Measuring Low Energy Nuclear Cross Sections using ICF

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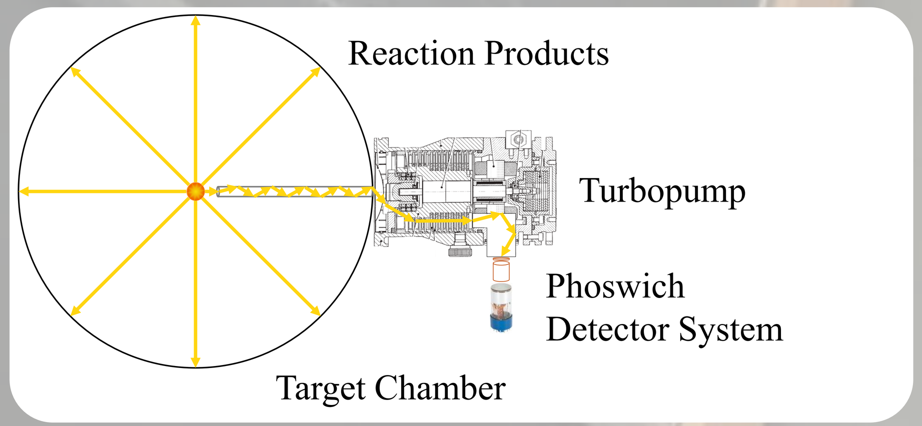
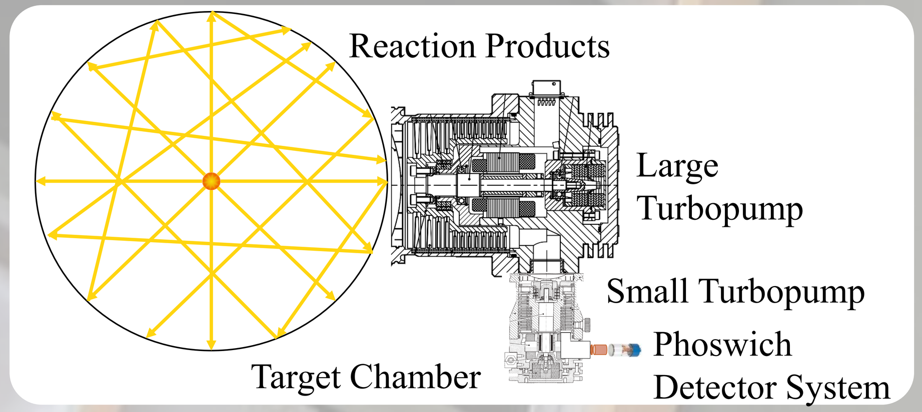
I. Abstract

Inertial confinement fusion is a tool that can be used for fundamental nuclear science measurements. In the method under consideration, nuclear reaction products in the expanding atomic gas following the target implosion will be collected and trapped using a turbomolecular pump. The beta-decay of reaction products with half-lives ranging between 20 ms and 10 s will be measured in-situ using a phoswich detector system starting milliseconds after the implosion. Several previously unmeasured low-energy deuterium and tritium radiative capture and stripping cross sections could possibly be measured using this technique. To study the feasibility, several small scale experiments are being carried out at Houghton College and SUNY Geneseo to simulate the rapid release of gas by the ICF target, its subsequent capture and decay counting.

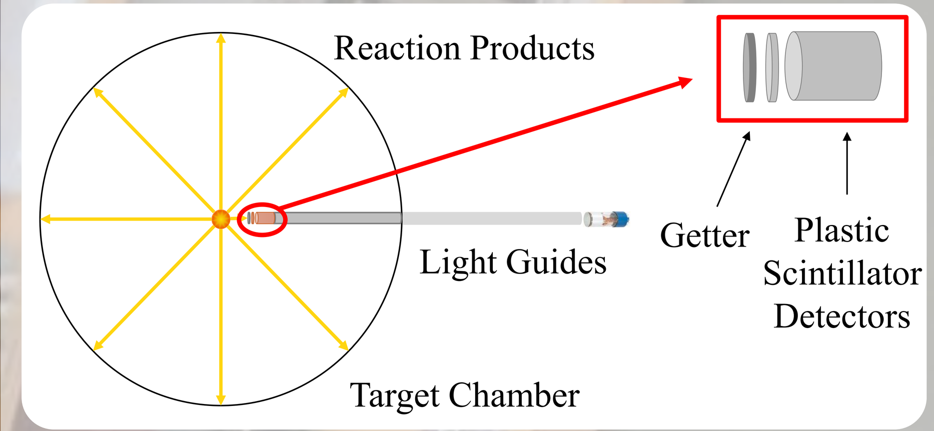
II. ICF Experimental Setup



Method 1. Some fraction of the reaction products will be captured through the collection tube, trapped, and detected.



Method 2. All reaction products will be collected and trapped by a large turbopump system.



Method 3. Some reaction products will stick to a getter placed in front of the detector system, near the target center.

III. Theory

Several zero threshold energy, light ion triton and deuteron reactions produce nuclei with sub-second half-lives. Total yield and number of trapped product nuclei has been estimated using TALYS and other predicted cross sections.

		11.8 keV DT Shot		18.3 keV DT Shot	
Reaction	Half-life	Yield	Captured	Yield	Captured
$^{3}H(t,\gamma)^{6}He$	807 ms	Branching ratio of	~10^{-7} to $^{3}H(t,2n)^{4}He$	8×10^{4}	200
$^{6}Li(t,p)^{8}Li$	840 ms	2-10$\times10^{5}$	1000-6000	4-16$\times10^{5}$	2000-9000
$^{7}Li(t,\alpha)^{6}He$	807 ms	1-3$\times10^{5}$	500-1500	1-4$\times10^{5}$	700-2300
$^{9}Be(t,\alpha)^{8}Li$	840 ms	2.3×10^{4}	130	8×10^{4}	460
$^{9}Be(t,\gamma)^{12}B$	20.2 ms	2.8	0.02	3.0	0.02
$^{10}B(t,p)^{12}B$	20.2 ms	78.3	0.44	923	5.2
$^{11}B(d,p)^{12}B$	20.2 ms	372	2.09	1735	9.8
$^{13}C(t,\gamma)^{16}N$	7.1 s	0.05	0.0003	0.1	0.001
$^{13}C(t,\alpha)^{12}B$	20.2 ms	8.2	0.05	108	0.6
$^{13}C(t,p)^{15}C$	2.45 s	1.2	0.01	17.7	0.10
$^{14}N(t,p)^{16}N$	7.1 s	0.06	0.0003	2.5	0.01
$^{15}N(d,p)^{16}N$	7.1 s	0.10	0.0006	2.0	0.01

Table 1. Reactions that might be measureable using the OMEGA laser. Estimates for yields and number of trapped product nuclei are given for two typical OMEGA shots. Rows highlighted in yellow indicate the most feasible reactions.

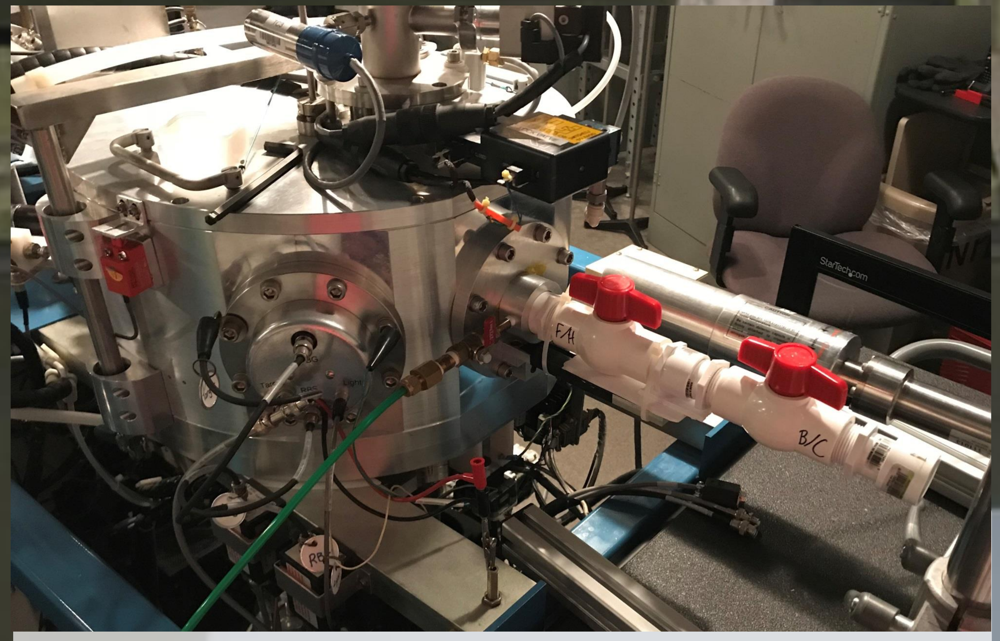


Figure 1. The argon gas cell target for creating ^{41}Ar was attached to the end of the deuteron beam line at SUNY Geneseo.

IV. ^{41}Ar Experiment

Deuterons from the Tandem Pelletron Accelerator at SUNY Geneseo induced the $^{40}Ar(d,p)^{41}Ar$ reaction. The resulting ^{41}Ar gas was then transported to Houghton College and released into the vacuum chamber. Gas entering the collection tube was trapped in the turbopump foreline. The HPGe and silicon surface barrier detectors counted the foreline trap for about one half-life, 109 minutes.

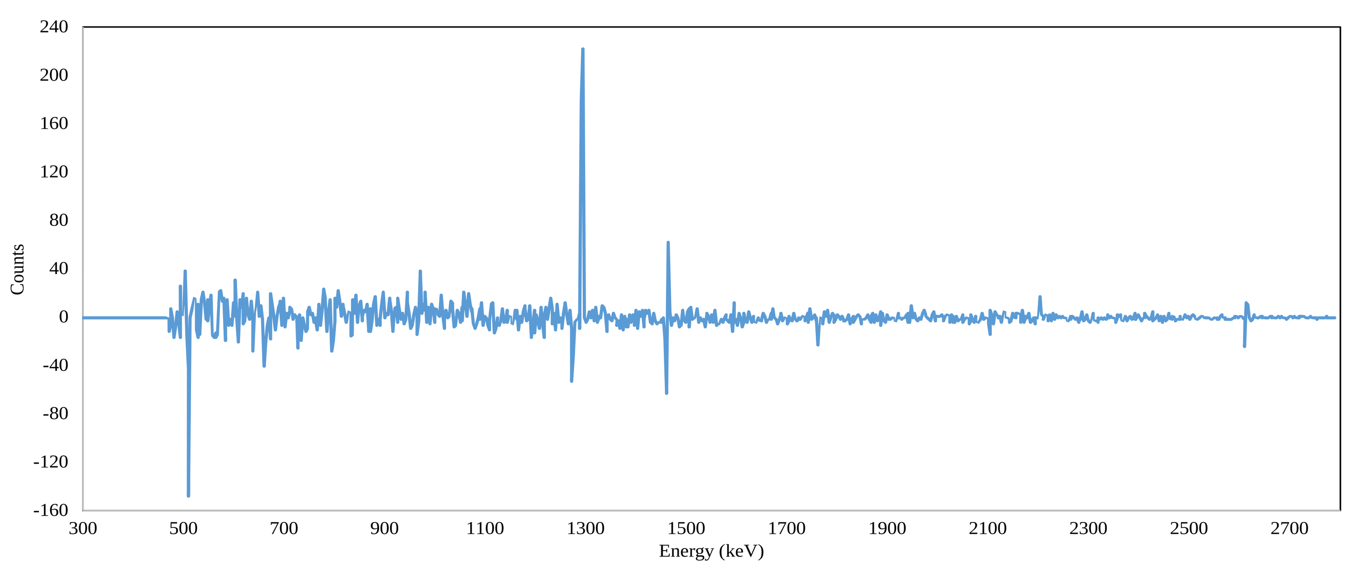


Figure 2. Background-subtracted gamma energy spectrum of ^{41}Ar gas showing pronounced 1293 keV gamma ray line from ^{41}Ar.

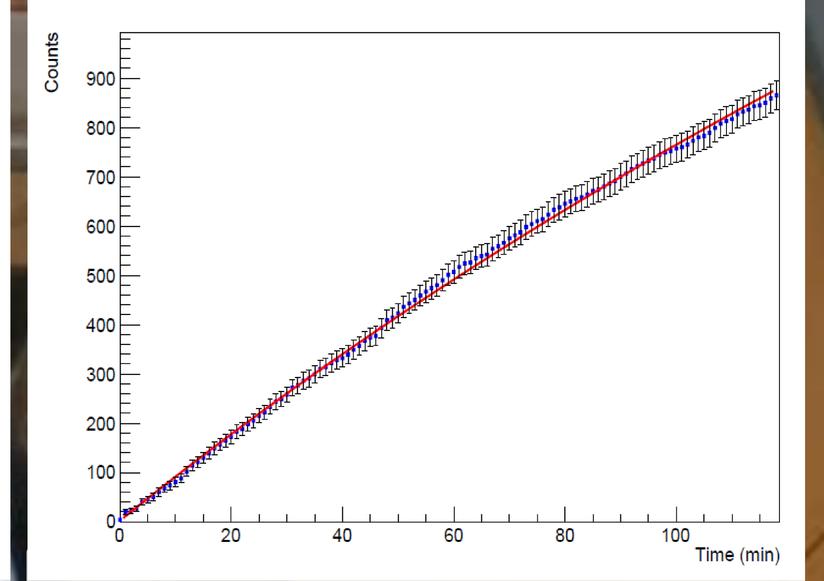
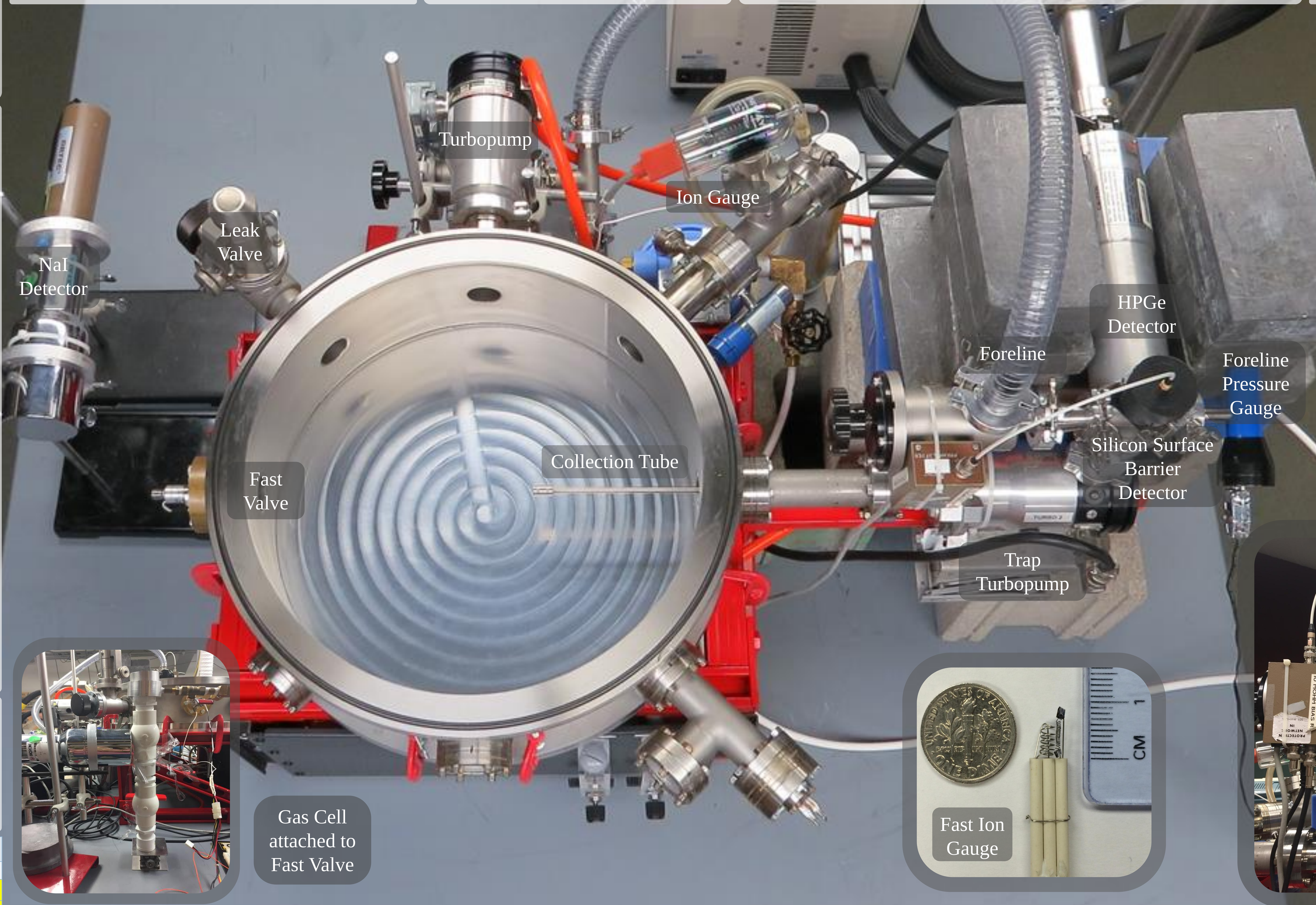
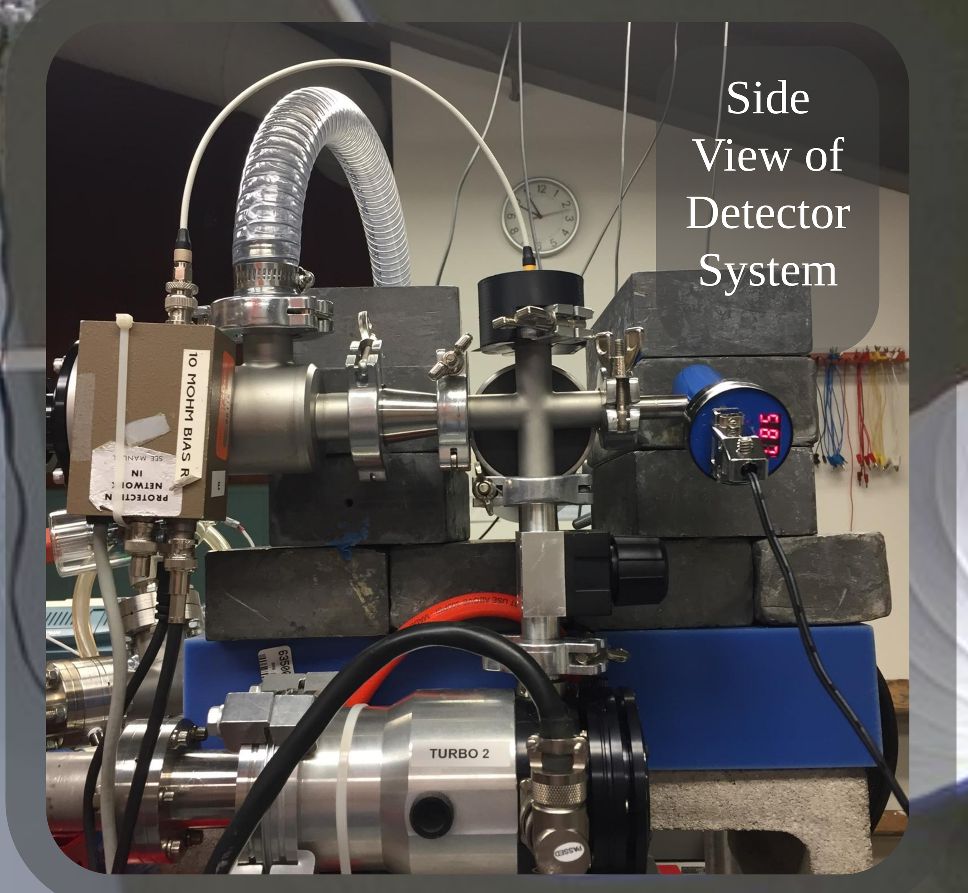


Figure 3. HPGE ^{41}K growth curve fit yielded a half-life of 110 ± 7 min. (SSB detector: 119 ± 12 min).





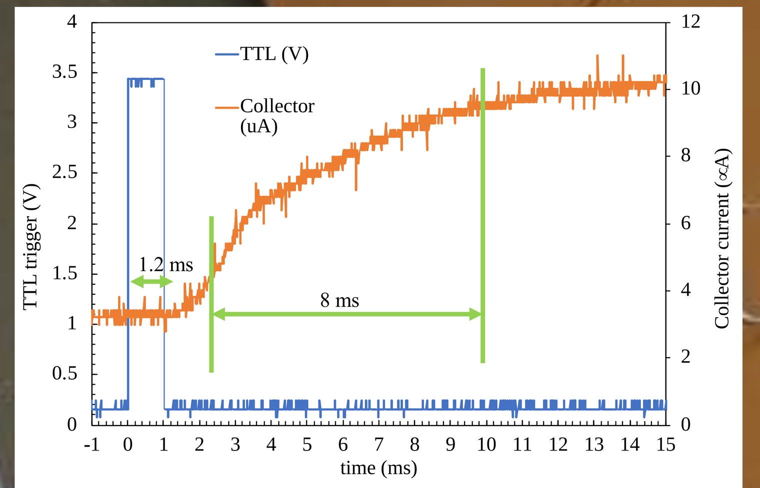


Figure 4. Current output from the fast ion gauge as a pulse of air is released.

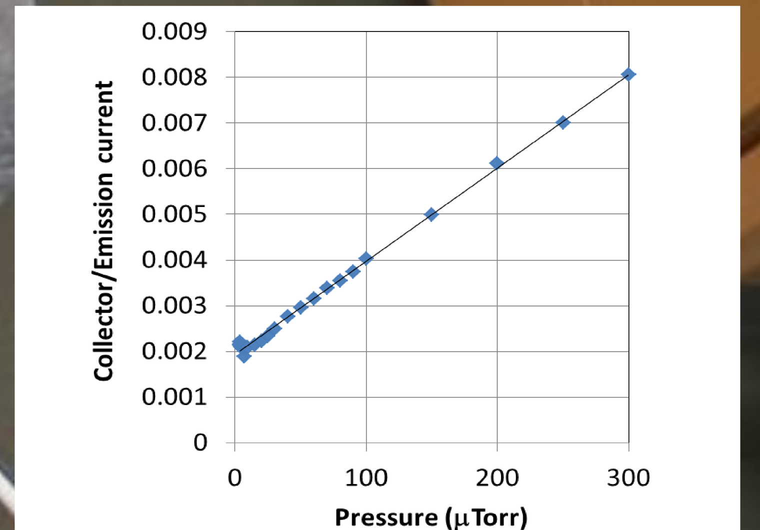


Figure 5. Calibration curve for a fast ion gauge.

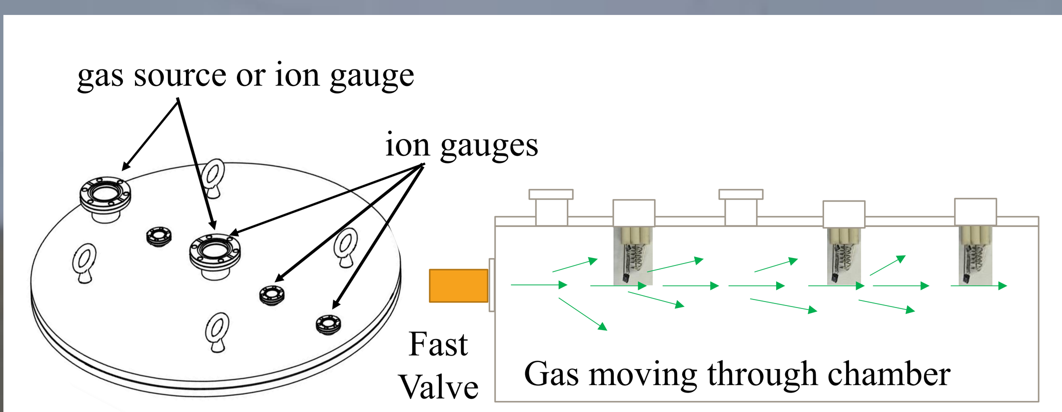


Figure 6. Multiple fast ion gauges in the lid will measure the motion of the pressure front on a 100 µs time scale.

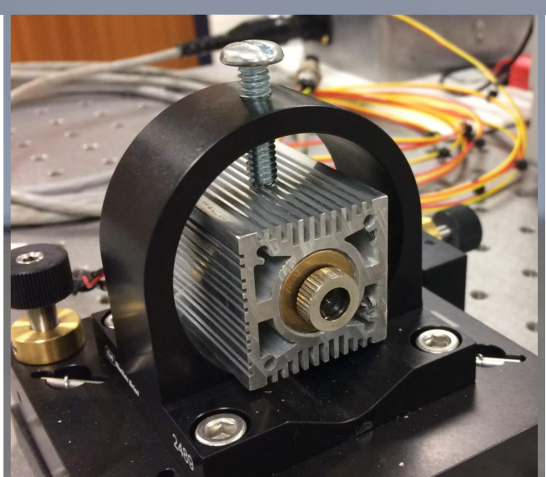


Figure 7. 6 Watt 450 nm wavelength laser for future experiments.

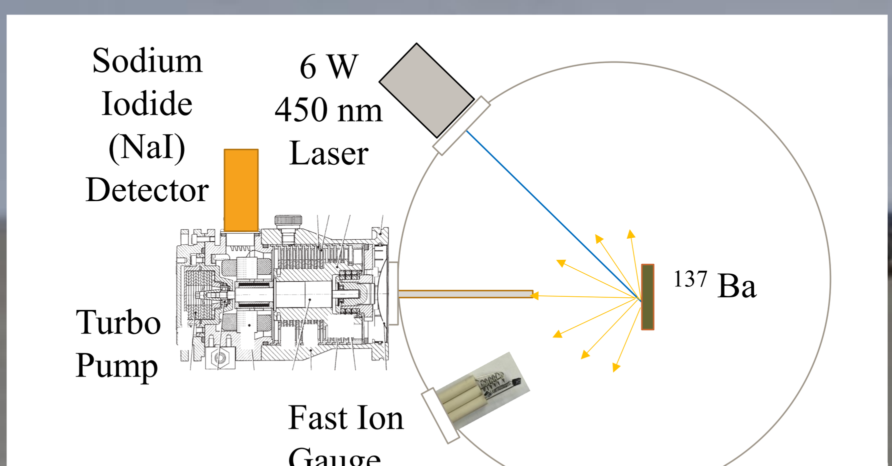


Figure 8. A film of ^{137}Ba (from ^{137}Cs generator) will be hit with the laser, vaporized, captured, and detected.

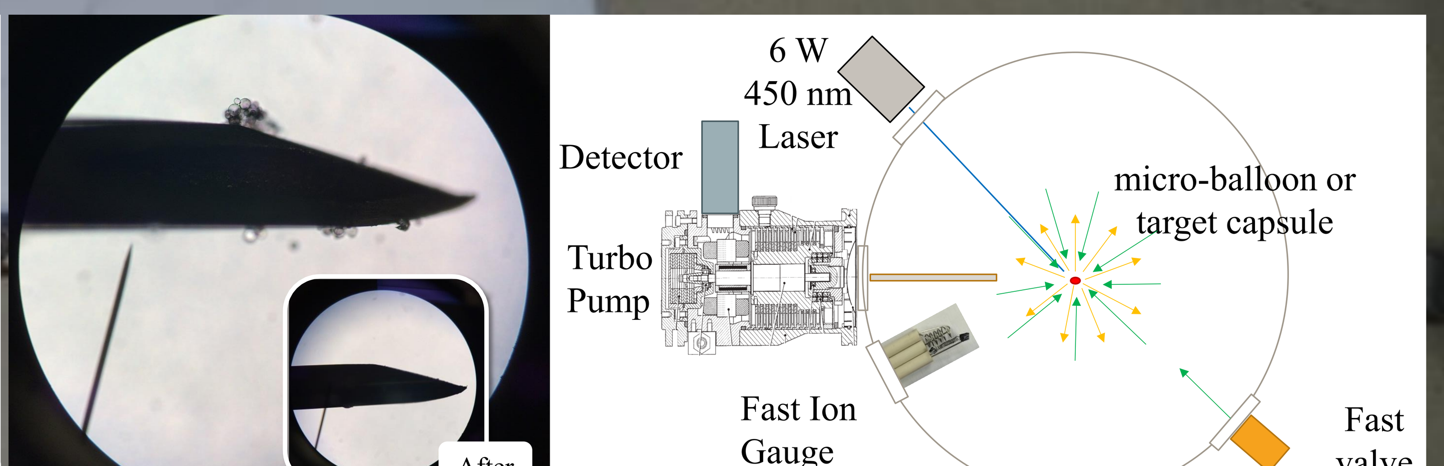


Figure 9. He gas diffuses through the walls of a target capsule. The laser hits the target to rapidly release the gas. The image shows microballoons before and after being hit by the laser.