LBNL/UC Report

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http://nucleardata.berkeley.edu

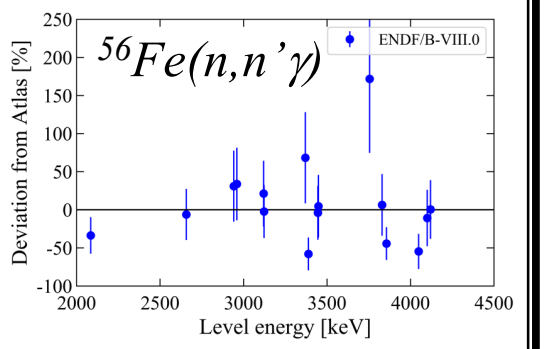
Berkeley's efforts are driven by identified evaluation, validation and experimental nuclear data needs

The "Baghdad Atlas" The first (n_{fast},n'γ) benchmark database

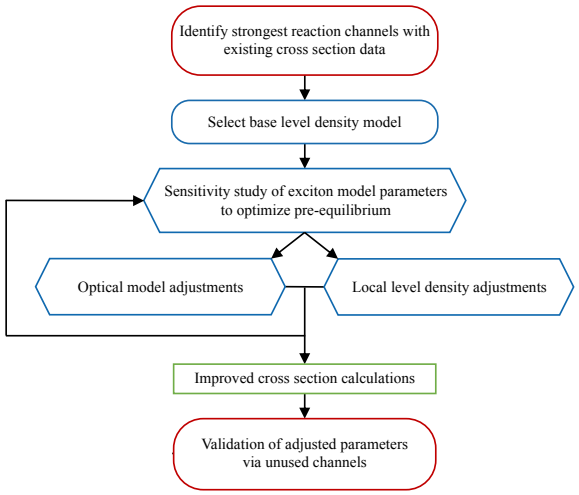
ATLAS

OF GAMMA-RAY SPECTRA FROM THE INELASTIC SCATTERING OF REACTOR FAST NEUTRONS

Comparison to ENDF



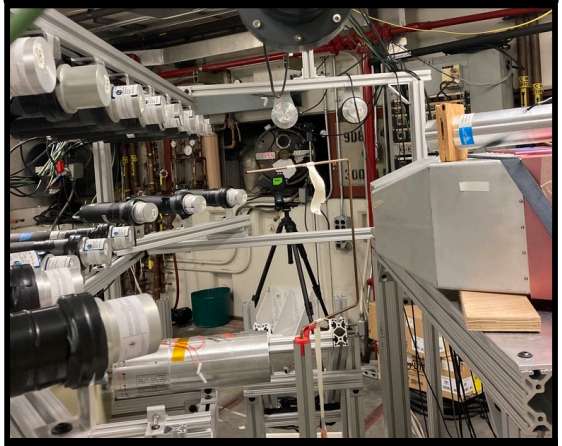
The "ChENDF" quest: Developing an evaluation approach for (p,x) for $E_p \geq 100$ MeV



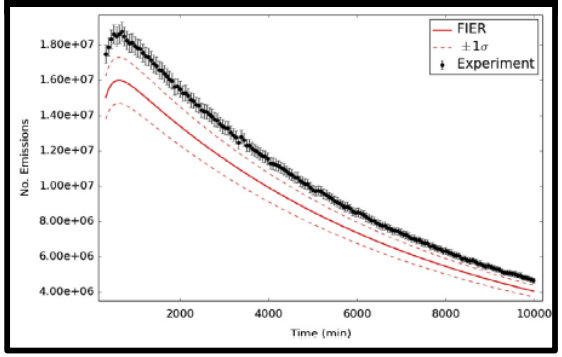
$^{93}Nb(p,x)$ to 200 MeV

Weighting Method	Default χ^2_{tot}	Adjusted χ^2_{tot}
Cumulative σ	3.62	1.55
Maximum σ	3.73	1.49

Improving fission yield and (n,n'γ) data



Comparison to FIER



Much of this is being done in collaboration with other labs/programs

FY20-21 Personnel & FTE Breakdown

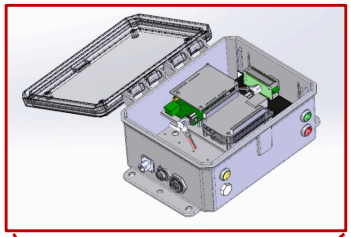
Name	Position	USNDP Activity	USNDP %	Other support
L.A. Bernstein	Staff	Coord, Measure., (n,n'γ)	70%	NA-22, UC, Isotopes
M.S. Basunia	Staff	ENSDF, XUNDL	95%	Isotopes
A.M. Hurst	Staff (UC)	(n,γ), (n,n'γ)	40%	NA-22, DTRA
J.C. Batchelder	Staff (UC)	β-p evaluation, ENSDF	75%	Isotope Program
B.L. Goldblum	***Staff***	***ML, Measurements***	***50%***	***NA-22, ARPA-E***
A.S. Voyles	PD → RE	Reac. measure., comp.	25%	Isotope Program
J.A. Brown	Staff (UC)	^{238}U(n,n'γ), (n,f) yields	25%	DOE-NE, NA-22
J.T. Morrell	GS*	(n,x) Isotope Production	0%	Isotope Program
C. Apgar				***pe Program***
J. Matheny				A
E.F. Matthews	GS	Fission modeling	0%	NSSC Fellow
M. Fox	GS*	^{75}As(p,x) to 200 MeV	50%	Isotope Program
W. Younes	***Consultant***	***ML, Fission Cov.***	***40%***	***N/A***
P. Vincente-Valdez	***GS****	***ML for reaction eval.***	***25%***	***UC***
J. Tuli	Consultant	ENSDF	40%	n.a.

And now you will get to hear from some of the people who are doing the work

USNDP ≈47%

We are using experience extracted using AI/ML from large multi-sensor datasets for nuclear data applications (Bethany)

multisensor



motion

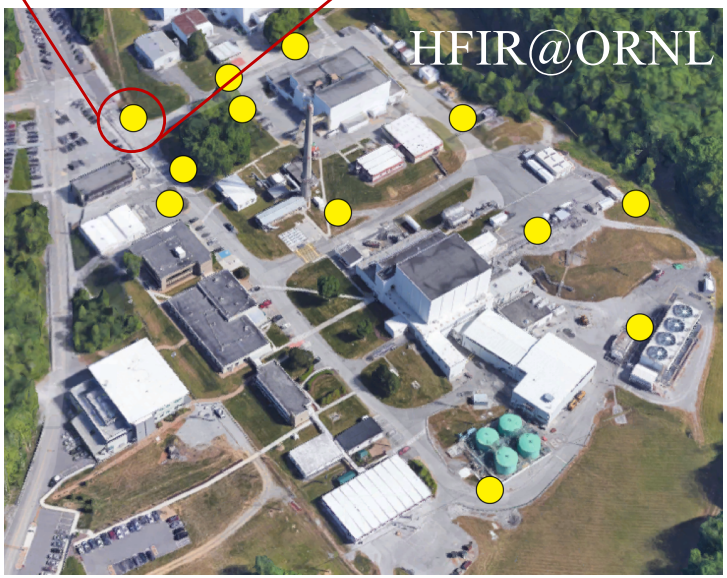
light

magnetic field

pressure

temperature

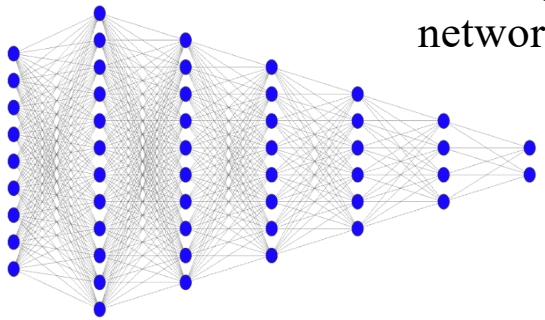
vibrations



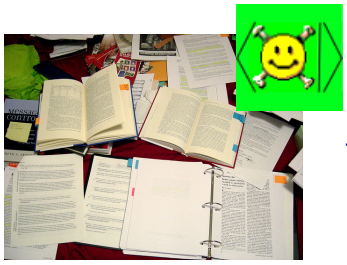
Leverage NNSA NA-22 ML software base for transferable, explainable ML models to advance reaction cross section evaluation and benchmarking (Goldblum LBNL)

Physics-guided neural networks (Karpatne 2017)

Experimental Data →

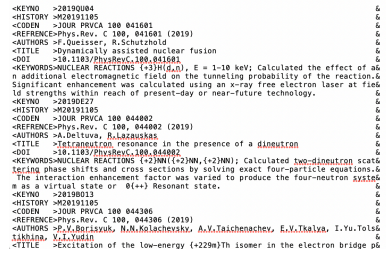


→ ML-generated cross sections



→

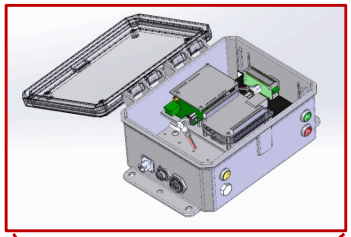
Natural Language Processing for Categorization →

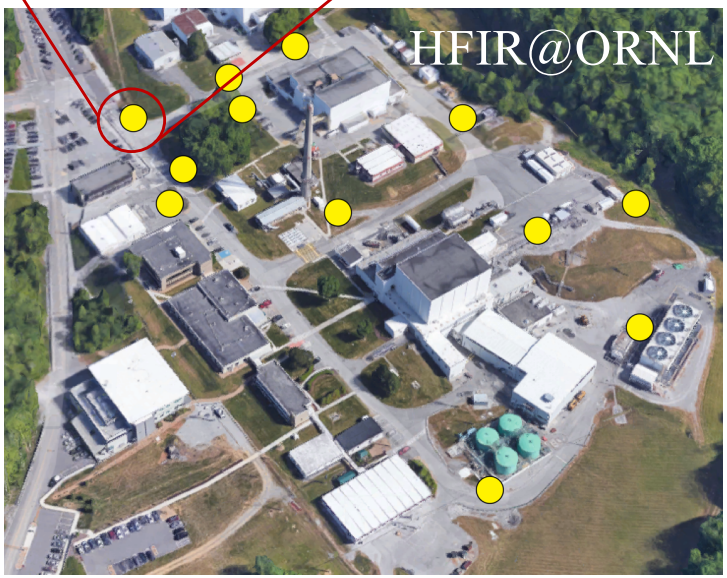


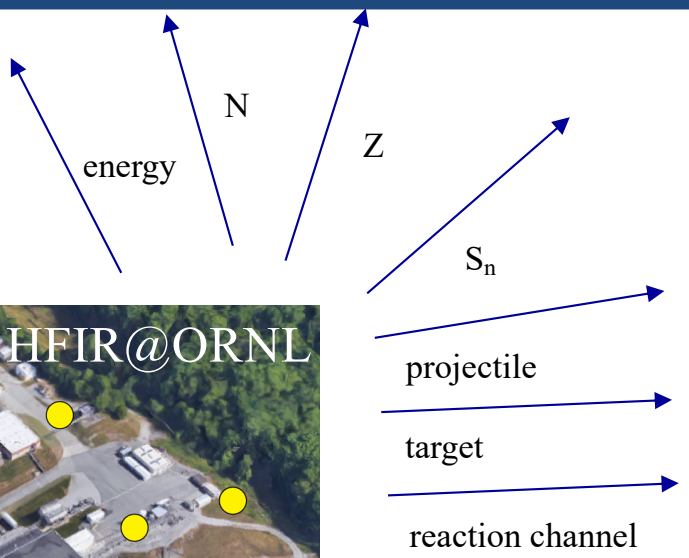
Auto-generated NSR entries

We are using experience extracted using AI/ML from large multi-sensor datasets for nuclear data applications (Bethany)

multisensor







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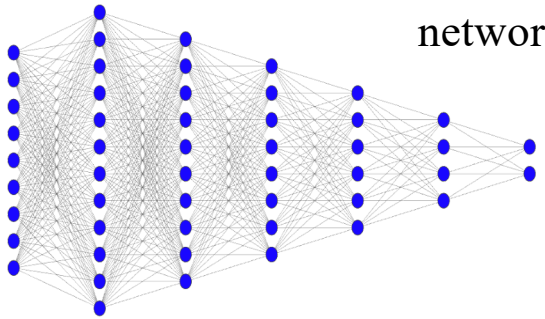
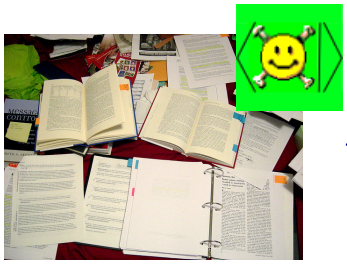
Physics-guided neural networks (Karpatne 2017)

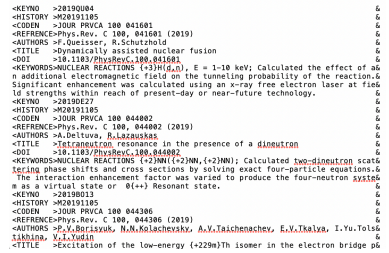
Experimental Data →



→ ML-generated cross sections



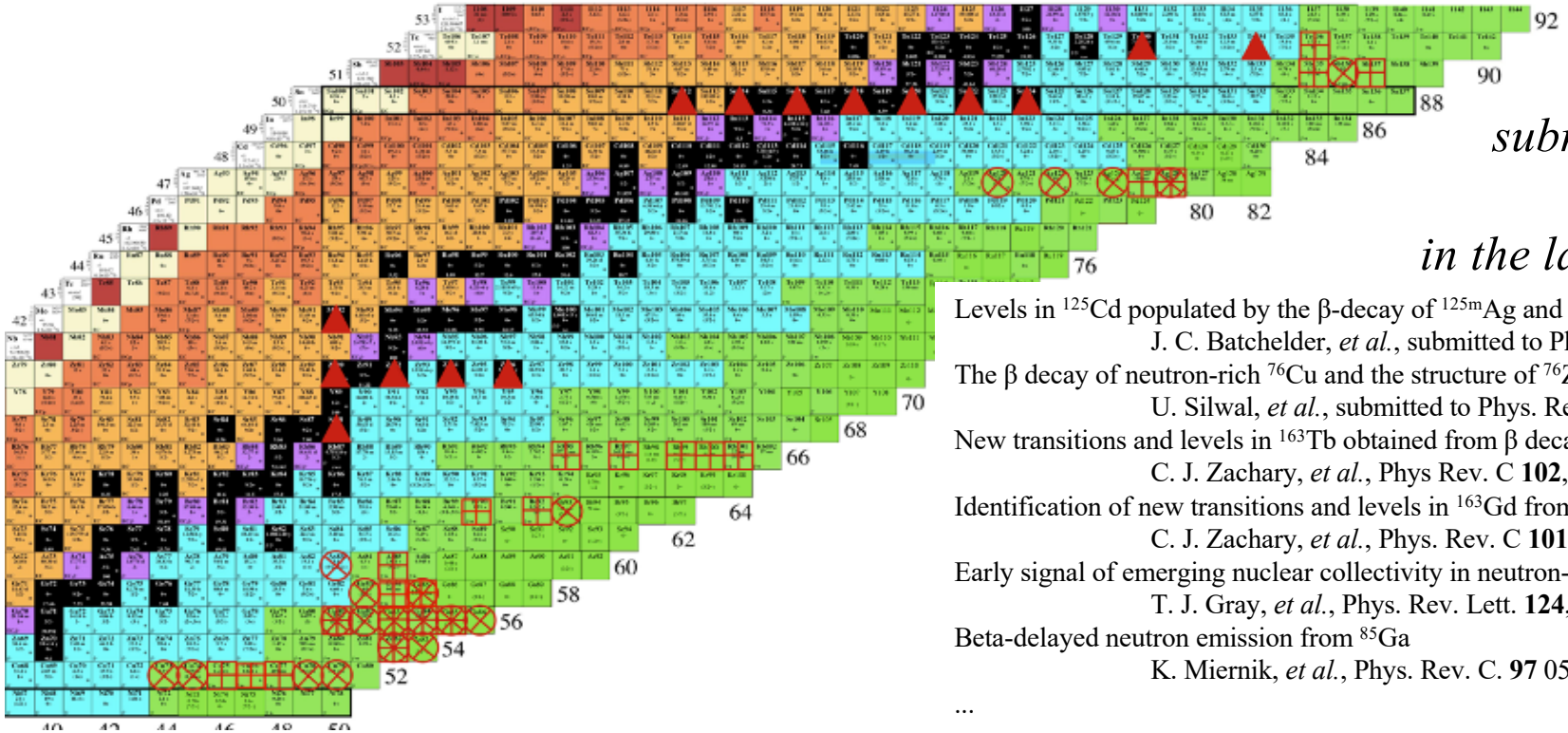
→ Natural Language Processing for Categorization →



Auto-generated NSR entries

In addition to publishing the first β-p horizontal evaluation in 20 years* We are helping bring fission fragment decay data to publication (Batch)

- 58 fission fragment experiments completed in 115 days of beam time at HRIBF via ^{238}U(p,f) from 2010 to 2012 (shutdown of the facility).
  - 29 papers published (+2 in production) to refereed journals (PRL, PRC,…)
  - Grad students heavily involved.
  - Several more datasets to analyze ($^{127\text{-}128}$Ag, $^{199\text{-}101}$Rb, ...)
  - Many more papers to come out of this data!



10 papers submitted and published in the last 4 years

Levels in ^{125}Cd populated by the β-decay of ^{125m}Ag and ^{125}Ag
J. C. Batchelder, *et al.*, submitted to Phys. Rev. C.

The β decay of neutron-rich ^{76}Cu and the structure of ^{76}Zn
U. Silwal, *et al.*, submitted to Phys. Rev. C.

New transitions and levels in ^{163}Tb obtained from β decay studies
C. J. Zachary, *et al.*, Phys Rev. C **102**, 044302 (2020).

Identification of new transitions and levels in ^{163}Gd from β decay studies
C. J. Zachary, *et al.*, Phys. Rev. C **101**, 054312 (2020).

Early signal of emerging nuclear collectivity in neutron-rich ^{129}Sb
T. J. Gray, *et al.*, Phys. Rev. Lett. **124**, 032502 (2020).

Beta-delayed neutron emission from ^{85}Ga
K. Miernik, *et al.*, Phys. Rev. C. **97** 054317 (2018).

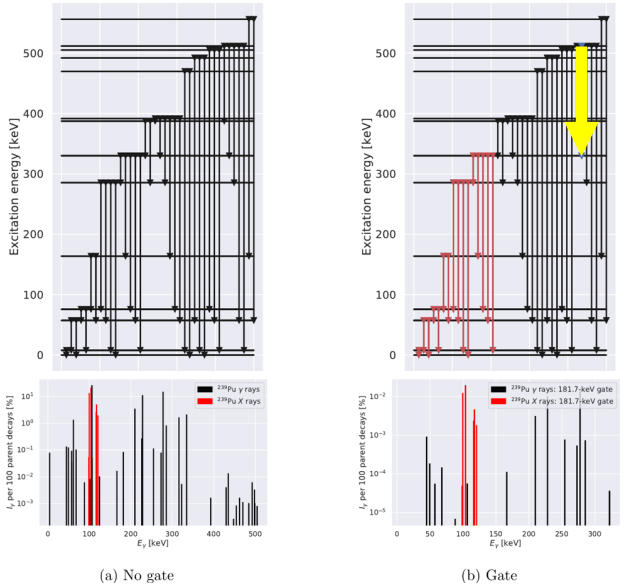
...

Aaron is developing a new γ-ray/X-ray coincident decay database in collaboration with Bruce Pierson from PNNL (Aaron)

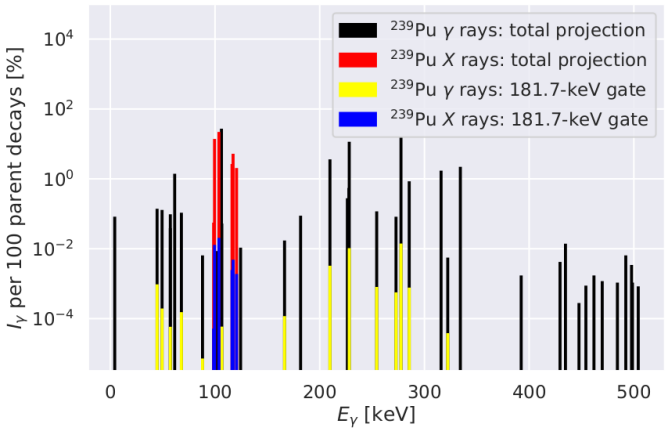
- Many applications require coincident decay data that include X-rays from internal conversion/electron capture.
- DTRA is developing a portable detector system (Lead PI: Bruce Pierson - PNNL) with Berkeley leading database development.
- A.M. Hurst has developed software that builds a new SQLite database that:
  - Is sourced directly from ENSDF into an XML hierarchy which in turn populates relational tables;
  - Encompasses α, EC and β-decay datasets;
  - *Provides coincident γ/γ intensities and γ/X-ray intensities on an absolute scale;*
  - Includes Jupyter Notebook narratives to illustrate database interaction methodologies and automation procedures.
  - Allows users to curate filtered datasets according to individual needs and preferred format.

Gated coincident intensities for decay data could be a useful tool for ENSDF as a whole

^{239}Pu decay Data:
Gating on the 181.7 keV line



(a) No gate (b) Gate

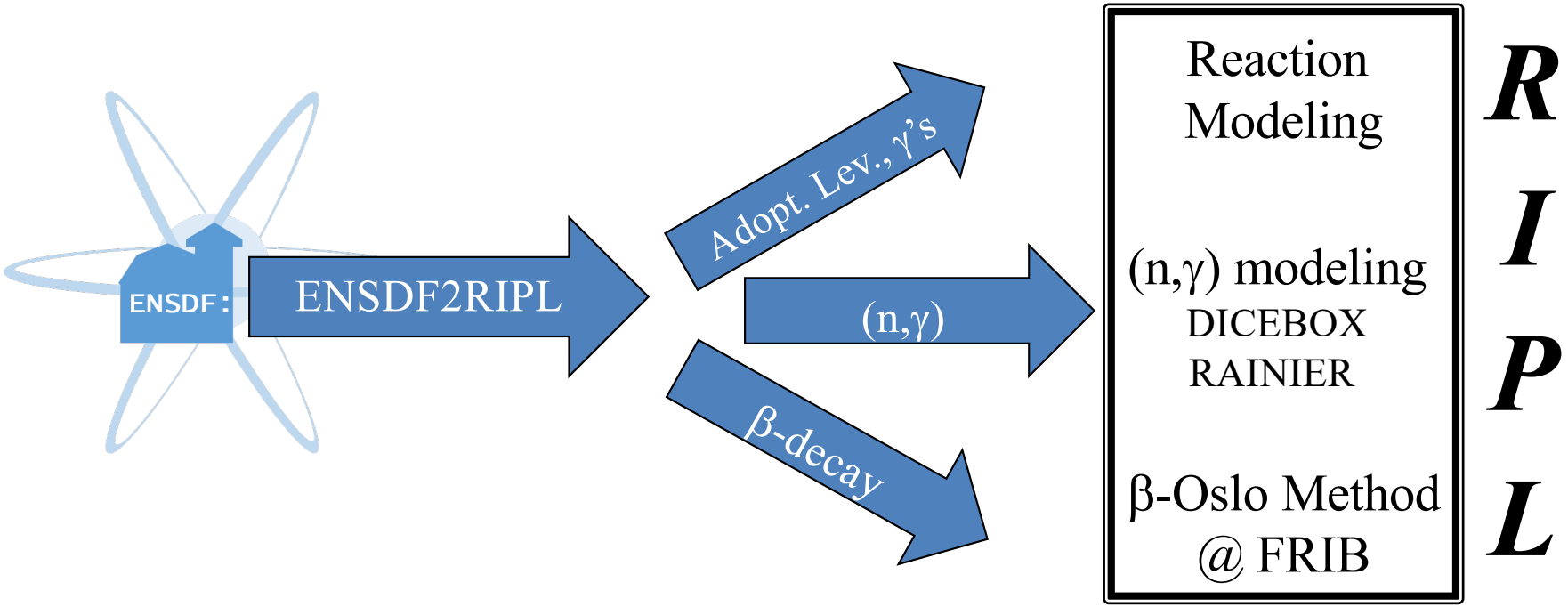


We are also using Aaron's ENSDF parser to produce up-to-date RIPL files to aid in reaction modeling

- The software that produced the γ-X ray database has allowed us to make new RIPL (Reference Input Parameter Library) files from up-to-date ENSDF (Current version is 2009).
- RIPL contains a subset of ENSDF information indexed by level energy (J^{π}, τ, I_{γ}, E_{γ}, α).

RIPL (and the like) is essential for reaction-model calculations.

- We are producing RIPL for both Adopted Levels and Gammas *and* specific source data sets (important for spin-limited experiments, e.g., capture, β-Oslo measurements[1]).



We plan to host data sets at UC Berkeley in the future

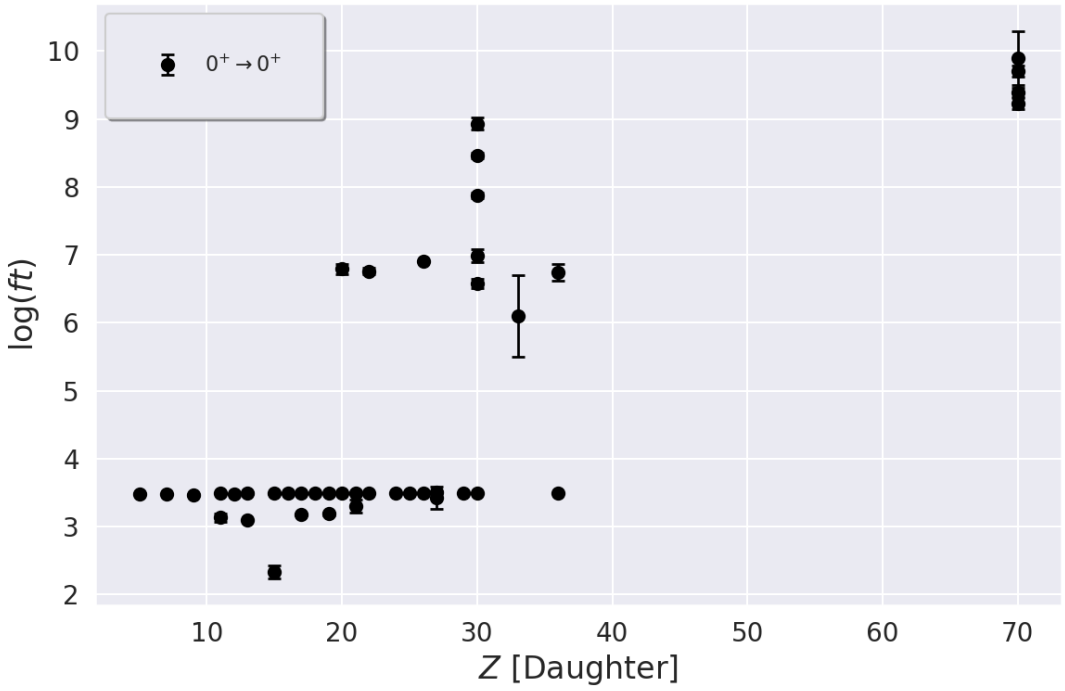
[1]S.N. Liddick *et al.*, PRL. **116**, 242502

$0^+ \rightarrow 0^+$ Transitions

```
<level id="Cs124_e26" index="26">
  <energy value="613.90" unit="keV">
    <uncertainty value="0.08" pdf="normal"/>
  </energy>
  <spins raw="(0,1,2)+" nspins="3">
    <spin value="0" rational="0.0" unit="hbar" assign="T" special="None" index="0">
      <parity value="1" sign="+" assign="F"/>
    </spin>
    <spin value="1" rational="1.0" unit="hbar" assign="T" special="None" index="1">
      <parity value="1" sign="+" assign="F"/>
    </spin>
    <spin value="2" rational="2.0" unit="hbar" assign="T" special="None" index="2">
      <parity value="1" sign="+" assign="F"/>
    </spin>
  </spins>
```

- Complete numerical interpretation of J^{π} field
- 124Ba EC decay $\rightarrow$ ^{124}Cs
- E (level) = 619.90 keV (daughter)
- J^{π} = (0,1,2)+ in ENSDF

- Parse entire ENSDF archive
- EC and β^+ decay data sets
- Select parent where J=0 and π=+ and both are unique and firm assignments
- Select daughter where J=0 and π=+ and both are unique and firm assignments
- log(ft) is reported "precisely" (i.e. no limits)



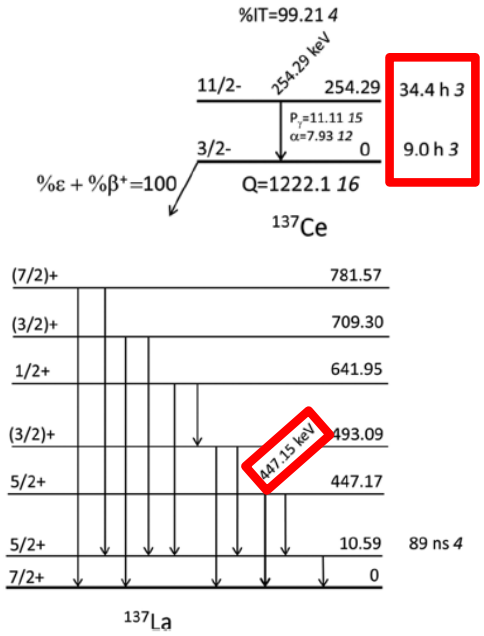
[1]S.N. Liddick *et al.*, PRL. **116**, 242502

Mass chain/nuclide Evaluation (Shamsu)

- Mass chain (pipeline/published):
  - A = 23 (final for pub.) – Basunia, Chakraborty
  - A = 186 (add. rev. com.) – Batchelder, Hurst, Basunia
  - A = 229 (add. rev. com.) – Singh, Tuli, Browne
  - A = 233 (pub. Dec 2020) – Singh, Tuli, Browne
- Mass chain evaluation (FY20/ongoing):
  - A = 24 – Basunia, Chakraborty, Hurst
  - A = 231 – Singh, Tuli (submitted FY21)
- Nuclide evaluation (IAEA):
  - ^{94,97}Zr, ^{97}Nb – Tuli
- Mass chain review: 1 (Basunia)

$^{137}Ce^{g}$ γ-ray emission probability P_γ (Shamsu)

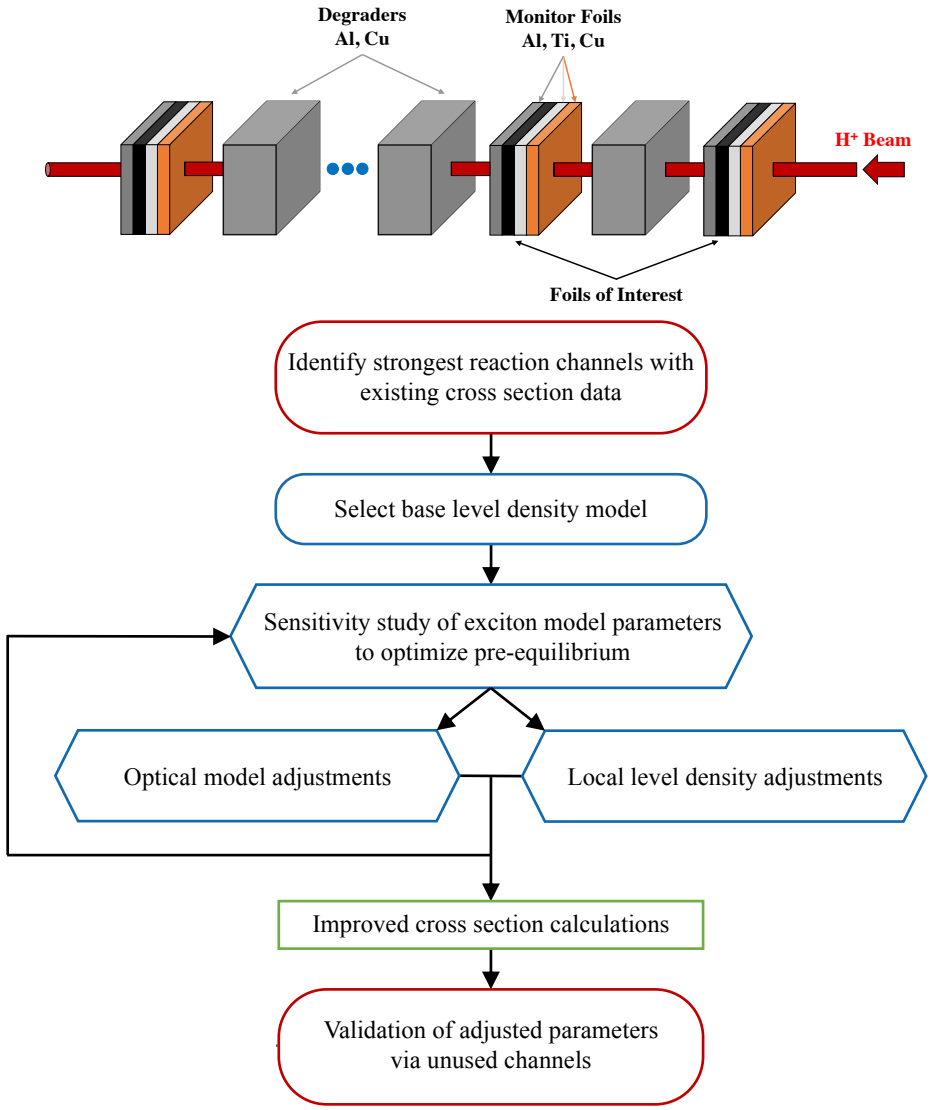
- We resolved a long overlooked issue brought up by Nesaraja at the 2019 NSDD meeting using $^{139}La(p,x)$ data taken at the 88-Inch cyclotron under the support of isotope program measurement.
- In Transient Equilibrium: $$\frac{P_{\gamma p}}{P_{\gamma d}} = \frac{I_{\gamma p}}{I_{\gamma d}} \times \frac{T_p}{T_p - T_d} = \frac{I_{\gamma p}}{I_{\gamma d}} \times F$$
- Henry, *et. al.* (PRC 12, 1314 , 1975) - **%Pγ(447)=2.24(10).**
- Basunia, *et. al.* (PRC 101, 064619, 2020) - **%Pγ(447)=1.21(3)**
- ***The earlier publication used the wrong ratio!***



- Other case (may be examined):
  - $^{68}Cu^{m,g}$ decay (3.75 min and 30.9 s) - can be carried out using our new rabbit system (FLUFFY)

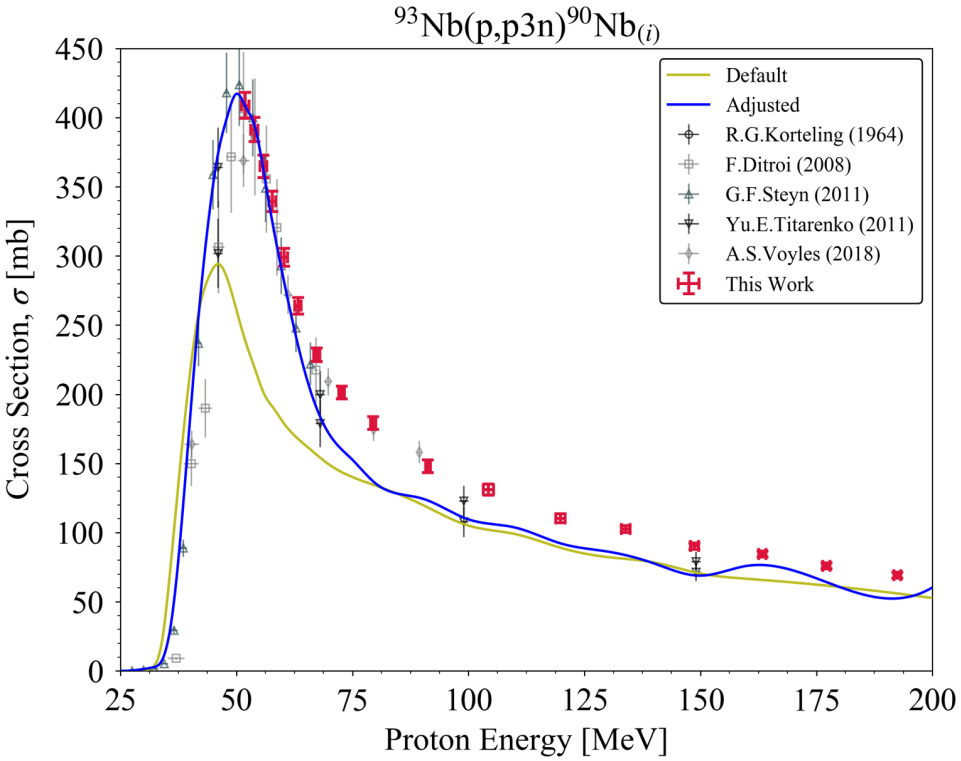
The method has been used for decay data normalization in ENSDF – evaluators are encouraged to consult the equation, if needed.

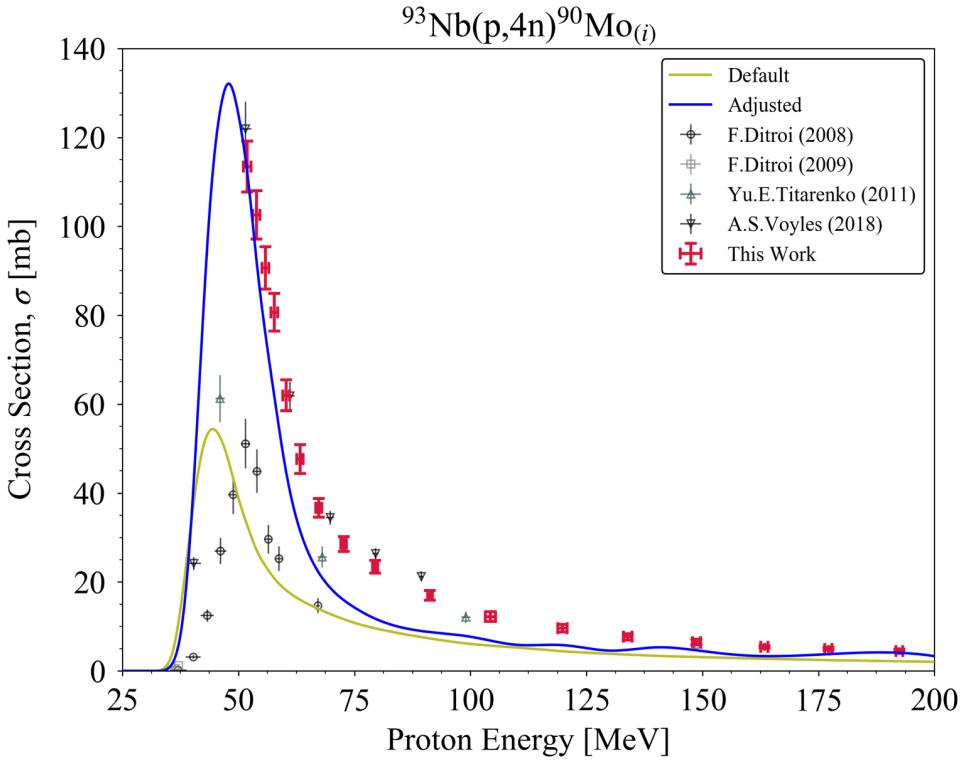
We are developing a high-energy (p,x) modeling approach as part of a LANL-BNL-LBNL* collaboration (Morgan)



- We have chosen to use the TALYS code since it allows for the exploration of reaction model physics, is well-documented and is easy to use.
- Level density and exciton model parameters are adjusted to match the strongest independent channels
- The modeling is validated via comparison to cumulative channels.
- Collaborators: LAB, M. Fox, J.T. Morrell, A.S. Voyles (UC/LBNL), E. Birnbaum, F.M. Nortier, E. O'Brien, C. Vermeulen (LANL/IPF), C. Cutler, D. Medvedev (BNL/BLIP)

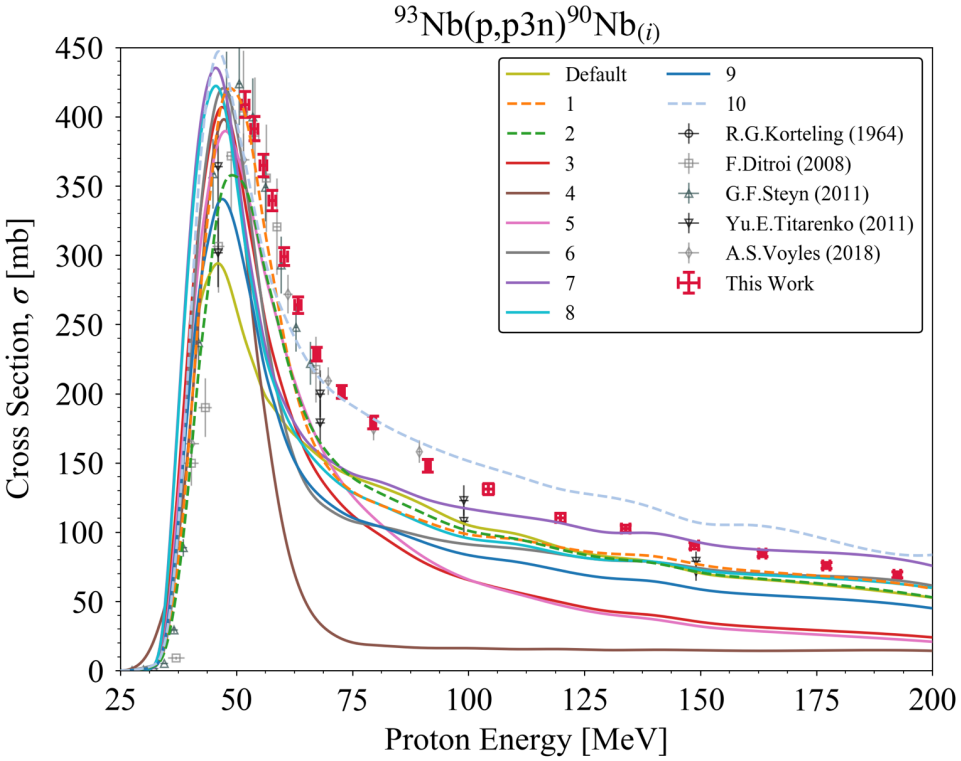
Fitting Procedure Applied to ^{93}Nb(p,x)



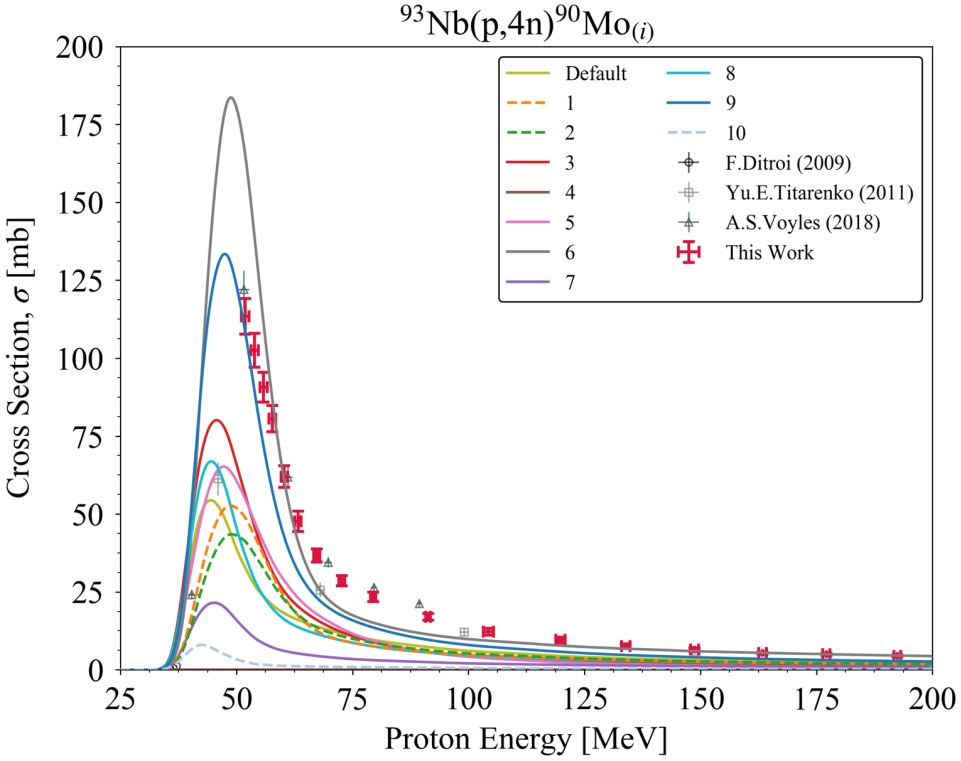


Weighting Method	Default χ^2_{tot}	Adjusted χ^2_{tot}
Cumulative σ	3.62	1.55
Maximum σ	3.73	1.49

What happens if we don't do the right thing?



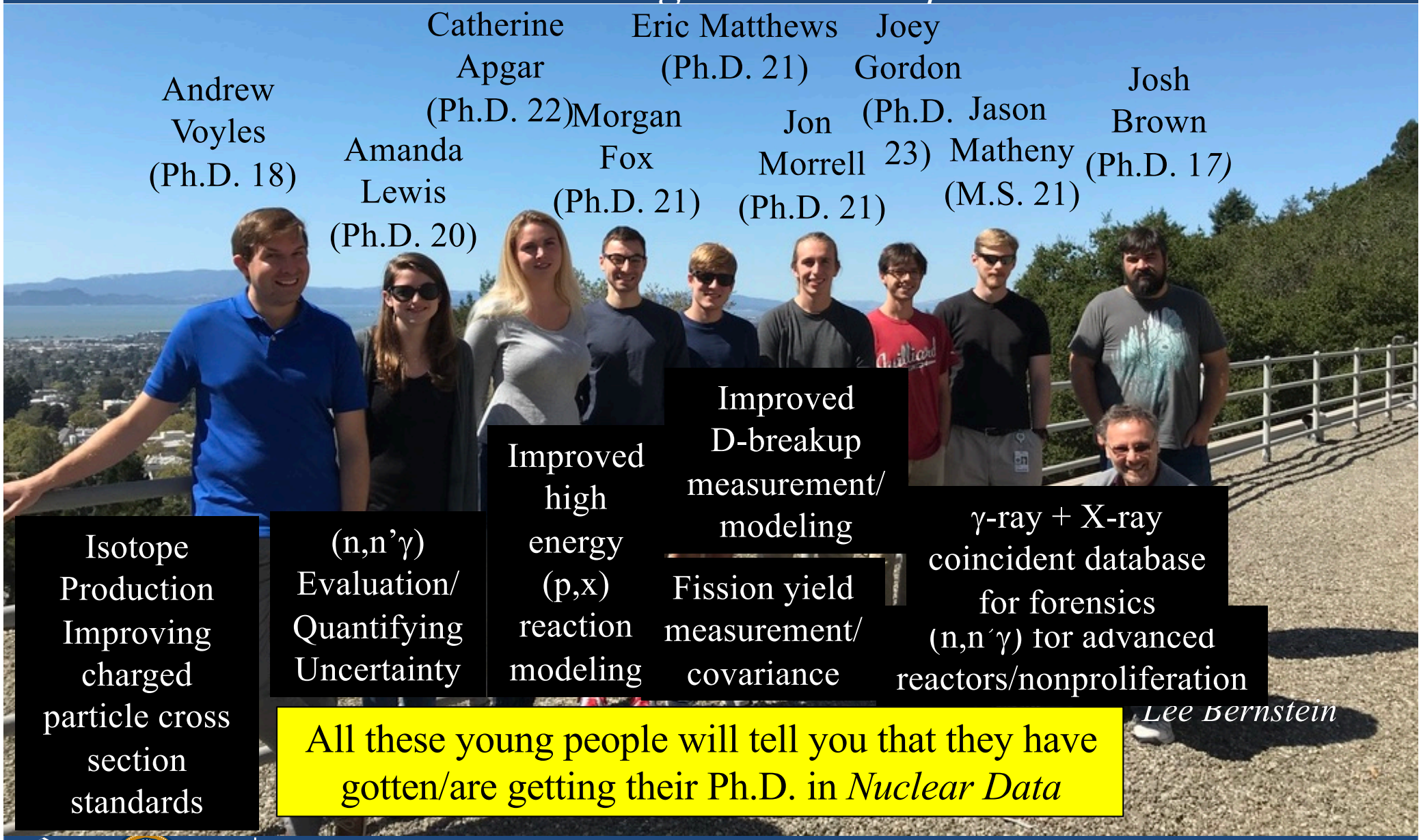
Models 1, 2, 10 perform best over default



Models 1, 2, 10 perform extremely poorly

What works well for (p,p3n) is completely wrong for (p,4n)!

Our goal is to address the data needs of the basic and applied nuclear science community *while training the next generation of nuclear scientists and engineers in the process*



All these young people will tell you that they have gotten/are getting their Ph.D. in *Nuclear Data*

2020 Publications (14)

1. J. T. Morrell, A. S. Voyles, M.S. Basunia, J. C. Batchelder, E. F. Matthews, L. A. Bernstein, "*Measurement of ^{139}La(p,x) Cross Sections from 35-60 MeV by Stacked-Target Activation*", Eur. Phys. Jou. A **56**, 13 (2020). doi:10.1140/epja/s10050-019-00010-0
2. J. C. Batchelder, "*Recommended Values for Beta-Delayed Proton Alpha Emission*", Atomic Dat. Nucl. Data Tables **132**, 101323 (2020). doi:10.1016/j.adt.2019.101323
3. T. J. Gray, J. M. Allmond, A. E. Stuchbery, C. -H. Yu, C. Baktash, A. Gargano, A. Galindo-Uribarri, D. C. Radford, J. C. Batchelder, J. R. Beene, C. R. Bingham, L. Coraggio, A. Covello, M. Danchev, C. J. Gross, P. A. Hausladen, N. Itaco, W. Krolas, J. F. Liang, E. Padilla-Rodal, J. Pavan, D. W. Stracener, and R. L. Varner, "*Early signal of emerging nuclear collectivity in neutron-rich ^{129}Sb*", Phys. Rev. Lett. **124**, 032502 (2020). doi:10.1103/PhysRevLett.124.032502
4. C. J. Zachary, N. T. Brewer, J. C. Batchelder, E. Wang, J. H. Hamilton, J. M. Eldridge, B. M. Musangu, A. V. Ramayya, C. J. Gross, K. P. Rykaczewski, R. Grzywacz, M. Madurga, D. Miller, D. W. Stracener, C. Jost, E. F. Zganjar, J. A. Winger, M. Karny, S. V. Paulauskas, S. H. Liu, M. Wolinska-Cichocka, S. W. Padgett, A. J. Mendez, K. Miernik, A. Fijalkowska, S. V. Ilyushkin, A. C. Dai, F. R. Xu, Y. X. Liu, and Y. Sun, "*Identification of new transitions and levels in ^{163}Gd from β decay studies* ", Phys.Rev. C **101**, 054312 (2020) doi:10.1103/PhysRevC.101.054312

2020 Publications (14)

5. M.S. Basunia, J.T. Morrell, M.S. Uddin, A.S. Voyles, C.D. Nesaraja, L.A. Bernstein, E. Browne, M.J. Martin, S.M. Qaim, "*Resolution of a discrepancy in the γ-ray emission probability from the β decay of 137Cesg*", Phys. Rev. C. **101**, 6 (2020) doi:10.1103/PhysRevC.101.064619
6. A. Bernstein, N. Bowden, B.L. Goldblum, P. Huber, I. Jovanovic, and J. Mattingly, "*Colloquium: Neutrino Detectors as Tools for Nuclear Security*", Rev. Mod. Phys. **92**, 011003 (2020). doi:10.1103/RevModPhys.92.011003
7. J.J. Manfredi, B.L. Goldblum, T.A. Laplace, G. Gabella, A. O'Brien, S. Chowdhury, J.A. Brown, E. Brubaker, "*Proton light yield of fast plastic scintillators for neutron imaging*", IEEE Trans. Nucl. Sci. **67**, 434 (2020). doi:10.1109/TNS.2019.2959979
8. T.A. Laplace, B.L. Goldblum, J.A Brown, J.J. Manfredi, "*Scintillator light yield measurements with waveform digitizers*", Nucl. Instrum. Meth. A **959**, 163485 (2020). doi:10.1016/j.nima.2020.163485
9. T.A. Laplace, B.L. Goldblum, J.A. Brown, D.L. Bleuel, C.A. Brand, G. Gabella, T. Jordan, C. Moore, N. Munshi, Z.W. Sweger, A. Ureche and E. Brubaker, "*Low Energy Light Yield of Fast Plastic Scintillators*", Nucl. Instrum. Meth. A **954**, 161444 (2020). doi:10.1016/j.nima.2018.10.122

2020 Publications (14)

10. Pascal Boller, Alex Zylstra, Paul Neumayer, Lee Bernstein, Christian Brabetz, John Despotopulos, Jan Glorius, Johannes Hellmund, Eugene A. Henry, Johannes Hornung, Justin Jeet, Jadambaa Khuyagbaatar, Lotte Lens, Simon Roeder, Thomas Stoehlker, Alexander Yakushev, Yuri A. Litvinov, Dawn Shaughnessy, Vincent Bagnoud, Thomas Kuehl & Dieter H. G. Schneider, "*First on-line detection of radioactive fission isotopes produced by laser-accelerated protons*", Scientific Reports **10**, 17183 (2020). doi:10.1038/s41598-020-74045-5
11. Nnaemeka Nnamani, Mauricio Ayllon-Unzueta, Karl van Bibber, Lee A Bernstein, Jasmina L Vujic, Jonathan T. Morrell, "*An Integral Experiment on Polyethylene Using Radiative Capture in Indium Foils in a High Flux D-D Neutron Generator*", Nuclear Science and Engineering **194**, 10 (2020). doi:10.1080/00295639.2020.1769964
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Another Opportunity for Nuclear Data

- I have been appointed to NSAC.
- The appointment letter states: "*You will be asked to provide expert advice in the field of nuclear science, as it relates to nuclear data needs for applied and basic science and engineering with specialization in measuring low-energy nuclear properties and cross sections.*"

This is an opportunity for us to build support for nuclear data activities through DOE and NSF and I will be looking to all of you (and the NDWG) to help fill this charge

One more personnel matter…

LBNL/UC Site Report

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I start a Joint Appointment at UC in 2021