# Recent status of laserwire development at KEK-ATF

Yosuke HONDA ( Kyoto university.)

- introduction
- experimental setup
- data taking and analysis
- summary and discussion

# collaboration

| | |
|---|---|
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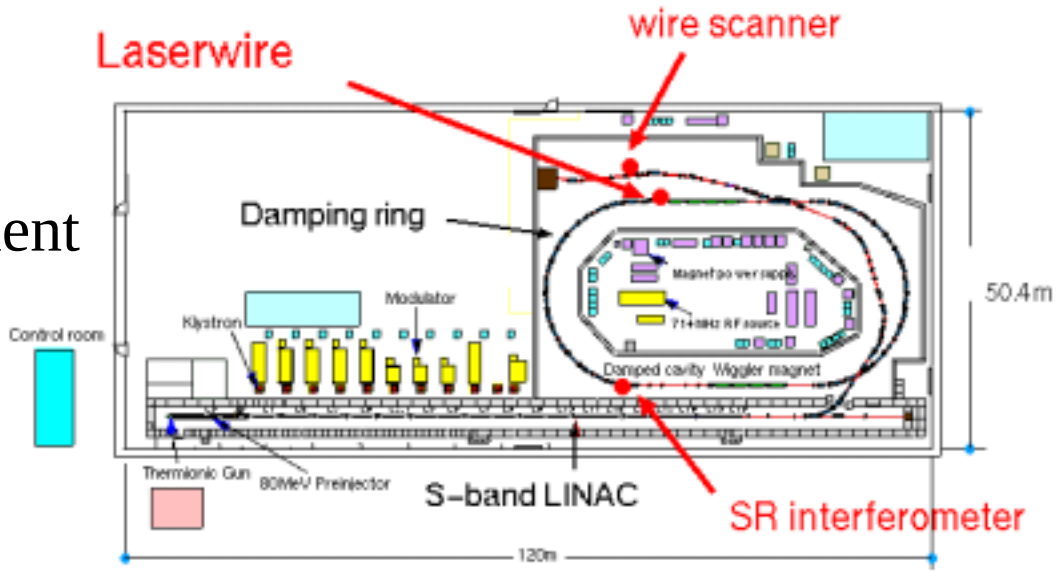
| Koichiro HIRANO , Masahiro NOMURA , Yoshio YAMAZAKI | **Japan Nuclear Cycle organization** |
| Mikio TAKANO | **National Institute of Radiological Science** |
| Hiroshi SAKAI | **The Institute for Solid State Physics** |

# introduction

- Laserwire monitor at ATF

  vertical emittance measurement in Damping ring

  - direct scanning
  - non-invasive method
  - dispersion negligible
  - multi-bunch measurement




- typical beamsize

  100 μm (horizontal)

  10 μm (vertical)

- requirement for laserwire

  thinness (~ 5 μm )

  intensity ( ~ 100 W )

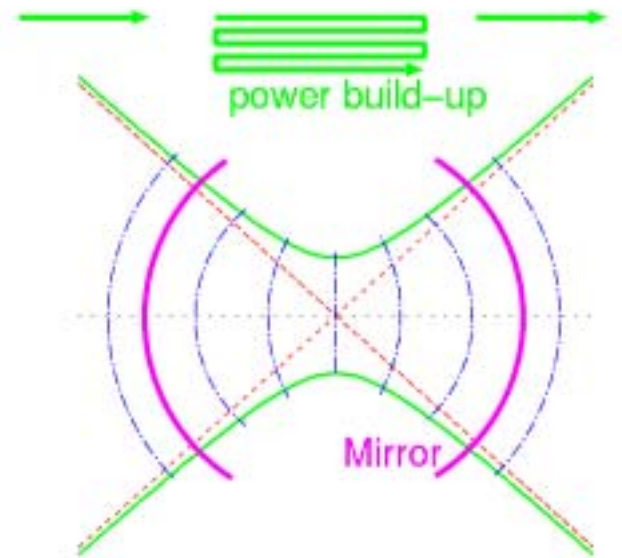
# introduction

- CW Laserwire with optical cavity

**Optical cavity**

power amplification

laser beam size control




CW ⇔ pulsed laserwire

easy to make a collision

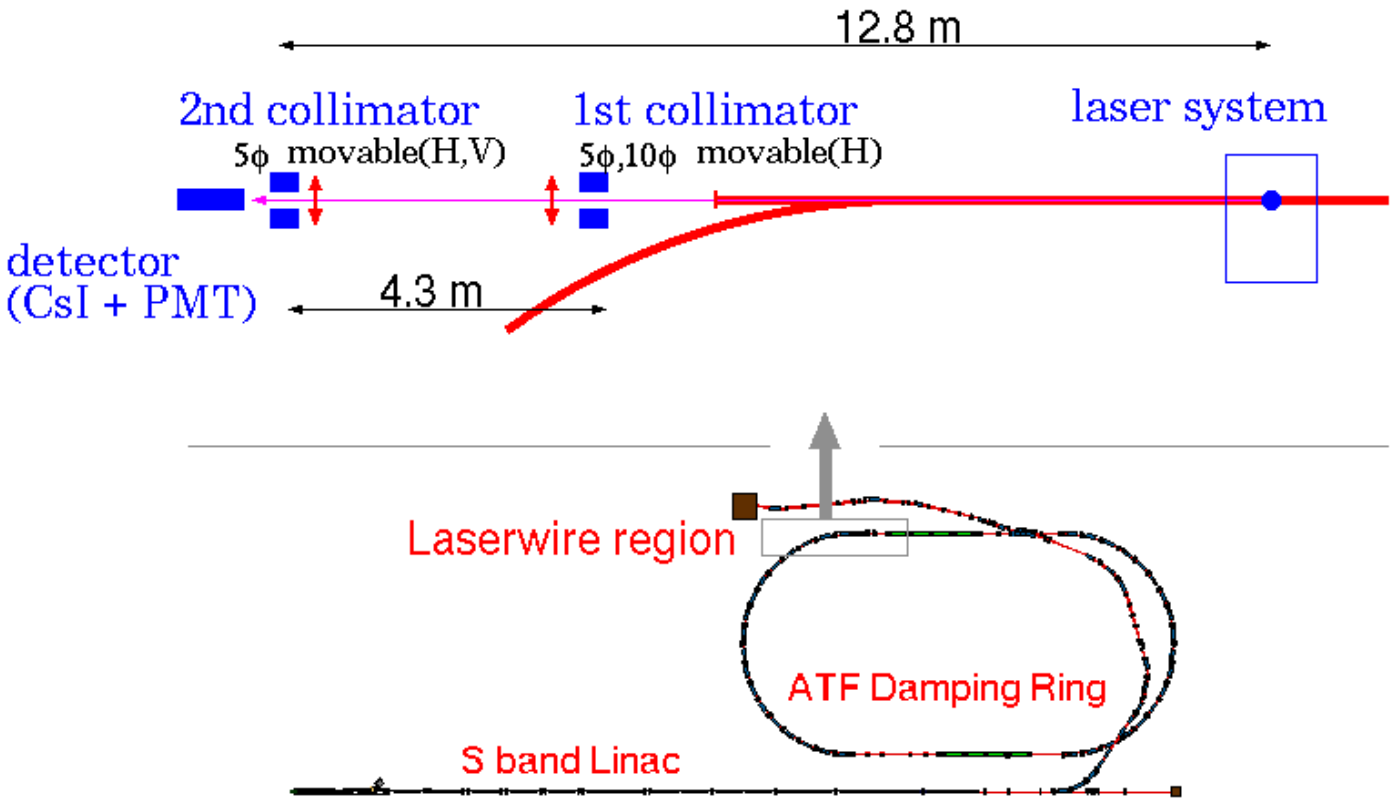
laser beam size is stable/measurable

no change is needed for multi-bunch measurement

cavity resonance control

mirror quality

# Laserwire experimental setup

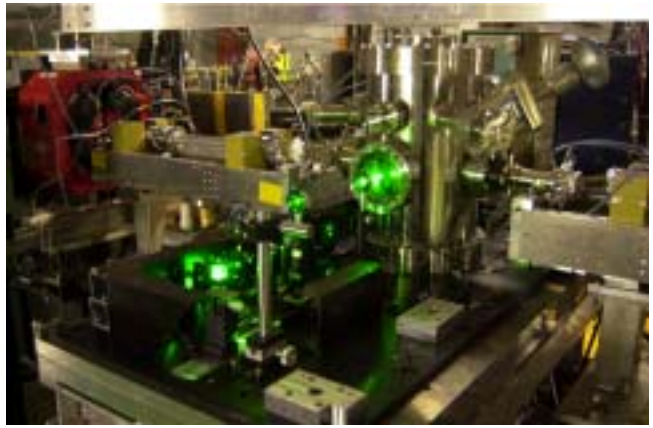


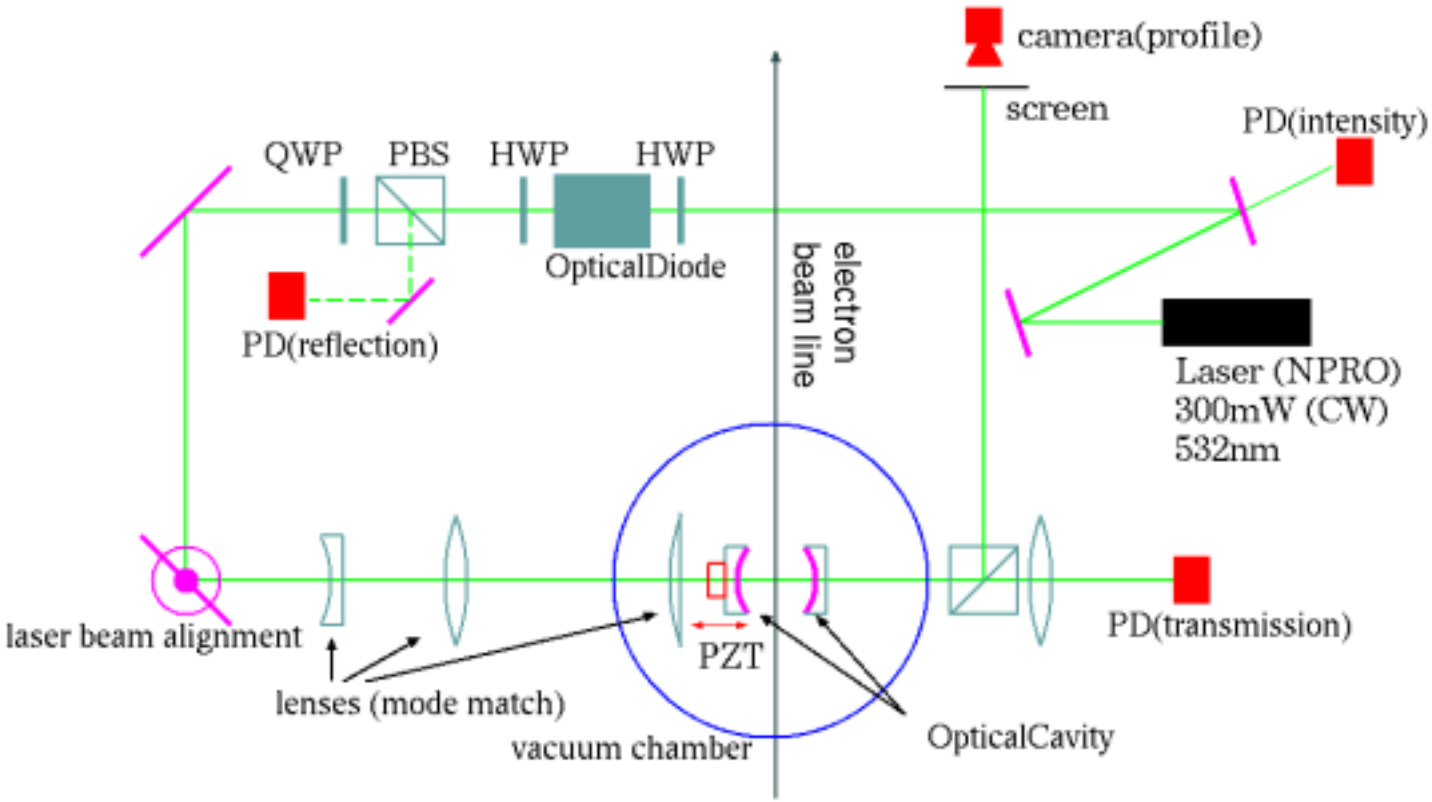

- laserwire
- detector
- data taking system

# Optics

whole optical system is

mounted on a movable table





# laser

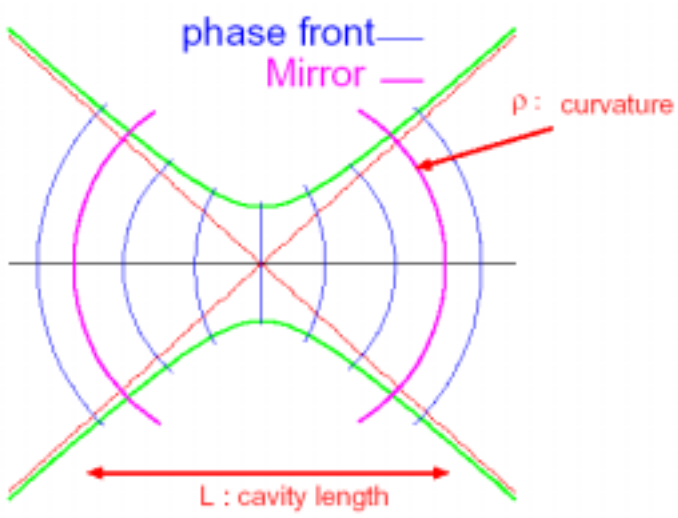
high power
stability in frequency (linewidth)

cavity resonant
width 10MHz

- LightWave Series 142
  - diode-pumped solid state laser
  - Nd:YAG (frequency doubled)
  - Non-Planar Ring Oscillator

| | |
|---|---|
| wavelength | 532 nm |
| CW power | 300 mW |
| spatial mode | TEM00 |
| longitudinal mode | single frequency |
| linewidth | <10 kHz (1msec) |

# optical cavity (Fabry Perot)




- mirror specification

| | |
|---|---|
| reflectance | 98.8% (front)<br>99.85% (end) |
| curvature | 20.00 ±0.02 mm |

- cavity specification

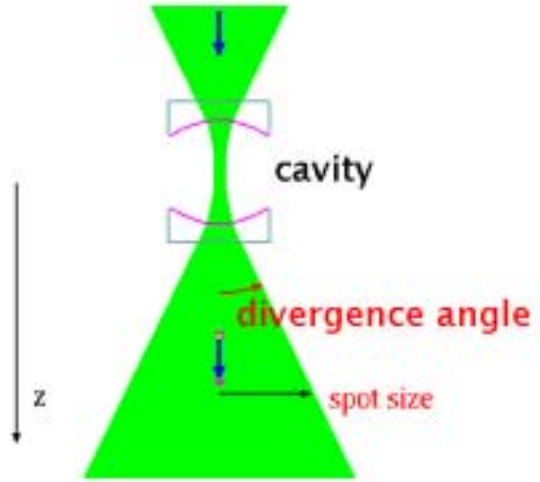
| | |
|---|---|
| configuration | nearly concentric |
| finesse | 480 ±20 |
| power gain | 470 ±30 |
| waist size | 6.0 ±0.1 μm (RMS) |
| Rayleigh range | 850 μm |

# laser beam waist size measurement

- beam divergence angle

$$\theta_0 = \frac{\lambda}{\pi\omega_0}$$

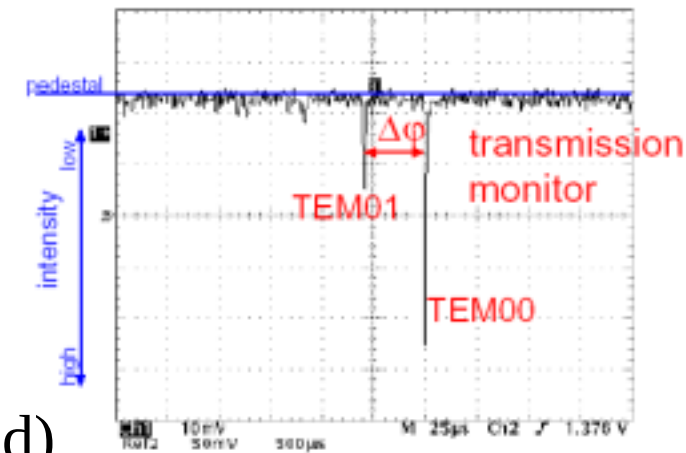
$$\omega_0 = 12.01 \pm 0.13 \mu m$$ (div. method)




- transverse mode phase difference

$$\frac{\Delta\varphi}{(\mathbf{fsr})} = \frac{\arccos(\mathbf{g})}{\pi} \qquad \omega_0^{\,2} = \frac{\lambda L}{2\pi}\sqrt{\frac{1+g}{1-g}}$$

$$\omega_0 = 12.20 \pm 0.17 \mu m$$ (mode method)

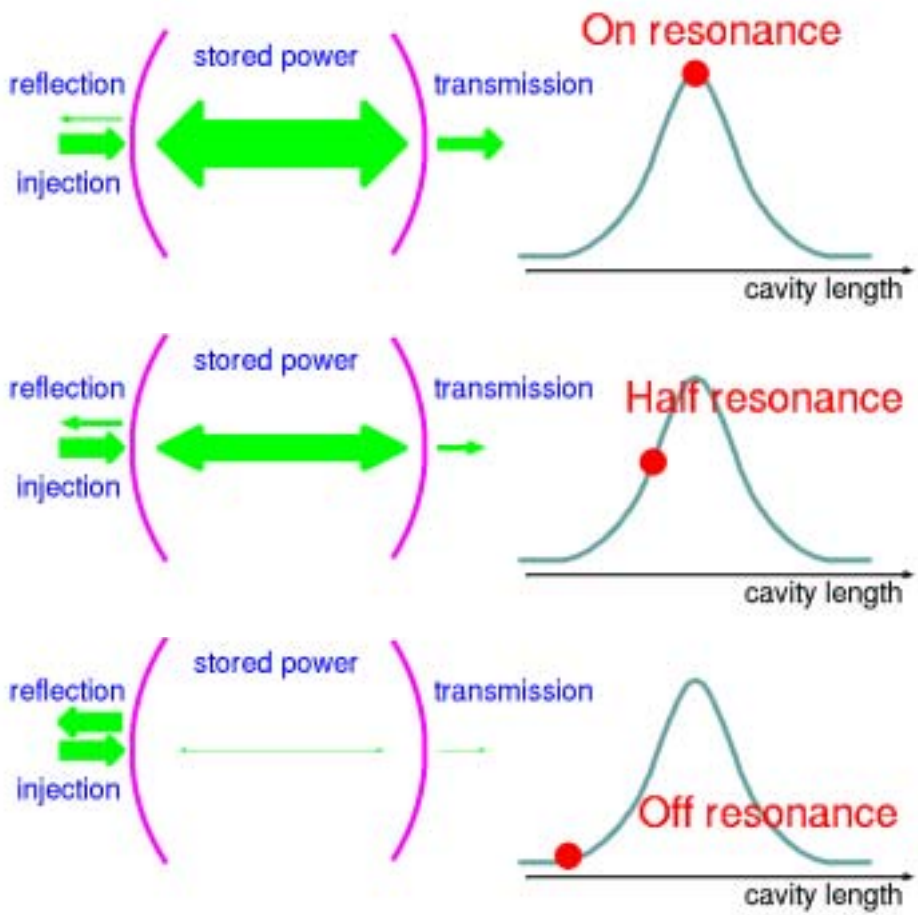



$\omega_0 = 12.08 \pm 0.21 \ \mu m$ (combined)

$\sigma_{laser} = 6.04 \pm 0.11 \ \mu m$ (gaussian target)

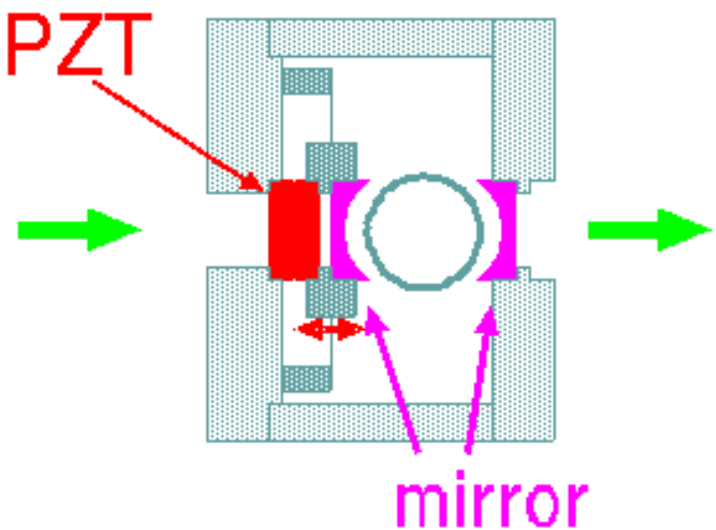
# cavity resonance and control

- power inside cavity



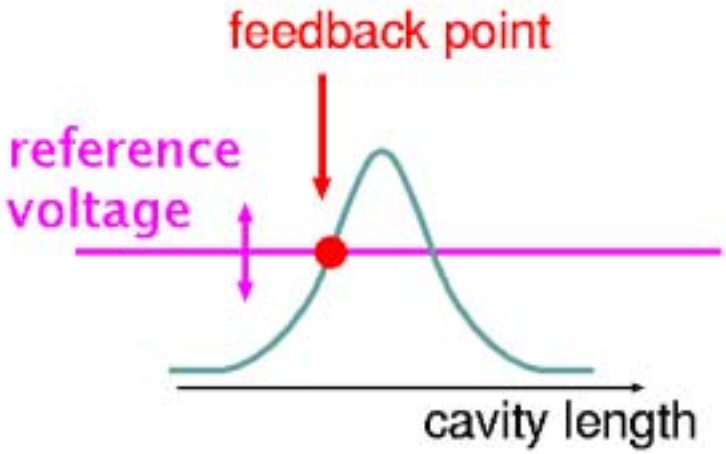

resonant width
= 0.5nm

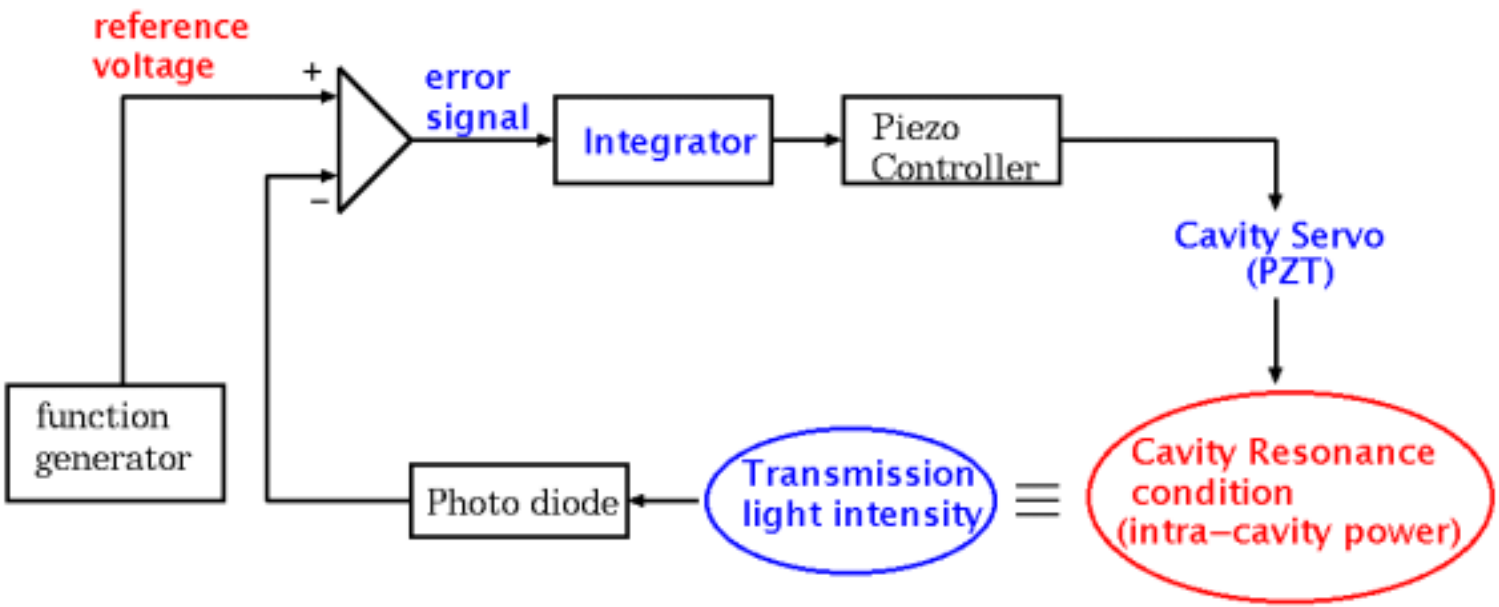
servo system
control cavity length



# cavity control

- < 0.1 nm control
- feedback control is necessary
- transmission intensity = reference voltage



# laser power modulation

- background subtraction
  Laser-ON / Laser-OFF measurement

  modulate intra-cavity power (feedback point )

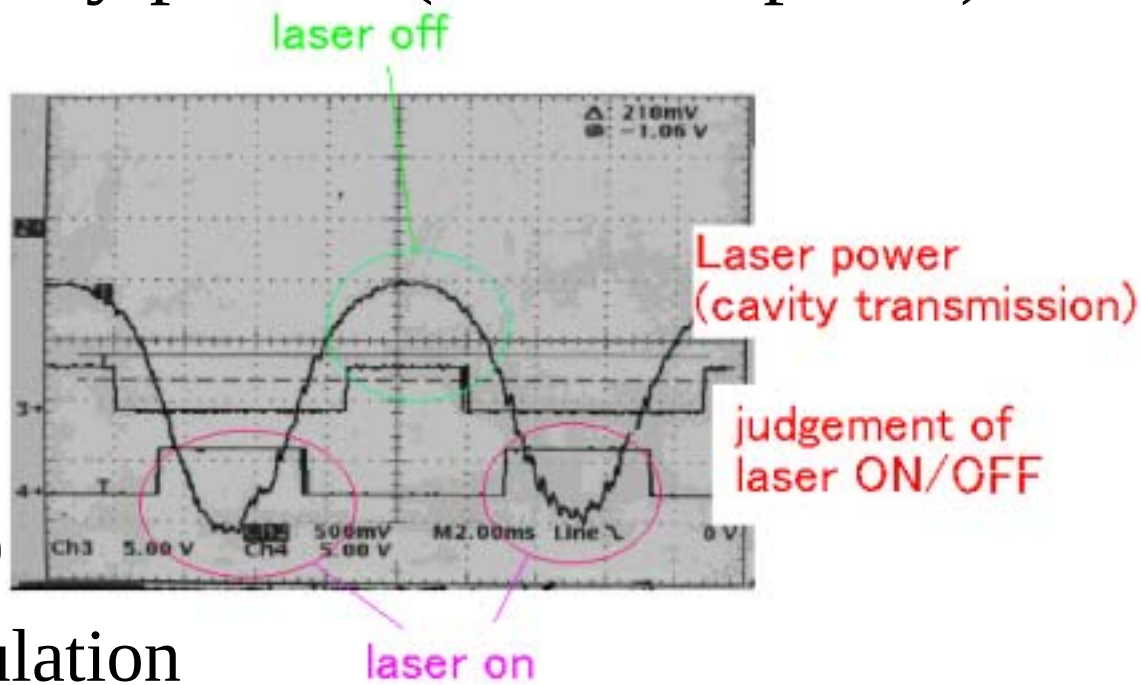
Laser-ON:
**30% (time)**

**85% of power (average)**

Laser-OFF:
**30% (time)**

**7.5% of power (average)**

113 Hz sinusoidal modulation



# Compton scattering and detector

- Compton scattering

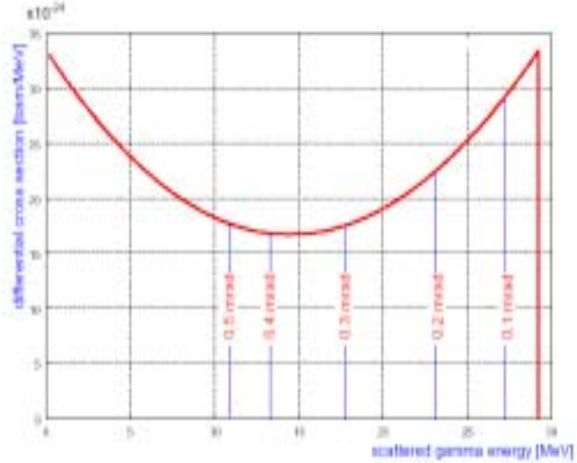
  1.28 GeV electrons

  **λ** = 532 nm photon

  90 degree crossing

  28.6 MeV (max gamma energy)

  23.0 MeV ( 0.2 mrad scattering angle )




- signal rate

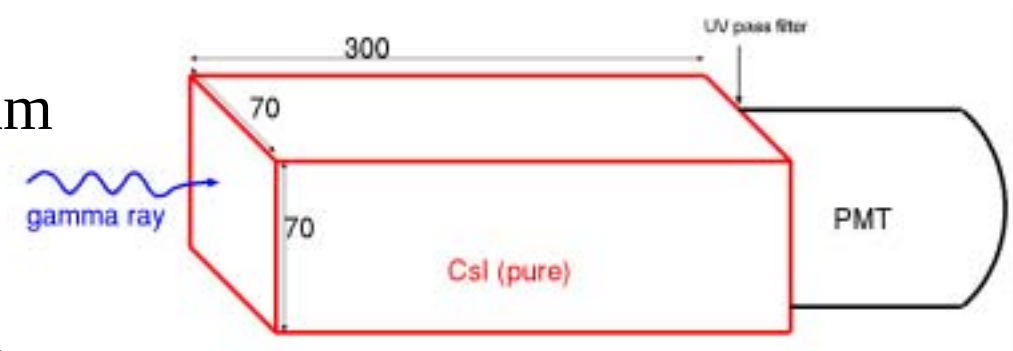
  ~ 10 kHz (signal + background ) << ring revolution ( 2MHz )

  no event pile-up

- CsI (pure) crystal

  70 mm ✕70 mm ✕300 mm

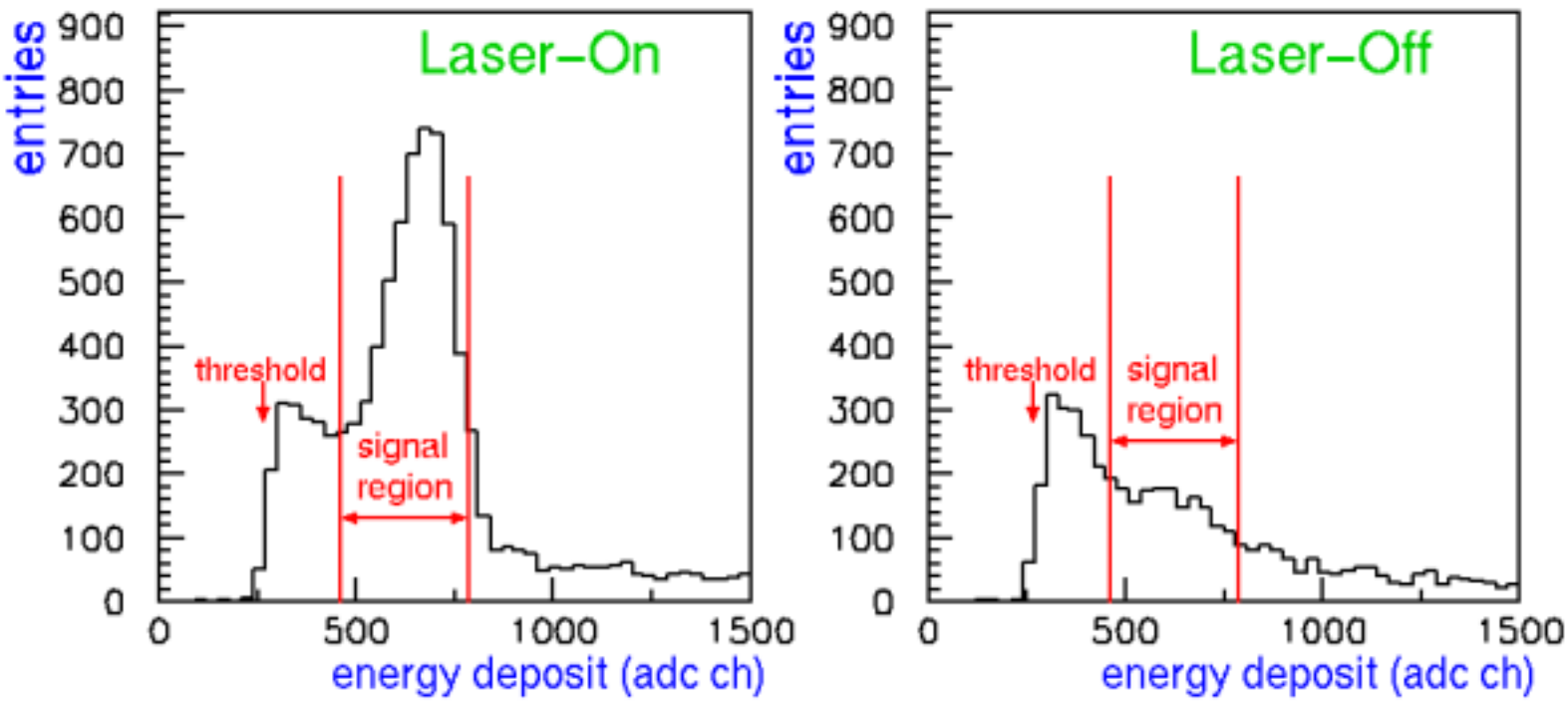
  2” photomultiplier



# Compton scattering signal

signal/background = 4 / 1

energy window (15MeV – 25MeV)



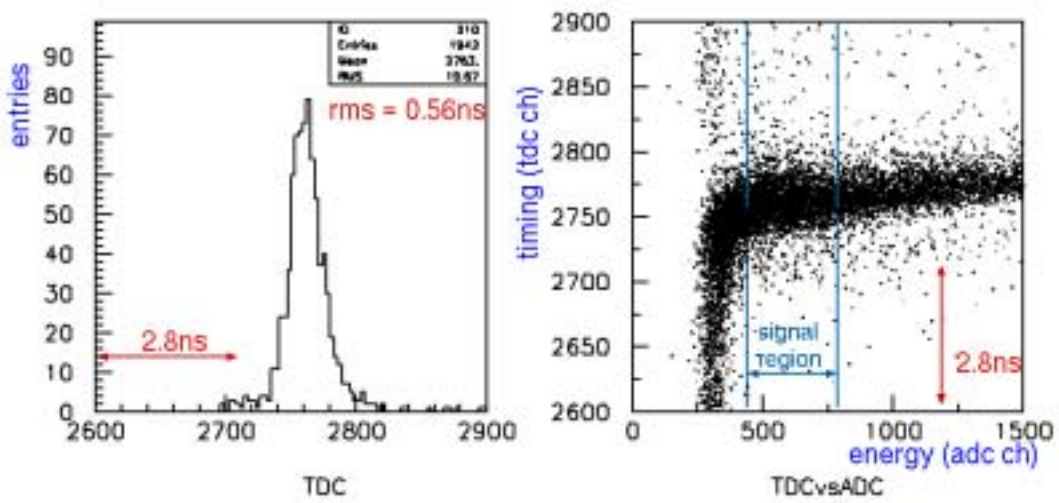
# detector time resolution

- time resolution

  PMT signal leading edge

  0.56 nsec resolution

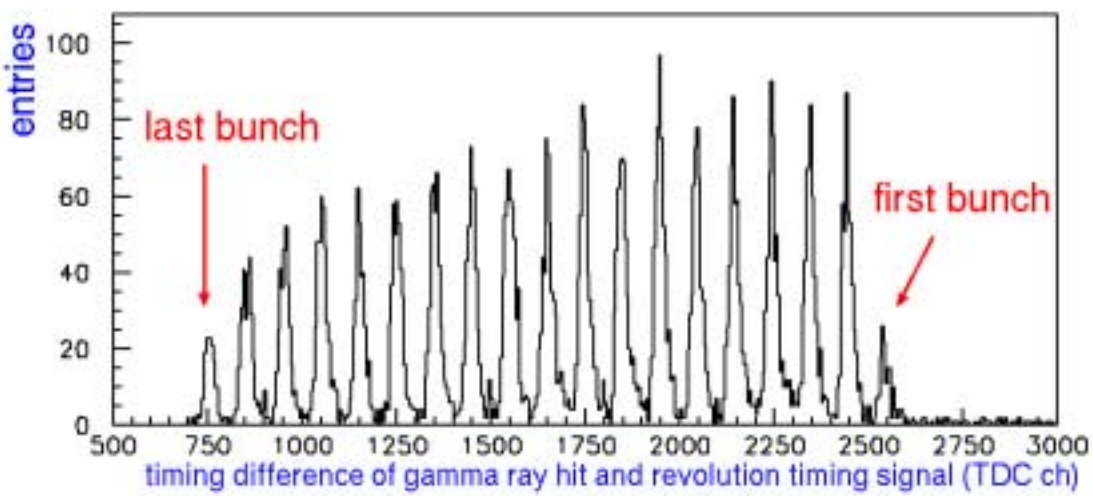
  (signal energy region)




- bunch ID

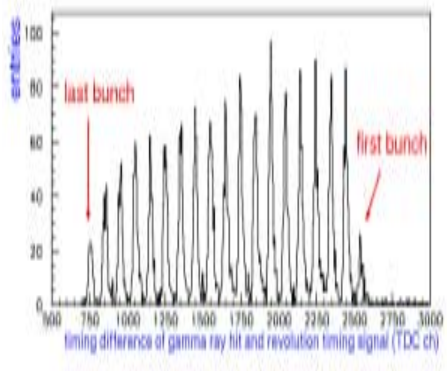
  multi-bunch

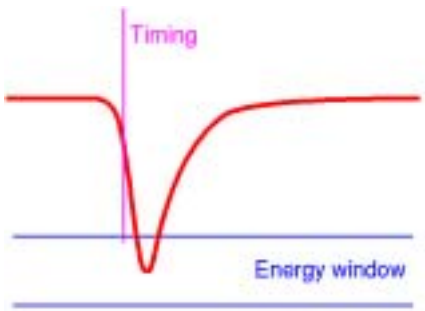
  ( 2.8 nsec spacing )

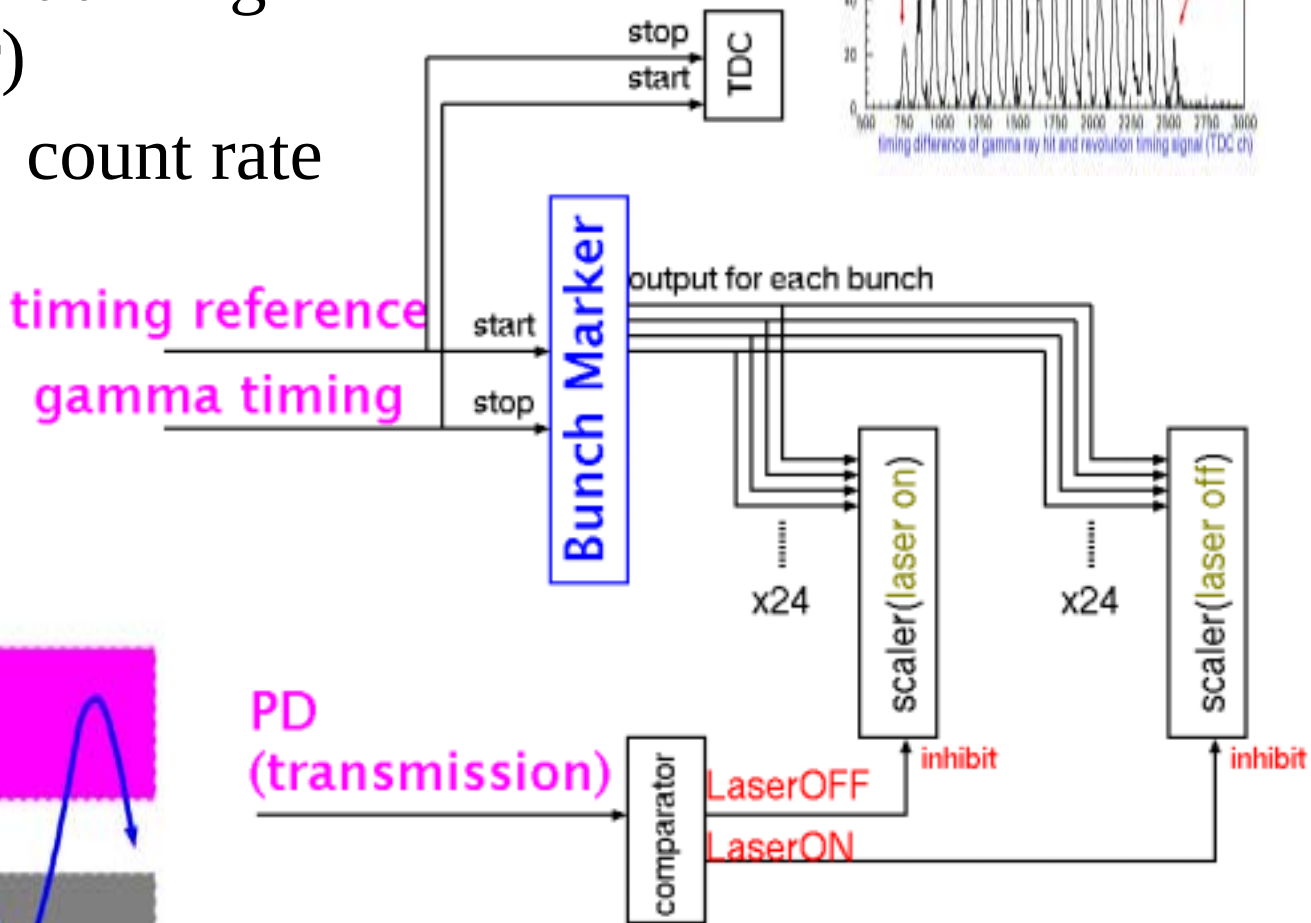


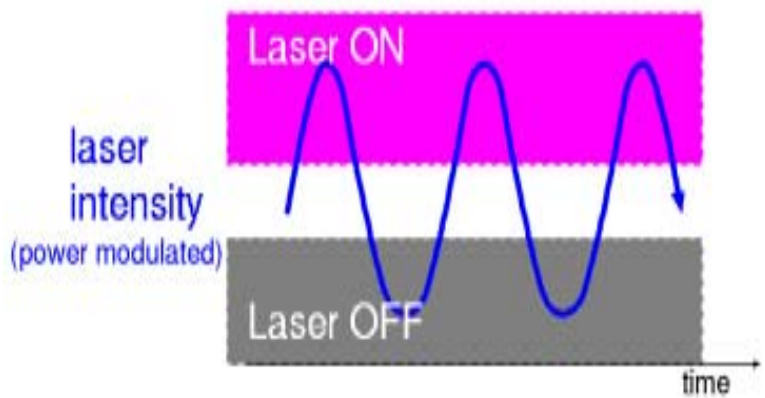
# signal processing

- bunch ID  by hit timing (bunch marker)
- laser ON/OFF  count rate



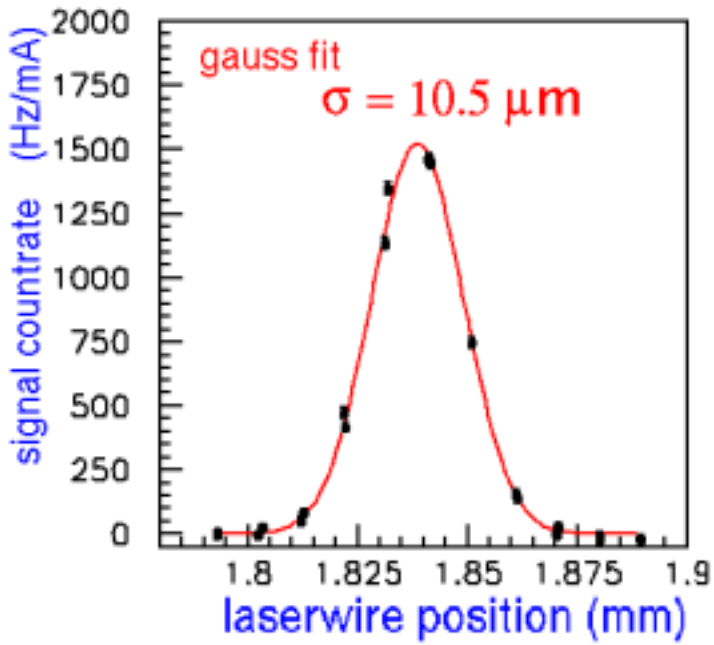



# data taking and analysis

- example




$\sigma_{peak} = 10.5 \pm 0.1 \quad \mu m \quad (\chi^2 = 50)$

(statistical error only)

$\sigma_{peak} = 10.5 \pm 0.2 \quad \mu m$

(stat. + systematic)

$\sigma_{laser} = 6.04 \pm 0.11 \quad \mu m$

$\sigma_{beam} = \sqrt{\sigma_{peak}^2 - \sigma_{laser}^2}$

$\sigma_{beam} = 8.62 \pm 0.25 \quad \mu m$

$\beta = 5.8 \pm 0.3 \quad m$

$\varepsilon_y = 1.28 \pm 0.10 \quad \times 10^{-11} \, m \, rad$

15 sec. for 1 position

10 min. for 1 profile

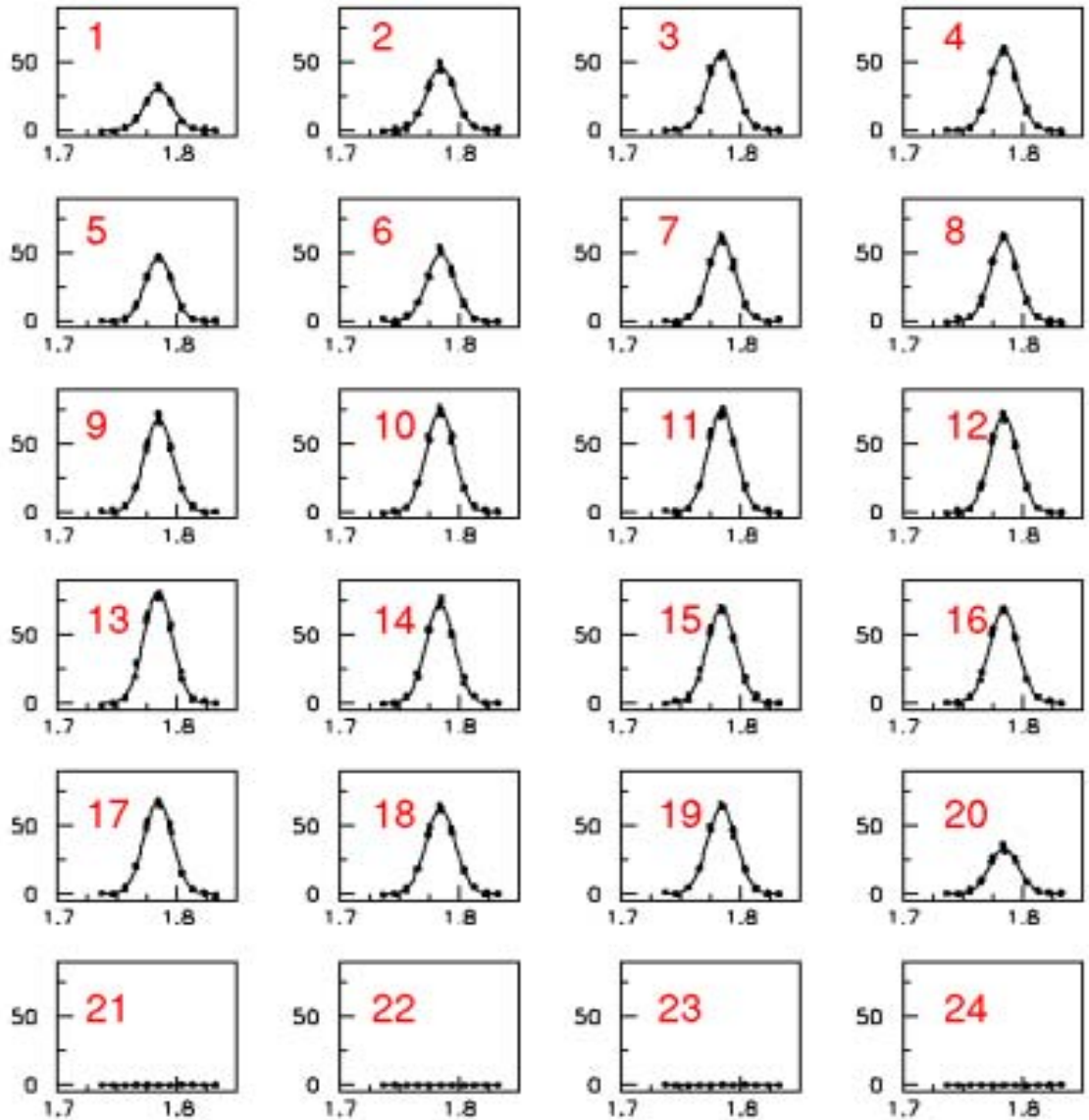
data reproducibility ( beam drift 1~2 μm )

# multibunch data

- beamsize of each bunch

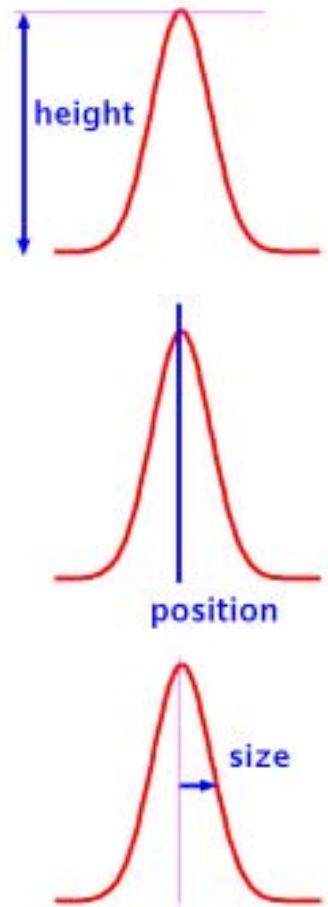
  count rate at each scaler channel

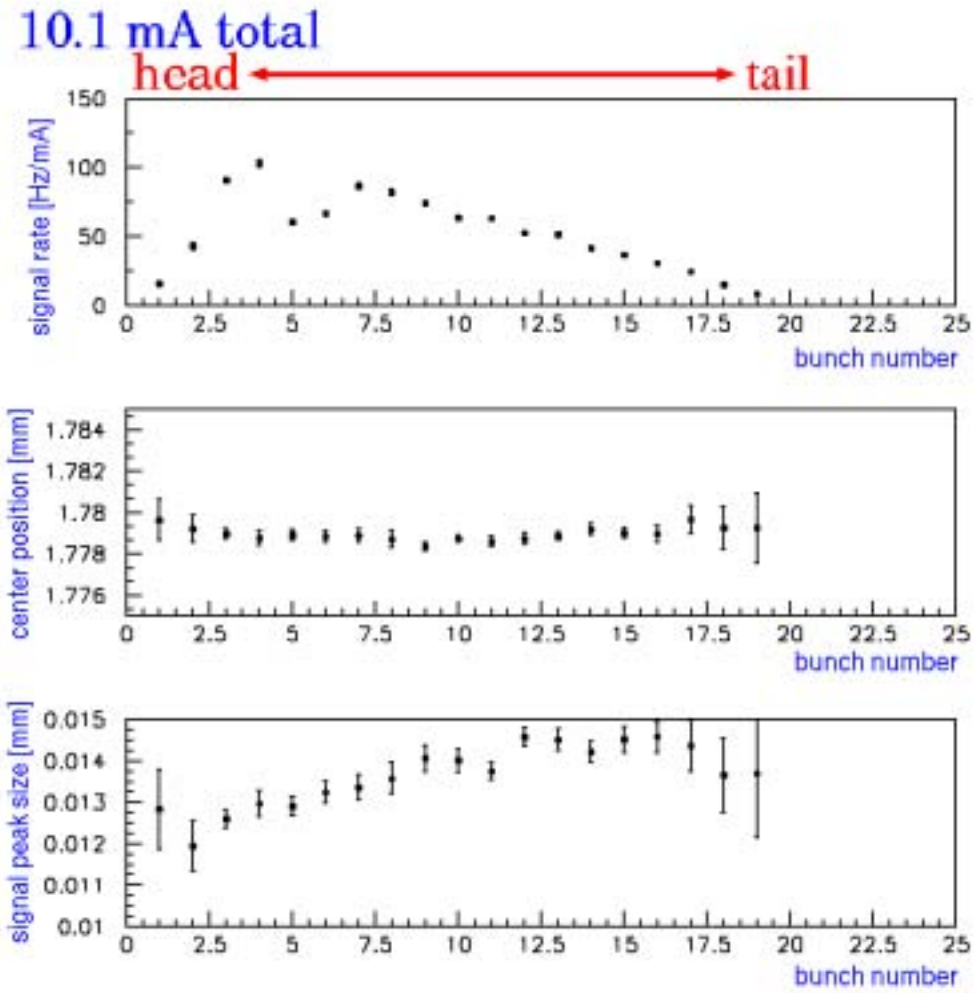
- 24 profiles for 1 scanning



# example

- measurement of each bunch in multibunch beam



# summary and discussion

- CW Laserwire with optical cavity
- performance of laserwire
  - effective laser power 100W
  - laser size 6.0 μm
- data taking
  - 10 min. for 1 profile
- multi-bunch measurement
  - measure beamsize of each bunch
- data reproducibility
  - beam orbit monitoring and/or faster scan speed