EXFOR, the nuclear physics perspective

B. Pritychenko

National Nuclear Data Center, Brookhaven National Laboratory, Upton, NY 11973-5000, USA

BROOKHAVEN NATIONAL LABORATORY

a passion for discovery

U.S. DEPARTMENT OF ENERGY | Office of Science

Introduction

- Who is using EXFOR ???
- Neutron resonance & ENDF evaluators? Yes!
- Nuclear physicists? May be, EXFOR is mostly neutron-, light particle-induced reactions. Present research involves heavier projectiles, FRIB will have primary U beam with subsequent secondary beams after fragmentation on Be target.
- Where EXFOR current content is appealing to scientists? Nuclear astrophysics.
- Now, we should discuss the present status and opportunities in EXFOR.

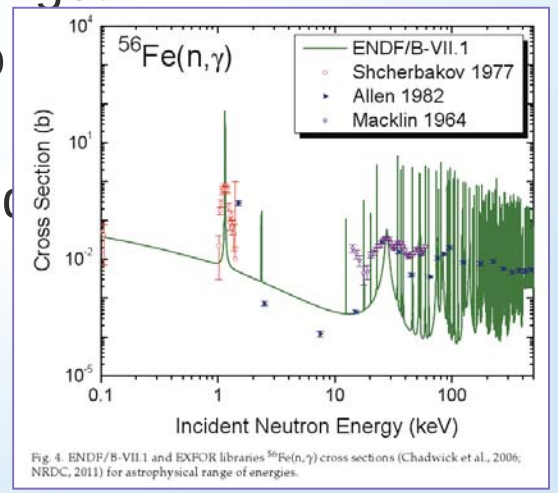


Fig. 4. ENDF/B-VII.1 and EXFOR libraries ^{56}Fe(n,γ) cross sections (Chadwick et al., 2006; NRDC, 2011) for astrophysical range of energies.

Changing Landscape

- We know that EXFOR started as neutron-induced reactions library and now days it is more charged-particle reaction database.
- Why neutron measurements are less frequent than in the past? Well, most stable target measurements are already done and there is no easy way to prepare a neutron target for inverse kinematics measurements.
- At the same time nuclear radioactive beams w and other targets measurements are booming
- Nuclear reaction measurements are still very a they evolved from stable targets and neutron/p projectiles to more advanced nuclear radioacti surrogate measurements.
- Embrace the new methods, do not try to fight it!!!

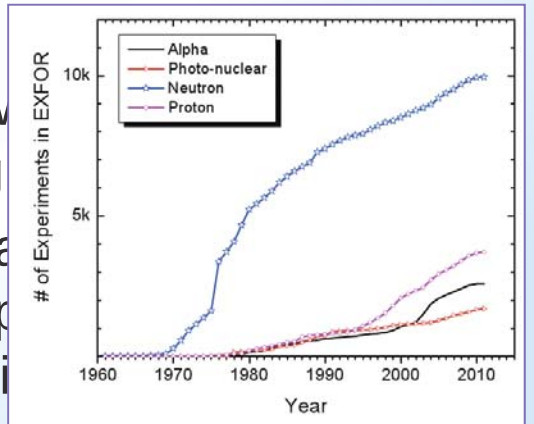


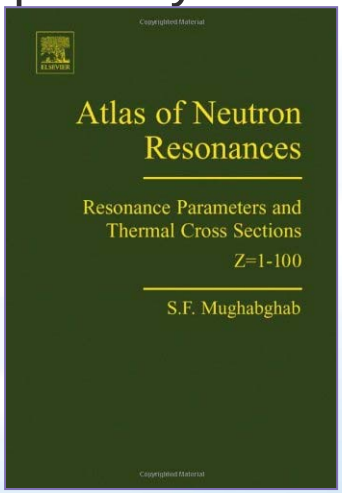
Fig. 9. Time and content evolution of the EXFOR database. Initially database scope was limited to neutron-induced reaction cross sections, later scope expansion included charge particle and photo-nuclear reactions.

Missing Data

- There is an opinion out there that EXFOR nearly complete for neutron and light charged particles, however, lets us listen to EXFOR super users:
  - F. Kaeppeler could not believe it and recommended me to look at CINDA to verify such statement. I lost the argument!
  - S. Mughabghab often conducts his own searches with NSR (CINDA is nice but out of data) and Google; he uses EXFOR to find the data, but still reads every article.
- Naohiko indicates that ~30% of charged particles are missing.
- NNDC users are often frustrated by lack of covariance data and double differential data in EXFOR vs. publications.
- Is it normal when compiler can make decision which data to compile and which to skip? I know that database scope was changing and not everything was compiled in the past.

Missing Data Strategies

- Volume of missing data is high, therefore, it has to be tackled in small parts to address research interests one by one, from nuclear energy to nuclear astrophysics.
- Broaden EXFOR scope and pick all relevant data.
- We already compiled KaDONiS, Atlas of Neutron Resonances data to ensure complete neutron reactions coverage.
- Why not to check Atlas of Neutron Resonances references against EXFOR; it was partially done for KaDONiS.



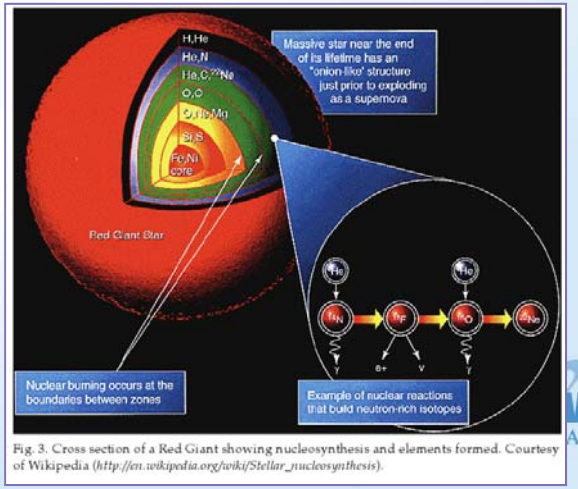


Fig. 3. Cross section of a Red Giant showing nucleosynthesis and elements formed. Courtesy of Wikipedia (*http://en.wikipedia.org/wiki/Stellar_nucleosynthesis*).

UNOBTainble Data

- Web Interface often finds entries, however, no data to plot.
- UNOBT Status helps with reporting statistics but brings a very little value to EXFOR.
- We should address these entries by digitizing plots!
- Data were mined with EXFOR Web Interface using Reaction-Accession #:

Area #	Total	UNOBT	UNOBT/Total, %
1	7,342	455	6.2
2	6,789	307	4.5
3	2,973	231	7.8
4	3,020	64	2.1
1-4	20,124	1,057	5.3

EXFOR Compilations

- Story behind the numbers: Important matrix that is used for performance estimates of EXFOR compiler.
- Present performance estimate includes only new entries, no real motivation to fix problems. Sometimes, required fixes are huge but it not affecting your performance!!! We need an appropriate category for significant (not cosmetic) fixes.
- Ultimate responsibility should rest on geography (place of measurement), I know that in the past things were compiled out of usual order. However, it creates more problems than solutions.
- Database ownership is not just compiling entries. It is responsibility for its future and handling user relations.

EXFOR Quality Assurance

- Present system is working reasonably well, it catches many format-related problems, however, we do not test the data.
- C0884 could pass (NDS IAEA, NRDC, SG 30), but it did not pass the users, they caught it. It was coded as (d,X) reaction!!!
- We need users contribution for quality assurance to work.
- EXFOR rookie comment: Observing discussions/arguments between Naohiko and Otto. How difficult EXFOR should be, if two most qualified people are still discussing the compilation?? Sometimes, I think that this is the most difficult database at NNDC, just look at the dictionaries.
- Finally, famous Quantity vs. Quality plot from U.S. business education: Quantity x Quality = const

User Relations

- EXFOR future is all about addressing the user needs: CSEWG, KaDONIS (Germany-Hungary), JINA, NIF (USA).
- Personal contacts Mughabghab, Kaeppler, Mashink, ….
- Engage higher education, like Prof. Y. Danon at RPI.
- Examples of user requests:

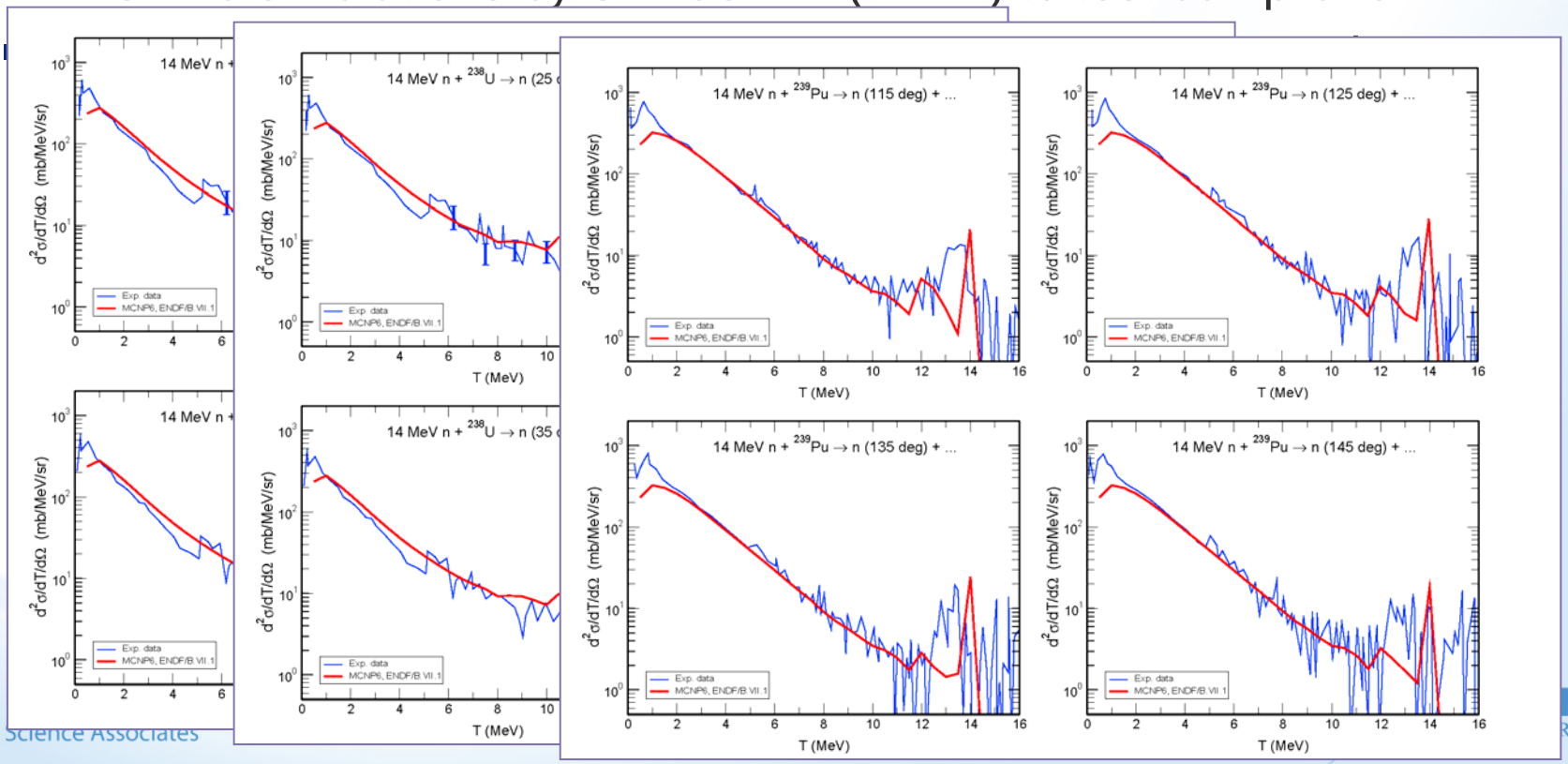
✓ NNDC is supporting XML format, M. Herman.

✓ Compilation of RAW DATA are questioned by many physicists and evaluators, the same for TOF data. May be these data should not be shown in simple EXFOR retrieval?

✓ Can we start compiling fragmentation reactions to bring FRIB, RIKEN, GSI, GANIL, ISOLDE, … + cosmic rays?

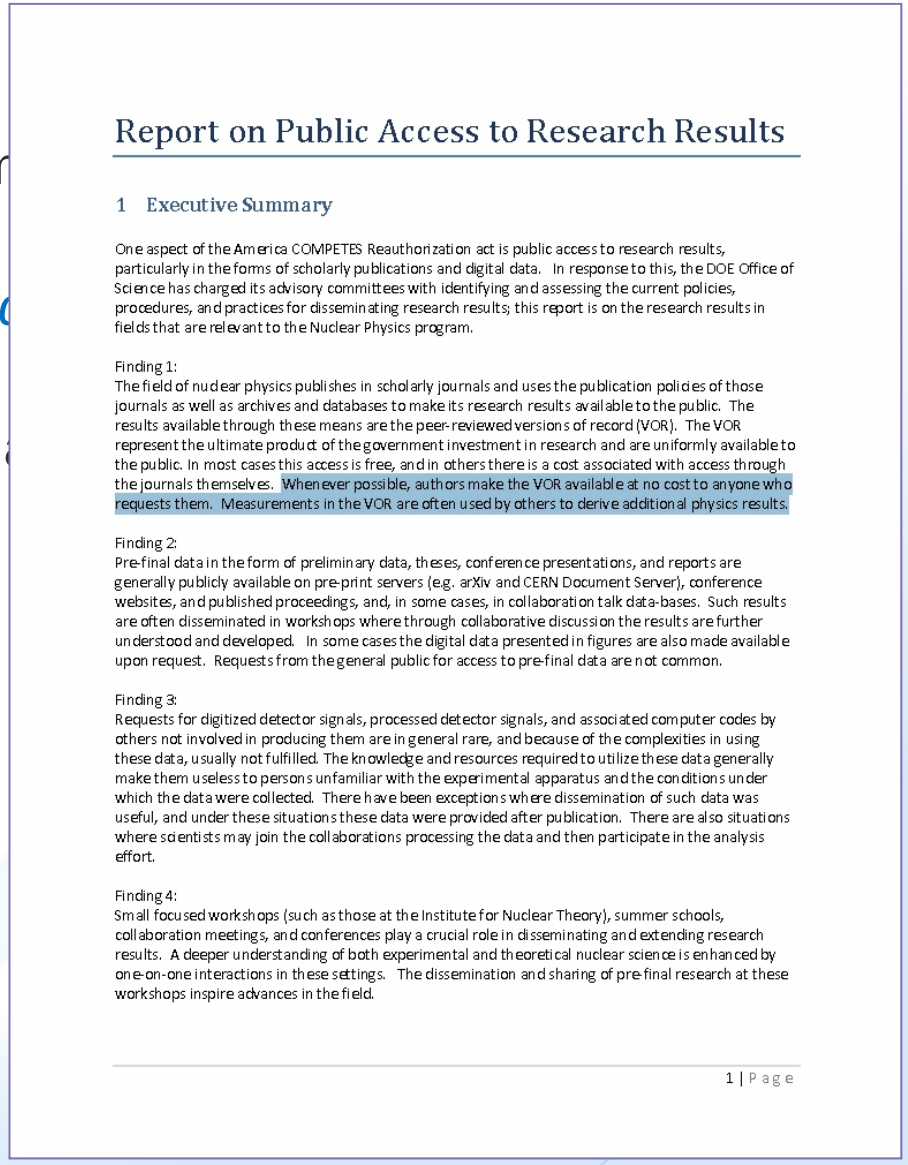
Cooperation with Nuclear Science

- Unpublished thesis by J.L. Kammerdiener (1972).
- 2013 EXFOR compilation #14329, 160+ plots.
- MCNP6 simulations by S. Mashnik (LANL) to test compilation.



Public Access to Research Results

- Problems with getting data from
- NSAC Sub-Committee Report: *http://science.energy.gov/~/mec RR_report_final.pdf*
- EXFOR compilers may inquire a home countries.



Report on Public Access to Research Results

1 Executive Summary

One aspect of the America COMPETES Reauthorization act is public access to research results, particularly in the forms of scholarly publications and digital data. In response to this, the DOE Office of Science has charged its advisory committees with identifying and assessing the current policies, procedures, and practices for disseminating research results; this report is on the research results in fields that are relevant to the Nuclear Physics program.

Finding 1:
The field of nuclear physics publishes in scholarly journals and uses the publication policies of those journals as well as archives and databases to make its research results available to the public. The results available through these means are the peer-reviewed versions of record (VOR). The VOR represent the ultimate product of the government investment in research and are uniformly available to the public. In most cases this access is free, and in others there is a cost associated with access through the journals themselves. Whenever possible, authors make the VOR available at no cost to anyone who requests them. Measurements in the VOR are often used by others to derive additional physics results.

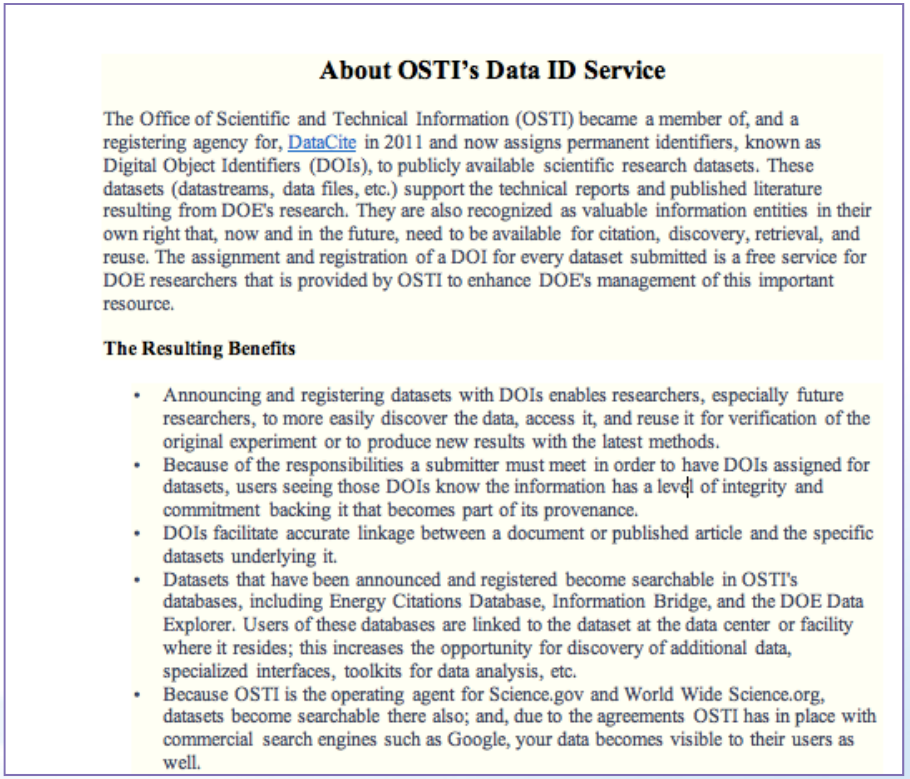
Finding 2:
Pre-final data in the form of preliminary data, theses, conference presentations, and reports are generally publicly available on pre-print servers (e.g. arXiv and CERN Document Server), conference websites, and published proceedings, and, in some cases, in collaboration talk data-bases. Such results are often disseminated in workshops where through collaborative discussion the results are further understood and developed. In some cases the digital data presented in figures are also made available upon request. Requests from the general public for access to pre-final data are not common.

Finding 3:
Requests for digitized detector signals, processed detector signals, and associated computer codes by others not involved in producing them are in general rare, and because of the complexities in using these data, usually not fulfilled. The knowledge and resources required to utilize these data generally make them useless to persons unfamiliar with the experimental apparatus and the conditions under which the data were collected. There have been exceptions where dissemination of such data was useful, and under these situations these data were provided after publication. There are also situations where scientists may join the collaborations processing the data and then participate in the analysis effort.

Finding 4:
Small focused workshops (such as those at the Institute for Nuclear Theory), summer schools, collaboration meetings, and conferences play a crucial role in disseminating and extending research results. A deeper understanding of both experimental and theoretical nuclear science is enhanced by one-on-one interactions in these settings. The dissemination and sharing of pre-final research at these workshops inspire advances in the field.

Future Cooperation with OSTI

- NNDC is starting cooperation with OSTI on database entry, data sets DOI assignments.
- OSTI has a formula for DOI assignment.



About OSTI's Data ID Service

The Office of Scientific and Technical Information (OSTI) became a member of, and a registering agency for, DataCite in 2011 and now assigns permanent identifiers, known as Digital Object Identifiers (DOIs), to publicly available scientific research datasets. These datasets (datastreams, data files, etc.) support the technical reports and published literature resulting from DOE's research. They are also recognized as valuable information entities in their own right that, now and in the future, need to be available for citation, discovery, retrieval, and reuse. The assignment and registration of a DOI for every dataset submitted is a free service for DOE researchers that is provided by OSTI to enhance DOE's management of this important resource.

The Resulting Benefits

- Announcing and registering datasets with DOIs enables researchers, especially future researchers, to more easily discover the data, access it, and reuse it for verification of the original experiment or to produce new results with the latest methods.
- Because of the responsibilities a submitter must meet in order to have DOIs assigned for datasets, users seeing those DOIs know the information has a level of integrity and commitment backing it that becomes part of its provenance.
- DOIs facilitate accurate linkage between a document or published article and the specific datasets underlying it.
- Datasets that have been announced and registered become searchable in OSTI's databases, including Energy Citations Database, Information Bridge, and the DOE Data Explorer. Users of these databases are linked to the dataset at the data center or facility where it resides; this increases the opportunity for discovery of additional data, specialized interfaces, toolkits for data analysis, etc.
- Because OSTI is the operating agent for Science.gov and World Wide Science.org, datasets become searchable there also; and, due to the agreements OSTI has in place with commercial search engines such as Google, your data becomes visible to their users as well.

Conclusions & Outlook

- EXFOR has bright future at E<1 GeV and it should evolve over time:
- ✓ Broad base: Much larger than NRDC group of users who understand EXFOR well, similar to ENSDF.
- ✓ We have to address current research and application needs, perhaps look in to nuclear fragmentation reactions, pay more attention to nuclear radioactive beams, surrogate reactions.
- ✓ Missing data problem will be addressed to satisfy super users and nuclear physicists.
- ✓ We need new metrics that will encourage compilation of incomplete entries.
- ✓ We have to start looking for new ideas, approaches and formats.