Literature: neutrons on oxygen

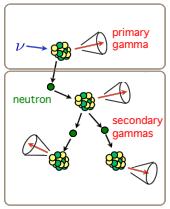
Corina Nantais
local meeting
28 June 2017

Measurement of gamma production from a neutron beam on water

A background to neutrino-oxygen nuclear de-excitation gammas after neutral current quasielastic scattering

Corina Nantais University of Toronto NuINT 2017

1. MOTIVATION



TO REDUCE SYSTEMATIC UNCERTAINTY IN T2K MEASUREMENT

Incident particle excites ^{16}O, and Super-K (SK) detects gammas from the nucleus de-exciting

600 MeV neutrino beam → single nucleon emission dominant [1]

Contribution of $p_{3/2}$ overwhelming
6.18 MeV from $(p_{3/2})_n$
6.32 MeV from $(p_{3/2})_p$
[1]

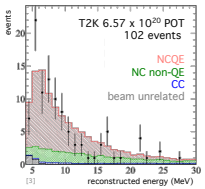
NCQE (neutral current quasielastic) de-excitation gammas

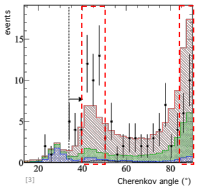
T2K made first observation at this energy [2]

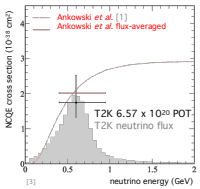
sterile neutrino and dark matter searches

POOR MODEL OF SECONDARY GAMMAS

MC simulations do not agree, compared currently used Geant3 GCALOR to Geant4 QBHP_BIC_HP, FLUKA, and PHITS
Based on various theoretical models, need data to establish reliable simulations







$(1.75 \pm 0.27\ (stat.)\ ^{+0.70}_{-0.36}\ (sys.)) \times 10^{-38}\ \mathrm{cm}^2$

T2K-SK neutrino-oxygen NCQE events

Selection cuts:
- 4–30 MeV reconstructed energy
- > 34° Cherenkov angle
- ±100 ns of beam timing
- fiducial volume
- reconstruction quality cuts

NEED TO UNDERSTAND SECONDARY GAMMA RAY PRODUCTION

An emitted neutron can excite another ^{16}O nucleus
Cannot be easily separated by energy or timing

2. EXPERIMENT

NEUTRON BEAM ON WATER, MEASURE GAMMA ENERGY

30–300 MeV neutrons escape nucleus in T2K neutrino-oxygen NCQE

Run 1	80 MeV	January 2015	E361 parasite
Run 2	50 MeV	June 2015	E400 parasite
Run 3	80 MeV	June 2016	E465 pilot
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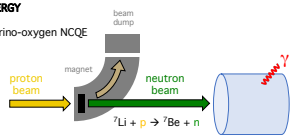
Run 5	80 MeV	March 2017	E487 pilot

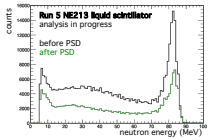


Osaka University's **RCNP**
(**R**esearch **C**enter for **N**uclear **P**hysics)

water filled acrylic container
(20 cm diameter, 25 cm length)

investigating several detectors:
HPGe, $LaBr_3$(Ce), CsI(Tl), and NaI(Tl)

NE213 liquid scintillator for neutron flux [4]

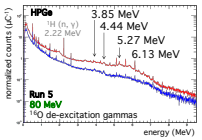


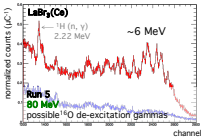
Run 1 & 2 were tests
both used NaI(Tl), which was found to have poor resolution
low statistics
→ no ^{16}O de-excitation gammas observed

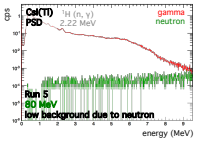
Run 5
analysis in progress

GAMMAS OBSERVED

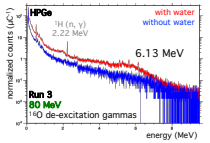
3.85 MeV
4.44 MeV
5.27 MeV
6.13 MeV



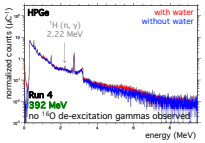




3. ANALYSIS IN PROGRESS



pair production e^+e^- annihilation
single ($-m_e$) and double ($-2m_e$) escape



higher energy did not result
in different de-excitation gammas

- HPGe has excellent resolution, yet expensive
- $LaBr_3$(Ce) has good resolution
- CsI(Tl) Pulse Shape Discrimination (PSD) to separate neutrons and gammas

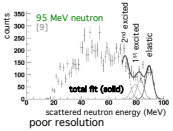
4. OVERVIEW OF NEUTRONS ON OXYGEN

GAMMAS OBSERVED

0.87 MeV	[5, 6]
1.09 MeV	[5, 6]
1.75 MeV	[7]
2.18 MeV	[5, 6]
2.74 MeV	[7, 8]
3.09 MeV	[7]
3.27 MeV	[5, 6]
3.68 MeV	[7, 8]
3.85 MeV	[7, 8]
4.19 MeV	[6]
4.44 MeV	[7]
6.13 MeV	[7, 8]
6.92 MeV	[7, 8]
7.12 MeV	[7, 8]

note that these used lower energy neutrons — thermal [5, 6], 6–17 MeV [7], 15 MeV [8]

SCATTERED NEUTRONS MEASURE ENERGY LEVELS



poor resolution

1st excited state:
6.13 MeV
6.92 MeV
7.12 MeV

2nd excited state:
9.84 MeV
10.34 MeV

6.05 MeV	[8, 9, 10]
6.13 MeV	[9, 10, 11, 12]
6.92 MeV	[9, 10, 11, 12]
7.12 MeV	[9, 10, 11, 12]
8.87 MeV	[10, 11]
9.84 MeV	[9, 11]
10.34 MeV	[9, 11]
11.1 MeV	[11]
11.52 MeV	[11]

besides 95 MeV [9] — 22 MeV [10], 24 MeV [11], 18–26 MeV [12]
lower energy neutrons

de-excitation gammas possible
for all of these energy levels

GAMMAS EXPLAINED BY EXCITED STATES OF ^{16}O, ^{17}O, ^{12}C, ^{13}C

6.13 MeV GAMMA FROM ^{16}O OBSERVED IN SEVERAL MEASUREMENTS
produced directly, in gamma cascades, or ^{16}O(n,p)^{16}N where ^{16}N → e^- + ^{16}O*

2.22 MeV ^{1}H(n,γ) IS WELL KNOWN

NO REFERENCE FOR 5.27 MeV, WHICH WE ATTRIBUTE TO ^{15}N

CROSS SECTION CALCULATIONS WILL BE COMPARED TO LITERATURE

REFERENCES

[1] A.M. Ankowski *et al.*, Phys. Rev. Lett. **108**, 052505 (2012)
[2] T2K Collaboration, Phys. Rev. D **90**, 072012 (2014)
[3] K. Huang, PhD thesis, Kyoto University (2015)
[4] D. Satoh *et al.*, Japan Atomic Energy Agency (2006)
[5] A.B. McDonald *et al.*, Nucl. Phys. **A281** (1977)
[6] R. B. Firestone *et al.*, Phys. Rev. C 93, 044311 (2016)
[7] V. J. Orphan *et al.*, Nucl. Sci. Eng. **42** (1970)
[8] K. Nyberg-Ponnert *et al.*, Phys. Scr. **4** (1971)
[9] P. Marmod *et al.*, Phys Rev C **74**, 054002 (2006)
[10] N. Olsson *et al.*, Nucl. Phys. **A509** (1990)
[11] M. S. Islam *et al.*, Nucl. Phys. **A464** (1987)
[12] P. Grabmayr *et al.*, Nucl. Phys. **A550** (1980)

Y. Ashida[1], G. Collazuol[2], D. Fukuda[3], A. Konaka[4,5], Y. Koshio[3], M. Mori[1], H. Nagata[3], T. Nakaya[1], C.Nantais[6], T. Shima[4], T. Shirahige[3], A. Suzuki[7], Y. Takeuchi[7], H. A. Tanaka[6], R. Wendell[1], T. Yano[6]
[1]*Kyoto University,* [2]*Università di Padova,* [3]*Okayama University,* [4]*RCNP, Osaka University,* [5]*TRIUMF,* [6]*University of Toronto,* [7]*Kobe University*

NuInt 2017 poster

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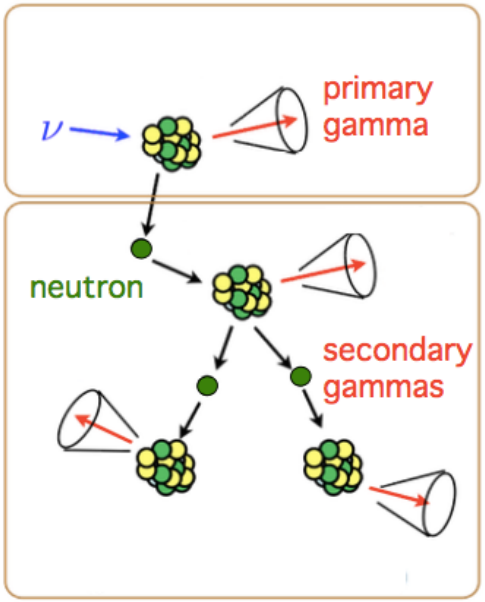

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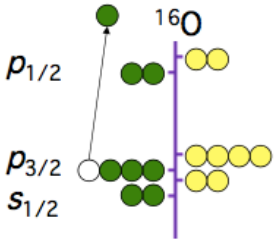

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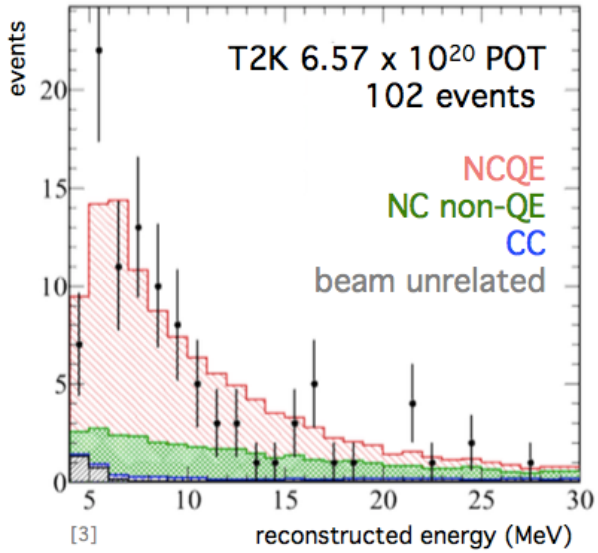

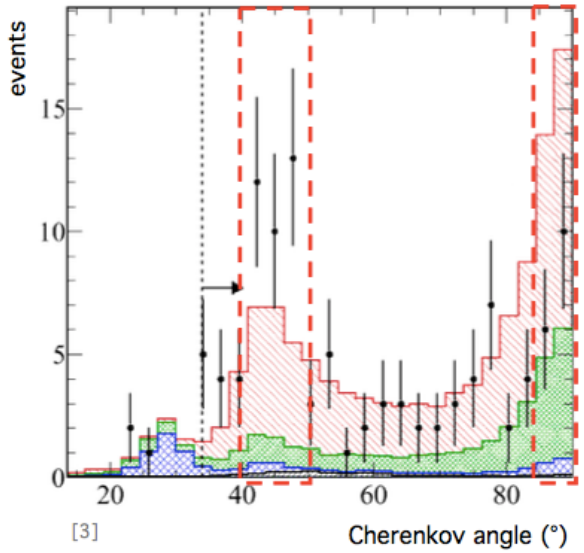

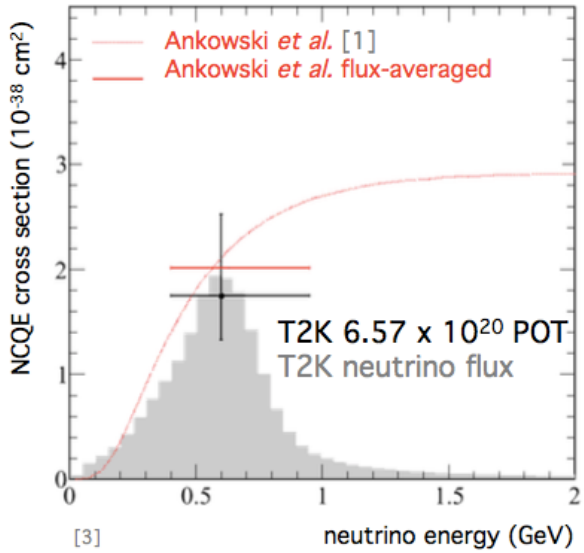

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Sakuda-san comments on mA,
would move prediction for cross section
→ need to look into

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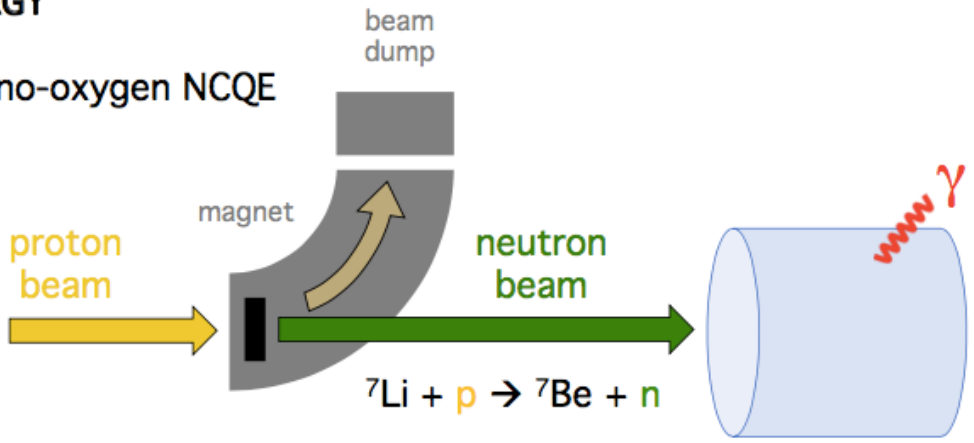

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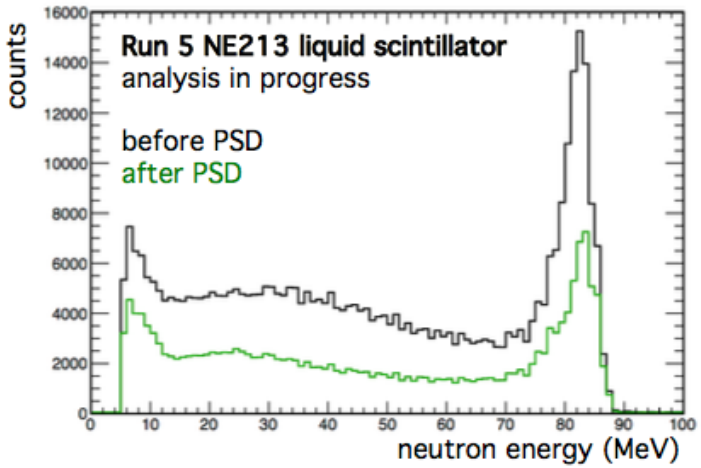

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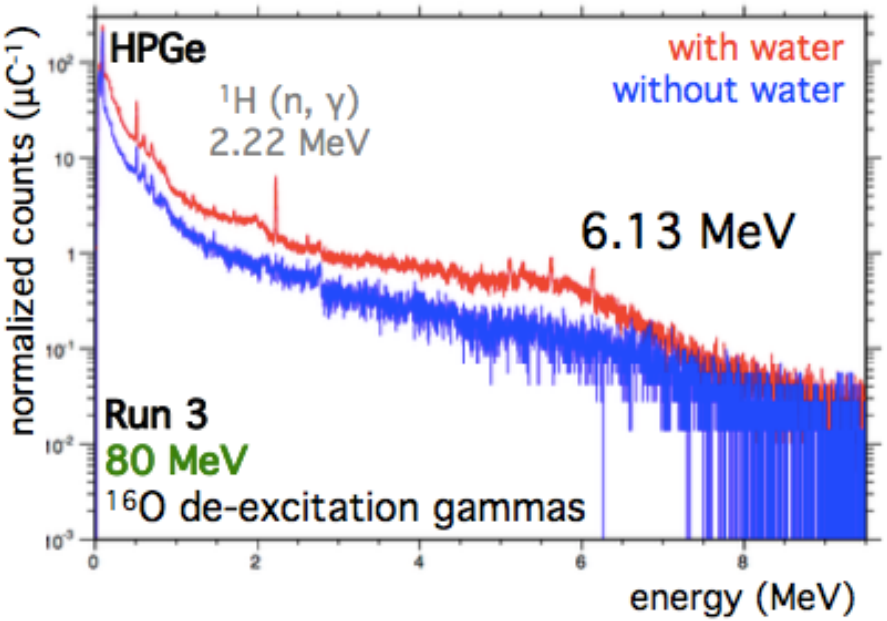

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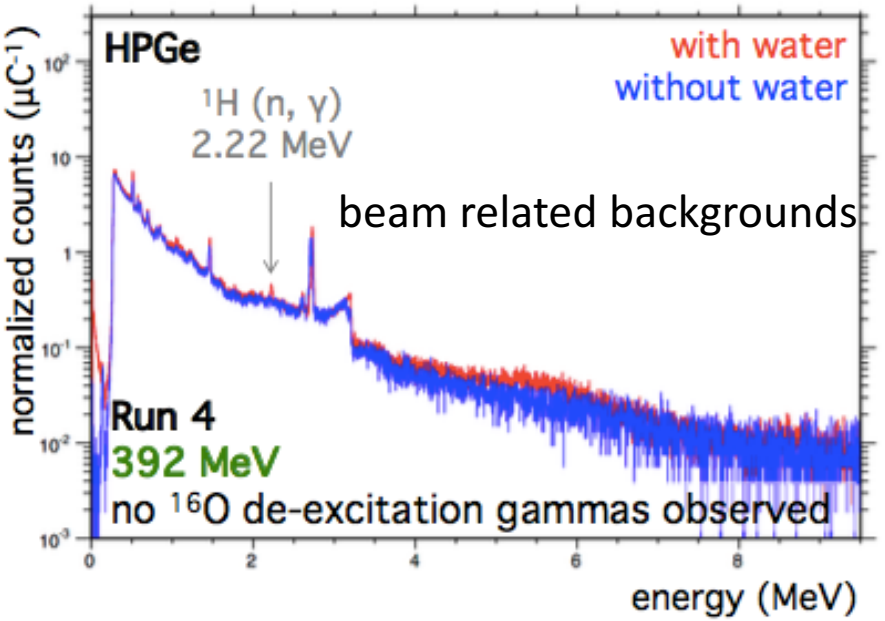

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Run 5
analysis in progress

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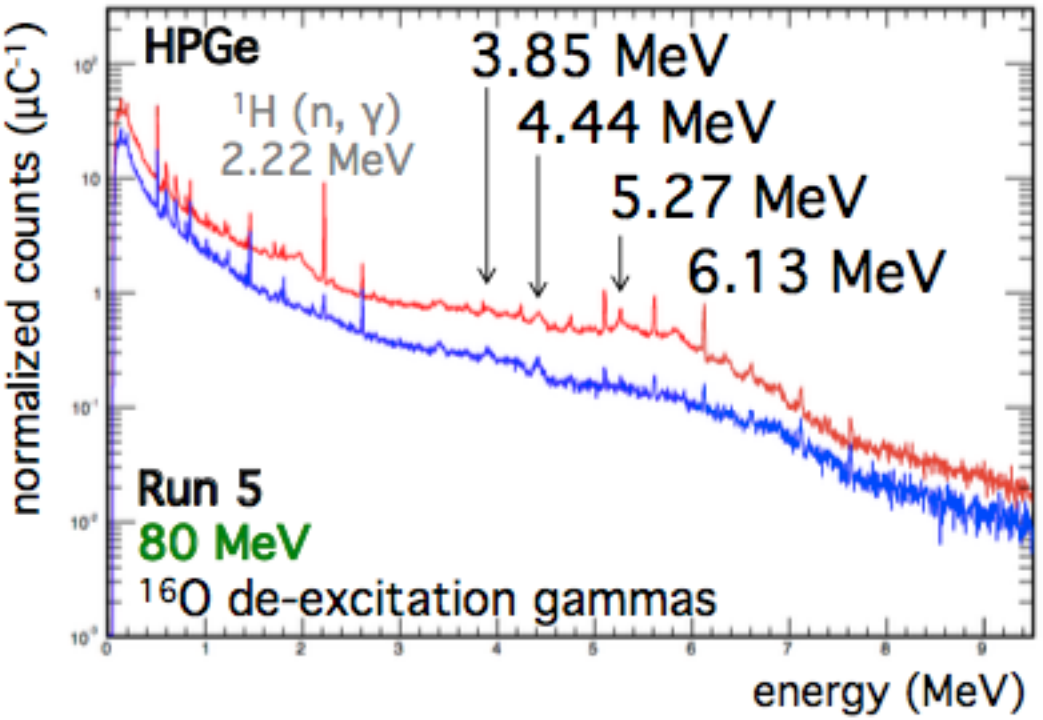
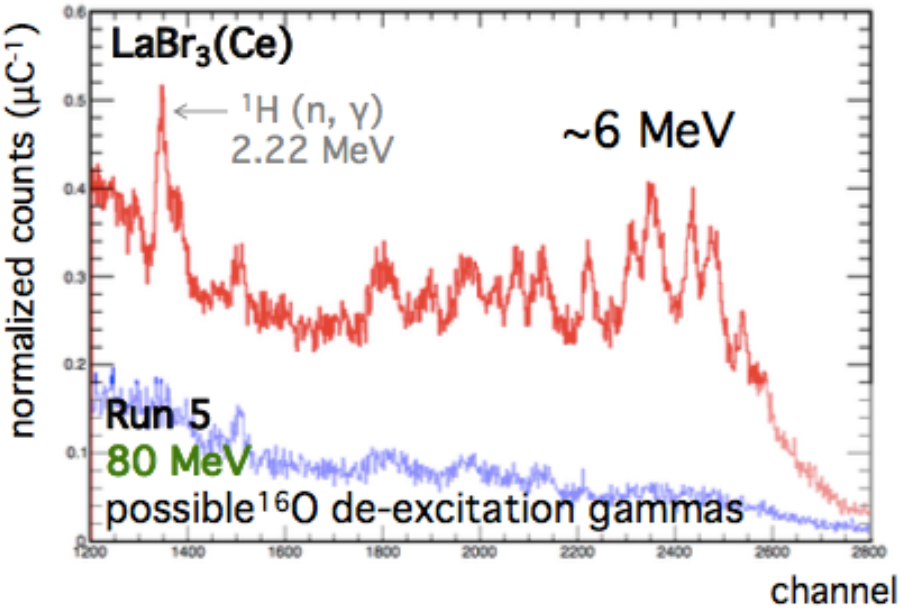
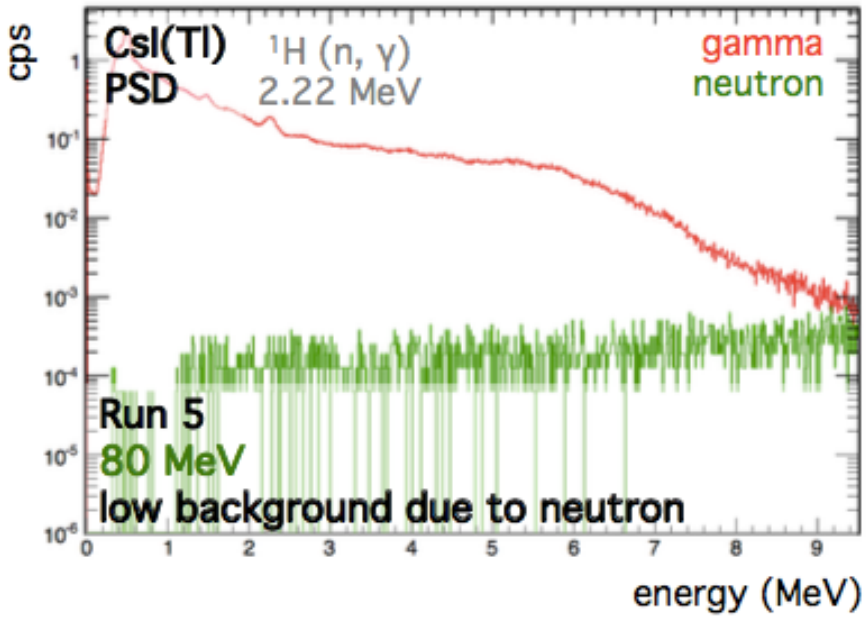


- energy calibration still in progress
- why no peaks in no water, resolution and statistics?





LaBr3(Ce) is still a candidate for final experiment

gamma energy resolution is poor, likely won't use for final experiment

Comparing our results to literature

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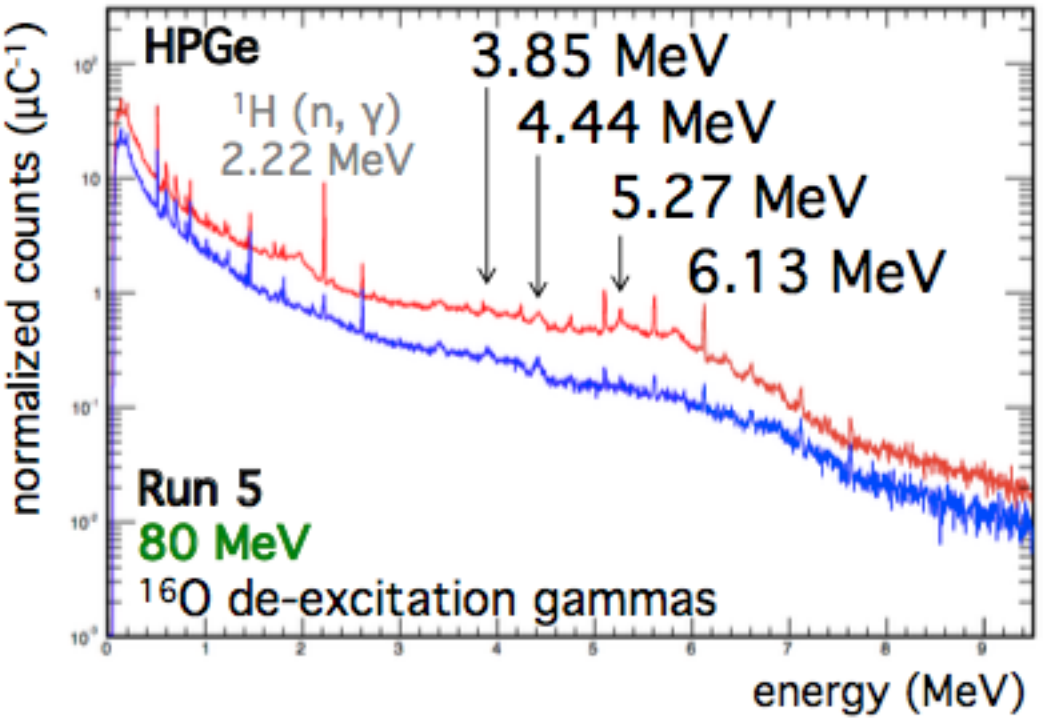


Familiar with ^{16}O 6.13 MeV and ^{15}N 5.27 MeV

Huang-san thesis, Table 4.5

gamma emission from pion absorption excited nuclei

"In NEUT, the pion absorption in nuclear medium is simulated using pion scattering data [132–134]. Gamma emission probability for each residual nucleus (such as $^{16}O^*$, $^{15}N^*$, $^{14}N^*$, $^{14}C^*$, $^{13}N^*$, $^{12}C^*$, and $^{10}B^*$) assigned using experimental results of pi-absorption at rest in water at CERN [136]."

residual nucleus	Energy level (MeV)	J^π	E_γ (MeV)	BR of $(X_\alpha \to \gamma + Y)$ (%)
^{16}O	6.13	3^-	6.13	1.7
^{15}N	5.270	$\frac{5}{2}^+$	5.27	0.5
^{14}N	2.313	0^+	2.31	0.3
	3.945	1^+	1.63+2.31	4.8
	5.106	2^-	5.11	0.7
		2^-	2.79+2.31	0.2
^{14}C	6.728	3^-	6.72	< 0.2
^{13}C	3.684	$\frac{3}{2}^-$	3.68	1.9
	3.854	$\frac{5}{2}^+$	3.85	1.0
^{12}C	4.439	2^+	4.44	4.0
^{10}B	0.717	3^+	0.72	1.3

^{16}O 6.13 MeV used in SK

(Huang-san thesis, p. 142)

>11 MeV neutron interacts with ^{16}O to form ^{16}N

beta-decay

$^{16}N \rightarrow e^{-} + {}^{16}O^{*}$

66% probability to produce 4.3 MeV electron and 6.13 MeV gamma

used in DT calibration

time delay

EXFOR

https://www-nds.iaea.org/exfor/exfor.htm

Target: O-16

Reaction: n,*

→ 198 results, look at reactions with gamma

- T4
- i grid – link to paper

first looked at all $^{16}O(n,g)$

- ~26 different IDs
- read summary
- if paper easily accessible by link, skimmed paper
- if skim was interesting, read paper

- some papers are repeated

EXFOR
(7)

McDonald 1977

```
#SUBENT      10668003
#AUTHORS     A.B.Mcdonald, E.D.Earle, M.A.Lone, F.C.Khanna,
#+           H.C.Lee
#REFERENCE   Nuclear Physics, Section A Vol.281, p.325
#YEAR        1977
#TITLE       Doubly radiative thermal neutron capture in 2H and
#+           16O experiment and theory
#REACTION    8-O-16(N,2G)8-O-17,,SIG
#QUANTITY    Cross section
#SUBP       10668003
#Ene,eV      Sig,mb      dSig,mb
 0.0253      0.003       0.019
#END
```

- upper limits on cross section for 2 photon emission
- $^{16}O(n,g)^{17}O$ total cross section 202 +/- 28 ub
- 82% 3.055 MeV level (2 g cascade)
- 18% 871 keV level
- neutrons thermalized to 0.025 MeV
- heavy water in PE bag
- 2.223 MeV $^{1}H(n,g)$ to monitor
- calibration sources dissolved in water
- background from Ge(Li)
- in agreement with Jurney 1963
  82% and 18% and 178 +/- 25 ub

McDonald1977

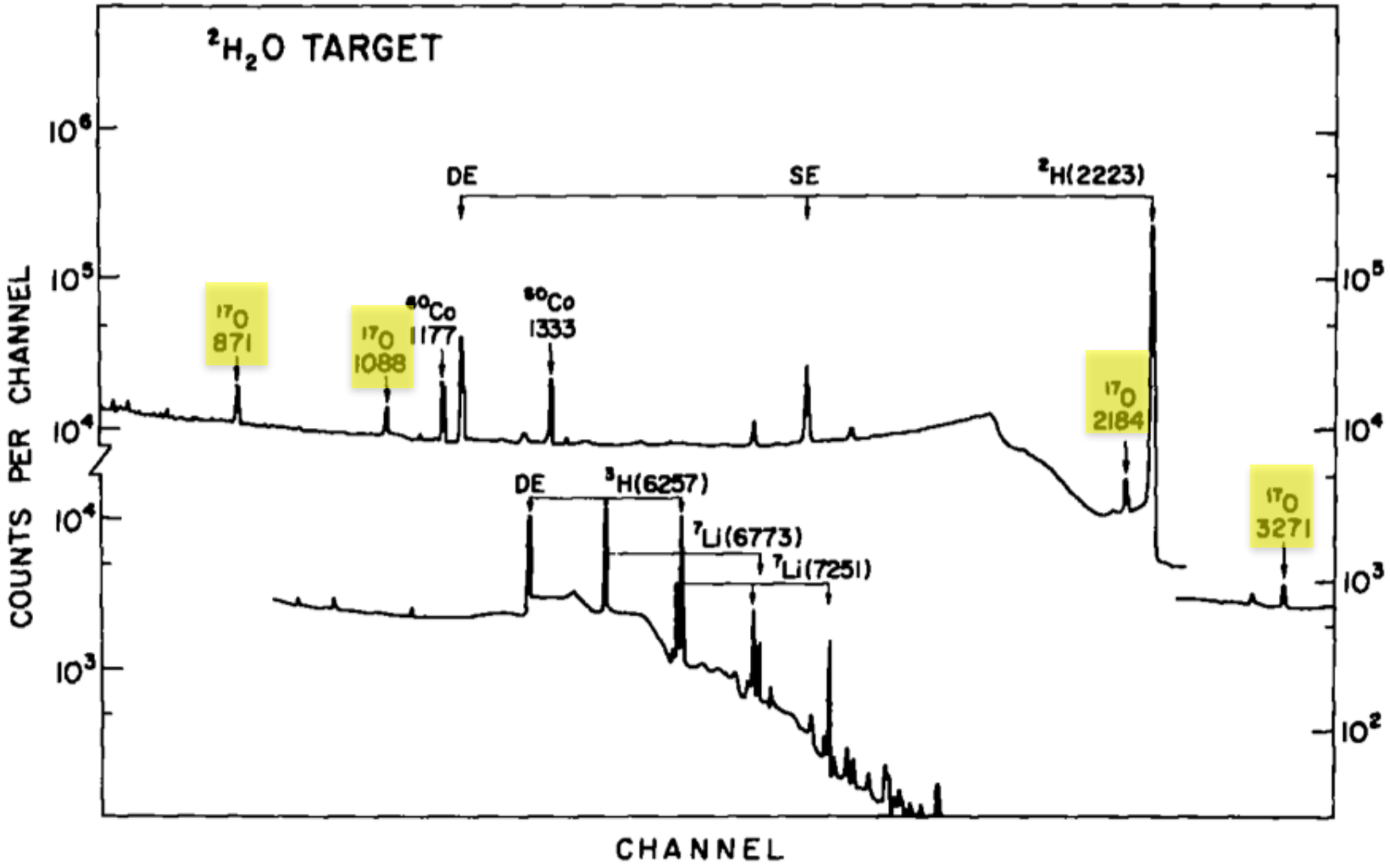


Fig. 8. Singles spectrum of γ-rays from the ^2H_2O target, used to determine the cross section and branching ratios for $^{16}O(n, \gamma)$. The peaks labelled DE and SE are double and single escape peaks, respectively.

McDonald 1977

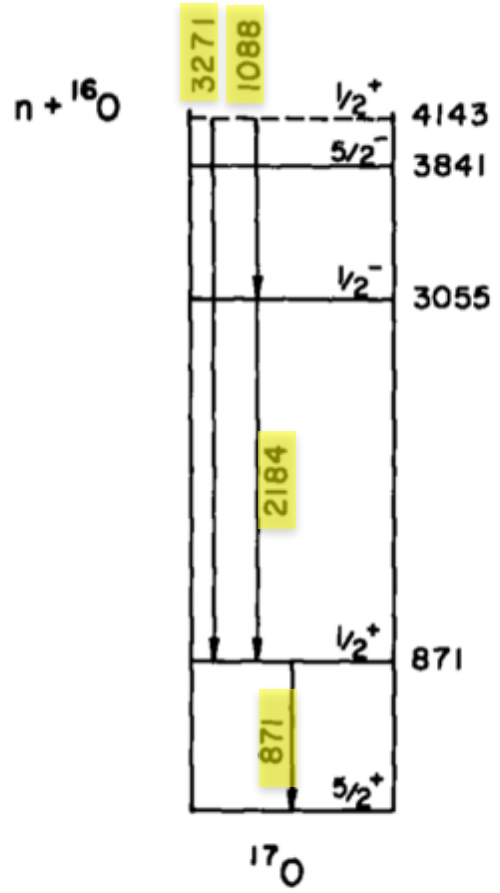


Fig. 7. Energy level diagram showing the transitions observed from the $^{16}O(n, \gamma)$ reaction. Energies are shown in keV.

EXFOR
(66)
1

Firestone 2016

```
#SUBENT        23296011
#AUTHORS       R.B.Firestone, Zs.Revay
#REFERENCE     Physical Review, Part C, Nuclear Physics Vol.93, p.044311
#YEAR          2016
#TITLE         Thermal neutron capture cross sections for 16,17,18O
#+             and 2H .
#REACTION      8-O-16(N,G)8-O-17,,SIG
#QUANTITY      Cross section
#SUBP         23296011
#Ene,eV        Sig,mb         dSig,mb
 0.0253        0.17           0.003
#END
```

TABLE III. γ-ray energies, intensities, and transition probabilities for the $^{16}O(n,\gamma)$ reaction.

E_γ (keV)	Mult	ICC	I_γ	P_γ(%)[a]
870.76 ± 0.08	$E2$	8.85×10^{-6}	100.0 ± 0.8	96.6 ± 0.5
1087.86 ± 0.08	$E1$	2.31×10^{-6}	83.8 ± 0.6	80.4 ± 0.5
2184.44 ± 0.09	$E1$	7.7×10^{-4}	84.8 ± 1.2	80.4 ± 0.5
3272.15 ± 0.10	$M1$	7.6×10^{-4}	16.9 ± 0.5	16.2 ± 0.4
4142.73 ± 0.13	$E2$	0.00122	3.5 ± 0.3	3.36 ± 0.24

[a]Constrained least-squares fit to the level scheme with a $\chi^2/f = 0.74$.

- cold neutrons beam
- D_2O targets, natural and enriched
- detect gammas with HPGe
- consistent with McDonald 1977 and Wüst
- 4.94530 MeV ^{12}C(n,g)
- 2.2232487 keV ^{1}H(n,g) 332.6 +/- 0.7 mb [Mughabghab2006 "Atlas"]
  → we should confirm that we measure that for ^{1}H(n,g), or normalize to that

^{16}O(n, INL)

- noticed mention of gamma in some summaries
- ~14 entries
- looked through 16 IDs → not finished

EXFOR
(80)
1

Nyberg-Ponnert 1971

```
#SUBENT      20245008
#AUTHORS     K.Nyberg-Ponnert, B.Joensson, I.Bergqvist
#REFERENCE   Physica Scripta Vol.4, p.165
#YEAR        1971
#TITLE       GAMMA RAYS PRODUCED BY THE INTERACTION OF 15 MEV
#+           NEUTRONS IN N, O, MG AND AL.-
#REACTION    8-O-16(N,INL)8-O-16,,SIG
#QUANTITY    Cross section
#SUBP       20245008
#Ene,MeV     dEne,MeV    Sig,mb      dSig,mb
 15.1        0.4         310         50
#END
```

- Ge(Li)
- water in plastic bag
- relative to 4.44 MeV $^{12}C(n,n')^{12}C$
- 2.22 MeV from $^{1}H(n,g)$
- background from scattered neutron
- corrected for:
  - variation in neutron flux in sample
  - neutron attenuation
  - multiple scattering
  - gamma attenuation
- (n,xg) where x is n', p, d, t, alpha
- $^{16}O(n,n'g)^{16}O$ and $^{16}O(n,alpha\ g)^{13}C$
- Doppler broadening for liftetimes <1ps
- 6.131 MeV 3^- is most intense
  - directly
  - cascade
  - $^{16}O(n,p)^{16}N$ where 68%

Nyberg-Ponnert 1971

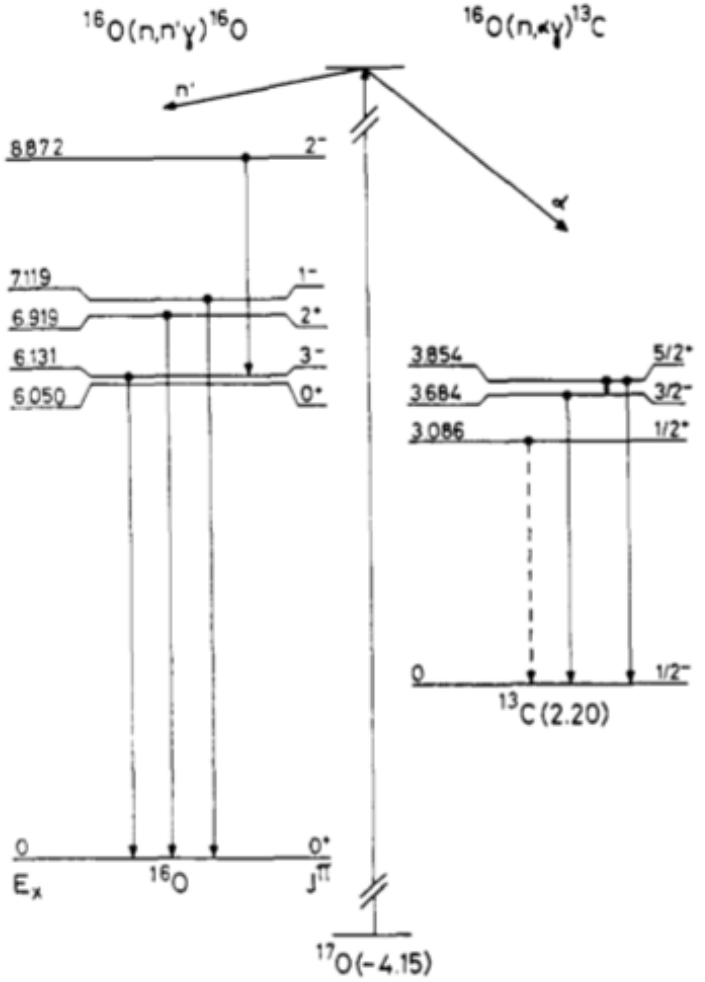


Fig. 6. Level scheme for the reaction $^{16}O(n,x\gamma)$. For further explanation see caption of Fig. 5.

6 gammas observed (solid)
1 gamma missed (dashed)

Nyberg-Ponnert 1971

Table IV. *Gamma rays from 15 MeV neutron interactions with oxygen*

E_γ (MeV ± keV)	Suggested reaction leading to the excited state	Suggested transition in the residual nucleus	Diff. 80° cross section (mb/sr)	Results of others (mb/sr at 90°)	
				Ref. [3]	Ref. [4]
2.735 ± 3	$^{16}O(n,n')^{16}O$	8.872 → 6.131	3.6 ± 0.6	2.6	3.8 ± 0.4
3.685 ± 3	$^{16}O(n,\alpha)^{13}C$	3.684 → 0	3.4 ± 0.5	4.3	5.5 ± 1.1
3.855 ± 3	$^{16}O(n,\alpha)^{13}C$	3.854 → 0	2.7 ± 0.4	2.7	2.6 ± 0.5
6.130[c]	$^{16}O(n,n')^{16}O$	6.131 → 0	11.5 ± 1.7[b]	9.2	10.4 ± 1.2[b]
6.906 ± 15[a]	$^{16}O(n,n')^{16}O$	6.919 → 0	4.0 ± 0.6	2.6	3.8 ± 0.9
7.112 ± 10[a]	$^{16}O(n,n')^{16}O$	7.119 → 0	4.5 ± 0.7	2.0	5.0 ± 1.0

[a] The γ-ray energies have been corrected for the Doppler shift.
[b] The cross sections have been corrected for the contribution from the (n,p) reaction.
[c] Used as standard calibration line.

EXFOR
(80)
2

Orphan 1970

```
#SUBENT      10097011
#AUTHORS     V.J.Orphan, C.G.Hoot, J.John
#REFERENCE   Nuclear Science and Engineering Vol.42, p.352
#YEAR        1970
#TITLE       Gamma-ray production cross sections for the
#+           O16 (n,x gamma) reaction from 6.35- to 16.52-mev
#+           neutron energy
#REACTION    8-O-16(N,INL)8-O-16,,SIG
#QUANTITY    Cross section
#SUBP        10097011
#Ene,MeV     dEne,MeV    Sig,mb      dSig,mb
 12.015      0.895       161         21
 13.44       0.53        168         24
 15.245      1.275       141         20
#END
```

from Table I

E_γ (MeV)	Final Nucleus	Transition Levels (MeV)
1.76	^{16}O	8.87 -7.12
2.743	^{16}O	8.87 -6.13
3.085	^{13}C	3.085-0
3.68	^{13}C	3.68 -0
3.85	^{13}C	3.85 -0
4.44	^{12}C	4.44 -0
6.129	^{16}O	6.129-0
6.92	^{16}O	6.92 -0
7.117	^{16}O	7.117-0

- 6.35–16.52 MeV neutron
- neutron energy by TOF
- Ge(Li)
- 125 degrees
- D2O in plexiglass, and empty
- NE211 for neutron flux
- 6.129 MeV is strongest
- 4.44 MeV from ^{12}C(n,n') in sample holder
- ^{16}O(n,n')^{16}O
- ^{16}O(n,alpha)^{13}C
- ^{16}O(n,n' alpha)^{12}C
- no gamma from ^{16}O(n,p)^{16}N
- no gamma from ^{16}O(n,g)^{17}O
  because cross section is small (~200 ub at thermal)
- well known nuclear levels, didn't measure energy
- Doppler broadening for short lifetimes
  (6.92 MeV and 7.117 MeV)
- uncertainties:
  - neutron flux
  - Ge(Li) efficiency
  - flux attenuation and multiple scattering
  - gamma attenuation

EXFOR (81)

Dimbylow 1980

```
#SUBENT        V0027071
#AUTHORS       P.Dimbylow
#REFERENCE     Physics in Medicine and Biology Vol.25, Issue.4, p.637
#YEAR          1980
#TITLE         Neutron cross-sections for elements of biomedical
#+             importance from 20 to 50 MeV
#REACTION      8-O-16(N,INL)8-O-16,,SIG,,,CALC
#QUANTITY      Cross section
#SUBP         V0027071
#Ene,MeV       Sig,mb
  20           198.1
  22           148.3
  24           125.7
  26           111.5
  28           103.4
  30           93.6
  32           86
  36           73.1
  40           61.8
  45           51
  50           44
  60.7         30.7
#END
```

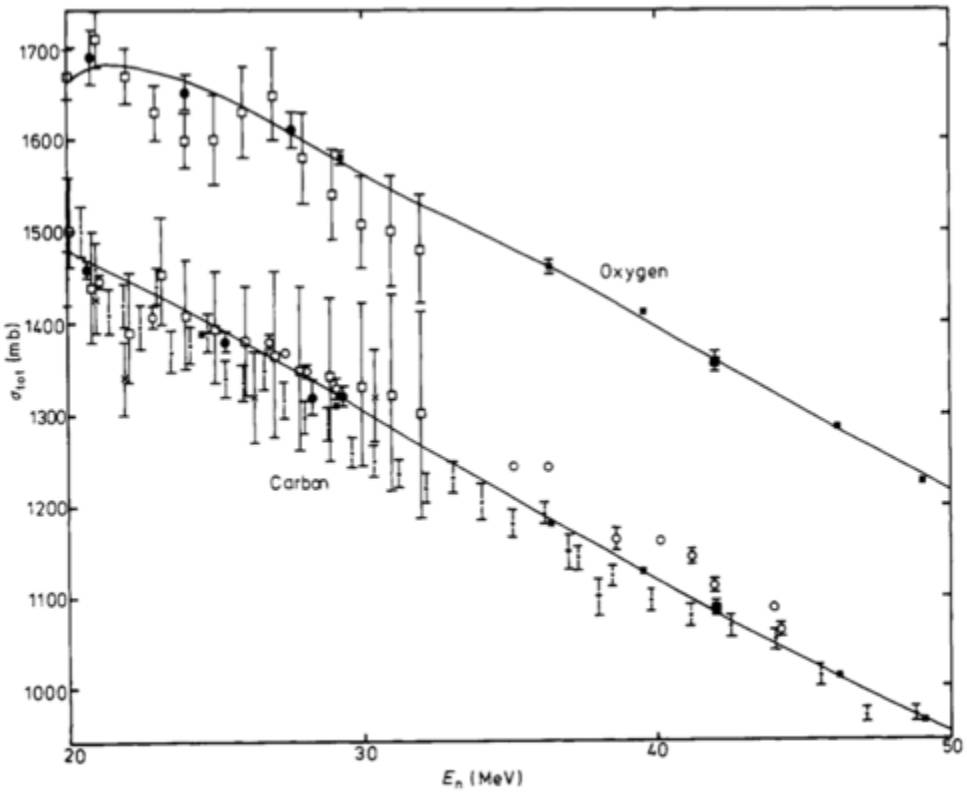


Figure 1. Calculated and experimental total cross-sections for carbon and oxygen from 20 to 50 MeV. • Bowen *et al* (1961); ○ Bubb *et al* 1974; □ Cierjacks *et al* 1968; ■ Hildebrand and Leith (1960); ● Peterson *et al* 1960; + Taylor and Wood (1953); × West *et al* 1965; ⋆ Auman *et al* 1972.

- theoretical
- C, N, O
- fit the experimental data
- elastic and nonelastic
- calculate individual reaction cross sections
- calculate emission probability of n, d, t, 3He, alpha
- no gamma

EXFOR
(83)
1

Mermod 2006

Author(s)	Title
P.Mermod, J.Blomgren, C.Johansson, A.Oehrn,M.Oesterlund,S.Pomp, B.Bergenwall, J.Klug, L.Nilsson, N.Olsson, U.Tippawan, P.Nadel-Turonski, O.Jonsson,A.V.Prokofiev,P.-U.Renberg, Y.Maeda, H.Sakai, A.Tamii, K.Amos, R.Crespo, A.M.Moro	95 MeV neutron scattering on hydrogen, carbon, and oxygen.

Institute

1USAGWU	George Washington University, Washington, DC	USA
2GERZFK	Forschungszentrum Dresden-Rossendorf (FZD), Dresden	Germany
2JPNTOK	Univ. of Tokyo, Tokyo	Japan
2PRTPRT	Portugal	Portugal
2SPNSEU	Sevilla University	Spain
2SWDFOI	Swedish Defence Research Agency (FOI), Stockholm	Sweden
2SWDUPP	Univ. of Uppsala	Sweden
3AULAML	Univ. of Melbourne, Parkville, Victoria	Australia
3TAICHM	Chiang Mai Univ.	Thailand

Reference

1) J,PR/C,74,054002,2006	Journ.: Physical Review, Part C, Nuclear Physics Vol.74, p.054002 NSR-KeyNo: 2006ME26 DOI: 10.1103/PhysRevC.74.054002 Web: http://publish.aps.org/abstract/PRC/v74/p054002	USA
2) T,Oehrn,2008	Thesis or dissertation Name.Oehrn	
3) C,2007NICE,2,1039,200704	Conf.: Conf.on Nucl.Data for Sci. and Technology, Nice 2007 Vol.2, p.1039 NSR-KeyNo: 2008MEZW DOI: 10.1051/ndata:07435	France

Reaction: [23030006]
Code: 8-O-16(N,INL)8-O-16,PAR,DA ZA=8016 IPART=1 MF=4 MT=51
Data-line(s): 12 Energy=94.8MeV
Product(s): 8-O-16

8-O-16(N,INL)8-O-16,PAR,DA	Partial differential cross section d/dA	DAP

^{16}O(n,n) first time at this energy
^{12}C(n,n) for normalization
^{12}C(n,n') and ^{16}O(n,n') cross sections

^{7}Li(p,n)^{7}Be
98 MeV proton beam, 5 uA
Faraday Cup for beam monitoring
94.8 +/- 0.5 MeV neutron, 2.7 MeV FWHM
low energy tail suppressed by TOF

SCANDAL experiment
plastic scintillator and CsI
H2O and D2O, 1 L in Al

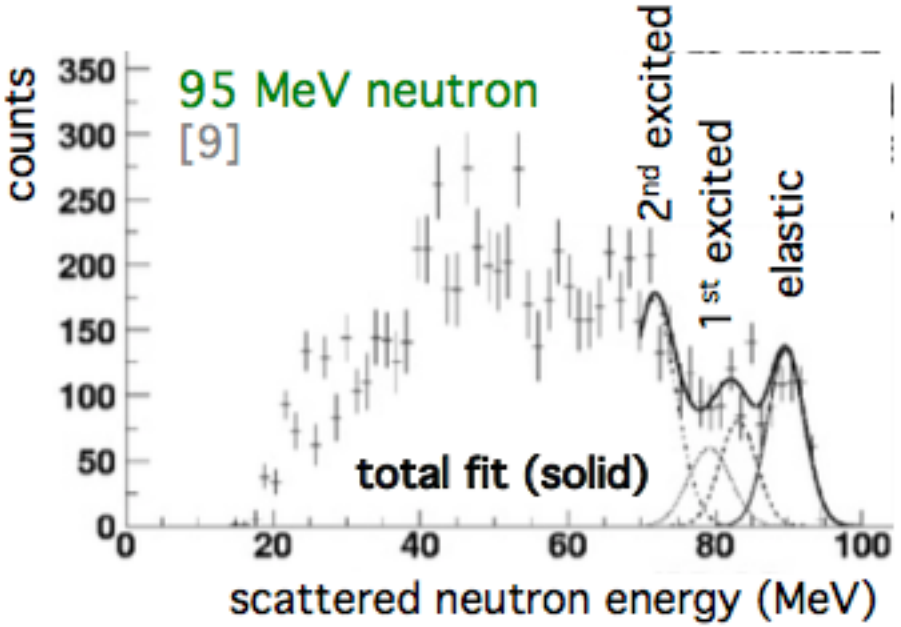
measure scattered neutron
didn't measure gamma

angular distribution

first excited state:
6.1 MeV 3^-
6.9 MeV 2_1^+
7.1 MeV 1^- (weak)

second excited state:
9.8 MeV 2_2^+
10.4 MeV 4^+ (dominates)

2 entries in EXFOR?



poor resolution

1st excited state:
6.13 MeV
6.92 MeV
7.12 MeV

2nd excited state:
9.84 MeV
10.34 MeV

EXFOR
(83)
4

Olsson 1990

Author(s)	Title	
N.Olsson,E.Ramstroem,B.Trostell	-NEUTRON ELASTIC AND INELASTIC SCATTERING FROM BERYLLIUM, NITROGEN AND OXYGEN AT EN = 21.6 MEV.	
Institute		
2SWDSWR	Studsvik Science Research Laboratory	Sweden
Reference		
1) W,OLSSON,891006	Private communication Name.Olsson	
2) J,NP/A,509,161,9003	Journ.: Nuclear Physics, Section A Vol.509, p.161 NSR-KeyNo: 1990OL01 DOI: 10.1016/0375-9474(90)90379-Z	Netherlands
Reaction: [22127013] Code: 8-O-16(N,INL)8-O-16,PAR,DA ZA=8016 IPART=1 MF=4 MT=51 Data-line(s): 102 Energy=21.6MeV Product(s): 8-O-16		
8-O-16(N,INL)8-O-16,PAR,DA	Partial differential cross section d/dA	DAP

SiO_2 target

NE213 LqS PSD

measure scattered neutron
didn't measure gammas

doublet:
6.05 MeV O_2^+
6.13 MeV 3_1^+

doublet:
6.92 MeV 2_1^+
7.12 MeV 1_1^-

singlet:
8.87 MeV 2_1^+

elastic and inelastic agree with Islam 1987 (22 MeV)
elastic agrees with Lam 1985 (23 MeV) (didn't read)

EXFOR
83
7

Islam 1987

Author(s)	Title	
M.S.Islam,R.W.Finlay,J.S.Peter	ELASTIC AND INELASTIC SCATTERING OF NUCLEONS FROM 16O	
Institute		
1USAOHO	Ohio University, Athens, OH	USA
Reference		
1) J,NP/A,464,395,8703	Journ.: Nuclear Physics, Section A Vol.464, p.395 NSR-KeyNo: 1987IS04 DOI: 10.1016/0375-9474(87)90307-1	Netherlands
Reaction: [13194003] Code: 8-O-16(N,INL)8-O-16,PAR,DA ZA=8016 IPART=1 MF=4 MT=51 Data-line(s): 357 E-min=20.0MeV E-max=26.0MeV Product(s): 8-O-16		
8-O-16(N,INL)8-O-16,PAR,DA	Partial differential cross section d/dA	DAP

18–26 MeV neutron
NE213 PSD
measured scattered neutron
didn't measure gammas
Al_2O_3 target
consider multiple scattering
consider attenuation of neutron
some of same authors as Grabmayr 1980

Islam 1987

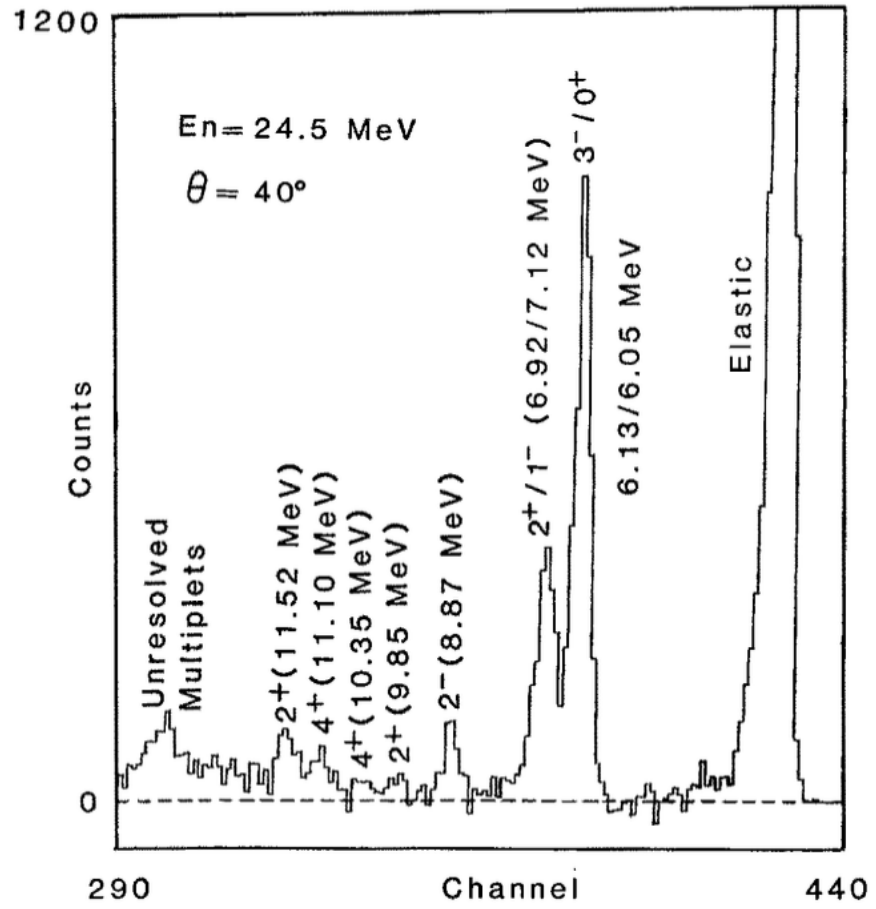


Fig. 1. Background-subtracted time-of-flight spectrum for neutron scattering from ^{16}O.

doublet:
6.05 MeV O^+
6.13 MeV 3^-

doublet:
6.92 MeV 2^+
7.12 MeV 1^-

8.87 MeV 2^-
9.85 MeV 2^+
10.35 MeV 4^+
11.10 MeV 4^+
11.52 MeV 2^+

Islam 1987

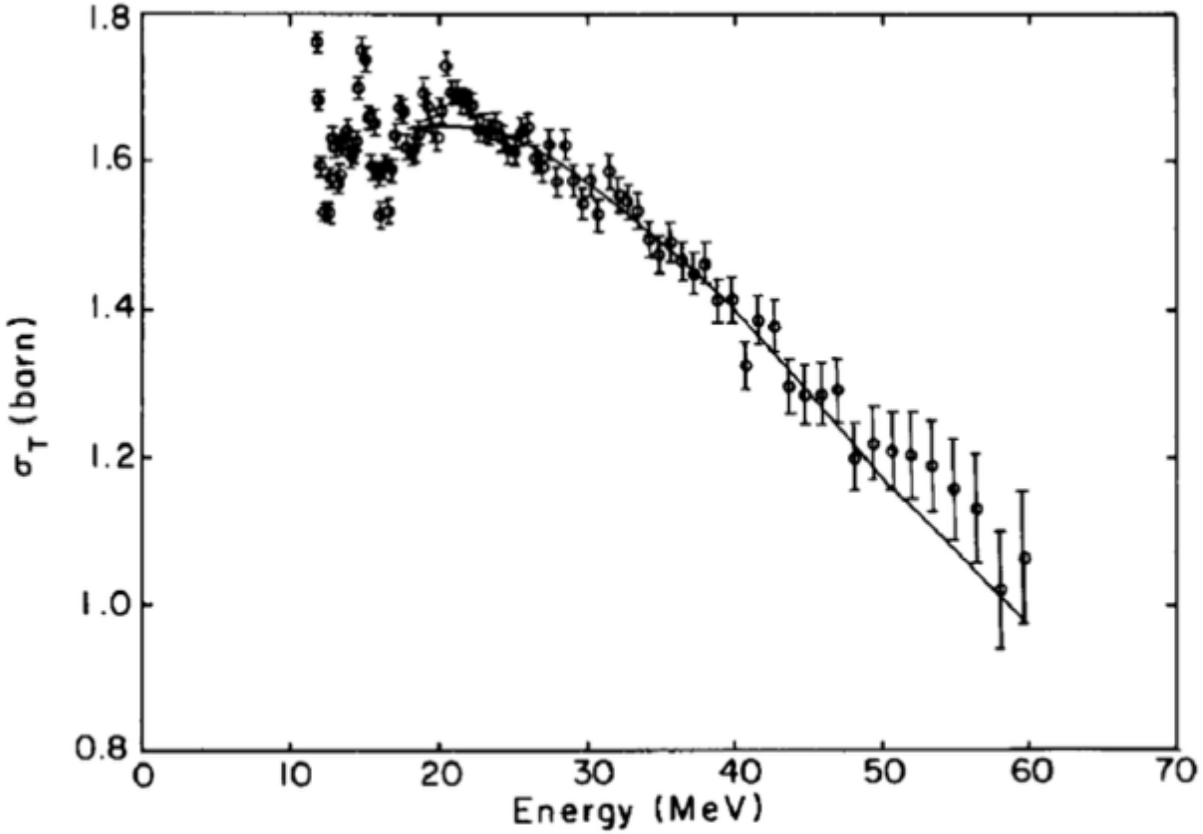


Fig. 4. The energy dependence of total cross sections. Circles are measured (ref. [42])) and the solid line is due to phenomenological spherical optical model calculations.

42) D.C. Larson, Oak Ridge Laboratory, private communication (1983) not published elsewhere?

EXFOR
(83)
9

Grabmayr 1980

Author(s)	Title	
P.Grabmayr,J.Rapaport,R.W.Finlay	ELASTIC AND INELASTIC SCATTERING OF 24-MEV NUCLEONS FROM OXYGEN ISOTOPES	
Institute		
1USAOHO	Ohio University, Athens, OH	USA
Reference		
1) J,NP/A,350,167,8012	Journ.: Nuclear Physics, Section A Vol.350, p.167 NSR-KeyNo: 1980GR15 DOI: 10.1016/0375-9474(80)90395-4	Netherlands
2) W,FINLAY,8104	Private communication Name.Finlay	
Reaction: [10965003] Code: 8-O-16(N,INL)8-O-16,PAR,DA ZA=8016 IPART=1 MF=4 MT=51 Data-line(s): 29 Energy=24.0MeV Product(s): 8-O-16		
8-O-16(N,INL)8-O-16,PAR,DA	Partial differential cross section d/dA	DAP

- 24 MeV neutrons
- ^{16,18}O water in Al cans
- TOF
- angular distribution
- background from empty can
- measured scattered neutron
- didn't measure gamma
- NE224 LqS
- 500 keV resolution
- PSD to eliminate gamma
- consider mass due to evaporation
- consider multiple scattering

consider flux attenuation

doublet:
6.13 MeV 3^-
6.05 MeV 0^+

doublet:
6.92 MeV 2^+
7.12 MeV 1^-

Summary

GAMMAS OBSERVED

0.87 MeV	[5, 6]
1.09 MeV	[5, 6]
1.75 MeV	[7]
2.18 MeV	[5, 6]
2.74 MeV	[7, 8]
3.09 MeV	[7]
3.27 MeV	[5, 6]
3.68 MeV	[7, 8]
3.85 MeV	[7, 8]
4.19 MeV	[6]
4.44 MeV	[7]
6.13 MeV	[7, 8]
6.92 MeV	[7, 8]
7.12 MeV	[7, 8]

note that these used lower energy neutrons

thermal [5, 6]
6–17 MeV [7]
15 MeV [8]

SCATTERED NEUTRONS MEASURE ENERGY LEVELS

Summary

6.05 MeV	[8, 9, 10]
6.13 MeV	[9, 10, 11, 12]
6.92 MeV	[9, 10, 11, 12]
7.12 MeV	[9, 10, 11, 12]
8.87 MeV	[10, 11]
9.84 MeV	[9, 11]
10.34 MeV	[9, 11]
11.1 MeV	[11]
11.52 MeV	[11]

besides 95 MeV [9]
lower energy neutrons

22 MeV [10]
24 MeV [11]
18–26 MeV [12]

de-excitation gammas possible
for all of these energy levels

Conclusion

- 6.13 MeV gamma from ^{16}O observed in several measurements
- produced directly, in gamma cascades or $^{16}O(n,p)^{16}N$ where $^{16}N \rightarrow e^- + ^{16}O$

- 2.22 MeV from $^{1}H(n,g)$ is well known and used as a standard

- no reference for 5.27 MeV, which we attribute to ^{15}N
- why not?

- can we see higher energy peaks

- look into giant dipole resonance
- for lower energy incident particle, e.g., < 100 MeV neutrino?

- future experiment: higher or lower neutron energy?

extra slides

$^{16}O(n, g)$

(63)

EXFOR

Author(s)	Title	
B.J.Allen,R.L.Macklin	Neutron Capture Cross Sections of 13C and 16O	
Institute		
1USAORL	Oak Ridge National Laboratory, Oak Ridge, TN	USA
Reference		
1) J,PR/C,3,1737,197105	Journ.: Physical Review, Part C, Nuclear Physics Vol.3, p.1737 NSR-KeyNo: 1971AL09 DOI: 10.1103/PhysRevC.3.1737 Web: http://publish.aps.org/abstract/PRC/v3/p1737	USA
Reaction: [101410042] Code: 8-O-16(N,G),,WID ZA=8016 IPART=1 MF=402 MT=6031 Data-line(s): 1 Energy=426.0keV Product(s): 0-G-0		
8-O-16(N,G),,WID	Resonance width	RP

442 keV ^{16}O resonance

referenced Lane et al. (1961)

too low, we don't care

Allen1971

(64)
1

EXFOR

Author(s)	Title	
M.Igashira,H.Kitazawa,K.Takaura	-VALENCE-NEUTRON CAPTURE IN THE 434 KEV P-3/2-WAVE RESONANCE OF O-16.	
Institute		
2JPNTIT	Tokyo Inst.of Technology, Tokyo	Japan
Reference		
1) J,NP/A,536,285,9201	Journ.: Nuclear Physics, Section A Vol.536, p.285 NSR-KeyNo: 1992IG01 DOI: 10.1016/0375-9474(92)90382-T	Netherlands
Reaction: [22263003] Code: 8-O-16(N,G),PAR,WID ZA=8016 IPART=1 Data-line(s): 2 Energy=434.0keV Product(s): 0-G-0		
8-O-16(N,G),PAR,WID	Partial width	RP

Igashira 1992

434 keV

280 keV neutron energy

too low, don't care

(64)
2

EXFOR

Author(s)	Title	
H.Kitazawa,M.Igashira,M.Shimizu, K.Muto,T.Oda,Y.Achiha, Y.-H.Lee,N.Mukai	.NON-STATISTICAL GAMMA-RAY EMISSION FROM BROAD NEUTRON RESONANCES ON P-SHELL AND SD-SHELL NUCLEI	
Institute		
2JPNTIT	Tokyo Inst.of Technology, Tokyo	Japan
Reference		
1) J,PR/C,46,(6),2364,199211	Journ.: Physical Review, Part C, Nuclear Physics Vol.46, Issue.6, p.2364 NSR-KeyNo: 1992KI23 DOI: 10.1103/PhysRevC.46.2364 Web: http://publish.aps.org/abstract/PRC/v46/i6/p2364	USA
2) C,94BOLOGN,,169,199411	Conf.: Meas.,Calc.and Eval.of Photon Prod.Data,Bologna 1994 p.169	Italy
Reaction: [22381004] Code: 8-O-16(N,G),PAR,WID ZA=8016 IPART=1 Data-line(s): 1 Energy=434.0keV Product(s): 0-G-0		
8-O-16(N,G),PAR,WID	Partial width	RP

no ^{16}O in paper?

EXFOR

```
#SUBENT      V1001039
#AUTHORS     S.F.Mughabghab
#REFERENCE   Atlas of Neutron Resonances, S.F.Mughabghab, 2006
#TITLE       Atlas of neutron resonances resonance parameters and
#+           thermal cross sections Z=1-100
#REACTION    8-O-16(N,G)8-O-17,,RI,,LIM,CALC
#QUANTITY    Resonance integral for limited energy range
#SUBP       V1001039
#Ene,keV     dEne,keV    Sig,mb      dSig,mb
 7427.25     7426.75     0.27        0.03
#END
```

theory

no access to book

EXFOR

```
#SUBENT      23297004
#AUTHORS     M.Kinoshita, Y.Nagai
#REFERENCE   Thesis or dissertation Name.Kinoshita
#YEAR        1999
#TITLE       Interference between resonant and nonresonant capture
#+           in 16O(n,g)17O
#REACTION    8-O-16(N,G)8-O-17,,SIG
#QUANTITY    Cross section
#SUBP       23297004
#Ene,keV     dEne,keV    Sig,mb      dSig,mb
 157         42          0.0347      0.0022
 349         32          0.161       0.017
 398         32.5        0.292       0.016
 427         23          0.319       0.019
 468         23.5        0.0379      0.0028
 498         26.5        0.0194      0.0018
 556         26          0.0401      0.0026
#END
```

no easy access to thesis

neutron energy?

EXFOR

```
#SUBENT      22356003
#AUTHORS     M.Igashira, Y.Nagai, K.Masuda, T.Ohsaki,
#+           H.Kitazawa
#REFERENCE   Astrophysical Journal Vol.441, p.L89
#YEAR        1995
#TITLE       Measurement of the 16O(n,g)17O reaction cross section
#+           at stellar energy and the critical role of nonresonant
#+           p-wave neutron capture
#REACTION    8-O-16(N,G)8-O-17,,SIG
#QUANTITY    Cross section
#SUBP       22356003
#Ene,MeV     Sig,mb      dSig,mb
 280         0.085       0.042
#END
```

too low energy?

(66)
4

EXFOR

```
#SUBENT      10668004
#AUTHORS     A.B.Mcdonald, E.D.Earle, M.A.Lone, F.C.Khanna,
#+           H.C.Lee
#REFERENCE   Nuclear Physics, Section A Vol.281, p.325
#YEAR        1977
#TITLE       Doubly radiative thermal neutron capture in 2H and
#+           16O experiment and theory
#REACTION    8-O-16(N,G)8-O-17,,SIG
#QUANTITY    Cross section
#SUBP       10668004
#Ene,eV      Sig,mb      dSig,mb
 0.0253      0.202       0.028
#END
```

same paper

EXFOR

```
#SUBENT      V1001038
#AUTHORS     S.F.Mughabghab
#REFERENCE   Atlas of Neutron Resonances, S.F.Mughabghab, 2006
#TITLE       Atlas of neutron resonances resonance parameters and
#+           thermal cross sections Z=1-100
#REACTION    8-O-16(N,G)8-O-17,,SIG,,,RECOM
#QUANTITY    Cross section
#SUBP       V10010381
#Ene,eV      Sig,mb      dSig,mb
 0.0253      0.19        0.019
#END
```

theory, recommended at time of entry

same book

(Firestone 2016 compared to this)

EXFOR

```
#SUBENT      22356004
#AUTHORS     M.Igashira, Y.Nagai, K.Masuda, T.Ohsaki,
#+           H.Kitazawa
#REFERENCE   Astrophysical Journal Vol.441, p.L89
#YEAR        1995
#TITLE       Measurement of the 16O(n,g)17O reaction cross section
#+           at stellar energy and the critical role of nonresonant
#+           p-wave neutron capture
#REACTION    8-O-16(N,G)8-O-17,,SIG,,MSC
#QUANTITY    Cross section
#SUBP       22356004
#Ene,MeV     Sig,mb      dSig,mb
 280         0.085       0.042
#END
```

different ID, but same paper as before
what is MSC?

EXFOR

```
#SUBENT      22356005
#AUTHORS     M.Igashira, Y.Nagai, K.Masuda, T.Ohsaki,
#+           H.Kitazawa
#REFERENCE   Astrophysical Journal Vol.441, p.L89
#YEAR        1995
#TITLE       Measurement of the 16O(n,g)17O reaction cross section
#+           at stellar energy and the critical role of nonresonant
#+           p-wave neutron capture
#REACTION    8-O-16(N,G)8-O-17,,SIG,,MXW
#QUANTITY    Cross section
#SUBP       22356005
#Ene,keV     Sig,mb
 45          0.034
#END
```

45 keV neutron energy?
same paper as previous two
what is MXW?

EXFOR

```
#SUBENT      20674006
#AUTHORS     N.Wuest, H.Seyfarth, L.Aldea
#REFERENCE   Physical Review, Part C, Nuclear Physics Vol.19, Issue.4, p.1153
#YEAR        1979
#TITLE       TWO-QUANTUM RADIATIVE THERMAL NEUTRON CAPTURE
#+           IN H-1.-
#REACTION    8-O-16(N,G)8-O-17,,SIG,,MXW
#QUANTITY    Cross section
#SUBP       20674006
#Ene,eV      Sig,mb      dSig,mb
 0.0253      0.187       0.01
#END
```

sum peak 871 + 1088

EXFOR

```
#SUBENT      11133006
#AUTHORS     E.Jurney, H.Motz
#REFERENCE   Argonne National Laboratory report series No.6797, p.236
#YEAR        1963
#TITLE       THERMAL NEUTRON CAPTURE IN D AND O16.
#REACTION    8-O-16(N,G)8-O-17,,SIG,,MXW
#QUANTITY    Cross section
#SUBP       11133006
#Ene,eV      Sig,mb      dSig,mb
 0.0253      0.178       0.025
#END
```

no easy access

(70)
1

EXFOR

```
#SUBENT      V1001040
#AUTHORS     S.F.Mughabghab
#REFERENCE   Atlas of Neutron Resonances, S.F.Mughabghab, 2006
#TITLE       Atlas of neutron resonances resonance parameters and
#+           thermal cross sections Z=1-100
#REACTION    8-O-16(N,G)8-O-17,,SIG,,MXW,RECOM
#QUANTITY    Cross section
#SUBP       V1001040
#Ene,keV     Sig,mb       dSig,mb
 45          0.038        0.004
#END
```

recommended at time of entry
same book
45 keV neutron energy?

EXFOR

```
#SUBENT      V0102013
#AUTHORS     Z.Y.Bao, H.Beer, F.Kaeppeler, F.Voss,
#+           K.Wisshak, T.Rauscher
#REFERENCE   Atomic Data and Nuclear Data Tables Vol.76, p.70
#YEAR        2000
#TITLE       Neutron cross sections for nucleosynthesis studies
#REACTION    8-O-16(N,G)8-O-17,,SIG,,MXW,RECOM
#QUANTITY    Cross section
#SUBP       V0102013
#Ene,keV     Sig,mb      dSig,mb
 45          0.038       0.004
#END
```

together with previous, recommended at time
a review, 85 pages
low energy?

EXFOR

(71)

EXFOR # 23297.003

Author(s)	Title	
M.Kinoshita, Y.Nagai	Interference between resonant and nonresonant capture in 16O(n,g)17O	
Institute		
2JPNTIT	Tokyo Inst.of Technology, Tokyo	Japan
Reference		
1) T,KINOSHITA,19990214	Thesis or dissertation Name.Kinoshita	
Reaction: [23297003] Code: 8-O-16(N,G)8-O-17,,SIG,,RAW ZA=8016 IPART=1 MF=3 MT=102 Data-line(s): 7 E-min=157.0keV E-max=556.0keV See Data Table Product(s): 0-G-0, 8-O-17		
8-O-16(N,G)8-O-17,,SIG,,RAW	Cross section	CS
The data dependent of:		
DEP,23297002	Number of partial neutron captures	

no easy access to thesis

EXFOR

```
#SUBENT      10141005
#AUTHORS     B.J.Allen, R.L.Macklin
#REFERENCE   Physical Review, Part C, Nuclear Physics Vol.3, p.1737
#YEAR        1971
#TITLE       Neutron Capture Cross Sections of 13C and 16O
#REACTION    8-O-16(N,G)8-O-17,,SIG,,SPA
#QUANTITY    Cross section
#SUBP       10141005
#Ene,keV     Sig,mb      dSig,mb
 45          0.0002      0.0001
#END
```

same paper as before
45 keV neutron energy?

(73)

EXFOR

EXFOR # 31430.002

Author(s)	Title	
Huang Zhengde,Zhu Lihua,Hou Long, Ding Dazhao	The measurement of the O-16(n,gamma)O-17 reaction at the pygmy resonance region.	
Institute		
3CPRAEP	China Inst. of Atomic Energy, Beijing	China
Reference		
1) J,CNP,16,(3),270,1994	Journ.: Chinese J.of Nuclear Physics (Beijing). Vol.16, Issue.3, p.270	China
2) W,HuangZhengde,1994	Private communication Name.Huangzhengde	
Reaction: [31430002] Code: 8-O-16(N,G)8-O-17,PAR,DA ZA=8016 IPART=1 Data-line(s): 12 E-min=7.0MeV E-max=14.0MeV Product(s): 0-G-0, 8-O-17		
8-O-16(N,G)8-O-17,PAR,DA	Partial differential cross section d/dA	DAP

no easy access

(74)
1

EXFOR

```
#SUBENT      23298002
#AUTHORS     T.Matsushima, H.Kitazawa
#REFERENCE   Thesis or dissertation Name.Matsushima
#YEAR        2003
#TITLE       Resonant and nonresonant captures of low energy
#+           neutrons by light nuclides
#REACTION    8-O-16(N,G)8-O-17,PAR,SIG
#QUANTITY    Partial cross section
#SUBP       23298002
#Ene,keV     dEne,keV    Sig,mb      dSig,mb
 390         26.5        0.1018      0.0094
 390         26.5        0.1849      0.0122
 428         23          0.2391      0.0218
 428         23          0.4184      0.0312
 470         28.5        0.044       0.0027
 470         28.5        0.0791      0.0038
 549         28          0.0013      0.0001
 549         28          0.0155      0.0004
#END
```

why are energies repeated?
no easy access

(74)
2

EXFOR

```
#SUBENT      22356002
#AUTHORS     M.Igashira, Y.Nagai, K.Masuda, T.Ohsaki,
#+           H.Kitazawa
#REFERENCE   Astrophysical Journal Vol.441, p.L89
#YEAR        1995
#TITLE       Measurement of the 16O(n,g)17O reaction cross section
#+           at stellar energy and the critical role of nonresonant
#+           p-wave neutron capture
#REACTION    8-O-16(N,G)8-O-17,PAR,SIG
#QUANTITY    Partial cross section
#SUBP       22356002
#Ene,keV     Sig,mb      dSig,mb
 280         0.03        0.03
 280         0.055       0.03
#END
```

why repeated energy?
same paper

EXFOR

```
#SUBENT      22263002
#AUTHORS     M.Igashira, H.Kitazawa, K.Takaura
#REFERENCE   Nuclear Physics, Section A Vol.536, p.285
#YEAR        1992
#TITLE       VALENCE-NEUTRON CAPTURE IN THE 434 KEV P-3/2-WAVE
#+           RESONANCE OF O-16.
#REACTION    8-O-16(N,G)8-O-17,PAR,SIG
#QUANTITY    Partial cross section
#SUBP       22263002
#Ene,keV     dEne,keV    Sig,mb      dSig,mb
 280         35          0.03        0.03
 280         35          0.055       0.03
#END
```

why repeated energy?
same paper as before

EXFOR

```
#SUBENT      20674005
#AUTHORS     N.Wuest, H.Seyfarth, L.Aldea
#REFERENCE   Physical Review, Part C, Nuclear Physics Vol.19, Issue.4, p.1153
#YEAR        1979
#TITLE       TWO-QUANTUM RADIATIVE THERMAL NEUTRON CAPTURE
#+           IN H-1.-
#REACTION    8-O-16(N,G)8-O-17,PAR,SIG,,MXW
#QUANTITY    Partial cross section
#SUBP       20674005
#Ene,eV      Sig,mb      dSig,mb
 0.0253      0.153       0.006
#END
```

same paper
partial cross section

EXFOR

EXFOR # 23297.002

Author(s)	Title	
M.Kinoshita, Y.Nagai	Interference between resonant and nonresonant capture in 16O(n,g)17O	
Institute		
2JPNTIT	Tokyo Inst.of Technology, Tokyo	Japan
Reference		
1) T,KINOSHITA,19990214	Thesis or dissertation Name.Kinoshita	
Reaction: [23297002] Code: 8-O-16(N,G)8-O-17,PAR,SIG,,RAW ZA=8016 IPART=1 Data-line(s): 14 E-min=157.0keV E-max=556.0keV Product(s): 0-G-0, 8-O-17		
8-O-16(N,G)8-O-17,PAR,SIG,,RAW	Partial cross section	CSP

no easy access

(77)

n	Display	Year	Author-1	Energy range,eV	Points	Reference	Subentry#	NSR-Key	Info+
1)	8-O-16(N,G)8-O-17,PAR,SIG,G C4: MF=? MT=?								
Quantity: [CSP] Partial gamma-production cross section									
1	+ i X4 X4+ X4± T4	2016	R.B.Firestone+	2.53e-2	1	+ J,PR/C,93,044311,2016	23296002	2016FI04	E2=8.7e5
2	+ i X4 X4+ X4± T4			2.53e-2	1		23296003	2016FI04	E2=8.7e5
3	+ i X4 X4+ X4± T4			2.53e-2	1		23296004	2016FI04	E2=8.7e5
4	+ i X4 X4+ X4± T4			2.53e-2	1		23296005	2016FI04	E2=8.7e5
5	+ i X4 X4+ X4± T4			2.53e-2	1		23296006	2016FI04	E2=8.7e5
6	+ i X4 X4+ X4± T4			2.53e-2	1		23296007	2016FI04	E2=8.7e5
7	+ i X4 X4+ X4± T4			2.53e-2	1		23296008	2016FI04	E2=8.7e5
8	+ i X4 X4+ X4± T4			2.53e-2	1		23296009	2016FI04	E2=8.7e5

same paper, look there

(192)

EXFOR

EXFOR # 23296.010

Author(s)	Title	
R.B.Firestone, Zs.Revay	Thermal neutron capture cross sections for 16,17,18O and 2H .	
Institute		
1USAUCX	University of California, Berkeley, CA	USA
2GERMUN	Technische Universitaet Muenchen	Germany
3HUNKFI	Centre for Energy Research (EK), Budapest	Hungary
Reference		
1) J,PR/C,93,044311,2016	Journ.: Physical Review, Part C, Nuclear Physics Vol.93, p.044311 NSR-KeyNo: 2016FI04 DOI: 10.1103/PhysRevC.93.044311 Web: http://publish.aps.org/abstract/PRC/v93/p044311	USA
Reaction: [23296010] Code: (8-O-16(N,G)8-O-17,,SPC)//(8-O-16(N,G)8-O-17,,SPC) ZA=8016 IPART=1 Data-line(s): 5 Energy=0.0253eV Product(s): 0-G-0, 8-O-17		
8-O-16(N,G)8-O-17,,SPC	Gamma spectrum	SP

same paper

^{16}O(n, INL)

EXFOR
(79)

Dickens 1970

```
#SUBENT      10096021
#AUTHORS     J.K.Dickens, F.G.Perey
#REFERENCE   Nuclear Science and Engineering Vol.40, p.283
#YEAR        1970
#TITLE       The 16O(n,x gamma) Reaction for E(n) between 6.7 and
#+           11 MeV.
#REACTION    8-O-16(N,INL)8-O-16,,DA,G,4PI
#QUANTITY    Angular distribution of particle spec. * 4pi
#SUBP       10096021
#Ene,MeV     Sig,mb
 6.72        14
 6.87        44
 6.95        27
 7.02        25
 7.4         88
 7.45        90
 7.5         74
 7.7         95
 7.89        180
 7.93        181
 8.09        90
 8.28        167
 8.55        235
 9           195
 9.5         173
 10          210
 10.5        148
 11          212
#END
```

6.7–11 MeV neutrons

6.129 MeV
6.92
7.117
*1.760
1.955
2.748
8.877*

3.09 from 13C
3.68
3.86

read paper (seemed similar to Orphan1970)

(80)
3–5

```
#SUBENT      40229002
#AUTHORS     E.M.Burymov
#REFERENCE   Soviet Journal of Nuclear Physics Vol.9, p.546
#YEAR        1969
#TITLE       Cross-section for excitation of O-16, Al-27, Cr-52 and
#+           Zn-64,66,68 levels by 14.6-MeV neutrons
#REACTION    8-O-16(N,INL)8-O-16,,SIG
#QUANTITY    Cross section
#SUBP       40229002
#Ene,MeV     Sig,mb       dSig,mb
 14.6        240          16
#END
```

no easy access, 3 entries?

(82)

```
#SUBENT      40229005
#AUTHORS     E.M.Burymov
#REFERENCE   Soviet Journal of Nuclear Physics Vol.9, p.546
#YEAR        1969
#TITLE       Cross-section for excitation of O-16, Al-27, Cr-52 and
#+           Zn-64,66,68 levels by 14.6-MeV neutrons
#REACTION    8-O-16(N,INL)8-O-16,,SIG,,AV
#QUANTITY    Cross section
#SUBP       40229005
#Ene,MeV     Sig,mb      dSig,mb
 14.6        240         7
#END
```

same paper
no easy access

(83)
3

Author(s)	Title	
A.Takahashi, M.Gotoh, Y.Sasaki, H.Sugimoto	Double and single differential neutron emission cross sections at 14.1 MeV for natFe, 16O and and natNi	
Institute		
2JPNOSA	Osaka Univ., Osaka	Japan
Reference		
1) R,OKTAV-A-92-01,1992	Report: Osaka Univ., OKTAVIAN Reports No.92, p.01	Japan
Reaction: [22766012] Code: 8-O-16(N,INL)8-O-16,PAR,DA ZA=8016 IPART=1 MF=4 MT=51 Data-line(s): 48 Energy=14.1MeV Product(s): 8-O-16		
8-O-16(N,INL)8-O-16,PAR,DA	Partial differential cross section d/dA	DAP
The data dependent of:		
DEP,22766010		

no easy access

(83)
5

Author(s)	Title	
G.Boerker,R.Boettger,H.J.Brede, H.Klein,W.Mannhart,R.L.Siebert	-ELASTIC AND INELASTIC DIFFERENTIAL NEUTRON SCATTERING CROSS SECTIONS OF OXYGEN BETWEEN 6 AND 15 MEV.	
Institute		
2GERPTB	Physikal. Techn. Bundesanst., Braunschweig	Germany
Reference		
1) C,88MITO,,193,88	Conf.: Conf.on Nucl.Data For Sci.and Technol.,Mito 1988 p.193	Japan
2) R,PTB-N-1,8905	Report: Phys.Techn.Bundesanst., Neutronenphysik Reports No.1	Germany
Reaction: [22113005] Code: 8-O-16(N,INL)8-O-16,PAR,DA ZA=8016 IPART=1 MF=4 MT=51 Data-line(s): 177 E-min=9.011MeV E-max=14.888MeV Product(s): 8-O-16		
8-O-16(N,INL)8-O-16,PAR,DA	Partial differential cross section d/dA	DAP

no easy access

(83)
6

Author(s)	Title	
M.Baba,M.Ishikawa,T.Kikuchi, H.Wakabayashi,N.Yabuta,N.Hirakawa	Double differential neutron emission cross sections of Be-9, O-16, Al-27, V-51, Mn-55	
Institute		
2JPNTOH	Tohoku Univ., Sendai	Japan
Reference		
1) C,88MITO,209,198805	Conf.: Conf.on Nucl.Data For Sci.and Technol.,Mito 1988 p.209	Japan
2) W,BABA,1990	Private communication Name.Baba	
3) R,NETU-50,198803	Report: Tohoku Univ., Dept.of Nucl.Engineering Reports No.50	Japan
4) C,88MITO,291,198805	Conf.: Conf.on Nucl.Data For Sci.and Technol.,Mito 1988 p.291	Japan
Reaction: [22157034] Code: 8-O-16(N,INL)8-O-16,PAR,DA ZA=8016 IPART=1 MF=4 MT=51 Data-line(s): 60 E-min=14.1MeV E-max=18.0MeV Product(s): 8-O-16		
8-O-16(N,INL)8-O-16,PAR,DA	Partial differential cross section d/dA	DAP

no easy access

(83)
8

Author(s)	Title	
M.Baba, M.Ono, N.Yabuta, T.Kikuti, N.Hirakawa	Scattering of 14.1-MeV neutrons from 10B, 11B, C, N, O, F and Si	
Institute		
2JPNTOH	Tohoku Univ., Sendai	Japan
Reference		
1) J,RE,92,223,1986	Journ.: Radiation Effects Vol.92, p.223 NSR-KeyNo: 1986BA35	UK
Reaction: [21984090] Code: 8-O-16(N,INL)8-O-16,PAR,DA ZA=8016 IPART=1 MF=4 MT=51 Data-line(s): 30 Energy=14.2MeV Product(s): 8-O-16		
8-O-16(N,INL)8-O-16,PAR,DA	Partial differential cross section d/dA	DAP
The data dependent of:		
DEP,21984089	Double differential cross section given	

no easy access

(83)
10

Author(s)	Title	
W.E.Kinney,F.G.Perey	Neutron elastic- and inelastic- scattering cross sections for oxygen in the energy range 4.34 to 8.56 MeV	
Institute		
1USAORL	Oak Ridge National Laboratory, Oak Ridge, TN	USA
Reference		
1) R,ORNL-4780,197204	Report: Oak Ridge National Lab. Reports No.4780 NSR-KeyNo: 1972KIZU	USA
Reaction: [10276014] Code: 8-O-16(N,INL)8-O-16,PAR,DA ZA=8016 IPART=1 MF=4 MT=51 Data-line(s): 26 E-min=7.54MeV E-max=8.56MeV Product(s): 8-O-16		
8-O-16(N,INL)8-O-16,PAR,DA	Partial differential cross section d/dA	DAP

no easy access

(83)
11

EXFOR # 20496.003

Author(s)	Title	
G.C.Bonazzola, T.Bressani, E.Chiavassa, L.Naldi,B.Minetti, A.Pasquarelli	-BACKWARD SCATTERING OF 14.1 MEV NEUTRONS FROM O-16.-	
Institute		
2ITYTUR	Universita degli Studi di Torino + INFN Torino	Italy
Reference		
1) J,NCL,5,226,7209	Journ.: Lettere al Nuovo Cimento Vol.5, p.226 NSR-KeyNo: 1972BO52 DOI: 10.1007/BF02752614	Italy
2) C,72BUD,,134,7208	Conf.: Nucl.Structure Conf.,Budapest 1972 p.134	Hungary
3) J,NIM,87,291,7010	Journ.: Nuclear Instrum.and Methods in Physics Res. Vol.87, p.291	Netherlands
Reaction: [20496003] Code: 8-O-16(N,INL)8-O-16,PAR,DA ZA=8016 IPART=1 MF=4 MT=51 Data-line(s): 14 Energy=14.1MeV Product(s): 8-O-16		
8-O-16(N,INL)8-O-16,PAR,DA	Partial differential cross section d/dA	DAP

angular distribution