EPJ Web of Conferences **86**, 00068 (2015)
DOI: 10.1051/epjconf/ 20158600068

Summary of FUSION14

M. Dasgupta[1,a]

[1] *Department of Nuclear Physics, RSPE, Australian National University, Acton, ACT 2601, Australia*

Abstract. A summary of the main advances in the topics discussed at the FUSION14 conference is presented along with an outlook for these topics.

You all must have been wondering about the identity of the summary talk speaker. I was wondering too until about 9.00 p.m. yesterday, when the Chair of the conference dropped a bombshell by requesting me to give the summary talk. This will be a talk sans-slides; preparing them would have meant staying up all night which would not have been easy after the sumptuous conference banquet! I will instead give my impressions of the topics that were covered at this conference.

It is seventeen years since the start of the FUSION series of meetings, although there were at least two international meetings that served as precursors to the FUSION series. It was at one of these meetings, the 1991 Daresbury Workshop on Heavy-ion Collisions, where the concept of extracting experimental distribution of fusion barriers [1] was proposed by Rowley *et al.* Later that year, the high precision measurements made by the group led by Jack Leigh at the Australian National University made it an experimental reality [2]. The strength of the concept is that it allows a very sensitive measure of couplings and hence after all these years still serves a critical test of models. Fusion excitation function measurements that enable the extraction of experimental barrier distributions with small uncertainties are however difficult and time consuming. A new method to enable the extraction of barrier distribution from quasi elastic scattering measurements, using the sum of differences, has been proposed at this conference by Hagino *et al.* This is an interesting avenue to pursue in view of the ease of quasi-elastic scattering measurements and we look forward to the applications of this method.

Moving to energies well below the average barrier, we have seen beautiful measurements presented at this conference [3] from the Padova group and from the group at Bhabha Atomic Research Centre. Deep sub-barrier fusion measurements, first pioneered by Jiang *et al.* [4, 5], require a lot of care and ingenuity. It has proved to be a fertile area of theoretical ideas which is excellent for the field. We are however far from understanding the phenomenon of "deep sub-barrier hindrance" as we do not yet have predictive theories. In my view, a good theory must be predictive and that is the only way to ensure the physics input is right. I believe that the fundamental understanding will emerge, hopefully by next FUSION conference, with both experimentalist and theorists working hand-in-hand.

Nucleon, multi-nucleon and cluster transfer reactions has been, in my view, a unifying theme of this conference. There were many contributions in this area as transfer not only affects capture, but also the subsequent evolution to formation of heavy elements and the reaction dynamics of weakly bound nuclei. It was very exciting to see the use of microscopic calculations though advances in applications of the Time Dependent Hartree Fock technique [6, 7]. Expanding this capability in the coming few years should lead to insights not only in transfer but also in fusion and quasifission dynamics. These advances are something we can look forward to at the next FUSION meeting.

Studies to understand the reaction dynamics leading to formation of heavy elements have led to a rich array of observables that have been measured experimentally. We saw some very beautiful and complete sets of measurements of evaporation-residue cross-sections, fission anisotropies, mass distributions, mass-angle distributions. Our understanding of the dynamics will definitely be enhanced by the development of theoretical models that attempt to explain all the measured quantities. In addition to the ongoing efforts to produce new elements, we also heard about extremely interesting new projects and we look forward to the results.

Experimental studies of reactions induced by light weakly bound stable and unstable nuclei have shown that breakup and fusion cannot be understood in a straightforward manner as originally thought. It is thus not surprising to see many contributions in this area trying to reconcile the various measured reaction outcomes with observed fusion cross-sections. Experiments have clearly shown that transfer followed by breakup plays a strong role. However this (two-step) breakup process cannot yet be described by the Continuum Discretised Coupled Channels model. This is a problem for the field and methods to find ways to describe such breakup processes will help immensely in advancing the field.

[a] e-mail: mahananda.dasgupta@anu.edu.au

Fusion, transfer and breakup are aspects that all link to nuclear astrophysics. In both nuclear physics and nuclear astrophysics, indirect methods or extrapolations are used when direct measurements are not possible [8]. Thus for fusion at energies of astrophysical interests, where measurements are very difficult if not impossible, a well-accepted and tested understanding of deep sub-barrier hindrance will be extremely useful. More accurate nuclear physics inputs of reaction rate are necessary for nucleosynthesis studies and we heard of advances not only in the measurements, but also in calculations using the Trojan horse method.

Now to the nuclear physics related developments in our host country - India. As illustrated in the overview talk by Dr. Amit Roy, India has excellent facilities that are already available and others are under development. Some include state-of-the-art developments – for example my university in Australia uses the LINAC resonator control system developed by Bhabha Atomic Research Centre in Mumbai, and it works like a dream. The measurement of fusion angular momentum distributions and neutron-multiplicity measurements that have been and can be made are important for answering questions right from deep sub-barrier fusion to fission dynamics. Whilst attending the talks and the poster session, what struck me most was the impressive number of young people who are engaged in nuclear physics research. This is very heartening as it is crucial for maintaining the vitality of the field.

As was mentioned in the opening session, the nucleus is a many body quantum system. The many body aspects combined with the isolated nature of nuclei means that we are able to probe the rich dynamics. It makes our field fascinating and links our field to the global challenge of understanding (and harnessing) quantum many-body physics. The richness of our field and the advances in experimental and theoretical methods will, I believe, continue to reveal new facets of many body dynamics. Thus, we can look forward with anticipation to the next FUSION meeting.

Acknowledgments

The author acknowledges the financial support from Australian Research Council grants DP110102858 and FL110100098.

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