Microscopic study of the low-energy enhancement in the gamma-decay strength of vanadium-50

J. K. Dahl [1], A. C. Larsen [1], N. Shimizu [2,3] and Y. Utsuno [3,4]

[1] Department of Physics, University of Oslo, N-0316 Oslo, Norway
[2] Center for Computational Sciences, University of Tsukuba, Tsukuba, Ibaraki 305-8577, Japan
[3] Center for Nuclear Study, the University of Tokyo, Hongo, Tokyo, 113-0033, Japan
[4] Advanced Science Research Center, Japan Atomic Energy Agency, Tokai, Ibaraki 319-1195, Japan

Gamma strength function

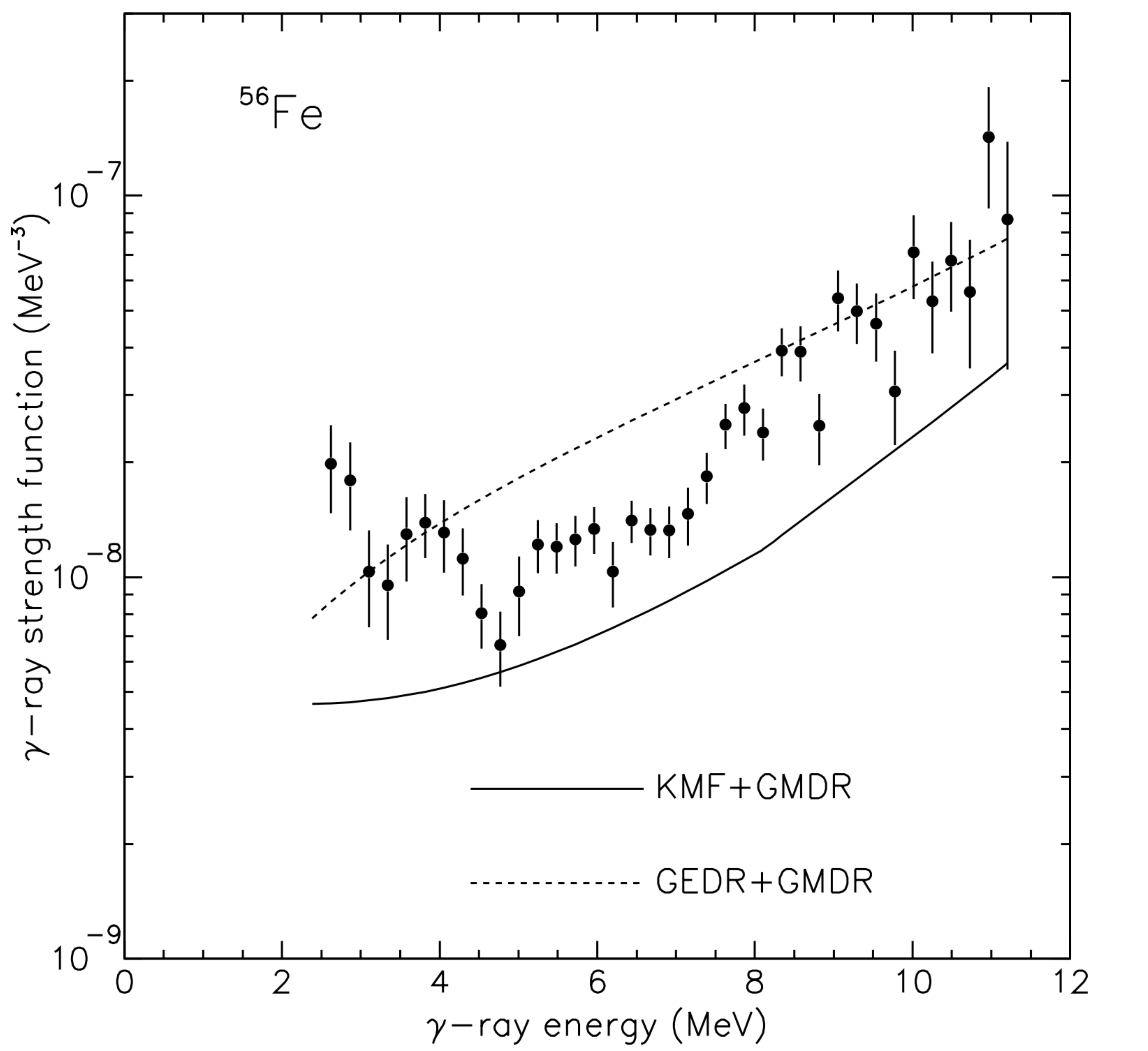


Figure 6.6: Radiative strength function for ^{56}Fe. The experimental RSF (data points) is given in arbitrary units. The models KMF+GMDR and GEDR+GMDR are in absolute units, see text for details.

Fig.: The GSF of 56Fe calculated with the Oslo Method.
First observation of the low-energy enhancement.
E. Tavukcu, PhD dissertation (2002) doi.org/10.2172/15003346

Low-energy enhancement

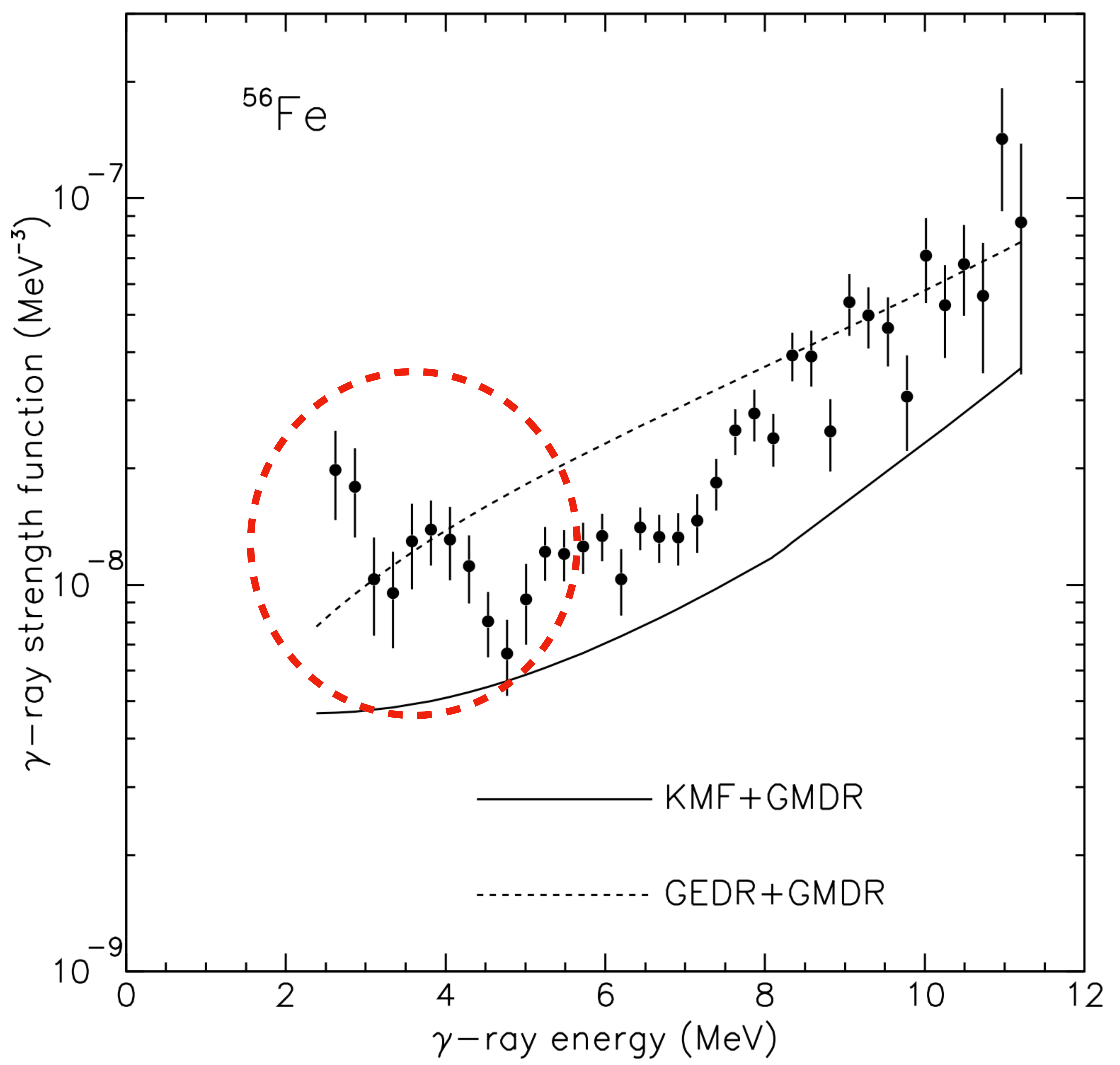
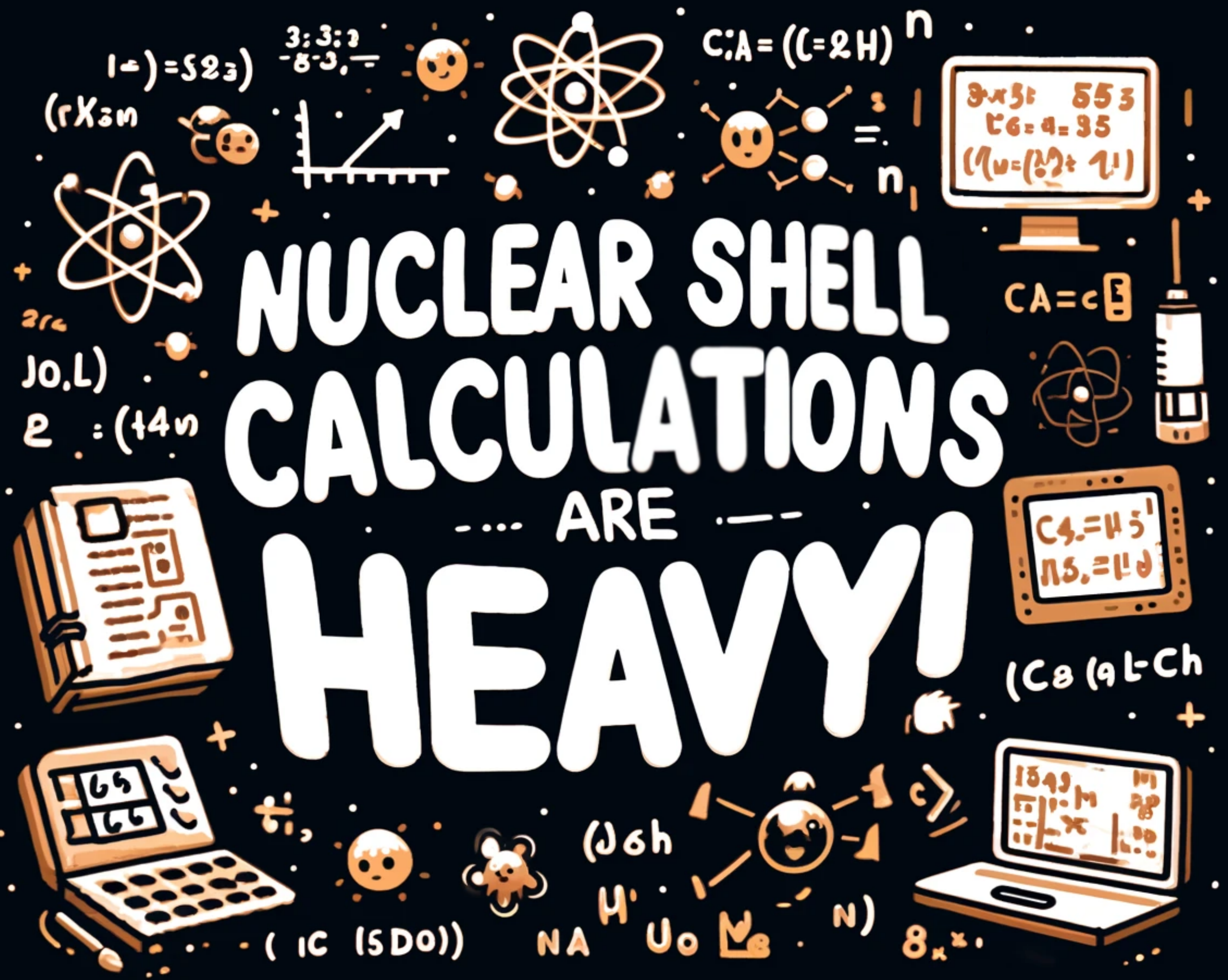
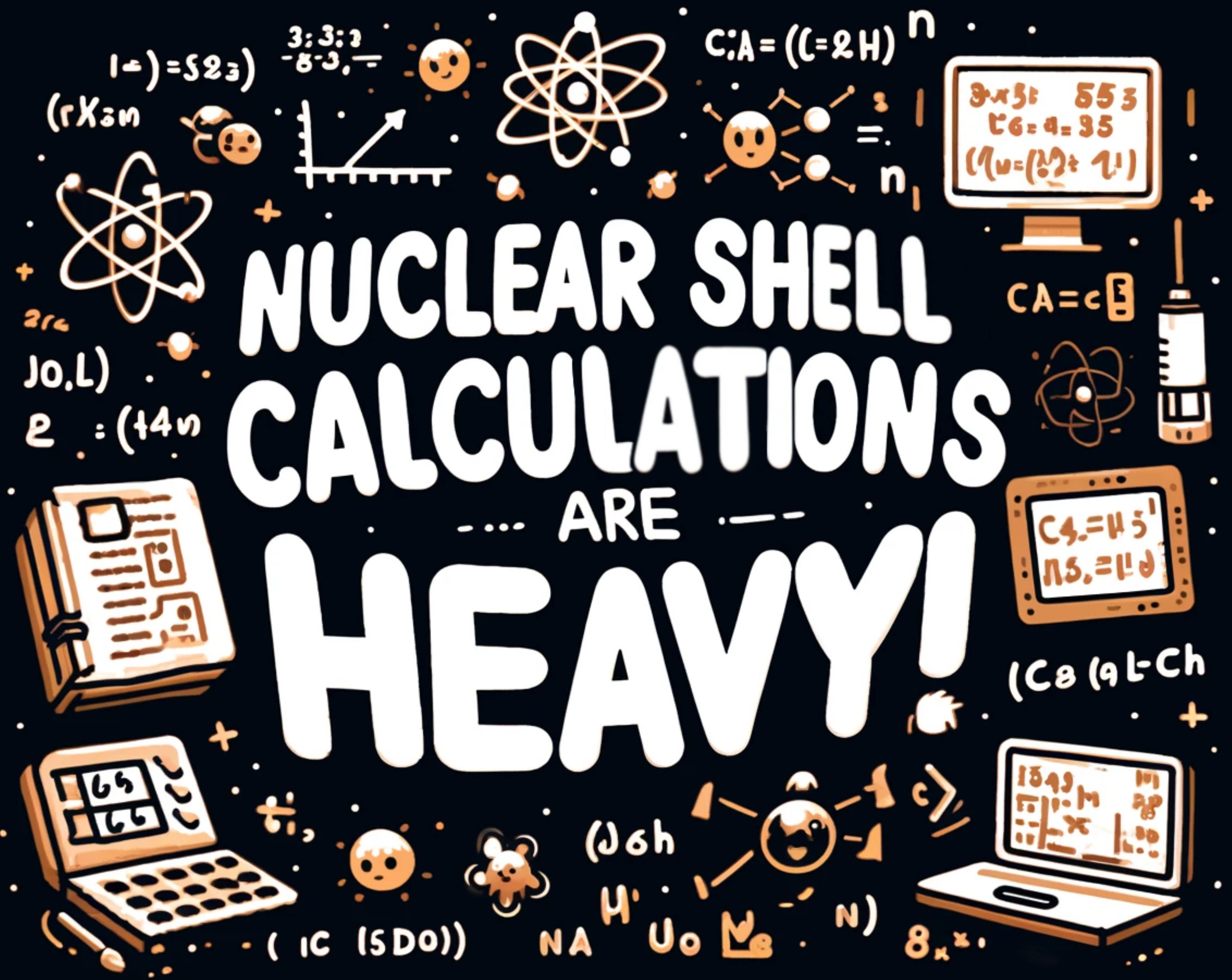


Figure 6.6: Radiative strength function for ^{56}Fe. The experimental RSF (data points) is given in arbitrary units. The models KMF+GMDR and GEDR+GMDR are in absolute units, see text for details.

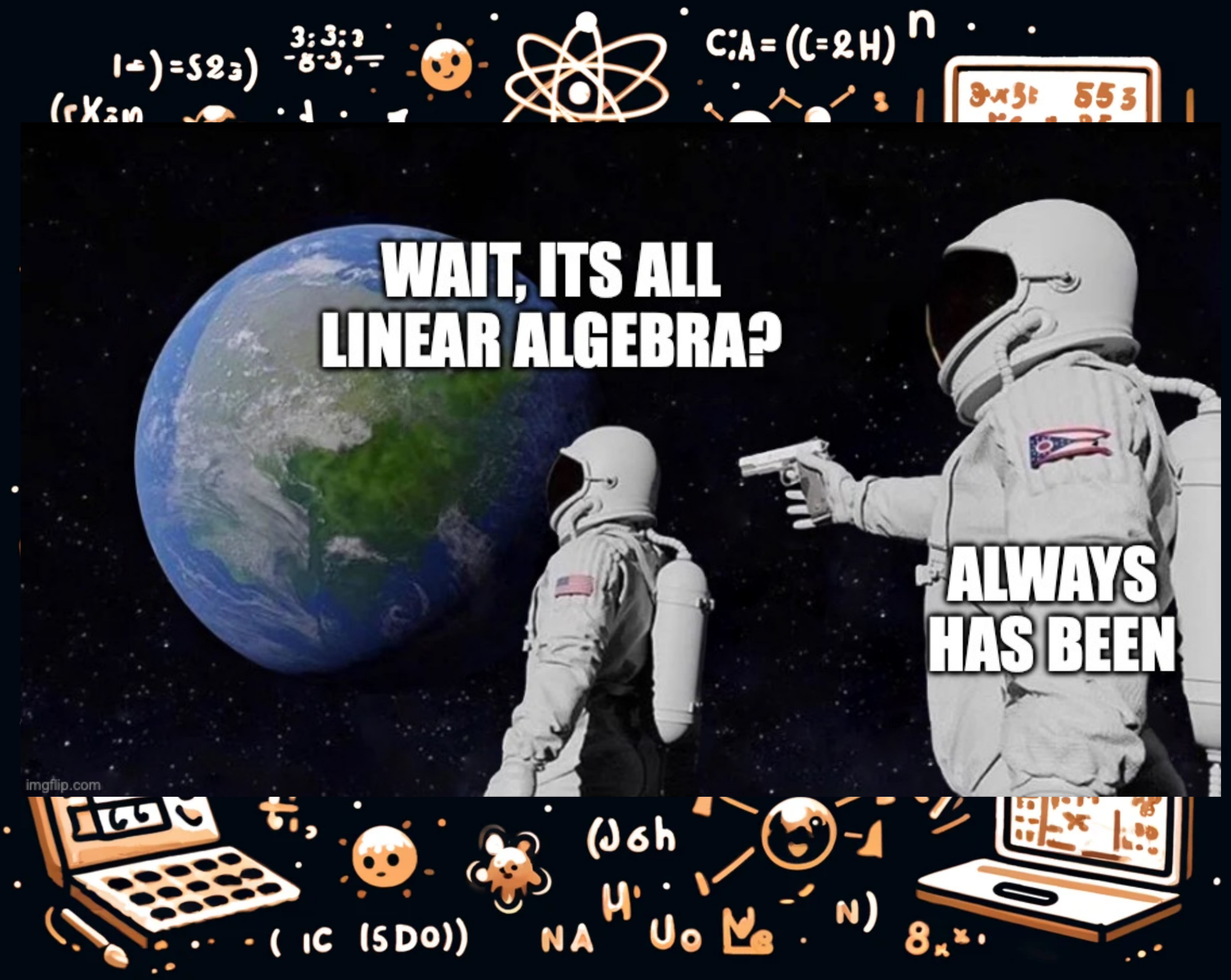
Fig.: The GSF of 56Fe calculated with the Oslo Method.
First observation of the low-energy enhancement.
E. Tavukcu, PhD dissertation (2002) doi.org/10.2172/15003346


NUCLEAR SHELL CALCULATIONS
ARE
HEAVY!

- Wavefunctions & operators
- Wave functions = vectors
- Operators = matrices

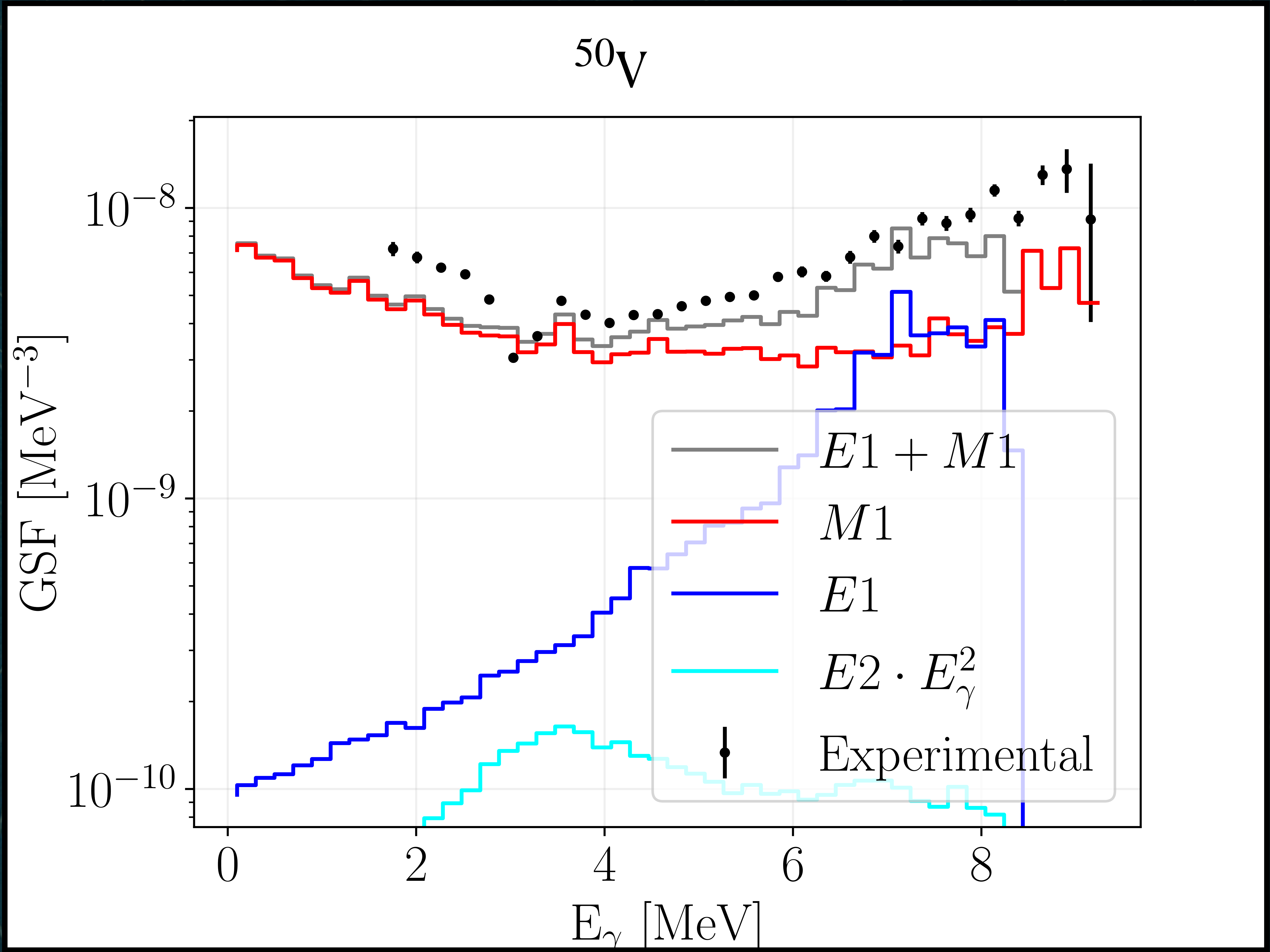


- $\hat{H}\psi = E\psi$
- Wave functions = vectors
- Operators = matrices
- Quantum physics is just linear algebra! easy peasy
- 6×10^8 basis states
- 3600 eigenstates
- Over two million dipole transitions!



E1 or M1?

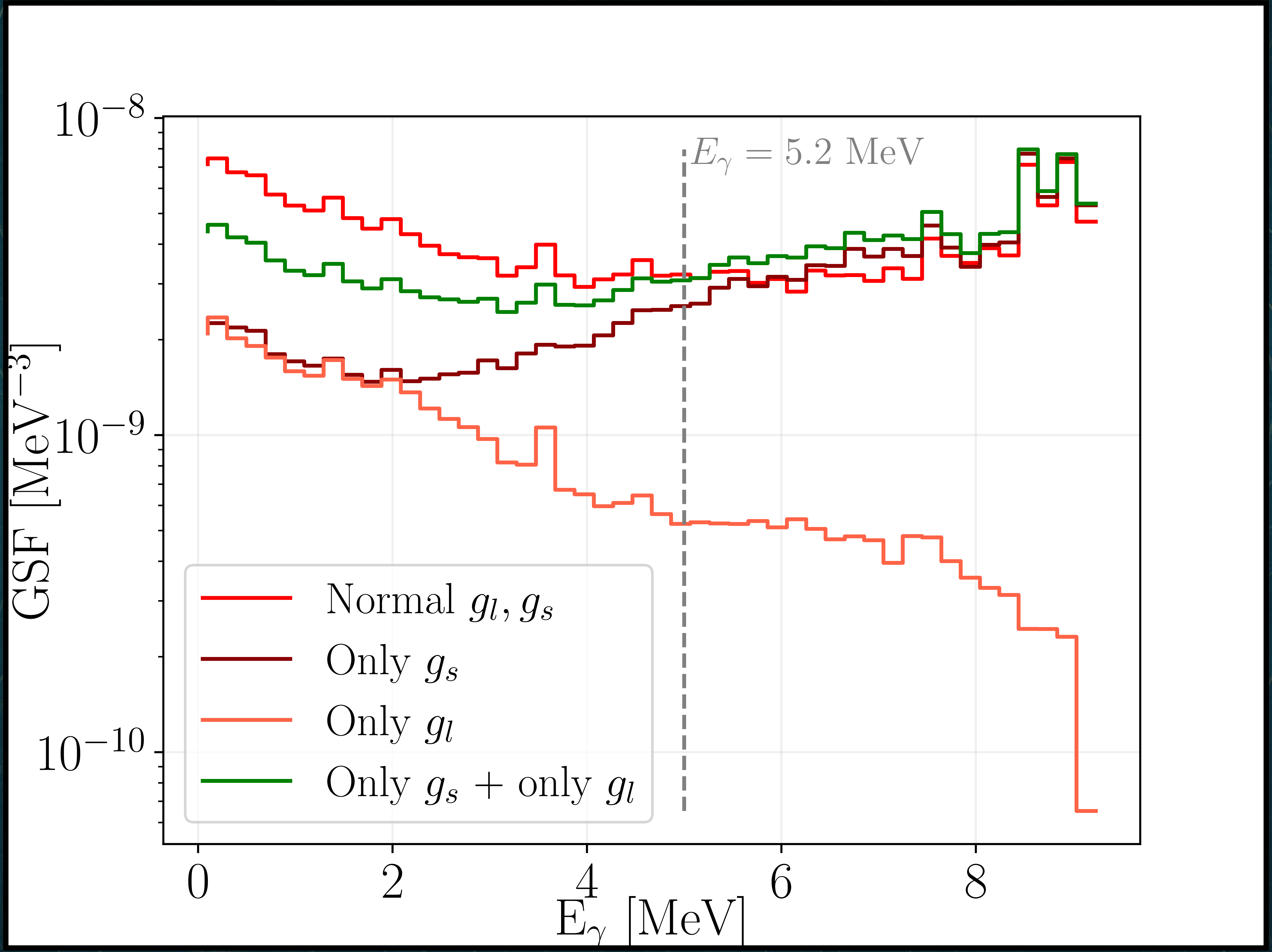
E1 or M1?



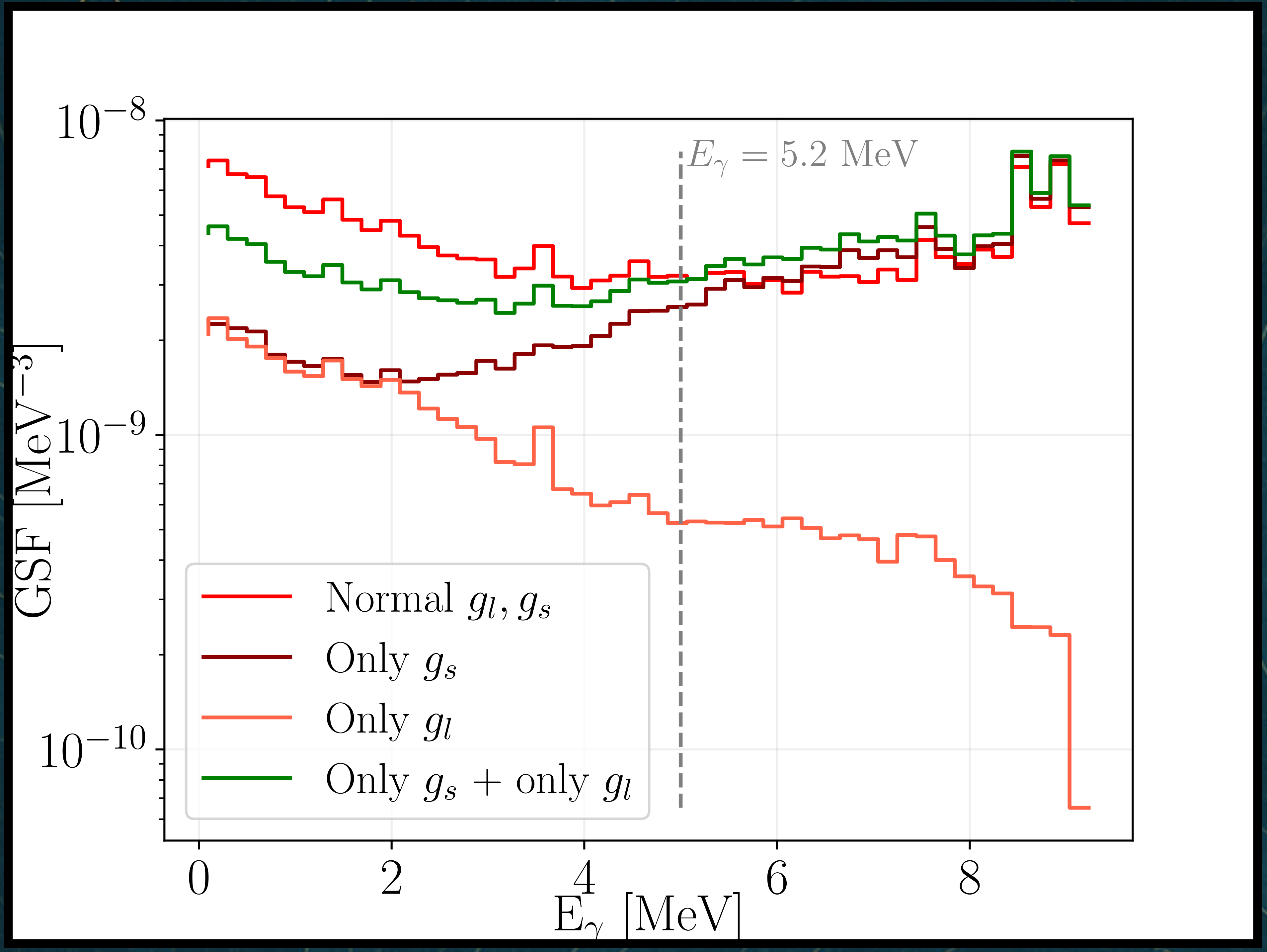
^{50}V
10^{-8}
10^{-9}
10^{-10}
GSF [MeV^{-3}]
0
2
4
6
8
E$_\gamma$ [MeV]
$E1 + M1$
$M1$
$E1$
$E2 \cdot E_\gamma^2$
Experimental

The M1 operator: $\hat{M}1 = g_l\hat{L} + g_s\hat{S}$

The M1 operator: $\hat{M}1 = g_l\hat{L} + g_s\hat{S}$



The M1 operator: Interference angle



$$B(M1) = \frac{|\langle \Psi_f \| \hat{M}1 \| \Psi_i \rangle|^2}{2J_i + 1}$$

$$|\underbrace{\langle \Psi_f \| g_l \hat{L} \| \Psi_i \rangle}_{:=M_l} + \underbrace{\langle \Psi_f \| g_s \hat{S} \| \Psi_i \rangle}_{:=M_s}|^2 = M_l^2 + M_s^2 + 2M_l M_s$$

$$\cos\theta = \frac{M_l M_s}{|M_l||M_s|}$$

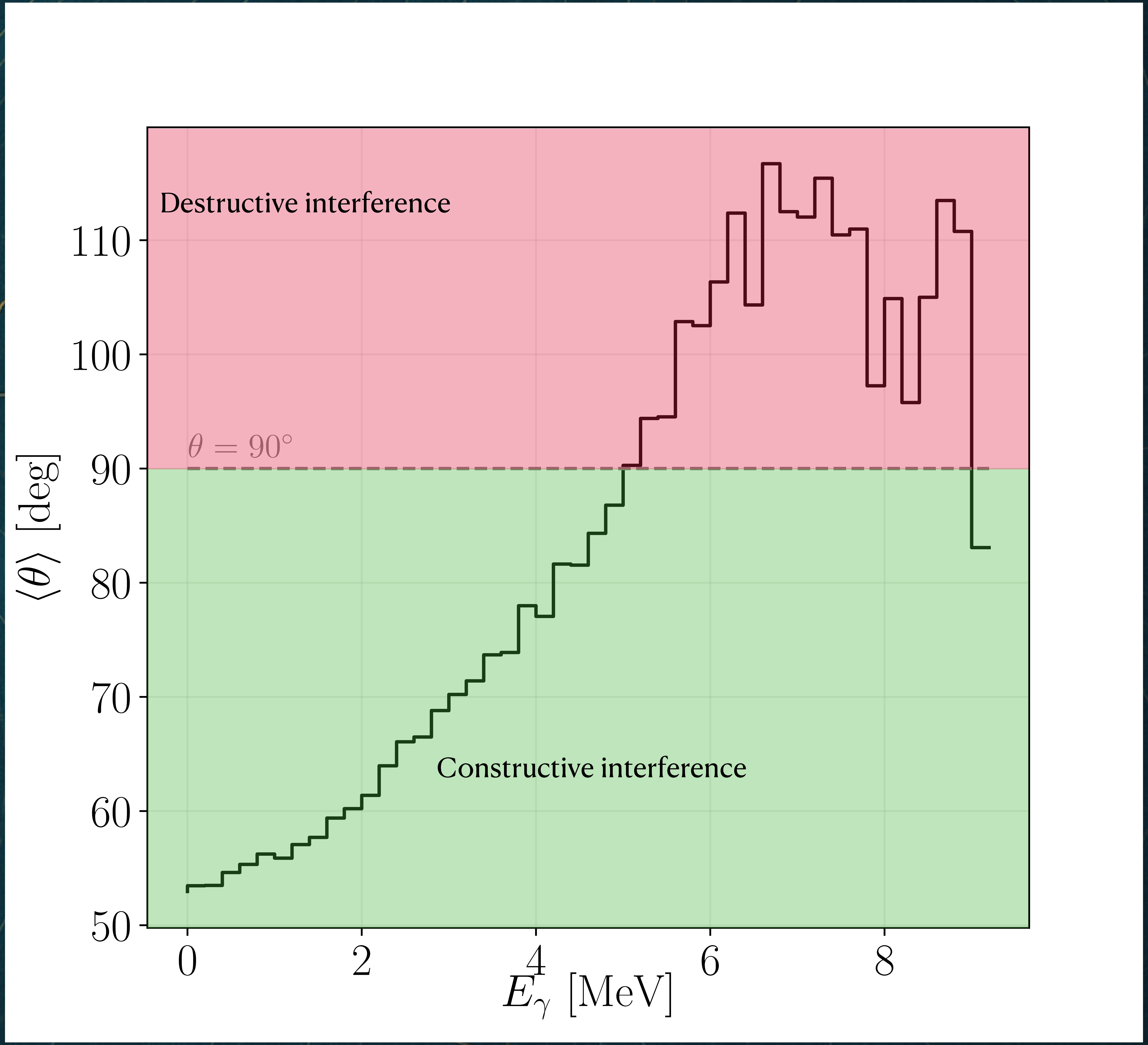


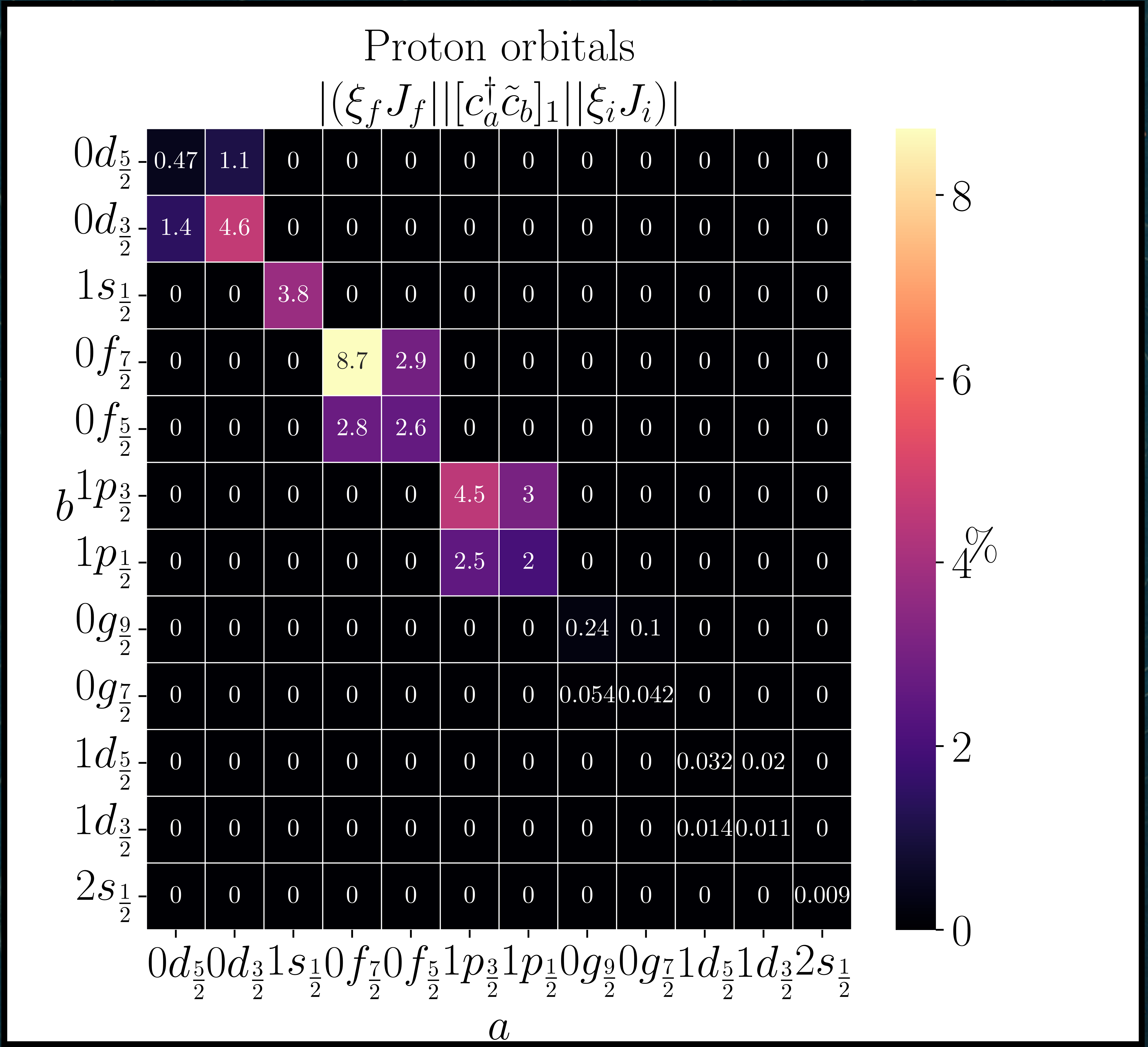
Fig. 2: Interference angle between **S** and **L** as a function of gamma energy.

One-body transition density

$$\rho_{fi}(\alpha, \beta) = \langle \Psi_f | c_\alpha^\dagger c_\beta | \Psi_i \rangle$$

$$\langle \Psi_f | \hat{M}1 | \Psi_i \rangle = \sum_{\alpha\beta} \langle \alpha | \hat{M}1 | \beta \rangle \langle \Psi_f | \hat{c}_\alpha^\dagger \hat{c}_\beta | \Psi_i \rangle$$

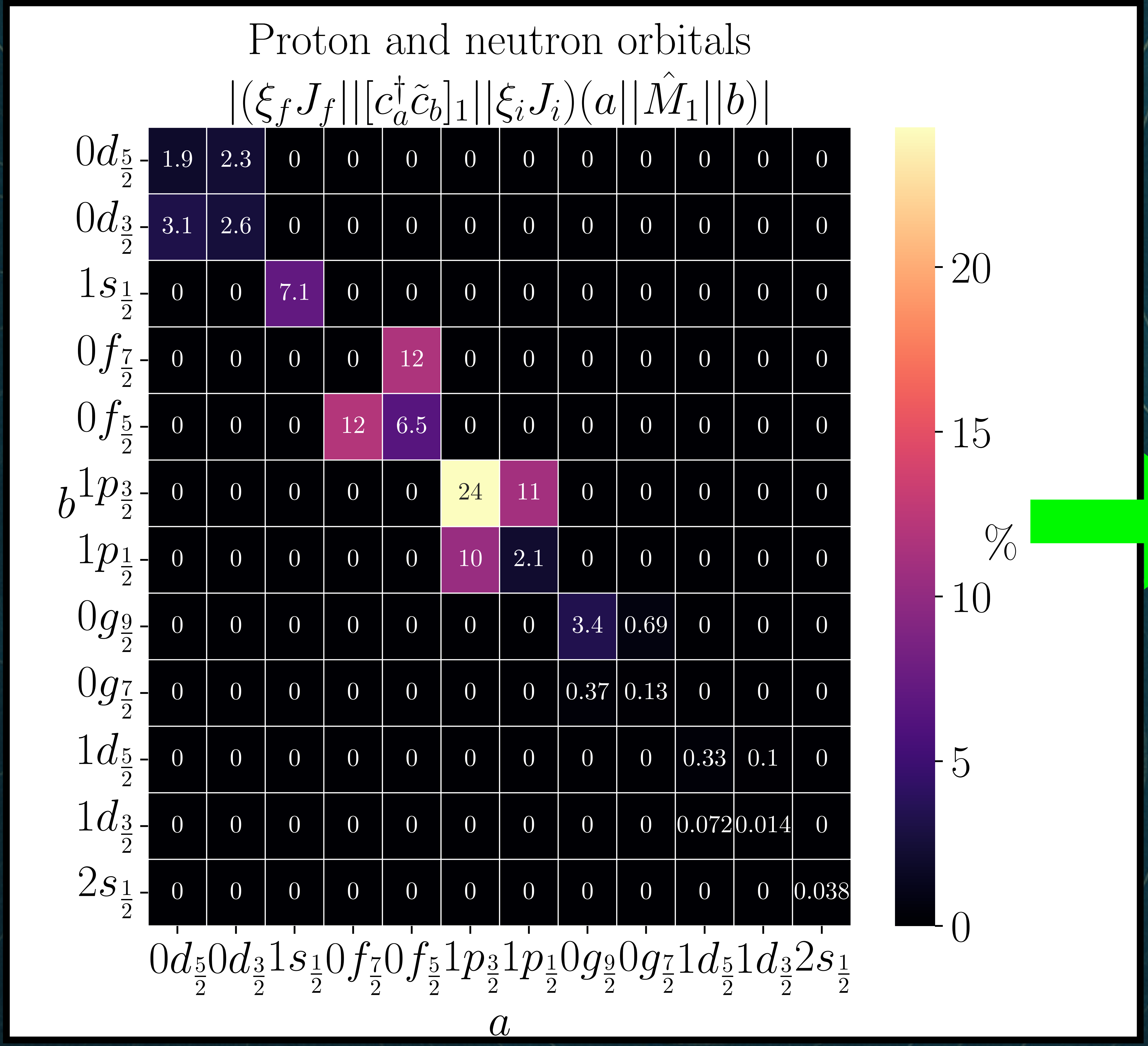
One-body transition density

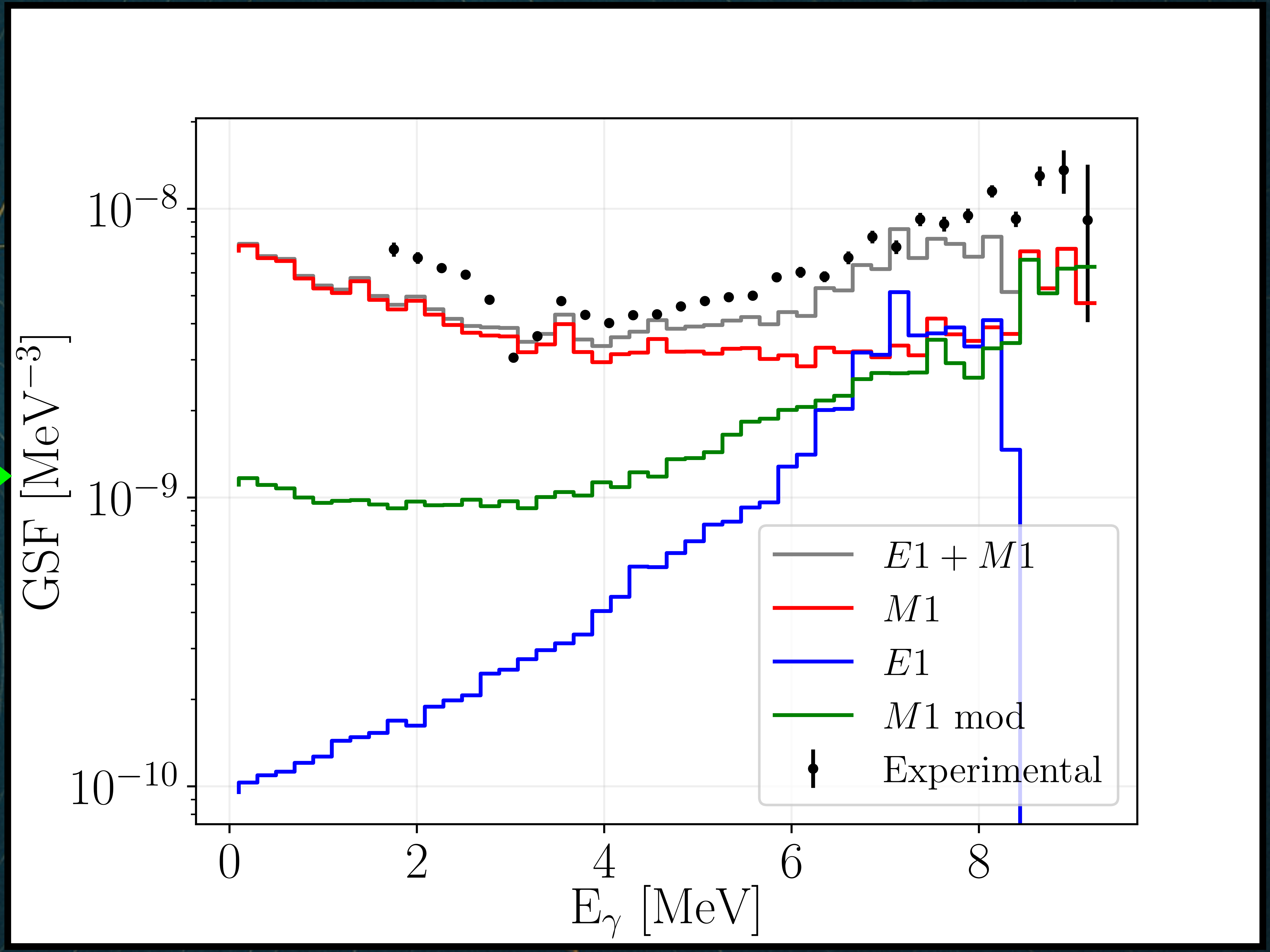


One-body transition density

- $\langle \Psi_f | \hat{M}1 | \Psi_i \rangle = \sum_{\alpha\beta} \langle \alpha | \hat{M}1 | \beta \rangle \langle \Psi_f | \hat{c}_\alpha^\dagger \hat{c}_\beta | \Psi_i \rangle$

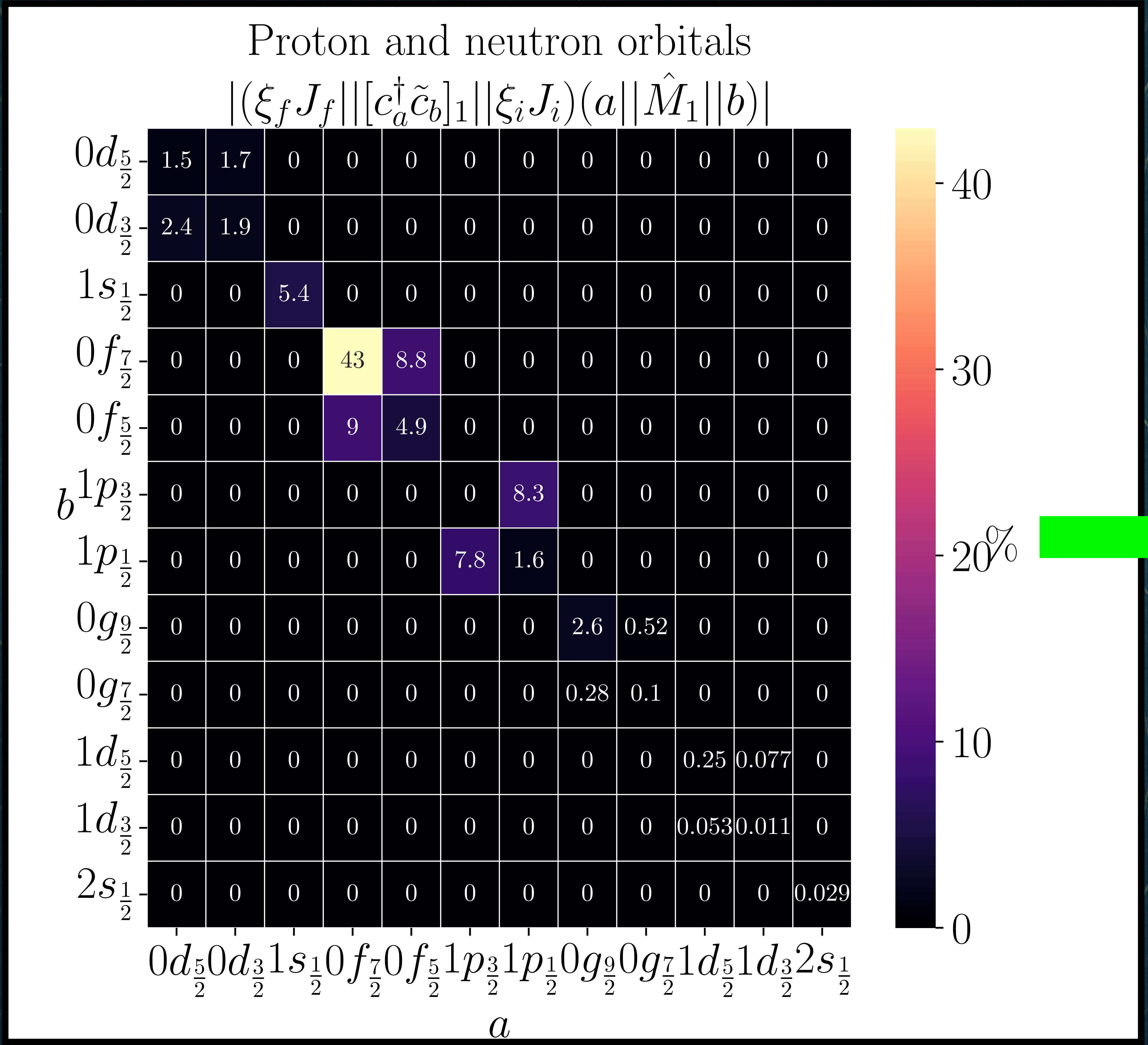
Removing 0f7/2 -> 0f7/2

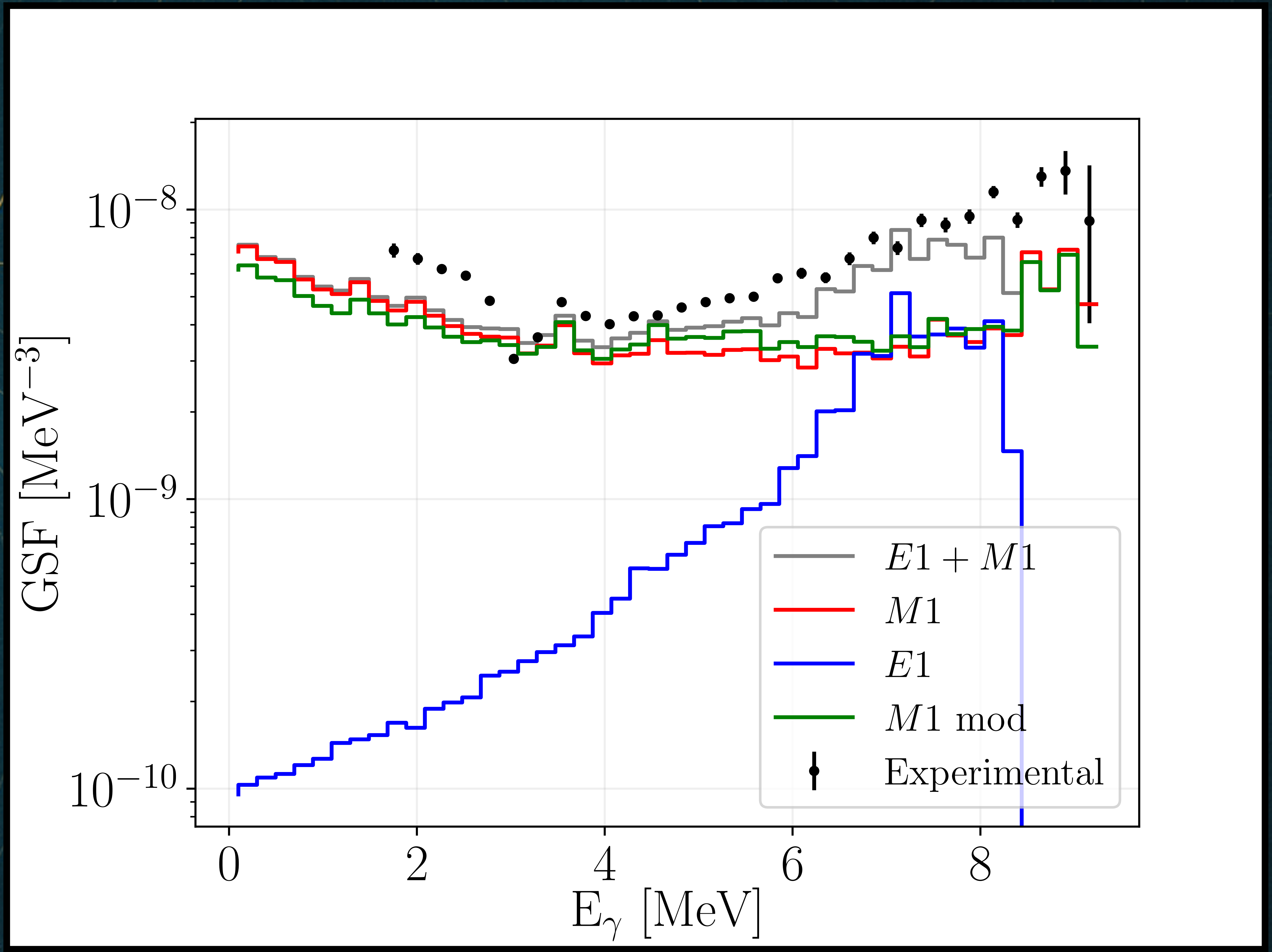




One-body transition density

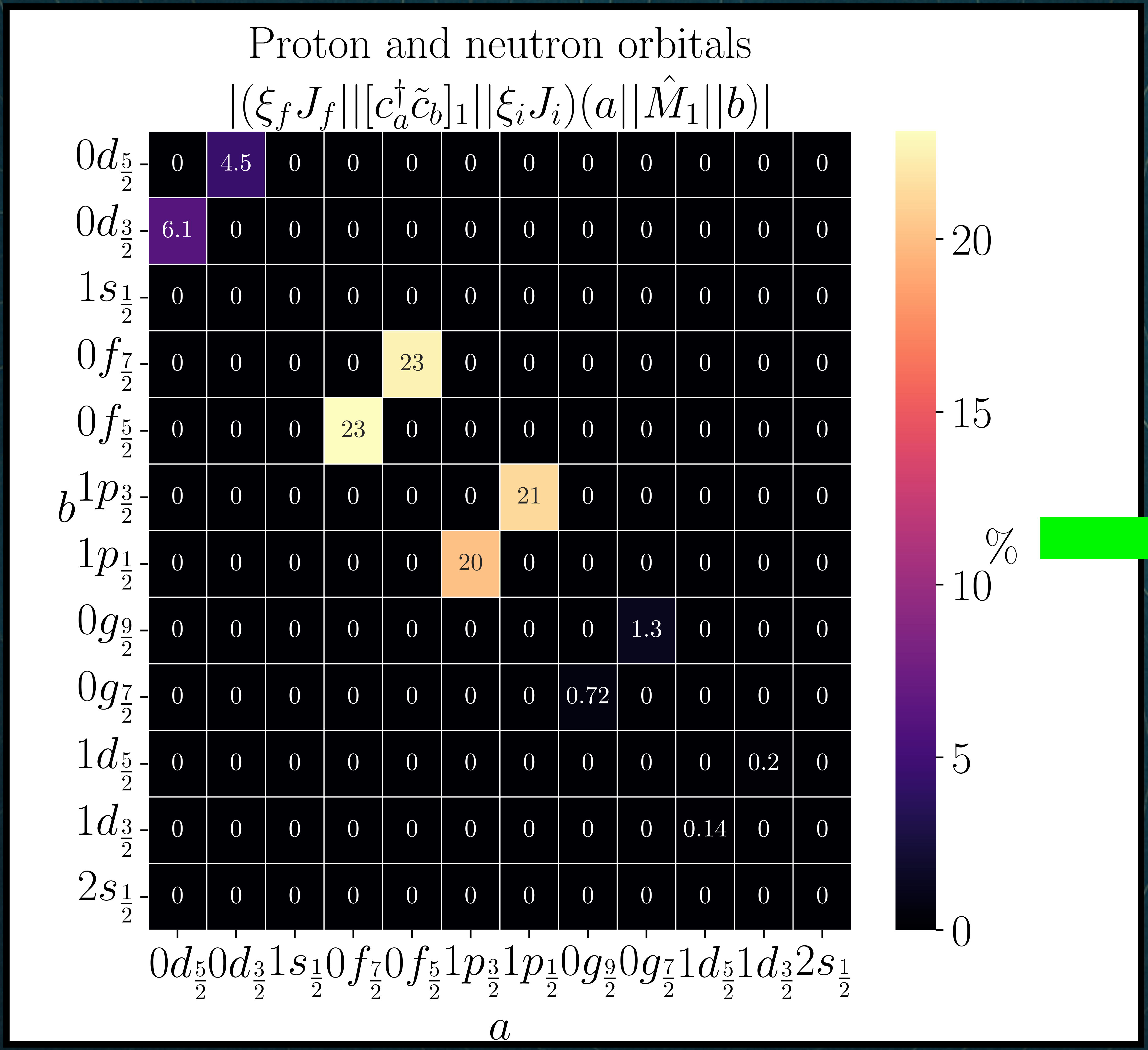
Removing 1p3/2 -> 1p3/2

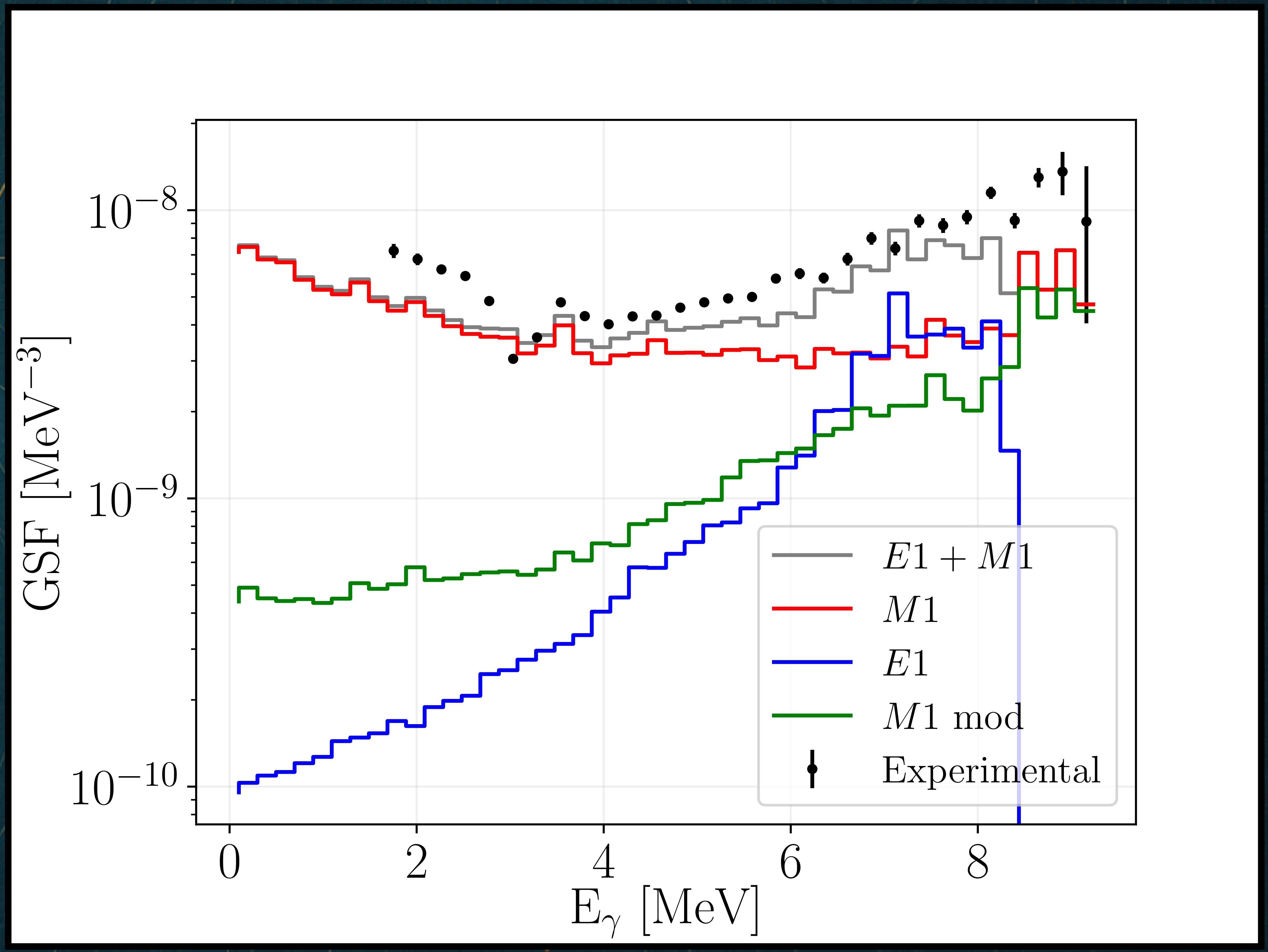




One-body transition density

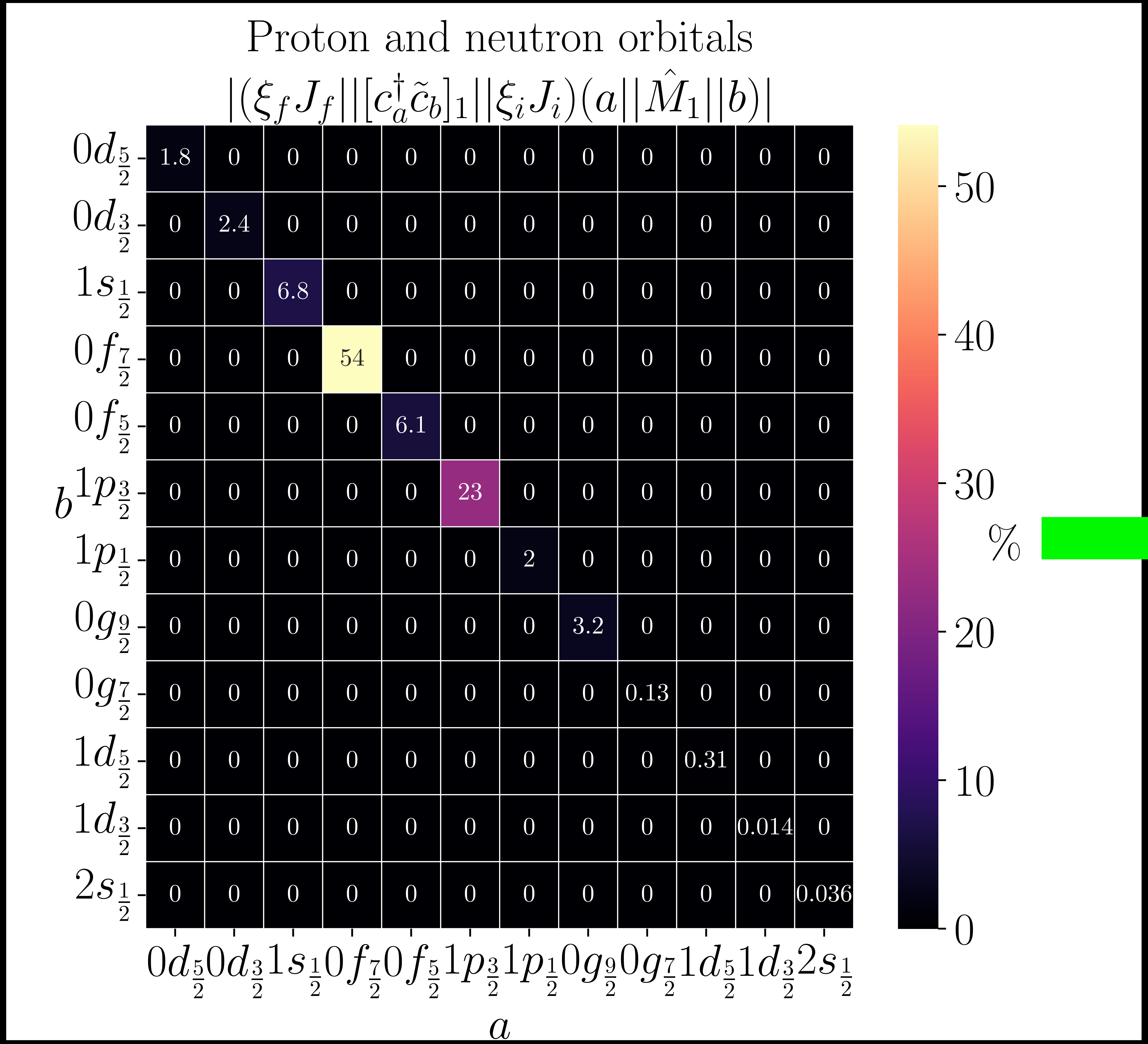
Removing the diagonals

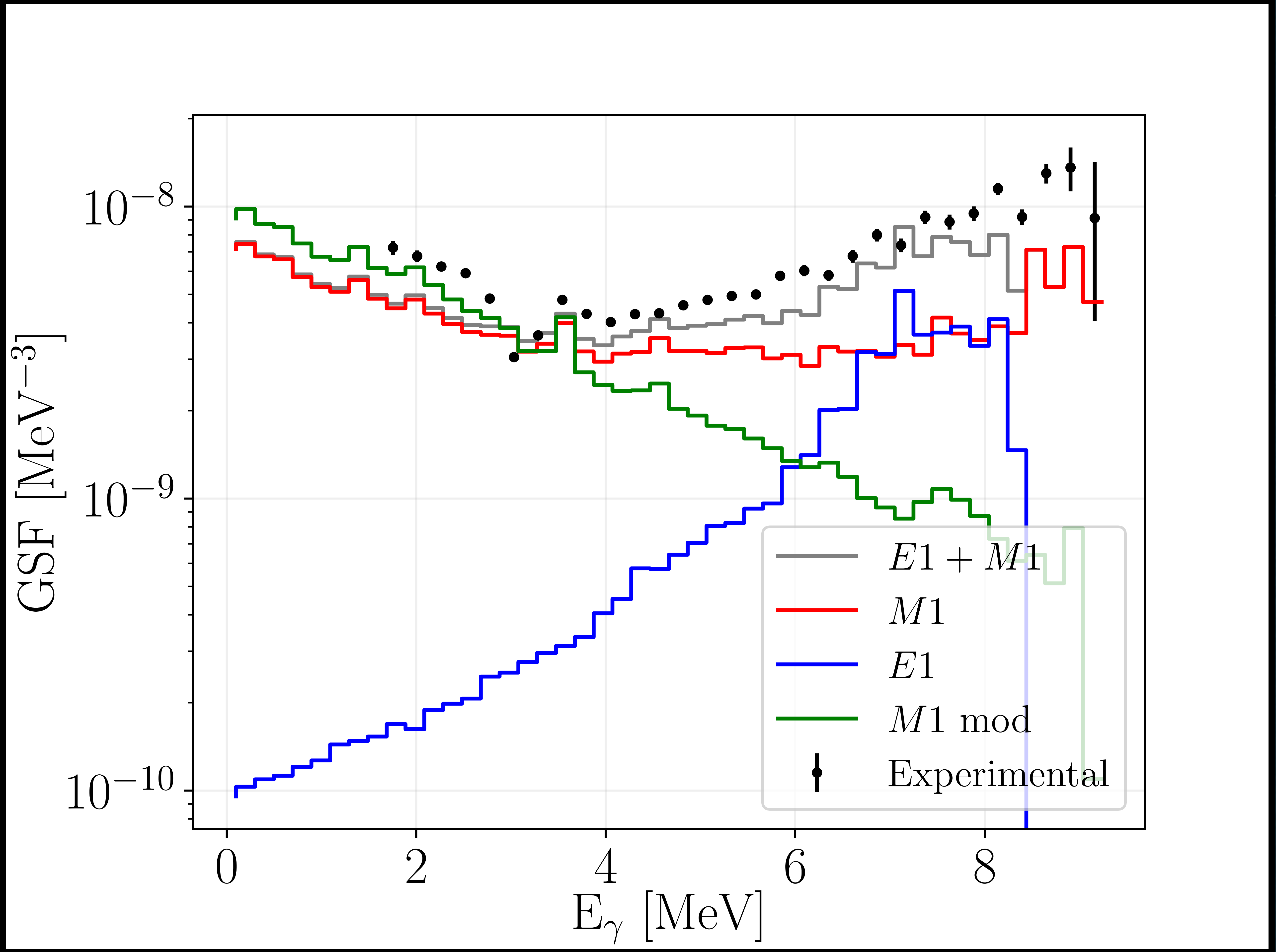




One-body transition density

Removing the off-diagonals





THANK YOU

FOR YOUR ATTENTION

Microscopic study of the low-energy enhancement in the gamma-decay strength of vanadium-50

J. K. Dahl [1], A. C. Larsen [1], N. Shimizu [2,3] and Y. Utsuno [3,4]

[1] Department of Physics, University of Oslo, N-0316 Oslo, Norway
[2] Center for Computational Sciences, University of Tsukuba, Tsukuba, Ibaraki 305-8577, Japan
[3] Center for Nuclear Study, the University of Tokyo, Hongo, Tokyo, 113-0033, Japan
[4] Advanced Science Research Center, Japan Atomic Energy Agency, Tokai, Ibaraki 319-1195, Japan

- We have reproduced the low-energy enhancement (LEE) of vanadium-50 with large-scale shell-model calculations (fig. 1).
- The LEE is caused by M1 transitions (fig. 1).
- Constructive interference between the **S** and **L** terms of the M1 operator enhances the LEE (fig. 2).
- 0f7/2 -> 0f7/2 proton transitions are the principal driver of the LEE (fig. 3).

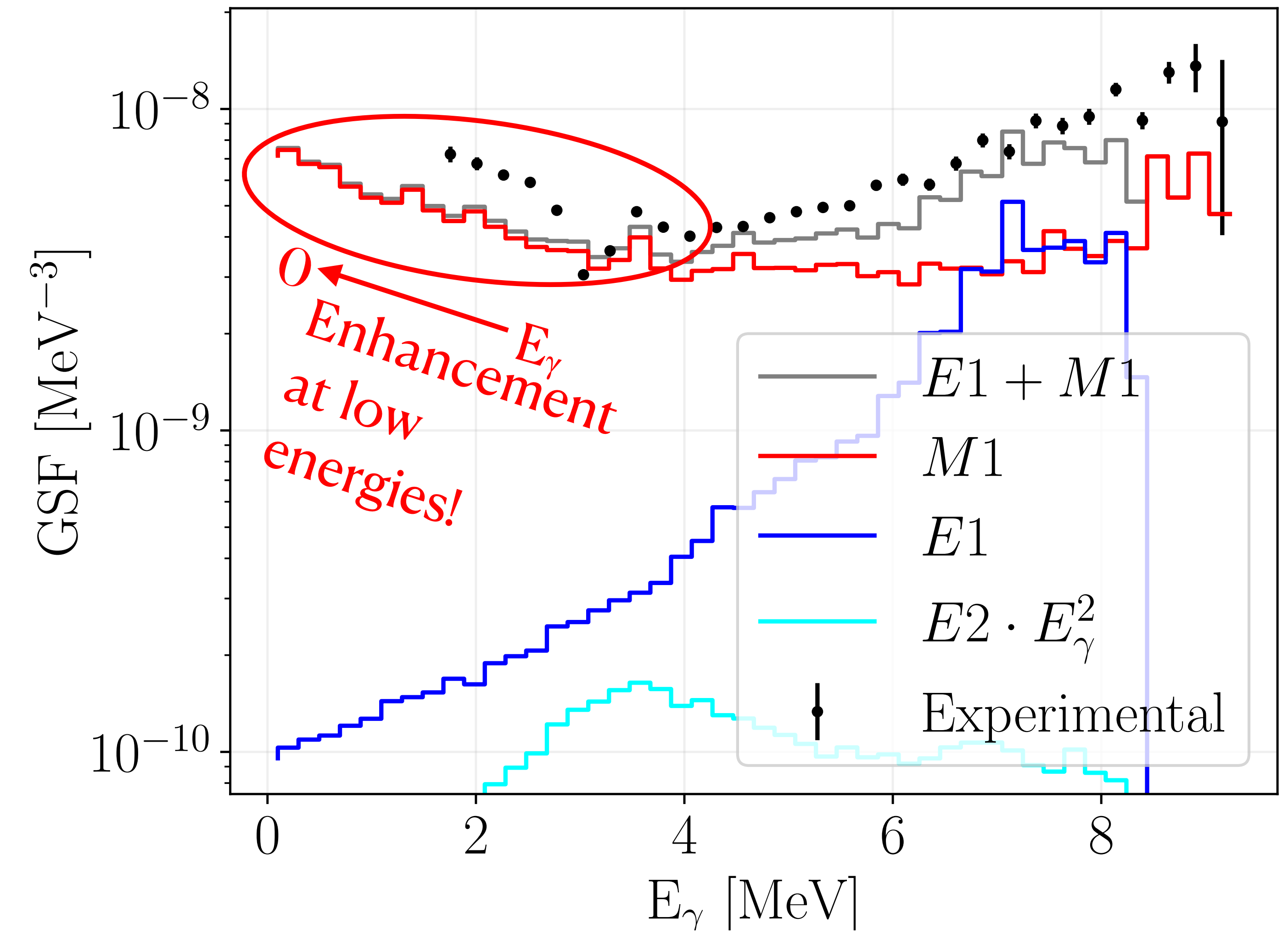


Fig. 1: Calculated gamma-strength function in solid lines. Experimental data in dots (10.1103/PhysRevC.73.064301).

arxiv.org/abs/2510.23779

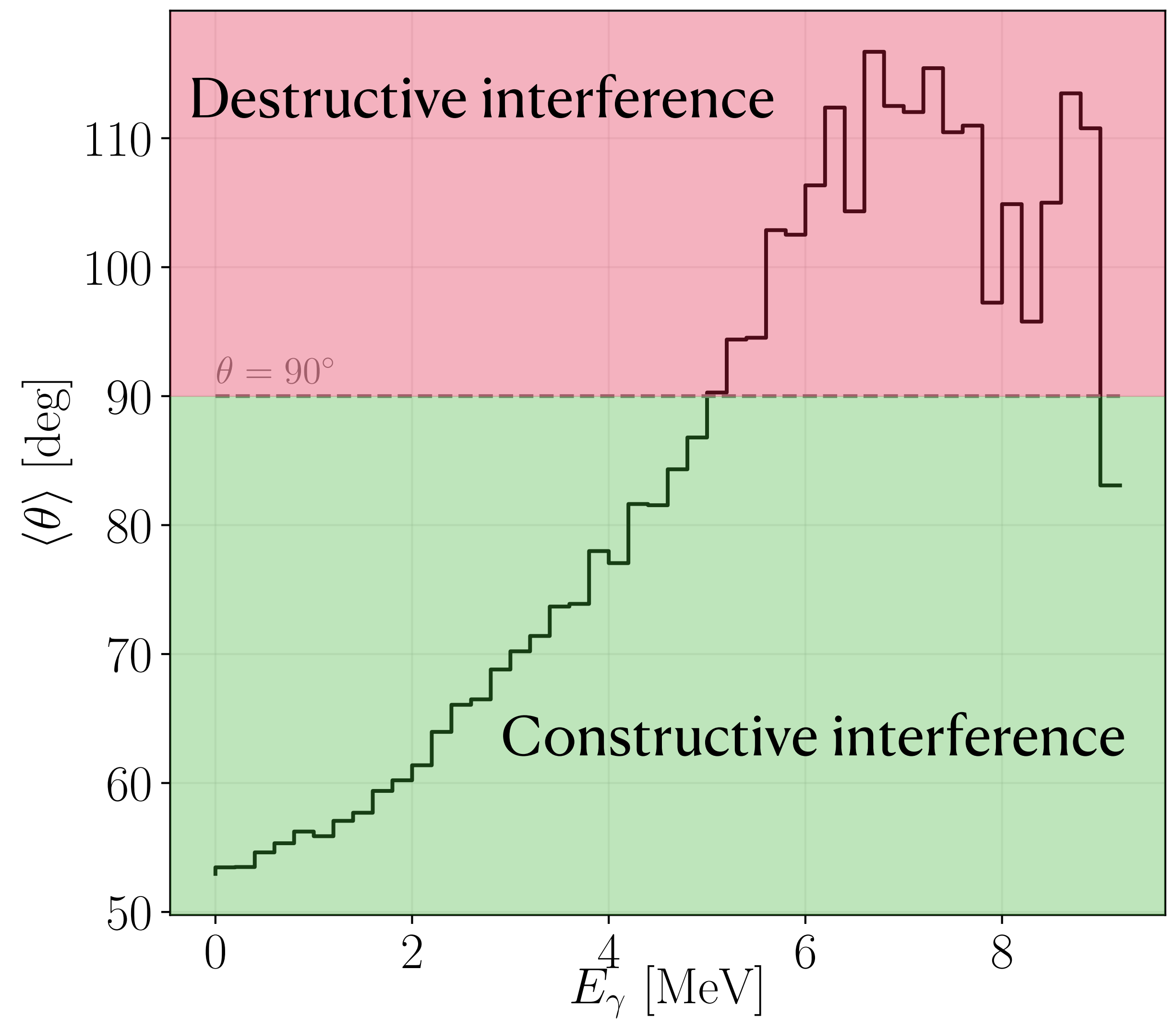


Fig. 2: Interference angle between **S** and **L** as a function of gamma energy.

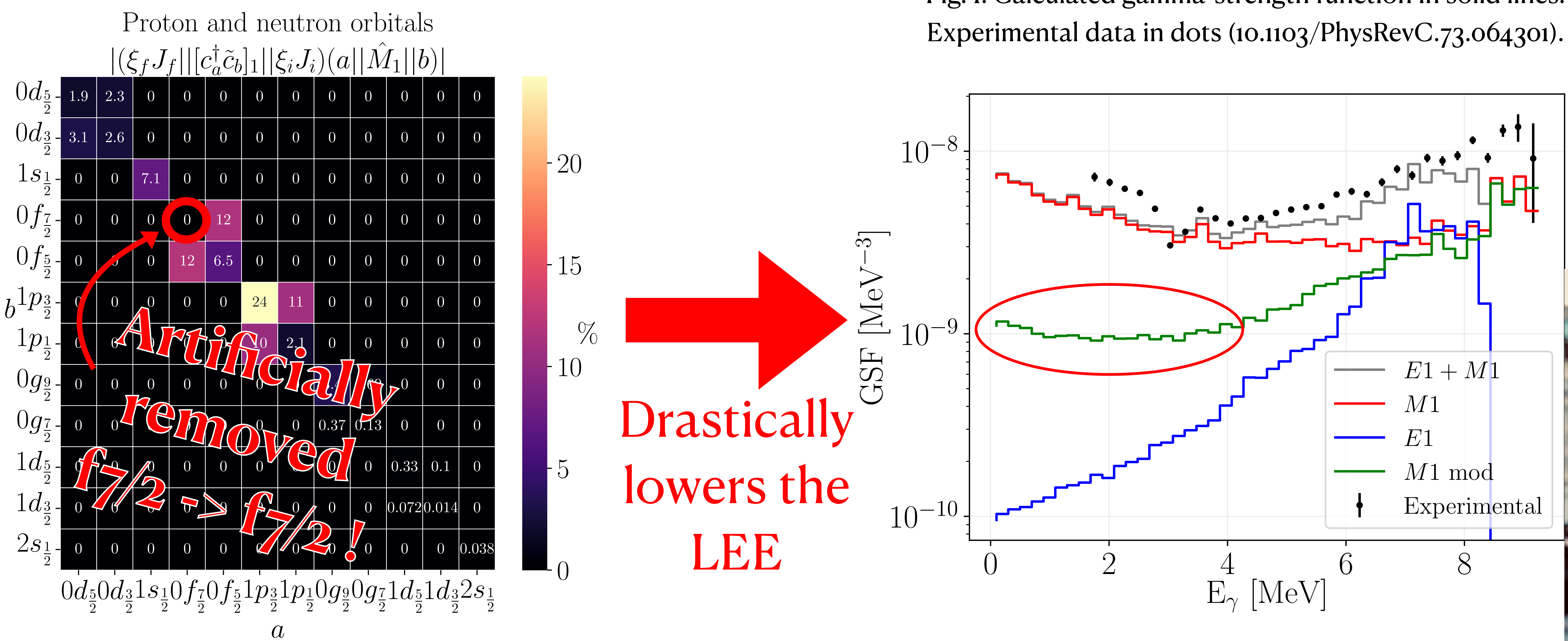


Fig. 3: Left: Map of reduced one-body transitions densities, f7/2 -> f7/2 removed. Right: The resulting modified M1 strength function.