High Resolution Validation of Next Generation Turbulent Flow Models Using Neutron Beams, Laser Fluorescence, and Liquid Helium

Landen McDonald, M.R. Fitzsimmons, G.L. Greene, (Dept. of Physics and Astronomy University of Tennessee, Knoxville), A. Mezzacappa (ORNL/UTK), Shiran Bao, W. Guo (Florida State University), Xin Tong, Xin Wen, and Yu Zhao (ORNL)

Objectives

Demonstrate particle tracking velocimetry (PTV) using neutron beams to create metastable He molecules in superfluid helium

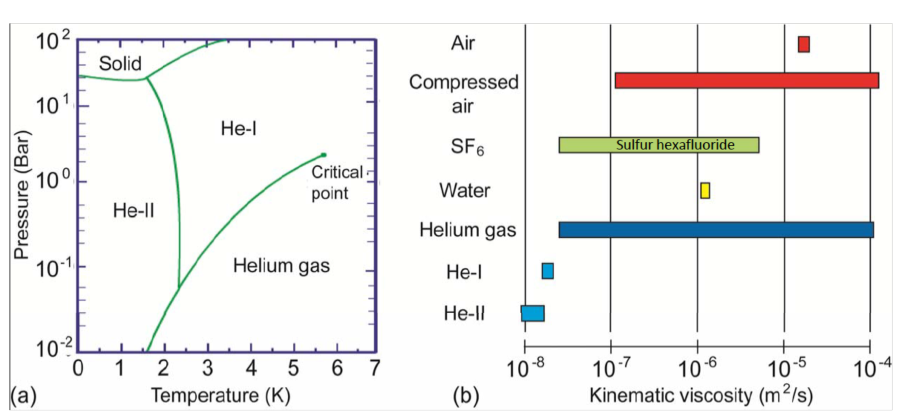
Apply technique to map extremely turbulent fluid flow around models with specific geometries

Background

Reynolds Number

$$Re = \frac{VL}{\upsilon}$$

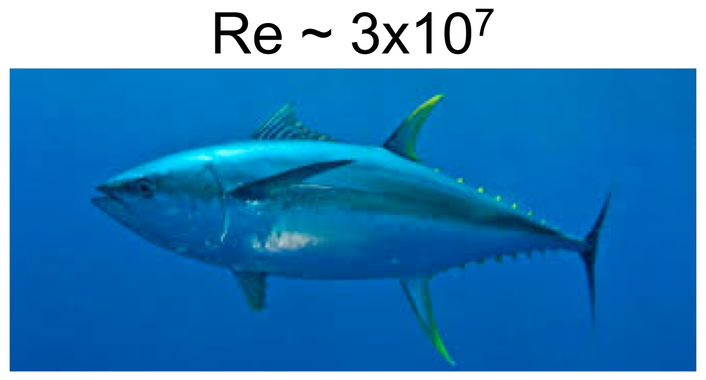
V = velocity
L = characteristic length
υ *= kinematic viscosity*



Modern turbulence data acquired in 1980's

Re ~ 3x10^6

Re ~ 3x10^7

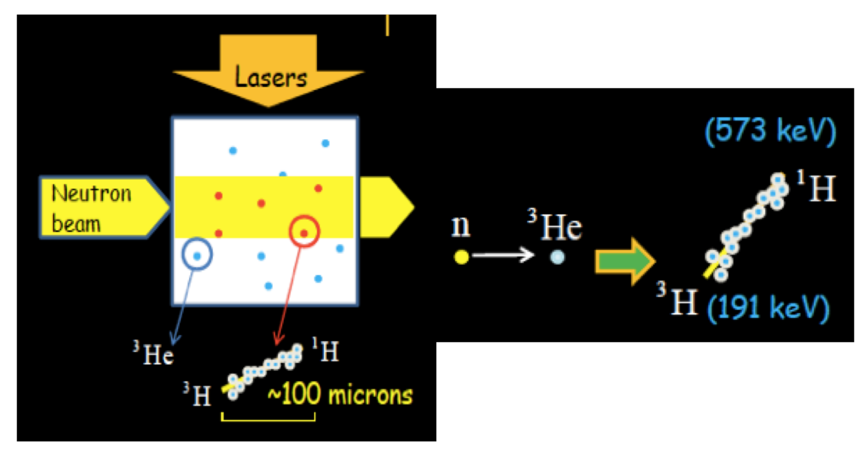


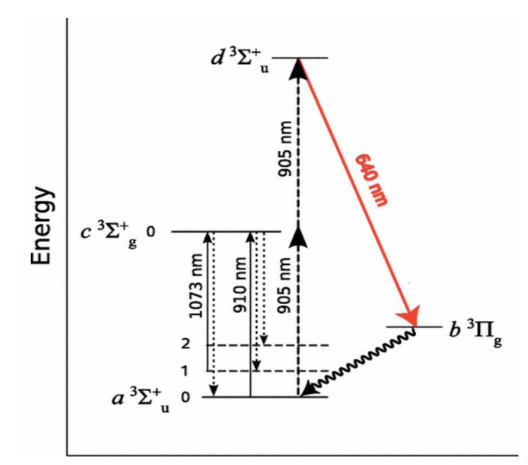
Re ~ 10^9

Our Approach

We are conducting a proof of principle experiment in which we are able to map the temporal evolution of 3D velocity fields that achieve up to Re ~10^8 for large volumes.

This is achieved via the neutron capture by ^{3}He atoms and optical excitation using high-power lasers that cause the helium to fluoresce.

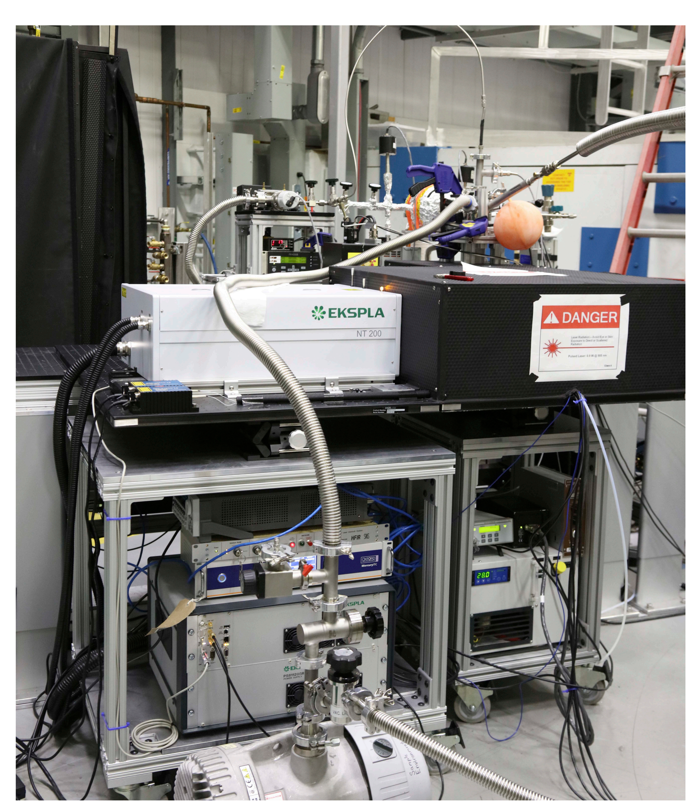




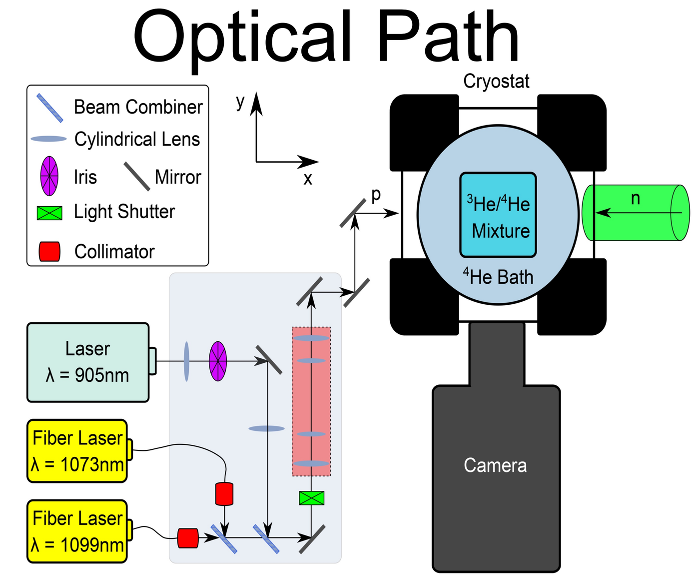
These tracers only track the normal fluid phase (> 1K) and do not perturb the flow.

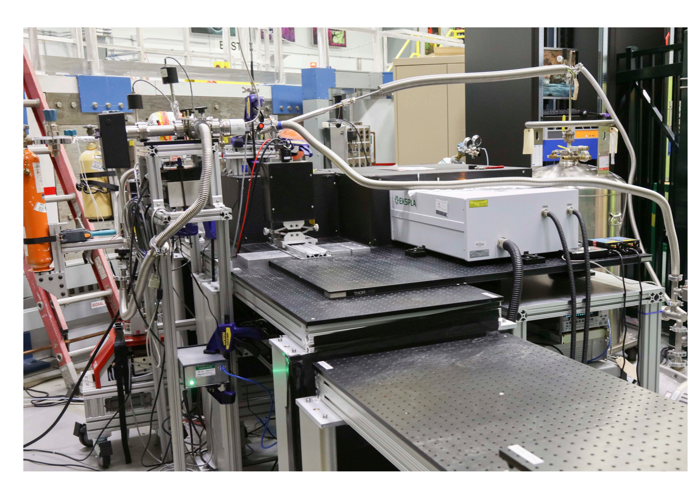
Experimental Setup

LARMOR Beamline



Optical Path

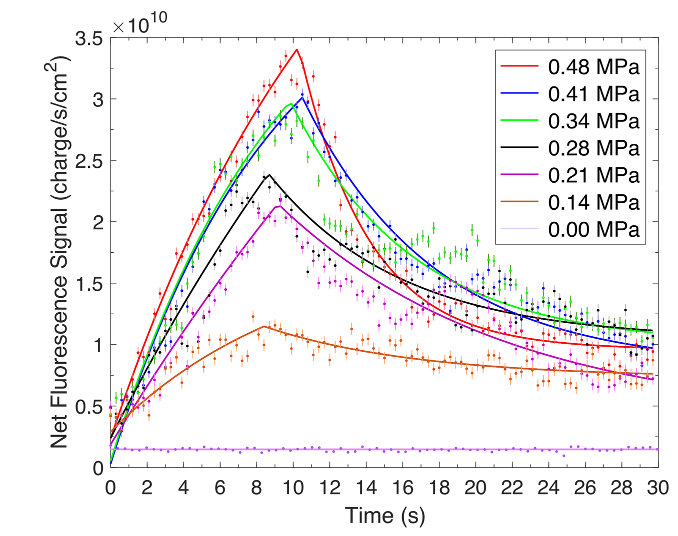


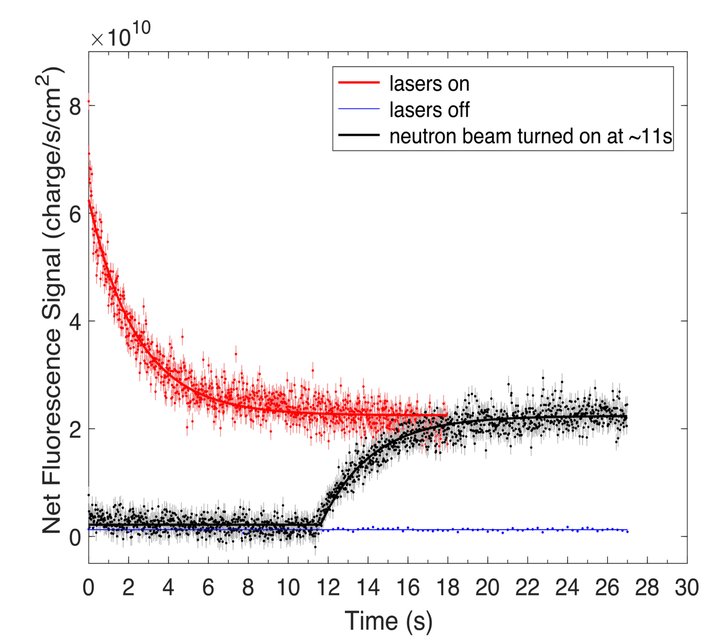


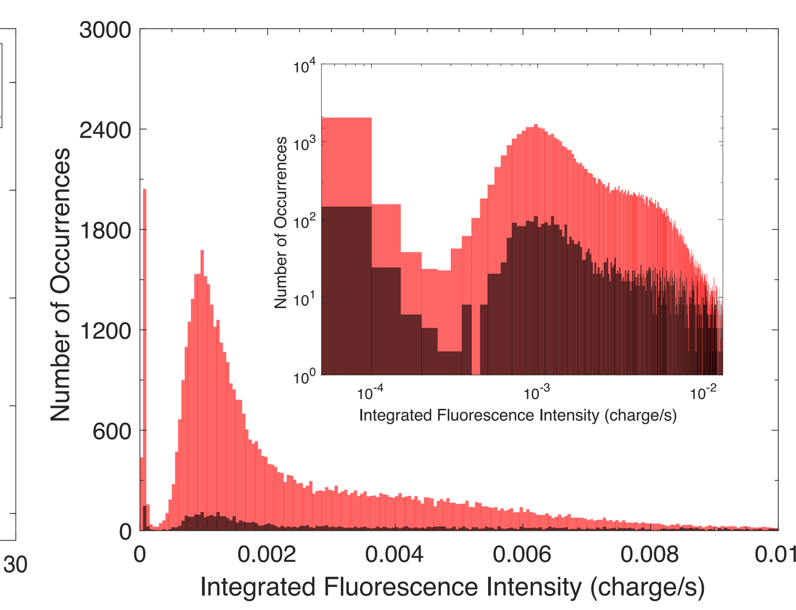
Results

4 successful experimental cycles at ORNL's High Flux Isotope Reactor (HFIR)

Proved that this reaction can be observed and captured using an ICCD camera







Future Development

- Currently improving experimental design and fully automating testing in order to operate continuously with little intervention
- Heat flush technique used to generate counter flow
- Observe flow around specific geometries
- Compare results to turbulent flow models and validate Direct Numerical Simulations (DNS)
- Create user facility at ORNL

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OAK RIDGE National Laboratory | SPALLATION NEUTRON SOURCE

This work is supported by Laboratory Directed Research and Development (LDRD-SEED) Program of Oak Ridge National Laboratory, managed by UT-Battelle, LLC, for the U. S. DOE (PNR). ORNL's High Flux Isotope Reactor is operated by the Scientific User Facilities Division, BES, U.S. DOE. (XW attending experiments)

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