Lecture 4: two cases

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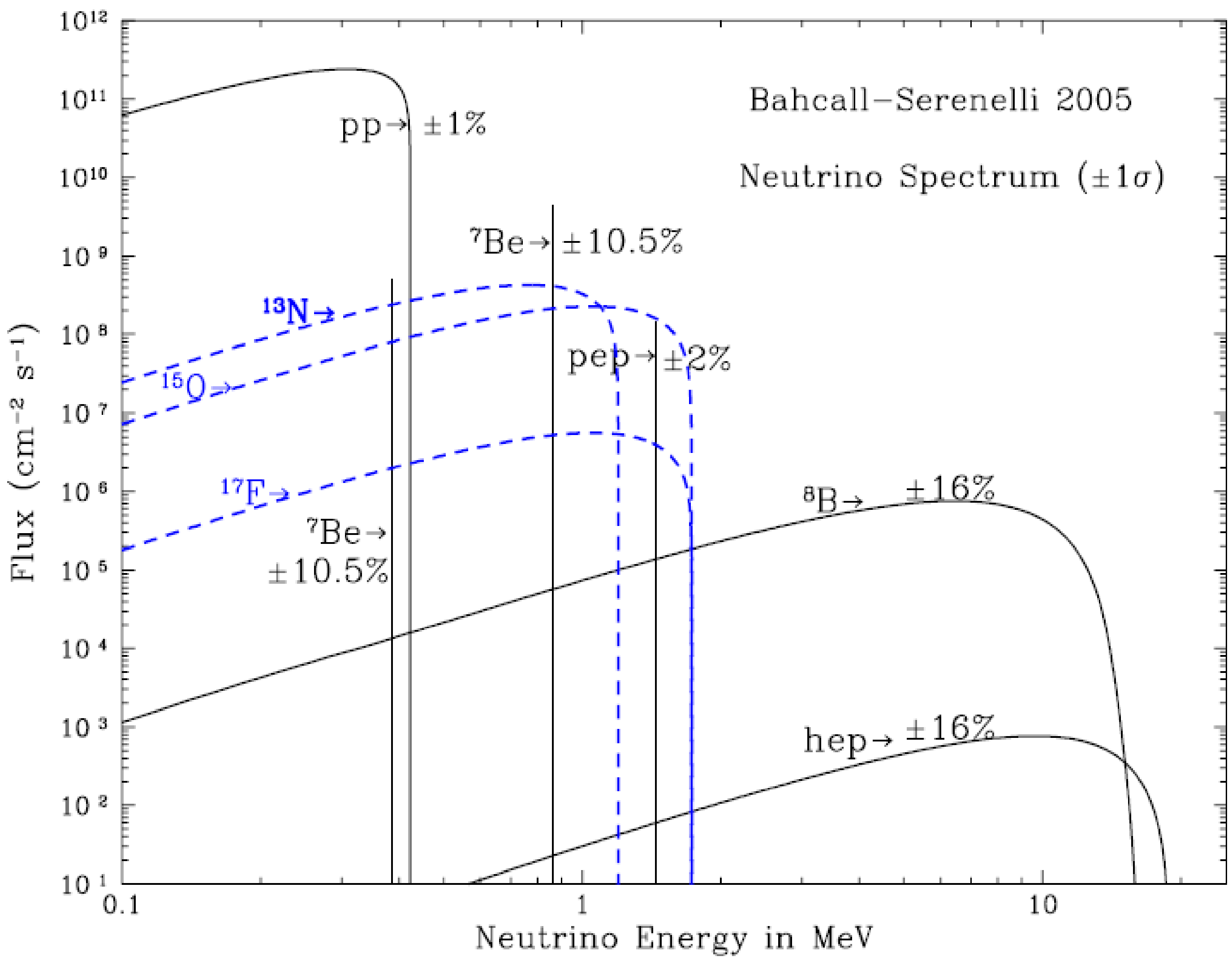
Two cases: $^{3}He(\alpha,\gamma)^{7}Be$ and $^{12}C(\alpha,\gamma)^{16}O$

Hydrogen burning and solar neutrinos

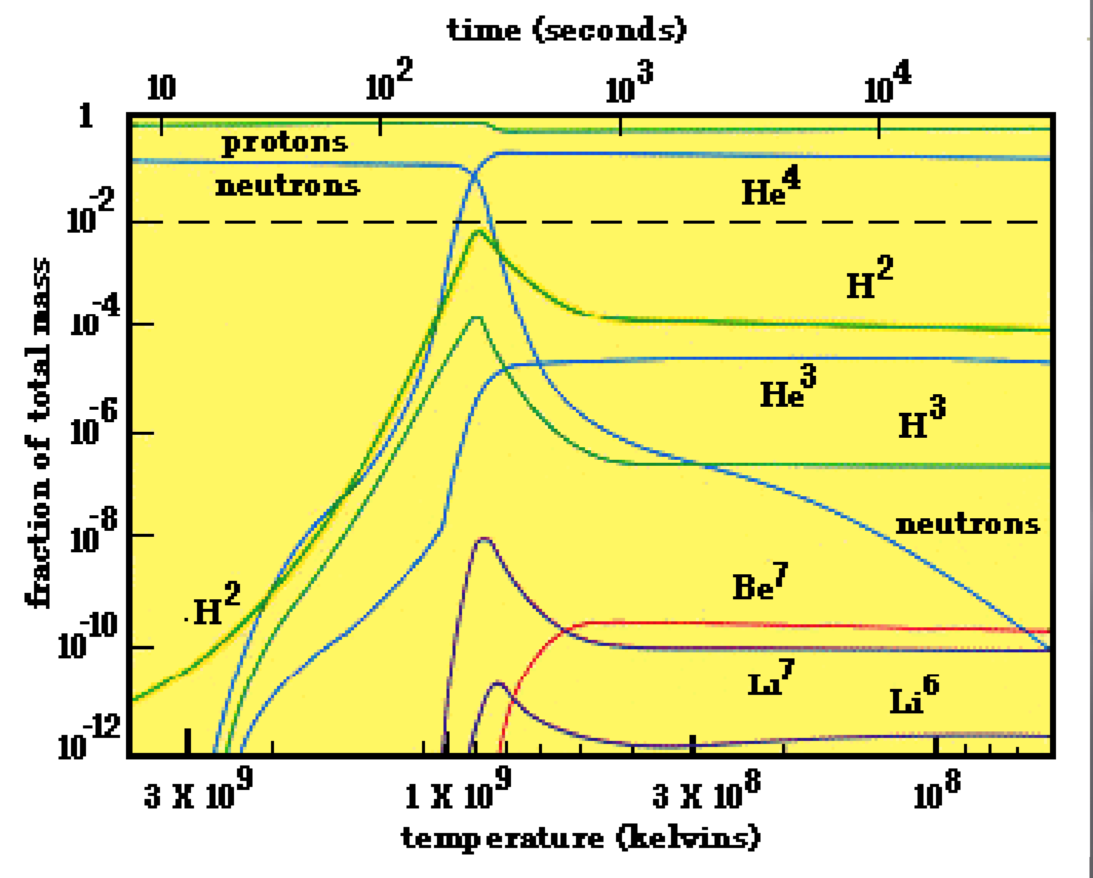


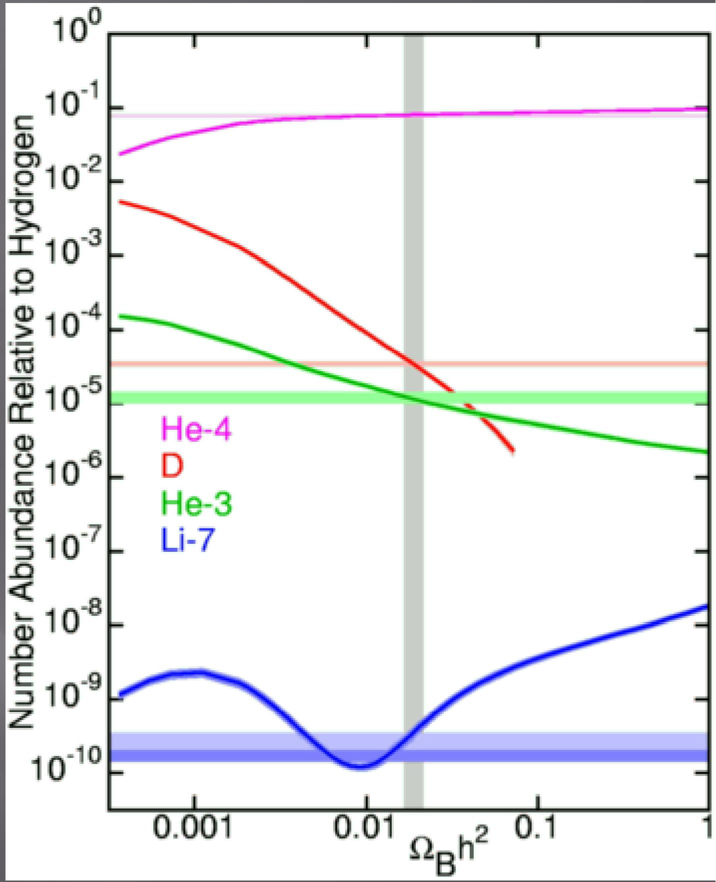
e.g. Haxton 2008

Neutrino oscillations

Neutrino astronomy (solar metallicity)

Big Bang Nucleosynthesis

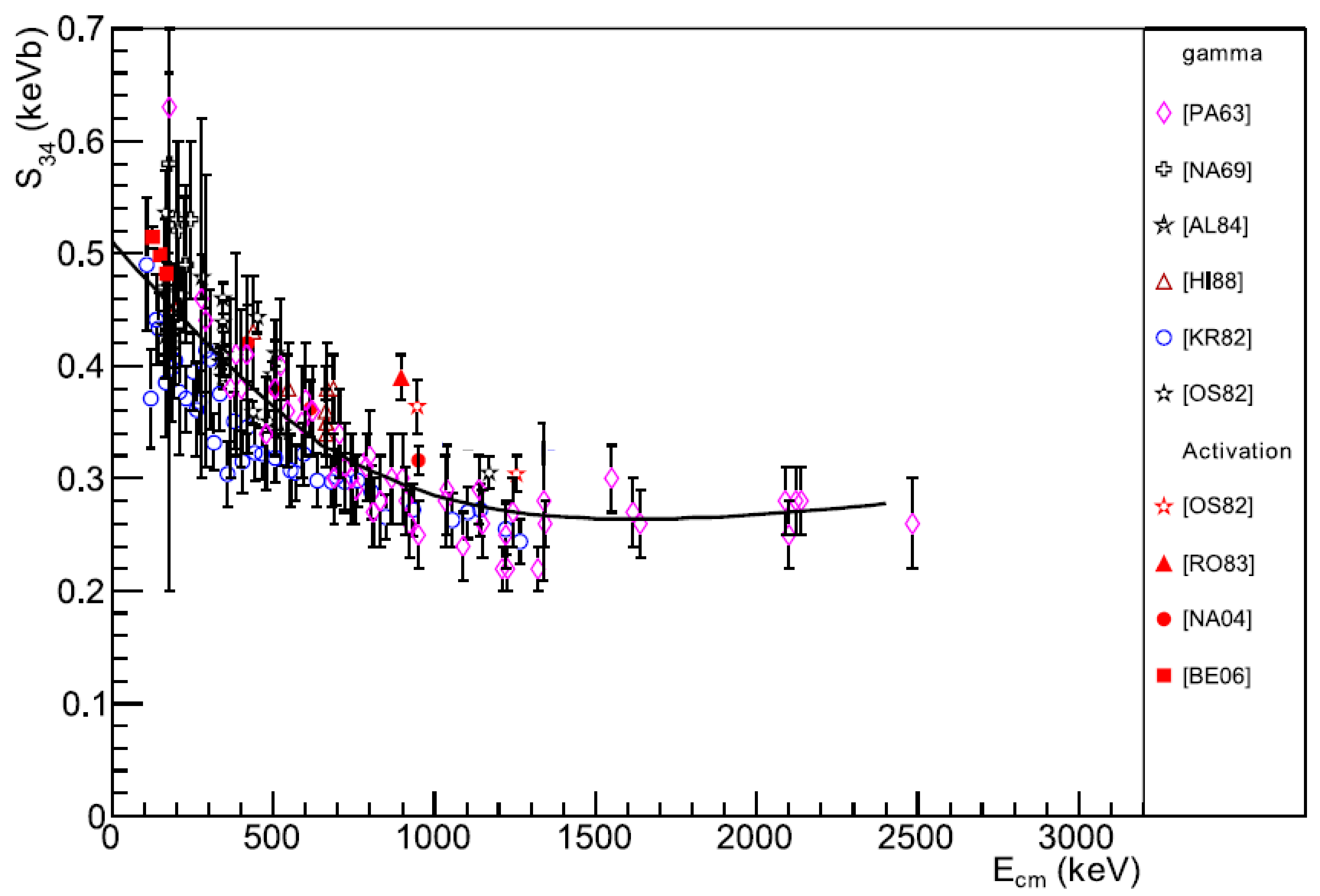


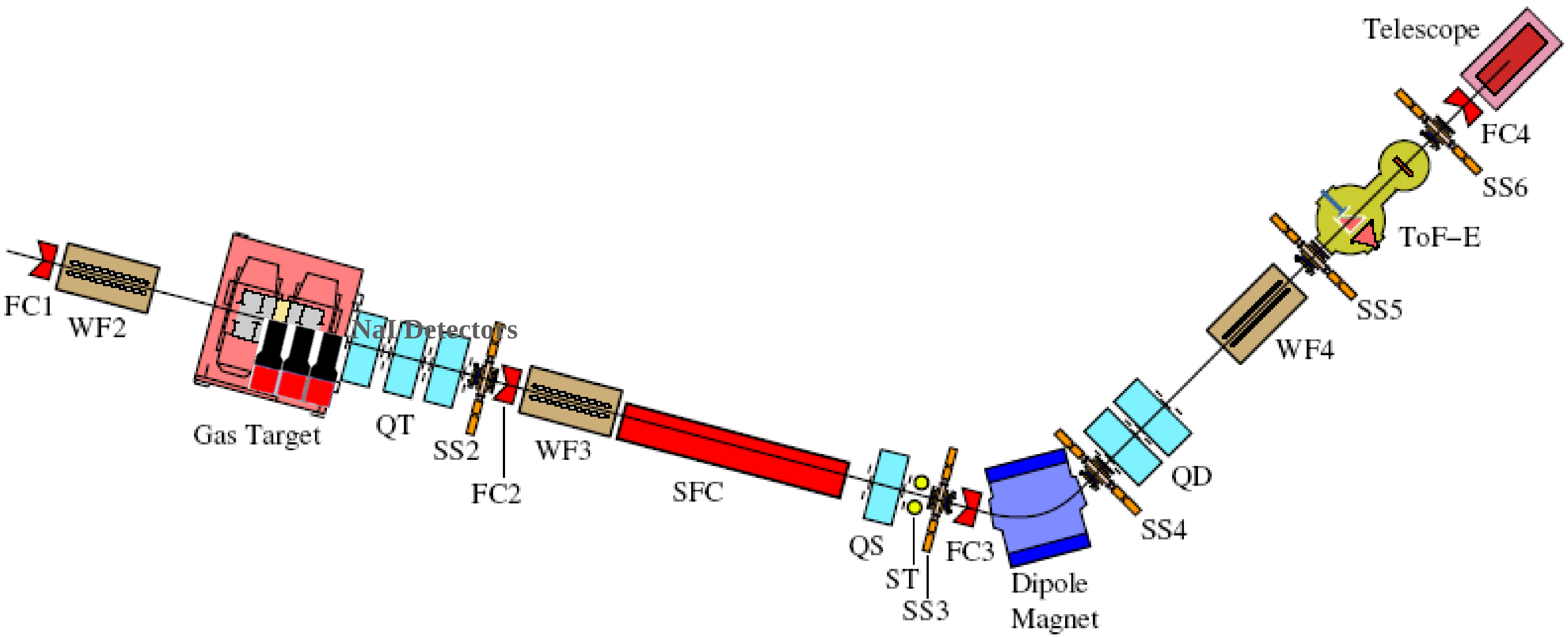


^{7}Li problem ?

http://www.astro.ucla.edu/~wright/BBNS.html

$^3He(\alpha,\gamma)^7Be$



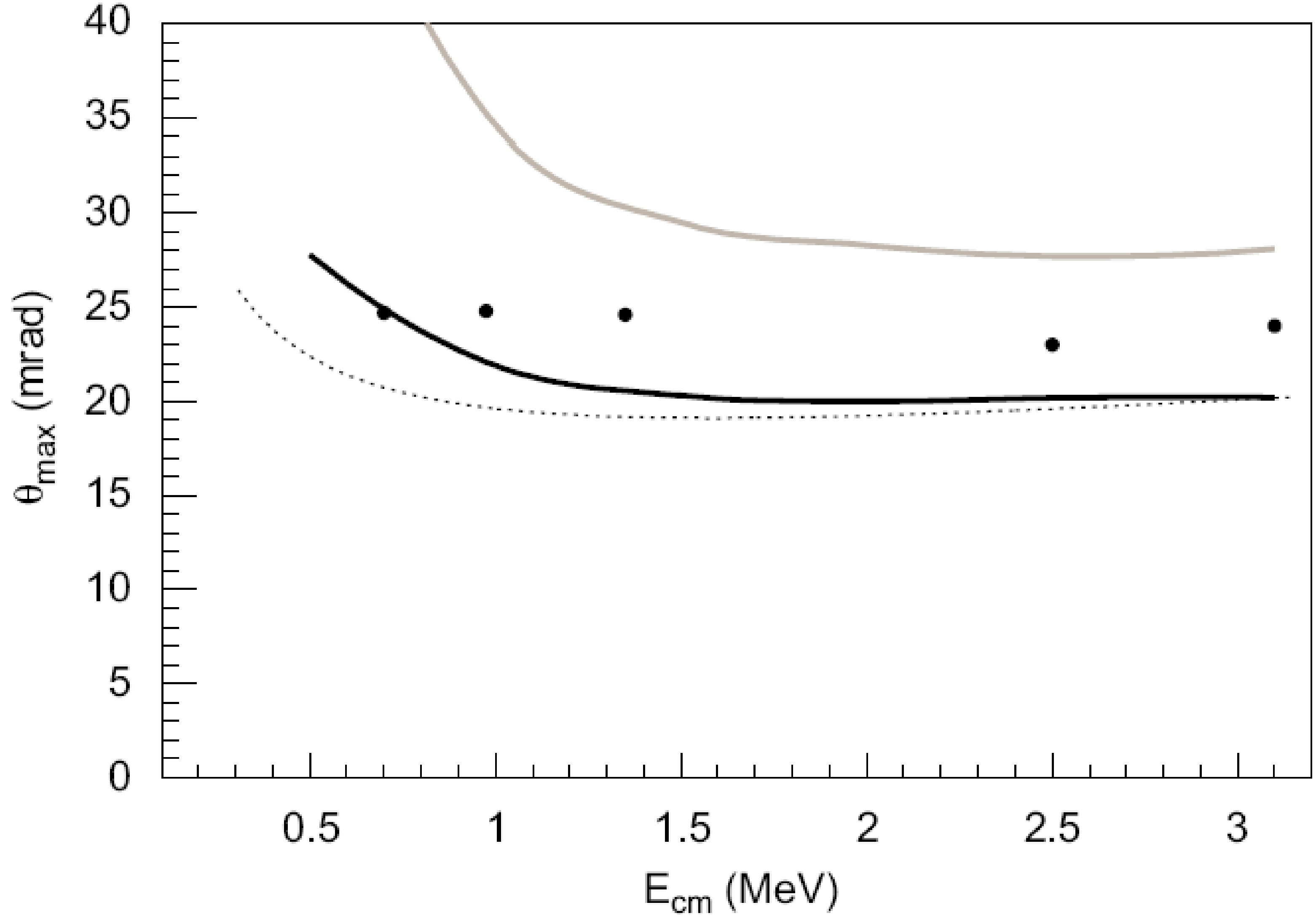


$$\sigma_{tot}(E_{eff}) = \sum_q \frac{N_{^7Be,q}}{N_{^4He,q} \cdot T(q)} \cdot \frac{1}{N_{^3He}\epsilon_{^7Be}}$$

$$\frac{\sigma_\gamma(E_{eff})}{\sigma_{tot}(E_{eff})} = \frac{\sum_q N_{\gamma,q}/N_{^4He,q}}{\sum_q N_{^7Be,q}/N_{^4He,q}} \cdot \frac{N_{^3He}}{\int N_{^3He}(z)\epsilon_\gamma(z)dz}$$

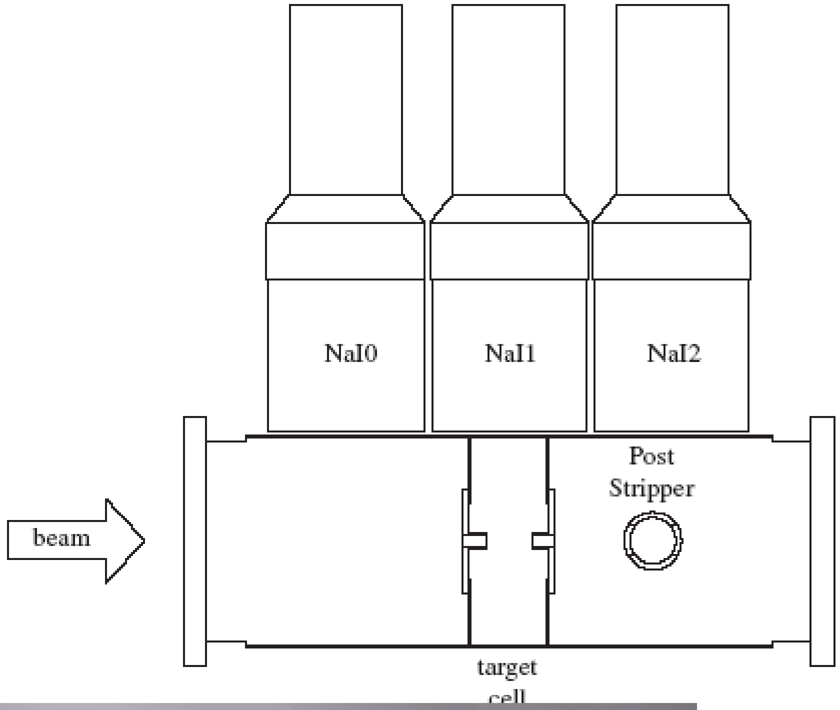
Di Leva et al NIM A 595 (2008)

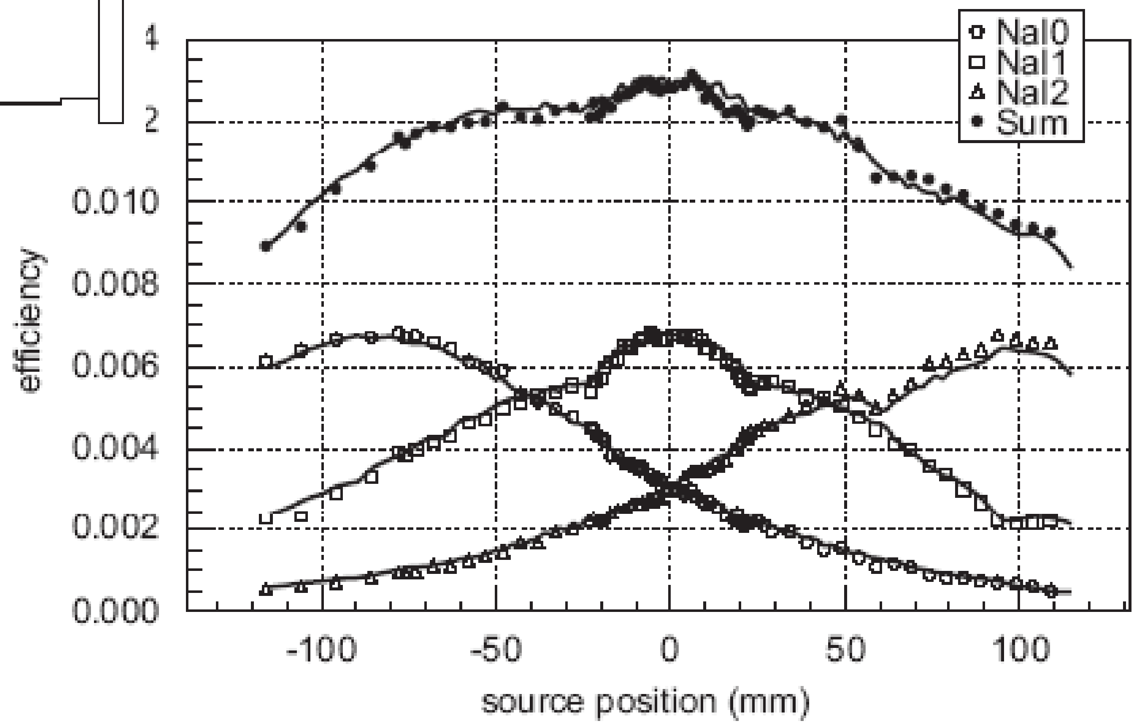
Acceptance



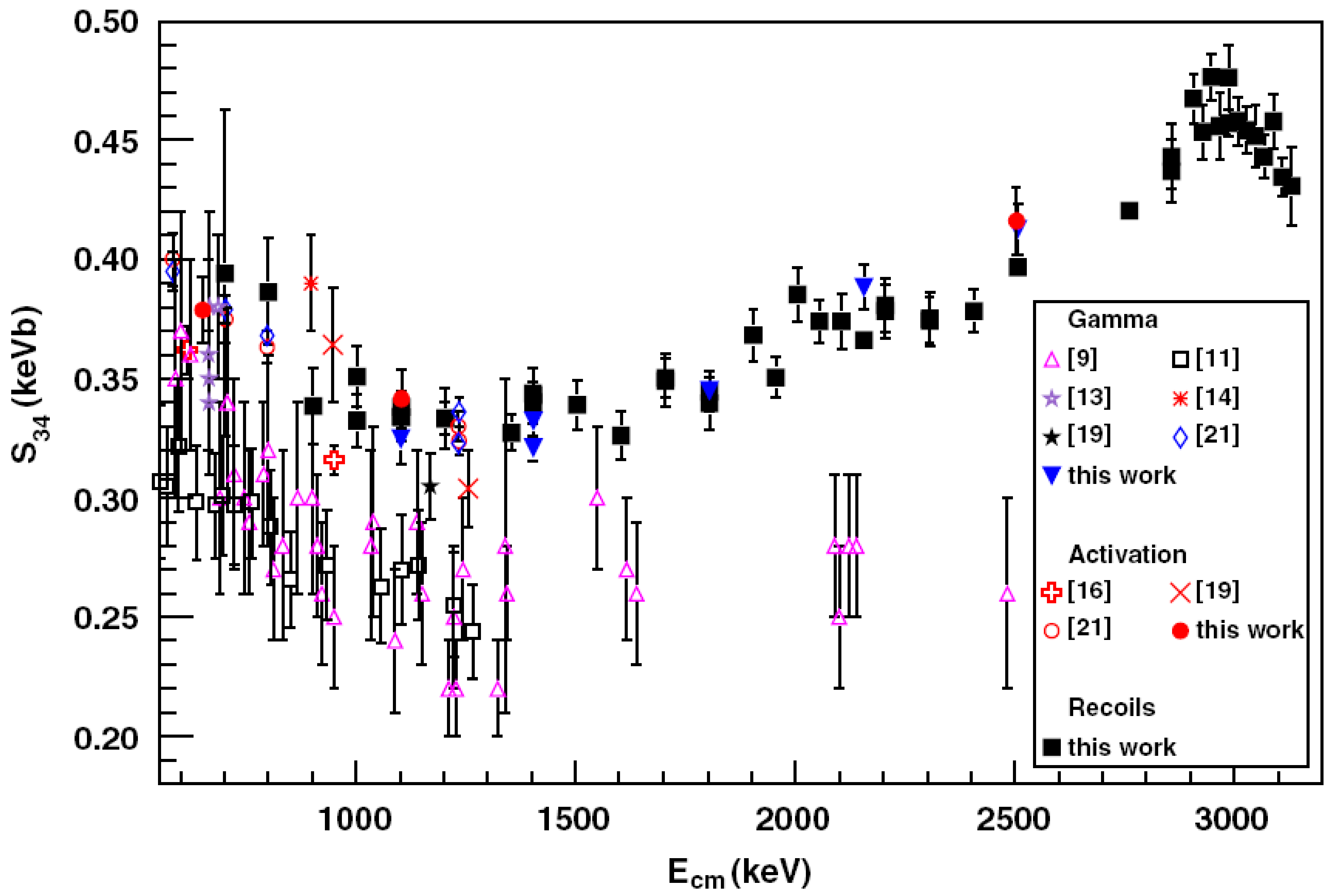
Di Leva et al NIM A 595 (2008)

Gamma ray detection efficiency

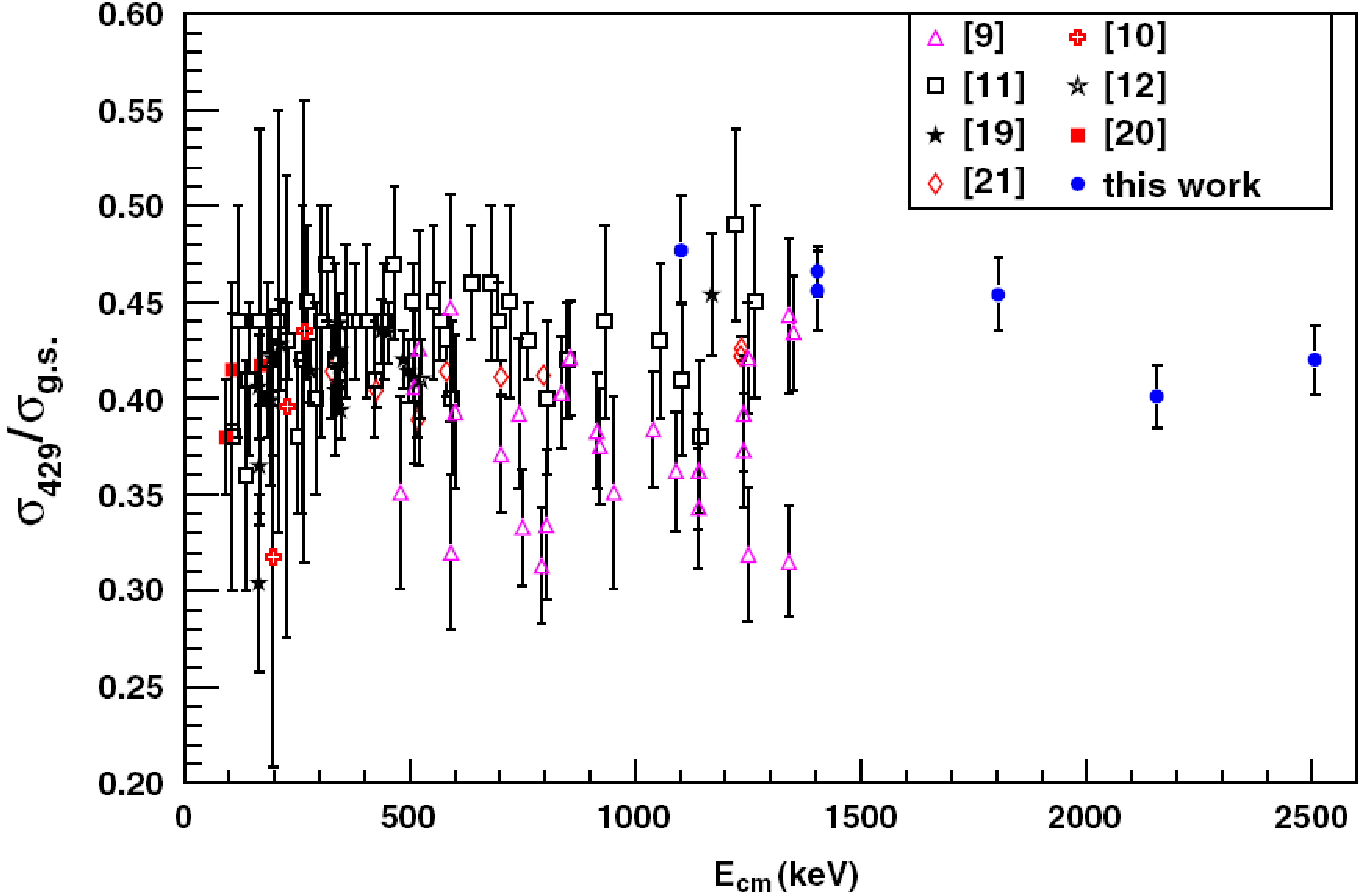




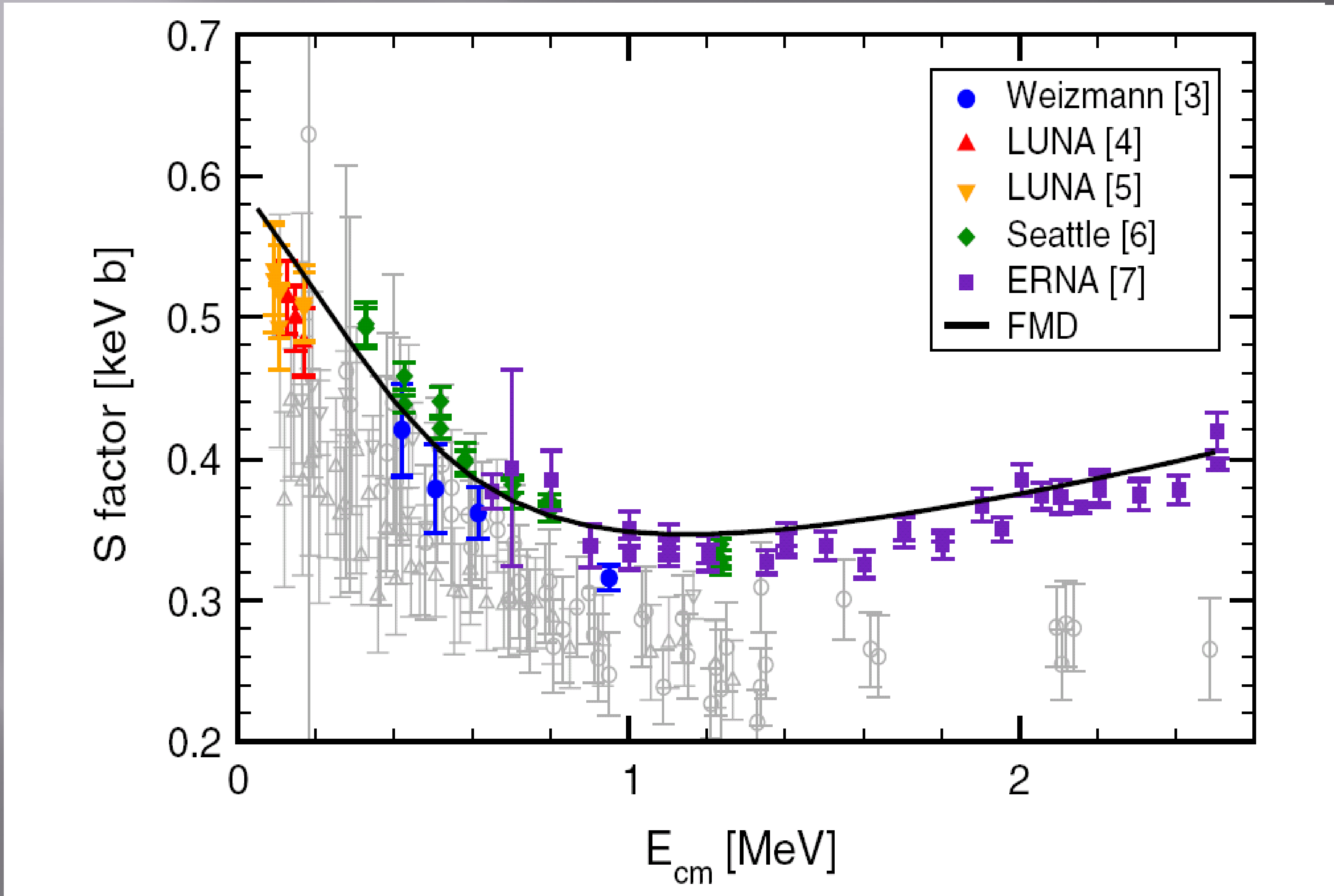
Di Leva et al NIM A 595 (2008)



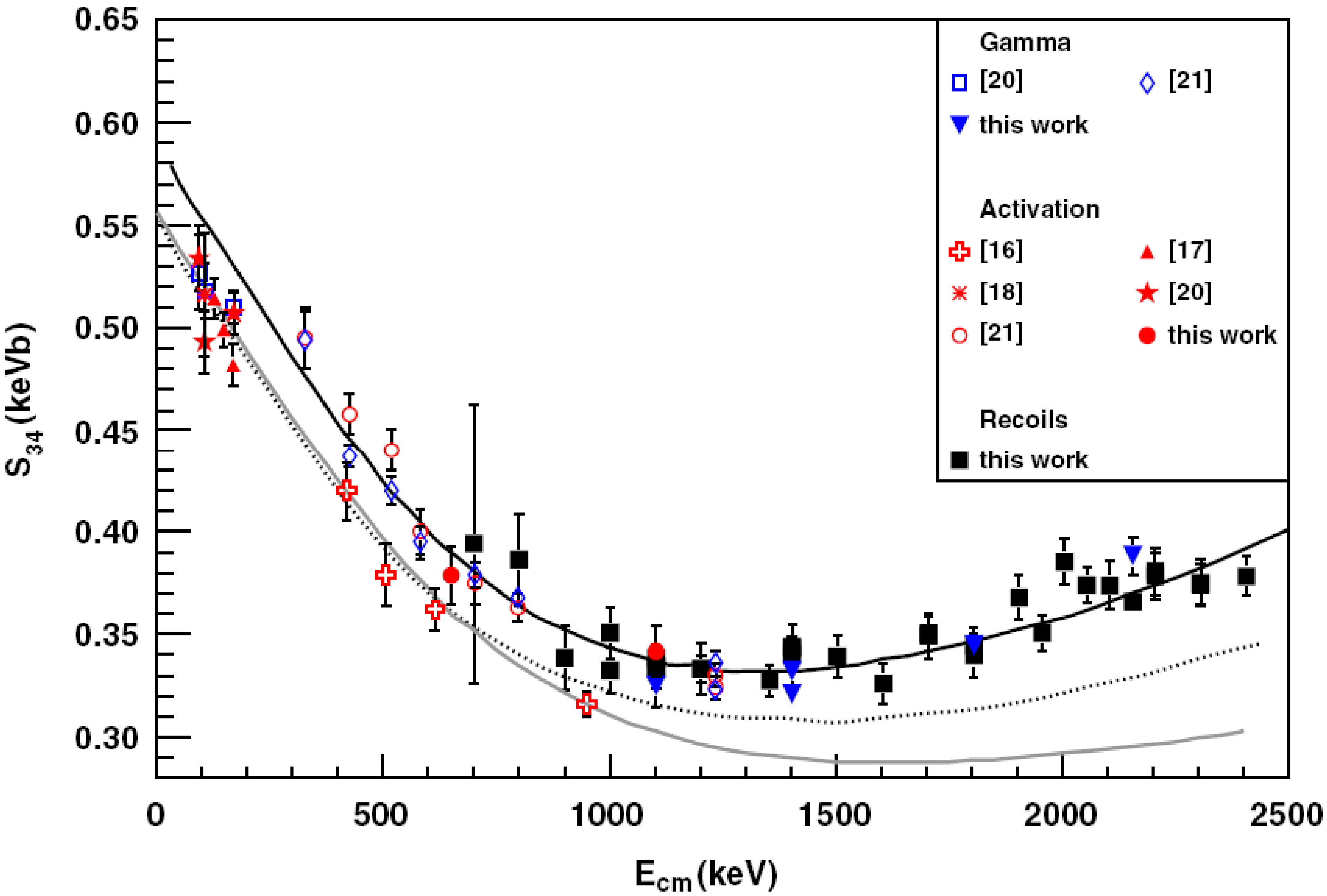
Di Leva et al, PRL 102, 232502 (2009)


0.60
0.55
0.50
0.45
0.40
0.35
0.30
0.25
0.20
$\sigma_{429}/\sigma_{g.s.}$
0
500
1000
1500
2000
2500
E_{cm} (keV)
[9]
[10]
[11]
[12]
[19]
[20]
[21]
this work

$^3He(\alpha,\gamma)^7Be$

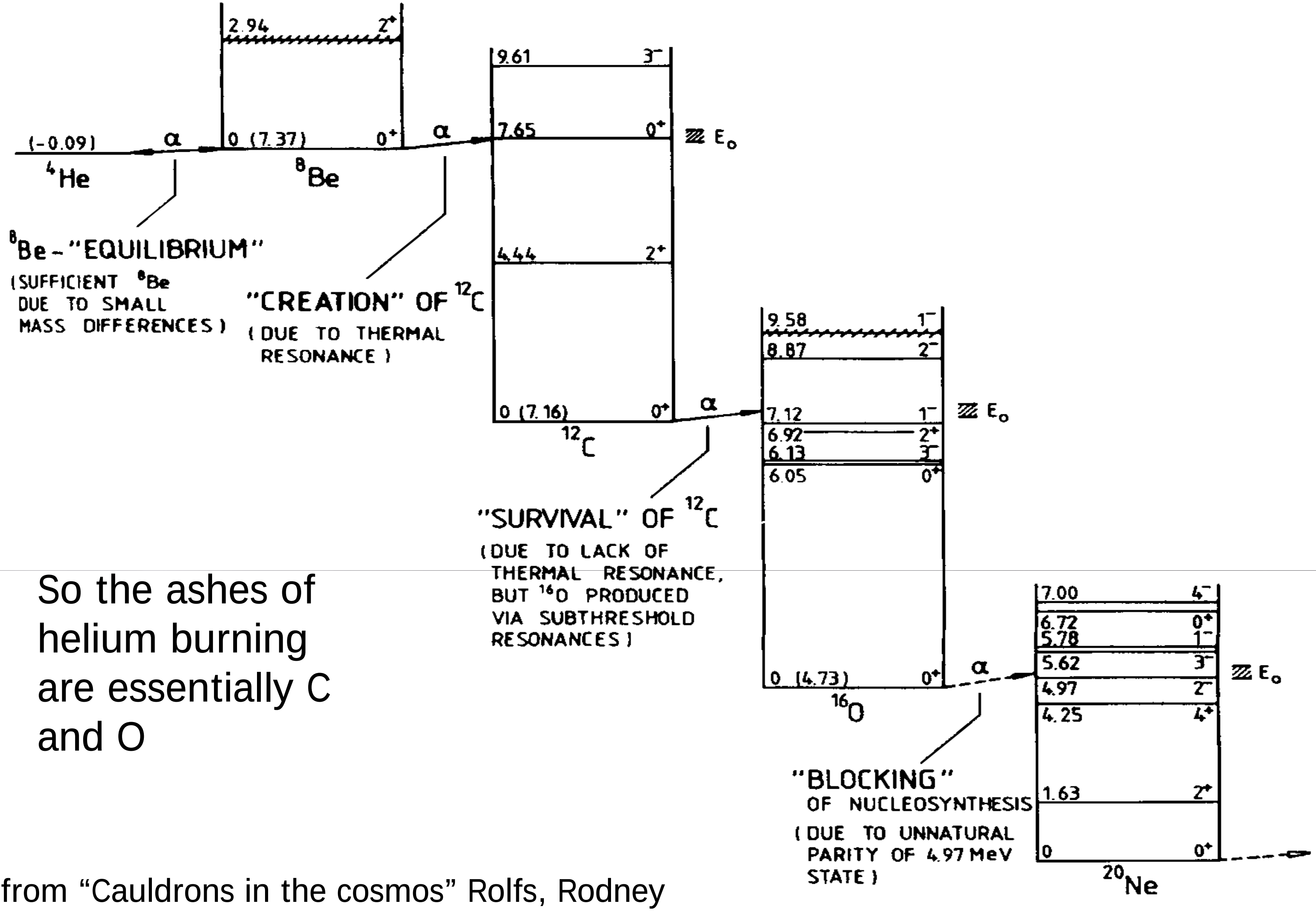


T.Neff ,PRL 106 (2011)



It might be mostly a normalization problem

Stellar Helium burning

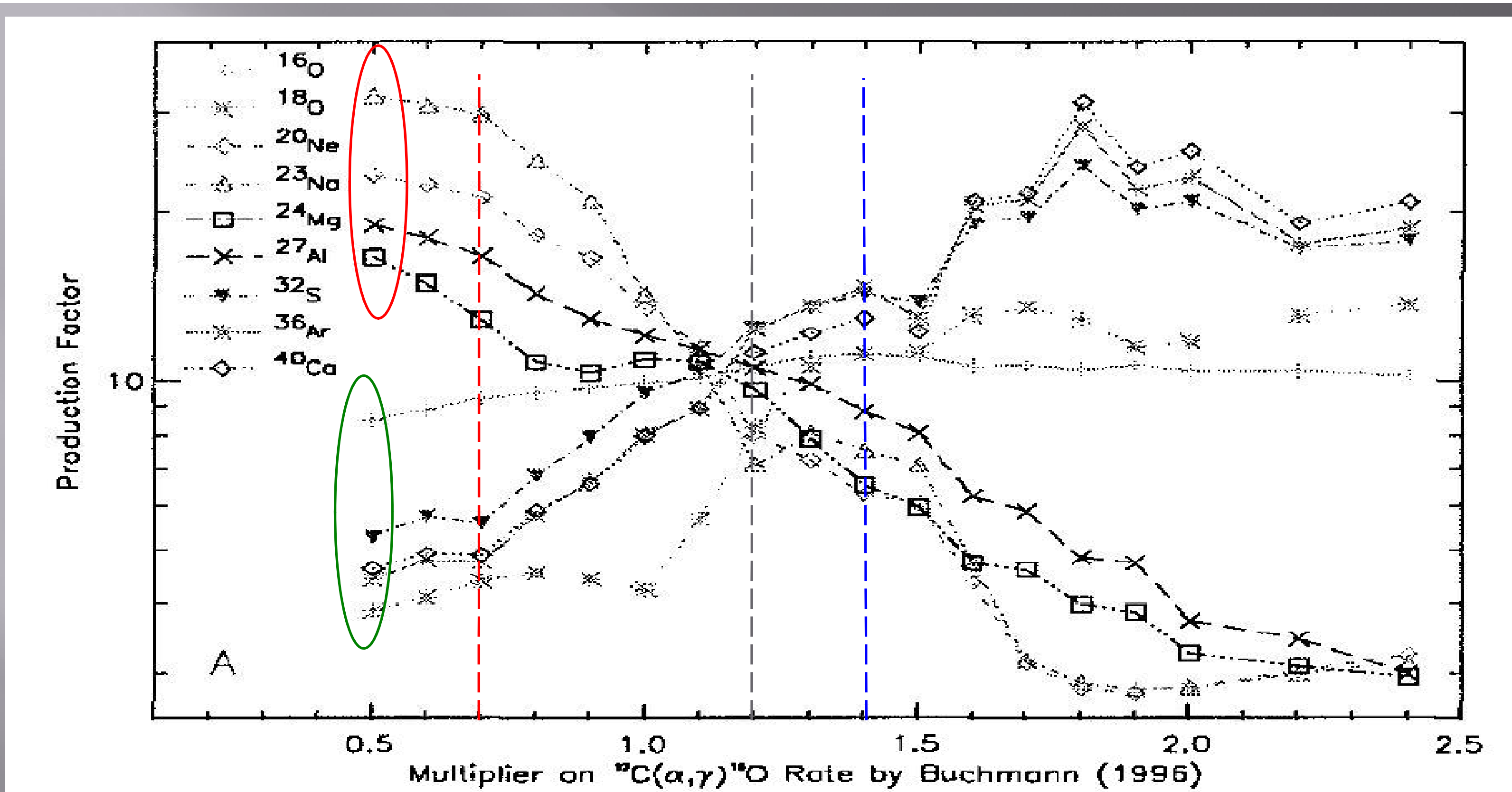


So the ashes of helium burning are essentially C and O

from "Cauldrons in the cosmos" Rolfs, Rodney

Astrophysical determination of S_{300}

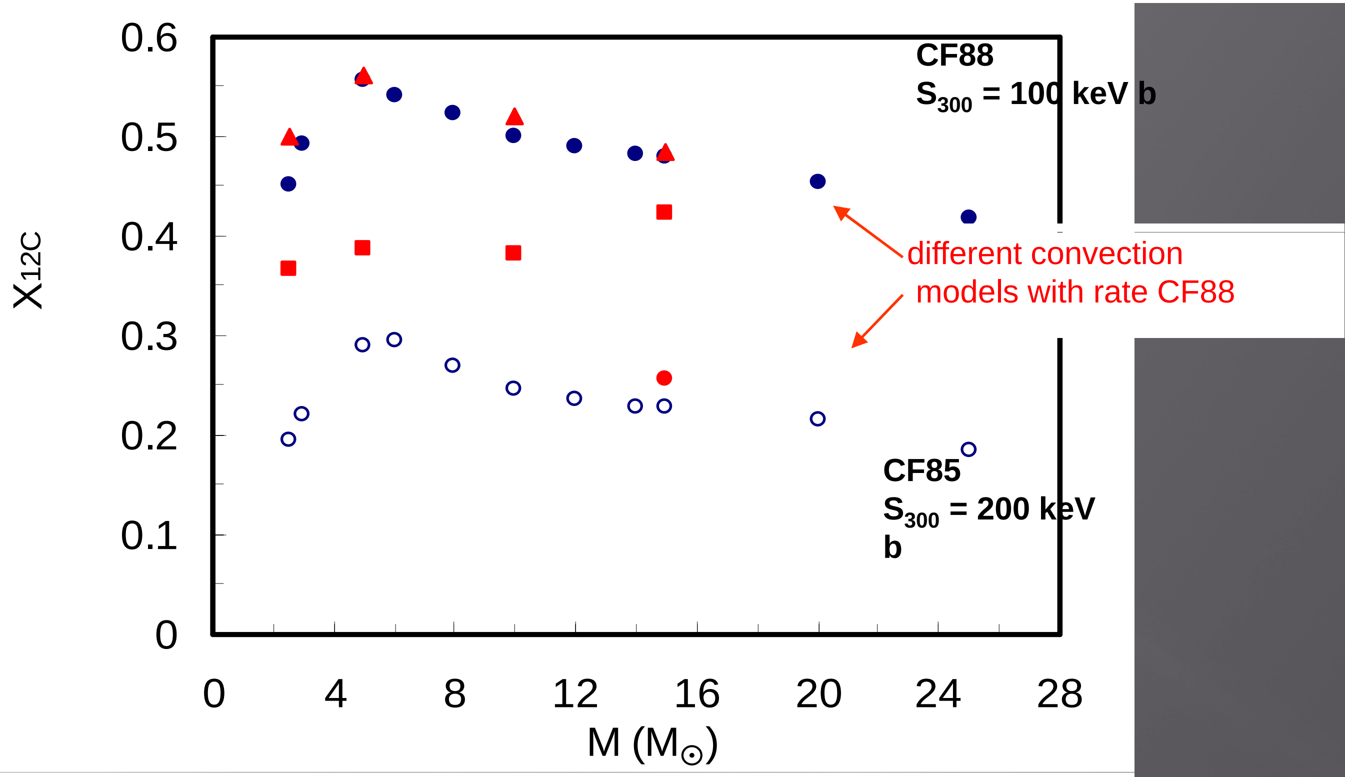
Astrophysical … core after He burning



S_0=170 ± 20 keV b [Woosley et al.NIC 7 (2003)]

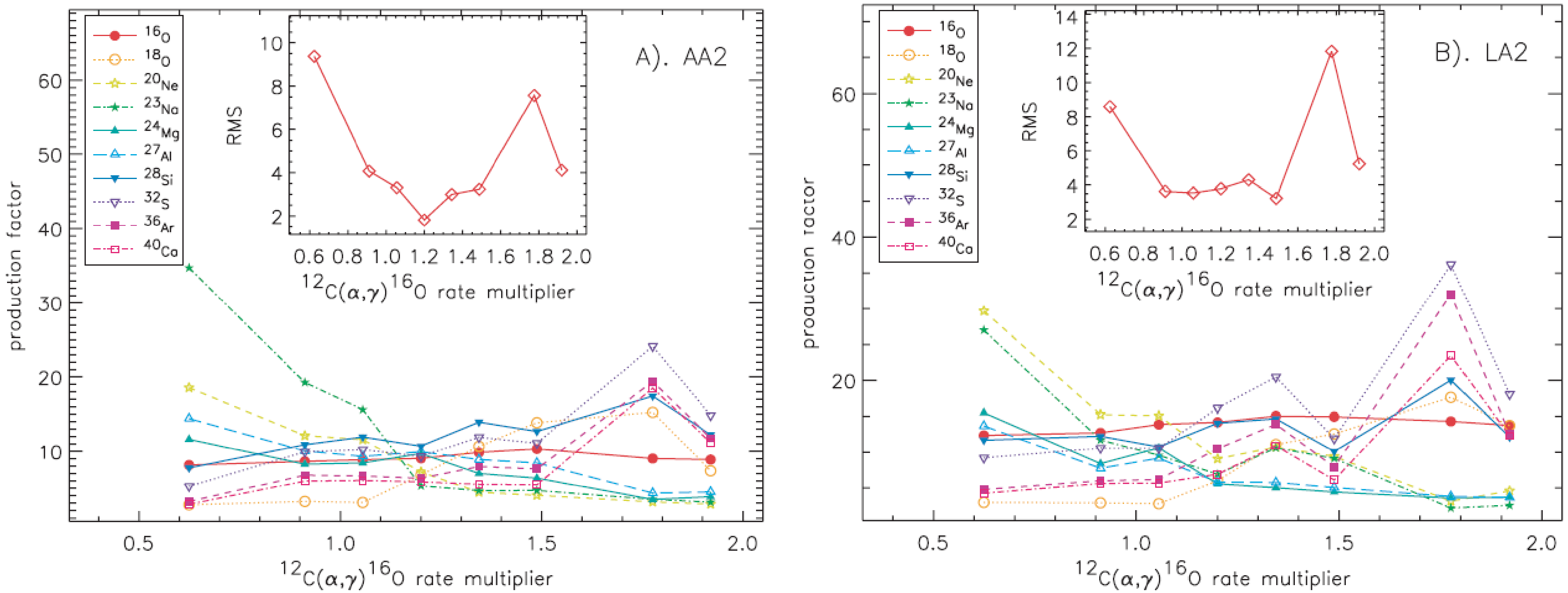
C = 0.26 ± 0.03

Astrophysical Astrophysical determination of S_{300} core after He burning



G. Imbriani et al. 2001, ApJ 2001

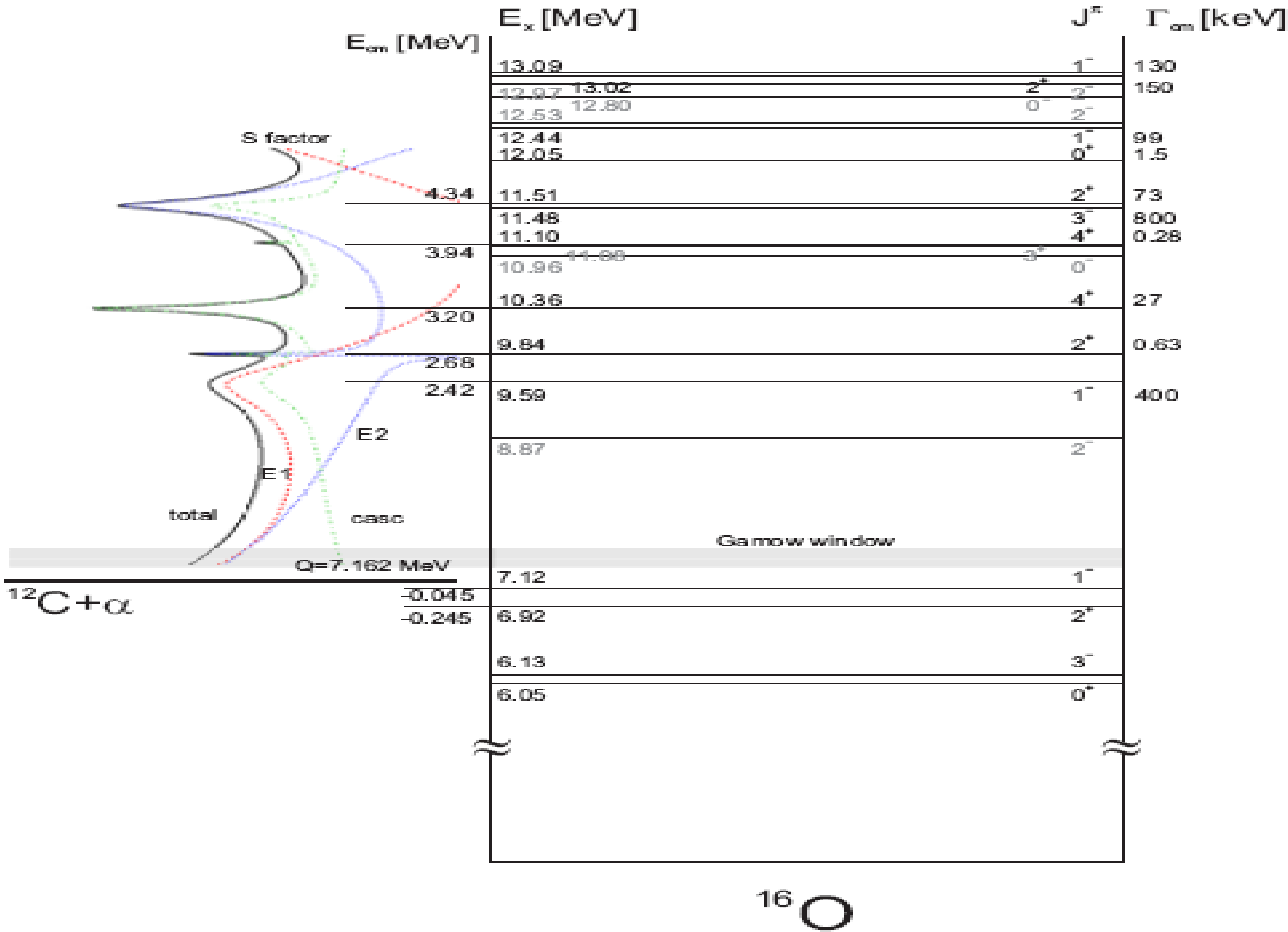
Effect of „different solar abundances“



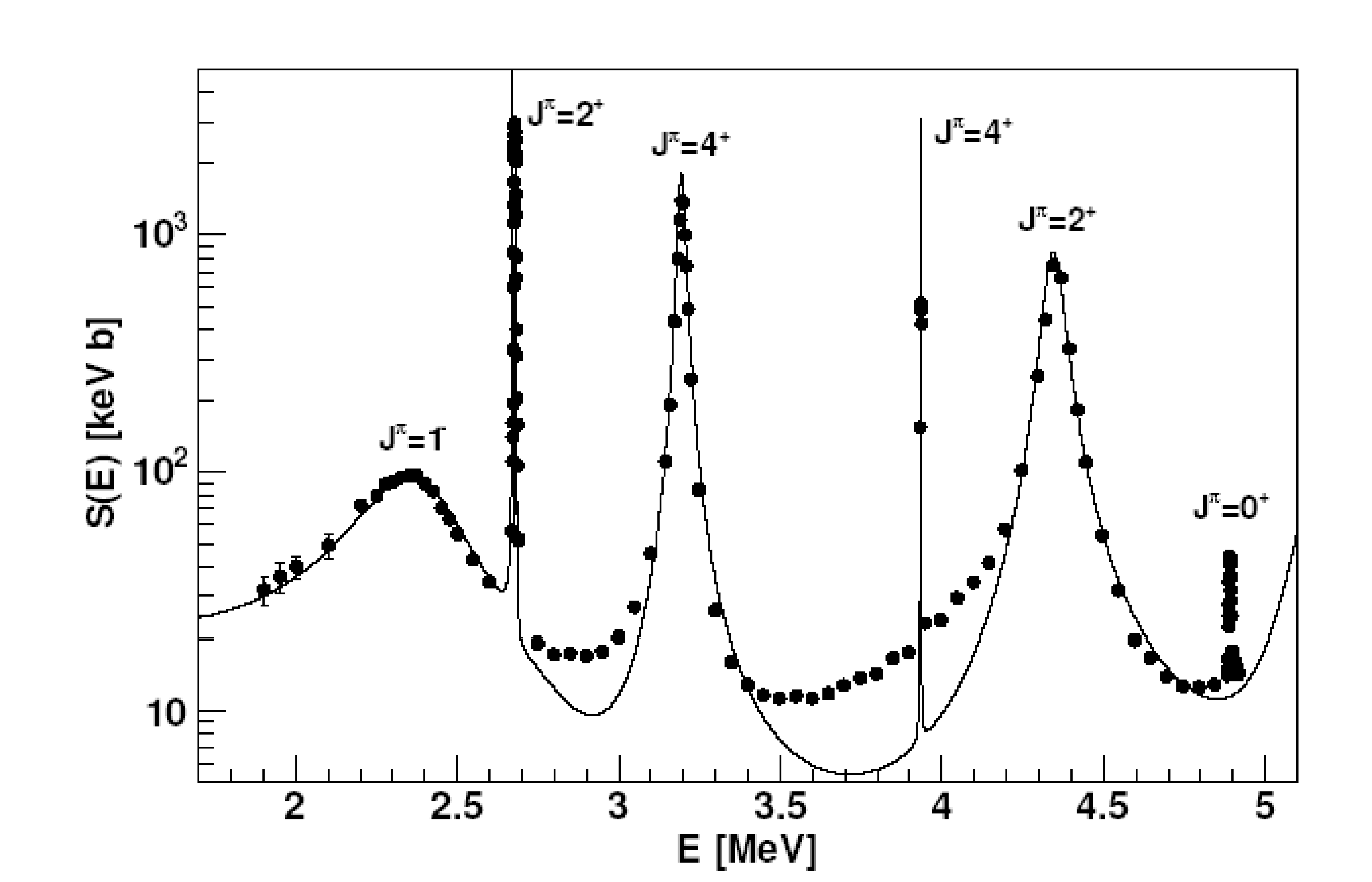
Anders and Grevesse,
Geochim. Cosmochim. Acta 53 (1989) 197

Lodders, Astroph. J. 591 (2003) 1220

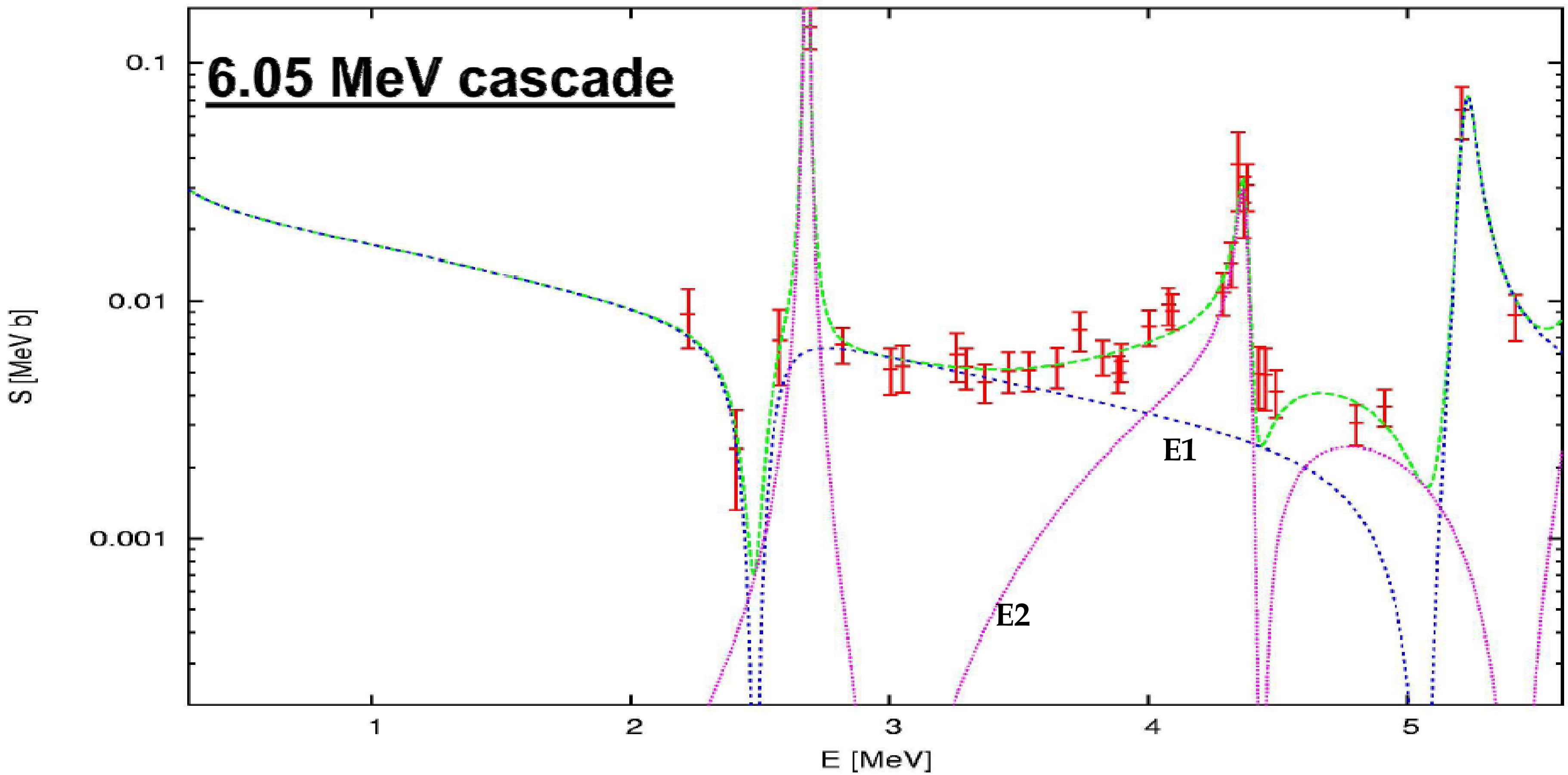
Tur C., Heger A. and Austin S. M., ApJ 671, 821-827 (2007)



E_x [MeV]
J^π
Γ_cm [keV]
E_cm [MeV]
13.09
1⁻
130
12.97
13.02
2⁺
2⁻
150
12.53
12.80
0⁻
2⁻
S factor
12.44
1⁻
99
12.05
0⁺
1.5
4.34
11.51
2⁺
73
11.48
3⁻
800
11.10
4⁺
0.28
3.94
11.08
3⁺
10.96
0⁻
10.36
4⁺
27
3.20
9.84
2⁺
0.63
2.68
2.42
9.59
1⁻
400
E2
8.87
2⁻
E1
total
casc
Gamow window
Q=7.162 MeV
12C+α
7.12
1⁻
-0.045
-0.245
6.92
2⁺
6.13
3⁻
6.05
0⁺
16O

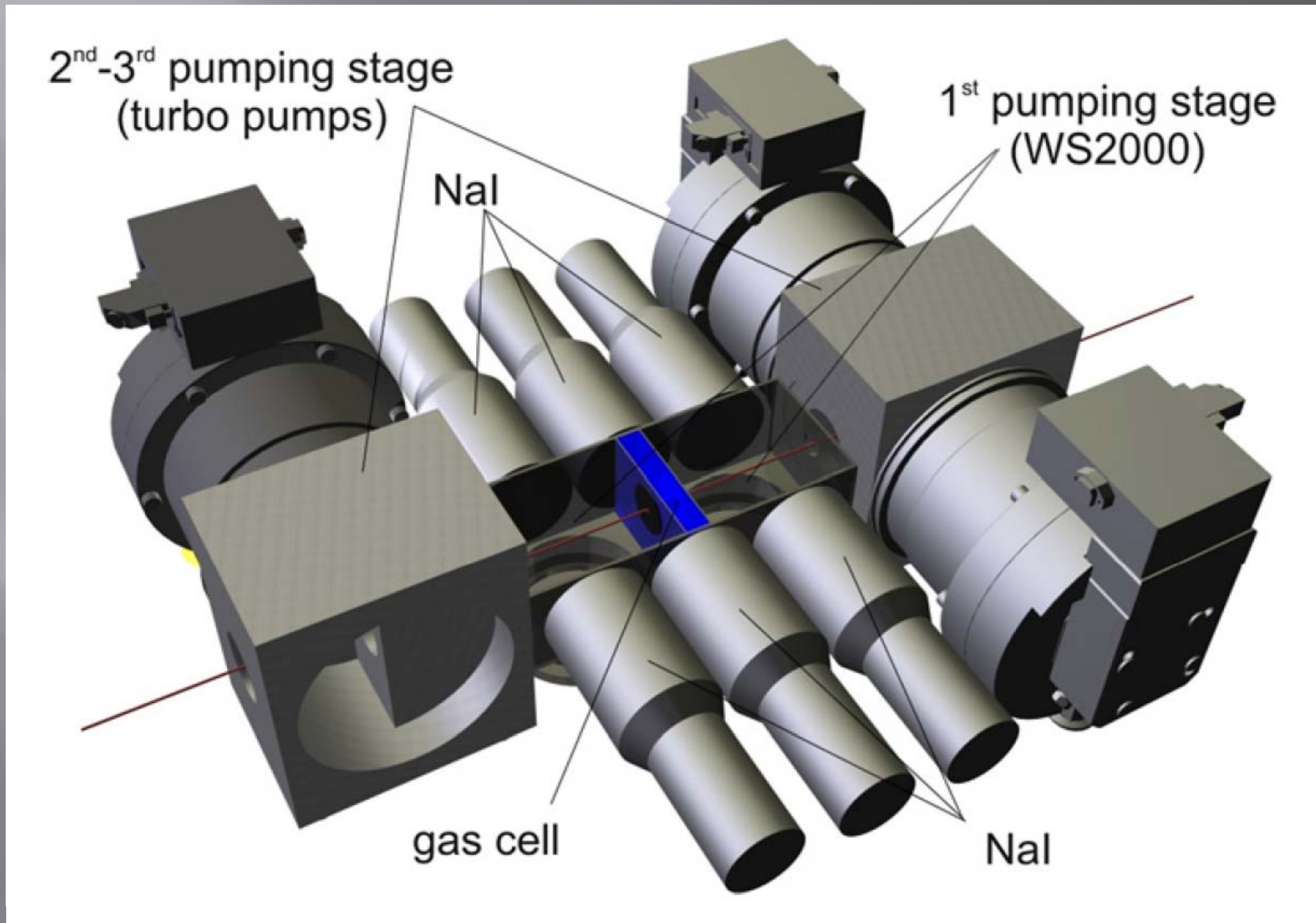


Schuermann et al Eur. Phys. J. A 26, 301{305 (2005) vs Kunz Astrophys. J. 567, 643 (2002)

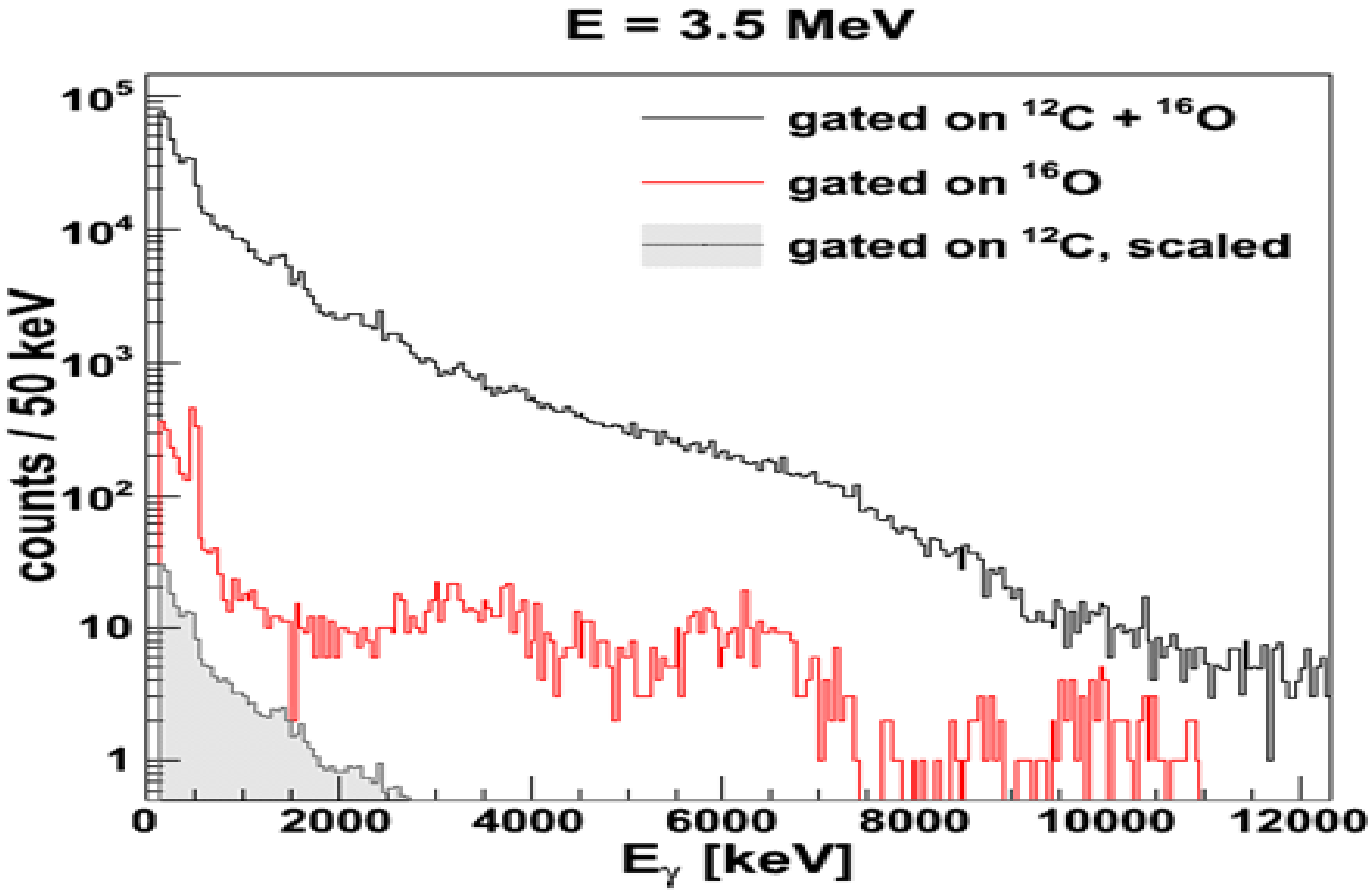


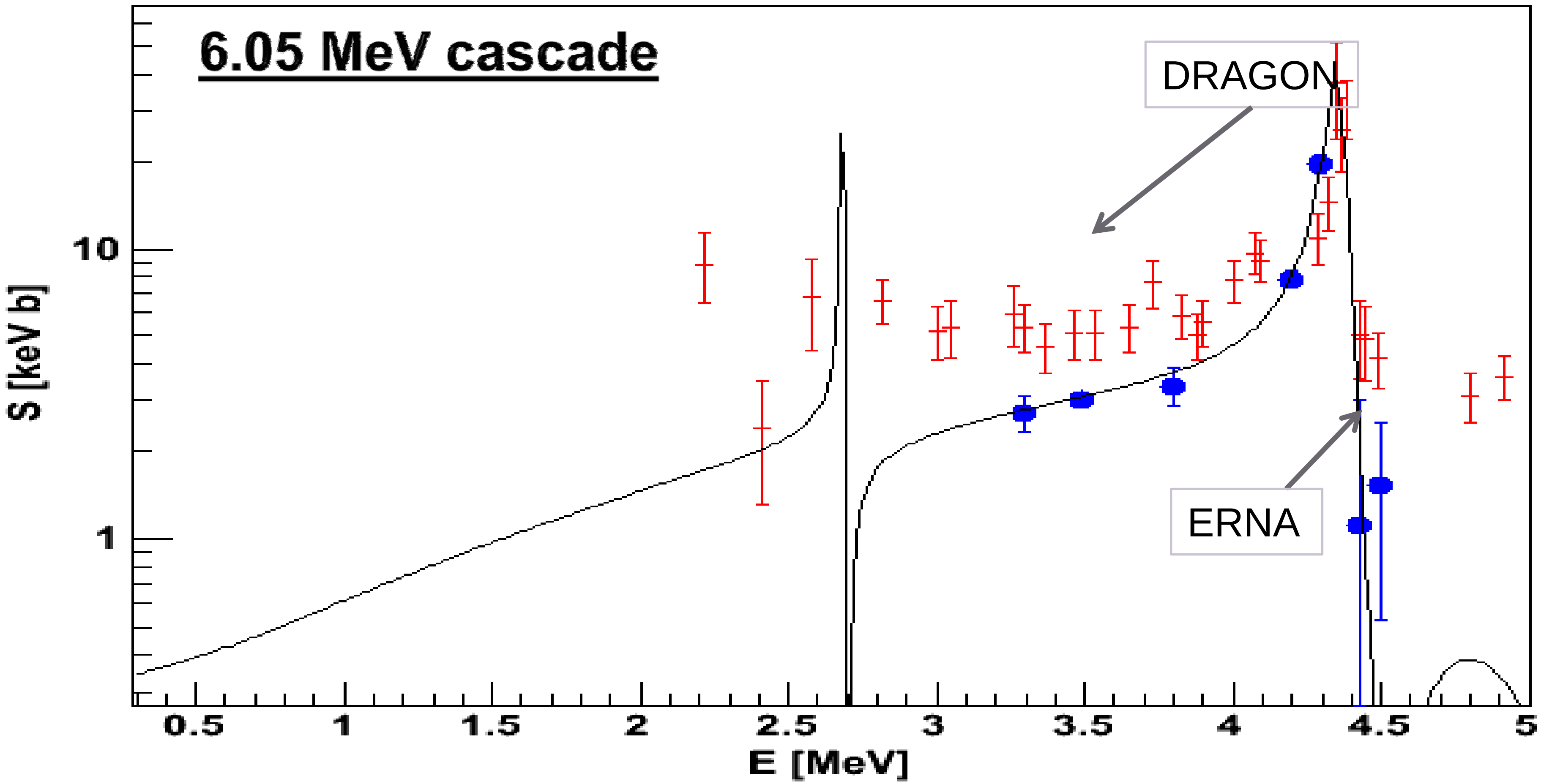
$S_{605} = 25_{-15}^{+16}$ keV b, i.e. ~ 15% of S(300)

C. Matei et al., Phys. Rev. Lett. 97(2006)


2nd-3rd pumping stage
(turbo pumps)
1st pumping stage
(WS2000)
NaI
gas cell
NaI

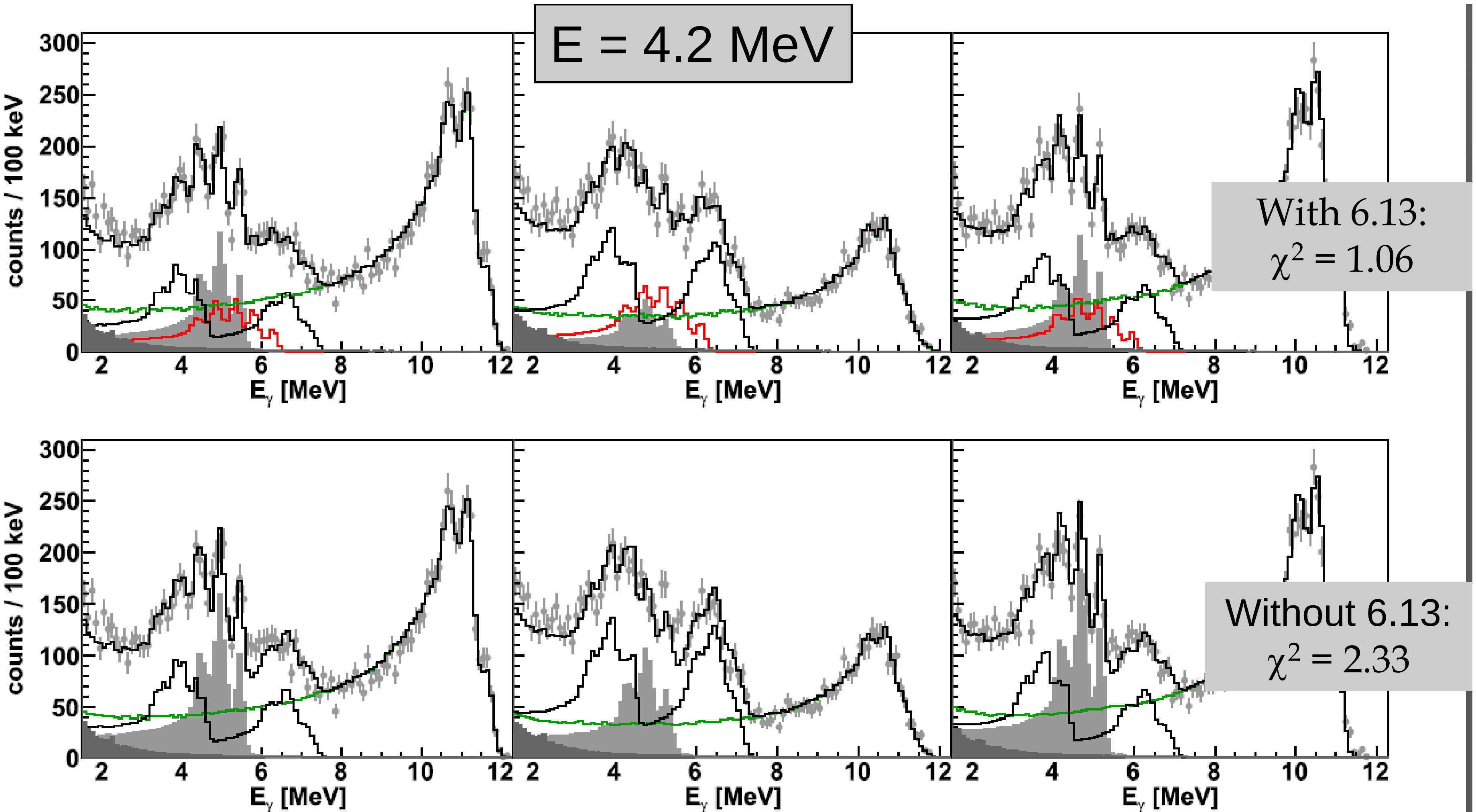
γ–ray detection



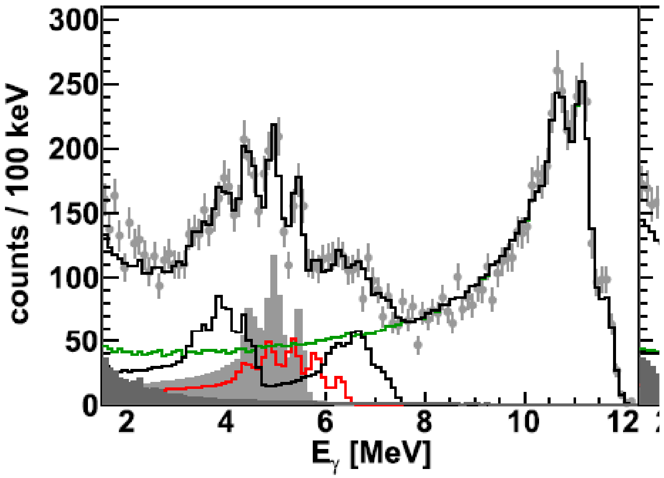


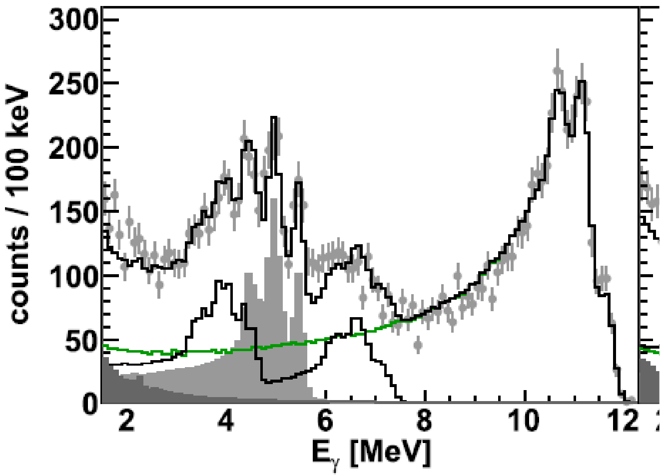
$S_{605}(300) < 1$ keV b

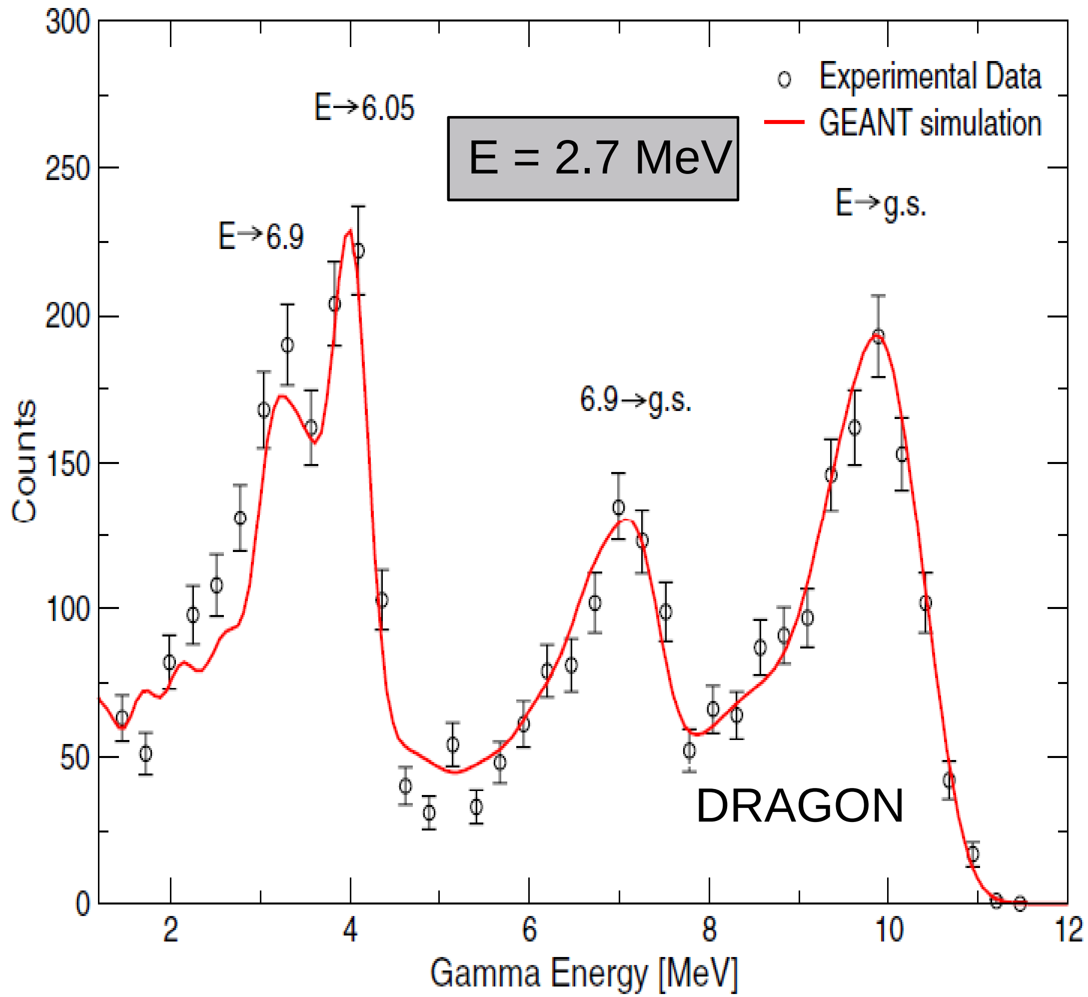
D. Schürmann et al., Phis. Lett.B 703(2011)



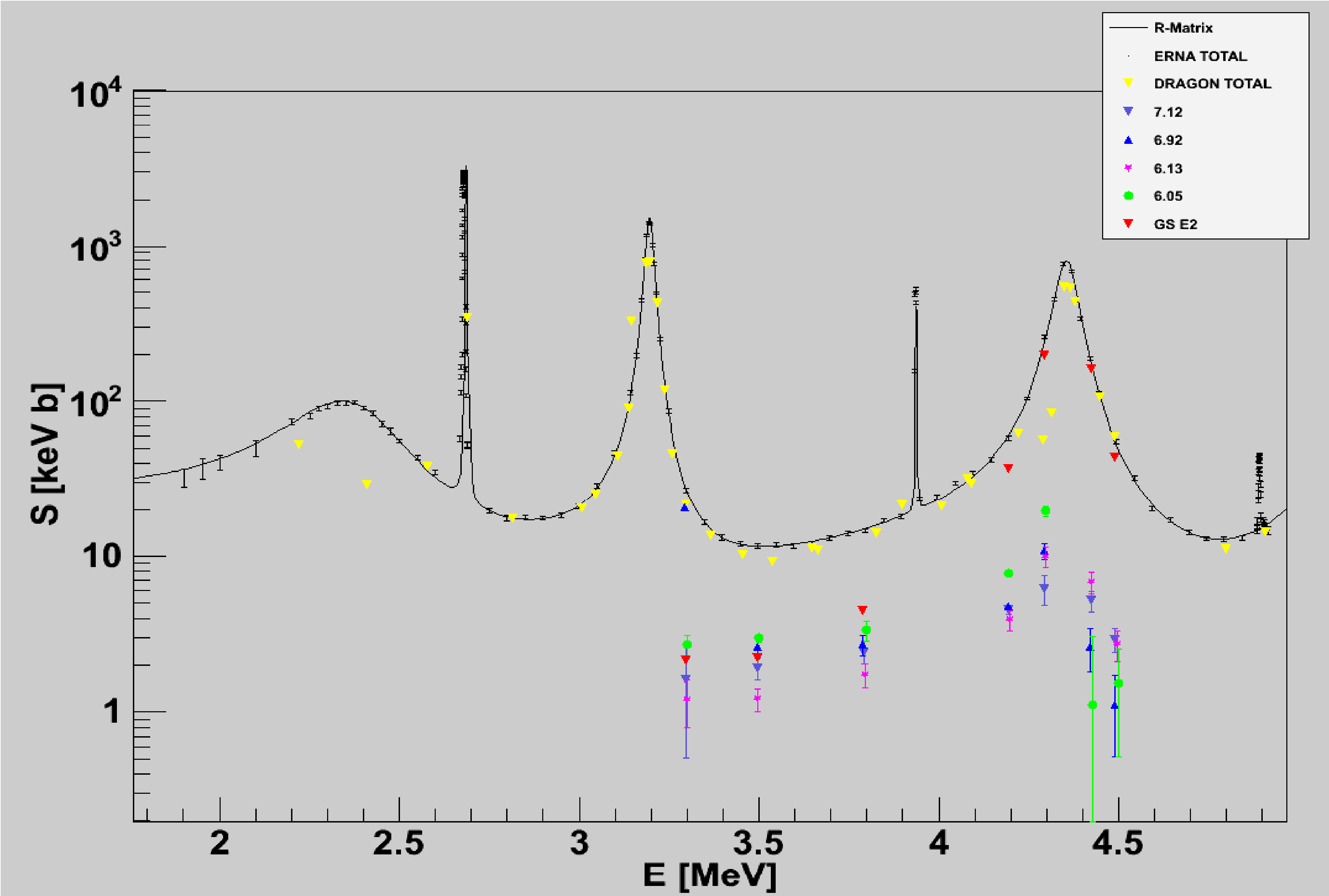
forward center backward







forward center backward

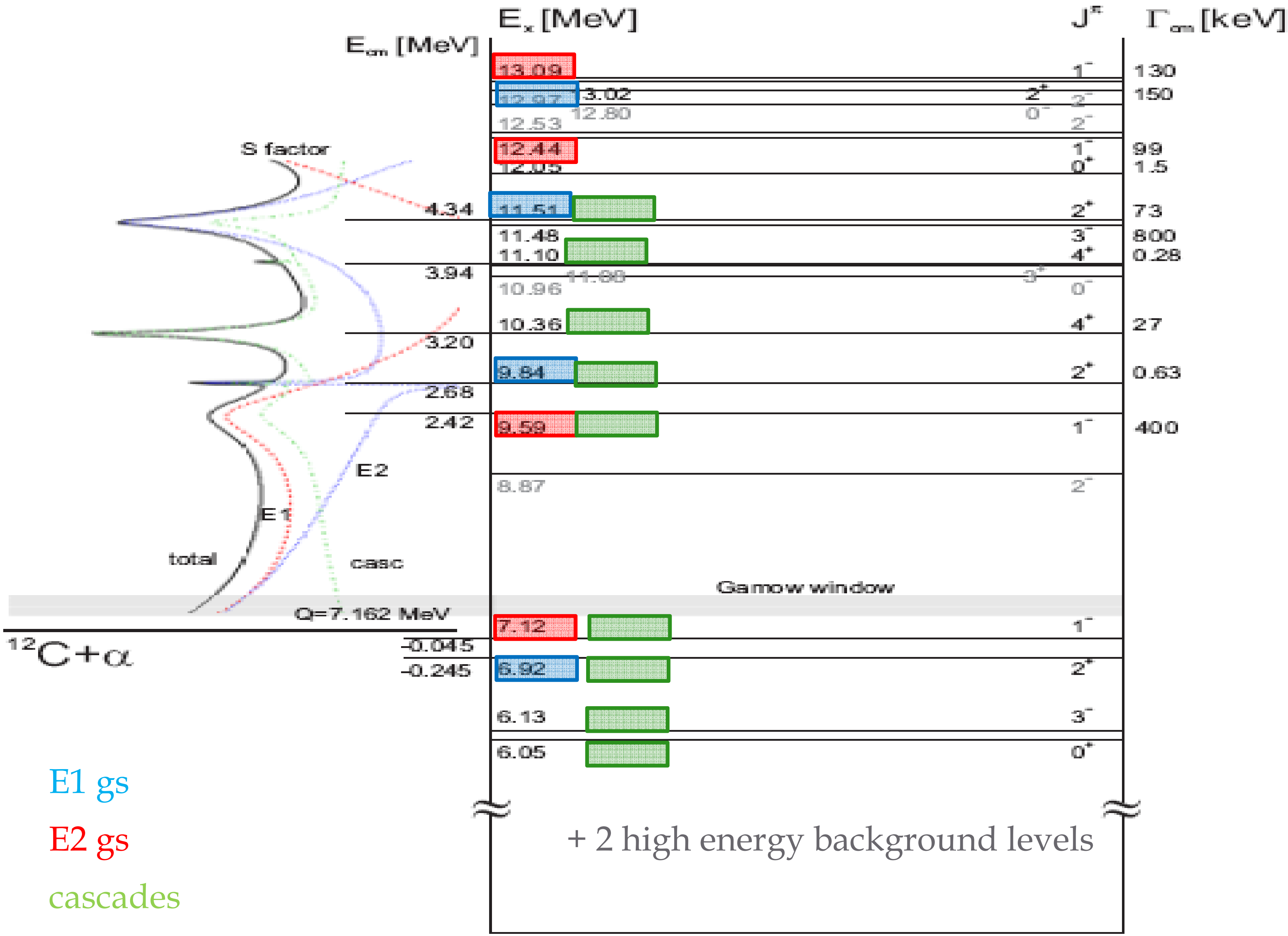


ERNA vs C. Matei, Ph.D. thesis

New R-Matrix calculation

- R-matrix code: inclusion of normalization in fitting procedure . MC estimation of uncertainty on S(300) (see lecture #4)
- Review and selection of data consistent with the model (for g-ray: E1 vs E2, sufficient energy resolution etc)
- Simultaneous fitting of elastic scattering, ^{16}N α-decay, γ-ray and total cross section data.

D. Schürmann et al., Phys. Lett. B 2012

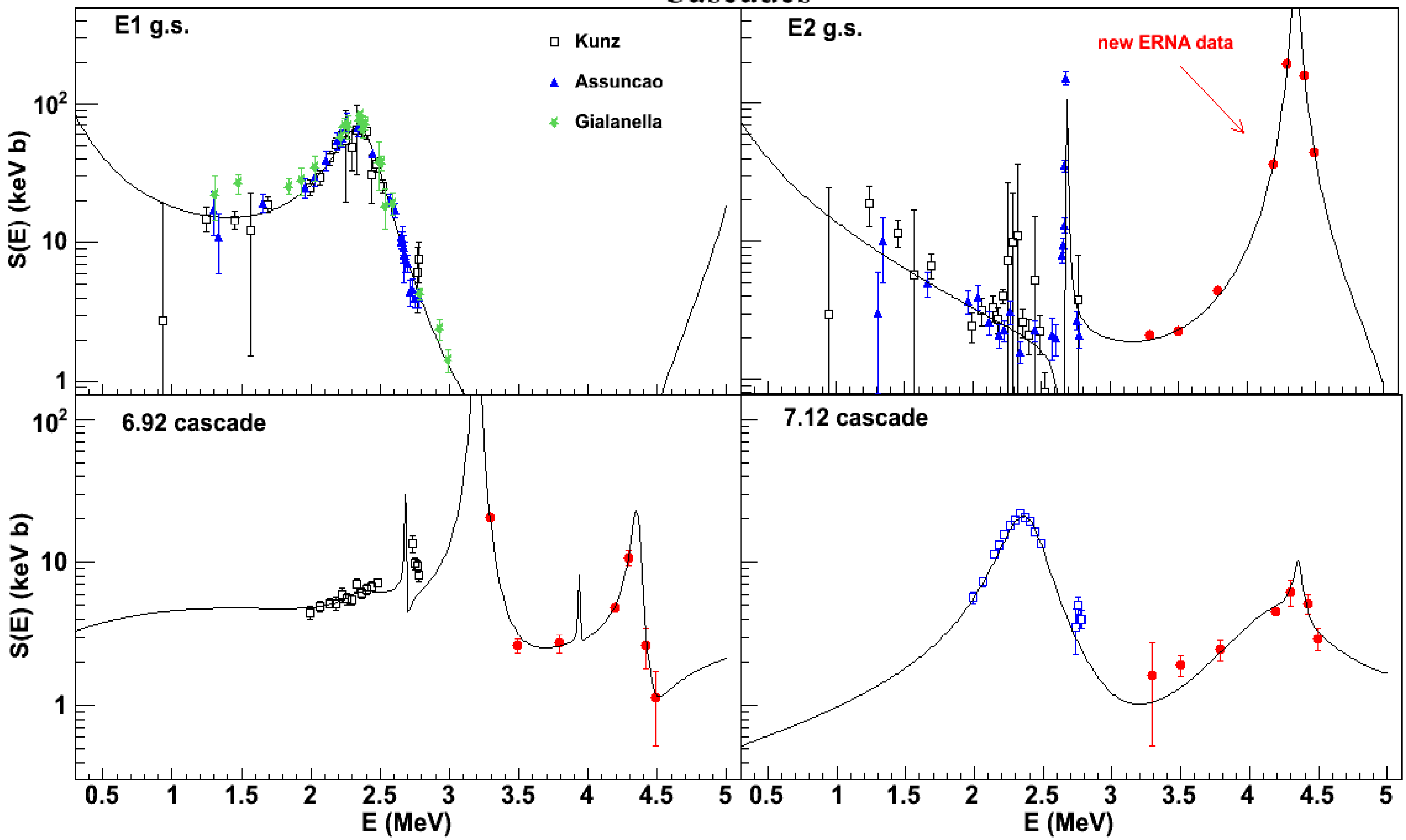


E1 gs

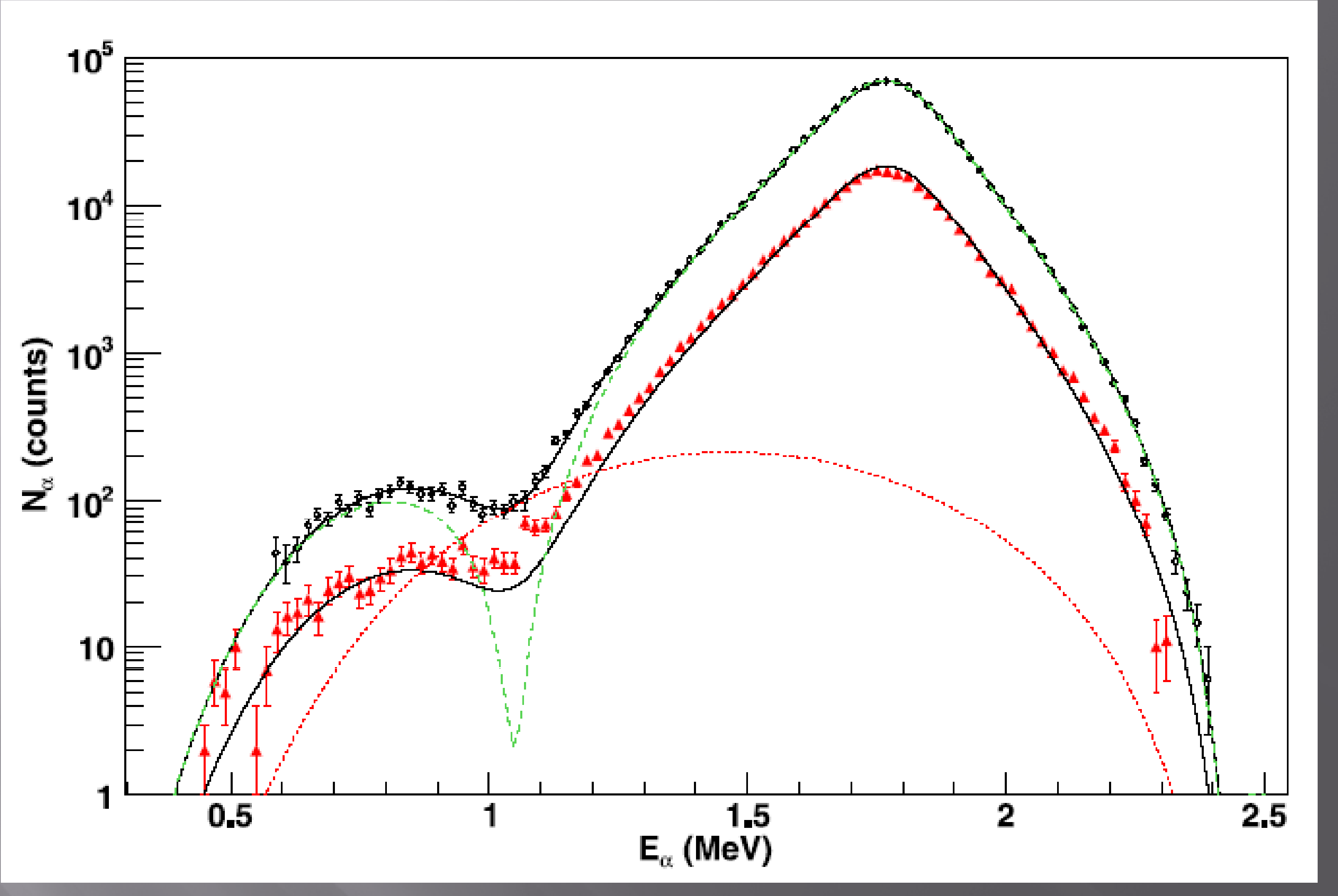
E2 gs

cascades

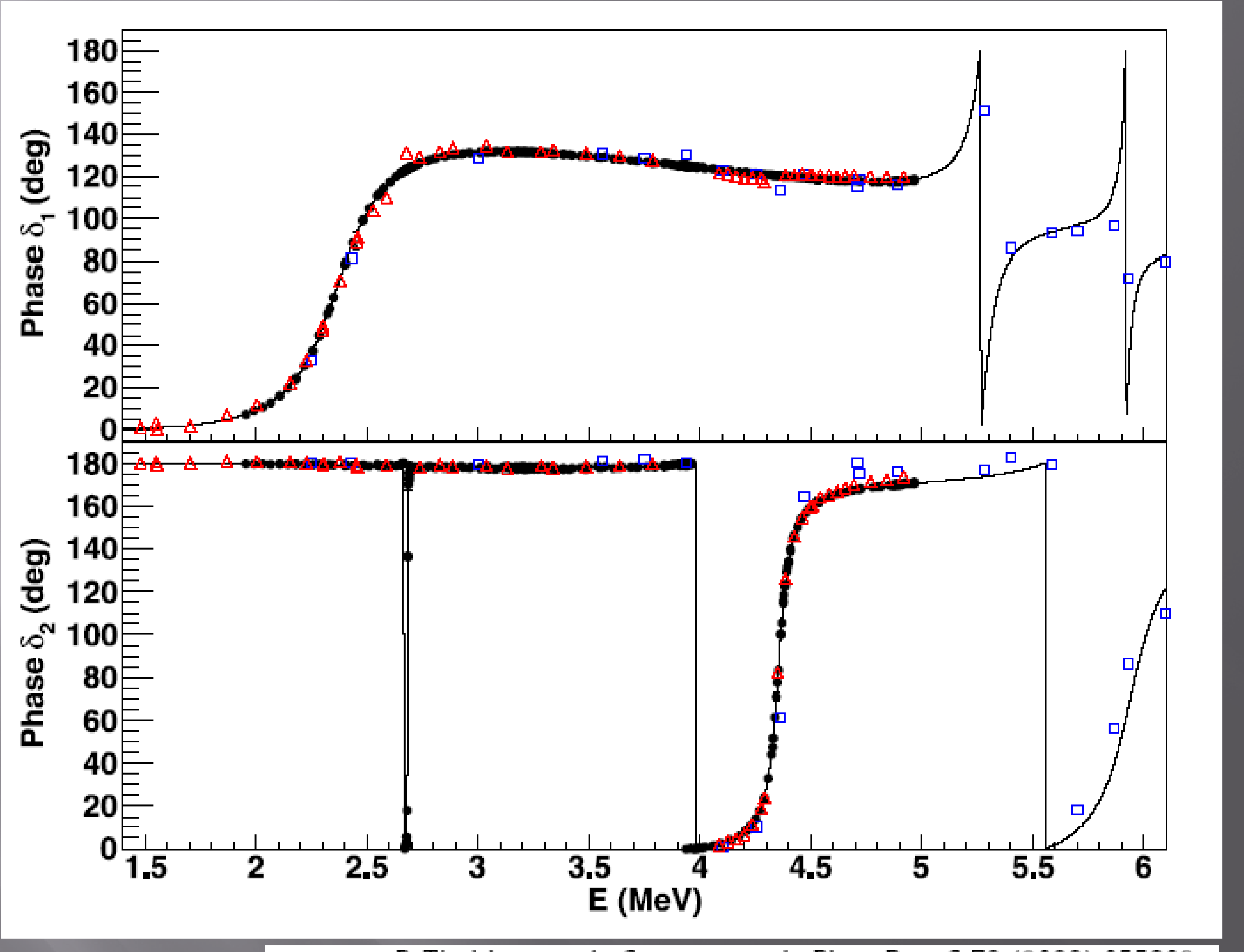
Cascades



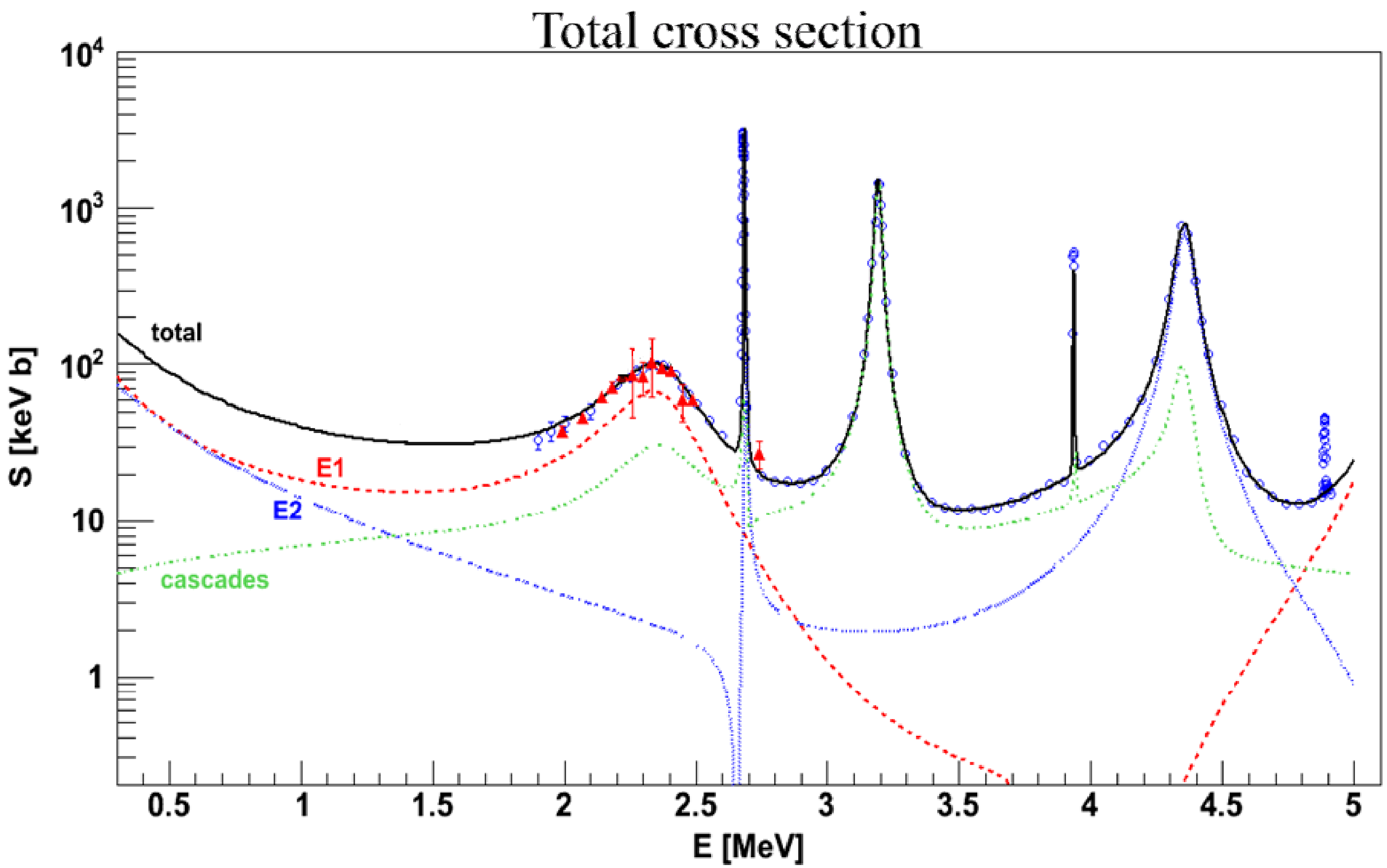
Data: Kunz et al Phys. Rev. Lett. 86 (2006)
Assuncao,et al PRC 73, 055801 (2006)
Gialanella et al Eur. Phys. J. A 11 (2001)



Data: R.E. Azuma, L. Buchmann, et al., Phys. Rev. C 50 (1994) 1194.
X.D. Tang, K.E. Rehm, et al., Phys. Rev. C 81 (2010) 045809.



Data: P. Tischhauser, A. Couture, et al., Phys. Rev. C 79 (2009) 055803.
M. D'Agostino Bruno, et al., Nuovo Cimento Ser. A 27 (1975) 1.
R. Plaga, H.W. Becker, et al., Nucl. Phys. A 465 (1987) 291.



$S(300)=161\pm19_{stat}{}^{+8}{}_{-2\,sys}$

- Good fit to all data. Uncertainty ~ 12%. Still some tension in the estimate of the γ_α of the subthreshold states.

- Future program for $^{12}C(\alpha,\gamma)\,^{16}O$: solve the open issues in ERNA and possibly in underground lab – LUNA MV