



UNIVERSITÀ  
DEGLI STUDI  
DI PADOVA

**"Application of CT Scanning in Industry" Conference**  
Danish Technological Institute, Taastrup, 31<sup>st</sup> May 2011

**International round robin on dimensional computed tomography:**  
Preliminary results of the "CT Audit" project

**CT Audit**

**Simone CARMIGNATO**  
University of Padova – DTG  
Laboratory of Industrial and Geometrical Metrology

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### Contents of presentation

- The 'CT Audit' Project
- Participants
- Test objects and procedures
- Comparison results
- Conclusions



University of Padova  
Simone CARMIGNATO  
International round robin on dimensional computed tomography  
Taastrup, 31 May 2011  
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### Introduction / Motivations



- **CT systems are increasingly used** in dimensional metrology because of their many advantages
- However, CT measuring systems are affected by additional **traceability problems** with respect to traditional CMMs
- Lack of standardization implies difficulties in **testing and comparison of actual metrological performances**

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## The 'CT Audit' project

'CT Audit' is the first international round robin on Computed Tomography (CT) systems for dimensional metrology. The project is organized by Laboratory of Industrial and Geometrical Metrology, University of Padova, Italy.

The CT Audit project is organized in the following phases:

Project phases	2009			2010												2011					
	9	10	11	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3	4	5	6
Plan, Participants definition	█	█	█																		
Reference items calibration																					
Circulation																					
Analysis of results																					
Reporting and dissemination																					

\*Final CT Audit Workshop in October 2011, in Padova

The coordinator keeps the Participants' results **confidential** and ensures that each Participant can only identify its own anonymous results in the final report.

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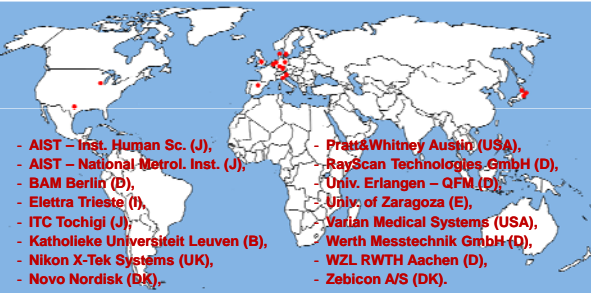
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## Participants

CT Audit involves 16 CT systems world wide, from important institutions and companies in Europe, America and Asia.



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


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## Calibrated items

Four calibrated objects are used for circulation:

-  Item 1: "CT Tetrahedron", provided by University of Padova, Italy.
-  Item 2: "Pan Flute Gauge", provided by University of Padova, Italy.
-  Item 3: "Calotte Cube", provided by Physikalisch-Technische Bundesanstalt, Germany.
-  Item 4: "QFM Cylinder", provided by QFM – University Erlangen-Nuremberg, Germany.

The four calibrated objects are sent to the Participants during the circulation together with detailed **measurement procedures**.

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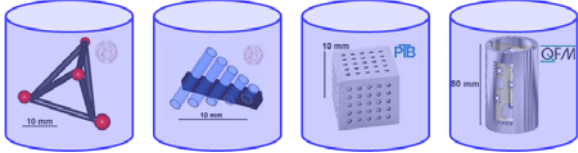
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## Sealed containers

- Items are protected in **thin plastic sealed boxes**, for:
  - reducing the risk of damages,
  - limiting contamination
  - avoiding measurements with other sensors.




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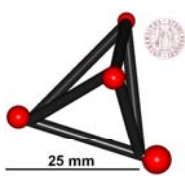
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## Item Nr. 1

### Item Nr. 1: "CT Tetrahedron"



4 calibrated ruby spheres  
on a carbon fibre frame.  
 $\varnothing_{\text{spheres}} = 3 - 5 \text{ mm}$

Item developed by  
University of Padova.

#### Required measuring tasks:

- Diameters of spheres
- Form error of spheres
- Distances between centers of spheres

**Dimensional stability:** dimensional variations are within the calibration uncertainty (demonstrated through repeated CMM calibrations before and after the circulation)

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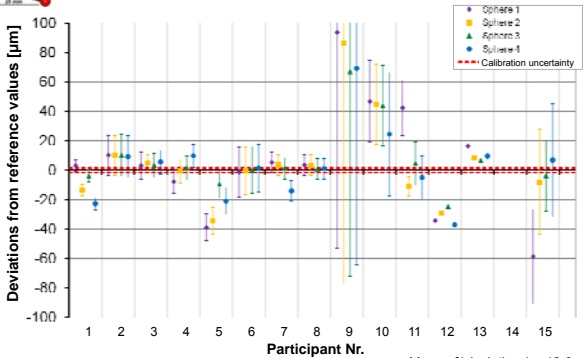
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## Diameters of spheres




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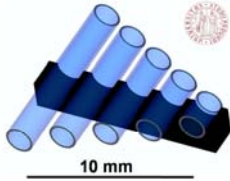
### Item Nr. 2

#### Item Nr. 2: "Pan Flute Gauge"

Top view:



Side view:



5 calibrated glass tubes on a carbon fibre frame.

- $\varnothing_{inner} = 1.5 \text{ mm}$
- $\varnothing_{outer} = 1.9 \text{ mm}$
- $L = 2.5 - 12.5 \text{ mm}$

Item developed by University of Padua.

#### Required measuring tasks:

- Inner diameters
- Outer diameters
- Lengths

**Dimensional stability:** dimensional variations are within the calibration uncertainty (demonstrated through repeated CMM calibrations before and after the circulation)

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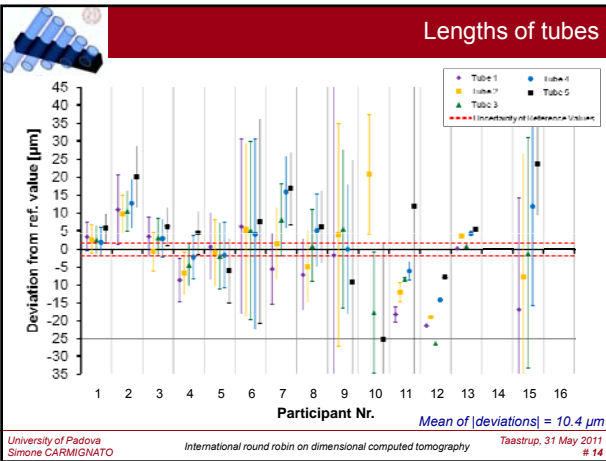
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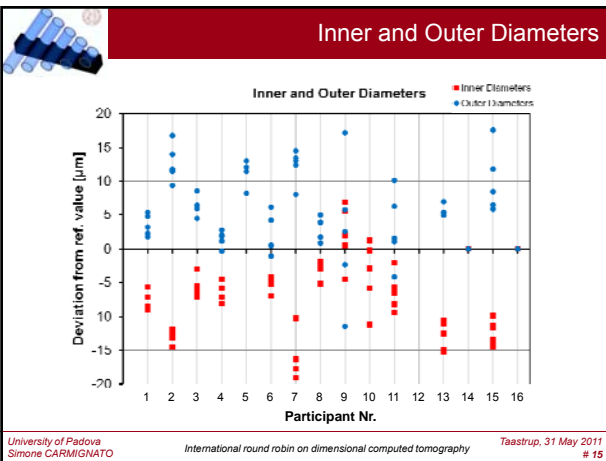
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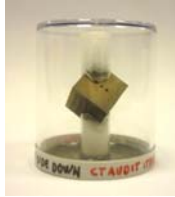
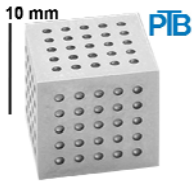
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### Item Nr. 3

#### Item Nr. 3: "Calotte cube"



75 spherical calottes on three sides of a titanium hollow cube.

- Cube side = 10 mm
- $\varnothing_{\text{spheres}} = 0.8 \text{ mm}$

Item developed by PTB, Germany.

#### Required measuring tasks:

- Diameters
- Form errors
- Coordinates of centres
- Distances between centres

**Dimensional stability:** dimensional variations are within the calibration uncertainty (demonstrated through repeated CMM calibrations before and after the circulation)

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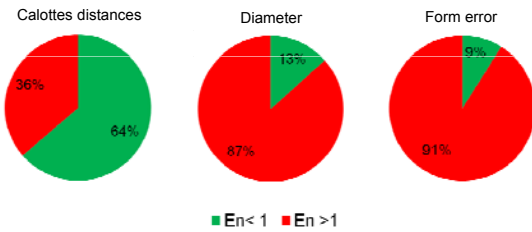
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### $E_N$ values

$$E_N = \frac{|Value(lab) - Value(ref)|}{\sqrt{U(lab)^2 + U(ref)^2}}$$

$E_N$  values for CT measurements of **Calottes distances**, **Diameters** and **Form errors**:




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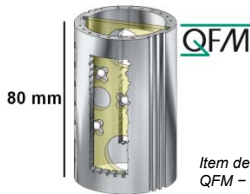
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### Item Nr. 4

#### Item Nr. 4: "QFM Cylinder"



Titanium cylinder with several geometrical features and a ball plate with five sapphire balls.

- Cylinder length = 80 mm
- Outer diam. = 50 mm

Item developed by QFM - University Erlangen-Nuremberg, Germany.

#### Required measuring tasks:

- outer and inner diameter of the titanium cylinder
- diameters of calotte spheres embodied on top and bottom faces of the cylinder
- spheres distances of the ball plate
- diameter of smallest measurable cylindrical micro structure

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## Conclusions and expected results

- The first international intercomparison of CT dimensional measuring systems was running from March 2010 to March 2011.
- Four calibrated standards:
  - Item 1: CT Tetrahedron
  - Item 2: Pan Flute Gauge
  - Item 3: Calotte cube
  - Item 4: QFM Cylinder
- Main results:
  - Quantification of typical errors in CT metrology
  - Identification of main error sources (Threshold, Scale, Beam-hardening, ...)
  - Evaluation of Participants' uncertainty calculation methods
  - Contribution to standardization of testing procedures
  - Establishment of an international network of laboratories using CT systems for dimensional metrology




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E-mail: [simone.carmignato@unipd.it](mailto:simone.carmignato@unipd.it)

**Thank you for your attention!**

**CT Audit**

CT-Audit project website:

[www.gest.unipd.it/ct-audit](http://www.gest.unipd.it/ct-audit)

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