Introduction to the Theory of Accelerators

Lecturer: Grigory Trubnikov
7th and 8th semesters
Total number of lectures, 7th/8th semester
Lectures: 34/34; practical classes 17/34

Course aims
- Studying the physics of charged particle accelerators.
- Studying the engineering of charged particle accelerators.
- Learning how to do related calculations

Prerequisites: nuclear physics, higher mathematics, elementary particle physics, electrical engineering, probability theory.

1. Course contents
   1.1. Theme names and their content


1.1.2. Accelerators of straight action: Accelerators of the transformation type. The cascade accelerators. Electrostatic accelerators.

1.1.3. Cyclical accelerators:
   1.1.3.1. Transveral stability and focusing. Focusing by a non-homogeneous magnetic field. Criterion of stability and betatron oscillations in periodic systems. Simplest elements of the focusing system. Description of the system of particles in the phase space, Liouville theorem, Courant-Shnider invariant, emittance of the beam.
   1.1.3.2. Induction acceleration. The betatron. Linear betatron (The linear induction accelerator).
   1.1.3.3. HF– acceleration. Auto-phasing in cyclic accelerators: equilibrium particle, principle of the auto-phasing, phase oscillations, effective mass and the critical energy.
   1.1.3.4. Perturbations and tolerances in cyclic accelerators: resonances of the betatron oscillations, parametric resonance, resonances of connections, non-linear resonances. Synchrotron oscillations in the presence of perturbations.
   1.1.3.5. Methods of cooling the beams of charged particles in cyclic accelerators: radiational, electronic, ionizational (muonic) and stochastic cooling. Spatial charge and coherent instabilities. Static effects of the spatial charge; incoherent shift of the frequency of the betatron oscillations (the Lanselet formula). Coherent oscillations of the beams. Increments of the coherent instabilities. Impedance of the cylindrical camera. The Kyle-Shnell criterion. Landau attenuation and other kinetic effects. Instabilities in the chains of small clots. Other types of the coherent instabilities.

   1.1.3.6. Types of the cyclical resonance accelerators. Their description and construction. Magnets and their power supply. Accelerating systems. Cyclical accelerators with a constant magnetic field (cyclotron, synchrocyclotron, microtron). Cyclic accelerator with the constant orbit – the synchrotron.
1.1.4. Linear resonance accelerators:
1.1.4.1. Main characteristics of the accelerating systems. Peculiarities of the systems with the standing wave. Diaphragmatic waveguide. The resonator with the drift tubes.
1.1.4.2. Dynamics of the particles in linear resonance accelerators. Longitudinal movements in the field of A wave. Pre-grouping of the particles. Focusing of the particles in linear resonance accelerators.
2.1.4.3. Effects of the spatial charge in linear accelerators. Longitudinal movement in the self-consistent field. Loading by the current and optimization of the accelerator parameters. Influence of the Coulomb field.
2.1.4.4. Construction and the parameters of linear accelerators. Linear resonance accelerators of the electrons. Linear accelerators of the ions. Superconducting linear accelerators.

2.1.6. Sources of the charged particles: Electronic guns. Ion sources on the base of the high-voltage discharge. ECR-sources. Laser ion sources. Ionic sources with the electronic beam-ionizator. Sources of the polarized ions.


2.1.8. Vacuum in the accelerators. Radiational safety of the accelerators: Interaction of particles with the residual gas in the accelerator: ionization losses and their fluctuations (straggling), single and multiple scattering. Typical vacuum conditions in different accelerators. Radiational safety of the accelerators.

Practical classes

Coursework
Design, functioning principles, and specifics of JINR's basic facilities (up to 20 themes of the coursework).