Optimization of the CT scan quality (Item No.: P2550700)

Curricular Relevance

Area of Expertise: ILIAS	Education Level: Physik	Topic: Hochschule	Subtopic: Moderne Physik	Experiment: Röntgenphysik

Difficulty	Preparation Time	Execution Time	Recommended Group Size
Difficult	1 Hour	2 Hours	2 Students

Additional Requirements:	Experiment Variations:
• PC • Sample for CT-Scan	

Keywords:

Number of projections, stop angle, exposure time, image statistics, binning

Overview

Short description

Principle

The quality of the image will improve with a number of parameters. In this experiment the different factors influencing the quality of the CT Scan are investigated. One of the most important parameters is the number of projections. This is due to a longer scan time which results in better image quality and less noise and to the fact that more sampling has been taken and the features of the sample can be reconstructed more accurately. The accuracy and quality of the reconstruction improves not only with the number of projections but also with the total angle the projections were taken under. Optimal results are achieved with 360°.

Fig. 1: Experimental set-up

Equipment

Position No.	Material	Order No.	Quantity
1	XRE 4.0 X-ray expert set, with tungsten tube	09110-88	1
2	XRCT 4.0 X-ray Computed Tomography upgrade set	09180-88	1

Tasks

1. Evaluate the number of projection.
2. Evaluate the stop angle.
3. Evaluate the exposure time.
4. Evaluate the binning.

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Set-up and Procedure

Set-up

Attach the XRIS to its stage.

Place the Digital X-ray detector XRIS on the rail at position $30\,\mathrm{cm}$. The back side of the XRIS stage cor-responds to its position on the rail. This position is called the 'source to detector distance' SDD (mm).

Fig. 2: Set-up of the XRIS
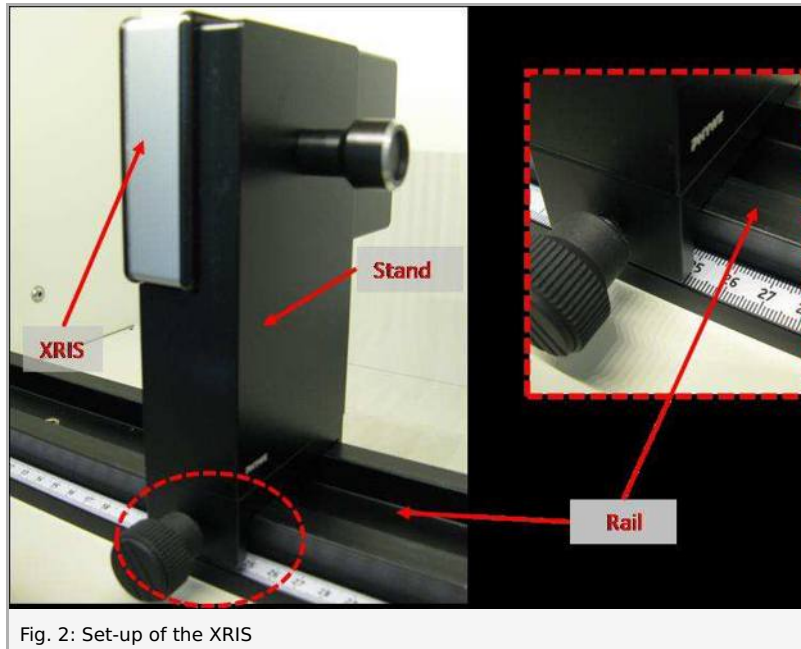
Place the rotation stage XRstage on the rail at position $25\,\mathrm{cm}$. The back side of the XRstage corre-sponds to its position on the rail. This position is called the 'source to object distance' SOD (mm).

Connect the XRstage cable with the 'Motor' connection block in the experiment chamber. Attach the sample table to the XRstage with the fastening screw.

Fig. 3: Set-up of the XRstage
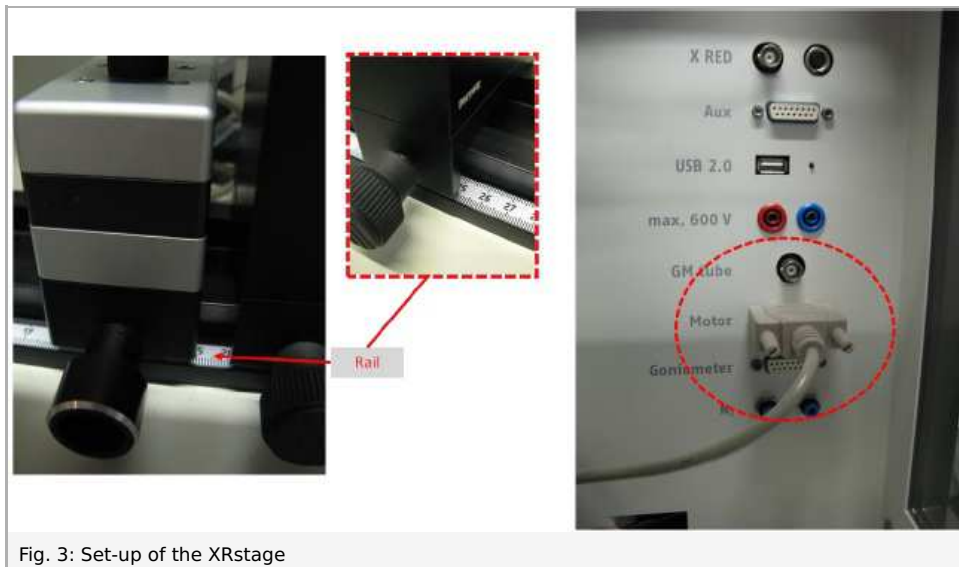
Connect the X-ray unit via USB cable to the USB port of your computer (the correct port of the X-ray unit is marked in Fig. 3).

Fig. 4: Connection of the computer

Procedure

- Start the "measureCT" program. A virtual X-ray unit , rotation stage and Detector will be dis-played on the screen. The green indication LED on the left of each components indicates that its presence has been detected (Fig. 5).

- You can change the High Voltage and current of the X-ray tube in the corresponding input win-dows or manually on the unit. (Fig. 5).

- When clicking on the unit pictogram additional information concerning the unit can be retrieved (Fig. 5).

- The status pictogram indicate the status of the unit and can also be used to control the unit such as switching on and off the light or the X-rays (Fig. 5).

- The position of the XRIS and XRstage can be adjusted to its real position either by moving the XRIS pictogram or by filling in the correct value in the input window (Fig. 5).

- The settings of the XRIS can be adjusted using the input windows. The exposure time controls the time between two frames are retrieved from the detector, the number of frames defines how many frames are averaged and with the binning mode the charge of neighbouring pixels is averaged to reduce the total amount of pixels in one frame.
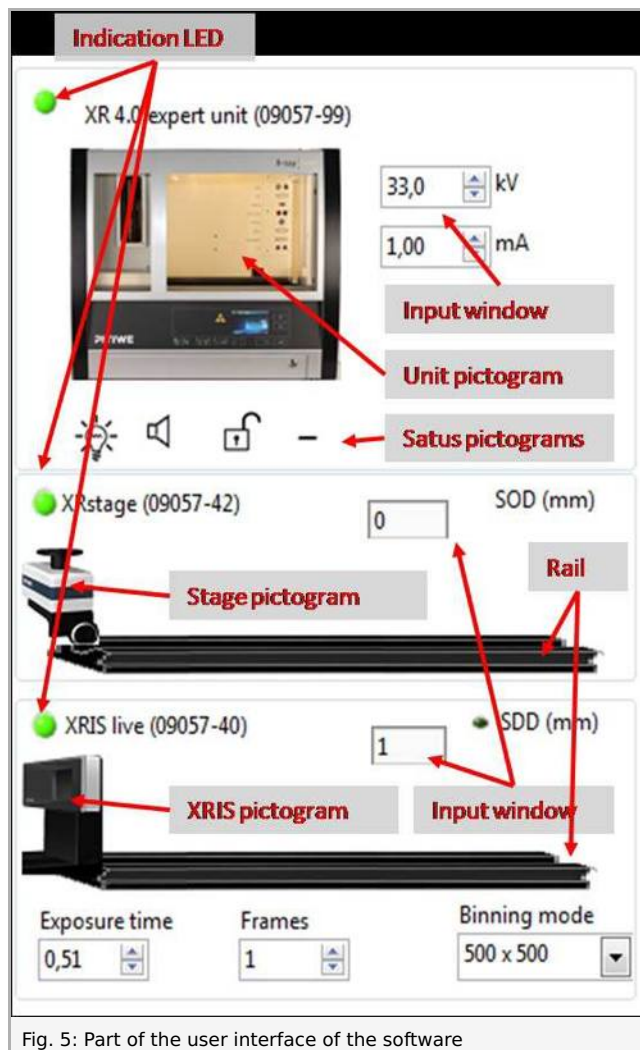

Fig. 5: Part of the user interface of the software

Experiment execution

1. Evaluate the number of projections

- Adjust the XRIS settings and X-ray unit settings according to Fig. 6 or load the configuration from the predefined CTO file 'Experiment 7' (see Fig. 6).
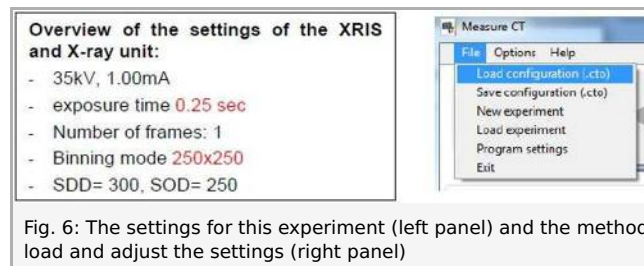

Fig. 6: The settings for this experiment (left panel) and the method load and adjust the settings (right panel)

- Start a new experiment, give it a unique name and fill in your details (Fig. 6). Alternatively it is also possible to load this experiment with pre-recorded images and open this manual. The correct configuration will be loaded automatically as well but the functionalities of the software will be limited to avoid overwriting the existing data.
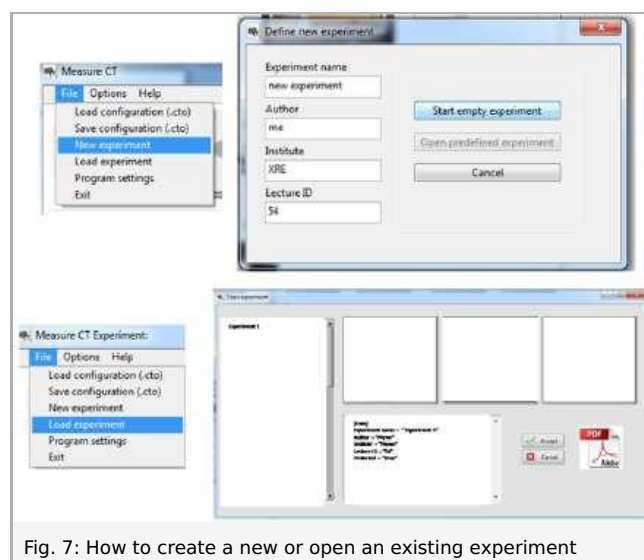

Fig. 7: How to create a new or open an existing experiment

- Switch on the X-rays (Fig. 8.1) and activate the 'Live view' (Fig. 8.2). When the Live view is activated, every new image that is retrieved from the X-ray detector is displayed. The Detector exposure load bar (Fig. 8.3) indicates the average degree of fill for each pixel. **It is very important to remain below the maximal fill degree of the detector**. Otherwise the detector will be saturated and won't work properly. If the saturation level is reached, the 'detector exposure' load bar will turn red. (see experiment 1 for more details).

- Calibrate the detector by clicking on "Calibrate'(Fig. 8.4). When the calibration is successfully performed, the indication LED (Fig. 8.5) will turn green. The Load bar (Fig. 8.3) will disappear and the Contrast/intensity cursor (Fig. 8.6) will become available. (see experiment 1 for more information).

- Place object XXXX in the centre of the sample stage and close the door.

- Adjust SOD (Fig. 8.7) and SDD (Fig. 8.8) in the software according to the actual position.

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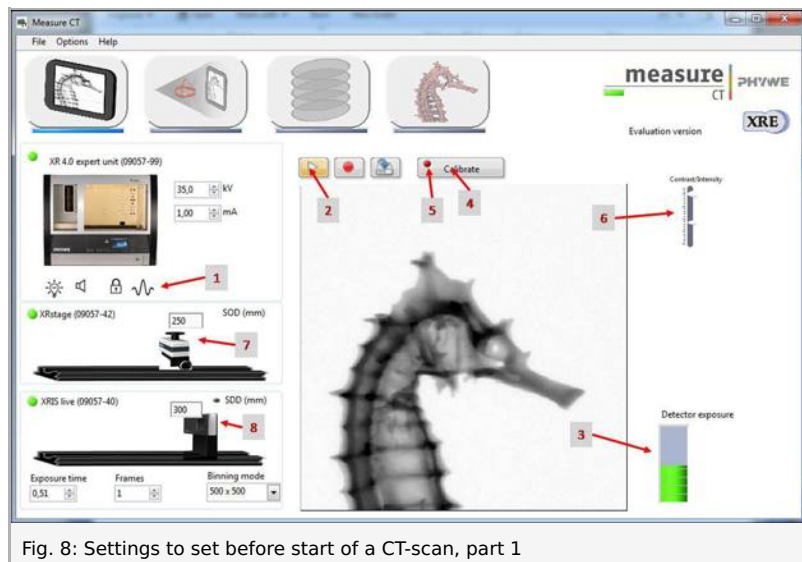
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Fig. 8: Settings to set before start of a CT-scan, part 1

- Go from the "Live view page" to the "CT scanning page". The indication pictogram will turn blue when the page is activated.

Fig. 9: CT scanning page

- In the CT scan page, change the number of projections to 50 (Fig. 10.8).

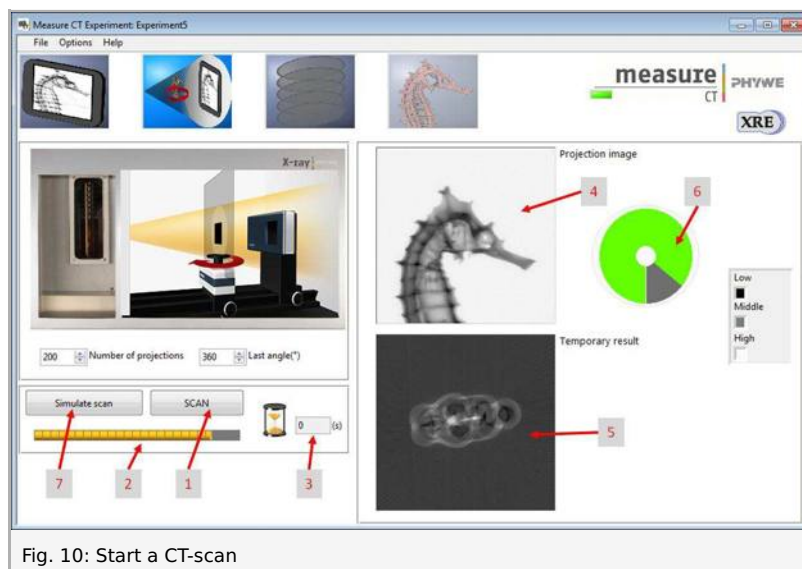- Start a CT scan (Fig. 10.1). More info in experiment 5.

Fig. 10: Start a CT-scan

- When the CT scan is finished it is possible to proceed to the reconstruction. Go from the "CT scanning page" to the "Data reconstruction page". The indication pictogram will turn blue when the page is activated.
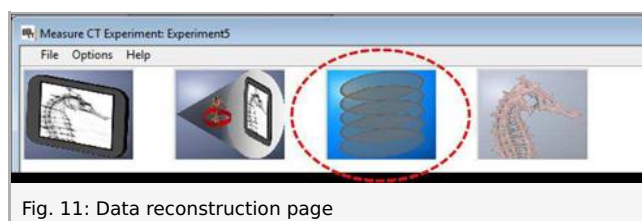

Fig. 11: Data reconstruction page

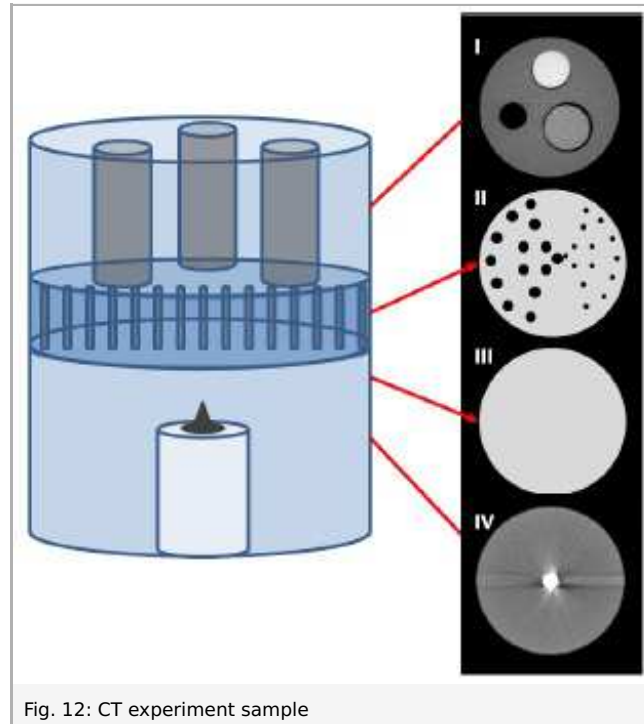- Find the slice in the centre of the object that looks like Fig 12.II.

Fig. 12: CT experiment sample

- Optimise the centre of rotation (see experiment 5 and 6 for more information).

- Open the image viewer, the corresponding slice will be visible. Click on save (see experiment1), select the radiographies folder in the experiment and save the image as tif with the name bin250_50_250.

Fig. 13: Image viewer button for the slice image and the directory to save the resulting image

- Close the image viewer.

- Go back to the CT scan page and adjust the number of projections to 100. perform a scan. When is asked to overwrite the data click 'ok'.

- Repeat the previous steps (find COR, open viewer,...) and save the slice as bin250_100_250.

- Repeat this also for 200 and 400 projections and save the images accordingly.

- Reconstruct the entire volume with 400 projections.

- Evaluate the result with the image viewer.

Note: The quality of the image will improve with the number of projections. This is caused by two factors. The first factor is the longer scan time which results in better image quality due to less noise (see next steps of experiment), the second factor is that more sampling has been taken and the features of the sample can be reconstructed more accurately.

2. Evaluate stop angle

- Go back to the CT scan page and click on simulate. During the simulation it is possible to click on pause. Run this (with generating temporary results) and pause at approx. 180°, 270°, 300° and 360°.

- After the simulation open the image viewer corresponding with the temporary results that were generated in the 'reconstructed' folder of the experiment. You have now taken 400 projections over 360°, calculate which number of projections correspond with 180°, 270°, 300° and 360° and save these slices in the same folder as you did for the previous experiment under the name bin250_400_180degr,.....

Note: The accuracy and quality of the reconstruction improves not only with the number of projections but also with the total angle the projections were taken under. optimal results are achieved with 360°.

3. Evaluate the exposure time

- Go to the live view page.

- Change the exposure time to 0.5 sec, calibrate again and do again a scan with 200 projections. Find the slice that corresponds with fig 12.III, open the viewer and save the slice as bin250_200_500.

- Repeat this for an exposure time of 1sec and save the slice as bin250_200_1000.

- Open the image viewer and select the folder with images. Select the 'bin250_200_250' image. Move the cursors to the central region of the slice and calculate statistics and write down the sigma, do that for all three images. It is important to use the same region for all three images!

Fig. 14: calculate the image statistics
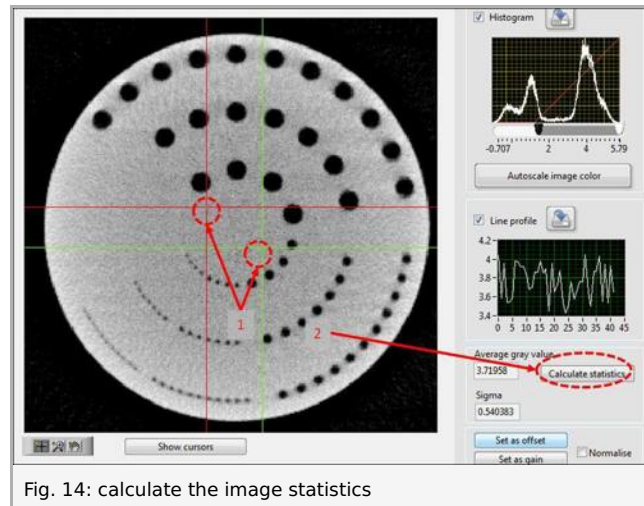
Note: In the first part of this experiment both the total scan time as the number of projections was increased to obtain better quality images. In this part of the experiment the total scan time is increased while the accuracy of the images is unchanged. Longer scans result in less noisy images and thus better results.

4. Evaluate the binning mode

- Go back to the Live View page and change the binning to 500x500, adjust the exposure time to $0.25\,\mathrm{sec}$ and perform a scan with 400 projections.

- Go to the reconstruction page and select the slice that corresponds to fig 12.II.

- Save the image in the image viewer as bin500_400_250.

- Compare the image with the corresponding image of the bin 250 slices.

Note: In binning 500, more details will be visible than in binning 250 but for the same scan time, the statistics of the bin 250 will be better.

Theory

CT scan and reconstruction

When a CT scan is performed, several radiographies (projections) are recorded at different angles through the sample. By having data about the transmission of the object under different angles it is possible to calculate the µ value at each location in the sample.

If we have for example a cylindrical object, one detector row will have a profile corresponding to picture xxx.
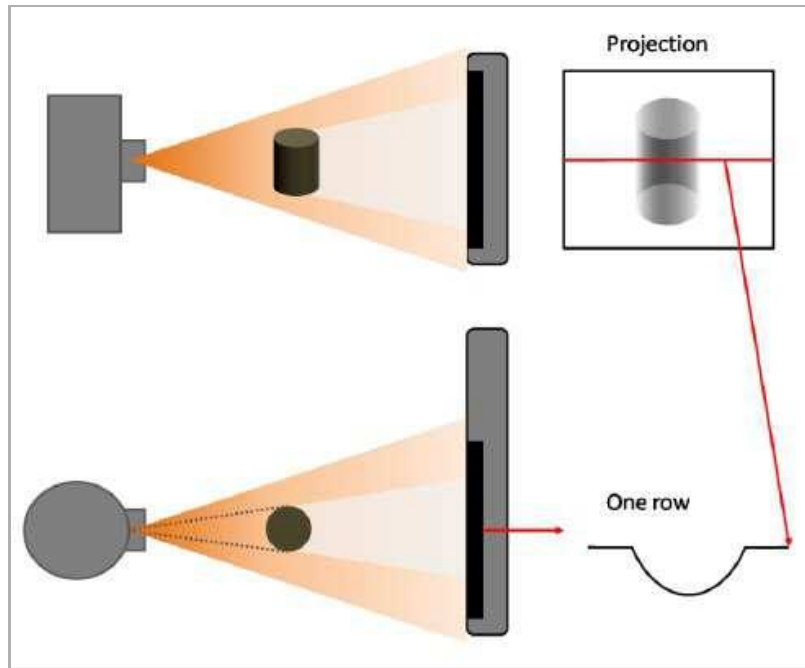
During the reconstruction process, the information of the two images are back-projected in a virtual array and the signal of each of the projections is summed.

The more projections are taken, the more correct the result will be. However, it has been proven that this back-projection and summation is not analytically correct. Therefore the projection data first has to be fil-tered before being back-projected and summed.
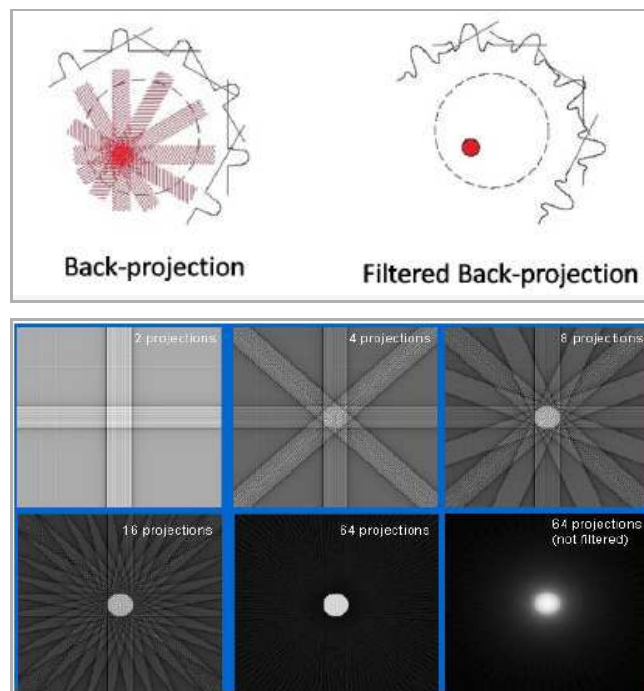
When the reconstruction of one detector row over 360° is successfully performed, the result is one virtual slice through the object. This slice is often saved as a single image and each pixels of the image actually represents one voxel (volume element) of the object.

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