

**NUCLEAR ENERGY & GLOBAL SECURITY**  
**TECHNOLOGIES**

Comparison of Uranium Analysis Techniques  
Presented by Dr. Amir Mohagheghi  
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Radiation Measurements Cross Calibration (RMCC) Annual Workshop  
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**Presentation Outline**

- **Nuclear Detection Methods**
  - *Gamma Spectroscopy*
  - *Alpha Spectroscopy*
  - *ICP Mass Spectroscopy*
- **New Research Area: ATTA**



### Gamma Spectroscopy Analysis

- The aim of gamma spectroscopy is to identify and quantify isotopes that emit gamma or x-ray radiation.
- Typical gamma spectroscopy system consists of a High Purity Germanium (HPGe) detector, graded shielding, signal processing electronics, and the control & analysis software.
- The sample is prepared by placing it in a calibrated geometry (e.g. Marinelli Beaker) and then placed on the detector for spectrum acquisition and analysis.

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### Examples of Gamma Spectroscopy Systems



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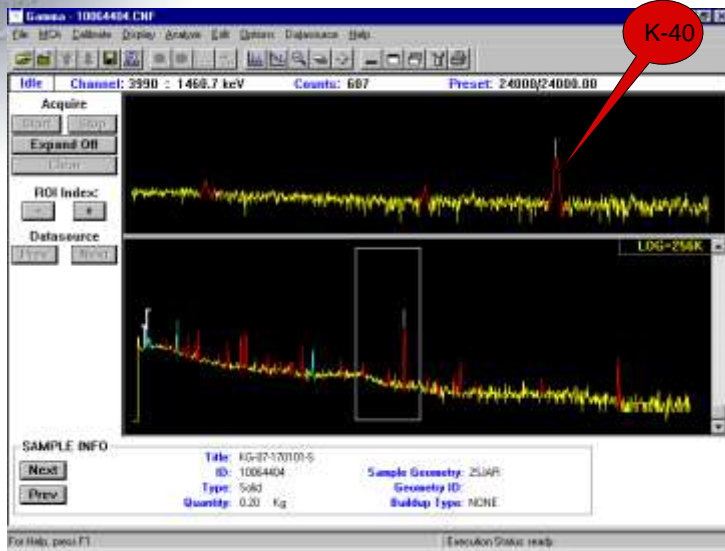
### Examples of Prepared Samples



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### Gamma Spectrum Example



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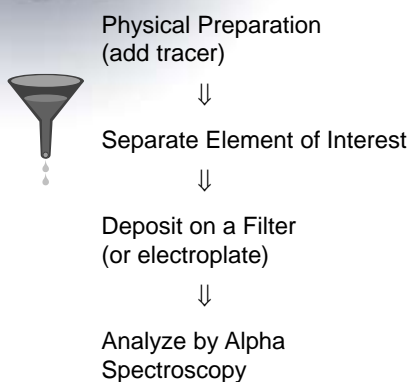
## Gamma Spectroscopy Summary

- **Advantages:** Sample preparation is simple, fast analysis, can look for a large number of isotopes (typically 50)
- **Issues:** The detection limit for U is high for water samples; Interference (e.g. Ra-226 interference can inflate the U-235 values in soil samples); Careful sample preparation required to match calibration standards.
- **Typical Detection Limits for Soil**
  - U-238: 0.15 pCi/g (0.45 µg/g)
  - U-235: 0.07 pCi/g (0.033 µg/g)
  - U-234: 100 pCi/g (0.016 µg/g)

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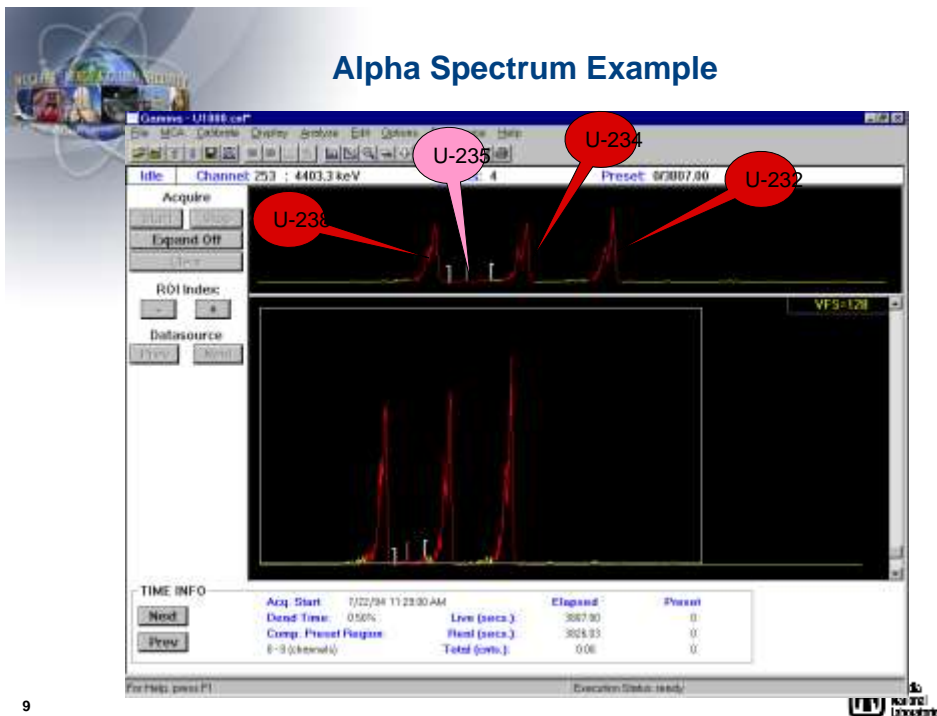


## Alpha Spectroscopy Analysis



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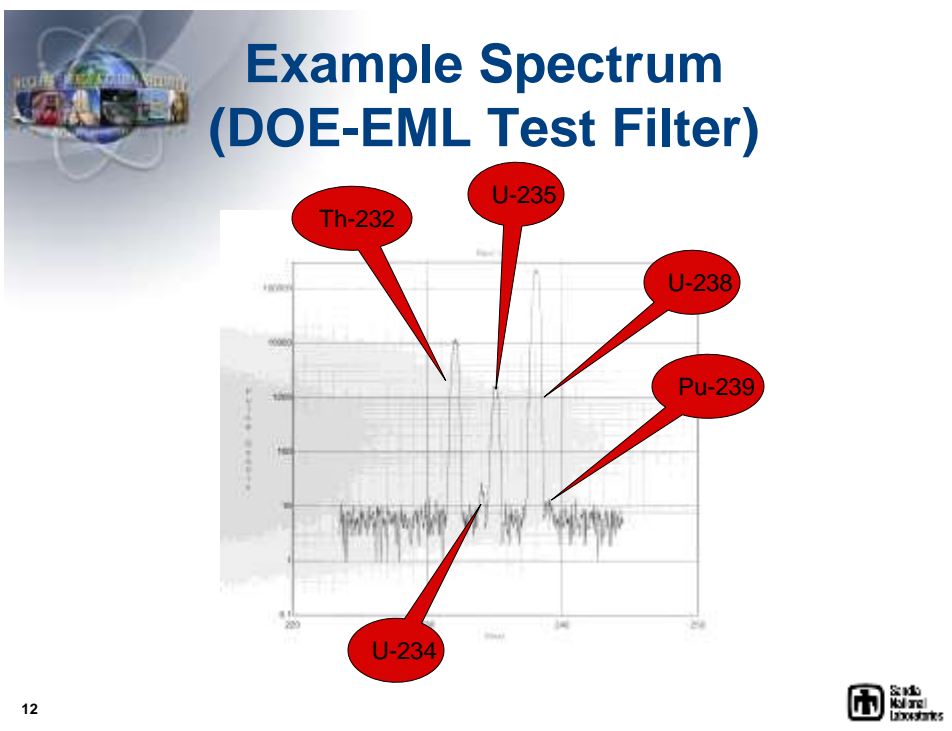
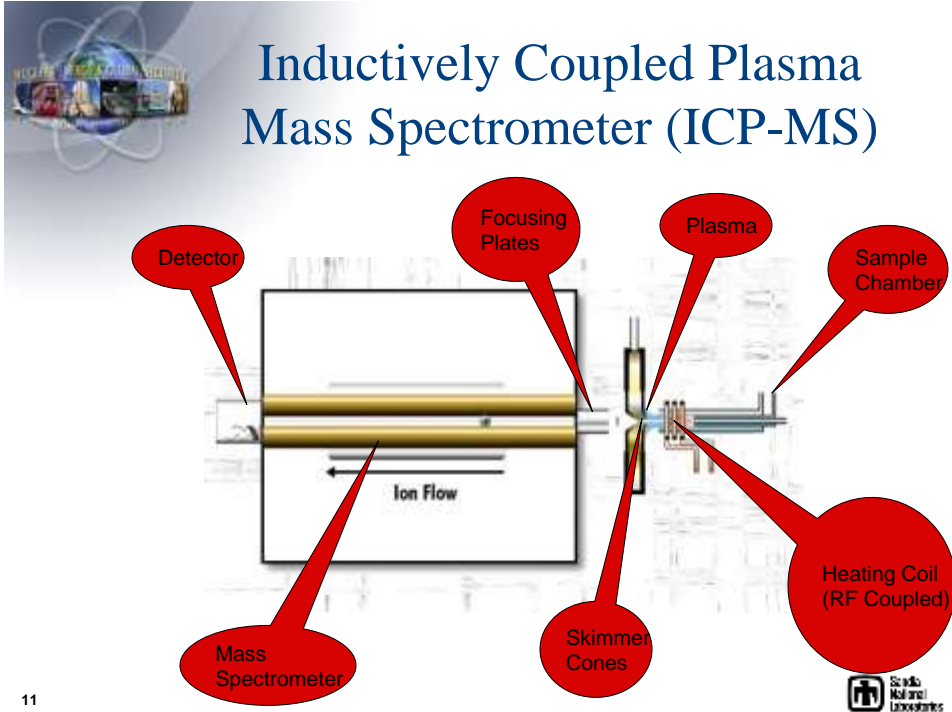


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### Alpha Spectroscopy Summary

- **Advantages: Low detection limits and selectivity**
- **Issues: Labor intensive; Longer analysis times; Isotope ratio measurements will need special attention; Mixed Waste**
- **Detection Limits for Soil:**
  - *U-234: 0.01 pCi/g (1.6E-6 µg/g)*
  - *U-235: 0.01 pCi/g (0.005 µg/g)*
  - *U-238: 0.01 pCi/g (0.03 µg/g)*

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## ICP-MS (Perkins Elmer Elan 6100)

### Procedure Validation



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## ICP-MS Sample Preparation for Water

- **Filter (if necessary)**
- **Analyze**

|       | DL (ng/L) | Precision | Accuracy |
|-------|-----------|-----------|----------|
| U-235 | 0.1       | 4%        | -5%      |
| U-238 | 2.0       | 3%        | -4%      |

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## ICP-MS Sample Preparation for Bioassays

- Mix 1 mL of Urine with 1 mL of Nitric Acid and 18 mL of DI Water
- Analyze

|       | DL (ng/L) | Precision | Accuracy |
|-------|-----------|-----------|----------|
| U-235 | 2         | 3%        | -2%      |
| U-238 | 9         | 4%        | 5%       |

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## ICP-MS Sample Preparation For Soil

- Mix ~0.1 gram of soil with 15 mL of Conc. Nitric Acid, 5 mL DI Water, 5 mL HF
- Digest using a Microwave oven
- Volume up to 50 mL using DI Water
- Take 5 mL and volume up to 25 mL with DI Water
- Analyze

|       | ng/g<br>ICP-<br>MS | pCi/g<br>ICP-<br>MS | pCi/g<br>Gamma | pCi/g<br>Alpha |
|-------|--------------------|---------------------|----------------|----------------|
| U-234 | 0.3                | 2                   | 150            | 0.01           |
| U-235 | 0.3                | 0.001               | 0.08           | 0.01           |
| U-238 | 8.0                | 0.003               | 0.5            | 0.01           |

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## ICP-MS Method Summary

- **Advantages:**
  - *Low detection limits for long lived isotopes*
  - *Accurate isotope ratios*
  - *Simple sample preparation*
- **Issues:**
  - *High DL for short lived isotopes*
  - *U-238 background*
  - *Isotopic interferences (e.g. U-238, Pu-238)*
  - *Complicated instrument (high maintenance and constant tweaking)*

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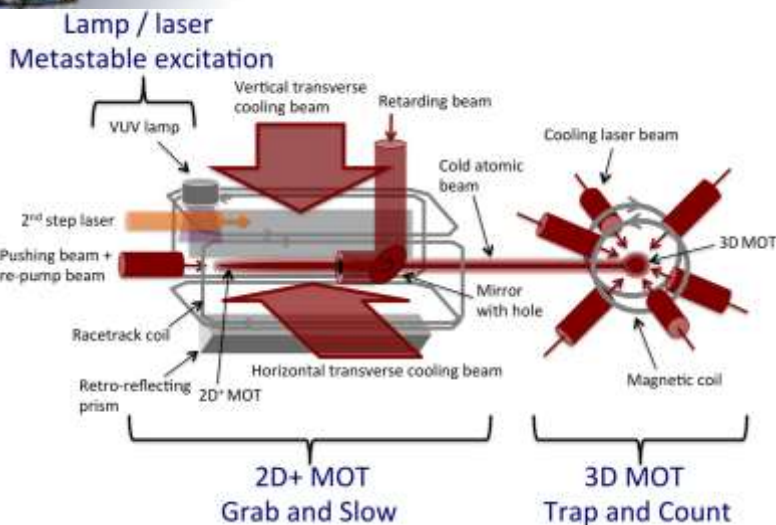
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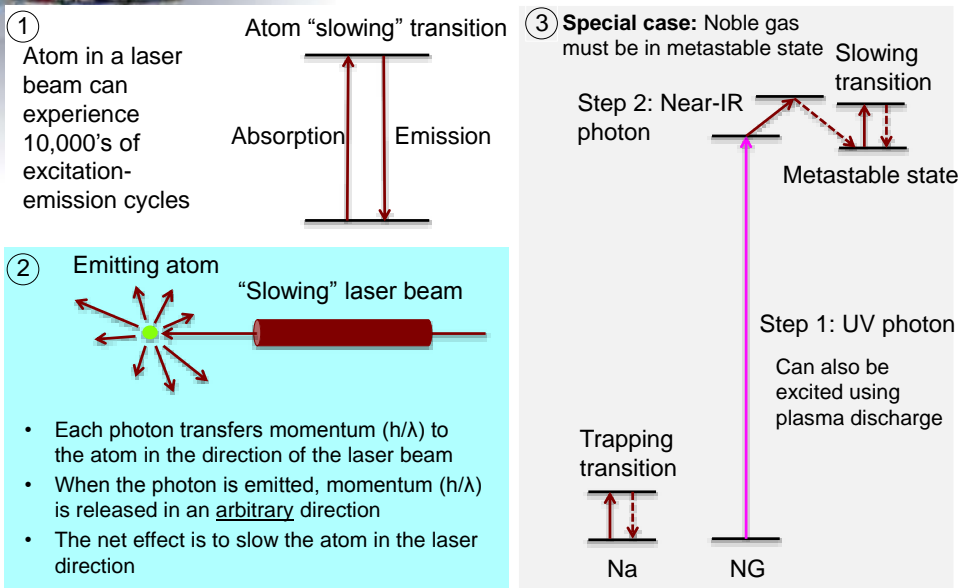
## Atom Trap Trace Analysis (ATTA)



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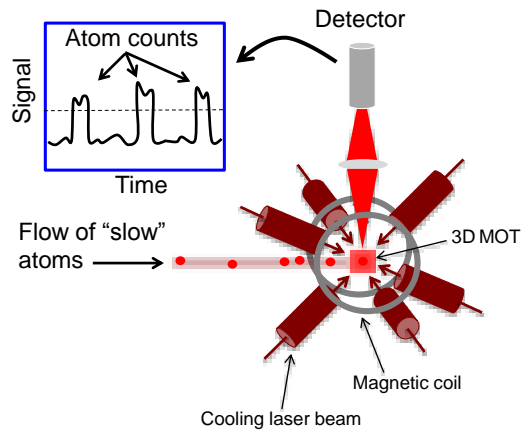
## ATTA uses light to slow atoms





## Atoms are counted in a 3D MOT

- Magneto-optical trap (MOT)
- Six laser beams push the atom to the center
- A magnetic field “tunes” the atom levels so the transition is resonant with the laser if the atom strays from center
- Thus, the atom is trapped at center, where it emits light and can be counted
- Only atoms and isotopes excitable by the laser are trapped and counted

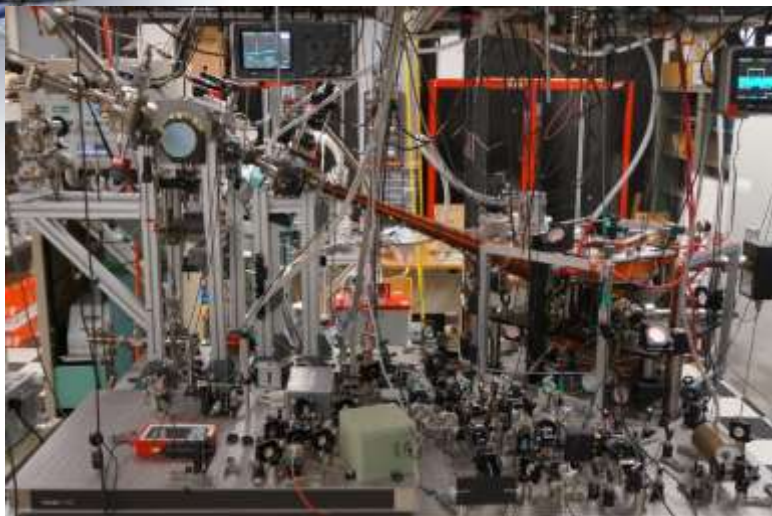


Atoms must be slowed prior to trapping

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## ATTA System



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Thank you for your time