

## A quasi-real photon method Weizsacker -Williams approximation for $A(e,X)$ vs. $A(\gamma,X)$

Bogdan Wojtsekhowski and Ashot Gasparian

$$e(e, e' + e_r + \gamma) / e(e, e' + e'')$$

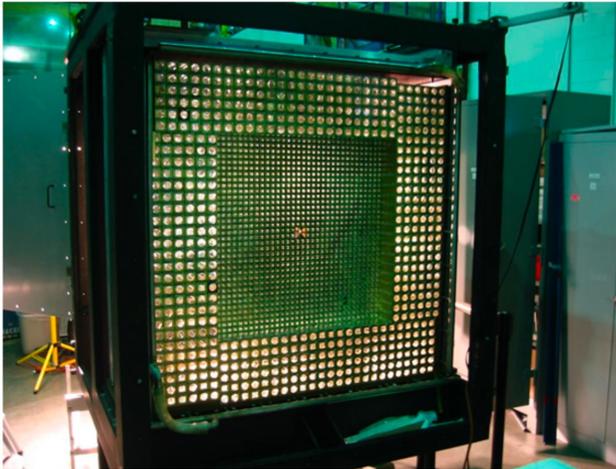
The 90-year old theory proposed by E. Fermi and further developed by C.F. Weizsaker and E.J. Williams **can be tested by using Compton scattering** of the quasi-real photons from atomic electrons. Currently known tests have modest accuracy which could be improved by at least a factor of 10.

Electron CS was tested by PrimEx at 5GeV (PLB 797 (2019) 134884)

The proposed experiment will use  $H(e, e' + e_r + \gamma)$  reaction with selection of the events with the elastic  $\gamma$  - electron scattering kinematics. The proposed detector system will use the existing PRad-II experimental setup, including the HyCal calorimeter and GEM coordinate detectors.

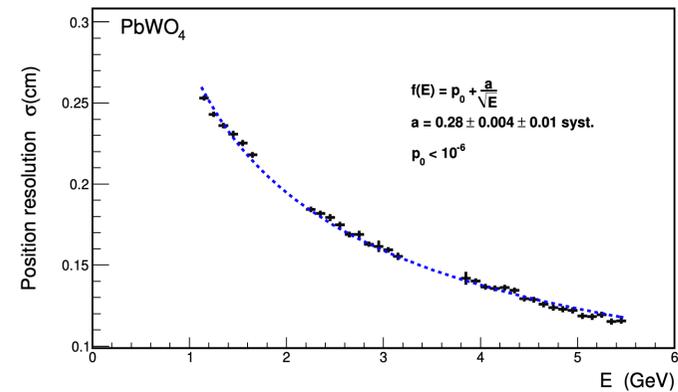
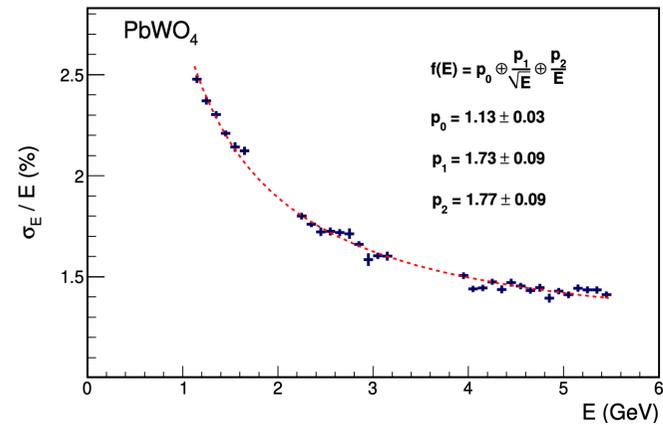
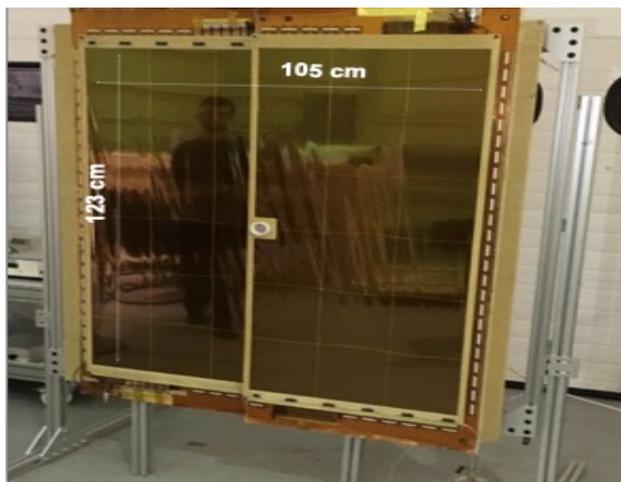
# PRAD detector system

## HyCal



High energy and coordinate resolutions

Two layers, GEMs



Combined efficiency > 99.5%

## A quasi-real photon flux

Why is it interesting to measure?

How can LEEPP do such a measurement?

What is projected accuracy?

## A quasi-real photon Weizsacker -Williams approximation for $A(e,X)$ vs. $A(\gamma,X)$

On the Theory of the impact between atoms and electrically charged particles

E. Fermi

*Z.Phys.* 29 (1924) 315-327 • DOI: [10.1007/BF03184853](https://doi.org/10.1007/BF03184853)

Radiation emitted in collisions of very fast electrons

C.F. von Weizsacker (Copenhagen U.)

*Z.Phys.* 88 (1934) 612-625 • DOI: [10.1007/BF01333110](https://doi.org/10.1007/BF01333110)

Nature of the high-energy particles of penetrating radiation and status of ionization and radiation formulae

E.J. Williams (Nordita)

*Phys.Rev.* 45 (1934) 729-730 • DOI: [10.1103/PhysRev.45.729](https://doi.org/10.1103/PhysRev.45.729)

A quasi-real photon method Weizsacker -Williams  
approximation for  $A(e,X)$  vs.  $A(\gamma,X)$



# A quasi-real photon flux

PHYSICAL REVIEW C **68**, 014601 (2003)

## Experimental test of virtual photon theory via electrodisintegration and photodisintegration of the deuteron

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(Received 6 January 2003; published 3 July 2003)

Virtual photon theory (VPT) has long been suggested as a means of extracting photoreaction cross sections from measurements of cross sections for equivalent electron-induced reactions. Experimental information on the validity of VPT is, however, extremely limited. A test of VPT is reported in this paper. Measurements of the cross section for the  $d(e,p)e'n$  reaction at energies between 165 and 365 MeV have been performed for outgoing proton angles of  $40^\circ$ ,  $90^\circ$ , and  $120^\circ$ . From these results, cross sections for the  $d(\gamma,p)n$  reaction have been extracted using VPT, and are compared with  $d(\gamma,p)n$  cross sections measured concurrently using a bremsstrahlung beam.

# A quasi-real photon flux

EXPERIMENTAL TEST OF VIRTUAL PHOTON THEORY . . .

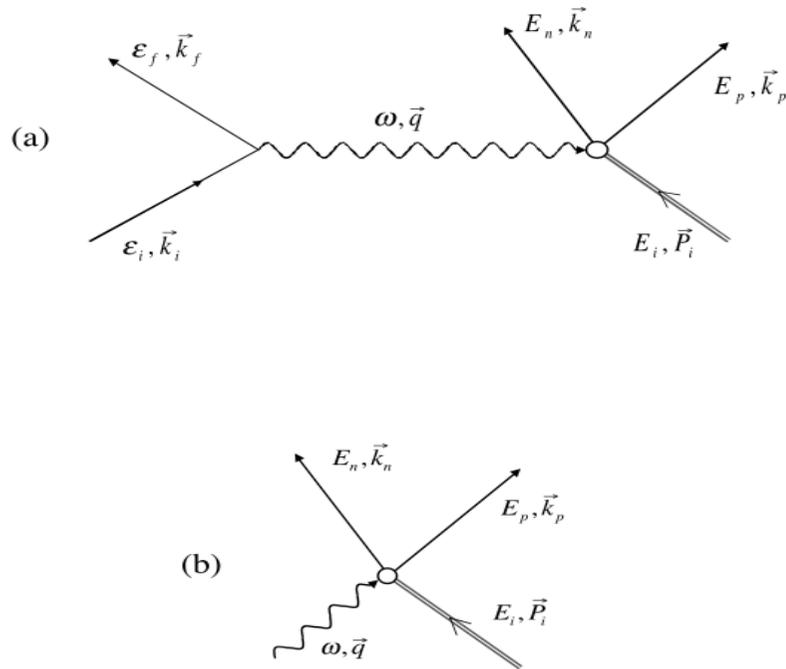


FIG. 1. Diagram of the (a)  $d(e,p)e'n$  and (b)  $d(\gamma,p)n$  reactions in the laboratory frame showing various kinematical quantities associated with each particle.

The value of the ratio at  $\Delta E/E_e \sim 0.4$  is seen to increase from 1.1 at  $120^\circ$  to 1.2 at  $90^\circ$ , and then to 1.6 at  $40^\circ$ , indicating a worsening breakdown of VPT as the proton angle decreases

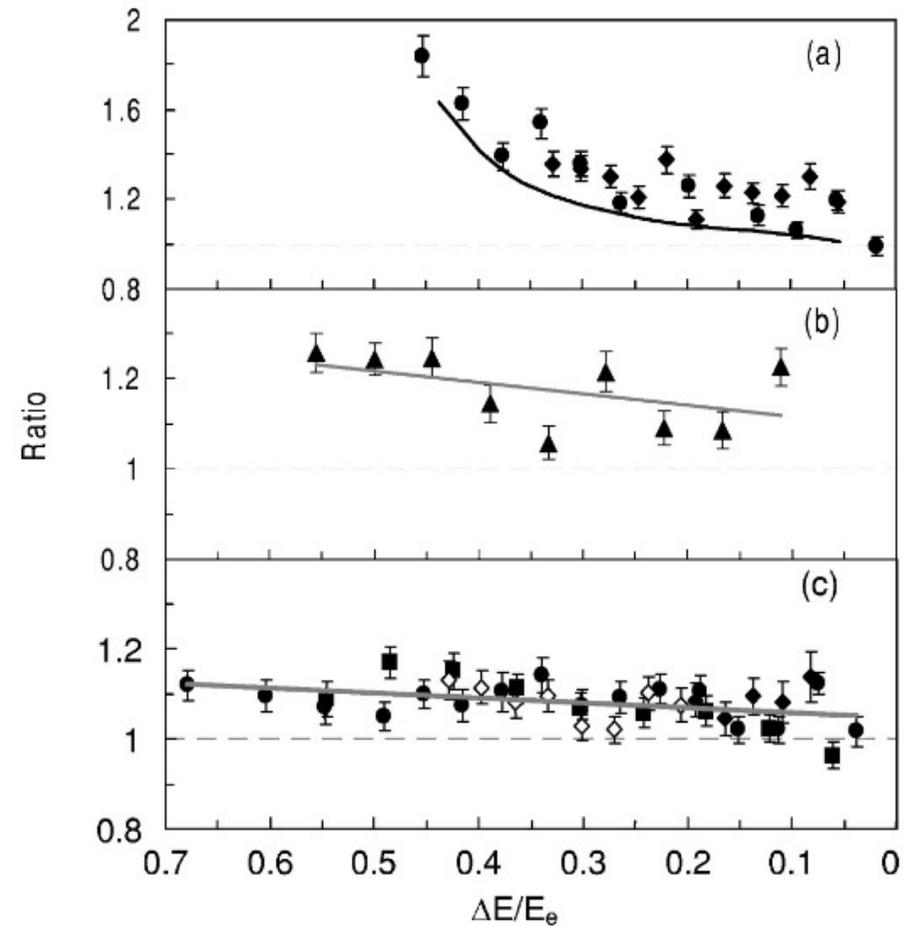


FIG. 7. The ratio of the deuteron photodisintegration cross section [determined by applying virtual photon theory to the measured  $d(e,p)e'n$  cross sections] to the measured cross sections of Soos [23]. (a)  $40^\circ$  for  $E_e = 265$  MeV and  $365$  MeV; (b)  $90^\circ$  for  $E_e$

# A quasi-real photon flux

PHYSICS REPORTS (Section C of Physics Letters) 15, no. 4 (1975) 181–282. NORTH-HOLLAND PUBLISHING COMPANY

## THE TWO-PHOTON PARTICLE PRODUCTION MECHANISM. PHYSICAL PROBLEMS. APPLICATIONS. EQUIVALENT PHOTON APPROXIMATION

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Received 25 April 1974

Revised version received 5 July 1974

### 6.5. EPA. The $\omega$ -distribution

Let us show that the distribution in the photon frequency can be obtained by a simple integration of (6.16) over the region of small  $q^2$  (i.e. over the validity region for (6.16)) and find out the limits of this region together with the accuracy of the approximations.

After integrating (6.16) over the region  $q_{\min}^2 \leq -q^2 \leq q_{\max}^2$  the cross section can be written in the form

$$d\sigma = \sigma_\gamma(\omega) dn(\omega); \tag{6.17a}$$

# A quasi-real photon flux

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$$d\sigma = \sigma_\gamma(\omega) dn(\omega); \quad (6.17a)$$

$$dn(\omega) = \int_{q_{\min}^2}^{q_{\max}^2} dn(\omega, q^2) = N(\omega) d\omega/\omega;$$

$$N(\omega) = \frac{\alpha}{\pi} \left[ \left(1 - \frac{\omega}{E} + \frac{\omega^2}{2E^2}\right) \ln \frac{q_{\max}^2}{q_{\min}^2} - \left(1 - \frac{\omega}{2E}\right)^2 \ln \frac{\omega^2 + q_{\max}^2}{\omega^2 + q_{\min}^2} - \frac{m_e^2 \omega^2}{E^2 q_{\min}^2} \left(1 - \frac{q_{\min}^2}{q_{\max}^2}\right) \right]. \quad (6.17b)$$

For the description of the  $\omega$ -distribution, one should choose a lower limit of the  $q^2$ -integration region which is equal to the kinematic limit (6.11), i.e.  $q_{\min}^2 = m_e^2 \omega^2 / E(E - \omega)$ .

The upper limit  $q_{\max}^2$  is usually less than the kinematic limit  $4E(E - \omega)$  (6.11). The value of  $q_{\max}^2$  differs from problem to problem and is defined either by cut off parameters (6.13–6.15) or by the experimental limitations.

# A quasi-real photon flux

PHYSICAL REVIEW D **96**, 016004 (2017)

## Validity of the Weizsäcker-Williams approximation and the analysis of beam dump experiments: Production of an axion, a dark photon, or a new axial-vector boson

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Beam dump experiments have been used to search for new particles,  $\phi$ , with null results interpreted in terms of limits on masses  $m_\phi$  and coupling constants  $\epsilon$ . However these limits have been obtained by using approximations [including the Weizsäcker-Williams (WW) approximation] or Monte Carlo simulations. We display methods to obtain the cross section and the resulting particle production rates without using approximations on the phase space integral or Monte Carlo simulations. In our previous work we examined the case of the new scalar boson production; in this paper we explore all possible new spin-0 and spin-1 particles. We show that the approximations cannot be used to obtain accurate values of cross sections. The corresponding exclusion plots differ by substantial amounts when seen on a linear scale. Furthermore, a new region ( $m_\phi < 2m_e$ ) of parameter space can be explored without using one of the common approximations,  $m_\phi \gg m_e$ . We derive new expressions for the three-photon decays of dark photon and four-photon decays of new axial-vector bosons. As a result, the production cross section and exclusion region of different low mass ( $m_\phi < 2m_e$ ) bosons are very different. Moreover, our method can be used as a consistency check for Monte Carlo simulations.

DOI: [10.1103/PhysRevD.96.016004](https://doi.org/10.1103/PhysRevD.96.016004)

# A quasi-real photon flux

## Quasi-free Compton Scattering and the Polarizabilities of the Neutron<sup>\*</sup>

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**Abstract.** Differential cross-sections for quasi-free Compton scattering from the proton and neutron bound in the deuteron have been measured using the Glasgow/Mainz photon tagging spectrometer at the Mainz MAMI accelerator together with the Mainz 48 cm  $\varnothing \times 64$  cm NaI(Tl) photon detector and the Göttingen SENECA recoil detector. The data cover photon energies ranging from 200 MeV to 400 MeV at  $\theta_{\gamma}^{\text{LAB}} = 136.2^{\circ}$ . Liquid deuterium and hydrogen targets allowed direct comparison of free and quasi-free scattering from the proton. The neutron detection efficiency of the SENECA detector was measured via the reaction  $p(\gamma, \pi^+ n)$ . The "free" proton Compton scattering cross sections extracted from the bound proton data are in reasonable agreement with those for the free proton which gives confidence in the method to extract the differential cross section for free scattering from quasi-free data. Differential cross-sections on the free neutron have been extracted and the difference of the electromagnetic polarizabilities of the neutron has been determined to be  $\alpha_n - \beta_n = 9.8 \pm 3.6(\text{stat})_{-1.1}^{+2.1}(\text{syst}) \pm 2.2(\text{model})$  in units of  $10^{-4} \text{fm}^3$ . In combination with the polarizability sum  $\alpha_n + \beta_n = 15.2 \pm 0.5$  deduced from photoabsorption data, the neutron electric and magnetic polarizabilities,  $\alpha_n = 12.5 \pm 1.8(\text{stat})_{-0.6}^{+1.1}(\text{syst}) \pm 1.1(\text{model})$  and  $\beta_n = 2.7 \mp 1.8(\text{stat})_{-1.1}^{+0.6}(\text{syst}) \mp 1.1(\text{model})$  are obtained. The backward spin polarizability of the neutron was determined to be  $\gamma_{\pi}^{(n)} = (58.6 \pm 4.0) \times 10^{-4} \text{fm}^4$ .

# Quasi-free Compton Scattering and the Polarizabilities of the Neutron<sup>\*</sup>

K. Kossert<sup>1a,b</sup>, M. Camen<sup>1c</sup>, F. Wissmann<sup>1b,d</sup>, J. Ahrens<sup>2</sup>, J.R.M. Annand<sup>3</sup>, H.-J. Arends<sup>2</sup>, R. Beck<sup>2</sup>, G. Caselotti<sup>2</sup>, P. Grabmayr<sup>4</sup>, O. Jahn<sup>2</sup>, P. Jennewein<sup>2</sup>, M.I. Levchuk<sup>5</sup>, A.I. L'vov<sup>6</sup>, J.C. McGeorge<sup>3</sup>, A. Natter<sup>4</sup>, V. Olmos de León<sup>2</sup>, V.A. Petrun'kin<sup>6</sup>, G. Rosner<sup>3</sup>, M. Schumacher<sup>1</sup>, B. Seitz<sup>1</sup>, F. Smend<sup>1</sup>, A. Thomas<sup>2</sup>, W. Weihofen<sup>1</sup>, and F. Zapadtko<sup>1</sup>

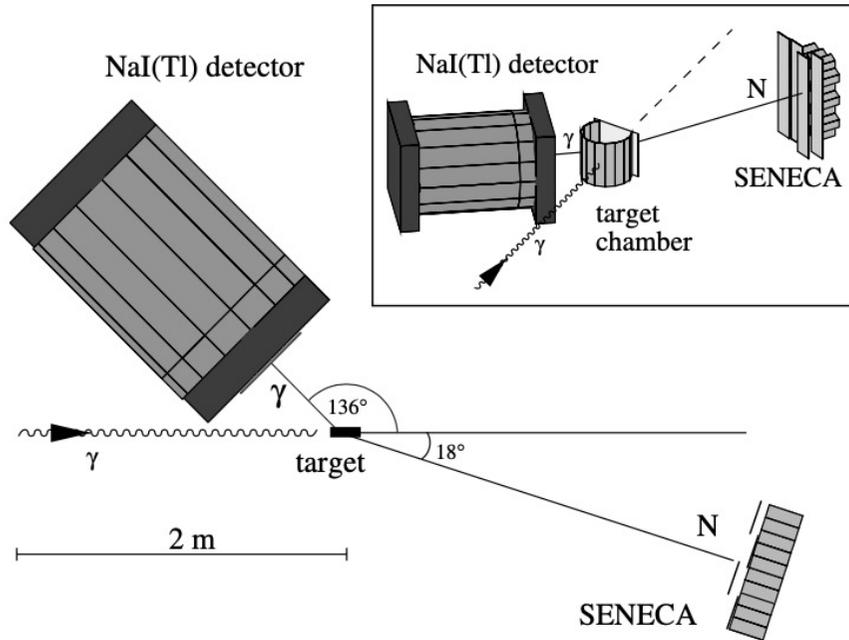


FIG. 1. Experimental arrangement used for the present experiment on Compton scattering by the proton and quasifree Compton scattering by the proton and the neutron. Compton scattering events were identified through coincidences between the Mainz 48 cm  $\varnothing \times 64$  cm NaI(Tl) photon detector positioned at  $\theta_{\gamma}^{\text{lab}} = 136^{\circ}$  and the Göttingen segmented recoil counter SENECA positioned at  $\theta_N^{\text{lab}} = 18^{\circ}$ . The inset shows a perspective view of this arrangement.

$$\alpha_n - \beta_n = 9.8 \pm 3.6(\text{stat})_{-1.1}^{+2.1}(\text{syst}) \pm 2.2(\text{model}). \quad (3)$$

By combining it with  $\alpha_n + \beta_n = 15.2 \pm 0.5$  [14], we obtain

$$\alpha_n = 12.5 \pm 1.8(\text{stat})_{-0.6}^{+1.1}(\text{syst}) \pm 1.1(\text{model}), \quad (4)$$

$$\beta_n = 2.7 \mp 1.8(\text{stat})_{-1.1}^{+0.6}(\text{syst}) \mp 1.1(\text{model}). \quad (5)$$

POSSIBILITY TO STUDY PHOTON SCATTERING BY PROTON IN THE  
REACTION  $ep - ep\gamma$

A.I. Lvov, V.A. Petrunkin

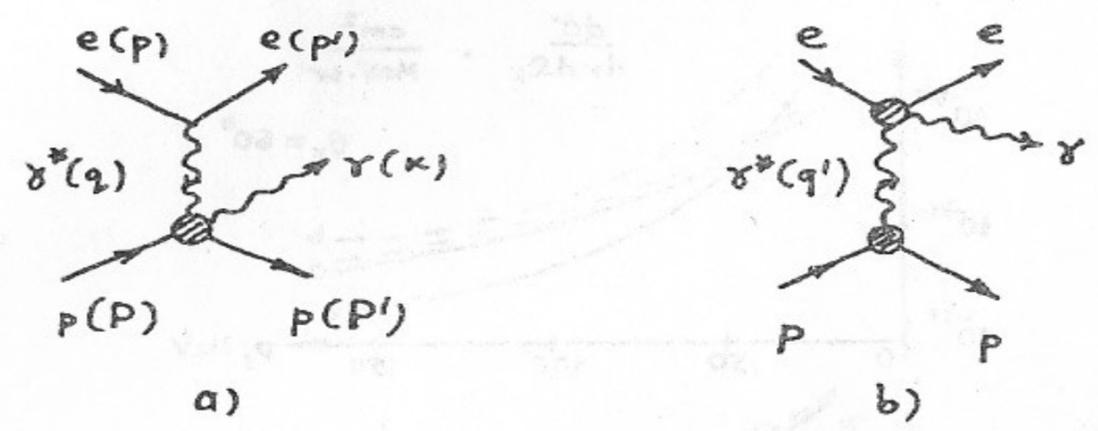
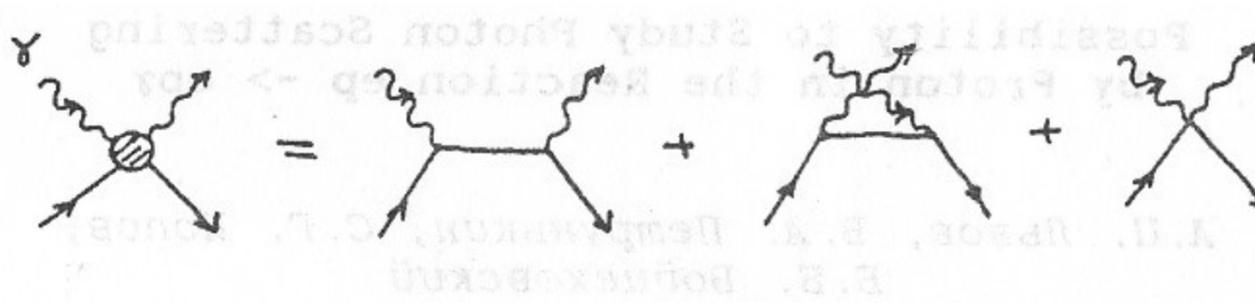
*P.N. Lebedev Physical Institute Leninsky Prospect 53, Moscow 117924, USSR*

S.G. Popov and B.B. Wojtsekhowski

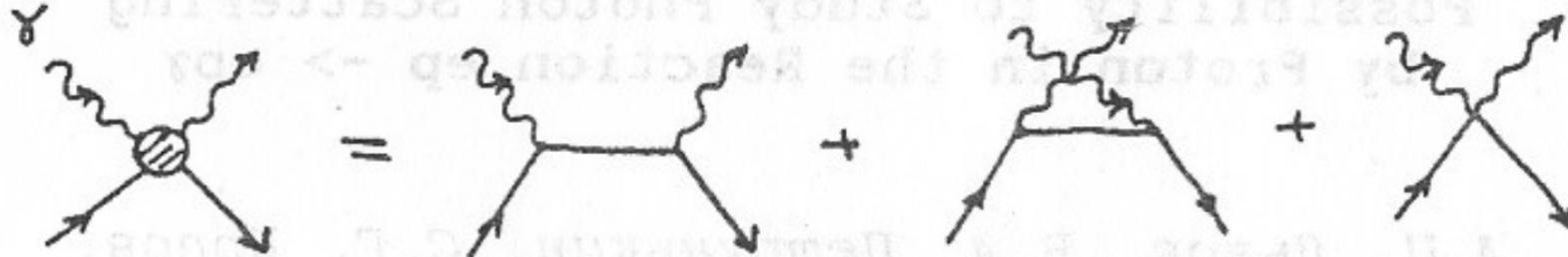
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(Dated: 1991)

arXiv:2510.17008



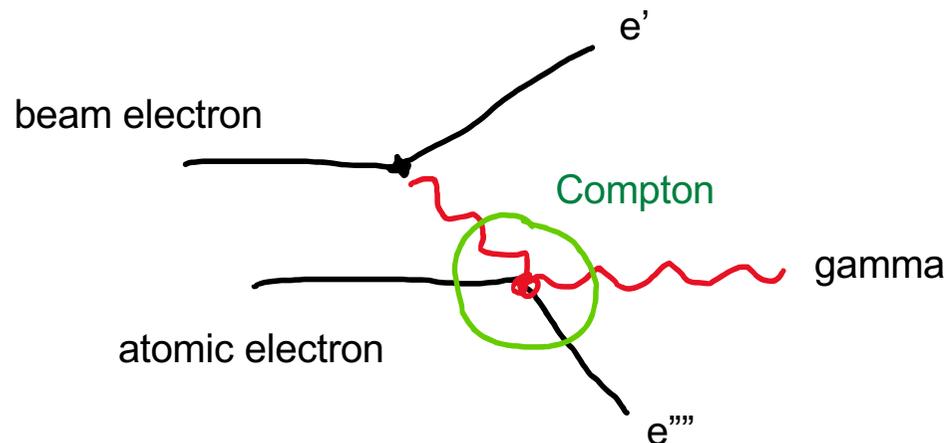
# Nucleon polarizabilities



Achieving an effective luminosity in the  $\gamma^*p$ -collisions  $L_\gamma = 10^{33} \text{ cm}^{-2} \text{ s}^{-1}$  that is far beyond the possibilities of the tagged photon method, and achieving yields  $\approx 10^3$  events/hour.

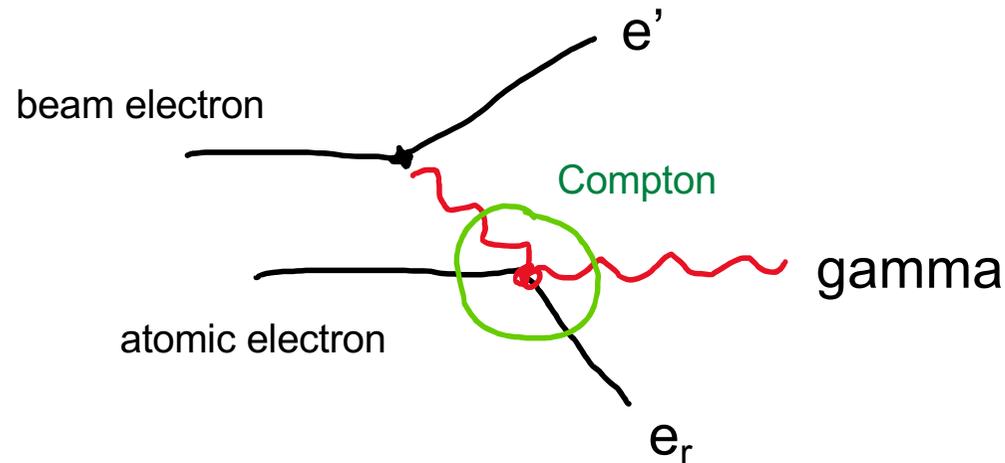
## A quasi-real photon flux measurement

- Low intensity electron beam
- PRAD detector system: two GEMs + HyCal
- Detection of an electron + an electron events - Luminosity monitor
- Detection of an electron + an electron + gamma events
- Ratio of those rates allows us to find the quasi-real photon flux



## A quasi-real photon flux measurement

Event rate for  $e' + e_r + \text{gamma} \sim 0.02 \times 0.5 = 1\%$  of Moller rate



In GeV energy range it will be done during PRAD-II