DE LA RECHERCHE À L'INDUSTRIE

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INTRODUCTION ABOUT METROLOGY AND LNHB

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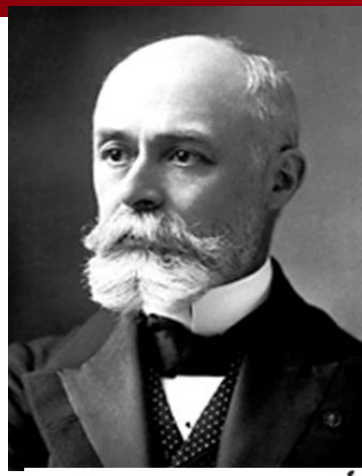
LNE
Le progrès, une passion à partager

list

THE LABORATOIRE NATIONAL HENRI BECQUEREL (LNHB)



The Laboratoire National Henri Becquerel (LNHB) is:

- Laboratory of the French alternative energies and Atomic Energy Commission (CEA)
- Designated institute of the French metrology institute : LNE (Laboratoire National de métrologie et d'Essais)

2 buildings located in the Saclay CEA Center (30 km south Paris)

In charge of radioactivity standards (Bq, Gy)
Permanent staff: 53

3 laboratories

Activity (Bq) (24)

Nuclear decay data (4)

Dosimetry (Gy) (22)

A FEW WORDS ABOUT METROLOGY

What is metrology ?

Wikipedia: **Metrology** is the science of measurement. Metrology includes all theoretical and practical aspects of measurement.
The word comes from greek

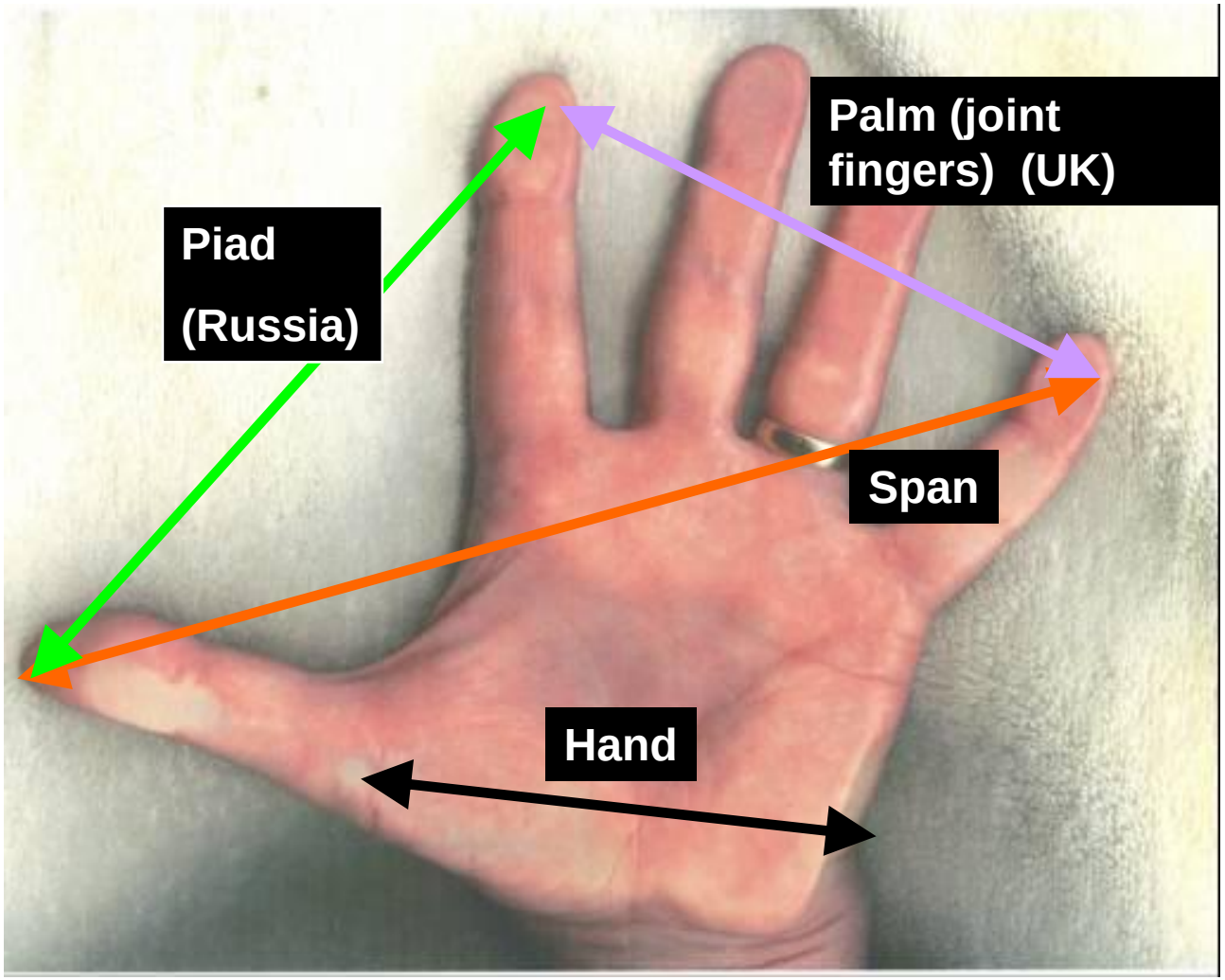
“μέτρον” (*metron*), "measure“
“λόγος” (*logos*), “speech, oration, discourse, quote, study, calculation, reason".

International vocabulary of metrology – Basic and general concepts and associated terms (VIM) 3rd edition (JCGM 200:2012)
Metrology: Science of **measurement** and its application

*NOTE : Metrology includes all theoretical and practical aspects of measurement, whatever the **measurement uncertainty** and field of application.*

A FEW WORDS ABOUT METROLOGY

Some historical measurement units around the world

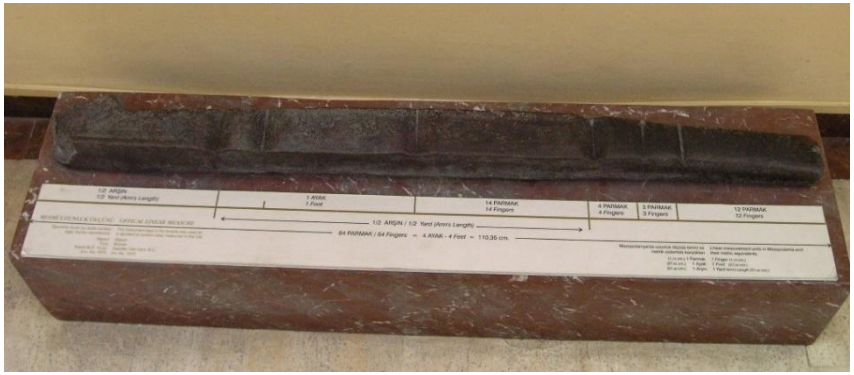


A FEW WORDS ABOUT METROLOGY

The **cubit** *(lat. cubitus)* is a unit of lenght used several thousands of years.

One name but different lengths …

Royal	Egypt	52 to 54 cm
Natural (small)	Egypt	45 cm
Roman	Rome	44.45 cm
Cyrenaïca	Greece	46.31 cm
Medium	Greece	47.42 cm
Black	Saudi	64.9 cm
Mesopotamian	Mesopotamia	53.34 cm
Hashimi	Persia	54.05 cm
Jude	Israël	42.81 to 44.45 cm
Babylonian	Babylon	49.61 cm



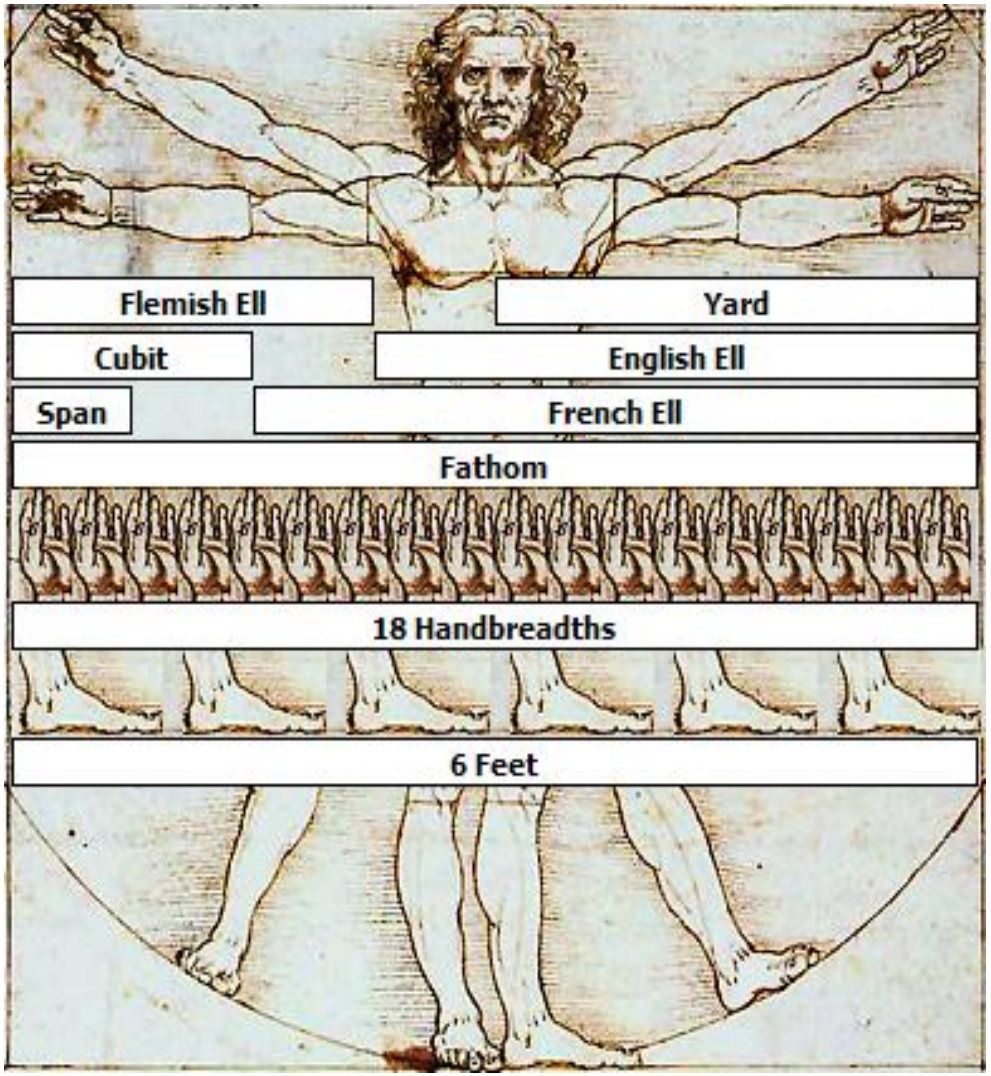
Nippur cubit, graduated specimen (3rd millennium B.C.) (Archeological Museum of Istanbul (Turkey).

Cubit rule Egyptian NK from Liverpool museum

A FEW WORDS ABOUT METROLOGY

Different units depending on the countries, on the professional community, etc…

One cubit = 24 fingers
= six palms
= 1½ foot



A REVOLUTIONARY IDEA…

Creation of the **decimal metric system** at the time of the French Revolution

Deposition of two platinum **standard**s representing the metre and the kilogram, on 22 June 1799, in Paris
July 4, 1837 : Law → Decimal system in France

First step in the development of the present **International System of Units**.

Development to facilitate trade

Later : Time reference : linked to railways

INTERNATIONAL ORGANIZATION

1874 : *CGS system*, a unit system based on **centimeter, gram, and second**

May 20, 1875

« Convention du mètre » signature (17 countries – today 56)

Bureau International des Poids et Mesures (BIPM)

(International Bureau of Weights and Measures)

1889 : 1st CGPM (General Conference on Weights and Measures)

International prototypes for the metre and the kilogram. Together with the second as the unit of time -> MKS system based on **metre, kilogram, and second.**

1954 : 10th CGPM : introduction of **the ampere, the kelvin and the candela** as base units,

1960: 11th CGPM : The name International System of Units, with the abbreviation SI

1964: 12th CGPM : Becquerel (derived unit)

1971: 14th CGPM : adding the **mole**

Système International d'unités

The recommended practical system of units of measurement is the International System of Units (*Système International d'Unités*, **SI**). This SI consists of a set of **base units**, **prefixes** and **derived units**,

Name	Symbol
metre	m
Kilogram	kg
Second	s
Ampère	A
Kelvin	K
mole	mol
candela	cd

Derived units: are formed by combining the base units according to the algebraic relations linking the corresponding quantities.

N, Pa, J, W, Hz,..
lm, lx, …
V, C, F, H, Wb, T, …
Bq, Gy, Sv, …
…

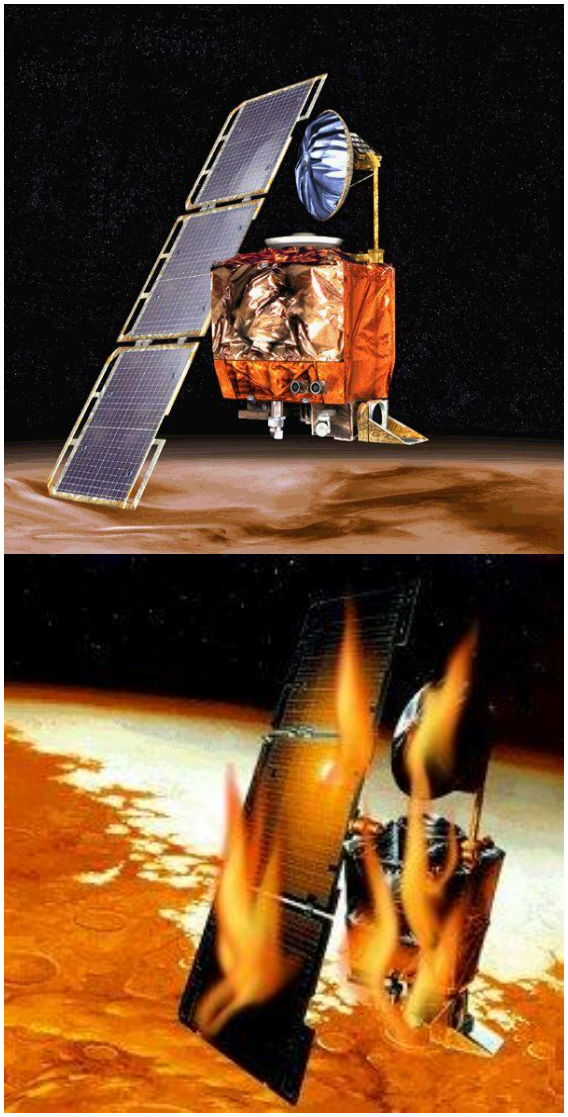
The SI is not static but evolves to match the world's increasingly demanding requirements for measurement.

Evolution of derived units :

calorie ->joule (1 cal= 4.1855 J) 1 J = 1 W.s = 1 N.m = 1 kg $m^2.s^{-1}$.
Radioactivity unit : curie (1 g ^{226}Ra) → becquerel (1 decay per second) 1 Ci = 3,7 10^{10} Bq

Problem of units …

Mars Climate Orbiter (1999)



2 development teams using different units systems…

- Output of the software in imperial unit : pound-seconds (lbf x s)

- Input was expected in SI unit : newton-second (N.s)

1 pound-force= 4.48 newtons

→ Destruction of the NASA space probe

Cost : US$ 125 M

International organisation

Bureau International des Poids et Mesures (BIPM)

“The mission of the BIPM is to ensure and promote the global comparability of measurements, including providing a coherent international system of units for:

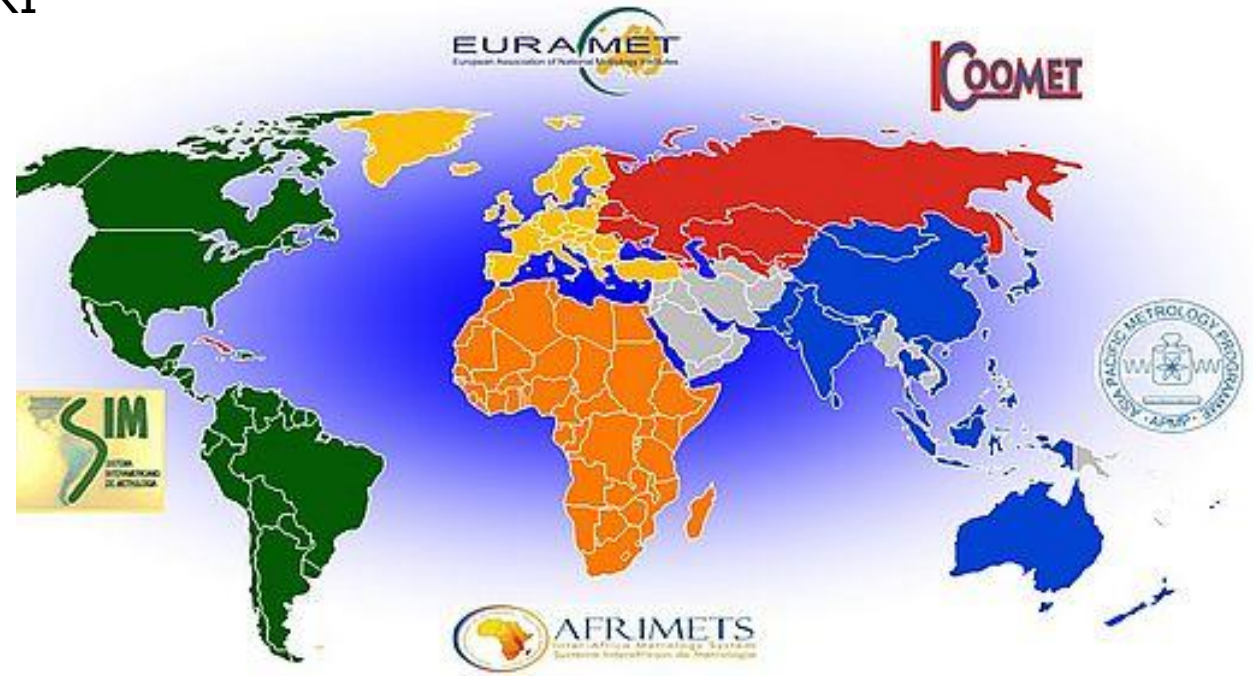
- **Scientific discovery and innovation,**
- **Industrial manufacturing and international trade,**
- **Sustaining the quality of life and the global environment.**

http://www.bipm.org/

International organisation

Consultative Committees (for the different fields)
Ionizing Radiations : CCRI

Regional Organisations
EURAMET



BIPM / CCRI

EURAMET

VNIIM
Russia

NMSIA
South Africa

NIST
USA

LNE-LNHB

PTB
Germany

NPL
GB

...

Système International de Référence (SIR)

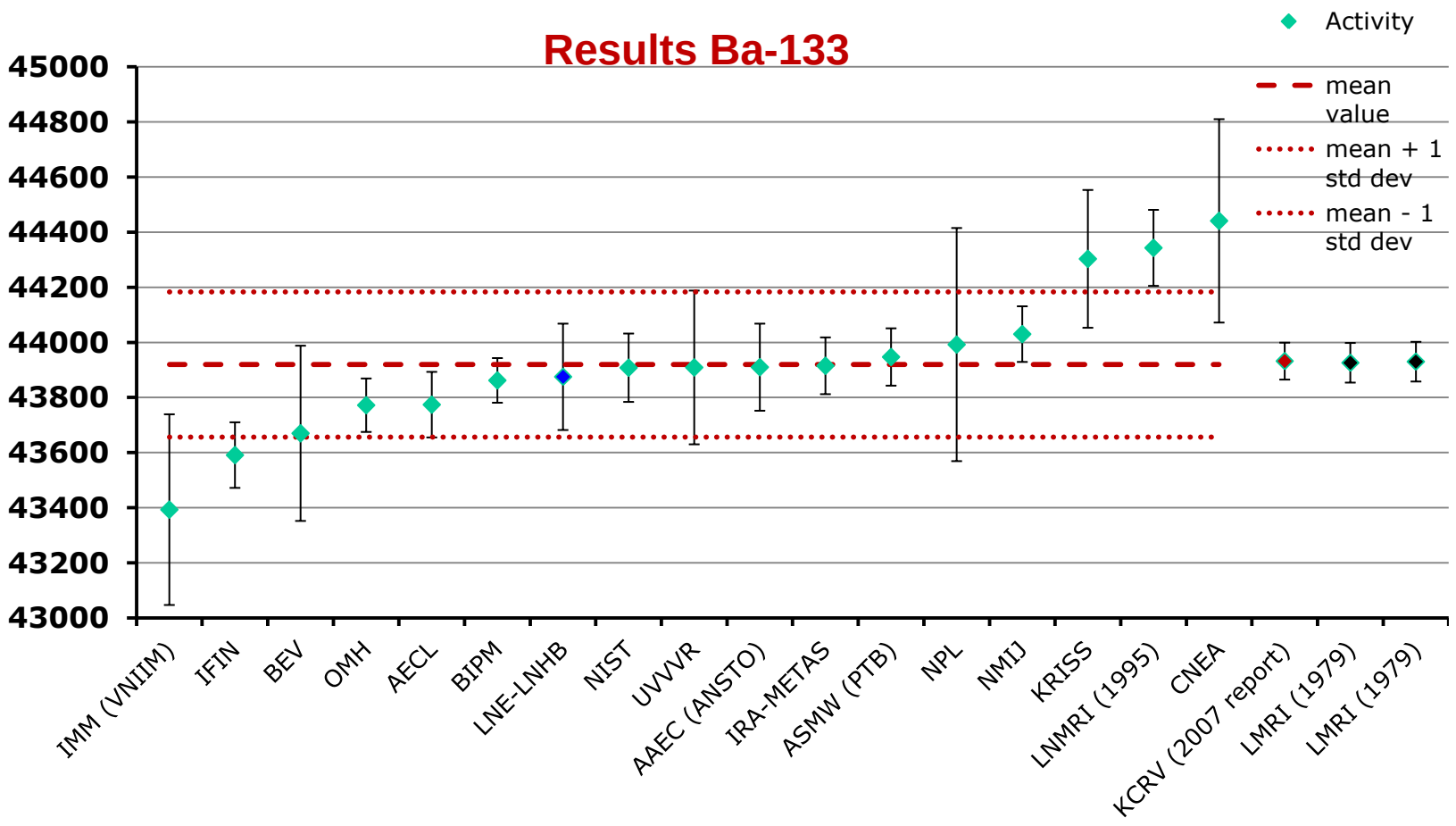
Together with the National Metrology Insitutes (NMIs), the BIPM The BIPM provides equivalence and mutual recognition of reference standards, traceable to the SI.

In the field of ionizing radiation : Système International de Référence (SIR)

The γ-ray emitters, in liquid or gaseous form, are sent to the BIPM where they are compared with standard sources of very long life times (^{226}Ra) using pressurized ionization chambers.

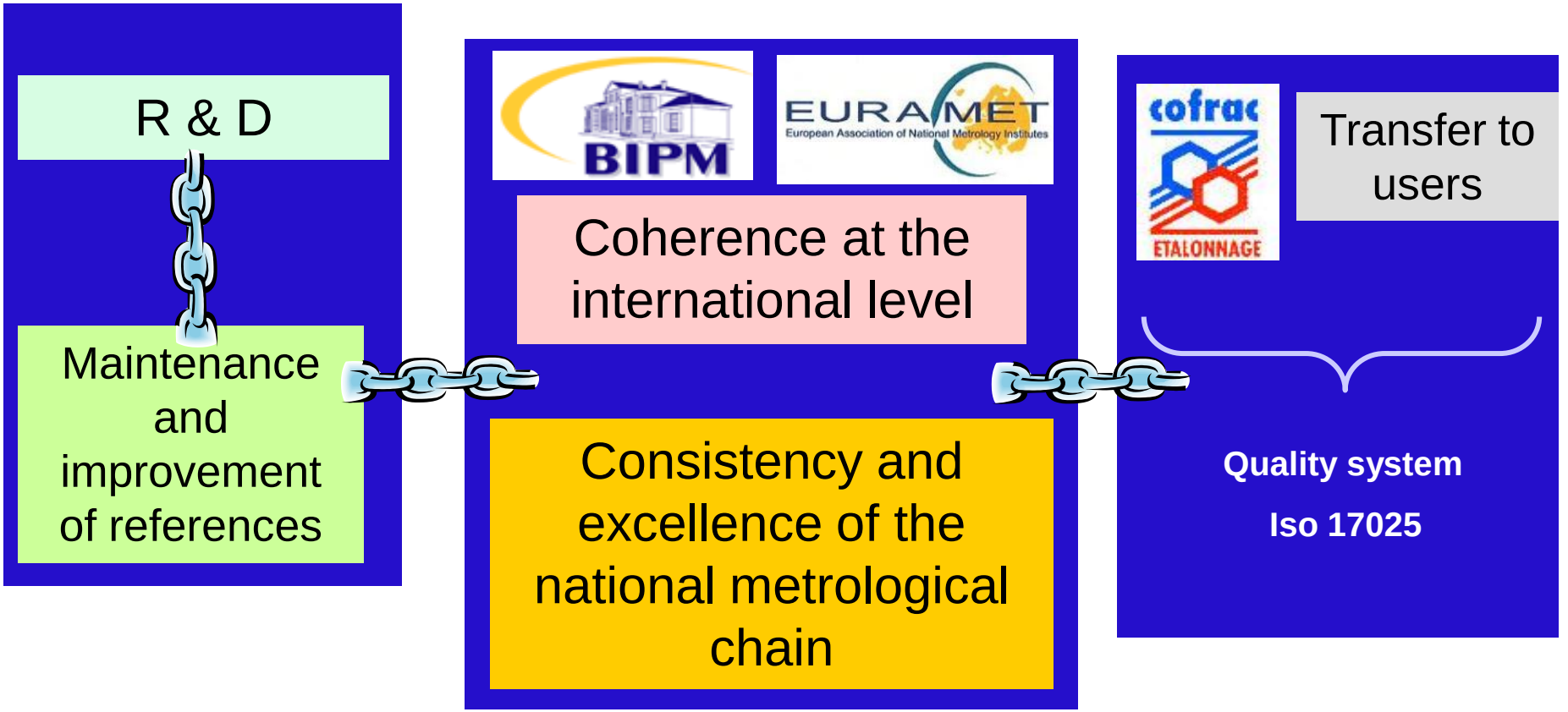
International comparisons

Système International de référence (SIR) (BIPM)

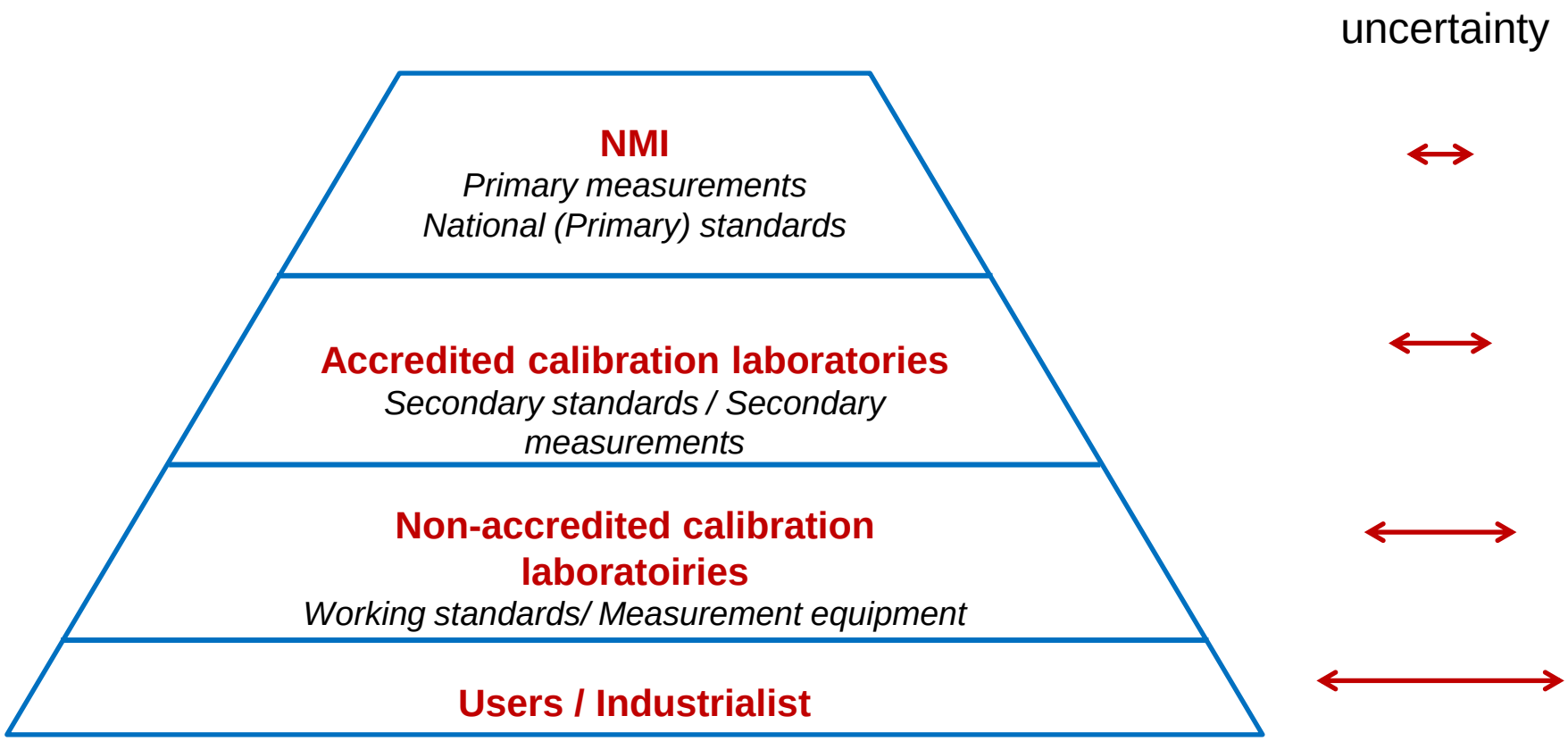


Missions of the NMIs

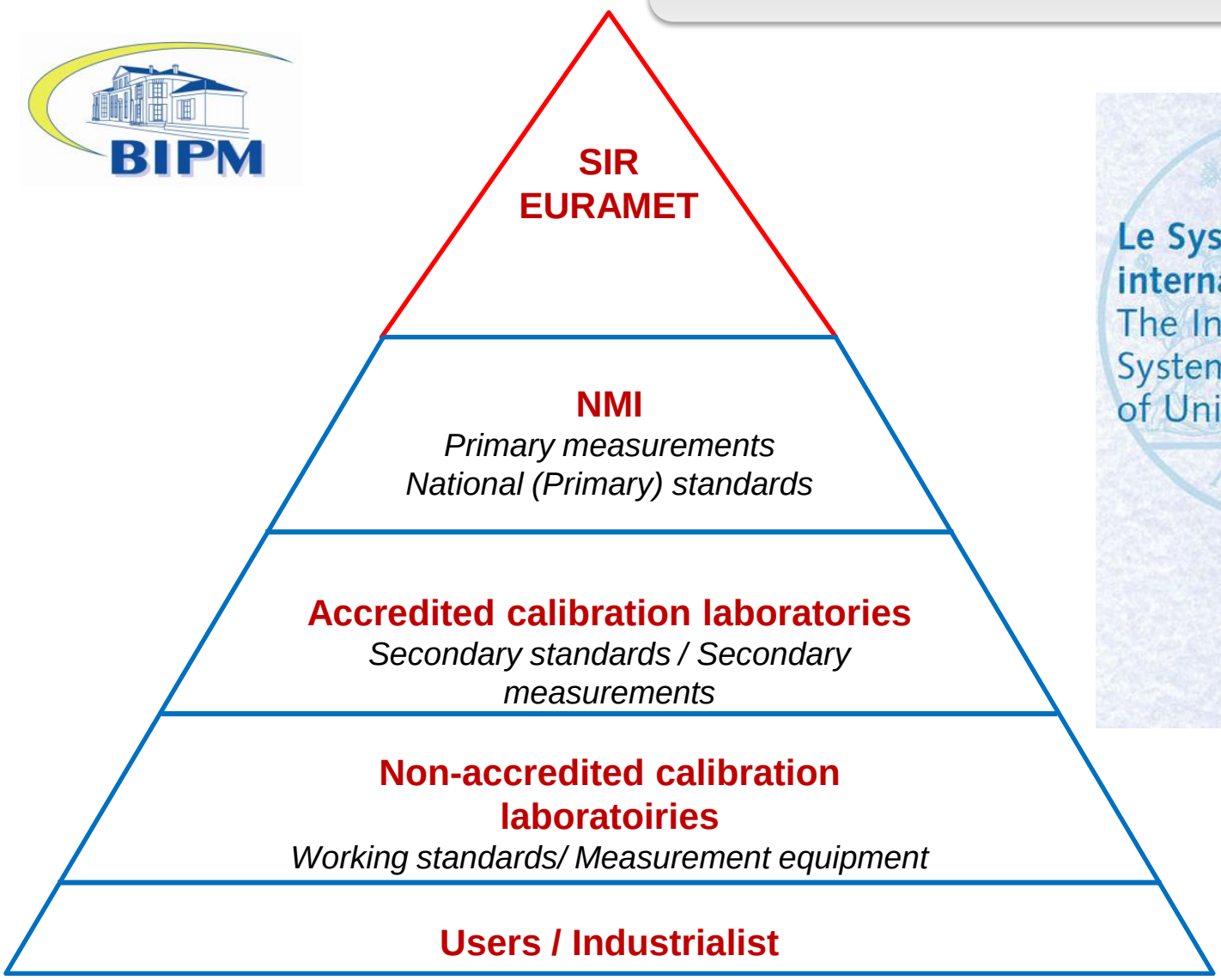
To allow users access to **metrological references** they need under a rigorously established **traceability**



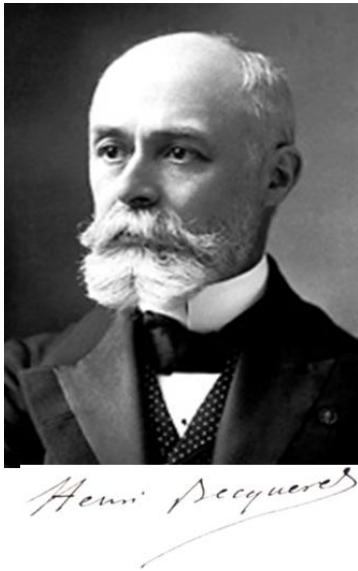
National metrology chain



International metrology chain



Activity measurements



At LNHB:

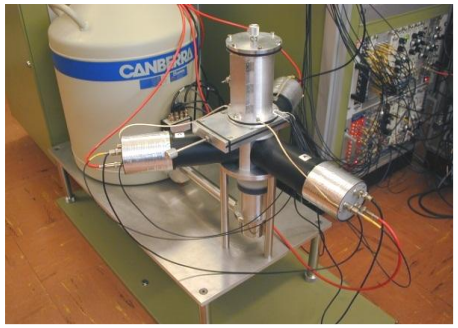
Different techniques to fit the radionuclide specificity (decay scheme and physical state (liquid, solid, gas)):

- Coincidence technique measurements
- 4p β-γ counting
- Liquid scintillation counting - Development of the TDCR method
- Gaz counting
- Alpha counting
- ^{222}Rn specific standard
- Calibration transfer by Ionization chambers

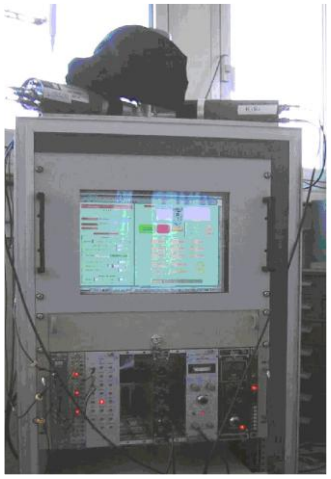
Mass (volume) activity relative uncertainty : a few 10^{-3}

Validation by participation to SIR (International Reference System) of the Bureau International des Poids et Mesures (BIPM)

Radioactivity metrology



Activity measurements by β-γ coïncidences



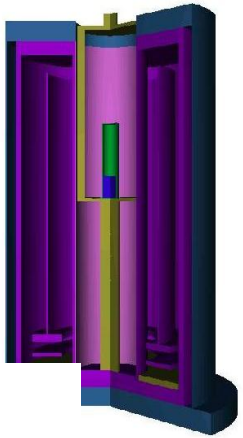
Beta-emitting nuclide measurements by liquid scintillation (TDCR)

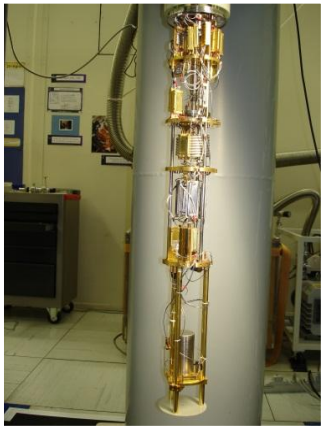
Radiochemistry and source preparation

222Rn primary standard

Neutron flux measurements

Calibration transfer LNHB : Ionisation chamber (well-type)





Cryogenic detectors

National metrology chain

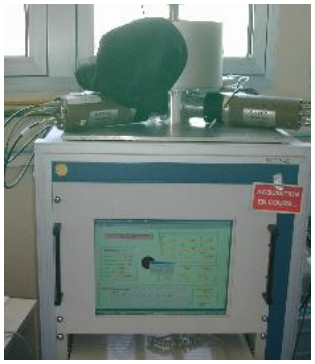
^{18}F activity

Medical application : users needs close to the best possible measurements

Laboratoire National Henri Becquerel

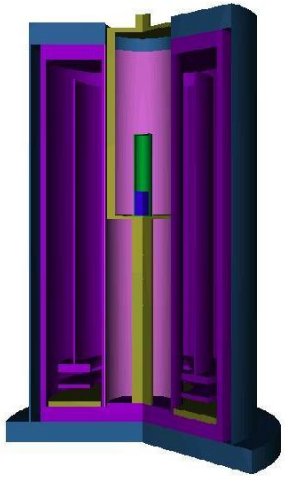
Primary measurement

TDCR method



Seconday measurement

Ionisation chamber



User: activimeter

Hospital

Relative uncertainty

0.5 %

1.5 %

3 - 4 %

PHOTON SPECTROMETRY AT LNHB

10 HPGe calibrated detectors

(1 low-activity et 1 high activity : source at 3 m from the detector)

1 Si(Li) detectors

Energy range :
Some 100 eV -> 4 MeV

Activity range : mBq -> GBq (10^{12})

Photon spectrometry

3 mains tasks:

Measurement of gamma impurities in standard solutions – identification and quantification

Activity measurement (relative uncertainty: about 1% as the efficiency calibration is achieved with about 0.5 % relative uncertainty)

Measurement of photon emission intensities

Photon spectrometry

Conventional equipment

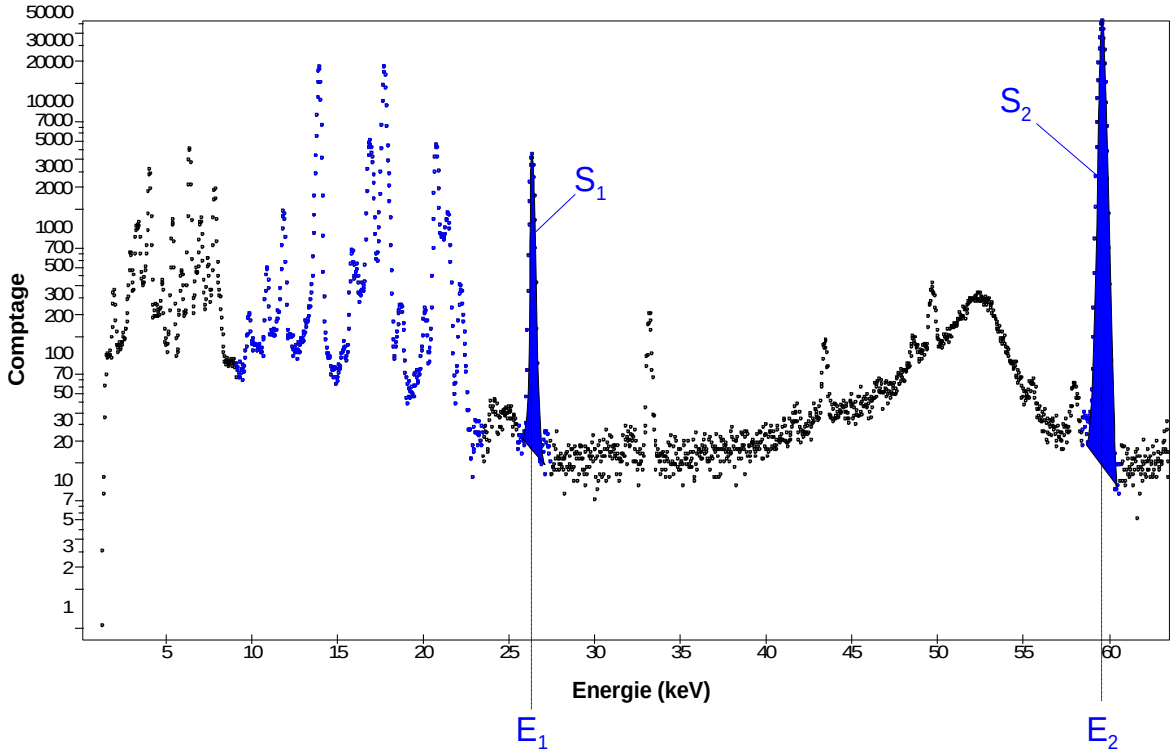
Conventional detectors and associated analogue electronics

But used with cautions :

- Accurate and reproducible source positioning system
- Source-to-detector distance = about 10 cm
  - To reduce positioning uncertainties
  - To reduce coincidence summing corrections

Photon spectrometry

Basic principle: activity measurement



Measured data :

E_1 …… E_n (Energy)

S_1 …… S_n (Peak area)

Tabulated data :

I_1 …… I_n (Emission intensity)

Full-energy peak efficiency :

ε_1 …… ε_n

$$A = \frac{S_n}{t \cdot \varepsilon_n \cdot I_n} \quad \text{x corrective factors}$$

Main corrective factors:

- Coincidence summing
  (some 10^{-2} for a radionuclide with cascade decay scheme at 10 cm)
- Geometry transfer (reference calibration : point source)
- Software «ETNA » developed at LNHB