Design of the intense neutron source based on Muon Catalyzed Fusion for irradiation materials of fusion reactors and other applications

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In the framework of collaboration among ENEA (Italy), PSI (Switzerland) and Kurchatov Institute (Russia), the design study for a new intense 14 MeV neutron source based on muon catalyzed fusion was developed.

Negative pions are produced inside a strong magnetic field region (B = 8-15 T) by an intense deuteron beam interacting with a Lithium target (L = 1,5 m, Φ = 1,5 cm). The pions and the muons from pion decay in flight are collected along the field lines in the backward direction and stop in a liquid deuterium-tritium mixture. Using a 25 MW deuteron beam at 1 GeV/N (12 mA = 7,5 x 10^{16} d s^{-1}), a number of 3 x 10^{16} p^{-} s^{-1} can be generated decaying to muons, of which up to 10^{15} s^{-1} stop in a (3-10) litre D-T target. With Xc = 100 fusion per μ-, μCF produces 14 Mev neutrons with a source strength of more as 10^{17}n s^{-1} , i.e. a neutron power of 200 KW and average neutron flux about 10^{14} cm^{-2} s^{-1}, that is the achievable neutron flux for sample irradiations (about 10 dpa/y) in test volume of several liters.

The lay-out allows to realize two different irradiation zones and, correspondingly, two intense neutron sources :

- an isotropic 14 MeV neutron source of about 10^{17} ns^{-1} (see above) and
- a high spallation neutron source of about 2 x 10^{16} ns^{-1}.

The intense 14 MeV neutron source based on muon catalyzed fusion is not competitive against the spallation neutron source for the ADS project. But the peculiarity to have monocromatic energy neutrons can be useful for studying the incineration rate of a ADS reactor.

In this paper we present the general project: interaction particles, neutron, thermo-fluid dynamic and structural calculations, design of the components. Beginning from the pion target, we have expanded the region of optimisation of the efficiency of negative pion production by deuterons respect to the region considered previously both for deuteron energy and primary target geometry. Dependencies of the pion yield on the target size and deuteron energy have been investigated in detail as well the escape of the pions and muons in the converter.

Moreover this paper focuses on a number of technological solutions for the proposed design of components that appear to be particularly critical:

- vessel (synthesiser) with liquid deuterium-tritium producing the μ-catalyzed fusions and the neutrons;
- heat removal from the Li target (first target) up to 25 MWatt;
- solenoid for a about 7 T magnetic field with internal radius about 80 cm;
- shielding (neutrons and heat) of the 14 MeV neutrons in a < 80 cm thickness;
- tritium facility.