Compton Scattering of Picosecond Electron and CO2 beams

T. Hirose (TMU) @BNL user meeting, Jan. 31, 2002

Japan/US cooperation in high energy physics (Supported by JSPS from 1998)

"Development of a pico-second CO2 laser for production of polarized positron beams at linear colliders"

Japan: Tokyo Metropolitan University(TMU)

KEK(High Energy Accel. Research Organization)

Waseda University

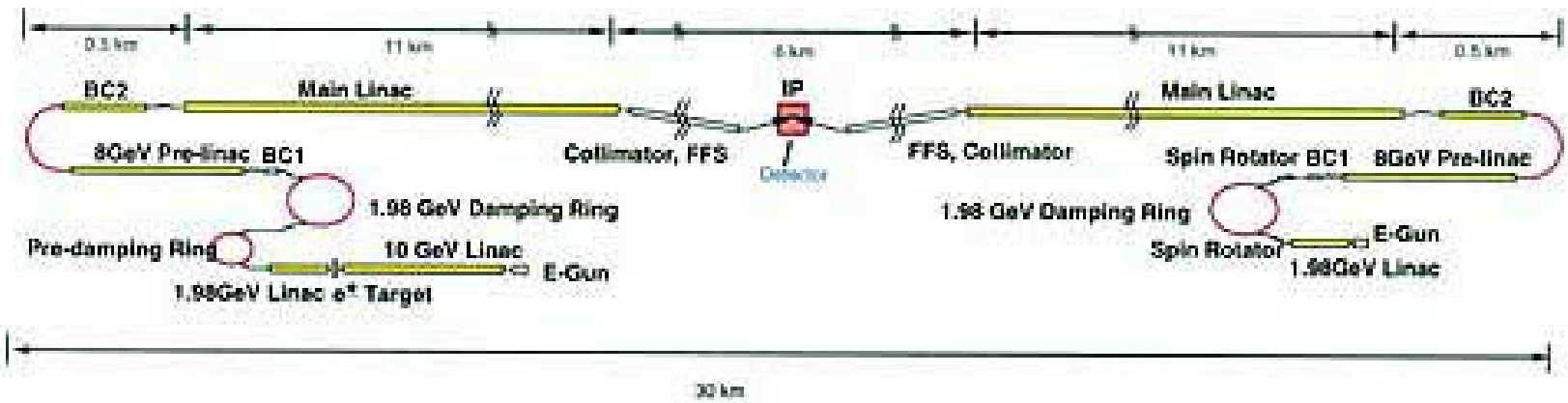
US: BNL-ATF

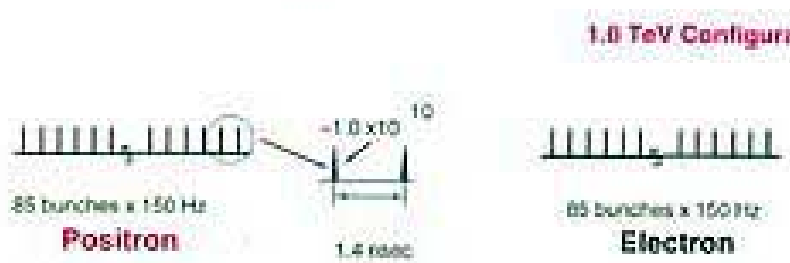
1. Polarized positron beam for an e+e- linear collider JLC

2. Review of activities both at BNL and KEK

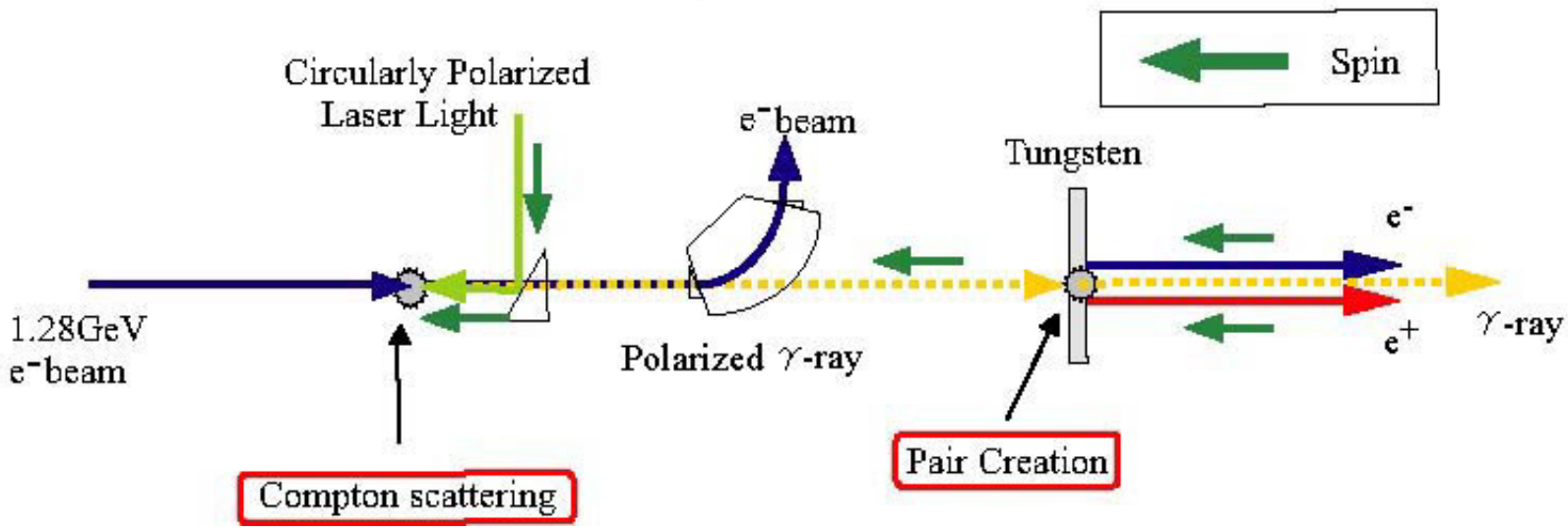
Electron-Positron Linear Collider JLC

500 GeV JLC-I → 1.5 TeV JLC





Schematic design for a polarized positron



Jpn. J. Appl. Phys. **35** (1996) 3677

LSS (Laser Synchrotron Source)

Budget :

	Facilities(yen)	Traffic expenses
1998	5,000,000	1,500,000
1999	7,000,000	2,800,000
2000	10,000,000	4,200,000
2001	12,000,000	5,500,000
Total	34,000,000	14,000,000

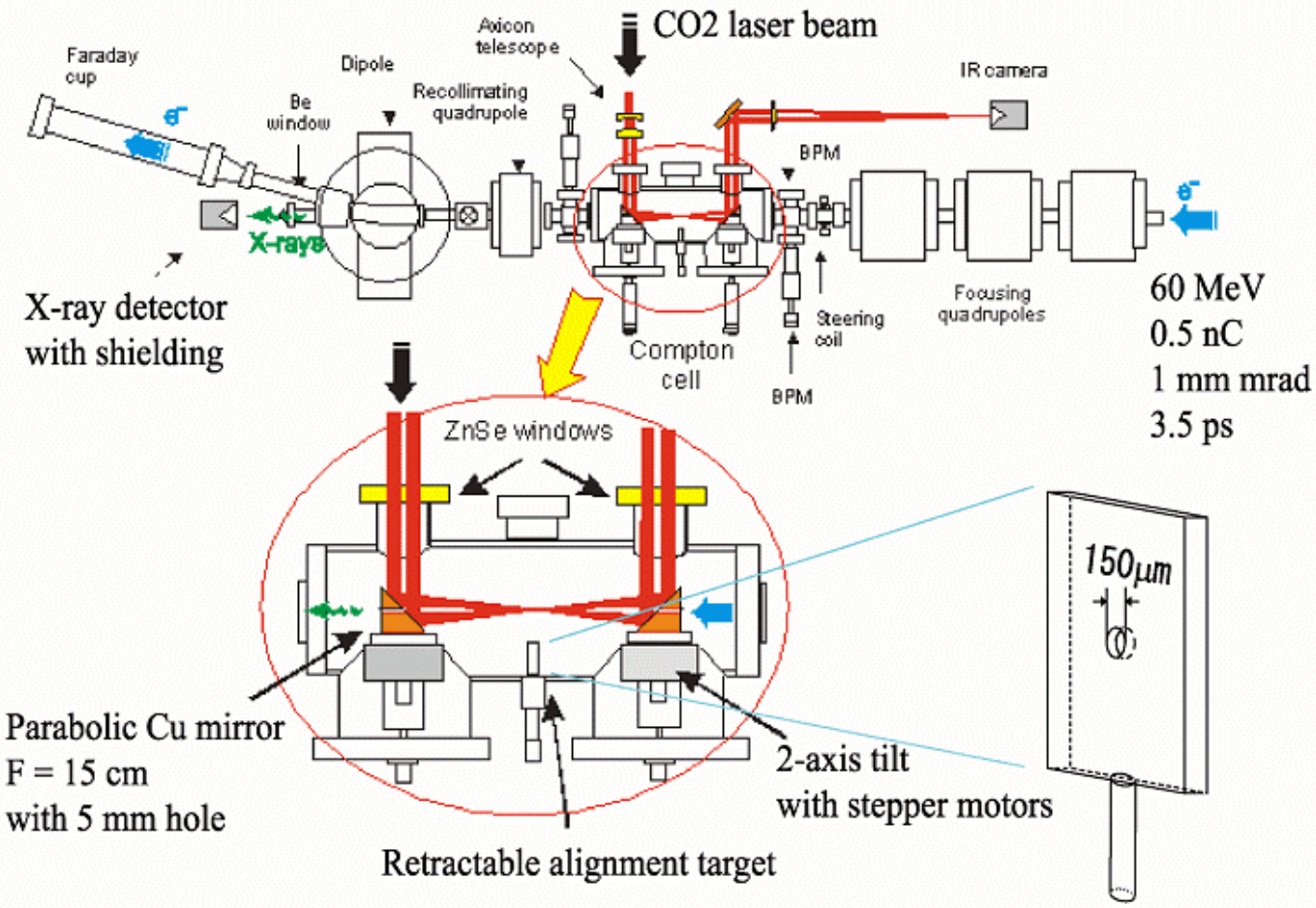
BNL-ATF e-: 60 MeV, CO2 laser, Emax = 6 keV

- Nonlinear Compton process
- Compton-in-capillary (Plasma channel)

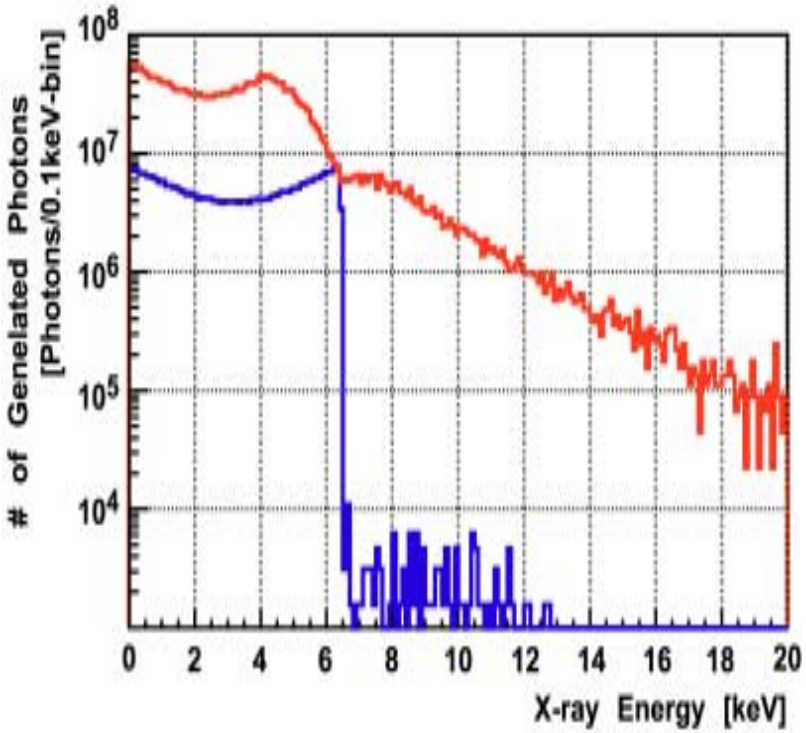
KEK-ATF e-: 1,.28 GeV, Nd:YAG laser, Emax = 54 MeV

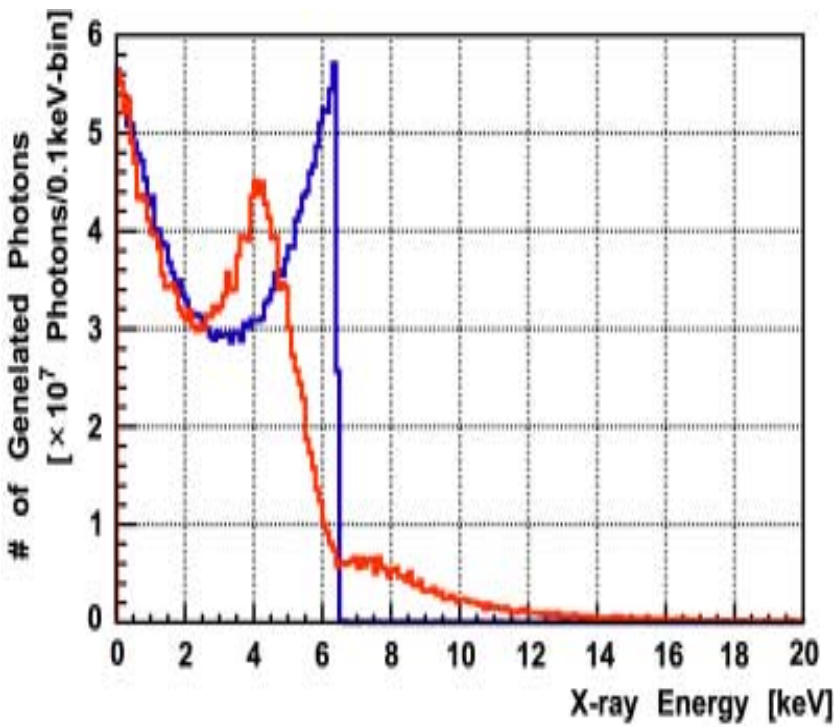
- Polarization measurement
- Conceptual design for JLC

Compton Chamber



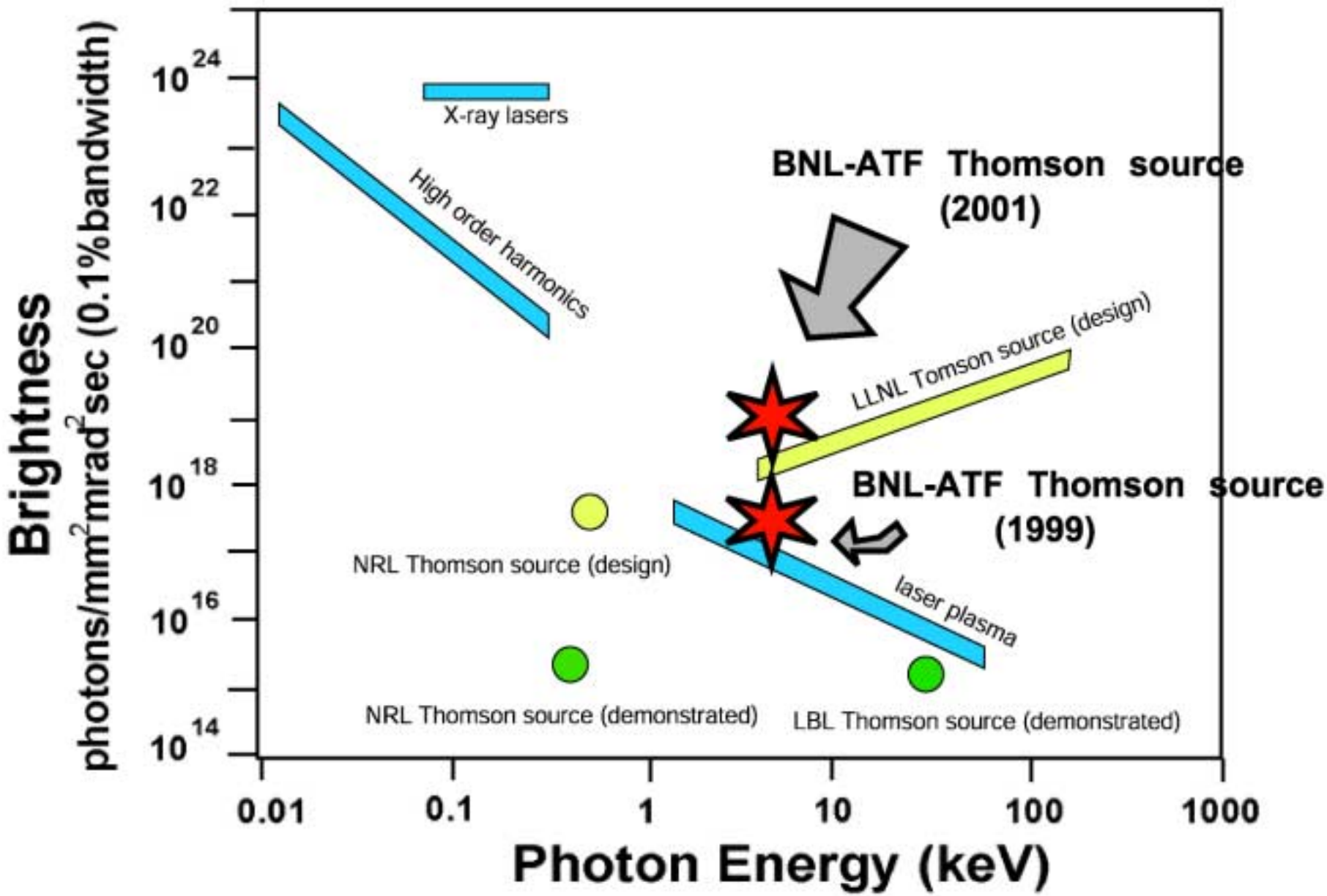
Experimental Result



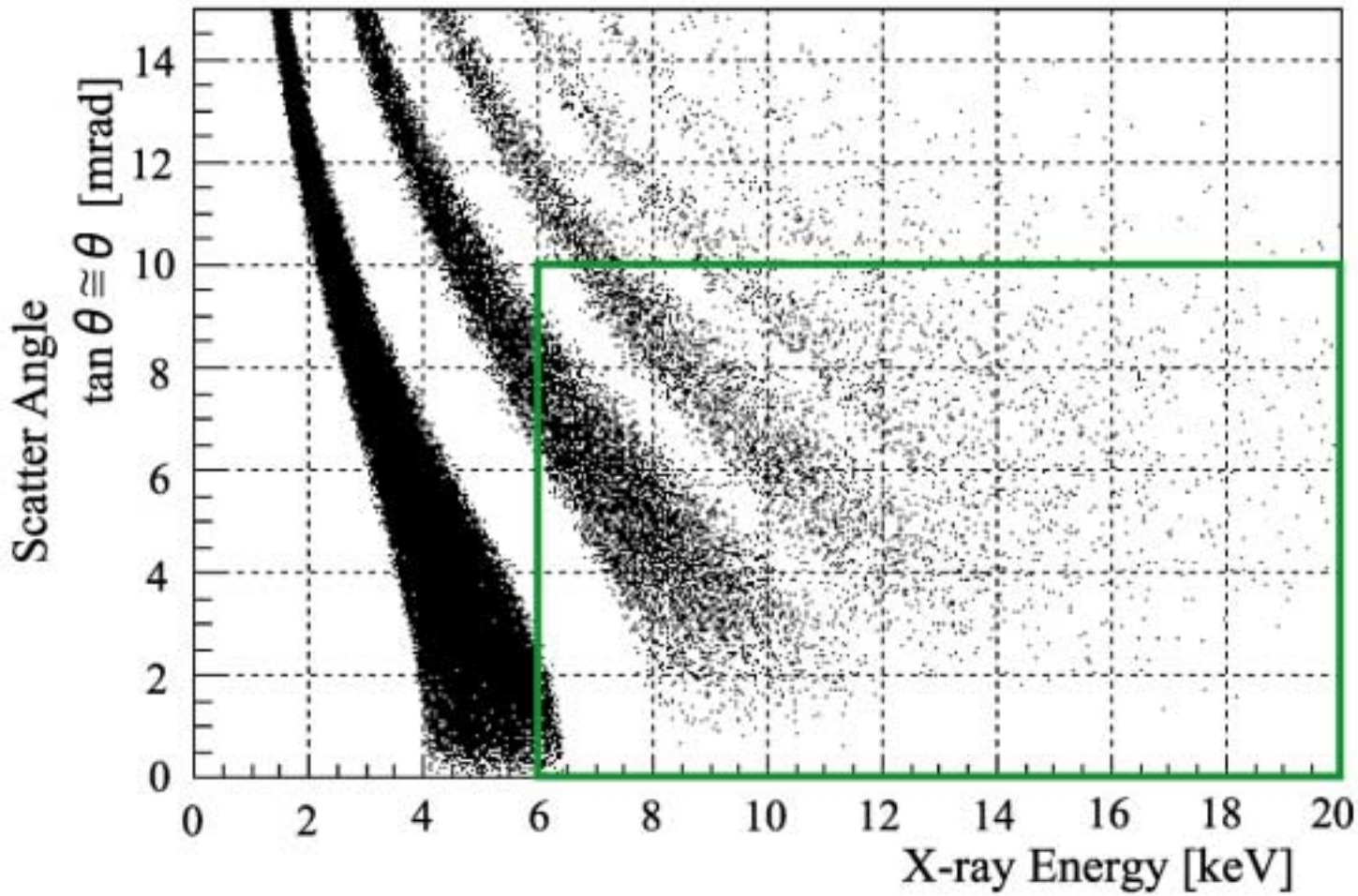


A: 3J, 200ps, 15GW $\Rightarrow$ $a = 0.05$

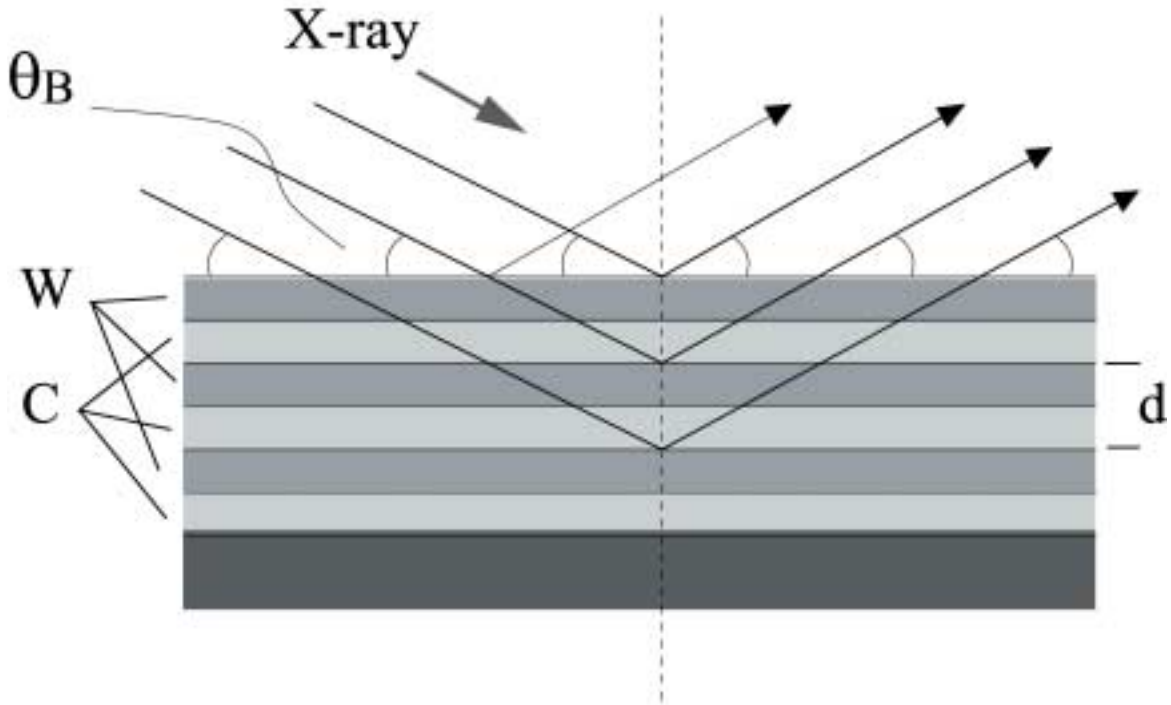
B: 3J, 3ps, 1TW $\Rightarrow$ $a = 1.09$


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)

Simulation by CAIN



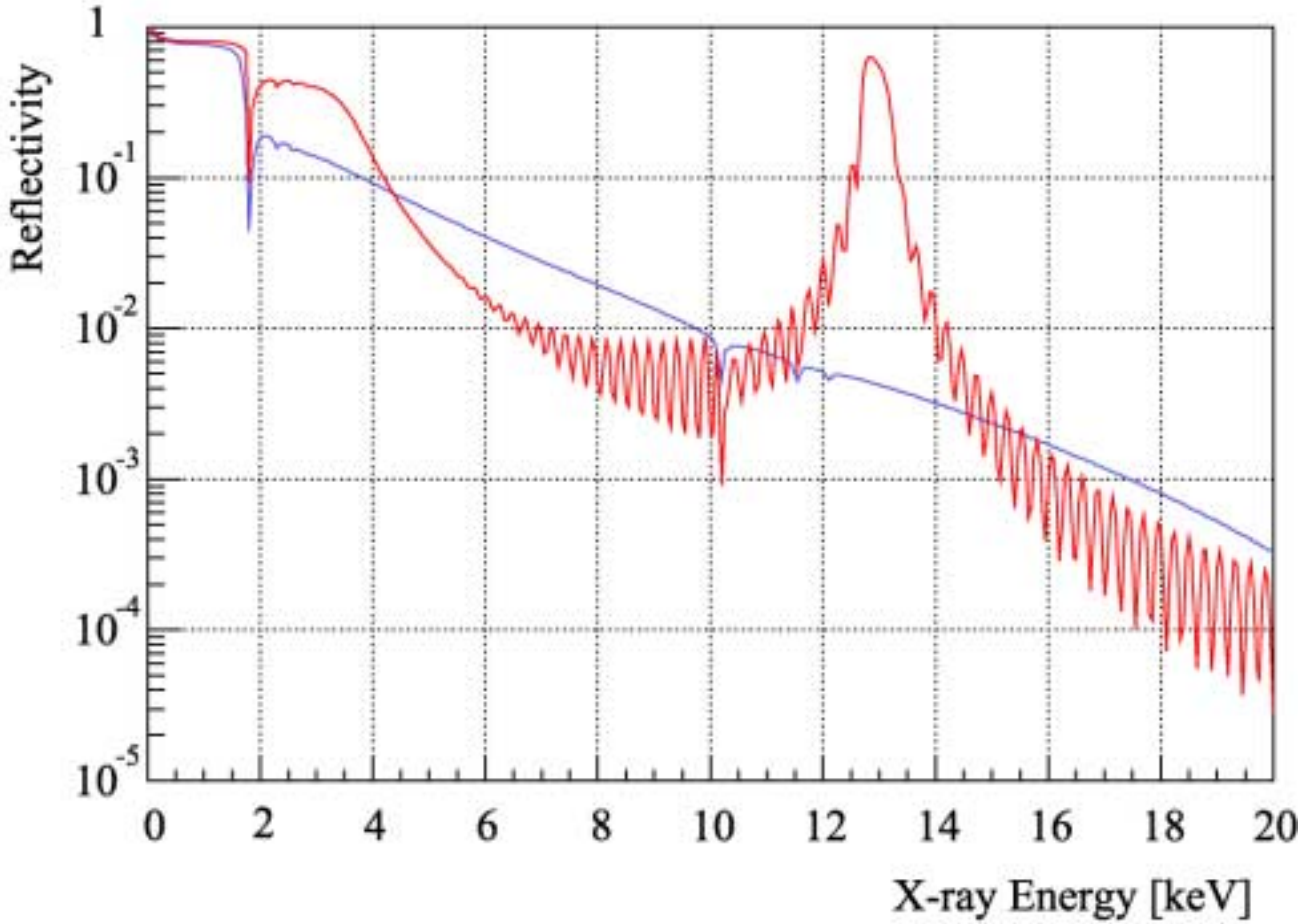
Multilayer Crystal



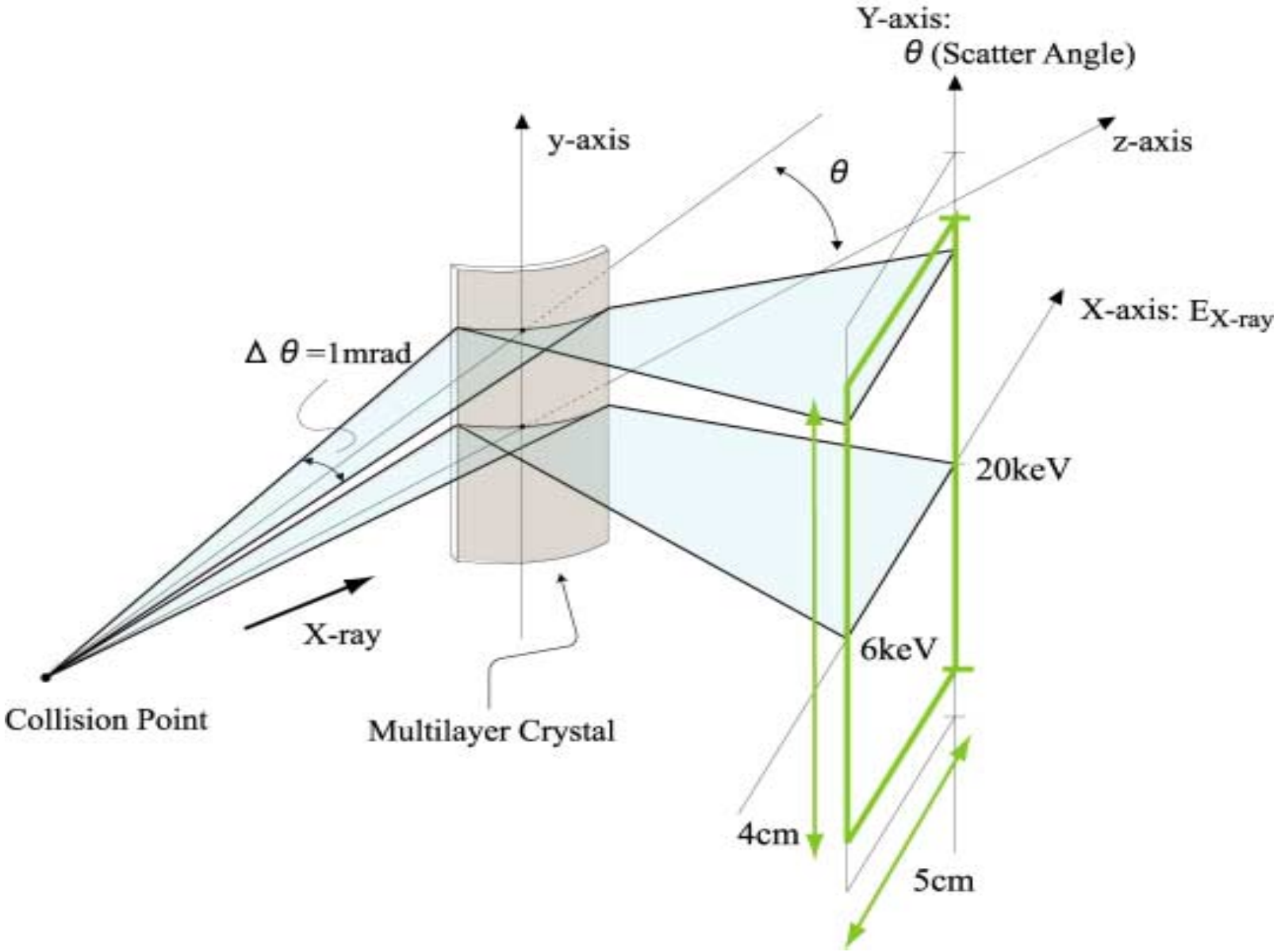
45 layers of W/C (d=30A)

$$\sin\theta_B = n \cdot \frac{0.207}{E_{X-ray}\,[keV]}$$

Reflectivity of Multilayer Crystal



45 layers 1 layer


Y-axis:
θ (Scatter Angle)
y-axis
z-axis
θ
X-axis: $E_{X\text{-}ray}$
Δ θ =1mrad
20keV
6keV
X-ray
Collision Point
Multilayer Crystal
4cm
5cm

JLC e^+ beams : exceptionally high intensity

$$10^{10}\ e^+ / bunch$$

High energy laser beam: 10J

Nonlinear Compton process

Diminish the e+ polarization

$\Downarrow$

High intensity and high polarization

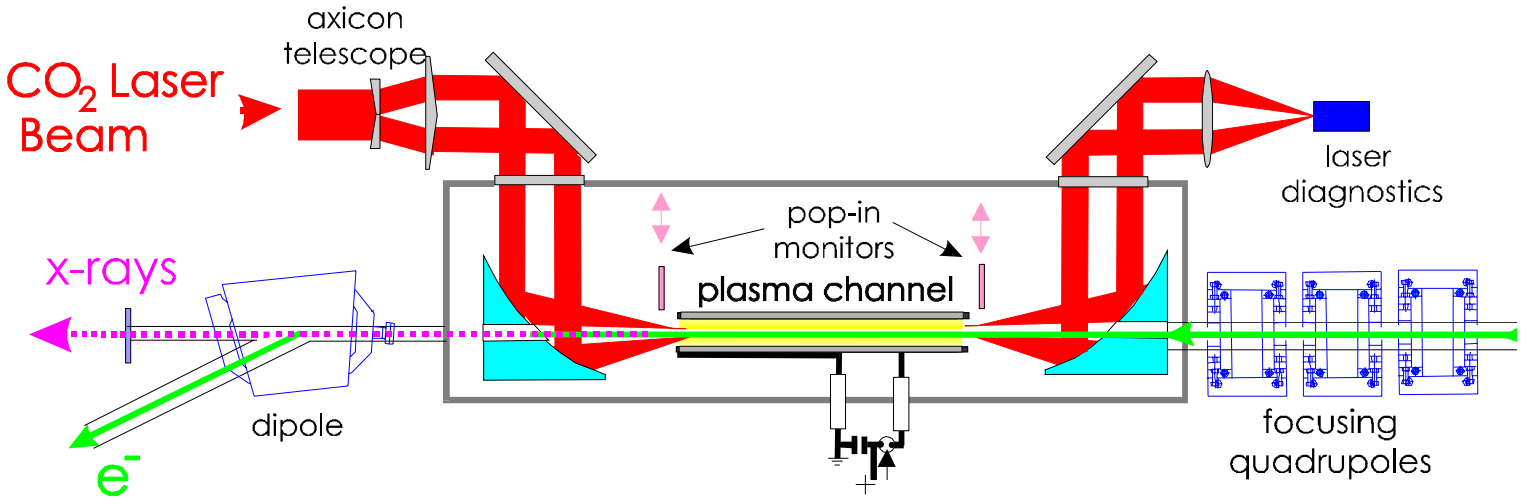
$\Downarrow$

Relatively low energy laser beam

Extend interaction distance

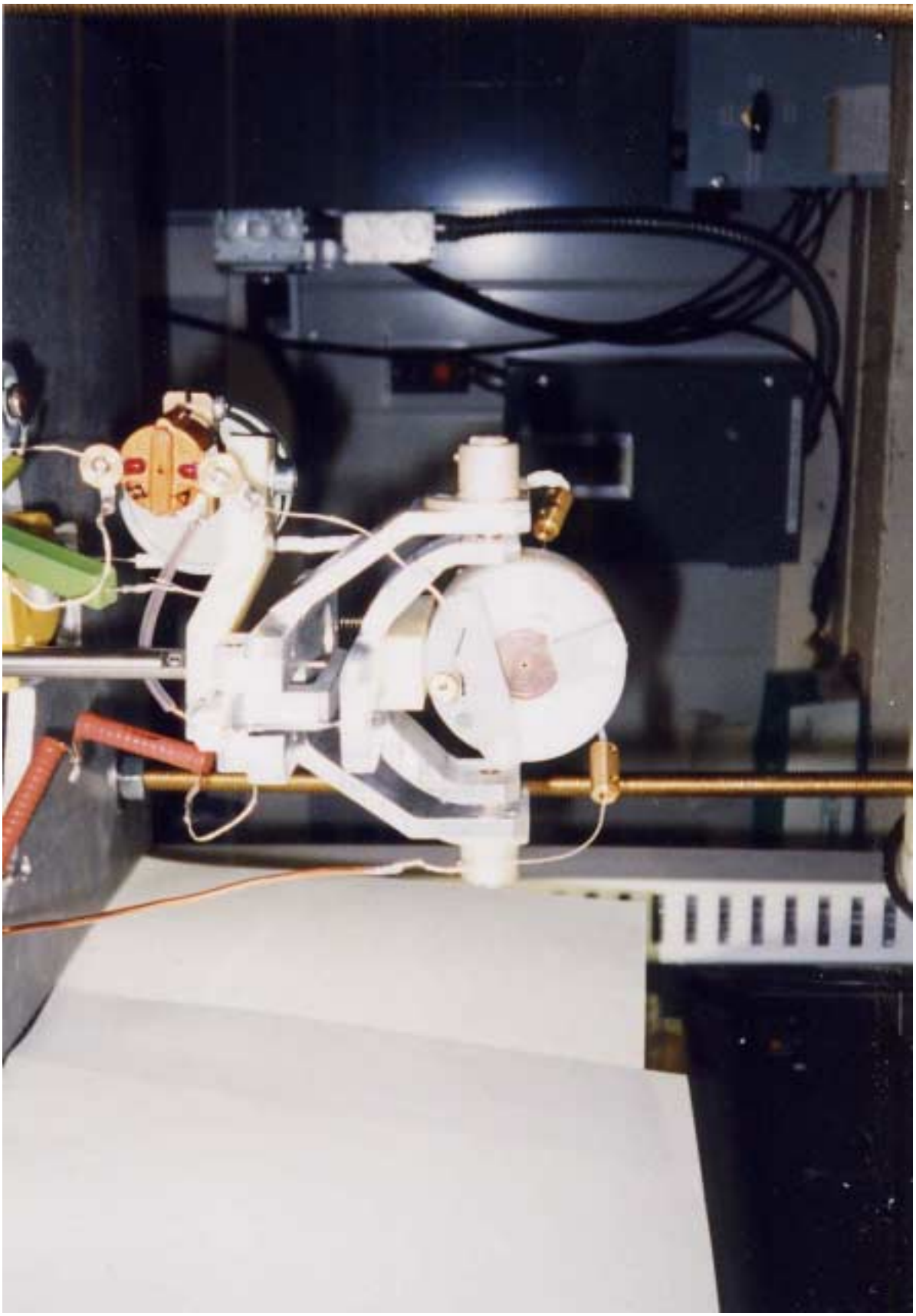
$\Downarrow$

Plasma Channel

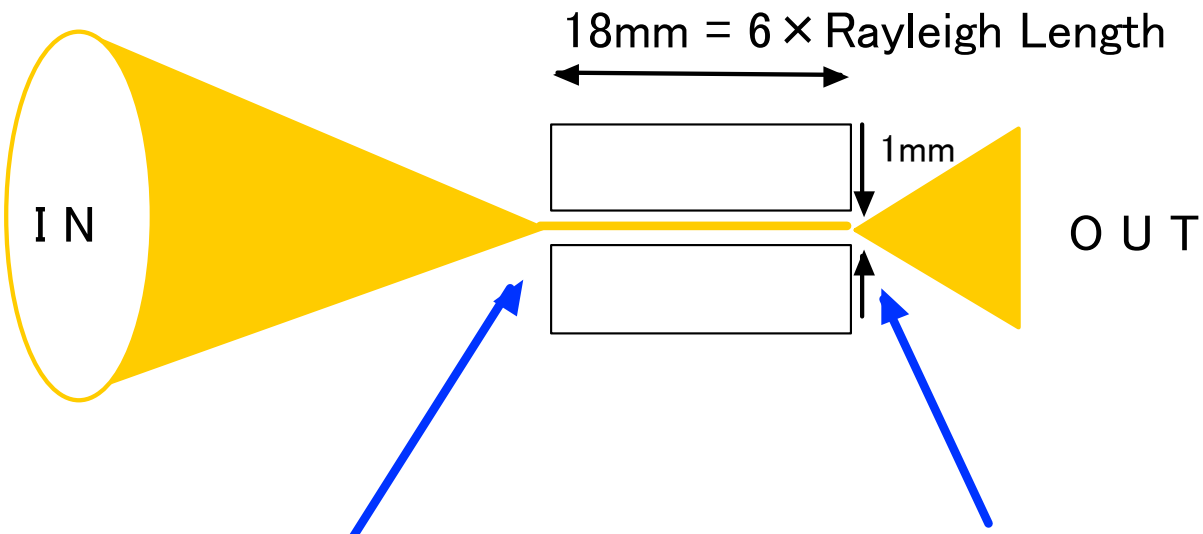


$$n_{cr} = \frac{\pi m c^2}{e^2 \lambda^2}$$

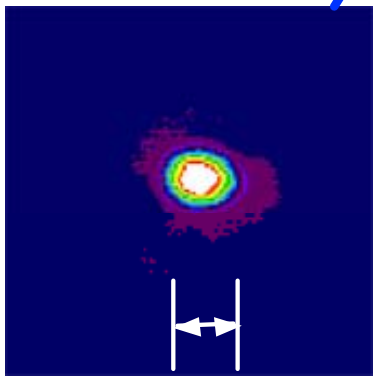
$$n_{cr}(CO_2) \approx 10^{19} / cm^3 \approx \frac{1}{100} n_{cr}(YAG)$$



Transportation of CO_2 Laser through the Plasma Capillary

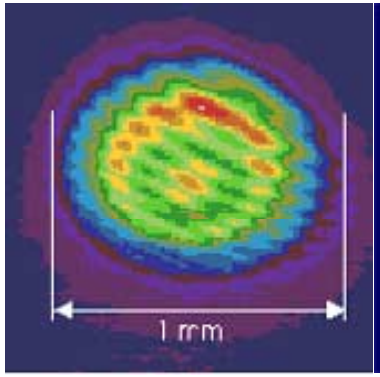


Focal Point

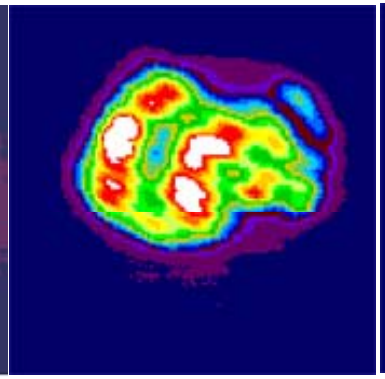


0.15mm (FWHM)

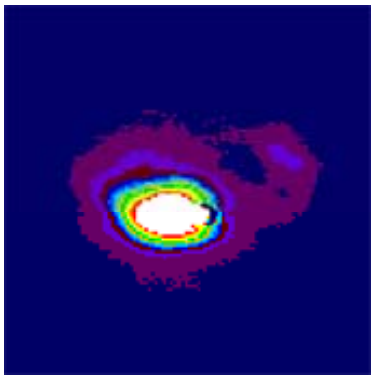
w/o Capillary



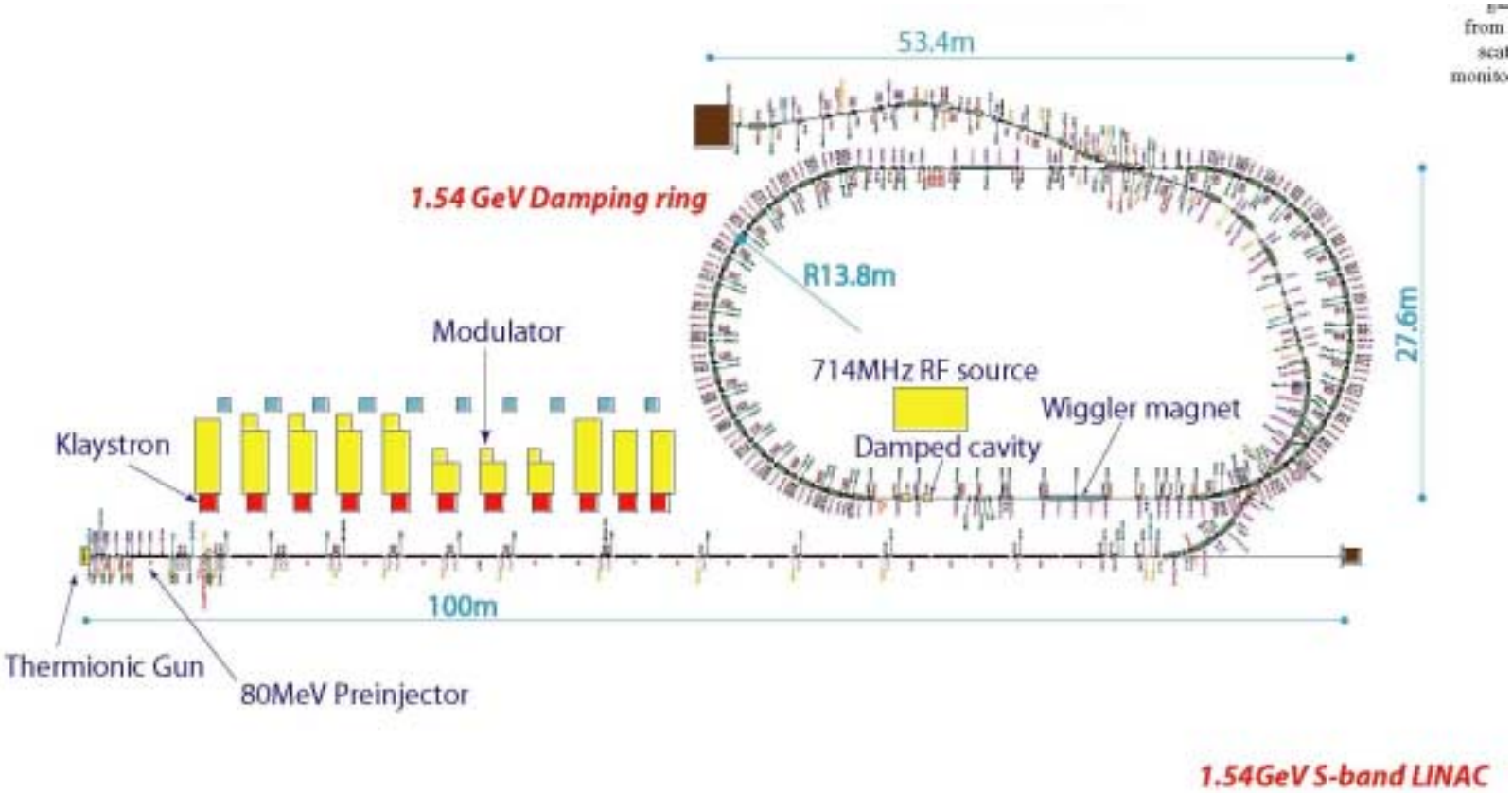
with Capillary
w/o Plasma



with Plasma

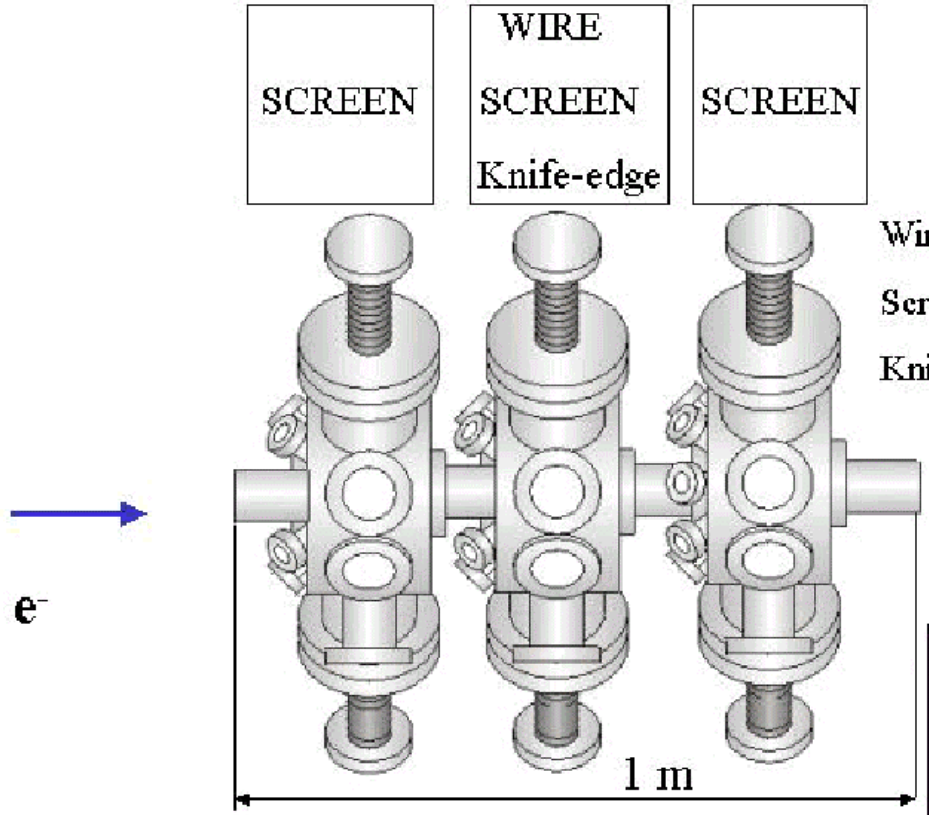


High Energy Accel. Research Organization (KEK)



Accelerator Test Facility for LC

New Compton Chamber



Wire : electron beam size

Screen : position

Knife-edge : laser size

Laser

Nd:YAG

λ = 532 nm

I = 400mJ/pulse

Beam Size [μm]				
σ_{e^-}		20		
σ_{laser}	265	130	265	

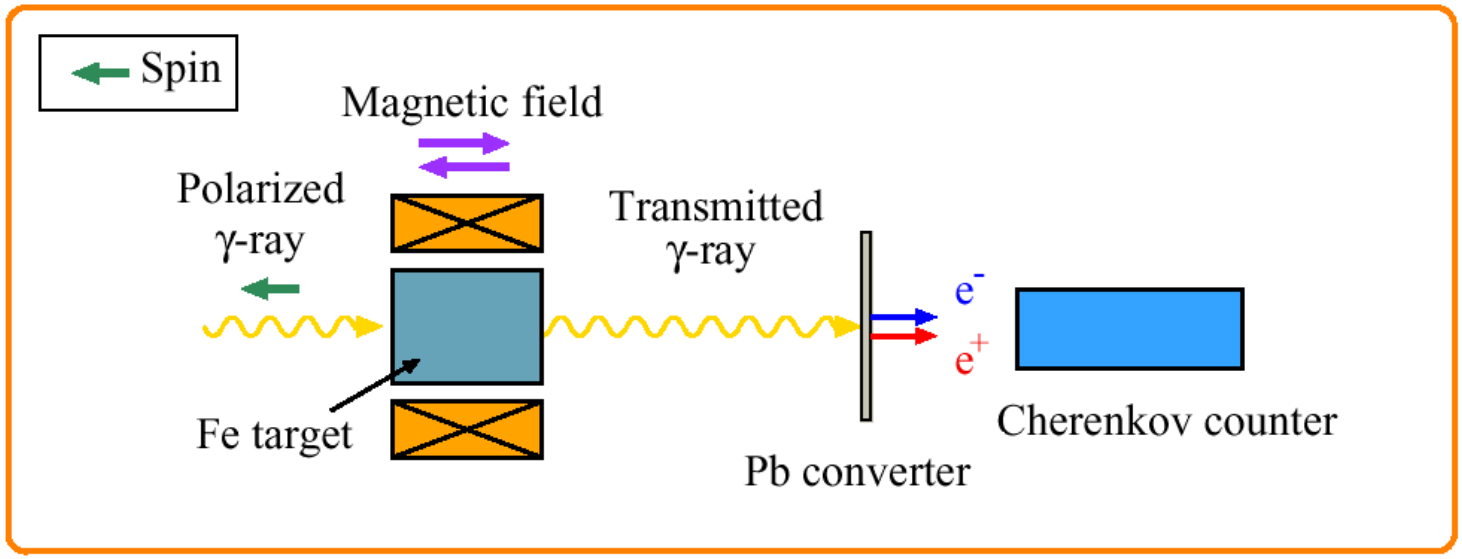
γ-ray Polarization Measurement

Cross section of Compton scattering

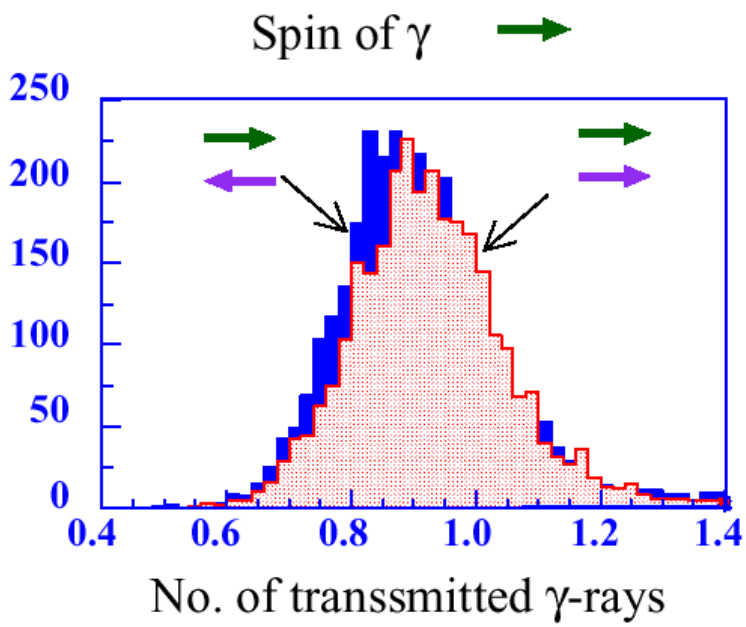
$$(\sigma_{comp}(\uparrow\uparrow) < \sigma_{comp}(\uparrow\downarrow))$$

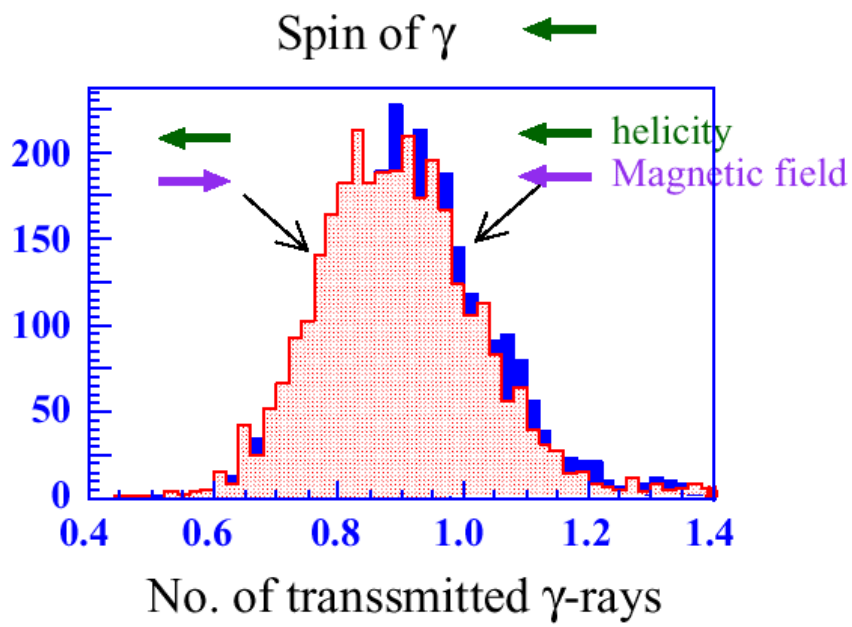
$$\Downarrow$$

Transmission depends on the direction of the magnetic field



Measured Asymmetry





A = 1.0 ± 0.2 %

A = -0.9 ± 0.2 %

(Error: statistical)