# *"Near-field" Experiments*

Intensity Frontier Neutrino Subgroup Workshop 2013
Nu7 Working Group: Neutrinos and Society

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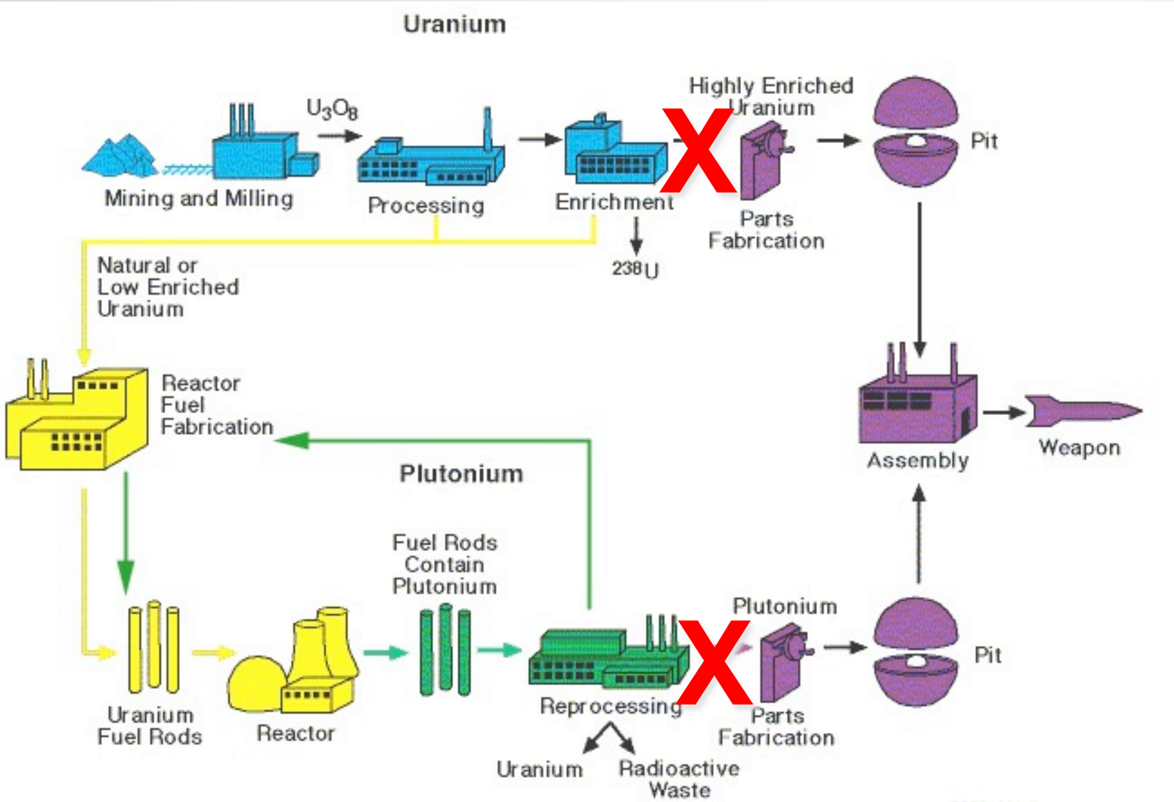
# IAEA Monitors Fissile Material in Civil Nuclear Cycles: *under NPT and Negotiated Safeguards Agreements*




- Current reactor safeguards involve:
  - **Checking Input and Output Declarations**
  - **Item Accountancy**
  - **Containment and Surveillance**
- While largely effective, these techniques consume significant resources
- Since no direct Pu production or power measurement is made, more difficult to exclude undeclared production

**Antineutrino detectors could provide continuous, non-intrusive, unattended measurements suitable for reactor safeguards regimes**

# “Near-field” demonstrations and R&D by broad AAP community have lead to IAEA Interest/Interaction

- Potential Interest in:
  - Improved knowledge of input plutonium mass at reprocessing facility or repository – currently no better than 5-10%
  - Research reactor power monitoring – currently uses intrusive tech.
  - Verification of bilateral agreements – maybe future role for agency
  - Detection with minimal overburden – allows widespread deployment


AAP 2011

IAEA International Atomic Energy Agency Atoms for Peace

**AGENDA**

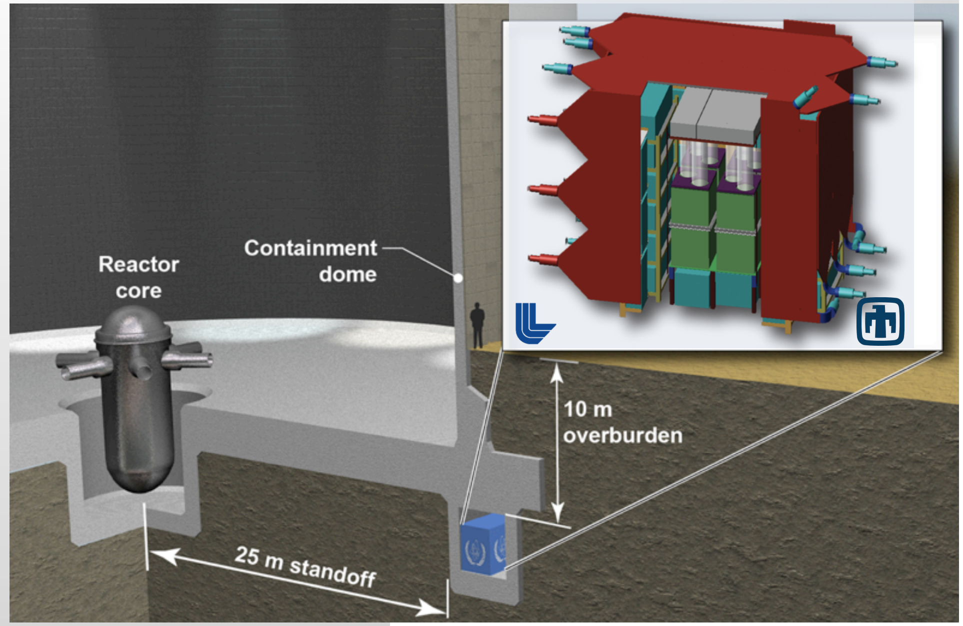
**Ad Hoc Working Group on Safeguards Applications of Antineutrino Detectors, 14 September 2011, Vienna, Austria**

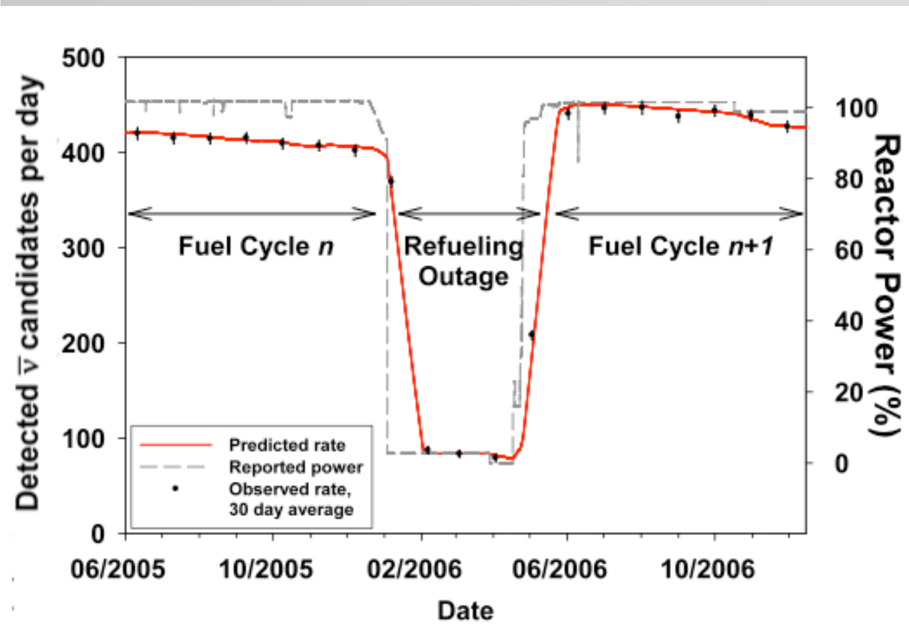
# Demonstrated Near-field Capabilities

LLNL/SNL SONGS1 detector (0.64t GdLS) deployed 24m from PWR, with ~25mwe overburden

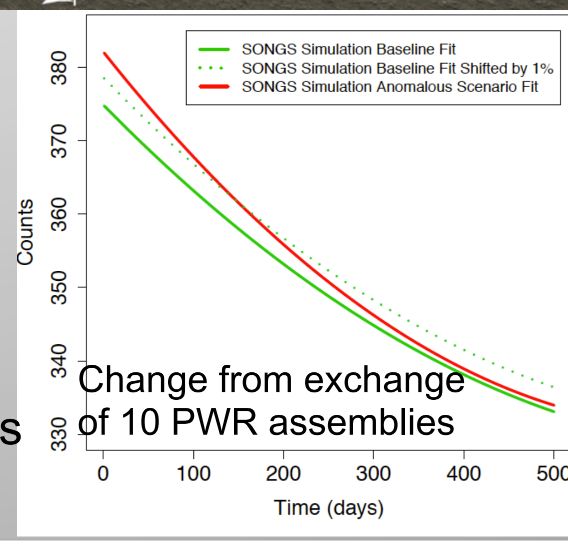
Provided verification of operational history, fuel loading through burnup

Signal rate depends on power and fuel composition



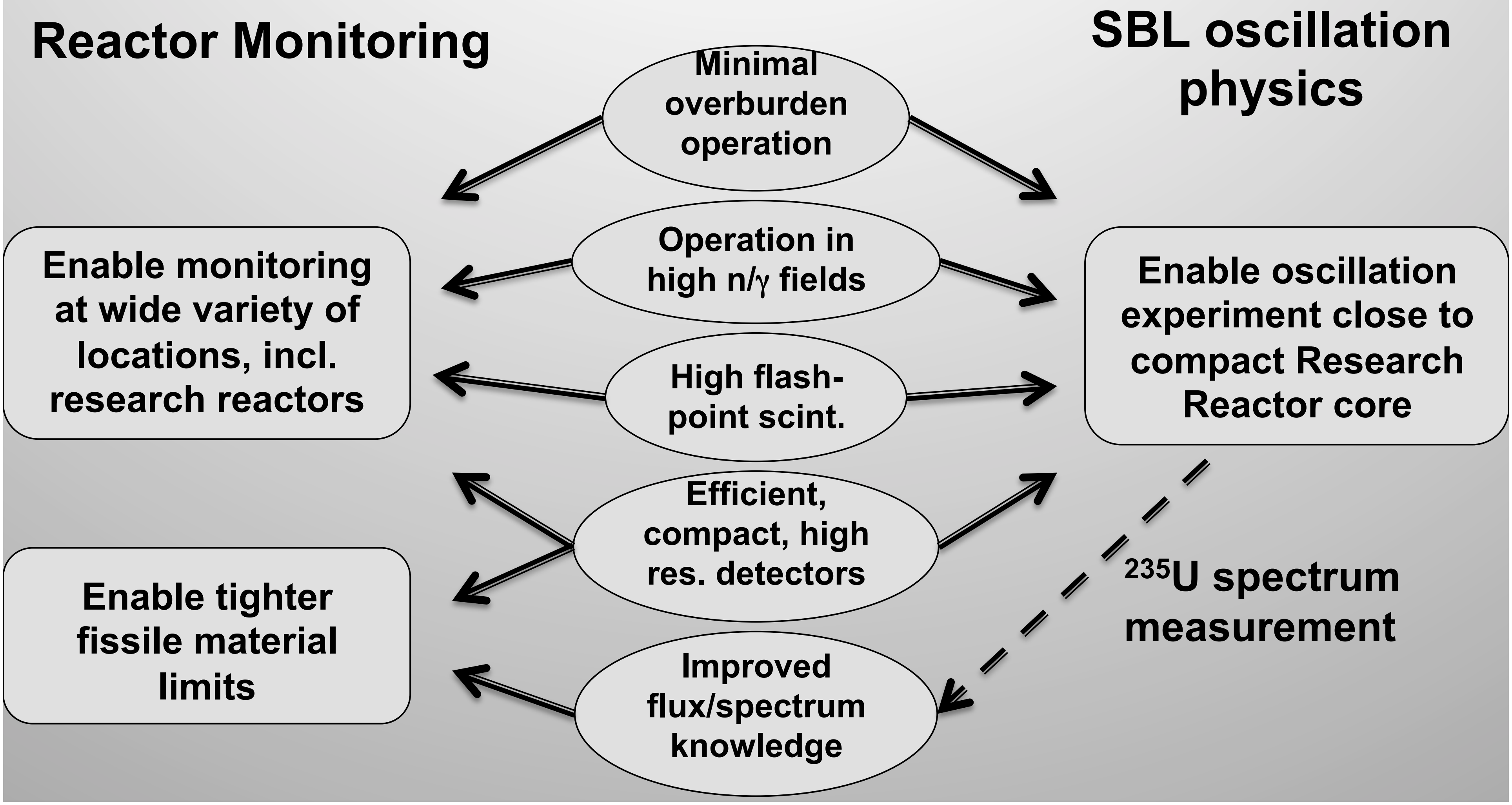




Fuel diversion sensitivity determined by effect on burnup slope, possibility of power changes



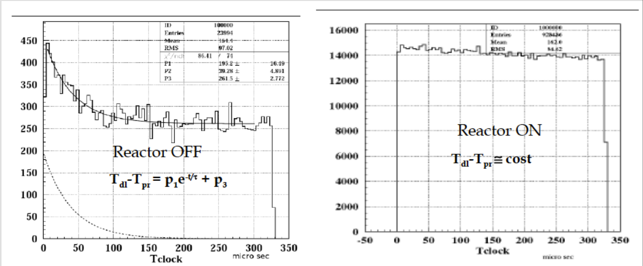
# Near-field Reactor Monitoring "Wish-List"

## Large overlap with Short-baseline oscillation efforts



# Minimal Overburden/High Bkg Operation
## Ongoing efforts show need for good selectivity/shielding

**CORMORAD: Gd/Plastic segments, no shield/veto**

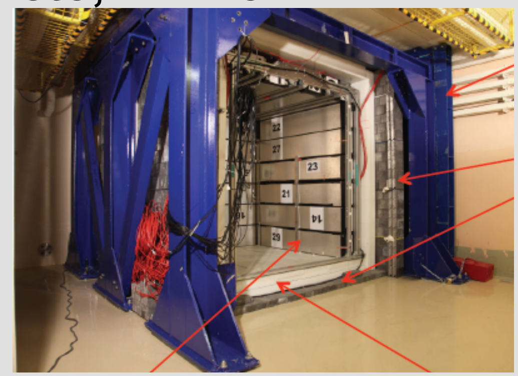



**Rnd. Bkg x$10^2$ Rx On/Off**
**Exp. signal/Obs.bkg ~1/100**

**PANDA36: Gd/Plastic segments, no shield/veto**

**Exp. signal/Obs. bkg ~1/50**

**Nucifer: GdLS, lead/poly/ veto, 7m from RR**

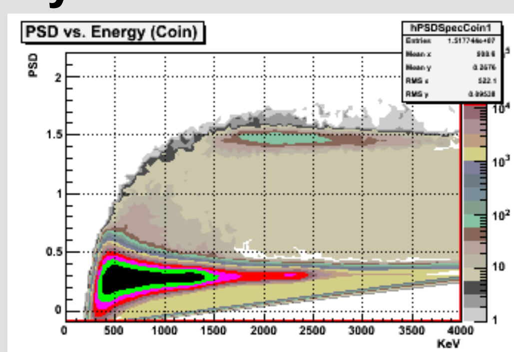


**Rnd. Bkg x$10^5$ Rx On/Off**

**LLNL/SNL: Gd-Water Cerenkov, poly shield/veto**

**Exp.signal/Obs.bkg ~1/100**

**SNL/LLNL: LiZnS/Plastic, poly shield/veto**




**Neutron capture PSD gives >$10^2$ bkg rej.**

Conclusion:

Careful assessment of cosmogenic and reactor background required

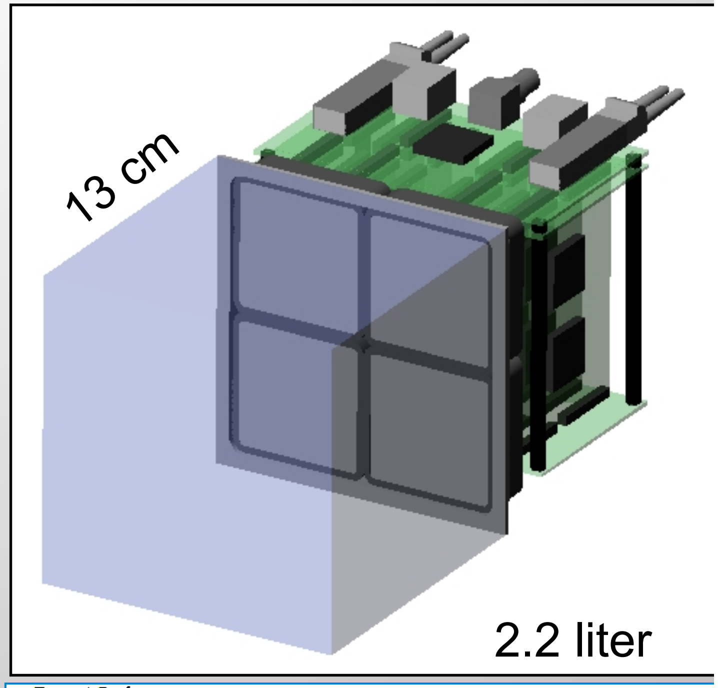
Detectors with high selectivity of e+ and/or neutron capture required

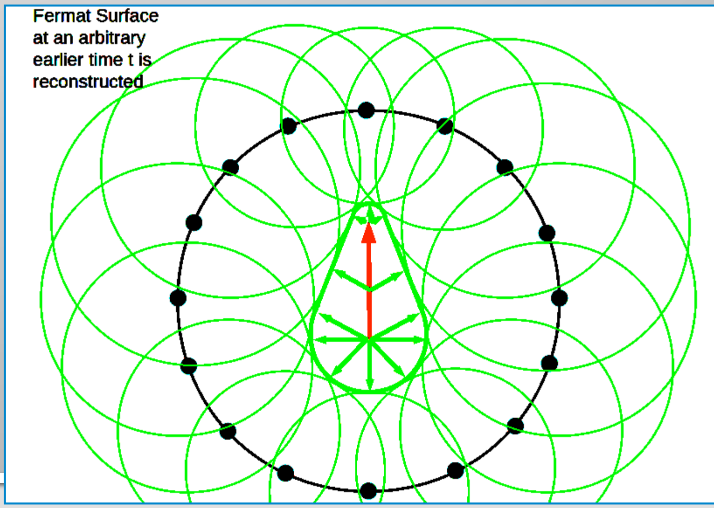
# Ongoing U.S. R&D: SNL/LLNL $^{6}$LiZnS Plastic Detectors

- Inhomogeneous combination of LiZnS screens and plastic blocks
- Strengths:
  - High neutron capture selectivity from PSD
  - Compact size due to $^{6}$Li capture agent
  - Commercially available materials
- Weaknesses:
  - 20-40% neutron capture efficiency (inhomogeneous)
  - Poor optical collection b/c of LiZnS properties
- Current and potential activities:
  - 4x15kg cells deployed in SONGS tendon gallery without shield – hope for reactor restart this year
  - Wavelength shifting plastics to improve optics

# Ongoing U.S. R&D: Hawaii, NGA Mini Timecube

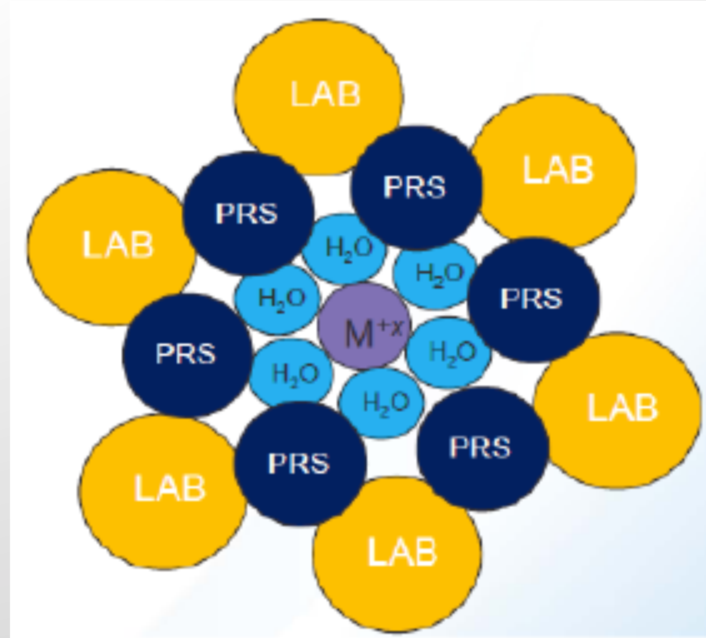
- Exploit fast, high granularity optical detectors and electronics to perform particle tracking in scintillator
- Strengths:
  - Potential for high selectively, bkg rejection
  - Potential for antineutrino directional information
- Weaknesses:
  - Existing fast optical sensors are small, expensive
- Current and potential activities:
  - Completing prototype using MCP PMT
  - Hope to integrate LAPPD

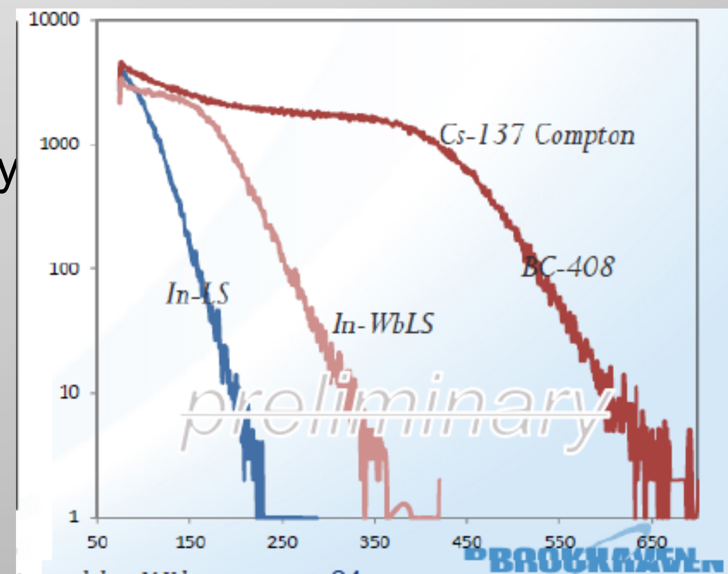


# Ongoing U.S. R&D: BNL Scintillator Development

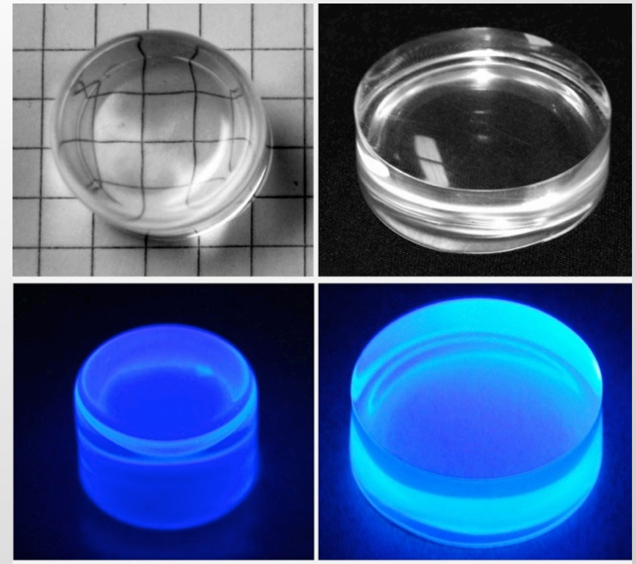
- Developing scintillators based on LAB and Water/Scint. emulsions (WbLS)
- Strengths:
  - High-flash point (LAB, WbLS) and low combustibility (WbLS)
  - Wide range of capture agents/metals can be loaded, e.g. $^{6}Li$, $^{10}B$, Gd,
- Weaknesses:
  - LAB may not give PSD required for high selectivity
  - Long term stability of $^{6}Li$ materials not yet tested
- Current and potential activities:
  - Further development of $^{6}Li$ liquid, neutron capture films, WbLS, …



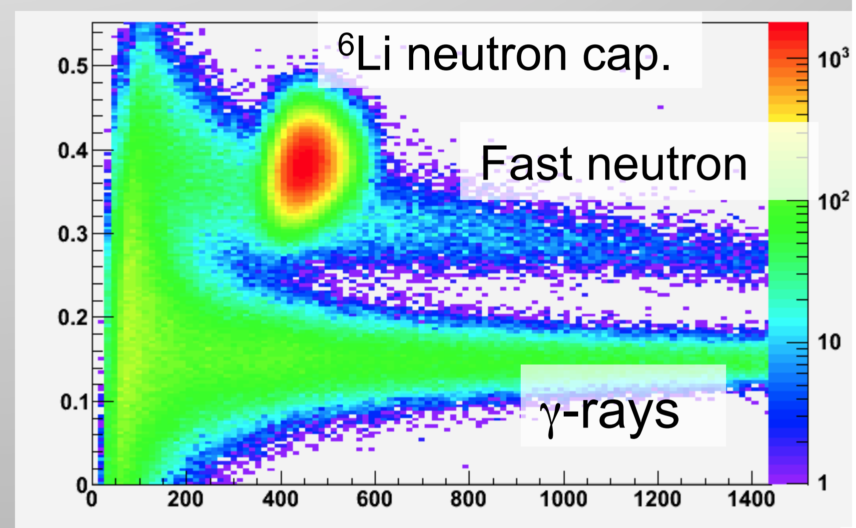
# Ongoing U.S. R&D: LLNL Scintillator Development

- Developing organic crystals, liquids, and plastics with good PSD and $^{6}$Li loading
- Strengths:
  - Good PSD obtained in plastic – now available commercially (undoped)
  - Have incorporated $^{6}$Li, $^{10}$B in plastic and liquid



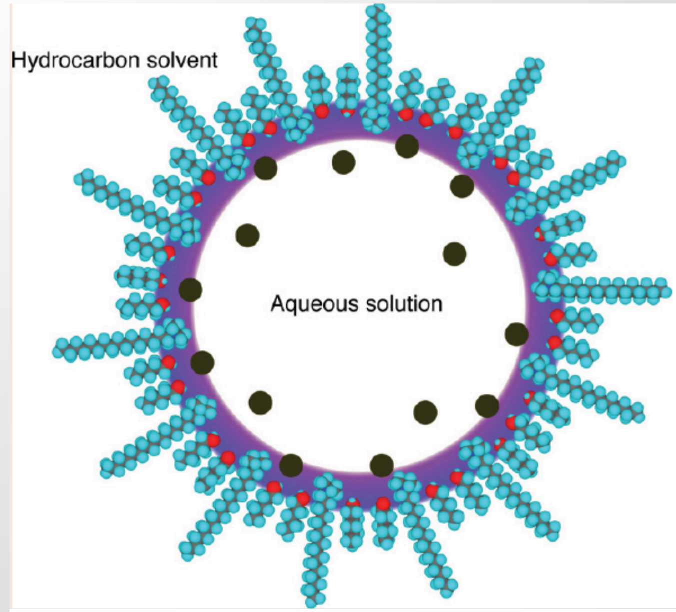
1" diam x 1" thick    2" diam x 1" thick

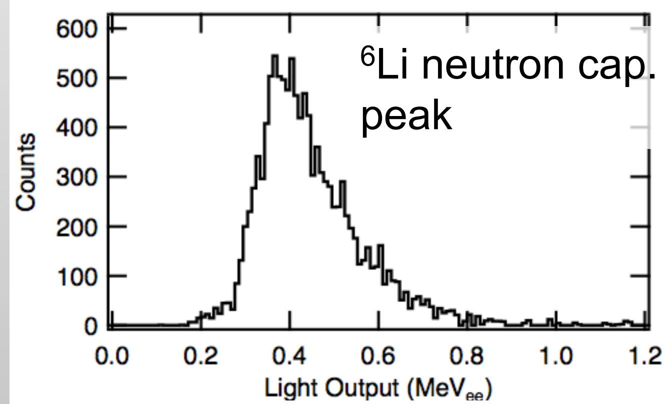
- Weaknesses:
  - $^{6}$Li plastic not in large scale production; potentially expensive
  - Long term stability of $^{6}$Li liquid not yet tested
- Current and potential activities:
  - Further $^{6}$Li liquid development

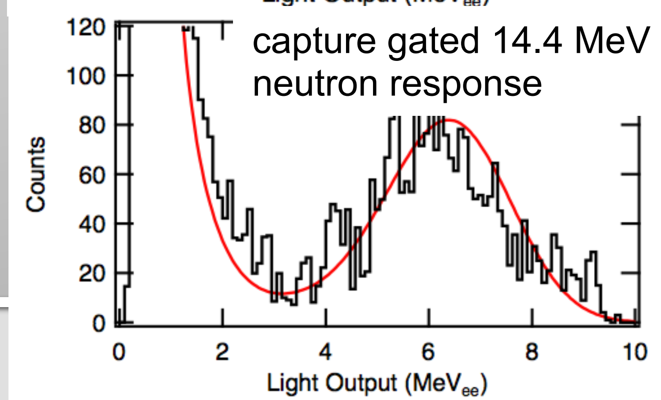


# Ongoing U.S. R&D: NIST Scintillator Development

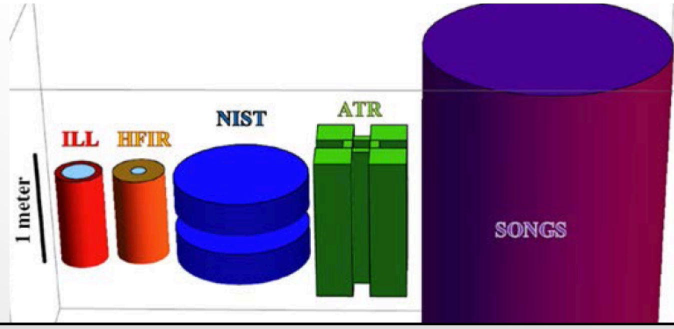
- Developing scintillator with high Li loading potential using micro emulsions
- Strengths:
  - Simple method to produce high Li loading
  - High flash point
- Weaknesses:
  - Not yet fully characterized
- Current and potential activities:
  - Characterize stability, PSD, attenuation length

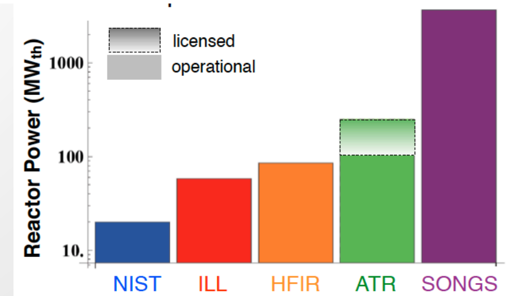


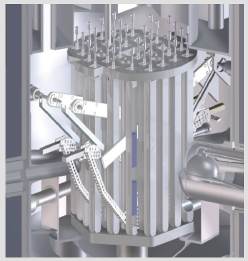
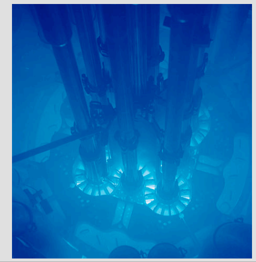
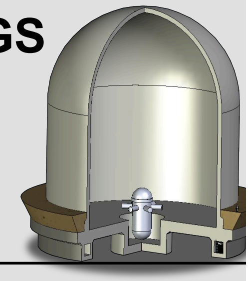



# Potential U.S. Reactor sites




| **Reactor** | **NBR NIST**  | **HFIR ORNL**  | **ATR INL**  | **SONGS**  |
|---|---|---|---|---|
| Power (MW$_{th}$) | 20 | 85 | 150 | 3400 |
| Core Size | Ø100cm x100cm | Ø60cm x100cm | Ø110cm x110cm | Ø3m x 3.8m |
| Operating Cycle | ~1/3 reactor off | ~1/3 reactor off | ~1/3 reactor off | Currently offline, limited cycle likely |
| Potential Deployment Sites | 4-13m baseline Above-grade, minimal overburden | 6-8m baseline Above-grade, minimal overburden | 12-20m baseline Below-grade, minimal overburden | 24 baseline, 25 m.w.e overburden |
| Reactor $\gamma$/n Background | Measurements underway | Measurements planned | Measurements planned | Negligible |

# Conclusions

- Near-field antineutrino detection has a large potential societal impact through improved reactor safeguards and treaty verification
- The Applied Antineutrino Physics community is actively developing this technique
- There is considerable overlap between the needs of Reactor Monitoring and Short Baseline oscillation physics experiments
- Many groups are actively developing enabling technologies, in particular Li-doped scintillators
- There are several unique reactor facilities in the U.S. that could host experiments and R&D efforts