Method Note – Sept 2025

Acquisitions for the PET Q Factor Calibration

Introduction

Quantitative PET requires corrections for dead time, scatter, and random coincidences as well as radioactive decay. This ensures the proportionality between activity within the FOV and the image value.

The highest level of quantitative accuracy is achieved by applying attenuation correction (AC) using the anatomical information that Bruker PET/CT and PET/MRI systems provide.

Even after applying the normalization and the above corrections, the reconstruction engine returns an image with arbitrary units. This means that the image needs to be multiplied by an overall scaling factor to set the image absolute units. This enables the calculation of SUV and allows the comparison of images taken under different conditions.

This global image factor is known as the Quantification or simply Q factor and it is generated after a set of known concentrations in a phantom is correlated with the image intensity obtained in the reconstructed images. Once the factor is calibrated, it is input into the system database and from then on, the system automatically reconstructs images absolutely calibrated. All Bruker PET systems provide fully quantitated images in kBq/ml or SUV (% injected activity) because this Q factor calibration happens for every system in the factory.

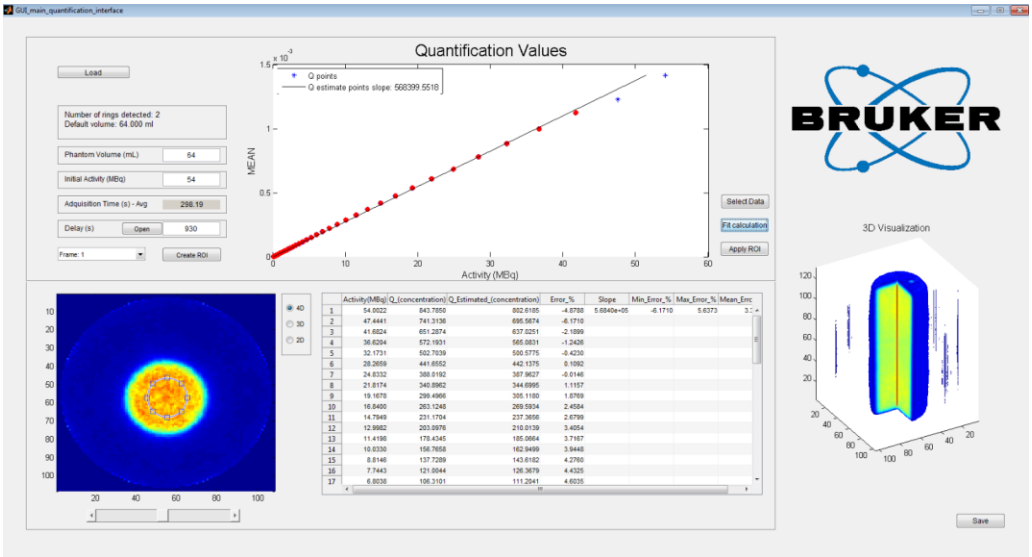


FIGURE 1. Bruker (internal) software used to calculate the Q factor to convert images from arbitrary units to kBq/ml A linear regression performed fitting measured concentrations in a phantom to image intensity values. The slope of the straight line is the Q factor. For each voxel size, a different Q factor is calculated. This is why when calibrating a Q factor we really mean a set of Q factors.

During preventive maintenance operations, after major PET repair operations or major software upgrades, a new Q factor calibration might be necessary. Sometimes the use of specific isotopes will require also new Q factors. The present note is intended to guide Bruker PET users in the acquisition of images from which Bruker personnel will generate new Q factor calibrations.

Data Acquisition

The user is assumed to be familiar with Bruker PET quality control workflows. Please refer to the specific instrument manual for guidance on the use of phantoms, their holders, protocols etc.

There are two alternatives to carry out the acquisitions that will enable Q factor calibrations. The first one involves a long acquisition, commonly acquired overnight for convenience. Here, the Bruker QC phantom is loaded with a high activity and left to decay over several half-lives inside the scanner. This procedure is adequate for short lived isotopes like C11 and medium lived PET isotopes like F18 and Ga68. For longer lived isotopes like Cu64 and Zr89 it makes more sense to carry out dilutions. The procedure for both types of calibration scans are below.

Long decay scan inside the scanner (adequate for F18, Ga68 and C11):

- Fill the Image Quality QA phantom with 35 – 40 MBq. As few minutes will go by before the acquisition starts, it is also acceptable to load a slightly higher value such that by the time the acquisition starts at least 30 MBq remain in the phantom.
- The exact value to be used in not important, what matters is that the value is known. Please write down the time and precise activity measured using the laboratory dose calibrator. It is essential that the laboratory dose calibrator is properly maintained and calibrated. Please, also make sure that the dose calibrator clock and the imaging device computer are synchronized.
- Inserting the QA phantom directly in the dose calibrator is a quick procedure but can lead to imprecisions. It is recommended for a 1 ml or similar syringe to be used, measuring the activity in the syringe before and after injecting the activity in the phantom. The difference, if no spill has happened, is the activity in the phantom.
- The phantom can be pre-filled with water. Distilled water is recommended to avoid the growth of algae or other microorganisms. Though, some isotopes or compounds may precipitate and drop out of solutions in water, so please respect your specific chemistry and use buffered solutions as appropriate.
- After the injection of the activity and when topping up with water to completely fill the phantom, try as practically as possible to minimize the size of the remaining bubble. The calibration process assumes that the full volume of the phantom is utilized. For some tips for handling the Image Quality QA phantom please see the tutorial video PET Image Quality QA | Bruker.
- Screw the lid on the phantom and wipe off the phantom on the outside to avoid the presence high activity concentration droplets which will generate hotspots in the PET image. Once closed, mix the phantom well.
- Ensure the phantom is centered in the FOV within a few millimeters. The situation to be avoided is when part of the active volume of the phantom is on the edge of the FOV or altogether outside. The specific phantom holder for each PET system makes this easy. It is useful to perform a quick PET Localizer acquisition (that is simply a 5 or 10 second duration acquisition and fast reconstruction), check the resulting image and correct the horizontal position as needed.
- Load and launch a dynamic scan of the following pattern repeated 24 times completing a total of 6 hours
    - 5 min acquisition.
    - 15 min pause.
- C11 is considerably shorter lived. Hence 5 min acquisitions followed by a 5 min pause for 2 hours will be sufficient.
- Acquire an Anatomical Reference (CT or MR) with FOV matching the PET FOV.

- Select the appropriately configured compound/isotope profile at study registration.
- Reconstruction settings: deactivate the decay correction. Apply Attenuation Correction.

Dilutions procedure (adequate for Cu64, Zr89 and similarly long-lived isotopes):

- Use the QC phantom or a 50 ml falcon tube.
- Suggested dilutions are 1, 5, 15 and 35 MBq, though the dilution range should cover the activity range of interest in your study. Carry out separate acquisitions for each of dilution. Due to dead-time limitations of certain dirty isotopes such as 89Zr, it is typical to use a narrower dilution range (e.g. 1, 5, and 15 MBq).
- The exact value used in each case is not relevant, what is very important is for the time and precise activity values to be recorded.
- Acquire for 5 min.
- Follow the instructions above about centering the phantom.

Inspect data prior to proceeding:

Inspect your data in a test scan and prior to continuing (see **Figure 2**). Correct any issues and re-image if necessary. Many issues may be resolved by re-centering the sample or mixing the sample.

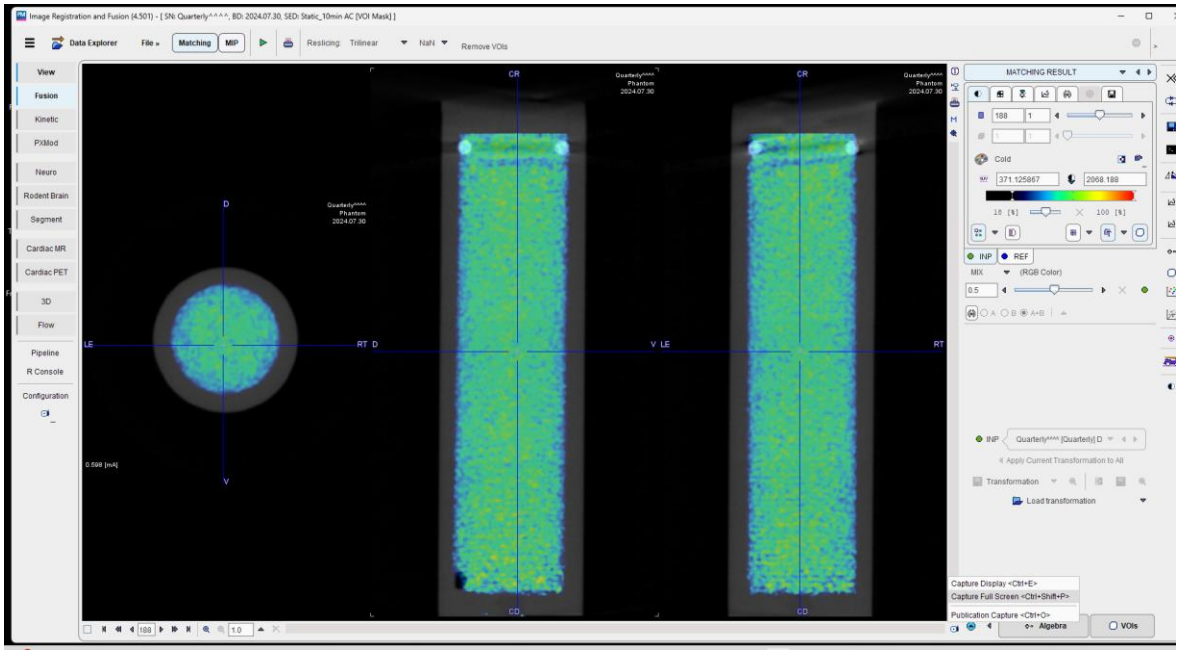


Figure 2. Exemplary Image Quality QA Phantom data is shown. The phantom should be well centered in the FOV, activity should be evenly distributed in the sample

Data Processing

Complete data table and send to NMI support

To calculate the PET Q factor for your isotope, details for the dose calibration activity and time, sample volume, acquisition and frame time, and activity measured by VOI are required. A representative table for the data required is shown below in **Table 1**. A blank table is provided in the Appendix for your convenience. Please send the complete details to NMI support prior to scheduling a remote session to configure the Q factor for your system.

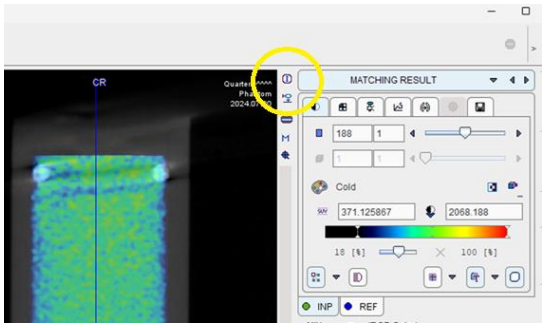
Isotope: **89-Zr**						
Dilution Number	Dose Calibrated Activity (kBq)	Sample Volume (mL)	Dose Calibrated Time (Date, Hr:Min)	Acqusition Time (Date, Hr:Min)	Frame Time Start/End (Sec)	VOI Measured Activity (kBq)
1	**303.4**	**50**	**July 9th, 13:10**	**July 9th, 13:30**	**0/600**	**401.0**
2	**1835.2**	**50**	**July 9th, 14:06**	**July 9th, 14:30**	**0/600**	**2339.1**
3	**3677.8**	**50**	**July 9th, 14:54**	**July 9th, 15:30**	**0/600**	**4704.4**

Table 1. Bold values are necessary to calculate a Q factor for your isotope.

Tips on collecting table details

Be sure to note the dose calibration and sample details during setup. Note the results in the table.

Acquisition, Frame, and VOI measurements may be collected using PMOD. To collect the Acquisition and Frame times, select the Series Information button.



Note the Acquisition Date and Time Displayed. Next, select the Edit Frame Times button. Select Offset to Zero. Note the Start and End time **(Figure 3)**. Note the results in the table.

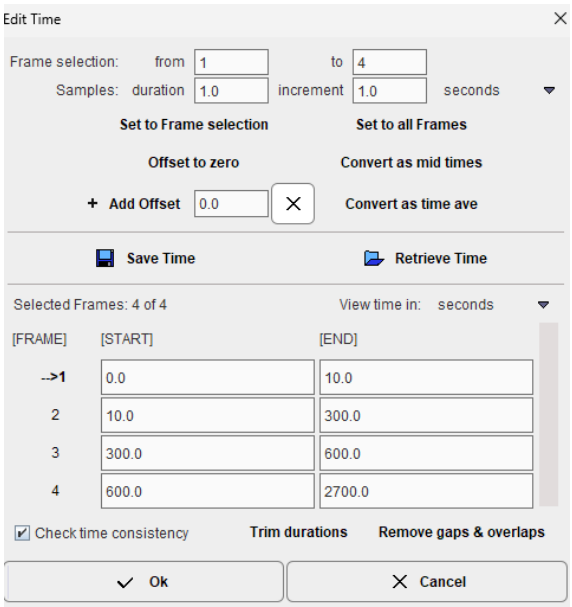


Figure 3. Start and End times for frames can be collected in the PMOD Edit Frame Times tool. Select Offset to Zero. Frame times shown here are for a dynamic PET acquisition.

Measure the activity of the phantom using the PMOD VOI tools. Create a VOI much larger than the boundaries of the PET phantom. In the statistics menu, set the Data Unit to kBq/cc and select TLG to give the total activity in the VOI region (Figure 4). Note the results in the table.

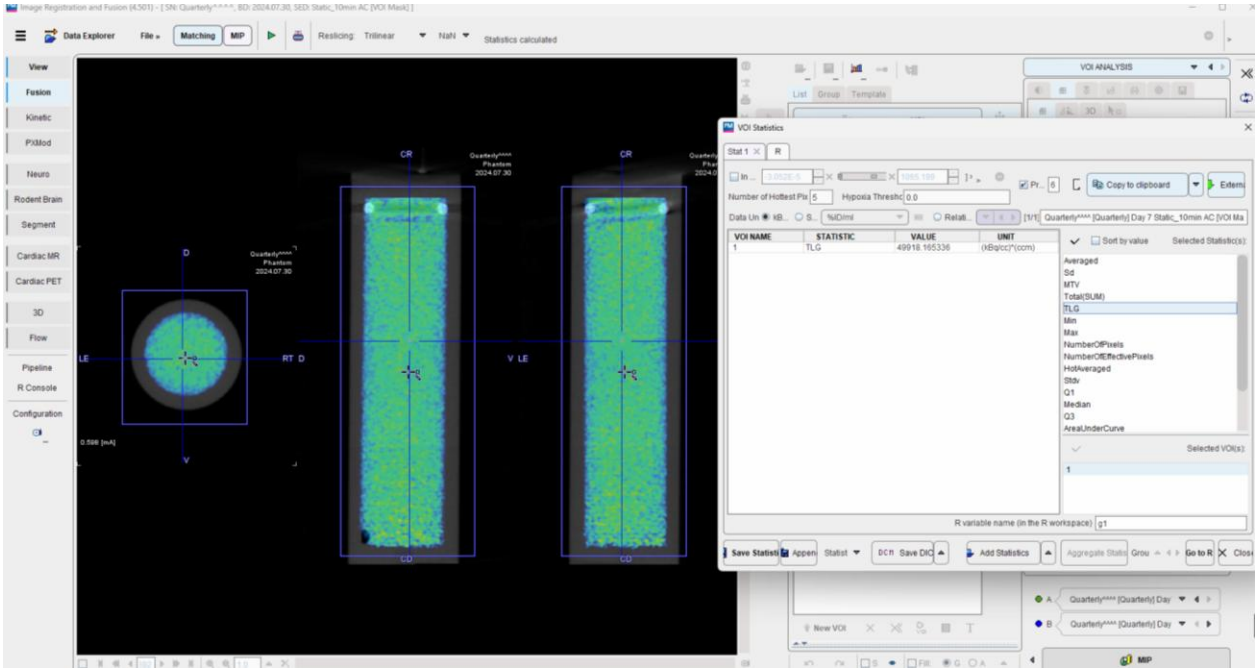


Figure 4. Collect the VOI measured activity using PMOD. Create a VOI larger than the phantom boundaries and noted in blue in the image. Set the data units to kBq and select the TLG statistic to provide a total activity for the VOI region.

Appendix.

Complete the table details prior to scheduling a remote session with NMI support to configure the Q factor.

Isotope:						
Dilution Number	Dose Calibrated Activity (kBq)	Sample Volume (mL)	Dose Calibrated Time (Date, Hr:Min)	Acqusition Time (Date, Hr:Min)	Frame Time Start/End (Sec)	VOI Measured Activity (kBq)
1						
2						
3						

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