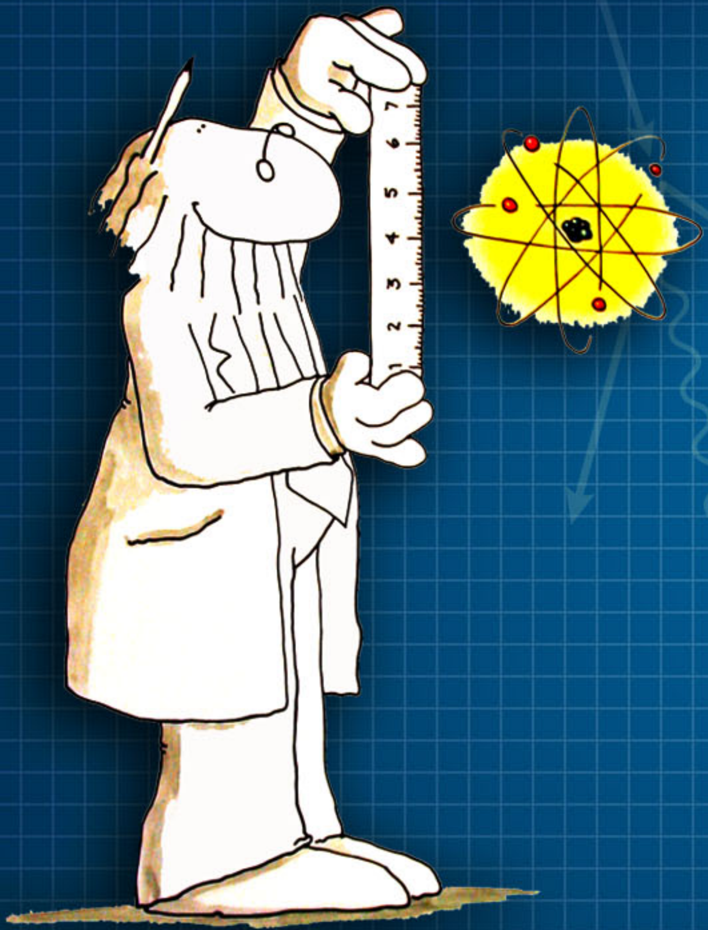


World-Wide Radiation Metrology: The BIPM, the CIPM MRA, and ICRU

Malcolm McEwen

Ionizing Radiation Standards

National Research Council, Canada

Note that the title did not mention the SI

Common units are integral to any concept of equivalent measurements but for comparison purposes the choice is somewhat arbitrary and therefore not the focus here.

A brief history of the SI:

1799 – two platinum standards of the metre and kilogram deposited in the Archives de la République in Paris

1875 – Convention du Mètre signed

1889 – 1st CGPM sanctioned a three-dimensional mechanical unit system (mass-length-time)

1954 – 10th CGPM added the ampere, the kelvin and the candela as base units

1960 – SI gets its name!

1971 – mole completes present total of seven units

Convention of the Meter / Convention du Mètre

- Signed in Paris in 1875 (representatives of 17 nations)
- Established permanent organizational structure for members on all matters relating to units of measurement
- Created the BIPM – Bureau International des Poids et Mesures
  - Intergovernmental organization (now 55 Member States)
  - Under authority of General Conference on Weights and Measures (CGPM)
  - Under supervision of the International Committee for Weights and Measures (CIPM)
  - Acts in matters of world metrology (demands for increasing accuracy, range and diversity)
  - **Facilitates needs to demonstrate equivalence between national measurement standards**
- Remains the basis of international agreement on units of measurement

What is the CIPM MRA?

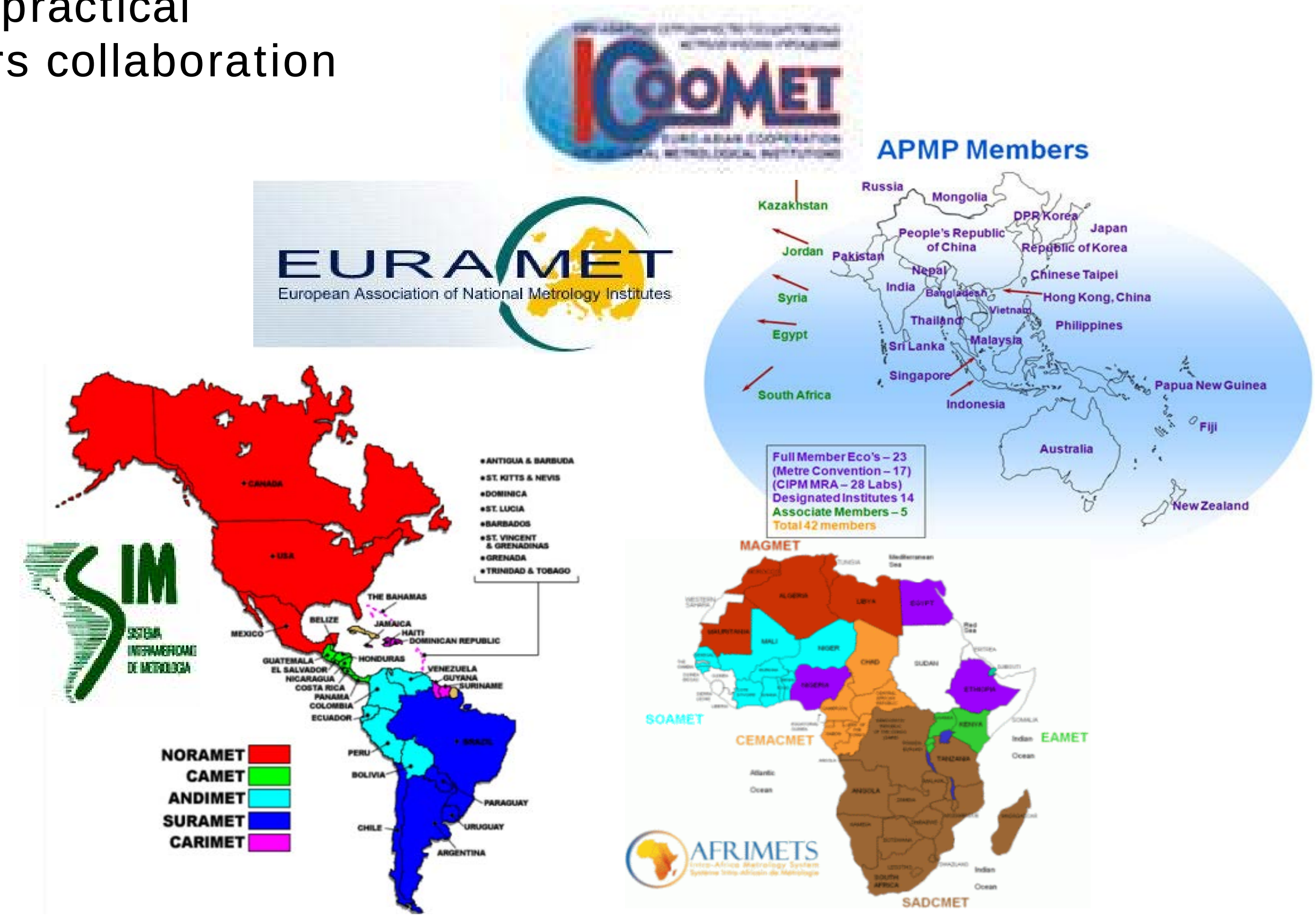
- **M**utual **R**ecognition **A**rrangement
- Paris 14 October 1999
- 40 entities originally, now 92 (plus 146 designated)
- Mutual recognition of
  - National measurement standards
  - Calibration and measurement certificates
- Structure
  - RMOs (Regional Metrology Organizations)
  - Member States
  - Associates of the CGPM
  - Designated Institutions

CIPM MRA

What are RMOs?

- Makes things a little more practical
- Fosters collaboration

Regional Metrology Organizations



CIPM MRA Participants in the Americas

Country	Institute	Date Signed
Argentina	INTI (CNEA designate)	14 Oct 1999
Bolivia*	IBMETRO	16 May 2008
Brazil	INMETRO (LNMRI/IRD designate)	14 Oct 1999
Canada	NRC-INMS	14 Oct 1999
Caribbean Community*	Designates in 11 countries (StKNBS)	12 Oct 2005
Chile	INN (CCEN designate)	18 Oct 2000
Costa Rica*, **	LACOMET	6 Oct 2004
Cuba (COOMET)*	NC (CENTIS and CPHR designate)	18 June 2001
Jamaica*	BSJ	21 July 2004
Mexico	CENAM (ININ designate)	14 Oct 1999
Panama*, **	CENAMEP AIP	16 Sept 2003
USA	NIST	14 Oct 1999
Uruguay	LATU (MIEM-LSMRI designate)	14 Oct 1999
International Organizations	IAEA; IRMM	14 Oct 1999

Associate of the CGPM ****Anticipating designating***

What about Ionizing Radiation?

Country	Institute	Field
Argentina	CNEA	Dosimetry, Radioactivity
Brazil	LNMRI/IRD	Dosimetry, Radioactivity, Neutron measurements
Canada	NRC-INMS	Dosimetry, Radioactivity, Neutron measurements
Chile	CCHEN	Dosimetry, Radioactivity (under development)
Mexico	ININ	Dosimetry, Radioactivity, Neutron measurements
St. Kitts and Nevis	StKNBS	Dosimetry (under development)
Uruguay	MIEM-LSMRI	Dosimetry
USA	NIST	Dosimetry, Radioactivity, Neutron measurements

What does the CIPM MRA do?

- It simplifies the process by which one country recognizes the standards of another
- Removes barriers to trade - previously calibration certificates issued by one country (e.g. where the device was manufactured) were not valid in another
- This resulted in endless negotiation of bilateral agreements
- Note it's an arrangement, not an agreement, although it does have legal standing

Organizational Structure – International Metrology

The organisation

The Metre convention

General Assembly
CGPM

Board of directors
CIPM

Executive committee
The Bureau

CEO
Director of the BIPM

Premises/ staff
BIPM

Working Groups

Subsidiaries
Consultative Committees
Joint Committees

In Ionizing Radiation BIPM does the following:

- *Establish and run comparisons,*
- *Maintain and develop the SIR (for radioactivity)*
- *Publish monographs on nuclear data and special issues of Metrologia*
- *Contribute to conferences, meetings*
- *Publish in scientific journals*
- *Transfer knowledge to NMI-staff (workshops and conferences at BIPM)*

Consultative Committees on IR

Consultative committees are the primary forum for discussing progress on primary standards and determining future directions (for NMIs and BIPM)

- Established in 1958 as CCEMRI (CCRI in 1997)
- 3 distinct sections – dosimetry, radioactivity, neutrons
- Activities
  - Definitions of quantities and units
  - Standards for x-ray, γ-ray, charged particle and neutron dosimetry
  - Radioactivity measurement and SIR
  - Advice to CIPM regarding IR standards and BIPM activities
  - Input to CCRI Strategy

Organizational Structure – International Metrology

The organisation
The Metre convention

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CEO
Director of the BIPM

Premises/ staff
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This is where the science occurs

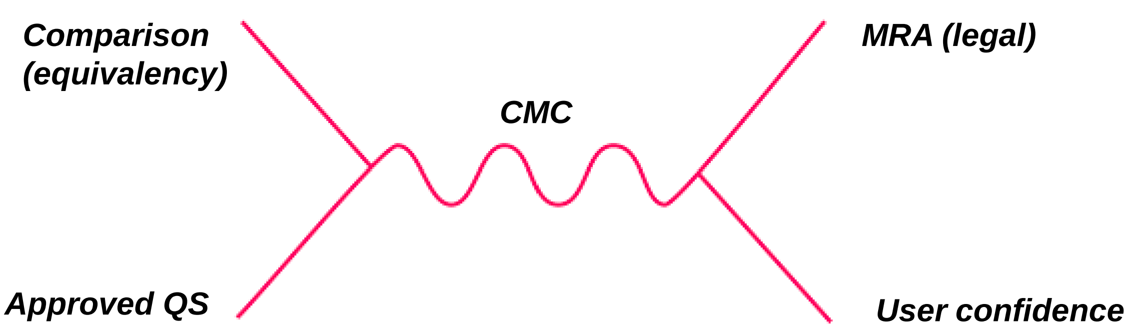
MRA is mediated by the CMC gauge boson

- In 2008, BIPM, ILAC and RMOs agreed to a clarified, common, annotated definition:

"A CMC is a calibration and measurement capability available to customers under normal conditions
(a) as published in the BIPM key comparison database (KCDB) of the CIPM MRA; or
(b) as described in the laboratory's scope of accreditation granted by a signatory to the ILAC arrangement"

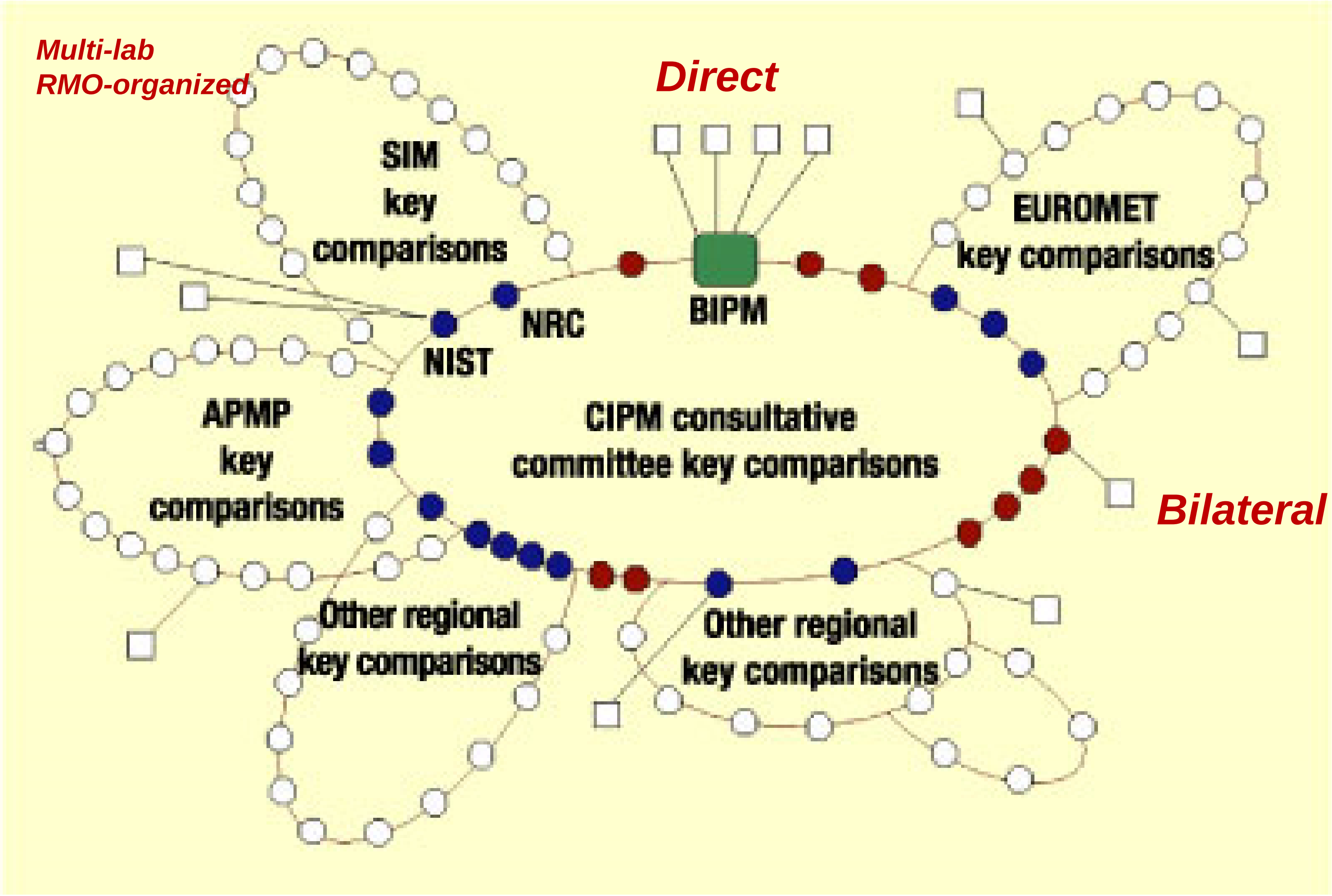
Not exactly a definition for a non-expert!

- A CMC is the formal ‘proof’ that a National Measurement Laboratory can carry out a particular measurement
- Comprises two components:
    1. Participation in a recognized comparison of a measurement standard with one or more other national standards
    2. Demonstration of an internationally recognized quality system for the dissemination of the standard



Quality Systems are left for another time …

There are various ways to compare and demonstrate equivalency



The target - equivalency

Components required:

1. An agreed comparison methodology to be used by each institution involved

   This is usually approved by the BIPM CC

2. Something to reliably transfer measurements from one location to another

   Will depend on methodology – ‘star’, ‘linear’, ‘single facility’

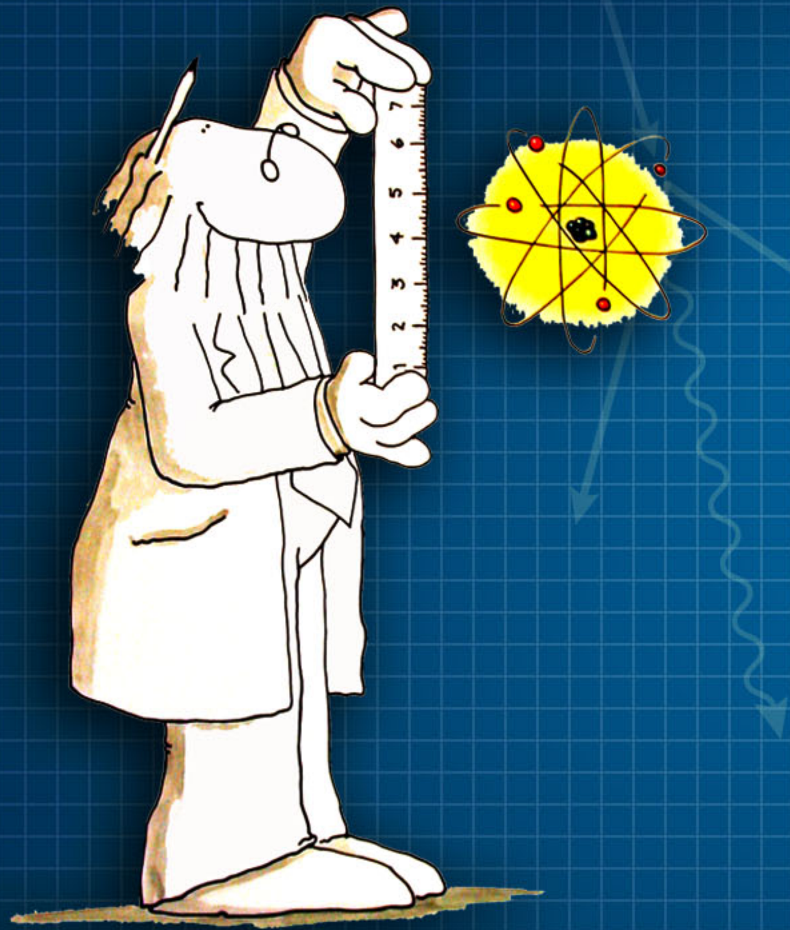
3. A consistent approach to estimating uncertainties

   The ISO GUM (JCGM 100) is the starting point

4. A stable comparison reference value (KCRV) to determine variations between participants

   Essential as comparisons often take several years to complete

Agreement with KCRV within stated (agreed) uncertainties = equivalency

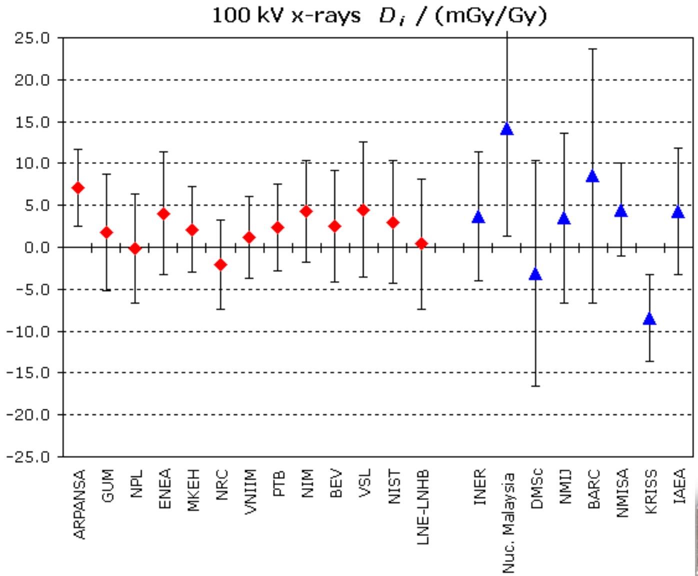


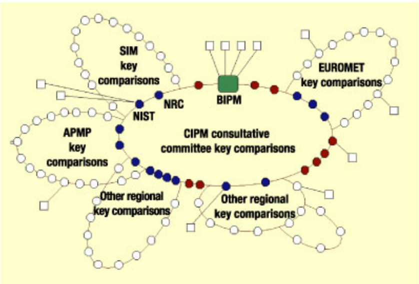
Lets look at some real comparisons within ionizing radiation

Comparisons in Dosimetry

- Currently, 43 comparisons in x and gamma rays, and electrons measurements (dosimetry) are listed in the Key Comparison Database (KCDB; Appendix B) http://kcdb.bipm.org

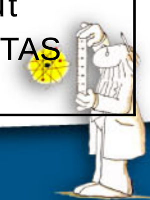
- Comparisons include
  - SIM, EURAMET, COOMET, APMP, CCRI(I), BIPM
- Steps of a comparison are:
  - Planned, in progress, measurements complete, Draft B, approved/published, equivalence





Dosimetry Comparisons

Comparison	Quantity	Energy	Year	Status
BIPM.RI(I)-K1	Air kerma	Co-60	Ongoing	
BIPM.RI(I)-K2	Air kerma	10-50 keV	Ongoing	
BIPM.RI(I)-K3	Air kerma	50-250 keV	Ongoing	
BIPM.RI(I)-K4	Absorbed dose to water	Co-60	Ongoing	
BIPM.RI(I)-K5	Air kerma	Cs-137	Ongoing	
BIPM.RI(I)-K6	Absorbed dose to water	4-25 MV (linac photons)	Ongoing	First round to be completed 2019
BIPM.RI(I)-K7	Air kerma	mammography	Ongoing	
BIPM.RI(I)-K8	RAKR (air kerma strength)	Ir-192 HDR	Ongoing	HDR only for first round, LDR to follow as standards are developed
BIPM.RI(I)-K9	Absorbed dose to water	50-250 keV	Under development	First bilateral comparison carried in 2016
BIPM.RI(I)-K?	Absorbed dose to water	4-25 MeV (linac electrons)	Under development	Trial comparison carried out between NPL, NRC and METAS



Dosimetry Comparisons – BIPM.RI(I)-K4

Co-60 absorbed dose to water

Fundamental to nearly all linac-based dose delivery worldwide

Key and supplementary comparisons - Results KCDB

↘ BIPM.RI(I)-K4

- Information
- Pilot / Contact
- Participants
- Results
  - Absorbed dose to water
- Print out

↘ Related links

- KCDB Statistics
- KCDB FAQs
- KCDB Reports
- CIPM MRA
- JCRB
- Find my NMI
- Metrologia

↘ Contact us

- BIPM.KCDB@bipm.org

BIPM.RI(I)-K4

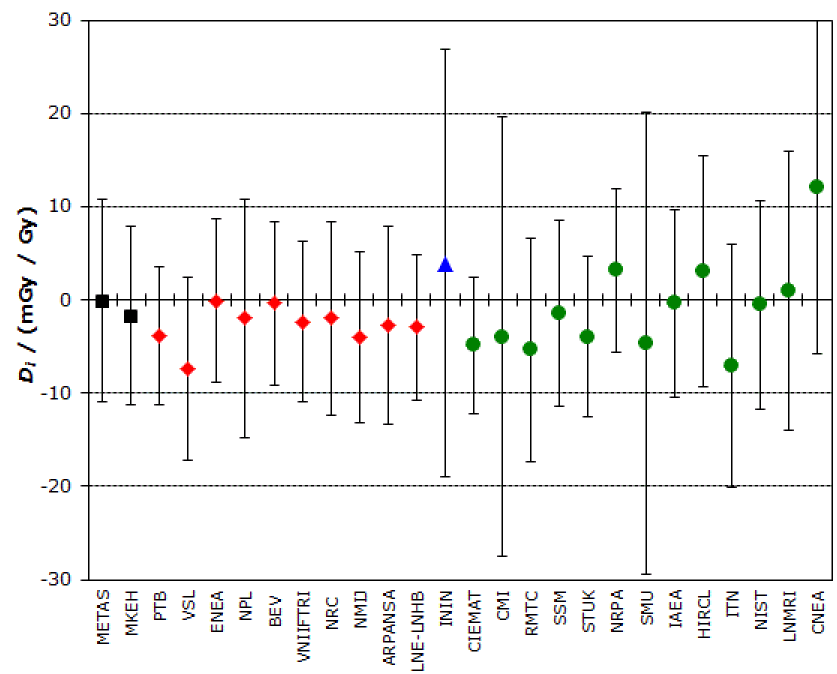
↘ Results

Laboratory individual measurements	Equivalence statements	Degrees of equivalence	Graph(s) of equivalence

BIPM.RI(I)-K4, SIM.RI(I)-K4, and EUROMET.RI(I)-K4

MEASURAND : Absorbed dose to water

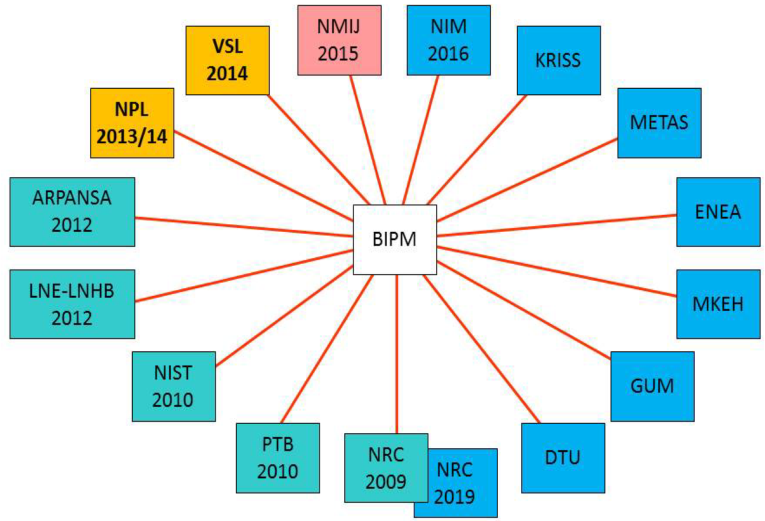
Degrees of equivalence, D_i and expanded uncertainty U_i (k = 2), expressed in mGy/Gy.



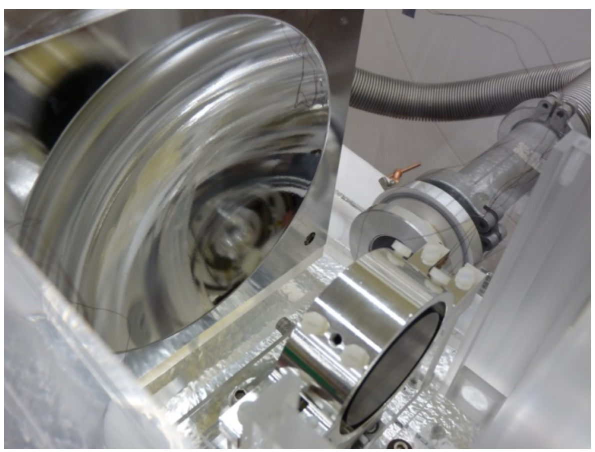
Red diamonds: participants in BIPM.RI(I)-K4
Black squares: BIPM.RI(I)-K4 participants' results that are more than ten years old
Blue triangle: participant in SIM.RI(I)-K4
Green circles: participants in EUROMET.RI(I)-K4

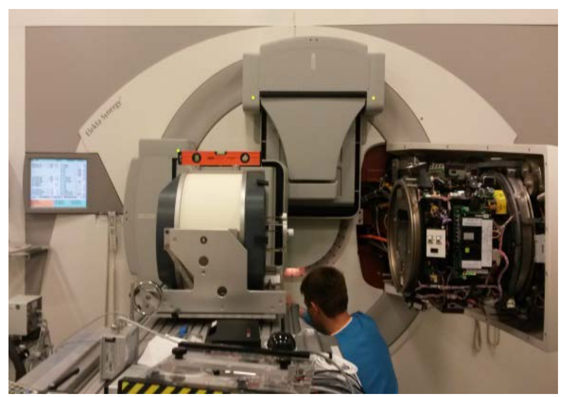
Dosimetry Comparisons – BIPM.RI(I)-K6

BIPM primary standard for clinical accelerator dosimetry



No linac beams at BIPM, so a travelling comparison was developed based on a transportable graphite calorimeter

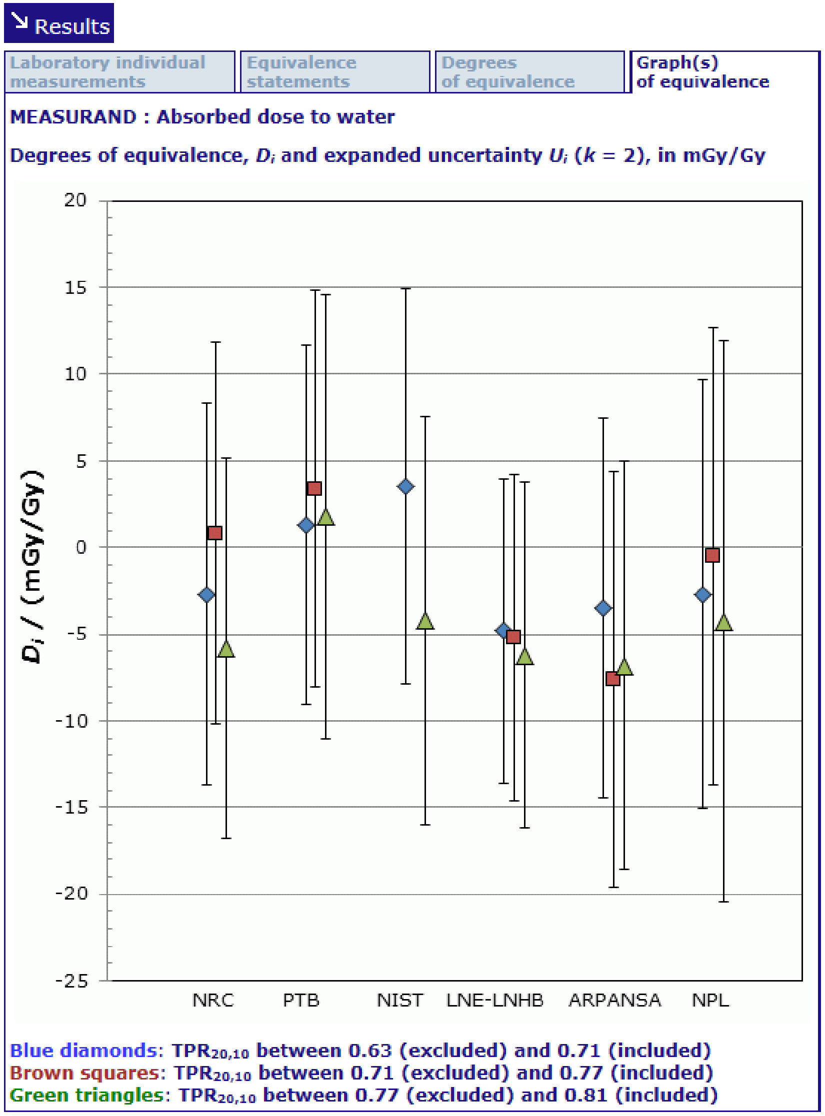




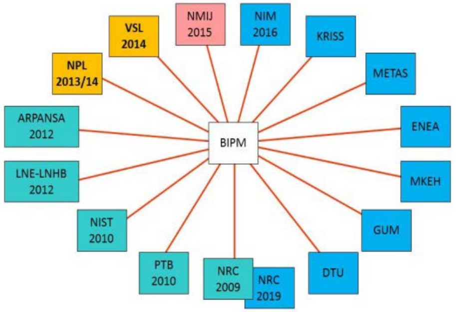
Newly built VSL water calorimeter mounted on the NPL linac couch.

First comparison was carried out at NRC in 2009

Dosimetry Comparisons – BIPM.RI(I)-K6



For dosimetry comparisons, CCRI(I) adopted the position that the BIPM result would be the KCRV (key comparison reference value).

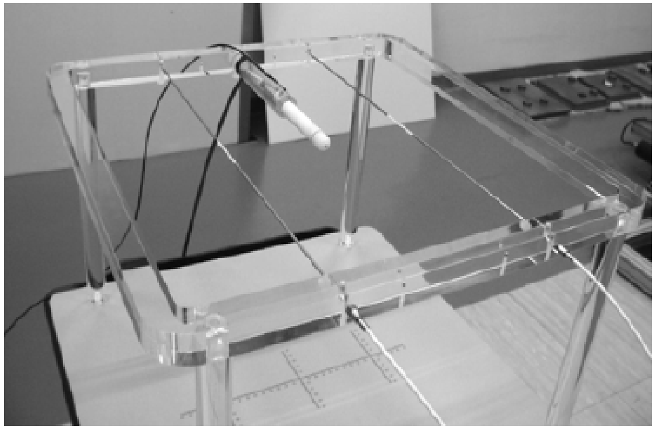


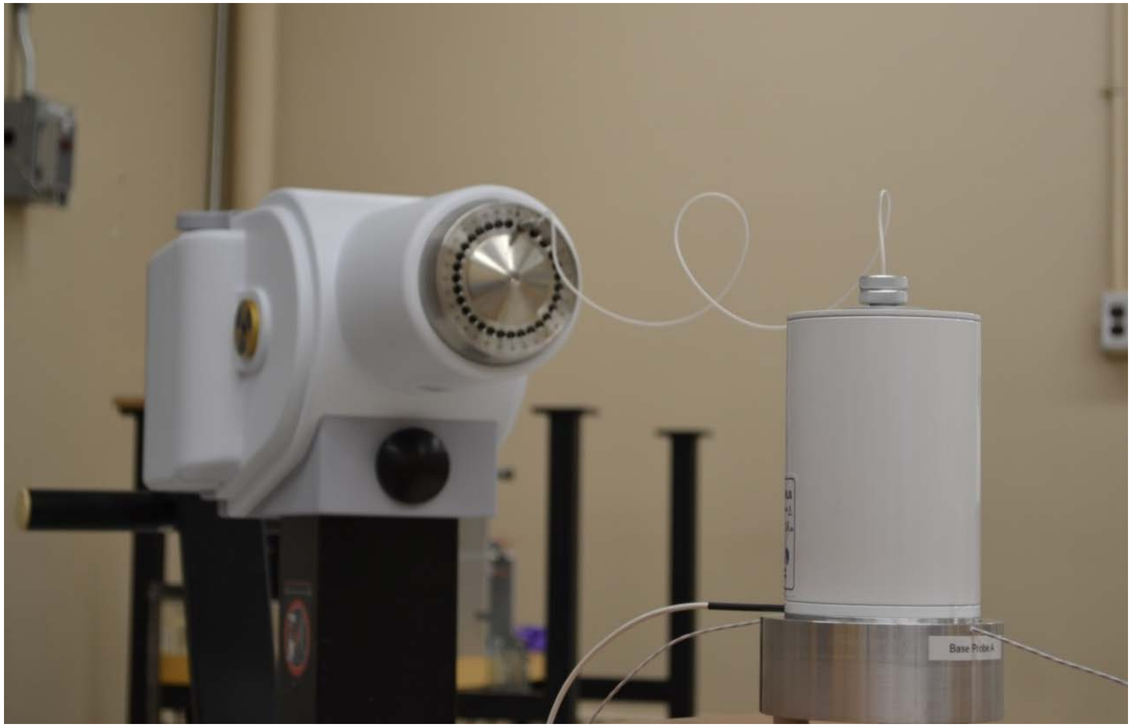
This is not the same as being the 'correct' answer!

But it's much simpler to interpret inter-laboratory differences than if some mean was used.

First round of labs with primary absorbed dose standards due to be completed in 2019.

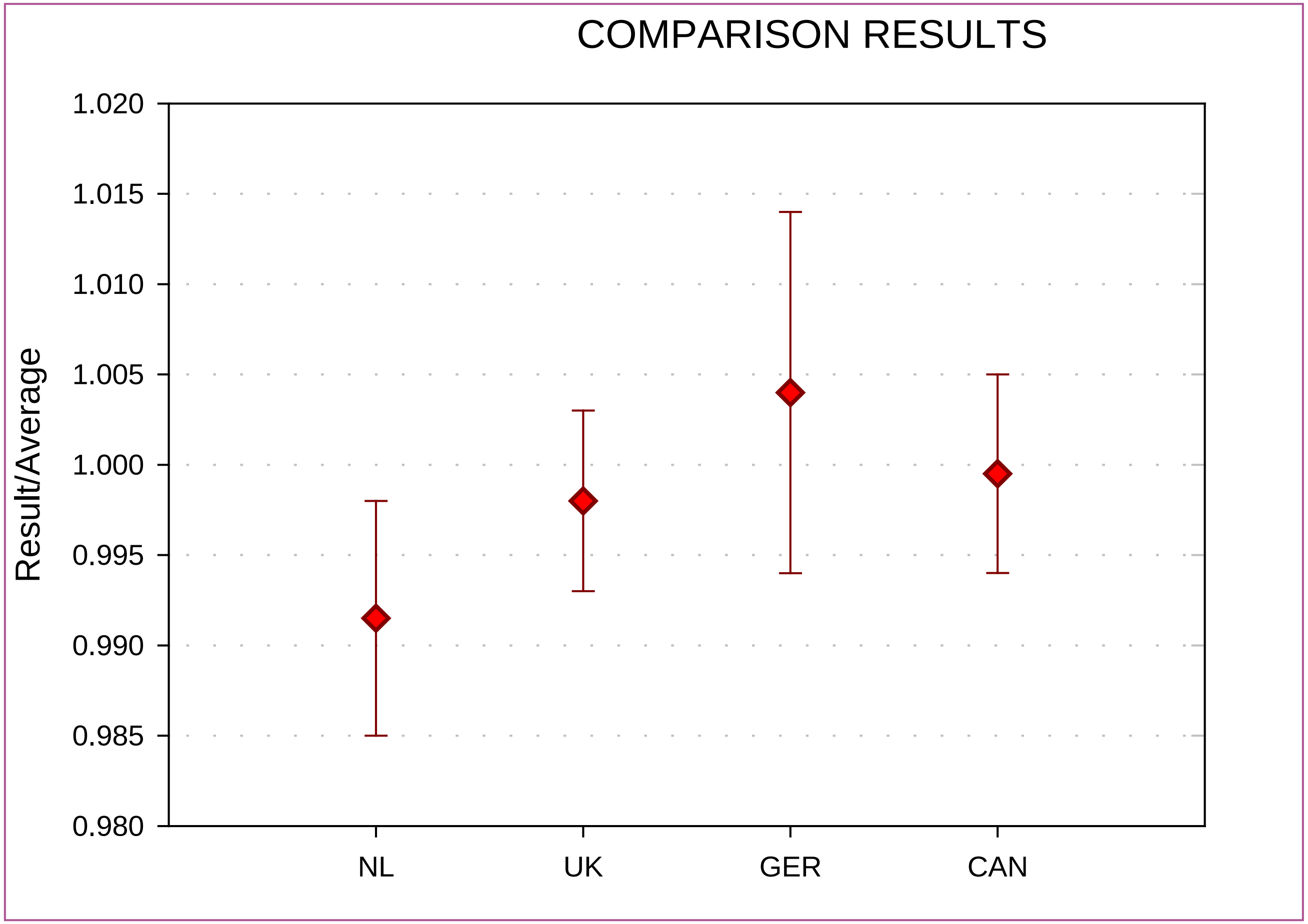
Ir-192 HDR air kerma





This requires another BIPM travelling standard, but simpler than for linac beams – just need to take two ion chambers (thimble, well)

Dosimetry Comparisons – BIPM-RI(I)-K8

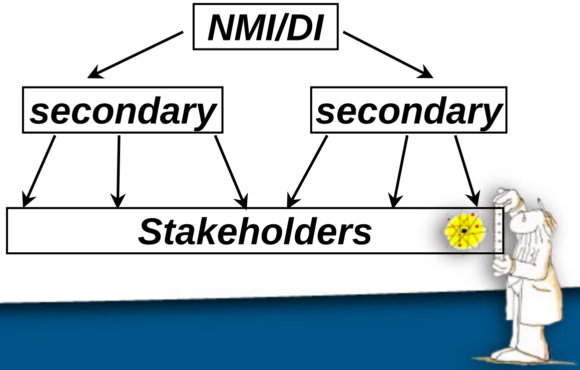


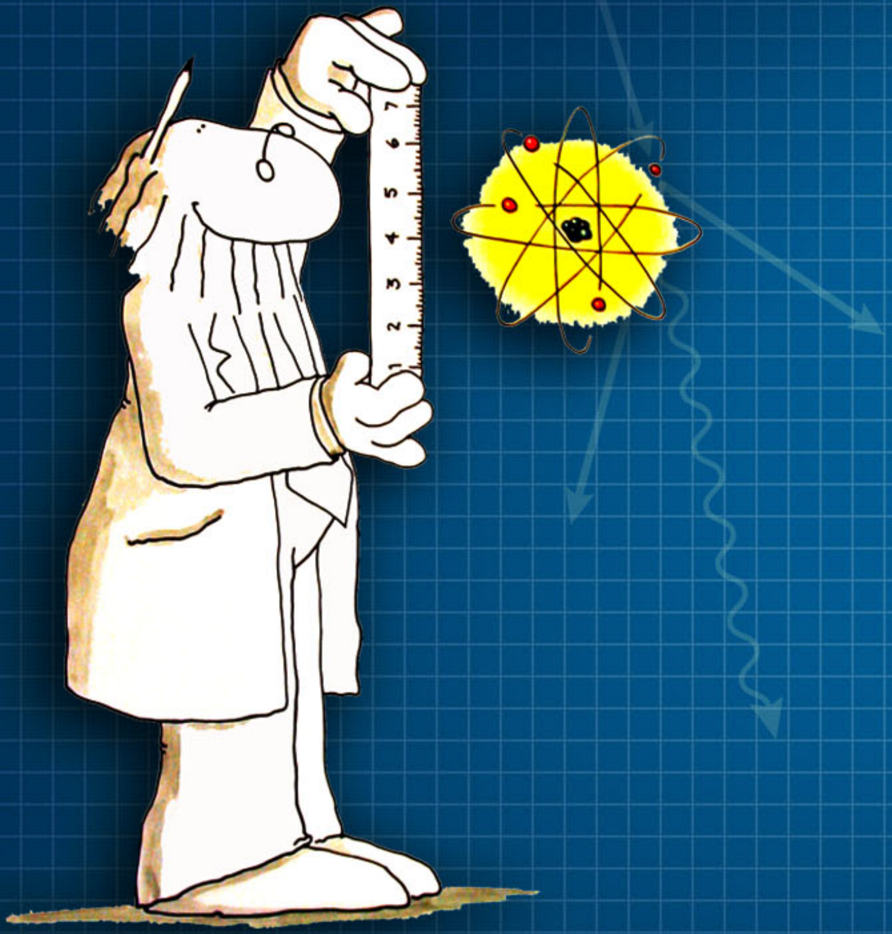
Good consistency seen with first four labs

Summary

- Measurement traceability enables international trade
- World-wide metrology supports legal and regulatory aims
- “Mutual Recognition” and “Equivalency” allow comparability within stated uncertainties
- Comparisons provide basis of analysis and confidence to customers
- International approach brings robustness and validity to measurements
- BIPM and the CIPM MRA provide the framework

CIPM MRA





THANK YOU