Bureau International des Poids et Mesures

Mission and role of the BIPM in the 21st Century

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“Enrico Fermi”
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Earliest Measurement Standards

Already ancient cultures like the Egyptians (about 3000 years B.C.) developed highly sophisticated metrology systems.

The Egyptian length standard the “cubit” was based on the length of the forearm of the Pharaoh.

A “primary” standard was then produced out of black granite. Secondary standards were made and distributed to the Egyptian buildings sites. Workers were issued wooden copies for day to day use. At each full moon the workers using the cubits were obliged to compare their wooden copy to the master copy of the building site.

Evolution of Metrological Needs

Pre industrialisation

Needs: local trade, taxation, basic engineering

Institution: Local Office of Weights and Measures

Industrialisation

Needs: national trade (increasingly also across borders), taxation, mechanical and early electrical engineering

Institution: National Office of Weights and Measures

With industrialisation, the need for an internationally agreed system of units arose:

The solution was to agree on the metric system

In 1875, the Metre Convention was signed by 17 industrial nations.

The Beginning of Metrological Research

In the years after the creation of the Meter Convention it became obvious that the old offices for Weights and Measures were not sufficient for the increasing metrological demands by industry.

While the BIPM was working on the fundamental metrology to improve the dissemination of the metre and the kg, in the member states a new type of institute dedicated to scientific metrology to meet national industrial needs, the National Metrology Institute emerged:

In 1887, the first institute for metrological research was founded: the Physikalisch-Technische Reichsanstalt in Berlin, Germany.

This type of institute proved to be a great success and soon in other countries similar institutes were created, first in the UK, then in the USA and in Japan.

Tasks of a National Metrology Institute

- Realisation and dissemination of units
- Development and validation of measurement procedures
- Knowledge transfer
- Consultation

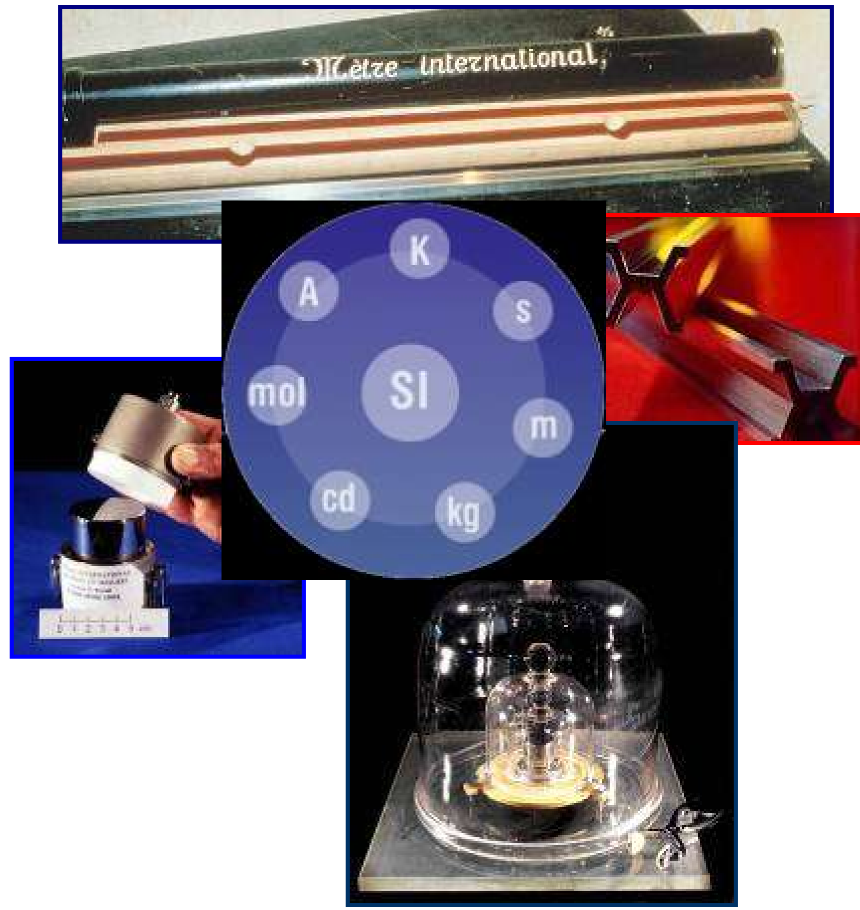
Customers: Government, Industry, Society, Academia

All the above requires a significant effort in R&D

Brief History of the SI and Metre Convention

The Metre Convention and the SI

- **20 May 1875** - The Metre Convention was signed in Paris by 17 nations. It established the BIPM which is a permanent organizational structure for member governments to act in common accord on all matters relating to units of measurement.
- **1889** - the international prototypes for the metre and the kilogram, together with the astronomical second as unit of time, create the first international system of units.
- **1954** - the ampere, kelvin and candela are added as base units.
- **1960** - the unit system is named as the International System of Units (SI)
- **1971** - the mole is added as the unit for amount of substance, bringing the total number of base units to seven.



Organs of the Metre Convention

BIPM

Headquartered in Paris, France and financed by supporting governments.

Maintains scientific laboratories in areas of: mass, time, electricity, ionizing radiation, and chemistry.

CIPM

Made up of eighteen individuals, different nationalities.

Meets annually to promote worldwide uniformity in units of measurement.

Is the management board for the BIPM

CGPM

Made up of representatives from Member States.

Meets in Paris typically every four years to discuss the status of international metrology.

The BIPM

It has headquarters near Paris, France. It is financed jointly by the Member States and Associates, and operates under the exclusive supervision of the CIPM.

Its mandate is to provide the basis for a single, coherent system of measurements throughout the world, traceable to the International System of Units (SI). This task takes many forms, from direct dissemination of units (as in the case of mass and time) to coordination through international comparisons of national measurement standards (as in electricity and ionizing radiation).

It maintains laboratories in areas of: mass, time, electricity, ionizing radiation, and chemistry.

It has an international staff of around 75.

Its budget for 2012 is around twelve million euros.

Main Technical Roles of the BIPM

Maintains the kilogram for the near future (until redefinition).

Creates and disseminates Coordinated Universal Time (UTC) based on weighted averages of ~ 200 clocks from over 50 National laboratories worldwide.

Maintains unique world reference facilities e.g., SIR (ionizing radiation and isotopes), ozone spectrophotometers.

Maintains travelling standards to compare fixed national references e.g., Josephson Junctions for the volt, Quantum Hall devices for the ohm, etc.

Coordinates international comparisons and networks e.g., organic chemistry reference materials for laboratory medicine.

Promotes traceable, accurate measurement for physical, engineering, chemical and medical quantities worldwide.

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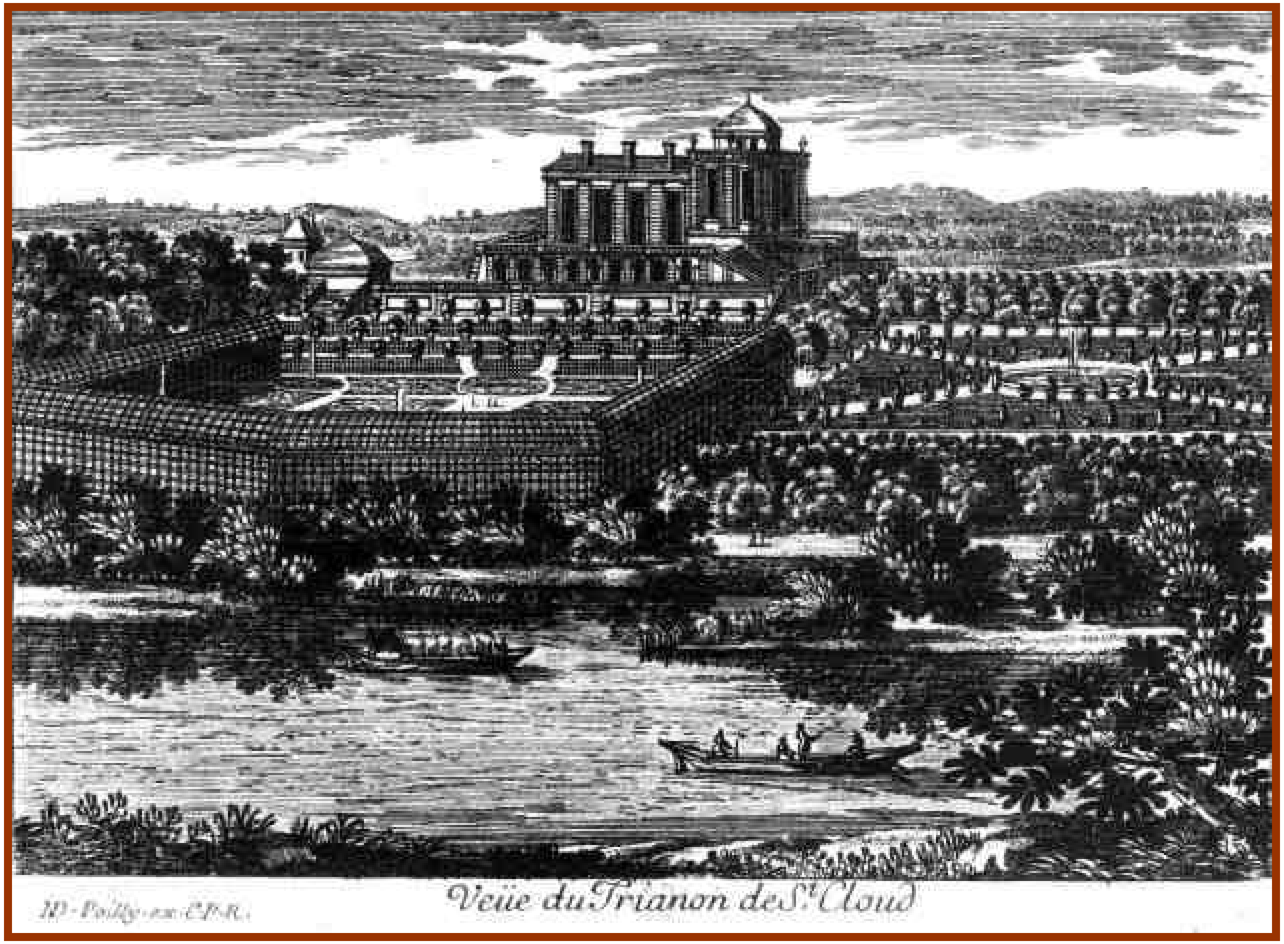


The Pavillon de Breteuil when given to the BIPM in 1870

The Pavillon de Breteuil today

Comité International des Poids et Mesures

The CIPM

Is made up of eighteen individuals, each from a different State. Its principal task is to promote worldwide uniformity in units of measurement by direct action or by submitting draft resolutions to the CGPM.

The CIPM meets annually and its duties include:

- consideration of the work of the BIPM
- consideration of reports presented to it by its Consultative Committees
- consideration of metrological work that Member States decide to do in common and sets up and coordinates activities between specialists in metrology
- making appropriate Recommendations
- issuing an Annual Report on the administrative and financial position of the BIPM to the Member States
- commissioning reports in preparation for CGPMs, and others such as the SI Brochure

CIPM 1894

CIPM 2011

The CIPM Consultative Committees

CCAUV	Consultative Committee for **Acoustics, Ultrasound and Vibration**
CCEM	Consultative Committee for **Electricity and Magnetism**
CCL	Consultative Committee for **Length**
CCM	Consultative Committee for **Mass and Related Quantities**
CCPR	Consultative Committee for **Photometry and Radiometry**
CCQM	Consultative Committee for Amount of Substance (**Chemistry**)
CCRI	Consultative Committee for **Ionizing Radiation**
CCT	Consultative Committee for **Thermometry**
CCTF	Consultative Committee for **Time and Frequency**
CCU	Consultative Committee for **Units**

Joint Committees

Committees of the BIPM and other international organizations, created for particular tasks of common interest.

JCTLM Joint Committee for Traceability in Laboratory Medicine.

The goal of the JCTLM is to provide a worldwide platform to promote and give guidance on internationally recognized and accepted equivalence of measurements in laboratory medicine and traceability to appropriate measurement standards.

JCGM Joint Committee for Guides in Metrology.

BIPM, IEC, IFCC, ILAC, ISO, IUPAC, IUPAP, OIML

The tasks of the JCGM are to **maintain and promote the use** of the Guide to the Expression of Uncertainty in Measurement (known as the **GUM**) and the International Vocabulary of Basic and General Terms in Metrology (known as the **VIM**).

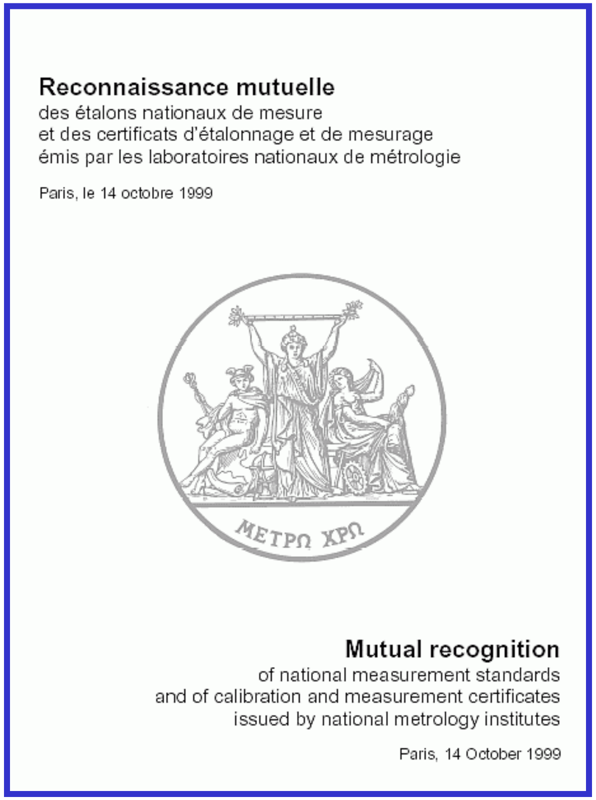
DCMAS Network Network on Metrology, Accreditation and Standardization for Developing Countries.

The CIPM MRA

In 1999, the CIPM established a Mutual Recognition Arrangement (MRA) of national measurement standards and of calibration and measurement certificates issued by NMIs.

The aim of the CIPM MRA is to provide the technical basis for the worldwide acceptance of national measurement standards and calibration and measurement certificates of NMIs as the foundation for wider agreements in support of world trade, commerce and regulatory affairs.

The CIPM MRA


Reconnaissance mutuelle
des étalons nationaux de mesure
et des certificats d'étalonnage et de mesurage
émis par les laboratoires nationaux de métrologie

Paris, le 14 octobre 1999

Mutual recognition
of national measurement standards
and of calibration and measurement certificates
issued by national metrology institutes

Paris, 14 October 1999

As of June 2012, CIPM MRA participation:

- 51 Member States of the BIPM
- 33 States/Economies that are Associates of the CGPM
- 3 International Organizations (IAEA, IRMM and WMO)

Participating NMIs have the obligation to:

- Implement quality/management systems that govern their delivery of services (ISO/IEC 17025 or ISO Guide 34).
- have their calibration and measurement capabilities (CMCs) peer reviewed and publicly declared in the KCDB
- take part in key comparisons that validate their technical proficiency

International Coordination and Liaison

Support of the Consultative Committees of the CIPM, including their Working Groups, by the provision of the Executive Secretaries.

Work with International Bodies (IBs, e.g., ISO and ILAC) and Intergovernmental Organizations (IGOs, e.g., OIML, IAEA).

Raise public awareness of the BIPM and the CIPM MRA through, for example, World Metrology Day activities.

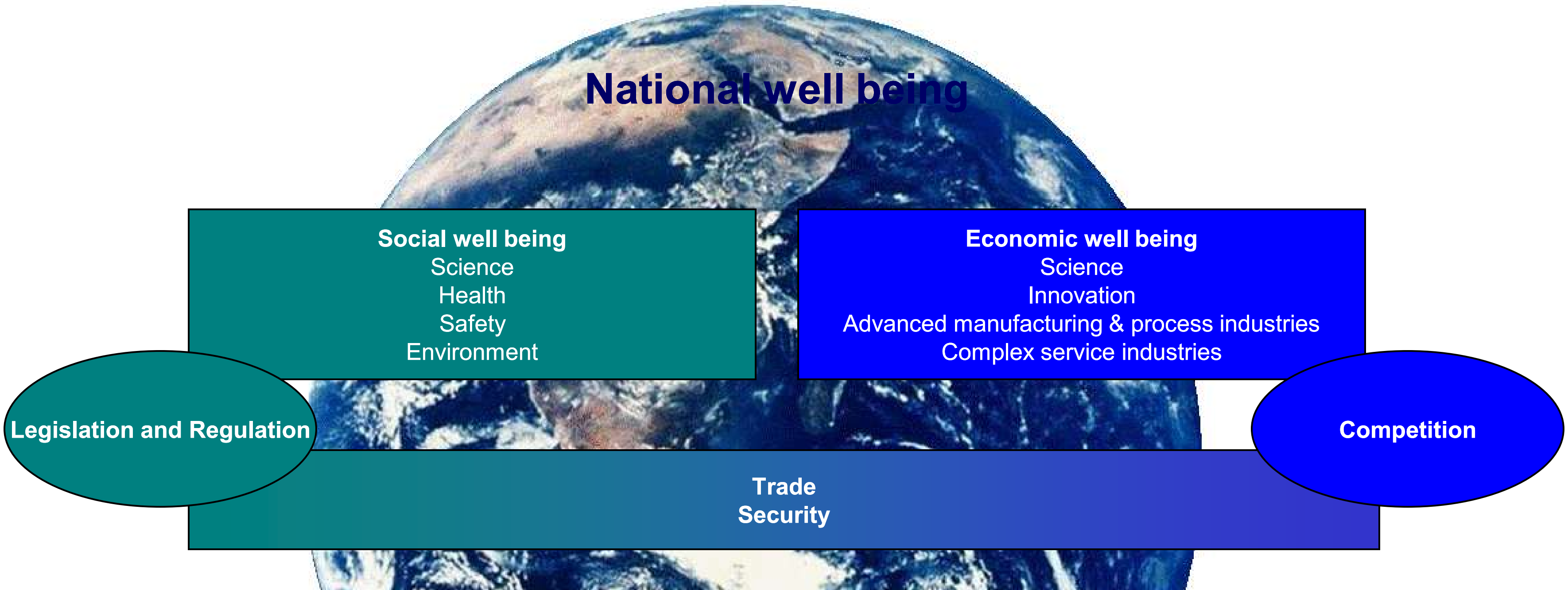
Act as a central resource for the planning and operation of workshops to address new areas such as physiological quantities, nanotechnology, climate change (with the WMO), etc.

The BIPM's Global Role

Working with Governments, National Metrology Institutes, and the accreditation community so as to maintain confidence in the world measurement system for science and trade.

To address the common interest of the NMIs of States Parties to the Metre Convention in dealings with international and intergovernmental bodies such as the World Meteorological Organisation, World Health Organisation, the International Federation of Clinical Chemistry, International Laboratory Accreditation Co-operation, International Organisation for Legal Metrology etc. as the occasion arises.

Participation in the Activities of the BIPM



- **The opportunity to participate in the structure that supports the International System of Units (SI)**
- **Providing scientific and technical forums that will helps NMIs to continuously improve their measurement capabilities**
- **Providing a recognized way to demonstrate competence, interoperability and international acceptance of NMI measurement capabilities**

Membership vs. Associate Status

Member State

Benefits:

- Voting rights in the CGPM
- NMIs may be members of the CCs if they meet the criteria
- NMIs may be signatories of the MRA; may take part in CC and RMO key comparisons and contribute to the KCRV
- May take part in BIPM Key Comparisons
- Entitled to a Pt-Ir kilogram at cost
- Free BIPM calibrations
- Staff may be guest workers at the BIPM
- May attend Directors' Meetings

Associate of the CGPM

Benefits:

- May attend the CGPM as an observer
- NMIs may be guests of the CCs if invited
- NMIs may be signatories of the MRA and may take part only in RMO key and supplementary comparisons
- Staff may be guest workers at the BIPM
- May attend Directors' Meetings

Challenges for the 21st Century

At the beginning of the 21st century we have come close to fulfil a dream:

To define all base units by means of fundamental constants.

The re-definition of the kg, the ampere, the kelvin and the mole will complete this dream.

While the 19th and the 20th century the core task of metrology was to provide and improve traceability for industry and science, for the 21st century the challenges lie in the fields of

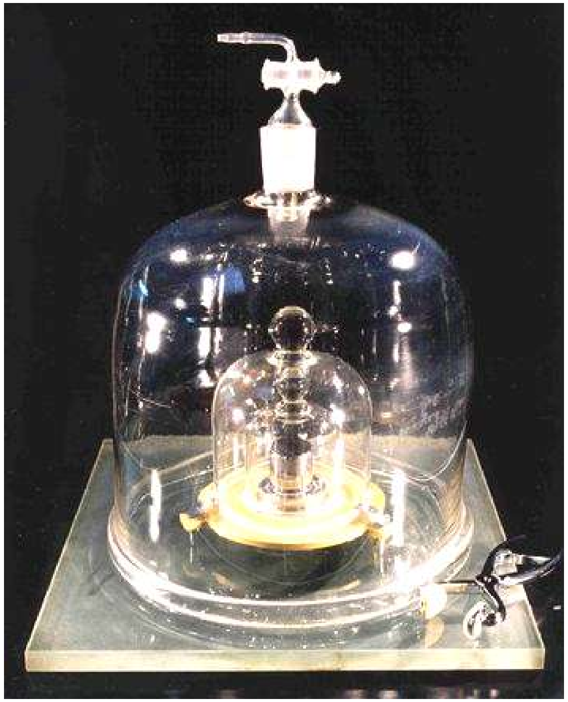
- **Metrology for climate change monitoring and the environment**
- **Metrology for health, in particular for diagnostics and therapeutics, as well as metrology for food safety**

Redefinition of the Kilogram: Why?

The kg is the only base unit of the SI that is still defined by an artefact.

3rd CGPM, 1901 :

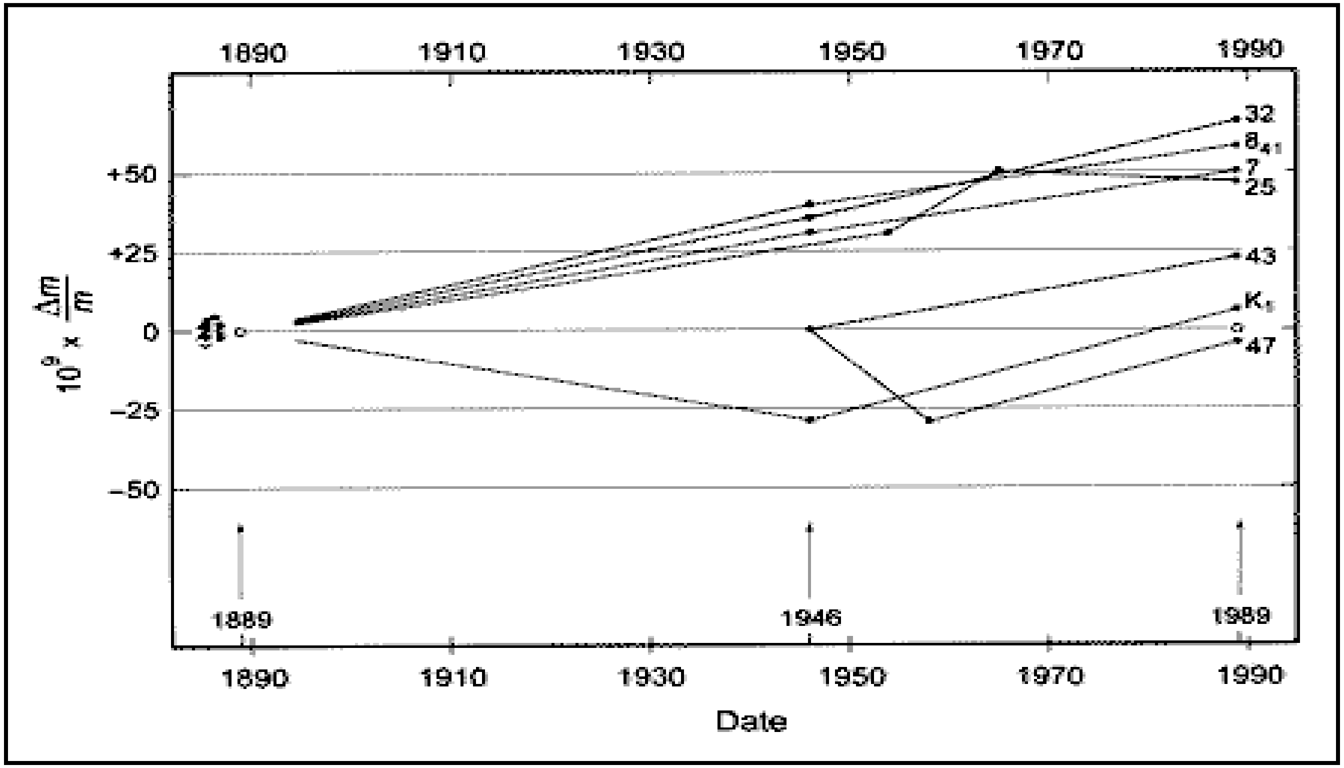
"The kilogram is the unit of mass; it is equal to the mass of the international prototype of the kilogram."



The international prototype of the kg was manufactured in 1880s, and put into service in 1889.

Made of 90 % Pt - 10 % Ir)

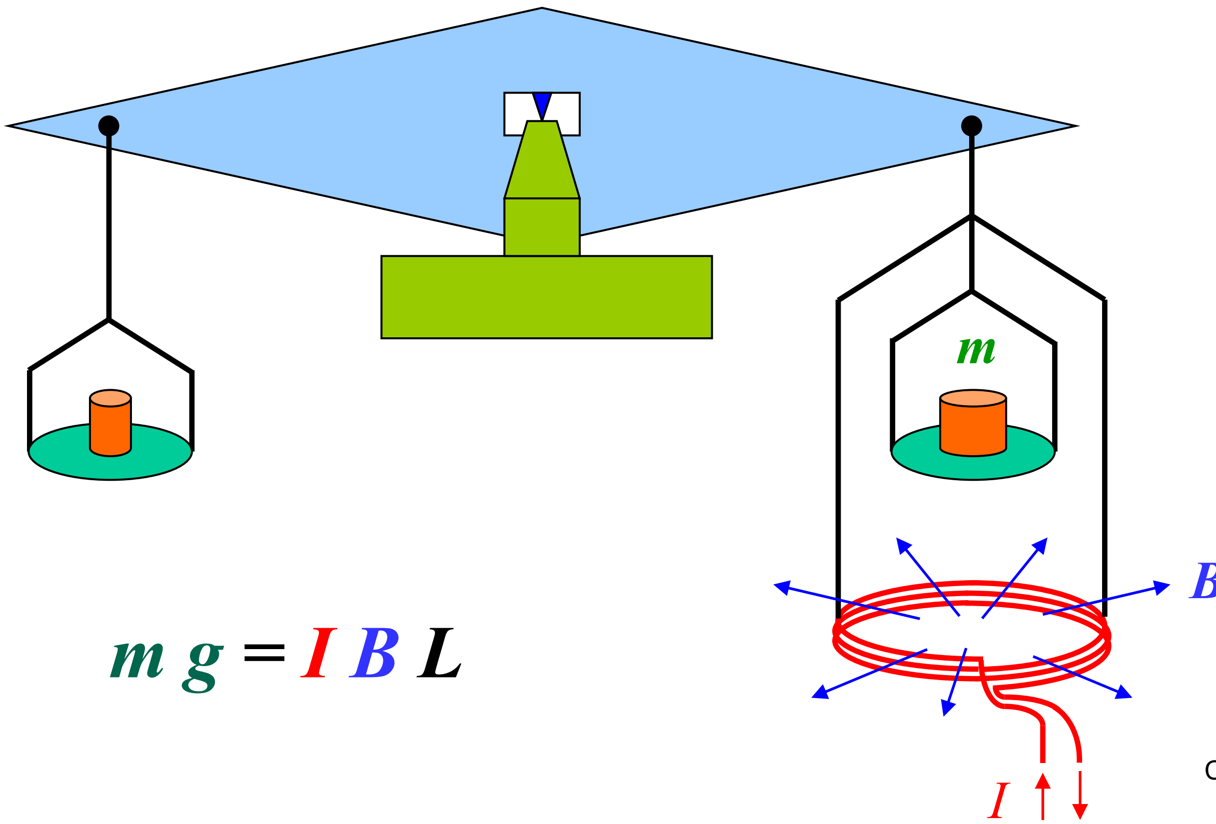
Relative Drift of the IPK



The graph shows the results from the verifications in 1946 and 1989

How Does a Watt Balance Work?

1. Weighing Phase:

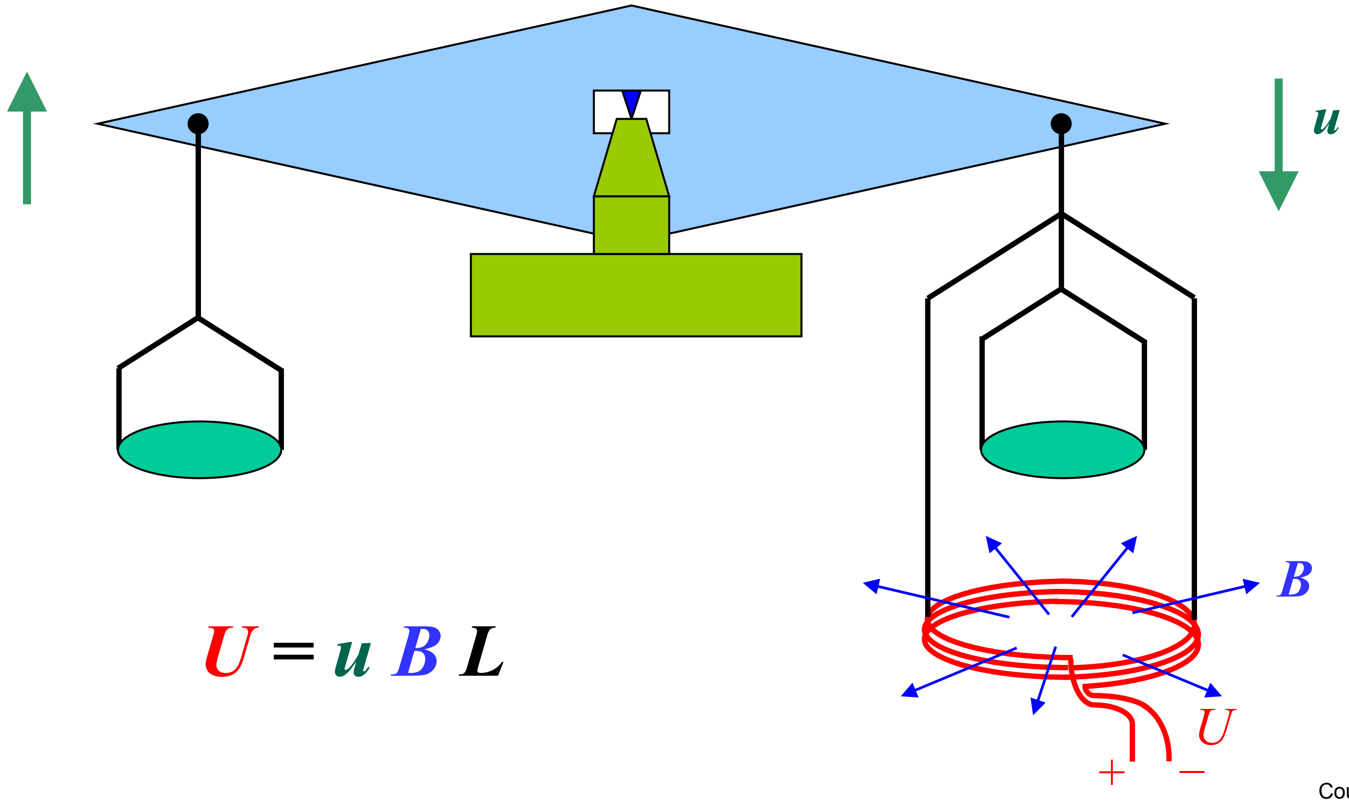


$$m\,g = I\,B\,L$$

Courtesy of NRC

How Does a Watt Balance Work?

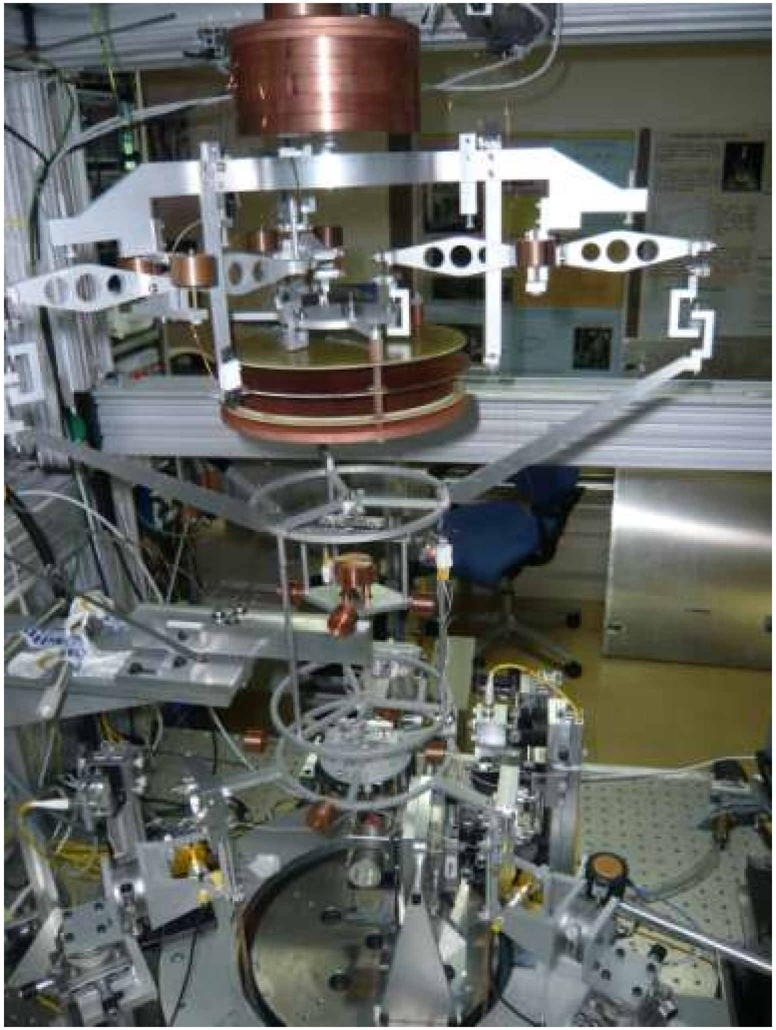
2. Moving phase (move the coil through the magnetic field at velocity ***u*** and measure the induced voltage, ***U***)



$$U = u\,B\,L$$

Courtesy of NRC

The BIPM Watt Balance



Present status

- "complete" experiment: *h* measurements can be carried out
- dedicated laboratory with vibration isolation ready
- relative and absolute (ICAG-2009) determination of *g*
- study on cryogenic watt balance started
- recently changed to 3-axis interferometer

Plans for 2012

- move to dedicated laboratory
- install final magnet
- install mass exchanger and coil position control unit
- install vacuum system
- use improved alignment system to reduce type B unc.

Target: uncertainty < 1 x 10^{-6}

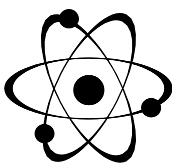
Linking m(28Si) to m(IPK)

silicon-28 atom

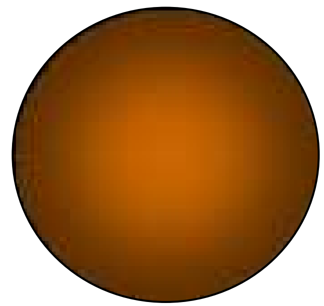
mass = $m(^{28}\mathrm{Si})$

sphere

mass = m , traceable to $m(\mathrm{IPK})$



× n



n atoms
to make a
1 kg sphere
($n \approx 2 \times 10^{25}$!)

$$m\left(^{28}\mathrm{Si}\right) = \left(\frac{1}{n}\right) m$$

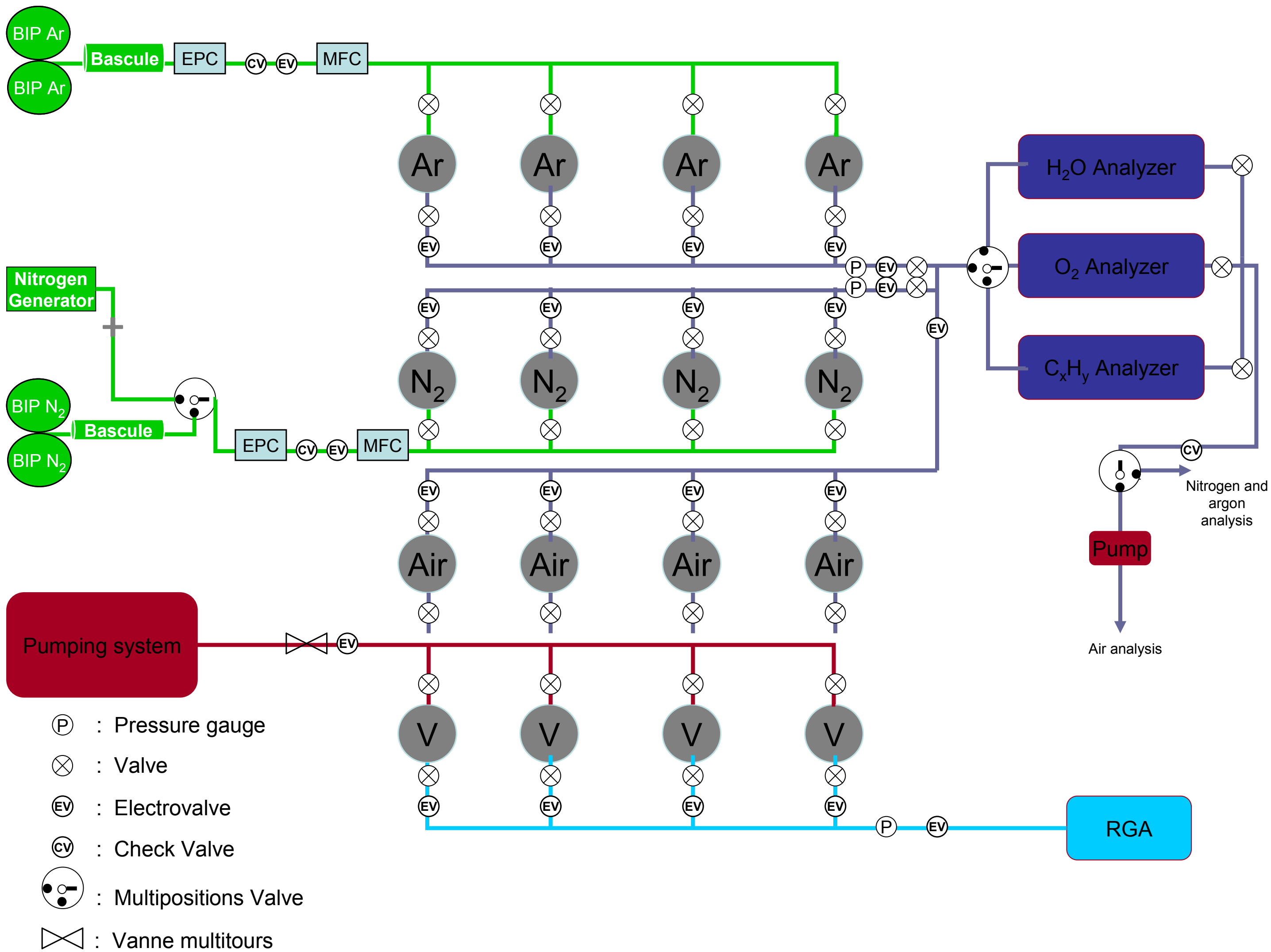
Requirements for Redefinition

CCM Recommendation G1 (2010) on necessary conditions before redefinition of the kilogram:

- **Three independent experiments capable of measuring *h* to 5 × 10−8 (*k* = 1)**
- **One of these experiments having an uncertainty of 2 × 10−8 (*k* = 1)**
- **consistency among all three (at *k* = 2)**

Meeting the goal will help ensure that mass metrology, including legal metrology, will benefit fully from the redefinition. The **mise en pratique** ***for the new definition of the kilogram is in draft form.***

Storage Network for the Pool of Artefacts



Future High-Energy Photon Dosimetry at the BIPM

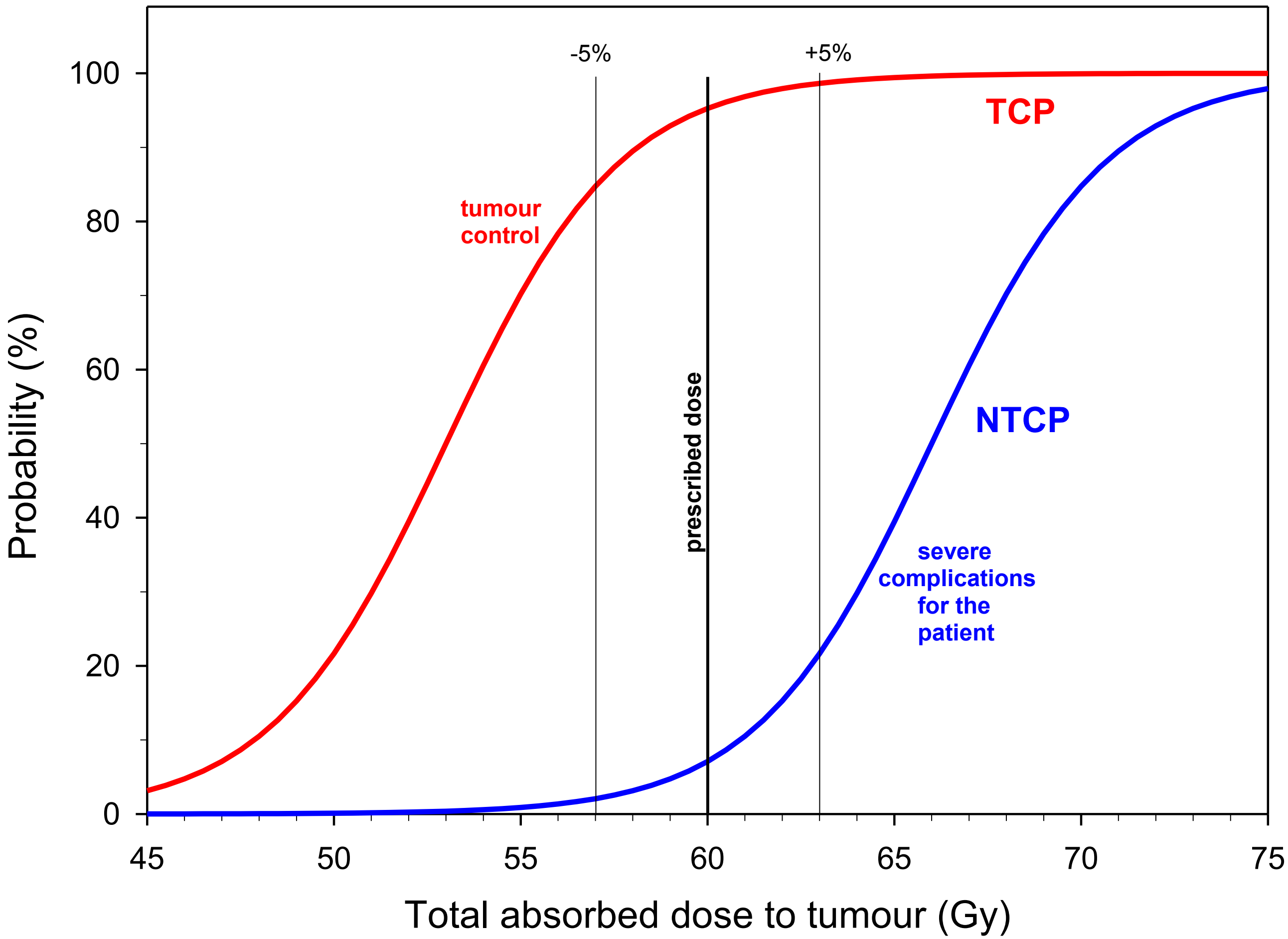
All Member States contributing to the BIPM operate LINACs for cancer treatment

Use of a LINAC by the BIPM together with the graphite calorimeter would provide:

- comparisons of primary standards for Member States particularly where their NMI operates a LINAC, to provide degrees of equivalence
- calibrations of national standards for those Member States where their NMI does not operate a LINAC

Schematic Representation: Expected Treatment Outcome

dose delivered to the patient within 5 %



International support for High-Energy Photon Dosimetry at the BIPM

World Health Organization

IAEA.org International Atomic Energy Agency

ICRU International Commission on Radiation Units & Measurements

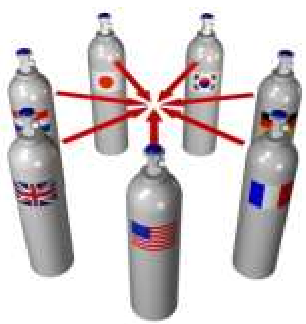
"For the SSDL network and the TLD programme, **WHO is directly dependent upon the quality of work carried out by the BIPM.** The suggestion to extend the facilities at the BIPM to include megavoltage dosimetry is thus emphatically supported."

"the IAEA could certainly **facilitate the use of the future BIPM calibration services by its Member States** through Technical Cooperation projects"

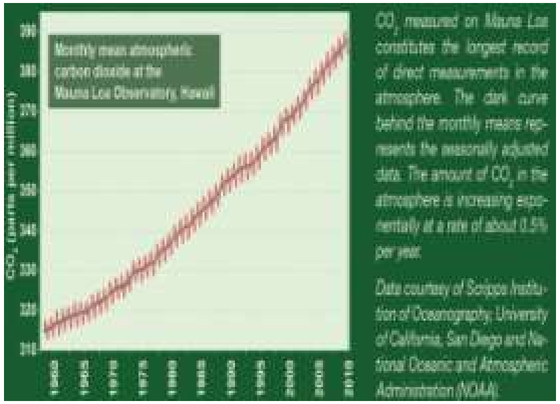
"The **success** over more than a half-century of the **BIPM program in ionizing radiation has been outstanding**, greatly **facilitating the improvement and harmonization of measurements of ionizing radiation worldwide**"

Responding to the Challenge of Greenhouse Gas Monitoring

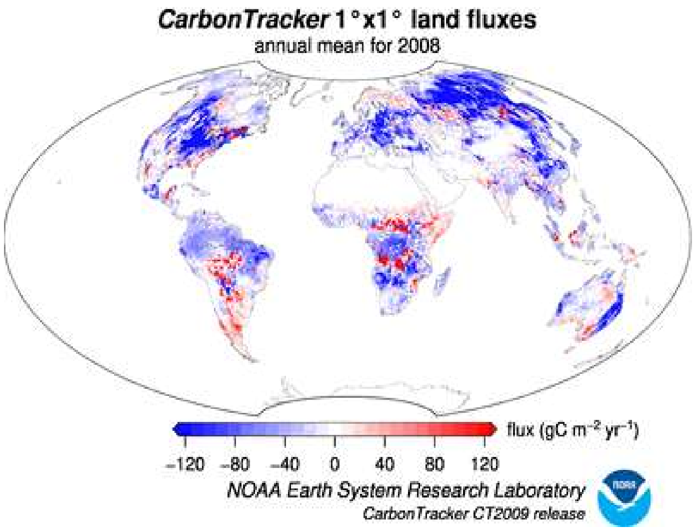
- Climate Change: Mitigation and Cap and Trade Legislation on GHG emissions
- Accurate data for informed policy decisions
- Verification of national emission inventories through measurement
- Major Observational network expansion
- Stringent requirements on equivalence of GHG calibration standards
- Degree of equivalence of GHG standards assured by BIPM coordinated comparisons



BIPM Key Comparisons



GHG monitoring stations/networks

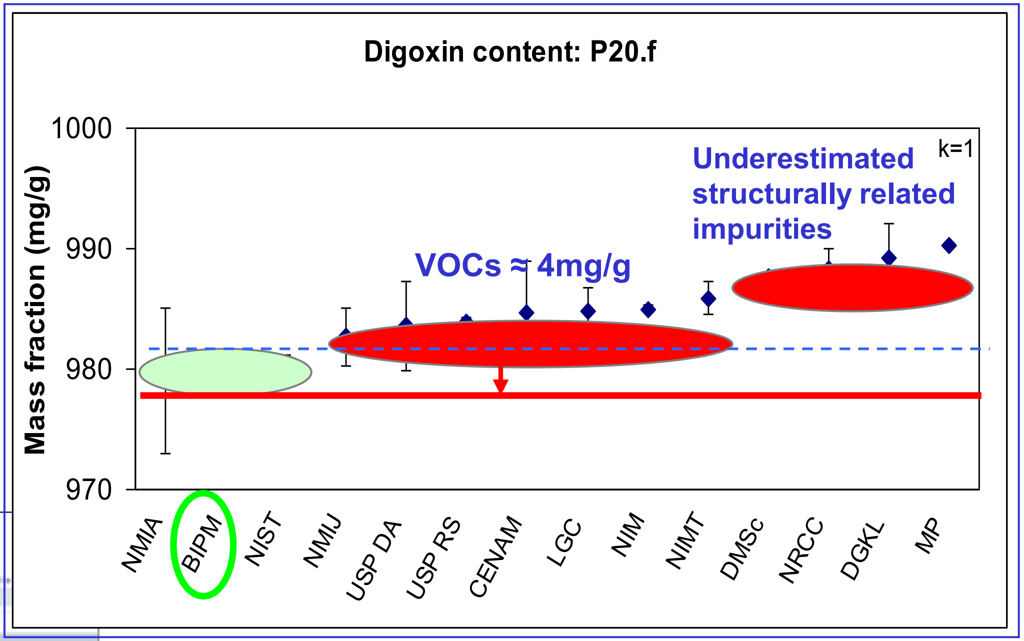


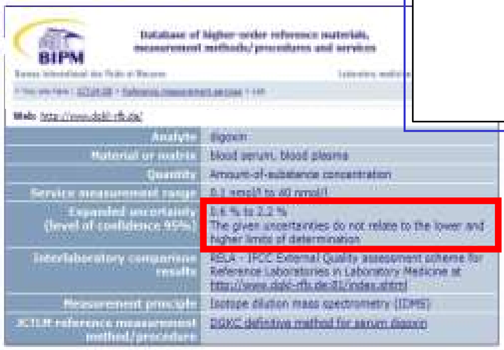
CO_2 Flux Maps – Emission Verification

Comparisons for Primary Calibrators for Laboratory Medicine, Pharma, Food Analysis and Forensics

Metrological traceability for organic analysis:

BIPM programme

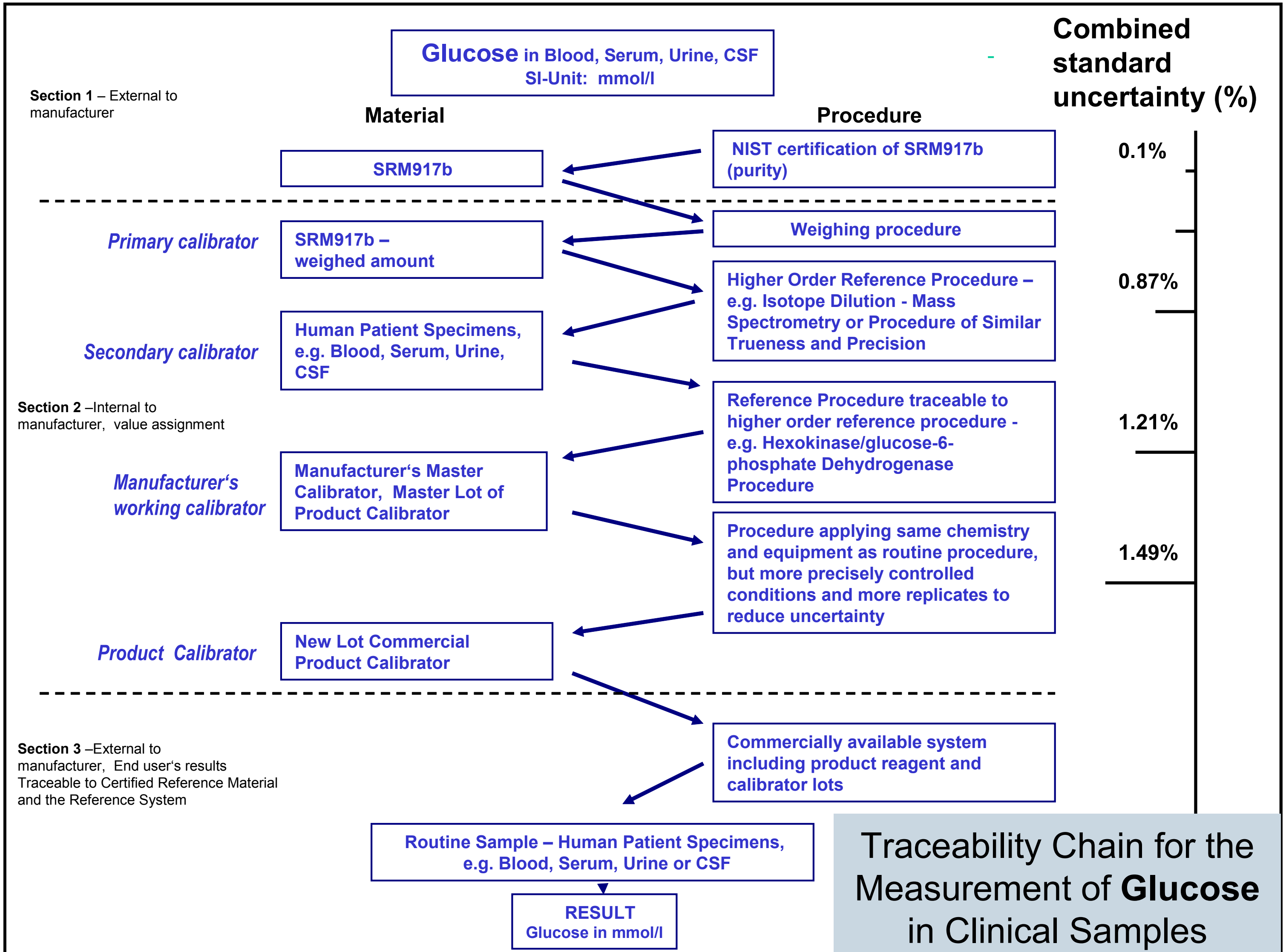




Database of higher-order reference materials, measurement methods/procedures and services

Analyte	digoxin
Material or matrix	blood serum, blood plasma
Quantity	Amount-of-substance concentration
Service measurement range	0.1 nmol/l to 40 nmol/l
Expanded uncertainty (level of confidence 95%)	0.6 % to 2.2 % The given uncertainties do not relate to the lower and higher limits of determination
Interlaboratory comparison results	RELA - IFCC External Quality assessment scheme for Reference Laboratories in Laboratory Medicine at http://www.dgkl-rfb.de:81/index.shtml
Measurement principle	Isotope dilution mass spectrometry (IDMS)
JCTLM reference measurement method/procedure	DGKC definitive method for serum digoxin

Metrological Traceability

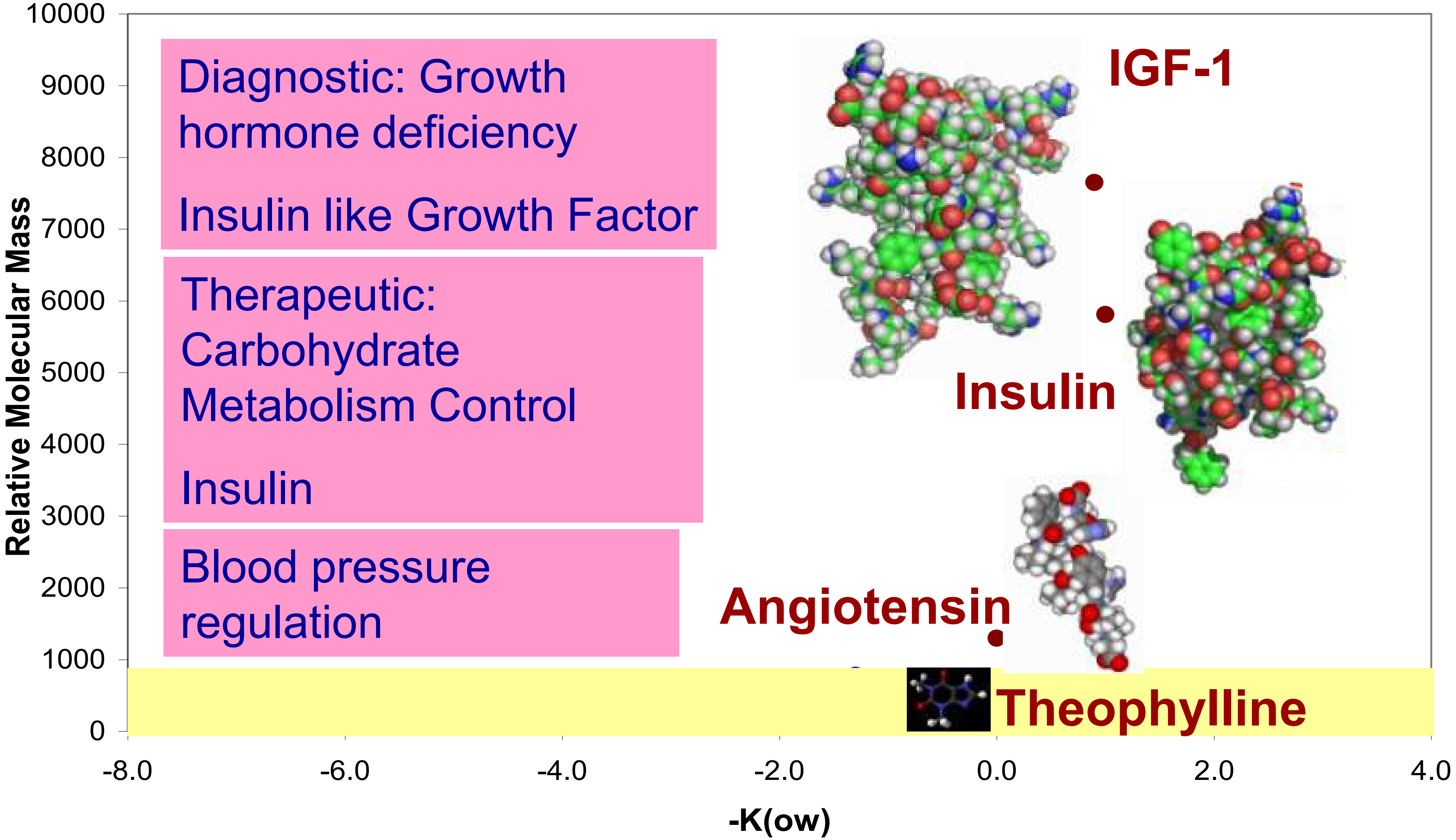


Traceability Chain for the Measurement of **Glucose** in Clinical Samples

SRM917 Glucose content
997 ± 2 mg

Metrology for Health: Improved Diagnostics and Therapeutics

Extension of Organic Primary Calibrator Comparisons



SI Metrology for Diagnosis and Treatment of Diabetes

- 220 million people worldwide have diabetes**
- 438 million people are expected to be affected by 2030 [†]
- Diabetes affects 25.8 million people in the U.S. (8.3% of the population)*
- $ 174 billion – estimated diabetes costs in the U.S. in 2007 (direct and indirect)*
- 2.6 million people diagnosed with diabetes in the UK [†]
- £ 9 billion (10% of NHS budget) spent on diabetes per year in the UK [†]

**WHO: Diabetes fact sheet N° 312, January 2011

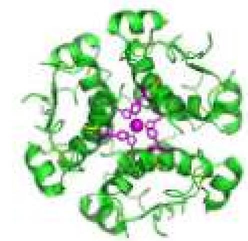
†Diabetes in the UK 2010 : key statistics on diabetes (Diabetes UK)

*Centers for Disease Control and Prevention. National diabetes fact sheet: national estimates and general information on diabetes and prediabetes in the United States, 2011. Atlanta, GA: U.S. Department of Health and Human Services, Centers for Disease Control and Prevention, 2011.

IU to SI value assignment of Insulin Primary Standards

Primary Calibrator- Recombinant Human Insulin (rhINS)

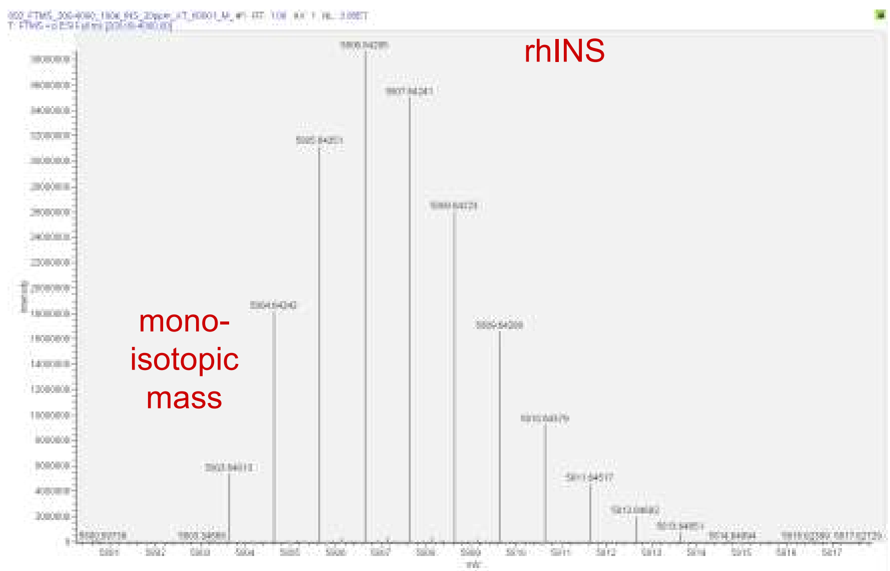
- A pancreas hormone, which plays a key role in the regulation of carbohydrates and fat metabolism in the body. A lack of insulin production/usage may lead to *Diabetes mellitus*.
- Small protein of two peptide chains (21+30 amino acids), MW of 5808 g/mol



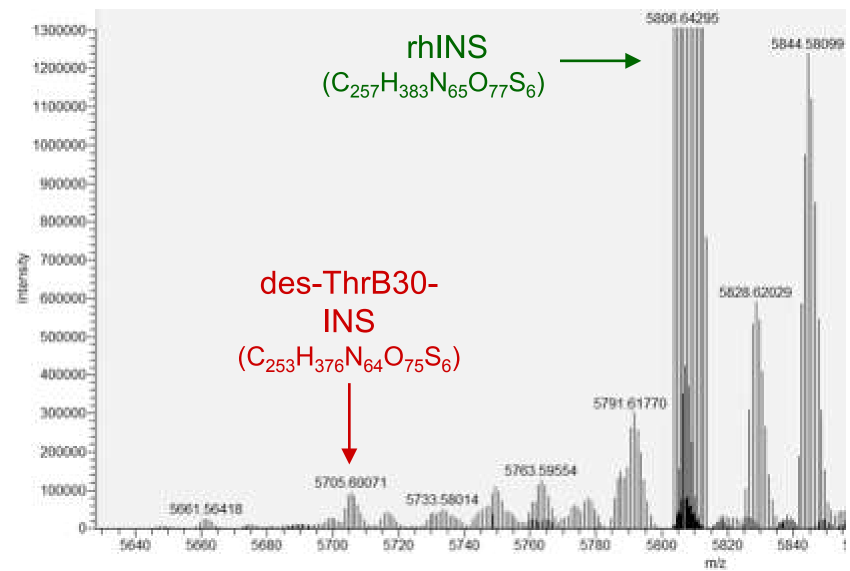
Zn complex of 3 rhINS-dimers

BIPM Project

- “Mass balance” purity value assignment study - determination of impurities of rhINS using multiple analytical techniques.
- LC-hrMS/MS is a powerful indispensable technique for the identification of structure related impurities of rhINS by accurate mass determination.



Deconvoluted infusion-MS spectrum: Isotope pattern of rhINS



Deconvoluted infusion-MS spectrum: rhINS and des-ThrB30 INS, an impurity which lacks the C-terminal amino acid Thr on the B chain of rhINS.

Aldosterone Test Kit Performance

EQAS audit, samples testing with two kits, target value (middle of Youden diagram) by ID-MS

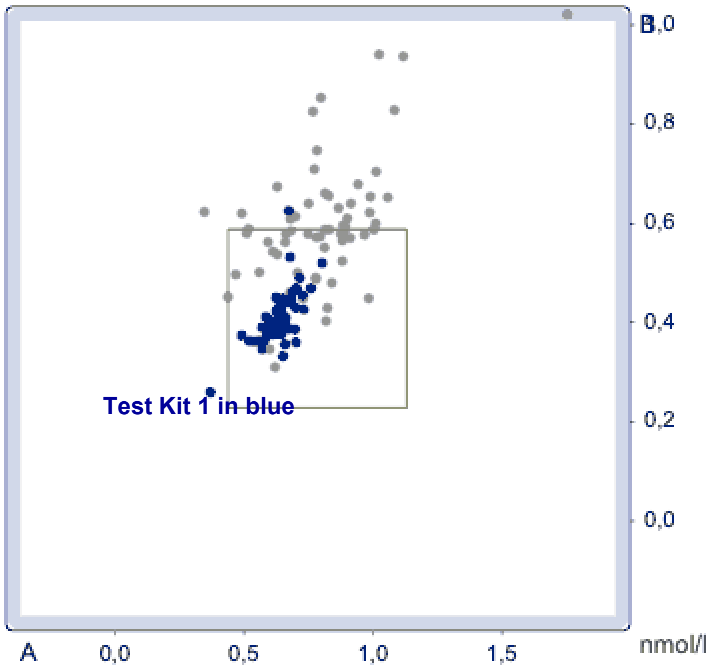
HM1/12

aldosterone

Radioaktivitätsmessung - Kit 44

Split 1

R f B



selected participants	64	
target value	0.783	0.408
limits	0.438 - 1.13	0.228 - 0.588
mean value	0.637	0.411
standard deviation	0.063	0.053
coefficient of variation	9.905	13.016

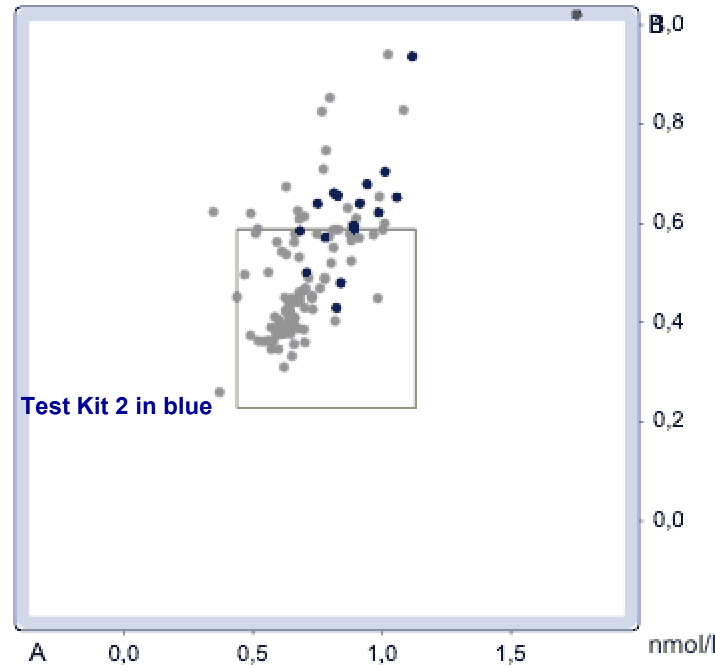
HM1/12

aldosterone

Radioaktivitätsmessung - Kit 111

Split 1

R f B



selected participants	17	
target value	0.783	0.408
limits	0.438 - 1.13	0.228 - 0.588
mean value	0.929	0.674
standard deviation	0.244	0.244
coefficient of variation	26.266	36.202

Bureau International des Poids et Mesures

Thank you for your attention