Production of Quasi-Monochromatic GeV Photons byCompton Scattering using Undulator X-ray Radiation at SPring-8

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Outline

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- **LEPS2 Activity at SPring-8**
- **Theory of Backward Compton Scattering of Quasi-Monochromatic γ-ray**
- **Preliminary Reflectivity Measurements of Single Crystal**
- **Plan of Test Experiment for γ-ray Production**
- **Summary**

Motivation

- **BCS using laser (infrared to ultra-violet) established with successful results, but extension of the maximum photon energy of γ-ray opens <u>new fields of the photo production experiments of nuclear and particle physics</u>**

⇨ **LEP and LEP2(BL31LEP) at SPring-8**

- **Quasi-monochromatic γ-ray**

⇨ **No tagging system (γ -ray intensity and energy are measured)**

- **In SR facility, many high power X-ray undulators. Very attractive to use as incident photon source for BCS**

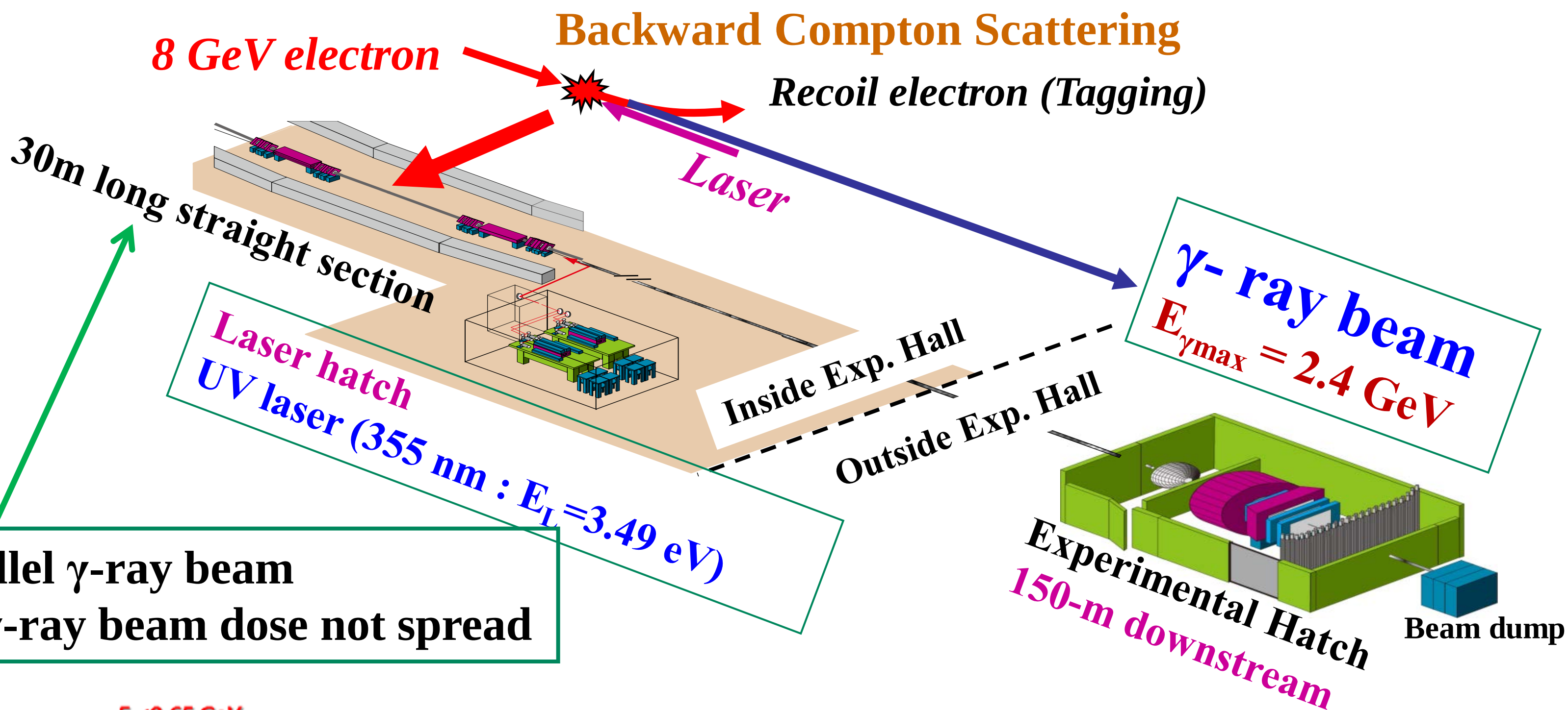
⇨ **Photon energy close to the kinematic limit**

- **Single crystal with high-reflectivity at normal-incidence (K-J. Kim et al.)**

⇨ **X-ray photon reflected back by a single crystal**

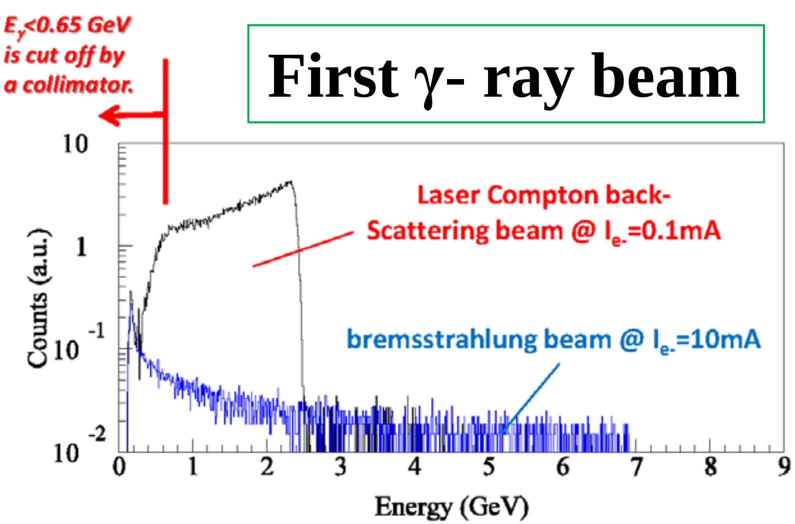
- **Low energy operation in future SPring-8**

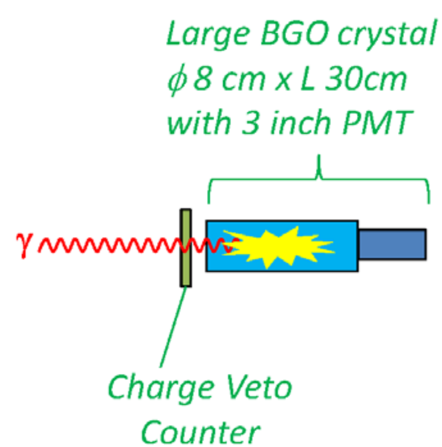
BL31LEP constructed at long straight section of SPring-8



Parallel γ-ray beam
➡ γ-ray beam dose not spread

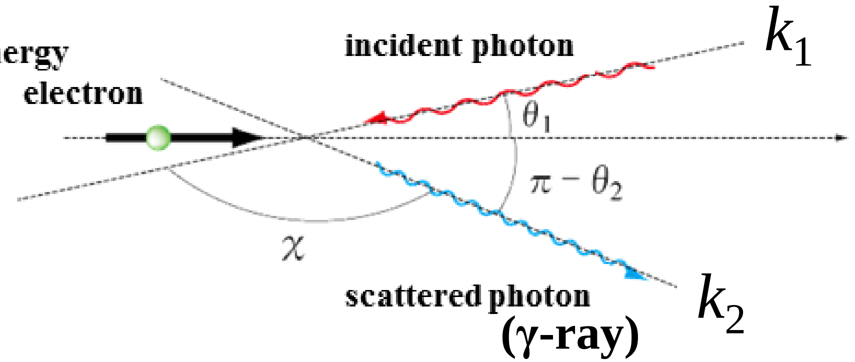
First γ- ray beam





Theory of Backward Compton Scattering

Schematic diagram of BCS



$$k_2 = k_1 \frac{1+\beta\cos\theta_1}{1+\beta\cos\theta_2+\frac{k_1}{E_e}(1-\cos\chi)} \qquad (1)$$

In case of head-on collision, maximum energy of scattered Photon :

$$k_{2\max} = \frac{k_1(1+\beta)}{1+\beta+\frac{2k_1}{E_e}} \approx \frac{4k_1E_e^2}{(m_ec^2)^2+4k_1E_e} \qquad (2)$$

When k_1 is 10 keV, E_e = 8 GeV ⇨ **k_{2max} ~ 8 GeV**

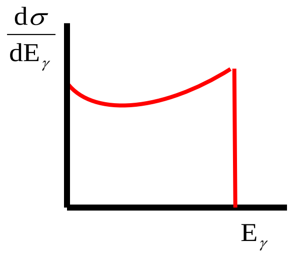
(photon energy of γ-ray is almost equal to electron energy).

Spectrum shape (Milburn, 1963)

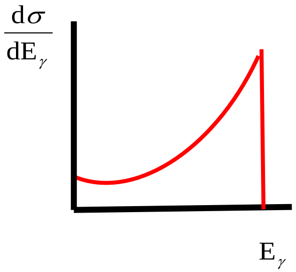
$$\frac{1}{\sigma_0}\frac{d\sigma}{d\left(k_2/E_e\right)} = \frac{3}{16\lambda}\left[\frac{\lambda^2(1-x)^2}{1+\lambda(1-x)} + 2\left(1+x^2\right) + O\left[x^n\right]\right] \quad (3)$$

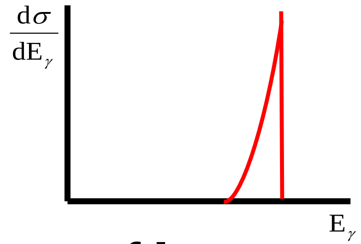
σ_0 : Thomson scattering cross-section,
$\lambda = 2\gamma k_1/m_e c^2$, $x = \cos\theta_0$ (θ_0 : photon scattering angle)

For small k_1 (e. g. laser light, E_1 = 3.49 eV), the second term of Eq. (3) is dominant. γ-ray spectrum is the parabolic shape with wide photon energy range.

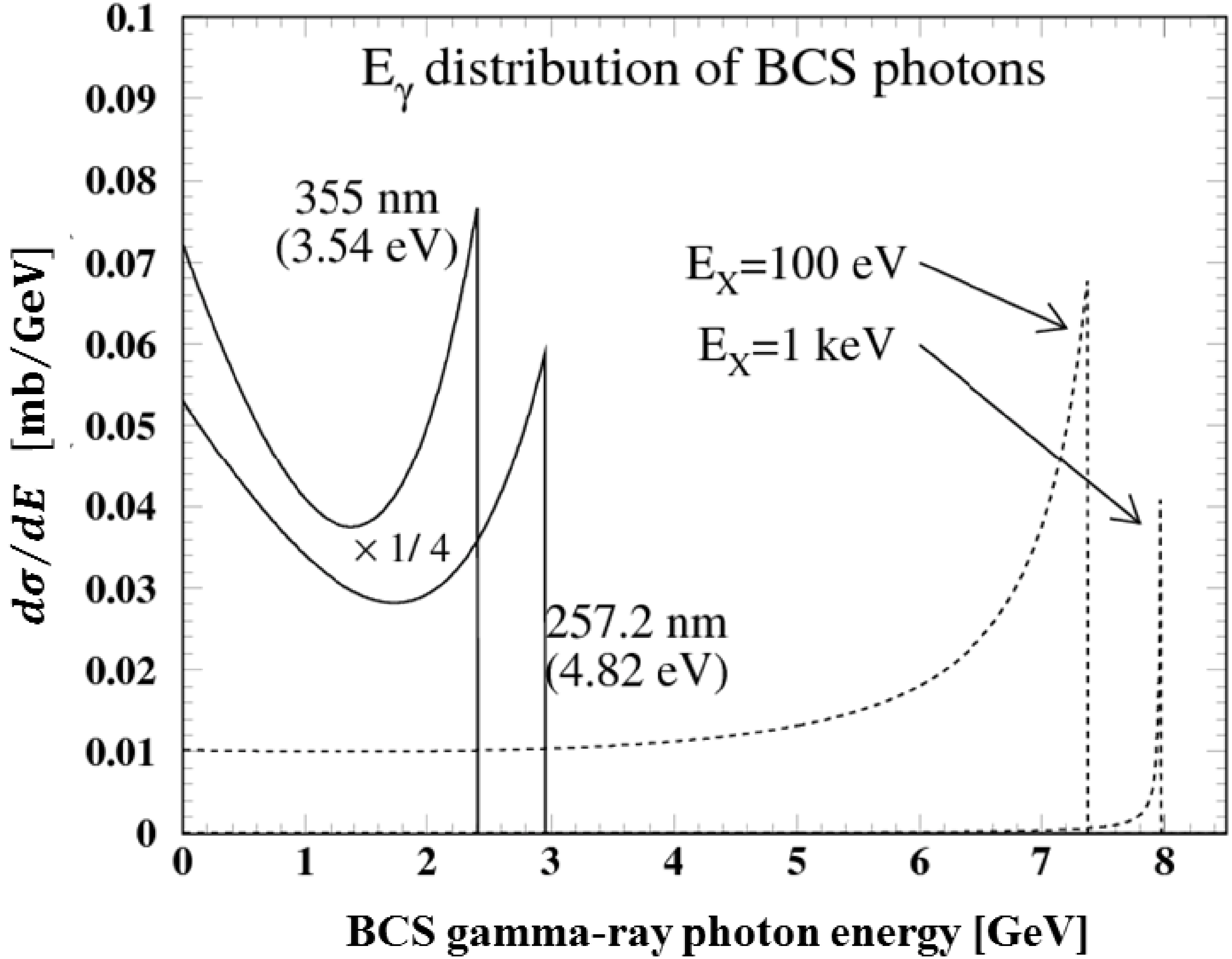


For large k_1 (e. g. undulator, E_1 > 100 eV), the first term is dominant and γ-ray spectrum damps in the low energy region.

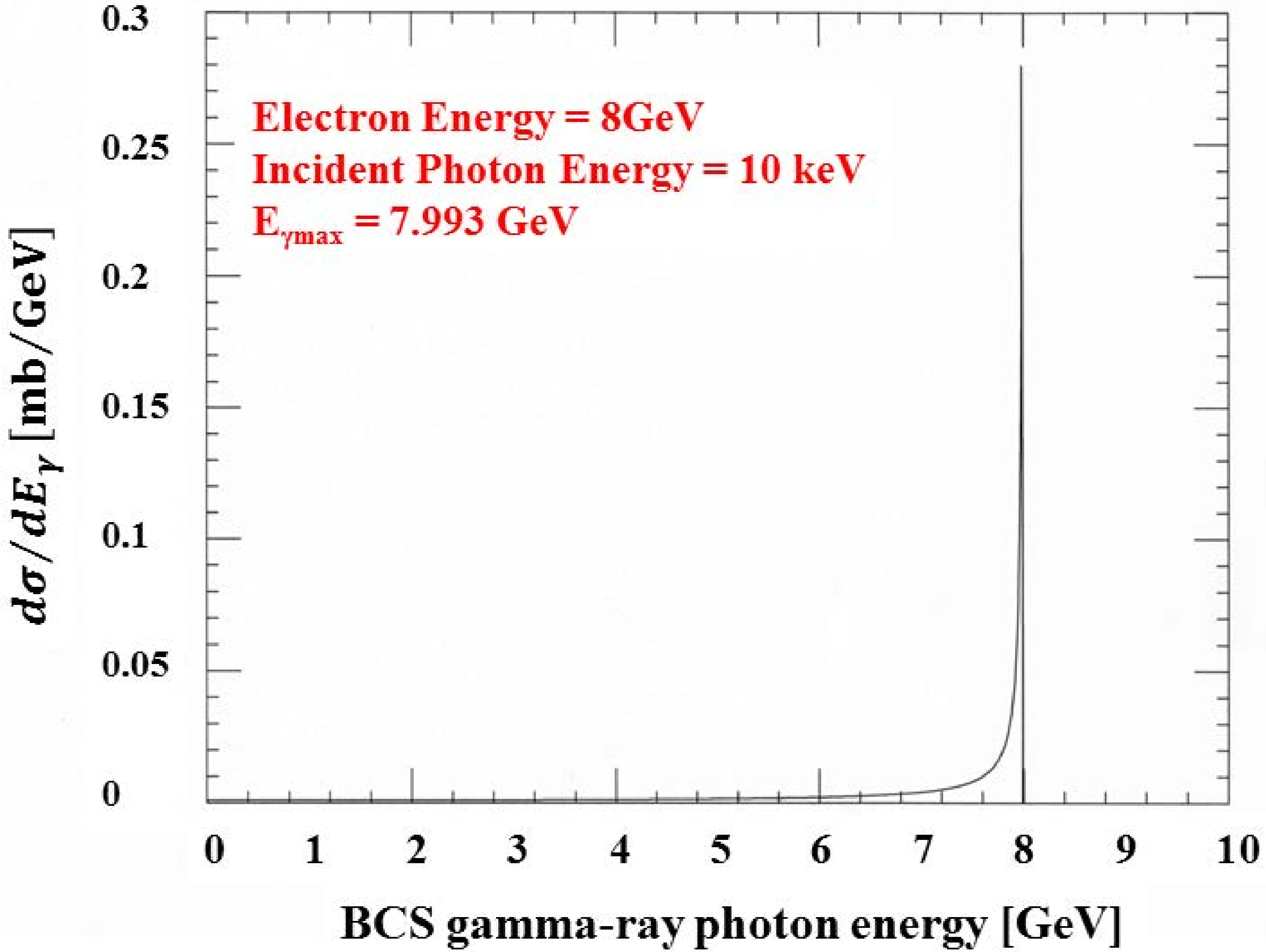




For very large k_1 (e. g. hard X-ray undulator, E_1 > 5keV), higher-order term x^n (n > 2) of Eq. (3) becomes important. γ-ray spectrum uprises steeply near the maximum BCS gamma-ray of k_{2max}.

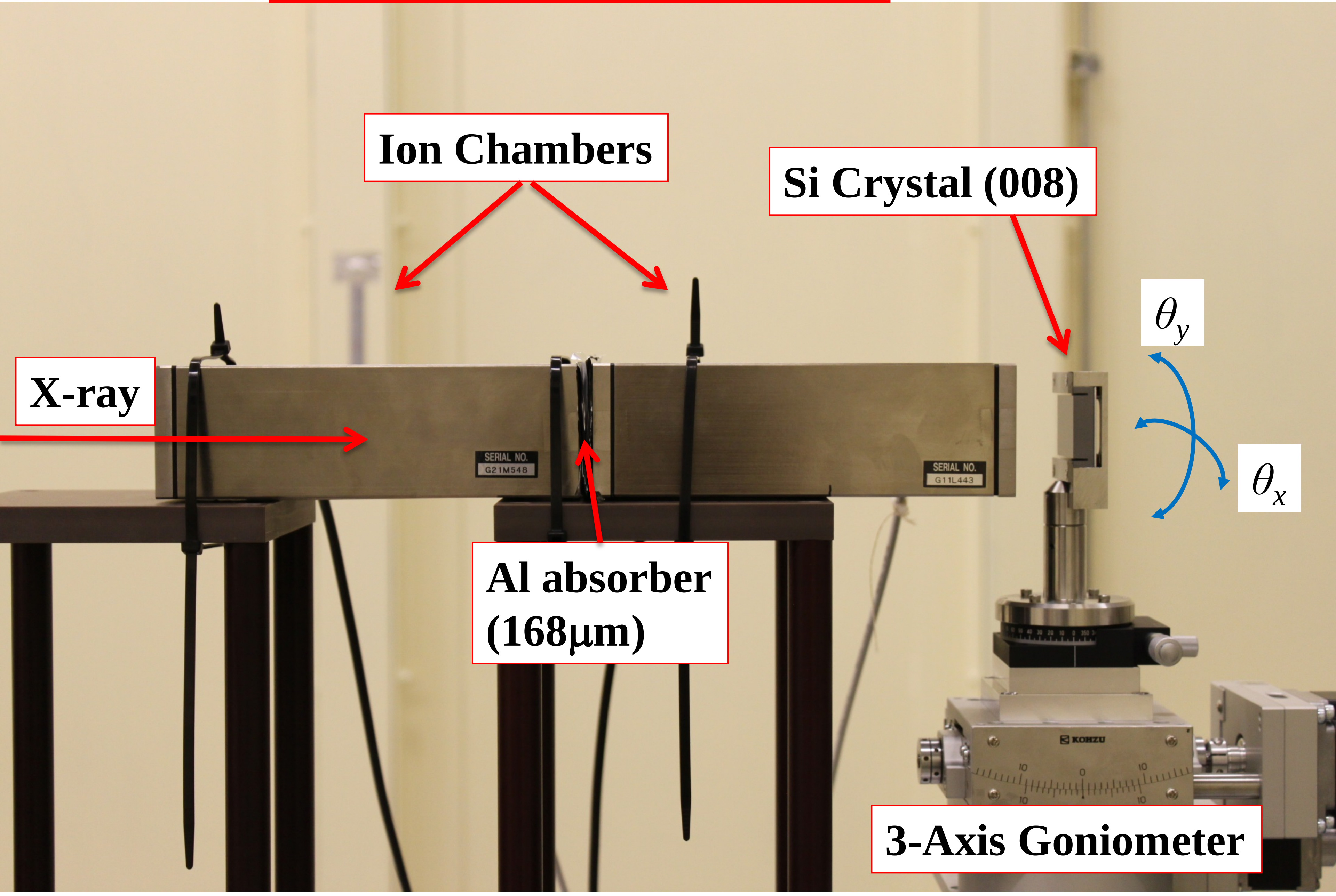


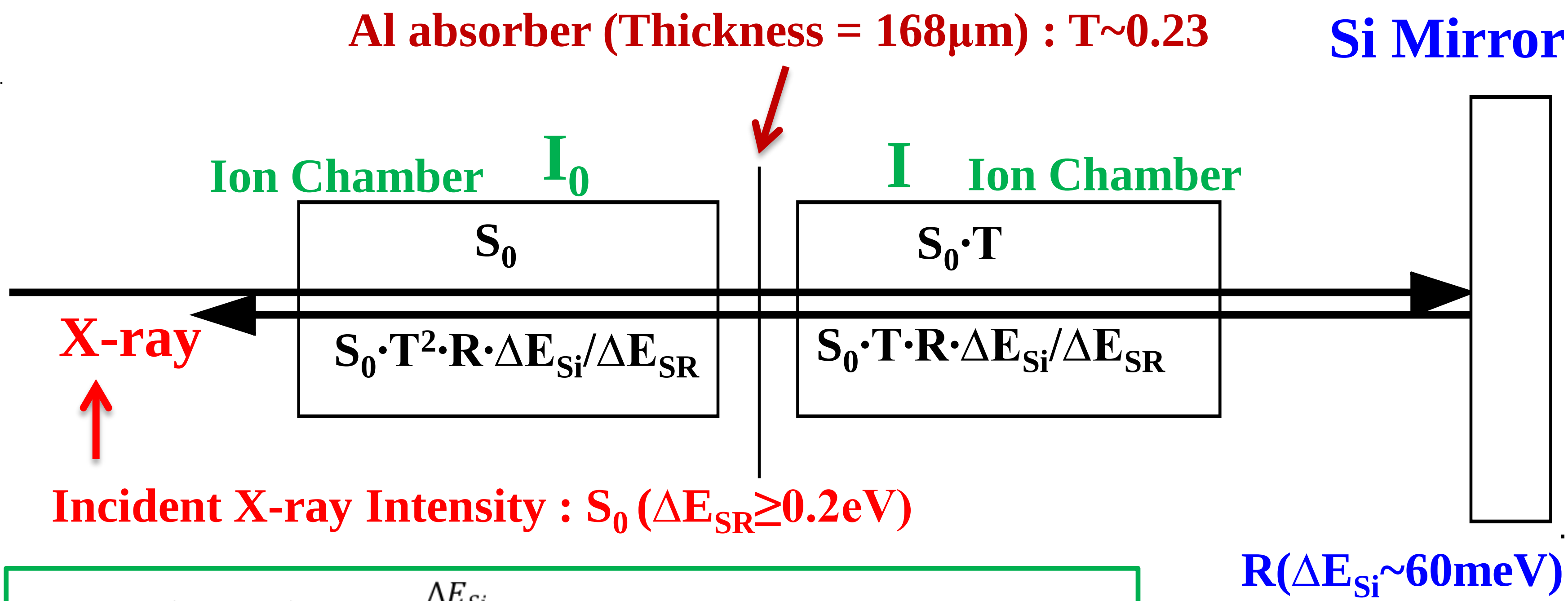
Calculated γ-ray distribution as a parameter of incident photon energy



10keV incident X-ray and Produced γ–ray in kinematic limit

Reflectivity Measurement





$$\frac{I}{I_0} = C \cdot \frac{S_0 \cdot T + S_0 \cdot T \cdot R \cdot \frac{\Delta E_{Si}}{\Delta E_{SR}}}{S_0 + S_0 \cdot T^2 \cdot R \cdot \frac{\Delta E_{Si}}{\Delta E_{SR}}} = C \cdot T \left(1 + R \cdot \frac{\Delta E_{Si}}{\Delta E_{SR}}\right) = 0.23C(1 + 0.3R)$$

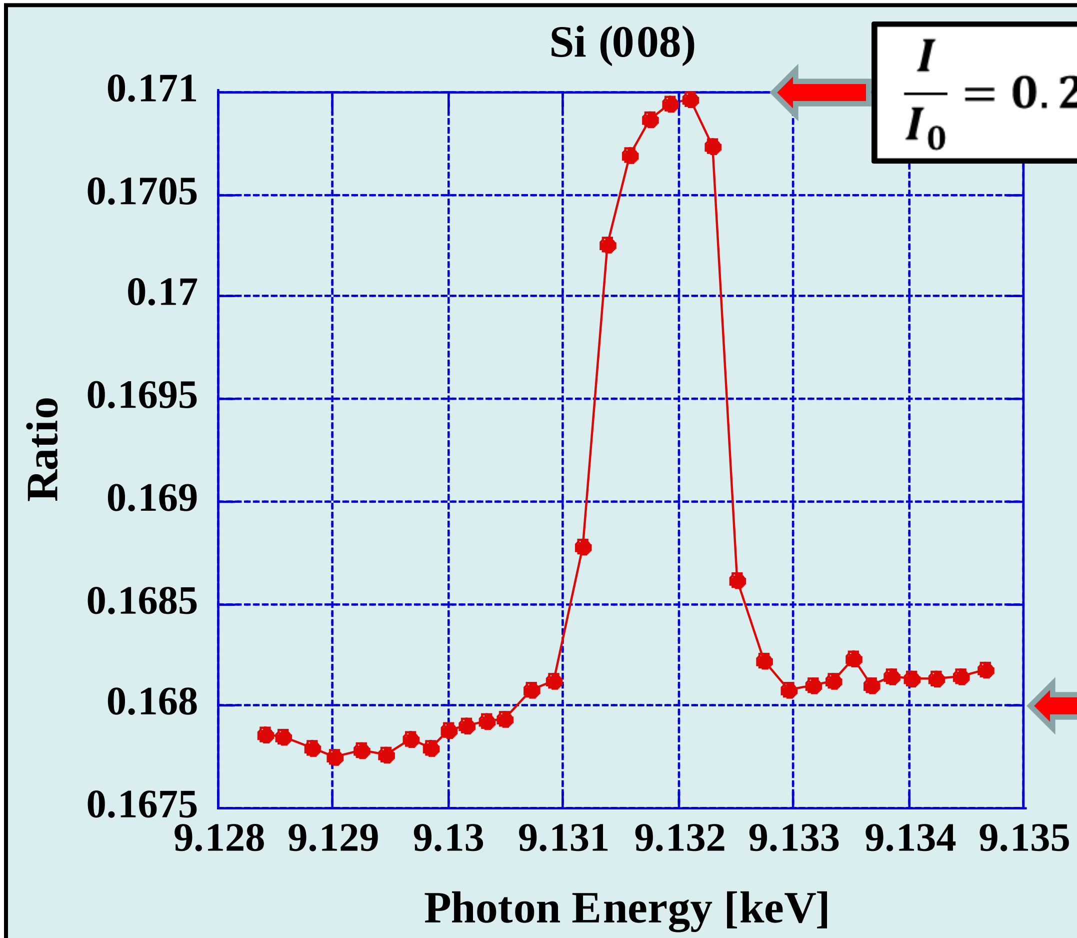
$$\frac{I}{I_0} = 0.23C = 0.168 \quad (R=0)$$

$$\frac{I}{I_0} = 0.23C(1 + 0.3R) = 0.171 \quad (R \neq 0)$$

→ **R≈0.06 (~6%)**

cf. Si (333) **R≈0.11 (~11%)**、Si (555) **R≈0.05 (~5%)**

Si (008) Bragg Reflection at normal-incidence



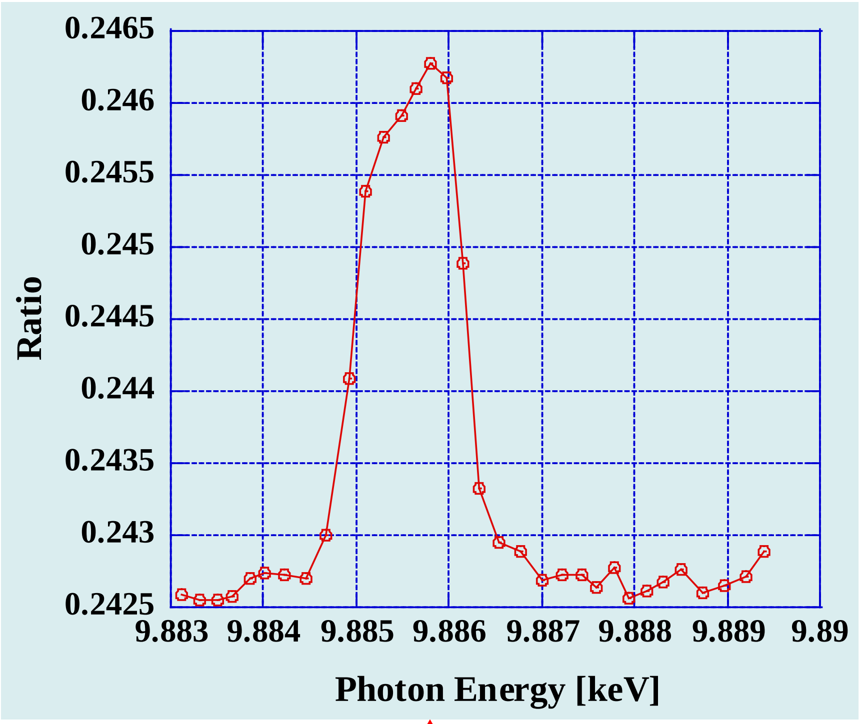
$$\frac{I}{I_0} = 0.23C(1 + 0.3R) = 0.171\ (R \neq 0)$$

$$R \approx 0.06(\sim 6\%)$$

$$\frac{I}{I_0} = 0.23C = 0.168\ (R = 0)$$

9.132 keV

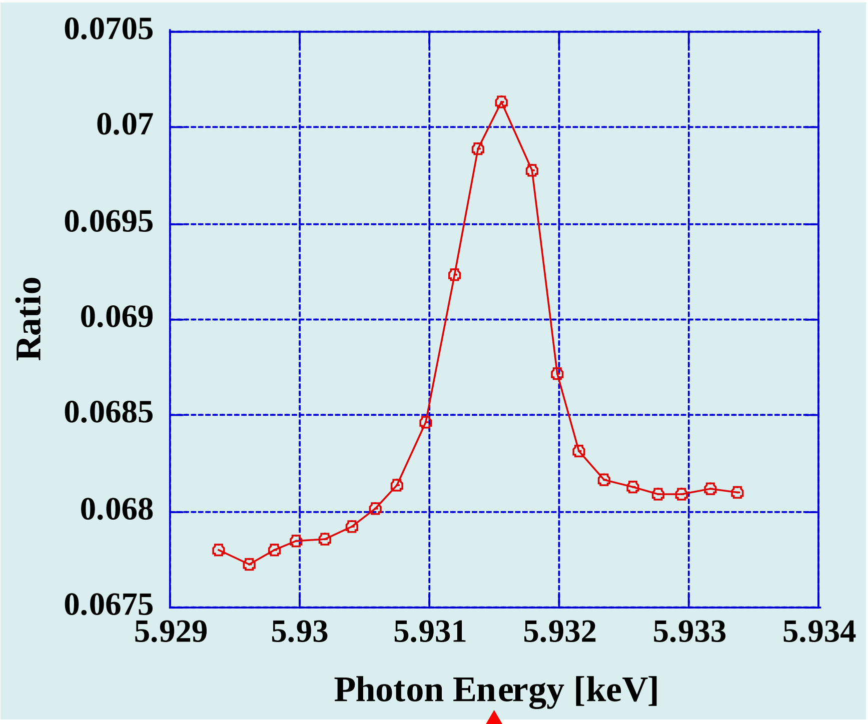
Si (5 5 5)



9.886 keV

Si (555) R≈0.05 (~5%)

Si (3 3 3)

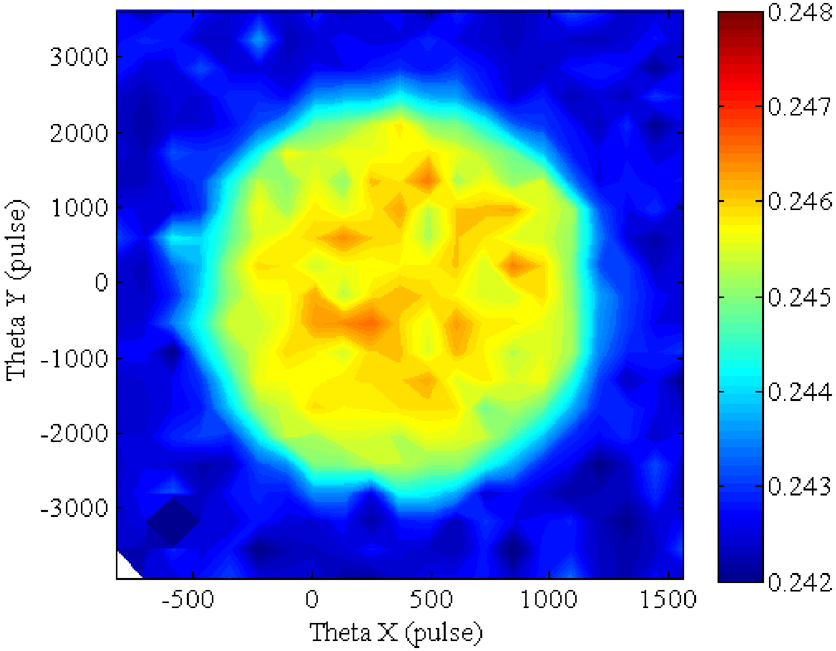


5.9315 keV

Si (333) R≈0.11 (~11%)

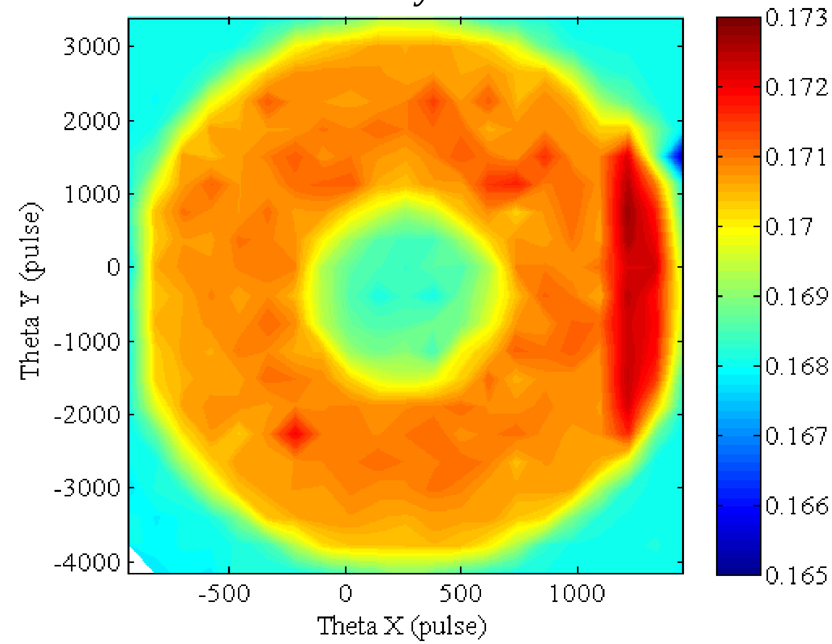
Scanning Pattern of ion-chamber output signal (I) by 2-axis (θ_x and θ_y) scanning

θ_x and θ_y : ±1.5



$\theta_x - \theta_y$ scan @ normal-incidence of 9.132 keV

θ_x and θ_y : ±1.5

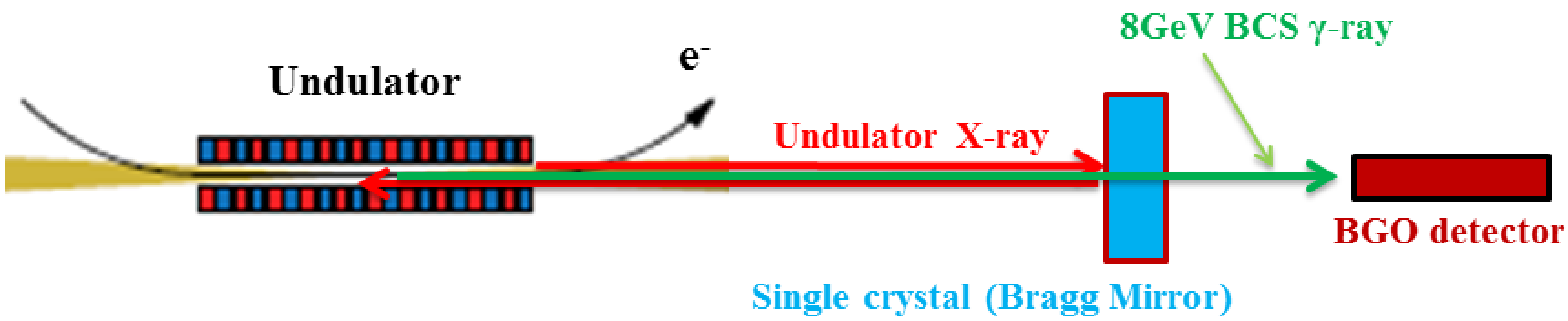


$\theta_x - \theta_y$ scan @ normal-incidence of 9.133 keV

Photon energy of incident X-ray matched Bragg condition at the normal-incidence (left) and unmatched (right).

Plan of Test Experiment for γ-ray Production

Schematic Drawing of γ-ray Production System



Multipole Wiggler

76mm × 51 periods

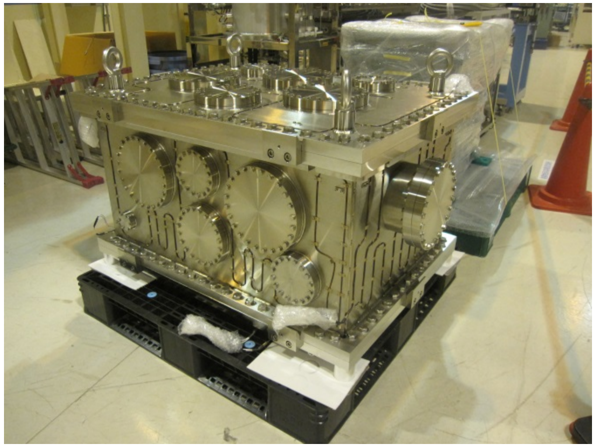
K_{max} = 5.8

Photon Energy = 5 ~ 30keV

Mirror Chamber

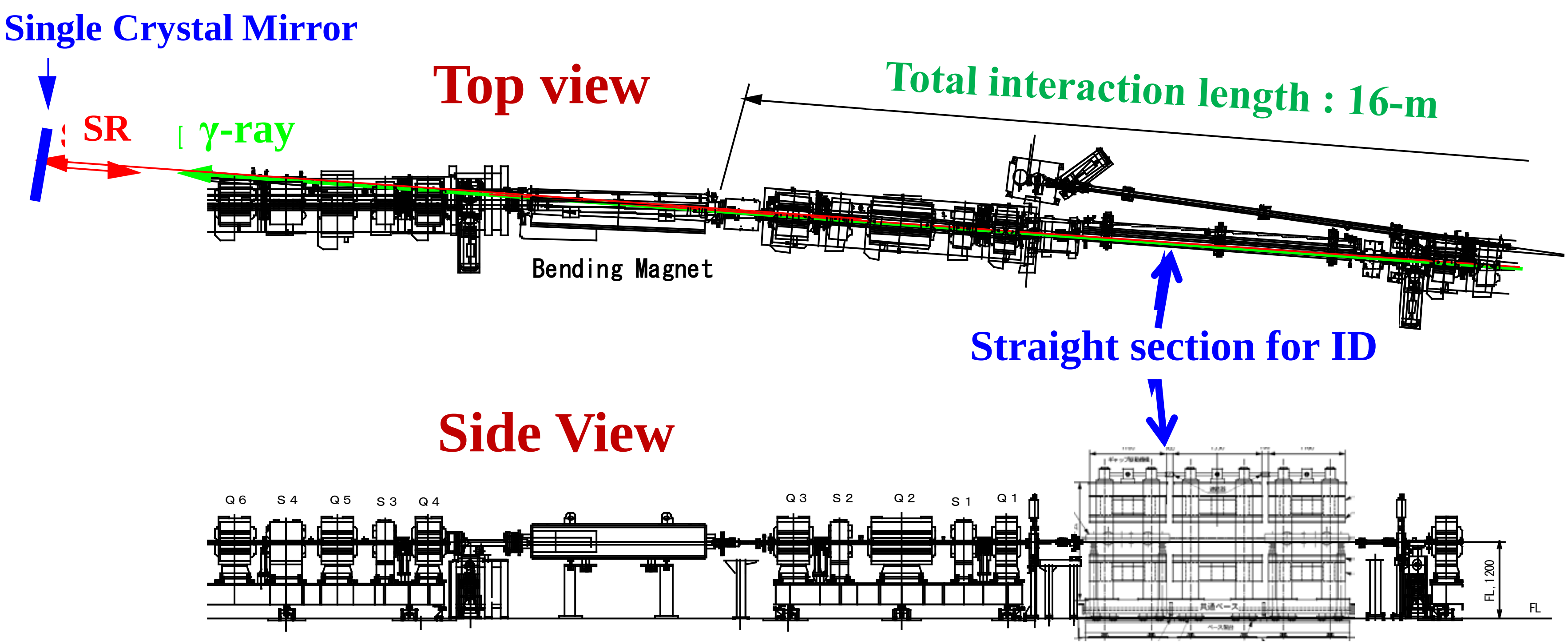
Mirror Cooling System

4-Axis Goniometer



γ-ray Detector

Plan of GeV Photons production at a beam diagnostics beamline, BL05SS



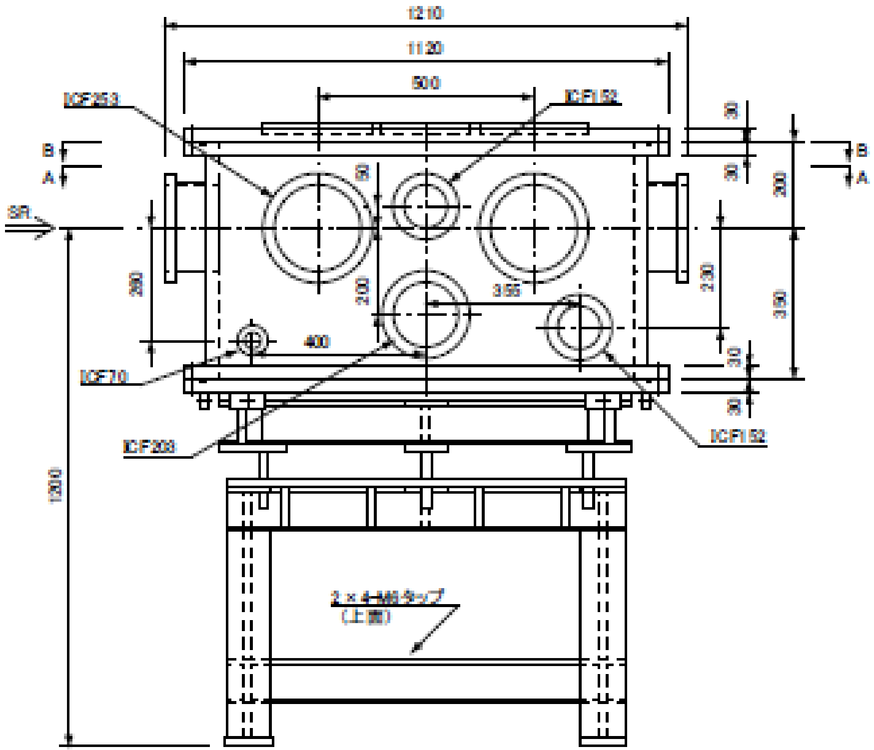
Multipole Wiggler

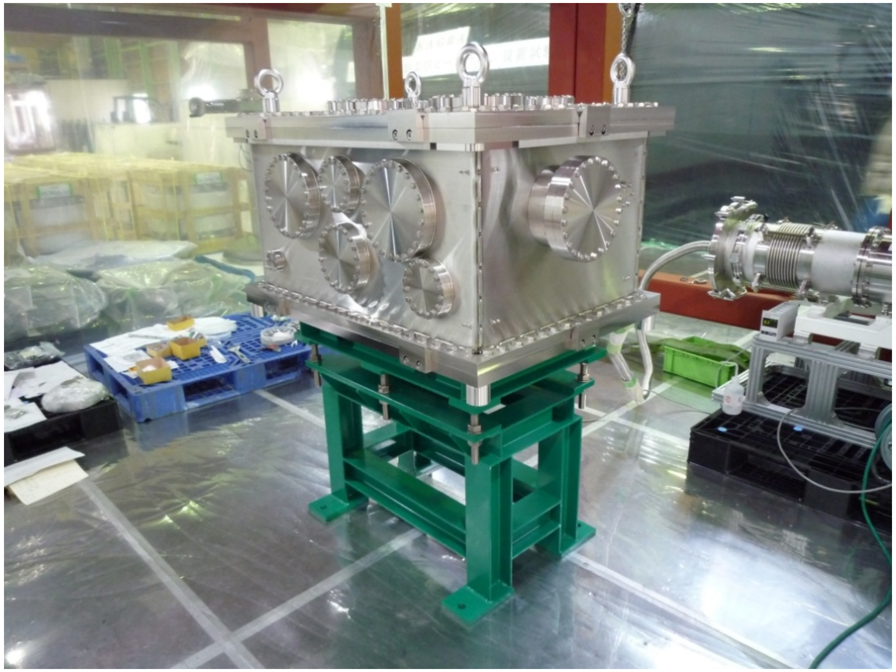
76mm × 51 periods

K_{max} = 5.8

Photon Energy = 5 ～30keV

Mirror Chamber

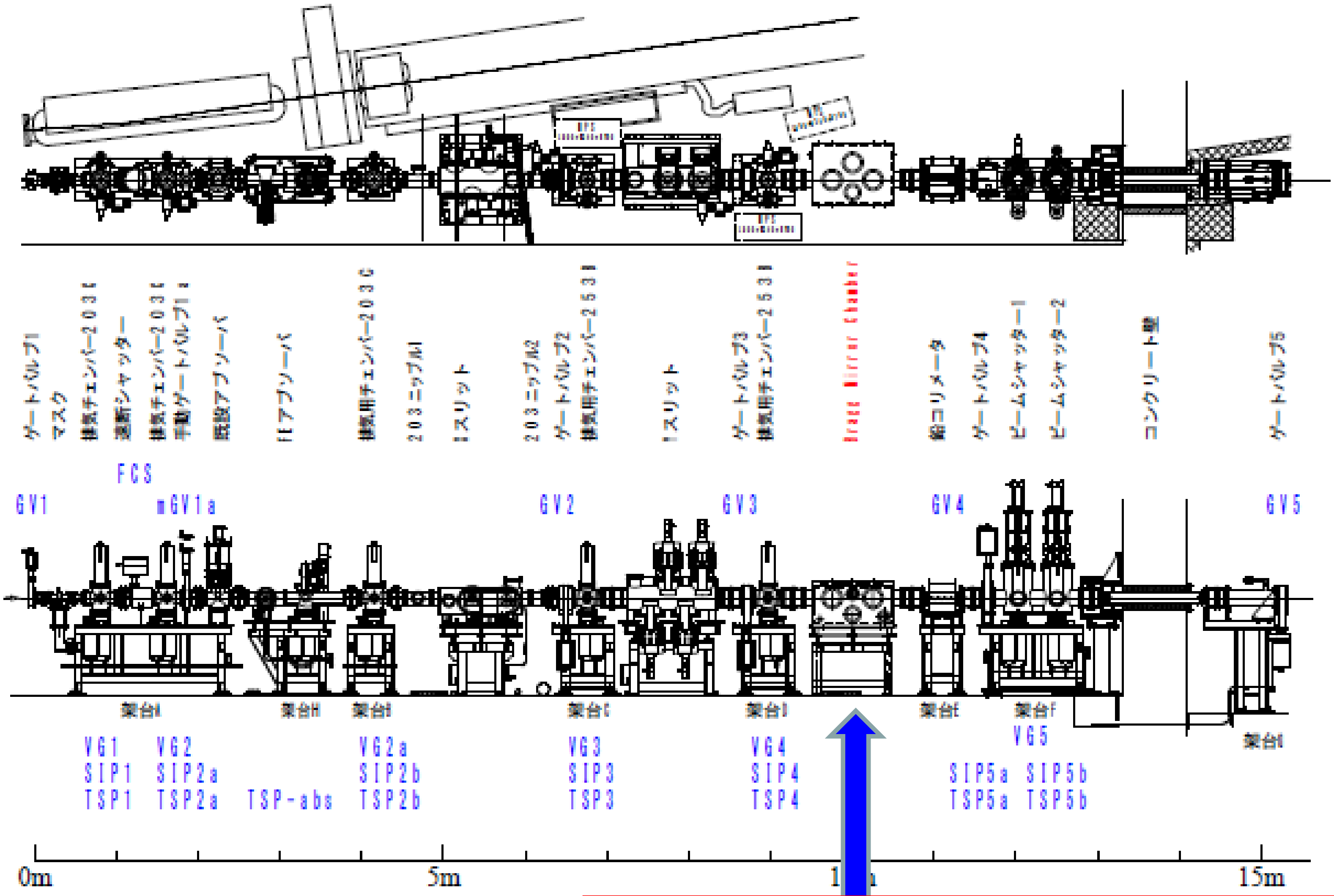




Outer Dimension : 1120 mm ×820 mm×610 mm

Mirror mounting system with cooling device
4-Axis Goniometer
(Focusing System)

Front-end of BL05SS at SPring-8



Mirror Chamber (29m from ID center)

Summary

- We proposed backward Compton scattering using undulator radiation to reflect back by Bragg mirror.
- Preliminary reflectivity measurement of silicon single crystal.
- Experimental setup of γ-ray production by BCS using a single crystal (diamond) is now under preparation.

Thank you for your attention