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Title: Possible Nuclear Safeguards Applications

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Possible Nuclear Safeguards Applications

WORKSHOP ON NEXT-GENERATION LASER COMPTON GAMMA SOURCE

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Nuclear Safeguards

- IAEA Definition (INFCIRC 153):
  - "The timely detection of diversion of significant quantities of nuclear material from peaceful nuclear activities to the manufacture of nuclear weapons or of other explosive devices of for purposes unknown, and deterrence of such diversion by the risk of early detection."

Material	SQ
Direct use nuclear material	
Pu[a]	8 kg Pu
^{233}U	8 kg ^{233}U
HEU (^{235}U $\geq$ 20%)	25 kg ^{235}U
Indirect use nuclear material	
U (^{235}U < 20%)[b]	75 kg ^{235}U (or 10 t natural U or 20 t depleted U)
Th	20 t Th

[a] For Pu containing less than 80% ^{238}Pu.
[b] Including low enriched, natural and depleted uranium.

IAEA collects information in various ways:
-State declarations
-Onsite inspections
-Analysis of open source and third-party information

Knowledge of isotopics and enrichment levels of materials under safeguards are critical.

The Nuclear Fuel Cycle

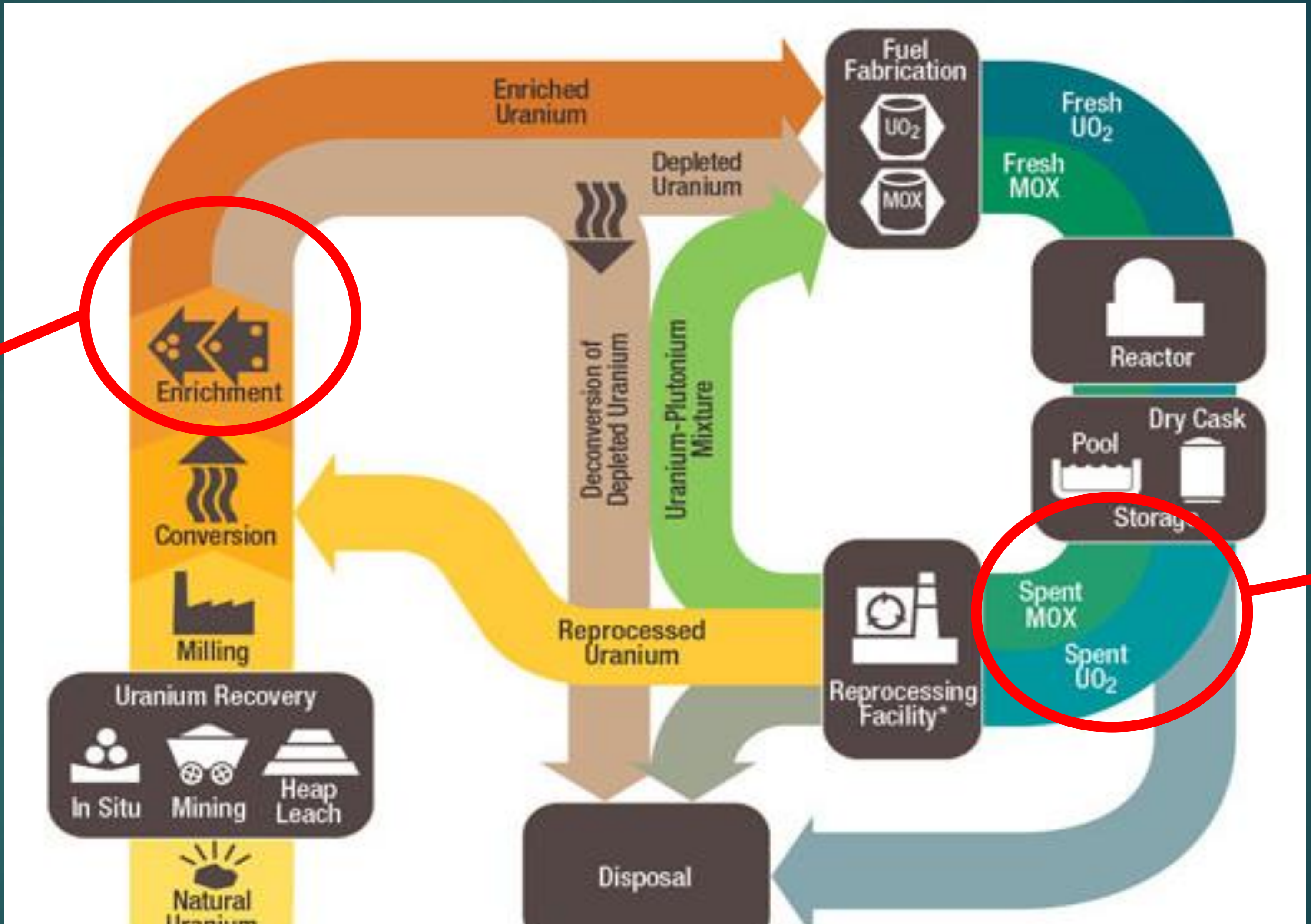
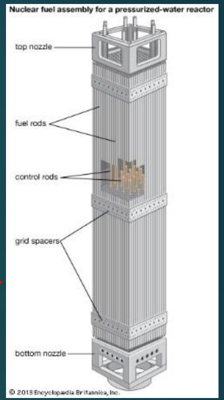


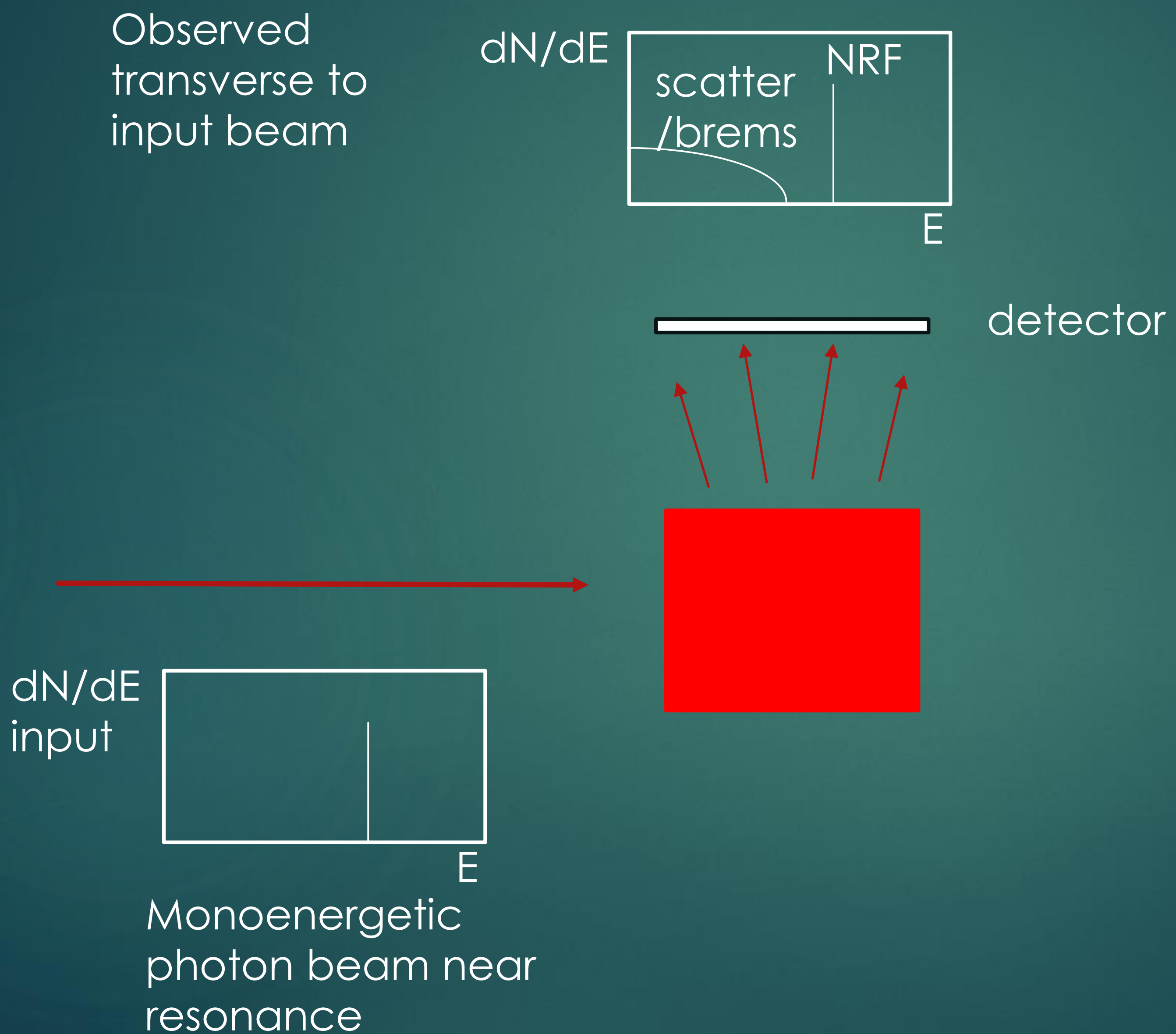
Image from nrc.gov

Precise enrichment assay
(UF6 in cylinders)



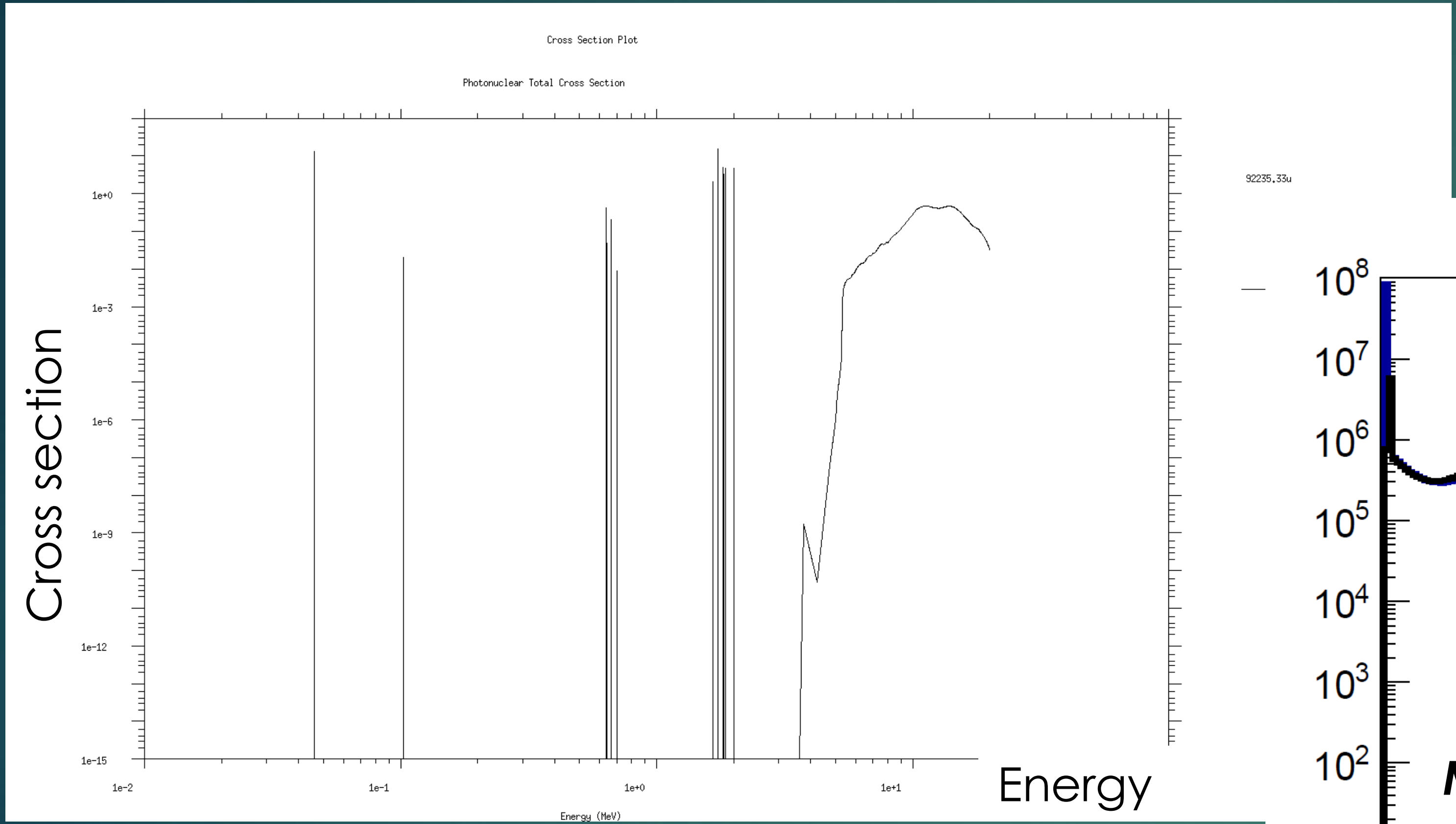
Spent fuel assay (determine plutonium content)

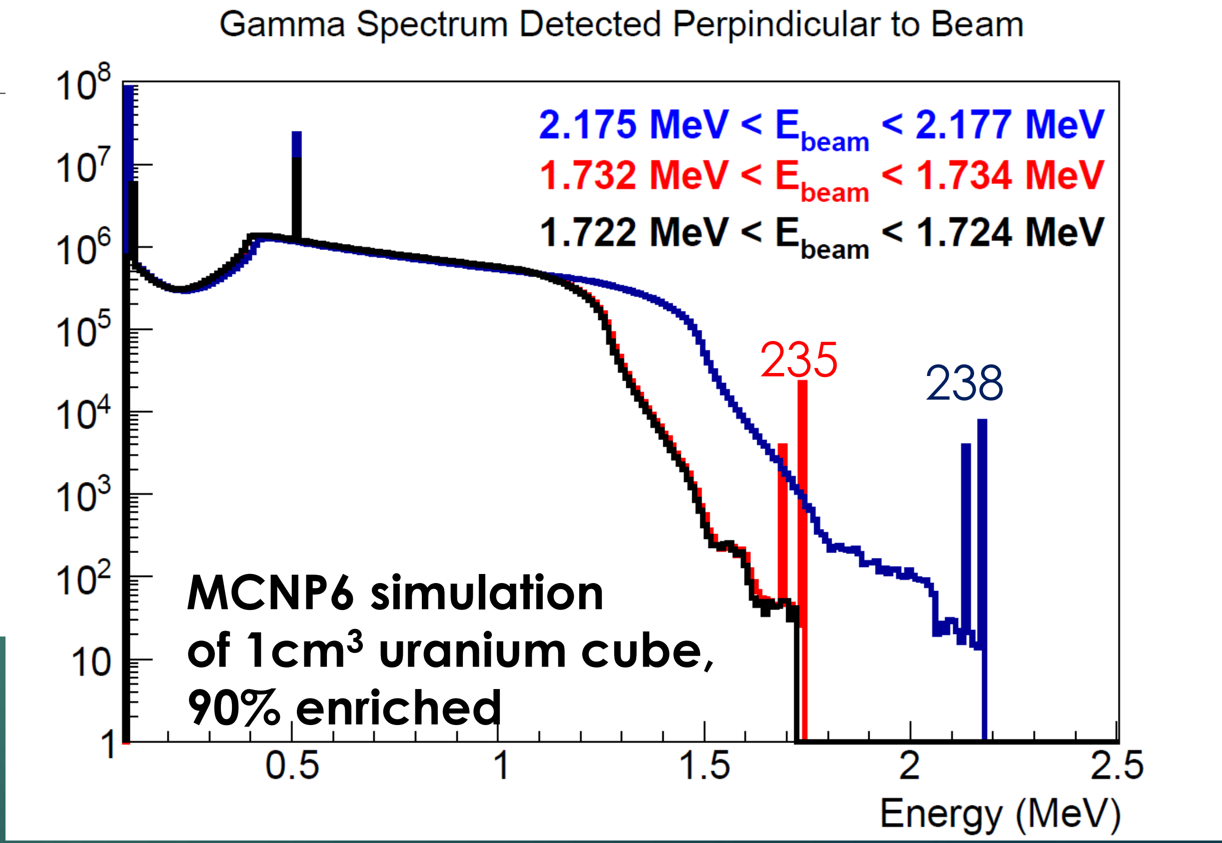
Precise isotopic determination via NRF



Photons transverse to input are from Compton, bremsstrahlung from converted electrons, x-rays, 511 keV
PLUS re-emitted NRF photons

Precise isotopic determination via NRF





- Some NRF lines in 235U, 239Pu measured

  PRC 78 041601 (2008)

- Complete measurements of other U, Pu isotopes will be necessary: day-1 measurements at next-generation facility

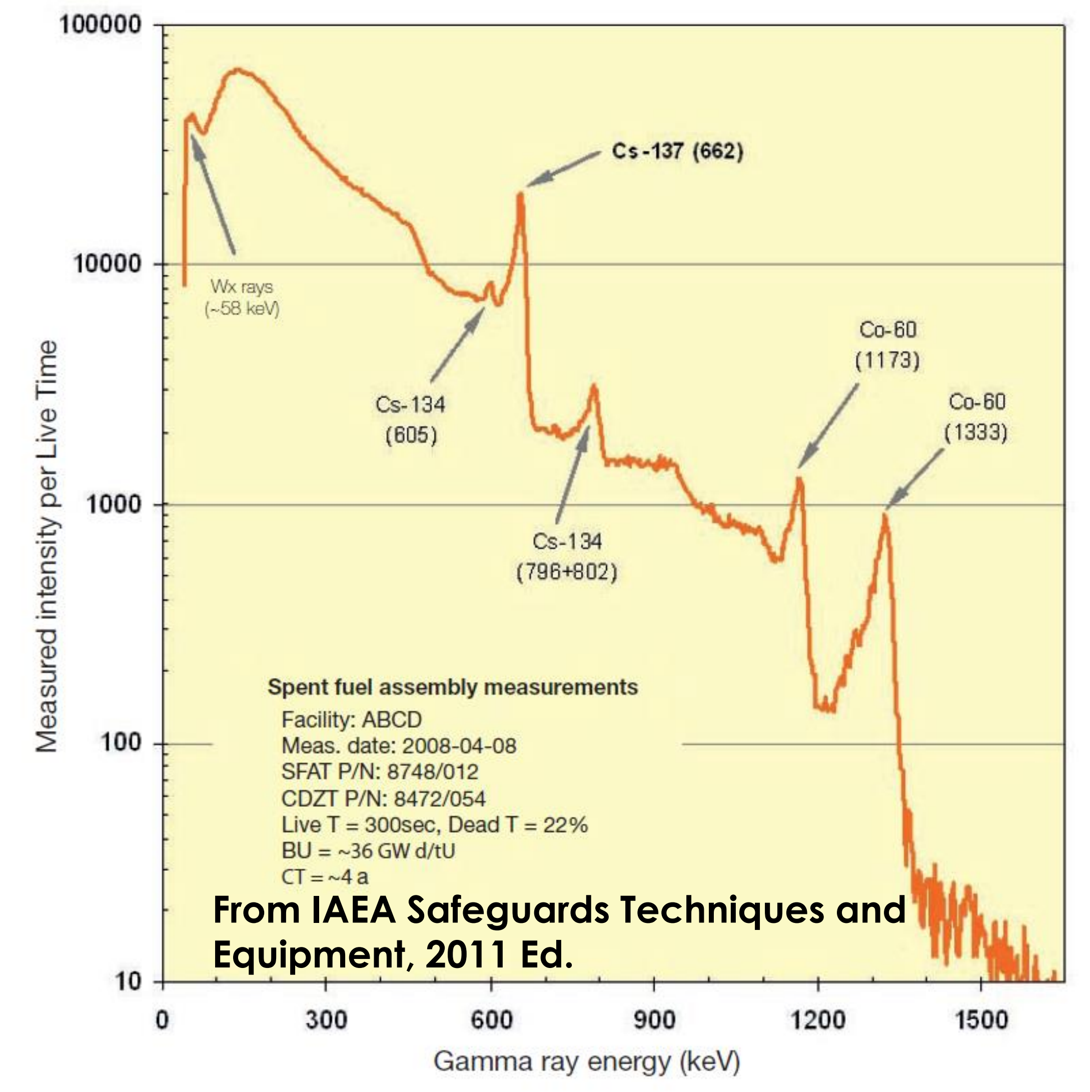
UF6 Enrichment Assay

- Gaseous enrichment methods use UF_6 as working gas
- Input, product, and tails are stored in steel cylinders
    - Current methods to determine enrichment:
        - Take a sample for mass spectrometry (highly disfavored by operators)
        - Measure 186 keV gammas with NaI, correcting for cylinder wall thickness. Subject to uncertainties due to deposits on inside of cylinder, cylinder wall corrosion
    - NRF photons ~2MeV, much more penetrating
    - Small relative corrections for NRF between U isotopes
- Enrichment measurement with NRF is a RELATIVE measurement, eliminate many systematics by comparing 235/238 ratio
- Combine with cylinder weight to derive total 235U mass for accountability

Non-Destructive Assay of Spent Nuclear Fuel

- Most of the world's plutonium is contained in spent commercial reactor fuel
- Currently, Pu mass in fuel is calculated with burnup codes, requiring knowledge of fuel history from operator (not independent)

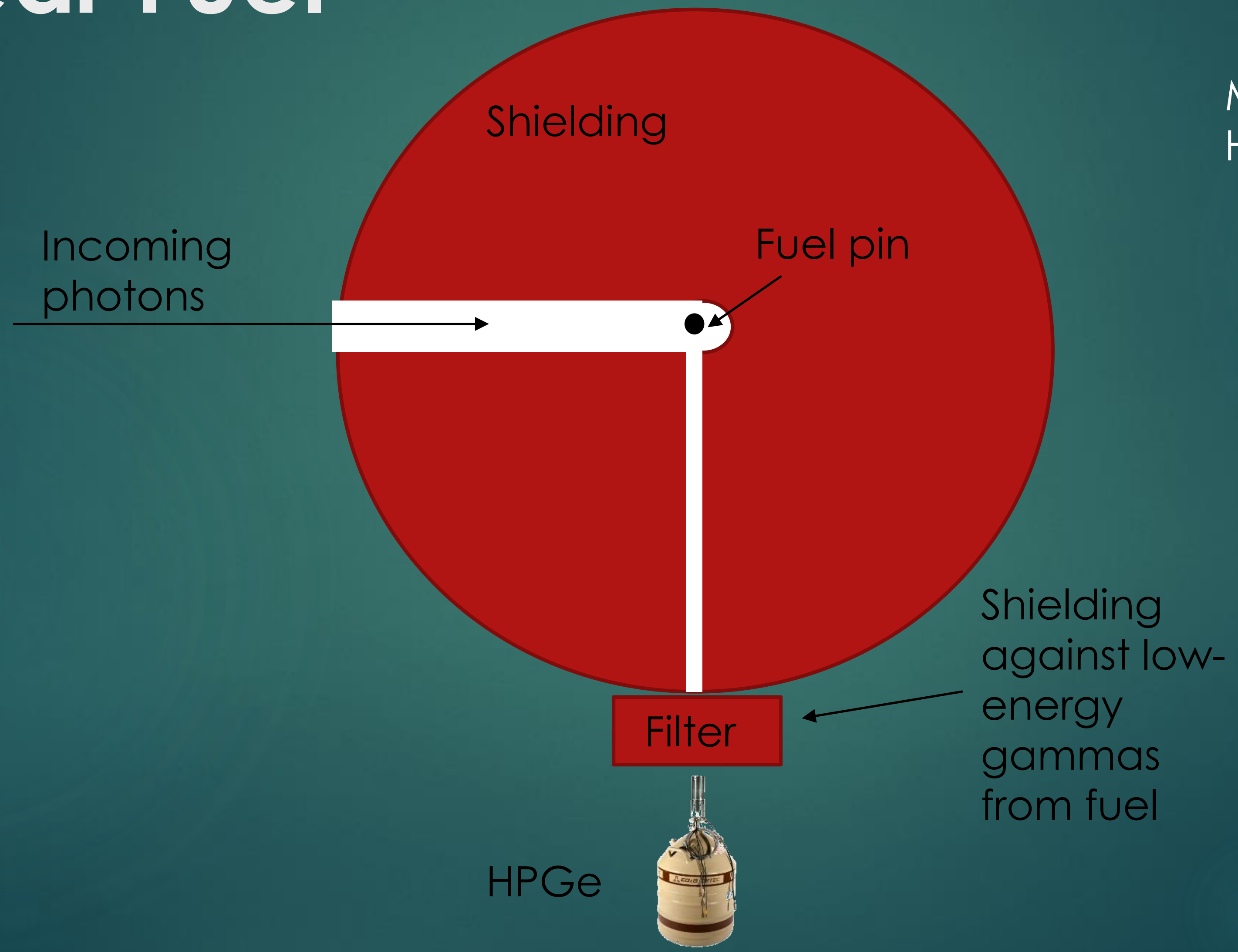
- Goal: independently account for plutonium mass in spent fuel, before reprocessing begins
- Typical passive measurements unable to directly determine total Pu content due to enormous backgrounds
- Also useful for assessing reactor performance, new fuel designs, measuring burnup



Many details in B. Quiter Phd thesis, UC Berkeley, 2010

Non-Destructive Assay of Spent Nuclear Fuel

Main challenge:
Handling spent fuel



Summary

- A way to non-destructively measure precise isotopics of ~kg and larger samples has multiple uses in nuclear safeguards
- Ideally this is a compact, fieldable device that can be used by international inspectors. Must be rugged and reliable.
- A next-generation source can be used as a testing ground for these techniques as technology develops

Other possible applications:

- Nuclear forensics (see Anton Tonchev's slides)
- Cargo scanning
- Radiography (dynamic?)