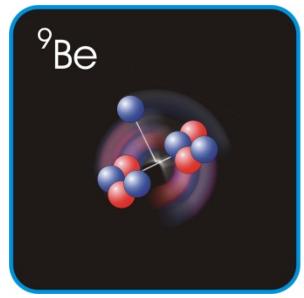
Ultra-fast protons shed light on role of dense clusters in nuclei

The atomic nucleus is made of confined nucleons in constant motion dominated by their interactions with the mean field of the nucleus - that is the average potential generated the many body system. This mean field spawned motion is called the Fermi motion and is a function of the atomic number.

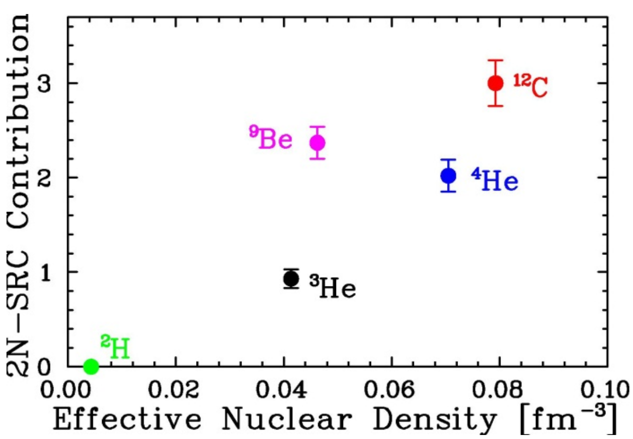
It is known for a long time that this picture of lumbering nucleons in a mean field is incomplete. The strong repulsive feature of the nucleon-nucleon (NN) interaction at short distances prevents nucleons from becoming close to each other and these short-range interactions generate highly energetic nucleons. A new Jefferson Lab experiment has quantified the effect and found that fully 25% of the protons in heavy nuclei move at velocities exceeding one quarter the speed of light!

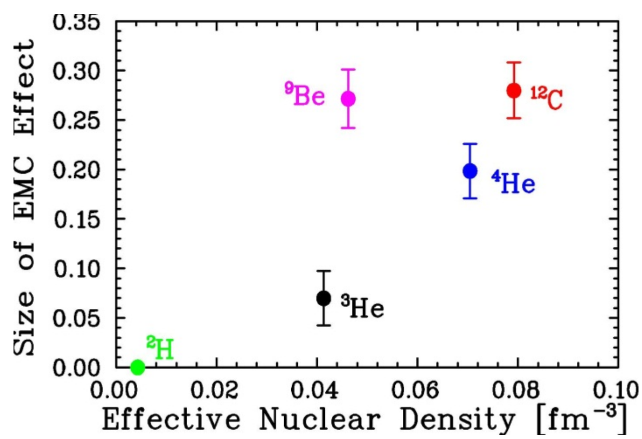


Because these ultra-fast nucleons come from short-range interactions, their abundance was expected to scale with the density of the nucleus. Our new measurement demonstrates that this expectation is incorrect: there are far more fast nucleons in Beryllium than expected based on its low density.

A recent measurement of the *quark distributions* in nuclei, which showed similar deviations in Beryllium, were interpreted as due to tight clusters of nucleons in Beryllium which have very high local density. These measurements of ultra-fast nucleons directly probe regions where nucleons are very close together. The fact that the *local environment* of the nucleon drives both the quark distributions and the generation of high-momentum nucleons also hints at an intriguing connection between the two seemingly disparate phenomena.

This paper, published in Physical Review Letters on March 2, 2012, is the product of the thesis work of former UVa graduate student Nadia Fomin, now at Los Alamos National Lab. Fomin was advised by UVa Research Professor Donal Day who led the experimental collaboration along with John Arrington of Argonne National Lab. The paper can be found online at http://prl.aps.org/abstract/PRL/v108/i9/e092502.





Anomalous behavior of Beryllium-9 for both the contribution from short-range correlations (SRCs – left panel) and modification of the quark distributions in nuclei (EMC effect – right panel).