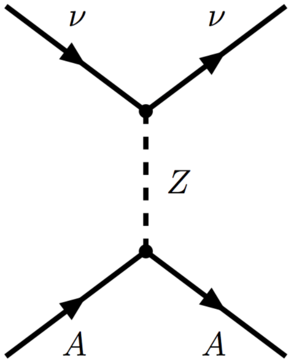

Discrepancies in the published expressions for the CEvNS cross section

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Motivation

All the CEvNS expressions may be reduced to

$$\frac{d\sigma}{dT} = \frac{G_F^2 \cdot [N - Z(1 - 4\sin^2\theta_W)]^2 F^2(q^2)}{4\pi} M \left\{1 - \frac{T}{E_\nu} - \frac{MT}{2E_\nu^2}\right\}$$

… but that’s not enough

From the first observations to the “precision measurement”:

- form factors
- NSI
- sinθ_w

requires ~1% precision!

Wish-to-have properties of the expression:

- describes scattering off an arbitrary spin nucleus
- includes the contribution from the axial current
- treats correctly the “spin flip” transitions

Papers being discussed

- **“Probing new physics with coherent neutrino scattering off nuclei”**

  J. Barranco, O. G. Miranda and T. I. Rashba, JHEP 12 (2005) [arXiv:hep-ph/0508299]

- **“Coherent neutrino-nucleus scattering and new neutrino interactions”**

  M. Lindner, W. Rodejohann, X.-J. Xu, JHEP 03 (2017) [arXiv:1612.04150]

- **“Coherency and incoherency in neutrino-nucleus elastic and inelastic scattering”**

  V. A. Bednyakov and D. V. Naumov, PRD 98 (2018) [arXiv:1806.08768]

JHEP 12 (2005)

Formula (2.5):

$$\frac{d\sigma}{dT} = \frac{G_F^2 M}{2\pi}\left\{(G_V + G_A)^2 + (G_V - G_A)^2\left(1 - \frac{T}{E_\nu}\right)^2 - (G_V^2 - G_A^2)\frac{MT}{E_\nu^2}\right\}$$

$G_V = \left[Z g_V^p + N g_V^n\right] F_{nucl}^V(q^2)$ and $G_A = \left[Z_{\uparrow\downarrow} g_A^p + N_{\uparrow\downarrow} g_A^n\right] F_{nucl}^A(q^2)$

Notes:

- no detailed calculation provided
- works for arbitrary nuclear spin since the spin is not specified

- What do “spin up” and “spin down” contributions to the axial part mean?
- How the arbitrary spin nucleus is treated in the calculation?

Can be rewritten neglecting axial contribution:

$$\frac{d\sigma}{dT} = \frac{G_F^2 \cdot [N - Z(1 - 4\sin^2\theta_W)]^2 F^2(q^2)}{4\pi} M\left\{1 - \frac{T}{E_\nu} - \frac{MT}{2E_\nu^2} + \frac{T^2}{2E_\nu^2}\right\}$$

JHEP 03 (2017)

Formulae (A.27) and (B5), detailed calculation provided:

$$\frac{d\sigma}{dT} = \frac{G_F^2 (2g_L^\nu Q_W)^2 F^2(q^2)}{4\pi} M \left(1 - \frac{T}{E_\nu} - \frac{MT}{2E_\nu^2}\right)$$ for spin 0

and $$\left.\frac{d\sigma}{dT}\right|_{\text{spin-}1/2} = \frac{G_F^2 (2g_L^\nu Q_W)^2 F^2(q^2)}{4\pi} M \left(1 - \frac{T}{E_\nu} - \frac{MT}{2E_\nu^2} + \frac{T^2}{2E_\nu^2}\right)$$

Compare with the one from JHEP 12 (2005):

$$\frac{d\sigma}{dT} = \frac{G_F^2 \cdot [N - Z(1 - 4\sin^2\theta_W)]^2 F^2(q^2)}{4\pi} M \left\{1 - \frac{T}{E_\nu} - \frac{MT}{2E_\nu^2} + \frac{T^2}{2E_\nu^2}\right\}$$

Discrepancy for the spin 0 case, numerically small, but raises questions:

- was the one in JHEP 12 (2005) derived for a spin 1/2?
- if no what’s the reason for such a discrepancy?

PRD 98 (2018)

Formula (48):

$$\frac{d\sigma_{\mathrm{coh}}}{dT_A}=\frac{G_F^2 m_A}{\pi}g_c\,\overset{\left(1-\frac{T}{E_\nu}-\frac{MT}{2E_\nu^2}\right)}{\overset{\parallel}{\left(1-\frac{T_A}{T_A^{\max}}\right)}}\,|G_V+G_A|^2,$$

not spin averaged

$$G_V=\sum_f g_V^f F_f\left(A_f\left[1-\frac{y\tau}{2}\right]+\Delta A_f\frac{y}{2}\right)$$ and $$G_A=\sum_f g_A^f F_f\left(\Delta A_f\left[1-\frac{y}{2}\right]+A_f\frac{y\tau}{2}\right)$$

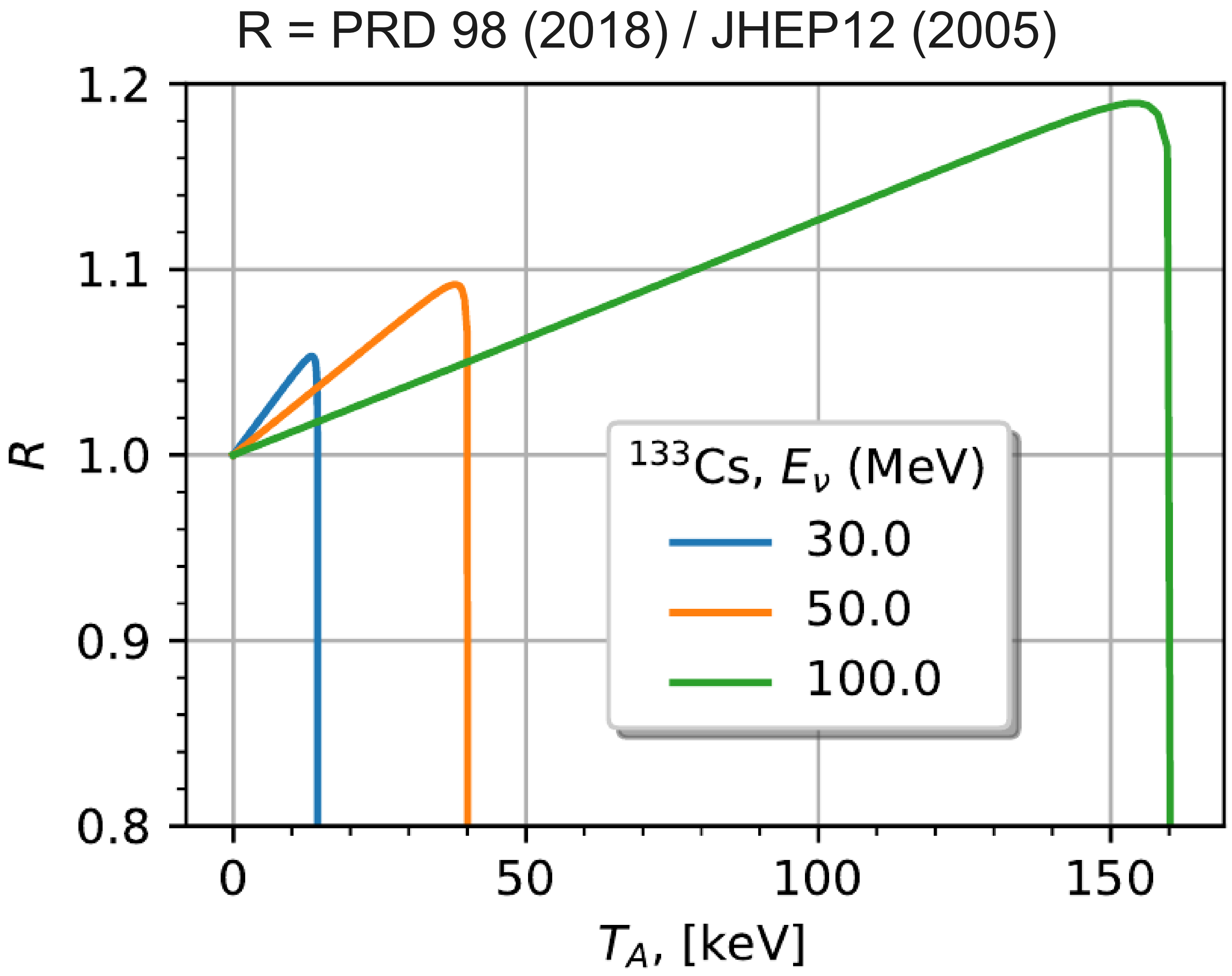
A_p = Z, A_n = N – numbers of nucleons

A_p = (Z_+ - Z_-), A_n = (N_+ - N_-) – nucleon’s projections on the incident neutrino momentum

Peculiarities:

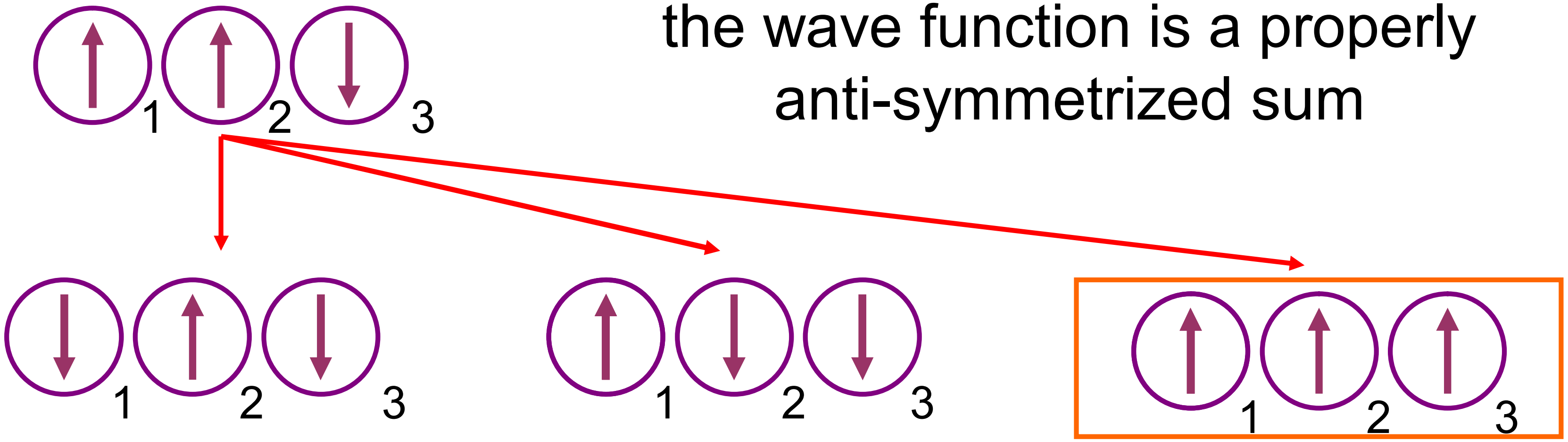
- corrections depending on nucleon’s mass and momentum
- projections of spins on the neutrino momentum instead of the total spin
- nucleus “spin flip” transitions are not taken into account

PRD 98 (2018) vs. JHEP 12 (2005)



“Spin flip” problem illustration

Consider three neutron system, J=½



the wave function is a properly anti-symmetrized sum

No spin flip transitions part: coherent scattering off all three neutrons, $\sigma \sim N^2$

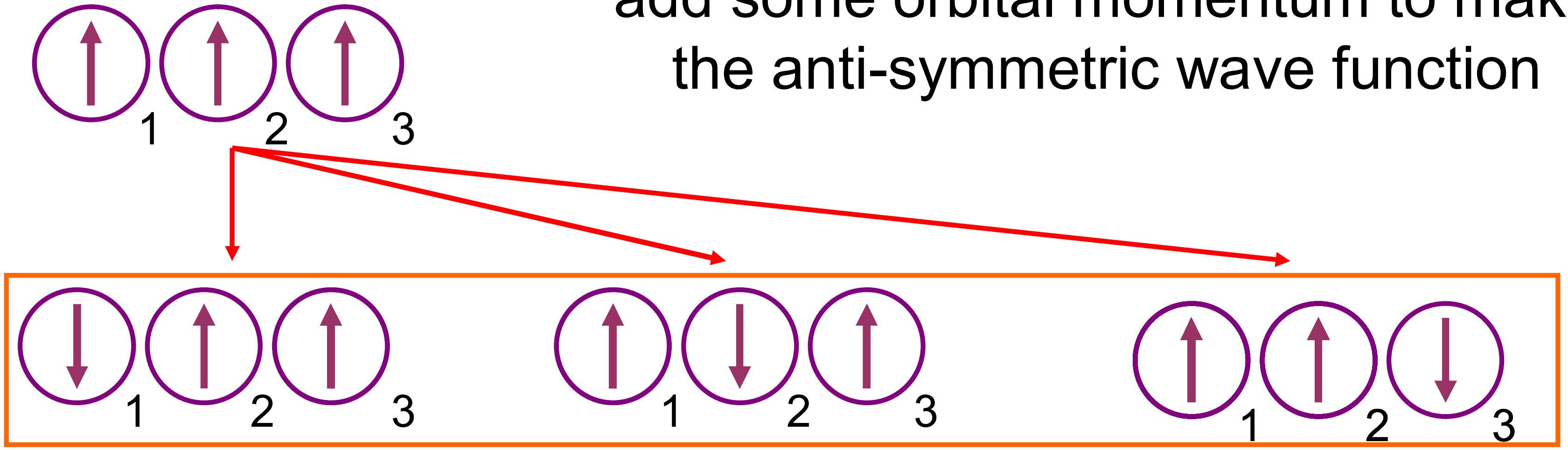
Spin flip: coherent if off 1 or 2 , inelastic if off 3, $\sigma \sim$ 

The illustration based on the discussion with D. Naumov

“Spin flip” problem illustration

Consider three neutron system, $S={}^{3}/_{2}$

add some orbital momentum to make the anti-symmetric wave function



<u>No spin flip transitions part</u>: coherent scattering off all three neutrons, $\sigma \sim N^2$

<u>Spin flip</u>: no coherent contribution at all?

The illustration based on the discussion with D. Naumov

Conclusion

This workshop is an ideal place to discuss, let’s do it…

Thank you for your attention!