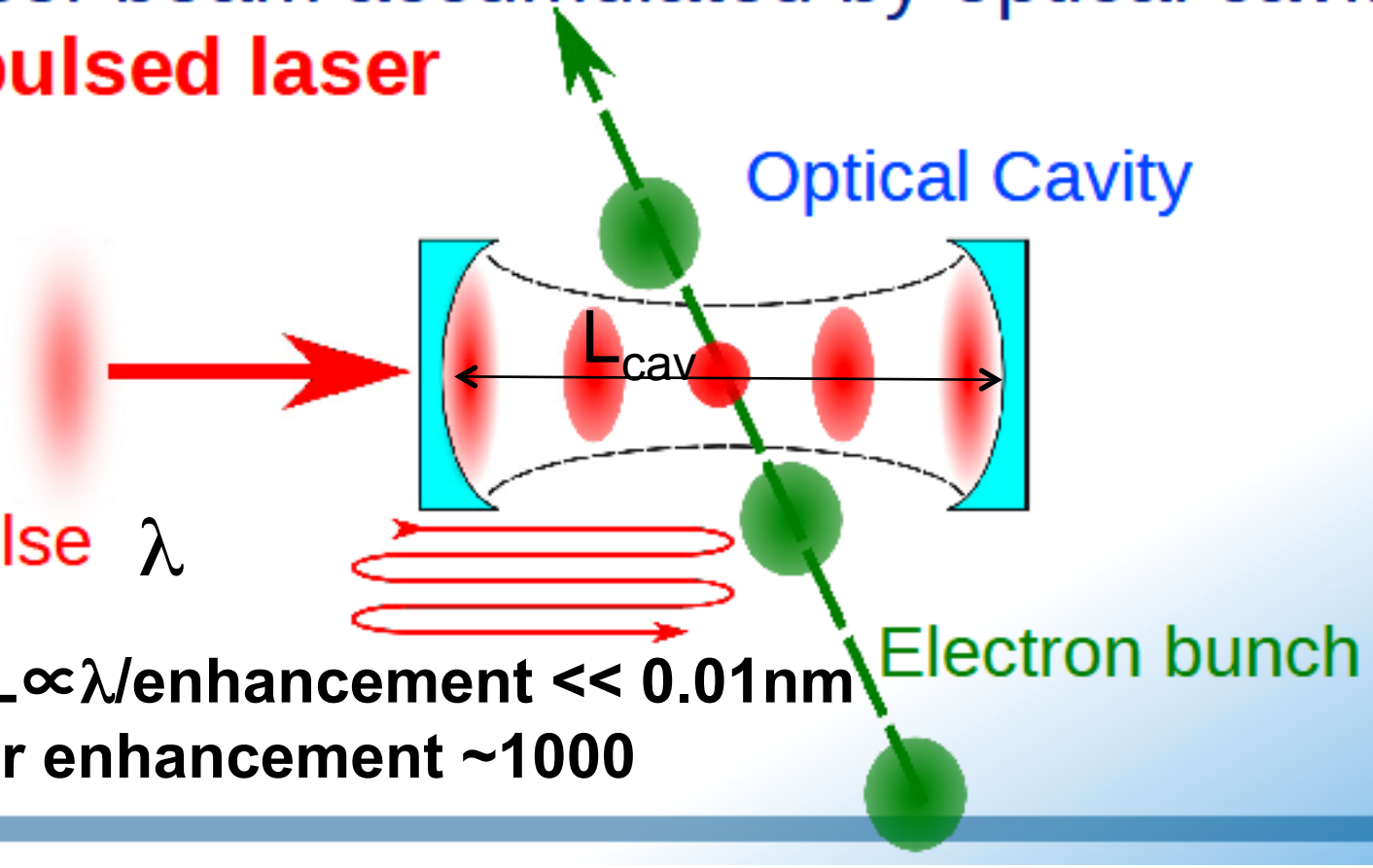
Miyoshi PosiPol2010

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

➡ **enhancement with optical cavity**

Laser beam accumulated by optical cavity

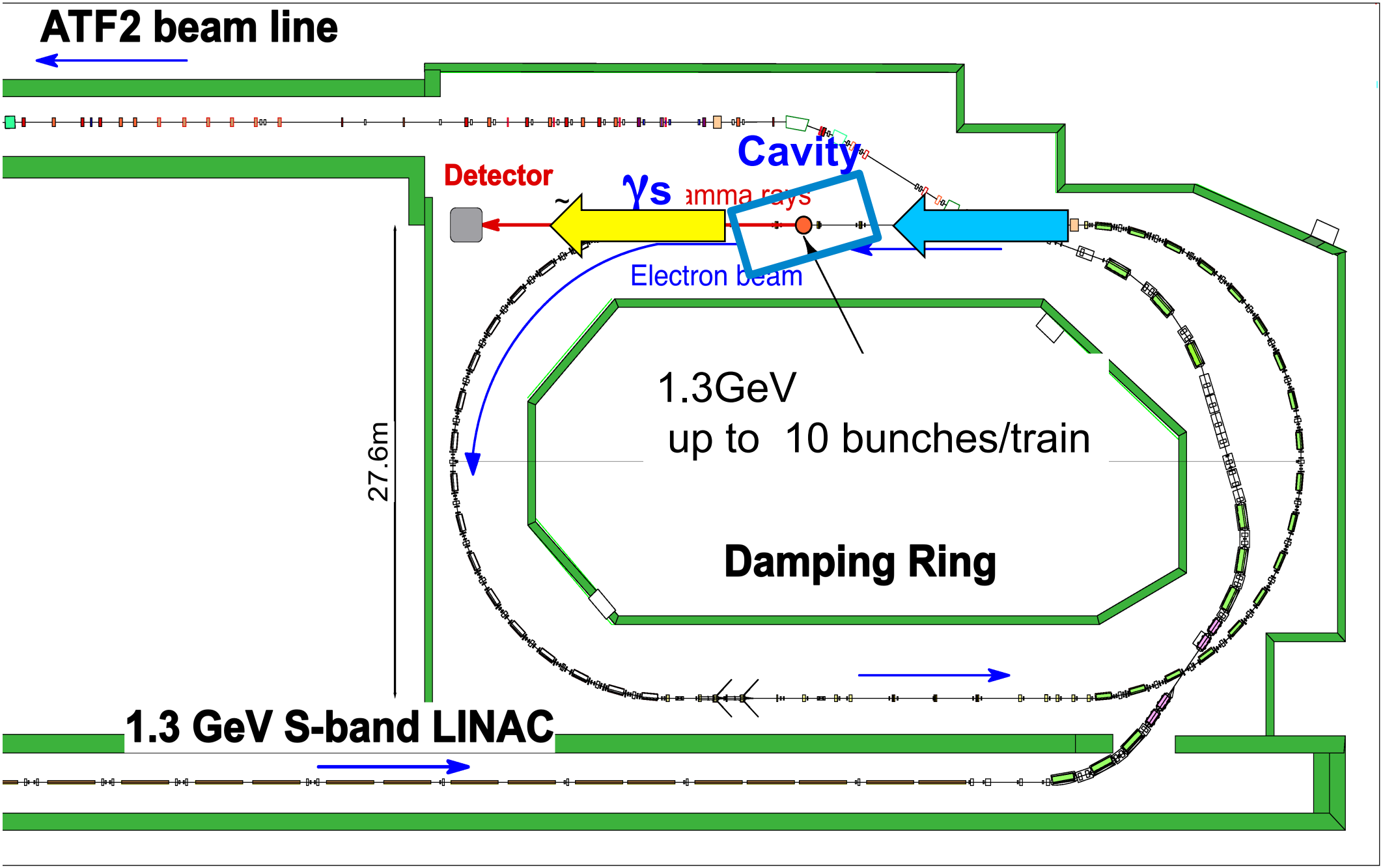
➡ **use pulsed laser**



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

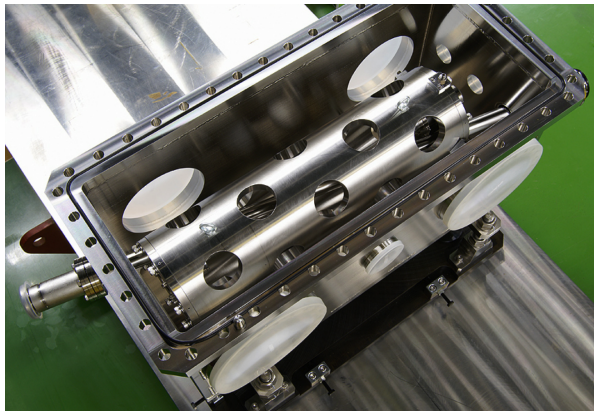
dL∝λ/enhancement << 0.01nm for enhancement ~1000

Experiments at the KEK ATF

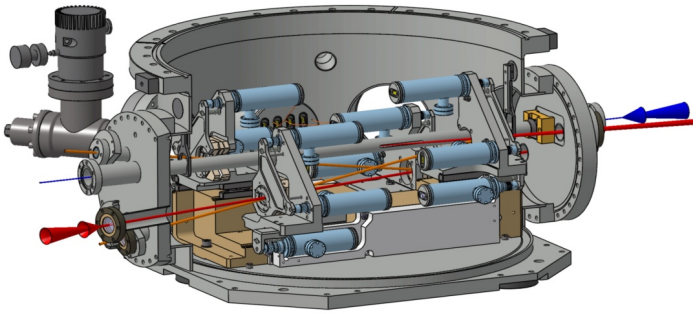


Brief History

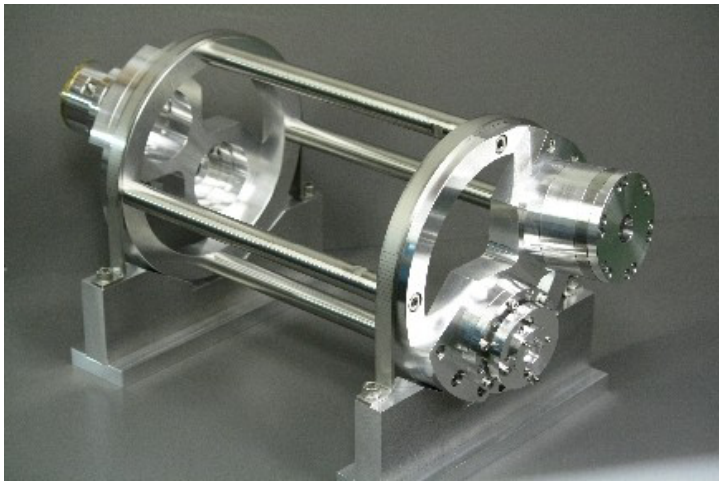
Brief History



- 2007: 2-Mirror cavity installed
  - 2.5kW 30γ rays generated/train
- 2010: French 4-Mirror cavity installed
  - γ rays confirmed



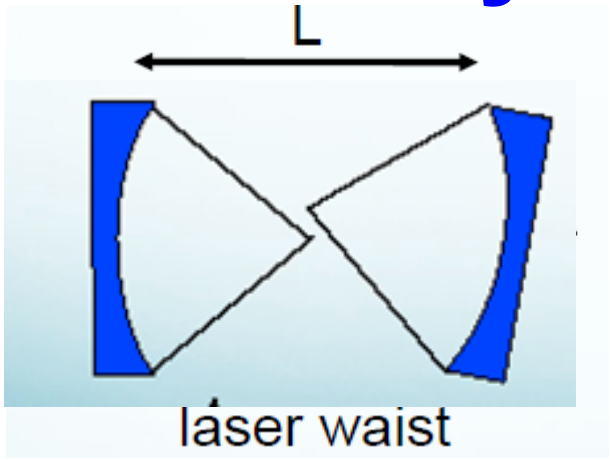
- 2011: The Earthquake
  - No major damage to our equipments.
- 2011: KEK-Hiroshima 4-mirror cavity installed
  - γ rays confirmed



- Early 2012: Multi-bunch gamma-rays measurement (K-H cavity)
- 2012: 128 photons/train observed (K-H cavity)

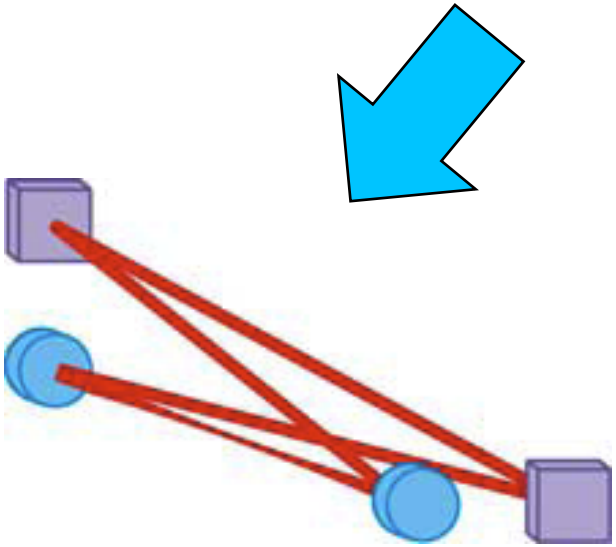
Why 4-mirror Cavity?

We should go to 3D 4-mirror Ring Cavity to get small sport size



2 mirrors is not stable for small spot size

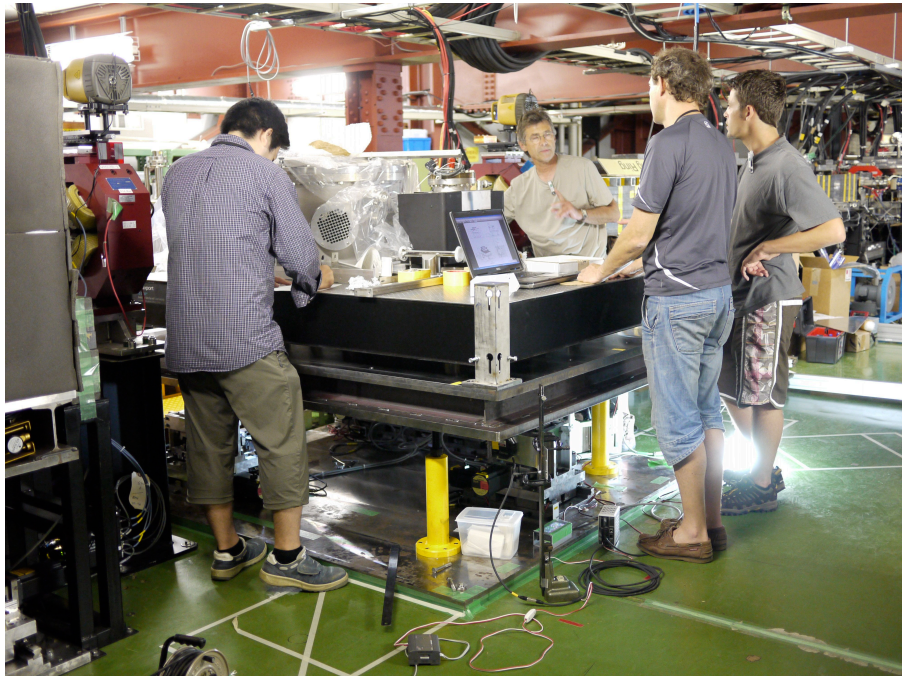
2d 4M has astigmatism

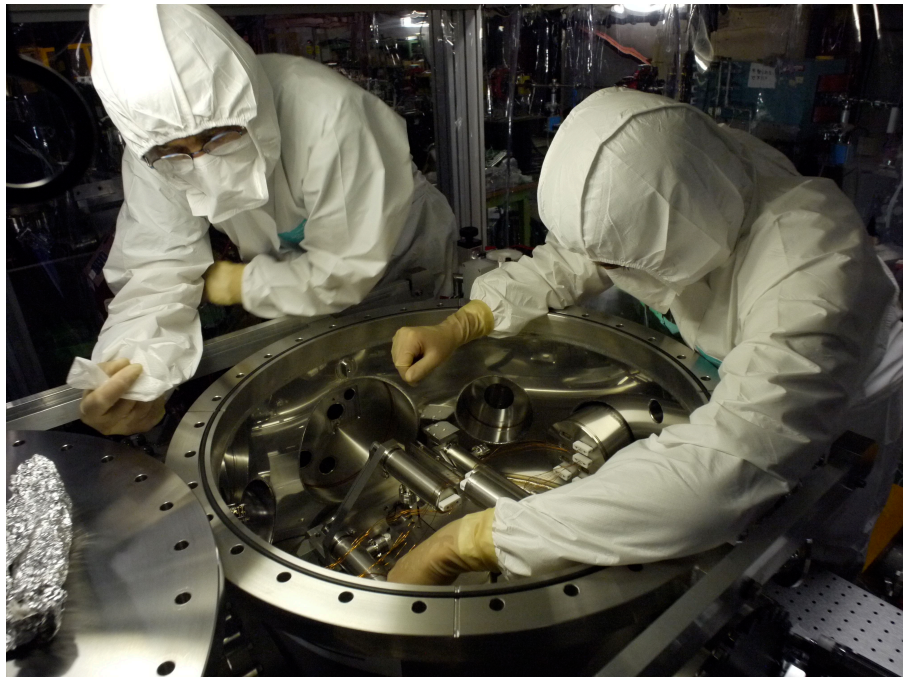


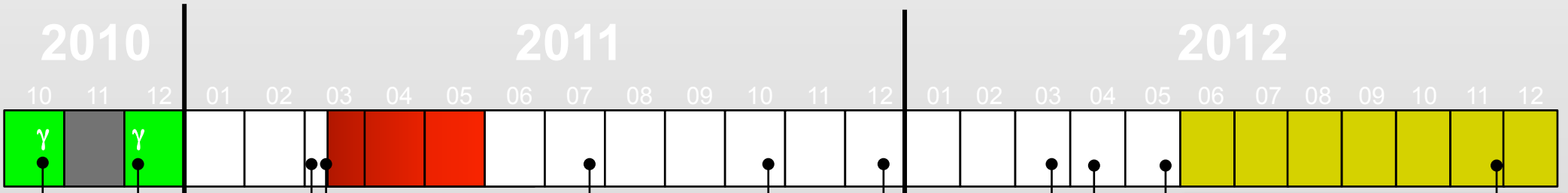
3D (or twisted) 4M ring cavity

French 4-mirror Cavity

2010 Summer: French cavity Installation







10/25 : γ observed

12/08 : γ observed

06/03 : Fibre amp damage

03/11 : earthquake

ATF Recovering

07/20 : Laser Failure

10/20
Locking more stable using **Frequency Shifter** 60% coupling

05/22
Equipment s sent to Orsay

11/29
Origami Laser sent to Orsay

New MENLO Laser + Fibre Amplifier under tests at LAL

Request to Terunuma-san

Gamma observed

New design required for Fibre amplifier

CELIA
Eric CORMIER

Laser Mode-lock unstable New Laser ?

MENLO
Laser *Orange*

12/17
12/26
New Mirrors Finesse 3000 installed
Coupling 59% on Air
20% on vacuum

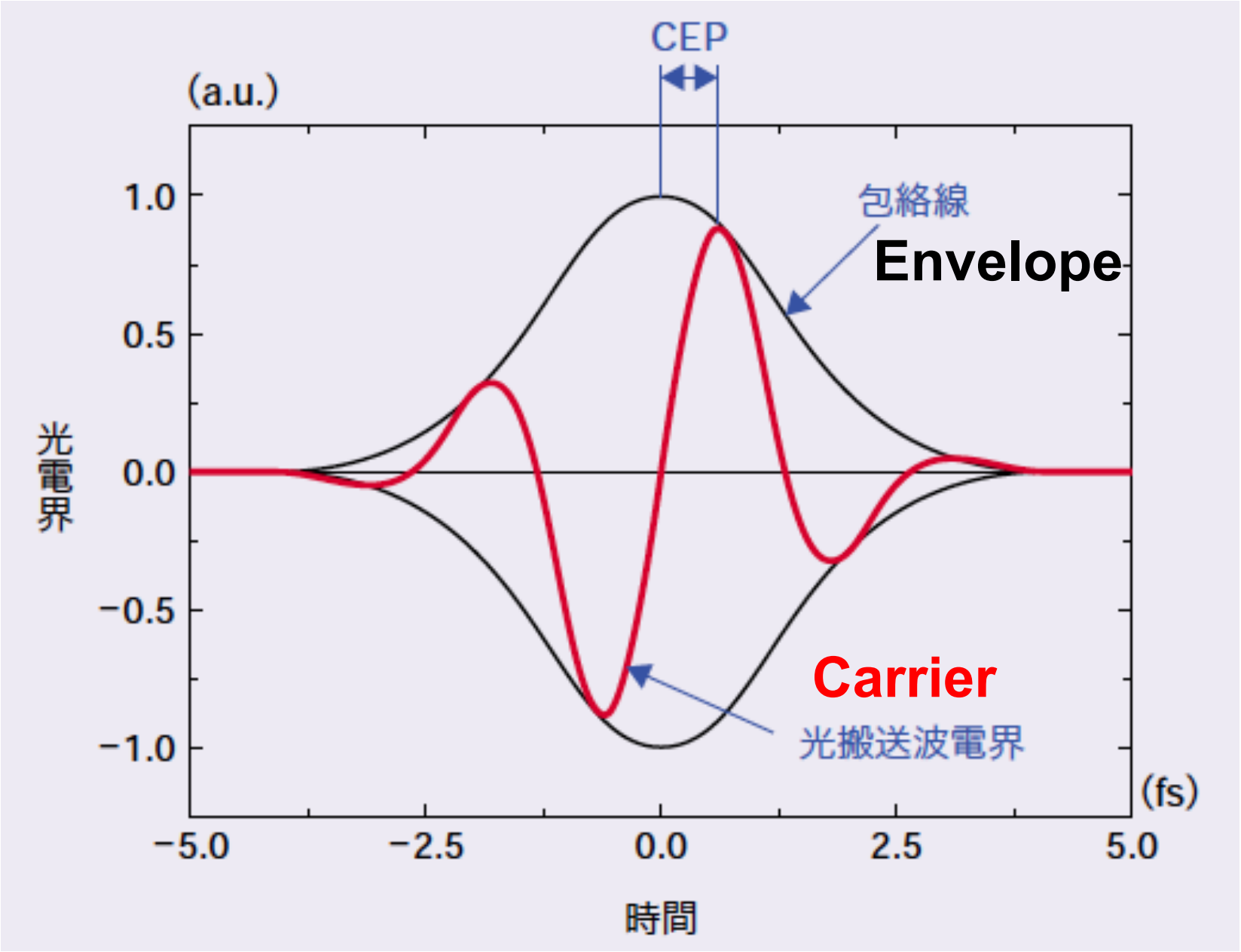
03/23
Sapphire Mirrors
Finesse 30000
Coupling 15% on air
3% under Vacuum

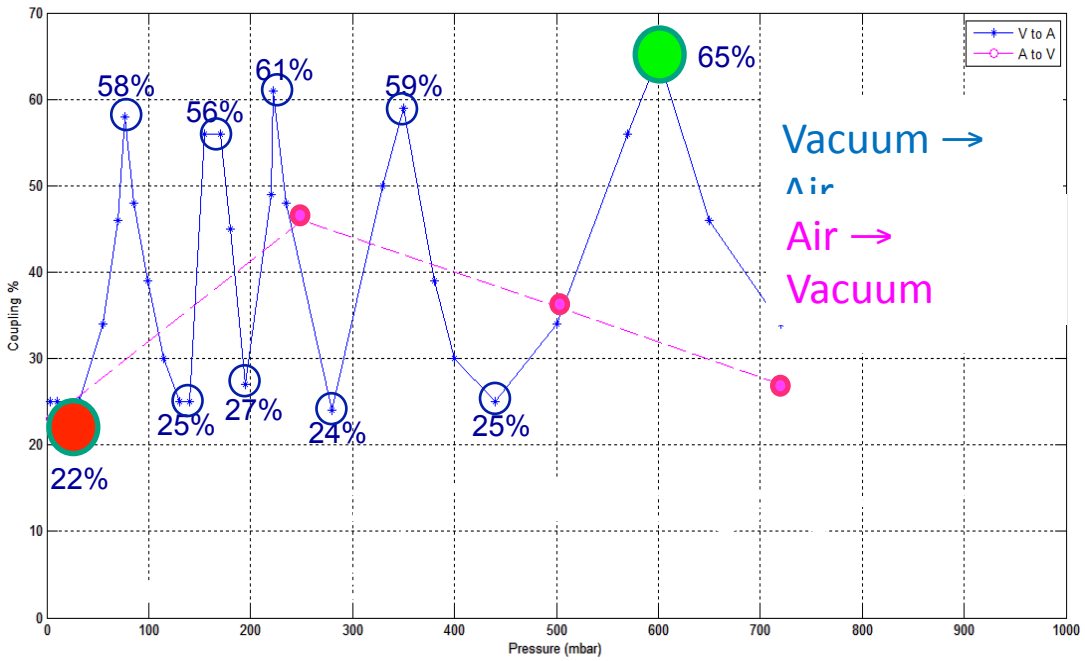
04/11
Setup on **Standby Mode**

decision

Challenge
F=30000
Problem: Coupling
Decrease in Vac.
CEP?

Issue:Carrier Envelope Phase (CEP)?



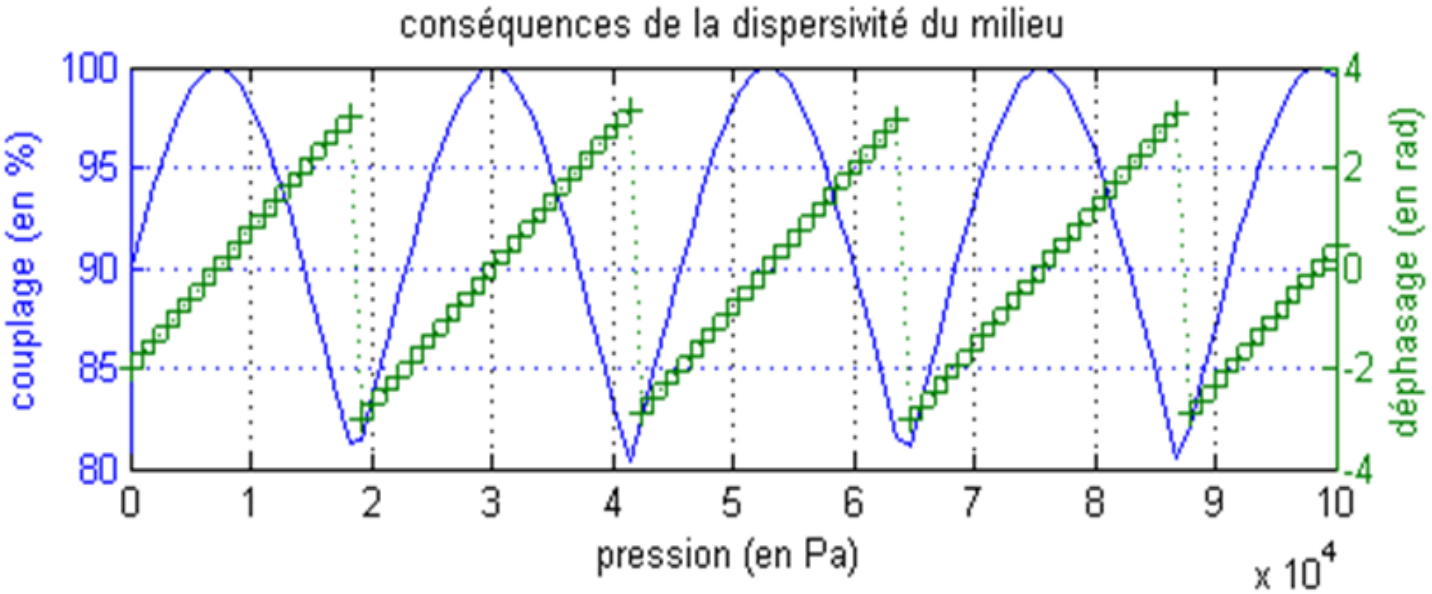


Issue : we observe a **Coupling dependance** versus cavity pressure

- Can be explained (simulation) if Laser <u>CEP is constant</u>

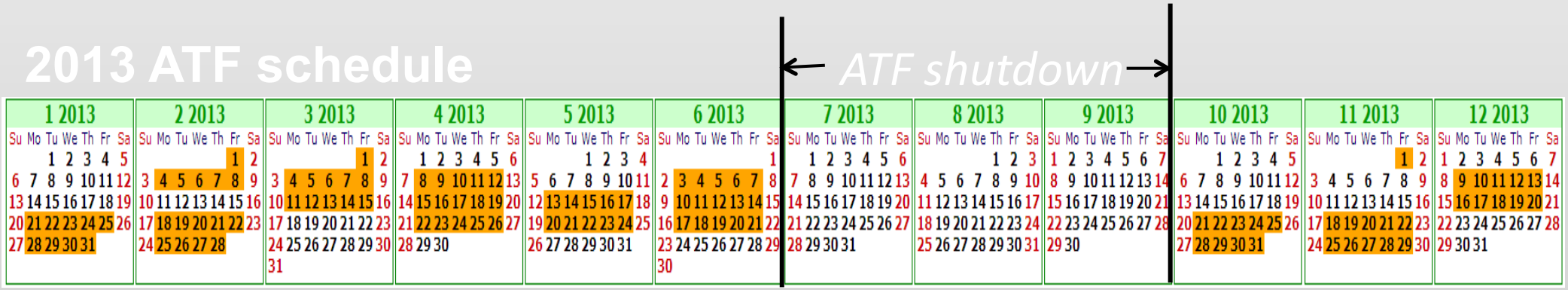
- Laser CEP <u>adjustment outside the laser</u> : AOM (ordered). Will be tested in February 2013.

Laser sent to Orsay on 11/29 (Terunuma san, Kakuta san)



Simulation result (Matlab) <u>(source : V. Bachelet)</u>

2013 ATF schedule



Origami / Orange tests

Full Setup Installation

Mirrors F=24000
Fibre Amplifier
Laser + Feedback

Compton Gammas γ

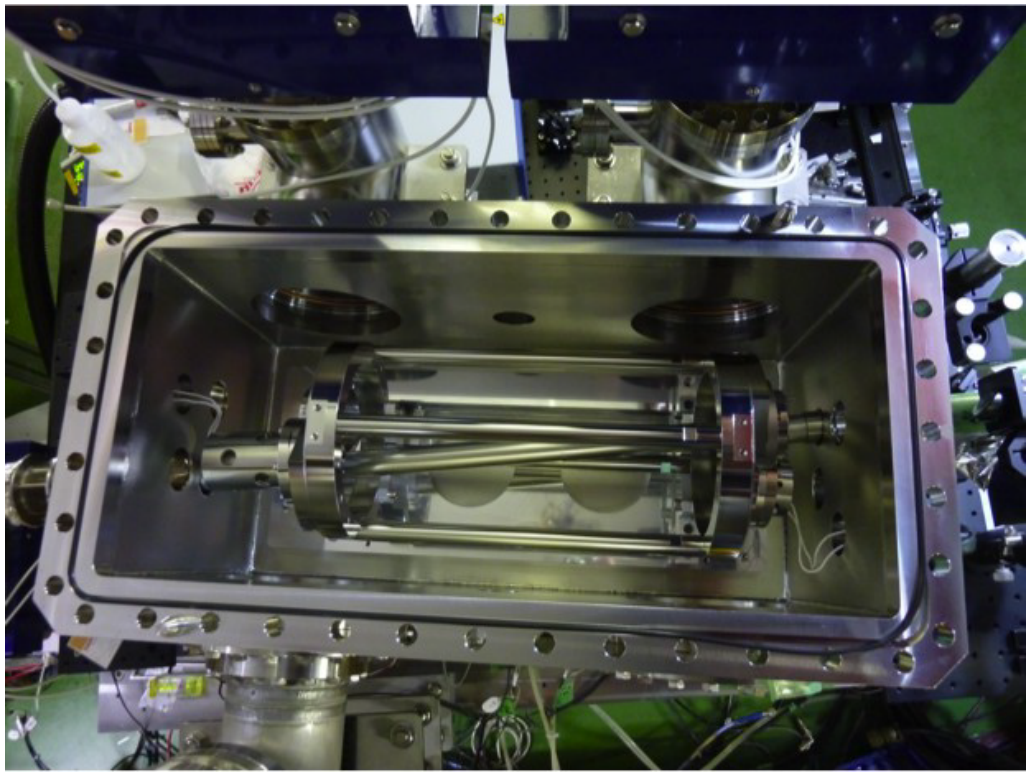
We need a full shutdown period :

- A full installation is required : feedback + laser + amplifier + high power tests
- New Silica mirrors (F=24000) to be installed in the cavity : alignment procedure

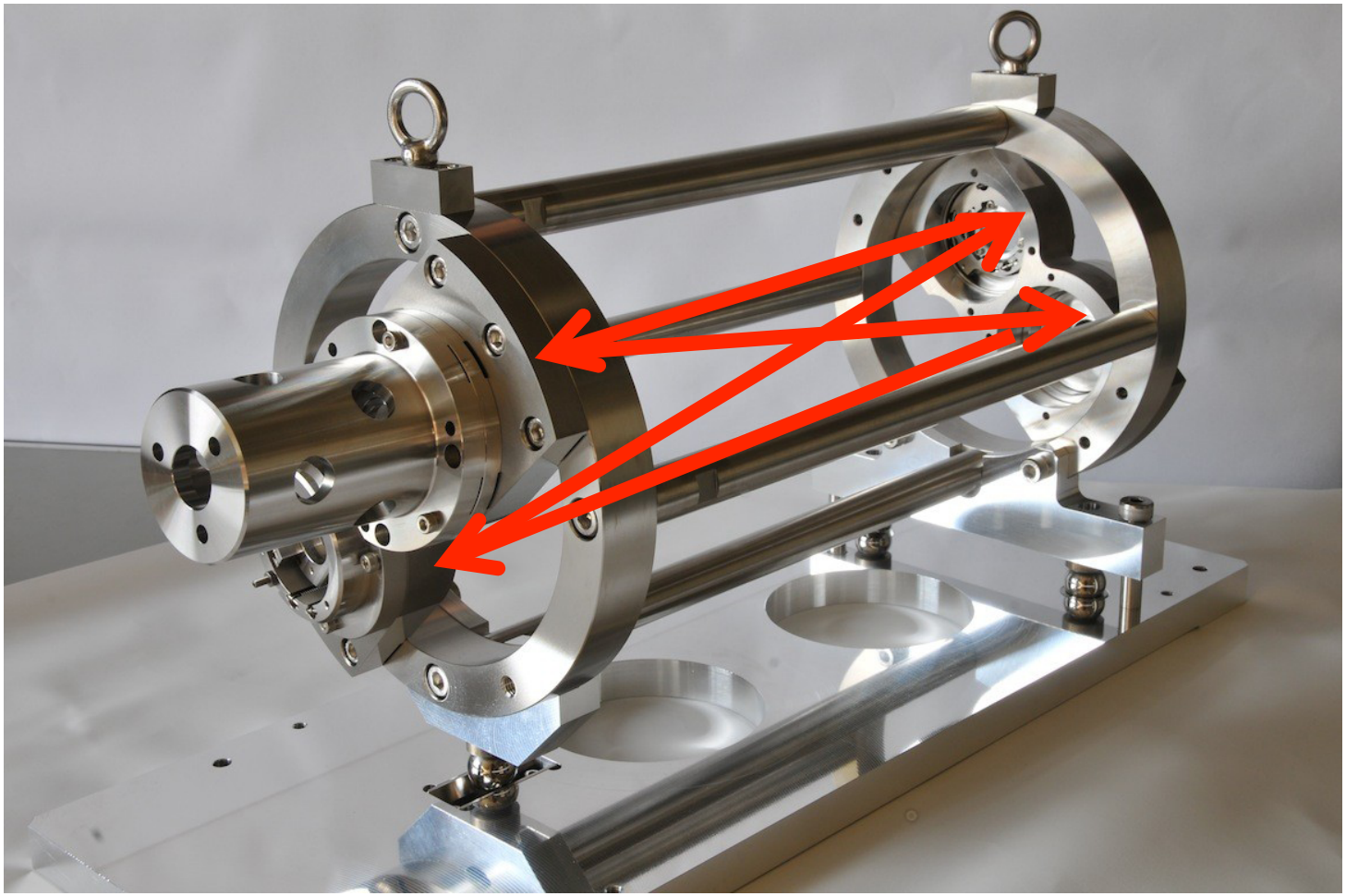
Decision : Expected installation during 2013 Summer ATF shutdown

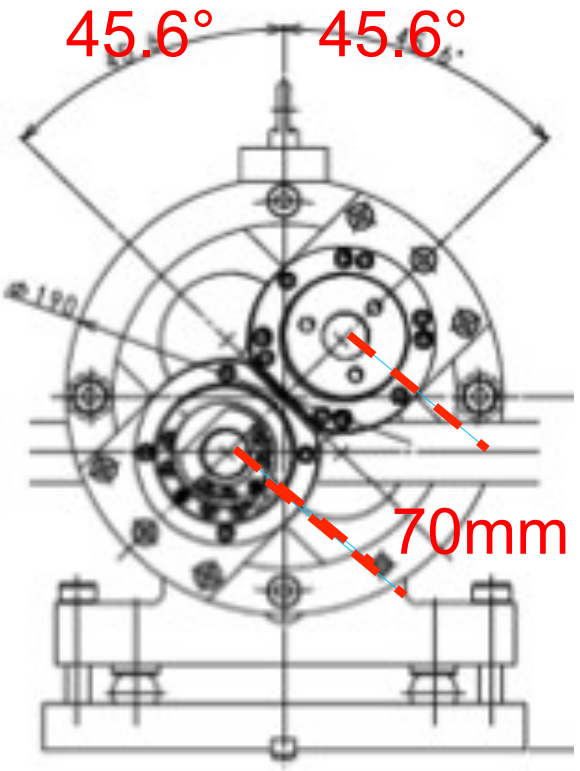
KEK-Hiroshima 4-mirror Cavity

2011 Autumn: KEK-Hiroshima Cavity Installation



New KEK-Hiroshima Cavity Installed into the ATF





Two 4-mirror cavities are at the ATF

KEK-Hiroshima
installed autumn 2011

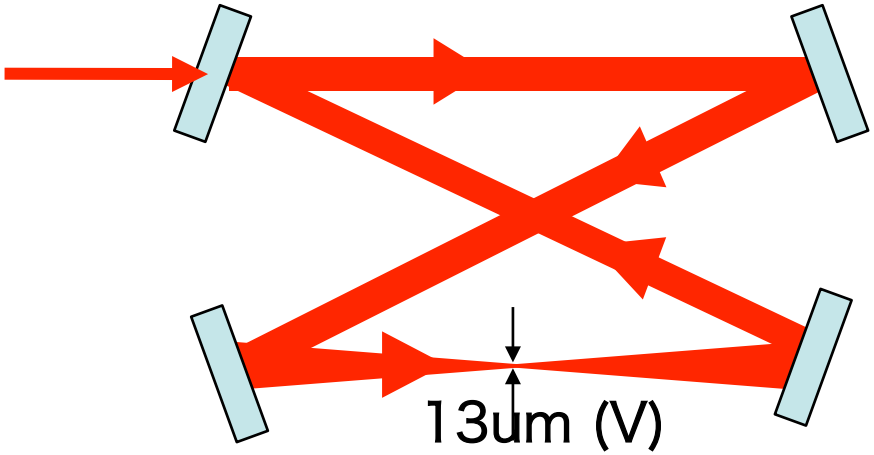
relatively simple control system
employs new feed back scheme

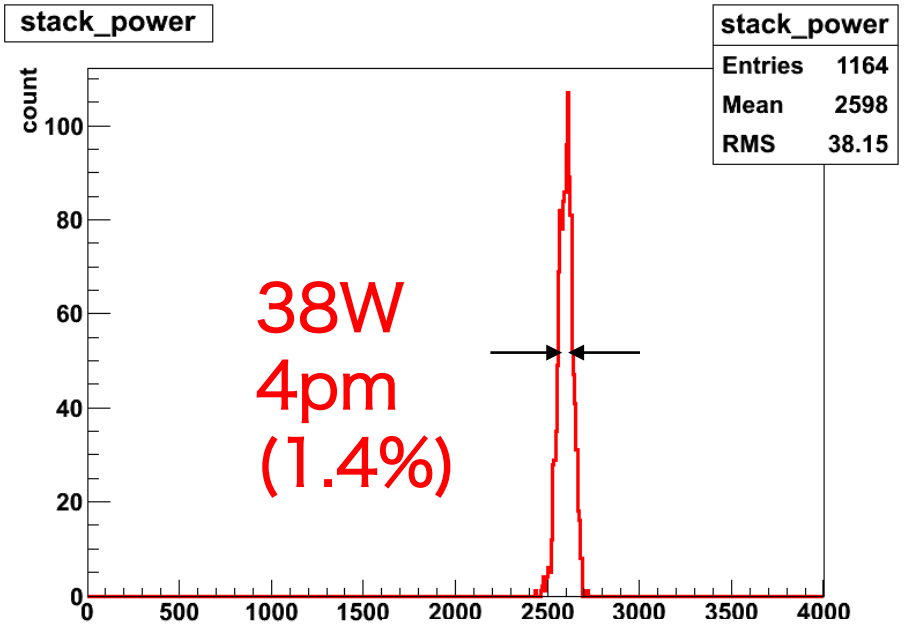
LAL-Orsay
installed summer 2010

sophisticated control
digital PDH feedback

Stable resonance with small spot size

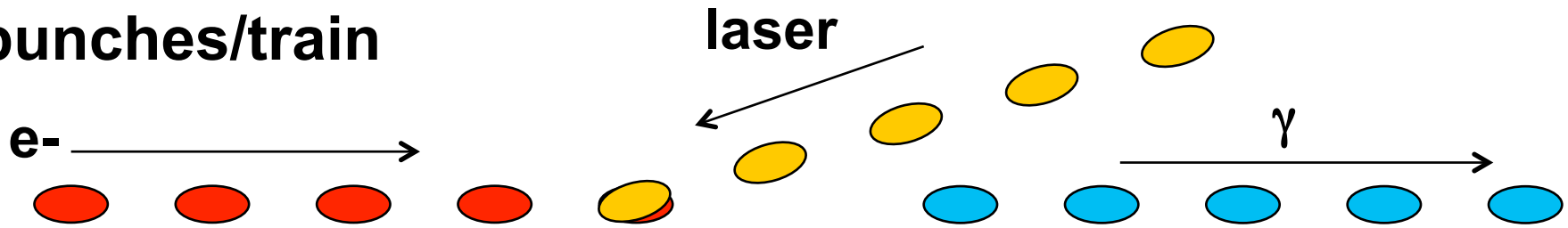
- Stable resonance by new feedback sys. (analog)
- 2.6kW average power w/ 1.4% fluctuation
- laser waist size at IP(σ)=13um (vertical scan)
- Finesse 4040+-110 (Enhance = 1200)





γ-ray Generation / electron

5bunches/train



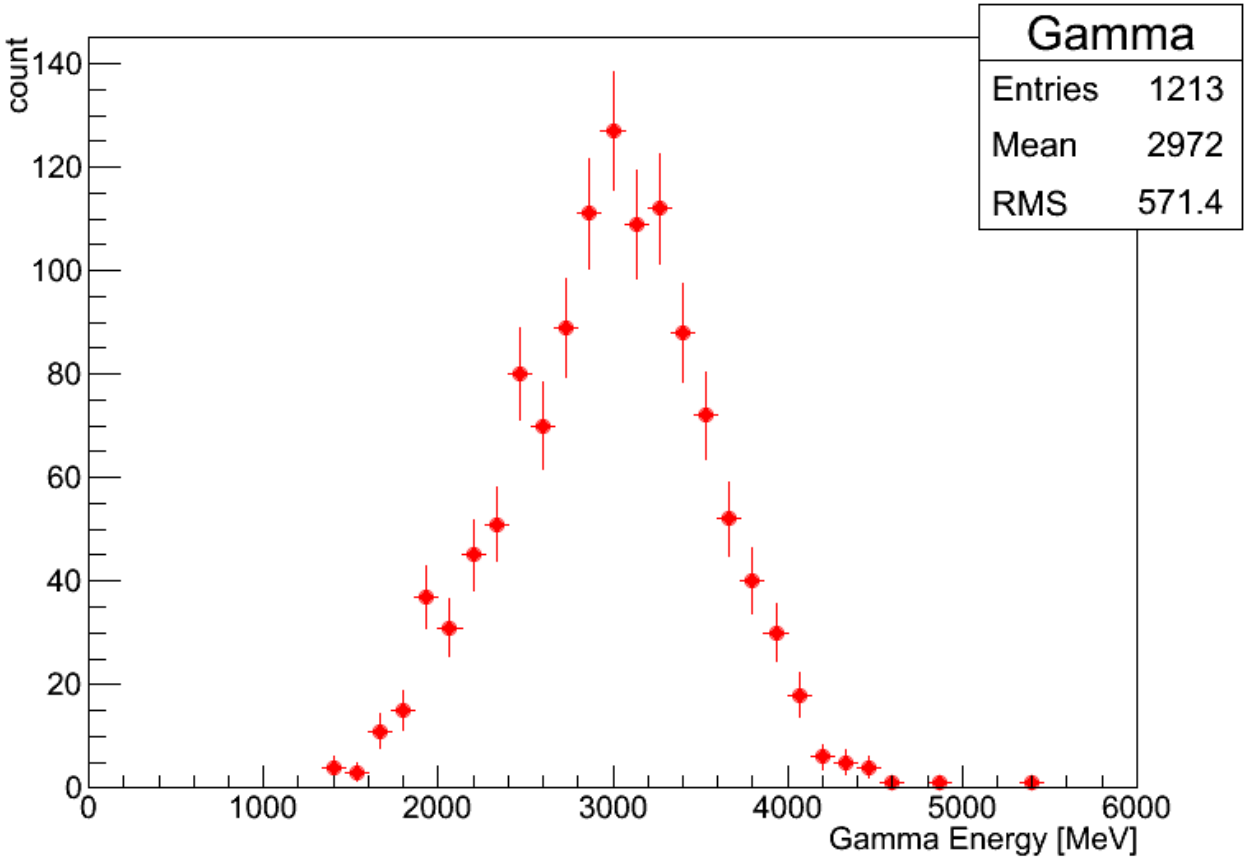
5.6ns

2970±20 MeV

⇒ ~128γs/train

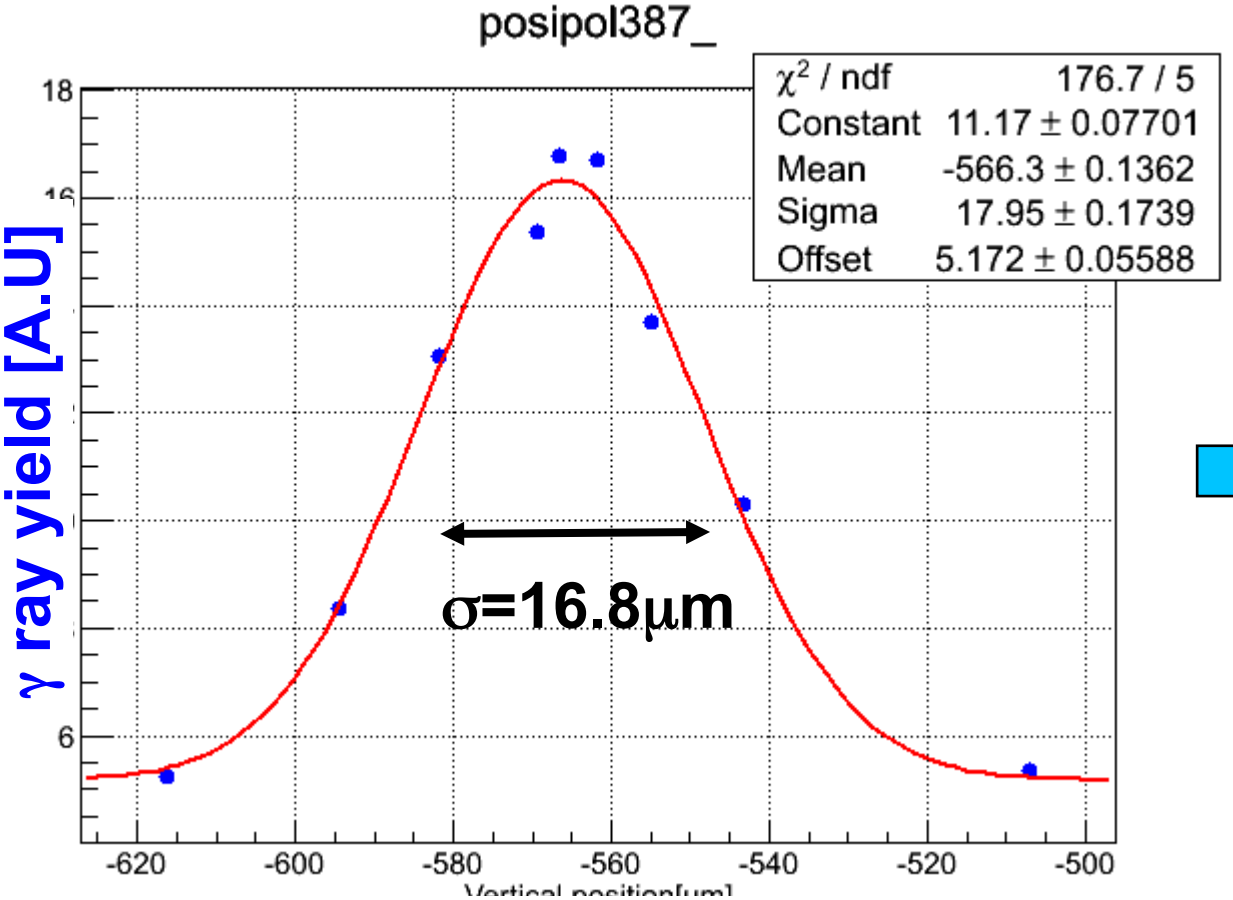
ATF 2.16MHz

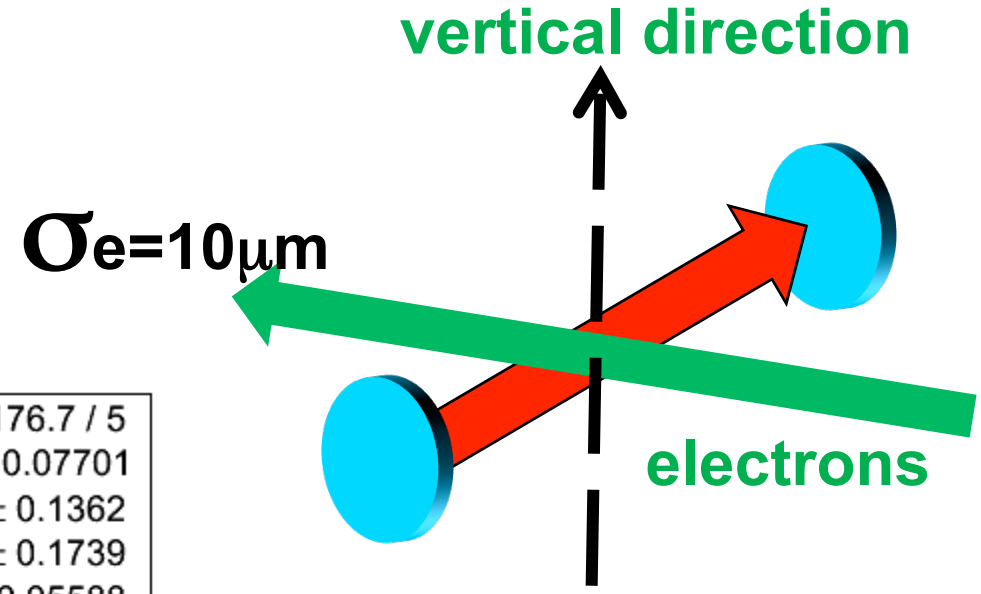
~2.6×10^8/sec



Eγ[MeV]

Laser vertical spot size 13μm achieved



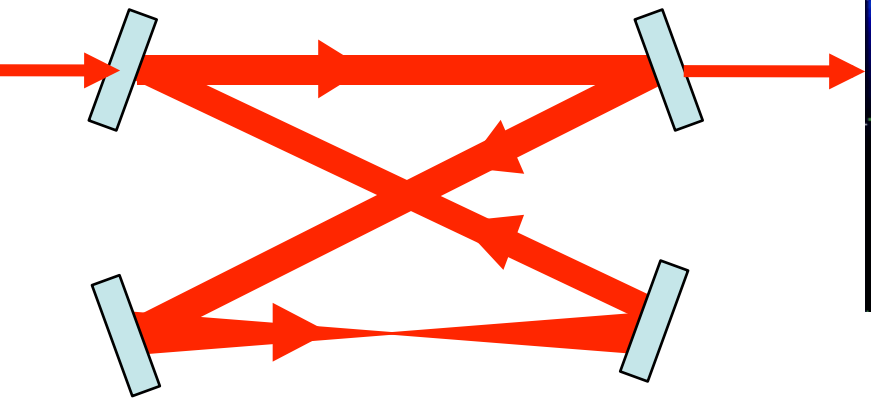


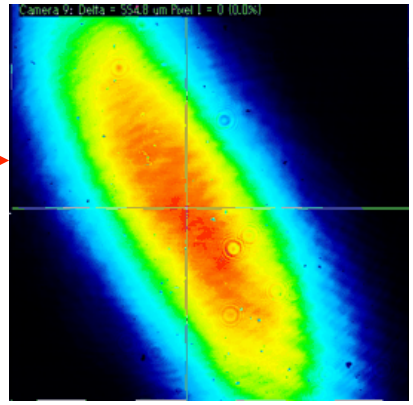
σL(V) =13μm

it was 30μm w/ 2 M cavity

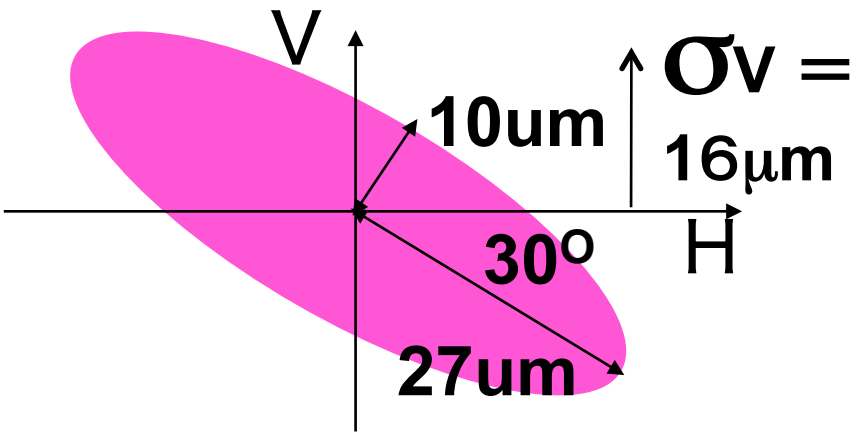
Laser profile at IP

Proflie measurement of transmission light



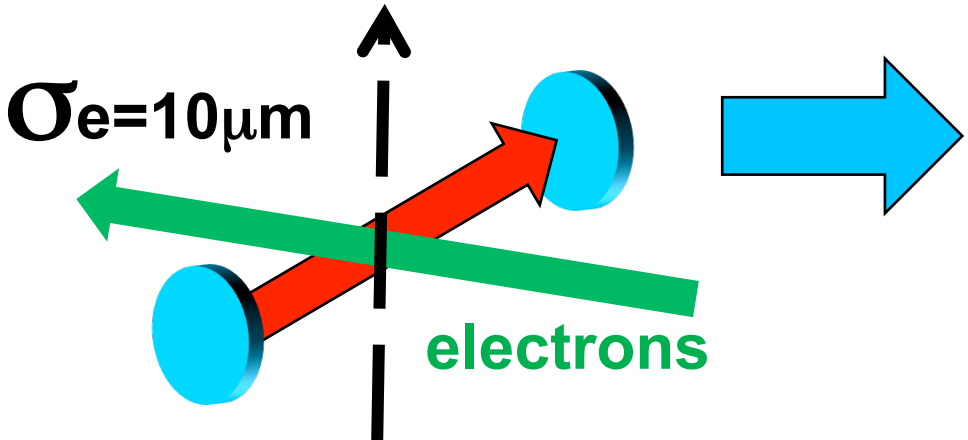


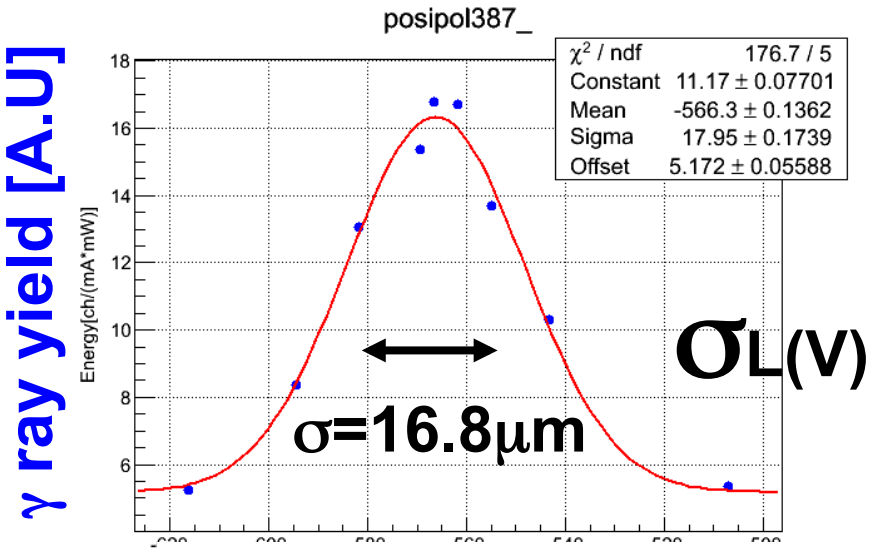
Proflie Estimation at IP vis T_matrix



Vertical Position Scan

vertical direction





Statuses and Plans

Status and plan of French Cavity

(1) Status

2010 Summer Installed

2010 Nov-Dec Gamma observed

2011 The Earthquake and Improvements

2012 Try to go higher finesse: 30000

Decrease of coupling in Vac.

CEP? Send the Laser to LAL

Simulation support CEP is cause.

(2) Plan 2013:

Laser with CEP control (ongoing@LAL)

Summer: Re Install whole system

Status and plan of KEK-Hiroshima Cavity

(1) Status:

2011 Autumm: Installed

2012 Multi-bunch g-ray generation:

Finesse: 4040 (enhance 1200)

Store 2.6 kW with 1.4% stability

Nγ=128/train (x4 of two-M cavity)

Small laser spot achieved 10x27μm^2

(Very stable. But not round as intended.)

(2) Plan:

Finesse 48,000 (16600 enhancement)

Digital Feedback (ongoing)

Summary

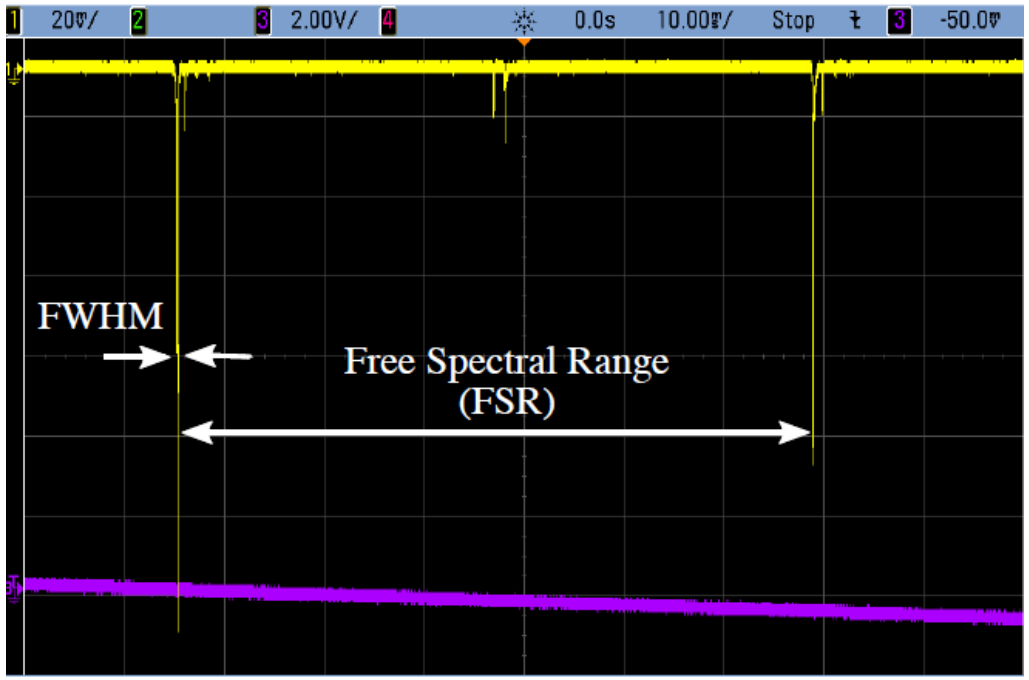
Summary

- Optical Cavity at the ATF is in progress for Polarized positron source for the ILC
  - Good collaboration between France – Japan team
    - information / technology exchange
- R&D of 4 mirror ring cavities are in progress
  - Sophisticated mechanism aminig very high laser power enhancement ,,, French team
  - Relatively simple but new cavity control practical experience w/ the ATF ,,, Japanese team
- More to come
  - more laser power, more γ rays
  - maturity toward the system

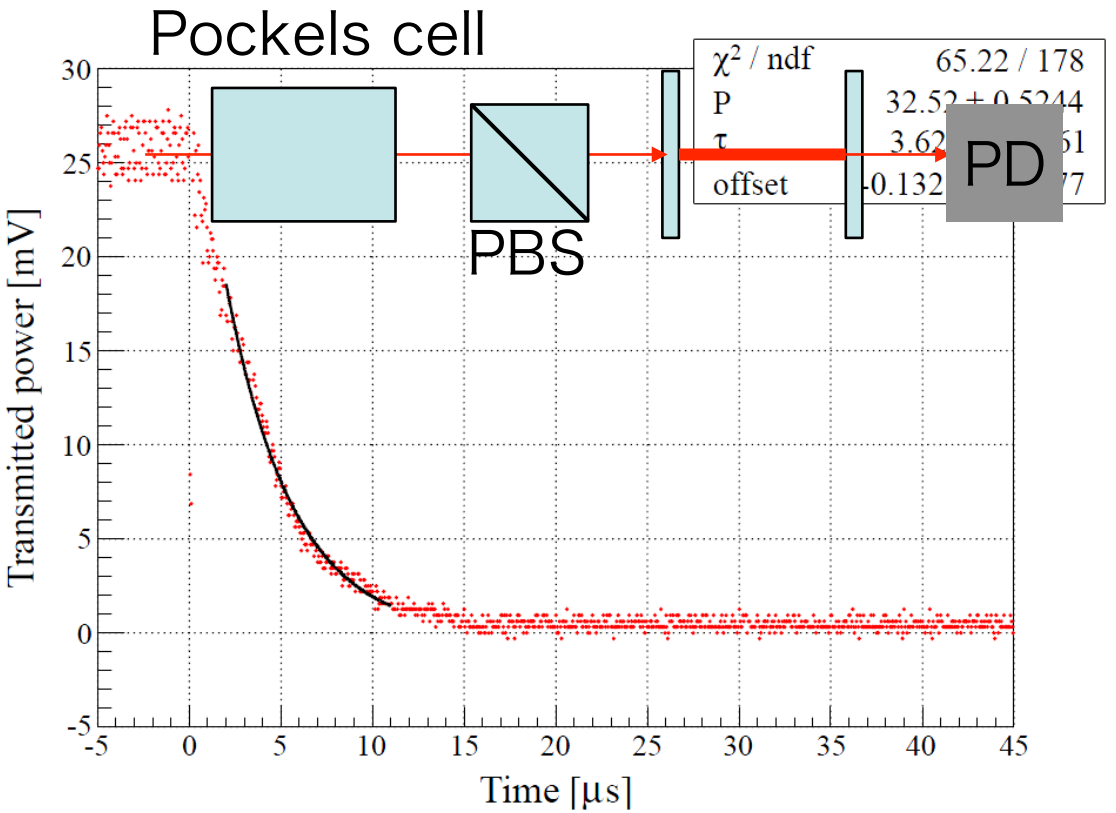
Backups

Finesse measurement

Airy Function



Decay time measurement



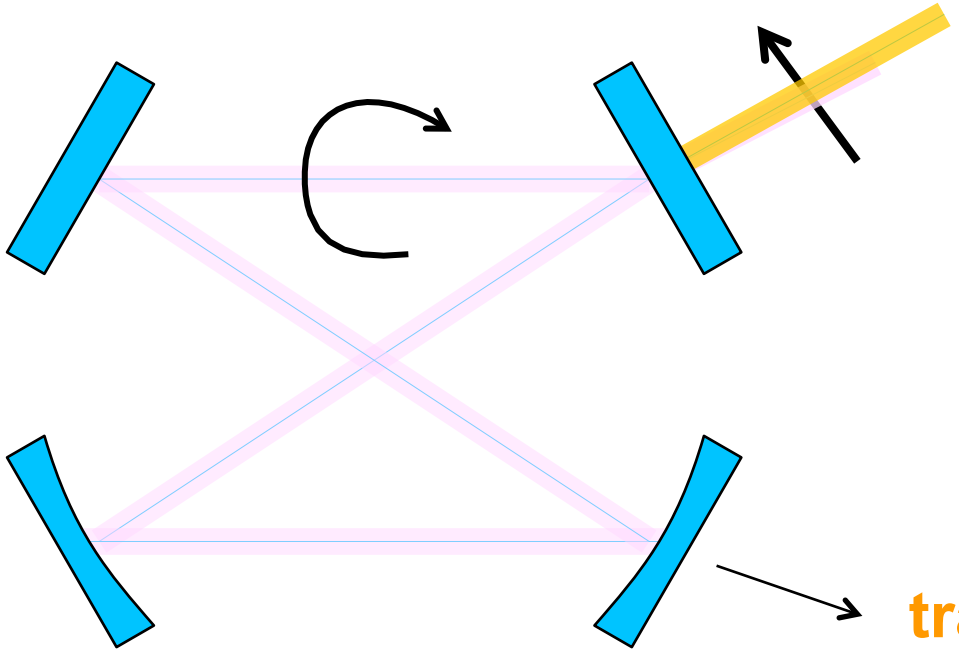
Finesse: 4040±420

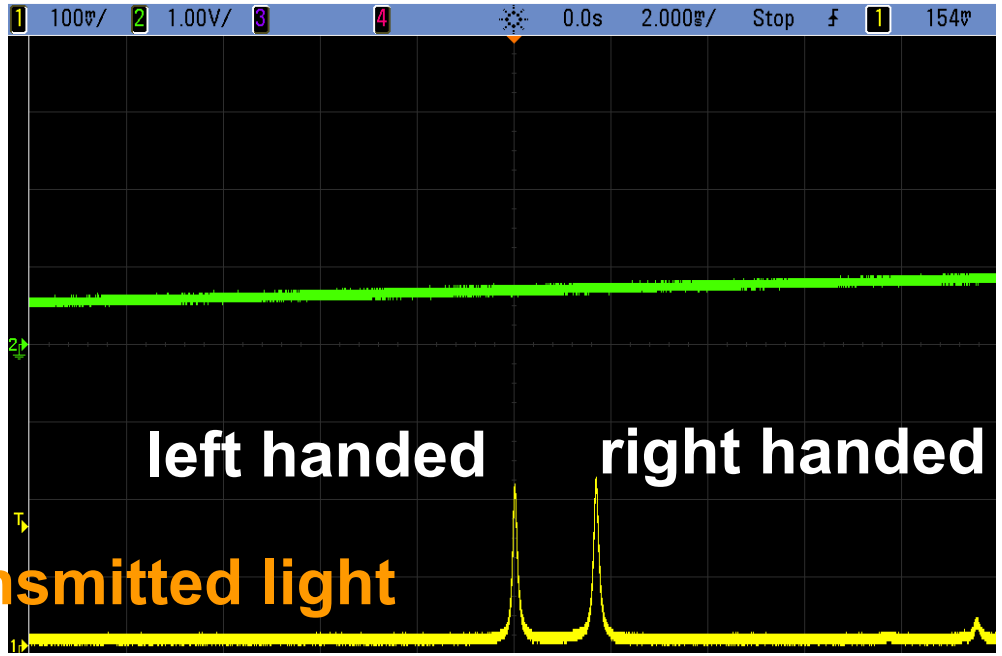
4040±110

Both Consistent but smaller than expected, 4830, from mirror reflectivity

3-Dimensional 4 Mirror Cavity

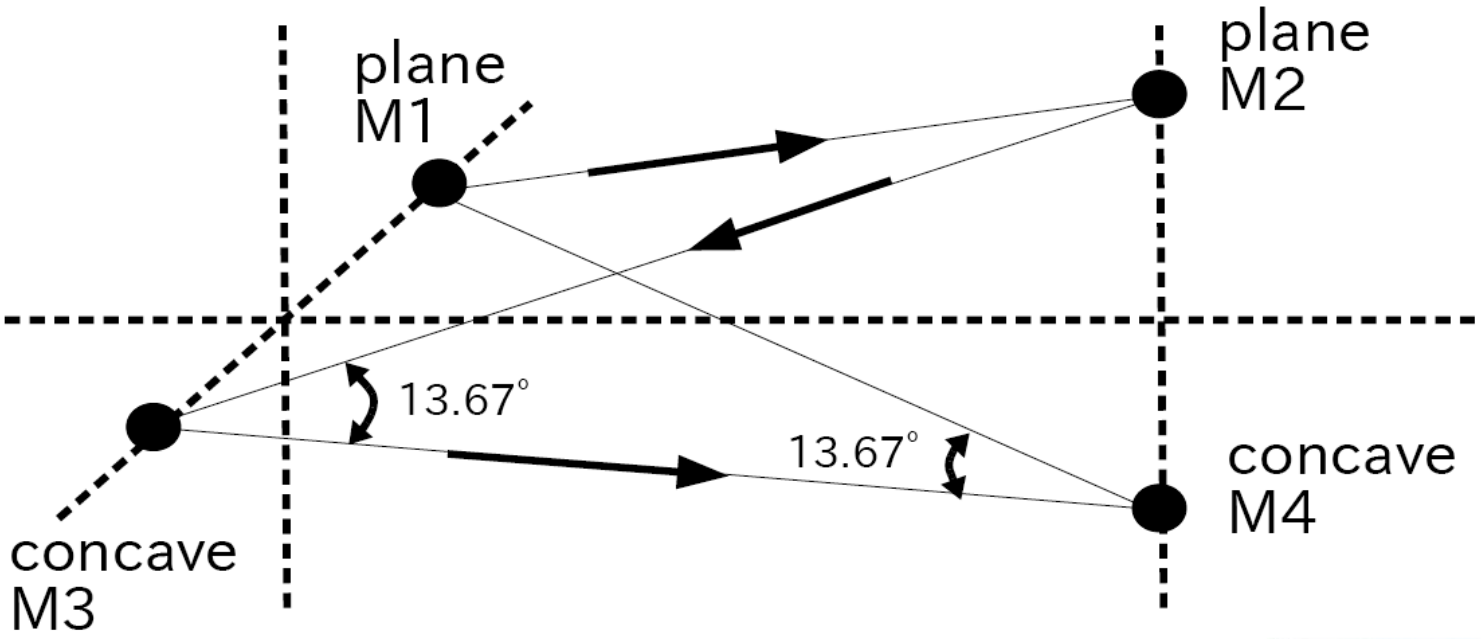
- Resonates only for circular polarization
  - geometric phase due to twisted pass
  - cavity only resonates with circular polarization
  - usable for pol. switching





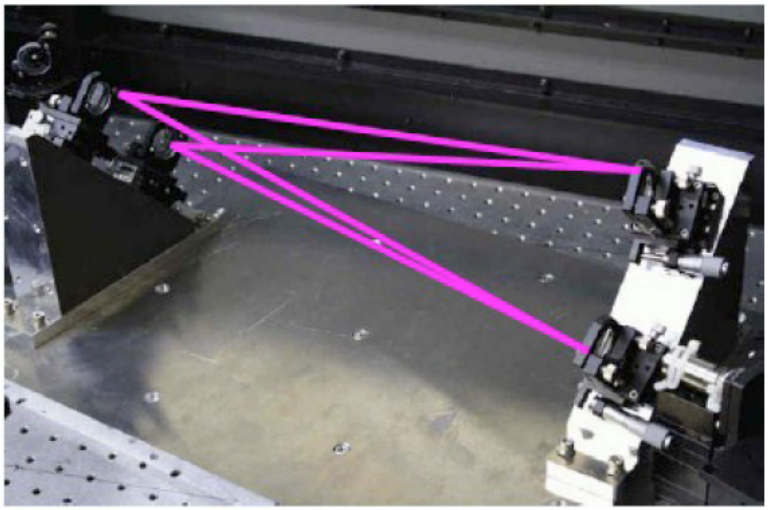
circumference of the cavity

Configuration of Test Bench

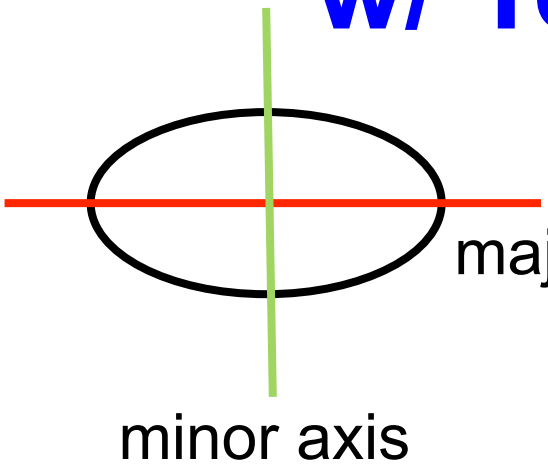


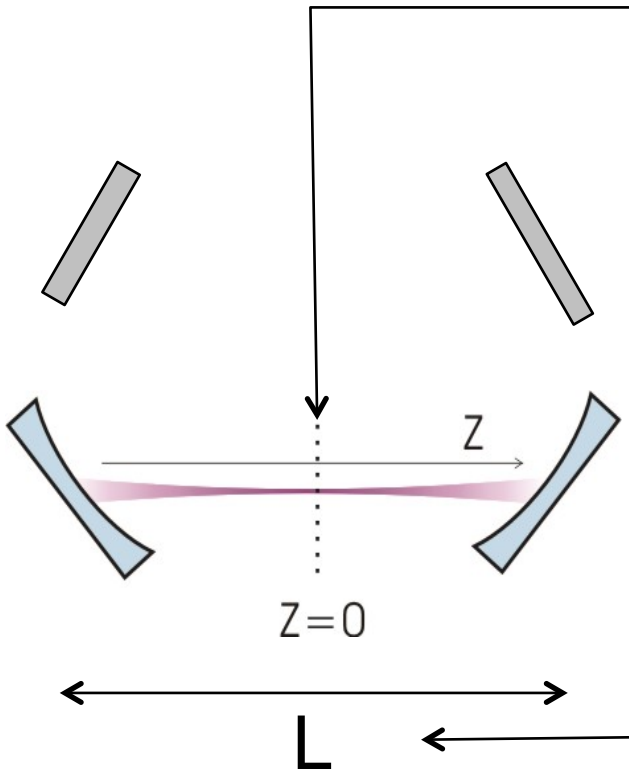
L1=M1-M2=420mm
L2=M2-M3=420mm
L3=M3-M4=420mm
L4=M4-M1=420mm

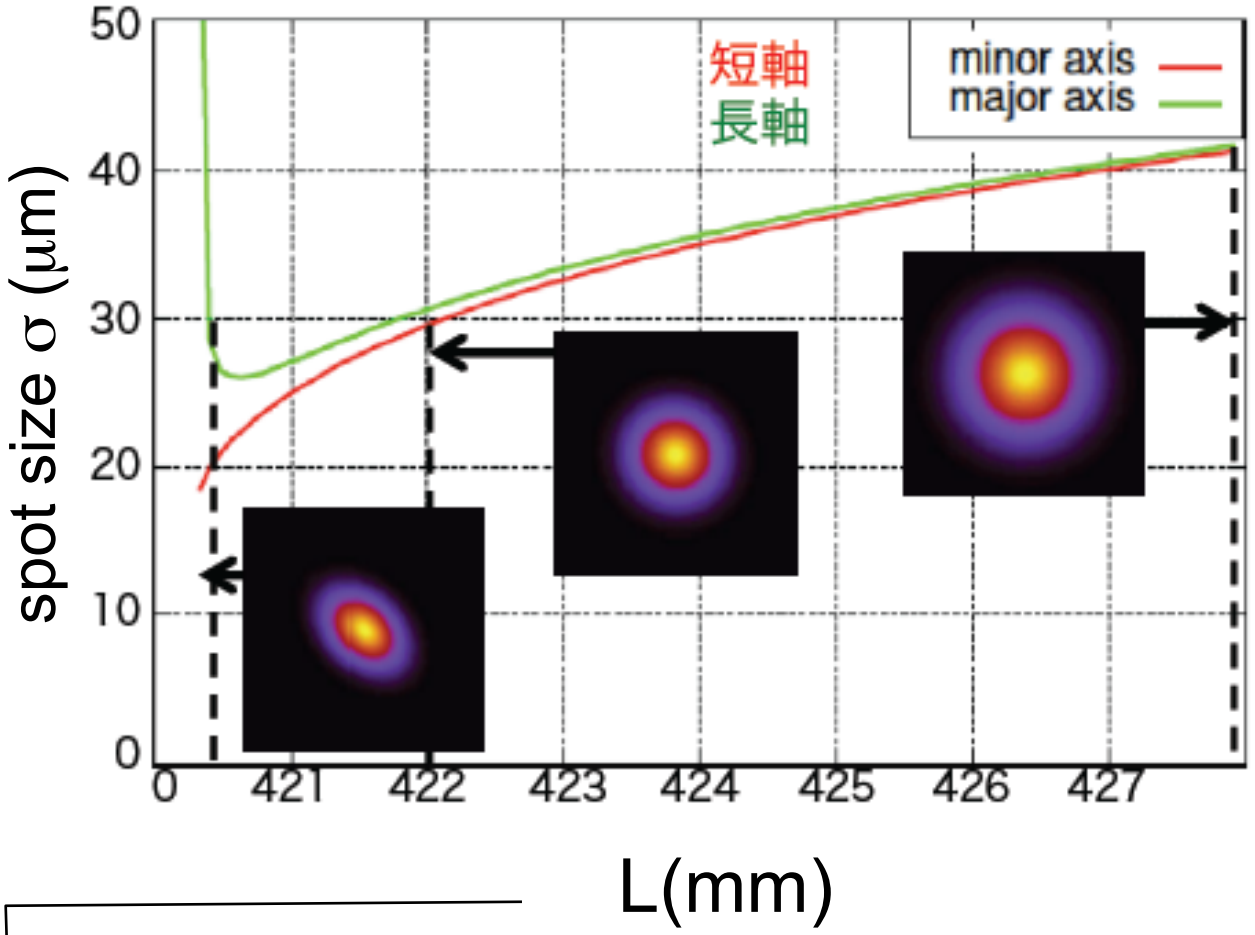
M2-M4=100mm
M1-M3=100mm



Calculation of Spot Size w/ Test Bench Geometry

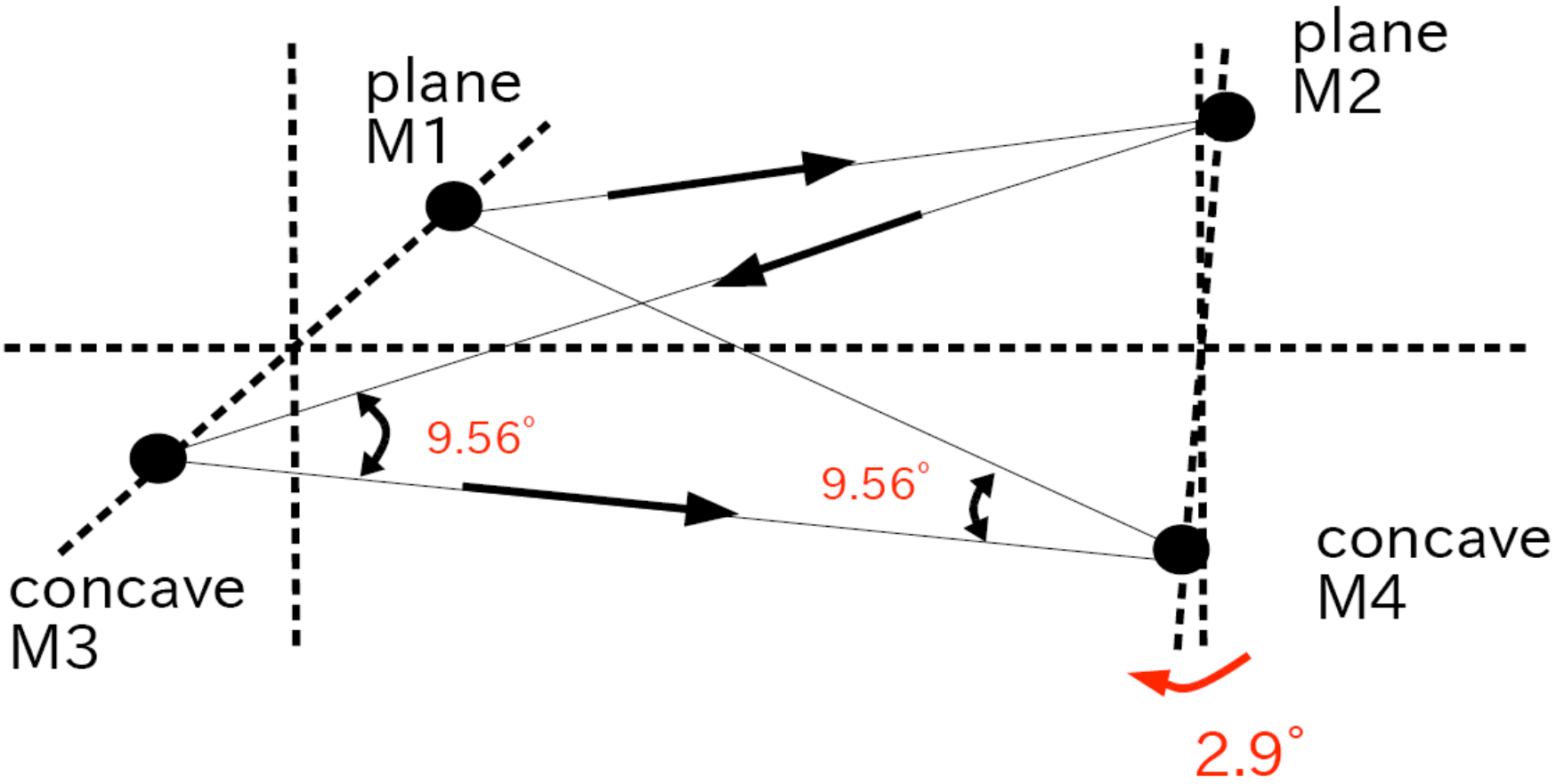






spot size is not sufficiently small with test bench geometry

New Geometry

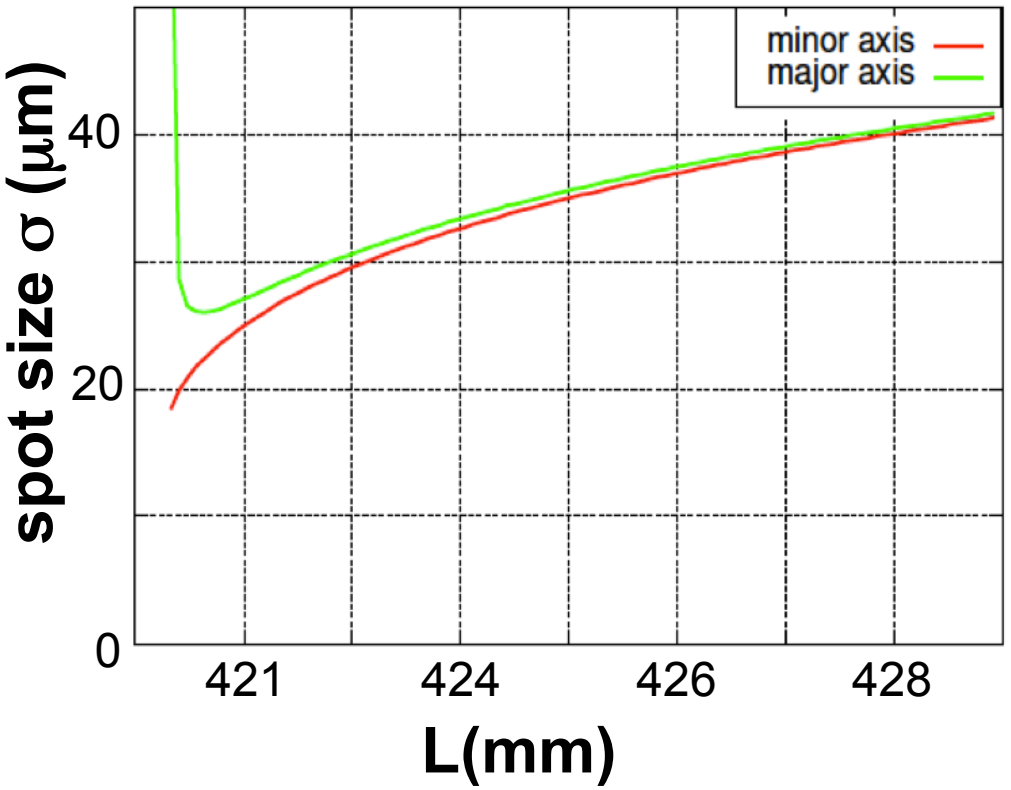


L1=M1-M2=420mm
L2=M2-M3=420mm
L3=M3-M4=420mm
L4=M4-M1=420mm

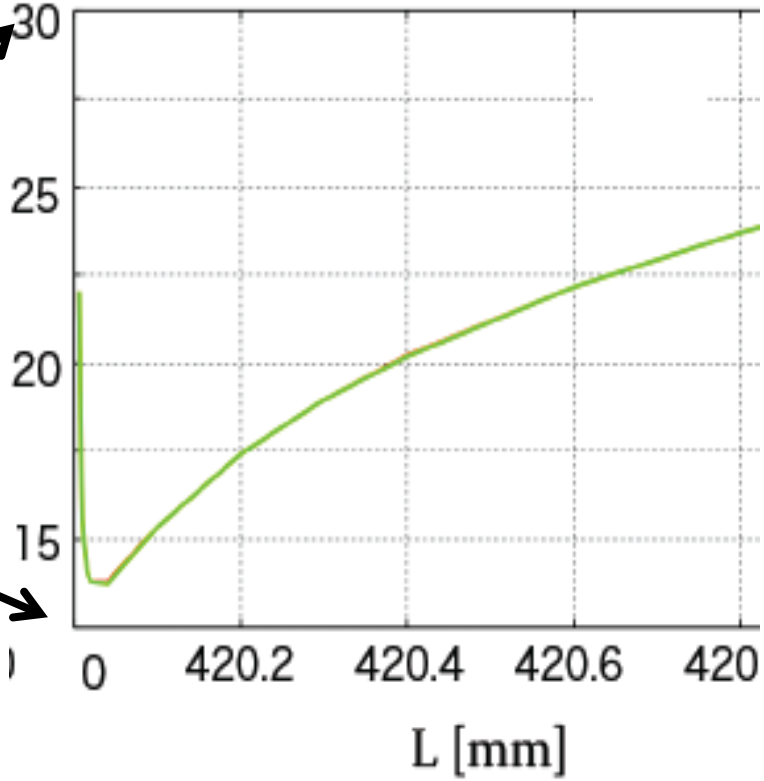
M2-M4=70mm
M1-M3=70mm

Expected Spot Size w/ New Geometry

Before optimization

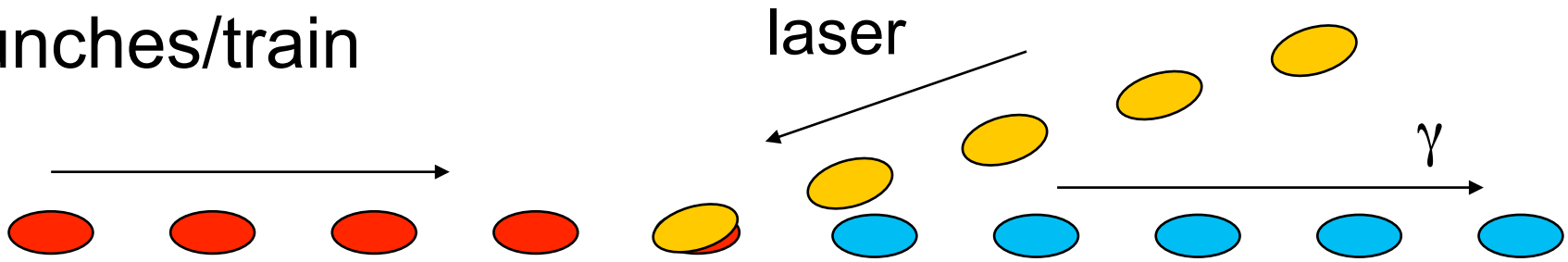


After optimization

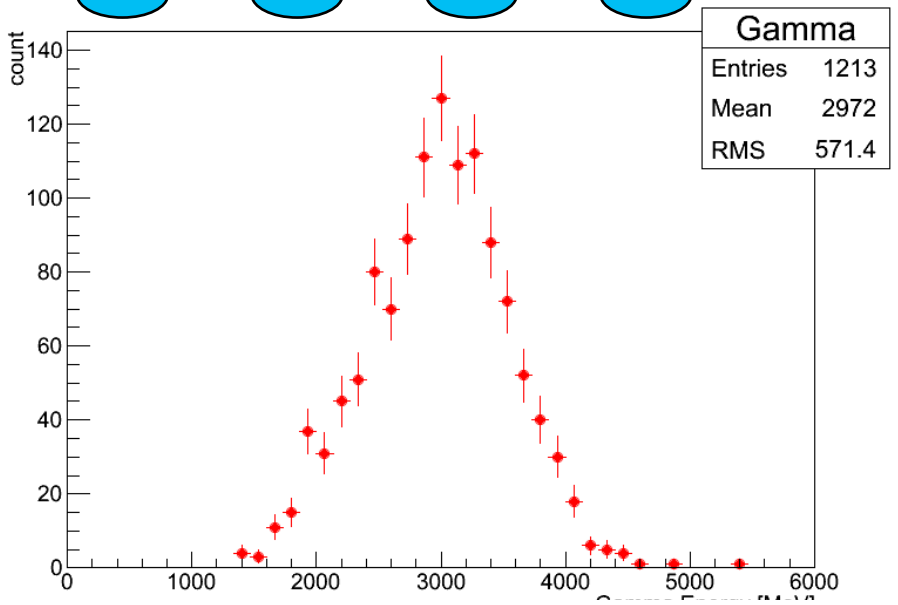


laser spot size of 15 μm is expected with new geometry

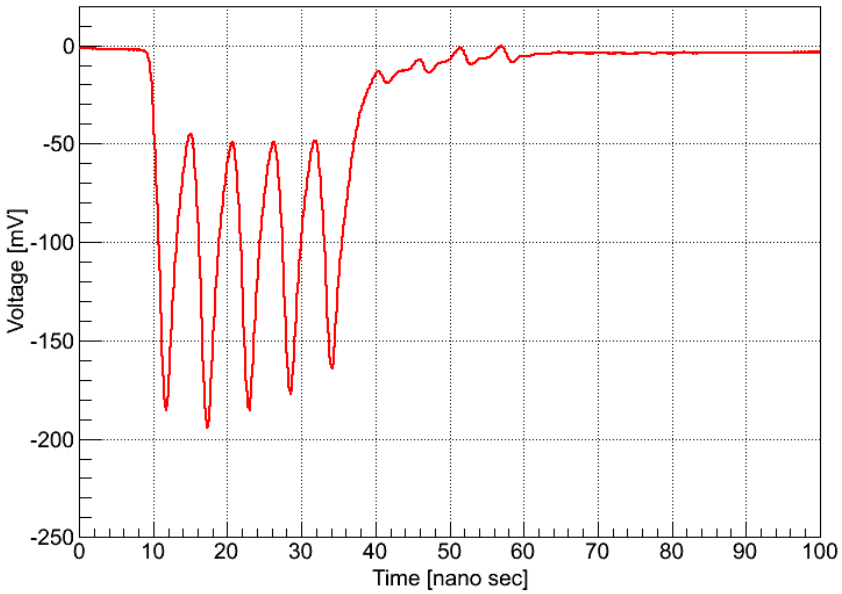
5bunches/train



・# of γs =123.8/train



•confirmed stable photons from each bunch

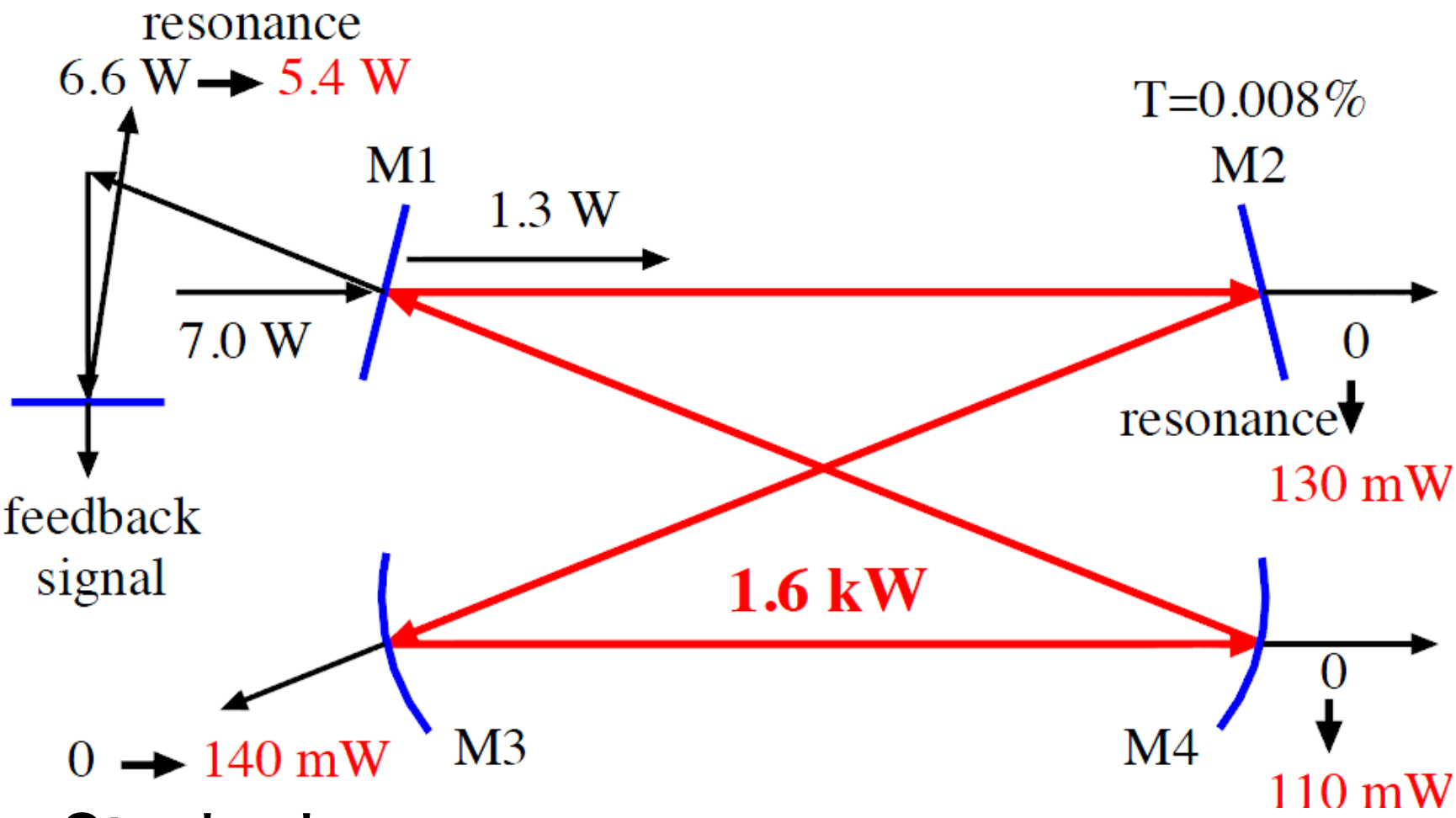


Status as the last meeting

- **What achieved**
  - **2.6 kW stored w/ 1.4 % stability**
  - **128 photons/train**
  - **laser waist size 13 μm in vertical direction**

- **What to be confirmed**
  - **finesse**
  - **power balance**
  - **laser profile at IP**

Power Balance



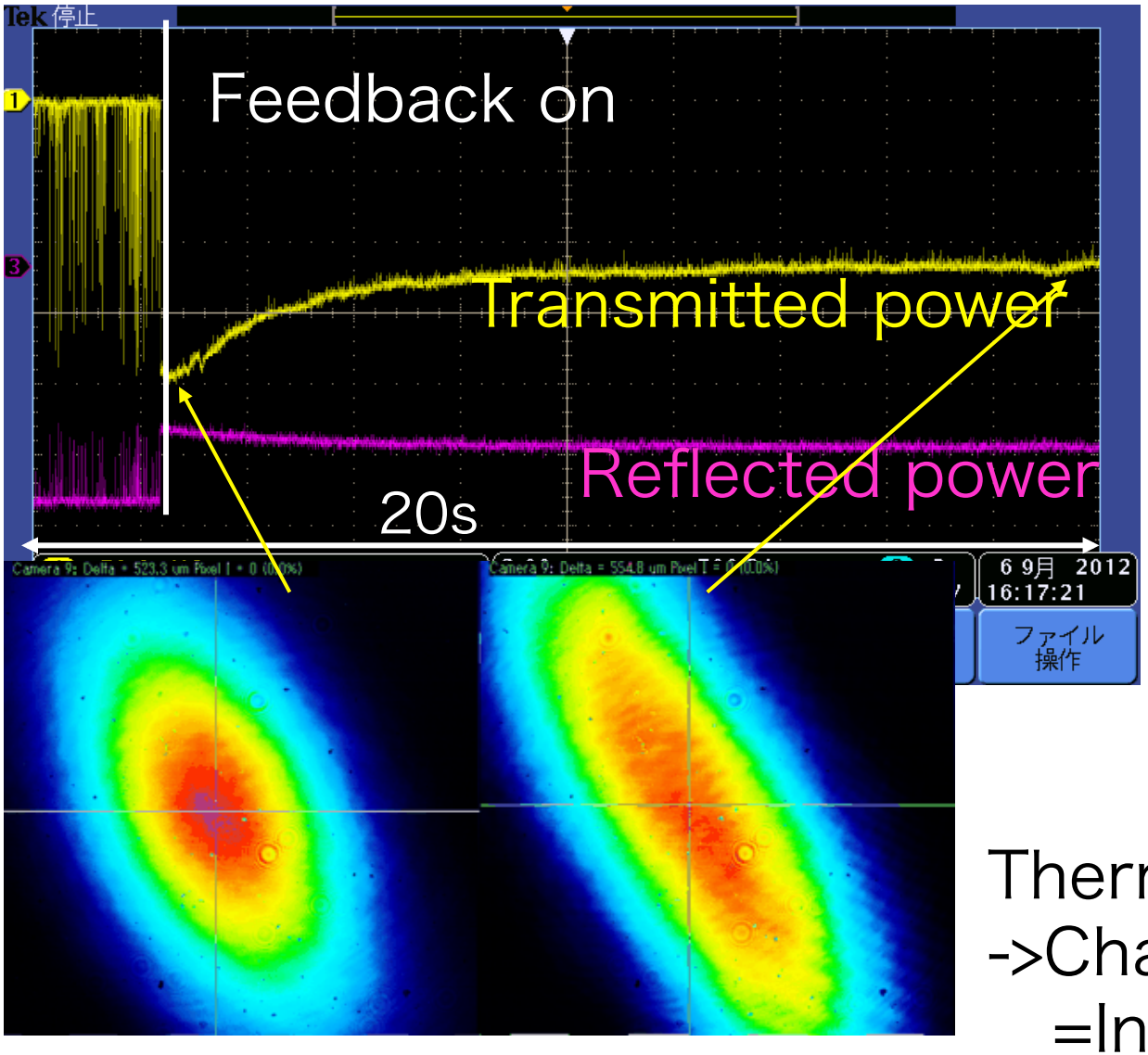
Stacked power

Injected Power x Enhancement =1.6kW

Tansmitted Power / Transmission =1.6kW

⇒Two Estimations are Consistent

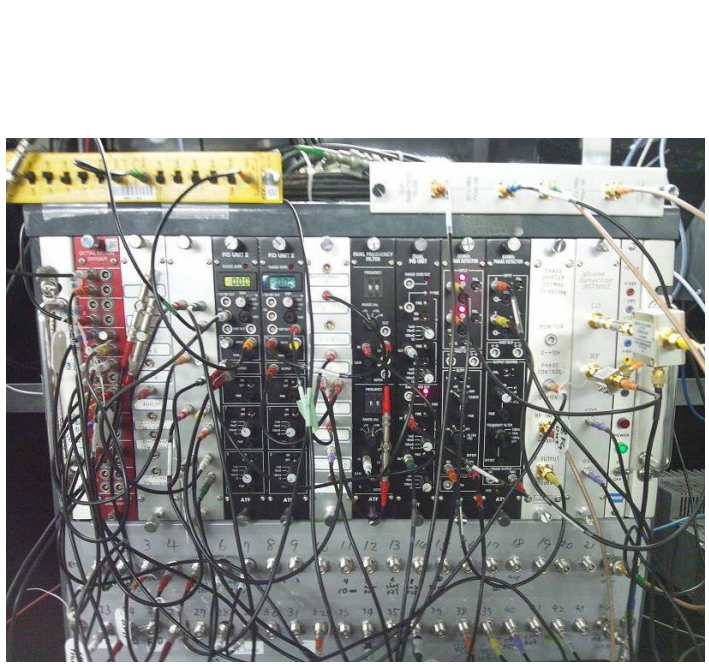
Decrease in stack power

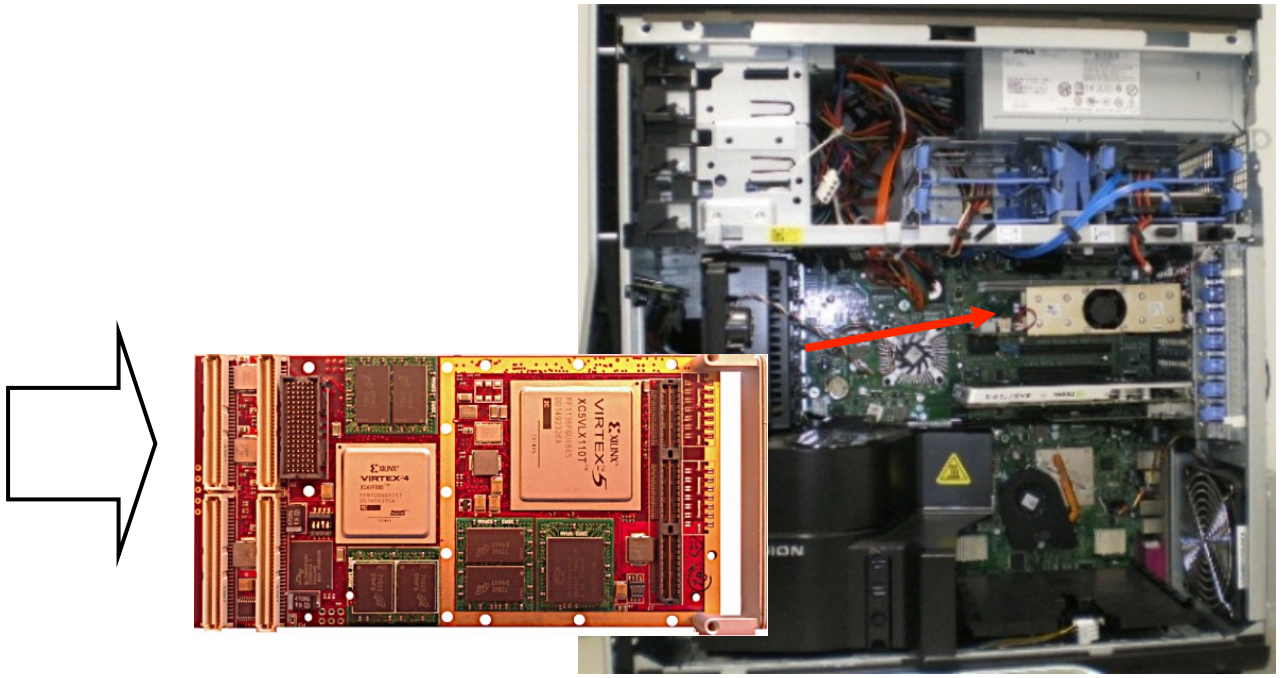


Thermal deformation of the mirr
->Change of transmitted pofile
=Incident efficency is reduced.

Ongoing: Installation Digital Feedback

Feedback circuit : analog -> digital





Expected Advantages

- large fexibility
- Auto control

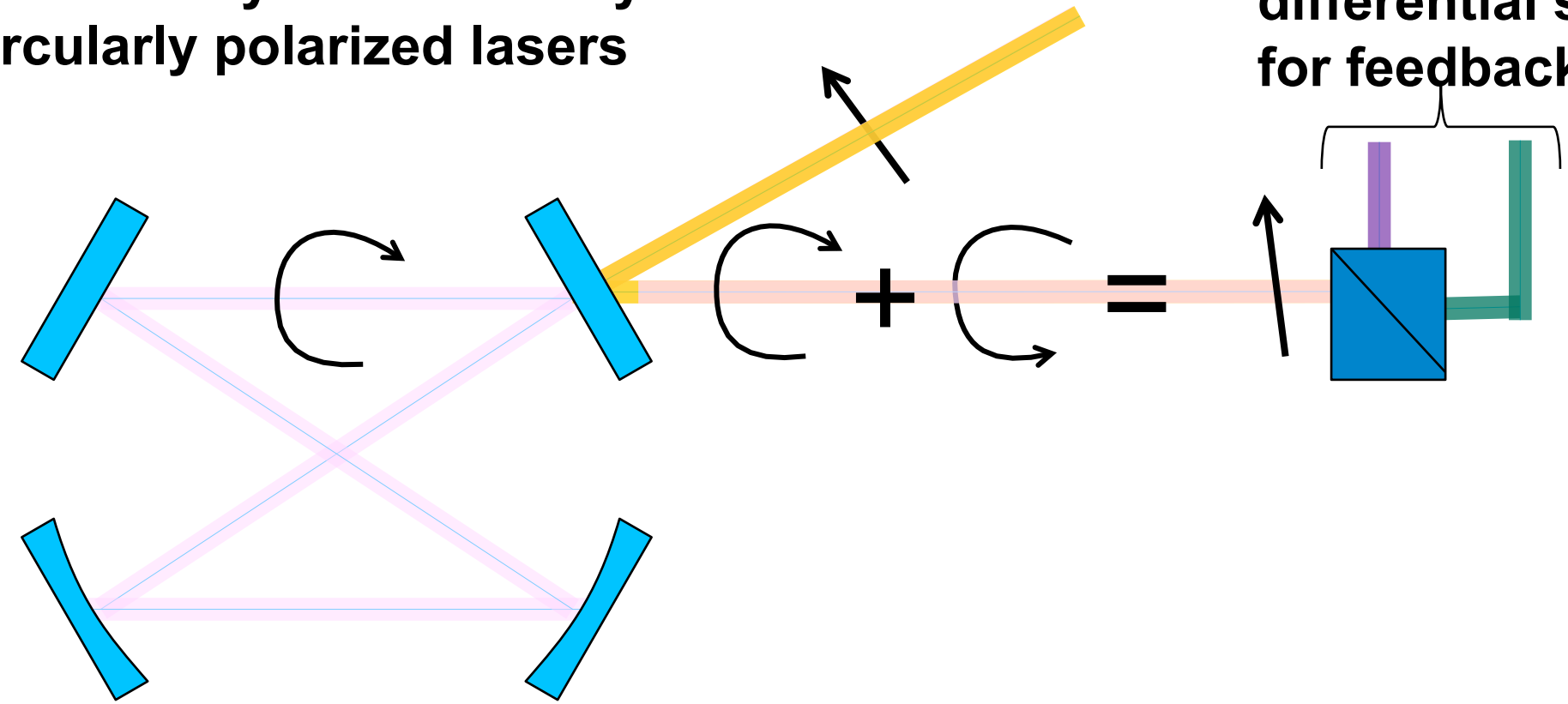
Cavity Length Feedback with 3D Feature

cavity length must be L = nλ/2 with very high precision

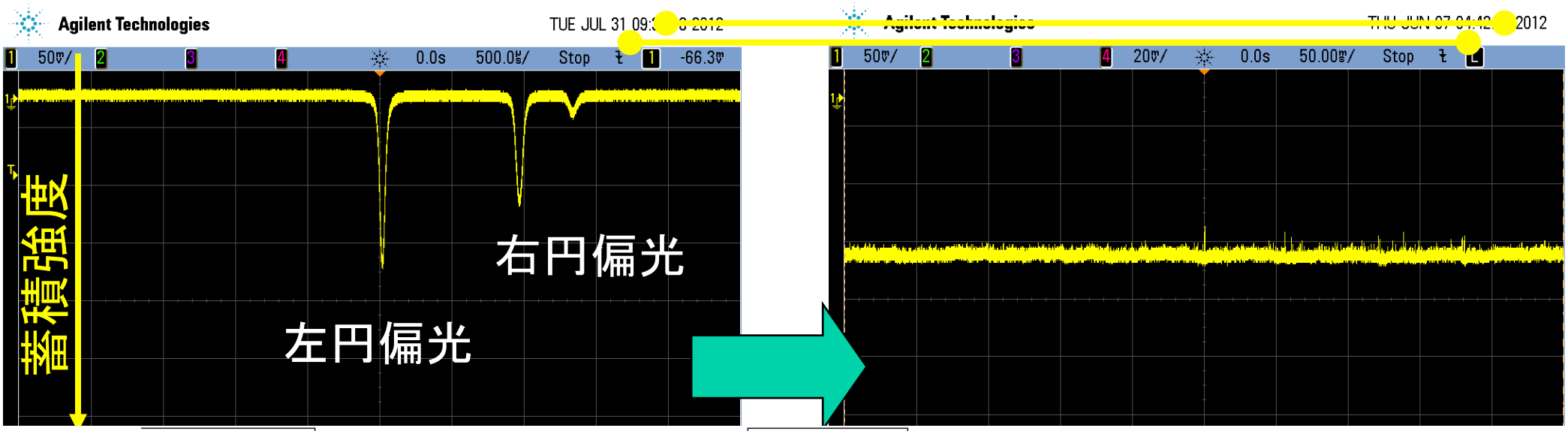
(for enhancement of 1900 dL<< 87pm while L = 1.64m)

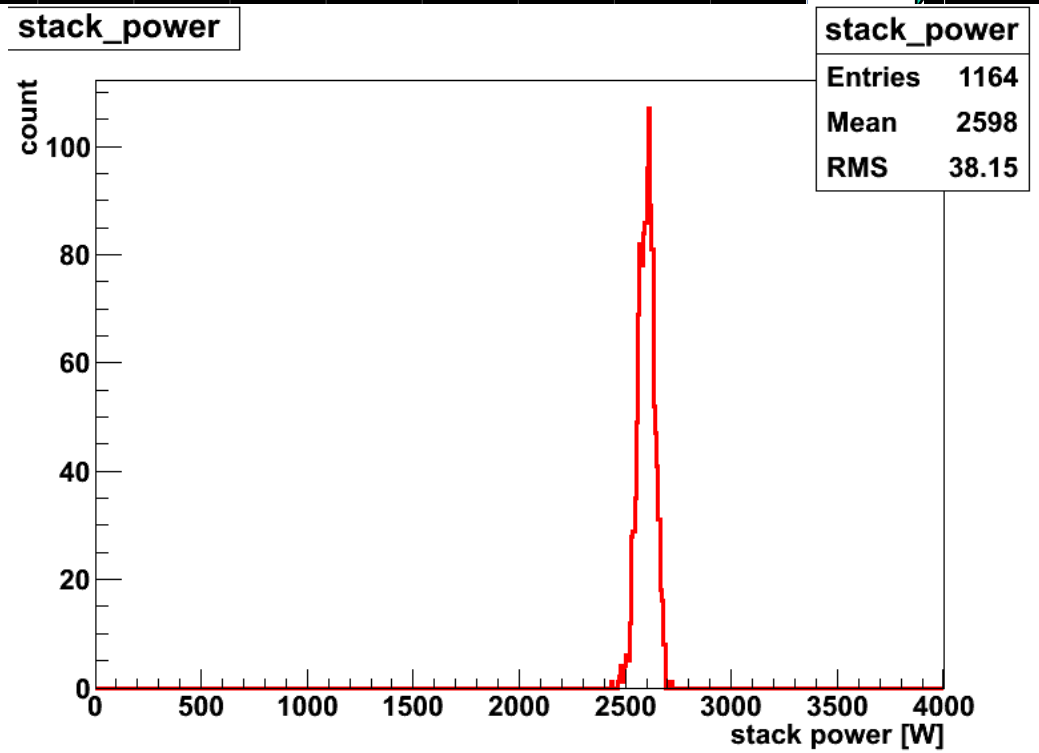
3D4M cavity resonate only with circularly polarized lasers

differential signal for feedback



Stored Laser Power in the Cavity

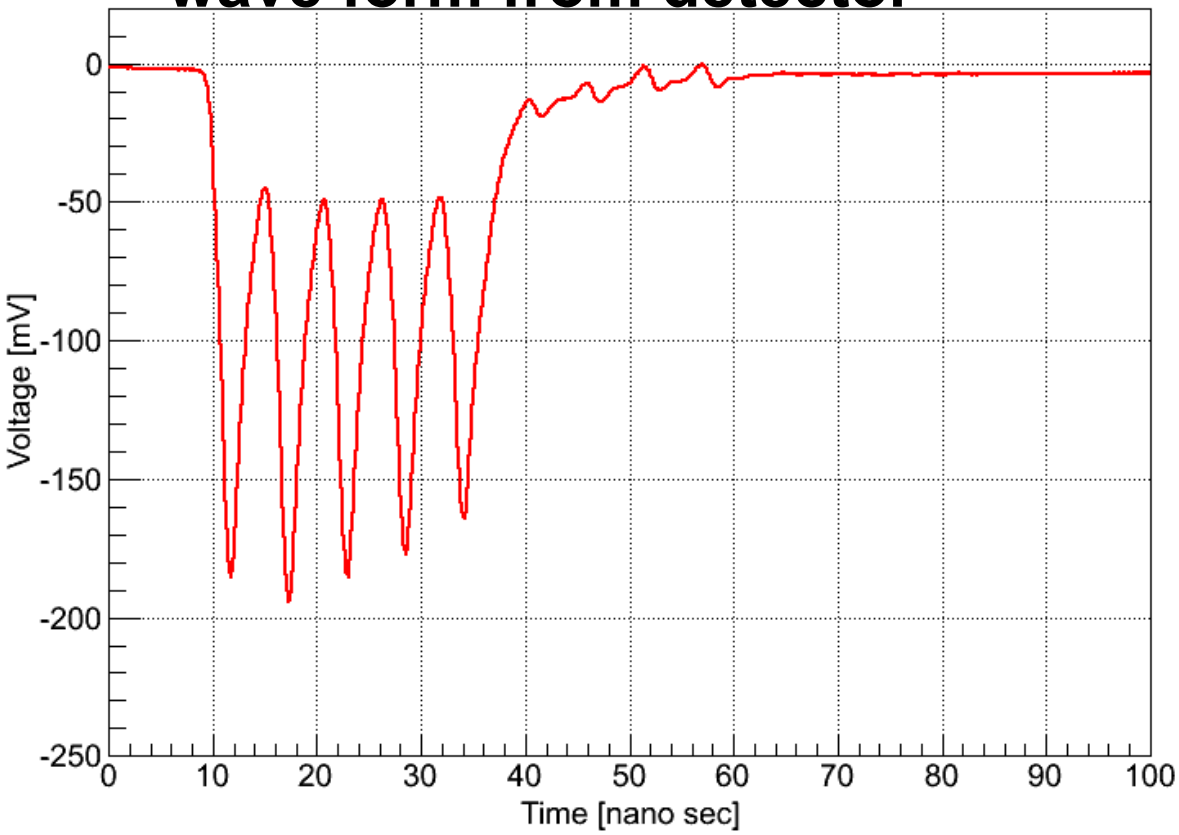




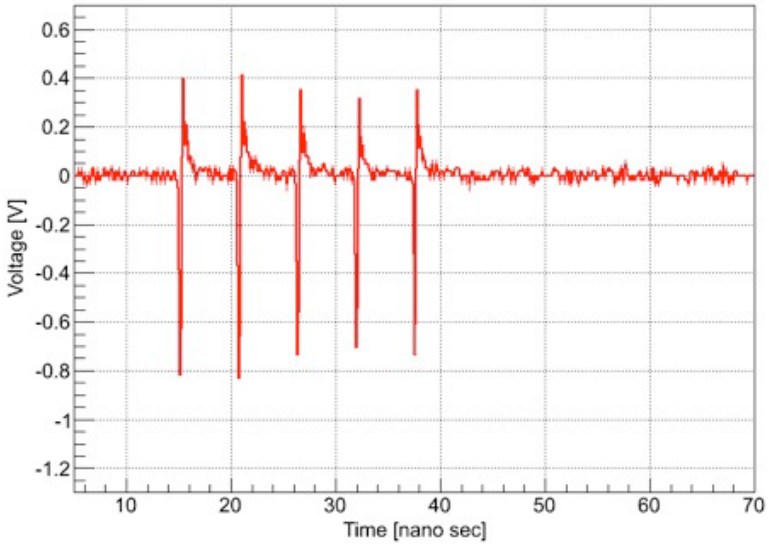
Laser Power 2.6kW
Time Jitter＝8.0ps

Bunch-by-Bunch Measurement

wave form from detector



e- bunch monitor



◆～117/train ⇒ consistent w/ calorimeter measurement

◆no bunch dependence (yield is proportional to e- current)