# DEVELOPMENT AND CONSTRUCTION OF EXPERIMENTAL ADS AT ITEP

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*Abstract*

The purposes and current construction state of ITEP experimental accelerator driven system (ADS) are discussed. This hybrid electronuclear facility of moderate power integrates the pulse proton linac (36 MeV, 0.5 mA) and subcritical blanket assembly (heat power of 100 kW). The most part of equipment units are ordered for industrial manufacturing and partly under way. The facility is supposed to be used for investigations of the wide circle of problems concerning with both the accelerator-driver and the target-blanket assembly as well as the exploration of dynamic processes arising during their combined operation. It is planed some applied uses of the proton beams and neutron fluxes. It is possible in future to increase of the proton beam current and energy.

## 1 INTRODUCTION

Fast advance in element basis development for high-current linac those are drivers for power ADS of future (see, for example, projects AAA [1], KEK/JAERI [2], TRASCO [3], KOMAC [4], CONCERT [5], etc.) shows the real possibilities of energy electronuclear system creation.

ITEP's specialists are agree to the opinion that industrial ADS for transmutation will be based on proton beams of approximate values of energy and average current of 1 GeV and 30 mA correspondingly while for demo facilities these values might be limited by 600 MeV and 1-3 mA.

Experimental test ADS of much more modest energy, current and cost values are able to be used for study of some problems concerned with the work of hybrid systems as well as dynamics of mutual interaction of linac and reactor facility. These investigations will used for study of safety and reliability problems of both the complex facility and testing of elements such as linac-driver approaches, optimization of active cores, target and blanket unit study and some problems of new fuel cycles. All these data are very useful for future creation of full-scale facilities.

The creation of test ADS is concerned both as intermediate stage in development of high-power linac-driver (see, for example, KOMAC Test Facility [4] with proton energy of 20 MeV and 2 mA current) and as independent multiple purpose systems. The typical examples of the last approach are proposed Chinese facility that includes 150 MeV 3 mA linac [6] as well as Japanese Neutron Factory that is designed in Kyoto Institute for Nuclear Researches and will be based on proton or deuteron accelerator-driver with current of 1 mA and energy that is supposed to be increased step-by-step from 20 MeV to 500 MeV [7]. JINR facility based on 660 MeV 1.5 μA synchrocyclotron together with subcritical assembly under creation is also supposed to be useful for study of some dynamic problems of electronuclear systems.

Some tasks concerned with study of target and blanket parameters are carried out by use of reactor active core driving not by linac but by use of deuteron-tritium neutron generator [8-10].

It is worth to note there is still no full-complete ADS anywhere in the world.

## 2 ITEP EXPERIMENTAL ADS

The facility that is under construction in ITEP, Moscow, takes up an intermediate place between of currently developing full-range ADS and facilities are driven by D-T generators. The ITEP ADS is developed according to traditional for high-power installation scheme that includes proton linac and sub-critical blanket (Fig. 1) [11, 12].

36 MeV proton linac ISTRA-36 with the average current of 500 μA well be stood duty as a driver. Proton beam pulses of 100 mA of 220 μs duration are supposed to followed with the repetition rate of 25 pps The pulse beam power of 3.6 MW corresponds to 18 kW of average power. Linac consists of the 82 keV injector, 3 MeV 150 MHz RFQ section, 10 MeV 300 MHz DTL-1 section, LEBT, 36 MeV 300 MHz DTL-2 section and HEBT. The RFQ and DTL-1 sections are placed at the ground floor of the experimental room while the DTL-2 section is placed at the first floor of the building. Four channels of proton beam outlets at both 10 MeV and 36 MeV are also provided for other applications.

The subcritical assembly of 1.7 m in diameter and 2 m high includes neutron producing beryllium target, heavy-water blanket with both fast and heat fissile cores for neutron multiplication as well both heavy-water and graphite reflectors. The thickness of beryllium target was chosen equal to 6 mm in the initial variant. The proton beam with energy 36 MeV is completely absorbed within the first 2 mm. Additional thickness multiplies fast neutrons according to the reaction Be(n,2n). Due to that the flux of fast neutrons from a target is increased by 25 %. The thermal blanket has a triangular lattice with step of 110 mm. Fuel channels contain highly (90%) enrichment $^{235}$U. The height of an active zone of assembly is 110 cm. Vertical experimental channels are located in the blanket's reflector. Intensity of fast neutrons $3\times10^{14}$ n/s, thermal neutron flux in experimental channels $2\times10^{12}$ n/sm$^2$·s, thermal blanket power is 100 kW at $k_{eff} = 0.95$.

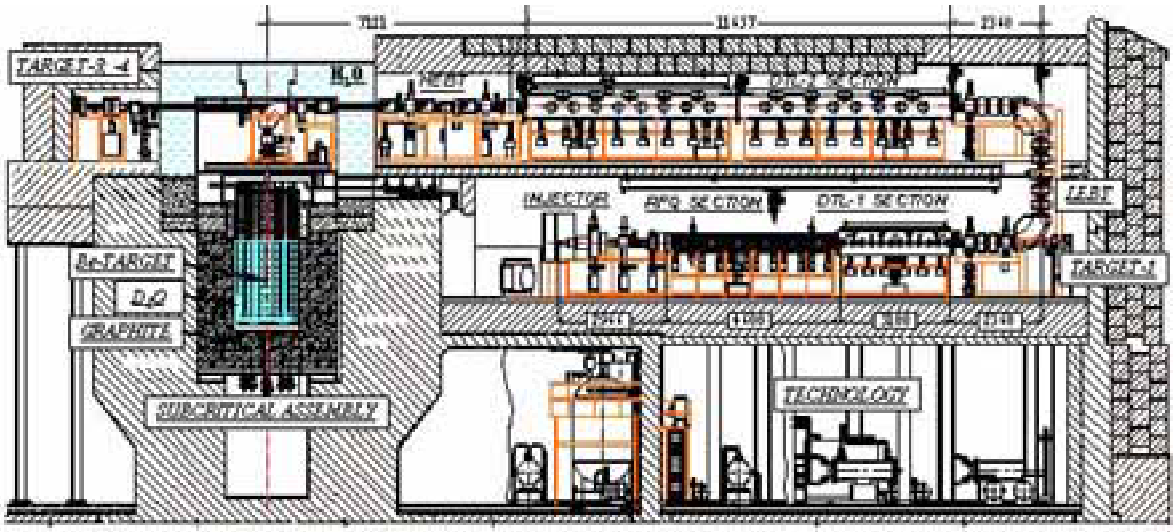


Figure 1: Experimental ADS of the ITEP.

## 3 TASKS OF THE FACILITY

**3.1** Study and development of technological aspects of electronuclear systems is one of the main tasks of ITEP's experimental ADS. The main purposes include the following points.

- Study of hybrid system dynamics.
- Development and experimental justification of ADS control and monitoring approaches.
- Experimental justification of principles for establishment of natural negative feed-back circuits as well as passive emergency shut-down of blanket.
- Experimental development of approaches for testimonial of control protection system elements at subcritical assemblies.
- Experimental modeling of off-normal situations including imitations of emergency situations as well as development of measures for their prevention.

**3.2** The linac is supposed to be used for the following procedures.

- Experimental study of linac regimes as well as the working of its systems at driving.
- Development of partial physical and technical approaches for use in power installations including methods of dosing and efficient change of beam current as well as efficiency of graphite absorbers of lost particles.

**3.3** The following procedures are planned to be carried out in target and blanket parts of both physical and technical aspects.

- Experimental works concerned with the choice of radioactive wastes transmutation strategy.
- Study of neutron and physical parameters of prospective fuel grids, in particular, for estimation of U-Th cycle efficiency.
- Study of both nuclear engineering and technology aspects for subcritical assemblies creation.
- Verification of blanket calculation codes.

**3.4** The following applications of both proton and neutron beams are planned.

- The proton beam of 10 MeV energy is supposed to be used for production of ultra-short-lived radionuclides ($^{11}$C, $^{13}$N, $^{18}$F, $^{110}$In, $^{76}$Br, etc.) for PET.
- 36 MeV proton beam is planned to be used for diagnostic application of radionuclides such as $^{67}$Ga, $^{68}$Ge, $^{81}$Rb, $^{111}$In, $^{123}$I, $^{201}$Tl etc.
- The 33 MeV outlet into atmosphere proton beam as well as neutron flux from blanket are supposed to be used for radioactive method of material study and for device testing.
- Both cold and ultra-cold neutrons are of interest for fundamental investigations.

**3.5** ITEP ADS is able to be served as the training center for both study and working on probation for specialists of reactor and accelerator fields as well as radiation technology applications.

## 4 STATUS

The facility is based on available linac resonators (Fig.2) and shut-downed heavy-water reactor (Fig.3). Up to date the main design and experimental works for project ground had been carried out yet. There are all the necessary co-ordinations and authorization papers. Some units of shut-down reactor has been dismantled. The initial part of linac was tested in temporary experimental room. The most part of special units has already been developed and created, the other part is in manufacturing stage. The standard equipment purchased for installation is also available.

## 5 POSSIBLE DEVELOPMENT

At the first stage of works the ADS physical start up of linac at moderate average current value of 20 μA is planned. The second stage is supposed to be finished at beam current of 500 μA. The further increase of beam current is possible at appropriate increasing of both linac

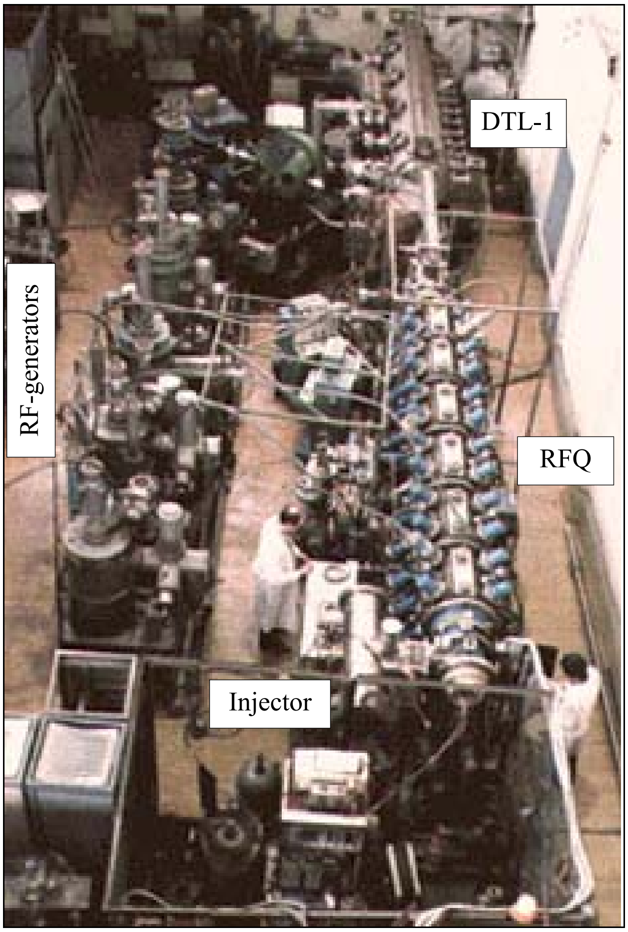


Figure 2: Front end (RFQ and DTL-1) of the linac-driver in temporary hall.

Figure 3: Reactor body.

technological systems as well as ion source characteristics. Heat-eliminating characteristics of existing resonators limit a value of beam current. At standard scheme of water cooling of resonators as well as 4-times increasing of RF system and injector power that corresponds to pulse beam characteristics of 220 μs duration 100 mA current and 100 pps repetition rate the value of the average beam current is supposed to be increased from 0.5 to 2.0 mA. It would increase the value of neutron intensity up to $1.2{\cdot}10^{15}$ n/s. The further beam current increasing is also possible at future advance in resonator cooling efficiency.

The placing of SC sections instead of the NC DTL-2 section (see Fig.1) would increase the value of output energy from 36 MeV to about 100 MeV at acceleration rate of about 8 MeV/m. It gives about 3 time increase of fast neutron intensity so the total value of intensity is supposed to be increased to $3.6{\cdot}10^{15}$ n/s.

The other possibilities of neutron flux increase are concerned with the use of multiple-layer targets with advanced level of neutron generation as well as increasing of neutron multiplication in blanket by means of subcriticality level decrease from 5 up to ~ 2%. The last is supposed to be possible after development of absolute reliable reactivity control system.

The evaluated values of neutron flux give opportunity to consider its application for boron neutron capture therapy method.

It is worth to note that neutron flux increase in the blanket is mostly important for decision goals of 3.3 and 3.4 (see upper) while it is not the critical parameter for the main problem of the hybrid installation (3.1), i.e. the study of complex systems those include linac and sub-critical assembly.

Pulse switching of output proton beam in three directions (left, forward and right) during the pause between beam pulses of about 10 ms helps not only to expand opportunities of the installation but to get the experience concerned with high intensity beam commutation as well as development of safe technology of the process for designing of high-power system.

## 6 CONCLUSTIONS

The creation of the experimental ADS at ITEP which would be one of first electronuclear hybrid facilities, it allows to reach give the following important issues.

- Experimental basis for study of technological, engineering and nuclear physics problems of electronuclear systems.
- Engineering basis for wide-profiled applications of both proton beam and neutron flux.
- The educational center for specialists training in above mentioned fields.

Moreover it will be shown an example of expedient use of shut-downed reactors of not great power.

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