GOBIERNO DE ESPAÑA
MINISTERIO DE CIENCIA E INNOVACIÓN
Ciemat
Centro de Investigaciones Energéticas, Medioambientales y Tecnológicas

International Intercomparison Exercise on Natural Radiation Measurements

under Field Conditions

Saelices el Chico (Salamanca, Spain), May 23-27, 2011

Measurement of External Environmental Gamma Radiation

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INTRODUCTION

- External environmental dose rate is probably the most used radiological parameter in radiation protection.

- It describes the exposure to external radiation sources, which dominates most of the human practices and is the second in natural sources after radon inhalation.

- In principle, it is easy to measure , standards and calibration preocedures are well established, many instruments are available at reasonable costs, large experience since radioactivity discovery…

BUT …

EURADOS: Comparison of early warning instruments since 1999

Country	Responsible for national network (Intercomparison)	Other participants (Intercomparison)
AUSTRIA	Federal Chancellery, Vienna (1999)	Bitt Technology (1999)
CZECH REPUBLIC	National Radiation Protection Institute, NRPI (1999)	
DENMARK	Risø National Laboratory, RNL (1999)	
FRANCE	Institute de Radioprotection et Sureté Nucleaire, IRSN (2002)	
GERMANY	Bundesamt für Strahlenschultz, BfS (1999)	Physikalisch-Technische Bundesanstalt, PTB (1999 & 2002)
GREECE	Greek Atomic Energy Commision, GAEC (2002)	Aristotle University of Thessaloniki (2002)
HUNGARY	Paks Nuclear Power Plant (2002)	Atomic Energy Research Institute (2002)
THE NETHERLANDS	National Institute of Public Health and the Environment, RIVM (1999)	
PORTUGAL	Direccao Geral Ambiente, DGA (1999)	
SPAIN	Consejo de Seguridad Nuclear, CSN (1999)	CIEMAT (1999 & 2002)
SWEDEN	Swedish Radiation Protection Authority, SSI (2002)	
SWITZERLAND	Swiss Nuclear Safety Inspectorate, HSK (2002)	
	Institut de Radiophysique Apliquée, IRA (2002)	
UNITED KINGDOM	No participant	Stirling University (2002)
		Consultant (1999 & 2002)

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INSTRUMENTS PARTICIPATING IN EURADOS 1999

ID	Type	Application	Manufacturer	Quantity	Units	Home Source
11	PC	Network	Bitt	H*(10)	nSv/h	Cs137
12	PC	Other	Bitt	H*(10)	nSv/h	Cs137
21	PC	Other	FAG	H*(10)	nSv/h	Cs137
22	PC	Other	Bitt	H*(10)	nSv/h	Cs137
23	PC	Network	Berthold	H*(10)	nSv/h	Cs137
24	GM	Other	Berthold	H*(10)	nSv/h	Cs137
25	IC	Other	Reuter Stokes	X	μR/h	Cs137
26	NaISc	Other	Tesla	Kair	nGy/h	Cs137
31	IC	Other	Reuter Stokes	X	μR/h	Information not supplied
32	IC	Network	Reuter Stokes	X	μR/h	Information not supplied
33	NaISc	Network	Bicron	counting	cps	Cs137
41	GM	Other	Hormann	Hx(10)	nSv/h	Information not supplied
42	GM	Network	Hormann	Kair	nGy/h	Information not supplied
43	GM	Other	Hormann	Kair	nGy/h	Information not supplied
51	PC	Network	Bitt	H*(10)	nSv/h	Co60
52	PC	Other	Bitt	H*(10)	nSv/h	Cs137
53	GM	Other	Genitron	H*(10)	nSv/h	Cs137
61	GM	Network	Hormann	Kair	nGy/h	Cs137
71	PSc	Other	MAB	H*(10)	nSv/h	Cs137
72	GM	Network	Berthold	H*(10)	nSv/h	Cs137
73	GM	Other	Genitron	Kair	nGy/h	Cs137
74	IC	Other	Reuter Stokes	X	μR/h	Cs137

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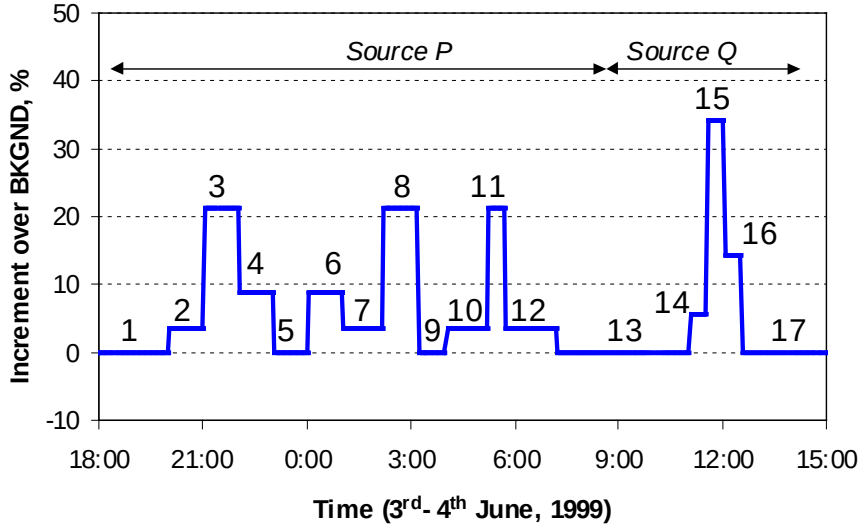
INSTRUMENTS PARTICIPATING IN EURADOS 2002

ID	Type	Application	Manufacturer	Quantity	Units	Home Source
081	GM	Network	Rados	H*(10)	nSv/h	Cs137 and Co60
082	IC	Other	Reuter Stokes	H*(10)	nSv/h	Cs137 and Co60
083	PSc	Other	APVL	H*(10)	nSv/h	Cs137
091	IC	Network	Reuter Stokes	Dair	nGy/h	Cs137
101	PC	Network	Bitt	H*(10)	nSv/h	Cs137
102	PC	Other	Bitt	H*(10)	nSv/h	Cs137
111	PC	Other	Eberline	H*(10)	nSv/h	Cs137
112	GM	Other	Rados	H*(10)	nSv/h	Cs137
113	IC	Network	SSI	H*(10)	nSv/h	Cs137
121	GM	Network	Horman	H*(10)	nSv/h	Cs137
122	IC	Other	Reuter Stokes	H*(10)	nSv/h	Cs137
123	GM	Network	Technidata	H*(10)	nSv/h	Cs137
131	IC	Other	Reuter Stokes	X	µR/h	Co60
132	IC	Other	Reuter Stokes	X	µR/h	Co60

- Most of the instruments measures H*(10)
- Instruments are mostly calibrated using Cs137 sources
- Two instruments use some background value which are automatically substracted from the current measurement

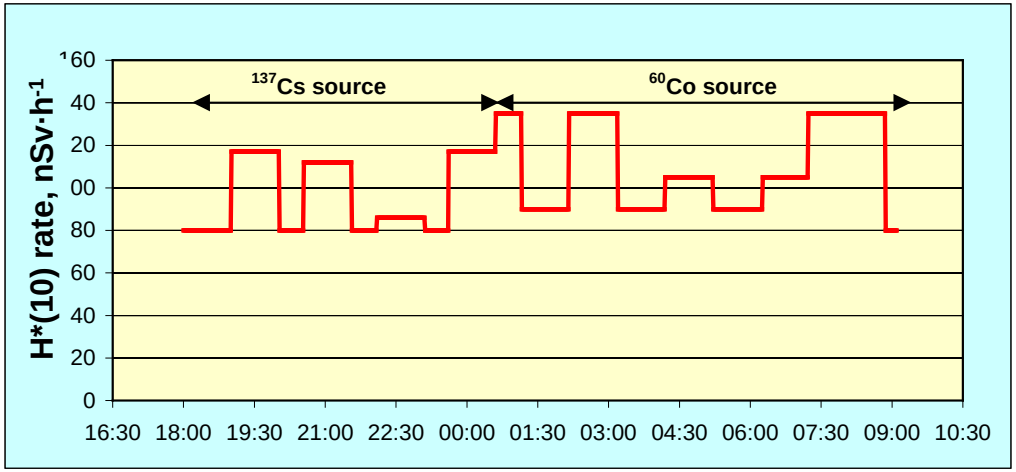
EURADOS: Comparison of early warning instruments since 1999: Risoe 1999

- Automatic device to program controlled gamma plume profiles
- Two ^{137}Cs encapsulated sources whish yield dose increments from 3% to 35%.
- Step time length: 10 minutes
- Plume simulation was produced continuosuly for 20 hours



EURADOS: Comparison of early warning instruments since 1999: PTB 2002

- Automatic device to program controlled gamma plume profiles kindly provided by Riso National Laboratory
- ^{137}Cs and ^{60}Co encapsulated sources yielding dose increments from 7% to 45%.
- Step time length: 10 minutes
- Plume simulation was produced continuosuly for 20 hours



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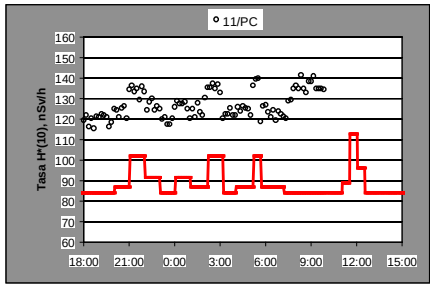
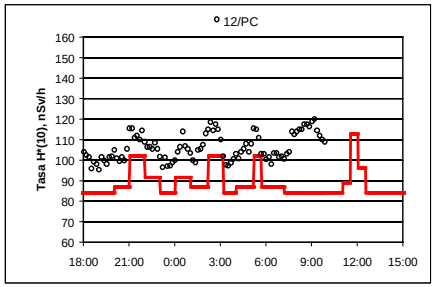
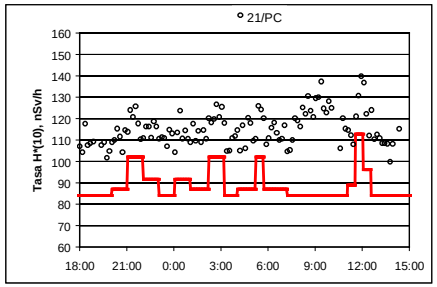
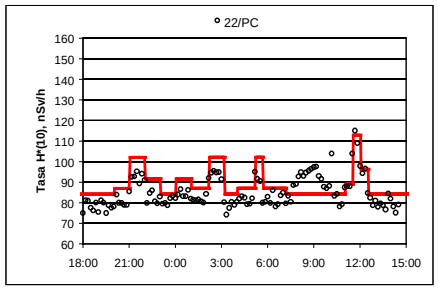
EURADOS 1998: Comparison of early warning instruments

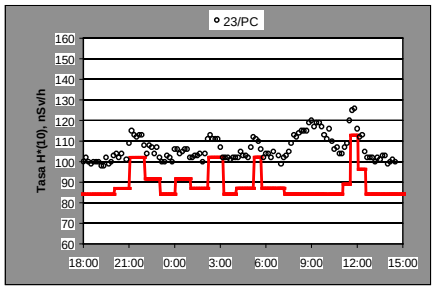
(a) Instrumentos calibrados en términos de Dosis equivalente ambiental, H*(10)

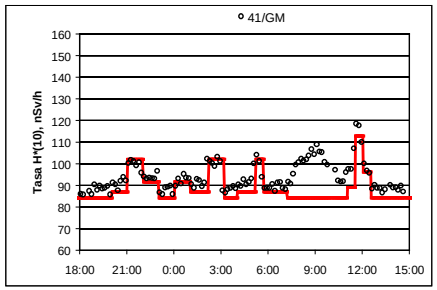


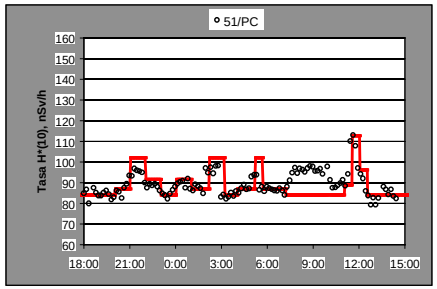


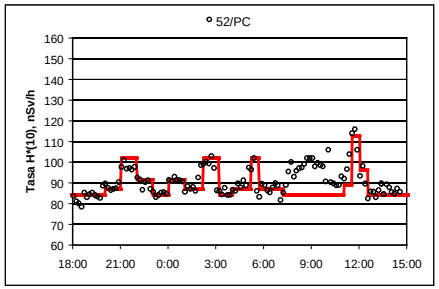


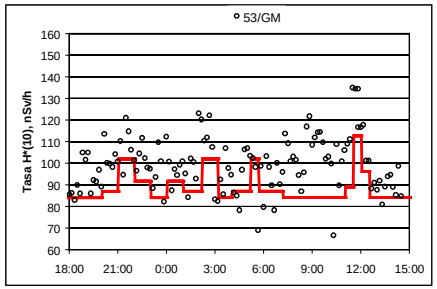


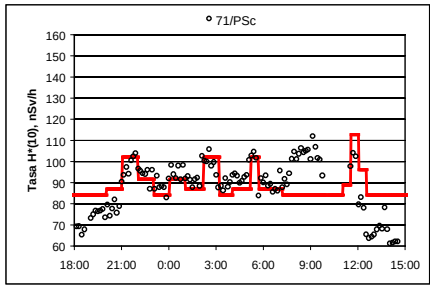


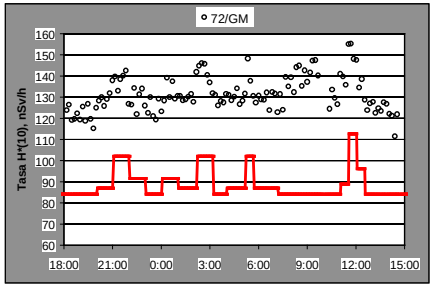












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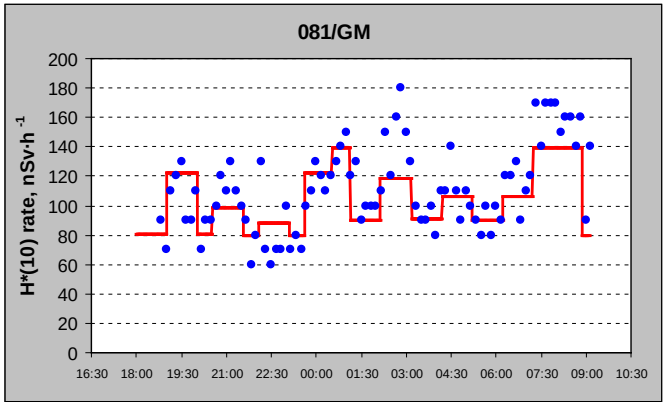
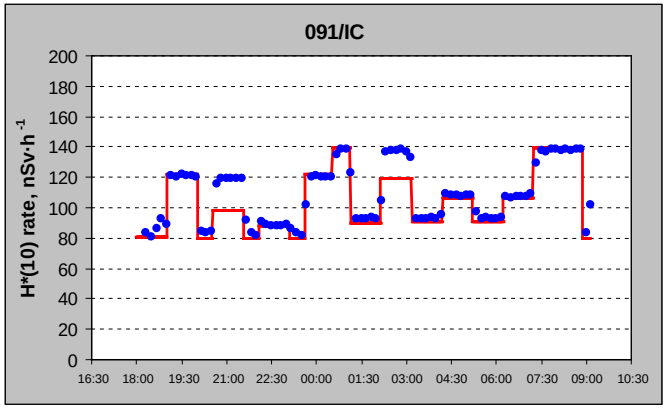
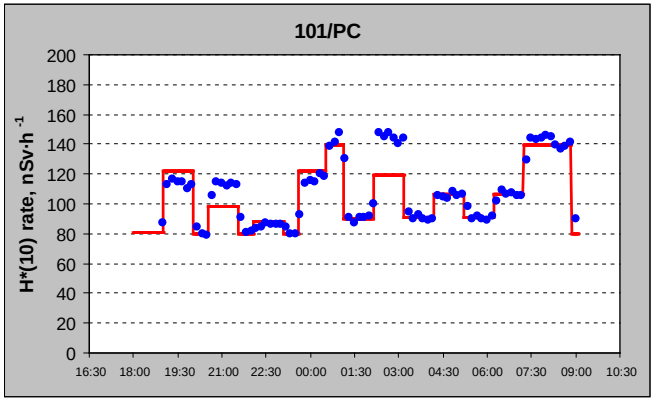
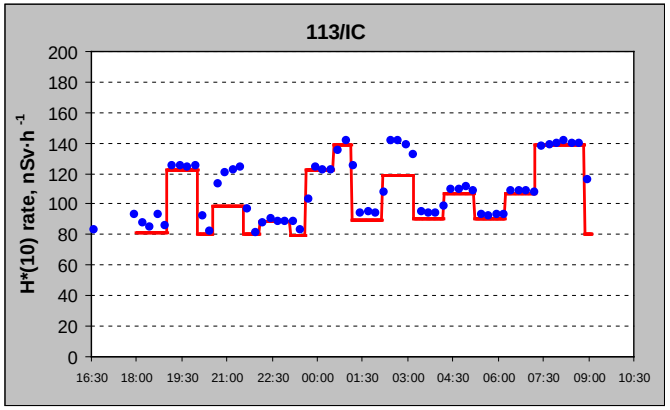
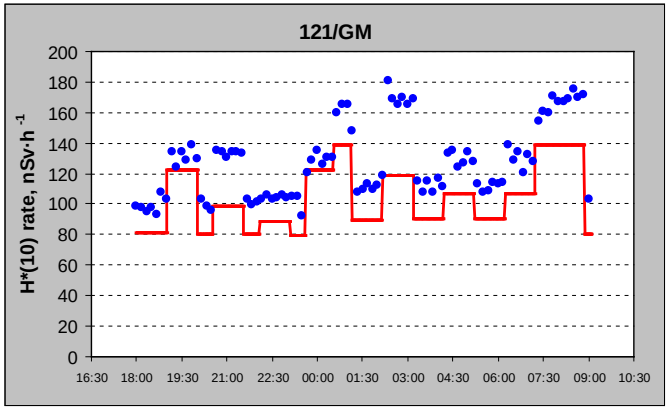
EURADOS 2002: Comparison of early warning instruments

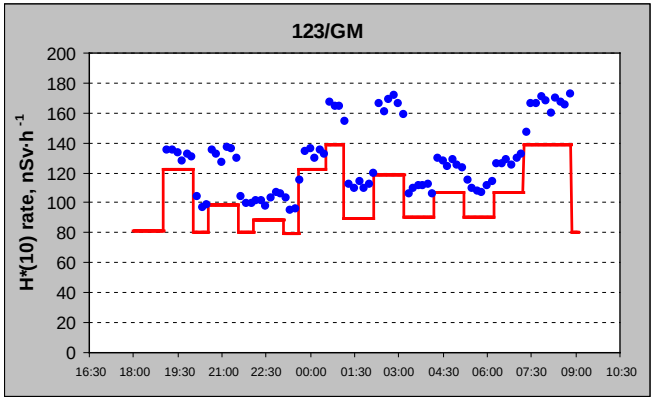






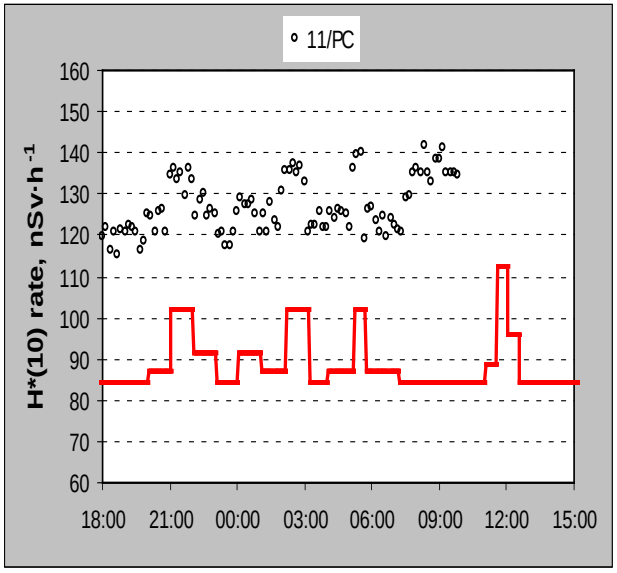


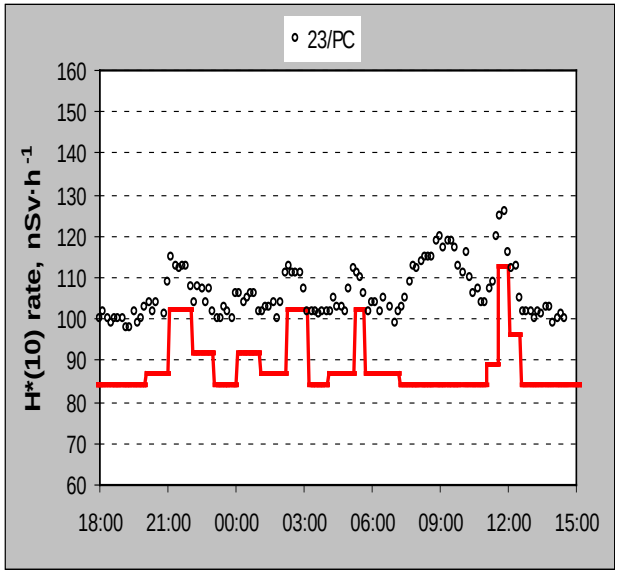


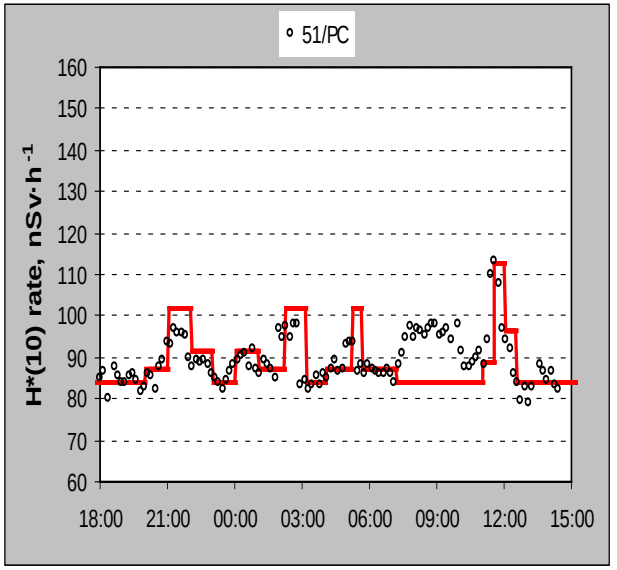


THE PROBLEM

CONCLUSION: Relevant differences often occurs when comparing simultaneous environmental dose rate measruements!!







THE REASONS WHY

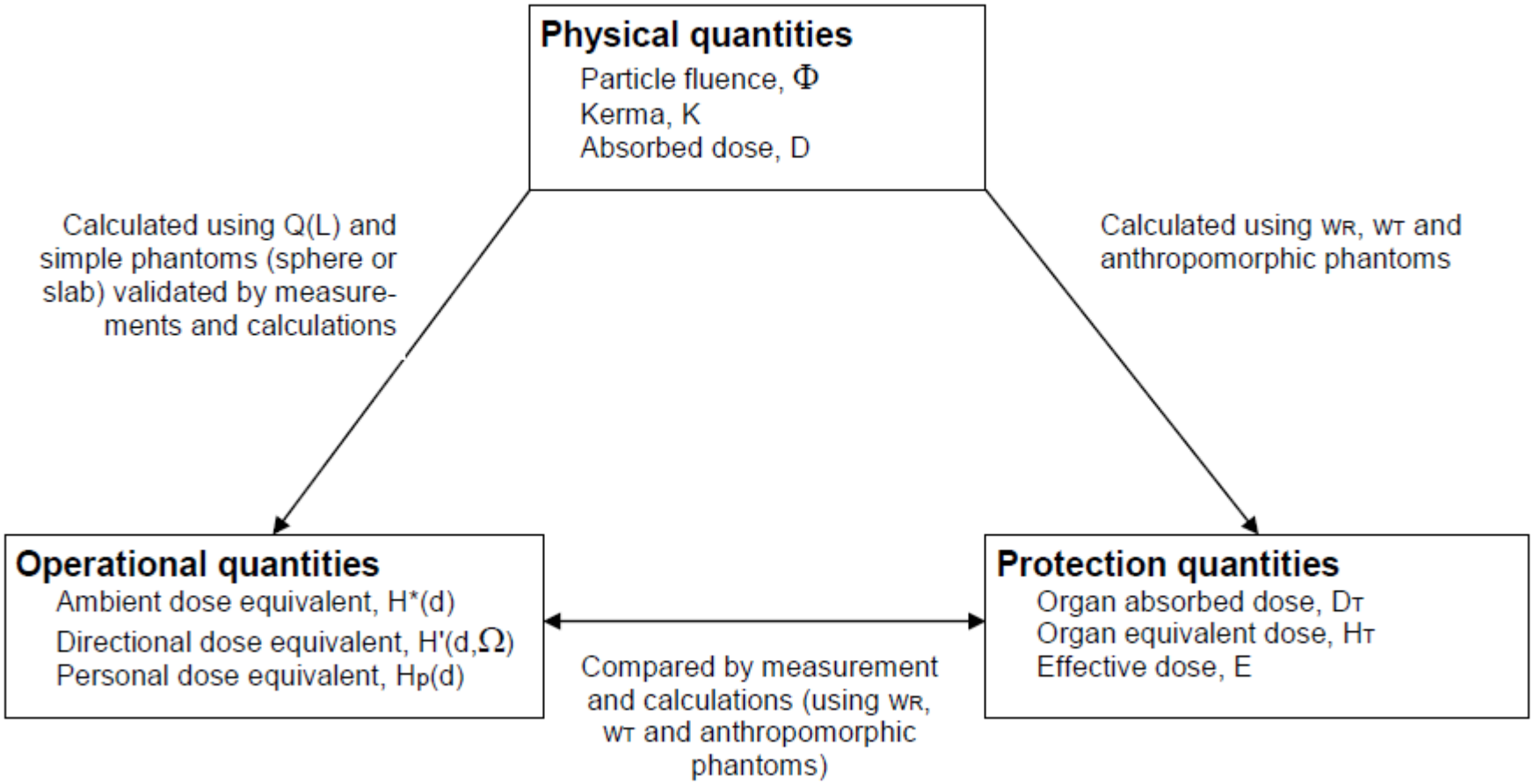
Why? Because accurate dose rate estimation is not so simply as:

Dose Rate = Signal x Calibration Factor

In fact, these are probably the most relevant factors affecting estimations:

- Quantity (and units!!!).
- Calibration conditions (procedure, reference energies, …)
- Sensitivity (time resolution).
- Inherent background.
- Photon Energy response.
- Cosmic Response.
- Angular Response.
- Environmental response (temperature, humidity, light…)

Quantities for external radiation dosimetry

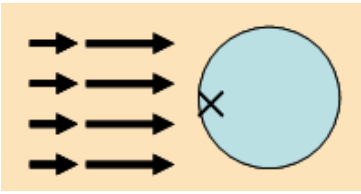


Quantities for external radiation dosimetry

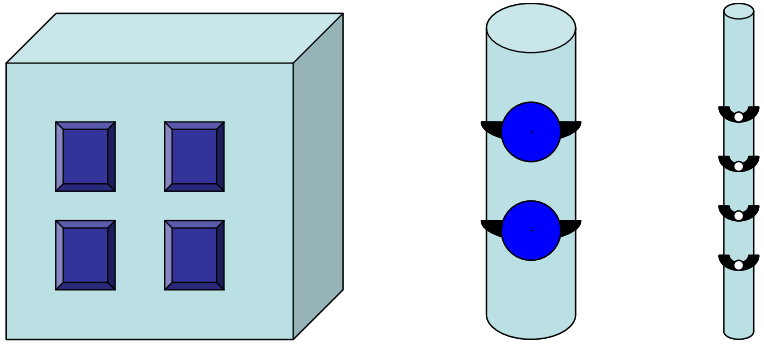
-Absorbed Dose and Kerma are numerically equal in electronic equilibrium conditions: $D_m \cong K_m$

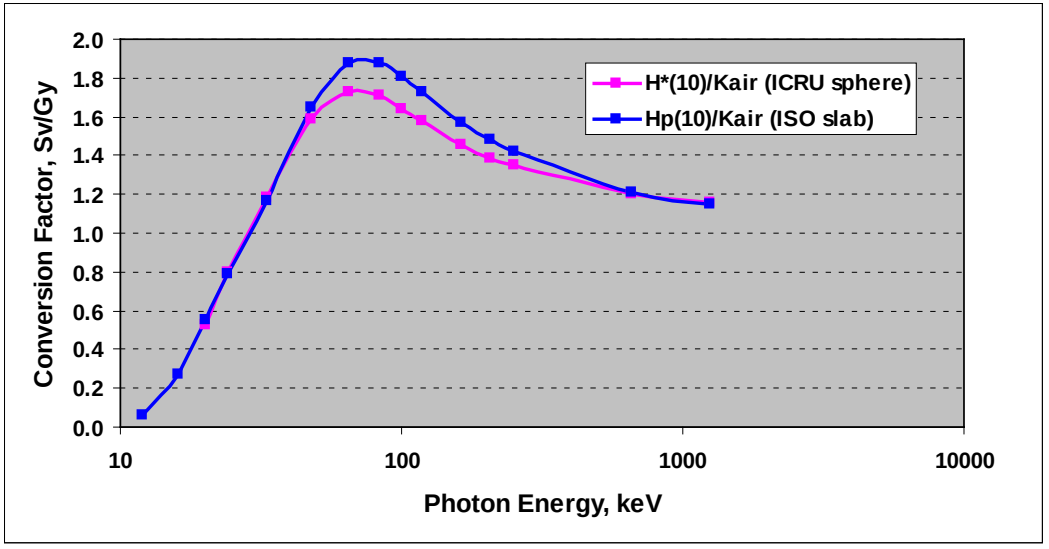
- Air Kerma and Exposure relationship is almost independent of photon energy.

$$X = K_{aire} \cdot (1 - g_{aire}) \cdot \left(\frac{e}{W}\right)$$



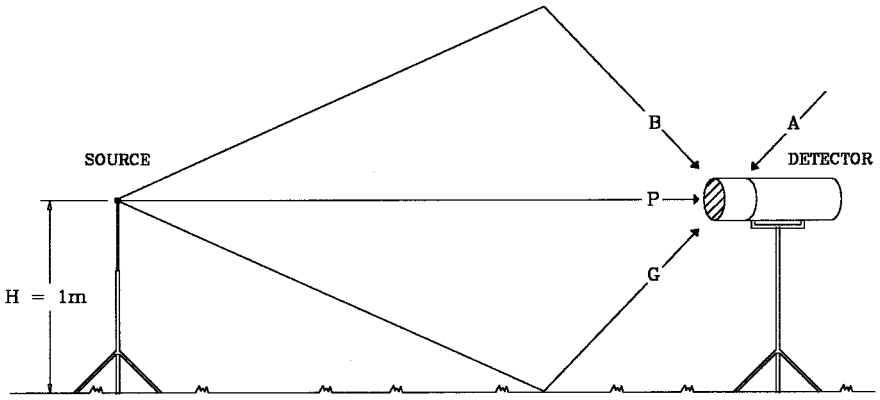
- Conversion Factors are needed to relate Air Kerma and Equivalent Dose quantities.

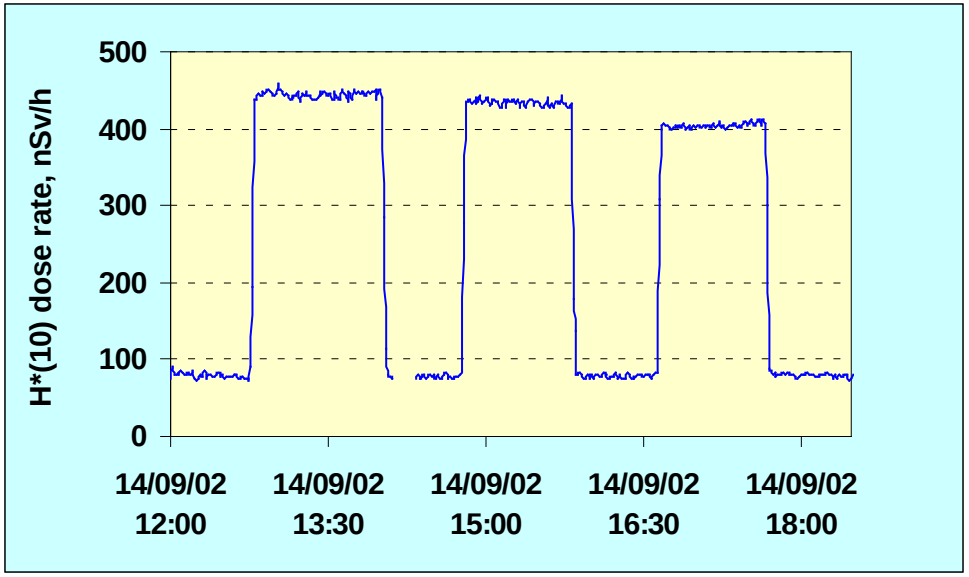




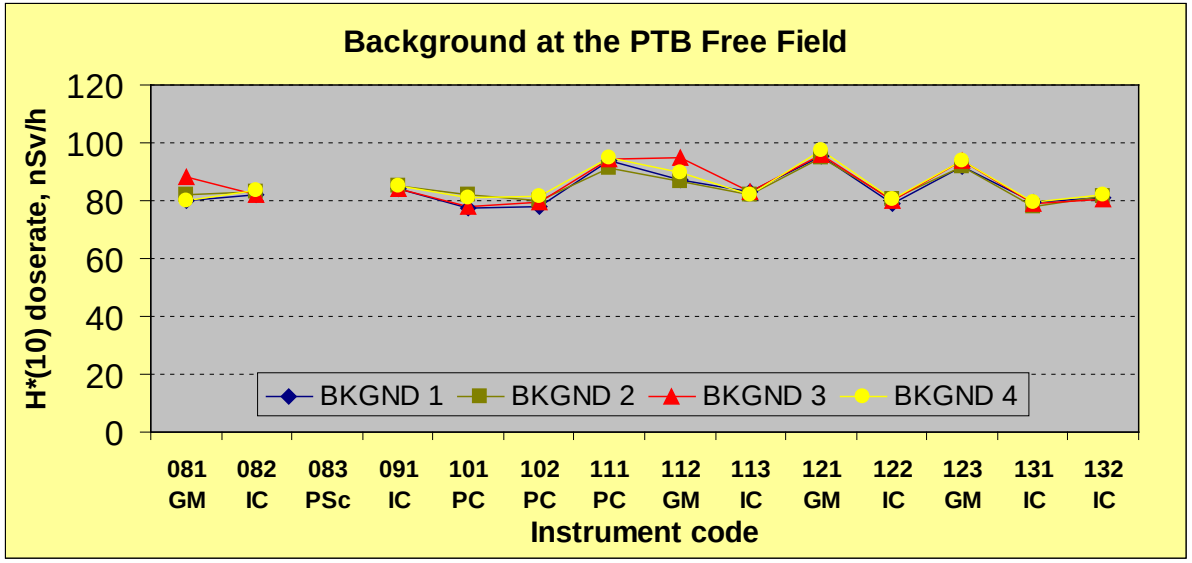
Free Field: Background and Calibration

- ^{137}Cs, ^{60}Co and ^{226}Ra encapsulated sources
- Reference distance: 5 m
- H*(10) rates: 330-400 nSv/h
- Reference values calculated by Reference instrument and MonteCarlo methods

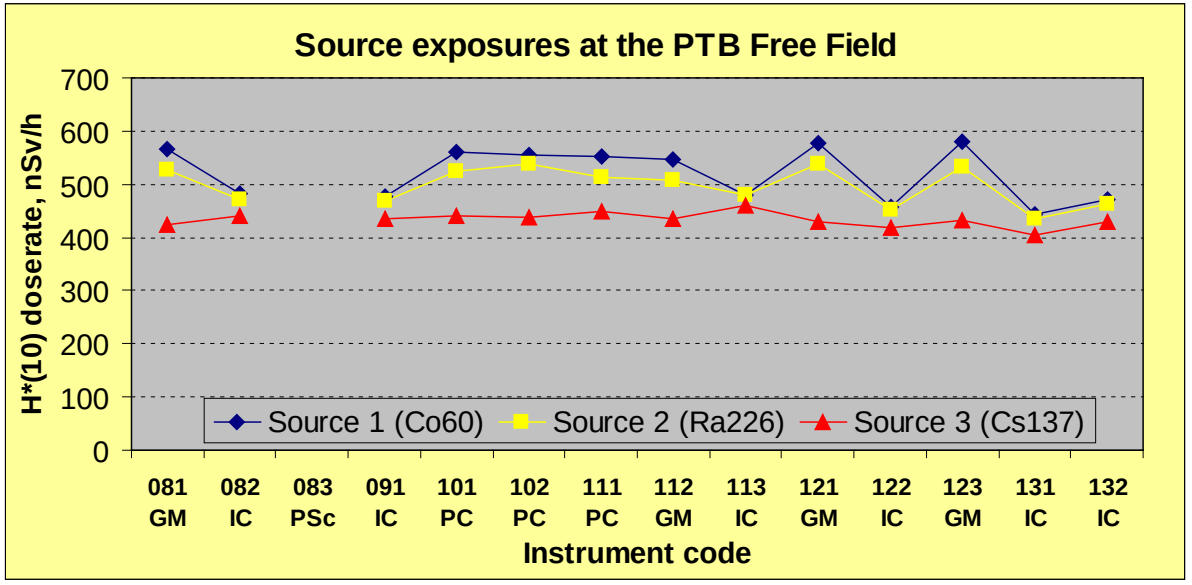




Results: Calibration Check



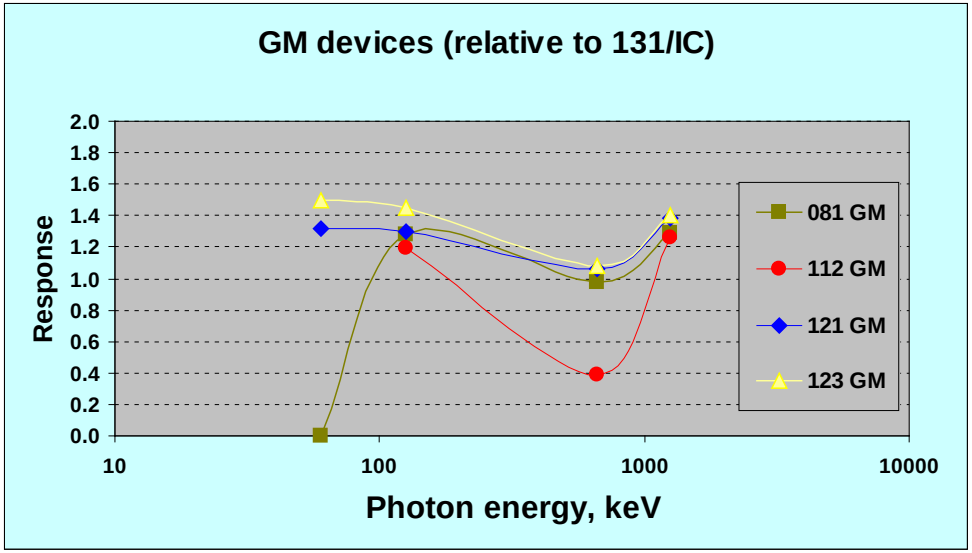
84.0±5.9 nSv/h (7%)
84.5±5.0 nSv/h (6%)
85.7±6.6 nSv/h (8%)
85.5±6.1 nSv/h (7%)

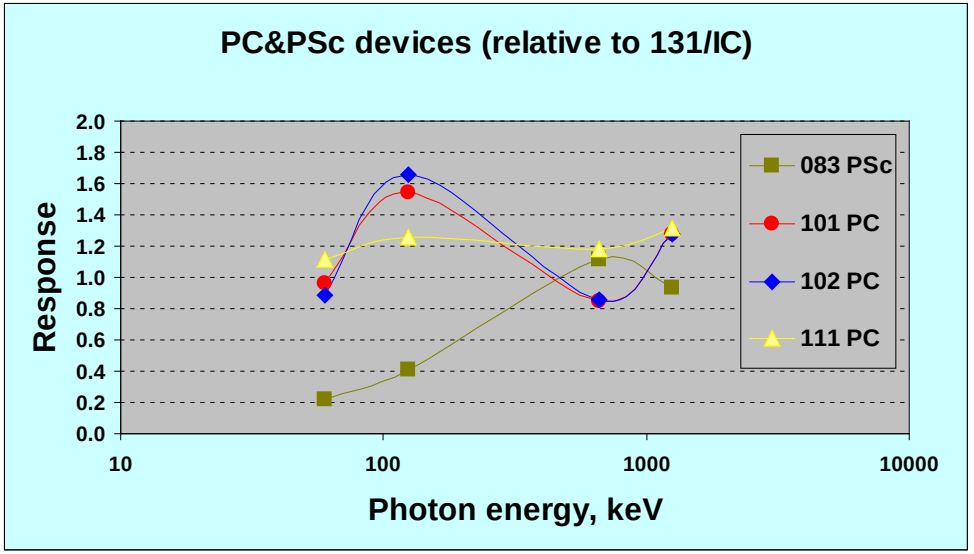


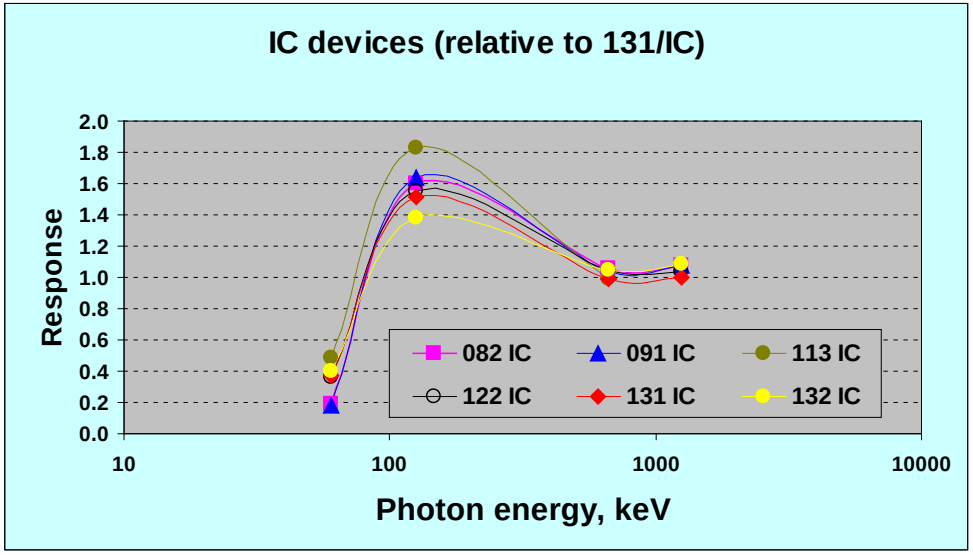
Co60: 520±48 nSv/h (9%)
Ra 226: 496±35 nSv/h (7%)
Cs137: 433±13 nSv/h (3%)

H*(10) Photon energy response

NOTE: Experimental inherent background has been substracted







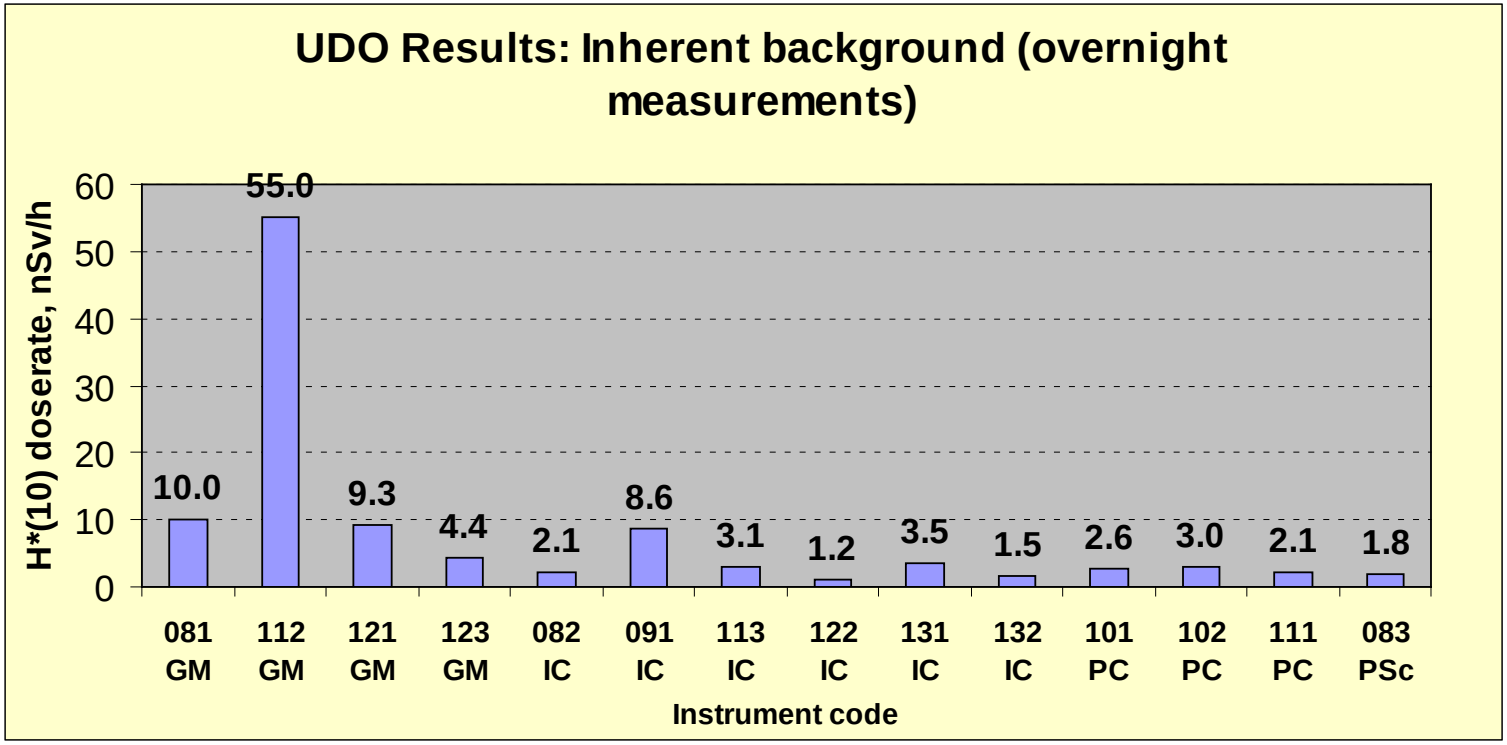
- **Important over-response figures for GM and PC when dealing with ^{60}Co and ^{226}Ra**
- **Slight but consistent differences have been encountered for Reuter-Stokes HPIC**

PTB UDO Ultra-low facility

- Located 925 m depth in the Asse Salt Mine (Germany)
- Rock Salt Activity (Bq/kg): 2-4 (^{40}K), <0.1 (^{238}U), <0.01 (^{232}Th)
- H*(10) doserate: ≈ 1 nSv/h
- Excellent room conditions and irradiation facilities (collimated beams)

Collimated beams exposures and Inherent background measurements at UDO PTB

- ^{241}Am, ^{57}Co, ^{137}Cs, ^{226}Ra and ^{60}Co encapsulated sources (60-1300 keV)
- Reference distance: 2 m
- Kair rates: 30-130 nGy/h
- Inherent background was obtained after overnight exposure without any radioactive source.



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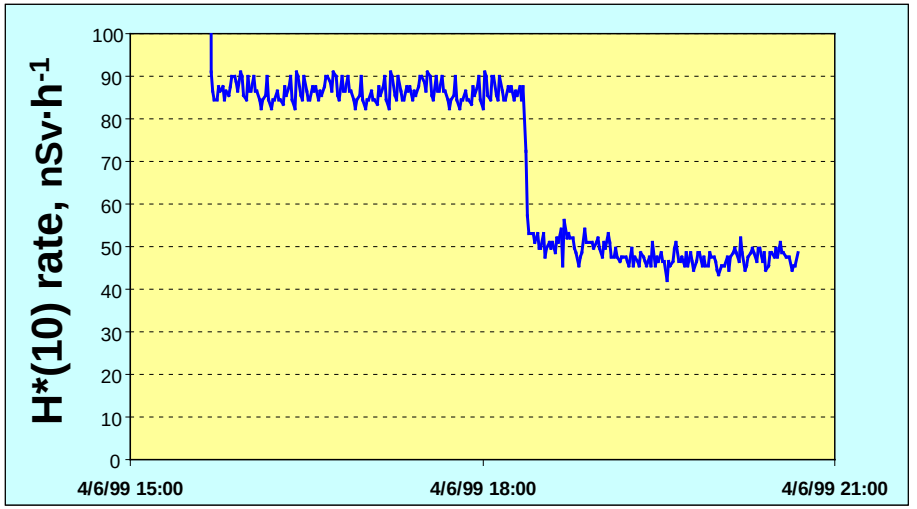
Measurement of the cosmic radiation



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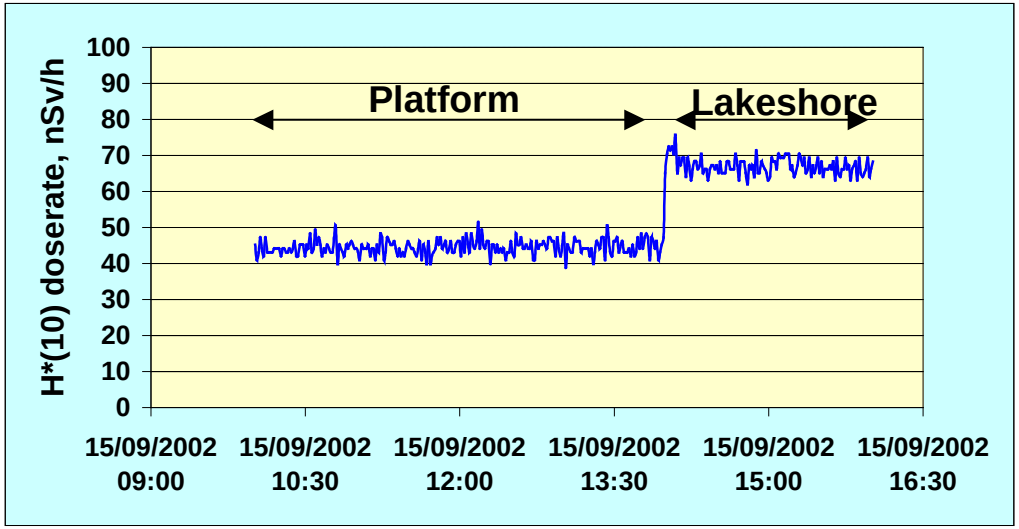
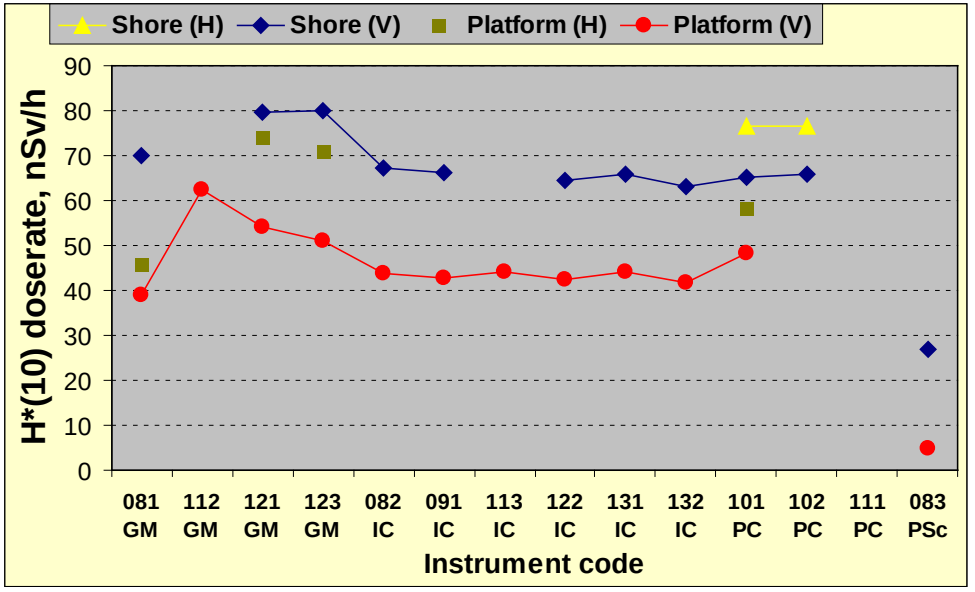
Cosmic&Terrestrial components (1/2)





Cosmic&Terrestrial components (2/2)

Reference levels for cosmic & terrestrial

•Muon doserate at PTB-Braunschweig (PTB coincidence PC instrument):

34 nSv/h

• Soft cosmic component (e^-, photons) is 30-40% of muon contribution (fluence):

10-13 nSv/h

totalising

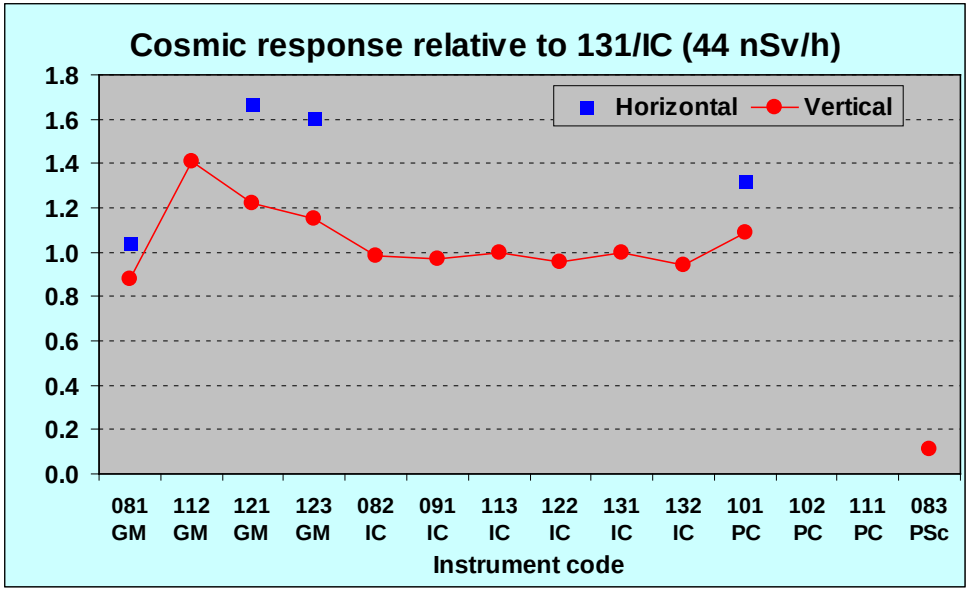
44-47 nSv/h

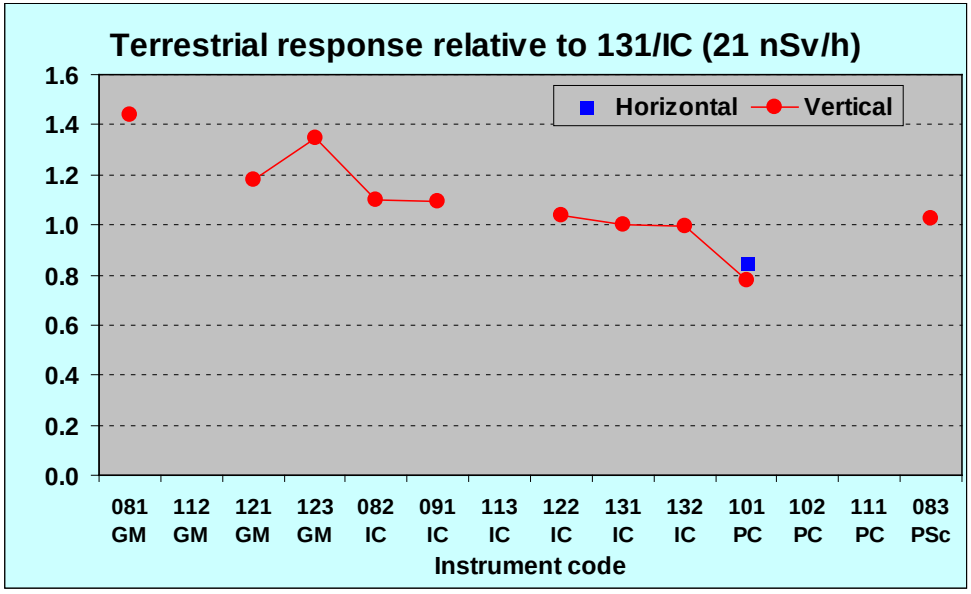
• Doserate at the platform from the Reference instrument 131/IC:

44 nSv/h

• Reference level for terrestrial component (by difference Lakeshore-Platform):

21 nSv/h





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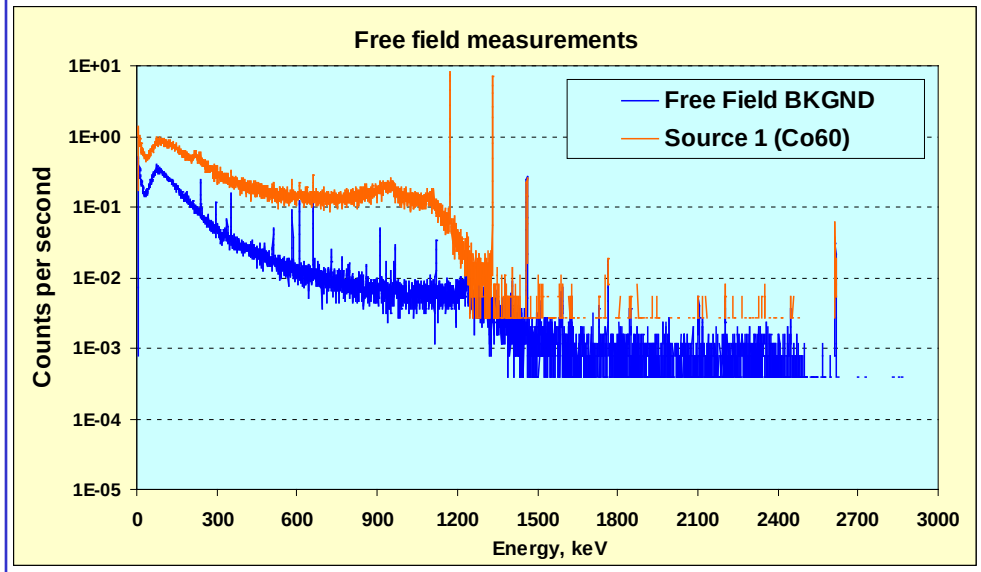
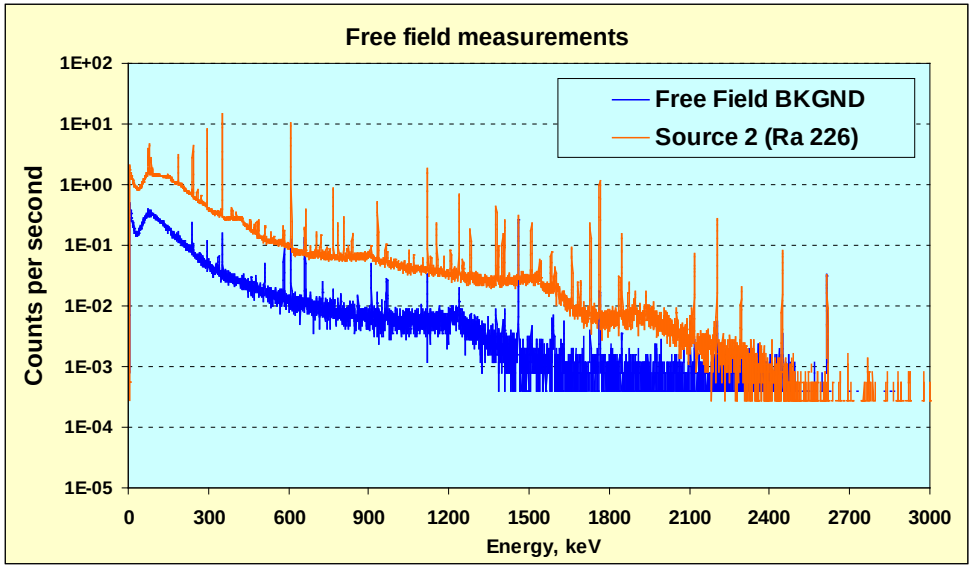
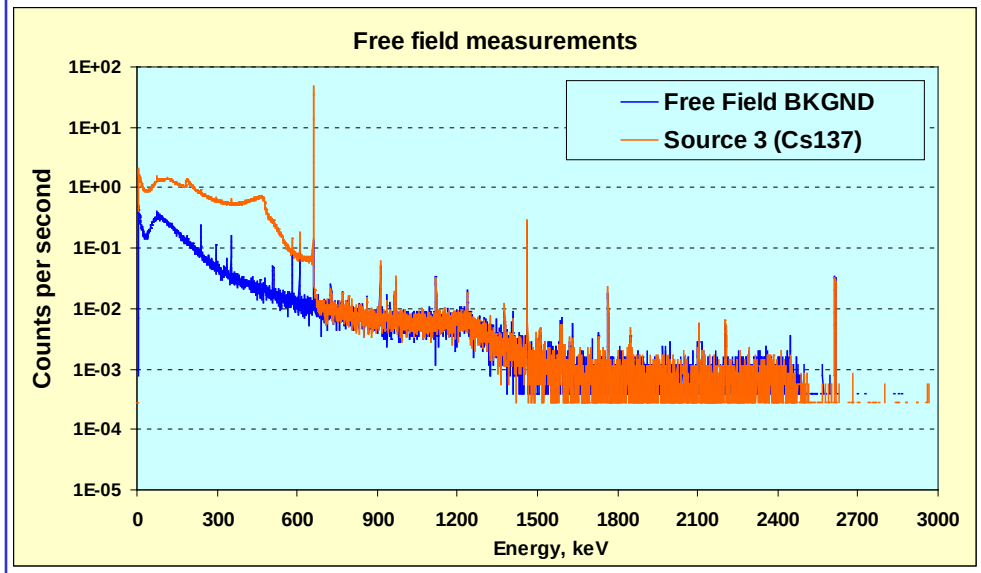
In situ Gamma Spectrometry







Reference levels for spectrometers

- Estimate of point source activity: Nominal source activity
- Other field measurements (no sources): Homogeneous nuclide distribution, Semi-infinite half space
- Air kerma rate from the direct beam (scattered radiation is not included)
- Values based on reference instrument (131/IC) measurements

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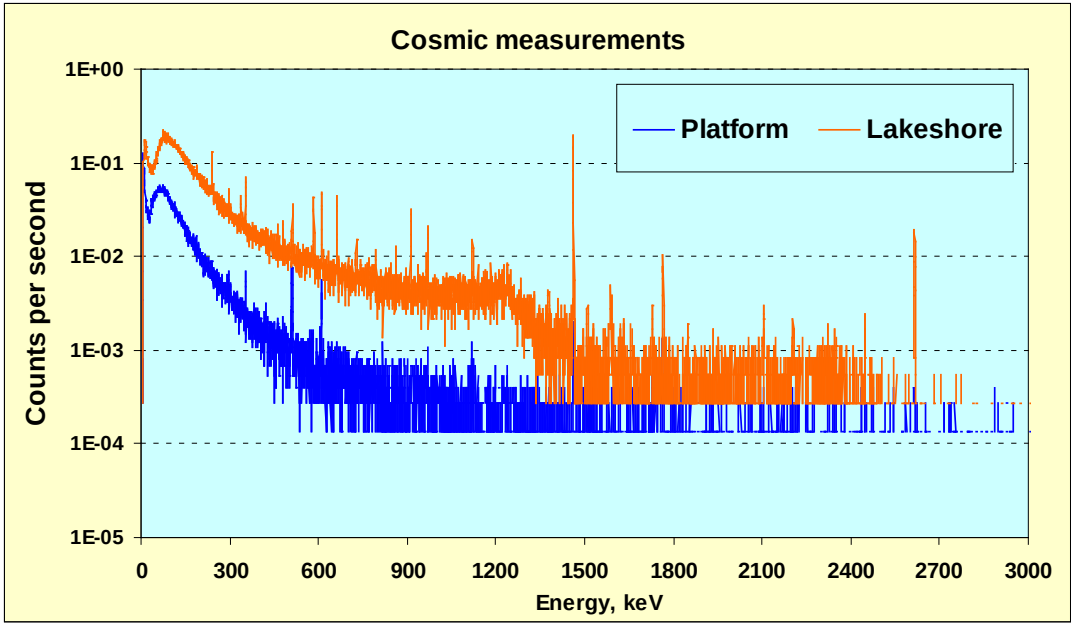
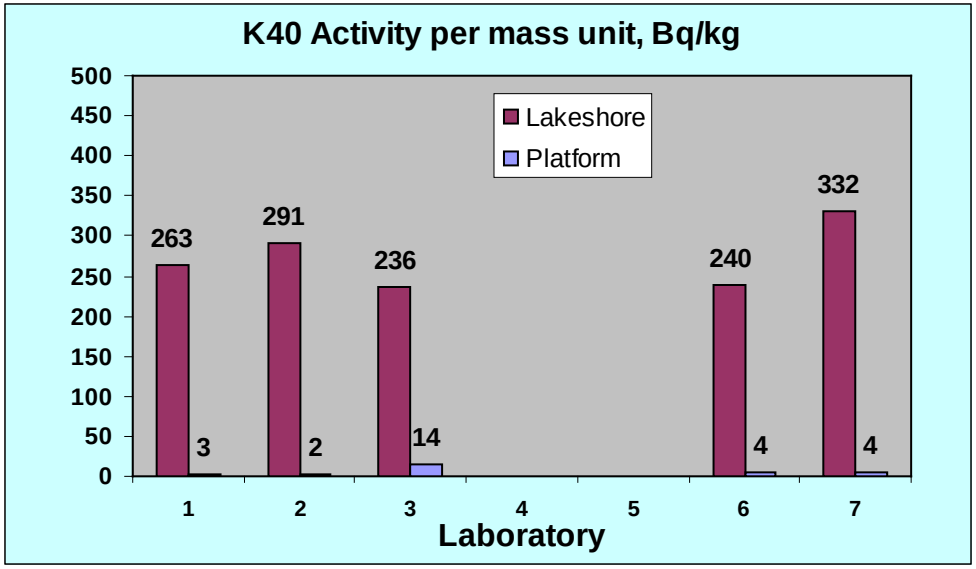
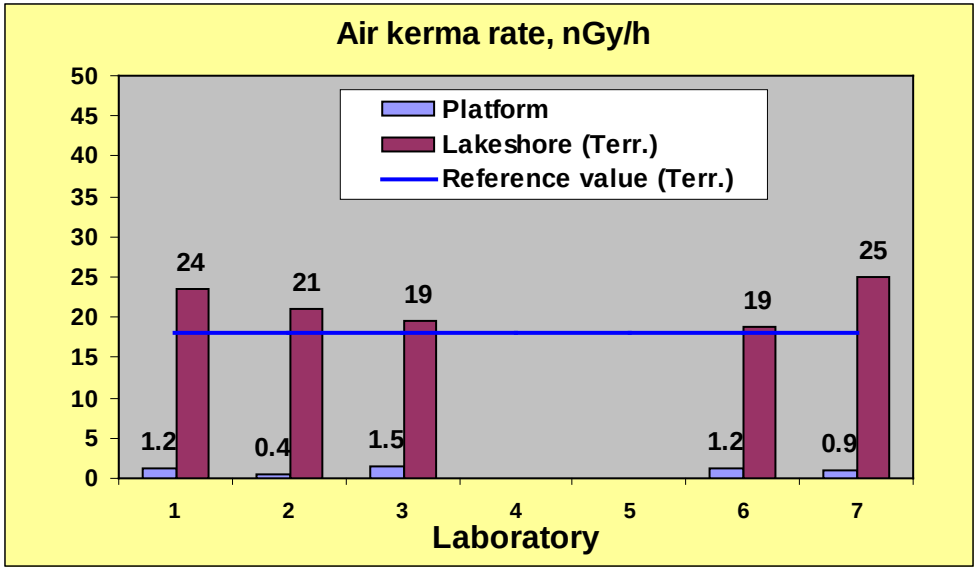
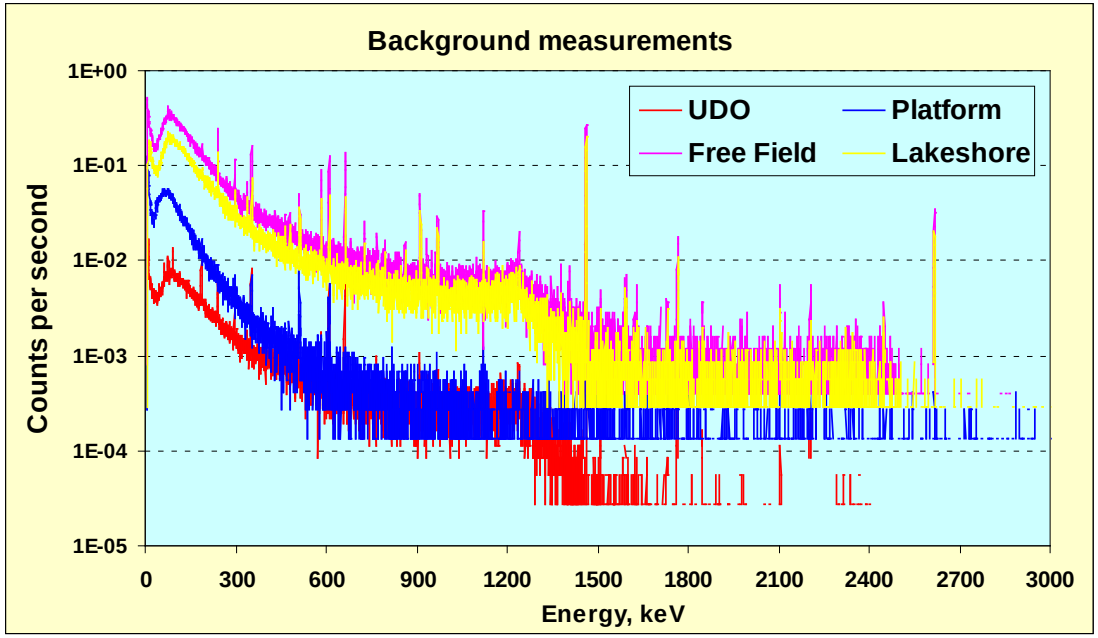
In situ gamma spectrometry

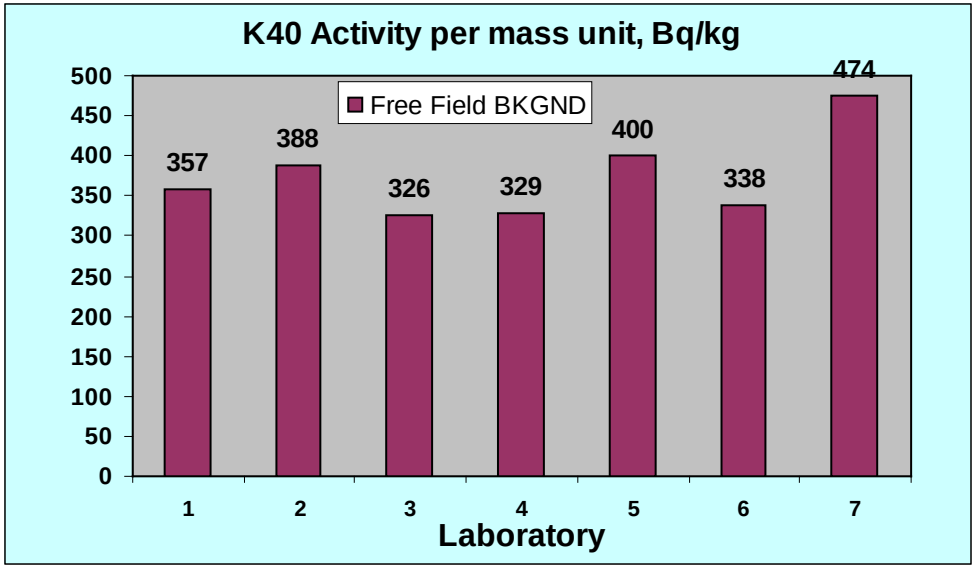


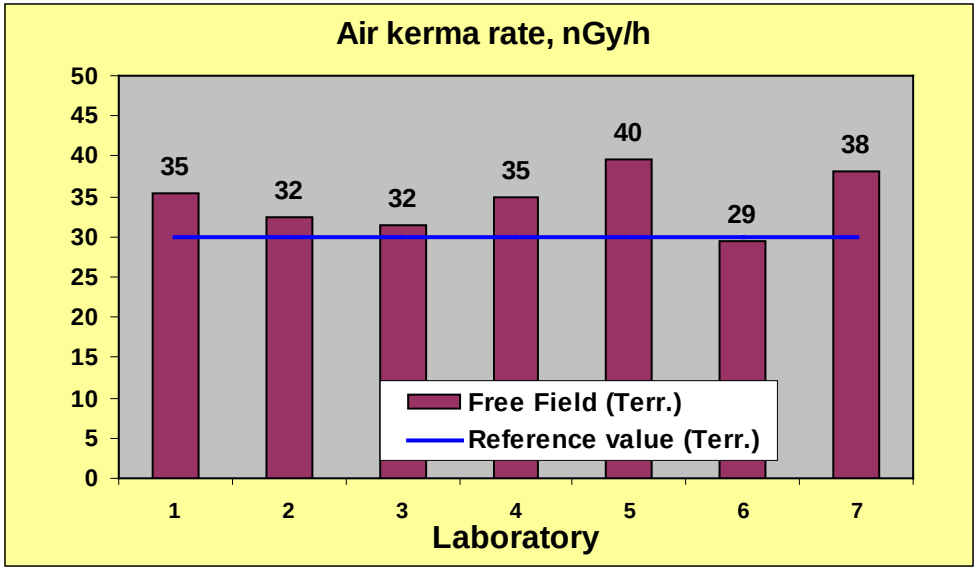




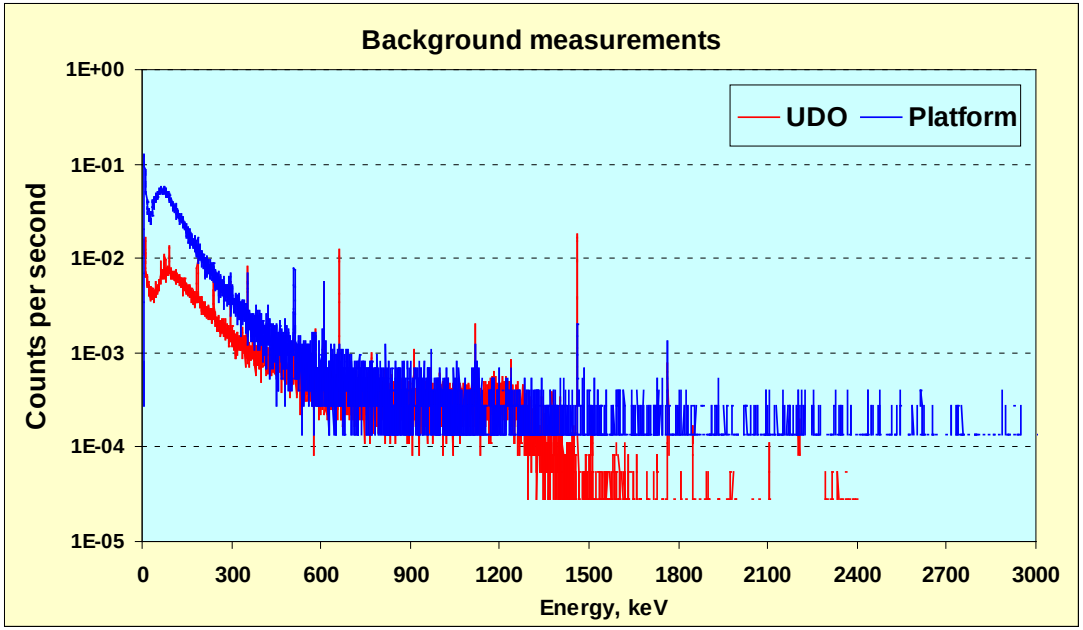
In situ gamma spectrometry

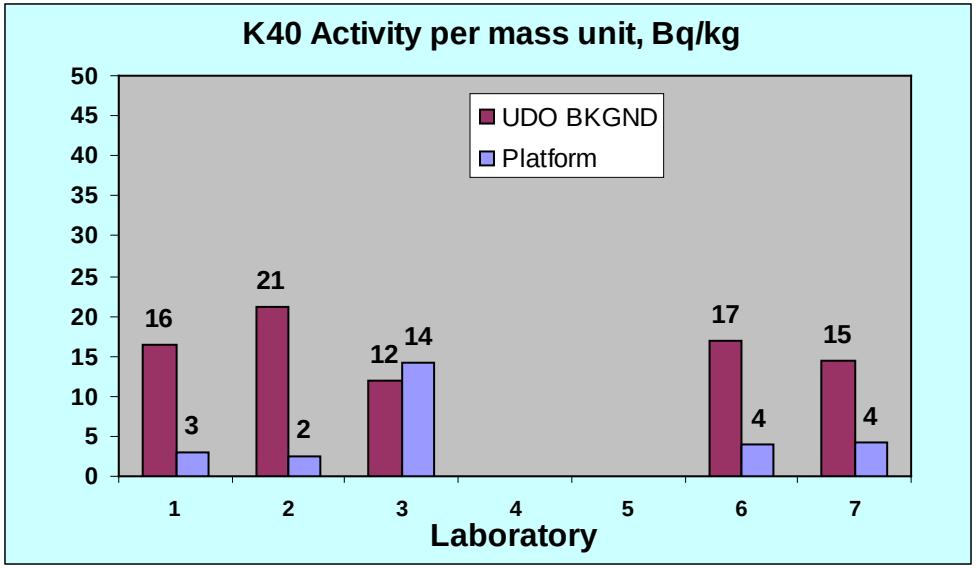


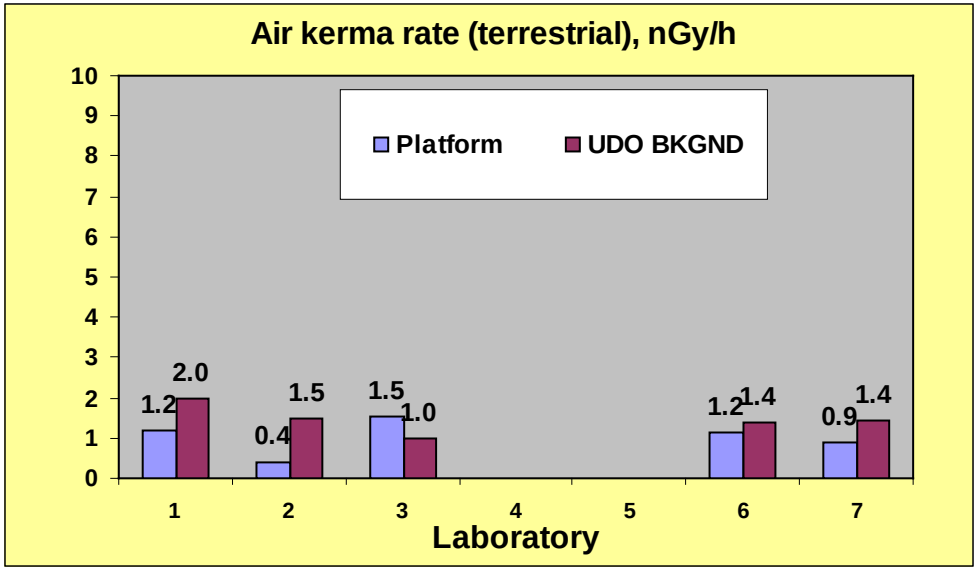




In situ gamma spectrometry







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CONCLUSION

Dose Rate = f(Signal, Quantity, Calibration, BKGND, Cosmic, Photon Energy, Angular, others)

You should read the indications of your dose rate monitor and then apply the corresponding corection factors according to the field conditions.

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Realistic calibration fields for environmental Dose rates and in situ gamma spectrometry

Wismuth GMBH, Gera, Germany

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Cosmic & Terrestrial Studies in … Santander!

Resultados GENIE-2000/ISOCS ordenados por series

	Santander CMT Bq/kg	Santander Bahía Bq/kg	Aguilar Orilla Bq/kg	Aguilar Lago Bq/kg
Th-234	<AMD	<AMD	<AMD	<AMD
Pa-234m	<AMD	<AMD	<AMD	<AMD
Ra-226	79.3 ± 14.8	19.5 ± 5.5	28.9 ± 15.7	17.0 ± 8.4
Pb-214	34.1 ± 1.0	4.1 ± 0.4	21.1 ± 1.0	7.3 ± 0.5
Bi-214	37.1 ± 0.8	3.3 ± 0.2	22.8 ± 0.9	6.2 ± 0.5
Pb-210	<AMD	<AMD	<AMD	<AMD
Ac-228	34.0 ± 1.0	<AMD	17.4 ± 0.9	3.8 ± 0.4
Pb-212	31.7 ± 0.9	1.8 ± 0.4	17.1 ± 0.7	7.7 ± 0.6
Bi-212	31.3 ± 4.3	1.3 ± 1.2	22.2 ± 4.3	<AMD
Tl-208	13.3 ± 0.3	0.7 ± 0.1	6.9 ± 0.4	1.0 ± 0.1
K-40	391.7 ± 9.7	28.8 ± 1.6	383.4 ± 9.8	14.1 ± 1.6
Cs-137	0.4 ± 0.3	0.0 ± 0.0	8.8 ± 0.5	0.0 ± 0.0

Resumen de tasa de kerma en aire

	Santander CMT 43° 29' N, 3° 48W 58 m nGy/h	Santander Bahía 43° 29' N, 3° 48W 0 m nGy/h	Aguilar Orilla 42° 47' N, 4° 2' W 970 m nGy/h	Aguilar Lago 42° 47' N, 4° 2' W 970 m nGy/h
Serie U-238	16.8 ± 0.4	1.6 ± 0.1	10.3 ± 0.4	2.9 ± 0.2
Serie Th-232	13.6 ± 0.5	0.3 ± 0.1	7.2 ± 0.5	1.4 ± 0.1
K-40	16.3 ± 0.4	1.2 ± 0.1	16.0 ± 0.4	0.6 ± 0.1
Cs-137	0.1 ± 0.1	0.0 ± 0.0	1.5 ± 0.1	0.0 ± 0.0
Terrestre SEGIS	46.8 ± 1.4	3.1 ± 0.3	34.9 ± 1.4	4.9 ± 0.4
Cósmica SEGIS	36.5 ± 2.8	37.1 ± 2.6	54.3 ± 3.6	55.4 ± 3.6
Cósmica CARI6	36.9	35.9	53.0	53.0
Total SEGIS	83.2 ± 3.1	40.2 ± 2.6	89.3 ± 3.8	60.2 ± 3.6
Total PIC	79.1 ± 0.9	40.1 ± 0.9	89.4 ± 0.9	52.8 ± 0.9
Cociente SEGIS/PIC	1.05 ± 0.05	1.00 ± 0.09	1.00 ± 0.05	1.14 ± 0.09

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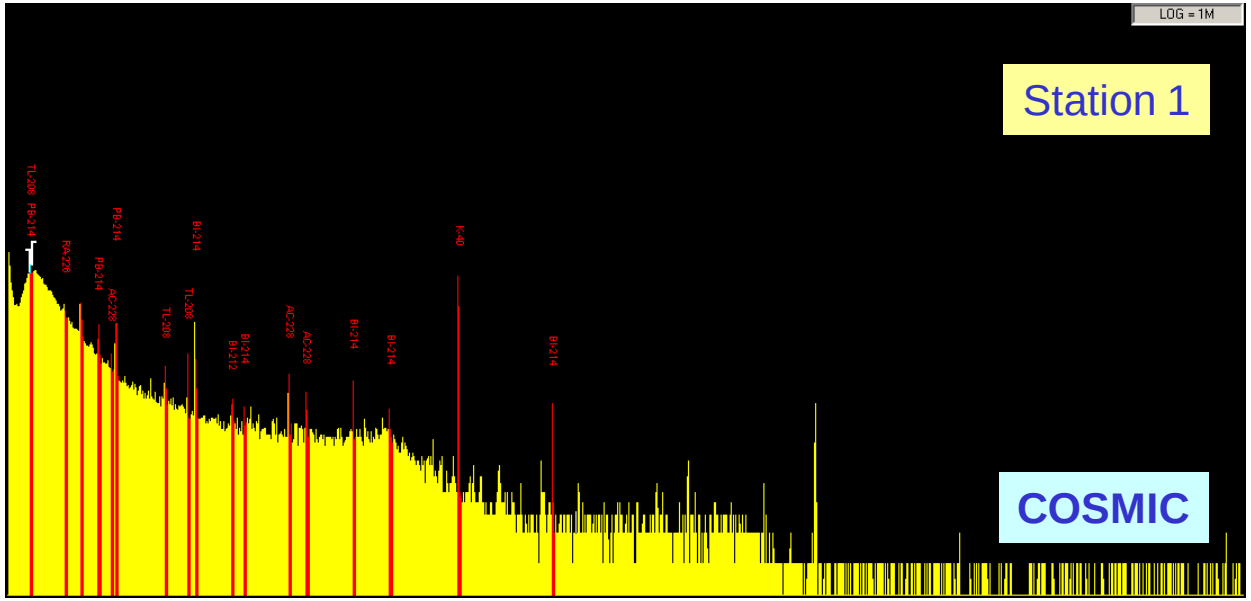

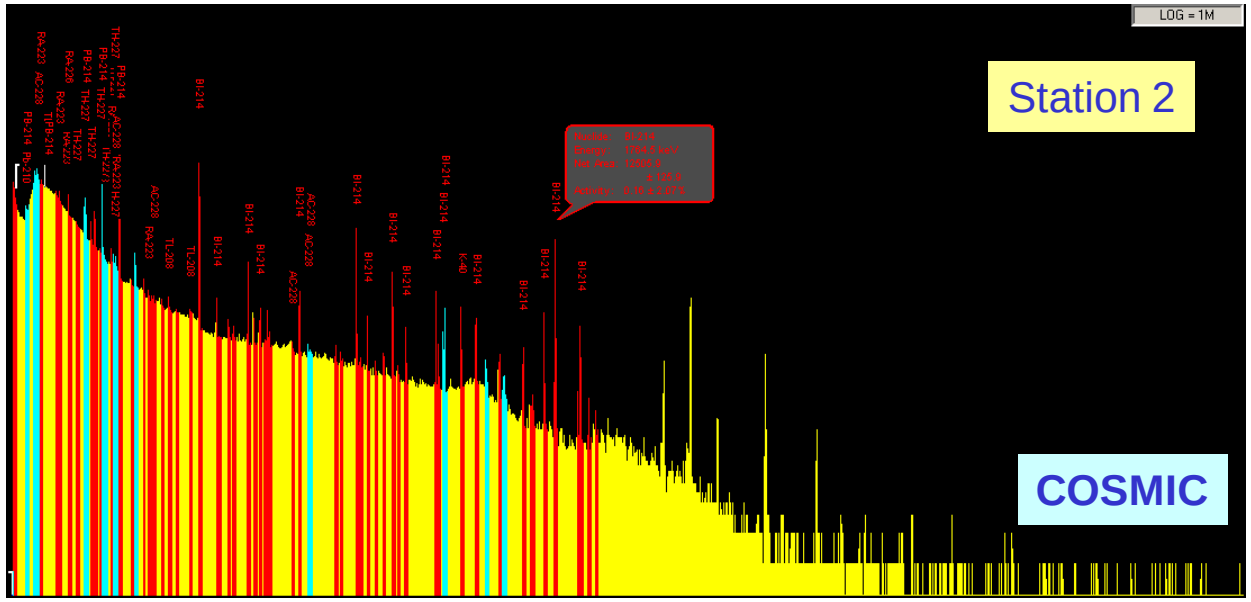

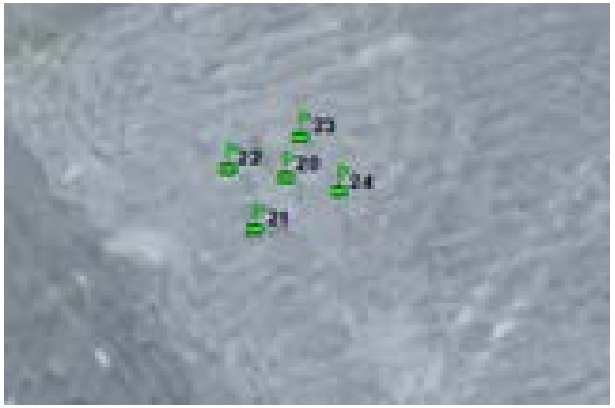

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	Station 1 Bq/kg			Point 17 Bq/kg			Station 2 Bq/kg		
K-40	750	-	1150	600	-	900	750	-	1200
Th-234	< AMD			250	-	350	< AMD		
Pa-234m	< AMD			6	-	7	< AMD		
Ra-226	< AMD			700	-	800	5500	-	7500
Pb-214	30	-	40	220	-	230	4500	-	5500
Bi-214	30	-	50	210	-	250	4000	-	6000
Pb-210	< AMD			< AMD			2500	-	9500
Ac-228	15	-	30	30	-	40	40	-	80
Pb-212	15	-	20	30	-	40	50	-	100
Bi-212	25	-	30	50	-	80	< AMD		
Tl-208	5	-	10	15	-	20	10	-	30
U-235	< AMD			< AMD			< AMD		
Th-227	< AMD			< AMD			1300	-	2300
Ra-223	< AMD			< AMD			1400	-	2300
Cs-137	< AMD			< AMD			< AMD		

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	Zona	Estación 1	Estación 1	Estación 1	Estación 1	Estación 1	Estación 1	Estación 1
	Punto de medida	1	2	4	6	8		17
	X -UTM, m	701704.7	701707.3	701708.5	701700.9	701700.8	Promedio	701696.1
	Y-UTM, m	4501191.2	4501196.1	4501187.0	4501186.5	4501195.6	Puntos 1,2,4,6,8	4501238.9
	Z, m (snm)	719.3	719.1	719.1	720.0	719.1		719.8
	Notas							
CIP	**Fecha de medida**	25/04/2011	25/04/2011	25/04/2011	25/04/2011	25/04/2011	25/04/2011	25/04/2011
RSS-112	**K_{aire}, nGy/h**	111 ± 4	112 ± 4	110 ± 5	110 ± 4	107 ± 4	110 ± 2	173 ± 5
RSS-131	**K_{aire}, nGy/h**	112 ± 4	113 ± 5	110 ± 4	111 ± 4	105 ± 4	110 ± 3	174 ± 5

	Zona	Estación 2	Estación 2	Estación 2	Estación 2	Estación 2	Estación 2
	Punto de medida	20	21	22	23	24	
	X -UTM, m	701541.8	701539.6	701537.7	701542.8	701545.6	Promedio
	Y-UTM, m	4502440.1	4502436.4	4502440.6	4502442.9	4502439.0	Puntos 20 a 24
	Z, m (snm)	719.2	719.5	720.1	720.0	719.3	
	Notas						
CIP	**Fecha de medida**	26/04/2011	26/04/2011	26/04/2011	26/04/2011	26/04/2011	26/04/2011
RSS-112	**K_{aire}, nGy/h**	1862 ± 12	1831 ± 15	2008 ± 17	1901 ± 12	1815 ± 28	1883 ± 69
RSS-131	**K_{aire}, nGy/h**	1803 ± 66	1785 ± 67	2005 ± 31	1908 ± 30	1798 ± 68	1860 ± 85

Station 1 (Points 1 a 9): 0.110 ± 0.005 µGy/h (k=2)
Point 17: 0.173 ± 0.005 µGy/h (k=2)
Station 2 (Pointss 20 a 24): 1.80 ± 0.05 µGy/h (k=2)

2011 Intercomparison at Saelices el Chico

- In each station, please measure as many points as you can WITHIN the signals.

- 1.00 m high are indicated in some points.

- Results should be given in terms of air kerma. Conversion factors are given below.

- You should send a form per instrument, filled with all the requested information. PLEASE DON'T FORGET TO EXPRESS YOUR UNCERTAINTY.

Nuclide (Mean Photon Energy)	$H^*(10)/K_{air}$ Sv/Gy	H*(10)/X nSv/μR	K_{air}/X nGy/μR
^{241}Am (59.5 keV)	1.740	15.250	8.764
^{57}Co (122 keV)	1.447	12.683	8.764
^{137}Cs (661 keV)	1.200	10.517	8.764
^{226}Ra (840 keV)	1.179	10.336	8.764
^{60}Co (1.25 MeV)	1.160	10.166	8.764

2011 Intercomparison at Saelices el Chico

INTERNATIONAL INTERCOMPARISON EXERCISE ON NATURAL RADIATION MEASUREMENTS UNDER FIELD CONDITIONS

Saelices el Chico (Salamanca), Spain May 23-27, 2011

External Gamma Radiation Exercise

Participant ID:

INSTRUMENT DESCRIPTION:
Instrument Model: Manufacturer:
Detector Type: Ion Chamber, GM, Proportional Counter, Scintillator, other (please specify)

CALIBRATION (according to an existing calibration certificate from a metrological laboratory or from the manufacturer)
Quantity: Exposure (X), Air Kerma (Kair), Air Absorbed Dose (Dair), Ambient Dose Equivalent H*(10), Photon Dose Equivalent Hx(10), other (please specify):
Nuclide and Photon Energy: Cs-137, Co-60, Ra-226, other (please specify)

If necessary, please provide the conversion factors from instrument readings to Air Kerma rate at 661 keV photons (Cs-137) in nGy/h:

	INSTRUMENT READINGS			*AIR KERMA RATE, nGy/h*	
Point #	Value	Uncertainty (k=1)	Units	Value	Uncertainty (k=1)
1				0	0
2				0	0
4				0	0
6				0	0
8				0	0
17				0	0
20				0	0
21				0	0
22				0	0
23				0	0
24				0	0

Other comments from the participant:

Date:

Signature: