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Title: Nuclear Data Needs for Space-based Nuclear Detonation Detection

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Nuclear Data Needs for Space-based Nuclear Detonation Detection

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Space-based Nuclear Detonation Detection (SNDD)

- Support nuclear treaty verification
- Three space platforms:
  - GPS (navigation + SNDD) at medium earth orbit
  - Defense Support Program and Space and Atmospheric Burst Reporting System at geosynchronous orbit
    - Geometric dispersion is ~5×10^{-21} particles/cm^2 at geosynchronous orbit
- Nuclear emissions at different altitudes create different signals
  - In air:
    - Hot plasma create x-rays which cause air expansion hot enough to emanate in optical regime
    - Prompt gamma rays create free electrons which turn in magnetic field to emanate in radiofrequency domain
  - In space:
    - X-rays, prompt gamma rays, delayed gamma rays, and neutrons travel freely
  - In between:
    - Some of each, depending…

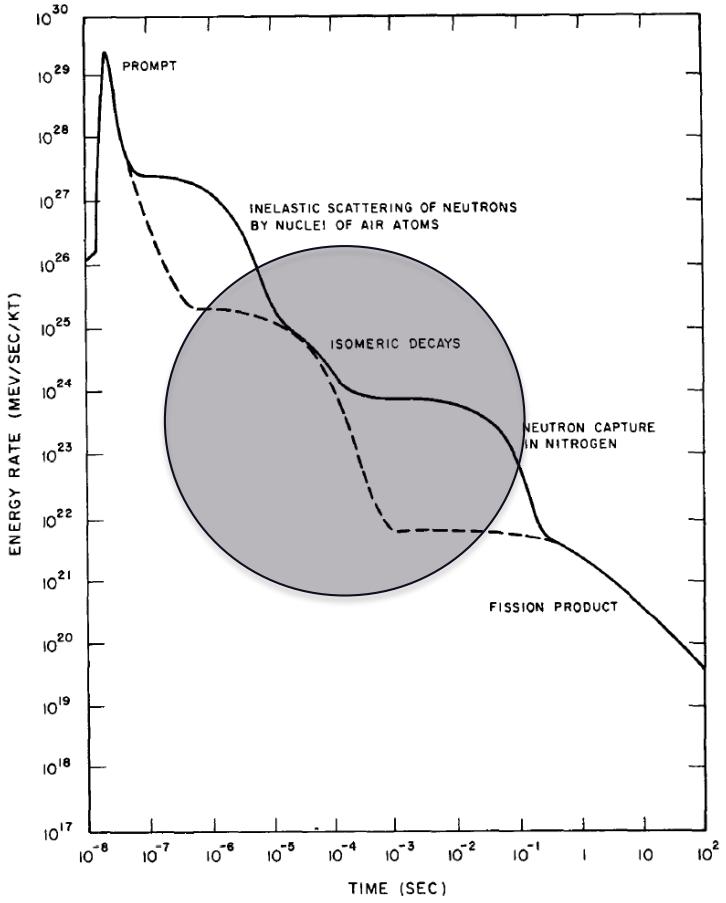
Pertinent Timeframes and Energy Domain (Delayed Gamma Rays and Neutrons)

- Timeframe spans approximately 100 ns to 100 s
  - Prompt gamma ray signals are early time (<1 ms)
  - Delayed gamma ray signals from ~1 ms to 100 s
  - Neutrons arrive over ~1ms to 100 s

- Energy domain is ~1 keV to ~20 MeV
  - Neutrons arrive with energies through entire energy domain
  - Both prompt and delayed gamma rays from ~100s keV and ~8 MeV
    - Due to both transmission through atmosphere and detector choices

Early Time Delayed Gamma Ray Needs

- Significant difficulties and uncertainties in early time gamma ray emissions from fission fragments
  - 100 microsec to about 100 ms
  - Short-lived isomeric decays
  - Bounds on broad energy grouping
  - Half-lives of isomeric isotopes
  - Production estimates from U-235, U-238, Pu-239



*Extracted from Effects of Nuclear Weapons, pg. 328

Impact of Accurate Fission Product Production

- Key needs:
  - More incident neutron energies
    - Pu-239 now has epithermal fission
    - Forward modeling of source is limited by lack of smooth transition from asymetric to symmetric fission
      - Predicting isotopic ratios is carries more uncertainty than simply using current accepted values
  - Isotopic decay half-lives ~0.5 s can have significant uncertainties
    - 0.5 s ± 0.5 s makes for broad uncertainty estimates
    - Can cause naive network decays schemes using linear solvers to become very stiff
      - Alternate methods have been developed
        - » Integral methods, exponential moment methods, secular equilibrium approximations, etc.
- Less impactful data
  - Low probability production events (<$1/10^8$ fission events)

Importance of Uncertainty Quantification

- All senior leadership reporting characterizes or attempts to quantify uncertainty
  - Identification has a confidence reported
  - Other quantities of interest use best value and uncertainty bound

- Implementing approach to estimate uncertainty in delayed gamma rays using declared ENDF uncertainty
  - Initiative to include Monte Carlo sampling of half-life and energy uncertainties for forward modeling
  - Encapsulating uncertainty in results is ongoing challenge

Improvements from Recent Measurement Campaigns

- *Extracted from "Measurement of Short-Lived Fission Product Yields for ^{237}Np via γ-ray Spectroscopy", dated 1 November 2020, by Sean Burcher*
- Results from this experiment will be compared to FPYs of ^{235}U, ^{238}U, ^{239}Pu, and ^{233}U
  - ^{235}U, ^{238}U, and ^{239}Pu irradiations have been completed
    - See A. Tamashiro's talk (SQ.0007) later in this session for ^{239}Pu work
  - ^{233}U irradiation planned for early/mid 2021
  - Self-consistent FPY results for 5 actinides
    - All irradiations utilized GODIVA
    - All γ-ray count utilized the same experimental setup
    - All data will be analyzed/re-analyzed with the codes developed in this work
- Full Results to be published in future Nuclear Data Sheet Article

Questions?