# A DESIGN OF 3 GeV CW ELECTRON ACCELERATOR FACILITY

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## Abstract

A further progress of high-energy nuclear physics is related to the possibility of obtaining continuous intense polarized beams of 2-4 GeV electrons and gamma-quanta with low emittance and energy spread.

A design of the accelerator facility proposed for these purposes is briefly outlined in this report. The design is based on the upgrading of the 2 GeV Kharkov electron linac (ELA) and the construction of a stretcher ring (SR) at its termination. Operation in the beam storage mode is intended also for nuclear physics experiments using internal targets and for producing synchrotron radiation.

Reported are general characteristics of the ELA-SR complex, and the results of numerical computer simulation of a slow beam extraction at the third-order resonance of horizontal free oscillations with due regard for the radiation and synchronous oscillations.

Further progress in experimental nuclear and elementary particle physics research is related to the development of 2-4 GeV continous-beam electron accelerators. Most projects of such facilities intend to provide existing high-current pulsed linacs with stretcher rings for transforming the time structure of the beam. In the recently proposed alternative design of the Continous Electron Beam Accelerator Facility (CEBAF) [1] the continuous electron beam will be accelerated up to an energy of 4 GeV in a superconducting linac with a recirculating loop.

The accelerating-storage complex with a quasi-continuous electron beam to reach an energy of 3 GeV, which involves the construction of a stretcher at the termination of the existing linear accelerator, is being developed at the Kharkov Institute of Physics and Technology. The original SR design [2] has essentially been revised to improve its parameters, in particular, the energy range was chosen to be between 0.5 and 3 GeV. The layout of the stretcher and experimental halls is given in Fig. 1.

The linear accelerator produces electron beam pulses, 1.4 $\mu$s long, with a repetition rate of 300 Hz. An ELA beam energy spread of $\pm$ 1 % is reduced down to $\pm$ 0.1 % by the energy compression system incorporated in the beam transport line from the ELA to the SR. The beam emittance in both planes is the same and equals $\pi \cdot 10^{-7}$ mrad. To match the phase volume of the ELA beam to the longitudinal SR acceptance, the beam is prebunched at the third subharmonic of the ELA operating frequency. A two-turn injection in the SR with a kicker magnet in the horizontal plane at 2 cm from the equilibrium orbit is chosen. This way of injection provides a 'hollow' beam, which is necessary for efficient extraction at the third-order resonance of betatron oscillations.

Two beam extraction channels can operate simultanously. The internal SR beam will be used for the production of Compton and tagged photons and for jet target experiments. The photon tagging system, based on the modified bending magnet, has the following parameters: 0.3 - 0.8 $E_0$ tagging interval, 1 - 10 MeV resolution, $10^7$ $s^{-1}$ intensity.

The SR lattice is of a separated function type and consists of four quadrants. Each circular bend of the quadrant consists of 8 dipole magnets with a bending angle of 11.25° and a bending radius of 8.89 m and 7 quadrupole magnets which ensure achromatism of the straight section of the orbit. Five quadrupole magnets in the straight section of the orbit ensure constant amplitude function values at the electrostatic septum and inflector sites. The amplitude and dispersion functions are illustrated in fig. 2. The horizontal tune $\nu_x$ is varied by two pulsed quadrupoles. The focusing system allows one to adjust the vertical tune $\nu_z$ in the range from 5.09 to 5.25, keeping $\nu_x$ at 16/3. This is important for tuning away from depolarising resonances when operating with polarized electron beams in the energy range 0.5 - 3 GeV.

To compensate for the chromaticity of the ring in a circular bend, four sextupole magnets will be installed in each bend; the amplitude and phase of the 16th harmonic of the sextupole field are adjusted by the sextupole magnets positioned by one in each of the four straight sections. The cubic nonlinearity in the magnetic field can be adjusted by four octupole magnets. The deviation of the angle of extraction is compensated by two sextupole pulsed lenses located in the straight sections. The orbit will be corrected in vertical and horizontal planes by means of 32 dipole magnets.

Figure 3 shows schematically the beam extraction section. A typical list of parameters for the septum-magnets, electrostatic septum and the inflector used in the injection and extraction systems is given in Table 1.



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Table 1

| | | |
|---|---|---|
| Electrostatic septum length (m) | | 1.8 |
| Field strength in the electrostatic septum (kV/cm) | | 35 |
| Electrostatic septum thickness (mm) | | 0.1 |
| Magnetic septa | large | small |
| Septum length (m) | 0.7 × 2 | 0.5 × 2 |
| Septum thickness (mm) | 6 | 1.5 |
| Field strength (T) | 0.75 | 0.182 |
| Inflector magnetic field strength (T) | | 0.05 |
| Inflector length (m) | | 1.5 |

Figure 4 gives the beam representation in the (X,X') plane and the beam cross section in the (X,Z) plane after passing through the electrostatic septum, which were obtained by simulating the particle dynamics taking into account the radiation damping and synchrotron oscillations in the achromatic extraction using the RADA program [3].

To produce the synchrotron radiation with a shorter wavelength, it is planned to install a wiggler magnet in one of the SR straight sections.

The operating frequency of the stretcher ring RF system has been chosen to be 699.3 MHz. In order to make up for synchrotron radiation losses and also to provide an adequate quantum lifetime $\tau_q = 1.7$ s, the amplitude of an accelerating voltage at a maximum electron energy of 3 GeV should be equal to 3 MV. This keeps the rate of particle losses during injection and extraction within 1%. This value of accelerating voltage is sufficient for beam storage at 2.6 GeV with $\tau_q = 4$ hours and for experiments with internal beams.

Six 5-cell cavities with a total shunt impedance of 90 MΩ, which are installed in two straight sections, will be employed for RF compensation. The possibility of using the on-axis coupled biperiodic compensated structure, that is less sensitive to manufacture errors and transient beam loading effects, is considered. Each cavity will be fed from a 100 kW clystron.

A polarized electron beam facility, consisting of two spin rotators, provides the change of spin orientation from longitudinal to vertical before injection in the ring and back from vertical to longitudinal after extraction, the beam energies ranging from 0.6 to 3.0 GeV. Figure 5 shows the energy regions available for spin-rotator operation versus the bending angle $\varphi_1$ in the first dipole magnet for the case of the total bending angle in the spin rotator being $\varphi_1 + \varphi_2 = 67.5°$. The bending magnets in beam transport lines are similar to those of the ring. Figure 6 illustrates the strength of the spin-rotator solenoid $(H \cdot l)$ as a function of the particle energy $(\varphi_1 = 22.5°, \varphi_2 = 45°)$.

The principal parameters of the SR are listed in table 2.

The SR vacuum system units and vacuum inserts are designed and arranged so as to ensure the electrodynamic smoothness of the chamber. An aluminum alloy will be used as a main material for the vacuum chamber.

Table 2

| | |
|---|---|
| Energy (GeV) | 0.5 - 3.0 |
| Magnetic field in bending magnets (T) | 0.18 - 1.125 |
| Orbit length (m) | 213.06 |
| Betatron tune | $\nu_x = 5.33, \nu_z = 5.12$ |
| Momentum compaction factor | 0.048 |
| Oscillation damping time (msec) at E = 3 GeV | $\tau_x = 6.48, \tau_z = 5.29$ <br> $\tau_s = 2.42$ |
| Radiation losses (MeV/turn) at E = 3 GeV | 0.806 |
| RF frequency (MHz) | 699.3 |
| Accelerating voltage (MV) | 3 |
| Beam duty cycle | ~ 1 |
| Beam emittance (mrad) | $\pi \cdot 10^7$ |
| Beam losses during extraction (%) | ~ 1 |
| Energy spread of the extracted beam(%) | ± 0.1 |

To decrease the photodesorption coefficient and the time of reaching the operating pressure, the chamber will be cleaned using a glow discharge and baking at 150°C. The ion pumps provide a vacuum of ~ $10^{-8}$ torr at a stored current value up to 0.5 A.

Beam diagnostics includes:

- beam position monitors - a set of 35 electrostatic pickups that measure beam centroid position and beam current;
- fluorescent screens;
- secondary emission monitors for beam profile measurements;
- inductive beam current monitors for beam current measurements in injection and extraction beam lines;
- synchrotron radiation monitors for measuring the position and emittance of the beam.

The control system of the complex has a three-level network of mini- and microcomputers connected with controlled units through the CAMAC modules.

The upper level is based on a two-processors minicomputer with a 'common bus', to which operator consoles are directly connected. It is responsible for all operator interaction and maintenance of the machine log and check-point files.

The intermediate control level involves the computers responsible for functioning of various SR systems. They are placed in the hall locating a central computer, and are compatible with the latter in hard- and software, being equipped with a common set of terminals.

The lower level includes microprocessors and CAMAC controllers which provide primary information collection and sorting, as well as direct control of various equipment.

## References


1. US Nuclear Physics: Some like it cold. CERN Courier 1986, v.26, N3, p. 17-18.
2. E.V. Bulyak, V.A. Vishnyakov, P.I. Gladkikh et al., Trudy 9-go Vsesoyuznogo soveshchaniya po uskoritelyam zaryazhennykh chastits (Dubna, 16-18 October, 1984). Dubna, JINR, 1985, v.2, p.272-275.
3. Yu.N. Grigor'ev, S.G. Kononenko, A.S. Mazmanishvili, Ibid. p. 289-291.

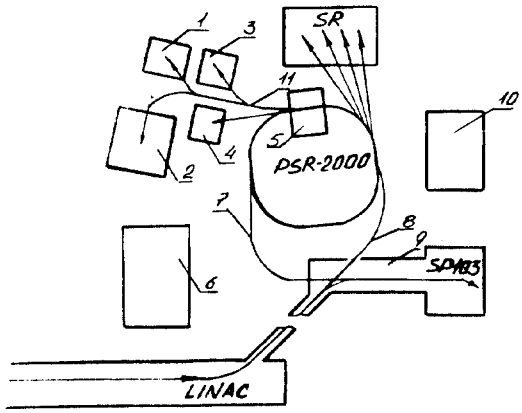


Fig. 1. General layout of the electron linac, stretcher ring and experimental halls. 1-5, 9: experimental halls; 7: first extraction line; 11: second extraction line, 8: the injection line; SR: the synchrotron radiation hall.

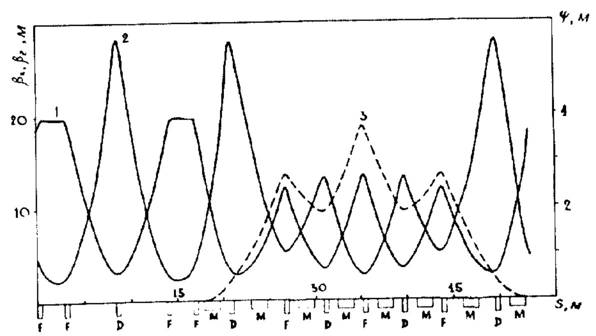

Fig. 2. Amplitude ($\beta_{x,z}$) and dispersion functions of one quadrant. 1: $\beta_x$; 2 : $\beta_z$; 3 : $\psi$.

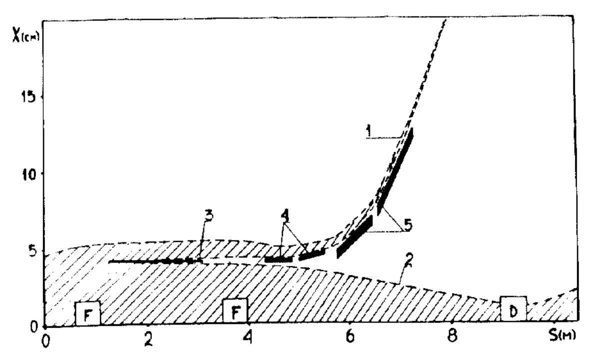


Fig. 3. Beam extraction from the stretcher ring. 1: extracted beam; 2: stored beam; 3: electrostatic septum; 4,5: septum magnets.

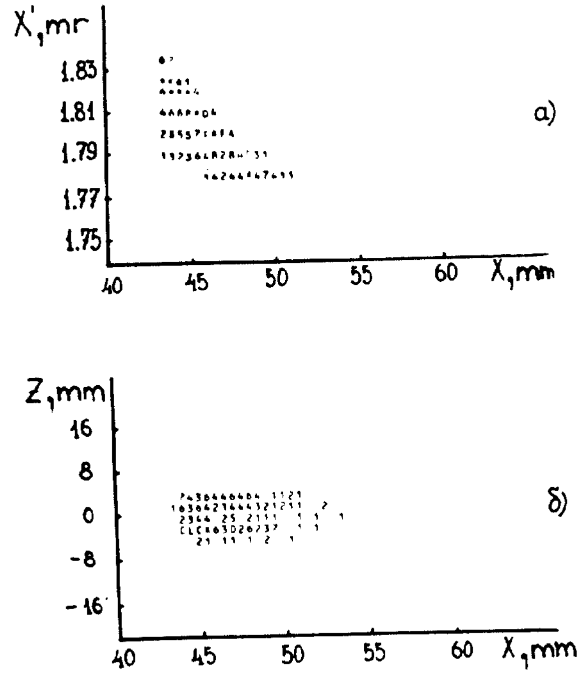


Fig. 4. a) Phase representation of the extracted beam at the electrostatic septum exit.
b) Transverse beam dimensions at the electrostatic septum exit.

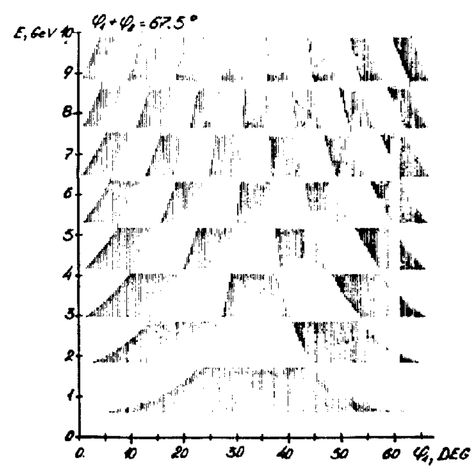


Fig. 5. The operating energy range of the spin rotator (shaded areas) versus the bending angle $\varphi_1$ in the first dipole magnet for the case of the total angle of beam bend in the rotator $\varphi_1 + \varphi_2 = 67.5°$.

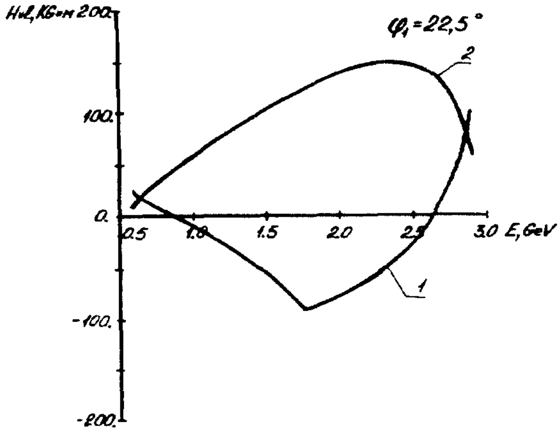


Fig. 6. The strength of spin rotator solenoids, H · l, versus particle energy.
H is the solenoid field,
l is the solenoid length.
1: Hl of the 1st solenoid
2: Hl of the 2nd solenoid.