EUROPEAN SYNCHROTRON RADIATION FACILITY

INSTALLATION EUROPEENNE DE RAYONNEMENT SYNCHROTRON

ESRF

Experiment Report Form

The double page inside this form is to be filled in by all users or groups of users who have had access to beam time for measurements at the ESRF.

Once completed, the report should be submitted electronically to the User Office via the User Portal:

https://wwws.esrf.fr/misapps/SMISWebClient/protected/welcome.do

Reports supporting requests for additional beam time

Reports can be submitted independently of new proposals – it is necessary simply to indicate the number of the report(s) supporting a new proposal on the proposal form.

The Review Committees reserve the right to reject new proposals from groups who have not reported on the use of beam time allocated previously.

Reports on experiments relating to long term projects

Proposers awarded beam time for a long term project are required to submit an interim report at the end of each year, irrespective of the number of shifts of beam time they have used.

Published papers

All users must give proper credit to ESRF staff members and proper mention to ESRF facilities which were essential for the results described in any ensuing publication. Further, they are obliged to send to the Joint ESRF/ ILL library the complete reference and the abstract of all papers appearing in print, and resulting from the use of the ESRF.

Should you wish to make more general comments on the experiment, please note them on the User Evaluation Form, and send both the Report and the Evaluation Form to the User Office.

Deadlines for submission of Experimental Reports

- 1st March for experiments carried out up until June of the previous year;
- 1st September for experiments carried out up until January of the same year.

Instructions for preparing your Report

- fill in a separate form for each project or series of measurements.
- type your report, in English.
- include the reference number of the proposal to which the report refers.
- make sure that the text, tables and figures fit into the space available.
- if your work is published or is in press, you may prefer to paste in the abstract, and add full reference details. If the abstract is in a language other than English, please include an English translation.

ESRF	**Experiment title:** Validation of spectral CT compared to monochromatic SR CT : application to human knees	**Experiment number**: MD-1045
Beamline:	**Date of experiment**: from: 10 March 2017 to: 13 March 2017 and from: 5 July 2017 to: 8 July 2017	**Date of report**: 08/09/2017
Shifts:	**Local contact(s)**: Herwig Requardt, Alberto Mittone	*Received at ESRF:*

Names and affiliations of applicants (* indicates experimentalists):

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Report:

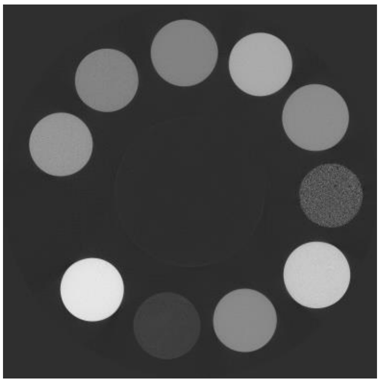
The goal of this experiment was twofold: i) to acquire monochromatic images of both tissue characterization phantoms and biological samples, which will provide a unique gold standard methodology to assess and validate spectral computed tomography (SCT) scanners for different applications, and ii) to explore the contribution of SCT to assess osteoarthritis (OA) in comparison with convectional CT.

We selected tissue characterization phantoms (GAMMEX RMI 467, CIRS 062) made of plastic inserts which are surrogates for human tissues and are widely used by the CT community data, and inserts containing standard clinically used contrast agents (iodine and gadolinium). Biological samples were human excised knees (n=5) taken from l'Institut d'Anatomie Paris Descartes and were provided by the B2OA (Bioingéniérie et Bioimagerie ostéo-articulaire) CNRS 7052, Université Paris Diderot.

SR CT imaging was performed on beamline ID17 due to the availability of a setup for monochromatic imaging at large FOV (~9cm). We used the 2k Frelon camera (45 µm pixel size; FOV: 9 cm) with FOV extended to 16 cm using the half acquisition method (same resolution, but double of projections and reconstruction over 360 degrees). We acquired monochromatic images of phantoms at different energies ranging from 30 keV to 120 keV, in 10 keV steps, and at two energies around the K-edge of contrast materials. Knee samples were scanned at only three different energies (55, 75 and 100 keV) due to the higher attenuation of knees.

Phantom results

SR has been first compared to the manufacturer stoichiometry for each insert. All images were reconstructed with a 4x4 binning. In order to obtain reference values, a cylindrical ROI with a 24 mm diameter was selected for each insert and energy. The 30 keV energy was discarded because many pixels had a low signal. There seems to be a systematic underestimation by a couple of percent, which we are investigating (figure 1). The next step is to repeat the analysis with SCT data and compare all results. These analyses are very relevant to provide necessary feedback to improve SCT scanners and reference SR data will be made available to increase the impact.



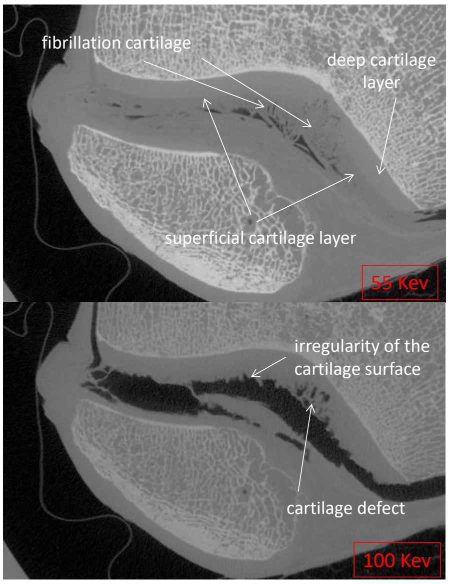
Energies (keV)	40	50	60	70	80	90	100
CIRS (%)							
Lung inhale	0.5	1.7	1.4	-4.7	2.1	3.5	9.3
Lung exhale	-5.2	-6.6	-5.5	-9.8	-7.6	-5.7	-3.7
Adipose	-3.6	-0.8	-0.6	-2.8	-2.1	-0.3	-1.1
Breast	-1.7	-1.4	-1.8	-3.0	-2.6	-1.6	-1.6
Muscle	-1.7	-2.5	-2.1	-3.9	-2.3	-1.5	0.2
Liver	-4.5	-2.2	-2.1	-3.8	-3.0	-1.2	-2.0
Trabecular bone	-6.2	-4.9	-4.6	-5.3	-4.9	-4.0	-4.2
Bone 800	-7.3	-5.5	-4.9	-5.3	-4.9	-4.1	-4.1
Bone 1250	-7.2	-5.0	-4.1	-4.6	-3.6	-3.0	-2.5

Figure 1. Left: Reconstructed image for one of the phantom configurations. Right: Percentage of the relative average difference of the mean in each insert for CIRS phantom inserts.

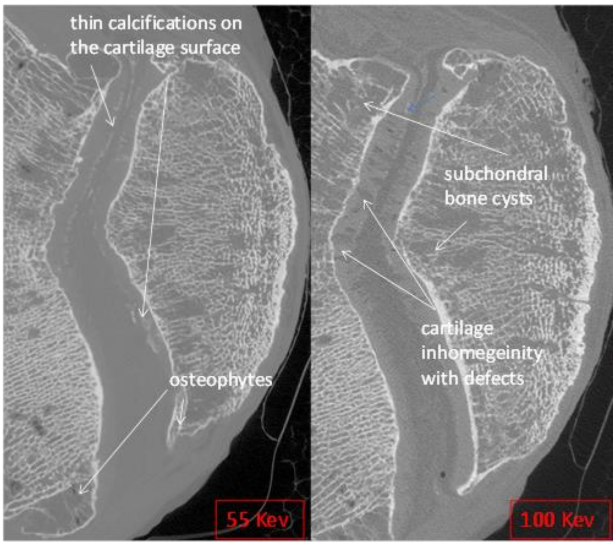
Knee results

Since the beam height was around 5mm, we had to stack about 17 stacks of scans with an overlap to cover a sufficiently large region of interest around the knee joint. All scans were reconstructed and aligned to obtain the 3D image of the full ROI. Some scans had to be excluded due to problems in sample conditioning resulting in 4 exploitable data sets.

These results brought us a proof of concept that X-rays energy-based imaging could provide extra information on the cartilage with respect to standard CT (preliminary results to be published). We observed different details of the cartilage structure such as defects, surface irregularity and fibrillation, and micro-calcifications. Deep and superficial zones of the cartilage corresponding to different orientation of the collagen fibers and different mechanical behaviors are distinguished. We can see on the images also details of bony structure such as osteophytes and subchondral bone cysts. The results are illustrated in figure 2. These results show the unique, great potential of X-ray energy-based imaging for imaging cartilage integrity but additional data sets should be acquired.



Normal Knee classified as KL=0



Osteoarthritic Knee classified as KL=4

Figure 2. Reconstructed images from a control and OA patient.