

# Update of the compilation effort at BNL

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NATIONAL LABORATORY



BROOKHAVEN SCIENCE ASSOCIATES

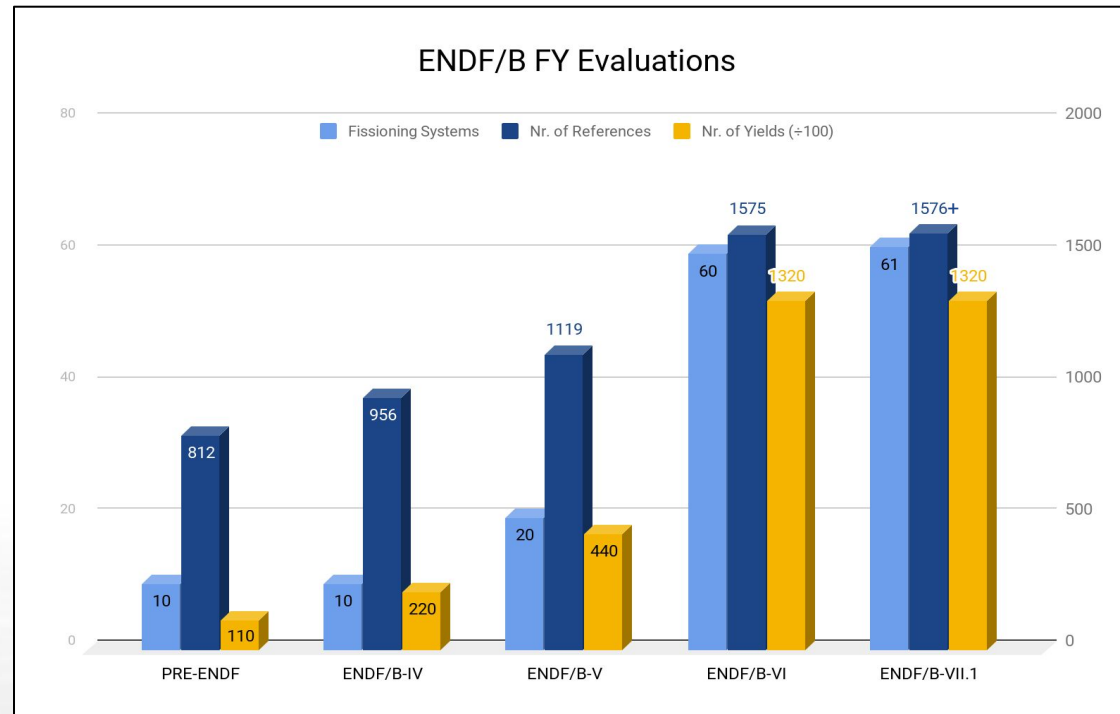
# Outline

- Status of the current evaluations
- A new evaluation for  $^{238}\text{U}$ : motivation
- Ongoing work at NNDC:
  - NSR + EXFOR compilation
  - EXFOR to JSON (G. Fabricante & V. Zerkin)
  - Status of experimental data compilation
- Summary and Timeline

# Status of current evaluations of FPYs

## ENDF/B-VIII inherited FPYs from ENDF/B-VII.1

- Revision and update of FYs for  $^{239}\text{Pu}+n$  (new evaluation at 2 MeV)
- Other FYs largely based on the Eng&Rid evaluation of 1993 (that extended the 1983 evaluation from 34 to 60 fission reactions).



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## JEFF3.3 updated FYs in the new release (UKFY3.7)

- includes new measurements (up to 2016)
- GEF used to predict mass+charge distros of FYs (superseding 5-gaussian fit & Wahl's  $Z_p$  model)

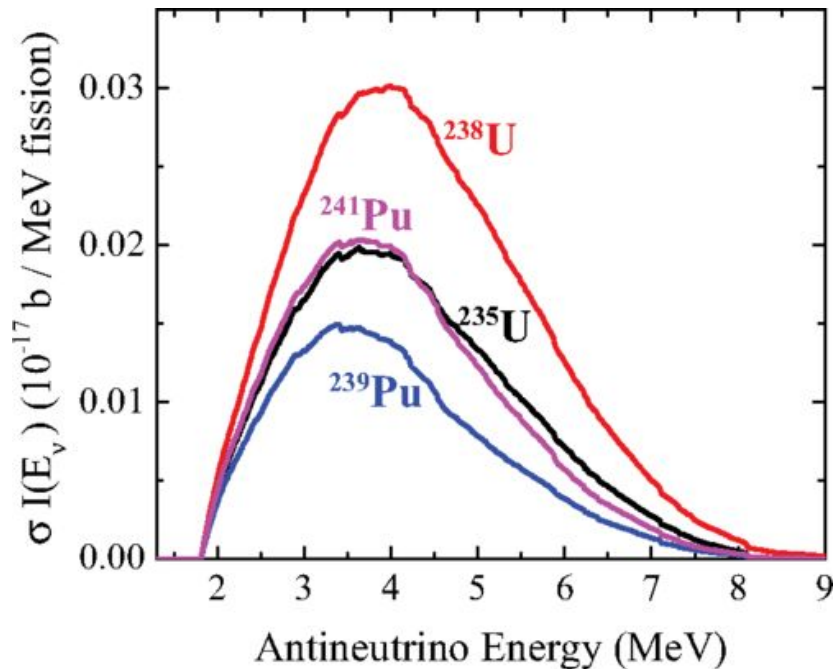
# Motivation for new $^{238}\text{U}$ Recomm. Exp. Yields

General update/improvement of FY from a system that does not have an overwhelming amount of data

1. New experiments since the last revision (in 1990s)
2. Update of old experimental values with new nuclear data
3. New information on IYRs

# Motivation for new $^{238}\text{U}$ Recomm. Exp. Yields

- summation calculations for reactor  $\bar{\nu}$  spectra



A. A. Sonzogni, T. D. Johnson, and E. A. McCutchan  
*Phys. Rev. C* 91, 011301

DECAY DATA



FISSION YIELDS

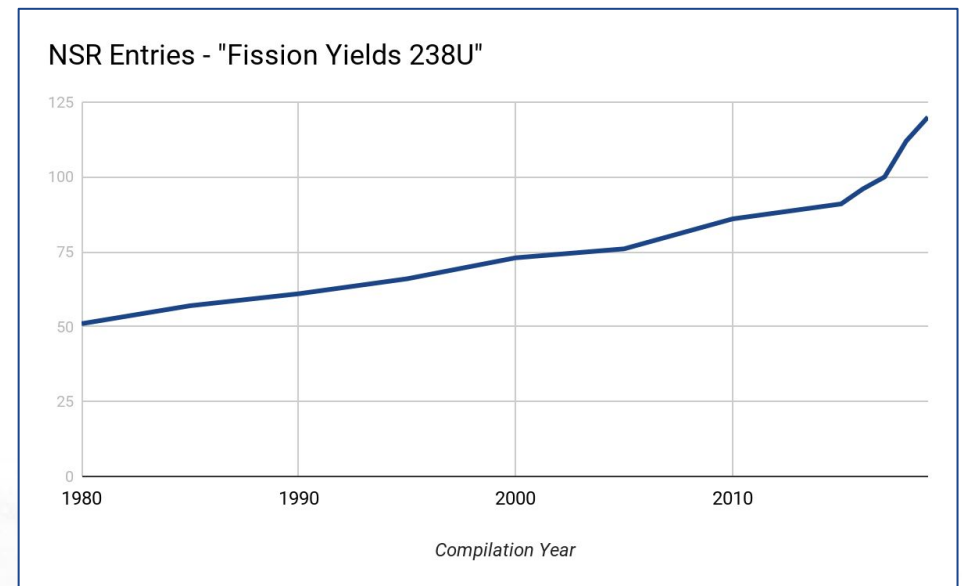
Can a new close look at CFY from  $^{238}\text{U}$  give some insight on the reactor antineutrino anomaly?

Talks by G. Fabricante & A. Sonzogni  
**Friday morning**

# Ongoing effort at NNDC: NSR & EXFOR


- Continued work to include new and *not-so-new* experimental datasets in EXFOR
- References of England & Rider's work
- Mills' evaluation work + references


Boris Pritychenko, J. Totans,  
Olena Gritzay



# A *working format* for experimental FY data

- Adapting the format of experimental files to the needs of FY compilation (simpler, lighter, more intuitive)
- Make it easier to access, plot, verify and update experimental values currently stored in the EXFOR format
- Modernizing the format to make it more human-friendly

 **Experimental Nuclear Reaction Data (EXFOR)**  
Database Version of 2019-10-24

The EXFOR library contains an extensive compilation of experimental nuclear reaction data. Neutron reactions have been compiled systematically since the discovery of the neutron, while charged particle and photon reactions have been covered less extensively. The EXFOR library contains data from 22888 experiments (see [statistics](#) and recent database [updates](#)).  
EXFOR Web Database & Tools Paper: NIM A 888 (2018) 31. Mirror-sites 

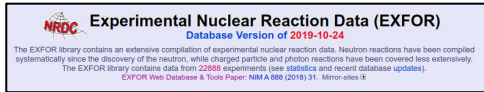


**{ JSON }**  
JavaScript Object Notation

G. Fabricante, V. Zerkin



# A working format for experimental FY data



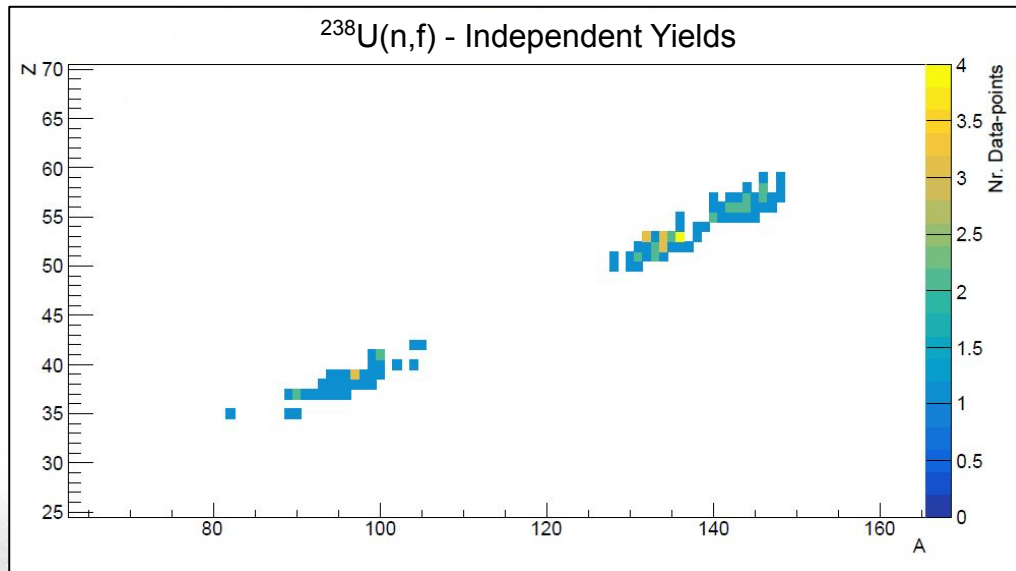
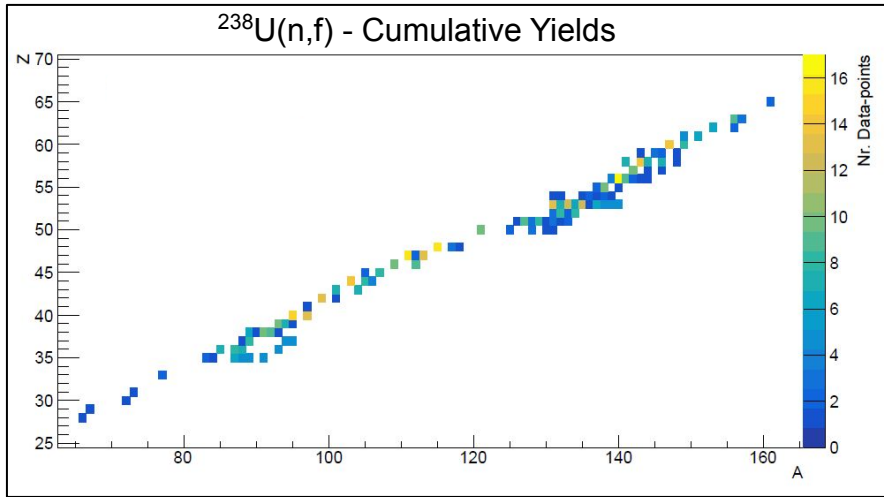
ENTRY	13251	20190204	20190708	20190630	1448
SUBENT	13251001	20190204	20190708	20190630	1448
BIB	12	30			
TITLE	Low-yield products from fission of Th232, U235, and U238 with 14.8-MeV neutrons				
AUTHOR	(D. R. Methaway, B. Mendoza, T. E. Voss)				
REFERENCE	(J. PR, 182, 1251, 1969)				
INSTITUTE	#doi:10.1103/PhysRev.182.1251				
FACILITY	(IUSALRL)				
INC-SOURCE	(NGEN,IUSALRL) ICT neutron generator.				
DETECTOR	(D-T) The neutrons are produced by the reaction of deuterons on tritium in a rotating target assembly.				
METHOD	(PROPC) Gas-flow beta proportional counters. (NAICR) NaI(Tl) gamma detectors. (CHSEP,FGAM) The irradiations were usually 8 h in length, producing up to 4x10**12 fissions in the Th232, 3x10**13 fissions in the U235, and 1.5x10**13 fissions in the U238. After the neutron irradiations, the target foils were dissolved in the presence of 10-20-mg amounts of carriers for each of the desired products. The samples were counted on gas-flow beta proportional counters or NaI(Tl) gamma counters.				
MONITOR	(39-Y-89(N,2N)39-Y-88,,SIG) Flux monitor.				
ERR-ANALYS	(DATA-ERR) Data uncertainties given include uncertainty in counting efficiencies and counting statistics, and standard deviation. Not included is 6% uncertainty in number of fissions.				
STATUS	(TABLE) Table II, page 1254.				
HISTORY	(19890717C) VM (20190204A) BP: Updated to new date formats, lower case. Corrections according last EXFOR rules and Dict. Updated entry, corrected fission yields units from PC/FIS to PRD/FIS.				
ENDBIB	30				
COMMON	2	3			
EN	EN-RSL				
MEV	MEV				
	14.8	0.3			
ENDCOMMON	3				
ENDSUBENT	37				
SUBENT	13251006	20190204	20190708	20190630	1448
BIB	6	20			
REACTION	(92-U-238(N,F)ELEM/MASS,CUM,FY)				
SAMPLE	(92-U-238,ENR=0.998) The target foils varied in thickness from 5 to 20 mils and in weight from 1 to 15 g.				
MONITOR	((MONIT)92-U-238(N,F),,SIG)				
MONIT-REF	((MONIT),W.Hart,R,AHSB(S)R-124,1967)				
DECAY-DATA	((1.)28-NI-66,2.290,B)				
	((2.)29-CU-67,2.560,B)				
	((3.)30-ZN-72,1.940,B)				
	((4.)39-Y-93-6,10.1HR,DG)				
	((5.)56-BA-140,12.800,DG,1596.,0.962)				
	((6.)60-ND-147,11.04D,DG,531.,0.131)				
	((7.)62-SM-153,1.940,B)				
	((8.)64-GD-159,0.773D,B)				
	((9.)65-TB-161,6.960,B)				
	((10.)66-DY-166,3.40D)				
	((11.)67-ER-166,6.1340D,B)				

JSON	Raw Data	Headers
Save	Copy	Collapse All Expand All
format:	"JSON.FY-0.1.3"	
now:	"2019-10-10T20:18:11.000Z"	
program:	"Converter EXFOR-TO-JSON.FY, by V.Zerkin, IAEA-NDS, 2019 (ver.2019-10-10)"	
input:	{-}	
output:	{-}	
datasets:		
0:		
type:	"data"	
id:	"13251006"	
NSR:	"1969NE07"	
subent:	{-}	
entry:	{-}	
author:	"D.R.Methaway"	
year:	1969	
ref1:		
code:	"J.PR.182.1251.1969"	
exp:	"Jour: Physical Review, Vol.182, p.1251 (1969)"	
reaction:		
code:	"92-U-238(N,F)ELEM/MASS,CUM,FY"	
Proj:	"N"	
Target:	"92-U-238"	
ReactionType:	"FY"	
DataType:	"CUM,FY"	
Quantity:	"Cumulative fission-product yield"	
IndVarFamCode:	"0 2 7"	
incEnergies:		
0:		
incEnergy:	14800	
incEnergyWidth:	150	
incEnergyUnits:	"KEV"	
DataUnits:	"PART/FIS"	
Products:		
0:		
Z:	28	
A:	66	
Nucl:	"Ni-66"	
CUM_FY:	8.5e-7	
dCUM_FY:	9e-8	
t12sec:	197856	
Radiations:		
0:	{-}	
1:		
Z:	29	

- Not meant to substitute EXFOR
- Only storing information of interest for the compiler/evaluator
- Human-friendly format with obvious variable names
- Data stored with consistent units (normalization of FYs to 2)
- Active collaboration with V. Zerkin (IAEA): developed a code to convert from EXFOR to JSON.

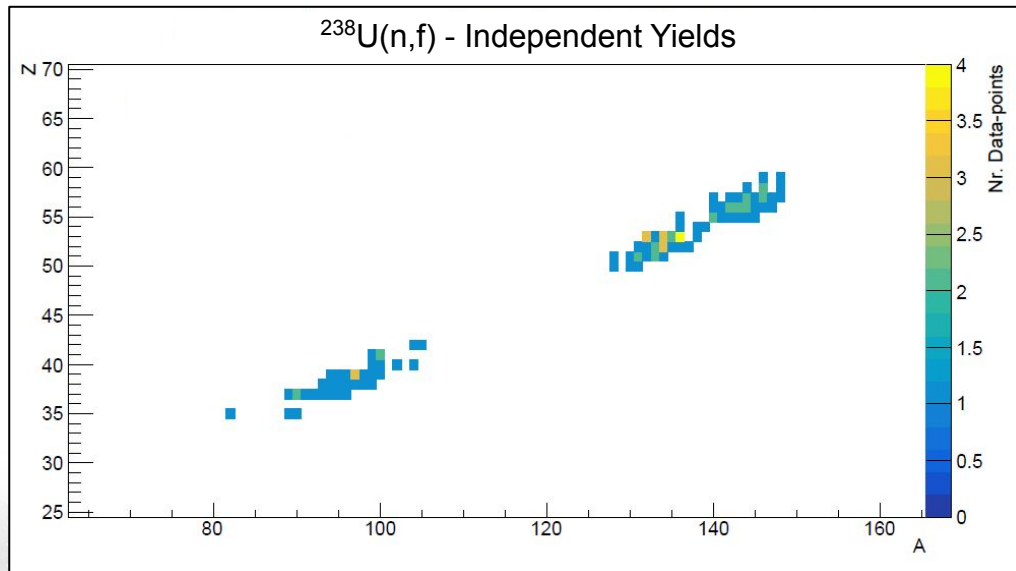
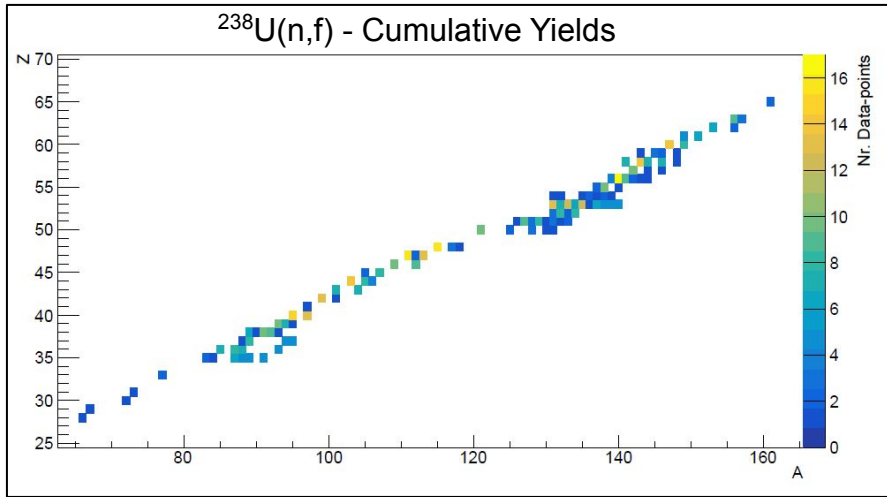
G. Fabricante, V. Zerkin

# Current status of the compilation effort



NSR - BibNr	NSR link	Exp I/O	X4 data (entrynr)		pdf I/O	Details	En / E*	Note (from I)
2019RA07	<a href="#">https://</a>	1	n/a		0 1	1-n transfer reaction (CN: 238U)	7.4MeV Eex	
2019RA23	<a href="#">https://</a>	1	n/a		0 1	1-n transfer reaction (CN: 239U)	near barrier fission	
2019FO04	<a href="#">https://</a>	1	<a href="#">https://www.n</a>	<a href="#">https://www.nndc</a>	14522 1		fast	
2017PE08	<a href="#">https://</a>	1	n/a		0 1		CoulEx	SOFIA/A
2017WI09	<a href="#">https://</a>	1	<a href="#">https://www.n</a>	<a href="#">https://www.nndc</a>	23403 1	anomaly (see 2019FO04)		
2017NA17	<a href="#">https://</a>	1	<a href="#">https://www.n</a>	<a href="#">https://www.nndc</a>	33106 1	charge distributions		
2017HI10	<a href="#">https://</a>	1	n/a		0 1	inv-kin   multinucleon transfer reaction   FFMD	E* > 10-20 MeV	
2017UL01	<a href="#">https://</a>	1	n/a		0 1	inv-kin   NO FY data		
2016GO02	<a href="#">https://</a>	1	n/a		0 1	FY mass distro   new data? Also see: LLNL	0.5-14.8 MeV	dual-fiss
2016DU22	<a href="#">https://</a>	1	<a href="#">https://www.n</a>	<a href="#">https://www.nndc</a>	14463 1	mass landscape / Fragment Y	1-30MeV	
2015NA13	<a href="#">https://</a>	1	<a href="#">https://www.n</a>	<a href="#">https://www.nndc</a>	33093 1	FP offline: Y, peak/valley ratio	E=6.35, 8.53, 12.52 MeV	
2015BH09	<a href="#">https://</a>	1	<a href="#">https://www.n</a>	<a href="#">https://www.nndc</a>	14423 1	92Sr 97Zr 99Mo 132Te 133I 140Ba 143Ce 14 8.9 MeV		TUNL
2015VO11	<a href="#">https://</a>	1	<a href="#">https://www.n</a>	<a href="#">https://www.nndc</a>	0 1	inv-kin		
2014TO09	<a href="#">https://</a>	1	<a href="#">https://www.n</a>	<a href="#">https://www.nndc</a>	14402 1	XS / Yields?	<200 MeV	
2014HA25	<a href="#">https://</a>	1	<a href="#">https://www.n</a>	<a href="#">https://www.nndc</a>	23280 1	XS / Yields?	0.2-5 MeV	
2014GO06	<a href="#">https://</a>	1	<a href="#">https://www.n</a>	<a href="#">https://www.nndc</a>	41598 1	FF yields		
2014BH11	<a href="#">https://</a>	1	n/a		0 1	FPY ratio	E=4.6, 9.0, 14.5 MeV	
2013NA18	<a href="#">https://</a>	1	<a href="#">https://www.n</a>	<a href="#">https://www.nndc</a>	33052 1	FY mass distro	E=3.72, 5.42, 7.75, 10.09 MeV	
2013KH11	<a href="#">https://</a>	1	<a href="#">https://www.n</a>	<a href="#">https://www.nndc</a>	41483 1	FFY's	E=5, 6.5 MeV	
2013GR14	<a href="#">https://</a>	1	<a href="#">https://www.n</a>	<a href="#">https://www.nndc</a>	14377 1	deduced atomic X-ray yields per fission	0.7-400MeV	
2012FI07	<a href="#">https://</a>	1	<a href="#">https://www.n</a>	<a href="#">https://www.nndc</a>	14441 1	FPs mass distro	0.00001 - 10 MeV	
2012RUZZ	<a href="#">https://</a>	1	n/a		0 1			
2011RY09	<a href="#">https://</a>	1	n/a		0 1	of 2011RY04?		
2010SE15	<a href="#">https://</a>	1	n/a		0 1	99Mo/95Zr/137Cs/140Ba/141,143Ce/147Nd	E=0.4-1.9 MeV	LANL
2010AD13	<a href="#">https://</a>	1	<a href="#">https://www.n</a>	<a href="#">https://www.nndc</a>	41529 1	inv-kin --> the X4 file doesn't contain all info?		

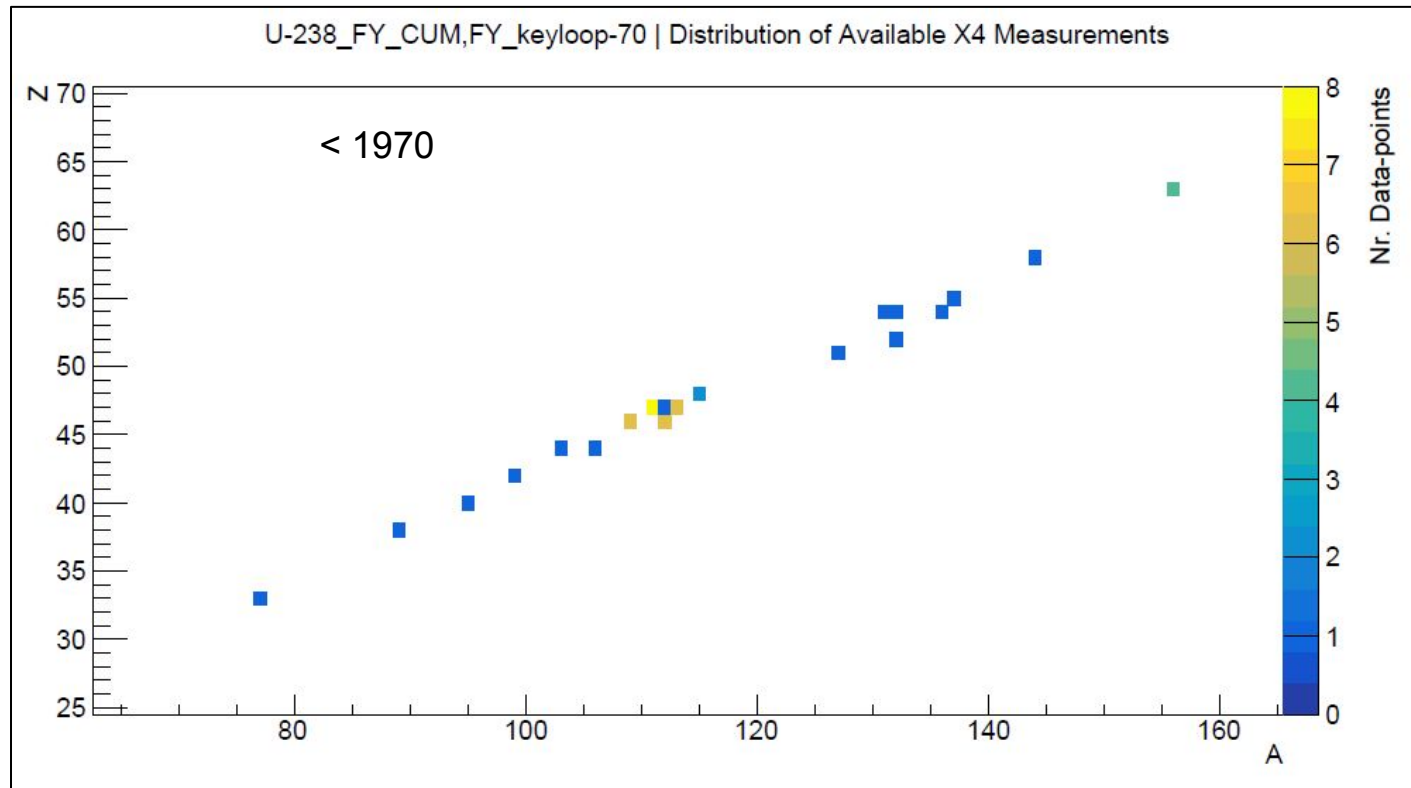
# Current status of the compilation effort



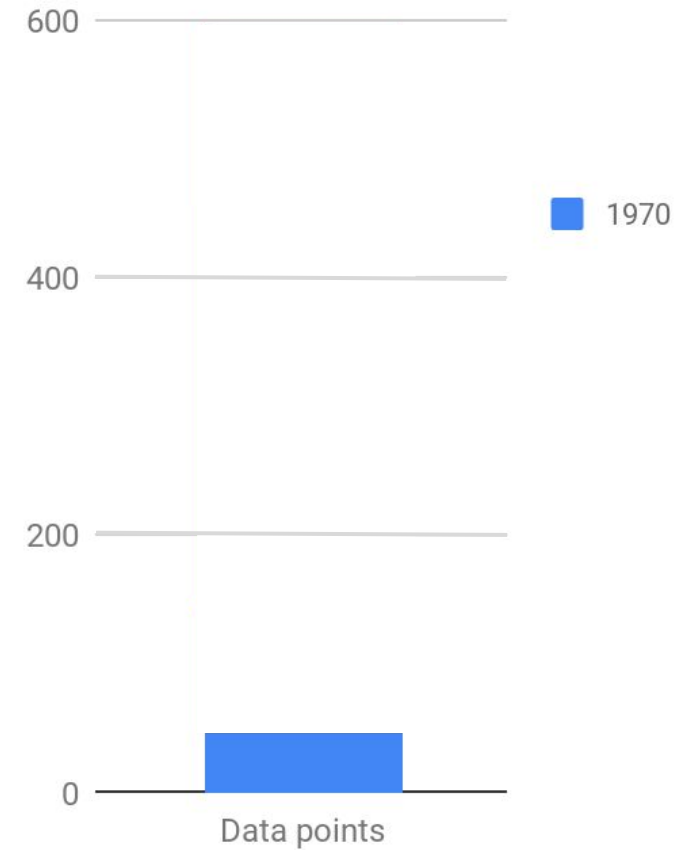
NSR - BibNr	NSR link	Exp I/O	X4 data (entrynr)		pdf I/O	Details	En / E*	Note (from I)
2019RA07	<a href="#">https://</a>	1	n/a		0	1-n transfer reaction (CN: 238U)	7.4MeV Eex	
2019RA23	<a href="#">https://</a>	1	n/a		0	1-n transfer reaction (CN: 239U)	near barrier fission	
2019FO04	<a href="#">https://</a>	1	<a href="#">https://www.nndc</a>	<a href="#">https://www.nndc</a>	14522	1	fast	
2017PE08	<a href="#">https://</a>	1	n/a		0	1	CoulEx	SOFIA/A
2017WI09	<a href="#">https://</a>	1	<a href="#">https://www.nndc</a>	<a href="#">https://www.nndc</a>	23403	1	anomaly (see 2019FO04)	
2017NA17	<a href="#">https://</a>	1	<a href="#">https://www.nndc</a>	<a href="#">https://www.nndc</a>	33106	1	charge distributions	
2017HI10	<a href="#">https://</a>	1	n/a		0	1	inv-kin   multinucleon transfer reaction   FFMD E* > 10-20 MeV	
2017UL01	<a href="#">https://</a>	1	n/a		0	1	inv-kin   NO FY data	
2016GO02	<a href="#">https://</a>	1	n/a		0	1	FY mass distro   new data? Also see: LLLNL 0.5-14.8 MeV	dual-fis
2016DU22	<a href="#">https://</a>	1	<a href="#">https://www.nndc</a>	<a href="#">https://www.nndc</a>	14463	1	mass landscape / Fragment Y	1-30MeV
2015NA13	<a href="#">https://</a>	1	<a href="#">https://www.nndc</a>	<a href="#">https://www.nndc</a>	33093	1	FP offline: Y, peak/valley ratio	E=6.35, 8.53, 12.52 MeV
2015BH09	<a href="#">https://</a>	1	<a href="#">https://www.nndc</a>	<a href="#">https://www.nndc</a>	14423	1	92Sr 97Zr 99Mo 132Te 133I 140Ba 143Ce 14 8.9 MeV	TUNL
2015VO11	<a href="#">https://</a>	1	<a href="#">https://www.nndc</a>	<a href="#">https://www.nndc</a>	0	1	inv-kin	
2014TO09	<a href="#">https://</a>	1	<a href="#">https://www.nndc</a>	<a href="#">https://www.nndc</a>	14402	1	XS / Yields?	<200 MeV
2014HA25	<a href="#">https://</a>	1	<a href="#">https://www.nndc</a>	<a href="#">https://www.nndc</a>	23280	1	XS / Yields?	0.2-5 MeV
2014GO06	<a href="#">https://</a>	1	<a href="#">https://www.nndc</a>	<a href="#">https://www.nndc</a>	41598	1	FF yields	
2014BH11	<a href="#">https://</a>	1	n/a		0	1	FPY ratio	E=4.6, 9.0, 14.5 MeV
2013NA18	<a href="#">https://</a>	1	<a href="#">https://www.nndc</a>	<a href="#">https://www.nndc</a>	33052	1	FY mass distro	E=3.72, 5.42, 7.75, 10.09 MeV
2013KH11	<a href="#">https://</a>	1	<a href="#">https://www.nndc</a>	<a href="#">https://www.nndc</a>	41483	1	FFY's	E=5, 6.5 MeV
2013GR14	<a href="#">https://</a>	1	<a href="#">https://www.nndc</a>	<a href="#">https://www.nndc</a>			on	0.7-400MeV
2012FI07	<a href="#">https://</a>	1	<a href="#">https://www.nndc</a>	<a href="#">https://www.nndc</a>				0.00001 - 10 MeV
2012RUZZ	<a href="#">https://</a>	1	n/a					
2011RY09	<a href="#">https://</a>	1	n/a					
2010SE15	<a href="#">https://</a>	1	n/a					E=0.4-1.9 MeV LANL
2010AD13	<a href="#">https://</a>	1	<a href="#">https://www.nndc</a>	<a href="#">https://www.nndc</a>				all info?

Share with us your favourite FY values

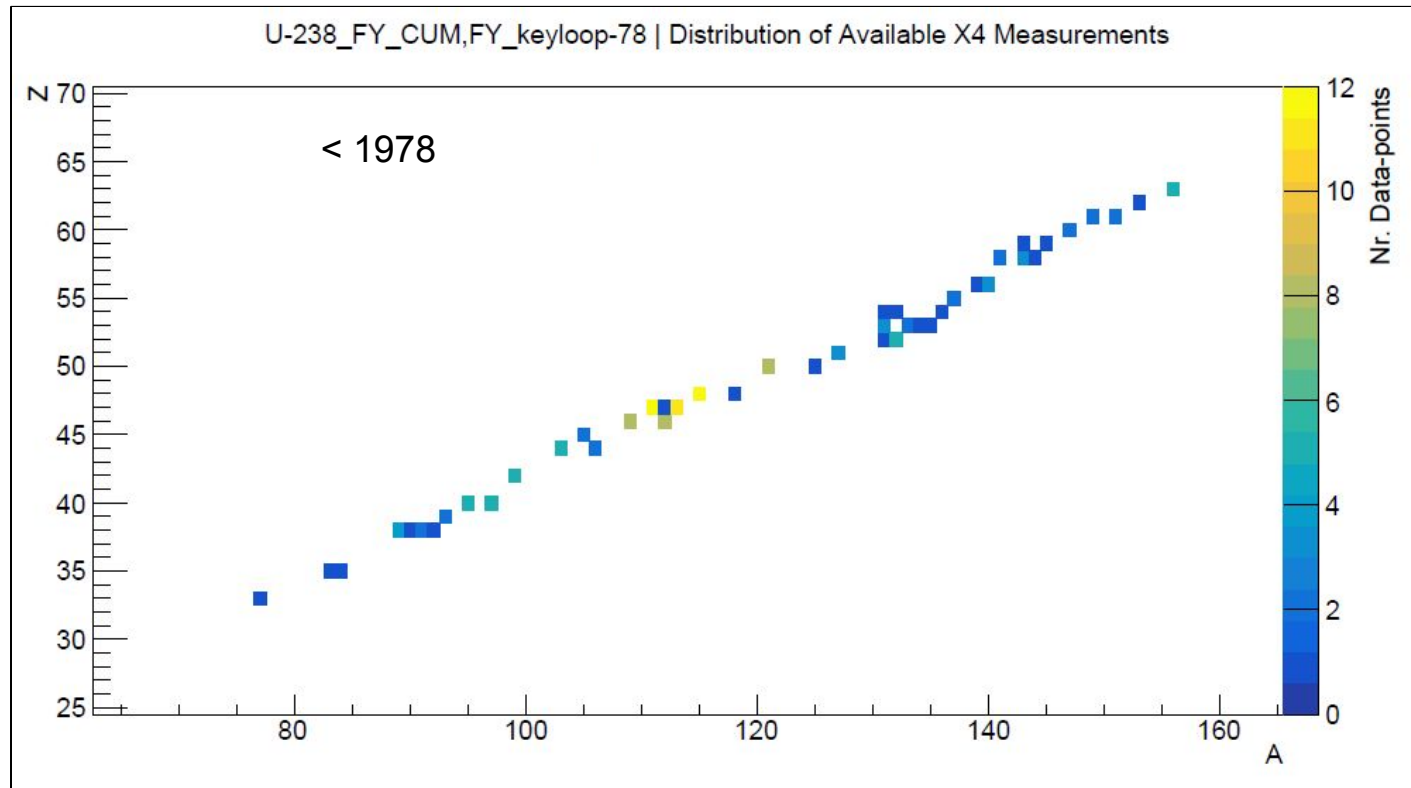
# How much new data?



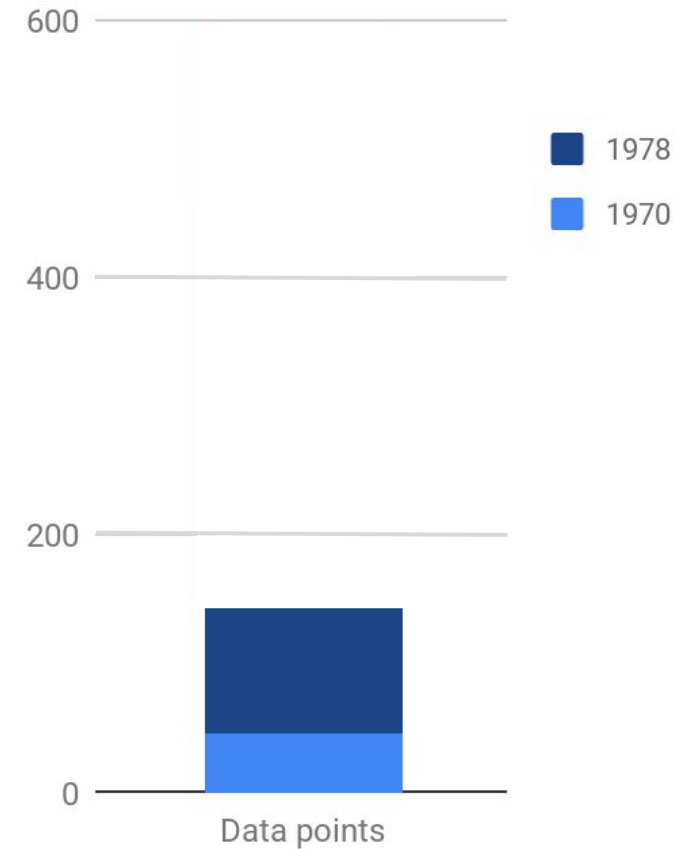
$^{238}\text{U}(n,f)$  CFY



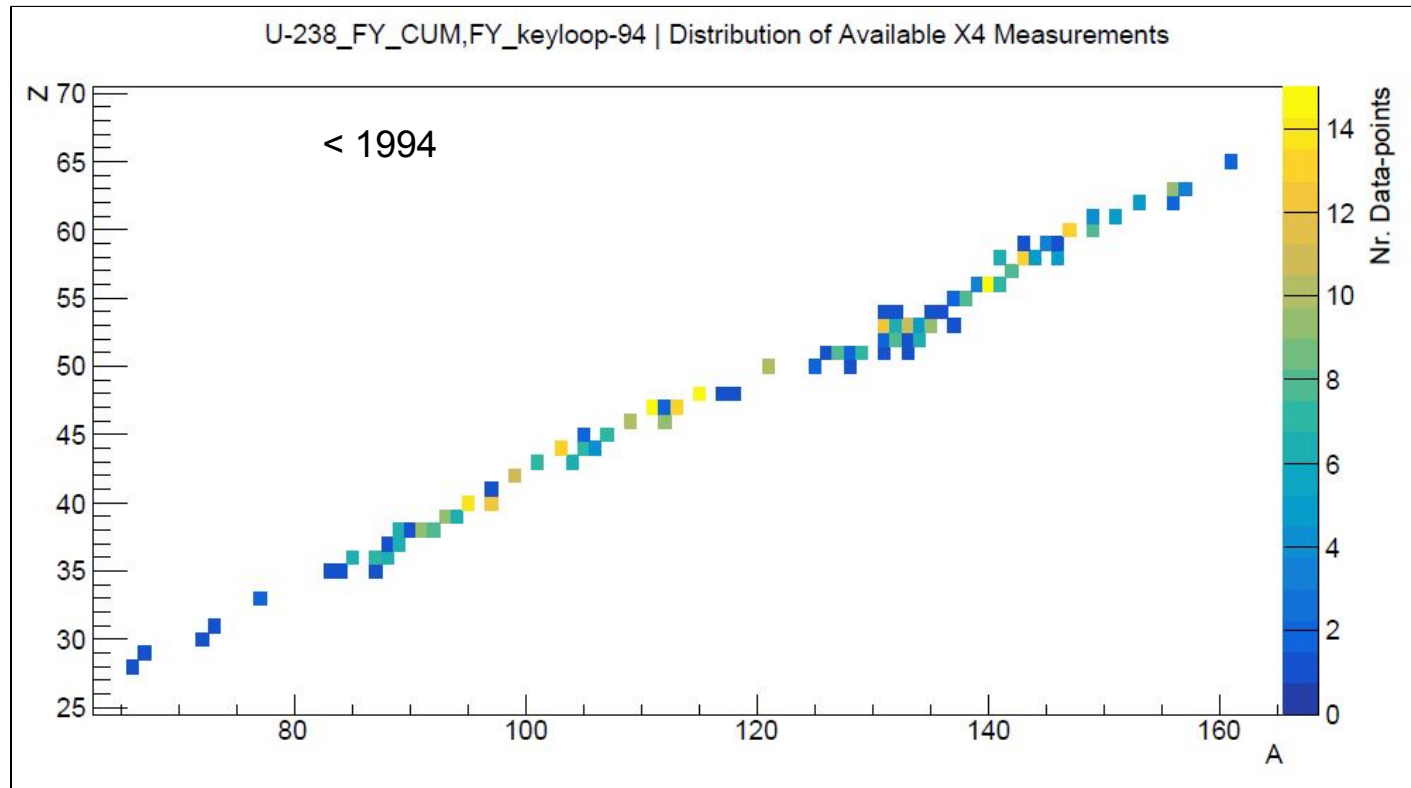
# How much new data?



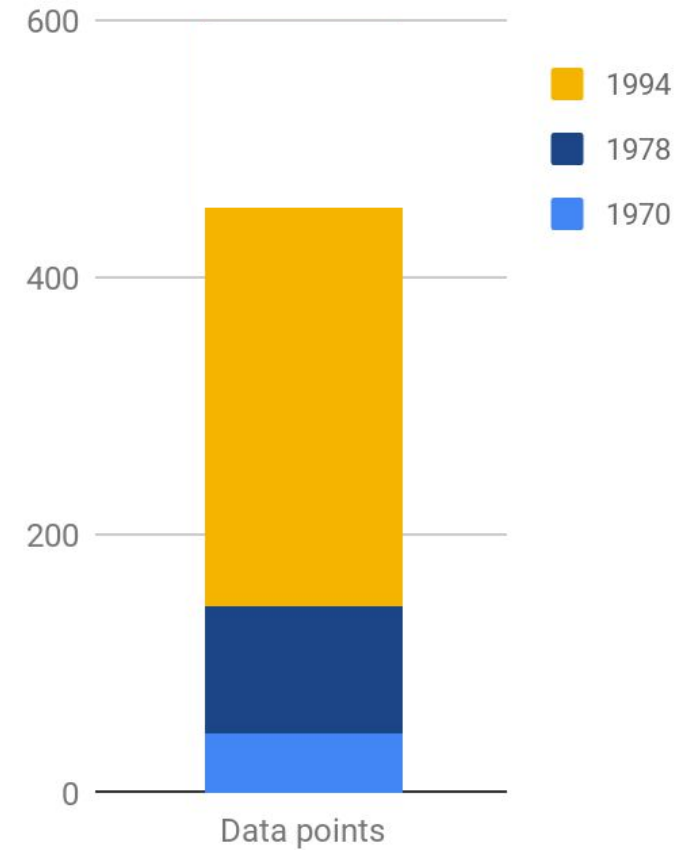
$^{238}\text{U}(n,f)$  CFY



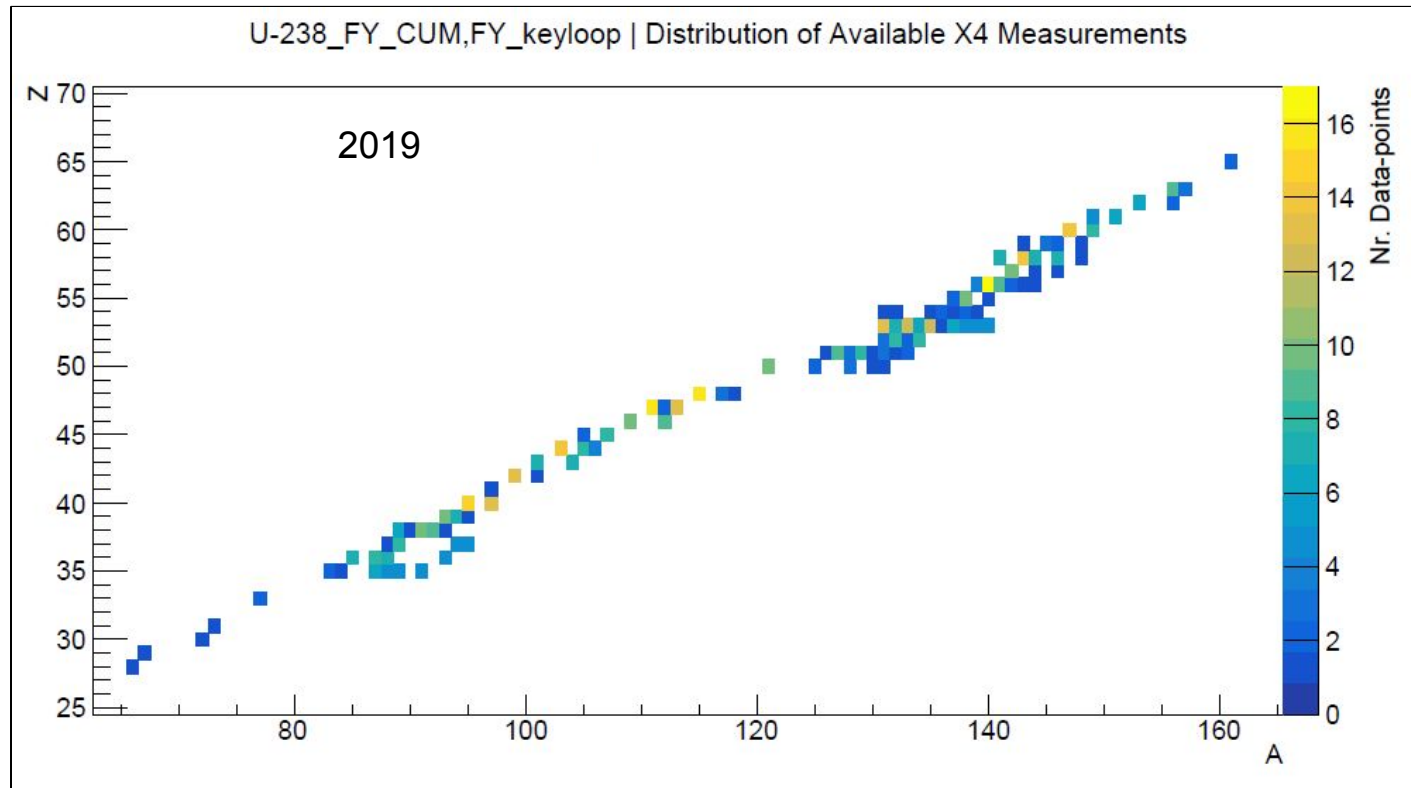
# How much new data?



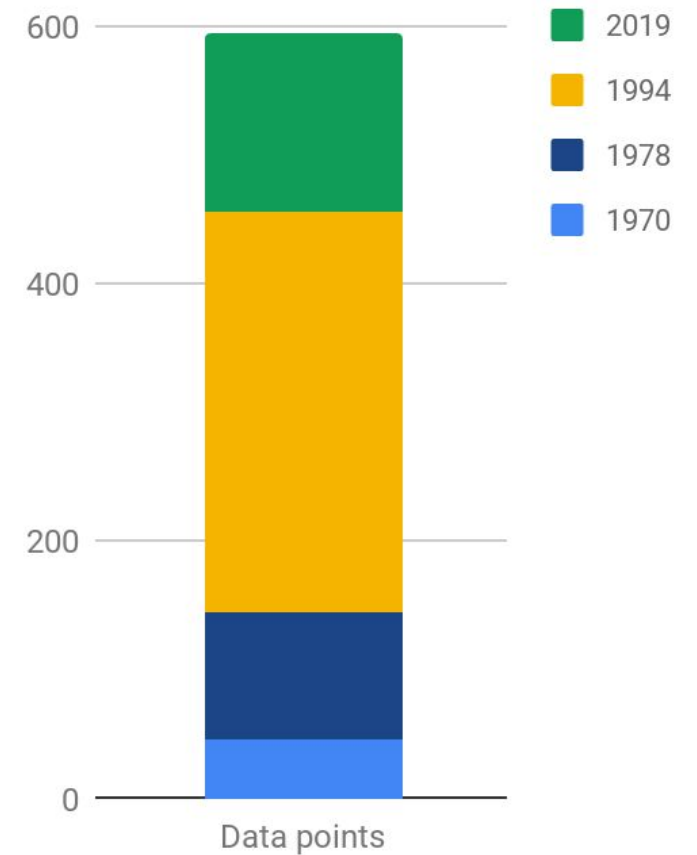
## $^{238}\text{U}(n,f)$ CFY



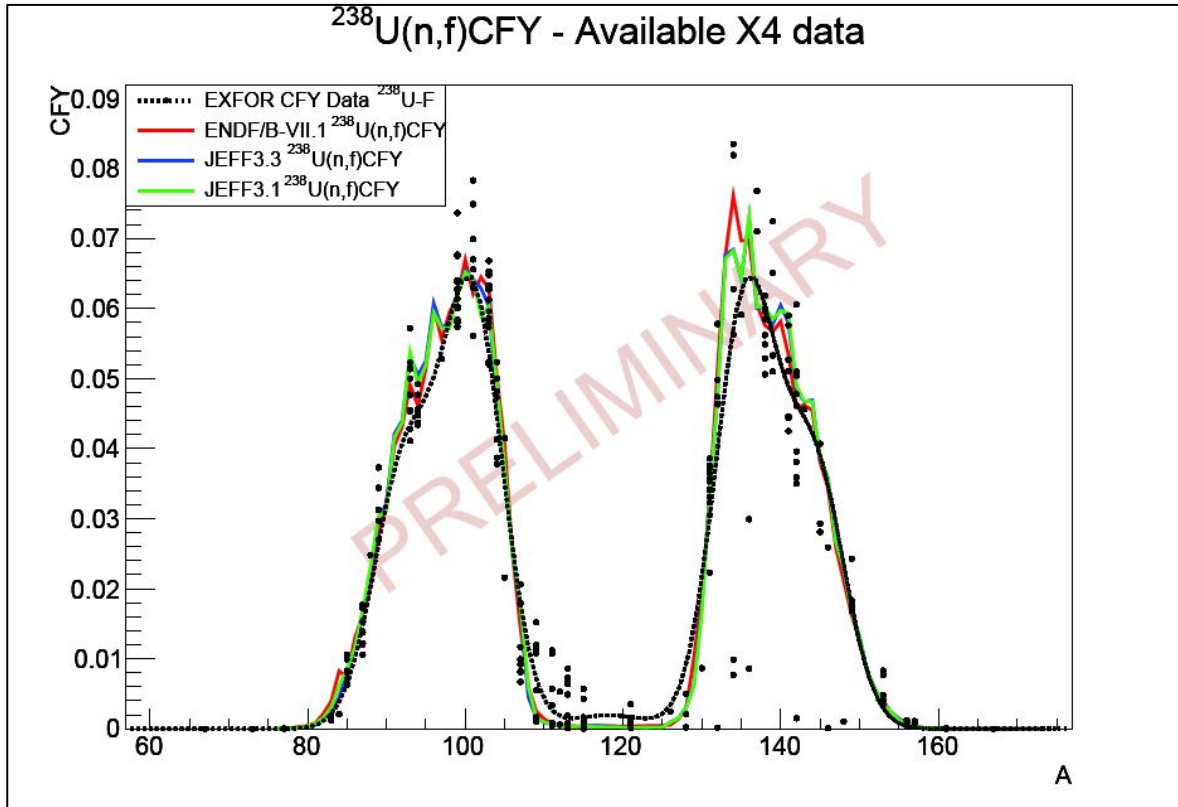
# How much new data?



## $^{238}\text{U}(n,f)$ CFY



# Current status of the compilation effort



Compilation of  $^{238}\text{U}(n,f)$  FY Bibliography + "New" data?



Retrieval of available data from EXFOR



Conversion to JSON



Correction of data points



Isomeric Yield Ratios



Averaging / Recommended Experimental Yields



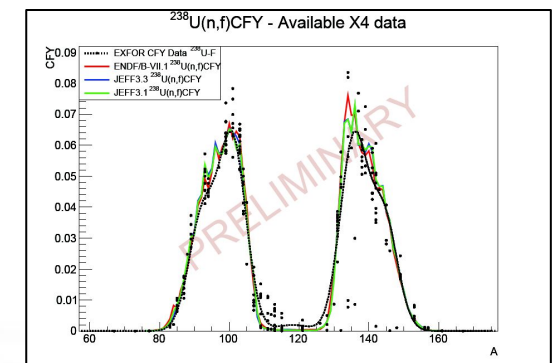
# Summary and Outlook

- Continued work for EXFOR + NSR update and extension
- Bibliographic compilation of references for  $^{238}\text{U}(n,f)$  experiments
- Conversion of existing EXFOR entries to JSON and compilation of new experiments in the new format
- Analysis & comparison of existing data to reach R.E. FYs by spring 2020.

NSR - BibNr	NSR link	Exp I/O	X4 data (entrynr)	pdf I/O	Details	En / E*	Not (from f)
2019RA07	<a href="https://nndc.gov/">https://nndc.gov/</a>	1	n/a	0	1-n transfer reaction (CN: 239U)	7.4MeV Exc	
2019PA23	<a href="https://nndc.gov/">https://nndc.gov/</a>	1	n/a	0	1-n transfer reaction (CN: 239U)	near barrier fission	
2019FO04	<a href="https://nndc.gov/">https://nndc.gov/</a>	1	<a href="https://www.nndc.gov/">https://www.nndc.gov/</a>	14822	1	fast	
2017PE08	<a href="https://nndc.gov/">https://nndc.gov/</a>	1	n/a	0	1	CouEx	SOFAV
2017W09	<a href="https://nndc.gov/">https://nndc.gov/</a>	1	<a href="https://www.nndc.gov/">https://www.nndc.gov/</a>	23403	1	anomaly (see 2019FO04)	
2017NA17	<a href="https://nndc.gov/">https://nndc.gov/</a>	1	<a href="https://www.nndc.gov/">https://www.nndc.gov/</a>	33106	1	charge distributions	
2017H10	<a href="https://nndc.gov/">https://nndc.gov/</a>	1	n/a	0	1	inv-kin   multinucleon transfer reaction   FFM; E* > 10-20 MeV	
2017UL01	<a href="https://nndc.gov/">https://nndc.gov/</a>	1	n/a	0	1	inv-kin   NO FY data	
2018G02	<a href="https://nndc.gov/">https://nndc.gov/</a>	1	n/a	0	1	FY mass distro   new data? Also see: LLNL 0.5-14.8 MeV	dual-fis
2016DU22	<a href="https://nndc.gov/">https://nndc.gov/</a>	1	<a href="https://www.nndc.gov/">https://www.nndc.gov/</a>	14463	1	mass landscape   Fragment Y	1-30MeV
2018NA13	<a href="https://nndc.gov/">https://nndc.gov/</a>	1	<a href="https://www.nndc.gov/">https://www.nndc.gov/</a>	33093	1	FP offline: Y, peak/valley ratio	E=6.35, 8.53, 12.52 MeV
2018H09	<a href="https://nndc.gov/">https://nndc.gov/</a>	1	<a href="https://www.nndc.gov/">https://www.nndc.gov/</a>	14423	1	92Zr 92Zr 98Mo 132Te 133I 140Ba 143Ce 14.8 MeV	TUNL
2019VO11	<a href="https://nndc.gov/">https://nndc.gov/</a>	1	<a href="https://www.nndc.gov/">https://www.nndc.gov/</a>	0	1	inv-kin	
2014TO09	<a href="https://nndc.gov/">https://nndc.gov/</a>	1	<a href="https://www.nndc.gov/">https://www.nndc.gov/</a>	14402	1	XS   Yields?	<20 MeV
2014HA25	<a href="https://nndc.gov/">https://nndc.gov/</a>	1	<a href="https://www.nndc.gov/">https://www.nndc.gov/</a>	23280	1	XS   Yields?	0.2-5 MeV
2014GO06	<a href="https://nndc.gov/">https://nndc.gov/</a>	1	<a href="https://www.nndc.gov/">https://www.nndc.gov/</a>	41598	1	FF yields	
2014KH11	<a href="https://nndc.gov/">https://nndc.gov/</a>	1	n/a	0	1	FFY ratio	E=4.6, 9.0, 14.5 MeV
2013NA18	<a href="https://nndc.gov/">https://nndc.gov/</a>	1	<a href="https://www.nndc.gov/">https://www.nndc.gov/</a>	33052	1	FY mass distro	E=3.72, 5.42, 7.75, 10.09 MeV
2013KH11	<a href="https://nndc.gov/">https://nndc.gov/</a>	1	<a href="https://www.nndc.gov/">https://www.nndc.gov/</a>	41463	1	FFYs	E=5, 6.5 MeV
2013QR14	<a href="https://nndc.gov/">https://nndc.gov/</a>	1	<a href="https://www.nndc.gov/">https://www.nndc.gov/</a>	14377	1	deduced atomic X-ray yields per fission	0.7-400MeV
2013FI07	<a href="https://nndc.gov/">https://nndc.gov/</a>	1	<a href="https://www.nndc.gov/">https://www.nndc.gov/</a>	14441	1	FPs mass distro	0.00001 - 10 MeV
2012RUZZ	<a href="https://nndc.gov/">https://nndc.gov/</a>	1	n/a	0	1		
2011RY09	<a href="https://nndc.gov/">https://nndc.gov/</a>	1	n/a	0	1		
2010SE15	<a href="https://nndc.gov/">https://nndc.gov/</a>	1	n/a	0	1	99Mo/95Zr/137Cs/140Ba/141,143Ce/147Nd	E=0.4-1.9 MeV
2010AD13	<a href="https://nndc.gov/">https://nndc.gov/</a>	1	<a href="https://www.nndc.gov/">https://www.nndc.gov/</a>	41529	1	inv-kin --> the X4 file doesn't contain all info?	

Experimental Nuclear Reaction Data (EXFOR)  
Database Version of 09-18-24

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JavaScript Object Notation



# Update of the compilation effort at BNL



BROOKHAVEN SCIENCE ASSOCIATES

# Current status of the compilation effort



Plots of CFY compared with libraries ...

