National Physical Laboratory

Measurement of Airborne Radioactivity by the CTBTO

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What is the CTBTO?

- The **C**omprehensive **T**est **B**an **T**reaty **O**rganisation

- An international organization established by the States Signatories to the Comprehensive Test Ban Treaty on 19th November 1996

- Their main task is the establishment of the 337 facility International Monitoring System and the International Data Centre, and the development of operational manuals, including for on-site inspections.

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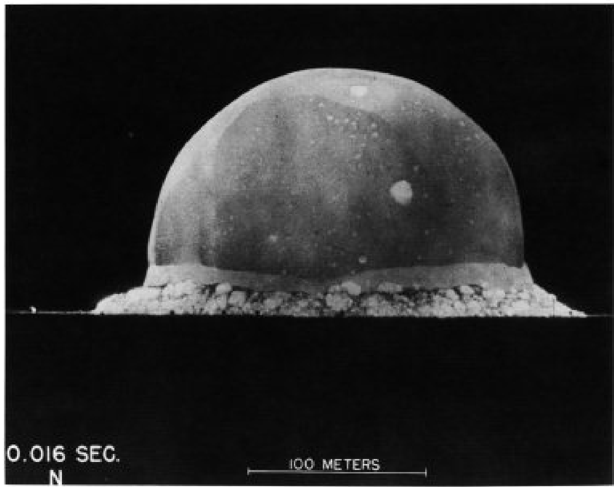
Aims of the CTBTO

- To detect, locate and identify nuclear weapons tests down to 1kT equivalent
- The data used to detect, locate and analyse events are processed immediately, with the first automated products being released within two hours
- The data comprise lists of seismoacoustic events and radionuclides that have been detected by monitoring stations
- Analysts subsequently review these lists in order to prepare quality controlled bulletins
- Implications of getting it wrong are not good



Monitoring Technologies

- The aim – what, where, when, how, who (but not why)
- **Seismological** monitoring system – size, location and time of underground tests
- **Hydroacoustic** monitoring detects acoustic waves – size, location and time of underwater tests
- **Infrasound** network detects very low-frequency sound waves in the atmosphere – size, location and time of atmospheric tests
- **Radionuclide** network of 80 stations uses air samplers to detect radioactive particles released from atmospheric explosions and vented from underground or under water explosions (the ‘smoking gun’).

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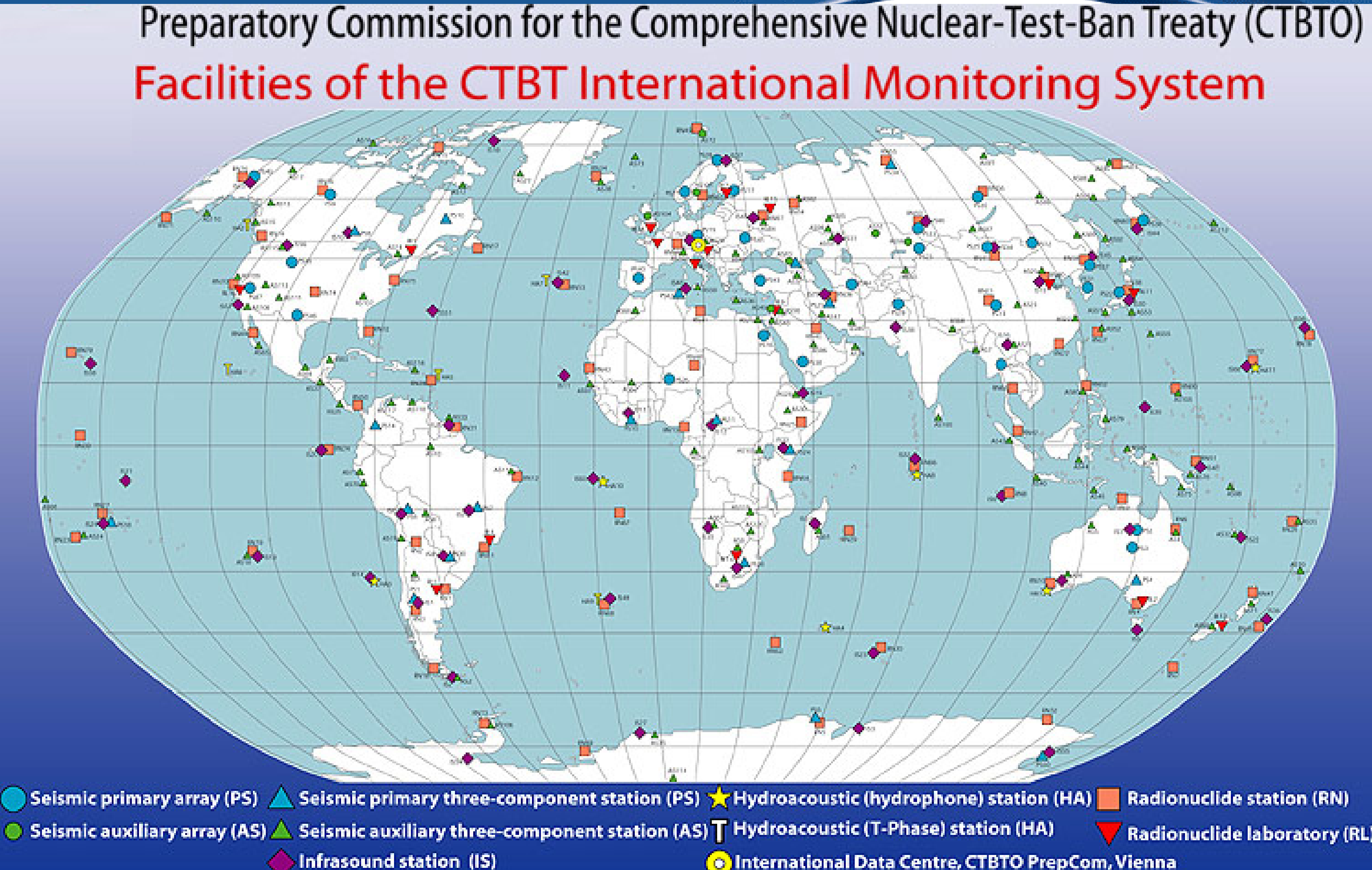
Network Locations



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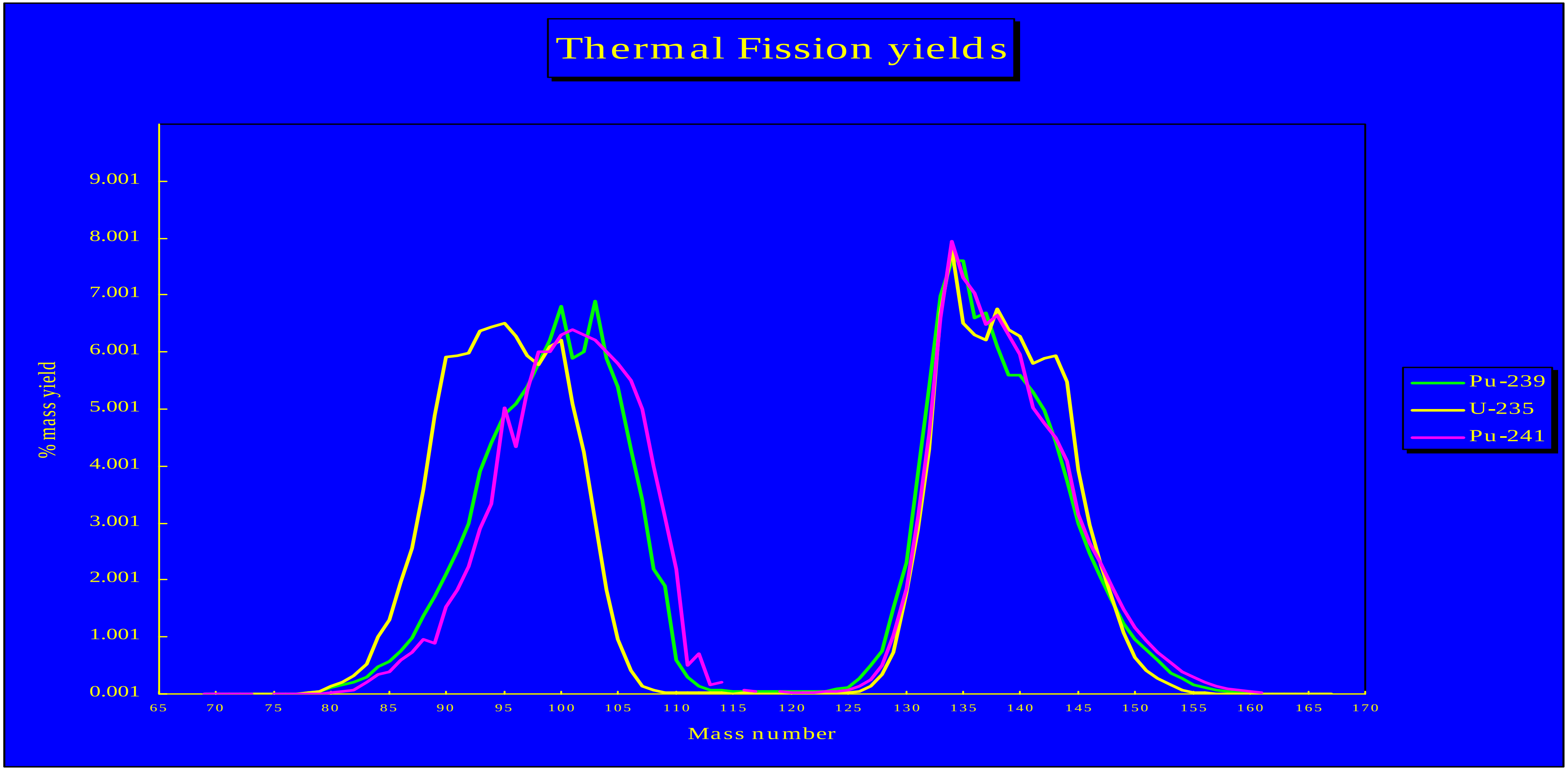
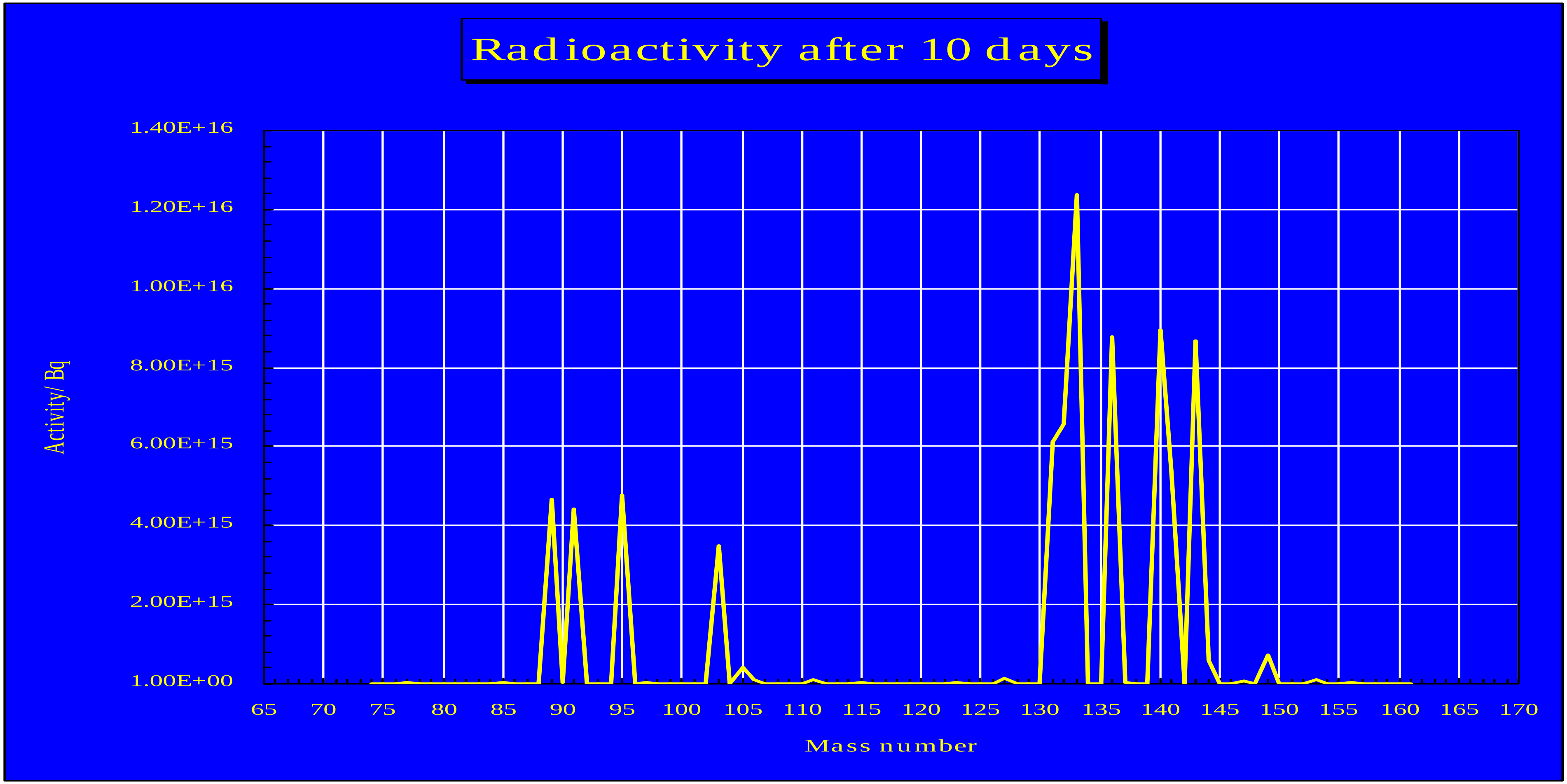
Nuclear Weapon

- Initial fission reaction (20 kT - ^{239}Pu)
- Fuels second fission reaction (<500 kt ^{239}Pu or ^{235}U)
- second fission reaction fuels fusion reaction (yield depends how much fuel $^{2}H/^{3}H$ in the form $Li^{2}H$)
- finally, fast neutrons induce addition fissions in the weapon containment (yield depends on rest of weapon – ^{238}U)
- Fission products elements from Zinc to Terbium, all volatalised

Fission Products

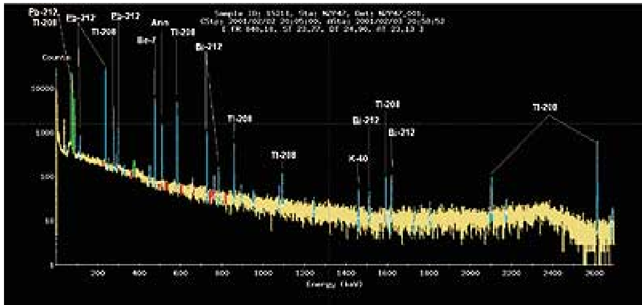


Radioactivity remaining



Radionuclide monitoring

- The radionuclide network of 80 stations uses air samplers to detect radioactive particles released from atmospheric explosions and vented from underground/underwater explosions
- Half of the stations in the radionuclide network also have the capacity to detect noble gases
- The relative abundance of different radionuclides in these samples can distinguish between materials produced by a nuclear reactor and a nuclear explosion
- The associated radionuclide laboratories are used to analyse samples that are suspected of containing radionuclide materials that may have been produced by a nuclear explosion
- The presence of specific radionuclides provides unambiguous evidence of a nuclear explosion



Performance requirements

- For the network of radionuclide stations:

  90% probability of detection within 14 days of any event >1 kT
- Distinguish between nuclear explosion and:

  Radon (allow the sample to decay)

  Radioactive Xenon used in nuclear medicine

  Emissions from civil nuclear facilities

  Cosmogenic radionuclides
- Based on the detection of ^{140}Ba with a detection limit of 10 μBq/m^3
- 1 kT = ~4×10^{12}J = 1.3×10^{23} fissions = 5 PBq ^{140}Ba
- Trying to detect not very much at all of the device!

Radionuclide monitoring stations

Air flow:	500 m^3/hour
Collection time:	24 hours
Decay time:	$\leq$24 hours
Measurement time:	$\geq$20 hours
Reporting time:	$\leq$72 hours
Reporting frequency:	Daily
Collection efficiency:	$\geq$80% for 0.2 μm and $\geq$60% for 10 μm
Measurement:	High resolution γ spectrometry, 88-1836 keV
Sensitivity:	ε_γ >40% leading to 10-30 μBq/m^3 for ^{140}Ba
Data availability:	$\geq$95%
Down time:	$\leq$7 days in a row, $\leq$15 days per year

Xenon monitoring stations

- Air flow: 0.4 m^3/hour
- Sample volume: 10 m^3
- Collection time: $\leq$24 hours
- Measurement time: $\leq$24 hours
- Reporting time: $\leq$48 hours
- Reporting frequency: Daily
- Nuclides monitored: ^{131m}Xe, ^{133}Xe, ^{133m}Xe and ^{135}Xe
- Measurement: β–γ coincidence counting or high resolution γ spectrometry
- Sensitivity: 1 mBq/m^3 for ^{133}Xe
- Data availability: $\geq$95%
- Down time: $\leq$7 days in a row, $\leq$15 days per year

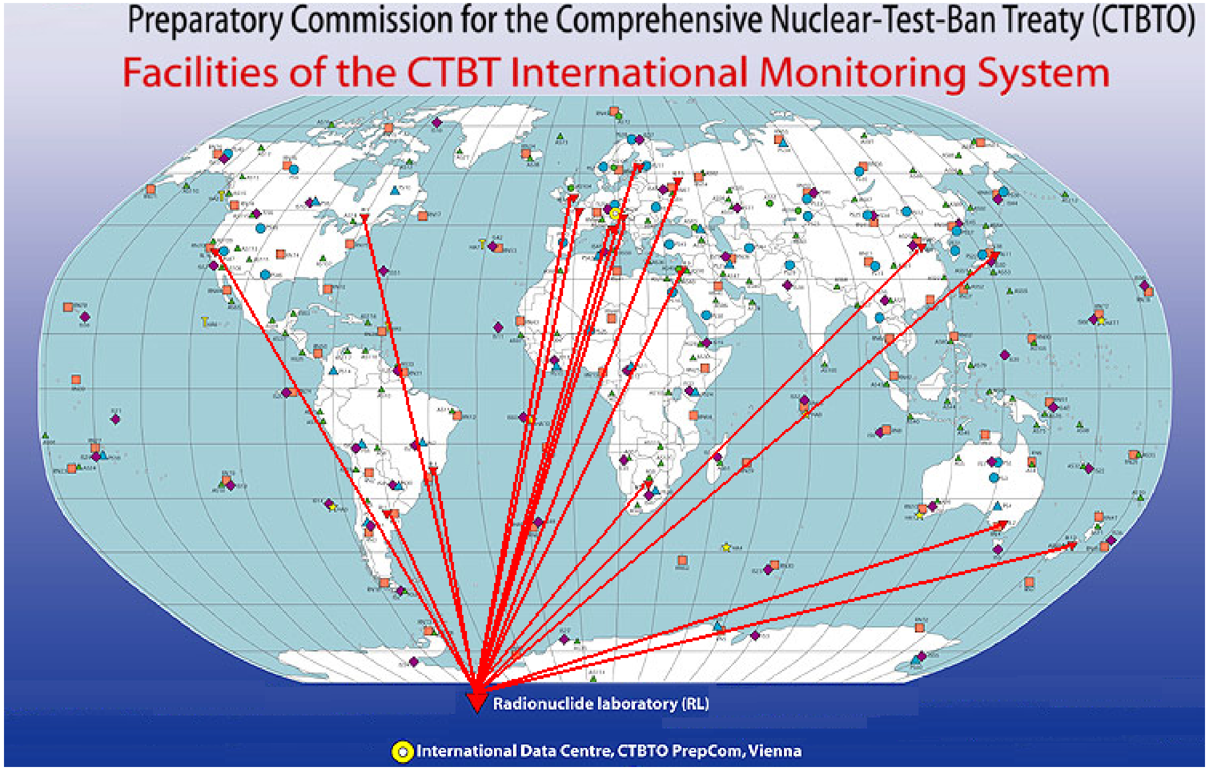
Supporting measurement

- Network of 16 radionuclide laboratories around the world
- Provide more detailed analysis of filters if required

Key Nuclides:

$^{95}Zr/^{95}Nb$ –	timing
^{99}Mo –	timing
^{106}Ru –	fuel
$^{132}Te/^{132}I$ –	event
$^{140}Ba/^{140}La$ –	timing
$^{141}Ce/^{144}Ce$ –	fuel

Pure α and β emitting fuel and casing activation products



CTBTO Country Profile for the UK

Location	Type	Treaty Code	Coordinates	
			Lat	Lon
Eskdalemuir EKA	Auxiliary Seismic Station	AS104	55.3	-3.2
BIOT/Chagos Archipelago	Hydroacoustic Station	HA08	-7.3	72.4
Tristan da Cunha	Hydroacoustic Station	HA09	-37.2	-12.5
Tristan da Cunha	Infrasound Station	IS49	-37.0	-12.3
Ascension	Infrasound Station	IS50	-8.0	-14.3
Bermuda	Infrasound Station	IS51	32.0	-64.5
BIOT/Chagos Archipelago	Infrasound Station	IS52	-5.0	72.0
AWE Blacknest Chilton	Radionuclide Laboratory	RL15	TBD	TBD
BIOT/Chagos Archipelago	Radionuclide Station	RN66	-7.0	72.0
St. Helena	Radionuclide Station	RN67	-16.0	-6.0
Tristan da Cunha	Radionuclide Station	RN68	-37.0	-12.3
Halley, Antarctica	Radionuclide Station	RN69	-76.0	-28.0

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Noble gas sampling

- Xenon is adsorbed on charcoal, purified and concentrated
- Need to remove water and CO_2

  Interfere with adsorption of Xenon on charcoal
- Radon needs to be removed

  Variable concentrations, but much larger than radioactive Xenon

  Gas chromatography is used to separate Radon and Xenon
- Variable background

  Nuclear medicine (mainly ^{133}Xe)

  Nuclear power

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Noble gas measurement

- ^{131m}Xe, ^{133}Xe, ^{133m}Xe and ^{135}Xe emit γ–rays and similar energy X–ray
- Can use γ spectrometry to detect ^{133}Xe (81 keV, 37%), ^{133m}Xe (233 keV, 10%) and ^{135}Xe (250 keV, 90%)
- ^{131m}Xe emits 30 keV X-rays, but no γ–rays; ^{133}Xe, ^{133m}Xe and ^{135}Xe also emit X–rays at this energy
- Use β–γ coincidence counting techniques to reduce background for ^{133}Xe and ^{135}Xe
- Use γ–β coincidence counting (gated on 30 keV X–ray) with an energy resolving β detector to reduce background for ^{131m}Xe and ^{133m}Xe

Noble gas interferences

- ^{131m}Xe, ^{133}Xe, ^{133m}Xe and ^{135}Xe can be present at ground level with activities of up to 100 mBq/m^3 from nuclear power and from medical use
- Typically 3-10 mBq/m^3 in the industrialiased regions of the northern hemisphere

- $(^{133m}Xe:^{133}Xe)_{reactor}$ ~0.1 $(^{133m}Xe:^{133}Xe)_{weapon}$ ~10
- $(^{135}Xe:^{133}Xe)_{reactor}$ ~0.01 $(^{135}Xe:^{133}Xe)_{weapon}$ ~100

- Medically used ^{133}Xe is practically pure
- Activity ratios are more important than activity concentrations in this case:
  $(^{131m}Xe:^{133}Xe:^{133m}Xe:^{135}Xe)_{weapon} \sim 1:10^4:10^5:10^7$

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Particulate sampling

- Particulate activity is captured on organically based band filters of differing types
- Filter exposed for 24 hours
- Allowed to decay for 24 hours

  Radon daughter nuclides (mainly ^{212}Pb) decay over this period, reducing interference with ^{140}Ba

  All other major radon daughters decay to zero in 24 hours
- Measured for 24 hours
- Data reported to IDC in Vienna

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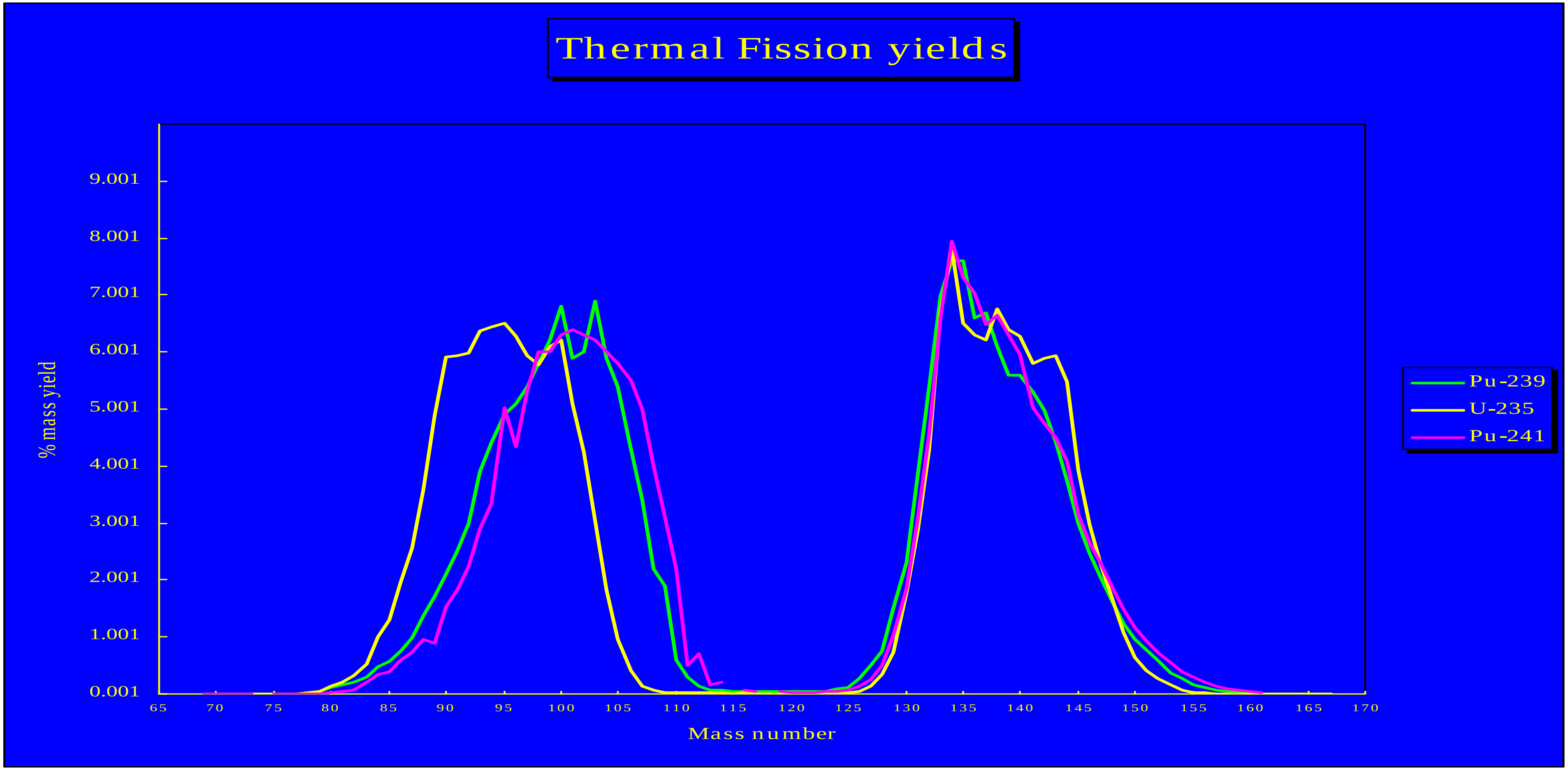
Fission Products



Particulate measurement

- Need for calibration standards
- Filter standards prepared from solution standards
- Detectors calibrated directly (88-1836) keV
- Monte Carlo and other modelling techniques not used
- Comparison exercises to verify quality of information supplied
- CTBTO has very similar quality requirements to ISO 17025

Comparison exercises

- 2000:

  ^{22}Na, ^{124}Sb, ^{125}Sb, ^{134}Cs, ^{137}Cs, ^{154}Eu, ^{155}Eu, ^{210}Pb

  Activity levels 5 – 250 Bq/filter
- 2001:

  ^{91}Y, ^{95}Zr/^{95}Nb, ^{99}Mo, ^{99m}Tc, ^{103}Ru , ^{106}Ru, ^{132}Te/^{132}I, ^{137}Cs, ^{140}Ba/^{140}La, ^{141}Ce, ^{144}Ce, ^{147}Nd

  Activity levels 5–75 Bq/filter
- 2002:

  ^{91}Y, ^{95}Zr/^{95}Nb, ^{99}Mo, ^{99m}Tc, ^{103}Ru , ^{106}Ru, ^{127}Sb, ^{132}Te/^{132}I, ^{137}Cs, ^{140}Ba/^{140}La, ^{141}Ce, ^{147}Nd, ^{154}Eu, ^{155}Eu

  Activity levels 0.1–10 Bq/filter