Flying over Radioactivity: The Elba Case

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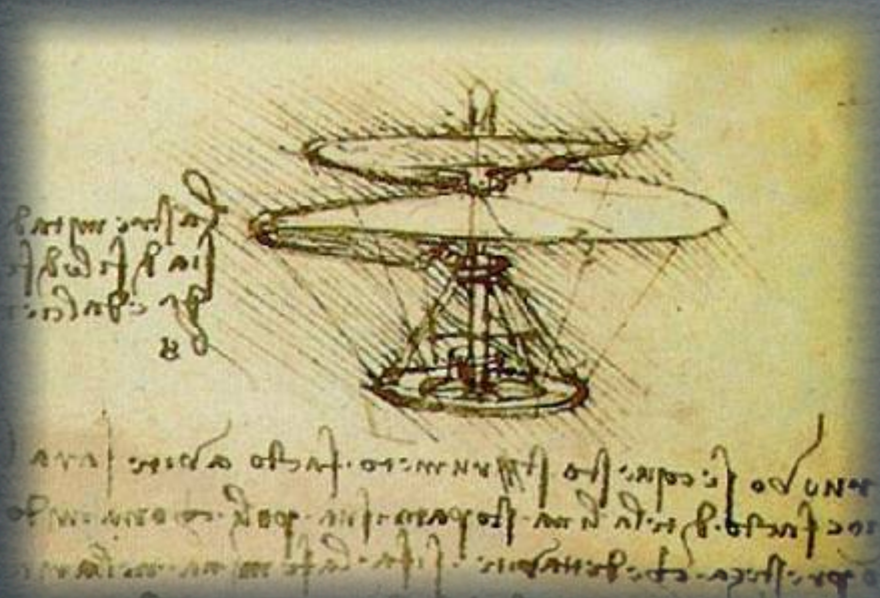


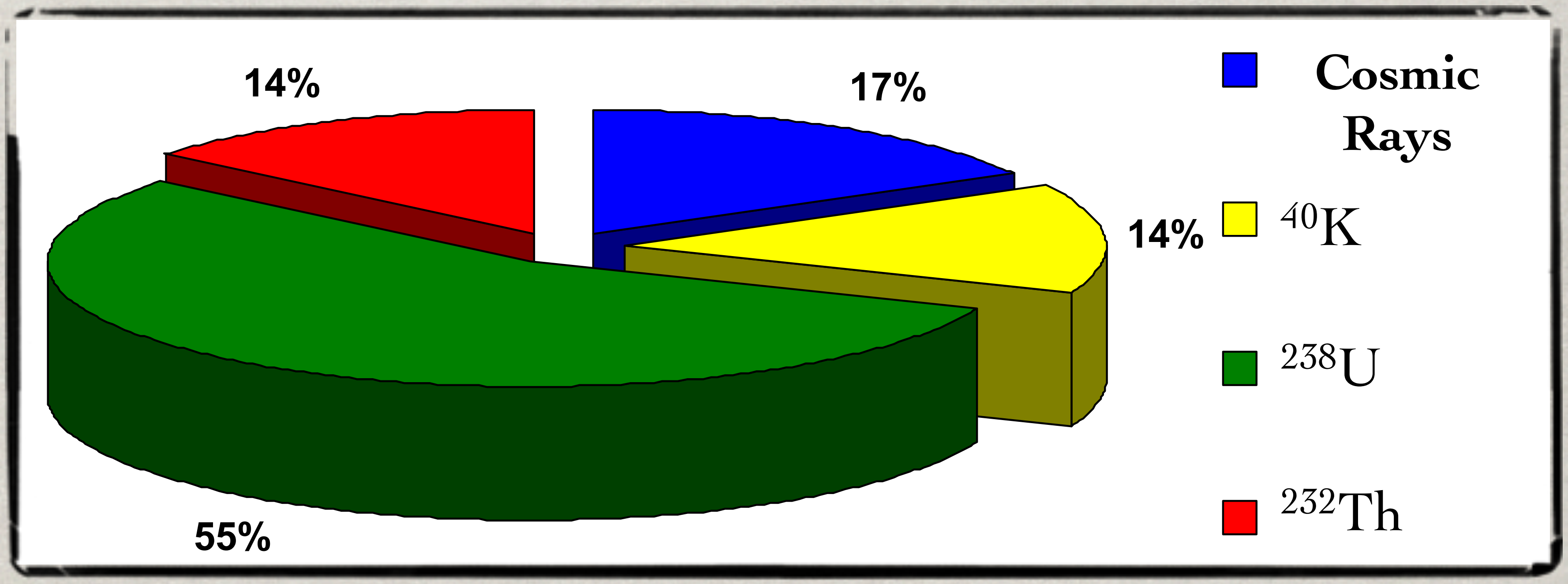
Frontier Detectors for Frontier Physics
12th Pisa Meeting on Advanced Detectors
La Biodola, Isola d'Elba (Italy) - May 20 - 26, 2012

OUTLINE

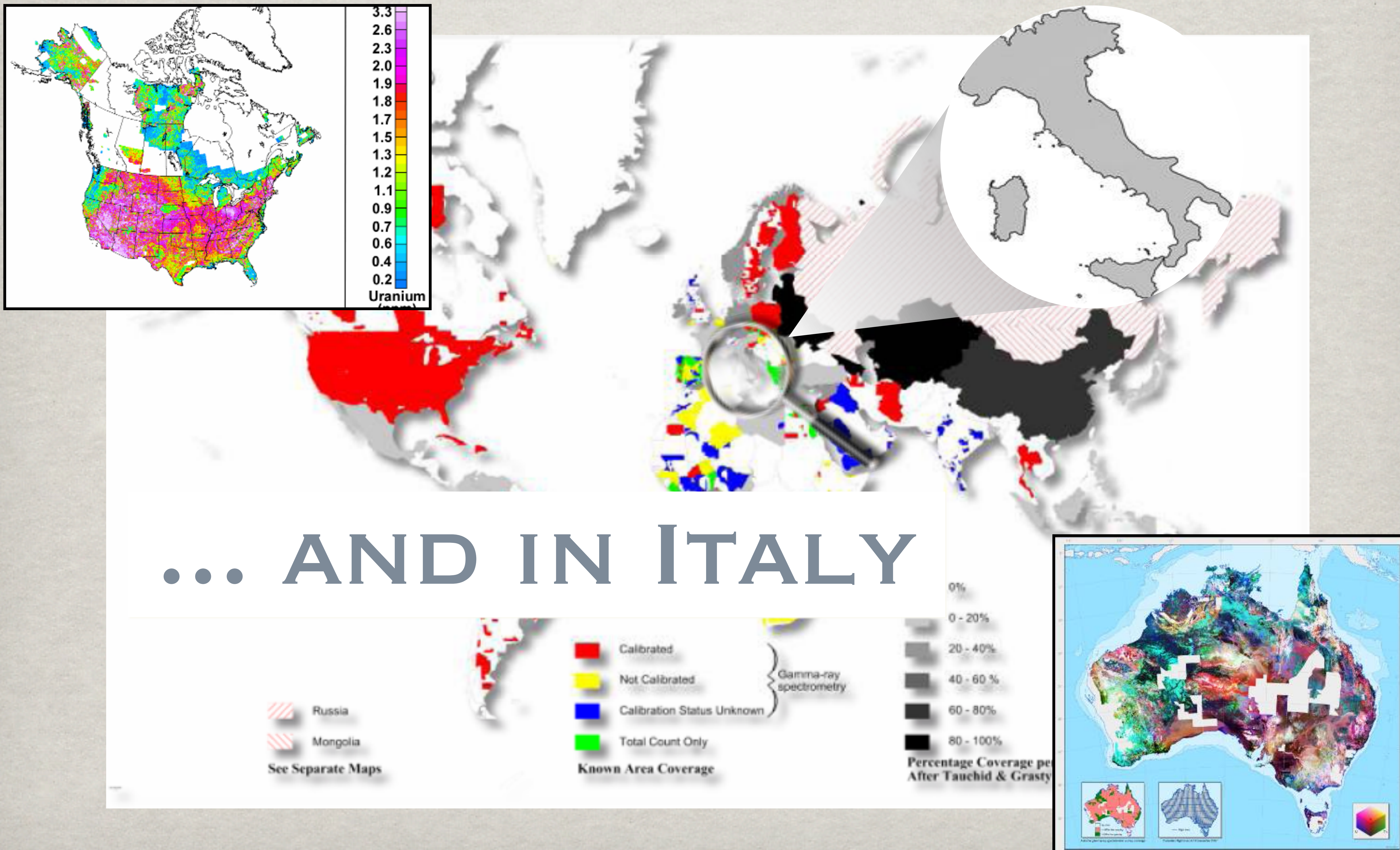
- Natural Radioactivity and Rad-Nat project
- The AGRS setup
- The data analysis
- The flight on the Elba Isle

Natural Radioactivity

Averaged Annual Dose: 2.44 mSv



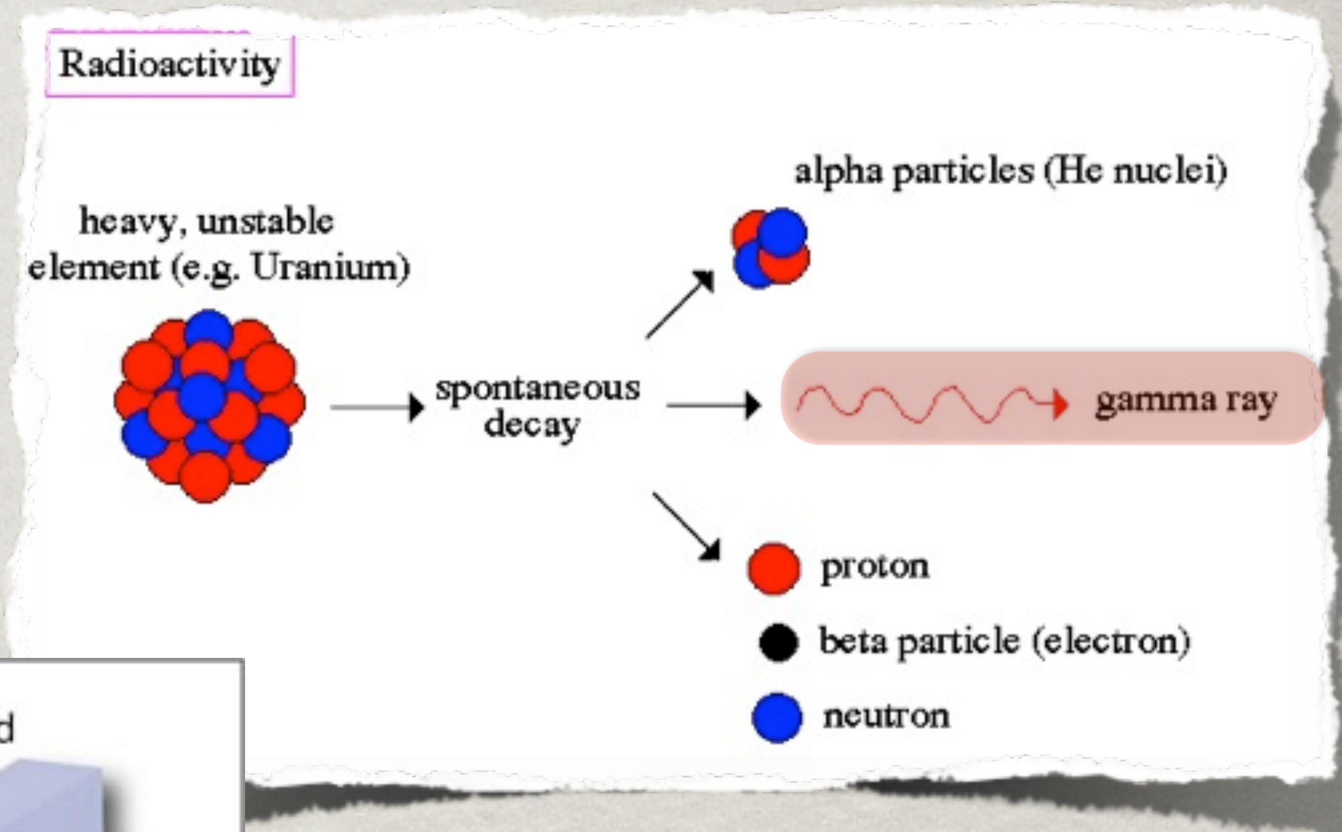
AROUND THE WORLD ...

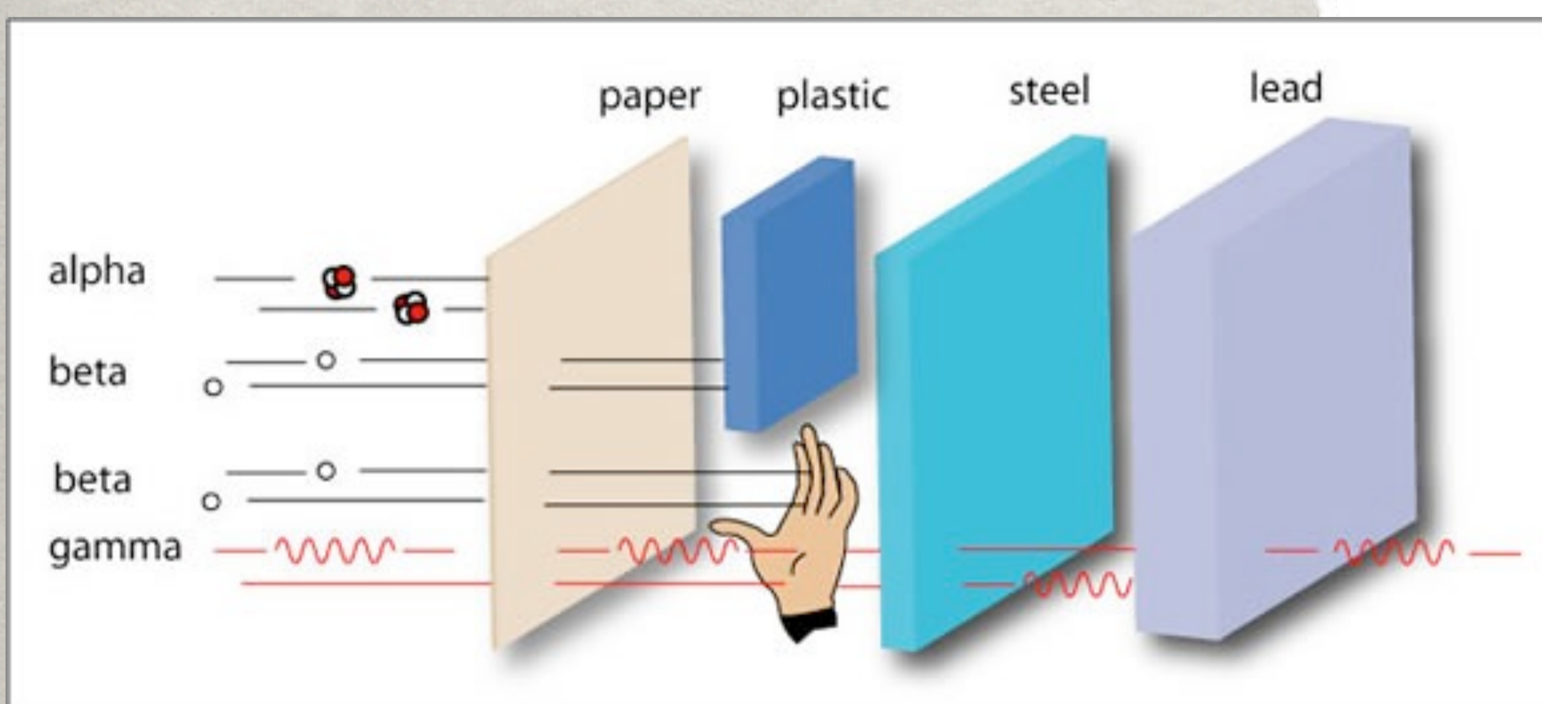


... AND IN ITALY

Gamma Decay Detection

thanks to its penetrability the gamma radiation is optimal to perform fast outdoor measurements





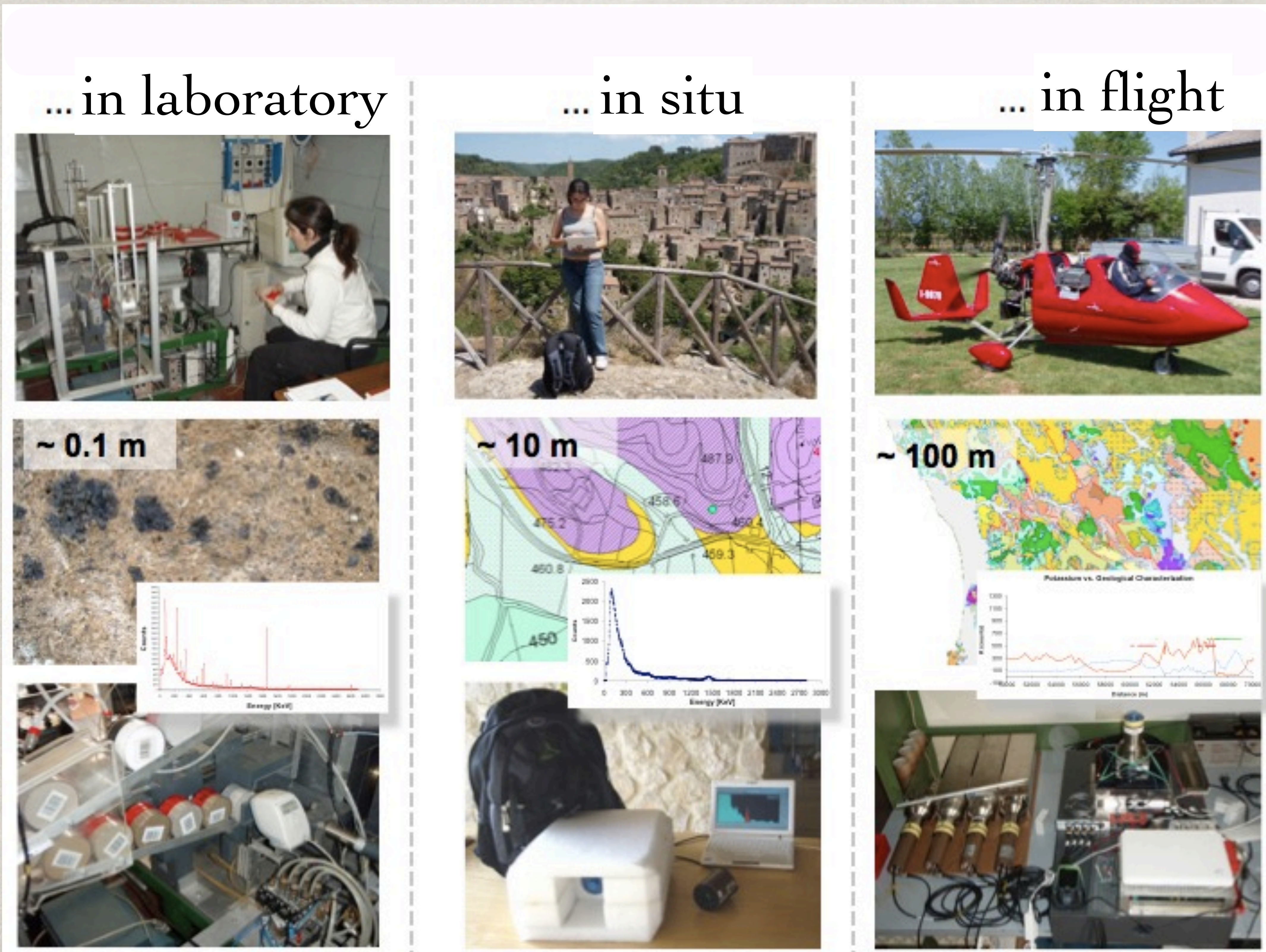
The gamma-ray energy corresponds to the emitting nuclide

the Rad-Nat Project

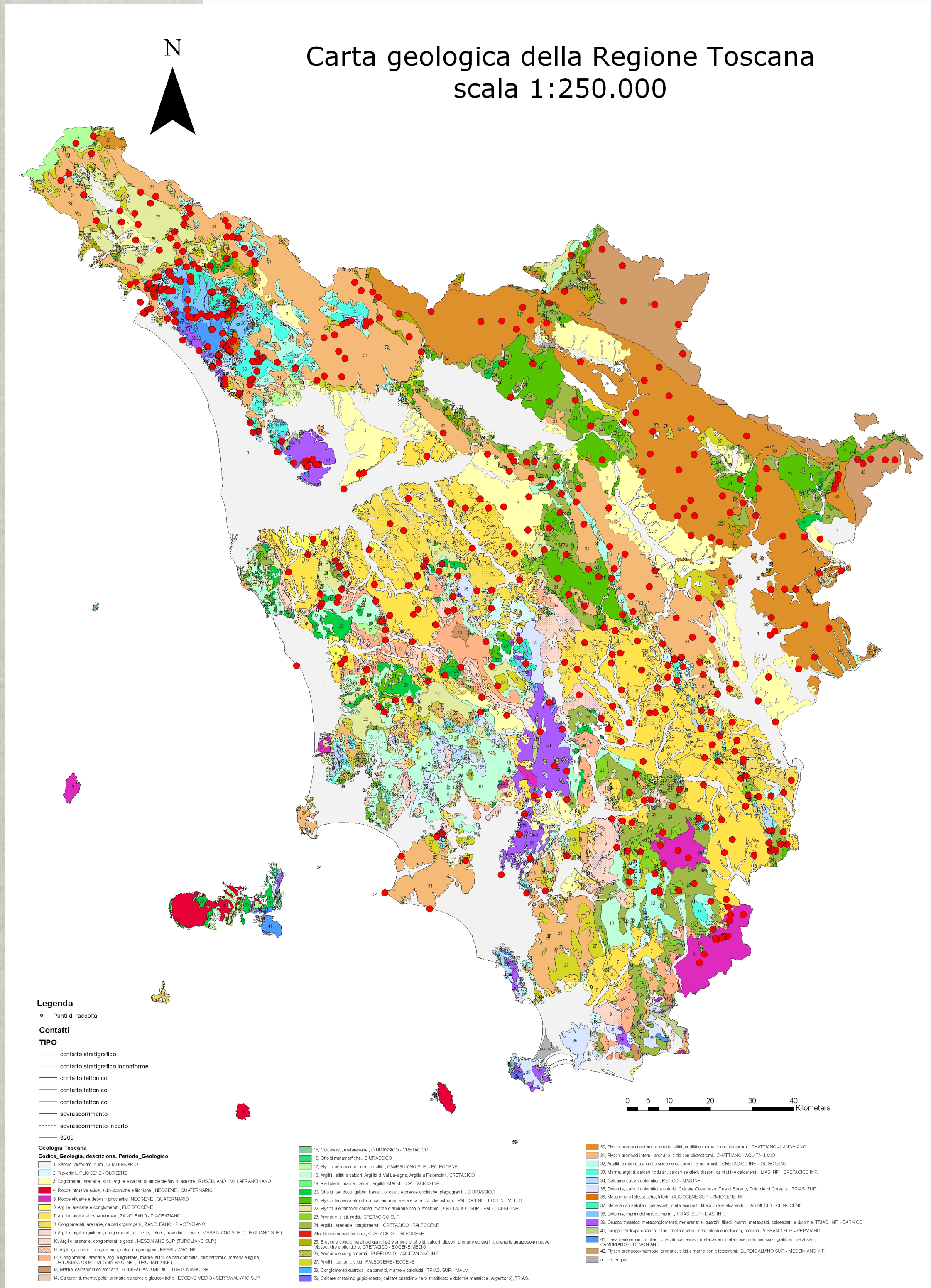
The Rad-Nat (and then Rad-Monitor) project is made by a collaboration between the INFN and the CGT of San Giovanni Valdarno (Siena)

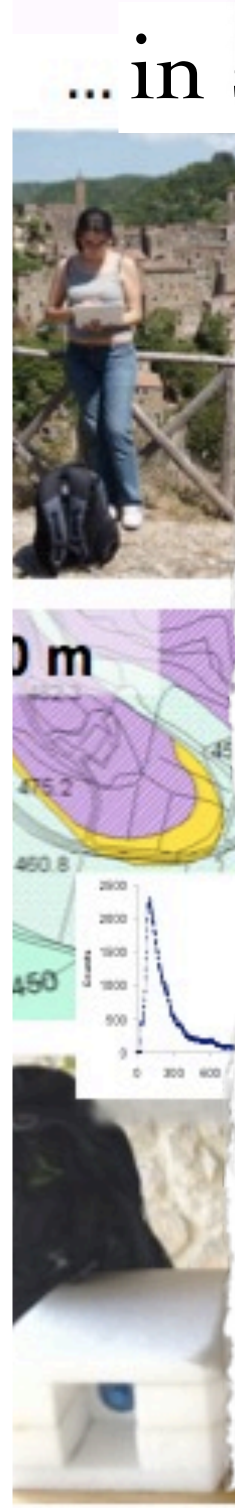
- Geological Interest
- Reference to evaluate fallout effects
- Monitoring critical situations
- Certifications (water, building materials ...)
- R&D on new instruments and analysis procedures

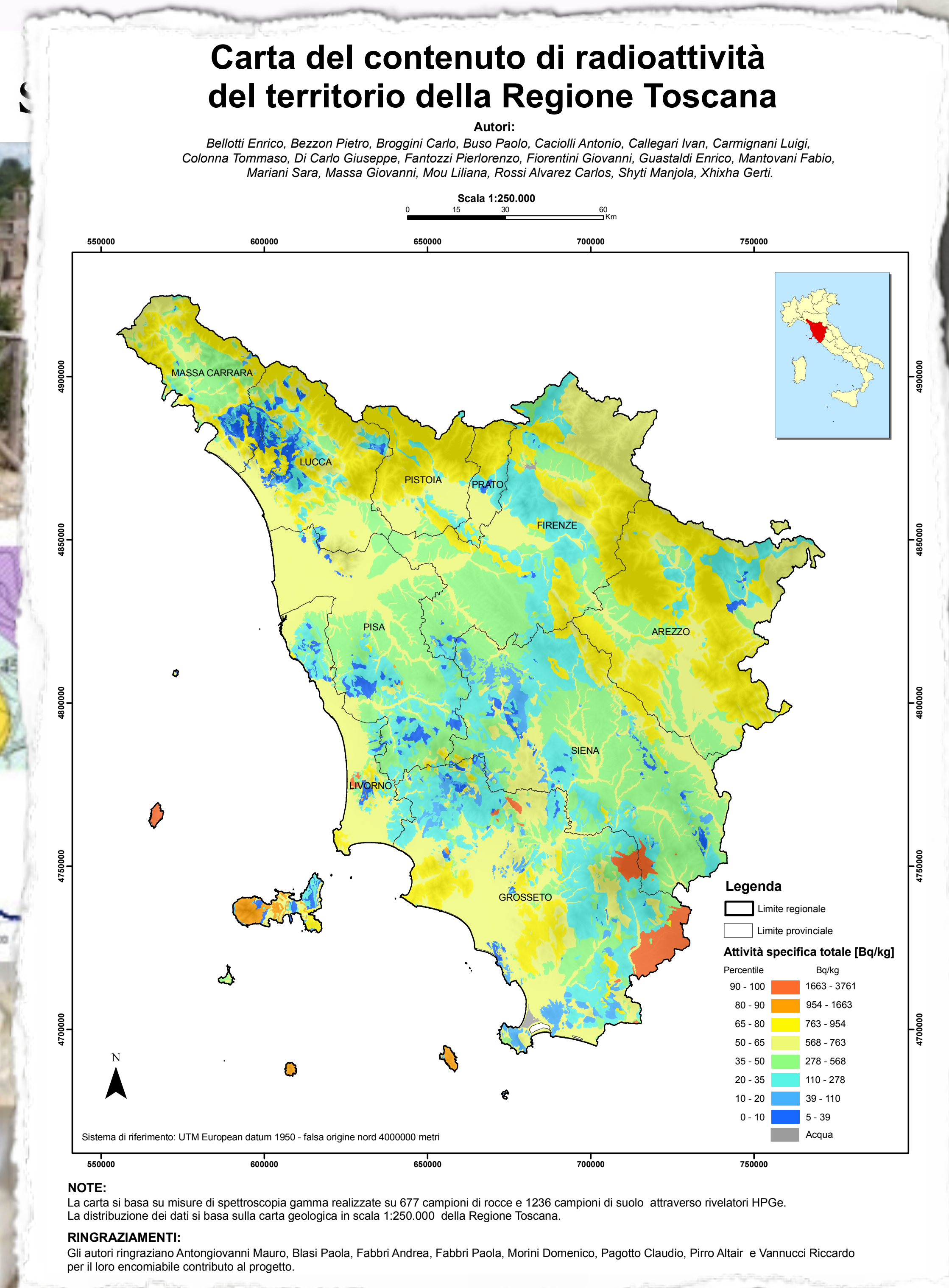
THE RAD-NAT PROJECT



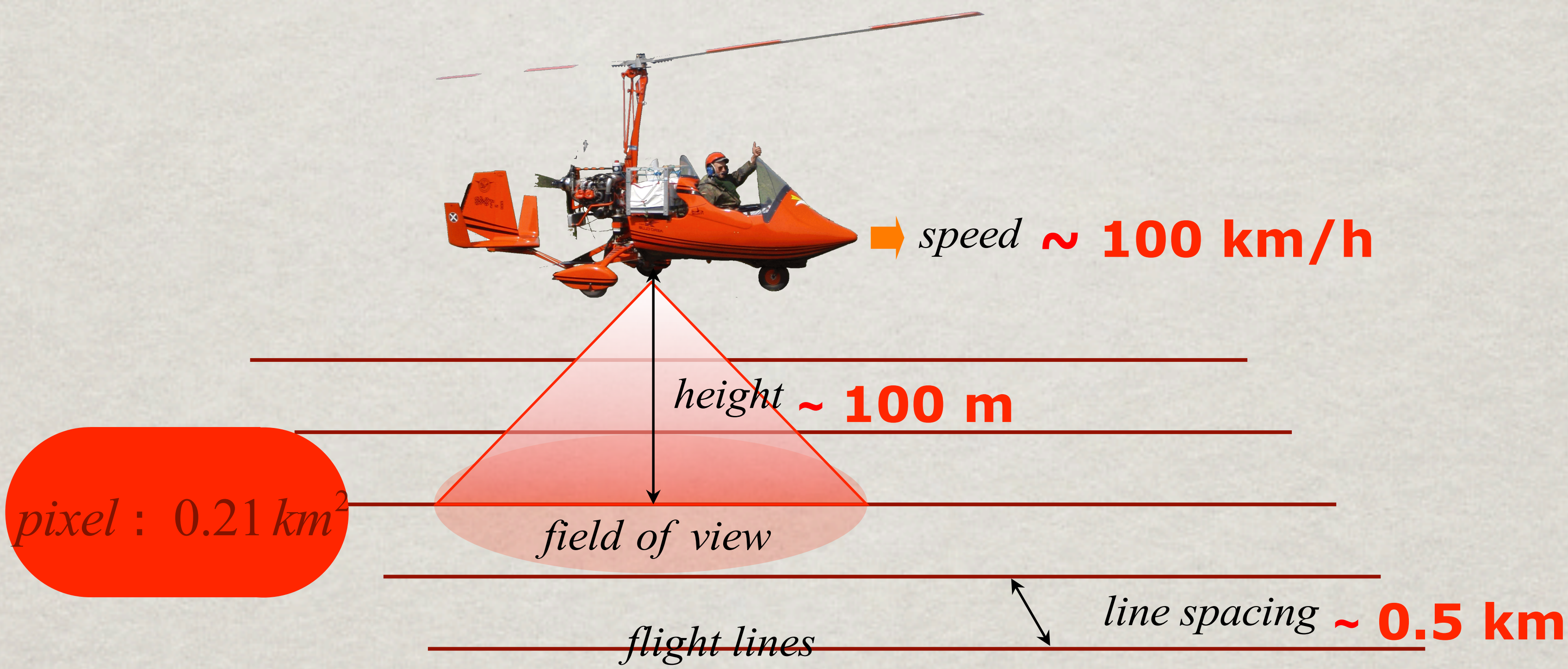
THE RAD-NAT PROJECT





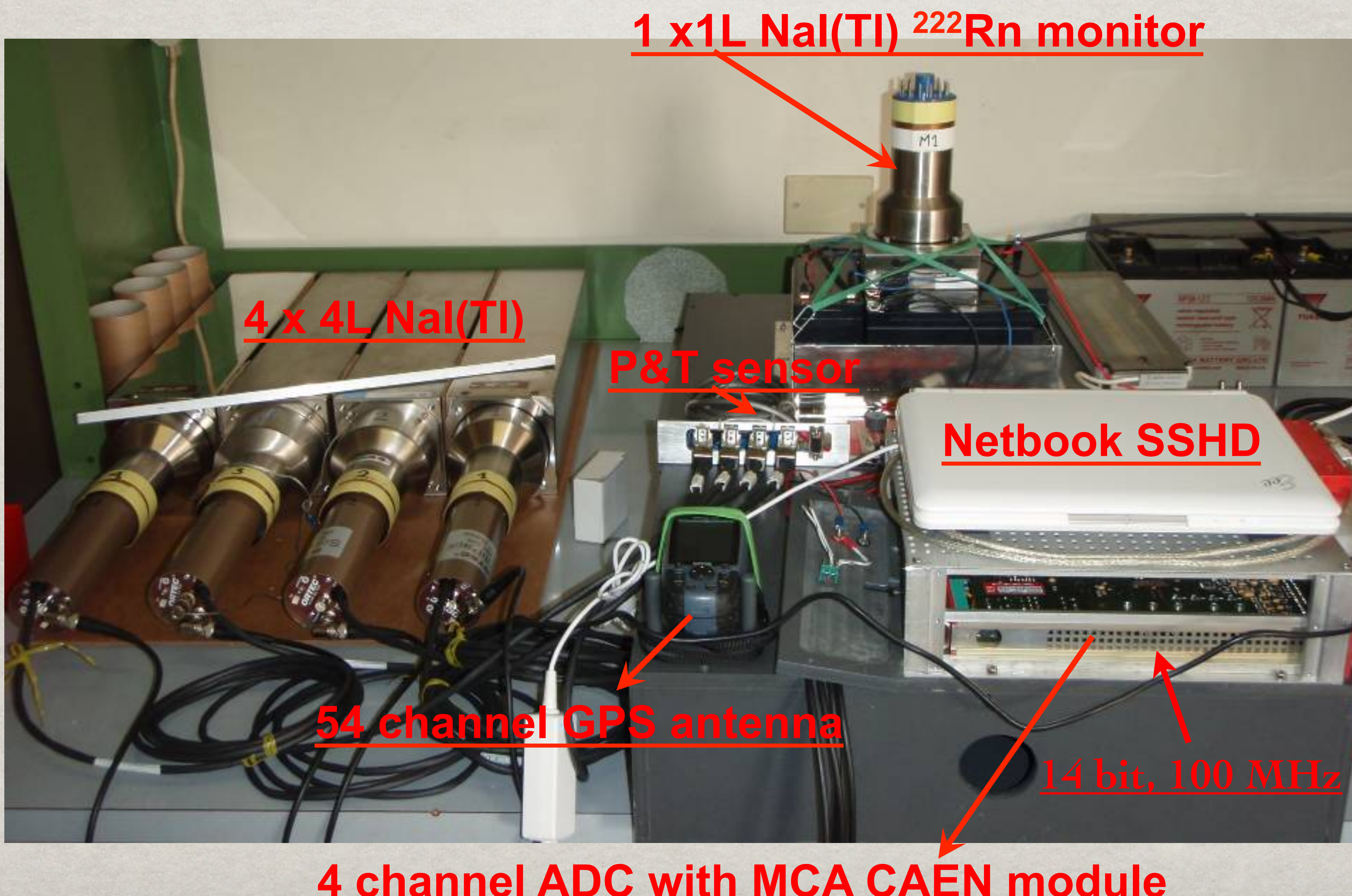


The Airborne setup:
the principles of measurements

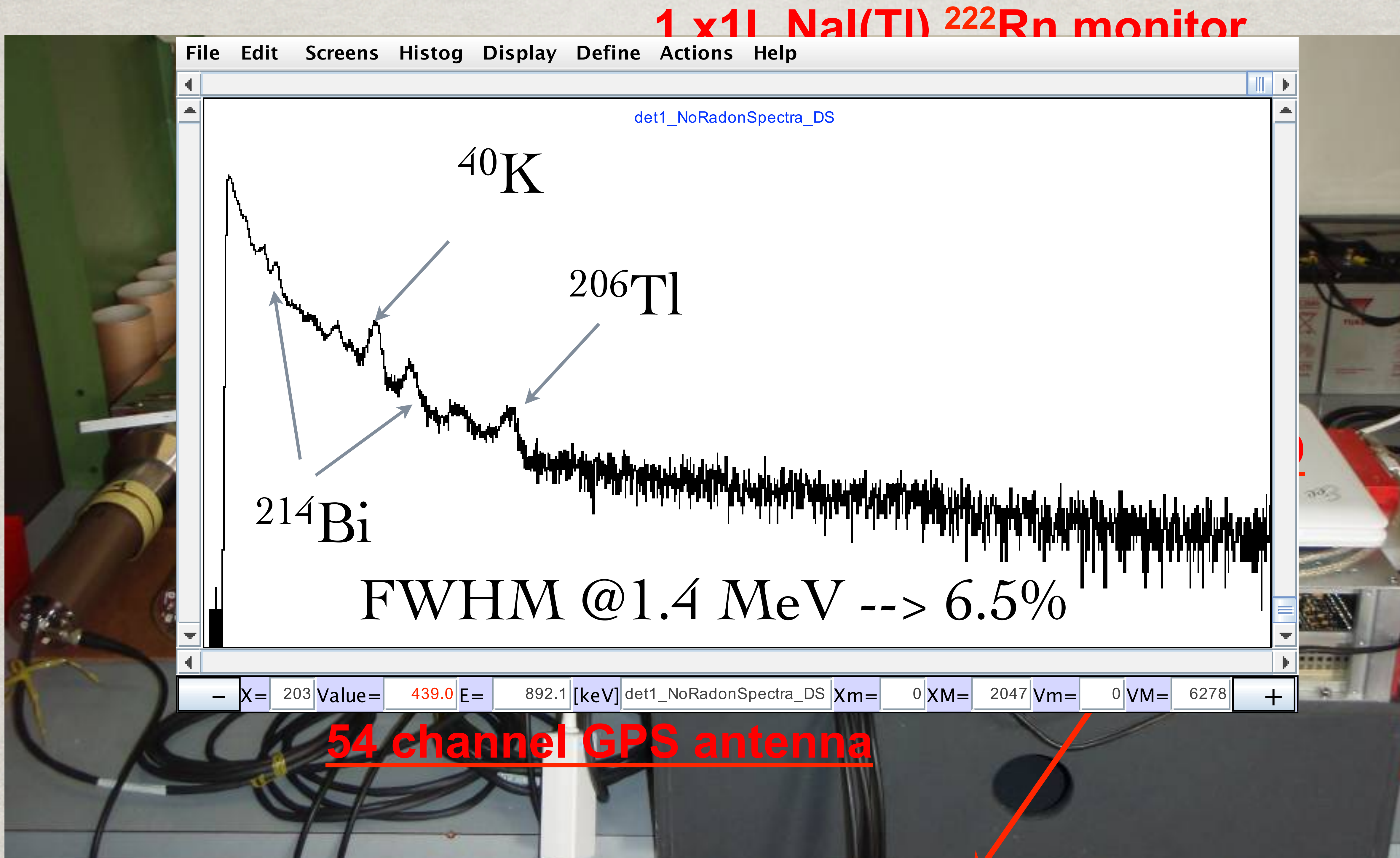


- The 16L detector runs in list mode
- Radon spectra acquired every 20 s
- GPS, temperature and pressure saved every 2 s
- measured area radius about 500 m
- Elba flight was done in 2.5 h

The Airborne setup: The all Components



The Airborne setup



4 channel ADC with MCA CAEN module

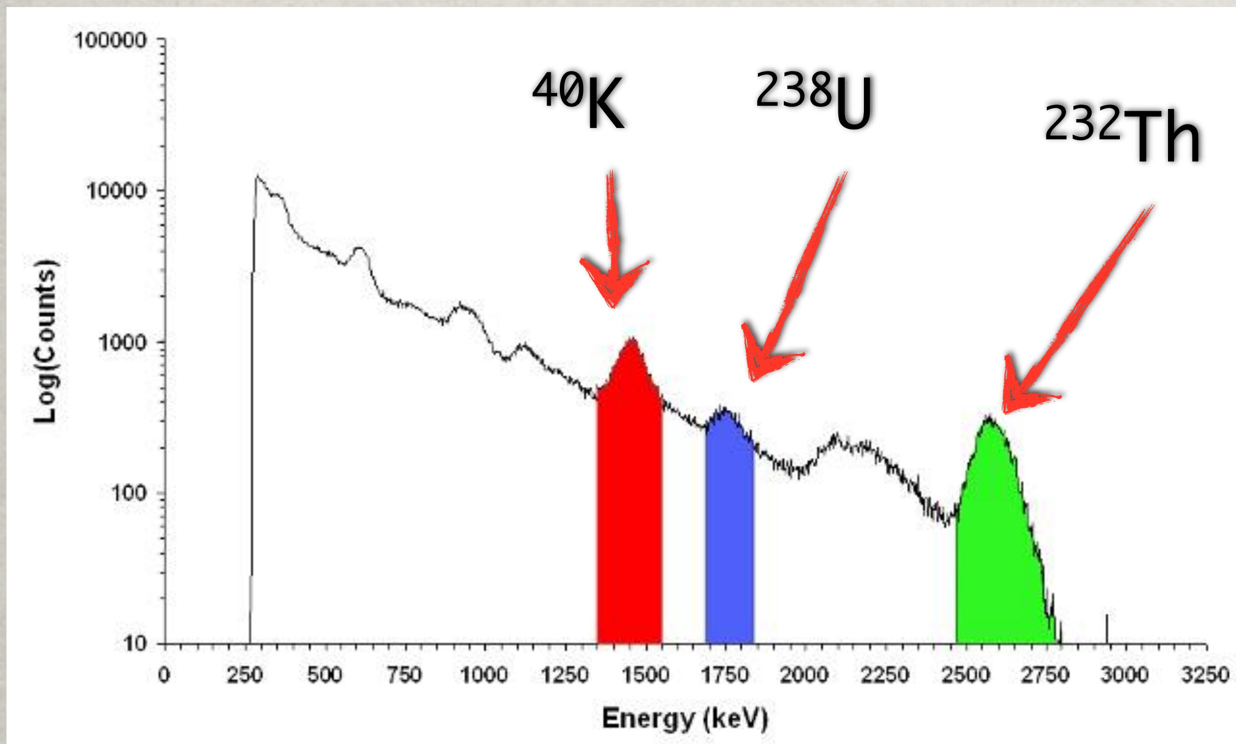
Spectra Analysis

- FSA+NNLS method
- altitude corrections to relate the measured concentration with the ground one
- radon subtraction affects the eU content increasing its systematic errors

Based on the experimental points the concentration maps are made by applying the collocated cokriging procedure guided by the geological chart.

<u>Final uncertainties around 30%</u>

Spectra Analysis

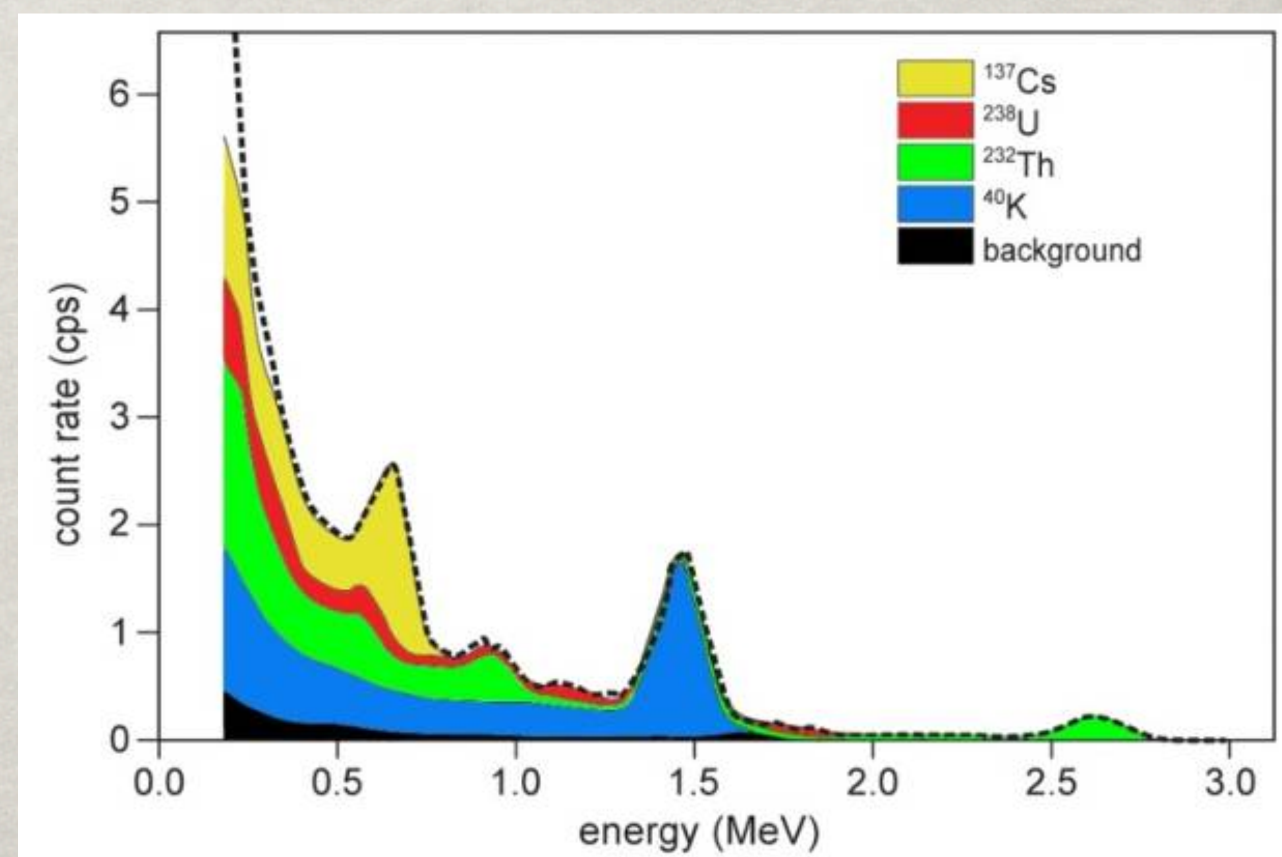


Window Analysis Method

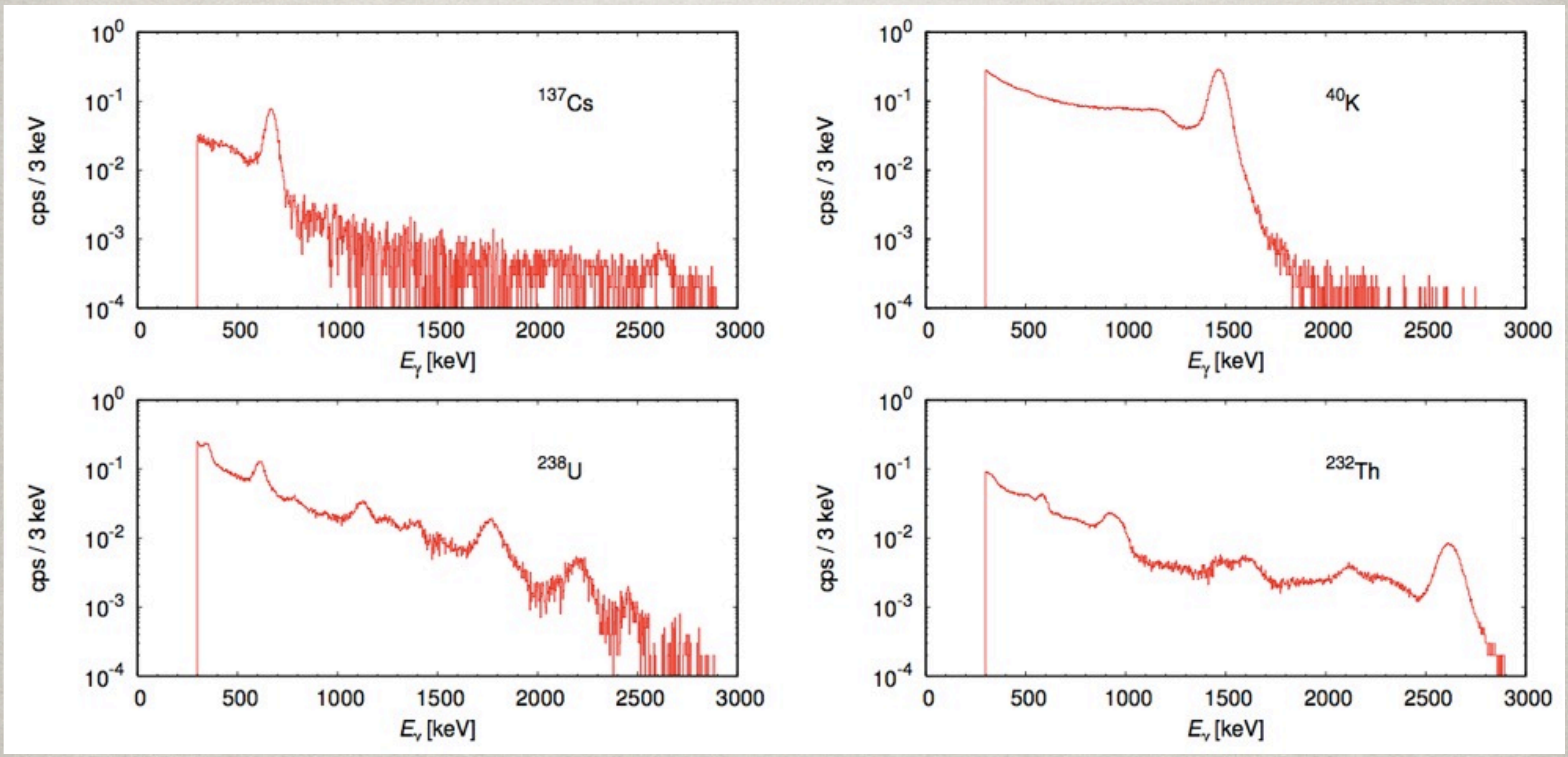
The IAEA approach is to monitor three or four relatively broad spectral windows, corresponding to main photopeaks.

Full-Spectrum Analysis

In FSA method the shape of the total spectrum is taken into account and is “unfolded” into spectra for the individual radionuclides (sensitive spectra) and a background spectrum



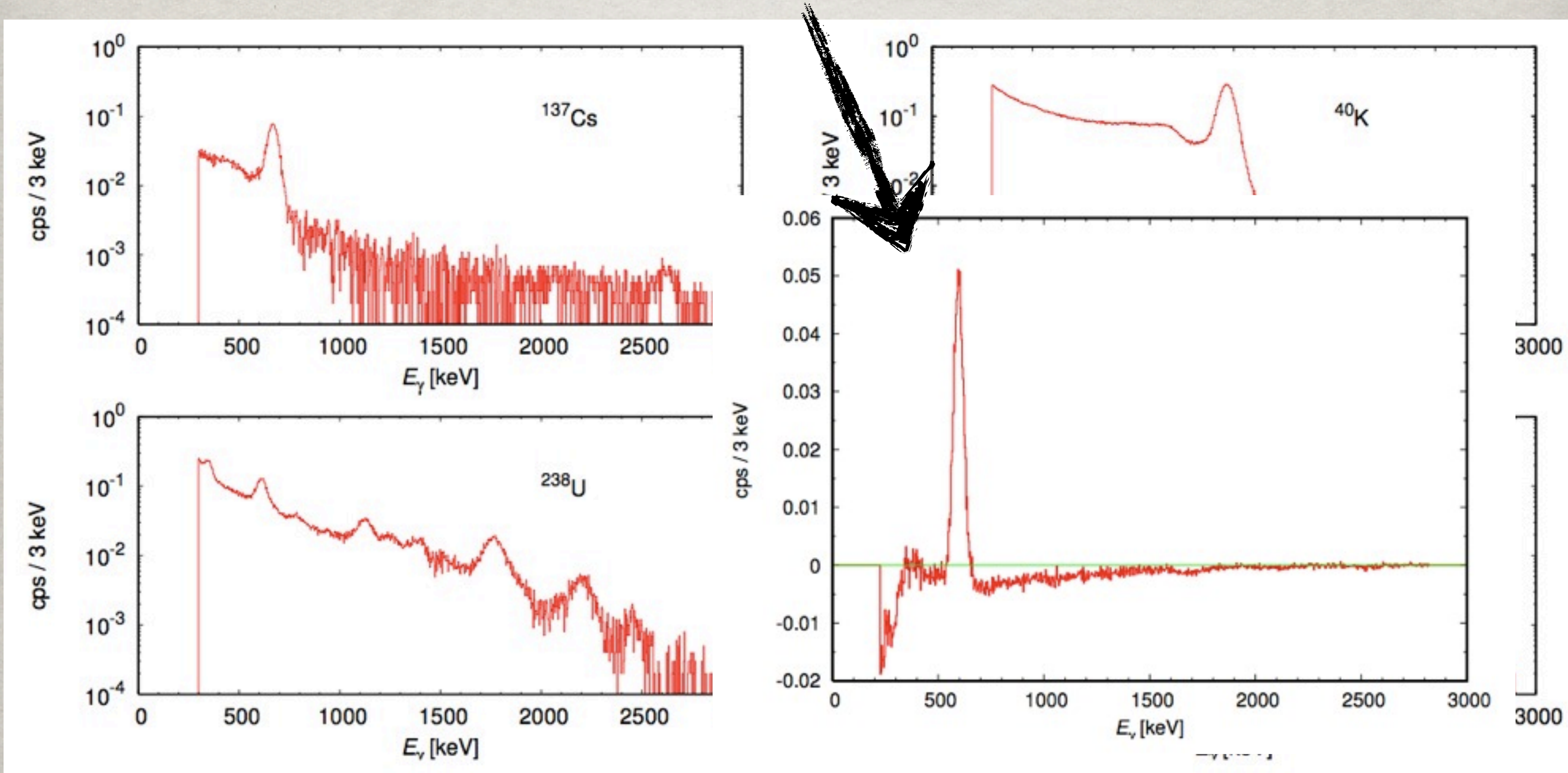
The Sensitive Spectra



Caciolli et al. Science of the Total Environment, 414(2012)639

The Sensitive Spectra

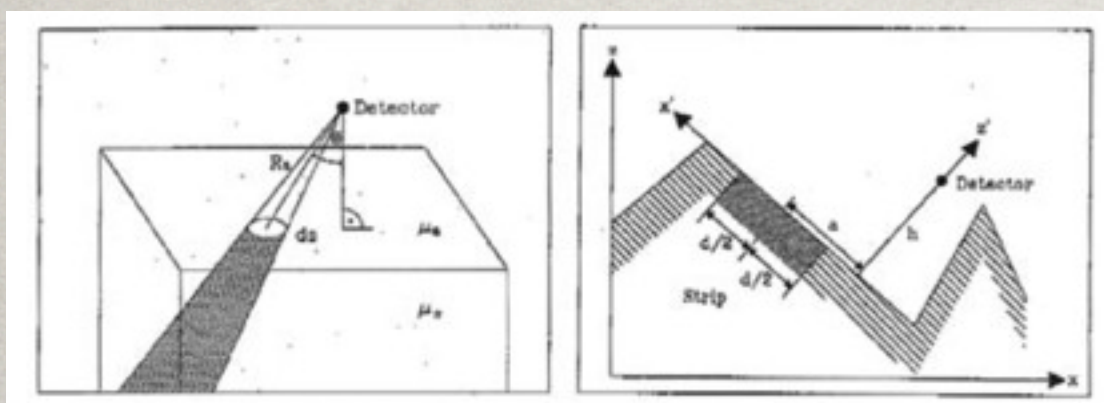
The Non Negative Least Square constraint has been introduced in the analysis to avoid non physical results



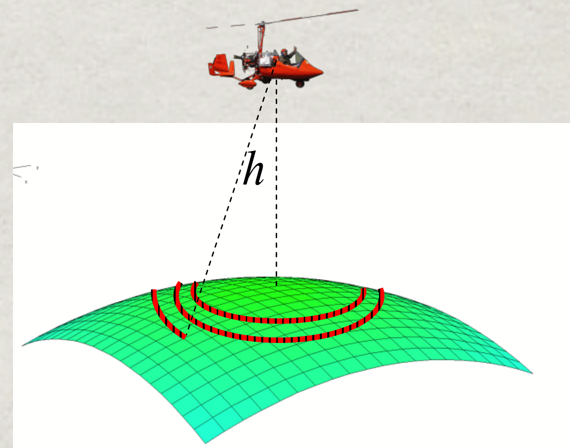
Caciolli et al. Science of the Total Environment, 414(2012)639

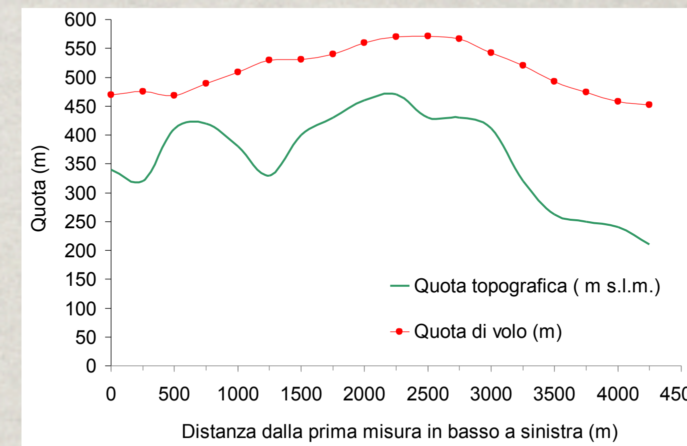
Topography Corrections

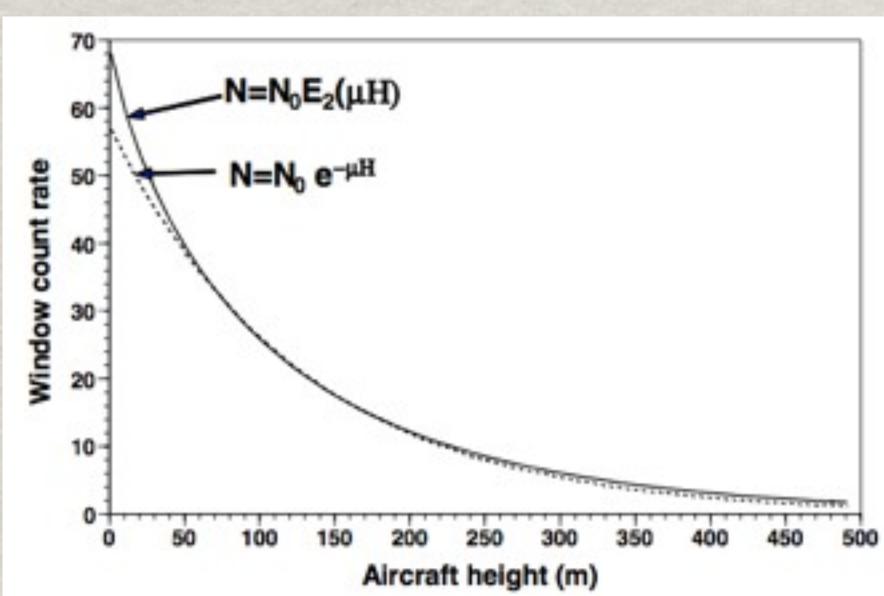
The measured element abundances are reduced to a flat ground surface placed at 100 m, by taking into account the topography of the terrain and the actual flying altitude



Schwarz et al. First BREAK 10(1992)11







Then following step is to apply the attenuation factor for each radioelements in order to determine the proper concentrations at ground surface

The altitude is derived by using the pressure and temperature measurements and the Laplace equation. It mandatory to monitor also this variables on ground.

^{222}Rn Correction

A 10 cm x 10 cm x 10 cm NaI(Tl) detector is placed in top of the system and works as monitor of the radon gas. Its cps in the total spectra are due to the radioactivity from ground and from the radon gas in air.

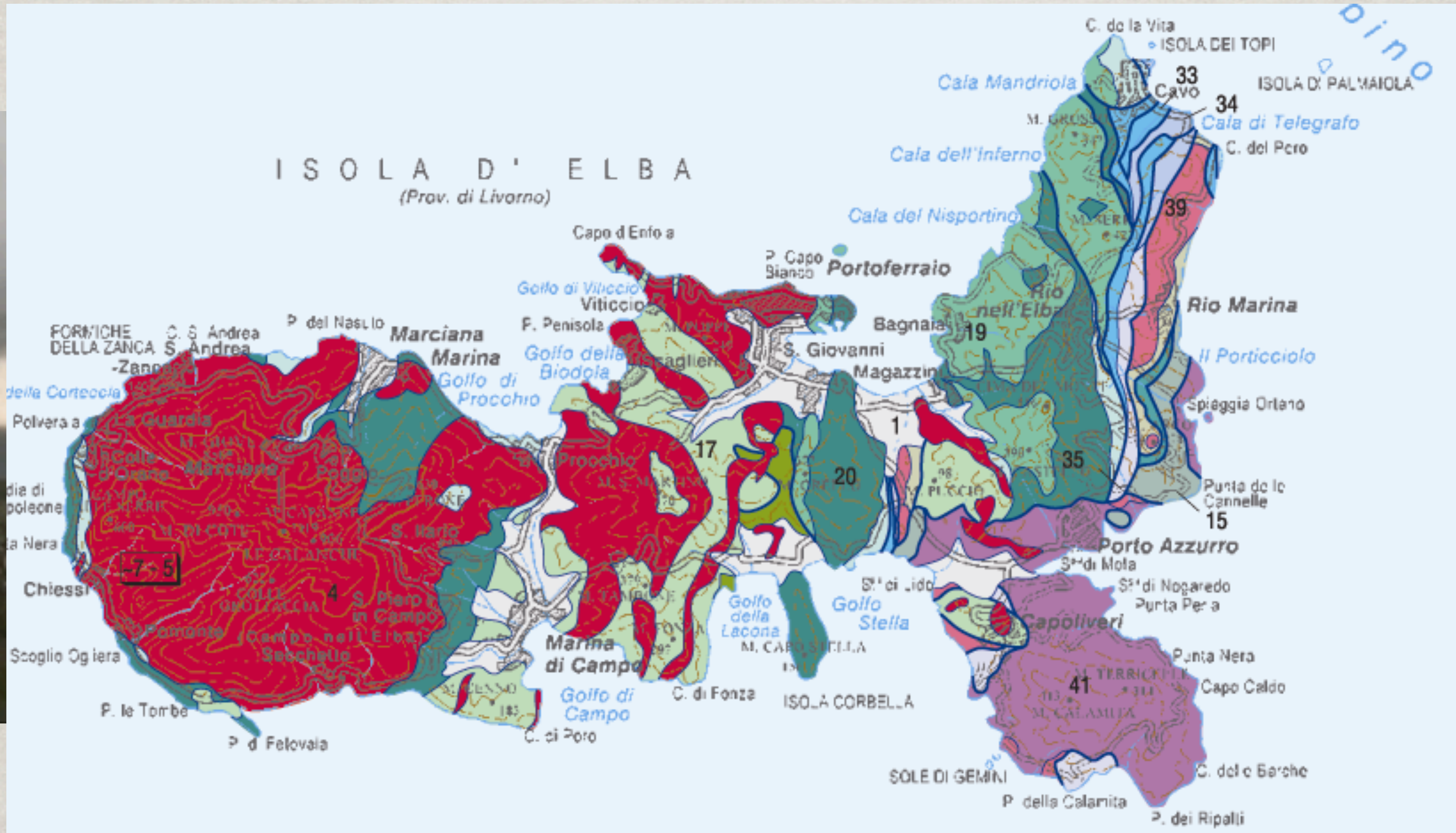
$$CR = \alpha K + \beta(U + Rn_{4L}) + \gamma Th + \delta Rn + BG$$

Since on water the signal comes out only from ^{222}Rn, cosmic rays and intrinsic background the path from Viareggio to the Elba Island was used in order to evaluate the radon correction. By measuring this value at the beginning and at the end of the flight it was possible to evaluate also the fluctuation of radon concentration during the flight time.

The radon was estimated to contribute to the eU concentration for less than 0.2 ppm which is a not negligible value only where the eU abundance is very low.

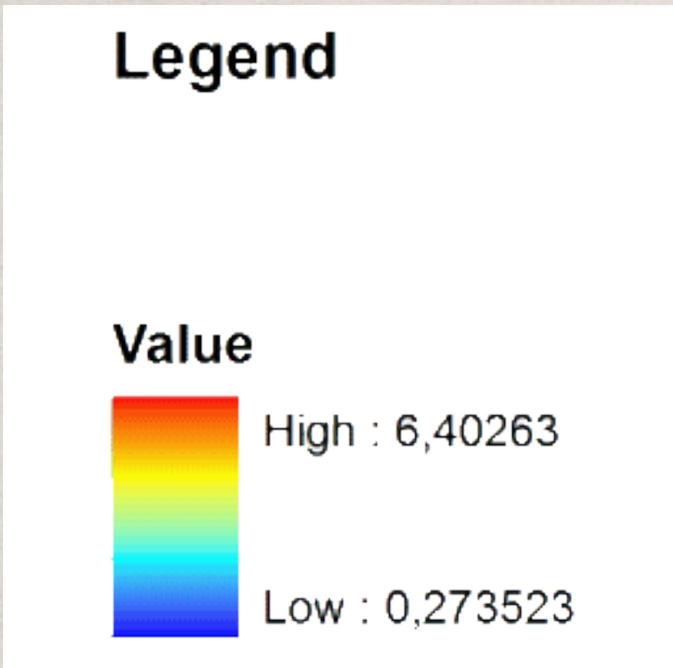
The Elba Island ... an ideal case

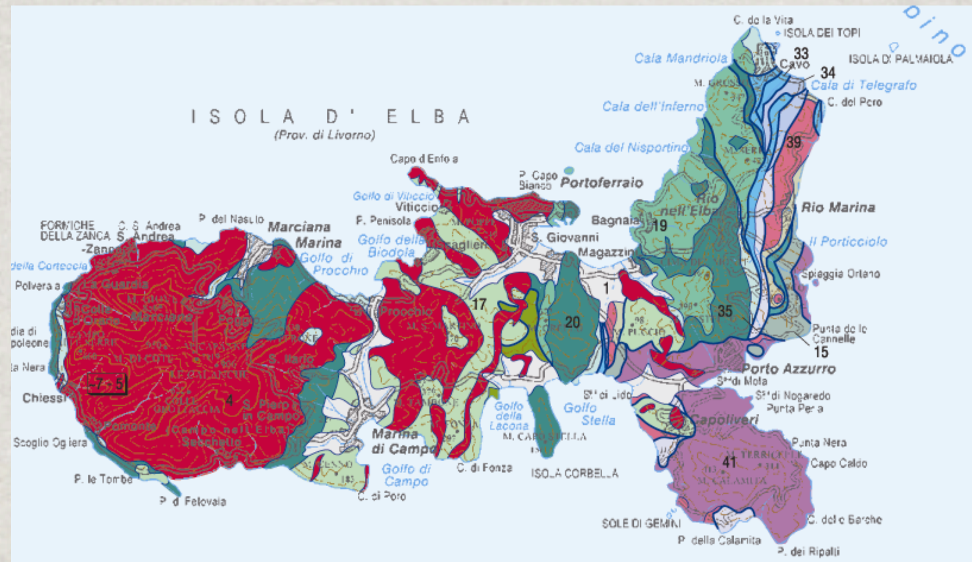
The Elba Island … an ideal case

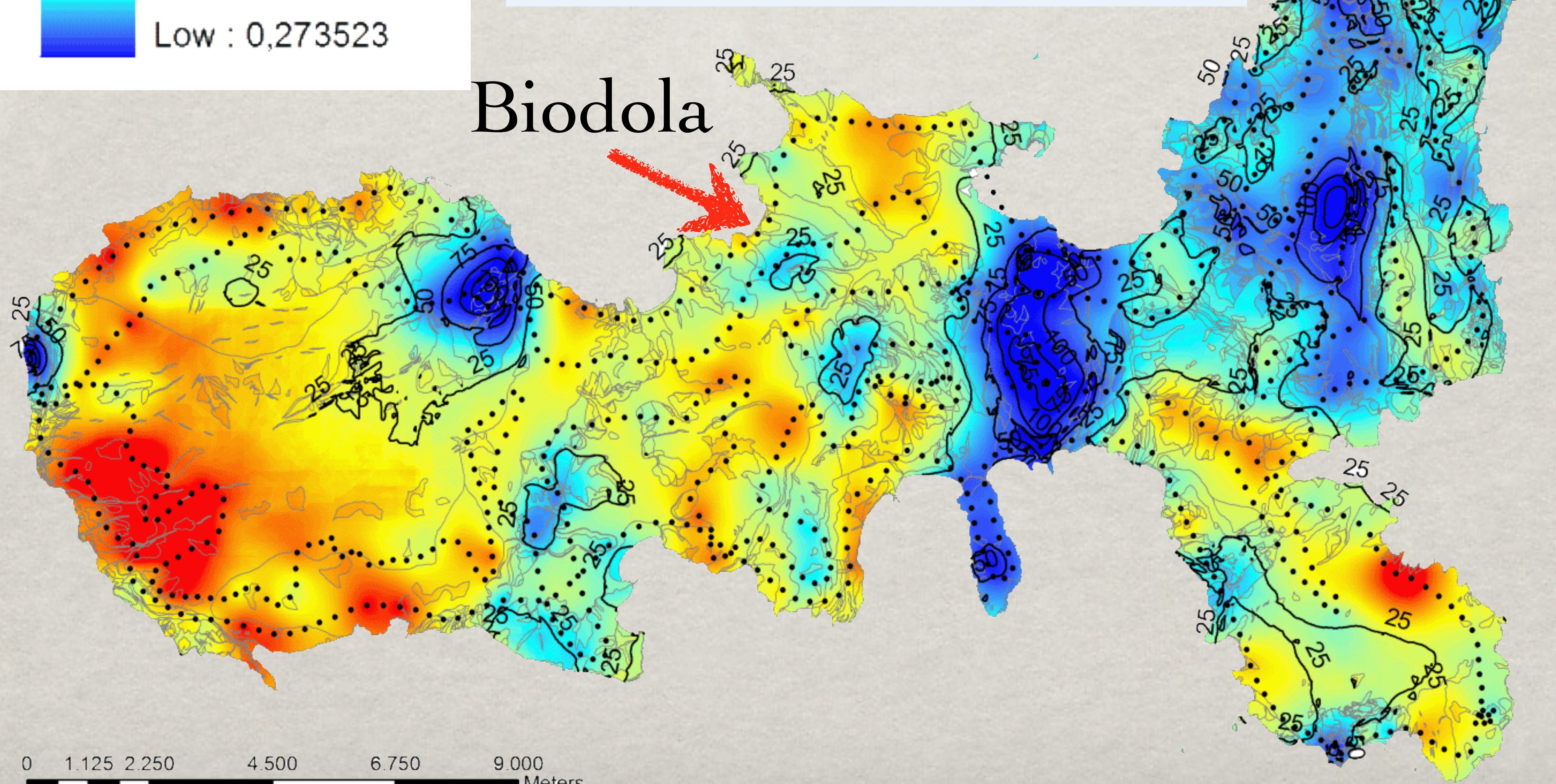


73 formations latitudinally oriented which are also representative of the Tuscany Appennini in a relatively small island (225 km^2)

^{40}K chart of Elba







Guastaldi et al. submitted to Geoderma

Conclusions

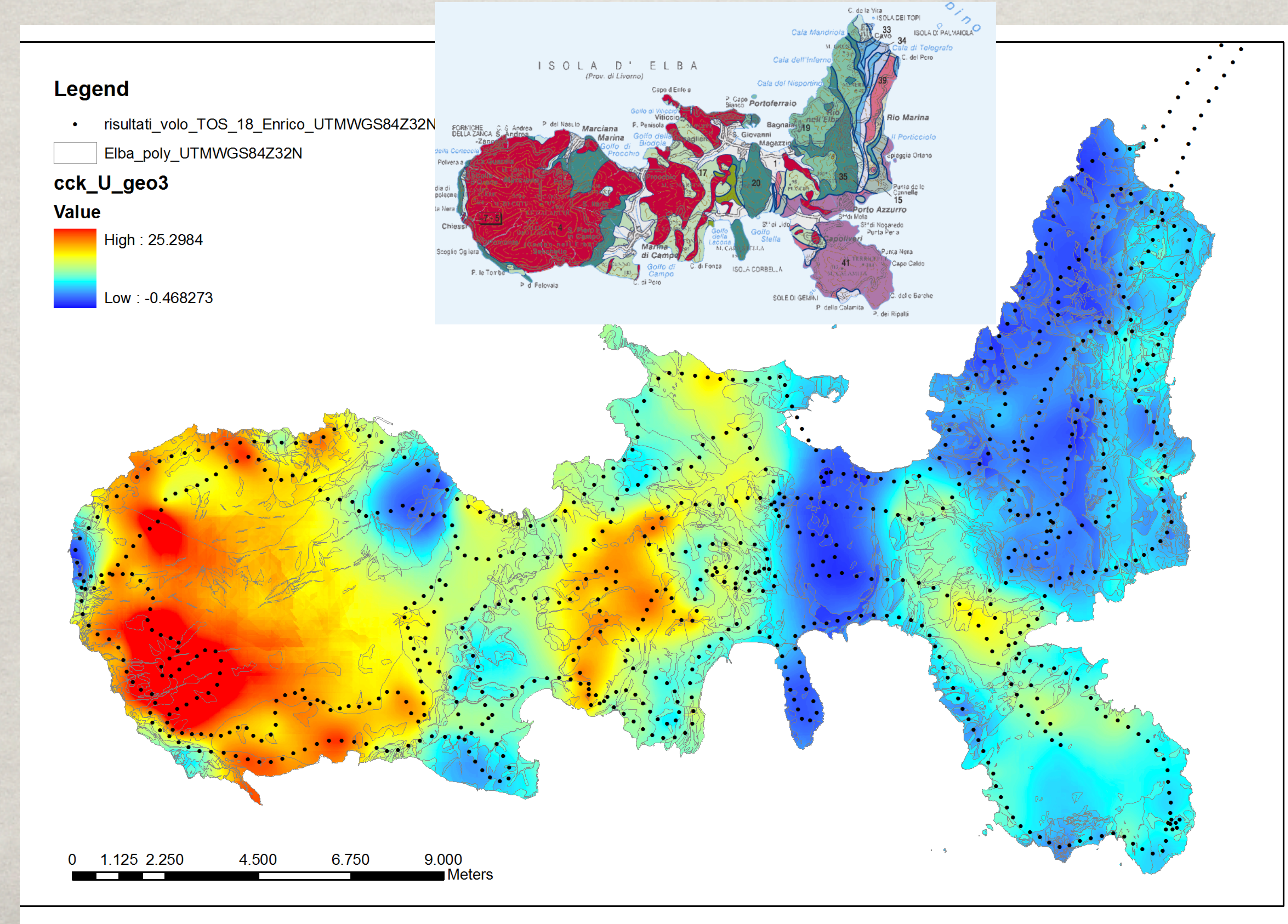
- The Rad_Monitor project is designed to measure the environmental radioactivity by using different gamma-ray spectroscopy methods
- A new AGRS system (16L NaI(Tl) detector) is developed and tested on the Tuscany region
- The first chart of the Elba Island was done by combining the information of radioactivity with the geological one
- New test flights are planned in order to reduce the systematic errors

Bellotti Enrico, Bezzon Pietro, Broggini Carlo, Buso Paolo, Callegari Ivan, Carmignani Luigi, Colonna Tommaso, Di Carlo Giuseppe, Fantozzi Piero, Fiorentini Giovanni, Guastaldi Enrico, Mantovani Fabio, Mariani Sara, Massa Giovanni, Rossi Alvarez Carlos, Xhixha Gerti, Shyti Manjola, Claudio Pagotto, Mauro Antongiovanni, Antonio Caciolli, Liliana Mou

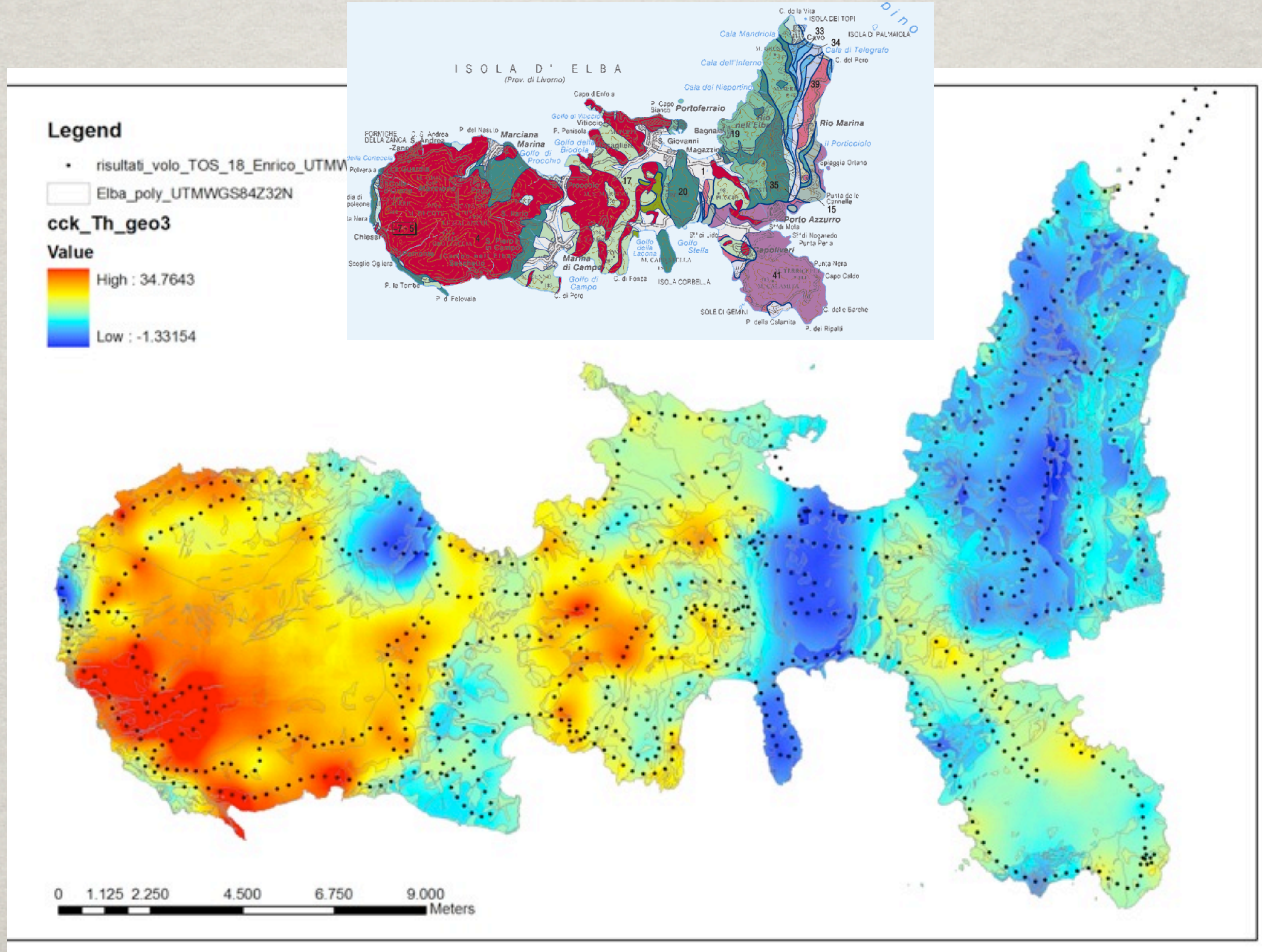

Grazie per l'attenzione!

Extra slides

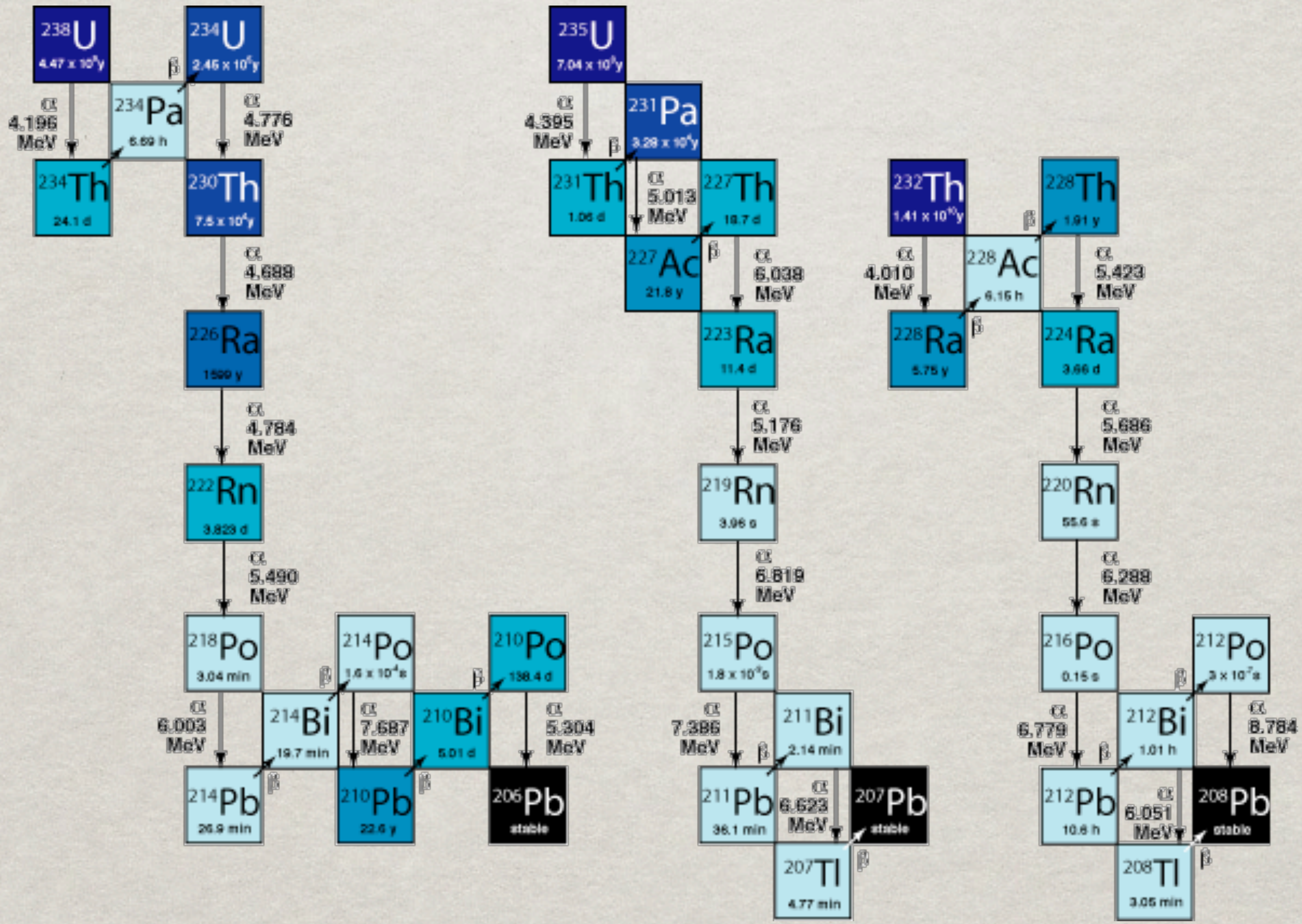
^{238}U chart of Elba



^{232}Th chart of Elba

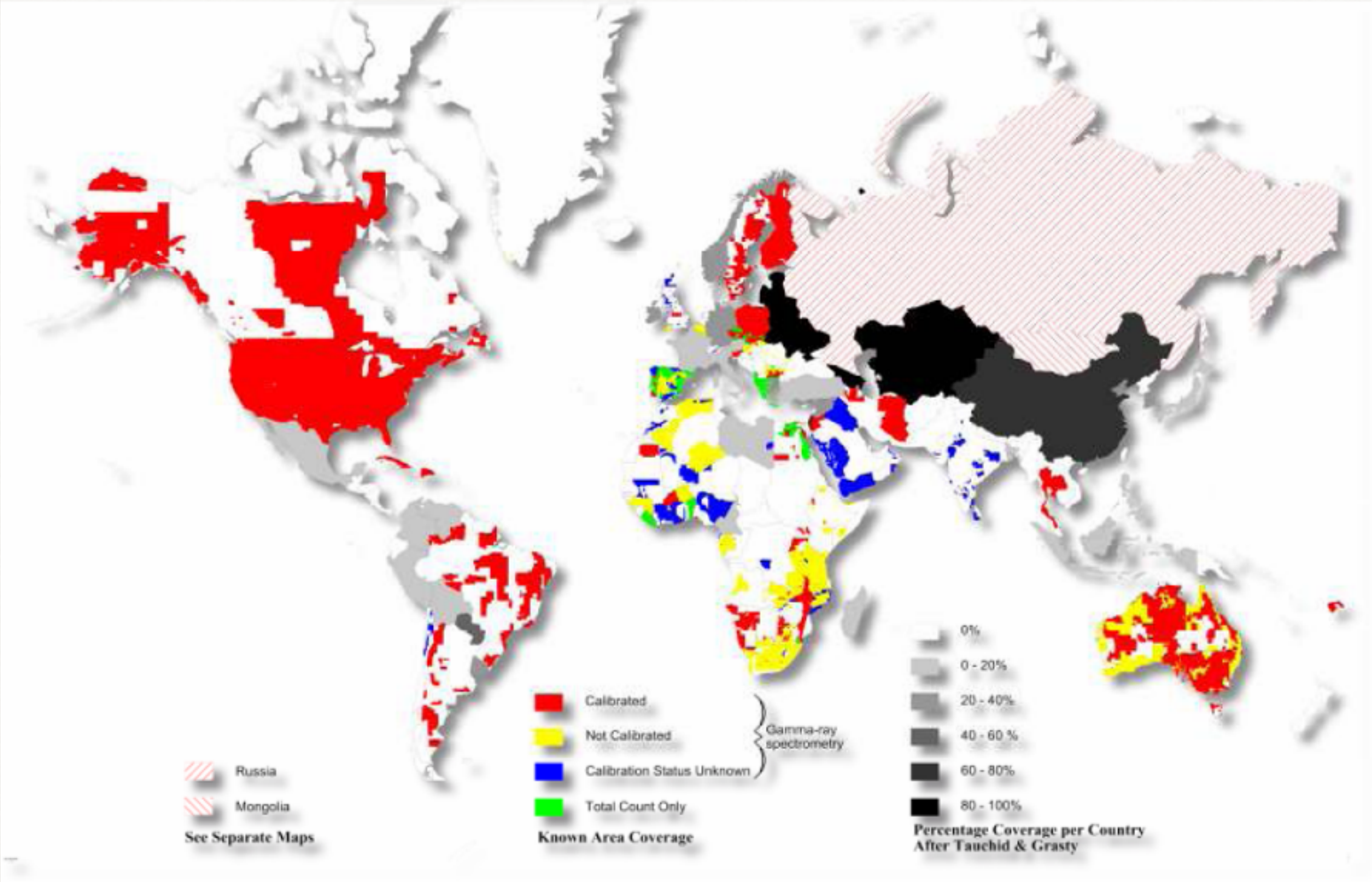


DECAY CHAINS



In our gamma measurements the secular equilibrium is supposed

around the World ...



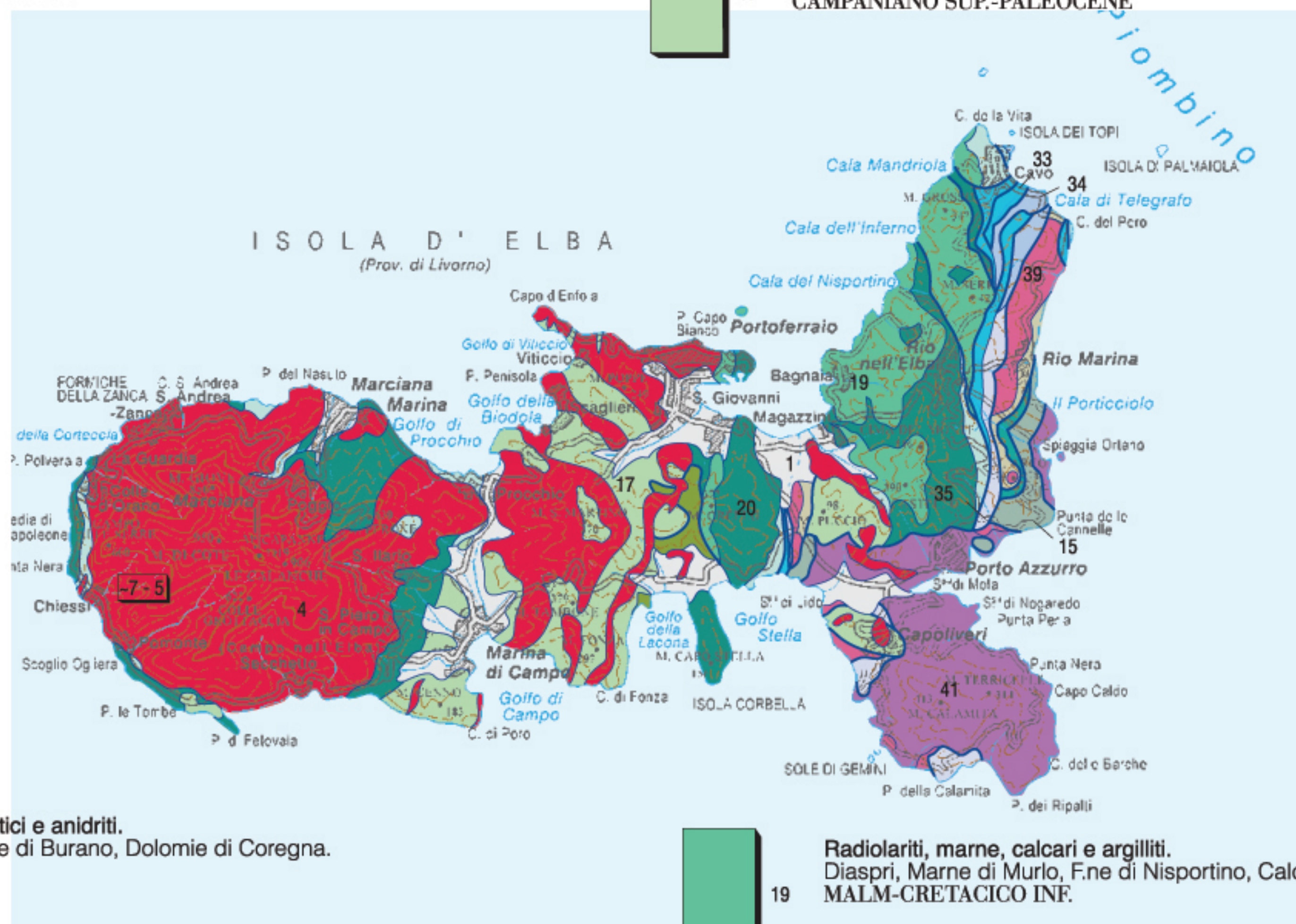
Geological Reference

4 **Rocce intrusive acide, subvulcaniche e filoniane.**
NEOGENE-QUATERNARIO

33 **Marne, argilliti, calcari nodulari, calcari selciferi, diaspri, calcilutiti e calcareniti.**
Calcari ad angulati, Rosso ammonitico, Calcare selcifero di Limano, Marne a *Posidonomya*, Calcare selcifero della Val di Lima, Diaspri, Calcari ad aptici, Maiolica.
LIAS INF. - CRETACICO INF.

20 **Ofioliti: peridotiti, gabbri, basalti, oficalciti e brecce ofiolitiche, plagiograniti; (presenti anche come masse disarticolate all'interno delle formazioni del Dominio Ligure Esterno).**
GIURASSICO

17 **Flysch arenacei: arenarie e siltiti.**
Arenarie di M. Gottero, Arenarie di Montecatini, Flysch dell'Elba, F.ne di Marina di Campo, Arenarie di Ghiaieto.
CAMPANIANO SUP.-PALEOCENE



35 **Dolomie, calcari dolomitici e anidriti.**
Calcare cavernoso, F.ne di Burano, Dolomie di Coregna.
TRIAS SUP.

41 **Basamento ercinico: filladi, quarziti, calcescisti, metacalcari, metarcose, dolomie, scisti grafitosi, metabasiti.**
Filladi inferiori, Filladi e quarziti di Buti, Scisti di Ortano, Gneiss del Calamita, Porfiroidi e scisti porfirici, Quarziti e filladi superiori, Scisti a Graptoliti, F.ne di Risanguigno, Dolomie a *Orthoceras*.
CAMBRIANO? - DEVONIANO

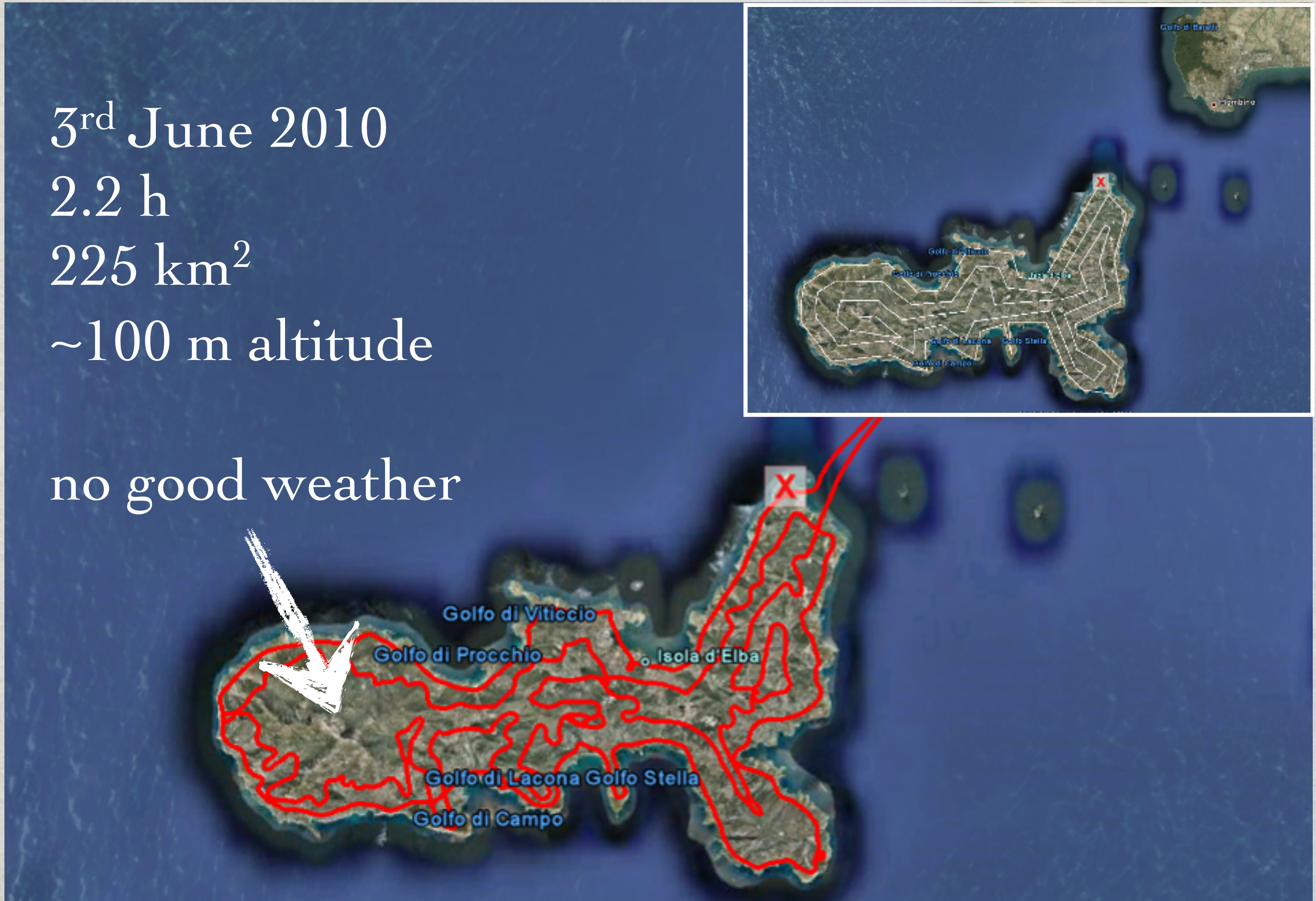
19 **Radiolariti, marne, calcari e argilliti.**
Diaspri, Marne di Murlo, F.ne di Nisportino, Calcari a Calpionelle.
MALM-CRETACICO INF.

1 **Sabbie, ciottolami e limi (depositi alluvionali, eolici, lacustri, palustri, lagunari e di spiaggia).**
QUATERNARIO

Flight path

3rd June 2010
2.2 h
225 km^2
~100 m altitude

no good weather



Laboratory Measurements

In Situ Samples Collection

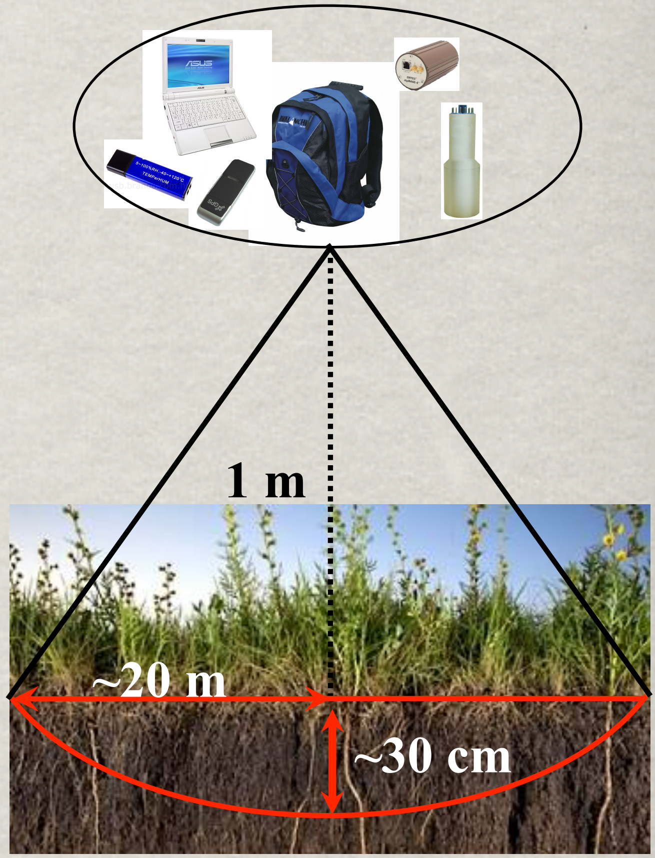
Laboratory Measurements

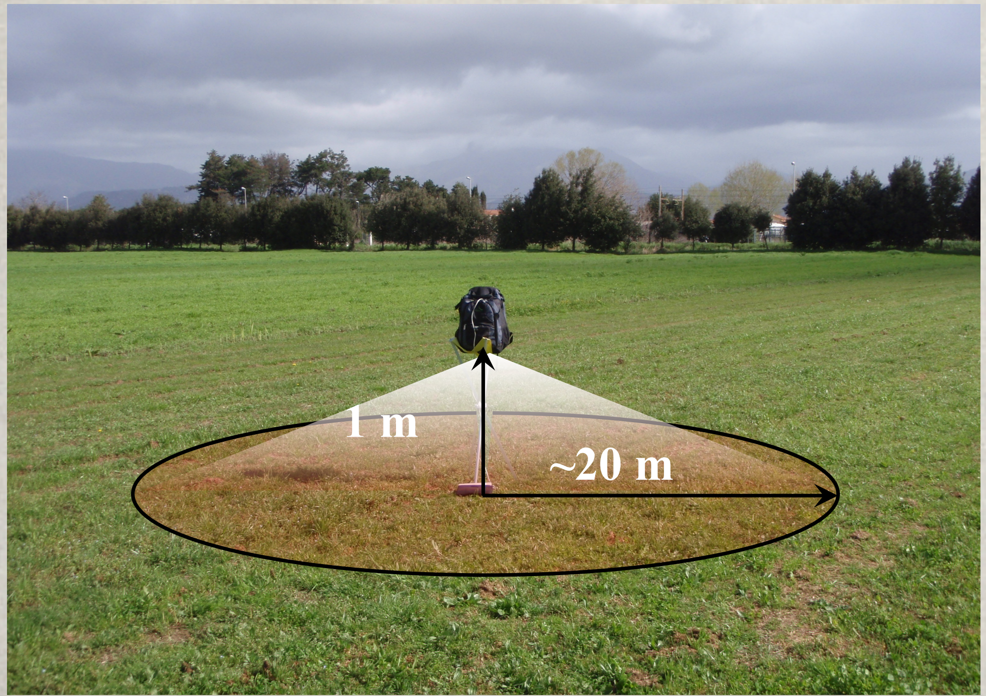
- 2 HPGe faced
- lead and copper shielding
- high resolution
- 1h measurements
- completely automatized

Xhixha et al. submitted to J. Rad. Env.

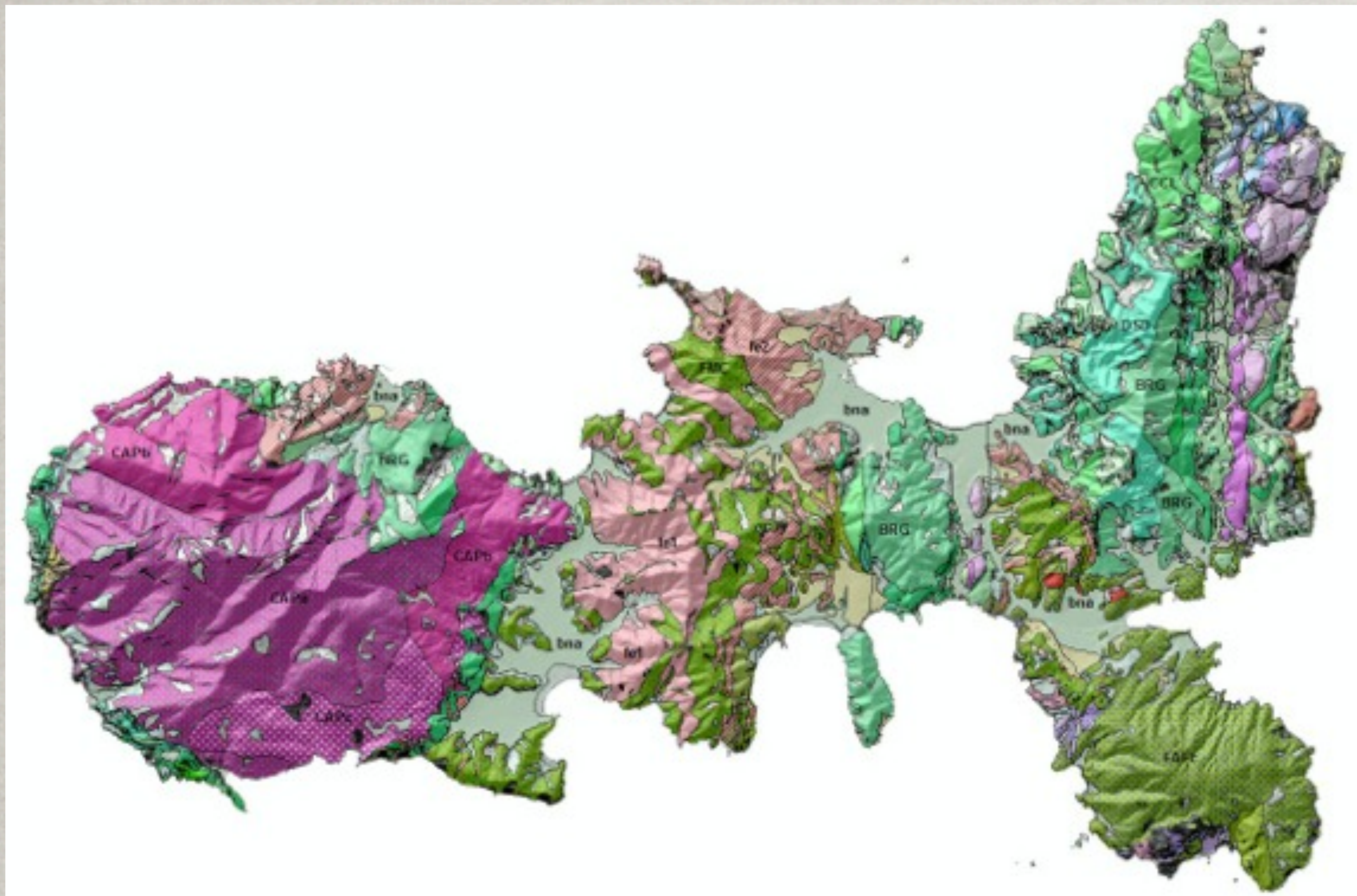
Portable Detector

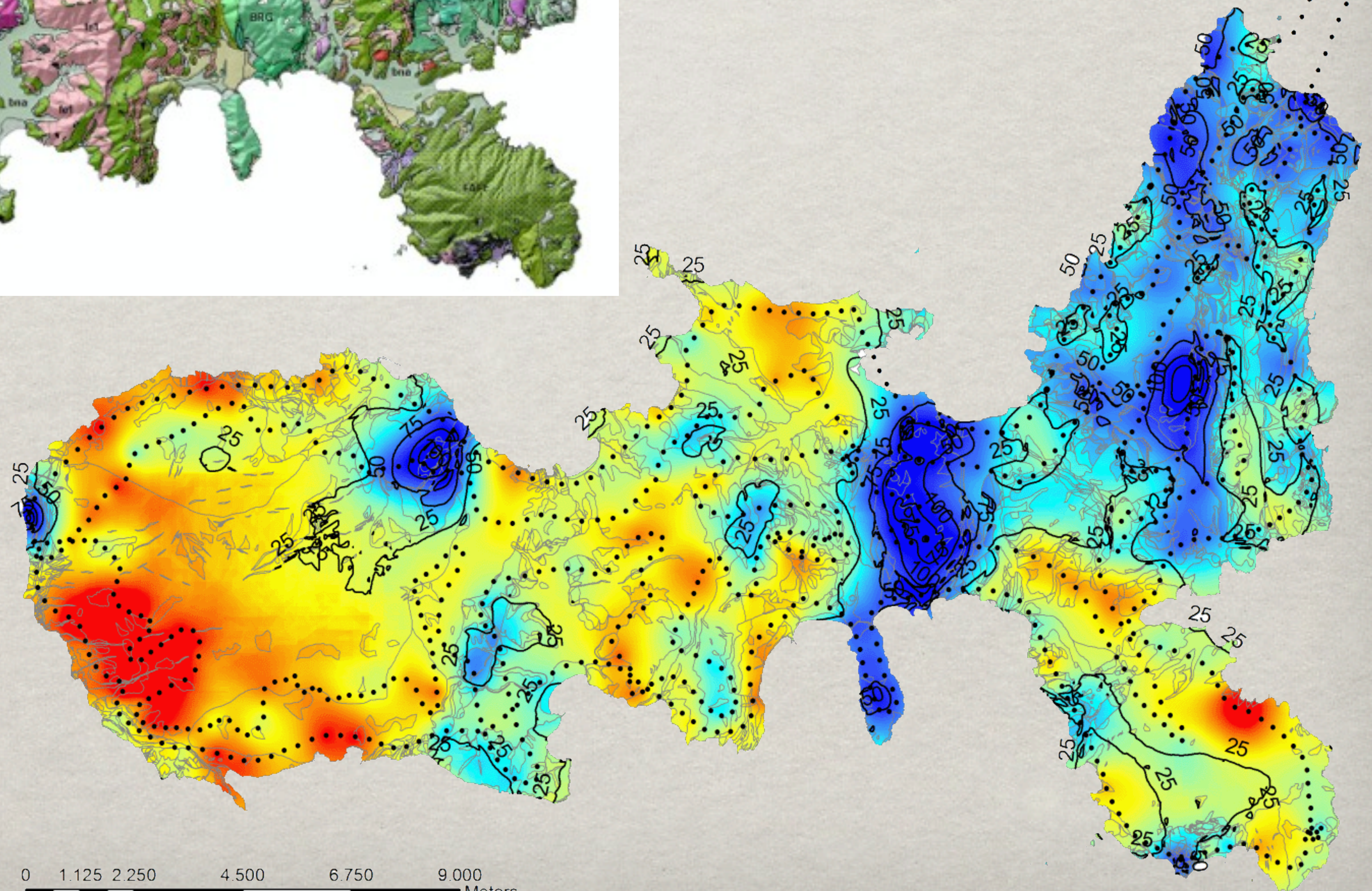
NaI(Tl) 1 liter detector controlled by a DiGiBase preamplifier.
The signal is acquire by MAESTRO software





It is possible to measure in static position or in movement.
5 minutes spectra enough to reduce the statistics errors below 5%



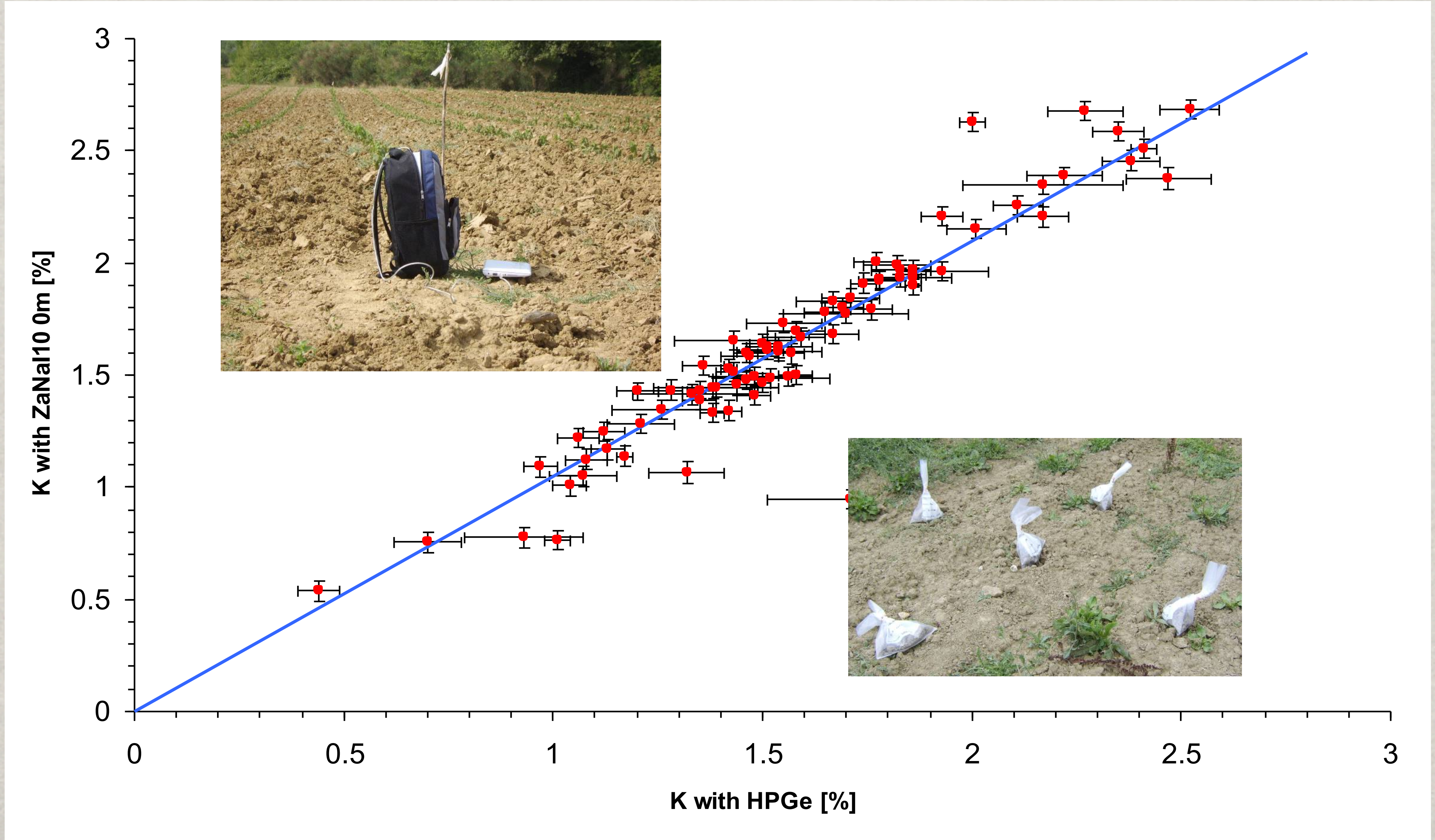

0 1.125 2.250 4.500 6.750 9.000
Meters

EXPERIMENTAL UNCERTAINTIES

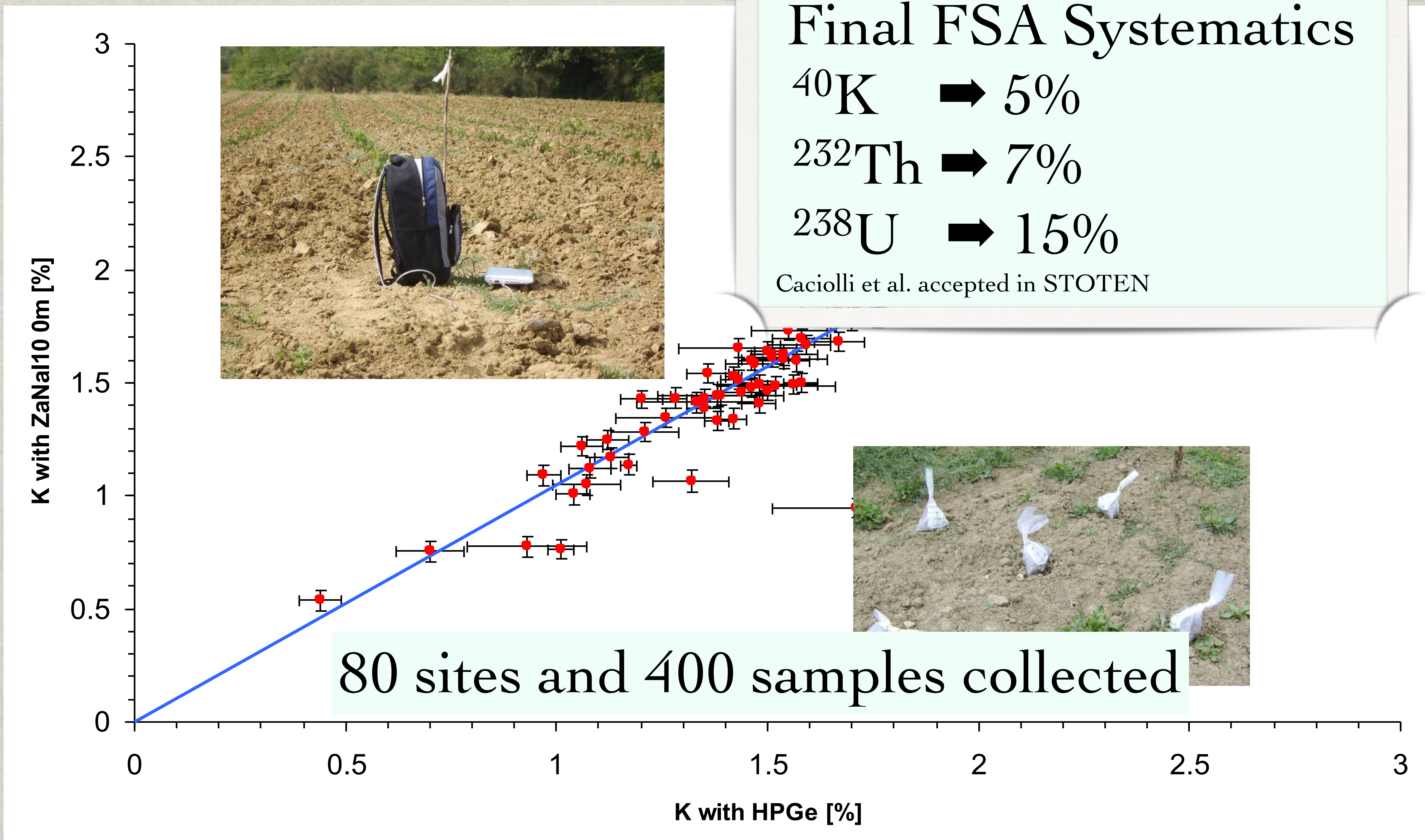
source	relative uncertainty
altitude corrections	8%
spectra deformation due to calibration on ground	< 15%
Radon (only for uranium)	average 20%
statistics	5%-15%

Method Validation

The validation has been done measuring with the portable NaI(Tl) and by collecting samples in the same place



Method Validation



Final FSA Systematics

^{40}K ➡ 5%

^{232}Th ➡ 7%

^{238}U ➡ 15%

Caciolli et al. accepted in STOTEN

80 sites and 400 samples collected

FSA method

$$N(i) = \sum_{k=1}^{4} C_k S_k(i) + B(i)$$

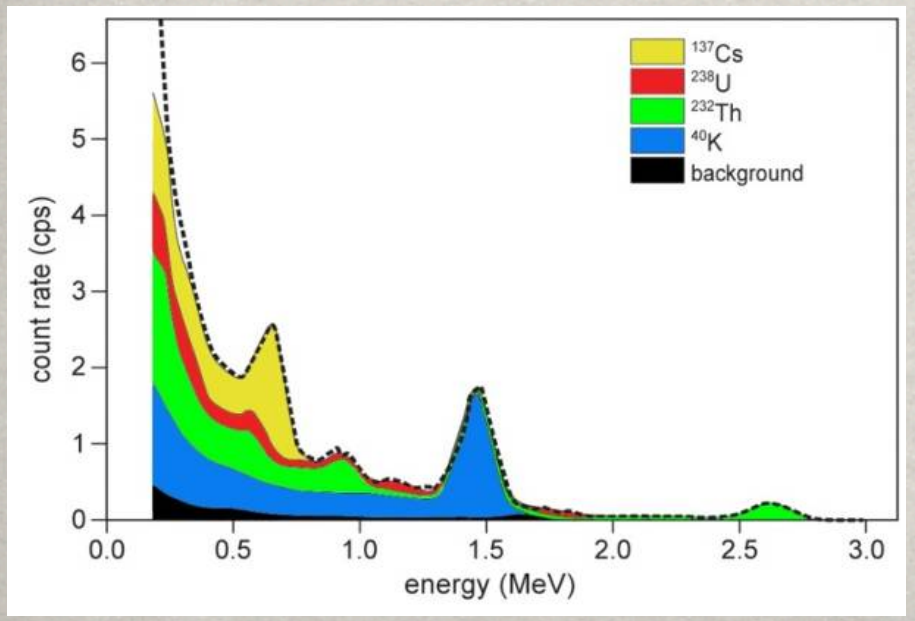
channel *i* in acquired spectrum

selected radionuclide

radionuclide concentration

channel *i* in the sensitive spectrum of the k element

intrinsic background



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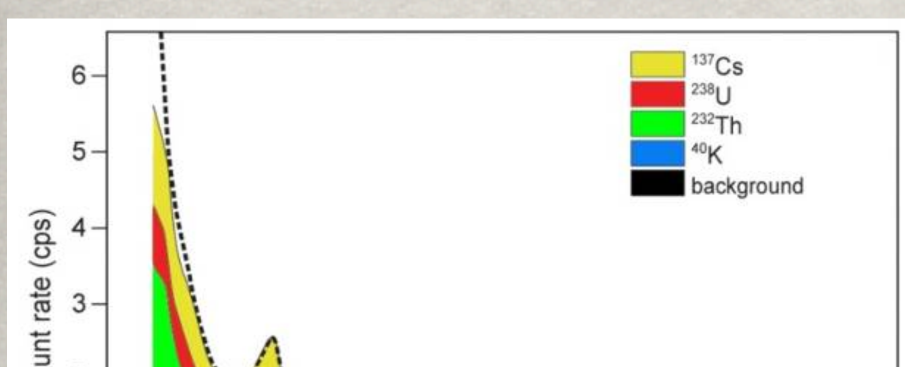


The FSA allows to measure the concentration of not only natural radioisotopes but also the anthropic one, like ^{137}Cs

FSA method

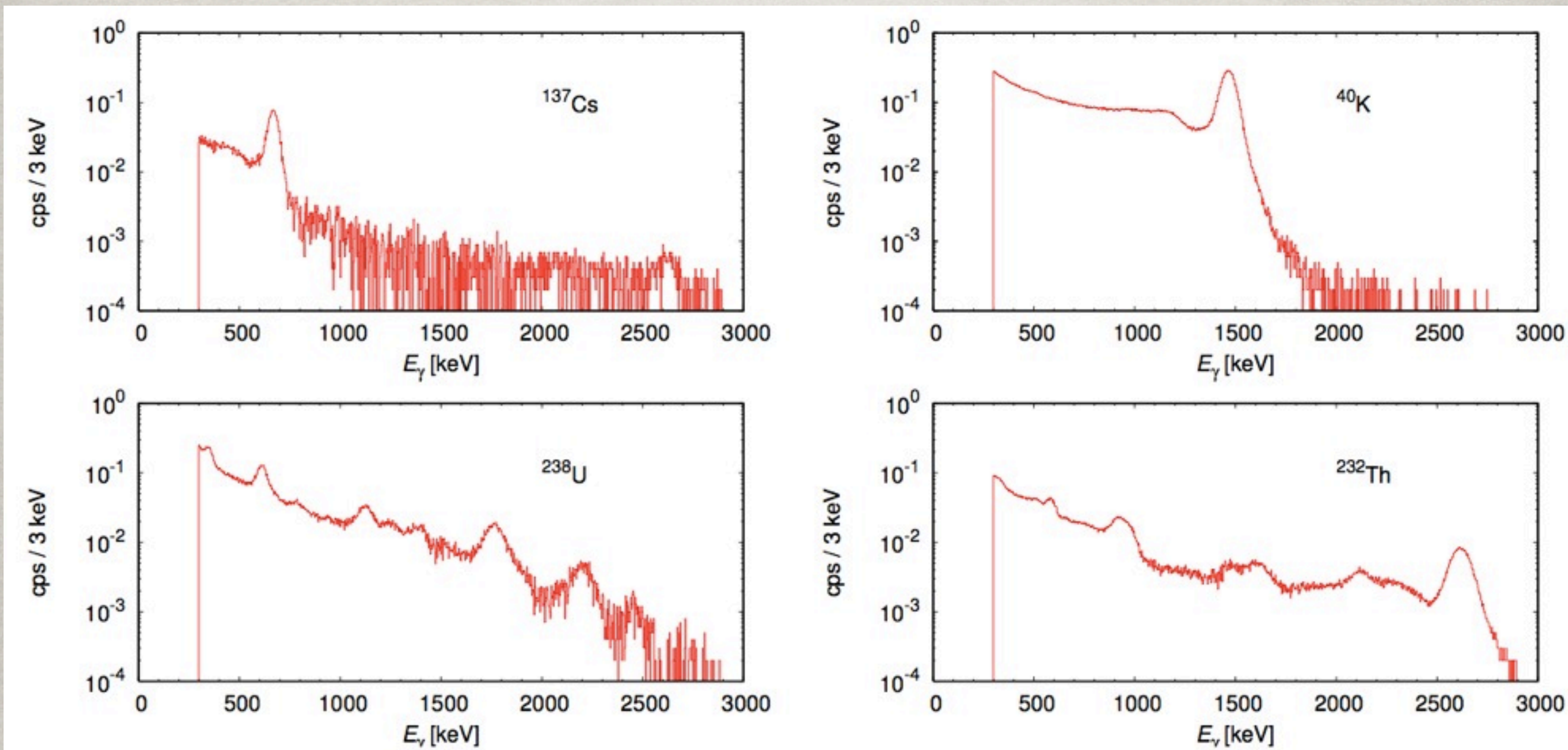
$$N(i) = \sum_{k=1}^{4} C_k S_k(i) + B(i)$$

$$\chi^2 = \frac{1}{n-5} \sum_{i=1}^{n} \left[N(i) - \sum_{k=1}^{4} C_k S_k(i) - B(i)\right]^2 / N(i)$$

- by measuring in sites with unbalanced element concentration we can calibrate our system and derive the sensitive spectra [S]
- the concentration matrix [C] is obtained by collecting samples in the calibration sites and then measuring them with the laboratory system

$$[S] = [C]^{-1} \times [N]$$

The Sensitive Spectra



Caciolli et al. Science of the Total Environment, 414(2012)639