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Title:	"What's that peak doing there???" 70 years of fission studies and discovery at LANL
Author(s):	Mosby, Shea M.
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“What’s that peak doing there???”

70 years of fission studies and discovery at LANL

Dr. Shea Mosby for the LANSCE-NS group
Los Alamos National Laboratory

Westmont College Physics Seminar
August 30, 2013

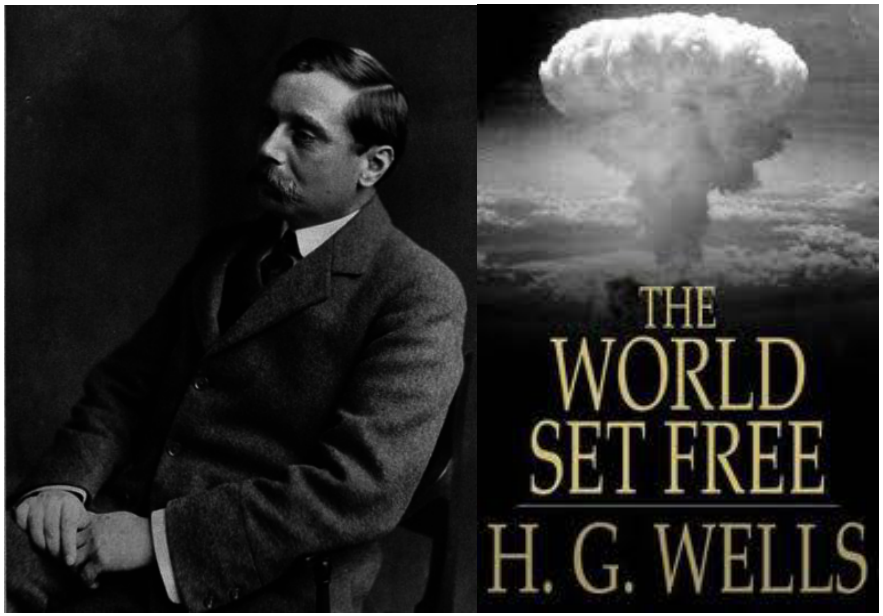
Who am I?

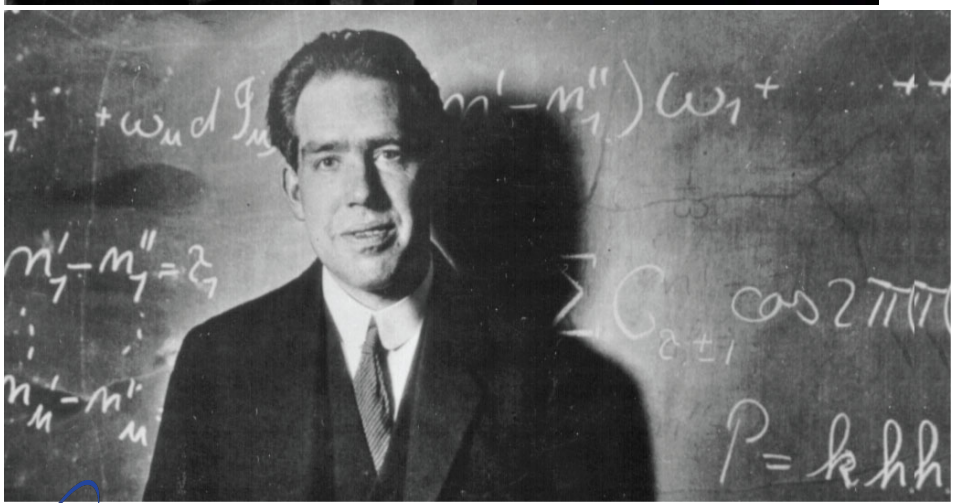
- Westmont College 2003 - 2007
- Michigan State University 2007 - 2011
- Los Alamos National Laboratory 2011 - 2013

Shameless Plug for Nuclear Chemistry

- So I'm married to a nuclear chemist...
- There's a Nuclear (Chemistry) Summer School every summer open to undergrads
- ...so if you're a Chemistry student and find anything I say interesting, come talk to me afterward!

A Brief History of Fission (pt 1)





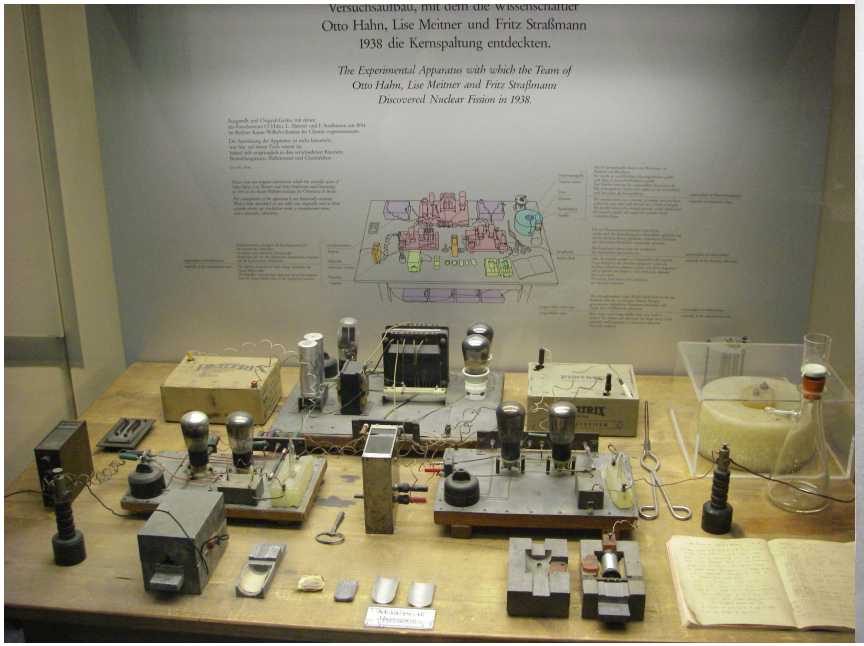
- 1896: Becquerel discovers radioactivity
- 1905: Einstein proposes mass-energy equivalence
- 1907 - 1910: Rutherford disproves “plumb pudding”
- 1913: Bohr Model of Atom
- First discussion of weapons in Science Fiction(!)
  - 1914: H. G. Wells publishes *The World Set Free*
- 1932: Chadwick discovers the neutron
- 1934: Fermi bombards uranium with neutrons, Noddack suggests fission (ignored)

Remarks from an Astrophysicist

"If, indeed, the sub-atomic energy in the stars is being freely used to maintain their great furnaces, it seems to bring a little nearer to fulfilment our dream of controlling this latent power for the well-being of the human race - or for its suicide."

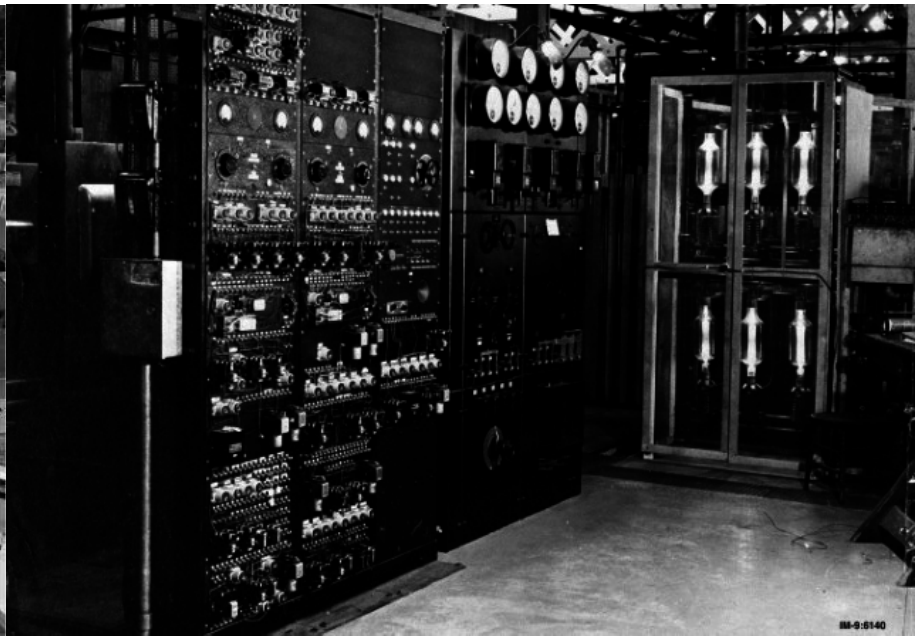
-Arthur Eddington, *The Observatory*, XLIIL **557**, 1920

A Brief History of Fission (pt 2)



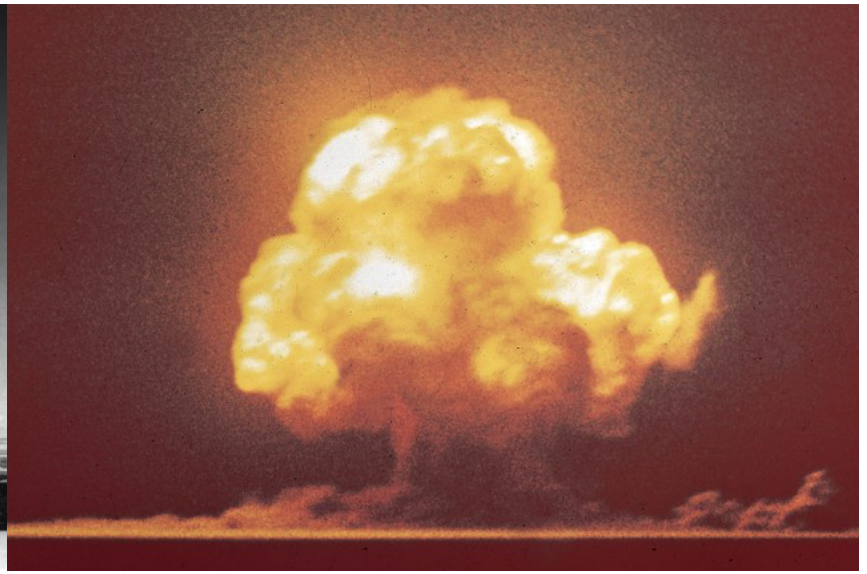
- 1938: Otto Hahn bombards uranium w/ neutrons, find barium??
  - Wrote to Lise Meitner who explained as fission
- Meitner predicts prompt energy release, Otto Frisch confirms
- One month later (Jan 1939) the community discusses in Washington DC
- ... and WW2 begins

Einstein's Letter and the Manhattan Project



- August 1939: Szilar and Wigner (Hungarian physicists) convince Einstein to write a letter to Roosevelt
- Meetings, meetings, and reports...
- By 1942 project is directed by Army Corps of Engineers under "Manhattan District"
- 1943: Los Alamos lab begins operations - by July 1945 a device is ready to test

Trinity



- Successful test July 16, 1945
- Equivalent of 21,000 tons of TNT
- August 1945 brings use in anger and surrender
- WW2 officially ends on September 2

Some of our other (more recent) work

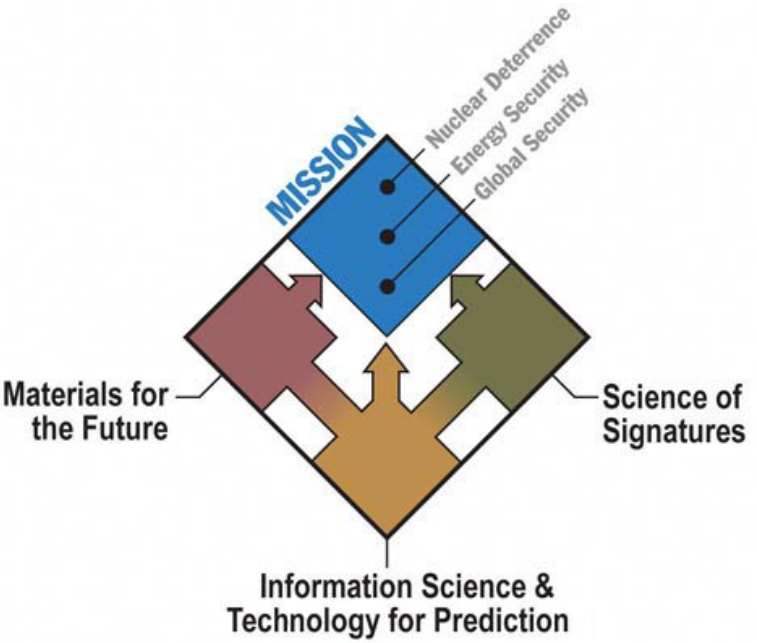
Many subdisciplines of nuclear physics and related fields...

- Understanding the details - fundamental science
- Civilian uses of atomic energy
- Medical isotope production
- Nuclear astrophysics
- Imaging techniques
- Safeguards and stockpile stewardship

...and lots of others, including “spinoff” technology

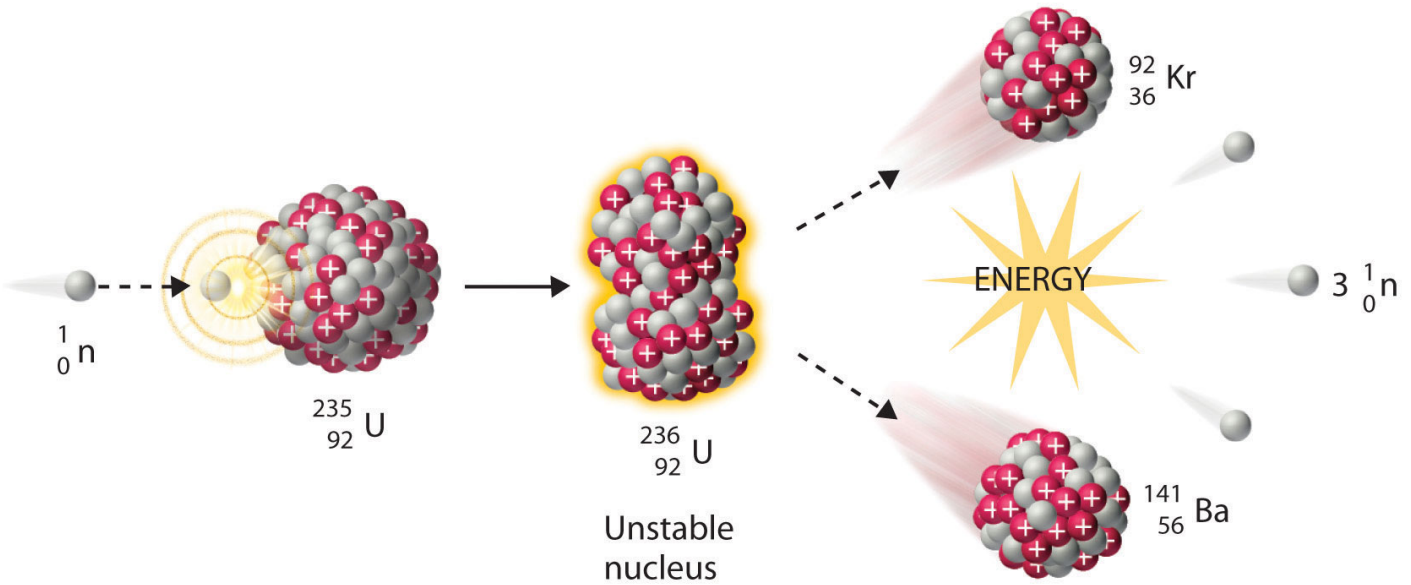
I’m involved in the experimental nuclear physics side - particularly fission related work at the moment.

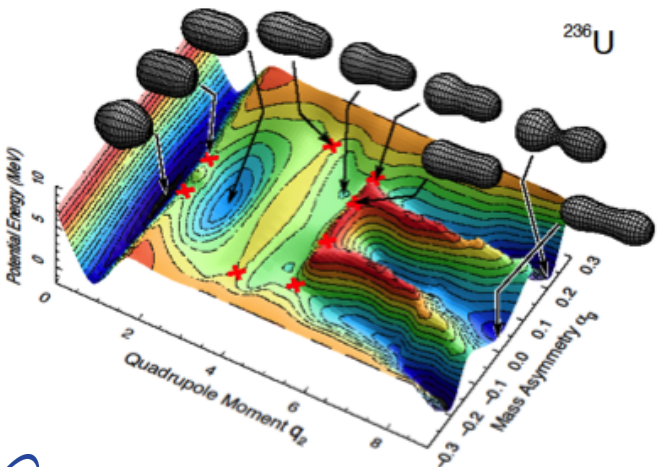
A Broader Look at LANL Today



- Photovoltaics
- Mars Rover
- Climate Change
- Accelerators / Electrodynamics
- Biofuel
- High Field Magnets
- Carbon Sequestration
- Extreme Scale Computing
- Biosecurity
- Lasers (Trident, NIF Collaborator)

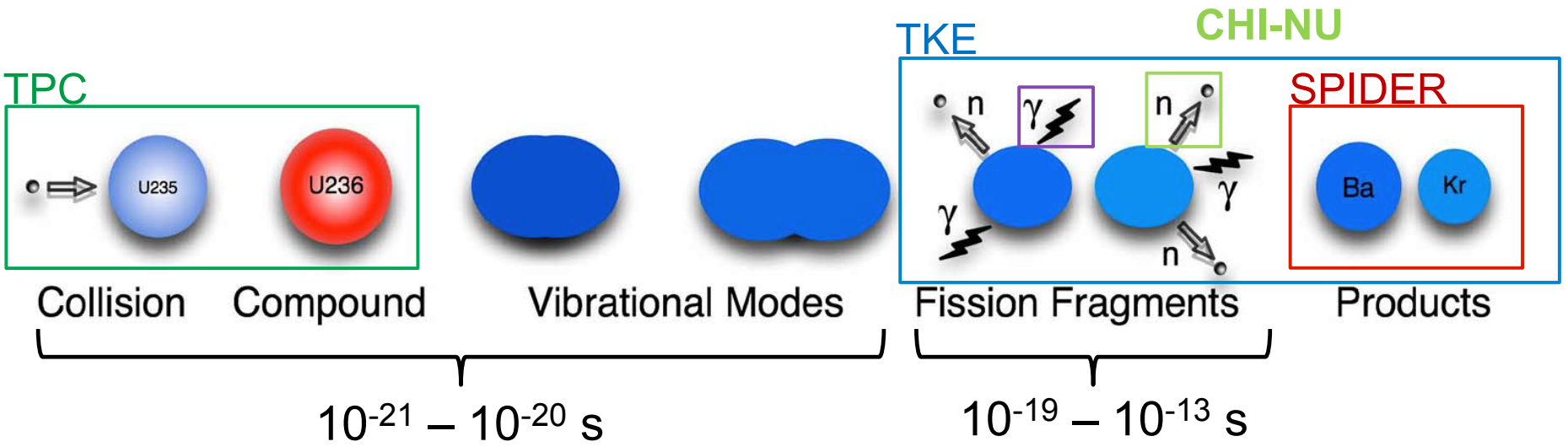
So what is nuclear fission?





1. Incident neutron excites nucleus to "fission barrier" (10^{-20} s)
2. Nucleus evolves to scission (10^{-20} s)
3. Fragments accelerate away (10^{-19} s)
   - $\geq$1000 resulting mass combinations!
4. Neutrons, γ-rays emitted (10^{-17} - 10^{-13} s)

What do we want to know?



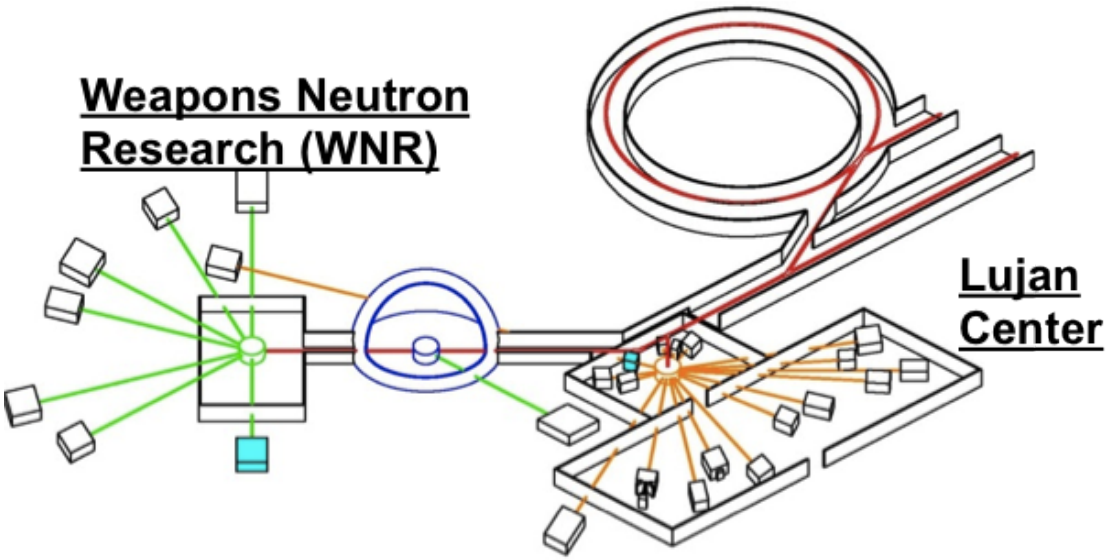
Observables

- Prompt and total γ-ray spectrum
- Prompt neutron output spectrum
- Cross sections
- Mass yields
- Kinetic Energy release
- Correlations!

Instruments

- NIFFTE TPC - cross sections
- TKE - kinetic energy vs. mass, charge, neutron energy
- DANCE - γ-ray spectra
- CHI-NU - neutron outputs
- SPIDER - high fidelity mass yields

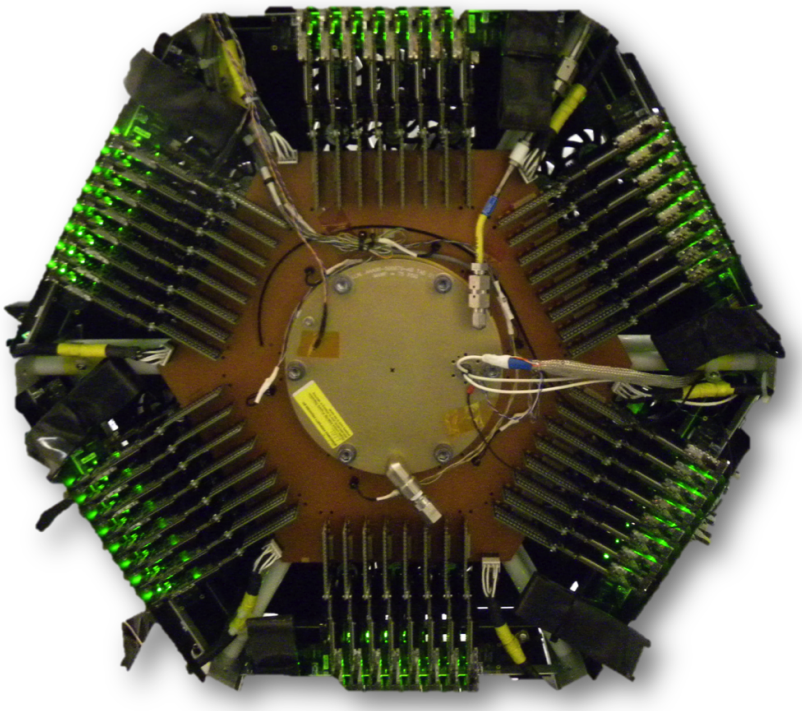
Where we work



- 1/2 mile long LINAC drives 800 MeV proton beam
- Neutrons produced by spallation (smash protons into some material)
- Beam delivered to multiple areas simultaneously:
  - WNR: nuclear physics
  - Lujan Center: materials science / nuclear physics
  - Proton Radiography: applications
  - Ultra Cold Neutrons: fundamental physic
  - Isotope Production Facility: medical / applications

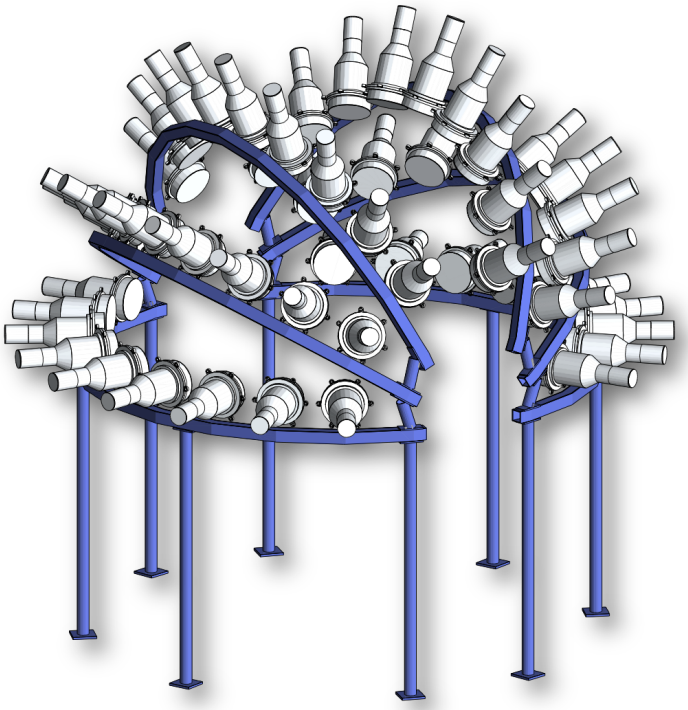
A Tour of our Equipment (pt 1)

NIFFTE TPC



- 6,000 readout channels to reconstruct 3d particle tracks
- Used for precision cross sections

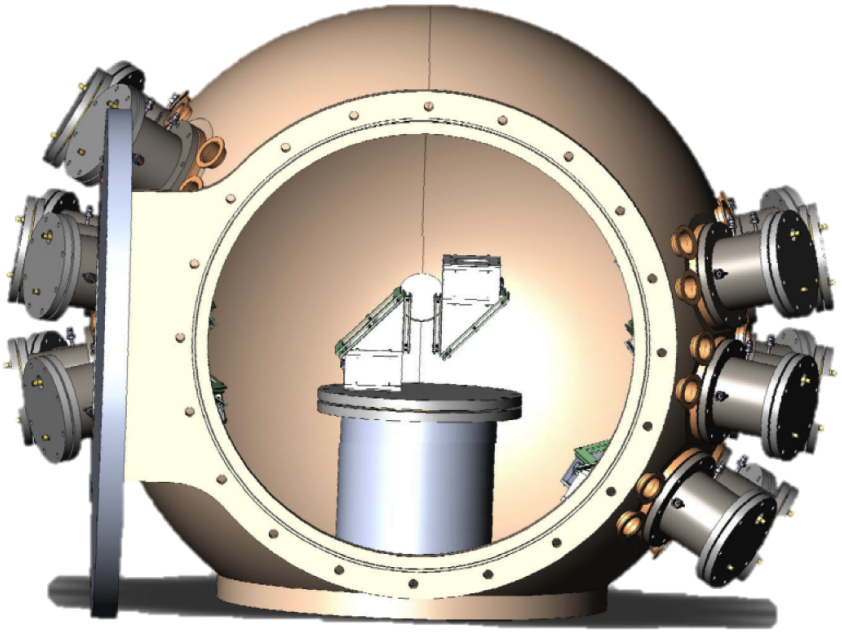
Chi Nu



- 20 neutron detectors measure fission neutron outputs
- Specially designed mounting system, experimental hall to reduce background

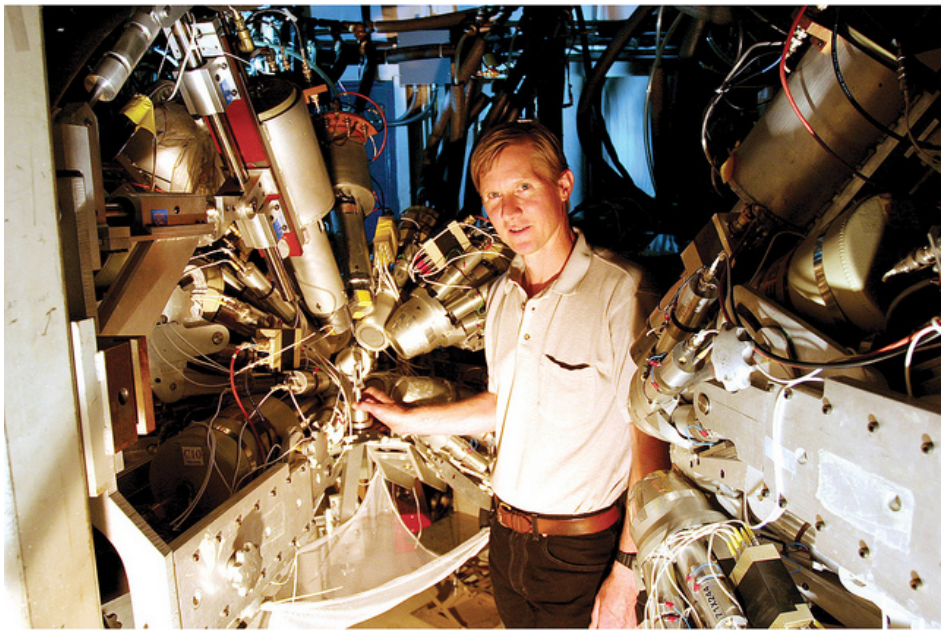
A Tour of our Equipment (pt 2)

SPIDER



- 9 spectrometer arm pairs measure velocity, energy of fragments
- "2E-2V" method of obtaining high resolution mass yields

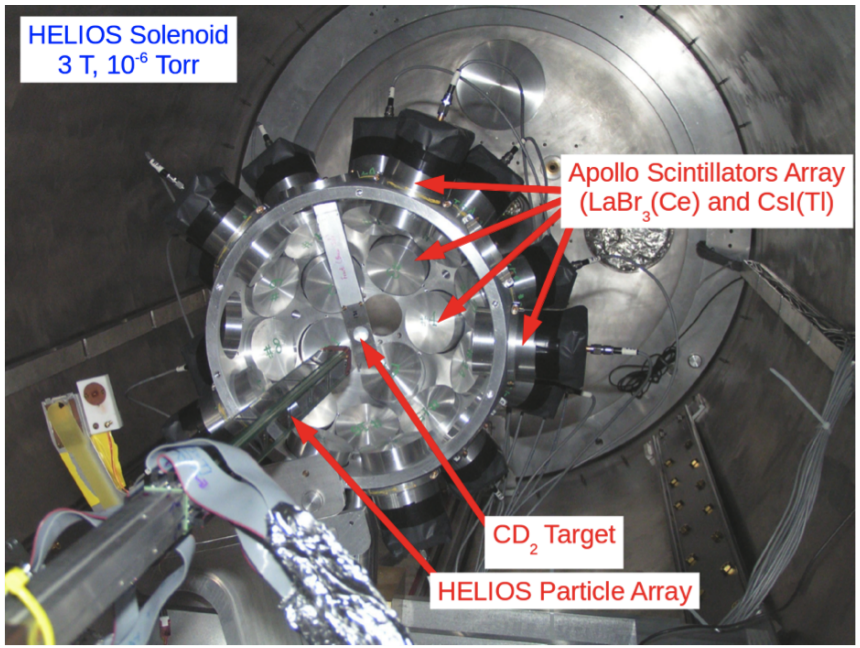
GEANIE



- 20 High Purity Germanium detectors
- High resolution γ-spectroscopy for structure studies

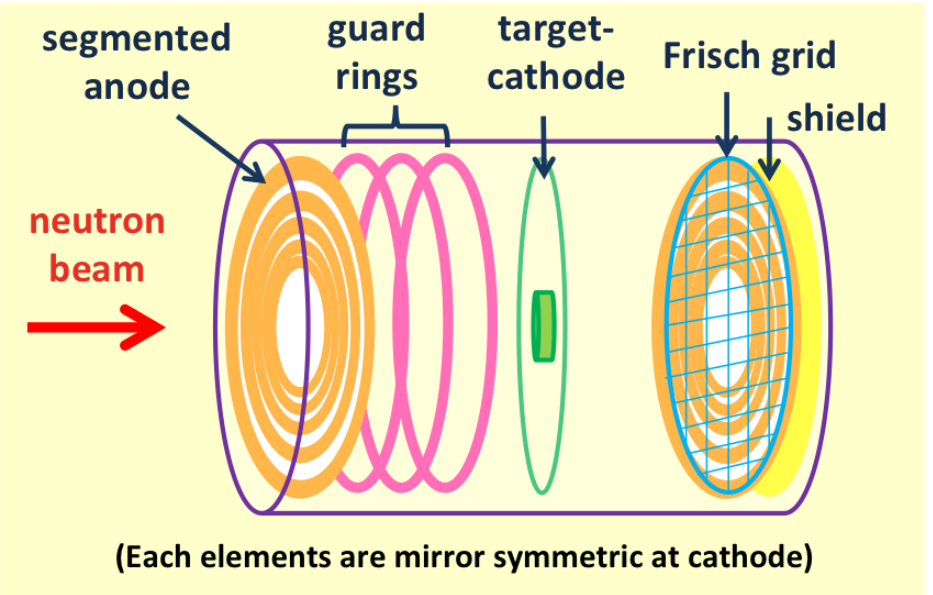
Non-fission developments

APOLLO



- 21 scintillator crystals *inside a 3 Tesla magnetic field*
- Study γ de-excitation following neutron capture
- Inverse kinematics using rare isotope beams

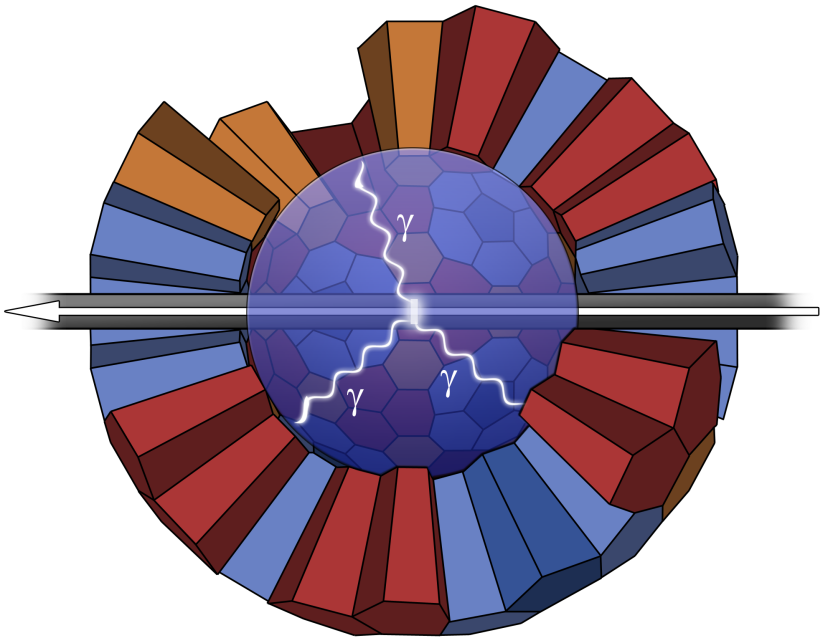
LENZ

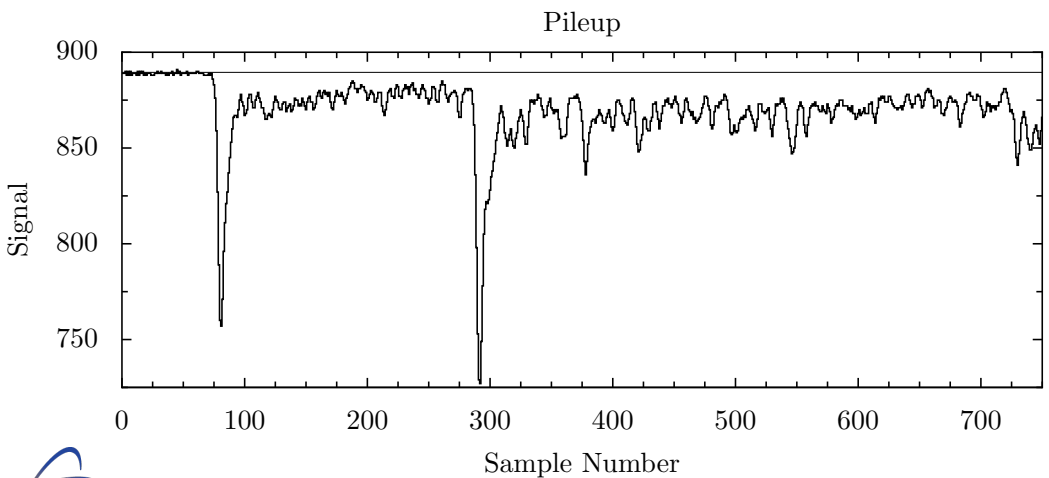


- Charged particle detectors for studying astrophysics relevant reactions
- In early stages of development

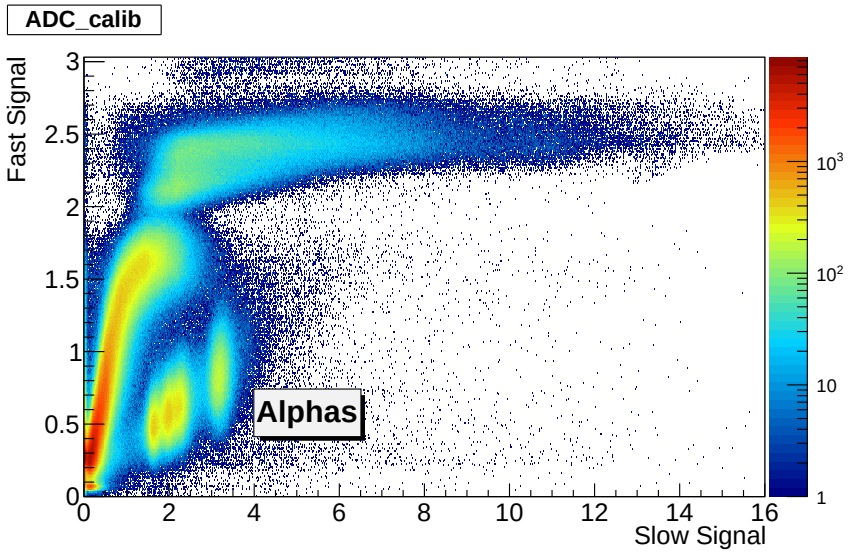
A Detector for Advanced Neutron Capture Experiments

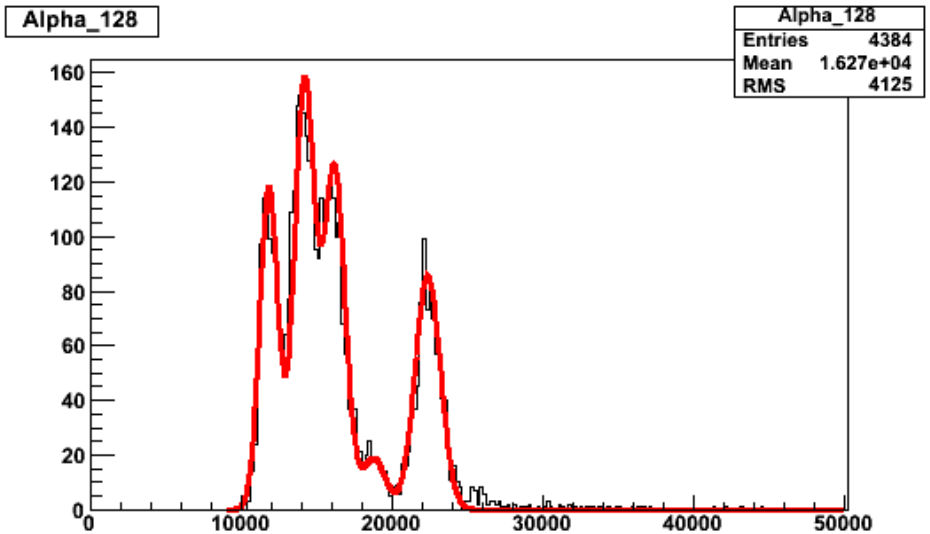
- 160 BaF_2 crystals
- 320 channels of digital DAQ
- 800 Mbytes/sec raw data rate - equivalent to 320 DVDs/hour
- 15 computers process in real time - data reduction of $\sim$500x
- 85% Efficiency - calorimeter



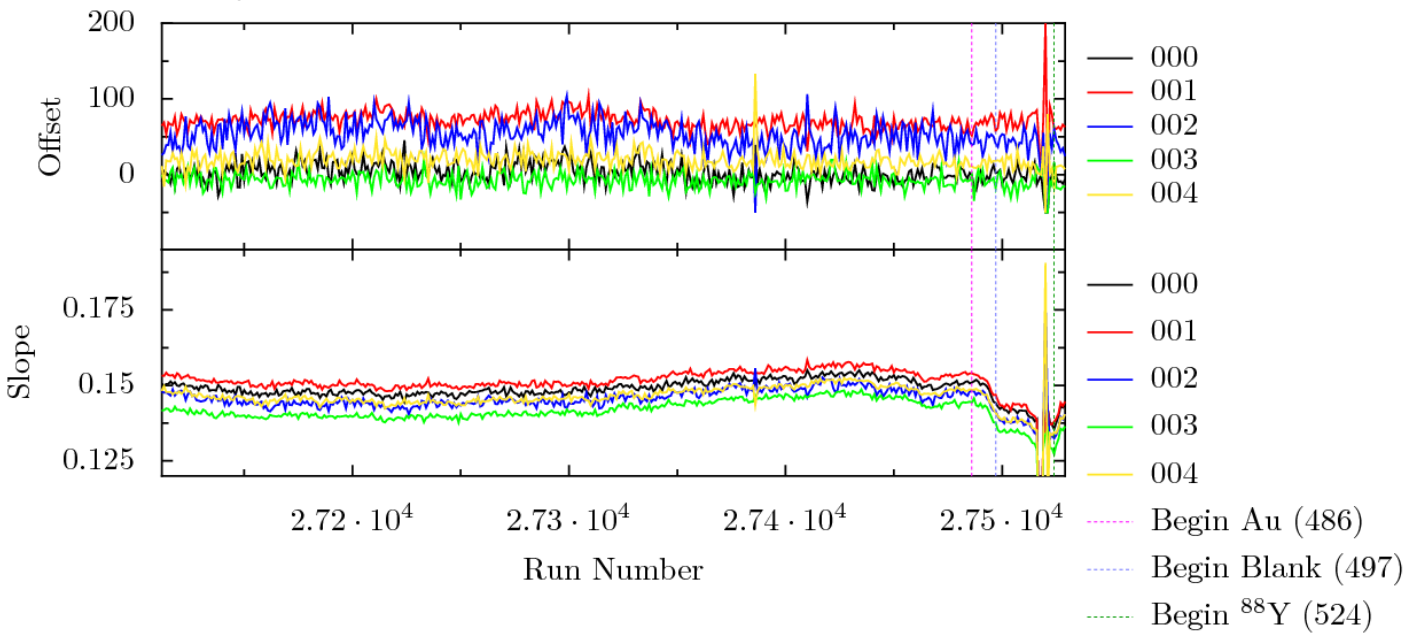


Energy Calibrations / Drift Corrections

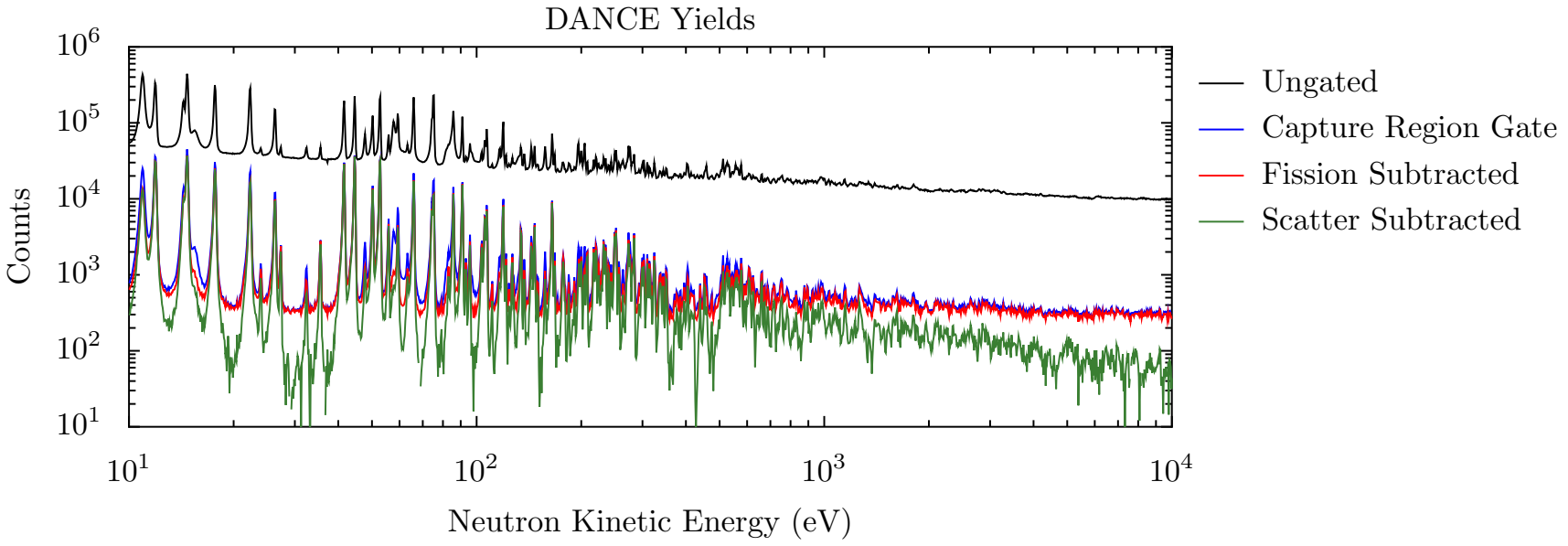


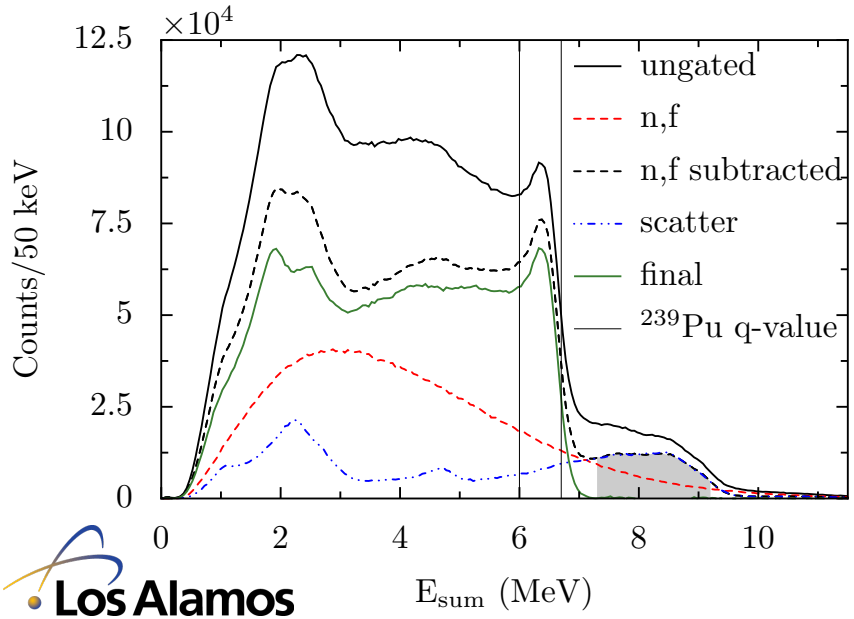


- Natural α background seen with PSD
- Use for energy calibration
- Run by run gain tracking



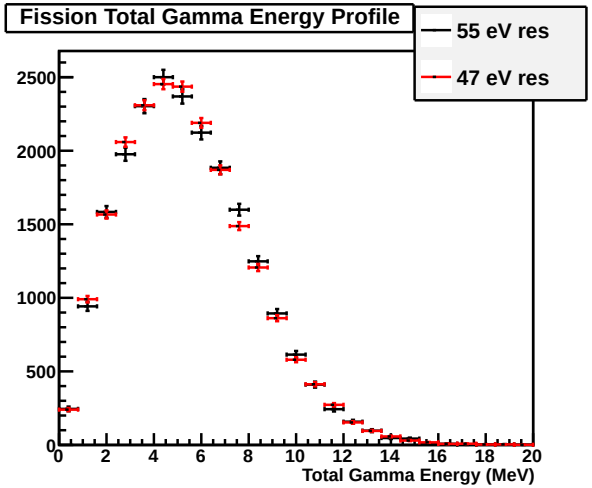
Data Analysis Overview

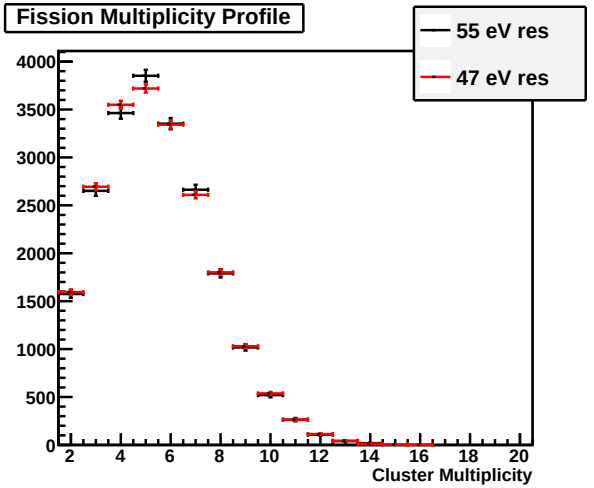


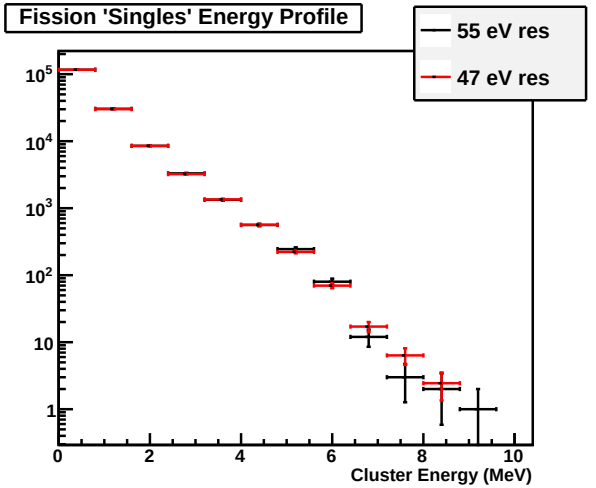


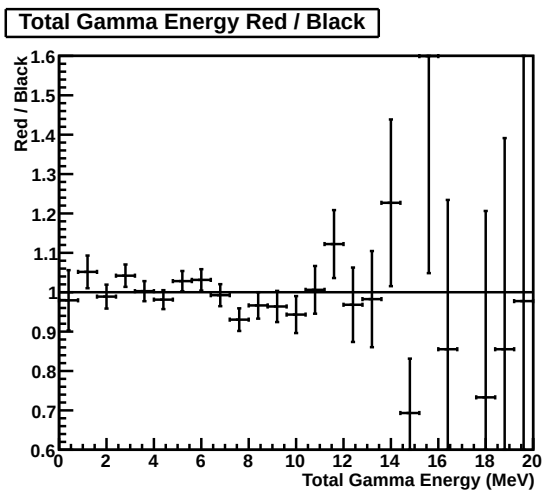
- Interesting signal (capture) sits atop background
- Primary challenge for this analysis: appropriately characterize, subtract off these backgrounds
- Detailed information from DANCE makes this possible

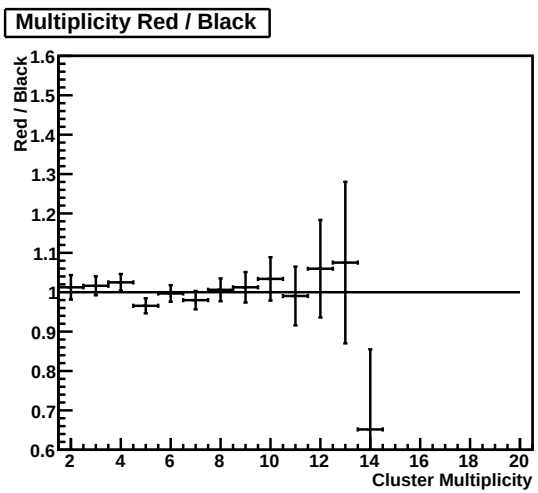
Some surprises *are* left in fission science!

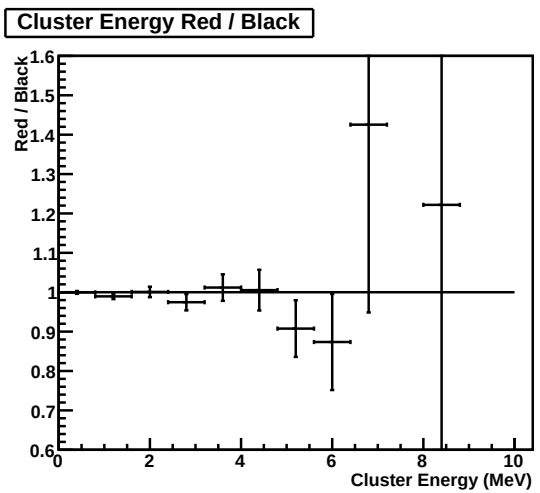






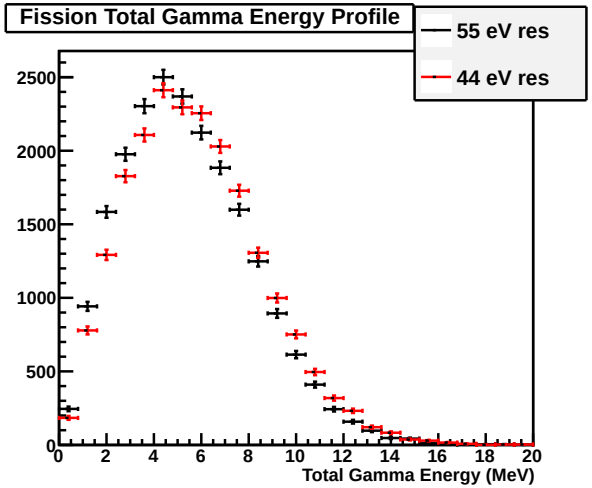


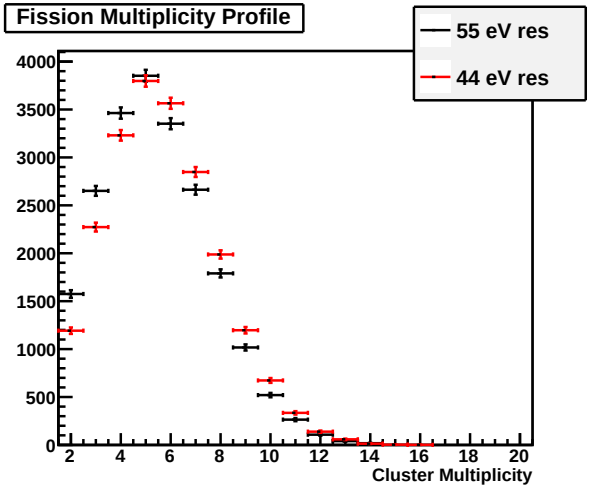


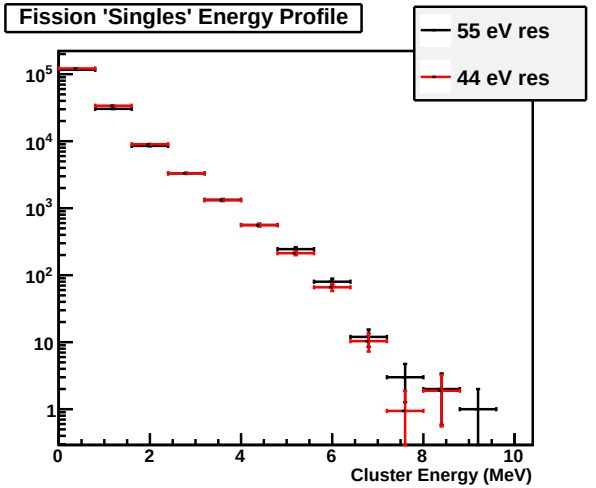


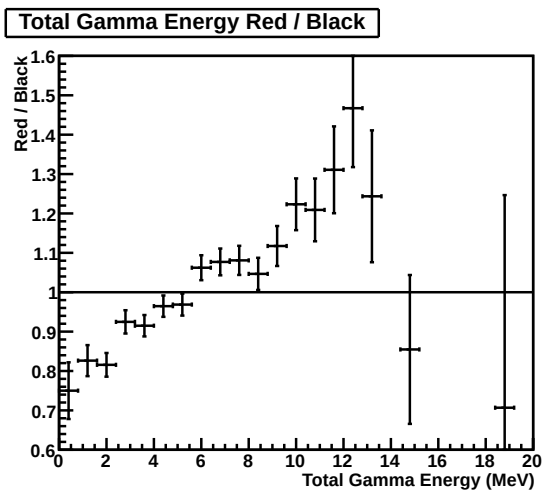
- This is what you'd expect...

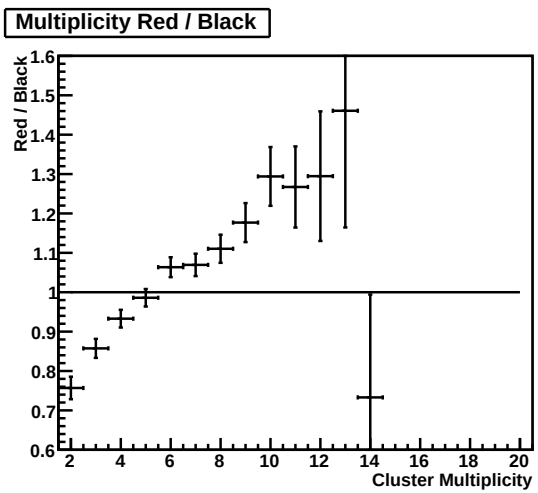
Some surprises *are* left in fission science!

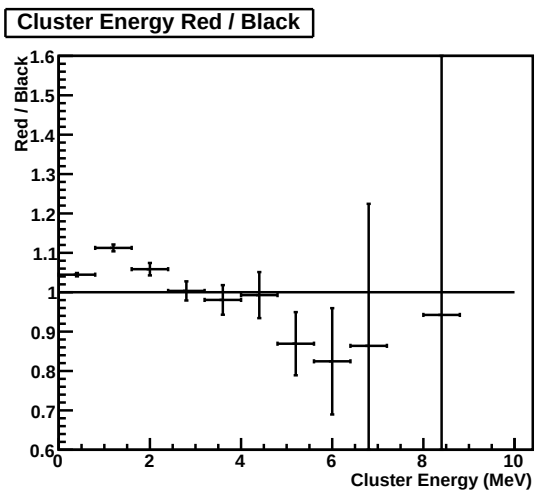






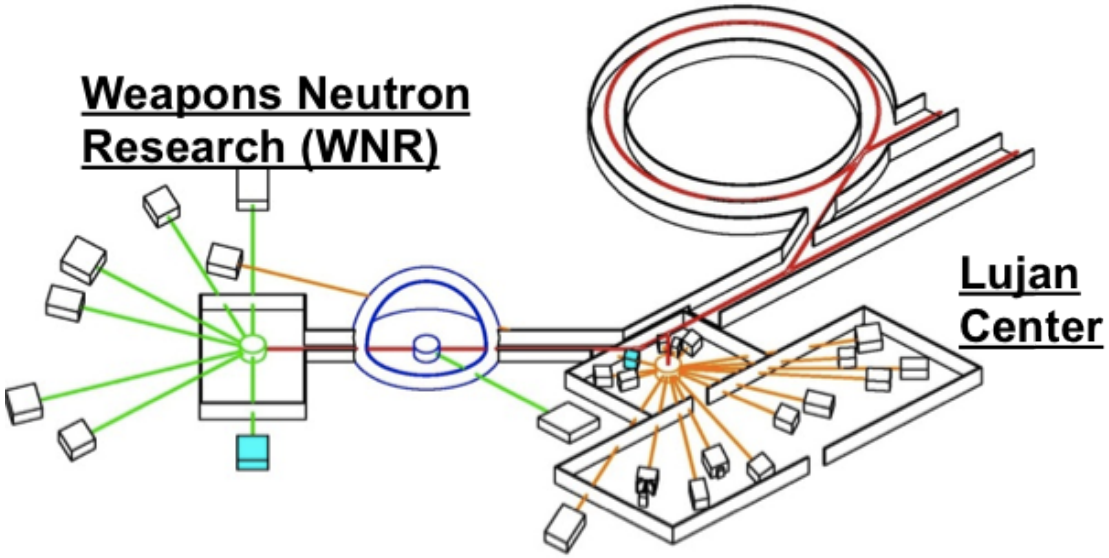






- ...and this is what we get!

This Fall...



Remember, we run many experiments in parallel...

- TKE experiment measures energy release, mass yields
  - Adding in γ detectors to to look for more new phenomena
- SPIDER 1st data with beam for high resolution masses
- DANCE hardware/software upgrade begins
- ... and that's just the new stuff!

Wrapping it up...

- LANL has a long history in nuclear science / fission studies
- ...but the total scope of the lab is vastly greater
- There's still a lot to learn!
- We're actively growing our experimental capabilities
- Lot's of exciting science will get done over the next few years!

Acknowledgements

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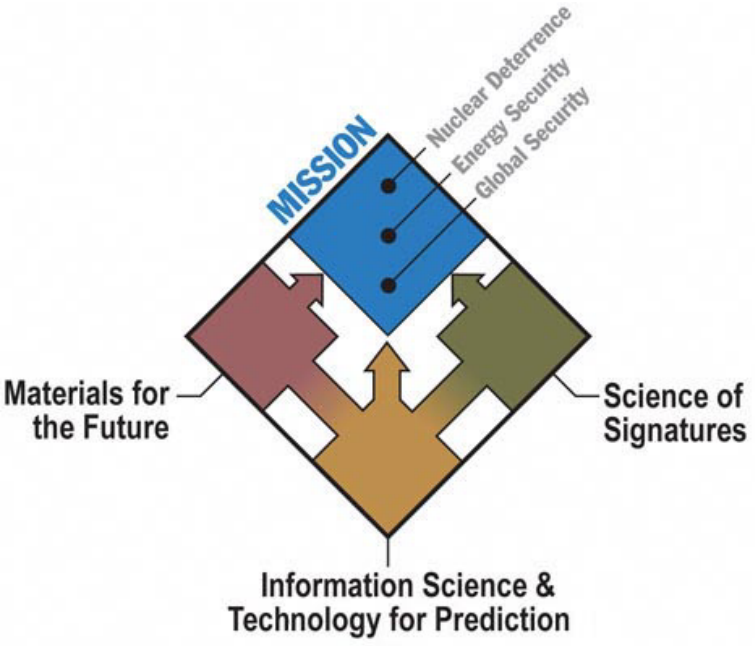
Thanks for listening!



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