Notre Dame Science
Department of Physics

QUANTIFYING QUANTUM DYNAMICS IN SLOW COLLISIONS OF ATOMIC NUCLEI: FORMATION OF NEW ELEMENTS

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(Refreshments at 3:30 P.M. NSH 202)

Colloquium

Quantum effects such as superposition, interference, tunneling and entanglement are observed in dynamical systems of atoms and molecules. These effects are also well-established in low-energy nuclear collisions forming new elements, which occur at the time, length and energy scales of zepto-second, femto-meter and million electron-volts, respectively. The structure of complex, atomic nuclei manifests itself through intrinsic quantum states associated with collective, single-particle and cluster degrees of freedom. These could be excited in different phases of a collision, determined by the strength of the many-body interactions between the colliding nuclei. It results in the dynamical dislocalization of an initially evolving quantum superposition of internal states (decoherence [1,2]), affecting reaction outcomes.

Understanding and quantifying quantum dynamics in low-energy nuclear collisions is essential for determining key reaction rates that drive the evolution of stars. These rates are often very difficult to be measured on Earth. However, measurements, with high precision and selectivity, are being planned at a number of facilities, such as at the accelerator facility at Notre Dame and at the rare-isotope beam facility at MSU. These experimental activities also require, to be successful, dedicated theoretical efforts for improving the nuclear reaction theory, making it better the guidance and interpretation of measurements.

I will introduce an innovative quantum approach to low-energy nuclear reaction physics [3], which allows one to quantify the role and importance of quantum decoherence in reaction observables, such as fusion cross sections. Some topical applications will be highlighted, such as understanding (i) astrophysically-important fusion rates, (ii) super-heavy elements formation, and (iii) the possibility of controlling reaction outcomes with super-intense and ultra-short laser pulses.

[1] H.D. Zeh, Seminare Poincare **1** (2005) 115; eprint quant-ph/0512078.
[2] W.H. Zurek, Phys. Today **44** (1991) 36; eprint quant-ph/0306072.
[3] A. Diaz-Torres, Phys. Rev. C **82** (2010) 054617.

All interested persons are cordially invited to attend.