Neutron Detection Techniques

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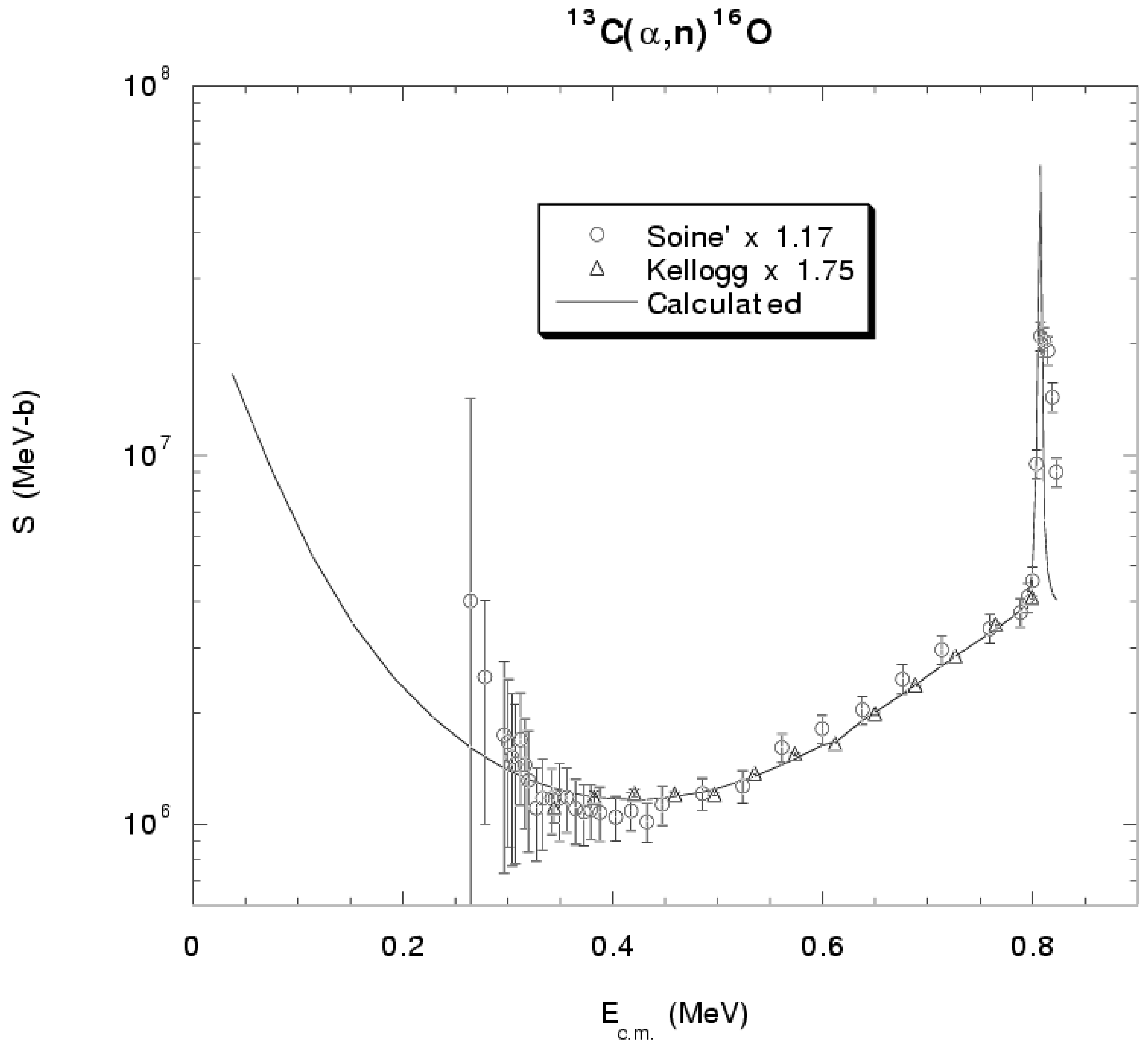
S-Process Neutron Sources: ^{13}C$(\alpha, n)^{16}$O and ^{22}Ne$(\alpha, n)^{25}$Mg

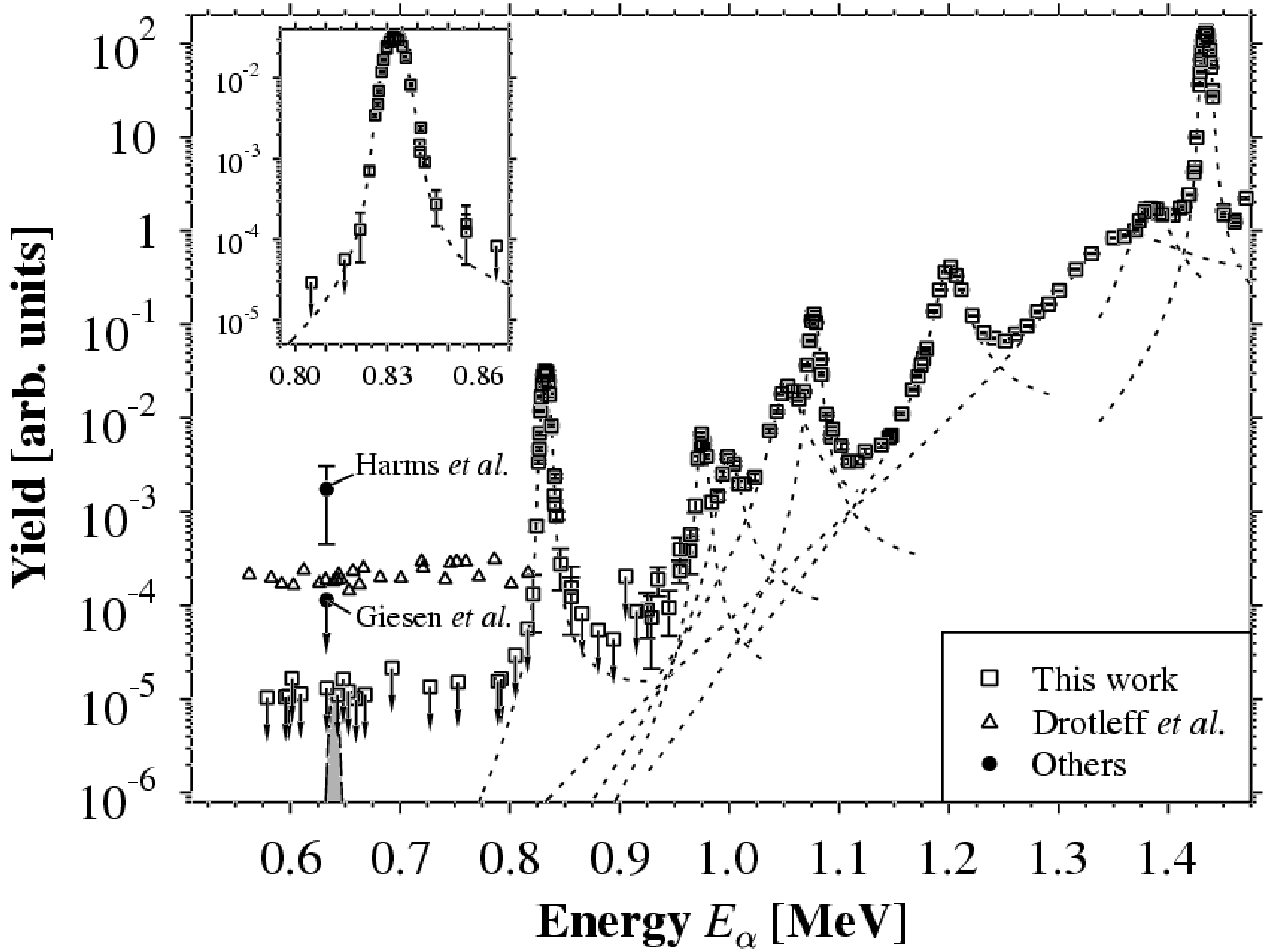
- Astrophysical Questions:
  - Where does the S-Process take place?
  - What is the neutron density?
- ^{13}C(α, n)
  - $T \approx 1 \times 10^8$ K
  - Sub-threshold resonances ??
- ^{22}Ne(α, n)
  - $T \approx (2-3) \times 10^8$ K
  - Low-energy resonances ??
- Existing measurements are clearly limited by cosmic-ray induced backgrounds.

Possible Approaches

- Detection of fast neutrons with scintillator
  – early C. N. Davids ^{13}C(α, n) measurements
- Detection of moderated neutrons with proportional counters
- Detection of high-energy γ rays from capture of moderated neutrons
  – recent F. Käppeler *et al.* ^{13}C(α, n) measurements
- Recoil separator for ^{22}Ne$(\alpha, n)^{25}$Mg ?



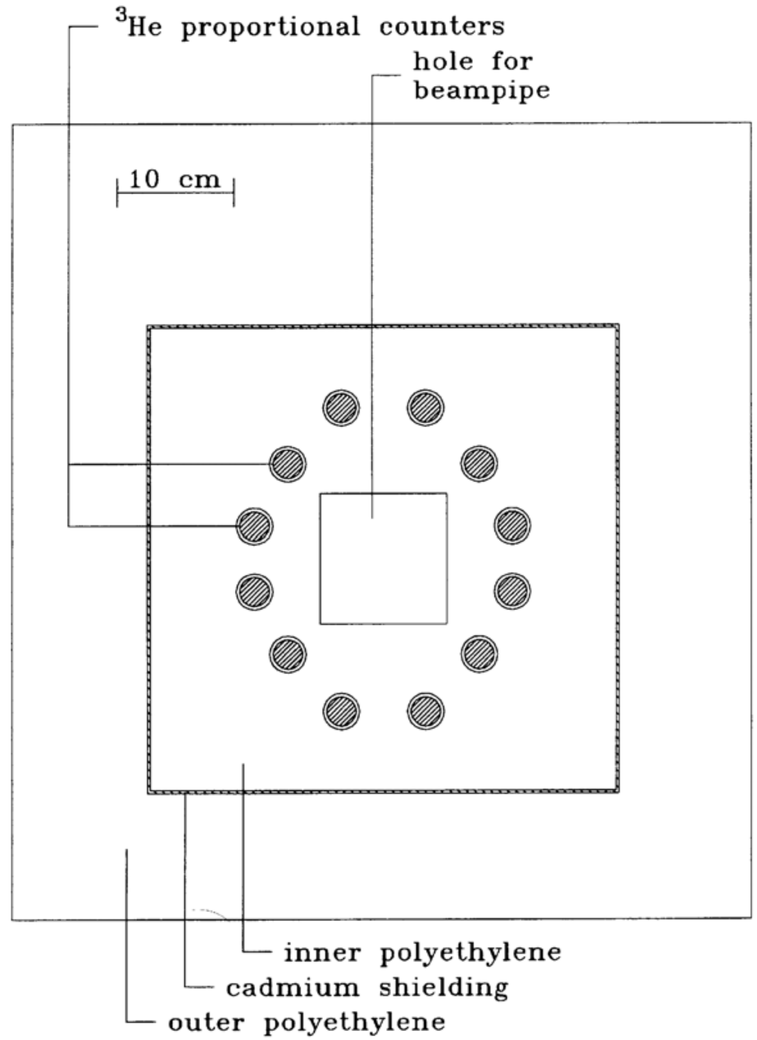
The S-factor for the $^{13}C(\alpha, n)^{16}O$ reaction. The solid curve is an R-matrix fit to these and other data. Figure from G. M. Hale, Nucl. Phys **A621**, 177c (1997). See also S. Kubono *et al.*, Phys. Rev. Lett. **90**, 062501 (2003).



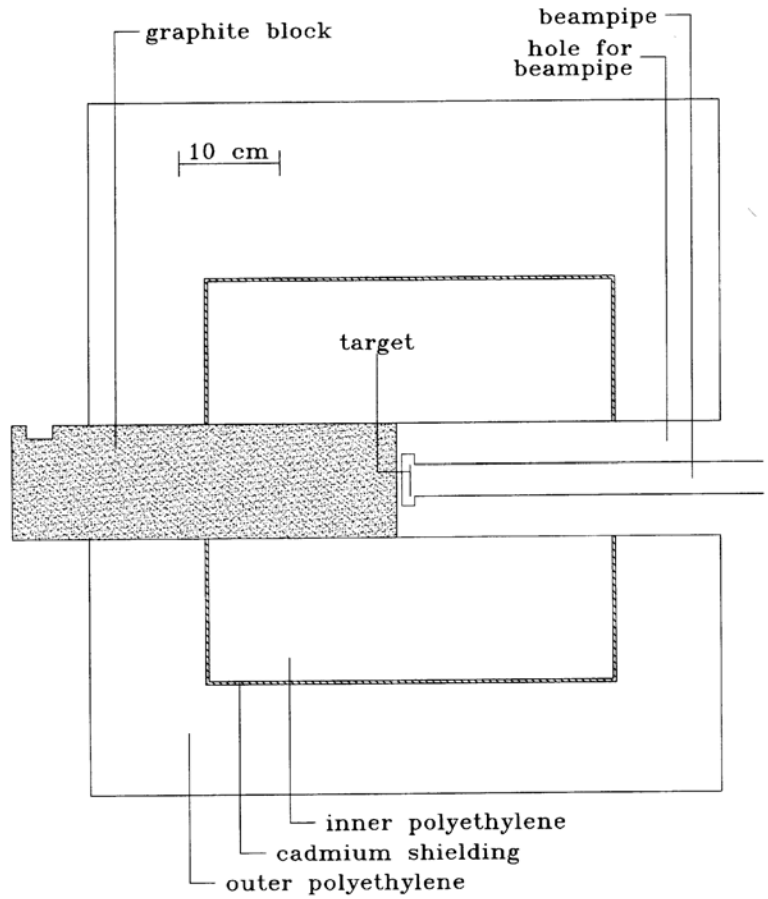
State-of-the-art excitation function for the ^{22}Ne$(\alpha, n)^{25}$Mg reaction. Figure from M. Jaeger *et al.*, Phys. Rev. Lett. **87**, 202501 (2001). See also P. E. Koehler, Phys. Rev. C **66**, 055805 (2002).

Neutron Detection By Moderation

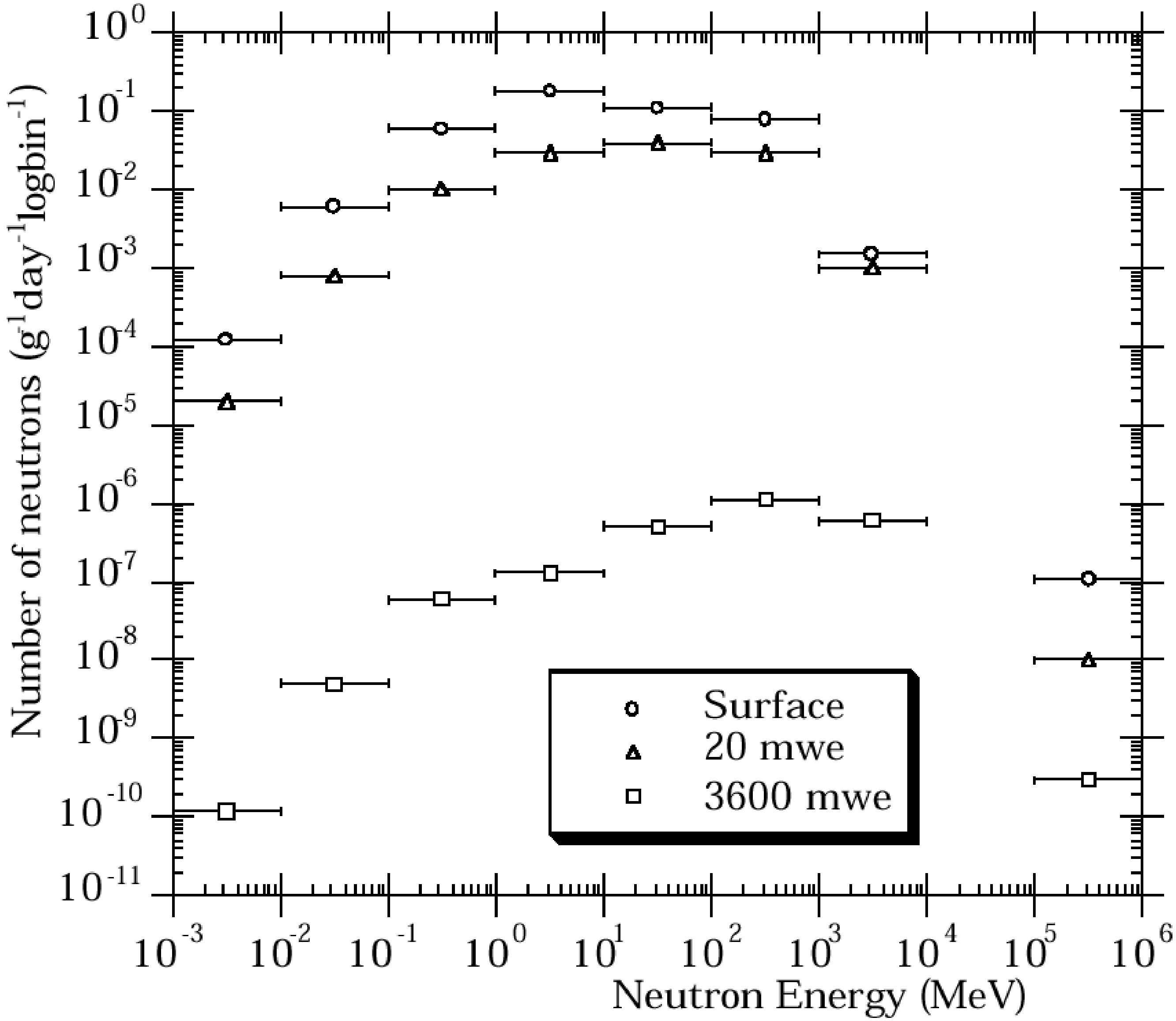
- Theory of Operation:
  - thermalize neutrons in polyethylene
  - detect neutrons in proportional counters (^{3}He or BF_3 filled)
- High (20-50%) detection efficiency.
- Insensitive to γ rays and charged particles.
- Little sensitivity to initial neutron energy or emission angle.
- Background level in present experiments is $\approx$ 0.1 neutron/second, almost all due to cosmic-ray induced neutrons.
- Going underground would clearly help; at some point the α activity in the proportional counters must be addressed.



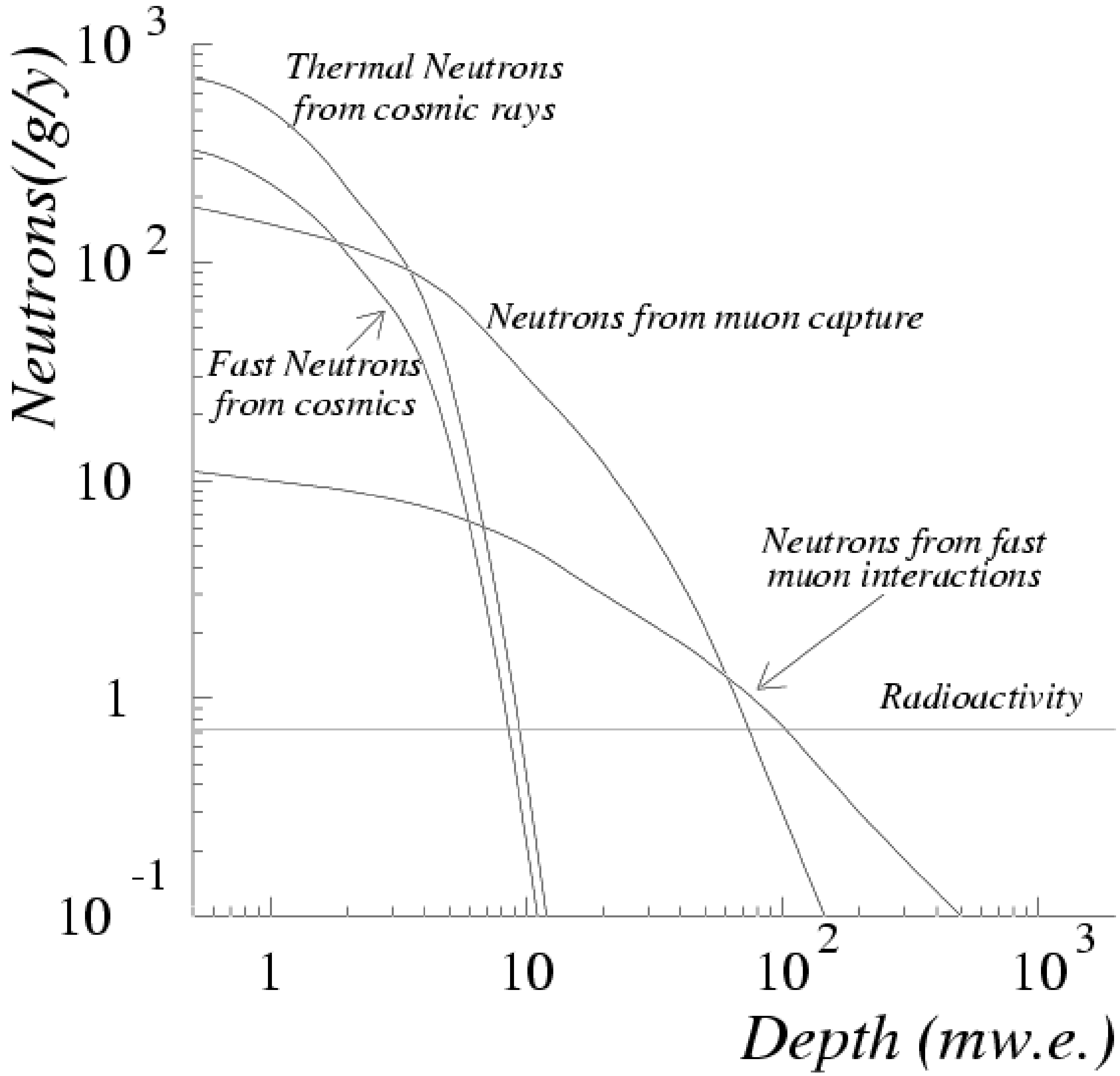
Front view of the Caltech neutron detector. Figure from P. R. Wrean, Caltech PhD Thesis (1998).



Side view of the Caltech neutron detector. Figure from P. R. Wrean, Caltech PhD Thesis (1998).



Cosmic ray muon induced neutron spectra as a function of depth. From N. J. T. Smith *et al.*, Int. Workshop on Identification of Dark Matter (World Scientific, 1997) p. 385-390.



Rate of neutron production as a function of depth underground in meters of water equivalent. From S. Eichblatt, preprint CDMS 97-01-25 (1997).

Summary

- (α, n) measurements are presently limited by cosmic-ray-induced backgrounds and would thus benefit greatly from the shielding of a deep underground site.

- The challenges of reducing neutron backgrounds for in-beam experiments are similar to those faced in other measurements: e.g. solar neutrinos or dark matter searches.

- Here is a useful compilation of information on neutron backgrounds at various underground sites: `http://www.physics.ucla.edu/wimps/nBG/nBG.html`