COHERENT ELASTIC NEUTRINO-NUCLEUS SCATTERING (CEνNS) EVENT RATES FOR Ge, Zn & Si DETECTOR MATERIALS

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INTRODUCTION

Realistic nuclear structure calculations are presented for the event rates due to coherent elastic neutrino-nucleus scattering (CEνNS), assuming neutrinos from (π-DAR), from nuclear reactors and from Earth's interior. From the perspective of nuclear physics, the present calculations have been carried out within the framework of the deformed shell-model (DSM), based on realistic nuclear forces and assessed on the reproducibility of spectroscopic nuclear properties **[1]**.

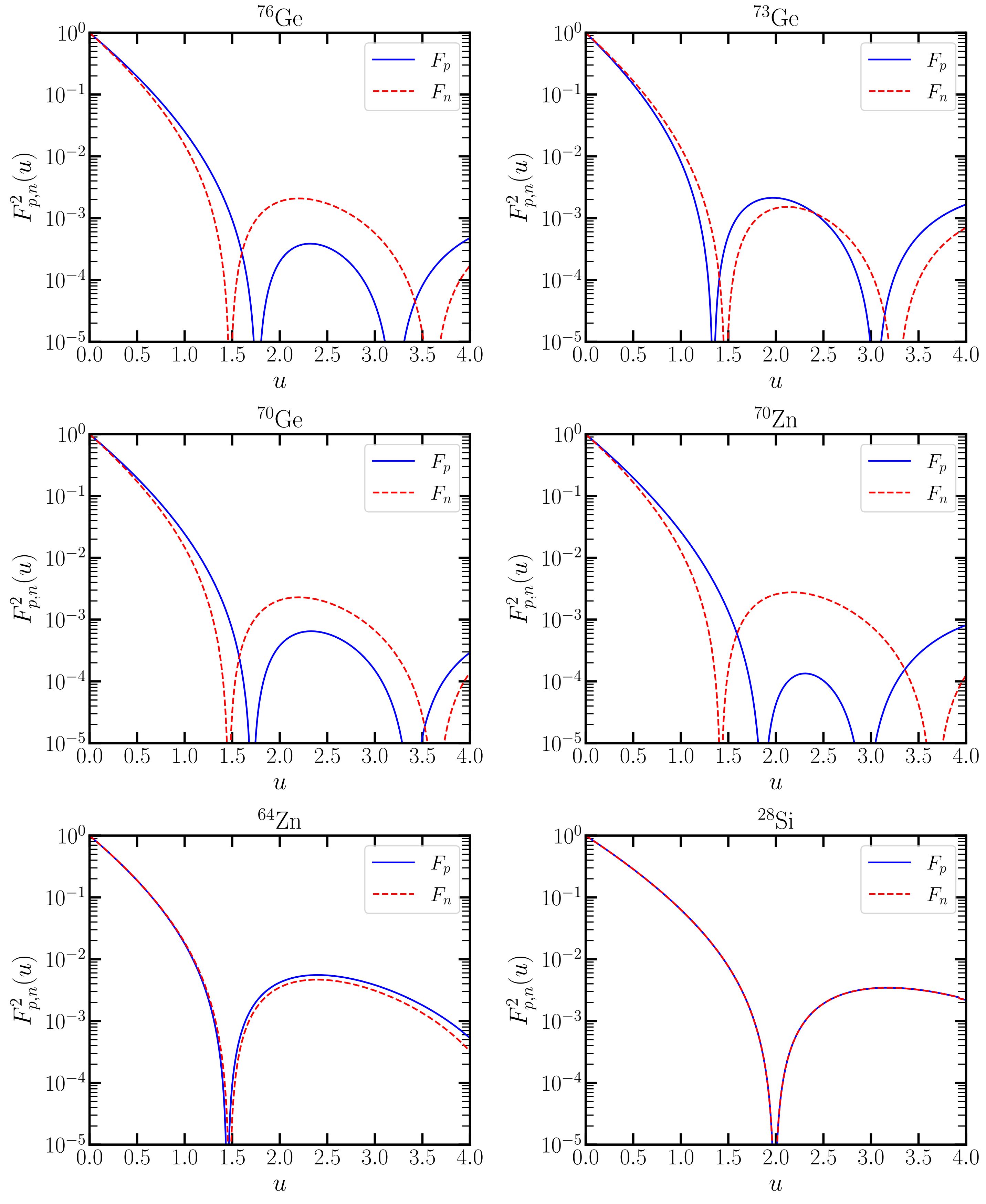
CEνNS IN THE STANDARD MODEL

The Standard Model CEνNS cross section, for a nucleus (A,Z) with mass m_A reads [2]

$$\boxed{\left(\frac{d\sigma}{dT_A}\right)_{\mathrm{SM}} = \frac{G_F^2 m_A}{2\pi}\left[g_V^p Z F_p(Q^2) + g_V^n N F_n(Q^2)\right]^2\left[2 - \frac{2T_A}{E_\nu} - \frac{m_A T_A}{E_\nu^2}\right]}$$

- G_F: Fermi constant
- T_A: nuclear recoil energy
- E_ν: neutrino energy
- $F_{p,n}(Q^2)$: proton/neutron nuclear form factor
- Standard Model couplings to Z^0 boson: $g_V^p = 1/2 - 2\sin^2\theta_W$ and $g_V^n = -1/2$

FIGURE 1



Square of proton (solid line) and neutron (dotted line) form factors for ^{70,73,76}Ge, ^{64,70}Zn and ^{28}Si as a function of $u = q^2 b_l^2/2$.

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NUCLEAR STRUCTURE CALCULATIONS WITHIN DSM

- **Assume axial symmetry**
- **Model space**: a set single-particle (sp) orbitals + an effective two-body Hamiltonian
- **Lowest-energy intrinsic states**: by solving the HF single-particle equation self-consistently
- **Excited intrinsic configurations**: via particle-hole excitations over the lowest intrinsic state
- Intrinsic states $\chi_K(\eta)$: do not have definite angular momenta

States of good angular momentum, projected from an intrinsic state $\chi_K(\eta)$

$$|\psi^J_{MK}(\eta)\rangle = \frac{2J+1}{8\pi^2\sqrt{N_{JK}}}\int d\Omega\, D^{J^*}_{MK}(\Omega) R(\Omega)|\chi_K(\eta)\rangle$$

- N_{JK}: normalization constant
- $R(\Omega) = \exp(-i\alpha J_z)\exp(-i\beta J_y)\exp(-i\gamma J_z)$: general rotation operator
- Ω: Euler angles (α, β, γ)
- $|\psi^J_{MK}(\alpha)\rangle$ projected from different intrinsic states are not in general orthogonal to each other
- Band mixing calculations are performed after appropriate orthonormalization

The resulting eigenfunctions are of the form [3]

$$\boxed{|\varphi^J_M(\eta)\rangle = \sum_{K,\alpha} S^J_{K\eta}(\alpha)|\psi^J_{MK}(\alpha)\rangle\,, \qquad S^J_{K\eta}(\alpha):\ \text{expansion coefficients}}$$

TABLE 1

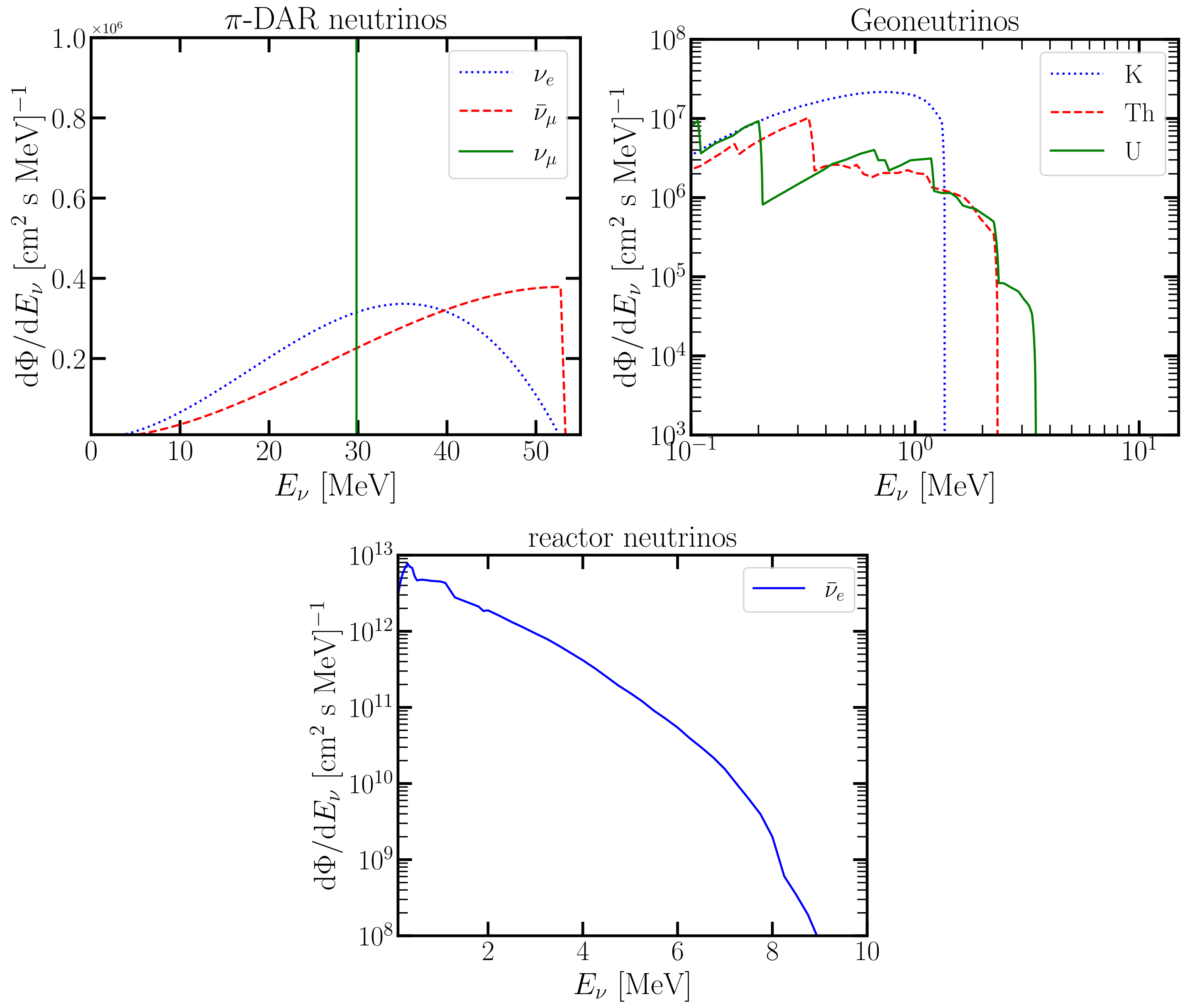
Property \ Nucleus	Germanium			Zinc		Silicon
	^{70}Ge	^{73}Ge	^{76}Ge	^{64} Zn	^{70} Zn	^{28} Si
isotopic abundance (%)	20.52	7.76	7.75	49.2	0.6	92.2
ground state spin (J^π)	0^+	$9/2^+$	0^+	0^+	0^+	0^+
h.o. length (fm)	1.894	1.907	1.920	1.865	1.894	1.625

Nuclear structure properties of the studied isotopes.

LABORATORY AND EARTH NEUTRINO SOURCES

- pion decay at rest
- reactor antineutrinos $\bar{\nu}_e$
- geoneutrinos

FIGURE 2



Laboratory (π-DAR, reactor) and Geoneutrino (from K, Th and U decay chains) neutrino spectra.

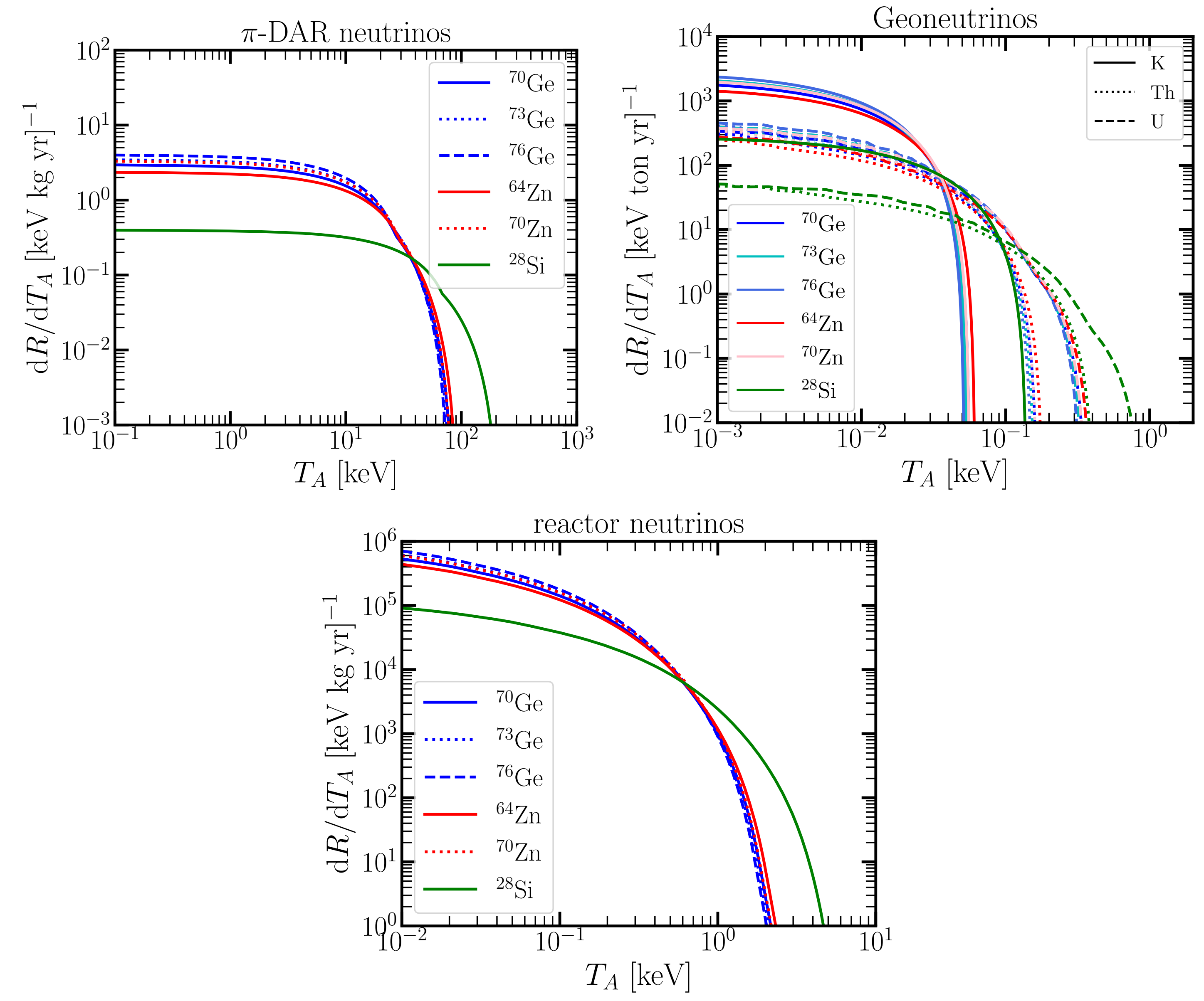
RESULTS: EXPECTED EVENT RATES

Differential number of CEνNS events [4,5]

$$\boxed{\frac{\mathrm{d}R}{\mathrm{d}T_A} = t_{\mathrm{run}}\, N_{\mathrm{target}} \sum_{\nu_\alpha}\int_{\sqrt{\frac{m_A T_A}{2}}}^{E_\nu^{\max}} \frac{\mathrm{d}\Phi_{\nu_\alpha}}{\mathrm{d}E_\nu}\left(\frac{d\sigma}{dT_A}\right)_{\mathrm{SM}} \mathrm{d}E_\nu}$$

- $\mathrm{d}\Phi_{\nu_\alpha}/\mathrm{d}E_\nu$: neutrino flux for the flavor α
- t_{run}: exposure time
- N_{target}: number of target nuclei

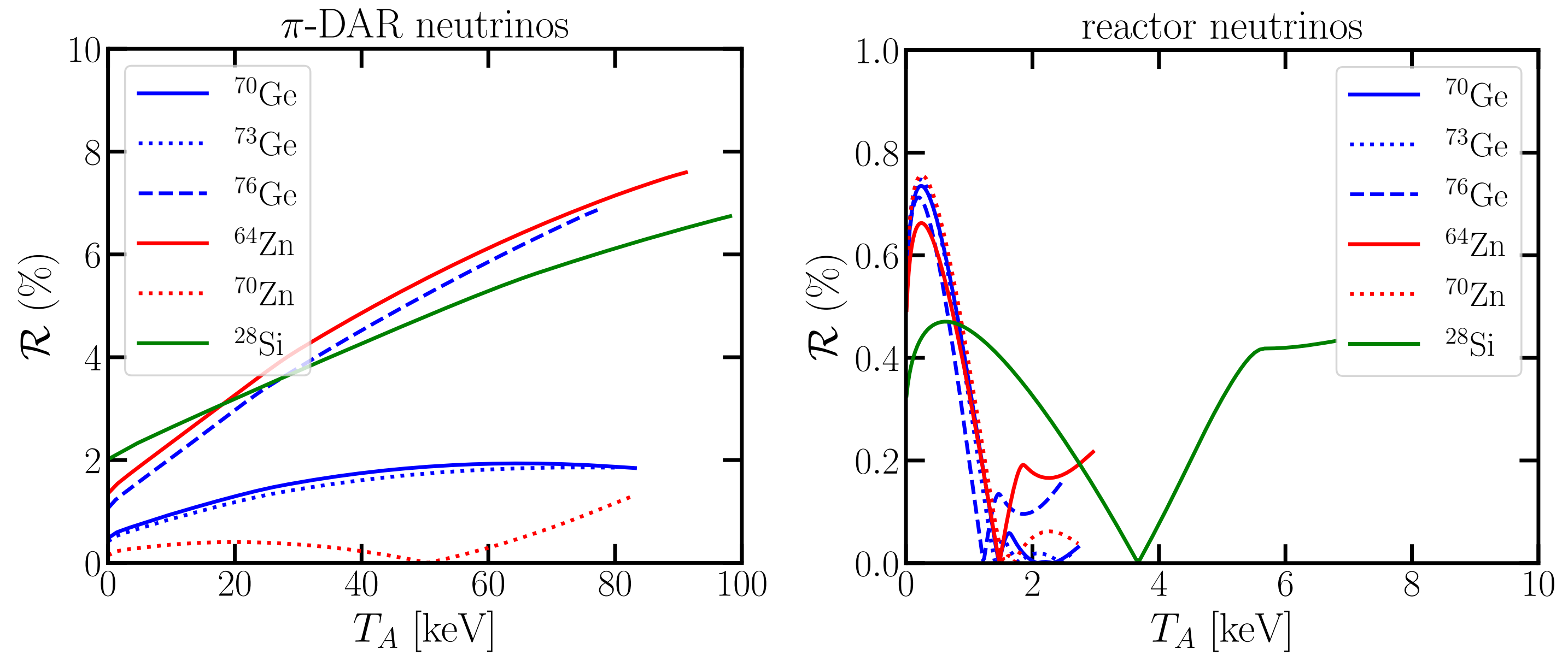
FIGURE 3



Differential number of events for the different laboratory and Earth neutrino sources.

CONCLUSIONS

FIGURE 4



Percentage difference between DSM calculations and those involving the effective Klein-Nystrand form factor parametrization, calculated as $\mathcal{R} = \frac{|R_{\mathrm{DSM}} - R_{\mathrm{KN}}|}{R_{\mathrm{DSM}}}$ [5].

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