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THE LADON PHOTON BEAM WITH THE ESRF-5 GeV
MACHINE.

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 G. Giordano, G. Matone, M. Mattioli^(x), G. Pasquariello, P. Pelfer^(o), P. Picozza,
 E. Poldi^(x), D. Prospero^(o) and C. Schaerf^(x):

THE LADON PHOTON BEAM WITH THE ESRF-5 GeV MACHINE.

The backward Compton scattering of Laser light against high energy electrons can produce useful yields of monochromatic and polarized photons. This has been recently proved with the LADON photon beam obtained at Frascati⁽¹⁾.

The differential cross section in the laboratory for the head-on collision (see Fig. 1) depends only on the electron energy E and the emission angle θ ⁽²⁾ and can be written as:

$$\frac{d\sigma}{d\Omega} = \frac{4r_0^2\gamma^2}{(1+n^2+2z)^2} \left[\frac{2}{1+n^2} \left(\frac{z^2}{1+n^2+2z^2} - \frac{n^2}{1+n^2} \right) + 1 \right], \quad (1)$$

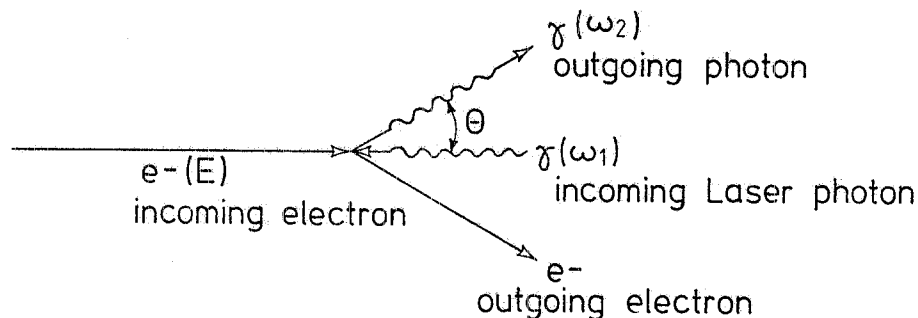


FIG. 1 - Kinematics of the Laser photon-electron head-on collision.

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where:

$$\begin{aligned}
 r_0 &= \text{classical electron radius} = 2.8 \times 10^{-13} \text{ cm}; \\
 \gamma &= E/m \text{ (m = electron rest mass)}; \\
 n &= \gamma \theta; \\
 z &= \frac{2 \omega_1 E}{m^2} \\
 \omega_2(\omega_1) &= \text{outgoing (incoming) photon energy.}
 \end{aligned}$$

On the other hand, the total cross section

$$\sigma_T = \int \frac{d\sigma}{d\Omega} d\Omega = \frac{8}{3} \pi r_0^2 = 0.665 \text{ barn}$$

is energy independent; in other words, with increasing energy, the photons produced are more and more concentrated in the backward direction, but their total number keeps constant.

The energy of the emerging photon is determined by its emission angle θ , and is given by:

$$\omega_2 = \frac{2 E z}{1 + n^2 + 2z} \quad (2)$$

The maximum values obtained at $\theta = 0$ for different Laser wavelengths are reported in Fig. 2.

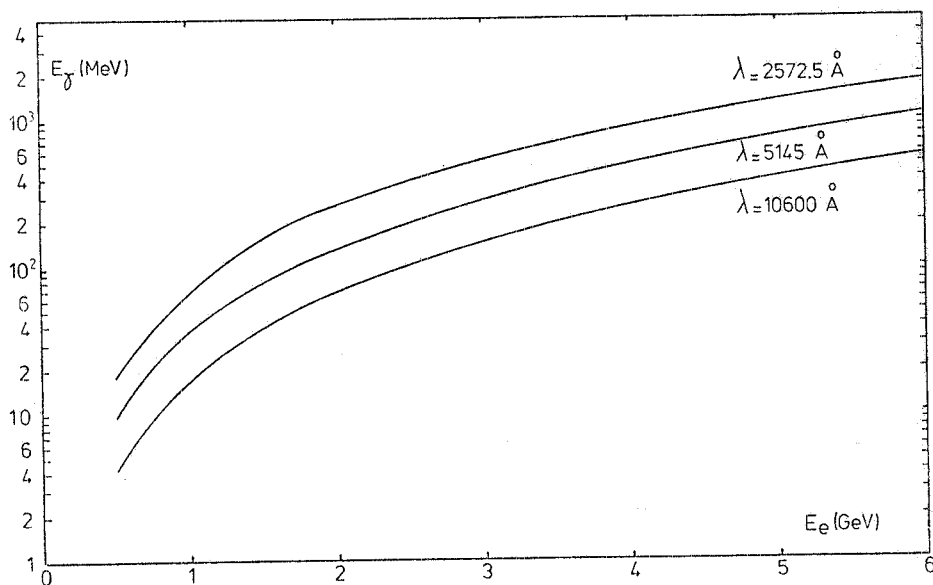


FIG. 2 - Obtainable photon energies for different Laser lines versus electron energy.

The Laser light is completely polarized and the linear polarization of the outgoing photons comes out to be(2):

$$\langle P \rangle \approx 1 - \left(\frac{\Delta \omega_2}{\omega_2} \right) \approx 1 - (\gamma \theta_c)^4 \quad (\theta_c = \text{collimation half angle}),$$

as a consequence of the conservation of helicity for relativistic electrons.

Aim of the present paper is to explore the possibility to realize a monochromatic and polarized photon beam with this technique at the ESRF-5 GeV machine which has been recently presented (May 1979) by the "ad hoc Committee on Synchrotron Radiation" of the European Science Foundation.

Following the design project⁽²⁾, the list of the main parameters of the ESRF-machine can be summarized as shown in Table I.

The magnet lattice, studied for a very low emittance, provides small values of the spatial and angular distribution widths $\sigma_{x,z}$ and $\sigma'_{x,z}$. This lattice has a twelve-fold symmetry (12 cells) and is made of 48 bending magnets, 216 quadrupoles, 12 long straight sections of 6.8 m and 12 short straight sections of 3 m. Fig. 3 shows one half-cell of this lattice.

Considering an horizontal emittance of $\sim 1.1 \times 10^{-2} \text{ mm} \cdot \text{mrad}$ and a vertical emittance smaller by an order of magnitude, the beam sizes at centre of the straight sections and at 5 GeV are shown in Table II.

TABLE I - Parameter list of the ESRF-5 GeV machine.

Energy	5 GeV
Beam current	565 mA
No. of stored electr.	7.12×10^{12}
Mean radius	96.2 m
RF frequency	500 MHz
Harmonic number	1008
Natural bunch length	10 mm $\Rightarrow \sim 30 \text{ psec}$
Beam lifetime	$8 \div 10 \text{ h}$

TABLE II - Beam sizes at centre of the straight sections at 5 GeV.

	σ_x (mm)	σ'_x (mrad)	σ_z (mm)	σ'_z (mrad)
6.8 m straight	0.58	0.02	0.09	0.012
3.0 m straight	0.11	0.10	0.04	0.030

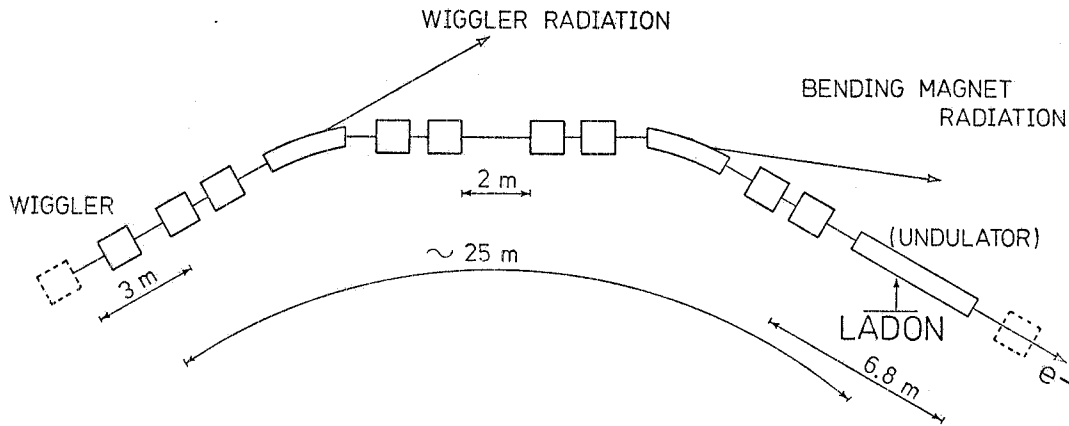


FIG. 3 - 1/24 (15°) of the complete ring.

The better angular divergencies together with the greater length suggest to locate the LADON facility on the 6.8 m long straight section otherwise used to host the undulators.

The simplest arrangement one can imagine is a Laser cavity as long as the whole straight section according to the sketch represented in Fig. 4.

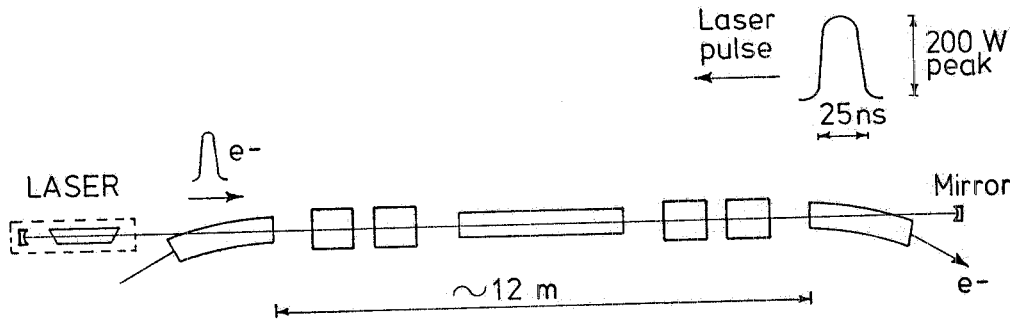


FIG. 4 - Laser arrangement on the straight section.

This solution cannot prevent the collisions to take place inside the quadrupoles region where the angular divergencies are certainly worse than the numbers quoted here⁽³⁾. This difficulty could be overcome by pulsing the Laser (mode locking technique)⁽⁴⁾ and using a limited number of circulating bunches (~ 20 ; 1 bunch every ~ 30 m).

The beam intensity and energy resolution for three Laser lines (Argon: 5145 Å; Argon second harmonic: 2573 Å; Nd-YAG: 10600 Å) have been estimated via Monte Carlo⁽⁵⁾ assuming a Laser beam spot size $\sigma_L = 0.71$ mm and the following conditions:

ESRF-Machine	Mode-locked Laser
Harmonic number : 20	Frequency : 10 MHz
Repetition frequency : 10 MHz	Pulse width : ~ 25 ns
Stored current : 500 mA	Peak power : 200 W

The gamma ray intensities, reported in Fig. 5, have been obtained by scaling linearly with energy the beam parameters given in Table II.

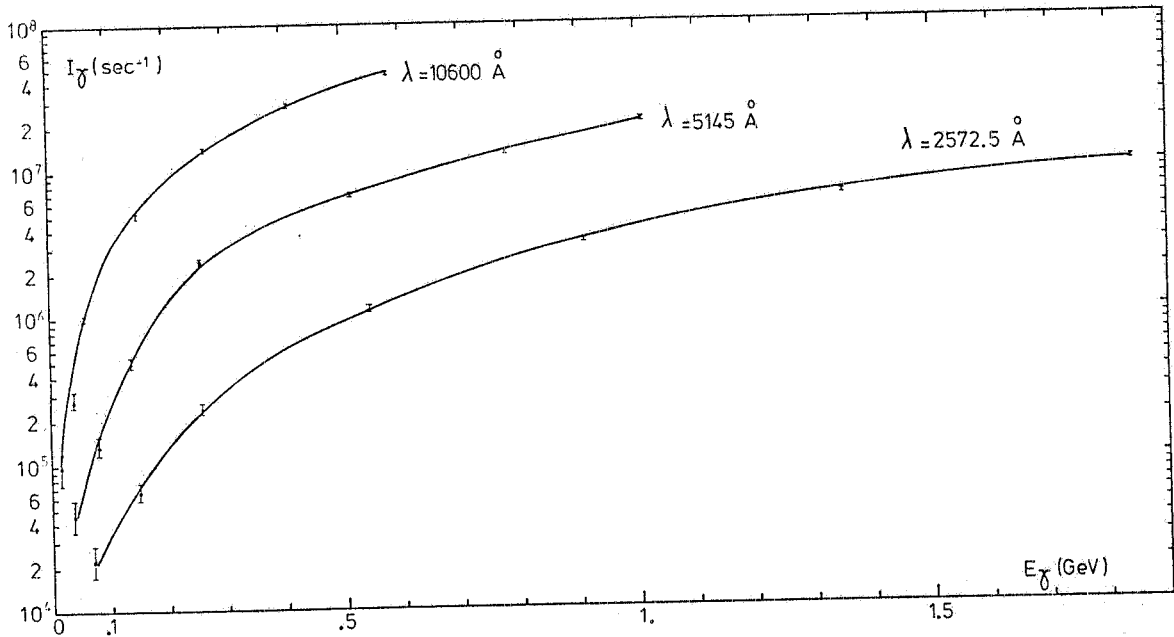


FIG. 5 - Obtained photon intensities at different wavelengths versus photon energy. Full lines are fits by eye through the Monte Carlo points.

For every energy the accepted solid angle has been defined as $\Delta\Omega = \pi\sigma_x'^2$. Under the same conditions Fig. 6 shows the obtainable energy resolution at different wavelengths. Typical energy spectra are shown in Figs. 7 and 8.

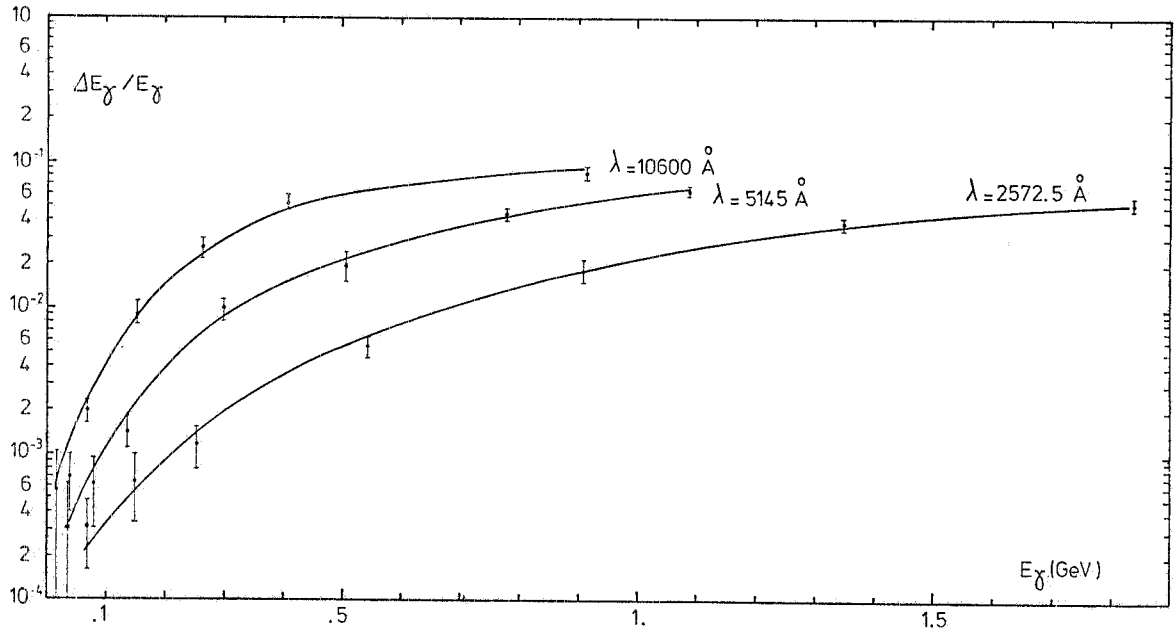


FIG. 6 - Energy resolutions at various wavelengths versus photon energy.

As it has been observed with the LADON beam at Frascati⁽¹⁾ the only source of background is due to the bremsstrahlung of the electrons against the residual gas inside the vacuum pipe. Its contribution under the energy peak can be estimated to be less than 1% with a vacuum of $\sim 10^{-10}$ torr.

Supposing a total number of Laser-electron interactions of $2 \times 10^8 \text{ sec}^{-1}$, the beam lifetime can be predicted to be

$$\tau \sim \frac{7 \times 10^{12}}{3.6 \times 10^3 \times 2 \times 10^8} \approx 10 \text{ h}$$

and is comparable with the lifetime calculated taking into account the conventional beam losses.

An example of topics which can be covered in coincidence experiments both in nuclear and particle physics are:

- 1) Pion condensation phenomena in medium and heavy nuclei ($E_\gamma \sim 300 - 400 \text{ MeV}$);
- 2) Isobaric resonances and exchange currents in nuclei by π -photoproduction around 300 - 400 MeV;
- 3) Parity violation in π -photoproduction at threshold;
- 4) (γ, pn) reaction to probe pair correlation and quasi-deuteron models in nuclei;
- 5) Photodisintegration of light nuclei at high energy with polarized gammas.

We would like to thank Prof. Y. Farge, chairman of the "ad hoc Committee on Synchrotron Radiation" of the ESF, for his great interest in the study of this facility and the useful discussions we had with him during the Aussois Meeting on the ESRF.

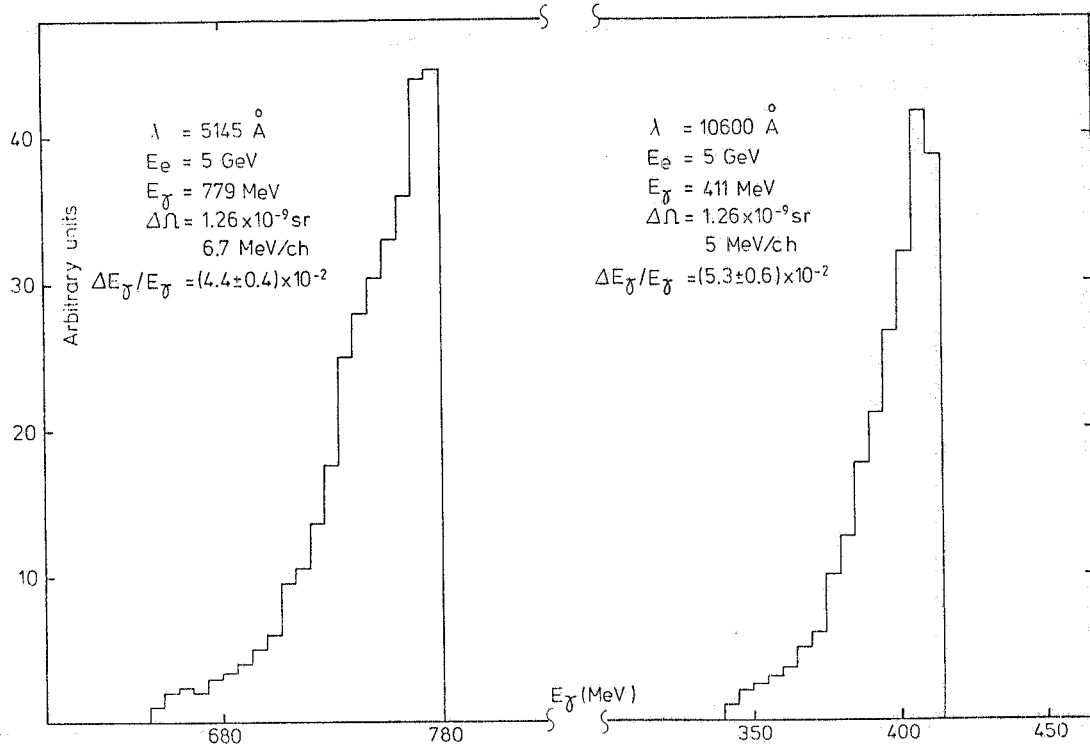


FIG. 7 - Typical energy spectra at 5 GeV.

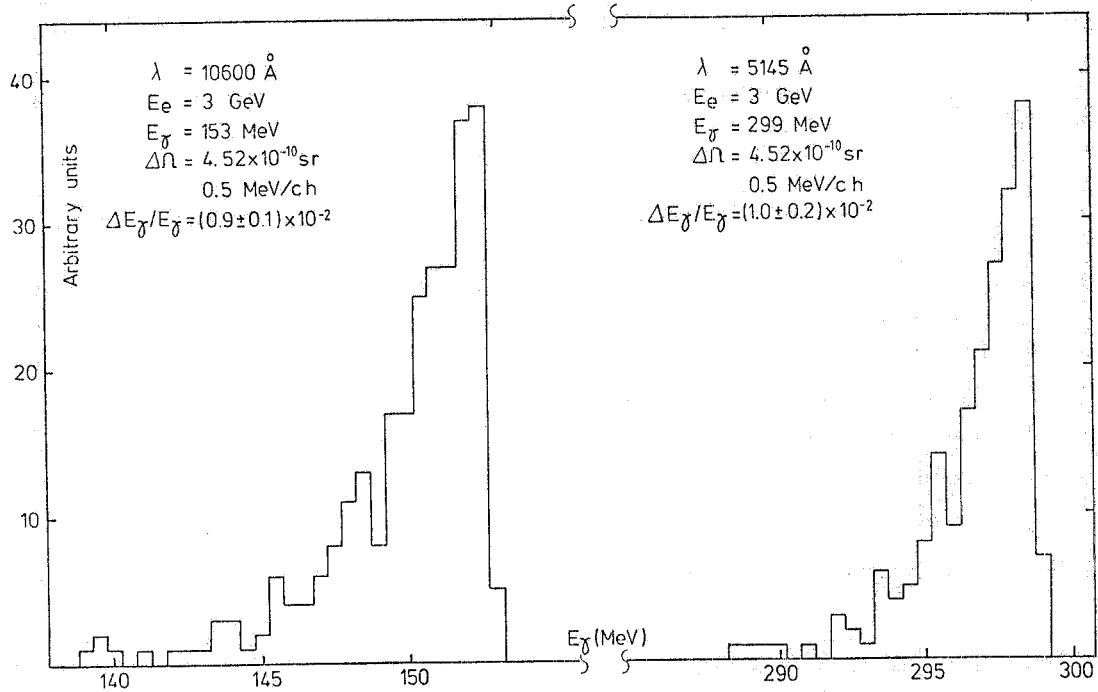


FIG. 8 - Typical energy spectra at 3 GeV.

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