Proposal of experimental facilities for studies of nuclear data and radiation engineering in the Intense Proton Accelerator Project

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A proposal is given on the facilities and experiments in the Intense Proton Accelerator Project (J-PARC) relevant to the nuclear data and radiation engineering, nuclear astrophysics, nuclear transmutation, accelerator technology and space technology and so on.

1. Introduction

The Intense Proton Accelerator Project named J-PARC is now promoted as the joint project between Japan Atomic Energy Research Institute (JAERI) and High Energy Accelerator Research Organization (KEK) [1,2]. J-PARC is a accelerator complex consisting of intense proton-linac (400, 600 MeV), 3 GeV proton synchrotron and 50 GeV proton-synchrotron. A schematic layout of the facility is shown in Fig.1 [1,2]. The intensity and time-structure of the proton beam are shown in Fig.2. In the project, three major facilities will be constructed [1,2]:

1) a facility for nuclear and particle physics, and neutrino science using 50 GeV protons,
2) a material and life science facility using an intense moderated neutron beam produced by a spallation reaction of 3 GeV 1MW proton beam, and
3) a transmutation facility for basic research on nuclear transmutation of radioactive wastes with an accelerator-driven system (ADS) using a 600 MeV proton beam [1].

Muon science research is also planned in the 3 GeV accelerator facility.

The intense moderated neutron beams and various energy proton beams provided by J-PARC will open new possibilities in the research of neutron nuclear data for the nuclear astrophysics and nuclear transmutation, and the radiation science relevant to the accelerator and space technology. In the present plan of J-PARC, however, such facilities are not included explicitly. Furthermore, we have to remember that the 12 GeV proton synchrotron and the 500 MeV proton booster at KEK which has been a unique particle source in Japan in the high-energy region should be shutdown with the start of operation of J-PARC. Considering these situations, installation of facilities for radiation engineering in J-PARC is very important and indispensable.

From this view point, four divisions in Atomic Energy Society of Japan, i.e.-Reactor Physics, Radiation Science and Technology, Nuclear Data, and Accelerator & Beam Science-, organized a working group to discuss and propose experimental facilities and research for radiation sciences and ADS in J-PARC. The proposals are as follows [3]:

1)An intense moderated neutron beam line in the life science facility for nuclear astrophysics and ADS, 2)radiation science experiments in the 50 GeV beam line in the nuclear and particle physics facility, and 3)a beam course for nuclear data and the radiation science in the transmutation facility as well as 4) proposals for research in the transmutation facility.

The present report describes outlines of proposals 1)-3) relevant to the nuclear data and radiation

science [3]. For more details, see Ref. [3].

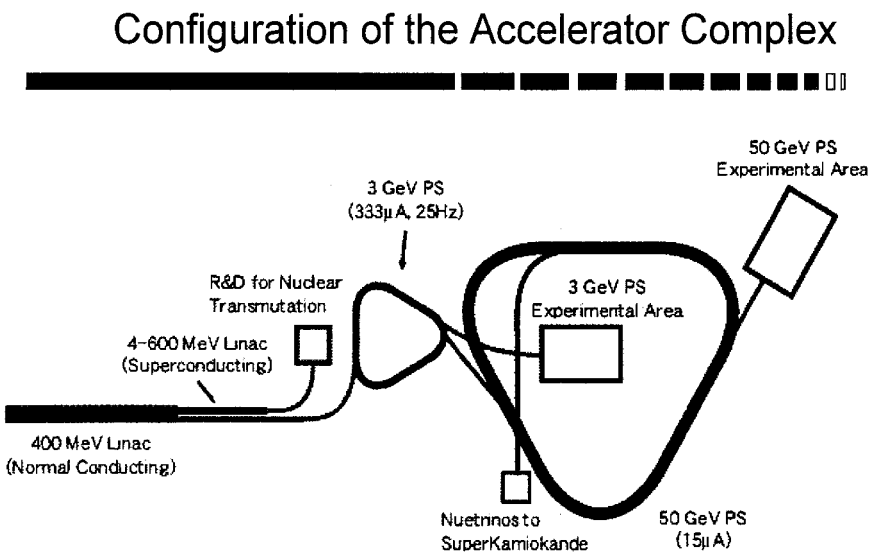

Fig.1 Schematic view of the intense proton accelerator facility, J-PARC [1,2].

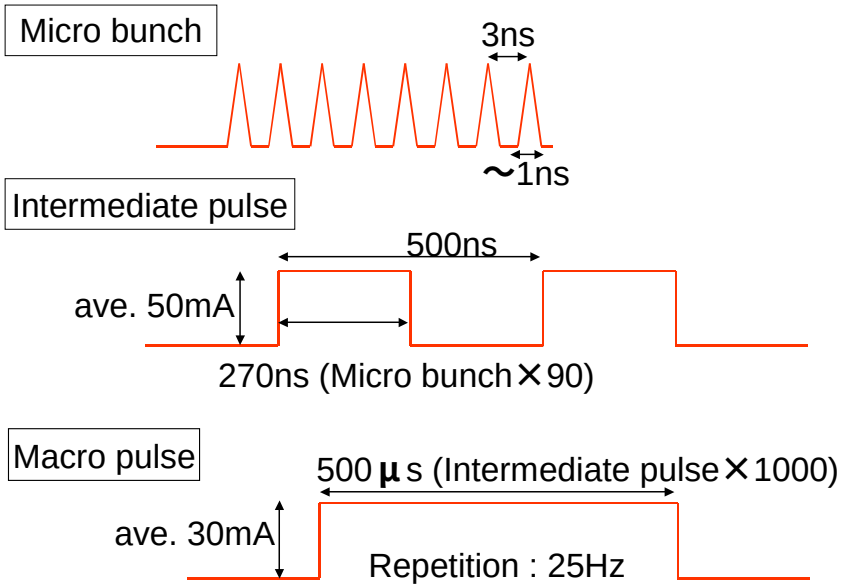

Fig.2. Time structure and intensity of proton beam in J-PASRC [1,2].

2. Proposals

The J-PARC project is divided into two phases; 1)in the first phase, 3 GeV and 50 GeV beam will be provided, and materials and life science facility and nuclear & particle physics facility will be installed, 2)in the second phase, the 600 MeV linac and its beam line and the nuclear transmutation facility, and the neutrino science facility will be installed.

The proposals 1) and 2) correspond to phase-1, and 3) and 4) to the periods of phase-II.

2.1 Neutron beam line for nuclear data measurements on astrophysics and accelerator-driven system

The schematic view of the proposed beam line is illustrated in Fig.3. The line is expected to be installed as one of the beam lines around the mercury spallation neutron target and the associated moderators. As shown in Fig.3, it is utilized mainly to measure capture and fission cross-sections using a time-of-flight method for the thermal to hundreds of keV region which are of crucial role for the nuclear astrophysics and ADS. The intense neutron beam will newly enable cross-section measurements for elements with very high radio-activity and/or very small sample amount that were not possible thus far. For the advantages, the beam line will provide new generation of neutron nuclear data in the field of nuclear astrophysics and ADS. Figure 4 shows an example of nuclide synthesis chart for Se, Br and Kr where the neutron capture cross-section of ^{79}Se plays a key role to the synthesis mechanism because it has a relatively long half-life of 65,000 years. Similarly, the nuclear data for actinide nuclei obtained in the facility will greatly contribute to establish the data base for the design and operation of the transmutation facility.

2.2 Radiation engineering experiments in 50 GeV nuclear and particle physics facility

The planned experimental facility at 50 GeV beam line is shown in Fig.5 [1,2]. The T0 beam line and associated experimental hall for test experiment enables experiments for GeV range particles using primary and secondary particles and are very useful to perform differential and integral experiments relevant to high-energy accelerator technology and space technology:

1)differential cross-sections for the production and scattering of nucleons, muons, and heavy particles,

2) integral experiments for the shielding and radiation effects of high energy nucleons, and

3) development and characterization of radiation detectors for high energy particles.

The differential experiment 1) provides information on the source term in ADS, the transport and the effects of high-energy accelerator particles and cosmic-rays. These data are required to upgrade theoretical models which are currently used for the design of accelerator shielding and ADS. Figure 6 shows an example of the problem of the nuclear model code presently used. Integral experiments are needed in particular to guarantee the safety designs of accelerator systems based on the differential data. The item 3) is also essential to promote the research experiments that will be carried out in the high-energy facility. In the experiments, secondary beams will be utilized as well as a primary proton beams extracted with a scatterer.

2.3 A Beam line in the transmutation facility.

In the transmutation facility, research on basic physics of transmutation and irradiation effects of target elements will be conducted using a critical assembly and an irradiation cell for 600 MeV protons, respectively [1,2]. To promote the research, a comprehensive data base is requested on neutron and charged-particle production by the interaction of primary protons with constituent elements. The data status is, however, quiet unsatisfactory [3]. Therefore, experiments to obtain differential data should be promoted concurrently with the integral experiments using the facility.

In Fig.7, an idea for the beam line is illustrated. In the plan, a “kW target” is newly proposed in addition to “10 W target” in the current design plan [1,2] to get intense and short-burst proton beam required for the differential experiments. A short proton burst is achieved by picking up a fraction (< ns) of micro-bunch (Fig.2) of a beam to the irradiation facility with a laser-charge- exchange and a foil stripping method. In this scheme, it will be possible to provide about a 800 W proton beam to the target guaranteeing that the maximum beam power delivered into the critical assembly is less than 10 W. These lines will be used as powerful facility for differential measurement and integral benchmark experiments on neutron and secondary particle production.

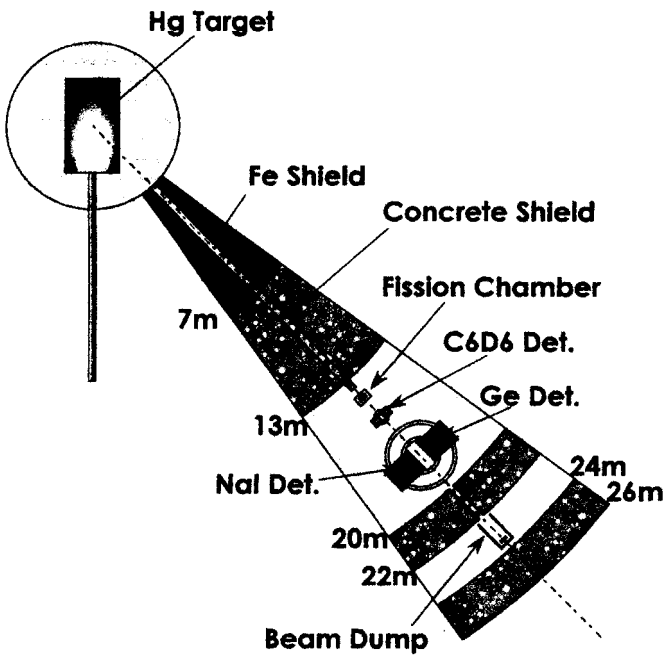

Fig.3: Proposal of neutron beam line in material and life science facility for nuclear astrophysics and ADS [3].

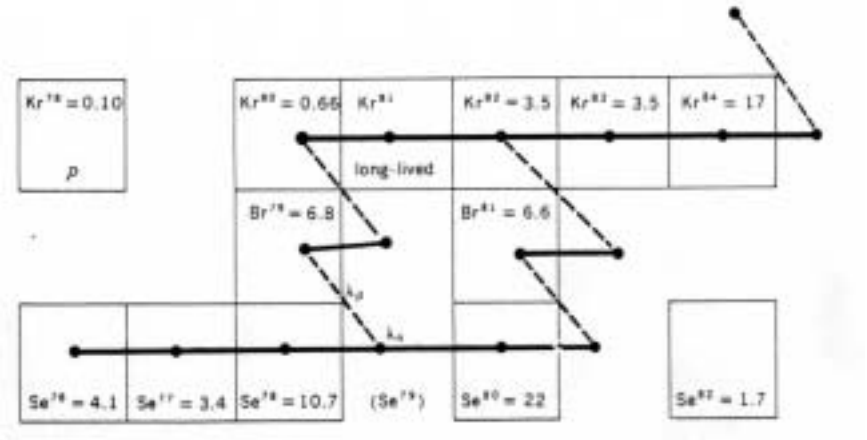

Fig.4: Nuclear synthesis chart for Se, Br and Kr [3].

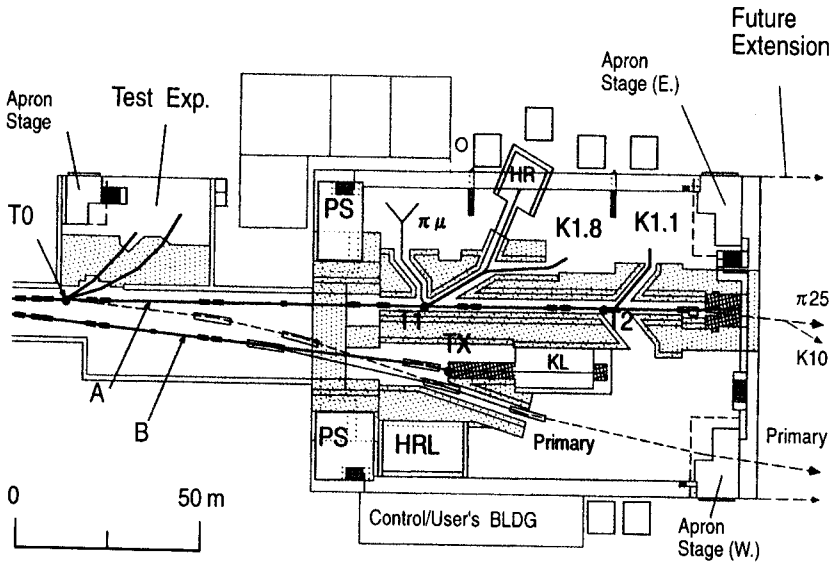

Fig.5: Schematic view of 50 GeV nuclear and particle-physics facility [1,2].

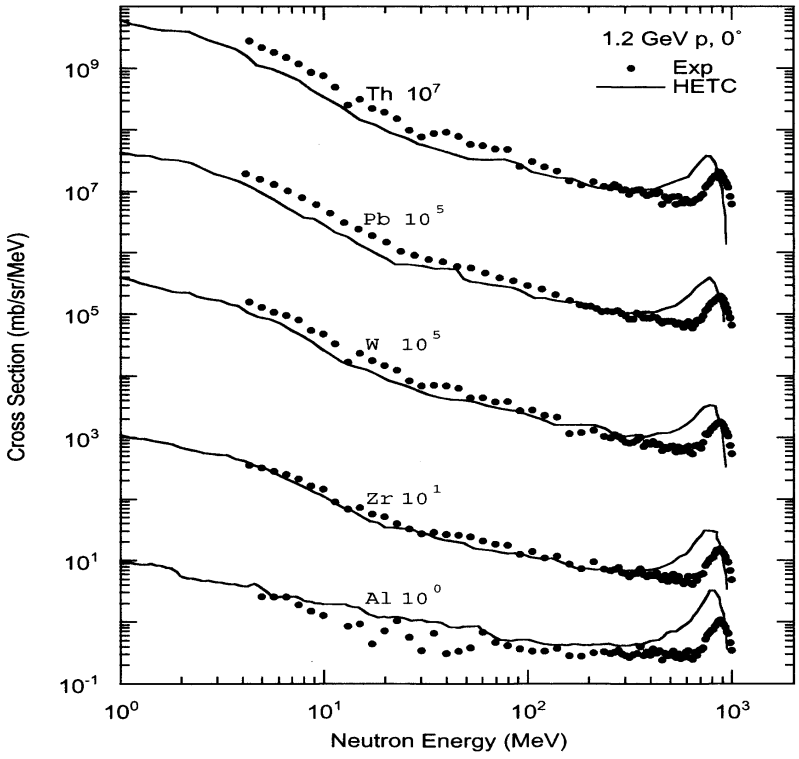

Fig.6; Comparison of the HETC calculation with experimental data for neutron production by the (p,n) reactions with 1.2 GeV protons [3].

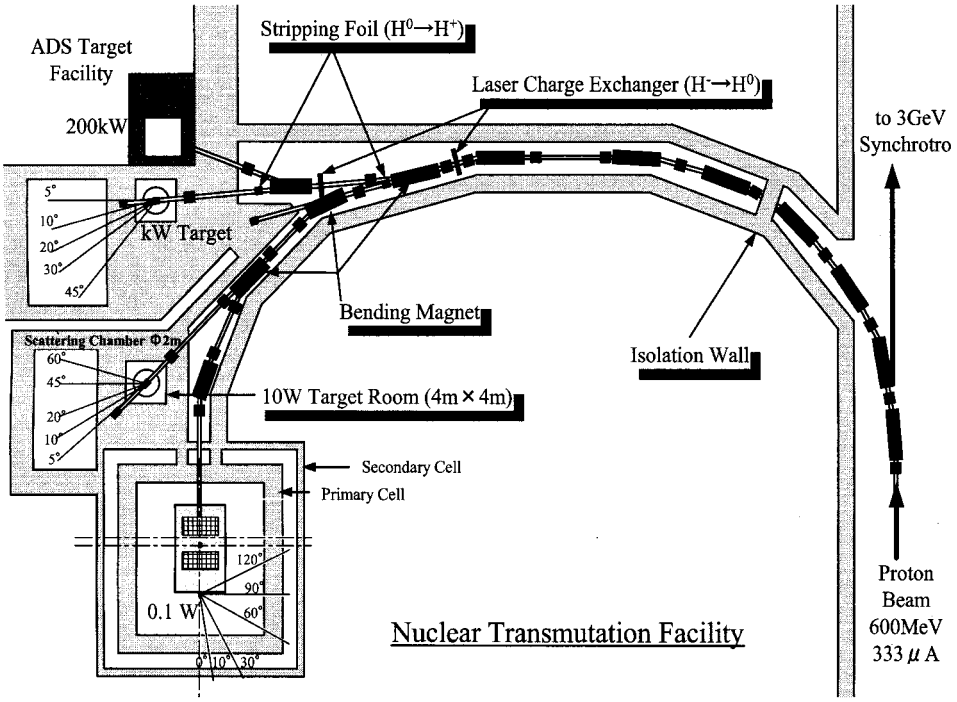

Fig.7: Proposal of “kW beam line” in the nuclear transmutation facility [3]

3. Summary

We have presented proposals for facilities and experiments in the intense proton accelerator facility J-PARC relevant to nuclear data and radiation engineering. The facility will be very powerful and productive one owing to distinguished performance such as beam power and/or short burst duration.

We highly expect that the proposals are realized in the near future, and are ready to cooperate with the project team in design and construction of the proposed facilities. About the neutron beam course in the material and life science facility, a letter of intent has been already presented to project management team with the project title of “Neutron beam line for nuclear astrophysics and accelerator-based system”.

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References:

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[2] http://j-parc.jp/
[3] Genshikau-Kenkyu Vol.47 (No.1) July 2002 (in Japanese)