NATIONAL QA PROGRAMME

INMRI ENEA

The National radioactivity surveillance network

☐ In Italy the control of radioactivity in foodstuffs and environment is carried out by a national radioactivity surveillance network

☐ The network is coordinated by the ISPRA APAT (Italian Environmental Protection Agency)

INMRI ENEA

National QA Program (QAP)

☐ Regards the national network for environmental radioactivity surveillance

☐ To achieve and maintain an adequate and uniform reliability level of the network for each measurement condition

☐ Established since 1983

☐ Carried out by ENEA-INMRI under request of the National Agency for Environmental Protection (APAT)

☐ Based on periodical calibration and intercomparison campaigns

☐ Main objects: Beta counting and γ-ray spectrometry in environmental samples

☐ Effective in reducing to about 10% the maximum deviation of the results among the network laboratories

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QAP general objectives:

a) to assure <u>traceability</u> of measurement results of the network laboratories to the national standards of radionuclide activity

b) to assure a uniform level of <u>accuracy</u> for the measurements performed by all network laboratories

QAP Procedures

☐ These general objectives are fulfilled respectively by periodical <u>calibration</u> and <u>intercomparison</u> campaigns.

☐ The calibration campaigns are carried out in specific measurement conditions.

☐ The intercomparison campaigns are needed to assess the main sources of error in measurement procedures and perform consequent actions for accuracy improvement.

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QAP Participants

☐ Participants in the QAP were the laboratories belonging to the radioactivity surveillance network

☐ Total number of participants ranging from 10 to 50

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Organisational aspects of the QAP

☐ Standard sources and calibration certificates

☐ Technical guides

☐ Detailed questionnaire for results

☐ Extensive use of E-mail

☐ Participants were given closed codes

☐ Bilateral meetings with each participant

☐ General meeting for results presentation

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Gamma intercomparison 1997: two typical good results

INMRI ☀ ENEA
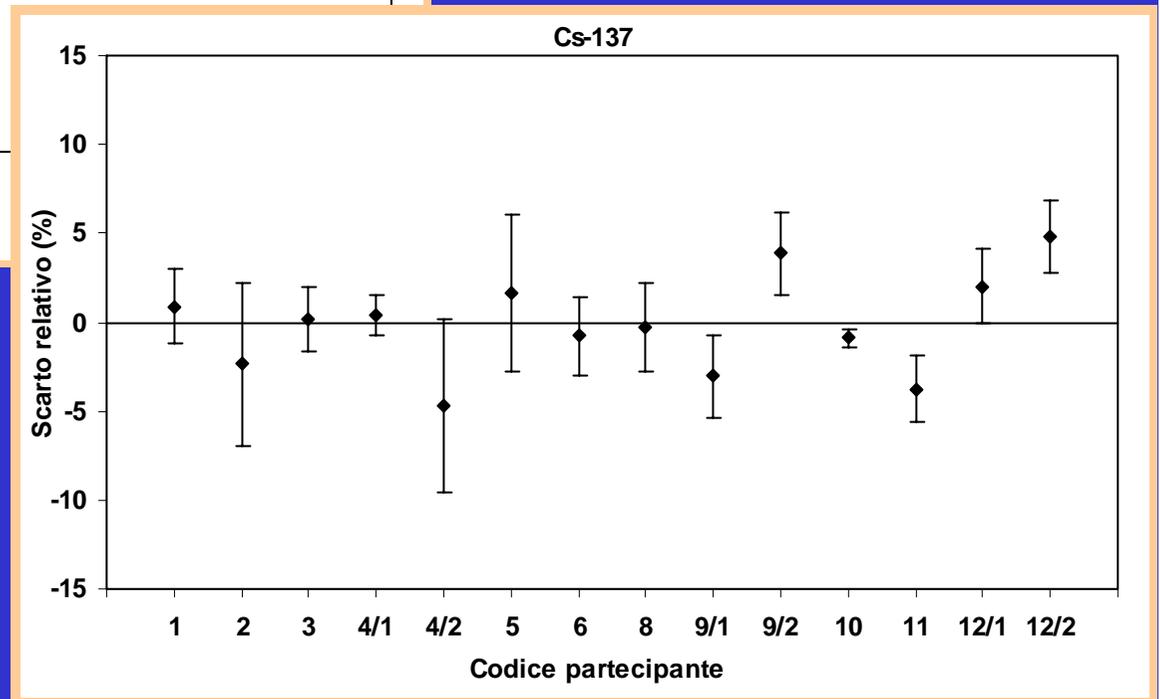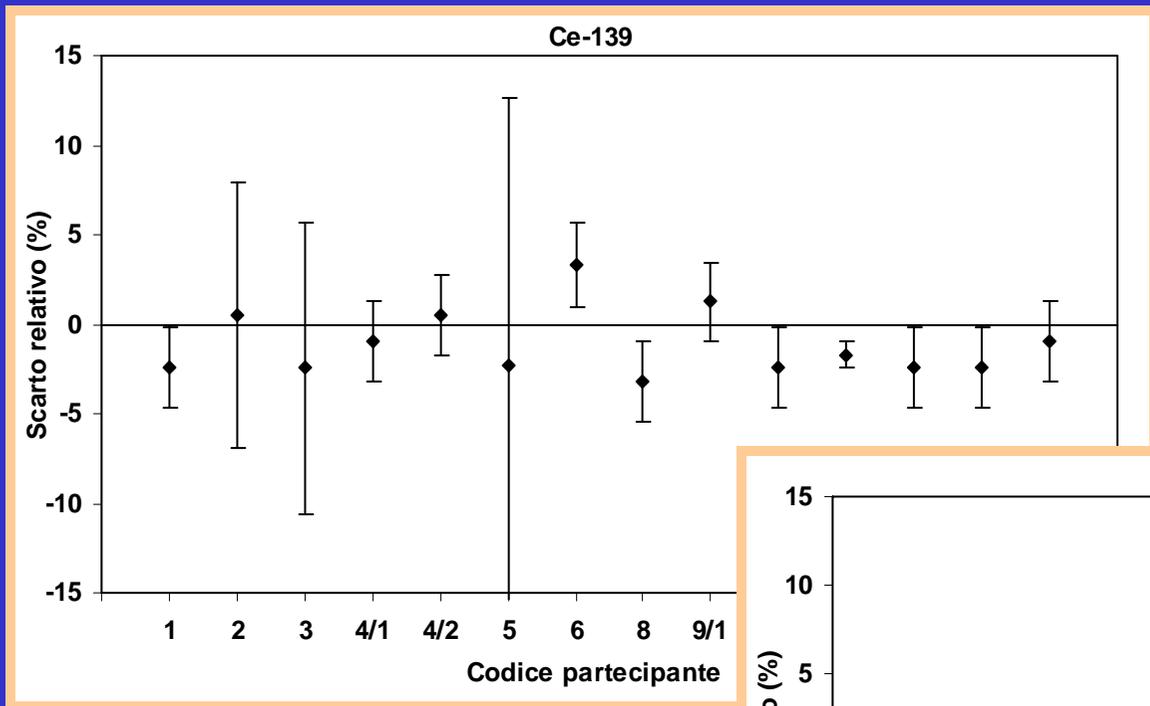
Gamma intercomparison 1997: detection of systematic errors (coincidence summing effect)
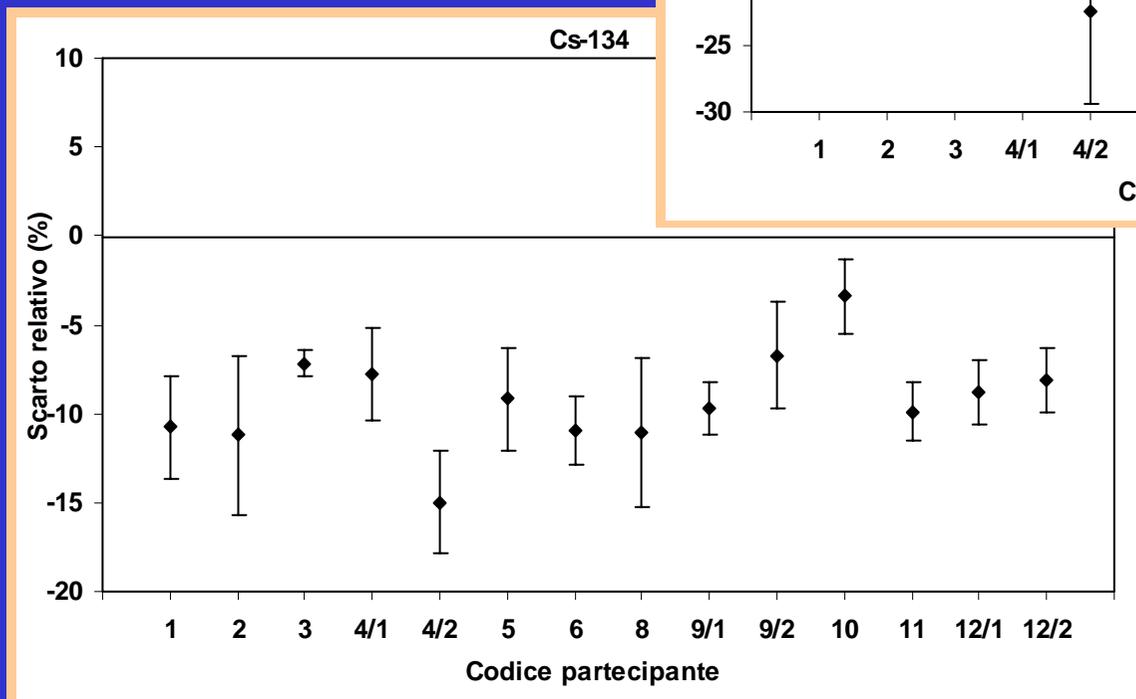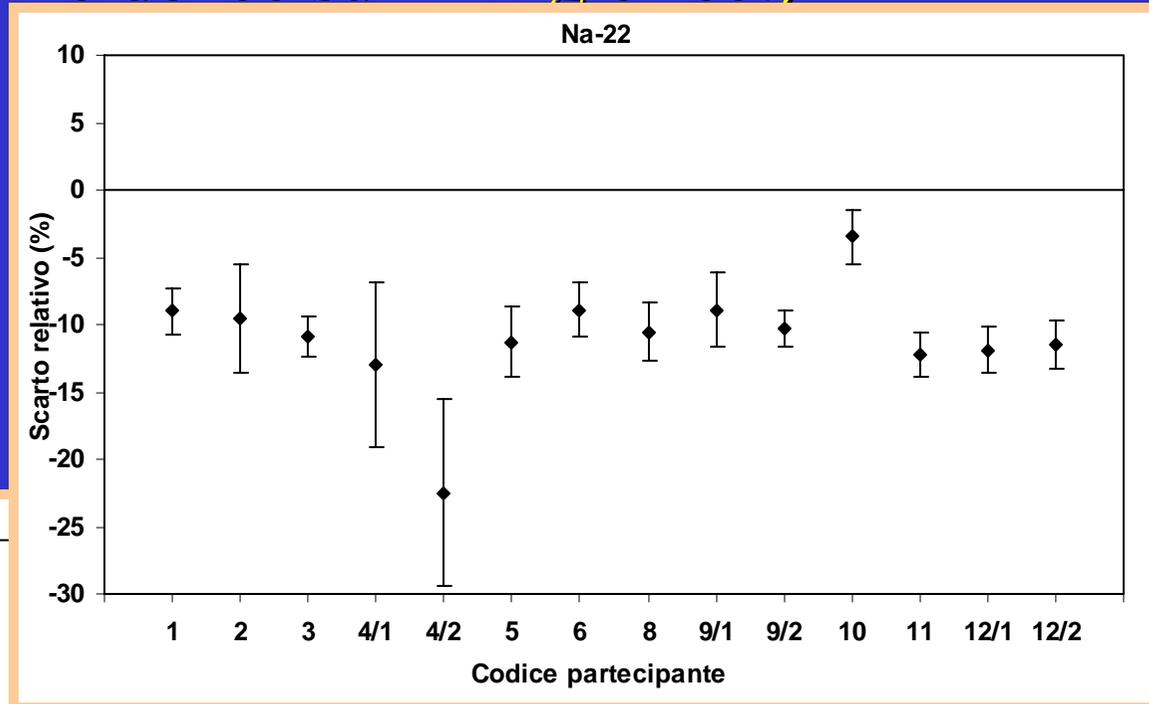
Gamma intercomparison 1997: errors due to spectral deconvolution
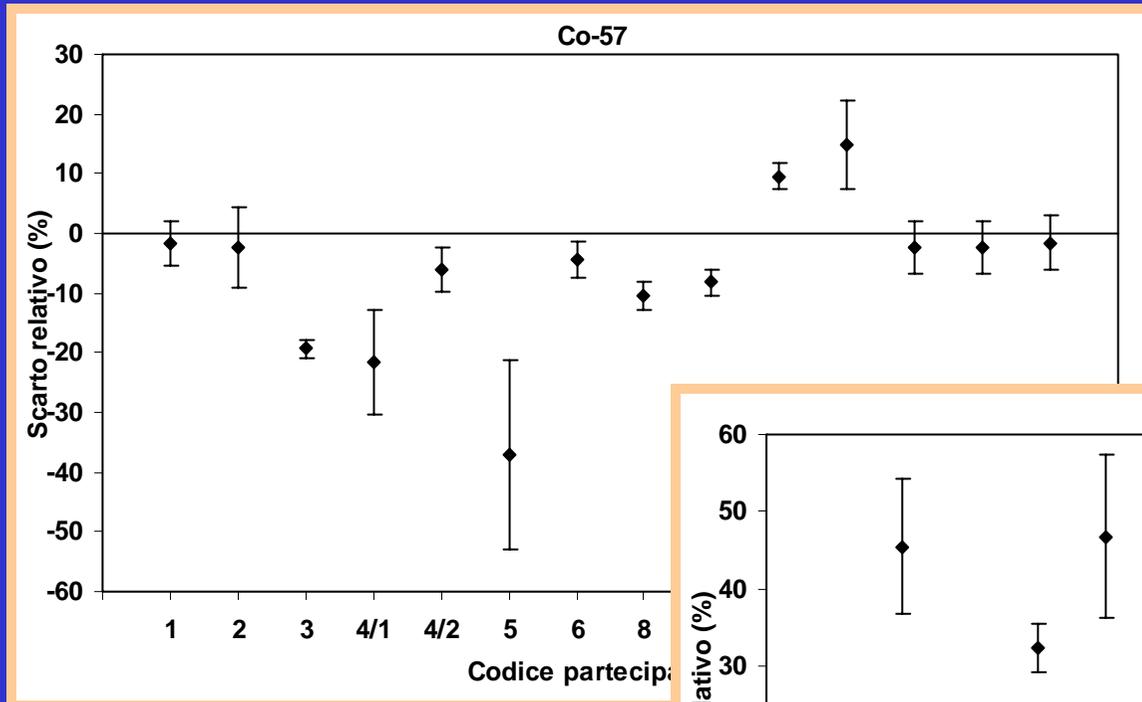
STANDARD SOURCES FOR THE QA PROGRAMME

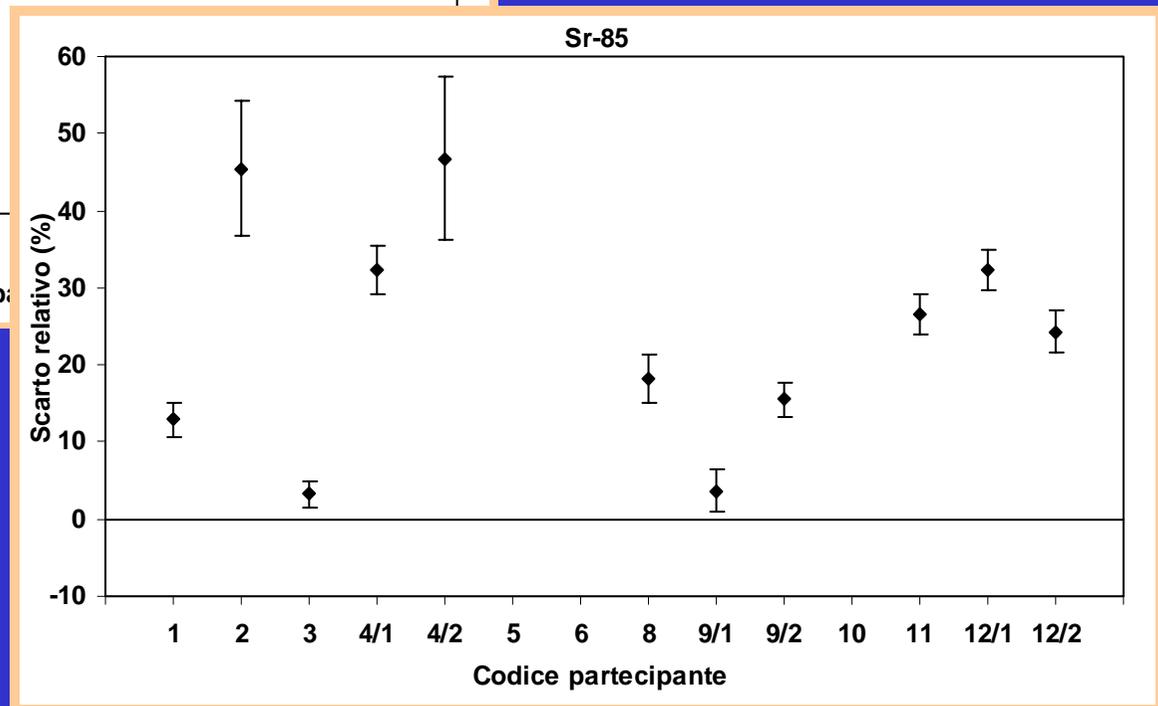# Standard sources for the QA programme of radioactivity surveillance network

☐ The radioactive sources needed for the different phases of the QAP were prepared by the INMRI-ENEA.

☐ A large number of different types of standard sources were needed to take into account the large variability of matrices routinely measured by the network laboratories.

☐ Paper filters, liquid solutions and point sources were the main source geometries considered for beta and gamma measurements.

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Mission of the INMRI-ENEA: the Italian Primary Metrology Institute for ionizing radiation quantities

- 1- Development of national standards
- 2- Certification and accreditation of calibration centers
- 3- Standardization of measurement methods

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International traceability
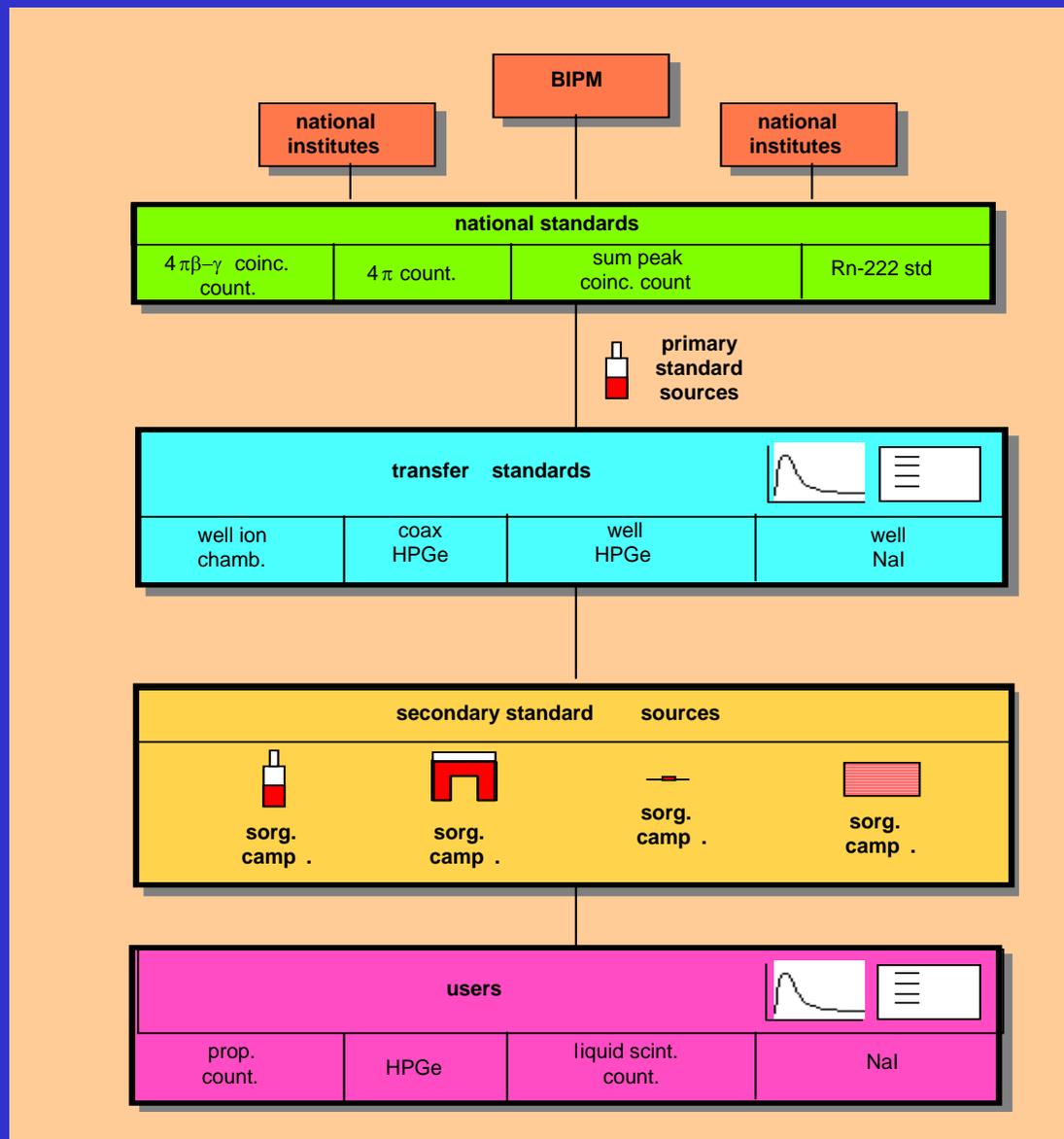
International traceability and equivalence are established by:

☐ <u>International comparisons</u>:
- organised by the "Bureau International des Poids et Mesures" (BIPM)
- International reference system (SIR-BIPM)
- Regional Metrology Organisations (EUROMET,…)

☐ <u>Bilateral comparisons between NMI's</u>

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ENEA-INMRI primary standards for radionuclide metrology

Physical quantity	Radiation type	Measurement method	Measuring interval	u_C (1σ, %)
activity	β - γ α - γ x - γ	$4\pi\beta$–γ Coincidence counting	1 ÷ 20 kBq	0.1 ÷ 2
activity	γ - γ	Sum-peak counting	1 ÷ 20 kBq	0.5 ÷ 3
activity	γ, β, α	4π counting	1 ÷ 20 kBq	0.5 ÷ 5
activity	α, γ (^{222}Rn)	^{222}Rn - ^{226}Ra separation	1 ÷ 20 kBq	1
Surface emission rate	β, α, x	2π sr counting	1 ÷ 20 kBq	0.5 ÷ 2
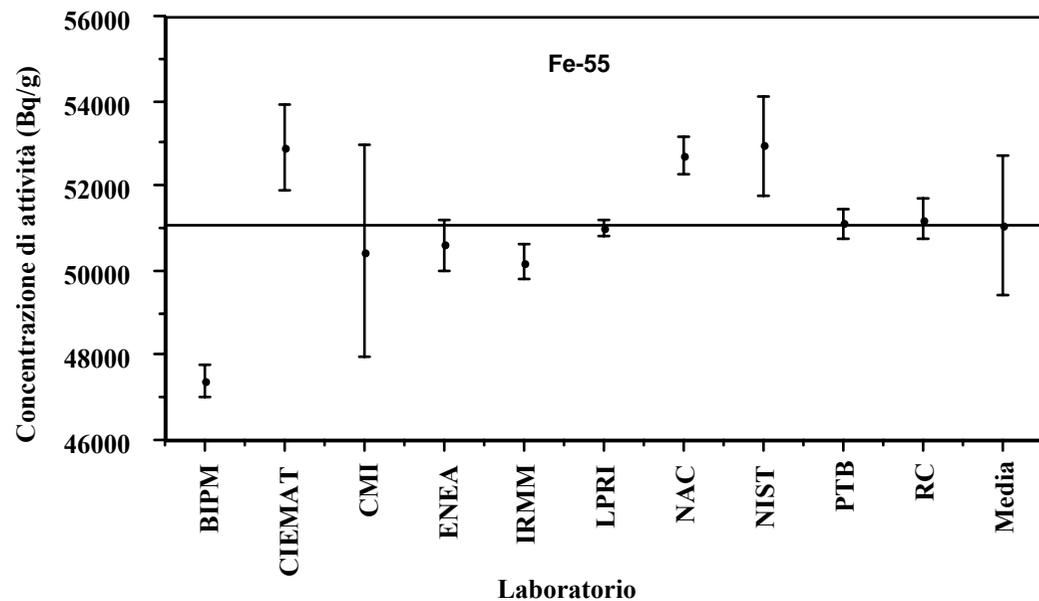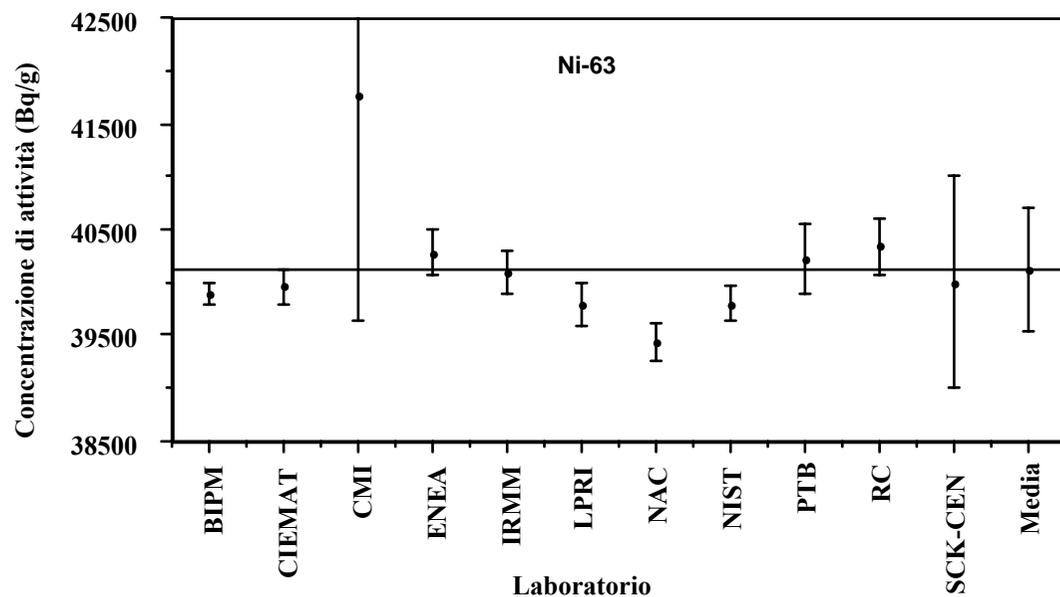
Example: Results of an international comparison on radionuclide activity measurements (Ni-63 and Fe-55)

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ENEA-INMRI secondary standards for radionuclide metrology

Physical quantity	Radiation type	Measurement method	Measuring interval	u_C (1σ, %)
Activity	γ 40 keV ÷ 3 MeV	Well-type ionisation chamber	10 kBq ÷ 20 MBq	0,2 ÷ 3
Activity	γ 40 keV ÷ 3 MeV	HPGe coaxial detector	1 Bq ÷ 100 kBq	0,5 ÷ 5
Activity	γ 3 keV ÷ 3 MeV	HPGe coaxial detector	1 Bq ÷ 100 kBq	0,5 ÷ 5
Activity	γ 30 keV ÷ 3 MeV	HPGe well-type detector	1 Bq ÷ 100 kBq	0,5 ÷ 5
Activity	X, γ (^{222}Rn)	NaI(Tl) well-type detector	1 ÷ 13 kBq	1,2
Surface emission rate	β, α, X > 6 keV	2π sr proportional counter	1 ÷ 20 kBq	1

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Preparation of standard sources and reference materials by quantitative deposition

- Preparation of the master solution
- Stabilisation of the master solution (acidification and carrier addition)
- Standardisation of the master solution
- Dilution by gravimetric/volumetric methods
- Preparation of standard sources and reference materials by quantitative deposition of the standardised solution
  - Deposition on solid supports
  - Spiking in acetone bath
  - Incorporation in resins
  - Introduction in gel
- Characterisation of the standard sources and reference materials (homogeneity, stability and leakage tests)

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Standard sources prepared by ENEA-INMRI for calibration of radionuclide activity measurment instruments

Source type	Emitted radiations	Activity level
point sources (< 20 mm^2)	β, γ	from 50 Bq to 1 MBq
extended area ($10 \div 400$ cm^2)	α, β, γ	from 50 Bq to 1 MBq
electrodeposited ($0,2 \div 1$ cm^2)	α	from 10 Bq to 5 kBq
gas sources (< 100 cm^3)	γ (^{222}Rn)	from 1 kBq to 50 kBq
Liquid or solid matrices (1 cm^3 $\div 100$ dm^3)	β, γ	from 1 Bq kg^{-1} to 1 MBq g^{-1}
Marinelli beaker ($0,5 \div 2$ dm^3)	γ	from 1 Bq to 100 kBq
Reference atmosphere ($0,1 \div 1$ m^3)	α, β, γ (^{222}Rn)	from 1 kBq m^{-3} to 500 kBq m^{-3}

Geometry of standard sources for efficiency calibration
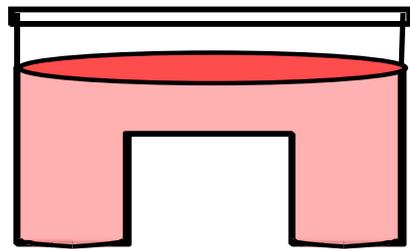
Marinelli beakers   **Liquid solutions**
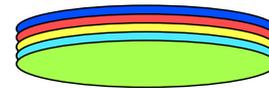
Point source   **Paper filters**

Standard sources for gamma-ray spectrometry

- Paper filters, liquid solutions, Marinelli beakers, point sources, spiked filters: main source geometries considered for gamma emitting radionuclides.

- <u>Calibration</u> sources mainly prepared with mixtures of single-photon emitters with different and well spaced energy lines (60 keV- 2 MeV).

- <u>Intercomparison</u> sources prepared to simulate experimental difficulties frequently encountered in daily measurement practice such as those due to self-absorption correction, coincidence summing and spectral deconvolution.

INMRI ENEA

CERTIFIED REFERENCE MATERIALS

Certified Reference Materials

☐ A special need was expressed by the network laboratories concerning reference materials for gamma-ray spectrometry with different chemical-physical characteristics.

☐ These materials were needed for calibration of spectrometers used for volume source measurements.

☐ A number of these reference materials was then developed with different density and chemical composition of the materials and different spiking nuclides.

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Spiked Reference Materials developed at ENEA-INMRI

Matrix	Density (g/cm^3)	Number of samples
Silice	0.4	2
Kaolin	0.6	2
Zeolite	0.8	2
HCl 0.2 N	1.00	8
Gel	1.00	3
HCl 0.5N	1.004	2
Gel	1.006	2
HCl 1N	1.01	10
HCl 2N	1.03	8
Gel	1.03	3
HCl 0.2 N + KCl	1.05	5
Gel	1.05	3
HCl 4N	1.06	3
Glucose	1.30	2
Soil	1.30	5
Sand	1.60	5
Sand	1.75	5
Simulated filters	-	1
TOTAL	-	71

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Example: Low-level mixed nuclide standard solutions

Radionuclide	Activity conc. (Bq/g)	Radionuclide	Activity conc. (Bq/g)
Am-241	1.3	Cs-134	0.7
Cd-109	4.3	Cs-137	0.4
Co-57	0.1	Mn-54	0.4
Ce-139	0.1	Y-88	0.6
Ra-226	0.4	Zn-65	0.7
Ba-133	0.6	Na-22	0.7
Sr-85	0.2	Eu-152	1.1

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QC of Spiked Reference Materials

- The QC is based on the comparison of the full-energy-peak efficiency values obtained, for the different samples, on a HPGe γ-ray spectrometer in Marinelli beaker counting geometry.

- The full-energy-peak efficiency values for the different materials were normalised to a reference sample composition (HCl 2N) allowing the reduction of the acceptability criteria on which the QC is based.

- Two theoretical models, to compute the self-attenuation corrections, were compared obtaining a satisfactory agreement in the considered range of sample parameters.

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Characteristics of the HPGe detector used for characterisation of SRMs

Type	EG&G Ortec, GEM-15190
Geometry	Closed-End coaxial
Material	HPGe p-type
Energy range	40 - 10000 keV
Crystal radius	25.40 mm
Crystal height	41.2 mm
Core radius	4.65 mm
Core height	27.70 mm
Absorbing layer	2.45 mm Al
Inactive Ge	800 mm
Relative efficiency (NaI)	15%
FWHM	0.9 keV (at 122 keV)
	1.9 keV (at 1332 keV)
Peak to Compton ratio	44:1

Detector geometry

☐ Needed for calculation of:
   ■ Full-energy peak and total efficiencies
   ■ Self-absorbtion correction

☐ Determined by X-ray radiography

old detector (1970)

new detector (1985)
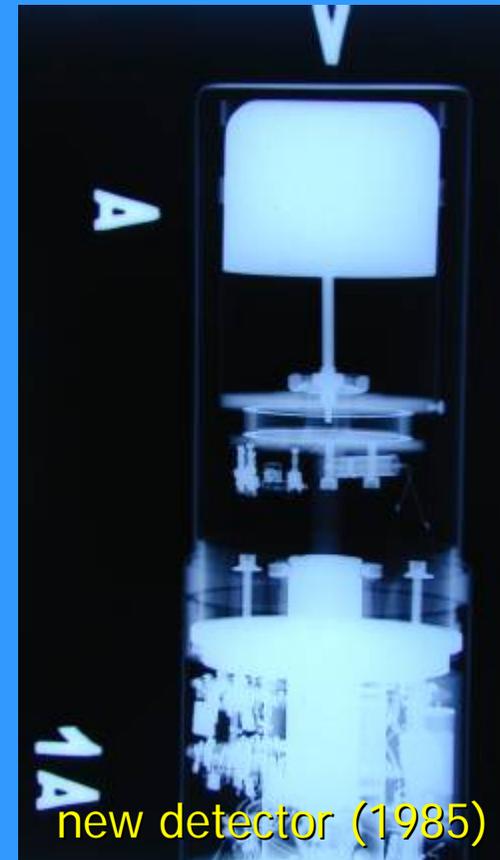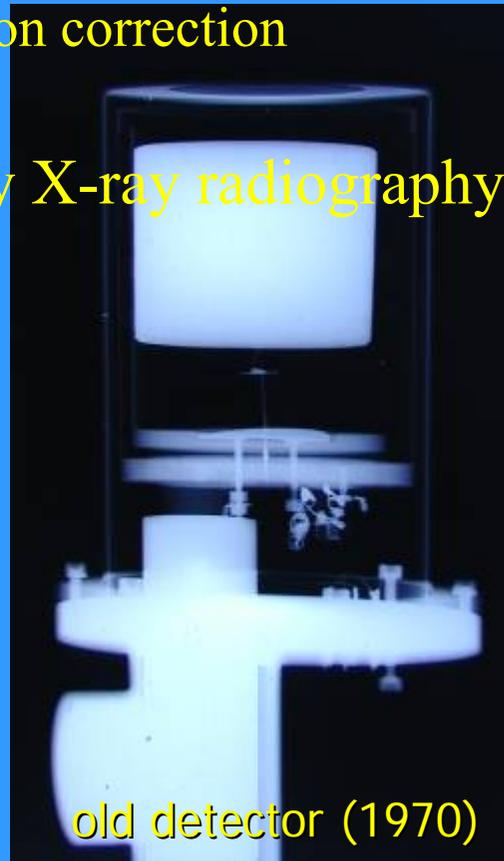
Measurement of the linear attenuation coefficient of the matrix

(linear attenuation of a collimated photon beam)

$$\frac{I}{I_0} = \int_0^L e^{-\mu x}\, dx$$

$$I = I_0\, \frac{1 - e^{-\mu L}}{\mu L}$$

Comparison of measured and calculated (X-Com) linear attenuation coefficients (tuff sample)

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Self absorbtion correction

(1 L Marinelli Beaker)

a) E = 59.5 keV

b) E = 661.7 keV
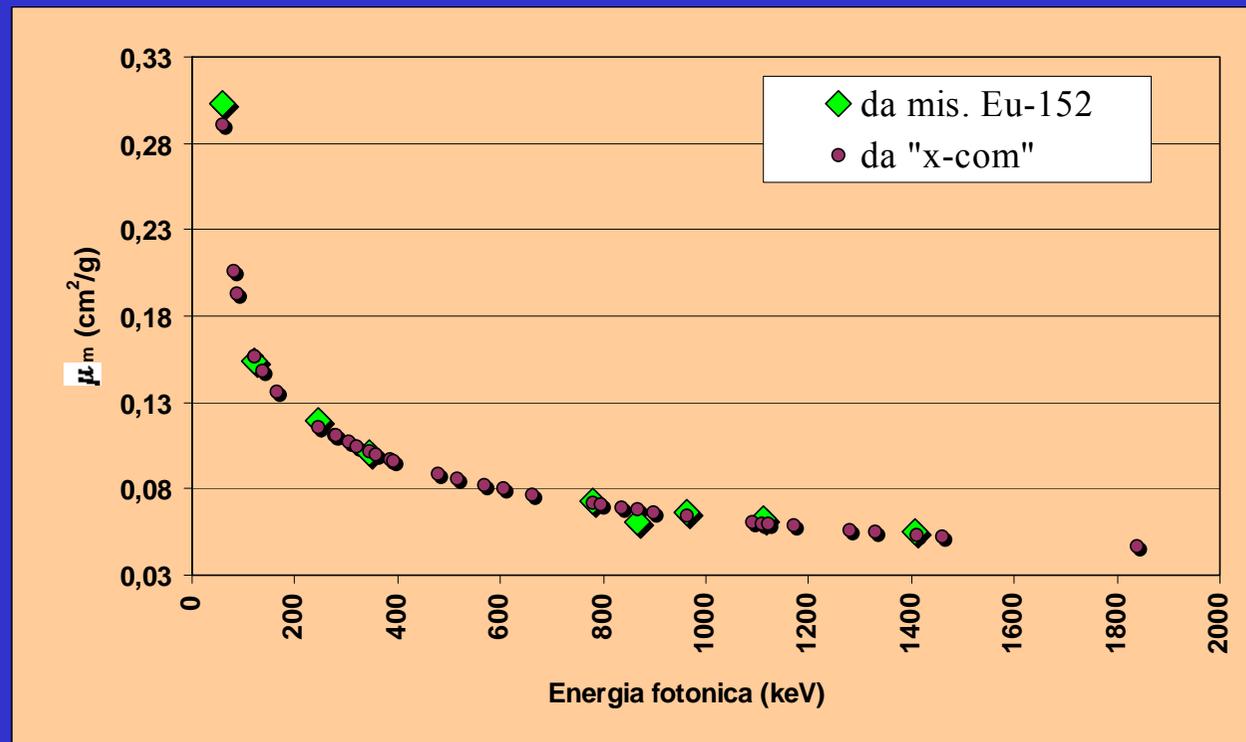
c) E = 1332.5 keV

Example of homogeneity test of SRMs

The relative deviation of the full-energy-peak efficiency values at 59.5 keV (a), 661.7 keV (b) and 1332.5 keV (c), from their respective average values are reported for each sample. The two dashed lines indicate the ±2σ limit bands.

INMRI ENEA
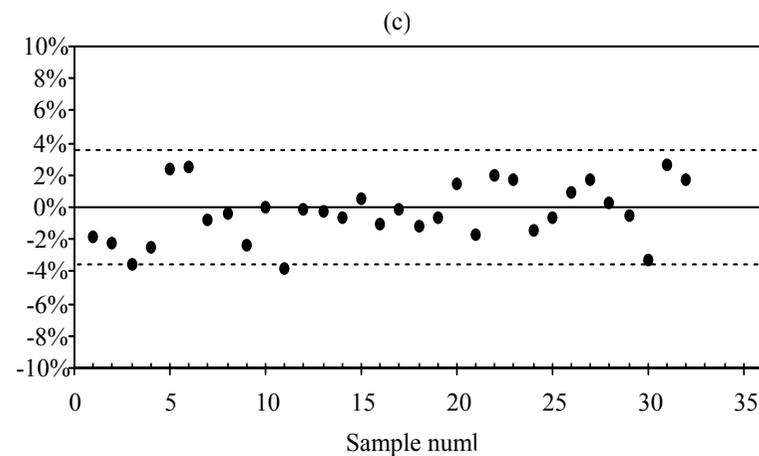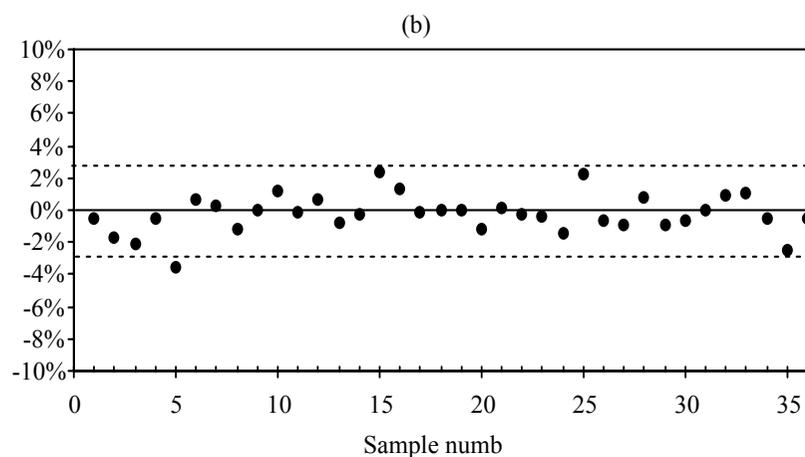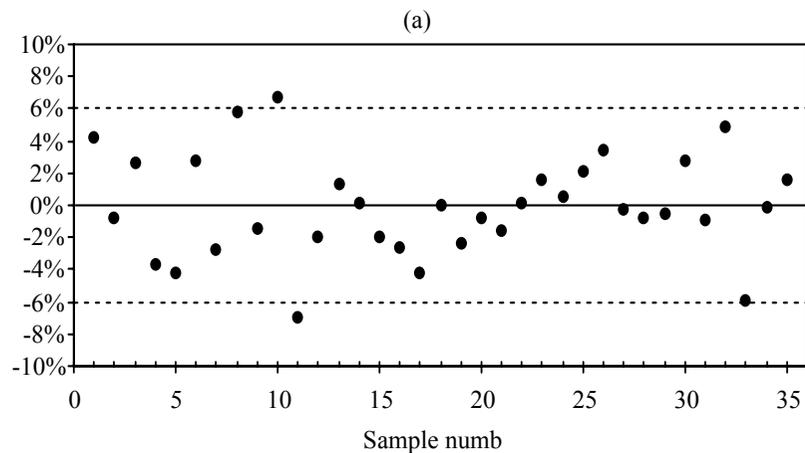
2004-2005 COMPARISON: SIMULATED AIR FILTERS

The 2004-2005 intercomparison

- 2004-2005 intercomparison campaign carried out for γ-ray spectrometry measurements on spiked simulated filters

- About 60 sources were prepared and distributed to the participating laboratories

- Application of coincident summing and geometry corrections

- Determination of the MAR for specific radionuclides and measurement conditions

Source preparation scheme

^{152}Eu (# 1503) ^{57}Co (# 1116) ^{60}Co (# 40) ^{134}Cs (# 201) ^{137}Cs (# 1574)

HCl 1N + carriers

MRL-1837

MIX

SF-1838

SF-1917

SF-1918

SF-1919

SP-1920

SP-1921

SP-1922

n° 80 sources on disk (filter geometry) deposition by volumetric method

n° 2 sources on disk (filter geometry) deposition by gravimetric method

n° 3 sources on disk (point source geometry) deposition by gravimetric method
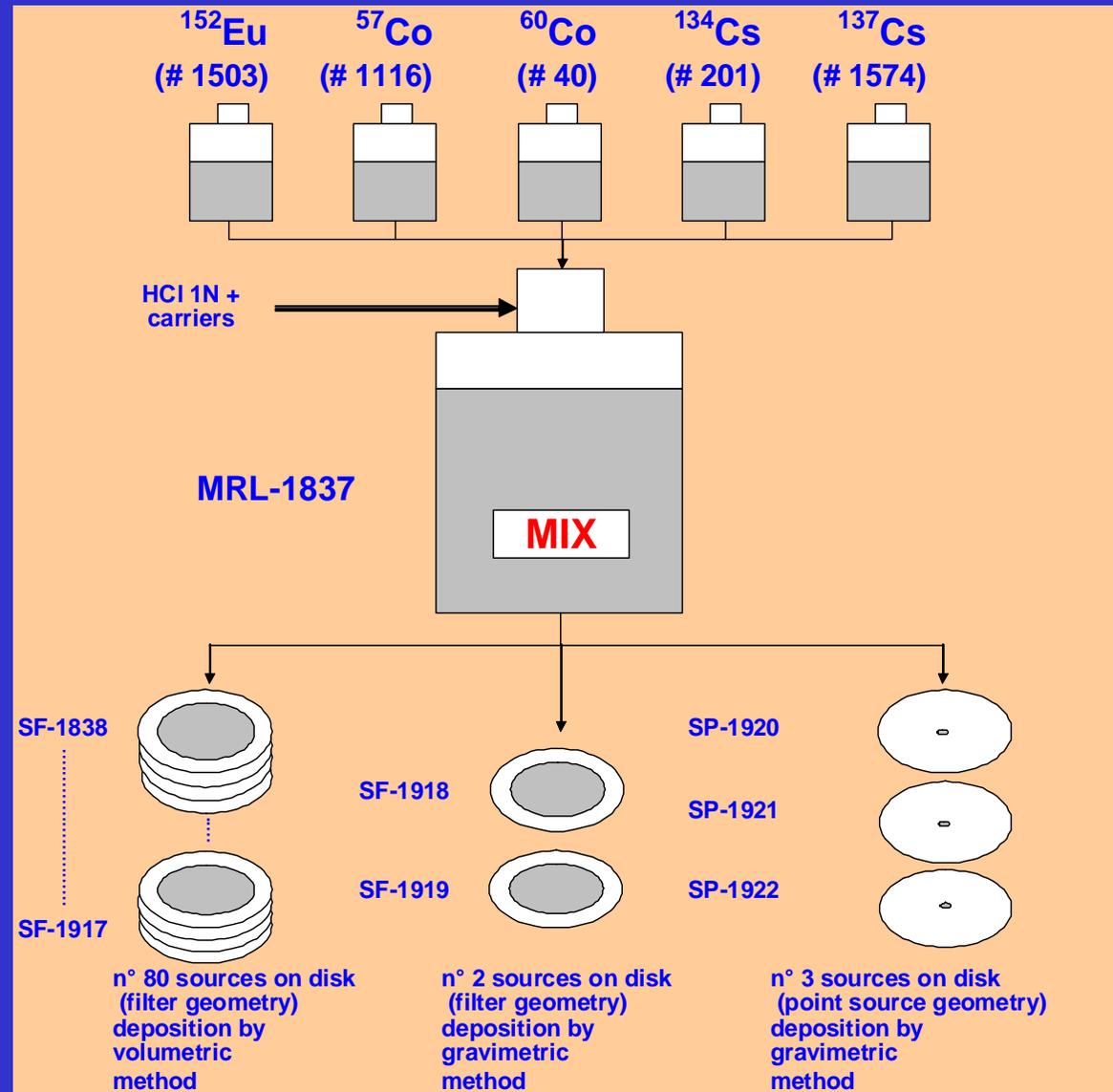
Main steps for preparation of the master solution

☐ Preparation of single-nuclide standard solutions (Co-57, Cs-134, Cs-137, Co-60, Eu-152)

- ■ Standardization
- ■ Dilution and stabilization
- ■ Purity check

☐ Preparation of the mixed-nuclide standard solution

- ■ Quantitative gravimetrical mixing
- ■ Stabilization
- ■ Quality control
- ■ Calibration

Main steps for preparation of the "simulated filter" sources

- ☐ Definition of the spiking geometry (M.C. code simulation)
- ☐ Preparation of sources in the "simulated filter" geometry
  - ◼ N. 2 sources by gravimetric deposition (Reference set)
  - ◼ N. 80 sources by volumetric deposition (Working set)
  - ◼ Source sealing by adhesive paper
- ☐ Characterization of the Working set
  - ◼ Counting the Reference and Working source sets on two measuring systems (HPGe and NaI detectors)
  - ◼ Reproducibility check and source selection
  - ◼ Calibration of the working set
  - ◼ Certification

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Deposition of standard solution by gravimetric method with polyethylene picnometer

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Deposition of standard solution by volumetric method

Dispenser:
Brand Dispensette III (0.05 ml)

Handling

Serial dispensing

The flexible discharge tube with safety handle facilitates serial dispensing. It permits fast and precise dispensing even into narrow test tubes.

Dispensette® III, Analog-adjustable

Capacity ml		Subdivision ml	A* ≤ ± %	µl	CV* ≤ %	µl	without SafetyPrime™ recirculation valve Cat. No.	with SafetyPrime™ recirculation valve Cat. No.
0.05	0.5	0.01	1.0	5	0.2	1	4700 100	4700 101
0.2 -	2	0.05	0.5	10	0.1	2	4700 120	4700 121
0.5 -	5	0.1	0.5	25	0.1	5	4700 130	4700 131
1 -	10	0.2	0.5	50	0.1	10	4700 140	4700 141
2.5 -	25	0.5	0.5	125	0.1	25	4700 150	4700 151
5 -	50	1.0	0.5	250	0.1	50	4700 160	4700 161
10 -	100	1.0	0.5	500	0.1	100	4700 170	4700 171

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Deposition of master solution with polyethylene picnometer

The Working and Reference Sets of standard air filter sources

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Source counting

Correlation of count rates

HPGe count rate frequency distribution
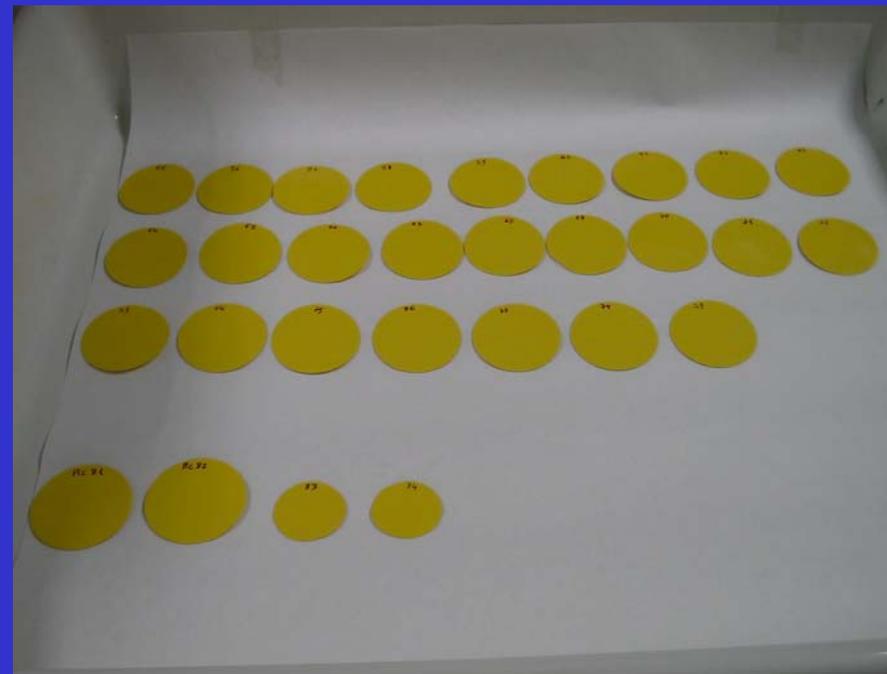
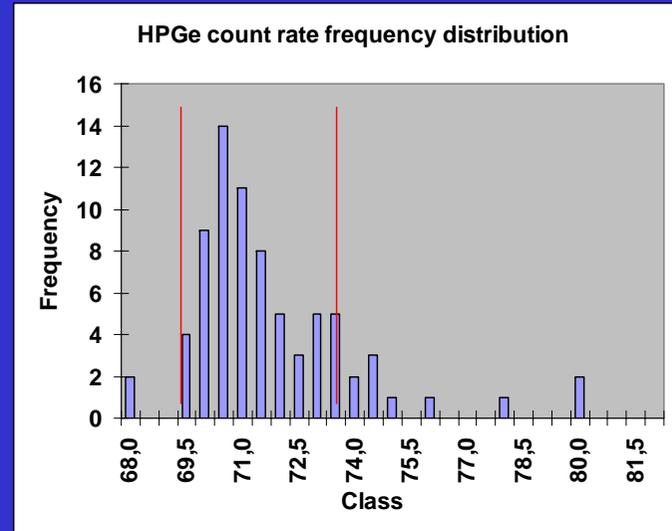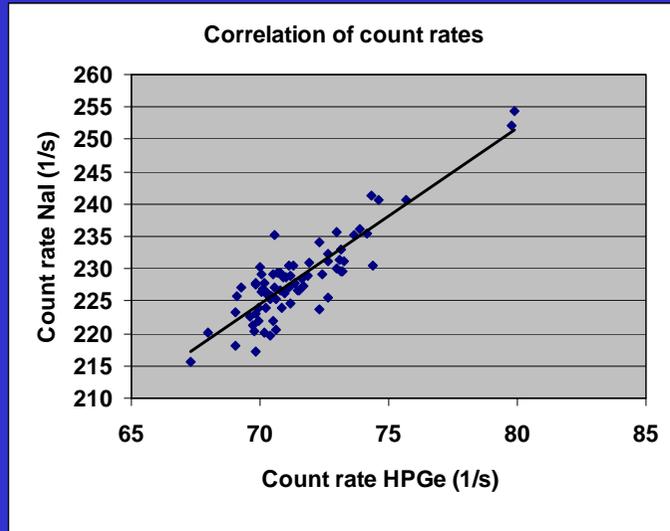|	HPGe-coax					NaI Well					RATIOS	
	ALL		SELECTED			ALL		SELECTED				
	Net count rate (s-1)	Deviation from average (%)	Net count rate (s-1)	Deviation from average (%)	Mass of solution (g)	Net count rate (s-1)	Deviation from average (%)	Net count rate (s-1)	Deviation from average (%)	Mass of solution (g)	NaI to HPGe	HPGe to NaI
AVERAGE	71,50	0,00	70,61	0,00	0,1930	228,32	0,00	226,14	-0,95	0,1930	3,20	0,31
ST.Dev	2,22	3,11	0,86	1,22	0,0060	6,59	2,89	3,67	1,61	0,0056	0,05	0,00
ST Dev (%)	3,1		1,2		3,1	2,9		1,6	-168,4	2,9	1,5	1,5
Count	76	76	55	55	76	72	72	54	54	72	72	72
Min	67	-6	69	-2,26	0,1817	216	-6	217	-5	0,1824		
Max	80	12	73	2,84	0,2156	254	11	235	3	0,2150		
Max-Min (%)	17	598	5	1749	17	16	576	8	-871	16		

Background	1,549					15,550						
Ref source n. 1	56,009				0,150	178,067				0,150		
Ref source n. 2	51,729				0,140	165,787				0,140		
R0/m0 1 (1/sg)					372,30					1183,64		
R0/m0 2 (1/sg)					368,80					1181,95		
AVERAGE (1/sg)					370,55					1182,80		
Dev (%)					-0,951					-0,143		

ST. Dev of the Activity	ALL	SELECTED
from variance (HPGe)	3,1%	1,1%
from variance (NaI)	2,8%	1,5%
from covariance (HPGe, NaI)	2,0%	0,9%

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Technical specification of the "Simulated filter" sources

- Support: polystyrene disc with aluminium ring
- Radionuclides: Co-57, Cs-134, Cs-137, Co-60, Eu-152
- Disk thickness: $0,30 \pm 0,05$ mm
- N° of drops dispensed: 19
- Spiking pattern: Reproducible pentagonal grid
- Average diameter of active deposit: 34 ± 1 mm
- Standard deviation of activity values: 1,5 %
- Calibration combined std uncertainty: 2-3 % (10 % per Co-57)
- Uniformity of radioactive deposit: ± 5 %
- Source stability > 99% (6 months)
- Radionuclidic impurity < 0,01%

INMRI ENEA
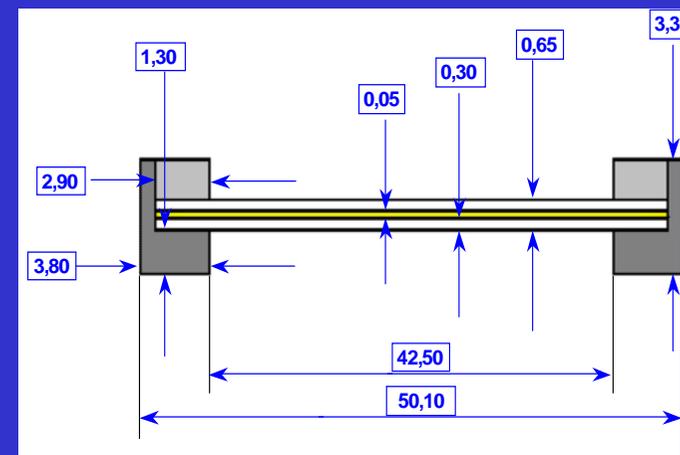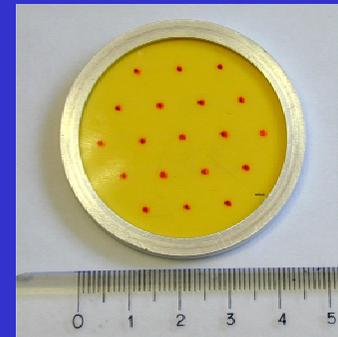
THE 2004-2005 INTERCOMPARISON

Participants (2004-2005)

APAT	E
APPA BOLZANO	E
APPA TRENTO	E
ARPA CALABRIA	E
ARPA CAMPANIA	E
ARPA EMILIA-ROMAGNA	E
ARPA FVG	E
ARPA LIGURIA	E
ARPA LOMBARDIA BERGAMO	E
ARPA LOMBARDIA CREMONA	E
ARPA LOMBARDIA MILANO	E
ARPA MARCHE	E
ARPA MOLISE	E
ARPA PIEMONTE ALESSANDRIA	E
ARPA PIEMONTE TORINO	E
ARPA PIEMONTE VERCELLI	E
ARPA SARDEGNA SASSARI	E
ARPA TOSCANA	E
ARPA UMBRIA	E
ARPA VALLE D'AOSTA	E
ARPA VENETO BELLUNO	E
ARPA VENETO PADOVA	E
ARPA VENETO VENEZIA	E
ARPA VENETO VERONA	E
ARPA VENETO VICENZA	E
ARTA ABRUZZO	E
AULSS 12 - VENEZIANA	O
C.I.S.A.M. - Pisa	O

C.R.I. ROMA	E
C.R.R. BARI	E
C.R.R. PALERMO	E
C.R.R. SARDEGNA	E
Commissione Europea-C.C.R. Ispra	O
ENEA C.R. CASACCIA	O
ENEA C.R. FRASCATI	O
ENEA C.R. SALUGGIA	O
ENEA C.R. TRISAIA	O
ENEA Fis-Ing C.R. BRASIMONE	O
ICIS-CNR PADOVA	O
INFN-LNF	O
ISPESL	O
IZS PUGLIA E BASILICATA	O
IZSLT ROMA	O
LENA - PAVIA	O
SOGIN CAORSO	O
SOGIN GARIGLIANO	O
SOGIN LATINA	O
SOGIN TRINO	O
UNIVERSITA' CATT. PIACENZA	O
UNIVERSITÀ DI BOLOGNA	O
UNIVERSITA' DI CAGLIARI	O
UNIVERSITA' NAPOLI-Sede Caserta	O
UNIVERSITA' NAPOLI-Sede Napoli	O
UNIVERSITA' PERUGIA	O
UNIVERSITA' POLITECNICO MILANO	O

Total number of participants: 55

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Critical aspects to be considered by participants
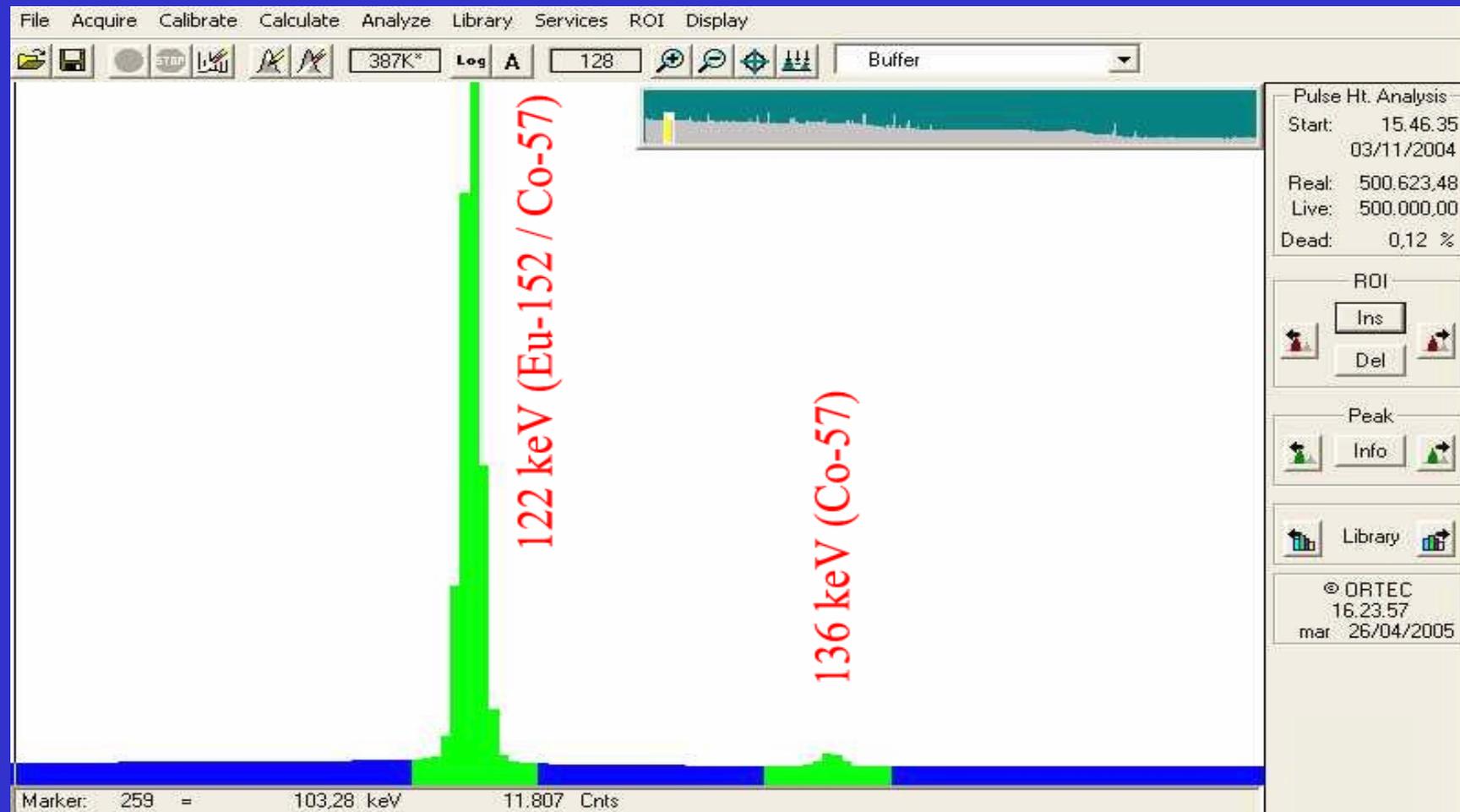
☐ Low radionuclide activities

☐ Non standard source geometry

☐ Coincident summing nuclides

☐ Spectral multiplets: 121.78 keV (^{152}Eu) – 122.06 keV (^{57}Co)

☐ Count rate of 136 keV (^{57}Co) peak at very low level

Typical spectrum with P-type HPGe detector
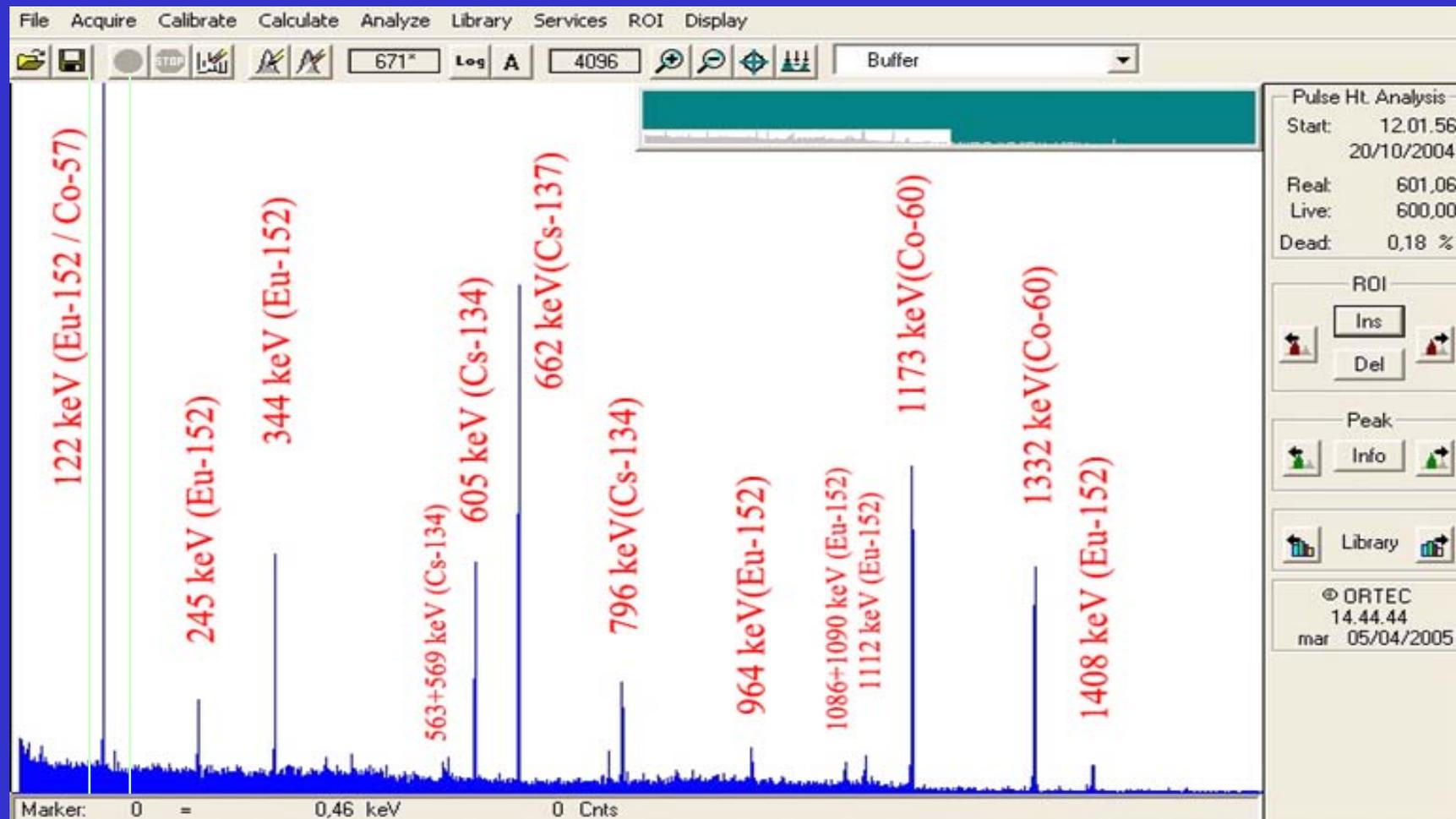
# Typical spectrum with P-type HPGe detector

Measurement instruments

Codice	RIVELATORE	TIPO	GEOM	Eff. Rel. (%)	Vol. sensibile (cm3)
1,0	HPGe	P	COAX	28,5%	137
2,0	HPGe	P	COAX	32,6%	144
4,0	HPGe	P	COAX	28,0%	148
5,0	HPGe	P	COAX	21,6%	104
6,0	HPGe	P	COAX	28,0%	159
8,0	HPGe	P	COAX	25,0%	90
9,0	HPGe	P	COAX		
10,0	HPGe	P	COAX	25,0%	134
11,0	HPGe	P	POZZ.	27,8%	120
12,0	HPGe	P	COAX	32,5%	139
13,0	HPGe	P	COAX	25,0%	
14,0	HPGe	P	COAX	30,0%	100
16,0	HPGe	P	COAX	30,0%	169
17,0	HPGe	P	COAX	28,0%	153
18,0	HPGe	P	COAX		105
19,0	HPGe	P	COAX	30,1%	130
21,0	HPGe	P	COAX	44,3%	61
22,0	HPGe	P	COAX	25,0%	
23,1	HPGe	P	COAX	28,0%	133
23,2	HPGe	P	COAX	19,0%	102
24,0	HPGe	P	COAX	81,7%	
25,0	HPGe	P	COAX	25,0%	120
26,0	HPGe	N	COAX		
27,0	HPGe	P	COAX	48,0%	194
28,0	HPGe	P	COAX	28,0%	120
30,0	HPGe	P	COAX	35,0%	217
31,0	HPGe	P	COAX	27,6%	128

Codice	RIVELATORE	TIPO	GEOM	Eff. Rel. (%)	Vol. sensibile (cm3)
34,0	HPGe	P(*)	COAX	59,5%	
35,0	HPGe	P	COAX	28,0%	
36,0	HPGe	P	COAX	20,0%	110
37,1	HPGe	P	COAX	29,9%	
37,2	HPGe	P	COAX	26,9%	
38,0	HPGe	P	COAX	30,0%	140
39,0	HPGe	P	COAX	25,0%	133
40,0	HPGe	P	COAX	25,0%	142
41,0	HPGe	P	COAX	70,0%	336
42,0	HPGe	P	COAX	25,0%	140
43,0	HPGe	P	COAX	28,0%	147
44,0	HPGe	P	COAX	33,0%	155
45,1	HPGe	N	COAX	36,0%	198
45,2	HPGe	P	COAX	26,5%	144
45,3	HPGe	N	COAX	40,0%	211
46,0	HPGe	N	COAX	50,2%	223
47,0	HPGe	P	COAX	30,0%	129
48,1	HPGe	P	COAX	25,0%	139
48,2	HPGe	P	COAX	30,0%	163
49,0	HPGe	P	COAX	55,7%	268
50,0	HPGe	N	COAX	24,1%	109
51,0	HPGe	P	COAX	20,0%	86
53,1	HPGe	P	COAX	25,0%	36
53,2	HPGe	P	COAX	25,0%	125
54,0	HPGe	N	COAX	61,2%	48
55,0	HPGe	P	COAX	43,5%	174

(*) Eff. Rel. a 1,3 MeV

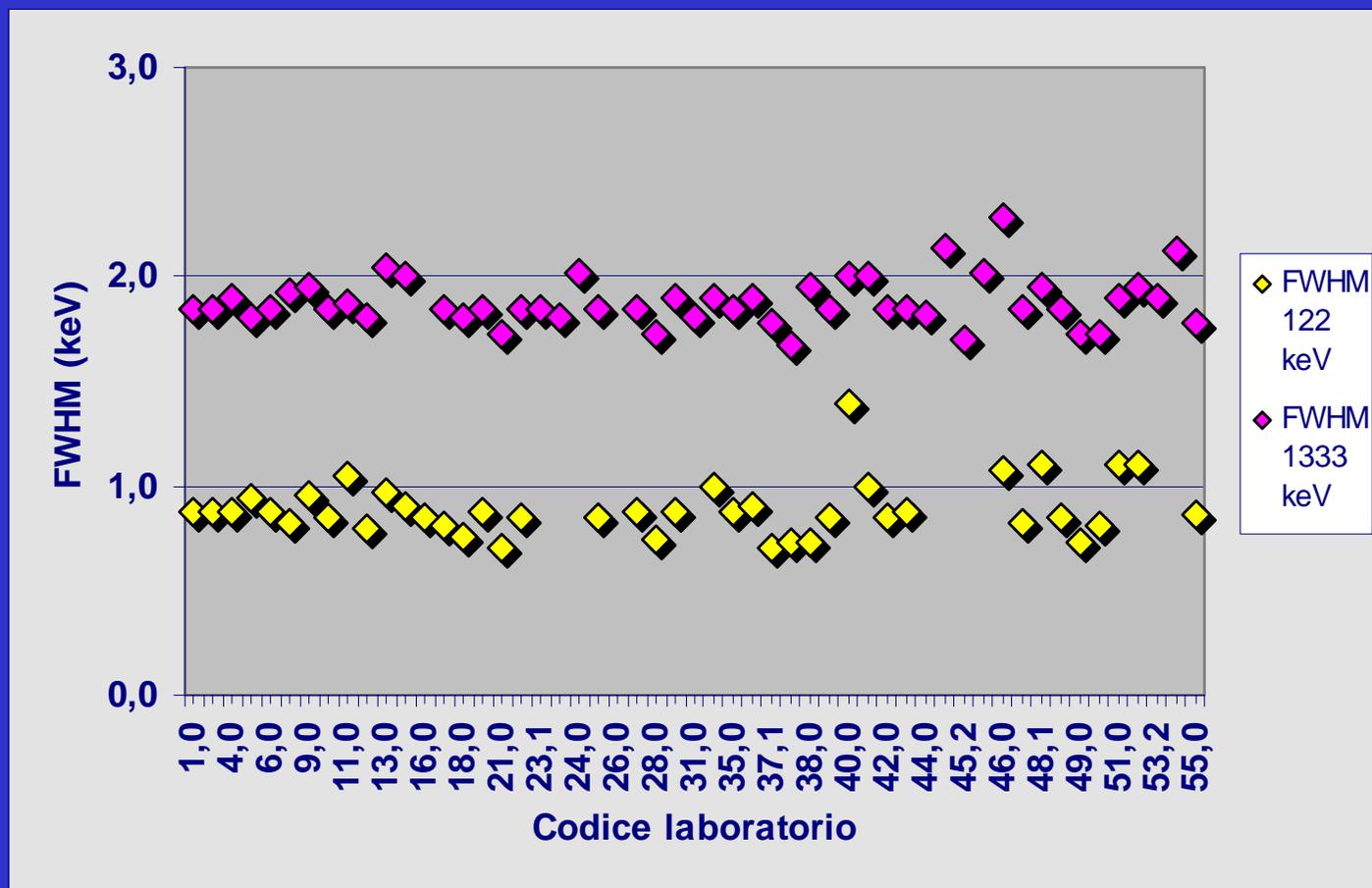INMRI · ENEA

Items Examined in data evaluation

- [ ] Nominal detector efficiency vs detector volume
- [ ] Procedures for detector calibration and uncertainties achieved
- [ ] Coincident-summing correction
- [ ] Geometry correction
- [ ] Counting times
- [ ] Dead time correction
- [ ] Energy resolution
- [ ] Background correction
- [ ] Counting efficiency
- [ ] Nuclide identification
- [ ] Accuracy in activity determination (deviation from reference values)
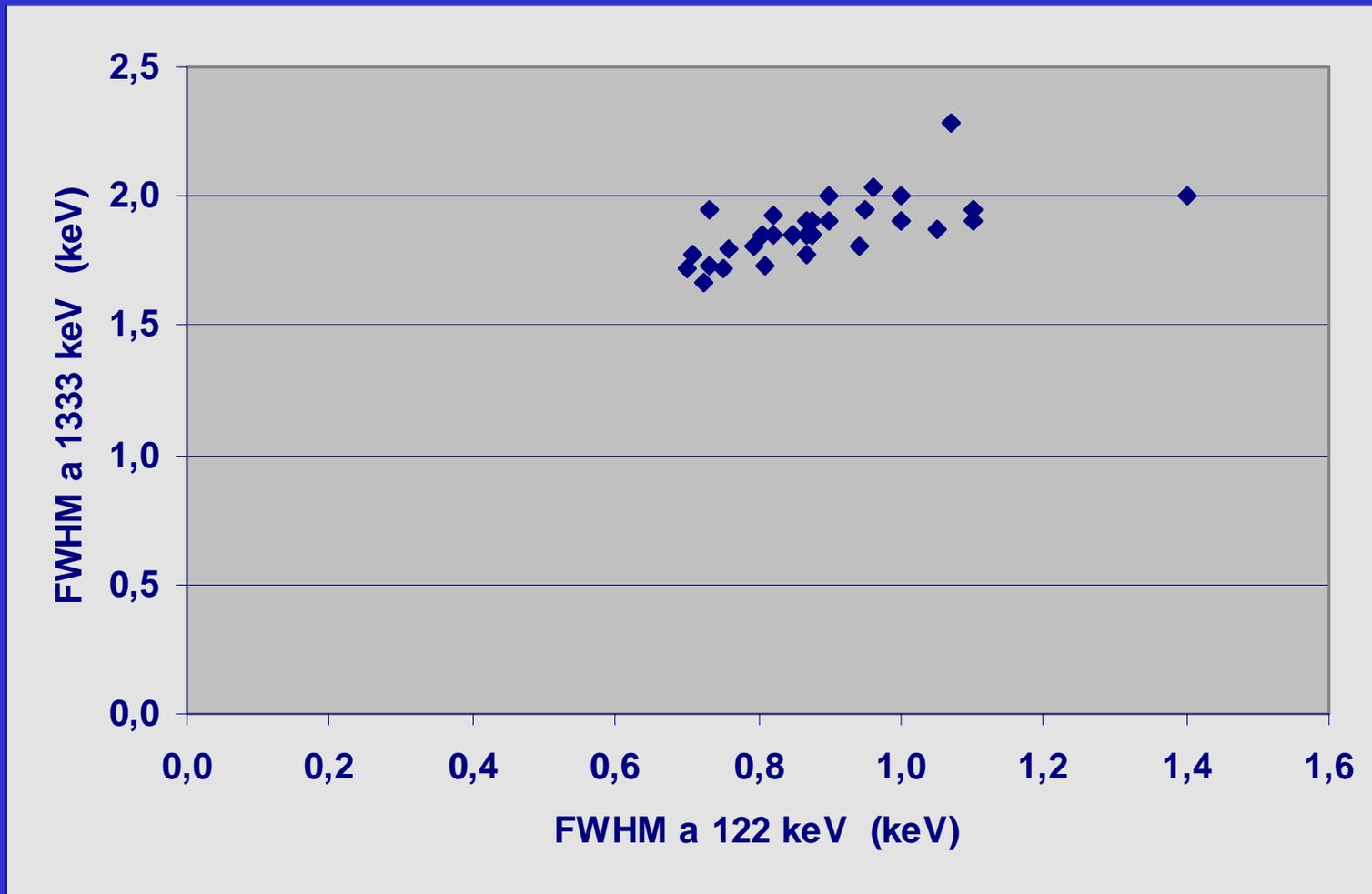- [ ] MDA

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Example: Dead time analysis

Dead time > 1%   (3 results.: Cod. 4 -44 -49)
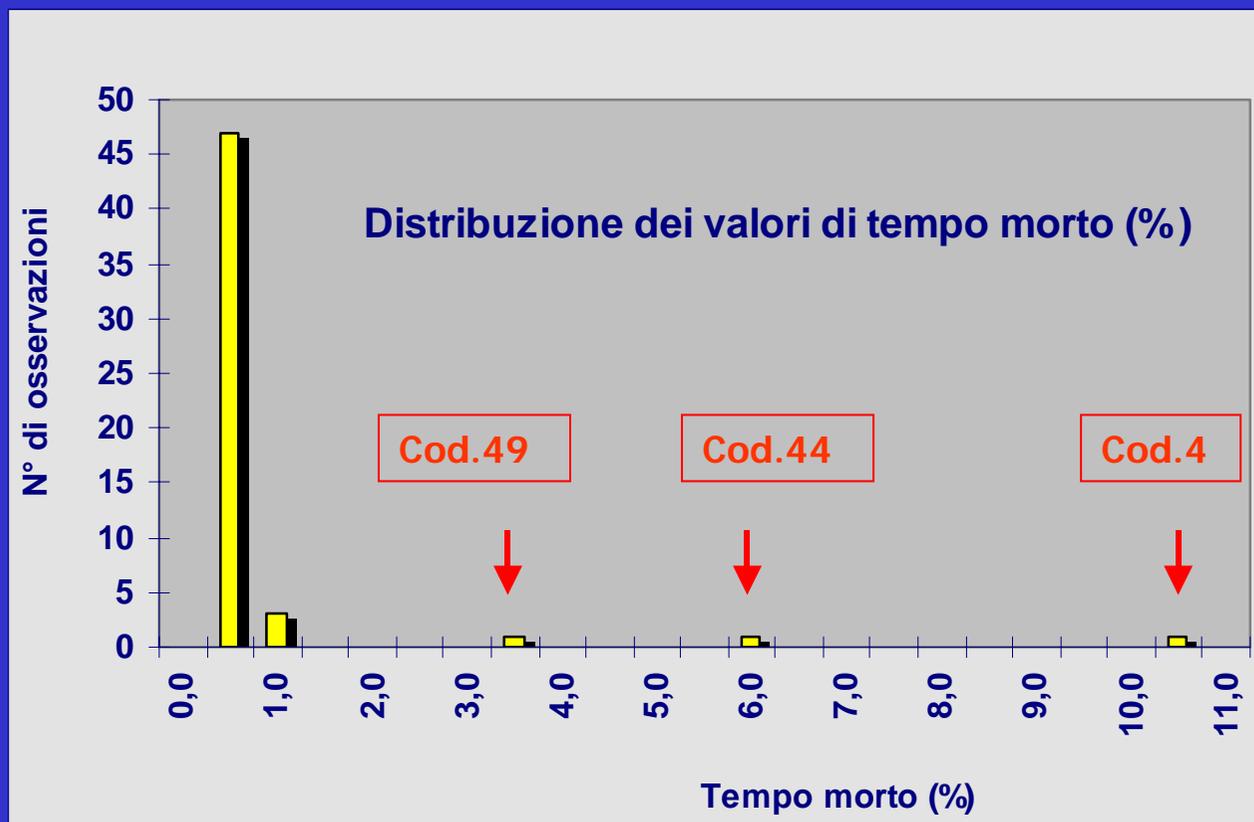
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Example: Energy resolution analysis (1)

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Example: Energy resolution analysis (2)
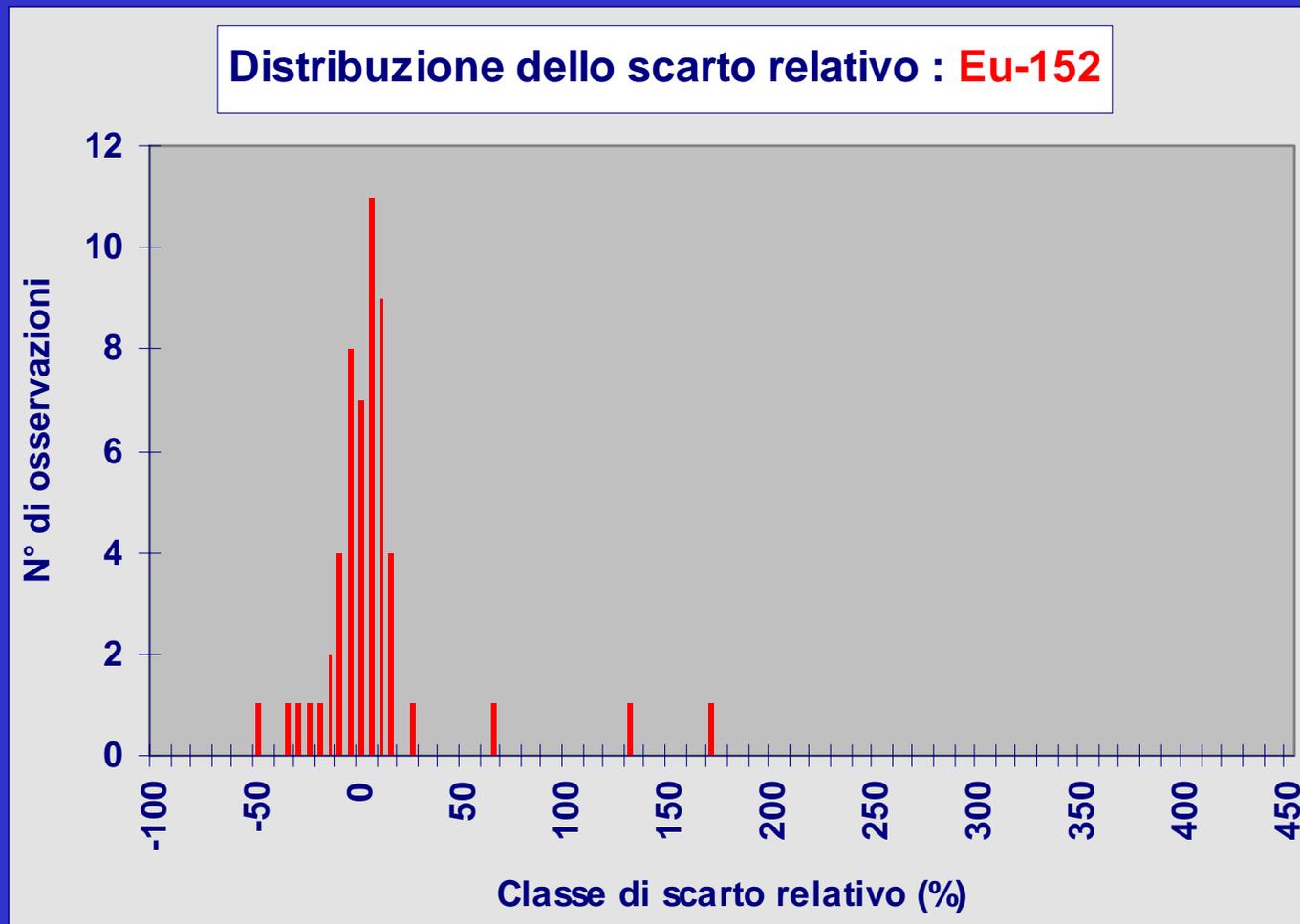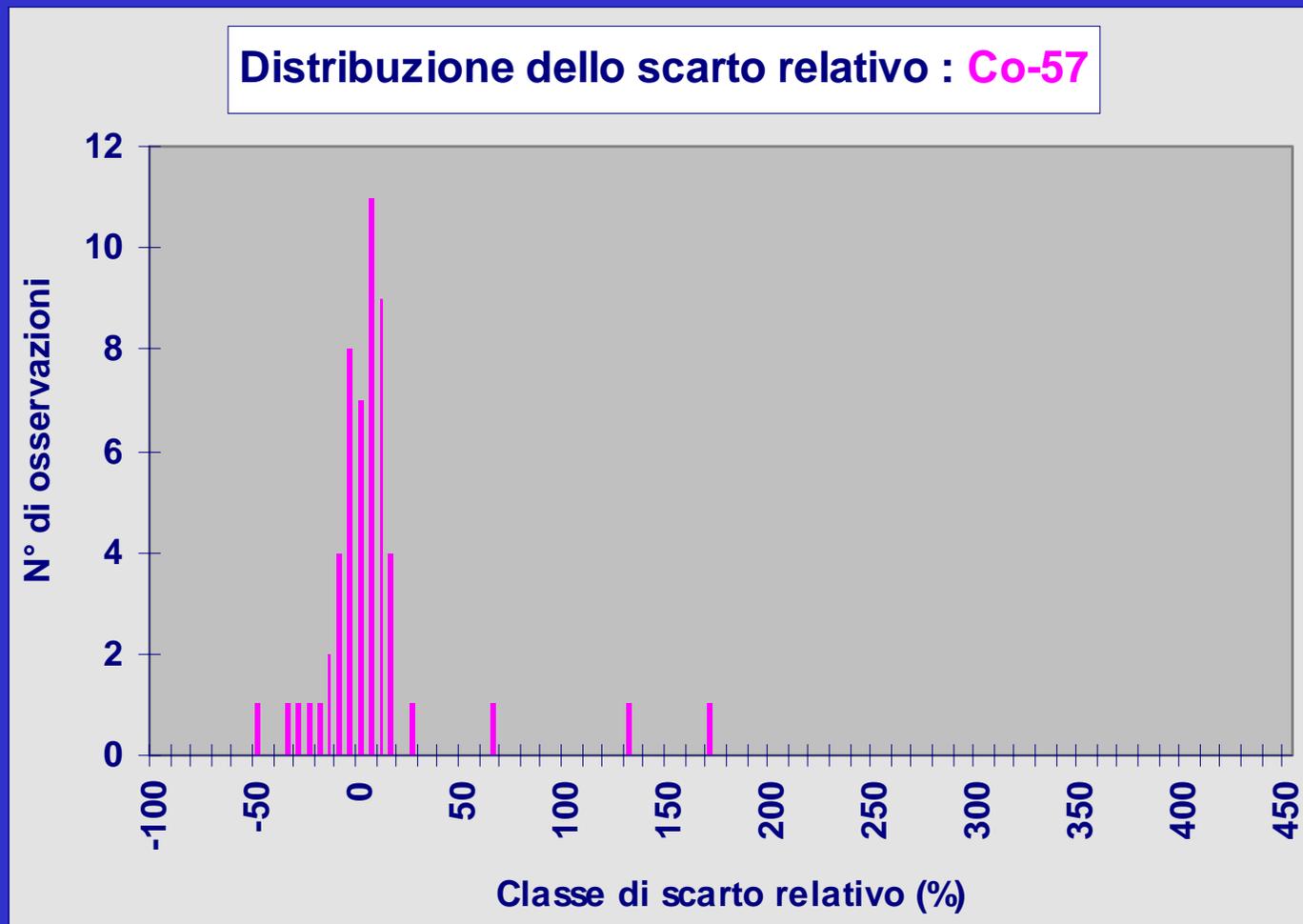
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Deviations from reference values

Distribuzione dello scarto relativo : Eu-152

N° di osservazioni

Classe di scarto relativo (%)

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Deviations from reference values

Distribuzione dello scarto relativo : Co-57

N° di osservazioni

Classe di scarto relativo (%)

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Deviations from reference values

Distribuzione dello scarto relativo : Co-60

N.58

Deviations from reference values

Distribuzione dello scarto relativo : Cs-134

N° di osservazioni

Classe di scarto relativo (%)

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Deviations from reference values

Distribuzione dello scarto relativo : **Cs-137**

N° di osservazioni

Classe di scarto relativo (%)

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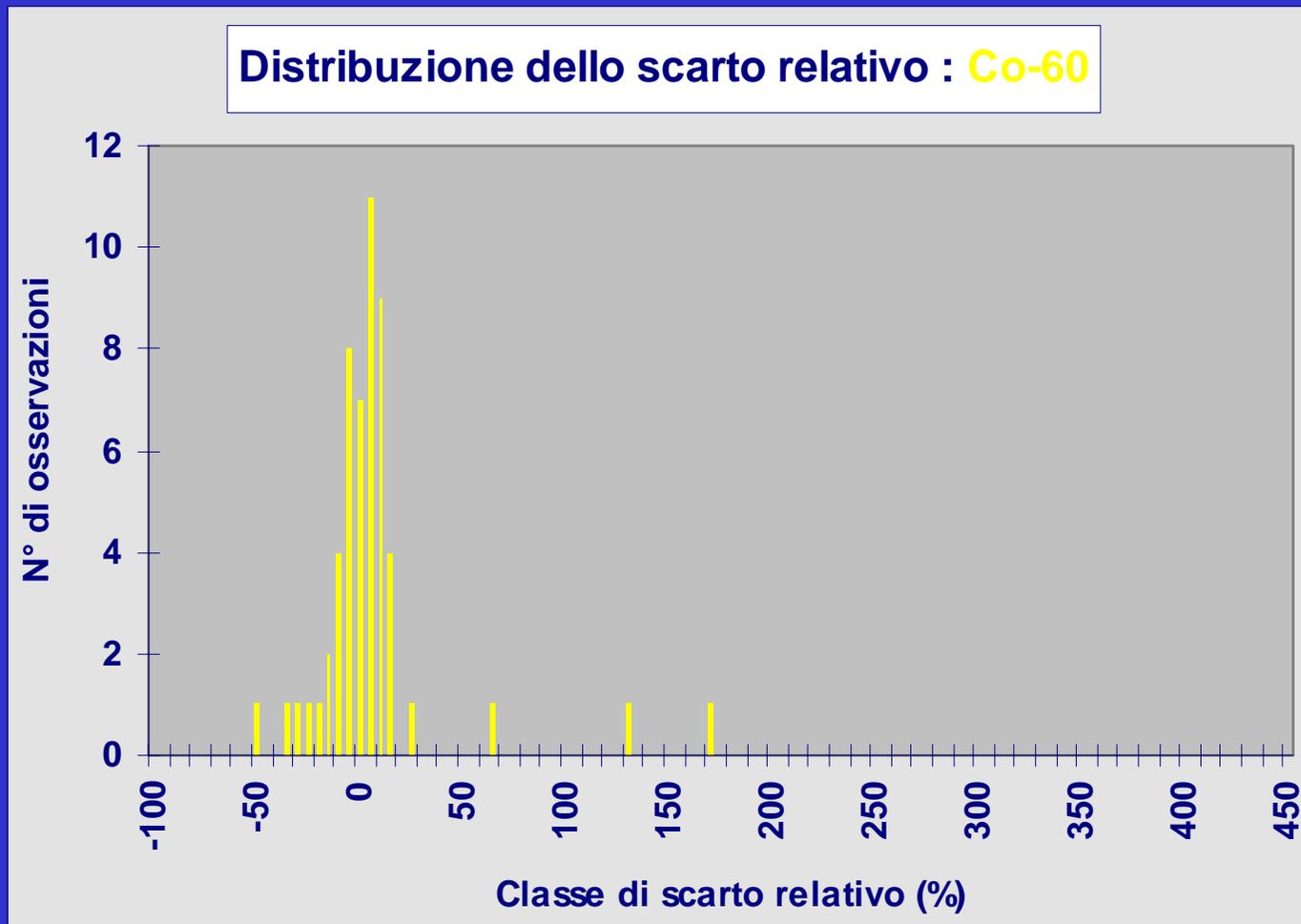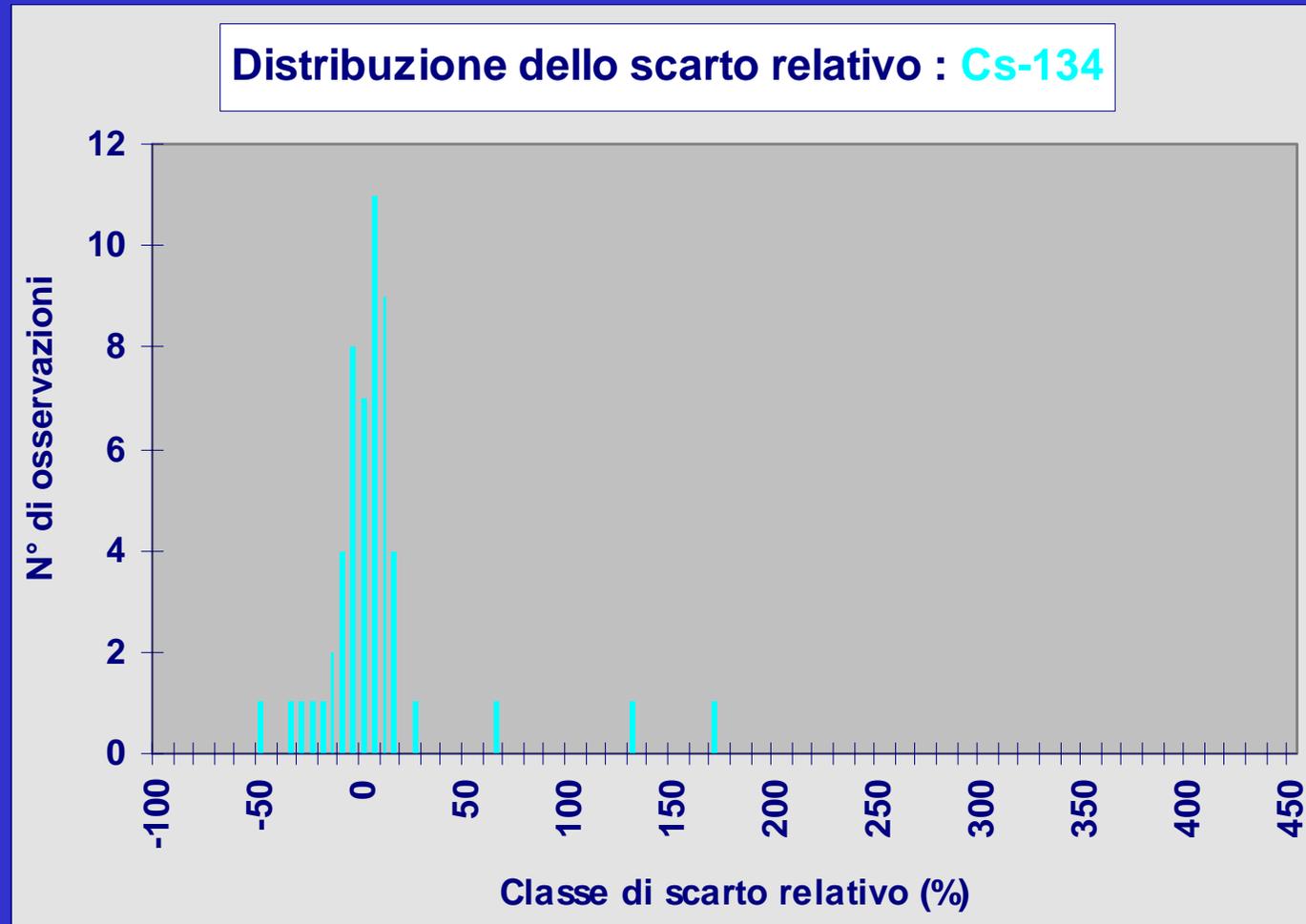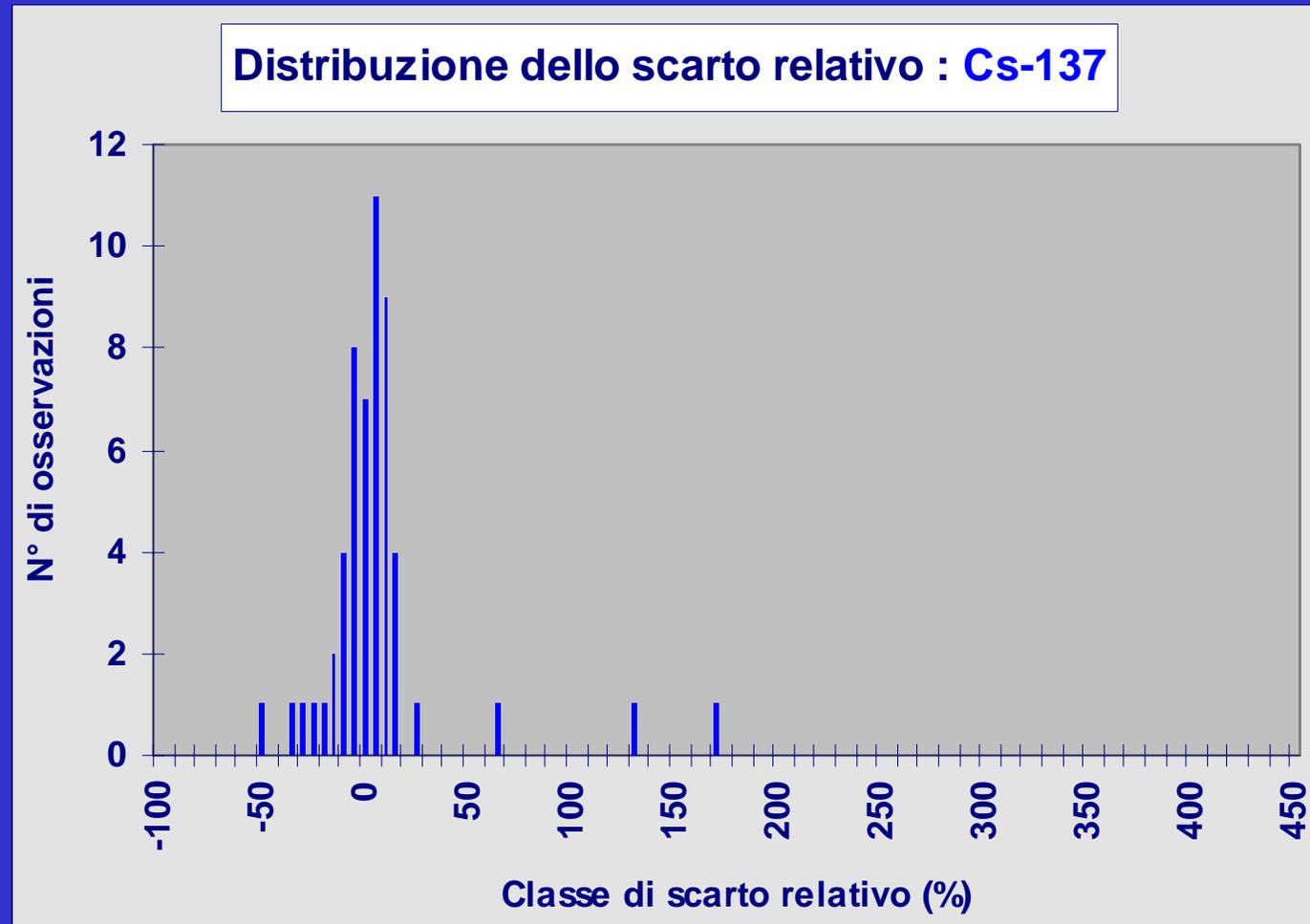
Conclusions

- ☐ Average accuracy level within 10-15% (non standard geometry)

- ☐ Outliers still present

- ☐ Corrections for coincidence-summing and geometry applied by several participants

- ☐ MDA not always correctly evaluated

RADON METROLOGY AT ENEA-INMRI

INMRI ∴ ENEA

Radon metrology
at INMRI-ENEA

- The INMRI-ENEA has been involved since 1990 in research and development of radon measurement standards

- The INMRI-ENEA has set up the experimental equipment for calibration of a large variety of radon measurement instruments

TRACEABILITY of radon calibrations

Ra-226 Reference source
(liquid solution)

Ra-226 Reference Measurement System
(ionisation chamber +. HPGe det.)

Ra-226 standard sources
(liquid solution)

Rn-222 Reference Measurement System
(electrostatic cell)

Rn-222 Transfer Measurement System
(NaI well-type detector)

Rn-222 standard sources
(gas source)

Ra-226 standard sources
(charcoal matrix)

Rn-222 standard sources
(radon-in-water standard)

Rn-222 Reference
Atmosphere
(radon chambers)

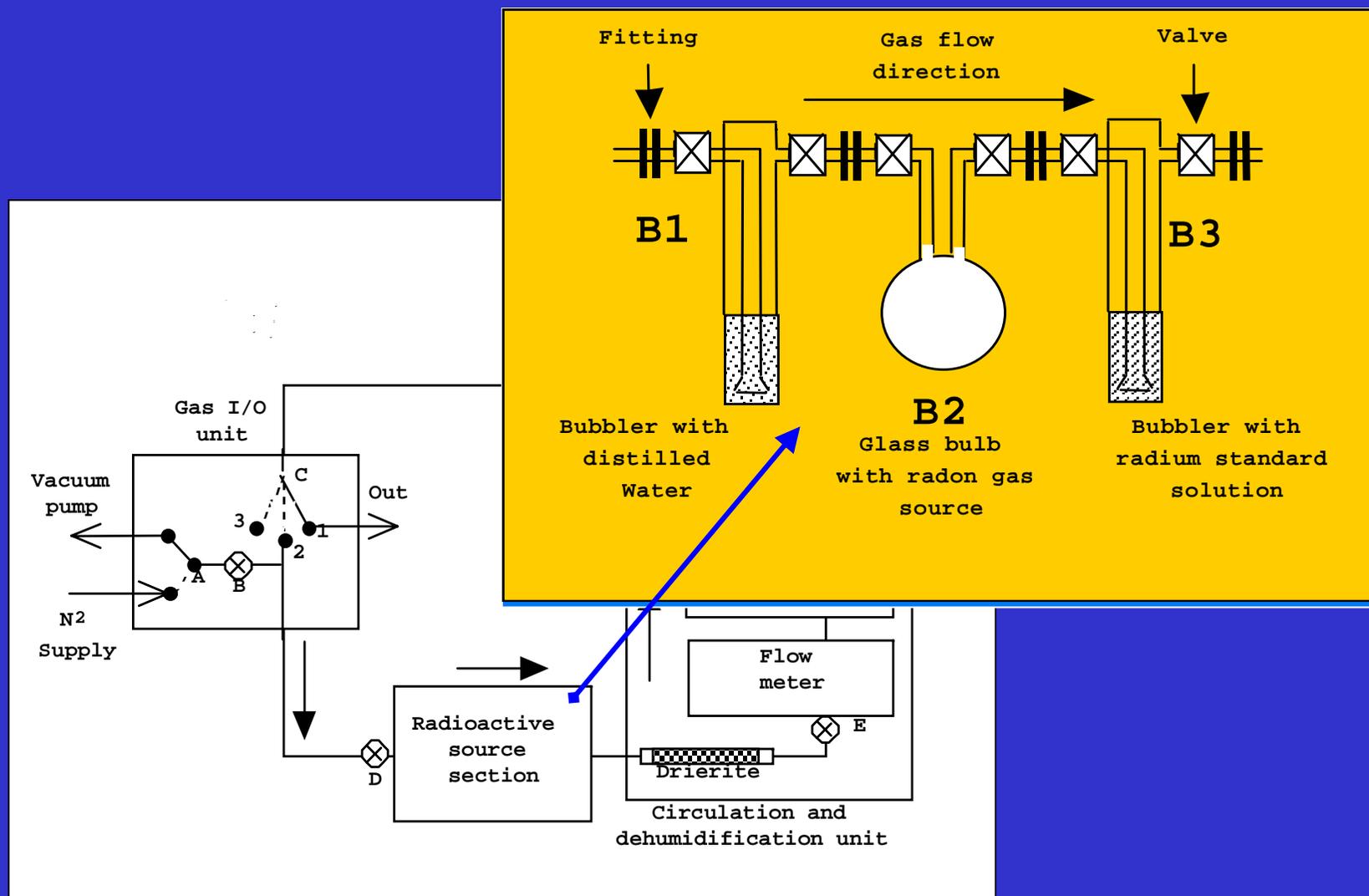# EQUIVALENCE of radon calibrations

❑ International comparisons (BIPM, EUROMET) support the equivalence of national standards

❑ EUROMET intercomparison (radon-in-air)

The Rn-222 Reference Measurement System

Fitting

Gas flow direction

Valve

B1

B3

B2

Bubbler with distilled Water

Glass bulb with radon gas source

Bubbler with radium standard solution

Gas I/O unit

Vacuum pump

Out

N2 Supply

C

3

1

2

A

B

Radioactive source section

Flow meter

Drierite

Circulation and dehumidification unit

D

E
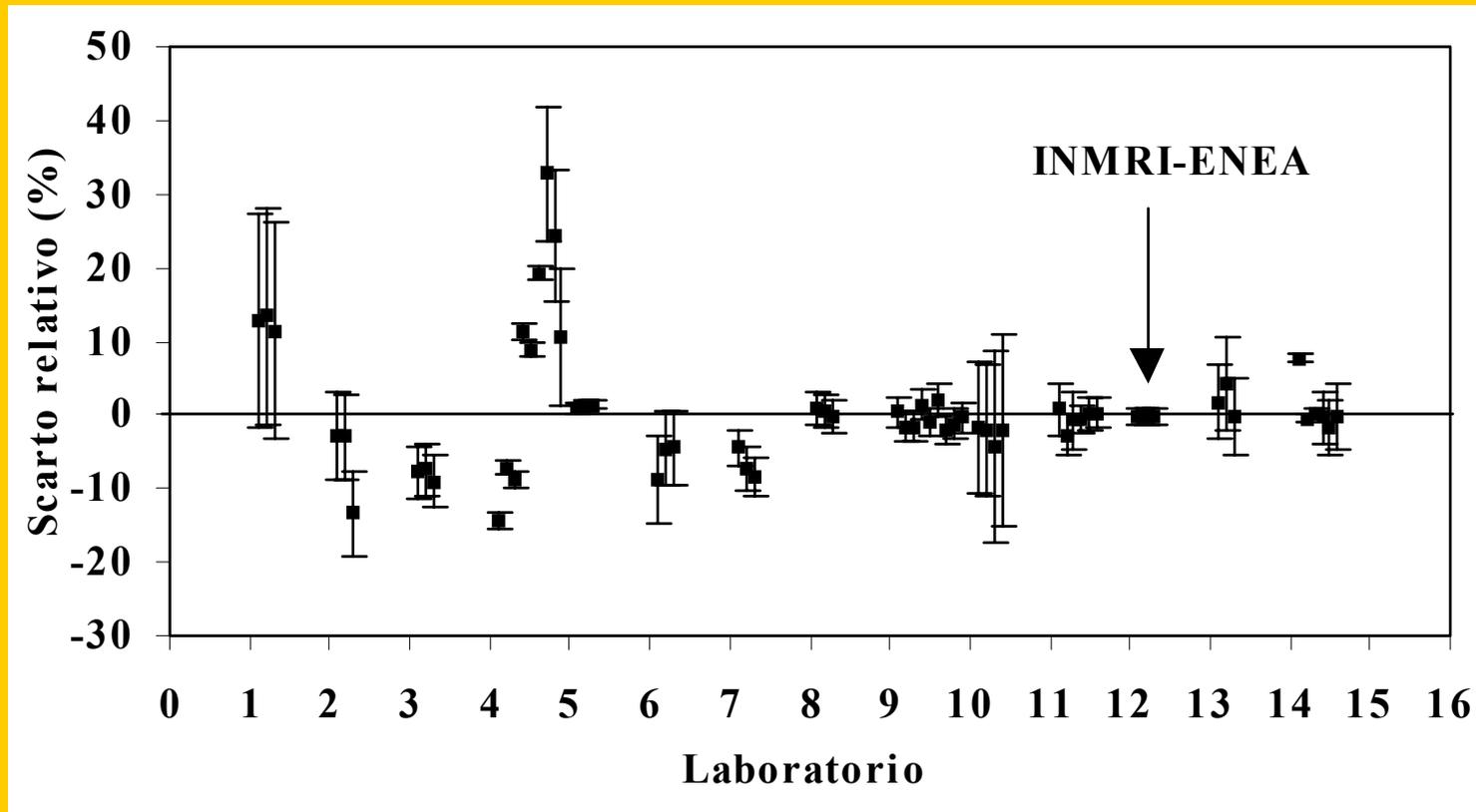
The Rn-222 Reference Monitor

to the measuring system

Si detector

H.V. +4 kV

Pressure gauge

Gas outlet

Gas inlet

Stainless steel tank

Electrical insulator shield
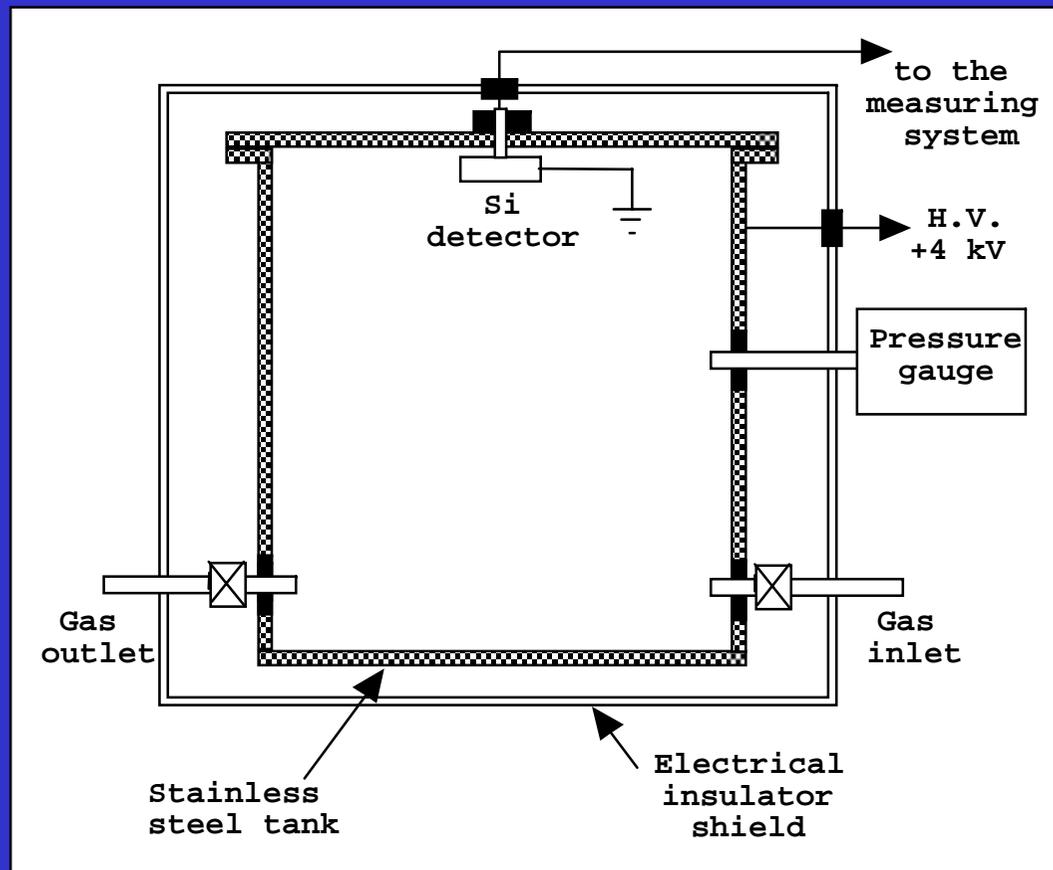
Schematic picture of the glass bulb used for radon gas sampling

est 9 mm

42 mm

est 8 mm
int 3 mm

64 mm

42 mm

Frontal section   Lateral section
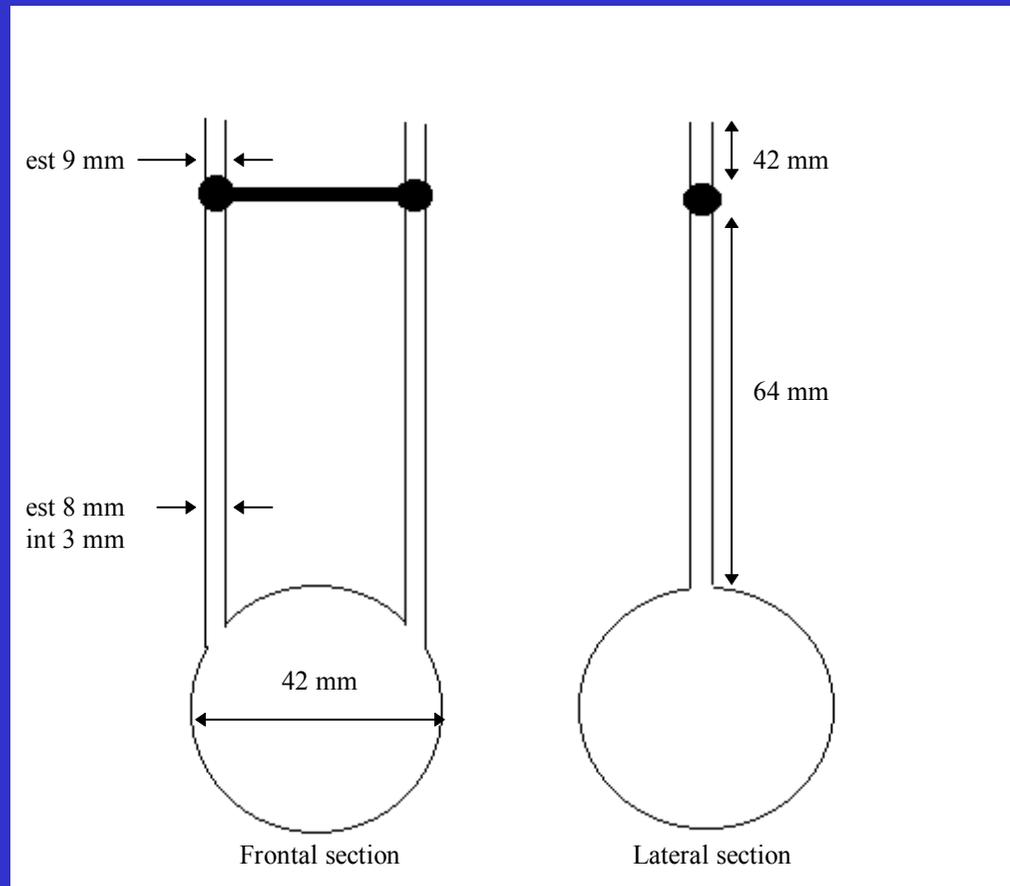
Calibration procedure for radon-in-air measurement instruments

☐ Radon activity in gas source is measured by the Rn-222 RMS

☐ Radon is transferred in a closed chamber

☐ The chamber volume is measured

☐ The activity concentration is calculated

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DIAGRAM OF THE CALIBRATION CIRCUIT
(for passive detectors, continuous/diffusion monitors)

Radon chamber

T U P

P
U
T

Radon
measuremet
instrument or
detector

P
U
T

T U P

Reference
volume

Gas flow
meter

Radon ref.
monitor

Gas flow

Circulation
pump

Humidity
control

Standard
source

Gas In/Out

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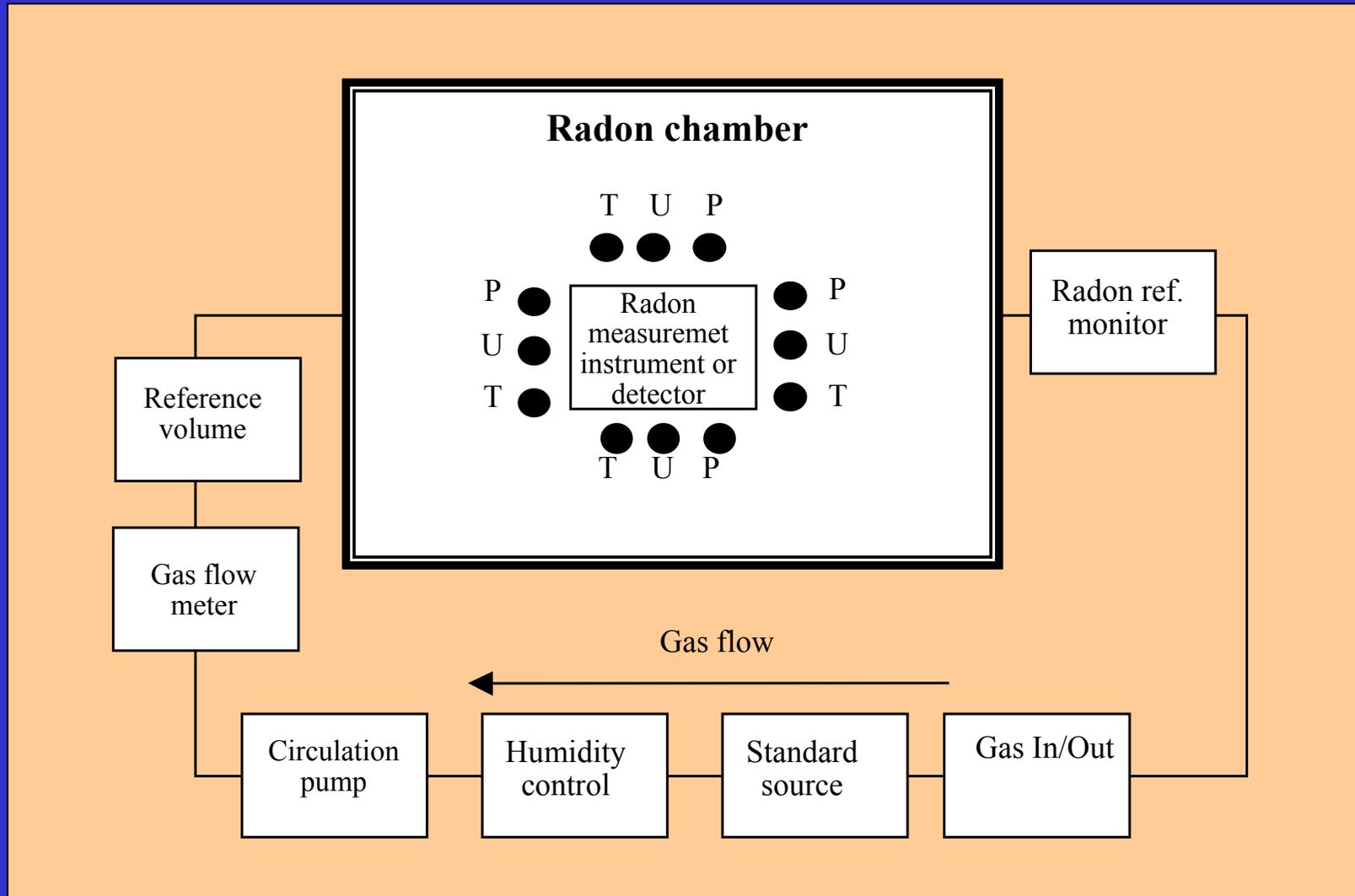
Main characteristics of the standard atmosphere

Influence parameter	Working interval	Stability (%)
Rn concentration	0,5 kBq m^{-3} - 5 kBq dm^{-3}	2
Rn activity	0,5-20 kBq	1
Chamber volume	4 dm^3 - 1 m^3	0,5
Temperature	18 - 24 °C	10
Relative Humidity	55 - 65 %	10
Pressure	800 - 1000 mbar	10
Carrier gas	C Air, N$_2$, He$_2$	-
Air particulate	0,4 - 0,9 μ Filtration	20
Exposure duration	1 - 72 h	-
Exposure	0,5 – 1000 kBq h m^{-3}	-

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Source of uncertainty	Standard unc. (%)
Homogeneity	3,2
Air particulate (ref. monitor)	2,6
Gas flow	2,4
Chamber volume	2,1
Radon transfer	2,1
Long term stability (ref. monitor)	2,1
Temperature correction (ref. monitor)	1,5
Pressure correction (ref. monitor)	1,5
Linearity (ref. monitor)	1,5
Relative Humidity correction (ref. monitor)	1,3
Activity measurement	1,2
Counting statistics (ref. monitor)	0,4
Background (ref. monitor)	0,1
Radon decay	0,1
Combined standard uncertainty	**6,8**

Standard atmosphere: components of the standard uncertainty

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RADON-IN-WATER STANDARD

COMPONENTS:

☐ Radon-in-water generator;

☐ Radon-in-water measurement systems:

◾ HPGe gamma-ray spectrometrer

◾ Alpha/beta liquid scintillation counter

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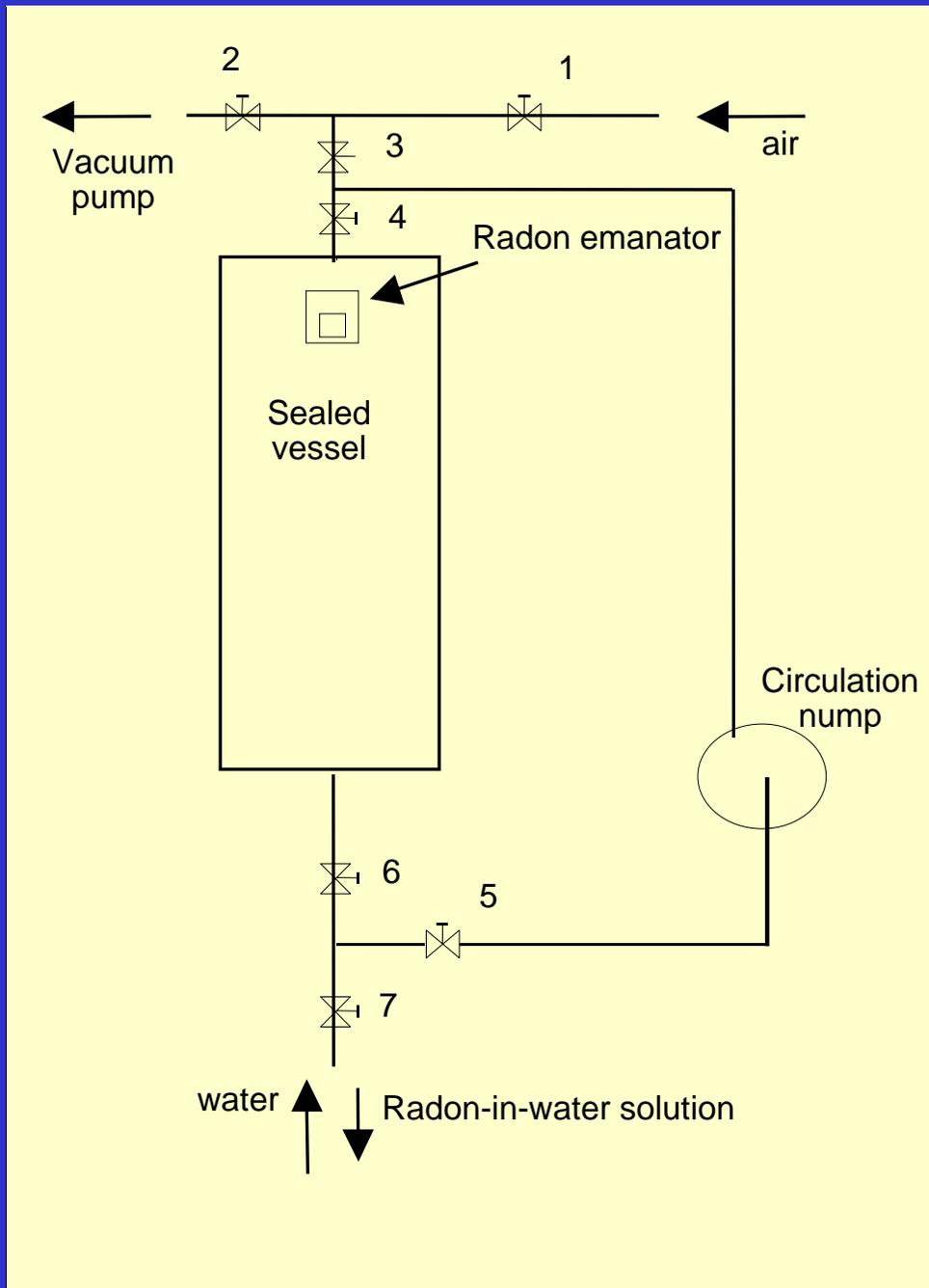
Diagram of the radon-in-water generator

Main characteristics of the radon-in-water standard

Radon activity concentration	200 – 10000 Bq/L
Combined standard uncertainty	1.9%
Radium content	<0.1 Bq/L
Volume of solution	10 mL – 4 L

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Uncertainty budget of the radon-in-water concentration

Source of uncertainty	Standard uncertainty (%)
Activity of the radium standard source	0.6
Reproducibility	0.8
Radon adsorption	1,0
Counting statistics (gamma-ray spec.)	0.6
Counting statistics (LSC)	1.2
Combined standard uncertainty	**1.9**

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Future developments

- Extensive calibration program
- Intercomparison campaign on radon measurements

Reference materials for Nuclear Medicine 2004-2009

☐ Extensive calibration on radionuclides with short half-life used in Nuclear Medicine Department both for diagnostic and therapy: ^{18}F, ^{64}Cu, ^{124}I, ^{99m}Tc.

☐ Calibration uncertainty lower than 2,5% (k=1)

Thank you

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