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18. The JAERI-KEK Joint Project on High Intensity Proton Accelerator and Overview of Nuclear Transmutation Experimental Facilities

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Abstract:

A status of the JAERI/KEK joint project on High Intensity Proton Accelerator is overviewed. It is highlighted that Experimental facilities for development of the accelerator driven system (ADS) for nuclear transmutation technology is proposed under the project.

1. ADS for nuclear transmutation

Nuclear energy system can not be completed without establishing its nuclear waste management system. Although it has been addressed that the principle scenario of the waste stream in Japan is the deep land burial of high level waste (HLW), the HLW still remains as potential hazards. Accordingly it is encouraged to pursue a way to reduce HLW to mitigate a potential load of the waste management. The accelerator driven system (ADS) has been recognized world wide as an attractive option for the nuclear transmutation of HLW. Japan Atomic Energy Research Institute has proposed an ADS concept for the nuclear transmutation of HLW. By the ADS, a hazard level of HLW is estimated to be reduced 1/200 comparing to a case without ADS introduction in 500 years.

2. Key technology needs for ADS

To realize ADS, fundamental researches and technical developments are required in various areas involving spallation target technology, sub-critical reactor physics, hybrid system operation and controls, the nuclear transmutation process, thermal-hydraulics, and material developments, etc. Among them, the development of the material for a proton beam window of the spallation target and the sub-critical reactor physics driven by the high energy proton beam are identified most important to evaluate the technical feasibility for ADS.

3. Overview of the joint project on high intensity proton accelerator

In the meantime, a project on high intensity proton accelerator has been jointly proposed by JAERI and KEK, and has approved to start in 2001 by the government. The project, namely JKJ project, aims at explore forefront sciences in various research fields. The proposal has two phases. The "Phase 1" accelerator complex consists of

- 400-MeV normal-conducting Linac,
- 600-MeV Linac (superconducting) to increase the energy from 400 to 600 MeV,
- 3-GeV synchrotron ring, which provides proton beams at 330 μA (1 MW), and
- 50-GeV synchrotron ring, which provides proton beams at 15 μA (0.75 MW).

In addition, an upgrade towards 5-MW proton beam power at the few GeV energy region is proposed as a "Phase 2" project of the present proposal.

At the initial stage, the normal conducting 400 MeV Linac will be used as an injector to the 3-GeV ring. At the stage when the superconducting 600 MeV Linac becomes stable, however, this 600-MeV Linac will be switched as the injector to the 3 GeV ring.

At the 50-GeV Proton Synchrotron (PS) nuclear/particle physics experiments using kaon beams, antiproton beams, hyperon beams and primary proton beams are planned. Using kaon beams, production of strangeness in nuclear matter become possible, and the study of the influence of nuclear matter on this impurity probe of a strange particle will be performed. Experiments on kaon rare decays, such as $K^0 \to \pi^0 \nu\bar{\nu}$ to measure CP matrix elements, an experiment on neutrino oscillation from ν_μ to ν_τ using the Super-Kamiokande as a detector, etc. will also be carried out.
The 3-GeV ring will be used to provide beam power of 1 MW. Extensive physics programs which cover nuclear/particle physics, condensed matter physics, materials sciences and structural biology will be carried out there. Among them the major highlights are materials sciences and structural biology using neutrons produced in proton+nucleus spallation reactions. Since a neutron has a magnetic moment but no electric charge, neutrons can be used for the study of magnetic properties of matter. Also, since the neutron has a mass which is similar to that of the hydrogen atom, neutrons can probe sensitively the location and dynamic behavior of hydrogen atoms in materials. The role of hydrogen atoms in biological cells is of particular interest in life science and, there, the neutron beams play a crucial role for these studies. In addition to neutrons, muon beams are also important in which μSR (muon spin rotation/relaxation), muon catalyzed fusion, and other materials sciences can be conducted. Also, particle-physics experiments such as a μN→eN conversion experiment can be performed. Radioactive beams produced from the 3-GeV PS are also useful to nuclear/astro physics research.

Finally, the high-current 600-MeV Linac will be used for R&D for the accelerator-driven nuclear transmutation.

The accelerator and experimental facilities are to be constructed in the southern area of Tokai site. JAERI team identified that the high intensity proton beam to be available in the project is extremely useful to initiate the ADS development. As the first step of the research program, two experimental facilities for ADS are proposed to be built.

4. Experimental facilities for ADS research under the joint project

They are (1) Accelerator Material Irradiation Facility, and (2) ADS Physics Experimental Facility. Proton beams of 600 MeV with 0.33 mA (200 kW at maximum) to these facilities through the superconducting Linac. The facility is designed to be located at the area between NUCEF and Linac line. The Accelerator Material Irradiation Facility is to test materials of the beam window and the spallation target system with lead-bismuth (Pb-Bi) as the first candidate of target/coolant material. On a preliminary evaluation, dose rates of more than 10 dpa (Displacement per Atom) per year could be achieved. The ADS Physics Experimental Facility uses low power proton beam up to 10 W. The low power of 10 W beam is extracted from main H^- 200 kW beam via a laser charge exchange scheme the idea of which is developed by the JAERI team. Basic sub-critical reactor physics, e.g., sub-criticality, reactivity, power profile, etc. and reactor power control with the beam power are to be studied by using the low power proton beam. For this purpose, a critical assembly with maximum reactor power of 500 W is to be constructed. It will be the first demonstration anywhere in the world of the sustained stable integral operation of a spallation target and a fast neutron sub-critical core driven by a proton beam. This talk deals with the conceptual study of two experimental facilities, giving a baseline design and a preliminary safety study.

As the research and development for Accelerator Material Irradiation Facility, a liquid Pb-Bi loop for the material test was installed in JAERI/Tokai at the end of January. The loop was successfully operated at 450 degree centigrade with 50 degree centigrade of temperature difference for more than 1200 hours.

As the safety analysis for ADS physics experimental facility, the influence of the hypothetical accident was preliminary evaluated. It was shown that the dose rate around the facility can be controlled at low level by the multiple mechanisms of an emergency reactor shutdown.

The group for the experimental facility design was unified with the research

group for the transmutation system in this April. This new group, named as "Nuclear Transmutation Group", will make broad research and development for the partitioning and transmutation technology to reduce the environmental burden of long-lived high level waste, as well as the development of the ADS Experimental Facility.

5. Status of ADS facilities and summary

Unfortunately, construction of the ADS facilities are postponed to the second phase due mainly to the financial constraint. Even though the ADS facility is still defined in the second phase, we have to work on hard to show more attractive scenario of ADS to have strong support from the society and to prepare more firm design of facility itself. In particular, the delay should be utilized as a leading time to establish the reactor safety analysis with respect to the proton beam injection to the sub-critical core.