Experimental Study of Laser-Compton Scattering in the Non-linear Regime

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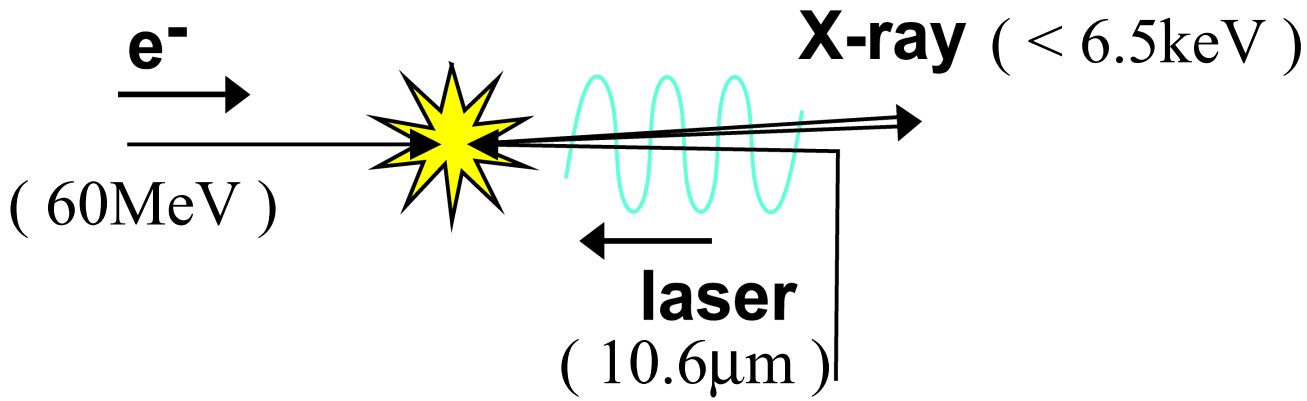
Out Line

- Introduction
- About non-linear Compton scattering
- Experimental setup
- Simulation
- Summary

Future light source via laser-Compton scattering

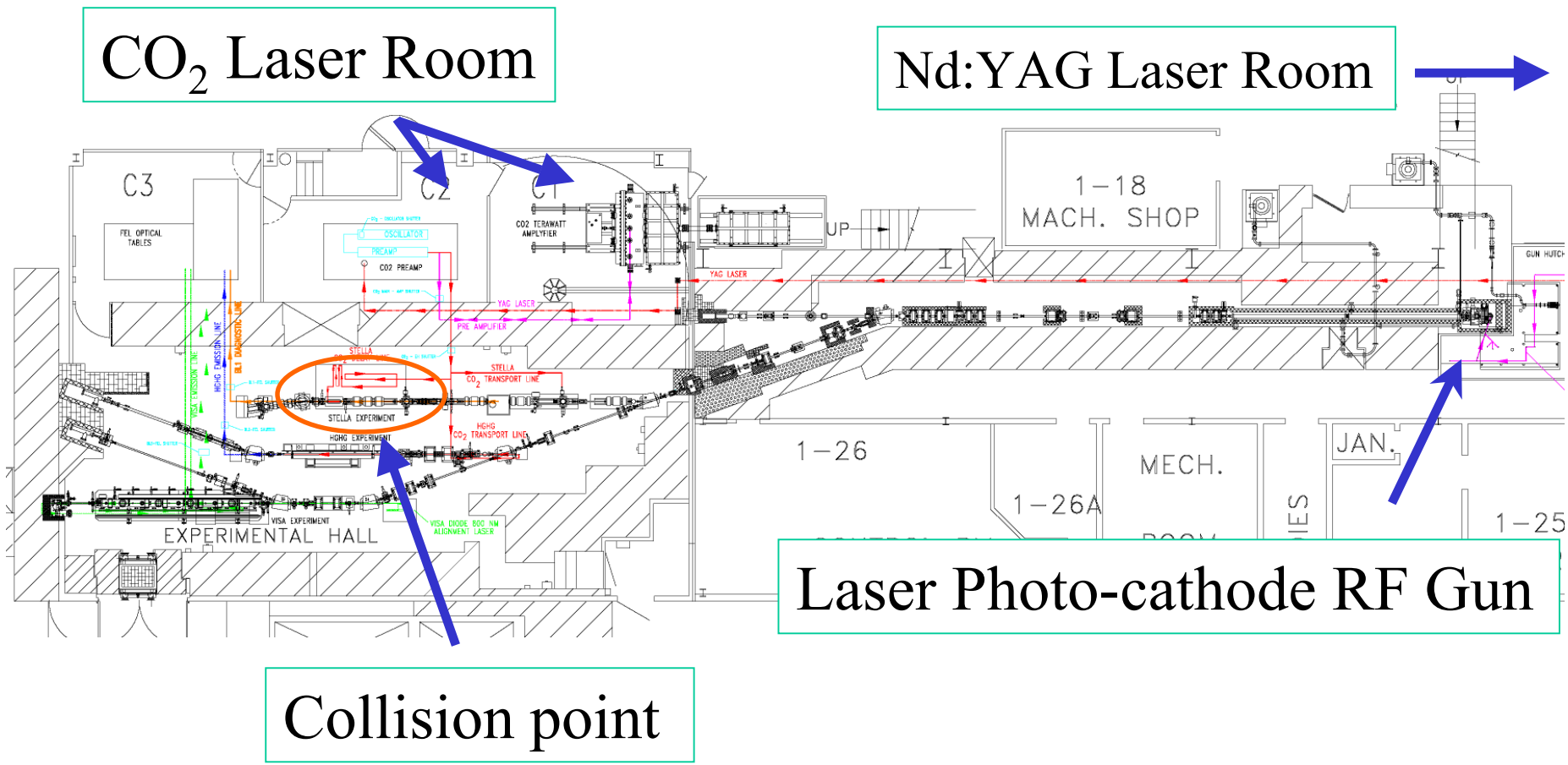
(Laser Synchrotron Source : LSS)



Features of LSS

- Compact
- It can produce photon pulses of ultra short duration
  (~ psec, ~ several hundred fsec)
- Easy to control polarization of generated photons

Site of the experiment at BNL (Accelerator Test Facility)



We had two runs of laser-Compton experiment and observed intense X-rays via inverse Compton scattering in the linear regime between the CO_2 laser and 60MeV, 0.5nC electron beams.

Result

In 1999 : 3×10^6 photons / 3.5 psec for 600MW CO_2 laser

In 2001 : 1.7×10^8 photons / 3.5 psec for 14GW CO_2 laser

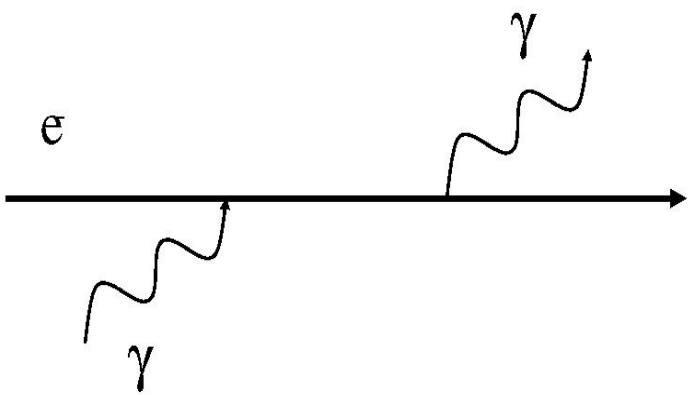
In near future …

CO_2 laser will be upgraded to 1TW

non-linear Compton scat. is expected

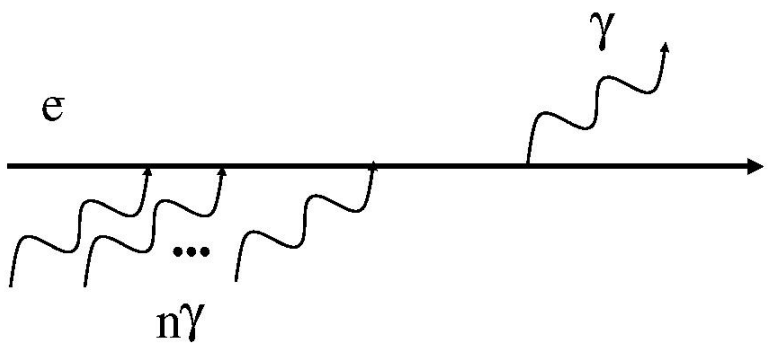
Compton Scattering in …

Linear regime



$$e + \gamma \rightarrow e' + \gamma'$$

Non-linear regime



$$e + n\gamma \rightarrow e' + \gamma'$$

Normalized Vector Potential

Magnitude of the non-linear process is characterized by the normalized vector potential.

$$a = \frac{e}{m_e c^2}\sqrt{-< A_\mu A^\mu >}$$

$$= 0.60\times 10^{-9}\cdot \lambda[\mu\mathrm{m}]\cdot I^{1/2}[\mathrm{W/cm}^2]$$

(λ : laser wavelength, I : laser intensity)

$a < 1$: linear process is dominant

$a > 1$: non-linear process is dominant

Planed laser parameters on the upgrade
(use in simulations)

pulse power : 3J/pulse

pulse duration : 3psec

spot size at a focal point (RMS) : 32μm

polarization : ciruclar

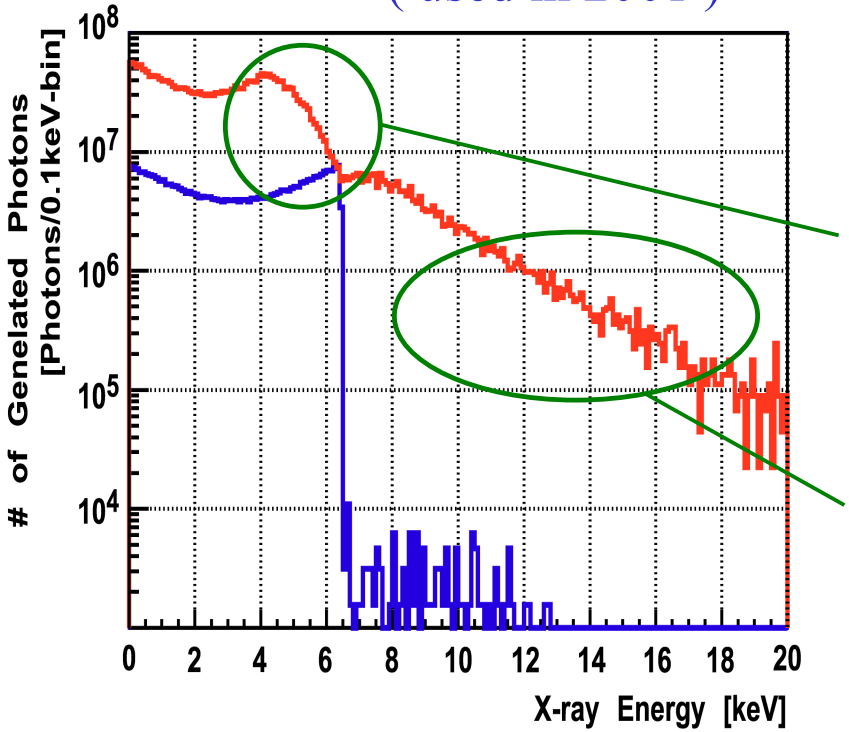
normalized vector potential : $a = 0.77$

peak power : ~ 1TW

Typical energy spectra of generated photons by high power and low power laser (simulation)

A: high power laser ($a = 0.77$)

B: low power laser ($a = 0.04$)
(used in 2001)

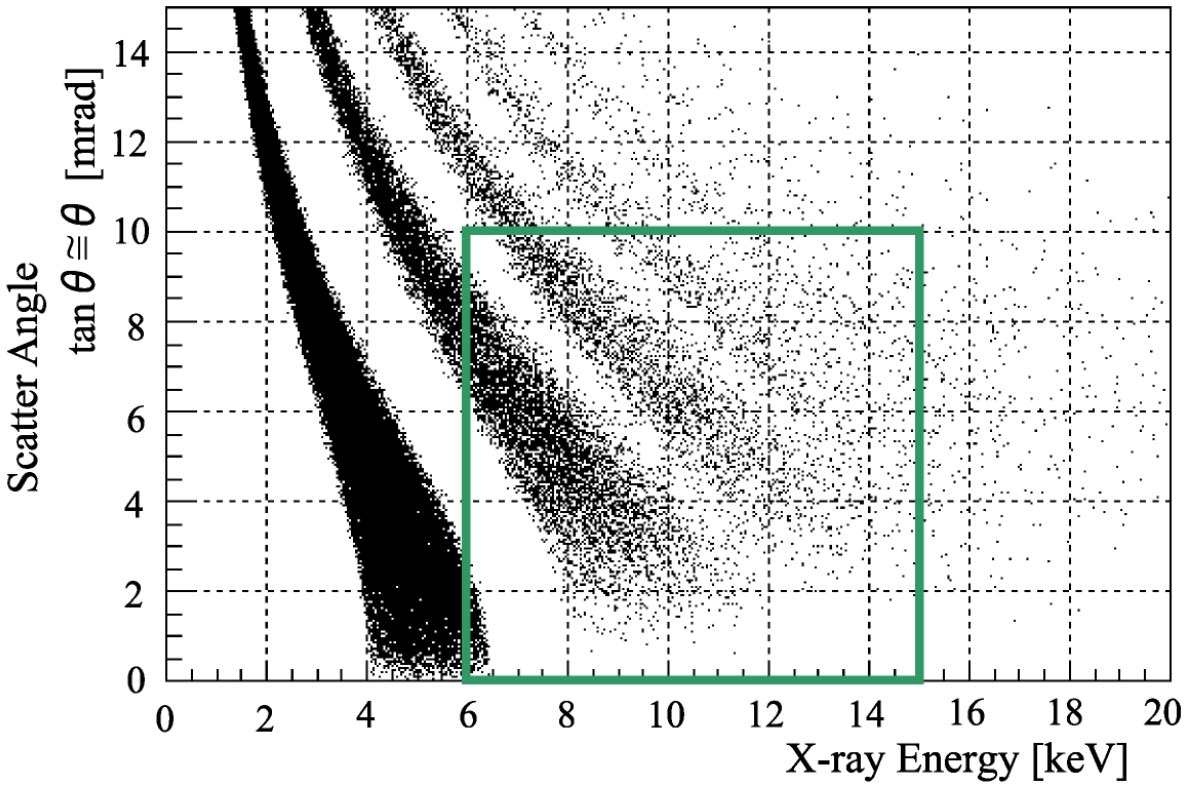


Characteristics of the spectrum for high power laser

- Smooth shoulder due to an electron mass shift in the laser field
- Higher energy photons from non-linear Compton scattering

Energy and angular distribution in the non-linear regime

(simulated at $a = 0.77$)



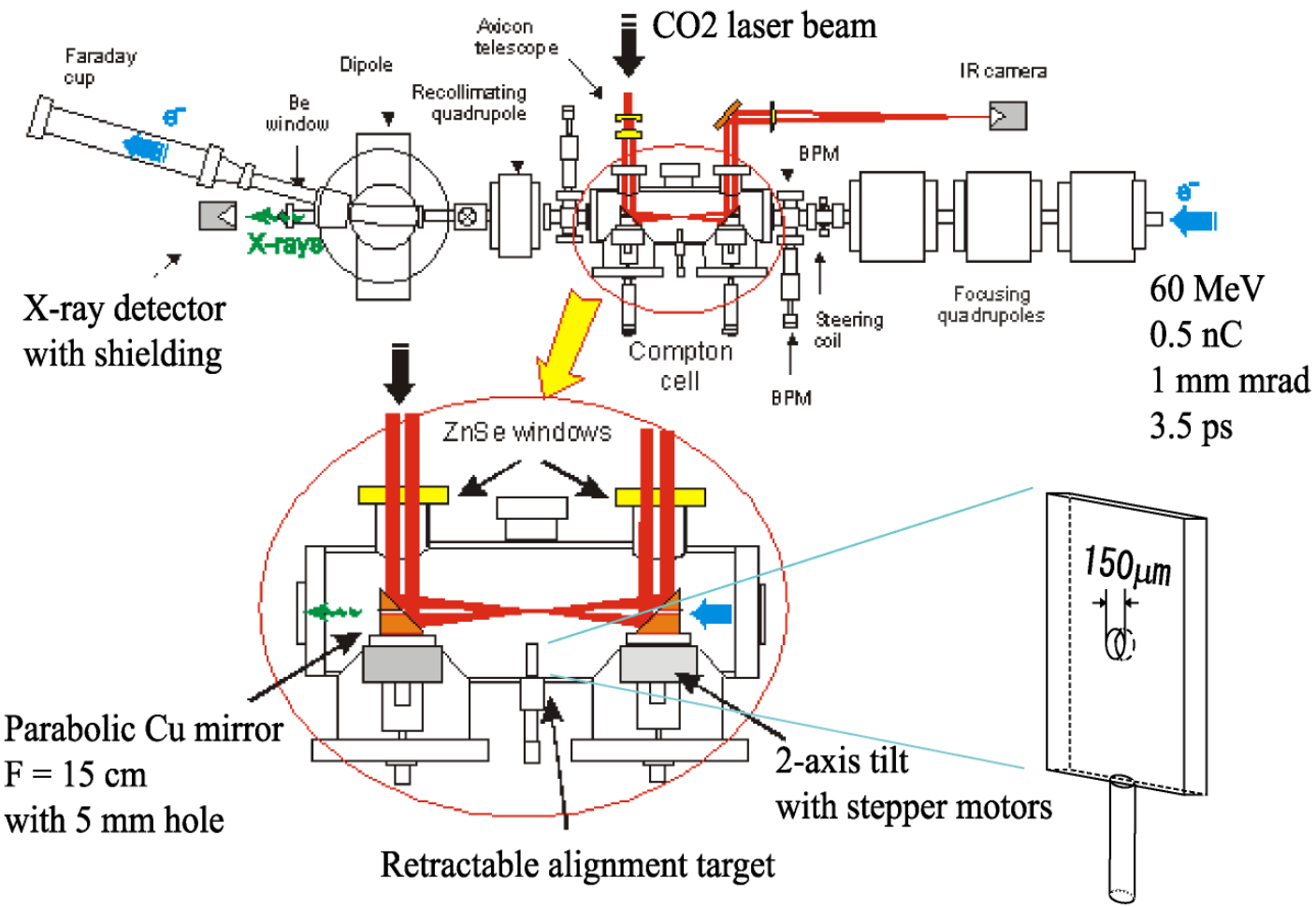
Our interest is in measuring the energy and angular distribution of the photons generated by higher order scattering (in the square)

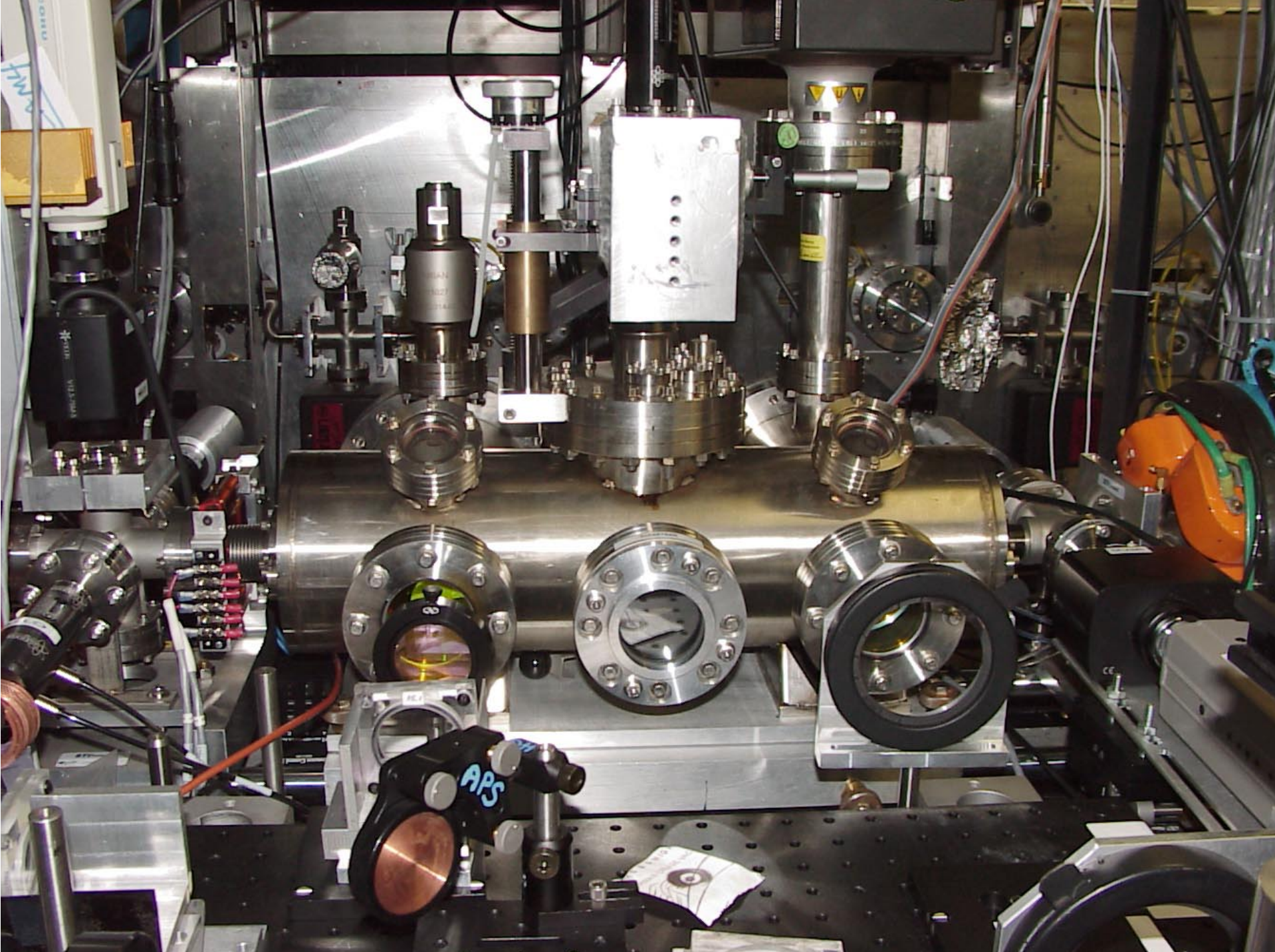
CAIN is a MC simulation code for the interactions between electron, positron, photon and high power electromagnetic field.

Included interactions

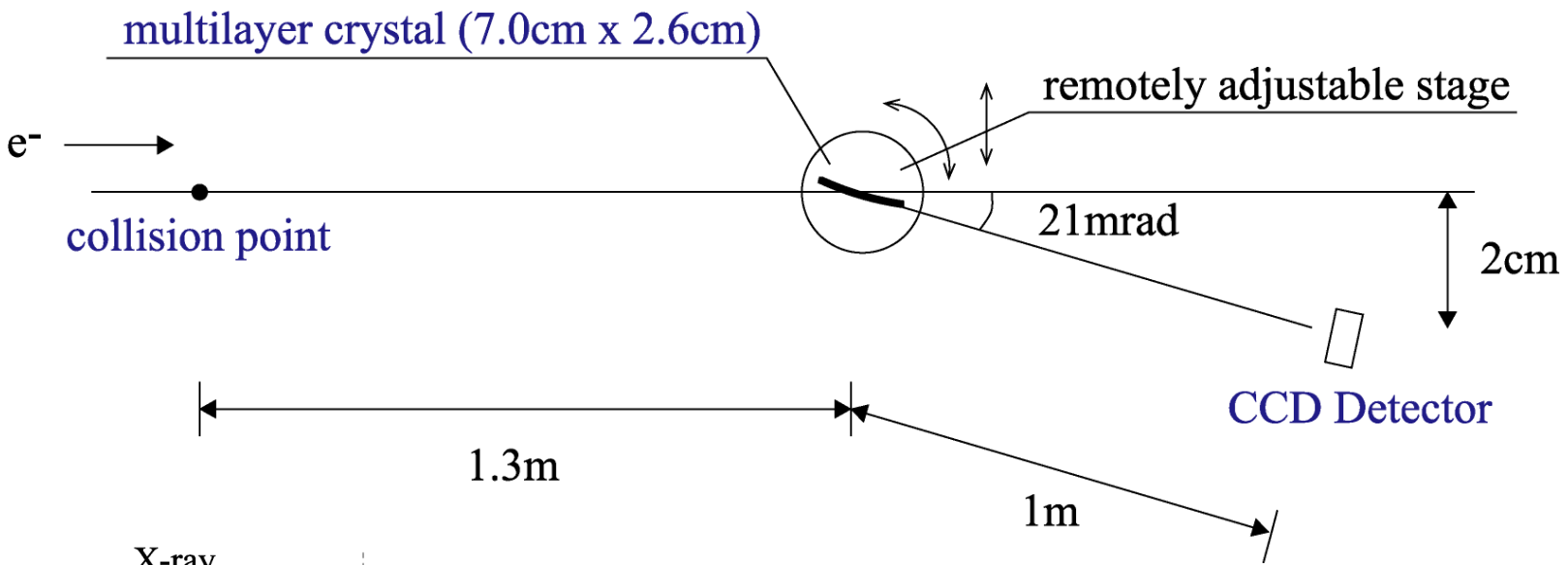
- non-linear Compton scattering between electron/positron and strong electromagnetic field
- synchrotron radiation and coherent pair creation in a strong electromagnetic field
- etc …

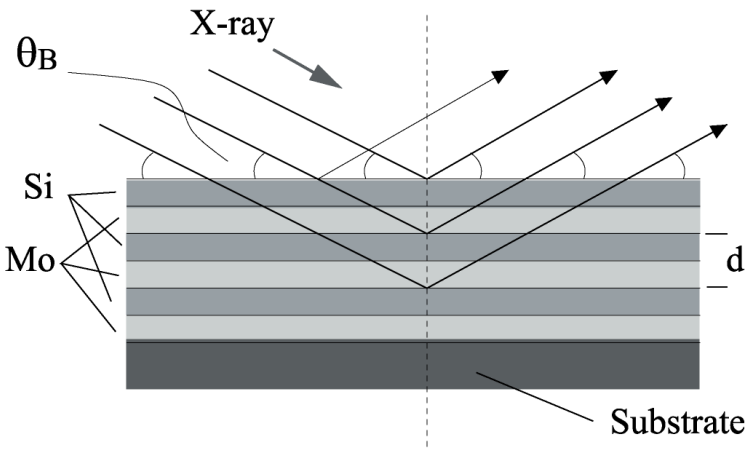
Experimental setup




APS

Schematic of the 2-D Spectrograph





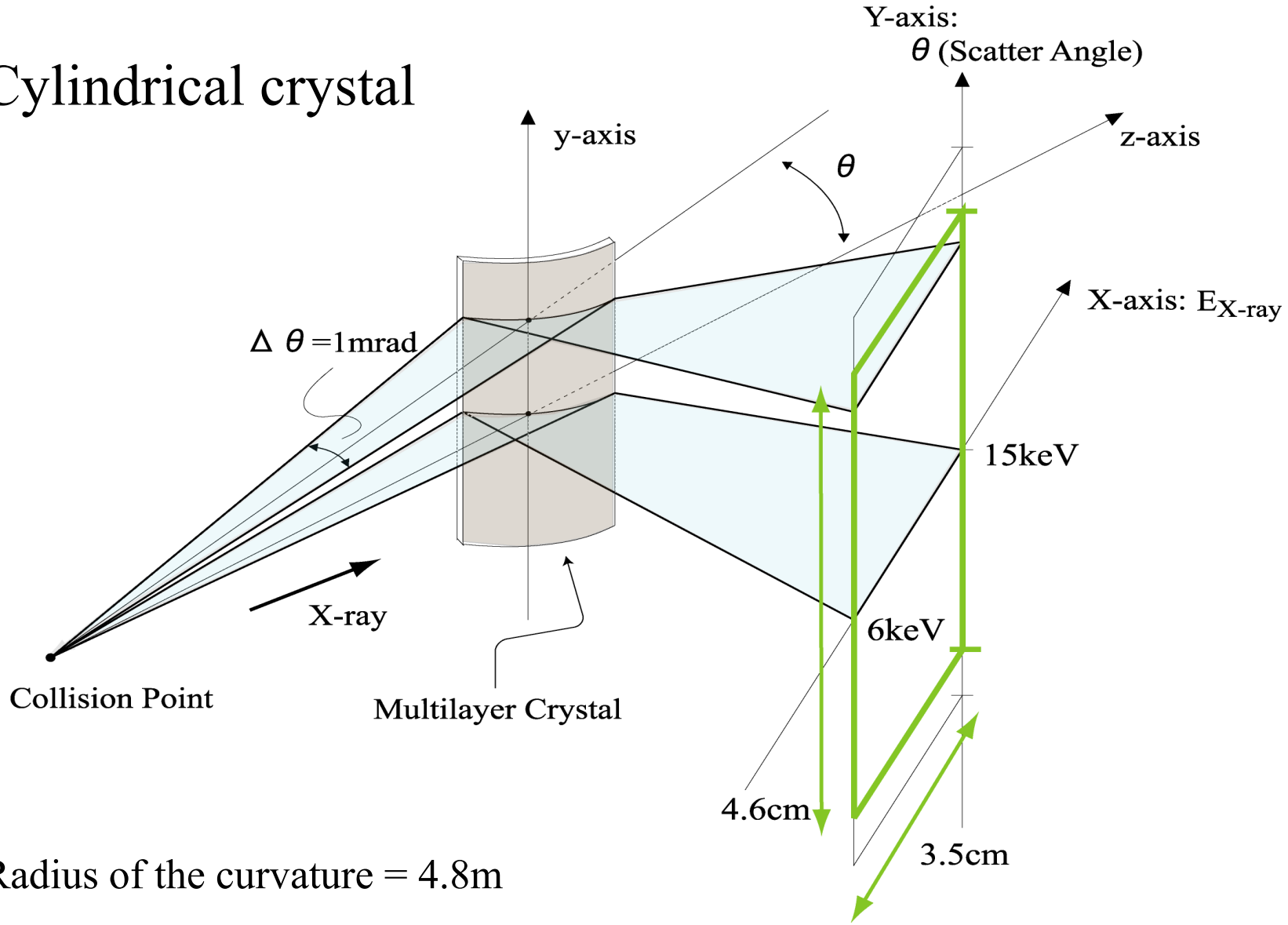
Si/Mo multilayer crystal
(45 pairs, d = 40A)

Bragg's law

$$\sin\theta_{\mathrm{B}} = n \cdot \frac{0.155}{E_{\text{X-ray}}[\mathrm{keV}]}$$

(n : order of diffraction)

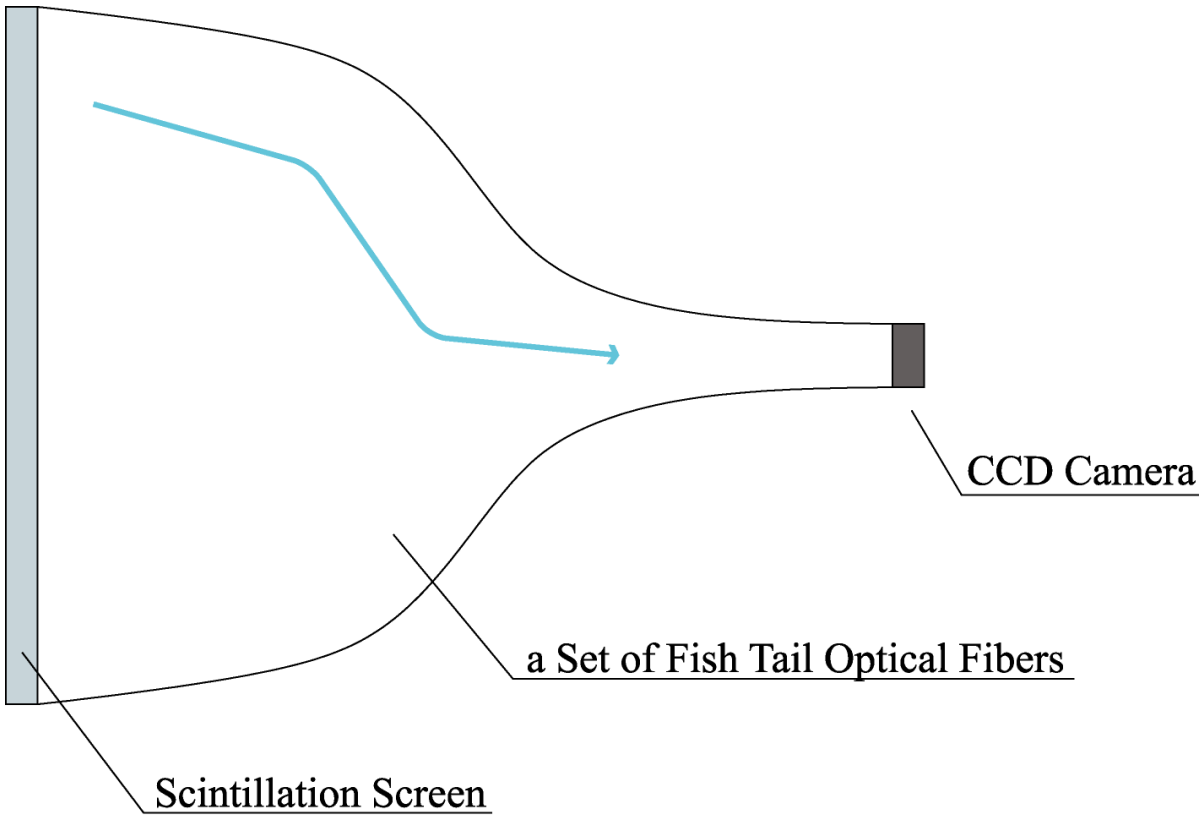
- Cylindrical crystal



Radius of the curvature = 4.8m

Size of the crystal = 7.0cm (width) × 2.6cm (height)

Position sensitive detector (MarCCD detector)



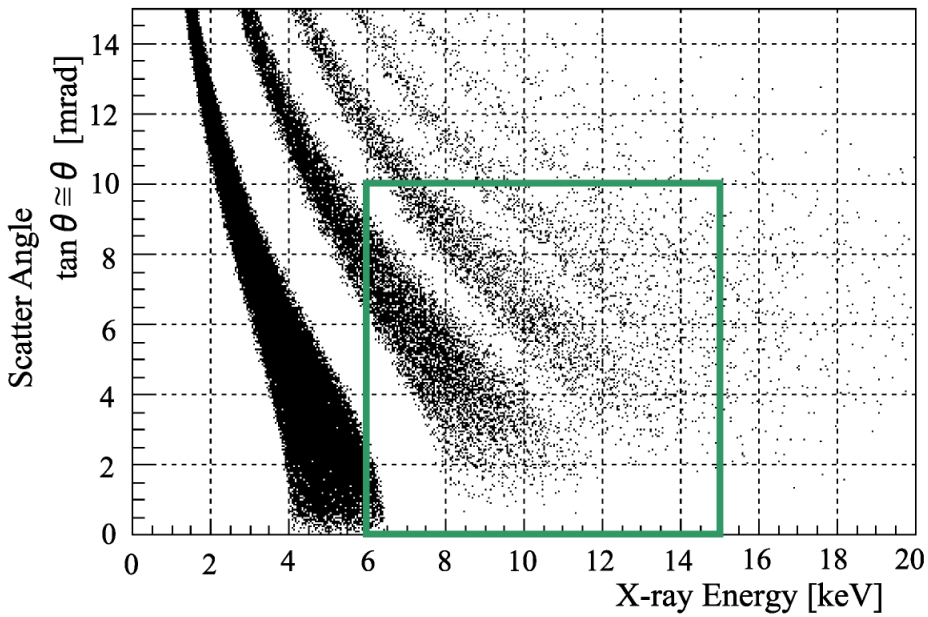
The CCD camera has 2k×2k pixels.

The position resolution is about 80μm on the scintillation screen.

Trace simulation of the Spectrograph

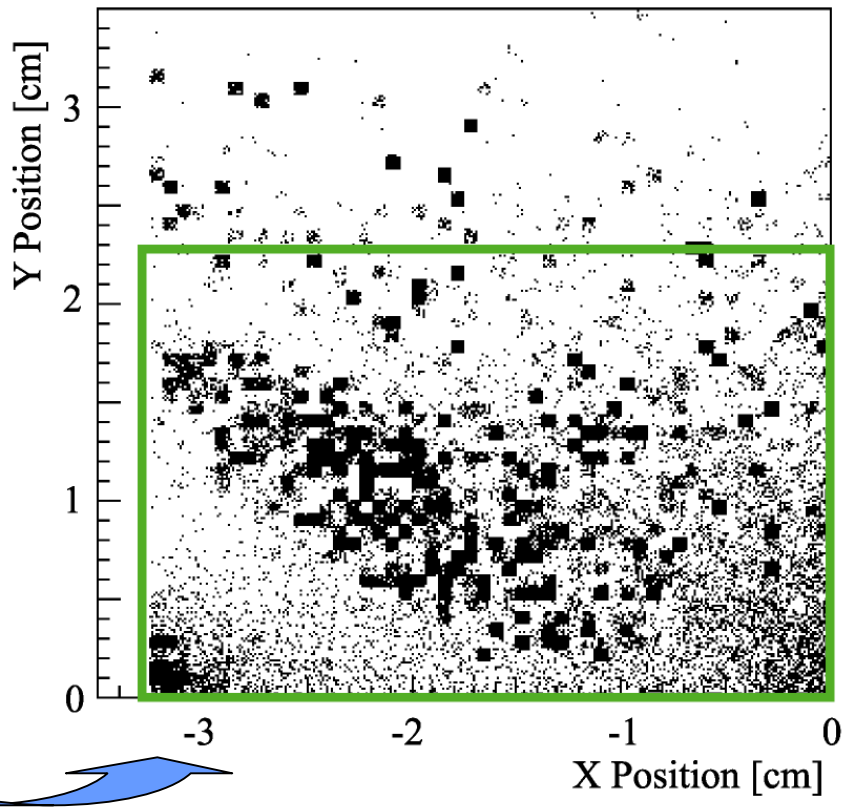
- Generated X-ray distribution
  (simulated by CAIN)

Laser parameters (circular polarize):
3J, 3psec, 32micron (a = 0.77)



- Position distribution
  on the detector

(bin size = 0.63mm x 0.63mm)



X-ray trace simulation

(Used the database in the Center of X-ray Optics, LBL)

Summary

- In near future, our CO_2 laser will be upgraded and the power will reach 1 TW. We expect to observe non-linear Compton scattering of the electron and laser beams in this situation.

- Two dimensional X-ray spectrograph using a cylindrical multilayer crystal and a position sensitive detector was designed to monitor energy spectrum and angular distribution for each pulse of X-rays generated by non-linear Compton scattering.