The Elettra project : status report

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THE ELETTRA PROJECT: STATUS REPORT

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Sincrotrone Trieste is a private company whose aim is that of constructing and operating ELETTRA, a third generation (low emittance) synchrotron light source. The share holders are public institutions such as: The Research Area of Trieste, SPI - a branch of IRI for industrial promotion - and the financing agency Friulia of the Region Friuli-Venezia Giulia. The statute of the company allows for and encourages international collaboration as well as the utilization of the laboratory by private industries. Its Board of Directors is chaired by Carlo Rubbia. Two committees, headed by Sergio Tazzari and Franco Bassani, advise on the machine project and on the scientific programs.

ELETTRA is optimized to cover the needs of the scientific community of synchrotron light, with particular emphasis for experiments not feasible today at existing machines. The inputs to the conceptual design have been those of building a storage ring with a large number of straight sections capable of hosting long insertion devices, reaching high brilliance up to 1 keV in first harmonic from undulators and high spectral flux from wigglers up to 20 keV. Good tunability ranges from undulators were also required on the basis that many experiments (such as SEXAFS and Constant Initial State Photoemission) need large photon energy intervals. These design goals will be achieved by a storage ring optimized for very low emittance electron or positron beams in the energy range from 1.5 to 2 GeV.

The construction of the laboratory will start in Trieste in a few months with the aim of commissioning the machine at the end of 1992. The site chosen is of about 45.8 hectares, almost flat, on the solid limestone rock of the Trieste carstic plateau, near Basovizza 10 Km from downtown Trieste. The site, defined as T8, is shown in Fig. 1 together with its surroundings.

Injection System and Storage Ring

Electrons have been chosen as accelerating particles, leaving positrons as an option for a second phase. The advantage as compared to positrons is a much simpler injection system and higher injection rates. The drawback of this choice is the capability of an electron beam to trap ions in the storage ring enhancing the emittance of the beam and inducing a decrease of the lifetime. Extensive simulations of this phenomena have shown that the problem is alleviated for ELETTRA with its low emittance beam and high current.

Due to the high requirements on orbit stability and reproducibility, a full energy injection scheme with a 100 MeV linear pre-accelerator and a full energy (2 GeV) booster synchrotron has been chosen. A schematic layout of the accelerators is shown in Fig. 2. The booster synchrotron and the Linac are located inside the storage ring in order to avoid interference with the synchrotron light beamlines.

The Linac - whose order has already been placed to the CGR-MeV - is specified in such a way that it will be possible to drive an infrared Free Electron Laser (FEL) with a laser wavelength range between 2 and 20 μm.

In the normal operation mode the ring will be filled with 432 equidistant bunches. A macropulse of about 250 ns length is injected from the 100 MeV Linac into the booster synchrotron in a single turn via a septum magnet and a full-aperture kicker. After acceleration to the operating energy, it is then extracted from the booster, again in a single turn, by means of a slow beam bump, a fast kicker and a pair of septum magnets. In this way the storage ring is repetitively filled to its maximum current of 400 mA. For some time-resolving experiments, a single bunch is needed in the machine. In this case a macropulse of about 1 ns length is accelerated in the Linac and captured in the booster in one single RF bucket. The injection timing permits the repetitive filling of the same bunch until the maximum current of 8 mA is reached.

The magnet lattice selected for ELETTRA is a double bend achromat made out of twelve identical units. Since there was no constraint on the circumference of the ring, the lattice has been expanded to a total length of 259.2 meters in order to approach the Chasman-Green minimum in emittance. The lattice incorporates 12 long straight sections. Eleven of them will be used to accommodate undulators and wigglers while one of them will be dedicated to the injection scheme. The insertion device beamlines will be complemented by an appropriate number of bending magnet beamlines. Achromat structure and lattice functions are shown in Fig. 3. A selection of storage ring parameters is given in the annexed Table 1.

The energy lost through synchrotron radiation is recovered by means of four 500 MHz accelerating cavities, 60 kW each. To guarantee the required beam lifetime, a momentum acceptance large enough to accommodate Touschek scattered particles must be provided, which in turn leads to a total accelerating voltage of 1.8 MV per turn. At the maximum current of 400 mA and at 2 GeV, the cavities must supply to the beam a total power of 128 kW (102 kW must be provided to compensate the energy loss from bending magnets). Four separate amplifiers have been chosen, each of which supplies one cavity. The cavities for ELETTRA have been designed to minimize multipacting and higher order mode excitations, which leads to a smooth shape of the cavity. The fabrication of the cavity body has just been contracted to Trieste firms and the first prototype has been delivered recently.

The narrow gap undulators foreseen in the straight sections make the machine particularly sensitive to beam gas scattering. To achieve a sufficient beam lifetime, it is necessary to obtain an operating pressure around 10^{-9} Torr. The major load of gas in an operating storage ring is caused by the interaction of the synchrotron radiation with the surface of the vacuum chamber. In ELETTRA, most of the radiation coming from each bending magnet is directed outside the beam chamber through a slot and stopped at a discrete photon absorber that is located directly above an ion getter vacuum pump. In addition, distributed non evaporable getter pumps are used in the bending magnets, while further 96 small ion pumps, distributed along the donought, provide the requested average pressure in presence of the maximum beam current of 400 mA at the maximum energy of 2 GeV.

Source Performance and Beamline Instrumentation

Fig. 4 shows the spectral flux as obtained from bending magnets and from a typical 1.5 Tesla wiggler. Fig. 5 shows the spectral brilliance, reaching values between 10^{18} and 10^{19}, of 3 representative undulators (see Table 2 for the corresponding parameters). If the third harmonic is taken into account, besides high spectral brilliance, good tunability is achieved in the range from 10 eV to about 2 keV. The very high brilliance of ELETTRA undulators will improve the signal to noise ratio and will decrease considerably present days exposure times. Besides, energy, spatial and temporal resolutions will be improved by orders of magnitude.

For the ELETTRA insertion devices, the effect of magnetic field errors on the radiation properties is under investigation in order to determine realistic magnetic field amplitude and periodicity tolerances respectively (and hence constructional tolerances). The important topic of the effect of insertion devices on linear and non-linear electron beam dynamics is also receiving a good deal of attention.

In order to fully utilize the high performances offered by the insertion devices, one must solve new problems which arise in the construction of beamline optical elements. One of the most challenging problems is the effect of high power densities on mirrors and gratings since thermally induced slope errors can reduce transmission and resolution. For VUV and soft X-ray beamlines, grazing incidence mirrors are usually the first optical element and a study of the thermally induced errors has been carried out using finite element analysis. The first results of this study prove that the effects are significant suggesting therefore further numerical calculations and experimental measurements.

Another problem that must be explored concerns the quality of the optical elements with regard to accuracy. Studies of new optical designs in which only plane and spherical surfaces are used for focussing and monochromatization are being carried out. In collaboration with a group of the University of Padova, a new Czerney-Turner type monochromator is currently studied. A complete raytracing analysis including the effect of slope errors, shows that a resolving power in excess of 6000 will be obtained. The photon flux obtainable on the sample from a beamline equipped with this monochromator and a U2 type undulator is shown in Fig. 6. Particular attention will be paid to higher order filtering, stray light and mirror contamination. Although such problems are common to optics for bending magnet beamlines, the higher quality of insertion device beams requires that they have to be tackled in a completely different way.

Analyzers and detectors are also causing concern because of the high photon flux and brilliance expected. In particular, channeltrons and channelplate detectors of electron analyzers available at present on the market are likely to saturate. Therefore, new kinds of toroidal analyzers are going to be developed.

Scientific Programs

Basically, ELETTRA will provide undulator radiation from a few eV to about 2 keV in third harmonic and wiggler radiation in the range 1-20 keV. So far no official decision has been taken by the *Sincrotrone Trieste* regarding the beamlines to be implemented. Some of the possibilities being discussed so far are listed below (the first three have been recommended by the Program Advisory Committee):

i) Core level photoemission spectroscopies (SuperESCA);
ii) Spin polarized photoemission spectroscopies (for surface magnetism);
iii) X-ray diffraction (for crystallographic research);
iv) Soft X-ray microscopy;
v) Time resolved luminescence and non-linear spectroscopy;
vi) VUV-Soft X-ray high resolution photoemission;
vii) EXAFS in dispersive and fluorescence modes;
viii) Gas phase photoemission;
ix) Surface diffraction.

In addition, the choice of a Linac as preinjector will allow the planning of R&D on fourth generation synchrotron radiation sources such as free electron lasers.

Many national institutions and several foreign research institutions, in particular from Austria, Switzerland, U.S.A. and Yugoslavia, have shown a strong interest in the Trieste facility. This will lead to joint ventures for the construction and use of a number of beamlines.

TABLE 1

Parameters of ELETTRA

E_{max}	2	GeV
Design current	400	mA
Achromat structure	Double Bend	
Number of achromats	12	
Circumference	259.2	m
Horizontal emittance	$7.1 \cdot 10^{-9}\pi$	m-rad
Dipole field	1.2	T
Dipole critical energy (at E_{max})	3.2	keV
Magnets		
- Dipoles	24	
- Quadrupoles	108	
- Sextupoles	72	
Maximum number of bunches	432	
Bunch length (r.m.s.)	30	ps
Beam lifetime	>10	hrs
Single bunch current	8	mA
Insertion devices	11	
Available length on straight sections	4.8	m
Insertion device minimum gap (at 2 GeV)	20	mm
RF - frequency	499.65	MHz
RF - voltage (max)	1.8	MV/turn

TABLE 2

Undulator parameters

Type	λ_o(m)	B_o(T)	K	N	P_t(kW)	P_d(kW/mrad^2)
U1	0.088	1.12	9.2	56	6.2	4.3
U2	0.056	0.65	3.4	89	2.1	4.0
U3	0.044	0.44	1.8	114	0.98	3.4

Wiggler parameters

g(mm)	B_o(T)	λ_o(m)	N_p	K	K/γ (mrad)	P_t(kW)	P_d(kW/mrad^2)
20	1.5	0.125	69	17.5	4.5	9.9	3.6

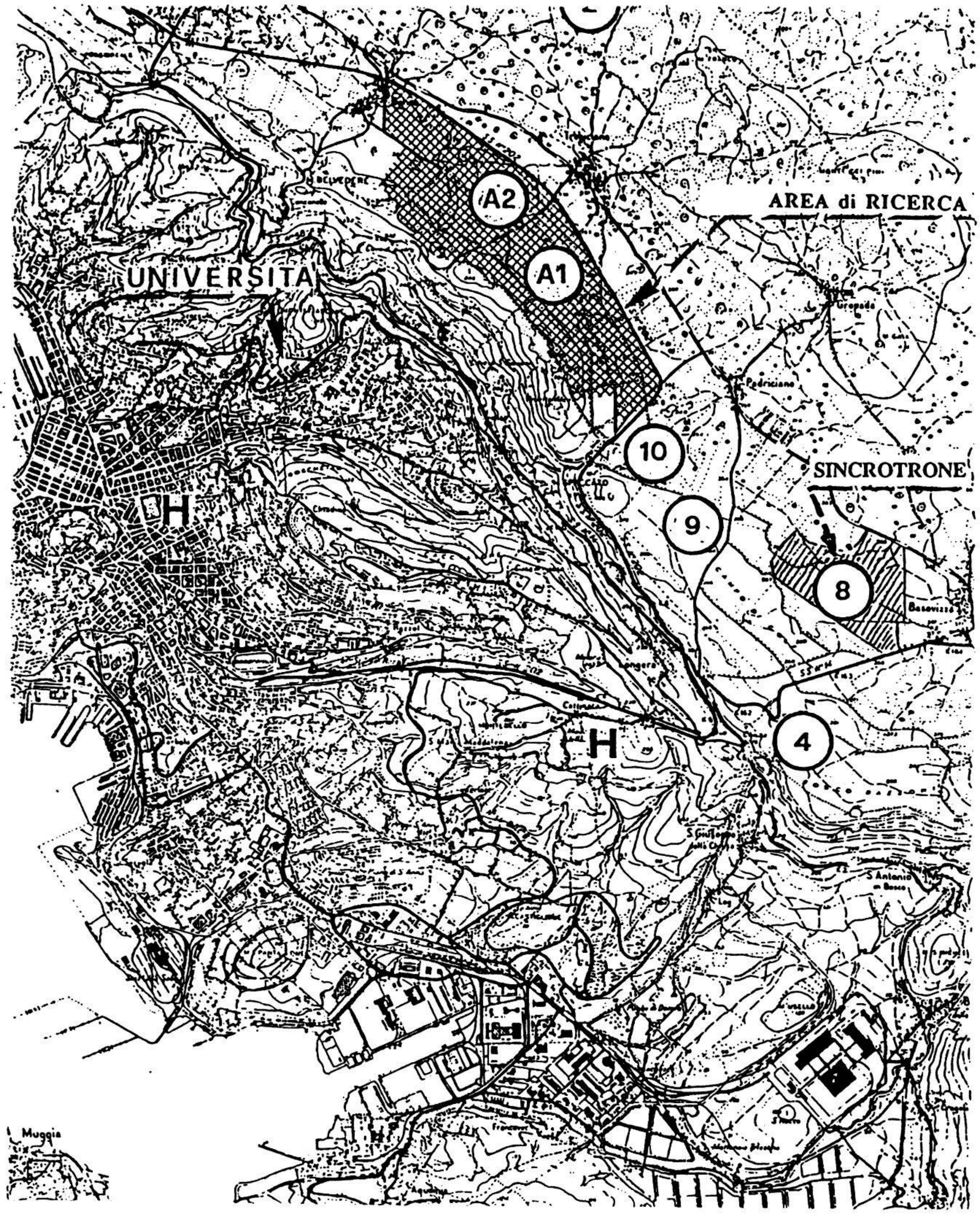

Fig. 1 Map of the site (T8) and surroundings.

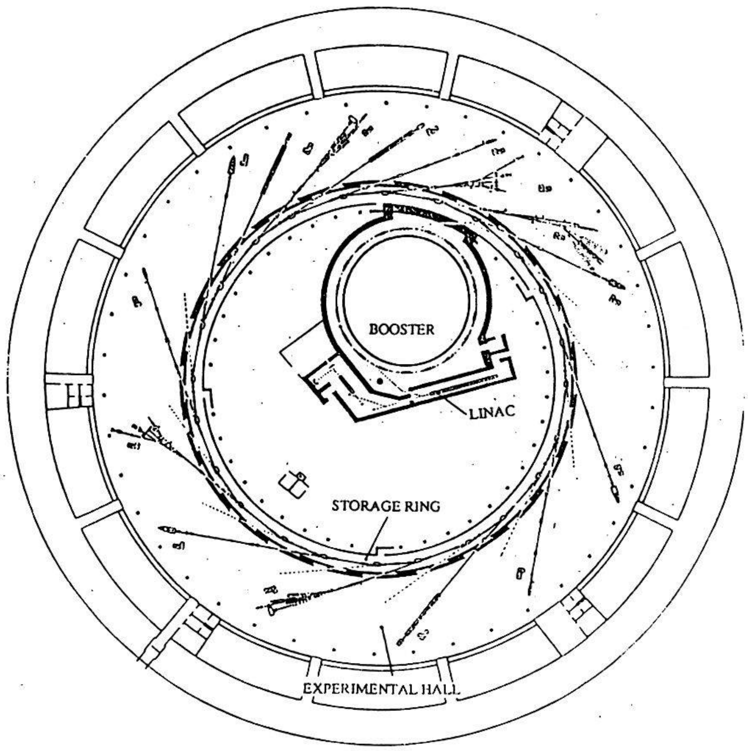

Fig. 2 Layout of the linac, booster, storage ring and experimental hall.

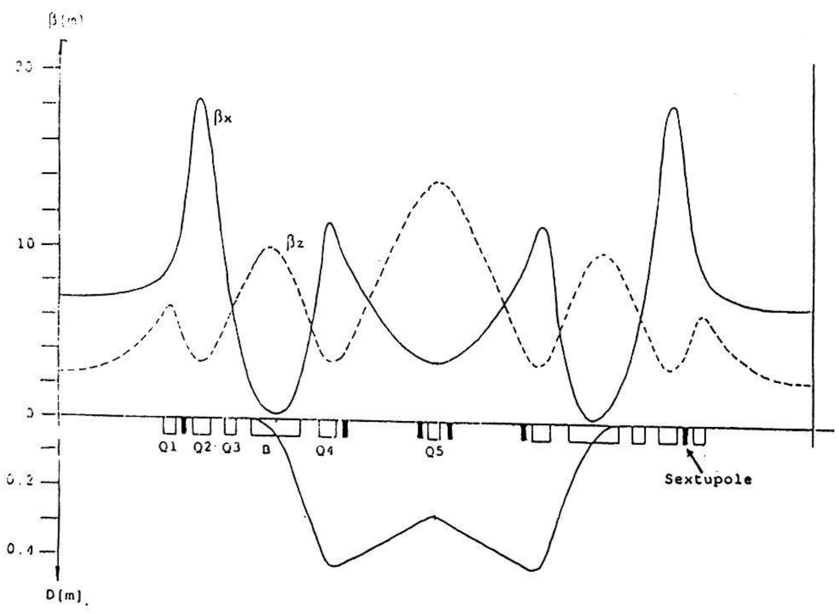

Fig. 3 Achromat structure and lattice functions.

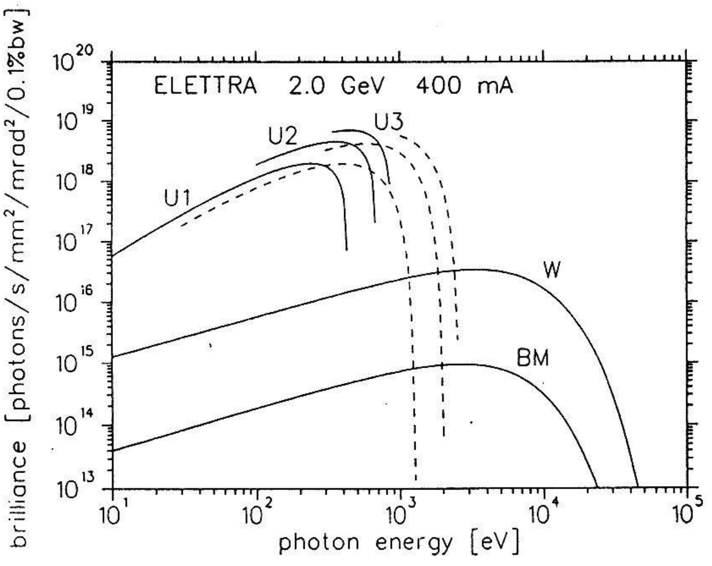

Fig. 4 Flux obtained from an ELETTRA's bending magnet and from a 1.5 Tesla, 35 periods multipole wiggler.

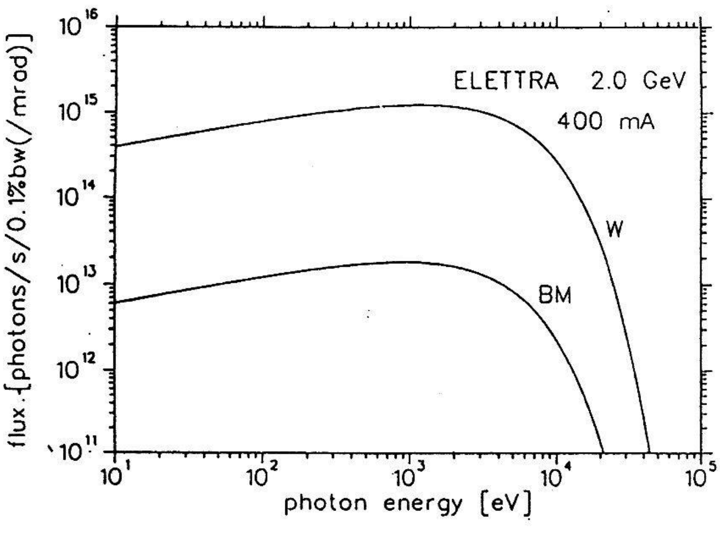

Fig. 5 Spectral brilliance from three typical undulators. Dashed curves refer to third harmonic radiation.

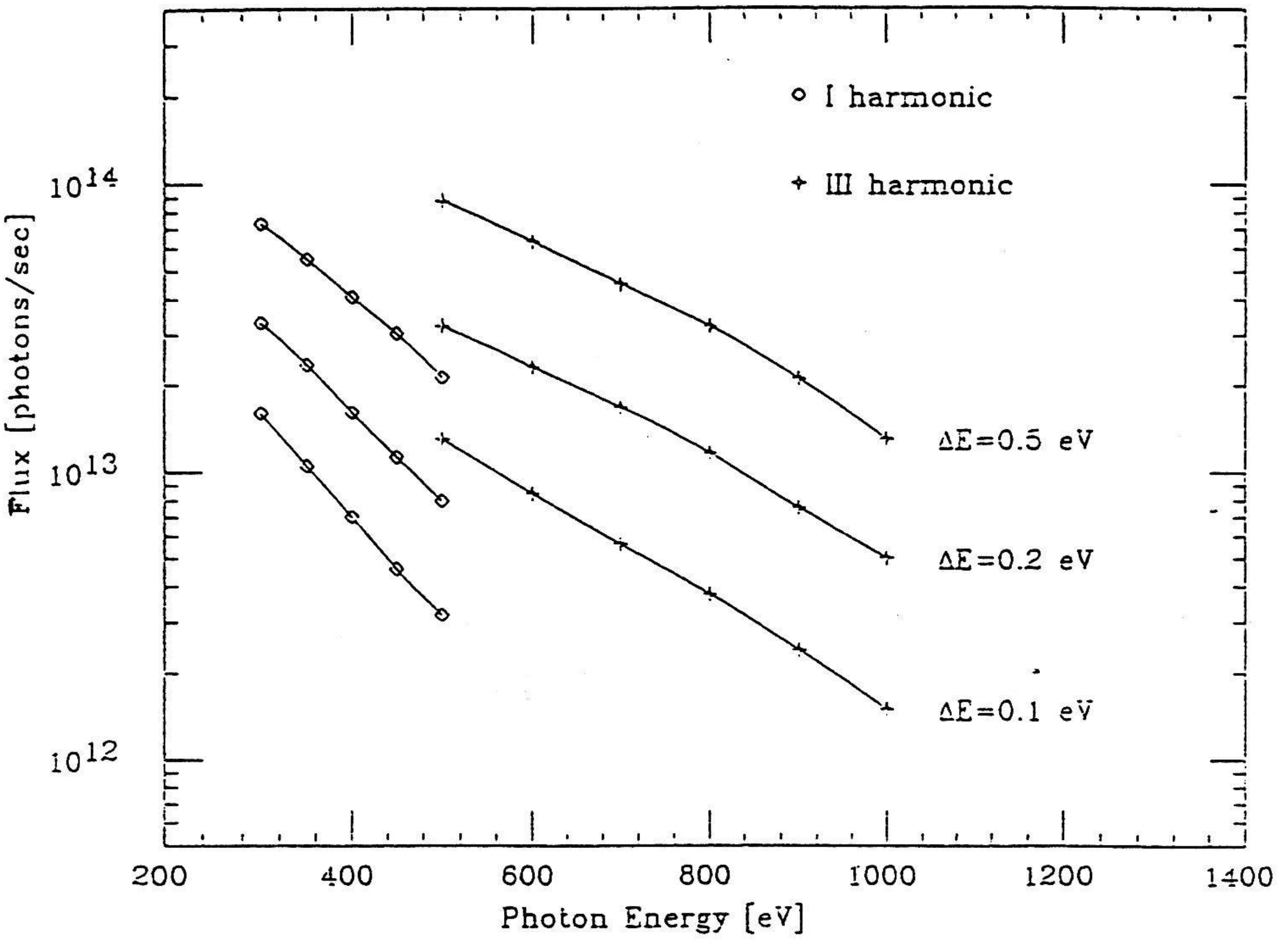

Fig. 6 Photon flux expected on the sample, from an U2 undulator, at three different energy resolutions.