



# CERN METROLOGY LABORATORY

## CAD DESIGN REQUIREMENTS APPLIED TO METROLOGY AT CERN

CATIA FORUM #27

Ahmed CHERIF  
21<sup>st</sup> September 2017

# CERN Metrology laboratory



CERN EN-MME-MM

Ahmed CHERIF



# METROLOGY PEOPLE



EN ENGINEERING DEPARTMENT

STAFF



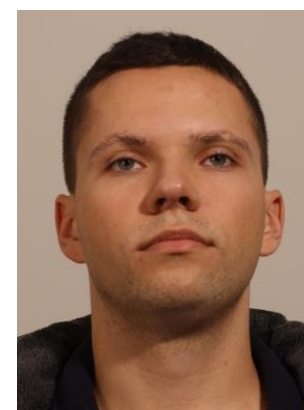
Didier



Dominique



Ahmed



Bartosz  
VIA

FELLOW - VIA

INDUSTRIAL  
CONTRAT S193



Jean-Philippe



Patrice



Cyril



Claude  
PACMAN PhD



# CERN MEASUREMENT LABORATORY

## Mandate



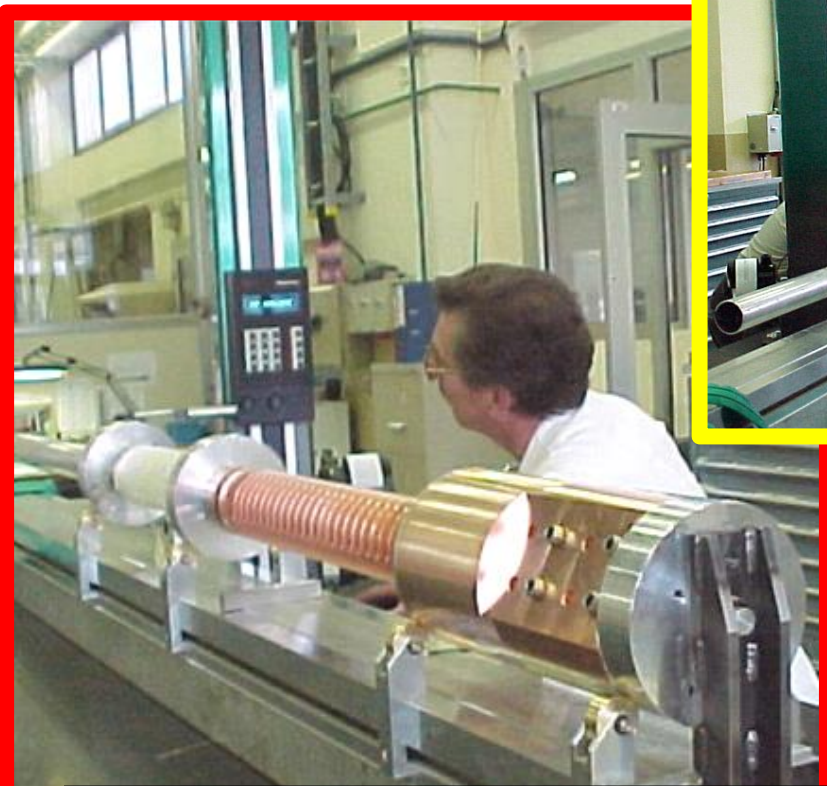
- Conformity measurements
- Measurements and tests (R&D)
- Items adjustment in defined positions
- Calibration measurement
- Gages measurements
- Give to customer and subcontractors technical support (tools, measurements, ISO standards, drawings)



# METROLOGY EQUIPMENT



EN/M&M ENGINEERING DEPARTMENT



**CURRENT LEADS 13 kA**  
**Straightness and Perpendicularity**



**CMS CRISTAL SAMPLE**  
**Flatness and parallelism**

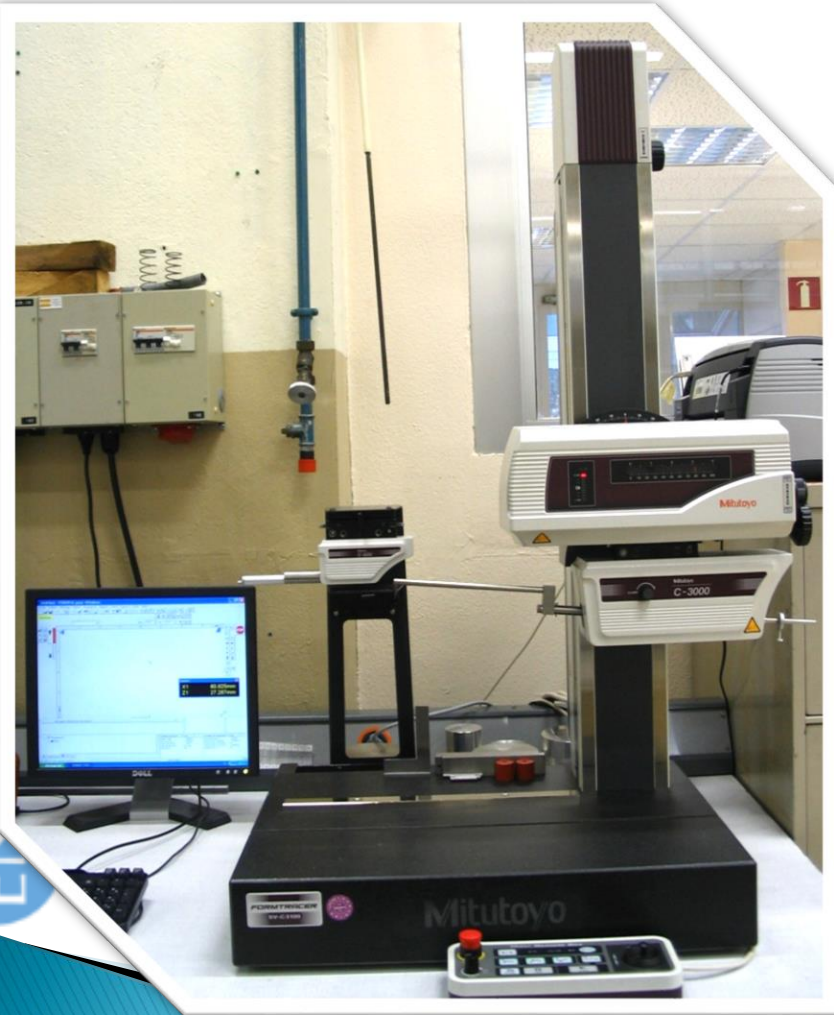




# METROLOGY EQUIPMENT



ENI ENGINEERING DEPARTMENT



profile



Roughness



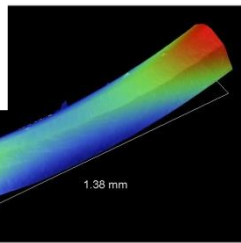


# METROLOGY EQUIPMENT



## Roughness

**CLIC**



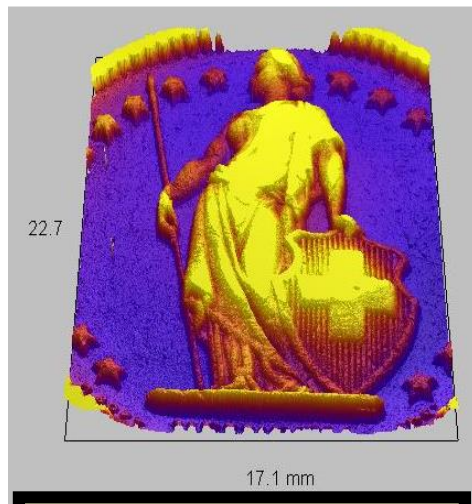
**Veeco 3-Dimensional Interactive Display**

Date: 09/26/2005  
Time: 16:45:32

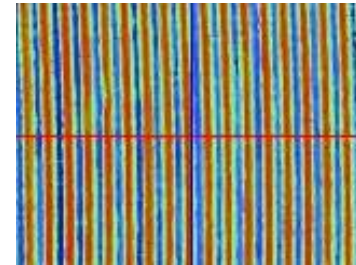
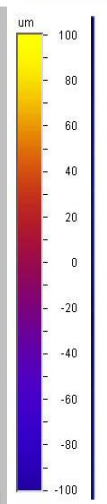
Surface Stats:  
Ra: 0.974 um  
Rq: 274.34 um  
Rz: 2.64 um

Measurement Info:  
Magnification: 2.56  
Measurement Mode: VSI  
Sampling: 3.28 um  
Array Size: 1728 X 1402

Title:  
Note:



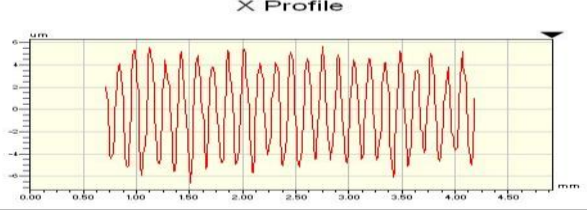
**2 CHF coin**



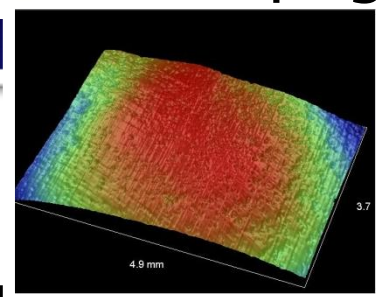
Pc Height: 0.0  
Sample Lengths: 5  
X Asmt#: 3.467 mm  
X Lines Used: 478

**X Average Stats:**

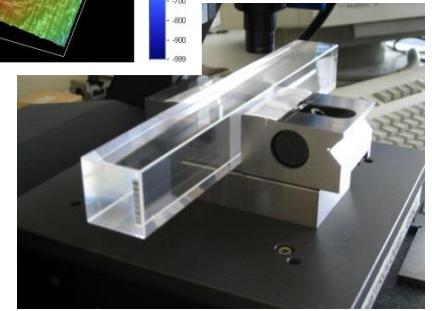
| Mean:           | Std Dev: |
|-----------------|----------|
| Rq: 3.967 um    | 0.052 um |
| Ra: 3.010 um    | 0.049 um |
| Rt: 12.074 um   | 0.401 um |
| Rp: 5.862 um    | 0.165 um |
| Rv: -6.361 um   | 0.263 um |
| Rsk: -0.037     | 0.032    |
| Rku: 1.928      | 0.027    |
| Rz: 10.913 um   | 0.218 um |
| Rmax: 11.883 um | 0.384 um |
| Rpm: 5.365 um   | 0.124 um |
| Rvm: -6.527 um  | 0.178 um |



## Topography

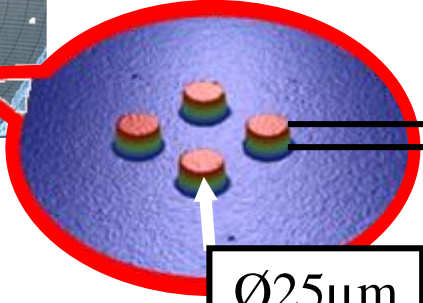
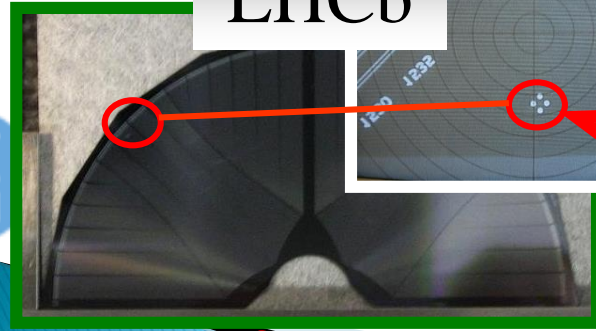


**CMS**



**LHCb**

**200x**



**Ø25µm**

**5µm**

**8 cm**



# METROLOGY EQUIPMENT

## CMM

ENI ENGINEERING DEPARTMENT



**FERRANTI**

**750x500x500mm**  
 $MPE_E: 3+L/300$



**LEITZ**

**PMM-C infinity**

**High accuracy**  
**1200x1000x700mm**  
 $MPE_E: 0.3+L/1000$



**ZEISS**

**Prismo ULTRA**

**2400x1200x1000mm**  
 $MPE_E: 1.2+L/500$



**OLIVETTI 4 AXIS**

**1600x900x600mm**  
 $MPE_E: 4+L/300$



**ZEISS**

**O-INSPECT 863**

**800x600x300mm**  
 $MPE_E: 2.2+L/150$



# CLIC DISKS TOLERANCES

Technical drawing showing CLIC disks with various views and annotations. Key features include:

- Dimensions:  $\text{Ø}66 \pm 0.1$ ,  $\text{Ø}25 \pm 0.1$ ,  $\text{Ø}38 \pm 0.1$ ,  $0.9 \pm 0.0025$ ,  $0.2 \pm 0.0025$ ,  $0.03 \pm 0.02$ .
- Surface finish:  $Ra0.025$ .
- Tolerance zones:  $0.002$ ,  $0.005 \text{ A B}$ ,  $0.003 \text{ B}$ ,  $0.005 \text{ A B}$ .
- Surface texture: SURFACE ELLIPTIQUE.
- Scale: 10:1 (Detail C), 20:1 (Detail B).
- Material: CLADS120001.
- Other features:  $R0.5$ ,  $0.2 \times 45^\circ$ , SHARP EDGE,  $1.2 \pm 0.1$ ,  $D \pm 0.2$ ,  $D \text{ 4:1}$ .

Release information:

RELEASE OR  
 WORKS OF ANY  
 KIND INSIDE

Material: CLADS120001

Surface finish:  $Ra0.8$  (✓)

Revision table:

|      |            |           |      |                     |
|------|------------|-----------|------|---------------------|
| IND. | DATE       | MOD/NOME  | ZDNE | MODIFICATION        |
| A    | 2008-06-20 | D. GUCKOV |      | tolerances changing |

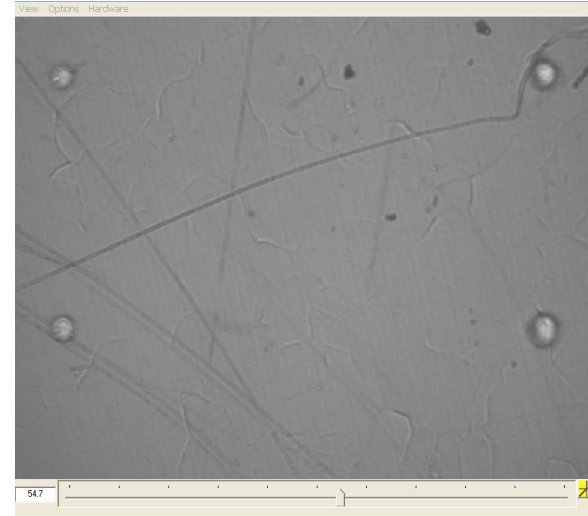
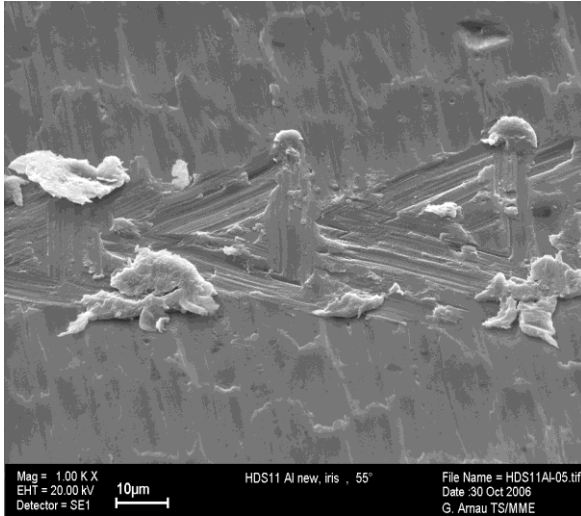
Part number: 0124 2 A



# Probing = marks on the parts



EN ENGINEERING DEPARTMENT



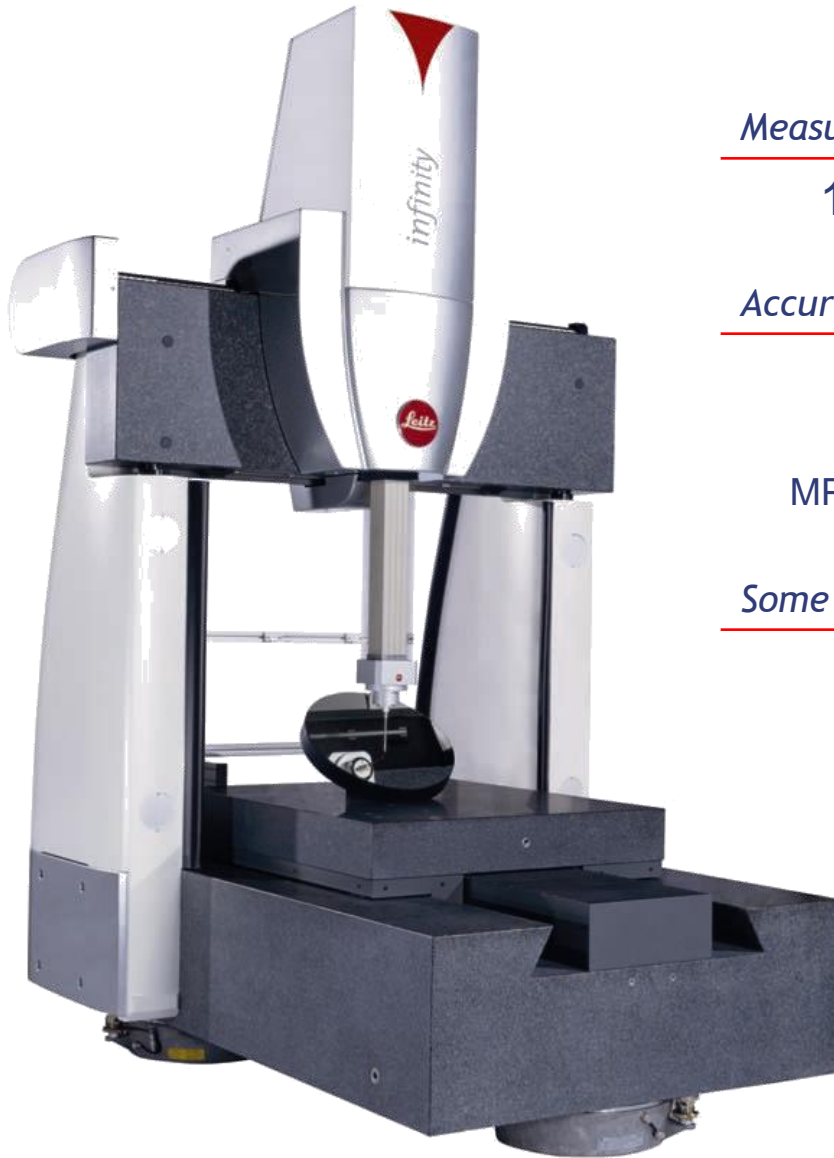


# Leitz PMM-C Infinity



EN ENGINEERING DEPARTMENT

EN



## *Measuring Range*

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10.12.7 1200 x 1000 x 700 mm<sup>3</sup>

## *Accuracy (according to ISO 10360)*

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MPE E **0.3 + L/1000** μm

MPE P **0.4** μm

MPE THP 1.2 μm / 59s

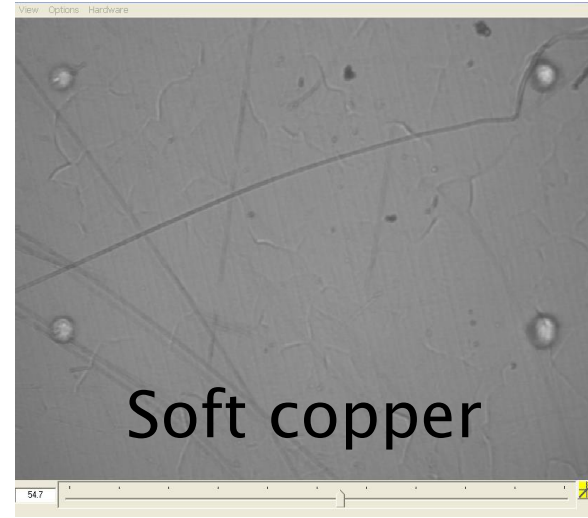
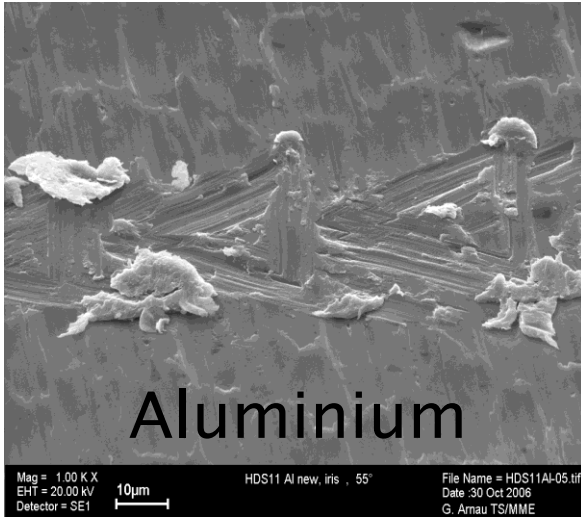
## *Some References*

---

- ▶ Modus, USA
- ▶ Sandia, USA
- ▶ Nano Precision Products, USA
- ▶ Bosch, Germany



# Probing = marks on the parts



## Same scale and area



## Soft copper



# Needed environment

## Measuring room specifications :

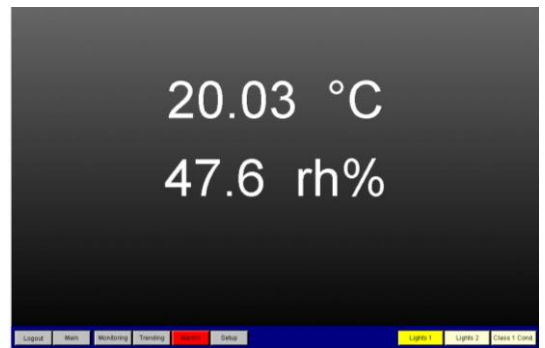
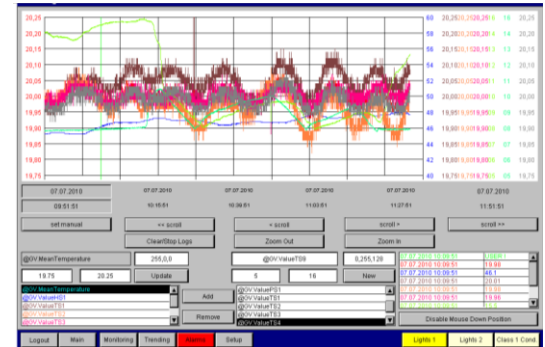
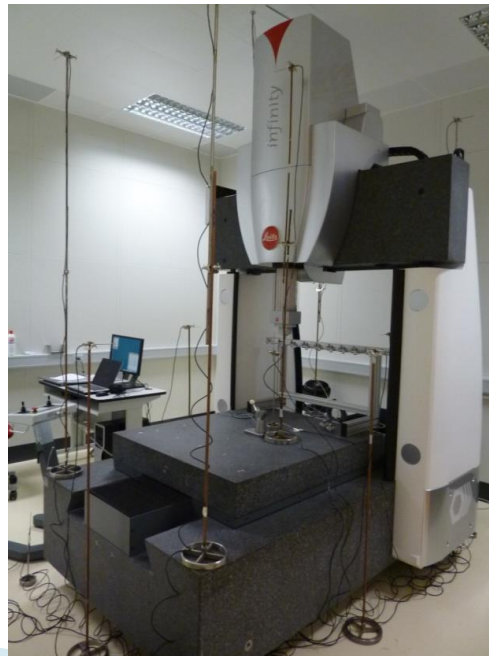
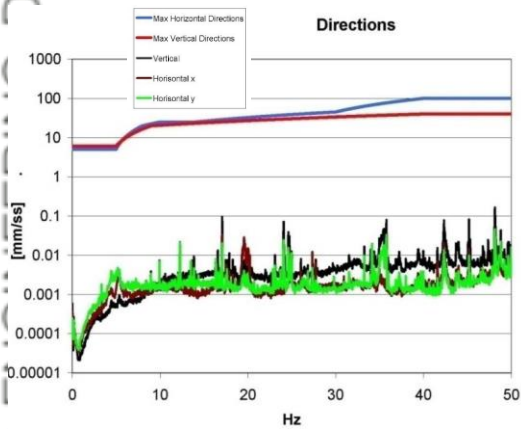
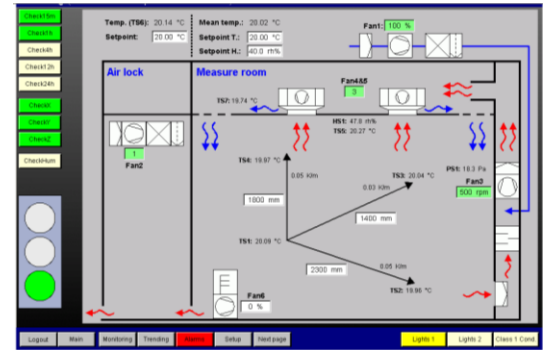


# Class 1

Reference temperature :  
**20 °C** according to VDE/VDI  
2627 standard

Temperature gradients:

- 0.2 K / Hour
- 0.4 K / Day
- 0.1 K / Meter





# Work environment

## MEASURING ROOM

## AIR LOCK



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# ZEISS PRISMO Ultra



ENGINEERING DEPARTMENT

EN



## Measuring Range

24.12.10 2400 x 1200 x 1000 mm<sup>3</sup>

**Dec. 2017 : 18.12.10 1800 x 1200 x 1000 mm<sup>3</sup>**

## Accuracy (according to ISO 10360)

MPE E **1.2 + L/500** μm

MPE P **0.8** μm

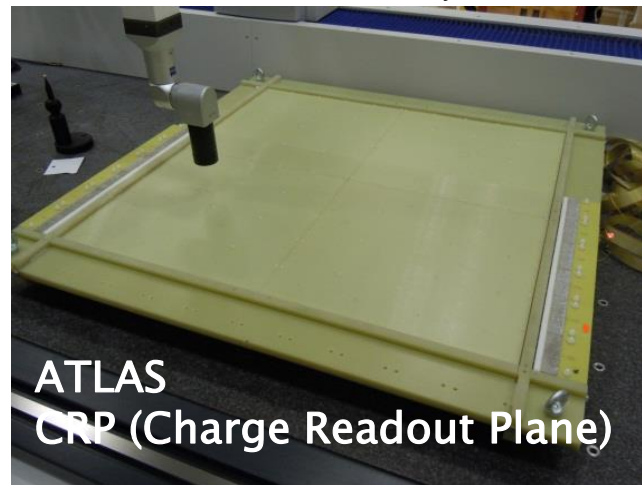
MPE THP 1.2 μm / 45s

## Some References

- ▶ Bosch, Germany
- ▶ Eurocopter, France
- ▶ Weillenstein, Germany



11T Coil



ATLAS  
CRP (Charge Readout Plane)

21st September 2017

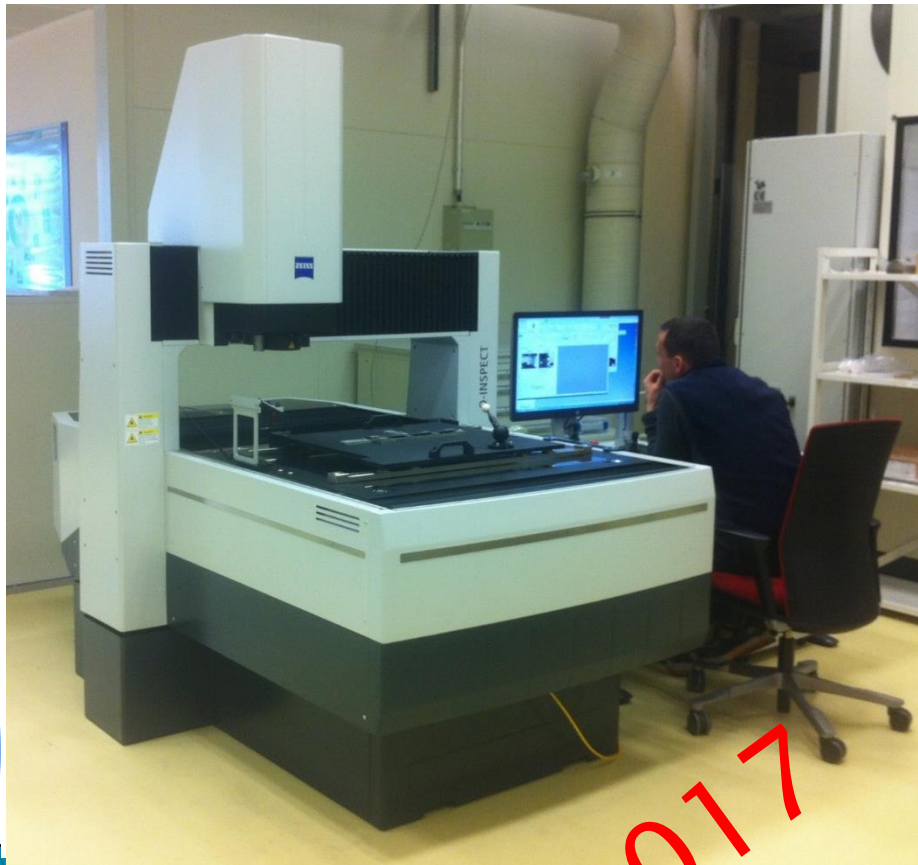


# METROLOGY EQUIPMENT



## O-INSPECT 863 with Scanning Head Vast XXT

### OPTICAL CMM



Strokes: X 800 Y 600 Z 300 mm

Measurement uncertainty  
w.r.t. ISO 10360-2

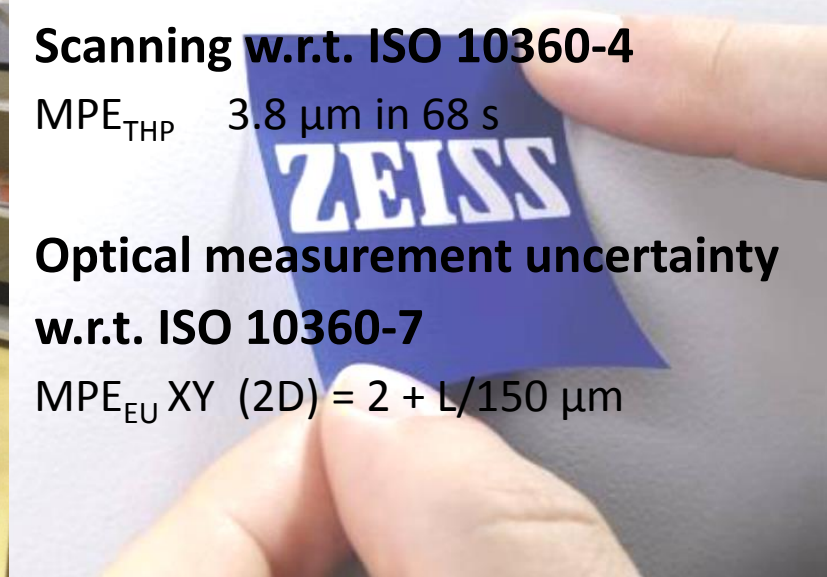
$$MPE_{E0} \quad (3D) = 2.2 + L/150 \mu\text{m}$$

Scanning w.r.t. ISO 10360-4

$$MPE_{THP} \quad 3.8 \mu\text{m in 68 s}$$

Optical measurement uncertainty  
w.r.t. ISO 10360-7

$$MPE_{EU} \quad XY \quad (2D) = 2 + L/150 \mu\text{m}$$





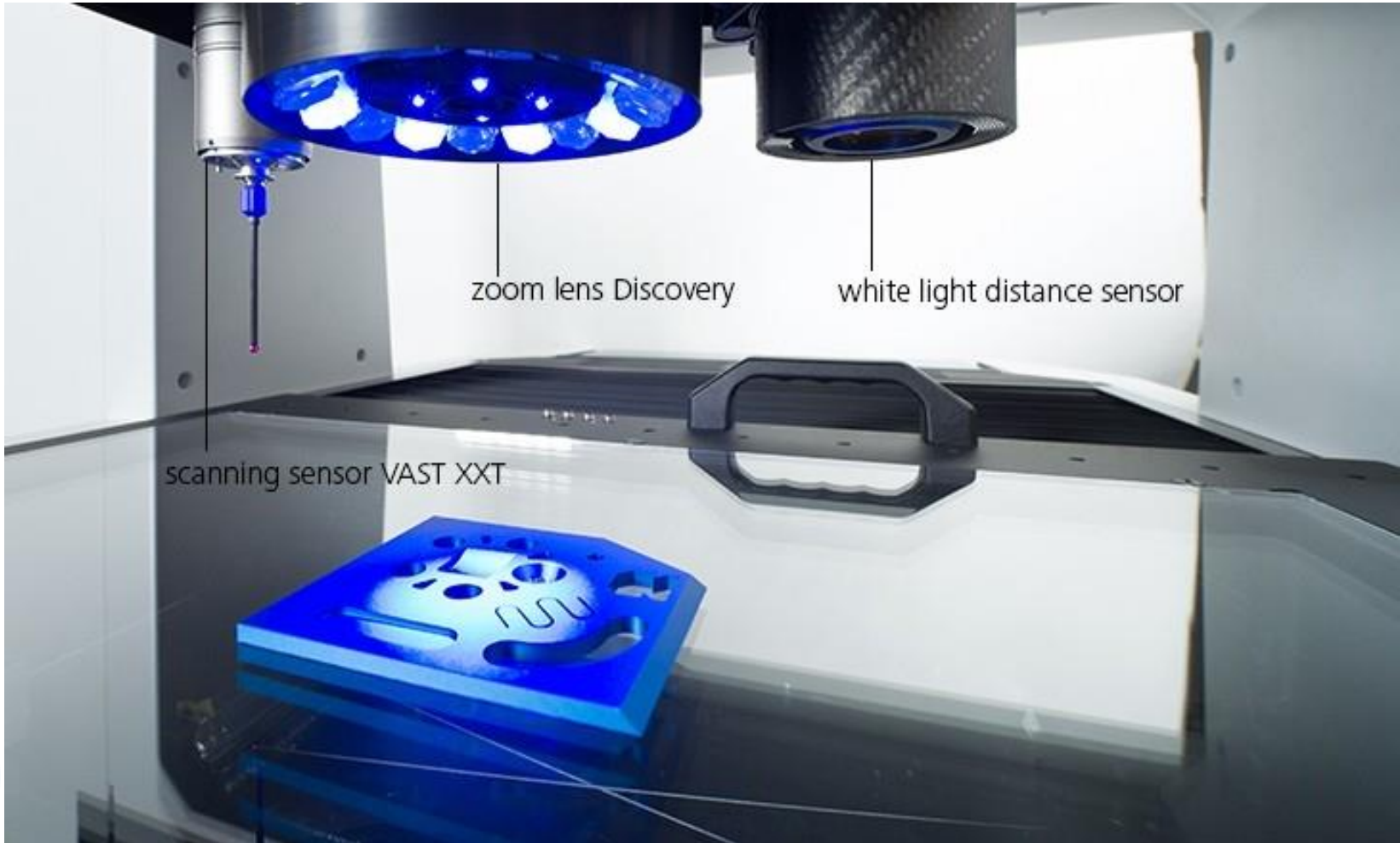


# Sensors (Multisensor)



ENGINEERING DEPARTMENT

EN



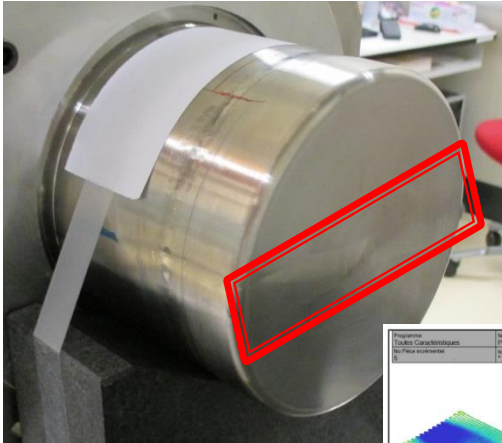
Courtesy of ZEISS



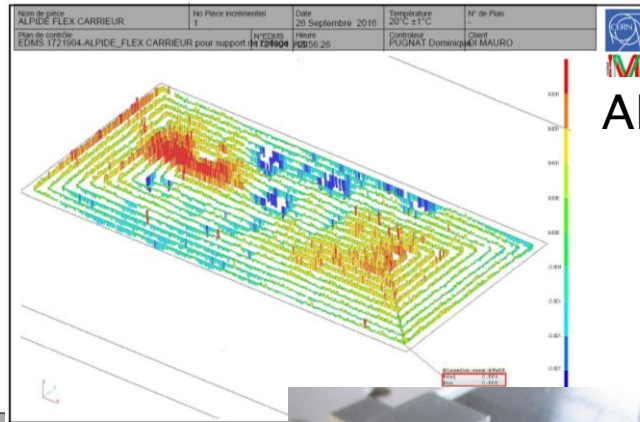
# Measurement examples



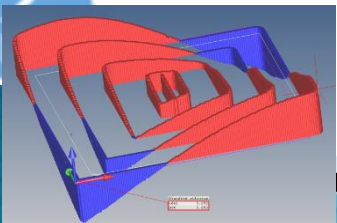
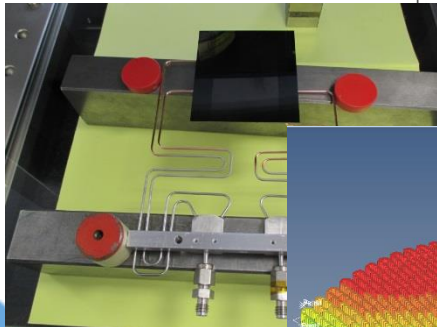
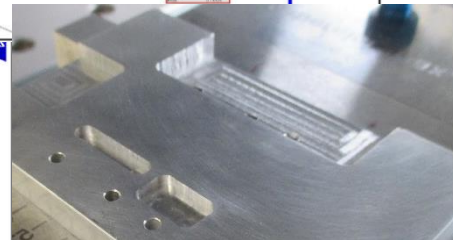
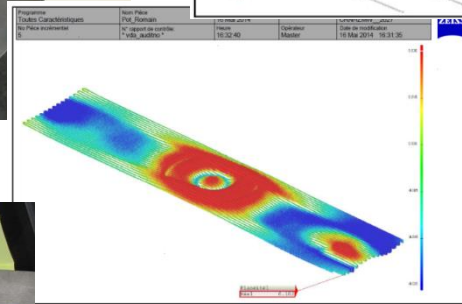
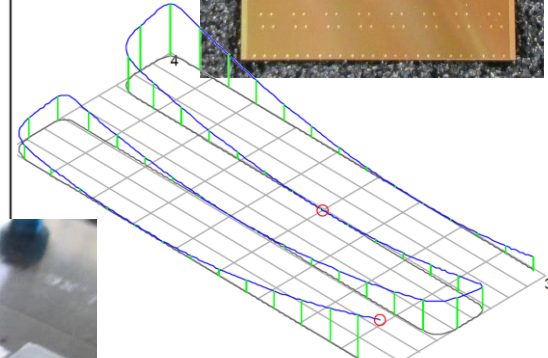
ENGINEERING DEPARTMENT



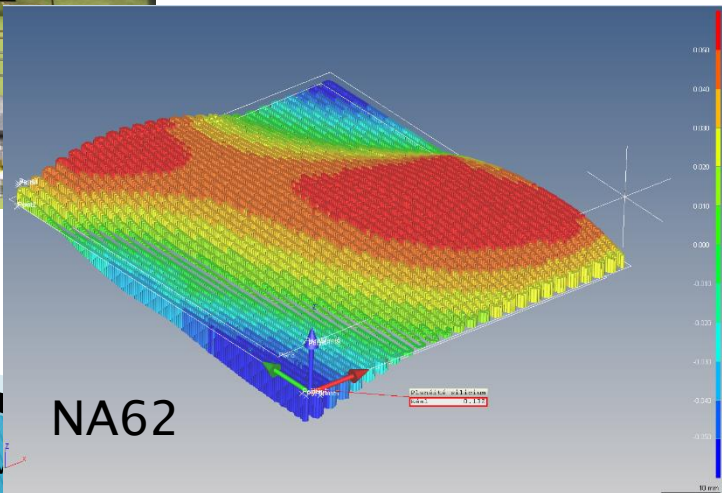
TOTEM Roman pot



ALICE ITS



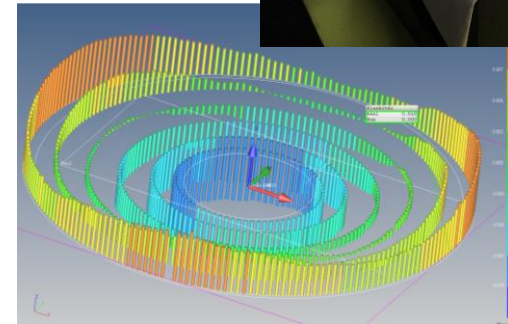
CATIA FORUM



NA62



CLIC



September 2017



# TRANSPORTABLE EQUIPMENT

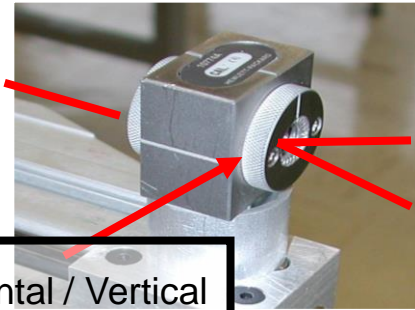


## LASER INTERFEROMETER

ENGINEERING DEPARTMENT



SUPPORT FOR CMS TRACKER



Horizontal / Vertical Dial

## LONG LENGTH MEASUREMENT DEVICE



ATLAS END CAP CALORIMETER

## ROMER ARM



TUNNEL



QRL



ALICE



# TOMOGRAPH

## Microfocus X-ray system

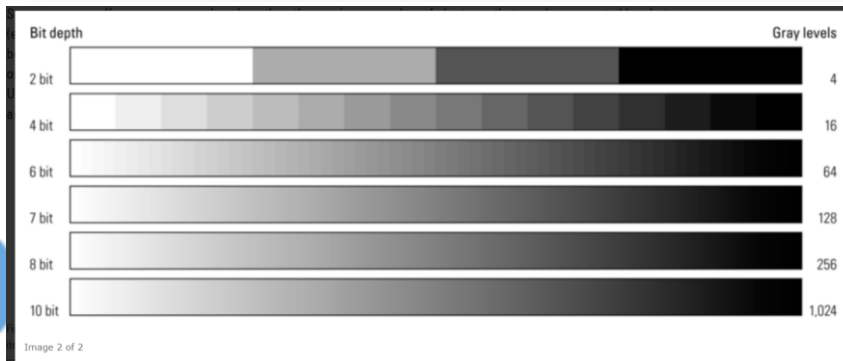


ENGINEERING DEPARTMENT



## ZEISS METROTOM 1500 Delivery December 2017

- FDD: 1500 mm
- Max. voltage  $\geq 225$  kV, max.
- Focal spot size  $\leq 7$   $\mu\text{m}$ ;
- Imager : 2048 x 2048 pixels,
- Max. pixel size: 200  $\mu\text{m}$ ,
- Image processing : 16-bit;  
65 535 grey levels



10 bit : 1024



# PRINCIPLE

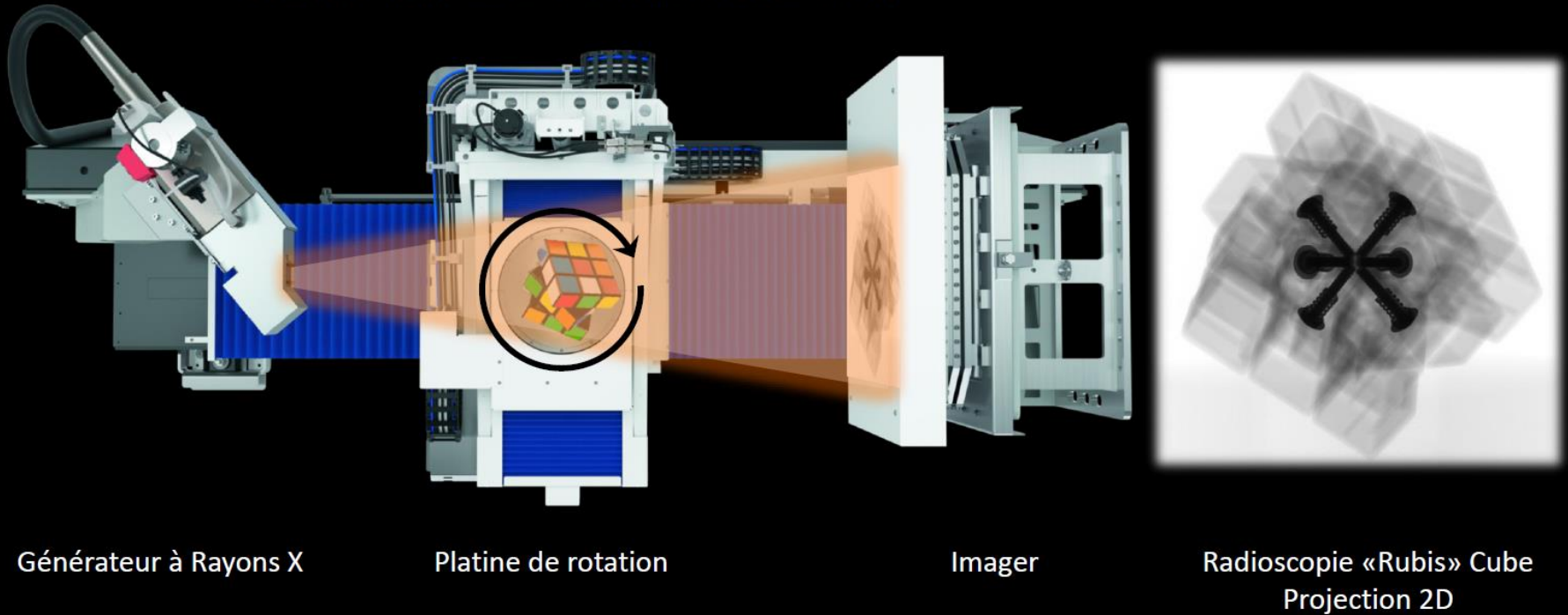


Rubis Control SA

CONFIDENTIAL

## PRINCIPE DE LA TOMOGRAPHIE

Vue du dessus intérieur Zeiss Metrotom 800 – 225kV



CONFIDENTIAL



# POTENTIAL



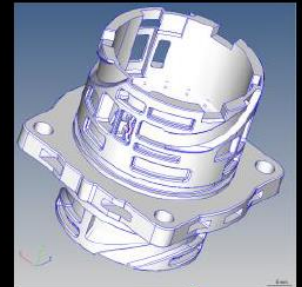
CONFIDENTIAL

## LES POSSIBILITÉS

Rubis Control SA



### Reverse engineering

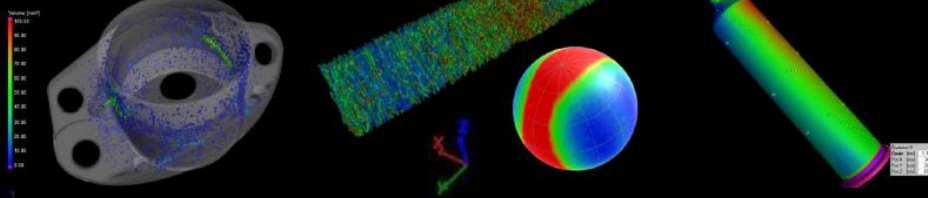


### Analyse

#### Orientation de fibres

#### Santé matière

#### Epaisseur de parois



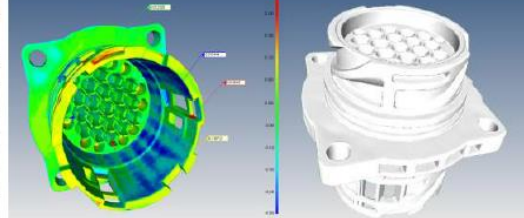
### Métrieologie

#### Mesures

#### Comparaison CAO

#### Extraction STL

| Objet       | Position  | Objet T10 | Objet T10 | Objet T10 | Objet T10 |
|-------------|-----------|-----------|-----------|-----------|-----------|
| 1-1000-0001 | -131.1000 | 0.1000    | 0.1000    | 0.1000    | 0.1000    |
| 1-1000-0002 | 0.1000    | 0.1000    | 0.1000    | 0.1000    | 0.1000    |
| 1-1000-0003 | 0.1000    | 0.1000    | 0.1000    | 0.1000    | 0.1000    |
| 1-1000-0004 | 0.1000    | 0.1000    | 0.1000    | 0.1000    | 0.1000    |
| 1-1000-0005 | 0.1000    | 0.1000    | 0.1000    | 0.1000    | 0.1000    |
| 1-1000-0006 | 0.1000    | 0.1000    | 0.1000    | 0.1000    | 0.1000    |
| 1-1000-0007 | 0.1000    | 0.1000    | 0.1000    | 0.1000    | 0.1000    |
| 1-1000-0008 | 0.1000    | 0.1000    | 0.1000    | 0.1000    | 0.1000    |
| 1-1000-0009 | 0.1000    | 0.1000    | 0.1000    | 0.1000    | 0.1000    |
| 1-1000-0010 | 0.1000    | 0.1000    | 0.1000    | 0.1000    | 0.1000    |



ZEISS CALYPSO  
2016



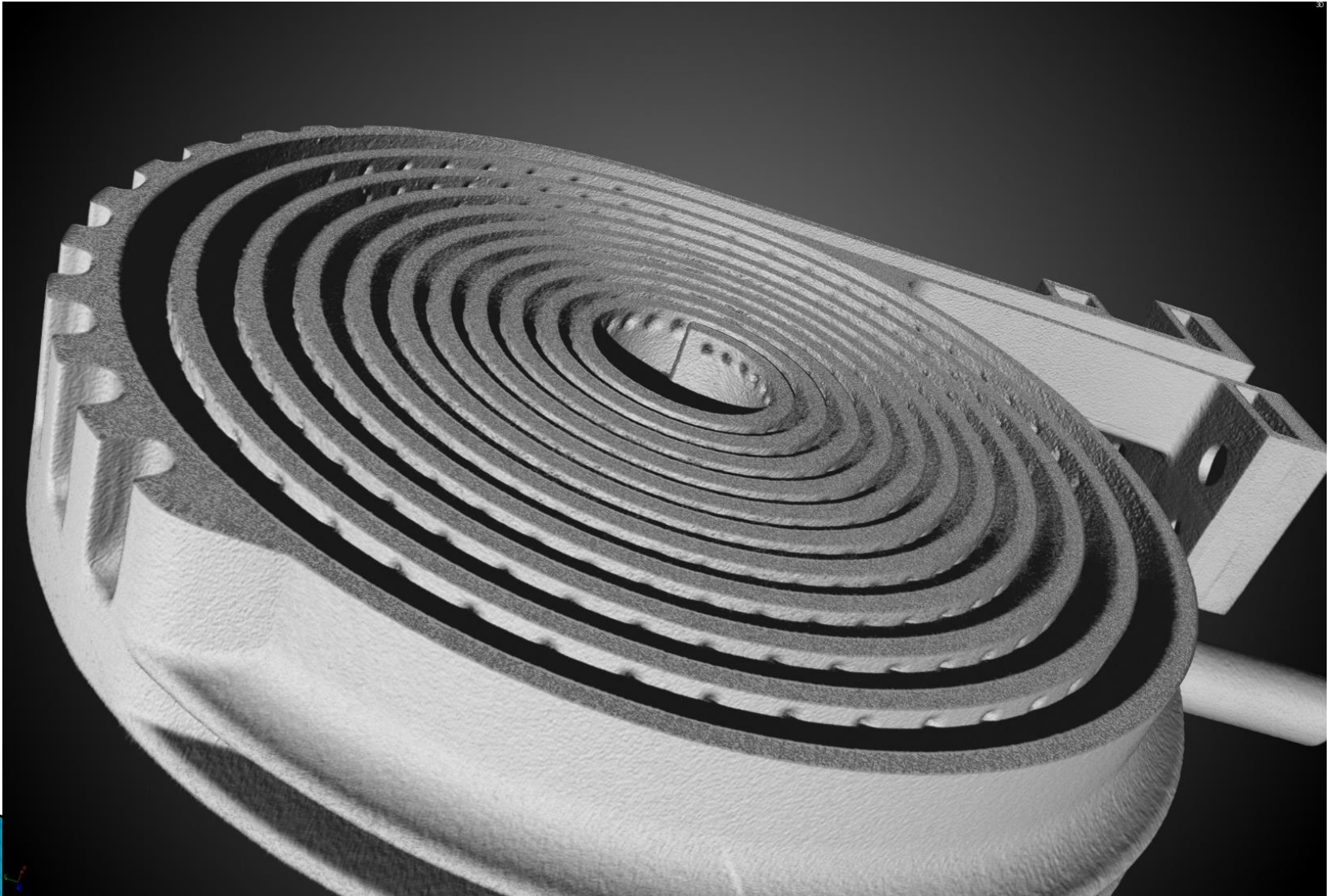


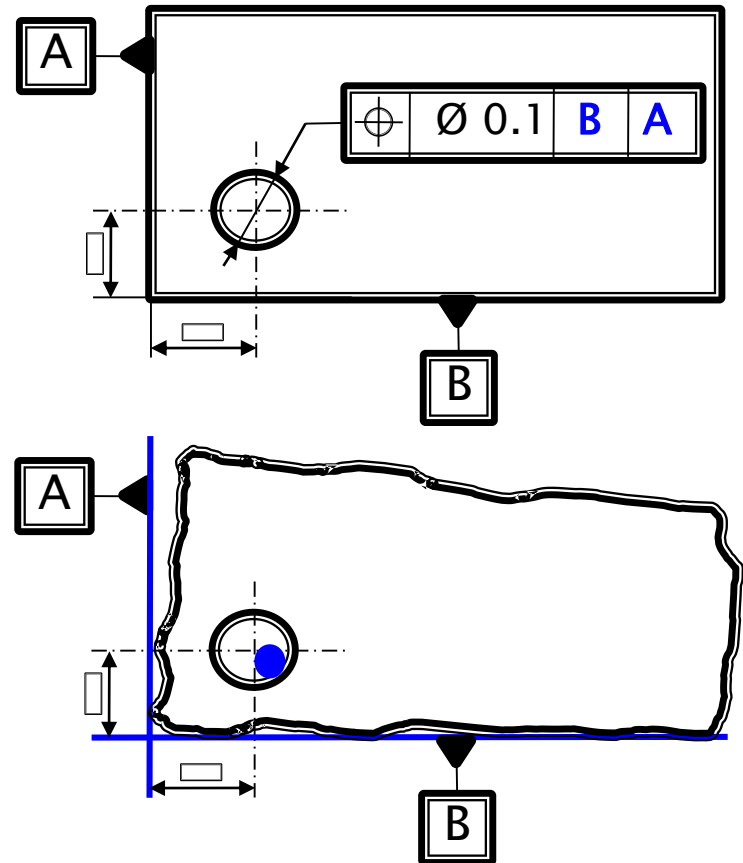
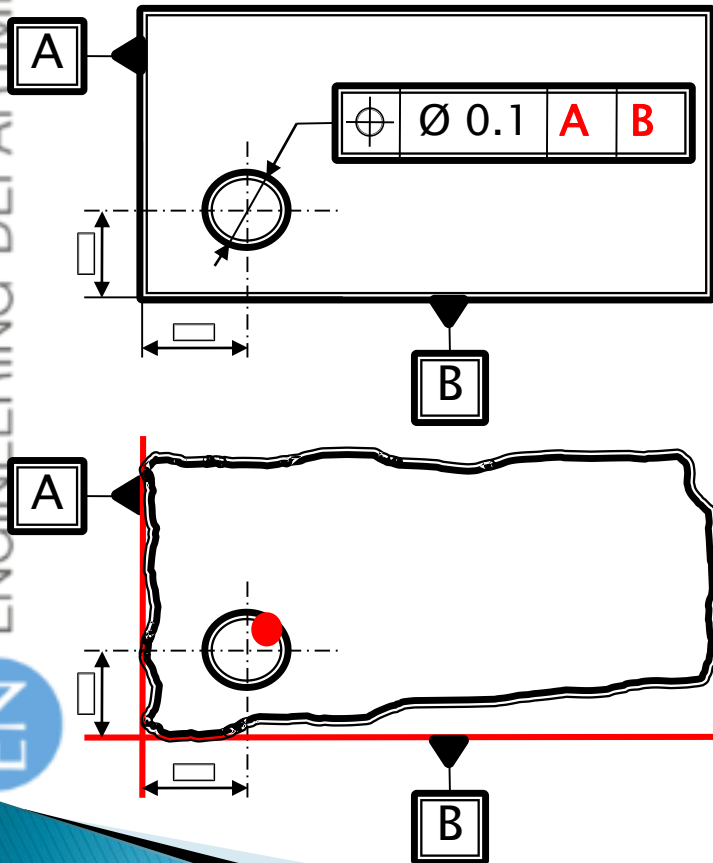
# SPIRAL LOAD – CLIC



ENGINEERING DEPARTMENT

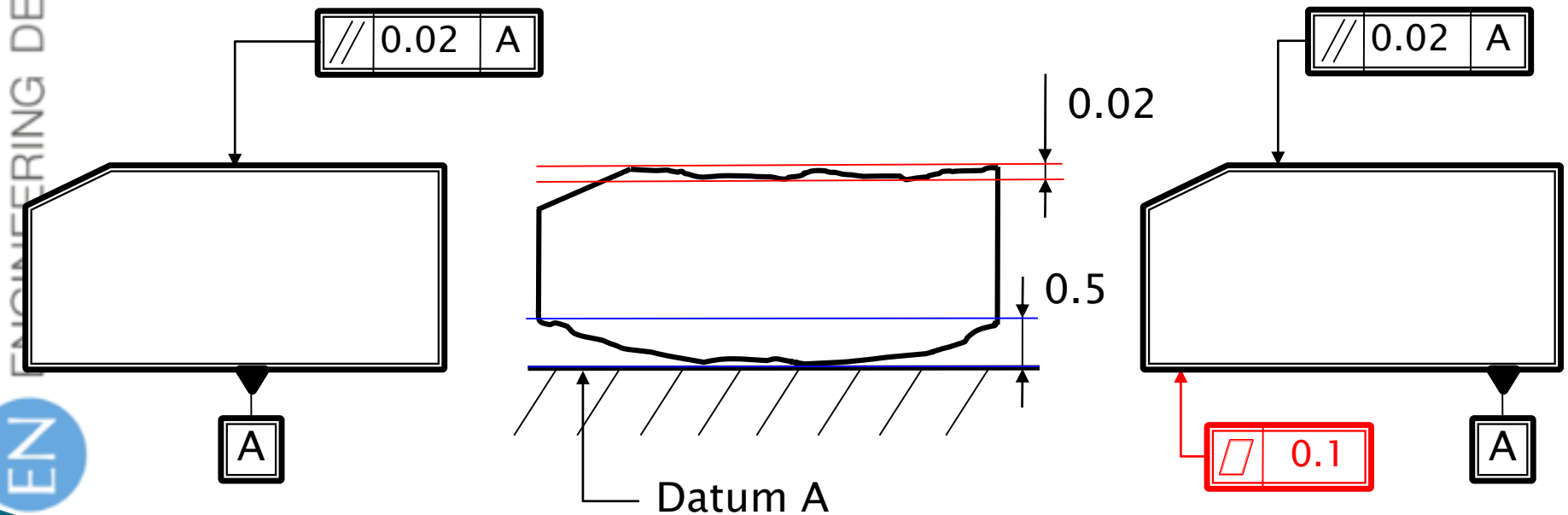
EN







Take care for the geometry and quality of the references surfaces

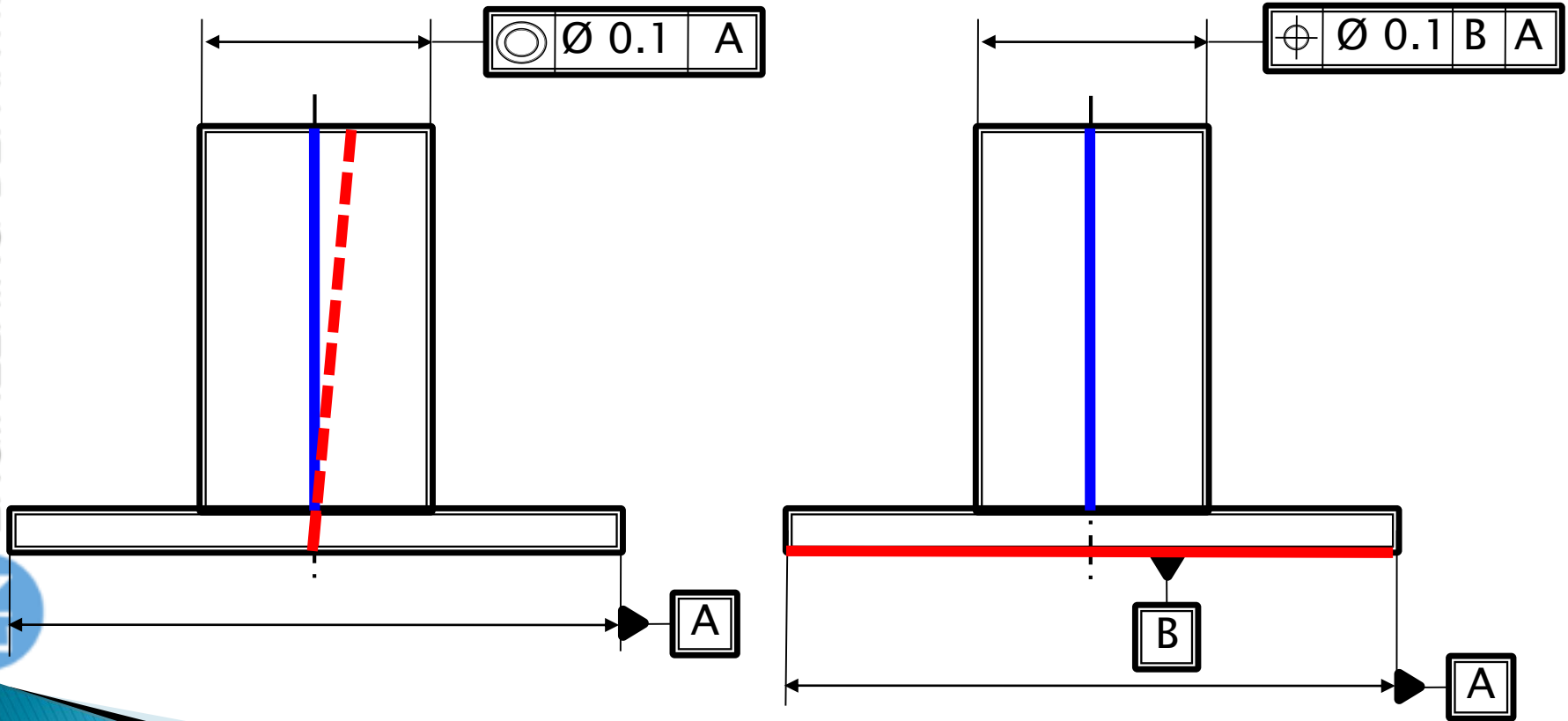




# PROJECTION ERRORS



FN ENGINEERING DEPARTMENT

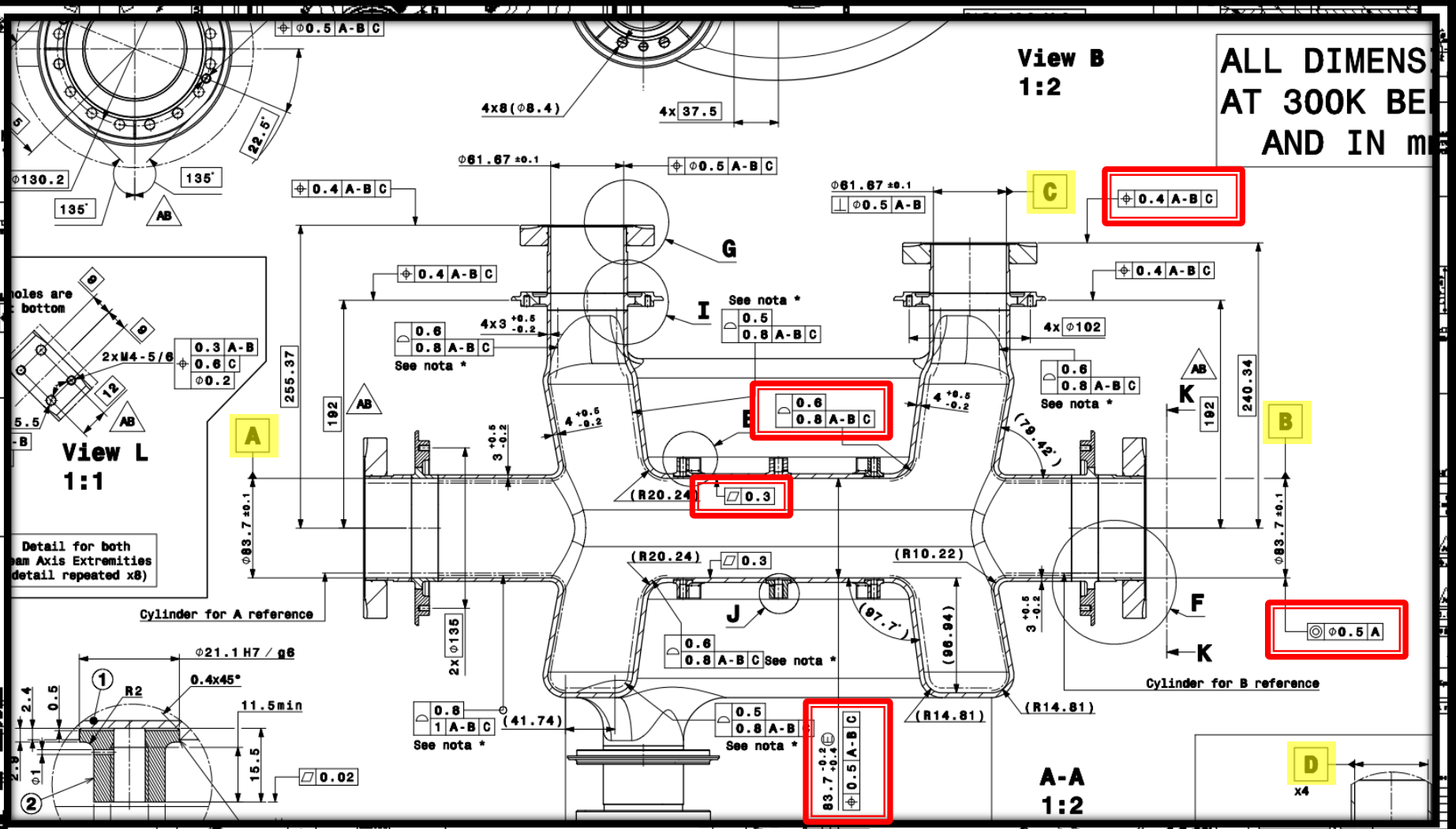




# TOLERANCES



- ▶ Are they always justified?
  - Pragmatism (like in the USA)
  - Realism (Customers do not know what a micron is)
- ▶ Parts are often out of tolerances and clients accept them anyway and most of the time it works!!!  
Even if costumers impose tight tolerances, you should refuse if it is not justified
- ▶ Manufacturing quotation is also depending of the tolerances, surface requirements on the drawing
  - The means (tools & machine) for manufacturing and measurement are not the same when the tolerances are different for the same shape



**View B  
1:2**

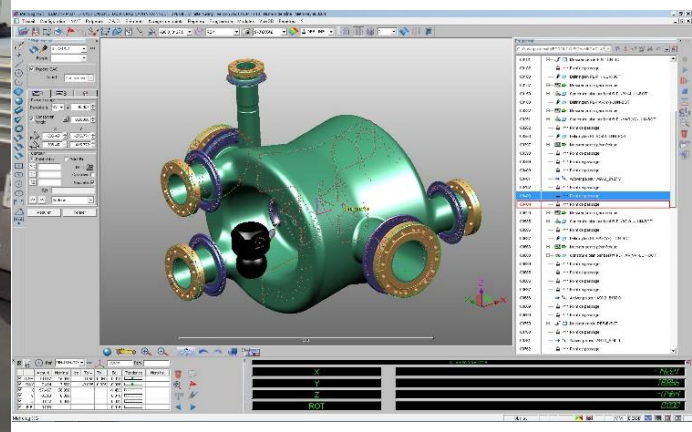
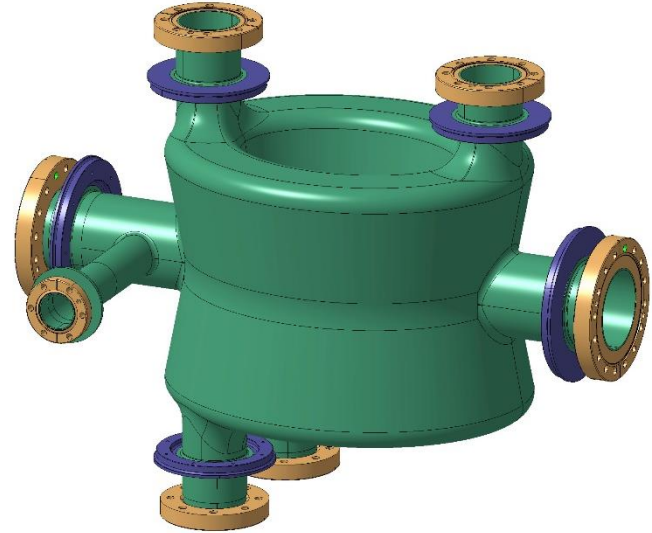
**ALL DIMENS  
AT 300K BE  
AND IN m**

**A-A  
1:2**

**D  
x4**

**Isometric view  
1:3**

|           |            |            |     |
|-----------|------------|------------|-----|
| DATE      | 2014.08.20 | DESIGNER   | ... |
| APP'D     | ...        | CHECKED    | ... |
| PART NAME |            | LHCACR0001 |     |



LF



MÉTROLOGIE EN-MME-MM  
RAPPORT DE CONTRÔLE  
N° EDMS : 1744037



Contrôleur : BULAT Bartosz  
Date de la mesure : 20/03/2017  
Machine : Olivetti  
Précision des mesures : ± 6 µm  
Température : 20°C ±1°C



MÉTROLOGIE EN-MME-MM  
RAPPORT DE CONTRÔLE  
N° EDMS : 1744037

Nom du programme : EDMS:1744037 - SPS CRAB CAVS

Conclusion du contrôle  
CONFORME  
NON CONFORME

VISA MME  
Nom :  
Date :

| Référence                                       | Théorique | Mesuré   | Tol -  |
|---|-----------|----------|--------|
| FLAN-LBOT-Z+EXT Cercle en 30 pts sur AUTO       |           |          |        |
| DIAM  | 113.000   | 112.982  | -0.050 |
| RAY   | 56.500    | 56.491   | -0.025 |
| X   | -254.366  | -249.995 | -0.050 |
| Y   | 114.017   | 114.217  | -0.050 |
| Z   | 90.224    | 90.298   | -0.050 |
| E.F.  |           | 0.012    |        |
| PL-LUNBOT-Z+ANN Plan en 32 élément(s)           |           |          |        |
| DIST  | 187.000   | 192.732  |        |
| I   | 1.000     | 1.000    |        |
| J   | -0.000    | -0.001   |        |
| K   | -0.000    | -0.002   |        |
| E.F.  |           | 0.019    |        |
| CER-ANNBNTI-LUNBOT-Z+ Cercle en 33 pts sur AUTO |           |          |        |
| DIAM  | 112.000   | 111.936  | -0.050 |
| RAY   | 56.000    | 55.968   | -0.025 |
| X   | -187.500  | -193.814 | -0.050 |
| Y   | 114.017   | 114.163  | -0.050 |
| Z   | 90.224    | 90.165   | -0.050 |
| E.F.  |           | 0.021    |        |
| PL-LUN-BOT-Z- Plan en 6 élément(s)              |           |          |        |
| DIST  | 237.966   | 243.612  |        |
| I   | 1.000     | 1.000    |        |
| J   | -0.000    | -0.001   |        |
| K   | -0.000    | 0.002    |        |
| E.F.  |           | 0.011    |        |
| FLAN-LBOT-Z-EXT Cercle en 27 pts sur AUTO       |           |          |        |
| DIAM  | 113.000   | 112.984  | -0.050 |
| RAY   | 56.500    | 56.492   | -0.025 |
| X   | -254.366  | -250.006 | -0.050 |



CATIA



MÉTROLOGIE EN-MME-MM  
RAPPORT DE CONTRÔLE  
N° EDMS : 1744037



Vue LABELS-1

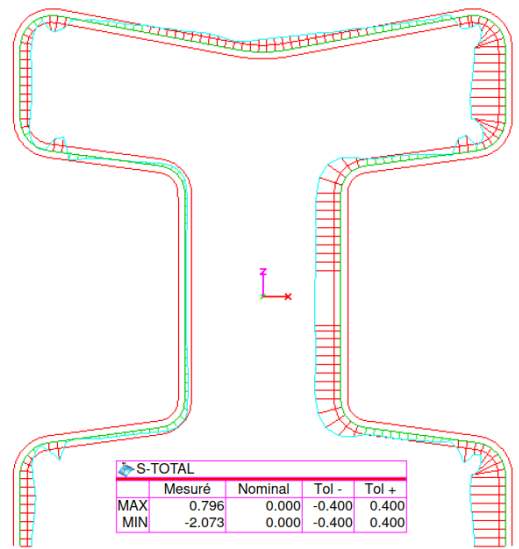
|  |   |   |   |
|--|---|---|---|
| REF-A-EXT<br>DIAM 151.871<br>RAY 75.935<br>X<br>Y<br>Z | PL-FLANGE-SMALL<br>DIST 233.156<br>-0.003 | FLAN-SMALL-EXT<br>DIAM 70.000<br>RAY 35.000 | PL-LUN-TOP-LONG<br>DIST 242.343<br>-1.000 |
|--|---|---|---|



MÉTROLOGIE EN-MME-MM  
RAPPORT DE CONTRÔLE  
N° EDMS : 1744037

- PL DIST I J K
- PL DIST I J K
- PL DIST I J K
- PL DIST I J K

Vue S-TOTAL



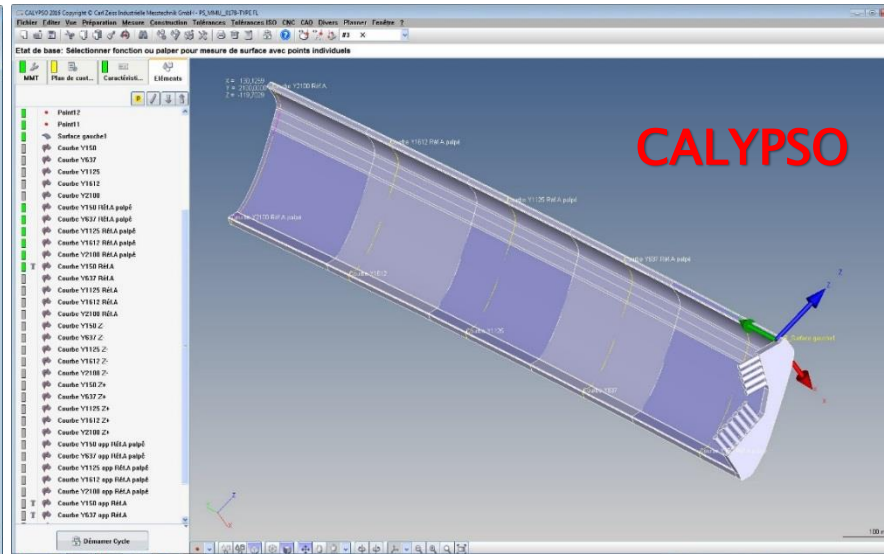
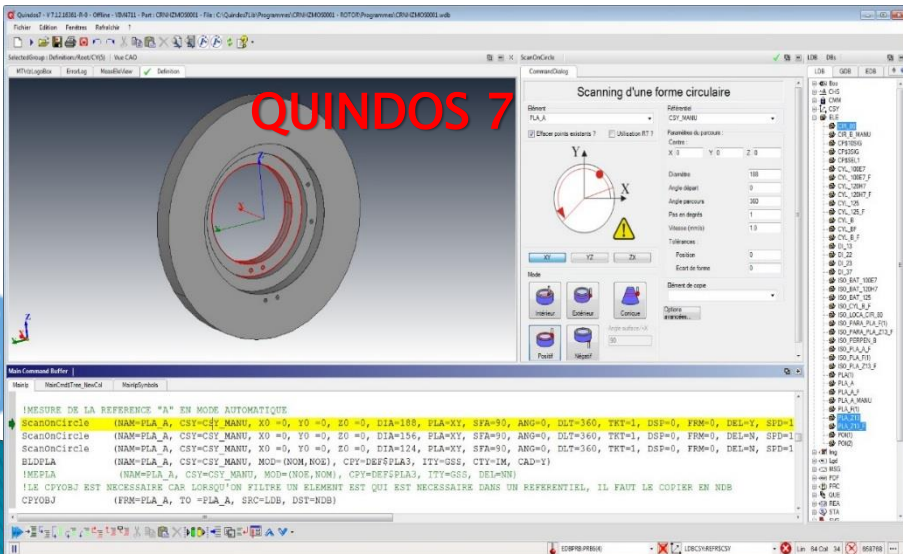
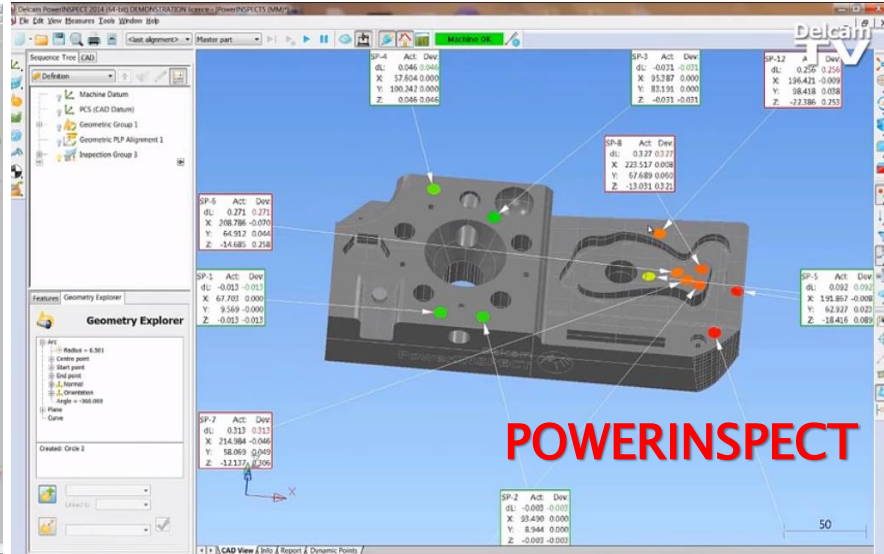
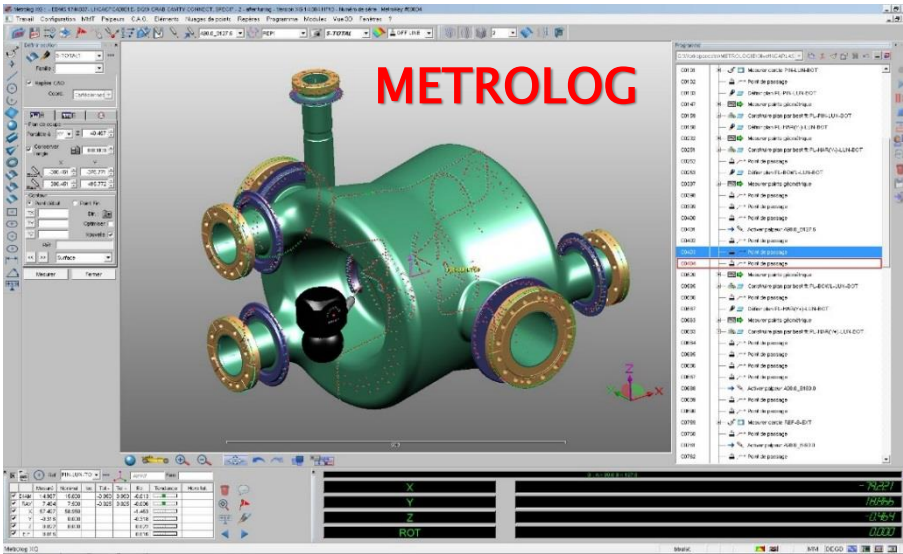
| S-TOTAL | Mesuré | Nominal | Tol -  | Tol + |
|---------|--------|---------|--------|-------|
| MAX     | 0.796  | 0.000   | -0.400 | 0.400 |
| MIN     | -2.073 | 0.000   | -0.400 | 0.400 |



# 4 Metrology software

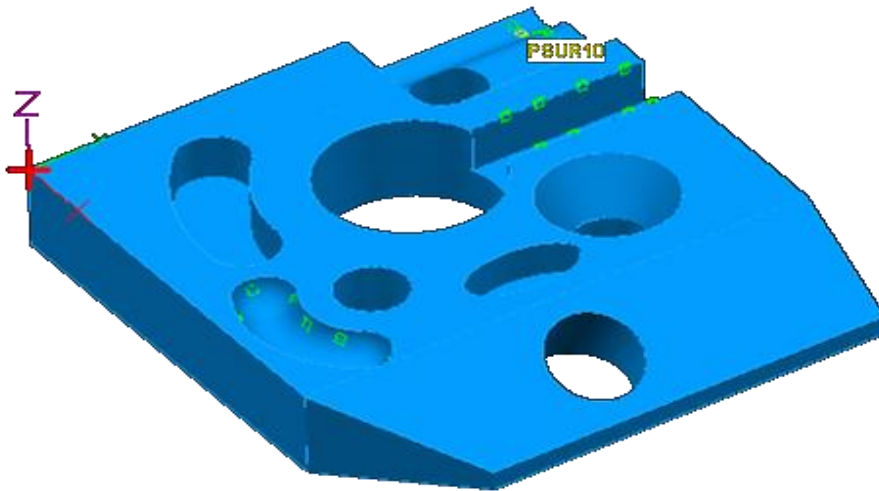


EN ENGINEERING DEPARTMENT





# CAD MODEL



**DO NOT "crack" the dimensions**

Dimensions should be the same either on the 2D drawing and on the CAD Model

**The 2D drawing is our contract**

- ▶ **Format**
  - STEP, STP, IGES, SAT...
  - CATIA
- ▶ **CAD Model approval?**
  - Who checks?
  - How?

**Don't forget, the metrology compares the results to the CAD**

- ▶ **Facets** (Could deal to errors for accurate parts)
  - CLIC parts for example



# PREFERENCES



- ▶ Recovery of the theoretical values directly from the CAD
- ▶ + Dimensional tolerances
- ▶ + Geometrical tolerances
  
- ▶ CAD Model available (on CDD or other) with each revision
  
- ▶ Think also measurement during the definition phase, specially datum
  
- ▶ The metrology service is available to help and advise





# Faced Problems



- ▶ Trueness of the CAD Model
- ▶ Construction elements
- ▶ CATIA Training is mandatory to be able to recover CAD models



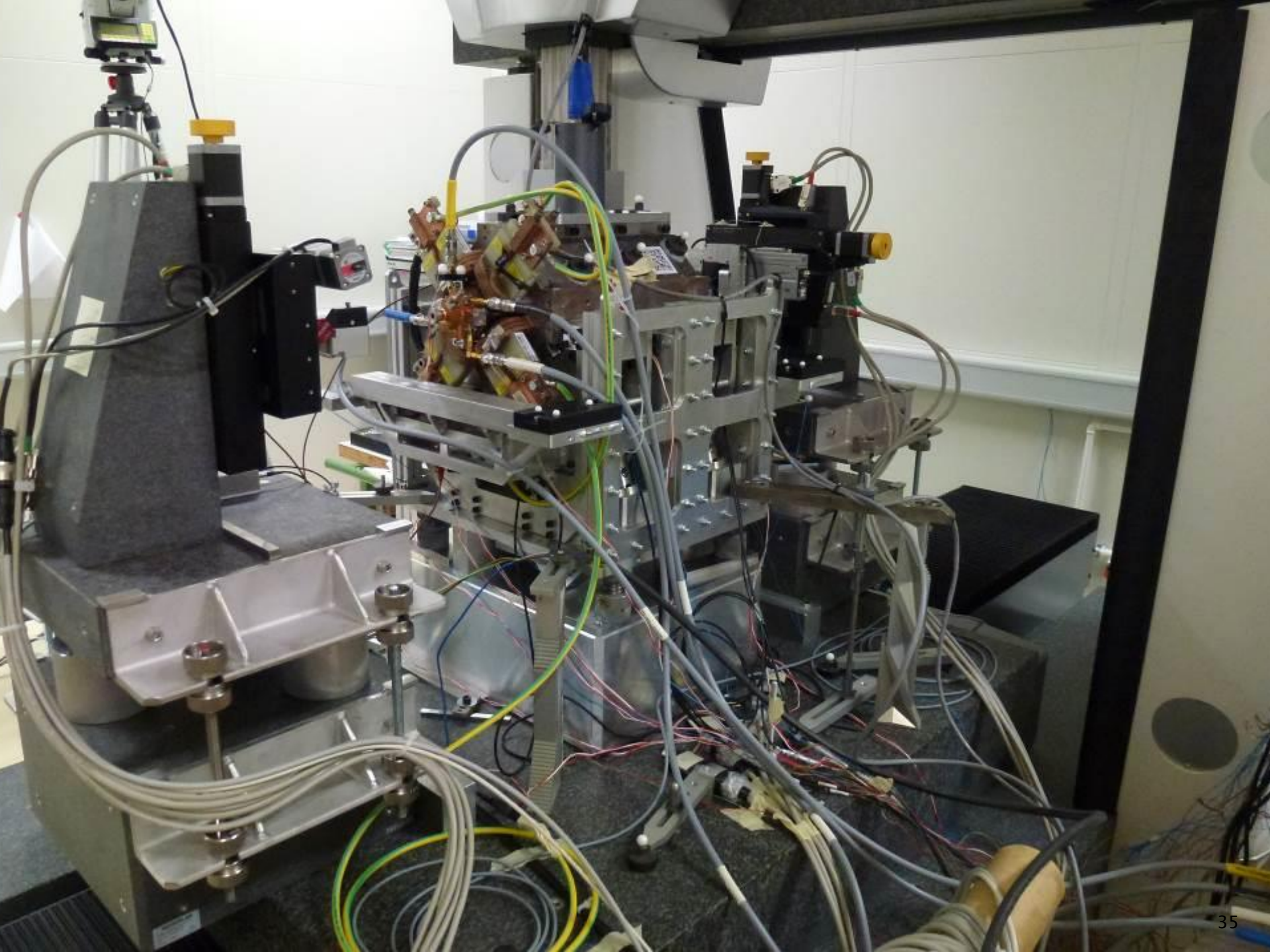
# Conclusions



▶ The metrology lab is :

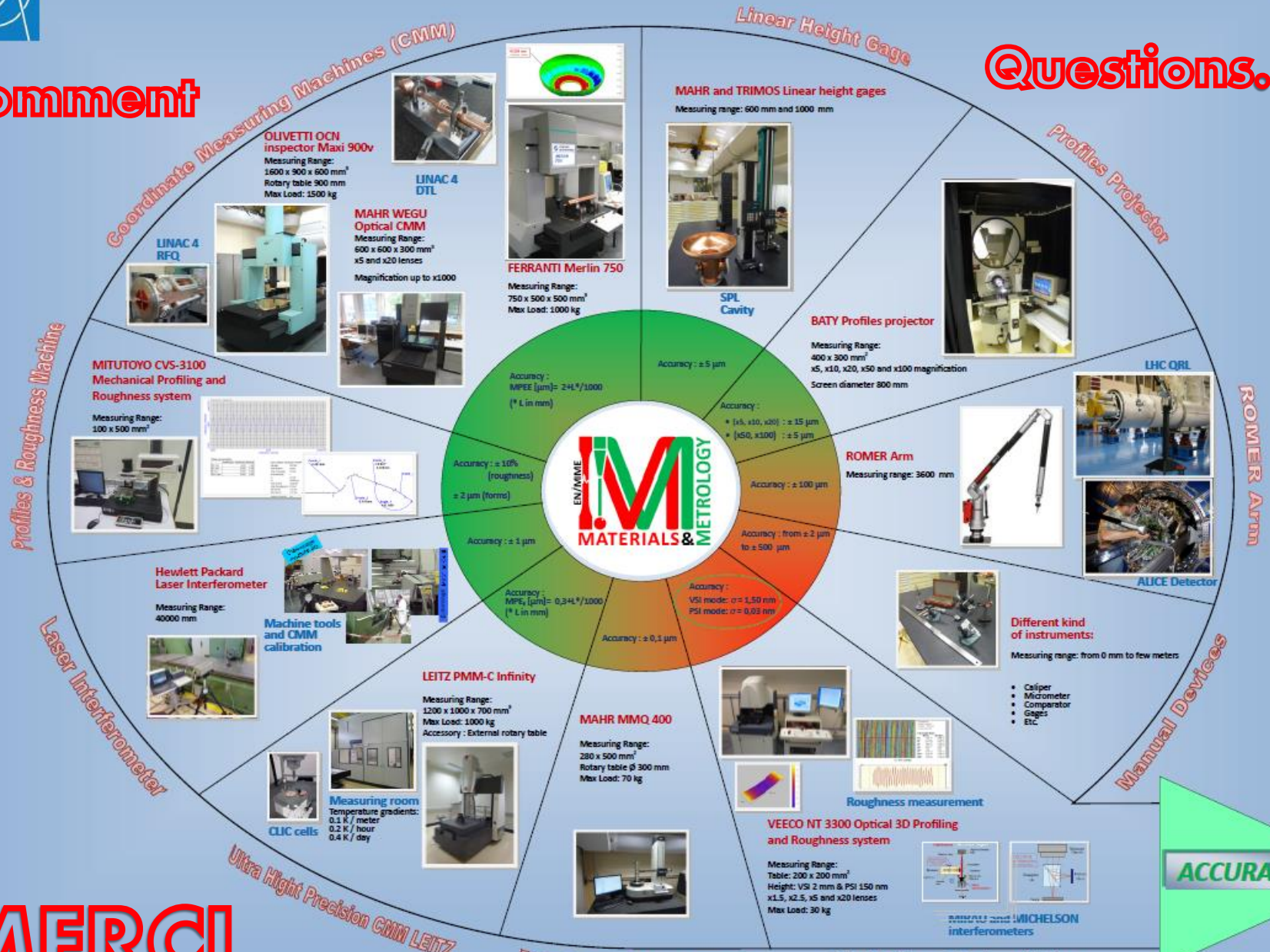
**Willing for collaboration with you**

- Able to perform all dimensional measurements for CERN applications
- Working on Improving its measurement methods and delays
- Improving measurement uncertainties
- Implementing the Quality assurance (ISO 9000)
- Giving support to projects
- More and more integrated from the design phase of the projects
- Collaborating with industrial partners and universities



**Comment**

**Questions...?**



**Coordinate Measuring Machines (CMM)**

**OLIVETTI OCN inspector Maxi 900v**  
 Measuring Range: 1600 x 900 x 600 mm<sup>3</sup>  
 Rotary table 300 mm  
 Max Load: 1500 kg

**LINAC 4 DTL**

**MAHR WEGU Optical CMM**  
 Measuring Range: 600 x 600 x 300 mm<sup>3</sup>  
 x5 and x20 lenses  
 Magnification up to x1000

**LINAC 4 RFQ**

**MAHR and TRIMOS Linear height gages**  
 Measuring range: 600 mm and 1000 mm

**Profiles Projector**

**FERRANTI Merlin 750**  
 Measuring Range: 750 x 500 x 500 mm<sup>3</sup>  
 Max Load: 1000 kg

**SPL Cavity**

**BATY Profiles projector**  
 Measuring Range: 400 x 300 mm<sup>2</sup>  
 x5, x10, x20, x50 and x100 magnification  
 Screen diameter 800 mm

**ROMER Arm**

**ROMER Arm**  
 Measuring range: 3600 mm

**LHC ORL**

**Alice Detector**

Accuracy : ± 5 µm

Accuracy : MPEE [µm] = 2.4 L<sup>1/3</sup> / 1000  
 (\* L in mm)

Accuracy : ± 10% (roughness)  
 ± 2 µm (forme)

Accuracy : ± 1 µm

Accuracy : MPE [µm] = 0.34 L<sup>1/3</sup> / 1000  
 (\* L in mm)

Accuracy : ± 0.1 µm

Accuracy : ± 15 µm  
 ± 5 µm (x50, x100)

Accuracy : ± 100 µm

Accuracy : from ± 2 µm to ± 500 µm

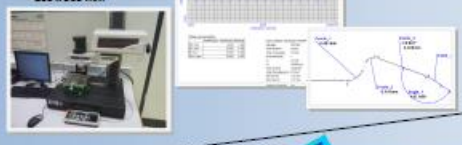
Accuracy : VSI mode: σ = 1,50 nm  
 PSI mode: σ = 0,03 nm

**Different kind of instruments:**  
 Measuring range: from 0 mm to few meters

- Caliper
- Micrometer
- Comparator
- Gages
- Etc

**Manual Devices**

**MITUTOYO CVS-3100 Mechanical Profiling and Roughness system**  
 Measuring Range: 100 x 500 mm<sup>2</sup>



**Hewlett Packard Laser Interferometer**  
 Measuring Range: 40000 mm



**Machine tools and CMM calibration**



**LEITZ PMM-C Infinity**  
 Measuring Range: 1200 x 1000 x 700 mm<sup>3</sup>  
 Max Load: 1000 kg  
 Accessory : External rotary table

**Measuring room**  
 Temperature gradients:  
 0.1 K / meter  
 0.2 K / hour  
 0.4 K / day

**CLIC cells**



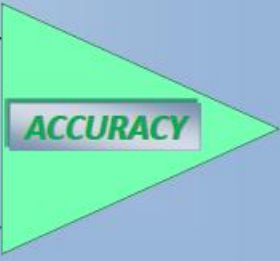
**MAHR MMQ 400**  
 Measuring Range: 280 x 500 mm<sup>2</sup>  
 Rotary table: Ø 300 mm  
 Max Load: 70 kg



**VEECO NT 3300 Optical 3D Profiling and Roughness system**  
 Measuring Range: Table: 200 x 200 mm<sup>2</sup>  
 Height: VSI 2 mm & PSI 150 mm  
 x1.5, x2.5, x5 and x20 lenses  
 Max Load: 30 kg

**Roughness measurement**

**MICHELSON interferometers**



**MERCI...o**

**Ultra High Precision CMM LEITZ**

**Formtester MAHR MMQ400**

**Optical Profiling and Roughness Machine**



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