

2nd No Core Shell Model Workshop Summary and Outlook

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Workshop Summary

The No Core Shell Model is alive and well and thriving worldwide!

TRIUMF NCSM Workshop 2011: 15 participants

TRIUMF NCSM Workshop 2012: 32 participants

ADVANCES

Improved understanding of 3NF at N3LO

SRG: “soft” designer interactions to improve convergence

NCSM/RGM with three-particle projectile

Many new applications, benchmarks and extensions

NCSM within an EFT-Framework

Uncertainty Quantification/Error Analysis

Improved computer codes and storage algorithms

From 2011

Three Nucleon Forces

The 3N force is here to stay! Can the 4N force be far behind?

1. Theoretical Work: Much work remains to be done. The full delta force; the 3N force in sub-leading order (N³LO); the 4N force in N³LO, etc.

Clearly need more people-power!

2. Applications: To significant and relevant problems, e.g., ¹⁴C beta lifetime, ¹⁴F, superallowed Fermi beta decay... The NEW predictive power of theory!

3. Approximations: Averages, centroids, etc. Do we want to do this?

If the 3N forces are really so important in determining the true properties of nuclear structure and reactions, why not make the effort to include them as fully as possible?

From 2012

Nuclear Forces: Three-nucleon Forces

Need to include the 3NF at N³LO, but it is very complicated.

How to economically include the effects of 3NFs?

Keeping with the spirit of the EFT and a sense of reality.

Testing approximations for higher-order terms in 3NFs.

Wide range of applications of 3NFs to problems in nuclear Physics: NCSM, CC, HH, SCGF, etc.

From 2011

The Similarity Renormalization Group (SRG)

A systematic approach to producing softer nuclear potentials, which can be used as bare interactions.

The era of DESIGNER RENORMALIZATIONS has arrived. One can choose G s so as to minimize many-body forces.

For OPEN QUESTIONS regarding the SRG see the TRIUMF colloquium by Dick Furnstahl.

From 2012

Similarity Renormalization Group

There has been a major flurry of SRG calculations in the past year.

These calculations have raised many new questions, e.g., the importance of many-body induced forces.

Are induced many-body forces for $A > 3$ needed? How significant are they?

From 2011

Nuclear Reactions: The NCSM/RGM

Much new progress: Several particle projectiles, NCSM + Green's function method, etc.

Use theoretical calculations of scattering results to test NN, 3N, etc. interactions.

The new predictive power of theory to assist both experiments and other theory.

From 2012 Nuclear Reactions: NCSM/RGM

Extension to three-particle projectiles, development for four-particle projectiles underway. Description of scattering in three-body cluster states.

Applications to exotic and loosely bound nuclei.

2011 & 2012

Extensions of the NCSM

1. Importance Truncations.
2. Ab initio NCSM in an $SU(3)$ -Scheme Basis.
3. No Core Monte Carlo shell model.
4. NCSM in an EFT framework (nucleons in a trap)
5. Ab initio No Core Shell Model with a core.
6. No Core Shell Model with the Continuum, etc.

From 2011

Theoretical Error Analysis

Uncertainty quantification/converging sequences

It is time for theorists to evaluate their own results by giving them an error estimate!

From 2012

Theoretical Error Analysis

Uncertainty Quantification:

Time to come to an agreement on error estimates. No more guesstimates.

Need an EFT for many-body calculations, so that we can quantify our errors.

OUTLOOK

How do we now build on the various and numerous successes of the NCSM?

Recruitment ---> Need more people

Things to do:

1. Use the NCSM and NCSM/RGM to predict new physics.
 - a.) E.g., use $NN + 3N + \dots$ forces to do Many-body Theory, then use the many-body results to build improved forces, i.e., the “looping effect” accelerates new advances.
2. Theoretical Error Analysis/Uncertainty Quantification
3. NCSM and NCSM/RGM extensions, e.g., use Monte Carlo
4. SRG and Designer Renormalizations

From 2012 **CHALLENGES/THINGS TO DO**

Develop a user friendly version of the 3NF at N3LO.

Using the full 3NF vs an approximation for it.

3NF at N3LO: With or without Deltas?

SRG in the many-body problem, induced many-body forces

Develop an EFT for nuclear many-body calculations.

More NCSM and NCSM/RGM applications and extensions.

Continued recruitment of more people to the field.

From 2011 & 2012 (continued)

Efficient and effective utilization of rapidly growing computational resources.

E.g., the forming of groups of theorists to attack a particular problem, such as the UNEDF collaboration and benchmark collaboration.

The sharing of resources for a common goal.

Our thanks to Petr Navratil for organizing this very successful and stimulating workshop, which has given increased excitement to the NCSM program.

Surely we are all hopeful of a possible “three-peat” in 2013!

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how matter came about, and they add a great deal of significance and importance to nuclear physics and to certain experiments in nuclear physics which would have only little importance to the problems we have discussed here. Perhaps in the next conference we should have a session where we discuss these things; it is not enough just to go to Mr. Cameron or Mr. Fowler and ask him what shall we measure, we ought to know why we do it.

The second and last point I would like to raise is this. To round up the conference I come back to the first remark of Peierls, when he opened up the conference and asked the question, why are we interested in nuclear structure. May I add my own little verse to this. I have heard many people say that Nuclear Structure is not a fundamental problem, the real thing is high energy physics; the object of nuclear structure is after all nothing else but solving a Schroedinger equation for A particles. I strongly disagree with this point of view. The discovery and the understanding of phenomena hidden in a many-body problem can be a task of fundamental importance, if the object itself is of central interest.

Physics inquires into the nature of things. The nucleus, our nucleus, is an essential part of nature, it is the centre of the atom. It is not just a little phenomenon, it is the most prominent constituent of matter. The understanding of the phenomena occurring in this nucleus is therefore of paramount importance. Hence Nuclear Physics is an essential part of physics. I found out that some theorists, both in the east and in the west, consider the only thing worth doing is elementary particle physics. Experimentalists usually don't say so because they work with real matter and hence they know that the nucleus is an important thing. These theorists, however, worship the theory of elementary particles, a theory which in fact doesn't even exist. They knock their heads daily against a wall of dispersion-relations, Mandelstam representations and the like. Let them do it. After all the proton and the meson are also an important part of nature. In fact we should give them all the moral support they need. They are a brave lot who fight a very difficult fight and some day they will find the theory. But don't let yourself be talked into believing that the nucleus is not interesting. It is so small and it has so few parts and still it shows a tremendous variety of phenomena. Its investigation requires the whole arsenal of presently available experimental techniques and its understanding makes use of almost all branches of theoretical physics. What a marvellous invention! It is worth devoting a lifetime to it.