APPLICATION OF 500 MEV PROTON BEAM FROM KEK BOOSTER SYNCHROTRON TO NEUTRON AND MESON PHYSICS AND MEDICAL TREATMENT

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KEK Booster Synchrotron was completed and the operation was commenced with improving the machine and adjusting the accelerated beam in the fall of 1974. And also, in the fall of the following year, the booster began to inject the 500 MeV proton beam to the main ring proton synchrotron. The repetition rate of the booster is 20 Hz. The main ring synchrotron requires nine pulses of the beam from the booster in its repetition period of two seconds, in which the booster has a capability to accelerate 40 pulses of the beam. An excess of about 15 pulses per second, therefore, is available for reseaches in various kinds of fields.

The first application of the beam is to the generation of an intense pulsed-neutron source. Recently, it has been recognized that the neutron sources generated by a medium-energy pulsed proton beam are considerably favourable in many respects such as the intensity of the produced neutron flux, the scale of the facility, the handling of neutron-production target, and so on in comparison with those of atomic piles. The meson production with an average output beam current of 2 μA from the booster is not so high among those of many meson factories in the world. However, unique experiments will be expected with the mesons produced by the shortly pulsed proton beam of 50 n sec in support of the complementary experiments with those by the slowly extracted beam from the main ring synchrotron. At any rate, it is significant for Japanese physicist to open the way to research the pion and muon physics. Medical use of the beam is one of the important applications to fields other than physics. High LET (Linear Energy Transfer) radiations such as neutrons, protons, heavy ions, and pions have remarkable effects on the treatment of cancer. Most of them can be produced by the proton beam from the booster except heavy ions.

Fig.1 shows the layout of a proposed new facility utilizing the booster proton beam. The facility is composed of a 500 MeV primary proton beam line, three major parts of the facility, i.e., the neutron and meson experimental areas and the secondary proton beam line for the medical use, and peripheral buildings such as control room for the primary proton beam, power supply and data processing rooms.

500 MeV proton beam line

This beam line follows to the line which separates the booster beam from that to be injected into the main ring with a pulsed magnet and leads to a beam dump located outside the main ring tunnel. The beam dump line has been completed in 1977. A pulsed magnet on the primary proton beam line switches the beam to any experimental areas at any time by choosing trigger pulses synchronizing to the repetition of the booster.

Neutron experimental area

This area is composed of a pulsed neutron source and the experimental areas for thermal, epi-thermal and cold neutrons. Neutron yields at various energy ranges are estimated as given in Table 1.

Meson experimental room

The main facility in the area is a superconducting solenoid magnet collecting the muons from the decaying pions, which is produced forward from a beryllium target of 12 cm in length. The yields of the pions ($p_\pi \lesssim 200$ MeV/c) and the muons ($p_\mu \sim 100$ MeV/c) are expected to be 1×10^6 and 1×10^5 particles/sec, respectively. In addition to the muon channel, a pion channel will be constructed at a large angle to the incident proton beam. This pion channel will be used for studying the biological effects of pions as well as the nuclear physics experiments.

Secondary proton beam line for the medical use

The main purpose of this line is to produce, a secondary proton beam of 200 to 300 MeV with the maximum momentum spread of 1 %. Slowing down the primary protons is performed by a degrader method. To get the beam intensity of 10^8 protons/pulse at the treatment and diagnosis room is not so difficult by this method. The secondary proton beam will be mainly used for developing and establishing the methods of cancer diagnosis.

Neutron exposure room for the cancer treatment

The room is located at the down-stream of the pulsed neutron source. Fast neutrons of 20 to 30 MeV, which can not be obtained at the other laboratory at present, will supply valuable informations on the medical treatment of cancer.

Table 1 Neutron yields expected with the booster proton beam

proton energy	500	MeV
repetition rate	20	Hz
number of available pulses	10∿15	pulses/sec
proton beam intensity	6×10^{11}	protons/pulse
neutron yield	20	neutrons/proton(U)
fast neutron yield	1.2×10^{13}	neutrons/pulse
fast neutron pulse width	∿50	nsec
slow neutron flux (at peak)		
cold (E<5 meV)	$\sim1\times10^{16}$	neutrons/cm^2·sec·ev at E = 2 meV
thermal (10 meV <E< 200 meV) (Δt = 10 ∿ 30 μsec)	$4\sim8\times10^{15}$	neutrons/cm^2·sec·ev
epi-thermal (Δt < 3 μsec)	1×10^{15}	neutrons/cm^2·sec·ev at E = 1 eV

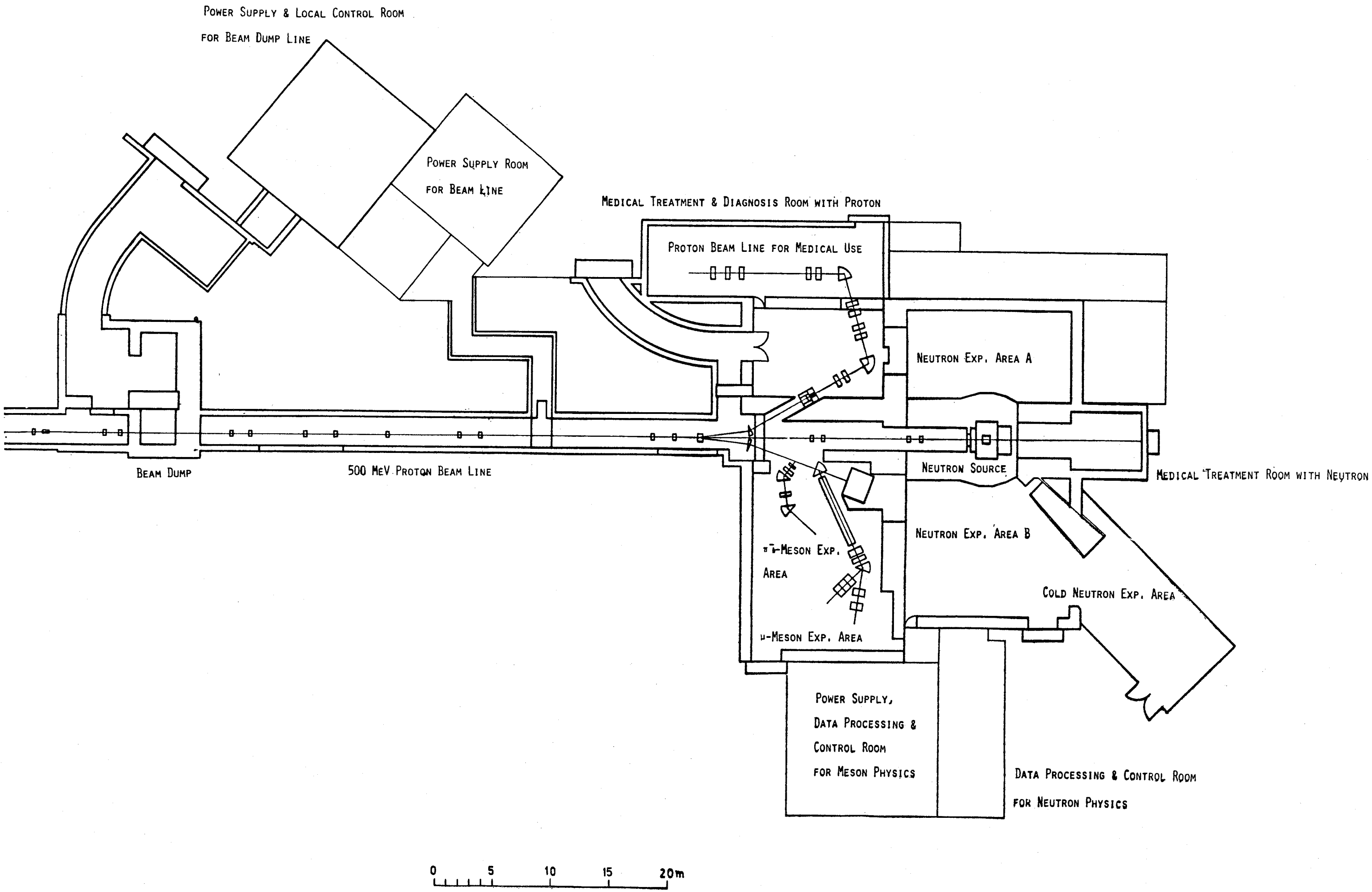

Fig.1 Layout of a proposed facility for neutron and meson physics and medical treatment with KEK booster proton beam.