Bureau International des Poids et Mesures

Units for the Universe

or

The Metre Convention and its role in the 21st Century

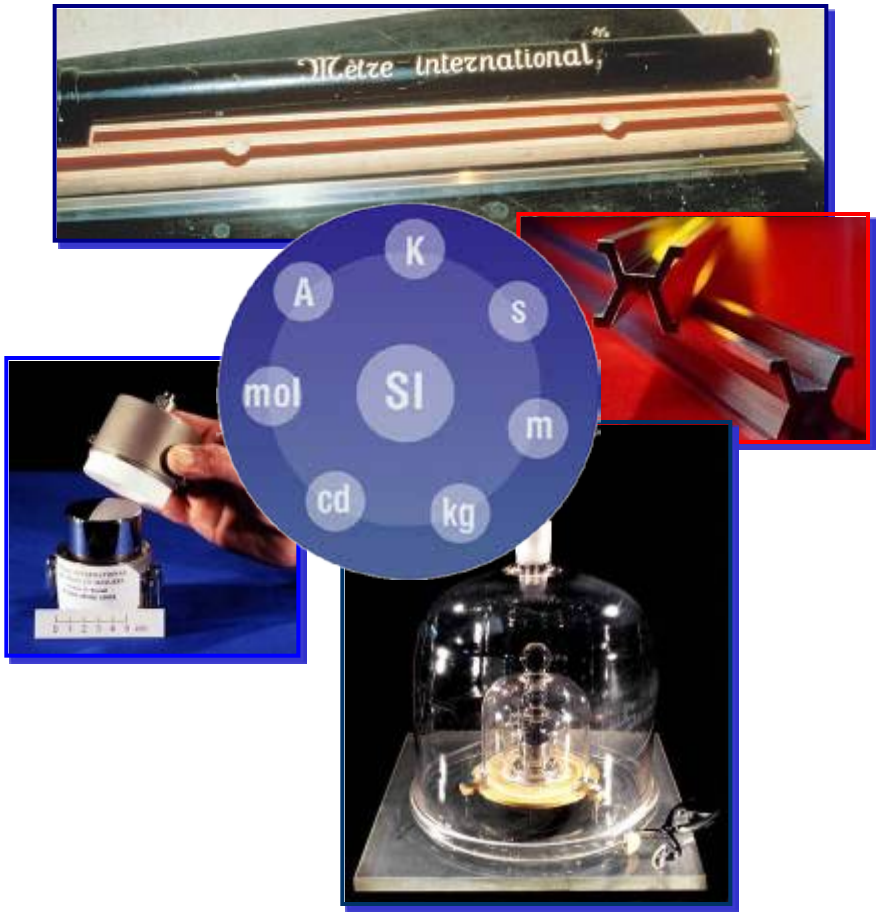
Professor Michael Kühne

Director, BIPM

Brief history of the Metre Convention and the SI

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.



Bureau International des Poids et Mesures

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.

BIPM's main technical roles

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.

BUREAU INTERNATIONAL DES POIDS ET MESURES

The Pavillon de Breteuil when given to the BIPM in 1870

Bureau International Des Poids Et Mesures

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.

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

Conférence Générale des Poids et Mesures

The CGPM

Is made up of **representatives** of the governments of the **Member States**. **Associates States and Economies** of the CGPM can attend its meetings.

Meets in Paris typically **every four years**; the 24th meeting of the CGPM was held in in October 2011, the 25th meeting will be in Autumn 2014

At each meeting

- it receives a **report** of the International Committee for Weights and Measures (CIPM) on **work accomplished**
- it discusses and examines the arrangements required to ensure the **propagation and improvement** of the International System of Units (**SI**)
- it endorses the **results** of new fundamental metrological determinations and various scientific resolutions of international scope; and
- it decides all major issues concerning the organization and development of the BIPM, including the **budget of the BIPM** for the next period.

Comité International des Poids et Mesures

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, and in support of world trade, 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.


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

ΜΕΤΡΩ ΧΡΩ

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

Paris, 14 October 1999

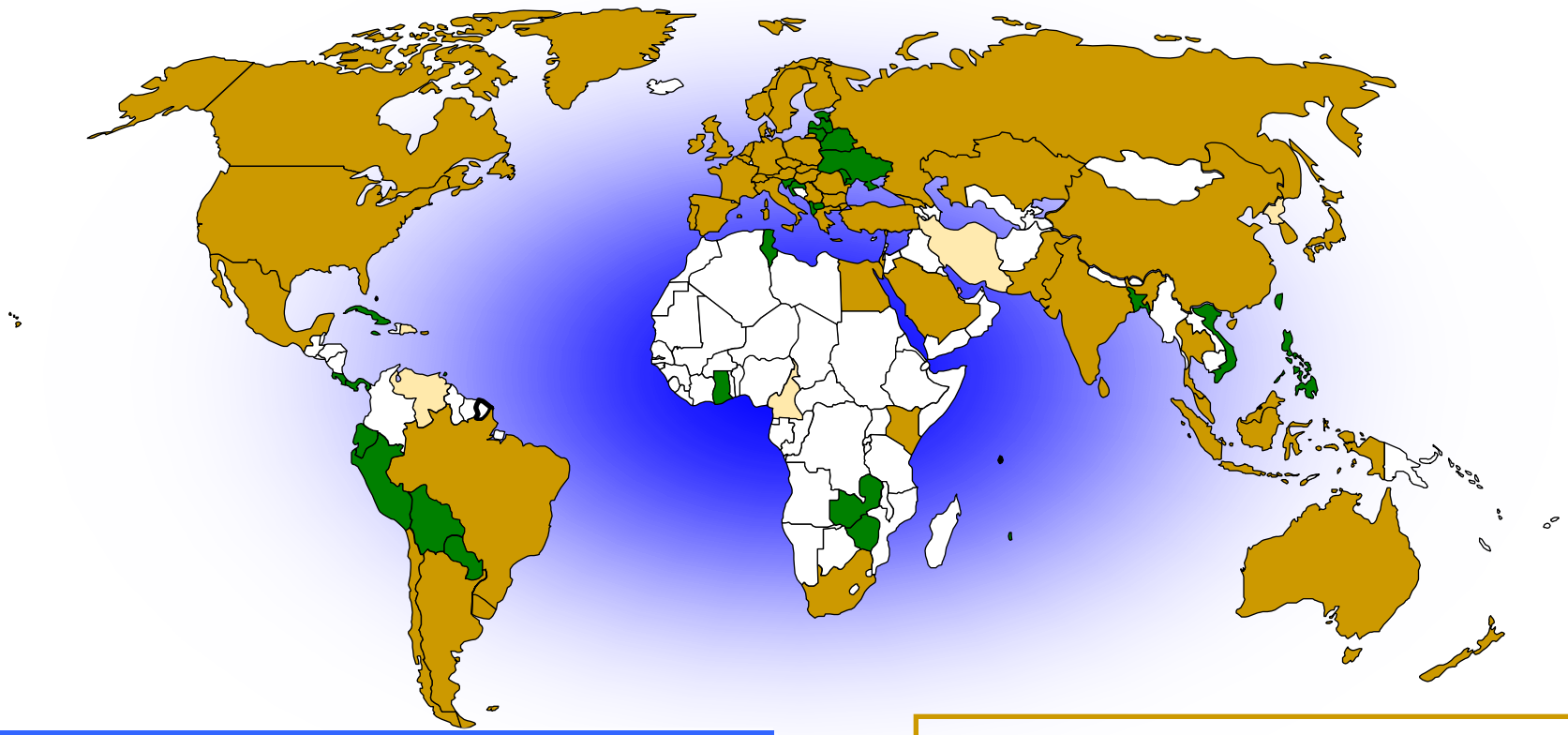
Currently, **CIPM MRA participants comprise of**:

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

Participating NMIs meeting this criteria:

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

CIPM MRA Participation



86 NMIs plus a further 138 designated institutes from
50 Member States
34 Associates of the CGPM
3 international organizations

Member participating in the CIPM MRA
Associate participating in the CIPM MRA

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.

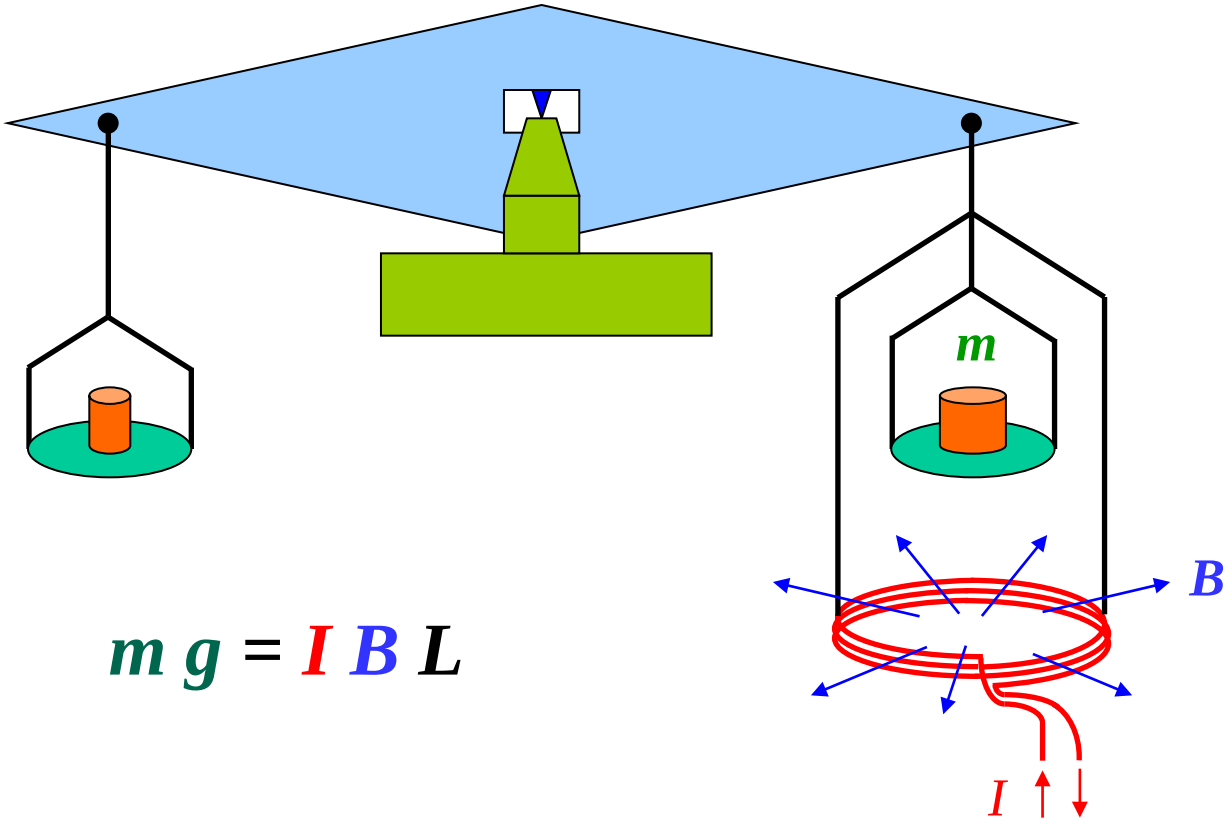
The re-definition of the kg, the ampere, the kelvin and the mole complete this dream.

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 challenge lies in in 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**

How does a watt balance work?

1. Weighing phase:

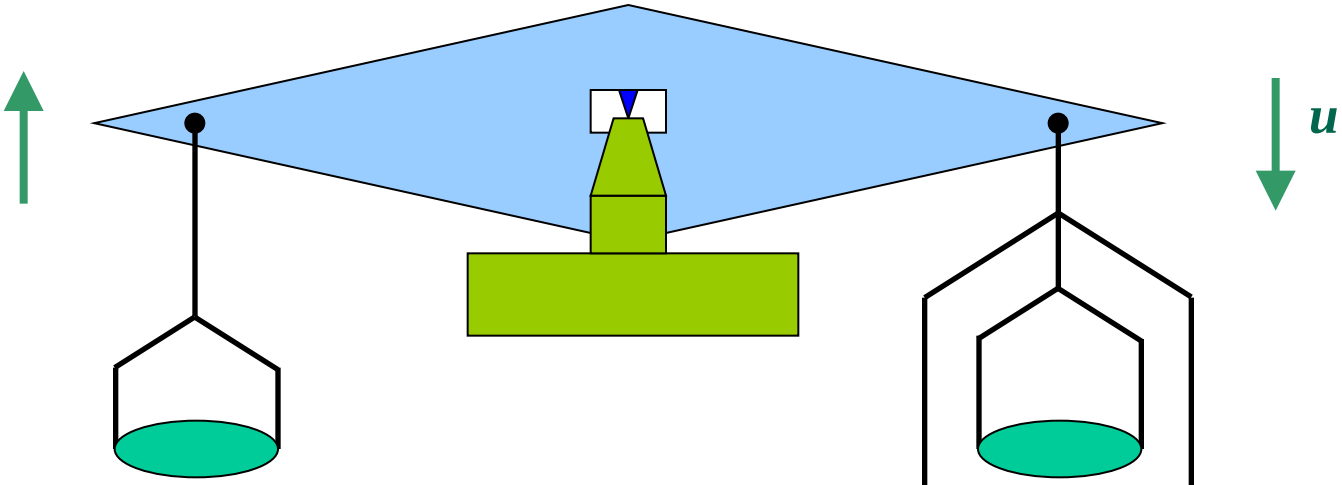


Courtesy of NRC

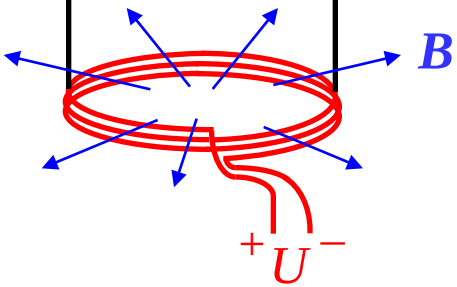
$$m\,g = I\,B\,L$$

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***).

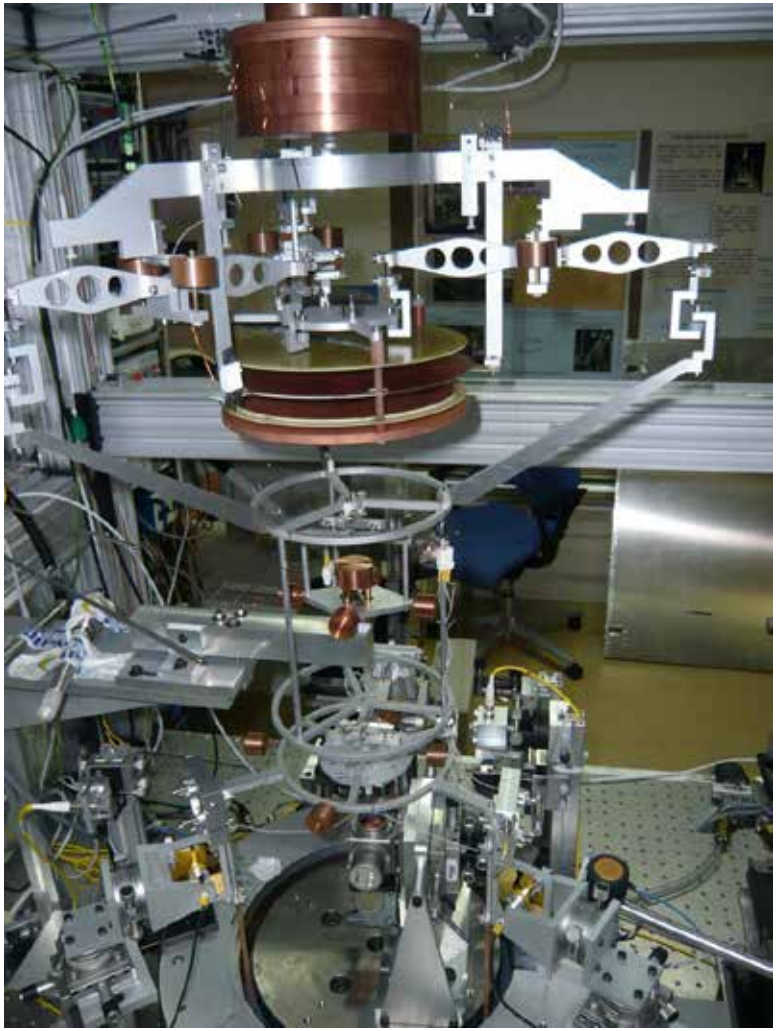


Courtesy of NRC



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

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

2011-2012

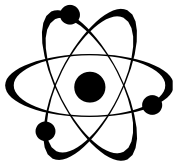
- move to dedicated laboratory
- install final magnet
- install mass exchanger and coil position control unit
- install vacuum system
- use improved alignment system to reduce type B unc.

Target uncertainty end 2012: $< 1 \times 10^{-6}$

linking m(28Si) to m(IPK)

silicon-28 atom,
mass = $m(^{28}\mathrm{Si})$

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



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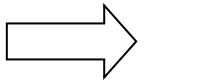
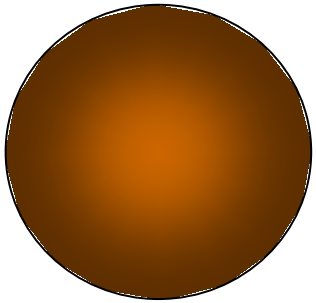
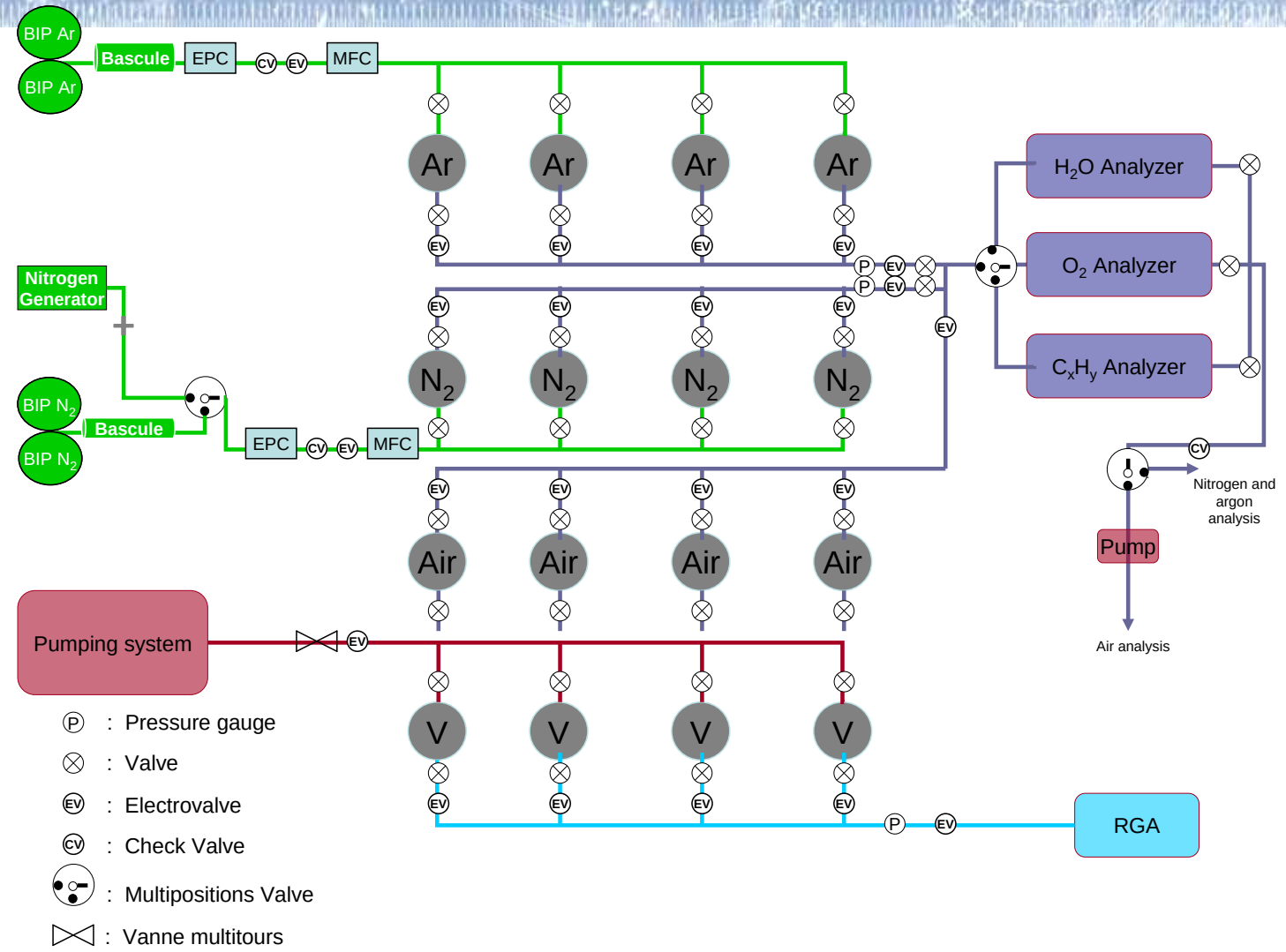




n atoms
to make a
1 kg sphere
(n » 2 ´ 10^{25} !)

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

Storage network for the pool of artefacts

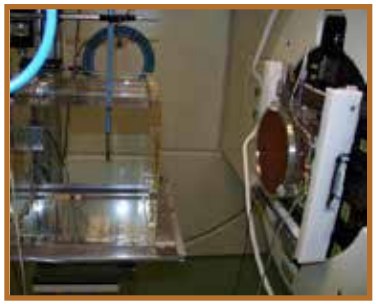


Future high-energy photon dosimetry at the BIPM

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

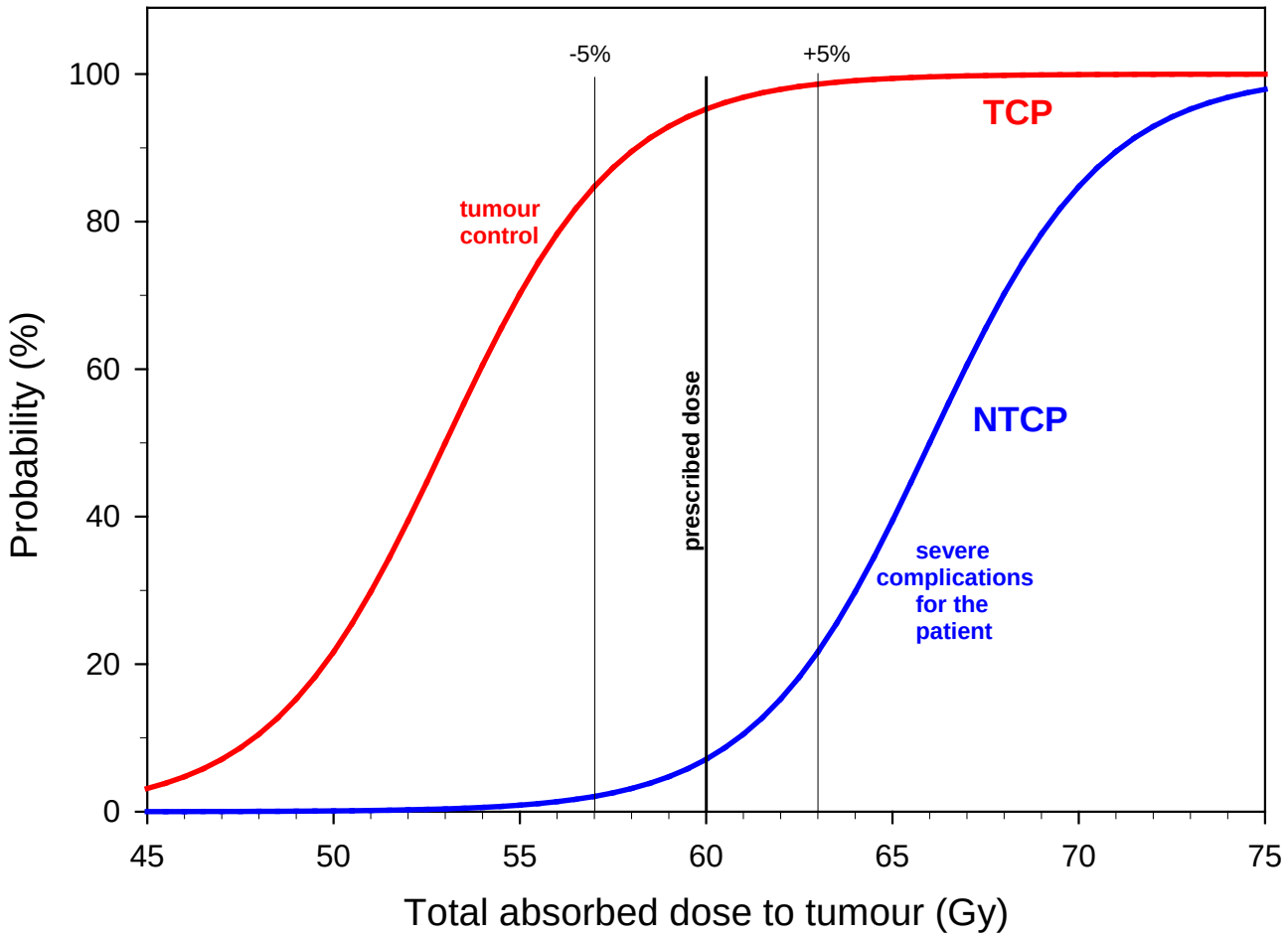
Use of a **LINAC by the BIPM** together **with** the **graphite calorimeter would provide:**

- 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**



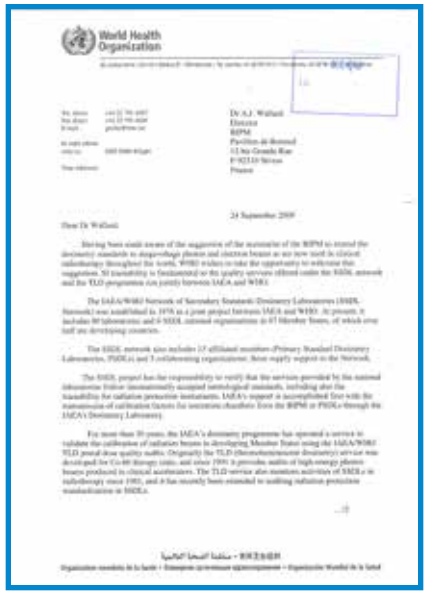
Schematic representation : expected treatment outcome

dose delivered to the patient within 5 %



International support for high-energy photon dosimetry at the BIPM

World Health Organization

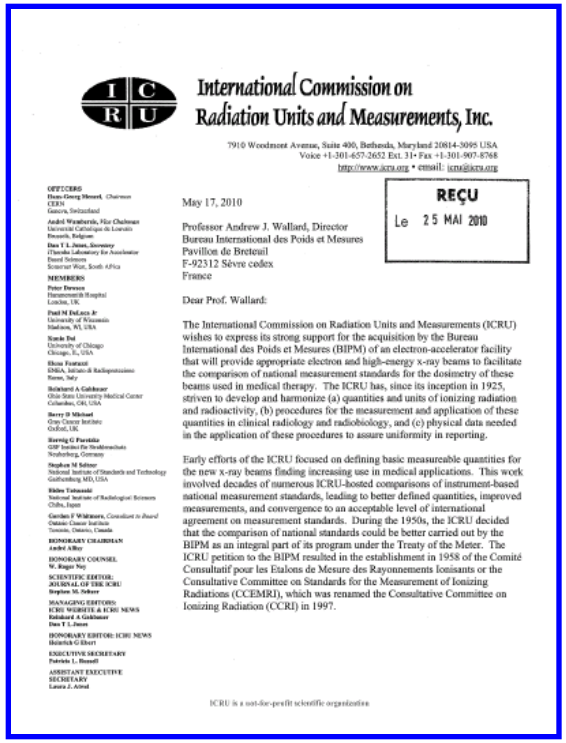


"For the SSDL network and the TLD programme, WHO is directly dependent upon the quality of work carried out by the BIPM. The suggestion to extend the facilities at the BIPM to include megavoltage dosimetry is thus emphatically supported."

IAEA.org International Atomic Energy Agency

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

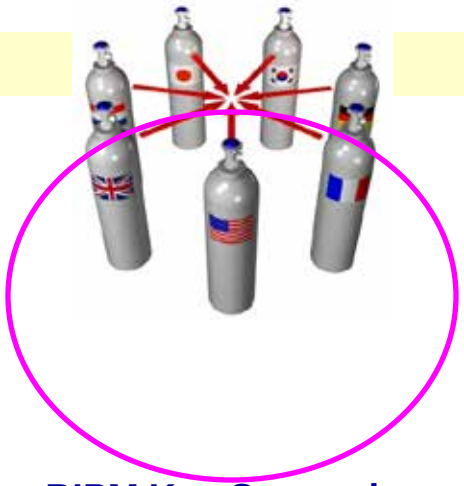
International Commission on Radiation Units & Measurements



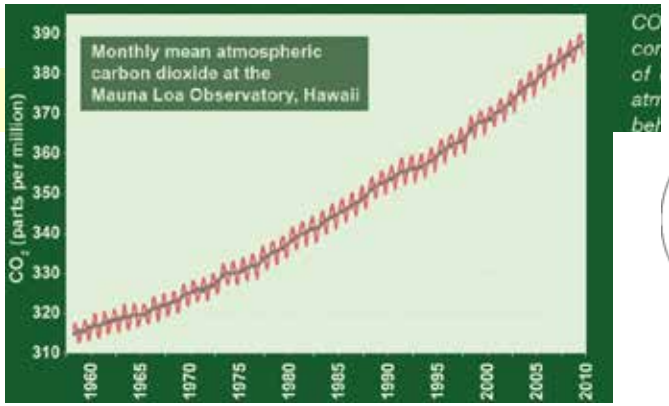
"The success over more than a half-century of the BIPM program in ionizing radiation has been outstanding, greatly facilitating the improvement and harmonization of measurements of ionizing radiation worldwide"

Responding to the Challenge of Greenhouse Gas Monitoring

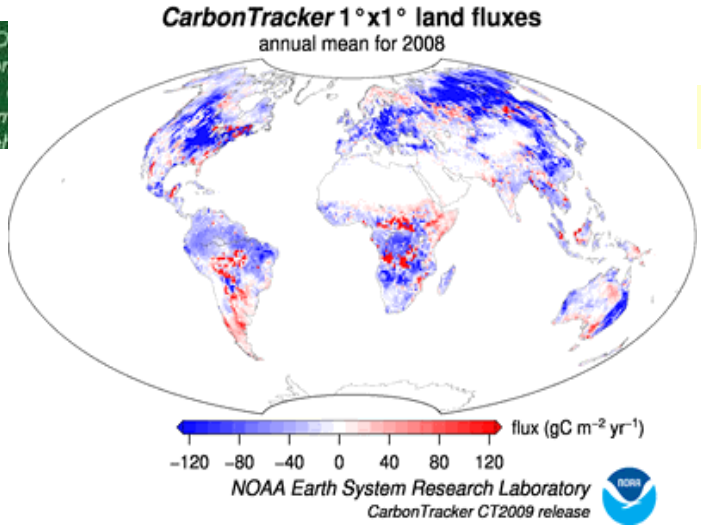
- **Climate Change:** Mitigation and Cap and Trade Legislation **on GHG emissions**
- Accurate data **for informed policy decisions**
- Verification **of national emission inventories through measurement**
- Major Observational **network expansion**
- Stringent requirements **on equivalence of GHG calibration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



BIPM Key Comparisons



GHG monitoring stations/networks

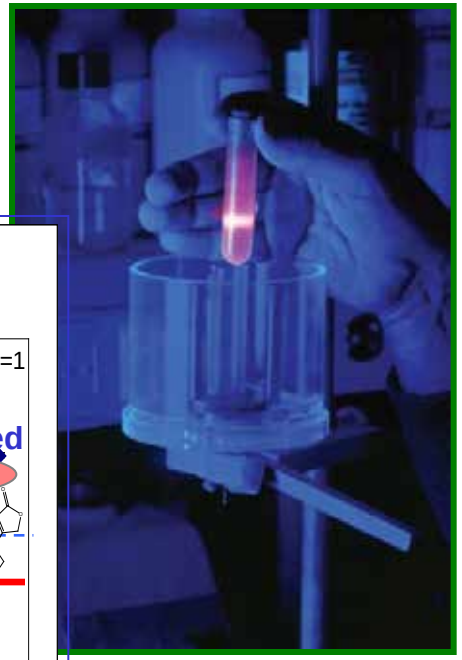


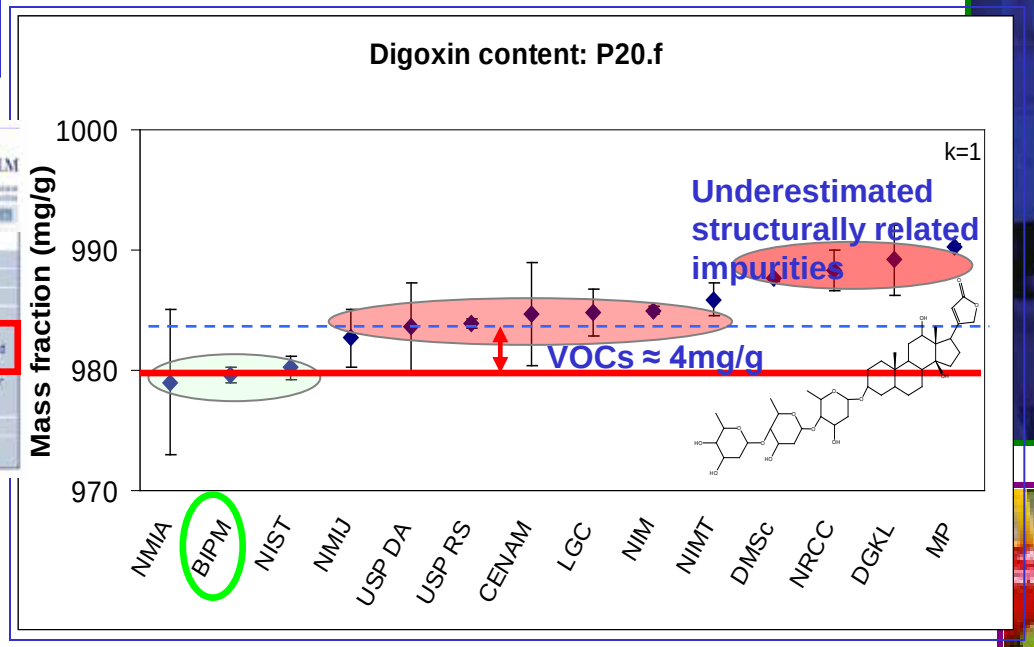
CO_2 Flux Maps – Emission Verification

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

Metrological traceability for organic analysis:

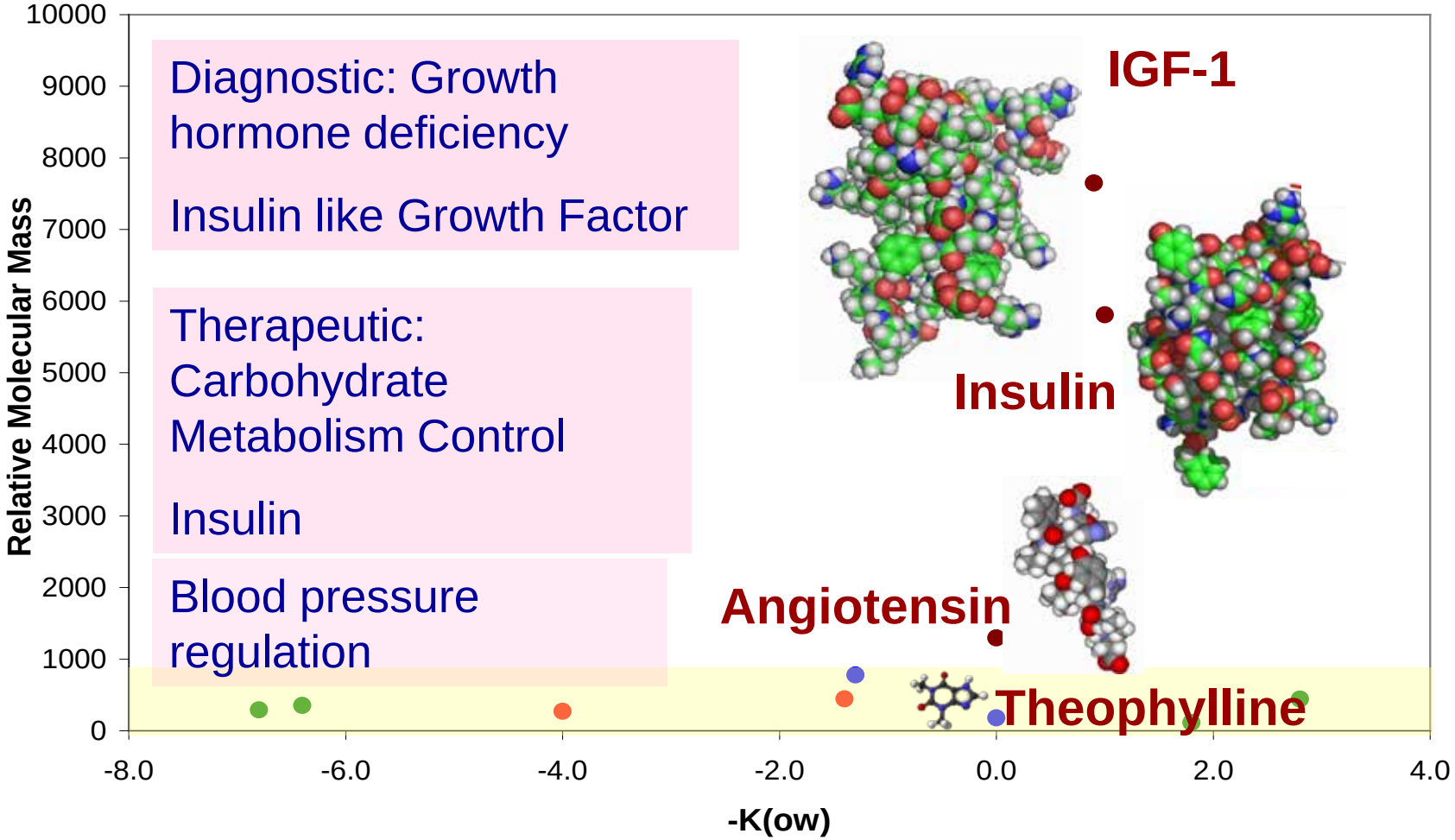
BIPM programme





Metrology for Health: Improved Diagnostics and Therapeutics

Extension of Organic Primary Calibrator Comparisons



SI Metrology for diagnosing and treating 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

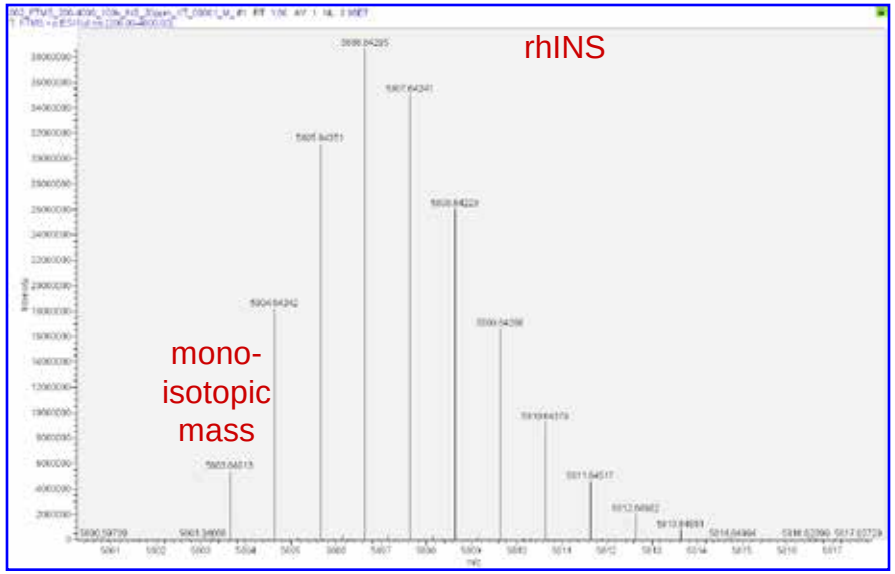
Primary Calibrator- Recombinant Human Insulin (rhINS)

- 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

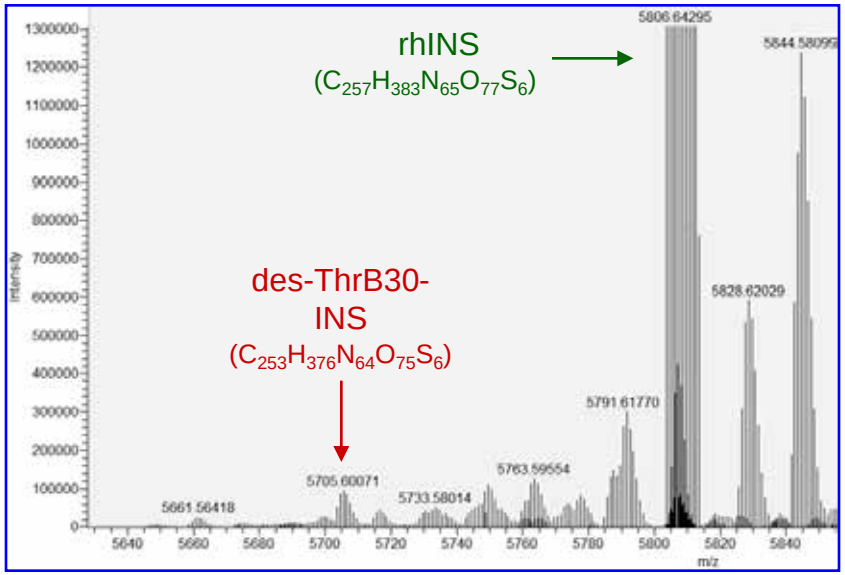
Zn complex of 3 rhINS-dimers

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

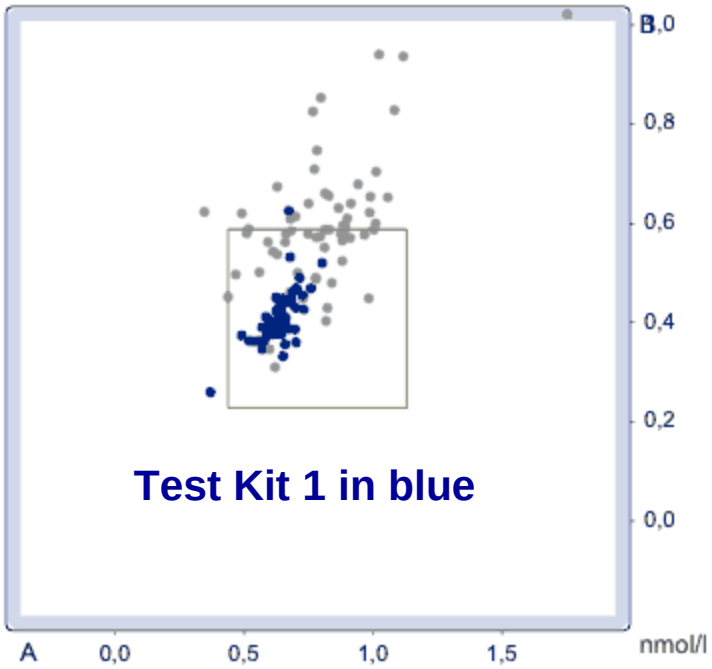
EQAS audit, samples testing with two kits, target value (middle of Youden diagram) by ID-MS

HM1/12

aldosterone

Radioaktivitätsmessung - Kit 44

Split 1



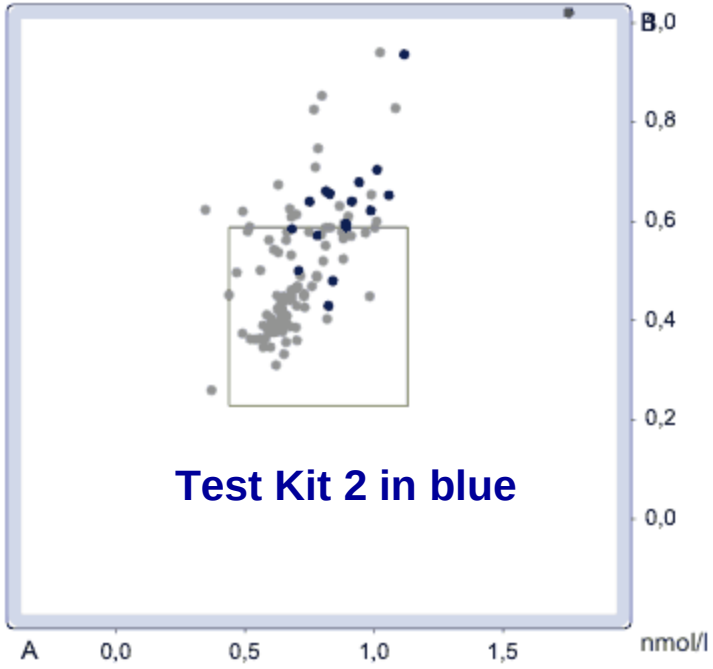
selected participants	64	
target value	0.783	0.408
limits	0.438 - 1.13	0.228 - 0.588
mean value	0.637	0.411
standard deviation	0.063	0.053
coefficient of variation	9.905	13.016

HM1/12

aldosterone

Radioaktivitätsmessung - Kit 111

Split 1



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

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.

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.

Conclusion

THE ROLE OF THE BIPM IS

WORLDWIDE UNFORMITY OF MEASUREMENT.

It achieves this through providing the necessary scientific and technical basis for such uniformity and by collaborating with other institutions and organisations that have related missions.

Thank you for your attention