Lawrence Livermore National Laboratory

Nuclear Science and National Security

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Nuclear science contributions to national security

- *Radiochemisty* – nuclear forensics, stockpile stewardship, NIF nuclear diagnostics
- *Nuclear Theory* – fission, fusion, nuclear reactions
- *Nuclear Experiment* – cross sections, diagnostics, detectors
- *Nuclear Data* – cross section evaluations, computational models

The scientists willing and able to take on the challenges presented by a changing world

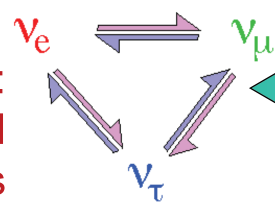
An example: rare event detection

Dark Matter and Neutrino Physics are top priorities in 21st century physics

Rare Event Detection

Fissile Material Search, Monitoring and Verification are top priorities for global nuclear security

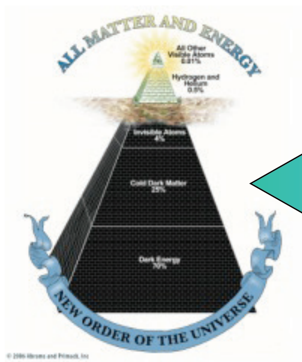
Neutrino Physics: oscillations and neutrino mass



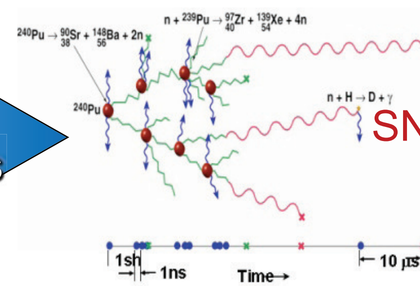
1-10 MeV antineutrinos

Pu Production: Reactor antineutrinos

Dark Matter: Axions and WIMPS



1 keV to 10 MeV
Neutrons and Gamma-rays

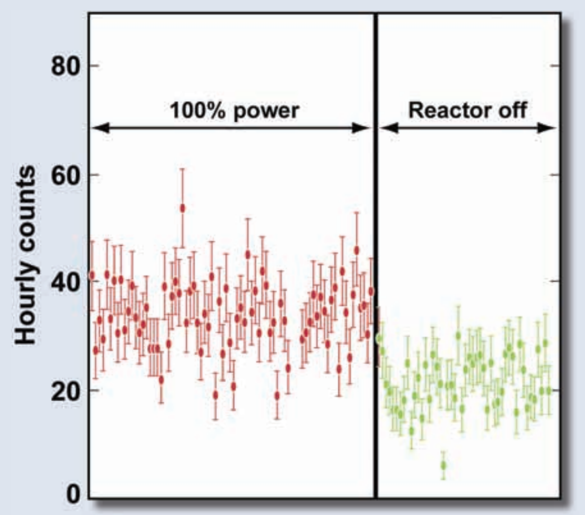


SNM Detection: gammas and neutrons

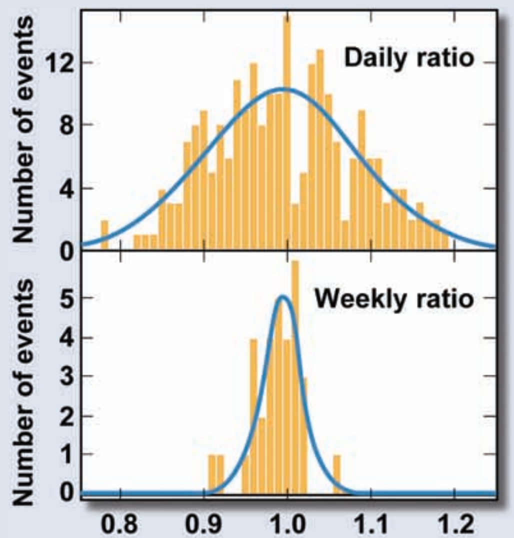
Rare neutral particle detection underlies nuclear security and fundamental nuclear science

Applying anti-neutrino detection to nuclear proliferation

Determine reactor on/off status within 5 hours with 99.9% C.L.

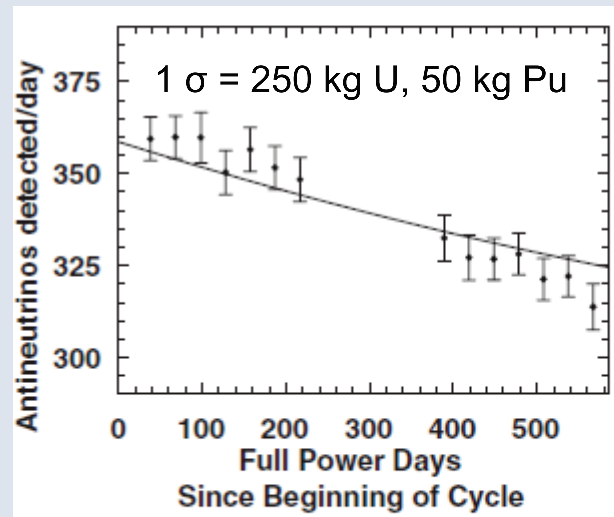


Measure thermal power to 3% in one week



J. Appl. Phys. 103, 074905 (2008)

Change in rate tracks burnup of U/Pu



JOURNAL OF APPLIED PHYSICS 105, 064902 (2009)

Anti-neutrinos are produced copiously in nuclear reactors, and cannot be shielded. Detectors can "standoff" from the reactors and make the measurements.

Provide technical assessment of potentially disruptive concepts

Draft Terms of Reference for a literature review and assessment of the state of research on the Nuclear Isomer ^{178m2}Hf and the potential for controlled energy release

Background: Nuclear isomers have long been proposed as novel High Energy Density Materials (HEDM). The former Soviet, Russian and US literature all contain published articles on the production of nuclear isomers and discussions on potential stimulated de-excitation mechanisms. Further, US research programs since approximately 2001 have unsuccessfully attempted to validate the HEDM nature and controlled energy release from nuclear isomers. Recently, the Senate Armed Service Committee (SASC) staff tasked the NNSA Office of Nonproliferation Research and Development (NA-22) to conduct an all-source literature review and produce a short written report that provides the current scientific assessment of the potential for controlled energy release from the nuclear isomer ^{178m2}Hf for energy and military uses, by the mechanism of enhanced decay through neutron inelastic scattering interactions. SASC staff request that the report be completed by the end of September 2008.

Key Research Question: Does either current scientific theory or previous experimental results support the claims made in the recent Russian literature that neutron induced stimulated de-excitation through inelastic scattering produces enhanced decay of the nuclear isomer ^{178m2}Hf, potentially providing substantial and controllable energy release?

Product: Written, all-source report, including citation index, that answers the research question above and provides supporting information.

The concern, new types of nuclear explosives

From a proponent’s presentation:

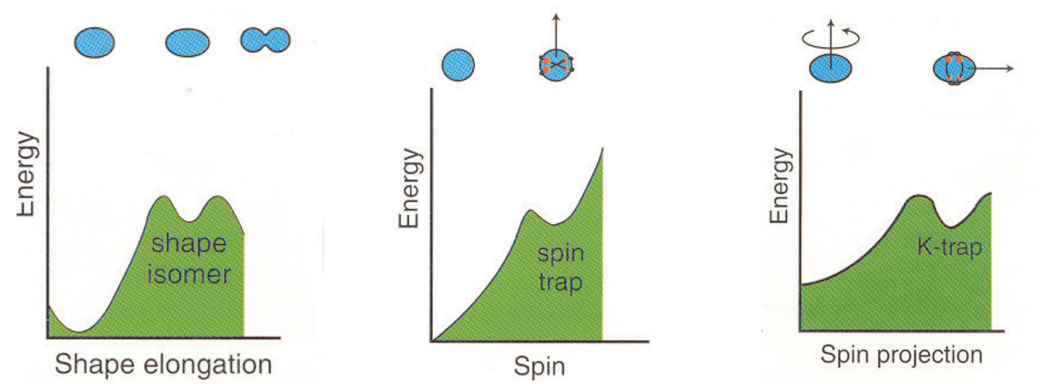
What's a nuclear isomer?

Frederick Soddy anticipated nuclear isomers in a 1917 discourse delivered to the Royal Society:

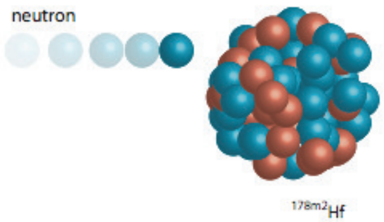
> *nuclei with the same atomic number and atomic charge but with distinct radioactive decay properties.*

A more modern view consistent with Soddy would define nuclear isomers as states of a nuclei with anomalously long life-times, due to forbidden or "hindered" decays to the ground state, from 10s ps to 10^{31} y.

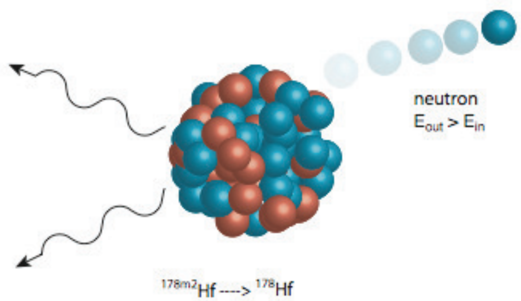
Nuclei are n-body quantum systems which exhibit both single-particle and collective behavior. Isomers exist as, "shape" isomers, spin isomers, *K*-isomer.



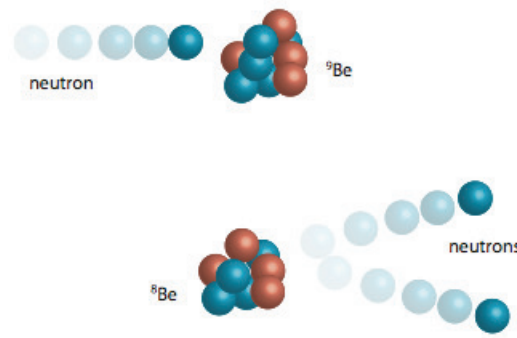
What is the “new kind of chain reaction”?



$^{178m2}Hf(n,n'\gamma)^{178}Hf$



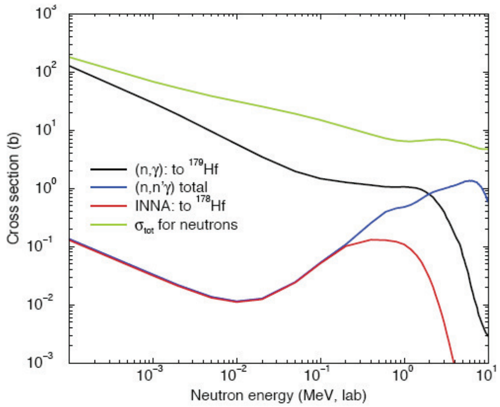
$^{9}Be(n,2n)^{8}Be$

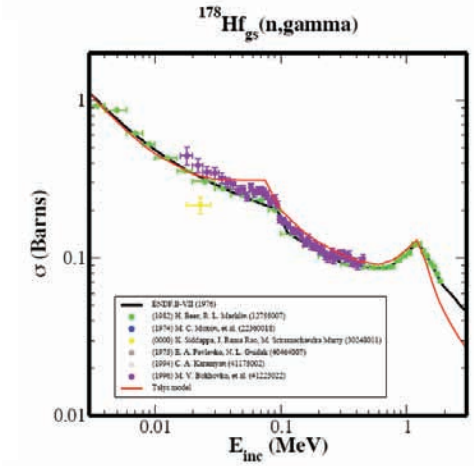


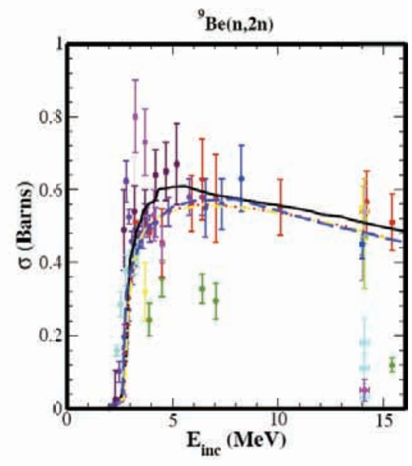
Inelastic Neutron Acceleration

Could this work?

Theory and data evaluation and experiment







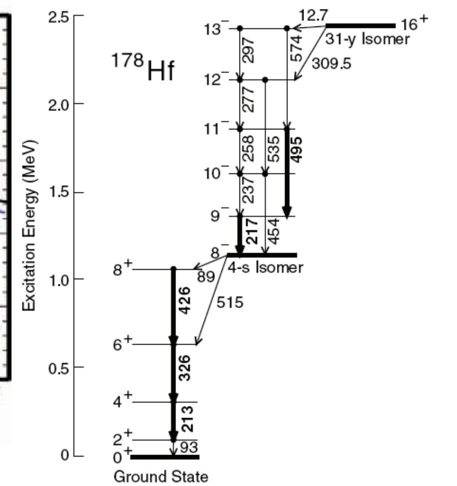


FIG. 1. Energy level diagram showing the decay of the 31-yr ^{178}Hf isomer. The transition energies are labeled in keV. Those transitions that were reported to be enhanced in [3,6] are highlighted.

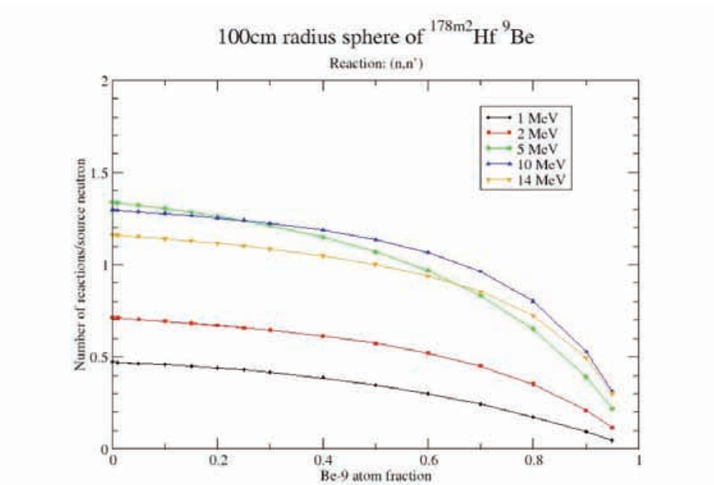
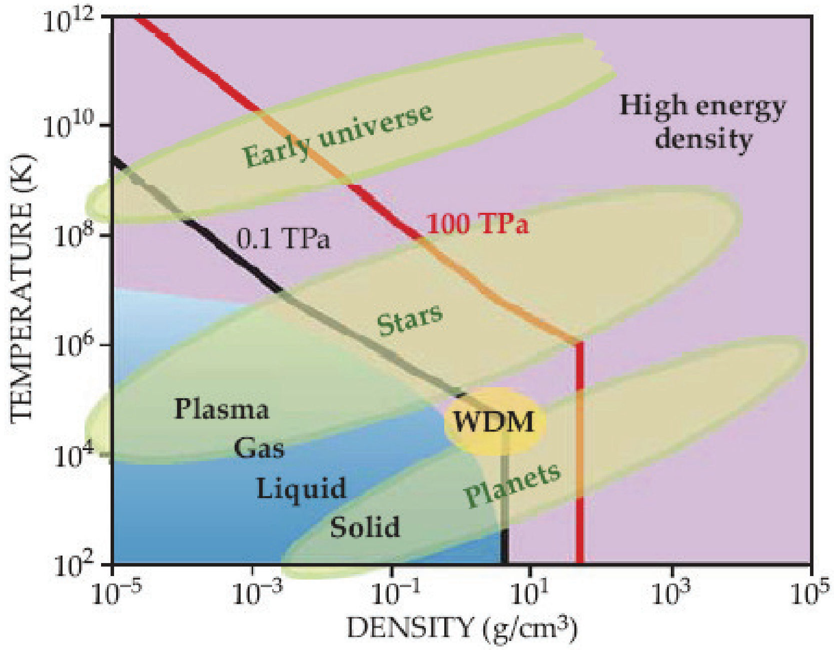
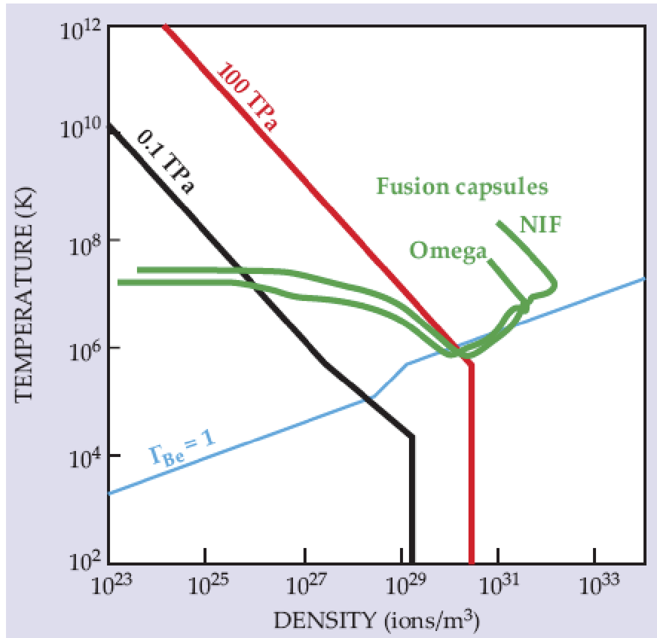


Figure 1. Effect of Beryllium concentration on the simulated (n,n') reactions per source neutron in a 100cm sphere of ^{178m2}Hf and ^{9}Be with a point source located at the center of the sphere. Results are shown for five neutron energies and can be found in Table I.

"The physical characteristics of ^{178m2}Hf do not provide the conditions necessary to sustain energy release in the infinite medium limit."

National Ignition Facility – nuclear-plasma physics

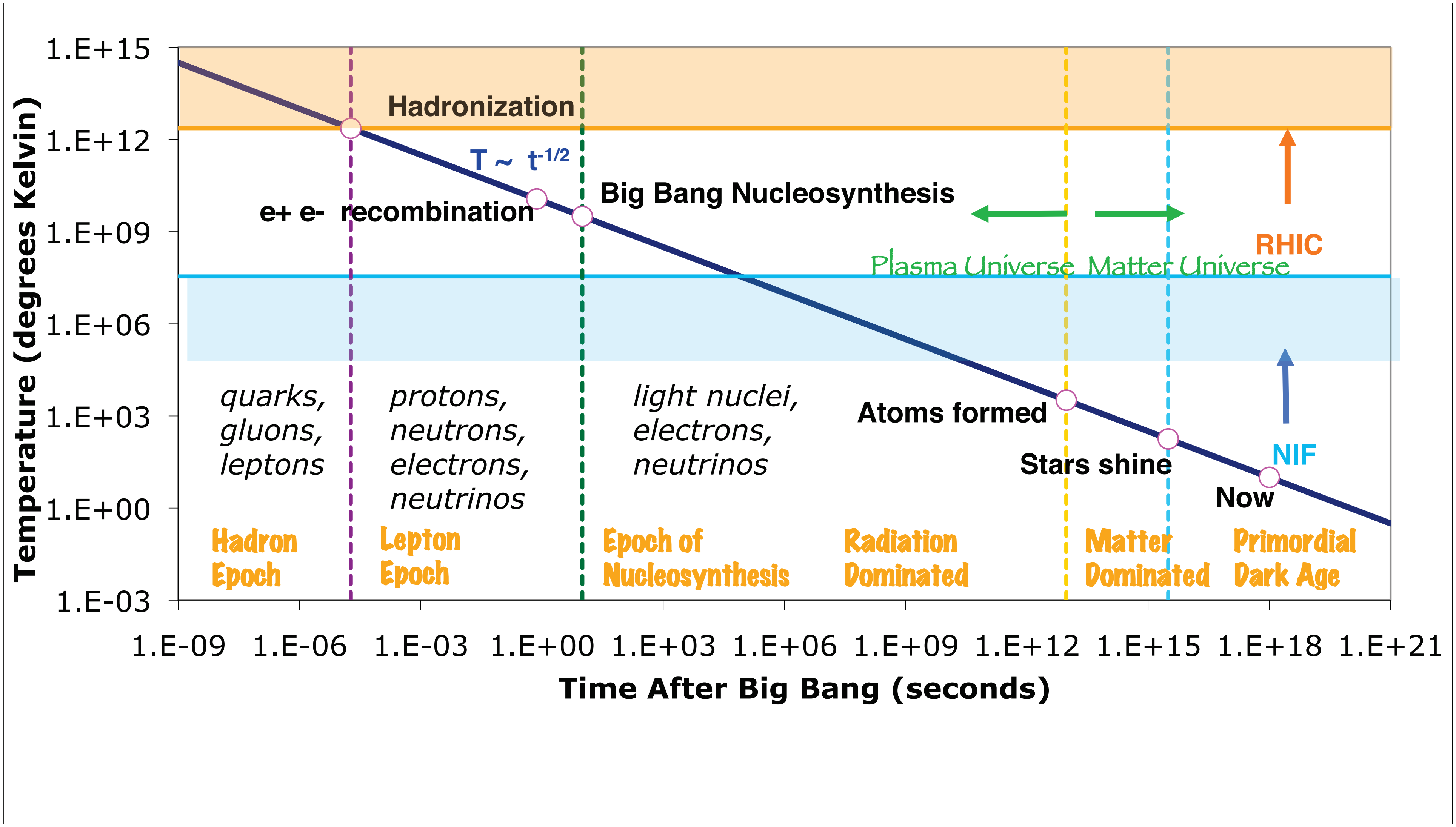




R. Paul Drake, *"High-energy-density physics"* *Physics Today* June 10, 2010 page 28

How do we study nuclear physics in a plasma?

The plasma universe....

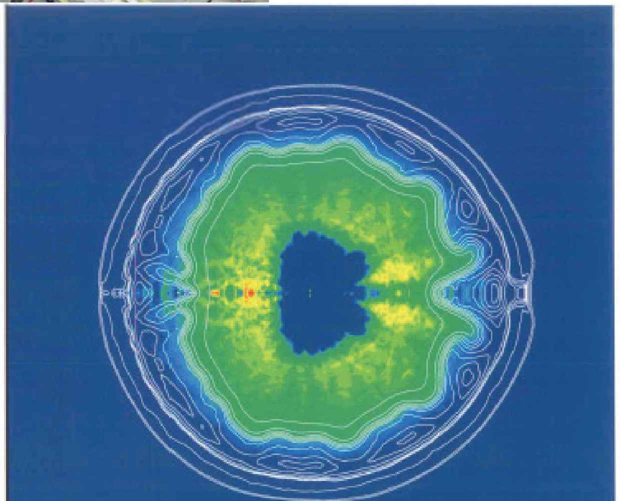


The NIF plasma environment

Hot/Dense
$k_b T$=1-20 keV
10^{35} cm^{-2}s^{-1}
$\rho \approx$10-1000 g/cm^3
10^{36} e/cm^2•s

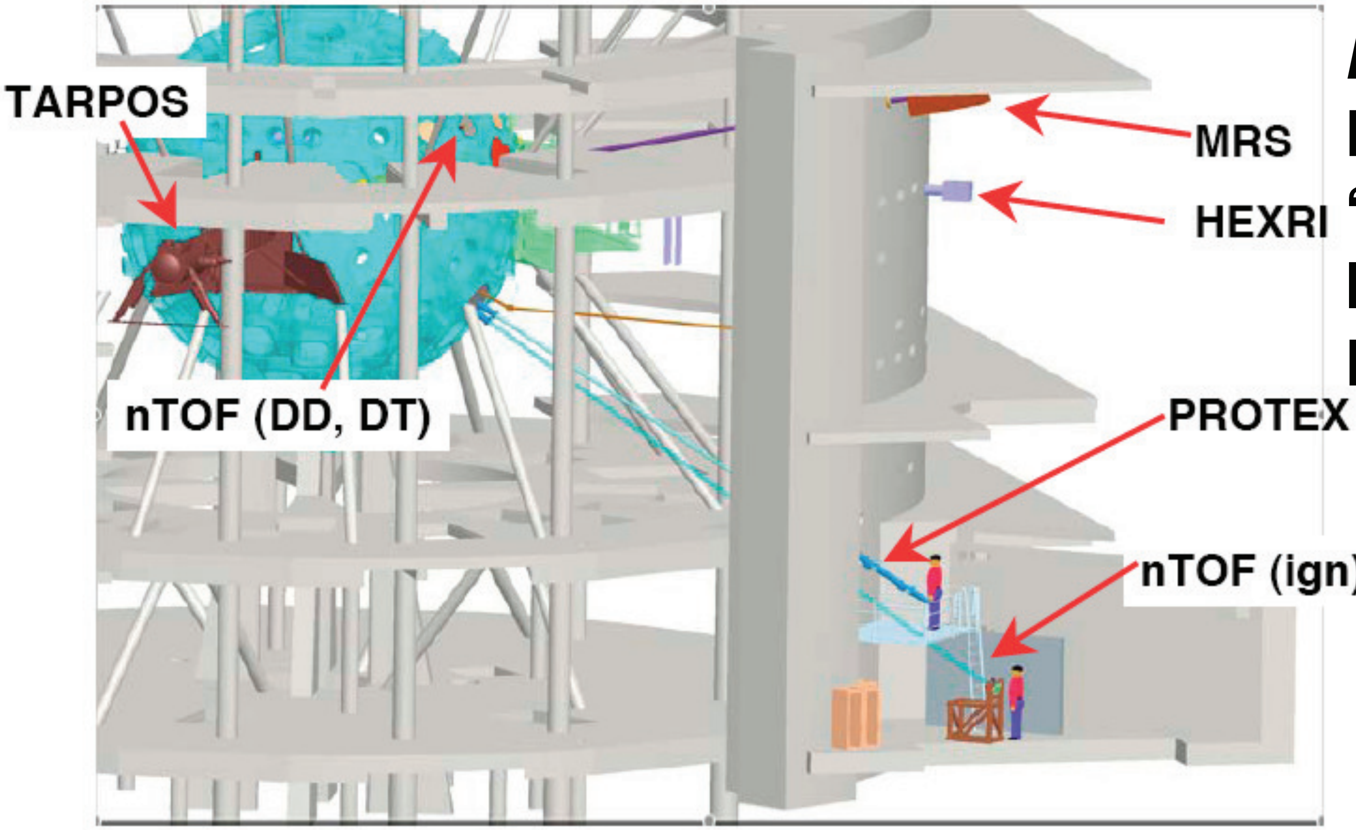
High Neutron Flux
$\approx 10^{30\text{-}35}$ cm^{-2} s^{-1}
(fluence=$10^{21\text{-}24}$ cm^{-2})

Radiochemstry diagnostics of ICF capsule mix



^{127}I(d,2n)^{127}Xe production

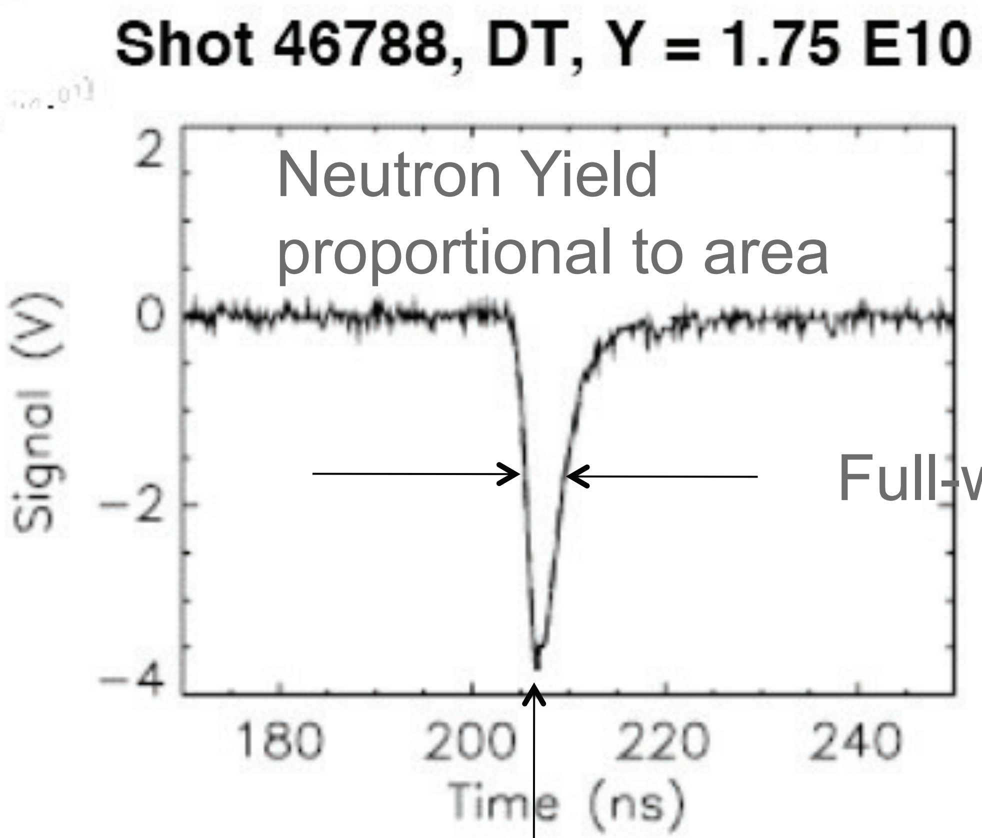
Nuclear diagnostics, e.g. neutron time-of-flight



Measure:
Neutron Yield
“Bang-time”
Ion Temperature
Down-scatter

Detectors designed, fabricated and calibrated by LLE

The nTOF detector signal



Neutron Yield proportional to area

D+T --> ^{4}He + n

Full-width half maximum

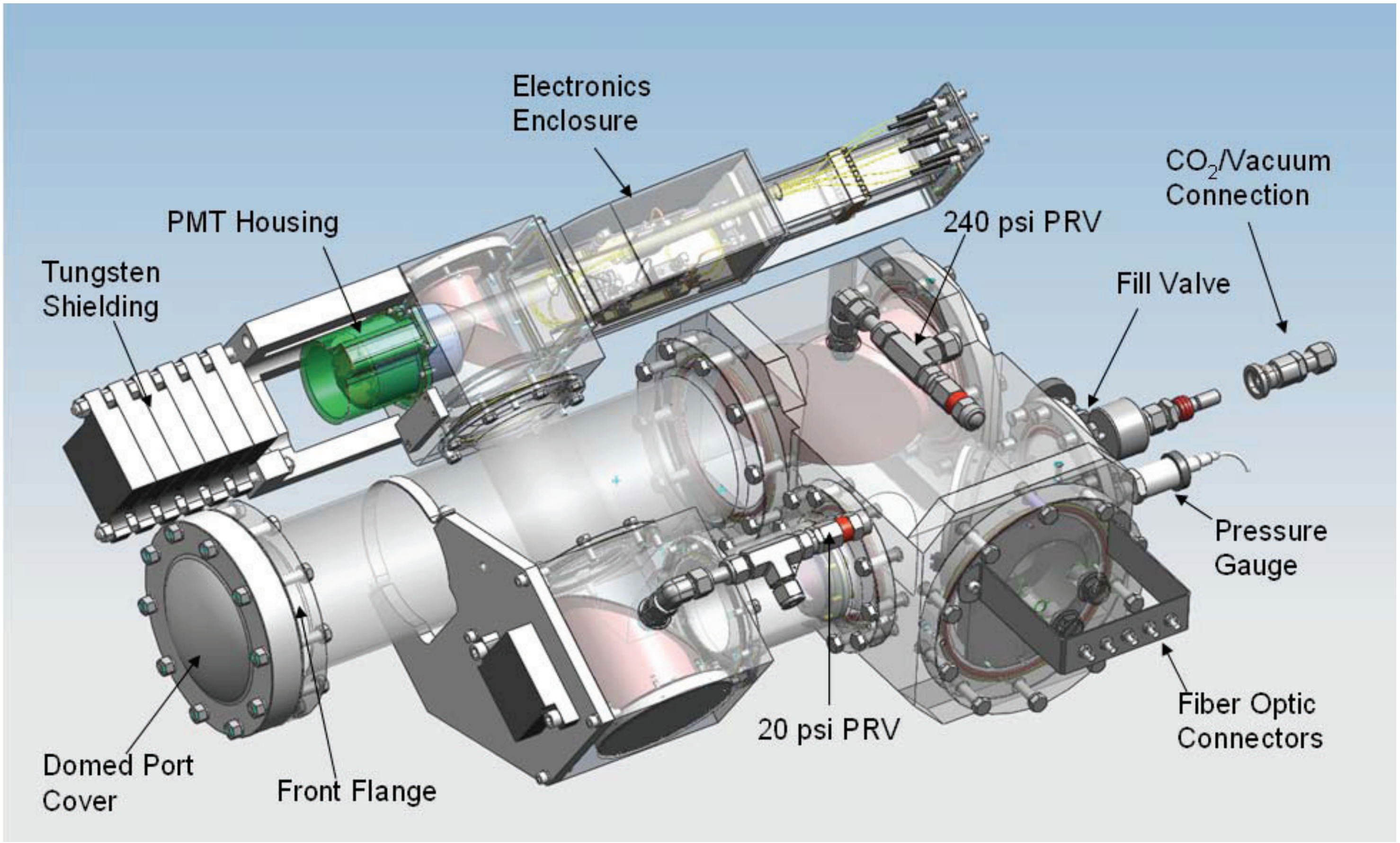
$\Delta t \sim \sqrt{T_{ion}}$

“bang-time”

Omega shot

Gamma Reaction History (GRH)

Measure all of the gamma-rays above a preset threshold energy, ~100ps time resolution



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Concluding remarks

There are many ongoing nuclear science projects driven by NNSA's and the Lab's national security mission.

The nuclear science program supports applications that meet the challenges presented by the changing national security "landscape."

Most important for the labs is to have the scientific workforce, both at the labs and through collaborations with the science community, ready and able to meet the challenges of the future.