Charge form factor and sum rules of electromagnetic response functions in ^{12}C

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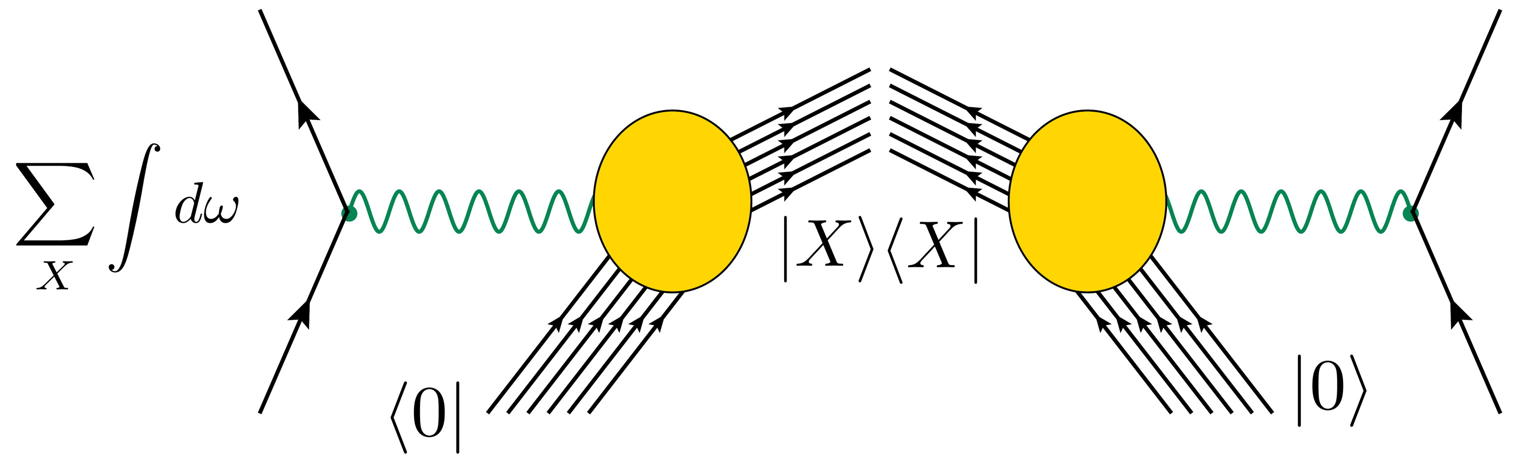
The electroweak response is a fundamental ingredient to describe the neutrino - 12-carbon scattering, recently measured by the MiniBooNE collaboration to calibrate the detector aimed at studying neutrino oscillations. As a first step toward its calculation, we have computed the sum rules for the electromagnetic response of ^{12}C including two-body meson exchange currents. Moreover, this calculation can be used to predict the results of the upcoming experiment at Jefferson Laboratory, which are not yet released.

SUM RULES AND FORM FACTOR

The sum rules of the response functions provide a useful tool for studying integral properties of the electron-nucleus scattering $e + {}^{12}\mathrm{C} \to e' + X$.



By using the completeness relation, they can be expressed as ground-state expectation values of the charge and current operators.

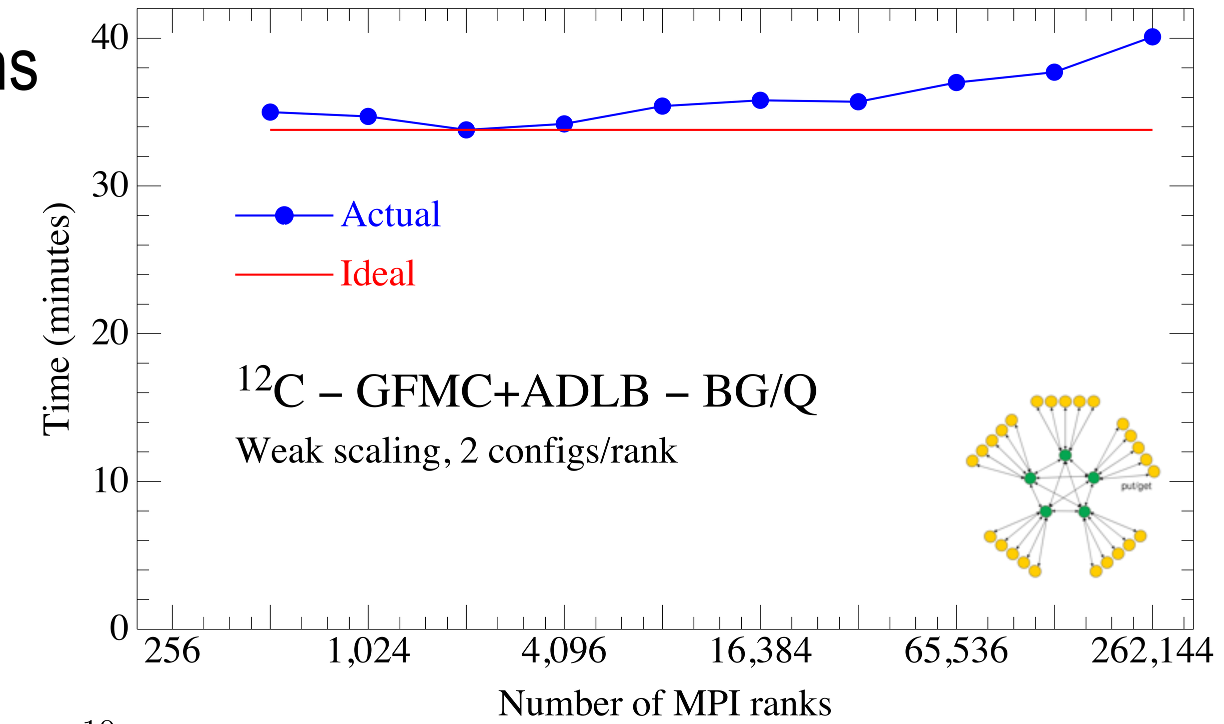
$$S_\alpha(q) = C_\alpha\left[\langle 0|O_\alpha^\dagger(\mathbf{q})\,O_\alpha(\mathbf{q})|0\rangle - |\langle 0;\mathbf{q}|O_\alpha(\mathbf{q})|0\rangle|^2\right]$$

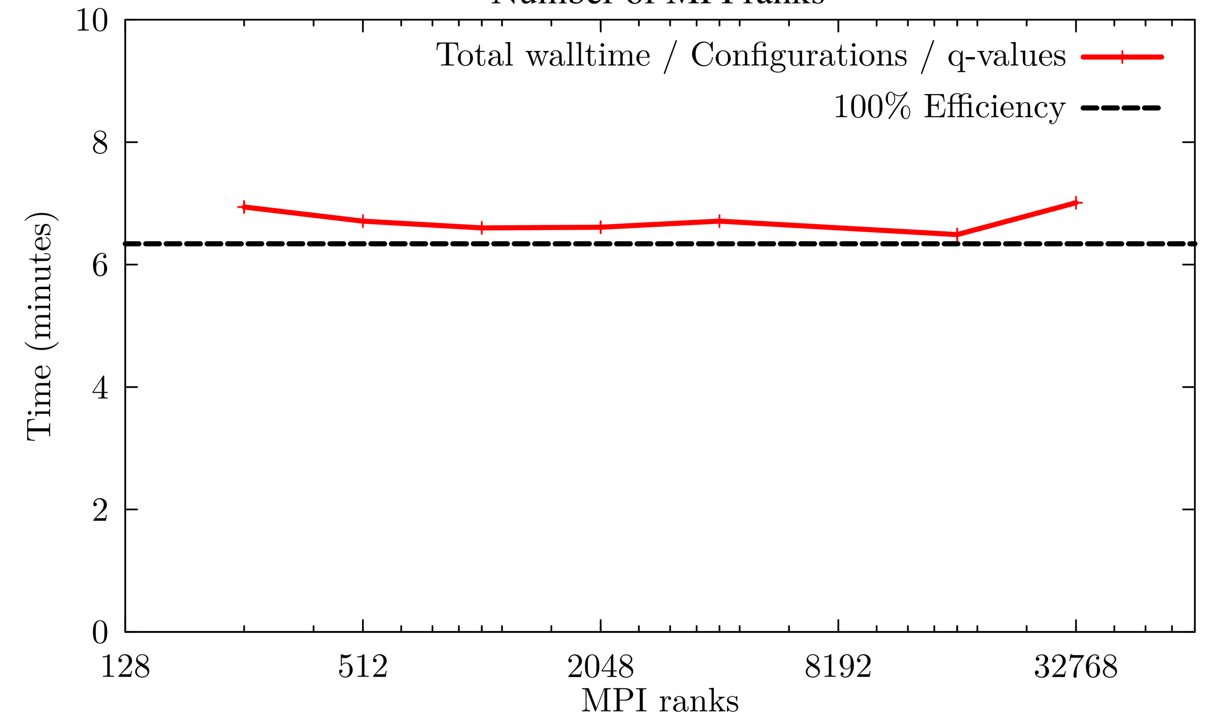
The elastic contribution of the longitudinal sum rule, proportional to the charge form factor |F(q)|, describing the spatial distributions of electric charge inside the nucleus, is subtracted.

GREEN'S FUNCTION MONTE CARLO ON MIRA

GFMC algorithms use projection techniques to enhance the ground-state component of a starting trial wave function using **realistic NN+NNN interaction.** $|\Psi_0\rangle = \lim_{\tau\to\infty} e^{(\hat{H}-E_0)\tau}|\Psi_T\rangle$

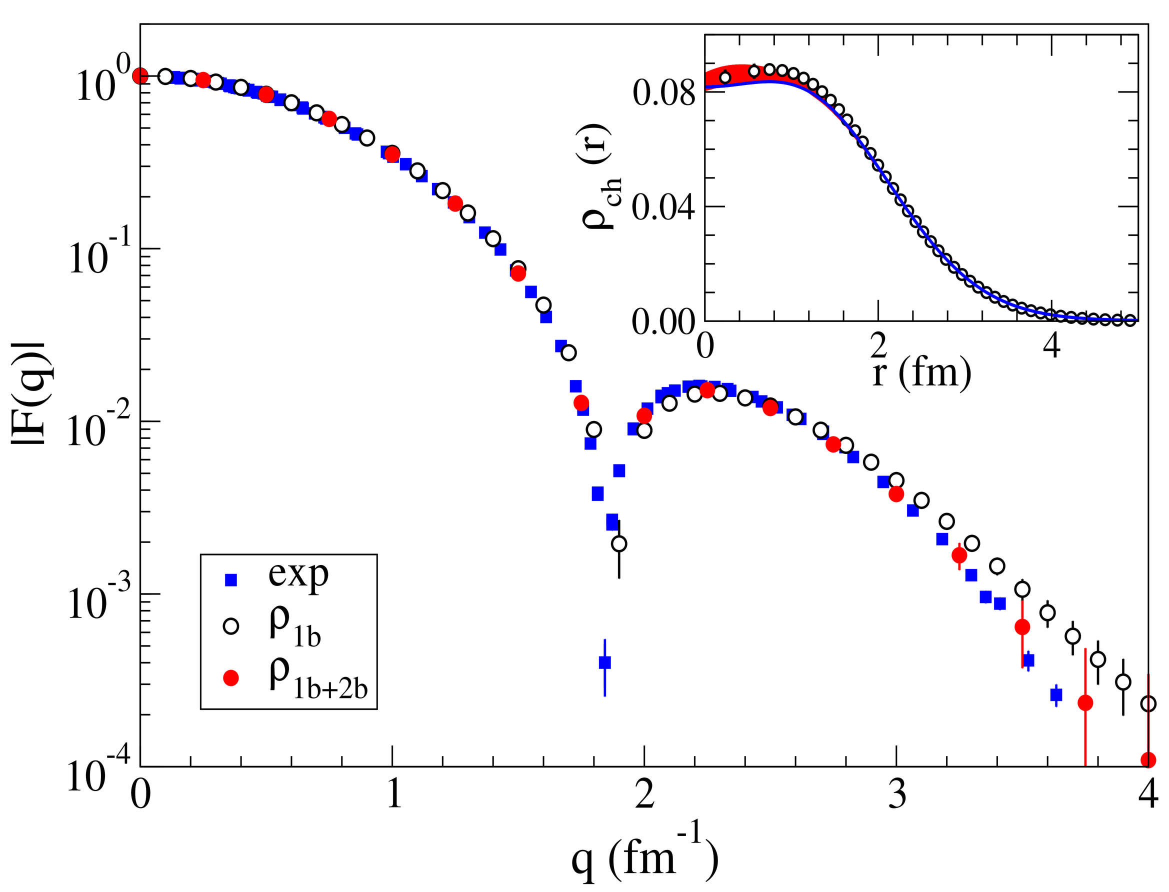
- The calculation of the energy and of the response functions allows for splitting one sample over many processors.
- We ported GFMC, together with the ADLB load-balancing library, to the 10-petaflop Mira computer at Argonne and demonstrated scaling to more than 250,000 MPI ranks with over 2 million threads.
- We conducted experiments to determine the best configuration of MPI processes per node and OpenMP threads per process for the sum rule calculations (4 ranks/node, 16 threads/rank).
- To perform this calculation we have used about 20 million hours of ALCF Early Science Program computing time.





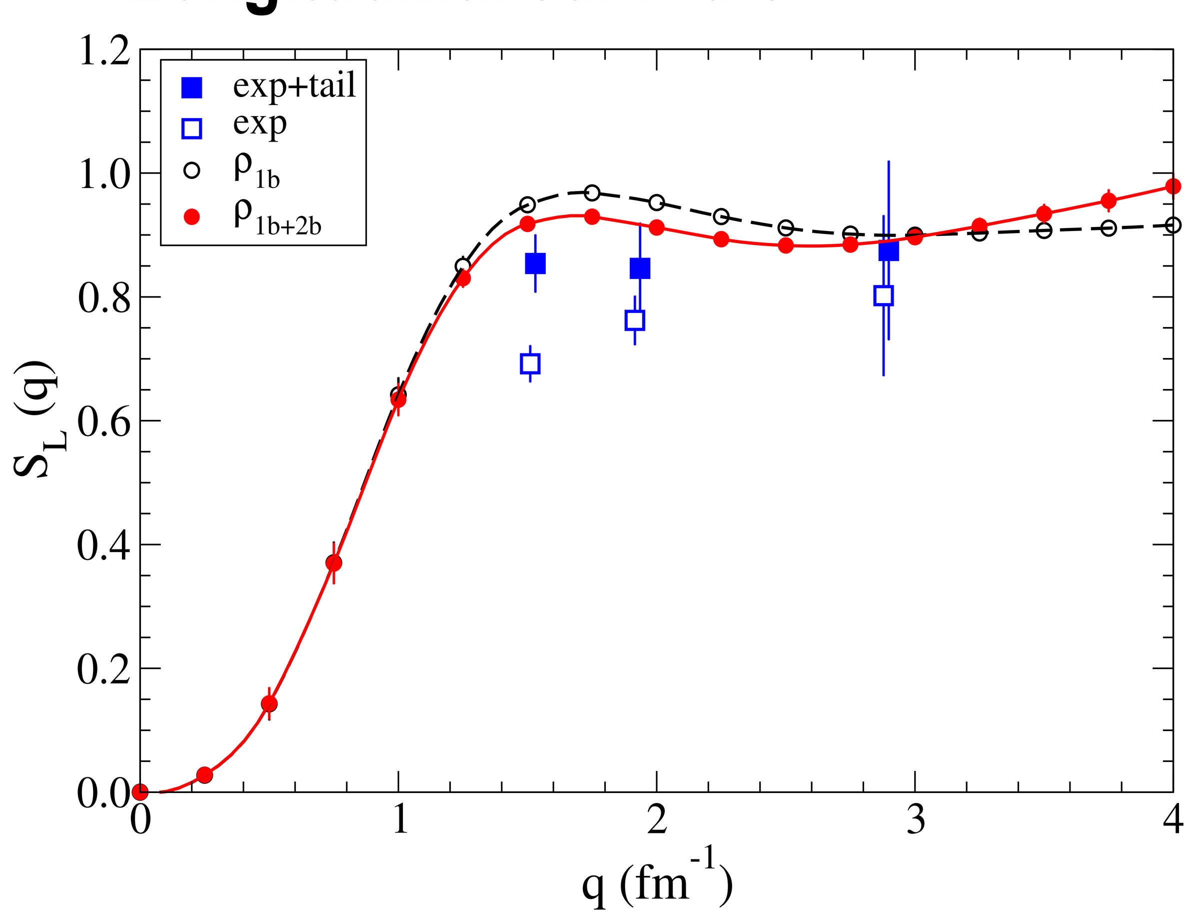
RESULTS

Longitudinal form factor



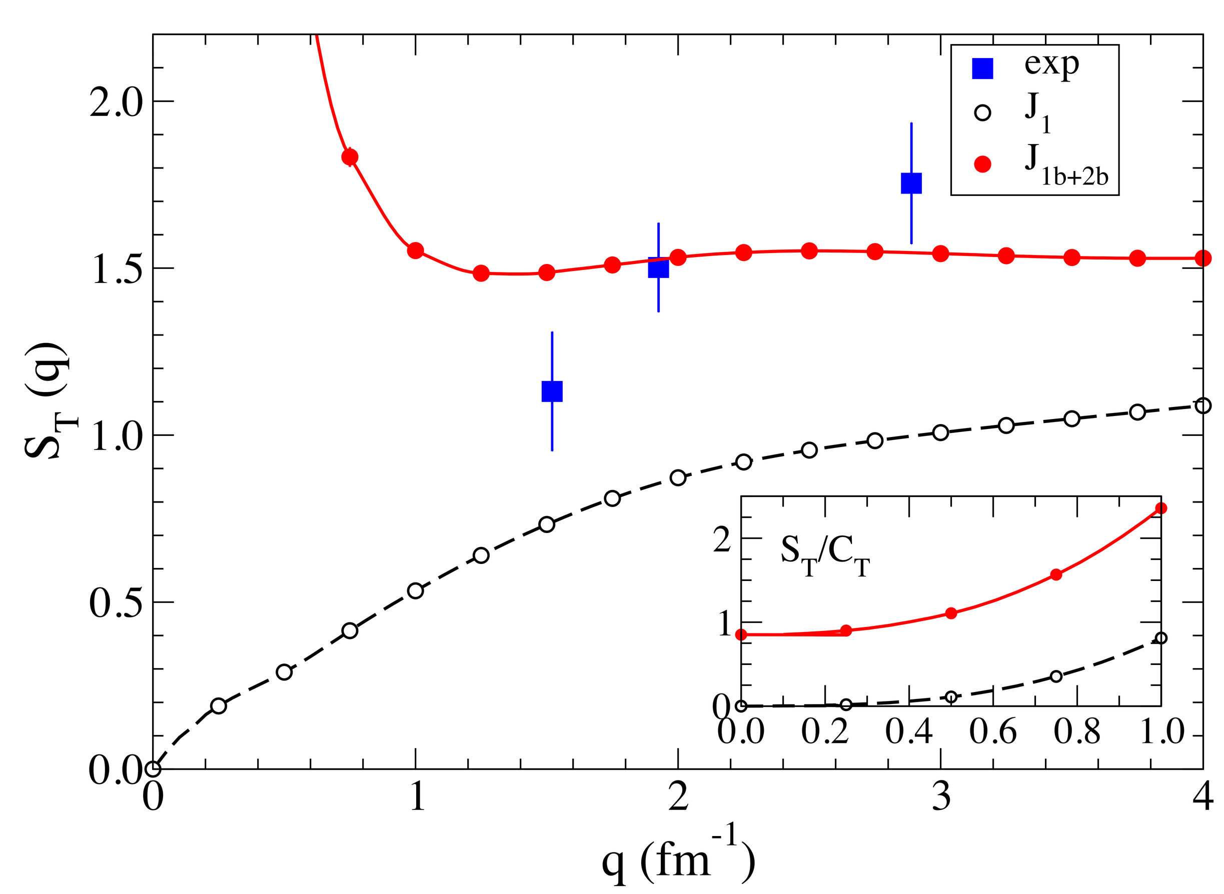
Two-body terms in the density operator bring theoretical prediction closer to experimental data in the high-momentum transfer tail.

Longitudinal sum rule



Satisfactory agreement with experimental values. No evidence for in-medium modifications of the nucleon electromagnetic form factors.

Transverse sum rule



Large two-body currents effect: at q≈500 MeV the increase with respect to the one-body case is about 50%.

FUTURE WORK

- Neutral current sum rules, allowing for the description of neutrino scattering on ^{12}C, are currently being implemented in the code.
- Euclidean elecromagnetic and weak response functions will enable us to make a more direct comparison with data.

NUCLEI Nuclear Computational Low-Energy Initiative
U.S. Department of Energy INCITE Leadership Computing
Argonne National Laboratory
ALCF Early Science Program