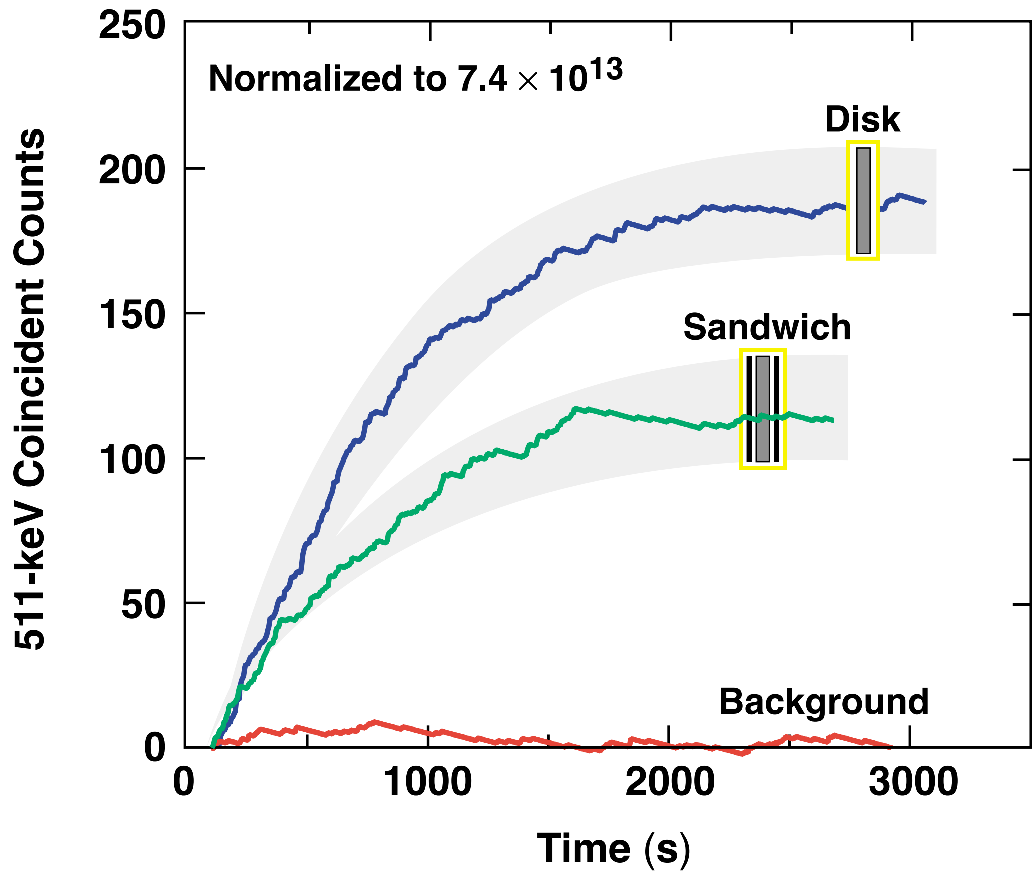
Current Status of Tertiary Neutron Diagnostic by Carbon Activation



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Summary

The present carbon activation system can be used for ρR measurements of DT cryogenic targets on OMEGA

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- The ρR of cryogenic targets can be determined from the tertiary neutron yield.
- We perform several tests on OMEGA to study background and contamination signal of carbon activation.
- For these tests we use DT-filled glass targets with very low ρR that don’t produce tertiary neutrons.
- Carbon disks were purged in vacuum at 1000°C and filled with different gases: Ar, N_2, CO_2, and air.
- Purification and proper packaging reduced the false signal from contamination and secondary reactions to an acceptable level.

Outline

Current status of the tertiary neutron diagnostic by carbon activation

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- Introduction
- Carbon as an activation material
- Carbon purification
- Experimental setup
- Experimental data
- Interpretation of experimental data
- Conclusion

Measurement of tertiary neutrons can be used to determine the ρR of ICF targets

- **Primary DT fusion reaction:**

  $$D + T \rightarrow \alpha + n \text{ (14.1 MeV)}$$

- **Secondary, 14.1-MeV neutrons scatter elastically in the fuel:**

  $$n + D \rightarrow n' + D' \text{ (0–12.5 MeV)}$$

  $$n + T \rightarrow n' + T' \text{ (0–10.6 MeV)}$$

- **Tertiary, in-flight fusion reaction:**

  $$D' \text{ (0–12.5 MeV)} + T \rightarrow \alpha + n'' \text{ (12–30 MeV)}$$

- **For NIF, the yield of tertiary neutrons is proportional to ρR.**

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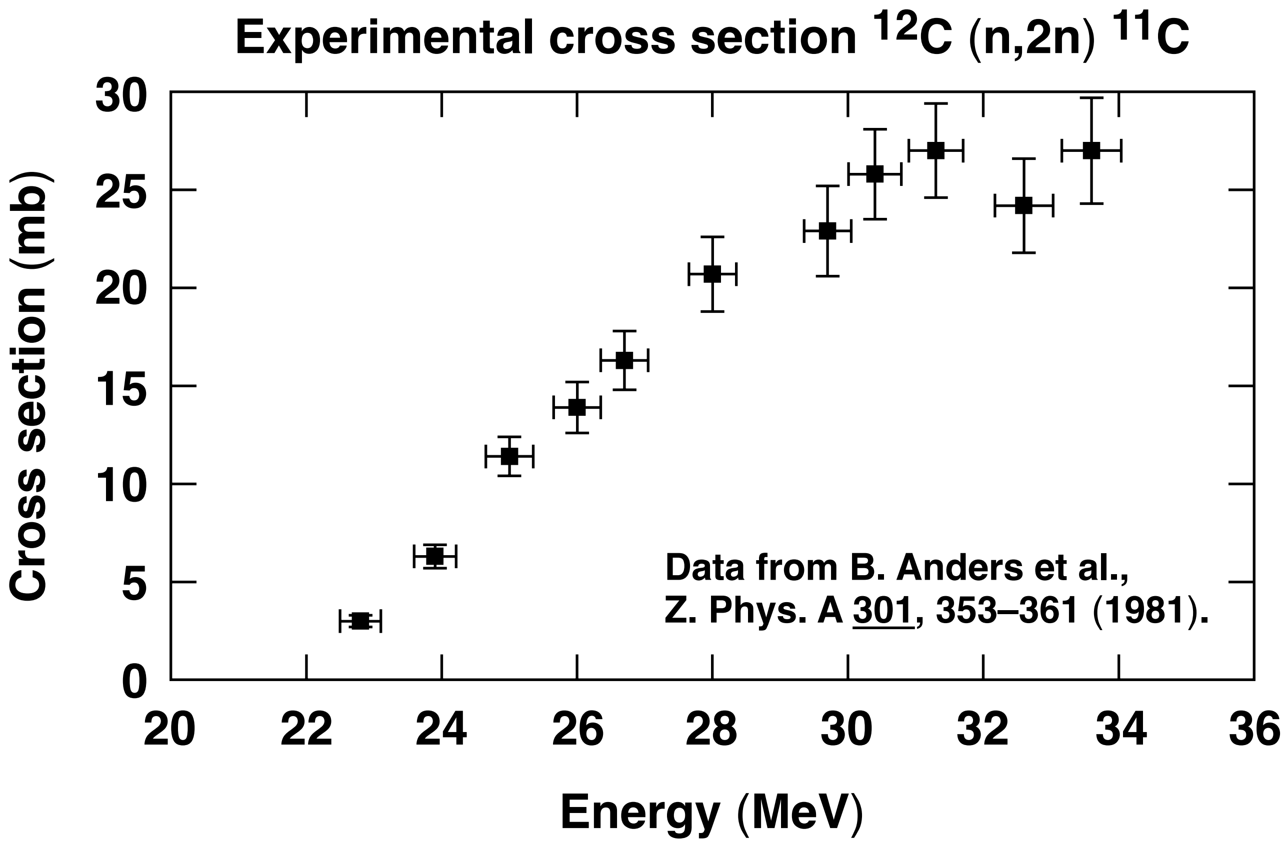
Carbon is a good tertiary activation material

- The (n, 2n) reaction in ^{12}C has a threshold of about 20 MeV.
- ^{11}C has a half-life of 20.3 min and emits positrons that produce two 511-keV gamma rays upon annihilation.



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Carbon must be very pure for tertiary activation

- Any contamination material that produces a positron emitter by interaction with 14.1-MeV neutrons will be the background for carbon activation.
- Since primary neutron yield is about 10^6 larger than tertiary yield, contamination should be less than one part per million.
- Contamination levels producing the same decay signal as carbon:

Material	Reaction	$N_{cont.}/N_{carbon}$
Cu	^{63}Cu (n,2n) ^{62}Cu	1.7×10^{-8}
Cu	^{65}Cu (n,2n) ^{64}Cu	3.5×10^{-7}
N	^{14}N (n,2n) ^{13}N	8.2×10^{-7}
Ni	^{58}Ni (n,2n) ^{57}Ni	1.6×10^{-5}
Cr	^{50}Cr (n,2n) ^{49}Cr	1.7×10^{-5}

A carbon purification facility was built at the State University of New York at Geneseo

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- Carbon disks were baked in vacuum at 1000°C for 8 hours.
- The carbon disks were cooled and stayed in a gas atmosphere for 24 hours.
- The carbon disks were then sealed in vacuum bags.
- The vacuum bags were opened 7 to 10 min before the laser shot.

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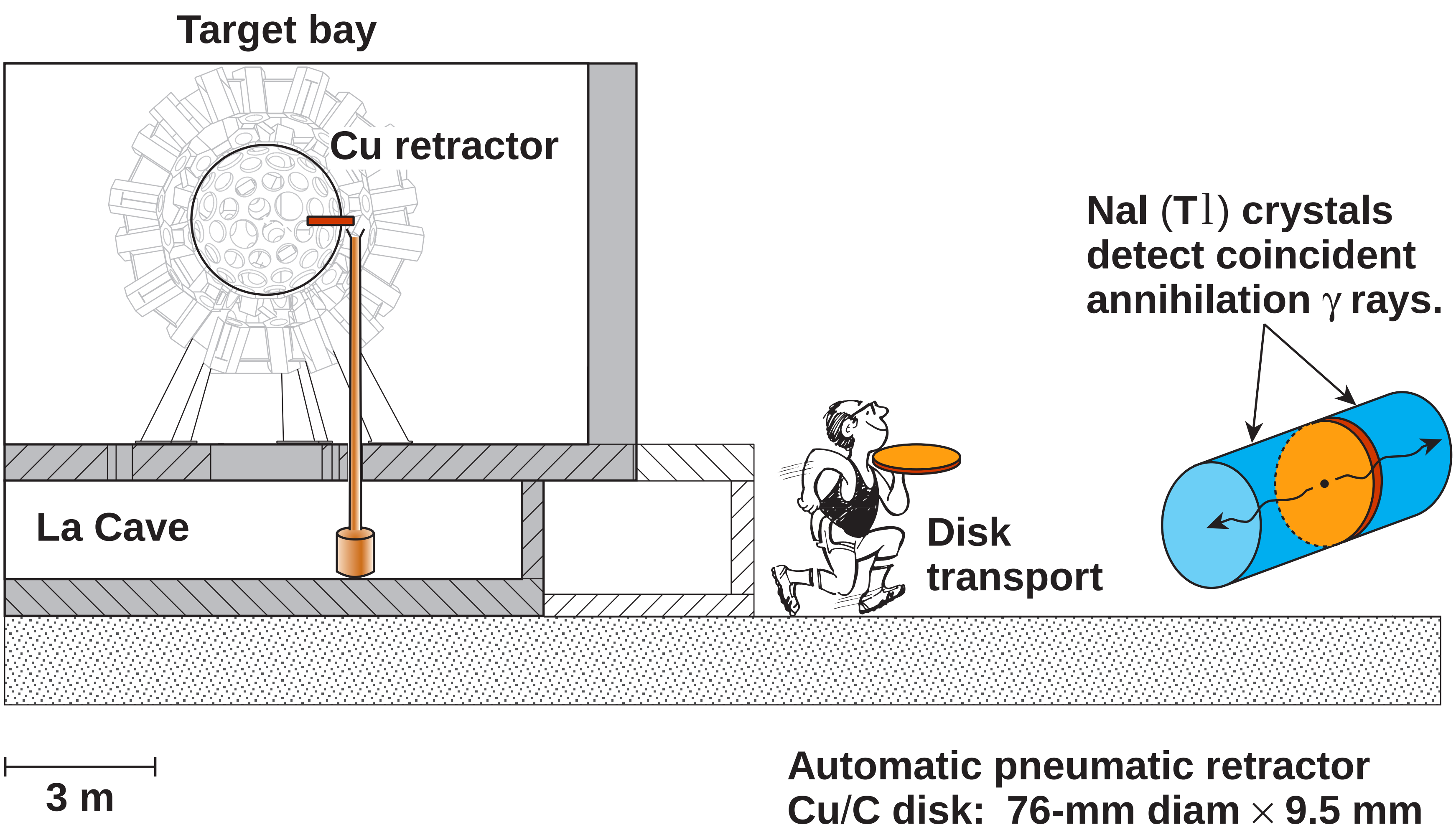
The OMEGA copper activation system is used for primary DT yield measurements, secondary yield measurements, and carbon activation R & D



Automatic pneumatic retractor
Cu/C disk: 76-mm diam × 9.5 mm
Disk-to-target distance: 40 cm

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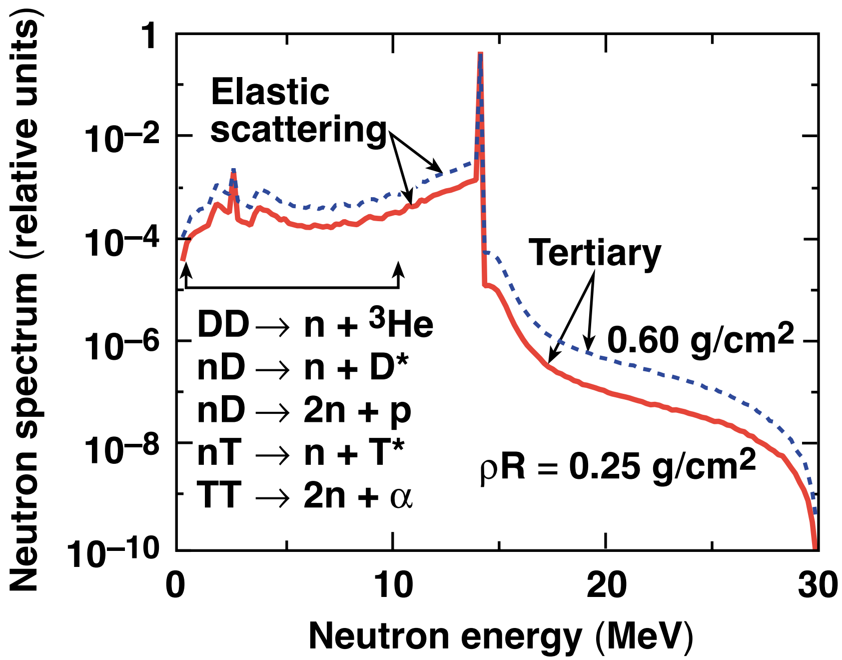
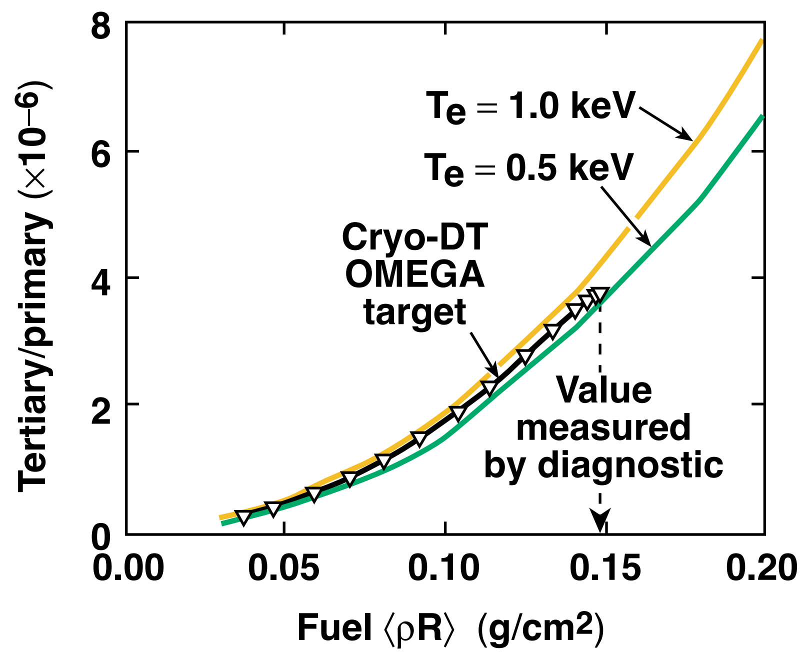
The present carbon activation system can be used for ρR measurements of OMEGA cryo-DT targets





Solid angle = 2.25×10^{-3} Activation/incident neutron = 4×10^{-2}
Efficiency = 20% Counts/produced neutron = 1.8×10^{-5}

At yield = 10^{14} and $\rho R = 0.1$ g/cm^2 3600 counts will be detected.

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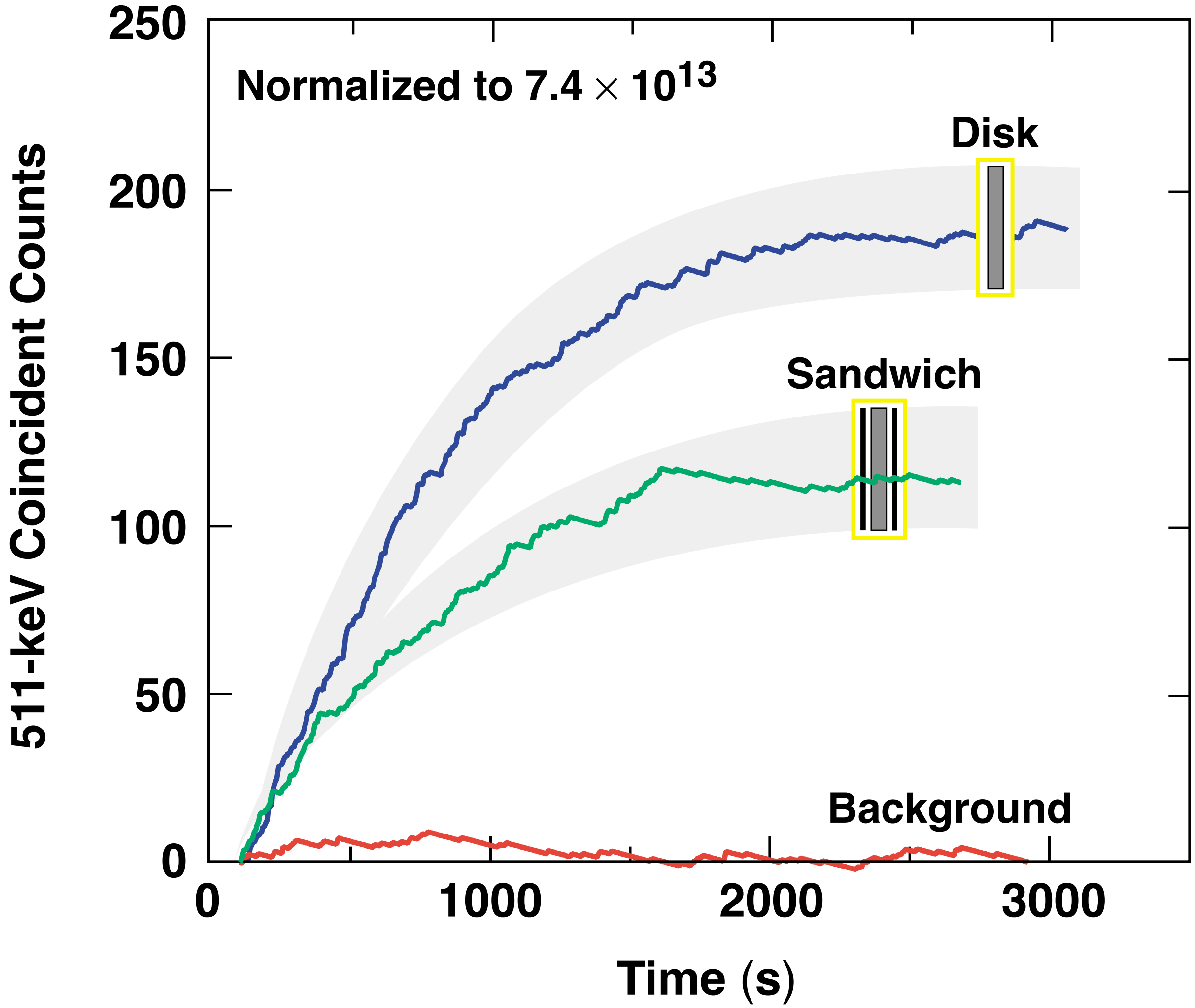
Carbon activation tests were carried out on the 30-kJ, 60-beam OMEGA laser system

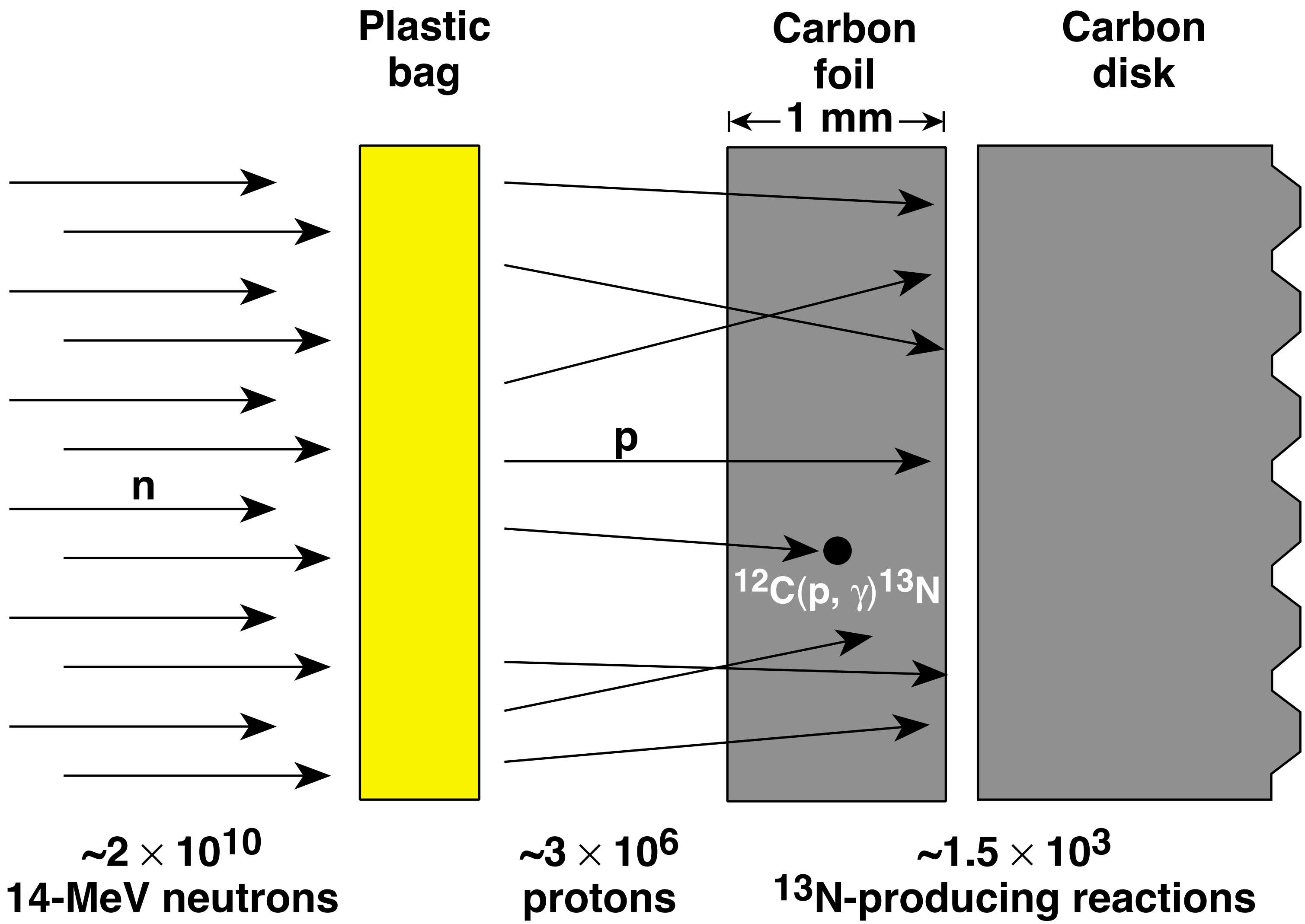
- Glass-shell targets filled with 20 atm of DT were used in implosion experiments.
- These targets have very low ρR and do not produce tertiary neutrons.
- A 1-ns square laser pulse shape was used in these studies.
- Primary DT neutron yield was measured by a neutron-time-of-flight (nTOF) scintillating counter.
- The neutron yield in these tests was from 4×10^{13} to 9.6×10^{13}.

With purification and proper packaging the contamination signal from carbon disk can be reduced substantially



- Expected number of counts from OMEGA DT cryo target is about 2660.

The importance of “sandwich” can be explained by the process shown here



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Pure samples, packaging, and handling procedures are all important for carbon activation diagnostics

Different factors in order of importance:

- Use pure carbon sample, without internal contamination.
- Carbon disk should be wrapped in a plastic bag to prevent external contamination.
- "Sandwich" carbon disk to shield from protons.
- Minimize disk contact with air before shot.

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