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Backward Compton Scattering of Laser Light against High-Energy Electrons: the LADON Photon Beam at Frascati (*).

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Summary. — In the present paper we present the experimental results obtained for the backscattering of laser light against the high-energy electrons stored in Adone with the laser cavity dumping technique. The characteristics of the obtained photon beam (LADON beam) are discussed and compared with the theoretical previsions given by the usual storage ring theory.

(*) To speed up publication, the authors of this paper have agreed to not receive the proofs for correction.

1. – Introduction.

The backward Compton scattering of laser light on high-energy electrons can produce monoenergetic and polarized photons of much higher energy, as has been pointed out as far back as 1963 (1,2). Several laboratories (3-6) studied and detected experimentally this process. Later (7,8), it was noticed that the high average current circulating in a storage ring, together with the photon flux available in a laser optical resonator, could produce a γ-ray beam of sufficient intensity to be used for photonuclear research.

The energy of the photons emitted in the backward direction depends mostly on the angle between the final-photon and incident-electron momenta. Therefore, by taking advantage of the backward peak in the differential cross-section, the photons can be collimated to select a narrow energy band. Energy spread and beam intensity increase with the accepted solid angle and, consequently, a compromise must be made between intensity and resolution.

Some years back, the Frascati National Laboratories were the venue for a project to produce a beam of intermediate-energy γ-rays using an argon ion laser ($\lambda = 5145$ Å) and the electron storage ring Adone ($E_e^{\max} = 1.5$ GeV). The experimental results obtained with reference to the beam intensity, energy resolution and polarization are reported here. The characteristics of the present γ-ray beam are (9,10)

1) a photon energy continuously adjustable between ~ 5 MeV and ~ 78 MeV, for an electron energy ranging from 0.37 GeV to 1.5 GeV;

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(1) R. H. Milburn: *Phys. Rev. Lett.*, **10**, 75 (1963).

(2) P. R. Arutyunyan and V. A. Tumanian: *Phys. Lett.*, **4**, 176 (1963).

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(7) R. Malvano, C. Mancini and C. Schaerf: Frascati report LNF67/48 (1967).

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(9) L. Casano, A. Marino, G. Matone, M. Roccella, C. Schaerf and A. Tranquilli: LNF-74/60 (1974); *Laser Unconventional Opt. J.*, **55**, 3 (1975).

(10) G. Matone, P. Picozza, D. Prosperi, A. Tranquilli, R. Caloi, C. Schaerf, S. Frullani and C. Strangio: *Photonuclear reaction*, II, in *International School on Electro and Photonuclear Reactions, Erice (Italy), 1976,* edited by S. Costa and C. Schaerf (Berlin, 1977), p. 149; invited contribution to the *Europhysics Study Conference on High Power Laser and Scientific Applications* (Oxford, 1975).

2) a beam intensity between $\sim 10^4$ and $\sim 10^5$ photons/s, depending on electron energy, electron current, laser power and photon energy resolution;

3) an energy resolution between $\sim 1\%$ and $\sim 10\%$ in the present working conditions of Adone;

4) an almost total linear polarization ($\langle P \rangle \sim 1$);

5) a low background of photons of different energy;

6) a time microstructure similar to that of the electrons in the storage ring: pulses as short as few ns separated by 117 ns.

This facility is, therefore, a very advanced tool for the study of many features of photonuclear reactions in the energy region $(5 \div 80)$ MeV, around and above the giant collective resonances.

2. – Experimental set-up.

The interaction region between electrons and photons is located in the centre of straight section No. 2 of the Adone storage ring (see fig. 1). A high-power argon ion laser with a cavity dumper is aligned with its output beam on the axis of the straight section with an accuracy of the order of 10^{-5} rad. The laser light enters the Adone vacuum system through an antireflection coated lens and then impinges upon a totally reflecting mirror at the exit from the straight section. The reflected light collides head-on with the incoming electrons. Photons scattered at 180° pass through a collimator located 45 m away from the interaction region. The experimental hall, located after the collimator, houses the beam detection and analysing systems.

The laser cavity dumper (11) is driven at the same frequency (8.568 MHz) of the Adone accelerating radio-frequency and produces short pulses (~ 15 ns) of laser light. By adjusting the time delay between the electron and the laser pulses, the interaction takes place in the centre of the straight section, where the phase spaces of the electron and laser beams are minima.

3. – Photon intensity.

The photon intensity has been measured with a NaI(Tl) detector and a lead glass Čerenkov counter (~ 6 radiation lengths) placed on the beam line at the end of the experimental area, as shown in fig. 1. The photons were counted in coincidence with a trigger derived from the Adone RF system

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(11) G. Giordano and G. Matone: Frascati report LNF-77/32 (1977).

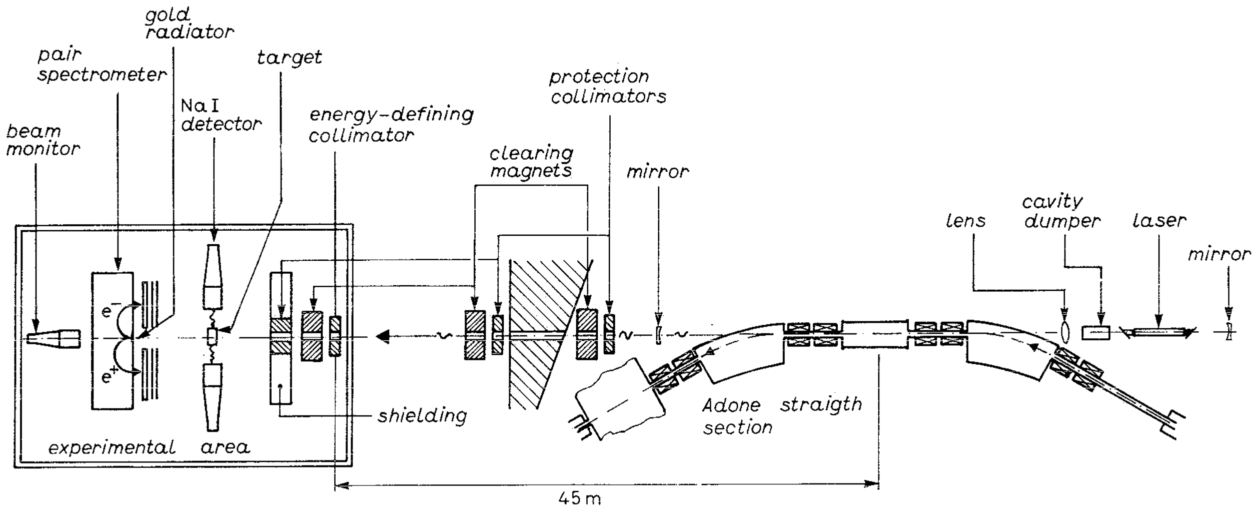

Fig. 1. – Overall view of the experimental set-up.

and were time correlated with the same signal. Photon yields were measured for many photon energies and corrected for detector efficiency.

Since the electron beam dimensions and divergences are current dependent, the photon flux is not strictly proportional to the electron current. Figure 2*a*)

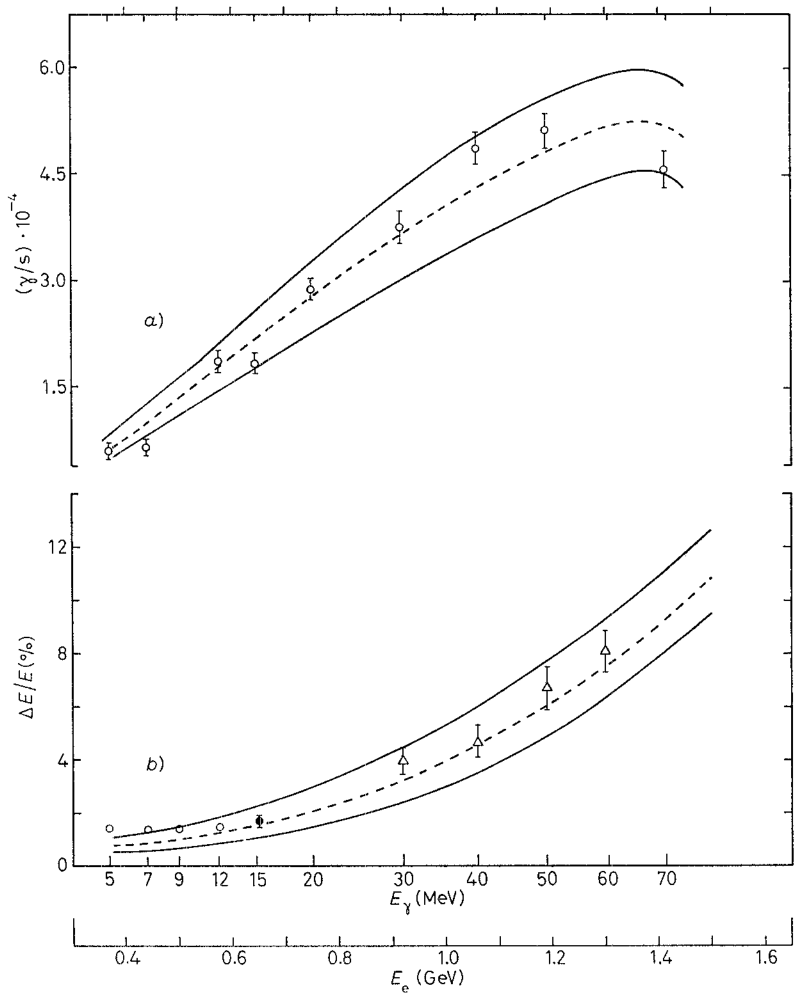

Fig. 2. – *a*) Photon flux, $I_e = 75$ mA, laser pulse $= 20\text{ W}\times 15$ ns, $\Omega = 2.5\cdot 10^{-8}$ sr; *b*) fractional energy resolution (full-width half-maximum), $I_e = 50$ mA, $\Omega = 2.5\cdot 10^{-8}$ sr. The dashed lines have been obtained via a Monte Carlo calculation (¹²) with the best estimates of the electron beam parameters. In these graphs the solid lines delimit the uncertainty we have in the knowledge of these parameters. ○ Ge(Li) detector, △ magnetic pair spectrometer, ● resonant scattering in ^{12}C. φ = misalignement angles $\simeq 3.5°$.

(¹²) C. Strangio: ISS P76/10 (1976).

shows the results obtained for an electron current $I_e = 75$ mA. Similar results are available for $10\ \text{mA} \leqslant I_e \leqslant 100$ mA. The error bars indicate mostly systematic errors due to possible misalignement between the colliding beams and to uncertainties in detector efficiency, measurements of laser power and electron current. These data have been measured with a laser energy per pulse of $3 \cdot 10^{-7}$ J ($20\ \text{W} \times 15$ ns) and an acceptance solid angle of $2.5 \cdot 10^{-8}$ sr.

The dashed line indicated in the figure has been obtained with a Monte Carlo calculation (¹²) under the assumption that the electron beam parameters are given by the usual storage ring theory plus some anomalous pulse lengthening and a correlated increase in the beam transversal dimensions and divergences. The solid lines delimit the present uncertainty in the estimates of the electron beam characteristics. Most experimental points lie inside the deligned region, showing a substantial agreement with the theoretical previsions.

4. – Beam polarization.

To verify the polarization of the γ-ray, at least at one energy, we have performed a very simple experiment, scattering 15.1 MeV photons from a ^{12}C target.

Two NaI(Tl) detectors were located at a scattering angle of 90°, one in the horizontal and the other in the vertical or polarization plane. The pulse height spectra obtained from the two counters are indicated in fig. 3. Triangles indicate the output from the vertical counter, the circles that from the horizontal one. If we consider that the 15.1 MeV level in ^{12}C is an ideal polarization analyser, the result should yield all the scattering strength in the vertical plane and nothing in the horizontal one. A strong difference between the pulse height spectra of the two counters is evident from the figure.

Corrections for the finite solid angle of the counters and the small misalignement of 3.5° between the vertical direction and the polarization plane, due to a small rotation of the laser tube, have been taken into account. After background subtraction, the result for the photon beam polarization is

$$\langle P \rangle = 0.99 \pm 0.02\ .$$

Another measure of the beam polarization was obtained during an experiment on deuteron photodisintegration (¹³). The cross-section of this process

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(¹³) R. CALOI, L. CASANO, W. DEL BIANCO, M. P. DE PASCALE, L. FEDERICI, S. FRULLANI, G. GIORDANO, B. GIROLAMI, L. INGROSSO, H. JEREMIE, G. MATONE, M. MATTIOLI, G. PASQUARIELLO, P. PELFER, P. PICOZZA, E. PRODI, D. PROSPERI and C. SCHAERF: LNF-80/15(P) (1980).

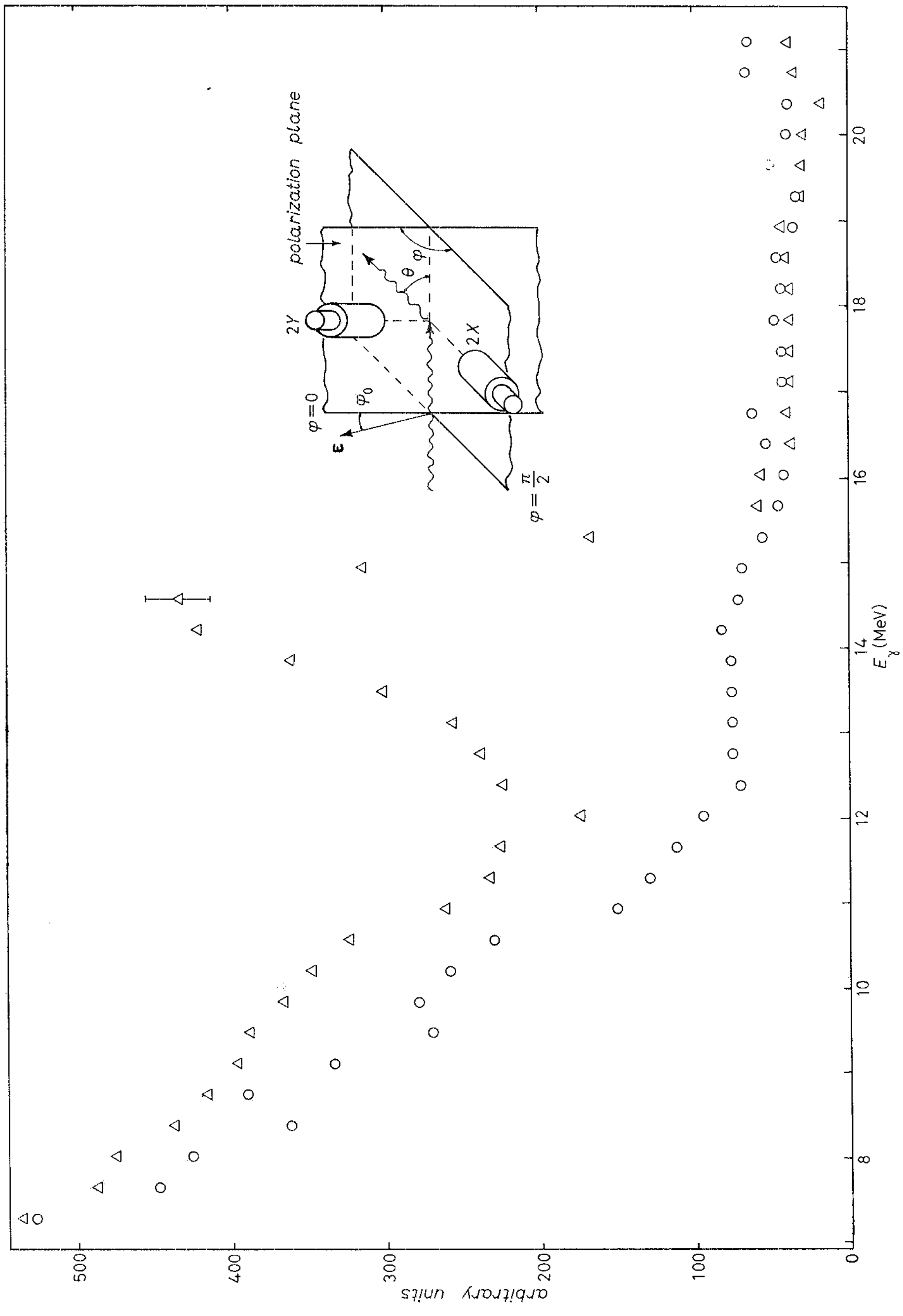

Fig. 3. – Spectra of 15.1 MeV γ-rays scattered from ^{12}C at $\theta = 90°$ in the horizontal and in the vertical plane. $\langle P \rangle = 0.99 \pm 0.02$, $E_e = 651$ MeV, ▵ $N^{\parallel}(2Y)$, ○ $N^{\perp}(2X)$.

depends upon the degree of linear polarization P of the beam as follows:

$$\frac{\mathrm{d}\sigma}{\mathrm{d}\Omega} = I_0(\theta) + PI_1(\theta)\cos 2\varphi = I_0(\theta)(1 + \Sigma(\theta)P\cos 2\varphi)\,,$$

where θ and φ are the usual emission angles of the revealed neutron.

A measure of the asymmetry

$$\frac{[\mathrm{d}\sigma/\mathrm{d}\Omega]_{\varphi=0} - [\mathrm{d}\sigma/\mathrm{d}\Omega]_{\varphi=\pi/2}}{[\mathrm{d}\sigma/\mathrm{d}\Omega]_{\varphi=0} + [\mathrm{d}\sigma/\mathrm{d}\Omega]_{\pi=\pi/2}} = \Sigma(\pi/2)\,P\,,$$

together with the value for Σ obtained by DEL BIANCO *et al.* (^{14}) at 20.3 MeV, gives in our case

$$\langle P\rangle = 0.97 \pm 0.06\,.$$

The two measures agree with, and thus confirm, the theoretically predicted value of ~ 0.999 (^{10}).

5. – Beam energy resolution.

The beam energy resolution is indicated in fig. 2*b*). For γ-ray energies up to 12 MeV it has been measured with a Ge(Li) detector. At photon energies higher than 30 MeV, a 180° pair spectrometer has been used. Figure 4 shows the comparison between an experimental spectrum at $E_\gamma \simeq 78$ MeV, obtained with the spectrometer after bremsstrahlung subtraction, and the corresponding Monte Carlo prediction.

At 15.1 MeV an indirect measurement of the energy resolution has been obtained by the resonant scattering of photons on ^{12}C.

Changing the electron energy by very small amounts, we run the photon peak over the very narrow resonance to obtain the beam energy profile (fig. 5). Using the well-known correlation between the energy of the primary electrons and that of the scattered photons, we have derived from this measurement the estimate of the photon energy resolution at 15.1 MeV indicated in fig. 2*b*). The results are in satisfactory agreement with the theory over the whole energy range. As in fig. 2*a*), the dashed line represents the theoretical prevision and the solid lines delimit the uncertainties produced by the limited knowledge of the electron beam parameters.

(^{14}) W. DEL BIANCO, H. JEREMIE, M. IRSHAD, G. KAJRYS and P. DE POMMIER: *Bull. Am. Phys. Soc.*, **24**, 648 (1979); to be published in *Nucl. Phys. A*.

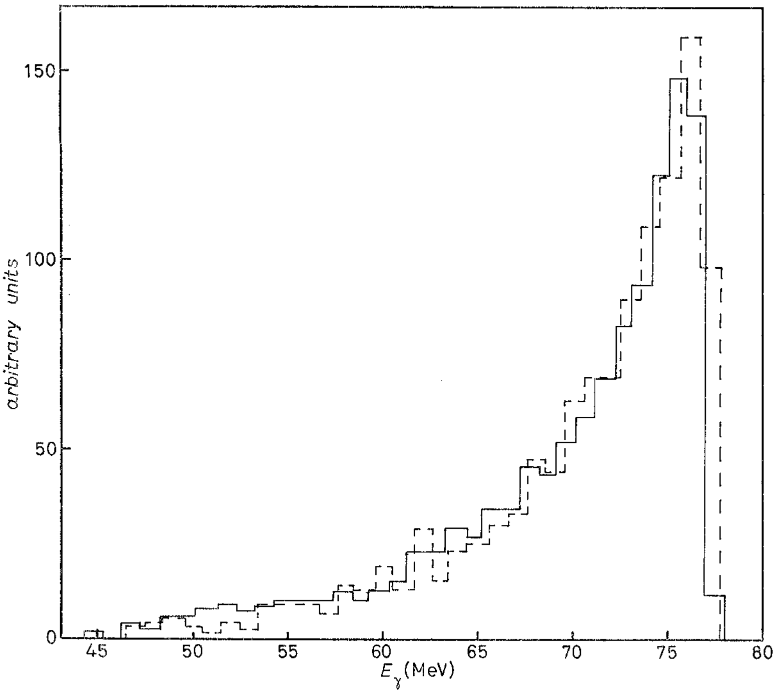

Fig. 4. – Experimental energy distribution obtained with the pair spectrometer with $E_{e^-} = 1500$ MeV, $E_\gamma \simeq 78$ MeV and $\Omega = 0.56 \cdot 10^{-8}$ sr, $(\Delta E_\gamma / E_\gamma)_{\text{FWHM}} \simeq 56\%$. – – – Monte Carlo, ——— magnet spectrometer.

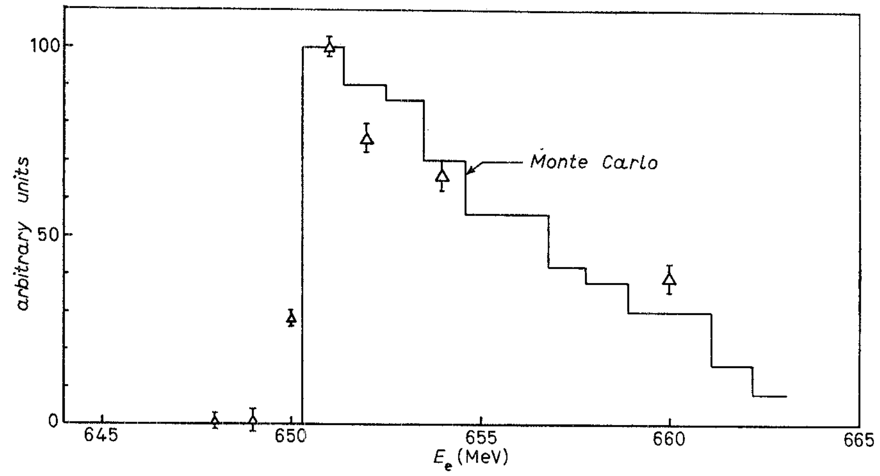

Fig. 5. – Beam energy profile obtained by varying the energy of the γ-ray beam incident on a ^{12}C target, 15.1 MeV, $I_e \sim 80$ mA, $\Omega = 2.36 \cdot 10^{-8}$ sr.

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● RIASSUNTO

In questo articolo si presentano i risultati sperimentali ottenuti con la diffusione all'indietro di luce laser sugli elettroni circolanti in Adone usando la tecnica del « cavity dumping ». Si discutono le caratteristiche del fascio di fotoni così prodotto (fascio LADON) e si paragonano i risultati con le previsioni teoriche fornite dall'usuale teoria degli anelli di accumulazione.

Резюме не получено.