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GEANT4 Simulation Package for Interactions Related to MuonicAtom and Muon-Catalyzed Fusion

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The muon-catalyzed fusion (μCF) is an established method in which nuclear reactions occur at low temperatures (at or below room) and pressure. The reduced size of diatomic muonic molecules (say *ddμ* or *dtμ*) allows fusion to occur due to the greatly enhanced wave-function overlap. Under the current dMu/DT collaboration, an attempt is being made to study the μCF rate and sticking fraction at a relatively higher temperature (but <3×10^3 K) and pressure (but <10^5 bar), using a diamond anvil cell with D-T mixture. In parallel, physics processes related to formation, transport, isotopic transfer, and other deexcitation processes of muonic atoms as well as μCF and reactivation of muons to the fusion cycles are being modeled in GEANT4.

In this work, our physics model development effort with the classes available in the GEANT4 source, e.g. G4MuonicAtom, G4MuonMinusAtomicCaptureAtRest added to new classes and study parameters will be narrated. Currently, G4MuonicAtom is derived from G4Ion with the specific Z and A numbers, and it's formed when negative muon slows down and is captured by the atom. During the lifetime of a muonic atom (2.193 μS); it undergoes several deexcitation processes, such as radiative process, Columb deexcitation, Auger process to come to the ground state; however; the excited state transfer:$(D)_n + T- > (T)_n + D$ influences the initial population muonic atoms in ground state which is the initiation of a complex μCF process. It is not only limited to D and T, rather the muonic atom gets transferred to other heavier nuclei. This transfer process depends on the interaction crosssection (σ) and q_{1s}, which is the probability of the lighter muonic atom coming to the ground state.

In the first stage, a separate class by the name of MuonicAtomTransfer has been worked out, where the excited state transfer based on these parameters has been devised with the the data available: Ref: PhysRevA.50.518. The output successfully carries out the transfer process before the muon is decayed in the orbit of the atom or captured by the nucleus. Later, diatomic molecule formation and in turn μCF is being devised based on the interaction lengths and sticking probabilities available from
Ref: https://muon.npl.washington.edu/elog/mucap/Talks+and+Presentations/091118_104846/dd.pdf
& LAMPF data considering several possible channels such as
1. $dt\mu- > \alpha\mu + n$ (sticking) or $dt\mu- > \alpha + \mu + n$ (no sticking), yield: 14.1 MeV
2. $dd\mu- > He_3\mu + n$ (sticking) or $dd\mu- > He_3 + \mu + n$ (no sticking), yield: 3.3 MeV
3. $tt\mu- > n + n + \alpha\mu$ (sticking) or $tt\mu- > n + n + \alpha + \mu$ (no sticking), yield: 11.3 MeV

The goal of the simulation is to compare measured sticking fractions with theory, and to simulate the effective sticking fraction (after reactivation) in various conditions of temperatures, pressure, and applied EM fields. The simulation is being carried out to support the experimental design of the diamond anvil cell μCF chamber. We are also trying to use the MuonicAtom physics developed to simulate the effect of heavy impurities, such as wall materials & window materials. We are planning to submit our MuonicAtom->DiatomicMuonicMolecule->uCF->Reactivation package to the GEANT4 distribution including example codes.
Ref: https://arpa-e.energy.gov/technologies/projects/conditions-high-yield-muon-catalyzed-fusion

In-person participation

No

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