



# **From the Boltzmann constant to industry – (some) EMRP supported projects from TC-T**

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# Introduction

- Some EMRP research projects from TC-T
- “Future proofing” the SI temperature unit
  - The Boltzmann constant [ $k$ ],
  - Implementing the new kelvin [ $\ln K$ ],
  - Novel dissemination methods [NOTED]
- Addressing challenges for industry and society
  - Industry (product quality, efficiency) [*HiTeMS*],
  - Energy security [eg Metrofission],
  - Meteorological measurements [Meteomet]

# Introduction

- Support SI unit the kelvin

Short term: New values of  $k$  for the unit redefinition (to 2018)

Medium term: background data and techniques for *MeP*-K (now to - early 2020s)

Long term: new scale and primary thermometry implementation (mid-late 2020s)

# Introduction

- Support SI unit the kelvin

Short term: New values of  $k$   
for the unit redefinition

Medium term: background  
data and techniques for  
*MeP-K*

Long term: new scale and  
primary thermometry  
implementation

- Essential to ensure

Reliable realisation +  
dissemination of the  
kelvin into the future

Support the needs of  
wide user base in  
industry, power  
generation, health,  
meteorology, research

# **“Future proofing” the SI unit the kelvin**

**The Boltzmann constant**  
**Implementing the new kelvin**

# The iMERAPlus joint research project: Determination of the Boltzmann constant for the redefinition of the kelvin



## Partners:

Physikalisch-Technische  
Bundesanstalt



Danish Fundamental  
Metrology



## Collaborators:

Universidad de Valladolid

UVa

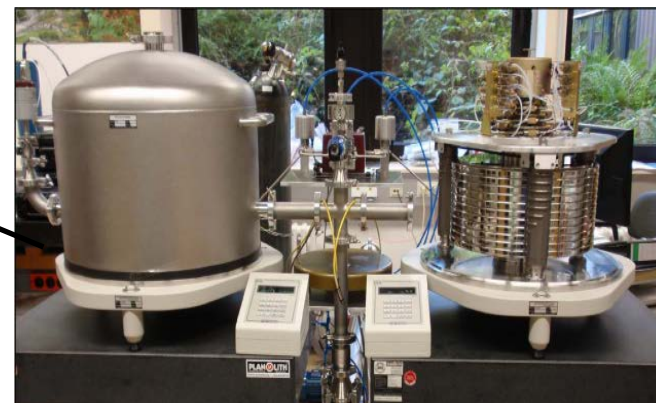


# Different multidisciplinary scientific approaches...

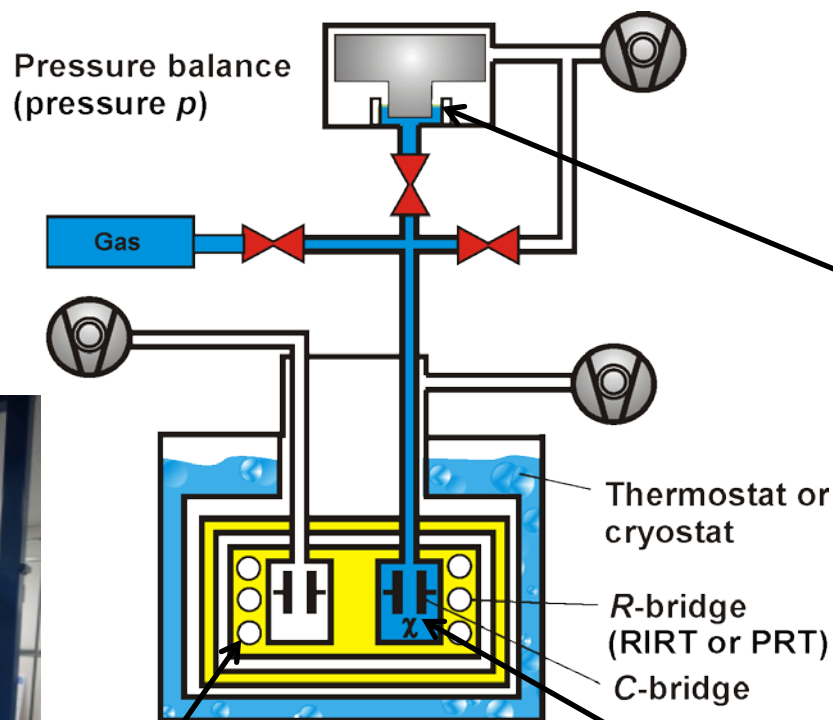
| Work Package                        | Partners<br>(WP Leader in Bold)                                                        |
|-------------------------------------|----------------------------------------------------------------------------------------|
| Dielectric Constant Gas Thermometry | <b>PTB</b> , INRiM                                                                     |
| Acoustic Gas Thermometry            | <b>INRiM</b> , CEM + Univ. Valladolid, IRMM, LNE-INM/CNAM, NPL                         |
| Doppler Broadening Thermometry      | <b>LNE-INM/CNAM</b> + Univ. Paris North, DFM, INRiM + Univ. Naples & Polytechnic Milan |

# Dielectric constant gas thermometry

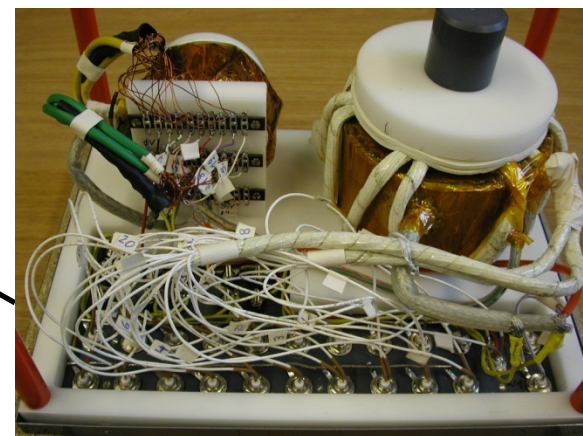
**Pressure (with balances)**



**Temperature**

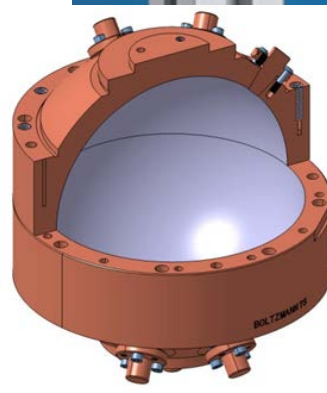
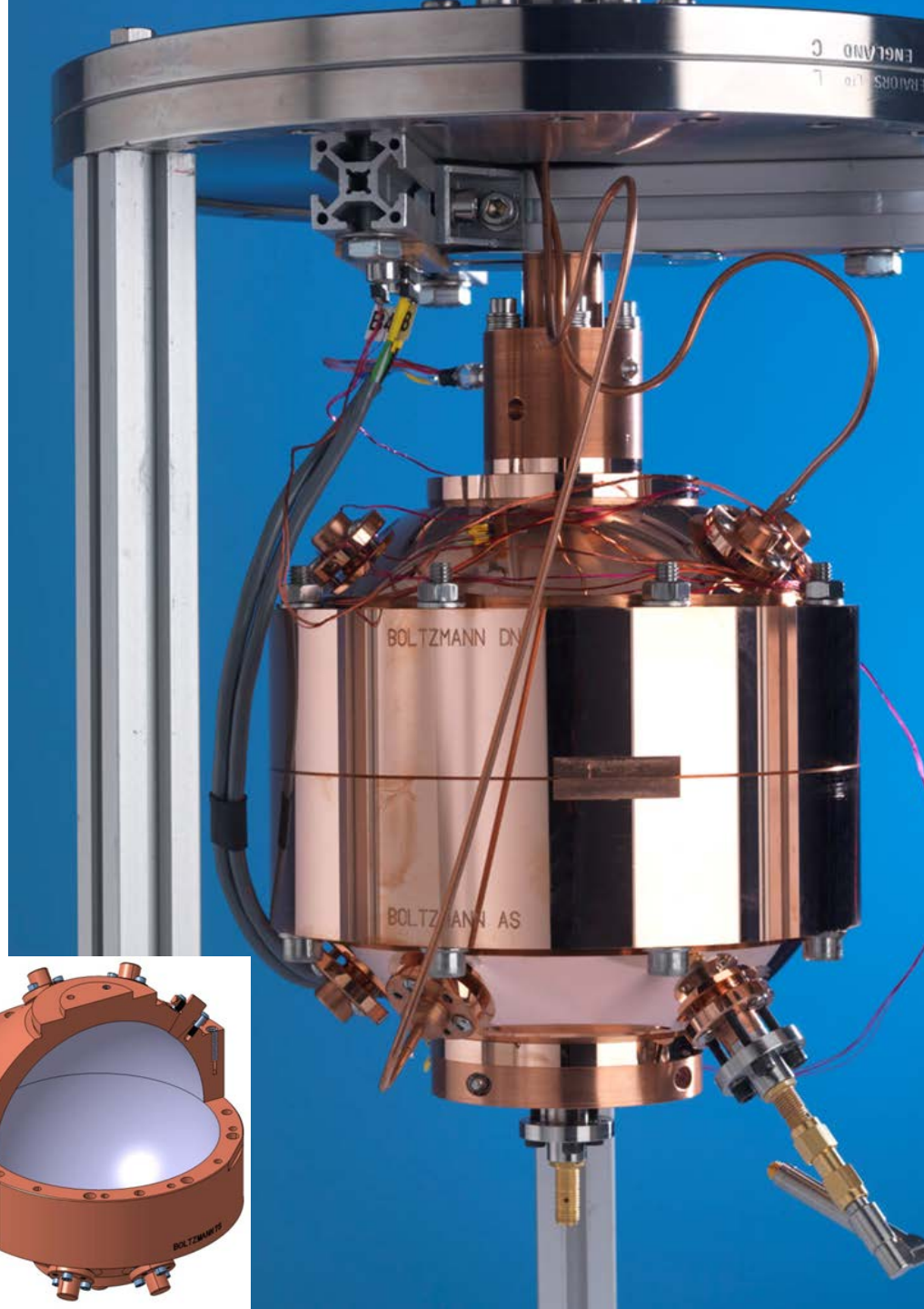


**Capacitance ratio**



# Acoustic gas thermometry

- NPL diamond turned copper quasi-sphere
- Speed of sound in argon gas [isotopes to <1ppm]
- Average radius to <1ppm



# Acoustic gas thermometry

Three independent methods to get average radius

**Microwaves**

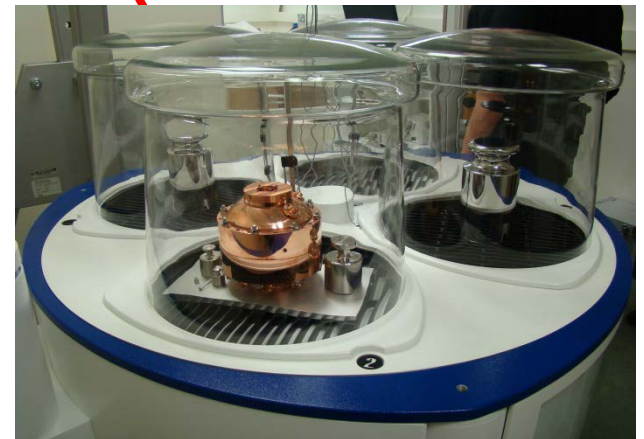


**Coordinate measuring machines**

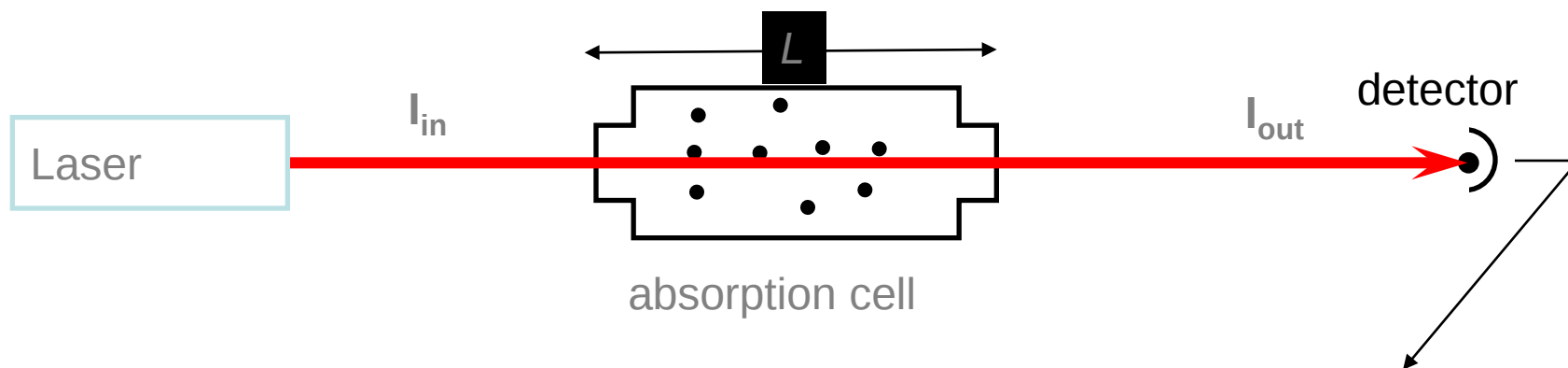


Use two independent methods to confirm microwave approach

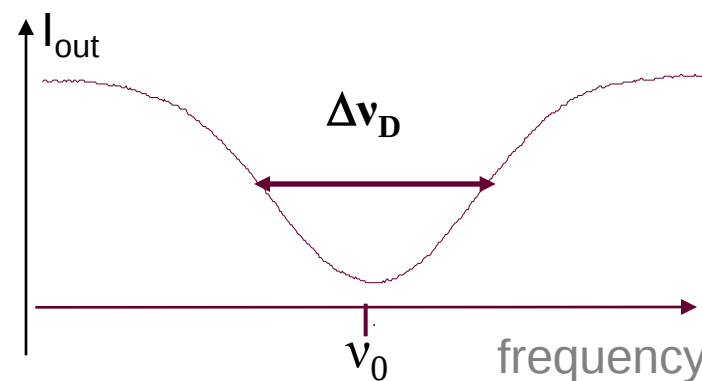
**Pyknometry**



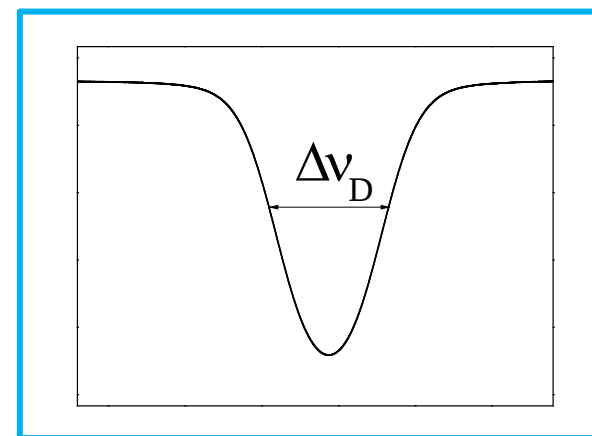
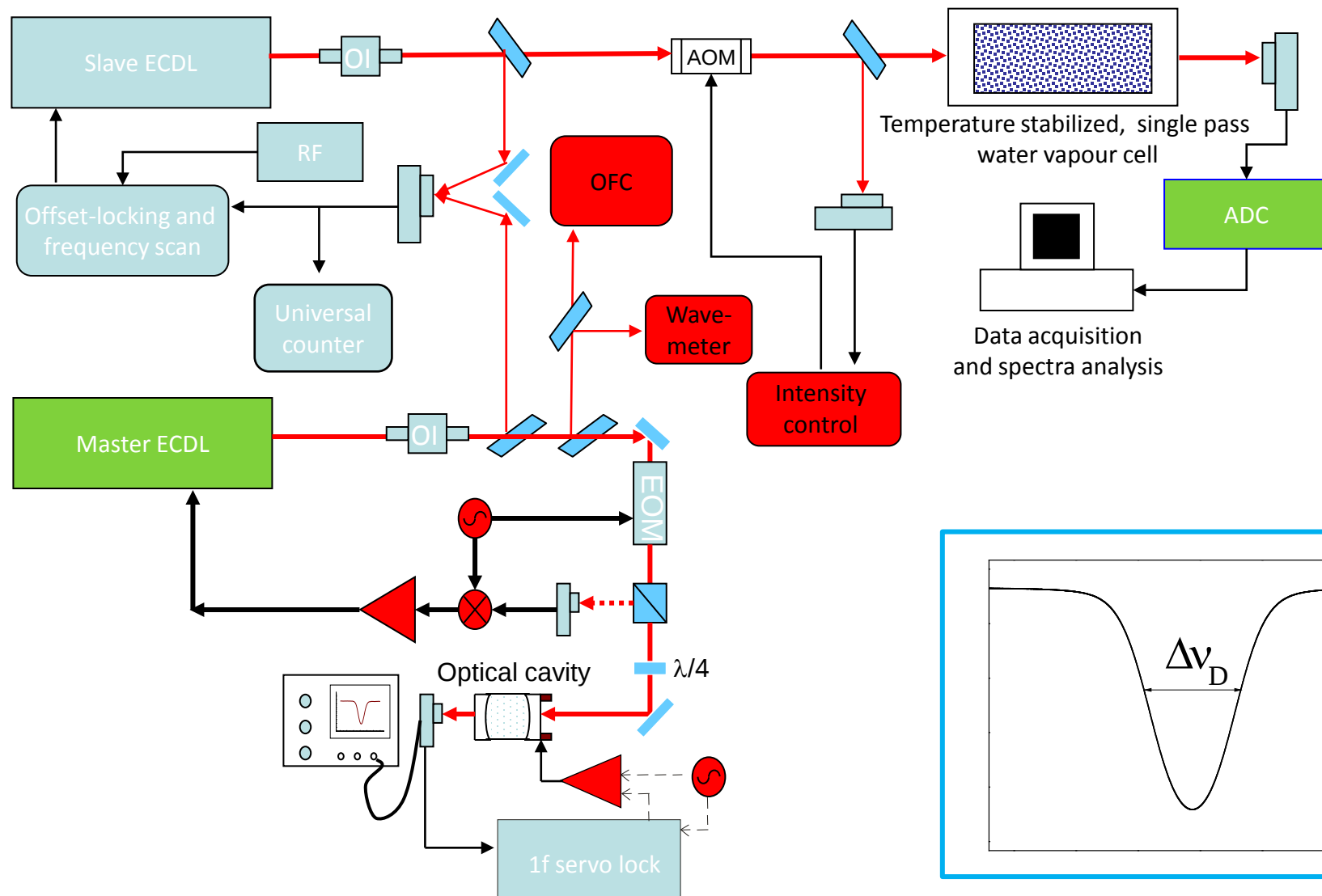
# Doppler broadening thermometry



Spectral line width depends on temperature  
Very complex laser optics required!



# Doppler broadening thermometry



# Impact

- Of 12 experiments around world to measure  $k$ , 8 of them within Euramet
- Euramet will make dominant contribution to the final CODATA revaluation of  $k$  before the unit redefinition

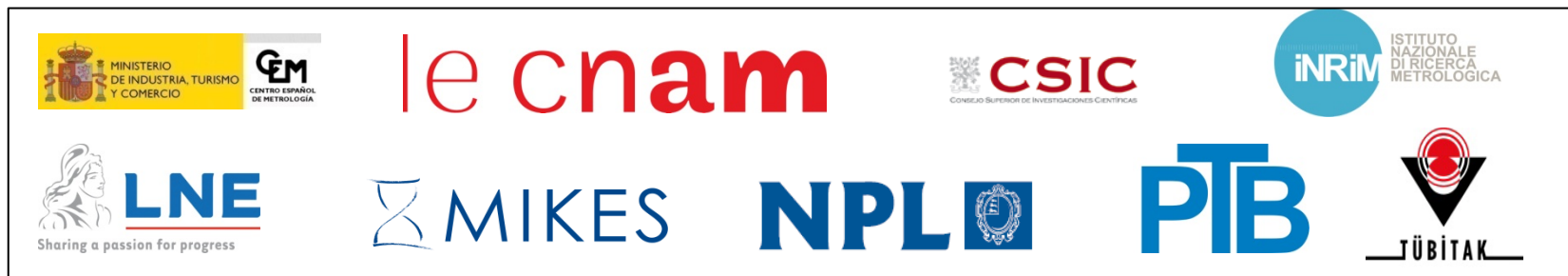
# Implementing the new kelvin: InK

**In recent mid-term review the InK was rated  
technology position – dominant  
impact – high**

# Partners/Collaborators/REGs



## ■ Funded Partners



## ■ Unfunded Partners



## ■ Integral REG

## Collaborators

## REG3



# Partners/Collaborators/REGs

## ■ Funded Partners



## ■ Unfunded Partners



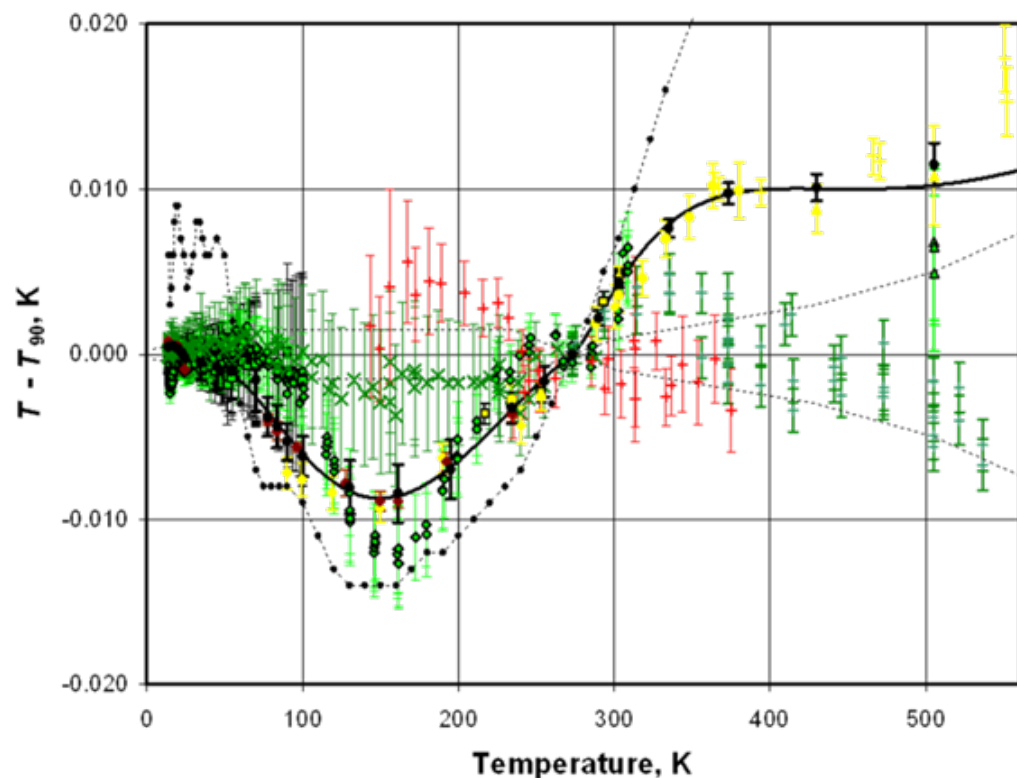
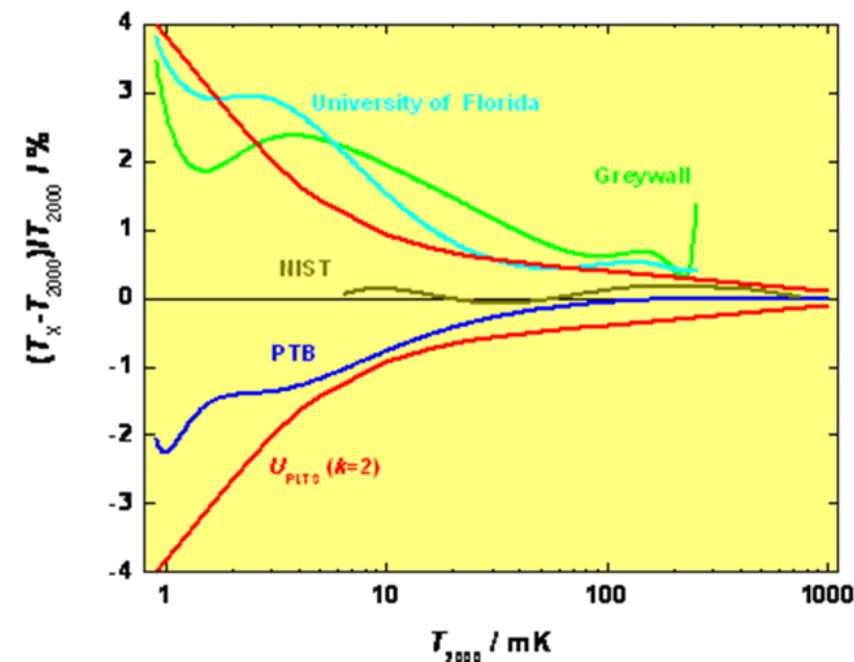
## ■ Integral REGs      Collaborators      REG3



# InK – overview

- Runs from Oct 12-Sep 15
- Demonstrate feasibility of **a direct implementation of the new kelvin** without recourse to a defined scale
  - Develop/demonstrate primary thermometry methods that could challenge/supplant the defined scales at high ( $>1300$  K) and low ( $<1$  K) temperatures
- Step change improvement in primary thermometry methods 0.9 mK to 3000 K

# The two temperature scales ITS-90, PLTS-2000



# InK scientific impact

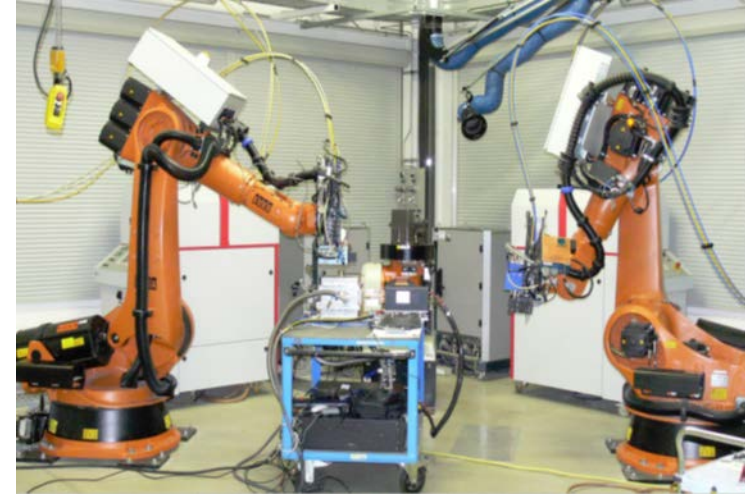
- International Scientific Meeting workshop at the Royal Society Kavli Centre on 18-19 May 2015 with InK special edition of *Phil Trans*
- Numerous recommendations to CCT
- Annual progress reports to CCT, EURAMET TC-T and other RMO thermometry technical committees
- **FIRST MAJOR STEP TOWARDS FULL IMPLEMENTATION OF *MeP*-K AND THE NEXT TEMPERATURE SCALE**

# Summary

- EMRP is creating a European based world leading Centre of Excellence in SI focused thermometry
- This research will ensure that a framework is in place for long term reliable realisation and dissemination of the SI unit the kelvin
- The Euramet leadership position will grow with strategic fundamental SI thermometry projects within EMPiR

# And finally

- EMRP has enabled the creation of a European led world leading Centre of Excellence in SI focused thermometry
- *Ensures framework is in place for long term reliable realisation and dissemination of the SI unit the kelvin*
- This leadership position will grow with strategic fundamental SI projects within EMPIR
- Improvements driven by these high level projects has impacted on a broad front on temperature measurement in industry, power generation, meteorology....



- Improvements driven by these high level projects has lead to impact on a broad front in practical temperature measurement in industry, power generation, meteorology....
- But that's a story for another day.....

