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EXPERIMENTAL AREA OF MOSCOW MESON FACTORY

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Abstract The beam channeling, the proton storage ring, the neutron source, pion and muon beams at the Moscow meson factory are discussed.

INTRODUCTION

The I-st stage of the experimental area of Moscow meson factory (fig.1) uses the linear accelerator[1] which accelerates H^- ion beam and proton beam (one of them can be polarized) simultaneously with peak current 50 mA to peak energy 600 MeV and the beam channeling. The main features of this facility design for the nuclear and the particle physics experiments at the intermediate energies, the solid state physics experiments and other applications are:

(i) the particles energy may be continuously variable;
(ii) two or more proton beams may be used simultaneously at independently variable intensities;
(iii) the macroscopic duty factor of the proton beams may be varied from a continuous beam to a pulsed beam with the current 10-20 A;
(iv) short-pulsed beam with variable frequency in the region from 0.1 to 2 MHz is available.

BEAM CHANNELING

The linear accelerator has an 1 % duty factor. The acceleration of H^-ions is crucial for obtaining multiple beams and multiturn charge-exchange injection to PSR (Proton storage ring). The beam channeling during the accelerating cycle injection into PSR and obtaining of multiple beams are shown in fig.2.

At first, main H^- beam is divided into four pencil proton beams H_1^+,H_2^+,H_3^+,H_4^+ and remaining H^- by stripping of part of H^- beam by the carbon foils before each of the divider doublets (the pairs of the equal dipolar magnets of the opposite polarity) and the polarized proton beam H^+as it is shown in fig.2. H and the proton beams have been separated

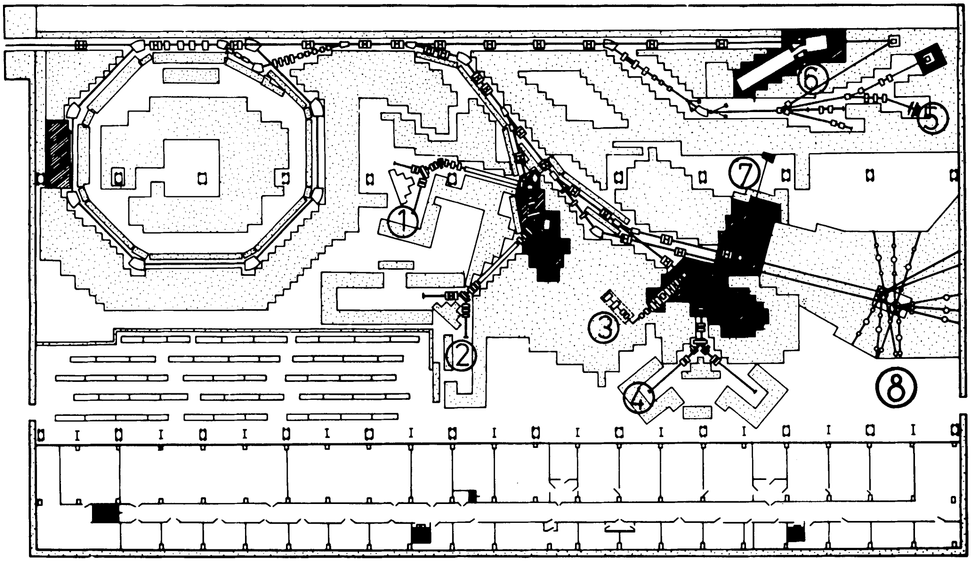

FIGURE 1 Layout of the I-st stage of the experimental area of Moscow meson factory. 1 - muon beam for μSR - techniques, 2 - muon beam, 3 - low energy pion beam and spectrometer with $\Delta E/E = 10^{-3}$,4 - high energy pion beam 5, - polarized proton and neutron beams, 6- μ - e - conversion search, 7 - pion X-rays search in hydrogen, deuterium and light nuclei, 8 - neutron source.

in vertical plane at 1 cm and 2 cm at the exit of the divider doublet. The remainder of the H^- beam is used for injection into PSR, it is shaped by the stripping foils. $H^-$and the proton beams are transported via one beam pipe. The focusing cells are used for transporting all beams. It consists of four equal alternate gradient quadrupoles (in our case two quadrupole doublets) and makes the minus unit matrix transportation available for H^- and the proton beams.

PROTON STORAGE RING (fig.3)^2

The time structure of the ion beams after the linear accelerator is determined by the construction features. To shape the time structure and to keep average current for various experiments the proton storage ring is used as a compressor or a stretcher. Receiving a 100 μs beam pulse from the proton linac the PSR as a compressor delivers 330 ns (or smaller) pulse current of the proton beam for the neutron source, the PSR as a stretcher delivers the continuous beam for the meson targets or fast repetition pulsed beam for the muon experiments. Extraction of a proton beam from PSR is carried out during a pause of the time structure of the linear accelerator. The PSR is built

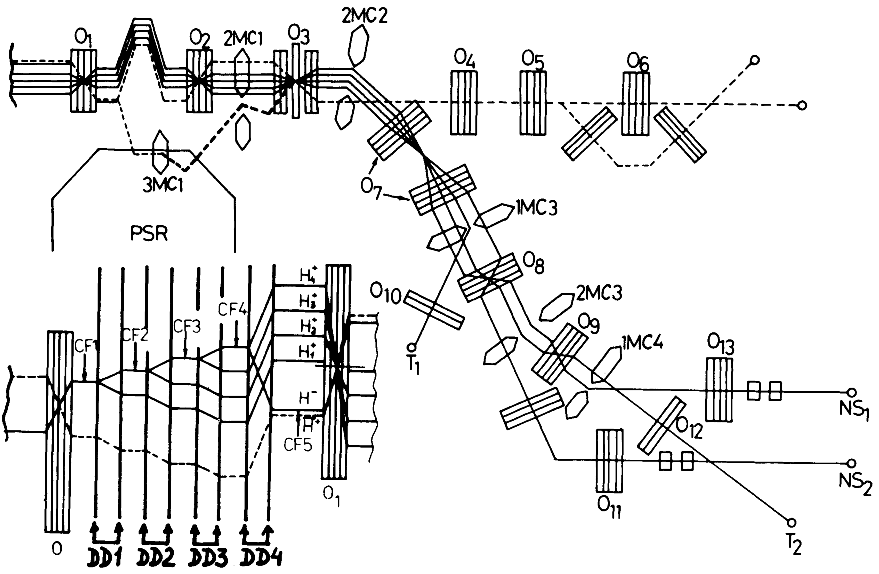

FIGURE 2 Beam channeling diagram. PSR - proton storage ring, NS - neutron source, O - focusing cells, T - pion production targets, MS - septum-magnets, DD - divider doublets, CF - carbon foils.

in the beam channeling as a part of the beam layout.
Compressing of the beam is achieved by the one-turn extraction as soon as the filling process is finished. The initial time structure is shaped to provide an azimuthal void (bunch structure) to exclude the beam losses during the rise time of the kicker magnet field. In this case the ring magnet structure is adjusted as an isochronous one i.e.

$$\alpha = \gamma^{-2} \qquad (1),$$

where α is a momentum compaction factor, γ is the energy.
There is no necessity to use RF system to keep the bunch structure. Similar storage idea has been proposed and experimentally studied at the CERN[3]. The condition (1) might be maintained in our case only approximately because α-values is deviated along bunch. In our case the magnitude of deviation is $\Delta\alpha_0 = 0.018$ for linear density of the particles $3 \cdot 10^{11}$ m^{-1}, it corresponds to extension of the length of the bunch to 2 m in 100 μs, it is the negligible by comparison with 75 m.
For stretching mode operation the mechanism of the extraction particles by reduction of the particles momentum transmitted (pass) through target is chosen (fig.3)[4]. In the half of the period structure where this particles will be displaced relative to a closed orbit the splitter magnet

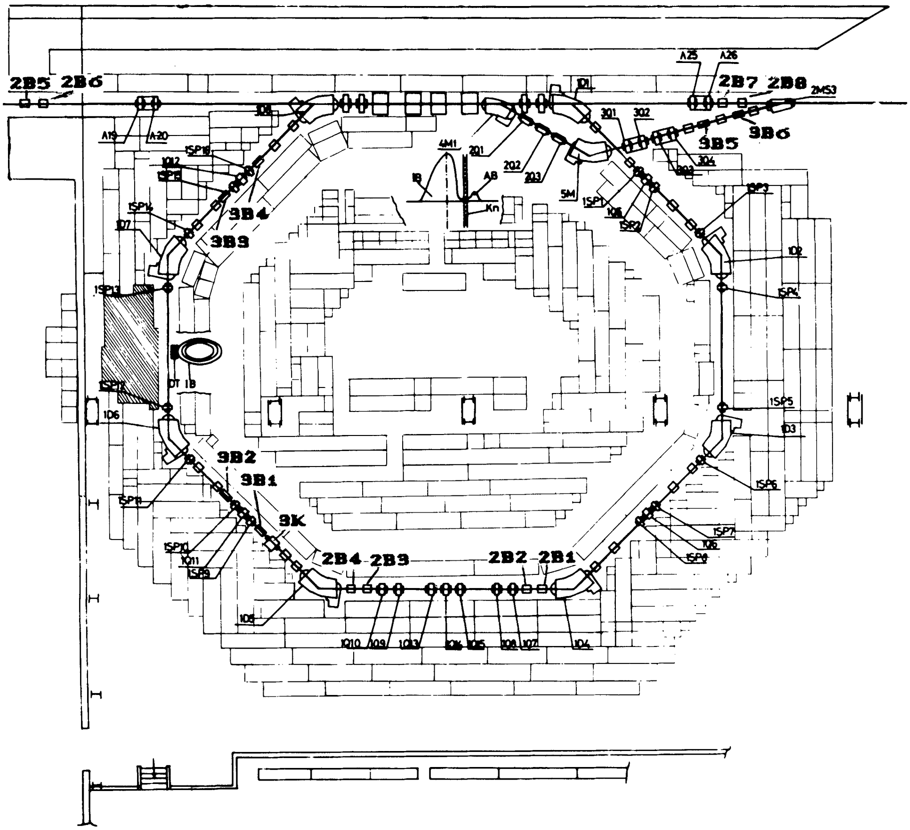

FIGURE 3 The proton storage ring. 1D1 - 1D8 - the mine dipole magnets: B = 1.45 T, aperture 20×12 cm^2 HOR × VERT, bending angle = 45°; 1Q1 - 1Q15 - the quadrupoles: Ø = 20 cm, length = 0.4 m, G = 4.5 T/m; 1SP - the sextupoles: Ø = 20 cm; 2B1 - 2B8 - the bump magnets for injection; 3K - the kicker magnet for the one turn extraction ; DT - slow extraction target; IB - circulating beam; AB - the extraction beam in stretcher mode; Kn - septum of the splitter magnet.

is set for bending the circulation beam. The magnitude of the displacement is

$$\Delta r = \Psi \cdot \Delta P/P_o \qquad (2),$$

where Ψ is the dispersion function.

The magnet structure is chosen as to optimize both the separation between the closed orbit and the extracted beam and the losses of the particles due to interaction with the target. We have chosen this mechanism extraction because for the case of the incoherent coulomb shift of the betatron oscillation -0.09 resonance mechanism extraction can't be implemented effectively. Extraction time is determined by the bump magnets which shifts the beam onto the target.

The essential characteristics of the storage ring are as follows:

Orbit circumference (Circulation period)	102.8 m (430 ns)	
Number of storage turns	240	
Maximum intensity per pulse	$3\cdot10^{13}$	
Stored beam emittance*	3π	cm.mrad
Max incoherent tune shift(smooth approx,)	-0.09	
Peak current	11	A
Momentum compaction factor*	0.371	
Kicker-magnet strength*	0.02	T•m
Kicker-magnet rise time*	100	ns
Radial emittance**	2π	cm.mrad
Axial emittance**	6π	cm.mrad
Target thickness (carbon)**	4.4	mm
Relative momenta decrease**	-0.002	
Dispersion function magnitude at the		
target azimuth	11.3	m
extractor splitter magnet azimuth	0	m
β-function magnitude at the		
target azimuth	6	m
Spill time**	8.5	ms
Beam expansion rate**	3	μm/rev
The depth of beam penetration into the		
target	0.3	mm
Maximum heat deposition in the target**	1	KWt
Intensity loss for the nuclear		
interaction in the target**	1	%
Intensity loss at splitter magnet**	0.2	%
Emittance of the extracted beam		
radial**	0.5	cm.mrad
axial**	7	cm.mrad

* - only for compress mode operation
** - only for stretcher mode operation

NEUTRON SOURCE (Fig.4)[5]

The proton driven spallation neutron sources are preferable

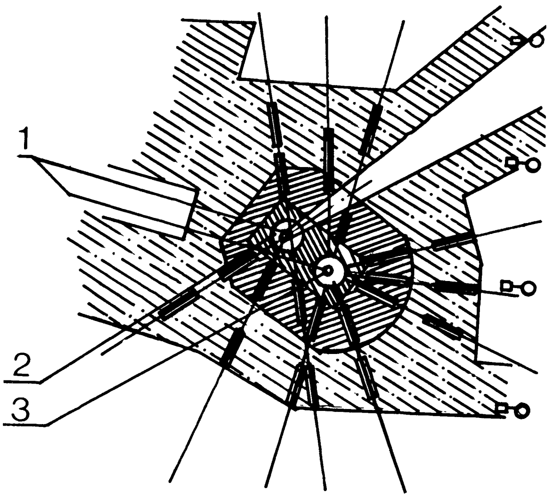

FIGURE 4 Proton driven spallation neutron source
1 - the proton beams;
2 - the quasistationary neutron source;
3 - the pulsed neutron source

to the reactors. They are ecology safe and can be optimized for the kind of the neutron scattering experiments (Fig.4). The neutron source consists of two high-Z high density targets for neutron production. First target is used for the pulsed neutron source with the system of the thin light water moderators. Second target is used for the quasistationary source with the heavy water moderator and with the liquid deuterium moderator. The neutron beams pass via the channels, penetrating through the steel and the concrete shielding into the experimental hall and along the external neutron beam pipes. The parameters of the neutron flux for the uranium targets are given in the table.

TABLE Neutron beam parameters for the uranium target.

Kind of neutrons	Average density n/cm^2s	Peak density n/cm^2s	Pulse duration μs	Remarks
Fast	$6\cdot10^{14}$	$6\cdot10^{16}$	100	Channel within target
Thermal	$4\cdot10^{12}$	10^{15}	40	At H_2O-moderator surface
	$7\cdot10^{13}$	$2\cdot10^{14}$	4000	Channel within D_2O-moderator
Cold	$4\cdot10^{13}$	$8\cdot10^{13}$	5000	At LD_2-moderator surface
Fast*	$3\cdot10^{14}$	10^{19}	0.3	Channel within target
	$6\cdot10^{16}$	-	0.3	Into solid angle 4π
Resonant*	$5\cdot10^{13}$	-	0.3	Neutrons at energy 100-215eV, emitted into solid angle 2 ster 3cm thickness H_2O-moderator surface
Thermal*	$1.7\cdot10^{13}$	$5\cdot10^{15}$	3.5	At H_2O-moderator surface

* - for proton storage ring.

PION AND MUON BEAMS (Fig.1)

Two pion channels are being constructed. The beamline 4 (Fig.1) has been designed for the experiments in the momentum range of the pions from 200 to 520 MeV/c. Maximum pion intensity at the exit of the channel is 10^{11} s^{-1} for π^+ or $2\cdot10^{10}s^{-1}$ for π^- when the momentum spread is $\Delta P/Po = 5$ % ,the pion-generation carbon target size is $2\cdot2\cdot100$ mm^3 and the proton current beam is 1 mA. The momentum resolution of the channel corresponds to $\Delta P/P_o = 0.3$ % .The beamline 3 is the low energy pion channel and the spectrometer. It is planned to carry out the pion-nuclear interaction experiments at the pion energy from 10 to 100 MeV with the energy resolution ≤ 100 KeV and the angular resolution ≤ 50 mrad. The beamline 3 will be used in two modes:

(i) dispersion mode, when the spectrometer compensates the dispersion of the channel;

(ii) achromatic mode ,when the beam spot size at the target before spectrometer will be 2 mm in comparison with 100 mm in (i).

The dispersion plane of the beamline is vertical, the scattering plane is horizontal, angular range of position of spectrometer being from 0° to 145°. Compensation of the second order aberrations is used.

Three muon channels are under construction. Characteristic feature of them is a use of the superconducting solenoids. One of those (6 in fig.1)[6] is the ultra-high intensity low energy muon source for μ - e conversion search and some other experiments. The designed μ^- stop rate is $0.7\cdot10^{11}s^{-1}$ and μ^+ stop rate is $10^{11}s^{-1}$ at the detector system when the average beam current is 100 μA. The proton beam is injected into the superconducting solenoid. A compound target of the tungsten or the molybdenum separate plates is used for production of the low energy pions. The pions are captured by the magnetic field, decay in flight and the muons are pushed with high efficiency backward due to the magnetic field gradient.

Two muon channels (1 and 2 in fig.1) are used for "decay" muon production in traditional scheme. They use one pion production target. The front end of the channel 1 consists of a "shell" magnet and a quadrupole doublet and views the target at an angle of 150° from the proton beam direction. For "decay" muon production this system selects pions with a momentum 120 MeV/c and focuses (delivers) them into the 8 m decay section of the 5 T superconducting solenoid. For the "surface" muon beams these elements are tuned to the momenta of about 30 MeV/c and the field in the solenoid is decreased. The "shell" magnet with the various gradient of the field along the beam axis captures the pions in the solid angle 100 mster, the momenta spread is 10% .

The extraction part of the channel delivers the muon beams to two experimental areas with the following parameters: the momenta is (30 - 100) MeV/c, the momenta spread is 10 % , the intensity is $2\cdot10^{9}\ s^{-1}$ for μ^+ and $5\cdot10^{8}\ s^{-1}$ for μ^-, using the beam spot size of 10 cm. The extraction part is not frosted and must be fitted for each kind of the experiments. This channel will be predominantly used by the experimentalists using the muon spin rotation techniques.

The front end of the channel 2 views the target at the proton beam direction and delivers the pions of both charges into one 8 m, 5 T superconducting solenoid. The front end of the channel consists of two quadrupole doublets separated by four bending magnets and a quadrupole pole lens. They form two achromatic channels for positive and negative pions and use the common head and exit quadrupole doublets. Designed parameters of the front end of the channel 2 are: pion momenta is 200 MeV/c, capture solid angle is 50 mster, the momenta spread is 10% . The extraction part consists of two legs for positive and negative muons. The main parameters of the muon beams are: the muon momenta is 110 MeV/c, the momenta spread is 10 % , the intensity is $8 \cdot 10^9$ s^{-1} for μ^+ and $2 \cdot 10^9$ s^{-1} for μ^-, using the beam spot size of 9 cm.

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