Proposals for NFRP-07 of Euratom Work Programme 2019-2020: *Safety Research and Innovation for Partitioning and/or Transmutation*

CIEMAT is interested to participate in the R&D&i for Partitioning and Transmutation in different frameworks: either for a proposal coordinated around the initiative of CERN for NFRP-07, within a proposal coordinated by SCK-CEN around MYRRHA, or a combination of these two or even of more initiatives, and eventually we could also support a proposal for NFRP-05.

In this note we indicate in generic terms a selection (not exclusive) of the contributions and topics we are interested, and in addition we develop in more detail one particular proposal because its potential relevance and impact.

Generic topics of interest for CIEMAT within proposals for NFRP-07 of Euratom Work Programme 2019-2020: *Safety Research and Innovation for Partitioning and/or Transmutation*

1) ADS-Dynamics experimental demonstration at non-zero power described in more detail in the attached proposal,
2) Contributions to neutronic of and thermalhydraulics transients of fast ADS lead or Pb/Bi cooled in general and for ADS dedicated to P&T in particular,
3) Contributions to partitioning methodologies and global analysis of implications of the fuel cycle characteristics to the industrial feasibility of different reprocessing strategies and their optimization including also elements of the advanced fuel fabrication,
4) Participation in additional experimental campaigns at ADS mock-ups of zero power to complete the validation of the physics of the subcritical systems, for example, when it implies fuel different than Uranium and different combinations of materials and operational conditions. Also contributing to progress into the integration of reactivity monitoring and control systems.
5) Nuclear data Sensitivity/Uncertainty analysis of detailed ADS designs like MYRRHA and EFIT, covering different parameters additionally to the reactivity, like reactivity coefficients, β_{eff}, $\Lambda_{eff,}$ damage to materials, etc. At present even with the best libraries the uncertainties of simulations of fast systems in general and ADS in particular are larger than what was indicated by the corresponding NEA WG. With progressively more complete uncertainties libraries, Sensitivity and uncertainty (S/U) analyses are becoming increasingly widespread for the analysis of the propagation of such uncertainty. Sensitivity analyses allow identifying the most important neutron-induced nuclear data. The study could benefit from better libraries and methods and apply the calculations to fully detailed concepts to identify potential nuclear data measurements or integral experiments that could reduce the simulations uncertainties down to the required margins.
6) Propagation of uncertainties in fuel cycle scenarios hypothesis. Up to now, nuclear fuel cycle scenario analyses are focused on the calculation of the output indicators of the fuel cycle (e.g.: amount of separated materials, the number of facilities needed for transmutation or the gallery length required for the deep repository) given a set of boundary (input) conditions, a scenario. However, recent research involves the uncertainties in the input parameters as part of the assessment by means of local or global methods. The propagation of uncertainties has shown that the amount of Pu and minor actinides in the fuel cycle are very sensitive to some parameters such as the power of the ADS or its fuel composition. This may have an impact in the total generation of high level waste to be stored in the final repository. This impact should be assessed using realistic values of the uncertainty in the input parameters and it could allow a more realistic assessment of advantages of different fuel cycle options.

ADS-Dynamics experimental demonstration at non-zero power

During the past 20 years there has been significant progress for the design of Accelerator-Driven Systems, ADS, for nuclear waste transmutation and other applications (such as thorium fuel cycle). However, all the experimental validations have been carried out so far at zero-power in the core. Subcriticality provides ADS with a different kinetics and dynamics and a low but significantly non-zero power experiment of the ADS dynamics would provide important information at moderate costs, useful for MYRRHA or other full power prototypes. It is expected that the first coupling between a proton beam and the MYRRHA subcritical core will occur within 10 to 15 years, so the experiment has to be performed before that milestone. The experimental test should be designed to validate and optimize various reactivity monitoring techniques, to validate the simulation of the ADS, to simulate experimentally transients during planned operations (start-up, shutdown, etc.) and transients induced by accidental conditions but far from fuel failure. In addition, the instrumentation for operation at full power will be different from the one used in the previous experiments and the proposed experimental tests will help to validate the transition from one instrumentation to the other. Furthermore, the experiments should be extrapolable to the full power conditions.

The suggestion is to setup a specific ADS for this purpose, profiting as much as possible from existing facilities and resources to reduce the cost and the time towards commissioning. Ideally, the best representativity would be obtained with components very similar to MYRRHA: high energy, continuous current accelerator; fast neutron core; liquid metal coolant for both the target and the core; and a central extended target with vertical injection. However, none of these conditions is absolutely required to demonstrate a significant part of the ADS dynamics and to optimize and validate the operation protocols of subcritical transients at power. However, what would be necessary is to have an intense accelerator that can be used to generate an intense neutron source, the possibility to couple it with an spallation target and an experimental reactor with a thermal power of the order of the MW, including a versatile cooling system able to extract that heat but to allow significant changes of the fuel and coolant temperatures, a flexible control and monitoring system, and the conditions to license the operation of the resulting coupled device. Some of the potential facilities where these tests could be proposed are INR/RAS (at Troitsk, Russia), KIPT (at Kharkov, Ukraine), PSI (at Villigen, Switzerland) or the planned Myrrha_100 (at Mol, Belgium). For the design of the proposed experimental facility, it is important to take into account, that in addition to the campaign of transients and validation of control systems, the device could constitute an interesting facility to validate other pending aspects of ADS technologies, such as tests of transmutation targets, irradiation effects near the spallation target, etc..

Several preparatory activities in view of the above program, oriented to demonstrate its feasibility, optimize the conceptual design of the experiments, agree conditions with the facilities and perform some preparatory experiments, could be proposed as a broad work package within an EURATOM NFRP-07 proposal, including:

- Review of the characteristics of the facility accelerator and optimization: beam energy, intensity, time structure and duty-cycle, efficiency, average time between failures, monitoring and control.
- Design and optimization of the spallation/conversion target, including beam injection, cooling and source importance monitoring.
- Optimization of the core using available local resources, including available fuel, optimization of the cooling and control rods systems, optimization of reactivity coefficients and operation conditions.
- Optimization of the instrumentation: core instrumentation, subcritical reactivity instrumentation, joint core/accelerator control system.
- Experimental validation of the instrumentation, including core, target and accelerator and tests at the selected facility.
- Optimization of the measurement plan, ensuring the possibility to extrapolate the results from the test to the final ADS for waste transmutation or thorium fuel and taking care of their needs.
- Preparatory licencing studies, for the changes needed respect to the present and licensed configurations, this could require the collaboration with the operators of the facilities, eventually from non EURATOM members or associates.