10TH ECNDT Moscow 2010, June 7-11

SIMULATION OF ULTRASONIC, EDDY CURRENT AND RADIOGRAPHIC TECHNIQUES WITHIN THE CIVA SOFTWARE PLATFORM

Ph. DUBOIS*, S. LONNÉ*, F. JENSON and S. MAHAUT****

*   EXTENDE, 86 rue de Paris, 91400 ORSAY, France
** CEA, LIST, F-91191 Gif-Sur-Yvette, France

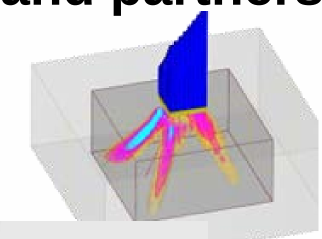
OUTLINE

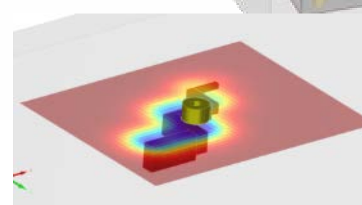
- **Introduction**
- **UT simulation**
  - **Coarse grain structures**
  - **3D CAD geometry**
- **ET simulation**
  - **Simulation with combined flaws**
  - **GMR's sensors**
- **RT simulation**
  - **Generalities**
  - **Weld inspection**
- **Conclusion**

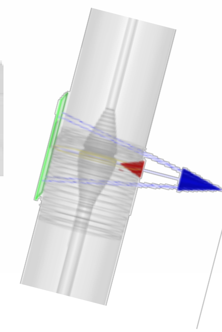
Introduction

- **Use of simulation in NDT**
  - Design of new methods and probes (e.g. phased arrays)
  - Qualification of methods, performance demonstration
  - Interpretation of complex results, automatic diagnosis
  - « Virtual testing » at the designing stage of parts
  - Training

- **Development of the CIVA software by CEA-LIST and partners**
  - Multi-technique platform: UT, ET and RT
  - Used by more than 130 companies in the world
  - Validation within international benchmarks







- **Distributed by** EXTENDE CIVA

- **This presentation: new skills in UT, RT, ET simulation with CIVA 10 (to be released by end of June)**

OUTLINE

- Introduction
- UT simulation
  - Coarse grain structures
  - 3D CAD geometry
- ET simulation
  - Simulation with combined flaws
  - GMR's sensors
- RT simulation
  - Generalities
  - Weld inspection
- Conclusion

UT: Coarse grain structures

Motivation

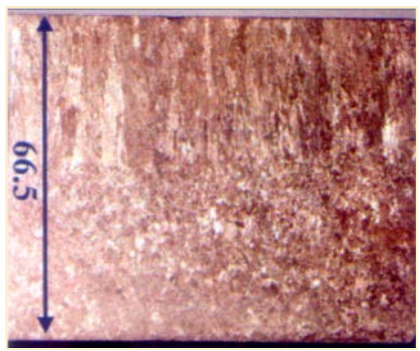
- Detection and characterization of defects in Centrifugally Cast Stainless Steel components (CCSS)

Background

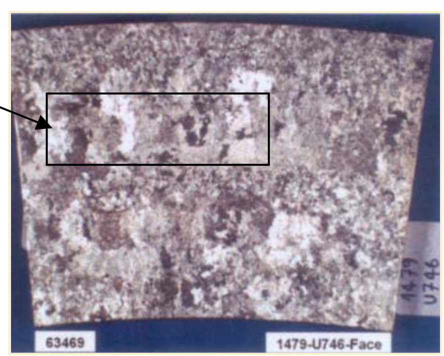
- Inspection difficulties due to the particular metallurgical structure of such materials
  - large grains (up to 20 mm)
  - heterogeneous equiaxed / columnar structure
  - stratified structure

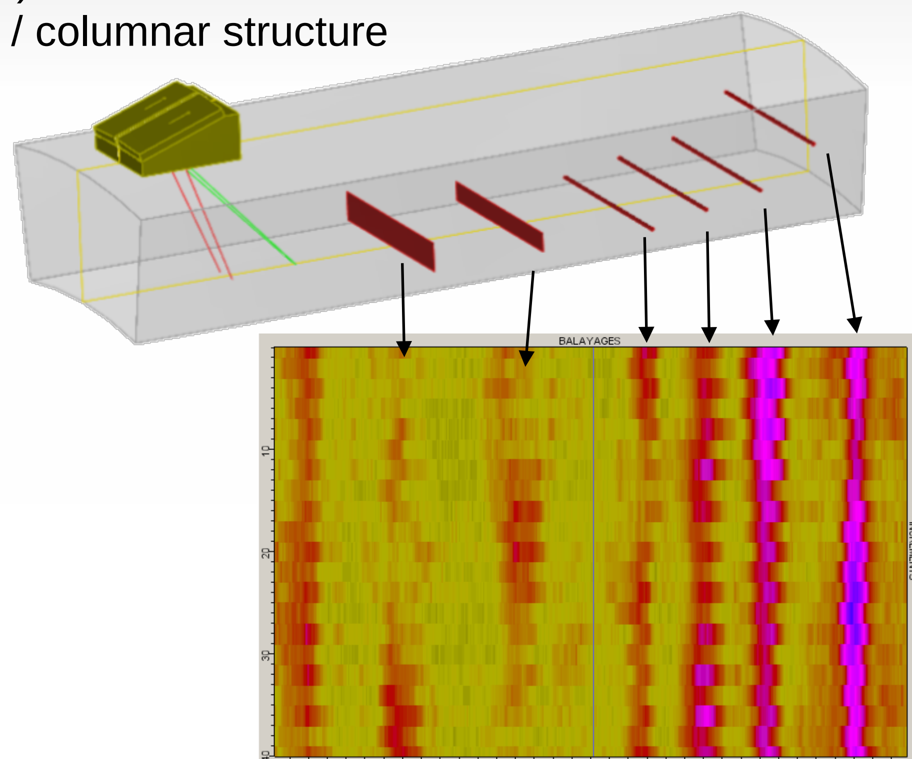
Columnar grains

Equiaxed grains



Large grains





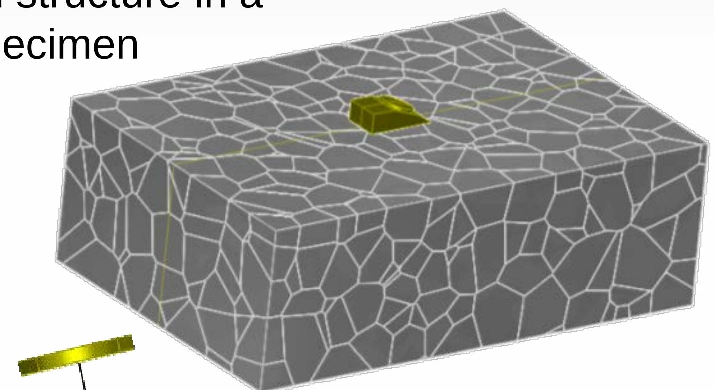
Strong variability of the echoes depending on the transducer position

UT: Coarse grain structures

Modeling Approach

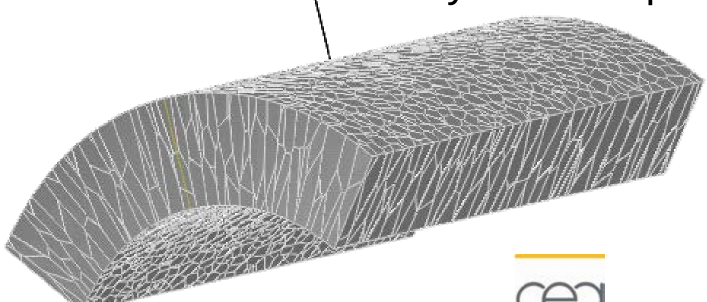
1. Structure description using Voronoï diagrams

- Equiaxed structure in a planar specimen



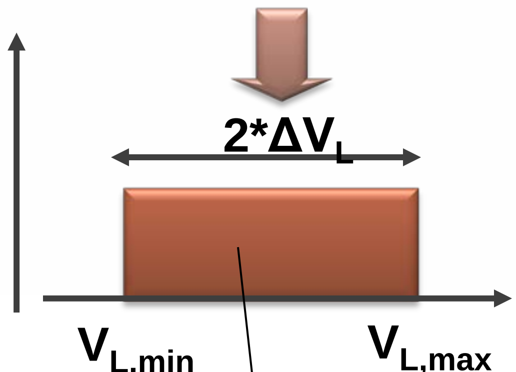
CIVA NDE 10

- Columnar structure in a cylindrical specimen

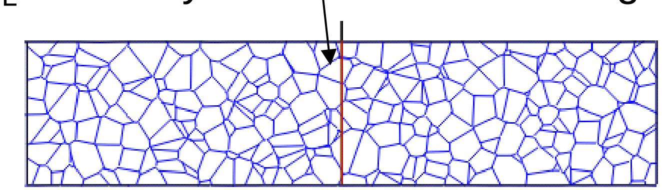


2. Description of elastic properties

- Isotropic elastic material properties
- Velocity values (VL) for each cells are fixed randomly by using a uniform distribution



V_L randomly fixed for each macro-grain

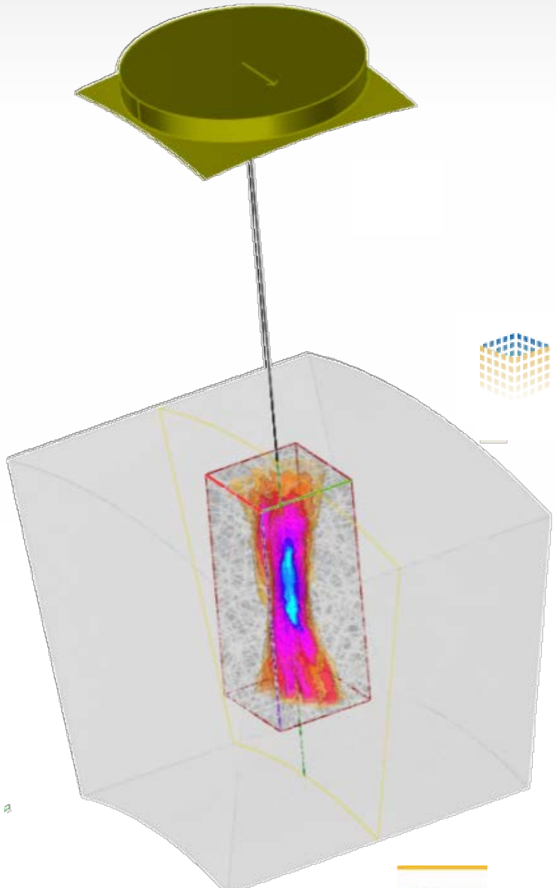


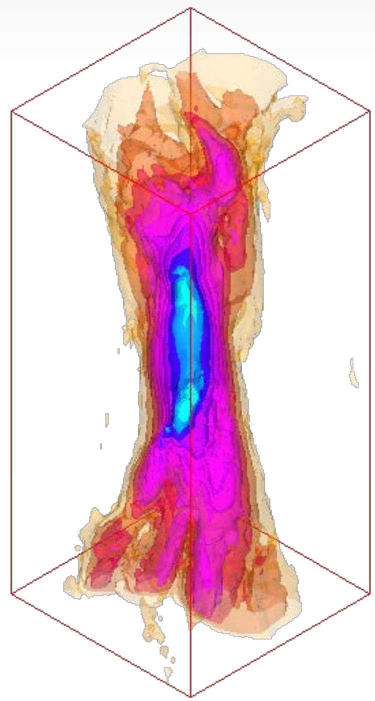
cea list EXTENDE CIVA

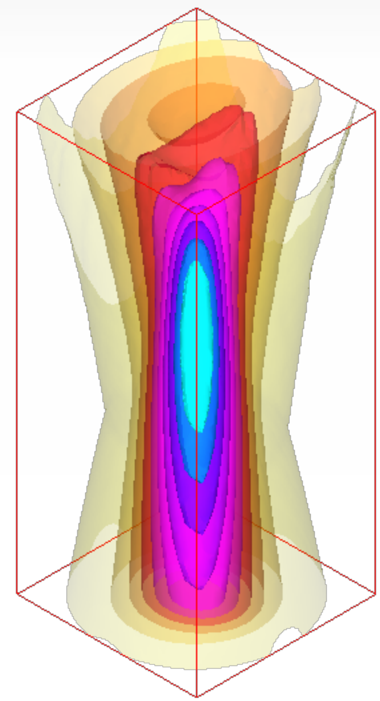
UT: Coarse grain structures

Radiated Beam simulation

- Focused probe, 1 MHz, 0° L-waves
- Voronoï description : 800 cells (mean size ~10 mm), DVL=3%







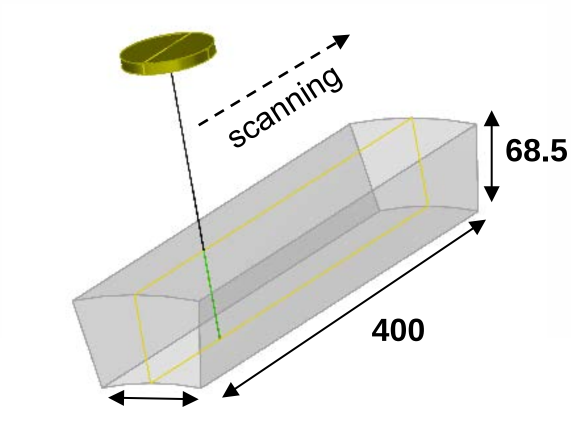
- Coarse structure
- Homogeneous steel

UT: Coarse grain structures

Back-wall echo measurement for various probe positions

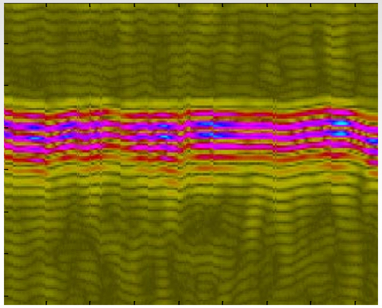
Back-wall echo measurement setup

- **Inspection setup**
  - L0
  - 1 MHz
  - H_{water}=150 mm
  - P_{focus}=70mm



External radius : 417 mm

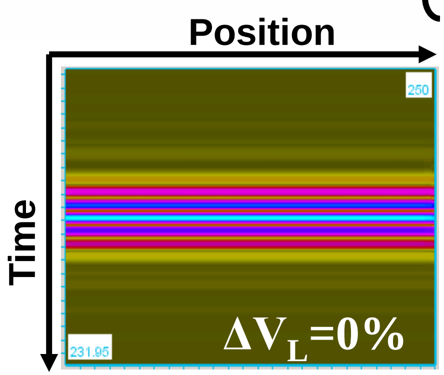
Probe displacement along the cylinder axis

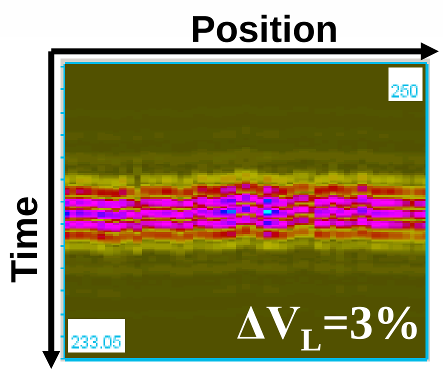


Displacement: 0-250 mm

Back-wall echo simulation

Voronoi diagram
- # cells = 1500
- Mean cell size ≈ 12 mm





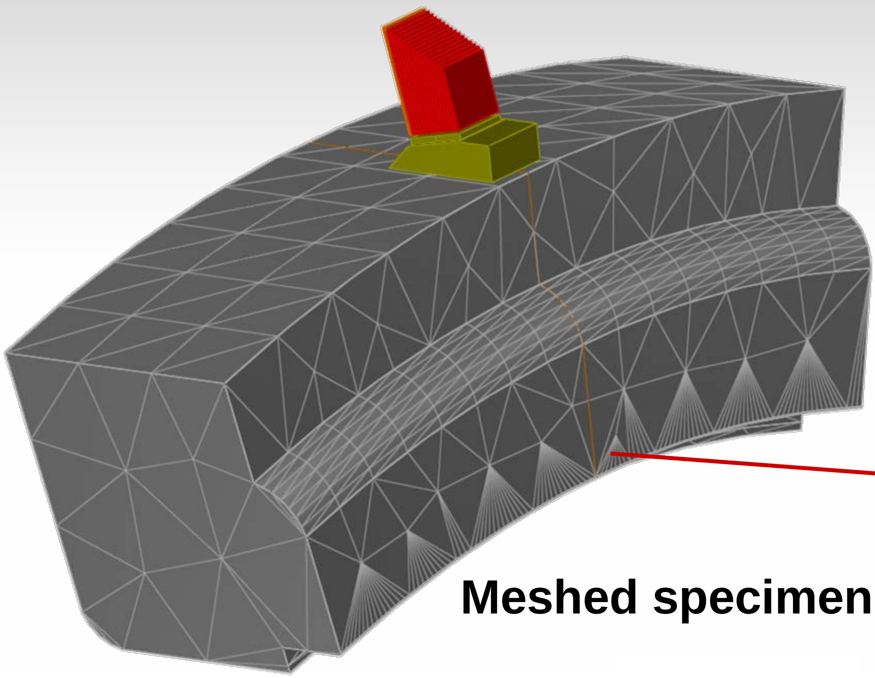
OUTLINE

- Introduction
- **UT simulation**
  - Coarse grain structures
  - **3D CAD geometry**
- ET simulation
  - Simulation with combined flaws
  - GMR's sensors
- RT simulation
  - Generalities
  - Weld inspection
- Conclusion

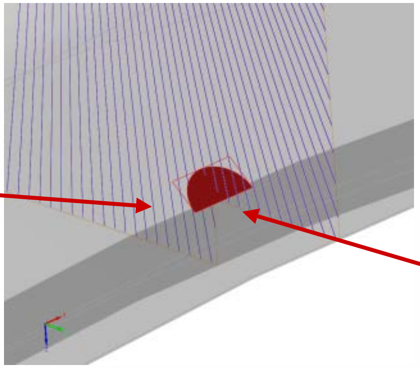
UT: Flaw detection in 3D CAD test pieces

3D CAD part inspection

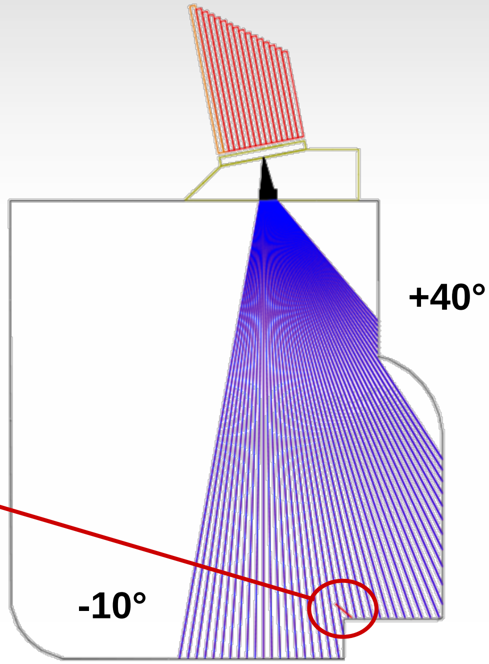
Use of a phased array sectorial technique for detection of a crack close to the vertical wall (no available scanning close to the edge)



Meshed specimen



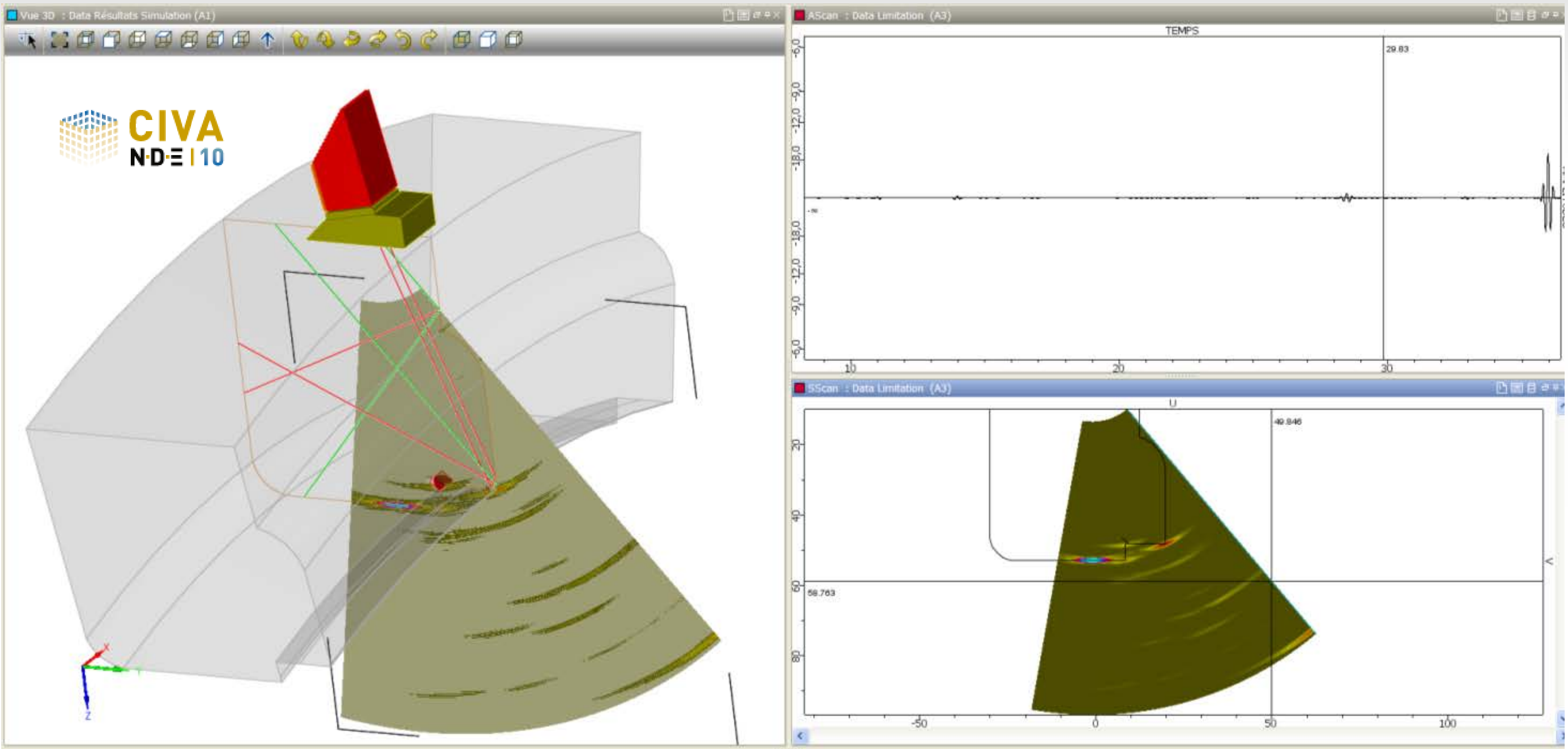
Tilted flaw
(semi-elliptical shape)



- **UT simulation accounts for :**
  - **Longitudinal + Transverse + Converted Modes**
  - **Echoes of the specimen boundaries + interaction with the flaw**

UT: Flaw detection in 3D CAD test pieces

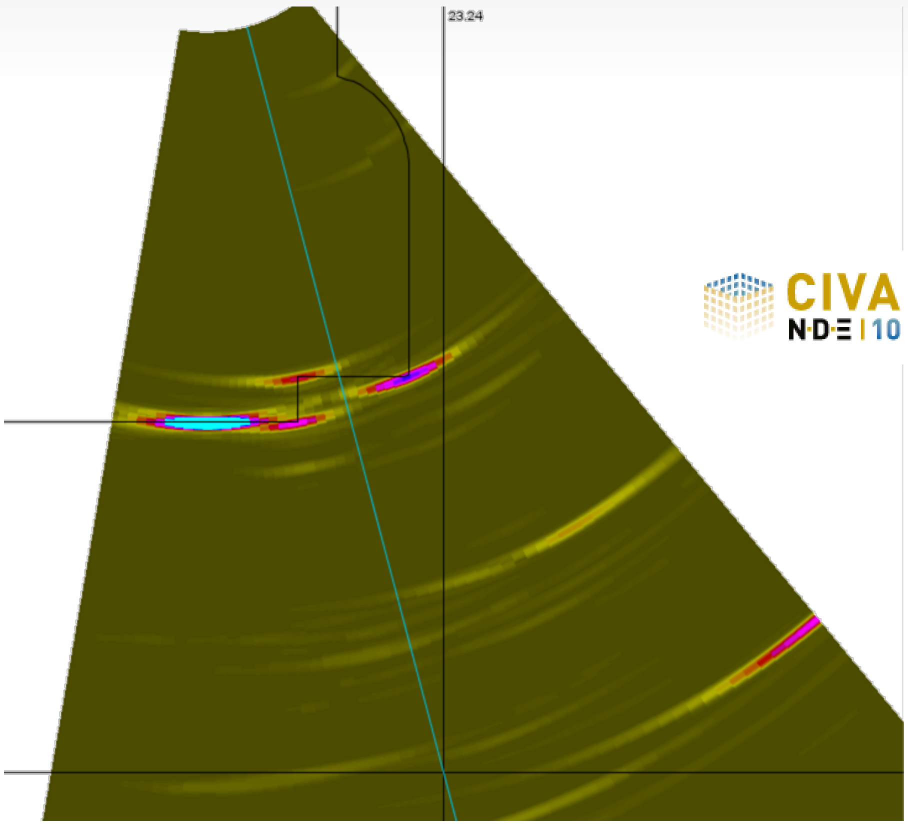
UT simulation result with back wall + flaw echoes (all L and T modes)



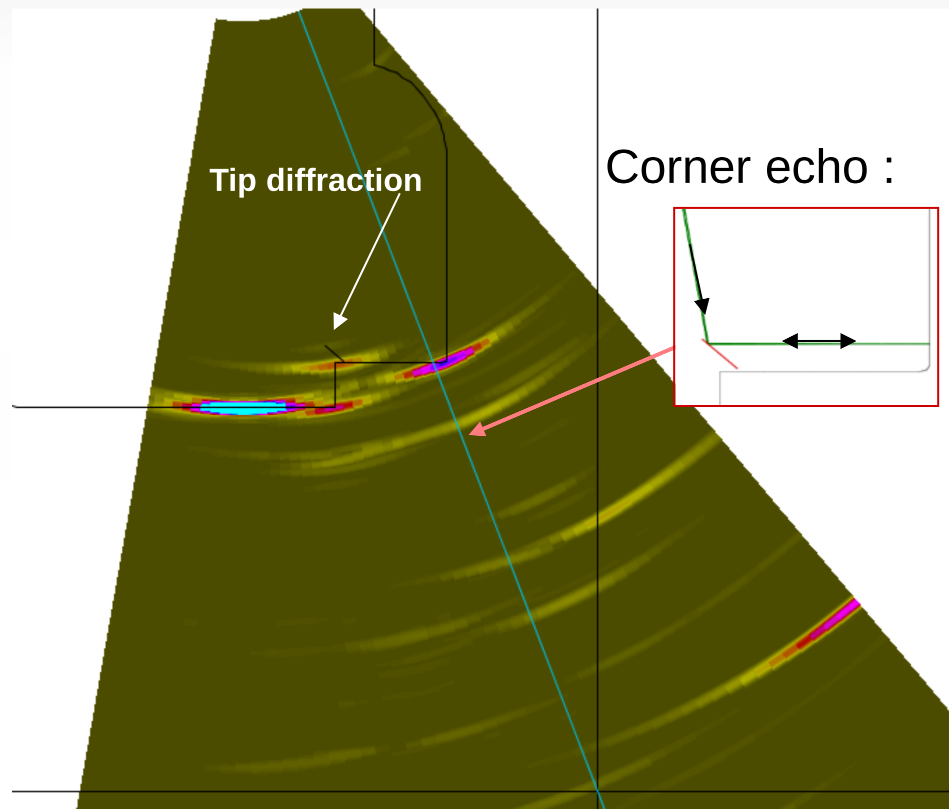
UT: Flaw detection in 3D CAD test pieces

Interpretation: comparison between computation with and without the flaw

- **UT simulation WITHOUT flaw : only geometrical echoes**



- **UT simulation WITH a flaw: geometrical echoes + echoes from the flaw**



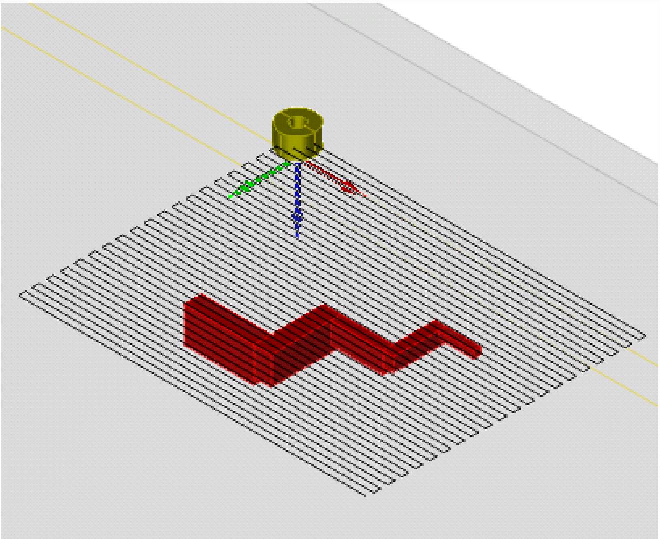
OUTLINE

- Introduction
- UT simulation
  - Coarse grain structures
  - 3D CAD geometry
- **ET simulation**
  - **Simulation with combined flaws**
  - GMR's sensors
- RT simulation
  - Generalities
  - Weld inspection
- Conclusion

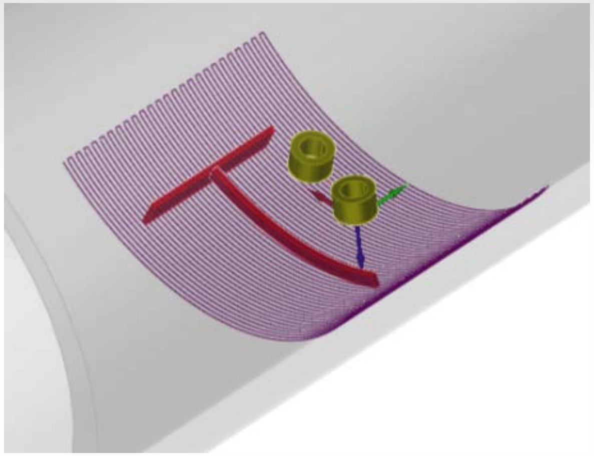
ET: Simulation with “Combined” flaws

- CIVA 10 allows defining several flaws in a given configuration
- Interactions between various flaws are accounted for
- Typical configurations are as following:

  - **Plates**

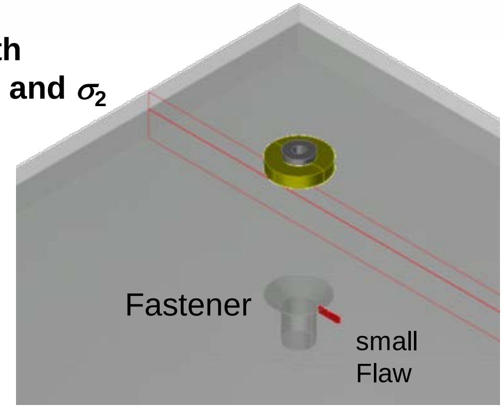


  - **Tubes**



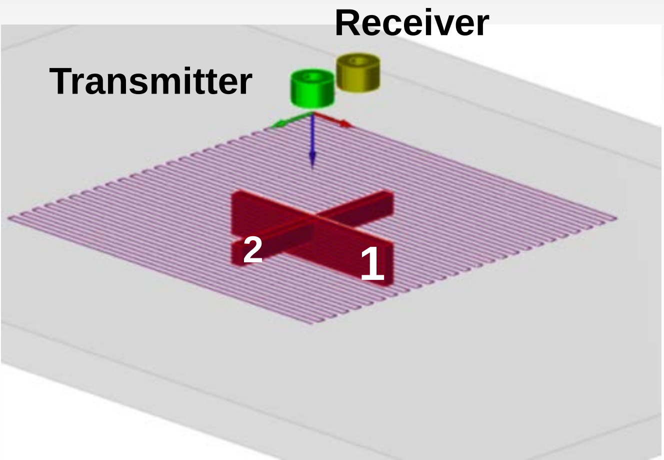
  - **Riveted structures**

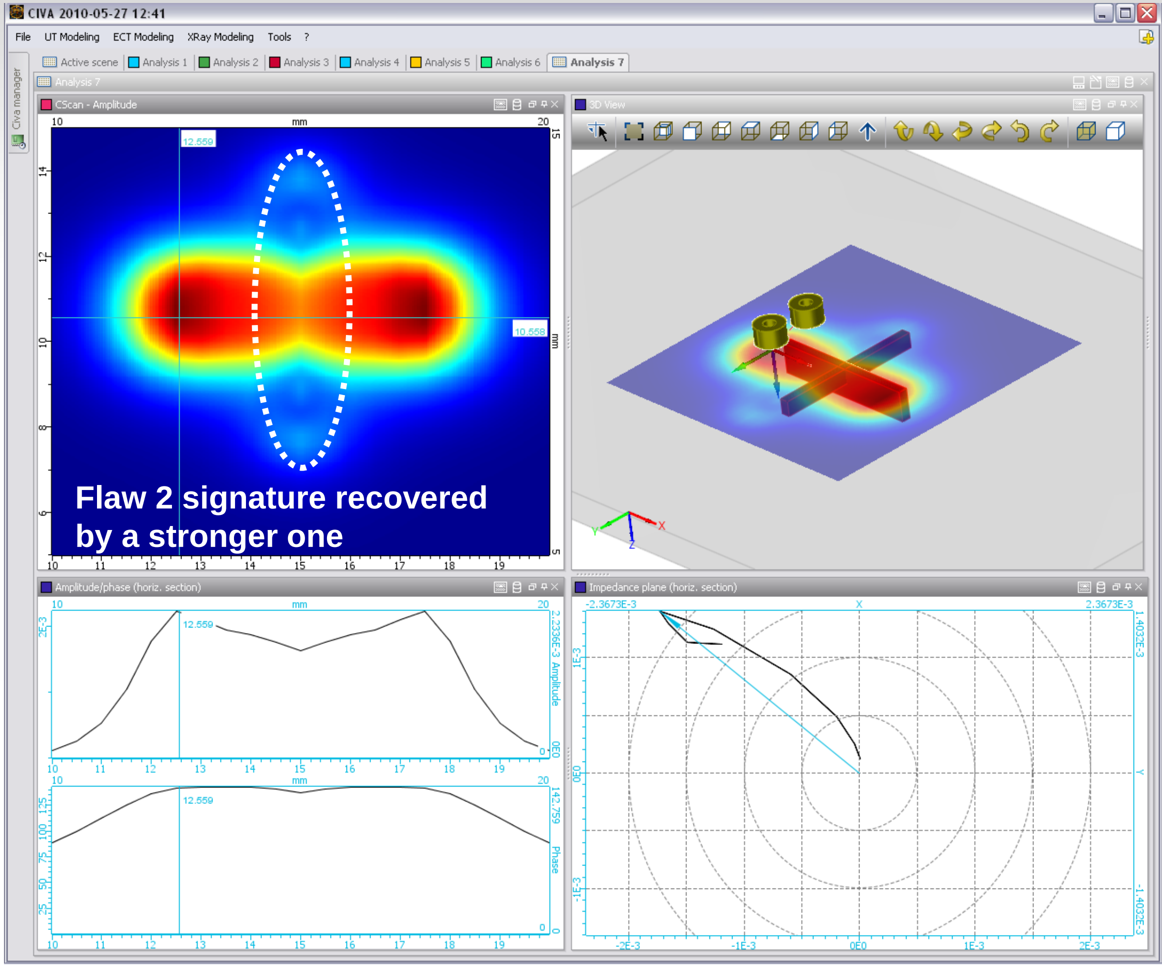
2 layers with conductivities σ_1 and σ_2



ET: Simulation with “Combined” flaws

SIMULATION example

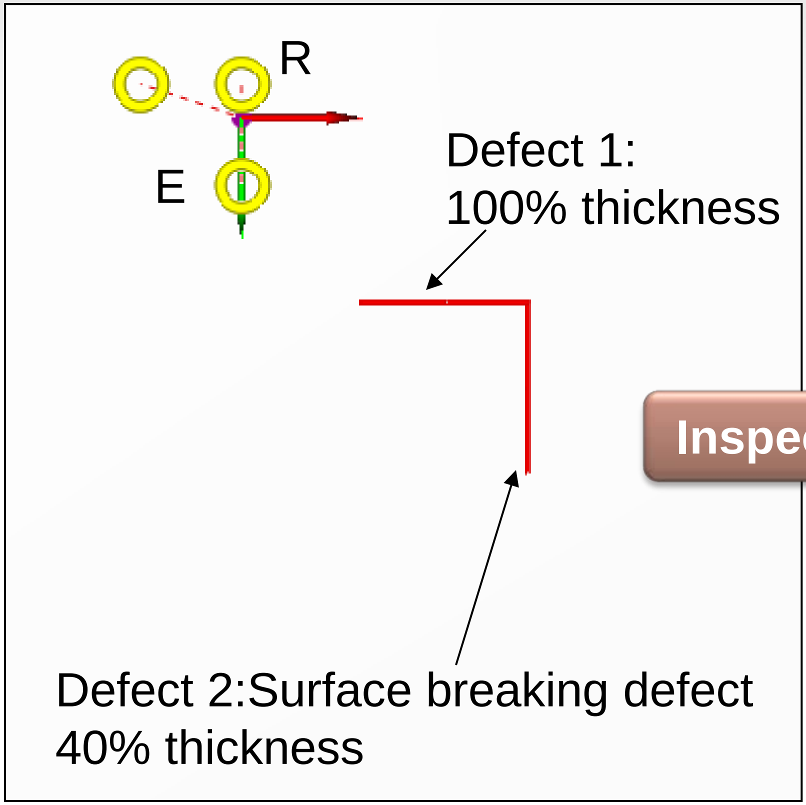




- Frequency 100 kHz
- Inconel plate
- Flaw n°1 : 100% thickness
- Flaw n°2 : 50% thickness

ET: Simulation with “Combined” flaws

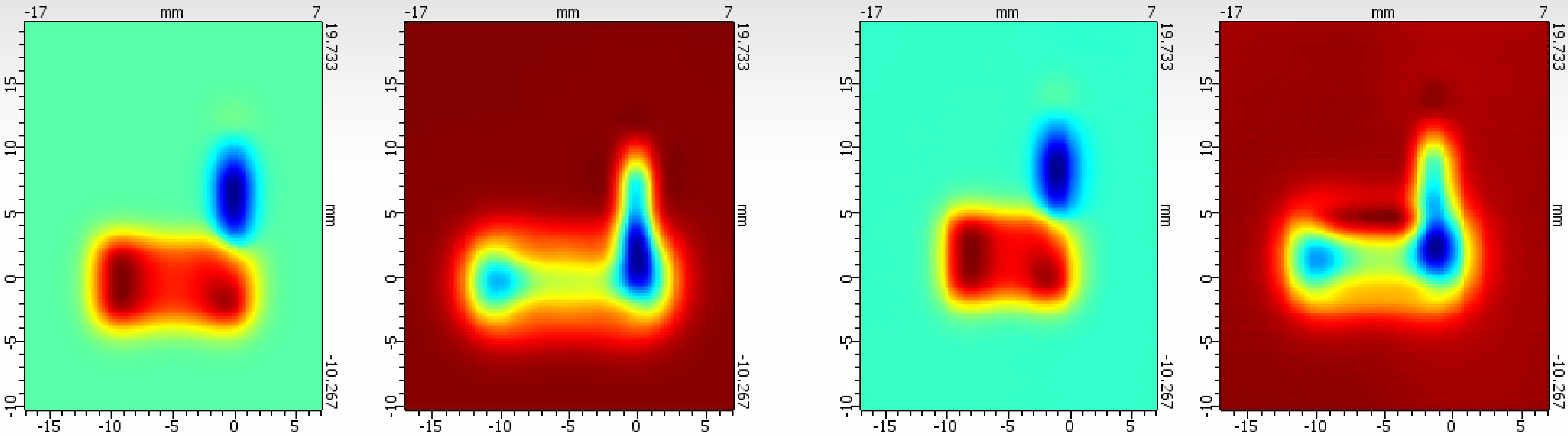
Experimental Validation



Inspection: 300Khz

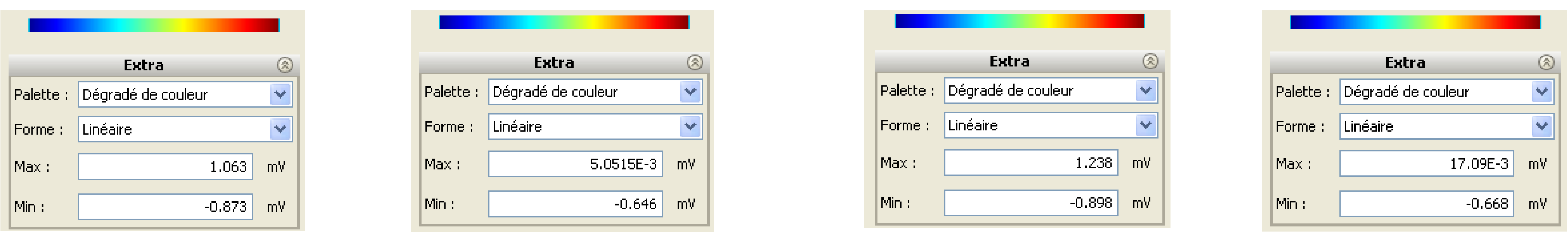
ET: Simulation with “Combined” flaws

Experimental Validation



Simulation

Experiment



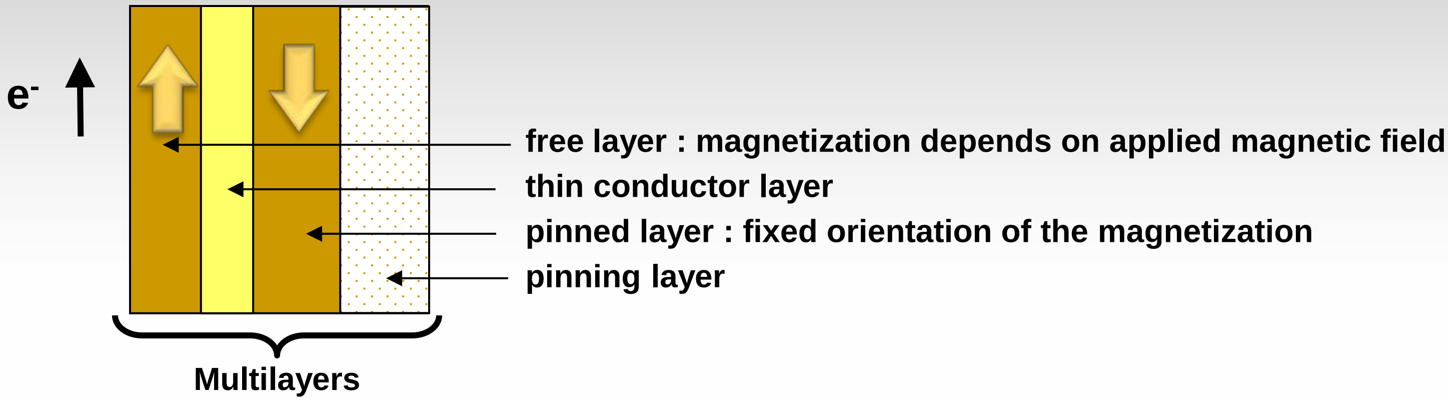
Real part | Imaginary part | Real part | Imaginary part

OUTLINE

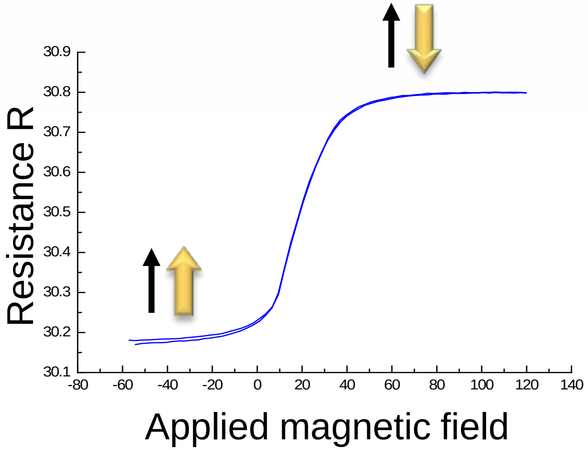
- Introduction
- UT simulation
  - Coarse grain structures
  - 3D CAD geometry
- **ET simulation**
  - Simulation with combined flaws
  - **GMR's sensors**
- RT simulation
  - Generalities
  - Weld inspection
- Conclusion

ET: Magnetic probes, GMR sensors

Principles of GMR (Giant Magneto Resistance) sensors



Variation of the resistance as a function of the applied field

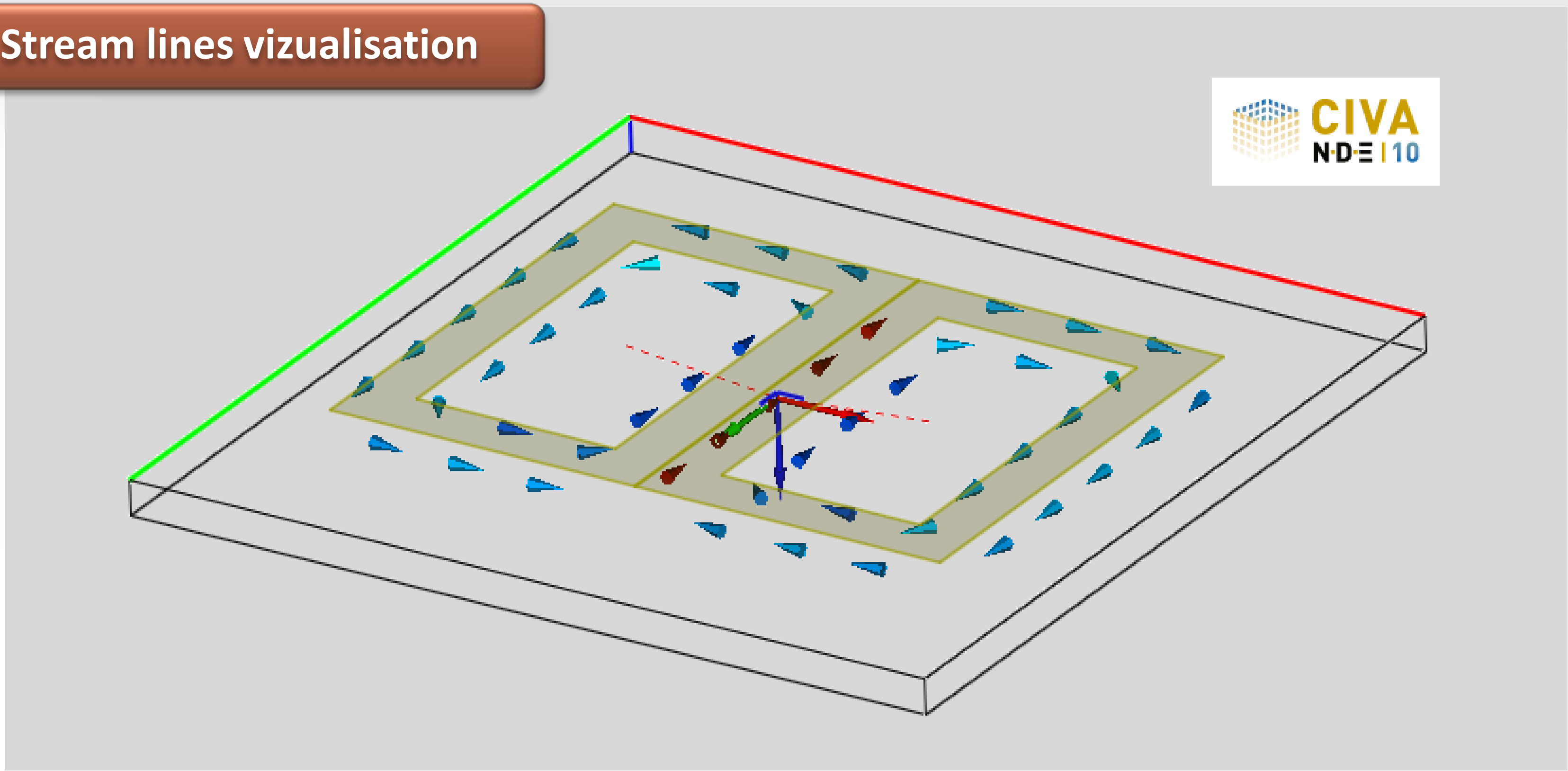


- **Two major advantages:**
  - **Very high sensitivity (at low frequencies : better than classical coil**
    - 1. Detection of buried defects
  - **Small sensors (<~ mm²) : high resolution**
    - 2. Detection and separation of small flaws

ET: Magnetic probes, GMR sensors

SIMULATION of GMRs with CIVA software

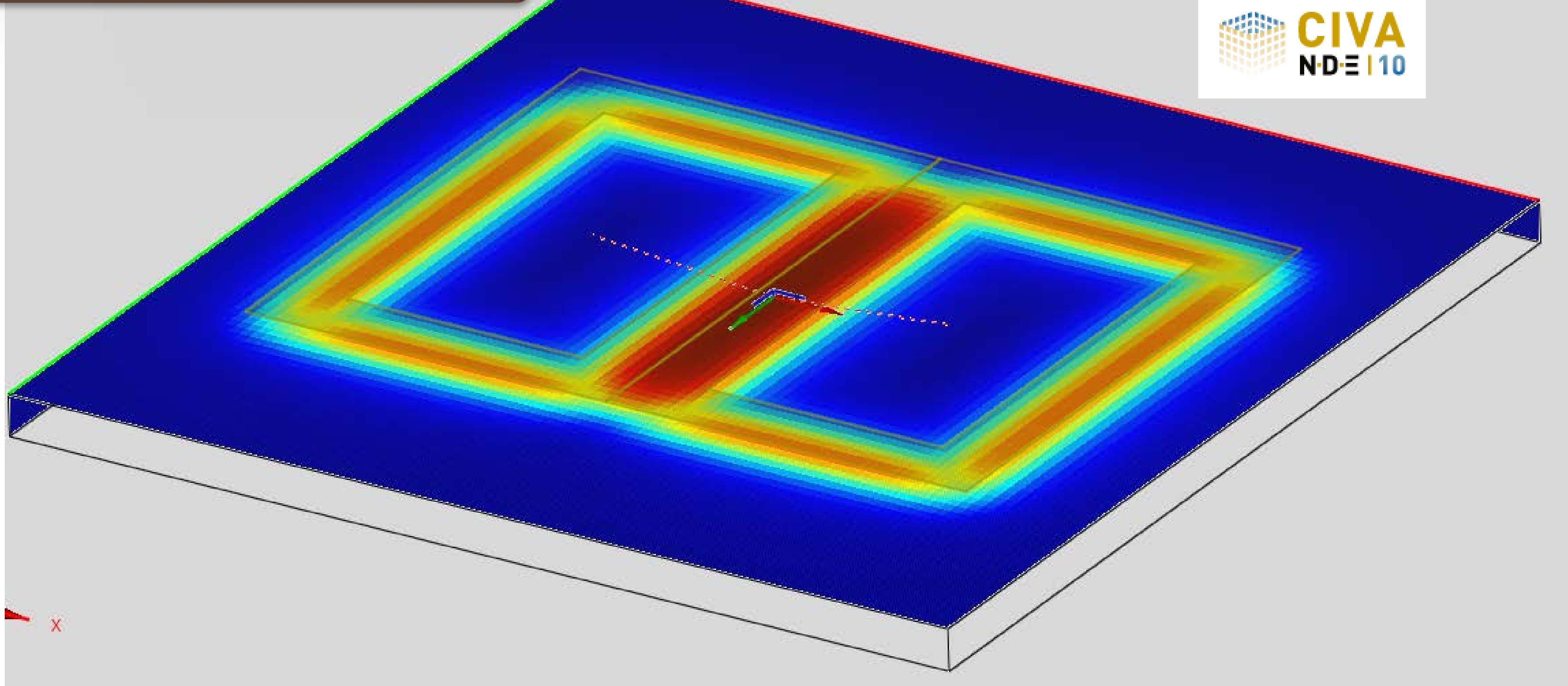
Stream lines vizualisation



ET: Magnetic probes, GMR sensors

SIMULATION of GMRs with CIVA software

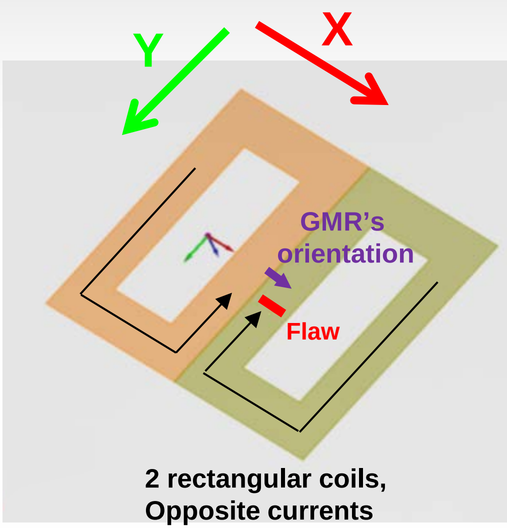
Electric Field vizualisation



ET: Magnetic probes, GMR sensors

SIMULATION of GMRs with CIVA software

Defect Response

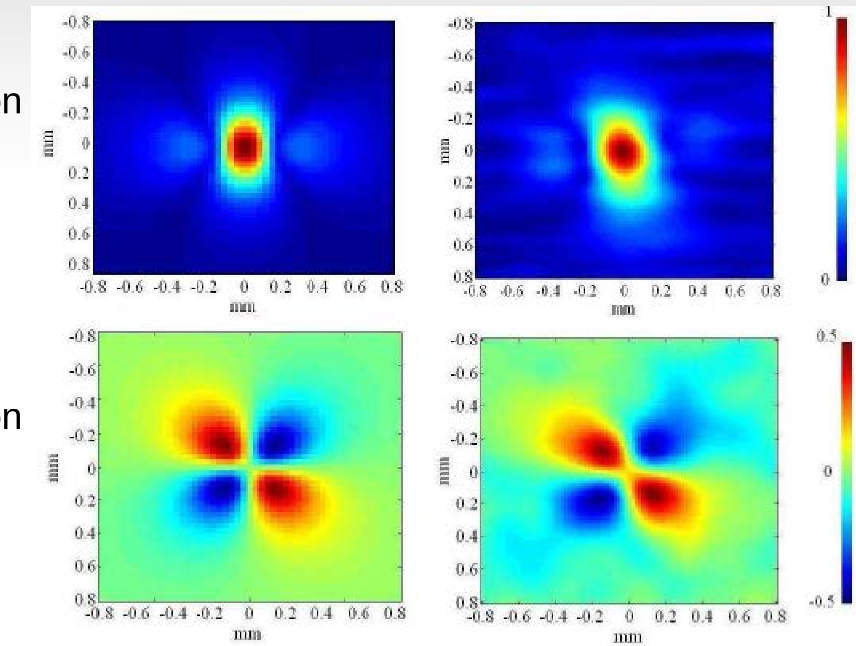


- Inspection settings:
  - Flaw = 100 µm3
  - Frequency = 1 MHz
  - Current foil = 10x30 mm²
  - Sensor's lift-off = 200 µm

Simulations (CIVA 10) Measurements

Bx configuration (amplitude)

By configuration (real part)



- Good agreement simulation/experiment
- ECT response shape varies according to the orientation of the GMR : potential defect characterization

OUTLINE

- Introduction
- UT simulation
  - Coarse grain structures
  - 3D CAD geometry
- ET simulation
  - Simulation with combined flaws
  - GMR's sensors
- **RT simulation**
  - **Generalities**
  - Weld inspection
- Conclusion

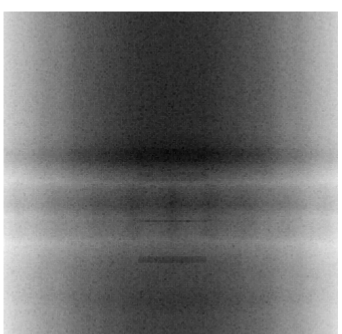
RT: Generalities

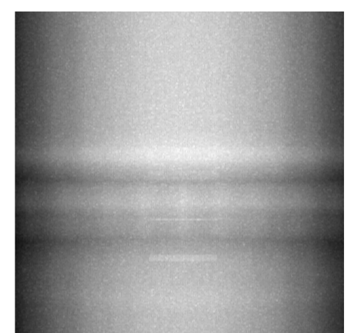
Background

- Mix of two model implemented since CIVA 9 in order to enable in CIVA the best features in Gamma and X-Ray
- Develop a Collaborative plate-form to integrate a new code architecture global to Radiola's partners (European project).
- Create a powerful global RT simulation software combining the best software already developed in France
- Part of Radiola's project has been integrated onto CIVA 10.0 version

CIVA 10 and further

- New tools for the Monte-Carlo simulation:
  - Parallelization of the Monte-Carlo computation is now available
  - Possibility to re-load a previously computed Monte-Carlo result
- Integration of new visualization tools
- Thanks to the new architecture, integration of new kinds of specific detectors is quite easy for the future



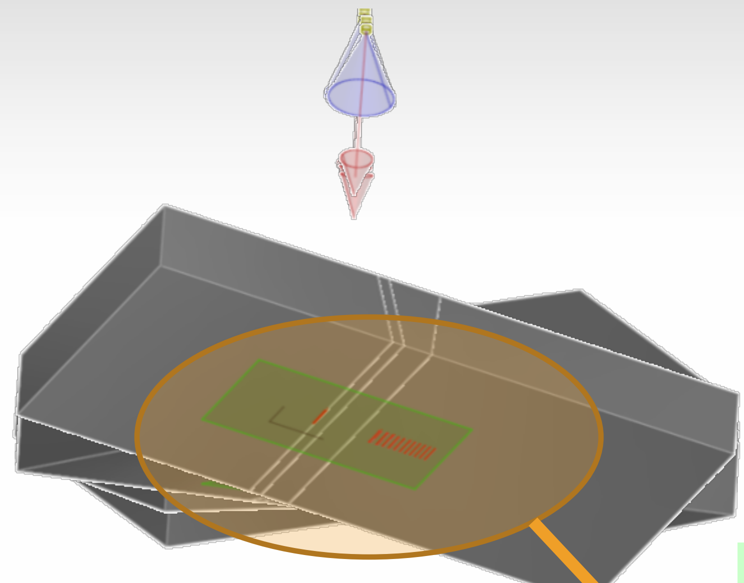


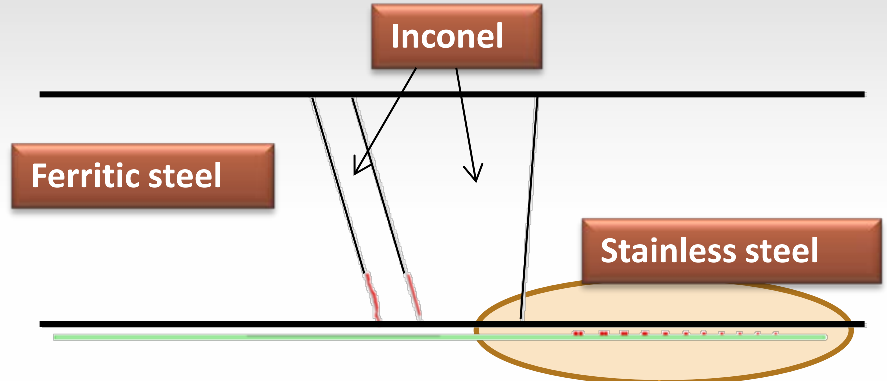
OUTLINE

- Introduction
- UT simulation
  - Coarse grain structures
  - 3D CAD geometry
- ET simulation
  - Simulation with combined flaws
  - GMR's sensors
- **RT simulation**
  - Generalities
  - **Bi-Metallic Weld inspection**
- Conclusion

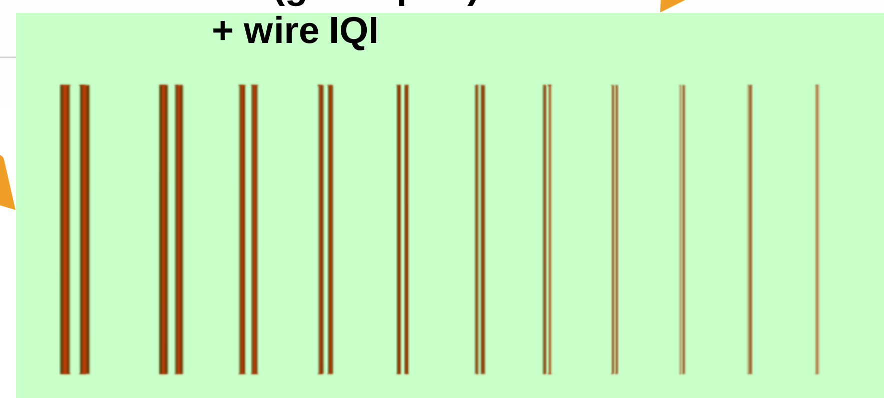
RT: Bi-metallic Weld inspection

Bi-metallic weld with a complex crack



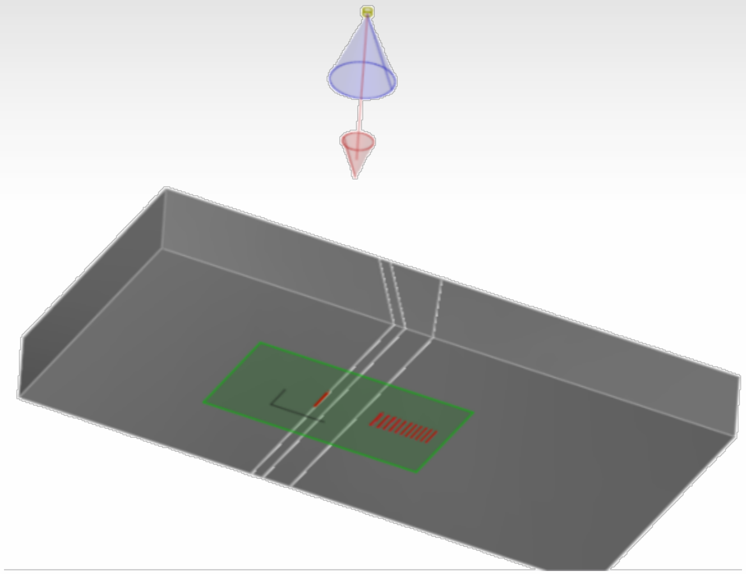


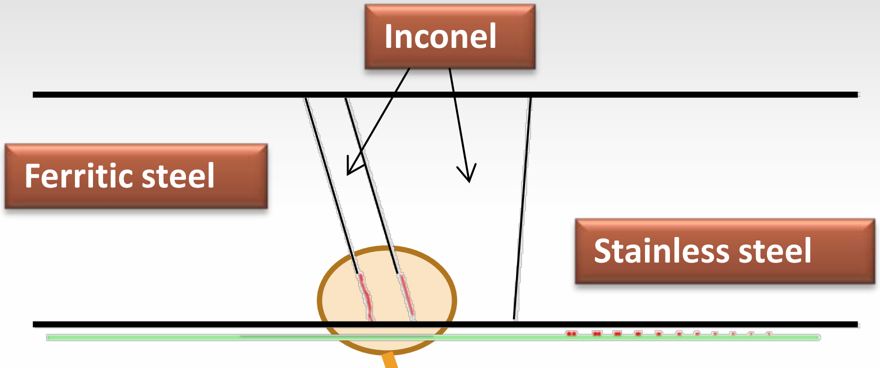
Detector (green part)
+ wire IQI

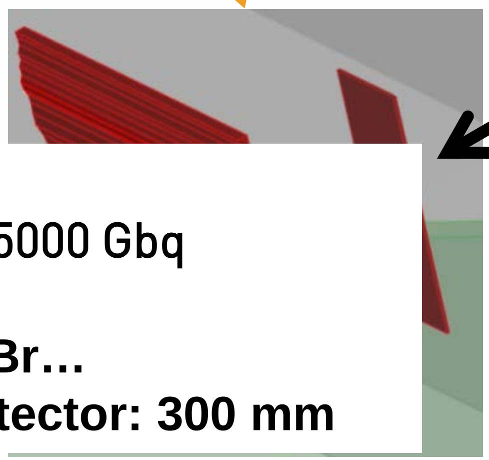


RT: Bi-metallic Weld inspection

Bi-metallic weld with a complex crack



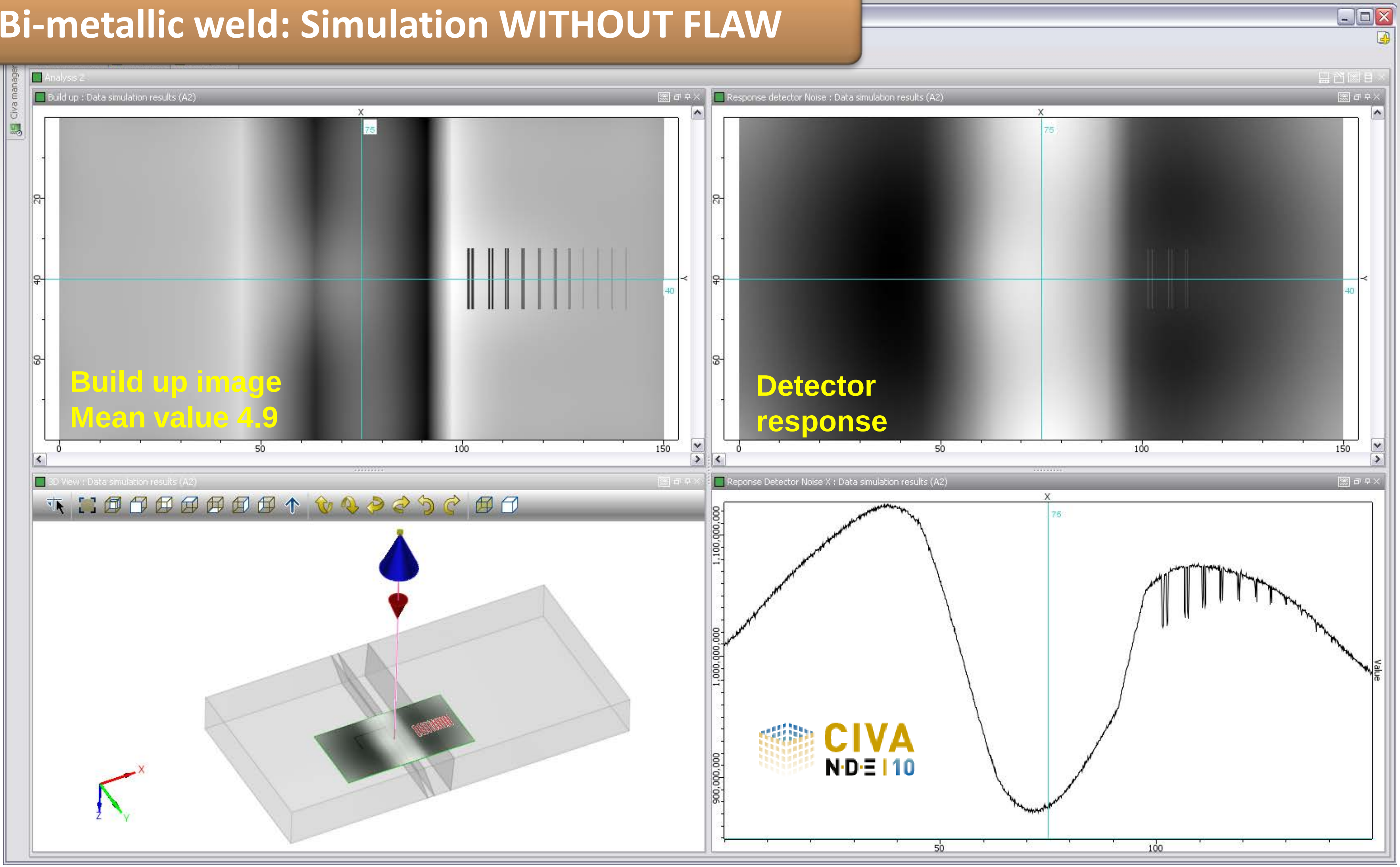




- **Inspection settings:**
  - Source: Ir192, Activity 5000 Gbq
  - **Exposure time: 2h**
  - **Detector: 1mm of AgBr…**
  - **Distance Source / Detector: 300 mm**

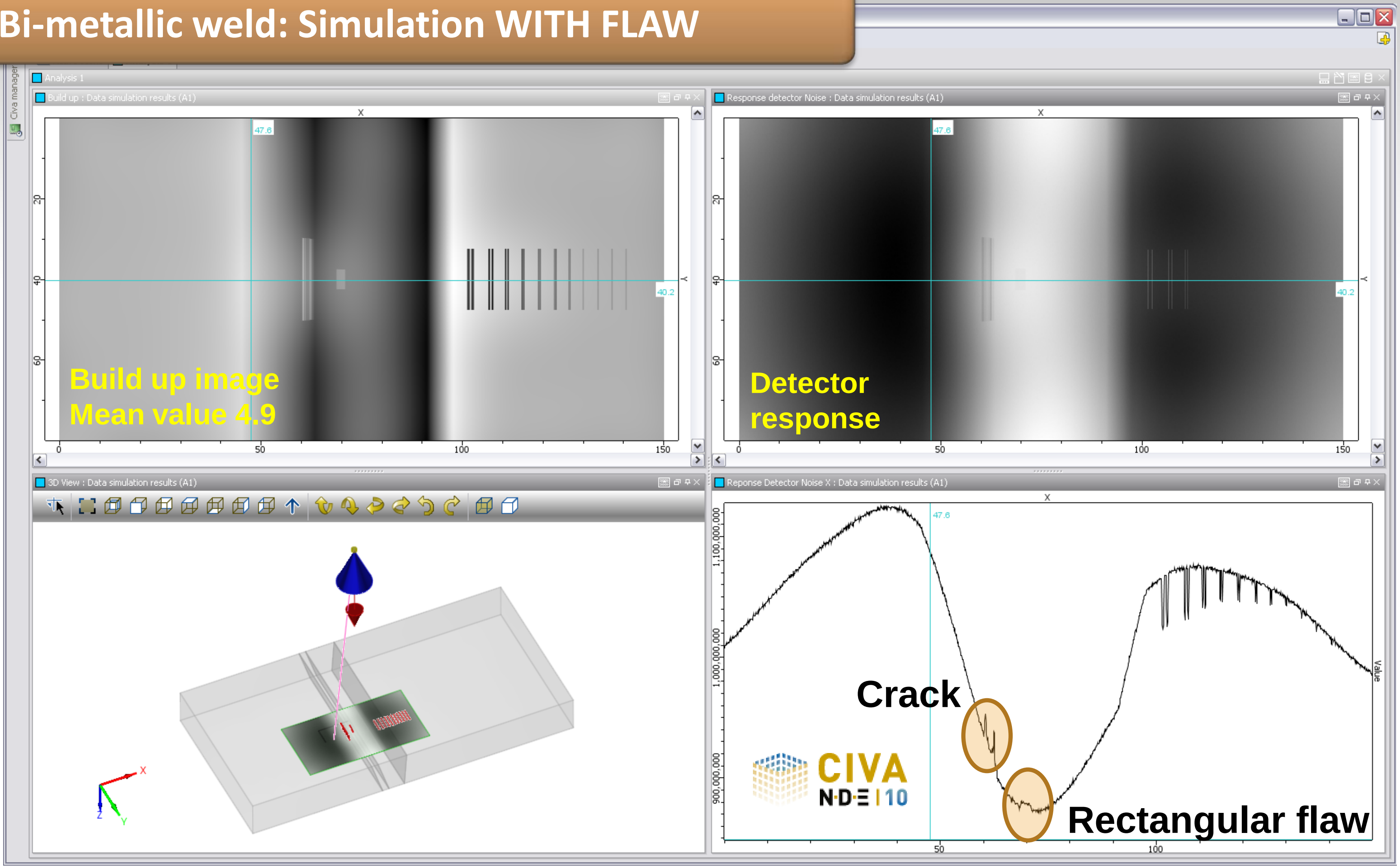
RT: Bi-metallic Weld inspection

Bi-metallic weld: Simulation WITHOUT FLAW



RT: Bi-metallic Weld inspection

Bi-metallic weld: Simulation WITH FLAW



OUTLINE

- Introduction
- UT simulation
  - Coarse grain structures
  - 3D CAD geometry
- ET simulation
  - Simulation with combined flaws
  - GMR's sensors
- RT simulation
  - Generalities
  - Bi-Metallic Weld inspection
- **Conclusion**

Conclusion

- Simulation codes for UT, ET and RT are gathered within the same software platform: CIVA
- NDT realistic inspections can be simulated within the CIVA platform for those three techniques
- CIVA 10 version released by end of June 2010
- Simulation capabilities widely extended in this major version
- Experimental validations carried-out to ensure reliability of CIVA simulations

http://www-civa.cea.fr

http://www.extende.com