

# **Ionizing Radiation**

**Professor Giorgio Moscati  
President CCRI**

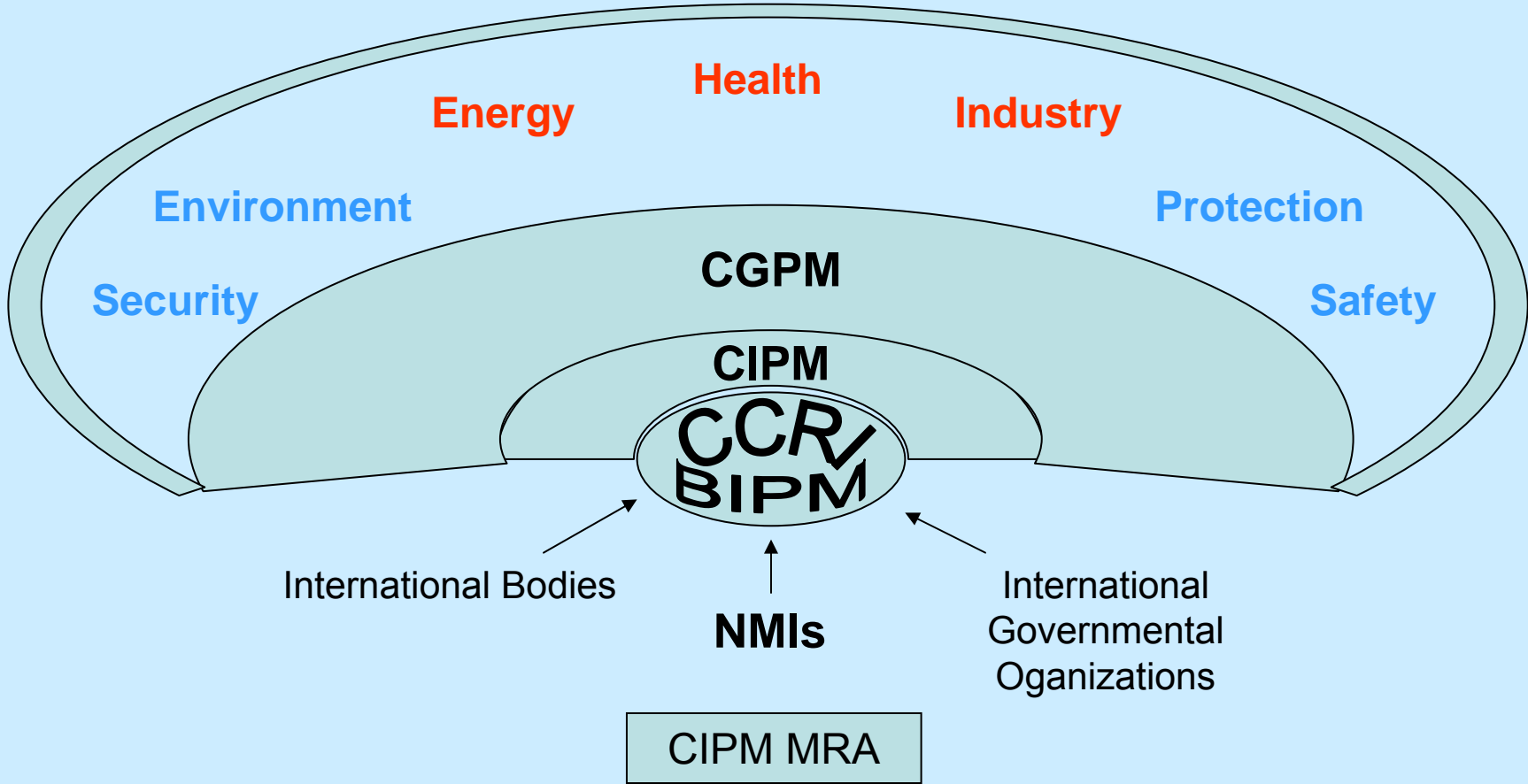
**Consultative Committee for Ionizing Radiation**

**Comité consultatif des rayonnements ionisants**

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# CCRI created by CIPM in 1958

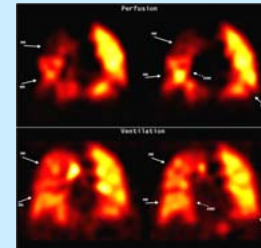


# Ionizing radiation

- Health



Cancer therapy



Nuclear medicine



Interventional radiology

- Energy



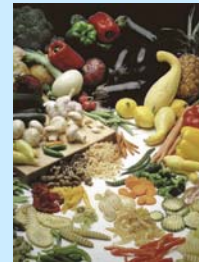
Nuclear power

Natural activity



- Industrial

Product sterilization



Food

- Environment

- Safety

- Protection



Non-destructive testing (motor engine piston)

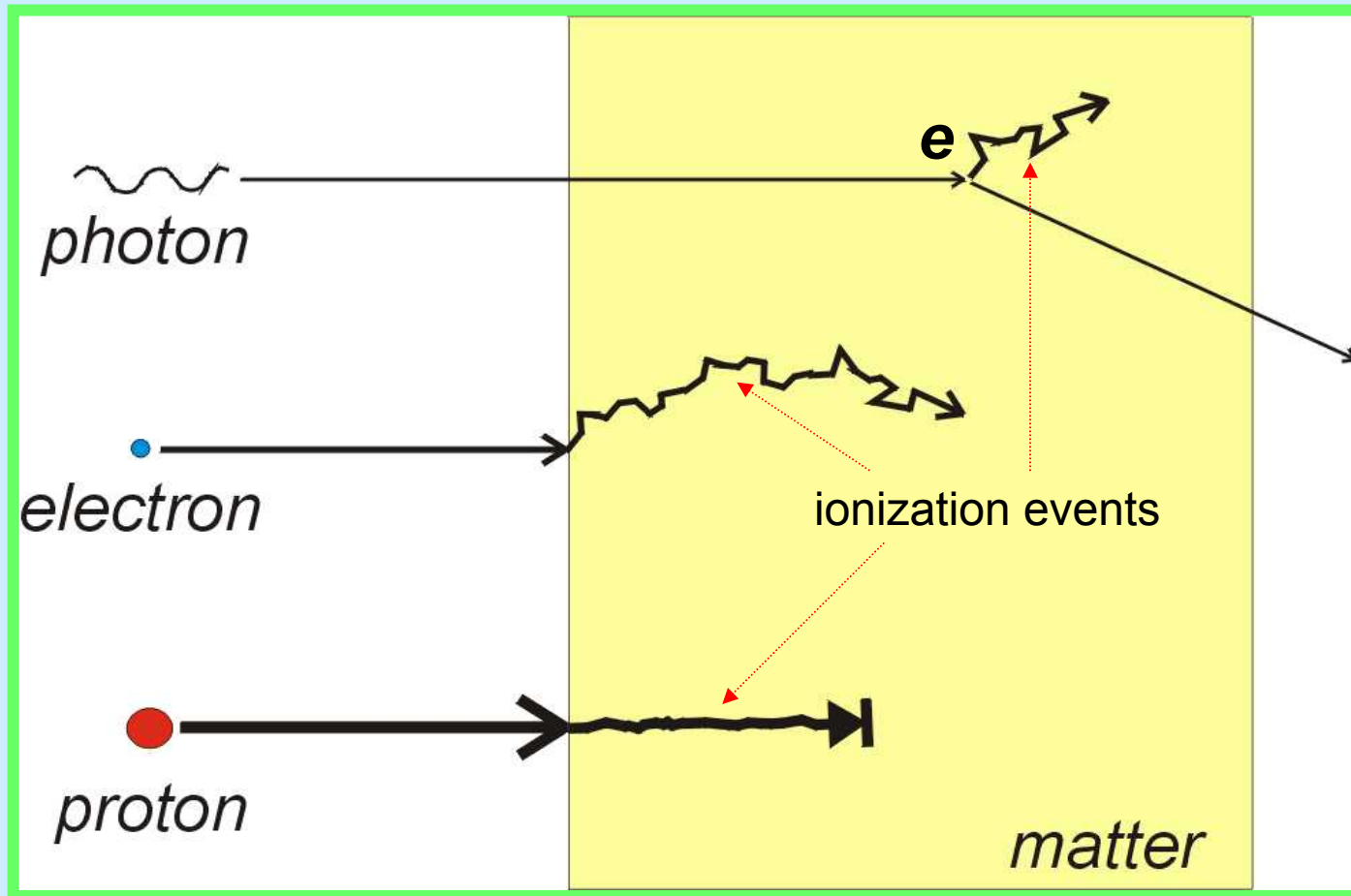


Pharmaceuticals



Decontamination

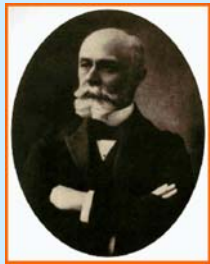
# Ionizing radiation



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# Radiation discoveries and effects



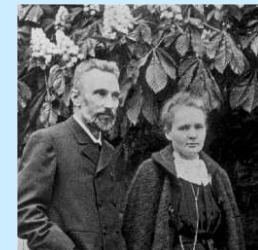
Henri Becquerel  
- activity 1896



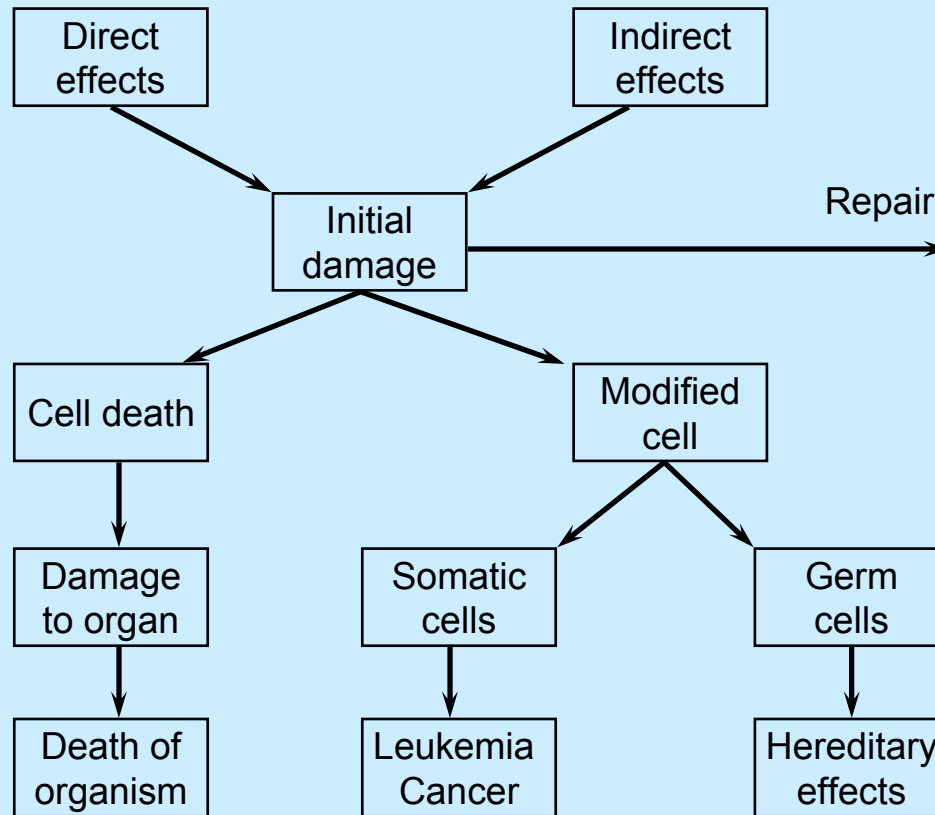
James Chadwick  
- neutrons 1932



Wilhelm Röntgen  
- x-rays 1895



Pierre and Marie Curie  
- radium & polonium 1898



Deterministic effects

**Radiotherapy**

Stochastic effects

**Protection**

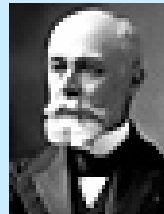
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# Metrological quantities / units

- Activity / Bq ( $s^{-1}$ )

- mBq environmental
- Bq natural levels in food
- kBq natural human body content
- MBq nuclear medicine diagnosis
- GBq nuclear medicine therapy
- TBq radiotherapy sources
- PBq nuclear accident release
- EBq reactor core



**Henri Becquerel**

- Dose equivalent / Sv (J/kg)

- nSv natural background
- $\mu$ Sv occupational
- mSv limitation



**Rolf Sievert**

- Air kerma and Absorbed dose / Gy (J/kg)

- nGy environmental
- $\mu$ Gy occupational
- mGy diagnostic
- Gy radiotherapy
- kGy product sterilization



**Hal Gray**

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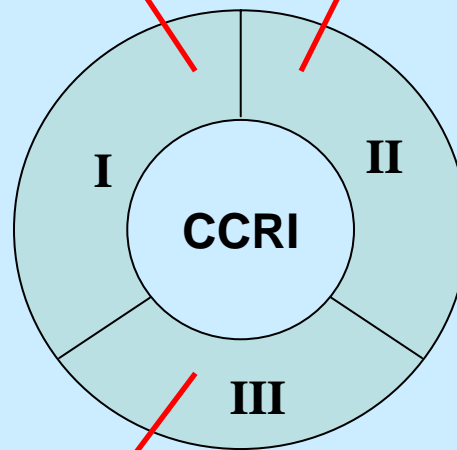
# Structure of the CCRI

## Dosimetry of x- and $\gamma$ -rays, charged particles

- 26 Members and Observers (3 international)
- 2 Working Groups

## Radionuclide metrology

- 25 Members and Observers (5 international)
- 6 Working Groups



Biennial meetings

## Neutron metrology

- 14 Members and Observers (3 international)
- 1 Working Group

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# Highlights (HL) of the past 4 years

1. Generic groupings table
2. Changes to international and national air kerma standards
3. Publication of key comparison results and CMCs
4. *Metrologia* special issues
5. *BIPM Monographies* 5, 6 and 7

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# HL1. Generic Groupings Table

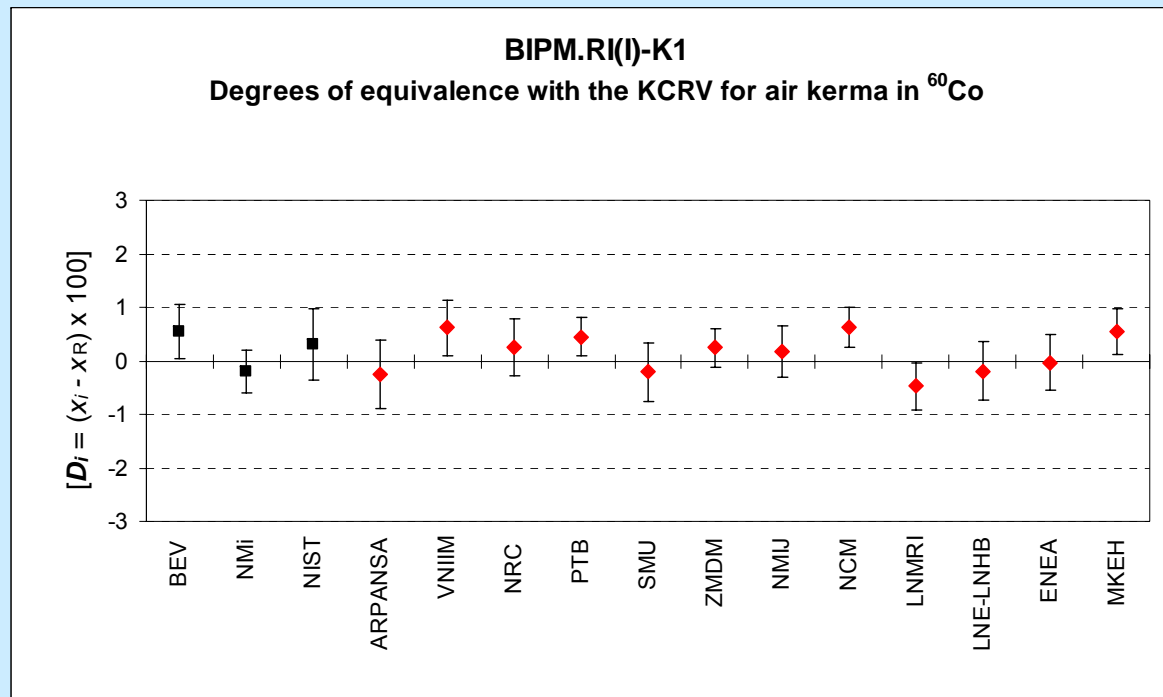
- Published on the CCRI web site
- Identifies 152 radionuclides by 17 generic measurement methods
- Colour-coded according to difficulty with estimated expanded uncertainties
- All radionuclides compared over a 10 year cycle

Nr	Nuclide	4P-BP/AP-PC/PP/LS-GR-NA/GH-CO/AC	4P-XR/AE-PC/PP/LS-GR-NA/GH-CO/AC	4P-AP-LS-00-00-HE	4P-XR/AE/PH-LS-00-00-CN/TD	4P-BP/AP/XR/AE-NA/CS-00-00-HE	4P-PH-NA-00-00-HE	4P-BP/AP-PP-00-00-HE	4P-XR/AE-PP-00-00-HE	SA-AP-PS-00-00-00	UA-BP-PC/PP/LS-GR-NA-CT/AT	4P-AP/BP/PH/AE/XR-LS-00-00-CN	4P-AP/BP/PH/AE/XR-LS-00-00-TD	4P-BP-PP-00-00-HE	4P-BP-PC-00-00-IG
1	H-3											1	1		1
2	Be-7		2						1			2	2		
3	C-11											2	2		
4	C-14										3	2	2		1
5	F-18	1						2				3	3		
6	Na-22		0.5		2		1					2	2		
7	Na-24	0.5					0.6	1				2	2		
8	Al-26	1.5										2	2		
9	P-32										1.5	1.5	1.5	1.5	
10	P-33										1.5	1.5	1.5	1.5	
11	S-35										3	2	2	3	
12	Cl-36										1.5	1	1	2	



# HL2. $^{60}\text{Co}$ air kerma standards

- Changes to international and national standards for **air kerma**
- Publication of key comparison results

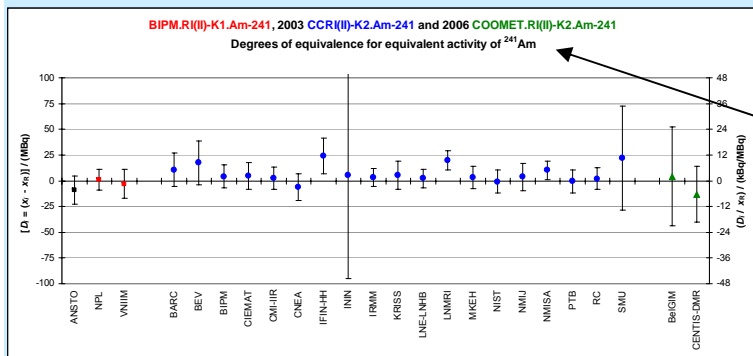


Black results = more than 10 years old – repeats scheduled

# HL3a. Key comparisons and CMCs\*

- 140 Key comparisons (26 RMO – Regional Metrology Organization)
- 29 Supplementary comparisons (8 CIPM)
- 46 Comparison reports published in last 4 years
- 3463 CMCs\*

## <sup>241</sup>Am activity linked comparisons



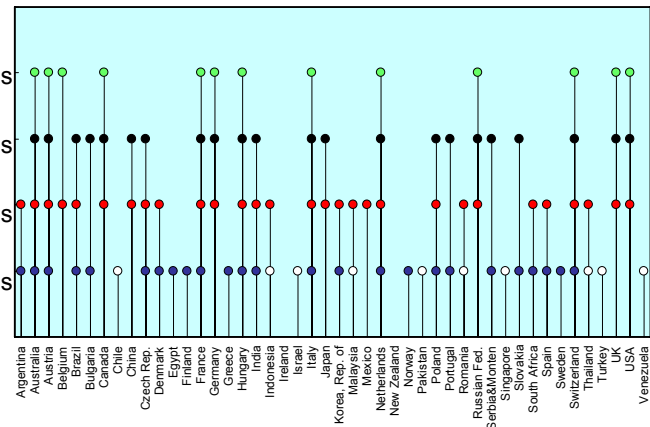
Absorbed dose comparisons

Air kerma comparisons

Activity comparisons

Dosimetry calibrations

## Member State involvement at the BIPM



○ : traceability to the BIPM established through calibrations made for the IAEA

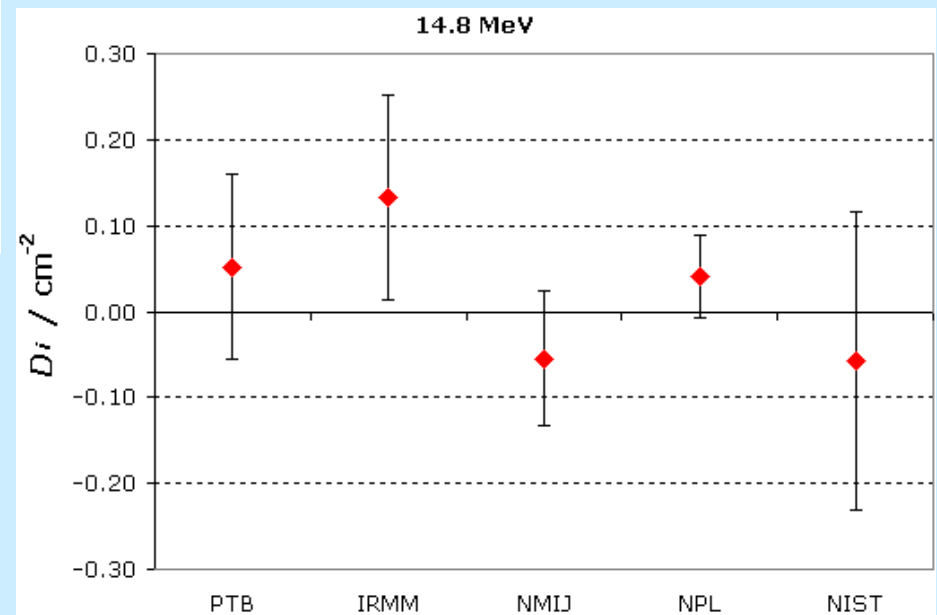
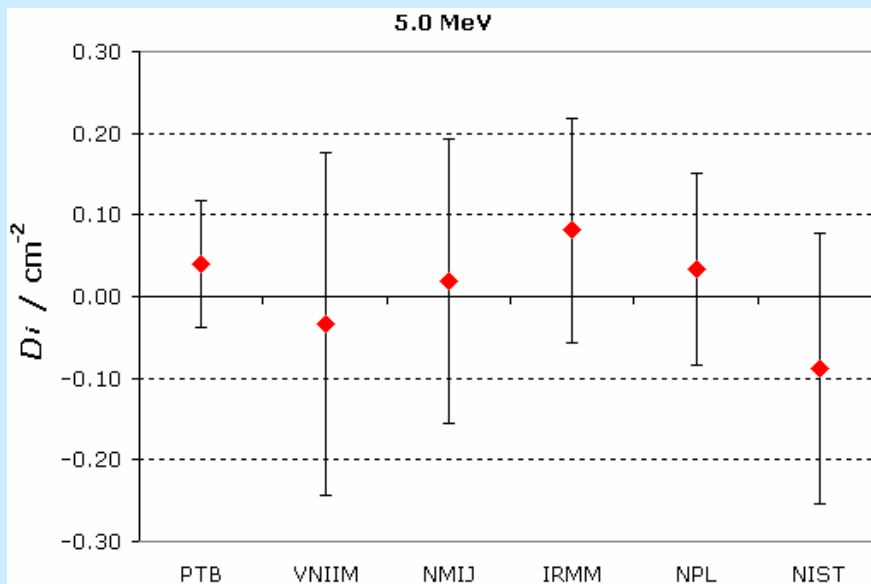
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\*Calibration and Measurement Capabilities

# HL3b. Key comparisons

- Neutron fluence comparisons 2001 published (Pilot PTB)

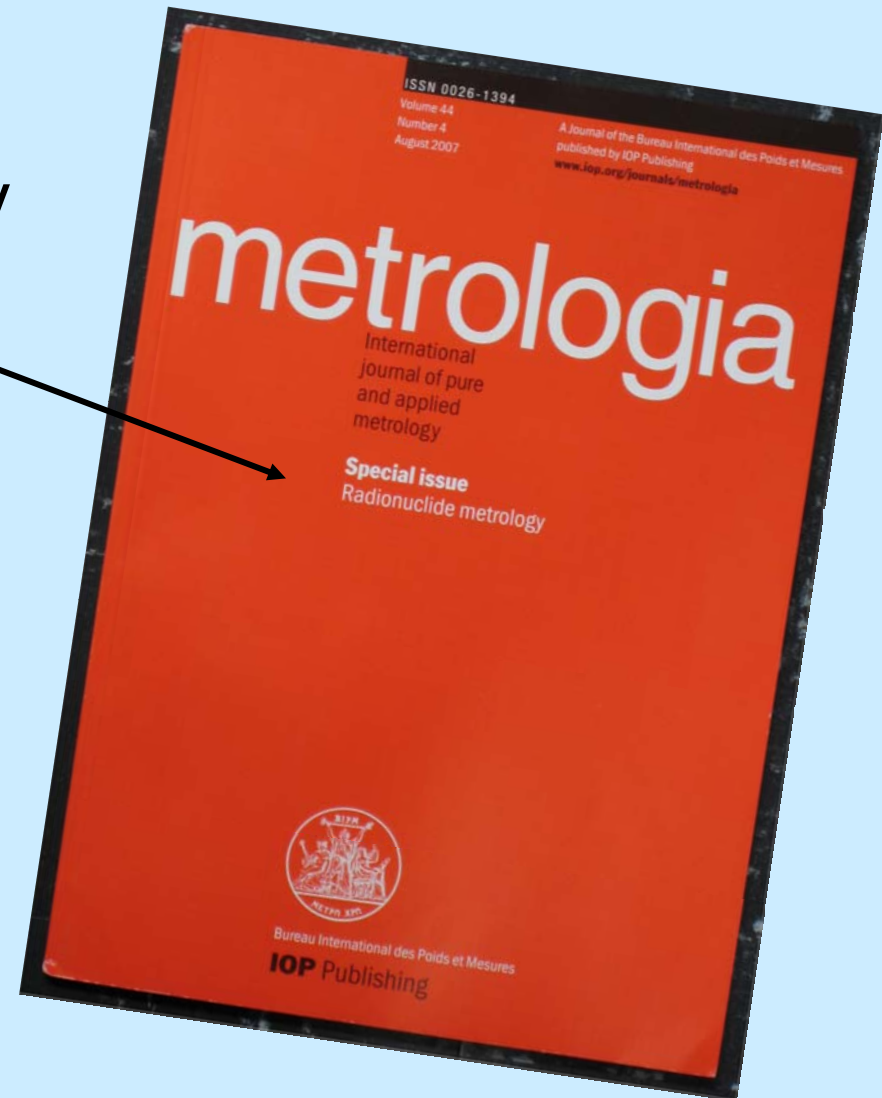


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# HL4. *Metrologia* special issues

- Radionuclide metrology  
2007 **44** N°4
- Radiation dosimetry  
(2008)
- Neutron metrology  
(2009)

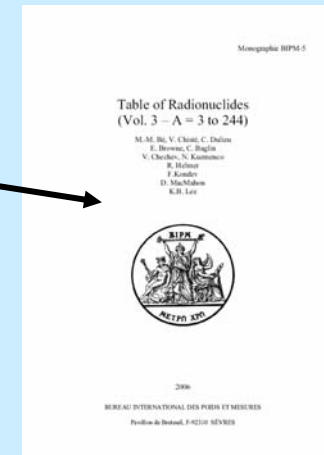


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# HL5(a). *BIPM Monographies*

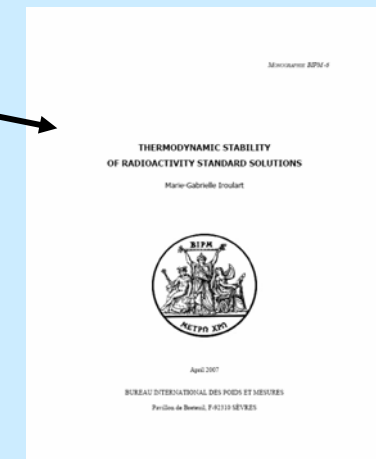
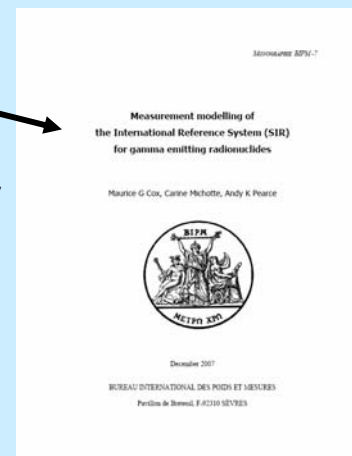
- Table of radionuclides  
N°5 in 3 volumes (2004,  
2006)



- Stability of solutions  
N°6 (2007)

- Modelling the SIR\*  
N°7 (2007)

- \* International Reference System for  
gamma emitting radionuclides



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# HL5(b). BIPM *Monographie 5*

- Lead laboratory LNE-LNHB
- Decay Data Evaluation Project
- Published in 3 volumes to date
- Full decay schemes and probabilities
- International input, including the IAEA
- Fully accessible electronically and updated
- Recommended for international consistency

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# Future work (FW) programme

1. High-energy photon and electron dosimetry
2. Proton dosimetry
3. Brachytherapy comparisons
4. Comparison of short-lived radionuclides
5. Mammography comparisons
6. Neutron metrology challenges

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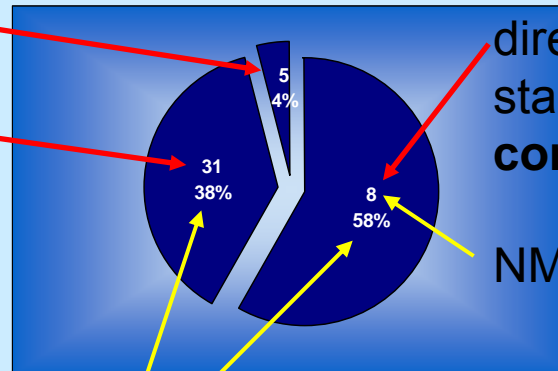
# FW1.(a) High-energy dosimetry for radiotherapy



- > 6092 clinical accelerators world-wide (DIRAC-IAEA)
  - 5877 in Member States
  - 111 in Associate States
  - 114 Rest of the World
- > 90 000 000 patient treatments per year using high-energy beams (beam quality  $Q$ )

## Member States traceability for high-energy absorbed dose

$^{60}\text{Co}$  comparisons or calibrations - **need direct ( $Q$ ) traceability to reduce uncertainty and mistakes**



direct ( $Q$ ) primary standards - **need comparisons**

NIMs



NRC Canada

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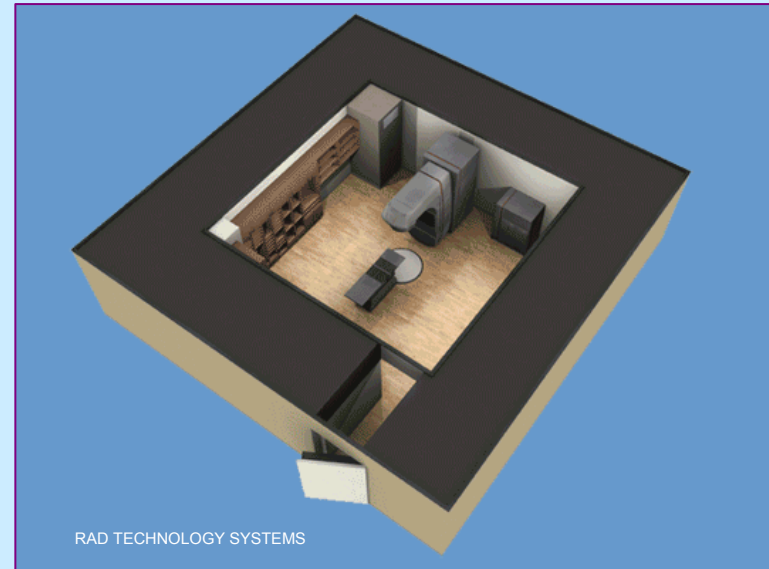
Clinical accelerators

# FW1.(b) High-energy dosimetry

- CCRI high-energy photon and electron dosimetry project for the BIPM
- CCRI Working Group on the linear accelerator project and high-energy dosimetry comparisons
- Freely available to all NMIs, for comparisons and calibrations at radiotherapy beam qualities  $Q$



**Proposed BIPM high-energy facility**



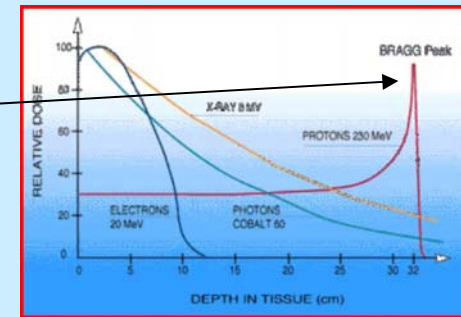
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**BIPM Primary standard  
graphite calorimeter**

# FW2. Proton Dosimetry

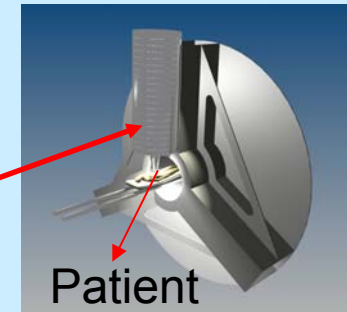
- Bragg peak – energy deposited at the tumour depth
- >15 clinical machines worldwide



MD Anderson Cancer Center, Texas

- Compact machines being developed e.g. dielectric wall accelerator

LLNL patent pending



- Calorimetry standards needed for dosimetry

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# FW3. Brachytherapy comparisons

- $^{192}\text{Ir}$  sources (e.g. breast cancer)
  - Transfer instruments to circulate to NMIs
- $^{125}\text{I}$  seeds (e.g.) prostate cancer
  - Seeds characterized and distributed to NMIs for measurement
- Needs a 6 month secondment to the BIPM

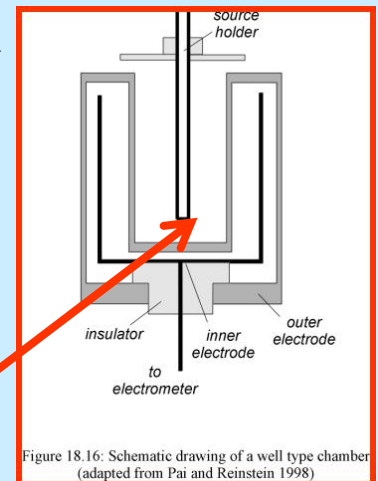


Figure 18.16: Schematic drawing of a well type chamber (adapted from Pai and Reinstein 1998)

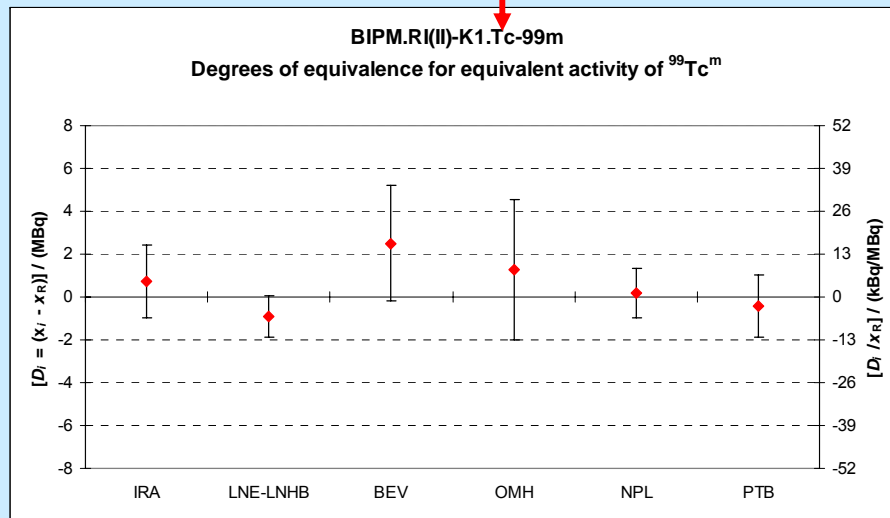
Brachytherapy  
source

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# FW4. Short-lived radionuclides

- Half-lives  $< 2$  d e.g.  $^{99}\text{Tc}^m$  (6 h)
- Measurements made at the distant NMI using the transfer instrument
- Linked to the SIR at the BIPM



N.B. need to extend to non-European NMIs



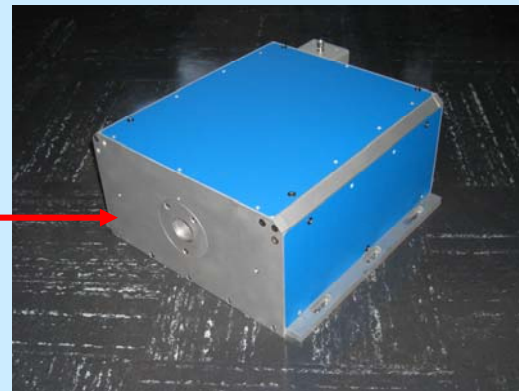
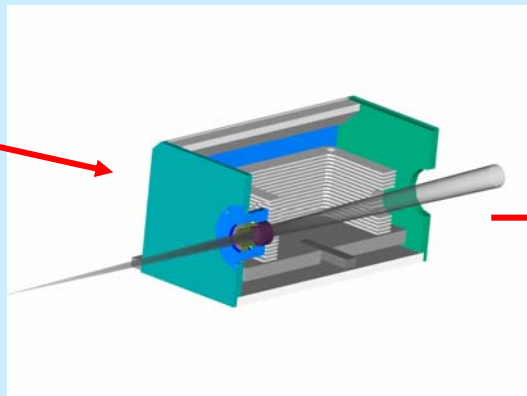
Portable SIR Transfer Instrument

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# FW5. Mammography comparisons

- Pilot studies (PTB and NMi) with transfer instruments 2006
- BIPM free-air chamber standard 2007
- Molybdenum target x-ray tube facility 2008
- BIPM ongoing comparisons to start 2008

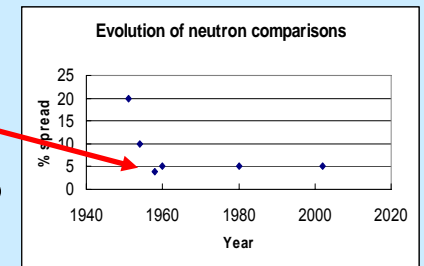


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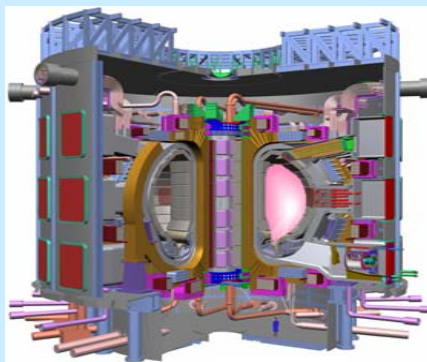
# FW6. Neutron metrology challenges

- Improvement in comparison results
- Radiotherapy with high-energy neutrons
- Characterization of work-place fields
- Laser based ion and neutron sources
- Developments in fusion technology

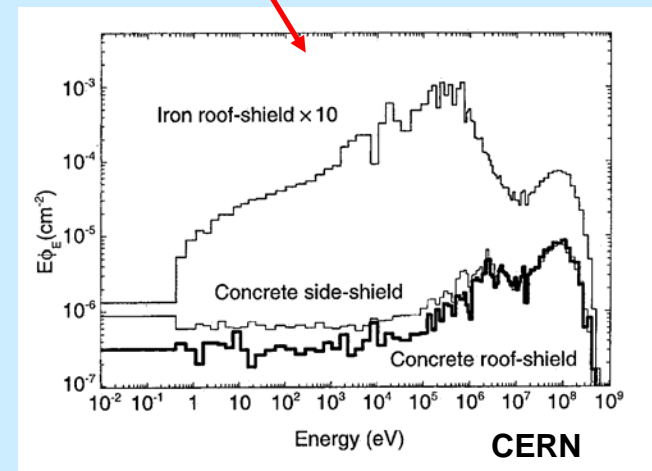


No improvement in spread for 40 years

ITER at Caderache, France



International Tokamak Experimental Reactor



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# 50 years of the CCRI

- The CCRI was created in 1958
- First meeting in Spring 1959
- 2009 will be 50th anniversary
- Celebration with
  - 3 *Metrologia* special issues
  - Seminars and Workshops
  - Historical review
  - Vision for the next 50 years

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# Thank-you for your kind attention

## The CCRI looks forward to your continued support

- Acknowledgements
  - The Chairmen of the CCRI Sections & WGs
  - The Executive Secretary of the CCRI
  - CCRI Members and Observers
  - The BIPM Director
  - The BIPM Staff, especially in  
Ionizing Radiation

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