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Weapons Science Program Integration Nuclear Physics

Friday, September 13, 2013

Todd Bredeweg, Carol Burns, Mark Chadwick, Skip Kahler, Bob Little, Steve Sterbenz, Morgan White and Chuck Wilkerson

Special thanks to the cast and crew who execute our Nuclear Physics Programs!

Abstract

Over the last several months, ASC, SC, ICF, and ADX management have begun a process to improve integration of the weapons science programs, and that will hopefully better be able to maintain critical capabilities at the lab in view of funding vagaries. We began by taking a high level look at the body of work presently being executed, the needs of the DSW program, and the work scope being requested by NNSA. From that high level view, we've identified 11 high level groupings that represent the strategic investment areas for weapon science within the ASC, SC and ICF programs. These categories and the approximate level of investment in FY 13 are shown herein. These investments do not include LDRD, DSW R&D, or any leveraged WFO/GS work. This presentation covers the Nuclear Physics portfolio.

Description of each area

Non-Pu Materials Research

- All materials research that isn't Pu or dynamic HE work or nuclear. Scope includes EOS, strength, damage, opacities of all materials, including HE, but excluding Pu. This includes implementing and V&V of material models in codes, developing and calibrating material models, non-HE driven experiments, and analyzing experiments.

Hydro and Shock Physics Research

- All mix and ejecta modeling and experiments. All dynamic HE experiments, other than sub-crits, including pRad, DAHRT hydros, all small-scale dynamic HE experiments, flux generators (but not loads), and experiment data analysis. This includes developing, calibrating, and V&V of HE burn models. HE material properties such as EOS goes into Materials. JMP is included here.

Nuclear Physics

- **All nuclear physics, including rad-chem, code implementation and V&V.**

Nuclear Design

- Certification and assessment technology, engineering V&V, and data archiving

FY13 Strategic Investment Balance

Research Area	FY 13 Investment ($M)	Percent of Total Investment
Integrated Codes	39	11
Computer Operations	62	18
Computer Platforms	37	11
Computer Science	17	5
High Energy Density Research	37	11
Subcritical Experiments	19	5
Plutonium Research	21	6
Non-Pu Materials Research	39	11
Shock Physics and High Explosive Research	32	9
Nuclear Physics	10	3
Nuclear design - certification and assessment technology	36	10
Total	**~349**	

Nuclear Physics
or, All Things Nuclear

Capabilities Required

Theory and Modeling

Evaluation and Processing Codes

Experiments at National Facilities

- **NCERC**
- **TUNL**

Experiments at LANL

- **LANSCE WNR**
- **LANSCE Lujan**
- **C-NR Radiochemistry**
- **C-NR Count Rooms**

Diagnostics

Interface Control

Materials characterization

Nuclear design

Archival data

Integrated Codes

Computer Operations

GS Programs

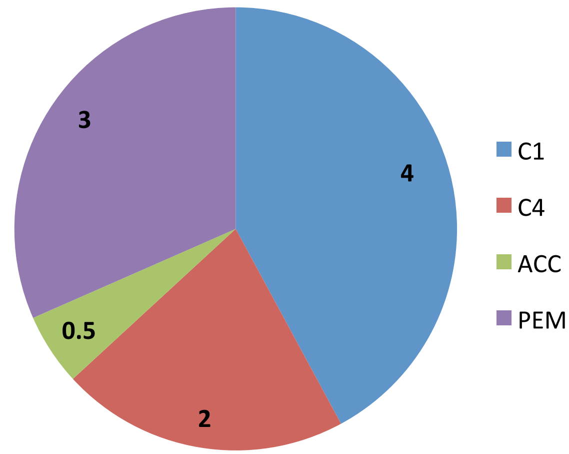
RTBF

LLNL

Nuclear Energy (DOE/NE)

National Criticality Safety Program (DOE/NCSP)

FY14 Funding ($M)

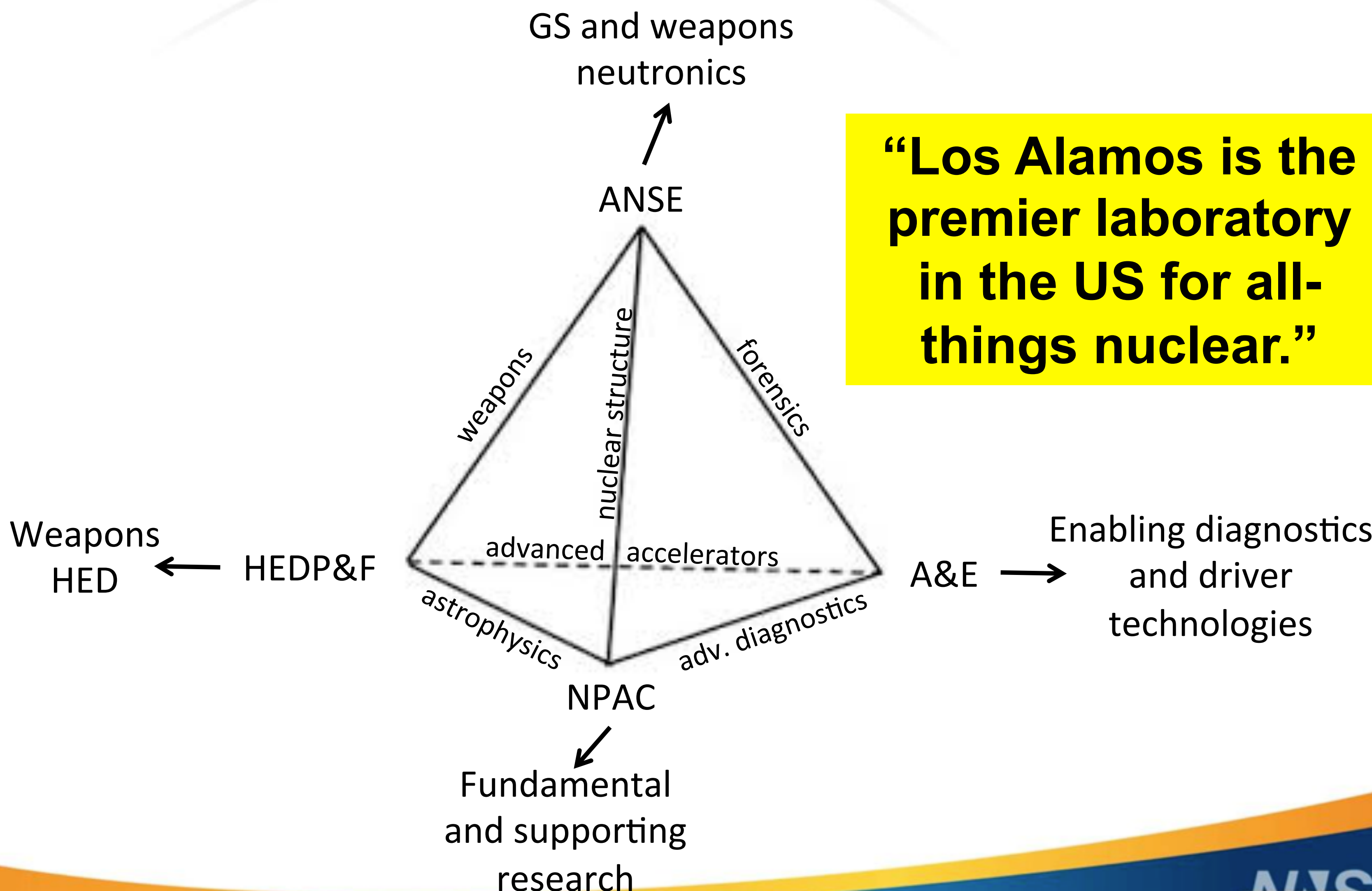


	FY13	FY14
C1	4.1	3.9
C4	2.4	2.0
ACC	0.3	0.5
PEM	3.9	3.0

Outline

- Role of nuclear science in understanding nuclear weapons performance through diagnostics
- Drivers and priorities
- Experimental facilities and activities
- Theory, modeling, evaluation, processing, libraries
- Verification and validation (V&V)
- Linkages to GS and other programs
- Gaps

Nuclear and Particle Futures
A (Soon-To-Be) New Laboratory Pillar



"Los Alamos is the premier laboratory in the US for all-things nuclear."

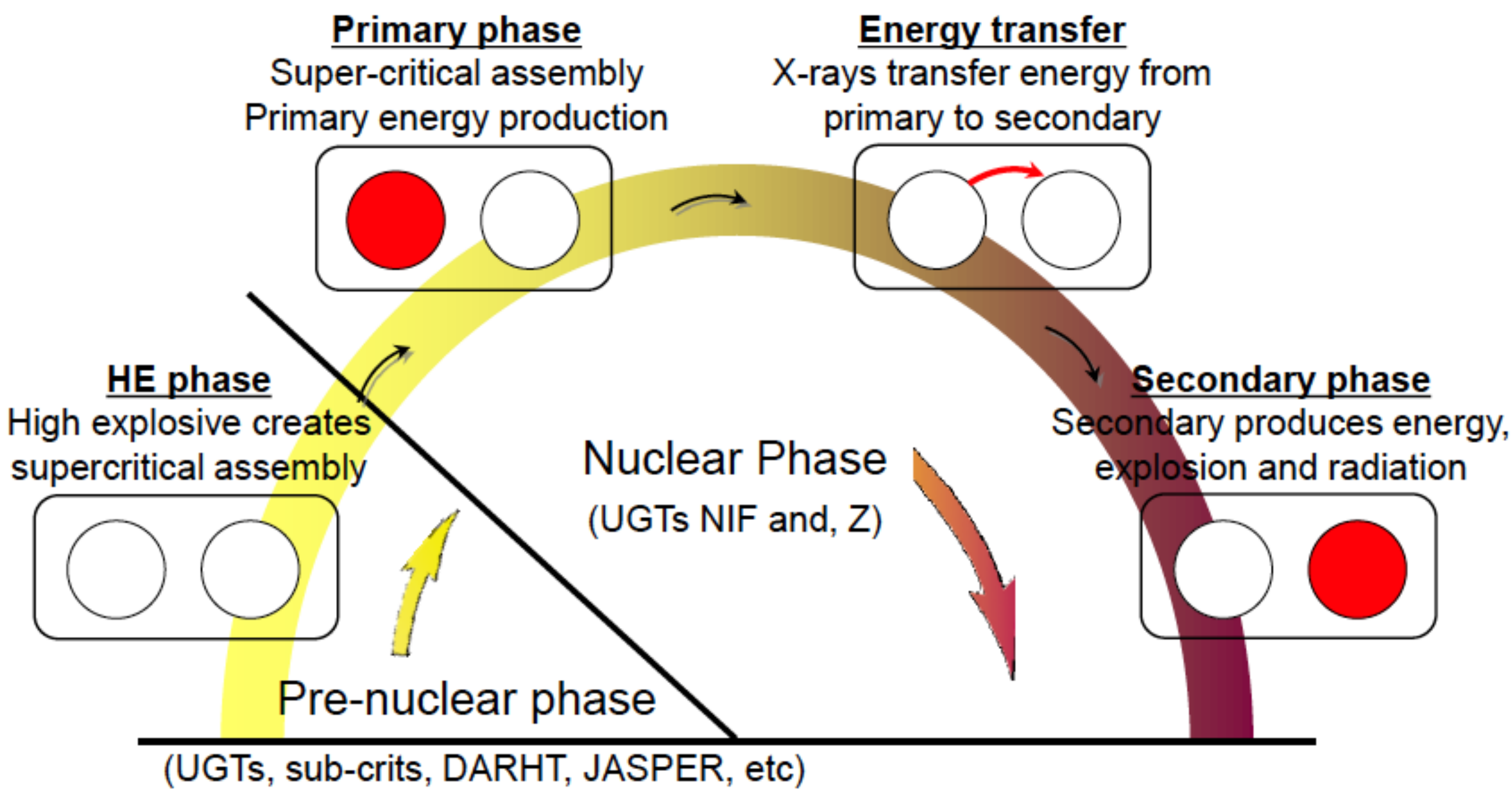
Stockpile Stewardship Delivers

- Confidence in the nation's nuclear deterrence
- Credible alternatives to UGTs to resolve performance questions
- Confidence in enabling technologies for the broader national security missions
- Smarter LEP decisions
  - Determine lifetime for components more accurately
- Faster resolution of stockpile issues with utilization of science and advanced computing

"… <u>The entire nuclear deterrence posture is inherently rooted in and inseparable from scientific and technical excellence</u>. Critical decisions ranging from annual assessment of specific systems to changes in manufacturing methods, testing, and deployment are inevitably derived from highly technological methodologies. In order to deal with the changing face of deterrence, including more widely dispersed nuclear knowledge, the U.S. must continue to maintain excellence in nuclear-based science and technology that is second to none." *

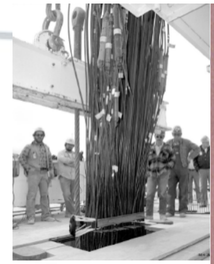
** FY 2012 Stockpile Stewardship and Management Plan, Report to Congress, NNSA, April 15, 2011*

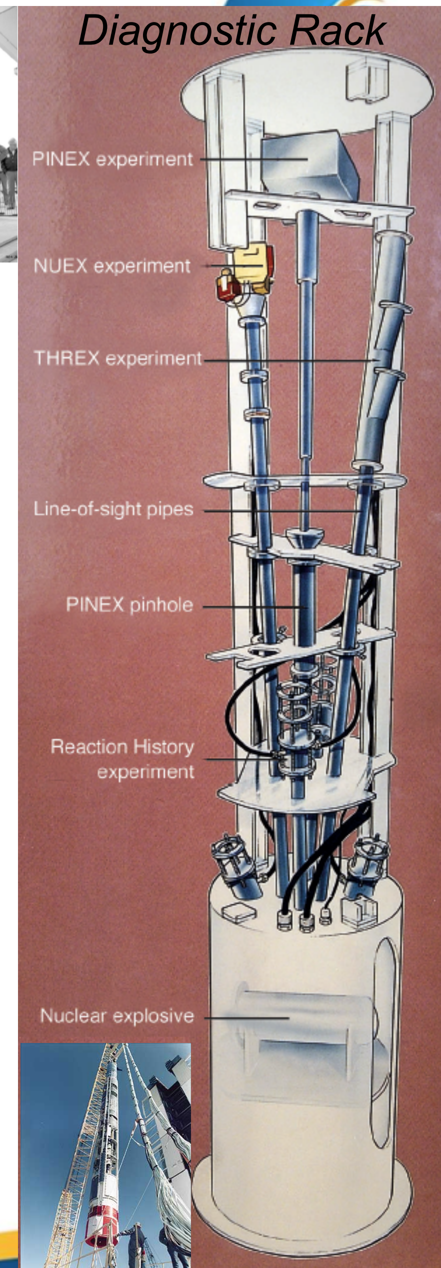
Nuclear Weapon Function Overview

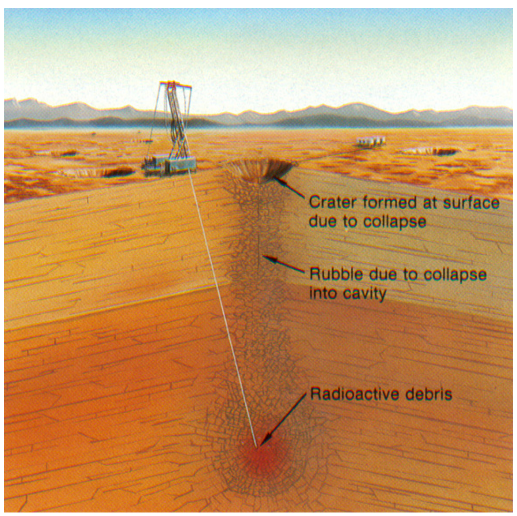


The Stockpile Stewardship Program develops and deploys experimental tools to accurately understand and predict the physics and materials properties at each phase of the nuclear explosives package (NEP).

Nuclear Test Diagnostics Are, Well, Nuclear







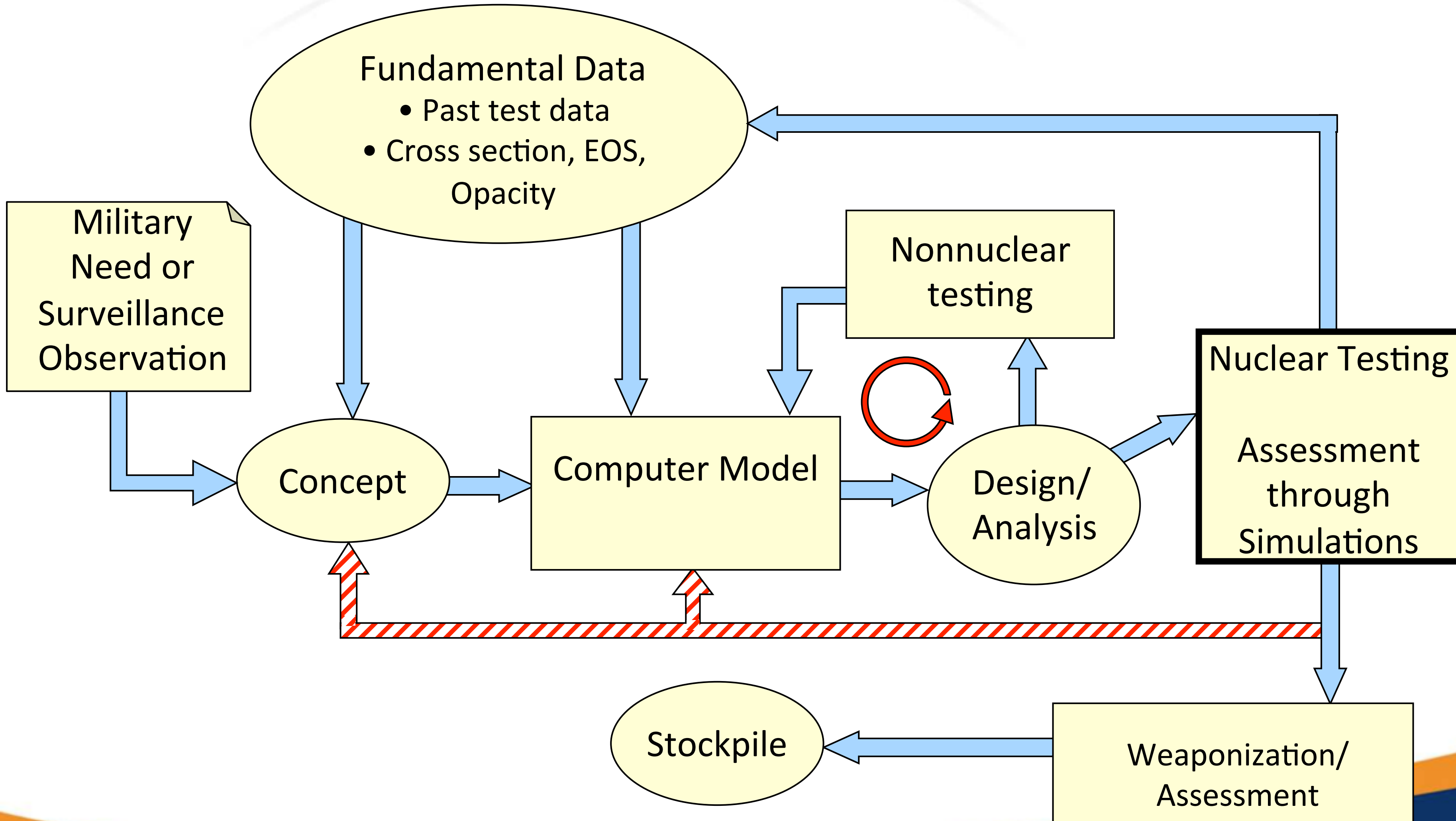
- Rack (with device) lowered to bottom of hole (4-12 ft dia., 650-2300 ft deep)
- Hole is filled with various materials (stemming) to preclude venting

- Nuclear device emits radiation (neutrons, gamma rays, and x-rays)
- Measured by various experiments (consist of line-of-sight pipes, detectors, cables, signal processing and data recording hardware)

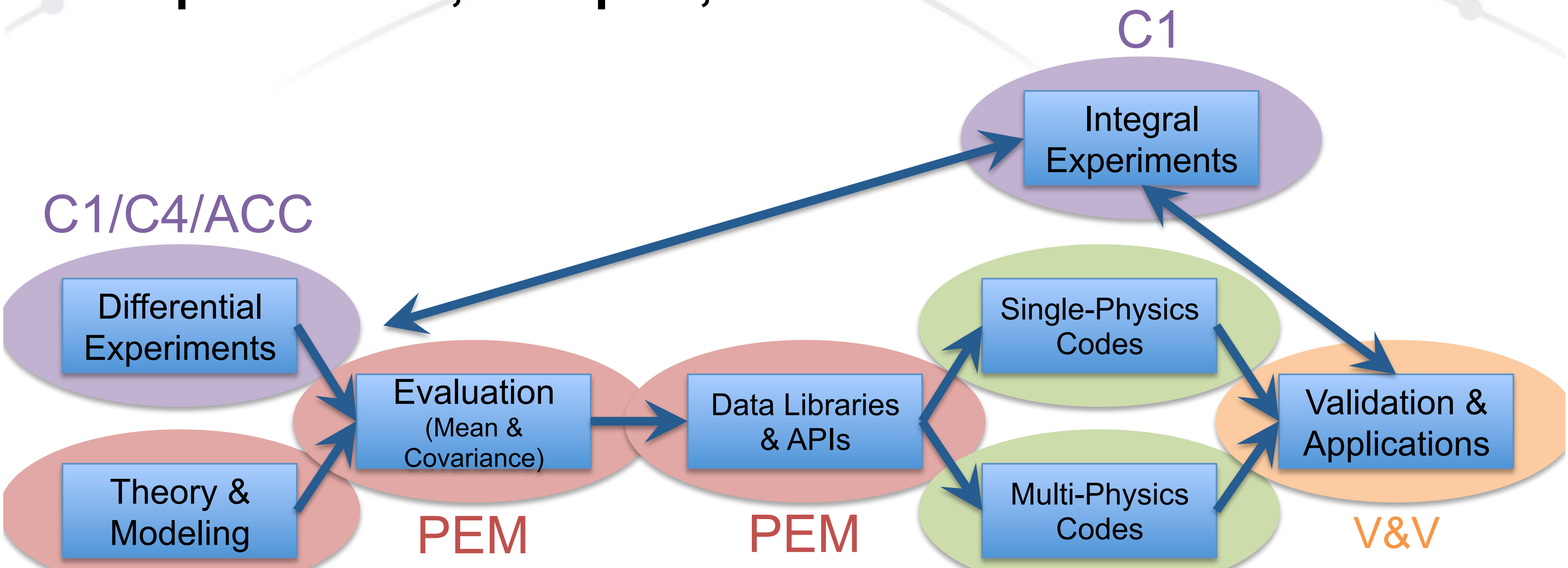
- Radiochemistry provides another diagnostic technique
- Small quantities of material placed at various locations in the device
- Transformed via neutron interactions
- Drillback recovers samples that are analyzed to assess performance

adapted from LA-UR-05-7608

Scientifically Informed Design and Analysis for Stockpile Stewardship Has Been Adapted From The Testing Era.



The Nuclear Science Enterprise at Los Alamos Is Comprehensive, Complex, and Coordinated



PEM

Cross-section and emission measurements

Heuristic and advanced theory development

Expert judgment and evaluation tools

ENDF/B libraries
-neutron
-gamma (photons)
-charged particles
-decays

Nuclear data processing

Nuclear data libraries
-neutron/photon
-charged particles
-thermonuclear rx
-radchem

Standardized interfaces

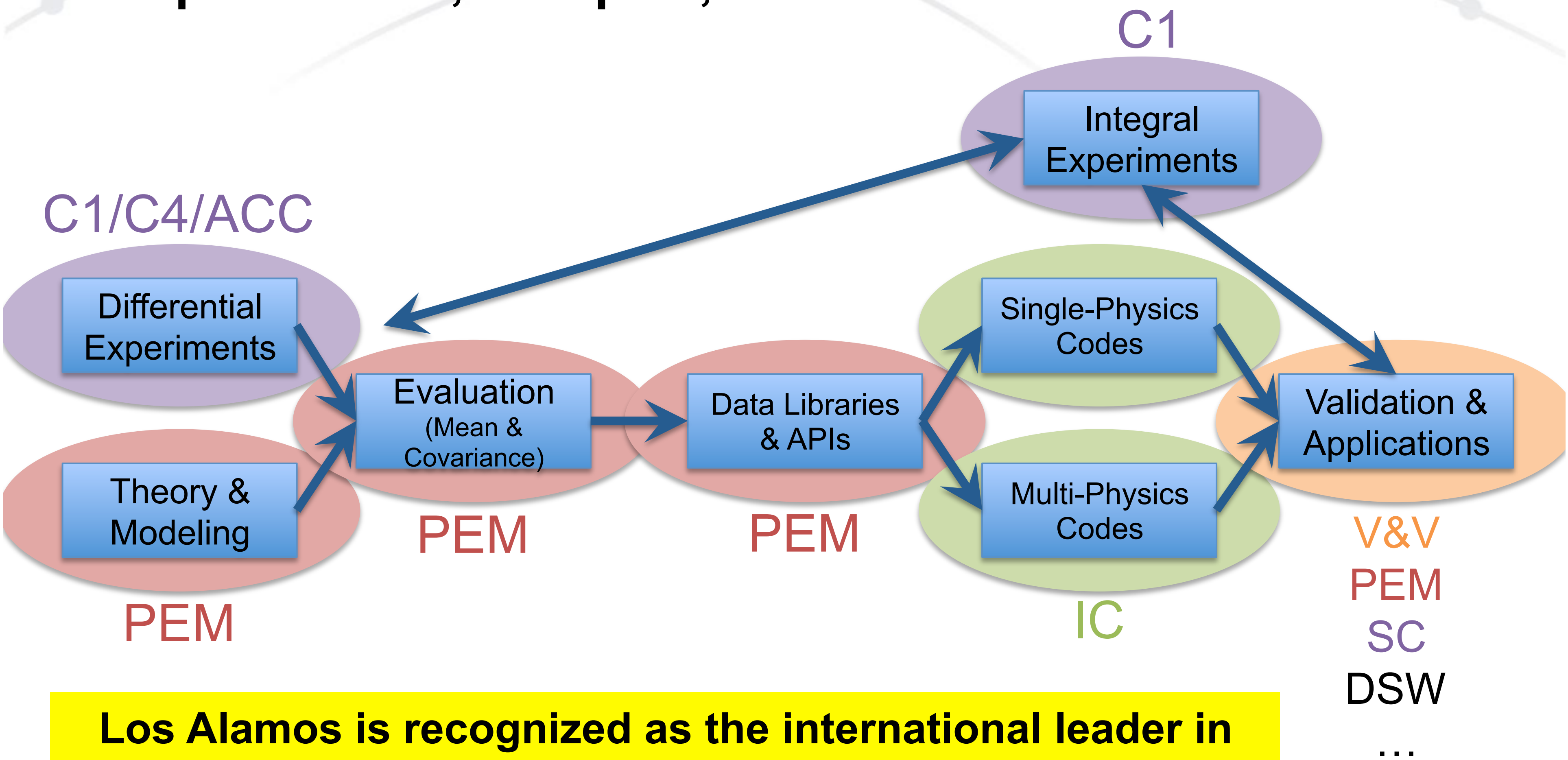
IC

Integral data

Single-physics
- critical assemblies
- pulsed spheres
Multi-physics
- NTS data

V&V
PEM
SC
DSW
…

The Nuclear Science Enterprise at Los Alamos Is Comprehensive, Complex, and Coordinated



Los Alamos is recognized as the international leader in many aspects of the global nuclear science enterprise.

How Priorities Are Determined

- Nuclear Physics was one of the five Technical Working Groups at the start of the National Boost Initiative
  - Nuclear science is key to understand and diagnose weapons performance
- The National Boost Initiative, Primary Assessment Plan, Secondary Assessment Strategy, and Predictive Capability Framework all identify many advances needed in nuclear science
- In 2011, the nuclear science community assessed these varied needs and created the "Radiochemistry Roadmap" (a joint LANL/LLNL report) to organize and prioritize this work
  - A comprehensive plan across the nuclear science phase-space

The ultimate priority is to deliver the required capabilities in nuclear science to the weapons design community. This can only be done through tight integration of Science Campaigns and ASC.

Untangling Compensating Errors Will Require Coordinated Efforts to Improve Underlying Fundamental Data Constrained by Relevant Integral Experiments (1)

- Uncertainty quantification studies (2005-2009) identified uncertainties in nuclear data as a critical component to understanding nuclear weapons performance
  - These efforts led directly to our current Advanced Fission Measurements
  - However, “It is, we believe, premature to establish long-range priorities for the program based [only] on current sensitivity analysis.” JASONs 2008
  - Other key measurement campaigns have been motivated by expert judgment

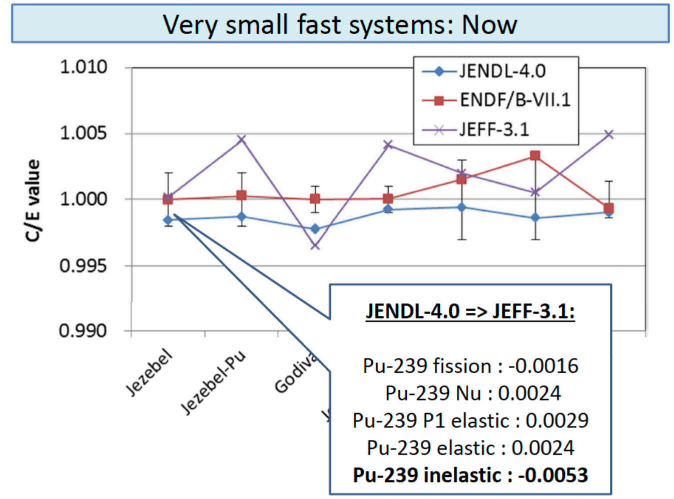
Nuclear driven uncertainties can be constrained using a combination of improved differential (LANSCE) and integral (NCERC) experiments and advanced theory.

Untangling Compensating Errors Will Require Coordinated Efforts to Improve Underlying Fundamental Data Constrained by Relevant Integral Experiments (2)

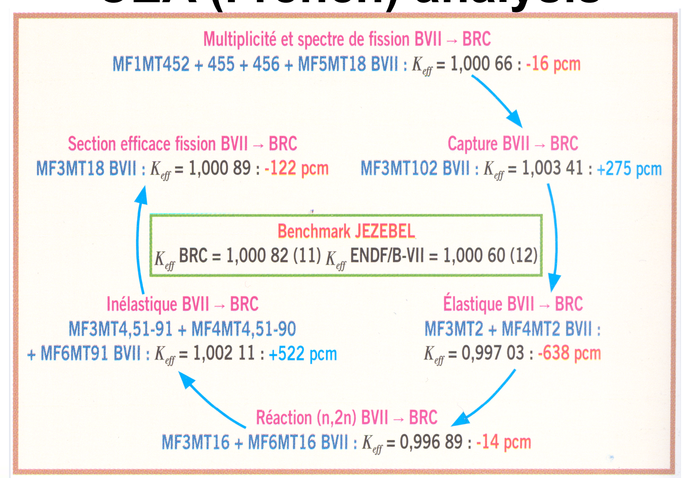
- Delayed critical assembly experiments are:
  - the most precise measurements we can make of neutron reactivity
  - the integral experiments we use to constrain overall uncertainties in neutron simulations
- Critical assembly analysis shows that changes between differential data evaluations are 2-5x larger than the overall integral experimental uncertainty.

The international consensus is that we are getting the "right" neutronics answer for the wrong reasons. However, the uncertainties due to nuclear data can be reduced with new capabilities to the a point that will allow NTS data to be used to better discriminate between issues in other physics.

Japanese analysis



CEA (French) analysis



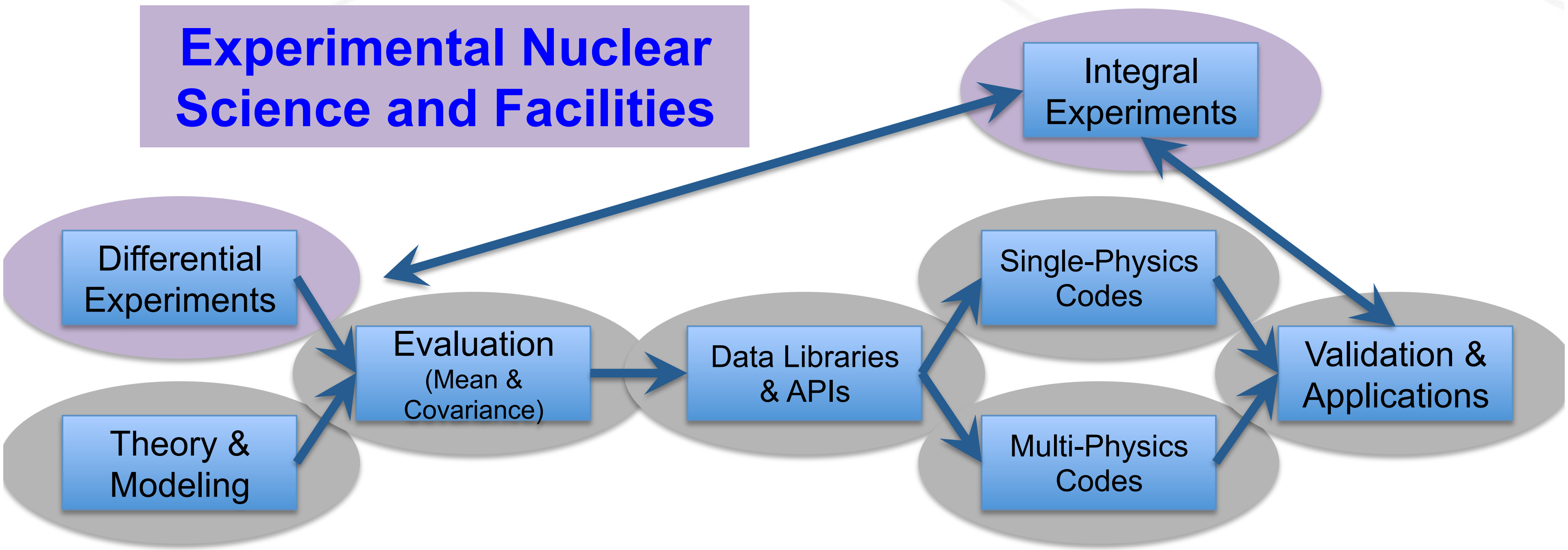
Major Technical Priorities

- Precise actinide (fission) cross sections, spectra, and yields
- Neutron capture on actinides and radiochemistry detectors
- We must deliver an improved capability to perform routine sensitivity and uncertainty analysis within integrated weapons studies
- Enhanced use of all available nuclear diagnostics within validation and certification efforts

Our focus is on delivering ever improving data and capabilities to our customers.

- Longer range we need to better understand charged particles and nuclides off the line of stability

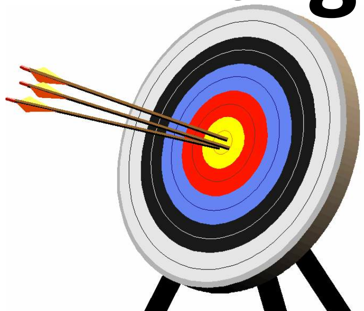
The Nuclear Science Enterprise at Los Alamos Is Comprehensive, Complex, and Coordinated



We have developed world-class new capabilities to meet the weapons physics mission, but do rely on some facilities that are at risk.

Nuclear Science Experiments Require Unique Facilities That Are A Precious National Resource

Targets



Sources

Detectors

- High-Importance Targets
  - Uranium, plutonium, americium, …
  - Light isotopes up to oxygen
  - Structural materials
  - Dosimetry (detector) materials
- Incident particles
  - neutrons from 1E-11 to 30 MeV
  - gammas from 1 keV to 30 MeV
  - light ions from 1 to 30 MeV
  - heavy ions: ??
- More comprehensive detectors
  - Total xs, absorption, scattering, fission, nubar, emission distributions
  - Sooner or later, someone asks for all reaction channels, all emissions

Experiments used as the basis for creating evaluated data require benchmark level characterization of the sources, targets and detectors

Facilities – LANL and Other With LANL People or Direct Contracts

- LANSCE/WNR (LANL) – Sources/Detectors
- LANSCE/Lujan (LANL) – Sources/Detectors
- Van de Graaf (Triangle Universities Nuclear Laboratory) – Sources
- NCERC (LANL/NTS) – Sources/Targets/Detectors
- Dense Plasma Focus DPF (NTS) – Sources/Detectors
- C-NR Radiochemistry (LANL) [&LLNL] – Sources/Targets
- Radiochemistry (Oregon State University) - Targets
- Measurement Facilities (LANL) – Sources/Targets/Detectors
- LANSCE/IPF(LANL) - Targets
- HIFR High Flux Reactor (ORNL) – Targets
- National Isotope Development Center (ORNL) – Sources/Targets
- Commercial Suppliers – Sources/Targets

- NIF (LLNL) / Omega (Rochester) – Sources/Detectors

***Not in priority order.**

The Immense Phase-Space Required to Describe Nuclear Reactions Requires a Targeted, Prioritized Experimental Program

Actinides:
- Uranium
- Neptunium
- Plutonium
- Americium
- Others?

Light:
- Hydrogen
- Helium
- Lithium
- Beryllium
- Boron
- Carbon
- Nitrogen
- Oxygen

Structural:
- Aluminum
- Titanium
- Vanadium
- Chromium
- Manganese
- Iron
- Cobalt
- Nickel
- Copper
- Gallium
- Niobium
- Molybdenum
- Tin
- Tungsten

Detectors:
- Scandium
- Arsenic
- Rubidium
- Yttrium
- Zirconium
- Rhodium
- Silver
- Indium
- Antimony
- Tellurium
- Europium
- Gadolinium
- Terbium
- Thulium
- Lutetium
- Tantalum
- Rhenium
- Iridium
- Platinum
- Gold
- Thallium
- Lead
- Bismuth

Trace / Other:
- Argon
- Magnesium
- Silicon
- Phosphorus
- Sulfur
- Chlorine
- Potassium
- Calcium
- Zinc

Fission Products

Steel is not Iron

The fission neutron mean free path can vary dramatically due to alloys and trace elements.

Fe56	Iron	Carbon Steel	SS316
82 cm	8.2 cm	5.1 cm	2.9 cm

A dramatic example but many others with 10-30% swings

U236 is not U235

U236 is a threshold actinide (~ 1 MeV) with a fission cross section 1/2 to 2/3 of U235 over 1 – 20 MeV

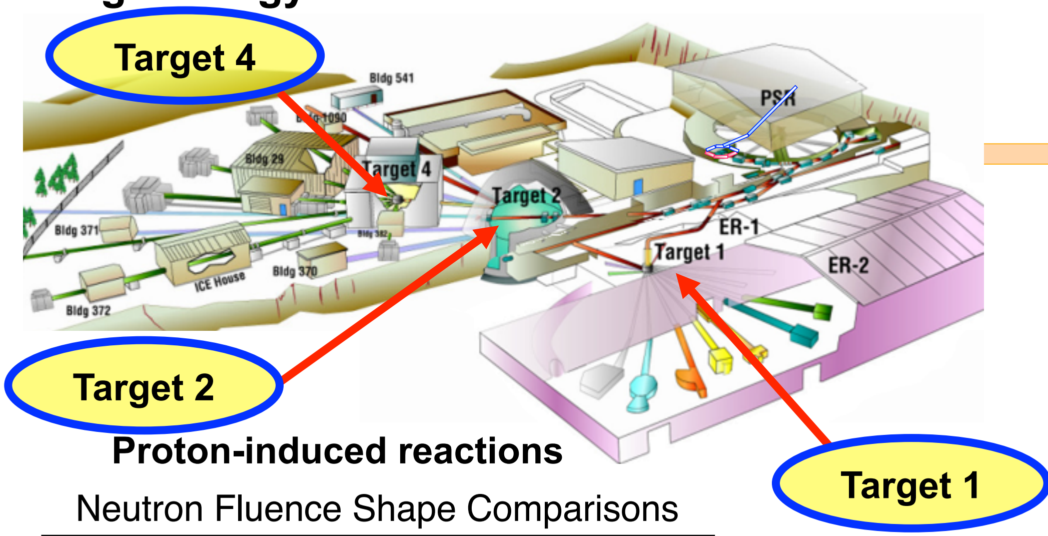
Theory And Evaluation Are Required To Span The Phase-Space Missing From Experimental Data.

The Los Alamos Neutron Science Center LANSCE

There is more than nuclear science at LANSCE.

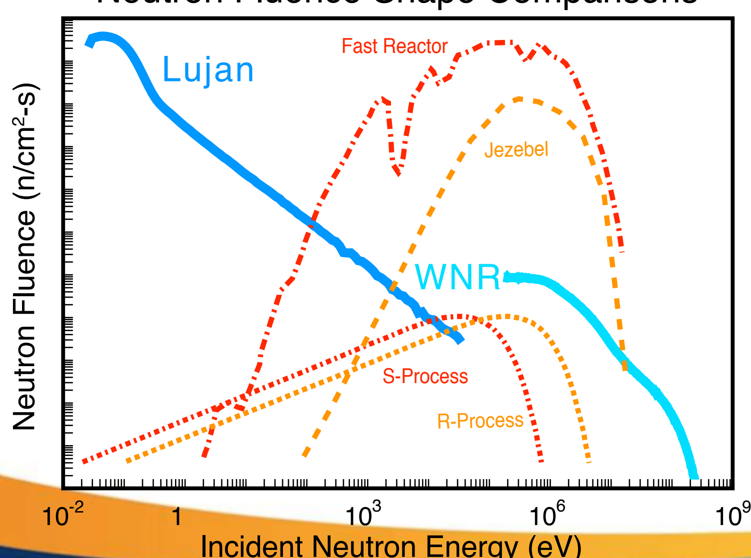
Nuclear Science Research At LANSCE

High-energy neutron research



Proton-induced reactions

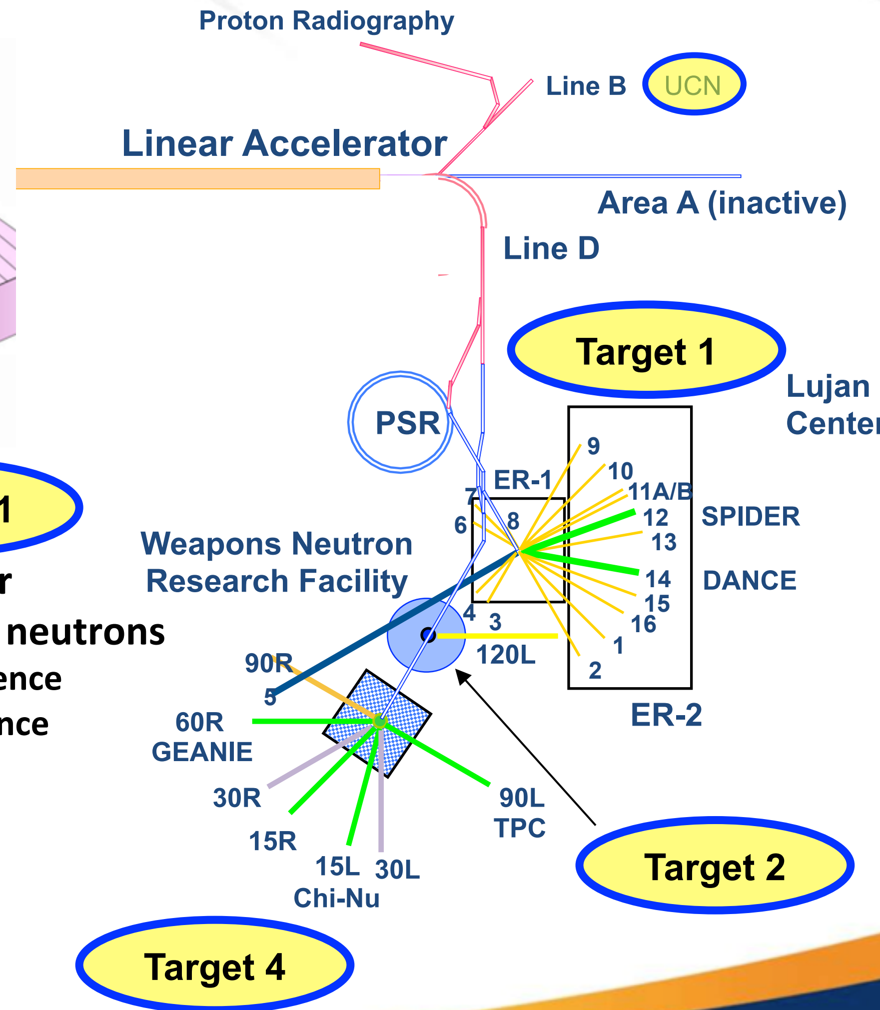
Neutron Fluence Shape Comparisons



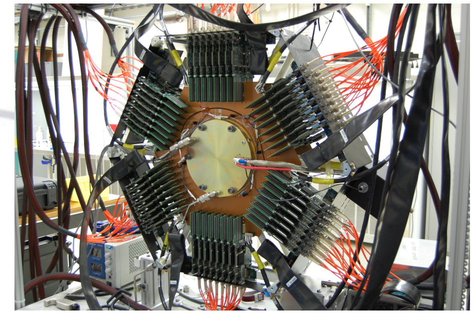
Lujan Center

Low-energy neutrons

- **Material science**
- **Nuclear science**



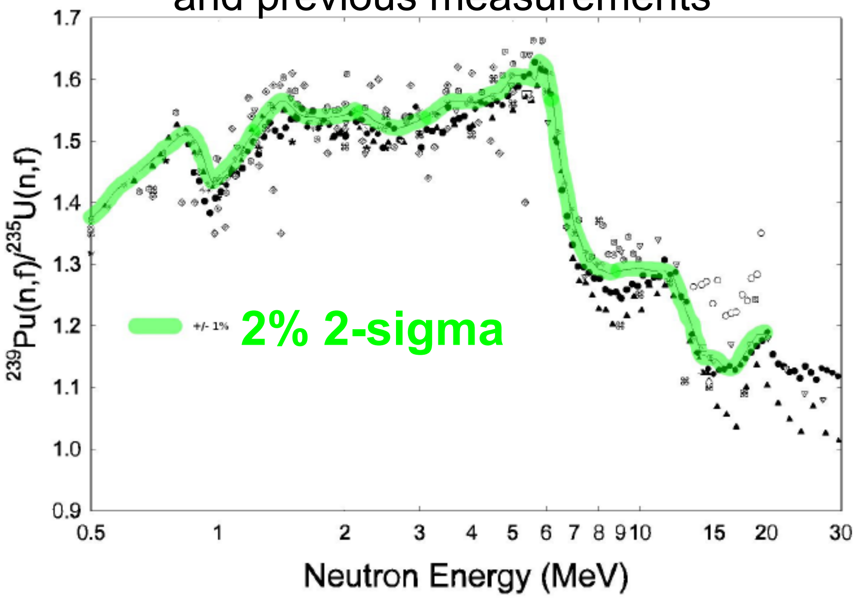
The Fission Cross Section Is The Obvious Part of the Neutron Source Term

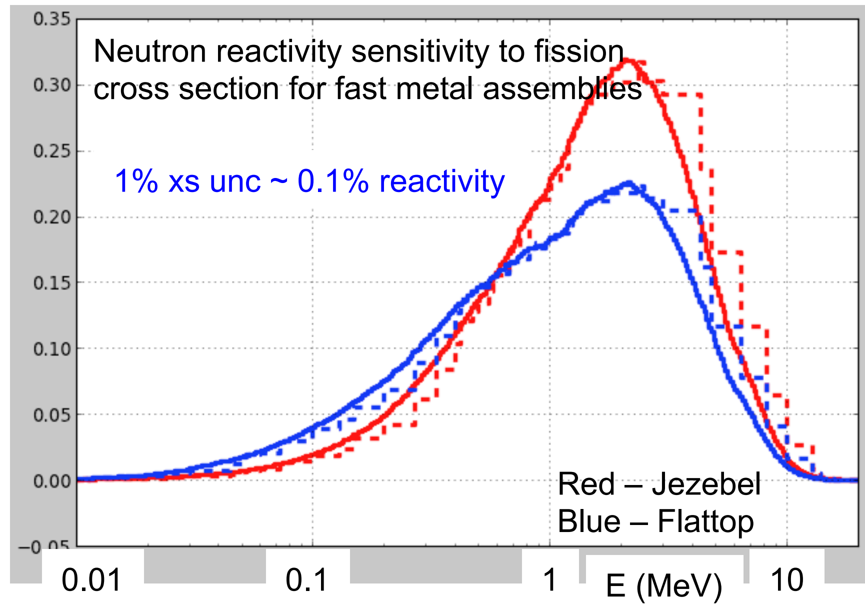


TPC (LLNL/LANL)

source = nubar * xs * pfns

Pu239(n,f) / U235(n,f) desired accuracy
and previous measurements





Pu239(fission) ratio to U235(fission) March 2015

Pu239(fission) ratio to H1(n,p) 2016-2017

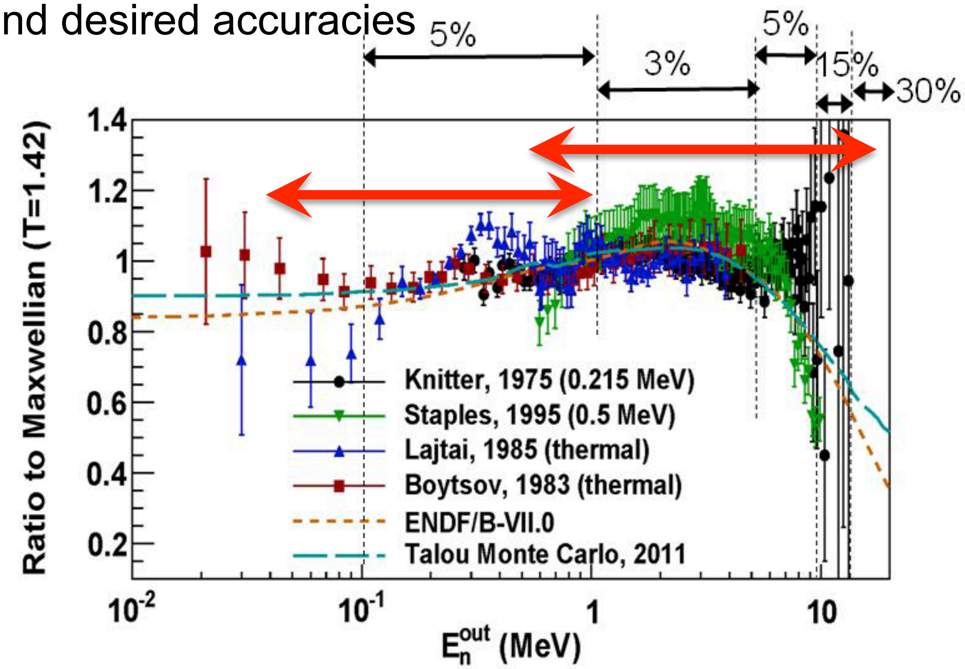
Out year plan includes measurements of other actinides

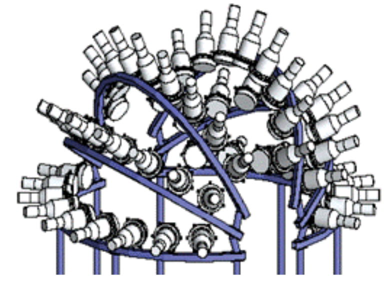
Exploratory plans are considering use for other charged-particle measurements.

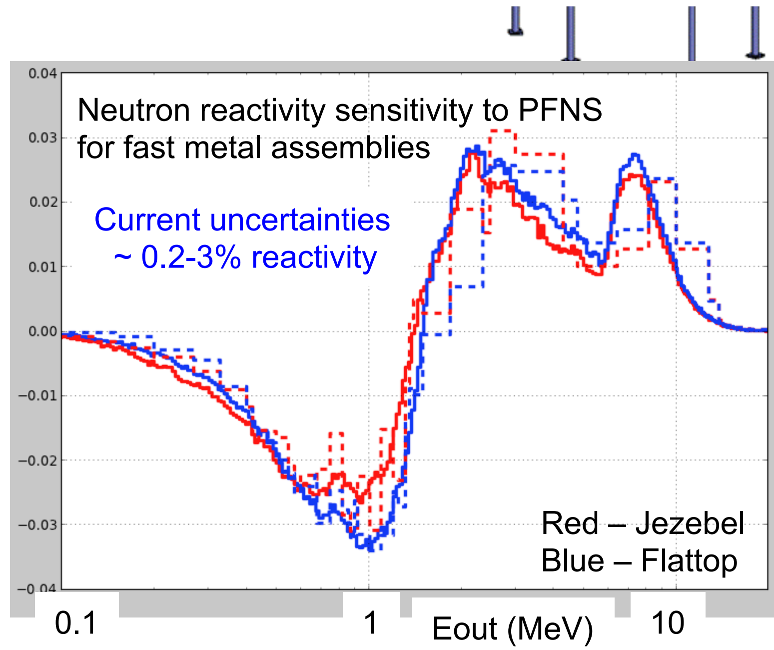
Current Schedule and Outyear Plans

Prompt Fission Neutron Spectra (PFNS) Are the Source Driving Activations (Radiochemistry) in Addition to Their Impact on Neutron Reactivity

PFNS previous measurements and desired accuracies







Low-energy measurements September 2014

High-energy measurements September 2016

Out year plan includes measurements of other actinides

Exploratory plans are considering use for elastic/inelastic scattering measurements.

Current Schedule and Outyear Plans

More Comprehensive Experimental Data Are Helping Identify Questionable Assumptions Within Theory and Modeling

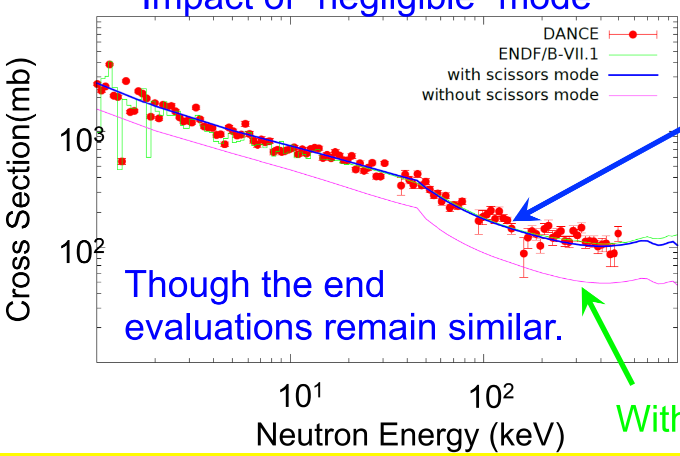
- While not an official "Standard" the evaluated ^{238}U (n,gamma) cross section uncertainties are less than 3% over incident n energies 10 eV - 2.2 MeV

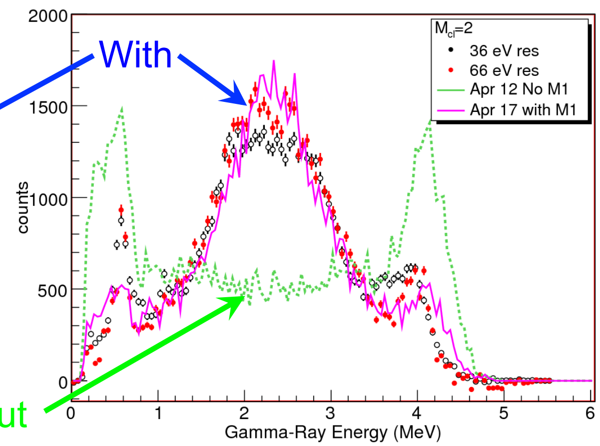
This accuracy is based on fitting "pure" experimental data. Previously, theory has been unable to reproduce these data.

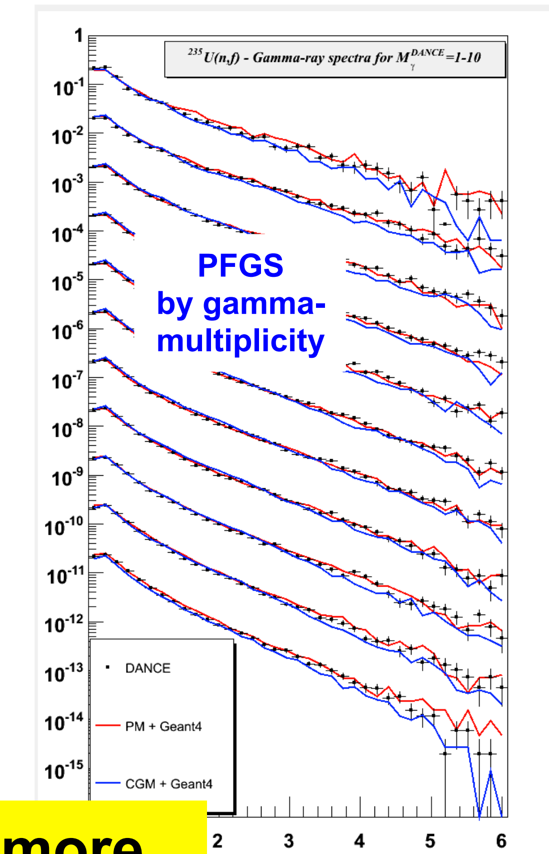
- Recent DANCE measurements highlighted missing underlying physics in the reaction model that have helped improve predictions (an 8x shift)

DANCE (LANL/LLNL)

Impact of "negligible" mode

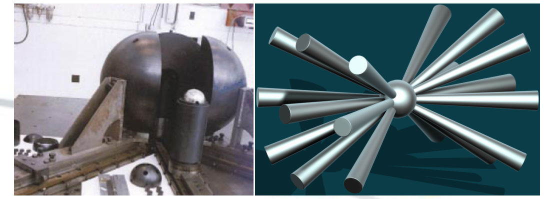






Additional physics added to theory based on more advanced, and detailed, experimental measurements.

Interpretation of the Number of Fissions Is Sensitive to the Details of Fission Product Yields

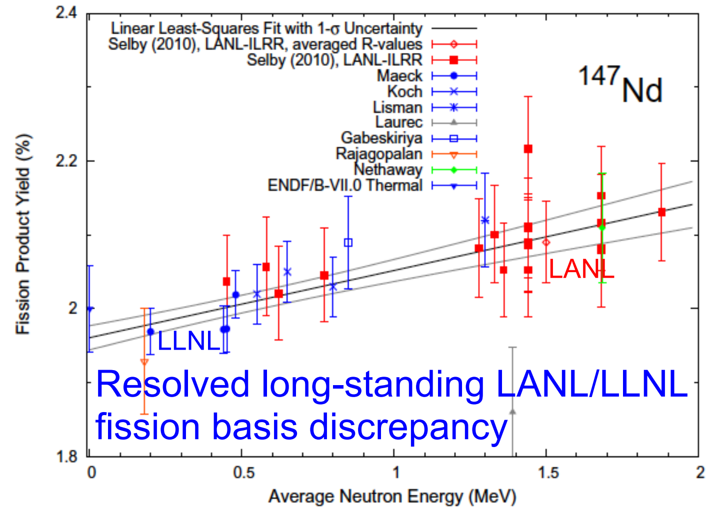


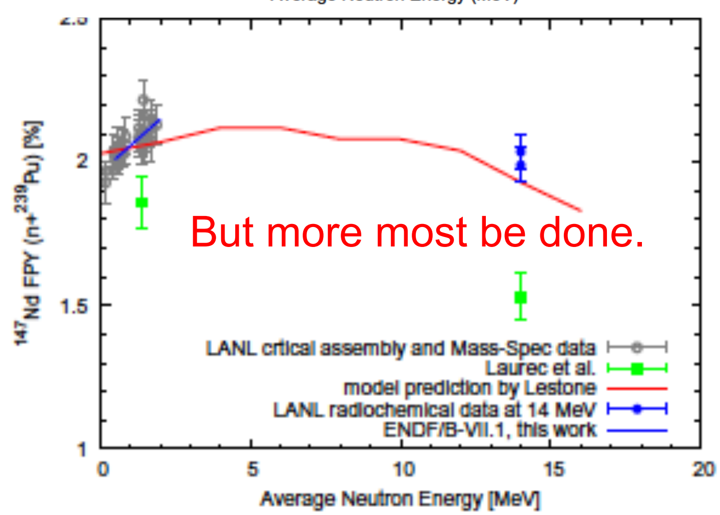
- Joint LANL/LLNL fission product review panel endorsed a possible energy dependence of ^{239}Pu(n,f)^{147}Nd fission product yield with fission neutrons (LA-UR-10-01598):

  4.7%/MeV from 0.2 to 1.9 MeV (M. Chadwick)

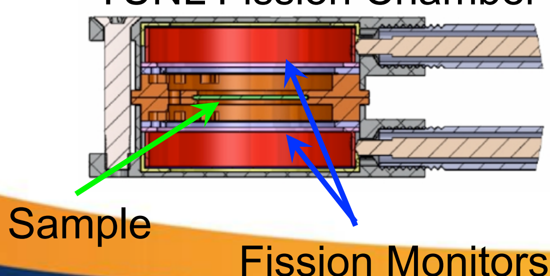
  3.2%/MeV from 0.2 to 1.9 MeV (I. Thompson)
- Mostly low energy data from critical assembly or fast reactors.
  - Very scarce experimental data MeV-range.
  - Large discrepancy (~25%) at 14 MeV

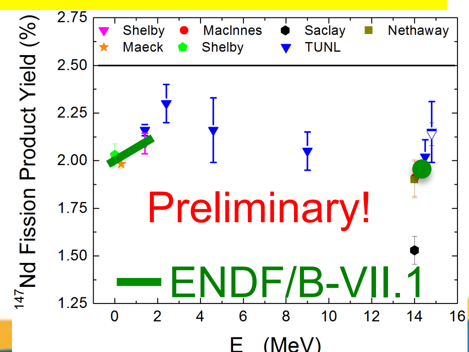
New experiments recommended to confirm 0.5-2.0 MeV range and settle high-energy dispute.





TUNL Fission Chamber





Facilities, Where We Are Not, But We Are Glad Are There

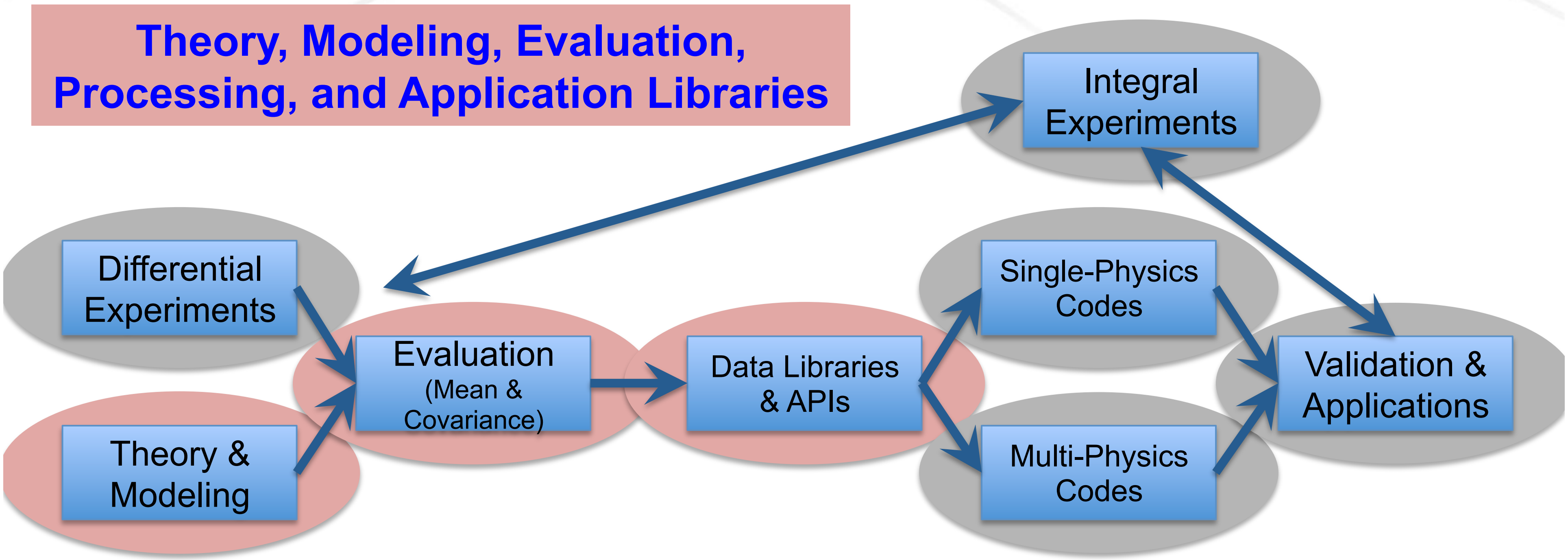
- Gaerttner Linear Accelerator (RPI)
- GELINA (EC/IRMM)
- Van de Graaf (EC/IRMM)
- Valduc (CEA)
- J-PARC (JAEA)
- n-TOF (CERN)
- Van de Graaf (Ohio University)
- Van de Graaf (University of Kentucky)
- Caribou (ANL)
- HIGS (TUNL)
- 88-inch Cyclotron (UC Berkeley)
- Various Research Reactors
- Other Russian and Chinese facilities

Evaluators in T-Division use measured data from all over the world.

LANL staff are actively engaged with the nuclear science community worldwide.

- 2022 - Facility for Rare Isotope Beams (FRIB, Michigan State)

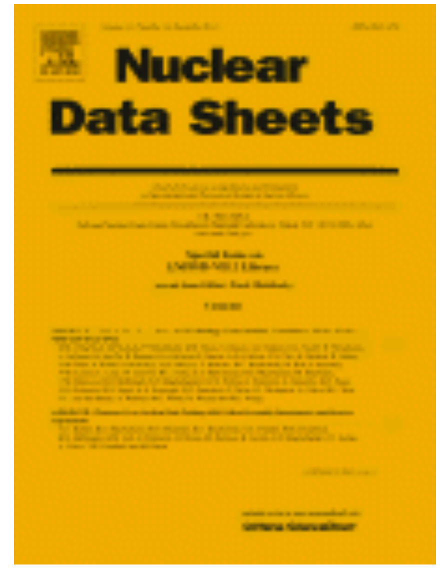
The Nuclear Science Enterprise at Los Alamos Is Comprehensive, Complex, and Coordinated



Collaborating with experimentalists, we use theory and modeling to deliver application-specific nuclear data libraries to the weapons program.

LANL is a Leader in the National and International Data Evaluation Community

- ENDF/B = the United States' Evaluated Nuclear Data File
  - The ENDF/B database is a national resource with an international user base.
  - ENDF/B's content is determined by the "Cross Section Evaluation Working Group (CSEWG)".
    - LANL plays a leading role in CSEWG activities …
      - M.B.Chadwick (XCP-DO) is chair of the Data Evaluation Committee.
      - A.C.Kahler (T-2) is chair of the Data Validation Committee.
        - » Staff members from T, XCP and XTD have contributed to developing and/or testing ENDF/B candidate data files.
  - ENDF/B-VII.1 released in 2011, VII.0 in 2006.
    - Serves a broad community – NW, criticality safety, nonproliferation, nuclear energy, …
    - Content described in peer-reviewed literature
      - Major impact: cited > 3000 times, journal > 1000 times.



*ENDF/B-VII.1: Chadwick et al, NDS **112,** 2887 (2011) & Kahler et al, **112,** 2997 (2011).*

*Additional validation testing: Van der Marck, **113,** 2935 (2012).*

LANL Plays a Leading Role in Creating the Technical Content of the ENDF/B Library

- LANL Contributions to ENDF/B-VII.1 include …
  - Improvements to selected actinides ($^{235,236,237,238,239}U$, $^{238,239,240,242}Pu$, $^{241,243}Am$), light elements (^{3}He, ^{6}Li, ^{9}Be, ^{nat}C, ^{16}O), structural materials (^{iso}Ti, ^{iso}V, Mn, ^{iso}Cr, ^{iso}Ni, ^{iso}W);
  - Covariance (Uncertainty) Data;
  - Fission Yield Data (from plutonium yield basis project).
- Next version in ~2016 will include a higher component of international collaboration
  - LANL is leading an international evaluation collaboration – CIELO = Collaborative International Evaluated Library Organization with initial work focused on evaluated data files for ^{1}H, ^{16}O, ^{56}Fe, $^{235,238}U$ & ^{239}Pu.
    - Goal is to remove many of the known compensating errors in the evaluated data.
    - Additional LANL focus is on light nucleus reactions, using LANSCE data & theory advances.

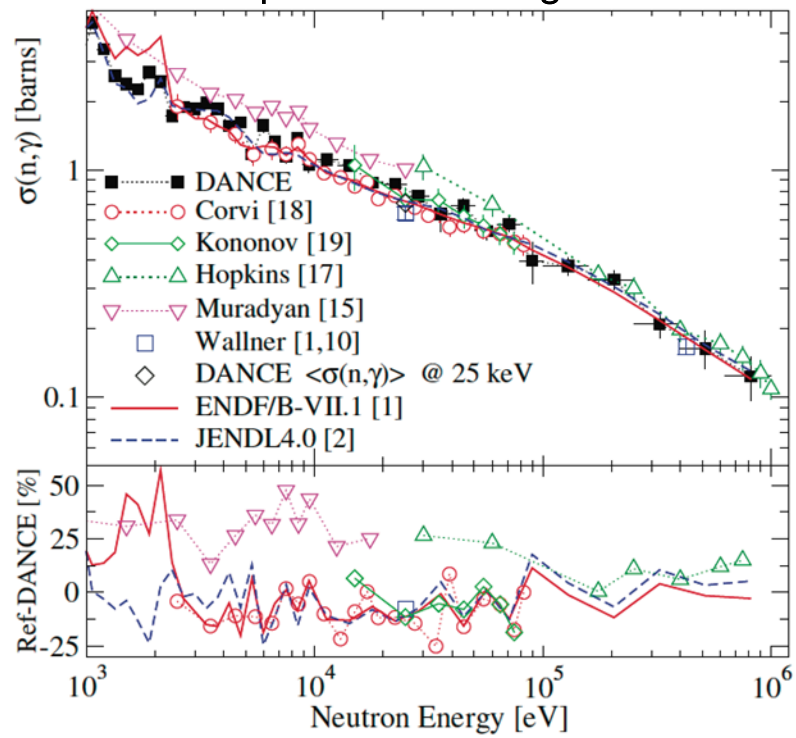
Physics Codes Used by T-2 for Nuclear Reactions & Structure

- Many capabilities – integrating measurement & theory to create ENDF formatted data files …
  - Codes play an essential role in supporting nuclear data evaluations.
  - Established codes include …
    - EDA (R-matrix for light nuclei, including thermonuclear TN reactions);
    - GNASH, CoH (Hauser-Feshbach, medium-to-heavy nuclei, inc. actinides);
    - FRLDM (fission physics using macro-micro model);
    - NJOY (processing) – a world standard for creating application libraries from ENDF formatted data files;
    - GLUCS (UQ – used also at NIST, LLNL, IAEA, in standards work).
  - Recently developed codes include …
    - CGM/F (MC Hauser-Feshbach for pfns), AVXSF-to-CoH (fission xs)
- Modernization & Maintenance of Code Bases – a continuing need.

Neutron Capture: New LANSCE/DANCE Detector Breakthroughs

- A new opportunity: use improved DANCE detector technology to accurately determine capture
  - **^{235}U** changes will be very important
  - Much work will be needed to take advantage of improved cross sections, but maintain good criticality performance
  - **^{239}Pu** urgently needs to be improved too – LANSCE work in progress (existing assessments date back to John Hopkins and Ben Diven, LANL, 1962!)

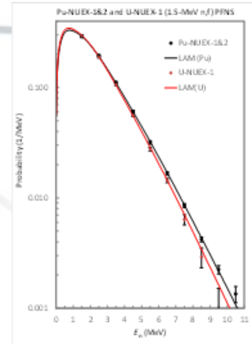
DANCE data shows ENDF (from Oak Ridge) was too high. The Japanese were right….



The major changes near 1 keV will affect the way "bomb thermal" neutrons distort radchem measurements.

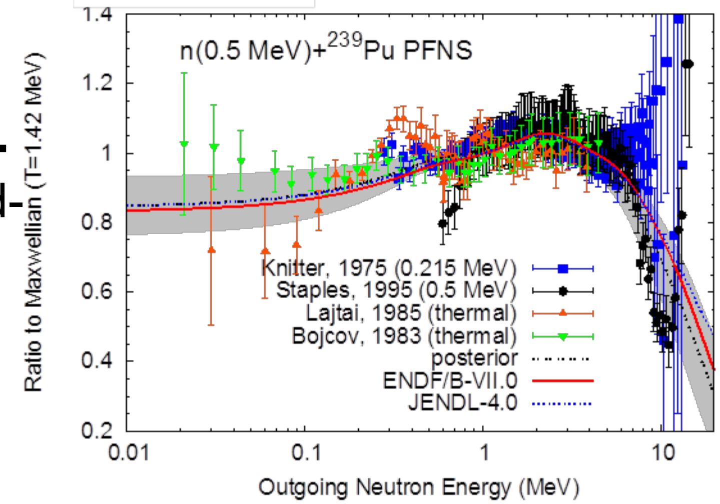
Advances in radiative neutron capture physics, obtained via a theory/experiment collaboration, will lead to more accurate assessments.

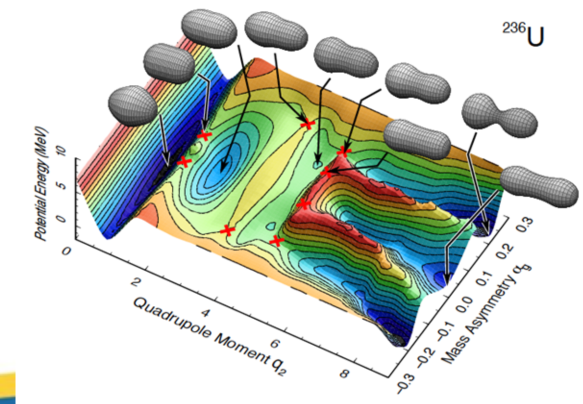
Nuclear Fission & Scattering Reaction Physics



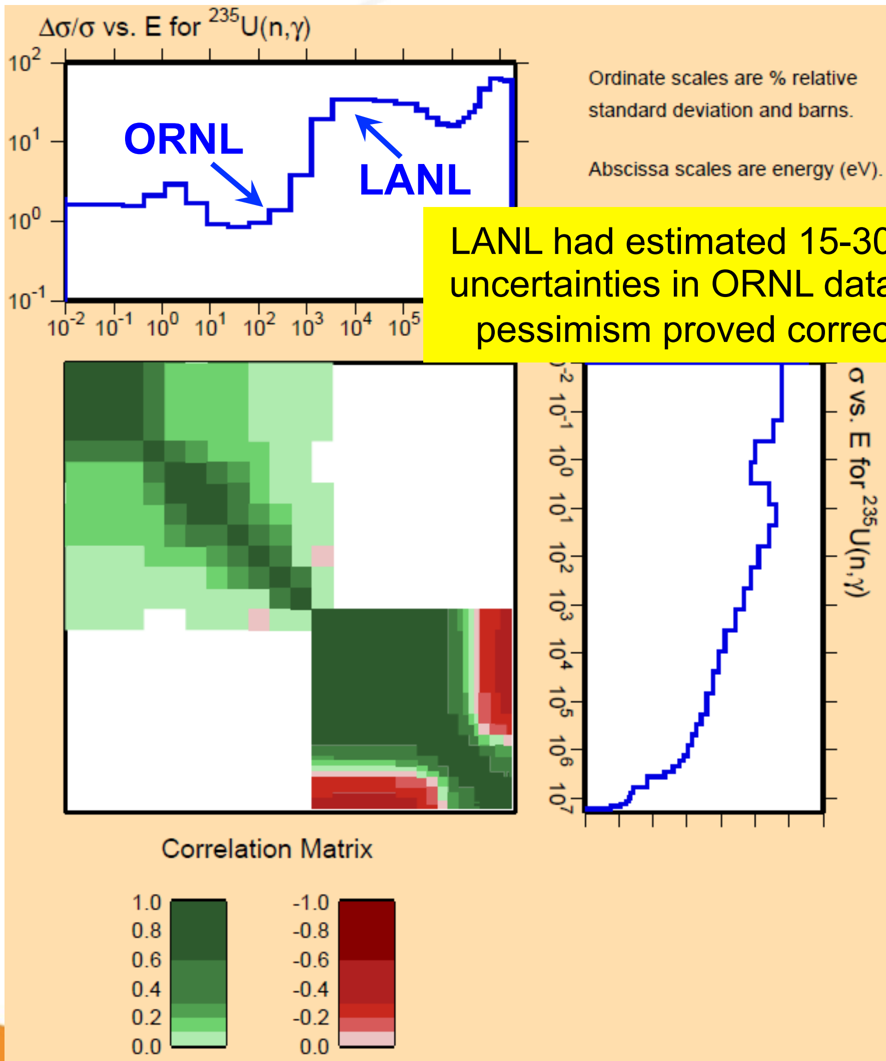
← NUEX extracted fission neutron spectrum, Lestone.

- **Challenge: "Putting it all together": Develop predictive capabilities to compute all fission data consistently, *e.g.*, fission cross sections, ν(E) & γ(E) spectra & multiplicity, fragment yields, …**
  - **Prompt fission neutrons:** Improved Madland-Nix model + Monte Carlo Hauser-Feshbach calculations; Chi-Nu experimental effort with LLNL **For weapons criticality**
  - **Fission cross sections**: modeling of intermediate structures in second well → R-matrix theory applied to fission; TPC (Tovesson) with LLNL **For weapons criticality**
  - **Fission fragment yields** as a function of excitation energy; Langevin equations; SPiDER LDRD/DR **For fission yield basis**
  - **Prompt fission photons**: Monte Carlo HF; New "first-ever" DANCE LANL-LLNL experimental data. **For prompt gamma diagnostics**





Covariance Data in ENDF/B-VII.1 – a Step Toward Routine S/U Capability



LANL had estimated 15-30% uncertainties in ORNL data – pessimism proved correct

- ENDF/B-VII.0 contained covariance data for 26 materials
- ENDF/B-VII.1 contains covariance data for 190 materials
  - Data include covariances for
    - Total, prompt and delayed nu;
    - Cross Sections;
    - Elastic Scattering Angular Distribution (P_1 moment);
    - Emission Spectra (PFNS only, so far);
    - Radioactive isotope production.

Still a developing field with much work needed to use on a production basis – use by MCNP under development (funded by DOE/NCSP).

Evaluated Data Must Be Processed Into Application Dependent Libraries

- NJOY2012 – A general purpose ENDF processing code
  - World-wide standard with large user base
  - Produces continuous-energy (ACE) data files, e.g. for MCNP
  - Produces general purpose multi-group files, e.g. for PARTISN
- NDI (Nuclear Data Interface) & associated data libraries
  - Provides general access to collections of ACE & multigroup data libraries
  - Standardized handling of run-time multigroup processing, e.g. group collapse
  - Data libraries include neutron and photon transport data
    - Neutron data include secondary emission data for gamma-rays and charged particles
  - Charged-particle libraries includes thermonuclear reaction rate data
  - Provides "meta" data needed to compute isotopic transmutations
  - Specialized libraries often produced on short-notice for emerging needs

NJOY and NDI have been helping ensure that advances in nuclear data quickly reach applications in a standardized, quality controlled process.

Efforts Are Well Coordinated Across Experimental, Evaluation and V&V

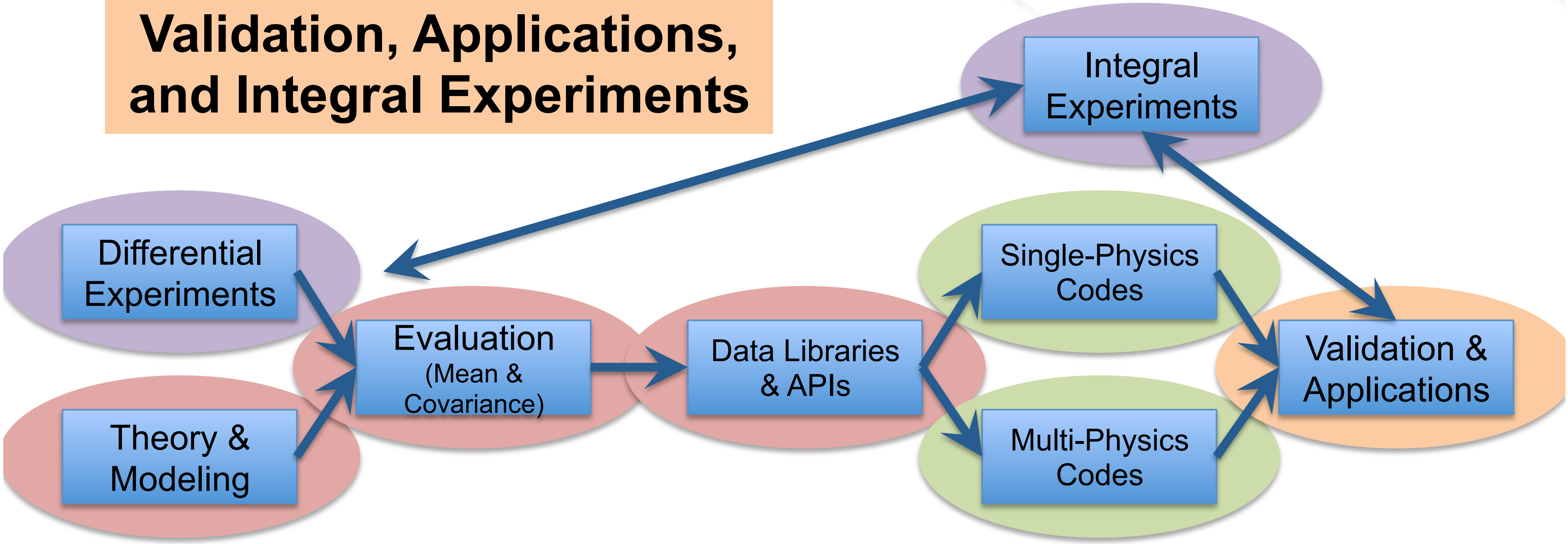
Chi-Nu is up first with new application library due in September 2014.

- Theorists meet with experimentals and statisticians bi-weekly to discuss how systematic errors propogate through these systems
- ASC/PEM FY13 L3 milestone to develop modern evaluation tools
  - Extend PFNS code package to higher incident neutron energies
    - Include pre-compound phenomena contributions calculated with COH **Complete**
    - Include experimental PFNS and neutron multiplicity
  - Perform complete evaluation using the Los Alamos model (LAM)
    - Extension to higher incident energies and multiple chance fission **Complete**
    - LAM with default parameters to reproduce ENDF/B-VII.1 results
    - Establish realistic experimental covariance matrices

Fundamental goal is for modern theory infrastructure to be integrated into the experimental data reduction process, including uncertainty analysis, leading to better evaluated data in shorter time cycles.

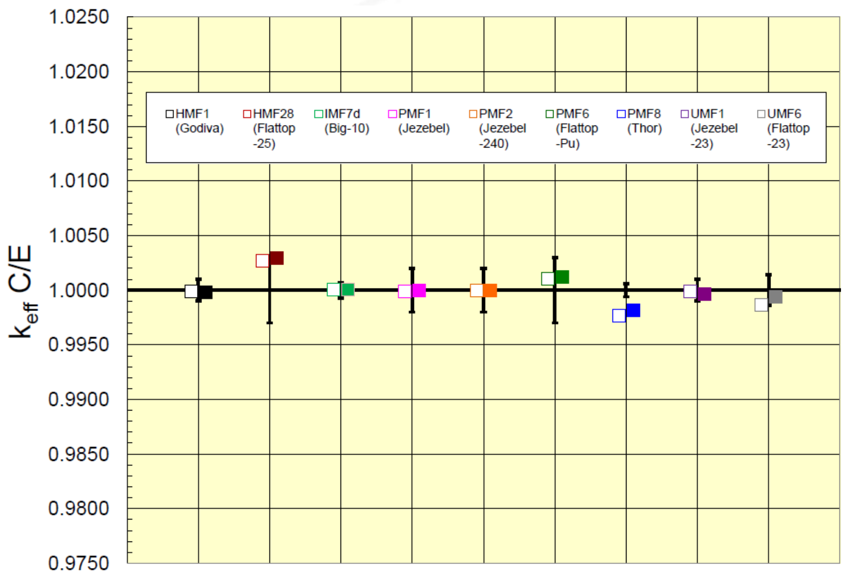
The Nuclear Science Enterprise at Los Alamos Is Comprehensive, Complex, and Coordinated

Validation, Applications, and Integral Experiments



Validation of Nuclear Performance Using NTS Diagnostics is Critically Dependent on Nuclear Science

ENDF/B is Good and Getting Better
ENDF/B is the National, and LANL, Standard

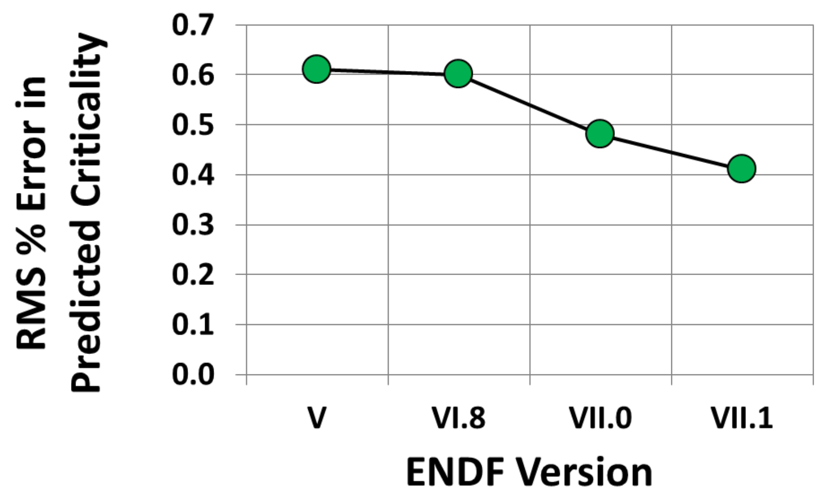


← "Open" symbol is ENDF/B-VII.0; "solid" symbol is ENDF/B-VII.1.

← With little change in the major actinide cross sections, the previously obtained good results should remain (and they do!).

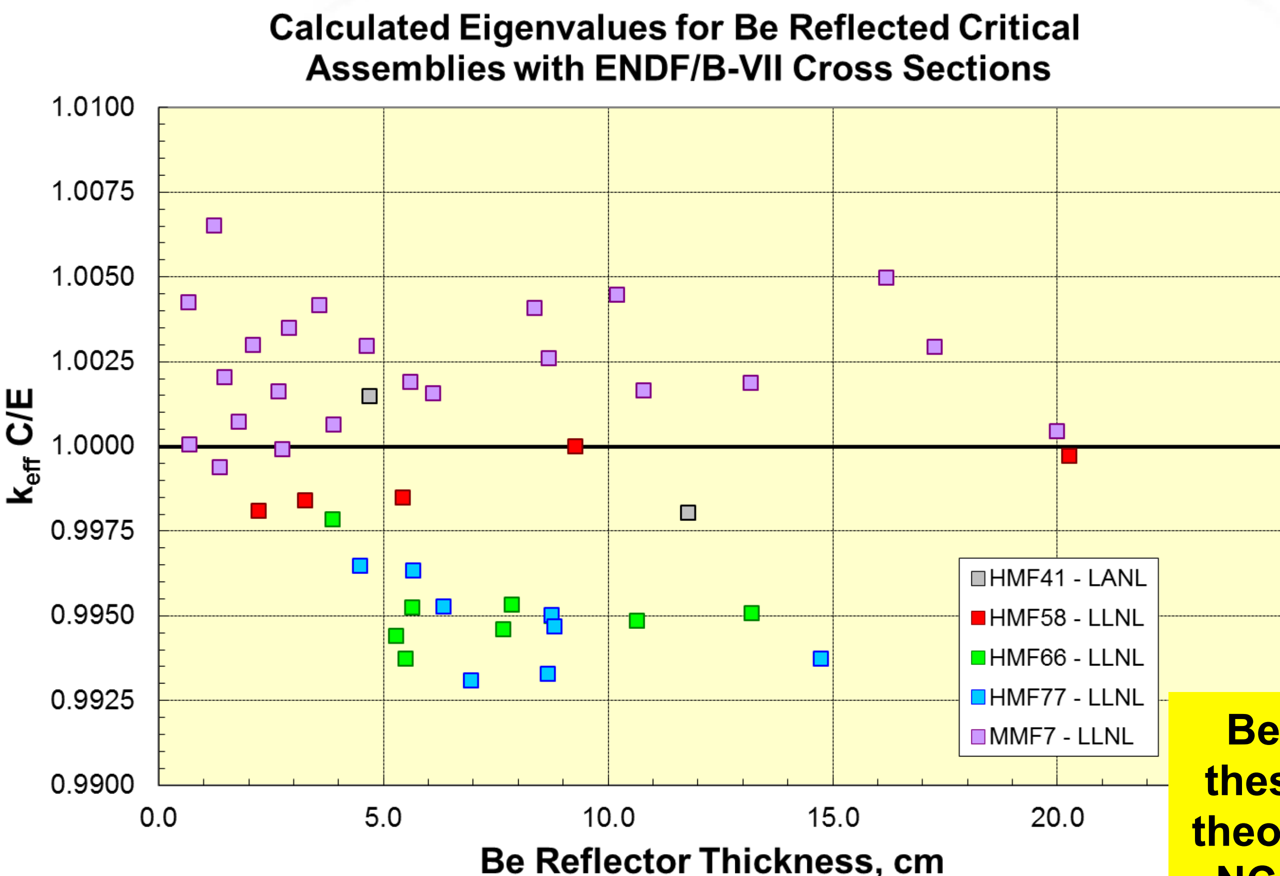
← The 5% range on the ordinate axis is an important interval in the criticality safety community.

119 critical assemblies in the MCNP validation suite … improved nuclear data for non-fissile materials in e71 is the primary driver for continuing improvement in calculated k_{eff}. →



Over 2000 benchmarks, defined in the International Criticality Safety Benchmark Evaluation Project (ICSBEP) Handbook, were evaluated using MCNP during ENDF/B-VII.1 data testing.

Despite Significant Progress Relevant Discrepancies Remain



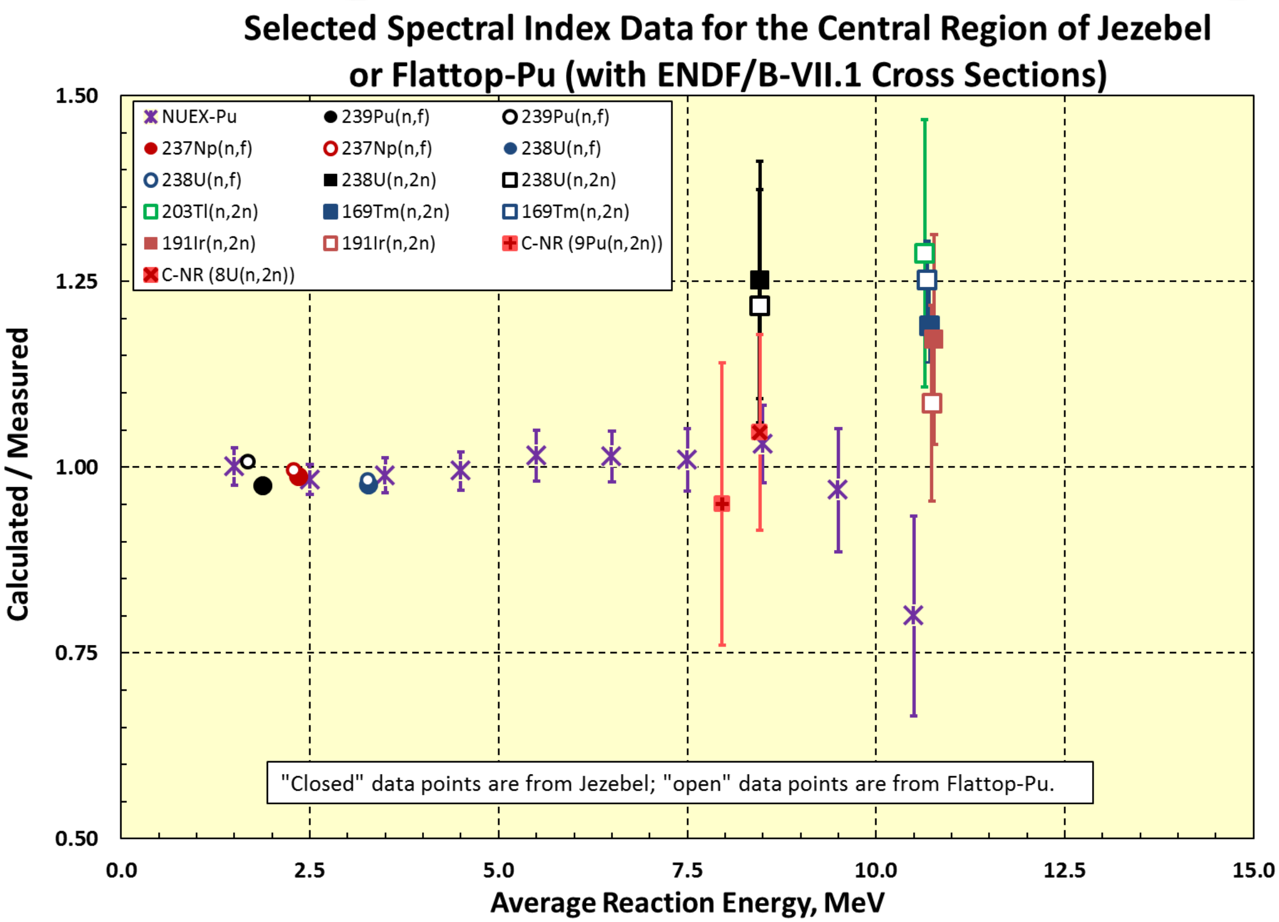
H in HMF = HEU core; M in MMF = mixed Pu/HEU core

Be reflected critical assemblies exhibit differing results …

- The HMF58, 66 & 77 critical assembly experiments were all performed at LLNL with the same materials in the late 1950s & early 1960s.
- The assessed measurement uncertainty is about 0.3%; a value much smaller than the spread in calculated eigenvalues.

Beryllium advances to reduce these discrepancies will involve theory (R-Matrix) work and future NCERC criticality experiments.

Spectral Index Results Indicate Potential Issues Within High-Energy PFNS



Selected Spectral Index Results for LANL Critical Assemblies.

Original experiments occurred in the 1950s to early 1970s & were recently re-analyzed by C-NR.

Need knowledge of past nuclear data in order to obtain reliable C/E results with today's nuclear data.

New experiments planned for NCERC in coming years will yield significantly reduced measurement uncertainties.

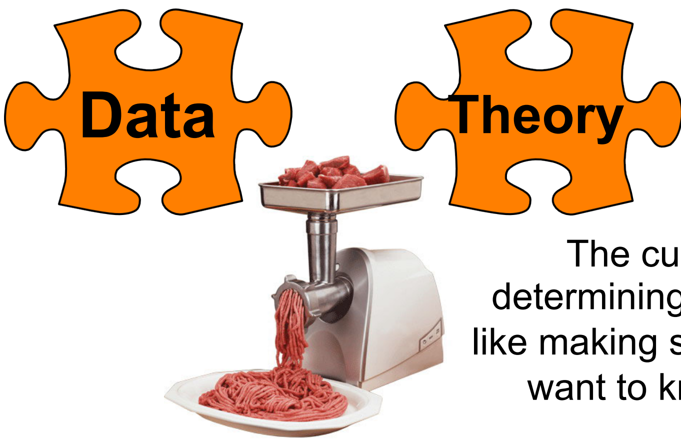
Similar C/E results in HEU (Godiva and Flattop-25) fueled assemblies exhibit a slightly decreasing trend at high energy.

Expecting Chi-Nu data to better define PFNS

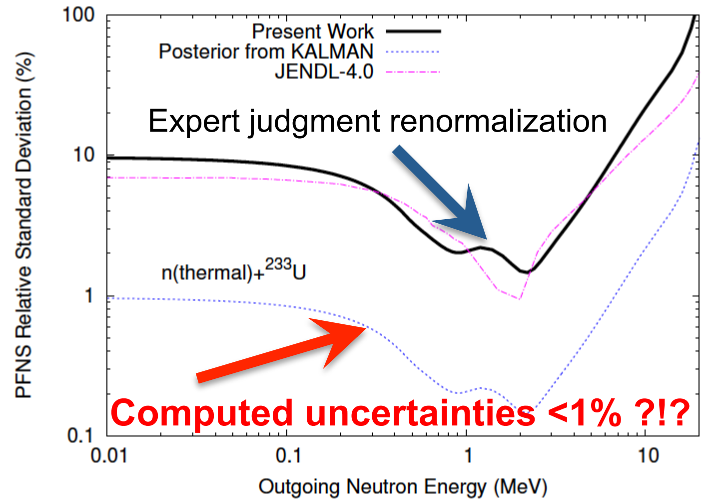
Improved Uncertainty Assessment Methodology Is Under Development To Handle Deficiencies In Experimental Data and Model Forms

Science is the belief in the ignorance of experts. – Richard Feynman

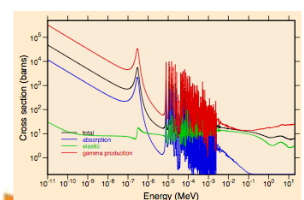
"What is Science?", presented at the fifteenth annual meeting of the National Science Teachers Association, in New York City (1966) published in *The Physics Teacher* Volume 7, Issue 6 (1969).

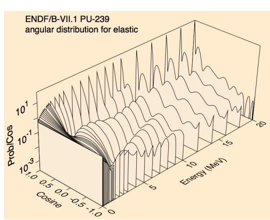


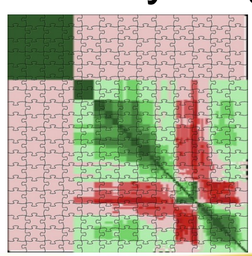
The current process of determining covariances is a bit like making sausage, you may not want to know what's inside.



XS for all reactions	distributions for all particles	uncertainties on everything



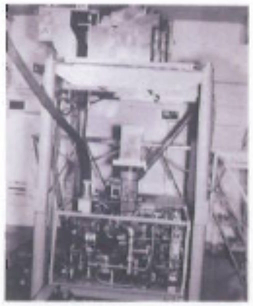




Deficiencies in experimental data and model forms can lead to uncertainties that do not always capture the true systematic errors.

Expert judgment is still essential!

Los Alamos Has Re-Established the Capability to Perform Critical Assembly Measurements at NCERC (NTS)



PLANET

JEZEBEL23

BIGTEN

JEZEBEL

Los Alamos TA-18

PLANET

COMET

FLATTOP

GODIVA-IV
Fast Burst Assembly

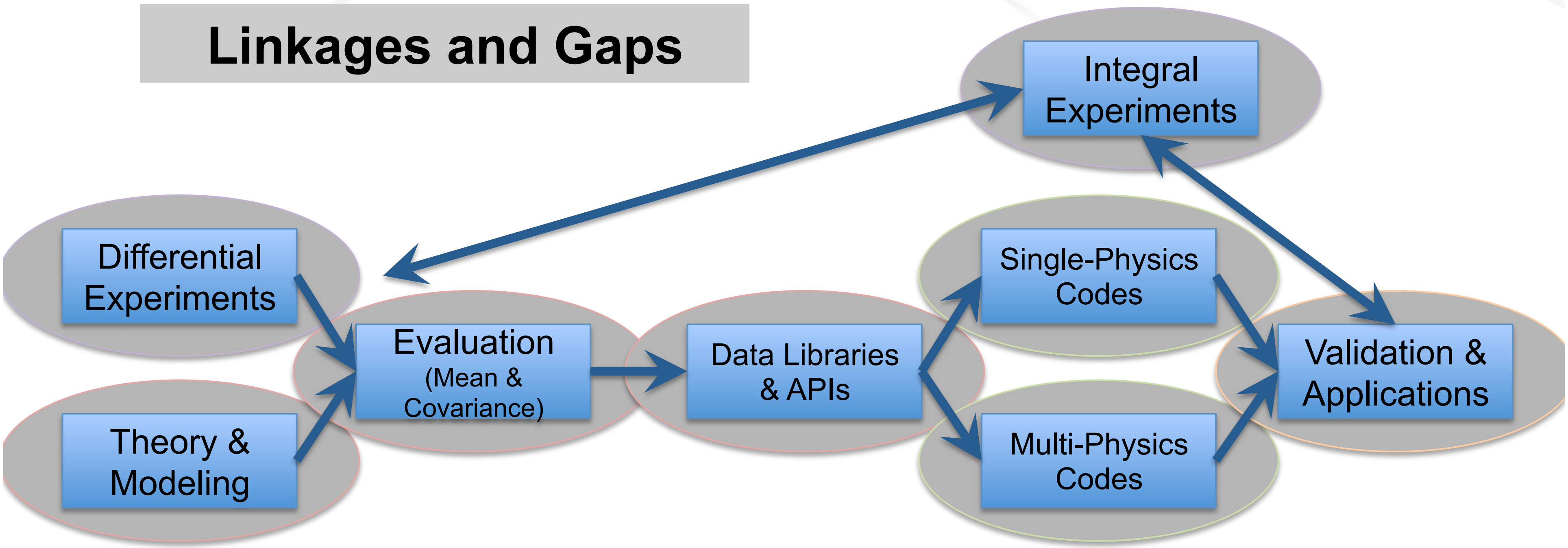
DAF / NCERC (NTS)

Los Alamos Has Led the Planning for New Experiments At NCERC to Benefit NW and GS Programs

- The first experiment at NCERC to obtain new data (9/8/2011) was an irradiation using Comet for radiochemistry analysis

- Planned experiments include
  - High precision HEU and plutonium assemblies
    - Understand the reproducibility and systematic errors associated with using critical assemblies to constrain broader uncertainty analysis
  - Prompt fission neutron spectrum (PFNS) shape
    - Measure reaction rates on wide variety of threshold detectors within critical configuration designed to closely follow actual PFNS
    - Complementary to Chi-Nu project to directly measure data
  - Beryllium reflected critical assemblies
    - Resolve inconsistency between two key historical sets of experiments
  - Alternate materials
    - Of interest to NCT (threat) and NTNF (forensics) communities
  - Probability of initiation (POI) benchmark
    - Better understand how criticality initiates

The Nuclear Science Enterprise at Los Alamos Is Comprehensive, Complex, and Coordinated



Our nuclear science program significantly benefits from other programs who are also dependent on these fundamental capabilities.

The Nuclear Science Community at Los Alamos Supported by ASC / SC Also Makes Substantive Contributions to GS and Other NNSA Programs

- Defense Threat Reduction Agency (DTRA)
- National Technical Nuclear Forensics (NTNF)
- Nuclear Counter Terrorism (NCT)
- Capabilities for Nuclear Intelligence (CNI)
- Nuclear Nonproliferation Program
- Nuclear Emergency Response
- Weapons INRAD (Intrinsic Radiation)
- Nuclear Criticality Safety Program (NCSP)
- DOE Nuclear Energy

It is important to recognize that advanced capabilities first developed for non-Stockpile programs usually provide benefit to DSW as well.

The Nuclear Weapons Science Effort Has Benefitted from Support of LDRD, NCSP and DOE Basic Science

- The nuclear science community has a strong record of successful LDRD-DR projects:
  - DANCE detector initial construction and several measurement campaigns
  - Improved americium and arsenic data for radchem
  - SPIDER to measure and predict fission product yields
  - 2014 new start – "The role of short-lived actinide isomers in high fluence environments."
- NCSP provides the vast majority of funding for NCERC
- Basic Science programs have supported NPAC aspect of the Nuclear and Particle Pillar
  - Research on nuclear structure benefits theory calculations
  - Overlap with key reactions in the s- and r-process

Gaps: Where We Should Be Doing More Because New Opportunities Have Arisen

- Uranium-235 and plutonium-239 capture
  - Recent DANCE breakthroughs make this possible
  - Significant impact with reduction of uncertainties from 30% to less than 10%
- Uranium-239 capture (no direct measurements exist or likely)
  - Previously, we had no path to reduce 30->100% uncertainties
  - New understanding in structure and other constraints enable improvements
- PFGS: prompt fission gamma-ray spectra
  - ENDF based on 1960s era data with no incident energy dependence
  - New DANCE data enable modern detailed evaluations
- V&V: 2014-2020 PCF focus shifts towards weapons performance
  - Strong desire for enhanced use of all available nuclear diagnostics
  - More rigid validation through understanding multiple constraints simultaneously
- Sensitivity / UQ Studies: through enhanced analysis tools
- Code modernization & future architectures: for NJOY, NDI, theory codes
- Correlated emission data: simulations of advanced detector technologies (SoS)

We plan to initiate effort in some of these areas in the coming years through re-prioritization. But more effort will be needed.

Gaps: Where We Intentionally Partner for Efficiency

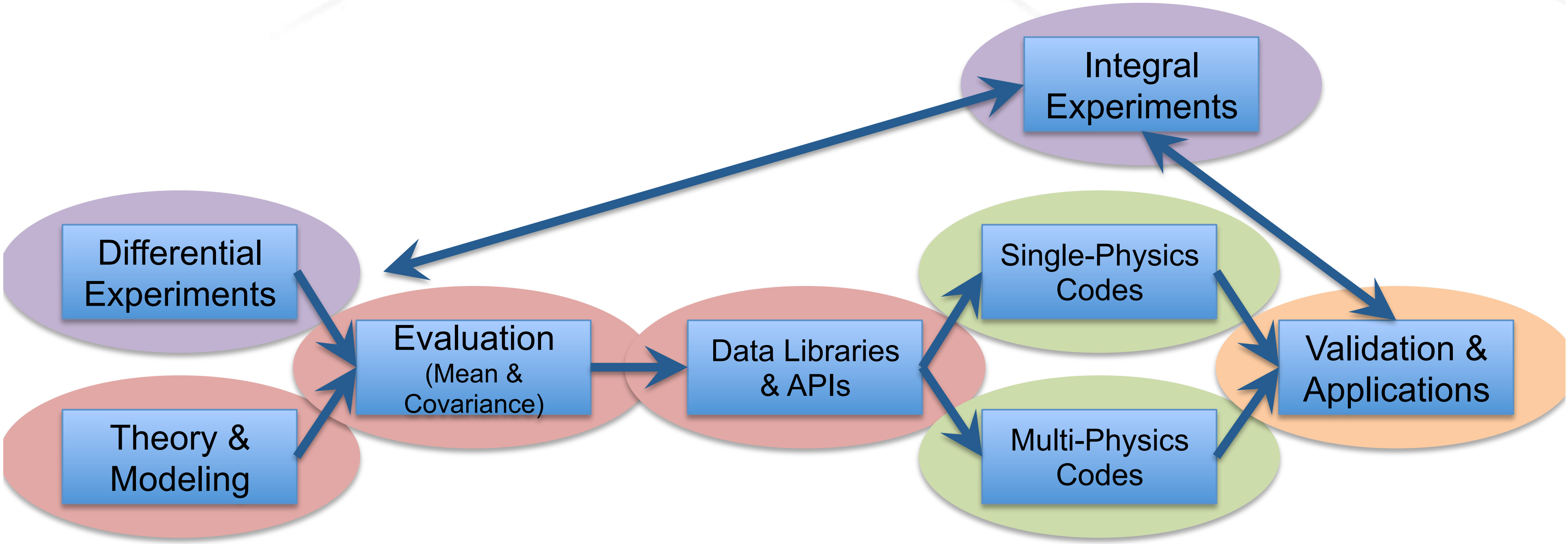
- Modernize the ENDF format
  - To become the international standard ~2016
  - Led by LLNL & international community with LANL in a supporting role
- High-energy density physics
  - Nuclear physics efforts at NIF & OMEGA
  - Strong LANL role in diagnostic development but only collaborative role in physics experiments
- CIELO: Collaborative International Evaluated Library Organization
  - LANL leads this effort, coordinated through OECD/NEA and IAEA
  - Longstanding IAEA nuclear data standards committee w/ strong LANL presence

We lead the work closest to our programmatic needs but greatly benefit from the work of others in closely related efforts.

Gaps: Where We Have Minimal Effort
Waiting For Dollars, Breakthroughs, or Clearer Requirements

- Advances for radchem diagnostics
  - New irradiation and fabrication facilities are making off-stability measurements possible
  - Thermal neutron capture at HIFR (ORNL), e.g. U237 measurement
  - Proton spallation at IPF (LANSCE), e.g. arsenic-73,74
  - Fission fragment beams using APOLLO at CARIBOU (ANL)
    - but need follow-on capabilities being built at FRIB (~2022)
- Excited states in actinides
  - Capability for theory predictions has been developed
  - Need for better understanding of experimental data
- NNSA nuclear science facilities upgrade
  - Joint proposal with LLNL (Workshop to be held Spring 2014)
  - Includes LANSCE pulse-stacking upgrade, chemistry labs, …
  - Designed to serve the broad nuclear science needs of NA-10, -20, -40 and -80.

The Nuclear Science Enterprise at Los Alamos Is Comprehensive, Complex, and Coordinated



As the recognized international leaders in many aspects of the nuclear science enterprise, we are able to make exceptional contributions to the nuclear weapons program.