Measuring Stellar Reaction Rates with Bubble Chamber

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Motivations
Learn more about the helium-carbon fusion reaction:
- Helium burning is an important process in stellar nucleosynthesis (star T = 20,000,000 K)
- The process we are investigating is the fusion of helium and carbon into oxygen

Why is the $^{12}$C($\alpha$,γ)$^{16}$O Reaction Important?
- Affects the synthesis of most of the elements of the periodic table
- Sets the N($^{12}$C)/N($^{16}$O) (≈0.4) ratio in the universe
- Determines the minimum mass a star requires to become a supernova

$^{12}$C($\alpha$,γ)$^{16}$O

Our Investigation
What is our experiment?
$^{12}$C($\alpha$,γ)$^{16}$O is very difficult to measure in the laboratory. We plan to obtain the rate for the helium-carbon fusion reaction by measuring the inverse process:
- The photo-disintegration of oxygen into helium and carbon:
  $^{16}$O($\gamma$,α)$^{12}$C

How does the Chamber Work?
1. Cell is cooled then filled with room temperature gas
2. Gas is cooled and condenses into liquid
3. Once cell is completely filled with liquid, pressure is reduced creating a superheated liquid
4. Nuclear reactions induce bubble nucleation
5. Camera detects bubble; system re-pressurizes
6. System depressurizes; ready for another cycle

Our Data
- The recoiled helium and carbon nuclei will heat up small parts of the unstable liquid causing it to vaporize. We capture this bubble event with a 100 Hz digital camera

Next Step
Goal <10%
- Currently, reaction rate error is large (±35%)
- Test the Bubble Chamber during the Summer of 2016
- Improve systematic uncertainties of our set up
- Move camera further back to allow for more radiation shielding
- Study acoustic signal to distinguish any background events (the helium-carbon bubbles have very distinct sound)

Summary
- Helium-carbon fusion to form oxygen is a very important reaction; it is considered to be the key reaction in the helium burning of stars
- For our purposes, it is much easier to measure the time reversal reaction (the disintegration of oxygen into helium and carbon when bombarded with gamma rays)
- At Jefferson Lab, we use our electron beam to generate gammas by colliding them into a copper radiator
- These gammas hit oxygen nuclei in laughing gas (N$_2$O) inside of the bubble chamber
- The helium and carbon nuclei from the breakup of oxygen heat up small parts of the unstable liquid vaporizing it
- This event generates a small bubble which we capture using a high speed digital camera

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