

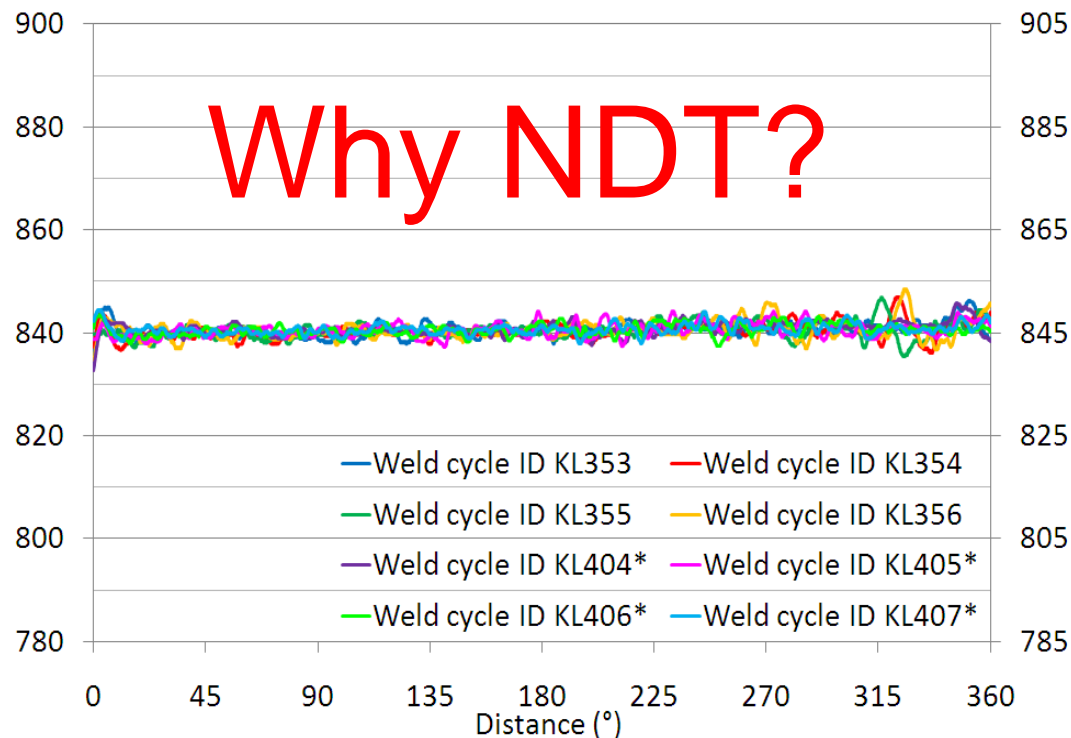


NDT of the copper friction stir welds

# The excellence of FSW

Very stable welding process

- Big margins to the process window
- Normally only limited JLH



# Why NDT?

- Process control – Joint line hooking
- "What if" scenarios
  - Other defects
- Regulations



# NDT development – Objectives

- To support the development of the manufacturing and welding processes
- To produce documentation as input for the planning of the encapsulation plant and the canister factory
- To develop the NDT techniques to be used in the final disposal system.

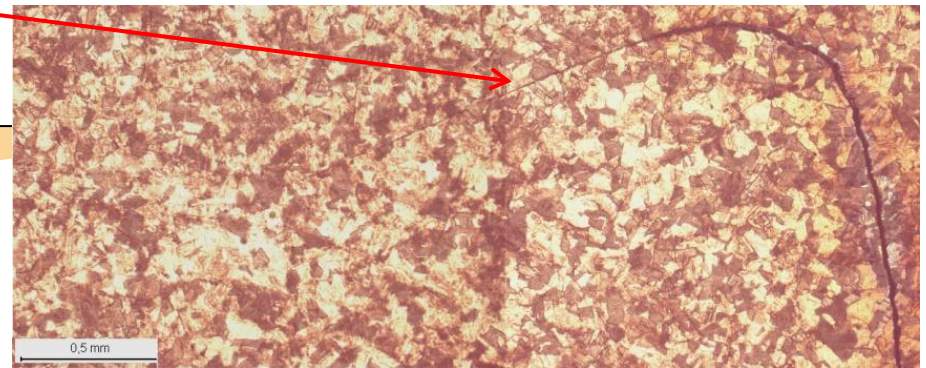
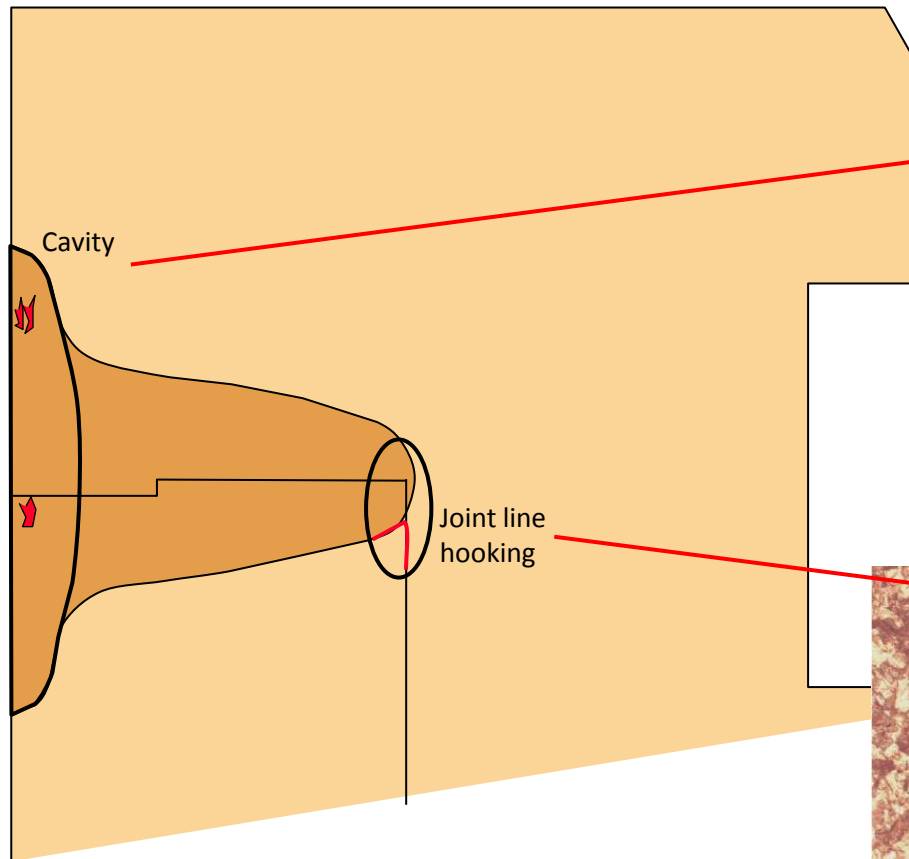


# History

- EBW inspection 1998-
  - Digital x-ray
  - Phased array ultrasonics
- FSW inspection 2003-
  - Based on the EBW-inspection techniques
  - Adapted for FSW geometry

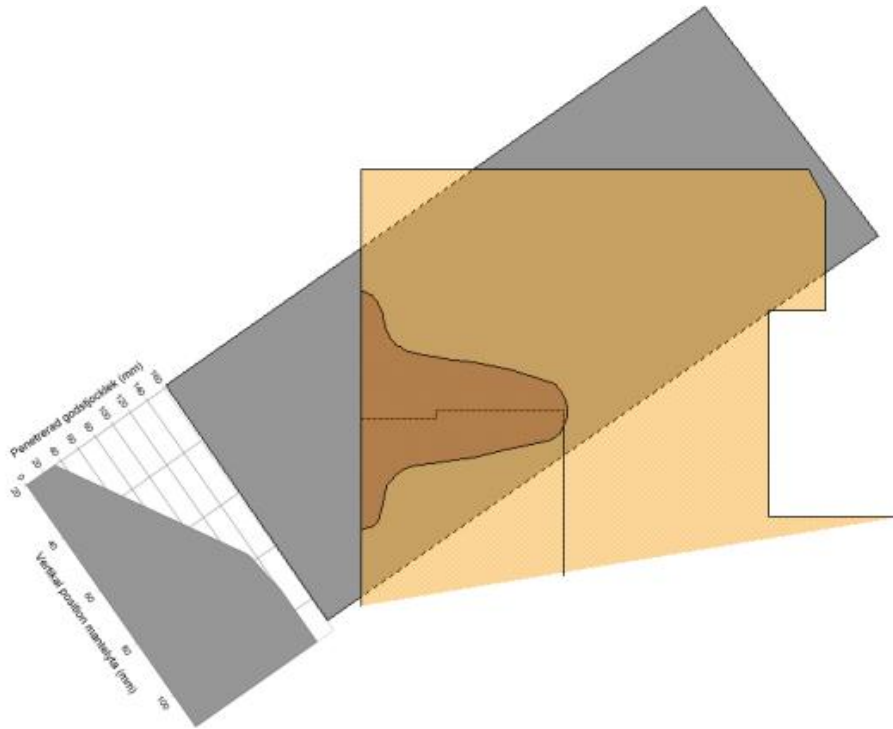


# What to find?

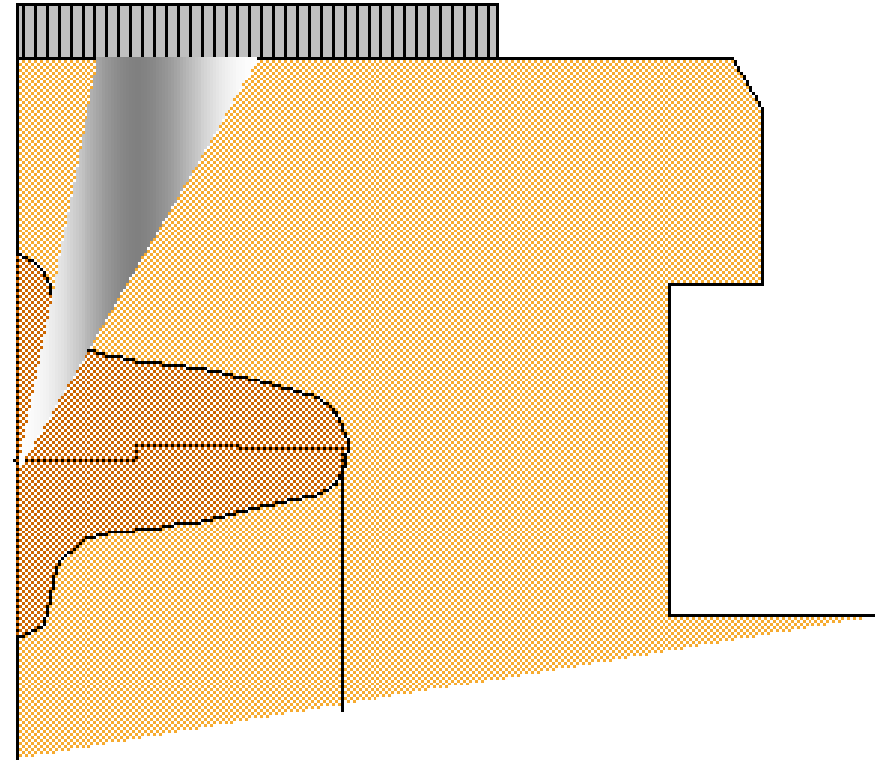


# Original inspection techniques

Digital x-rays

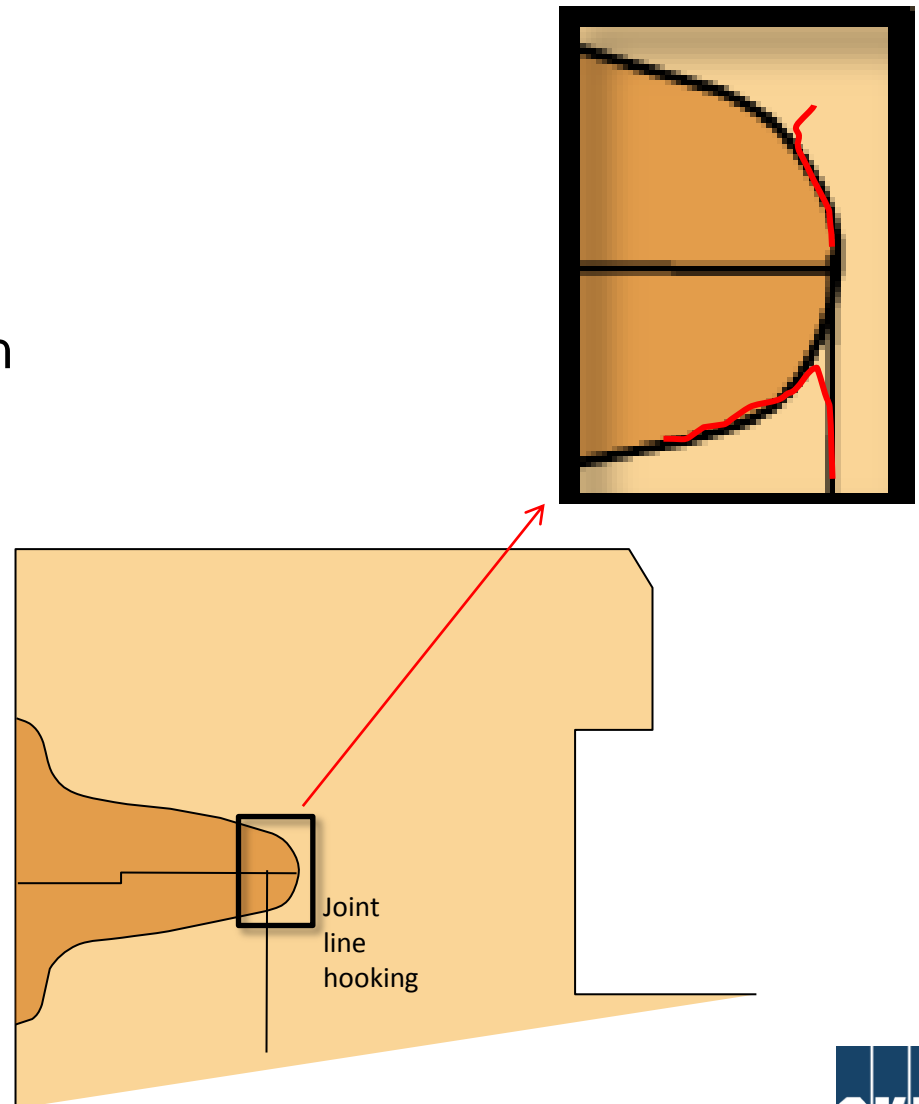


Phased array ultrasound



# Experiences

- JLH
  - High detection capability by ultrasound
  - Hard to size in radial direction
  - Properties changes by weld parameters
  - Give new conditions for NDT

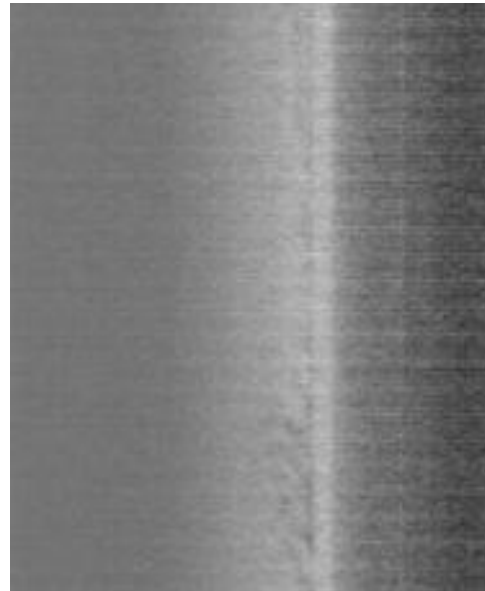




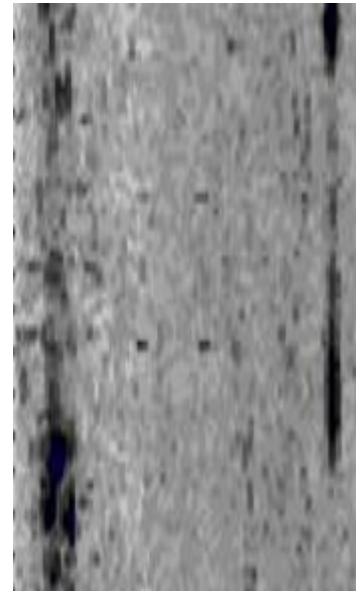
# Experiences

- JLH
  - Properties changes by weld parameters
  - Give new conditions for NDT
- Cavities
  - Irregular shape
  - Volumetric or non-volumetric
  - Demanding for NDT

X-rays

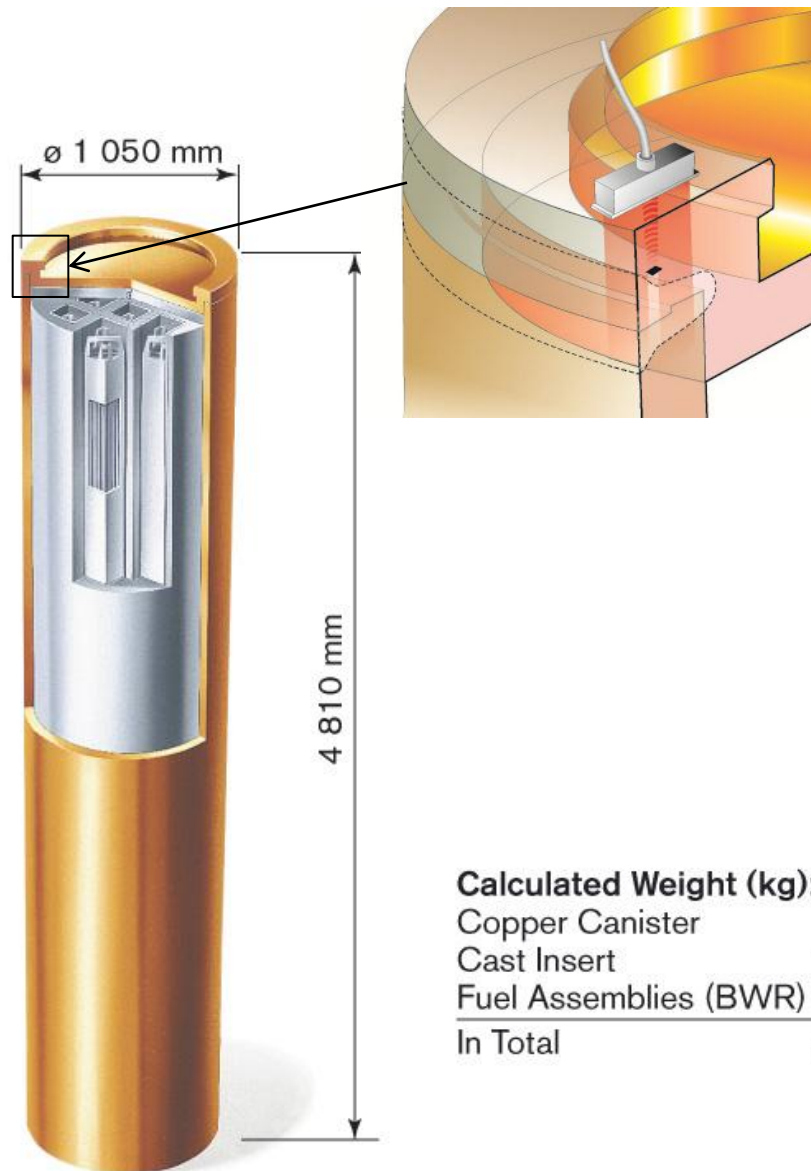


Ultrasound



# NDT development 2005-2011

- But! – Not only the welds
- Weld volume << canister



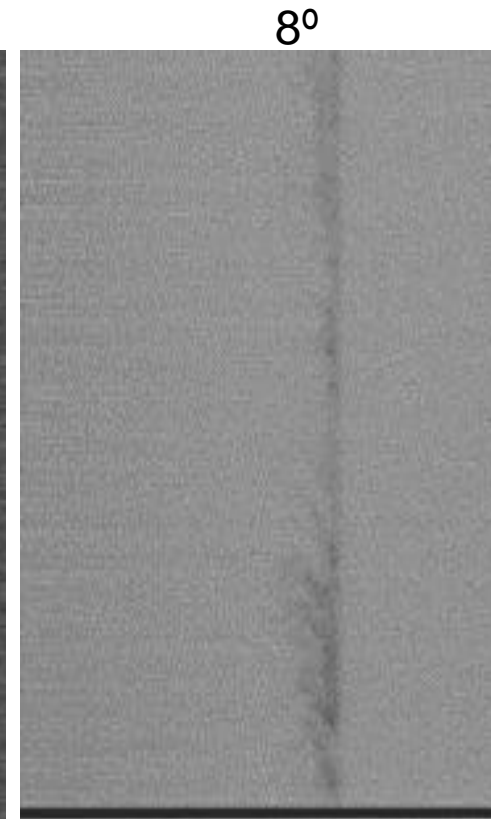
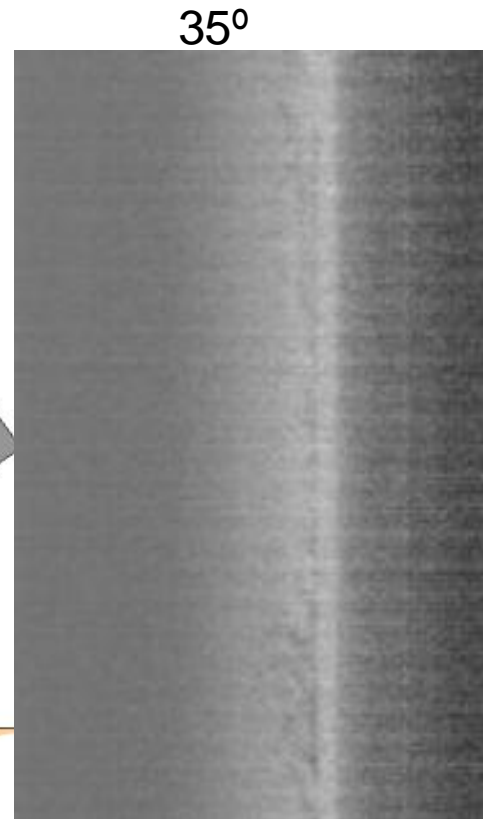
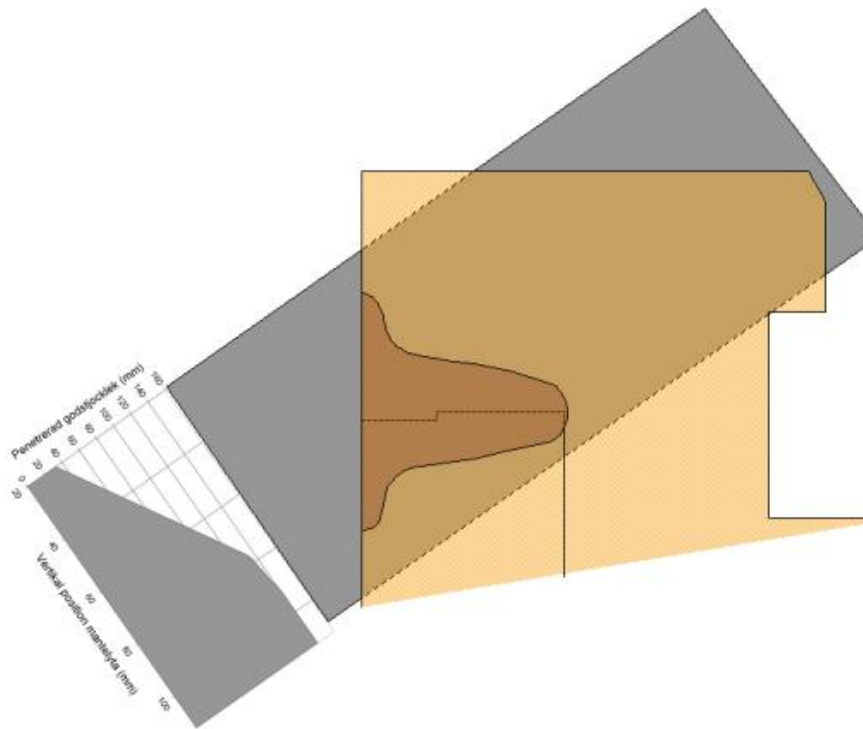
## Calculated Weight (kg):

Copper Canister	4 800
Cast Insert	15 900
Fuel Assemblies (BWR)	3 600
In Total	24 300

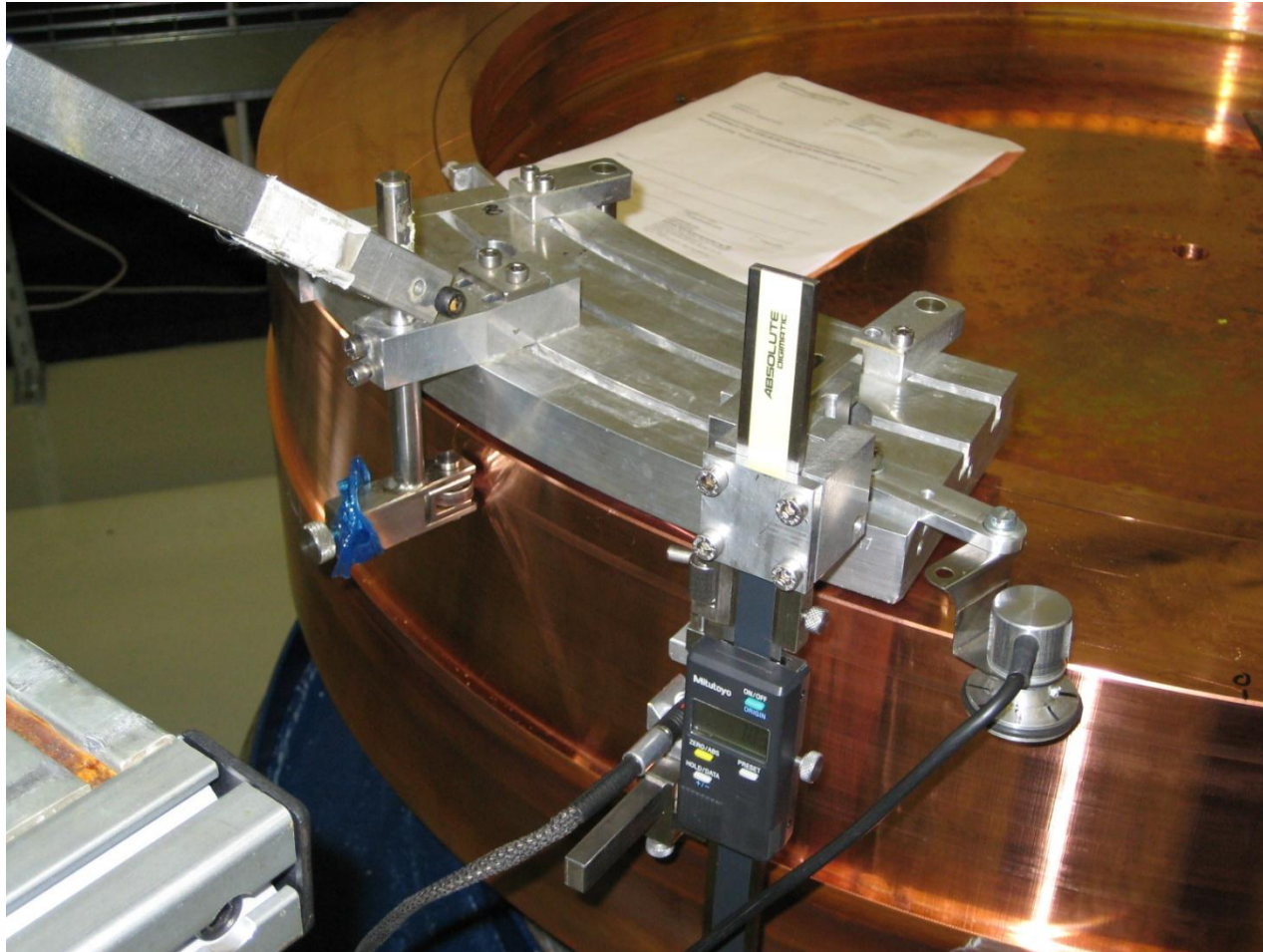


# Recent optimizations – X-rays for cavities

Decreased incidence angle

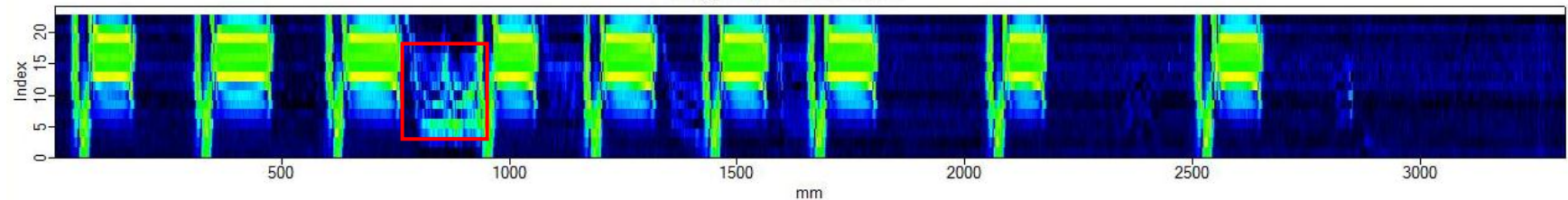


# Recent development – Eddy current inspection

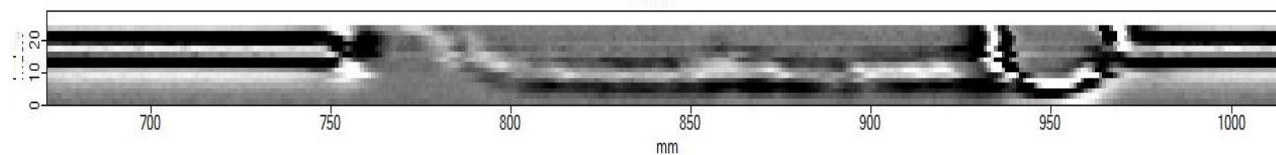


# Recent development – Eddy current inspection

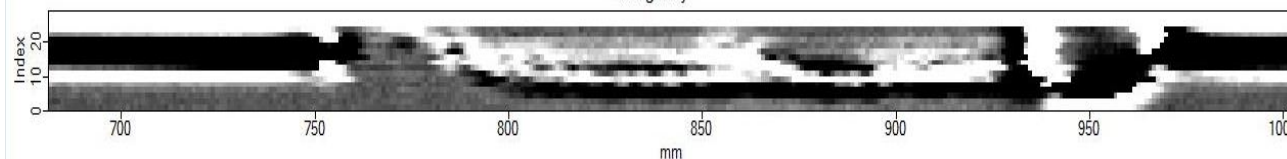
Magnitude TX 213 500Hz



Real



Imaginary



# Ongoing work

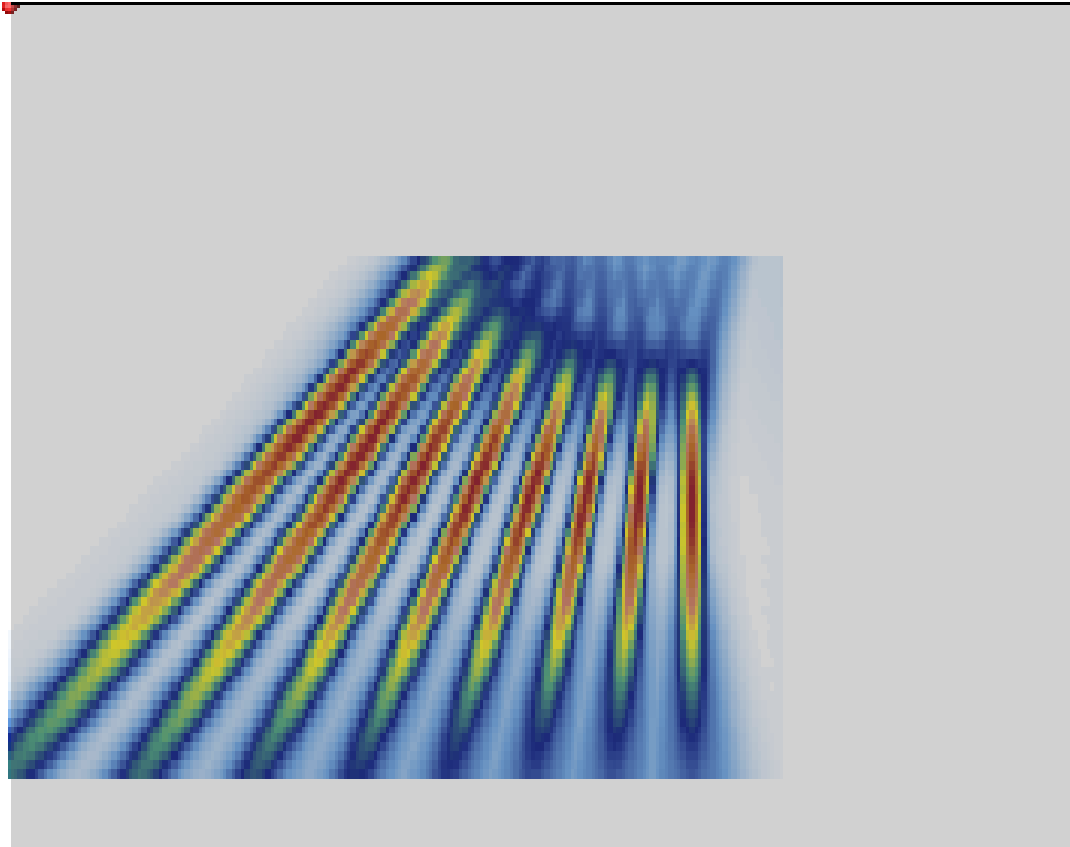
- Evaluation of x-ray detectors
- Optimization of phased array ultrasound



# Cavities – optimized phased array ultrasound

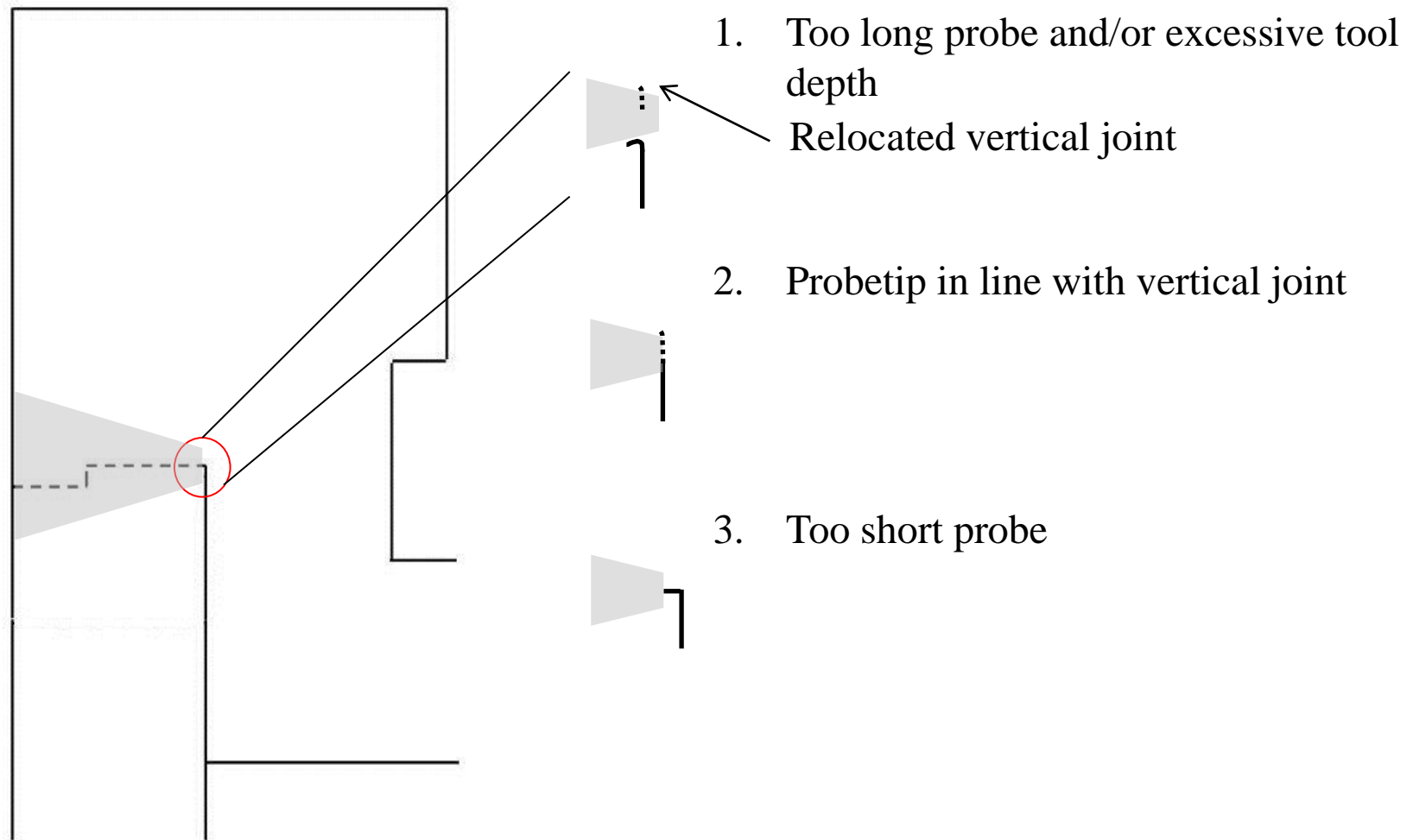
Variations in

- Focus depth
- Steering angle



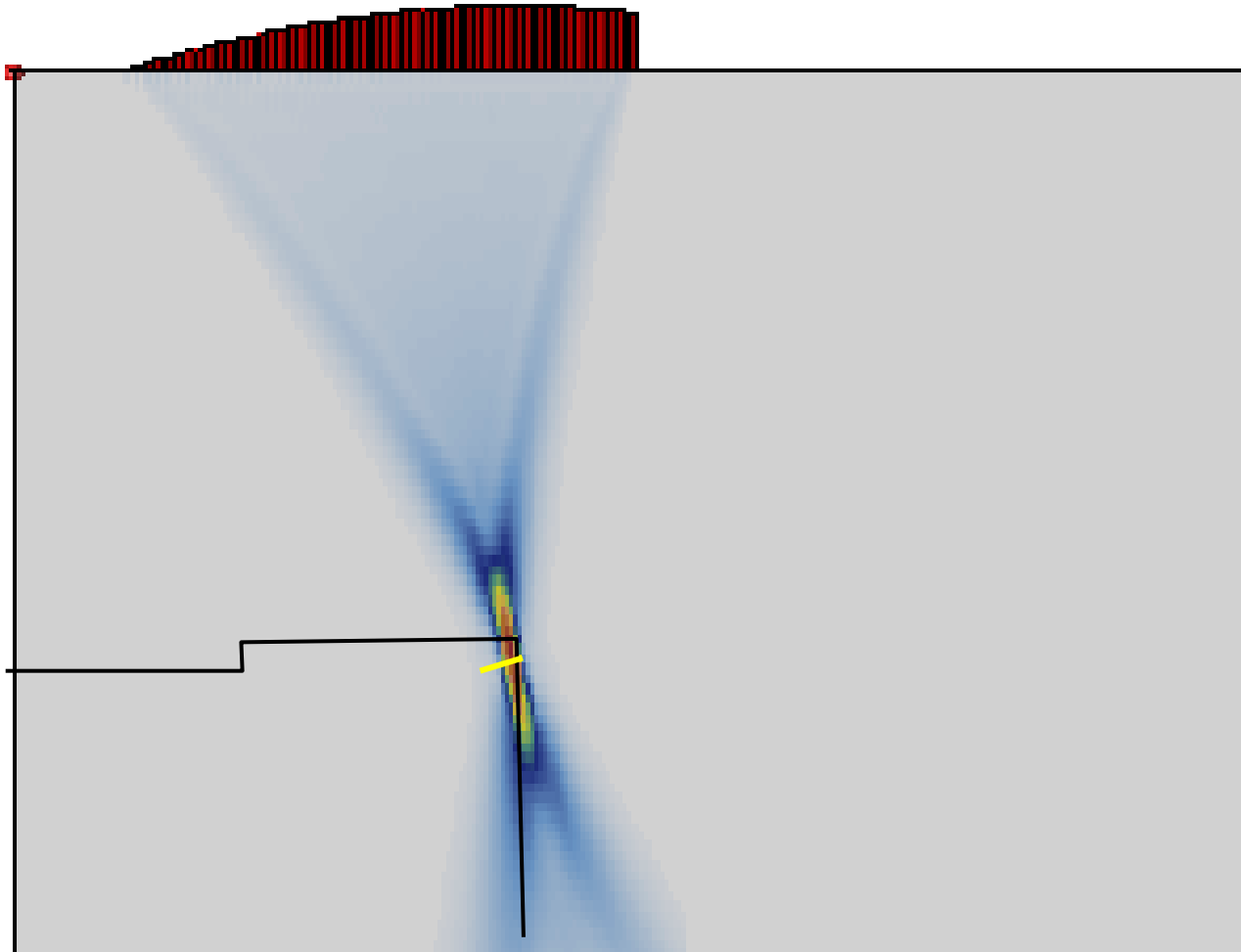


# Joint line hooking (JLH) - Variations

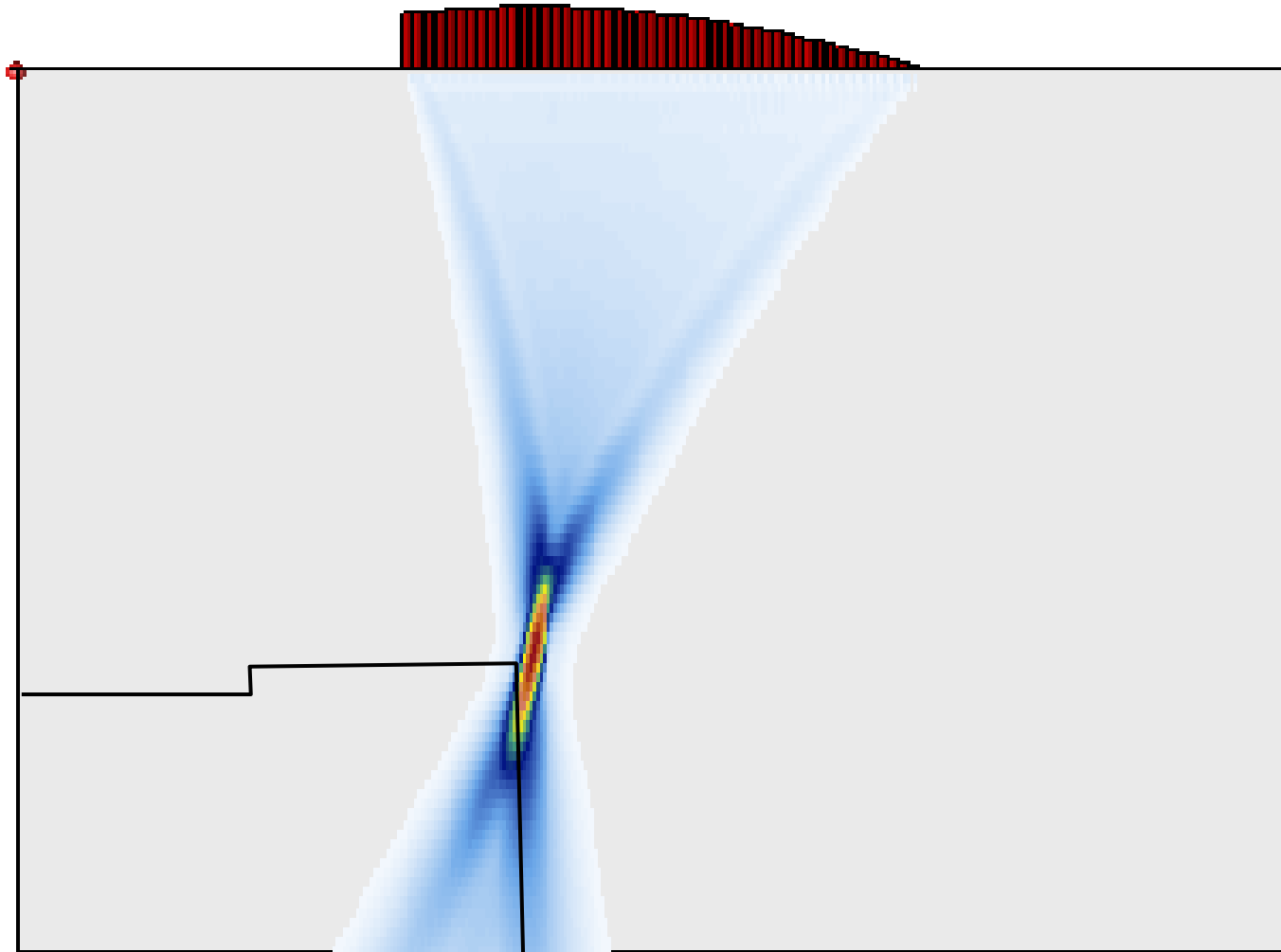




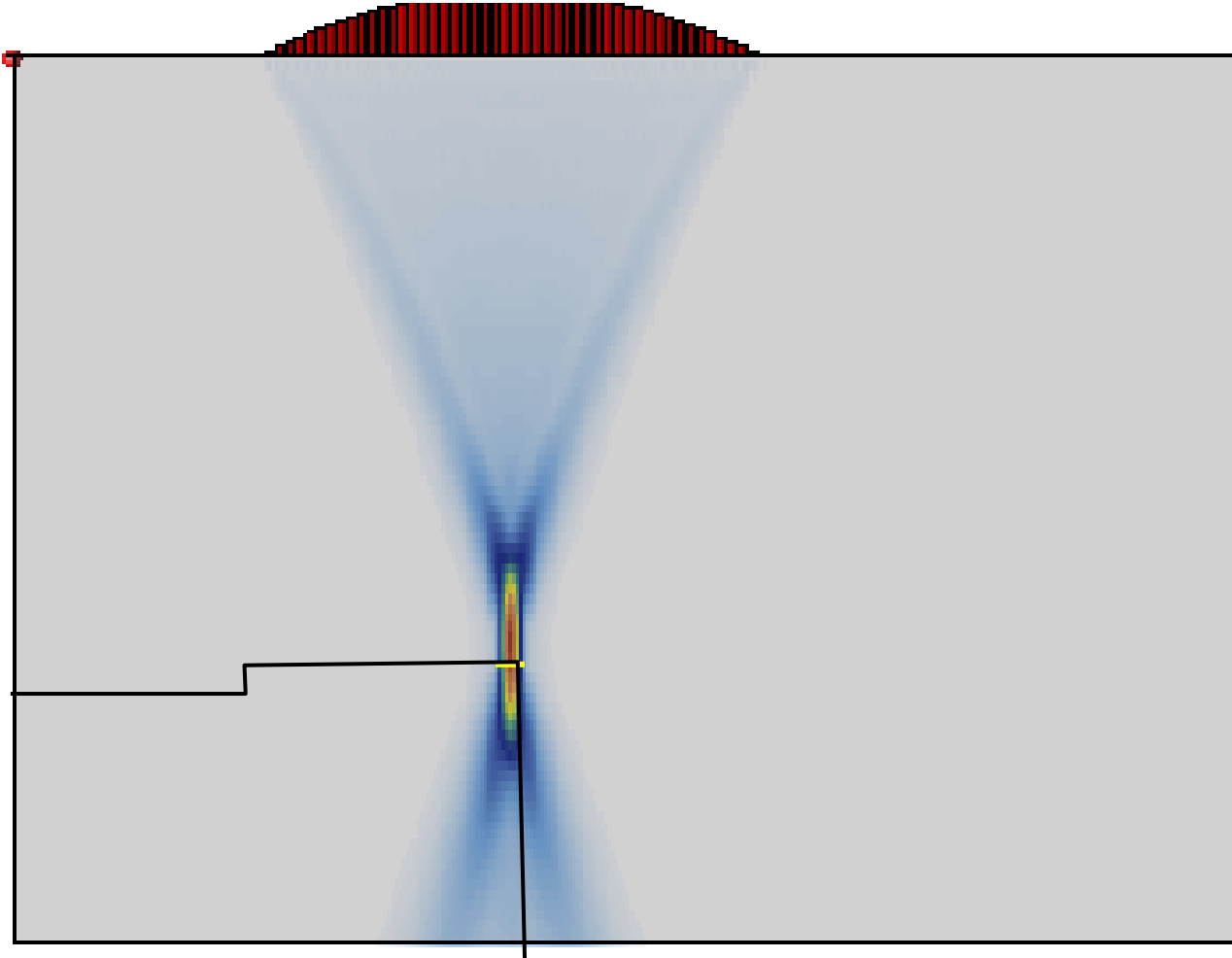
# JLH – optimized phased array ultrasound



# JLH – optimized phased array ultrasound



# JLH – optimized phased array ultrasound



# Inspection techniques

	Cavity	JLH
Digital x-rays	X	
Phased array ultrasonics	X	X
Eddy current	X	