POLITECNICO MILANO 1863

La misura del radon: aspetti strumentali e metrologici

Dr.ssa Luisella Garlati

AMBIENTE LAVORO

Introduzione

Argomenti trattati:

- Come si misura il radon: strumentazione attiva e strumentazione ad integrazione;
- Come si caratterizza la strumentazione: le camere radon;
- La riferibilità metrologica;
- Interconfronti in laboratorio e in campo;
- Aspetti strumentali da tenere in considerazione durante le campagne di misura.

Come si misura il radon

1- Metodi istantanei e continui (attivi)

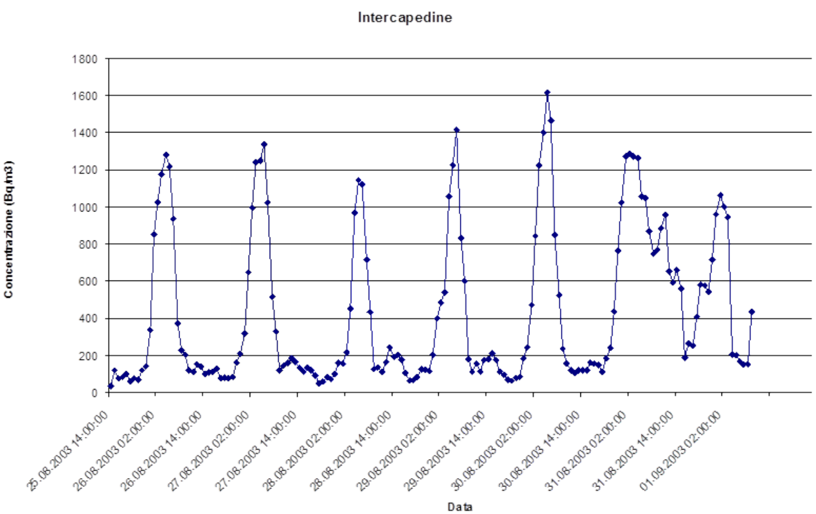
- Camere a ionizzazione
- Celle a scintillazione
- Dispositivi basati su campionamento su filtro

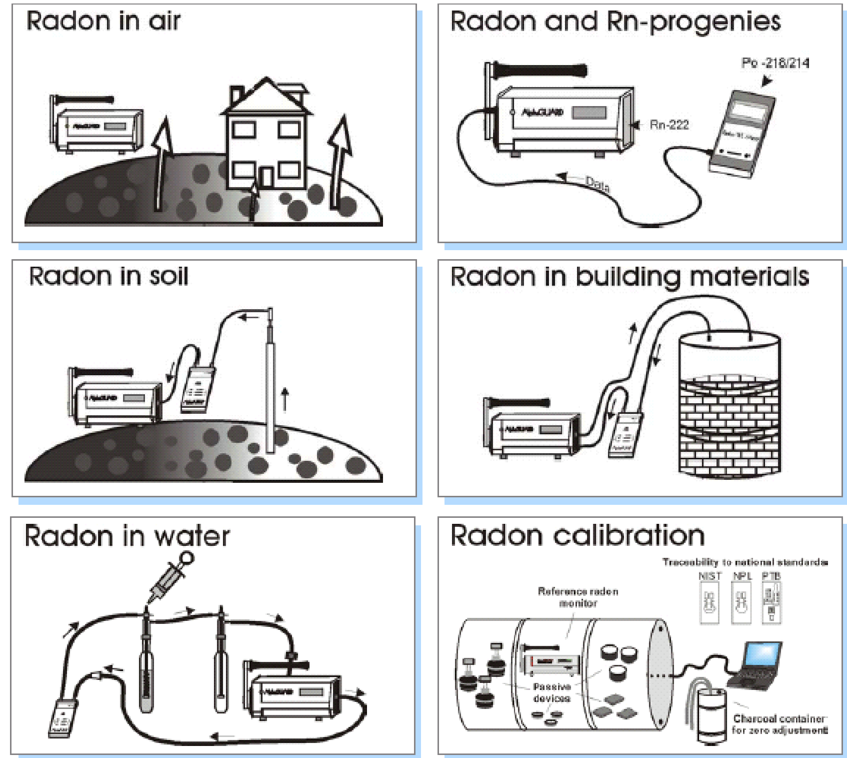
2- Metodi ad integrazione (passivi)

- Elettrete
- Rivelatori a tracce nucleari
- Carboni attivi

Metodi continui: camera a ionizzazione

AlphaGUARD





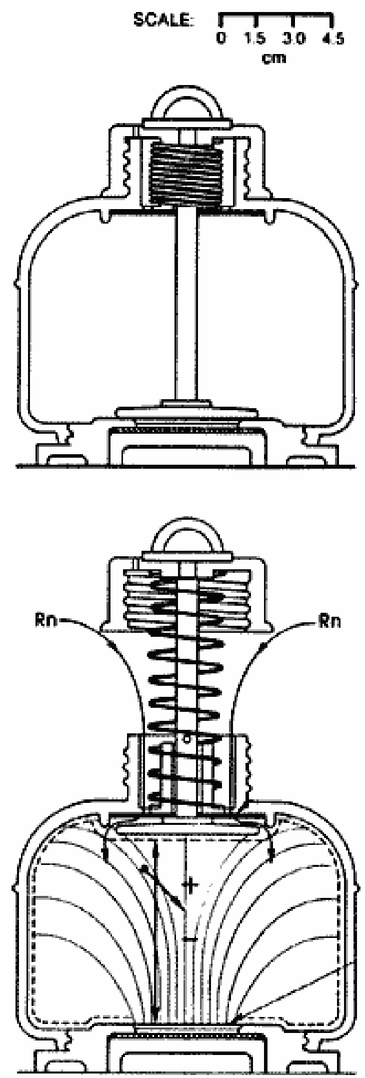
Metodi continui: altri strumenti

Metodi continui: semiconduttori

Dimensioni	120 x 69 x 22,5 mm
Peso	130 g (batterie incluse)

Dimensioni	200 x 150 x 90 mm
Peso	500 g circa

Metodi ad integrazione: elettreti



Metodi ad integrazione: CR-39

Rivelatori a tracce nucleari – CR 39

Acronimo di Columbia Resin 1939 (allile diglicole-carbonato)

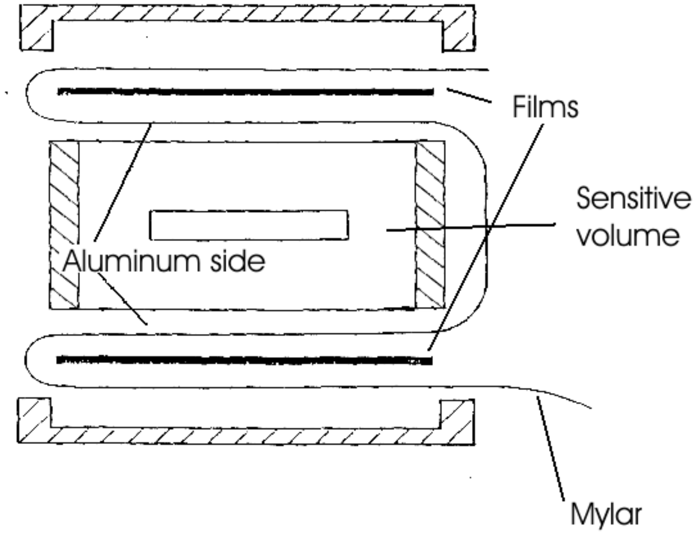



Metodi ad integrazione: LR-115

Rivelatori a tracce nucleari – LR 115

Nitrato di cellulosa prodotto dalla Kodak






Metodi ad integrazione: carboni attivi

Scintillazione liquida

Spettrometria gamma

Riferimenti standard internazionali

ISO 11665:2012 *composta da 9 parti*

Measurement of radioactivity in the environment -- Air: radon-222

ISO 13164:2013 *composta da 4 parti*

Water quality -- Radon-222

ISO 16641:2014

Measurement of radioactivity in the environment -- Air -- Radon 220: Integrated measurement methods for the determination of the average activity concentration using passive solid-state nuclear track detectors

Riferimenti standard internazionali – ISO 11665

ISO 11665-1:2012

Measurement of radioactivity in the environment -- Air: radon-222 -- Part 1: Origins of radon and its short-lived decay products and associated measurement methods

ISO 11665-2:2012

Measurement of radioactivity in the environment -- Air: radon-222 -- Part 2: Integrated measurement method for determining average potential alpha energy concentration of its short-lived decay products

ISO 11665-3:2012

Measurement of radioactivity in the environment -- Air: radon-222 -- Part 3: Spot measurement method of the potential alpha energy concentration of its short-lived decay products

Riferimenti standard internazionali – ISO 11665

ISO 11665-4:2012

Measurement of radioactivity in the environment -- Air: radon-222 -- Part 4: Integrated measurement method for determining average activity concentration using passive sampling and delayed analysis

ISO 11665-5:2012

Measurement of radioactivity in the environment -- Air: radon-222 -- Part 5: Continuous measurement method of the activity concentration

ISO 11665-6:2012

Measurement of radioactivity in the environment -- Air: radon-222 -- Part 6: Spot measurement method of the activity concentration

Riferimenti standard internazionali – ISO 11665

ISO 11665-7:2012

Measurement of radioactivity in the environment -- Air: radon-222 -- Part 7: Accumulation method for estimating surface exhalation rate

ISO 11665-8:2012

Measurement of radioactivity in the environment -- Air: radon-222 -- Part 8: Methodologies for initial and additional investigations in buildings

In preparazione: Measurement of radioactivity in the environment - Air: radon-222 - Part 9: Method for determining exhalation rate of dense building materials

Riferimenti standard internazionali – ISO 11665-4

ISO 11665-4:2012(E)

Contents

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Taratura

A.5.3 Calibration

If the calibration factor is not provided by manufacturer, each batch of sensors shall be calibrated upon receipt.

For a batch of sensors, calibration involves exposing a statistically significant number of sensors, typically at least 10 randomly chosen sensors per manufacturing batch, to reference atmospheres and applying the same chemical, or electrochemical, processing and track counting as used for measurement samples. Avoid reliance

B.5.3 Calibration

Calibration involves exposing several measuring devices (electret and accumulation chamber) to reference radon atmospheres. The electret voltage shall be measured by a specific electrometer before and after exposure to the reference atmosphere.

The gamma radiation dose rate shall be measured simultaneously.

The difference in potential thus determined is linked to the reference activity concentration.

The result obtained is the value of the calibration factor depending on the electret detector. This calibration factor is given by the manufacturer.

The electrometer response shall be checked regularly with reference electrets.

The correction factor of gamma radiation shall be determined by exposing several measuring devices (electret and accumulation chamber) to reference gamma radiation dose rates.

C.5.3 Calibration

Each batch of detectors shall be calibrated upon receipt if the calibration factor is not provided by manufacturer.

Camere radon e taratura degli strumenti

Norma internazionale IEC 61577:

Radiation protection instrumentation – Radon and radon decay product measuring instrument

Part 1: General principles (2006)

Part 2: Specific requirements for 222Rn and 220Rn measuring instruments (2014)

Part 3: Specific requirements for radon decay product measuring instruments (2011)

Part 4: Equipment for the production of reference atmospheres containing radon isotopes and their decay products (STAR) (2009)

Camere radon e taratura degli strumenti

STAR: System for Test Atmospheres with Radon

Si compone di:

- equipaggiamento per produrre l’atmosfera;
- equipaggiamento per contenere l’atmosfera;
- atmosfera di riferimento così creata;
- equipaggiamento e metodi per monitorare l’atmosfera.

Camere radon e taratura degli strumenti

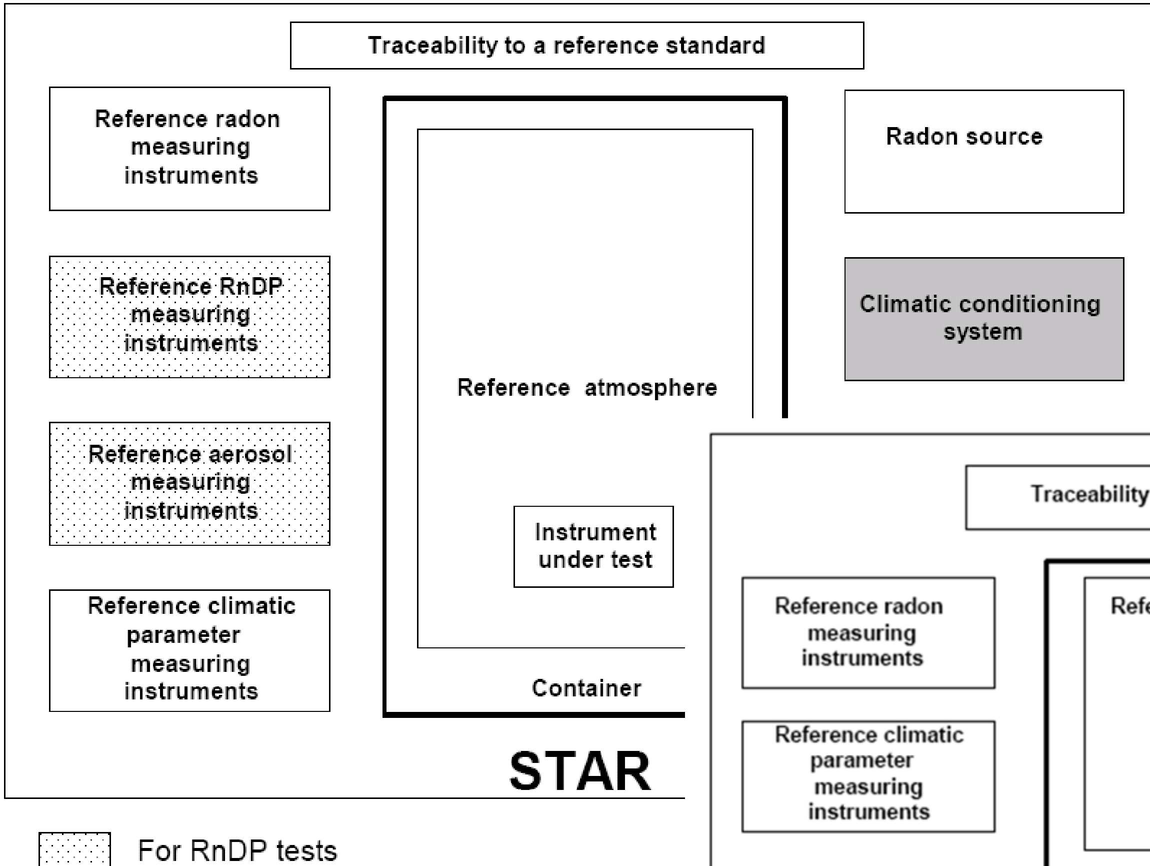


Figure 1 – Components of a ST

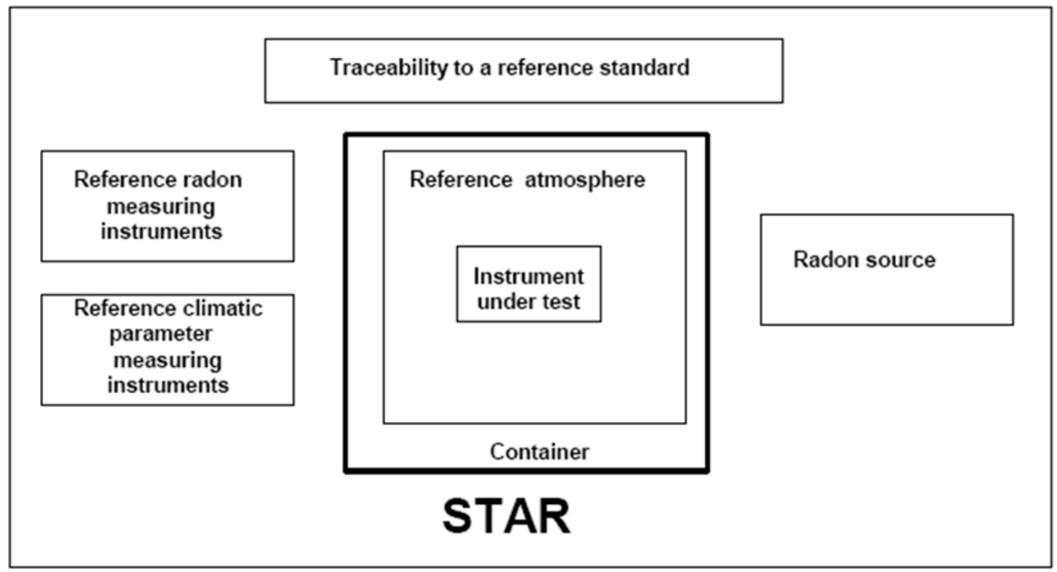


Figure 2 – Minimum requirements for a STAR

Camere radon e taratura degli strumenti

Table 1 – Reference and standard test conditions

Influence quantity	Reference conditions	Standard test conditions
Temperature	20 °C	18 °C to 22 °C
Relative humidity	50 %	40 % to 60 %
Atmospheric Pressure	1 013 hPa	860 hPa to 1 060 hPa
Ambient γ dose rate		<0,25 $\mu Sv \cdot h^{-1}$
Unattached fraction		<0,25
Volume number of aerosols	10^{10} particle$\cdot m^{-3}$	10^{8} particle$\cdot m^{-3}$ to 10^{12} particle$\cdot m^{-3}$
Aerosol size (AMTD or AMAD)*	0,2 μm	0,1 μm to 0,3 μm
* No requirement on the geometric standard deviation.		

Table 2 – Tests with variation of the influence quantities

Influence quantities	Range of values (unless otherwise indicated by the manufacturer)
Temperature	–25 °C to + 50 °C
Relative humidity	10 % to 100 % (condensing)
Atmospheric pressure	800 hPa to 1 080 hPa
Ambient γ dose rate	to be defined between STAR operator and manufacturer or user
^{222}Rn volumic activity (for ^{220}Rn measuring instruments)	10 $Bq\cdot m^{-3}$ to 1 $MBq\cdot m^{-3}$
^{220}Rn volumic activity (for ^{222}Rn measuring instruments)	10 $Bq\cdot m^{-3}$ to 1 $MBq\cdot m^{-3}$
c_{eq222} (c_{eq220} measuring instruments)	2 $Bq\cdot m^{-3}$ to 1 $MBq\cdot m^{-3}$
c_{eq220} (c_{eq222} measuring instruments)	0,05 $Bq\cdot m^{-3}$ to 100 $Bq\cdot m^{-3}$
Unattached fraction of $RnDP_{222}$	up to 0,9
Volume number of aerosols	10^{8} particle$\cdot m^{-3}$ to 10^{12} particle$\cdot m^{-3}$
Aerosol size[a] (AMTD or AMAD)	10^{-3} μm to 10 μm
[a] Tests with variation of aerosol size will be done after agreement between STAR operator, manufacturer and user.	

Camera radon CESNEF

Altre STAR europee

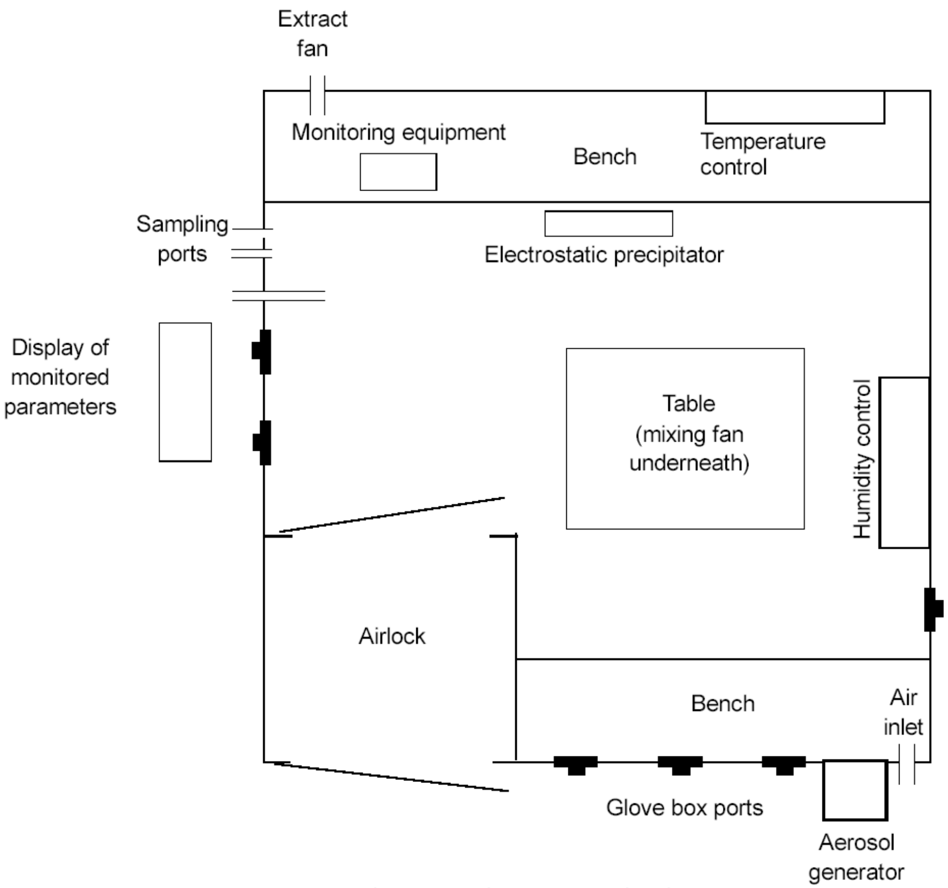
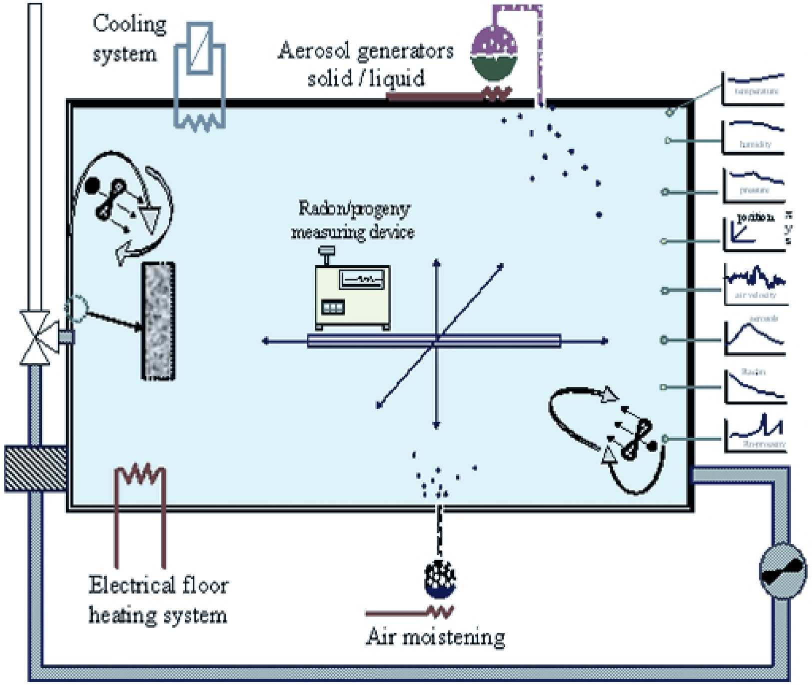


FIGURE 1 The NRPB radon exposure chamber

Public Health England (ex NRPB)

Altre STAR europee

Bundesamt für Strahlenschutz (Germania)



Part of the Calibration Service Laboratory with PAEC chamber for calibration of devices measuring radon progenies (30 m^3)

Altre STAR europee

BfS

Part of the Radon Calibration Service Laboratory with 0.4-cubic-metre stainless-steel containers, computer-controlled measuring and dosage system

Riferibilità metrologica

Bureau International des Poids et Mesures

Italy, ENEA-INMRI (Istituto Nazionale di Metrologia delle Radiazioni Ionizzanti)
Complete CMCs in Ionizing Radiation for Italy (.pdf file)

Activity. Single nuclide, gas, **1E+03 Bq to 2E+04 Bq**
Relative expanded uncertainty (k = 2, level of confidence ~95%) in %: **3.3**
Electrostatic cell, NaI well-type detector
Rn-222: gas source in air in glass bulb
Reference standard: Calibrated Ra-226 solution
Source of traceability: NIST
Internal NMI service identifier: EUR-RAD-ENEA-INMRI-2009

Istituto metrologico primario

Centri secondari – Laboratori Accreditati di Taratura

Riferibilità metrologica

CCRI(II)-K2.Rn-222

Information

Metrology area, branch	Ionizing Radiation, Section II (Measurement of Radionuclides)
Description	Total activity of Rn-222
Time of measurement	2015
Status	In progress
Reference(s)	CCRI(II)-K2.Rn-222 registration and progress form CCRI(II)-K2.Rn-222 Technical Protocol
Measurand	Total activity of Rn-222 in the container at the reference date
Transfer device(s)	Gaseous Rn-222 in metalic containers
Comparison type	Key comparison
Consultative Committee	CCRI (Consultative Committee for Ionizing Radiation)
Conducted by	CCRI (Consultative Committee for Ionizing Radiation)

Interconfronti

Perché importante svolgere interconfronti?

ISO/IEC 17025:2005(E)

5.6 Measurement traceability

Participation in a suitable programme of interlaboratory comparisons is required where possible.

Quindi se sono accreditato, devo partecipare ad interconfronti, oltre ad essere metrologicamente riferibile.

Interconfronti

Anche per gli interconfronti esiste uno standard internazionale:

ISO/IEC 17043:2010 - *Conformity assessment — General requirements for proficiency testing*

Chi eroga questi esercizi?

Spesso istituti metrologici primari oppure laboratori accreditati di taratura

Chi può partecipare?

Qualunque laboratorio voglia testare il proprio metodo

I risultati di questi esercizi sono anonimi

Interconfronti europei

Public Health England

Results of the 2013 PHE Intercomparison of Passive Radon Detectors

25 partecipanti, 7 italiani

Messgeräte zur Bestimmung der Radon-222-Aktivitätskonzentration oder der Radon-222-Exposition Vergleichsprüfung 2014

Instruments to Measure Radon-222 Activity Concentration or Exposure to Radon-222 – Intercomparison 2014

Fachbereich
Strahlenschutz und Umwelt

Elisabeth Foerster

Thomas Beck

Helmut Buchröder

Joachim Döring

Volkmar Schmidt

31 partecipanti, 14 italiani

Bundesamt für Strahlenschutz

Solo per misure ad integrazione

Interconfronti

Limite di questi interconfronti:

si svolgono in camera radon, con parametri ambientali circa costanti e per tempi brevi.

Le condizioni sono simili a quelle delle tarature.

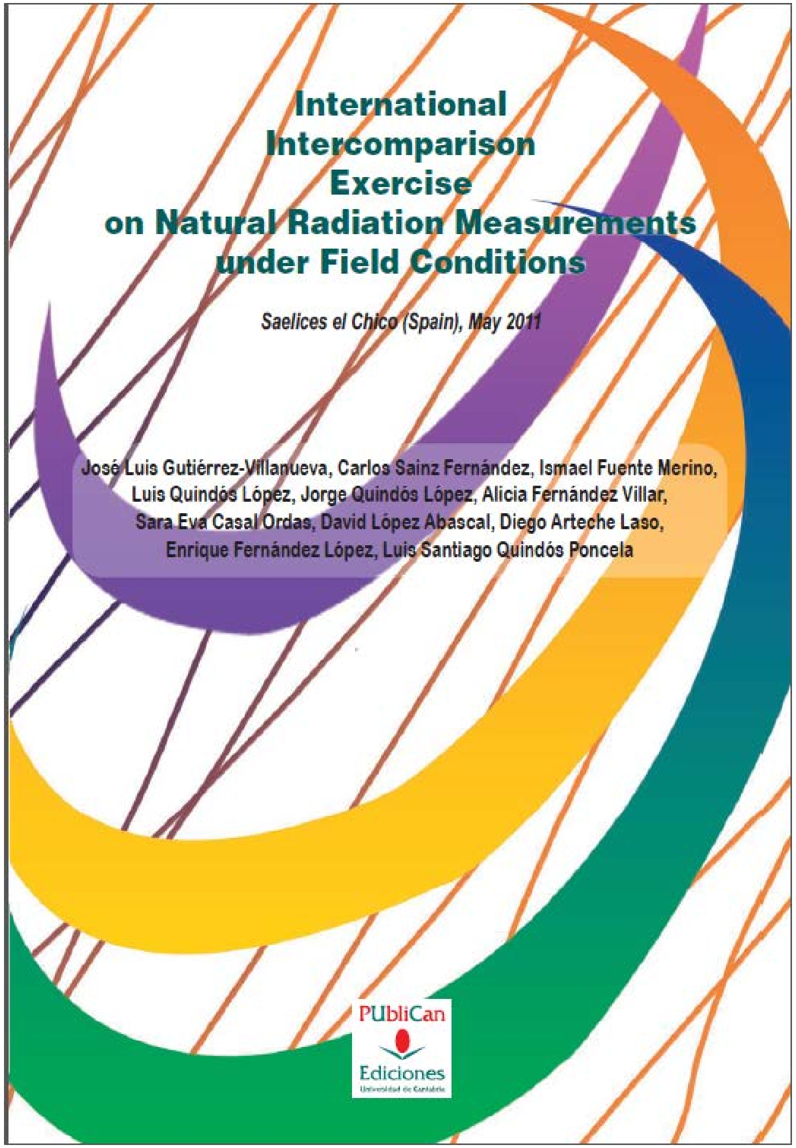
Ma siamo sicuri che misure in campo, con condizioni ambientali non stabili e per tempi molto più lunghi delle tarature, danno gli stessi risultati?

Interconfronto in campo

Primo tentativo di interconfronto in campo in Spagna nel 2011

Progetto ambizioso:

- Radon in acqua;
- Radon in suolo;
- Misure attive;
- Misure passive (integrazione);
- Rateo di dose gamma



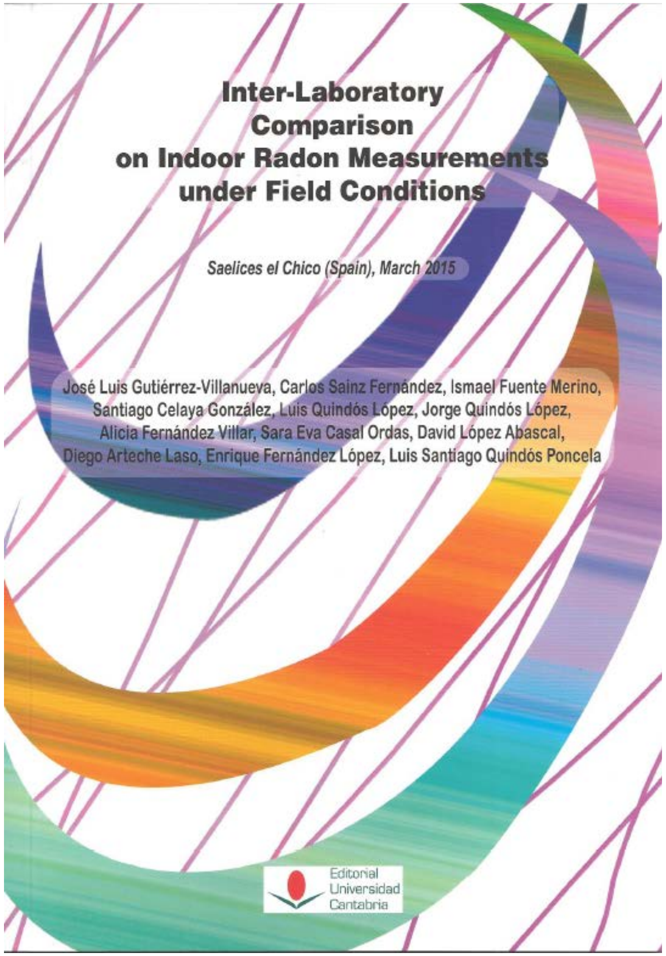
Interconfronto in campo

25 partecipanti, 3 italiani

Table 12: Participants in the exercise radon indoors with passive detectors

Country	Institution
Austria	Austrian Agency for Health and Food Safety
Belarus	Republic Center of Radiation Medicine and Human Ecology, Radiation Defence Laboratory
Belgium	Federal Agency for Nuclear Control
Germany	Bundesamt für Strahlenschutz
Hungary	RADOSYS Ltd
Italy	Dipartimento di Scienze Ambientali – Seconda Università di Napoli
Italy	Mi.am srl
Italy	ARPA
Norway	NRPA (Norwegian Radiation Protection Authority)
Poland	Institute of Nuclear Physics PAN
Portugal	Instituto Tecnológico e Nuclear, I.P.
Portugal	Laboratory of Natural Radioactivity, University of Coimbra
Romania	University Babes-Bolyai/Environmental Radioactivity and Nuclear Dating
Romania	IFIN-HH Bucharest
Slovenia	Institute of Occupational Safety
Spain	Grupo de Física de las Radiaciones. Departamento de Física. Universidad Autónoma de Barcelona
Spain	Universidad de Extremadura. Badajoz
Spain	Universidad de Las Palmas de Gran Canarias
Spain	University of Cantabria
Spain	University of Extremadura. Caceres
Spain	Instituto de Salud Carlos III
Spain	Medidas Ambientales
Sweden	Gammadata Mätteknik AB
Sweden	Independia Control AB
UK	HPA

Interconfronto in campo

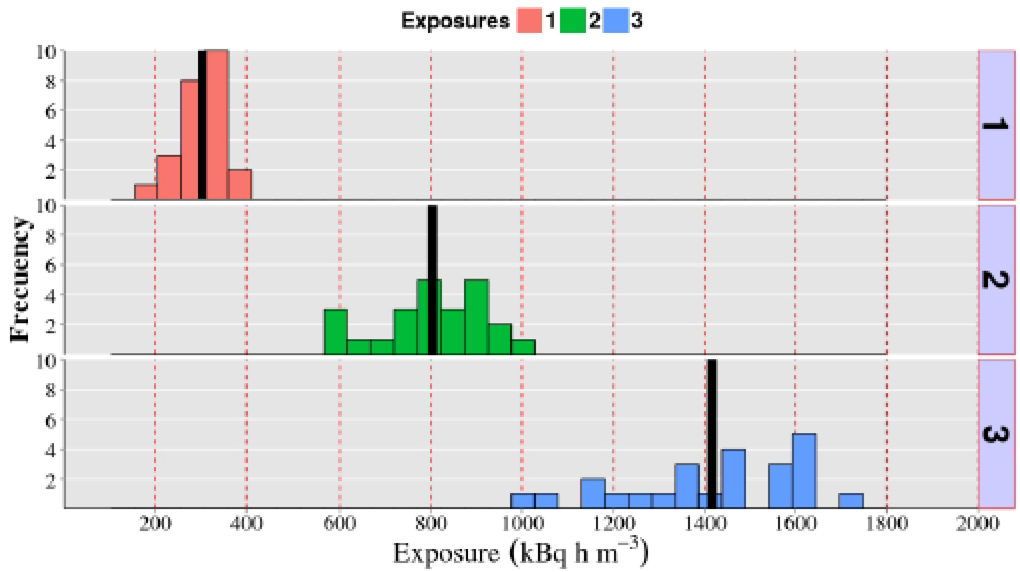


19 partecipanti, 10 italiani

Table 1: List of participants

Participant	Country	E-mail
A.P.P.A. (AGENZIA PROVINCIALE PER LA PROTEZIONE DELL'AMBIENTE) S.L.C. (SETTORE LABORATORIO E CONTROLLI)	Italy	mauro.bonomi@provincia.tn.it stefano.pegoretti@provincia.tn.it
ARPACAL	Italy	s.procopio@arpacal.it
ARPA FVG	Italy	silvia.pividore@arpa.fvg
ARTA Abruzzo	Italy	l.carnesale@artaabruzzo.it s.palermi@artaabruzzo.it
EUROPEAN COMMISSION Joint Research Centre (Nuclear decommissioning Unit Radiation Protection Sector Dosimetry Service)	Italy	Gianfranco.minchillo@ec.europa.eu Daniele.giuffrida@ec.europa.eu
FGM AMBIENTE	Italy	luisa.salvatori@gmail.com
Hainaut Vigilance Sanitaire	Belgium	marie_alice.cailleaux@hainaut.be
ISPRA	Italy	giancarlo.torri@isprambiente.it annamaria.sotgiu@isprambiente.it
Laboratório de Radioactividade Natural Universidade de Coimbra	Portugal	apereira@dct.uc.pt
Landauer Nordic	Sweden	Karl.Nilsson@landauernordic.se
MI.AM SRL	Italy	info@miam.it
Unitat de Física de les Radiacions, Universitat Autònoma de Barcelona	Spain	Victoria.moreno@uab.cat
Universidad de Extremadura	Spain	jdltp@unex.es
Universidad de Santiago de Compostela	Spain	juanm.barros@usc.es joaquin.peon@usc.es
Università del Salento Servizio di Prevenzione e Protezione	Italy	manuel.fernandez@unisalento.it
University of Cantabria	Spain	laruc@unican.es
Radosys	Hungary	ehulber@radosys.com
Regional Agency for Ligurian Environmental Protection ARPA GENOVA	Italy	silvio.incardone@arpal.gov.it massimo.bussallino@arpal.gov.it
Track Analysis Systems Ltd	UK	maria@tasl.co.uk

Interconfronto in campo



Interconfronti in campo non sono semplici da gestire in termini metrologici.

I risultati non sempre sono «confortanti», ma sono utili per migliorare.

Interconfronto Lurisia

The Organising Committee would like to thank the "Terme di Lurisia" Management, for their enthusiastic participation in Marie Curie's tunnel radon intercomparison organisation.

TERME DI LURISIA
Medical Thermal SPA

TIMETABLE

- ***15th May***: *Participants' registration*
- ***15th June***: *Payment deadline*
- ***30th June***: *Devices delivered to ARPA IVREA*
- ***July-August***: *Exposure in Lurisia tunnel*
- ***September***: *Devices returned to originating laboratories*
- ***30th November***: *Results and questionnaires returned;*
- ***31th January 2015***: *Participants own results reported;*
- ***March-April 2015***: *Final congress, including presentation of final Intercomparison's results and certificates' delivery.*

ORGANISING COMMITTEE

Francesco CARDELLINI	*ENEA – INMRI*
Enrico CHIABERTO	*Arpa Piemonte*
Luisella GARLATI	*Politecnico di Milano*
Daniele GIUFFRIDA	*JRC Ispra*
Mauro MAGNONI	*Arpa Piemonte*
Gianfranco MINCHILLO	*JRC Ispra*
Elena SERENA	*Arpa Piemonte*
Rosabianca TREVISI	*INAIL*

AIRP Associazione Italiana di Radioprotezione

PIEMONTE Arpa Agenzia Regionale per la Protezione Ambientale

ENEA Agenzia nazionale per le nuove tecnologie, l'energia e lo sviluppo economico sostenibile

INAIL ISTITUTO NAZIONALE PER L'ASSICURAZIONE CONTRO GLI INFORTUNI SUL LAVORO

IN-FIELD INTERCOMPARISON OF PASSIVE RADON MEASUREMENT DEVICES
LURISIA SPA, CUNEO, ITALY

July - August 2014

Terme di Lurisia

Roccaforte di Mondovì (CN)

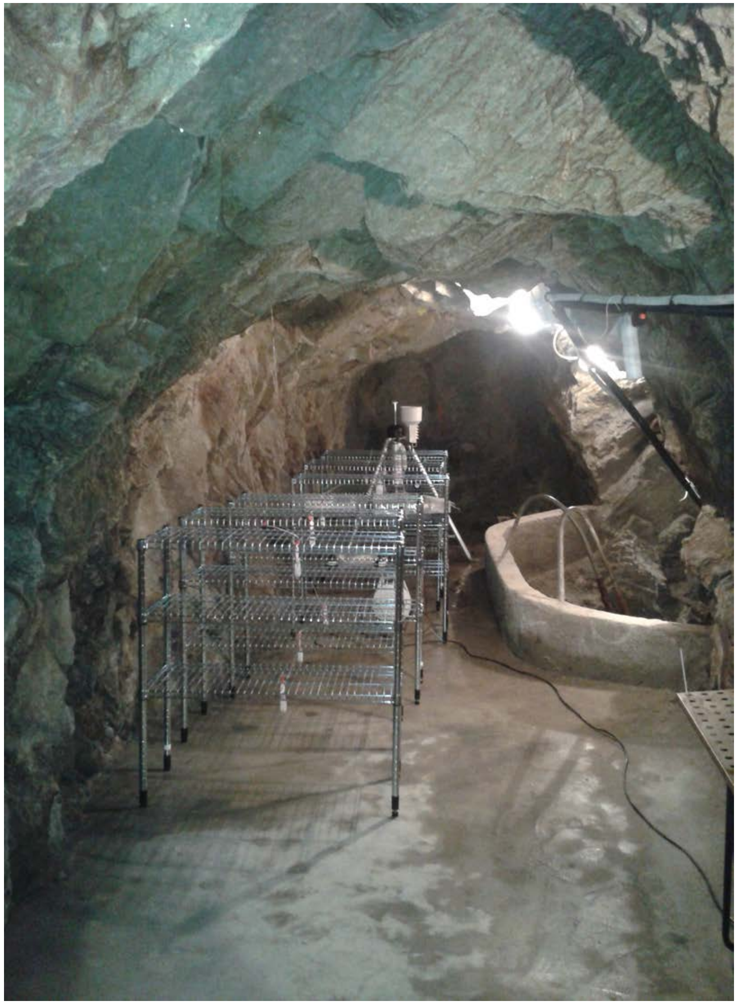
Interconfronto Lurisia

Buona risposta, soprattutto dai laboratori italiani

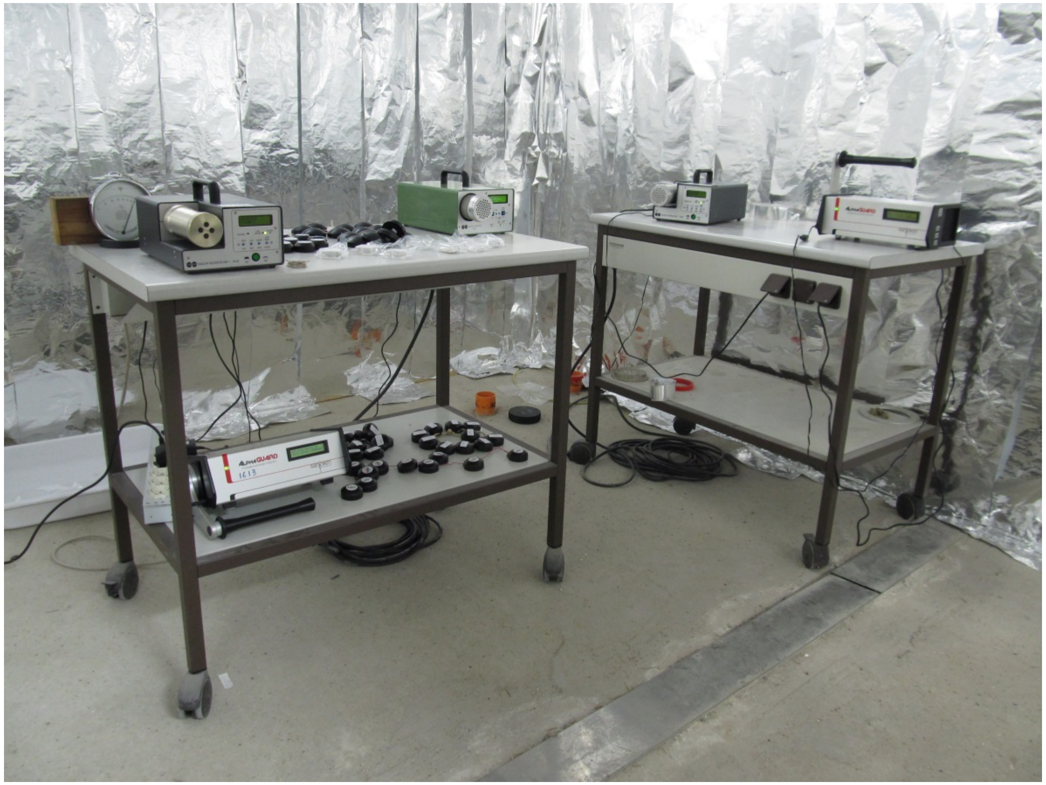
Table 1: List of Countries participating	
Italy	34
Spain	3
France	2
Germany	1
Austria	1
Slovenia	1
Sweden	1
Turkey	1
Argentina	1
Albania	1

Dispositivi	Percentuale
CR-39	66%
Elettreti	24%
LR115	10%

Interconfronto Lurisia



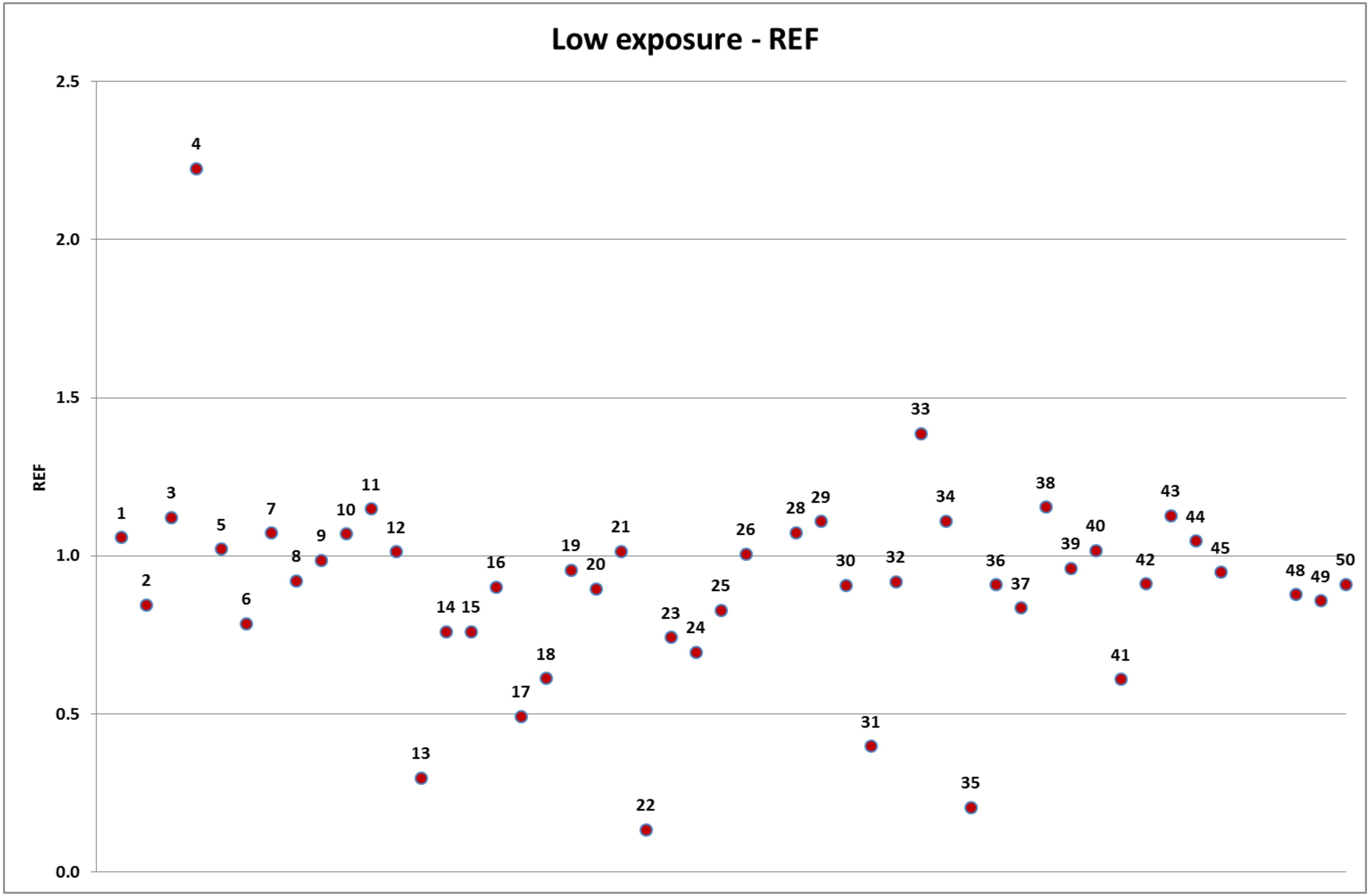
Fase preparatoria



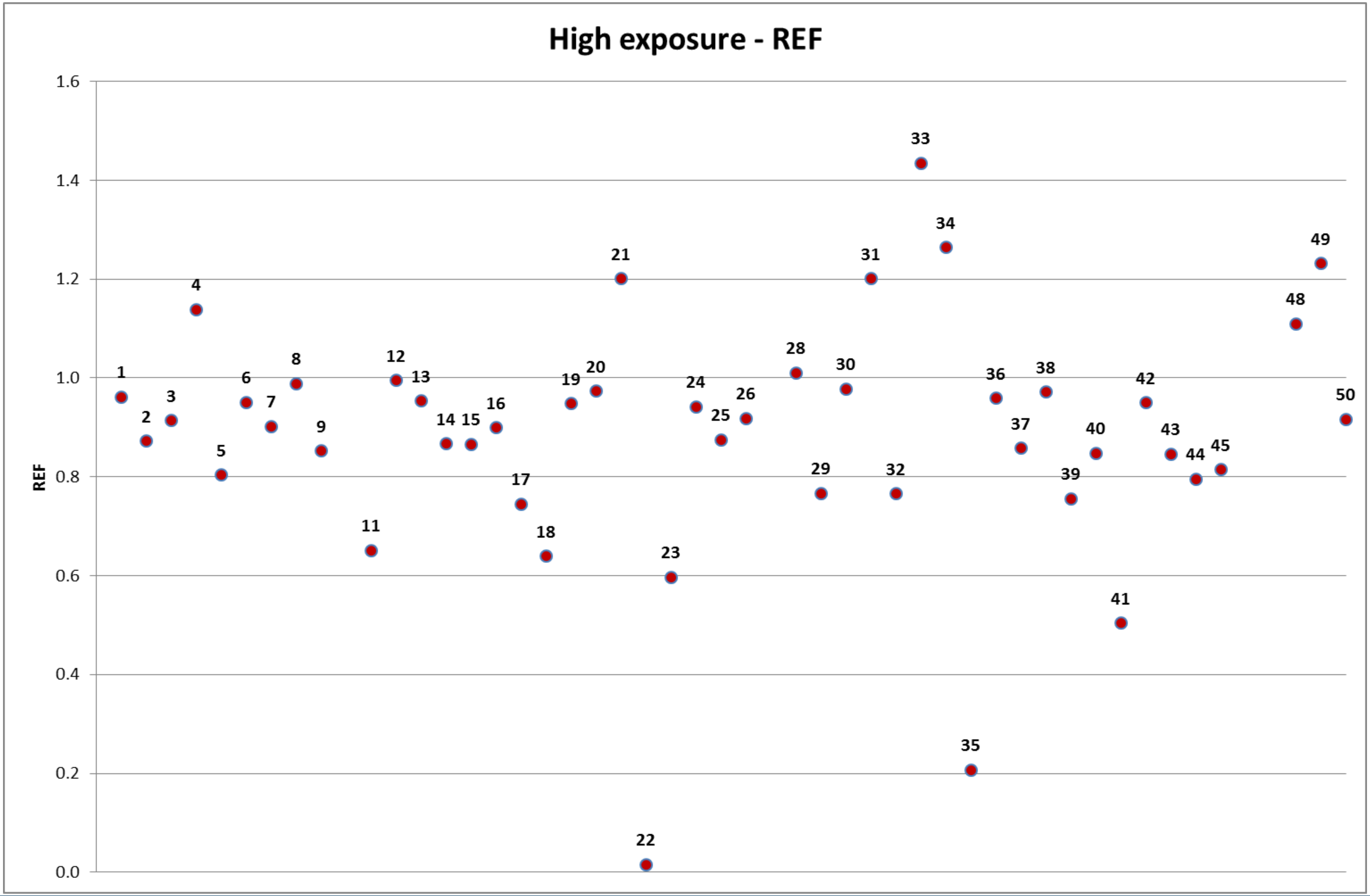
Interconfronto Lurisia

Esposizione

Interconfronto Lurisia



Interconfronto Lurisia



Qualche conclusione «utile» sull'interconfronto

In fase di organizzazione di una campagna di misure occorre tener presente una serie di elementi che possono inficiare la misura:

- ✓ condizioni ambientali
- ✓ tempistica
- ✓ polvere, condensa, ecc…
- ✓ trasporto
- ✓ archiviazione dati

Qualche considerazione

Importanza della scelta del dispositivo

- *Se dispongo solo di un certo tipo, aver presente i suoi limiti*

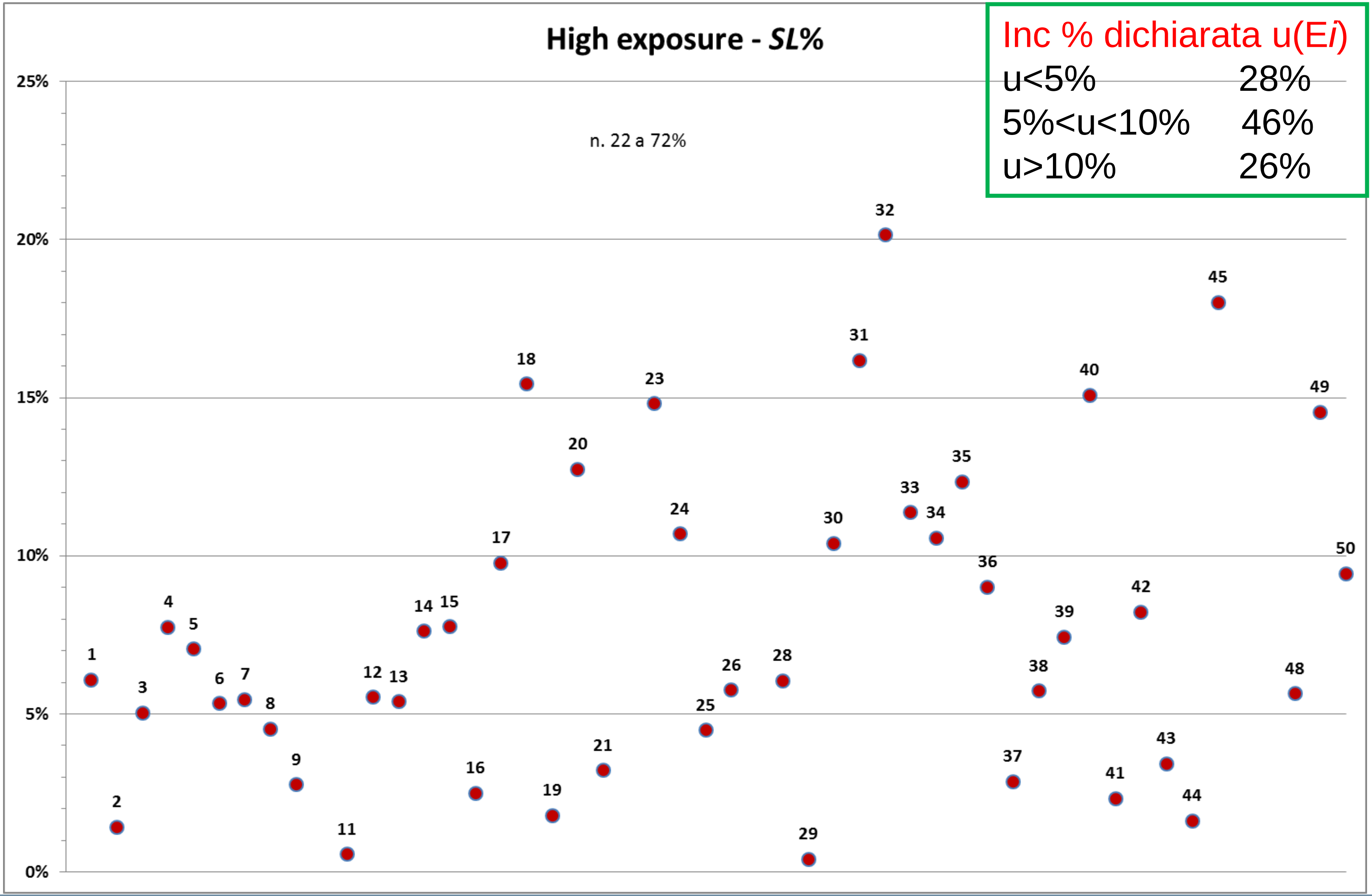
Importanza della qualità del materiale

- *Effettuare tutti i controlli necessari per essere sicuri di poter ottenere una misura sensata*
- *Effettuare le tarature (se) necessarie*

Importanza della corretta valutazione delle incertezze

- *Anche se non si è un laboratorio accreditato, non significa che non dobbiamo effettuarla*

Incertezza



Inc % dichiarata u(E*i*)

u<5%	28%
5%<u<10%	46%
u>10%	26%

Qualche considerazione

Per chi fa misure:

- Importanza di lavorare seguendo gli standard internazionali e delle procedure di qualità, anche senza essere accreditati;
- Importanza di partecipare ad interconfronti per poter migliorare e per «mettersi in discussione»;
- Importanza di conoscere a fondo il proprio sistema di misura.

Per chi commissiona delle misure:

- Verificare per quanto possibile la qualità del risultato;
- Il criterio economico non deve essere il metro di giudizio;
- Programmare correttamente la campagna di misure.

Grazie per l’attenzione

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