The LBNL/UCB Bay Area Nuclear Data (BAND) Group

Lee Bernstein

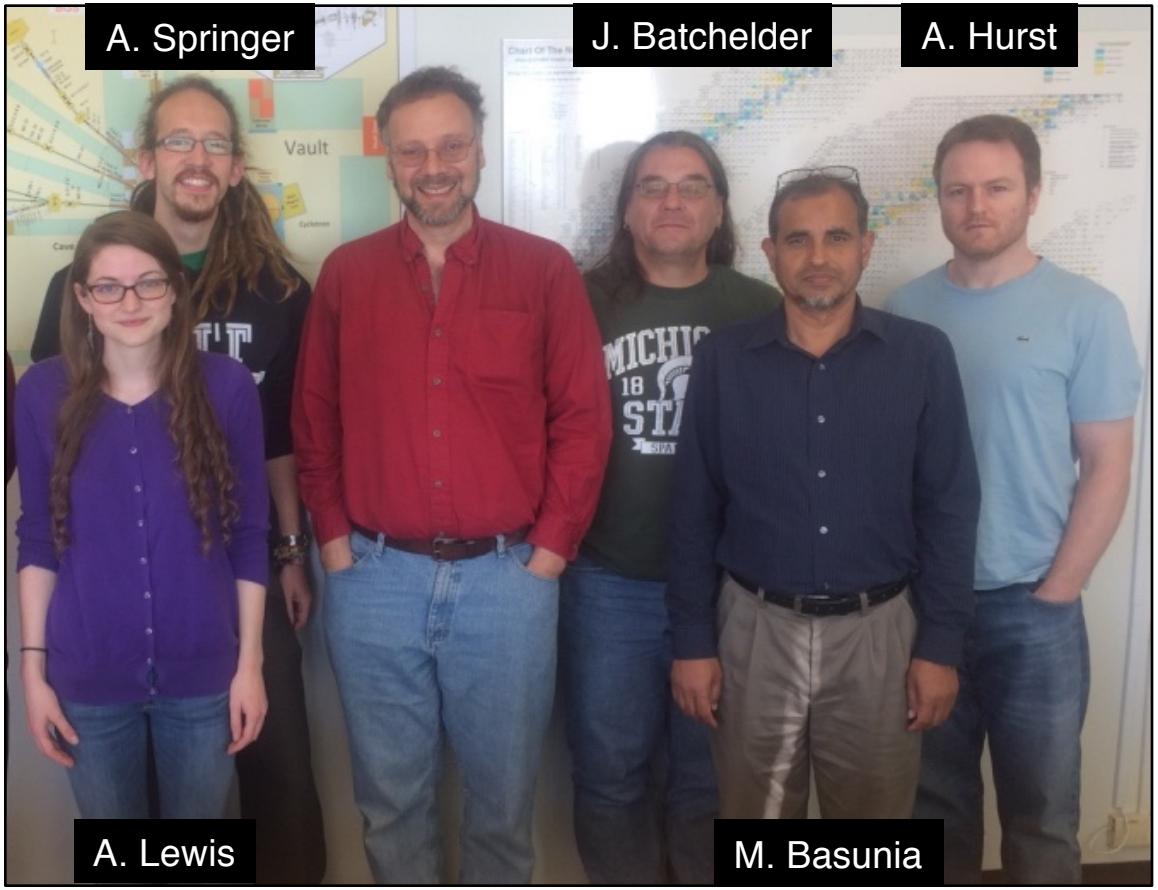
Nuclear Science Division - Lawrence Berkeley National Laboratory
Department of Nuclear Engineering – UC Berkeley

The BAND Group

Name	Institution	Activity	FY16 Funding (USNDP%)
L.A. Bernstein	LBNL/UCB	XUNDL/ENSDF, Teaching, Experiment	75%
M.S. Basunia	LBNL	ENSDF, XUNDL	100%
A.M. Hurst	UCB	EGAF, ENSDF, Database dev.	33%
R.B. Firestone	UCB	ENSDF, EGAF, RSF CRP	50%
C.M. Baglin	UCB	ENSDF	10%
J.C. Batchelder	UCB	ENSDF, XUNDL, Experiment	75%
L. Kirsch (G)	UCB	Experiment (^{56}Fe LD/RSF)	0% (SSGR)
A. Voyles (G)	UCB	Experiment (Medical Cross Sections)	0% (NRC)
A. Lewis (G)	UCB	Reaction Evaluation	0% (Rickover)
A. Springer (G)	UCB (Karlsurhe)	Experiment (Medical Cross Sections)	0% (UC funds)
H. Zaneb (G)	Lahore Univ.	Experiment (Medical Cross Sections)	0% (Pakistan)

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

The Bay Area Nuclear Data (BAND) Group*

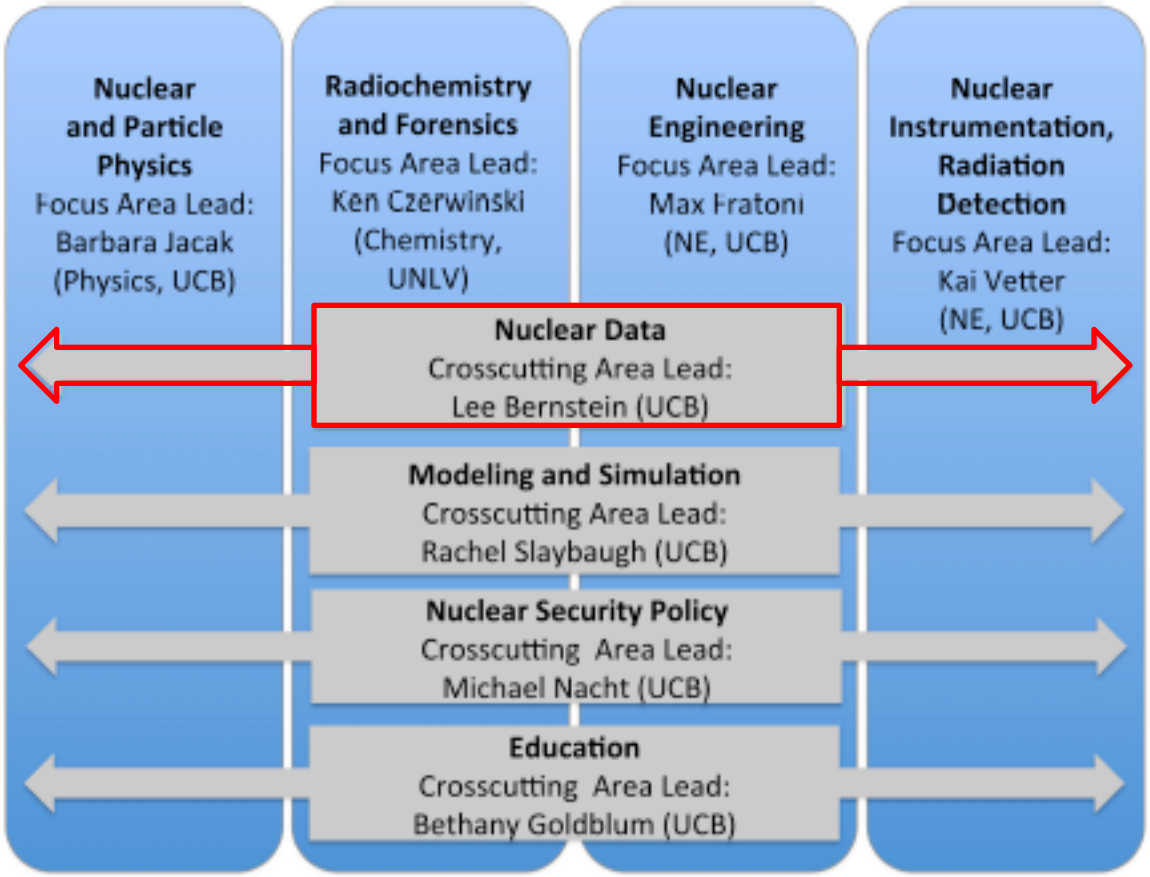


L. Kirsch

A. Voyles

*Camera shy: R.B. Firestone, C.M. Baglin, H. Zaneb (G), N. Fajardo (UG), S. Chong (UG)

Nuclear data is at the core of the successful Nuclear Science & Security Consortium Proposal ($25M/5 years)



Reviewer comments:

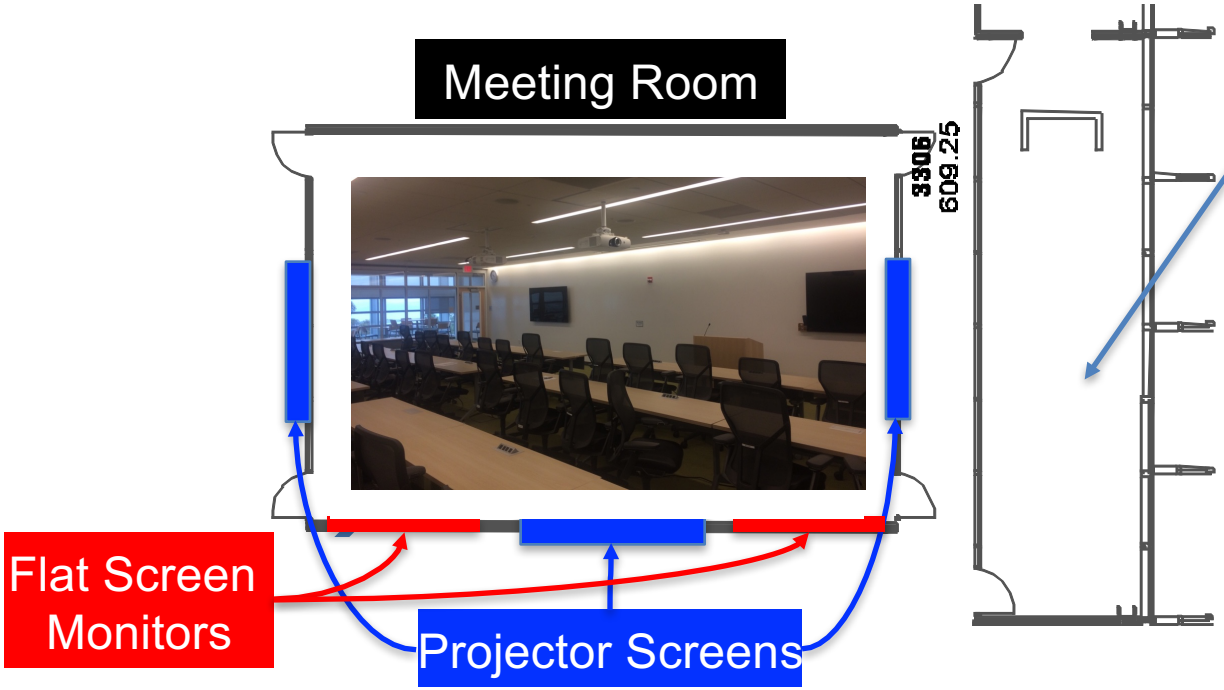
"The nuclear data thrust is very well thought out. This is a topic that universities can do well and it is true that nuclear data evaluators are getting rare…Improved nuclear data for safeguards is very important and sensitivity studies help to guide the data search."

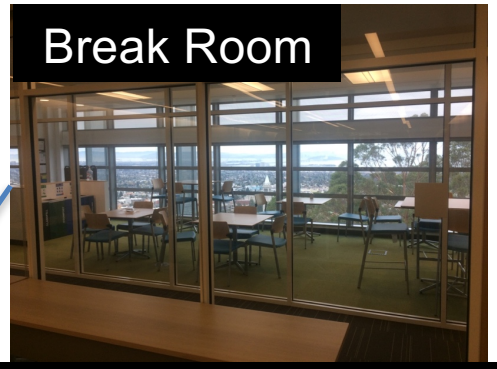
The nuclear data cross-cutting area grew out of NDNCA and the whitepaper process

NSDD 2017 – Berkeley CA

- Time/Location: May 24-27, LBNL Shyh Wang Hall
  - Free Wifi, Adjacent Break Room
- Catering and web hosting provided by the NSSC

Many agenda items were mentioned yesterday (policies, formats, implementation…)





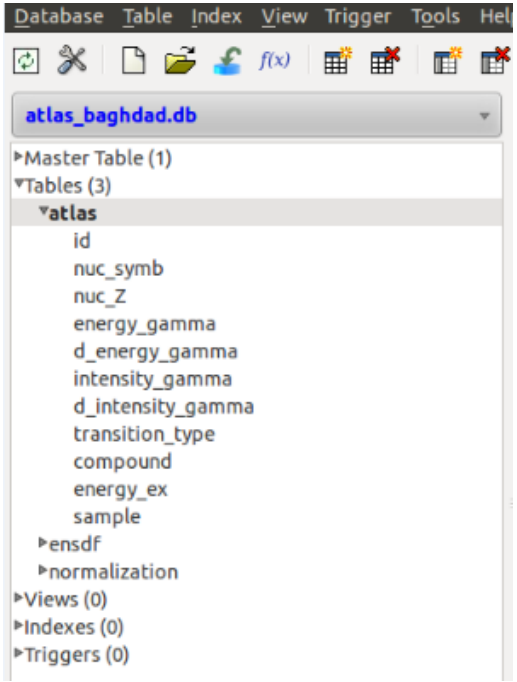
Baghdad (n,nγ) ATLAS (A.M. Hurst)

- The goal of the "Baghdad Atlas" project is to produce a database of γ-rays from (n,n'γ) from reactor fast neutrons*. The Atlas contains:
  - Energies and intensities for 7090 γ-rays from 105 elemental and stable targets
  - Level scheme data c. 1975 (≈70% of γ-rays placed)
- The ATLAS was scanned and digitized by Sleaford & Walston (LLNL)
- It was then vetted and made into a set of CSV files and an SQL database by A.M. Hurst & S. Chong.
- Two releases are planned:
  - <u>Applications Version</u>:
    - γ-ray energy & intensity (*DONE*)
    - Corrections for doublets done using ENSDF

      Ready for dissemination
  - <u>Research Version</u>:
    - Level data will be updated from ENSDF
    - (n,n'γ) data from other experiments entered.
- The research version can serve as the basis of a horizontal evaluation of (n,n'γ)

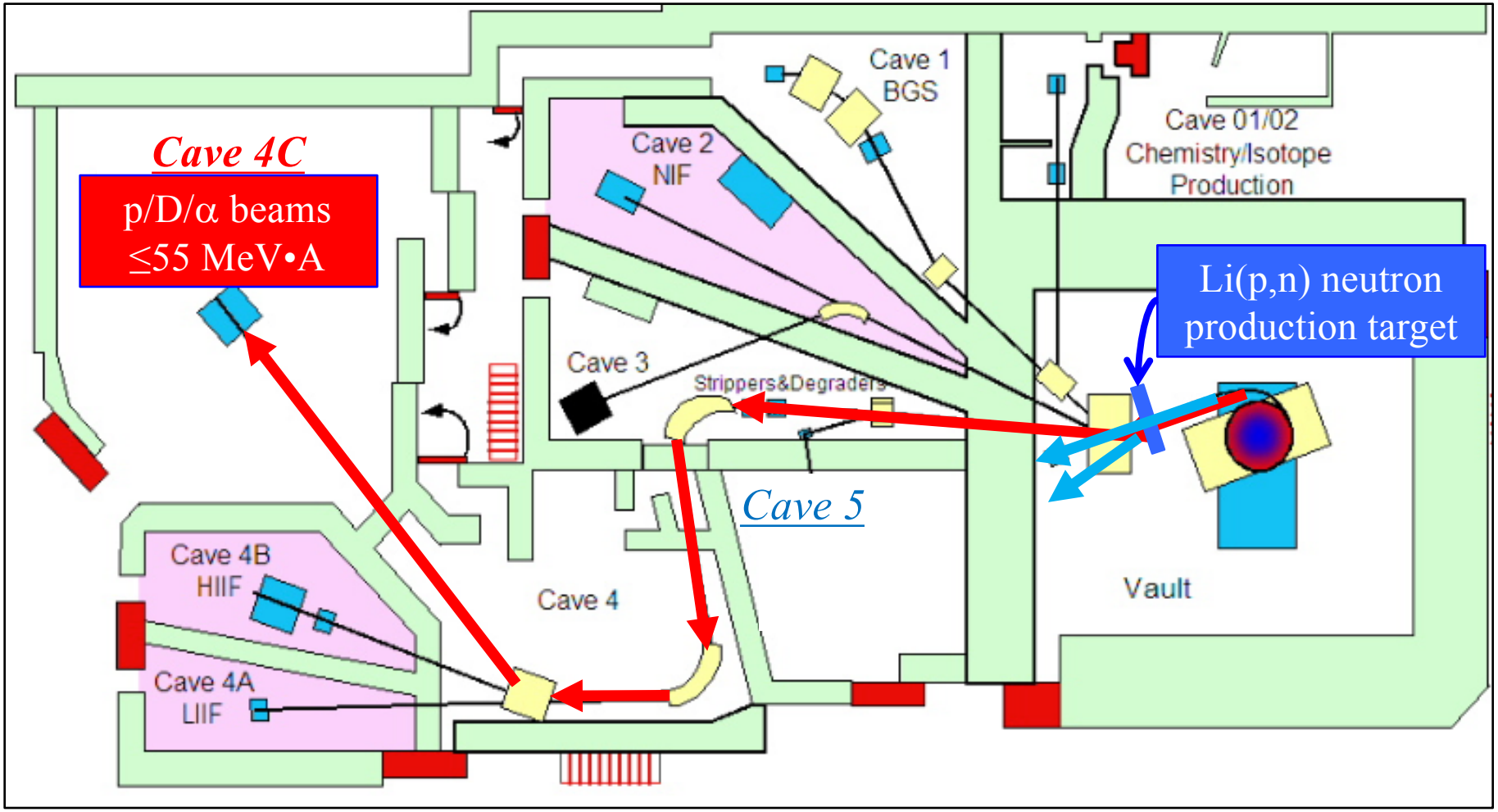
ATLAS

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

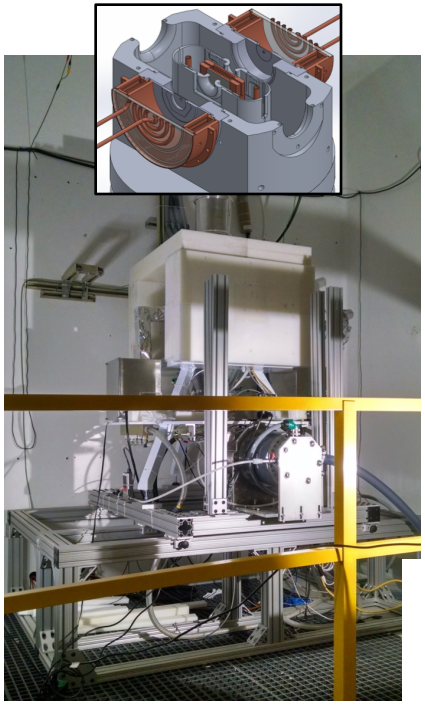


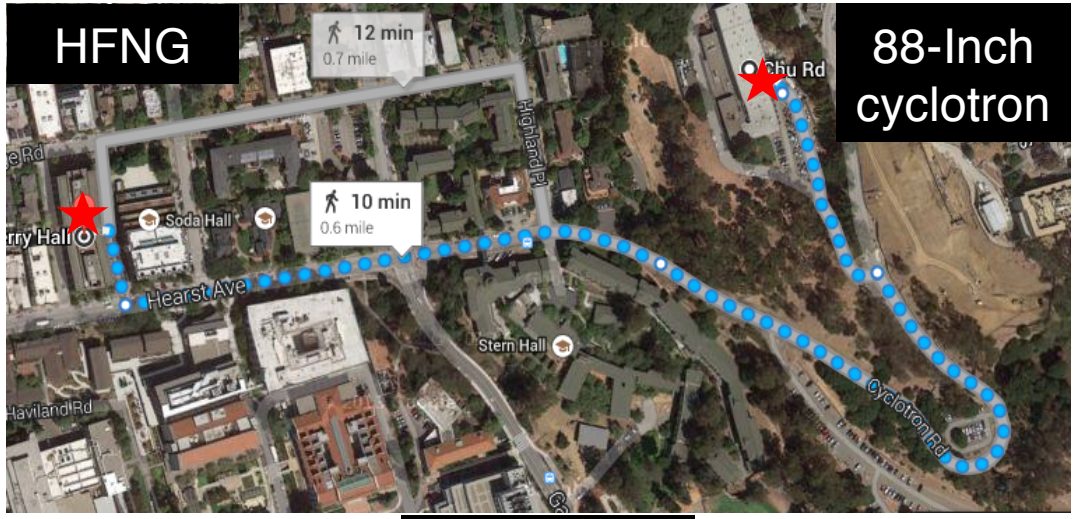
Warning: 290 errors were found in the OCR file!

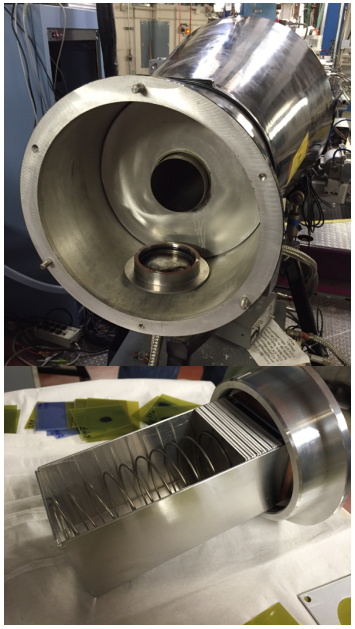
We've launched a medical isotope production cross section program with J. Engle (U. Wisc./LANL), E. McCutchan (BNL) and C. Nesaraja (ORNL)



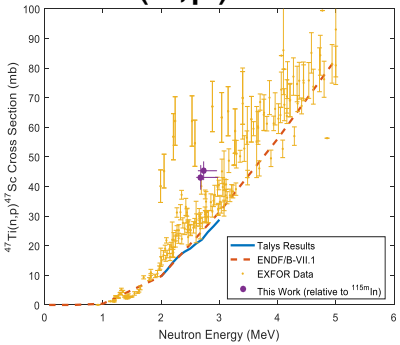
We have the first resulst from our student-led medical isotope production cross section measurements program



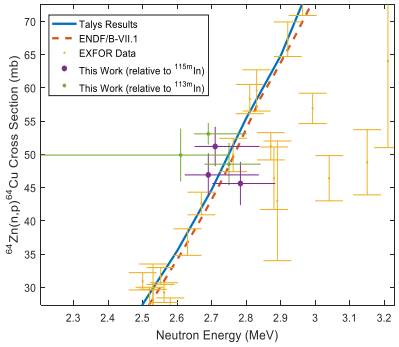




^{47}Ti(n,p)^{47}Sc

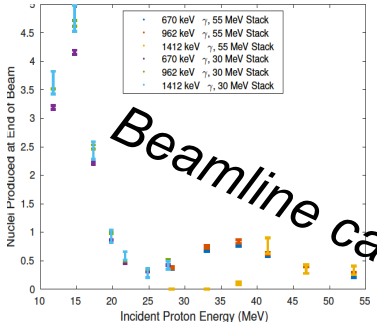


^{64}Zn(n,p)^{64}Cu



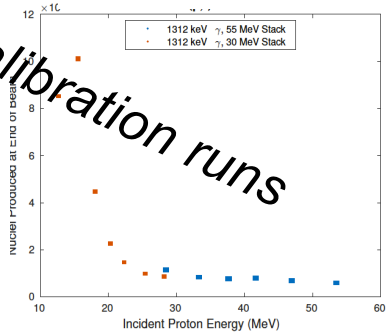
A. Voyles

^{nat}Cu(p,x)^{63}Zn



Beamline calibration runs

^{nat}Ti(p,x)^{48}V



We've prepared our first HFNG manuscript and will run the the first 88-Inch experiments in December: ^{54}Fe(p,α)^{51}Mn and ^{86}Sr(p,n)^{86}Y (A. Voyles CSEWG talk)

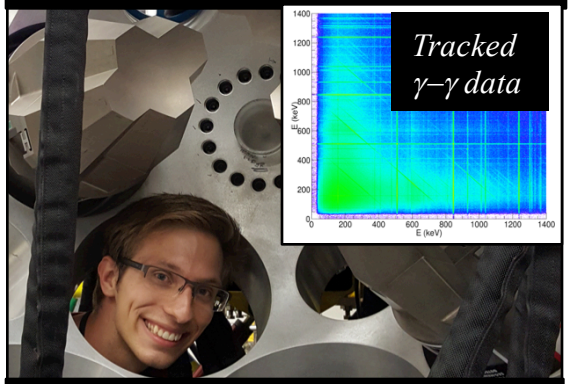
Our student Leo Kirsch is collaborating with the NSD structure group using $^{56}Fe(p,p'\gamma)$ GRETINA at ANL

The goals of this experiment include:

- *Determining E vs. M character of the RSF "up-bend" (M. Jones – LBNL)*
- *Improving discrete structure data (6 new levels added from 5.7-6.3 MeV)*
- *Getting Leo a Ph.D. ☺*

Level (keV)	E_γ (keV)	$t_{1/2}$ (fs)	ENSDF (fs)	Comments
2657 $2_2^+ \rightarrow 2_2^+$	1810	33(2)	21(1)	QC feeding
2960 $2_3^+ \rightarrow 2_2^+$	2113	20(4)	28(3)	2nd peak in window
3120 $1_1^+ \rightarrow 2_2^+$	2273	20(8)	19(1)	Agreement
3123 $4_2^+ \rightarrow 4_1^+$	1037	51(4)	47(12)	Agreement
3370 $2_4^+ \rightarrow 2_1^+$	2523	19(2)	17(3)	Agreement
3445 $3_1^+ \rightarrow 2_1^+$	2598	52(9)	29(5)	Low Statistics

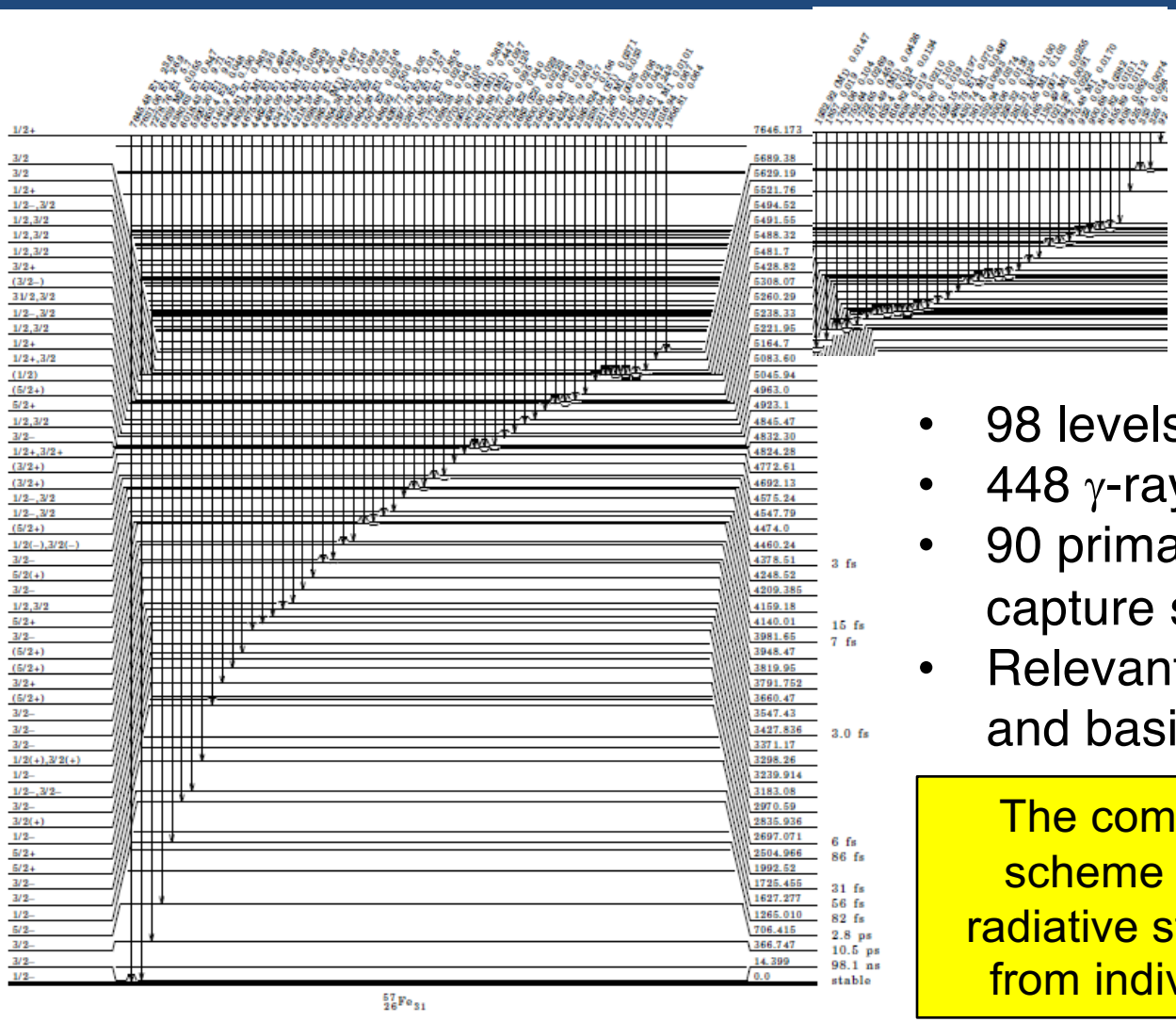
GRETINA



*Leo Kirsch**
(UCB Grad student)

*Stockpile Stewardship Graduate Research Fellow

We've also created a near complete level scheme of ^{57}Fe from an $^{56}Fe(n,\gamma)$ experiment at Budapest



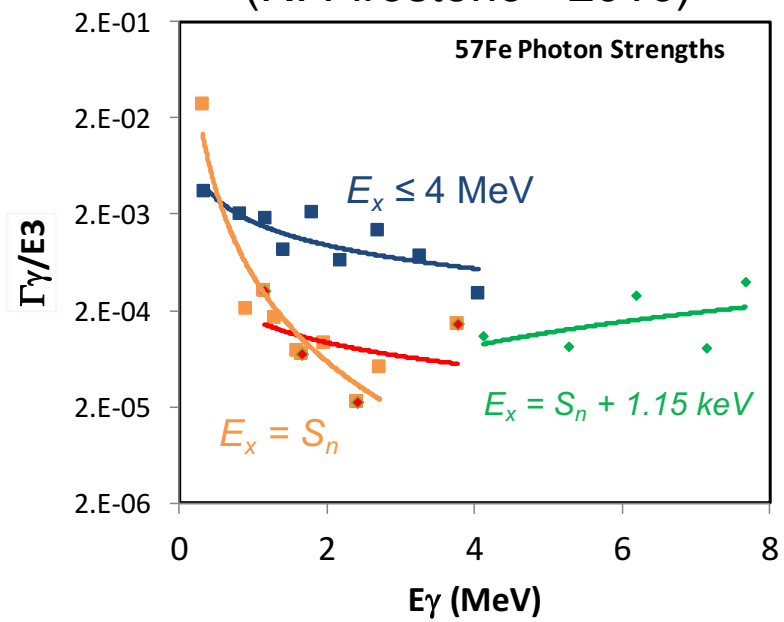
R.B. Firestone submitted to PRC

- 98 levels plus capture state
- 448 γ-rays in the level scheme
- 90 primary γ-rays from the capture state
- Relevant to both application and basic science

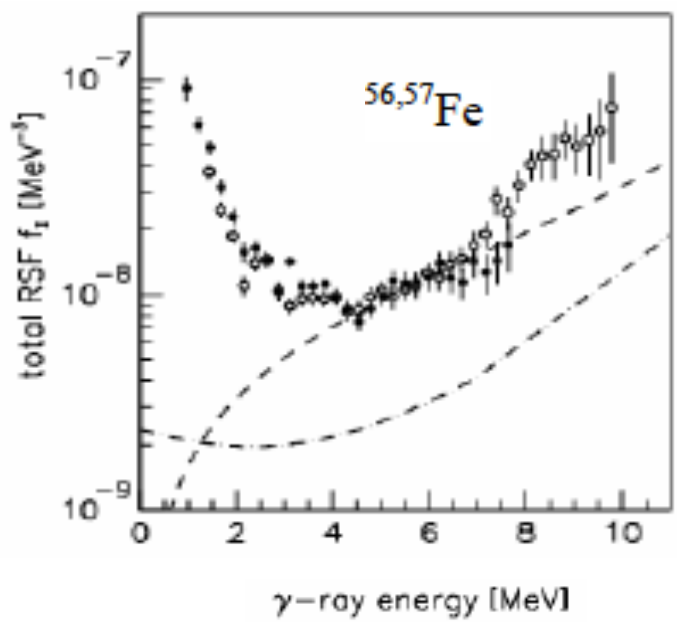
The completeness of the level scheme allows us to build the radiative strength microscopically from individual γ-ray transitions

The ^{57}Fe capture gamma data supports the idea of significant low energy strength in the Quasicontinuum

Average Measured Dipole Strength in ^{57}Fe (R. Firestone - 2016)



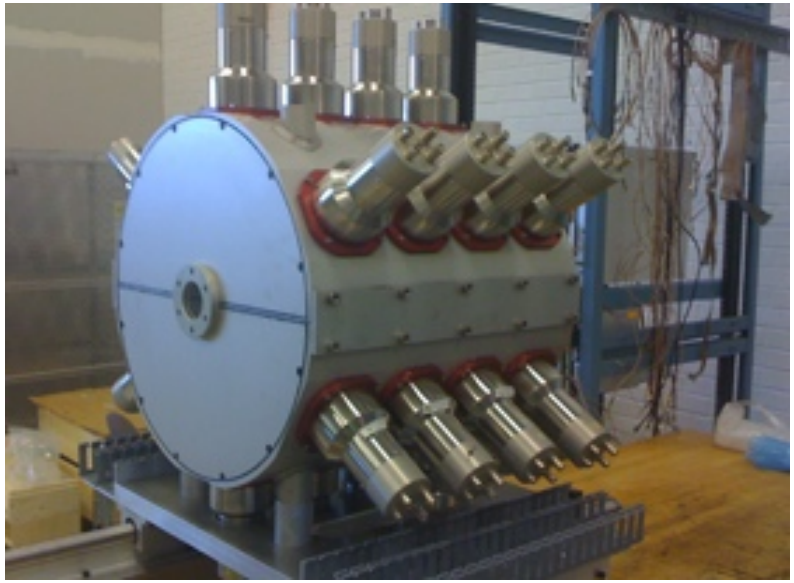
^{56,57}Fe Measured Dipole Strength (E. Algin – 2000, A. Voinov - 2006)

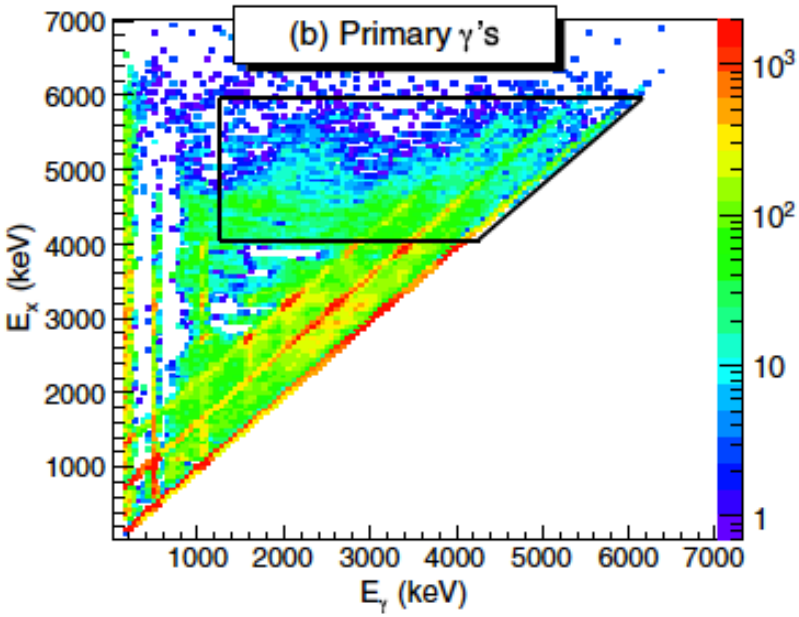


This work is part of a newly-approved IAEA Coordinated Research Project to create the first evaluated database of radiative strength

The β-Oslo method extends these studies to RIBs

A. Spyrou *et al.,* Phys. Rev. Lett. 113, 232502 (2014).





UCB NSSC Ph.D. student Adriana Ureche is part of this effort

$^{60}Mn \xrightarrow{\beta-} {}^{60}Fe$ (NSCL Experiment 15034) – 11/1-5/2016

$^{93}Rb \xrightarrow{\beta-} {}^{93}Sr$ (NSCL Experiment: 15136) – Approved Ph.D. Project

Ongoing Evaluation Activities

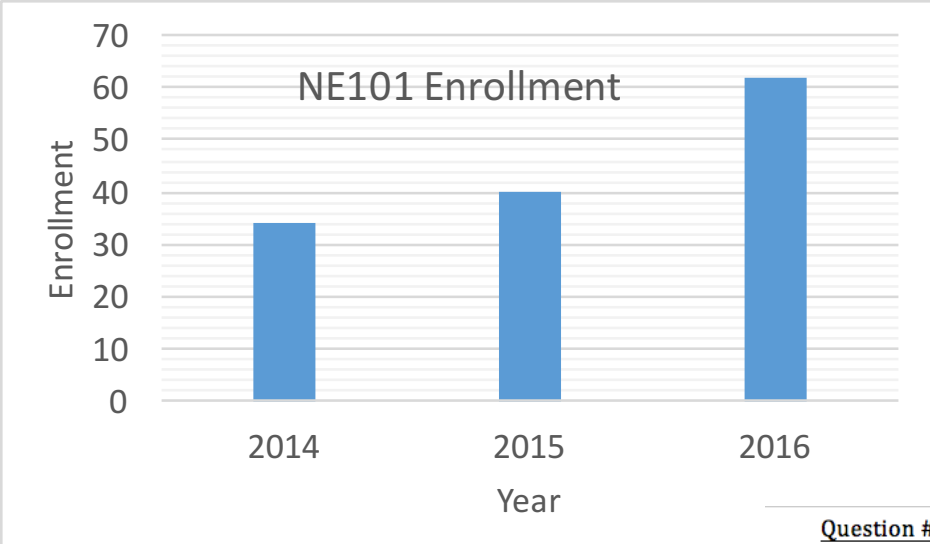
- XUNDL compilations by Basunia, Bernstein, Hurst and Batchelder
  - Specialization on neutron capture papers
- A-chain evaluations:
  - Basunia (59)
  - Bernstein (232 w/Nesaraja)
  - Batchelder w/Hurst (186)
- Single nuclide evaluations as follow-on to EGAF/capture gamma work (Hurst)
  - ^{186}Re (with Batchelder), ^{140}La, ^{181}W
- Expanding the "Research Version" of the Atlas into a (n,n'γ) evaluation in its own right

Summary

- Service to the Basic Science Community
  - Providing a reliable source of evaluated nuclear structure and decay data (ENSDF & XUNDL) for researchers worldwide
  - Helping improve our understanding of quasi-continuum nuclear structure (RSF) in reaction modeling & astrophysics
  - Helping to train the next generation of nuclear scientists and engineers
- Service to Applied Nuclear Science and Technology
  - Addressing long-standing issues in the production of radionuclides for medicine and national security
  - Improving neutron transport modeling through targeted measurements of (n,γ) and (p,p'γ)

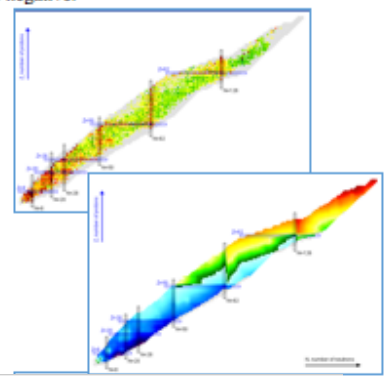
Our group's goal is to encourage interactions between the Basic and Applied Nuclear Science Communities

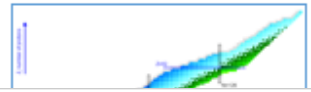
USNDP in education (at least at UCB)



Question #4: Nuclear Mix and Match
Write the appropriate quantity from the list below in the appropriate chart of the nuclides figures. Feel free to state the reasoning behind your choices. The color code is as follows: **Red** > **Orange** > **Yellow** > **Green** > **Blue**. **Note:** **Blue** is negative.

1. Q-value for β- decay
2. Q-value for β+ decay
3. Proton Separation Energy
4. Q-value for α-decay
5. Binding Energy/Nucleon
6. Q-value for β-decay followed by neutron emission.
7. Neutron Separation Energy
8. Energy of the 1st excited state
9. Energy of the 1st 4+ state divided by the energy of the 1st 2+ state





Question 2: The production of ^{239}Pu in a nuclear reactor.

a) What is the approximate rat
commercial reactor whose
($\sigma_{(n,\gamma)}$=98.7 b and $\sigma_{(n,f)}$=585

237Pu 45.64 D ε: 100.00% α: 4.2E-3%	238Pu 87.7 Y α: 100.00% SF: 1.9E-7%
236Np 1.53E+3 Y ε: 86.30% β-: 13.50%	237Np 2.144E+6 Y α: 100.00% SF≤ 2E-10%
235U 7.04E+8 Y 0.7204% α: 100.00% SF: 7.0E-9%	236U 2.342E7 Y α: 100.00% SF: 9.4E-8%

May 2016 Nuclear

Question #1

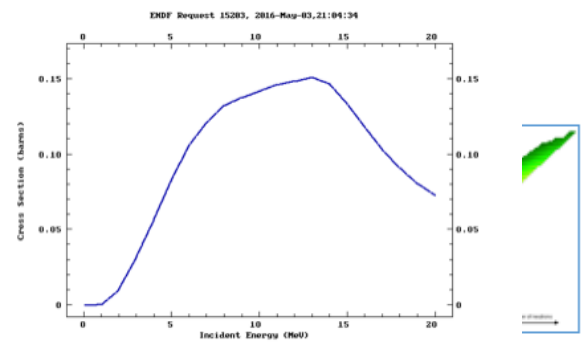
A neutron generator is being used to ger
The decay level scheme for ^{47}Sc is show
weights of ^{47}Sc and ^{47}Ti are both 47 g.

a) What particles are emitted in the
What are their maximum and mi

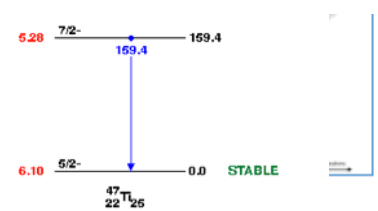
b) Which state in ^{47}Ti is most strongly populated in the decay of ^{47}Sc? How did you come to this conclusion? (Note: You may assume that the Fermi function for Ti is independent of energy.)

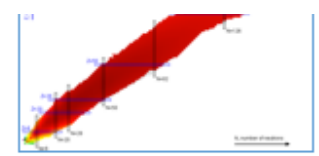
Question #2:

The ^{47}Sc was produced via irradiation of a 1 gram target of 100% enriched ^{47}Ti by a constant stream of 14 MeV neutrons over the course of 1 hour. A plot of the evaluated cross section for the reaction responsible for the production of ^{47}Sc is shown in the figure on the right.



a. Write the reaction which formed the ^{47}Sc using nuclear reaction notation.





Summary

- The past 2 years have seen an exciting new expansion of the nuclear data program at LBNL with a new connection to campus
- The new campus component is providing a natural connection to the applications community
- The NSSC renewal with its new Nuclear Data Cross-cutting Area, is bringing a new connection to Defense/Homeland Security Programs

Extra Slides

NP saw an opportunity to engage the outside community via Nuclear Data and they asked us to host a new workshop

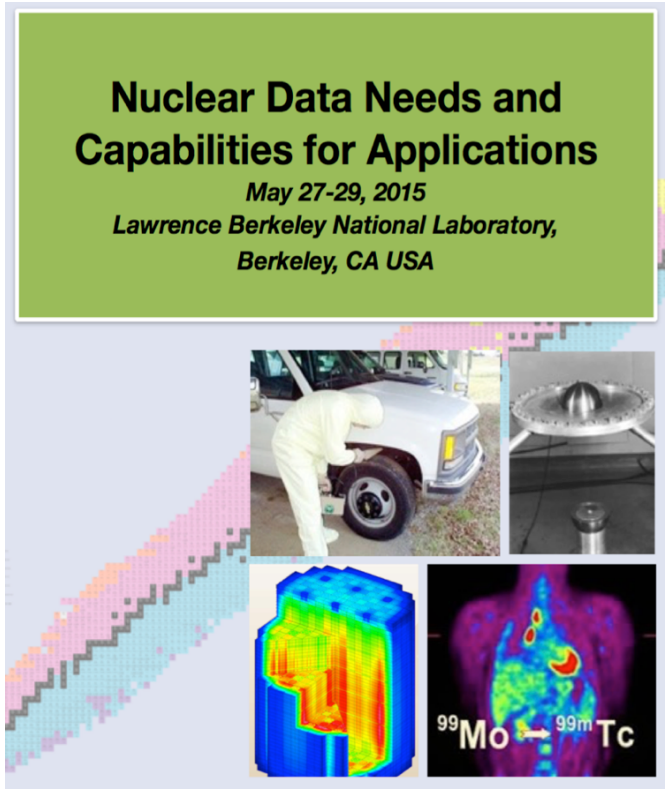
- 101 Participants and registrants from 30 institutions
- Days 1 & 2 features plenary talks on:
  - The US Nuclear Data Program (1)
  - *Nuclear Energy/Dosimetry Data Needs (5)*
  - *National Security Data Needs (6)*
  - *Isotope Production Data Needs (4)*
  - Capabilities/Facilities (8)
- Day 3: *Topical* breakout sessions

Nuclear Data Needs and Capabilities for Applications

May 27-29, 2015

Lawrence Berkeley National Laboratory, Berkeley, CA USA

The NDNCA whitepaper guides most BAND group activities



Editors

Bernstein, Lee (LLNL/LBNL/UCB)
Basunia, M. Shamsuzzoha (LBNL)
Brown, David (BNL)
Hurst, Aaron (LBNL)
Kawano, Toshihiko (LANL)
Kelley, John (TUNL)
Kondev, Filip (ANL)
McCutchan, Elizabeth (BNL)
Nesaraja, Caroline (ORNL)
Slaybaugh, Rachel (UCB)
Sonzogni, Alejandro (BNL)

Cross-cutting needs

1. Dosimetry Standards for E_n up to 60 MeV to support IFMIF, ADS, and spallation sources"
2. Fission "the 'Mother of All Fission Experiments,' where *TKE(A)*, ν, γ's fragment yields for a range of Actinides for E_n=thermal-20+ MeV".
3. ***Decay Data & γ–Branching Ratios* including an IAEA list of decay data for "certain medical isotopes"**
4. ***Neutron Transport Covariance Reduction*: Particular need for actinide (n,x) cross sections from 1-1000 keV"**
5. Expanded Integral Validation: such as semi-integral data (e.g., pulsed sphere) to diagnose (n,n_{el}), (n,n_{inel}) shortcomings "
6. Antineutrinos from Reactors: with a specific call for new data for $^{235,238}U$ and $^{239,241}Pu$…fission yields for odd-odd nuclei and β-spectral measurements"

http://bang.berkeley.edu/events/NDNCA/whitepaper