D.V. Efremov Scientific Research Institute of Electrophysical Apparatus, Saint Petersburg, Russia

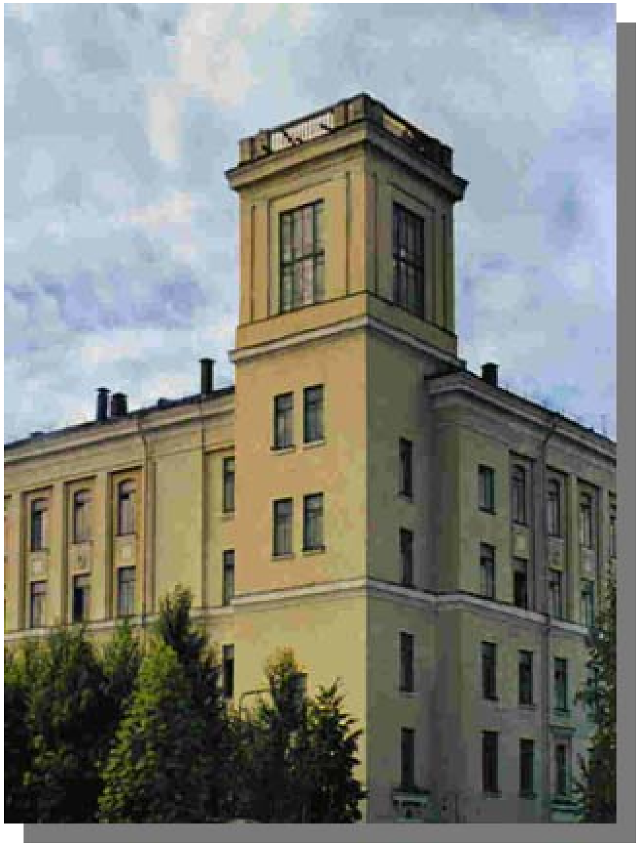
THE CC1-3 CYCLOTRON SYSTEM

V.G. Mudrolyubov[#], I.N. Vasilchenko, Yu.N. Gavrish, A.V. Galchuck, S.V. Grigorenko, V.I. Grigoriev, M.T. Kozienko, L.E. Korolev, A.N. Kuzhlev, Yu.I. Stogov, V.I. Ponomarenko, A.P. Strokach, S.S. Tsygankov, V.D. Shiltsev

D.V. Efremov Scientific Research Institute of Electrophysical Apparatus, Saint Petersburg, Russia

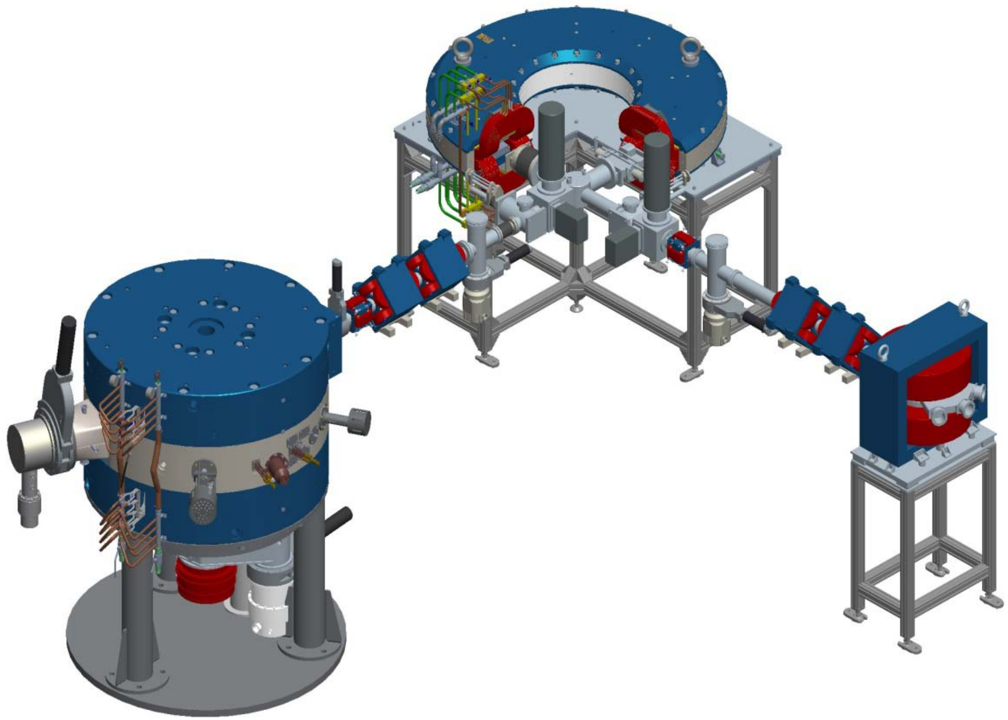
Nebojsa Neskovic, Petar Belicev, Aleksandar Dobrosavljevic, Velibor Vujovic

The Vinca Institute of Nuclear Sciences, Belgrade, Serbia



The CC1-3 cyclotron system

To attain the aforementioned parameters, we have chosen the version of the system consisting of a compact cyclotron with a beam-forming system and systems of power supply, automatic control, vacuum pumping and water cooling.



The compact cyclotron CC1-3 with a beam-forming system.

THE CC1-3 CYCLOTRON SYSTEM

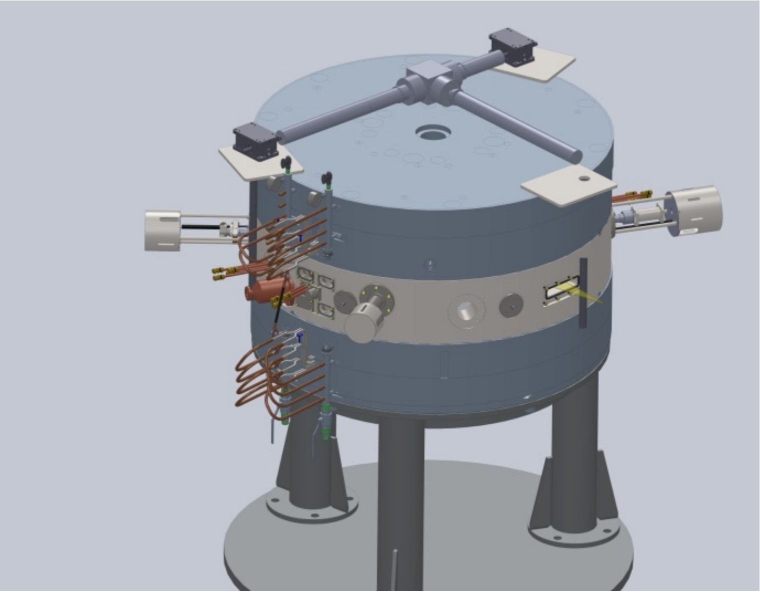
The CC1-3 cyclotron system has been designed at the D.V. Efremov Scientific Research Institute of Electrophysical Apparatus (NIIEFA), St. Petersburg with an active participation of specialists from the Vinca Institute of Nuclear Sciences, Belgrade, Serbia. The system will ensure effective technological facilities necessary to carry out analytical research in the Vinca Institute, in particular RBS, PES, NRA и PIXE spectroscopies.

Strict requirements are imposed for parameters of accelerated proton beams: the energy range should be from 1 to 3 MeV, spectrum width no more than 0.1%, accuracy of energy setting not worse than 1 keV and current ranging from 10 to 100 nA.

Technical characteristics of the CC1-3 cyclotron

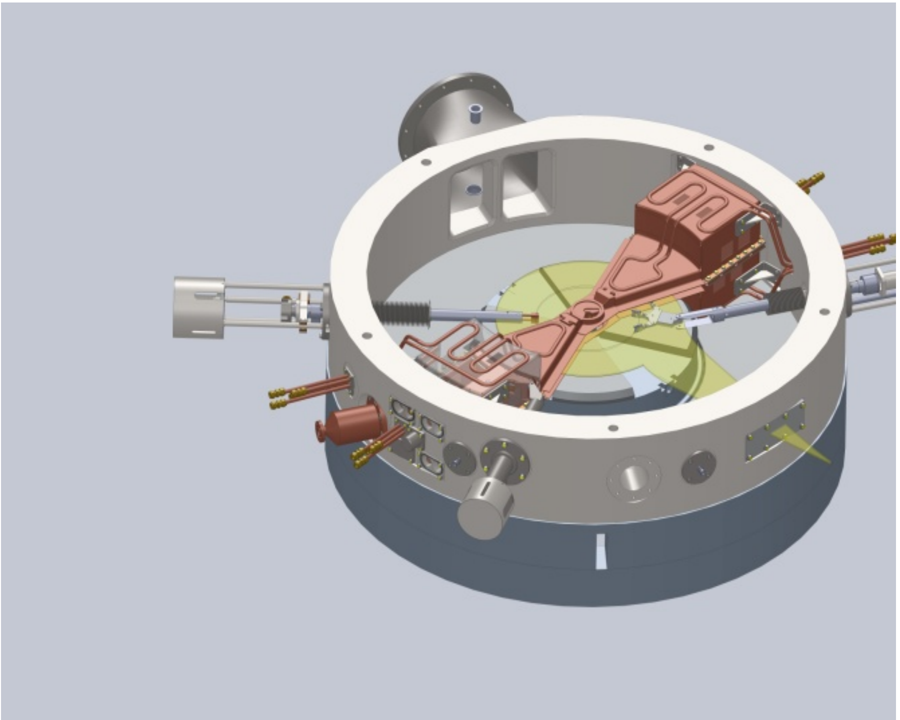
Cyclotron system, feature	Characteristics, value
Type of accelerated particles	H^-
Type of extracted particles	H+
Beam energy, variable, MeV	1…3
Spectrum width no more than,%	0.1
Beam current (extracted), μA	20
Type of magnet	«shielded»
Pole diameter, mm	600
Operating frequency, MHz	59.7
Number of dees	2
RF voltage amplitude, kV	25
RF generator power, kW	5
Type of ion source	external
Total power consumption, no more than, kW:	35
-beam on target	15
- stand-by	

Components of the cyclotron



The magnet of the cyclotron.

The major part of the cyclotron is a four-sector shielding-type electromagnet. The electromagnet is 1400 mm in dia, pole diameter is 600 mm and average induction is 0.98 T. Gap hills/values are 50/100 mm. The maximum acceleration radius for the 3 MeV energy is 250 mm. The power consumption of the magnet is 5.2 kW; its mass is 6.5 tons. The upper beam of the magnet can be moved upward up to 500 mm.



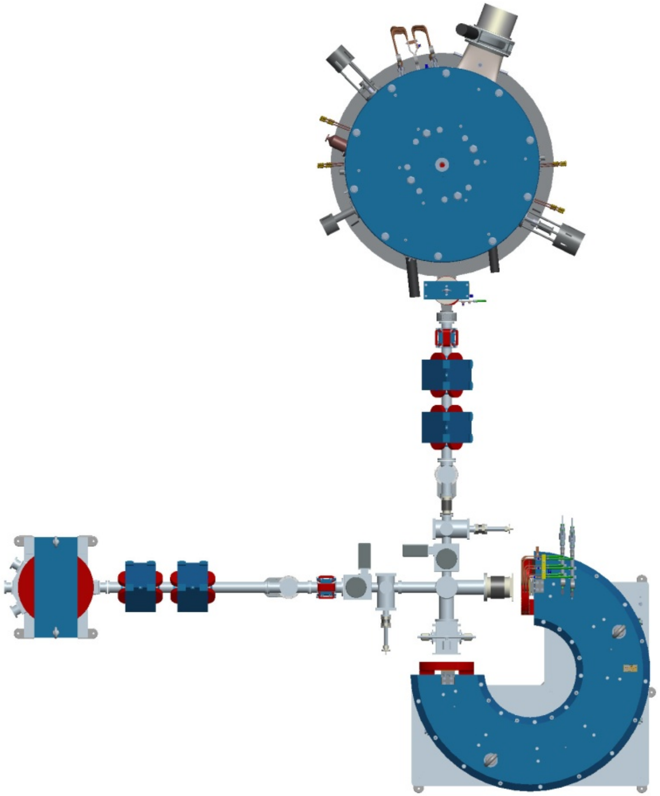
The vacuum chamber with resonance accelerating system, stripping device and probes.

The vacuum chamber of the cyclotron consists of a casing and two covers. The casing is a hollow thick-walled cylinder of carbon steel, which simultaneously is a part of the iron core. Pole pieces of the magnet with welded rings of stainless steel are the covers of the chamber. Such a structural concept provides necessary mechanical strength of the chamber and also forms a type of a volume to improve pumping of the vacuum chamber. A cryogenic pump, vacuum chamber of the matching magnet, RF power in-feeding device, AFT trimmer, stripping device and probes are fastened to flanges of the vacuum chamber casing.

The resonance accelerating system is located completely inside the vacuum chamber volume and is fixed to a side surface of the vacuum chamber casing. The system consists of two mirror-symmetrical quarter-wave resonators. An inner conductor of each resonator consists of a dee and a stem. The dees in the vicinity of the magnet axis are galvanically coupled. An outer conductor of the system is claddings of the magnet and vacuum chamber valleys as well as plates connecting the upper and lower claddings of chamber. The side surfaces of the valley claddings follow the shape of the side surfaces of the magnet sectors and serve as dummy dees. The system is equipped with an inductive RF power in-feeding device, AFT trimmer and RF-probe. Stems, dees and claddings are cooled with water. The central part of the dees is made removable and it is cooled by thermal contact with the dees. The operating frequency of the resonance system is 59.7 MHz and it corresponds to the 4th harmonic of the revolution frequency for hydrogen ions. The design power of active losses in each resonator is 1.6 kW at an RF voltage amplitude of 25 kV.

The high-frequency generator consists of a control and stabilization module and RF-power amplifier. The main parameters of the high-frequency generator are as follows: operating frequency – 59.7 MHz, frequency stability – 1.10^{-7}, phase stability – ±0.5°, output power – 5 kW and accelerating voltage amplitude stability – 10^{-3}. Generator triode 3CW5000A7 is used in the power amplifier. The RF power is transmitted to the resonance system through a flexible coaxial feeder.

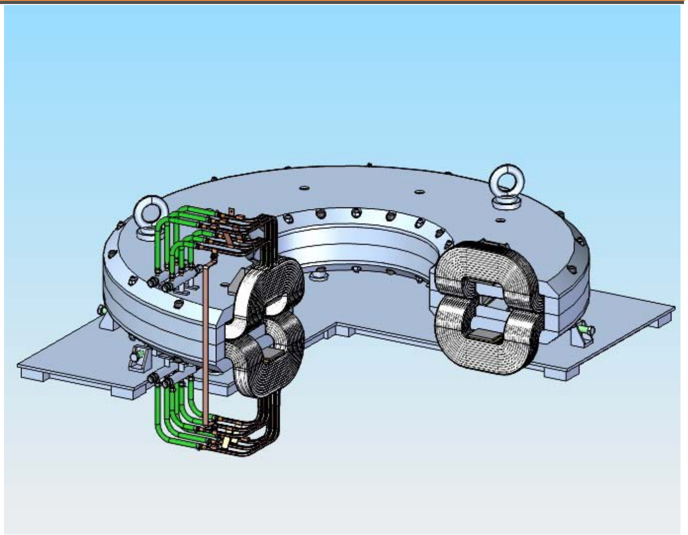
The external injection system is located under the electromagnet. The system consists of a source of negative ions with an ion-optical system for the beam additional acceleration and focusing, differential pumping chamber, two electrostatic lenses, spiral inflector and an ancillary equipment. The ion beam current at the injector output is 0.5 mA, ion energy is 11.5 keV, calculated normalized emittance is not more than 0.3 π mm·mrad.



The beam-forming system

The beam-forming system consists of matching magnet, two doublet of quadruple lenses, analyzer and switching magnet. To measure the beam parameters when it is transported to targets, the beam transport system contains the following diagnostic means: beam profile monitors (scanners), which are used to measure the beam profile in horizontal and vertical planes, and Faraday cups to measure the beam current.
Spectrum width no more than 0.1%.
Accuracy of energy setting not worse than 1 keV. Current ranging from 10 to 100 nA.

The major part of the beam-forming system is an analyzer, which consists of an analyzing magnet and two collimators installed at the inlet and outlet of the analyzing magnet vacuum chamber. The analyzing magnet ensures a bending angle of 270° with a bending radius of 600 mm. To expand the potentialities of the beam-forming system, three fixed dimensions of the input and output slits of 0.5, 1 and 2 mm are provided. The design energy resolution behind the output slit is not worse than 0.05%.



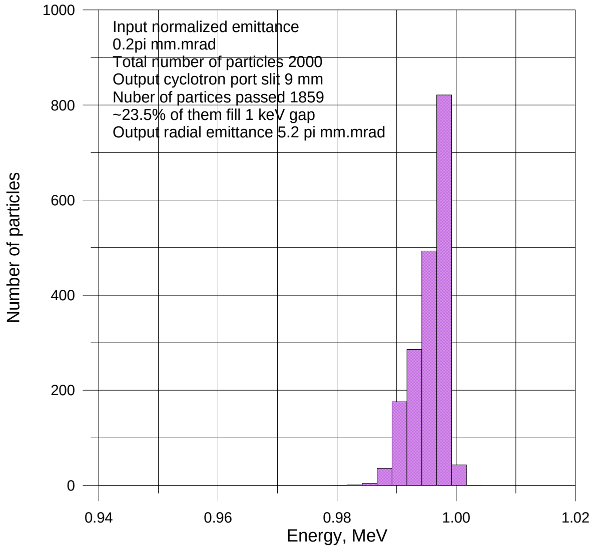
- The power supply system is intended to supply electric power to the cyclotron equipment. The maximum installed power of the equipment is 40 kW. The system consists of a power switchboard, two power supply racks for magnets and lenses and two power supply racks for the external injection system as well as power supply units for step motors and the mechanism moving upward the upper beam of the magnet.

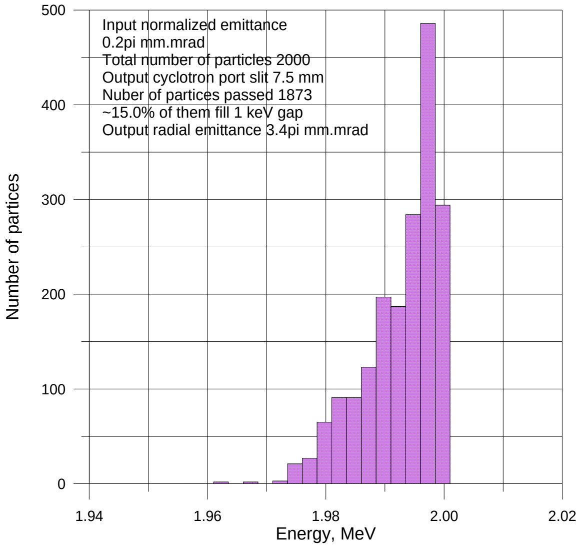
- The automatic control system is of distributed architecture. It consists of Mitsubishi and Fastwel IO controllers and computers, each being responsible for the control of one or several sub-systems of the cyclotron. The main unit of the control system is an industrial (host) computer, which inquires slave controllers and transmits the information acquired to computers of the operator’s workstation; receives commands from the operator’s workstation and performs their arbitration and distribution. Data exchange is realized via network interfaces of three types: the Ethernet, an upper level network, the ProfiBus DP and RS-485, low-level networks.

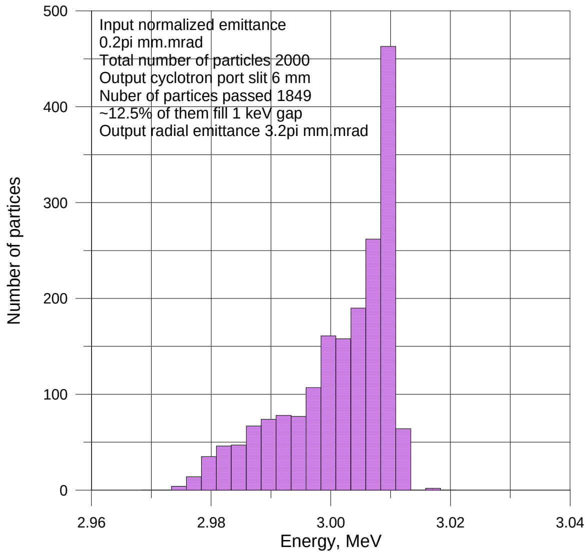
- The vacuum system contains a cryogenic pump used in the vacuum chamber of the cyclotron, four turbomolecular pumps for the external injection system and beam-forming system, mechanical dry pumps, gate valve, valves, leak valves and pressure gages to measure low and high vacuum.

- The equipment of the cyclotron will be cooled with distilled water circulating in the water-cooling loop of the cyclotron building. Four water distribution boards are used to distribute cooling water to remove the heat released by the heat-loaded components and units of the cyclotron, to control pressure and stabilize water flow rates.

Spectrum of extracted beam

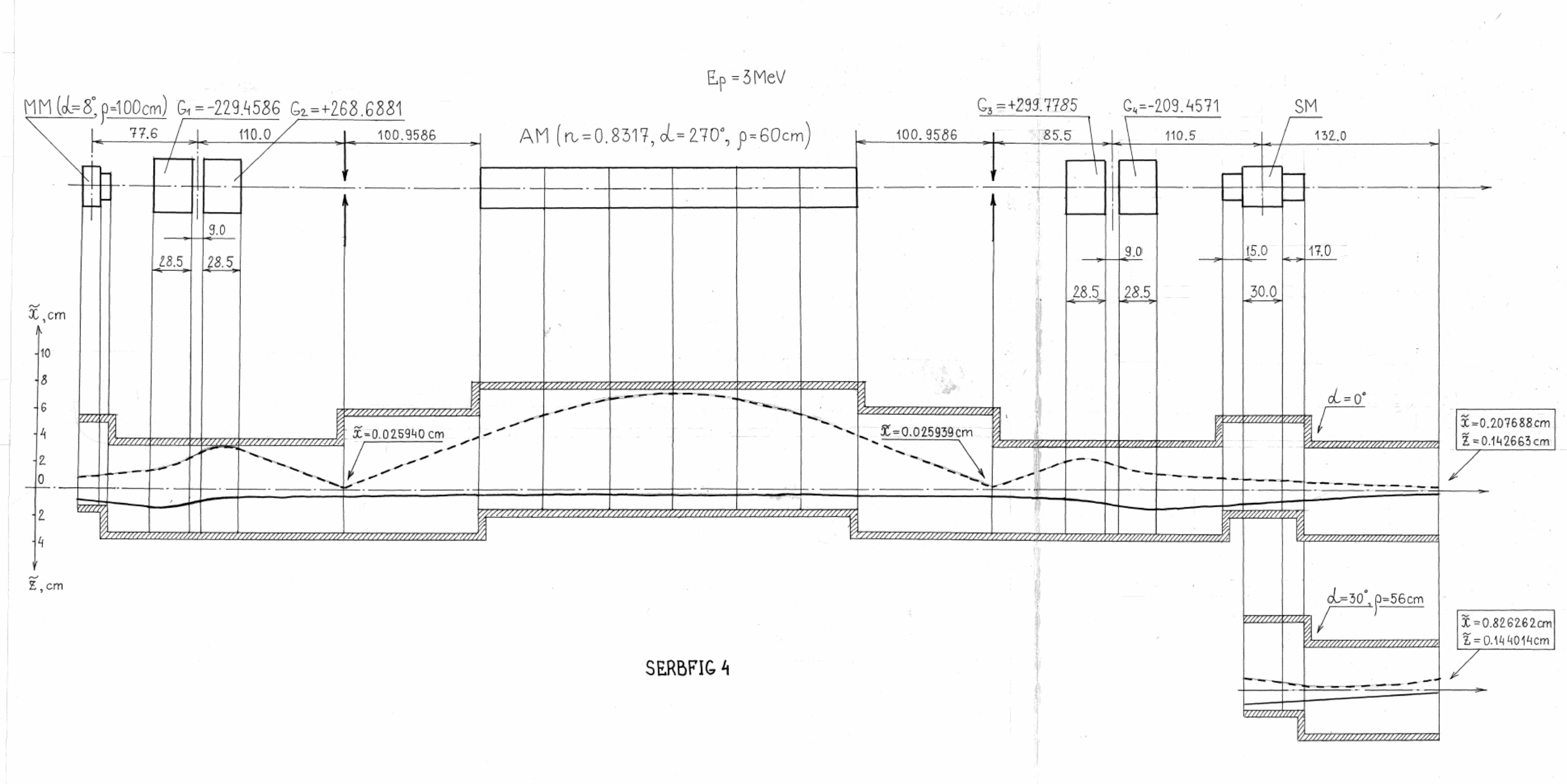






1 MeV: δE= 1 keV→23.5% 2 MeV: δE= 1 keV→15% 3 MeV: δE= 1 keV→12.5%

Beam envelope



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