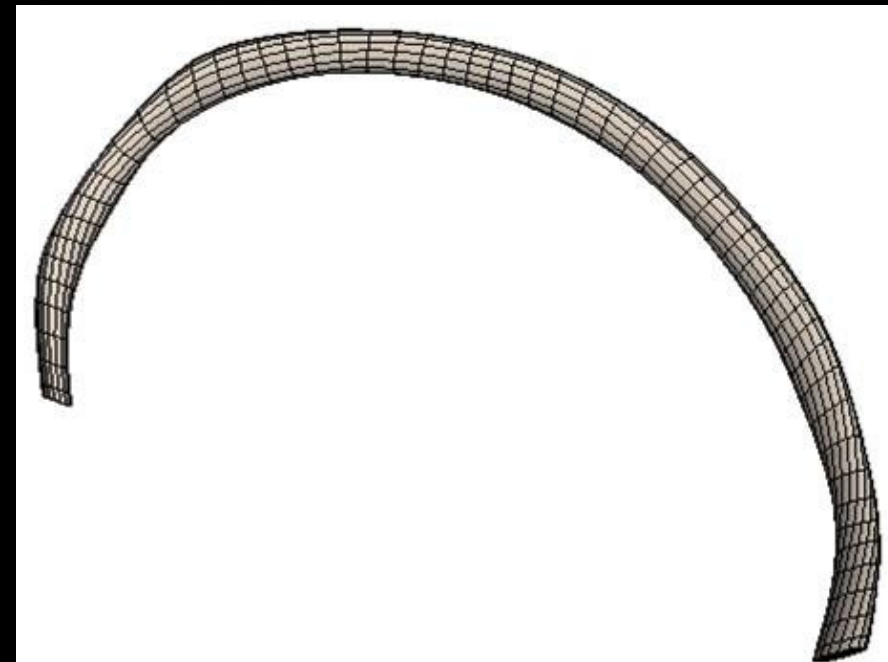


Identification and Modelling of the Ribs Mechanical Behaviour

*LAPORTE Sébastien **

TROSSEILLE Xavier °

*LAVASTE François **



Real World Accident

2007 Annual Assessment

Fatalities and injured people **decreased** between 2006 and 2007

(fatalities: **-2.1%** and injured persons: **0.7%**)

In France:

Number of killed persons: **4 838**

Number of injured persons: **110000**

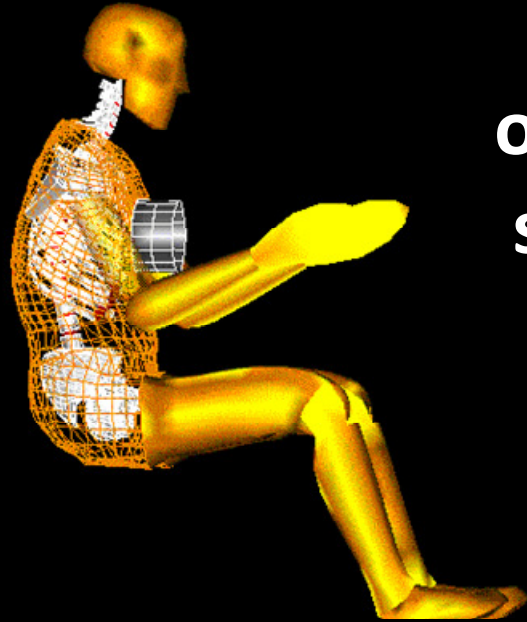
Total cost of victims: **€ 11.7 billion**

In automobile crashes, thoracic injuries are the **2nd** frequently found injuries in fatalities and serious injuries (AIS 4-6).

Introduction

Thorax FE models

⇒ to study responses under a crash environment



Human Body Model
developed by LAB and LBM
[Lizée *et al.*, Stapp 1998]



occupant protection
systems evaluation
(kinematics)



**detailed mechanisms
of injuries
(rib fractures)**

Objective

Aim of the study:

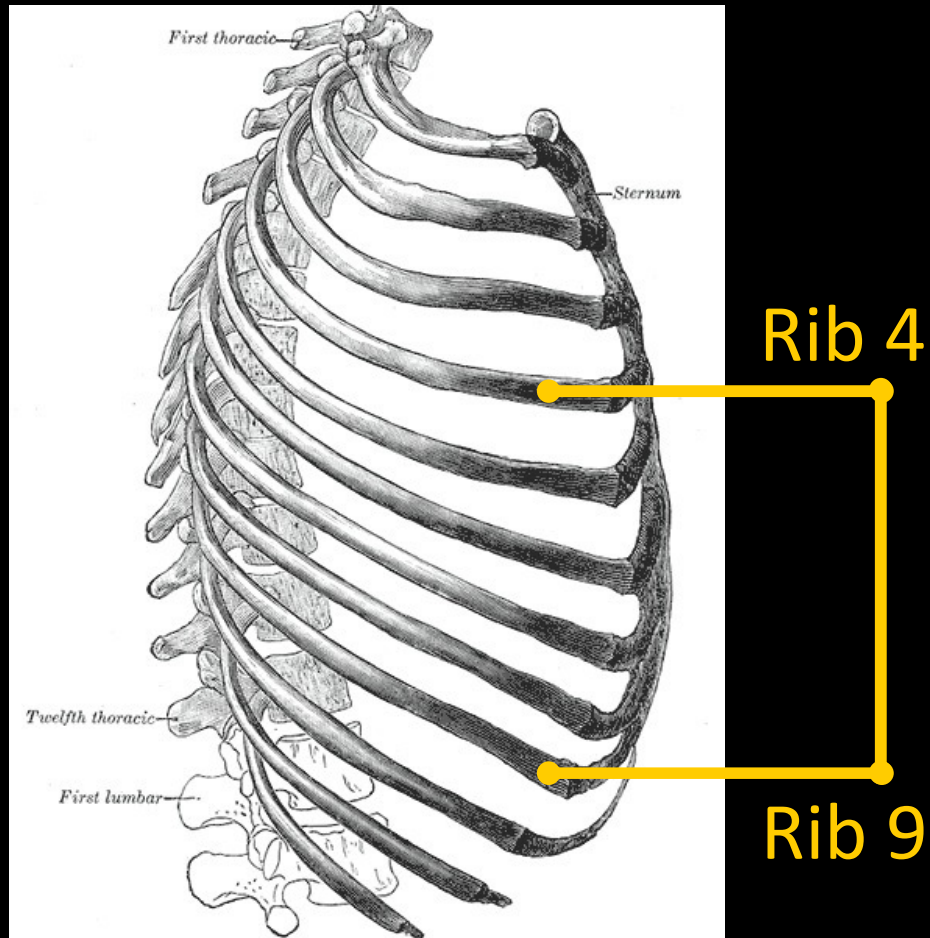
developing personalized FE rib models to understand the mechanical behaviour of human ribs.

How?

building FE rib models from CT scans and testing ribs in dynamics.

Material and Methods

5 rib cages (mean age: 65 years, SD: 4 years) \Rightarrow 30 ribs (level 4 to 9)



H. Gray 1918

Right hemi-thorax

Specimen preparation:

Ribs disarticulated from the vertebrae

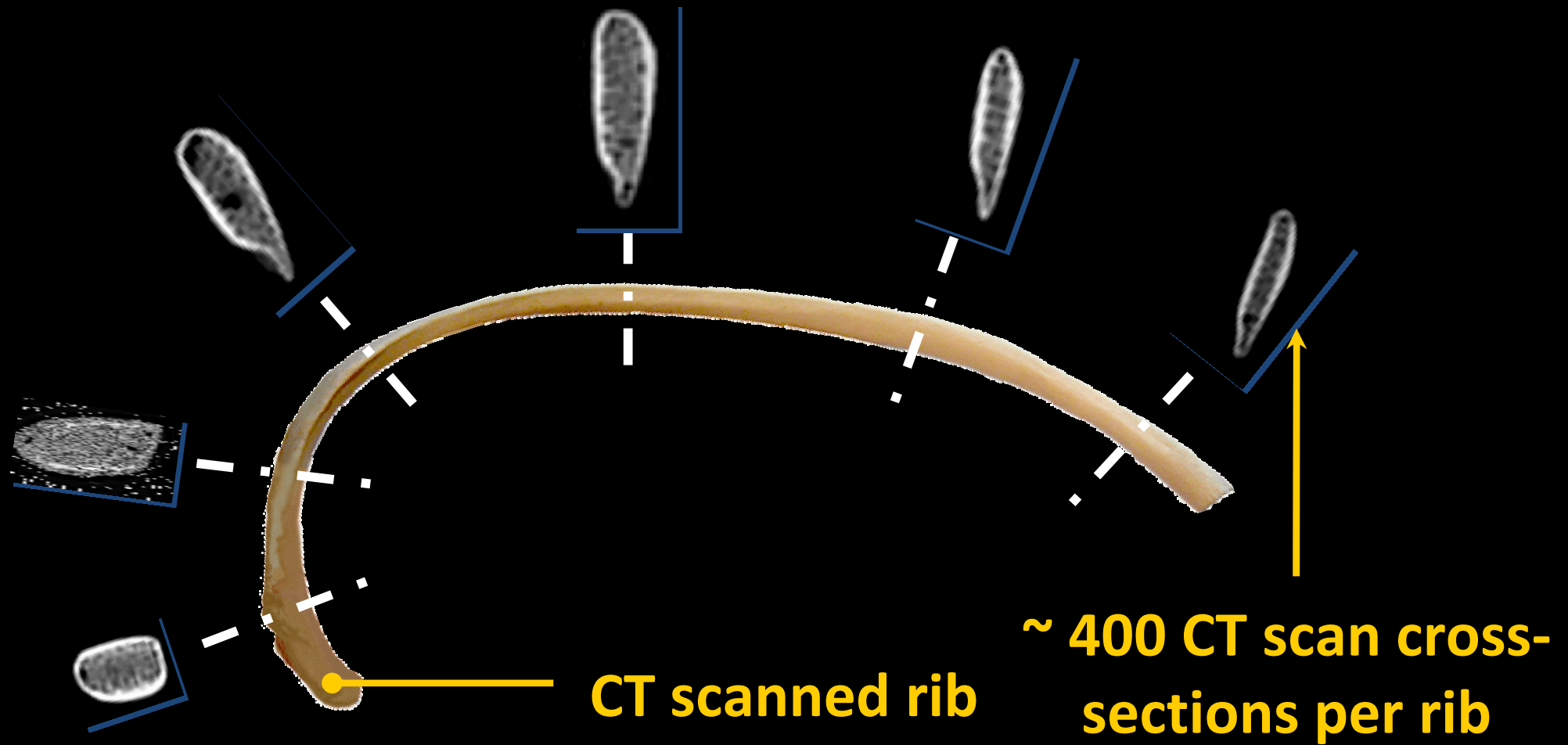
Costal cartilage and soft tissues removed

Storage:

Ribs frozen at -20°C in sealed plastic bag

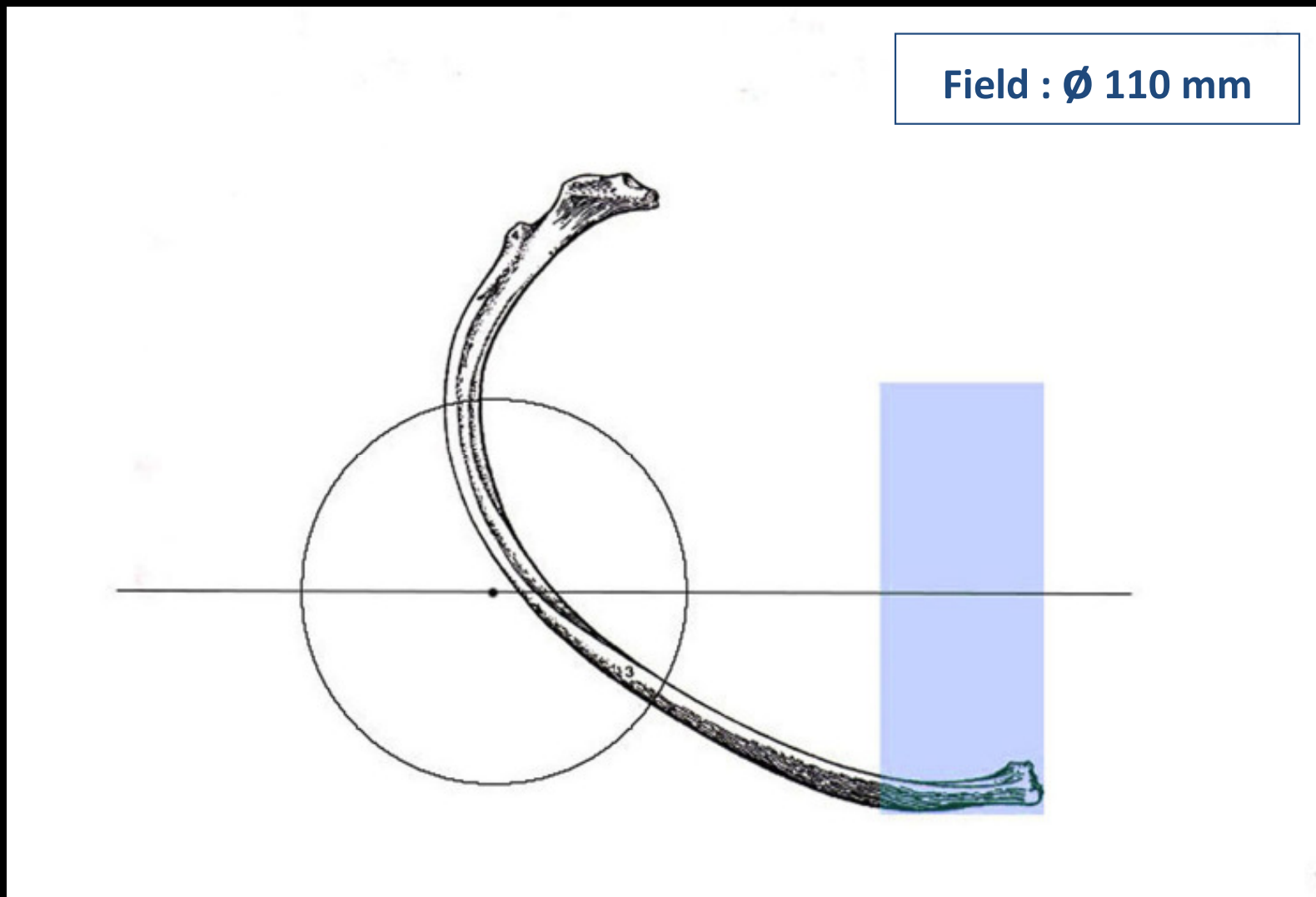
Material and Method

Geometry input by CT scan



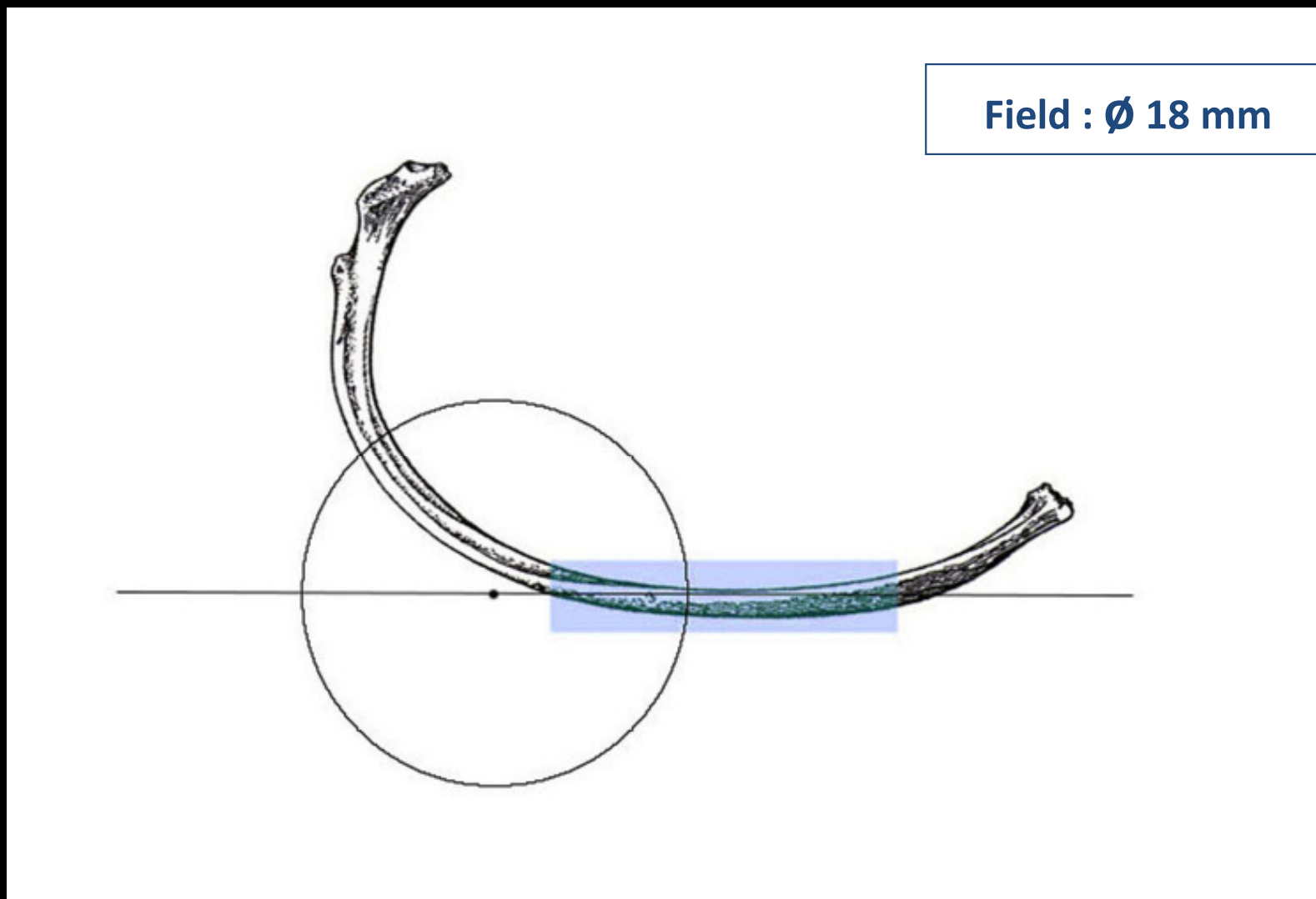
Material and Method

CT scanning method



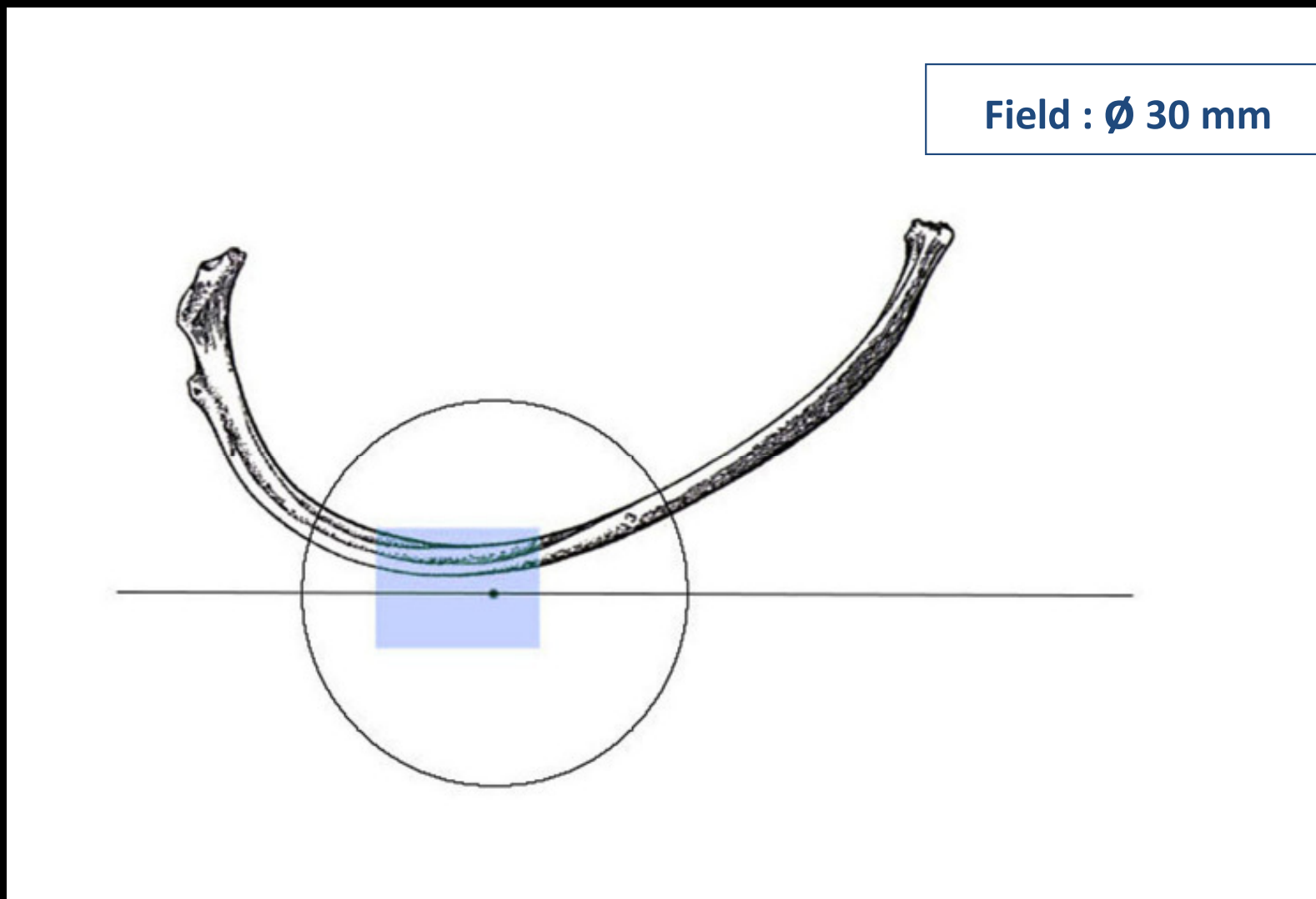
Material and Method

CT scanning method



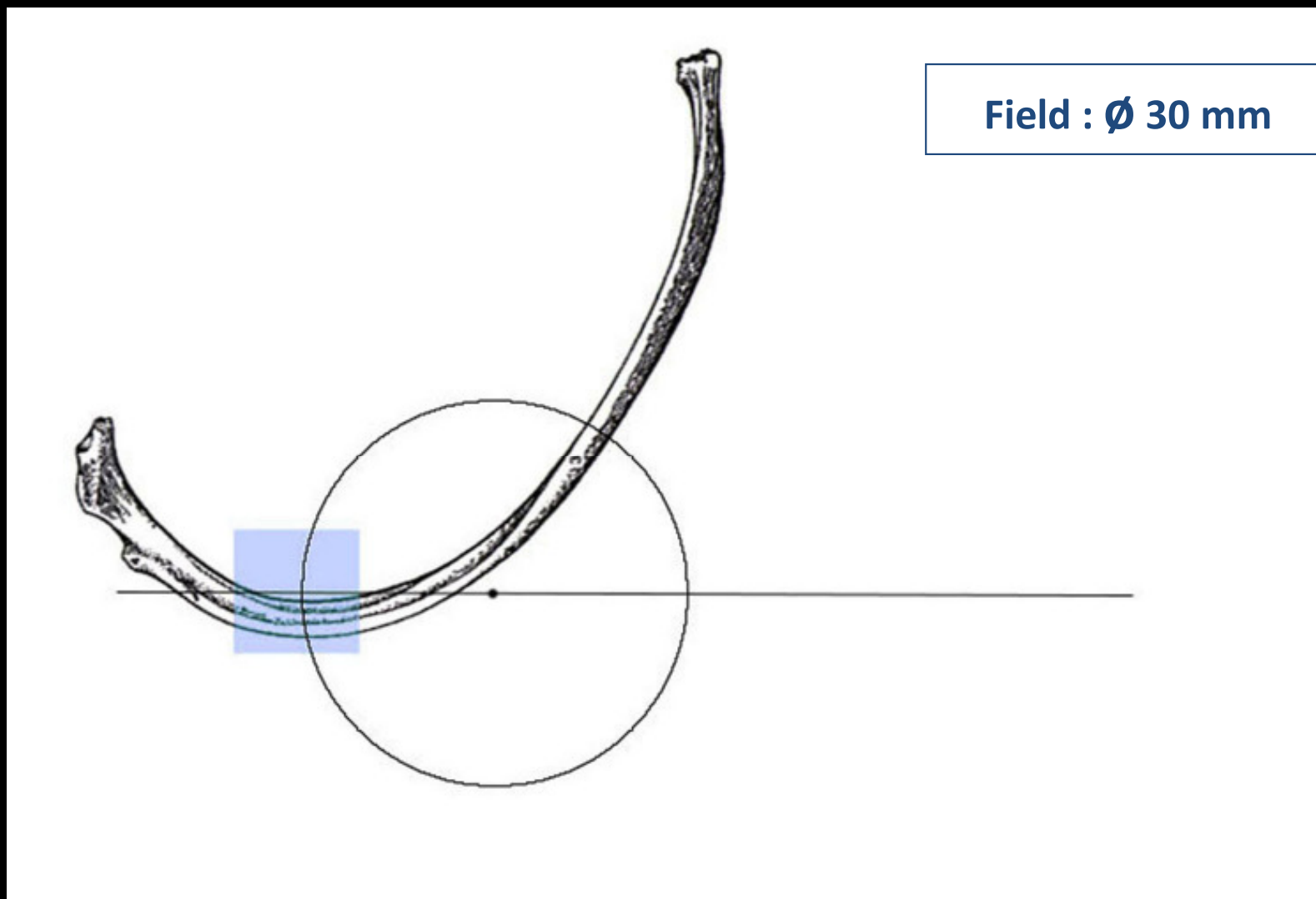
Material and Method

CT scanning method



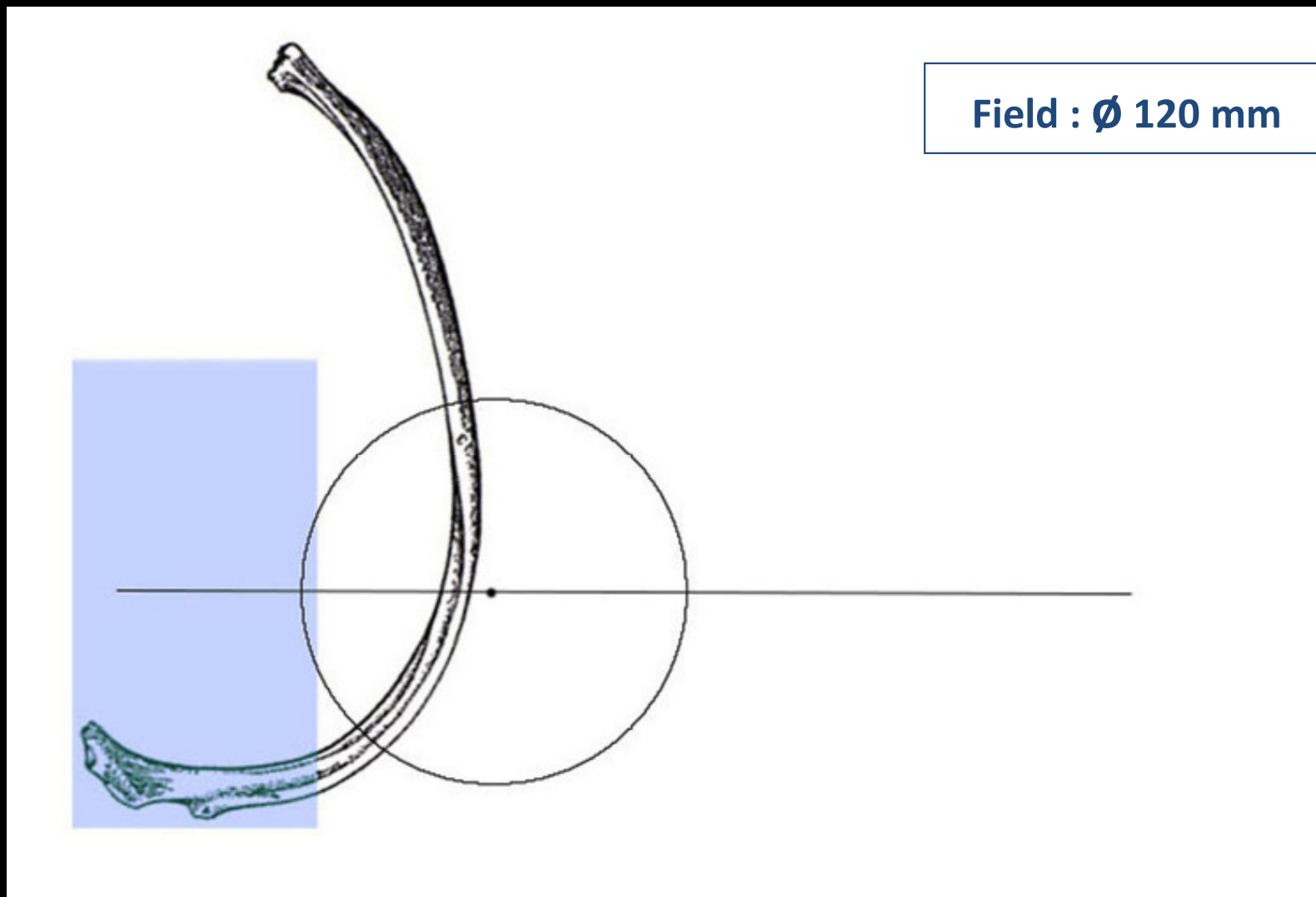
Material and Method

CT scanning method



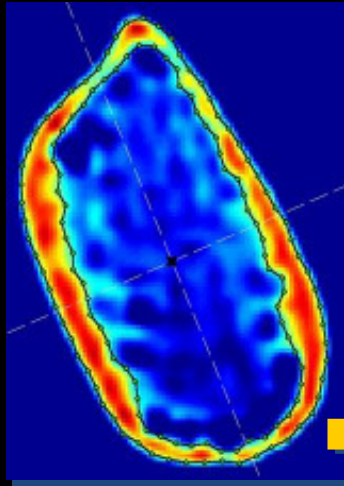
Material and Method

CT scanning method

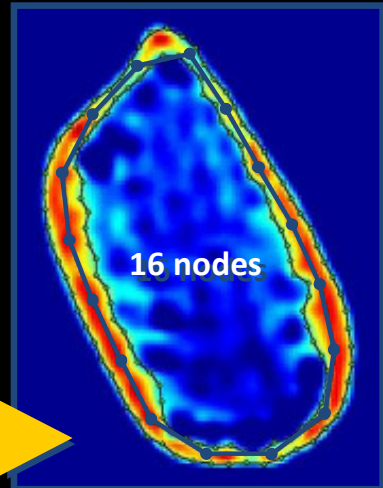


Materials and Methods

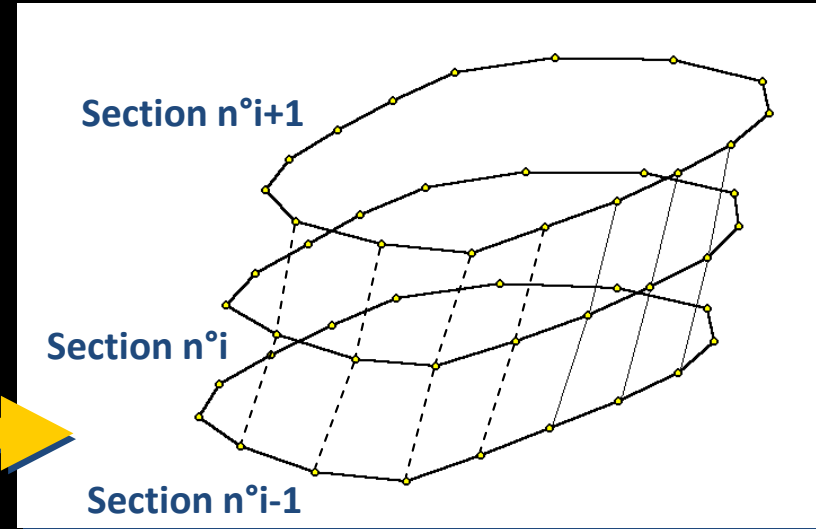
Meshing and FE modeling



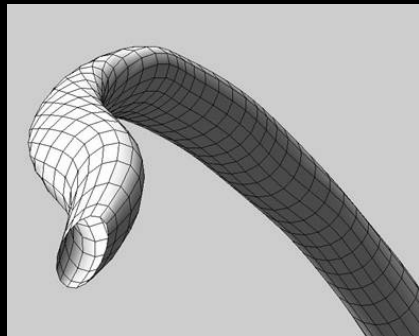
Compact bone borders



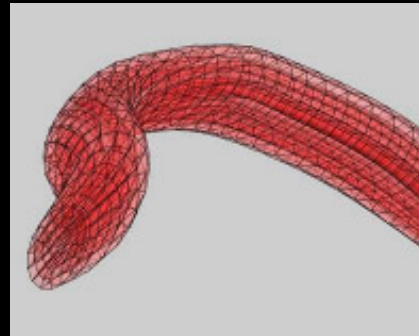
16-node median contour



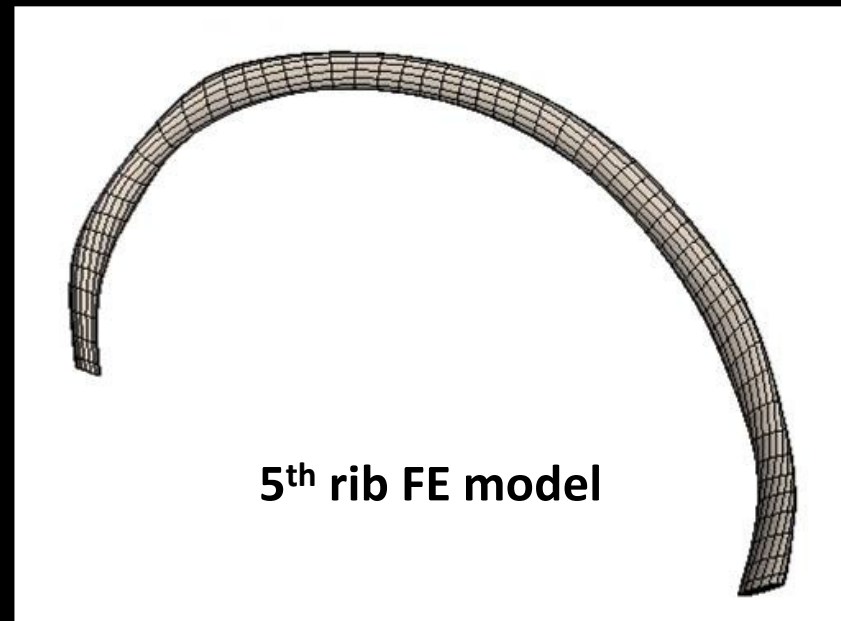
The mesh is defined by the sequence of contours



Compact bone: 4-node shell elements



Cancellous bone: 8-node brick elements

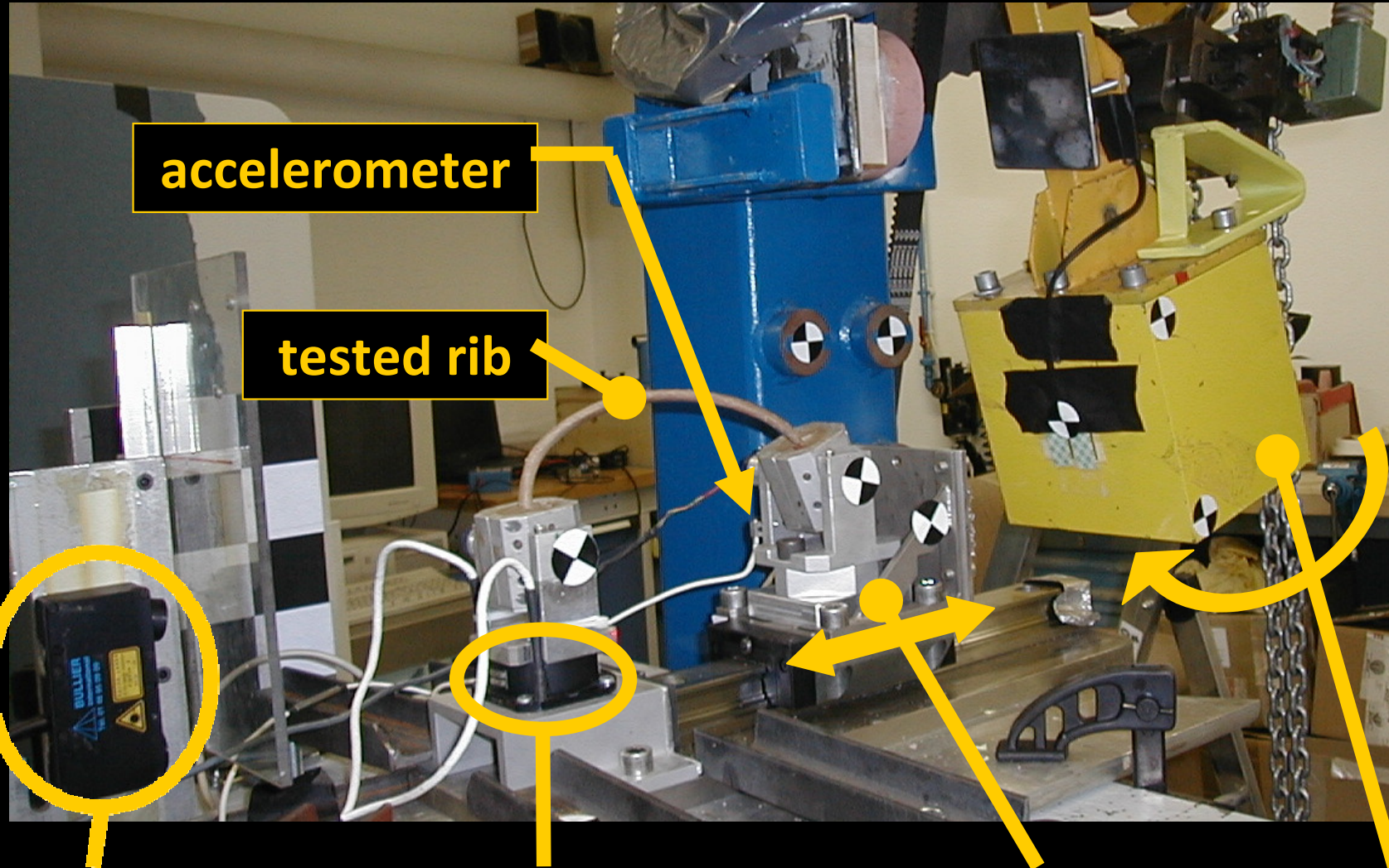


5th rib FE model



Material and Method

Test set-up and measurements



accelerometer

tested rib



Laser Sensor
(displacement)

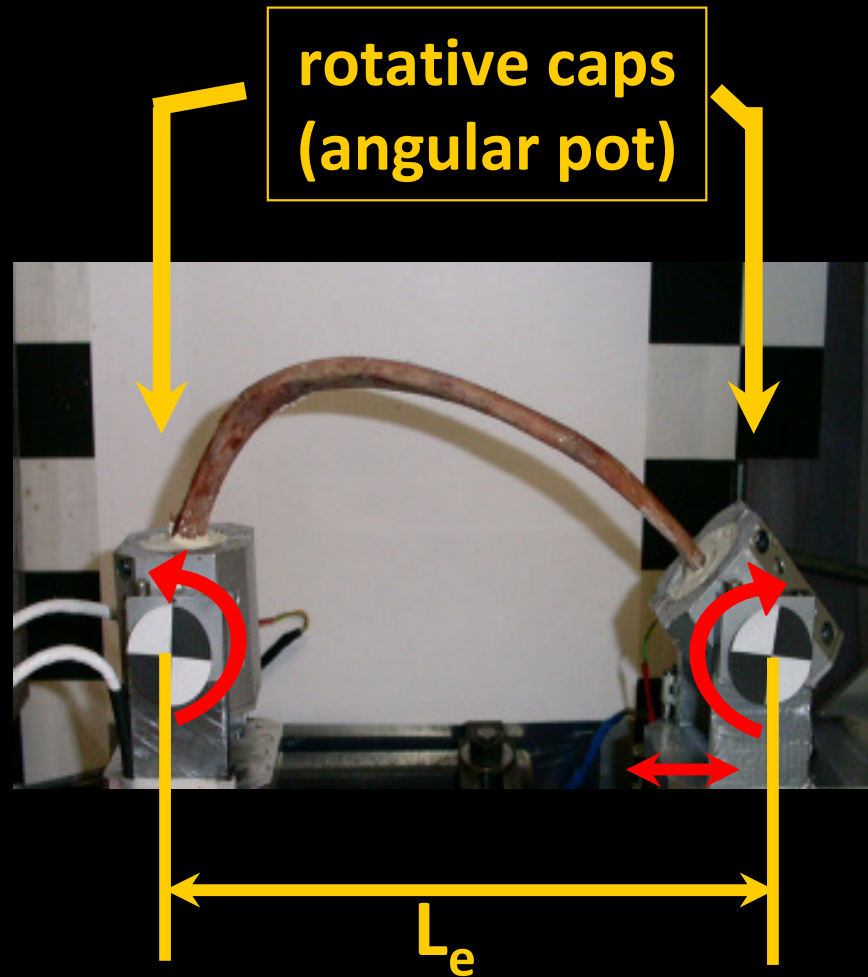
6 axis load cell
(fixed on the frame)

Mobile
trolley

Pendulum
(40 kg)

Material and Method

Test set-up and measurements



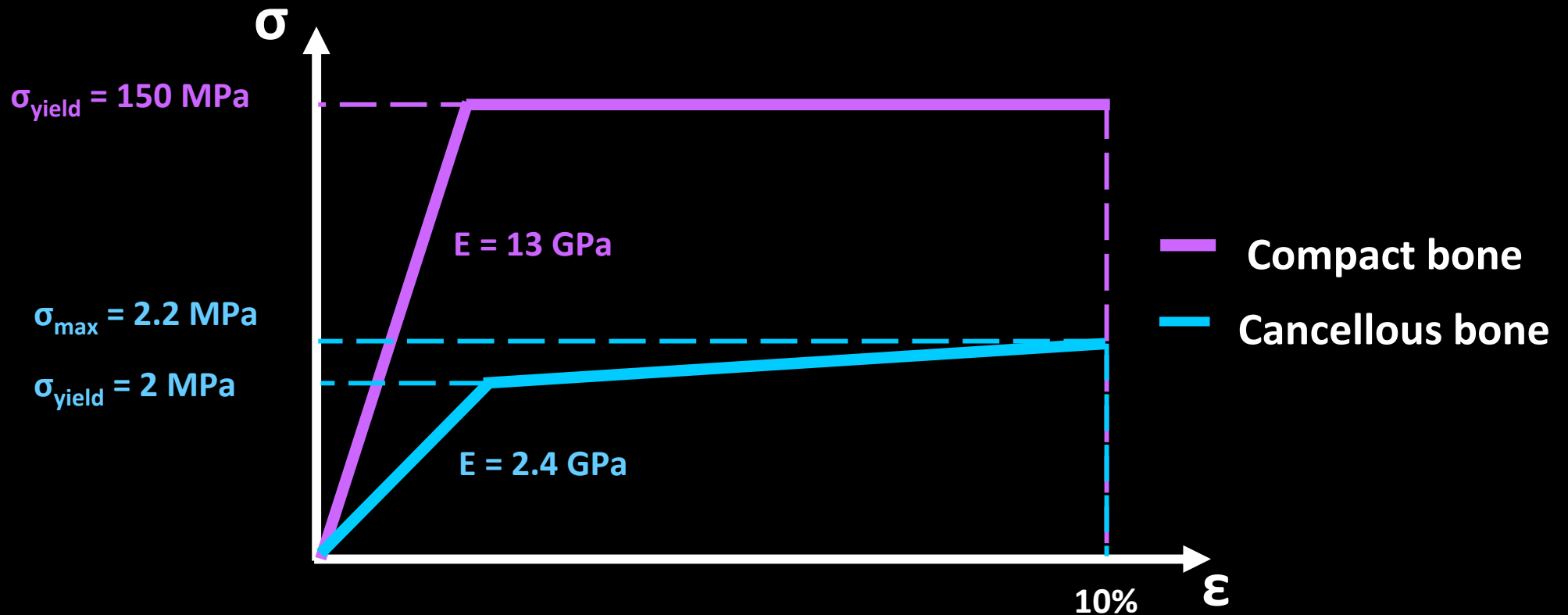
Material and Method

FE modeling

⇒ sixteen ribs tests simulated with the same material laws

➔ compact bone (shell) [three point bending tests]

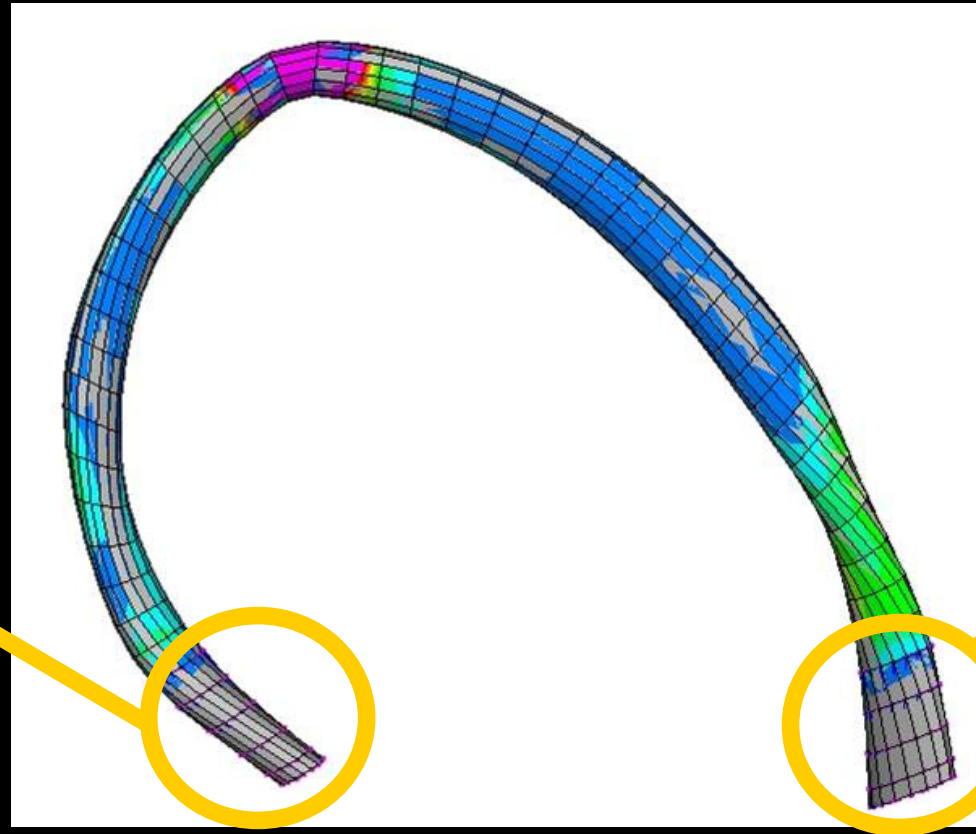
➔ cancellous bone (brick) [Deng *et al.*, Stapp 1999]



Material and Method

FE modeling: attachments

Posterior
attachment

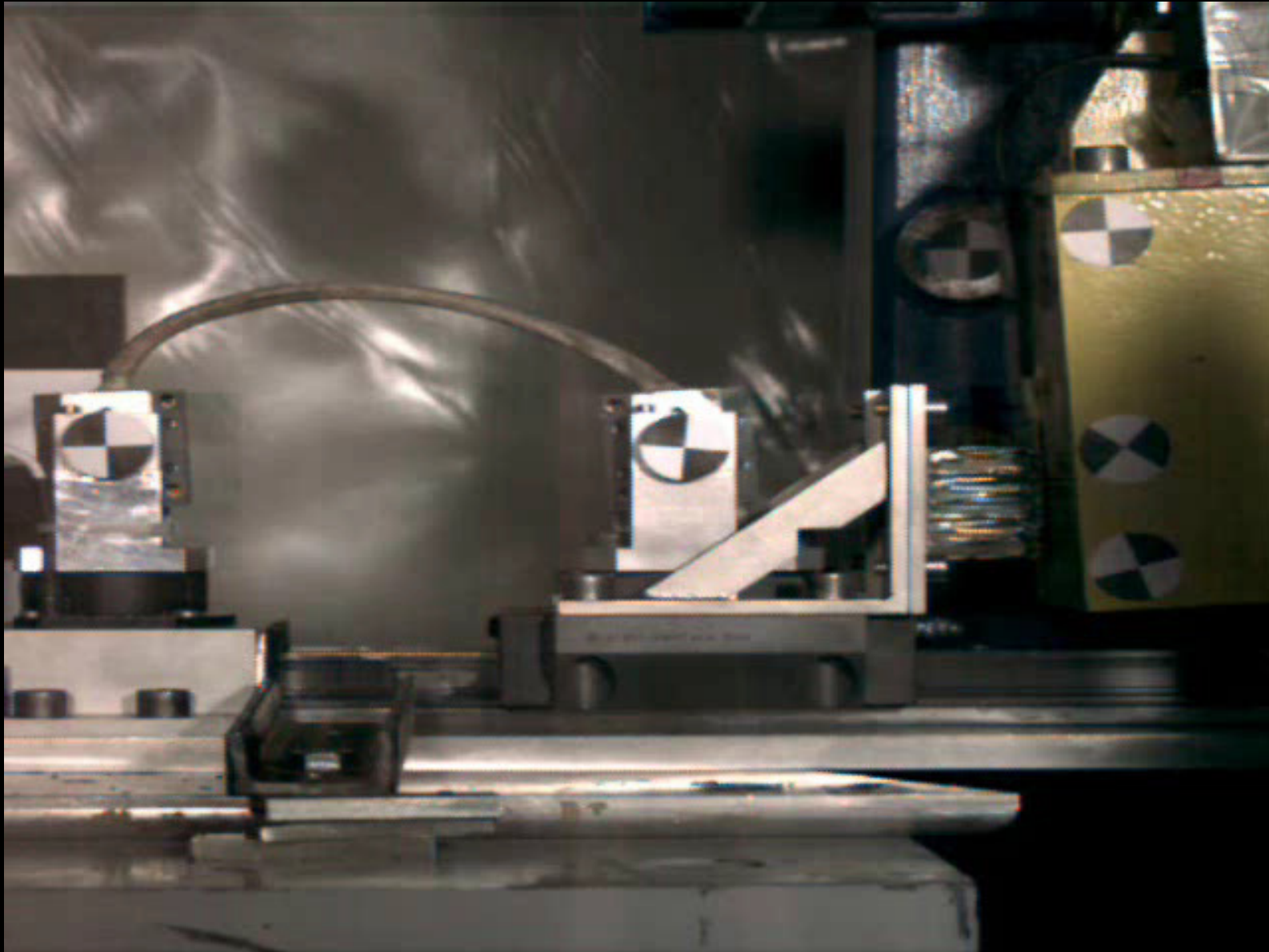


Anterior
attachment

- Rigid bodies: master nodes positioned to correspond with rotational axis
- Anterior master node displacement reproducing the mechanical test

Results

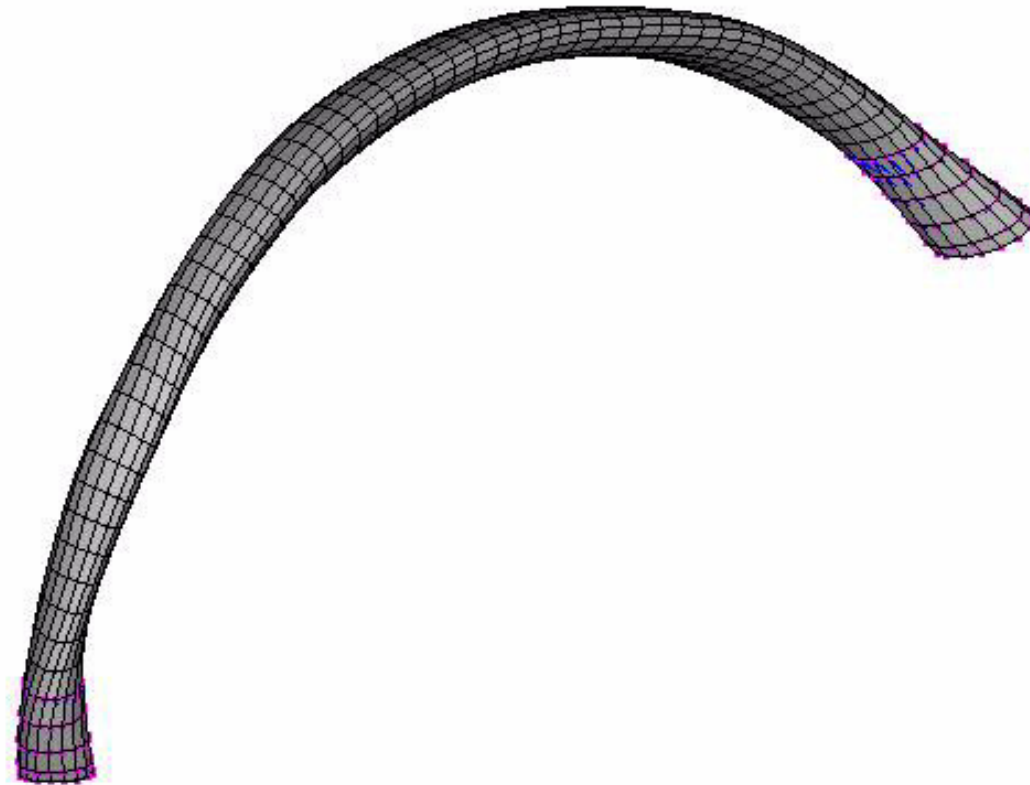
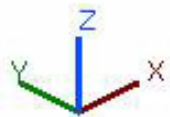
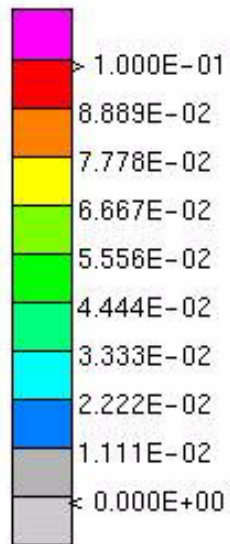
Physical test



Results

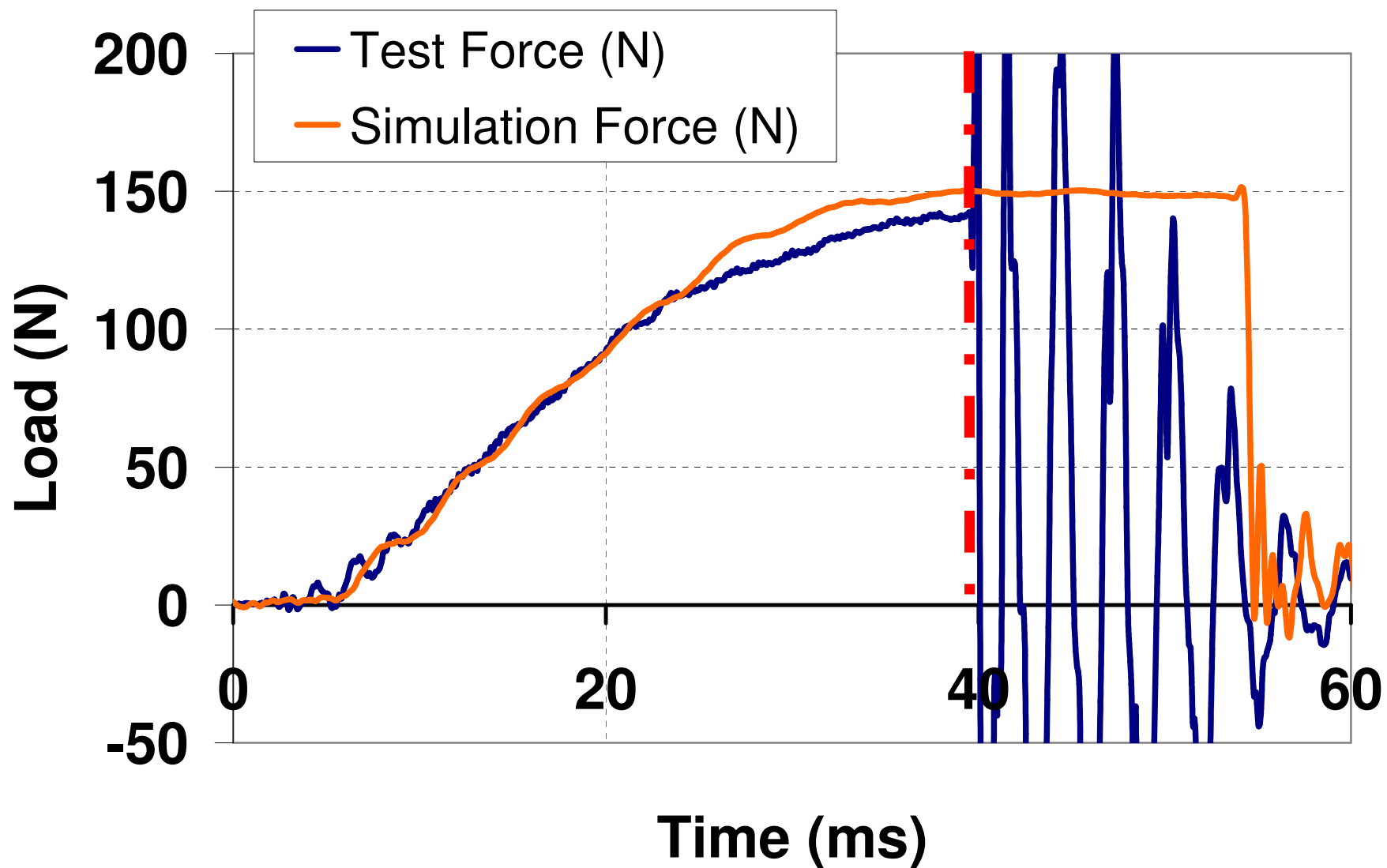
FE simulation

T548C7D2A001.gz : Strain Invariant,Plastic Strain : STATE 1 ,TIME 0.00000000E+00



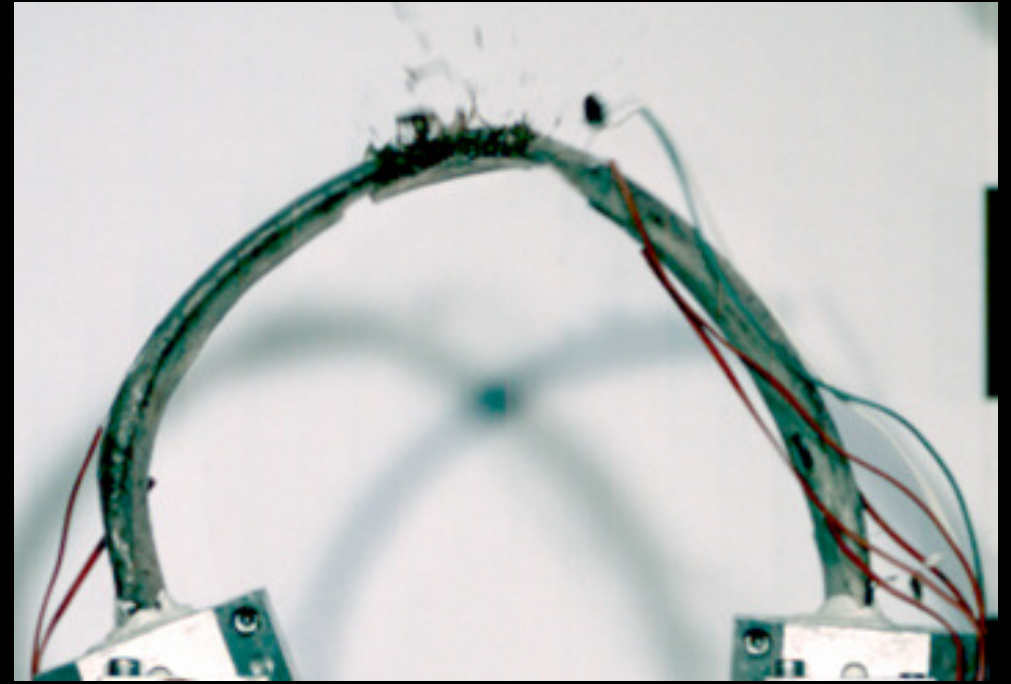
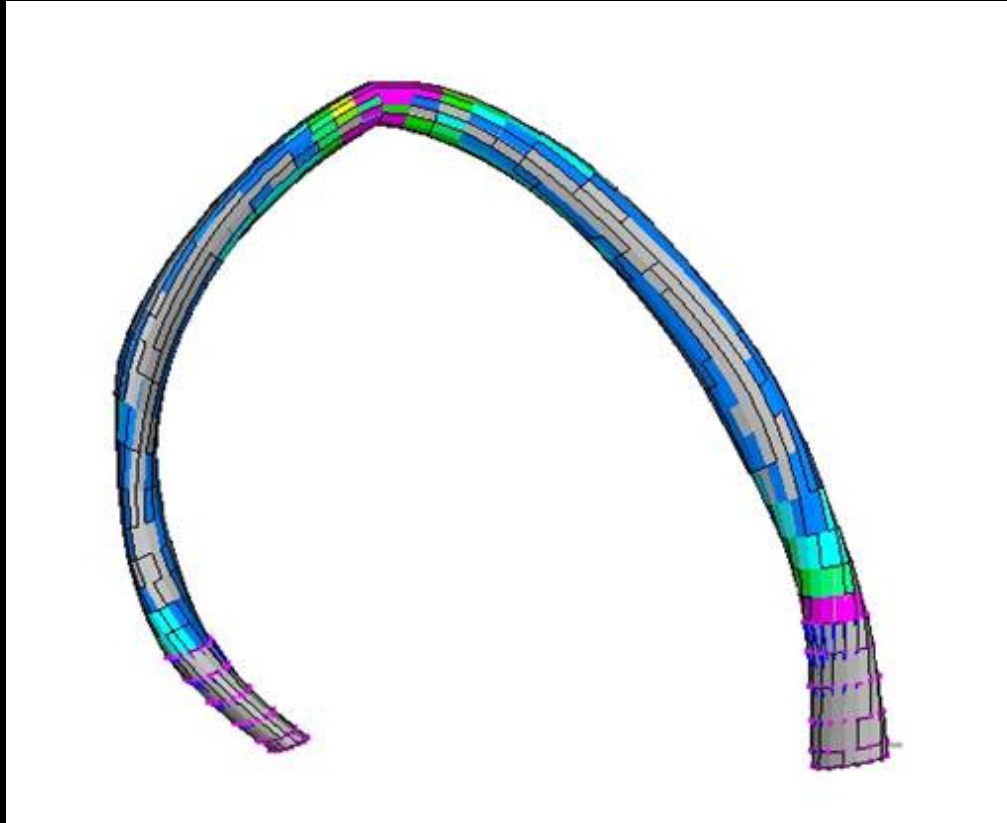
Results

Example: T548 rib 5R



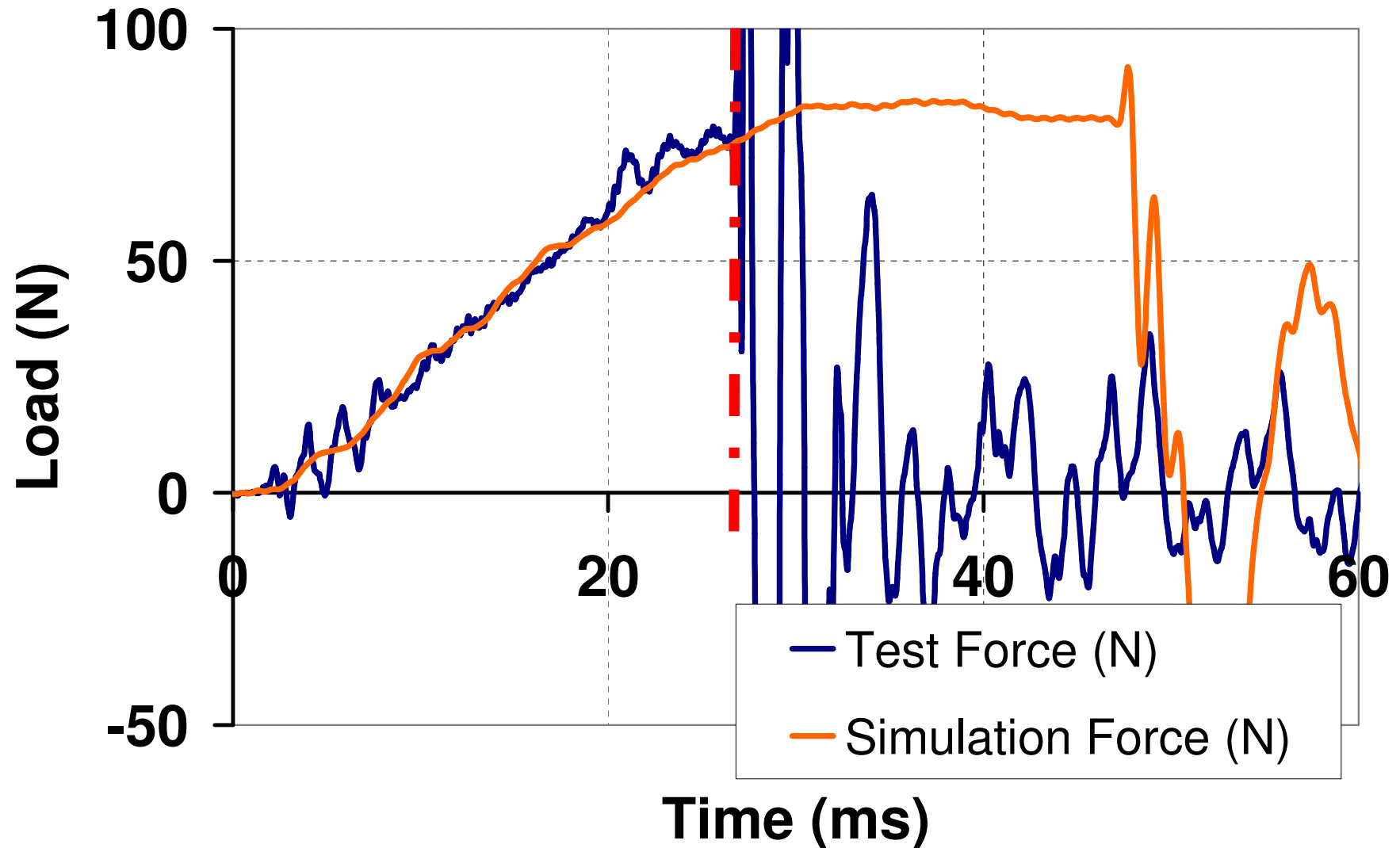
Results

Example: T548 rib 5R



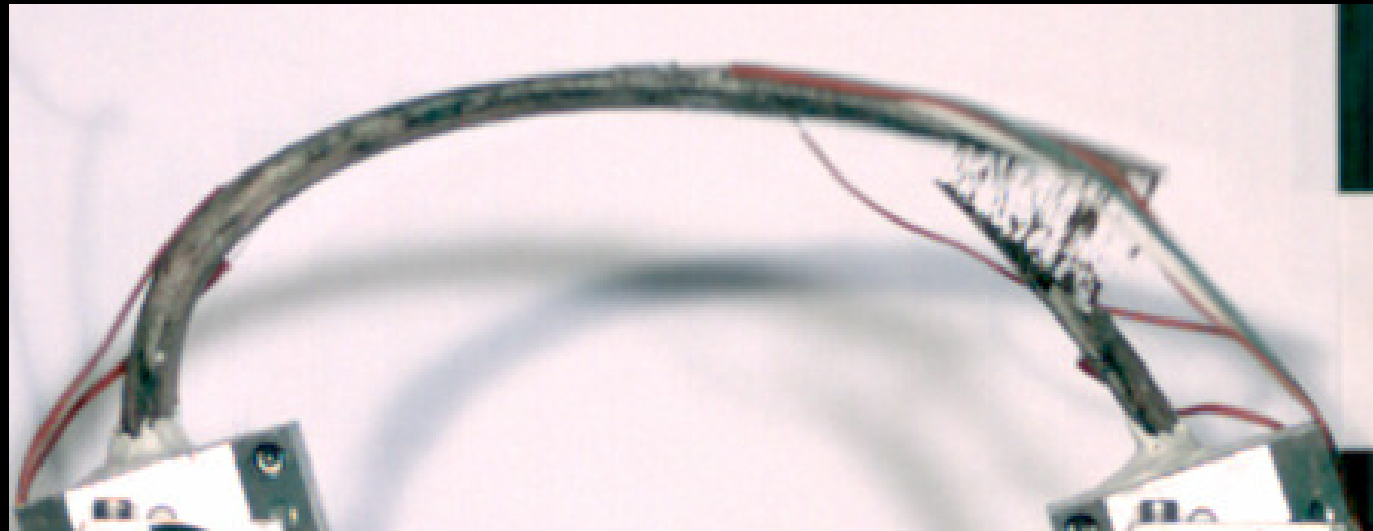
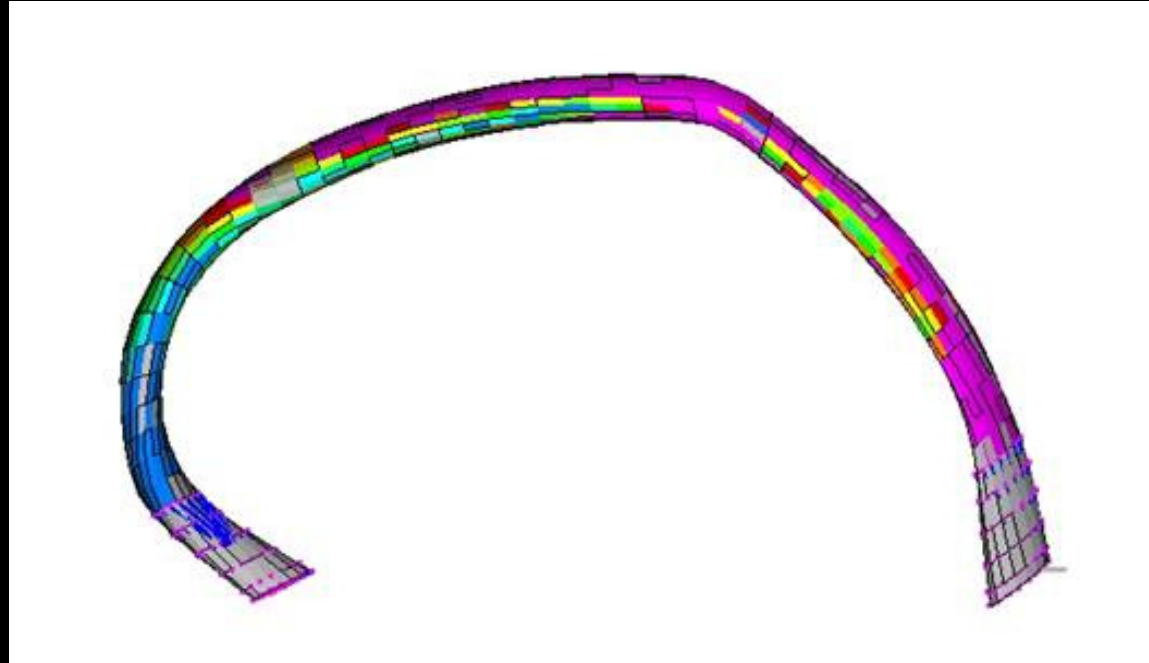
Results

Example : T544 rib 5L



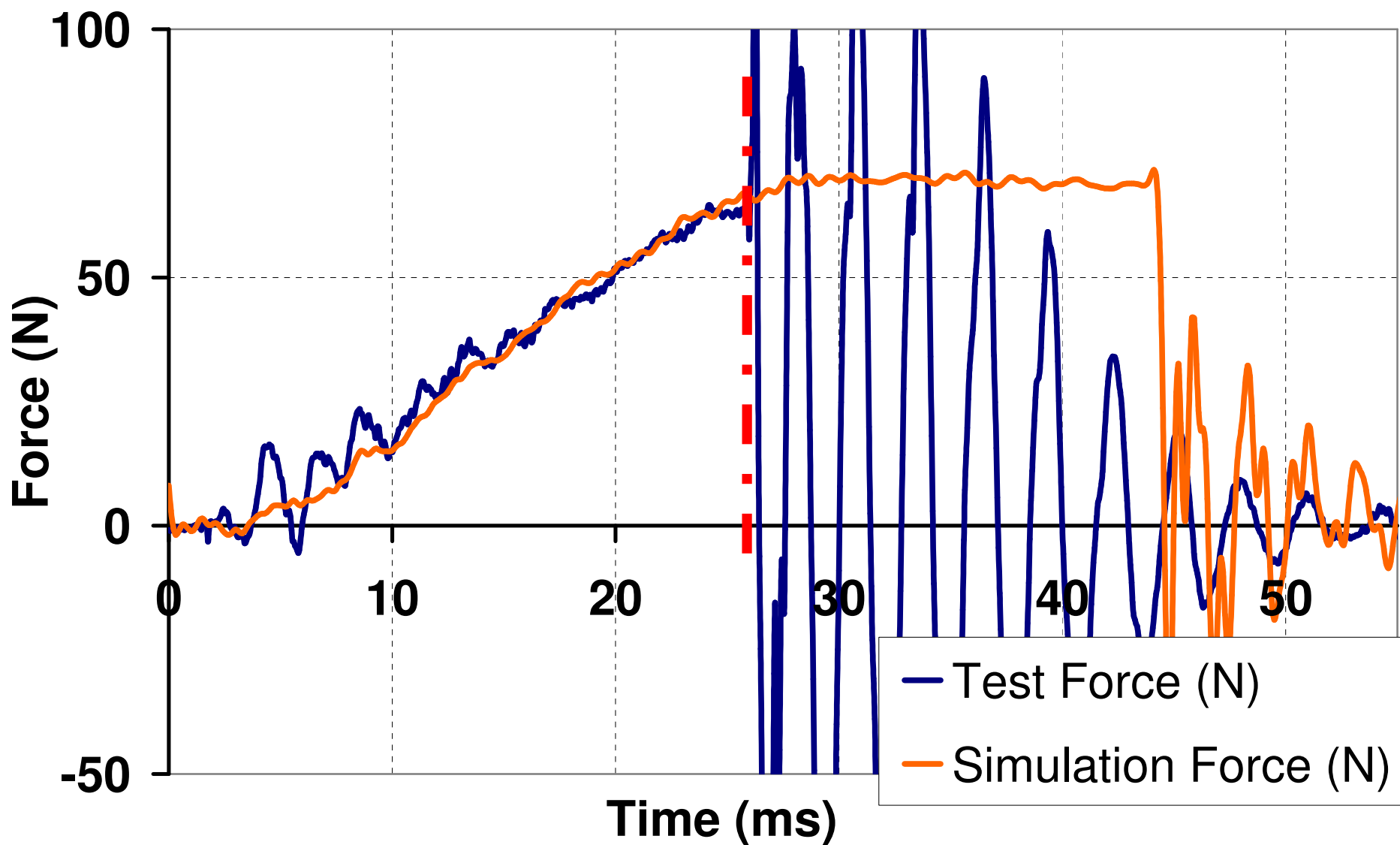
Results

Example : T544 rib 5L



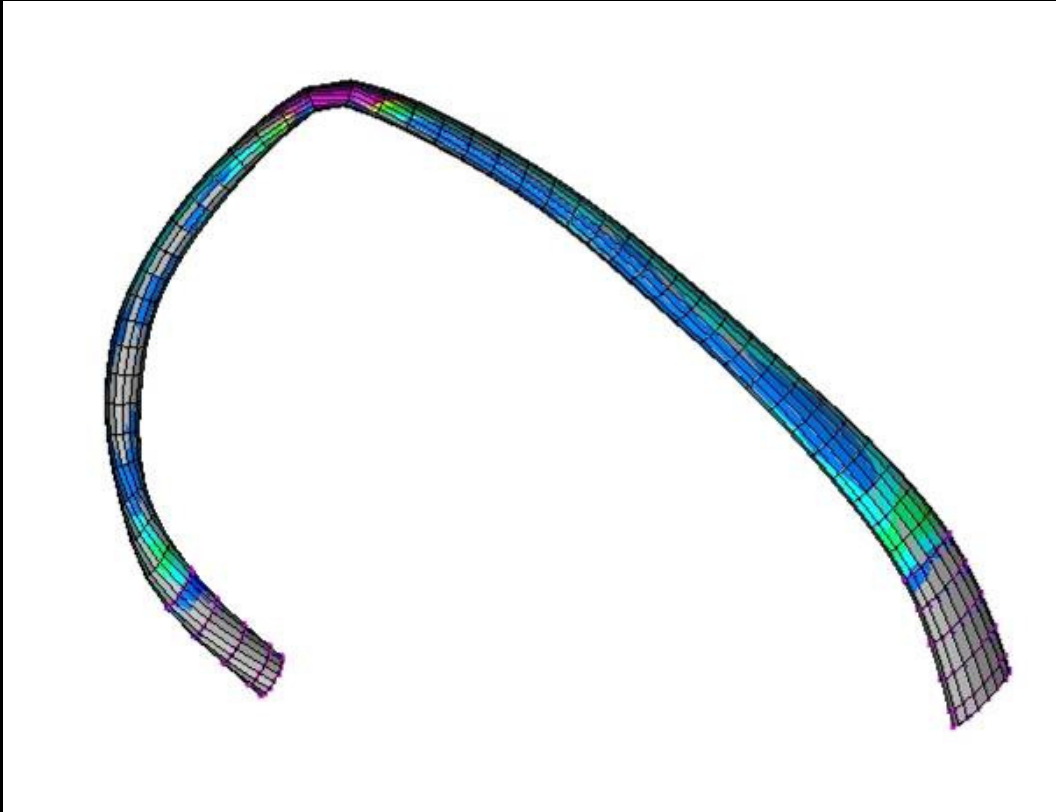
Results

Example : T176 rib 6L



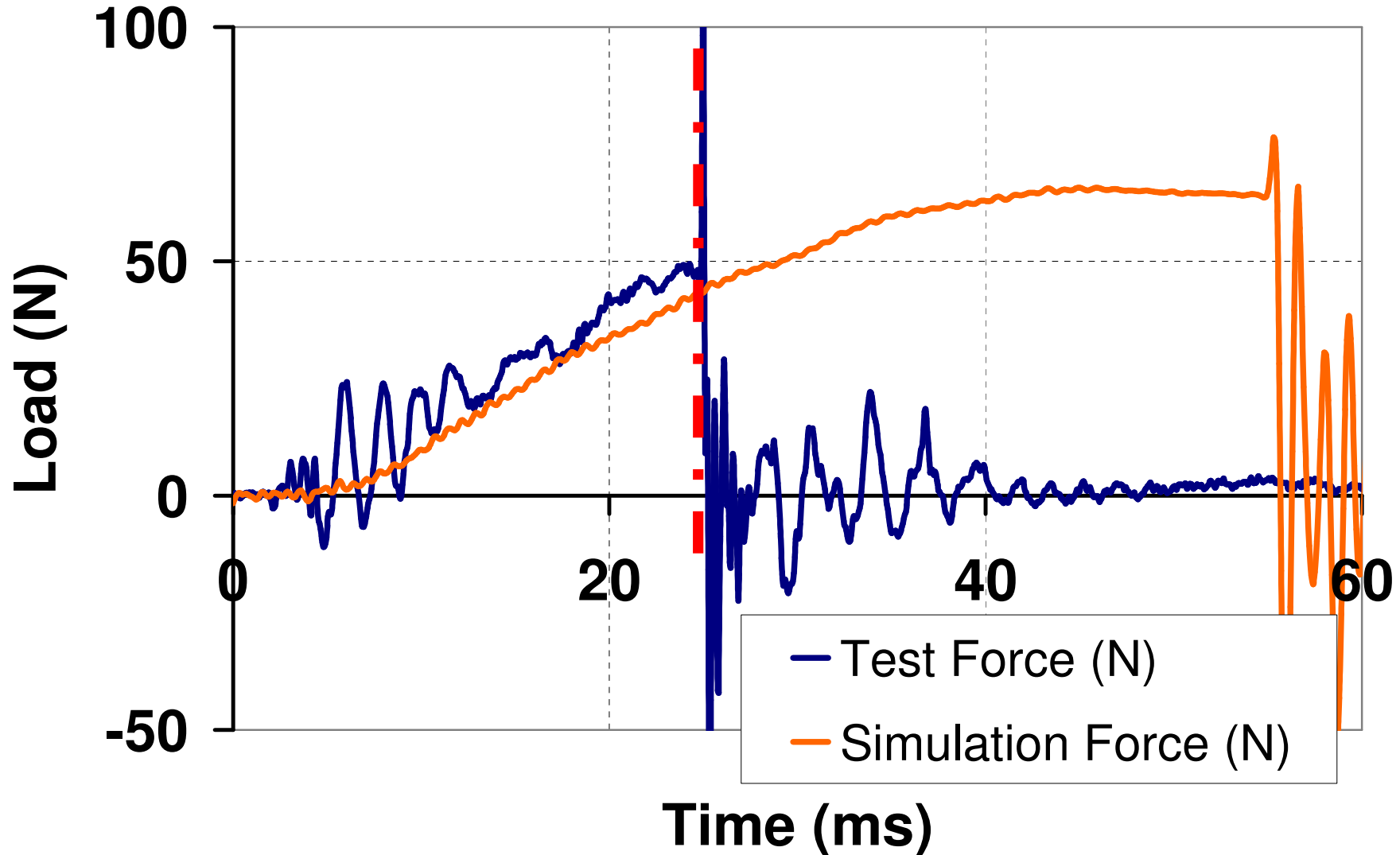
Results

Example : T176 rib 6L



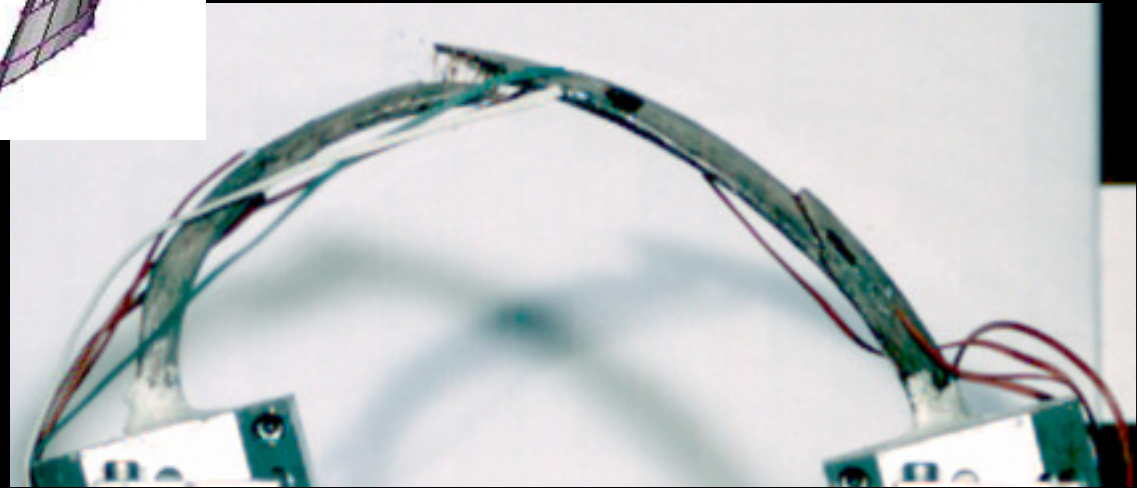
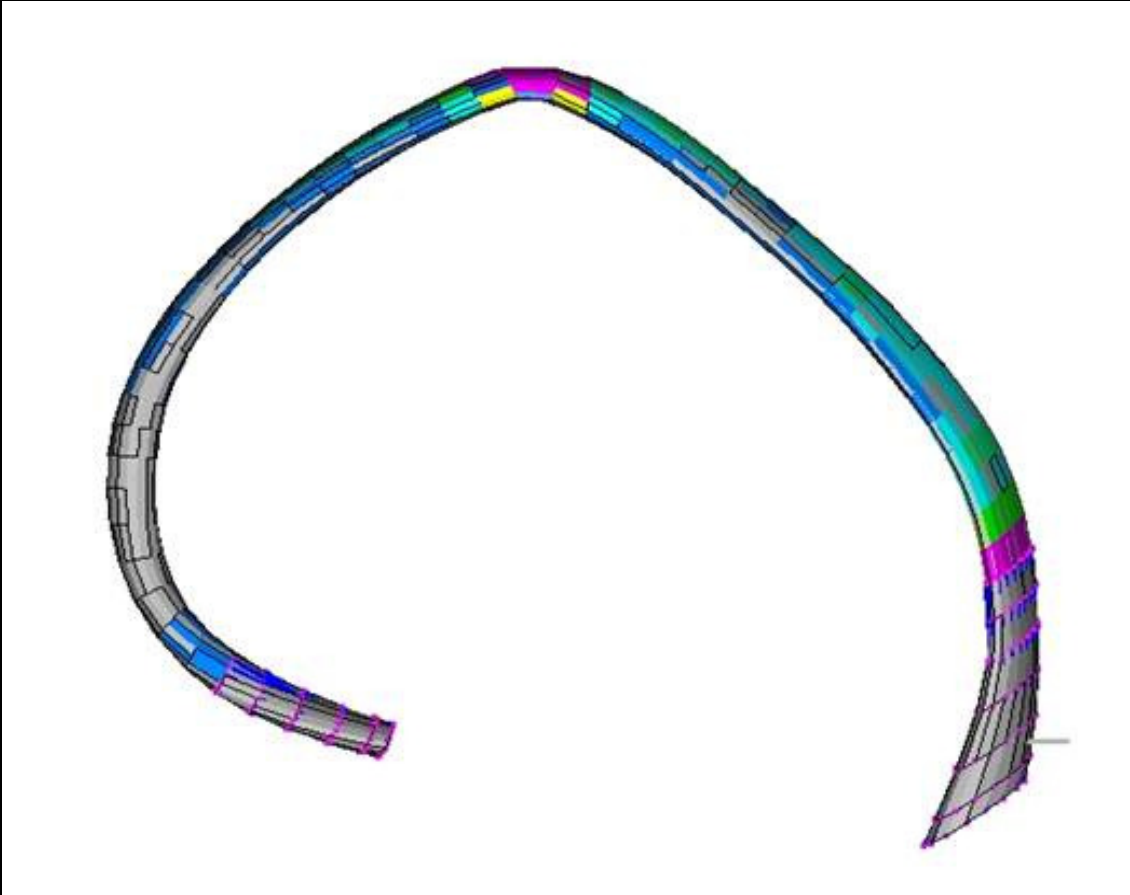
Results

Example : T176 rib 5L



Results

Example : T176 rib 5L



Results

FE modeling results : example of errors

Ref.	F_{\max} test (N)	F_{model} at time of failure (N)	Max strain (%)
T 548 Rib 5 R	141	149 (40 ms)	4.3 -3.3
T 544 Rib 5 L	78	72 (27 ms)	1.3 -1.3
T 176 Rib 5 L	49	41 (25 ms)	0.7 -0.7

max < 16%

For all ribs

Failure area

Discussion 1/2

- The location of the model-predicted fractures corresponds well with the experimental rupture sites.
- The general response of the model is in agreement with the test results.
- The simulations show a strong sensitivity of the mechanical properties to the rib geometry.
 - ⇒ models including personalized geometry were successfully developed and validated. They were used to identify the geometric influence on the structural response.

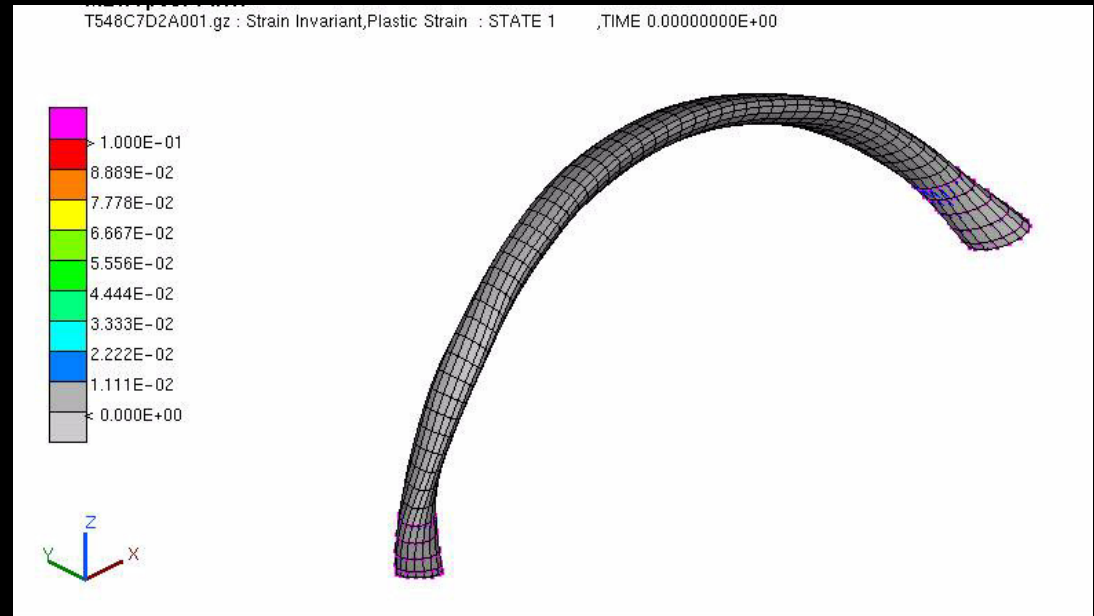
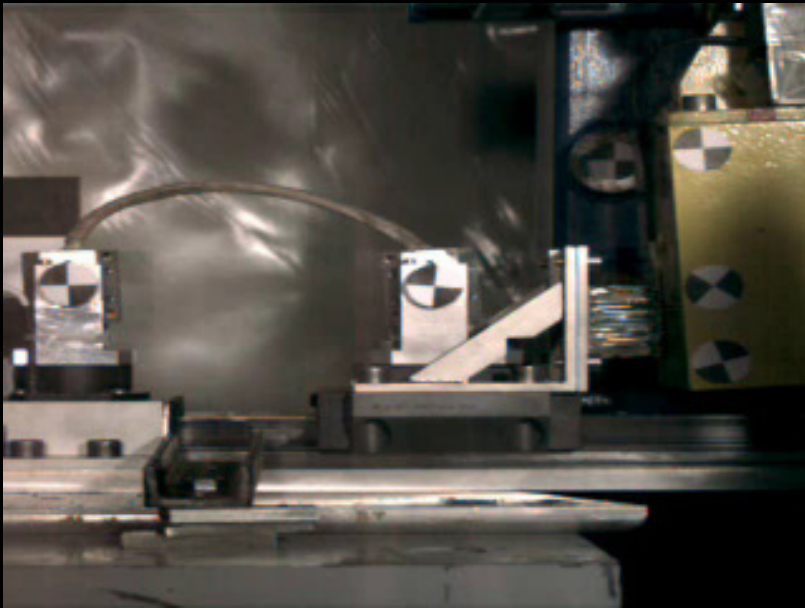
Discussion 2/2

Limitations:

- ✘ donors age [*Zioupos and Currey 1998, Zhou et al. 1996, Kent and Patrie 2005*]
- ✘ boundary conditions
- ✘ time of failure

Future work: Parametric Model of the ribs

Thanks for your attention



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