Workshop "Advanced Mechanics in Accelerator Technology" (AMAT),
19 April 2013, CERN

Materials studies and tests at CERN

- Mandate and expertise
- Equipment
- Examples of material studies and tests
- Perspectives

Stefano Sgobba
EN-MME-MM

EN-MME-


Didier Glaude


Lilian Remandet


Jean-Michel Dalin


Aline Piquiet


Ignacio Avilés


Barbora Bartova


Ana Teresa Pérez


Stephane Marcuzzi


Dominique Pugnat


Ahmed Cherif


Stefano Sgobba


Gonzalo Arnau Izquierdo


Floriane Leaux

March 2013


Patrice Francon

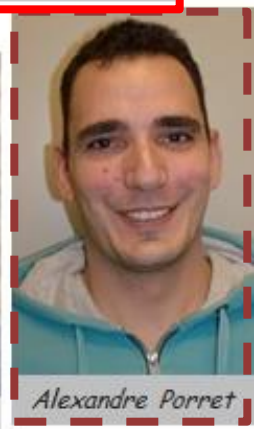

Jean-Philippe Rigaud


Philippe Deweulf


Alexandre Gerardin


Melinda Hiltbrand


Dawid Marcinek


Alexandre Porret

EN/MME MATERIALS & METROLOGY

Mandate Structure

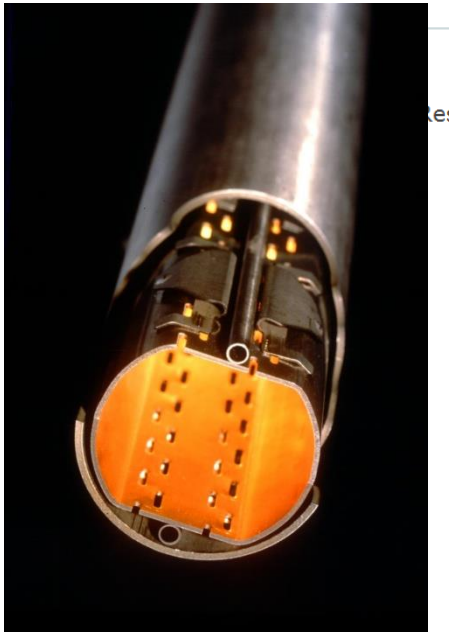
EN Engineering Department

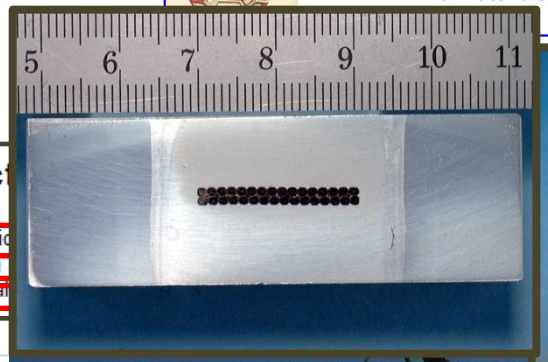
MME Mechanical & Materials Engineering

Home > Groups > MME > MM > - Mandate

Metallurgy and Metrology Sect

Undertakes the development, selection, specifi films. Provides support for the quality control of materials and components including chanical tests and measurements on materials and components. Performs failure anal



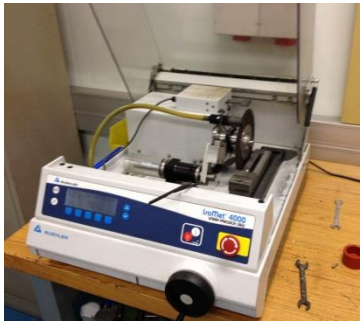


Microstructural characterization. Specimen preparation

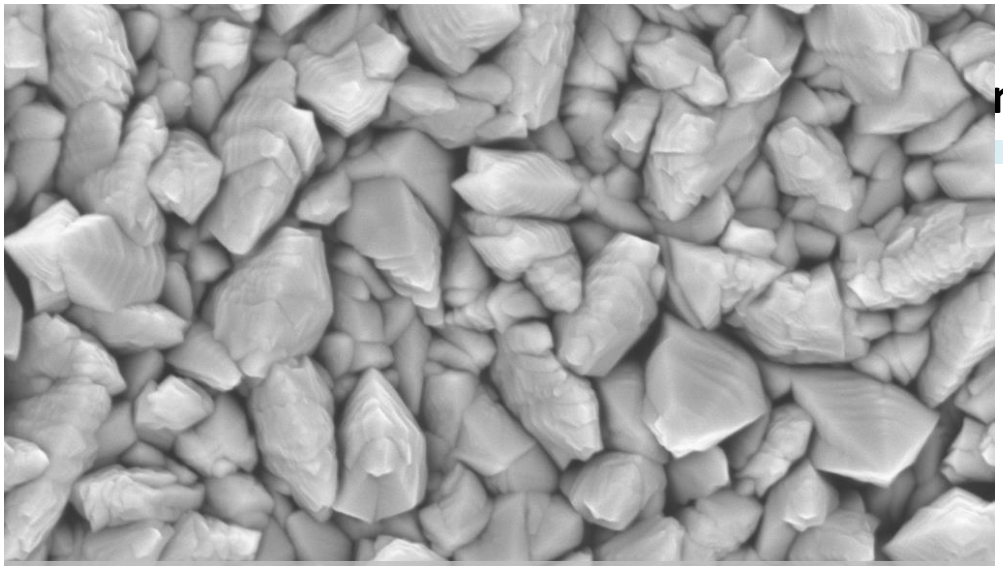
Sectioning
Linear precision Saw. *Buehler IsoMet 4000*
Precision diamond wire saws. *Well 3242 and 3241*

Mounting
Hot mounting presses. *Buehler Simplimet 1000 and 2000*
Cold mounting pressure chamber. *LamPlan M.M. 806*

Grinding & polishing
Manual polishing machines. *LamPlan M.M. 8027 S. and Plamopol 2*
Automatic polishing machines. *Buehler Phoenix 4000 and LamPlan M.M. 8055*
Vibratory polishing machine. *Buehler vibromet 2*
Automatic electrolytic polishing-etching. *ATM Kristall 620 with electrolytic cell*



n. Observation and analysis



Morphology of a Nb coating on Cu structure, original magnification 50000 x

Optical microscopy

Various stereo microscopes.

Metallographic microscope. *Leica DMRM*

Objectives for magnifications from x16 to x1500

Image analysis system

Digital portable microscope. *Keyence VHX-1000*

Resolution max 54 MPixel

Objectives 0 - x50, x20 - x200 and x100 - x1000

Chamber 190 mm x 300 mm x 265 mm

SE and BSE imaging detectors. Max resolution 4 nm

Beam 0.5 to 30 kV, 1pA to 500 nA

EDS analyser *Oxford Isis*.

FE-SEM. Zeiss Σigma

Chamber ø365 mm x 275 mm

SE, BSE, in-lens SE imaging detectors. Max resolution 1.5 nm

Beam 0.1 to 30 kV, 4 pA to 20 nA

EDS analysis *Oxford Inca* with 30 mm^2 SDD detector

EBSD analysis *HKL Chanel 5*

Spectroscopy and X ray diffraction

Powder XR diffraction. *Siemens D5000*

Cu and Cr X-ray sources

Vertical and horizontal goniometers

Portable OES analyser. *Oxford Instruments PMI MasterPro*

Calibrations for steels, Al, Ni, Cu and Ti alloys

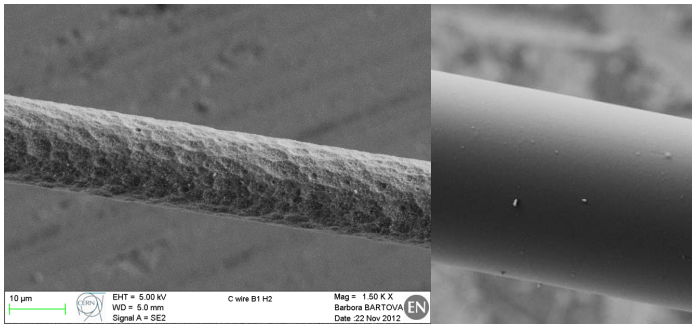
UV probe for S and P

New optical microscope being purchased in 2013

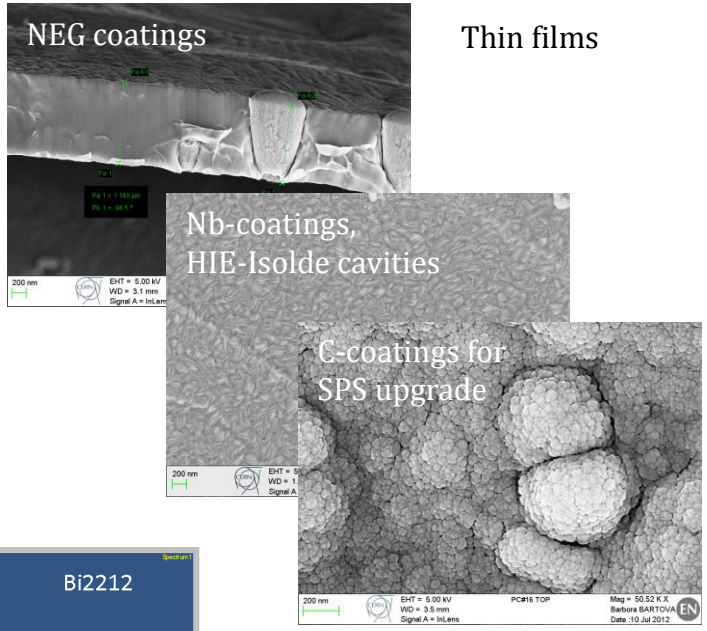
New SEM (replacement LEO) in 2015

Scanning Electron Microscopy and microanalysis support

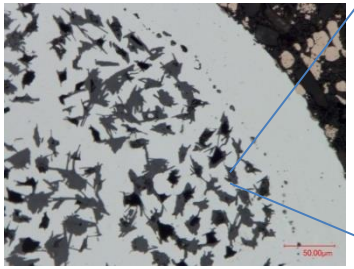
Carbon wires from SPS beam scan: region degraded by the beam (left) and unused reference (right, same scale)

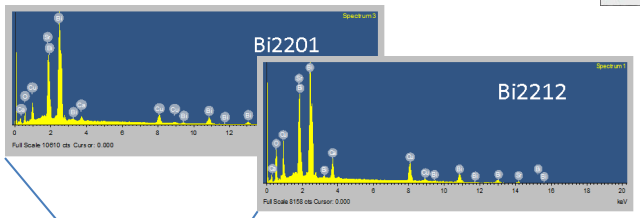


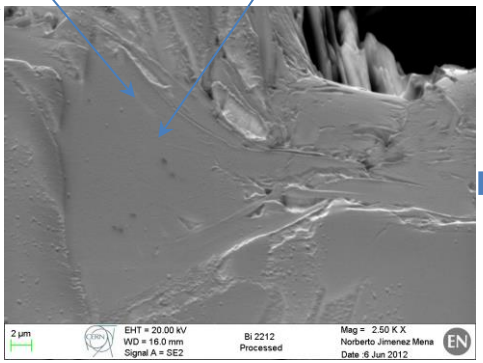
Thin films

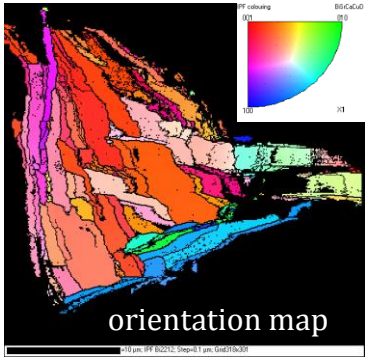


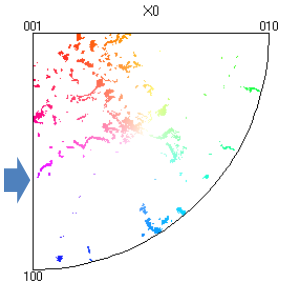
Microstructural characterisation by EBSD of Bi2212 wire











inverse pole figure

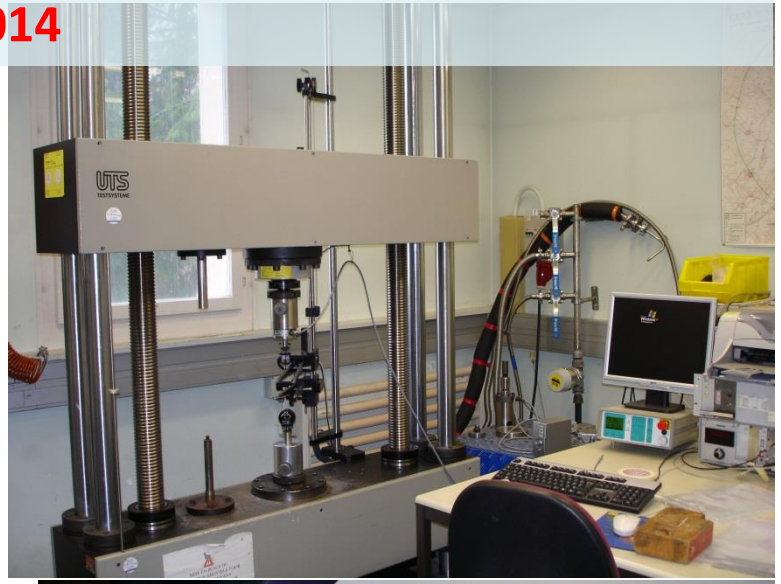
Mechanical testing

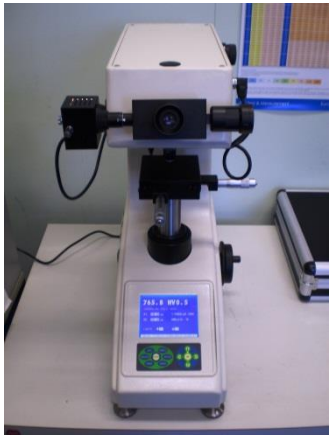
100 kN cryostat for tensile testing and eventually fracture mechanics at 4.2 K in construction (2013)

New dynamic mechanical testing unit in 2014

Tensile testing machines

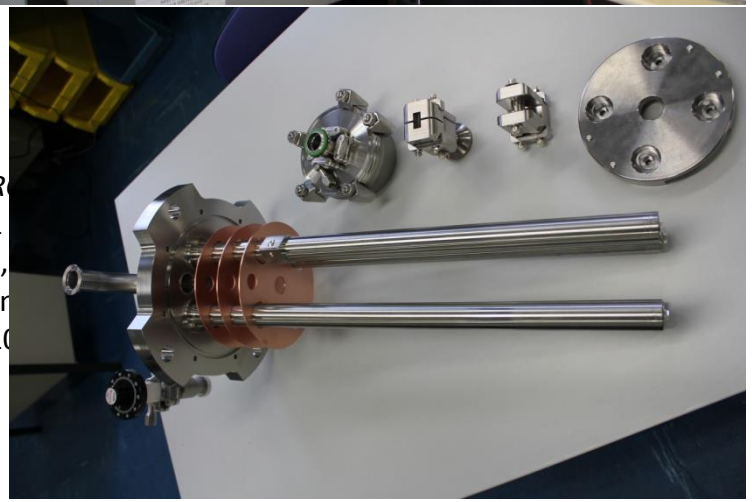
Two column electromechanical universal testing machine *UTS 200*
Load cells 1 kN, 20 kN and 200 kN, stroke 800 mm
Knives and clip-on extensometers
Tensile grips, compression plates, bending tools
System for tests at 77 K and 4.2 K, 25 kN load cell
Single column press *ZPM 1000-500.* Load cell 1 kN, stroke 500 mm



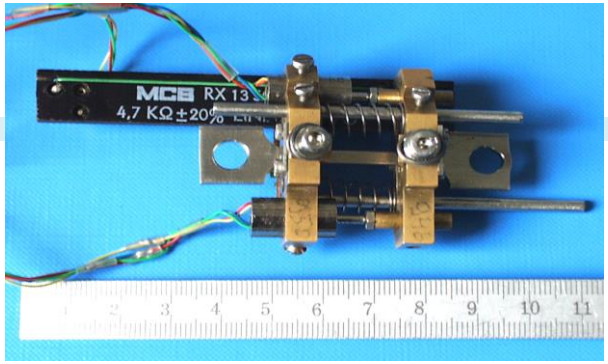


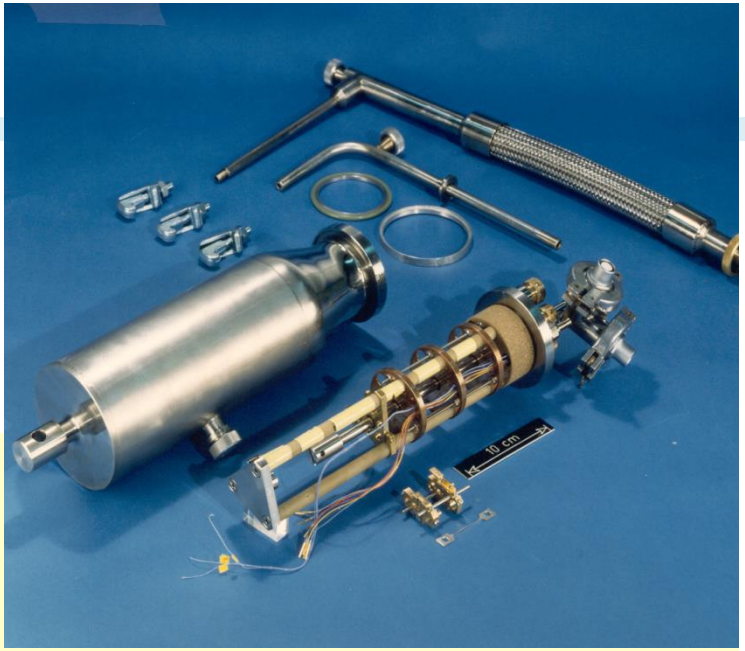
Hardness

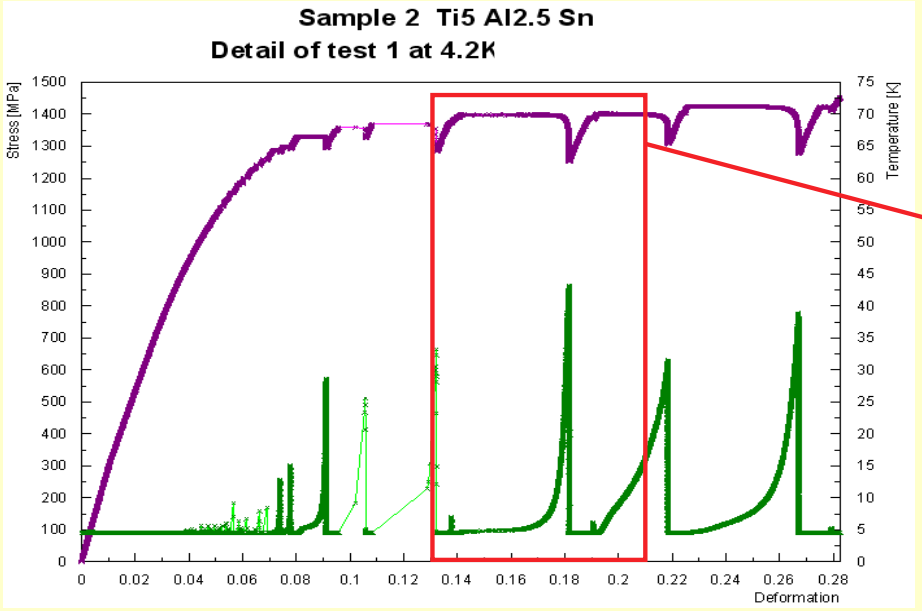
Hardness. *Wolpert 2R*
Load 1
Brinell,
Micro hardness autor
Load 1

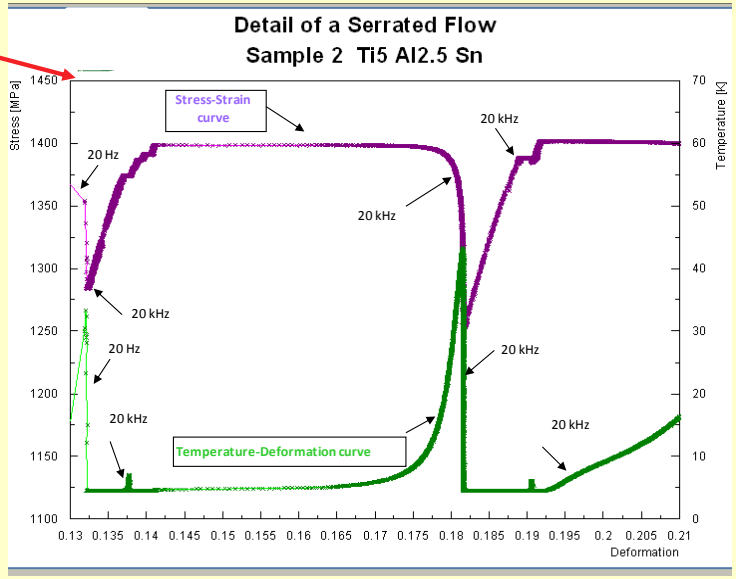


Mechanical testing at 4.2 K, the past…



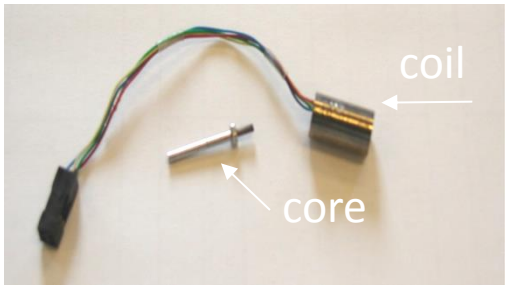




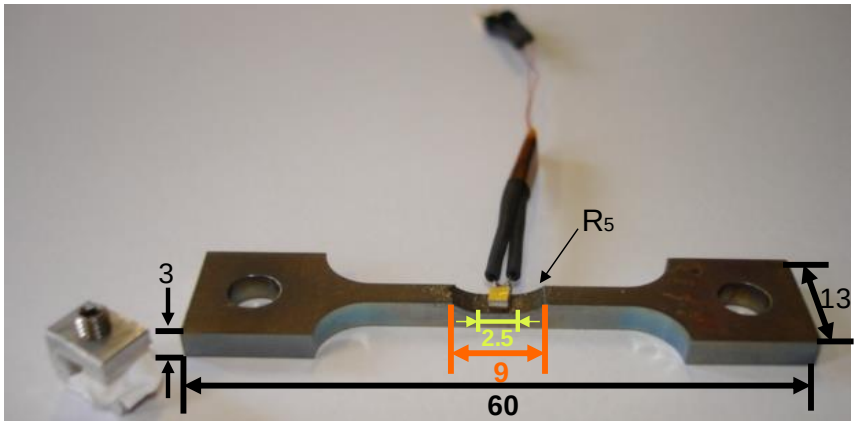


Evolution of the equipment

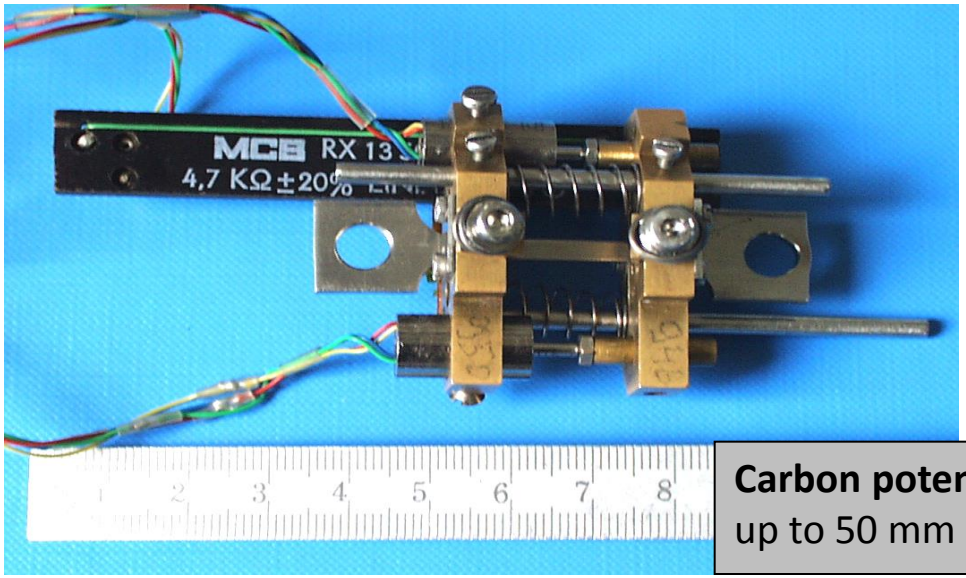
Internal load cell:
immersed in liquid He, based on a deformable 316LN ring equipped by strain gauges
conditioner: MVD2555 of HMB



LVDT:
range: up to 3 mm
resolution: 0.5 µm

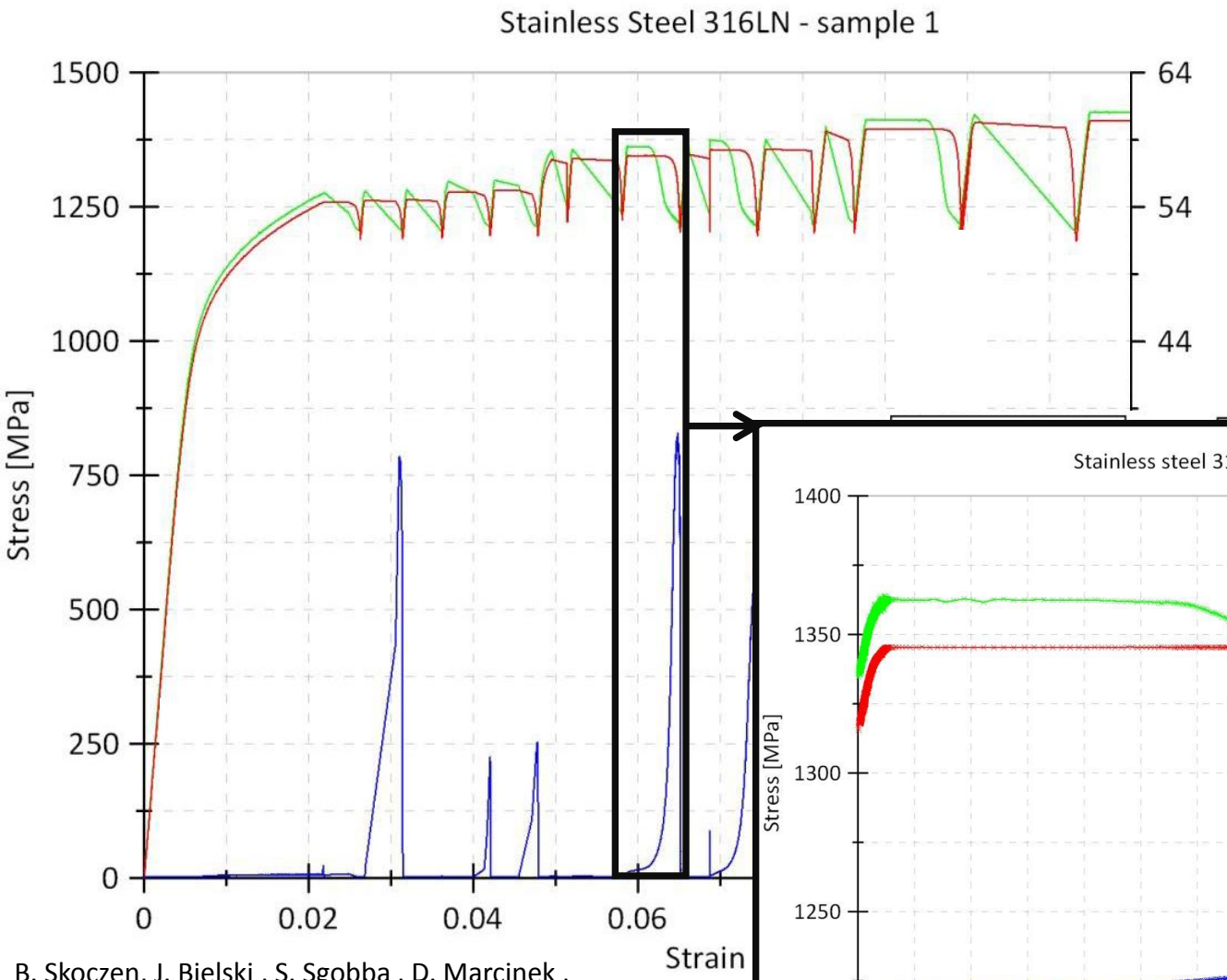


Temperature probe, CERNOX CX-1050-SD-30 (Lakeshore Cryotronics)**:**
thermal response time: 15 ms at 4 K
resolution: ± 15 mK



Carbon potentiometer: *range:* up to 50 mm *resolution:* 0.1 mm

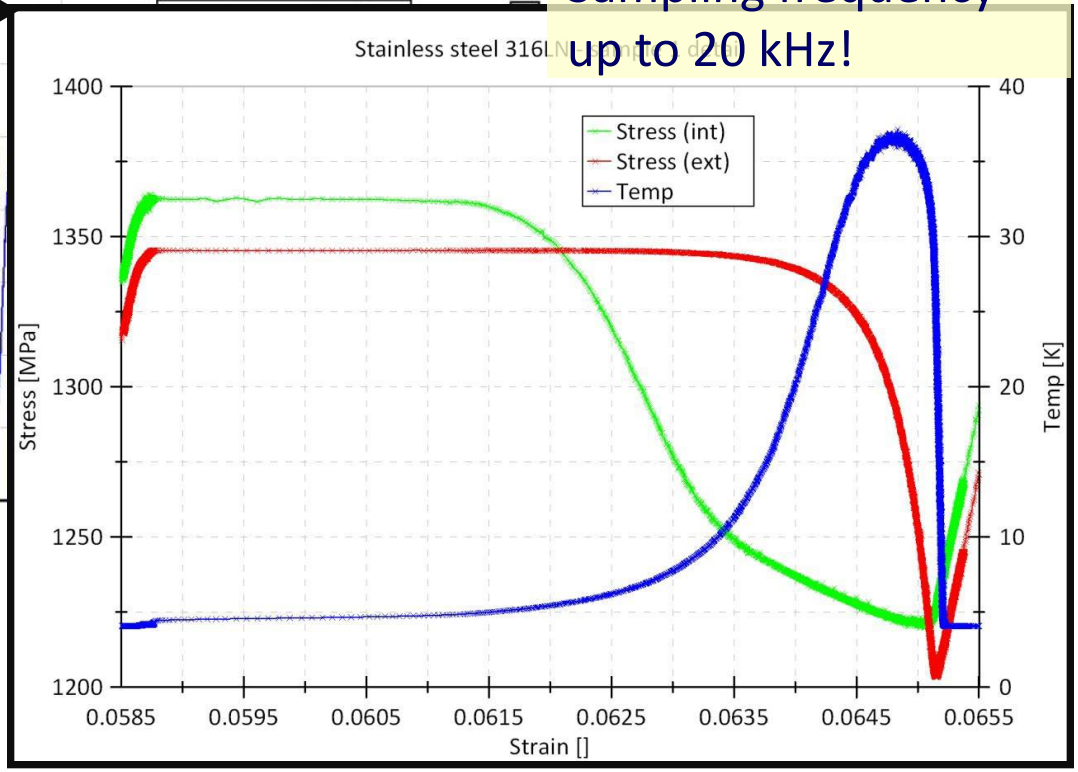
Evolution of the equipment

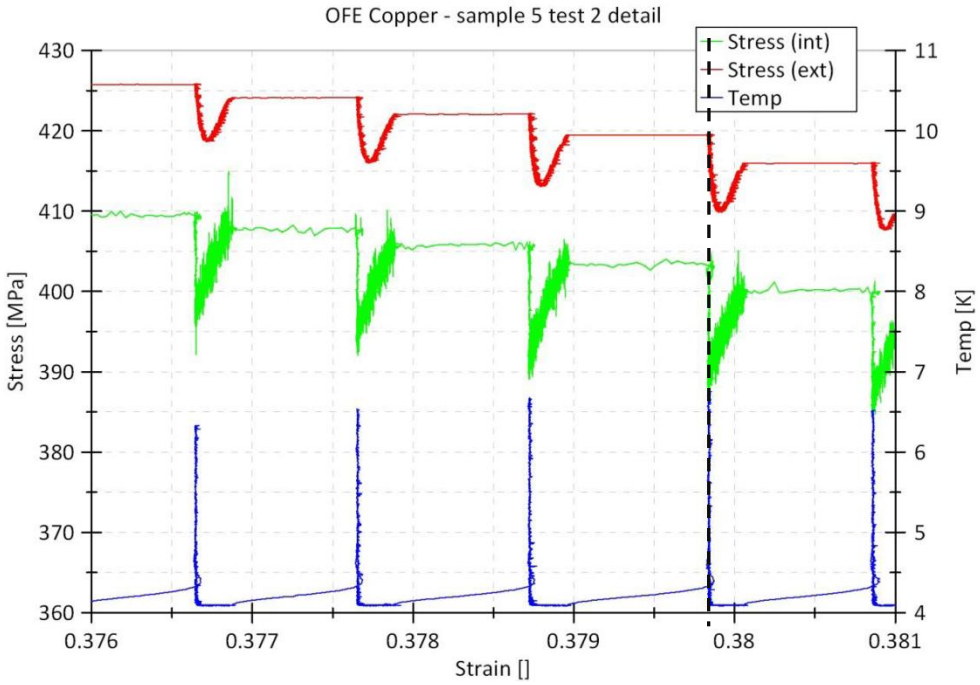


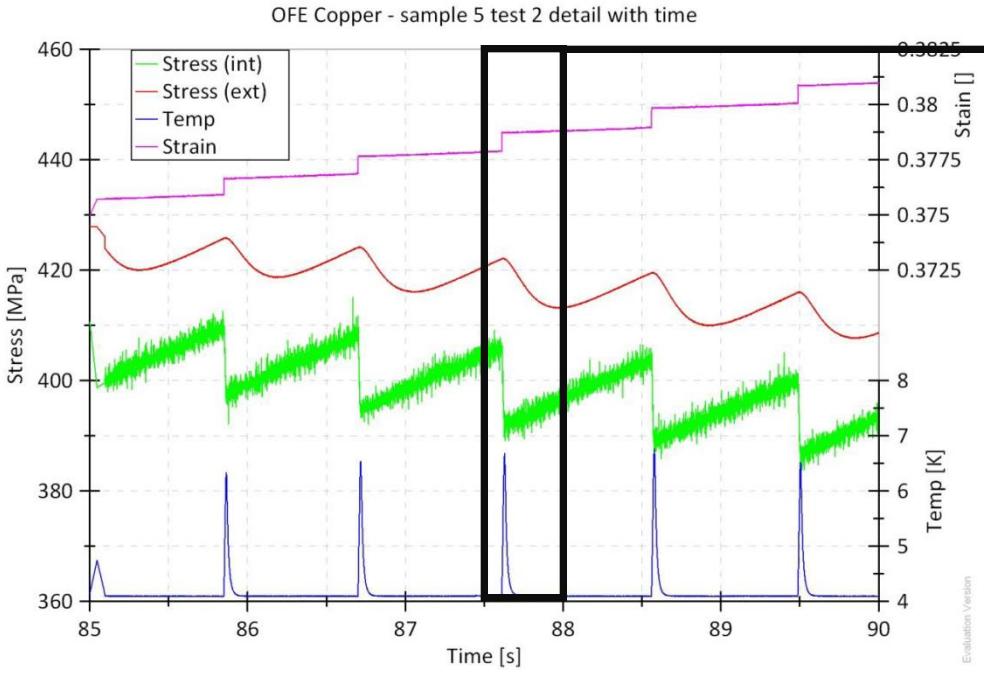
B. Skoczen, J. Bielski , S. Sgobba , D. Marcinek , *Constitutive model of discontinuous plastic flow at cryogenic temperatures,* International journal of plasticity, 26 (2010) 1659-1679

D. J. Marcinek, *Experimental Study of Discontinuous Plastic Flow, Phase Transformation and Micro-damage Evolution in Ductile Materials at Cryogenic Temperatures,* Master of Science Thesis, CERN and CUT, 2009

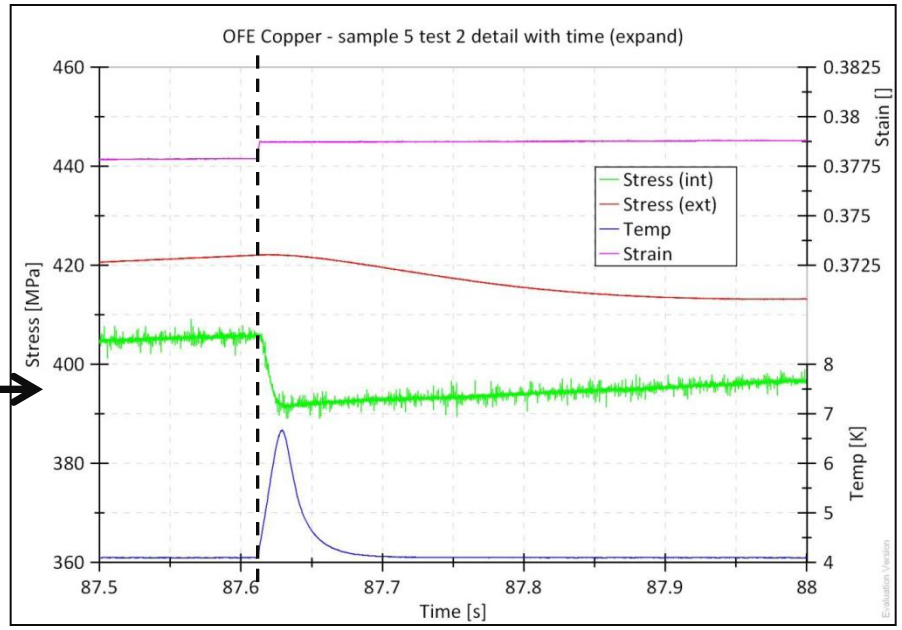
Sampling frequency up to 20 kHz!







OFE Cu, serrated yielding recorded during necking (engineering stress-engineering strain plot)



D. J. Marcinek, *Experimental Study of Discontinuous Plastic Flow, Phase Transformation and Micro-damage Evolution in Ductile Materials at Cryogenic Temperatures,* Master of Science Thesis, CERN and CUT, 2009

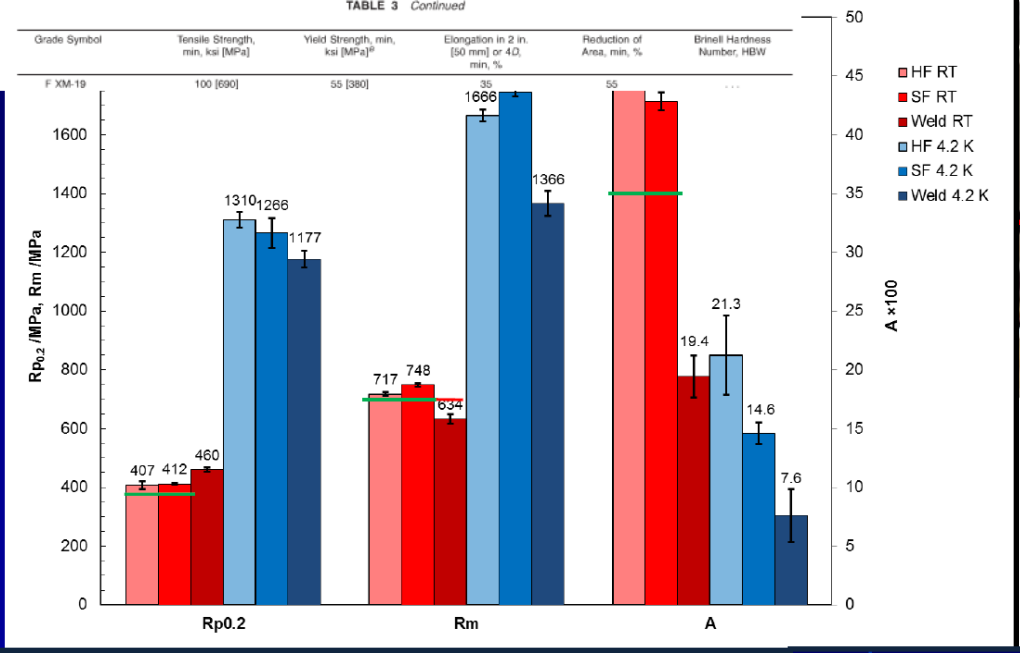
5.2 **Mechanical Testing**

The mechanical properties of forgings supplied under this specification shall meet the properties required by ASTM A182, Grade FXM-19.

A182/A182M – 10a

TABLE 3 *Continued*

Grade Symbol	Tensile Strength, min, ksi [MPa]	Yield Strength, min, ksi [MPa][B]	Elongation in 2 in. [50 mm] or 4D, min, %	Reduction of Area, min, %	Brinell Hardness Number, HBW
F XM-19	100 [690]	55 [380]	35	55	...

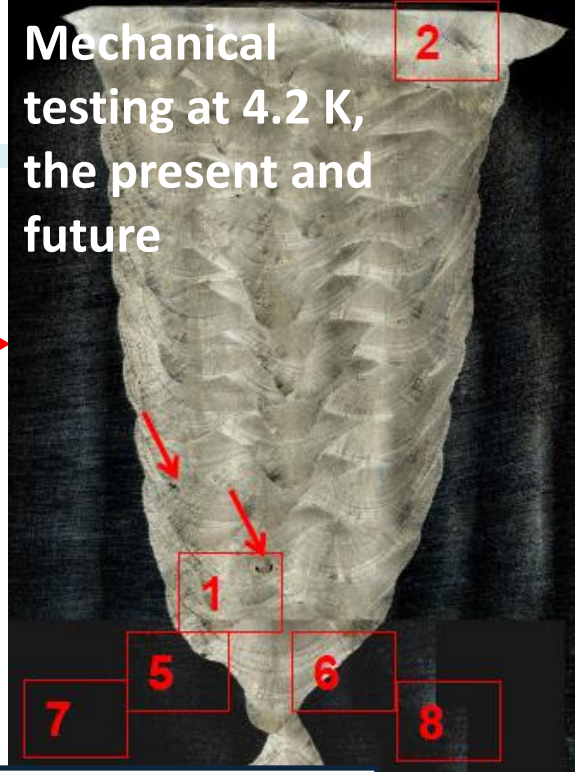


china eu india japan korea russia us

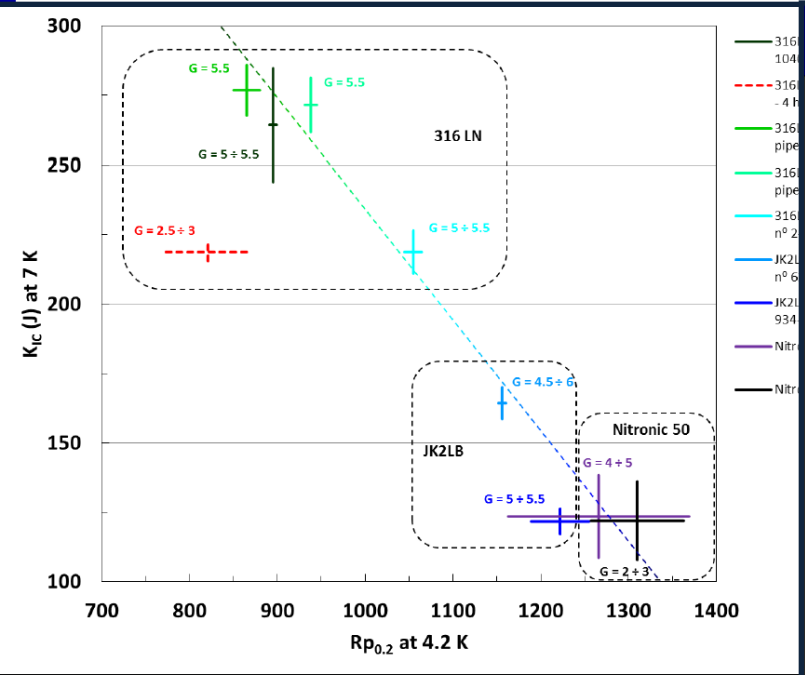
1/04/2012,

CERN

CS magnets



CERN + CEME

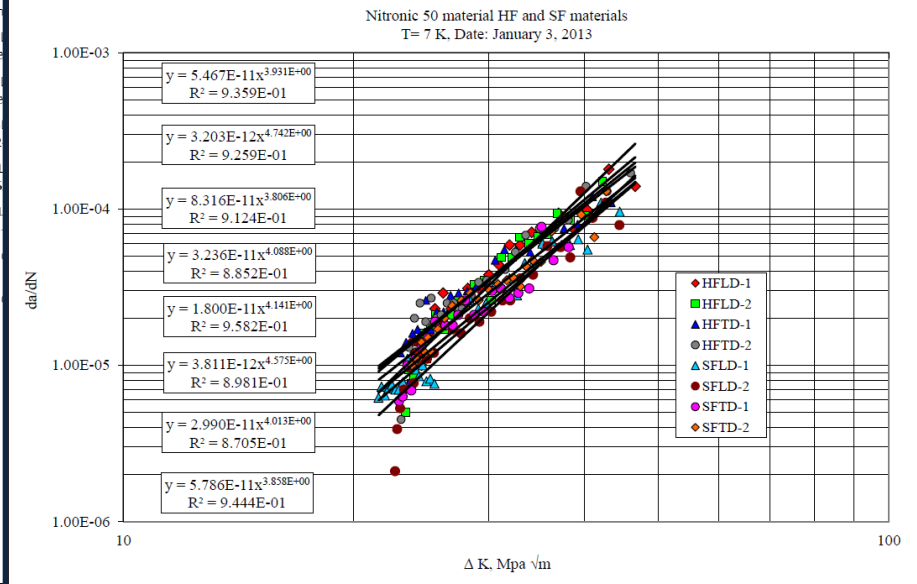


EN Engineering Department

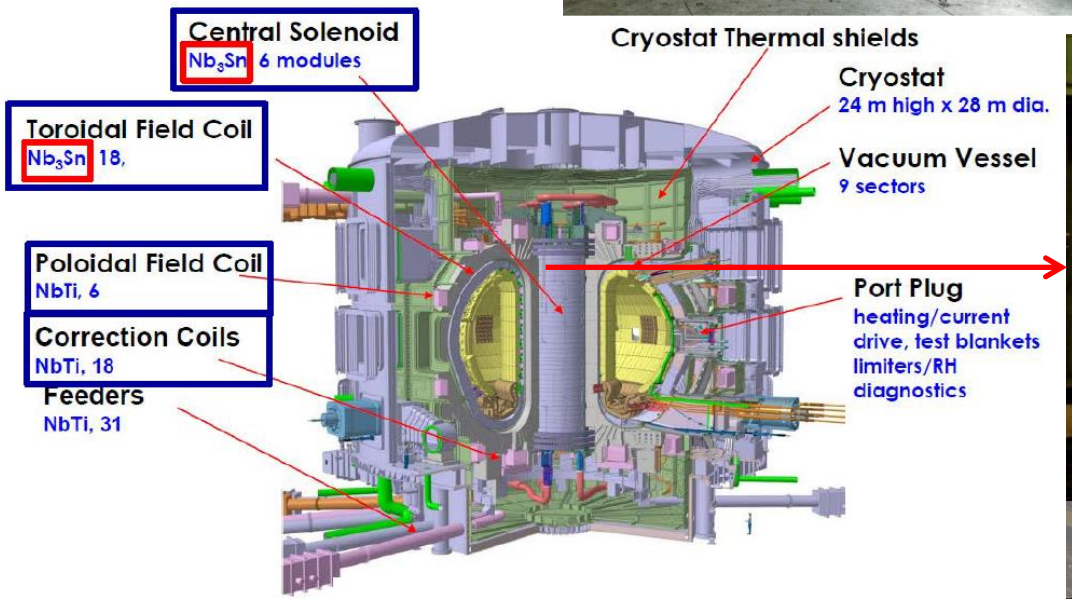
FCGR results Base metal

Document: 060741-14 © CEME: 2013

Fatigue crack growth rate and fracture toughness properties at 7 K of forged Nitronic 50 material and its welding



Courtesy of Kind



CS Nitronic 50 single piece, 15 m forged precompression tie plate, G & G Steel Inc., Russellville, AL /US

Non destructive testing

Visual testing, VT, two level 2 certified

Penetrant testing, PT, two level 2 certified

Ultrasonic testing, UT

Portable flaw detectors. *Krautkramer USN 60*

Gain 0 dB to 110 dB, probe from 0.25 MHz to 25 MHz,

Portable flaw detector with Phased Array mode. GE Phasor XS

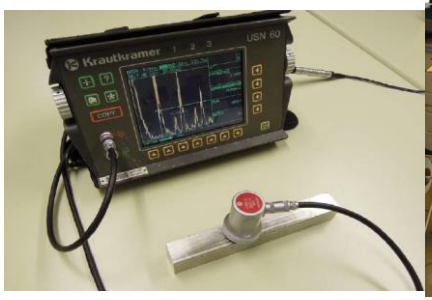
Gain 0 dB to 40 dB, probe from 0.5 MHz to 10 MHz,

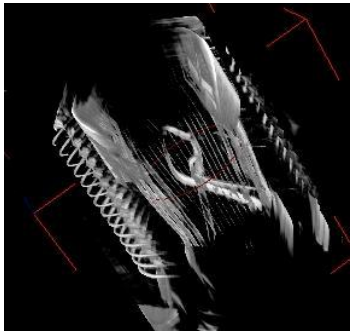
Various sectorial or linear transducers

Immersion tank scanner

Scan-surface: 500 mm x 500 mm, 0.1 MHz to 150 MHz

Level 3 and 2 certified operators





Radiographic testing, RT

Mobile X-ray computed tomogra

Mini-focus x-ray s

Flat panel detecto

Software for 3D r

X-ray sources. *Philips 160 kV*, 0.

Sieffert isovolt 16

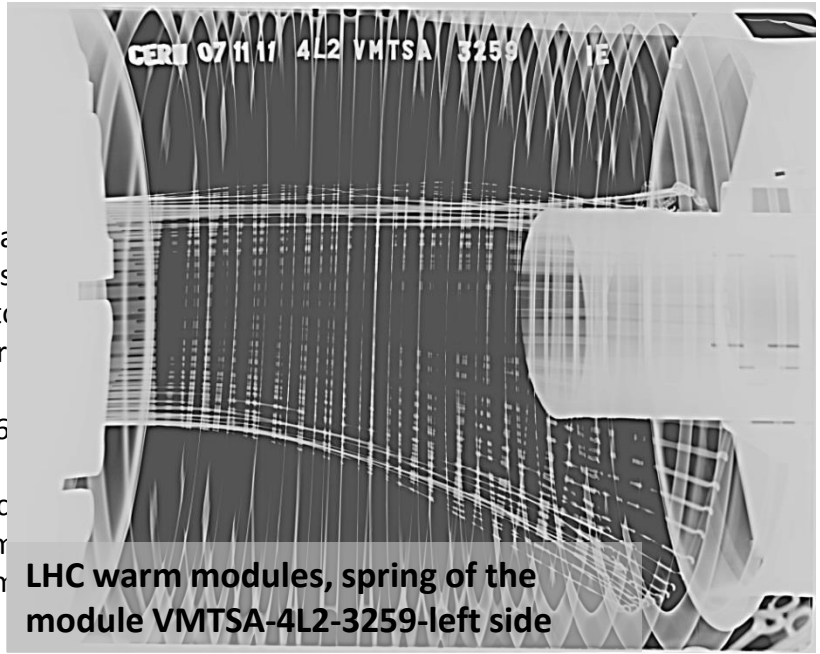
Computer radiography system

High definition sc

High resolution m

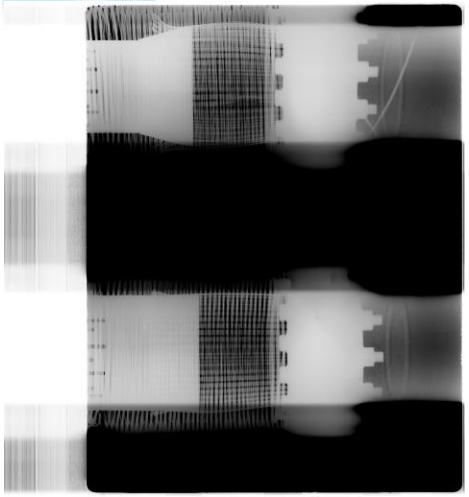
Controlled area (bunker) of 30 m

Level 2 certified operators

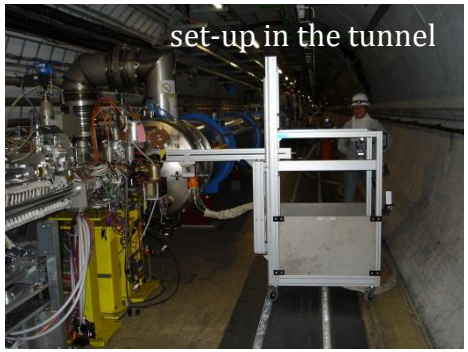


LHC warm modules, spring of the module VMTSA-4L2-3259-left side

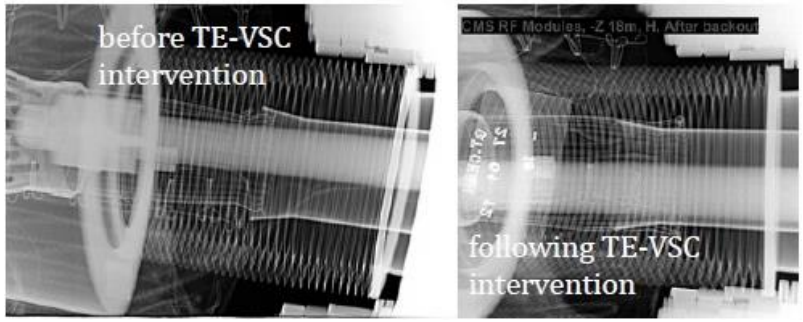
Non destructive testing

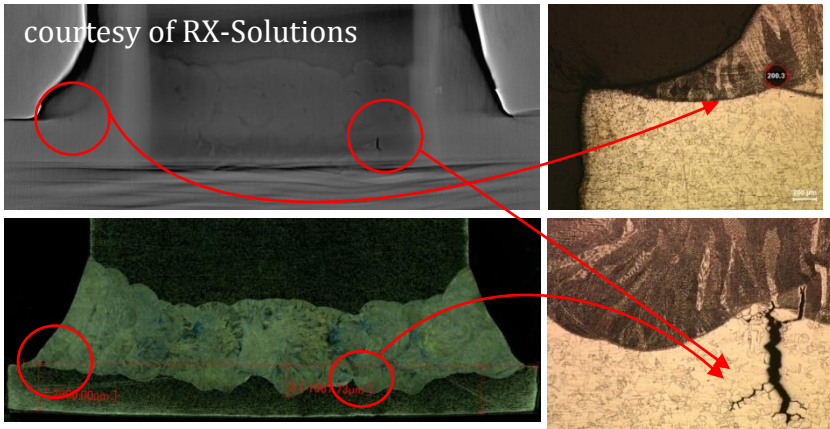


⇐ Computed Radiography Testing (RT) of LSS warm modules. Completion of the radiography campaigns during LHC technical stops. 1767 modules examined, 107 non-conformities identified to be repaired during LS_1, 46 nights.



⇓ Computed RT of CMS RF modules



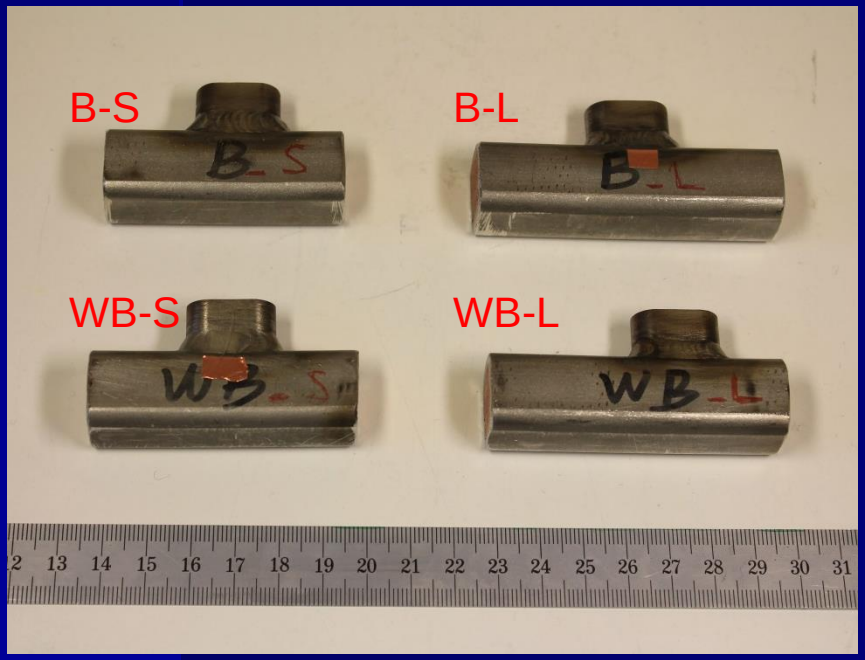


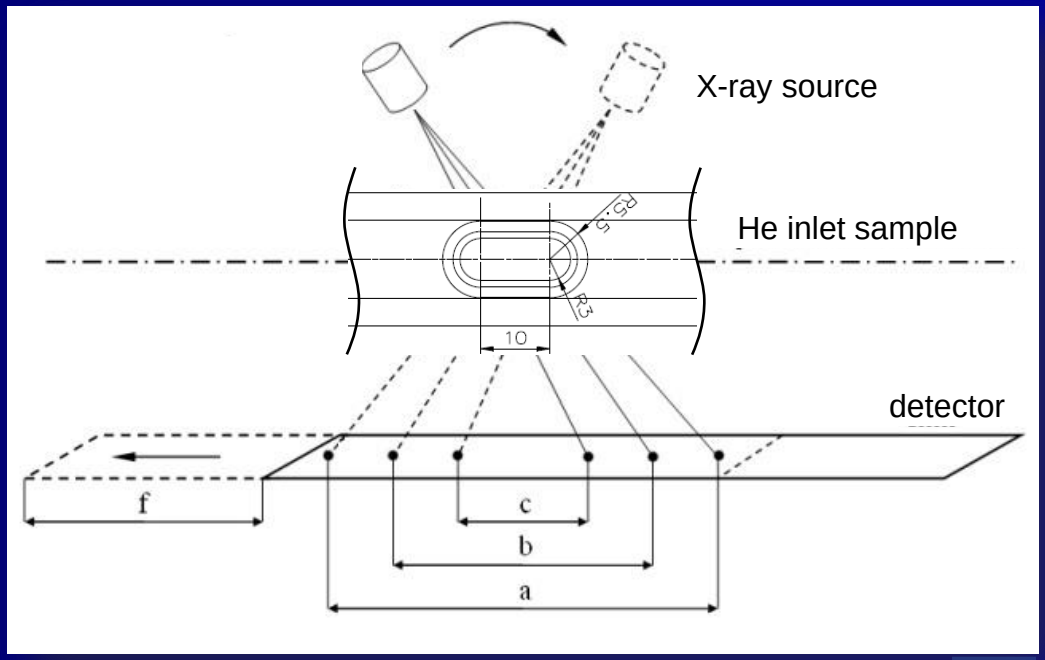
X-Ray tomography of ITER CC He-inlets: thin defects precisely identified and confirmed by metallography

⇐ Computed RT of ATLAS RF modules

Delivery and test description

- ITER CC He Inlets samples delivered to CERN by ASIPP in March 2013
- Two welded with buttering (B-L and B-S) and two without buttering (WB-L and WB-S)
- Laminography (planar tomography) of all four samples performed by RX Solutions /FR, allowing to access defects in the whole weld volume with higher resolution than through computed RT
- Classification following ISO 6520-1 and judged with respect to EN ISO 5817 - level B





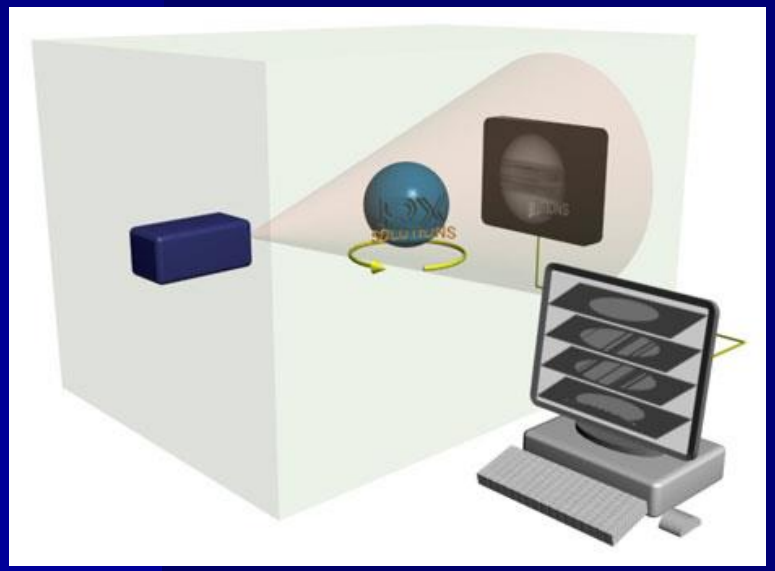
Laminography of WB-S sample

3D tomography
Technique description

Engineering Department

iter china eu india japan korea russia usa

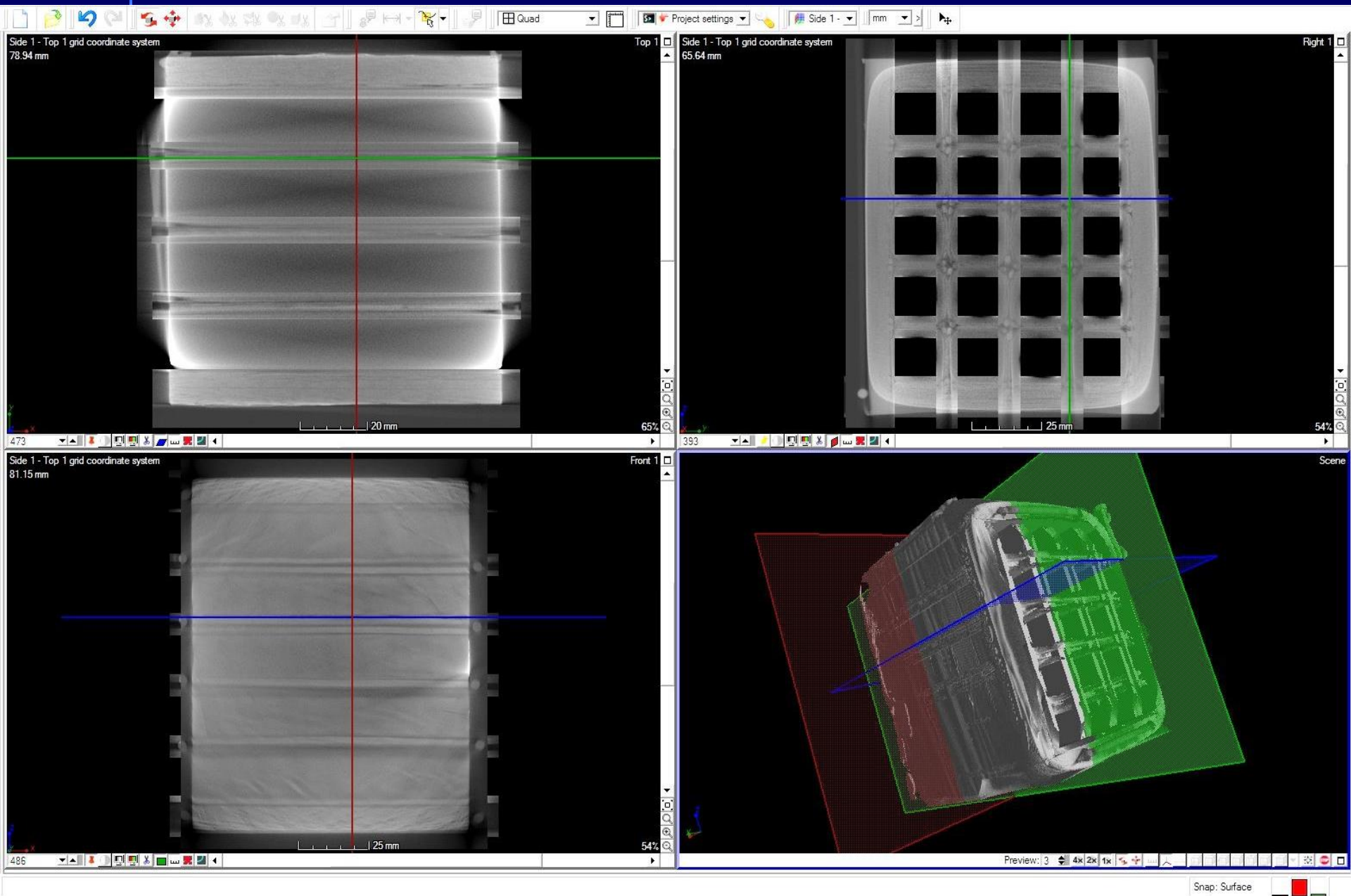
- Specimens placed on a mobile and rotatable stage
- Motorized zoom
- Full inspection of samples up to 240 mm length
- Sealed microfocus source, max. tension 150 kV
- HR area image sensor, 1920 pixels x 1536 pixels
- Detection surface: 200 mm x 250 mm
- 14 bits – 16000 gray levels
- 1-30 images /s



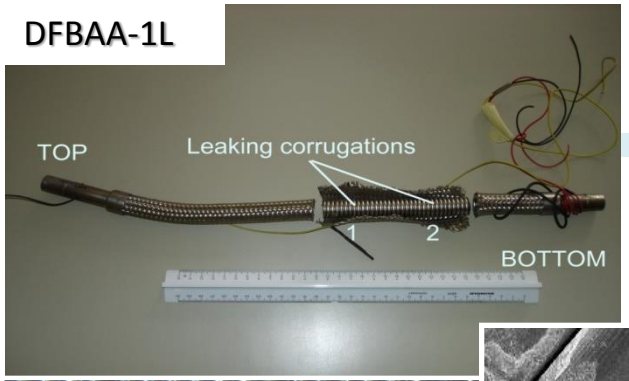
2nd sample of the VPI

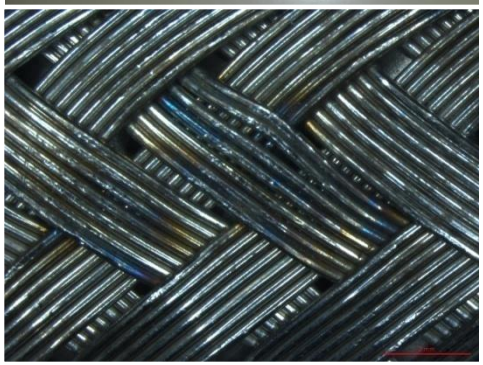
11 separate 360° scans were combined to compile a final single 3D object reconstruction while avoiding shadows due to steel conduits

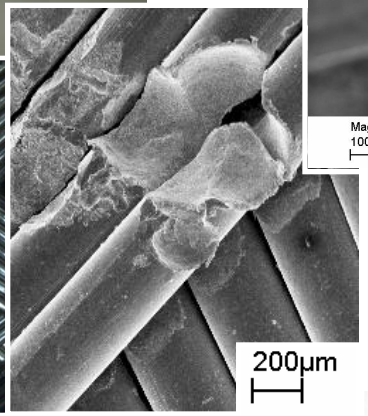
3D tomography
View in myVGL software

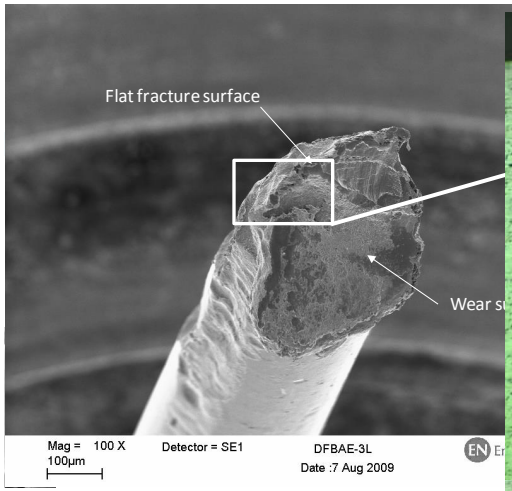


DFBAA-1L

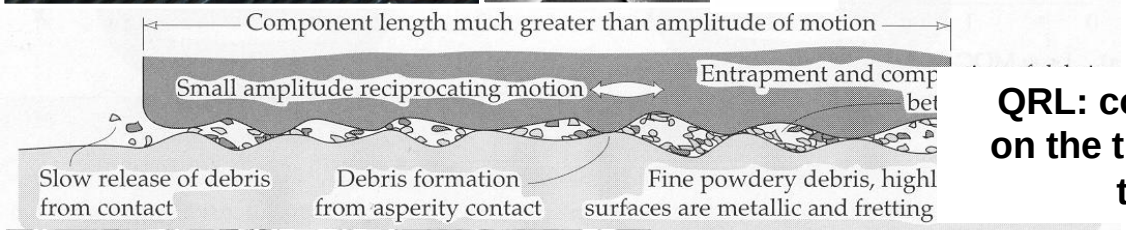






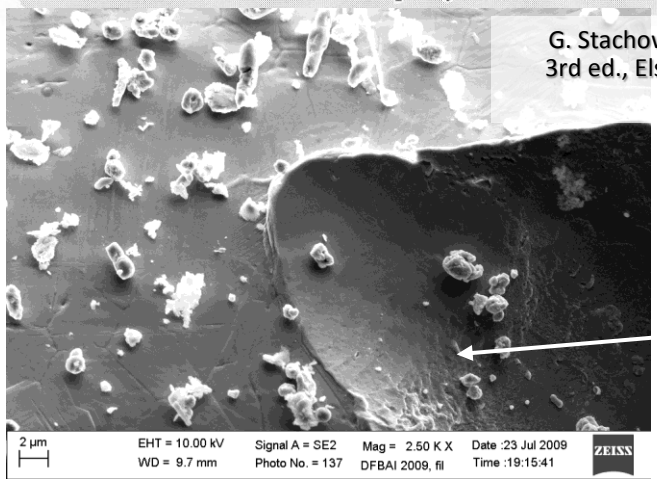


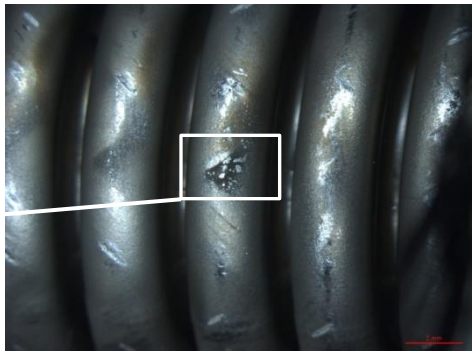
⇐ **Complex failure analysis of DFBA flexible metal hoses, TE-TM, 01/09/2009**

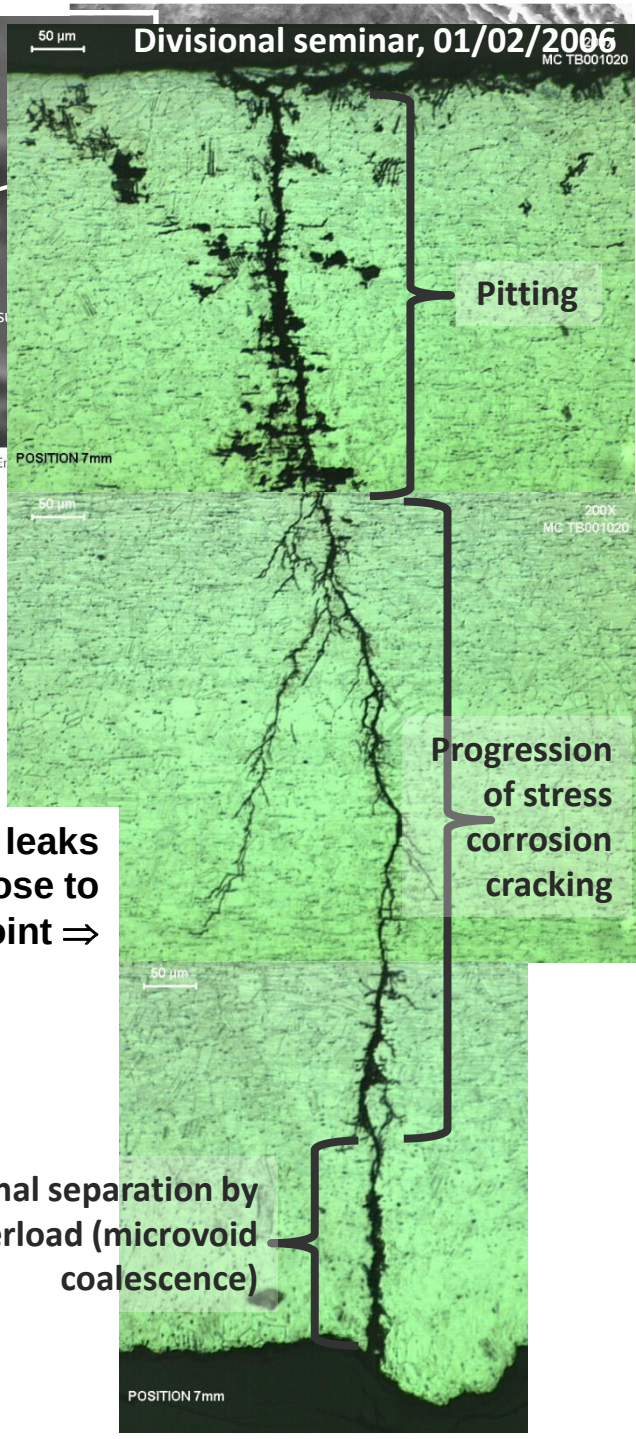


G. Stachowiak, A.W. Batchelor, Engineering Tribology, 3rd ed., Elsevier Butterworth-Heinemann, Amsterdam (2005)

QRL: corrosion leaks on the tube F close to the fix point ⇒

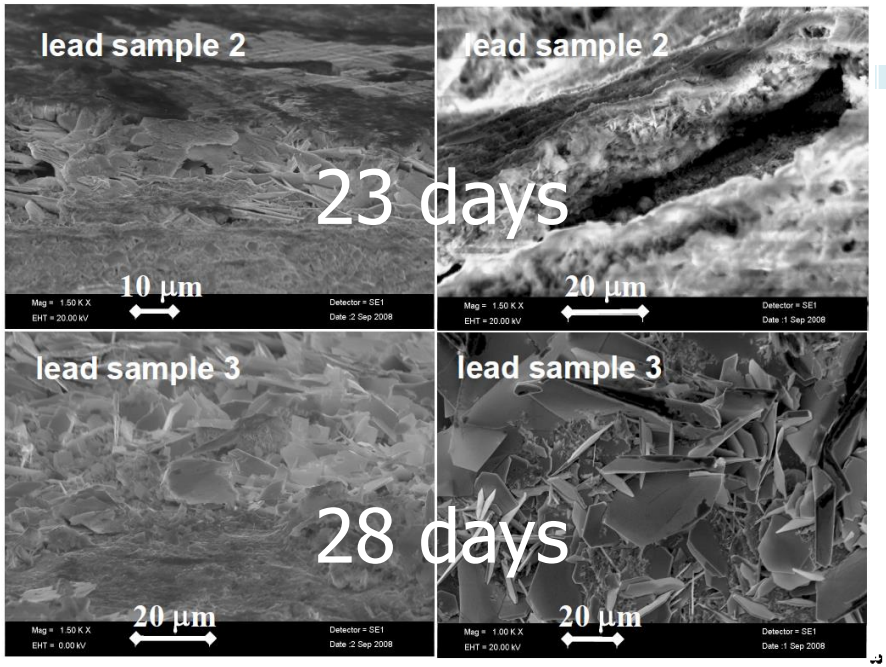




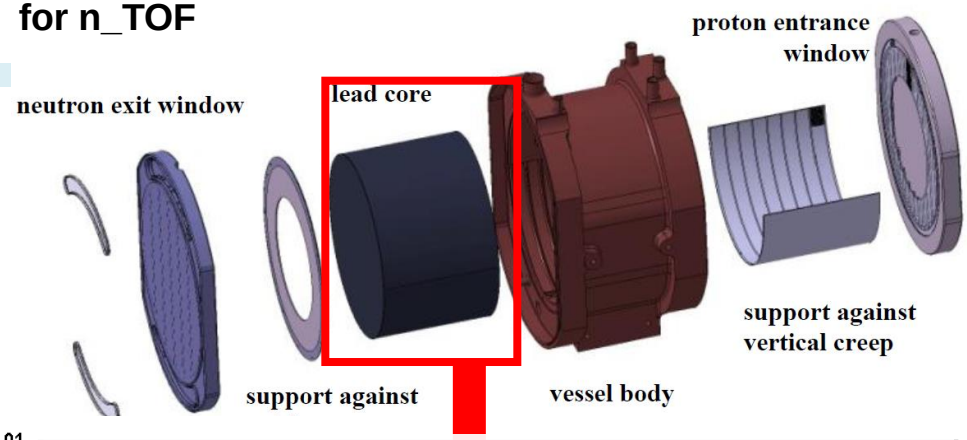


facing surface

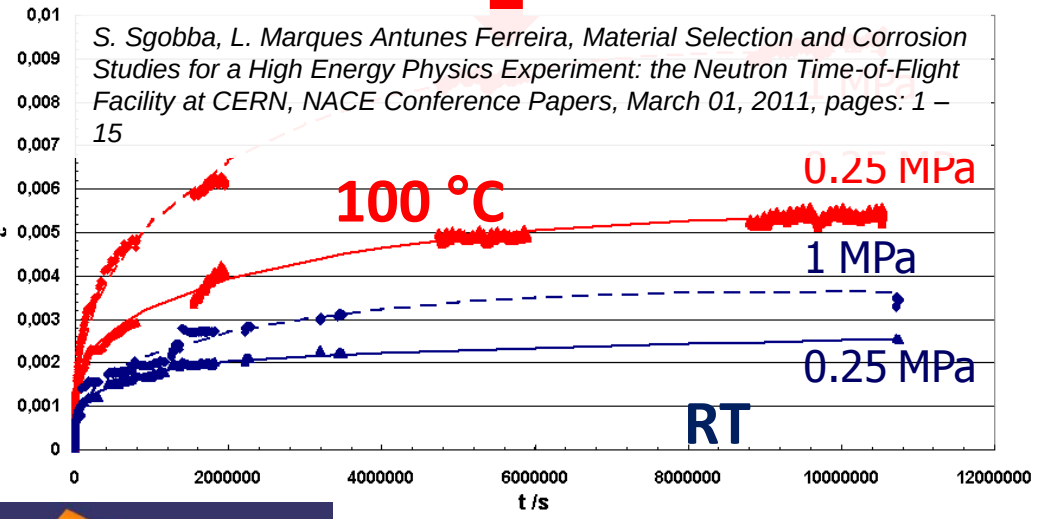
opposite surface



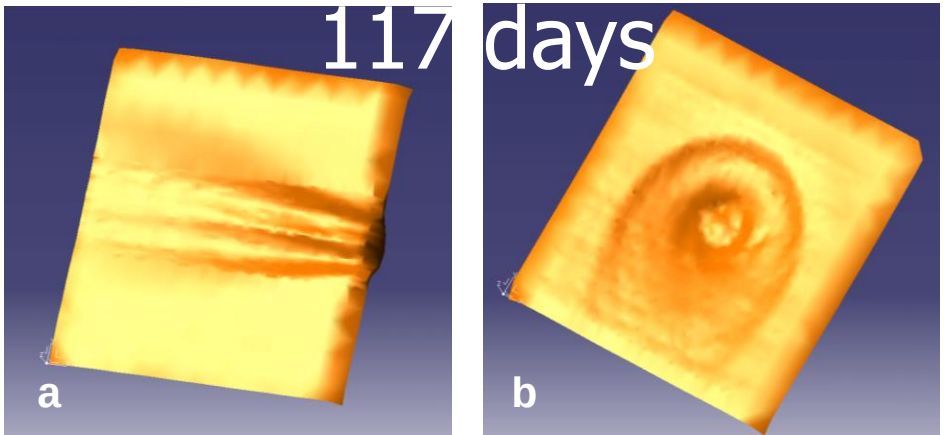
2008-2009, material selection and corrosion studies for n_TOF



S. Sgobba, L. Marques Antunes Ferreira, Material Selection and Corrosion Studies for a High Energy Physics Experiment: the Neutron Time-of-Flight Facility at CERN, NACE Conference Papers, March 01, 2011, pages: 1 – 15



erosion and impingement quantified by 3D metrology



Conclusions

- CERN-wide (and beyond) activity
- Limited but selected and highly specialized equipment
- Covers a wide range of materials, welds and components
- Provides support to CERN stores (specifications, identification of suppliers, audit…)
- Several decades of experience, including audit and follow-up of industrial production
- In house expertise completed by an extensive network
- Prone to intervene in or pilot activities with a strong emphasis on materials or controls
- Section very exposed to international exchanges and contacts:
    - Industrial partners
    - National labs, academy
    - CERN-ITER cooperation agreement (IO, DAs via IO)
- Training of students and fellows, hosted a large (3 digit) number of trainees since the creation of the section in the early 90ies