Compton Scattering of Picosecond Electron and CO_2 Beams

ATF User's Meeting, January 8th - 9th 2004
Brookhaven National Laboratory

Tetsuro Kumita

Depatment of Physics

Tokyo Metropolitan University

US-Japan Cooperation in the Field of High Energy Physics (Since 1998)

T. Hirose, S. Kashiwagi, M. Washio:

Advanced Research Institute for Science and Engineering, Waseda University

T.Kumita, Y. Kamiya, A.Ishimizu:

Department of Physics, Tokyo Metropolitan University

Y. Kurihara, K. Nakajima, T. Omori, T. Okugi, J. Urakawa, K. Yokoya:

High Energy Accelerator Research Organization (KEK)

I. Ben-Zvi, M. Babzien, K. Kusche, I. V. Pogorelsky, V. Yakimenko:

Accelerator Test Facility, Brookhaven National Laboratory

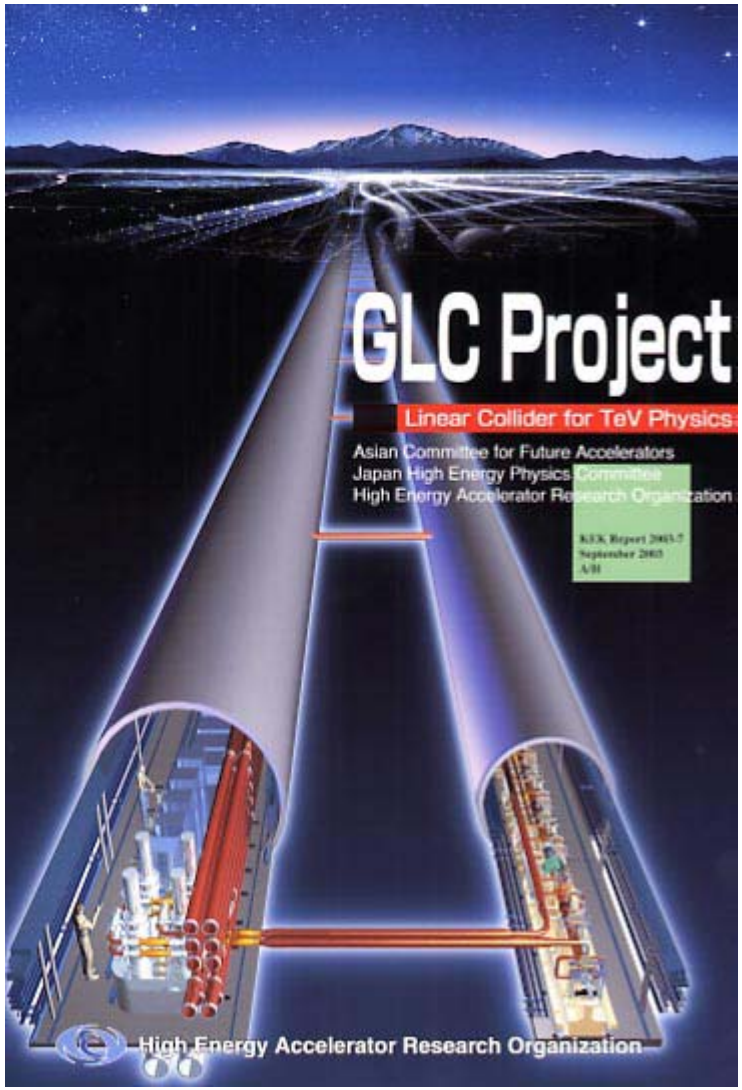
D. P. Siddens:

National Synchrotron Light Source, Brookhaven National Laboratory

D. Cline, F. Zhou:

University of California, Los ANgeles

Goal of the Cooperative Research



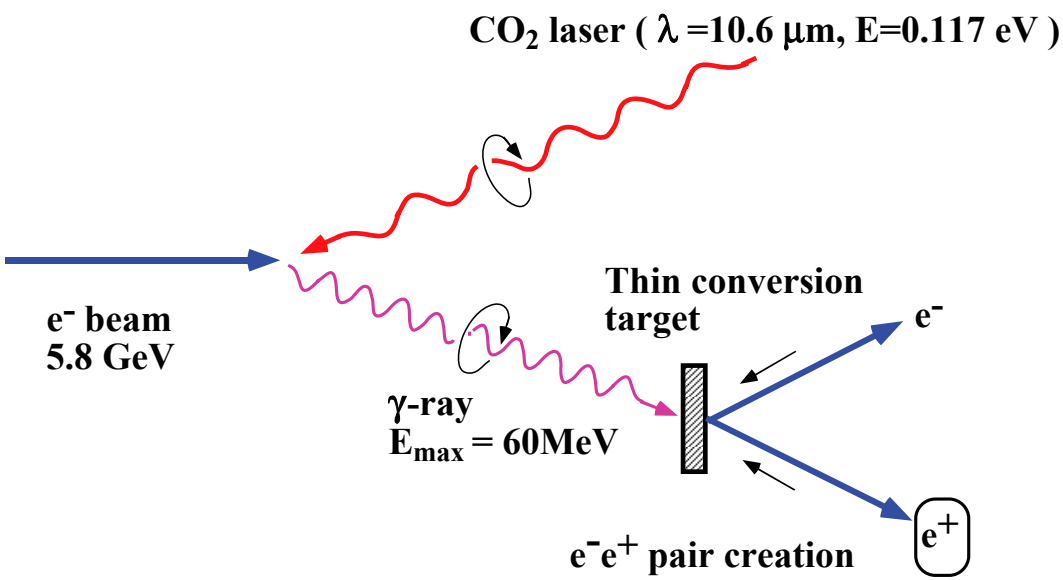
Development of polarized positron source for the future linear collider.

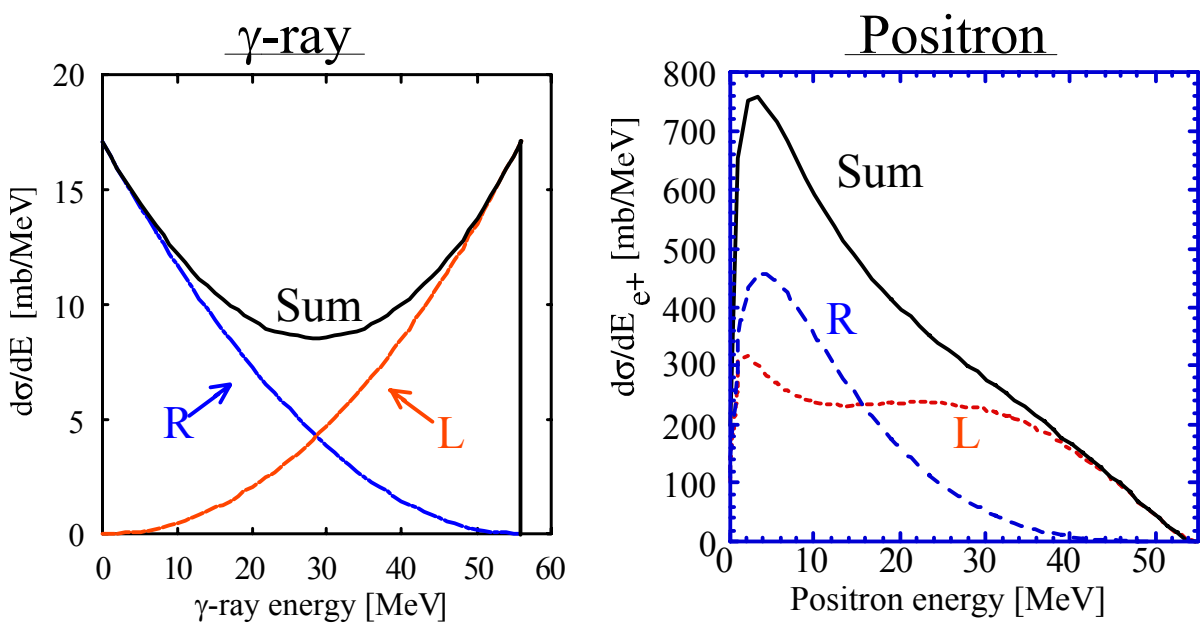
The linear collider project in Japan, formerly known as JLC (Japan Linear Collider), has received a new name GLC (Global Linear Collider).

GLC is a 30-km, E_{CM}=1TeV electron positron linear collider.

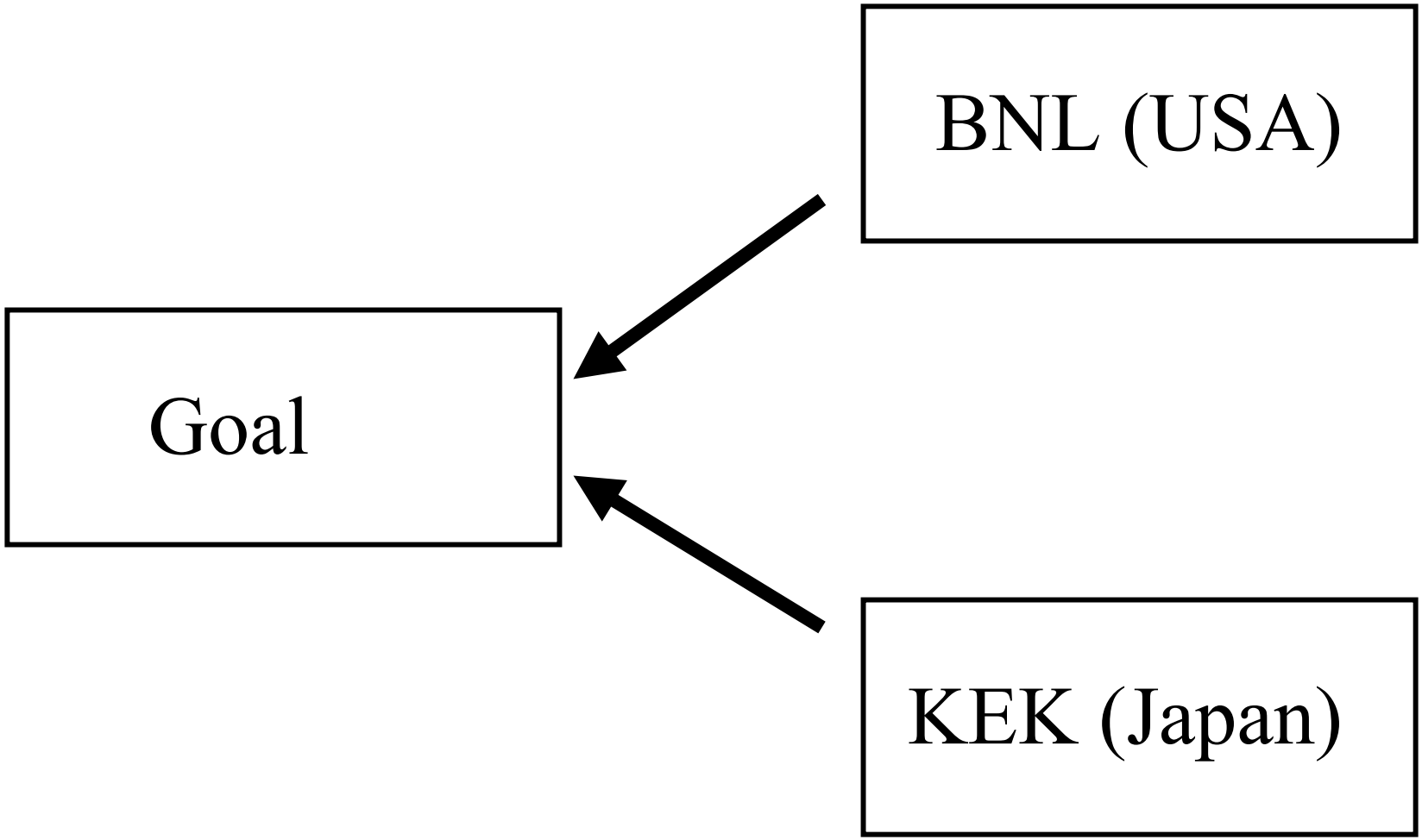
Spin polarization of both electron and positron beams allows us to make precise observation of exotic processes, such as SUSY particles.

Principle of polarized positron production

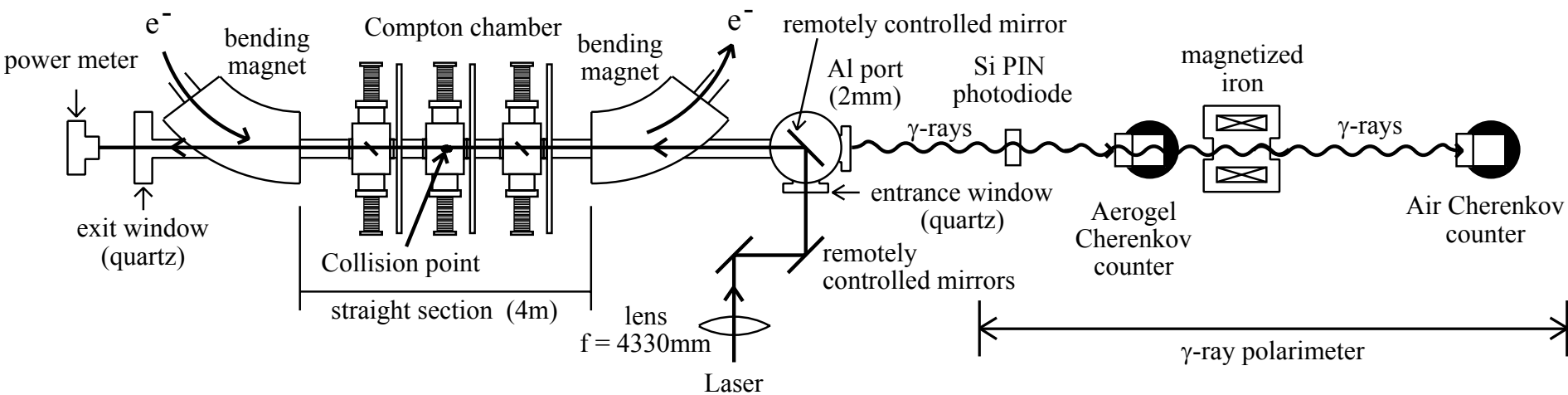




(Incident photon with right handed)


BNL (USA)
Goal
KEK (Japan)

Experiment at KEK, JAPAN

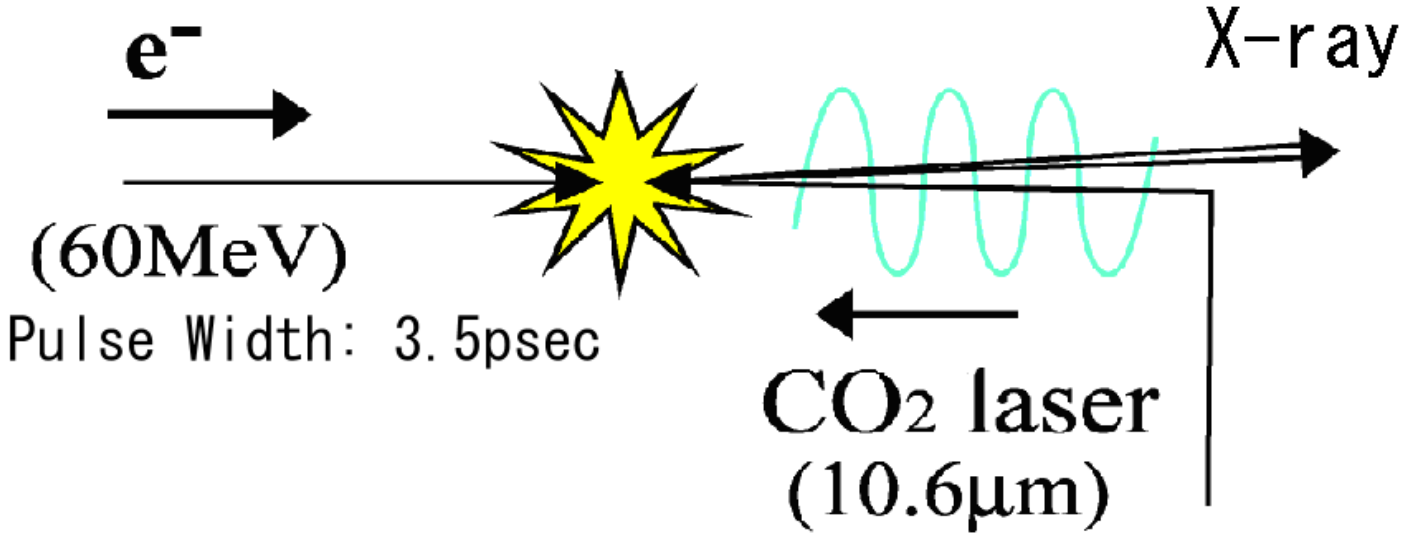


Production of polarized γ-rays via Compton scattering of 1.28GeV electron and 532nm Nd:YAG laser beams.

Polarization of produced γ-rays is measured utilizing transmission through a magnetized iron.

Currently, production of polarized positrons and polarization measurement are going on.

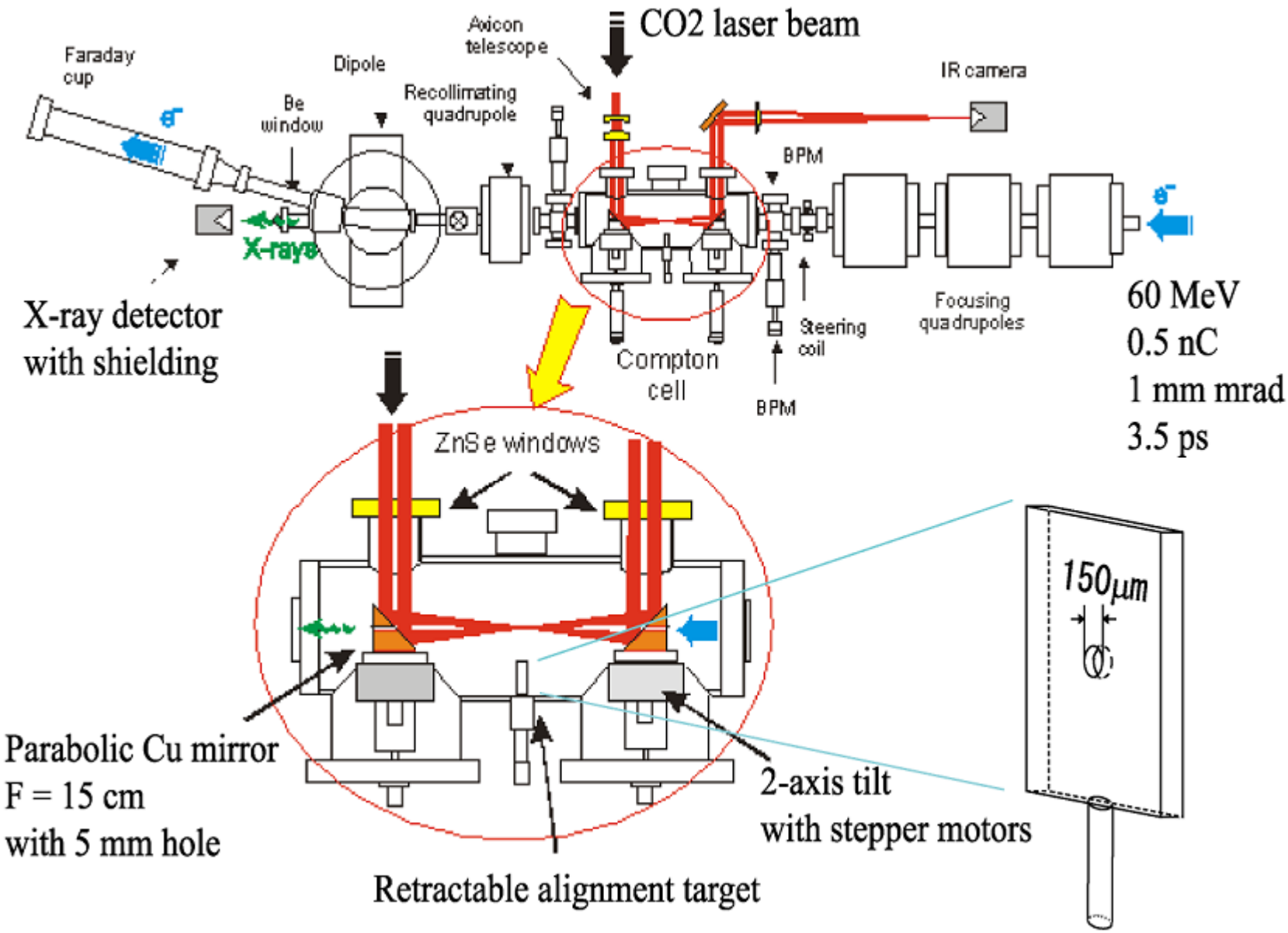
Experiment at BNL-ATF

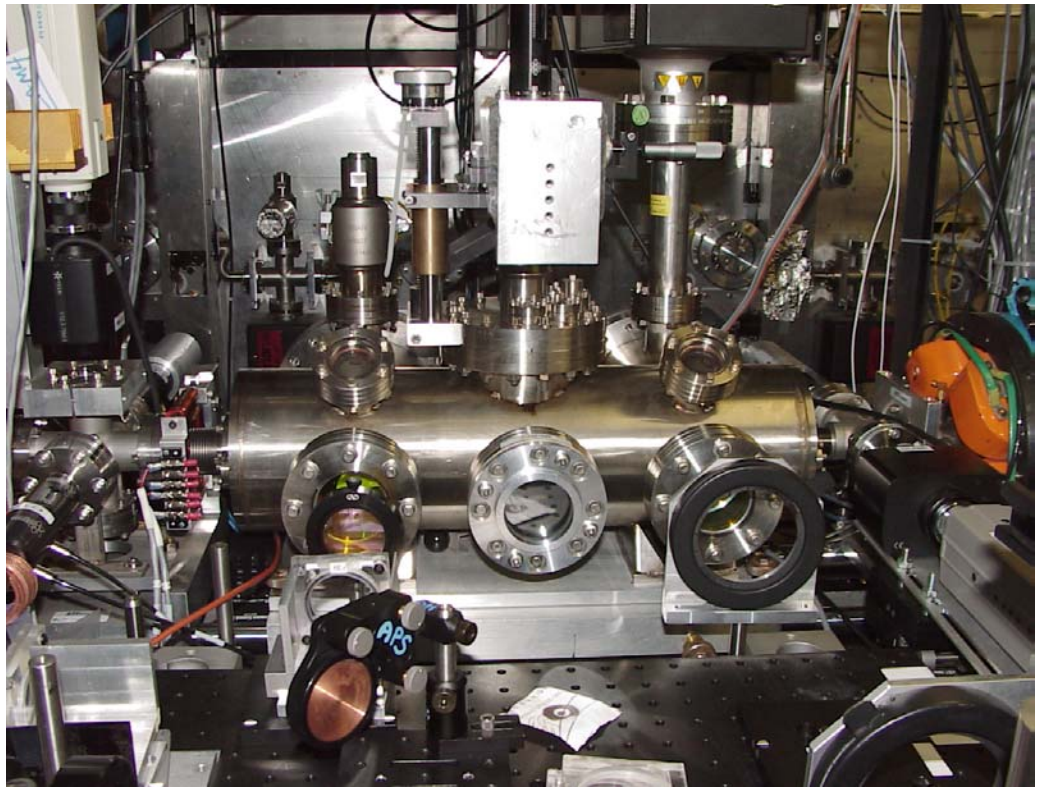


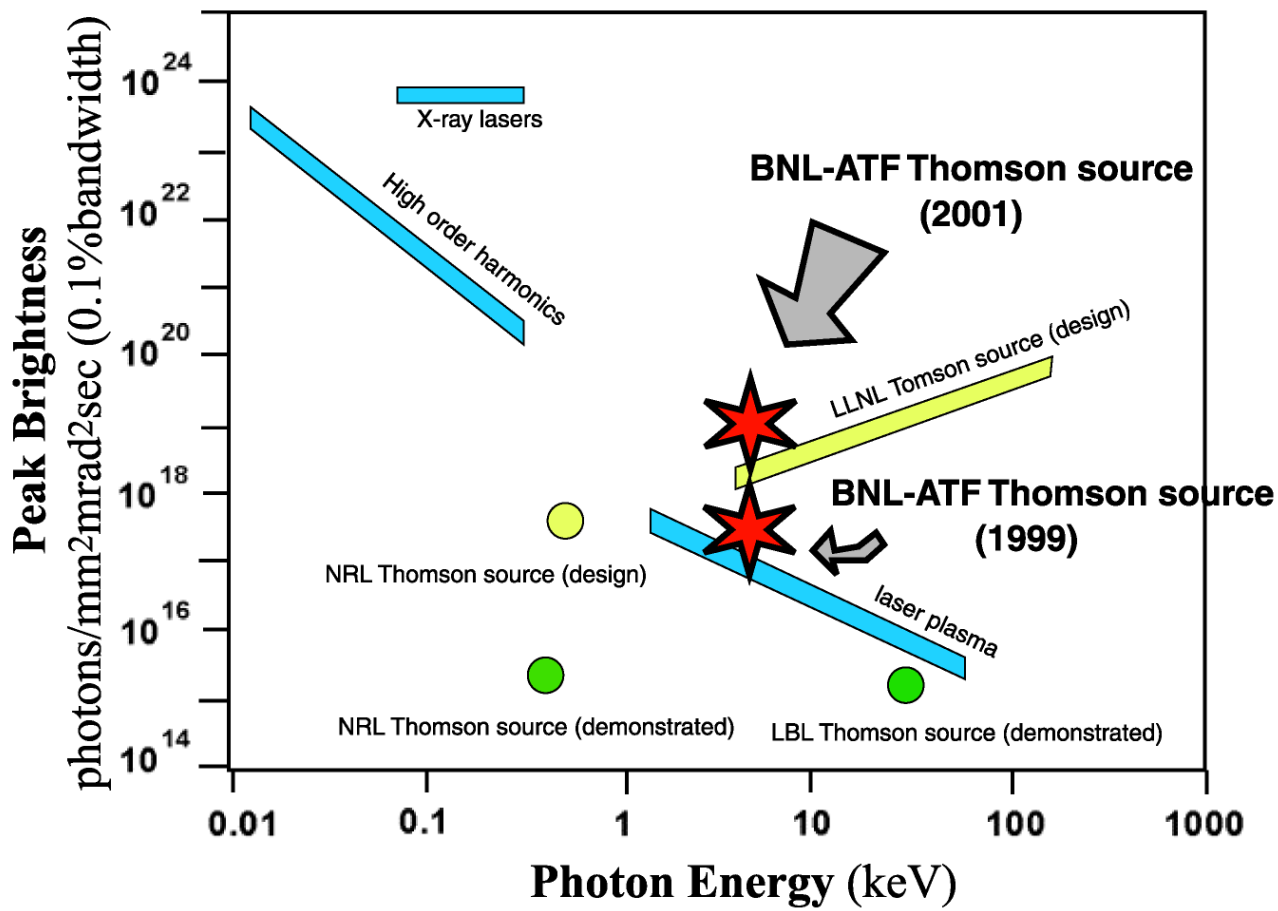
Production of high intensity X-rays via scattering of 60MeV electron and CO_2 laser beams.

Development of short pulse (~ psec) CO_2 laser

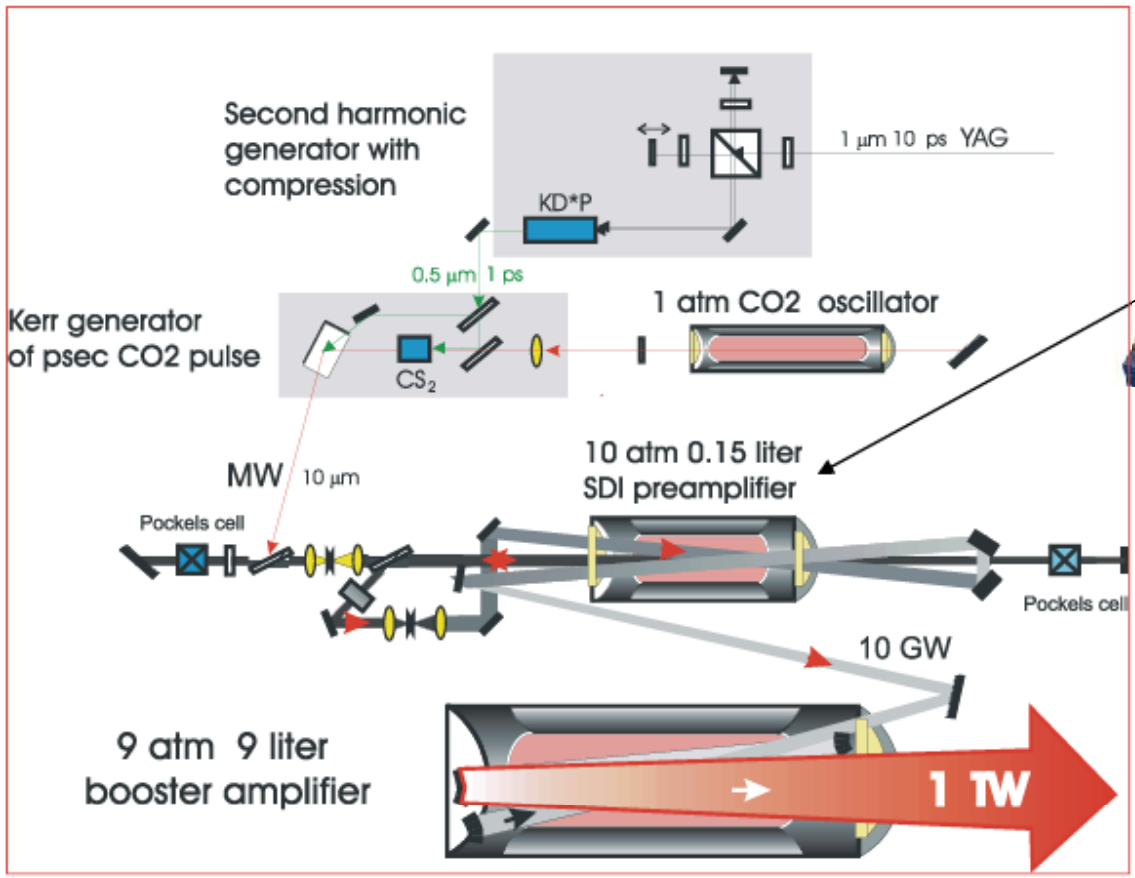
Study of the Nonlinear Compton scattering

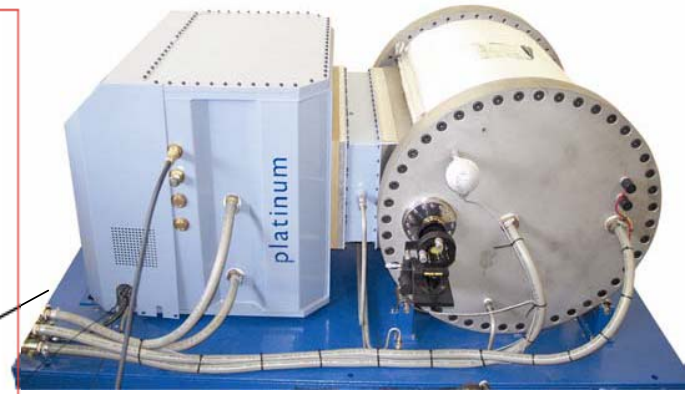

CO2 laser beam
Axicon telescope
Faraday cup
Dipole
Be window
Recollimating quadrupole
IR camera
BPM
X-rays
X-ray detector with shielding
Compton cell
Steering coil
BPM
Focusing quadrupoles
60 MeV
0.5 nC
1 mm mrad
3.5 ps
ZnSe windows
150μm
Parabolic Cu mirror
F = 15 cm
with 5 mm hole
2-axis tilt
with stepper motors
Retractable alignment target


APS


Peak Brightness
photons/mm2mrad2sec (0.1%bandwidth)
10^24
10^22
10^20
10^18
10^16
10^14
X-ray lasers
High order harmonics
BNL-ATF Thomson source
(2001)
LLNL Tomson source (design)
BNL-ATF Thomson source
(1999)
NRL Thomson source (design)
laser plasma
NRL Thomson source (demonstrated)
LBL Thomson source (demonstrated)
0.01
0.1
1
10
100
1000
Photon Energy (keV)

ATF CO_2 Laser System

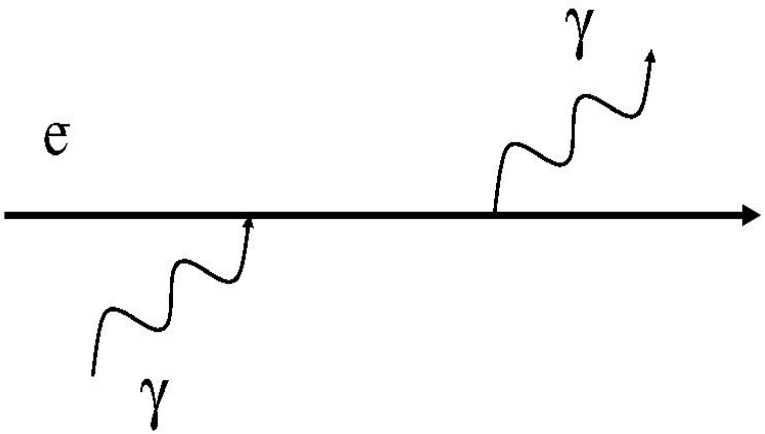


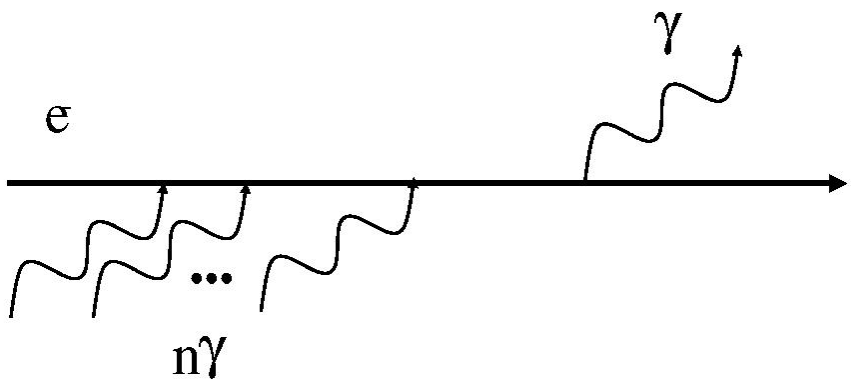


ATF CO_2 laser is under upgrade

15GW (3J, 180psec) → 1TW (3J, 3psec) – 10TW (30J, 3psec)

Nonlinear processes (multi-photon absorption) are not negligible for the TW laser.





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

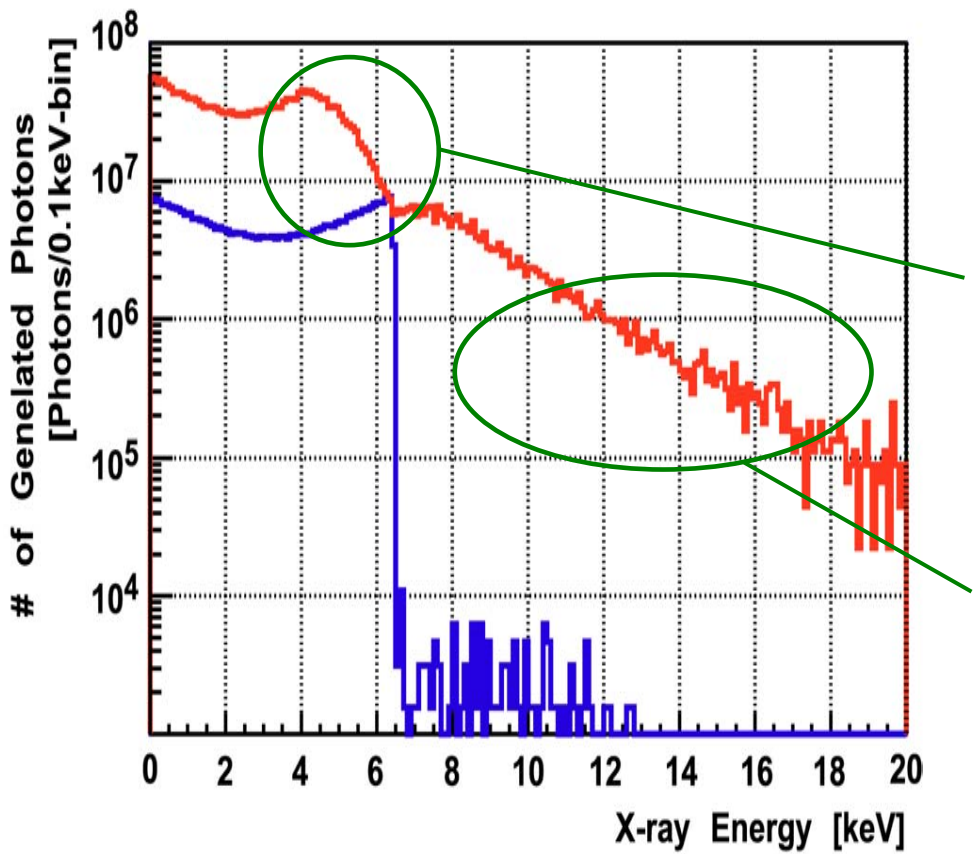
$$e + n\gamma \rightarrow e' + \gamma'$$

Polarization of the final state photons drops down due to the nonlinear processes.

X-ray Energy Spectrum simulated by CAIN

A: 1TW laser

B: 15GW power laser

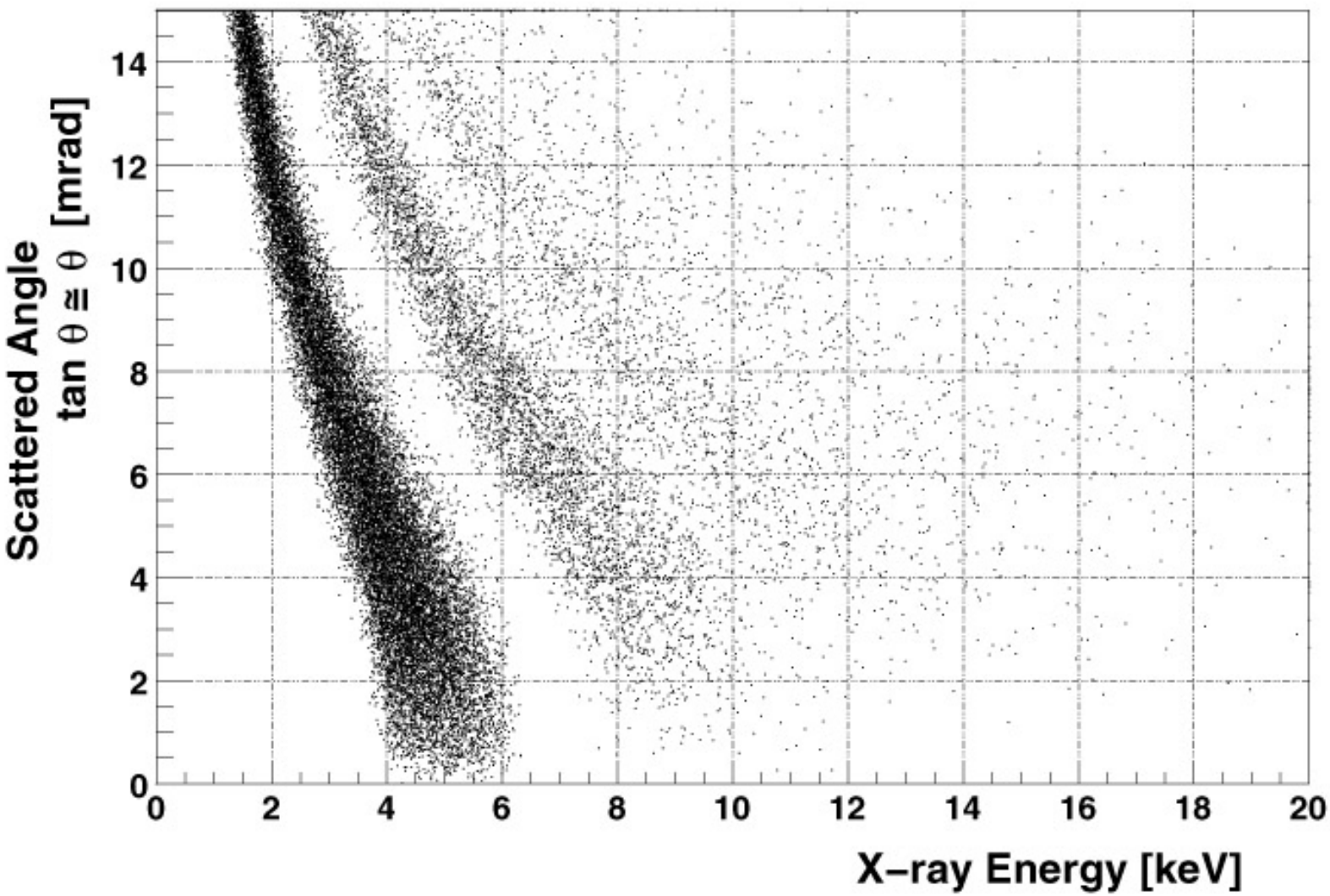


Characteristics of the spectrum for the 1TW laser

- Dull edge due to an electron mass shift in the laser field

- Higher energy photons from non-linear Compton scattering

Energy and Angular Distribution Simulated by CAIN .1TW.

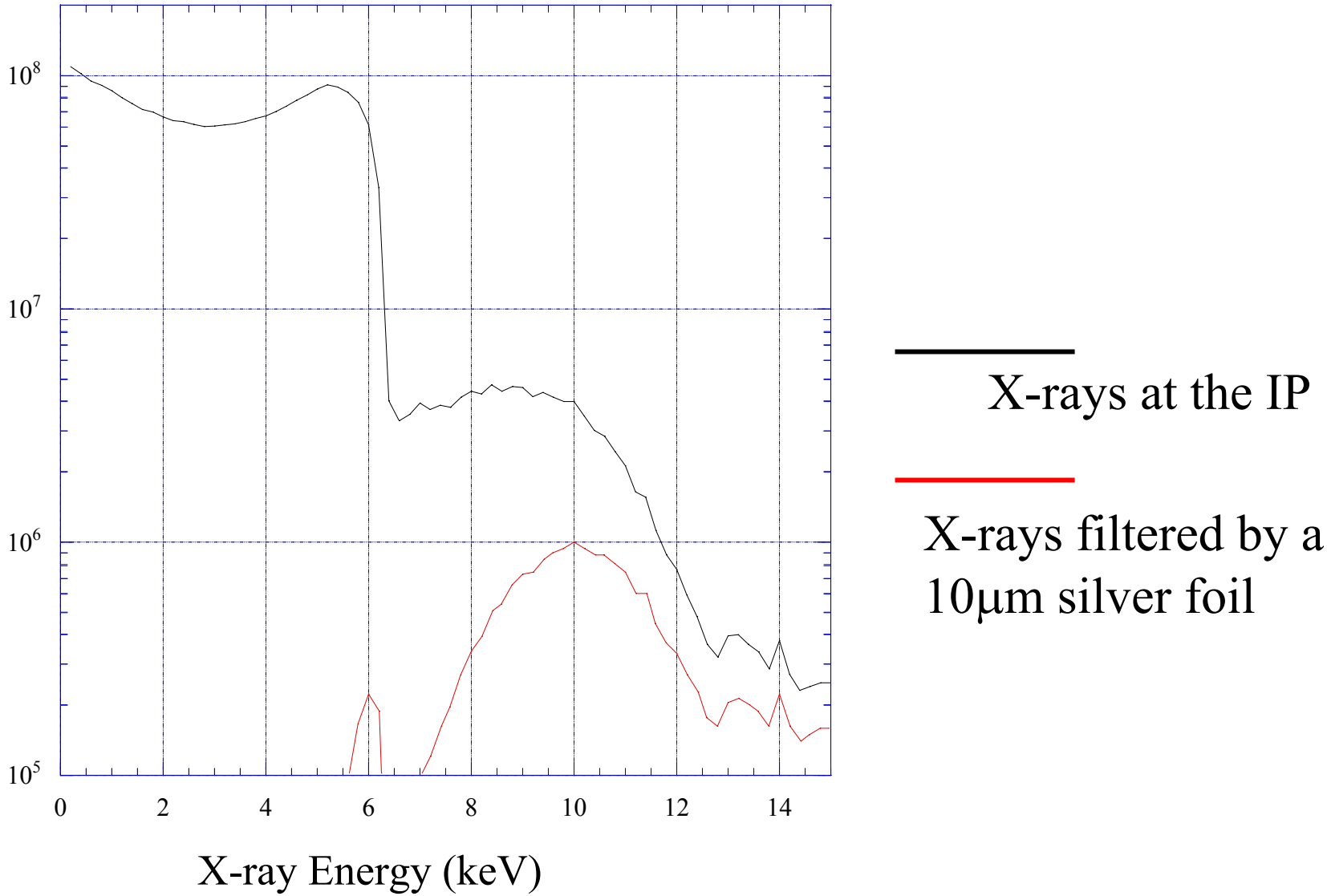


Plan of the Experiment in January-March, 2004

Peak power of the CO_2 laser reaches about 150 GW (5J/30psec).

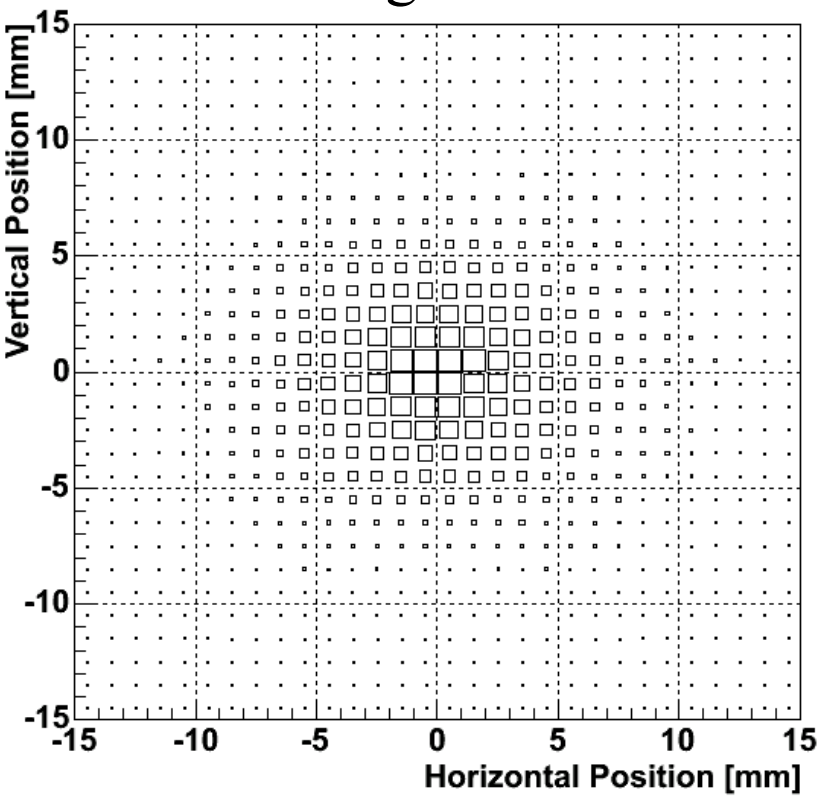
Nonlinear X-rays are observable if the laser spot size ~ 20μm using a silver filter to cut off lower energy X-rays.

X-ray energy spectrum simulated by CAIN (5J/30psec/20μm)

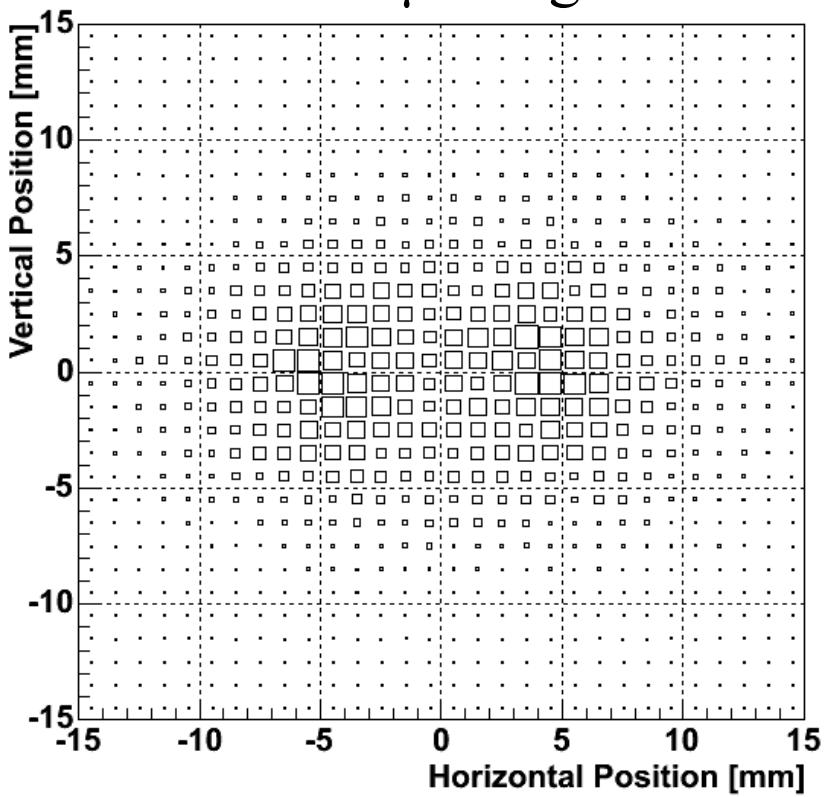


X-ray transverse profile at 140cm downstream from the IP

w/o Ag filter

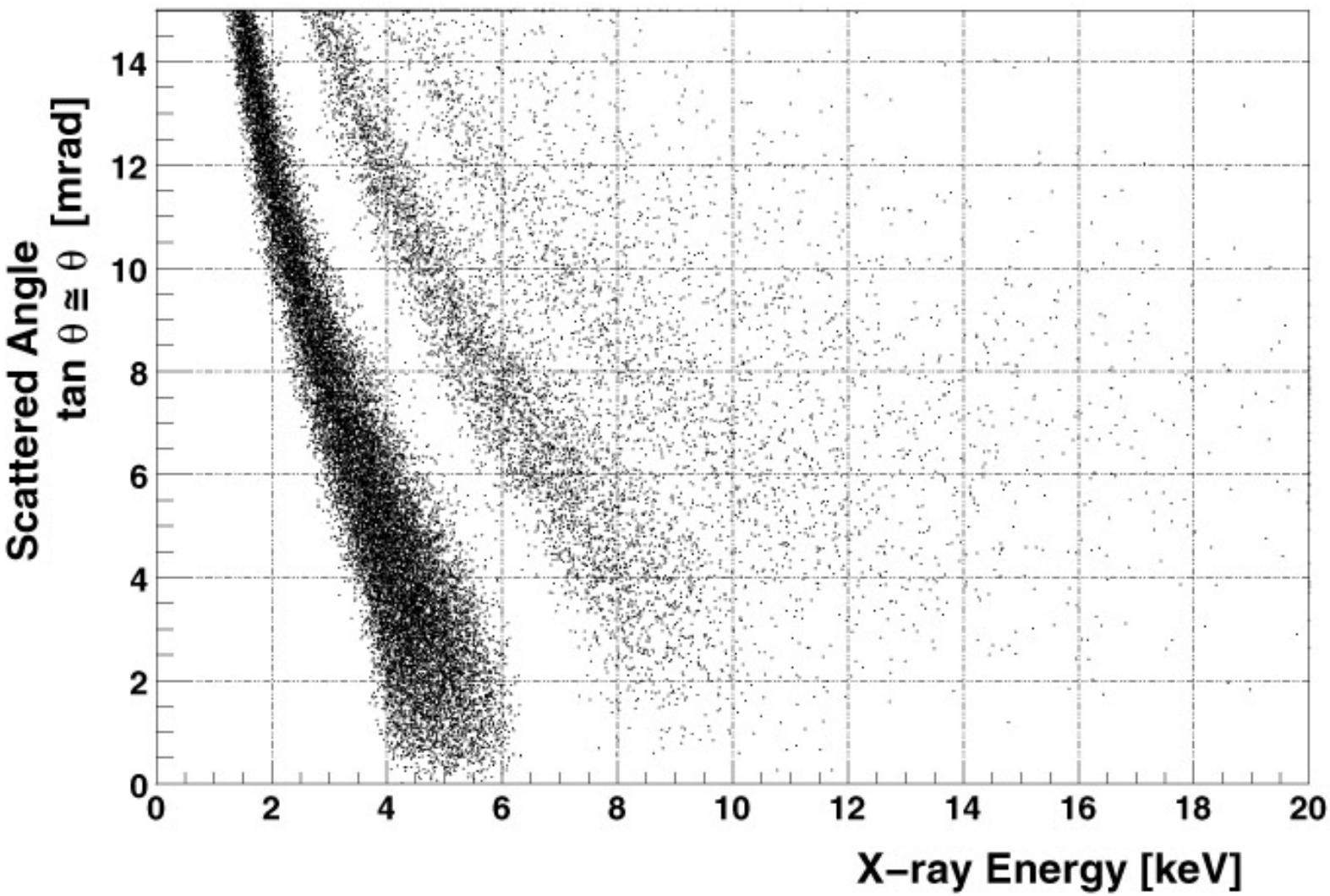


with a 10μm Ag filter

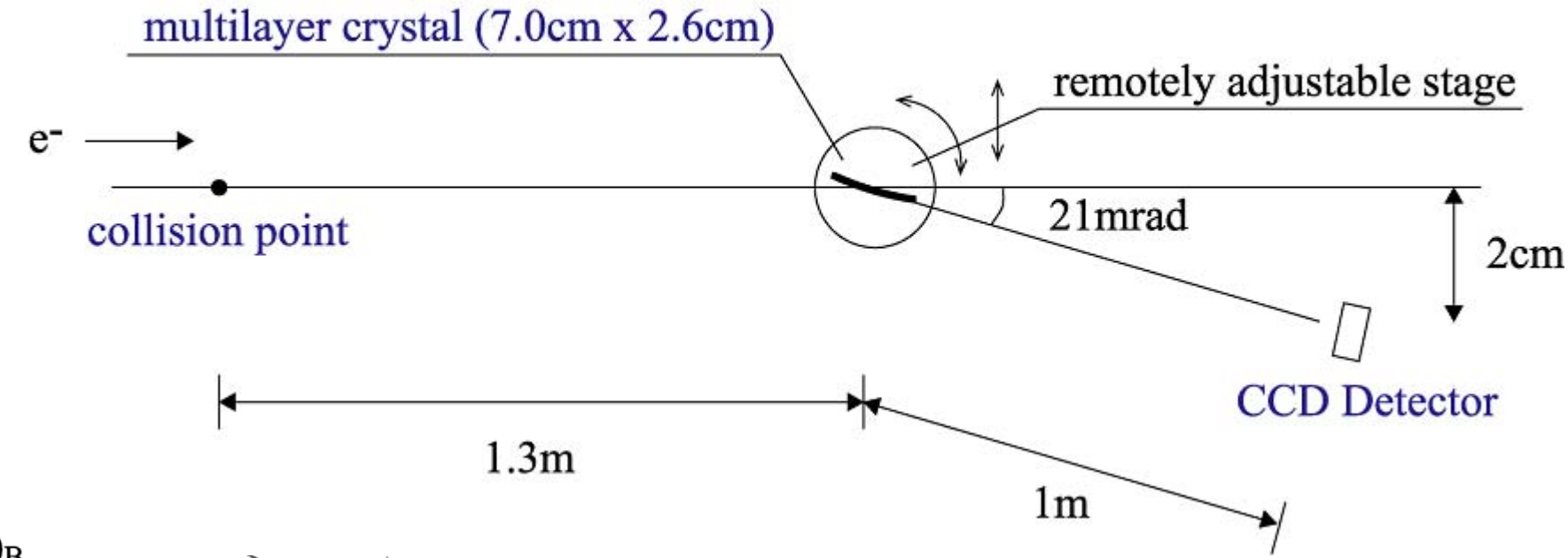


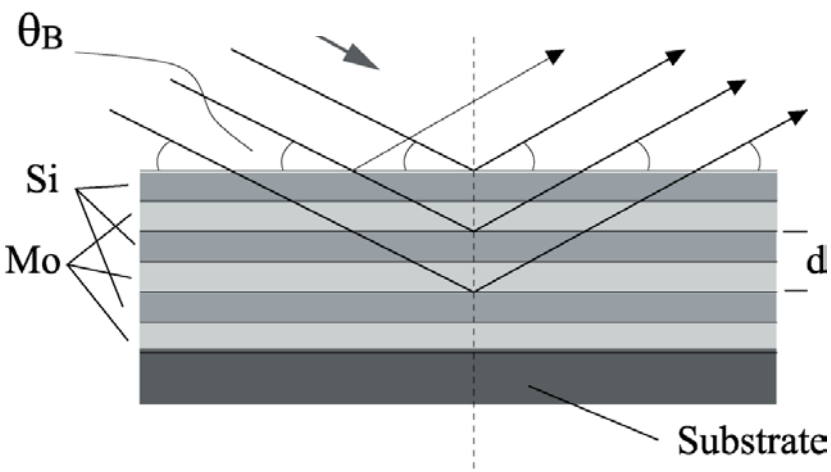
Polarization plane

Energy and Angular Distribution Simulated by CAIN .1TW.



X-ray Spectrometer Utilizing a Multilayer Optic



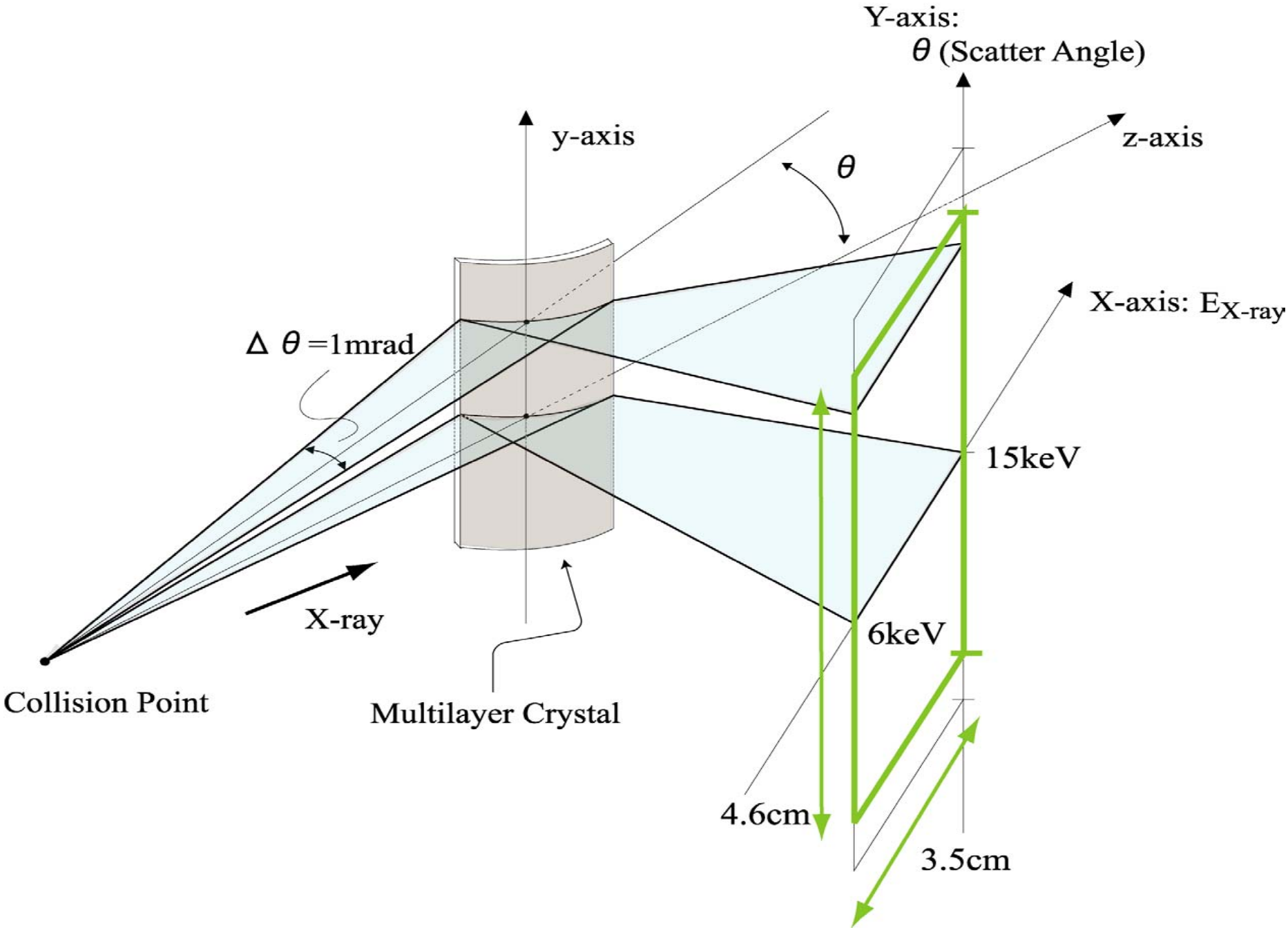


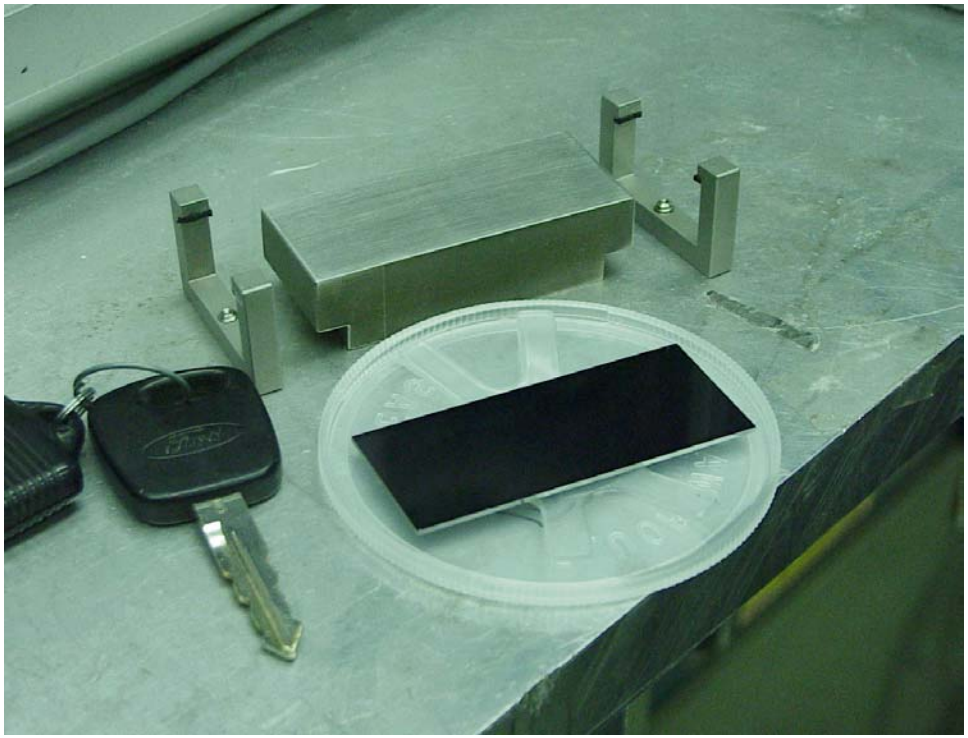
Si/Mo multilayer optic
(45 pairs, d = 40A)

Bragg's law

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

(n order of diffraction)

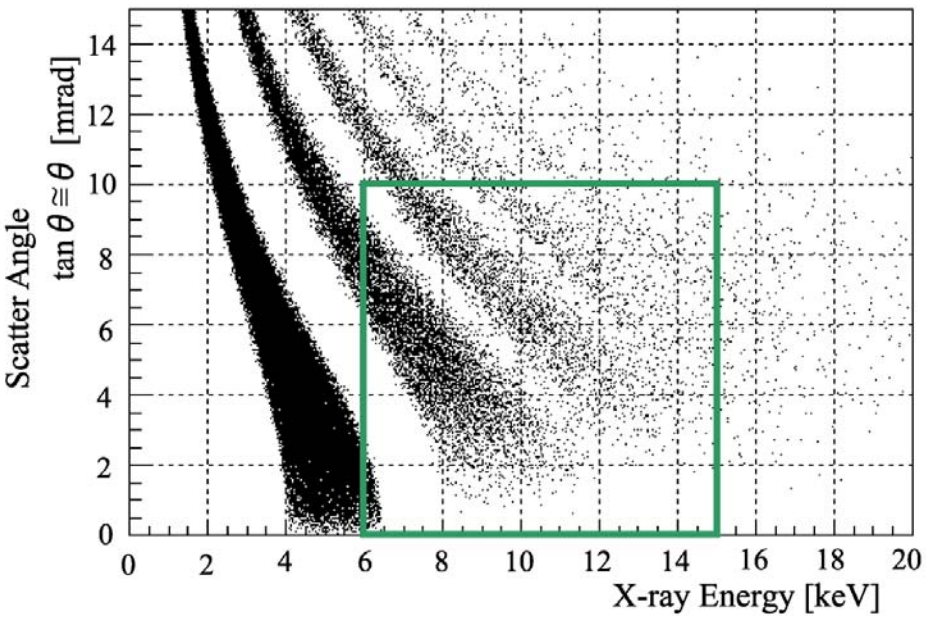

Y-axis:
θ (Scatter Angle)
y-axis
z-axis
θ
X-axis: E_X-ray
Δ θ =1mrad
15keV
6keV
X-ray
Collision Point
Multilayer Crystal
4.6cm
3.5cm



Ray trace simulation of the Spectrometer

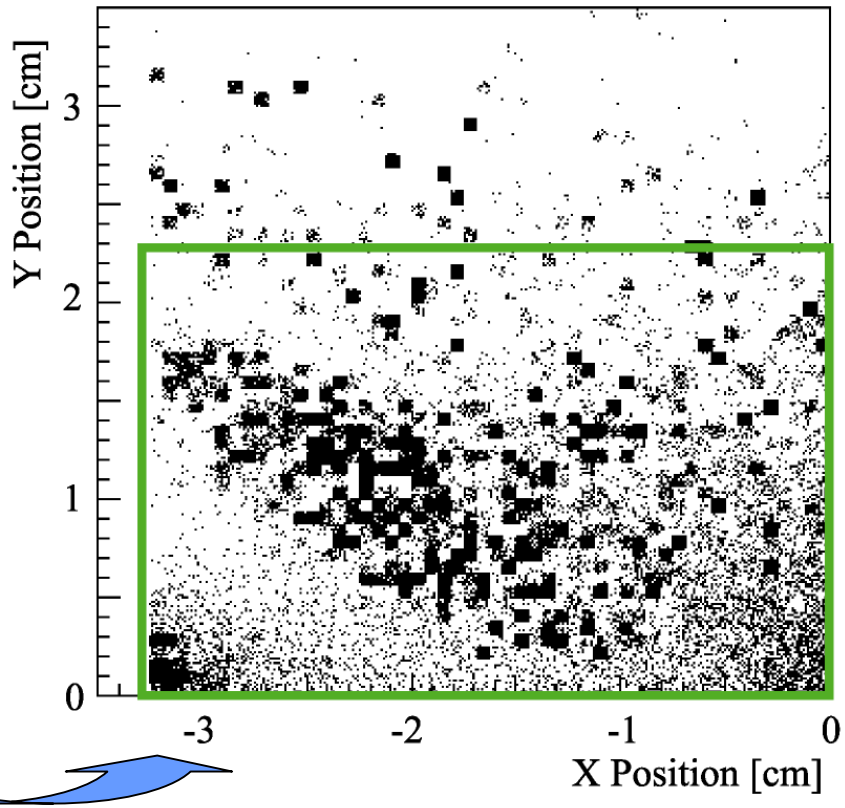
- Generated X-ray distribution
  (simulated by CAIN)

Laser parameters (circular polarized):
3J, 3psec (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)

S U M M A R Y

- Aim: Production of high intensity X-rays and study of the nonlinear Compton scattering using the picosecond CO_2 laser.
- Brightness of X-rays produced by our experiment is the world highest.
- Nonlinear Compton X-rays can be observed if the laser peak power reaches 150GW.