Characterization of nuclear and radioactive materials seized from illicit trafficking in Ukraine

V. Tryshyn, A.Berlizov

Institute for Nuclear Research
National Academy of Sciences of Ukraine

Outline

- Organizational and legislative basis
- Equipment and materials employed for NM and RM characterization at INR
- International co-operation
- Nuclear and radioactive materials characterized at the INR
- Recent cases of illicit trafficking
- Prospects

Existing legislative basis for preventing illicit trafficking of nuclear materials in Ukraine

- **The Law of Ukraine "On Nuclear Power Utilization and Radiation Safety"** (1995), the basic law of the Ukrainian nuclear legislation, established both legal relationships in the field of nuclear power utilization in Ukraine and main directions of the activities on legislative base creation.

- **The Decree No.198 of 20 March 1995** issued by Cabinet of Ministers of Ukraine "*On Ecological Monitoring Execution at the State Border Cross-points*" which charged the State Ecological Inspectorate of the MEPNS with responsibility to provide *"... ecological monitoring at the State border cross-points..."*.

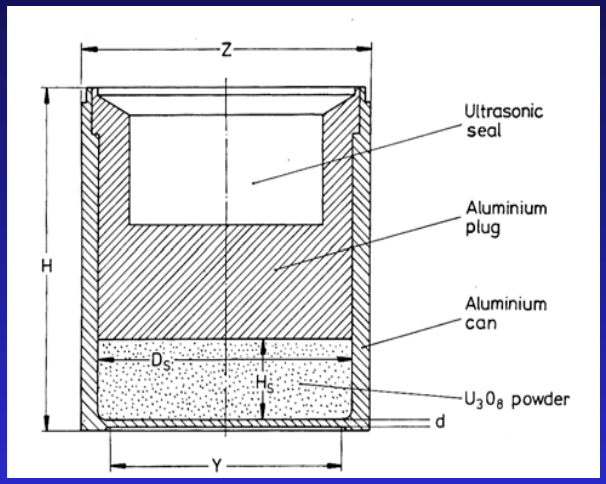
- **The Decree No.207 of March 4, 1997** issued by Cabinet of Ministers of Ukraine "On Establishment the Procedure of Executive Authorities and Relevant Legal Persons Interaction in the Case of Radioactive Sources Detection in Illicit Trafficking". The Decree established the *Procedure for Executive Authorities and Relevant Legal Persons Interaction in the Case of Radioactive Sources Detecting in Illicit Trafficking.* A status of the main expert organization was assigned to the Institute for Nuclear Research (Kiev).

- **The Decree No.813 of July 2, 2003** issued by Cabinet of Ministers of Ukraine "On Establishment the Procedure of Executive Authorities and Relevant Legal Persons Interaction in the Case of Radioactive Sources Detection in Illicit Trafficking".

Equipment and materials employed for NM and RM characterization at the INR

Standard Reference Material SRM 969

Material: U_3O_8 powder, m = 200 g, ρ = 2.5 g/cm³;
Externals: Z = 80 mm, H = 90 mm;
Sample volume: D_S = 70 mm, H_S = 20.8 mm;
Al window thickness: d = 2 mm.



Certified abundances in SRM 969 (mass fractions):

	SRM 031		SRM 071		SRM 194	
	C, %	1σ, %%	C, %	1σ, %%	C, %	1σ, %%
U-234	0.0020	5.0	0.0052	1.9	0.0171	0.6
U-235	**0.3166**	**0.06**	**0.7119**	**0.07**	**1.9420**	**0.07**
U-236	0.0146	1.0	0.0000	0.0	0.0003	16.7
U-238	99.6668	2.0E-04	99.2828	2.0E-04	98.0406	9.2E-04

	SRM 295		SRM 446	
	C, %	1σ, %%	C, %	1σ, %%
U-234	0.0279	0.7	0.0359	0.4
U-235	**2.9492**	**0.07**	**4.4623**	**0.07**
U-236	0.0033	3.0	0.0068	1.5
U-238	97.0196	1.5E-03	95.4950	1.7E-03

Certified Reference Material CRM 146

Material: U_3O_8 powder, m = 230 g, ρ = 3.78 g/cm^3;
Externals: Z = 80 mm, H = 90 mm;
Sample volume: D_S = 70 mm, H_S = 15.8 mm;
Al window thickness: d = 2 mm.

Certified abundances in CRM 146 (mass fractions):

	NBL 0041		NBL 0042		NBL 0043	
	C, %	1σ, %%	C, %	1σ, %%	C, %	1σ, %%
U-234	0.1486	0.12	0.3718	0.13	0.9800	0.15
U-235	**20.1070**	**0.05**	**52.4880**	**0.04**	**93.1703**	**0.003**
U-236	0.1973	0.3	0.2645	0.11	0.2937	0.4
U-238	79.5470	1.3E-02	46.8760	4.6E-02	5.5559	4.8E-02

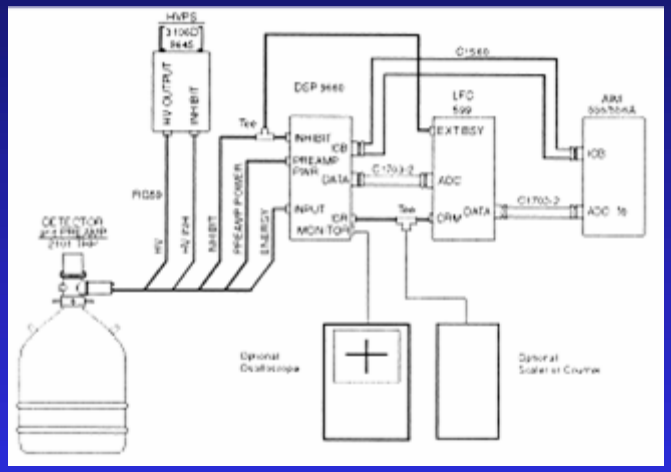
Portable U/Pu InSpector Systems

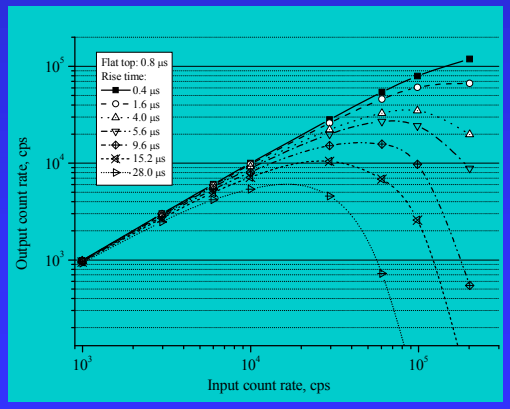
GL0515R:
FWHM=600 eV
at 122 keV

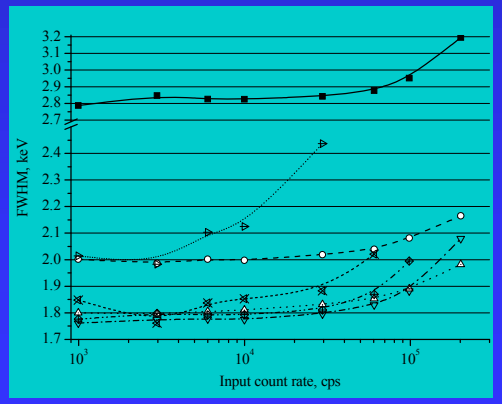
GL1015R:
FWHM=550 eV
at 122 keV

Portable Electronics:
- InSpector IMCA
- DSA-1000

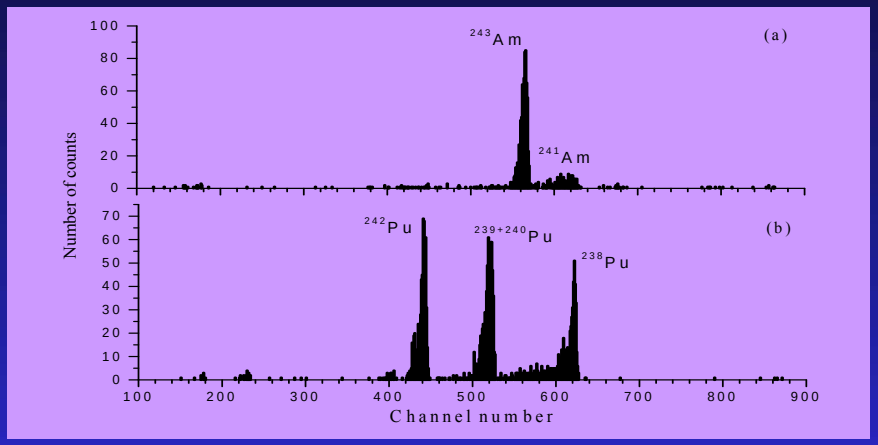
High-Energy Fixed HPGe Gamma-Spectrometer & High-Throughput Digital and Analog Electronics







4-Chamber Alpha-Spectrometer

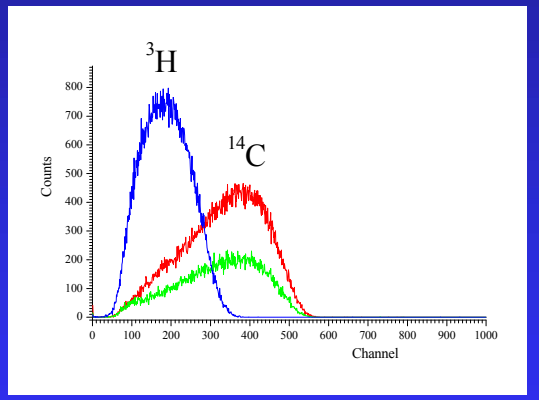


JCC-51 Active Well Coincidence Counter (AWCC)

- Active assay of HEU metal, UO_2 powder and pellets, U scrap, fuel rods etc.
- Passive assay of Pu
- 1.2 Ci AmLi GammaTron neutron source (Model AN-HP) is used in Active Interrogation Mode
- JSR-14 Shift Register

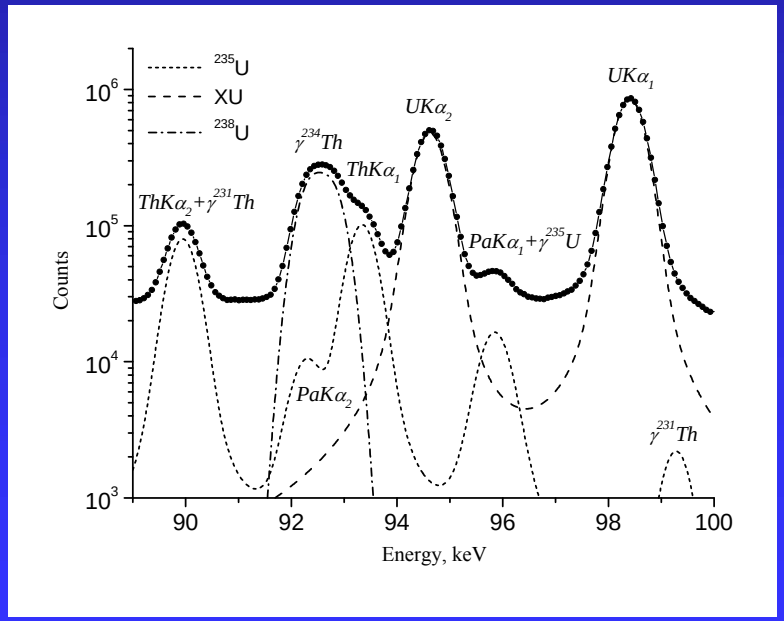
1220 Quantulus

Ultra Low Level Liquid Scintillation Spectrometer



Software & NuData Libraries

- GENIE-2000 V.2.1A: Basic Gamma-Spectroscopic Software with GammaAnalysis V.2.1A, Interactive PeakFit V.1.2, QA V.1.3, ProCount V.1.1 options
- MGAU V.2.2, V.4.0
- MGA V.9.63A
- FRAM V.3.4
- IMCA V.1.1
- NuChart V.4.0.0



International co-operation

- TACIS project U5/95 (1999-2001)
- TACIS Nuclear Safety Action Programme 2005 Task F (2008-2012) :
- TACIS Nuclear Safety Action Programme 2005 Task K (2008-2012) :
- Training of Ukrainian experts

TACIS project U5/95 (1999-2001) :
Providing Effective Assistance in Counteracting Against Non-Authorised Trafficking of NM

- Enhancing analytical capabilities of the Main Expert Organization of Ukraine
- Analytical trainings of INR's experts in ITU, Karlsruhe
- Model Action Plan Demonstration Exercise
- One-week training of specialists from involved Ukrainian organizations
- Development of a Handbook describing Response Procedure
- INR-ITU Nuclear Material Database Agreement

On-site actions: Observers and Participants

ITWG, IAEA, ITU, STUK, TACIS Monitoring Team, Delegation of the European Commission in Ukraine, State Nuclear Regulatory Administration of Ukraine, Kiev Institute for Nuclear Research, Authority of Ministry for Internal Affairs of Ukraine in Odessa region, Authority of Security Service of Ukraine in Odessa region, Authority of Ministry for Environmental Protection and Nuclear Safety of Ukraine in Odessa region, Local Sanitary and Epidemiological Service of Odessa region, State Enterprise “Radon”, Institute for Marine Ecology.

On-site actions (cont.)

Container was detected by representatives of the local Sanitary and Epidemiological Service

On-site actions (cont.)

Sub-sample was analyzed. Container was taken by “Radon” representatives for interim storage

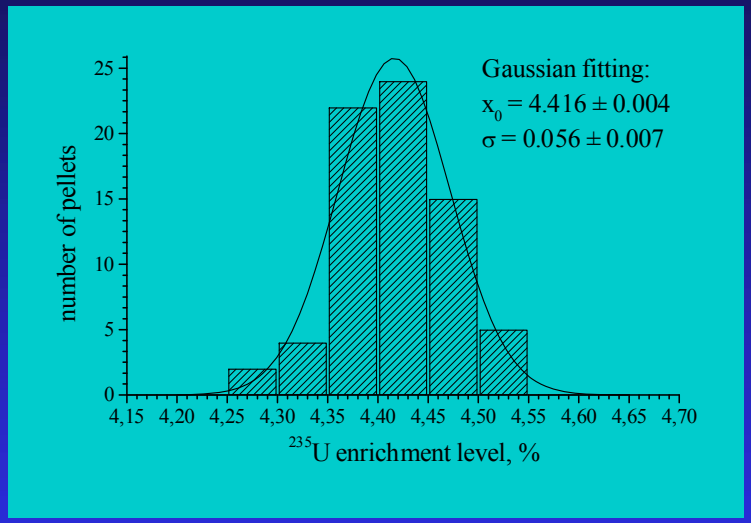
On-site characterization results

- Instrument – U/Pu Inspector

Container #	Measurement #	Counting time	Enrichment level, %
1	1	330 s	4.303 ± 0.115
	2	369 s	4.353 ± 0.106
2	1	362 s	4.427 ± 0.123
	2	328 s	4.065 ± 0.127

Results of the expertise at the INR

- Material - annular pellets, UO_2
- Number of pellets – 335
- Total weight – 1628.5 ± 0.2 g
- Ext. diameter – 7.55 ± 0.05 mm
- Hole ∅ – 2.4 ± 0.05 mm
- Uranium content – 1435.5 ± 0.2 g
- Enrichment level ^{235}U – 4.42 ± 0.03 %
- ^{235}U isotope weight – 63.4 ± 0.4 g



Query to the ITU's NM Database

1. Assembly Model and Pellet Supplier Identification

Assembly Model	**Assembly** Supplier	**Pellet** Supplier
VVER-440	**MZ**	**MZ (Elektrostal)**
VVER-1000	**CCP**	**MZ (Elektrostal)**
VVER-1000	**CCP**	**UMP(Ulba)**

2. Reactor Unit Identification

U235 = 4..4.5 w/o

Reactor	unit	Assembly Model	Fuel Matter	U235
Kola	4	VVER-440	U02	4.4
Rovno	1-2	VVER-440	U02	4.4
Dukovany	1-4	VVER-440	U02	4.0
Loviisa	1-2	VVER-440	U02	4.0
Balakovo	1-4	VVER-1000	U02	4.4
Khmelnitski	1-4	VVER-1000	U02	4.4
Kola	5-6	VVER-1000	U02	4.4
Kostroma	1-4	VVER-1000	U02	4.4
Rovno	3-4	VVER-1000	U02	4.4
S.Ukraine	2-3	VVER-1000	U02	4.4
Novovoronezh	5-7	VVER-1000	U02	4.4
Zaporozhe	1-4	VVER-1000	U02	4.4

3. Further measurements required:

Hole Diameter with min. accuracy of 0.2 mm U235 content with min. accuracy of 0.2 w/o

-> assembly model and fuel supplier can be further narrowed

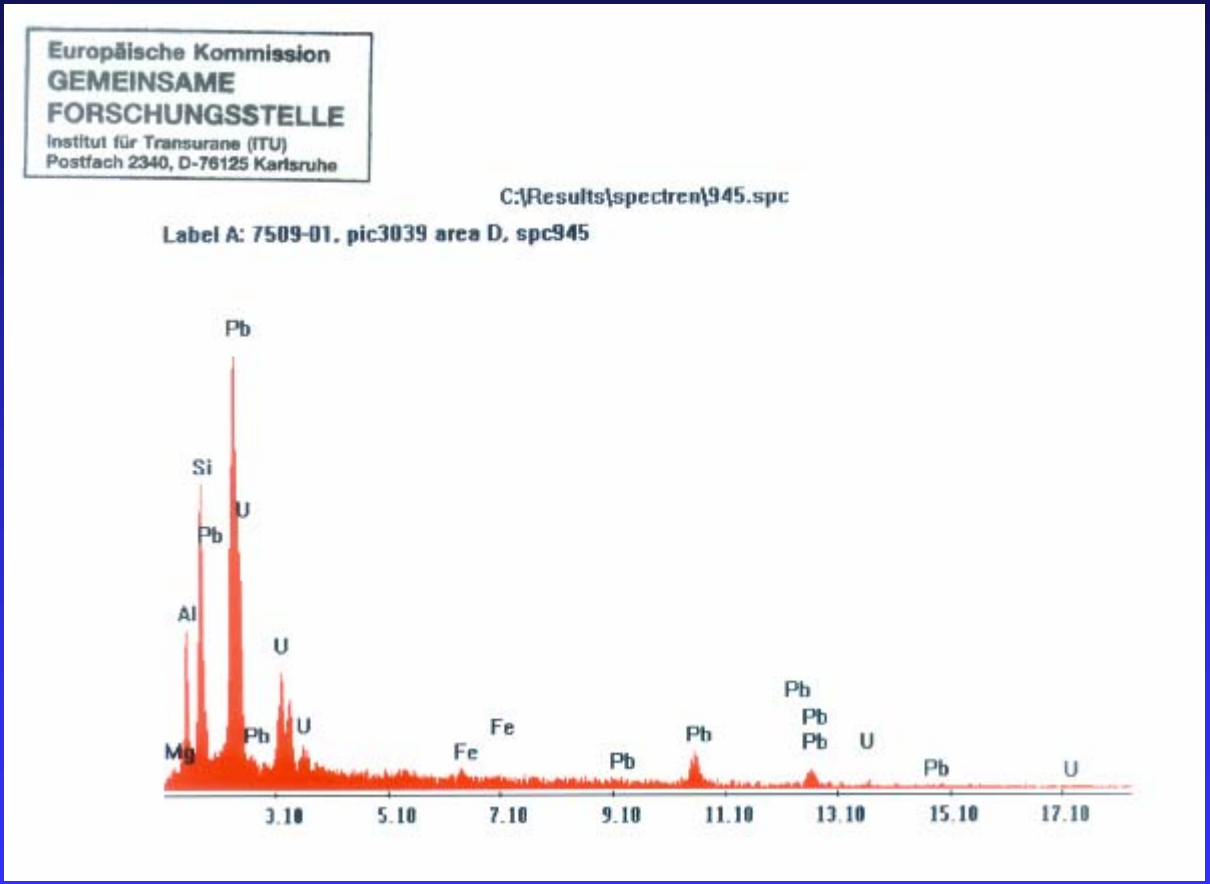
Impurities: **C, N, F, Mg, Al, Si, P, Ca, V, Cr, Mn, Fe, Ni, Cu, Md**

-> further information of fuel supplier and possibly production period can be derived

Joint analysis at the ITU (cont.)

- Exterior and interior views of pellet #1

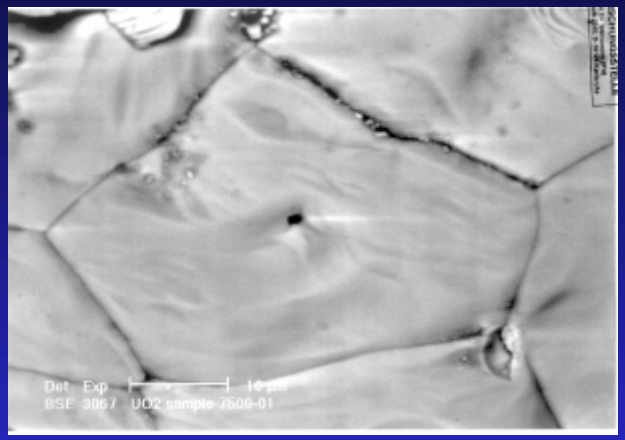
Joint analysis at the ITU (cont.)



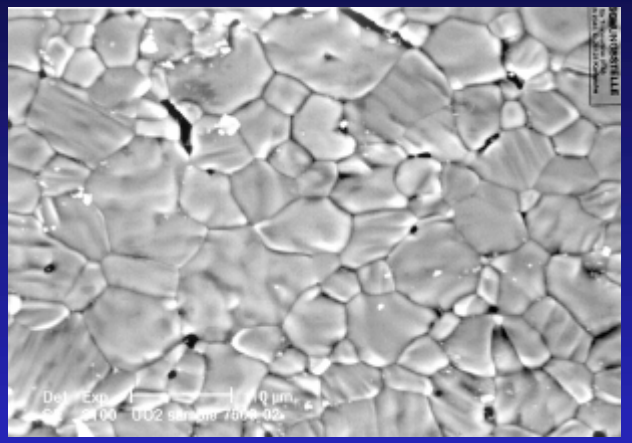
- SEM & EDX analysis of pellet surfaces

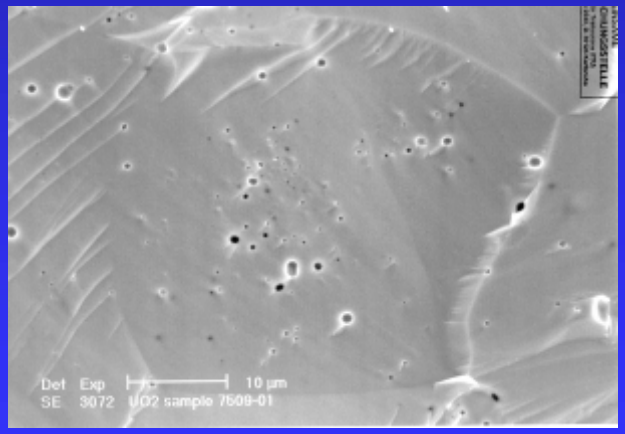
Joint analysis at the ITU (cont.)

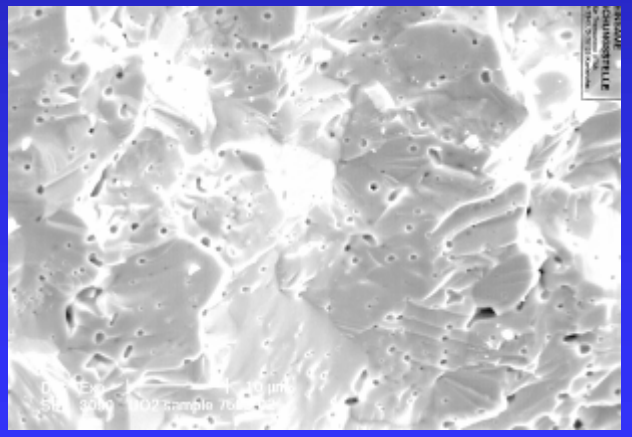
Pellet #1



Pellets #2-5







- SEM – grain size and porosity distributions

Joint analysis at the ITU (cont.)

- SEM, Titration and TIMS results

Mean values for the grain sizes of the pellet material, evaluated on 200 independent measurements for each pellet:

Pellet ##	1	2	3	4	5
Mean grain size, μm	32.7		6.0	8.5	10.7

Determined concentrations of uranium in the material of the pellets:

Pellet ##	1	2	3	4	5
Concentration, %	87.41(13)	87.83(13)	87.91(13)	87.54 (13)	87.84 (13)

Measured uranium isotopic composition of the pellet material:

Pellet ##	1	2	3	4	5
^{234}U, %	0.0409(28)	0.0386(27)	0.0376(26)	0.0402(28)	0.0404(28)
^{235}U, %	4.3657(15)	4.3851(15)	4.3856(15)	4.3846(15)	4.3844(15)
^{236}U, %	0.0024(24)	0.0079(78)	0.0052(52)	0.0015 (15)	0.016(15)
^{238}U, %	95.5909(14)	95.5684(14)	95.5716(14)	95.5598(14)	95.5596(14)

TACIS Nuclear Safety Action Programme 2005 Task F (2008-2012) :

Implementation of measures to combat illicit trafficking of radioactive and nuclear material in Ukraine

- Selection, purchasing and installation of equipment of the mobile expert laboratory of the Main Expert Organization of Ukraine (Institute for Nuclear Research - INR) for ensuring prompt response to the cases of detection of nuclear materials and sources of ionizing radiation in illicit trafficking
- Training of Ukrainian experts in the ITU and ISPRA
- Carrying out a model exercise with a real nuclear/radioactive material to work out a procedure of responding to the cases of illicit trafficking

TACIS Nuclear Safety Action Programme 2005 Task K (2008-2012) :

Enhance the capability for analysis of seized nuclear materials and radioactive substances at the Institute for Nuclear Research (INR) of the National Academy of Sciences of Ukraine

- Selection and purchasing the equipment for the determination of trace element content in nuclear materials and environmental samples by inductively coupled mass-spectrometry method (ICP-MS)
- Training of Ukrainian experts in the ITU
- Accreditation of the INR's expert laboratory in the State Committee for Standardization, Metrology and Certification of Ukraine
- Performing an inter-comparison exercise (e.g. INR-ITU-IAEA) on the characterization of the trace element content in a sample of nuclear material, seized on the territory of Ukraine

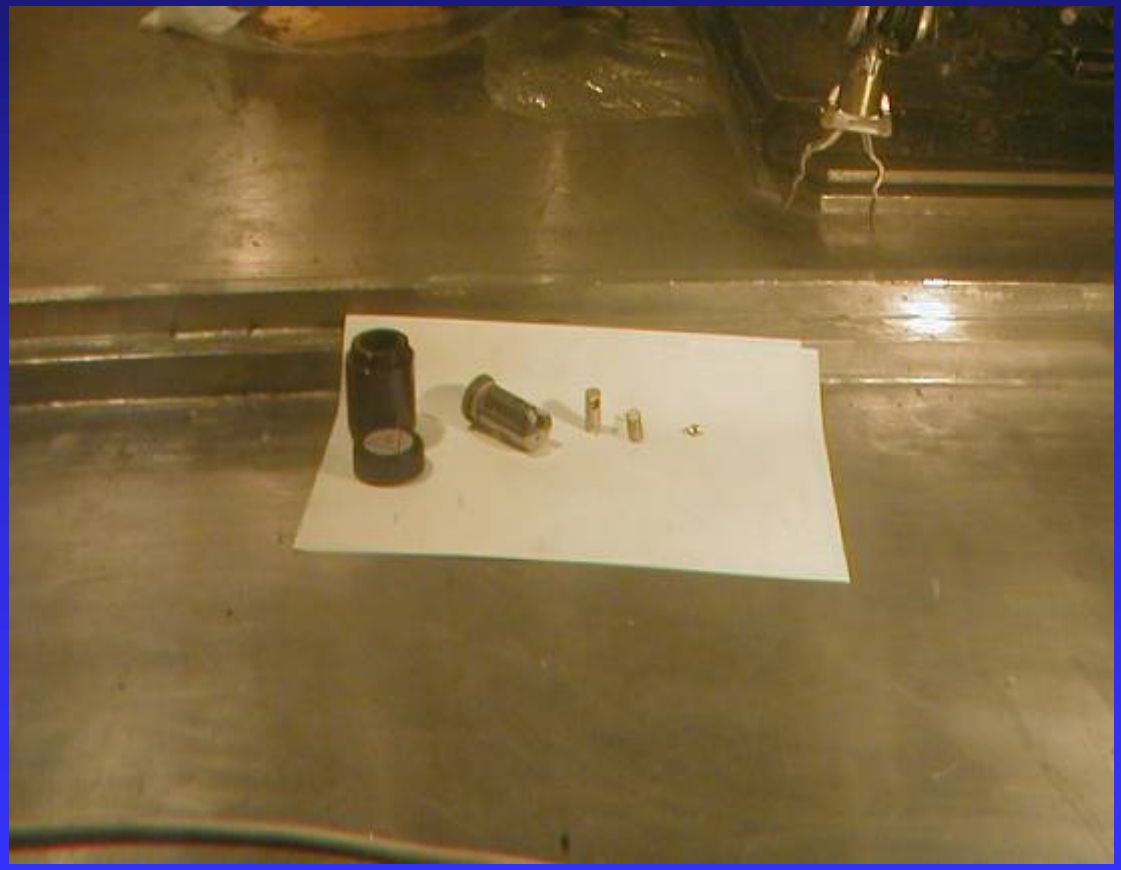
Training of Ukrainian experts

- Nondestructive Assay Fundamentals
  (30 aug – 10 sep 2004). George Kuzmycz Training Center, Kiev,Ukraine
- 7-th Nuclear Science Training Course with Nuclides.net
  (26 – 28 april 2006). ITU, Karlsruhe, Germany
- Nuclear Forensics Awareness and Law Enforcement Workshop
  (2 – 4 december 2008). ITU, Karlsruhe, Germany
- 1-st Advanced Training Course on Illicit Trafficking and Consequence Management with Nucleonica
  (22 – 24 april 2009). ITU, Karlsruhe, Germany

Recent cases of illicit trafficking

Example #1: 95 MBq Sr-90 source

(August, 2003)



Example #2: 0.7 Ci Cs-137 source

(August, 2003)

Example #3: 3.0 Ci Cs-137 source

(october 2003)

Example #4: GAMMARID container

(december 2004)

Depleted uranium: m = 12.8 кг

Isotopic abundances:

U-234 < 0.002%, U-235 – 0.28%, U-238 – 99.72%

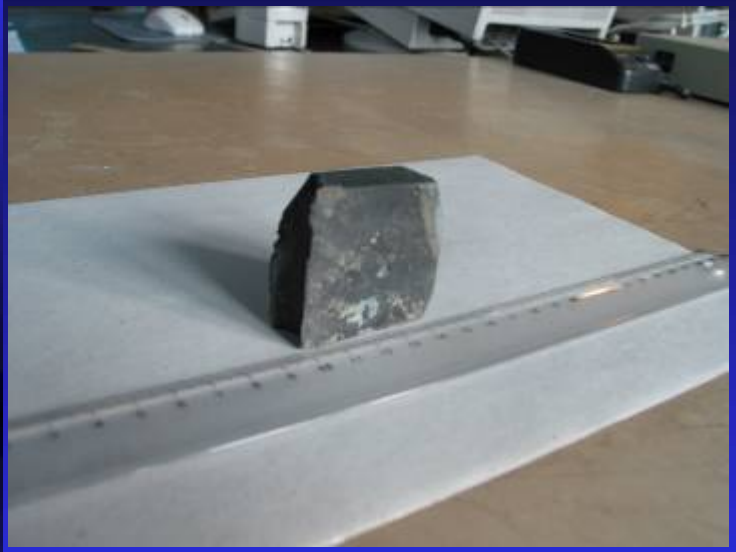
Ir-192 source was not present.

Example #5: Boryspil Airport Case

(march, 2005)

On-site actions

Example #5: cont'd



Laboratory analysis:

Sample analysis (MGAU, FRAM):
U-234 – 0,002 ± 0,001 % wt.,
U-235 – 0,390 ± 0,010 % wt.,
U-238 – 99,608 ± 0,010 % wt.

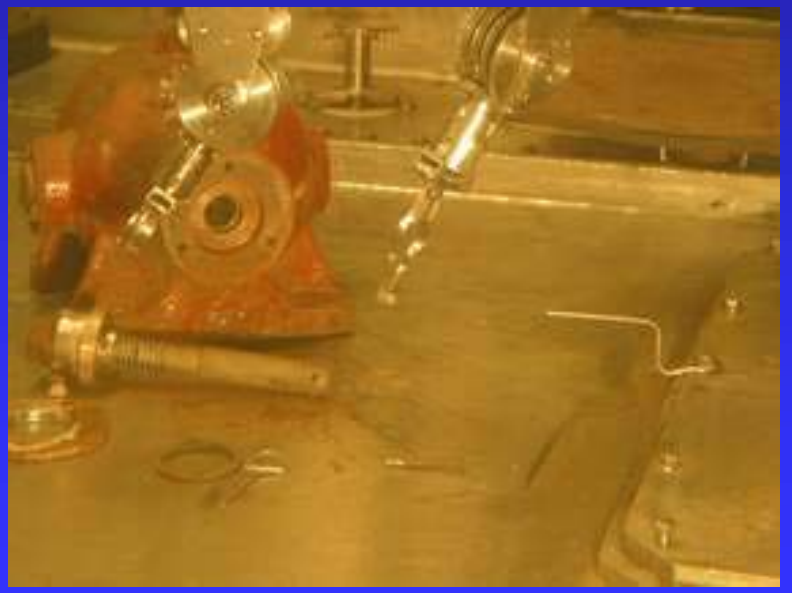
m = 577,850 ± 0,010 g

Analysis of microparticles smeared over surface of balances (dissolution, electrodeposition, alpha-spectrometry):
U-234 – 0.0021 ± 0.0005%,
U-235 – 0.30 ± 0.07%,
U-238 – 99.70 ± 0.07%

Example #6: 0.6 Ci ^{137}Cs source
(december 2006)

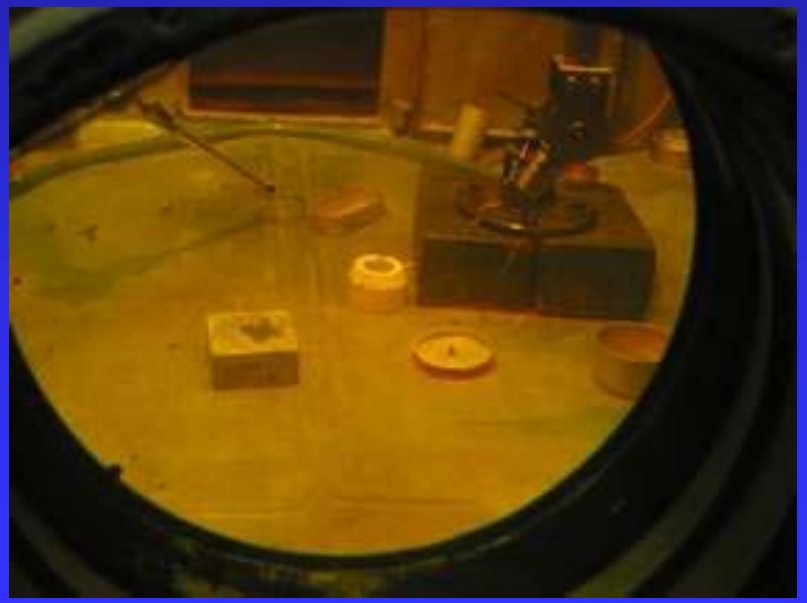
BGI-75A

Source extraction
in the “hot cells”



Example #6: cont'd

Gamma-spectrometry measures

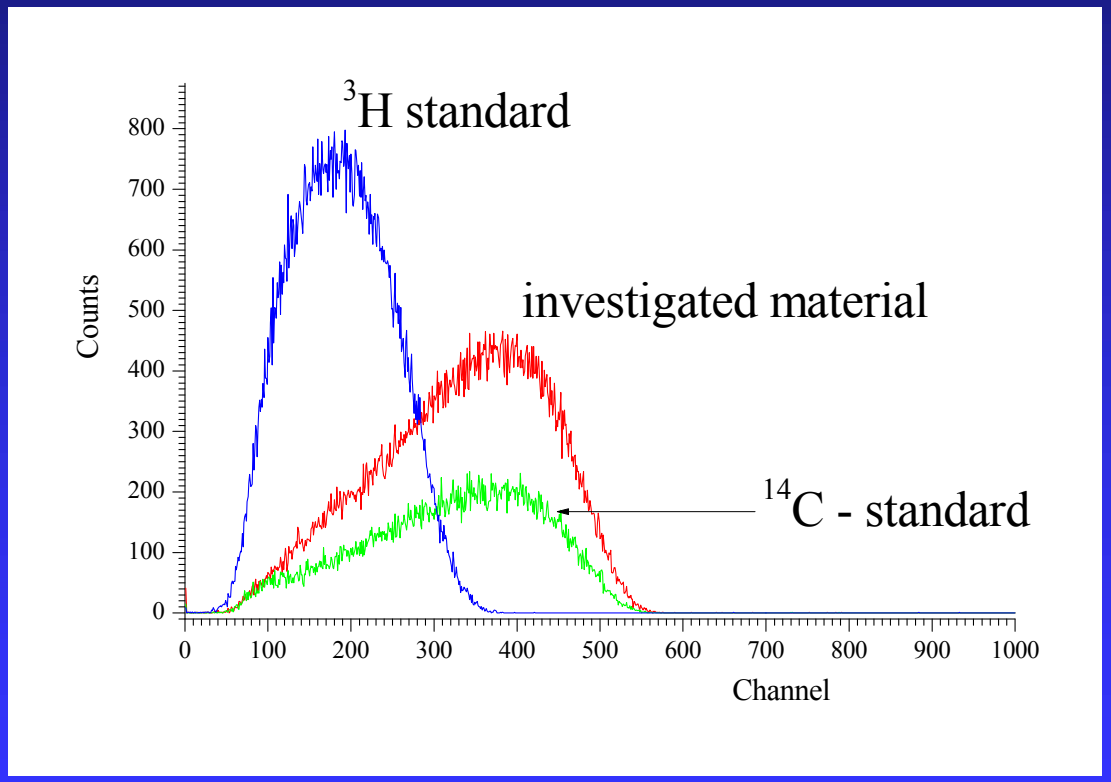


Example #7: Radioactive air mail parcel
(september 2007)

Mass of substance – 12 kg
Dose rate on the surface – 11 uSv/h
Specific activity ^{232}Th – 45 kBq/kg
Specific activity ^{226}Ra – 20 kBq/kg

Example #8: 40 MBq ^{14}C source
(july 2008)

Beta-spectrum (Quantulus 120)



Prospects

- Organization regional GUAM member-country nuclear-criminalistical laboratory in the Institute for Nuclear Research National Academy of Sciences of Ukraine

Thank you for your attention