

ClearPEM-Sonic: combined PEM and Ultrasound

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PHYSICS FOR HEALTH IN EUROPE WORKSHOP, CERN



Outline

- ◆ Introduction
- ◆ ClearPEM: a dedicated Positron Emission Tomograph
- ◆ Aixplorer: the 3D ultrasound / elastography system
- ◆ ClearPEM-Sonic: combining both worlds
- ◆ Outlook



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Introduction: Breast Cancer

- ◆ **1 woman in 8** will develop cancer throughout her life
- ◆ **2nd cause of cancer death** amongst women
- ◆ **Very good survival rates** if detected at an early stage
(> 75% of patients have a 10-yr disease-free survival if tumor < 5cm)
- **Breast cancer screening is now standard technique:**
 - ◆ **Palpation:** low sensitivity and specificity
 - ◆ **X-ray Mammography:** high sensitivity and specificity BUT less reliable for dense breasts, unsuited for young, pregnant women and implants
 - ◆ **Ultrasound:** complementary to X-ray
 - ◆ **Biopsy:** only to confirm previous indication

 - ◆ **MRI:** very high sensitivity BUT low specificity and high costs
 - ◆ **Whole-body PET:** only technique with metabolic information BUT low resolution and high costs
- **Room for a new technique**



The Pink Ribbon – the international sign for breast cancer awareness

Introduction: ClearPEM-Sonic

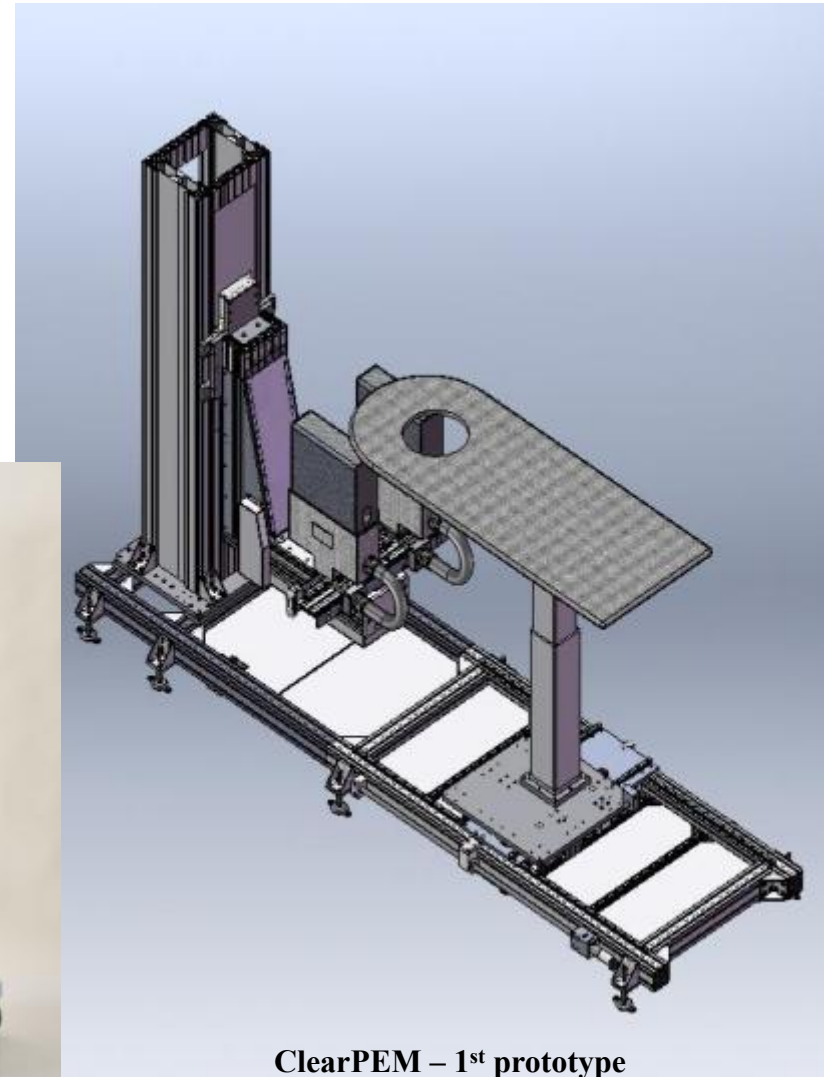
◆ ClearPEM-Sonic

- a project in the frame of CERIMED that combines:
 - a **dedicated mammography PET**, the ClearPEM
 - an **US transducer** working in elastographic mode from SuperSonicImagine
- partners: CERN, LIP, VUB, U2, LMA, APHM, IPC, Taguspark, SupersonicImagine

◆ Combines both information:

- ClearPEM: **METABOLIC** (1 to 2mm resolution)
- US detector: **MORPHOLOGIC** and **STRUCTURAL**

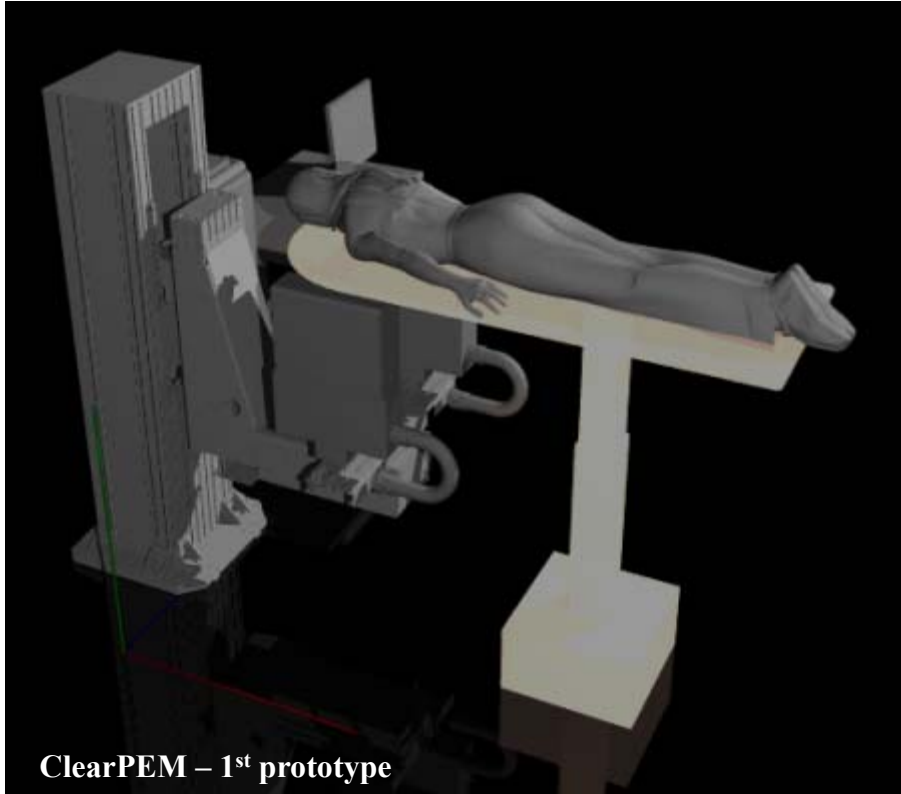
→ **an imaging modality that improves the diagnosis for patients with breast lesions**





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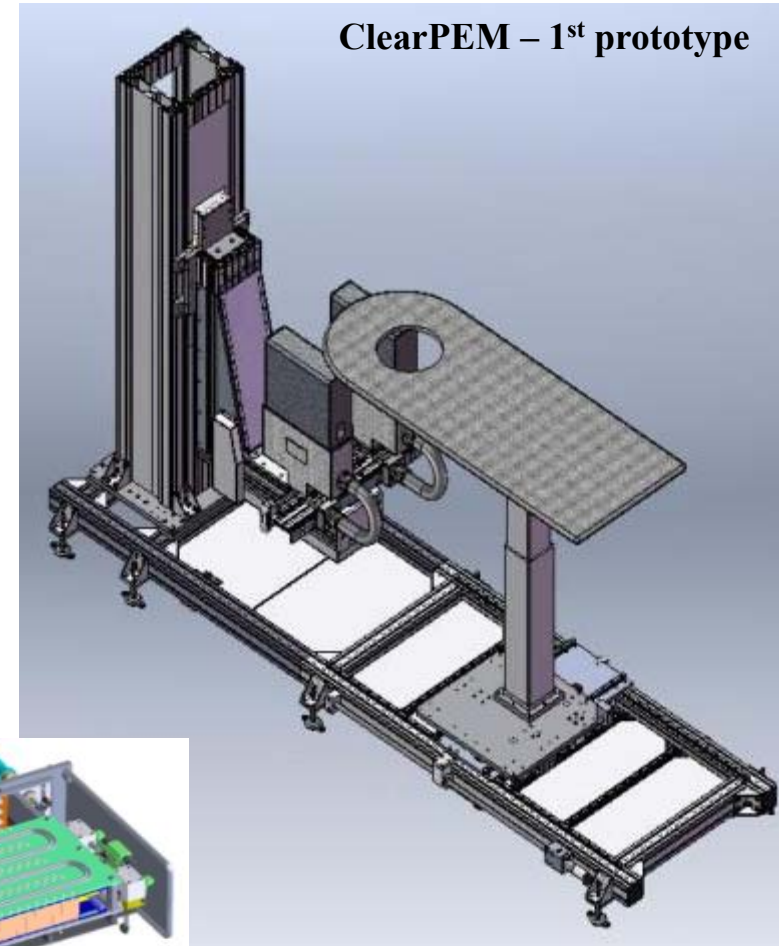


- ◆ **A dedicated mammography PET (Positron Emission Tomograph):**
 - Breast exams with the patient in prone position
 - The plates rotate around the breast
 - PEM plates can be rotated for axillary exams
- ◆ **Good spatial resolution : 1.4mm (FWHM)**
 - Fine crystal segmentation (2x2 mm)
 - Reduced parallax effect by optimised depth of interaction resolution: 2 mm
- ◆ **High Sensitivity:**
 - Solid angle coverage as large as possible
 - High photon interaction probability (20 mm long crystals)
 - High efficiency due to good energy resolution at 511 keV: 15.9%
- ◆ **Excellent Time Resolution:**
 - Single photon time resolution 1.5 ns (RMS)
 - Coincidence window: 5.2 ns

ClearPEM: The Machine

- ◆ 6144 LYSO:Ce crystals in 192 matrices
- ◆ APD readout on both sides of the crystal
- ◆ Fast Front-End readout with dedicated ASICs
- ◆ Two detector plates

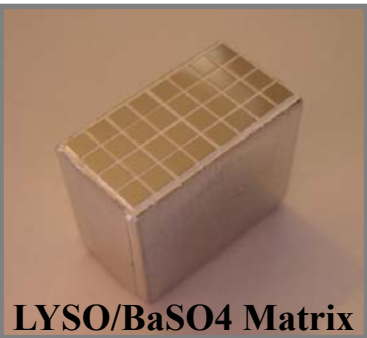
→ 0.8MHz acquisition rate



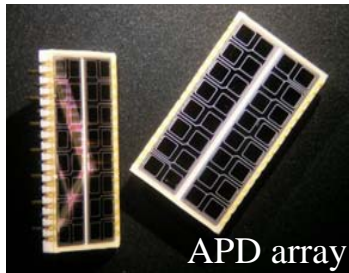
ClearPEM – 1st prototype



Detector Plate

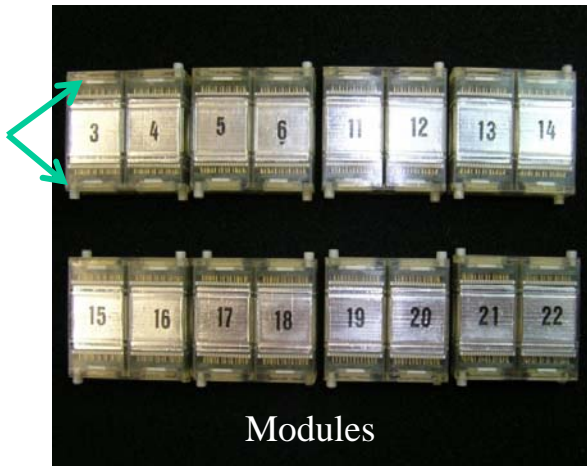


LYSO/BaSO4 Matrix



APD array

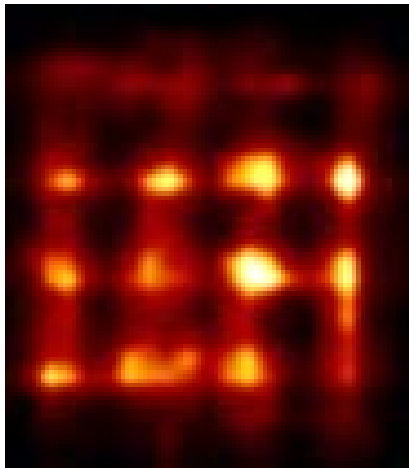
Front-back readout



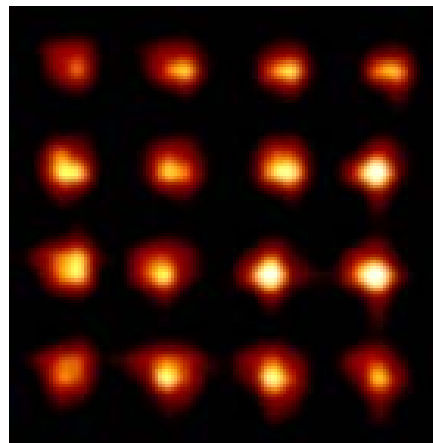
Modules

◆ Image Setup:

- 1mm Na-22 source moved along a grid with 5mm pitch
- 2 acquisitions with orthogonal plate orientations for each source location
- Simultaneous reconstruction of 16 source positions
- Reconstruction with and without considering DOI, i.e. the measurement of the photon interaction point with the crystal



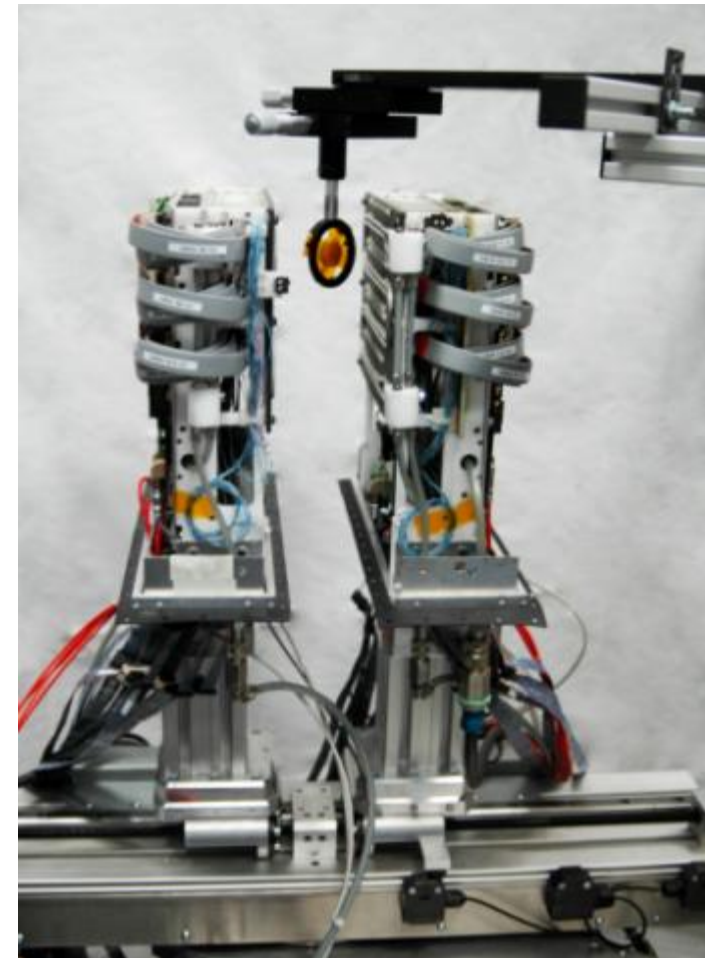
Without DOI:
increased parallax effect



With DOI

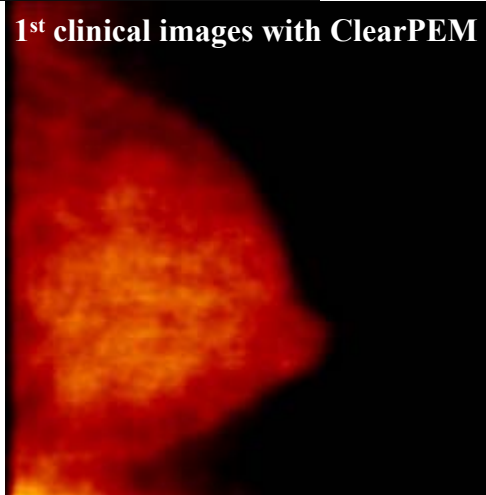
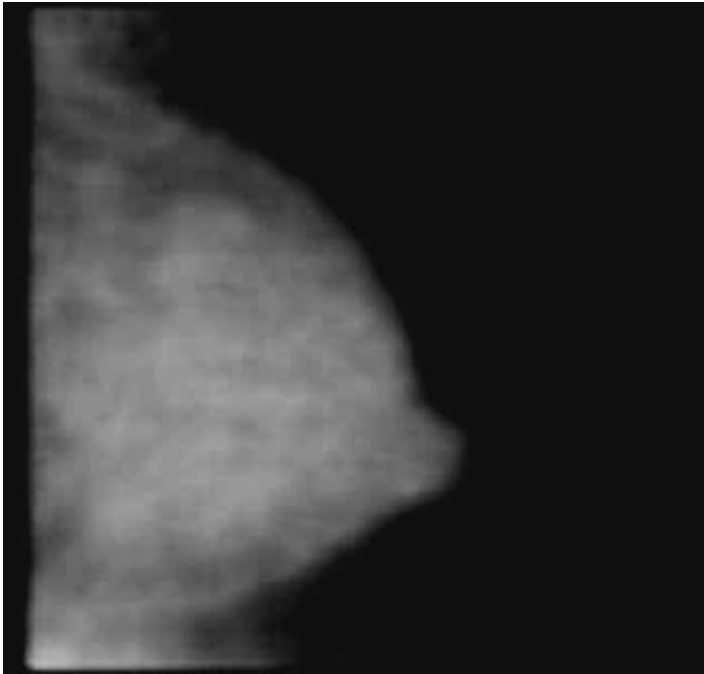
→ Results

- Horizontal FWHM: 1.3mm
- Vertical FWHM: 1.2mm



Test Setup with ClearPEM detector plates

ClearPEM: Current Status

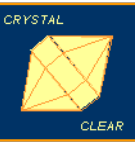


◆ Timeline:

- 2002: Project Start
- Autumn 2008: First prototype installed (IPO Porto)
- May 2009: Start of Phase 1 clinical trial (30 patients negative for breast cancer)
- May 2010: Phase 2 trial (150 patients with breast cancer)

◆ Conclusion:

- ClearPEM technological developments were **successfully completed**
- The detector **performance is excellent**
- ClearPEM is one of the most innovative APD-based PET systems



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US system: Presentation



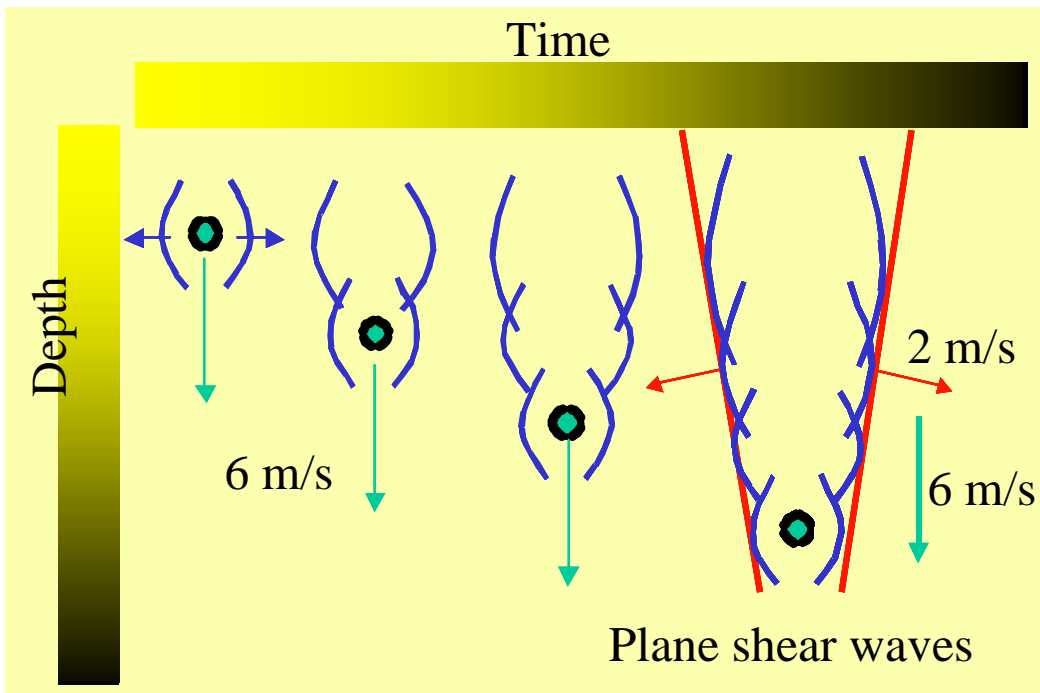
SuperSonic Imagine Aixplorer

- ◆ **SuperSonic Imagine Aixplorer:**
 - Real-time ShearWave™ **elastography**: a unique technology to quantify elastic properties of tissues
 - **3D imaging** with a conventional high frequency 3D mechanical linear probe for superficial application
 - Acquisition of a $40*40*40\text{mm}^3$ volume in less than 20s with high resolution B-mode and 3D SWE information
 - Voxel size $100\mu\text{m}*100\mu\text{m}*75\mu\text{m}$

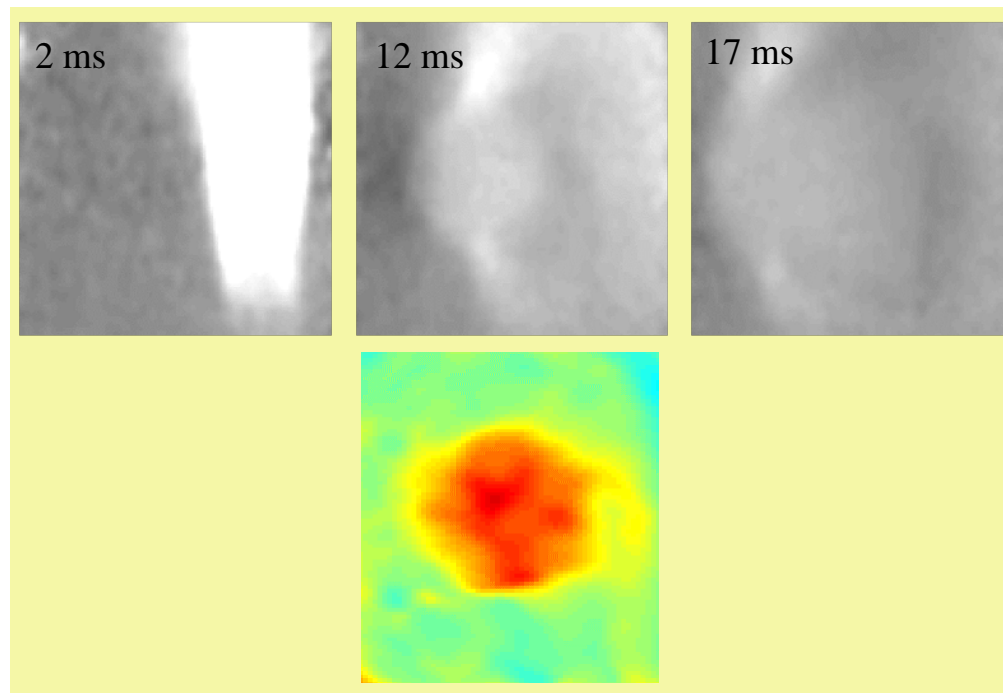
- **Provides important information for breast tumour diagnosis and follow-up:**
 - Morphology
 - Size, shape and volume
 - Acoustic signature and vascularisation
 - Local and global elasticity

- SSI: - injects a focalized beam that moves with supersonic speed through the tissue
- this long focused pulse creates Dynamic Radiation Force that generates transient Shear Waves
- this Shear Wave front is altered by different tissue stiffnesses
- this information is captured with Ultrafast™ imaging

→ User-independent, Real-time, Quantitative method

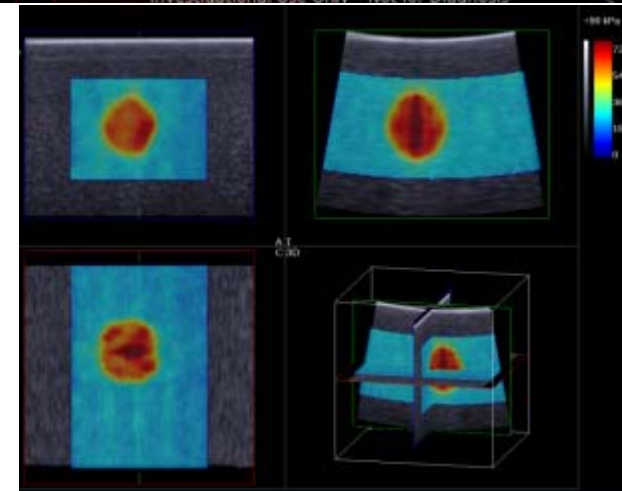
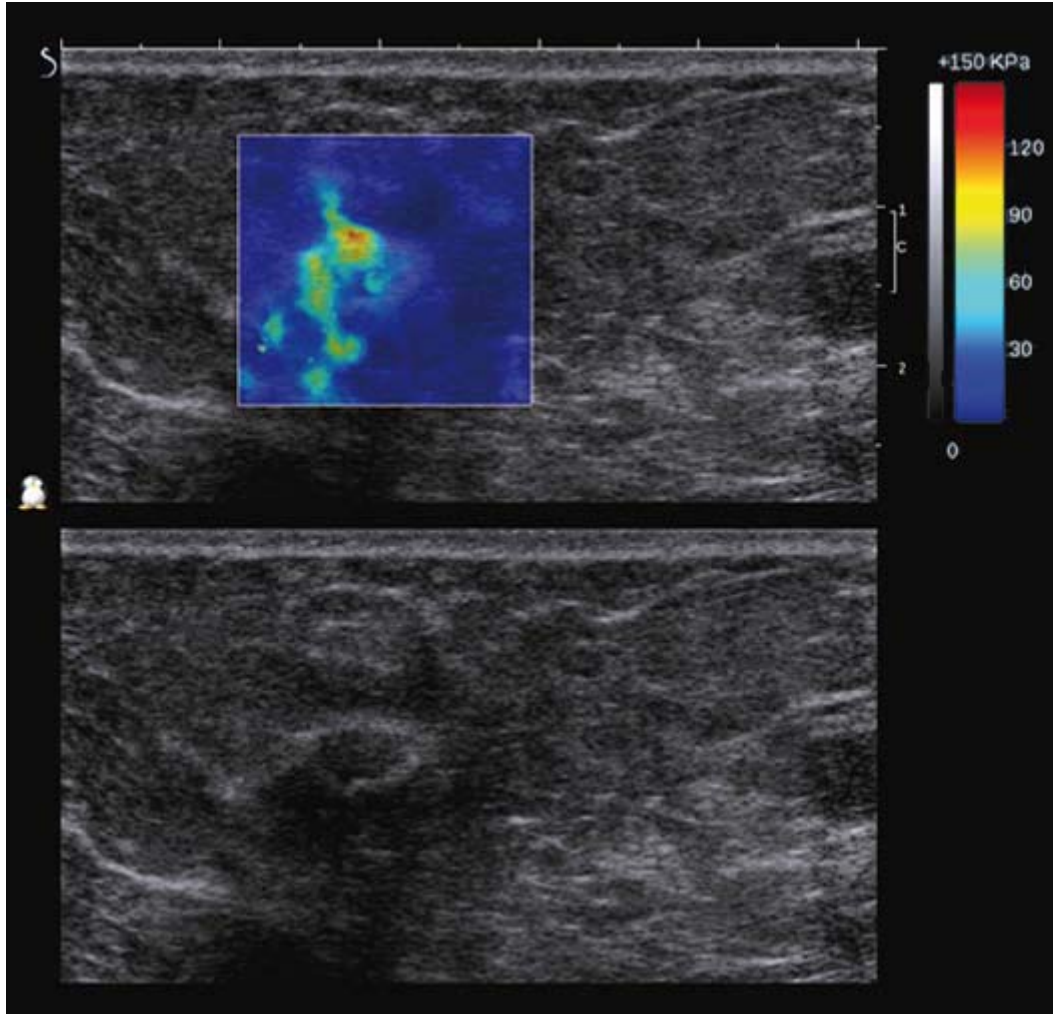


The principle of Shear Wave generation



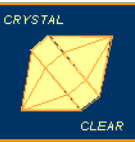
Shearwave propagation around a lesion

US system: 2D and 3D Information



2D image, millimetric lesion

3D image, phantom lesion

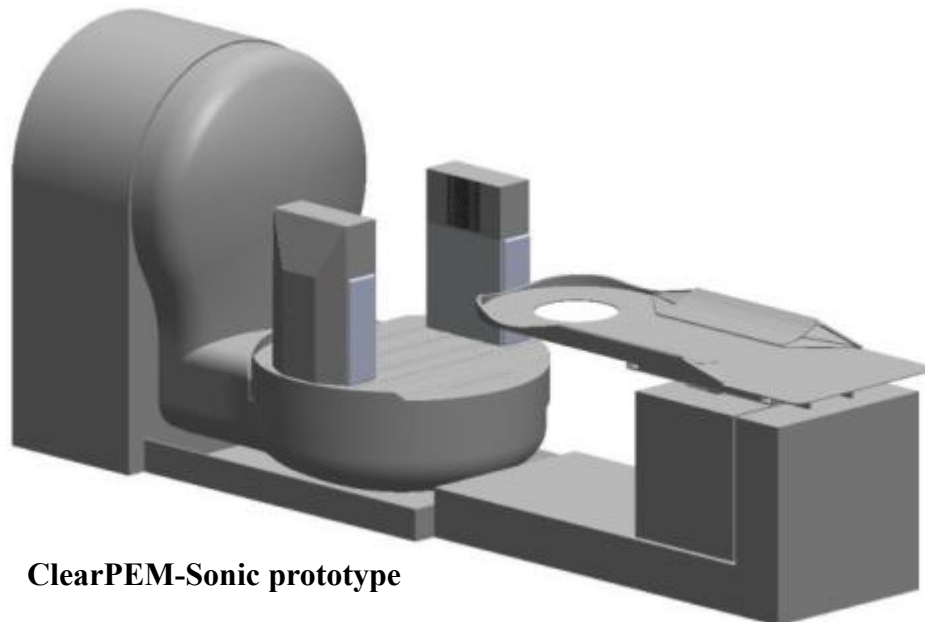


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ClearPEM-Sonic: Targets

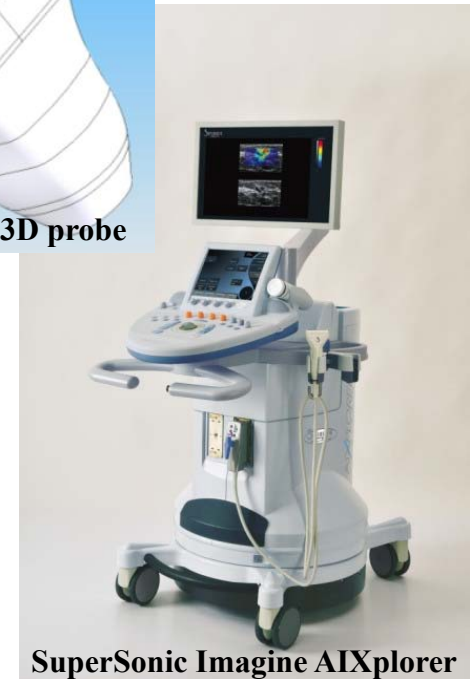
- ◆ **ClearPEM-Sonic: combining METABOLIC, MORPHOLOGIC and STRUCTURAL information into a multimodal PEM-US imaging technology**
- ◆ **Breast contention**
 - Patient shall not change her position during the whole exam
 - Breast shall not move during the whole exam
- ◆ **Mechanical integration**
 - Imaging of any ROI possible with both modalities
 - Modalities shall deform the breast the least possible
 - Shall not interfere with the respective other modality
 - Shall be user-friendly
- ◆ **Image Fusion**
 - Images from both modalities must be fused with sufficient precision



ClearPEM-Sonic prototype



Aixplorer 3D probe



SuperSonic Imagine Aixplorer

ClearPEM-Sonic: Breast Contention

◆ Best Solution:

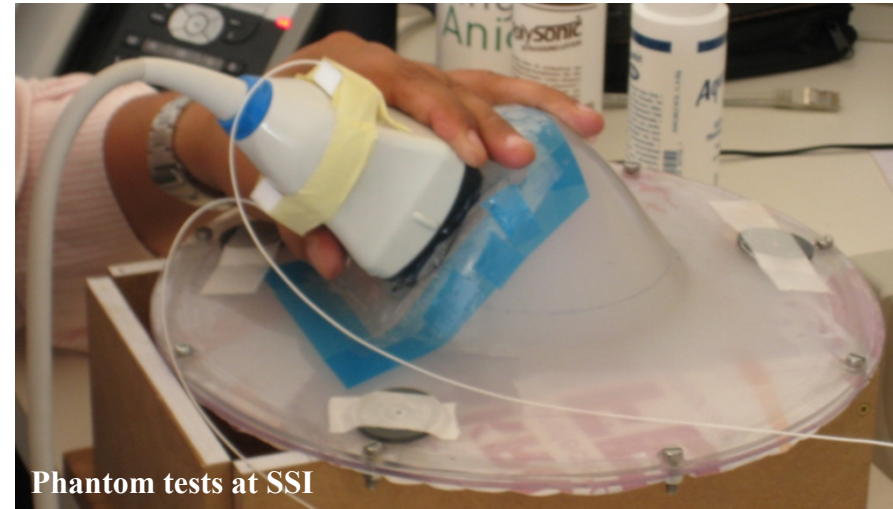
- **conical geometry adapted to the shape of the breast**
- **Window** places the US transducer into direct contact with the breast
- **Cone manually rotatable** around the vertical axis
- Different cones realised with different inner diameters and vertical elongations for varying breast sizes

◆ Main Advantage: No Compression

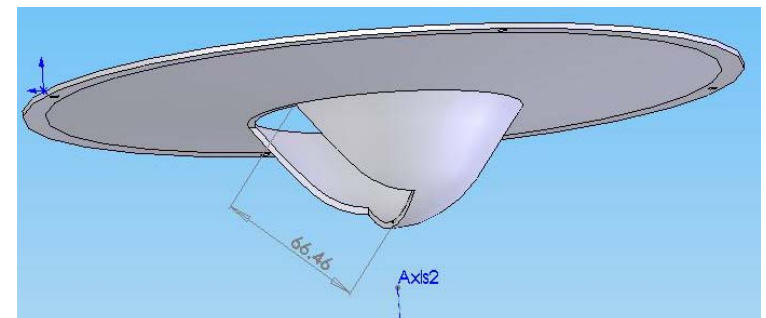
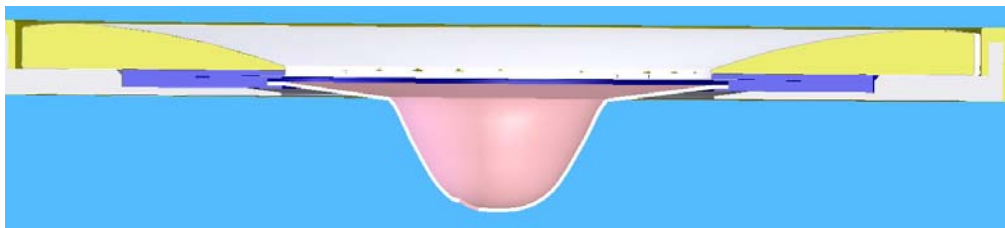
- more **comfort for the patient**
- **anatomically correct** imaging



Image courtesy of Dr. Valérie JUHAN (APHM)

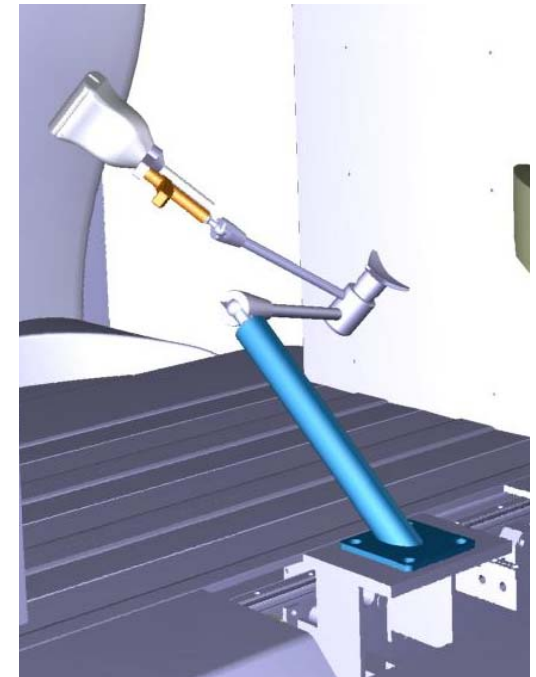
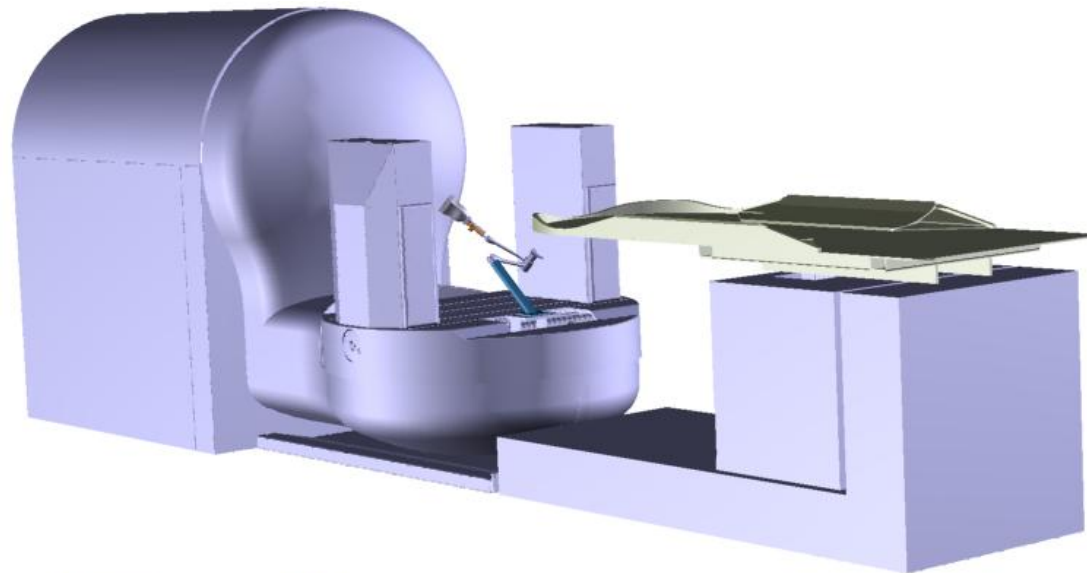


Phantom tests at SSI



ClearPEM-Sonic: Transducer Arm

- ◆ US transducer fixed to an arm that is fixed on the PET platform at 90 degrees to the PET plates:
 - Arm can place the transducer with any inclination in any position required by the operator
 - Arm can be removed for the initial PET exam
 - Possibility to acquire an additional PET image together with the US image

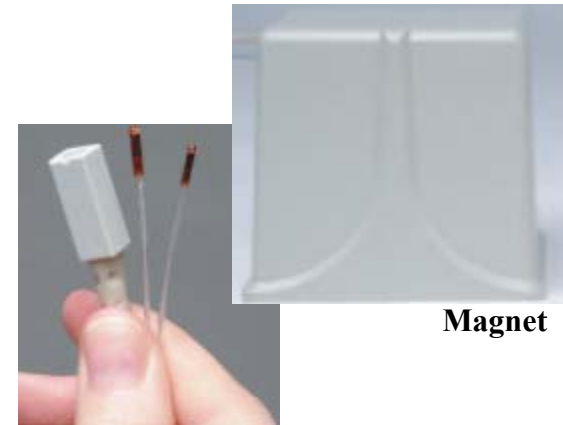


ClearPEM-Sonic: Image Fusion

- ◆ Images from both modalities need to be combined
 - PET and US do not see the same object
 - Desired **mapping precision** : $\approx 1\text{mm}$

- ◆ Localization in space:
 - PEM image position known in reference to the PEM plates
 - US transducer somewhere in the space
 - » need to localize the transducer position
 - magnetic positioning system: Ascension trakSTAR
 - 6D positioning (transducer position and inclination in space) with millimetric precision
 - » Induce artificial common features in both images
 - Fiducial markers visible by both the PET and the US modality, i.e. 511keV emitter in aluminium housing
 - » Use natural common features, like the skin and chest wall

- ◆ Software Fusion
 - Offline Reconstruction
 - Distortions between both images accounted for by means of common features

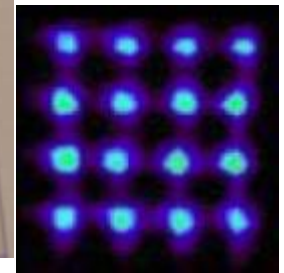


Position Sensor

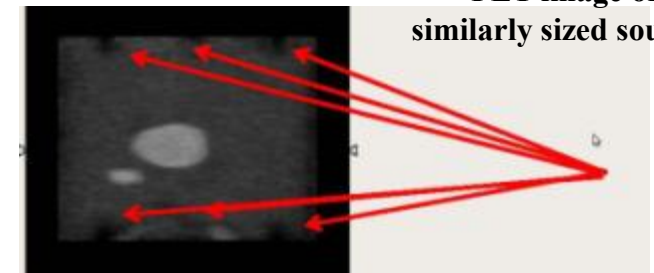
Magnet



Fiducial Markers

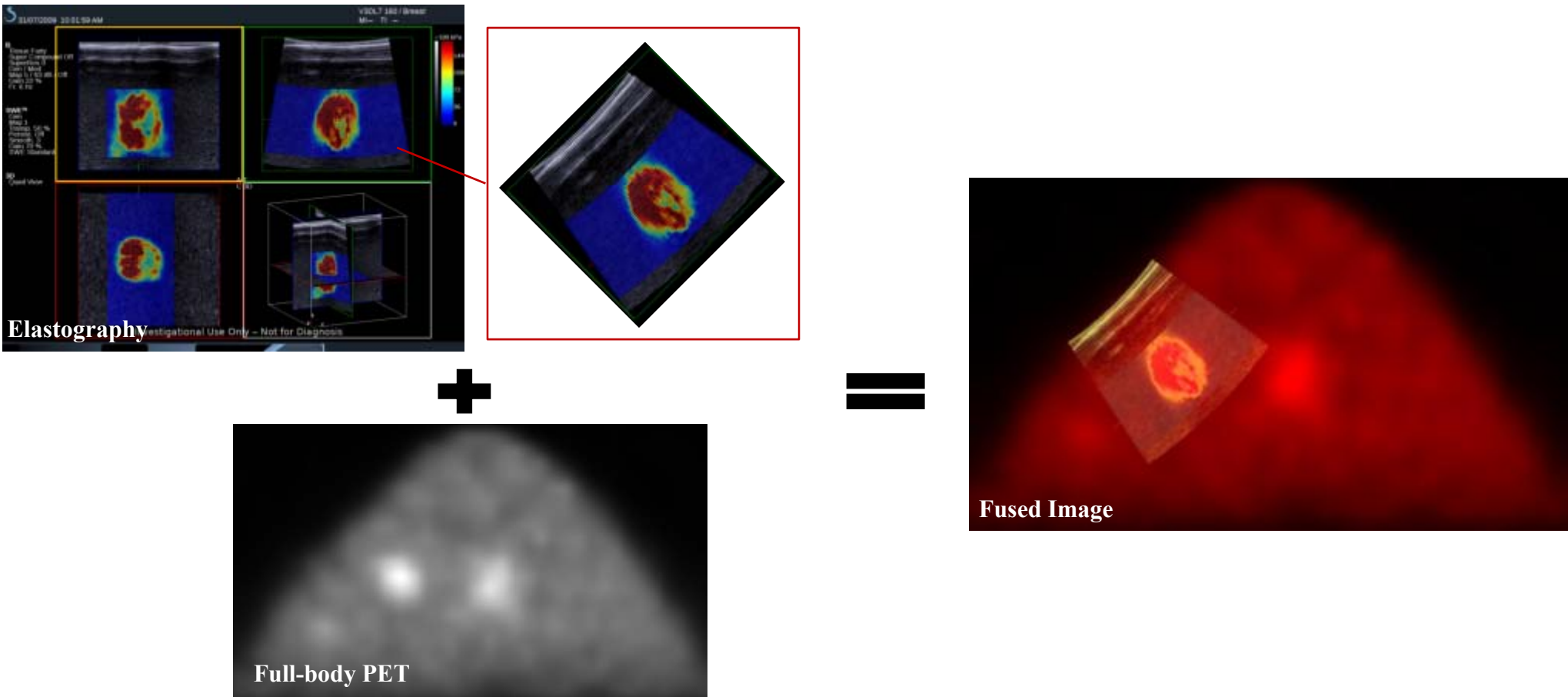


PET image of similarly sized sources



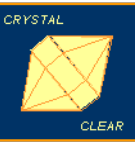
US image

ClearPEM-Sonic: Proof of Concept



- **Agar-Agar / Gelatin phantom with lesions** (developed by Dang JUN from Brussels University, see his talk)
- First image taken with SSI Aixplorer in **elastographic mode**, second image taken with **full-body PET** (IPO)

→ **Reconstructed images (courtesy Dang JUN) show it is possible to match both images using fiducial markers and the magnetic positioning system**



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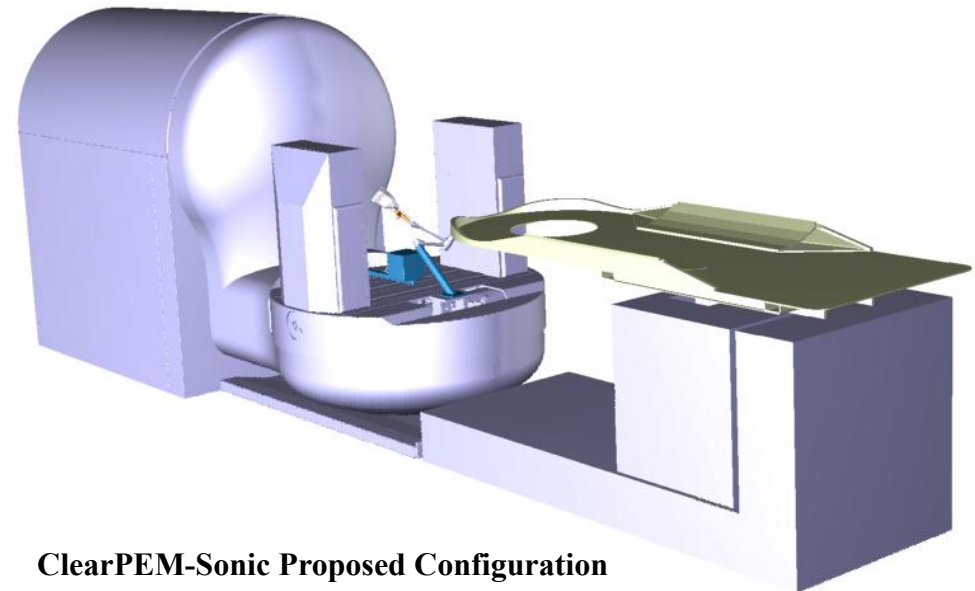
Outlook

◆ Project status:

- **ClearPEM** (Porto prototype): Phase 1 **clinical trials ongoing**
- SuperSonic Imagine **Aixplorer with 3D package** : **Clinical Trials ongoing** / Commercial Release Spring 2010
- **ClearPEM-Sonic** (installation at Hopital Nord, Marseille):
 - Assembly well advanced
 - Expected **delivery: Spring 2010**
 - Expected Start of **clinical trials: Summer 2010**

◆ Possible further implementations:

- Whole-breast 3D US imaging
- Biopsy
- SPECT



ClearPEM-Sonic Proposed Configuration