Sub-Barrier Fusion Cross-Sections of Neutron-Rich Light Nuclei

Indiana University, GANIL, Western Michigan Univ., Michigan State Univ.
Theory support: Vanderbilt Univ. (Oberacker & Umar); Indiana Univ. (C. Horowitz)

Physics Motivations:
Neutron Star Crust
Fusion Dynamics ⇒ EOS

The crust of an accreting neutron star is a unique environment for pycnonuclear (density driven) fusion of neutron-rich light nuclei which may be important for heating the crust and to determine its chemical composition.

Dynamics of neutron star merger is influenced by EOS.
Fusion Dynamics of Neutron-Rich Nuclei

TDHF calculations of $^{20}\text{O} + ^{12}\text{C}$
(Collaboration with Vanderbilt group)
$E_{\text{cm}} = 9.5$ MeV; $b = 2.5$ fm
BCS pairing (Lipkin-Nogami extension)
Neck formation, surface vibrations, density fluctuations all visible.

Once Skyrme interaction is fixed for ground state nuclei, fusion cross-section is parameter free and reproduces measured light nuclei cross-section. Enhancement of the fusion cross-section at and below the barrier related to neutron transfer for n-rich systems and dynamical effects.

IU: Sub-Barrier Fusion Cross-Sections of Neutron-Rich Light Nuclei
**Experimental Setup: compact, easily movable, quick setup**

\[ ^{20}\text{O} + ^{12}\text{C} \rightarrow ^{32}\text{Si}^* \]

\[ ^{20}\text{O} \quad 3\text{MeV/A} \]

- **Gas cell** (active ionization chamber):
  - Degrade beam energy from 3 MeV/A to 1-2 MeV/A
  - Event by event beam ID, rejection of beam contaminants

- **Gridless MCP detectors**:
  - Minimization of slit scattering

- **Active target MCP**:
  - Start for TOF (\(\Delta t \sim 250\text{ps FWHM})
  - Beam counting (Coincidence with upstream MCP)

- **Silicon detector**:
  - TOF and Energy measurement

- **Large efficiency** for residue detection (>90%, 75% in Si)

**Setup currently at FSU for \(^{18,19}\text{O} + ^{12}\text{C}\)**

**Data**:

\[ \sigma (\text{mb}) \]

**Graph**:

\[ 10^{0} \rightarrow 10^{1} \rightarrow 10^{2} \rightarrow 10^{3} \]

**References**:

- Eyal et al.
- Cujec et al.
- Christensen et al.
- IU (Electrostatic)
Future Needs

• Importance of measuring the fusion cross-section for isotopic chains
• Relatively small floor space requirement (9ft x 3ft on beamline)
• Few days of beam time per isotope to measure the excitation function
• Beam characteristics:
  ✷ Light neutron-rich beam: A<40
  ✷ Intensity of $10^3$ - $10^5$ pps
  ✷ Energy in the range 1-2 MeV/A
  ✷ Beam purity of at least 50% (event by event tagging)