Applications Utilizing Neutron Capture Gamma-rays

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Jo Ressler, on behalf of many
Lawrence Livermore National Laboratory

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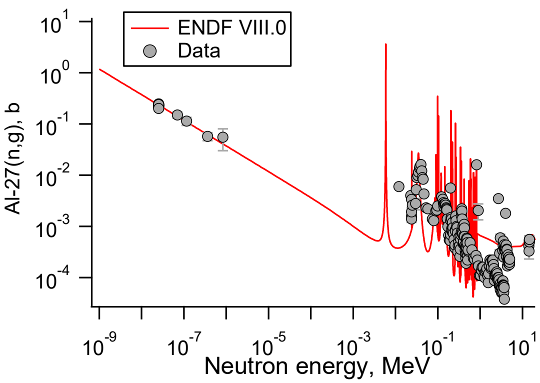
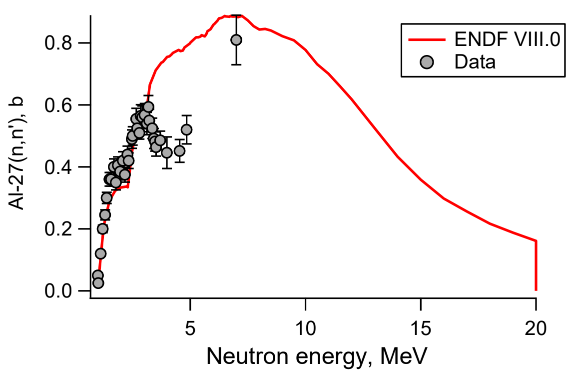
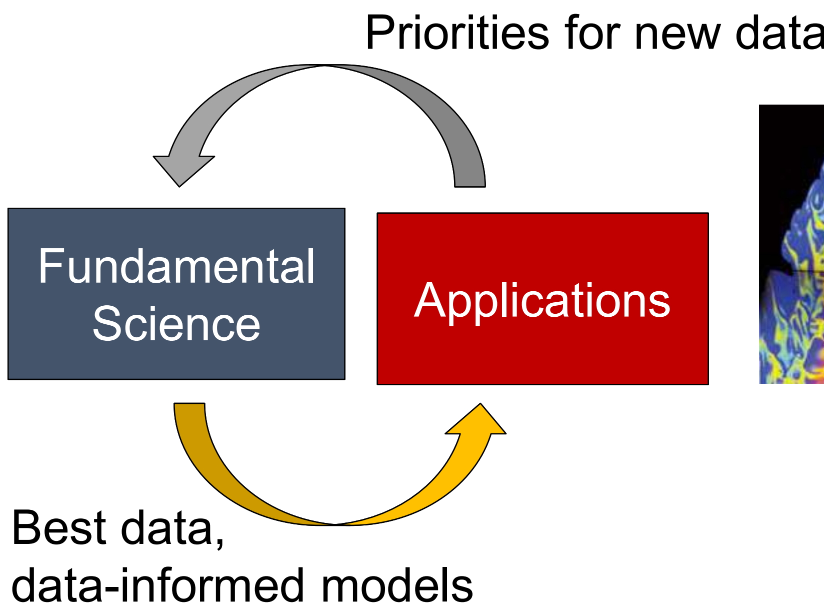
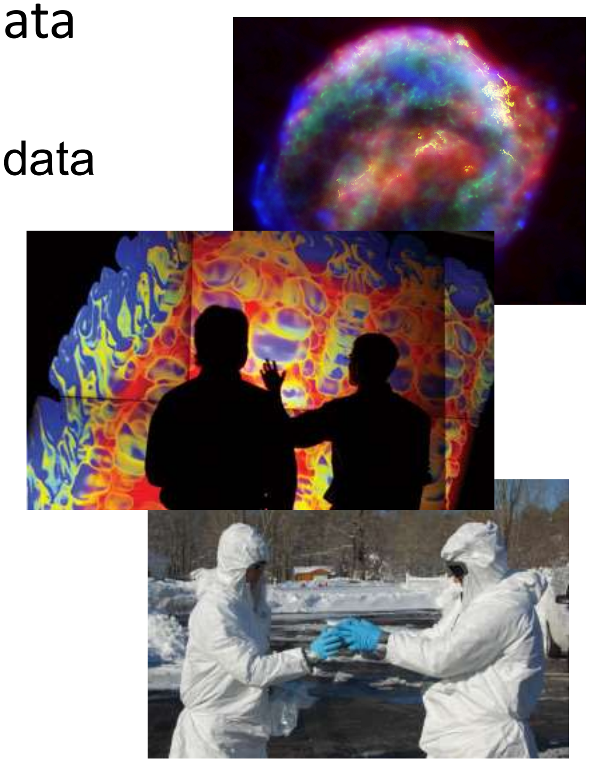
Fundamental science and applications are a partnership

- LLNL is involved in a number of applications that use nuclear physics
- These applications rely on accurate models and data



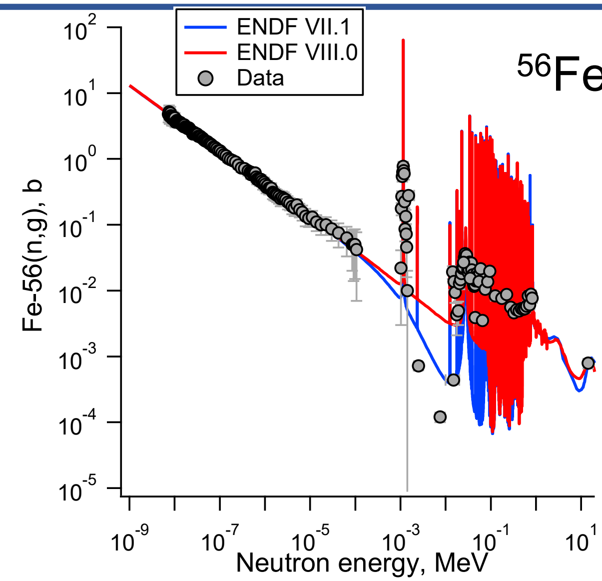




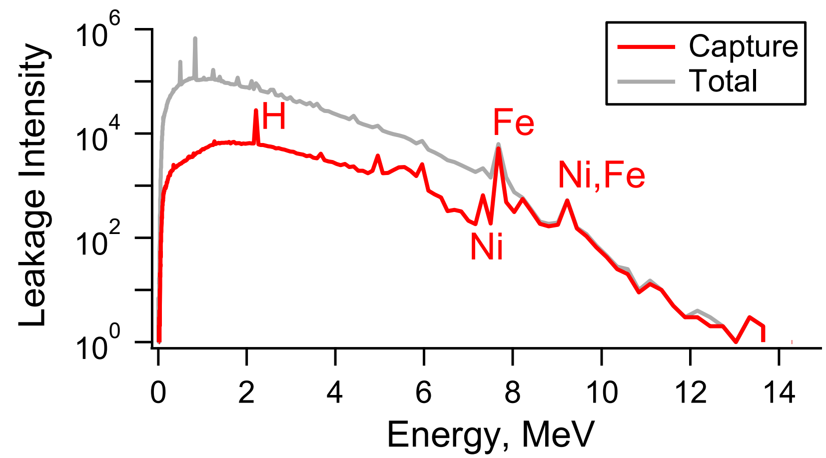


Focus today is on neutron capture *gamma* production

- Multiple applications at LLNL utilize neutron capture
- Applications using gamma production as a signal typically involve stable or near-stable nuclides
- Capture cross sections are highest at low neutron energies
  - High energy neutrons scatter to lower energies before capture
  - Thermal cross sections are well-known; resonance region and higher less so



80% Scaled
ICSB Benchmark PMF-44 Case 2:
Pu + Ni + Fe + Polyethylene
Mercury simulation



Capture gammas are used to identify materials where visual inspection is challenging

- Passive or active
  - Natural radioactivity
  - Neutron active interrogation
- Known or unknown
  - Verification
  - Identification

Emergency response teams

Everything

High energy: pass through shielding
Low background (S/N+)

GeMini

Gamma-Ray Spectrometer (GRS) deployed on NASA's Mercury MESSENGER: characterized surface isotopes

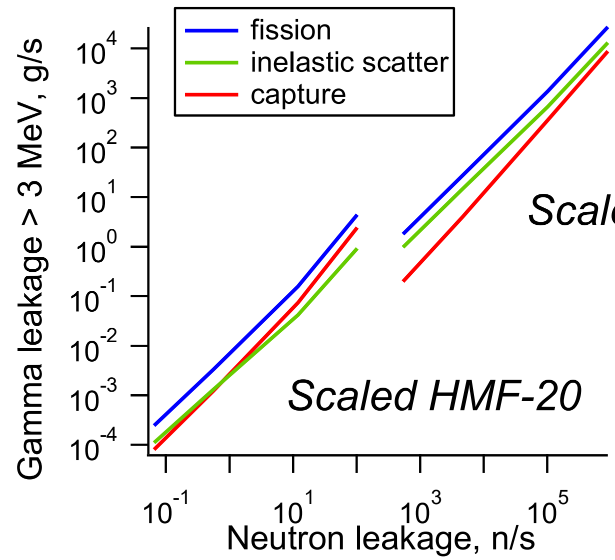
Three future missions planned: Psyche, Phobos, Titan

Light elements, silicates, Fe/Ni

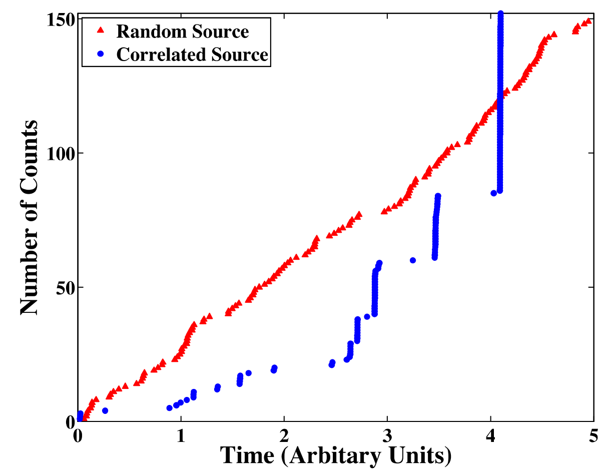
M. Burks (LLNL)

Gammas from capture reactions may improve our diagnostic capabilities

- Strength correlations
  - Gamma flux above 3 MeV indicative of neutron reactions
  - Can the high energy gamma rate be correlated to neutron rate or energy?
  - Need confidence that data at high energies are correct



- Time Correlations
  - Neutron correlations: multiplicity
  - Gamma correlations may also show utility
    - Demonstrated with high-multiplying systems and 2.2 MeV H capture lines
    - S/N challenges



S. Walston (LLNL)

Use of these signatures would also require detector development…

Energy deposition (gamma dose) is also a consideration

- Gamma imparts energy to surrounding environment
- Examples:
  - Personnel safety in laboratory spaces
  - Electromagnetic Pulse (EMP) effects
  - Planetary Defense applications

Everything:
Light elements (silicates)
Mid elements (metals)
Heavy elements (U, Th)

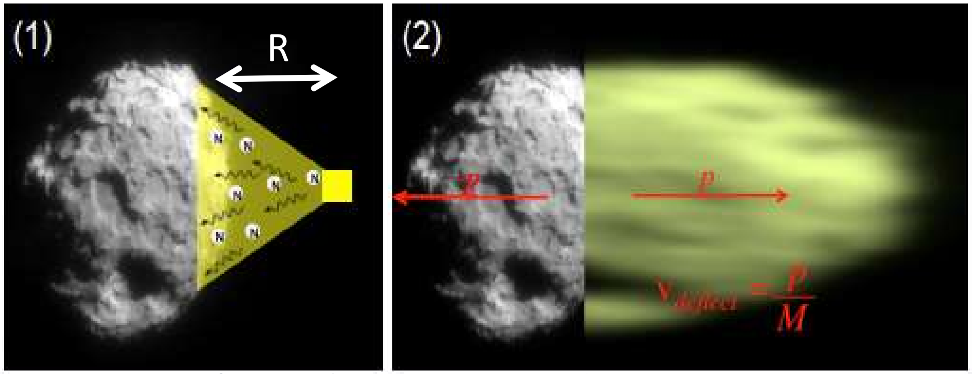
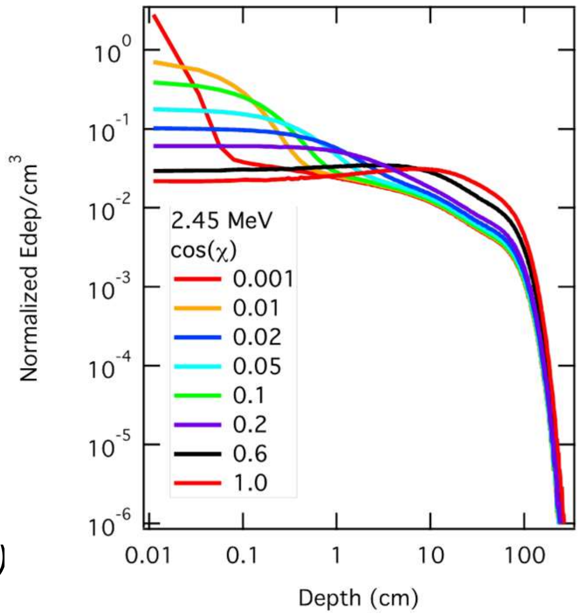
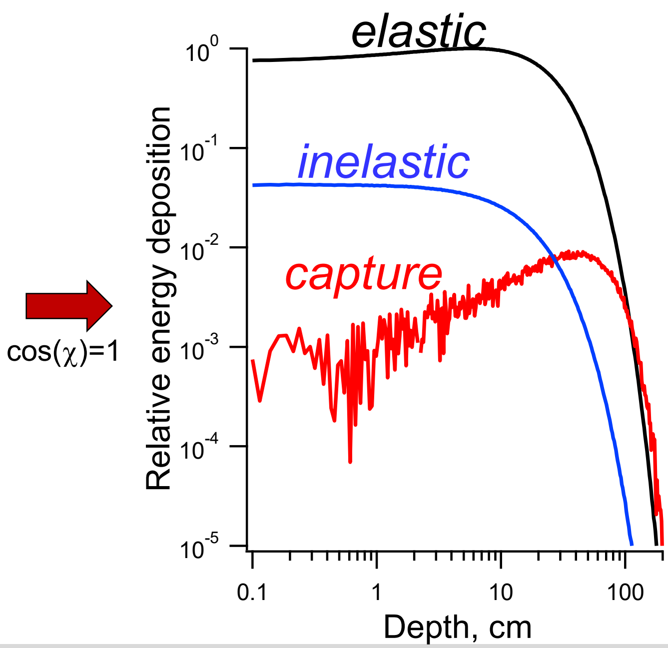


Figure courtesy of K. Howley, R. Managan and J. Wasem PDC 2015





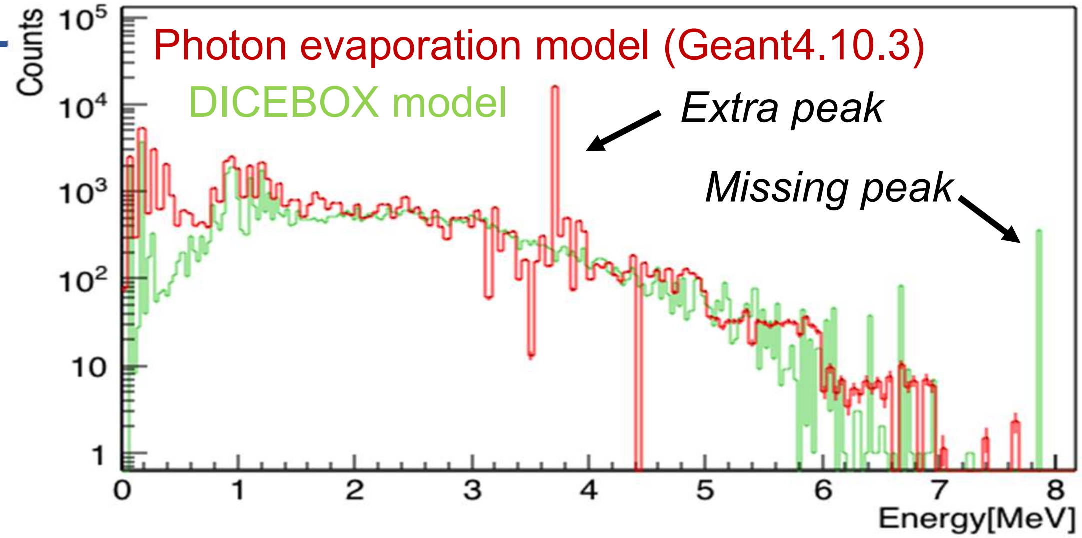
M. Syal and R. Managan (LLNL)

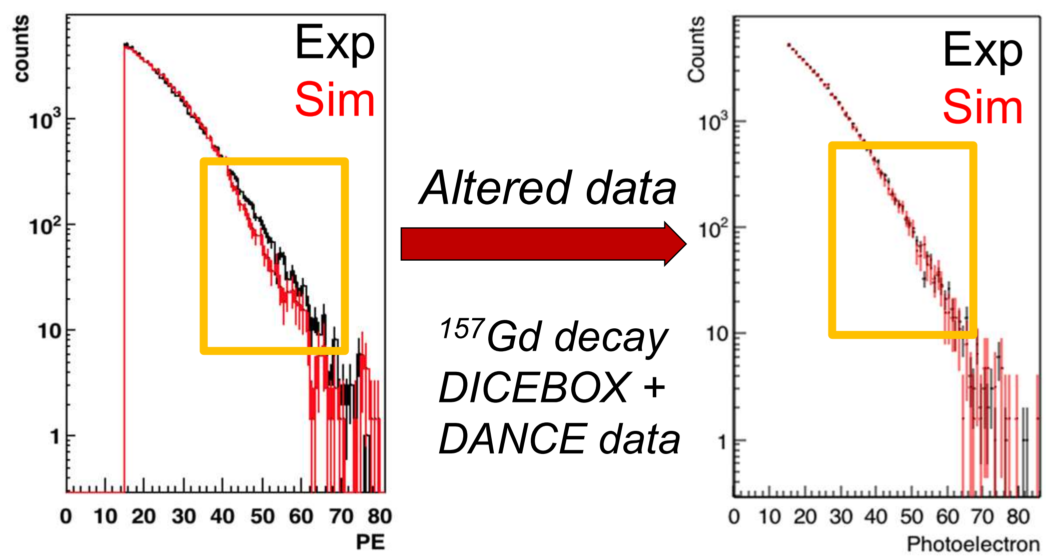
Accurate data are needed to understand scintillation detector response

- Multi-institution WATCHMAN effort uses Gd-doped water for neutrino detection
- Accurate data for ^{155,157}Gd are imperative toward engineering design and detection algorithms
- Recent work has highlighted the importance of improved data for ^{157}Gd
  - ^{155}Gd needs to be updated

^{155,157}Gd: Accurate photon evaporation model

F. Sutanto (U. Mich/LLNL)





Data needs cover a range of energies and isotopes over the applications considered

- Most applications start with higher-energy neutrons that scatter down to low energy and are captured
  - We need good models for scatter *and* capture
  - We are sensitive to a range of neutron energies above thermal
    - Cross sections can drop quickly, and data tends to be sparse

- Most applications using gamma production from captures involve stable or near-stable isotopes
  - But otherwise we are interested in pretty much everything…

- Both the cross-section and the photon decay pathway are of interest

- We rely on accurate data for input to applications-relevant simulations
  - Validation benchmarks would be helpful to test data libraries and simulations