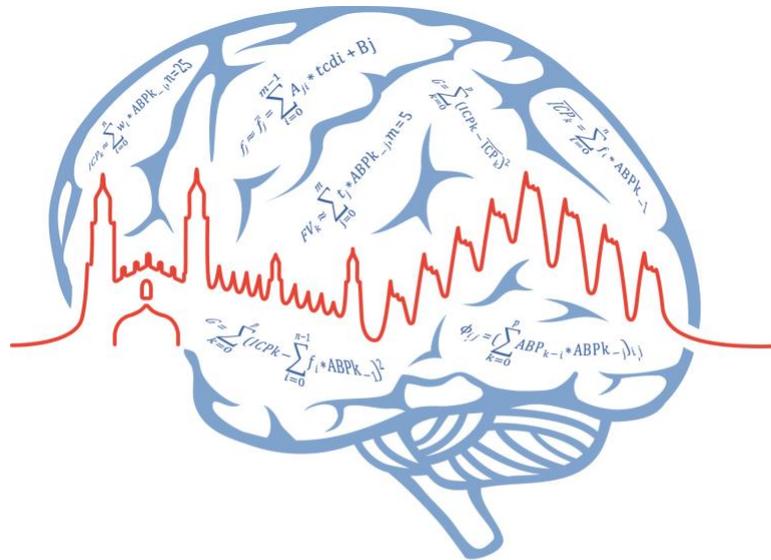


# ICM+ Standard of Procedures

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# ICM+<sup>®</sup>

**DWL TCD monitor with QL Software**

1 June 2020

<https://icmplus.neurosurg.cam.ac.uk>

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## Prerequisites

1. **A laptop (or a PC) with the latest ICM+ plus DWL TCD module.** The extra laptop may not be necessary if ICM+ is to run on the TCD computer itself.
2. **DWL TCD Doppler-Box® X via a Laptop, Multi-Dop® T and Multi-Dop® X, with the latest QL software version**



3. Ideally **ABP waveform** should be collected at the same time to make TCD measurements more meaningful, either from a **patient monitor or non-invasive ABP monitor**, using an appropriate ICM+ module
4. **Appropriate cables:**

Connection of Doppler-Box® X via Laptop, Multi-Dop® T and Multi-Dop® X with ICM+ laptop is via port 1 (above) and a null modem USB-USB cable, like this:



[https://www.ftdichip.com/Support/Documents/DataSheets/Cables/DS\\_USBMMC.pdf](https://www.ftdichip.com/Support/Documents/DataSheets/Cables/DS_USBMMC.pdf)

Alternatively a combination of USB-Serial cables, with **one** of them a null-modem (<https://www.startech.com/uk/Cards-Adapters/Serial-Cards-Adapters/USB-to-Null-Modem-RS232-DB9-Serial-Adapter-Cable-DCE-FTDI-ICUSB232FTN>) will work too.



Additionally, **Multi-Dop® T** and **Multi-Dop® X** can be connected to the ICM+ laptop by using a RS232 (female)-to-USB cable set-up.



RS-232 male connector

**USB Male to RS232 Female:**

CabeCreation USB to RS232 Adapter with FTDI Chipset



RS-232 male connector

**USB Male to RS232 Female:**

CabeCreation USB to RS232 Adapter with FTDI Chipset

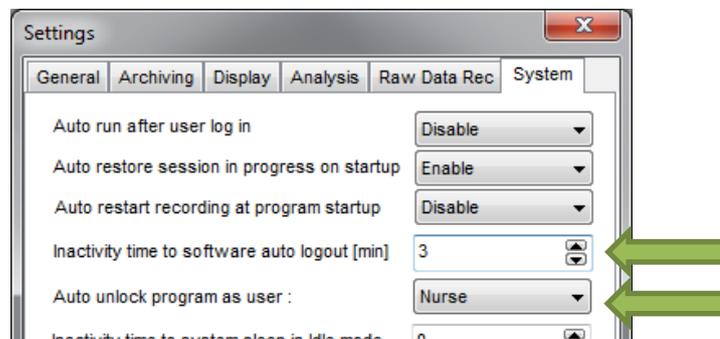


## Locking and unlocking ICM+

ICM+ includes a simple system of user based permissions, which allows it to be used safely in a clinical environment, also by people with minimal training, ensuring that the vital data collection process is not inadvertently interrupted or disturbed.

If your ICM+ is correctly configured when the program is run it will automatically initialize with the default user 'Nurse'. There are three other users already configured in ICM+, the Administrator, the Manager and the Operator. The users have been configured with progressively decreasing operational rights.

The **Nurse** is the user with the fewest rights in the software, effectively only being able to insert clinical events, browse the charts and starting new sessions, without any possibility to disrupt the data collection procedure. Please refer to the 'How to use the events form' for more details. After 3 minutes of inactivity (configured in the settings, figure below), ICM+ automatically switches to the default user, if configured, which for the data collection should be set to **Nurse**.

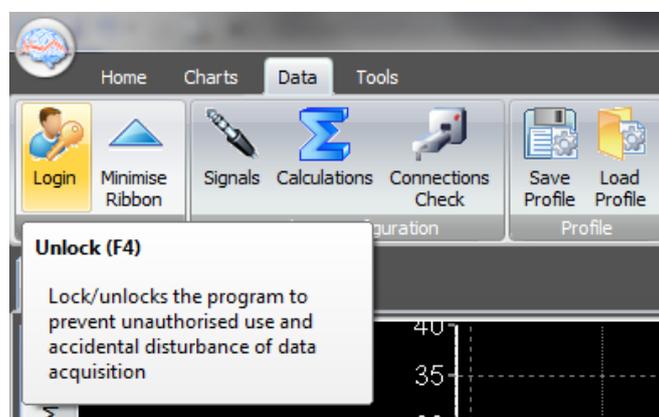


The **Administrator** is the user that will have full access to the full features of the application.

The **Manager** will have the same privileges but will not be able to manage user accounts.

The **Operator** will only be capable of starting new Recording sessions with available profiles, browsing data, inserting clinical information and display configuration.

Login (change users) form is accessible via a button on the main menu bar.



Or the speed tool bar, when the data collection is in progress



When the Login button is pressed, the User login form will appear.

User login form

Current user: **Administrator**  
 Default user: **Nurse**

Other user

Name:

Password:

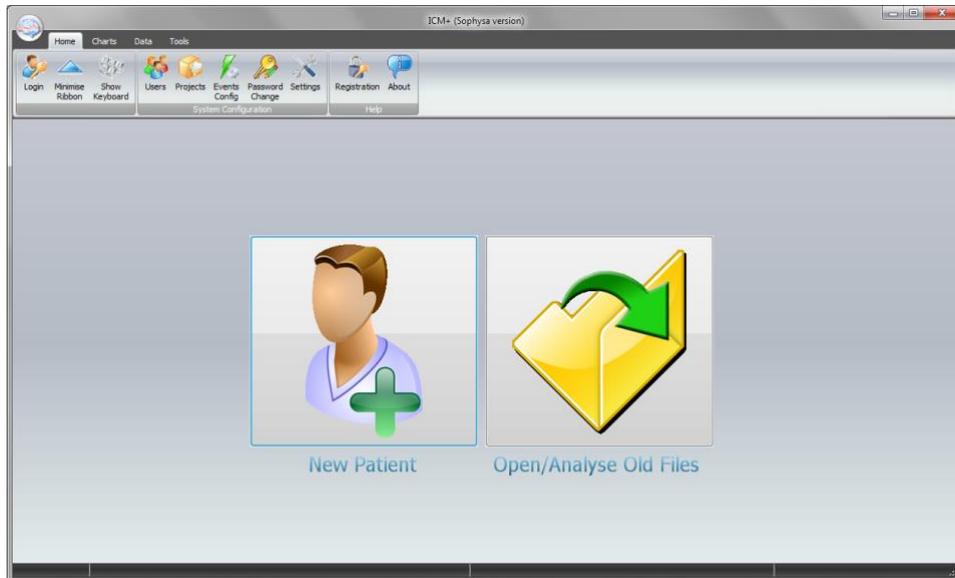
1	2	3
4	5	6
7	8	9
	0	Back

In this form you will find:

1. A button to the Default user and a button to lock the application so that nothing but the login button is accessible.
2. A key pad to insert the Password for a given use.
3. And a Drop-Down menu to select the user to login as.

## Starting a new data collection session

To create a new data acquisition session hit New Patient button.



This will bring up a new form, where patient details can be inserted:

More importantly a data acquisition/analysis profile (configuration) file should be selected, either from the history list box or loaded from the file system. These can then be modified if necessary using Signal Sources editor, or On Line Analysis editor.

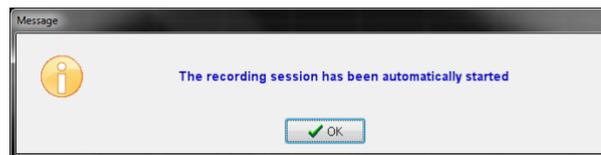
After the OK button is clicked, the Devices check is performed using Device Check dialog.



This dialogue is used to test the communication between the ICM+ and the monitor (the 'Test connections' button). If the test is successful the OK button can be pressed.

This menu can also be used to select the right connection, whether it is a serial connection (like the one presented in the picture) or an IP address. In the case of a serial port connection, the button auto allocate ports can be pressed and the application will search for the right port.

After this dialogue, ICM+ main display is presented and the session begins recording automatically, if configured in the used project. Otherwise use Start button (see next page).



If ICM+ **shuts down during a recording session** the next time it is run, the previous session is automatically restored, but here the user must first verify that all the signals are being received correctly in the Monitor button. After this the Start button must be pressed and the session resumes recording.



## Manually configuring data collection

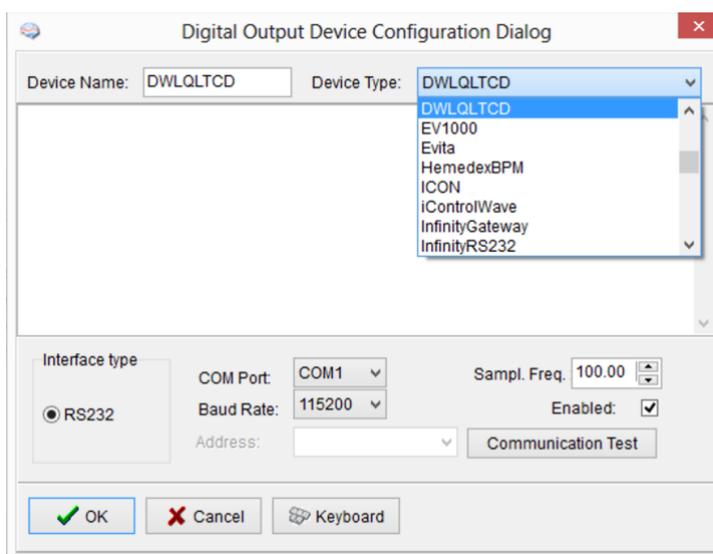
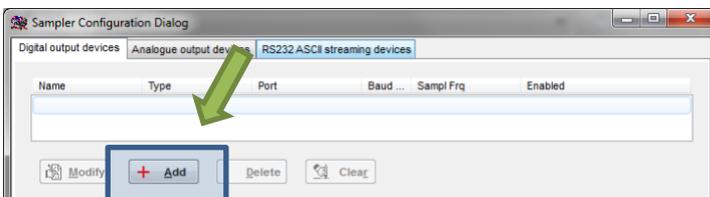
If there is no prepared profile available that includes desired data collection from the monitor or if there is a need to modify or add parameters downloaded from the monitor Signal Sources option needs to be used. This can be done in the New Data Acquisition Form:



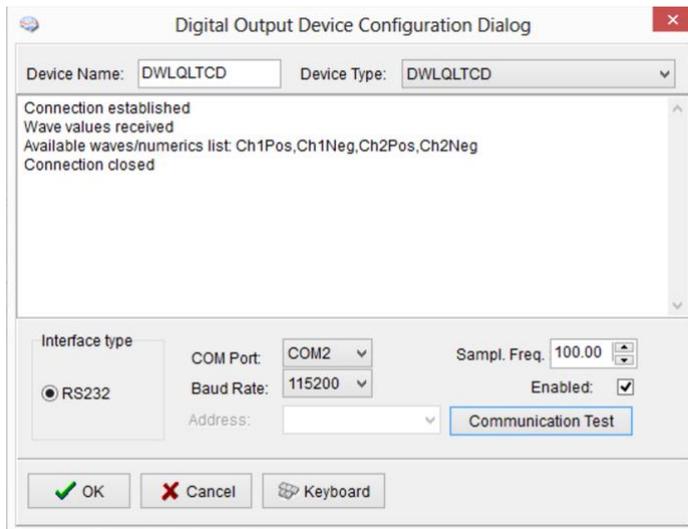
Or using Signals button in the main Menu (Data Section), with the data acquisition in pause mode. Please note that the recording must be stopped before the Signals button becomes enabled



This brings up the Sampler Configuration form:

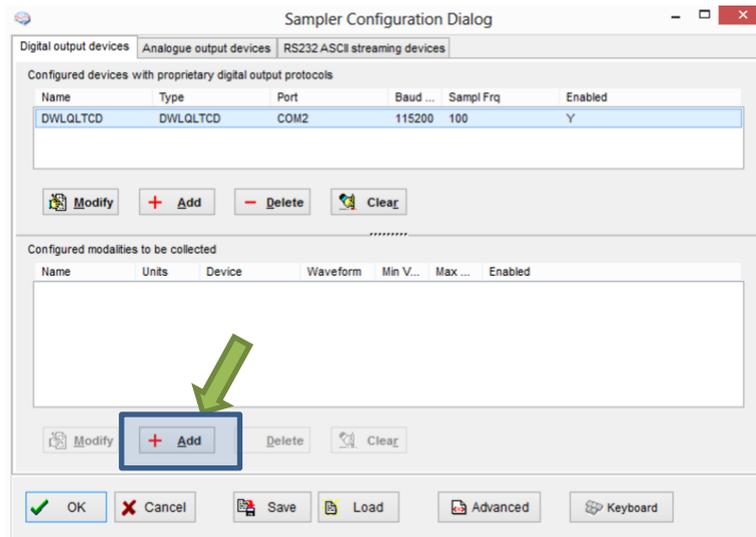


Clicking on Add button in the upper part (Digital Output devices tab) opens a Device Configuration dialog. Here, one can select the monitor module from the list of available (installed) interfaces, as well as specify the COM port to which the TCD connection cable is attached.

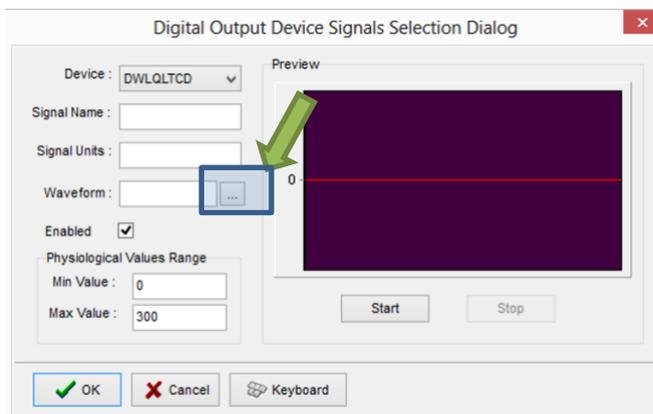


When the correct interface module (DWLQLTCD) and the correct COM port and Baud Rate (matching the one configured in the QL software) is selected, clicking on 'Communication Test' will try to establish communication with the monitor and the log of that communication is printed in the memo box, listing also all the parameters that are available to download from the monitor.

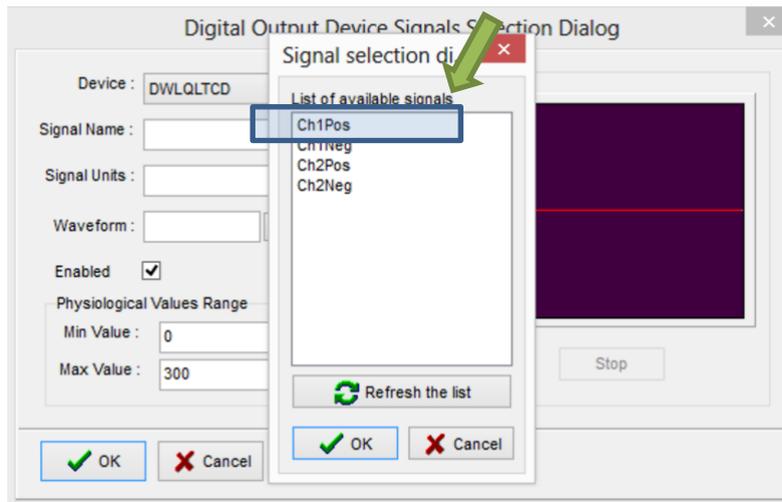
After the connectivity is confirmed the dialog can now be closed, which causes the device to be added to the data collection configuration. What remains to complete the configuration is adding all the desired parameters to be collected. This can be achieved by using the Add button in the lower part of the Sampler Configuration dialog.



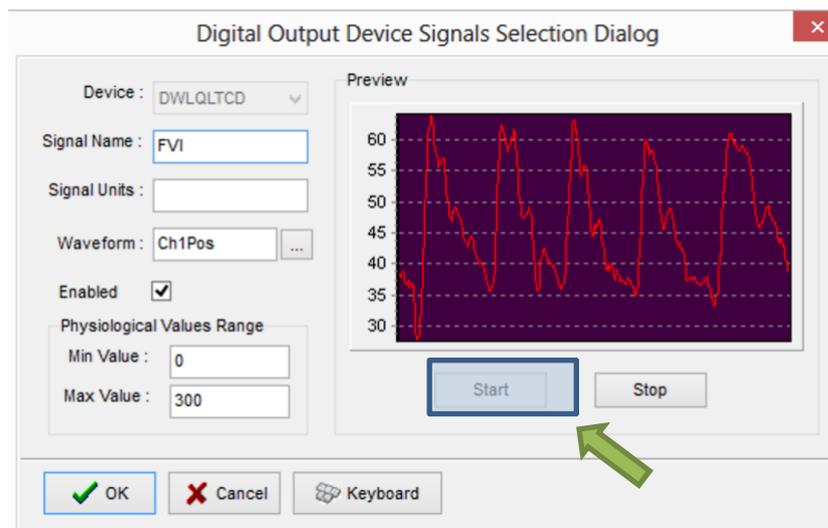
This opens a signal selection dialog:



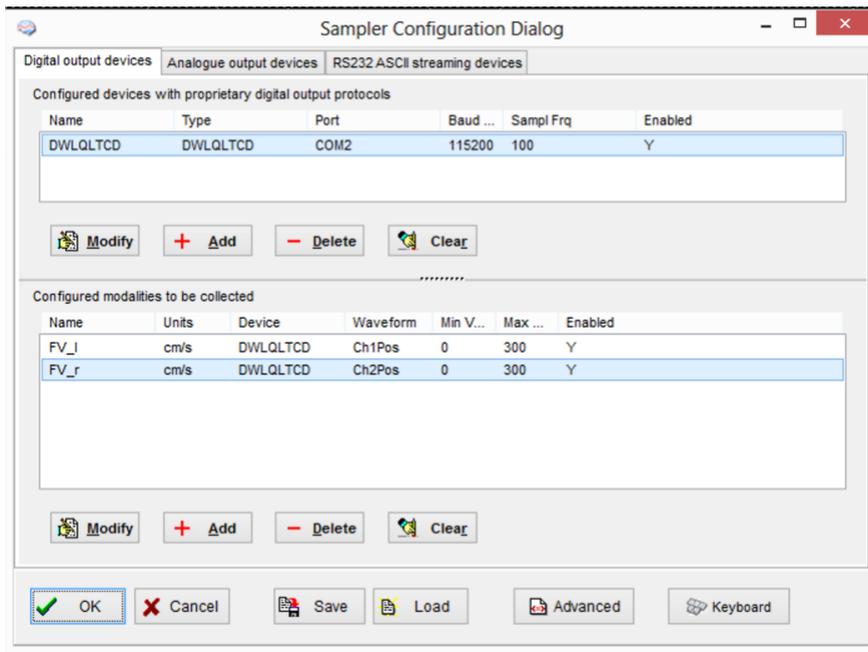
Using the little ‘...’ button one can select available signal, one at a time.



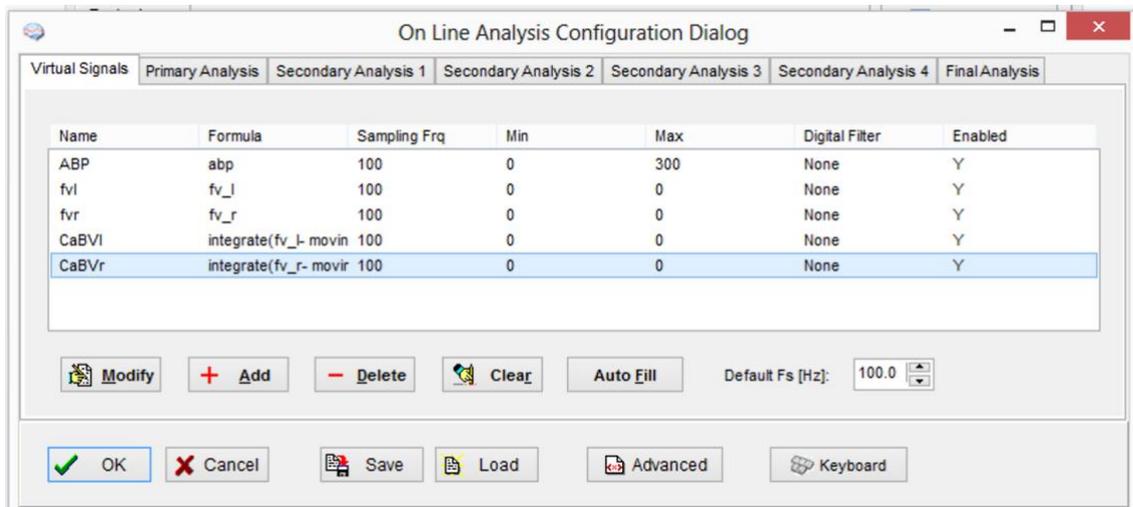
Once the waveform is selected one can test the data acquisition by clicking on Start button. If all is well OK button will close the dialog and add the new parameter to the data acquisition configuration.



This process can be repeated as many times as it is needed putting together the complete list of parameters to be collected, which complete the data acquisition configuration procedure. Name the velocity channels appropriately – eg FVI or FVr



Please note, that adding parameters/signals to the data collection will make ICM+ show and record the data through the Signal Monitor window but the trends charts will not automatically get configured to show them. This is because the trend charts only show results of calculations, not the raw data. So to display even just a mean trend of a newly added variable collected from the monitor ICM+ this needs to be configured first in the analysis section, as in picture below, and then the new trend added to the charts.



## Annotating clinical events

As soon as the acquisition of data starts the main menu tool bar will get minimised and in its place a small, 'data acquisition essentials', tool bar will open, as below.



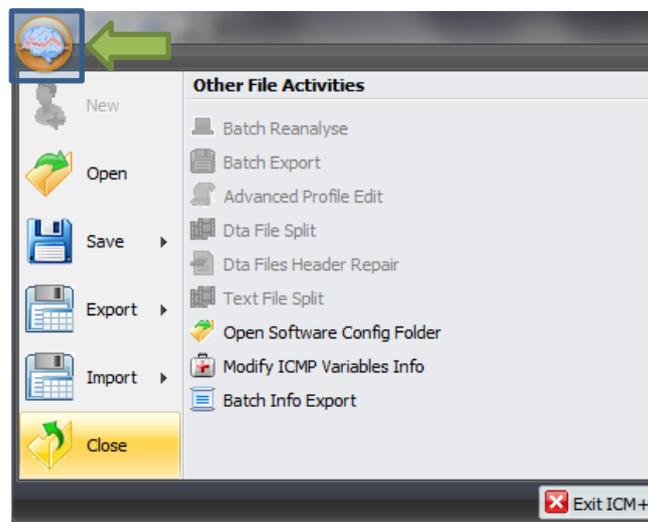
There, from left to right the following functions are accessible:

1. Log-in/Log-off form – to change the user (ie privileges)
2. Patient discharge/stop data collection session
3. Event annotation form (which will be disabled if no events are configured)
4. Free textual annotations form
5. An on-screen keyboard
6. The last button closes this tool bar and unfolds the main menu toolbars

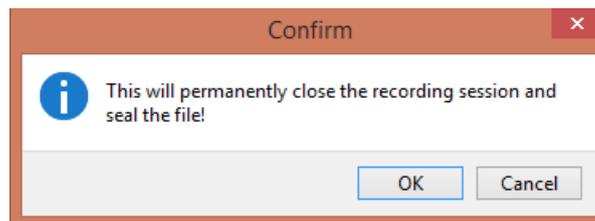
## Terminating the data collection session and archiving the data

When the data acquisition process is finished the recording session can be closed using the Close button present in the ICM+ button. This will initialize a cascade of forms that will eventually lead to the sealing of the file and subsequent archiving the data to the file server, if required.

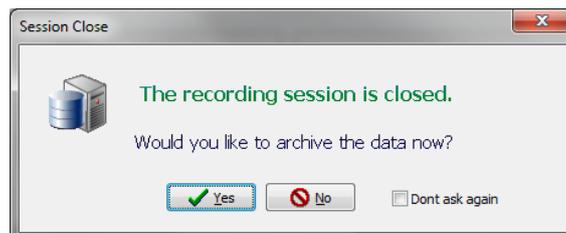
Closing a session is different from closing the program. To close the ICM+ application you need to press the red cross present on the upside corner of the right side of the screen. If ICM+ is closed (Exited) using this button or if the computer shuts down, the next time it is run, the recording session will be resumed with the same configurations it had at the moment of shutdown.



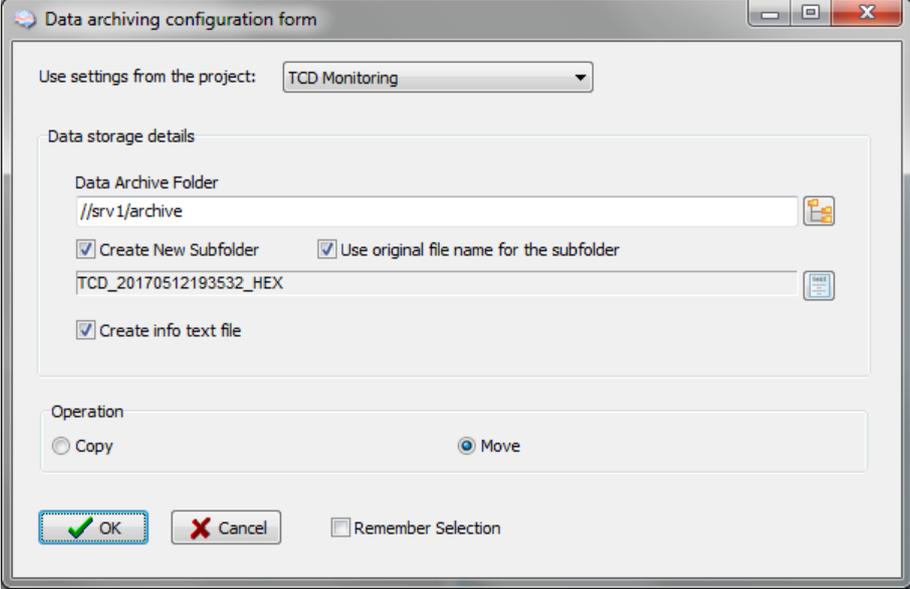
When this button is pressed a dialogue is presented prompting the user to confirm the closure of the recording session:



After confirming the end of the recording session another dialogue is presented prompting the user to archive the data:



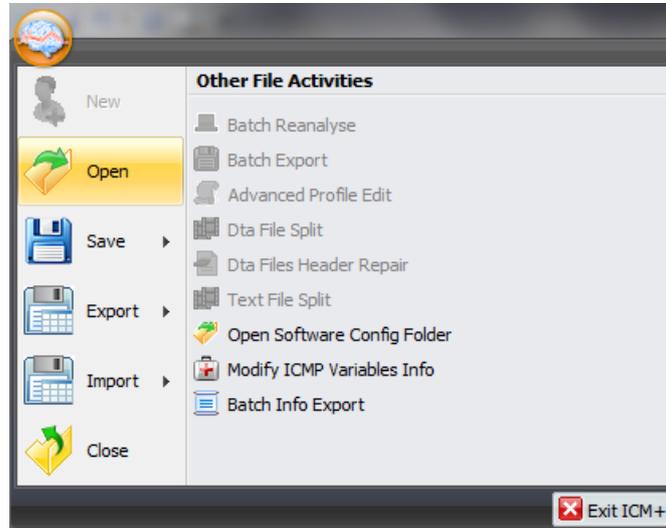
After confirming this dialogue the Data Archiving Form is presented, where the user can specify/confirm the location of the server and its share to use:



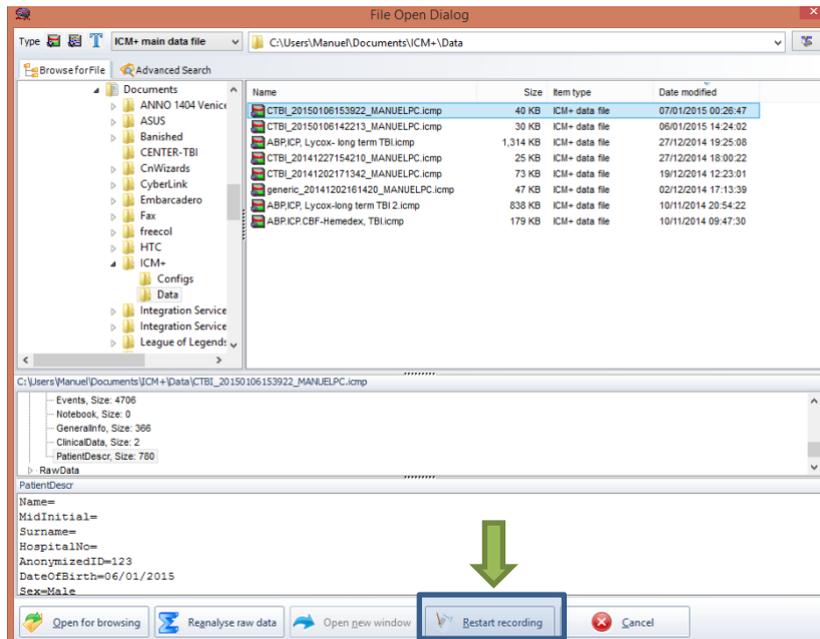
The image shows a Windows-style dialog box titled "Data archiving configuration form". At the top, it says "Use settings from the project:" followed by a dropdown menu set to "TCD Monitoring". Below this is a section titled "Data storage details" which contains a text field for "Data Archive Folder" with the value "//srv 1/archive" and a folder icon button. Underneath are two checked checkboxes: "Create New Subfolder" and "Use original file name for the subfolder". Below these is another text field containing "TCD\_20170512193532\_HEX" and a file icon button. At the bottom of this section is a checked checkbox for "Create info text file". Below the "Data storage details" section is an "Operation" section with two radio buttons: "Copy" (unselected) and "Move" (selected). At the very bottom of the dialog are three buttons: "OK" (with a green checkmark icon), "Cancel" (with a red X icon), and "Remember Selection" (with an unchecked checkbox).

## Restoring a closed data collection session

If a session was for some reason closed and a recording needs to be restored again the button open can be pressed.



The dialog that opens can be used to reopen the file in order to upload the data to our servers or to restore the recording session.

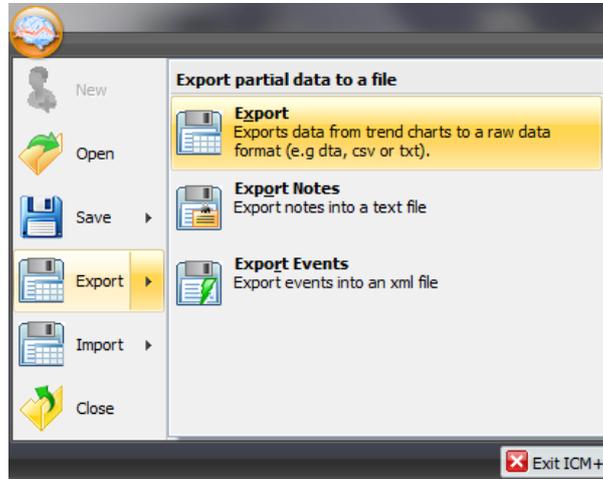


To reopen a file for inspection or to upload it is only necessary to double-click the desired file.

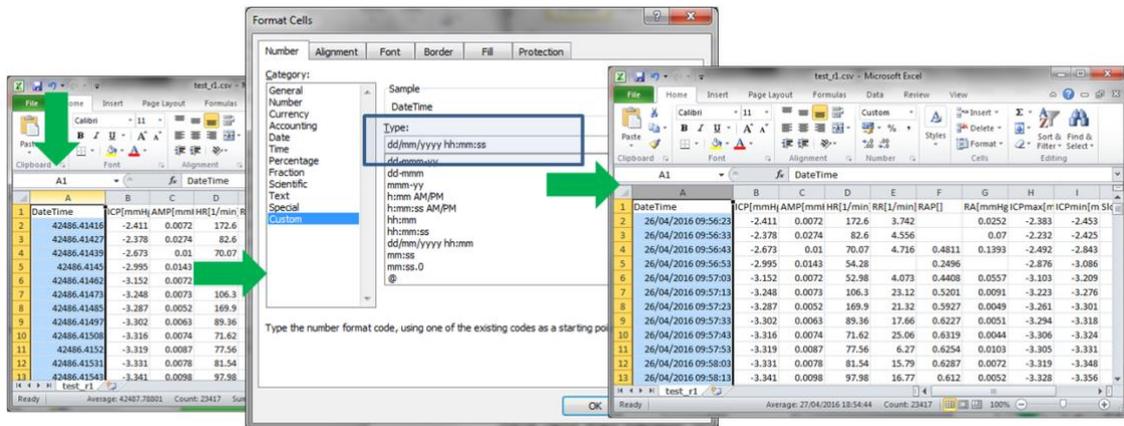
To restore the recording session, the highlighted button must be pressed and the recording resumes using the same profile as when it was closed.

## Exporting data to a csv (Excel) format

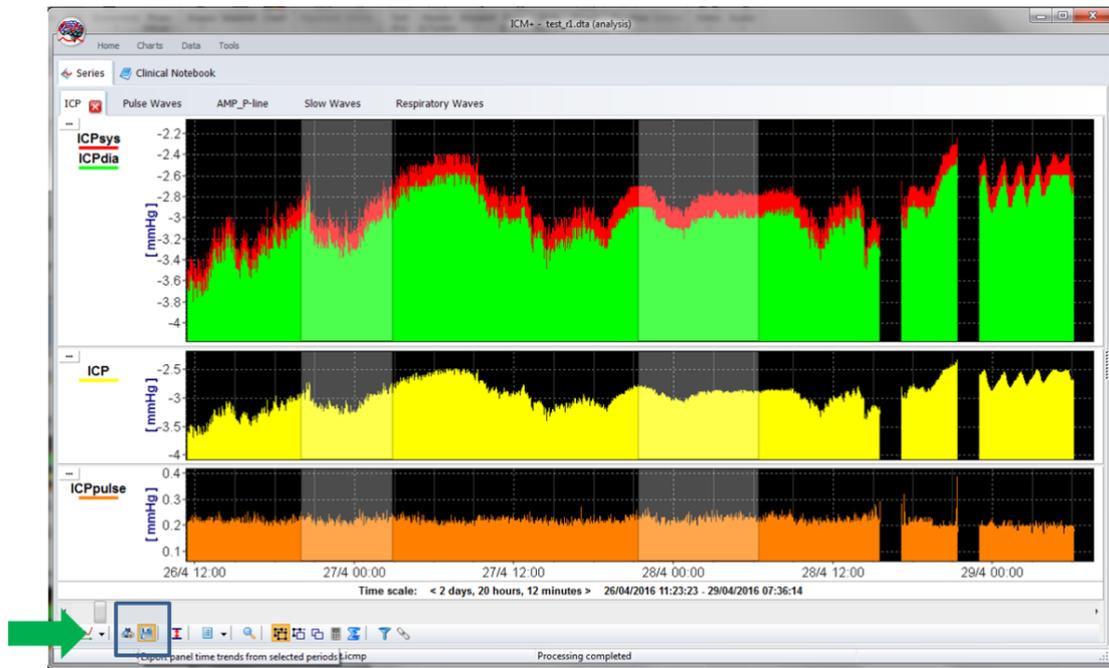
There are two ways the data can be exported from ICM+. One way is to select Export option in the main menu (the Brain icon).



This will export all the trend data from the memory, all the variables, in commas separated columns of values, with the first column containing the time stamps, in the internal Windows DateTime format. The DateTime format is essentially a number of days (and their fraction, which translate into time) since 31/12/1899. Imported into Excel it will initially showed up as those numbers, but if date or time (or combined) cell formatting is requested for that column the data and or time will be shown.



The second way of exporting data is to use the data export chart tool, located at the bottom of each charting vertical panel:



This will export data only from the variables plotted in the panel corresponding to the button toolbar, in this case it will be ICPsys, ICPdia, ICP and ICPpulse only, and only from selected time periods, if the selection tool is used, or the whole recording time, if not.

	A	B	C	D	E	F	G	H
1	DateTime	ICPsys[mmHg]	ICPdia[mmHg]	ICP[mmHg]	ICPpulse[mmHg]			
2	42668.57096	216.4	-3.937	0.744	220.4			
3	42668.57108	-2.629	-2.899	-2.743	0.2701			
4	42668.57119	-2.481	-2.647	-2.554	0.1663			
5	42668.57131	-2.406	-2.594	-2.511	0.1877			
6	42668.57142	-2.396	-2.594	-2.498	0.1984			
7	42668.57154	-2.396	-2.567	-2.484	0.1709			
8	42668.57166	-2.396	-2.539	-2.481	0.1434			
9	42668.57177	-2.396	-2.539	-2.476	0.1434			
10	42668.57189	-2.387	-2.539	-2.471	0.1526			
11	42668.572	-2.387	-2.521	-2.468	0.1343			
12	42668.57212	-2.341	-2.521	-2.462	0.1801			
13	42668.57223	-2.368	-2.53	-2.464	0.1617			
14	42668.57235	-2.359	-2.503	-2.459	0.1434			
15	42668.57247	-2.341	-2.521	-2.453	0.1801			
16	42668.57258	-2.313	-2.503	-2.431	0.1892			
17	42668.5727	-2.332	-2.512	-2.43	0.1801			
18	42668.57281	-2.313	-2.503	-2.426	0.1892			
19	42668.57293	-2.313	-2.503	-2.431	0.1892			
20	42668.57304	-2.332	-2.503	-2.433	0.1709			
21	42668.57316	-2.322	-2.503	-2.425	0.1801			

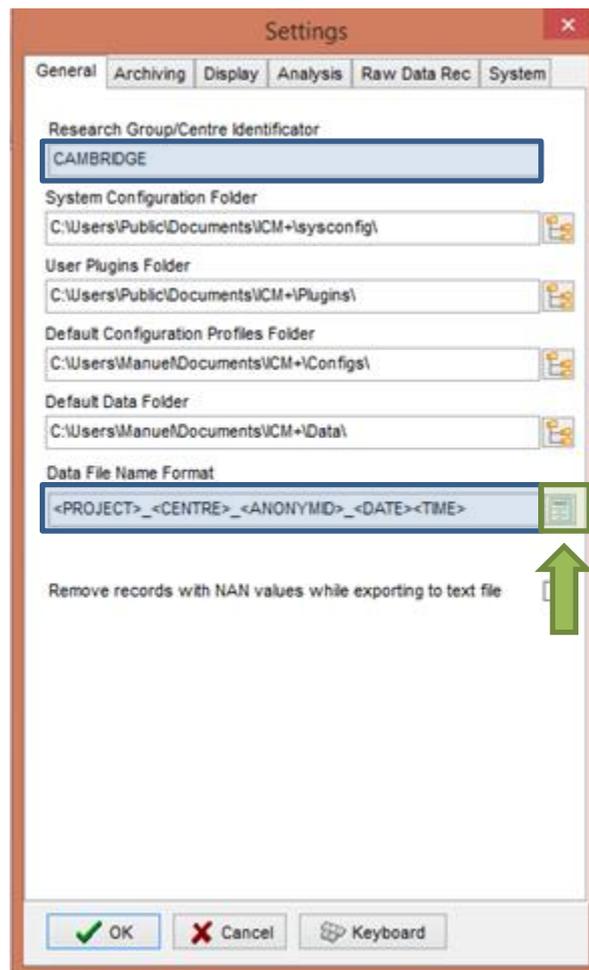
## Appendix 1: Configuring ICM+ system options

Most of the programmable behaviours of the software can adjusted via the Settings menu. This menu can be found by clicking the Home tab and the Settings button.



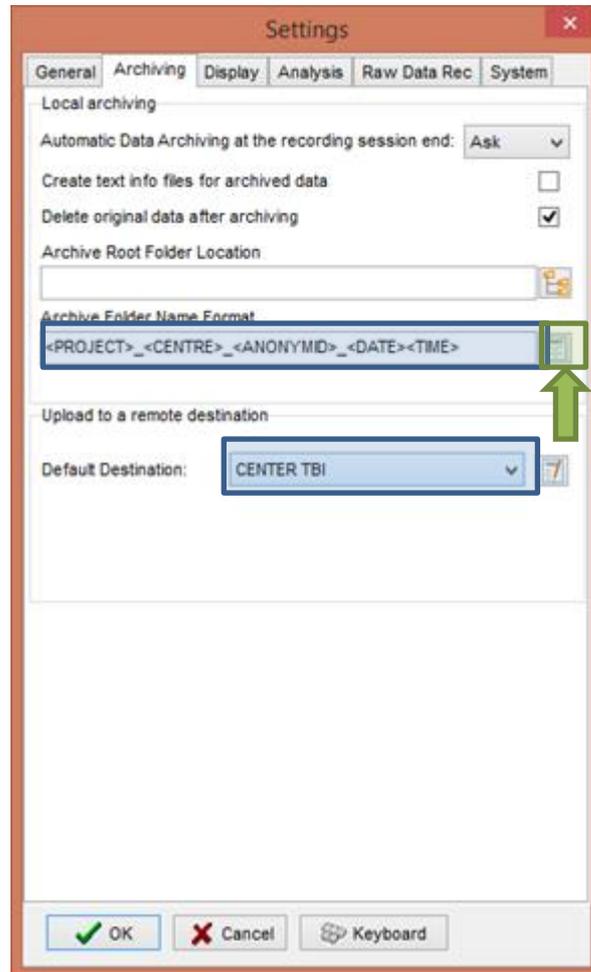
In the Settings menu you will need to configure several things:

- On the General tab:



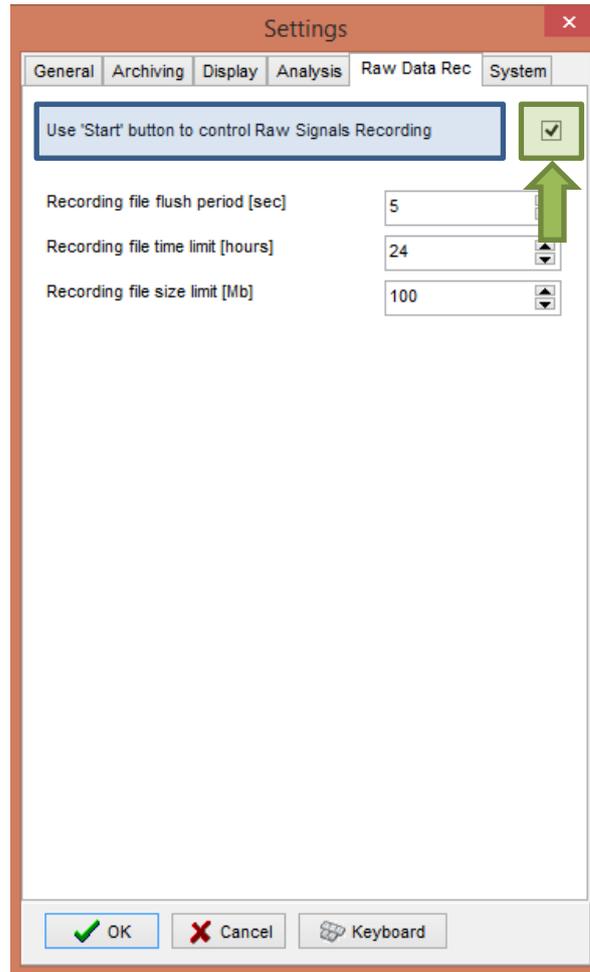
- The Research Group/Centre identification will be a unique name in the project that will identify the centre. This name should be fully inserted in capitals (ex. CAMBRIDGE).
- The **Data File Name Format** will be used to configure the structure to be used on the construction of the name of each data file. As each file generated in the study must have a unique identifier we agreed in using a structure that uses the format highlighted in the picture. A description on how to build this File Name format is presented further down in this appendix.

- On the Archiving tab:



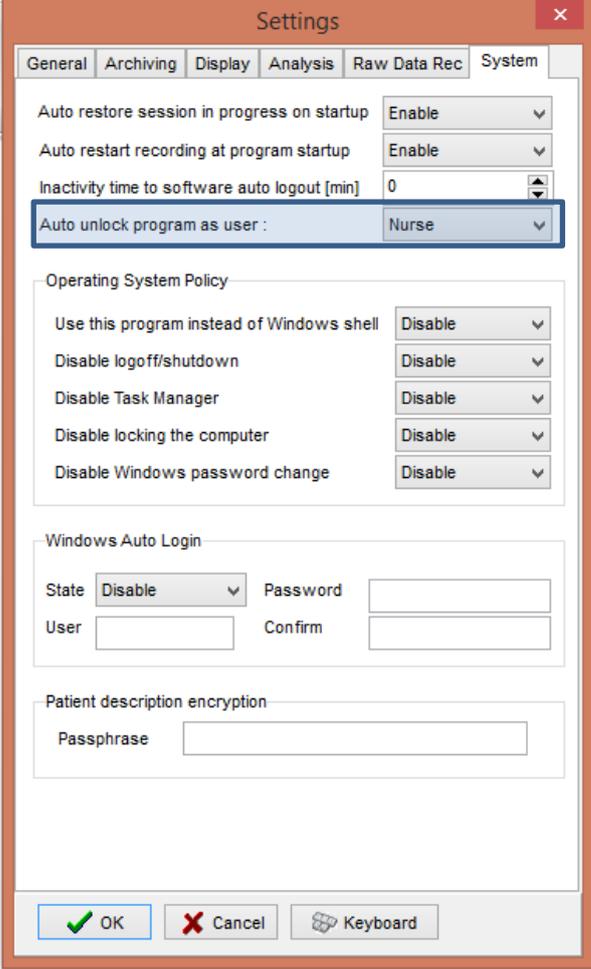
- The Archive Folder Name Format will follow the same structure as the Data File Name Format. This setting is used for organising local archival storage of the data files.
- The remote server Upload (accessible via the upload function) default Destination can be selected here but it is the matching setting in the Project configuration that will ultimately take precedence.

- On the Raw Data Rec tab:



- The Use 'Start' button to control Raw Signals Recording **must be checked if you are using ICM+ to record any data directly from bed side monitors**

- On the System tab:



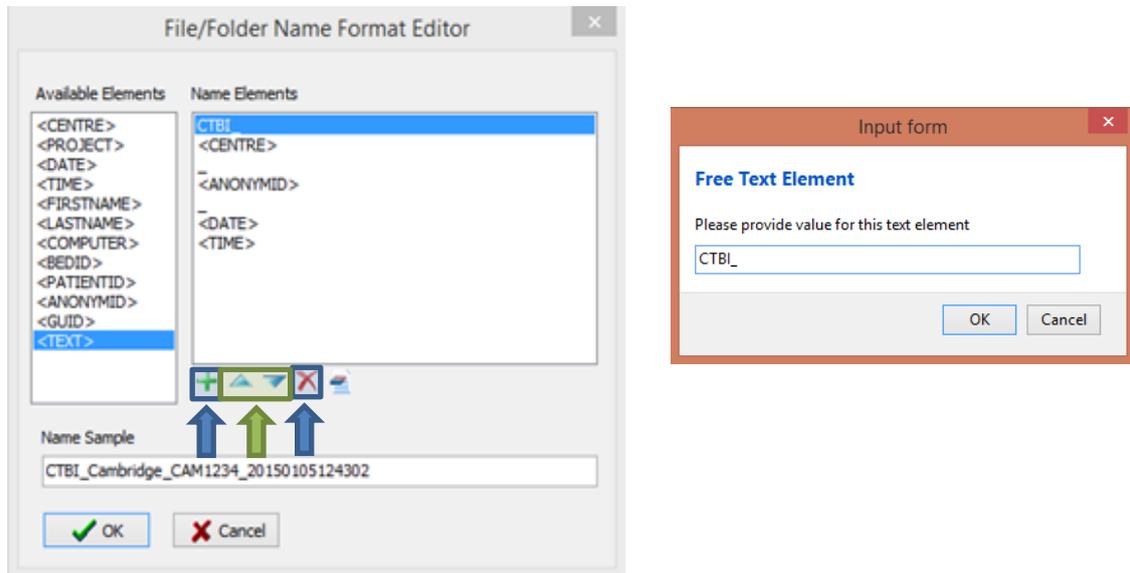
The screenshot shows the 'Settings' dialog box with the 'System' tab selected. The 'Auto unlock program as user' dropdown menu is highlighted with a blue border and set to 'Nurse'. Other settings include:

- Auto restore session in progress on startup: Enable
- Auto restart recording at program startup: Enable
- Inactivity time to software auto logout [min]: 0
- Operating System Policy:
  - Use this program instead of Windows shell: Disable
  - Disable logoff/shutdown: Disable
  - Disable Task Manager: Disable
  - Disable locking the computer: Disable
  - Disable Windows password change: Disable
- Windows Auto Login:
  - State: Disable
  - Password: [Empty field]
  - User: [Empty field]
  - Confirm: [Empty field]
- Patient description encryption:
  - Passphrase: [Empty field]

At the bottom, there are buttons for 'OK', 'Cancel', and 'Keyboard'.

- Set the Auto unlock program as user to Nurse. Setting the inactivity time to a value greater than 0, eg 10 min, will cause the software to auto log-in as that default user following a selected period of time without interaction with the software (this will only happen of course if the program was unlocked as another user)

To build the **Data File Name Format** you will need to click the highlighted button and the following form will appear:



In this form it is possible to add/remove any name element present in the Available Elements menu.

The '\_' and any additional static text can be inserted by using the element '<text>' and inserting the text to be added manually.

## Appendix 2: ICM+ configuration folders and files

ICM+ uses two locations (configurable via the Settings form) to store all its configuration files:

### Location 1: C:\Users\

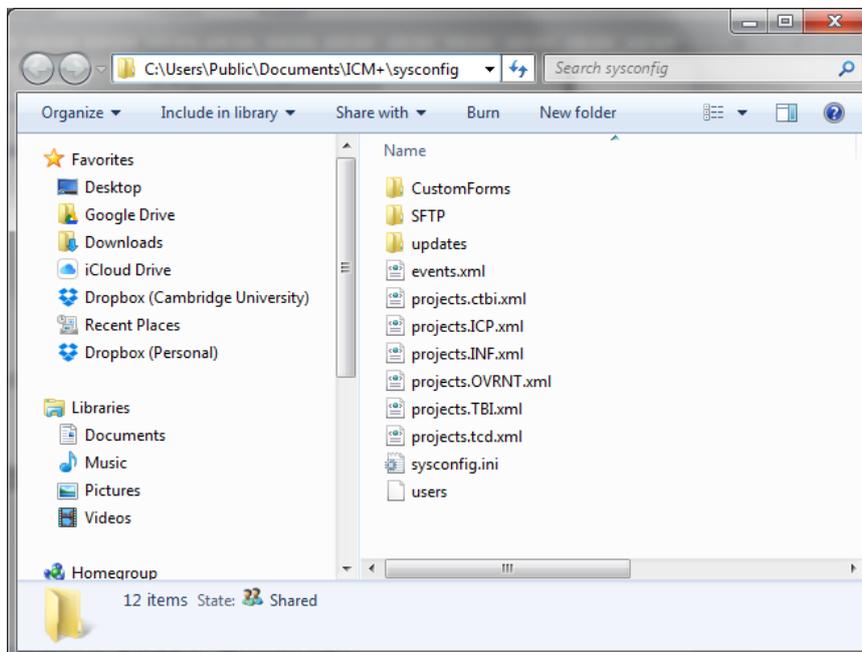
There are two subfolders here:

    ‘**Data**’ folder, where all the data recorded during the acquisition process is stored, and

    ‘**Configs**’ folder, used to store the data collection and analysis configuration ‘profile’ files, as in the figure below.

### Location 2: C:\Users\Public\Documents\ICM+

Here all the environment configurations/settings are stored. This location contains a folder called **Plugins**, where 3<sup>rd</sup> party function libraries reside, a folder called **TxtFilters**, containing parsing definitions for different text format data files, and a folder called **sysconfig** containing all the settings of the software, except the data collection and analysis profiles which are store in the Location 1 (as above). Although these files could be edited directly using a text editor ICM+ has specific user interface forms to edit all aspects of the program functionality.

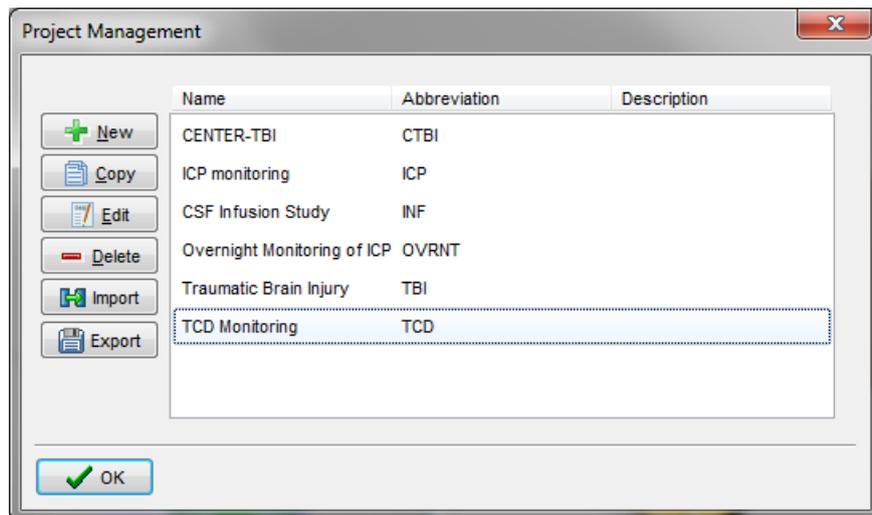


## Appendix 3: Editing ICM+ Projects

Projects contain various configurations specific to a particular research project. These can be edited using **Projects** button in the main menu tool bar.



Clicking this button will open the Project Management dialogue, where you create, copy, edit, delete, export/import selected projects to/from a file.



Double clicking on a selected project or clicking on Edit will open a Project Editor where all the custom project settings can be modified.

Project Configuration

General | Data Fields | Events | Data Archiving

Project Definition:

Name: TCD Monitoring      Abbreviation: TCD

Description:

Custom Module:

Data Folder: \\Mac\Home\Documents\VCM+i\Data

Config Folder: W:\VCM+i\Configs\1

Data File Name Format: <project>\_<date><time>\_<computer>

Default config profiles: Profile DWL with ABP via Intellivue.icm

Enforce default configuration profiles

OK Cancel Keyboard

1 . The project **abbreviation** will be part of the file name

2. '**Data Folder**' is a local folder where the data collected as part of this project will be stored

3. '**Config Folder**' is a folder (could be a network share) where the data configuration profiles are kept

4. **Data File Name Format** lists elements that will be used to create automatic file names for each new data acquisition sessions.

5. **Default config profiles** lists profiles that will be available to select in the new data acquisition forms.

Project Configuration

General | Data Fields | Events | Data Archiving

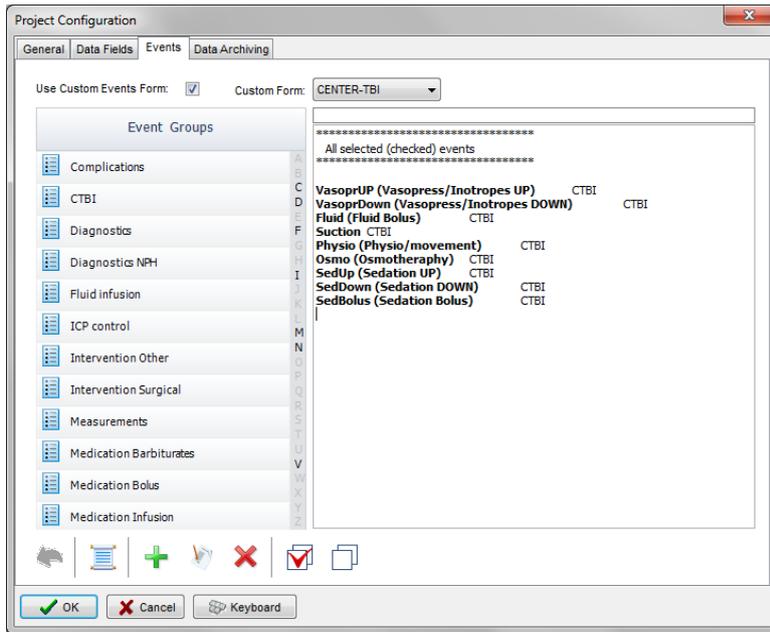
Data Fields Definitions

Name	Caption	Type	Description
GCS	GCS	Category	Glasgow Coma Score at admission
CT	CT Marshall score	Category	CT Marshall score at admission
TypeTBI	Type of TBI	Category	General type of brain trauma
Poltrauma	Poltrauma	Category	Other significant injury

Buttons: Add, Edit, Remove, Move Up, Move Dn

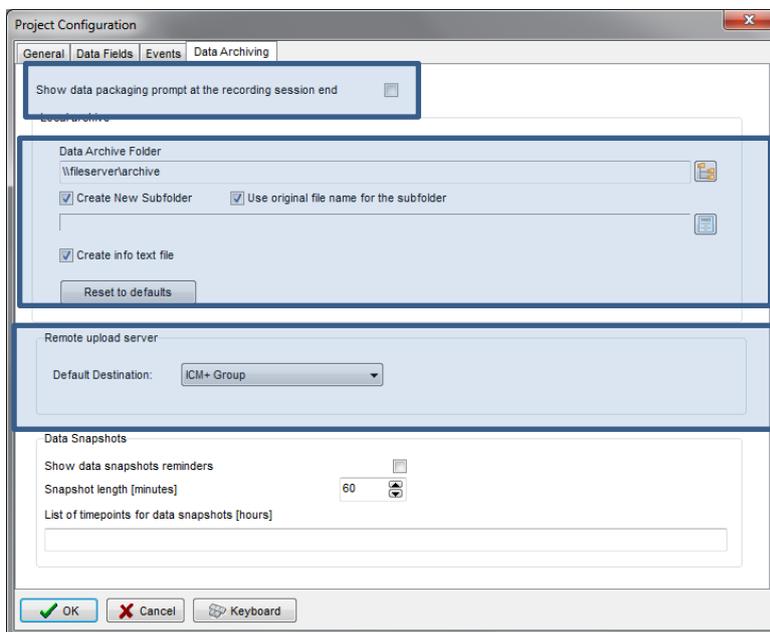
OK Cancel Keyboard

The data fields define placeholders for general clinical descriptors that characterise the patient at the time of admission to the critical care unit, that are useful to be kept together with the monitoring data.



This is where events that are already defined elsewhere (in the Events form), listed in the left panel (1), can be assigned to the particular project (listed in the right panel 2.).

Please note that there is also an option of using a customised event form (designed for CENTER-TBI project), selected using the 'Custom Forms' list box (3). It is possible however to add more events to the project but those will only be accessible from within the 'Event List' panel, toggled from the main menu tool bar panel, Charts section.



Here one can define the location and type of data archive procedure:

1. This should be ticked in order for you to be prompted to convert the file to archiving HDF5 format at the end of the recording session
2. Location of a local file server for data archiving,
3. the destination of a remote SFTP upload data server , configured in the Settings, and facilitating multicentre data collection projects

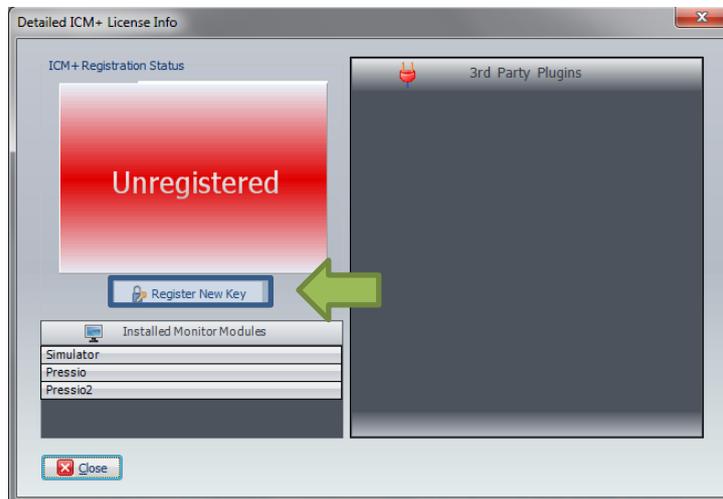
## Appendix 4: Registering ICM+

When ICM+ is successfully installed for the first time in a computer it needs to be registered. This will probably already be done for you when you get the laptops, but if any major update needs to be done you will have to register it again.

To register ICM+ you need to press the Registration button on the Home tab.



This will bring up the Detailed ICM+ License Info window where you will need to press the Register New Key button.



This will bring forth the ICM+ Registration Form.

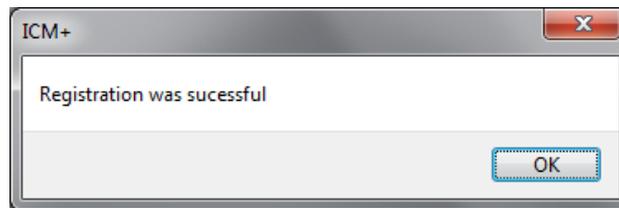
 A screenshot of the 'ICM+ REGISTRATION FORM'. The form has the following fields:
 

- InstallCode:** 905F4BC6C299 (highlighted in yellow, with a red note above it: 'Please quote this code for any further assistance')
- Username:** peter
- Institution:** University of Cambridge
- Computer:** HEX

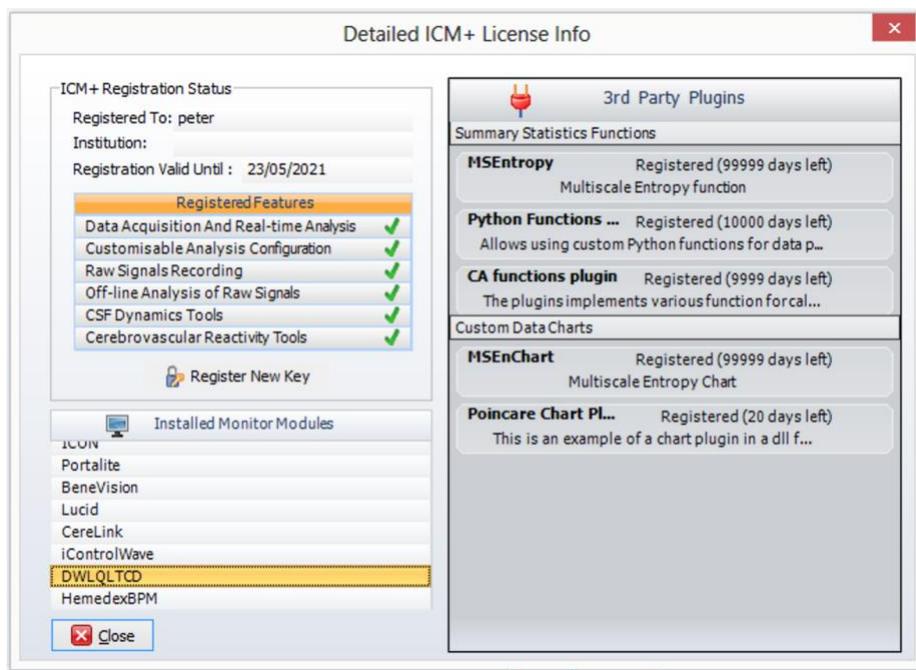
 Below the fields are two buttons: 'Copy Details' (highlighted with a blue box and a green arrow pointing to it from the left) and 'Email Details'. Below these is a section titled 'Register Now' with the instruction 'Please enter the registration key, then press the [Register] button' and an empty text input field. At the bottom of the form are three buttons: 'Register Now' (highlighted with a blue box and a green arrow pointing to it from the left), 'Cancel', and 'Keyboard'.

Using Copy Details button one can then copy the registration details to paste into an email and send to [ps10011@cam.ac.uk](mailto:ps10011@cam.ac.uk) with a request to generate a key. The Email Details is a shortcut for this when the computer is networked.

Once the key is received it needs to be pasted into the highlighted space and Register now button clicked upon which the registration successful dialogue should appear.



And the Detailed ICM+ License Info window should now look like this:



## Appendix 6: Preconfigured users and passwords

Administrator – 2718

Manager – 1618

Operator – 3142

Nurse – 1414

The users, their passwords, and their rights are fully configurable in the software, using Users form. The default users have been chosen to fulfil the following roles:

User	Role
<b>Administrator</b>	Complete access to all the software configuration options, the users and passwords
<b>Manager</b>	Access to all the configuration options, except the users and password. This will normally be the user to do the entire configuration needed for data collection.
<b>Operator</b>	Control of the data collection process using preconfigured profiles, and changes to the charts layout and properties.
<b>Nurse</b>	Access to clinical annotations tools only. This should be normally set up as the default user kept logged-in during the data collection process, in order to prevent any inadvertent disruption to data recording but at the same time allowing and encouraging quick access to the clinical annotations.
<b>Guest</b>	This 'user' has no rights, making it impossible to interact with the software in any way.

## Appendix 7: Selected relevant references

- 1: Smielewski P, Czosnyka M, Steiner L, Belestri M, Piechnik S, Pickard JD. ICM+: software for on-line analysis of bedside monitoring data after severe head trauma. *Acta Neurochir Suppl.* 2005;95:43-9.
- 2: Guending K, Smielewski P, Czosnyka M, Lewis P, Nortje J, Timofeev I, Hutchinson PJ, Pickard JD. Use of ICM+ software for on-line analysis of intracranial and arterial pressures in head-injured patients. *Acta Neurochir Suppl.* 2006;96:108-13.
- 3: Claassen JA, Meel-van den Abeelen AS, Simpson DM, Panerai RB; international Cerebral Autoregulation Research Network (CARNet).. Transfer function analysis of dynamic cerebral autoregulation: A white paper from the International Cerebral Autoregulation Research Network. *J Cereb Blood Flow Metab.* 2016 Apr;36(4):665-80.
- 4: Varsos G V., Richards HK, Kasprowicz M, Reinhard M, Smielewski P, Brady KM, et al. Cessation of diastolic cerebral blood flow velocity: The role of critical closing pressure. *Neurocrit Care.* 2014;20: 40–48. doi:10.1007/s12028-013-9913-3
- 5: Varsos G V., Kasprowicz M, Smielewski P, Czosnyka M. Model-based indices describing cerebrovascular dynamics. *Neurocrit Care.* 2014;20: 142–157. doi:10.1007/s12028-013-9868-4
- 6: Varsos G V, Budohoski KP, Czosnyka M, Koliass AG, Nasr N, Donnelly J, et al. Cerebral vasospasm affects arterial critical closing pressure. *J Cereb Blood Flow Metab.* Nature Publishing Group; 2014;11: 1–7. doi:10.1038/jcbfm.2014.198
- 7: Varsos G V, Koliass AG, Smielewski P, Brady KM, Varsos VG, Hutchinson PJ, et al. A noninvasive estimation of cerebral perfusion pressure using critical closing pressure. *J Neurosurg.* 2015;123: 638–48. doi:10.3171/2014.10.JNS14613
- 8: Varsos G V., Czosnyka M, Smielewski P, Garnett MR, Liu X, Adams H, et al. Cerebral critical closing pressure during infusion tests. *Acta Neurochir Suppl.* 2016;122: 215–220. doi:10.1007/978-3-319-22533-3\_43
- 9: Cardim D, Robba C, Donnelly J, Bohdanowicz M, Schmidt B, Damian M, et al. Prospective study on non-invasive assessment of ICP in head injured patients: comparison of four methods. *J Neurotrauma.* 2015; doi:10.1089/neu.2015.4134
- 10: Cardim D, Robba C, Bohdanowicz M, Donnelly J, Cabella B, Liu X, et al. Non-invasive Monitoring of Intracranial Pressure Using Transcranial Doppler Ultrasonography: Is It Possible? *Neurocrit Care.* 2016; doi:10.1007/s12028-016-0258-6
- 11: Cardim D, Czosnyka M, Donnelly J, Robba C, Cabella BCT, Liu X, et al. Assessment of non-invasive ICP during CSF infusion test: an approach with transcranial Doppler. *Acta Neurochir (Wien).* 2016;158: 279–87. doi:10.1007/s00701-015-2661-8
- 12: Cardim D, Schmidt B, Robba C, Donnelly J, Puppo C, Czosnyka M, et al. Transcranial Doppler Monitoring of Intracranial Pressure Plateau Waves. *Neurocrit Care.* Springer US; 2016; 1–9. doi:10.1007/s12028-016-0356-5
- 13: Schmidt B, Klingelhöfer J, Schwarze JJ, Sander D, Wittich I. Noninvasive Prediction of Intracranial Pressure Curves Using Transcranial Doppler Ultrasonography and Blood Pressure Curves. *Stroke.* 1997;28: 2465–2472. doi:10.1161/01.STR.28.12.2465
- 14: De Riva N, Budohoski KP, Smielewski P, Kasprowicz M, Zweifel C, Steiner LA, et al. Transcranial doppler pulsatility index: What it is and what it isn't. *Neurocrit Care.* 2012;17: 58–66. doi:10.1007/s12028-012-9672-6
- 15: Zweifel C, Czosnyka M, Carrera E, de Riva N, Pickard JD, Smielewski P. Reliability of the blood flow velocity pulsatility index for assessment of intracranial and cerebral perfusion pressures in head-injured patients. *Neurosurgery.* 2012;71: 853–61. doi:10.1227/NEU.0b013e3182675b42
- 16: Czosnyka M, Smielewski P, Kirkpatrick P, Menon DK, Pickard JD. Monitoring of Cerebral Autoregulation in Head-Injured Patients. *Stroke.* 1996. pp. 1829–1834. doi:10.1161/01.STR.27.10.1829
- 17: Budohoski KP, Reinhard M, Aries MJH, Czosnyka Z, Smielewski P, Pickard JD, et al. Monitoring cerebral autoregulation after head injury. Which component of transcranial Doppler flow velocity is optimal? *Neurocrit Care.* 2012;17: 211–218. doi:10.1007/s12028-011-9572-1
- 18: Czosnyka M, Smielewski P, Piechnik S, Steiner L a, Pickard JD. Cerebral autoregulation following head injury. *J Neurosurg.* 2001;95: 756–763. doi:10.3171/jns.2001.95.5.0756
- 19: Lang EW, Mehdorn HM, Dorsch NWC, Czosnyka M. Continuous monitoring of cerebrovascular autoregulation: a validation study. *J Neurol Neurosurg Psychiatry.* 2002;72: 583–6. Available: <http://www.pubmedcentral.nih.gov/articlerender.fcgi?artid=1737892&tool=pmcentrez&rendertype=abstract>