The 2016 R-Matrix Workshop on Methods and Applications

Abstracts book

Abstract ID : 1

Experimental application of the generalized R-matrix approach

Content :

Resonant reactions play an important role in astrophysics as they might significantly enhance the cross section with respect to the direct reaction contribution and alter the nucleosynthetic flow. Moreover, resonances bear information about states in the intermediate compound nucleus formed in the reaction. However, nuclear reactions in stars take place at energies well below ~ 1 MeV and the Coulomb barrier, exponentially suppressing the cross section, and the electron screening effect, due to the shielding of nuclear charges by atomic electrons, make it very difficult to provide accurate input data for astrophysics.

Therefore, indirect methods have been introduced; in particular, the Trojan Horse Method (THM) makes use of quasi-free reactions with three particles in the exit channel, a + A → c + C + s, to deduce the cross section of the reaction of astrophysical interest, a + x → c + C, under the hypothesis that A shows a strong x + s cluster structure. In recent years, a generalized R-matrix approach has been introduced by Akram Mukhamedzhanov, allowing one to deduce the resonance parameters from the THM cross section accounting for half-off-energy-shell effects. In this way, THM can be used to perform a full spectroscopic study of low-energy and sub threshold resonances. For the latter, the ANC can be deduced as well, establishing an alternative high accuracy approach to determine this crucial parameter and leading to an unification of the two mentioned indirect methods.

In this presentation we will discuss some experimental applications of the generalized R-matrix approach, which will be discussed in detail by Akram Mukhamedzhanov. Two recent cases will be shortly reviewed: the 19F(p,α)16O reaction, which is an important fluorine destruction channel in the proton-rich outer layers of asymptotic giant branch (AGB) stars, and the 13C(α, n)16O reaction, which is considered the neutron source for the main component of the s-process.

19F(p,α)16O data stop at about 200 keV, making it necessary to extrapolate its trend at lower energies. The THM was thus used to access this energy region, by extracting the quasi-free contribution to the 2H(19F,α16O)n and the 19F(3He,α16O)d reactions. The THM measurement shows the presence of resonant structures not observed before, showing up right at astrophysical energies, which cause an increase of the reaction rate at typical stellar temperatures.

In the case of the 13C(α, n)16O reaction, the role of the resonance close to the 17O->13C+α will be discussed, which has been subject of many works in the latest years. We have applied the THM to the 13C(6Li,n 16O)d quasi-free reaction to achieve an experimental estimate of such contribution. We will analyze the different results that are obtained when considering such resonance below and above the threshold, as well as the connection between THM and ANC approaches.

Primary authors : Dr. LA COGNATA, Marco (INFN-LNS)

Co-authors : Dr. TRIPPELLA, Oscar (UniPG & INFN-PG) ; Dr. MUKHAMEDZHANOV, Akram (Cyclotron Institute TAMU)

Presenter : Dr. LA COGNATA, Marco (INFN-LNS)

Track classification :

Contribution type : --not specified--

Submitted by : Dr. LA COGNATA, Marco

Submitted on Wednesday 17 February 2016

Last modified on : Wednesday 17 February 2016

Abstract ID : 4

AZURE2 Tutorial: 3He(a,g)7Be

Content :

The R-matrix code AZURE2 had been designed to fit charged particle induced reaction data important for nuclear astrophysics and then extrapolate the cross section down to the very low energies of interest. R-matrix is most useful for low mass charged particle reactions where broad resonance dominate the cross section. These reactions are those that occur during normal stellar burning. Very light reactions between several combinations of protons, deuterium, 3He, and 4He dominate the pp-chains. The CNO cycles are composed almost exclusively of (p,gamma) and (p,alpha) reactions. Just a few alpha particle induced reactions dominate helium burning, with a couple more acting as important neutron sources for the s-process. Higher mass reactions can also be treated with R-matrix but an increasingly complicated level structure has made these analysis quite challenging. In this tutorial we will take a look at the 3He(a,g)7Be reaction, an important reaction in big bang nucleosynthesis and in the pp-chains that dominate the energy production in our Sun. We will limit the analysis to the energy range between the alpha separation energy (the first particle threshold) and the proton separation (the second particle threshold) where most of the capture data are limited to. We will start with fitting 3He(a,a)3He data in order to try to constrain the direct component of the reaction through the subthreshold ANCs and the width of the single resonance in our energy range. This fitting requires several background poles since the hard sphere phase shifts are a poor approximation of the observed data. The analysis will then be extended to the capture data where cross sections to the ground state and first excited states, as well as total capture, will be analyzed. We will see how the cross section cannot be described but only an external capture model but also requires internal contributions, or background poles in our R-matrix description.

Primary authors : Dr. DEBOER, Richard J. (University of Notre Dame)

Co-authors :

Presenter : Dr. DEBOER, Richard J. (University of Notre Dame)

Track classification :

Contribution type : --not specified--

Submitted by : Dr. DEBOER, Richard J.

Submitted on Sunday 06 March 2016

Last modified on : Sunday 06 March 2016

Comments :

Status : SUBMITTED

Track judgments :

Abstract ID : 5

Estimating experimental covariances ... and the uncertainties within

Content :

This talk supplies the background to discuss how experimental data as well as uncertainties and covariances should be documented to provide the best-possible input for R-matrix nuclear data evaluations. In the last decade, significant efforts have been undertaken to supply covariances for evaluated nuclear data. These efforts were triggered by the objective to simulate economical, operational and safety margins for nuclear application devices such as next generation nuclear reactors. It is essential to estimate all uncertainties entering the evaluation process well to provide reasonable evaluated covariances for nuclear data applications. Estimating experimental covariances is one key piece to provide those.

However, despite the importance of estimating reasonable experimental covariances, the uncertainties on the resulting covariances can be large in real-case nuclear data evaluations. These uncertainties on covariances can be caused by using simplified uncertainty quantification methods instead of those recommended as best practice. The latter ones are, of course, more time-intensive. Another frequently encountered limitation when estimating experimental covariances is insufficient documentation or underestimated uncertainties of measurements.

Here, I will briefly summarize recommended best-practice uncertainty quantification methods for estimating nuclear data experimental covariances. The impact of this approach versus a simplified one on evaluated mean values, uncertainties and associated application benchmark calculations will be discussed by means of a general nuclear data evaluation problem. Also, the impact of underestimated experimental uncertainties will be shown. Then, "Peelle's Pertinent Puzzle", obtaining pathological evaluated mean values when evaluating with strongly correlated experimental covariances, will be briefly introduced. It will be shown that it can be avoided by estimating experimental covariances based on detailed experimental information. These examples set the stage for a discussion how experimental data,the measurement itself, the analysis of measured data as well as uncertainties should be documented to provide the best-possible input for R-matrix nuclear data evaluations.

Primary authors : Dr. NEUDECKER, Denise (Los Alamos National Laboratory)

Co-authors :

Presenter : Dr. NEUDECKER, Denise (Los Alamos National Laboratory)

Track classification :

Contribution type : --not specified--

Submitted by : Dr. NEUDECKER, Denise

Submitted on Friday 11 March 2016

Last modified on : Friday 11 March 2016

Comments :

Status : SUBMITTED

Track judgments :

Abstract ID : 6

Reflections on the History of R-Matrix Theory and its Application to Light Nuclear Reactions

Content :

We will first review the history of R-matrix theory, from the seminal papers of Kapur and Peierls (1938) and Wigner and Eisenbud (1946), through the "bible" of the theory published by Lane and Thomas in 1958, to the advent of the modern approach, enabled by Claude Bloch in 1957. Next we will discuss the different types of R-matrices given by different choices for the boundary values in the Bloch operator, and describe how they are related. We will show how only the full theory is able to impose three important physical constraints: unitarity, causality, and time-reversal invariance, on parametric descriptions of nuclear reactions. These depend on properties of the analytic continuation of the theory into the complex energy plane to describe resonances and other phenomena. A brief discussion of the various R-matrix codes that have been developed over the years will be given. Finally, we will highlight some of the multichannel analyses of reactions in light nuclear systems at Los Alamos, using the general R-matrix fitting code EDA, and indicate future directions for research in this area.

Primary authors : Dr. HALE, Gerald (Los Alamos National Laboratory)

Co-authors : Dr. PARIS, Mark (Los Alamos National Laboratory)

Presenter : Dr. HALE, Gerald (Los Alamos National Laboratory)

Track classification :

Contribution type : --not specified--

Submitted by : Dr. HALE, Gerald

Submitted on Thursday 17 March 2016

Last modified on : Thursday 17 March 2016

Comments :

Status : SUBMITTED

Track judgments :

Abstract ID : 7

Analysis of experimental data and uncertainty evaluation

Content :

Evaluated cross section data together with full uncertainty information are of primary importance for the performance and safety assessment of nuclear energy systems. Despite the increasing request from users and the ongoing effort to improve evaluated data libraries, the number of cross section data with covariance information for neutron induced reactions in the resonance region are rather scarce. In addition, when covariance data are present in the resonance region, they mostly result in rather low uncertainties. For example, the capture cross sections of 37Cl, 235U, 238U and 239Pu are recommended in the ENDF/B-VII.1 library with uncertainties of 1% and lower . Such uncertainty levels are below the accuracy that can be reached with the most up to date capture cross section measurement methods that are presently available.

Cross sections in evaluated data libraries are parameterized in terms of resonance parameters, determined from an adjustment to experimental data. In this presentation we will discuss the code REFIT, a resonance shape analysis code based on the Reich-Moore approximation of the R-matrix. We will especially focus on the description of experimental effects, such as sample inhomogeneities, multiple scattering, the effect of the resonance strength of the observed gamma spectrum etc.. All these corrections are essential for deriving the model parameters with high accuracy.

The importance of correctly propagating experimental uncertainties for deriving reliable covariance matrices of the model parameters will be also discussed.

Primary authors : Dr. KOPECKY, Stefan (European Commission - Joint Research Centre - Institute for Reference Materials and Measurements)

Co-authors : Dr. SCHILLEBEECKX, Peter (European Commission - Joint Research Centre - Institute for Reference Materials and Measurements) ; Dr. KIMURA, Atsushi (Japan Atomic Energy Agency, Nuclear Science and Engineering Directorate)

Presenter : Dr. KOPECKY, Stefan (European Commission - Joint Research Centre - Institute for Reference Materials and Measu

Track classification :

Contribution type : --not specified--

Submitted by : Dr. KOPECKY, Stefan

Submitted on Tuesday 22 March 2016

Last modified on : Tuesday 22 March 2016

Comments :

Status : SUBMITTED

Track judgments :

Abstract ID : 8

R matrix for Trojan Horse method as indirect technique in nuclear astrophysics.

Content :

Trojan Horse method (THM) is a powerful indirect method in nuclear astrophysics, which provides a unique tool to obtain the information about resonant astrophysical reactions at astrophysically relevant energies. The information about the resonant reaction x + A --> b + B is obtained via the THM reaction a + A --> s + b + B, where the Trojan Horse (TH) nucleus a=(sx). In the THM the compound system F*=x + A= b + B is formed in the subsystem of the reaction, while the outgoing particle s is treated as a spectator. The quasi-free kinematics provides the best conditions for measurements using the THM. It allows one to measure resonance states at very low (even at negative) energies. Usually one of the most convenient methods to analyze resonance reactions is the conventional R-matrix approach but in the case under consideration we deal with excitation of the resonance in the sub-system what requires generalization of the standard R-matrix method. I will discuss generalization of the conventional multi-level, multi-channel R-matrix for analysis of the TH reactions. In the generalized approach the TH reaction amplitude is parameterized in terms of the reduced width amplitudes, resonance energies and boundary conditions, which are the same parameters that are used in a standard R-matrix approach.

The application of the method will be demonstrated for some key astrophysical reactions.

Primary authors : Prof. MUKHAMEDZHANOV, Akram (Cyclotron Institute, Texas A University, College Station, TX, 77843)

Co-authors :

Presenter : Prof. MUKHAMEDZHANOV, Akram (Cyclotron Institute, Texas A&M; University, College Station, TX, 77843)

Track classification :

Contribution type : --not specified--

Submitted by : Dr. DEBOER, Richard J.

Submitted on Friday 25 March 2016

Last modified on : Friday 25 March 2016

Comments :

Status : SUBMITTED

Track judgments :

Abstract ID : 9

R-matrix theory in the analysis of fission cross-sections

Content :

We first outline the choice of channel boundaries for the outgoing fission particles and the treatment of intermediate structure in fission cross-sections. We then proceed to deal with the problem of averaging over intermediate and fine structure resonances by transformation from R-matrix parameters to S-matrix poles. The respective pros and cons of R-matrix and S matrix theory are discussed. The extent of possible validity of Lorentzian forms for intermediate resonance behaviour of fission widths is demonstrated using numerical examples. We draw attention to open problems that arise from this approach

Primary authors : Dr. LYNN, J. Eric (Los Alamos National Laboratory)

Co-authors :

Presenter : Dr. LYNN, J. Eric (Los Alamos National Laboratory)

Track classification :

Contribution type : --not specified--

Submitted by : Dr. LYNN, John

Submitted on Tuesday 29 March 2016

Last modified on : Tuesday 29 March 2016

Comments :

Status : SUBMITTED

Track judgments :

Abstract ID : 10

Error analysis in extrapolations

Content :

Often R-matrix fits are performed to determinethe value of the reaction cross at astrophysical relevant energy, that is itself not a fit parameter. Therefore, the determination of the uncertainty affecting the extrapolation requires the propagation of the uncertainties on all fit parameters through the fit function taking into account correlations. The situation can be complicated if the ML function strongly deviates from a Gaussian distribution in the neighborhood of the maximum defined by its variance, in which case the calculation of the error matrix is complicated. Since fast computers are available, an alternative Monte Carlo approach has been proposed [1], where the probability density distribution of the extrapolated cross section value, or in principle of any quantity derived related to the fit parameters, is sampled by a repetitive fitting to pseudo data sets obtained distributing the original data according to the appropriate probability density distribution.
The Monte Carlo approach is reviewed considering the case of 12C(alpha,gamma)16O as an example.

[1] L. Gialanella et al., Eur. Phys. J. A 11 (2001) 357.

Primary authors : GIALANELLA, Lucio (Dipartimento di Matematica e Fisica, Seconda Università di Napoli e INFN Sezione di Napoli)

Co-authors :

Presenter : GIALANELLA, Lucio (Dipartimento di Matematica e Fisica, Seconda Università di Napoli e INFN Sezione di Napoli

Track classification :

Contribution type : --not specified--

Submitted by : GIALANELLA, Lucio

Submitted on Tuesday 29 March 2016

Last modified on : Tuesday 29 March 2016

Comments :

Status : SUBMITTED

Track judgments :

Abstract ID : 11

Calculated Resonance Properties from the New Resolved Resonance Region Evaluations of Copper

Content :

A new resolved resonance region (RRR) evaluation for the two naturally occurring isotopes of copper, 63Cu and 65Cu was performed at Oak Ridge National Laboratory (ORNL) [1]. Over the past decade, large discrepancies between the computed and the experimentally recorded keff of criticality safety benchmark experiments containing copper were noticed by the nuclear data and criticality safety community [2]. The most notable of these benchmarks is the set of Highly Enriched Uranium METal fuels with copper reflectors from the Zeus experiment, that is, HEU-MET, from the International Criticality Safety Benchmark Evaluation Project (ICSBEP) [3]. The US DOE Nuclear Data Advisory Group, which maintains and constantly updates lists of materials that are considered important for applications in nuclear criticality safety identified 63Cu and 65Cu as "Important for measurement and evaluation in the next five years." [4]. Over 25 ICSBEP benchmark evaluations contain significant amounts of copper such that the new evaluation results in non-negligible changes in the calculated keff. Therefore, improving the copper resolved resonance region evaluation will not only allow for more accurate future criticality safety calculations involving copper as a material but will also result in better agreement between calculated and measured integral benchmark results.

Copper is also commonly used as a minor structural material in many fission power facilities. Copper is an important structural component in Scandinavian spent fuel final disposal canisters. Copper is an important heat sink material for fusion power reactors and is also used for diagnostics, microwave waveguides and mirrors in the International Thermonuclear Experimental Reactor (ITER). The neutron cross section of the copper isotopes is also important to the astrophysics community. The two stable isotopes of copper lie along the beta-decay valley of stable isobars involved in the s-process or slow-neutron-capture-process. The s-process occurs in stars and is responsible for the creation of approximately half of the stable isotopes heavier than iron and therefore plays an important role in the galactic chemical evolution.

The copper RRR evaluations in the ENDF/B-VII.1 library are based on the resonance parameters from Atlas of Neutron Resonances by Mughabghab [5]. To address the concerns of the performance of the copper isotopes in integral benchmarks, V. Sobes, L. C. Leal et al. [1] re-evaluated the RRR based on new and historic experimental data and extended the resolved resonance region of the two copper isotopes from 99.5 keV to 300 keV. Furthermore, experimental capture cross-section measurements were analyzed for the first time in the resonance evaluation of copper.

At the conference, this paper will present the derived resonance properties calculated from the new RRR evaluations of copper. The scattering radius from the Atlas of Neutron Resonances [5] was confirmed by fitting all of the new experimental measurements simultaneously with the historic data. The normalization and background for each set of experimental data found through the evaluation process of five experimental measurements at three different facilities will be reported. The level spacing distributions as well as the resonance width distributions will be compared to the Wigner distribution and the Porter-Thomas distribution as well as the updated average capture widths will be discussed. A new value for the strength functions of both naturally occurring isotopes will also be presented based on the new evaluations. Lastly, a couple of integral quantities that are of interest to the applications of the new evaluations will be discussed. The Maxwellian averaged capture cross section based on the new evaluations will be presented at several temperatures and compared to experimental measurements as well as to the calculation based on the ENDF/B-VII.1 evaluation. The capture resonance integral will also be presented and compared with the value from the Atlas of Neutron Resonances [5] and the calculated value from the ENDF/B-VII.1 evaluation.

1. V. Sobes, L. Leal, B. Forget, K. Guber, New Resolved Resonance Region Evaluations for 63Cu and 65Cu to Support Nuclear Criticality Safety Analyses, Nuclear Data Sheets, 115, March 2014.
2. Mosteller, R. D. Results for ENDF/B-VII.1 beta4. In CSEWG Annual Meeting, pages 18-21, Brookhaven National

Laboratory, November 2011
3. J. B. Briggs, et al. International handbook of evaluated criticality safety benchmark experiments. Report NEA/DOC (95), 4, 2015.
4. NDAG Committee. United States Department of Energy, Nuclear Criticality Safety Program, Five-Year Execution Plan for the Mission and Vision, FY 2011 through FY 2015. http://ncsc.llnl.gov/plan/NCSPFive-Year-Plan-2011-2015_Final_12-02-10.pdf, 2010.
5. S.F. Mughabghab, Atlas of Neutron Resonances: Resonance Parameters and Thermal Cross-Sections. Z=1-100, Elsevier Science, 2006.

Primary authors : Dr. SOBES, Vladimir (ORNL) ; Dr. GUBER, Klaus (ORNL) ; Dr. LEAL, Luiz (IRSN)

Co-authors :

Presenter : Dr. SOBES, Vladimir (ORNL)

Track classification :

Contribution type : --not specified--

Submitted by : Dr. SOBES, Vladimir

Submitted on Wednesday 30 March 2016

Last modified on : Wednesday 30 March 2016

Comments :

Status : SUBMITTED

Track judgments :

Abstract ID : 12

Cluster structures and what we can learn from resonant scattering

Content :

This presentation will provide an up-date on some of the challenges in nuclear clustering in particular focussing on 12C, 9B, 12Be and our present understanding of the nucleus 16O. Resonant scattering studies are important in helping pin down the nature of cluster states, and the talk will focus on future challenges. The application of resonant scattering to heavy systems is one such possibility. Results of 40Ca, 44Ca and 48Ca+alpha resonant scattering will be presented to seach for cluster-like structures in the isotopes 44Ti, 48Ti and 52Ti.

Primary authors : Prof. FREER, Martin (University of Birmingham)

Co-authors :

Presenter : Prof. FREER, Martin (University of Birmingham)

Track classification :

Contribution type : --not specified--

Submitted by : Prof. FREER, Martin

Submitted on Wednesday 30 March 2016

Last modified on : Wednesday 30 March 2016

Comments :

Status : SUBMITTED

Track judgments :

Abstract ID : 13

An R-matrix code AMUR for the cross-section evaluation and preliminary approaches to open issues in the analysis

Content :

Evaluated cross-section data are fundamental for the nuclear science and engineering. Recently, their uncertainty/covariance data are also being requested from the users, as it gives a guide to know reliability of the estimated values. R-matrix is a framework to deduce S-matrix (or T-matrix) from real observables, such as the cross-sections, under a certain boundary condition. Since the framework itself is strictly based on the quantum mechanics, R-matrix is believed to be one of the best approaches to the nuclear data evaluation in a resonant energy range, as it puts together the experimental and the theoretical knowledge.

In this talk, we present the status of our R-matrix code AMUR and review our recent attempts on the cross-sections evaluation for the light-nuclei, e.g., p+6,7Li, n+16O and n+14,15N. Through the sensitivity/covariance analysis to the resonance parameters, we also present the source of the physical constraint from the theory, which could allow us to understand the differences among measurements. R-matrix is a powerful tool in the nuclear data evaluation, however, there exists several open-issues which we have been pending or not well-understood yet. The main topic in this talk will be on how we are tackling such issues in practical data-evaluation :

1) One question is how to deal with the boundary parameters such as the channel radii and the boundary condition numbers. Although such parameters are often treated as arbitrary values, reasonable values should exist somewhere because they give, physically, the matching condition of the internal and external wave-functions. In our preliminary approach, the energy eigenvalues were fixed to those given in ENSDF, instead the boundary parameters were treated as parameters to be deduced from experimental cross-sections.
2) The second is the issues on the background (non-resonant) contribution which interferes with the resonances. Such a background comes from not only the bound/distant levels but also from the shape-elastic scattering and direct reactions. Particularly, in the standard R-matrix, let us point out that the hard-sphere well is assumed at the channel radii, whereas the nucleus has a diffuseness around the surface. We preliminary assumed hard-sphere equivalent radii which are different from the channel radii. We have not yet understood if such an approach could be acceptable physically, however, we found it gives better fits to the measurements than those by the standard approach especially for the differential cross-sections.
3) A number of experimental efforts have been devoted to the cross-section measurements. Indeed, measured data are essential to deduce the R-matrix parameters since we don’t have explicit knowledge on the nuclear structure. Nevertheless, there still remains, more or less, unknown systematic uncertainty, unexpected background and so on in the measurements. They are the limitation of the measurement, instead those issues could be solved/reduced through the R-matrix analysis with its theoretical constraint. For example, owing to the unitarity of S-matrix, we minimized a problem arising from the systematic difference among measurements by introducing a renormalization parameter for each measurement (LANL approach).

Primary authors : Dr. KUNIEDA, Satoshi (Japan Atomic Energy Agency)

Co-authors :

Presenter : Dr. KUNIEDA, Satoshi (Japan Atomic Energy Agency)

Track classification :

Abstract ID : 14

Can R-Matrix Results be More Accurate Than the Data Itself?; The case of 12C(a,g) *

Content :

Adding data points that are in sufficient agreement (2 sigma) to the ensemble of "world data" analyzed by R-Matrix formalism, indeed increase the precision of the final results, beyond the accuracy of the individual data points. This is owing to the familiar 1/sqrt(N) increased precision. However this is not true when adding data points that disagree by large factors (and many sigmas). Such disagreements are most likely systematic and can't be handled by a rigorous algebraic formalism. In such a case the experimental procedures must be evaluated and data selection must be employed. Indeed the final result depends on the choice of the included data. Rigorous criteria for removing data from the ensemble of "world data" must be developed before attempting to apply R-Matrix analyses.

Indeed this unsatisfactory situation has been prevailing over the last four decades in measurements of individual data points (at specific energies) of the astrophysical cross section factor of the 12C(a,g)16O reaction. It has hampered progress in extracting to stellar energies the needed s-factors.

This author developed strict criteria to exclude for example data points that are measured with large error bar nearing 100% or more [1]. Indeed current data cannot rule out major ambiguities in the extracted SE1(300) of approximately 80 or 10 keVb, and SE2(300) of approximately 60 or 155 keVb [1]. I have also demonstrated that current quoted s-factors are depended on the choice of data being analyzed by R-Matrix formalism [2]. Future measurements with gamma beams may indeed allow us to resolve these ambiguities [3].

[1] Moshe Gai, Phys. Rev. C 88, 062801(R) (2013).
[2] Moshe Gai, arXiv:1506.04501v1 [nucl-ex] 15 Jun 2015.
[3] Moshe Gai, Nucl. Phys. A928, 313 (2014).

* Work Supported in part by the USDOE grant number DE-FG02-94ER40870.

Primary authors : Prof. GAI, Moshe (University of Connecticut)

Co-authors :

Presenter : Prof. GAI, Moshe (University of Connecticut)

Track classification :

Contribution type : --not specified--

Submitted by : Prof. GAI, Moshe

Submitted on Thursday 31 March 2016

Last modified on : Thursday 31 March 2016

Comments :

Please schedule in the planned workshop on the 12C(a,g) reaction.
And many thanks for organizing this workshop.
Moshe Gai

Status : SUBMITTED

Abstract ID : 16

Overview of 12C(alpha,gamma)16O

Content :

This talk will review the current status as well as some history of the 12C(alpha,gamma)16O reaction from an R-matrix perspective. This reaction is essential for our understanding of helium burning in massive stars and also subsequent nucleosynthesis. Since the 1960s the R-matrix method has been utilized to predict the cross section at astrophysical energies based upon experimental inputs. The desire to better understand this important reaction rate has motivated many developments in phenomenological R-matrix analysis, such as the inclusion of sub-threshold resonances and the description of beta-delayed particle decay. In addition to 12C(alpha,gamma)16O data, modern analyses consider many reaction channels including 12(alpha,alpha), 12C(alpha,alpha')12C(4.4 MeV), and 12C(alpha,p)15N as well as information from beta decay and transfer reactions. Much of the recent improvement in the constraint on the low-energy 12C(alpha,gamma)16O S factor has come from extending the data set considered and analysis to higher energies and from indirect methods. The talk will conclude with a discussion of potential areas for future experimental and theoretical progress on this important reaction.

Primary authors : Dr. BRUNE, Carl (Ohio University)

Co-authors :

Presenter : Dr. BRUNE, Carl (Ohio University)

Track classification :

Contribution type : --not specified--

Submitted by : Dr. BRUNE, Carl

Submitted on Thursday 31 March 2016

Last modified on : Thursday 31 March 2016

Comments :

Status : SUBMITTED

Track judgments :

Abstract ID : 17

Evaluation of the differential cross-sections for Ion Beam Analysis

Content :

Ion Beam Analysis (IBA) is a suit of material characterization techniques that exploits energetic ion beams. The IBA method has become a routine technique in many research and industrial analytical laboratories. It is widely used in many fields from microelectronics to archeology and to environmental monitoring. The information about composition and structure of the near-surface layer of a sample is deduced from the energy spectra of backscattered primary particles, recoils, or nuclear reaction products originating from the interaction of the incident ions with nuclei located in the surface layers of the sample. All IBA methods (except for Rutherford backscattering spectrometry) strongly rely on the available differential cross section data. Of primary importance are the differential cross sections for proton and alpha non-Rutherford elastic scattering and for nuclear reactions induced by protons, deuterons, helium-3 and alphas with energy of less than about 5.0 MeV interacting with A ≤ 40 nuclei. The differential cross-sections are needed in order to derive element concentrations through computer simulation of measured spectra. A linear dependence of the registered signal both on the atomic concentration and on the cross section results in obvious constraints on the required accuracy of the employed data. It is evident that the concentration cannot be determined with the accuracy exceeded that of the cross section and consequently the precise knowledge of the cross sections is required. As a rule experiments undertaken to determine the required cross section have to precede an analytical work. Another way is to utilize previously published data. However, all the measured data should be evaluated prior to their widespread use. The reasons are as follows. On the one hand, the discrepancies in the reported cross section values are often far beyond quoted experimental errors, and on the other hand, due to cross sections dependence on a scattering angle the available data are valid only in the case of a scattering geometry very close to the geometry used in cross section measurements.

The evaluation of the data consists in producing on the base of available experimental points and the theoretical models the most reliable recommended differential cross sections for a given reaction/scattering in a sufficiently wide energy interval at any backward angle. In other words the givens are different sets of (generally inconsistent) experimental data measured at sparse points on energy and angle and the task is to find the most accurate possible smooth curves representing the cross-sections. It was shown in numerous papers that the evaluation of the cross sections by combining a large number of different data sets in the framework of the theoretical model made it possible to calculate excitation functions for analytical purposes for any scattering angle with a reliability exceeding that of any individual measurement.

As far as the cross-sections have resonance structure in the energy region typical for IBA it was natural to employ the R-matrix theory for the calculations. A home made code was developed and applied. In order to take into account broad single particle resonances the phases obtained in the frameworks of the optical model with Saxon-Woods real potential well and a surface absorption were used instead of hard sphere ones in the code. This made it possible to avoid introducing broad artificial resonances commonly used in order to reproduce a non-resonance background. A self consistent model which takes into account both direct (in the frameworks of DWBA) and resonance reaction mechanisms (using R-matrix) has been employed for the calculation of the (d,p)-reaction cross-sections at low energy. Details of the procedure and the obtained results are discussed.

The dissemination of the evaluated cross-sections is provided through the web site SigmaCalc (http://sigmacalc.iate.obninsk.ru) developed to allow the IBA practitioner having no expertise in nuclear physics to perform the cross section calculations for any scattering angle used in particular IBA facilities. The current state of the resource is described in [1]. The ultimate goal of the work is to provide the IBA community with a comprehensive source of the evaluated cross-sections which should eventually substitute experimental cross-sections still used for spectra simulations.

[1] A.F. Gurbich, Nucl. Instr. and Meth. B 371 (2016) 27.

Primary authors : Prof. GURBICH, Alexander (Institute for Physics and Power Engineering, Obninsk, Russia)

Co-authors :

Presenter : Prof. GURBICH, Alexander (Institute for Physics and Power Engineering, Obninsk, Russia)

Track classification :

Contribution type : --not specified--

Submitted by : Prof. GURBICH, Alexander

Submitted on Thursday 31 March 2016

Last modified on : Thursday 31 March 2016

Comments :

Status : SUBMITTED

Track judgments :

Abstract ID : 18

Neutron-Induced Breakup Reactions Using 100-ps Pulses from Direct-Drive D-T Implosions on OMEGA

Content :

Neutron interactions with deuterium leading to a three-body breakup are important testing grounds for modern nuclear theory. An accurate understanding of the process is also important for inertial-confinement fusion (ICF) research, where this reaction is a source of background neutrons for spectroscopic measurements. However, experimental data are scarce and incomplete, in particular, for neutron energies generated in ICF implosions using DD and DT fuels. Therefore, an experiment was conducted at the direct-drive Omega Laser Facility [1] to measure the cross section and energy spectrum of neutrons from n(D,2n)p breakup. Deuterium breakup was induced using monoenergetic (14.03-MeV) neutrons produced by imploding a glass microballoon filled with DT gas. One class of direct-drive ICF targets can generate DT fusion yields up to 1e14 into 4-pi steradians with a pulse width of ~100 ps and a source radius of <50-um when imploded. These neutrons were incident on an interaction vessel with a fractional solid angle of 1e−4 containing 60 mL of heavy water (D2O) positioned 9 cm from the imploding target. A high-dynamic-range neutron scintillation detector filled with oxygenated xylene, located 13.4 m from the target inline with the interaction vessel, and was used to record the neutron time of flight. [2] High-resolution spectra were obtained with up 1e6 neutron interactions in the scintillator volume, leading to a low statistical uncertainty of ~2%. Preliminary analysis of the neutron energy spectrum shows partial agreement when compared with recent theoretical calculations.[3,4]
This material is based upon work supported by the Department of Energy National Nuclear Security Administration under Award Number DE-NA0001944, the University of Rochester, and the New York State Energy Research and Development Authority. The support of DOE does not constitute an endorsement by DOE of the views expressed in this article.

1. T. R. Boehly et al., Opt. Commun. 133, 495 (1997).
2. C. J. Forrest et al., Rev. Sci. Instrum. 83, 10D919 (2012).
3. G. Hale, Los Alamos National Laboratory, private communication (2015).
4. A. Deltuva, Institute of Theoretical Physics and Astronomy, Vilinus University, Vilinus, Lithuania, private communication (2015).

Primary authors : Dr. FORREST, Chad (Laboratory for Laser Energetics (LLE))

Co-authors : Dr. SCHRODER, Wolf-udo (University of Rochester) ; Dr. KNAUER, James (Laboratory for Laser Energetics (LLE)) ; Dr. STOECKL, Christian (Laboratory for Laser Energetics (LLE)) ; Dr. BAHUKUTUMBI, Radha (Laboratory for Laser Energetics (LLE)) ; Dr. SANGSTER, Thomas (Laboratory for Laser Energetics) ; Dr. GLEBOV, Vladimir (Laboratory for Laser Energetics (LLE))

Presenter : Dr. FORREST, Chad (Laboratory for Laser Energetics (LLE))

Track classification :

Contribution type : --not specified--

Submitted by : Dr. FORREST, Chad

Submitted on Friday 01 April 2016

Last modified on : Friday 01 April 2016

Comments :

Is there a way to attach a PDF file for the abstract?

Abstract ID : 19

Commissioning the SONIK (Scattering of Nuclei in Inverse Kinematics) scattering chamber

Content :

The SONIK (Scattering of Nuclei in Inverse Kinematics) scattering chamber is a windowless gas target surrounded by an array of collimated, ion implanted Si charged particle detectors. SONIK was designed for the express purpose of making precision measurements of ^{7}Be(p,p)^{7}Be in inverse kinematics with the intent of constraining the ^{7}Be(p,γ)^{8}B astrophysical S-factor $S_{17}(0)$. The chamber was commissioned in July of 2015 at TRIUMF in Vancouver, BC Canada by measuring two elastic scattering reactions in inverse kinematics. ^{3}He(α,α)^{3}He was measured in order to characterize the apparatus and ^{7}Li(p,p)^{7}Li was measured in order to estimate the background due to this reaction, as ^{7}Li is expected to be a significant contaminant in the ^{7}Be beam for the planned measurement of ^{7}Be(p,p)^{7}Be. The commissioning of SONIK involved only partial instrumentation of the apparatus. As such, an additional measurement of ^{3}He(α,α)^{3}He with SONIK fully instrumented is planned in the near future. The data from this measurement will be compared to recent theoretical calculations from a no-core shell model with continuum using a renormalized chiral nucleon-nucleon interaction of the α + ^{3}He system. Several additional experiments that plan to utilize SONIK have already been approved to run with high priority, including ^{7}Be(α,α)^{7}Be and ^{15}O(α,α)^{15}O. Elastic scattering data provide valuable inputs for the extrapolation of astrophysical S-factors to stellar energies using phenomenological R-matrix fits. Resonant elastic scattering can also provide spectroscopic information at low level densities using the R-matrix formalism.

Primary authors : Dr. CONNOLLY, Devin (TRIUMF)

Co-authors : Dr. ALCORTA, Martin (TRIUMF) ; Dr. BRUNE, Carl (Ohio University) ; Mr. BURKE, Devin (McMaster University) ; Dr. DAVIDS, Barry (TRIUMF) ; Dr. FALLIS, Jenniffer (North Island College) ; Mr. FIRMINO, Arthur (University of Alberta) ; Prof. GREIFE, Uwe (Colorado School of Mines) ; Dr. HUTCHEON, Dave (TRIUMF) ; Mr. PANERU, Som (Ohio University) ; Dr. RUIZ, Chris (TRIUMF) ; Mr. WILLIAMS, Matthew (TRIUMF) ; Mr. WEINERBERG, Chaim (TRIUMF)

Presenter : Dr. CONNOLLY, Devin (TRIUMF)

Track classification :

Contribution type : --not specified--

Submitted by : Dr. CONNOLLY, Devin

Submitted on Friday 01 April 2016

Last modified on : Friday 01 April 2016

Comments :

Status : SUBMITTED

Track judgments :

Abstract ID : 20

Analysis of ^{13}C excited states above the a-threshold by R-matrix analysis of α+^{9}Be elastic and inelastic scattering data

Content :

The study of ^{13}C structure can represent an important tool to understand the effects of clusterization in light non-self-conjugated nuclei. The possible presence of rotational bands built on molecular states has been suggested in several papers [1,2]. Furthermore, in recent times, some theoretical papers [3,4] predicted the possible existence of states corresponding to the coupling of a valence neutrons to the ^{12}C Hoyle state.
To shed light on these interesting aspects, we performed a comprehensive R-matrix fit of elastic (α_0) and inelastic (α_1 and α_2 channels) scattering data collected by studying α+^{9}Be collisions in the energy range E$_\alpha$=3.5 − 10 MeV at several angles in direct kinematics [5]. Preliminary results of this analysis allow to refine the spectroscopy of excited states in ^{13}C in the excitation energy region between 13 and 17 MeV. In particular they suggest that: (1) the 13.41 MeV state could be assigned $7/2^+$, in agreement suggestions reported in Ref. [6] and possibly associated with the positive parity rotational band suggested in [1]; (2) a non-vanishing direct contribution is needed to reproduce the inelastic scattering cross section of the α_2 channel, that involves the second member of the ground state rotational band of ^{9}Be. The obtained results of this preliminary analysis will be discussed in the talk.

Primary authors : Mr. DELL'AQUILA, Daniele (Università di Napoli Federico II & INFN-Napoli)

Co-authors : Dr. LOMBARDO, Ivano (Università di Napoli Federico II & INFN-Napoli)

Presenter : Mr. DELL'AQUILA, Daniele (Università di Napoli Federico II & INFN-Napoli)

Track classification :

Contribution type : --not specified--

Submitted by : Mr. DELL'AQUILA, Daniele

Submitted on Friday 01 April 2016

Last modified on : Friday 01 April 2016

Comments :

Status : SUBMITTED

Track judgments :

Abstract ID : 21

Spin parity determination of unbound states in 26Mg from neutron spectroscopy

Content :

The 25Mg(n, tot) reaction cross section has been measured in the energy region of interest to s process nucleosynthesis at the neutron time-of-flight facility GELINA at EC-JRC-IRMM (Belgium). A highly-enriched metal sample (97.87% 25Mg) has been used for the measurement, in order to overcome the serious limitation of using natural material, because of the dominant abundance of 24Mg [1]. A resonance shape analysis based on the R-Matrix reaction theory had led to unambiguous spin parity assignment of some important unbound states in 26Mg. The result of this work will be presented with particular emphasis on the experimental evidence of states in 26Mg with parity 0+, 1-, 2+.... which can be populated by the 22Ne+alpha reaction. Therefore the resonance analysis here reported is of special interest for the characterization of the 22Ne(a,n)25Mg neutron source in red giant stars. In addition, the resonance shape analysis of cross section data from this work, also permits to accurate parametrize the 25Mg(n,g) cross section which has an important role as a neutron poison of the s process.

[1]C. Massimi, EPJ Web Conf. 66, 07016 (2014)

Primary authors : Dr. MASSIMI, Cristian (University of Bologna and INFN Bologna)

Co-authors : Dr. KOPECKY, Stefan (European Commission - Joint Research Centre - Institute for Reference Materials and Measurements) ; Dr. SCHILLEBEECKX, Peter (European Commission - Joint Research Centre - Institute for Reference Materials and Measurements) ; Dr. KOEHLER, Paul (Department of Physics, University of Oslo, N-0316 Oslo, Norway)

Presenter : Dr. MASSIMI, Cristian (University of Bologna and INFN Bologna) ; Dr. KOPECKY, Stefan (European Commission

Track classification :

Contribution type : --not specified--

Submitted by : Dr. MASSIMI, Cristian

Submitted on Friday 01 April 2016

Last modified on : Friday 01 April 2016

Comments :

Status : SUBMITTED

Track judgments :

Abstract ID : 22

Consideration of model defects associated with R-matrix based evaluations

Content :

The R-matrix theory is an elegant tool in reaction theory which maintains the essential features of quantum mechanics albeit the full microscopic details of the nuclear many-body problem are not necessarily available. Its basic concept relies on the distinction of an external and an internal space. In the latter the ignorance of the detailed microscopic behaviour is substituted by a set of basis functions, while in the external region the asymptotic multi-channel wave function is known in terms of the S-matrix. The border between the two regions is characterised by the so-called matching radius. This procedure leads to a simple expression of the so-called R-matrix (related to the inverse of the logarithmic derivative at the matching radius) in terms of a sum of pole terms and associated width parameters for each channel. Because of this, the R-matrix theory is well suited for the description of resonant reaction data and is a standard method for nuclear data evaluation in the resonance regime. Usually the poles and associated width parameters
are determind via fits to experimental data. This so-called phenomenological R-matrix representation suffers from a lack of predictive power, but provides excellent reproductions of the reaction cross sections despite its simplicity.

The description of reaction data by R-matrix theory is usually excellent. However, it is still an approach regarding the many-body character of the considered systems. Here model deficiencies are associated either with missing pole terms or with frequently used simplifications of the R-matrix. In addition also numerical errors may occur which are considered negligible here. In this contribution we reformulated the procedure developed by Schnabel [1] for the determination of model defects in order to apply them to the resonance regime. Within this procedure the model defects are described by a Gaussian process. Key of this formulation is a proper transformation of the data and reasonable assumptions for the associated correlations of the defects. The method is demonstrated on a schematic yet realistic example in order to show various facets of the procedure.

Work partly supported by Fusion of Energy via the specific grant F4E-FPA-168.02 and the Austrian Academy of Sciences via the KKKÖ matching grants Thomas Srdinko. The views and opinions expressed herein do not reflect necessarily those of the European Commission.

[1] G. Schnabel, Large Scale Bayesian Nuclear Data Evaluation with Consistent Model Defects(PhD Thesis, TU Wien, June 2015).

Primary authors : Prof. LEEB, Helmut (TU Wien, Atominstitut)

Co-authors :

Presenter : Prof. LEEB, Helmut (TU Wien, Atominstitut)

Track classification :

Contribution type : --not specified--

Submitted by : Prof. LEEB, Helmut

Submitted on Friday 01 April 2016

Last modified on : Friday 01 April 2016

Comments :

Abstract ID : 23

R-matrix theory and ab initio calculations of light-nucleus reactions

Content :

The no-core shell model with continuum is a theoretical framework to describe – from first principles, or ab initio – dynamic processes between light nuclei, capable of providing accurate evaluations of crucial reaction data for nuclear astrophysics, fusion-energy research, and other applications. Based on the `calculable' R-matrix theory, it starts from projectile, target and composite nucleus eigenstates obtained within the ab initio no-core shell model – a first-principles approach for nuclear bound states – and uses discrete as well as continuous (cluster) A-body basis states to describe the wave function in the interaction region. The scattering matrix – and from it any cross section – is then obtained by matching these solutions with the known asymptotic behavior of the wave function. In this talk I will briefly highlight how the R-matrix is computed in this context and how it relates to its more familiar counterpart used in phenomenological fits. I will then present state-of-the-art ab initio calculations for nucleon and deuterium scattering on light nuclei starting from chiral two- and three-body Hamiltonians. In addition, I will also discuss the progress toward the description of more complicated dynamical processes such as reactions with heavier projectiles, or involving transfers of nucleons, and the treatment of three-body continuum states.

Prepared by LLNL under Contract No. DE-AC52-07NA27344. This material is based upon work supported by the U.S. Department of Energy, Office of Science, Office of Nuclear Physics, under Work Proposal No. SCW1158.

Primary authors : Dr. QUAGLIONI, Sofia (Lawrence Livermore National Laboratory)

Co-authors : Dr. CALCI, Angelo (TRIUMF) ; Dr. DOHET-ERALY, Jeremy (TRIUMF) ; Prof. HORIUCHI, Wataru (Hokkaido University) ; Dr. HUPIN, Guillaume (CEA) ; Dr. NAVRATIL, Petr (TRIUM) ; Dr. ROMERO REDONDO, Carolina (LLNL)

Presenter : Dr. QUAGLIONI, Sofia (Lawrence Livermore National Laboratory)

Track classification :

Contribution type : --not specified--

Submitted by : Dr. QUAGLIONI, Sofia

Submitted on Friday 01 April 2016

Last modified on : Friday 01 April 2016

Comments :

Status : SUBMITTED

Track judgments :

Abstract ID : 24

R-matrix approach based on hybrid representation

Content :

Modern nuclear data evaluation is strongly based on nuclear reaction models which provide a good description of reaction cross sections for most energies and nuclei. However, these models are not applicable at low energies for which resonance behaviour is observed. At present this resolved resonance regime can only be described within R-matrix theory by adjusting poles and associated widths to describe the experimental data. Due to the conceptual differences between R-matrix theory and standard reaction models a smooth transition of the cross sections between the two different regimes is not obvious. The situation becomes particularly unsatisfactory for light nuclei for which the resonance regime goes up to relatively high energies.

In this contribution we aim at the development of a method which guarantees a smooth transition between the resonance regime and reaction calculations at higher energies based on the statistical model. Our approach takes advantage of the fact that R-matrix theory is an excellent tool for the solution of coupled-channel equations. In particular we apply a pseudo-potential concept together with a transfer- and deformation-inspired picture of open reaction channels. In order to obtain a good description of reaction cross sections in the transition region we optimize the pseudo-potentials. For the description of resonances at low energies a selected number of pole terms is added to the R-matrix associated with the pseudo-potential. The parameters (pole energies, widths) are adjusted to obtain a fair reproduction of the cross sections in the considered energy range. One challenge is the required unitarity of the R-matrix representation up to the transition regime because a high number of open channels may occur. Therefore the developed method is well suited for light nuclei (A<20), for which the number of open channels is limited up to relatively high energies. We present the current status of the development and apply the method to a resticted data set of neutron-induced reactions on oxygen.

Work partly supported by Fusion of Energy via the specific grant F4E-FPA-168.02 and the Austrian Academy of Sciences via the KKKÖ matching grants Thomas Srdinko. The views and opinions expressed herein do not reflect necessarily those of the European Commission.

Primary authors : Mr. SRDINKO, Thomas (TU Wien, Atominstitut)

Co-authors : Prof. LEEB, Helmut (TU Wien, Atominstitut)

Presenter : Mr. SRDINKO, Thomas (TU Wien, Atominstitut)

Track classification :

Contribution type : --not specified--

Submitted by : Mr. SRDINKO, Thomas

Submitted on Friday 01 April 2016

Last modified on : Friday 01 April 2016

Comments :

Status : SUBMITTED

Track judgments :

Abstract ID : 26

Underground Nuclear Astrophysics

Content :

It is in the nature of astrophysics that many of the processes and objects are physically inaccessible. Thus, it is important that those aspects that can be studied in the laboratory are well understood. Nuclear reactions are such quantities that can be partly measured in the laboratory. These reactions influence the nucleosynthesis of the elements in the Big Bang as well as in all objects formed thereafter, and control the associated energy generation and evolution of stars.

Since more than 20 years LUNA (Laboratory for Underground Nuclear Astrophysics) has been measuring cross sections relevant for hydrogen burning in the Gran Sasso Laboratory and demonstrated the research potential of an underground accelerator facility. Unfortunately, the number of reactions is limited by the energy range accessible with the 400 kV LUNA accelerator. The CASPAR (Compact Accelerator System for Performing Astrophysical Research) Collaboration is implementing a high intensity 1 MV accelerator at the Sanford Underground Research Facility (SURF) and overcome the current limitation at LUNA. The installation of the accelerator facility is almost completed and first experiments will start in late summer 2016. This project will primarily focus on the neutron sources for the s-process, e.g. 13C(alpha,n)16O and 22Ne(alpha,n)25Mg, and lead to unprecedented measurements compared to previous studies in Earth's surface laboratories.

However, next generation underground accelerator facilities are already on the horizon, and higher voltage accelerators equipped with ion sources that can provide heavier ion species as well as higher beam intensities will allow for studies of the 12C(alpha,gamma)16O reaction as well as 12C+12C fusion. In both reactions the extrapolation of existing direct data into the relevant astrophysical temperature range of helium and carbon burning, respectively, carries significant uncertainties and successful underground measurements would add greatly to our understanding of late stellar evolution.

Although in several cases underground studies significantly advance our knowledge on nuclear reaction cross sections in the relevant astrophysical energy region, R-matrix analyses remain a very important tool for a reliable determination of the reaction rates and associate uncertainties taking into account all available experimental parameters. A few selected reactions will be discussed in greater detail and open questions will be highlighted.

Primary authors : Dr. STRIEDER, Frank (South Dakota School of Mines & Technology)

Co-authors :

Presenter : Dr. STRIEDER, Frank (South Dakota School of Mines & Technology)

Track classification :

Contribution type : --not specified--

Submitted by : Prof. STRIEDER, Frank

Submitted on Friday 01 April 2016

Last modified on : Friday 01 April 2016

Comments :

Status : SUBMITTED

Track judgments :

Abstract ID : 28

R-matrix analysis and indirect measurement of 19Ne states relevant to novae explosions

Content :

J. E. Riley1, A. M. Laird1, N. de Séréville2, A. Parikh3, S. P. Fox1, H. Fairouz2, I. Stefan2, M. Assie2, B. Bastin4, F. Boulay4, A. Coc5, S. Franchoo2, R. Garg1, S. Gillespie1, V. Guimaraes2, C. Hamadache5, N. Hubbard1, J. Kiener5, A. Lefebvre-Schuhl5, F. de Oliveira4, L. Perrot2, A. Remadi4, D. Suzuki2, G. Verde2, T. Vincent5

1 University of York, Department of Physics, York YO10 5DD, UK
2 Université Paris Sud, Institut de Physique Nucléaire d'Orsay, Orsay 91406, France
3 Universitat Politècnica de Catalunya, Department de Física i Enginyeria Nuclear, Barcelona E-08036, Spain
4 Grand Accélérateur National d'Ions Lourds, BP 55027, France
5 Université Paris Sud, Centre de Sciences Nucléaires et de Sciences de la Matière, Orsay 91405, France

18F is an unstable nucleus produced via the H-CNO cycle during thermonuclear runaway in novae. Decaying via positron emission, its 110 minute half-life makes it one of the strongest observable sources of gamma rays during the first few hours of the explosion. Observations of this radiation would provide a direct test for current hydrodynamic models, however the distance at which this emission can be feasibly detected is dependant on the amount of 18F produced.

Abundance estimates are therefore critical and whilst production rates of the isotope are well known, its destruction via proton capture through unbound states in 19Ne requires further constraint. Despite previous experimental effort, predictions of 18F production still vary by a factor of two [1,2].

Due to the presence of a wide 3/2+ resonance at 665 keV above the proton threshold in the 18F+p channel, interference effects between other 3/2+ states create a large cross section uncertainty in the energy window of interest. Recent measurements of states above and below the threshold however have questioned several 3/2+ spin parity assignments and thus their interference [1].

The picture is further complicated by the presence of a 1/2+ resonance at 1.4 MeV [3] whose interference with a postulated broad subthreshold 1/2+ state [4] could negate the uncertainty from the 3/2+ states. There is also disagreement as to the nature of the -122 keV subthreshold state. A study in 2015 found its Jpi to be 1/2+ [5] contradicting a previous higher spin assignment [1].

The subject of this work has been to re-evaluate 19Ne state contributions to this uncertainty using an R-matrix analysis and to address these by performing an indirect experiment examining properties of the states of interest.

The region close to the proton threshold was studied closely using the charge exchange reaction 19F(3He,t)19Ne at IPN, Orsay. A Splitpole spectrometer analysed the momentum of the tritons in coincidence with the 19Ne decay products. Tagging on the tritons, a highly segmented Si array provided branching ratios and spin assignments for the states of interest. The results of this experiment and their impact on the reaction rate will be presented along with the implications for future studies of 19Ne.

[1] A. M. Laird et al., Phys. Rev. Lett. 110, 032502 (2013)
[2] A. Parikh et al., Phys. Rev. C 92, 055806 (2015)
[3] J. C. Dalouzy et al., Phys. Rev. Lett. 102, 162503 (2009)
[4] M. Dufour, P. Descouvemont, Nucl. Phys. A 735, 381-394 (2007)
[5] D. W. Bardayan et al., Phys. Left. B. 751, 311-315 (2015)

Abstract ID : 29

R-matrix analysis of the 3H(t,2n) neutron spectrum produced by inertial confinement fusion experiments

Content :

Inertial confinement fusion experiments produce thermonuclear plasmas of deuterium and tritium. The yields of 3H(t,2n) reactions produced by these experiments are used to diagnose plasma conditions. The yield is extracted from time-of-flight measurements of the neutron spectrum. The 3H(t,2n) neutron spectrum from fusion experiments stretches from 0 to 9 MeV, however the measurements have limited sensitivity below several MeV. An R-matrix description has been developed to model the spectrum [C. R. Brune et al., Phys. Rev. C 92 014003 (2015)] which constrains the unobserved region of the spectrum and reduces uncertainties in extracted 3H(t,2n) yields. A discussion of this model and its application to inertial confinement fusion experiments will be presented.

Primary authors : SAYRE, Daniel (Lawrence Livermore National Laboratory)

Co-authors :

Presenter : SAYRE, Daniel (Lawrence Livermore National Laboratory)

Track classification :

Contribution type : --not specified--

Submitted by : SAYRE, Daniel

Submitted on Friday 01 April 2016

Last modified on : Friday 01 April 2016

Comments :

Status : SUBMITTED

Track judgments :

Abstract ID : 34

R-matrix for beta-decay and three-body decays

Content :

In this contribution I will discuss challenges related to using R-matrix theory to describe :

- beta-delayed particle emission.
- Final states of more than two particles.
- Interference between identical particles in the final state.

Primary authors : Dr. FYNBO, Hans (Department of Physics and Astronomy, Aarhus University, Denmark)

Co-authors :

Presenter : Dr. FYNBO, Hans (Department of Physics and Astronomy, Aarhus University, Denmark)

Track classification :

Contribution type : --not specified--

Submitted by : Dr. FYNBO, Hans

Submitted on Tuesday 05 April 2016

Last modified on : Tuesday 05 April 2016

Comments :

Status : SUBMITTED

Track judgments :

Abstract ID : 30

Linking ab initio models, phenomenology, and data

Content :

An important task for reaction modeling is the synthesis of information about a reaction into a useable form. For example, astrophysics needs cross sections as continuous functions of collision energy, so that thermally averaged reaction rates can be computed. Experiments are (essentially) discontinuous measurements at discrete energies; they require both interpolation (between measured points) and extrapolation (to energies with cross sections too small to measure). Physically motivated models are needed for this task, and the phenomenological R-matrix has a long history as a model that includes the physics of Coulomb and angular momentum barriers, resonances, and unitarity in a fairly general way, while reducing nuclear structure physics to a set of parameters that can be fitted to reaction and scattering data. Other types of "phenomenological" models, like potential models and halo effective field theories, can play the same role with somewhat different strengths and weaknesses. All phenomenological models involve choices that are not uniquely decided by the input data, and in any case they are limited by the amount and quality of available data. In contrast, nucleon-level models of reactions offer information deriving directly from the nucleon-nucleon interaction and nuclear structure physics. They have historically done better with energy dependences than absolute cross sections; for radiative direct captures they are sometimes used as interpolation/extrapolation functions, with their normalizations adjusted ad hoc to match data. In the last decade, "ab initio" nucleon-level models, with quantitatively accurate nucleon-nucleon interactions as almost their sole inputs, have become possible for nuclei well into the p-shell. These essentially parameterless models provide alternative information of apparently comparable precision to experiment, even in their normalization. The question then arises of how ab initio models should be combined with experimental information to produce a phenomenology that compensates the weaknesses of each with strengths of the other. I will discuss the nature and limitations of existing ab initio constraints on direct capture cross sections, including cases in two- and three-nucleon systems where theory is now more reliable than the data. I will then discuss the prospects for developing direct links between ab initio and phenomenological models, so that phenomenological models can fold in both ab initio and experimental data. I will discuss the nature of the links that can and should be made, including some concrete examples regarding neutron capture on 7Li and proton capture on 7Be. I will also comment on the challenge of figuring out how to weight information from ab initio theory versus experiment in fitting a model.

Primary authors : Dr. NOLLETT, Kenneth (San Diego State University)

Co-authors :

Presenter : Dr. NOLLETT, Kenneth (San Diego State University)

Track classification :

Contribution type : --not specified--

Submitted by : Dr. NOLLETT, Kenneth

Submitted on Friday 01 April 2016

Last modified on : Friday 01 April 2016

Comments :

Status : SUBMITTED

Track judgments :

Abstract ID : 32

Study of states in 38Ca that are important for the 34Ar(a,p)37K reaction rate through 37K+p elastic scattering

Content :

X-ray bursts occur in binary systems when hydrogen-rich matter from a main-sequence star accretes onto a neutron star and ignites in a thermonuclear runaway. During the early stages of the burst, (a,p) reactions on certain proton-rich nuclei drastically affect the energy generation and the rise of the light curve. Little experimental information exists on these reactions. We recently measured 37K+p elastic scattering using a 4.6 MeV/u reaccelerated beam of 37K from the ReA3 facility at the NSCL bombarding a 30-micron thick polypropylene target. Elastically scattered protons were detected in a silicon-strip detector array arranged to cover backward angles in the center-of-mass, with the center-of-mass energy reconstructed from the angle and energy of the measured protons. Recoiling heavy ions were detected in coincidence to suppress background from fusion-evaporation reactions. An R-matrix analysis of the measured scattering cross sections is to be conducted to determine the properties of resonant states in 38Ca that are important for determining the 34Ar(a,p)37K reaction rate, one of the most important (a,p) reactions for understanding X-ray bursts.

Primary authors : LAUER, Amber (Louisiana State University)

Co-authors :

Presenter : LAUER, Amber (Louisiana State University)

Track classification :

Contribution type : --not specified--

Submitted by : AMBER, Lauer

Submitted on Friday 01 April 2016

Last modified on : Friday 01 April 2016

Comments :

Status : SUBMITTED

Track judgments :

Abstract ID : 35

New data on 14N(p,gamma)15O at 0.4 - 1.4 MeV for improved R-Matrix fits

Content :

For solar model calculations precise knowledge of the relevant fusion cross sections is needed. In the solar core the rate of the CNO cycle is dominated by the bottleneck 14N(p,gamma)15O reaction, because this is the slowest reaction of the cycle. A proton beam with energies of 0.4 - 1.4 MeV at the 3 MV Tandetron of Helmholtz-Zentrum Dresden-Rossendorf was used to study the non-resonant cross section of 14N(p,gamma)15O.

The new data for the S factor of capture to the excited state at 6.79 MeV and to the ground state were utilized in the R-Matrix formalism. Using the AZURE2 code, parameter optimizations and sensitivity studies were performed to understand the importance of hypothetical background poles and their influence on the Asymptotic Normalization Coefficient of the 6.79 MeV level. The contribution will discuss challenges encountered in the fitting process and results of the extrapolation to S(0).

Primary authors : Mr. WAGNER, Louis (Helmholtz-Zentrum Dresden-Rossendorf, Germany)

Co-authors :

Presenter : Mr. WAGNER, Louis (Helmholtz-Zentrum Dresden-Rossendorf, Germany)

Track classification :

Contribution type : --not specified--

Submitted by : Mr. WAGNER, Louis

Submitted on Thursday 14 April 2016

Last modified on : Thursday 14 April 2016

Comments :

Status : SUBMITTED

Track judgments :

Abstract ID : 36

Resonance and virtual states from a calculable R-matrix approach

Content :

The calculable R-matrix approach [1,2] is a powerful and widely used tool to solve the Schrödinger equation for scattering states. By extending this approach to complex energies, this can also be useful to study resonances [3], from the computation of Siegert states [4], and virtual states. This "complex-energy" R-matrix approach, which is not as commonly used as the usual "real-energy R-matrix" approach, will be presented and applied to several potential models. From these simple examples, the features of the method will be highlighted and a comparison with concurrent techniques, namely the complex-scaling method [5] (valid only for resonance states) and the Jost function method [6-10] (valid for both resonance and virtual states), will be done.

The "complex-energy" R-matrix approach can be combined with the no-core shell model with continuum [11-13] to provide an efficient ab initio technique to compute resonance properties and virtual-sate energies. This method will be applied to the alpha+N, alpha+3H/3He and 8Be+n systems [13-16] and differences between resonance properties deduced from this approach or from the inflexion points in the phase shifts will be discussed.

TRIUMF receives federal funding via a contribution agreement with the National Research Council of Canada. This work is supported in part by NSERC under Grant No. 401945-2011, by LLNL under Contract No. DE-AC52-07NA27344, and by the U.S. Department of Energy, Office of Science, Office of Nuclear Physics, under Work Proposal Number SCW1158.

[1] P. G. Burke, "R-Matrix Theory of Atomic Collisions: Application to Atomic, Molecular and Optical Processes". Springer, Berlin, 2011
[2] P. Descouvemont and D. Baye, Rep. Prog. Phys. 73 (2010) 036301
[3] B. I. Schneider, Phys. Rev. A 24 (1981) 1
[4] A. J. F. Siegert, Phys. Rev. 56 (1939) 750
[5] Y. K. Ho, Physics Reports 99 (1983) 1
[6] S. A. Sofianos and S. A. Rakityansky, J. Phys. A 30, 3725 (1997)
[7] S. A. Sofianos and S. A. Rakityansky, J. Phys. A 31, 5149 (1998)
[8] H. Masui, S. Aoyama, T. Myo, and K. Katō, Prog. Theor. Phys. 102, 1119 (1999)
[9] H. Masui, S. Aoyama, T. Myo, K. Katō, and K. Ikeda, Nucl. Phys. A 673, 207 (2000)
[10] H. Masui, S. Aoyama, and D. Baye, Prog. Theor. Exp. Phys. 2013 (2013) 123A02
[11] S. Baroni, P. Navrátil, S. Quaglioni, Phys. Rev. Lett. 110 (2013) 022505
[12] S. Baroni, P. Navrátil, S. Quaglioni, Phys. Rev. C 87 (2013) 034326
[13] P. Navrátil, S. Quaglioni, G. Hupin, C. Romero-Redondo, A. Calci, Phys. Scripta 91 (2016) 053002
[14] G. Hupin, S. Quaglioni, P. Navrátil, Phys. Rev. C 90 (2014) 061601
[15] J. Dohet-Eraly, P. Navrátil, S. Quaglioni, W. Horiuchi, G. Hupin, F. Raimondi, Phys. Lett. B (2016) http://dx.doi.org/10.1016/j.physletb.2016.04.021
[16] J. Langhammer, P. Navrátil, S. Quaglioni, G. Hupin, A. Calci, and R. Roth, Phys. Rev. C 91 (2015) 021301

Primary authors : Dr. DOHET-ERALY, Jérémy (TRIUMF)

Co-authors : Dr. NAVRÁTIL, Petr (TRIUMF) ; Dr. QUAGLIONI, Sofia (Lawrence Livermore National Laboratory)

Presenter : Dr. DOHET-ERALY, Jérémy (TRIUMF)

Track classification :

Contribution type : --not specified--

Submitted by : Dr. DOHET-ERALY, Jérémy

Abstract ID : 37

Constraining R-Matrix Fits with the Shell Model

Content :

The number of combinations of the sign of the reduced widths in a R-Matrix fit grows factorially with the number of levels when there is no external constraint. One method that has been explored to address this problem is to calculate the reduced width amplitudes and their signs using the shell model.

CRUNCHER, an m-scheme shell model code [1], was used to calculate the wave functions of the states in the compound nucleus and all nuclei which the compound nucleus can decay to. The spectroscopic amplitudes were calculated from the overlap of the compound nucleus wave function with the final nucleus and emitted particle.

The calculated reduced width amplitudes were used in a J-J coupling scheme to make as close a connection between the shell model and R-Matrix states as possible. The Ohio University R-Matrix code [2] is used primarily to fit both neutron scattering and neutron-induced charged-particle emission. It can be used in both J-J and L-S coupling modes.

The predictions of R-Matrix parameters by shell model calculations is used as a starting point. Several compound nuclei were fit. These the 7Li, 8Li [3], 10Be, 12B [4], and 14C [5] systems. These previous results will be reviewed as examples.

An R-Matrix fit is also often subject to numerous local minima. The code TWIDDLE was written to provide an alternative parameter search algorithm. Starting from a set of fit parameters, a random walk procedure is to explore the chi-squared parameter using parameter changes that are not necessarily small. This approach also allows discrete parameters, such as spins and parities, to treated as fit parameters.

We are currently working with the 11B compound nucleus. This fit includes the 10B(n,n), 10B(n,n'), 10B(n,p), 10B(n,t), 10B(n,alpha), and 6Li(alpha,n) reactions. The data set has been considerably augmented by 10B(n,Z) data we have recently taken at WNR/LANSCE.

References:
[1] D.A. Resler and S.M. Grimes, Computers in Physics 2 65 (1988).
[2] H.D. Knox, "The Ohio University R-Matrix Code", Internal Report, available on OSTI.
[3] H.D. Knox, D.A. Resler and R.O. Lane, Nuclear Physics A466, 245-279 (1987).
[4] P.E. Koehler, H.D. Knox, D.A. Resler, R.O. Lane, and D.J. Millener, Nuclear Physics A394, 221-244 (1983).
[5] D. A. Resler, H. D. Knox, P. E. Koehler, and R. O. Lane, and G. F. Auchampaugh, Physical Review C 29, 766 (1989).

Primary authors : Dr. MASSEY, Thomas (Ohio University)

Co-authors : Dr. RESLER, David (Ohio University)

Presenter : Dr. MASSEY, Thomas (Ohio University)

Track classification :

Contribution type : --not specified--

Submitted by : Dr. MASSEY, Thomas

Submitted on Friday 15 April 2016

Last modified on : Friday 15 April 2016

Comments :

Abstract ID : 38

SAMMY: An R-matrix Bayesian Nuclear Data Evaluation Code

Content :

SAMMY is a code developed by Oak Ridge National Laboratory (ORNL) for Bayesian fitting of R-matrix resonance parameters to neutron, proton, and α-particle differential cross sections data in resolved and unresolved resonance energy ranges. SAMMY provides facility-specific multi-component experimental resolution functions, including resolution functions of commercially available detectors, and it accounts for Doppler broadening of cross sections, multiple scattering effects, etc. For several decades SAMMY has been the foremost tool for R-matrix resonance parameter evaluations in the U.S. and abroad contributing many evaluated resonance parameter sets and their covariance matrices to nuclear data libraries. The Reich-Moore approximation for eliminated γ-ray channels employed for heavy nuclides will be described. A method for conversion between formal and alternative R-matrix parameters in the Reich-Moore approximation will be outlined. A coupling to integral benchmark experiments to inform evaluation of R-matrix parameters recently implemented in the SAMINT module of SAMMY will be outlined, and a report on SAMMY modernization efforts and various improvements will be given.

Primary authors : ARBANAS, Goran (ORNL)

Co-authors : Dr. SOBES, Vladimir (ORNL) ; HOLCOMB, Andrew (ORNL) ; PIGNI, Marco (ORNL) ; WIARDA, Dorothea (ORNL)

Presenter : ARBANAS, Goran (ORNL)

Track classification :

Contribution type : --not specified--

Submitted by : ARBANAS, Goran

Submitted on Friday 15 April 2016

Last modified on : Friday 15 April 2016

Comments :

Please include the "Notice" appearing in the Abstract anywhere the Abstract would be printed.

Status : SUBMITTED

Track judgments :

Abstract ID : 39

Reich-Moore R-matrix parameters for n+16O (*)

Content :

A preliminary set of resonance parameters for 16 O in the neutron energy range of thermal up to 6.12 MeV has been generated using the Reich-Moore approximation of the R-matrix code SAMMY (1) for Bc=−l boundary condition. We use this set of resonance parameters to quantify the effect of an R-matrix approximation available in SAMMY that has been used in previous evaluations of 16O. This approximation removes the term Sc(E)−Bc out of the formal R-matrix theory, where Sc(E) is the shift function defined as the real part of the logarithmic derivative of the wave function at the channel radius, B c is the boundary condition constant, and c is the channel label. One useful feature of this approximation is that R-matrix resonance energies are shown to correspond to peaks in measured cross sections, thus providing an intuitive way of verifying fitted resonance energies.

We show how this approximation is related to the conversion algorithm between "formal" and "alternative" R-matrix parameters developed by Brune(2). Brune showed that energy-dependent boundary condition Sc(E)−Bc=0 could be achieved by constructing an alternative R-matrix (in terms of alternative R-matrix parameters) while retaining complete consistency with the formal R-matrix theory. We show that the approximate resonance parameters obtained by SAMMY are approximately equal to Brune's alternative parameters. Furthermore, we show

that SAMMY's approximate parameters yields excellent agreement with formal R-matrix at resonance peaks, while causing small deviations in valleys. We quantify these deviations by comparing cross sections computed for approximate resonance parameters to those computed for formal R-matrix parameters. Formal R-matrix parameters were obtained by applying Brune's conversion algorithm to the approximate parameters, and then fitting them to data by SAMMY for Bc=−l boundary condition. Deviations caused by this SAMMY approximation are expected to be significantly smaller for heavy nuclides because Sc(E)−Bc is approximately zero for B c = −l at low energies and for low partial waves, in agreement with SAMMY approximation.

A particular emphasis was also devoted to the analysis and the definition of the external levels and their interplay with energy-dependent shift factors. Comparison and definition of different external functions will be discussed. We will report on the current status of evaluation work on the n+16O cross sections, their covariance

matrices, and comparison to experimental data in the resolved resonance region.

References

[1] N. M. Larson, Updated Users' Guide for SAMMY: Multilevel R-Matrix
Fits to Neutron Data Using Bayes' Equations, Report ENDF-364 and
ORNL/TM-9179/R6, Oak Ridge National Laboratory, Oak Ridge, TN (May
2003). Also report ORNL/TM-9179/R7 (2006).
[2] C. R. Brune, "Alternative parametrization of R-matrix theory," Phys. Rev. C 66, 044611 (2002).

Primary authors : Dr. PIGNI, Marco (Oak Ridge National Laboratory)

Co-authors : Dr. HOLCOMB, Andrew (Oak Ridge National Laboratory) ; ARBANAS, Goran (ORNL)

Presenter : Dr. PIGNI, Marco (Oak Ridge National Laboratory)

Abstract ID : 40

Study of O-14 through resonant alpha scattering

Content :

Resonant alpha scattering has been important for the study of alpha-clusterization, but search for clusters in light unstable nuclei has been limited by the availability of radioactive beams. Novel molecular cluster effects are predicted to exist in nuclei that are just a few nucleons away from stability. We have used resonant alpha scattering to search for cluster structure in unstable O-14 using a radioactive C-10 beam developed at the University of Notre Dame. The radioactive C-10 beam was used in conjunction with the Prototype Active-Target Time-Projection Chamber (PAT-TPC) to measure differential scattering cross sections with high precision. Preliminary analysis of our experiment and insight we can gain from R-matrix analysis will be presented.

Primary authors : AHN, Tan (University of Notre Dame)

Co-authors : ALLEN, Jacob (University of Notre Dame) ; Dr. AYYAD, Yassid (Research Center for Nuclear Physics) ; BARDAYAN, Dan (University of Notre Dame) ; Mr. BAZIN, Daniel (NSCL/MSU) ; Dr. BECEIRO-NOVO, Saul (NSCL-MSU) ; BECKER, Benedict (University of Notre Dame) ; BOESCHENSTEIN, William (University of Notre Dame) ; Mr. BRADT, Joshua (NSCL/MSU) ; Prof. BRODEUR, Maxime (University of Notre Dame) ; Ms. CARPENTER, Lisa (Michigan State University) ; Dr. CORTESI, Marco (National Superconducting Cyclotron Laboratory (Michigan State University)) ; Dr. DEBOER, Richard J. (University of Notre Dame) ; GUPTA, Yogesh (University of Notre Dame) ; GYURJINYAN, Armen (University of Notre Dame) ; HALL, Matthew (University of Notre Dame) ; HALL, Oscar (University of Notre Dame) ; HENDERSON, Samuel (University of Notre Dame) ; HU, Jun (University of Notre Dame) ; JENSEN, Louis (University of Notre Dame)

Presenter : AHN, Tan (University of Notre Dame)

Track classification :

Contribution type : --not specified--

Submitted by : AHN, Tan

Submitted on Friday 15 April 2016

Last modified on : Friday 15 April 2016

Comments :

A number of coauthors will need to be added.

Status : SUBMITTED

Track judgments :

Determining the ^{16}O(n,a) reaction cross section via a forward-propagating analysis with R-matrix formalism

H.Y. Lee and S. Mosby
P-27, Los Alamos National Laboratory, Los Alamos, NM 87545

G. Hale and M. Paris
T-2, Los Alamos National Laboratory, Los Alamos, NM 87545

M. White
XTD-5, Los Alamos National Laboratory, Los Alamos, NM 87545

Importance of precise knowledge on the ^{16}O(n,α) reaction cross section is motivated by multiple nuclear applications, since oxygen is commonly present in the form of either air or cooling water. In particular, precise reaction cross sections are crucial in the energy range of prompt-fission neutron spectrum, which is maximized at about 1.5 MeV with a maxwellian shape.

Although multiple experimental data sets exist up to date, the currently available evaluations [1] differ by 30 - 50 %, which questions the fidelity of this reaction cross section to be used for various applications. Previous measurements were performed not only on the ^{16}O(n,α) reaction [1–5], but also on the ^{13}C(α,n) reaction [6–8] in a time-reverse reaction, using the principle of detailed balance. The compound nucleus of ^{17}O, presenting well resolved resonances at the energy range of interest, challenges experimental energy resolutions or timing resolutions, when used with a Time of Flight method. I will review these previous measurements focusing on systematic uncertainties, normalization, effective energies with a thick target, and additional corrections.

Based on the latest ^{16}O(n,α) measurement performed at Los Alamos Neutron Science Center (LANSCE) using the LENZ (Low Energy NZ) instrumentation, we will discuss a new data analysis method, which is ongoing development of a forward-propagation approach with R-matrix formalism. With data redundancy from signal waveform analysis and Monte Carlo calculations using inputs from R-matrix driven cross sections, this *could* reduce systematic uncertainties, relative to a conventional approach of comparing only final cross sections between experiments and R-matrix calculations. We will present the progress of this development.

This work benefits from the LANSCE accelerator facility and is supported by the U.S. Department of Energy under contracts DE-AC52-06NA25396.

---

[1] V. Khryachkov, I. Bondarenko, V. Pronyaev, P. Prusachenko, A. Sergachev, N. Semenova, and T. Khromyleva, *A workshop of the Collaborative International Evaluated Library Organisation* (2013, Geel, Belgium) https://www.oecd-nea.org/science/wpec/nemea7/presentations.html

[2] R.B. Walton, J.D. Clement, and F. Boreli, Phys. Rev. **107**, 1065 (1957)

[3] E.A. Davis, T.W. Bonner, D.W. Worley, and R. Bass, Nucl. Phys. **48**, 169 (1963)

[4] G. Giorginis, V. Khryachkov, V. Corcalciuc, and M. Kievets, *International Conference on Nuclear Data for Science and Technology*, DOI:**10.105**/ndata:07481 (2007)

[5] A. Plompen, *A workshop of the Collaborative International Evaluated Library Organisation* (2013, Geel, Belgium) https://www.oecd-nea.org/science/wpec/nemea7/presentations.html

[6] S. Harissopulos, H.W. Becker, J.W. Hammer, A. Lagoyannis, C. Rolfs and F. Strieder, Phys. Rev. C **72**, 062801(R) (2005)

[7] K.K. Sekharan, A.S. Divatia, M.K. Mehta, S.S. Kerekatte, and K.B. Nambiar, Phys. Rev. **156**, 1187 (1967)

[8] J.K. Bair and F.X. Hass, Phys. Rev. C **7**, 1356 (1973)

Study of O-14 through resonant alpha scattering*

T. Ahn[1],† J. Allen[1], Y. Ayyad[2], D. W. Bardayan[1], D. Bazin[2], S. Beceiro Novo[2], B. Becker[1], W. Boeschenstein[1], J. Bradt[2], M. Brodeur[1], L. Carpenter[2], M. Cortesi[1], J. deBoer[1], Y. K. Gupta[1], A. Gyurjinyan[1], M. Hall[1], O. Hall[1], J. Hu[1], S. L. Henderson[1], L. Jensen[1], J. Kelly[1], J. Koci[1], J. J. Kolata[1], E. Lamere[1], A. Long[1], J. Long[1], W. Mittig[2], C. Nicoloff[1], P. O'Malley[1], C. Seymour[1], B. Schultz[1], R. Soussi Tanani[2], S. Strauss[1], B. Van de Kolk[1], A. Wightman[1], and M. Wolff[3]
[1]*Department of Physics, University of Notre Dame, Notre Dame, IN, 46637, U.S.A.*
[2]*National Superconducting Cyclotron Laboratory, Michigan State University, 640 South Shaw Lane, East Lansing, MI 48824, U.S.A. and*
[3]*Department of Physics, Wooster College, 308 E. University Street, Wooster, OH 44691, U.S.A.*

Resonant alpha scattering has been important for the study of alpha-clusterization, but search for clusters in light unstable nuclei has been limited by the availability of radioactive beams. Novel molecular cluster effects are predicted to exist in nuclei that are just a few nucleons away from stability. We have used resonant alpha scattering to search for cluster structure in unstable O-14 using a radioactive C-10 beam developed at the University of Notre Dame. The radioactive C-10 beam was used in conjunction with the Prototype Active-Target Time-Projection Chamber (PAT-TPC) to measure differential scattering cross sections with high precision. Preliminary analysis of our experiment and insight we can gain from R-matrix analysis will be presented.

* Supported by the National Science Foundation.
† e-mail: `tan.ahn@nd.edu`