

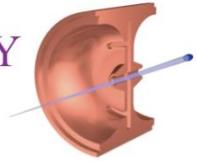
# Experimental Polarization Control of Thomson Scattering X-ray Source

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Aug. 30, 2017

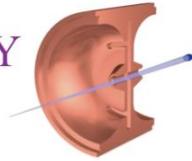




# Outline

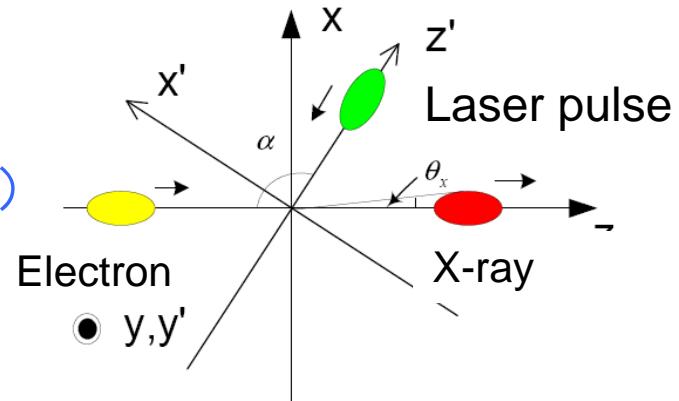
- Background
- Experiment
  - Simulation
  - Data collection
  - Data processing
- Summary





# Background

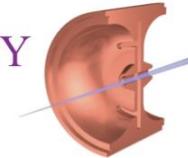
- Thomson Scattering Process
  - Interaction between photon and electron
  - Photon energy  $\ll$  electron energy (MeV)
- Features
  - Short pulse, high brightness, quasi monochromatic, wavelength continuously tunable(keV~MeV), polarization controllable.
- Application prospects
  - Life Science, biophysics, nuclear physics, X-ray polarization detector calibration and so on.



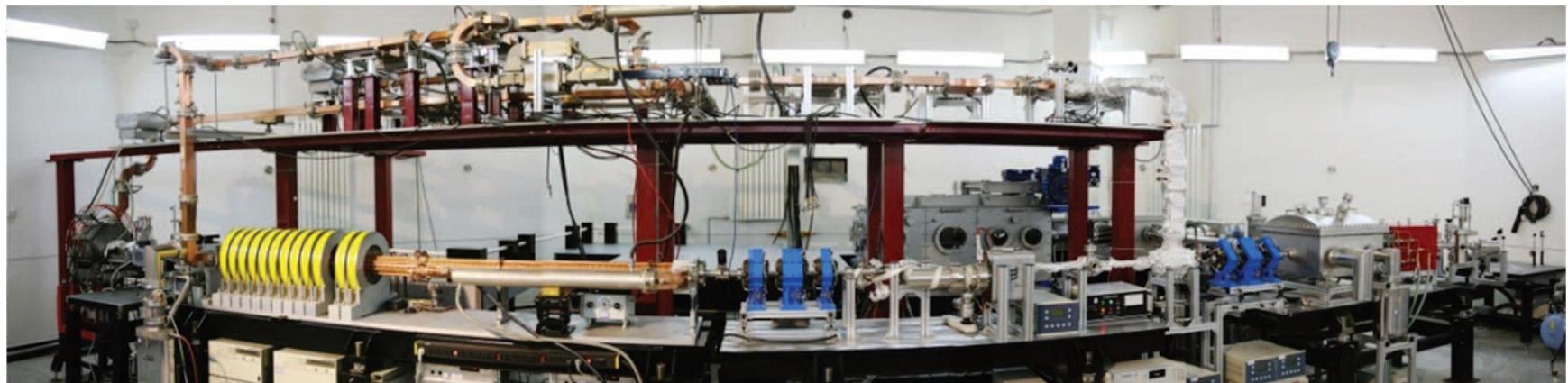
$$\frac{d\sigma}{d\Omega} = r_e^2 \frac{1-\beta^2}{(1-\beta\cos\theta)^2} \left[ 1 - \frac{\sin^2\theta \cos^2\phi}{\gamma^2(1-\beta\cos\theta)^2} \right]$$

$$\vec{E} = \frac{q}{4\pi\epsilon_0 c^2 r} \frac{\vec{e}_r \times \vec{e}_r \times \dot{\vec{v}}}{\left( 1 - \frac{\vec{v} \times \vec{e}_r}{c} \right)^3}$$

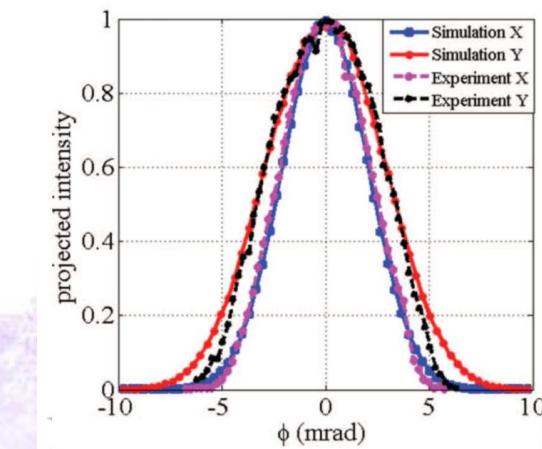
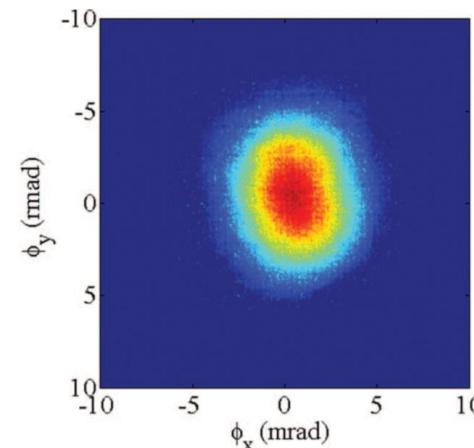
Radiation by moving charges

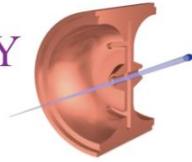


# Background



Parameters	
Photon energy/ keV	~50
Electron energy/ MeV	46.7
Laser wavelength/ nm	800
Count/per pulse	$\sim 10^7$





# Experiment Design

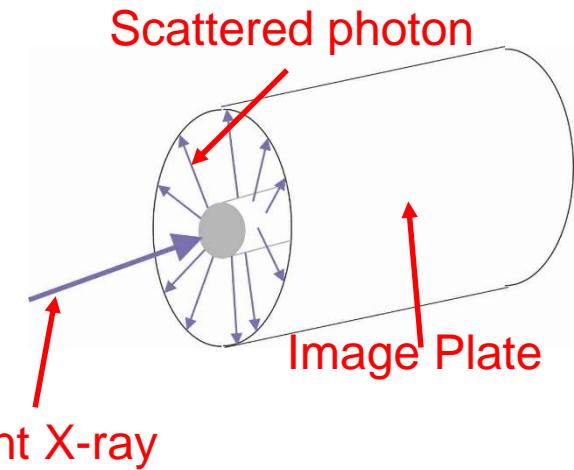
- Polarization measurement methods
  - Photoelectric effect: Soft X-ray
  - Compton scattering effect: Hard X-ray or Gamma ray
- Cross section of Compton scattering—Klein-Nishina formula

$$\frac{d\sigma}{d\Omega} = r_e^2 (1 - \sin^2 \theta \cos^2 \phi)$$



$$\frac{d\sigma}{d\Omega} = r_e^2 \left( 1 - \sin^2 \theta \frac{\cos^2 \phi + a \sin^2 \phi}{a+1} \right)$$

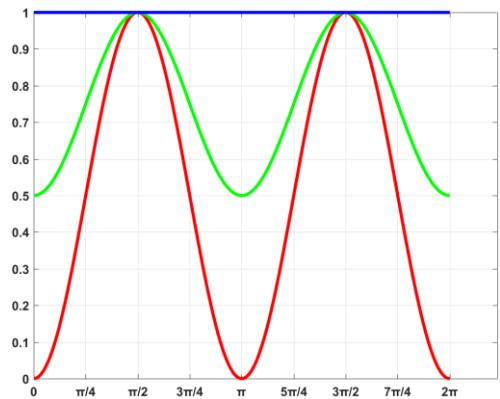
- The cross section distribution is depended on factor  $a$
- $a$ : the ratio of  $E_x$ 、 $E_y$
- The distribution of scattered photons in space → X-ray polarization



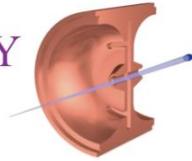
Incident X-ray

Scattered photon

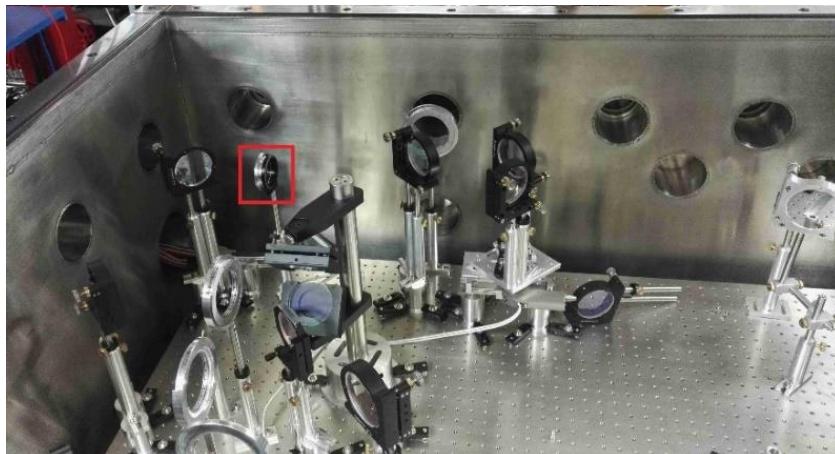
Image Plate



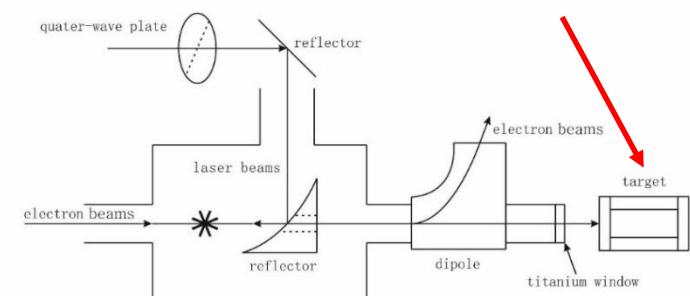
θ=90°



# Experiment Design

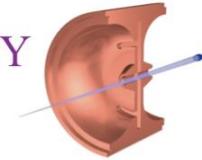


Quarter-wave plate



Target



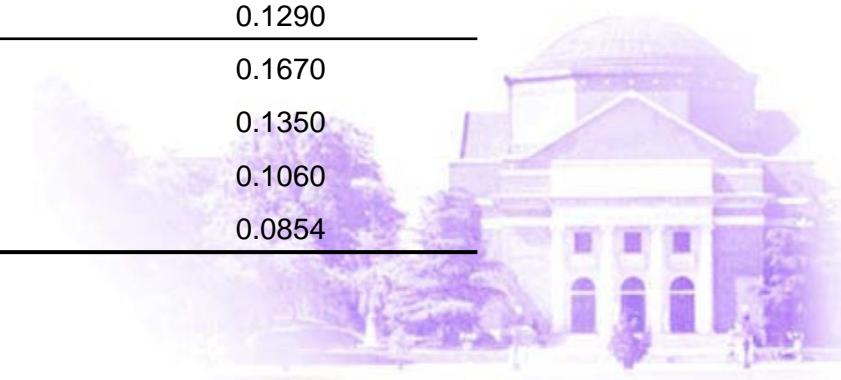


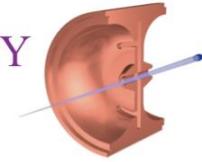
# Experiment Design

## Absorption / Compton scattering cross section

Photon energy	Material	Absorption (cm <sup>2</sup> /g)	Compton scattering (cm <sup>2</sup> /g)
50keV	PE	0.0089	0.1880
	C	0.0104	0.1630
	Al	0.1720	0.1500
	Fe	1.7000	0.1360
30keV	PE	0.0489	0.1930
	C	0.0571	0.1650
	Al	0.8720	0.1460
	Fe	7.7600	0.1290
10keV	PE	1.7800	0.1670
	C	2.0800	0.1350
	Al	25.6000	0.1060
	Fe	169.0000	0.0854

PE: Polyethylene





# Experiment Design



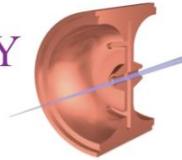
Target material: Polyethylene

Size: radius 1.5-cm, height 6-cm

Aluminum Ring: Inner radius 1.5-cm, outer radius 5-cm, thickness 0.5-cm

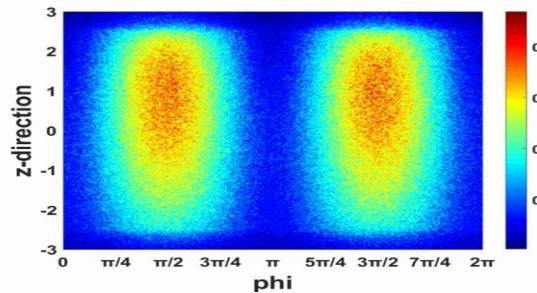
Record scattered photons with image plate



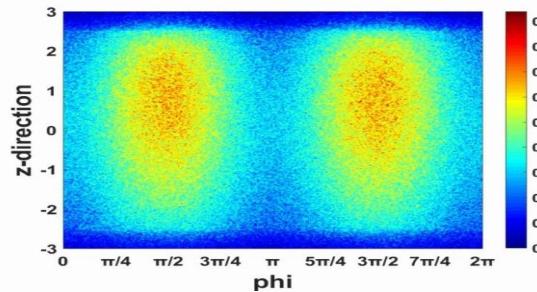


# Simulation

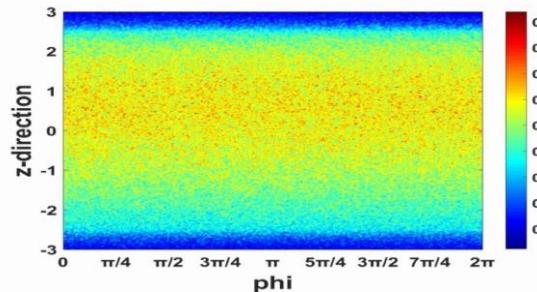
- Geant4: a toolkit for the simulation of the passage of particles through matter
- Initialize X-ray polarization
  - PrimaryGenerator.cc source files
  - Define the polarization of incident X-ray
- Scattered photons of simulated results by Geant4



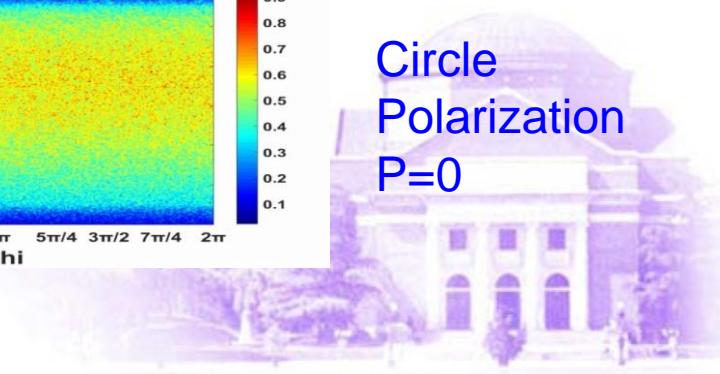
Linear  
Polarization  
 $P=1$

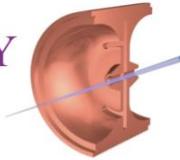


Elliptical  
Polarization  
 $P=0.5$

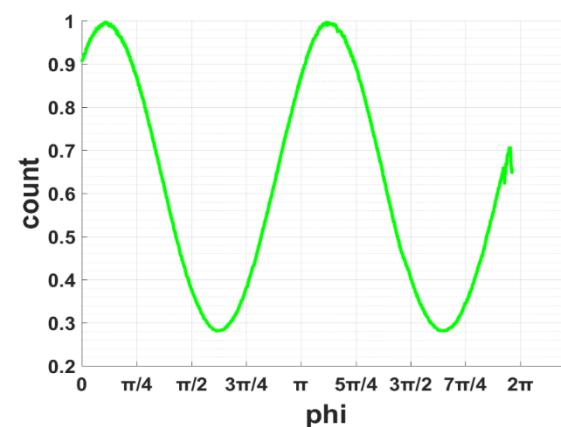
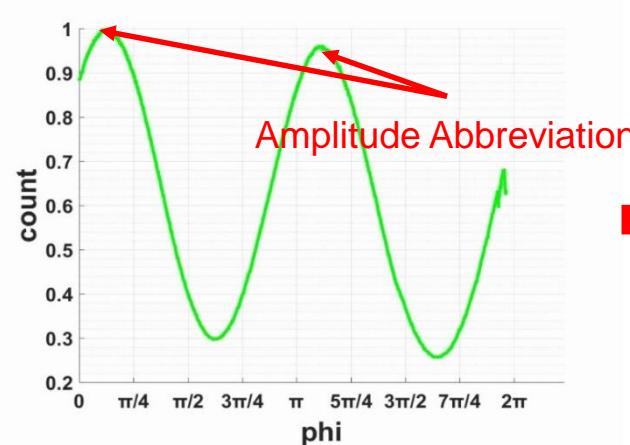
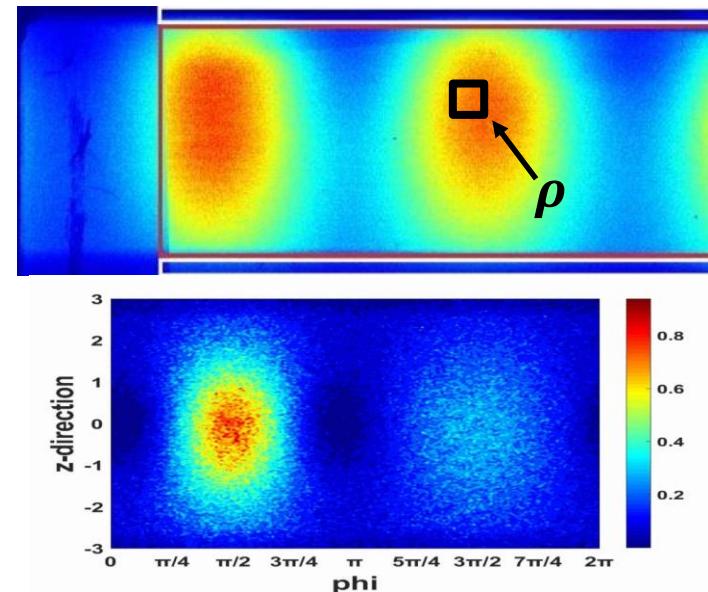
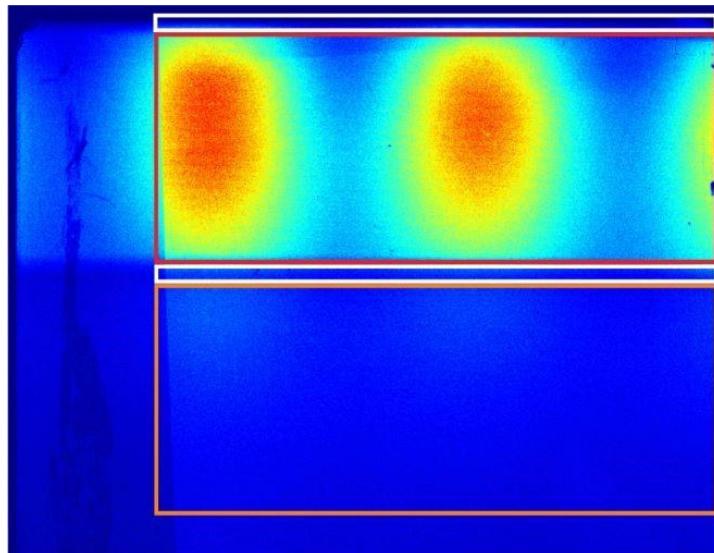


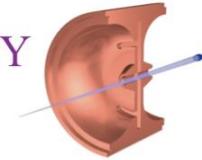
Circle  
Polarization  
 $P=0$



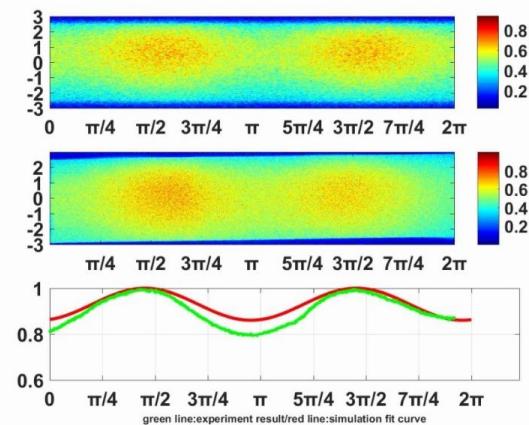
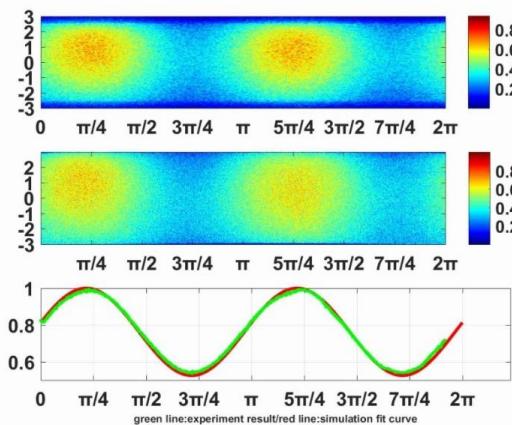
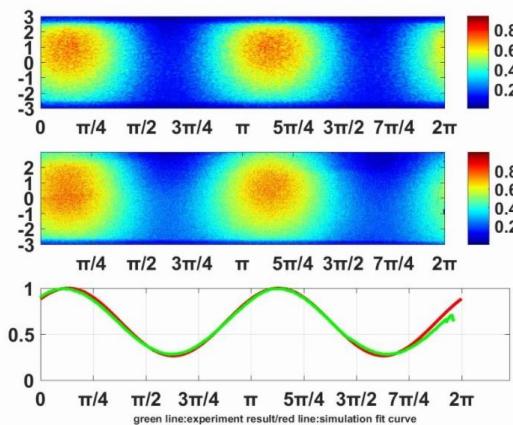


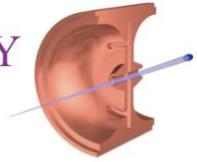
# Experiment Results



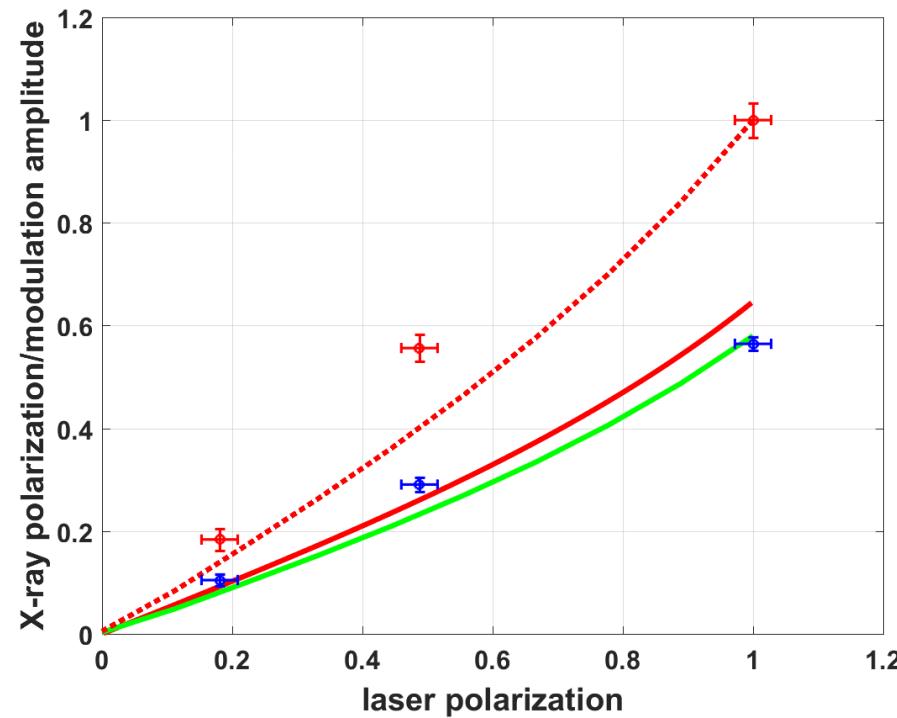


# Experiment Results





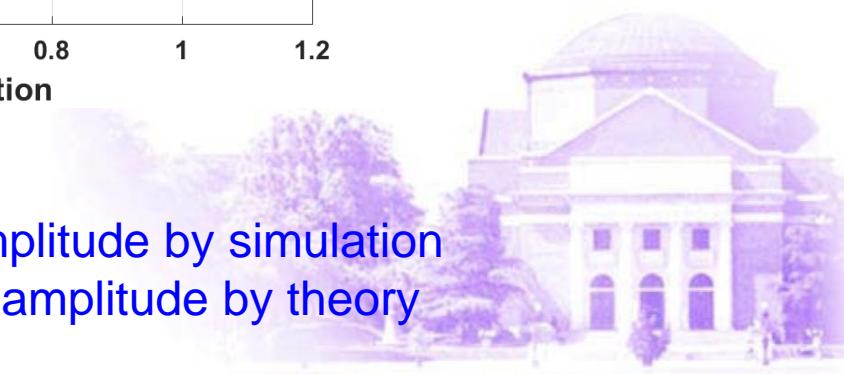
# Experiment Results

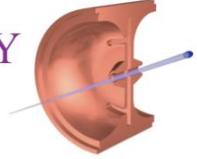


Dotted line: Polarization

Red solid line: modulation amplitude by simulation

Green solid line: modulation amplitude by theory





# Summary

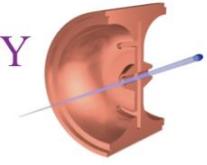
- Measure the polarization of Thomson Scattering X-ray source
- TTX experiment platform, experiment design, target material
- Mont carol simulation by Geant4
- The polarization of Thomson Scattering X-ray source is controllable and tunable





清华大学  
Tsinghua University

ACCELERATOR LABORATORY  
*of* TSINGHUA UNIVERSITY



Thanks !

