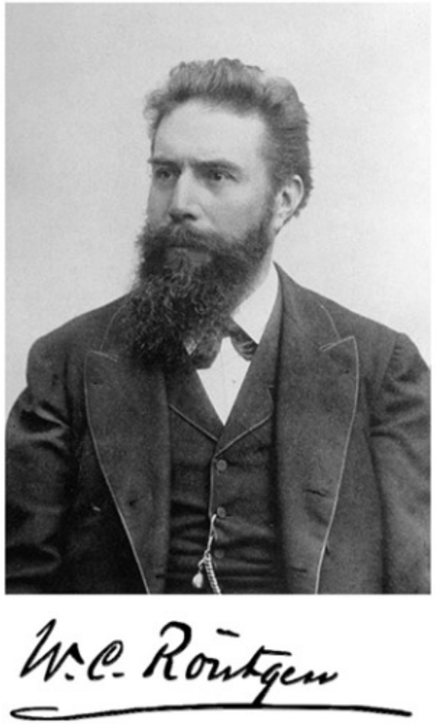
Applied physics innovations from the SBS project

B. Wojtsekhowski

- High accuracy magnetic compass
- Method of a sharp imaging CT scan

Roentgen (X-ray) technology since 1895



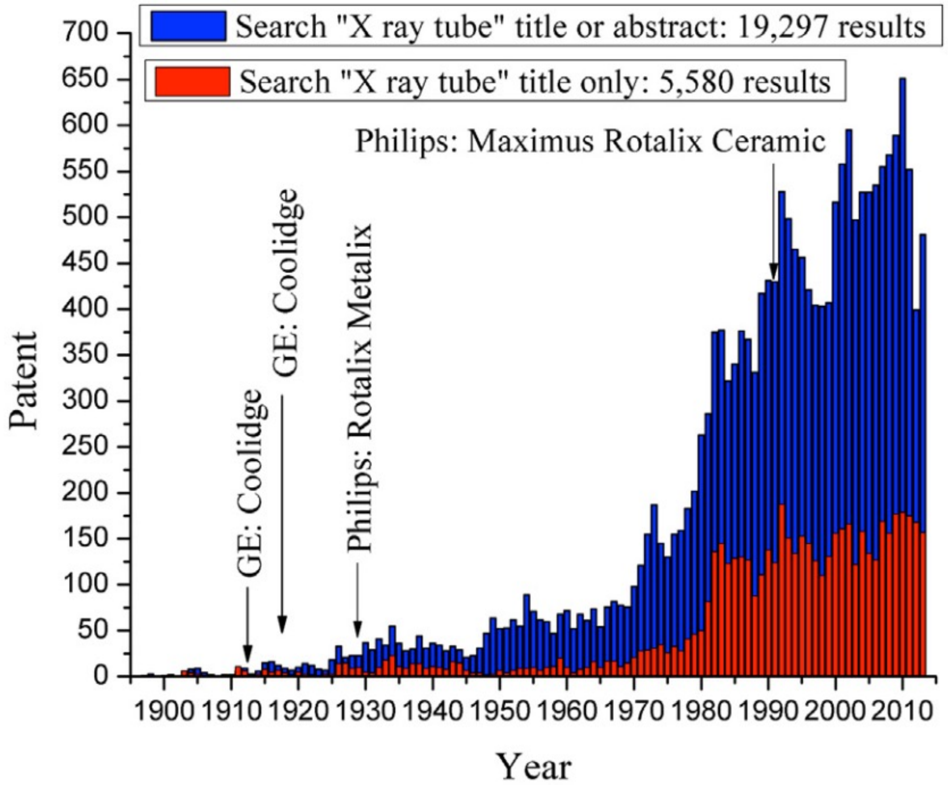


Image of a body in 3D

Photo from the Nobel Foundation archive.

Allan M. Cormack

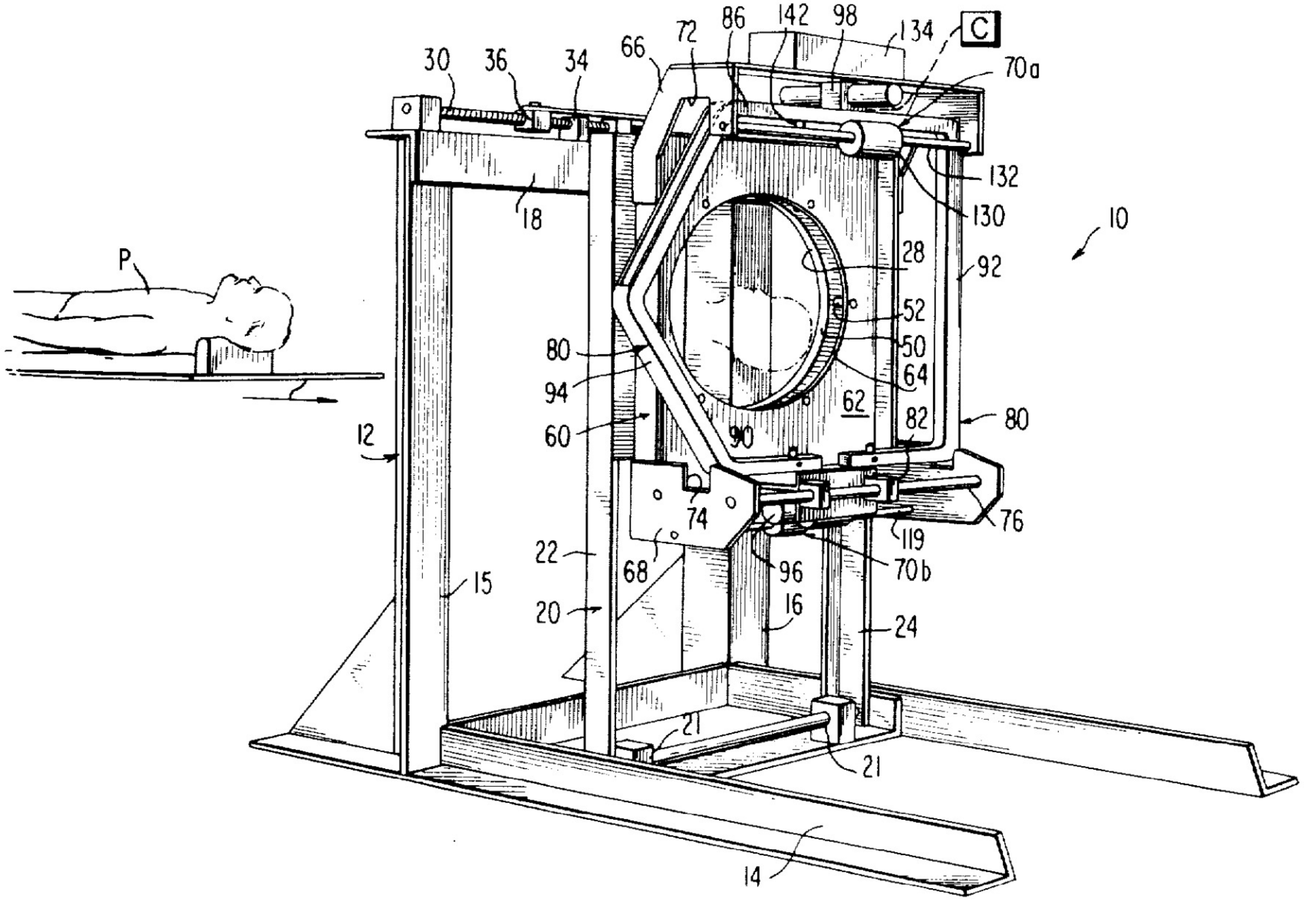
Prize share: 1/2

Photo from the Nobel Foundation archive.

Godfrey N. Hounsfield

Prize share: 1/2

The Nobel Prize in Physiology or Medicine 1
awarded jointly to Allan M. Cormack and Gc
Hounsfield "for the development of comput
assisted tomography"



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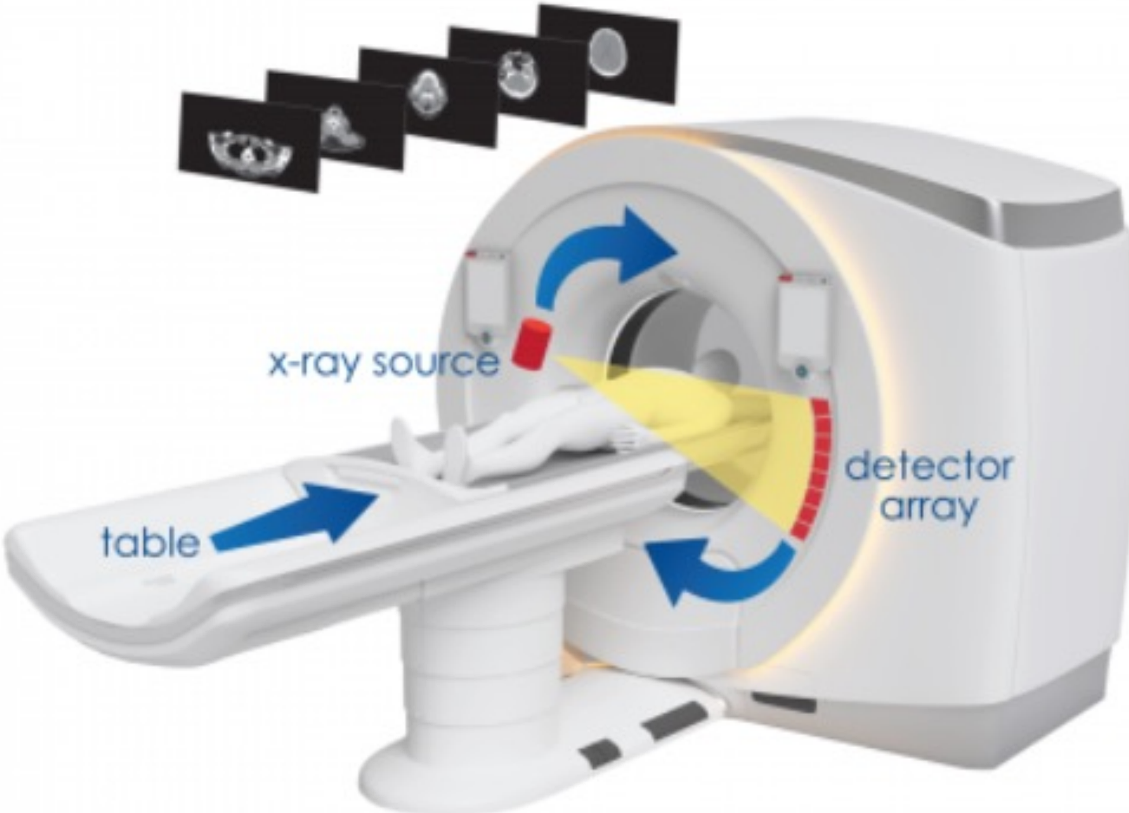
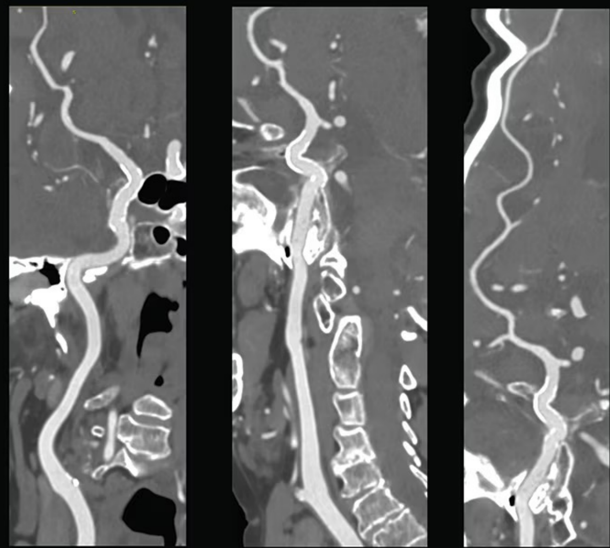


Image of a body in 3D

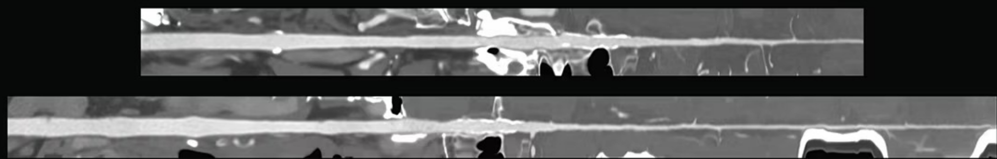
IMAGES COURTESY OF SAINT JOSEPH HOSPITAL – PARIS, DR. ZINS – FRANCE

Scan type	Helical 40mm
Rotation time, s	0.35
Pitch	0.984:1
Slice, mm	0.625
Reconstruction	DL-H
Algorithm	Standard
kV	120
mA	Mod.
CTDIvol, mGy	11
DLP, mGy-cm	330

Volume Illumination
TrueFidelity



TrueFidelity



Radiation dose in a CT-scan

CT scans deliver significantly higher X-ray intensities (and radiation doses) compared to conventional X-rays, with effective doses typically ranging from 1-10 mSv per scan. A single CT scan can equal the radiation dose of 50-450 chest X-rays, with doses highly dependent on protocol, body part, and patient

- **0.5 Sv (500 mSv):** Causes initial symptoms of radiation sickness.
- **1 Sv (1,000 mSv):** Causes sickness (nausea, vomiting), but generally not fatal.

Background Radiation: The average natural background radiation exposure for humans is approximately 0.0024–0.003 Sv (2.4-3 mSv) per year, which is over 1,000 times less than a lethal dose.

Long-term Effects: According to Wikipedia, 1 sievert (1,000 mSv) results in a 5.5% probability of eventually developing fatal cancer.

CT - large scale efforts

- Computerized Tomography has 100M scans per year in the US
- Primary technology used for several industrial fields
- 20 thousand related US patents
- Very large counting statistics is needed for a 3D object
- A new suggestion is a beam of polarized X-rays

X-ray interaction is mainly Compton physics

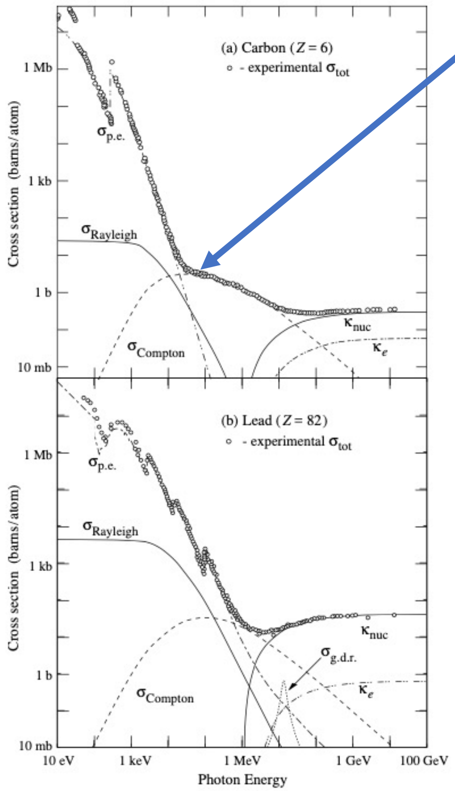


Figure 34.15: Photon total cross sections as a function of energy in carbon and lead, showing the contributions of different processes [50]:

X-rays

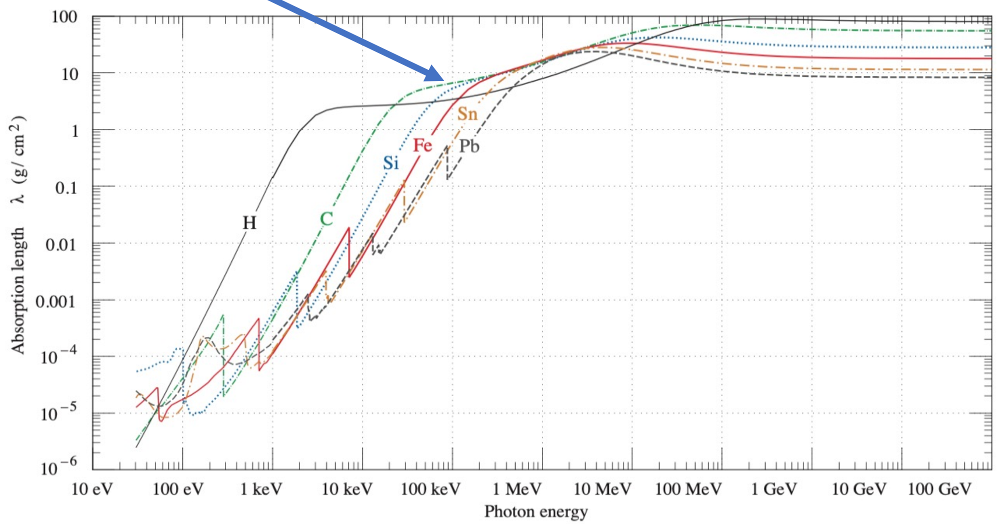


Figure 34.16: The photon mass attenuation length (or mean free path) $\lambda = 1/(\mu/\rho)$ for various elemental absorbers as a function of photon energy. The mass attenuation coefficient is μ/ρ, where ρ is the density. The intensity I remaining after traversal of thickness t (in mass/unit area) is given by $I = I_0 \exp(-t/\lambda)$. The accuracy is a few percent. For a chemical compound or mixture,

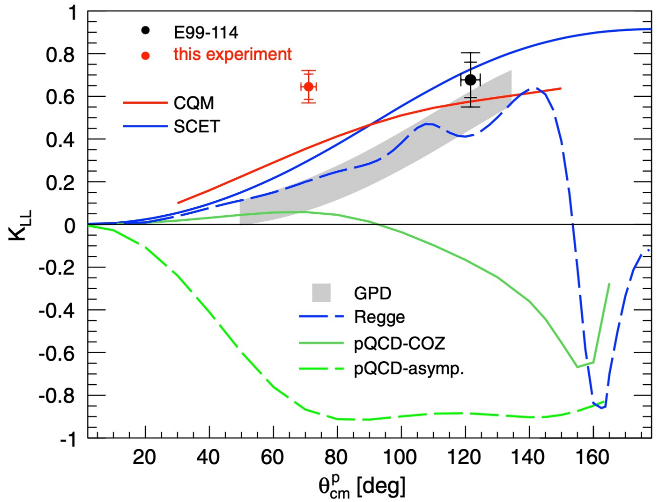
Compton physics at JLab: VCS, DVCS, WACS, Beam polarimetry

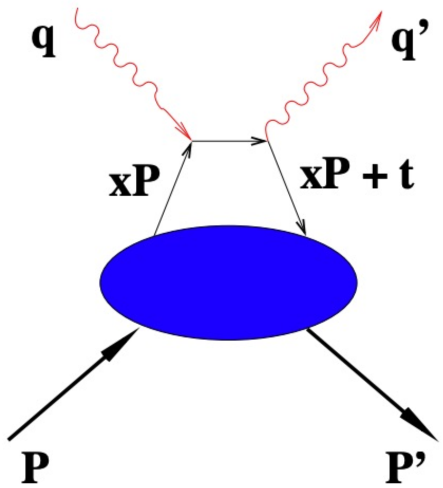
Polarization Transfer in Wide-Angle Compton Scattering and Single-Pion Photoproduction from the Proton

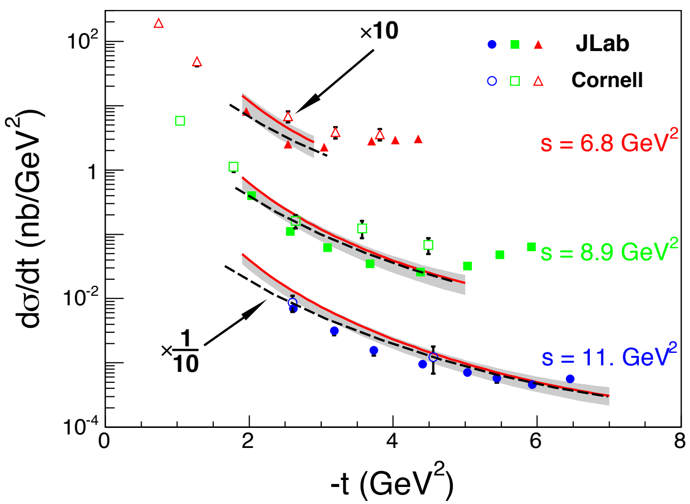
C. Fanelli[1,2], E. Cisbani[2], D. J. Hamilton[3], G. Salmé[1], B. Wojtsekhowski[4,*], A. Ahmidouch[5], J. R. M. Annand[3], H. Baghdasaryan[6], J. Beaufait[4] *et al.*

Compton-Scattering Cross Section on the Proton at High Momentum Transfer

A. Danagoulian[1], V. H. Mamyan[2,3], M. Roedelbronn[1], K. A. Aniol[4], J. R. M. Annand[5], P. Y. Bertin[6], L. Bimbot[7], P. Bosted[8], J. R. Calarco[9] *et al.* (Jefferson Lab Hall A Collaboration)



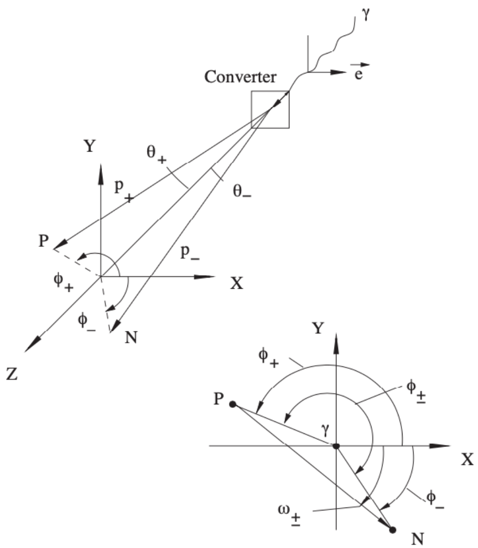




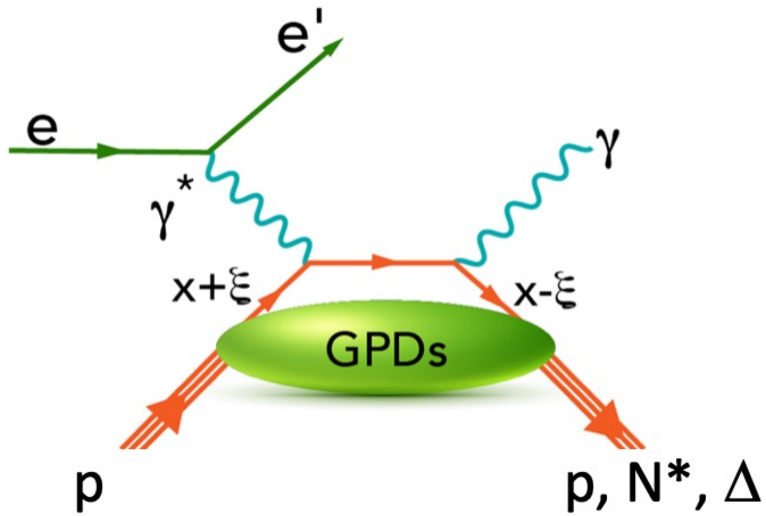
Compton physics at JLab: VCS, DVCS, WACS, Beam polarimetry

A pair polarimeter for linearly polarized high energy photons

C. de Jager[1], B. Wojtsekhowski[1], D. Tedeschi[2], B. Vlahovic[1,3], D. Abbott[1], J. Asai[4], G. Feldman[5], T. Hotta[6], M. Khadaker[7], H. Kohri[6], T. Matsumara[6], T. Mibe[6], T. Nakano[6], V. Nelyubin[1,2], G. Orielly[5], A. Rudge[8], P. Weilhammer[8], M. Wood[2], T. Yorita[6], and R. Zegers[9]



DVCS



Physics: DVCS photon polarimetry

Gluon tomography in nucleons by γ-polarimetry

Maxime Defurne

February 11, 2023

We propose to measure the degree of linear polarization of a photon produced by deeply virtual Compton scattering, never considered but rich in terms of new information about the proton structure. Indeed, the photon polarization is rigorously and straightforwardly related to the gluon transversity GPDs, still completely unknown today.

1 From gluon transversity GPDs to γ-polarization

1.1 A *simple* answer to: "Why γ-polarization?"

In deeply virtual Compton scattering (DVCS), a highly virtual photon is absorbed by the nucleon and the latter subsequently emits a high-energy real photon. At the partonic level, the process can be described by the diagrams presented in Figure 1. The process can be described in terms of helicity

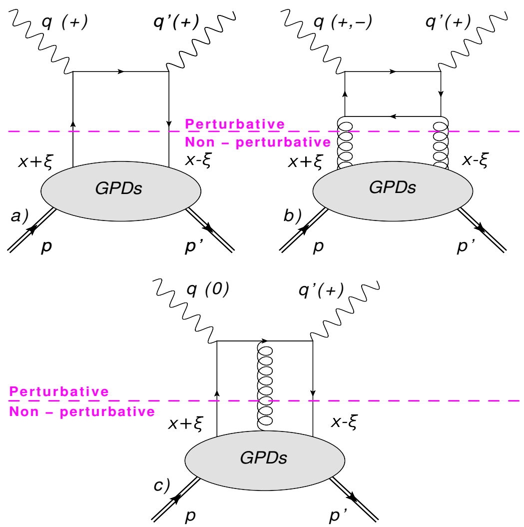
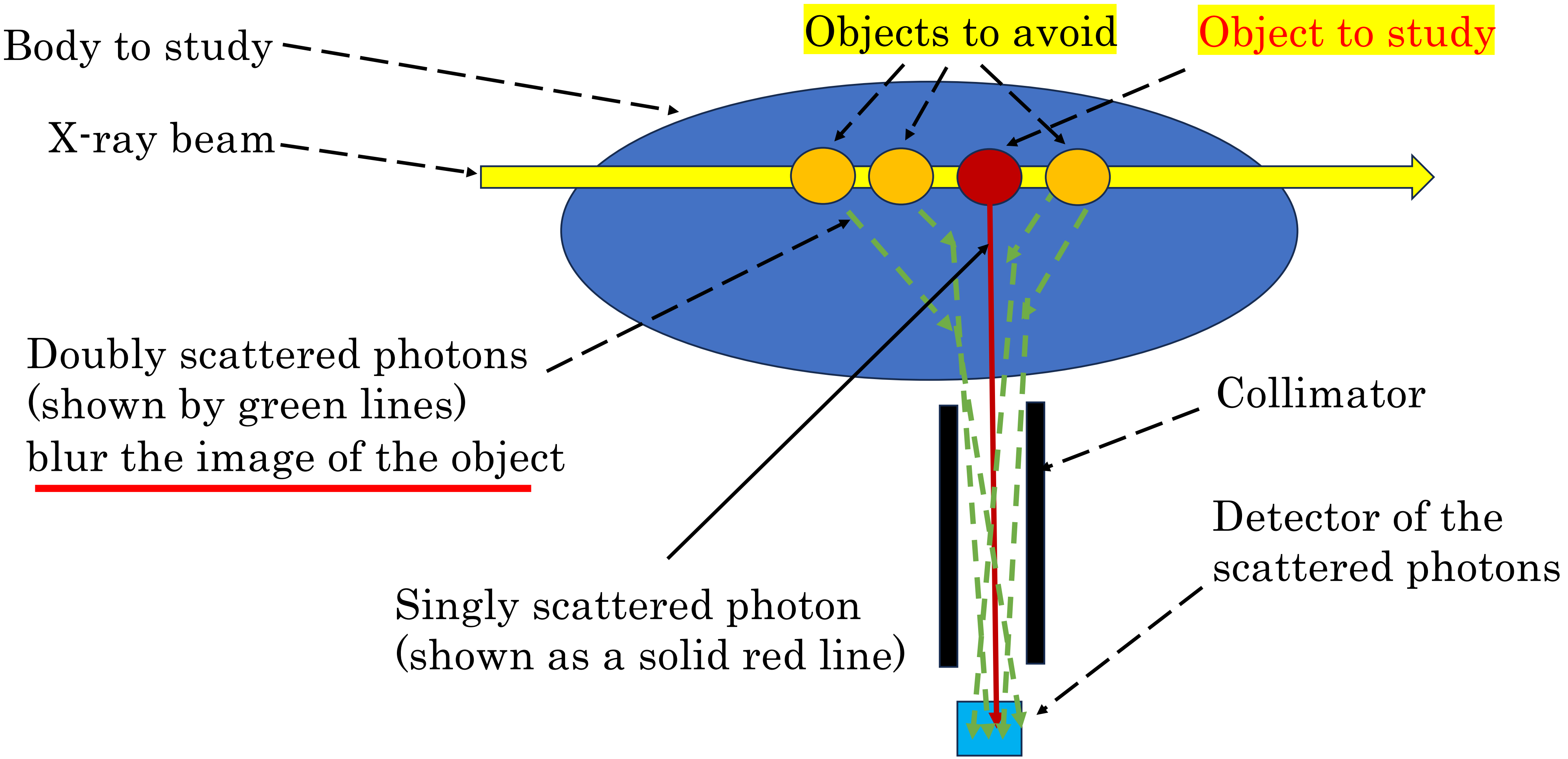
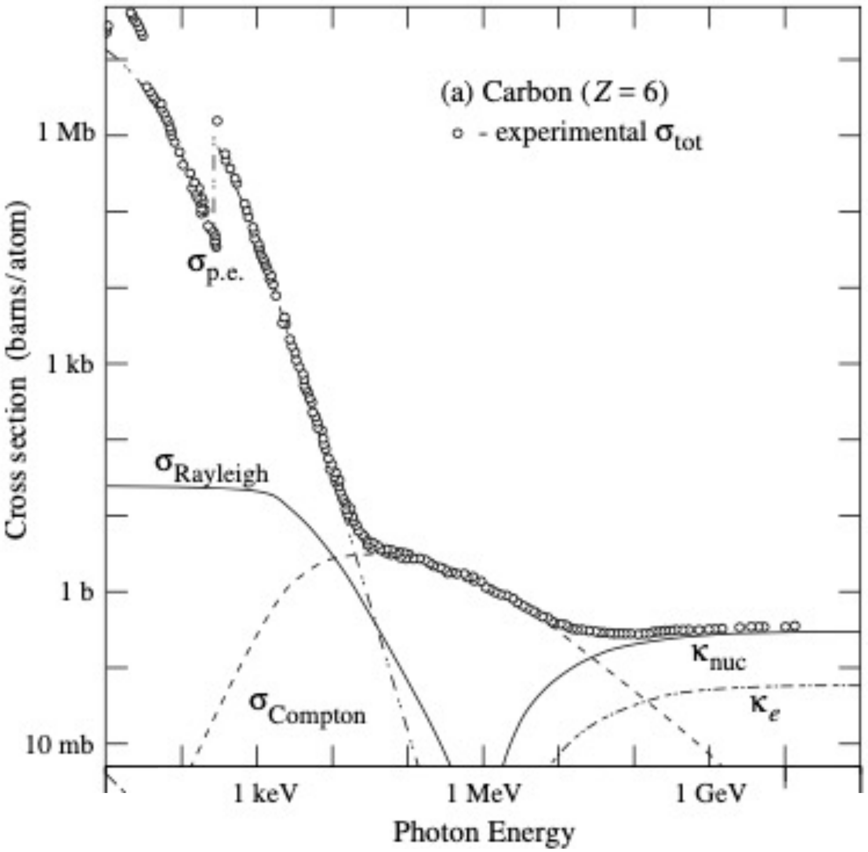
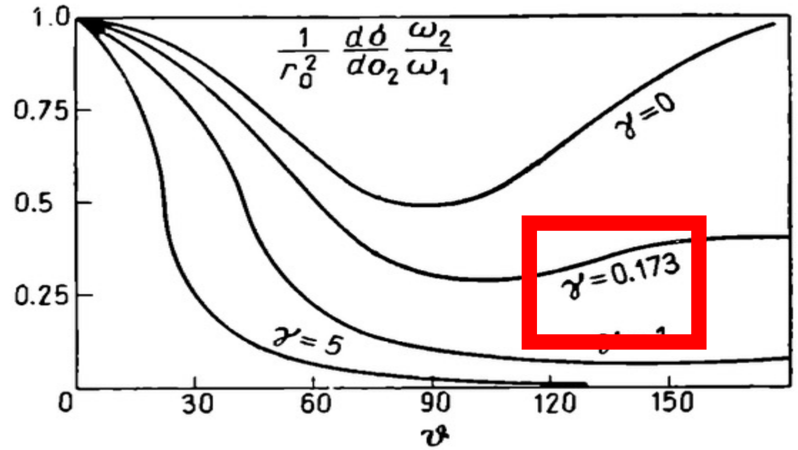


Illustration of the photon scattering in a sideways X-ray



Compton scattering physics (from an electron)





The Klein Nishina cross section:

$$\frac{d\sigma}{d\Omega} = \frac{1}{4} r_0^2 \frac{h\nu^2}{h\nu_0^2}\left[\frac{h\nu_0}{h\nu} + \frac{h\nu}{h\nu_0} - 2 + 4\cos^2\Theta\right]$$

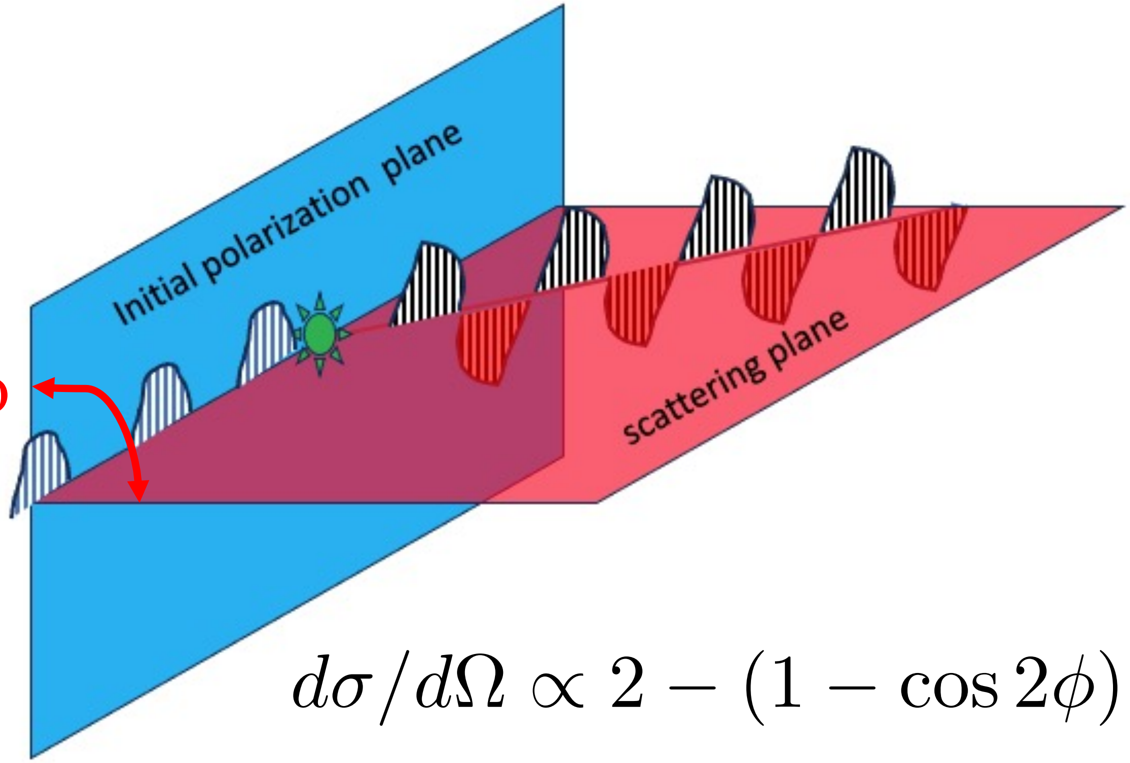
Where,

$h\nu_0$: energy of incident photon.

$h\nu$: energy of the scattered photon.

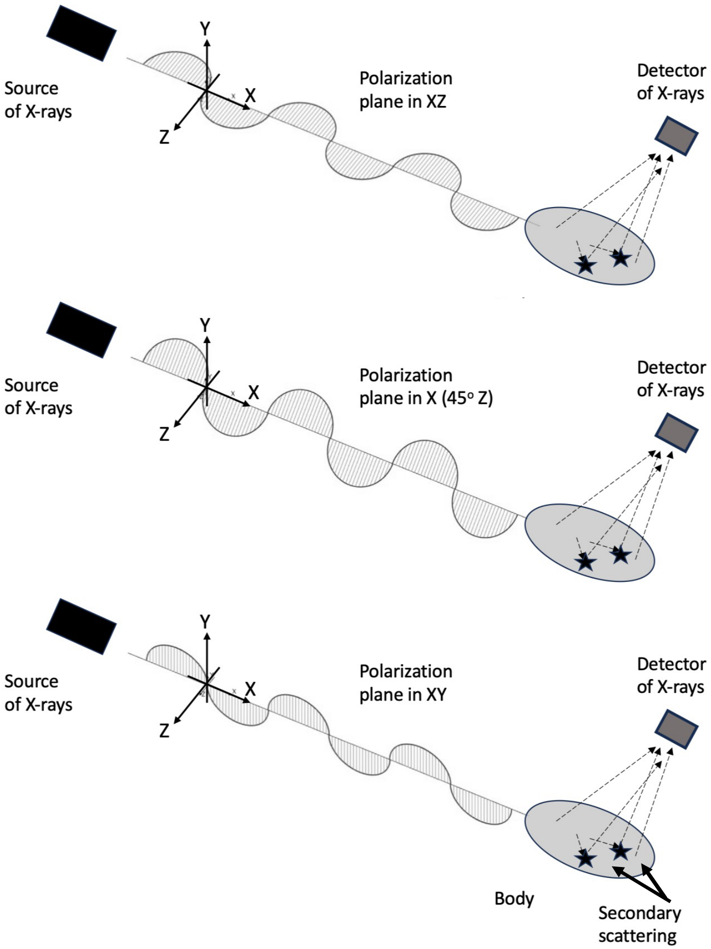
Θ : angle between the two polarization vectors

Compton scattering physics



$$d\sigma/d\Omega \propto 2-(1-\cos 2\phi)\times\sin^2\theta$$

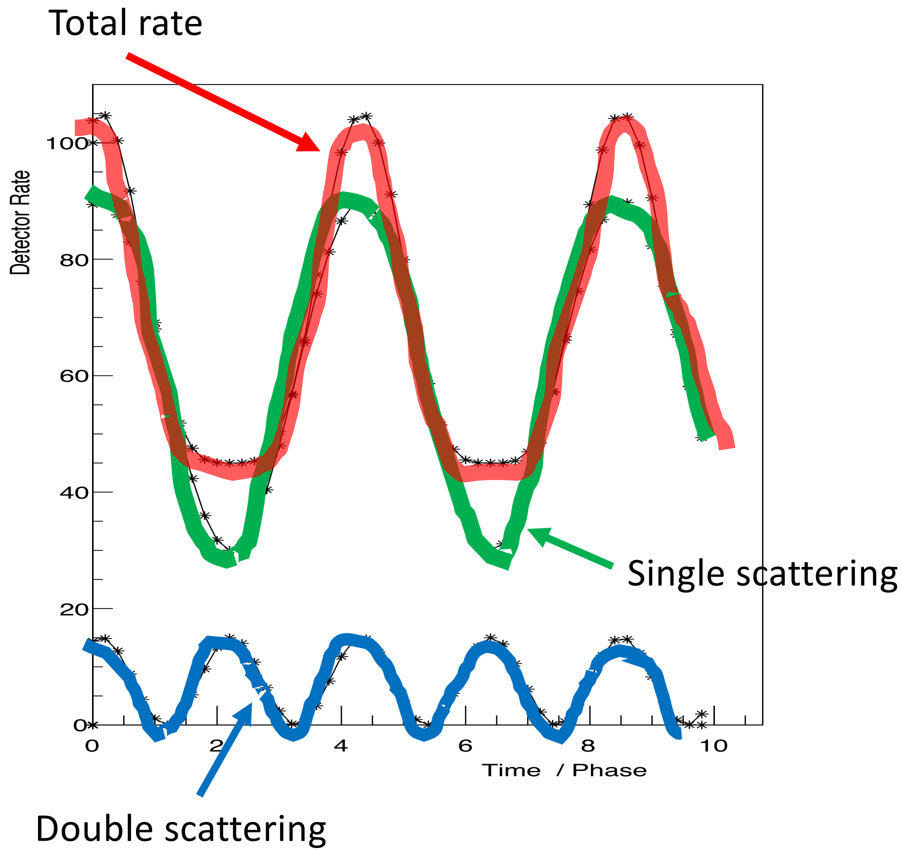
Concept of a new method: remove second+ harmonics



polarization angle
φ = 0 degrees

polarization angle
φ = 45 degrees

polarization angle
φ = 90 degrees



ALARA: As Low As Reasonably Achievable

- Polarized X-ray allows subtraction of the contributions from multiple scattering events
- Reduce blur of the image -> see objects lower density/smaller size
- Reduce required statistics -> lower radiation dose

Patent application: 2523(JSA) ID1540 27648_63968876 (1)

METHOD OF X-RAY SHARP IMAGING WITH SUPPRESSION OF MULTIPLE SCATTERING

APPLICATION #
63/968,876

RECEIPT DATE / TIME
01/27/2026 10:19:46 AM Z ET

The United States Government may have certain rights to this invention under Management and Operating Contract No. DE-AC05-06OR23177 from the Department of Energy.

Inventor: **Bogdan Wojtsekhowski**, VA (US); **Cynthia Keppel**, VA (US)

Assignee: **Thomas Jefferson National Accelerator Facility**

U.S. Cl. 382

Field of Classification Search 382/211, 382/263, 382/264

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(Continued)

ABSTRACT

A method of sharp X-ray imaging of a body with suppression of multiple scattering is presented. Generally, it is based on a linearly polarized X-ray and a modulated azimuthal scattering angle, $\boldsymbol{\varphi}$ between a polarization plane and the location of a scattered X-ray detector. Such modulation leads to variation of the detector counting rate. The good part of the rate comes from a singly scattered X-ray which has a modulation term proportional to cos(2$\boldsymbol{\varphi}$). At the same time, there is a bad part of the rate which comes from a doubly scattered X-ray which has a modulation term proportional to cos(4$\boldsymbol{\varphi}$) and even higher harmonics for multiple scattering. Our invention is a method of data