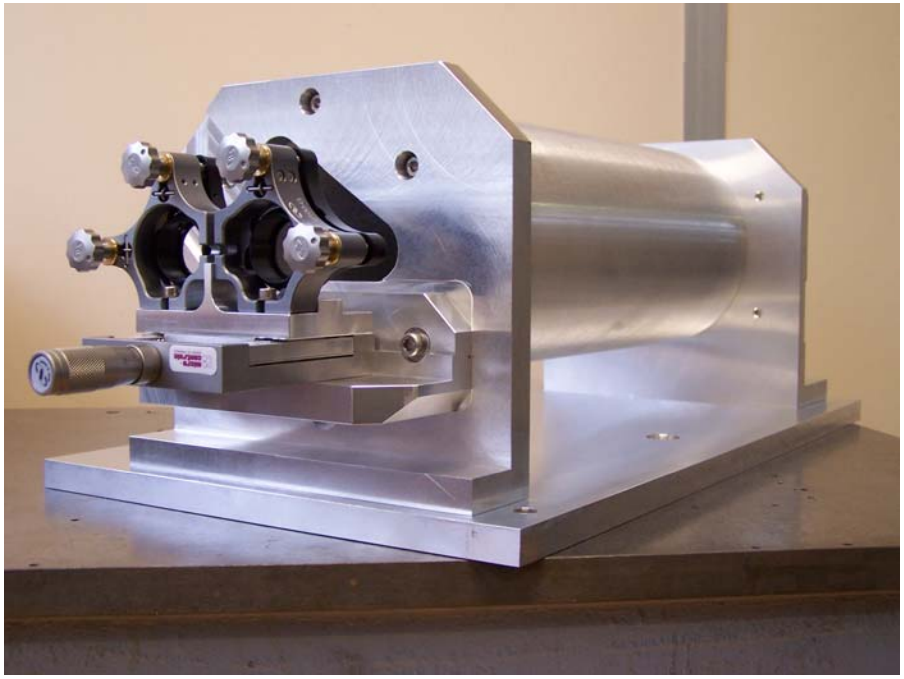
# Test of Optical Stacking Cavity at ATF towards Laser-Compton $e^+$ source



**Tsunehiko OMORI (KEK)**

on behalf of the French-Asia Compton Optical Cavity Collaboration

**TILC08@Sendai**

**4/Mar/2008**

# French-Asia
# Compton Optical Cavity Collaboration

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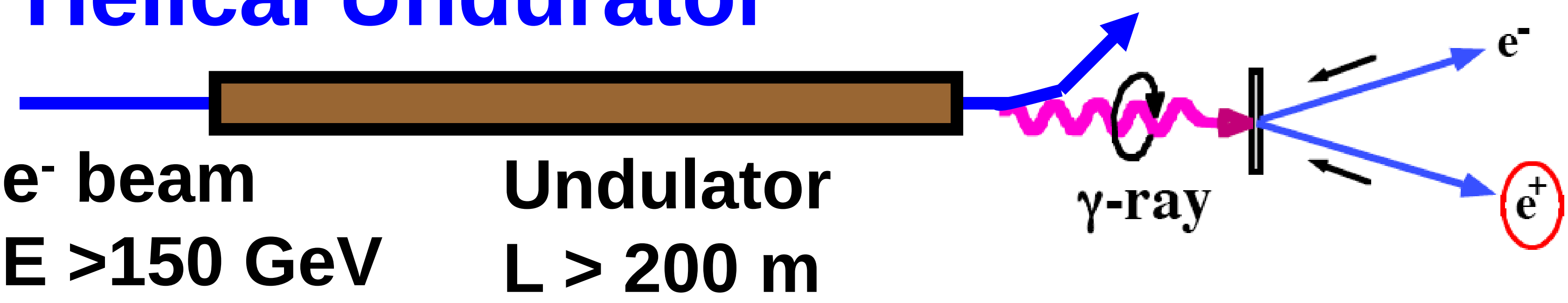
# Today's Talk

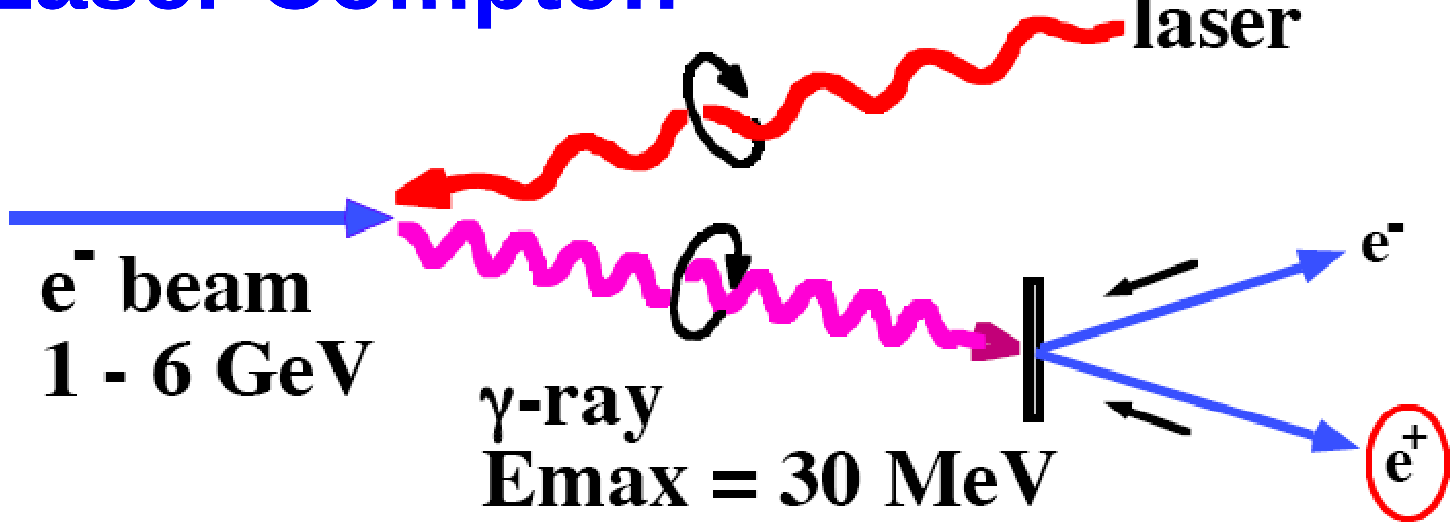
1. Laser-Compton $e^+$ source for ILC.
2. Why Stacking Cavity R/D
3. R/D in Japan/China (2-mirror Cavity)
4. R/D in France (4-mirror cavity)
5. World-wide collaboration
6. Summary

# Two ways to get pol. $e^+$

## (1) Helical Undurator




## (2) Laser Compton



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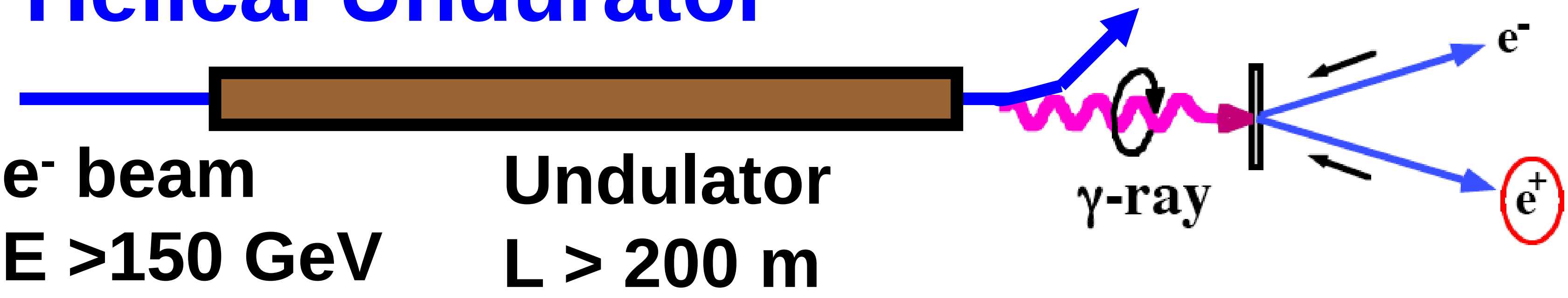
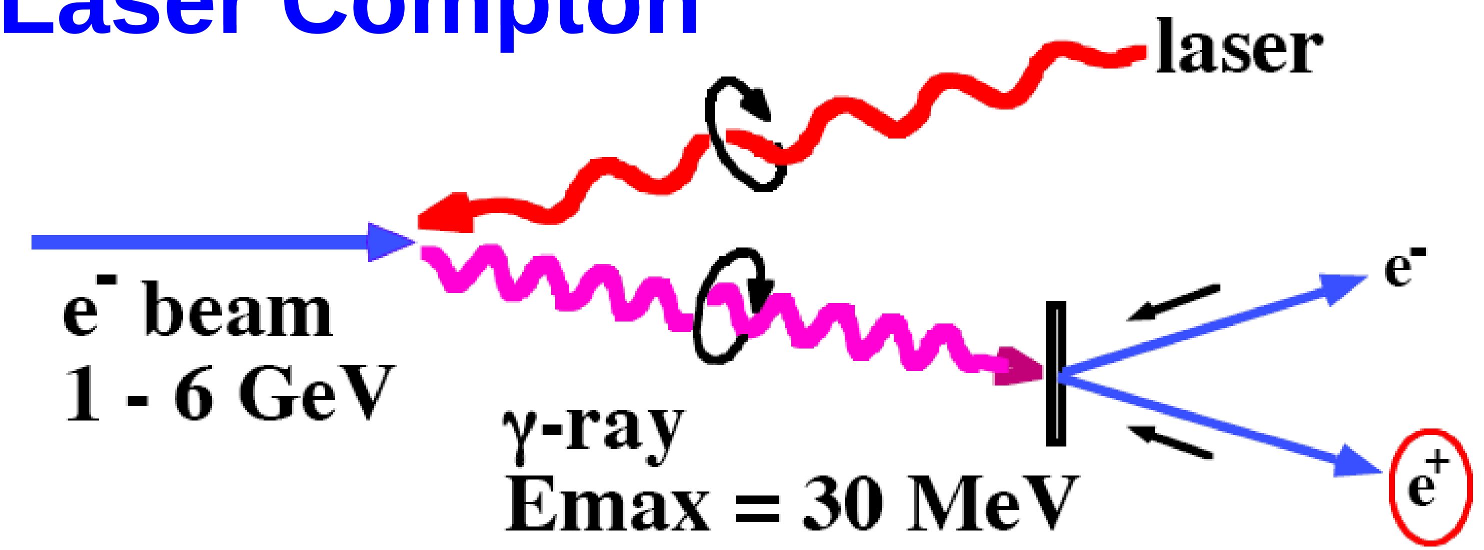



Our Proposal

## (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

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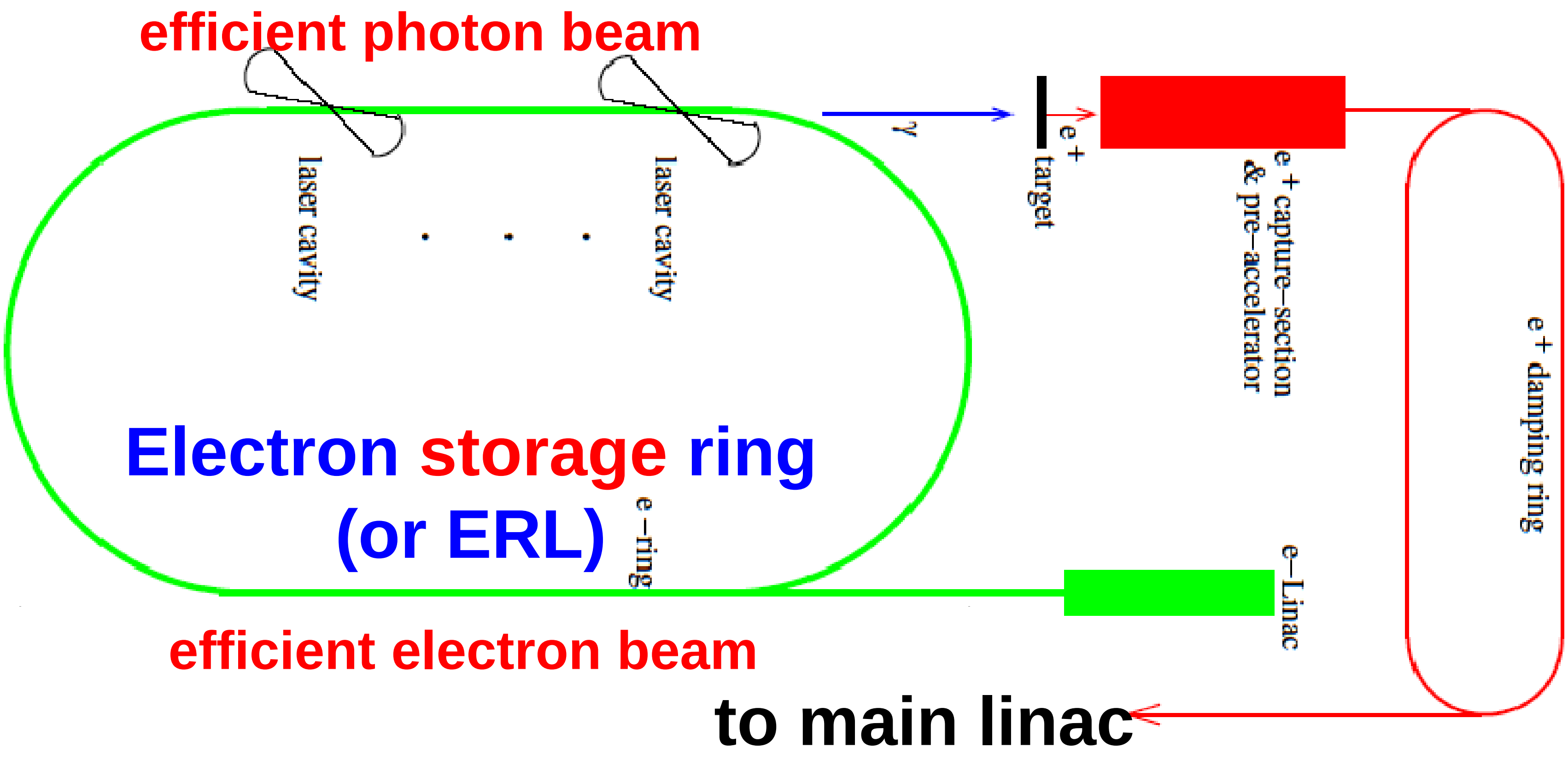
Laser-base $e^+$ : no problem

vi) Synergy in wide area of fields/applications

# Ring Base Compton (an exam

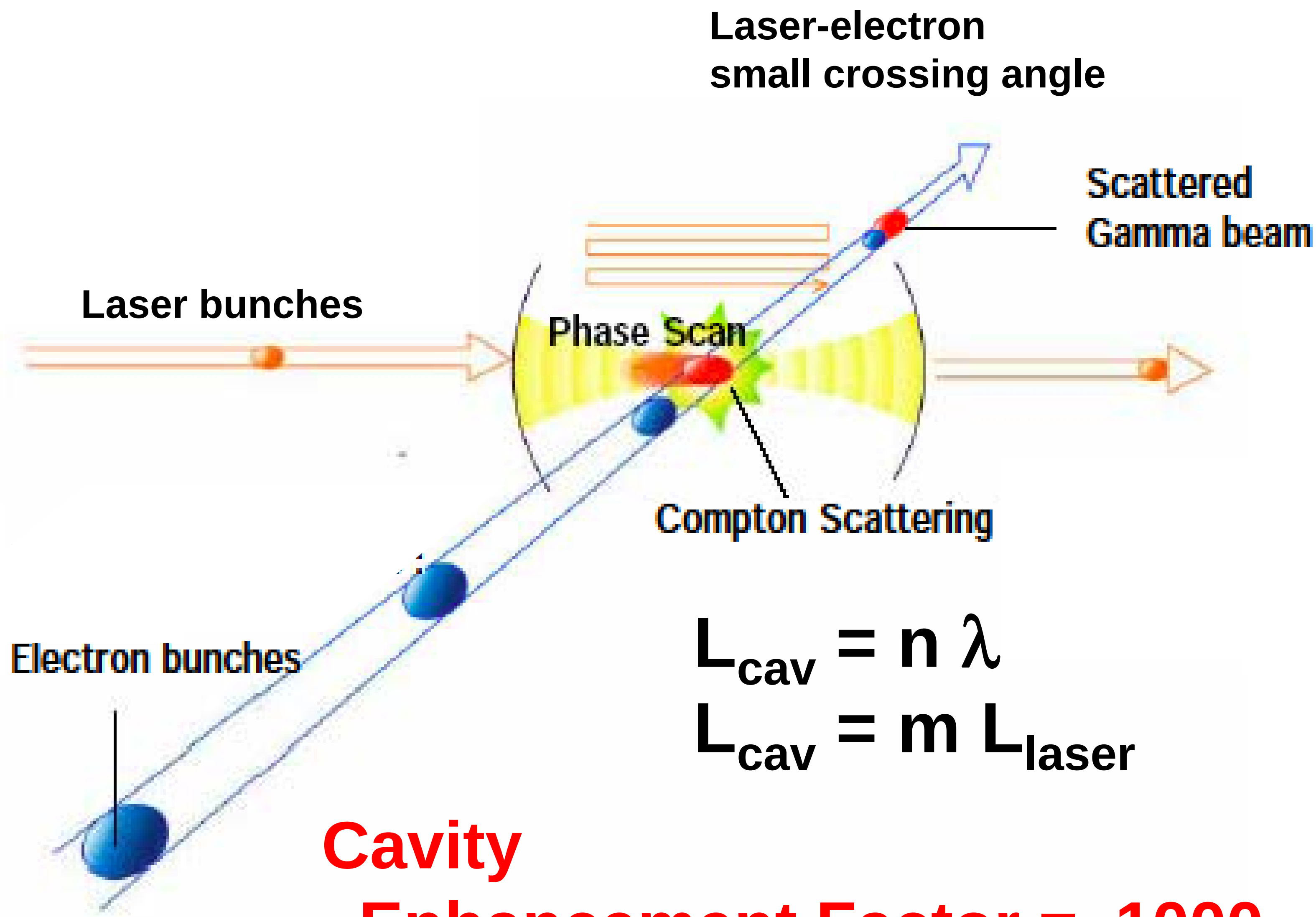
## Re-use Concept

laser pulse stacking cavities




positron stacking in main DR

# Laser Pulse Stacking Cavity




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

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

**Cavity**

**Enhancement Factor = 1000 - $10^5$**

# Why Stacking Cavity R/D?

a) The most uncertain part of the current design.
b) The efficiency of whole system highly depends on the optical cavity design.

- laser spot size
- collision angle
- enhancement factor
- compatibility with e-baem

Simulation alone is not effective in desiging cavity.

We need experimental R/D.

# 2-mirror cavity at ATF

## R/D in Japan/China

**Moderate Enhancement ~ 1000**

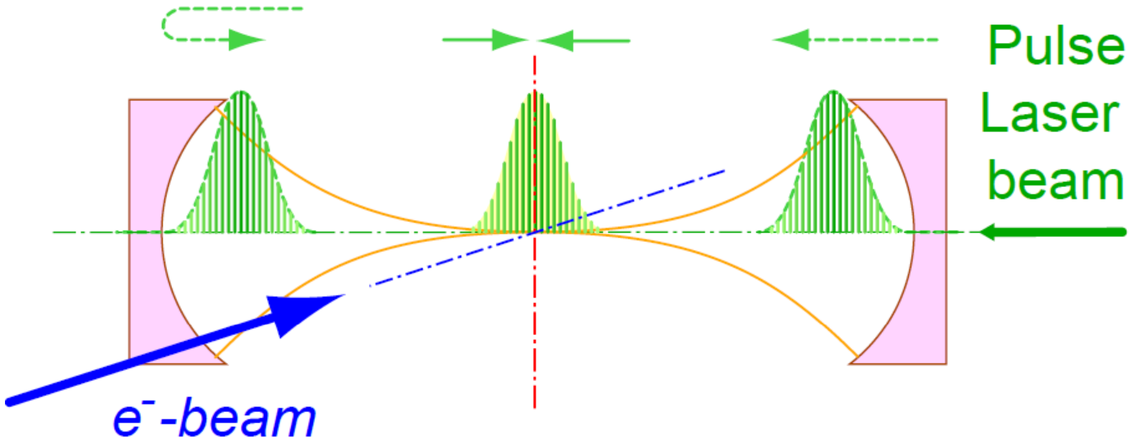
**Moderate spot size ~ 30 micron**

**Simple cavity stucture with two mirrors**

**Get experinence with $e^-$ beam**

# Experimental R/D in ATF

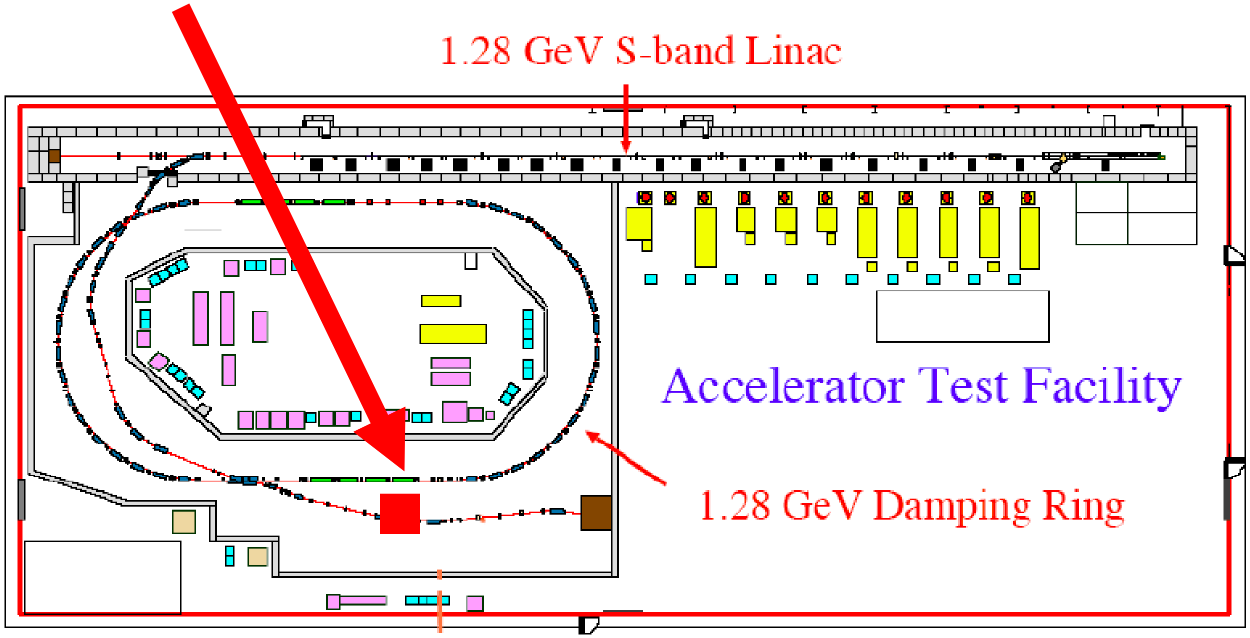
Hiroshima-Waseda-Kyoto-IHEP-KEK




**Make a fist prototype 2-mirror cavity**

**$L_{cav}$ = 420 mm**

**Put it in ATF ring**



# Points of R/D

## Achieve both

high enhancement & small spot
(less stabile) & (less stabile)

## Points for high enhancement factor

remove/suppress vibration

establish feed-back technology

## Points for small spot

$2\rho - L_{cav}$ --> +0

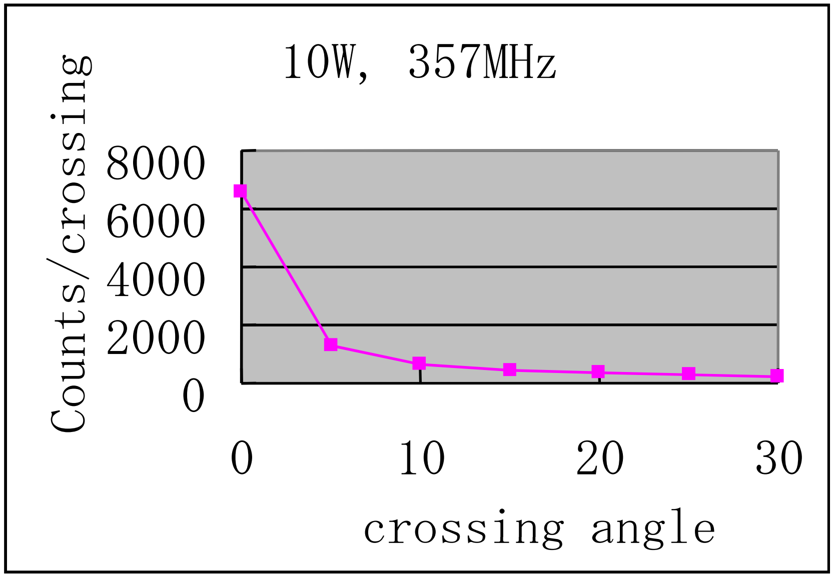
good matching between laser and cavity

all are common in pol. $e^+$ and laser wire

# Points of R/D (continued)

## Achieve smaller crossing angle

### Number of γ-rays strongly depends on crossing angle




**ATF**

**$e^-$ bunch length = 9 mm (rms)**

**Ne = $1 \times 10^{10}$/bunch**

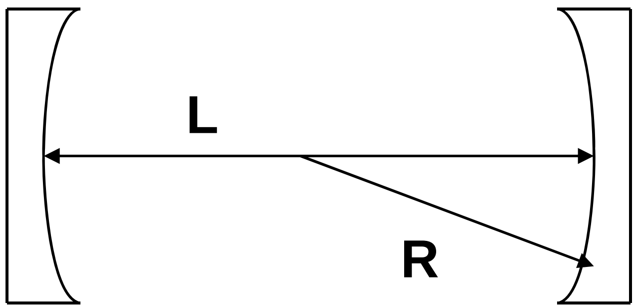
### --> Small crossing angle is preferable

### --> constraint in chamber design

**This in NOT common in pol. $e^+$ and laser wire**

# Laser stacking cavity with Two Spherical Mirrors

## Choice of R and spot size

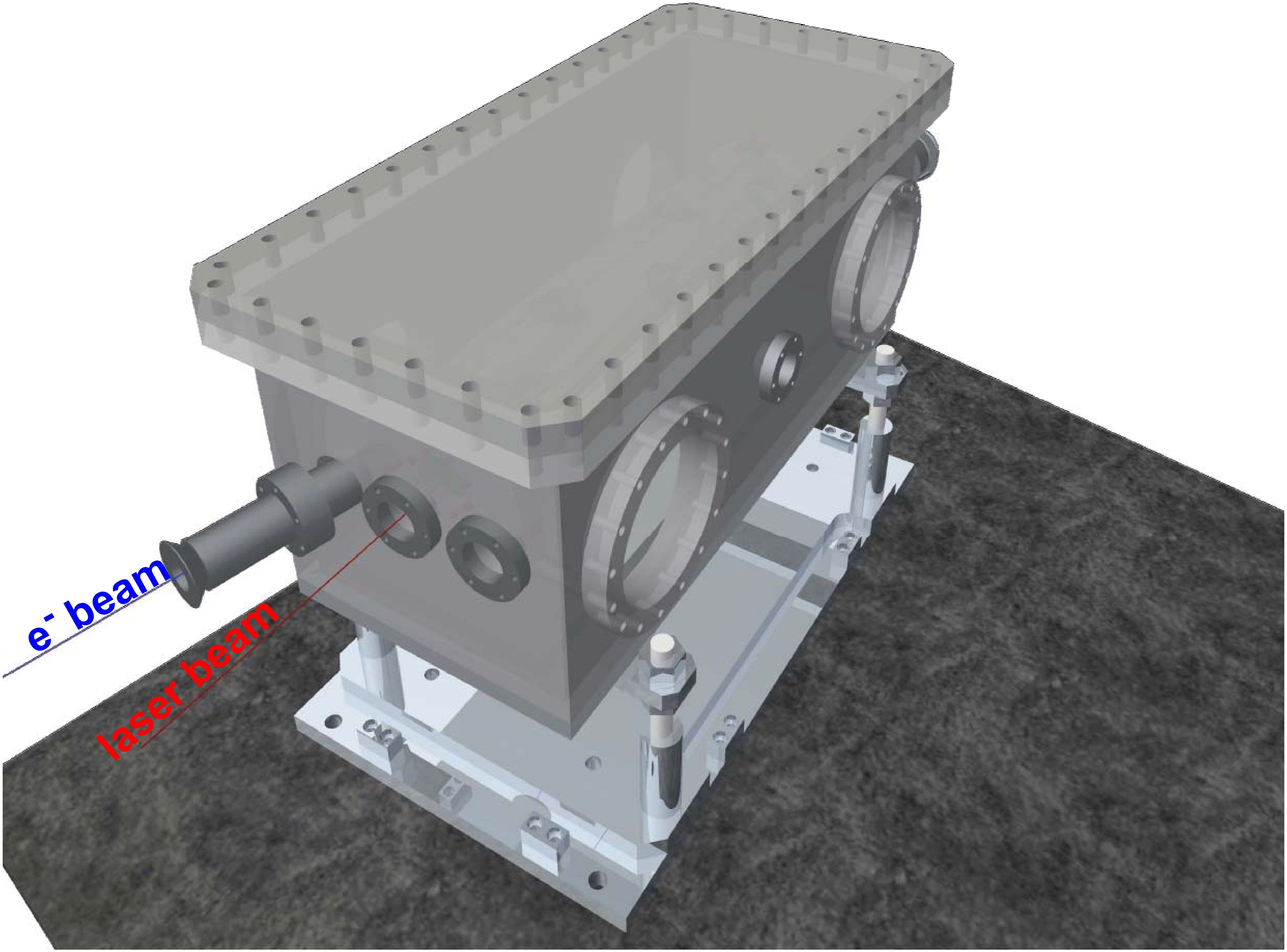



L = 420.00 mm

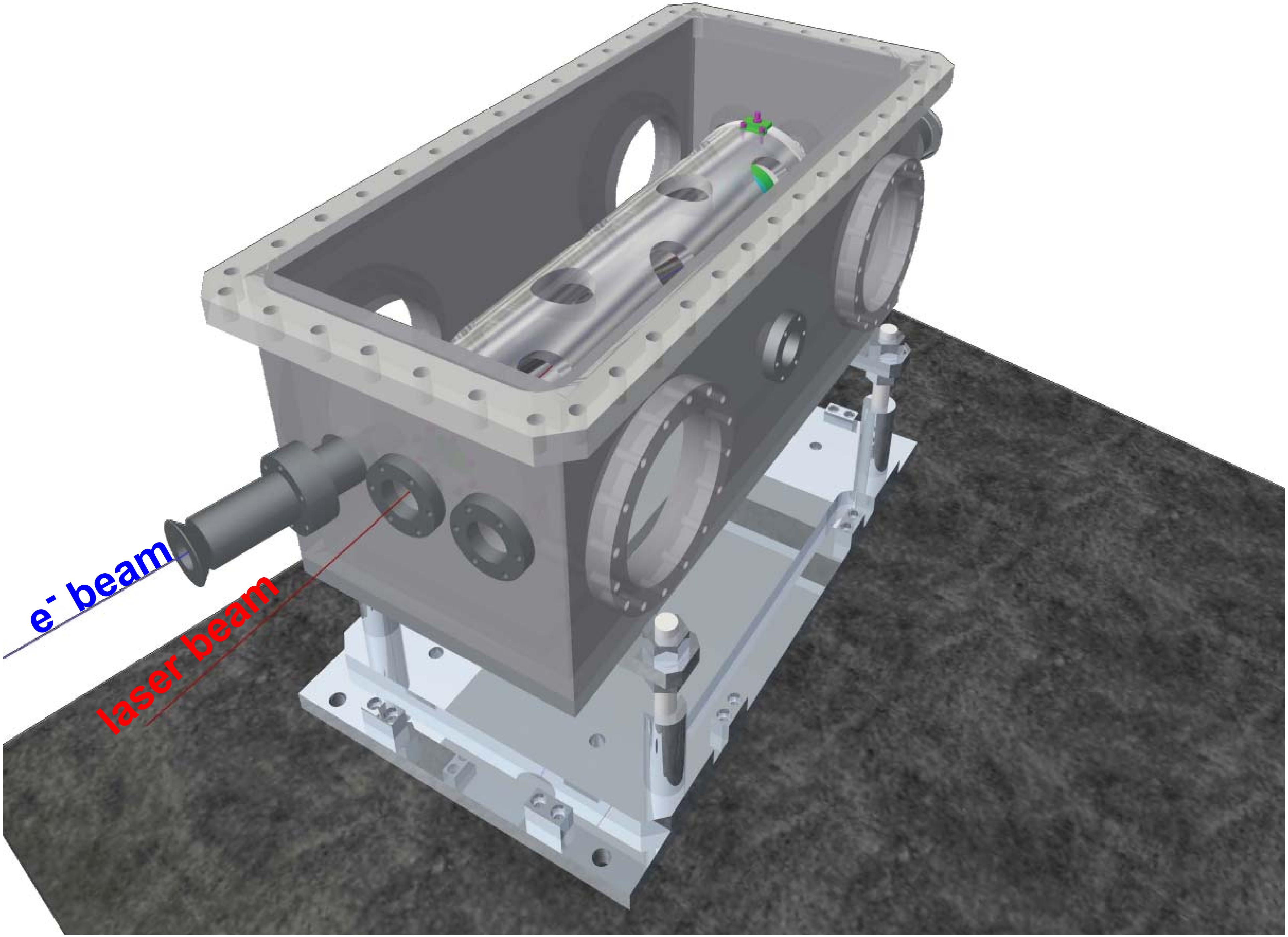
our choice for 1st prototype →

concentric configuration
**R + R ~ L**

| Mirror R (mm) | rms laser spot size (micron) |
|---|---|
| 250 | 88 |
| 211 | 35 |
| 210.5 | 30 |
| 210.1 | 20 |
| 210.01 | 11 |
| 210.001 | 6 |



e- beam
laser beam


e- beam
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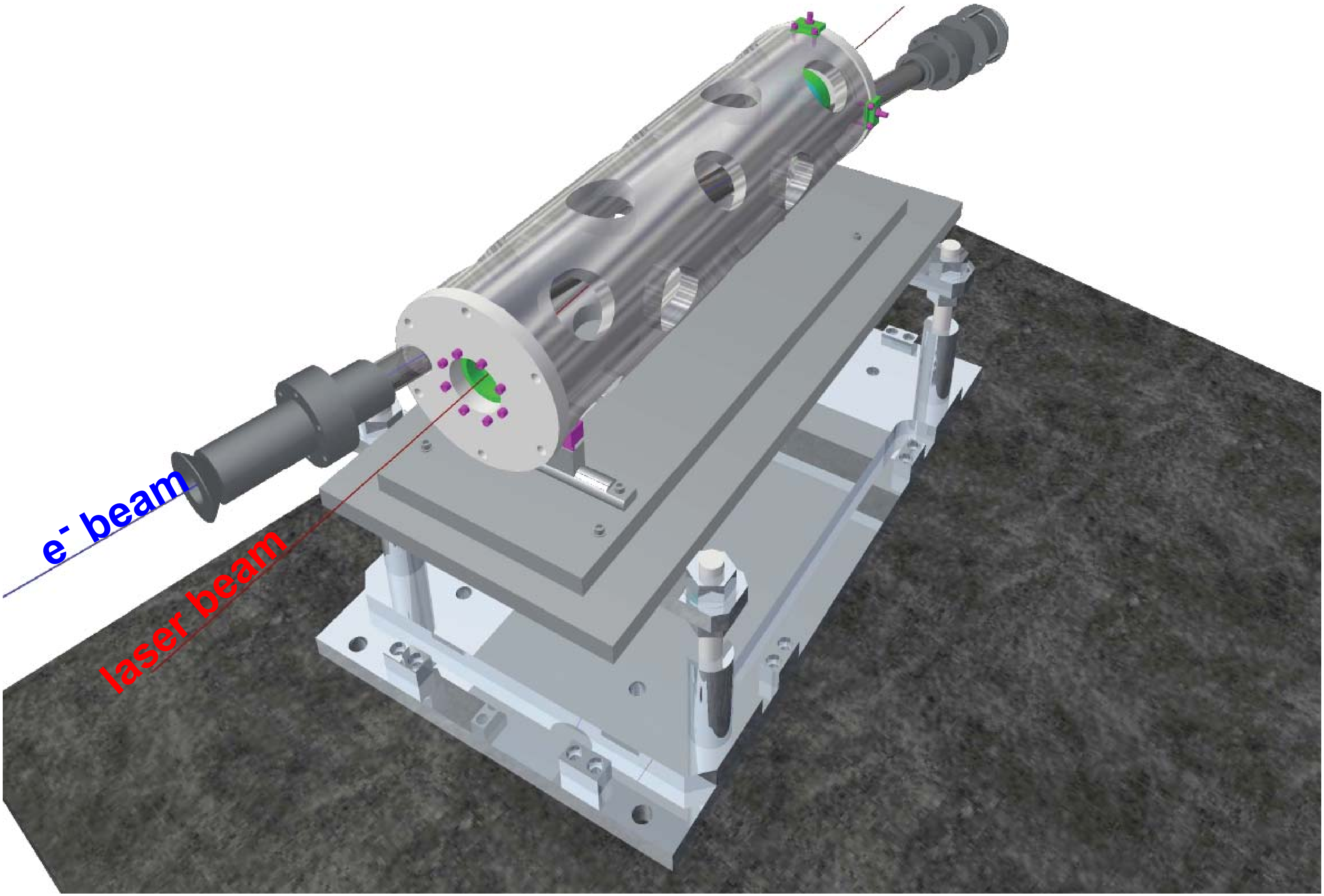
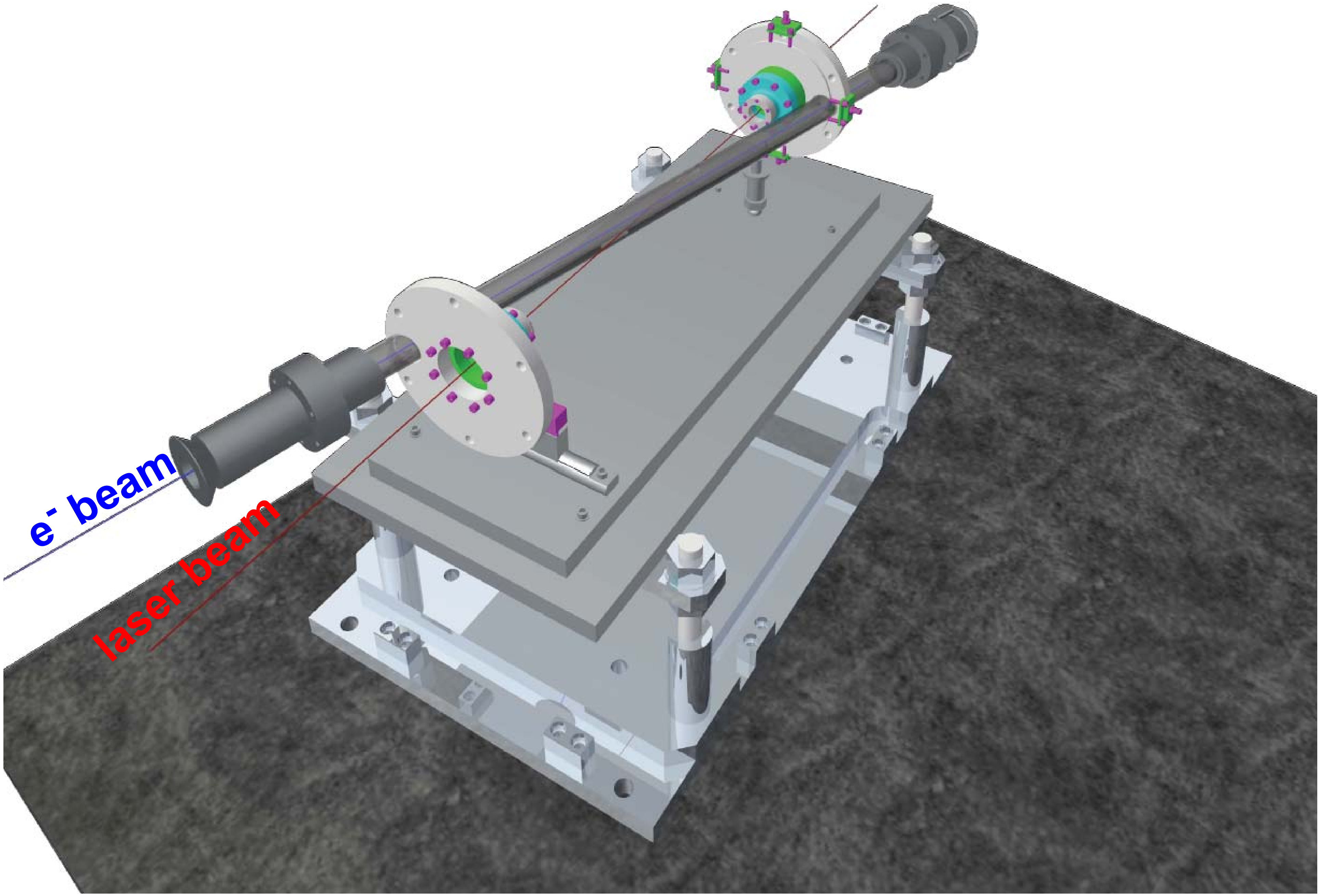
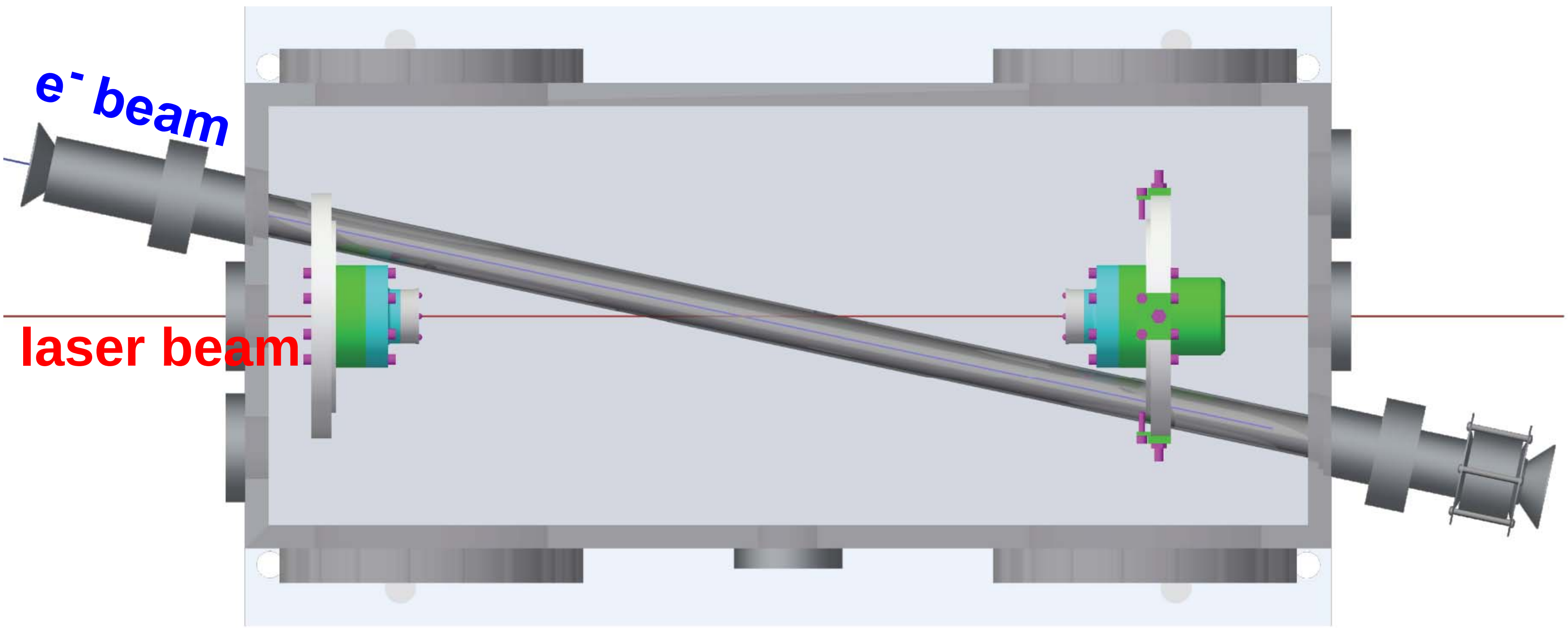

e⁻ beam
laser beam

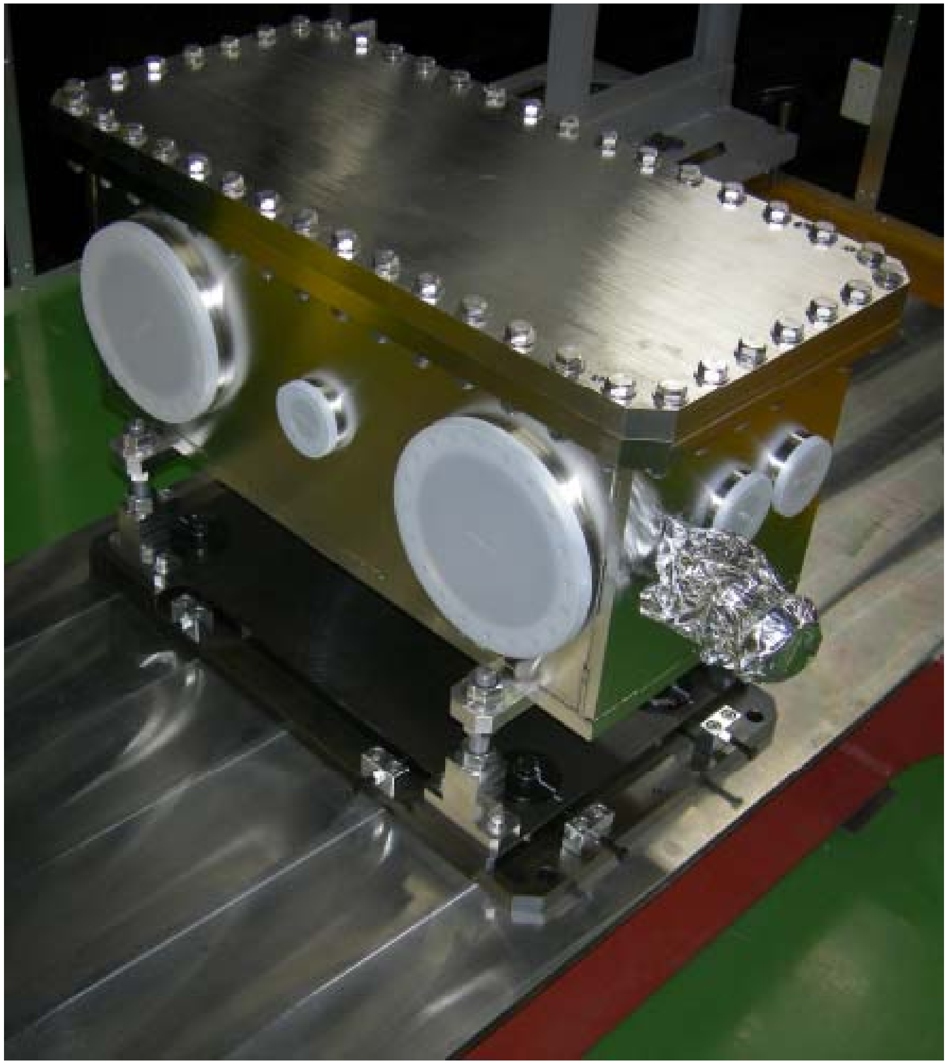


e- beam
laser beam


e⁻ beam
laser beam

**Optical Cavity**

**Vacuum chamber**



# Optical Cavity in Vacuum Chamber

# Summer 2007:  Assembling the mirror cavity

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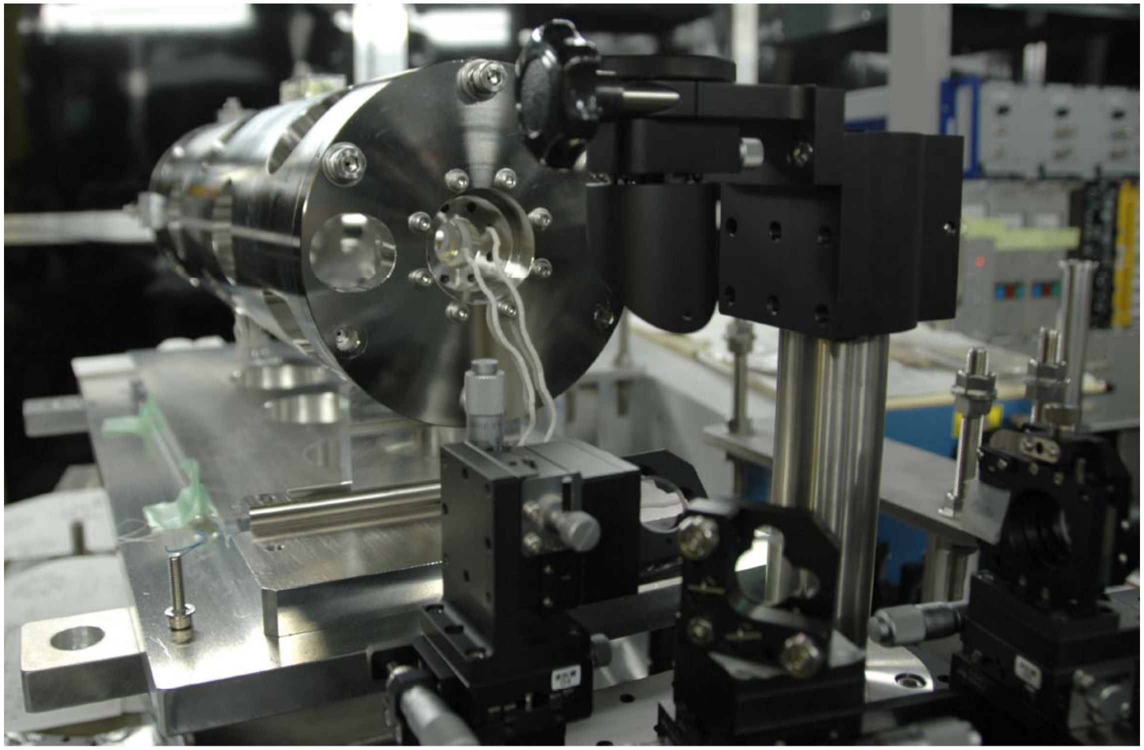
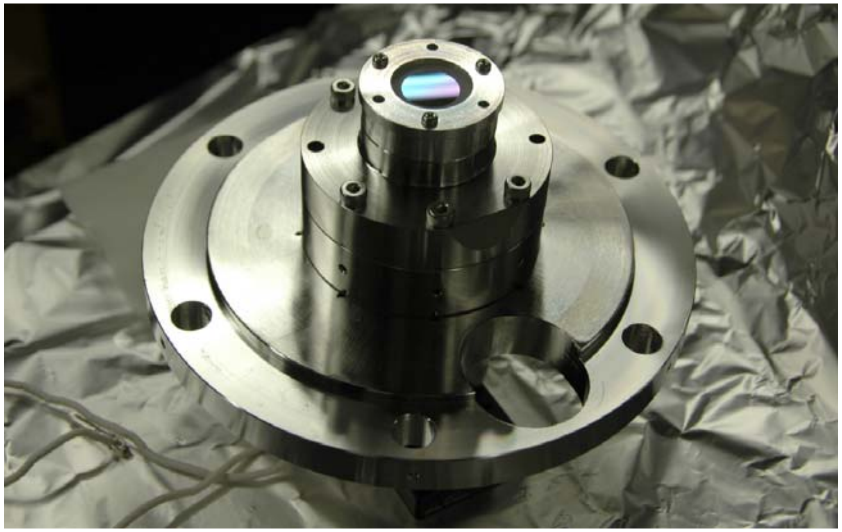
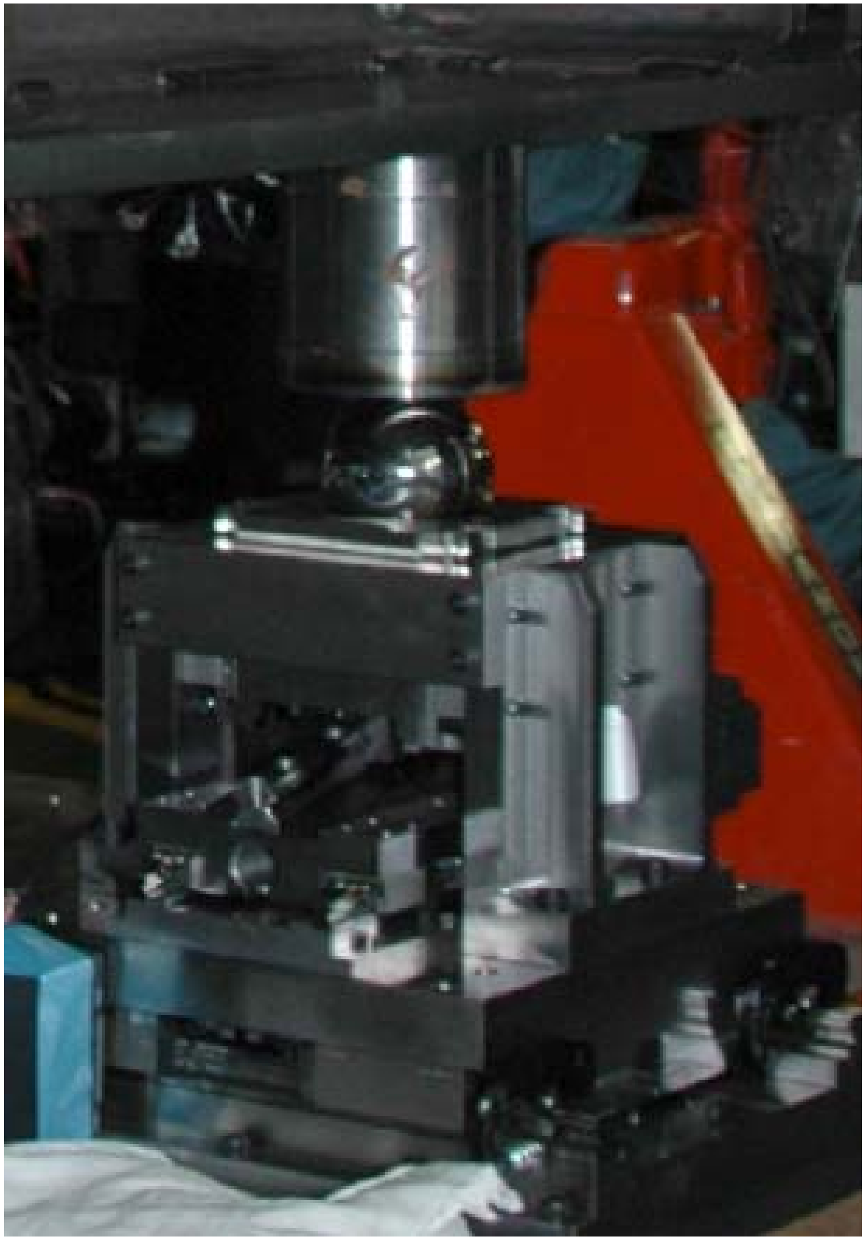




# October 2007: Install the 2-mirror cavity into ATF-DR



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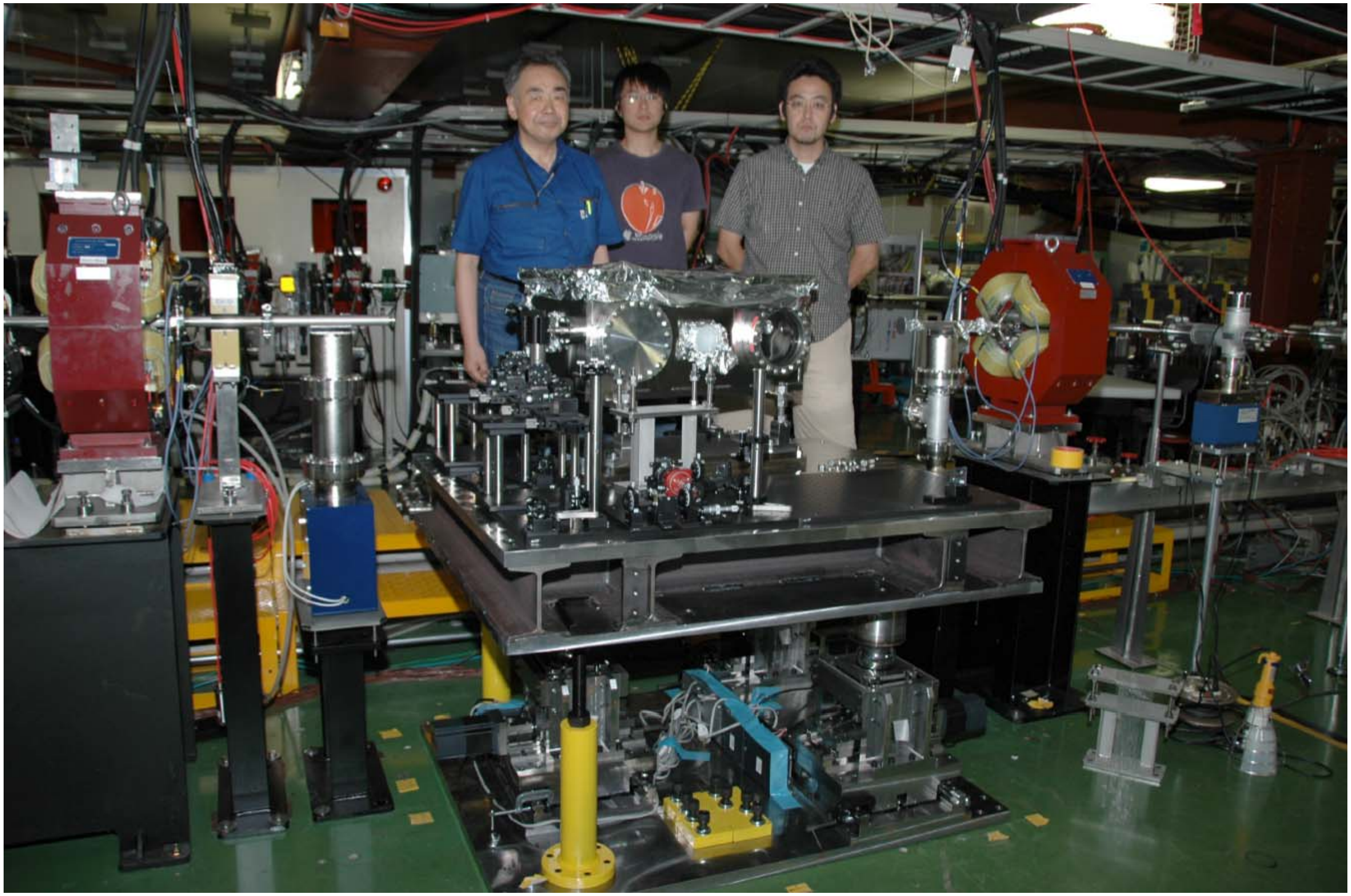

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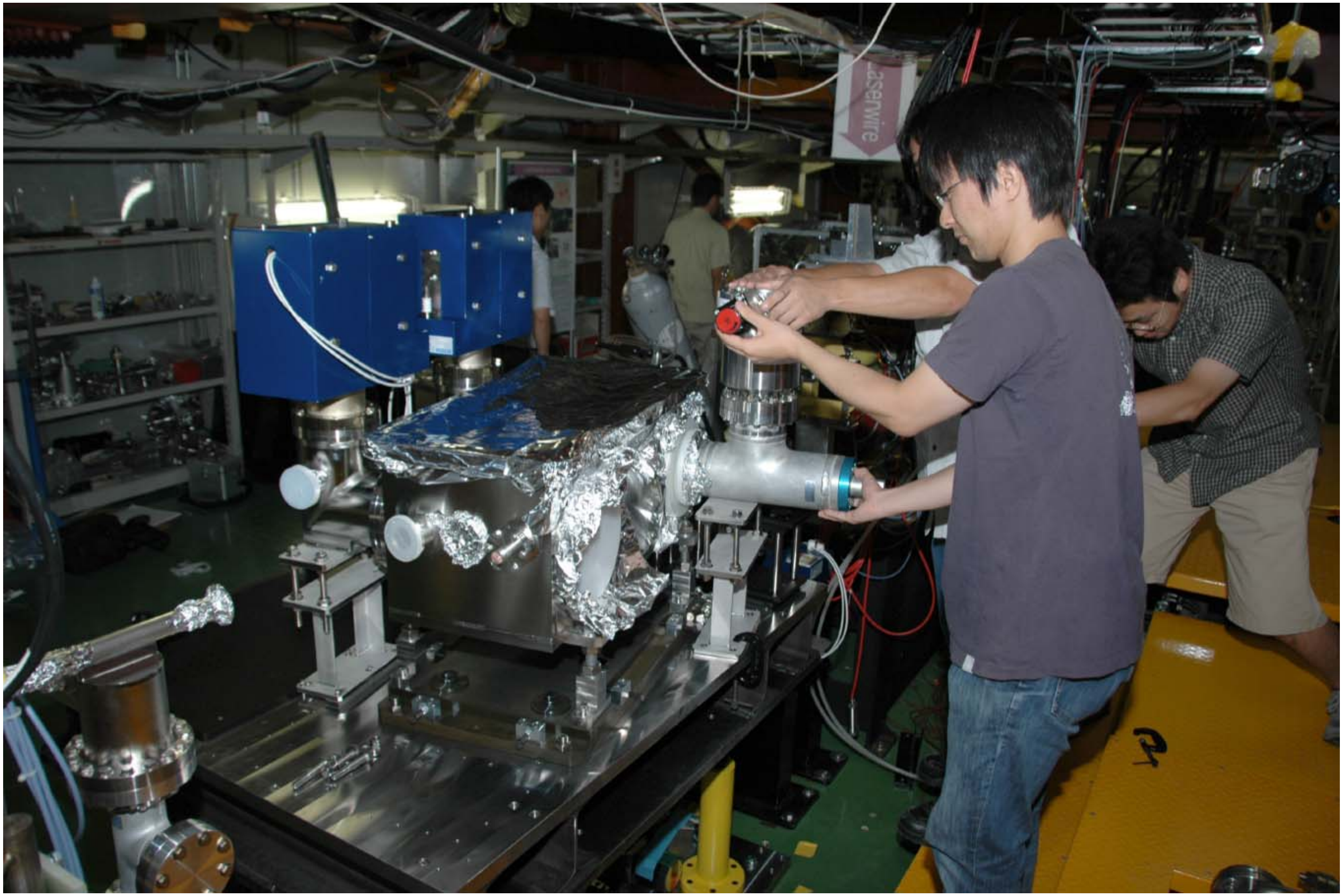


# Expected Number of $\gamma$-rays

**design values with R=99.9 %**

**Number of $\gamma$-rays/bunch**

Electron :Ne = $2\times10^{10}$ (single bunch operation)
Laser : 10 W (28 nJ/bunch)
Optical Cavity: Enhancement = 1000

$N\gamma$ =1300/bunch X-ing angle = 10 deg
$N\gamma$ = 900/bunch X-ing angle = 15 deg

**Number of $\gamma$-rays/second**

Electron :Ne =$1\times10^{10}$ (multi-bunch and multi-train operati
Electron 20 bunches/train, 3 trains/ring
Laser : 10 W (28 nJ/bunch)
Optical Cavity: Enhancement = 1000

$N\gamma$ = $8.5\times10^{10}$/sec X-ing angle = 10 deg
$N\gamma$ = $5.7\times10^{10}$/sec X-ing angle = 15 deg

# November - December 2007

## We were moving forward slowly but steady.

### Start with low R mirrors

R = 99.6 % (Finesse ~ 750, Enhance = 250)

### Made missing items.

Cabling of the Mover Table.

Software of the Mover Table.

Lead wall to protect the laser.

Gamma Detector and Calibration.

### Improved some items.

Laser path

### Still not ready

Stable Feedback of the laser sacking cavity

# Recent 2 months

**Try to get gamma-ray generation with no feedback of laser stacking cavity (with piezo scan).**

**We got the first collision (gamma-ray signal) on Jan/30th.**

**a mail from Araki-san in Jan/30th**

From: <saraki@post.kek.jp>
Reply-To: <sakae.araki@kek.jp>
Date: Wed, 30 Jan 2008 06:59:59 +0900 (JST)
To: <junji.urakawa@kek.jp>, OMORI Tsunehiko <tsunehiko.omori@kek.jp>
Subject: 1stdata

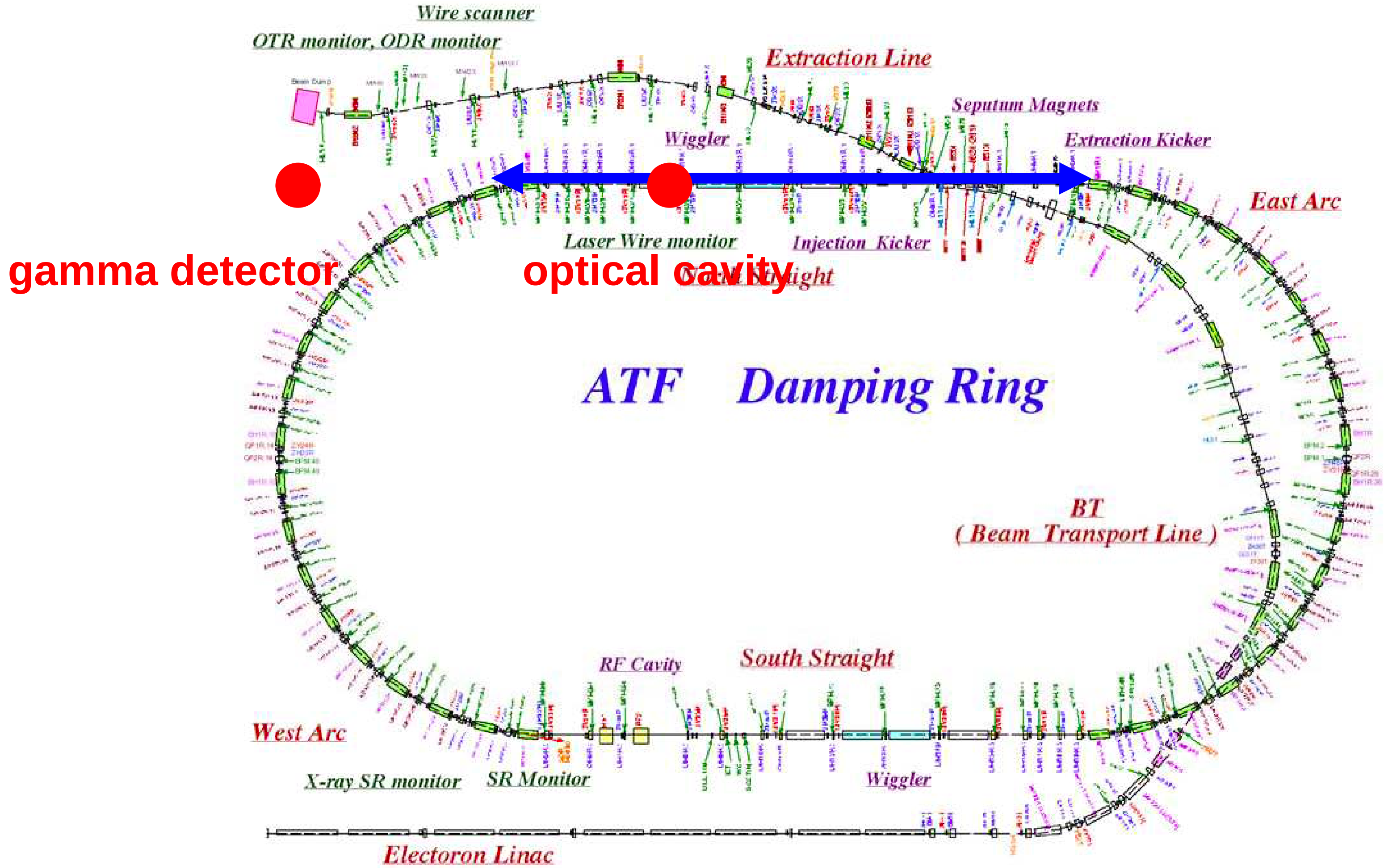
取り急ぎ連絡いたします。
まずは、1830に観測を確認いたしました。
ムーバー位置は＋２㎜とほぼアライメントの予想値付近でした。
現在セットアップを変更して、付近の観測をつづけます。
なお、昨日のデータを確認したところ形跡はありました。

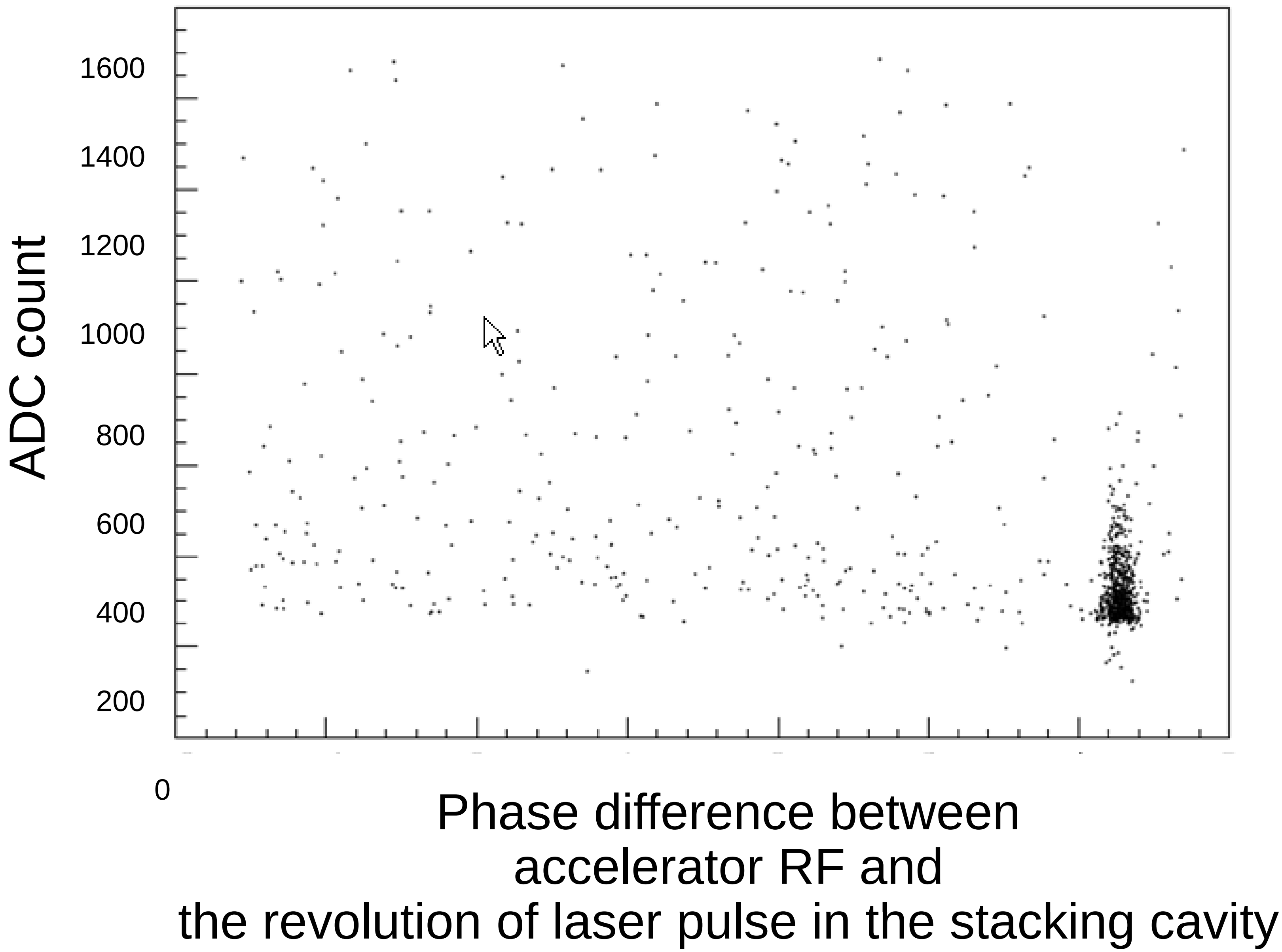
＃あらき。

Open ADC gate when electron bunch running north straight section and transmission light from optical cavity exceed threshold level.

No timing fixing between optical cavity and storage ring. Both accelerator RF and the revolution of laser pulse in the stacking cavity are about 357 MHz, but they are very slightly different. Difference of their phases are running.

Then observe the correlation between the phase difference vs detector out put.





ADC count
1600
1400
1200
1000
800
600
400
200
0
Phase difference between
accelerator RF and
the revolution of laser pulse in the stacking cavity

# In near future (in 2-3 months)

**We are still not so mature, yet.**

**But, we are establishing a feedback of the stacking cavity.**

**We are planning to achieve collision with a stable feedback of the stacking cavity by the end of May. (still with R = 99.6 %)**

# 4-mirror cavity at ATF

## R/D in France

**Very High Enhancement ~ 20000 - 100000**

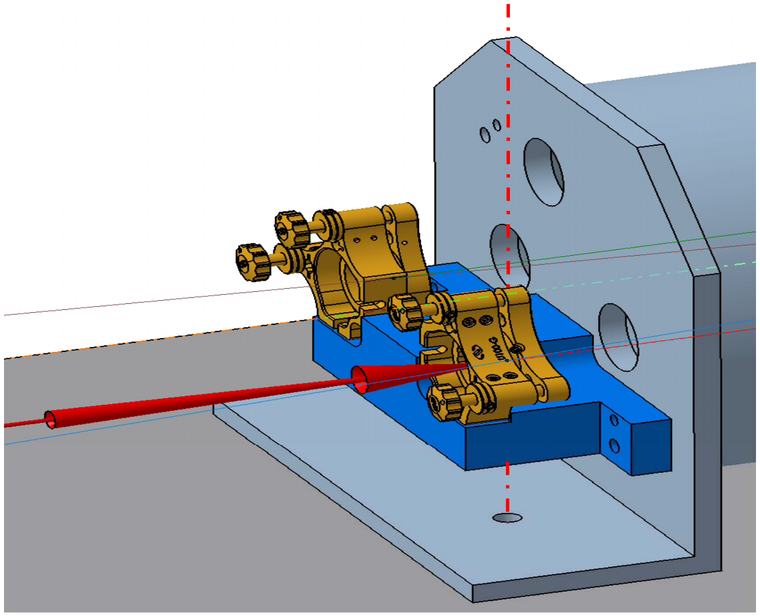
**Spot size ~ 30 micron in ATF**
**(~ 10 micron in ILC)**

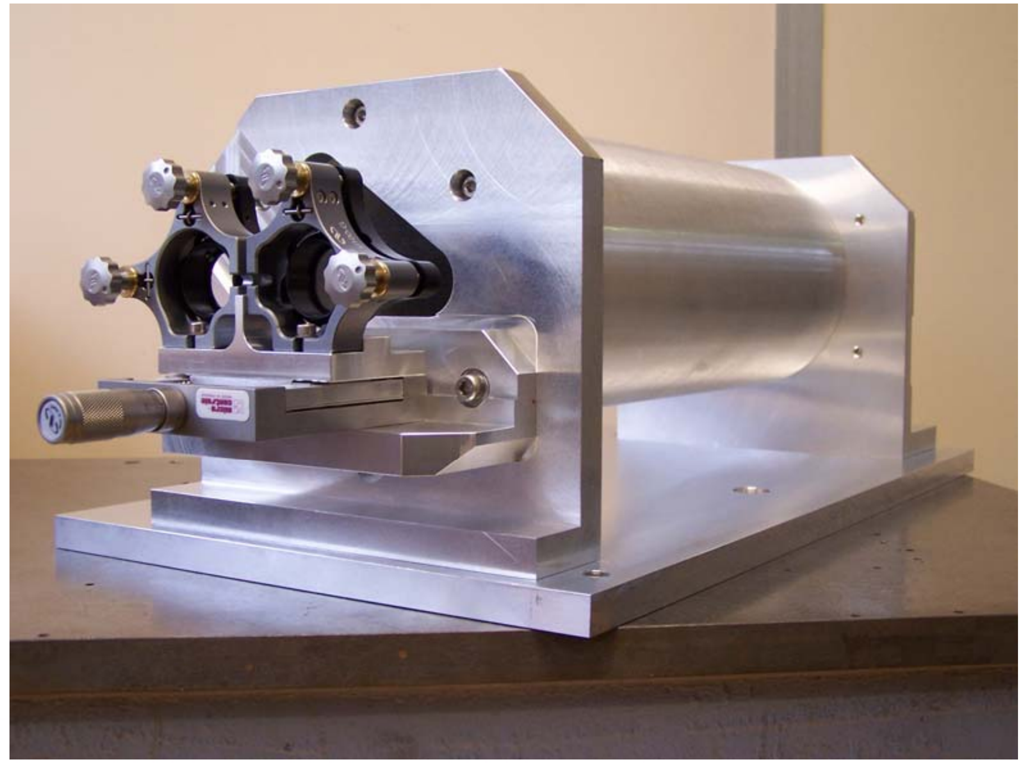
**Sofisticated cavity stucture with 4 mirrors**

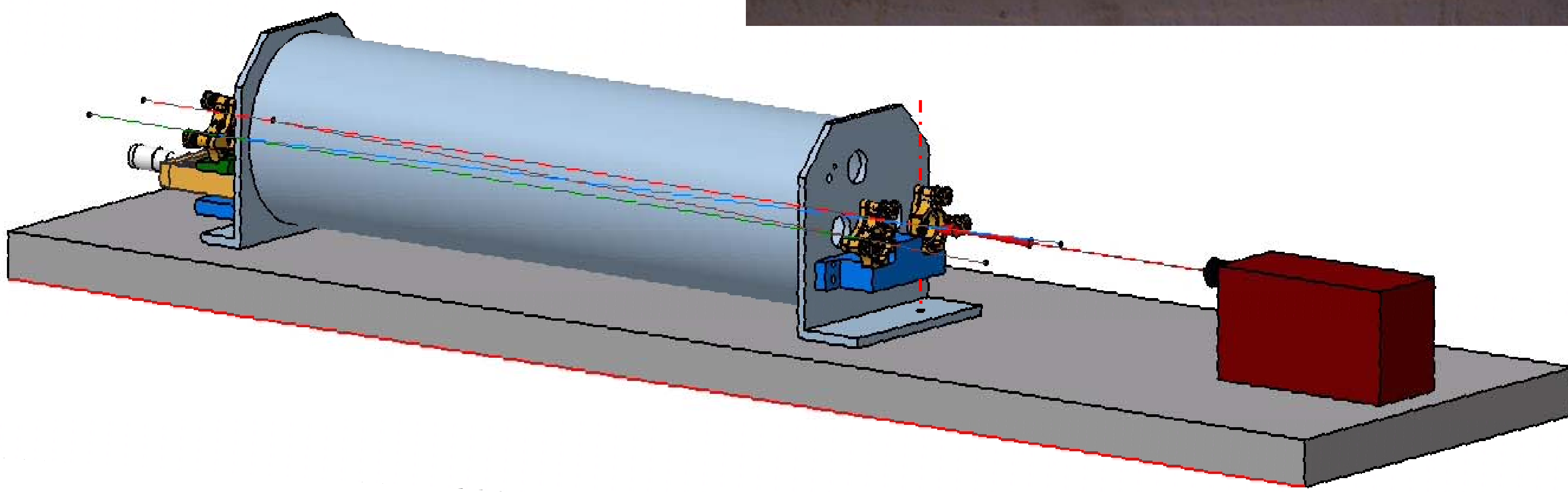
**Start with no $e^-$ beam**

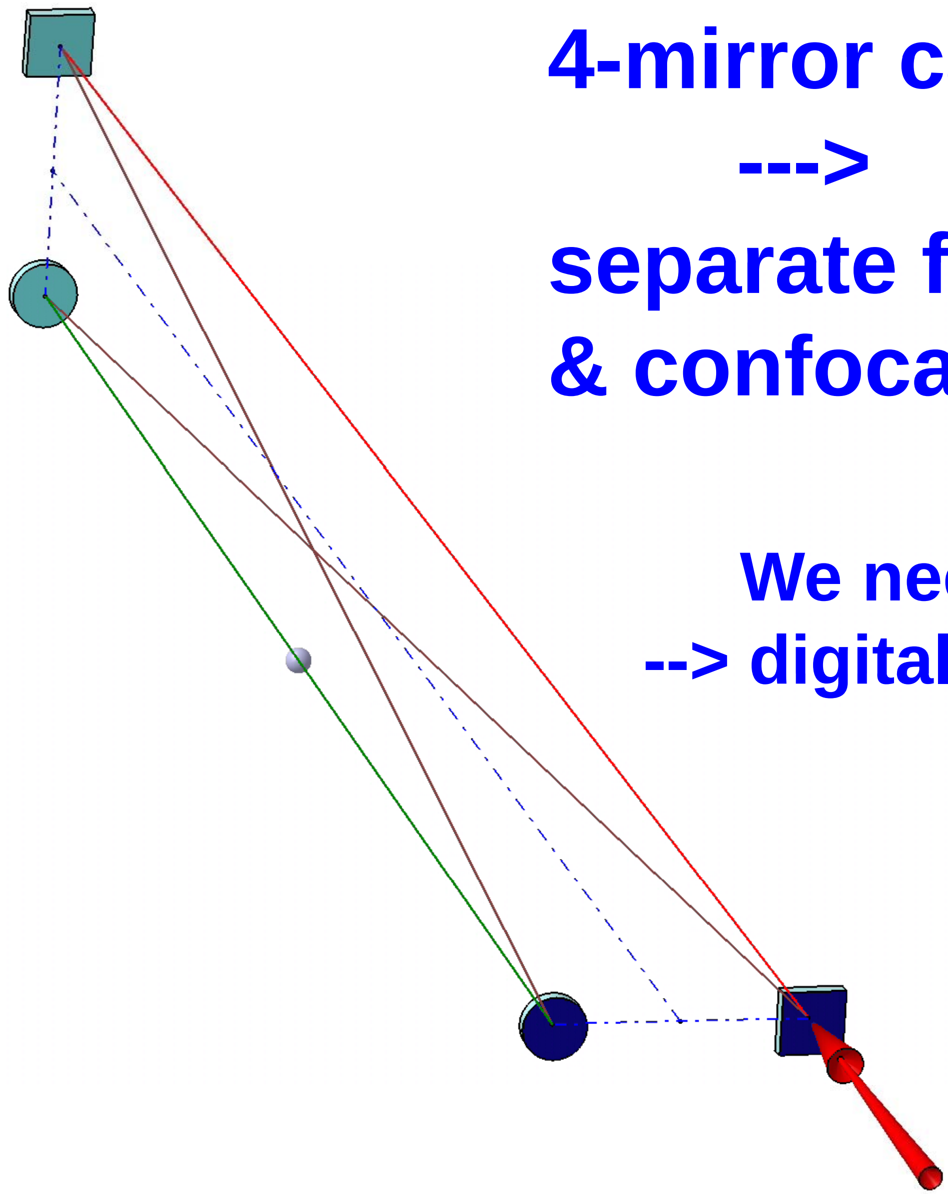
**Later we will make a $e^-$ beam compatible cavity**

# 4-mirror cavity in LAL









# 4-mirror cavity

--->

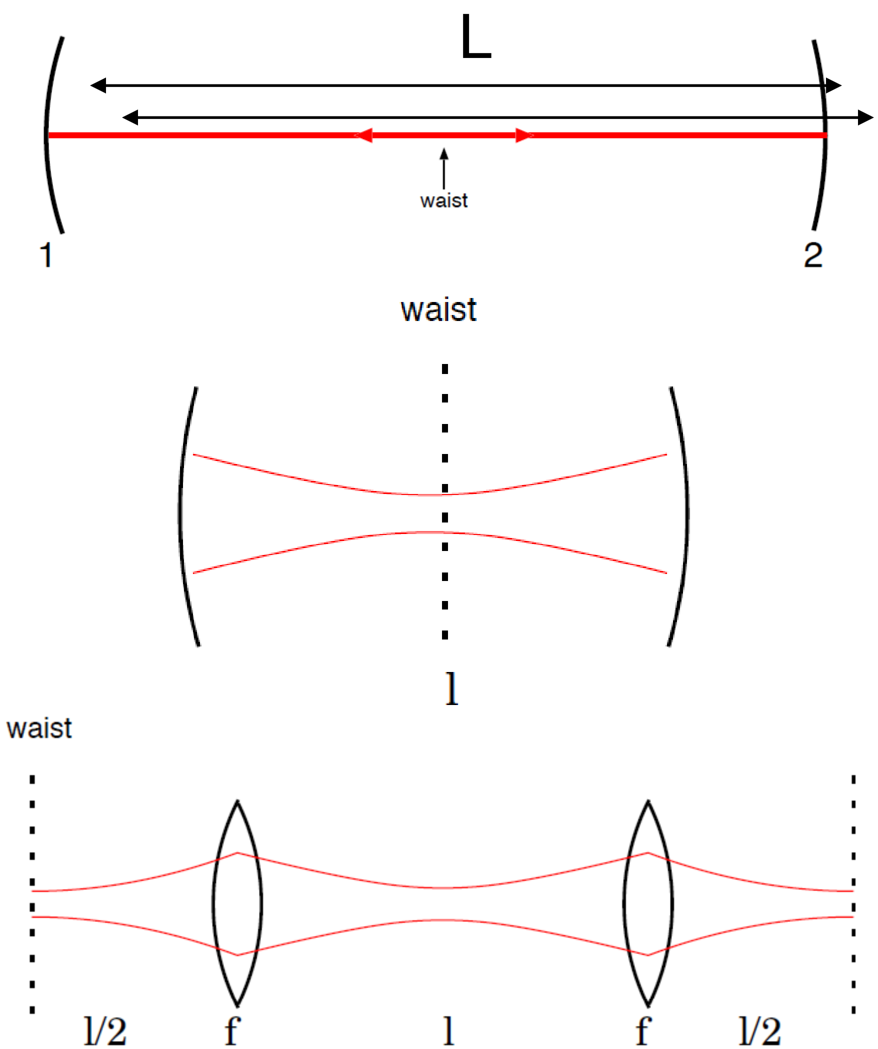
# separate functions
# & confocal configuration

**We need complicated control.**

**--> digital feedback**

# 2-mirror cavity

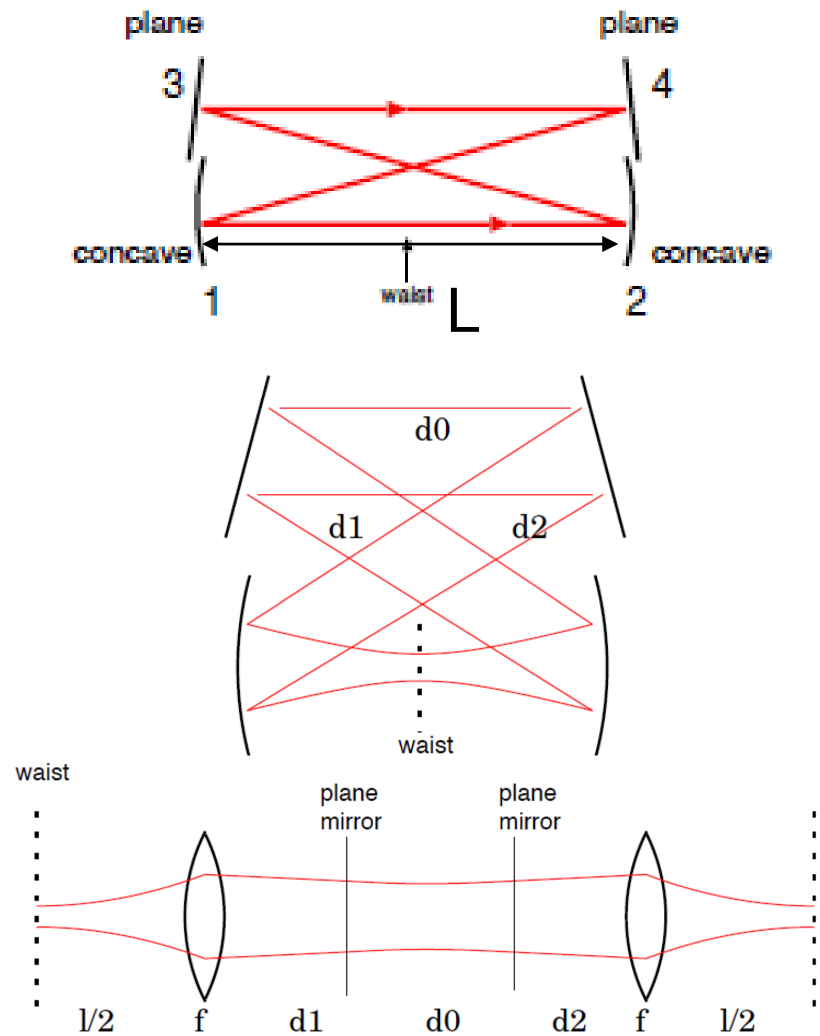
R1=R2=L/2




concentric

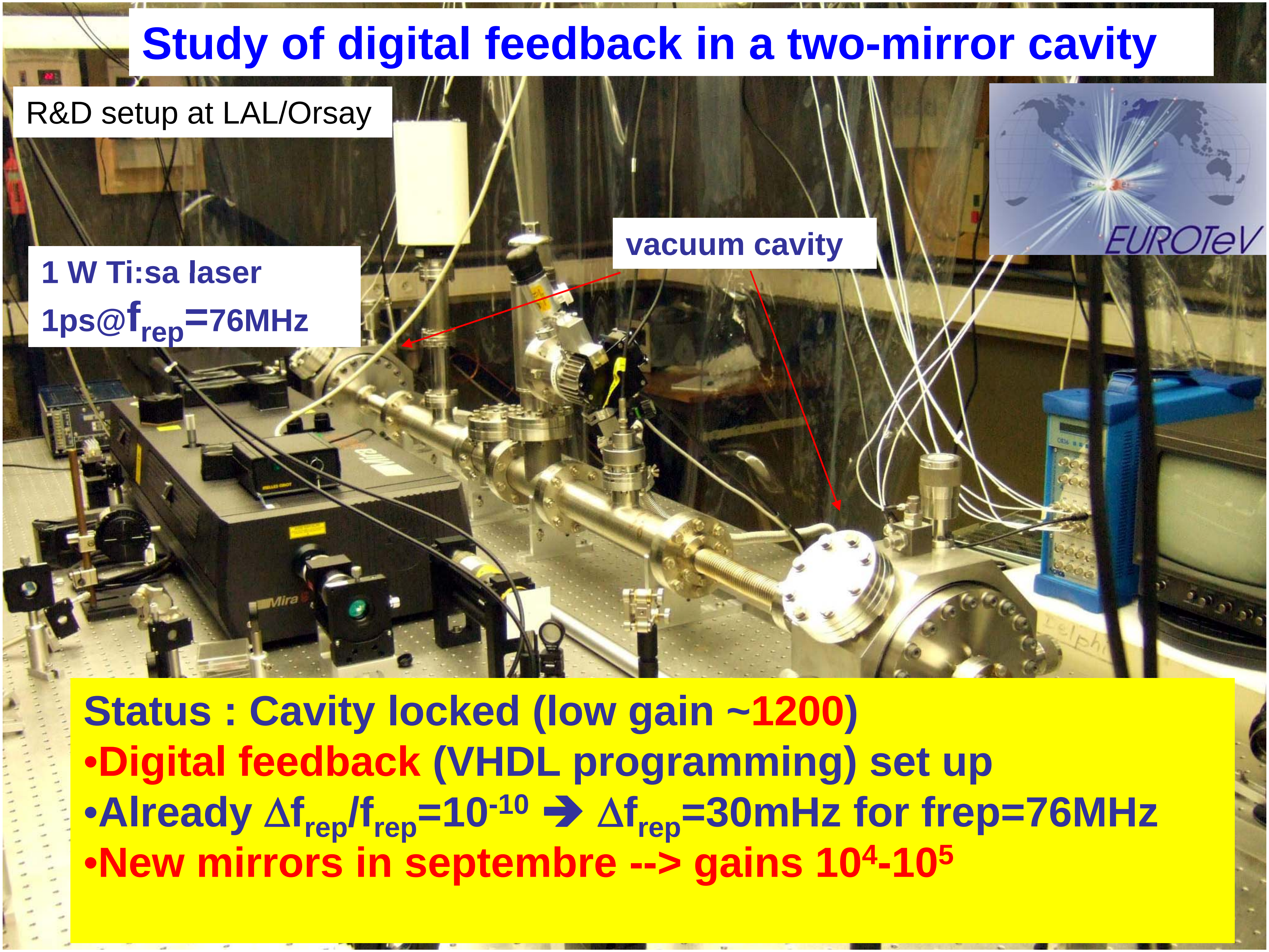
# 4-mirror cavity

R1=R2=L




confocal

# Study of digital feedback in a two-mirror cavity

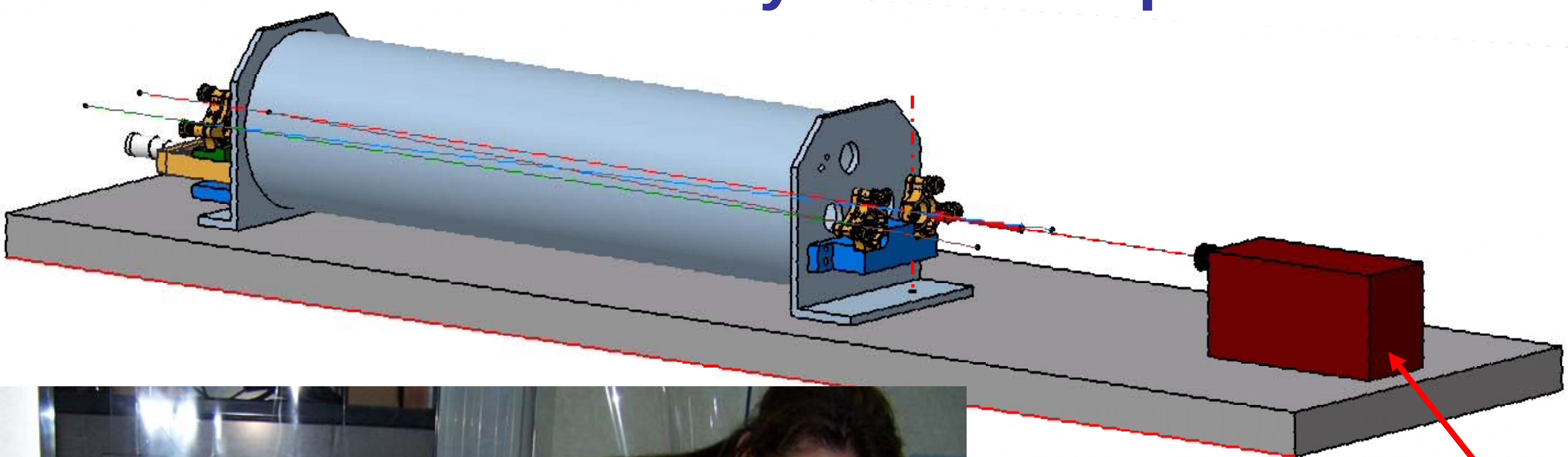


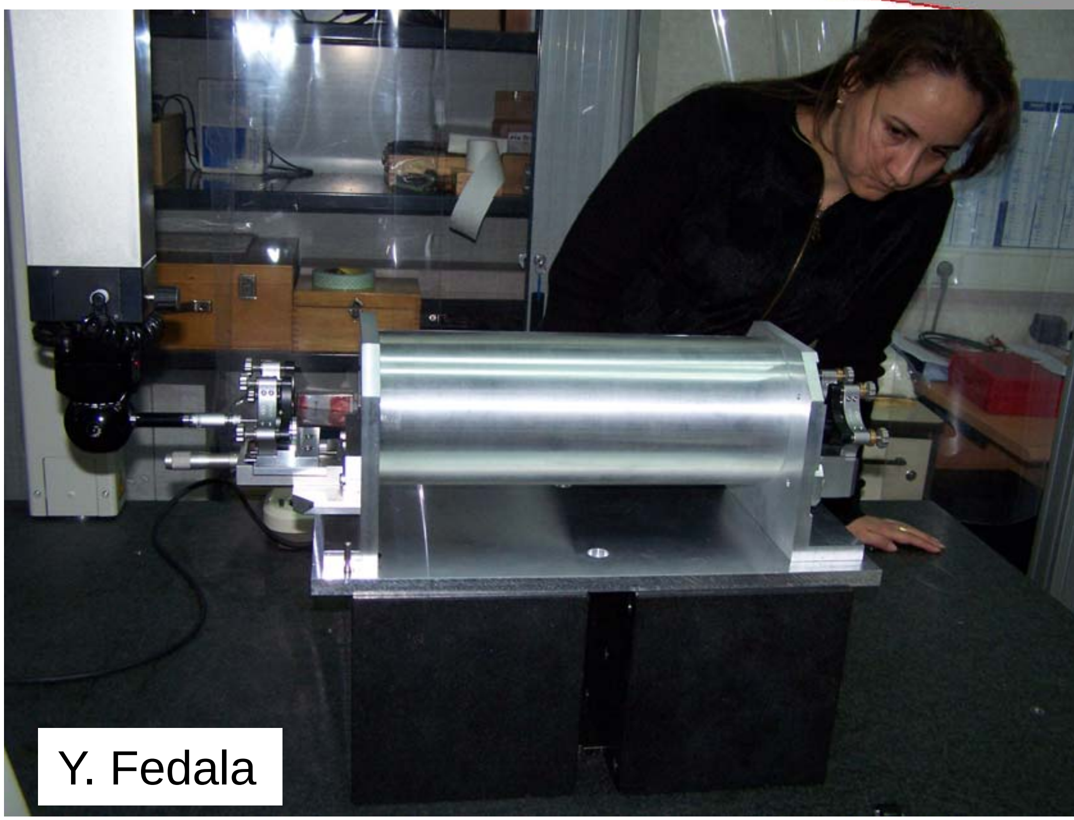

**Status : Cavity locked (low gain ~1200)**

- **Digital feedback (VHDL programming) set up**
- **Already $\Delta f_{rep}/f_{rep}=10^{-10}$ ➔ $\Delta f_{rep}$=30mHz for frep=76MHz**
- **New mirrors in septembre --> gains $10^4$-$10^5$**

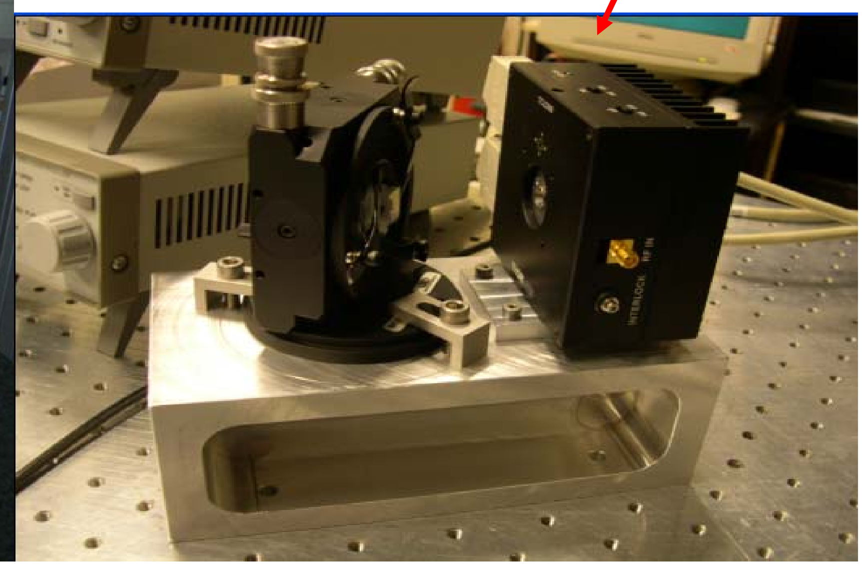
# Study of 4-mirror cavity is on going at LAL

## this cavity is not conpatible wth e-beam






Cw laser diode in
extended cavity config
(Littrow configuration)



# R/D in France and in Asia are Complementary

## R/D in France

**Very High Enhancement ~ 20000 - 100000**

## R/D in Japan/China

**Moderate Enhancement ~ 1000**

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In 2009: a $e^-$ beam compatible cavity in ATF

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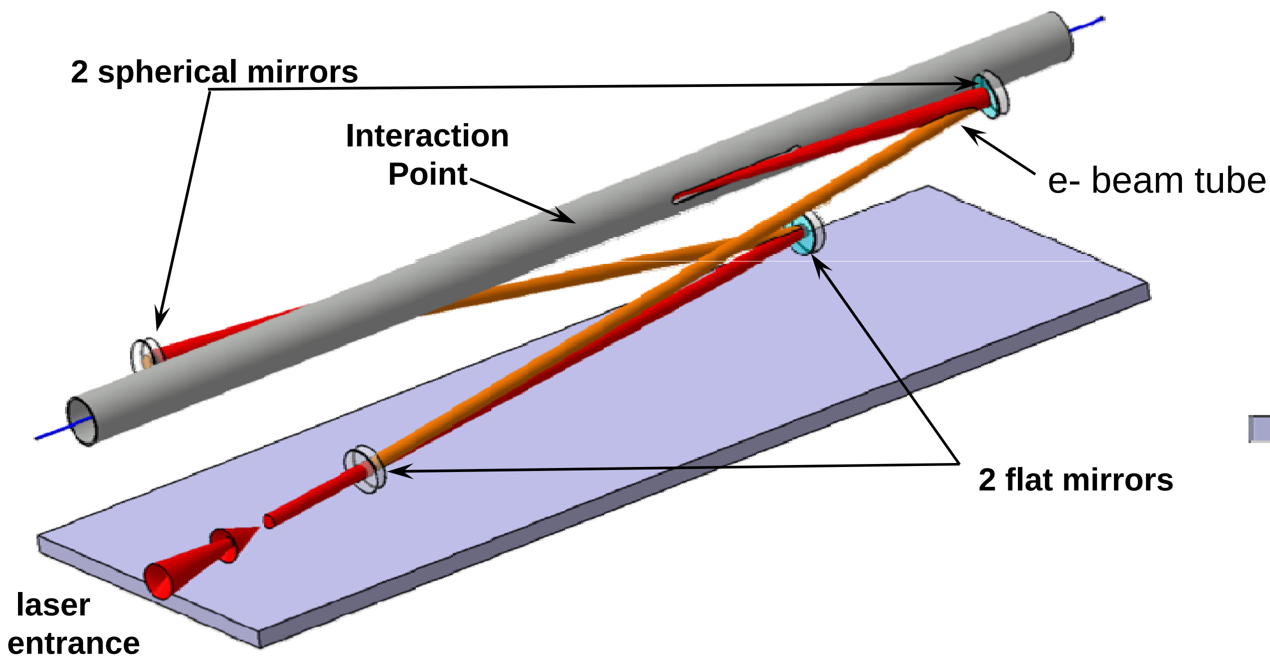
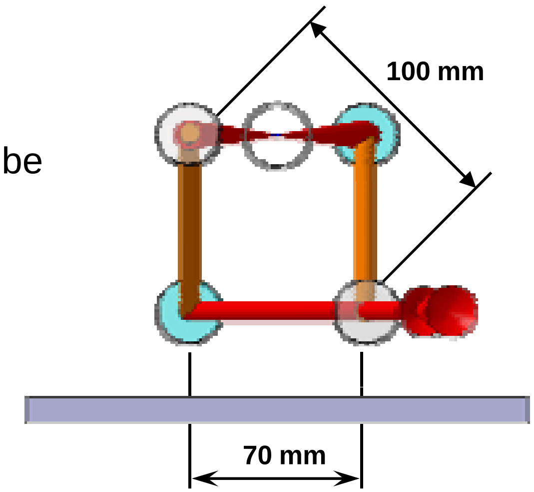
Analog feedback

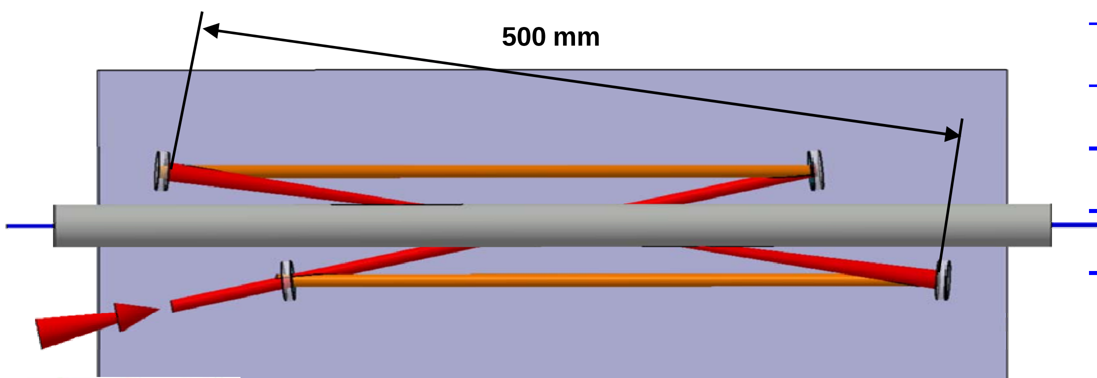
Get experinence with $e^-$ beam

# Cavity characteristics

**Confocal non planar**
**4 mirrors cavity**



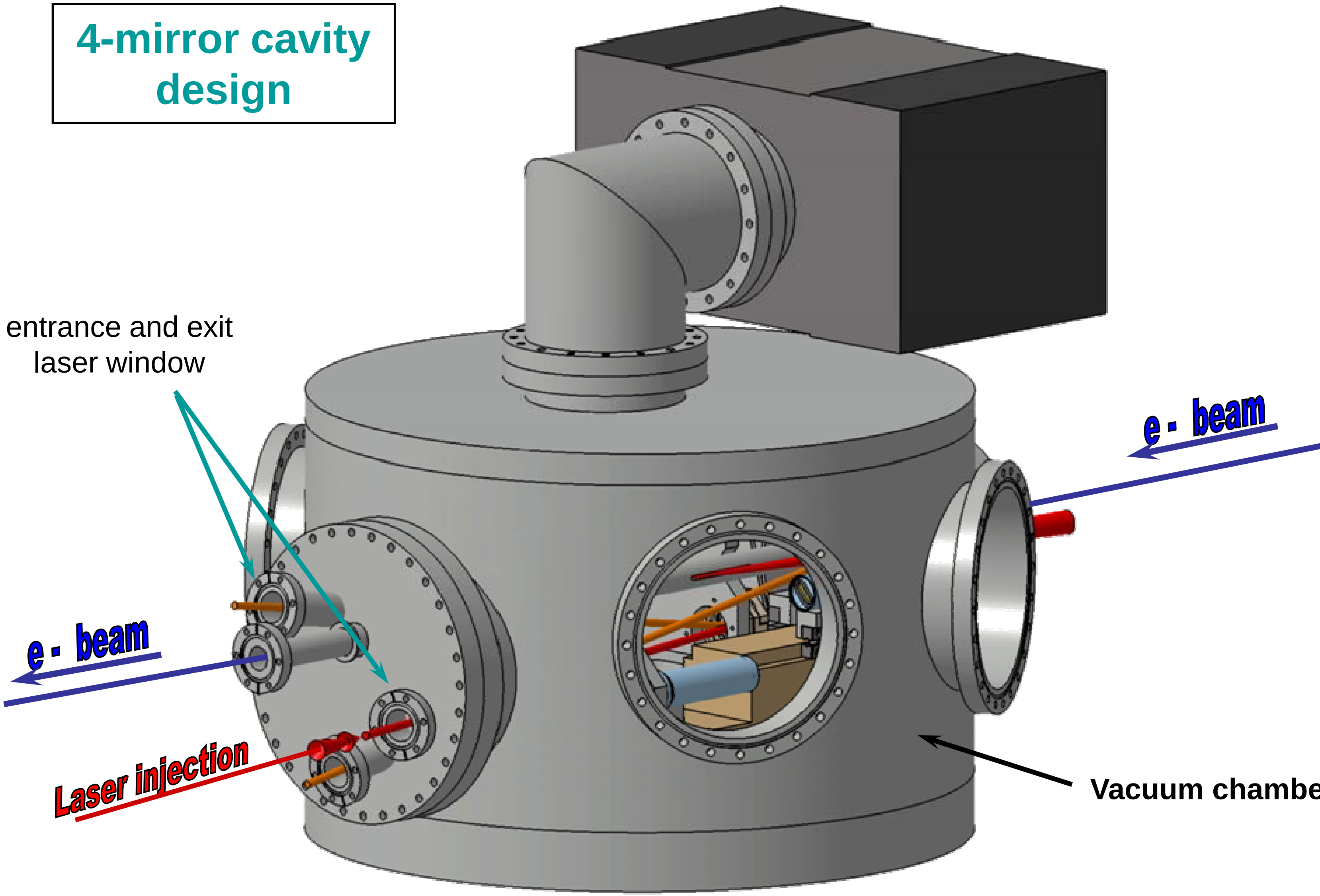




- **-Laser 178.5 MHz**
- **-Optical path de 1.680 m**
- **- Distance between the spherical mirrors 500mm**
- **- Curving radius of spherical mirrors 500 mm**
- **- Angle of Compton interaction 8°**

R. Cizeron
LAL 30/01/2008

LABORATOIRE DE L'ACCÉLÉRATEUR LINÉAIRE

# 4-mirror cavity design




R. Cizeron
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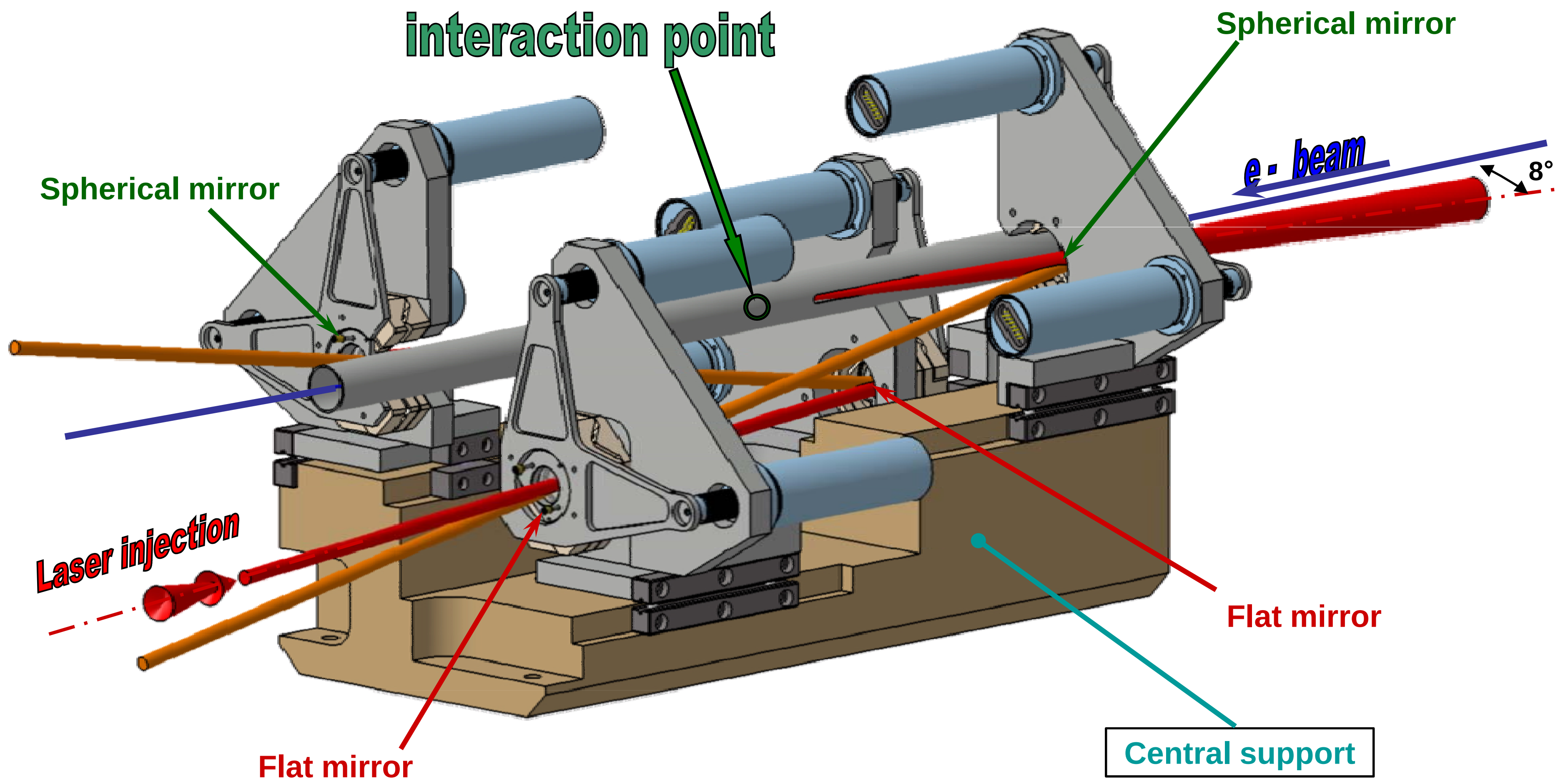
# 4-mirror cavity design

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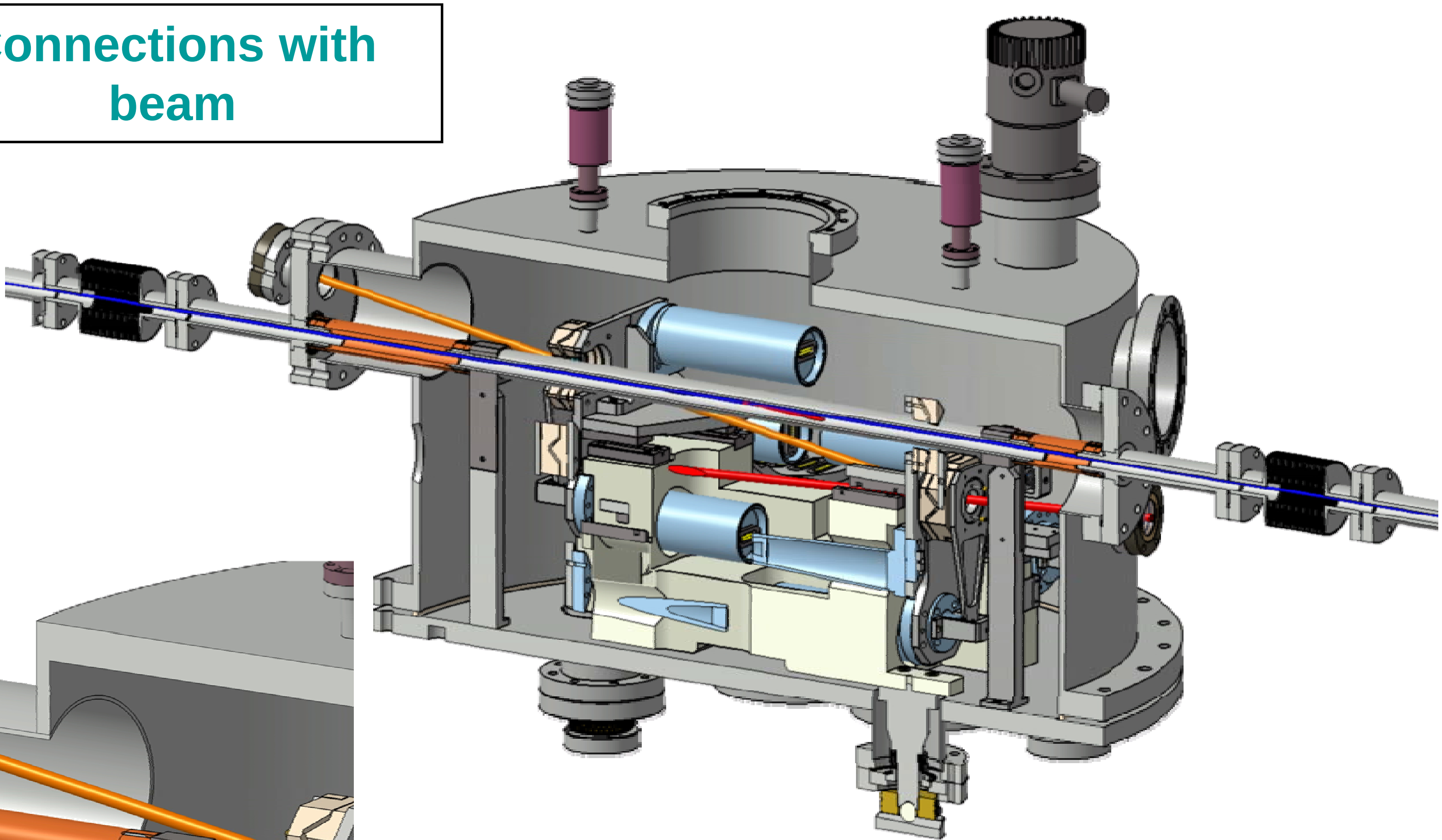
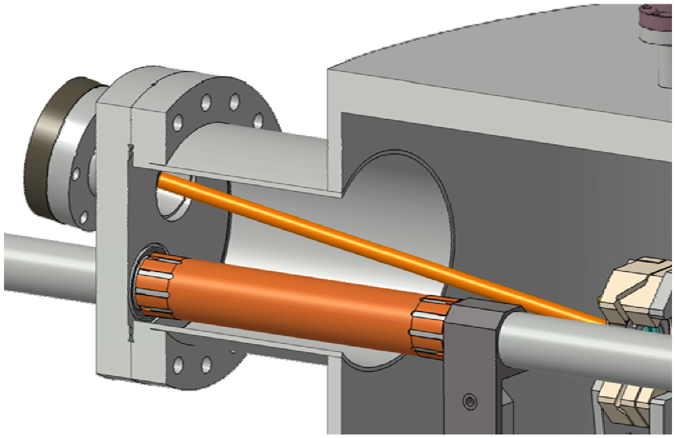
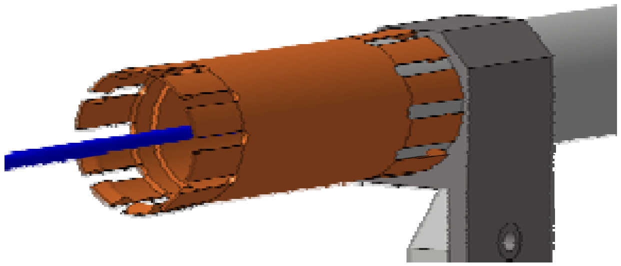
# Connections with beam







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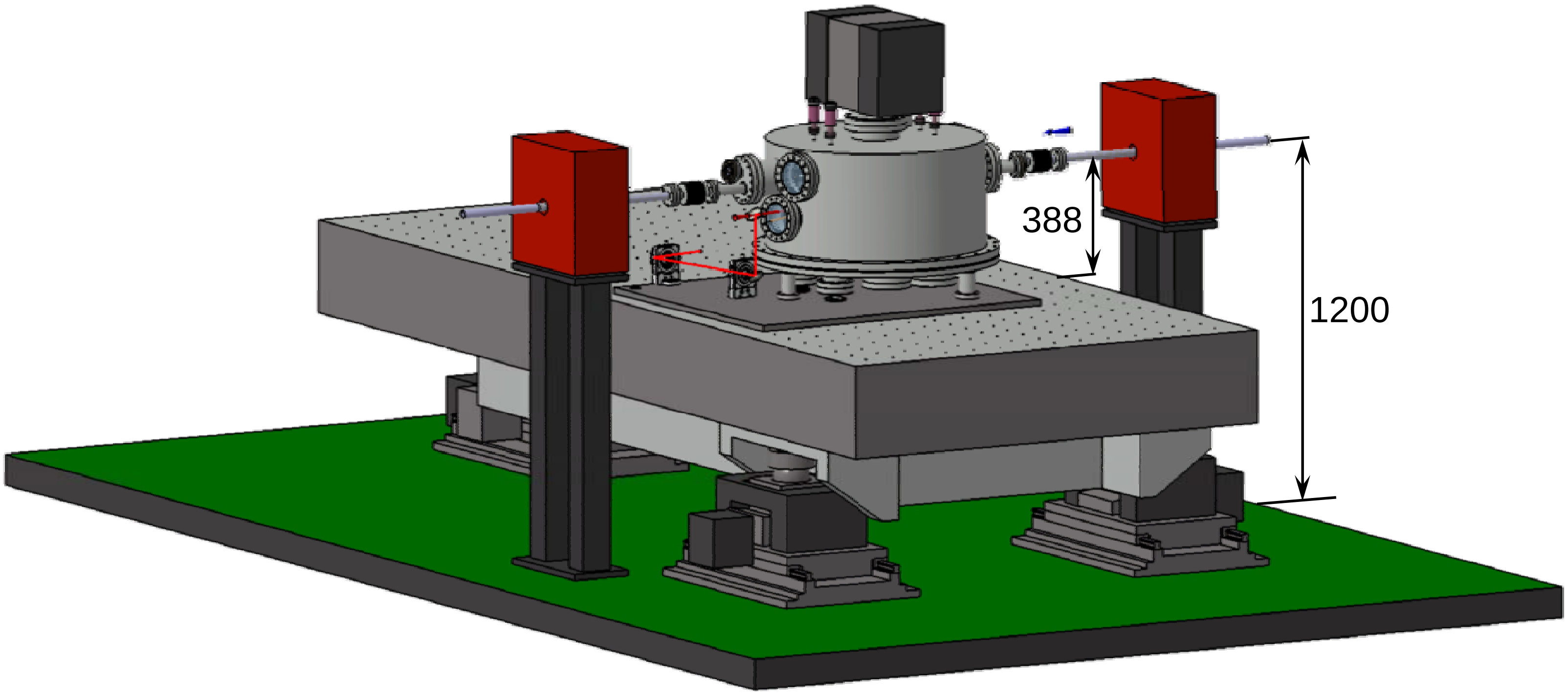
# Implementation at ATF

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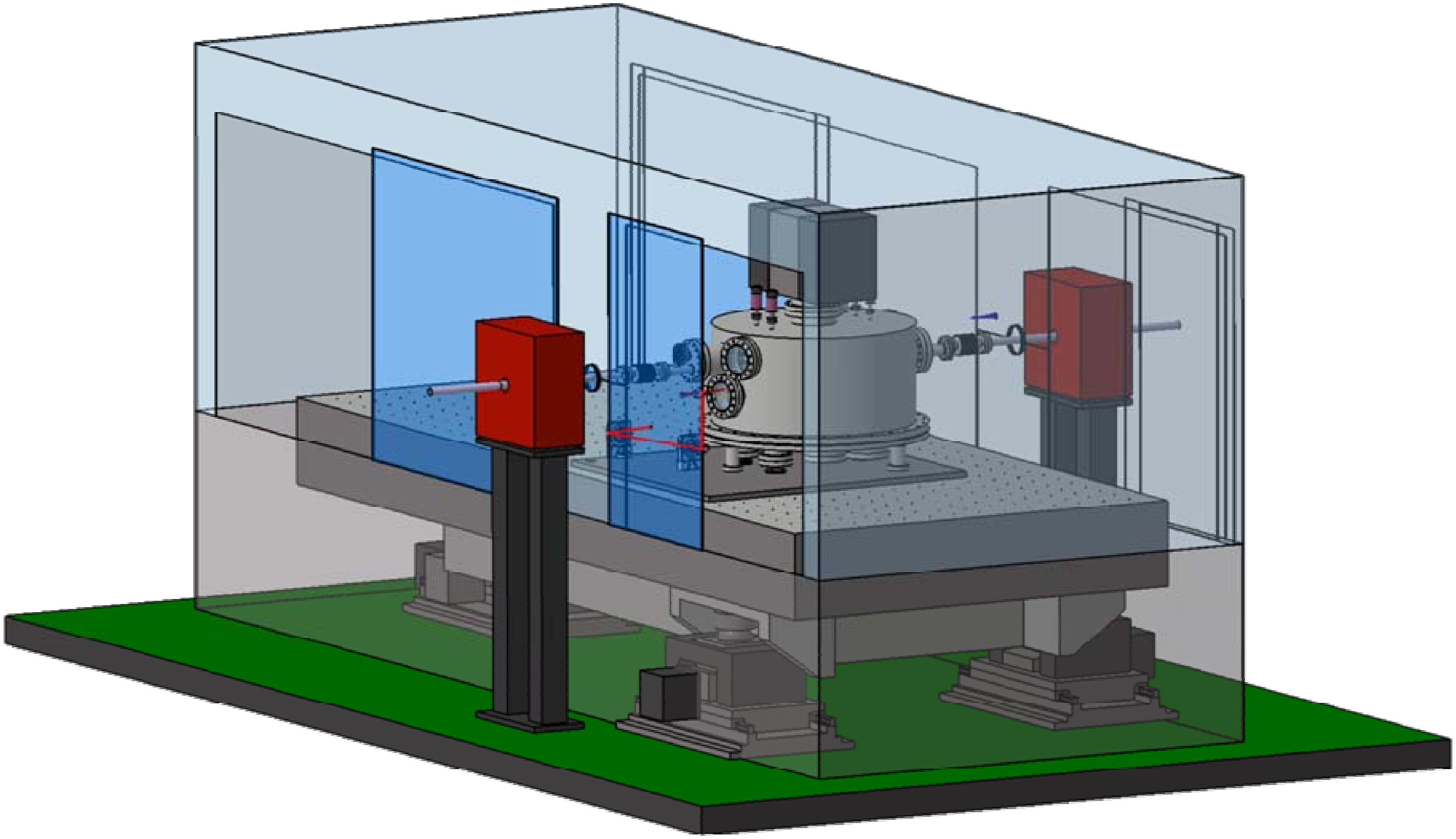
LAL 30/01/2008

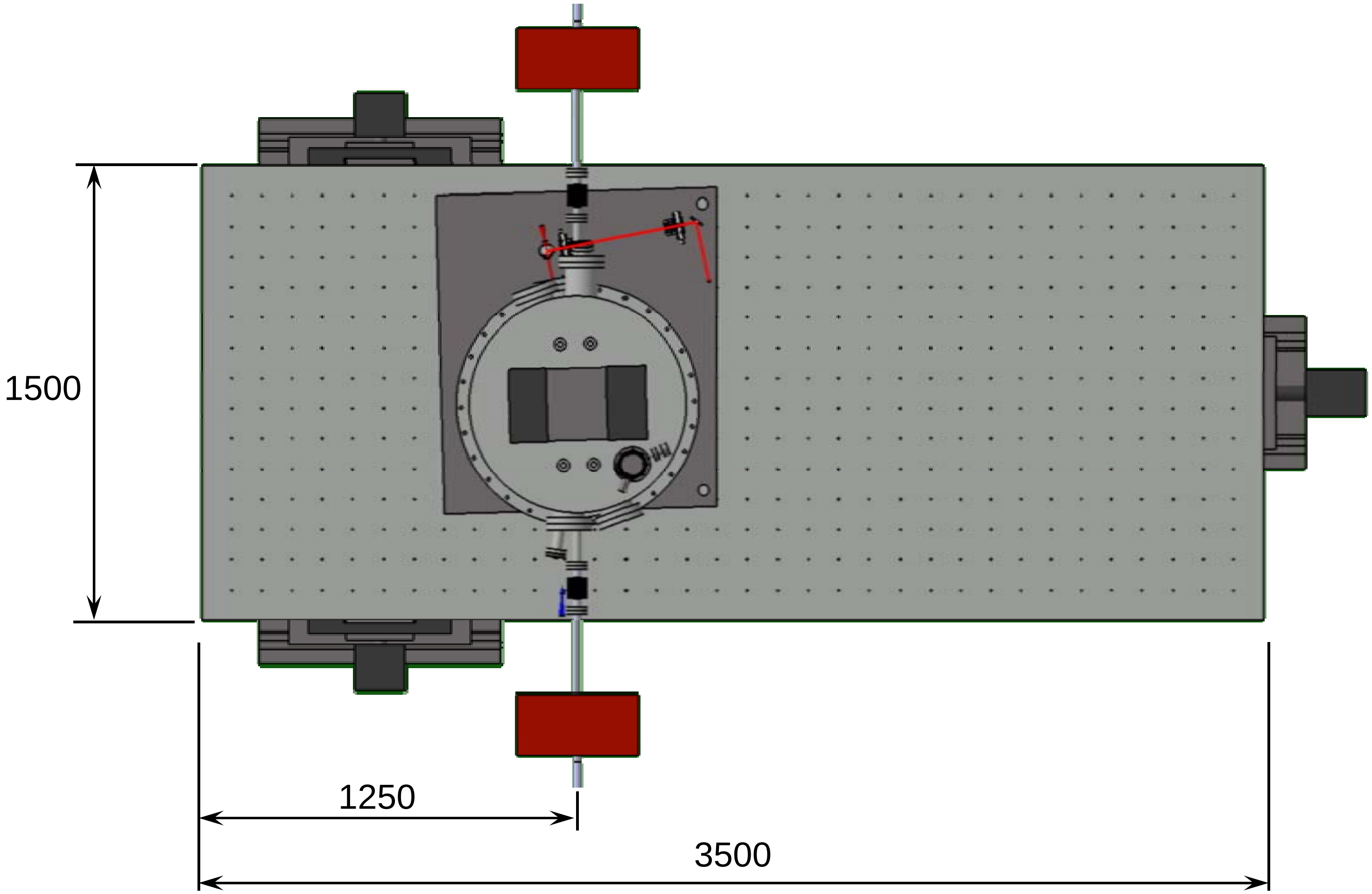
# Implementation at ATF



R. Cizeron
LAL 30/01/2008

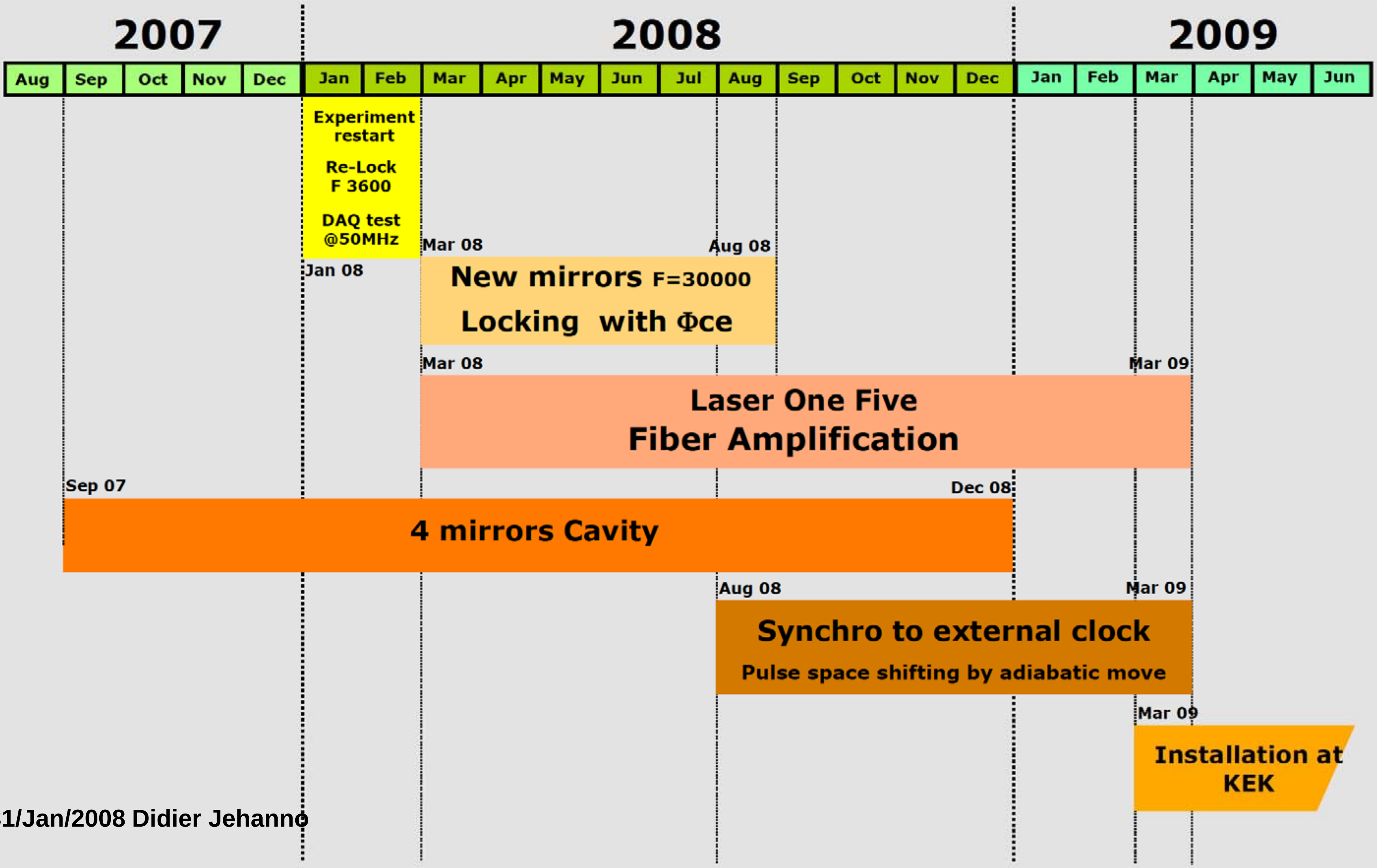
LABORATOIRE DE L'ACCÉLÉRATEUR LINÉAIRE

# Implementation at ATF




R. Cizeron
LAL 30/01/2008

# Planning (feedback & laser)




31/Jan/2008 Didier Jehanno

# R/D in France and in Asia are Complementary

## R/D in France

Very High Enhancement ~ 20000 - 100000

Moderate spot size ~ 30 micron (10 micron in ILC)

Sofisticated cavity stucture with 4 mirrors

Digital feedback

Start with no $e^-$ beam

In 2009: a $e^-$ beam compatible cavity in ATF

## R/D in Japan/China

Moderate Enhancement ~ 1000

Moderate spot size ~ 30 micron

Simple cavity stucture with two mirrors

Analog feedback

Get experinence with $e^-$ beam

# 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, Viktor Soskov, Didier Jehanno, M. Jacquet, R. Chiche, Yasmina Federa, 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 Geneve**
**26-27 April**

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

**POSIPOL 2007**
**LAL Orsay**
**23-25 May**

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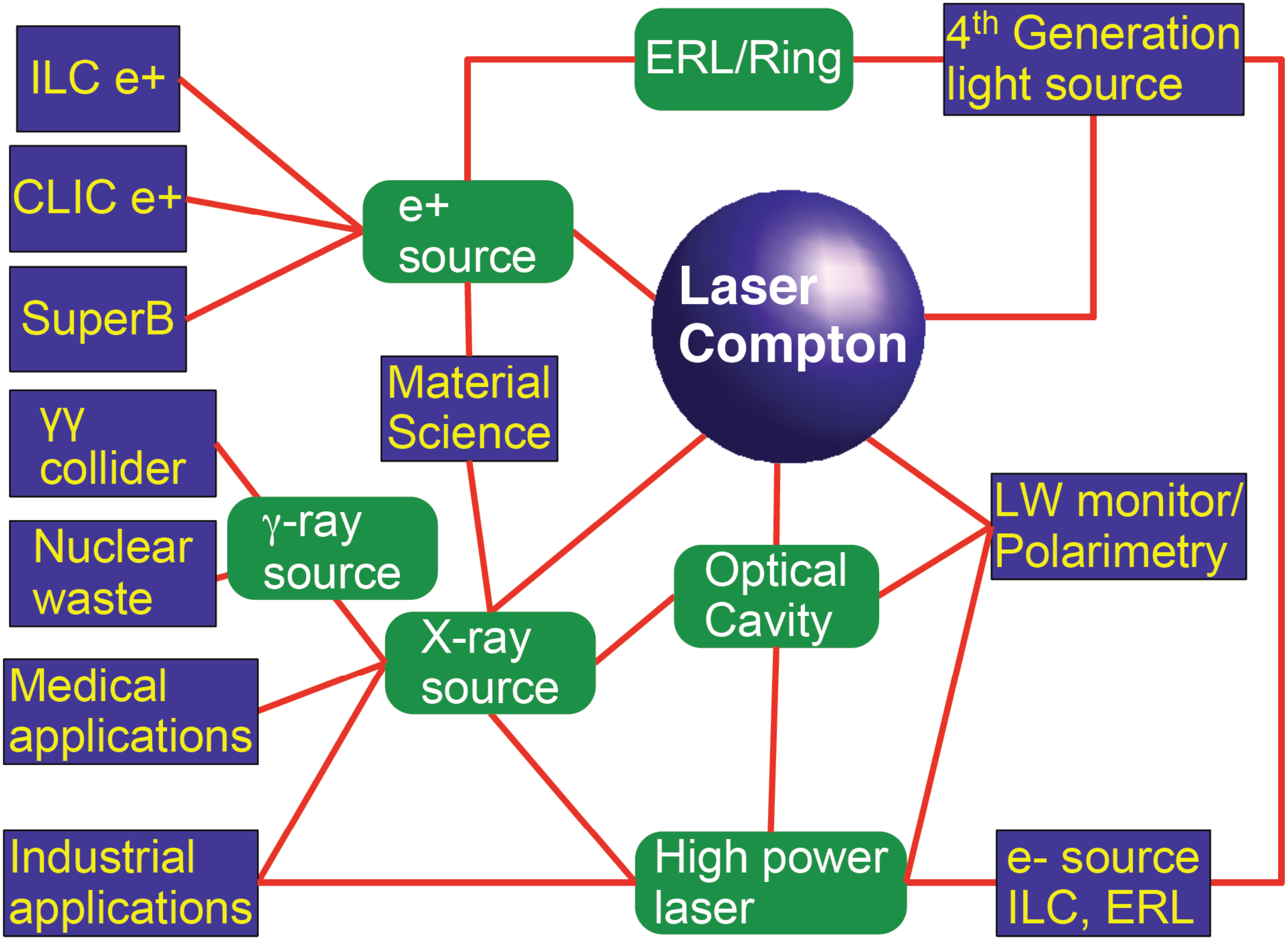
**POSIPOL 2008**
**Hiroshima**
**16-18 June**

# World-Wide-Web of Laser Compton



# Summary

1. Compton $e^+$ source is an advanced alternative of ILC $e^+$ source
2. Laser stacking cavity is a key.
3. In Asia, we are performing $\gamma$-ray generation by the 2-mirror cavity installed in ATF-DR.
4. In France, we are developing a very advanced cavity with 4 mirrors. In summer 2009, the 4-mirror cavity will be installed in ATF-DR for $\gamma$-ray generation.
5. We have a world-wide collaboration for Compton. Not only for ILC $e^+$ source. Also for many other applications.