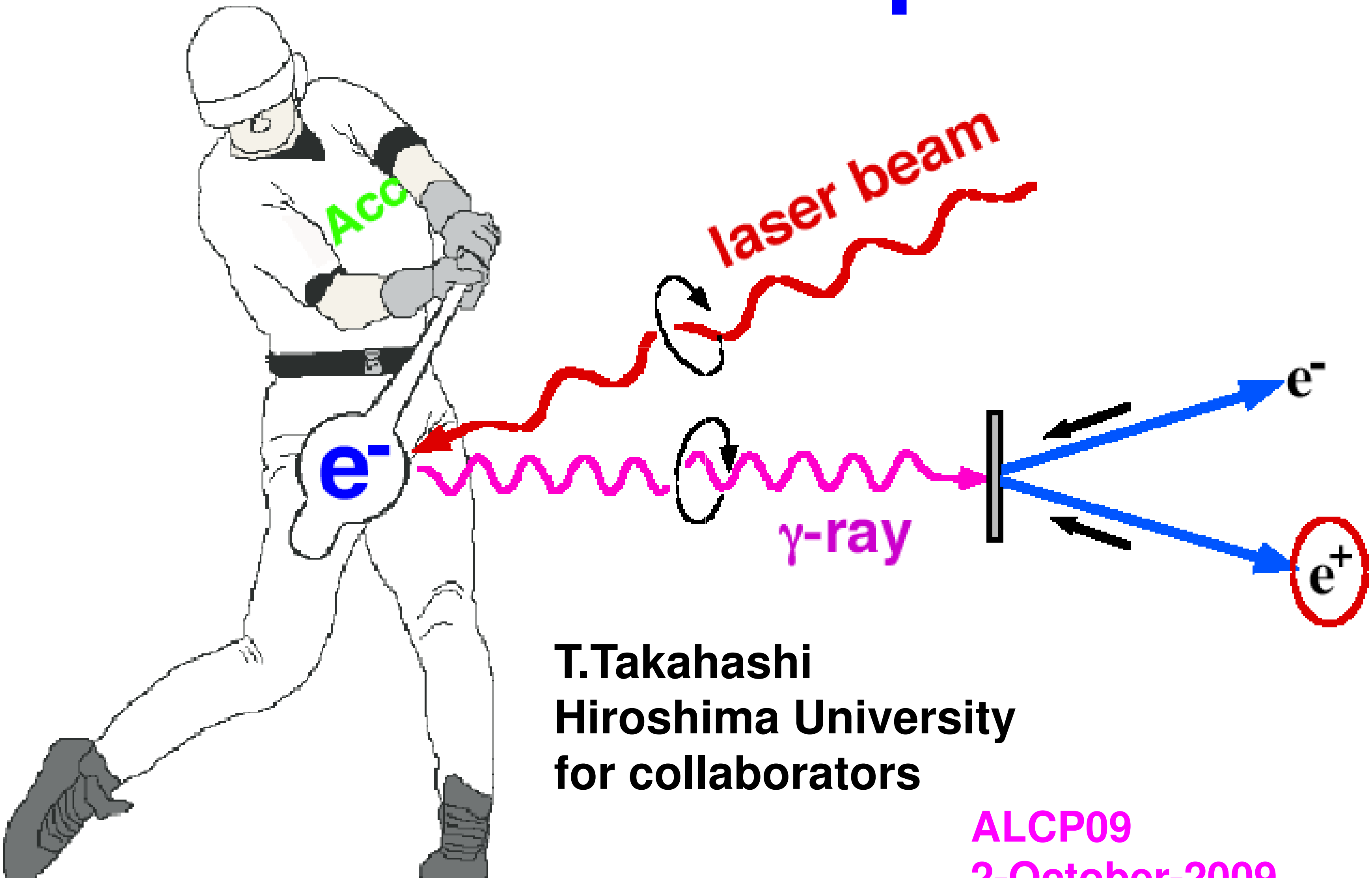
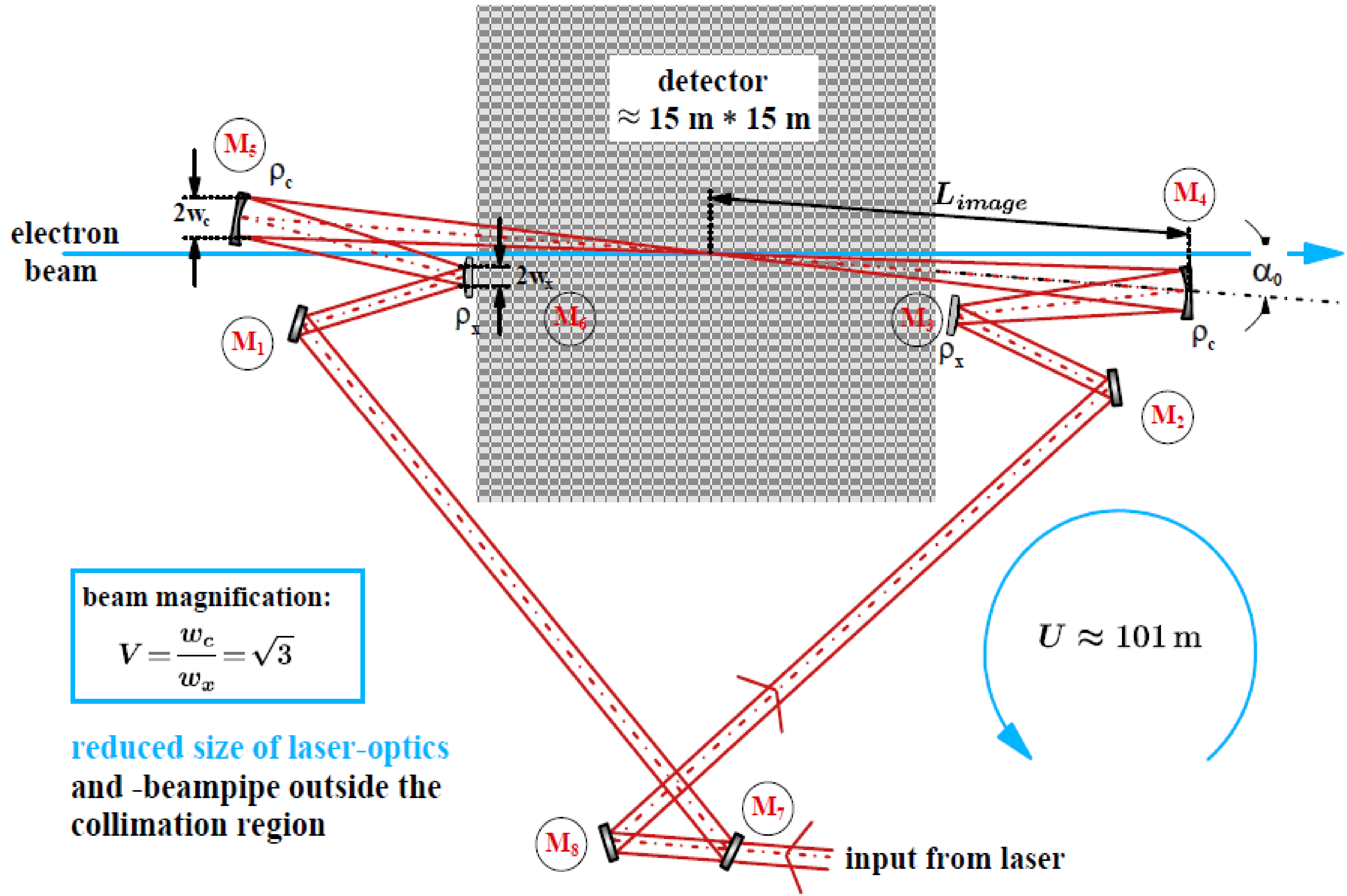
Compton Experiment at the ATF
~a status report~



T.Takahashi
Hiroshima University
for collaborators

ALCP09
2-October-2009

Proposed telescopic, passive, resonant external cavity

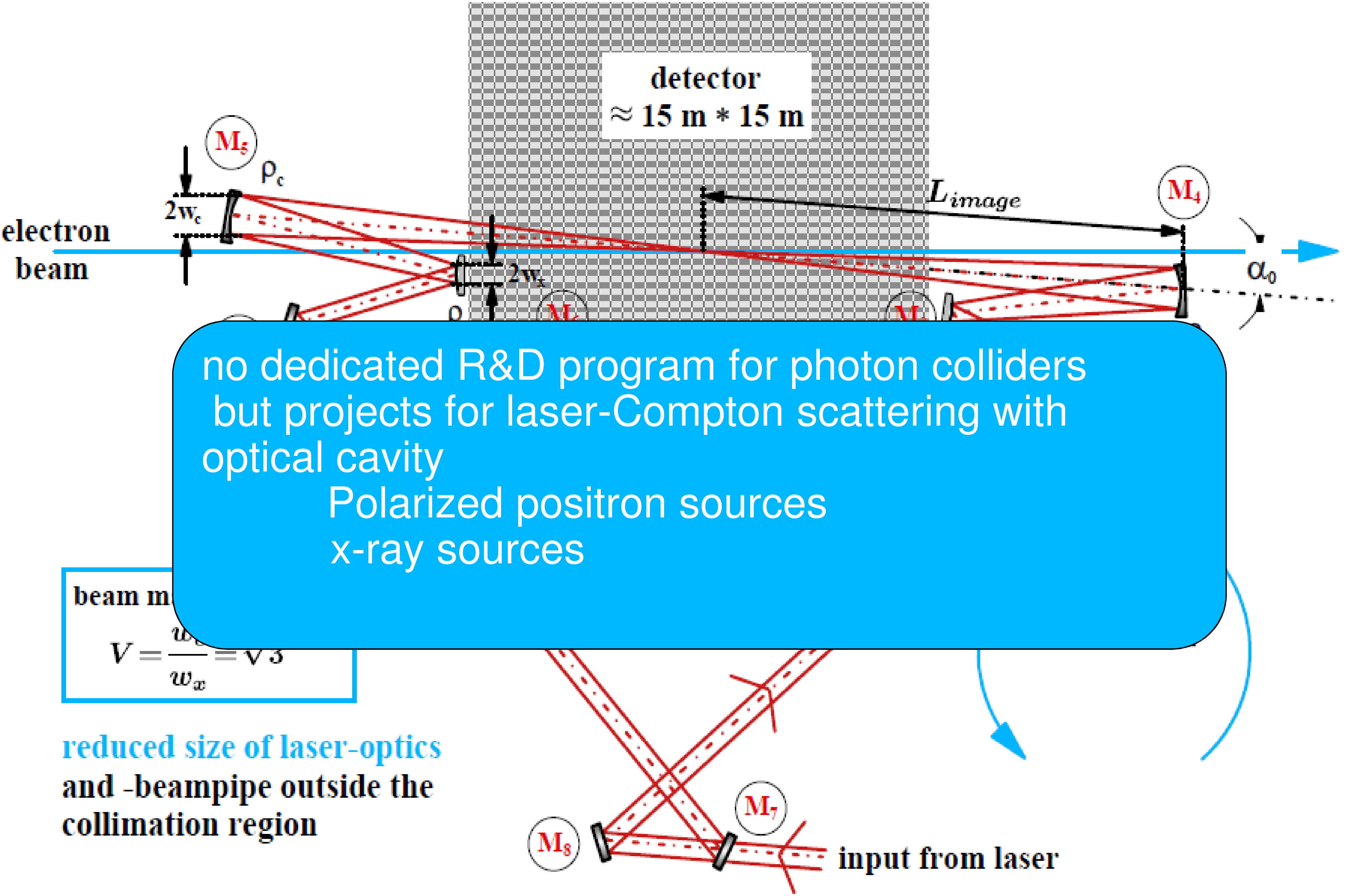


beam magnification:

$$V = \frac{w_c}{w_x} = \sqrt{3}$$

reduced size of laser-optics
and -beampipe outside the
collimation region

Proposed telescopic, passive, resonant external cavity



no dedicated R&D program for photon colliders
but projects for laser-Compton scattering with optical cavity

Polarized positron sources

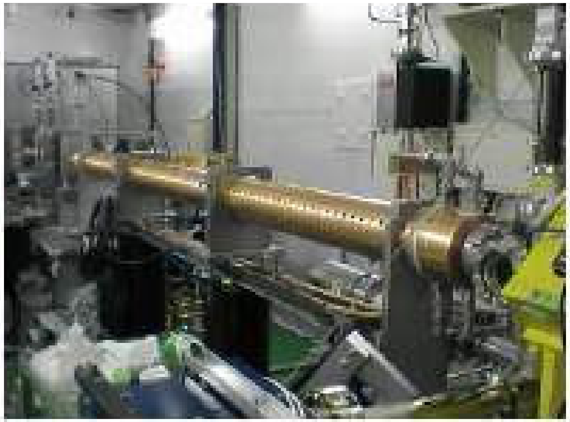
x-ray sources

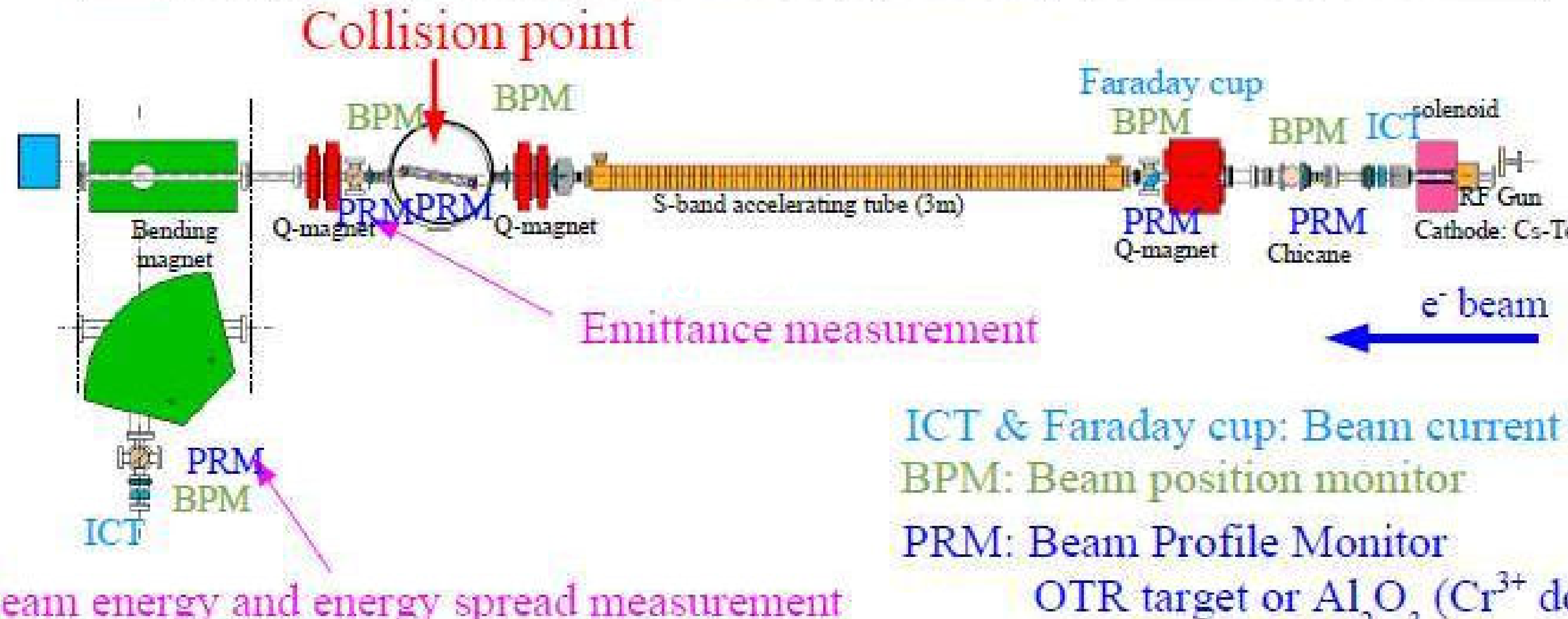
beam m…

$$V = \frac{w_c}{w_x} = \sqrt{3}$$

reduced size of laser-optics and -beampipe outside the collimation region

LUCX
Laser Undulator Compact X rayser





ICT & Faraday cup: Beam current monitor

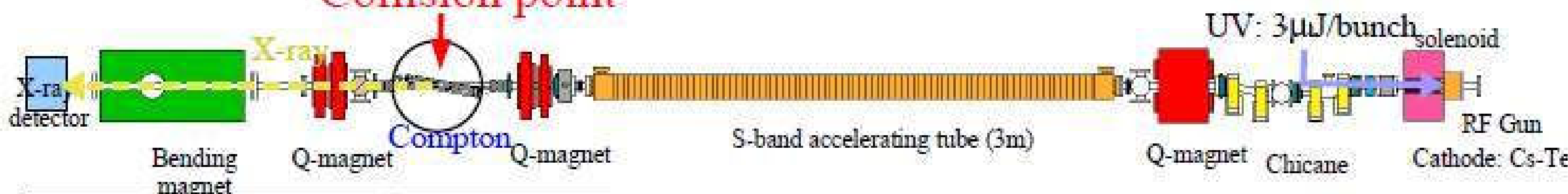
BPM: Beam position monitor

PRM: Beam Profile Monitor

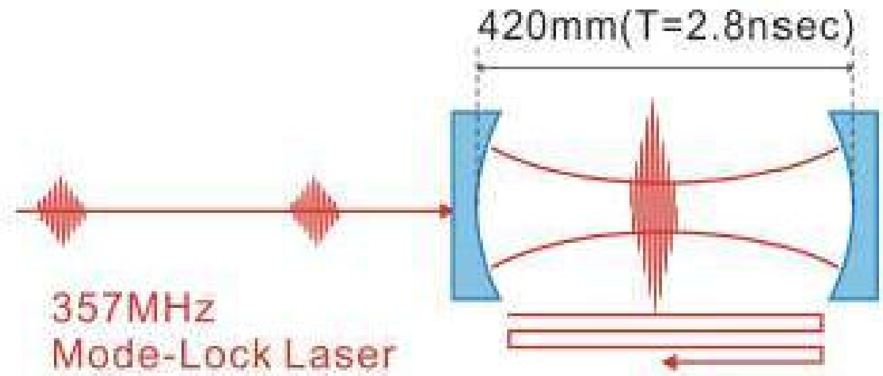
OTR target or Al_2O_3 (Cr^{3+} doped)

Pulsed Laser Cavity

The pulsed laser cavity is installed at the collision point.



Pulsed Laser cavity chamber



$$L_{cav} = n\lambda / 2$$

$$L_{cav} = mL_{laser}$$

100 Bunch generation by LUCX

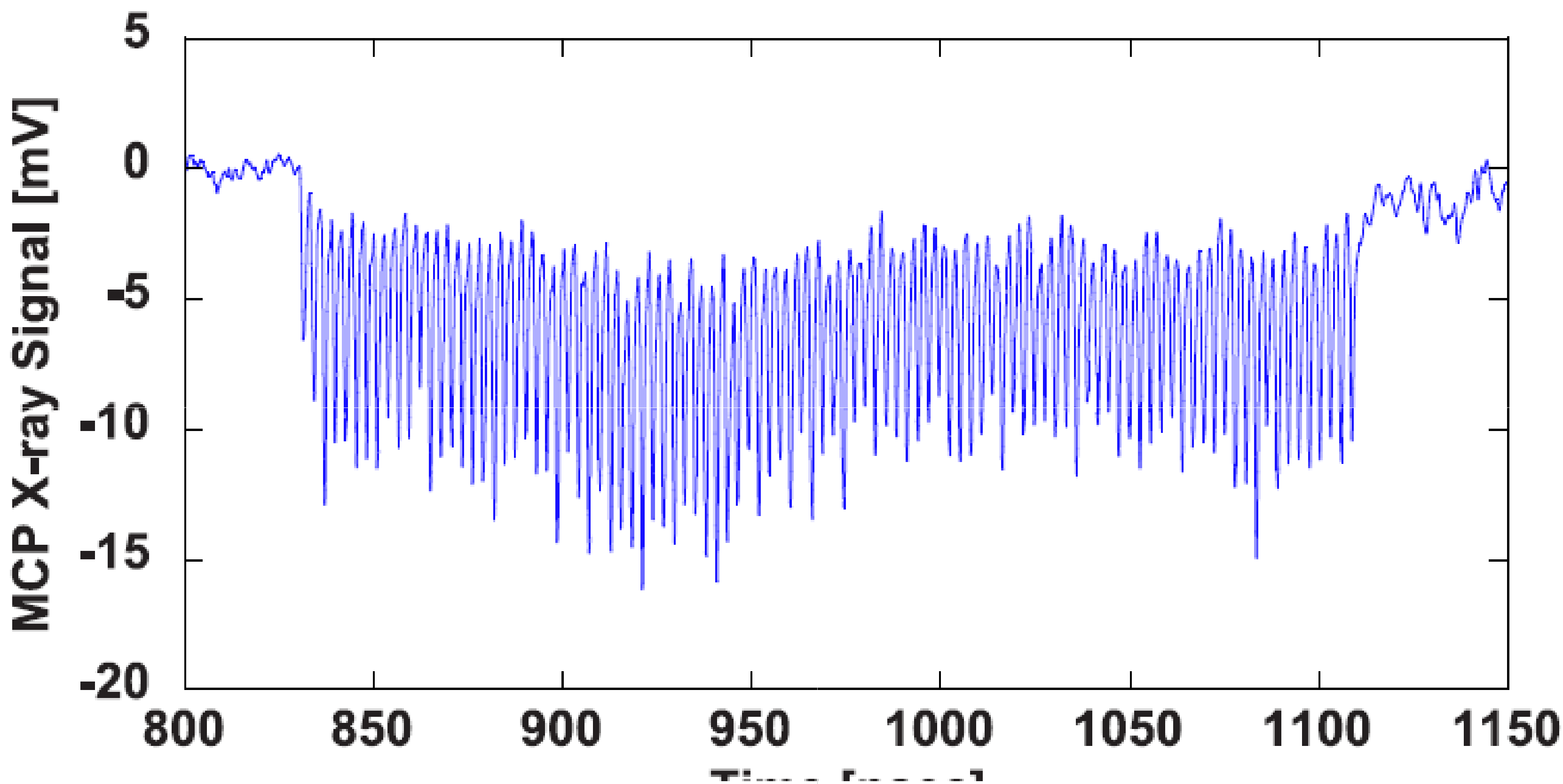
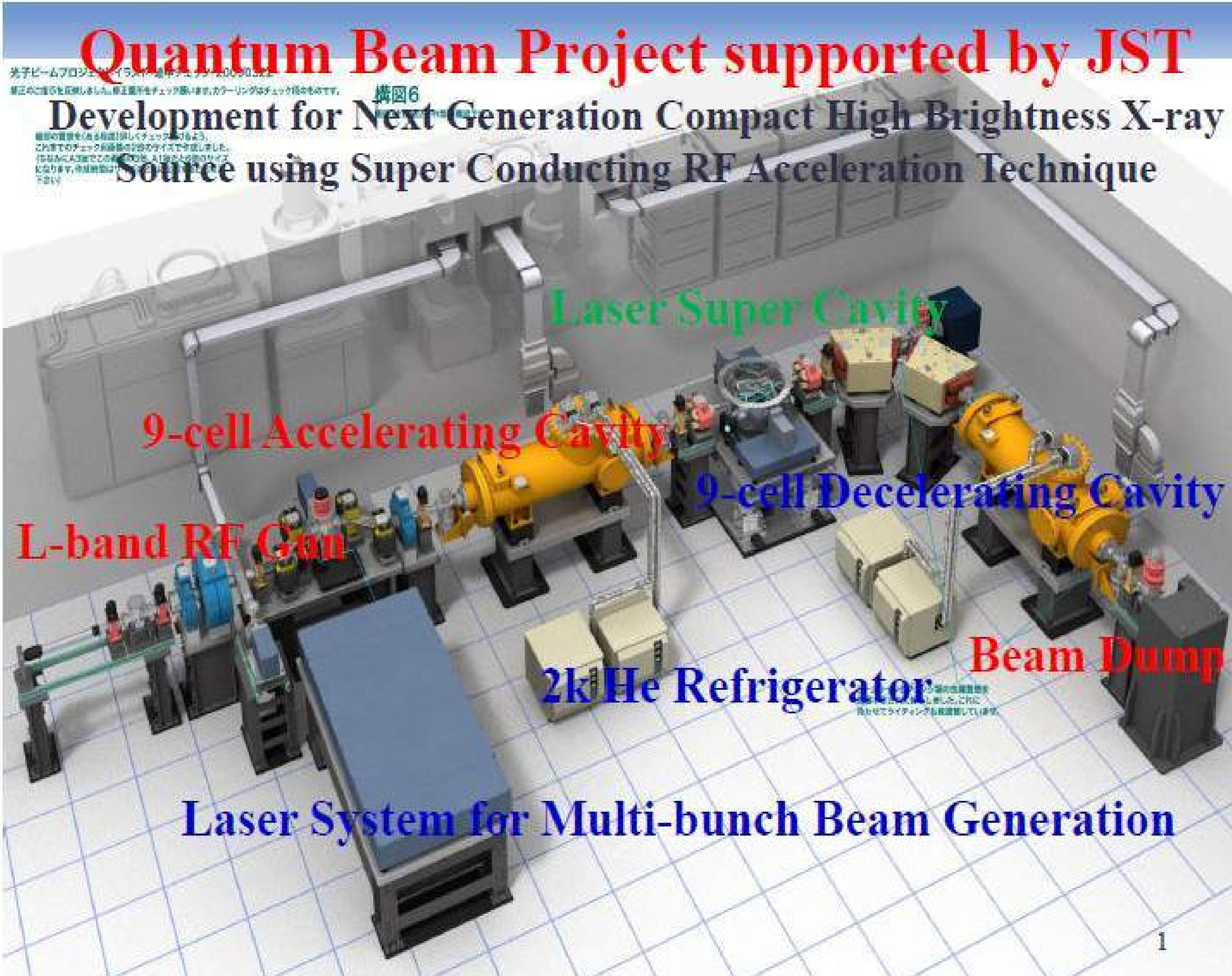


Table 5.1: Comparison of the number of produced X-rays

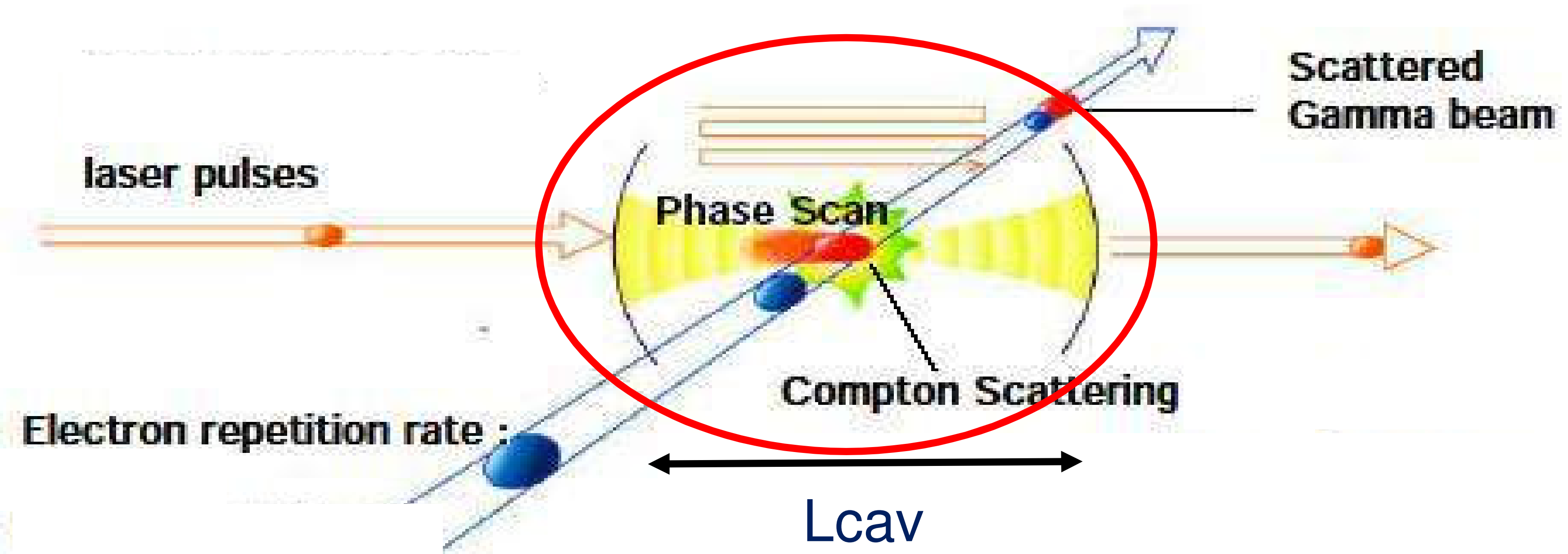
	Experiments	CAIN
Within Collimator	1.65×10^2 Photons/Train	2.0×10^2 Photons/Train
Total Number	0.93×10^4 Photons/Train	1.13×10^4 Photons/Train

Quantum Beam Project supported by JST

Development for Next Generation Compact High Brightness X-ray Source using Super Conducting RF Acceleration Technique



Optical Cavity for Laser-Compton



Higher laser power

L_{cav} = n $\lambda/2$, ΔL<nm laser for pulse stacking

->more enhancement the more precision

Laser should be focused for high power density

Efficient laser-Compton scattering

ΔT < ps

Accommodate laser cavity in the accelerator

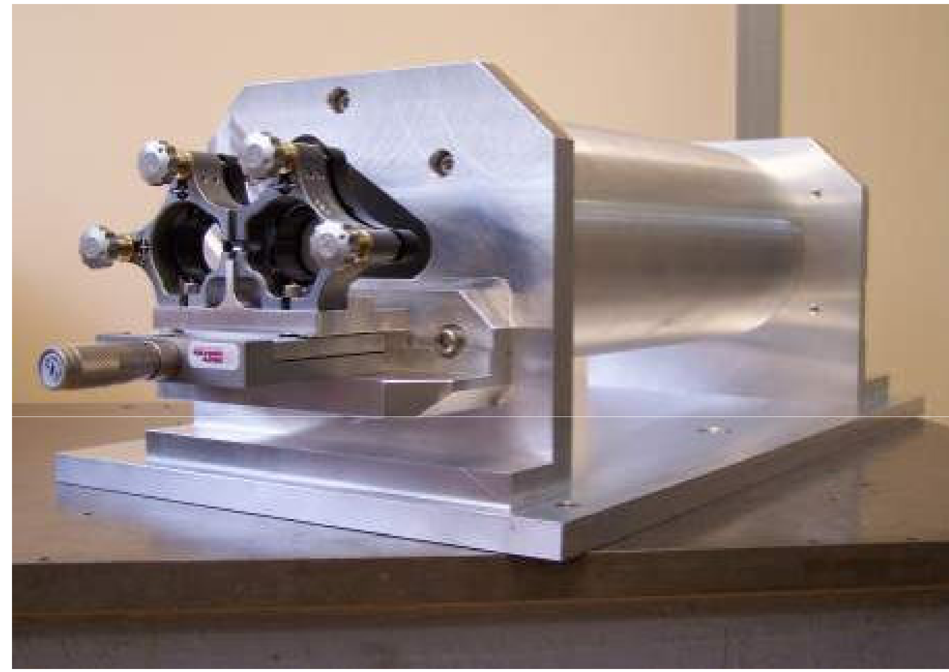
Two Prototype Cavities

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

moderate enhancement
moderate spot size
simple control

demonstration of γ ray gen.
accum. exp. w/ cavity and acc.

4-mirror cavities w/LAL



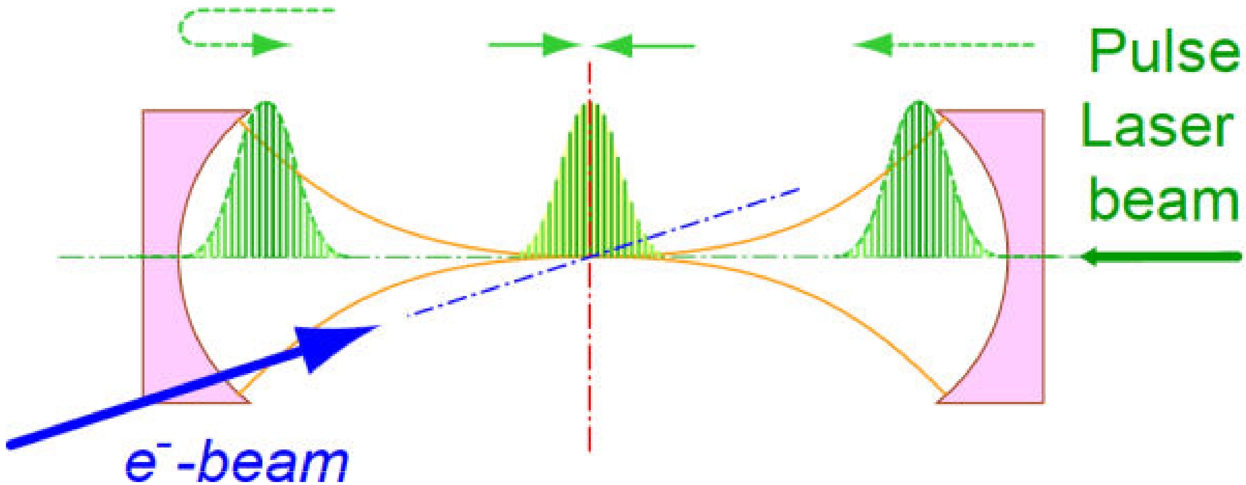
high enhancement
small spot size
complicated control

→ intense γ ray generation

2 MIRROR CAVITY STAUS

Experimental R/D in ATF

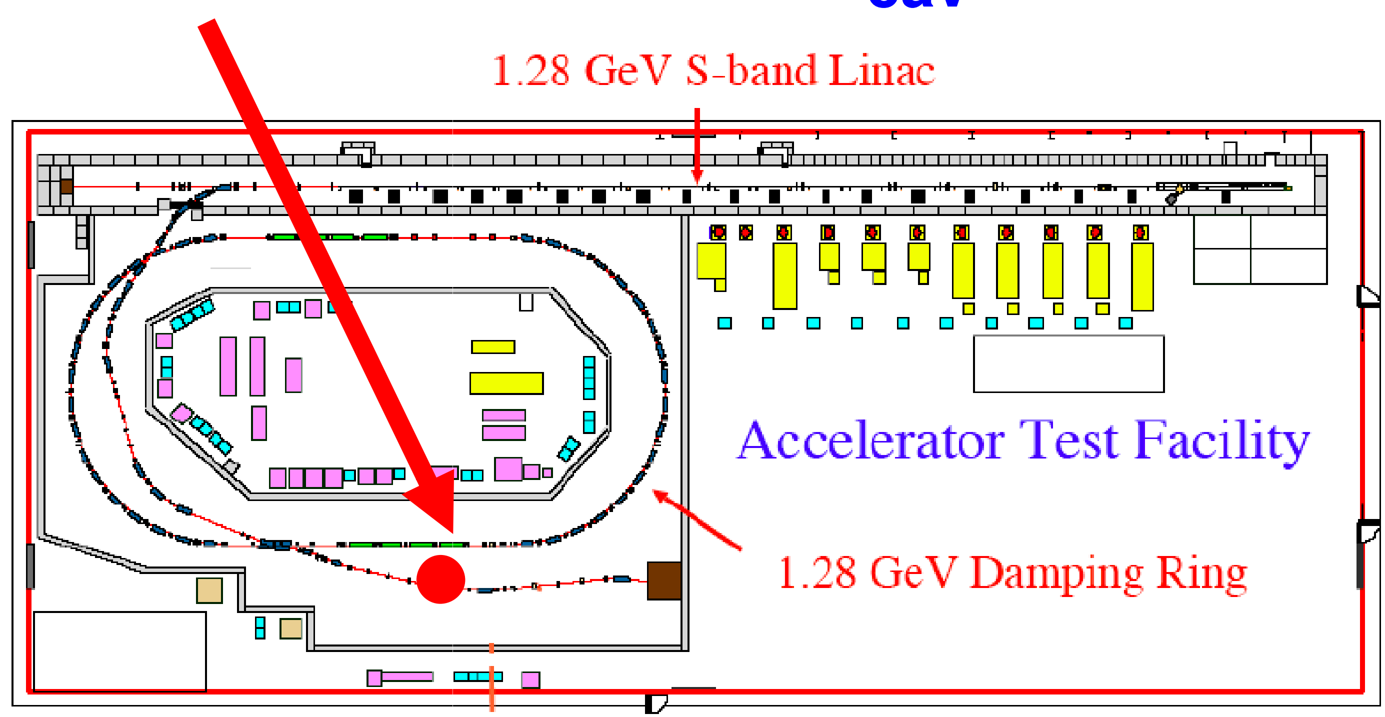
Hiroshima-Waseda-Kyoto-IHEP-KEK



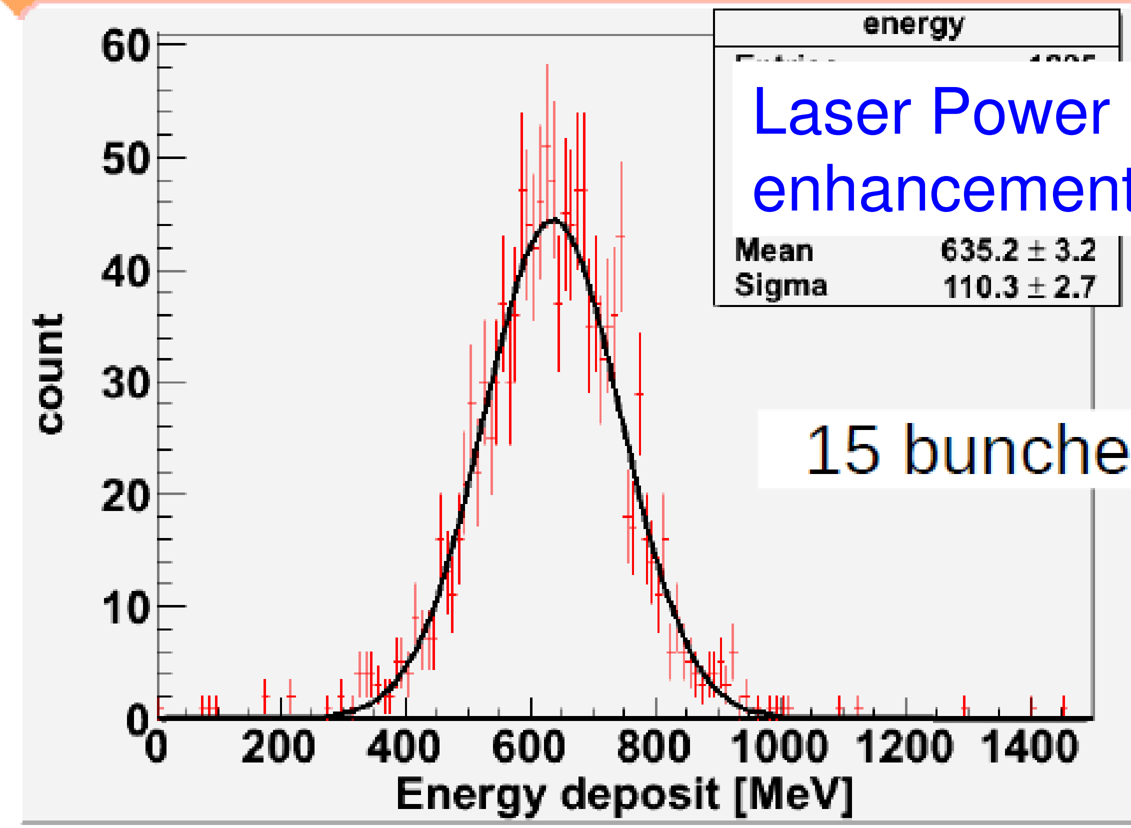
Make a fist prototype 2-mirror cavity

L_{cav} = 420 mm

Put it in ATF ring



Result



Laser Power enhancement 250

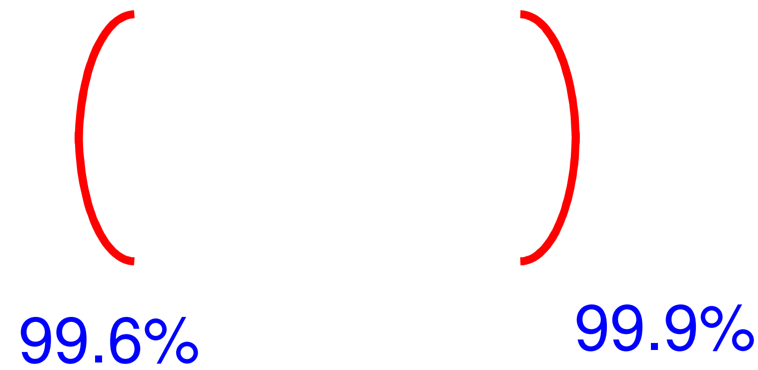
15 bunches / train

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

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

AFTER TILC09

- One of the Mirror was replaced with the higher reflectivity one
  - 99.6% -> 99.9%
  - power enhancement
    - 250 -> ~750
  - more precise controll required (~0.1nm)

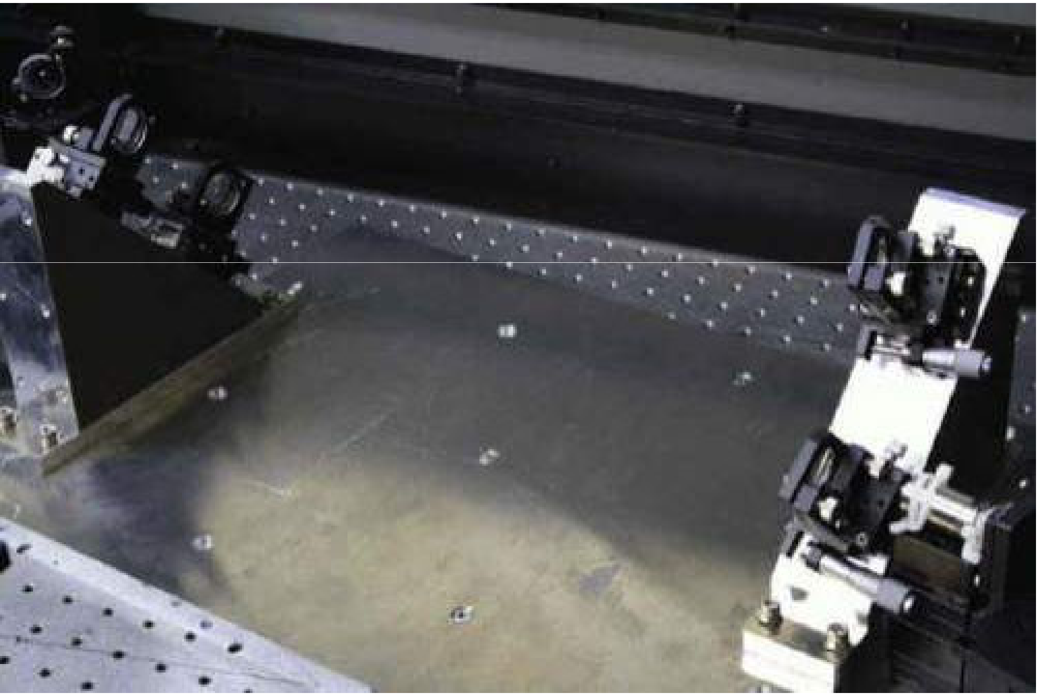


- Status of the cavity w/ new mirror
  - Finess ~2000 with feedback on before vacuum on
  - now in preparation for beam
  - hope to get 3 times more photons by the end of the year

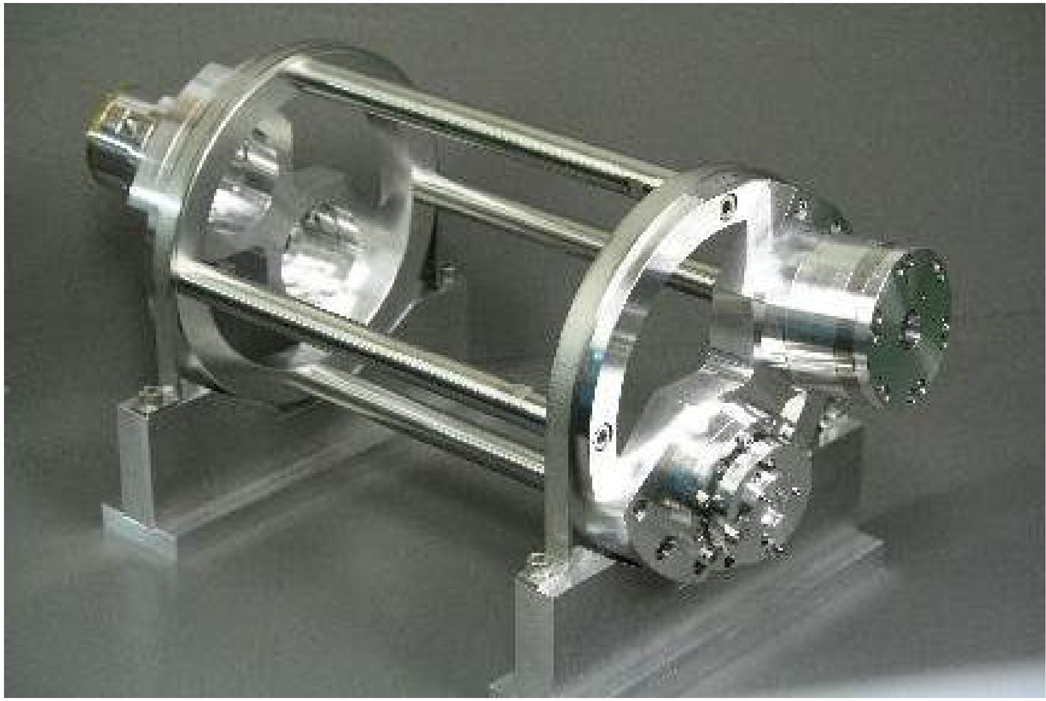
4 MIRROR CAVITY STATUS

4 MIRROR CAVITY STATUS

March 2009

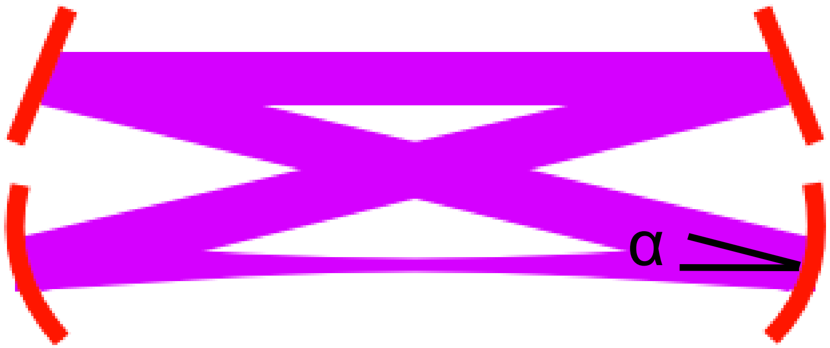


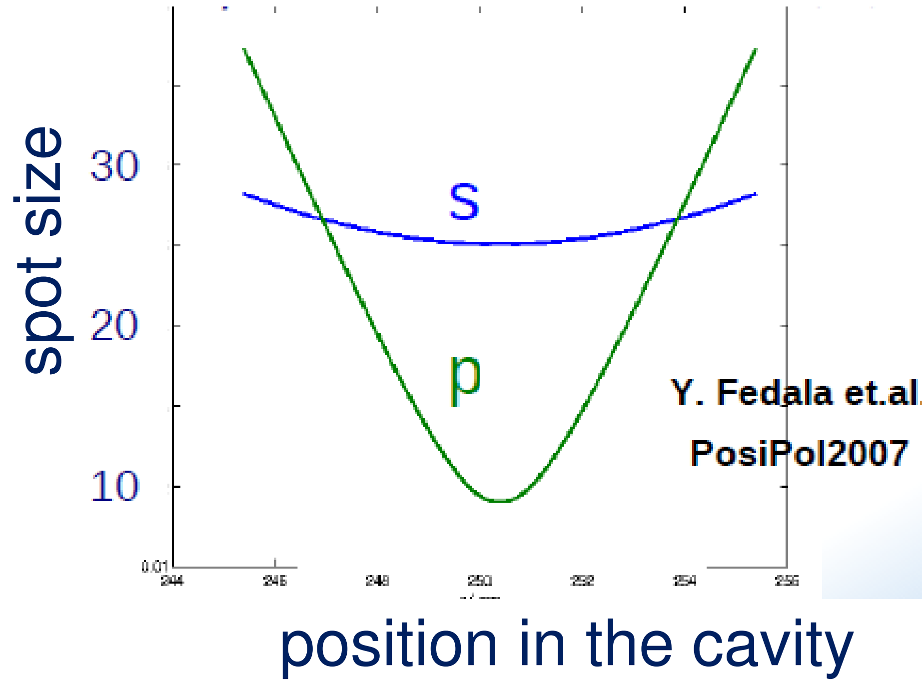
August 2009



2D configuration

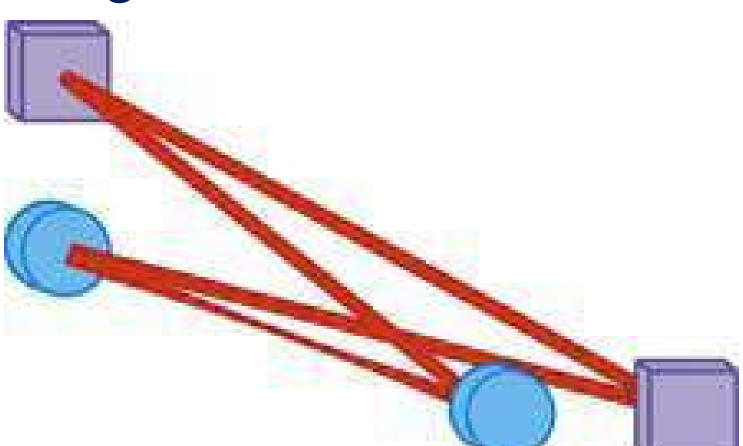
2D 4mirror cavity has astigmatism.

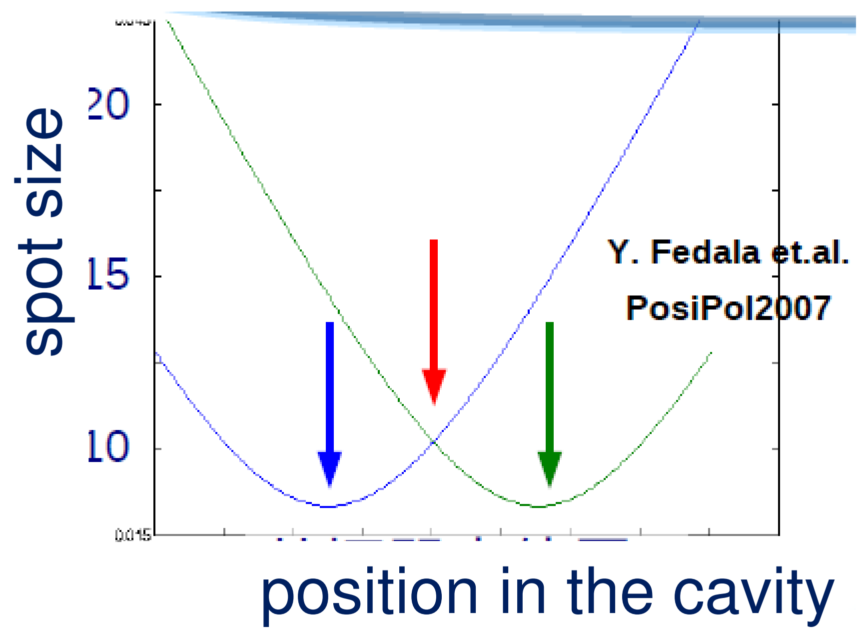




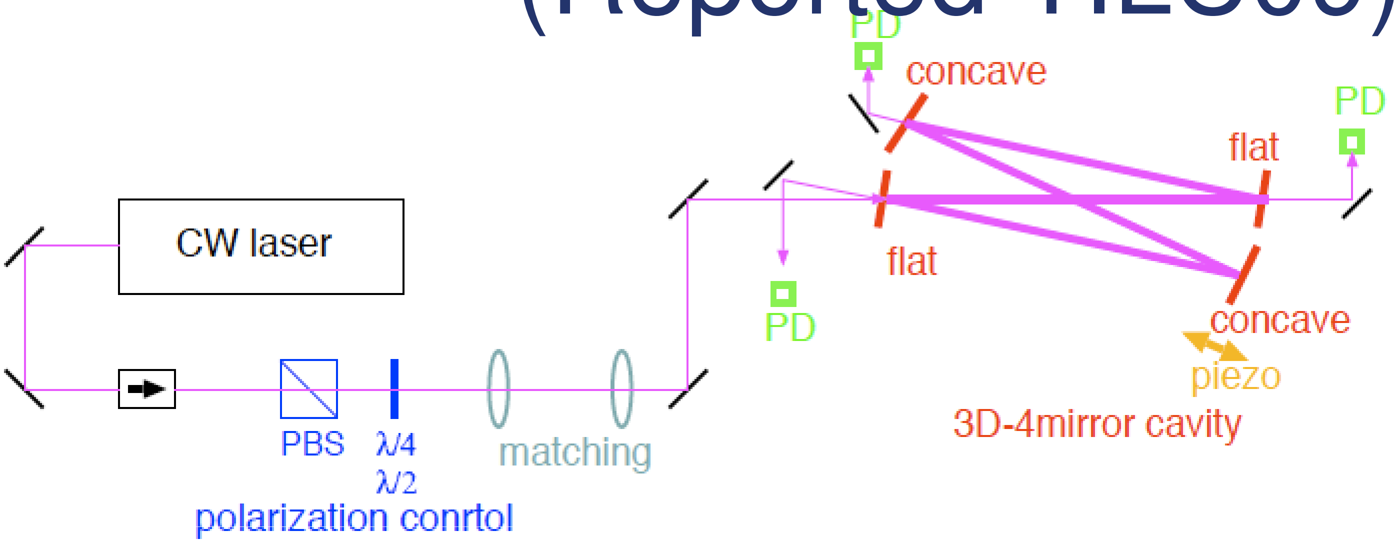
3D configuration

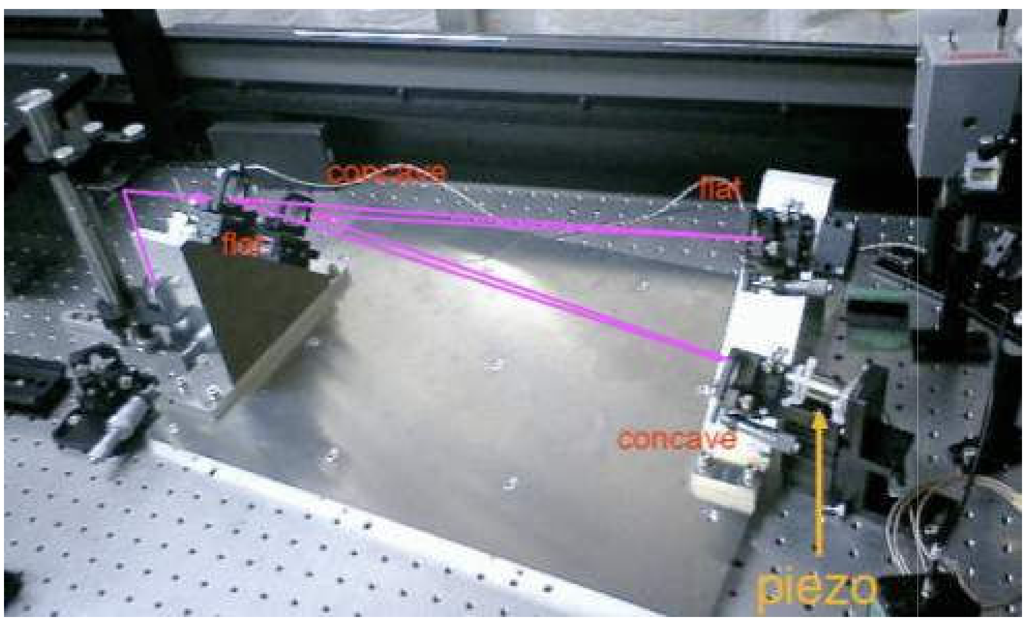
go to 3D config. to avoid astgmatism

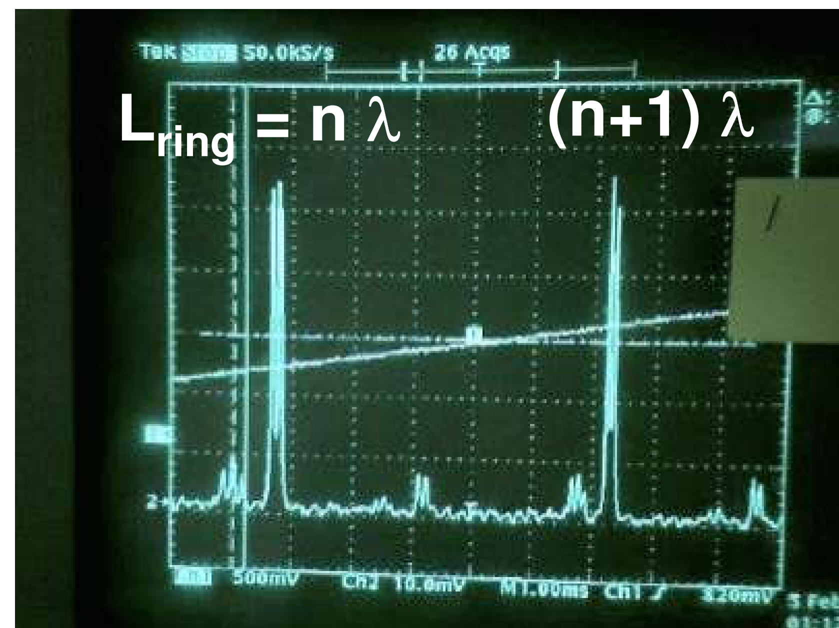




R&D of 4 mirrors cavity started at KEK (Reported TILC09)

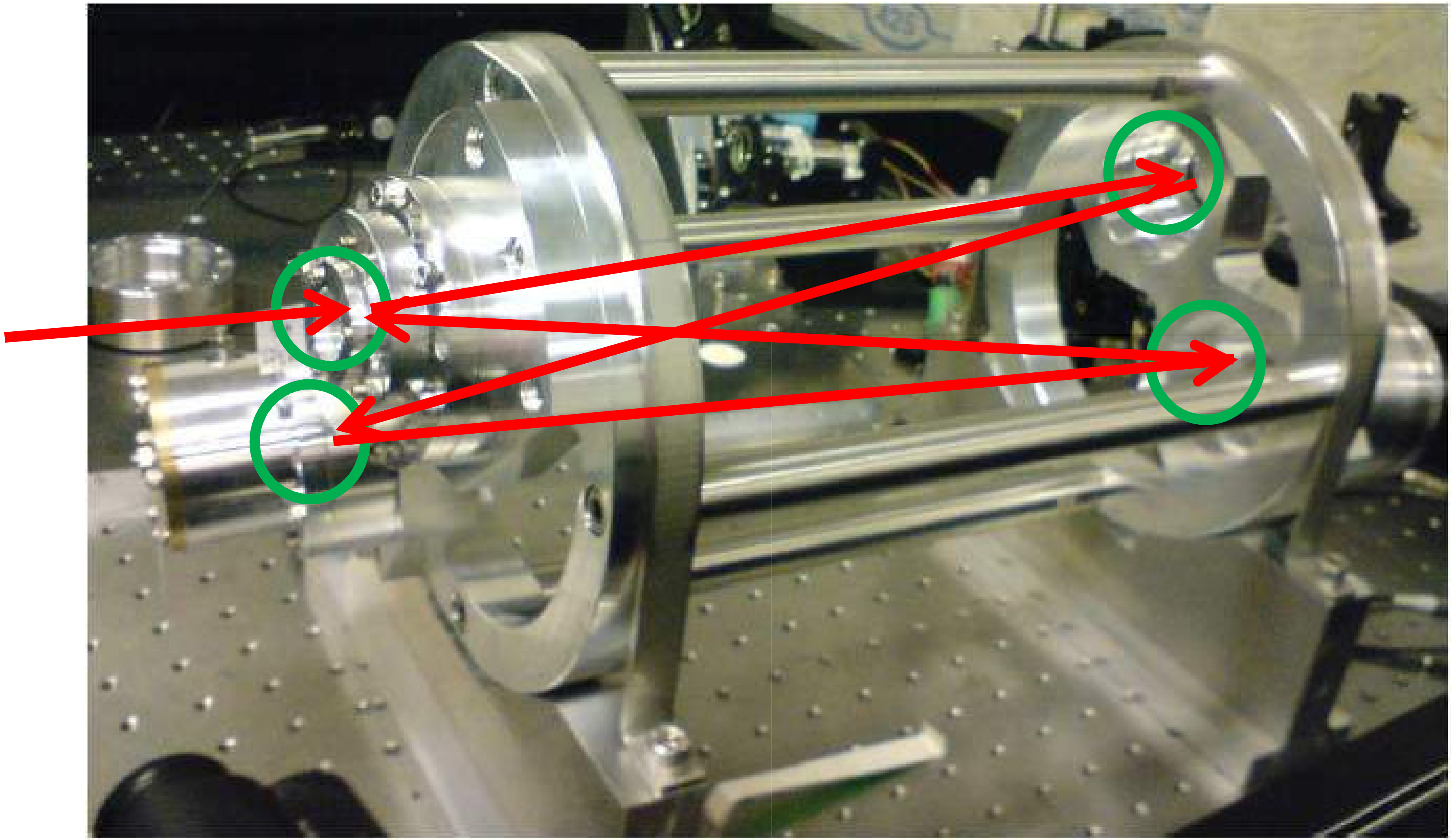




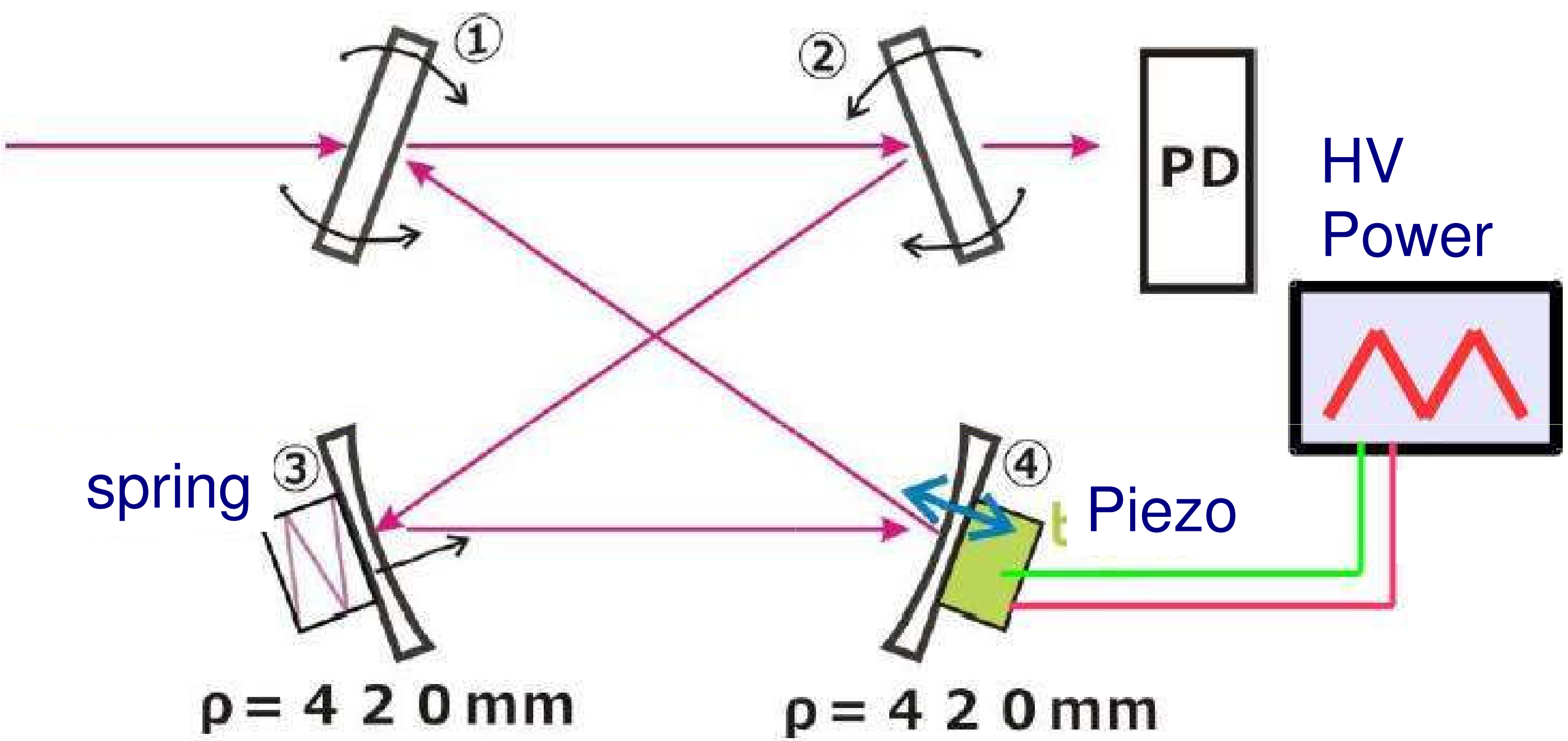


Honda

prototype 4 mirror cavity Constructed

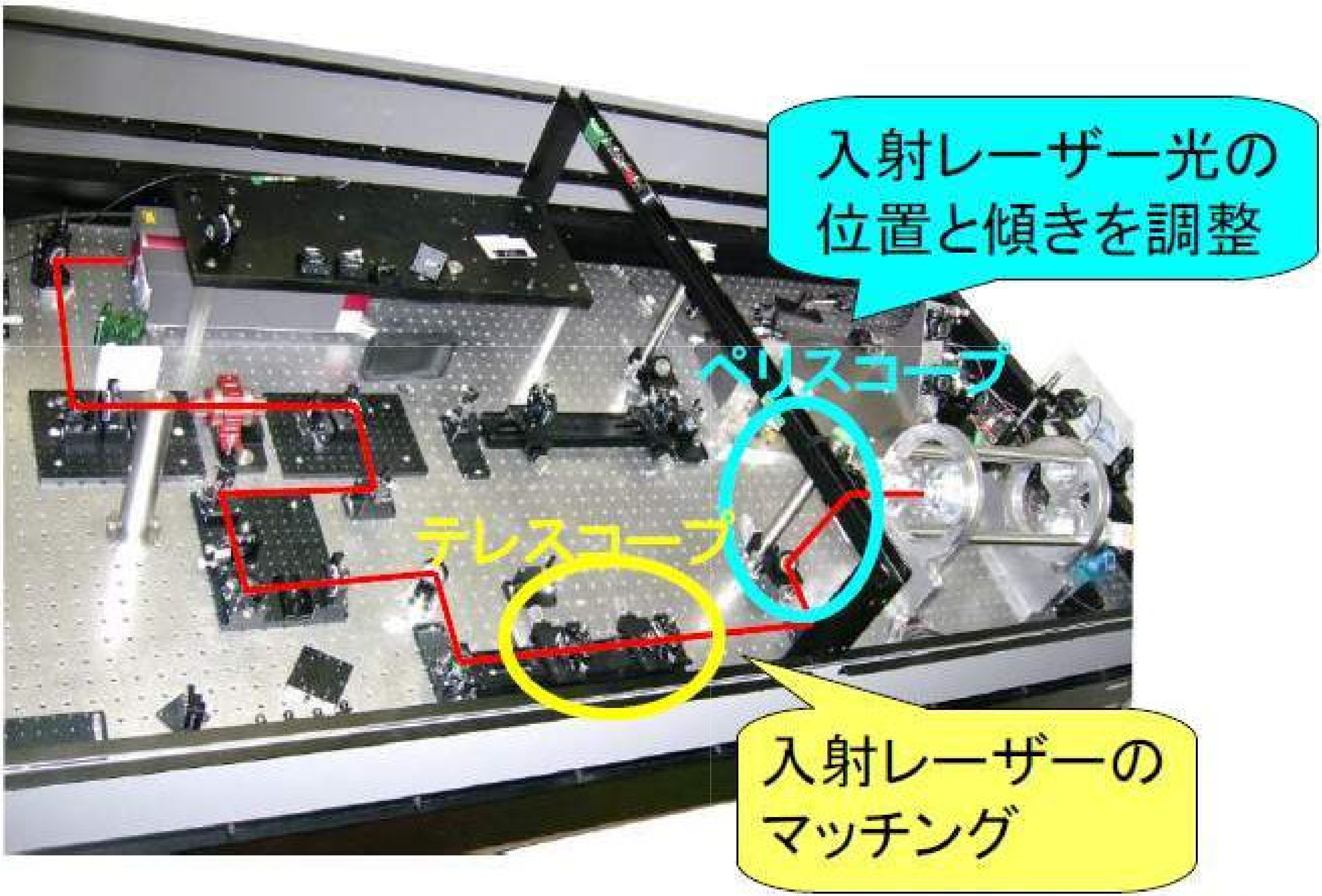


tuning mechanizm

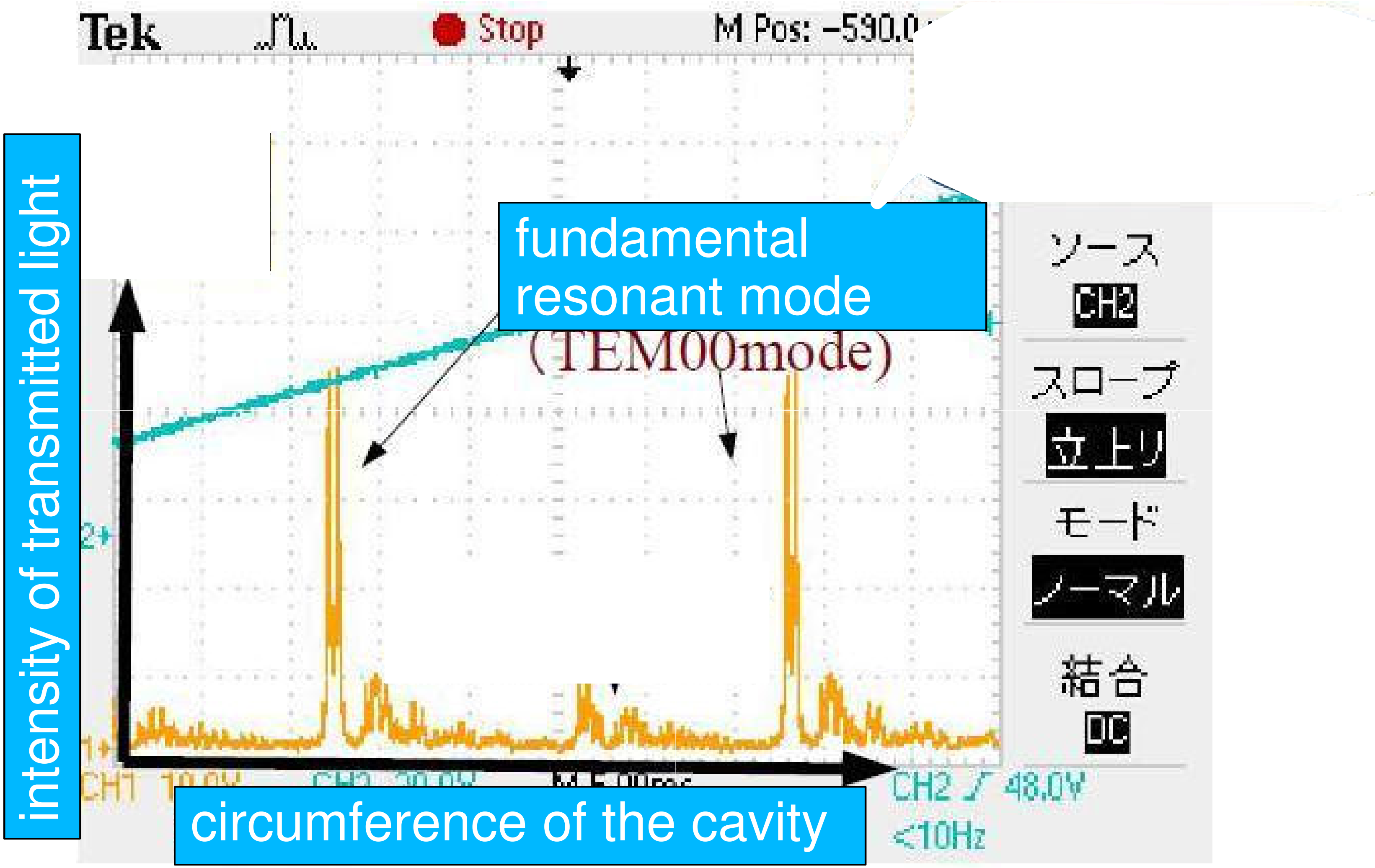


Objective: to establish method of:
mirror alignment, control cavity length
→ feed back to the beam compatible cavity

Prototype cavity on the optical table



status of initial tests



resonance of the cavity with injecting laser observed

polarization property of the 3 dimensional 4 M ring cavity

- circular polarization state get geometrical phase

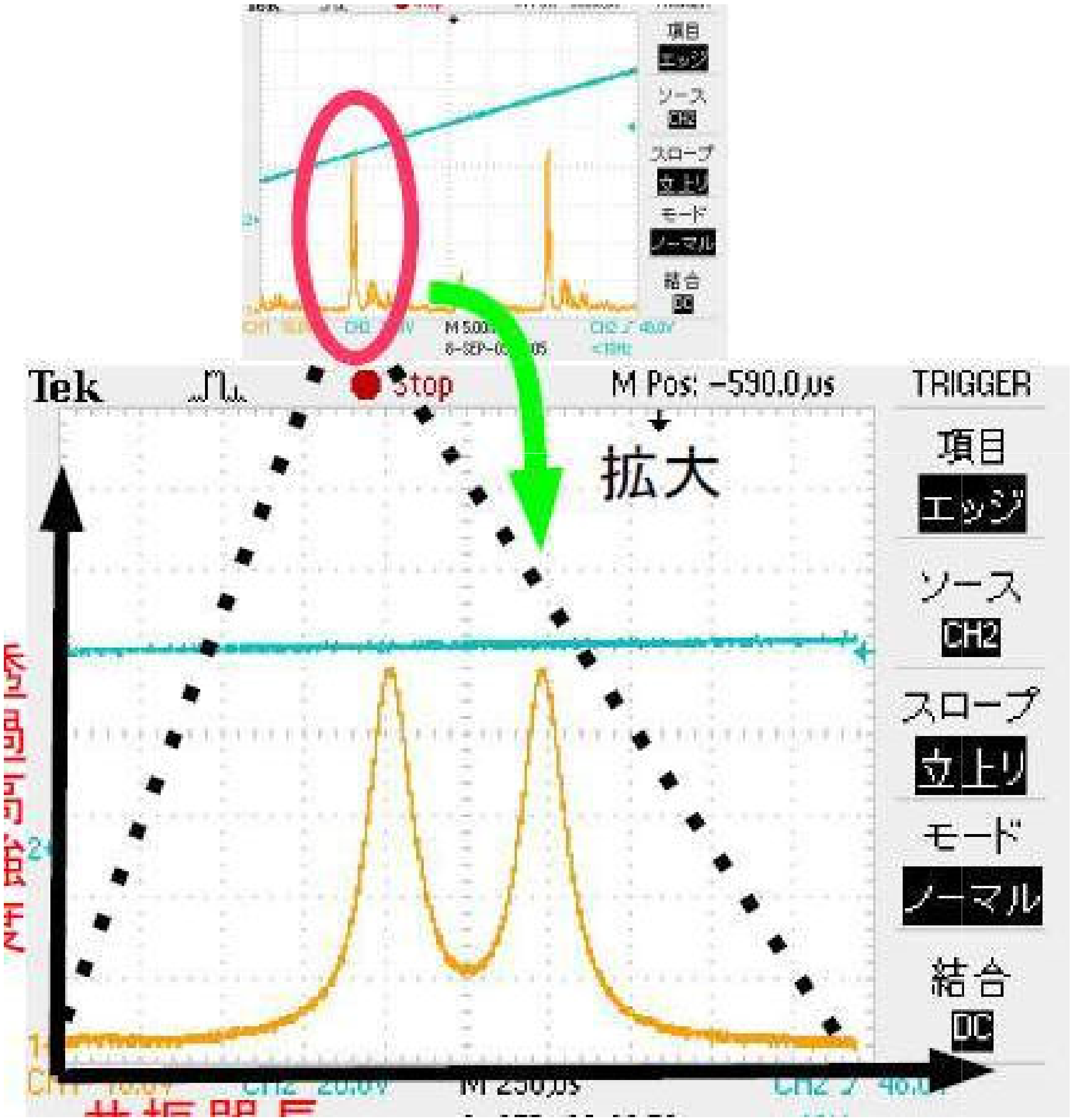
$$\frac{\vec{k}\cdot\vec{\sigma}}{\left|\vec{k}\cdot\vec{\sigma}\right|}\left|\psi_{\pm}\right\rangle = \pm\left|\psi_{\pm}\right\rangle \quad \left|\psi_{\pm}\right\rangle \rightarrow \exp(\pm i\Gamma)\left|\psi_{\pm}\right\rangle$$

- For linearly polarized photon, it is rotation of the direction of the polarization

$$\begin{pmatrix}\psi_s\\ \psi_p\end{pmatrix} \rightarrow \begin{pmatrix}\cos(\Gamma) & \sin(\Gamma)\\ -\sin(\Gamma) & \cos(\Gamma)\end{pmatrix}\begin{pmatrix}\psi_s\\ \psi_p\end{pmatrix}$$

⇒ 3D 4M cavities resonate only for
left or right handed circulate polarization at
defferent cavity length

two peaks



•two separated resonant peaks

each corresponds to
left or right handed polarization

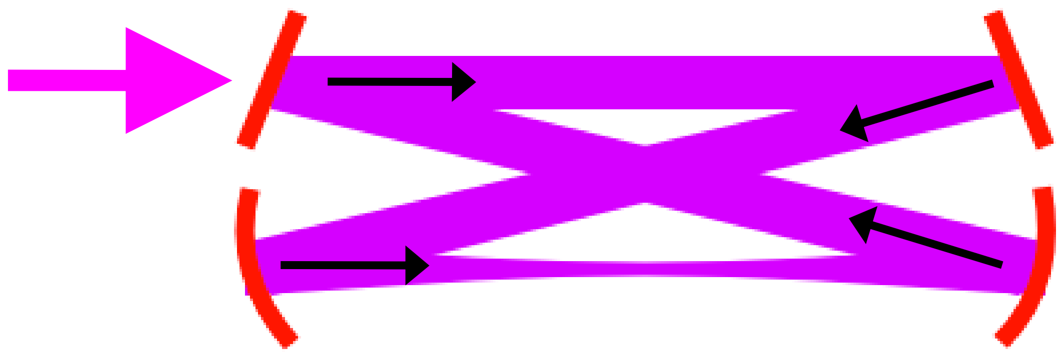
•3D cavity only resonates with circular polarization due to geometric phase

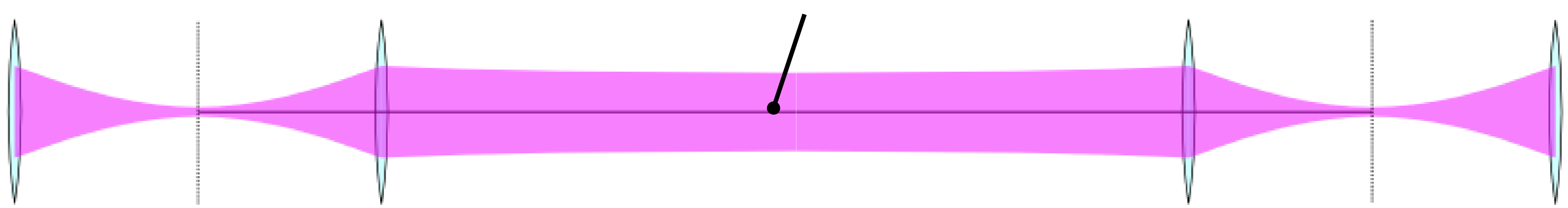
Useful to:
• generate circularly pol. γs
•fast switching

Summary

- 2 mirror cavity to demonstrate photon generation and to accumulate experience w/ beams
  - x250 laser power, 27γ/crossing at TILC09
  - enhancement ~750 to 1000 this year
- multiple projects for laser-Compton scattering are underway→all of them will use 4M ring cavity
  - Polarized positron source
  - X ray generation
- 4 mirror ring cavity for higher enhancement and small spot size
  - first prototype at KEK and being tested
  - installation of LAL cavity being ready

4-mirror ring cavity

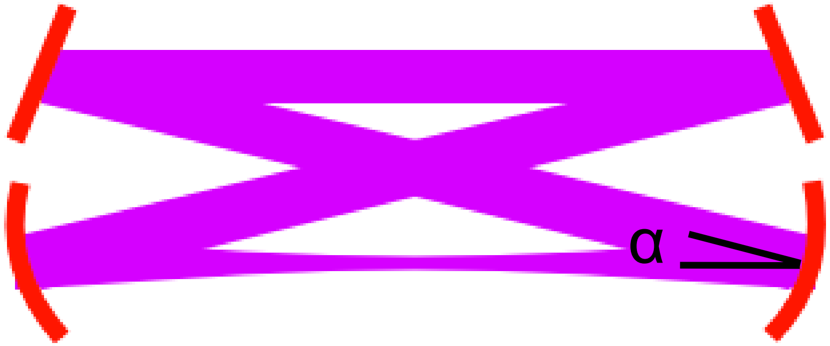




Equivalent Optics of the 4-mirror Cavity

tolerance : 4-mirror = 100 x 2-mirror

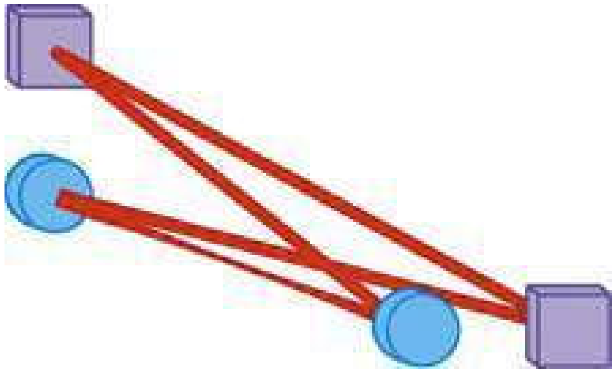
2D configuration

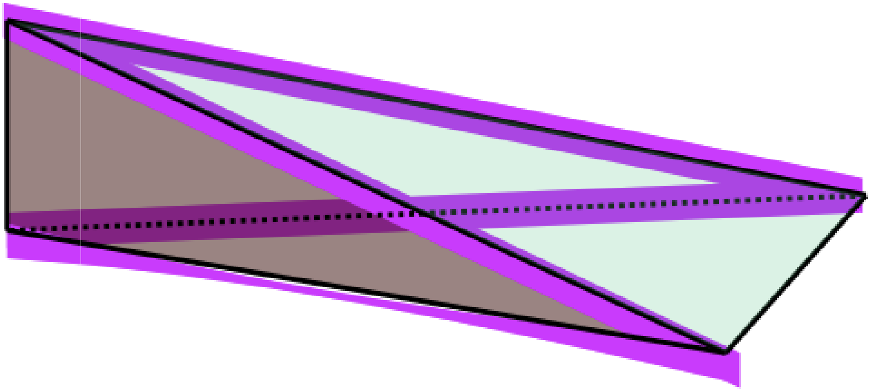


$$f_t = \frac{\rho}{2}\cos(\alpha/2)$$

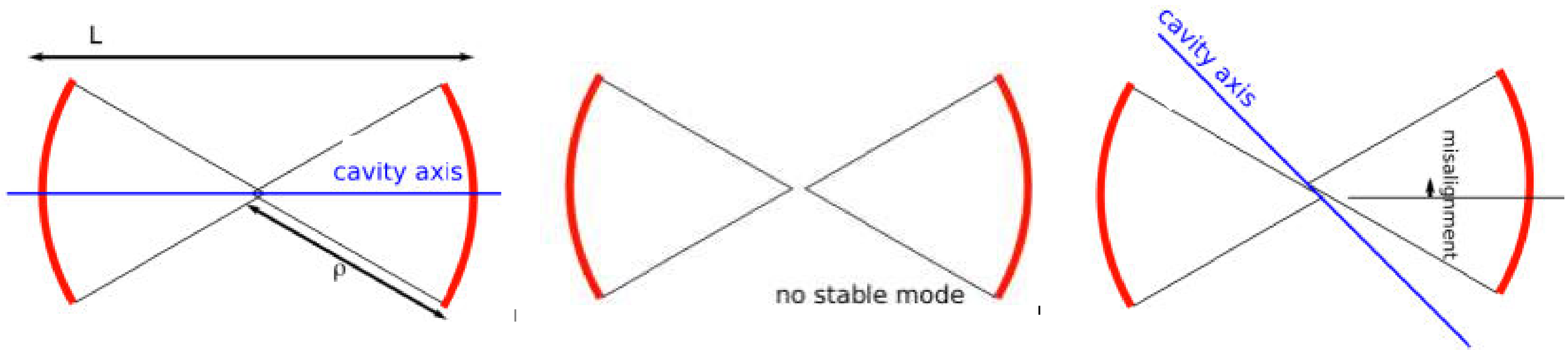
$$f_s = \frac{\rho}{2\cos(\alpha/2)}$$

3D configuration

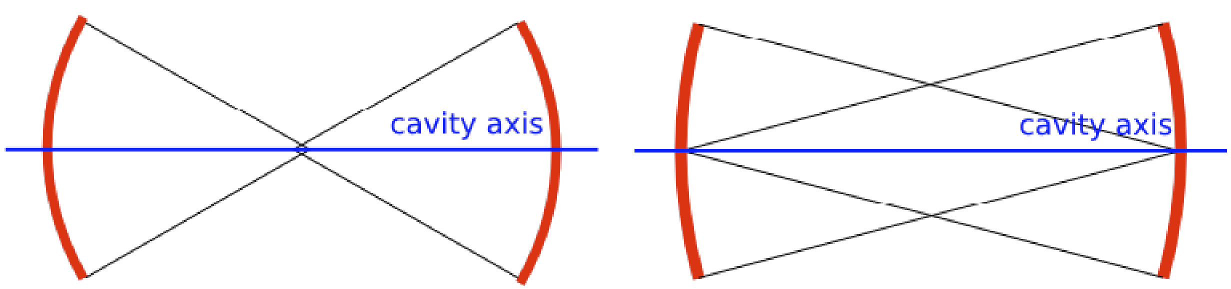




Tolerance of 2-mirror cavity



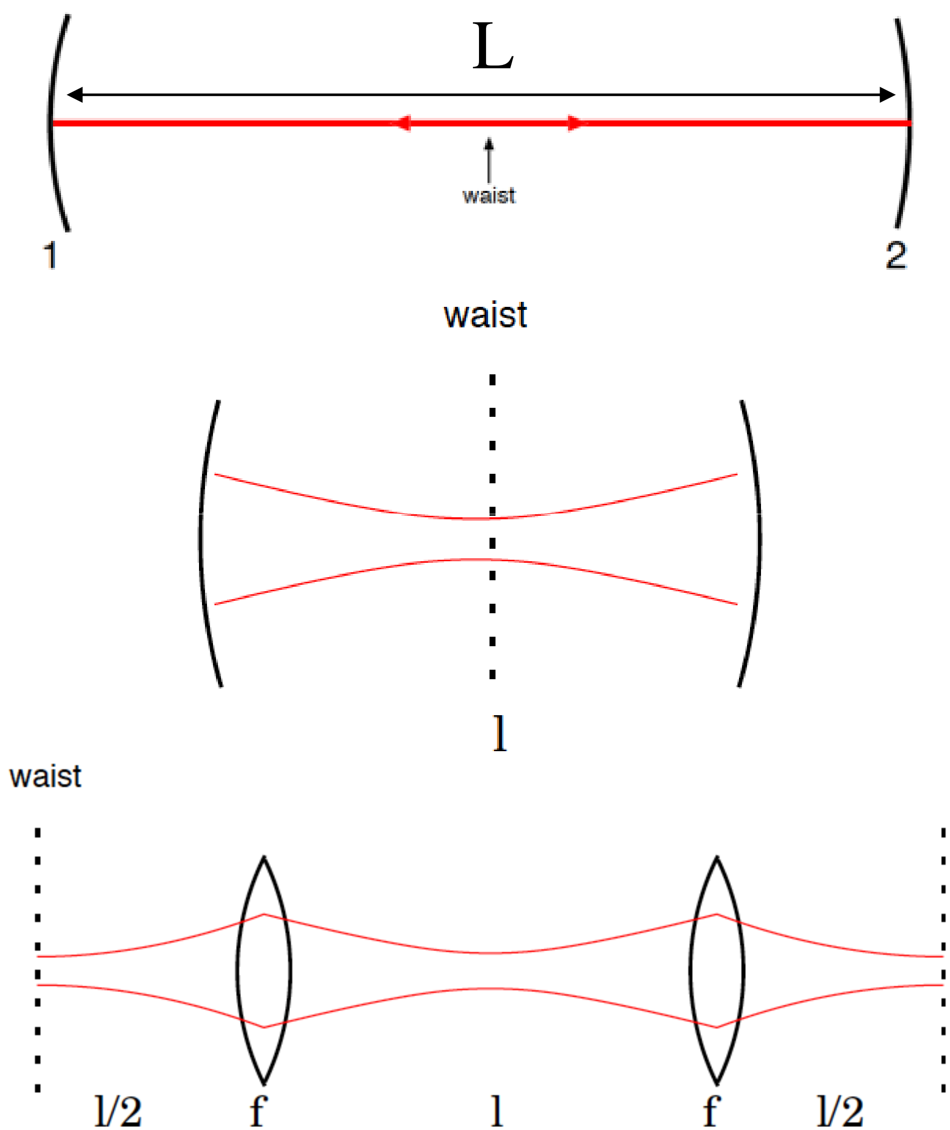
Concentric Configuration and Confocal Configuration



concentric confocal

2-mirror cavity

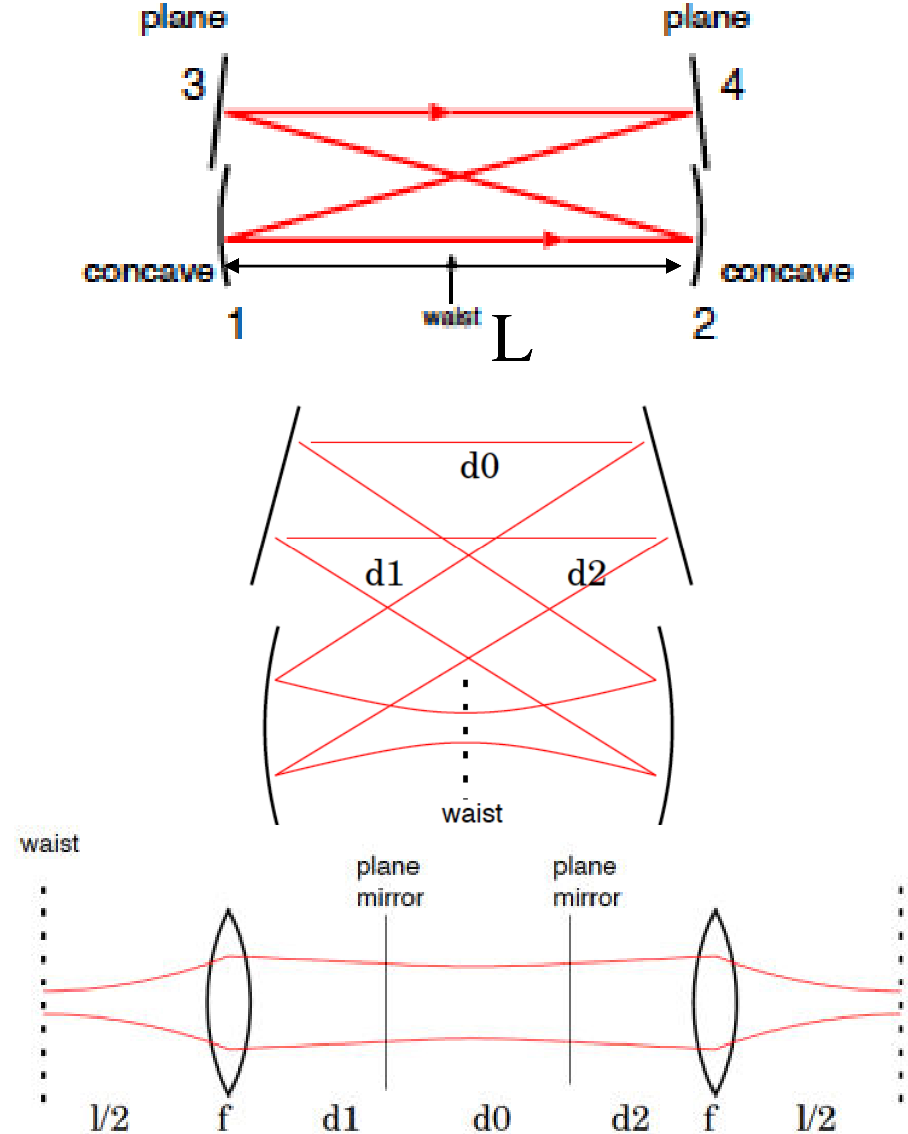
R1=R2=L/2



concentric

4-mirror cavity

R1=R2=L



confocal

data summary

bunch /train	current [mA]	Stacked Laser power[W]	γs/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