STATUS OF THE CONSTRUCTION OF THE INR MESON FACTORY

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Beam parameters and main features of the INR meson factory have been published elsewhere [1,2,3,4,5]. Only a general scheme (Fig. 1) and principle comments are given here.

The accelerator consists of three 750 keV injectors (H^+, H^- and H^+ polarized); initial part of the accelerator up to an energy of 100 MeV (5 cavities with drift tubes operating on the frequency 198.2 MHz); and the main part of the accelerator with maximum energy 600 MeV (27 disk and washer cavities at a frequency of 991 MHz). Beam extraction at the intermediate energy 160 MeV (after fourth cavity of the main part of the accelerator) is foreseen. Energy regulation under 160 MeV could be made by steps and then smoothly up to 600 MeV. Summary pulse current of both charge state ions equals 50 mA at the pulse duration 10^{-4} s and the repetition rate is 100 s^{-1} Total beam loss should be less than 10^{-3} - 10^{-4}.

The beam at the exit of the linac is deflected 140 mrad in the vertical plane and extracted to the main experimental area situated at ground level.

At the present time high stability pile foundation for the whole accelerator is complete, and the power building and the 100 MeV accelerator building are ready. The framework of the main accelerator tunnel is built completely and that of RF power gallery is nearly completed. Construction of the ventilation building, circulating water pump station, cooling station, transformer substations and the main experimental building is well advanced.

The initial operation of the accelerator is planned to be done with a proton injector (Fig. 2), which has been tested recently at 1 Hz repetition rate. A conventional duoplasmatron with a directly heated cathode and continuous flow of hydrogen is used as the H^+ ion source providing 500 mA peak current with the phase density 2 $A.cm^{-1}mrad^{-1}$ at the energy 50 keV. The accelerating tube has two gaps: 5 cm with 300 kV focusing voltage and 35 cm with a voltage 450 kV.

The H^+ injection channel consists of 9 solenoids, 3 quadrupole doublets, 2 bending magnets, 2 steering magnets and 2 bunching cavities. Preliminary beam transport tests have been performed by using just 4 solenoids. 16 mA peak current at the entrance of the first Alvarez cavity has been achieved while the current at the exit of the accelerating tube was nearly 80 mA. High intensity beam transport calculations have been done according to ref. 6.

The 750 kV pulse generator for the H^- injector is installed. The Dudnikov Type[7] H^- ion source ensures 100 mA peak current at the energy 20 keV with a pulse length of up to 200 μs and a repetition rate of 50 Hz. High frequency oscillations of the beam intensity do not occur in a band width 10 MHz. 85 % of the beam is constrained within the normalized emittance 0.15 π cm.mrad. An H^- injection beam line using quadrupole focusing is planned.

An H^+ polarized source with an atomic beam is under development[8]. It should provide 100 μA pulse current with a polarization of 0.9. The density of the atomic hydrogen flow $1.9.10^{20}$ $atom.srad^{-1}.s^{-1}$ and the Mach number 4.4 were achieved by cooling the dissociator channel to the temperature 77° K. The model of the ionizer using a deuteron beam with a density of 1 $A.cm^{-2}$ at the energy 12 keV had been tested. The ionization efficiency was found to be 10^{-2}. The rapid polarization sign reversal is foreseen without significant change of the beam intensity and the polarization ratio.

The laser source of the H^+ and H^- polarized ions is under development. The polarization occurs by capturing an electron from the optically oriented sodium atom[9]. The density of the sodium recharging target of 3.10^{3} $atom.cm^{-2}$ with a 95 % polarization degree and the density of the helium gas target in the ionizer of 10^{16} $atom.cm^{-2}$ have been reached experimentally. This makes it possible to get an entire conversion efficiency of the primary beam to polarized protons of the order of 10-15 % and to H^- $\sim$ 1 %. Successful realization of this method will result in getting a polarized proton current of more than 1 mA and the H^- polarized ion current of about 100 μA. Recently the polarized proton current of about 100 μA has been obtained in a pulsed mode. The polarization degree of 50 % has been gained when the recharging sodium target is placed in a magnetic field of 1.0 T. Increasing the field up to 1.5 - 2.0 T will raise the polarization degree up to 70 -80 %.

The acceleration of the polarized beam up to 750 keV will be done with the Kapchinski-Teplyakov accelerating structure[10] at the frequency 198.2 MHz, using the quarter wavelength monochromator to provide the following transport and merging with the beam of opposite charge[11].

Five cavities of the initial part of the linac have been manufactured and installed in place (Fig. 3). Manufacturing of the drift tubes as well as their magnetic measurements are proceeding on a full scale. The triode power generators at the frequency 198.2 MHz have been mounted (Fig. 4). One of these has been tested with equivalent load up to a level of 5 MW pulsed power at 1 Hz repetition rate.

Forty DAW accelerating sections[12] have been manufactured and tuned at a low level of the electromagnetic field. The accelerating resonator of the main part of the accelerator consists of 4 DAW accelerating sections coupled by three wave-guide bridges through bellows. The wave-guide bridges are excited on the H_{109} standing wave. The bellows provide the mechanical independence for the section alignment and allow the electric length of the bridge to be matched during the cavity tuning procedure. Additional tuning could be done with the help of two plungers inserted into both arms of the bridge. The "dispersion diagram" of the first 991 MHz resonator is shown in Fig. 5. The side modes are ± 2.5 MHz away from the principal mode. The adjustment of the resonant frequency as well as the symmetrization of the dispersion diagram and equalization of the average field in adjacent sections are made by changing the electric length of the bridge arms. As a result of tuning the resonant frequency of the first resonator it was found to be 990.812±0.005 MHz (the designed value is 990.80 ± 0.03 MHz). The difference in the average field between sections

resulted in

The removal of modes with azimuthal variations, out of the operating mode neighbourhood is provided by means of T-like resonant slits in the disks[13]. The modes of the main dispersion curve (continuous line) and hybrid modes (dashed line) are shown in Fig. 6 without and with T-slits. The estimate of the beam breakup instability caused by hybrid modes is given in ref. 14 for the INR meson factory.

One half of the total number of the 991 MHz klystron power amplifiers (Fig. 7) have been installed. Tests have been carried out on one of them when working on an equivalent load at pulsed power of up to 4.8 MW and a duty factor of 67.

Magnetic measurements of the 35 (out of 120) quadrupole doublets (Fig.8), comprising the focusing channel of the main part of the linac, show that the displacement of the magnetic axis with respect to the geometrical axis of the lens is less than 0.05 mm, the total nonlinearity is not more than 0.6 % and the r.m.s. mediane plane rotation is equal to 8'.

A considerable part of the beam diagnostic equipment and computer control system have been manufactured and installed.

The INR meson factory will be put into operation with significant delay with respect to other, similar facilities. For this reason we put into the experimental area design some unusual solutions[4] which give our factory competitive ability. Special features of the beam transport and beam sharing as well as the description of the secondary beam lines are given in ref. 5. The high intensity H^- beam gives us several important advantages in comparison with other meson factories: firstly - the beam can be divided in several independently and simultaneously used parts with the required intensity in each, secondly - easy regulation of the time structure of the primary beam becomes possible.

Fig. 9 shows beam channels, proton storage ring, installations and shielding comprising the first stage of the experimental complex which has to be a basis for the future development of the meson factory. The beam from the storage ring can be transported to any part of experimental area. With the help of the storage ring the linac beam can be transformed either into short pulses from 5 to 200 ns or into a beam without the bunching structure and with a duty factor ∿ 90 %.

The beam channeling during the accelerating cycle is shown in Fig. 10. First the H^- beam is divided in 5 beams by using the charge exchange device (Fig. 11). The beam 6 remains to be the H^- beam and will be used for injection into the storage ring. The beams of the two charge states are equally transformed in objectives O_1, O_2, O_3, O_4, O_5. Thus we will have six "primary" beams: 1 - polarized proton beam with an average current 10 μA; 2,3,4,5 - proton beams; 6 - H^- beam. With the help of objectives O_{10}, O_{11}, O_{12}, O_{13} the size of each beam at the experimental target may be changed from 2 mm up to 200 mm. The beam extracted out of storage ring between accelerating cycles (either pulsed or in "continuous" mode) can be directed to any experimental target by using the pulsed magnet PM which is placed in the middle of the objective O_3. The maximum magnetic force of that magnet should be 0.08 T.m, the top of the pulse should be stabilized to the accuracy of 1 %. The rise and the falltime of the pulse have to be less than 400 μs to provide 90 % duty-factor.

Water cooled mineral-insulated cables are used for the magnet windings in the primary beam channel as well as at the entrance of the secondary beam channels. The rest of the magnets are equipped with organic-insulated windings. Only standard power units are used.

The amount of shielding allows people to be in the experimental hall while the beam is on. The water and cable terminals, vacuum pumps, cables and tubes, drive units will be arranged in a special corridor separated from the beam tunnel by 1 m heavy concrete wall. People are allowed to work in the corridor when the beam is off. The counting room annex could be protected by additional movable shielding when the roof of the beam tunnel is opened for repair with the help of the slave manipulator or when heavy irradiated parts are transported through experimental hall.

Tables 1,2,3 contain the beam parameters.

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TABLE I:

PARAMETERS OF PION AND MUON BEAM.

N	CHANNEL	PION PRODUCTION ANGLE	ENERGY OF THE SECONDARY PARTICLES	AVERAGE INTENSITY FOR MAXIMUM OF THE SPECTRUM	
1.	HIGH ENERGY PION BEAM	5°	100÷350 MeV	10^{11} 10^{10}	π^+ π^-
2.	LOW ENERGY PION BEAM	[illegible]	[illegible] MeV	10^{10} [illegible]	π^+ π^-
3.	PION MEDICAL BEAM	[illegible]	[illegible]-15 MeV	$5\cdot10^{8}$	π^-
4.	WIDE-APERTURE CHANNEL AND SPECTROMETER	[illegible]	[illegible] MeV	$3\cdot10^{9}$ $5\cdot10^{6}$	π^+ π^-
5.	CHANNEL OF HIGH RESOLUTION SPECTROMETER	22°	[illegible]-35 MeV	$2\cdot10^{8}$ $5\cdot10^{7}$	π^+ π^-
6.	HIGH PURITY MUON BEAM	[illegible]	[illegible] MeV	10^{9} [illegible]$\cdot10^{8}$	μ^+ μ^-
7.	MUON BEAM FOR μSR EXPERIMENTS	[illegible]	[illegible] MeV	[illegible] $2\cdot10^{8}$	μ^+ μ^-
8.	PROTON BEAM		600 MeV	[illegible]	P

* CHANNEL NUMBER COINCIDES WITH THE NUMBER IN FIG. 9

TABLE III.

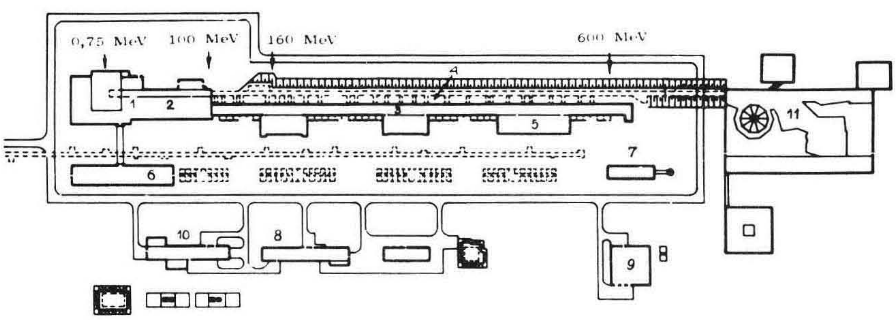
PARAMETERS OF NEUTRON BEAMS WITH URANIUM TARGET.[15]

PARTICLE	FLUX DENSITY (N/CM²SEC) AVERAGE	FLUX DENSITY (N/CM²SEC) PEAK	PULSE WIDTH (μSEC)	REPETITION RATE	REMARKES
LINEAR ACCELERATOR					
COLD NEUTRONS					
H_2-MODERATOR	$2\cdot10^{13}$	$2\cdot10^{15}$	110	100	ON THE MODERATOR SURFACE
D_2-MODERATOR	$4\cdot10^{13}$	$8\cdot10^{13}$	5000	100	
THERMAL NEUTRONS					
H_2O-MODERATOR	$2\cdot10^{13}$	$2\cdot10^{15}$	110	100	ON THE MODERATOR SURFACE
-"-	$4\cdot10^{12}$	$1\cdot10^{15}$	40	100	
D_2O-MODERATOR	$7\cdot10^{13}$	$2\cdot10^{14}$	4000	100	IN THE MODERATOR
FAST NEUTRONS	$5\cdot10^{13}$	[illegible]$\cdot10^{15}$	100	100	IN THE VERTICAL CHANNEL
-"-	$3\cdot10^{14}$	$3\cdot10^{16}$	100	100	IN THE TARGET
PROTON STORAGE RING					
THERMAL NEUTRONS					
H_2O-MODERATOR	$2\cdot10^{13}$	$5\cdot10^{15}$	35	100	ON THE MODERATOR SURFACE
FAST NEUTRONS	$3\cdot10^{14}$	[illegible]$\cdot10^{19}$	0,2	100	IN THE TARGET
-"-	$3\cdot10^{11}$	$1\cdot10^{20}$	0,2	0,1	NUMBERS OF NEUTRONS, ESCAPING IN 4π SOLID ANGLE PER SECOND
-"-	$6\cdot10^{16}$		0,2	100	

TABLE II.

BEAMS OF POLARIZED PROTONS AND NEUTRONS.

PARTICLES	INTENSITY	ENERGY OF PARTICLES	COMMENTS
$\vec{p}$	[illegible]	[illegible] MeV	[illegible]% POLARIZATION RATIO
n		UP TO 600 MeV	LENGTH OF THE CHANNEL 20 M. QUASI-ELASTIC PEAK IS USED.
$\vec{n}$		UP TO 600 MeV	POLARIZED PROTON BEAM IS USED WITH THE LIQUID DEUTERIUM TARGET. NEUTRON POLARIZATION RATIO ~[illegible]%.



1. INJECTOR
2. DRIFT TUBE LINAC
3. RF POWER BUILDING
4. MAIN ACCELERATOR TUNNEL
5. CENTRAL CONTROL ROOM
6. POWER BUILDING
7. VENTILLATION BUILDING
8. COOLING STATION
9. WATER PURIFICATION STATION
10. WATER PUMP STATION
11. EXPERIMENTAL AREA

Fig.1.The general scheme of the INR meson factory

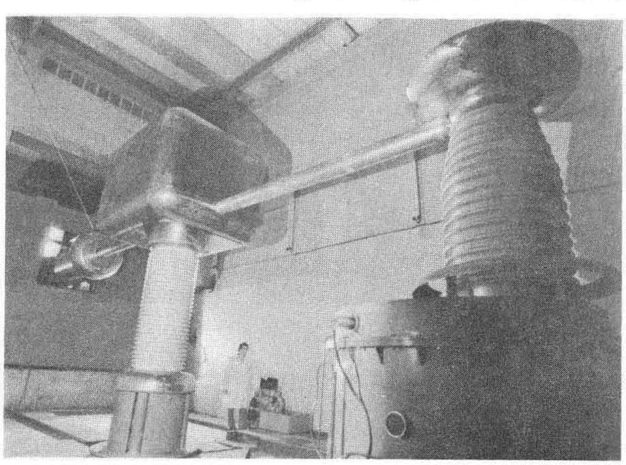


Fig.2. The Proton injector

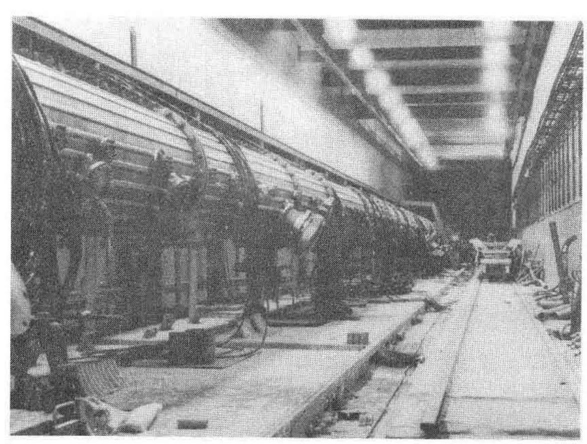


Fig.3. The drift tube cavities

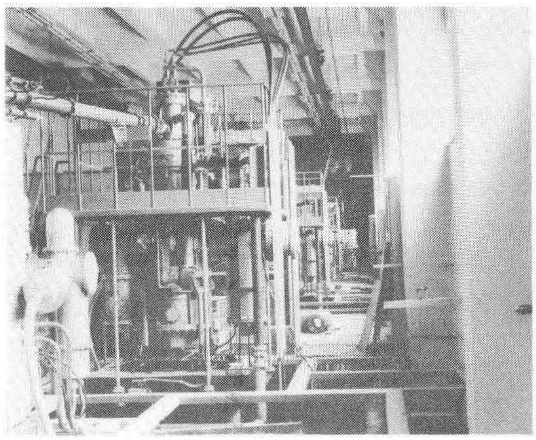


Fig.4. The 198.2 MHz triode power generator.

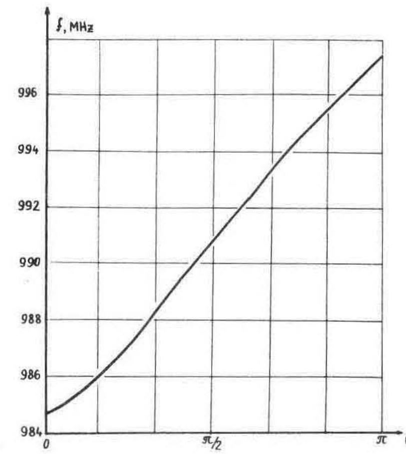


Fig.5. The "dispersion diagram" of the 991MHz resonator.

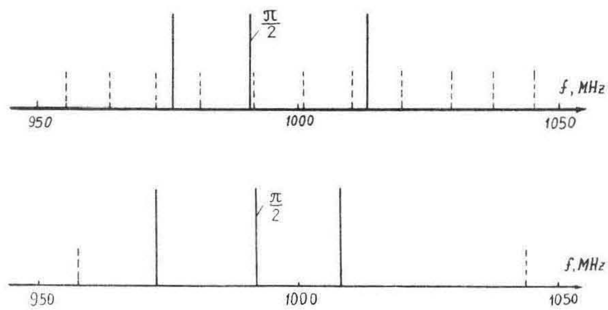


Fig.6. The removal of the hybrid modes

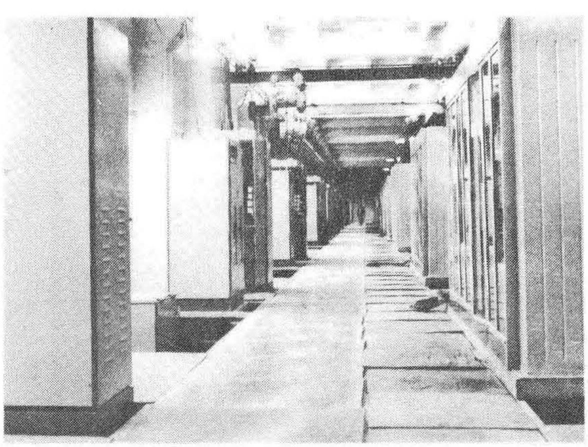


Fig.7. The 991 MHz klystron generators.

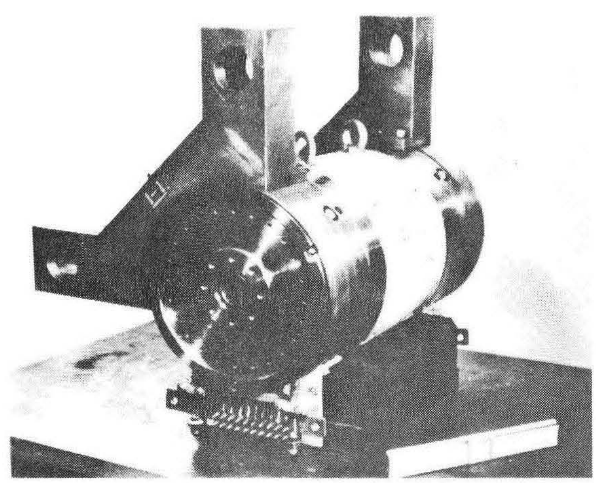
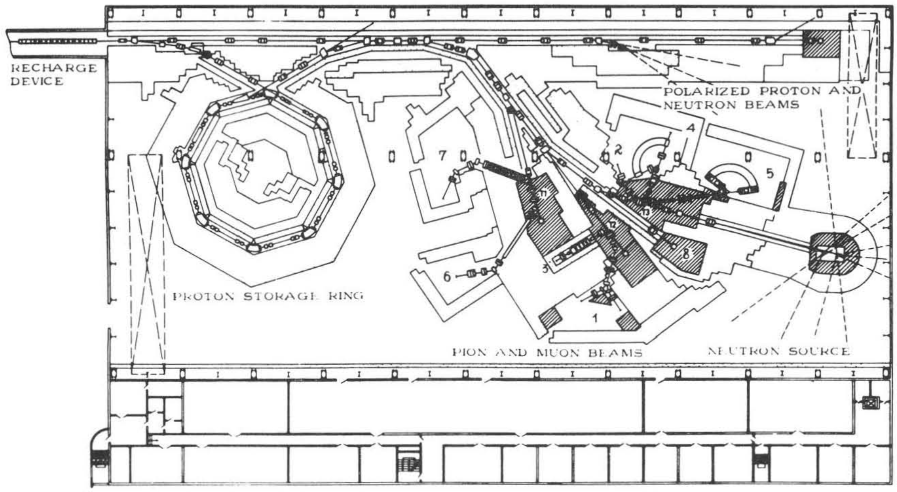
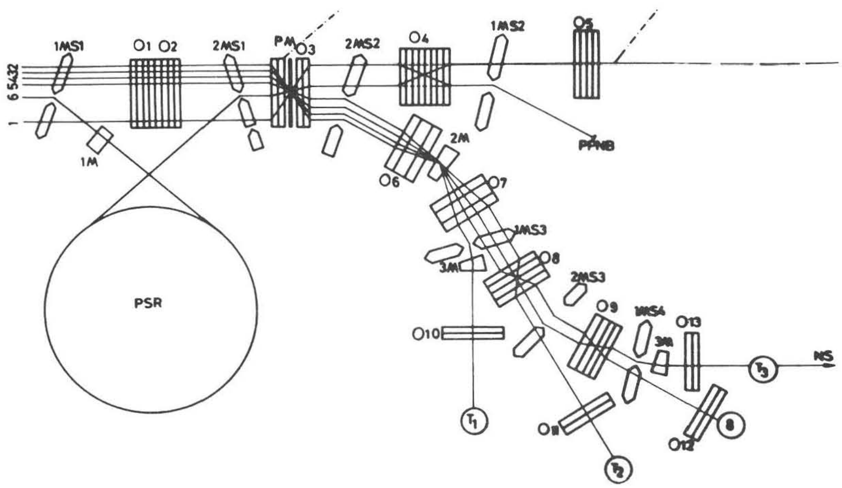


Fig.8. The quadrupole doublet.



1. HIGH ENERGY PION BEAM
2. LOW ENERGY PION BEAM
3. PION MEDICAL BEAM
4. WIDE-APERTURE PION BEAM AND SPECTROMETER WITH $\Delta E/E = 10^{-3}$
5. PION BEAM AND SPECTROMETER WITH HIGH RESOLUTION $\Delta E/E = 10^{-4}$
6. MUON BEAM
7. MUON BEAM FOR μSR
8. PROTON BEAM

Fig.9. The layout of the facility in the experimental building



PSR - PROTON STORAGE RING
Q_i - QUADRUPOLE OBJECTIVE
MS - IRON SEPTUM MAGNET
PM - PULSED MAGNET
NS - NEUTRON SOURCE
T_i - PION PRODUCTION TARGET
PPNB - POLARIZED PROTON AND NEUTRON BEAMS

Fig.10. The beam sharing scheme

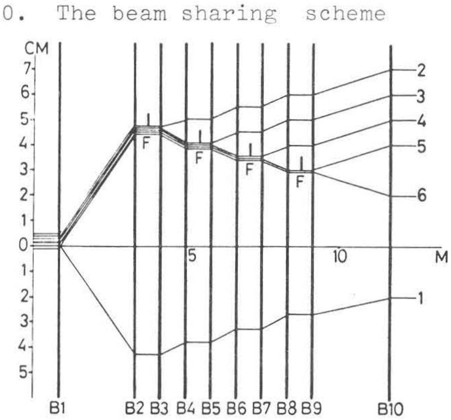


Fig.11. The recharging device scheme. F - recharging foil. B - bending magnet.