Safeguards for Fusion Energy Systems

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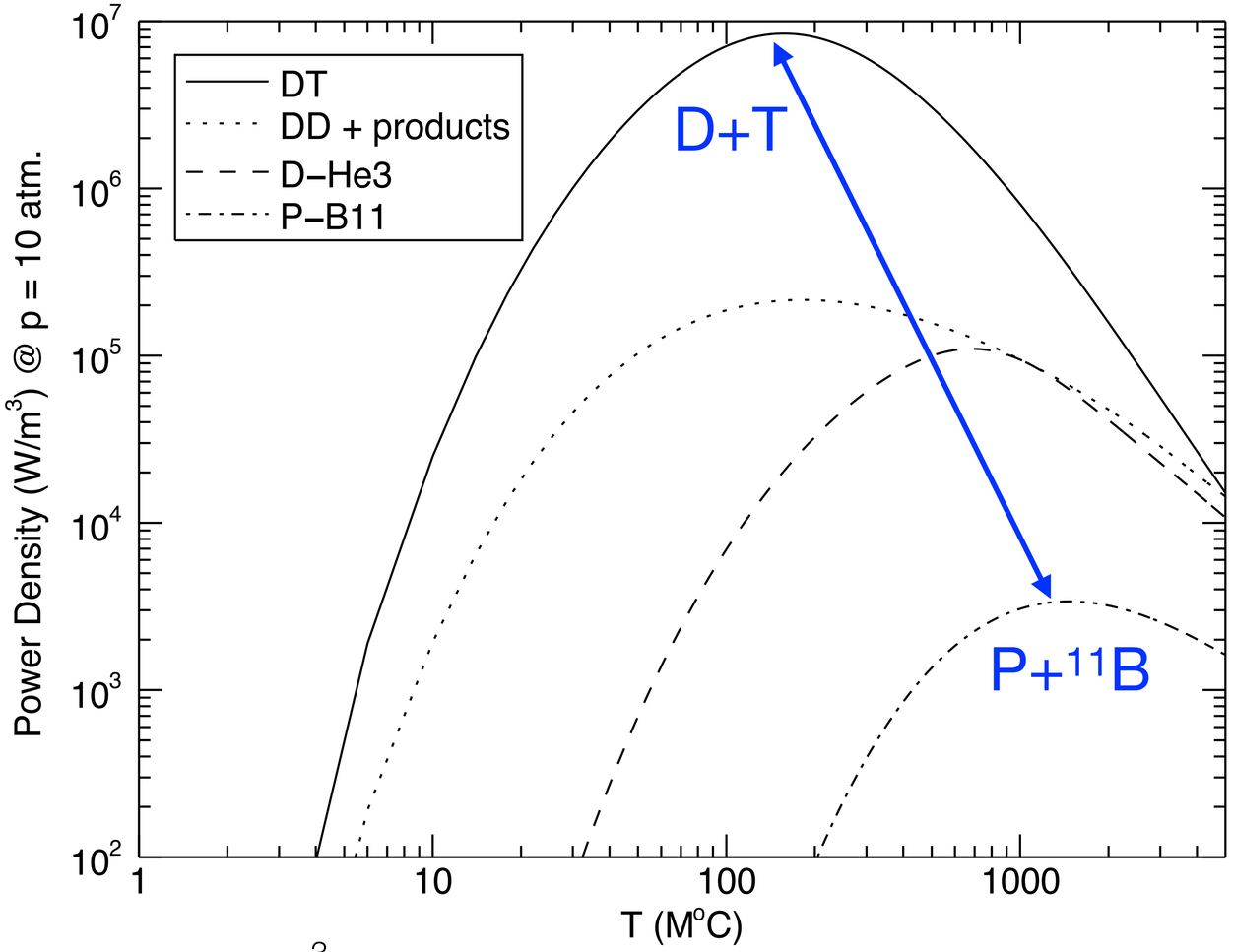
There are Potential Links between Fusion Energy and Nuclear Weapons

"…" ⇒ IAEA definition

- **DT and DD fusion reactions produce abundant neutrons that can be used to breed fuel for nuclear weapons.**
  - One "significant quantity" of Pu or ^{233}U = 8 kilograms, while a DT fusion system could produce up to ~ 3 kilograms / day / GWe.
- **Tritium is used in advanced nuclear weapons.**
  - U.S. weapons generally contain less than 20 grams of tritium, while a DT fusion system burns and breeds ~ 400 grams of tritium / day / GWe.
- **Some of the science of inertial fusion energy is classified.**
  - This is why the National Ignition Facility was constructed.
- **These issues will need to be addressed for public acceptance, and worldwide impact, of fusion energy.**

Fusion Systems can Reduce Neutrons and Tritium, but at the Price of Lower Power Density

DT provides 3000x the power density of P-^{11}B at 1/10 the temperature.

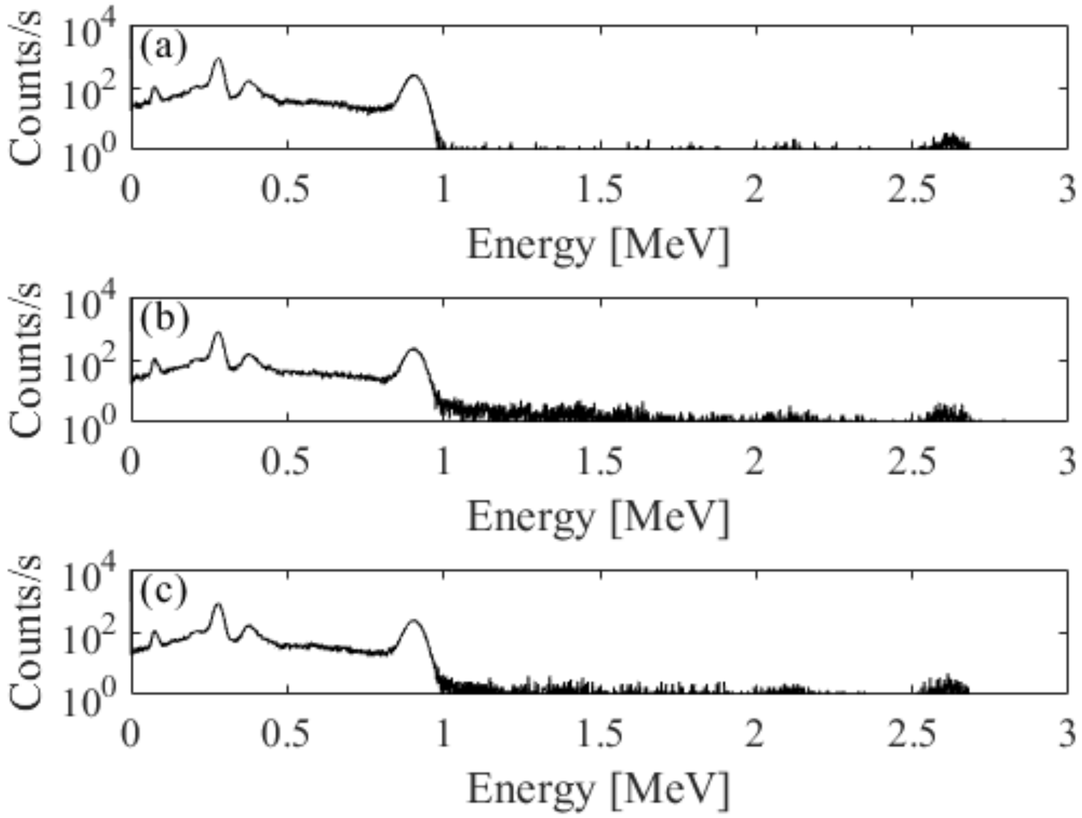


Breeding of Fissile Material can be Detected, but only if Safeguards are Implemented

- **A fusion safeguards system could confirm:**
  - No “source” material (^{238}U, ^{232}Th) is introduced into the system.
  - No “special fissionable material” (^{239}Pu, ^{233}U) is produced in the system.
- **Fusion safeguards can draw on existing IAEA technologies for:**
  - Sensitive “Environmental Sampling” for presence of nuclear materials.
  - On-Site Inspection (e.g., “Design Information Verification”).
  - Unattended Monitoring Systems (e.g., gamma spectra).
  - Containment and Surveillance (e.g., cameras, portal monitors).
- **This is easier than for fission systems. No source material, no special fissionable material, and no fission products should be present.**
- **We should follow IAEA guidelines for “Safeguards by Design”**

The Gamma Signature of Fission Products is Distinctive

NaI detector.
PbLi blanket with impurities.



No ^{238}U nor ^{232}Th

^{238}U for ~ 8 kilograms Pu per year

^{232}Th for ~ 8 kilograms ^{233}U per year

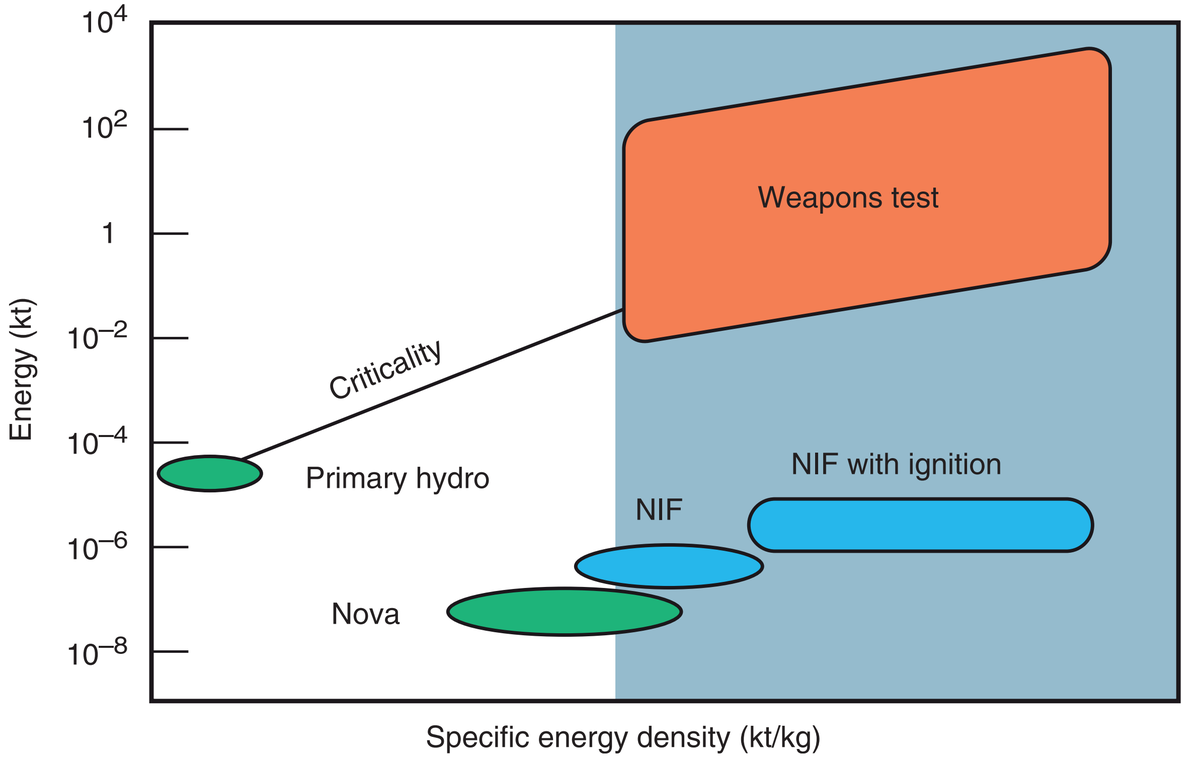
Spectra are very different above 1 MeV, even with low-resolution detector.

Evan Leppink, MIT
Unpublished calculations

Tritium is a Challenge

- **A DT system may have present kilograms of tritium / GWe.**
  - The fuel system may recycle kilograms of tritium / day / GWe.
- **Need to assure that grams of tritium are not diverted per year.**
  - The technology for tritium accounting will need improvement.
  - How much is: burned, released, held up (and where)?
- **Tritium technologies on the Nuclear Suppliers Group "Trigger List."**
  - Is this sufficient for limiting proliferation of tritium technology?
- **Safeguards technologies for tritium inspection, "unattended monitoring," and "containment & surveillance" need to be developed.**
  - Tritium safeguards should be implemented "by Design."

We Will Need to Control Information from Inertial Confinement Fusion R&D and Deployment



S. Libby, 1994
LLNL Energy and Technology Review

"In addition, information that could help countries develop more advanced boosted weapons or thermonuclear weapons could be gained from a thorough understanding of a fusion facility's operation." NAS, 2013

The Legal Framework is not Available for Safeguarding Fusion Energy Systems

- **IAEA safeguards agreements are keyed to declared quantities of “source” or “special fissionable material.”**
  - IAEA has limited authority through the “Additional Protocol” that allows “Complementary Access” to facilities to assure that all nuclear activities in a State are for exclusively peaceful purposes.
  - Environmental Sampling is permitted under Complementary Access.
- **The Nuclear Suppliers Group Trigger List, Export Control, and 123 Agreements are additional tools that can be used**.
  - But these do not affect fully domestic activities.
- **The fusion community should be at the forefront of pushing for the development of a legal framework to support fusion safeguards, so fusion energy can have world-wide impact.**

Next Steps

- **Technology R&D for fusion safeguards:**
  - Detecting production of special fissionable material.
  - Improving tritium accountancy, detection of tritium diversion.
- **Development of legal frameworks for:**
  - Safeguards at fusion power plants with no declared nuclear material.
  - Safeguards for tritium, and controls for tritium technology.
  - Protection of ICF-derived weapons information.

- **See also:**
  - R.J. Goldston, A. Glaser, “Inertial confinement fusion energy R&D and nuclear proliferation: the need for direct and transparent review,” Bulletin of the Atomic Scientists, **67**(3) (2011) 59
  - A. Glaser, R.J. Goldston, “Proliferation risks of magnetic fusion energy: clandestine production, covert production, and Breakout,” Nuclear Fusion **52** (2012) 043004
  - National Academies, “Assessment of Inertial Confinement Fusion Targets,” Ch. 3, (2013)