Initial nucleon state (impulse approximation)

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Abstract

The initial nucleon state is discussed in the impulse approximation, when the interacting nucleon takes all 4-momentum transfer from projectile, while the rest of nucleus behaves as spectator. The nucleon invariant mass distributions are shown for both 1p1h- (one particle, one hole) and 2p2h-kinematics, utilizing the nucleon momentum spread due to two-Γ generator (Back up).

1 Outline

1. 1p1h-kinematics.
2. 2p2h-kinematics.
3. Invariant nucleon mass distributions.
4. Conclusion.

2 1p1h-kinematics

A projectile, say ν, interacts with a on-shell nucleus in the rest, $(M_A, \mathbf{0})$. Inside the nucleus, nucleons move being interacting and bound. Then the nucleon(s) and the rest $(A-1)$ of the nucleus are off-shell. We suppose that the nucleon has momentum, $\mathbf{k}$, sampled according to the nucleon momentum distribution. Then, the initial nucleus state kinematics reads, in terms of the Lorentz vectors:

$$nucleon: \quad (M_A - \sqrt{(M_{A-1}+E_x)^2+k^2},\ \mathbf{k}),$$

$$(A-1)-spectator: \quad (\sqrt{(M_{A-1}+E_x)^2+k^2}, -\mathbf{k}),$$

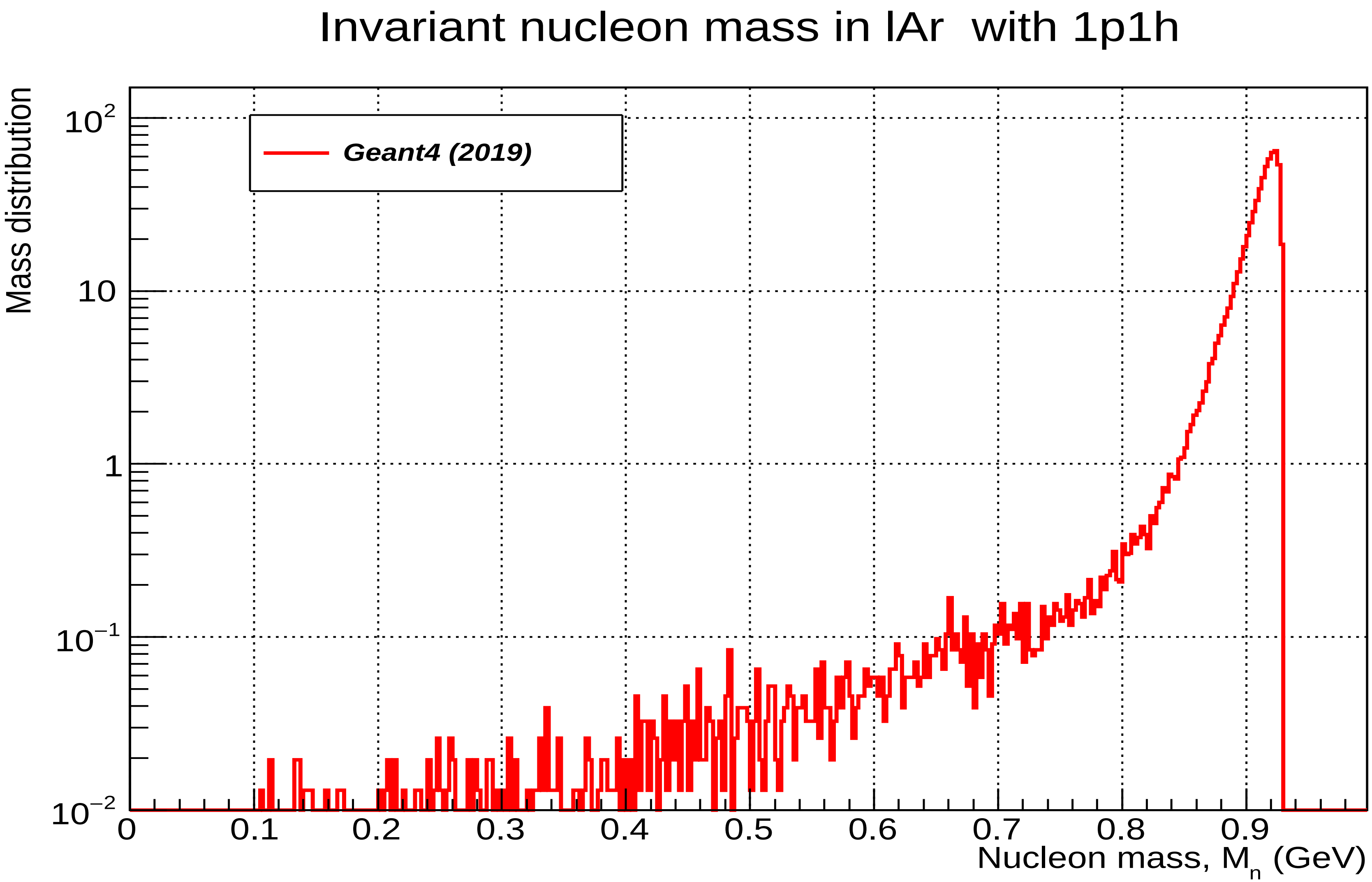
$$A-nucleus, \Sigma: \qquad (M_A, \mathbf{0}),$$

where E_x is the excitation energy of the rest nucleus depending on the atomic weight $(A-1)$.

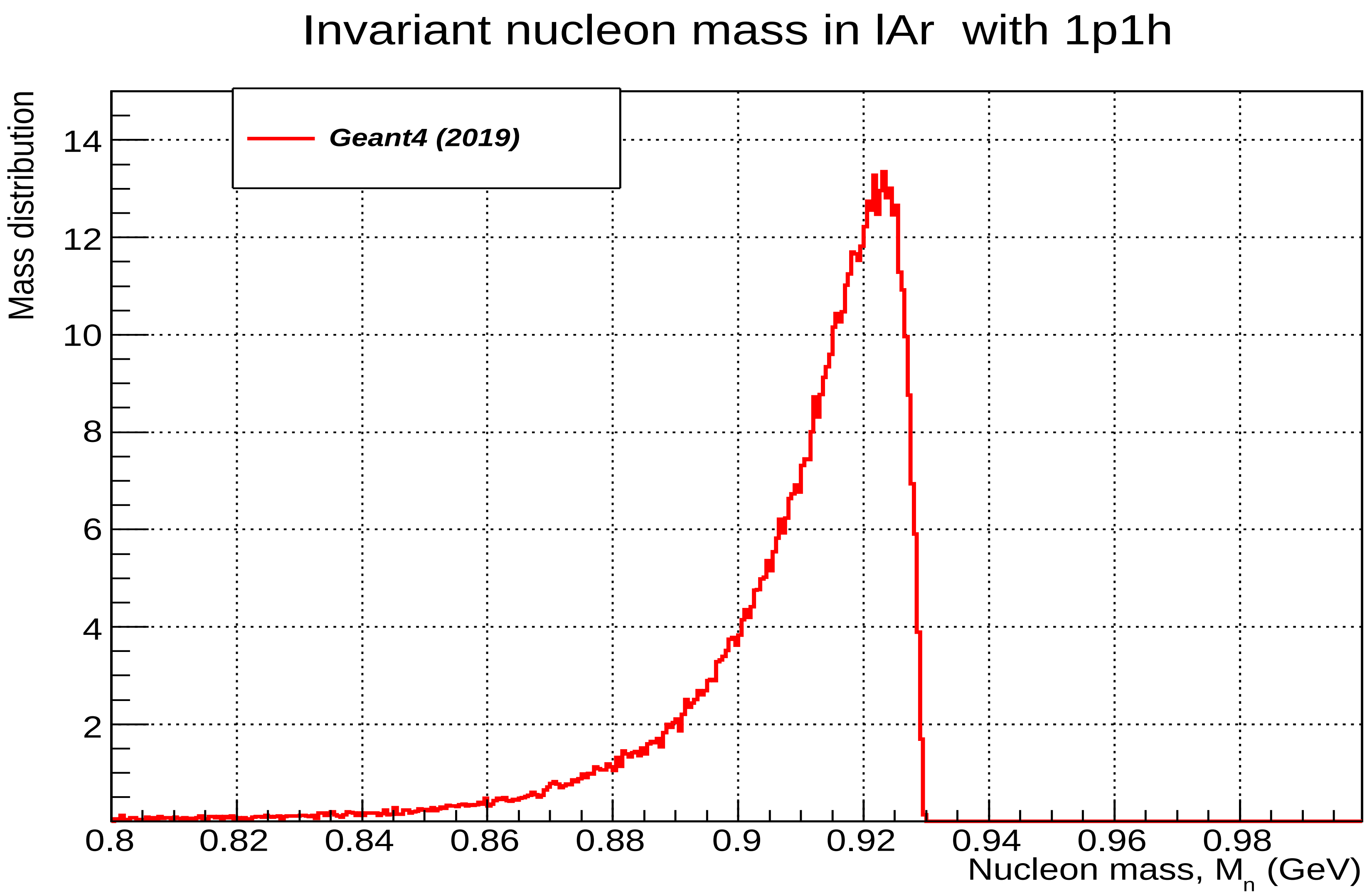
The nucleon invariant mass, M_n, is distributed according:

$$M_n^2 = \left[M_A - \sqrt{(M_{A-1}+E_x)^2+k^2}\right]^2 - k^2.$$

M_n is typically smaller (and spreaded) than the mass of free nucleon.



Invariant nucleon mass in argon



Invariant nucleon mass in argon (linear scale), MAX$\sim$923 GeV, FWHM$\sim$200 MeV.

3 2p2h-kinematics

If the nucleon momentum more than k_F (say, $k > 2k_F$), it is supposed that such high momenta can come from the interaction between individual nucleons through their hard-core potential. The kinematics reads:

$$1 - nucleon : \quad (\frac{1}{2}\left[M_A - M_{A-2} - 2E_x\right], \ \mathbf{k}),$$

$$2 - nucleon : \quad (\frac{1}{2}\left[M_A - M_{A-2} - 2E_x\right], \ -\mathbf{k}),$$

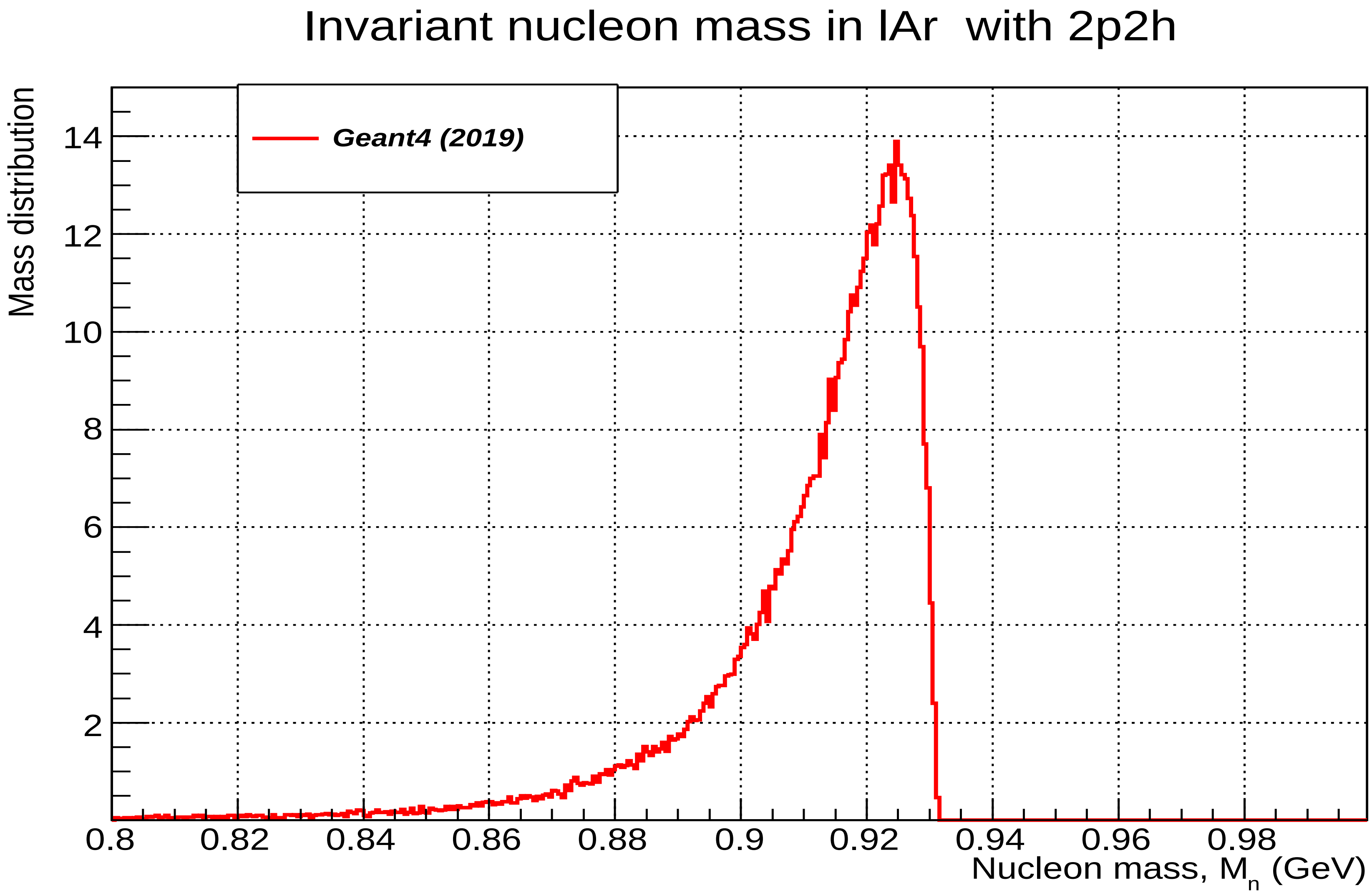
$$(A-2) - spectator : \quad (M_{A-2} + 2E_x, \mathbf{0}),$$

$$A - nucleus, \Sigma : \quad (M_A, \mathbf{0}),$$

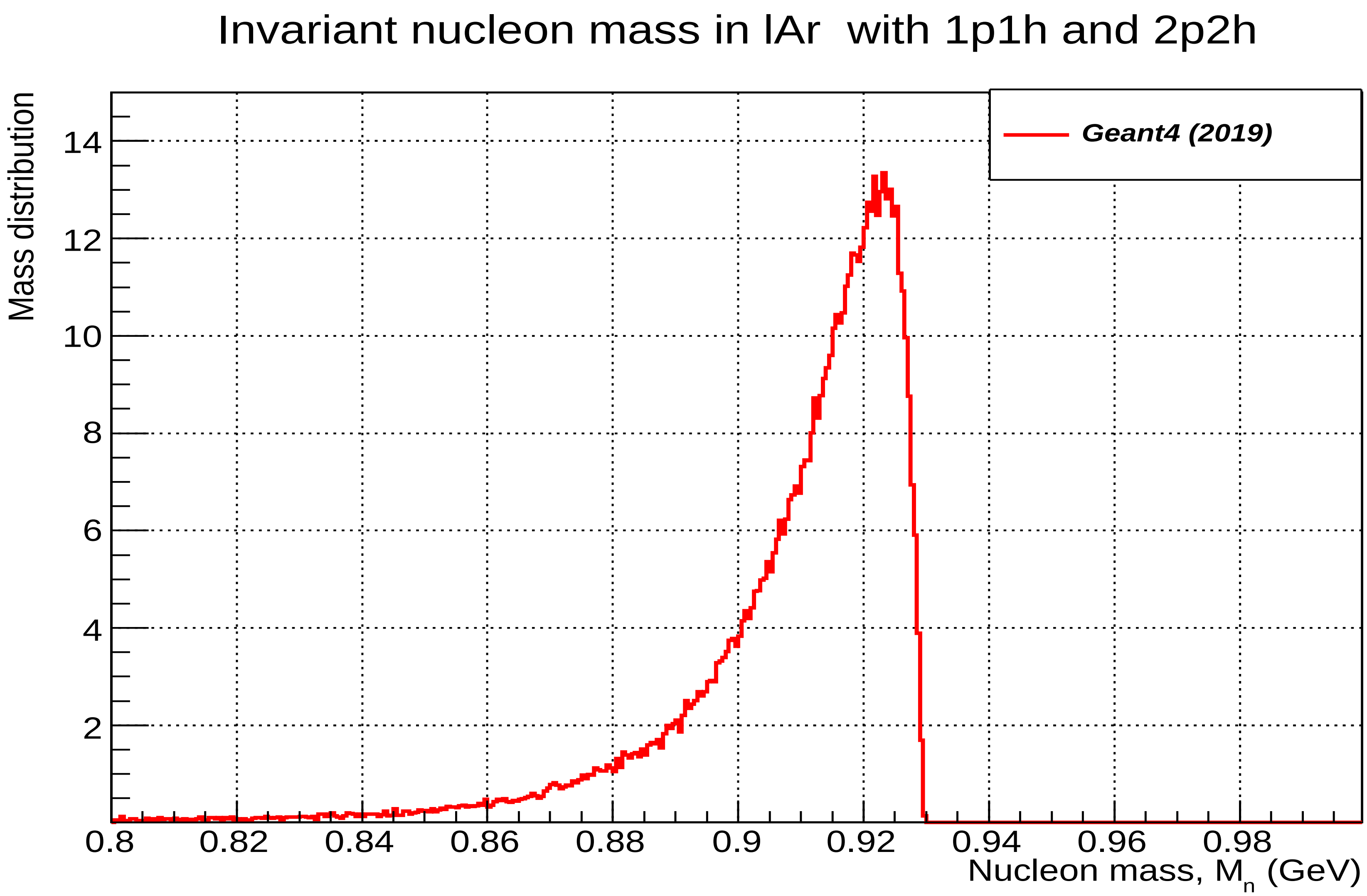
where E_x is the excitation energy of the rest nucleus depending on the atomic weight $(A-2)$.

The nucleon invariant mass, M_n, is distributed according:

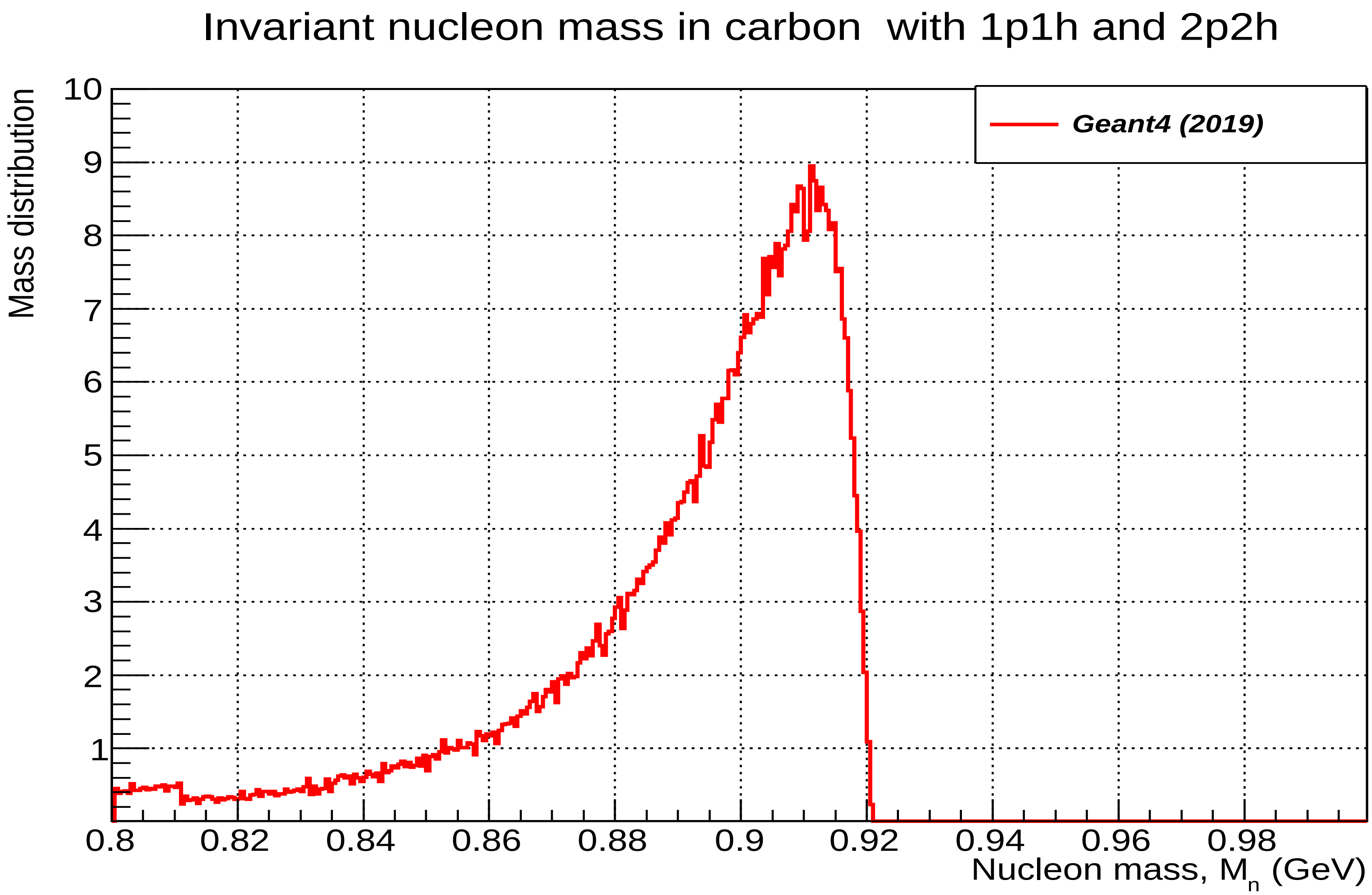
$$M_n^2 = \frac{1}{4}\left[M_A - M_{A-2} - 2E_x\right]^2 - k^2.$$



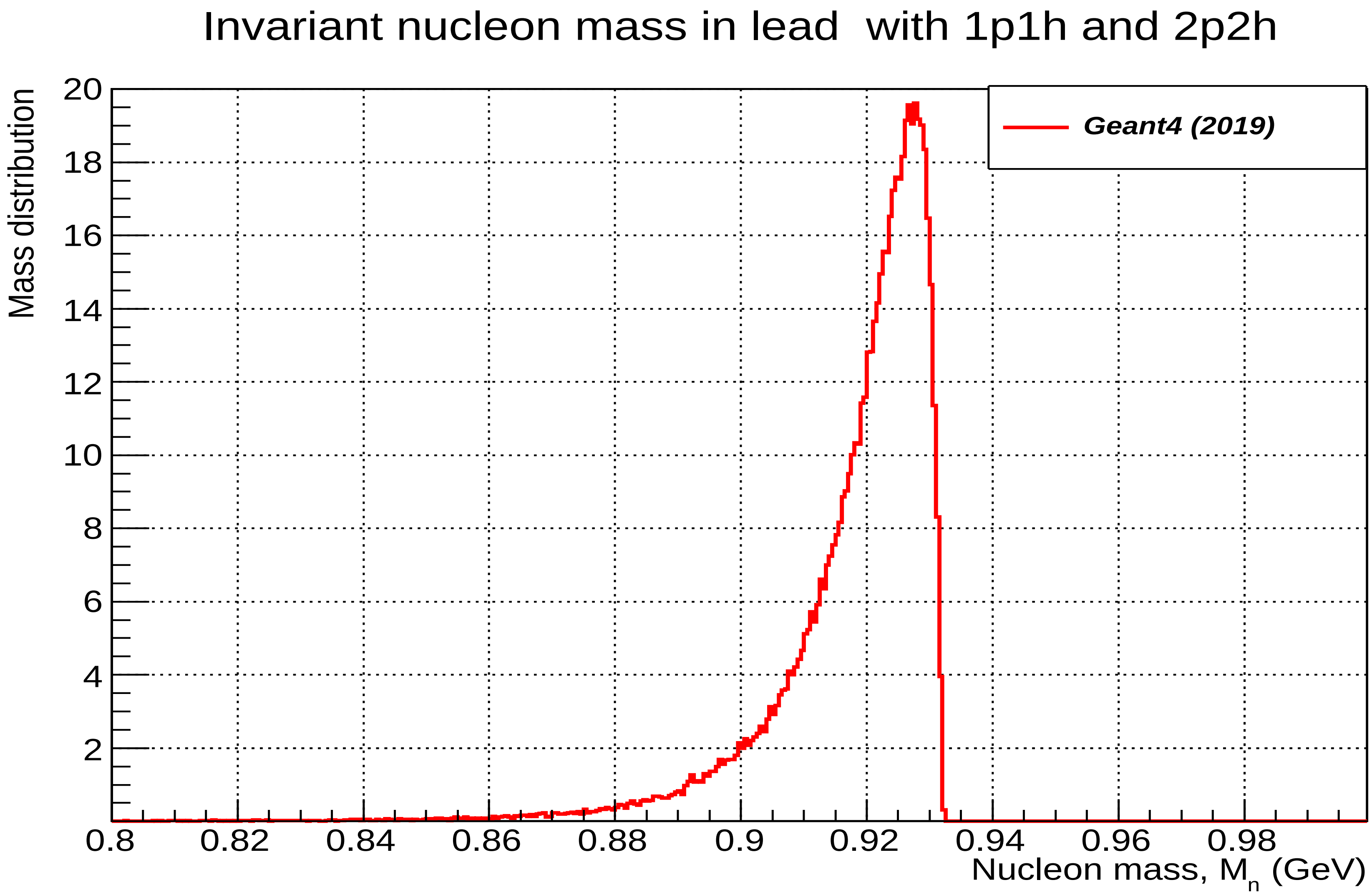
Invariant nucleon mass in argon (linear scale), MAX∼925 MeV, FWHM∼200 MeV.



Invariant nucleon mass in argon (linear scale, 1p1h→2p2h at $2k_F$), MAX∼923 MeV, FWHM∼200 MeV.



Invariant nucleon mass in carbon (linear scale, 1p1h→2p2h at $2k_F$),
MAX∼911 MeV, FWHM∼300 MeV.



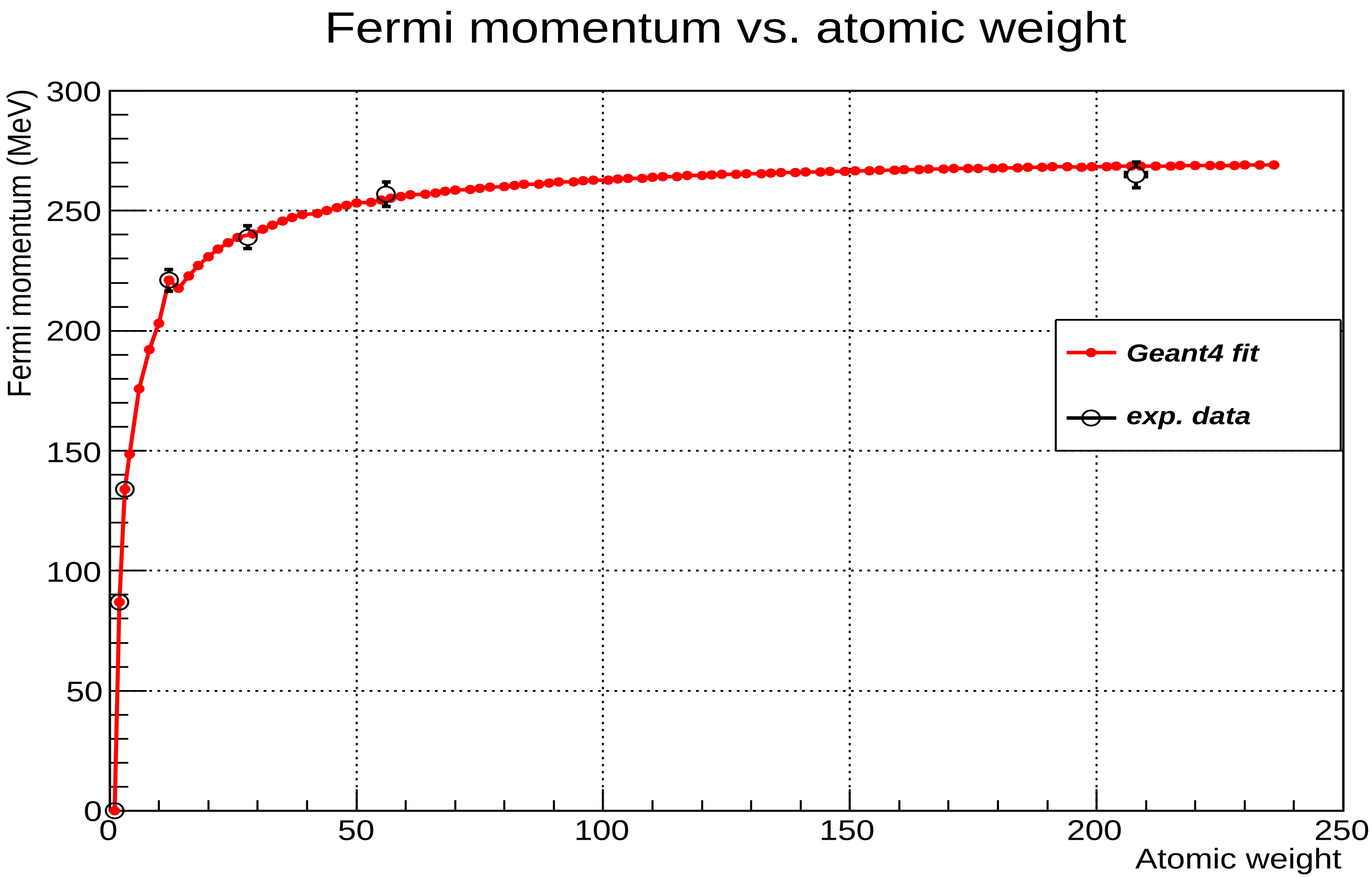
Invariant nucleon mass in lead (linear scale, 1p1h→2p2h at $2k_F$), MAX∼923 MeV, FWHM∼140 MeV.

4 Summary

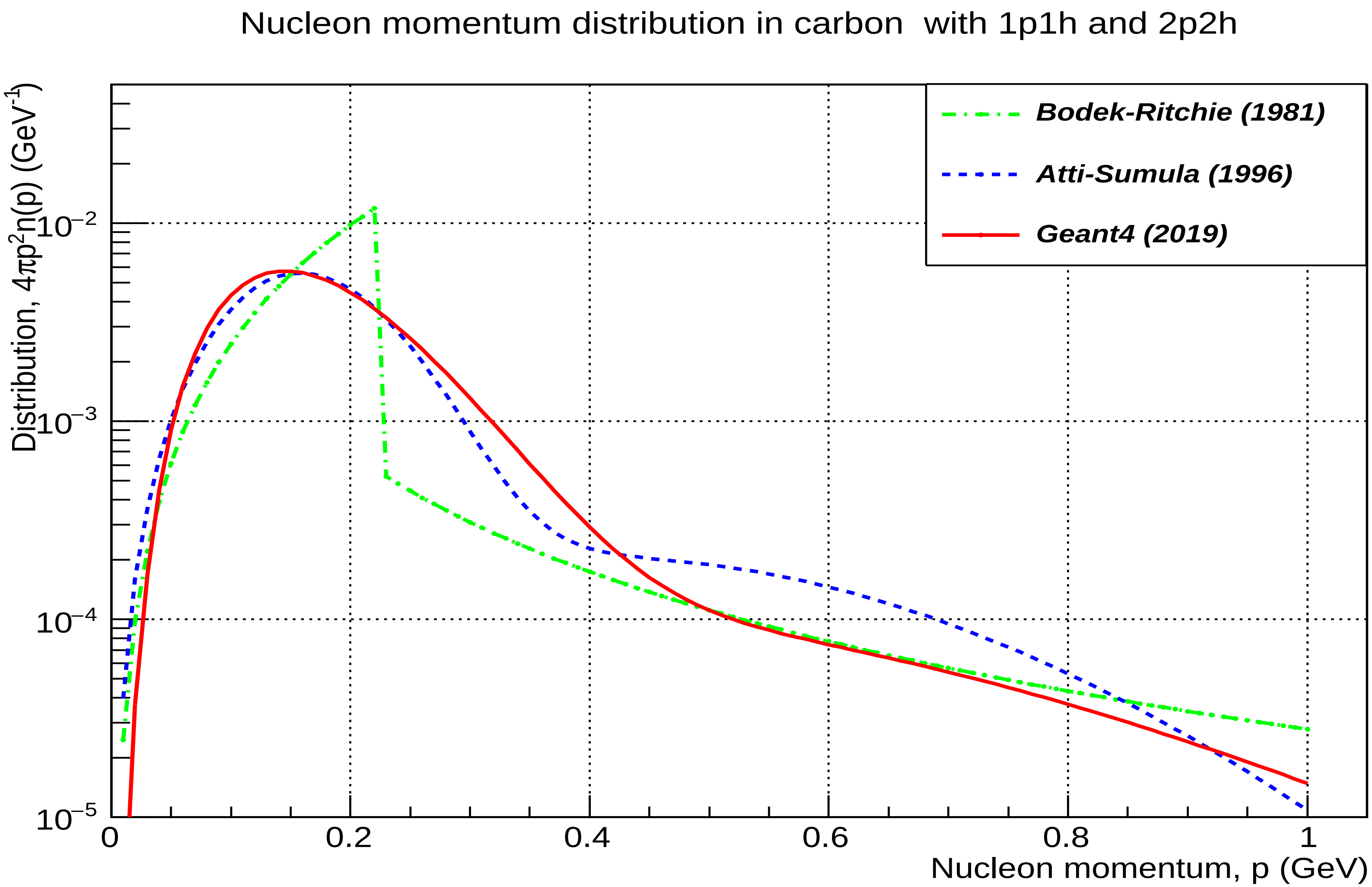
1. The initial nucleon state in terms of Lorentz vector is combined for both 1p1h- and 2p2h-kinematics using the nucleon momentum distribution.

2. The nucleon invariant mass distribution is shown for both 1p1h- and 2p2h-kinematics, reflecting the nucleon momentum distribution dependence on A.

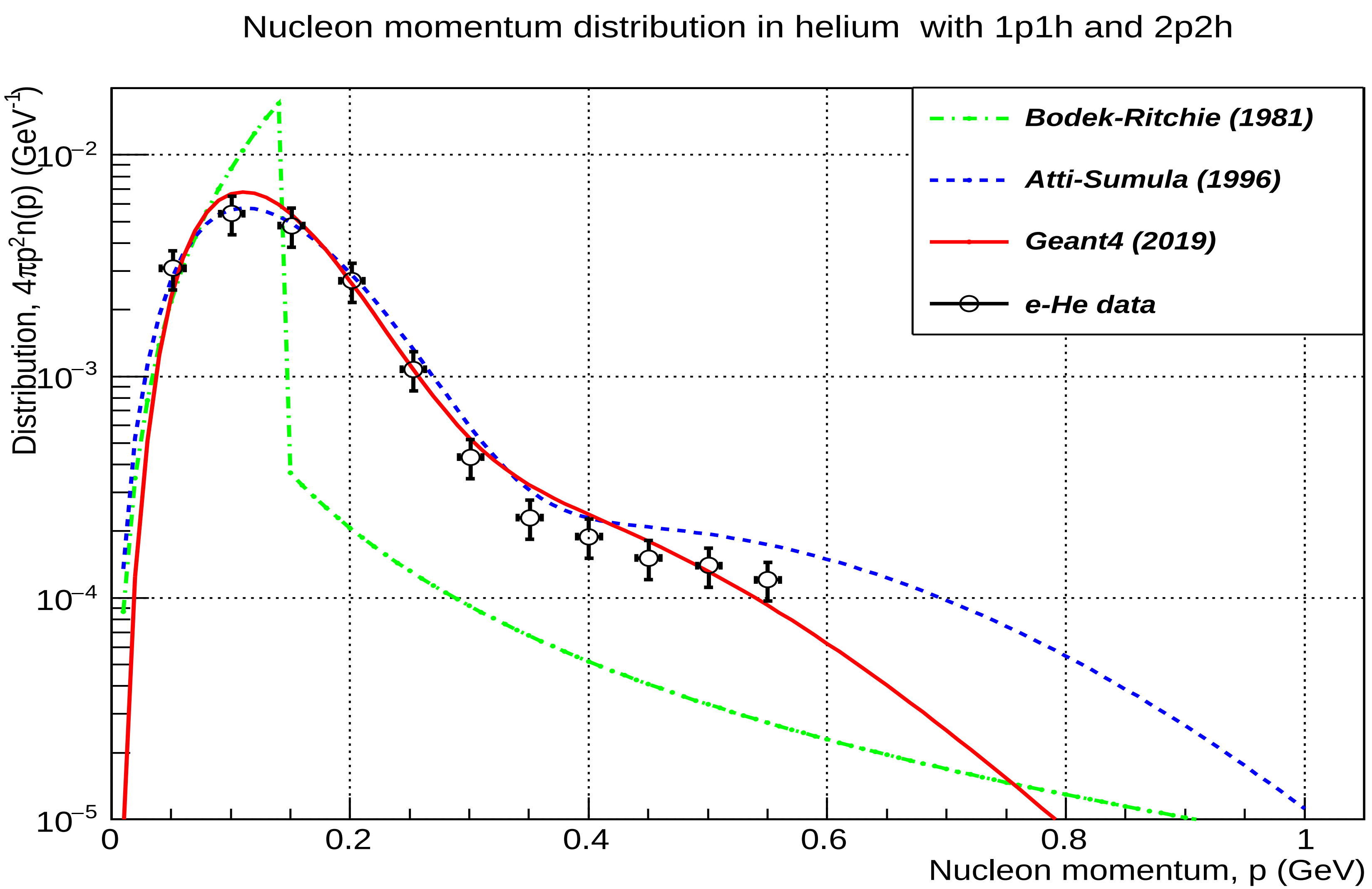
Back up



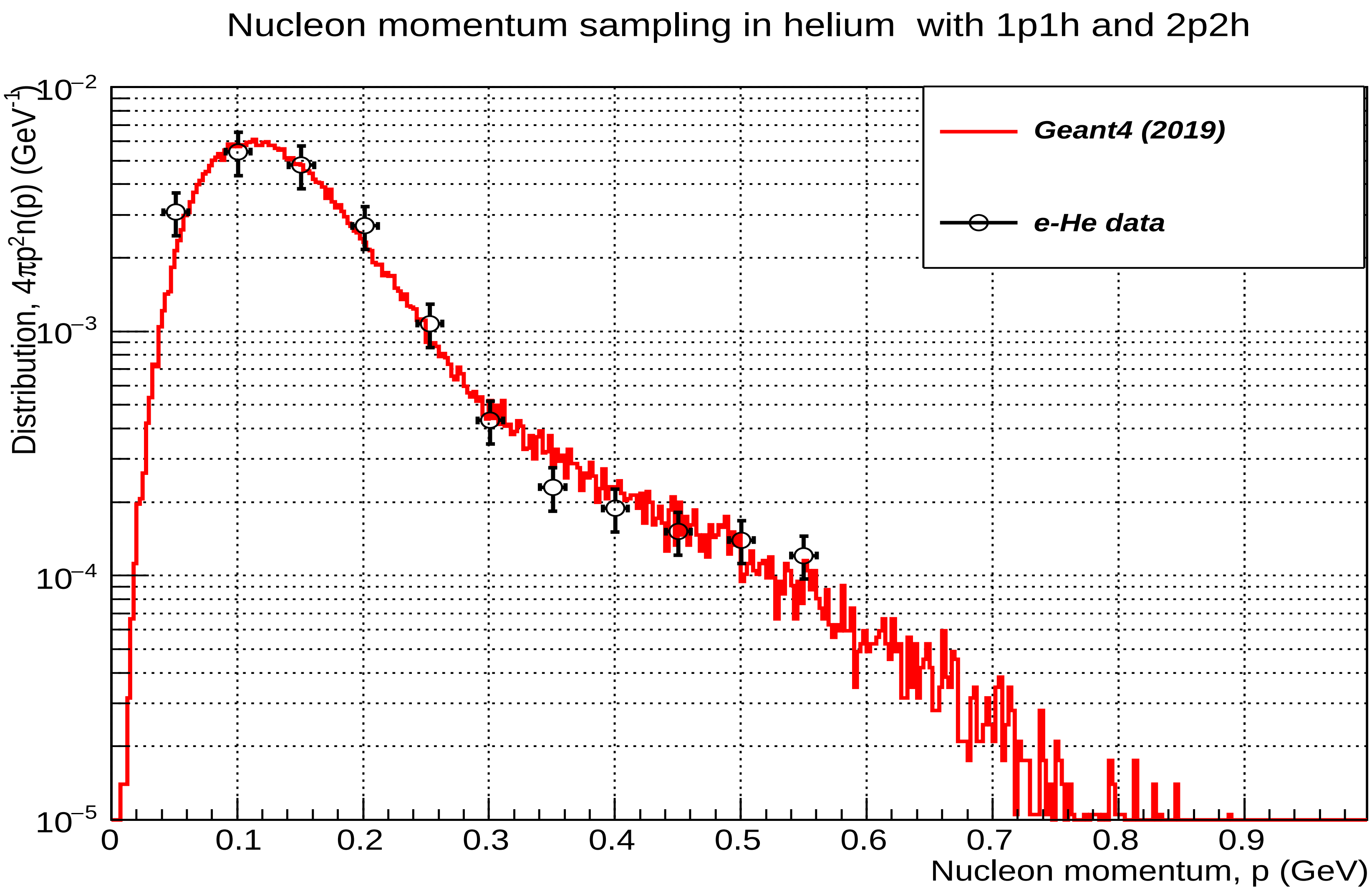
Fermi momentum vs. atomic weight for β-stable nuclei. The mean value is 251 MeV (close to GEANT4 value of 250 MeV)



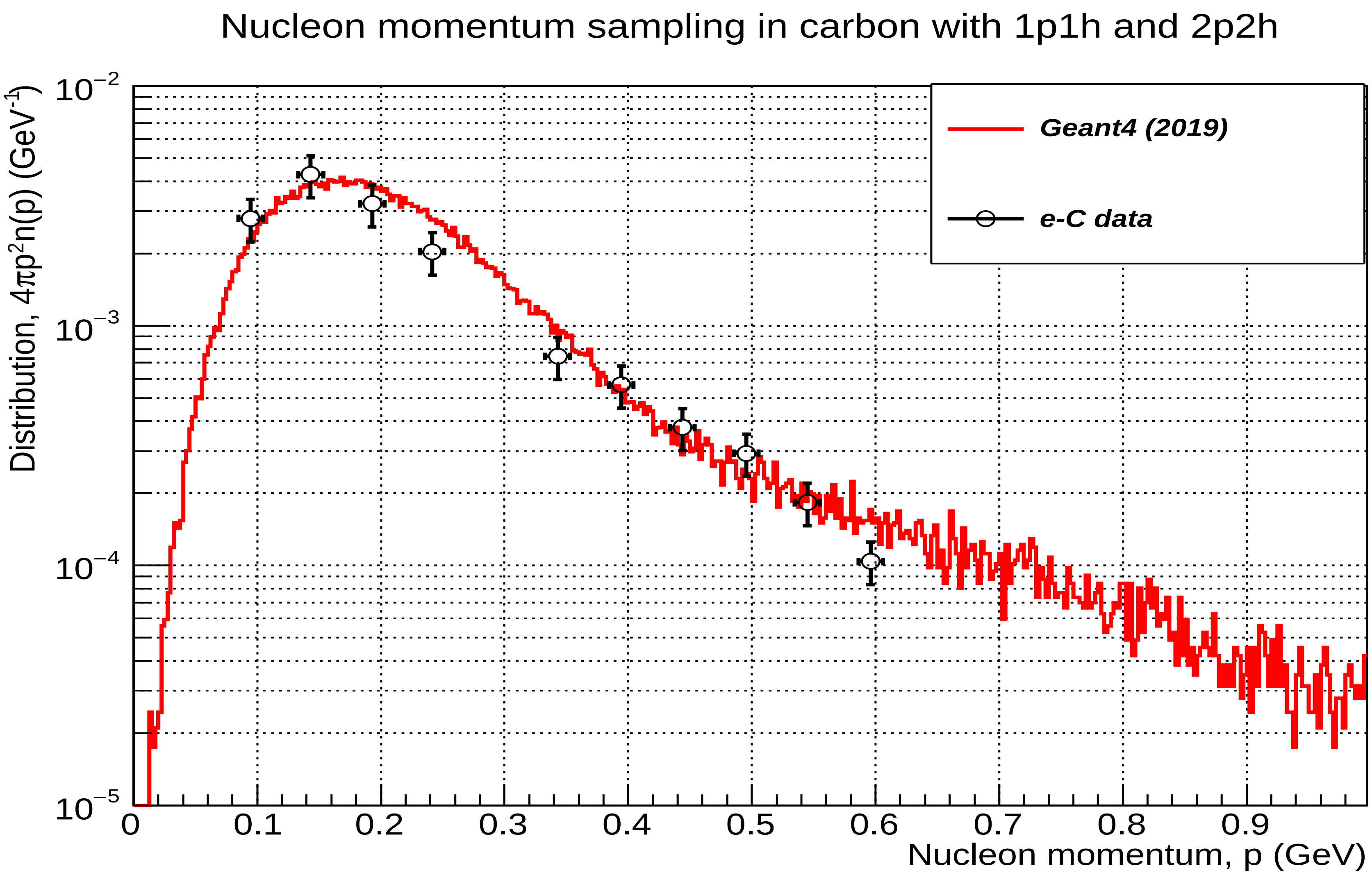
Nucleon momentum spectra for carbon.



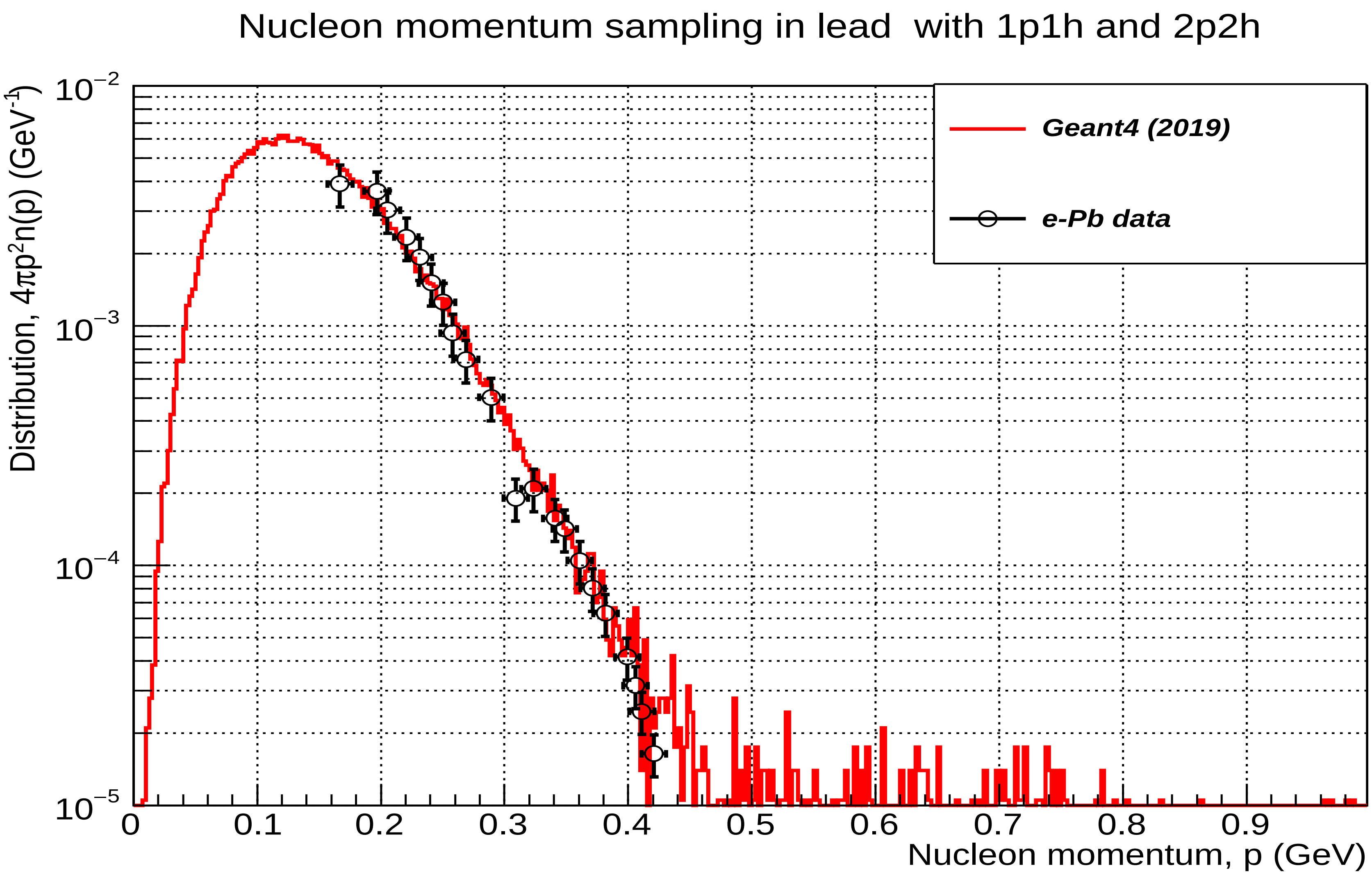
Nucleon momentum spectra for helium.



GEANT4 sampling (two Γ-functions) of nucleon momentum spectra for helium.



GEANT4 sampling (two Γ-functions) of nucleon momentum spectra for carbon.



GEANT4 sampling (two Γ-functions) of nucleon momentum spectra for lead.