INTERNATIONAL MEETING ON AIRBORNE GAMMA-RAY SPECTROMETRIC SOFTWARE

21 -22 May 2019 , Prague, Czech Republic

SÚRO Státní ústav radiační ochrany, v. v. i.
National Radiation Protection Institute

NUVIA CZ

SPECTRONICA

Marcel Ohera
Lukáš Skála
Anna Selivanova
Lukáš Kotík
Pavel Jurza

BASIC PRINCIPALS OF AGAMA AIRBORNE SOFTWARE

Reasons for develeping new program for airborne survey

- **Results coming from our IRIS not satisfactory. Producer is not willing to make any changes**
- **PRAGA4 used for post-processing developed in old-fashion environment and is not user-friendly**
- **Many separate software packages (project preparation, data post-processing, browsing, data converter, etc.)**
- **Other detectors are used for airborne measurements (mainly HPGe detectors and plastic detectors)**

Project Name:

Recovery Management Strategy for Affected Areas after Radiation Emergency

Period:
2017 – 2020

Responsible authority: ***National Radiation Protection Institute (SÚRO), CZ***
Co-operation: *Nuvia CZ, a.s., software development*
Spectronica, Australia , software development

PRAGA 4

post processing software for NaI(Tl) detectors

PRAGA 4 capabilities:

- Originally designed for geophysics
- LSQ – Least square method using Monte Carlo code (for 11 radionuclides, i.e. K, U, Th,Cs-137, Cs-134, Co-60, Ru-103, Mo-99,I-131, Ar-41 and Kr-88)
- Standard window (ROI) method based on processing IAEA standards (K, U, Th)
- Dose rate in nGy/h from power spectrum, dose rate from K, U a Th windows and from TC (used in geophysics 410 - 2800 keV)
- NASVD/MNF (methods for noise removal in spectra)
- Radon removal

AGAMA - NEW

post processing software for NaI(Tl) detectors

Project 2017-2020

AGAMA new capabilities:

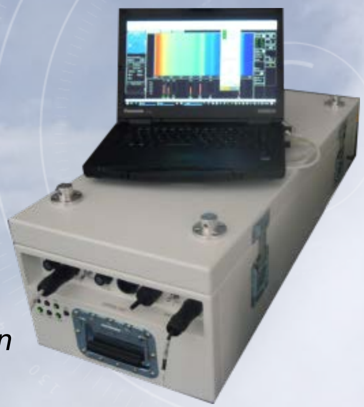
- Designed for emergency monitoring
- LSQ – Least square method using Monte Carlo code (for K, U, Th, Cs-137, Cs-134, Ru-103, I-131 – non-negative values)
- Extended window (ROI) method based on processing IAEA standards (K, U, Th, Cs-137)
- Dose rate in nGy/h from power spectrum, recalculated to 1m above the ground plus dose rate from activities (+ TC from PRAGA4)
- Cosmic dose rate calculation (depending on altitude above sea level)
- MDA calculation–Currie and ISO IEC 11929-2010
- Project preparation and data displayed in open free maps (replacing PEIConvert)
- Data browsing and quick data processing (replacing PEIDataViewer)
- Input /output data formats – PEI binary, ASCII, ERS 2.0 ANSI N.42 , KLM/KLZ output

Future software development

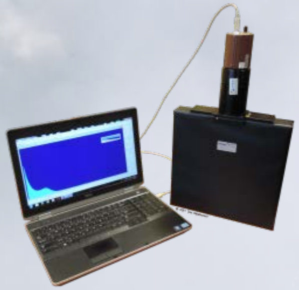
AGAMA software package

- *Other NaI(Tl) non-standard volumes, NASVD/(MNF) methods, radon removal*
- **HPGe – separate software package** - ready as separate package

Man – made nuclide activities calculation on ground using MCNP simulation, dose rate on ground calculation



- **Plastic detectors** - ready as separate package
- **UAV** – different detectors

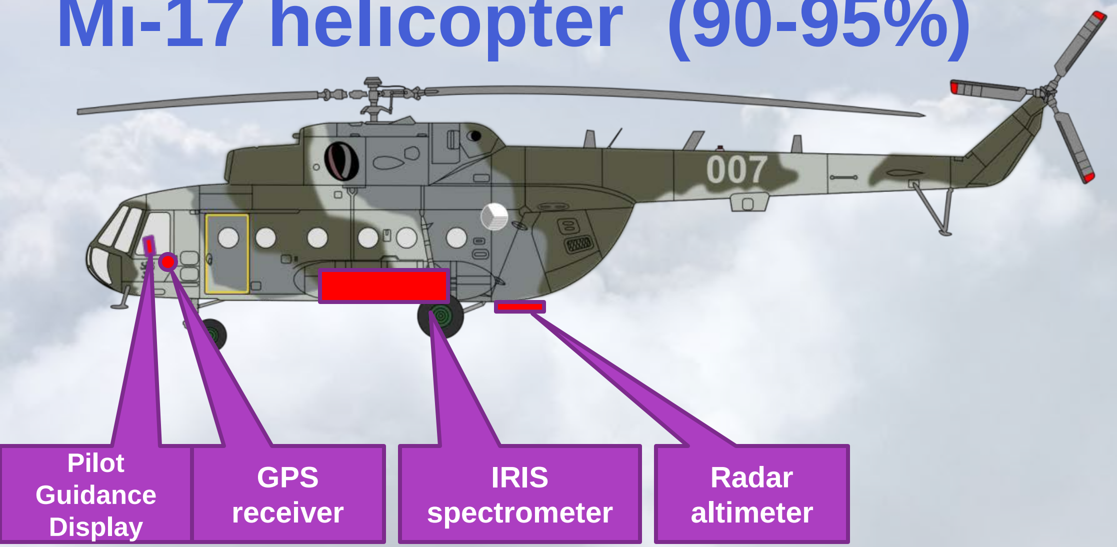


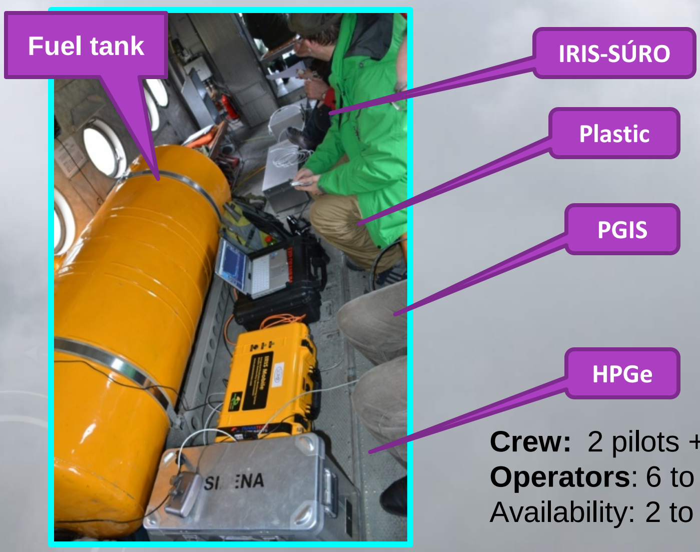
BASIC PRINCIPALS:

- Helicopter background and cosmics
- Extended Windows Methods (K, U, Th, Cs-137 activities, dose rates from activities)
- MCNP response matrixes for LSQ method + some EWM parameters
- Dose rates calculation from power spectrum
- LSQ method (including non-negative values) for natural radionuclides, Cs-137, Cs-134, Ru-103, I-131)
- Minimum detectable activities according to ISO-IEC 11929-2010

Helicopter background and cosmics

Mi-17 helicopter (90-95%)





Crew: 2 pilots + 1 navigator
Operators: 6 to 8 persons
Availability: 2 to 6 days per year

Bell 412 (5-10%)

Crew: 1 pilot + 1 navigator
Operators: 1 IRIS operator
Only IRIS system on board
Availability: Occasionally

Helicopter background and cosmics

Helicopter background and cosmic contribution important both for window and LSQ methods

- No sea
- Small water areas unsuitable
- Flights over larger water areas prohibited in CZ

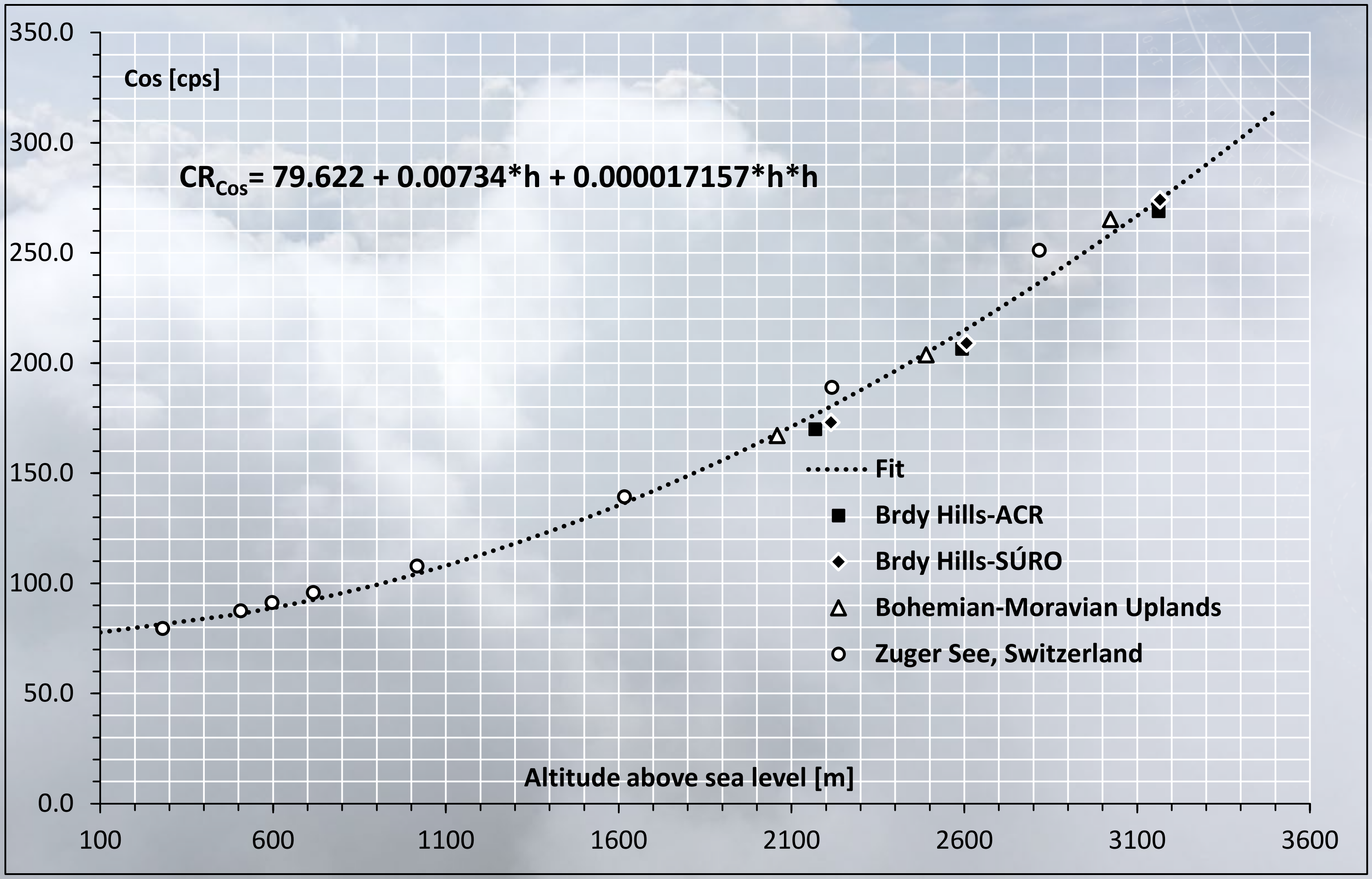
$$CR_{BKGD} = CR_{B,Heli} + S_c \times CR_{Cos}$$

where:
CR_{BKGD} is the combined cosmic and aircraft background in each spectral window,
$CR_{B,Heli}$ is the helicopter background in the window,
CR_{Cos} is the cosmic channel count,
and S_c is the cosmic stripping factor for the window

Location	GPS position	Water (ground) level above sea	Altitudes above sea level
Switzerland, Zugersee	47.1504803N, 8.4833119E	417 m (water); Zugersee	507, 597, 717, 1017, 1617, 2217 and 2817m
CZ-Bohemian-Moravian Uplands	49.430764N, 16.055372E 49.432796N, 15.899040E 49.449088N, 15.773195E	approx. 600 m (ground)	2059m 2490m 3023m
CZ-Brdy	49.597313N, 13.606682E 49.581171N, 13.420710E 49.564342N, 13.183049E	approx. 450-500m (ground)	2215m 2607m 3167m

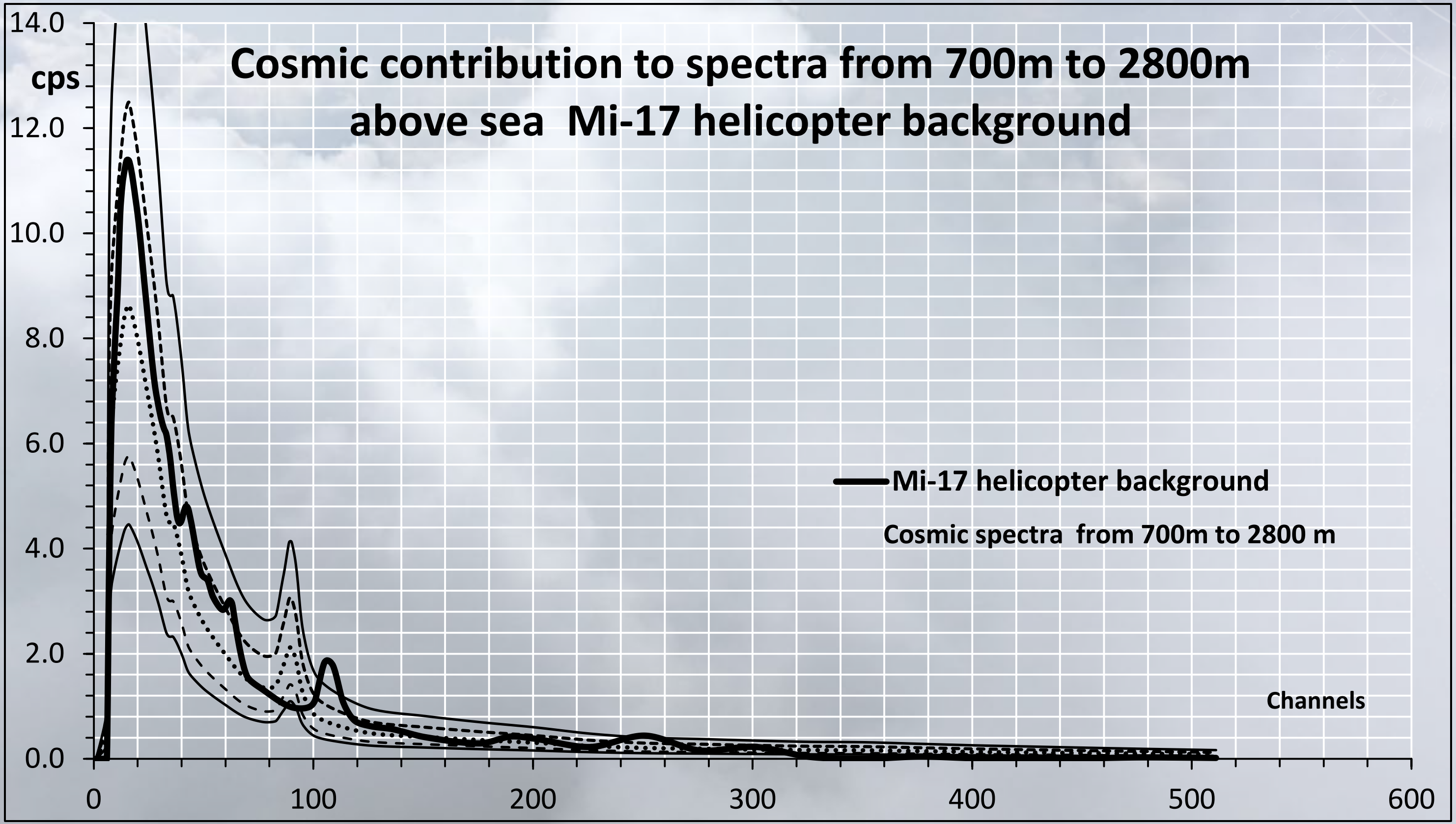
Helicopter background and cosmics

$CR_{BKGD} = CR_{B,Heli} + S_c \times CR_{Cos}$

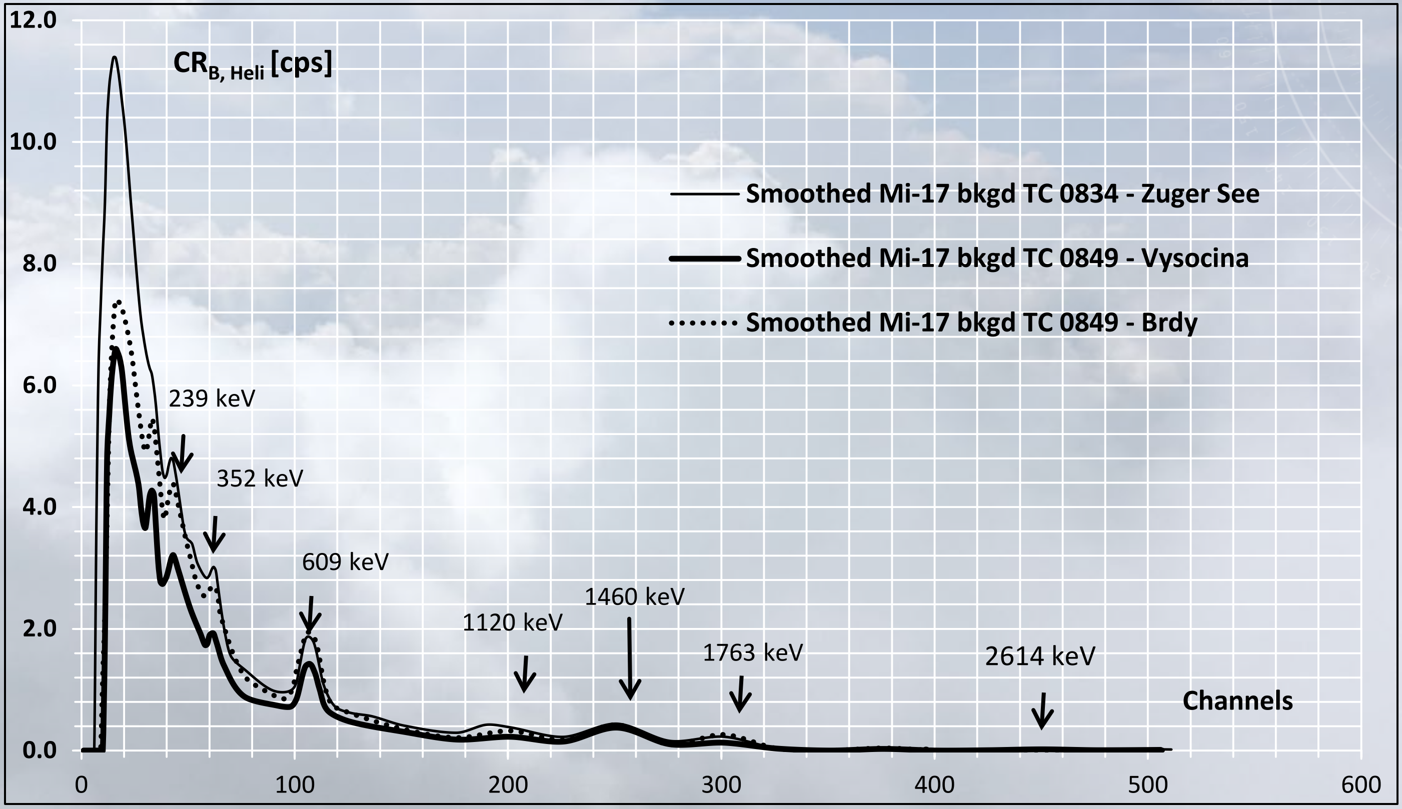


Helicopter background and cosmics

$$CR_{BKGD} = CR_{B,Heli} + S_c \times CR_{Cos}$$



Helicopter background and cosmics



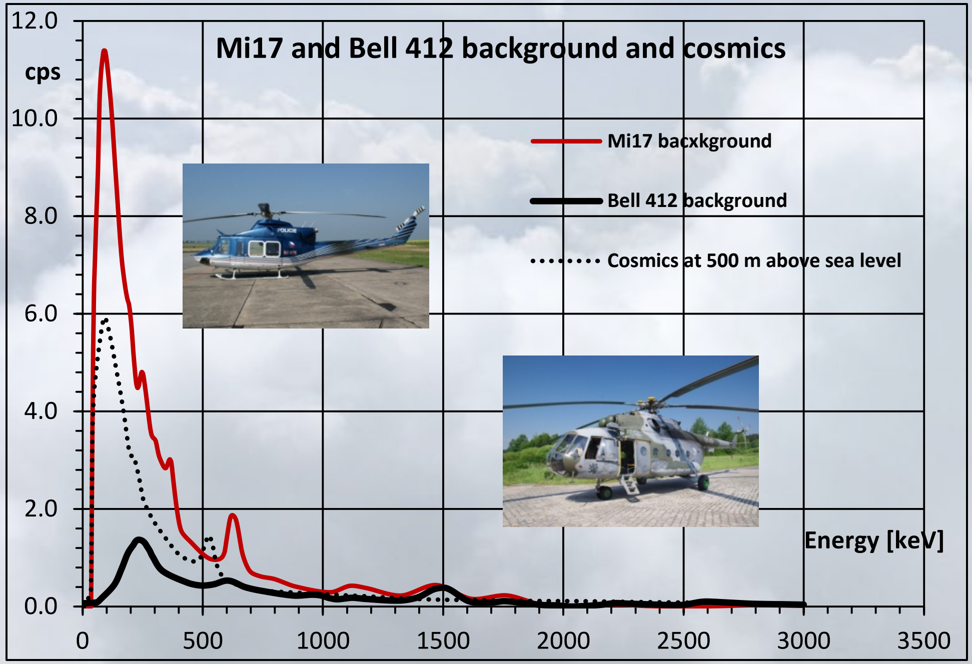
$$CR_{BKGD} = CR_{B,Heli} + S_c \times CR_{Cos}$$

Nuclide	Windows	S_c			
			ZugerSee	**Vysočina**	Brdy
Cs-137$_{(IAEA)}$	105-120		0.0805	0.0805	0.0805
Cs-137$_{(PEI)}$	98-130		0.1775	0.1775	0.1775
K	232-267		0.0631	0.0631	0.0631
U	283-317		0.0534	0.0534	0.0534
Th	411-480		0.0664	0.0664	0.0664

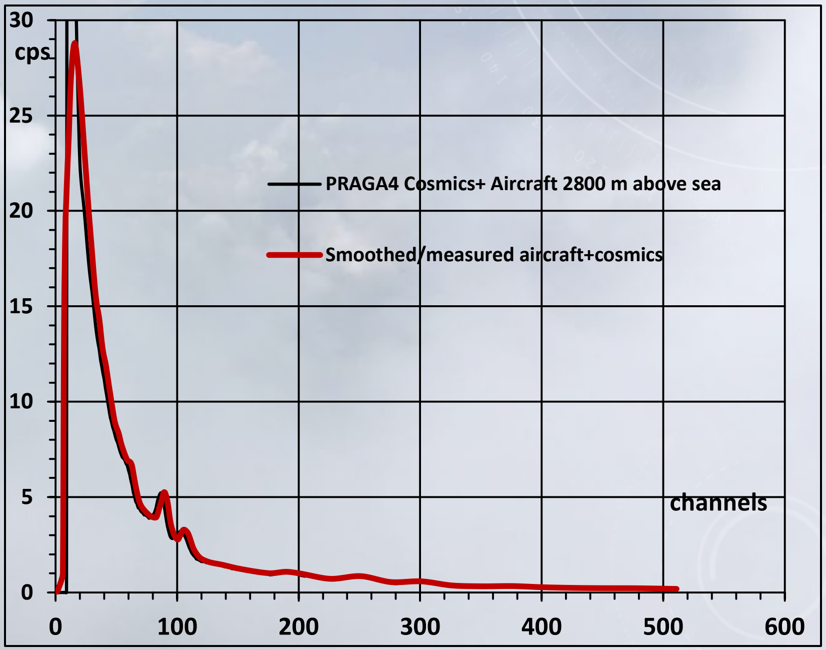
Nuclide	Windows	**$CR_{B,Heli}$**			
			ZugerSee	**Vysočina**	Brdy
Cs-137$_{(IAEA)}$	105-120		20.6	15.4	21.4
Cs-137$_{(PEI)}$	98-130		35.6	26.8	37.0
K	232-267		12.8	10.7	11.8
U	283-317		6.6	3.8	7.1
Th	411-480		0.7	0.7	0.1

Helicopter background and cosmics

Mi-17 and Bell 412 helicopter bkgd spectra

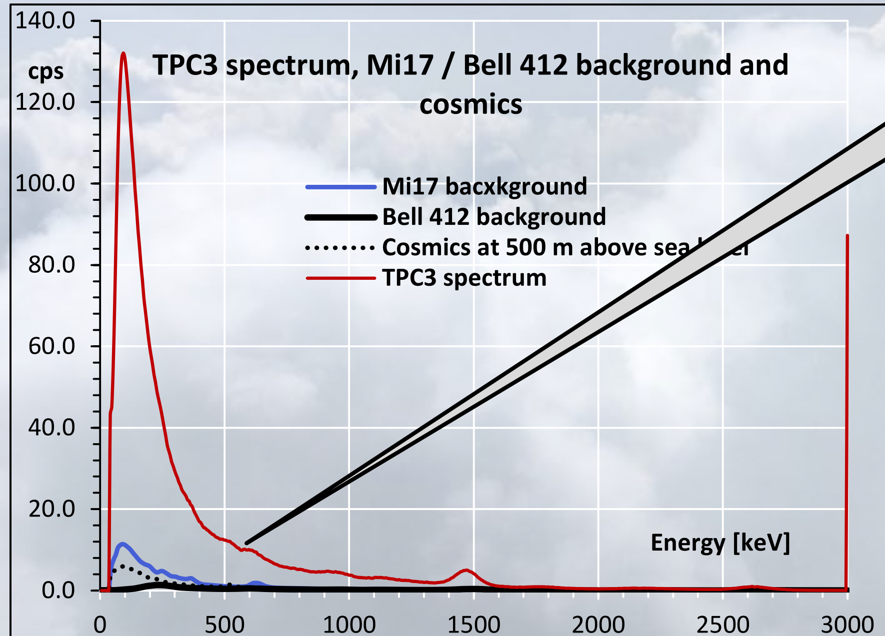


PRAGA4 bkgd model versus data measured



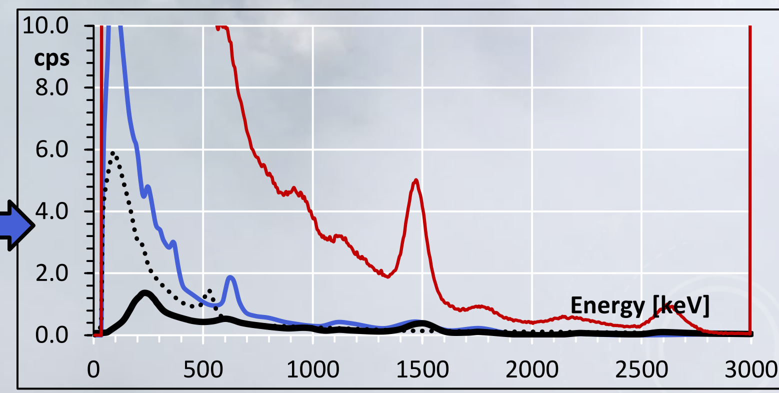
Helicopter background and cosmics

Spectrum plus helicopter bkgd/cosmics



K 599 Bq/kg
U 39 Bq/kg
Th 43 Bq/kg
Cs137 < MDA

Mi-17 helicopter bkgd ~ 9 to 12%
Cosmics ~ 3 to 5 %

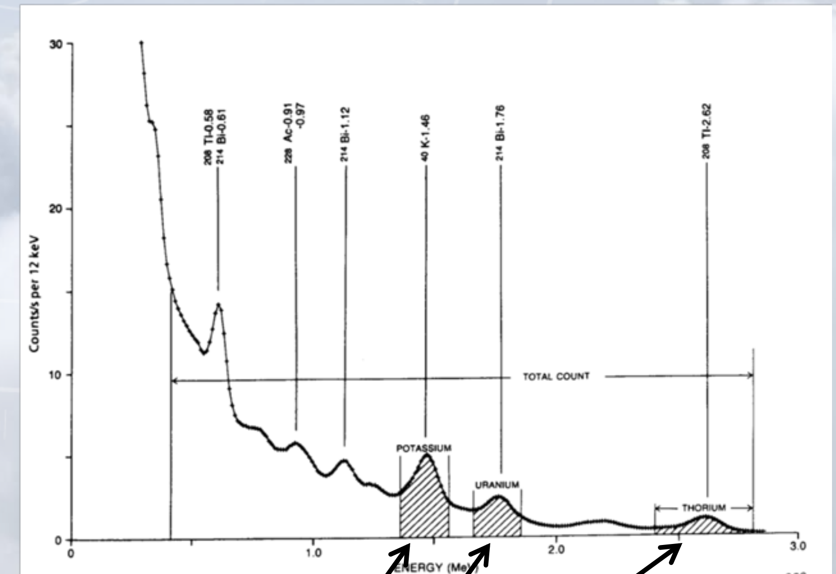


The background spectra were used in:

- Extended windows method (background in windows ^{137}Cs, ^{40}K, ^{214}Bi and ^{208}Tl)
- Air dose rate claculation at 1m above ground from power spectrum
- Background file in LSQ and NN-LSQ method

Extended window method

What is needed for standard windows methods



Airborne:

Total cps: n_K, n_U, n_{Th}

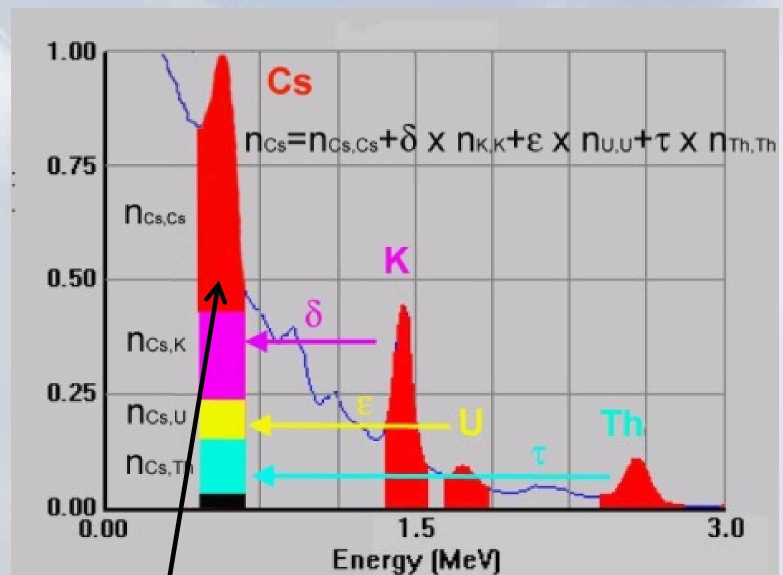
Stripping factors: $\boldsymbol{\alpha}$, $\boldsymbol{\beta}$, $\boldsymbol{\gamma}$, a

Stripping increase per 1m: $\boldsymbol{\Delta\alpha}$, $\boldsymbol{\Delta\beta}$, $\boldsymbol{\Delta\gamma}$, $\boldsymbol{\Delta}$a

Reference altitude to ground correction: ~ exponential

Sensitivities for reference altitude: $A_{K,K}$, $A_{U,U}$, $A_{Th,Th}$

What is needed for extended windows methods



Airborne:

Total cps: n_{Cs}, n_K, n_U, n_{Th}

Stripping factors: $\boldsymbol{\alpha}$, $\boldsymbol{\beta}$, $\boldsymbol{\gamma}$, a, $\boldsymbol{\delta}$, $\boldsymbol{\varepsilon}$, $\boldsymbol{\tau}$ (b=g=d=e=t=0)

Stripping increase per 1m: $\boldsymbol{\Delta\alpha}$, $\boldsymbol{\Delta\beta}$, $\boldsymbol{\Delta\gamma}$, $\boldsymbol{\Delta}$a, $\boldsymbol{\Delta\delta}$, $\boldsymbol{\Delta\varepsilon}$, $\boldsymbol{\Delta\tau}$

Reference altitude to ground correction: ~ exponential

Sensitivities for reference altitude: $A_{Cs,Cs}$, $A_{K,K}$, $A_{U,U}$, $A_{Th,Th}$

Extended window method – Portable ground spectrometers

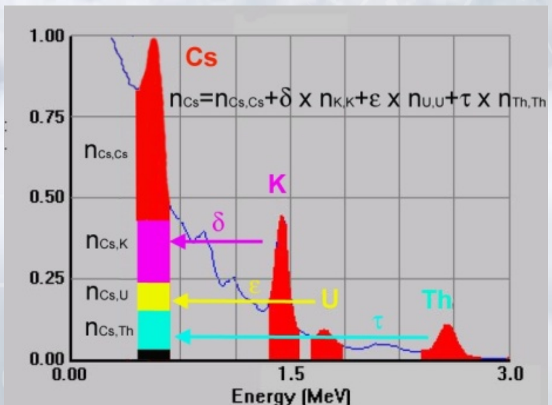
n_{ij} net count rate in ii-th window – background corrected,
c_{ij} activity concentration or surface activity – background corrected,
A_{ij} detection sensitivity

$$\begin{pmatrix} A_{CsCs} & A_{CsK} & A_{CsU} & A_{CsTh} \\ A_{KCs} & A_{KK} & A_{KU} & A_{KTh} \\ A_{UCs} & A_{UK} & A_{UU} & A_{UTh} \\ A_{ThCs} & A_{ThK} & A_{ThU} & A_{ThTh} \end{pmatrix} = \begin{pmatrix} n_{CsCs} & n_{CsK} & n_{CsU} & n_{CsTh} \\ n_{KCs} & n_{KK} & n_{KU} & n_{KTh} \\ n_{UCs} & n_{UK} & n_{UU} & n_{UTh} \\ n_{ThCs} & n_{ThK} & n_{ThU} & n_{ThTh} \end{pmatrix} \times \begin{pmatrix} c_{CsCs} & c_{CsK} & c_{CsU} & c_{CsTh} \\ c_{KCs} & c_{KK} & c_{KU} & c_{KTh} \\ c_{UCs} & c_{UK} & c_{UU} & c_{UTh} \\ c_{ThCs} & c_{ThK} & c_{ThU} & c_{ThTh} \end{pmatrix}^{-1}$$

IAEA rocommended energy windows

Nuclide	Energy [keV]	IAEA [keV]	PEI [keV]
^{137}Cs	662	618 -705	574 - 762
^{40}K	1460	1370 – 1570	1371 – 1571
^{214}Bi (uran)	1765	1660 – 1860	1664 – 1864
^{208}Tl (thorium)	2614	2410 - 2810	2414 -2801

Six new stripping factors



Standard windows method

Stripping factors α, β, γ, a, b = g = 0

Extended windows method

δ (K → Cs)
ε (U → Cs)
σ (Th → Cs)

d = e= t = 0

Final solution

$$n_{Th,Th} = \frac{n_{Th} - a \times n_U}{(1 - a \times \alpha)}$$

$$n_{U,U} = \frac{n_U - \alpha \times n_{Th}}{(1 - a \times \alpha)}$$

$$n_{K,K} = n_K - \gamma \times n_{U,U} - \beta \times n_{Th,Th}$$

$$n_{Cs,Cs} = n_{Cs} - \delta \times n_K - \varepsilon \times n_{U,U} - \tau \times n_{Th,Th}$$

Calibration pads

?

Solution of four equations with four unknown variables

$$n_{Css} = n_{Cs,Cs} + \delta \times n_{K,K} + \varepsilon \times n_{U,U} + \tau \times n_{Th,Th}$$

$$n_K = d \times n_{Cs,Cs} + n_{K,K} + \gamma \times n_{U,U} + \beta \times n_{Th,Th}$$

$$n_U = e \times n_{Cs,Cs} + g \times n_{K,K} + n_{U,U} + \alpha \times n_{Th,Th}$$

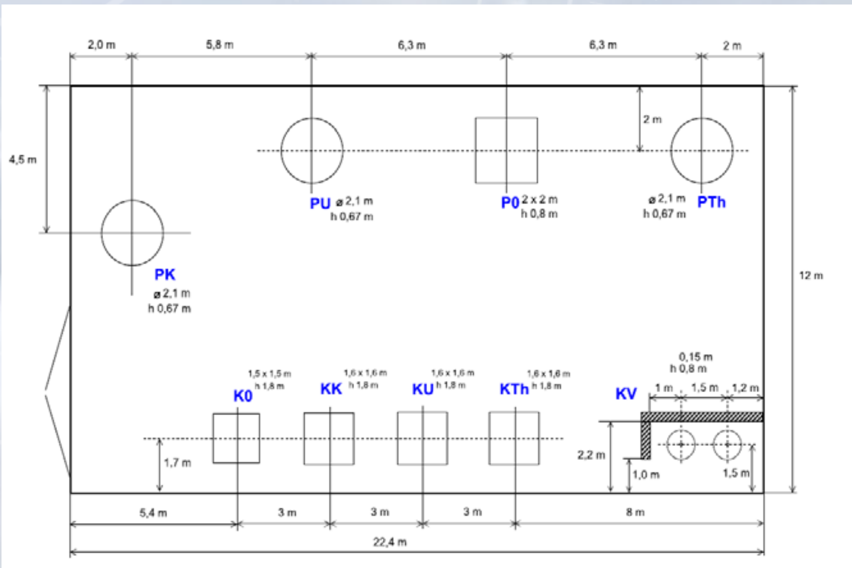
$$n_{Th} = t \times n_{Cs,Cs} + b \times n_{K,K} + a \times n_{U,U} + n_{Th,Th}$$

Extended window method – Airborne spectrometers

Calibration on calibration pads

The NaI(Tl) 4“ x 4“ x 16“ crystals were calibrated on standard four calibration pads in Diamo, s.p. Stráž pod Ralskem (K, U, Th and BKGD pads).

Calibration hall layout in Stráž pod Ralskem



IRIS pack (2 x 2 litres NaI(Tl) on K calibration pads

Activity concentrations on calibration pads

Activity concentrations on calibration pads

Standard	% K	ppm eU	ppm eTh
PK	15,33	2,4	2,1
PU	0,24	29,2	2,4
PTh	0,29	5,1	94,6
P0	0,02	0,3	0,9

1.95m diam. → infinite area

^{137}Cs calibration pad missing !!!

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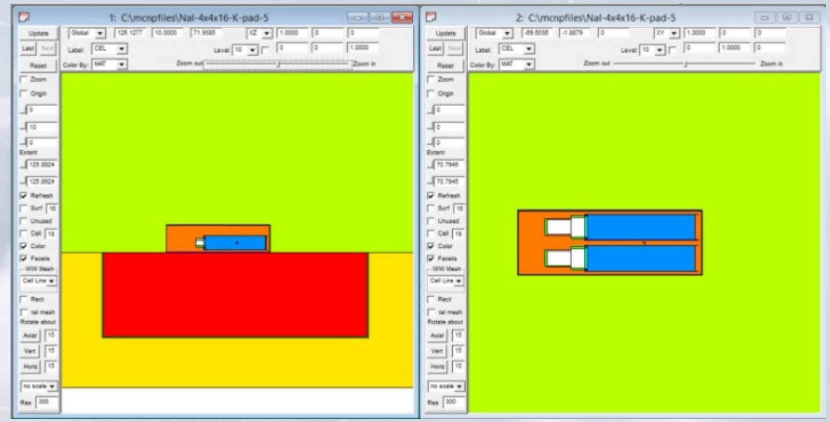
Extended window method – Airborne spectrometers

137 Cs calibration pad

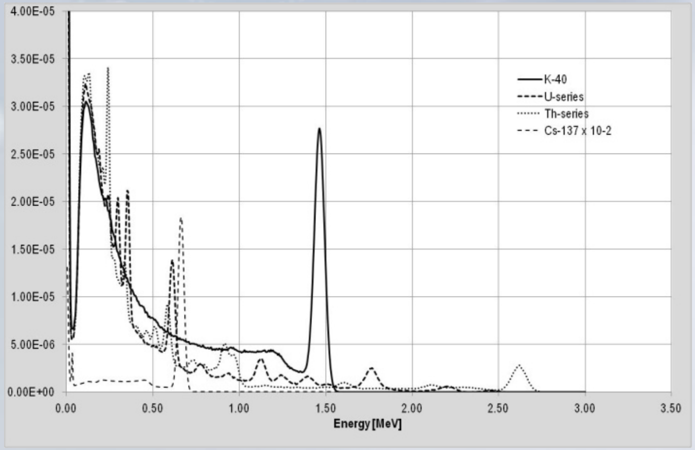
The Cs-137 pad was simulated in Monte Carlo simulation. The net background corrected cps $n_{i,i}$ were calculated from count rates n_i in i- energy windows (K, U, Th, Cs) and stripping factors were determined.

Finally, the Cs-137 pad simulation data in Monte Carlo and K, U, Th data from measurement were combined. The net background corrected cps $n_{i,i}$ were calculated from count rates n_i in i- energy windows (K, U, Th, Cs) .

MCNP simulation of calibration pads in Vised 24E

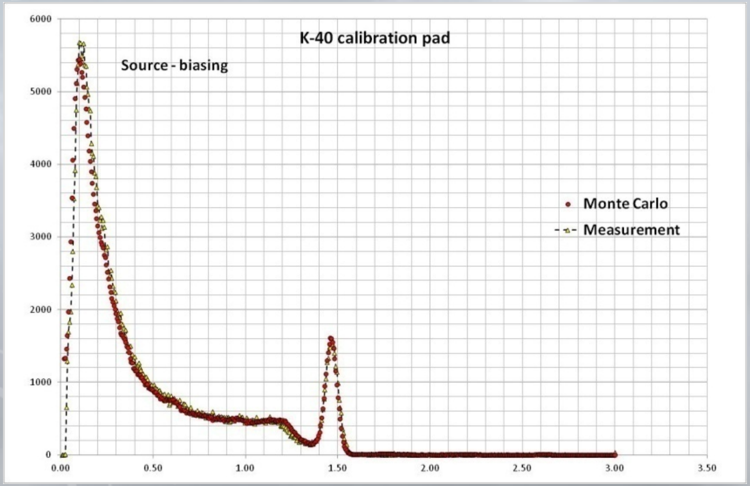


MCNP response matrixes for calibration pads in Straž pod Ralskem

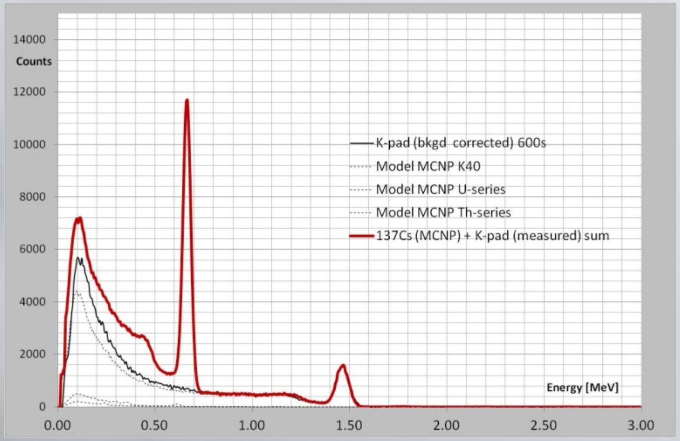


- K, U, Th calibration pads simulated
- ^{137}Cs simulated flat calibration pad located on standard calibration pads

K-pad (measurement) and K-pad (simulation

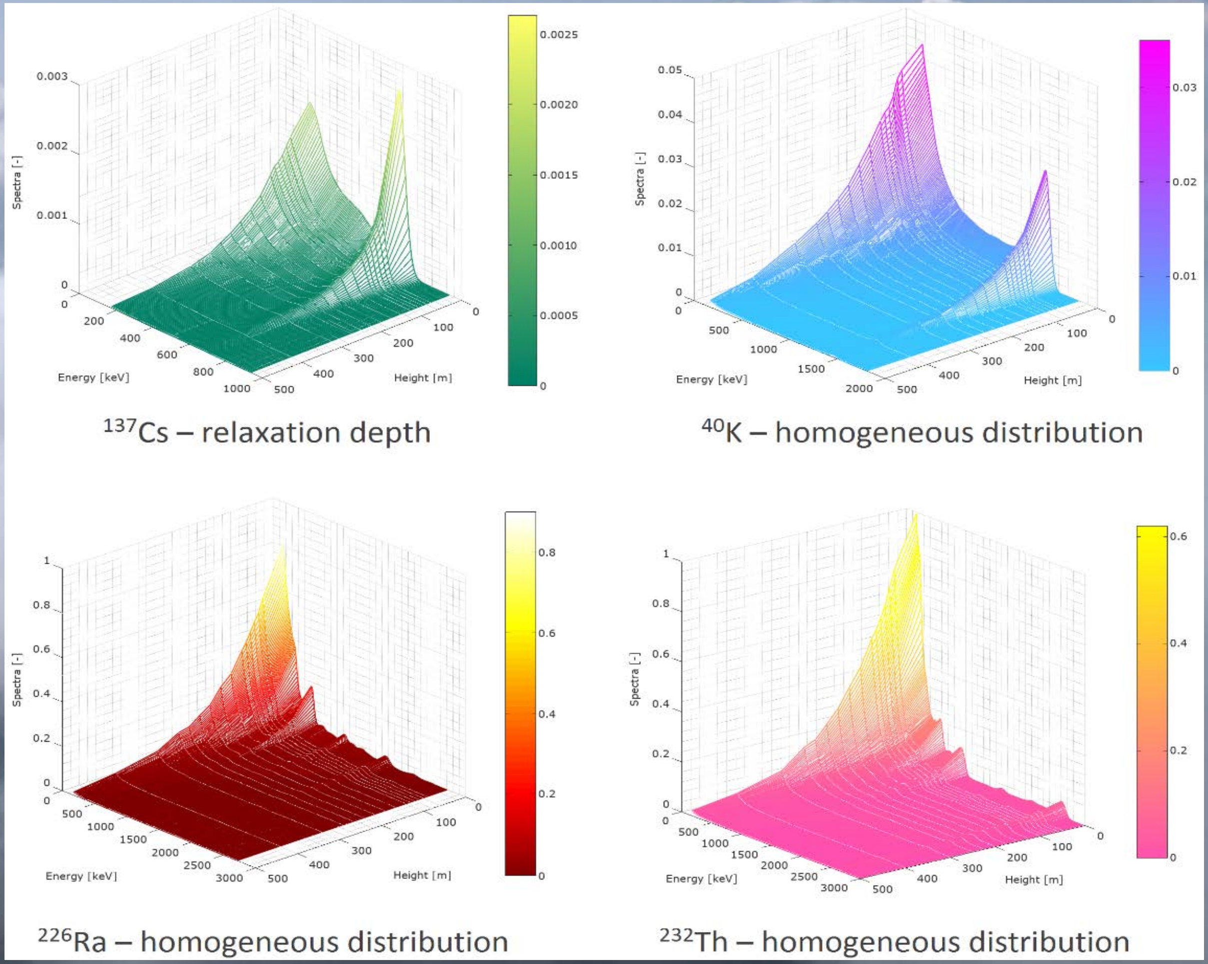


K-pad (measurement) and + ^{137}Cs (simulation)



Extended window method – Airborne spectrometers

Monte Carlo simulation – response matrixes for K, Ra, Th and Cs-137 (surface and exponencial distribution) for 4“x 4“x 16“ detector



^{137}Cs – relaxation depth

^{40}K – homogeneous distribution

^{226}Ra – homogeneous distribution

^{232}Th – homogeneous distribution

MCNP specifications:

Natural radionuclides:

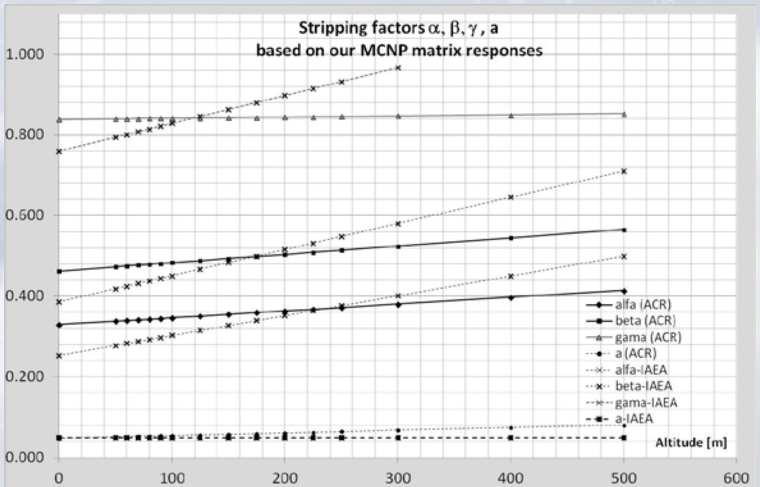
- Soil with thickness of 50 cm, ρ=1.52 g cm^{-3}
- Flight height from 0 m to 500m
- 4x4 litre NaI(Tl) crystal
- Energy threshold :30keV, max energy 3 MeV
- Branching factor > 1%
- Number of energies: K 1, U-series 31, Th-series 38, Cs-137 - 4, Cs-134 - 9.

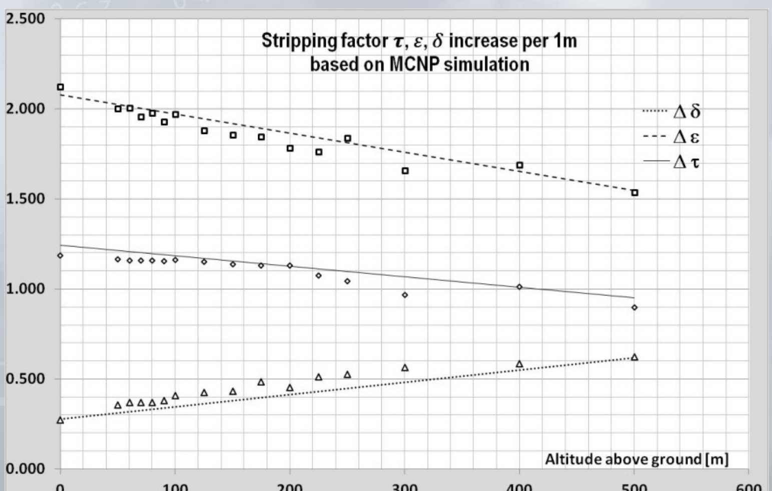
Deposition	Surface	Exponential (relaxation length 3 cm)
Height [m]	Radius [m]	Radius [m]
0		
1	150	50
25	300	300
50	400	400
60		
70		
80		
90		
100	500	500
125		
150		
175		
200		
225		
250	700	700
300		
400		
500	800	900

Extended window method – Airborne spectrometers

Additionally to the standard stripping factors α, β, γ and a, new stripping factors ***ε*** (U → Cs) ***τ*** (Th → Cs) ***δ*** (K → Cs) for Cs-137 were introduced.

Stripping factors were calculated based on MCN P simulation





Measured on calibration pads

	SÚRO IRIS	ACR IRIS	Grasty
α	0.343	0.330	0.254
β	0.475	0.463	0.386
γ	0.855	0.839	0.760
a	0.048	0.041	0.05
δ	0.278	0.272	*
ε	2.080	2.125	*
τ	1.243	1.188	*

Calculated by Monte Carlo

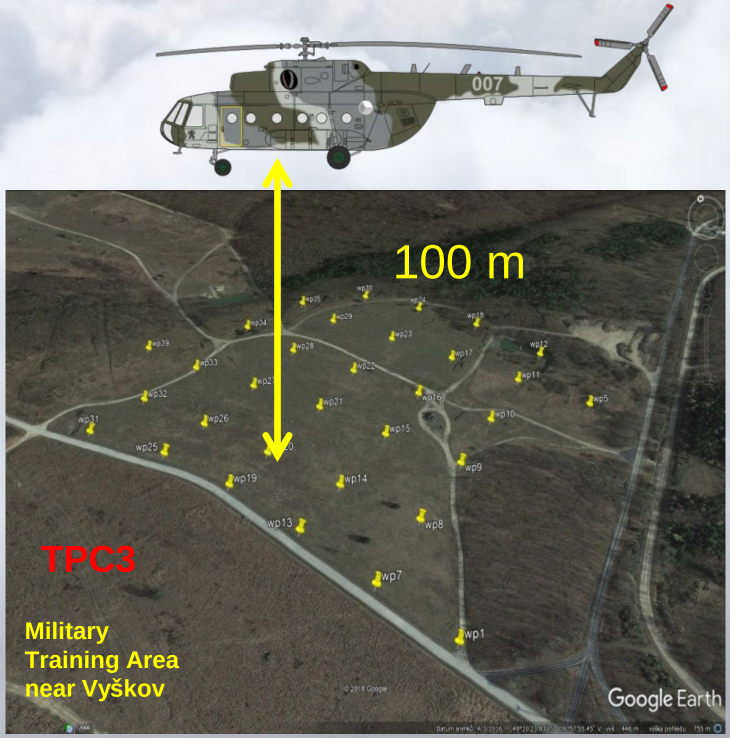
	SÚRO IRIS	ACR IRIS	Grasty
Δ*α*	0.000169	0.000169	0.00049
Δ*β*	0.000205	0.000205	0.00065
Δ*γ*	0.0000281	0.0000281	0.00069
Δ*δ*	0.000684	0.000684	*
Δ*ε*	-0.00106	-0.00106	*
Δ*τ*	-0.000583	-0.000583	*

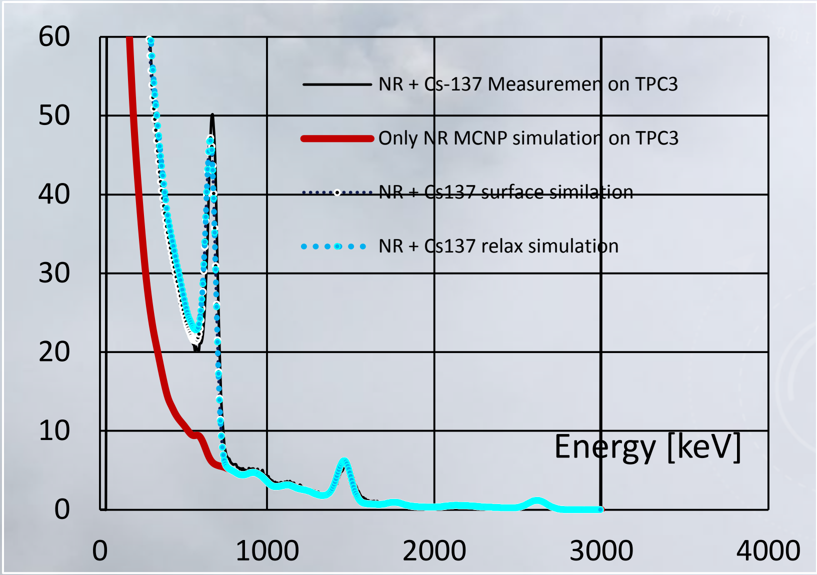
Extended window method – Airborne spectrometers

- Sensitivities for natural radionuclides were measured during hovering Mi-17 helicopter at the altitude of 100 m over the reference area near Vyškov.
- The ground activity concentrations were determined using ground
- HPGe measurements (in-situ).

- Due to low Cs-137 activity (<MDA) at the reference area, the sensitivity for Cs-137 was determined using Monte Carlo simulation.

- Surface activity of Cs-137 simulated and compared to a point source with activity of 2.646 GBq





Cs-137 [cps/kBq/m²]	K-40 [cps/Bq/kg]	U [cps/Bq/kg]	Th [cps/Bq/kg]
(5.8 ± 1.9)	(0.127 ± 0.015)	(0.271± 0.031)	(0.586 ± 0.050)

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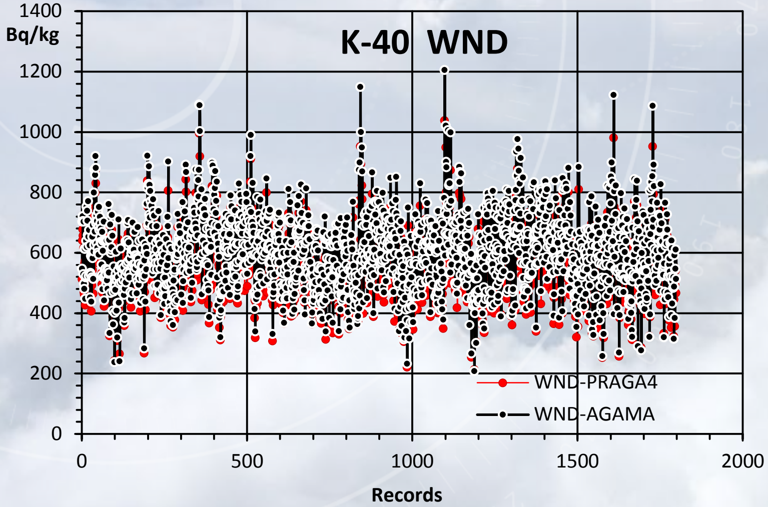
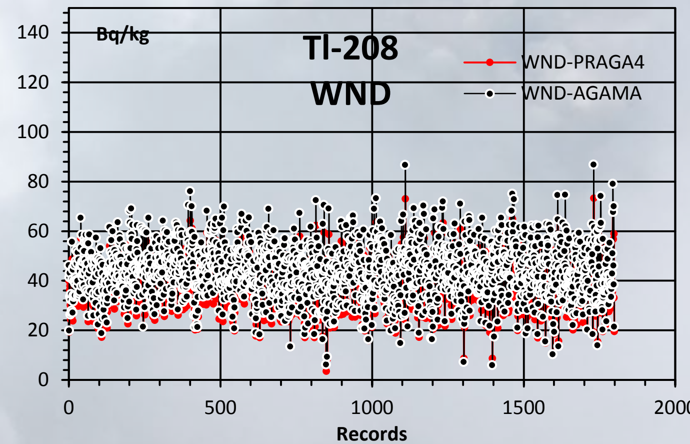
Extended window method – Airborne spectrometers Czech Republic

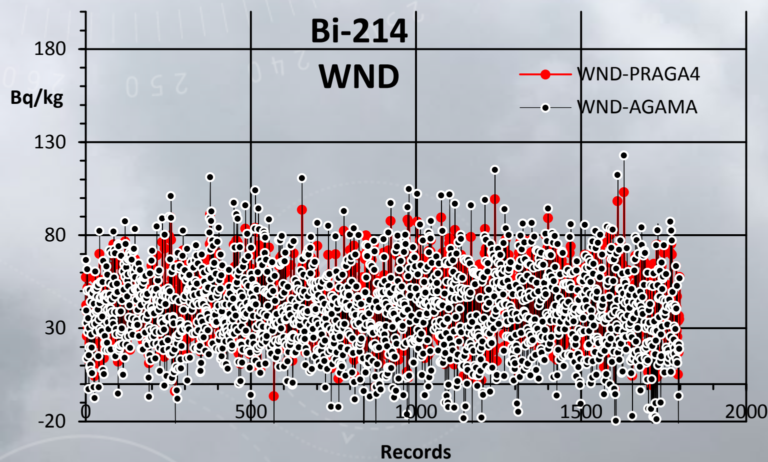
TPC3 – reference area

	Ground	AGAMA	Airborne PRAGA4
^{40}K [Bq/kg]	(599±98)	(587±125)	(556±110)
^{214}Bi [Bq/kg]	(39±7)	(38±23)	(43±16)
^{208}Tl[Bq/kg]	(43±7)	(42±11)	(39±9)
^{137}Cs[Bq/kg]	(1.8±0.5)	<MDA	N/A

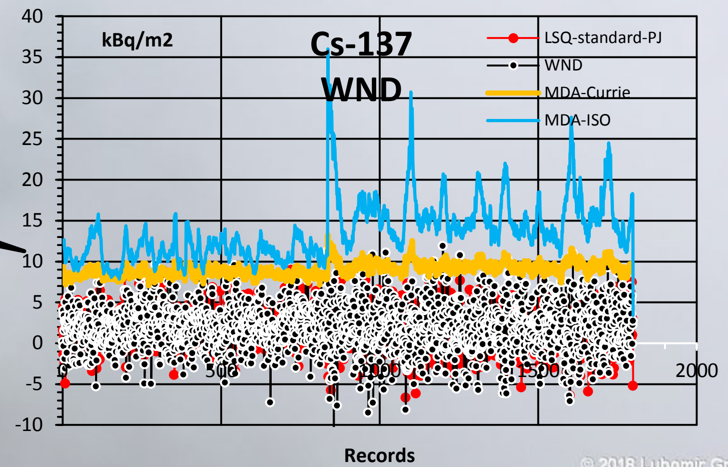
Sensitivity MCNP ?





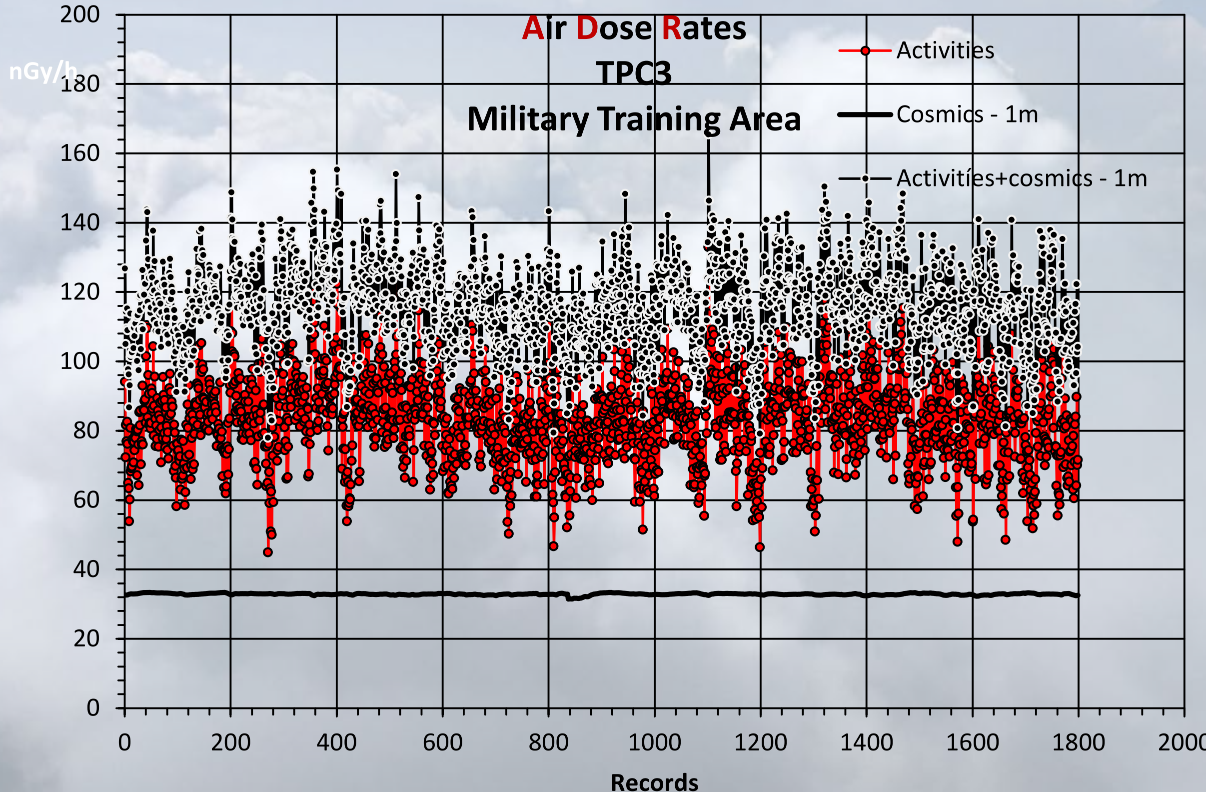


MDA Currie 8.6 kBq/m²
MDA ISO 9.4 kBq/m²



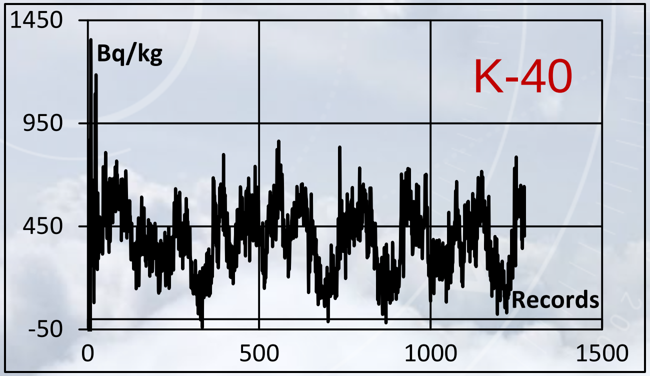
Extended window method – Airborne spectrometers
TPC3 –reference area – Czech Republic

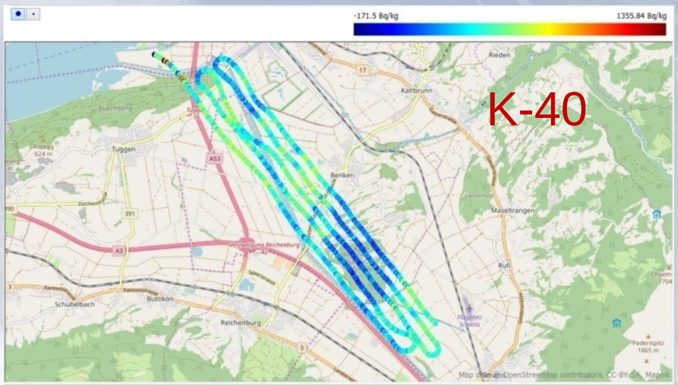
Result comparison
AGAMA x Ground measurements

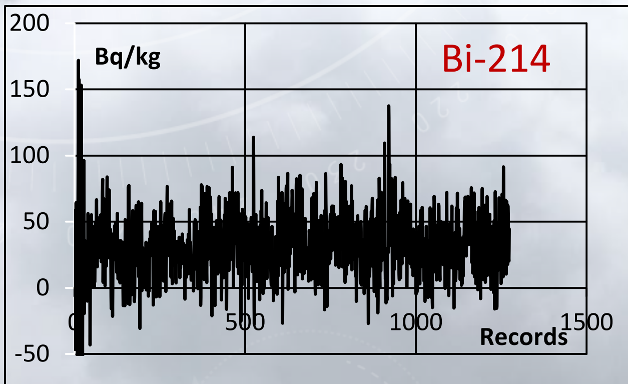


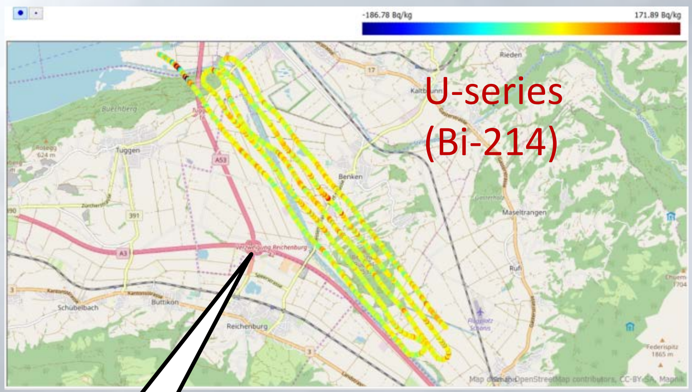
	Ground HPGe [nGy/h]	Airborne AGAMA [nG/h]	Airborne PRAGA4 [nG/h]
ADR_{Act}	(82 ± 5)	(85 ± 12)	**(67 ± 9)**
ADR_{Cos}	*	(32.9 ± 0.3)	*

Extended window method – Airborne spectrometers
RM2 – 90m - Switzerland - reference area



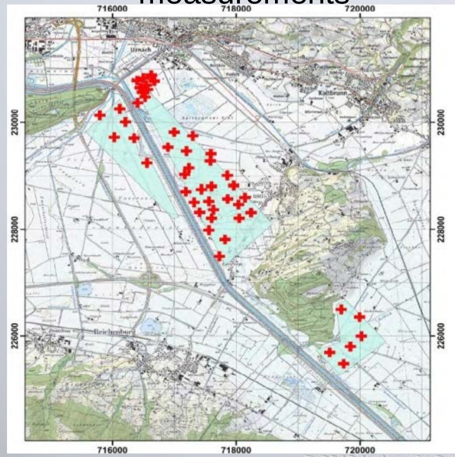




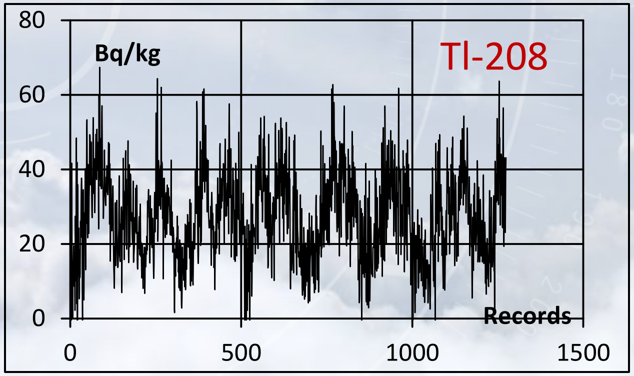


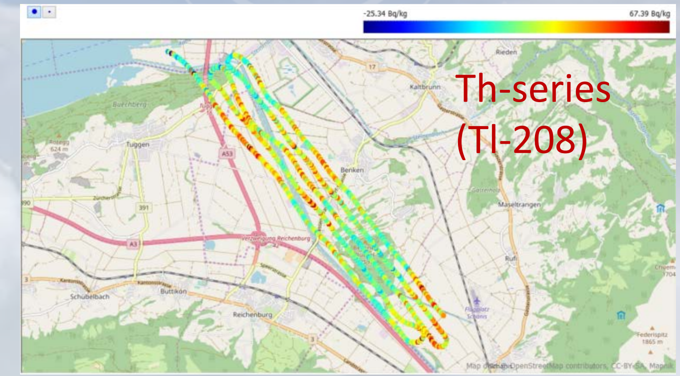
Created directly in AGAMA open free map

HPGe ground measurements

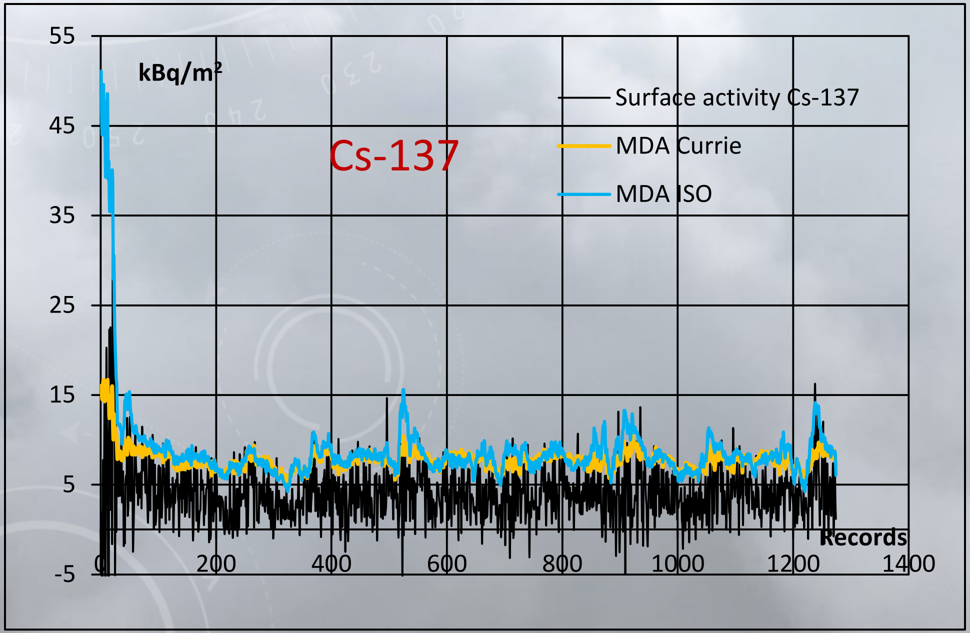


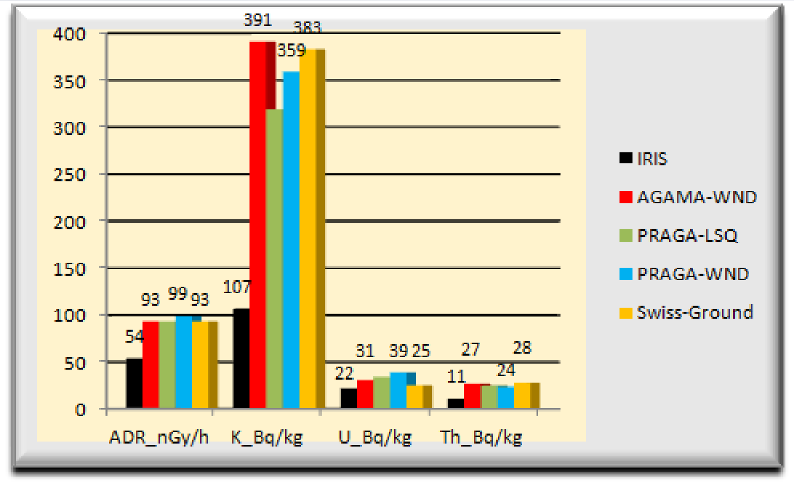
Extended window method – Airborne spectrometers
RM2 – 90m - Switzerland - reference area





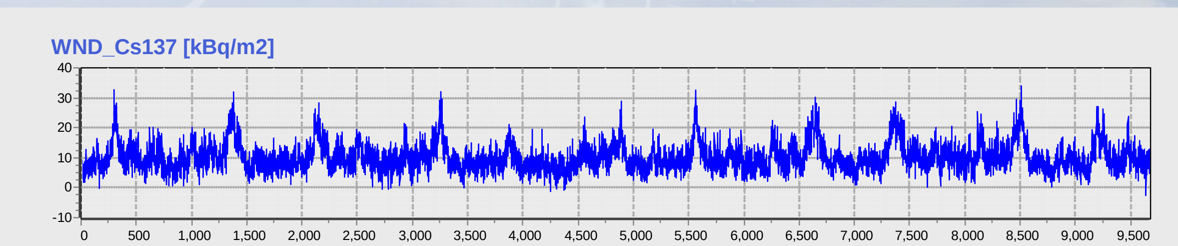
Data comparison – RM2-90m
- Ground data
- PRAGA-LSQ
- PRAGA-WND
- IRIS
- AGAMA-WND

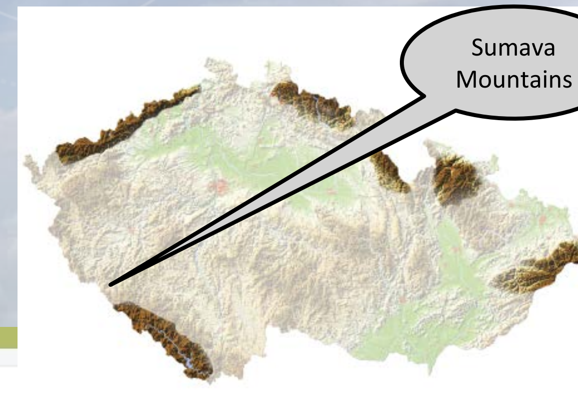




Extended window method – Airborne spectrometers
Šumava Mountains - Czech Republic – Chernobyl Cs-137 contaminated

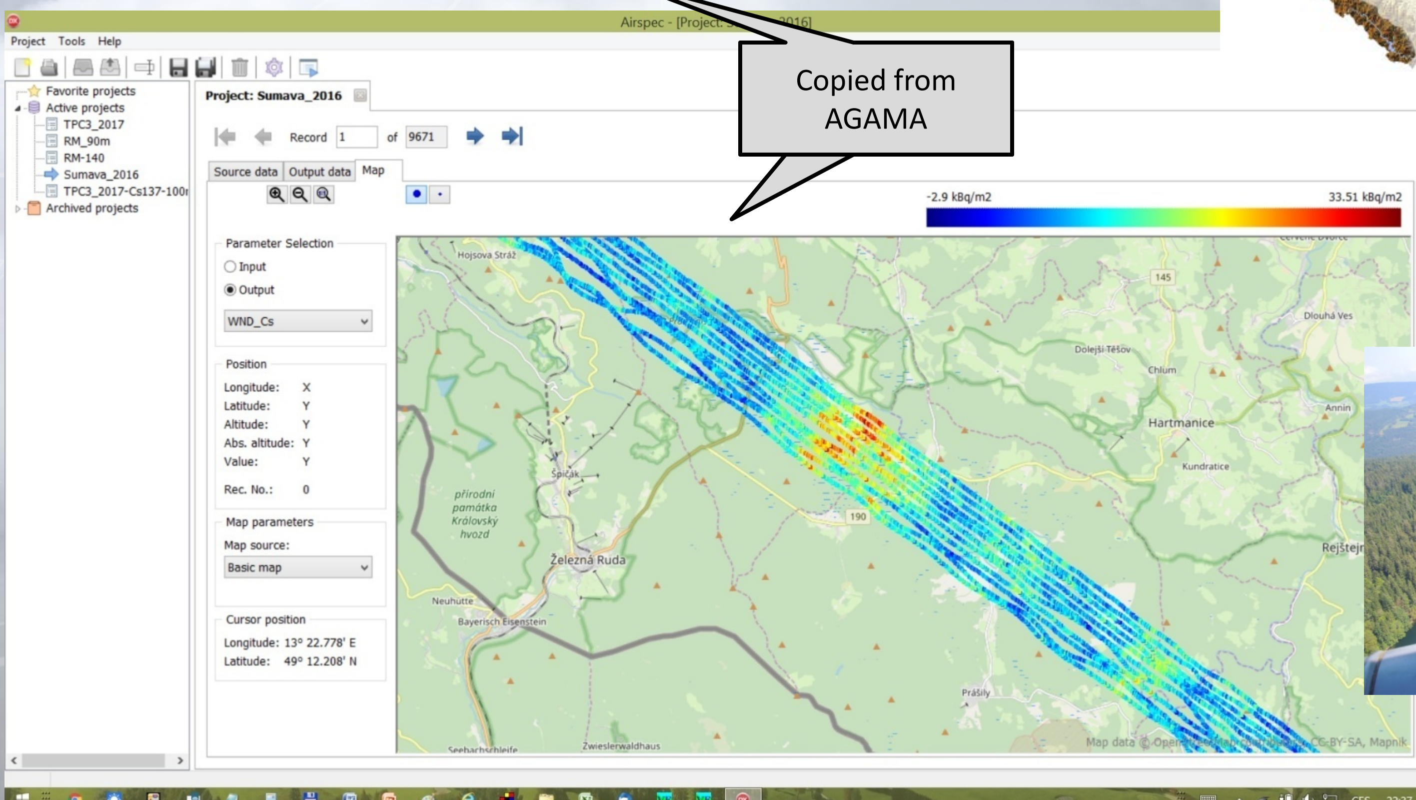
Some areas contaminated by Chernobyl's ^{137}Cs in 1986





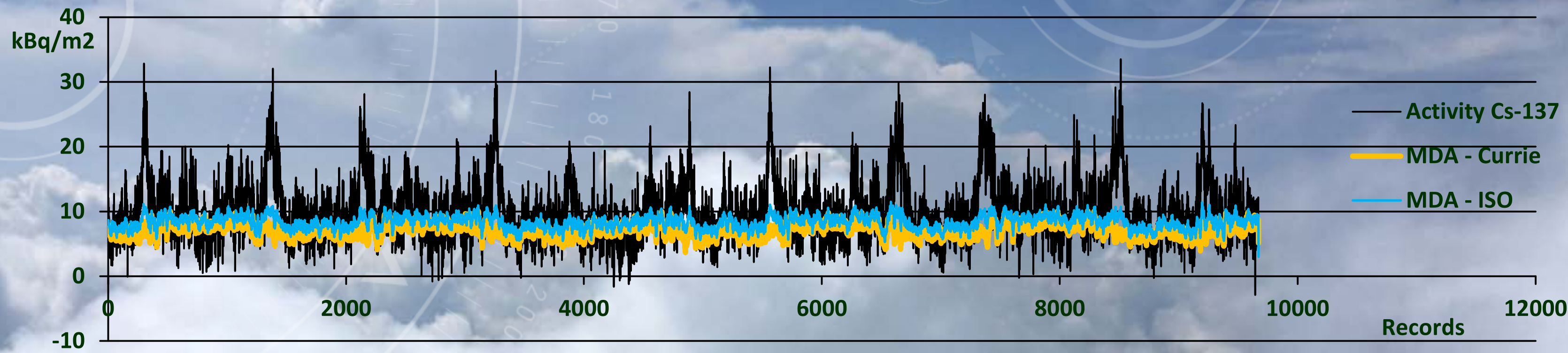
Sumava Mountains

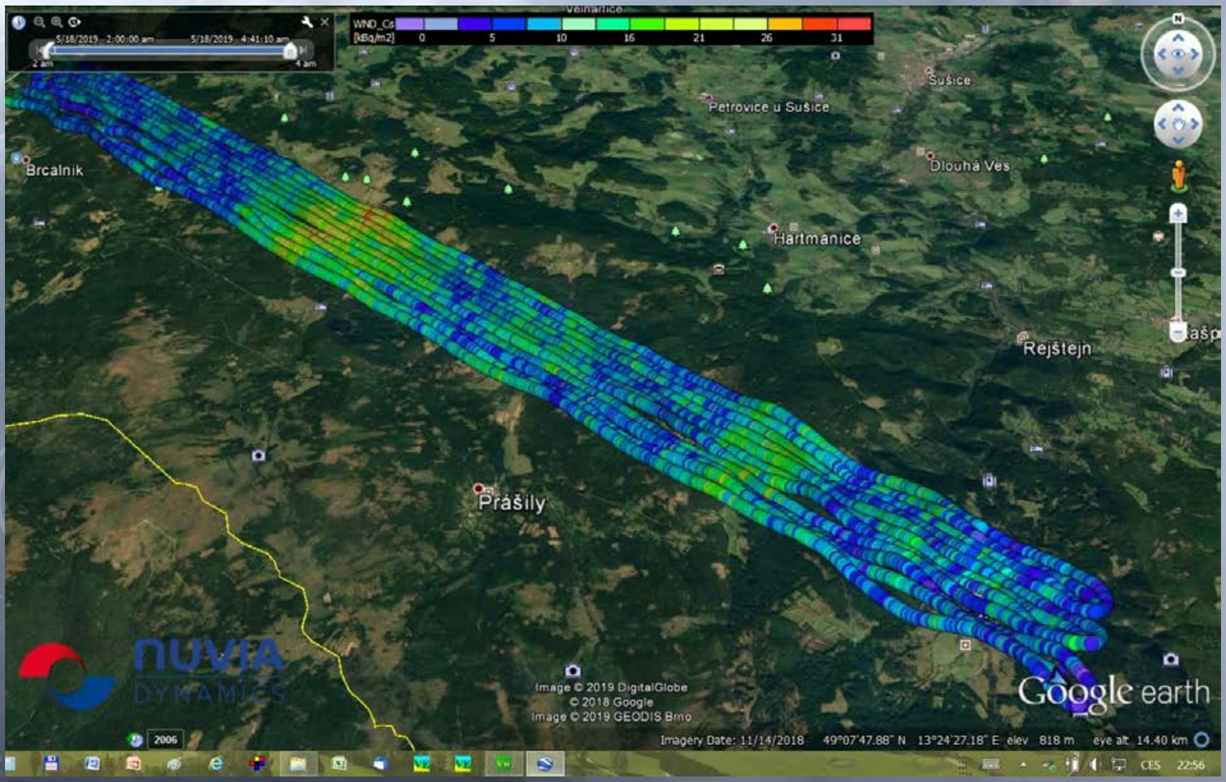
Copied from AGAMA



INTERNATIONAL MEETING ON AIRBORNE GAMMA-RAY SPECTROMETRIC SOFTWARE
PRAGUE 21 -22 May 2019

Extended window method – Airborne spectrometers
Šumava Mountains - Czech Republic – Chernobyl Cs-137 contaminated

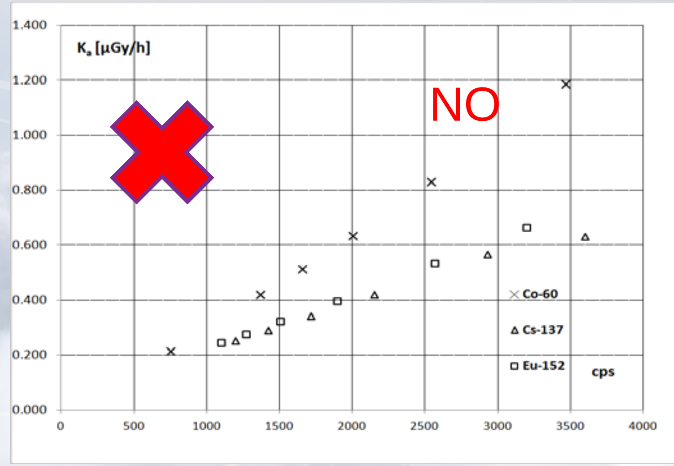


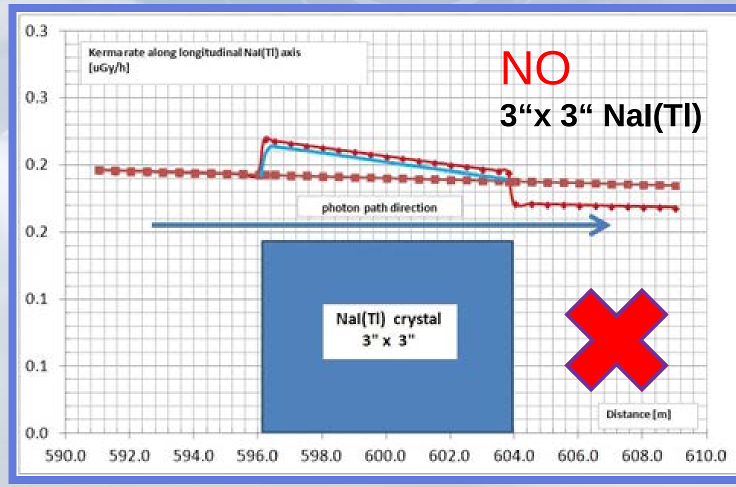


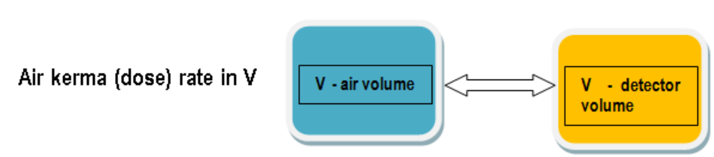
Air dose rate from power spectrum - IDEA

Air kerma rate in 3“x3“ NaI(Tl) crystal - too complex

Air Kerma Rate versus cps energy dependent

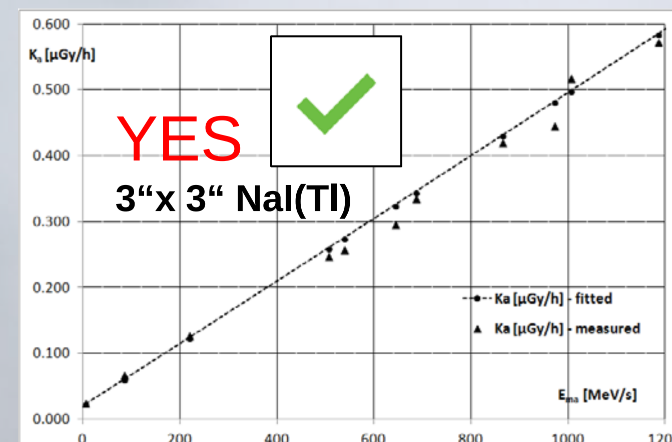






cps – does not work

$\Sigma\ n_i * E_i$
it works for wide energy range (up to 3 MeV) and higher energies (> 500 keV)



MEASURED or Monte Carlo simulation

Tested and calibrated ground detectors (NaI(Tl), HPGe, plastic detectors) for air kerma rates in environmental applications

Air dose rate from power spectrum

Principle of calibration

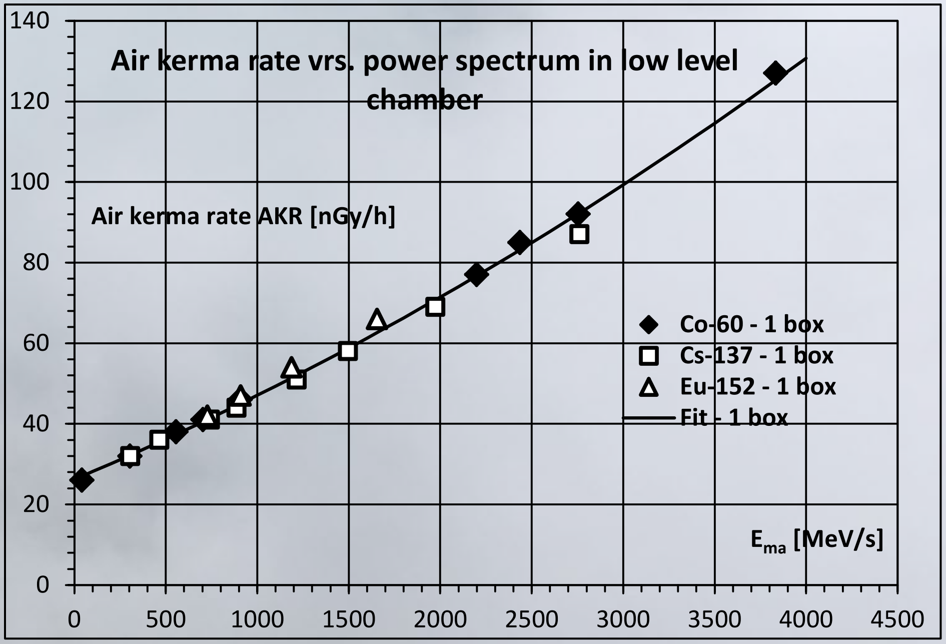
Spectrum → **Powerspectrum**

Energy independent

$$E_{ma} = \frac{\int E_a \times N(E_a)\,dE_a}{t}$$

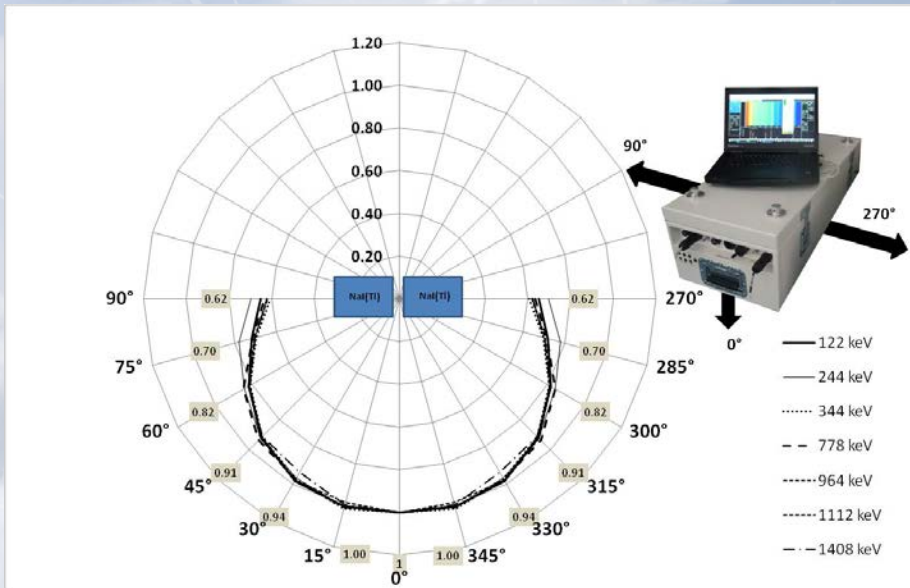
$$E_{ma} = \frac{\sum_{i=j}^{n} E_a \times N(E_a)}{t}$$

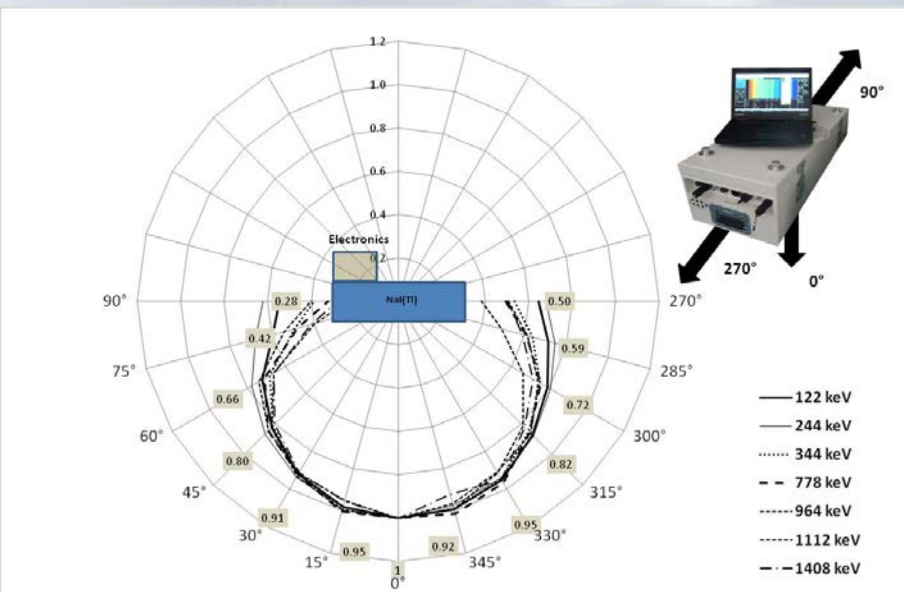
Calibration was done at Low Background Chamber at SÚRO for a range from 26 nGy/h to 120 nGy/h and at Calibration Room at University of Defence, NBC Department for > 120 nGy/h



Where
E_{ma} is the relative absorption energy rate in MeV/s,
t is the live time,
j is the initial channel number
n is the final channel number
$N(E_a)$ is the number of counts with an energy E_a in the interval E_a, $E_a + dE_a$ in a channel over the measuring time t.

Air dose rate from power spectrum





Angular dependence

$$\frac{N_f}{N_0} = \frac{\int_{\frac{\pi}{2}}^{\frac{3\pi}{2}} R(\theta)\frac{d\Phi}{d\theta}\,d\theta}{\int_{\frac{\pi}{2}}^{\frac{3\pi}{2}} \frac{d\Phi}{d\theta}\,d\theta}$$

$$R(\theta) = \frac{\frac{P_\theta}{t_\theta}}{\frac{P_0}{t_0}}$$

Final calibration for 1 IRIS pack 2 x 4 litre NaI(Tl) crystals

$$K_a = 23.2398 + 2.717\times10^{-2}\times1.18\times E_{ma} + 9.7791\times10^{-9}\times1.18^2\times E_{ma}^2$$

K_a is air kerma (dose) rate in nGy/h
E_{ma} is relative absorbed kerma rate in MeV/s

K_a corresponds to local air kerma (dose) rate AKR_{loc} on board

AKR_{loc} ~ terrestrial + aircraft + cosmics

Air dose rate from power spectrum

Needed:

Galt ……….altitude above sea level [m]
UsedAlt…...altitude above ground [m]
Cos ………. Cps in cosmic channel
Spectrum … in range up to 3 MeV

Example:

Average data on TPC3 reference area
Galt = 540 m
UsedAlt= 99 m
STP height = H =92 m
AVGR SPECTRUM

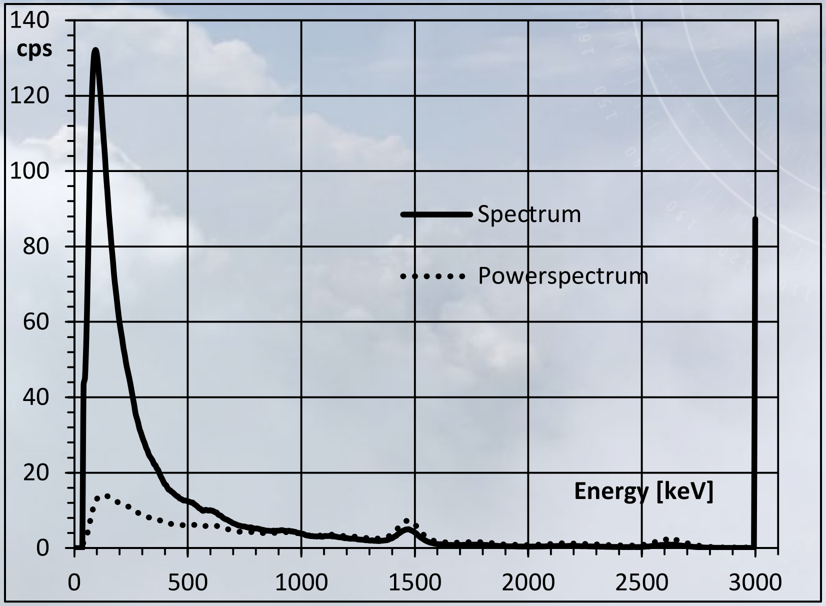
E_{ma} = 2019 MeV/s
$E_{ma\ (Heli+cos)}$ = 244 MeV/s
$E_{ma} - E_{ma\ (Heli+cos)}$ = 1775 MeV/s (2 packs)

Power spectrum → AKR_{loc}

$K_a = AKR_{loc}$ = 47 nGy/h

$AKR_{1m\text{-}ter}$ = 80 nGy/h

Average spectrum and powerspectrum



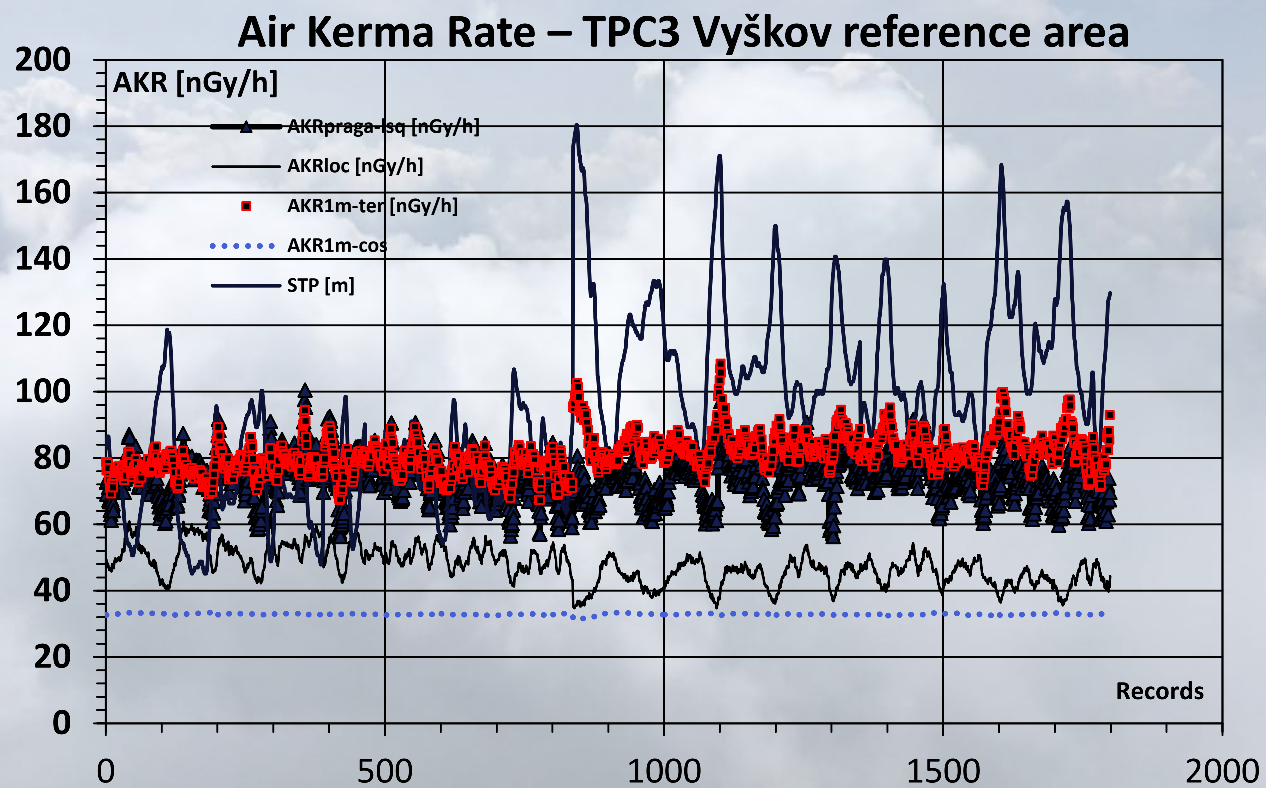
$$K_a = AKR_{loc} = 23.2398 + 2.717\times10^{-2}\times1.18\times E_{ma} + 9.7791\times10^{-9}(1.18)^2\times E_{ma}^2$$

$$AKR_{gr\text{-}1m} = AKR_{loc}/(1.0071\exp(-0.00582\times H))$$

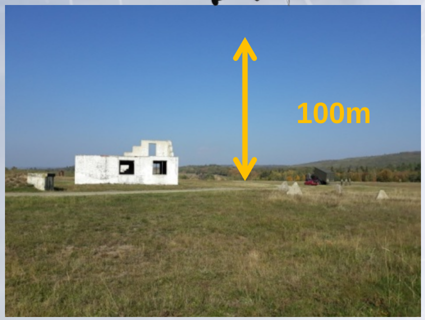
H … STP height

MCNP calculated
Exponential function slightly different for man-made nuclides

Air dose rate from power spectrum



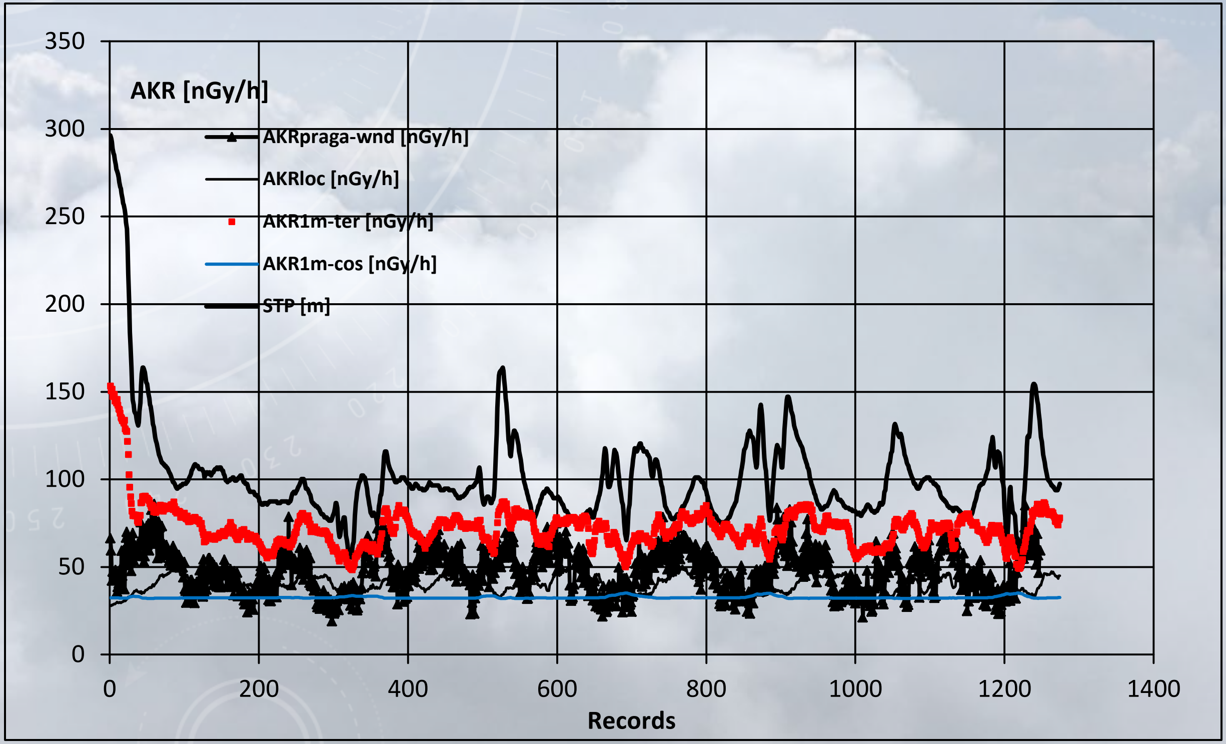
TPC3-
Vyškov



	ADR [nGy/h]
GROUND	(82 ± 5)
$AKR_{PRAGA-LSQ}$	(67 ± 9)
AKR_{Act}- AGAMA	(85 ± 12)
AKR_{1m-ter} -AGAMA- Pws	(80 ± 5)

AKR. ..air kerma rate,
ADR… air dose rate
Prerequisite:
ADR= AKR

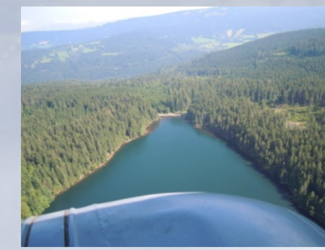
Air dose rate from power spectrum – RM2 - Switzerland

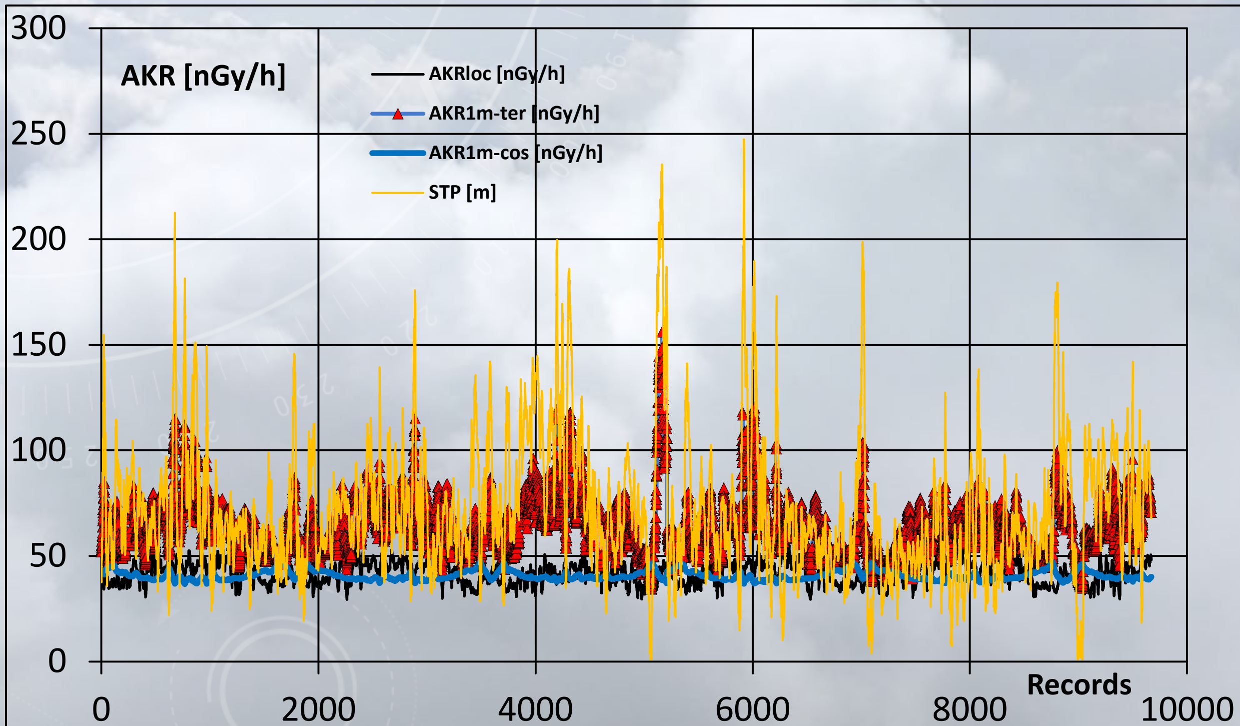


Linth Plain
Switzerland

	ADR [nGy/h]
GROUND	(61 ± 5)
$AKR_{PRAGA-LSQ}$	(67 ± 9)
AKR_{Act}- AGAMA	(60 ± 21)
AKR_{1m-ter} - AGAMA- Pws	(71 ± 8)

Air dose rate from power spectrum – Sumava





	ADR [nGy/h]
GROUND	*
$AKR_{PRAGA-LSQ}$	*
AKR_{Act}- AGAMA	(51 ± 21)
AKR_{1m-ter} -AGAMA- Pws	(64 ± 16)

Airborne HPGe spectrometry

Two versions of post-processing software compiled by Nuvia, a.s. are available HPGe

1. AirHPGeSpec for HPGe + digiDART 2. AirHPGeSpec for HPGe + DSPEC

digiDART

- Selectable measurement interval in seconds
- GPS module
- 4 selectable ROIs
- Data saved in csv file
- Spectra saved in selected time intervals
- Individual spectra displayed in GAMWIN
- Real time

DSPEC 25

- Event detection (event + time mark)
- Data saved into one spectrum file . gspl
- Altitude module + GPS module
- More selectable ROIs
- Individual spectra - step + floating average
- Real time

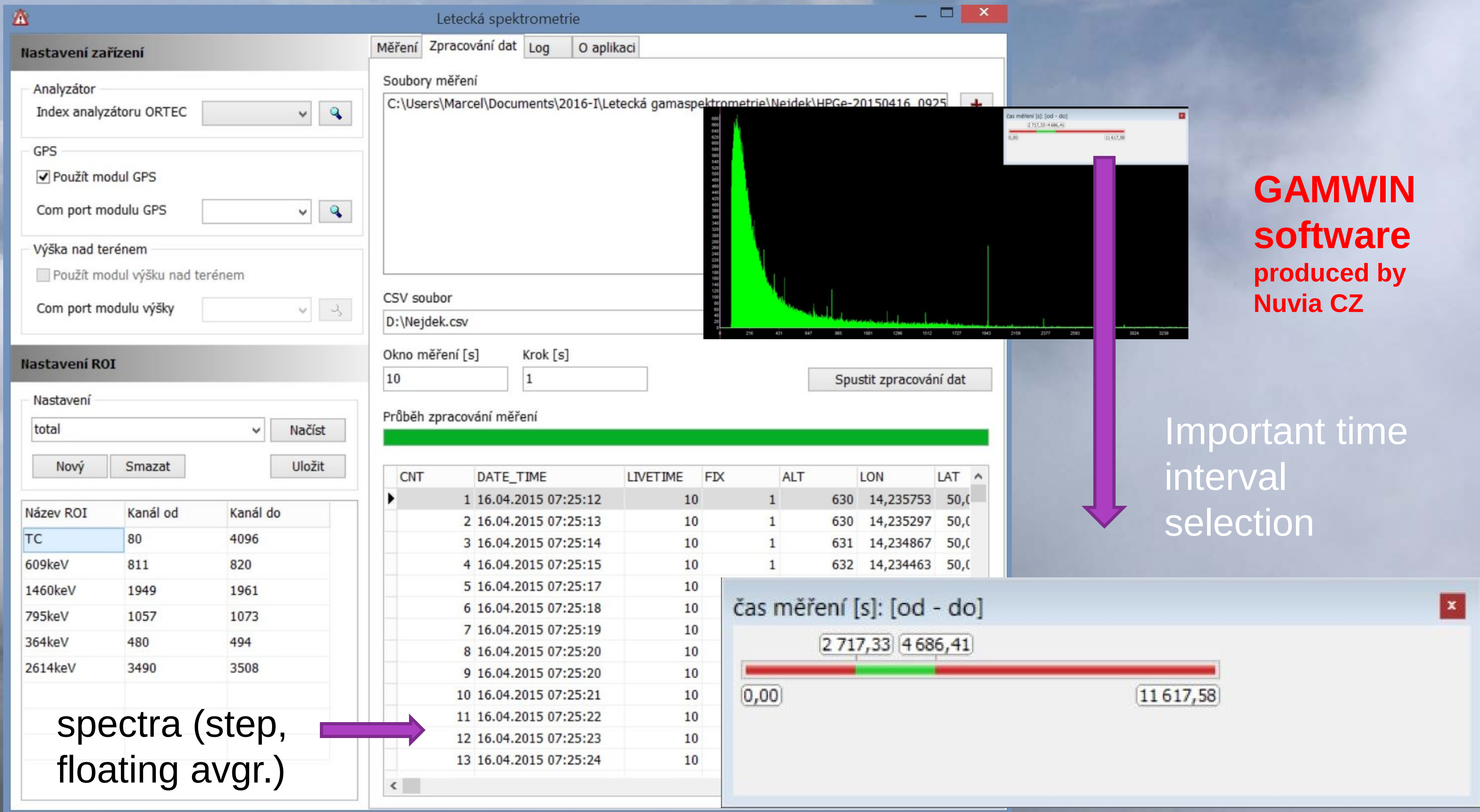
Two HPGe detectors are available for airborne HPGe gamma-ray spectrometry

1. HPGe produced by ORTEC GEM100P4; 100% efficiency ; 1.9 keV at 1.3 MeV (UNOB)
2. HPGe produced by Canberra GC5021 50% efficiency; 2.1 keV at 1.3 MeV (SÚRO);

AirHPGeSpec software

MAIN MENU – data processing

DSPEC 25



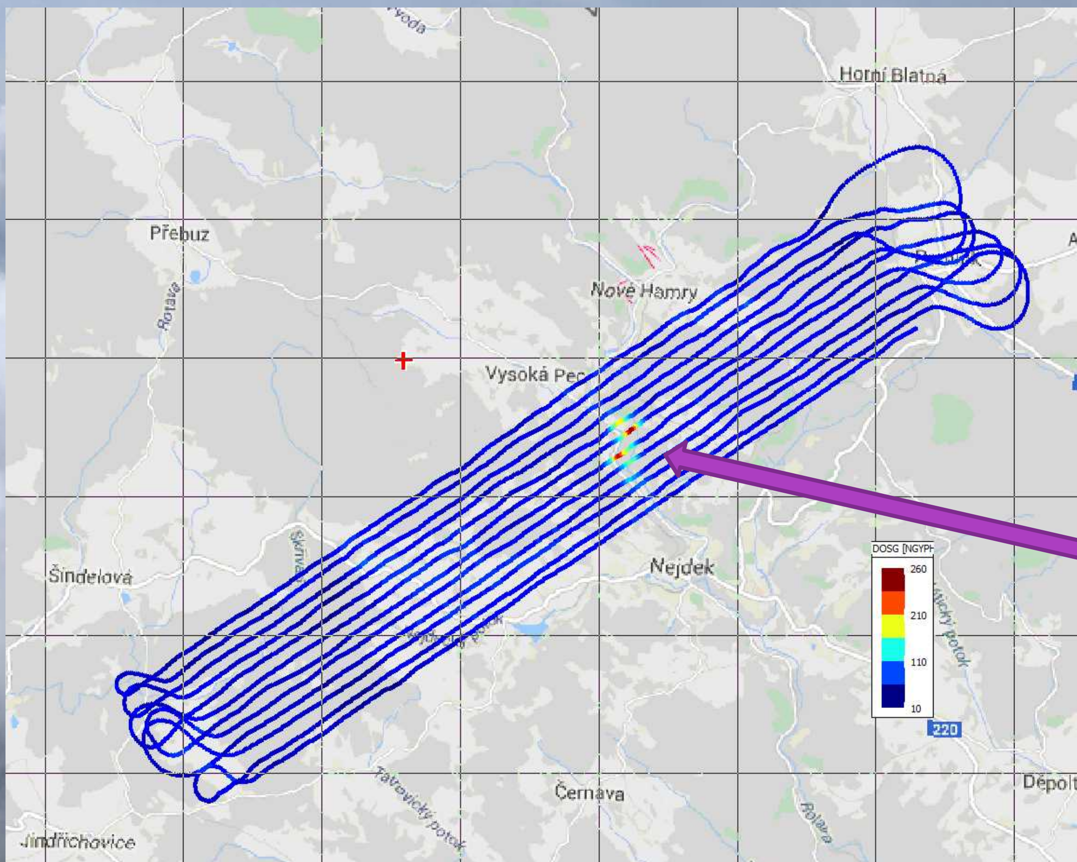
GAMWIN software produced by Nuvia CZ

Important time interval selection

spectra (step, floating avgr.)

AirHPGeSpec software

Example of HPGe detection, Nejdek, CZ



	cps	AE	D_{loc}	D_{gnd}
		[MeV/s]	[nGy/h]	[nGy/h]
LINE 5	161.8	44.5	90	257
LINE 6	203.8	56.7	110	344
LINE 7	228.7	62.2	118	385
LINE 8	170.2	47.4	95	278

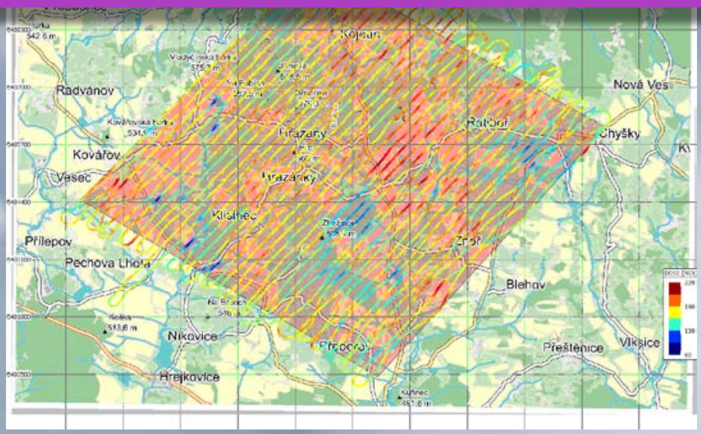
bkgd ≈ 74 cps /105 nGy/h on ground

- Measured by HPGe ORTEC GEM25 P- S, (25 % efficiency)
- Total count rate shown
- Ore processing plant in Nejdek, CZ (higher activity due to uranium processing)

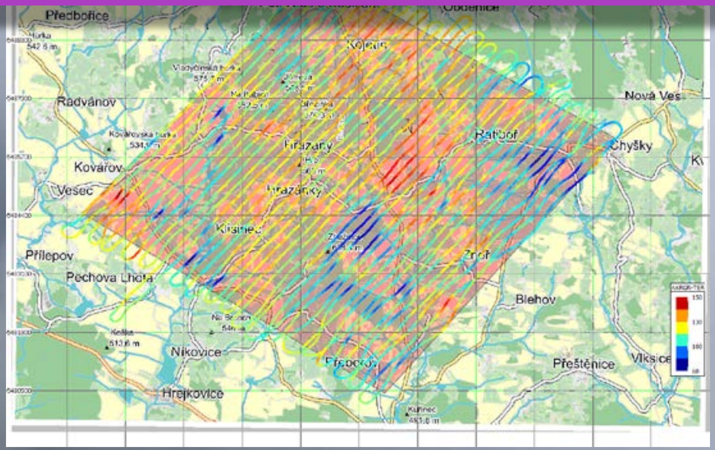
PLASTIC DETECTORS

Air Kerma Rate
- Local
- 1m above ground

Terrestrial component of air kerma rate 1m above ground
IRIS -PRAGA4



Terrestrial component of air kerma rate 1m above ground
Plastic detector 30x30x5cm



SÚRO

Thank You!