

Compilation of Fission Yields

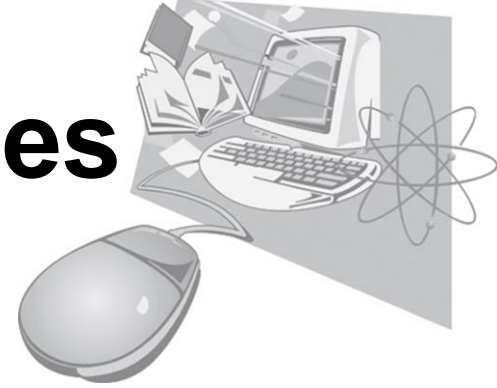
Boris Pritychenko

National Nuclear Data Center, BNL, Upton, NY 11973

BROOKHAVEN
NATIONAL LABORATORY

 U.S. DEPARTMENT OF
ENERGY

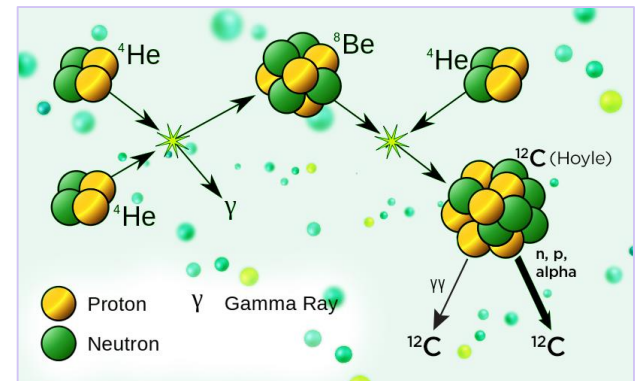
Compilation Databases



- There are three major compilation databases at NNDC: NSR, EXFOR and XUNDL.
- We will concentrate on NSR and EXFOR databases:
 - Nuclear Science References (NSR): all low- and intermediate-energy references for a broad use, not just nuclear structure and decay as before 90s.
 - Experimental Nuclear Reaction Data (EXFOR): all low- and intermediate-energy reaction data sets for neutron-, charged- and photo-induced reactions, not just neutron-induced as before 80s.
- The primary goal of both database efforts is a compilation of new data.
- The compilation scope and quality controls for NSR and EXFOR databases have evolved over the many years of operation. These facts plus lack of advanced computer tools in the past are responsible for missing references and data sets.

Value of Compilations

- Compilations create a basis for nuclear data evaluations and support research.
- Compilations are driven by
 - New results and discoveries in science
 - New rules and element names
 - Need for up-to-date databases
- NSR compilation of Notre Dame/MSU work on “Enhancement of the Triple Alpha Rate in a Hot Dense Medium”.



ND/MSU, PRL 119, 112701 (2017)

2017BE18 Phys.Rev.Lett. 119, 1127501 (2017)

M.Beard, S.M.Austin, R.Cyburt

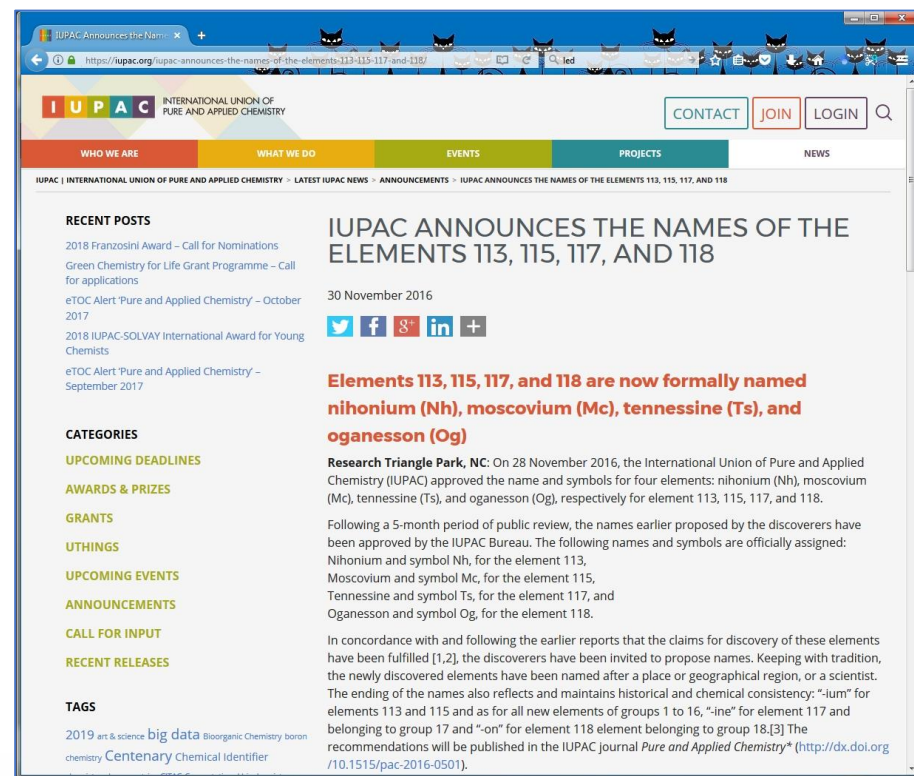
Enhancement of the Triple Alpha Rate in a Hot Dense Medium

NUCLEAR REACTIONS ${}^4\text{He}(\alpha, X){}^8\text{Be}$, ${}^8\text{Be}(\alpha, X){}^{12}\text{C}$, $E < 30$ MeV; calculated 3α σ , reaction rates; deduced that in hot and dense astrophysical environment the rate of the triple-alpha reaction can increase greatly over the value appropriate for helium burning stars owing to hadronically induced deexcitation of the Hoyle state.

doi: 10.1103/PhysRevLett.119.112701

Speed of Compilations

- Compilations should be performed in a timely fashion.
- International Union of Pure and Applied Chemistry (IUPAC) assigned names to Z=113, 115, 117 and 118 as Nh, Mc, Ts and Og, respectively, on November 30, 2016.
- As of January 5, 2017 these changes were implemented in NSR.
- 594 entries/keywords were identified and modified to reflect the latest naming convention.
- N. Otuka wrote an EXFOR memo.

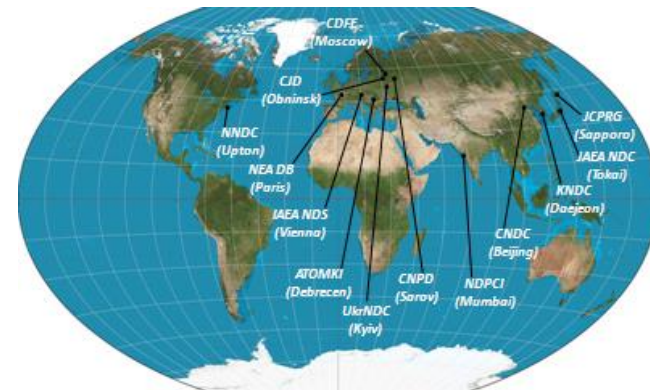


The screenshot shows the IUPAC website with the following content:

- Header:** IUPAC INTERNATIONAL UNION OF PURE AND APPLIED CHEMISTRY. Navigation links: CONTACT, JOIN, LOGIN.
- Menu:** WHO WE ARE, WHAT WE DO, EVENTS, PROJECTS, NEWS.
- Recent Posts:** 2018 Franzosini Award - Call for Nominations, Green Chemistry for Life Grant Programme - Call for applications, eTOC Alert: 'Pure and Applied Chemistry' - October 2017, 2018 IUPAC-SOLVAY International Award for Young Chemists, eTOC Alert: 'Pure and Applied Chemistry' - September 2017.
- Categories:** UPCOMING DEADLINES, AWARDS & PRIZES, GRANTS, UTHINGS, UPCOMING EVENTS, ANNOUNCEMENTS, CALL FOR INPUT, RECENT RELEASES, TAGS.
- Main Article:** IUPAC ANNOUNCES THE NAMES OF THE ELEMENTS 113, 115, 117, AND 118. Date: 30 November 2016. Social media icons for Twitter, Facebook, Google+, LinkedIn, and a plus sign.
- Text:** **Elements 113, 115, 117, and 118 are now formally named nihonium (Nh), moscovium (Mc), tennessine (Ts), and oganesson (Og)**. Research Triangle Park, NC: On 28 November 2016, the International Union of Pure and Applied Chemistry (IUPAC) approved the name and symbols for four elements: nihonium (Nh), moscovium (Mc), tennessine (Ts), and oganesson (Og), respectively for element 113, 115, 117, and 118. Following a 5-month period of public review, the names earlier proposed by the discoverers have been approved by the IUPAC Bureau. The following names and symbols are officially assigned: Nihonium and symbol Nh, for the element 113, Moscovium and symbol Mc, for the element 115, Tennessine and symbol Ts, for the element 117, and Oganesson and symbol Og, for the element 118. In concordance with and following the earlier reports that the claims for discovery of these elements have been fulfilled [1,2], the discoverers have been invited to propose names. Keeping with tradition, the newly discovered elements have been named after a place or geographical region, or a scientist. The ending of the names also reflects and maintains historical and chemical consistency: "-ium" for elements 113 and 115 and as for all new elements of groups 1 to 16, "-ine" for element 117 and belonging to group 17 and "-on" for element 118 element belonging to group 18.[3] The recommendations will be published in the IUPAC journal *Pure and Applied Chemistry** (<http://dx.doi.org/10.1515/pac-2016-0501>).

EXFOR Compilations Worldwide

- The EXFOR library was established in 1967 at a meeting of the four major nuclear data centers: Brookhaven National Laboratory, Upton, NY (Area # 1, USA, Canada); Nuclear Energy Agency (NEA) Databank, Paris, France (Area # 2, Western Europe and Japan); International Atomic Energy Agency, Vienna, Austria (Area # 3, Asia, Eastern Europe, Latin America, Africa, Australia and Oceania); and Institute of Physics and Power Engineering (IPPE), Obninsk, USSR (Area #4, Soviet Union => Russian Federation).
- The effort to translate all of the existing experimental nuclear reaction data sets, which were coded in the Sigma Center Information Storage Retrieval System (SCISRS) system format -1964, would be done later.



Missing Data

- EXFOR criticism by F. Kaepfeler (2006-2007) for nuclear astrophysics publications, and I started my work in EXFOR from KADoNiS references.
- Due to many historical and technical reasons not all nuclear physics papers and data sets were compiled, or data were not obtained by compilers for compiled entries.
- We address these issues at NNDC by adding missing references in NSR while in EXFOR we work on data recovery (e.g. nuclear archeology).
- Data recovery includes optical character recognition and data points digitization (Area #1: 11153, 14329). Both technologies work well with high quality images and become challenging otherwise.
- Finally, we work with scientists/evaluators on obtaining the missing publications and data sets, if available (i.e. ORNL n, tot and n, γ data).

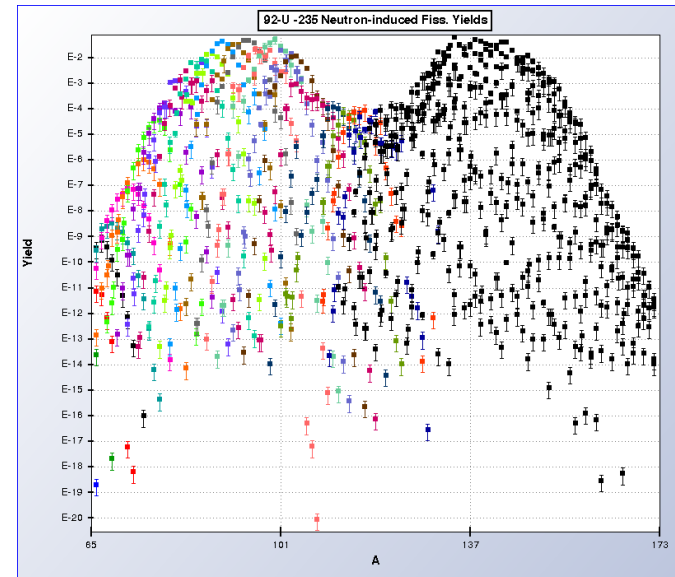
11153,exf: LA -3765 (1967),
Library Without Walls
ANL project

LAB ANGLE	SECS	SIGMA BELOW S.D.	SIGMA ABOVE S.D.	SUM	S.D.
40 DEG	0.4*PEV	10.2	3.4	49.8	1.9
50 DEG	0.4*PEV	11.8	3.4	48.2	2.0
72+100G	0.4*PEV	12.6	4.1	39.4	3.0
90 DEG	0.4*PEV	9.4	3.1	29.6	2.8
110 HPG	0.4*PEV	3.0	1.1	16.7	0.9
130 HPG	0.4*PEV	2.3	1.0	12.4	0.7

#14329, Thesis of
J.L. Kammerdiener (1972)

FY Compilation Completeness

- Fission Yields (FY) are fundamental for many applications.
- FY evaluation for U or Pu may contain up to 800 fission product nuclides: ENDF/B-VII.1 $^{235}\text{U}(n,\text{F})$ FY evaluation.
- Do we have a complete FY record in EXFOR?
- The EXFOR database contains 22,294 experiments (database entries). So, computer tools are needed to investigate it.
- The completeness of EXFOR was verified using the NSR database at NNDC (B. Pritychenko, O. Schwerer) + help of V. Zerkin (IAEA).



FY Compilations in EXFOR

- Two styles of data representation.
- Experimental data on neutron Fission Yields (FY) on U-235 for Xe-133.
- Products are encoded in EXFOR as Xe-133 or ELEM/MASS.
- Product & Enhanced search of products (Very useful but not trivial for many ``EXFOR experts’’).
- Negative energies for ratios were discovered in Web Interface.

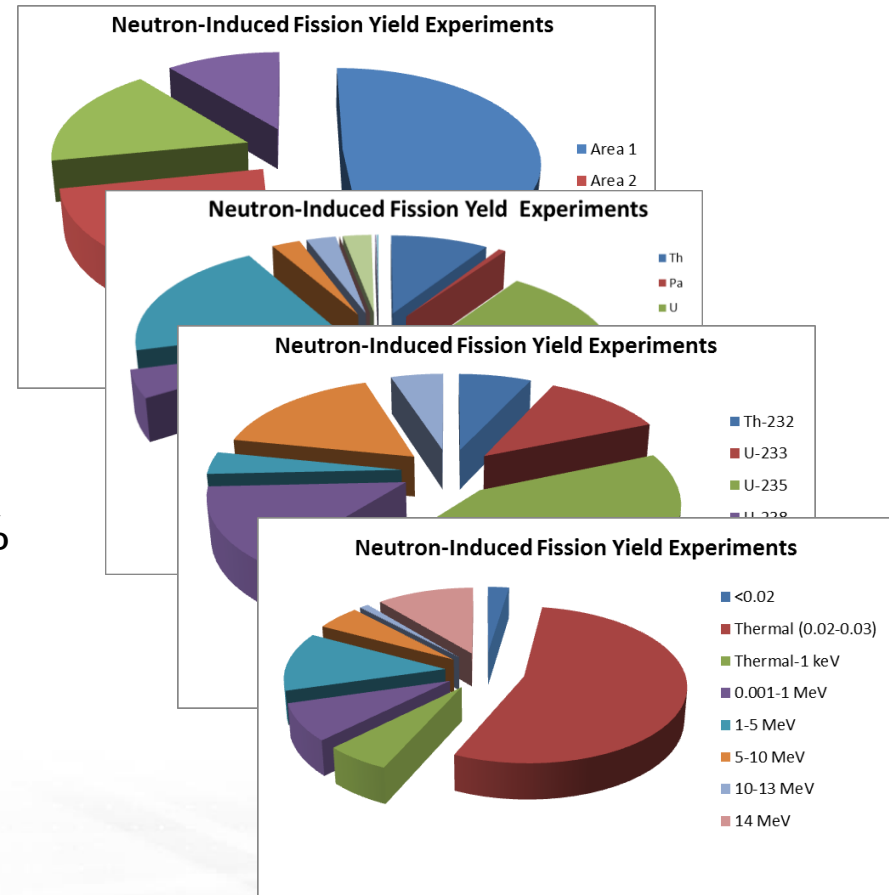
The screenshot displays the EXFOR database interface with the following components:

- Header:** "Experimental Nuclear Reaction Data (EXFOR) Database Version of 2018-01-16".
- Search Bar:** "Request #57491".
- Data Selection:** Includes options for "Retrieve", "Output" (X4+, EXFOR, Bibliography, TAB, C4, PlotC4), and "Plot".
- Table:** A table with columns: "Display", "Year", "Author-1", "Energy range, eV", "Points", "Reference", and "Subentry# RSB-key". The table lists 12 entries for the reaction $^{235}\text{U}(n, f)^{133}\text{Xe}$.
- Notes:** A sidebar on the left contains search criteria and database information.

Display	Year	Author-1	Energy range, eV	Points	Reference	Subentry# RSB-key
1	1953	B.Hatcock	2.53e-2	1	[pdf] + J.R. 93, 1488, 5309	13371003 (1953028)
2	1950	J.Macnamara	2.53e-2	1	[pdf] + J.R. 75, 129, 5004	13360002 (19500615)
3	1981	S.S.Bauer	2.53e-2	6	[pdf] + J.R./C, 24, 525, 186108	30666002 (19818204 Pub-Pub, 198106)
4	1981	S.S.Bauer	2.53e-2	4	[pdf] + J.R./C, 24, 525, 186108	30666002 (19818204 Pub-Pub, 198106)
5	1953	B.Hatcock	2.53e-2	1	+ R.S. 1662, 53	13426004 (1)
6	1984	G.P.Foods	1.40e7	2	[pdf] + J.R. 93, 159, 1984	12899006 (19847009 Pub-Pub, 198106)
7	1972	P.Alexander	1.40e7	2	[pdf] + J.R./A, 189, 229, 72	12879002 (19722839 Pub-Pub, 198106)
8	1972	P.Alexander	1.40e7	2	[pdf] + J.R./A, 189, 229, 72	22038002 (19722839 Pub-Pub, 198106)
9	1984	G.P.Foods	1.95e6	6	[pdf] + J.R./C, 30, 195, 1984	12899006 (19847009 Pub-Pub, 198106)
10	1953	B.Hatcock	2.53e-2	2	[pdf] + J.R. 93, 1488, 5309	13371002 (1953028 Pub-Pub, 198106)
11	1984	G.P.Foods	2.53e-2	6	[pdf] + J.R. 93, 159, 1984	12899003 (19847009 Pub-Pub, 198106)
12	1971	R.W.Sarbova	6	6	[pdf] + J.R. 93, 1546, 71	12829002 (19718289 Pub-Pub, 198106)

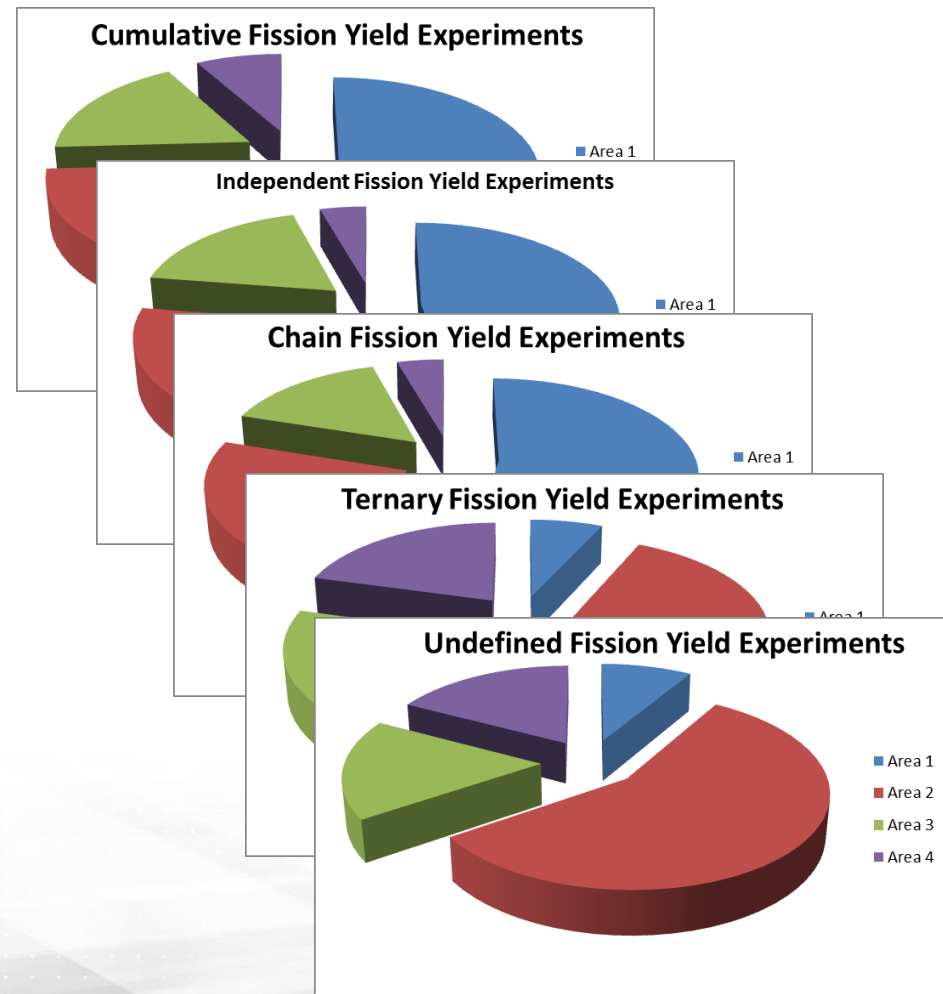
EXFOR Neutron FY Statistics

- FY by Numbers:
 - Articles: 817
 - Reactions: 1611
 - Data Sets: 2992
- FY by Area, Area #1: 48.8%
- FY by Element, U: 56.4%
- FY by Isotope, U-235: 41.9%
- FY by Energy, Thermal Neutrons: 54.4%
- All numbers in the current presentation represent the database state in April 2018.



More on EXFOR Neutron FY

- Cumulative FY
 - Articles: 502
 - Reactions: 585
 - Data Sets: 1197
- Independent FY
 - Articles: 226
 - Reactions: 436
 - Data Sets: 638
- Chains FY
 - Articles: 223
 - Reactions: 184
 - Data Sets: 427
- Ternary FY
 - Articles: 29
 - Reactions: 128
 - Data Sets: 154
- Undefined FY (discussed later)
 - Articles: 58
 - Reactions: 87
 - Data Sets: 110



Spontaneous FY (SFY)

- General SFY statistics
 - Articles: 189
 - Reactions: 345
 - Data Sets: 612
- SFY by Area, Area #1: 42.8%
- U(SF), Pu(SF), ^{252}Cf (SF)
- SFY by Element, dominated by ^{252}Cf (SF)

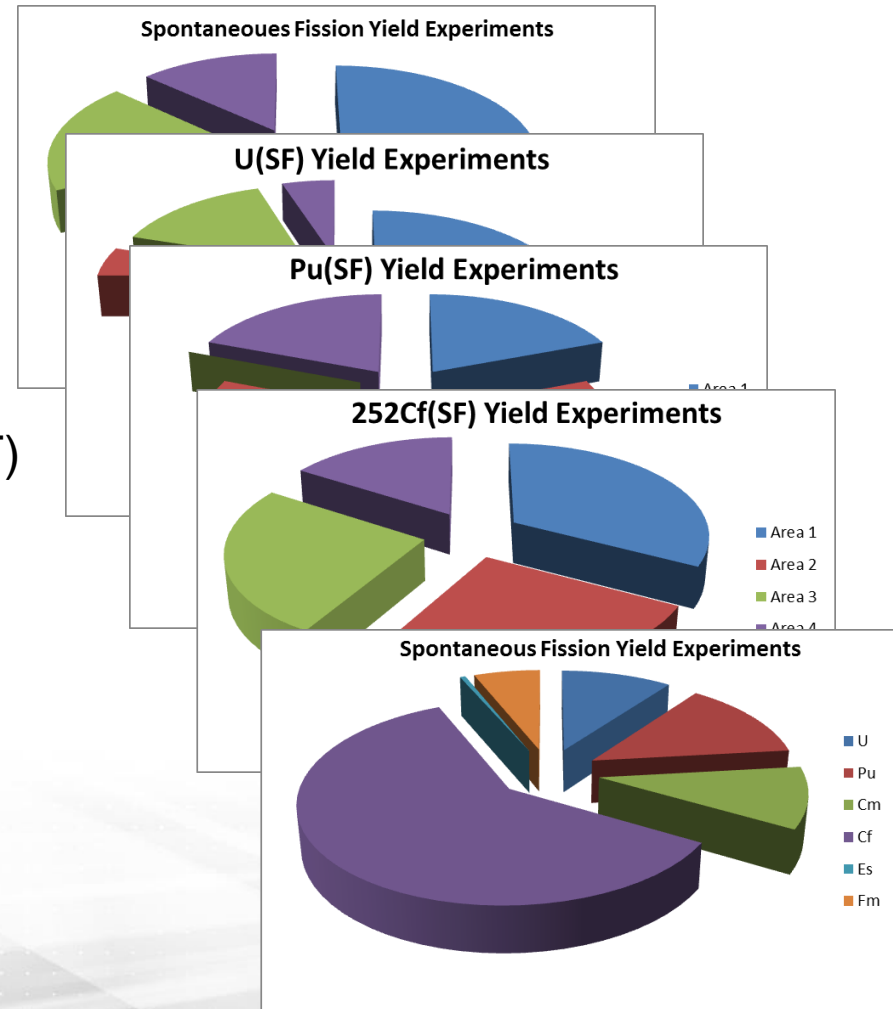
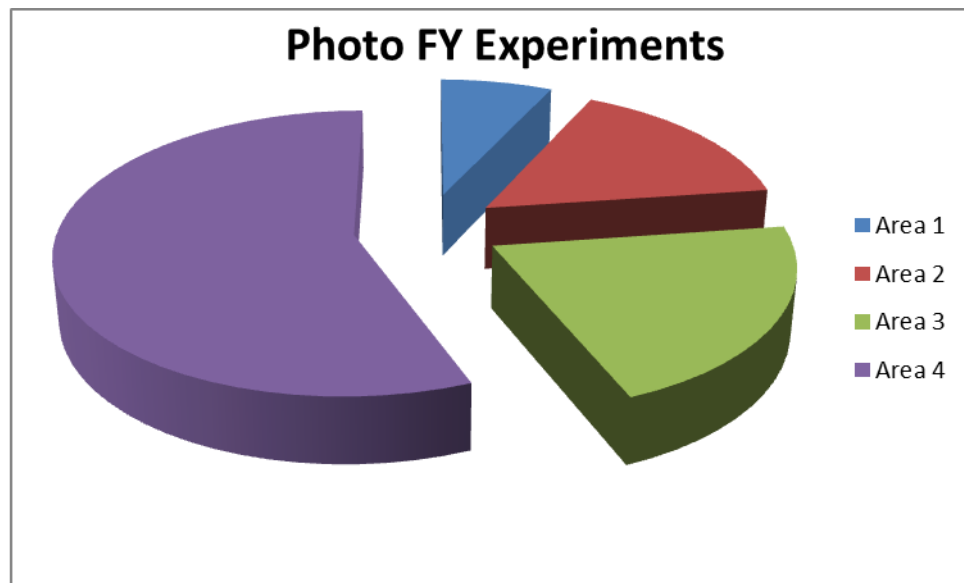


Photo FY

- General Photo FY statistics
 - Articles: 57
 - Reactions: 117
 - Data Sets: 189
- FY by Area, Area #1: 7.0 %
 - Clearly data are missing in the Area #1
- FY by Element, U: 49.1 %
- FY by Isotope: U-235: 12.3 %
- FY by Energy: Thermal: 0 % (Just a quality check)



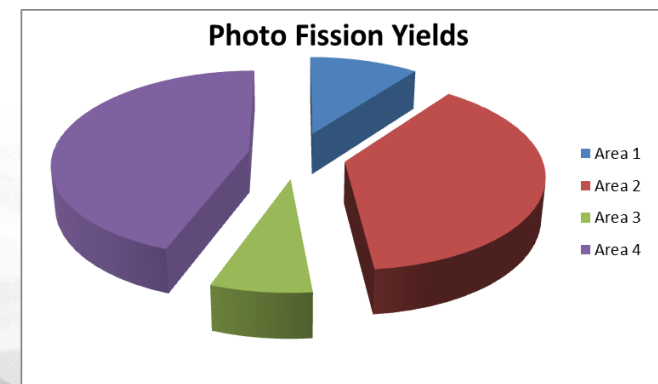
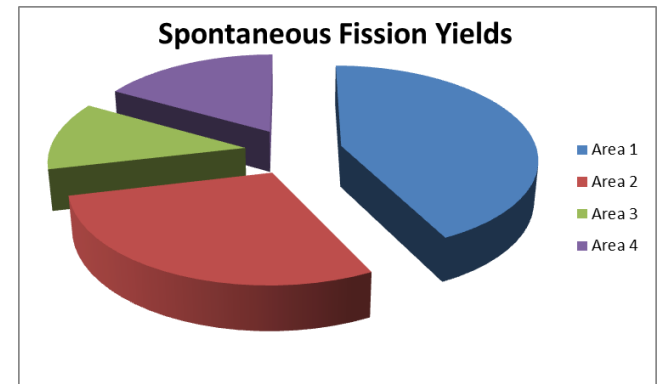
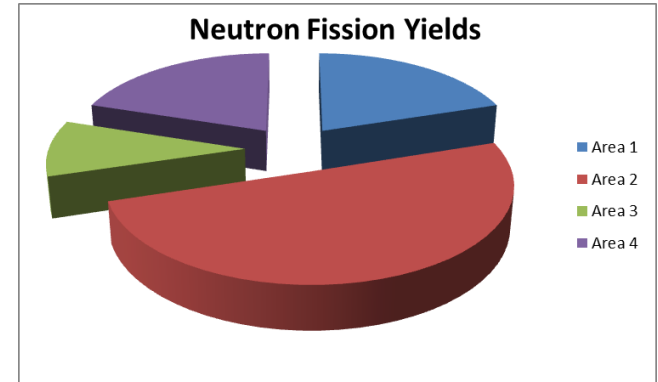
NSR FY Data

- Complementary check of FY using NSR database that contains 229,594 references (As of October 19, 2018).
- Simple NSR retrieval for $^{233}\text{U}(n,F)$ measured fission yields (exp. data only):
 - Total references: 102
 - Potentially missing in EXFOR: 40
- 40 cases should be reanalyzed and added to EXFOR if necessary.
- Data includes also other isotopes of U and Pu, $^{252}\text{Cf}(SF)$.

The top screenshot shows the NNDC website interface for Nuclear Science References (NSR). It includes a search bar, navigation tabs (Quick Search, Text Search, Indexed Search, Keynumber Search, Combine View, Recent References), and initialization parameters for a search. The search parameters are set to Target: 233U, Incident: N, and Measured: YIELDS. The search results page shows 102 matches and a list of references, including a reference from Eur. Phys. J. A 24, 379 (2005) and another from Proc. Intern. Conf. Nuclear Data for Science and Technology, Santa Fe, New Mexico, 26 September-1 October, 2004.

Work on FY References

- Finally, nuclear structure-like search for FY NSR references was conducted at NNDC:
 - Potentially Missing Neutron FY: 384
 - Potentially Missing Spontaneous FY: 142
 - Potentially Missing Photo FY: 126
 - Non-uniform findings in the areas: #3 small (IAEA), #2 large (NEA)
 - Ghent University results were ignored in the Area #2????
 - Yu.P. Gangrsky (Dubna) published a large number of preprints often on the same subject (rather background). Background noise in the Area #4.



NSR FY References

- New, updated, excluded (already existing) and difficult to find references for NF, SF and GF EXFOR entries.
- NSR impact
 - Project produced many modifications of NSR entries.
 - PDF collection assembly is in progress (540+), many thanks to J. Totans for rare reports.
- EXFOR impact
 - Area #1 papers will be compiled at NNDC, other references will be passed to the NRDC.

NF/Area	#1	#2	#3	#4	Sum
New	28	103	19	47	197
Updates	39	68	14	20	141
Excluded	2	16	1	7	26
Not Found	9	4	3	3	19
Total	78	191	37	77	383

SF/Area	#1	#2	#3	#4	Sum
New	33	27	9	18	87
Updates	15	9	5	6	35
Excluded	1	3	0	0	4
Not Found	11	2	3	0	16

	Experimen ts	Data Sets	Missing References	
GF/				
New	817	2992	384	69
Upd				40
Exc				2
Not	57	189	126	15
Total				26
	Spontaneou s (SFY)	189	612	142

Data Verification by O. Schwerer

- Data for Photo, Spontaneous and Neutron-Induced fission were verified by O. Schwerer
 - Spontaneous FY verification is in progress.
 - Overall numbers went down.
 - Many missing entries still remain.
 - Explanation: In the past, it was a policy not to list all FY references. These entries should be updated.
- Otto has managed EXFOR at the agency for many years; his analysis an explanation why experiments were missed are crucial for the project.

ID	Author	Publication	Year	Lab	Status	Comments
1	N.R. Keybanker	First Author				
2	20120951	R.D. Penney	1971	2017 USAMHG	NewEntry	
3	20140413	C. B. Pata	1971	2014 USATNL	add ref.	
4	20130450	L.A. Metz	1971	2013 USASNU	NewEntry	
5	20121907	J. Finn	2012	2012 USABNW	add ref.	
6	20111040	V. Davon	2011	2011 USAPPI	add ref.	
7	20110404	R.C. Wright	2011	2011 USASAS	add ref.	
8	20100401	M.B. Cheshick	2010	2010 USASAS	Not used	
9	20100113	R.D. Salby	2010	2010 USASAS	NewEntry	
10	20090402	W.L. Myers	2009	2009 USASAS	NewEntry	
11	20060407	R. Arvinksi	2006	2006 USASAS	NewEntry	
12	20020102	T. Ohnishi	2002	2002 USASAS	NewEntry	
13	1999ANZX	M. Anshu	1999	1999 USATAM	NewEntry	
14	19970404	W. Charlton	1997	1997 USATAM	NewEntry	
15	19920202	P. Zoller	1992	1992 USASAS	NewEntry	
17	19860211	S. Curtis	1986	1986 USASAS	Added 17.A.	
18	19860215	R.D. Lott	1986	1986 USASAS	Added 17.A.	
19	19860216	R.D. Lott	1986	1986 USASAS	Added 17.A.	
20	19860207	S. Curtis	1986	1986 USASAS	Added 17.A.	
21	19860206	P. Zoller	1986	1986 USABNW	add ref.	
22	19860217	O. Schwerer	1986	1986 USASAS	add ref.	
23	19860202	L. Robinson	1986	1986 USASAS	add ref.	
24	19860104	A. Probst	1986	1986 USASAS	add ref.	
25	19860202	T.M. Sambow	1986	1986 USASAS	add ref.	
26	19860206	W.A. Scherer	1986	1986 USASAS	add ref.	
27	19860202	S. Curtis	1986	1986 USASAS	NewEntry	
28	19860202	S.K. Pal	1986	1986 USASAS	add ref.	
29	19860202	S.K. Pal	1986	1986 USASAS	NewEntry	

Pilot FY Compilation Project

- Pilot project was launched at NNDC to estimate a time scale.
- Search for missing references at NNDC
 - Search for missing references (B. Pritychenko): ~160 h
 - Search for missing references (E. Betak): ~20 h
 - Verification (O. Schwerer): ~120 h
 - NNDC library work (J. Totans): ~120 h
 - Totals for searches and verification: 420 h
- Pilot Compilation Project
 - Compilation of 15 experiments (B. Pritychenko): ~120 h
 - Verification of 15 experiments (O. Schwerer): ~60 h
 - Corrections of 18 old entries (B. Pritychenko): ~60 h
 - Verification of 18 old entries (O. Schwerer): ~30 h
 - Totals for 15 new and 18 updated entries are 180 and 90 h, respectively.
- Please do not project the pilot project time scale to the whole effort!!! Rather consider the fact that NNDC already has invested 690 hours of work to FY compilations.

Pilot Project Findings

- NSR and EXFOR databases FY contents were improved because of the pilot project.
- EXFOR compilation rules often contradict with a spirit of physics.
- Spallation vs. Fission
 - Both process produce lighter nuclei but distributions are different.
 - Physicists like G. Seaborg simply measure spallation or fission product cross sections or yields but it is not sufficient for EXFOR.
 - SF5=SPL only when **spallation was explicitly measured**, measuring spallation products is not sufficient in EXFOR.
 - Both spallation and fission timescales are small (direct/compound) to be detected in experiments, so reactions are separated using the product distributions. Therefore, **it is difficult to understand the meaning of explicitly measured spallation**. EXFOR rules are confusing.
- Fission yield cross section compilation rules
 - SF5=IND is **redundant** for beta shielded products, so SF5 is **undefined** or blank.
 - N/A for fission yields according to Otto but we saw undefined FY previously, more work is necessary here.
- These rules create problems for computer programs and Web interface retrievals, and I discussed these issues with O. Schwerer extensively.

NSR/CINDA Work of V. Zerkin

- The similar task has been solved by Viktor Zerkin using NSR/CINDA.
- CINDA search for all missing references in NSR: n-1202; p-5998; d-2831; ^3He -2170; a-3061; g-794: **16056 missing**.
- NSR is really powerful, and NRDC users should explore NSR for missing references. **Personally, I believe that could have as many proton reaction papers as neutron papers.**
- Both approaches are complementary:
 - NSR/CINDA search is automatized.
 - Direct NSR search is more productive but requires more time, manual labor and specialized knowledge.
- For users with ENSDF background direct NSR search is preferable.
- Finally, CINDA/NSR computer search results validate the current work: **227 neutron fission references.**

Computer Index of Nuclear Reaction Data (CINDA)
Database Version of 2018-09-04

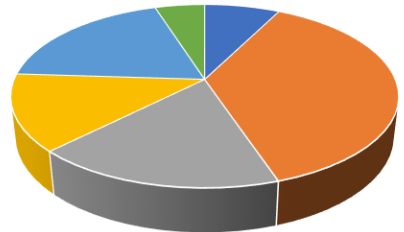
Standard Request Example: 124444-544

Request #4580
CINDA Data Search Results: Reference: 31 Lines: 63

Reference	Author	Lab	Enr	per	NBR	per	DOI
1. 2014-12-20	A. Chiriac	ORNL	10.1016/j.nucphys.2014.12.001				10.1016/j.nucphys.2014.12.001
2. 2014-12-20	A. Chiriac	ORNL	10.1016/j.nucphys.2014.12.002				10.1016/j.nucphys.2014.12.002
3. 2014-12-20	A. Chiriac	ORNL	10.1016/j.nucphys.2014.12.003				10.1016/j.nucphys.2014.12.003
4. 2014-12-20	A. Chiriac	ORNL	10.1016/j.nucphys.2014.12.004				10.1016/j.nucphys.2014.12.004
5. 2014-12-20	A. Chiriac	ORNL	10.1016/j.nucphys.2014.12.005				10.1016/j.nucphys.2014.12.005
6. 2014-12-20	A. Chiriac	ORNL	10.1016/j.nucphys.2014.12.006				10.1016/j.nucphys.2014.12.006
7. 2014-12-20	A. Chiriac	ORNL	10.1016/j.nucphys.2014.12.007				10.1016/j.nucphys.2014.12.007
8. 2014-12-20	A. Chiriac	ORNL	10.1016/j.nucphys.2014.12.008				10.1016/j.nucphys.2014.12.008
9. 2014-12-20	A. Chiriac	ORNL	10.1016/j.nucphys.2014.12.009				10.1016/j.nucphys.2014.12.009
10. 2014-12-20	A. Chiriac	ORNL	10.1016/j.nucphys.2014.12.010				10.1016/j.nucphys.2014.12.010
11. 2014-12-20	A. Chiriac	ORNL	10.1016/j.nucphys.2014.12.011				10.1016/j.nucphys.2014.12.011
12. 2014-12-20	A. Chiriac	ORNL	10.1016/j.nucphys.2014.12.012				10.1016/j.nucphys.2014.12.012
13. 2014-12-20	A. Chiriac	ORNL	10.1016/j.nucphys.2014.12.013				10.1016/j.nucphys.2014.12.013
14. 2014-12-20	A. Chiriac	ORNL	10.1016/j.nucphys.2014.12.014				10.1016/j.nucphys.2014.12.014
15. 2014-12-20	A. Chiriac	ORNL	10.1016/j.nucphys.2014.12.015				10.1016/j.nucphys.2014.12.015

Legend: Neutron (blue), Proton (orange), Deuteron (grey), ^3He (yellow), Alpha (dark blue), Photon (green)

Missing in EXFOR Nuclear Reaction References



■ Neutron ■ Proton ■ Deuteron ■ ^3He ■ Alpha ■ Photon

Conclusions

- Fission Yields is a big project that requires plenty of time, effort, specialized knowledge and a collaborative effort is necessary.
- NSR & EXFOR projects represent an excellent starting point for fission yields compilation and evaluation effort.
- We identified potential EXFOR database deficiencies using NSR database contents.
- These findings are verified by O. Schwerer and will be summarized in three NRDC memos.
- Pilot project has been conducted for further estimate and realistic analysis of the manpower FY effort. NNDC has invested 690 h into it.
- EXFOR compilation rules have to be revisited in order to avoid possible confusions and aligned with physics.
- Finally, no more missing data in present compilations, we need complete databases.

The IAEA Mission Statement

The International Atomic Energy Agency:

- is an independent intergovernmental, science and technology-based organization, in the United Nations family, that serves as the global focal point for nuclear cooperation;
- assists its Member States, in the context of social and economic goals, in planning for and using nuclear science and technology for various peaceful purposes, including the generation of electricity, and facilitates the transfer of such technology and knowledge in a sustainable manner to developing Member States;
- develops nuclear safety standards and, based on these standards, promotes the achievement and maintenance of high levels of safety in applications of nuclear energy, as well as the protection of human health and the environment against ionizing radiation;
- verifies through its inspection system that States comply with their commitments, under the Non-Proliferation Treaty and other non-proliferation agreements, to use nuclear material and facilities only for peaceful purposes.

NNDC Mission Statement

- The National Nuclear Data Center (NNDC) collects, evaluates, archives and disseminates nuclear physics data for basic nuclear research and for applied nuclear technologies.
 - The Center collects experimental information on nuclear structure and nuclear reactions, evaluates them employing nuclear physics theory and expertise in evaluating experimental techniques to provide recommended results, maintains nuclear databases and using modern information technology disseminates the results.
 - The data are kept in dedicated libraries, which are periodically updated.
 - The information is the product of the NNDC-coordinated US Nuclear Data Program that involves several National Laboratories and Universities, as well as, cooperating data centers and other interested groups worldwide.
 - There are two other major data banks operated by international organizations, one in Paris and another in Vienna.

Definitions of Fission Yields

- Independent fission yield (%): number of atoms of a specific nuclide produced directly (not via radioactive decay of precursors) in 100 fission reactions
- * Cumulative fission yield (%): total number of atoms of a specific nuclide produced (directly and via decay of precursors) in 100 fission reactions
- * Chain yield (Mass [number] yield) (%): It was used for the (sum of) cumulative yield(s) of the last (stable or long-lived) chain member(s) as well as for the isobaric sum of independent yields, and also for some yield types in between, e.g. the sum of cumulative yield of a product towards the end of an isobaric chain and the independent yield of its daughter. A complication arises due to β -delayed neutron emission: cumulative and — in consequence — chain yields are suffering increases by neutron emission from heavier mass chains and losses to lighter mass chains. In consequence, cumulative yields and chain yields are no more identical to the sum of the independent yields of their precursors. Two new clear definitions of this type of yields:
 - The (total) chain yield is defined as the (sum of) cumulative yield(s) of the last (stable or long-lived) chain member(s).
 - The mass (number) yields are defined as the sum of all independent yields of a particular mass chain and are this way distinguished from chain yields.
- Fractional independent/cumulative yields represent the independent or cumulative fission yield divided by the chain yield (or mass number yield) (%).
- Partial yields: Some methods of measurement provide yields for a specific condition (like a specific kinetic energy or a specific ionic charge state of the fission fragments). Such yields are called partial yields.
- Ternary yields.

Open Access Developments

- **Public access**

- America COMPETES Reauthorization Act of 2010 addresses public access to research results, particularly in the forms of scholarly publications and digital data
- Charge from DOE Office of Science: “Identify and assess current practices, policies and procedures to research results with report by 1-jul-2011.”

- **Report of the NSAC Sub-Committee on Public Access to Research Results**

- The nuclear physics community often submits research results to freely accessible databases such as the National Nuclear Data Center (NNDC, <http://www.nndc.bnl.gov/>)
...
- Programs like the U.S. Nuclear Data Program also provide an important service through critical independent evaluation efforts.

- **APS News** (<http://www.aps.org/publications/apsnews/201310/access.cfm>)

- Open Access Mandate will Include Raw Data.