# Background Rates Outside the OMEGA-60 Target Chamber Seconds to Minutes After a High-Yield Shot

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## I. Abstract

Inertial confinement fusion may be used to make fundamental nuclear science measurements of low-energy light-ion cross sections also of interest in astrophysics and fusion research. The feasibility of collecting and counting the beta decay of the reaction products (half-life 20 ms to 20 s) in the expanding neutral gas after the ICF shot is being studied using two types of “traps” – a getter and a turbopump. Both of these use phoswich detectors to identify beta particles and count the beta decays of the trapped product nuclei. One concern with this technique is that the background rate, even relatively long after the shot, may still be too high relative to the small number of detected product nuclei. An OMEGA ride-along experiment was performed to measure the background rates in these detectors from milliseconds to seconds after the laser shot.

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## II. Introduction

Light-ion nuclear cross sections are usually measured using accelerators. This method is impractical at low energies because of the time required to collect adequate statistics. A single ICF shot can produce the same yield of product nuclei in less than a nanosecond as tens or even hundreds of years of accelerator beam time.

Estimates show certain light-ion radiative capture (t,γ) and (d,γ) and stripping (t,p) and (d,p) reactions may have measurable yields using OMEGA.


**Figure 1. Chart of nuclides**. Stable nuclei (black) undergo thermonuclear (t,γ) and (t,p) reactions forming products (green) that beta decay with half-lives of 10s to 100s of milliseconds.

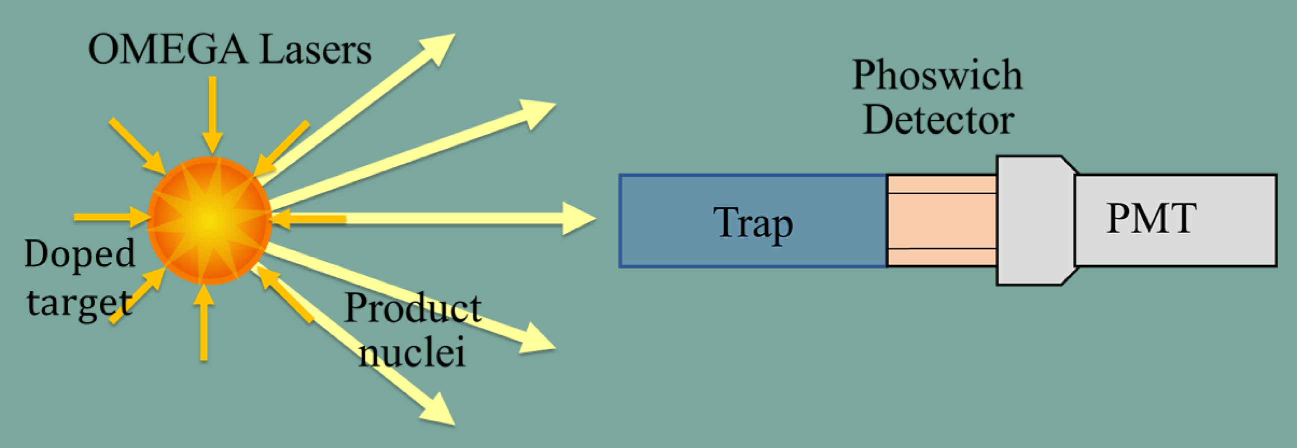



**Figure 2. Conceptual drawing of the proposed method.** The expanding neutral gas is captured and product nuclei decays can be counted by a phoswich detector.

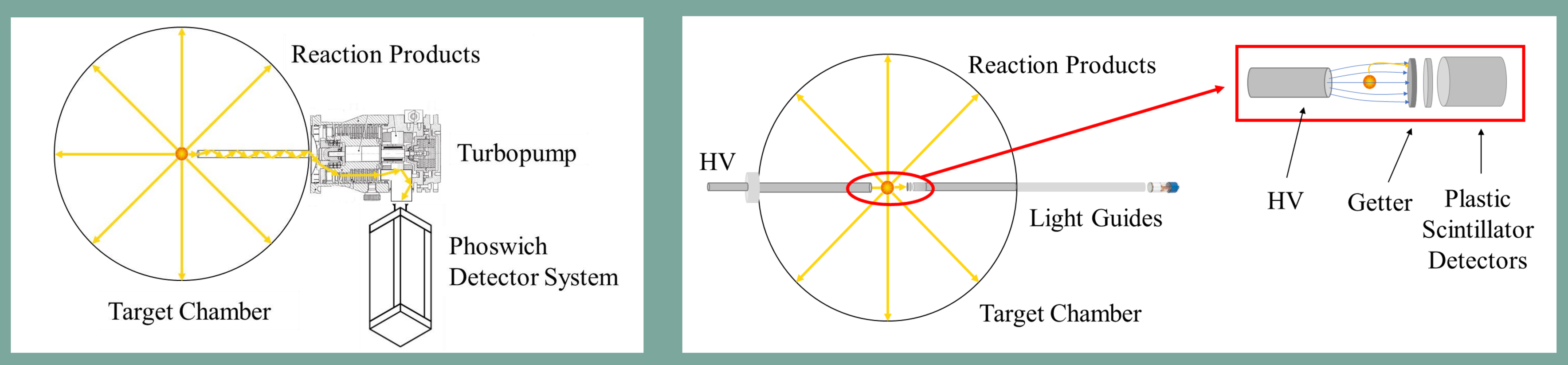
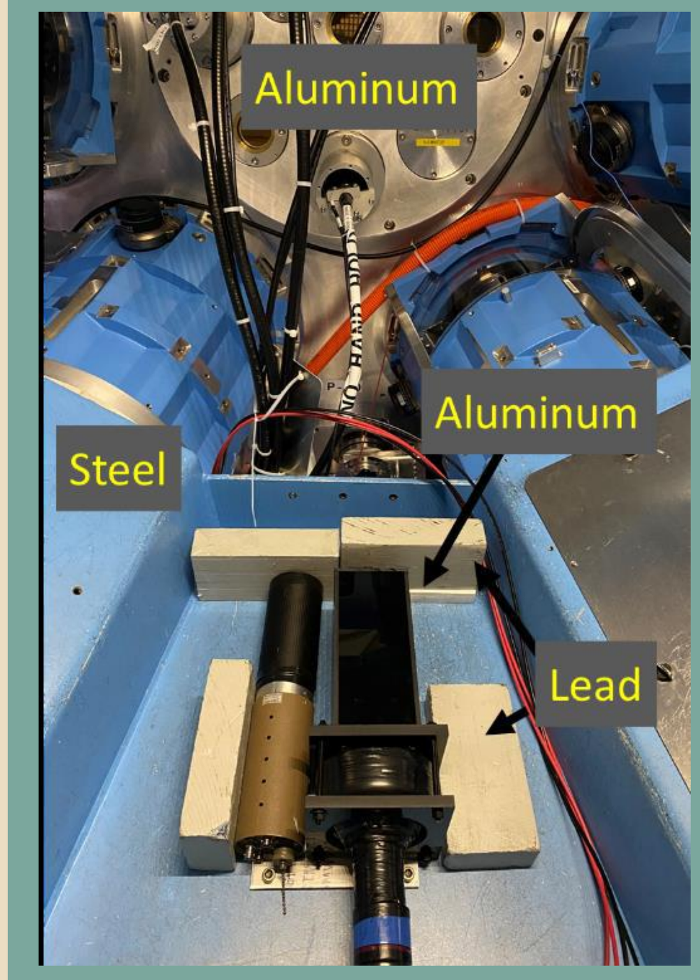
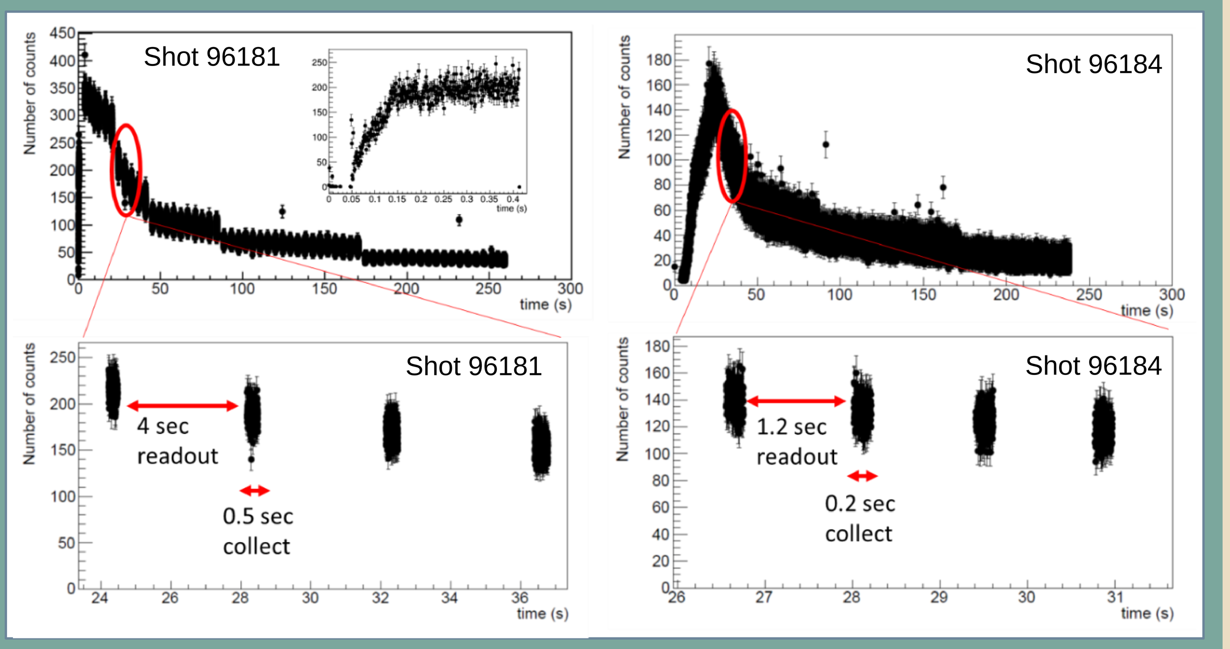



**Figure 3. Different Capture Methods: (Left)** Product nuclei are captured in a turbopump, then trapped and counted inside a phoswich detector. **(Right)** Product nuclei stick to a getter and decay. The resulting beta particles emit a pulse of light in the plastic scintillator, which travels along a light guide to a photomultiplier tube. In both methods the phoswich detector is made of a thin fast (dE) and a thick slow (E) plastic scintillator. The fast and slow components are later separated electronically to determine the energy deposited in each scintillator.

## III. LLE Ride Along Experiment

The background count rate milliseconds after a high-yield ICF shot is unknown. To address this, in Dec. 2019 the detectors were placed about 2.4 m from the OMEGA-60 target chamber wall during a series of high-yield DT shots ( ~$10^{14}$ neutrons). In order to protect the electronics from the EMP, the detectors were electrically isolated until about 1 ms after the shot. Once the protection relays were activated, the PMT was powered and phoswich detector signal pulses were digitized between 2 ms to 600 s after the shot.



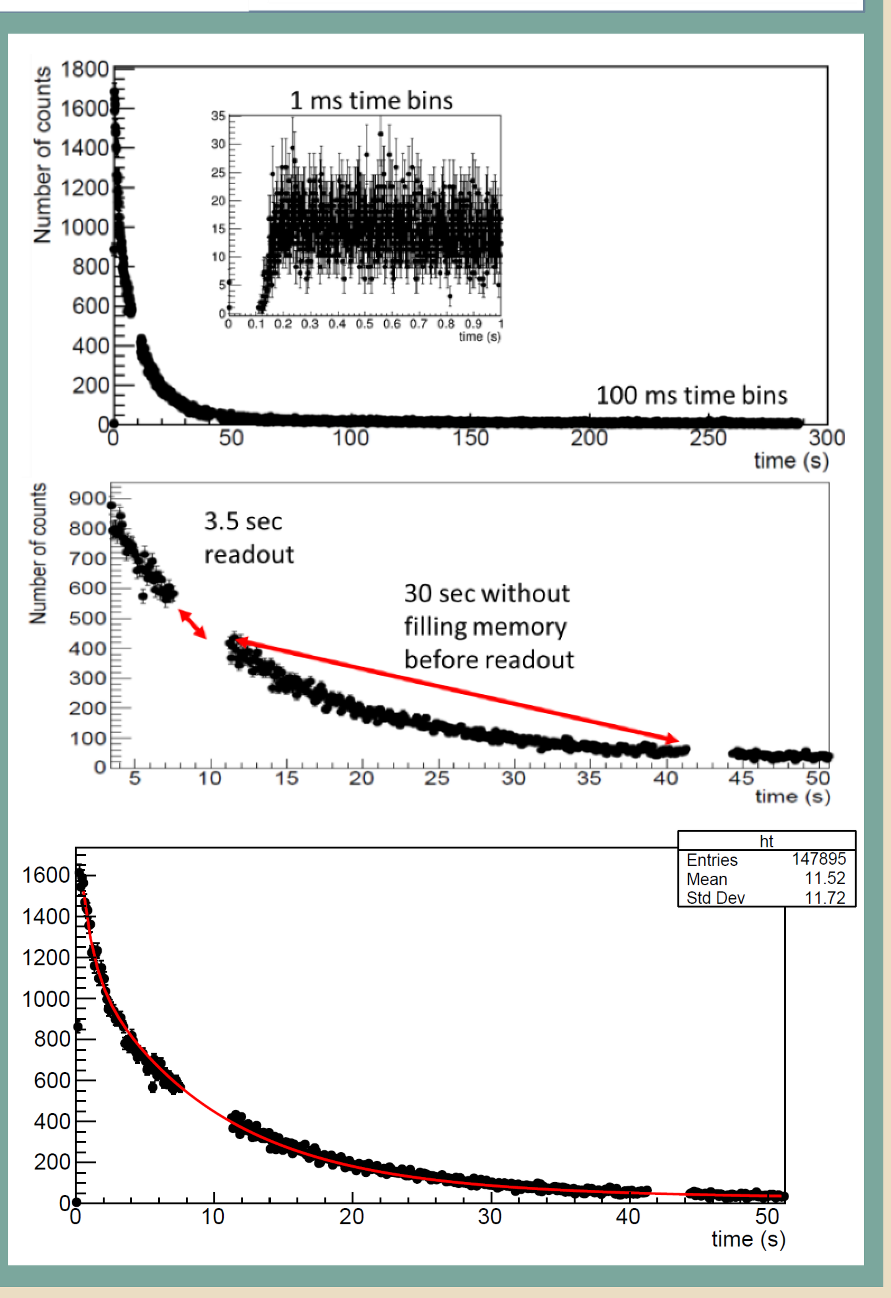




**Figure 4. (Above)** The detectors near the OMEGA target chamber.

**Figure 5. (Above Right) Turbopump detector background.** The decay curve for shot 96181, with 1 ms time bins not corrected for deadtime, shows the data acquisition system struggling to handle count rates of greater than 350,000 events/s. The inset shows the detector reached maximum event rate as early as 200 ms after the shot. For shot 96184 the FemtoDAQ timeout was reduced to 0.2 s, which allowed the data acquisition system to keep up better but delayed the maximum event rate to about 25 s after the shot.

**Figure 6. (Right) Getter detector background. (Top)** The getter collector decay curve with 100 ms time bins and the FemtoDAQ timeout set to 30 s. **(Inset)** The first second of the decay curve with 1 ms time bins. The count rate reaches a maximum of about 18,000 events/s at about 0.2 s. **(Middle)** The FPGA buffer fills in 3.5 s, is read out, then reaches the full 30 sec. without filling. **(Bottom)** Fit of two exponential decay functions plus a flat background.

## IV. Detector Simulations

In order to understand the behavior of the detector system, the detectors were simulated using GEANT4. The goal was calculating the absolute efficiency of the detector and for identifying possible sources of background events.

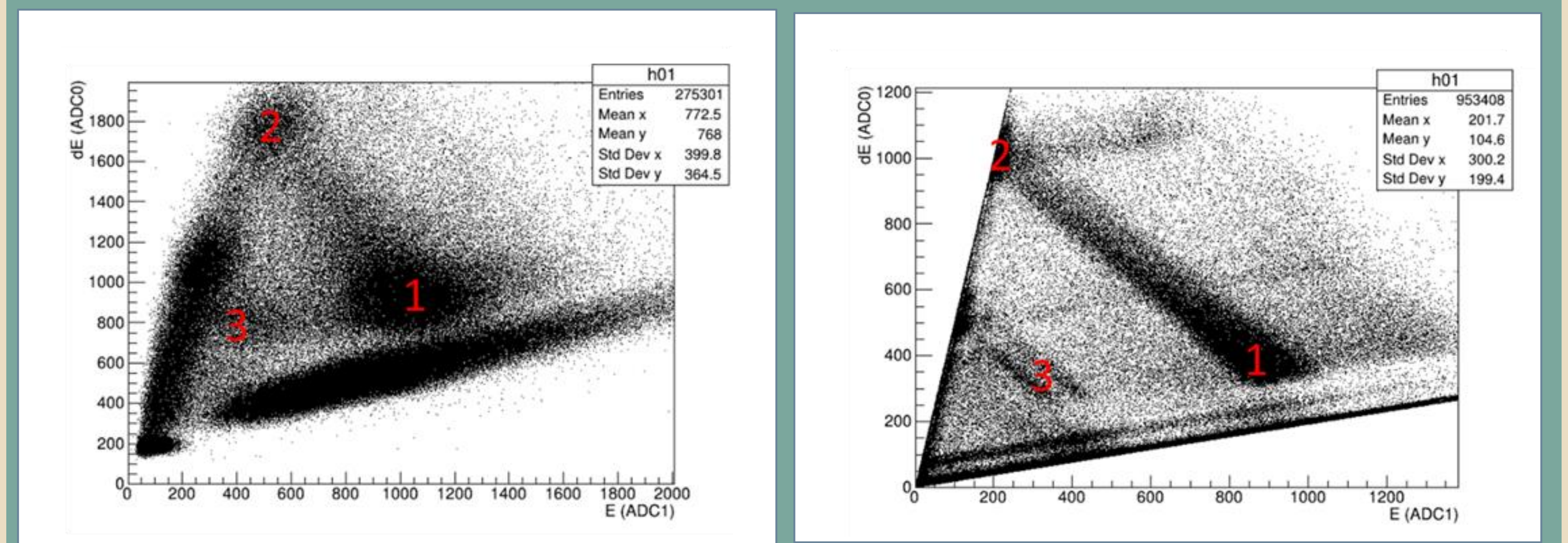


**Figure 7. (Left)** dE-E histogram with a Bi-207 source inside the turbopump trap detector. **(Right)** Geant4 simulation of the Bi-207 inside the turbopump trap. The features in both plots are numbered, (1) 976 MeV Bi-207 electrons, (2) 976 MeV electrons entering the dE detector at oblique angles, (3) 482 keV Bi-207 electrons

## V. Conclusions

1. The Getter detector background was low enough that reaction cross sections may be measurable using OMEGA.

2. The Turbopump detector background was too high for this, but may still be reduced using shielding.

3. Initial rates were too high for the acquisition system to digitize and store.

4. $^{27}Al(n,2n)\,^{26}Al^*$ and $^{16}O(n,p)\,^{16}N$ were identified as possible background sources.

| | $^{26}Al$ in Foil | $^{26}Al$ in Bar | $^{16}N$ Inside | $^{16}N$ Outside |
|---|---|---|---|---|
| Getter | 1,802 | $5.05\times10^7$ | | $3.49\times10^7$ |
| Turbopump | 198,800 | $5.05\times10^7$ | 250,600 | $3.40\times10^7$ |
| Detected decays per million simulated | | | | |
| Getter | 37,740 | 382 | | 164 |
| Turbopump | | 1,360 | 4,500 | 477,000 |
| Predicted number of decays detected | | | | |
| Getter | 67 | 19,300 | | 5,720 |
| Turbopump | | 68,900 | 1,128 | $1.56\times10^7$ |
| Predicted number of decays detected per 10 ms | | | | |
| Getter at 0.2 s | ~1 | 21 | | 5 |
| Turbopump at 30 s | | 3 | ~1 | 853 |
| Measured number of decays per 10 ms | | | | |
| Getter at 0.2 s | ~180 | | ~180 | |
| Turbopump at 30 s | ~1450 | | ~1450 | |

**Table 1.** Comparison of measured count rates with estimated $^{26}Al^*$ and $^{16}N$ rates based on GEANT4.

## VI. Future Plans