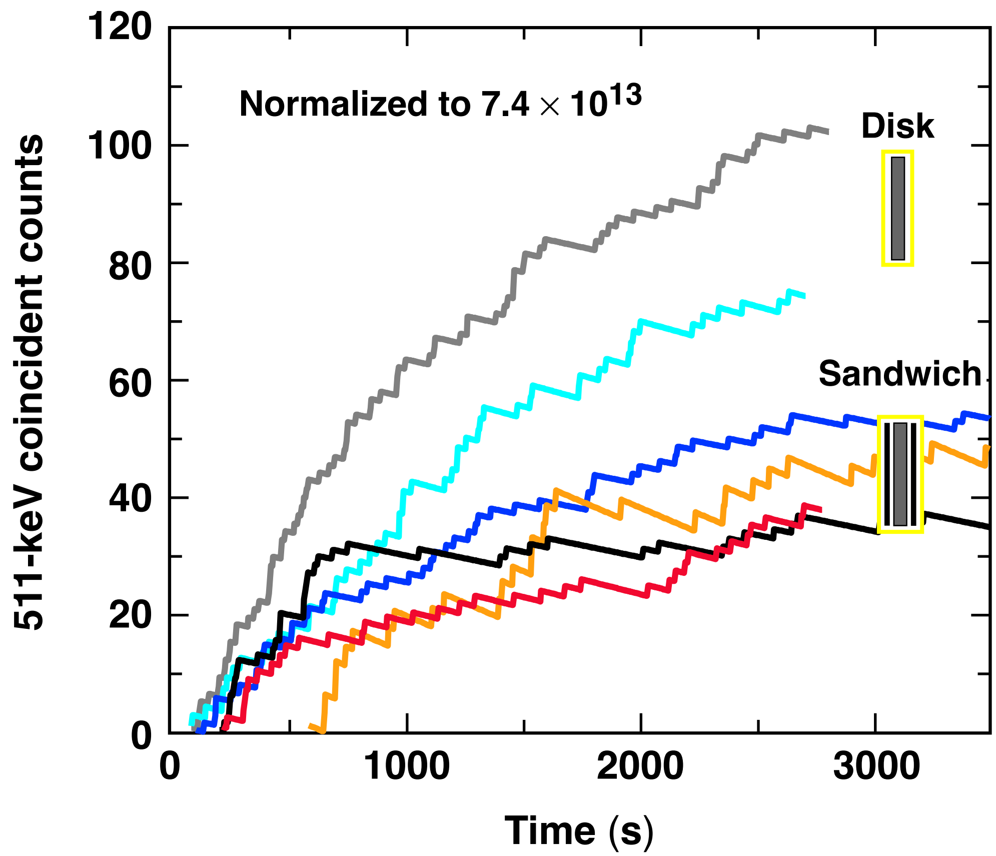
Tertiary Neutron Measurements by Carbon Activation



Vladimir Glebov
University of Rochester
Laboratory for Laser Energetics

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Contributors

D. D. Meyerhofer, P. B. Radha, T. C. Sangster, W. Seka,
S. Skupsky, J. M. Soures, and C. Stoeckl

University of Rochester
Laboratory for Laser Energetics

S. Padalino, L. Baumgart, R. Colburn, and J. Fuschino

State University of New York at Geneseo

Summary

The present carbon activation system is ready for ρR measurements of DT cryogenic targets on OMEGA

- In 2001 we created a purification facility and a packaging method to reduce the contamination signal in the carbon samples.
- A new carbon activation counting station at 120 m from the target eliminates direct background from OMEGA shots.
- Recent experimental results have demonstarted that background and contamination can be reduced to a level adequate for tertiary neutron measurements on OMEGA.

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:**

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

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

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

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

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

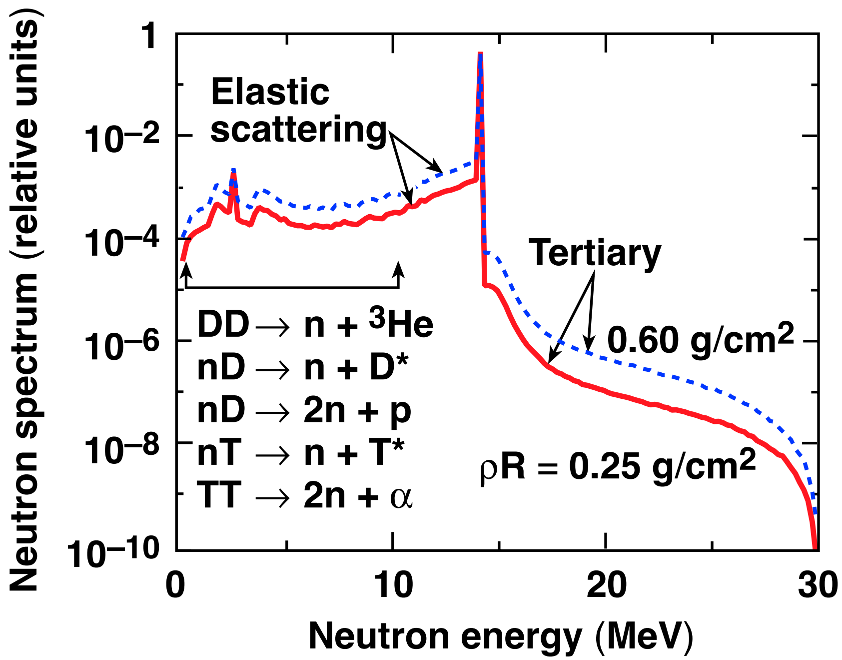
  $$\mathrm{D}'\ (0\ \text{to}\ 12.5\ \mathrm{MeV}) + \mathrm{T} \rightarrow \alpha + \mathrm{n}''\ (12\ \text{to}\ 30.0\ \mathrm{MeV})$$

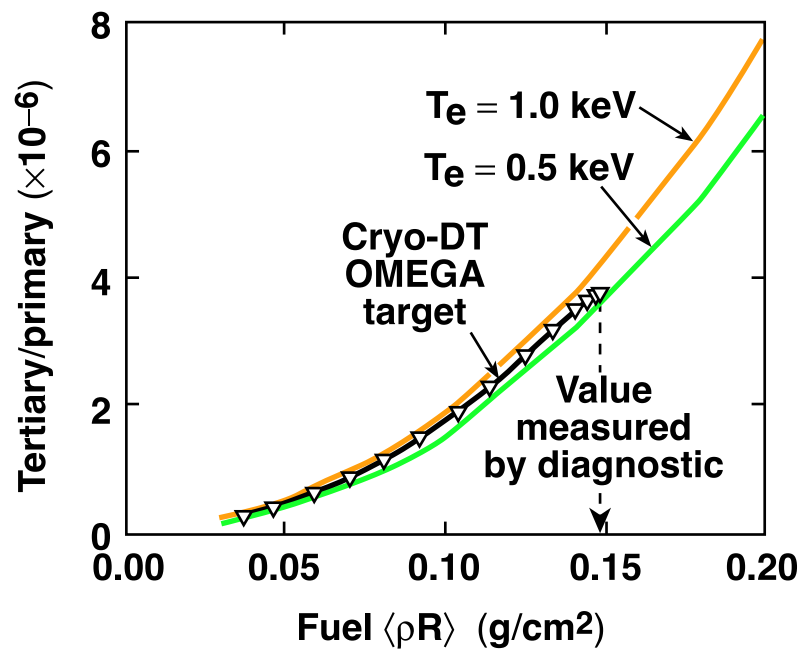
  $$\mathrm{T}'\ (0\ \text{to}\ 10.6\ \mathrm{MeV}) + \mathrm{D} \rightarrow \alpha + \mathrm{n}''\ (9.2\ \text{to}\ 28.2\ \mathrm{MeV})$$

- **For OMEGA, the yield of tertiary neutrons is proportional to $(\rho R)^2$.**

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

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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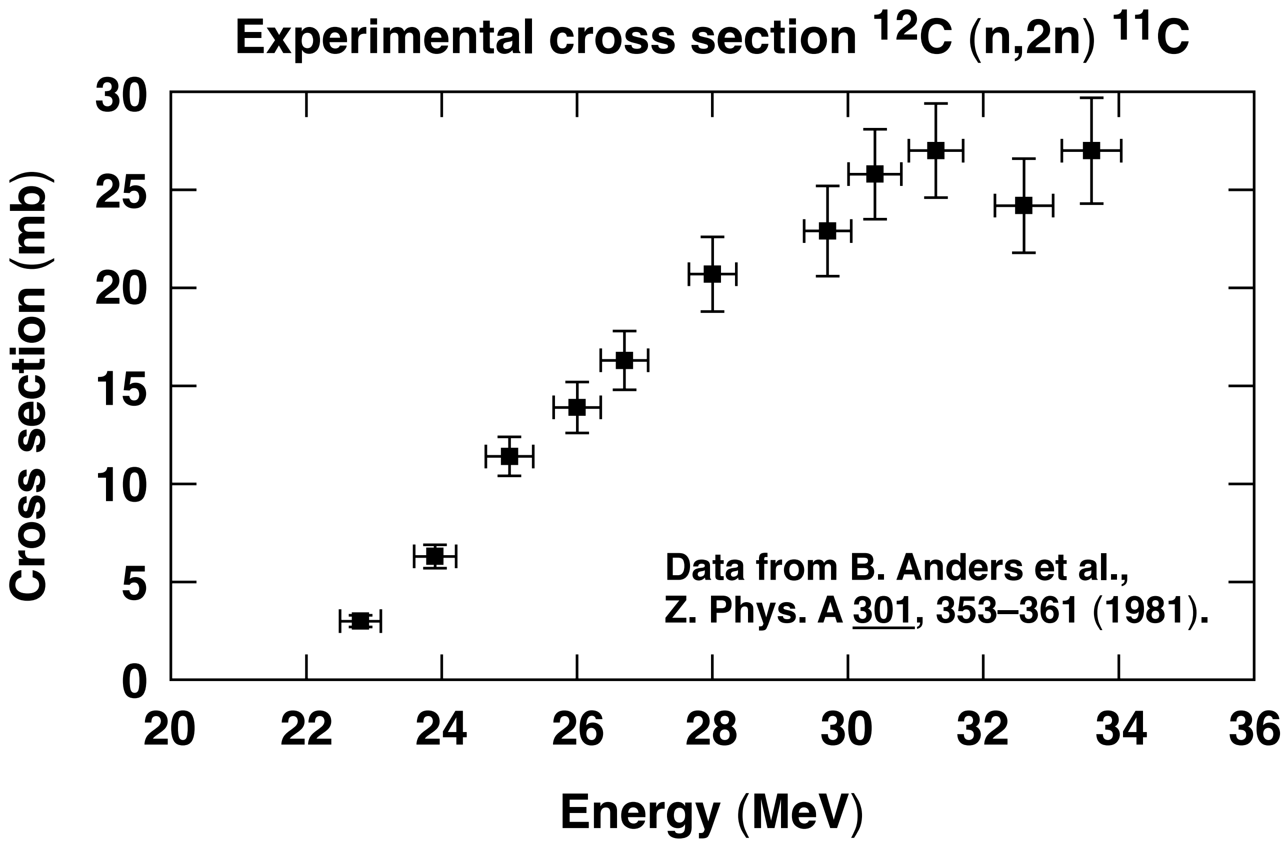
The carbon is a good tertiary activation material

- The (n, 2n) reaction in ^{12}C has a threshold of 18.7 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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The carbon must be very pure for tertiary activation

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- 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}

In our earlier experiments N_2 was the biggest source of contamination.

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

- Carbon disks were baked in vacuum at 1000°C for 8 hours to remove water and nitrogen.
- The disks stay under vacuum for 12 hours while cooling, to prevents fires.
- Oven was back filled with high-purity argon for 24 hours.
- Carbon disks were then sealed in vacuum bags in a glove bag with extra argon pressure.

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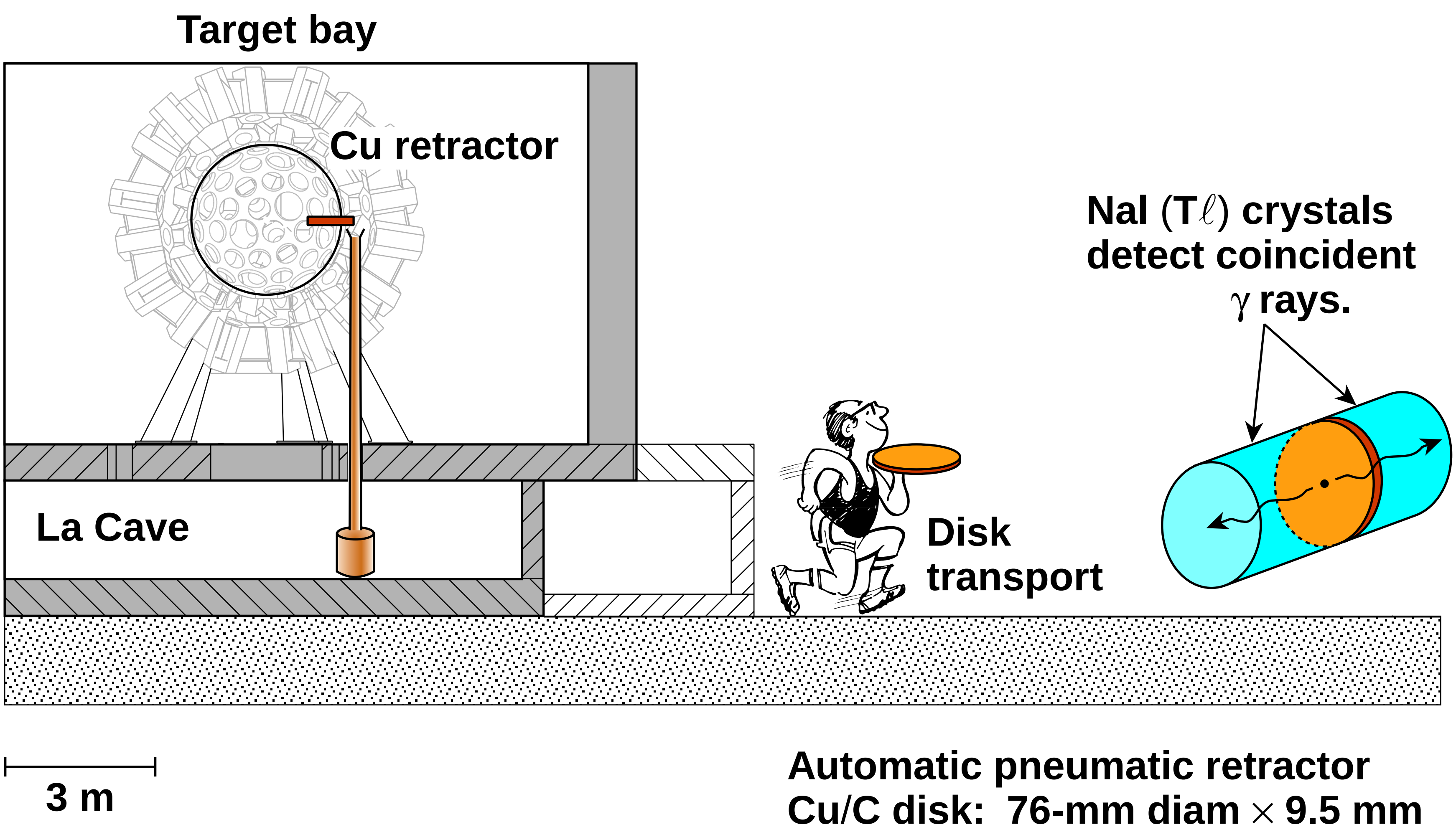
The OMEGA copper activation system is used for primary DT yield measurements, secondary yield measurements, and carbon activation R & D



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

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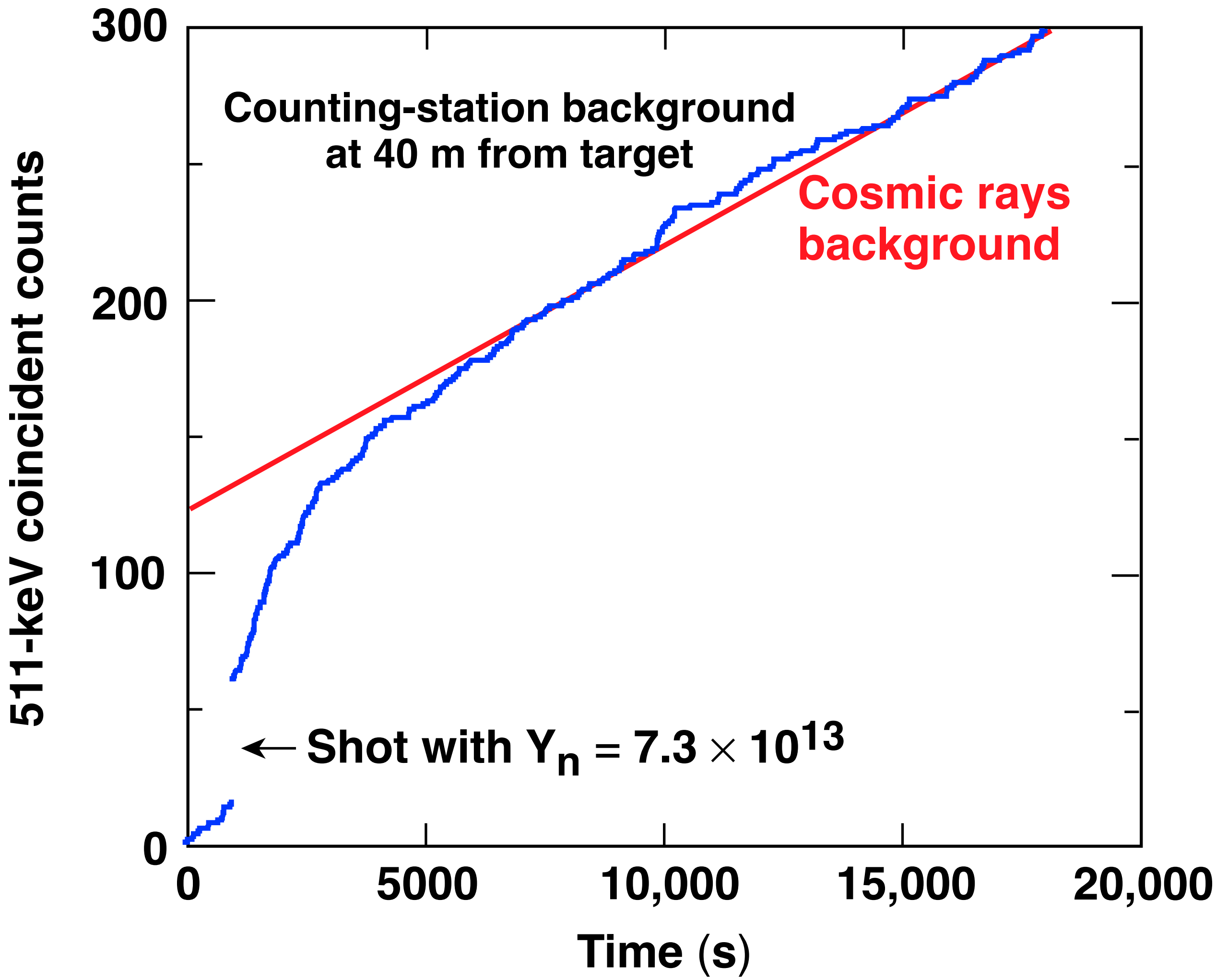
Carbon activation tests were carried out on the 30-kJ, 60-beam OMEGA laser system

- 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 yields in these tests ranged from 4×10^{13} to 9.6×10^{13}.

The background from high-yield shots in the counting station itself was eliminated on OMEGA



A new counting station was set up at 120 m from target.

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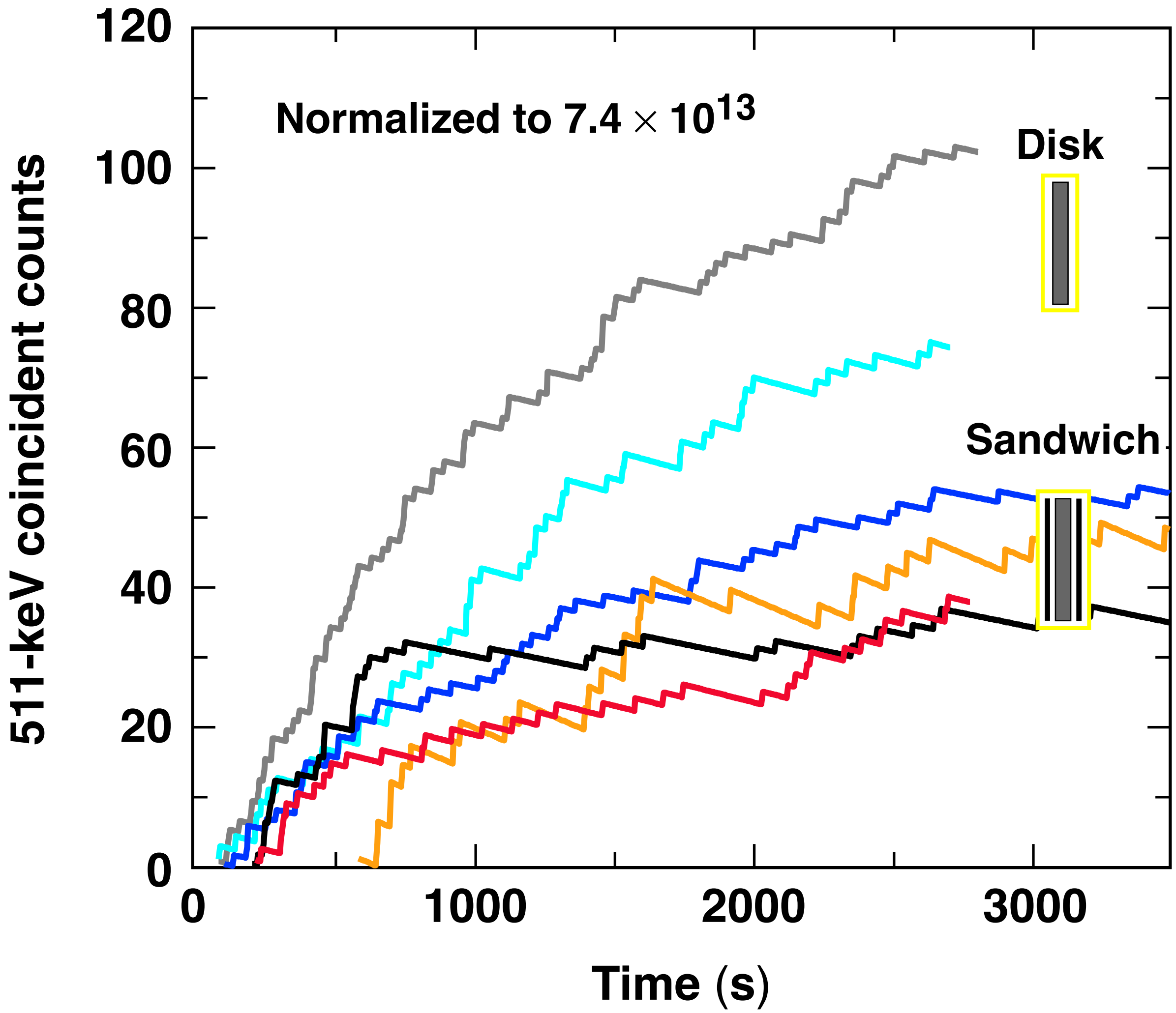
With the "sandwich" packaging, the contamination signals are below 50 counts



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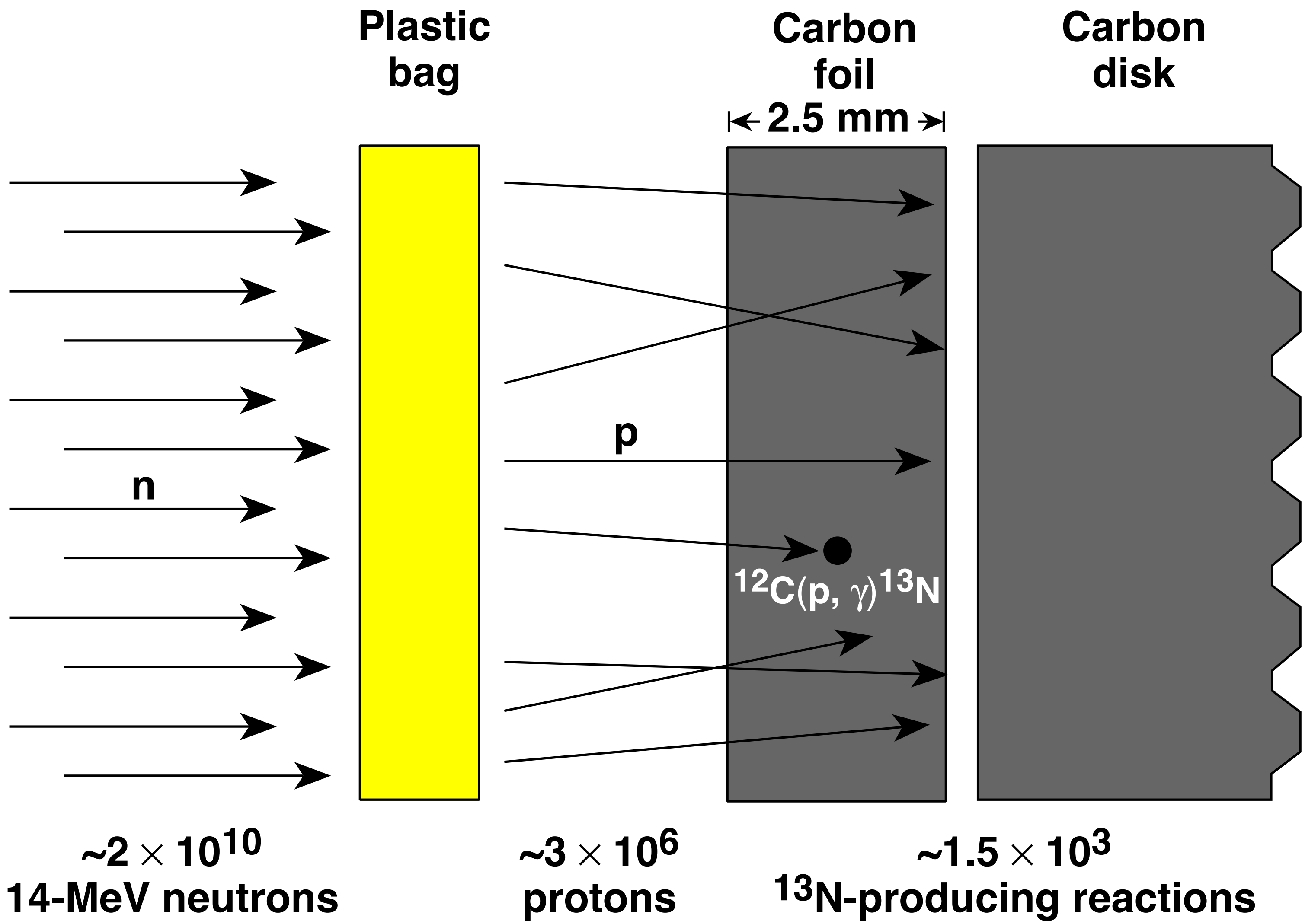
The importance of "sandwich" can be explained by the process shown here



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