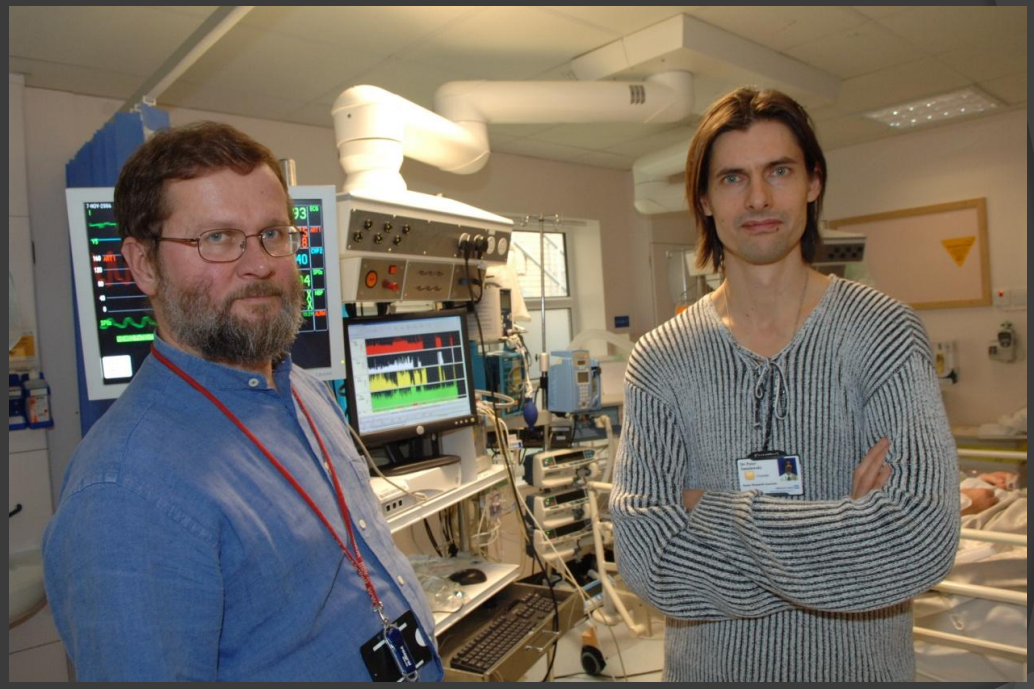
ICM+

Past, Present and Future

Dr Peter Smielewski
Dept of Clinical Neurosciences
University of Cambridge

Disclosure

ICM+ software is licensed by Cambridge Enterprise Ltd, subsidiary of University of Cambridge, UK.



Gentlemen pictured above (Dr M. Czosnyka, left, and Dr P. Smielewski, right) have financial interest in part of the licensing fee for the ICM+ software

ICM+ TALK OUTLINE

- Brief history of almost everything (related to ICM+)
- Principles of ICM+
- New developments
- Where do we go from here ?

ICM+ Timeline

1980 1990 2000 2010

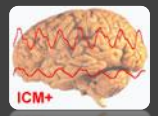
1982

Warsaw University of Technology

University of Cambridge

First ICP Analyser – Sinclair ZX Spectrum !

ICM+ Timeline

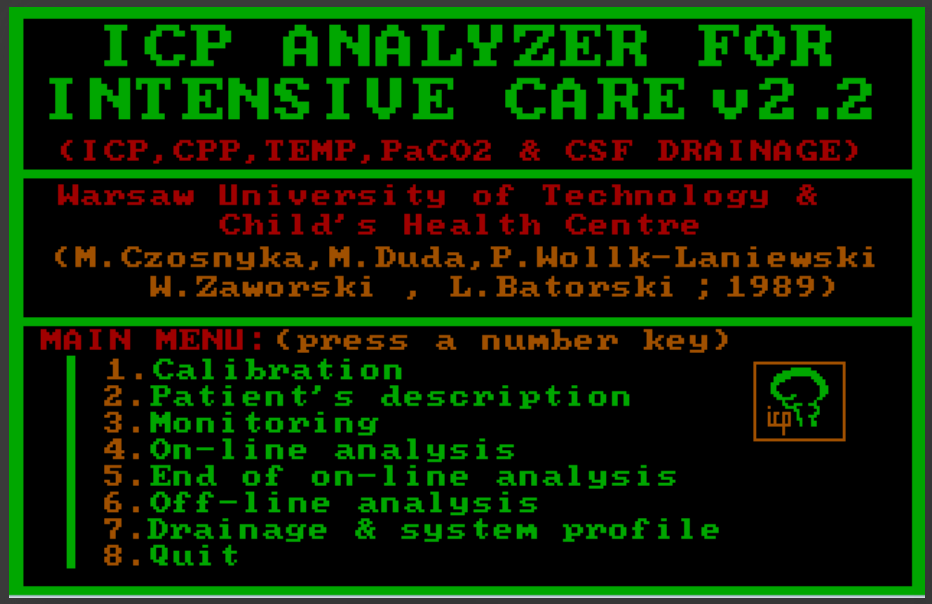


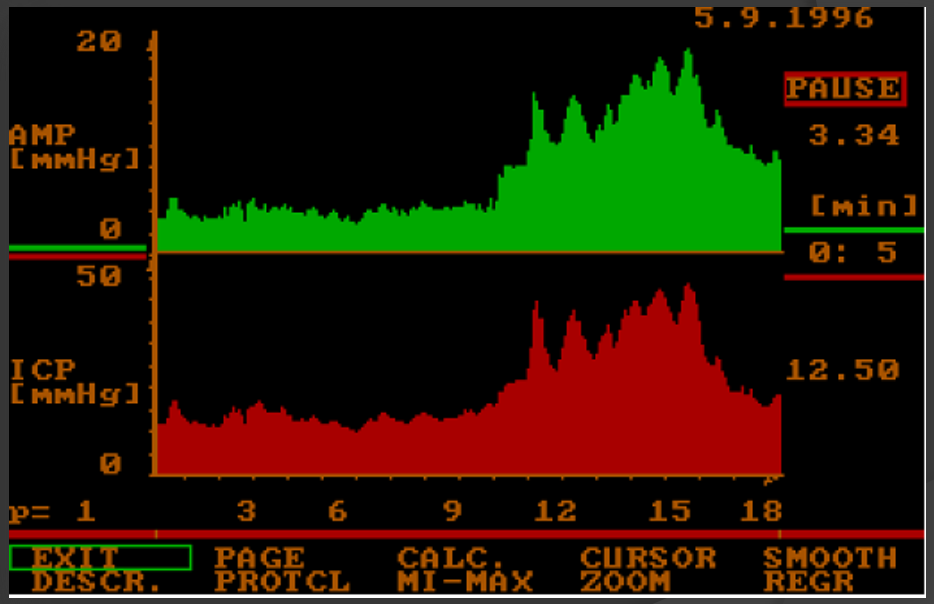
1980 — 1990 — 2000 — 2010

1985

Warsaw University of Technology — University of Cambridge

ICP Analyser for DOS





ICP via Analogue output

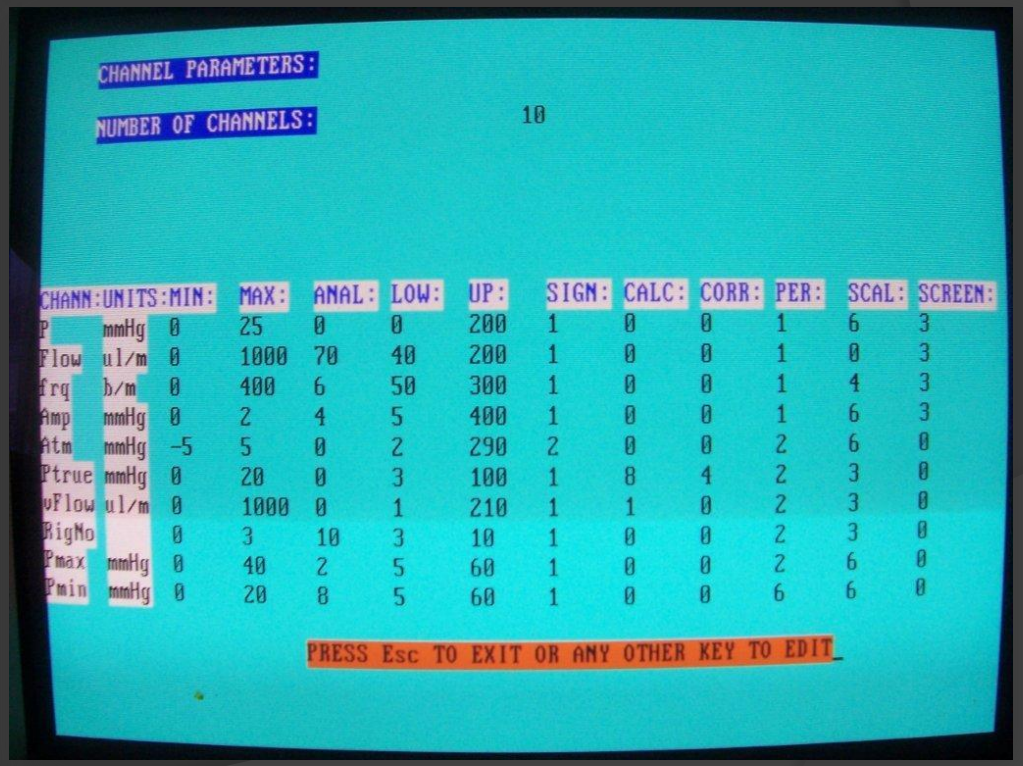
ICM+ Timeline

1980 1990 2000 2010

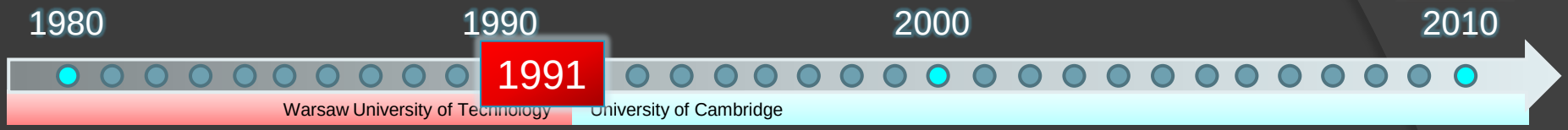
1991

Warsaw University of Technology — University of Cambridge

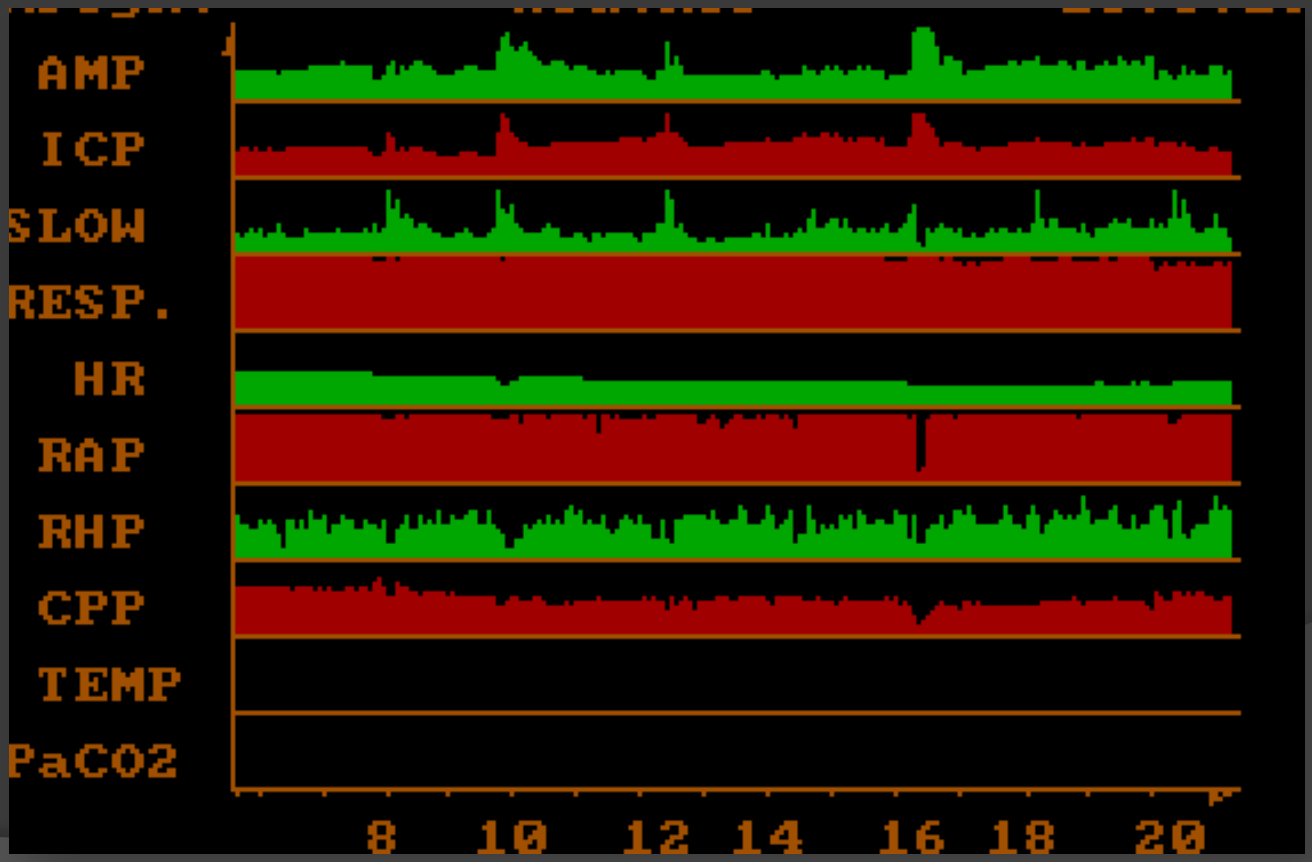
Intensive Care Monitor - ICM



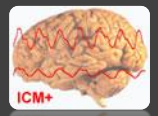
ICM+ Timeline



ICM trends examples



ICM+ Timeline



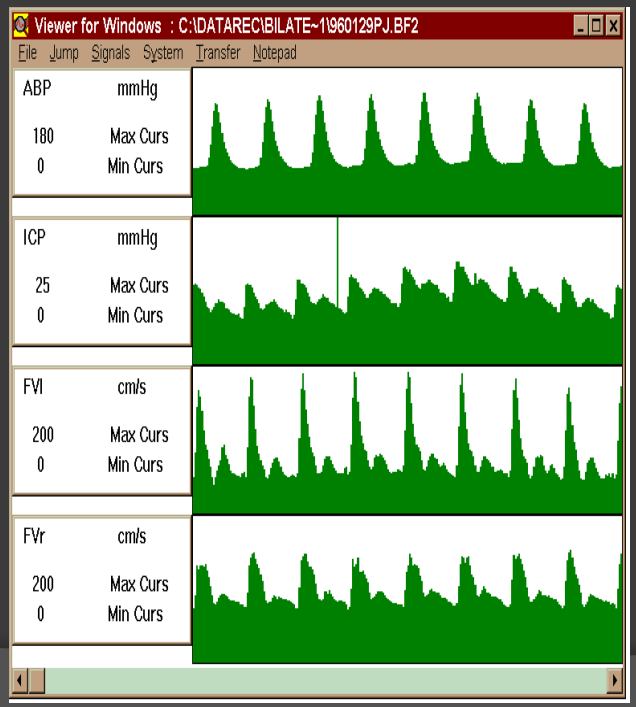
1980 — 1990 — 1992 — 2000 — 2010

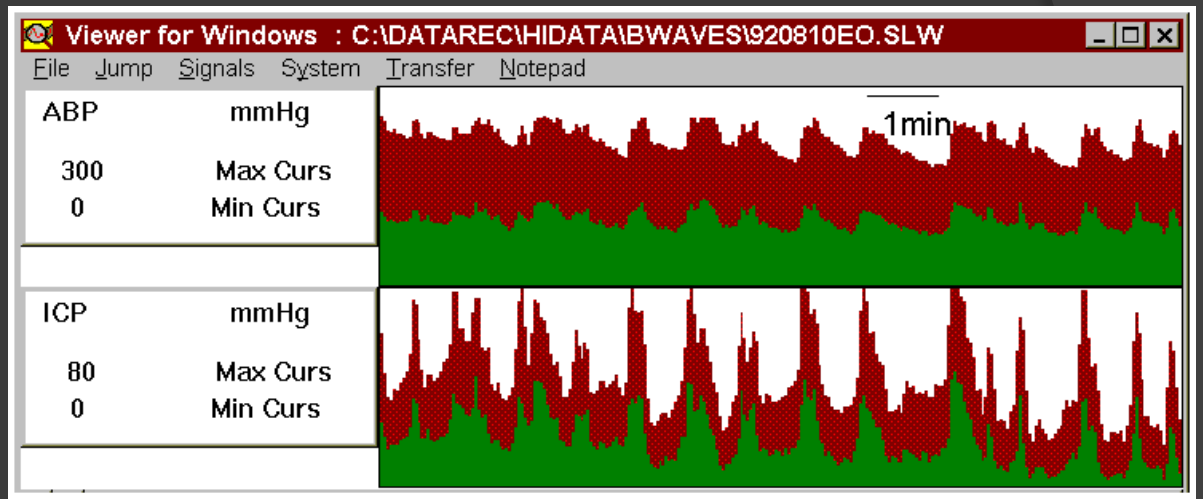
Warsaw University of Technology — University of Cambridge

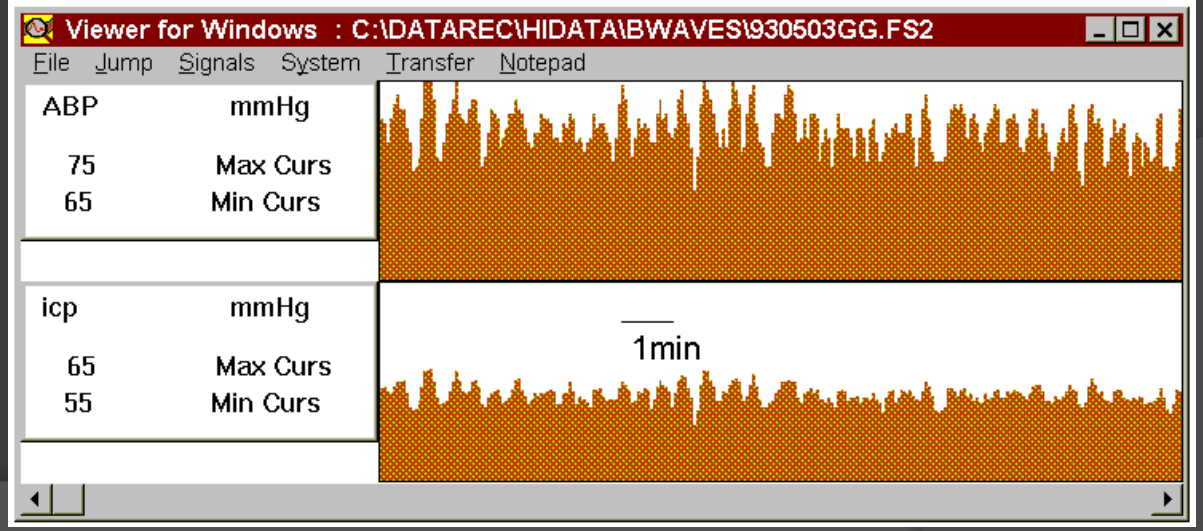
WREC

Windows Recorder

W. Zabolotny,
Warsaw University of Technology







ICM+ Timeline

1980 1990 2000 2010

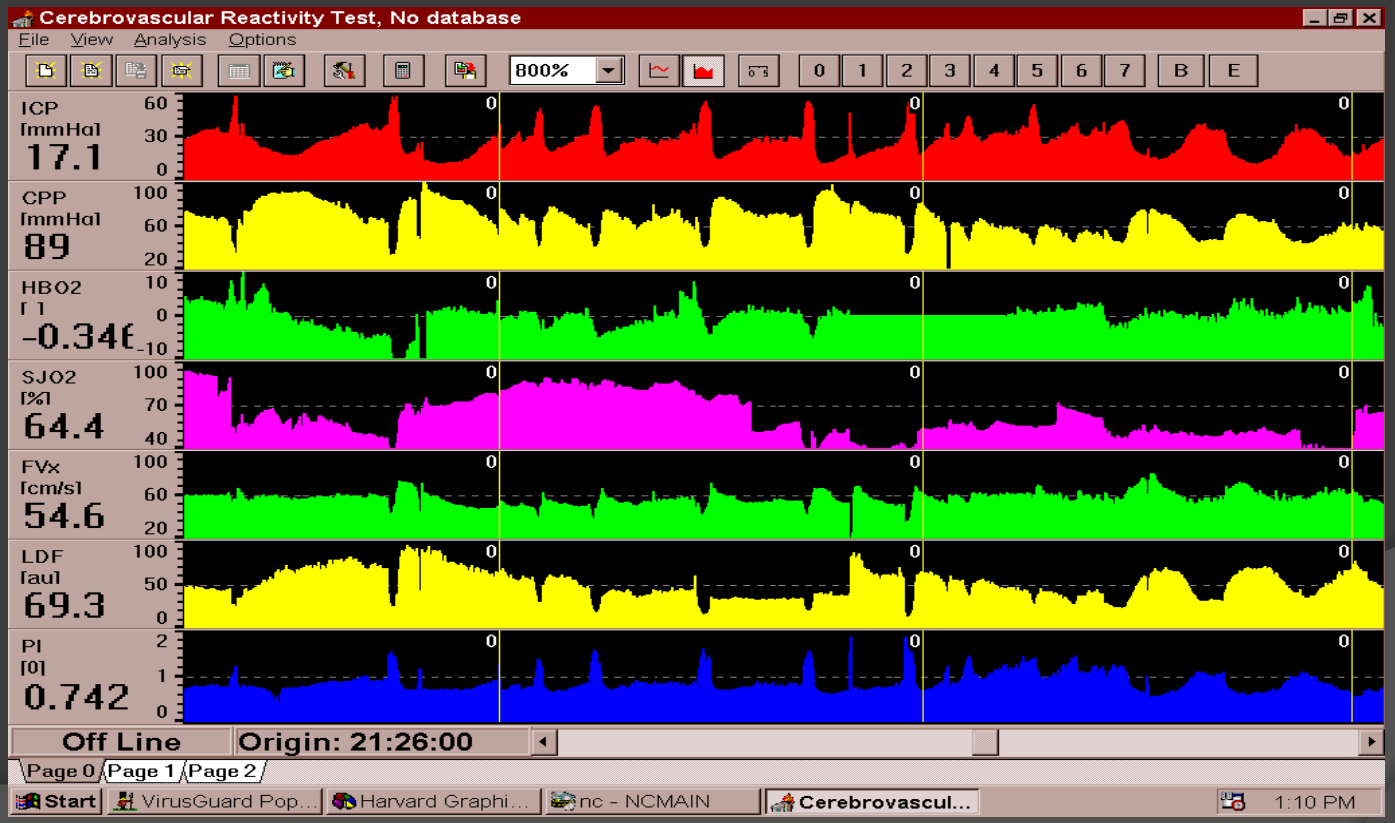
1995

Warsaw University of Technology

University of Cambridge

Biological Signals Analyser

Software for real time analysis of cerebrovascular reactivity tests



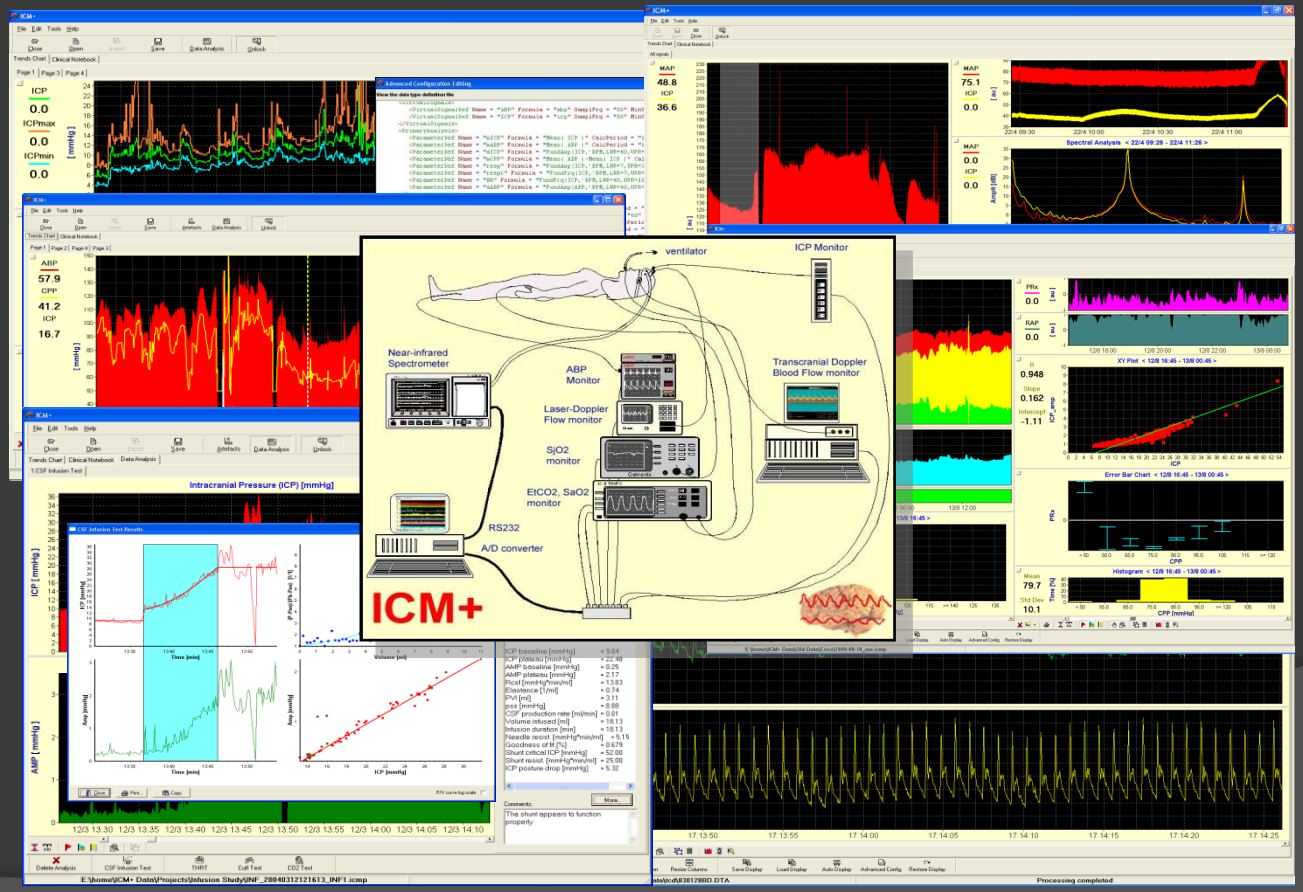
ICM+ Timeline

1980 1990 2000 2010

2000

Warsaw University of Technology | University of Cambridge

ICM+ begins



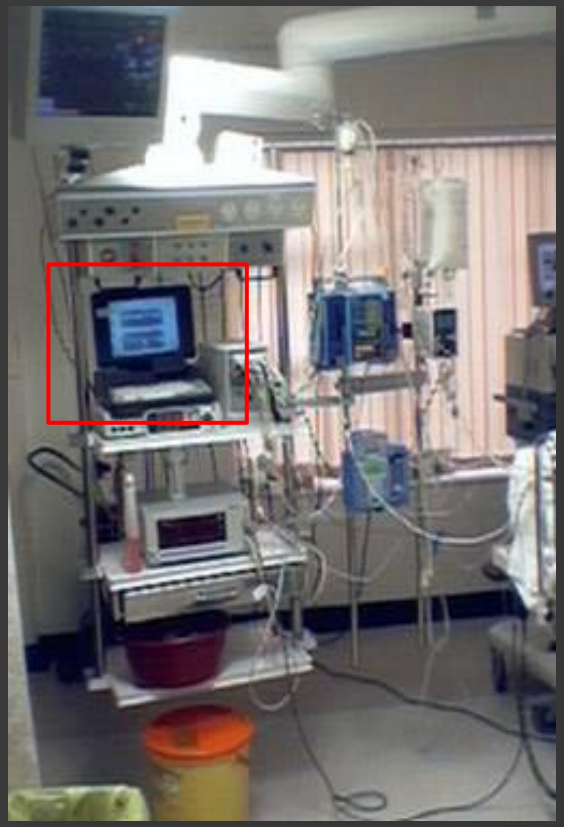
ICM+ Timeline

1980 1990 2000 2002 2010

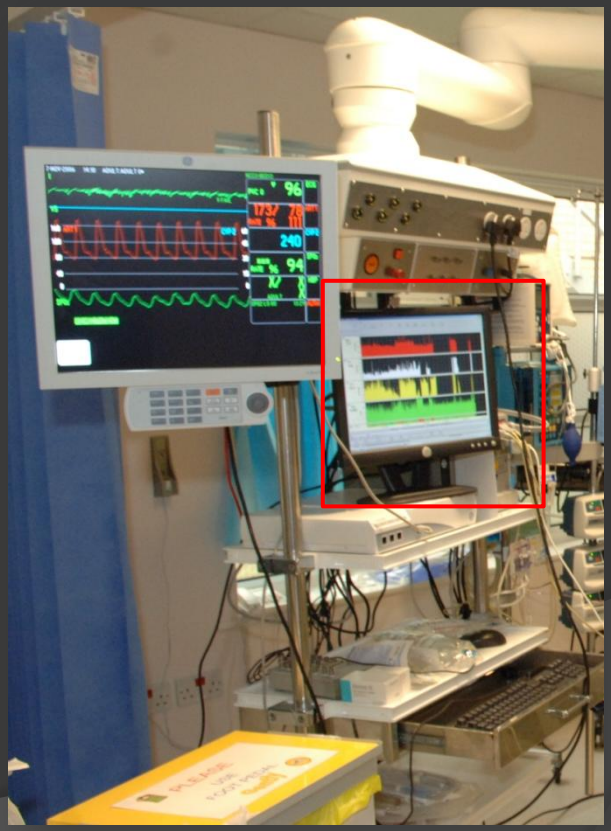
Warsaw University of Technology

University of Cambridge

ICM+ replaces ICM in the NCCU



ICM



ICM+

ICM+ Timeline

1980 1990 2000 2004 2010

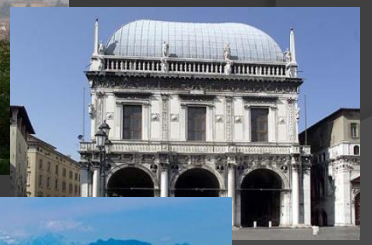
Warsaw University of Technology | University of Cambridge

Cambridge Enterprise (wholly own subsidiary of Cambridge University)

takes over IP rights to ICM+ and starts offering its licenses to other clinical research centres

First ICM+ Installation:
University Clinique, Brescia, Italy

Prof. N. Latronico, Dr F. Rasulo

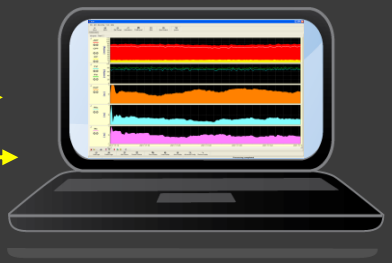


ICM+ Timeline

1980 1990 2000 2005 2010

Warsaw University of Technology | University of Cambridge

First Digital Interface: Phillips monitors



Department of Neurology,
Medical Centre Haaglanden,
The Hague, Netherland

Joseph T Tans

EXTENDED POLL DATA REQUEST

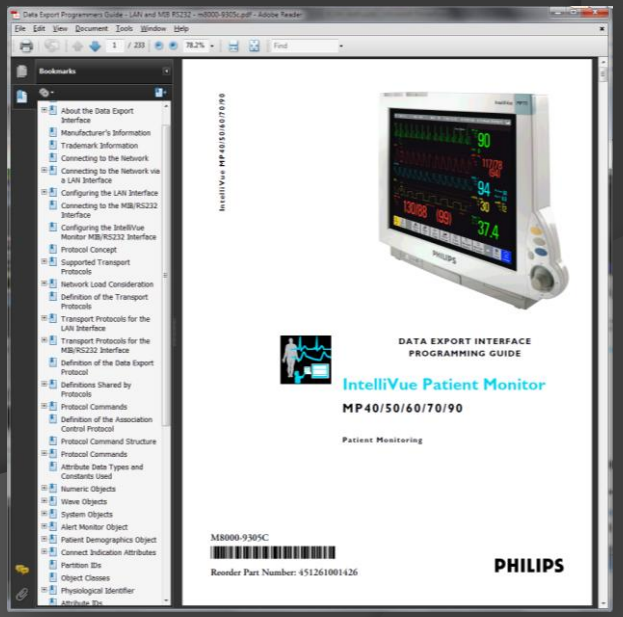
The next example shows a message which could be used to access averaged data. The message will only be accepted if the optional package for Poll Profile Extensions has been negotiated during the association phase.

```
SPpdu           session_id          : 0xE100
                p_context_id        : 2
                  {0xE1 0x00 0x00 0x02}
ROapdus         ro_type             : ROIV_APDU
                length              : 32
                  {0x00 0x01 0x00 0x20}
ROIVapdu        invoke_id           : 0
                command_type        : CMD_CONFIRMED_ACTION
                length              : 26
                  {0x00 0x01 0x00 0x07 0x00 0x1a}

ActionArgument
ManagedObjectId m_obj_class         : NOM_MOC_VMS_MDS
                context_id          : 0
                handle              : 0
u_32            scope               : 0
OIDType         action_type         : NOM_ACT_POLL_MDIB_DATA_EXT
u_16            length              : 12
                  {0x00 0x21 0x00 0x00 0x00 0x00 0x00 0x00
                   0x00 0x00 0xf1 0x3b 0x00 0x0c}

PollMdibDataReqExt
u_16            poll_number         : 1
TYPE            partition           : NOM_PART_OBJ
                code                : NOM_MOC_VMO_METRIC_NU
OIDType         polled_attr_grp     : all attribute groups
AttributeList
u_16            count               : 0
u_16            length              : 0
                  {0x00 0x01 0x00 0x01 0x00 0x06 0x00 0x00
                   0x00 0x00 0x00 0x00}
```

EXTENDED POLL DATA RESULT

The Extended Poll Data Result message contains an additional *sequence_no*, which is used if the client requests periodic replies.

```
SPpdu           session_id          : 0xE100
                p_context_id        : 2
                  {0xE1 0x00 0x00 0x02}
```



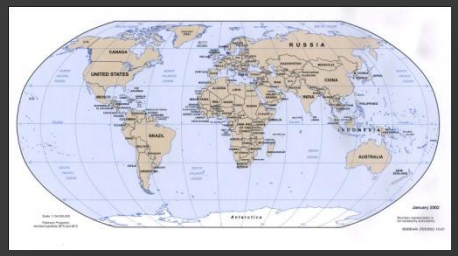
ICM+ Timeline

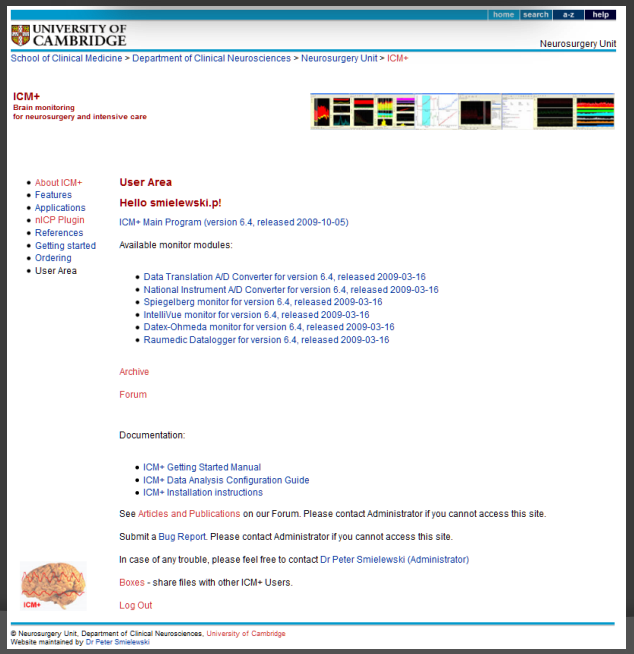
1980 1990 2000 2010

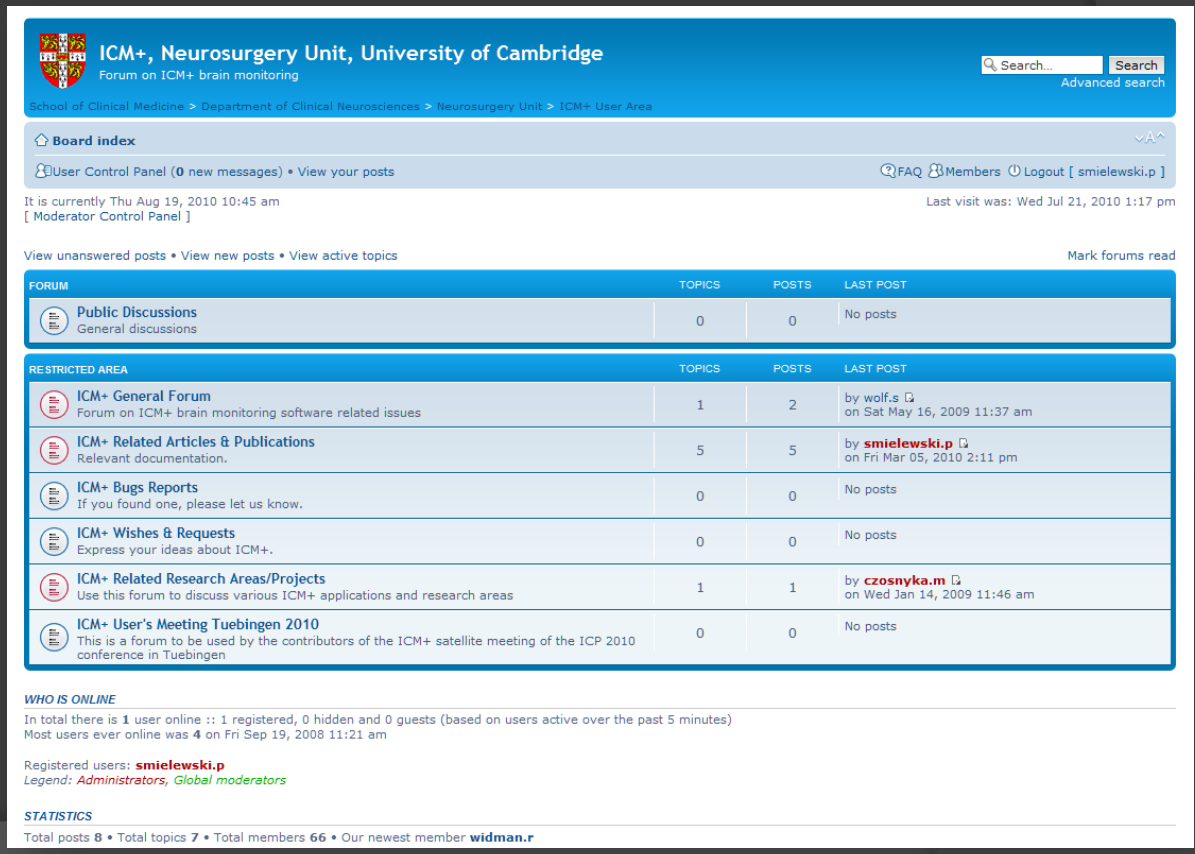
2008

Warsaw University of Technology | University of Cambridge

ICM+ Portal







ICM+ Timeline

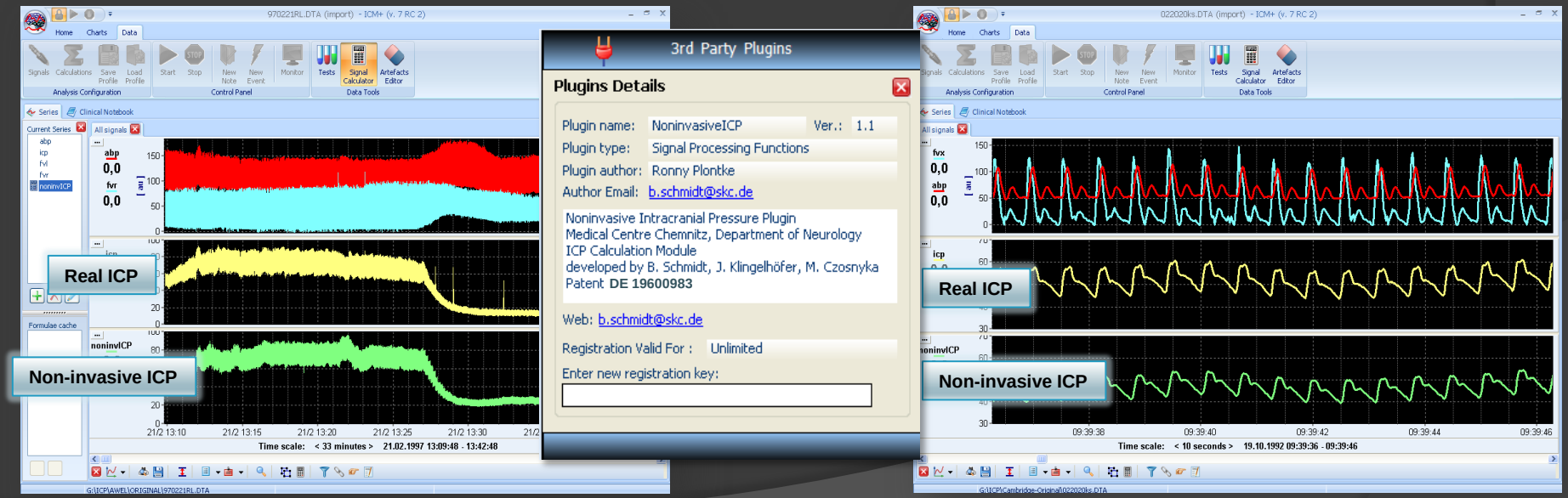
1980 1990 2000 2010

2009

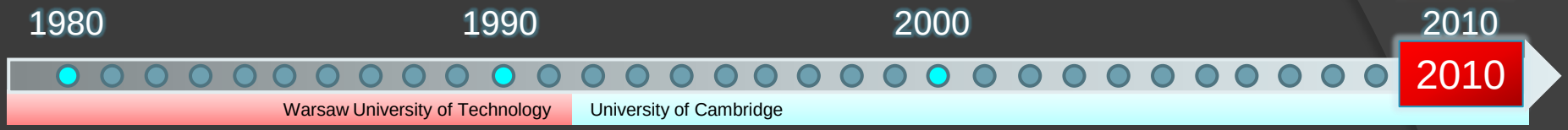
Warsaw University of Technology | University of Cambridge

The plug-in interface

The first plugin – Non-invasive ICP
by B Schmidt and R Plontke, Chemnitz, Germany



ICM+ Timeline



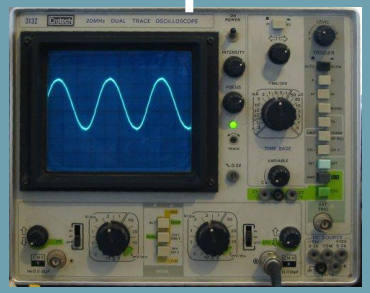
First ICM+ users' group meeting

ICM+ Principles

Data collection interfaces

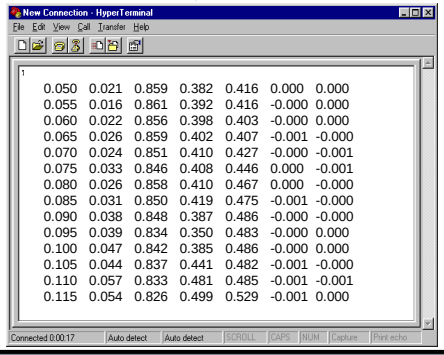
Analogue

Coax cable

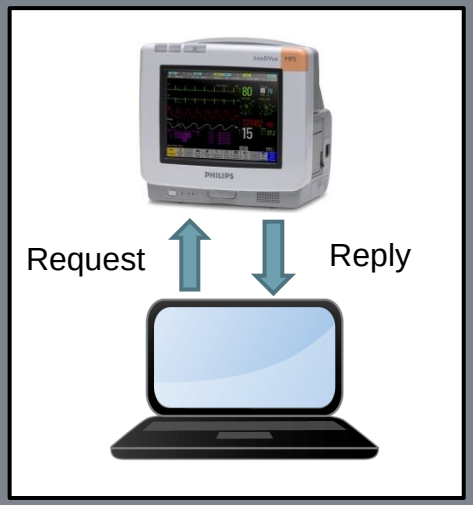


Digital (Serial Interface)

Ascii continuous export



Client/server model
Proprietary language

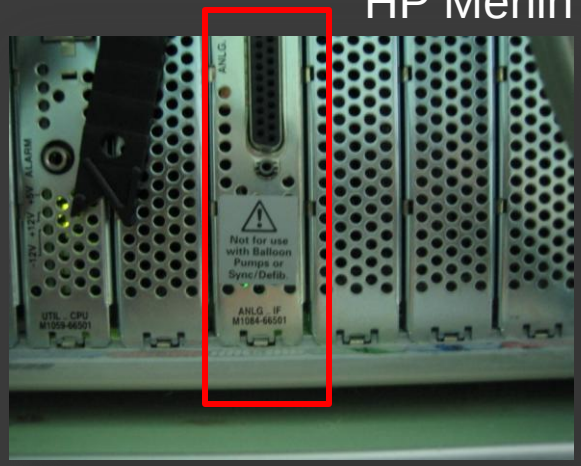


ICM+ Principles

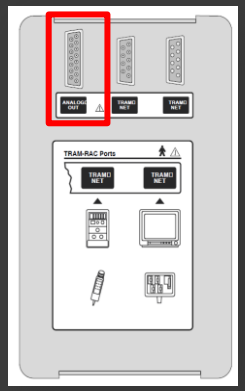
Analogue interface

DWL TCD

HP Merlin



Marquette



Drager

Spacelab

Surgical Display Controller

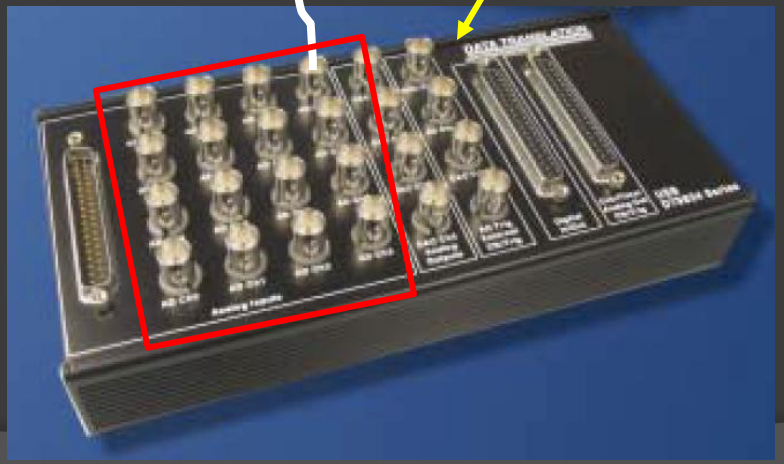
ICM+ Principles

Analogue interface

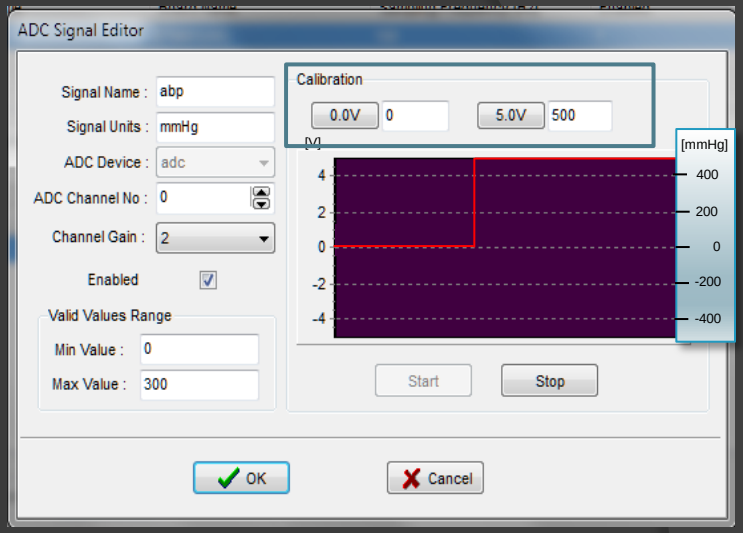
HP monitor module

Coax cable

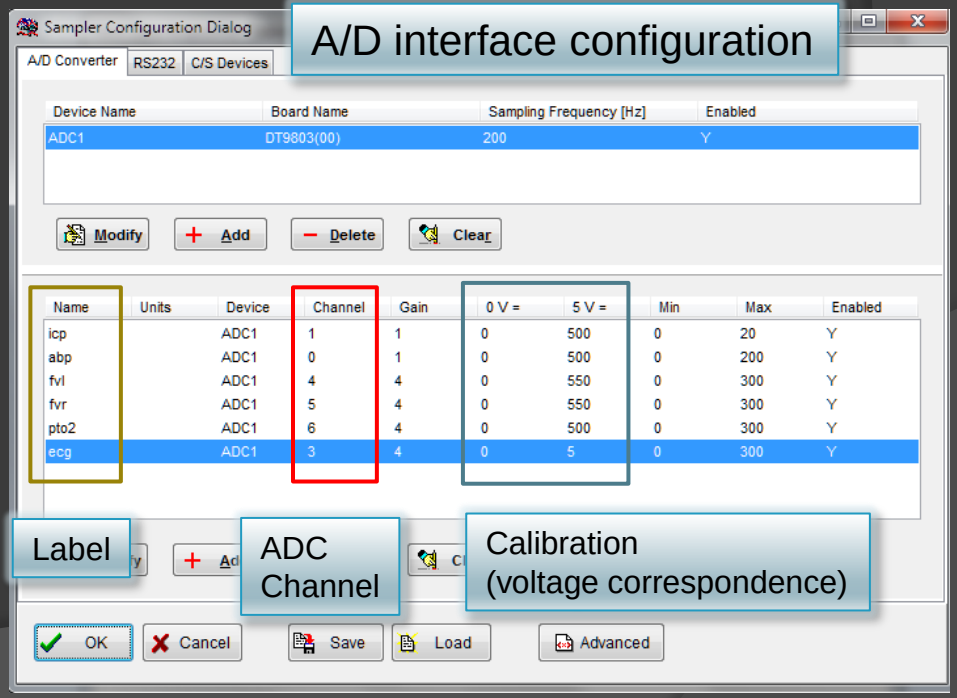
A/D Converter (ADC)



Signal calibration



A/D interface configuration



Label

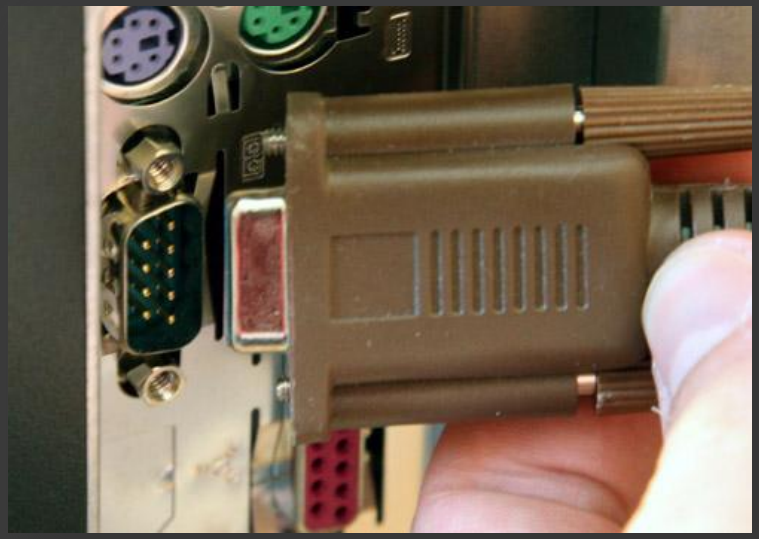
ADC Channel

Calibration (voltage correspondence)

ICM+ Principles

Digital Interface – network or serial (COM Port)

COM Port on a desktop PC

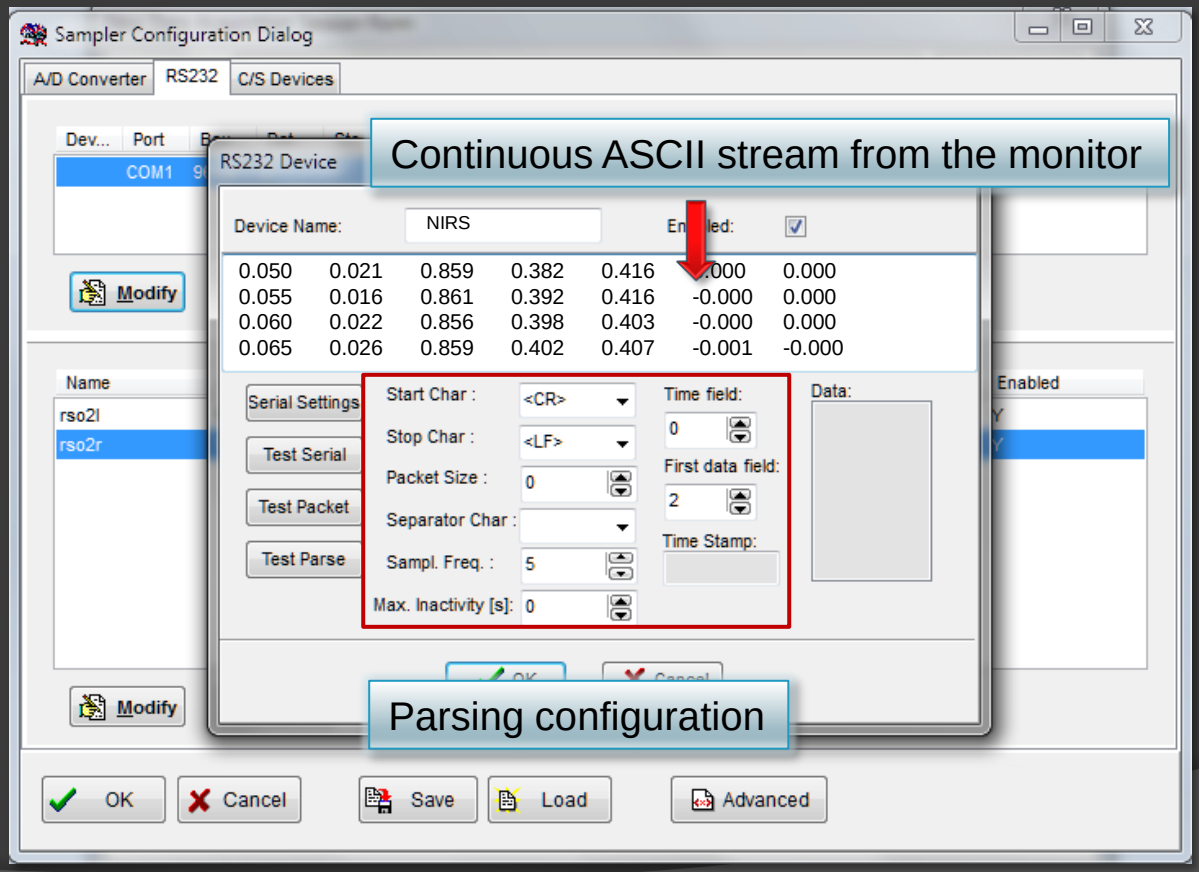


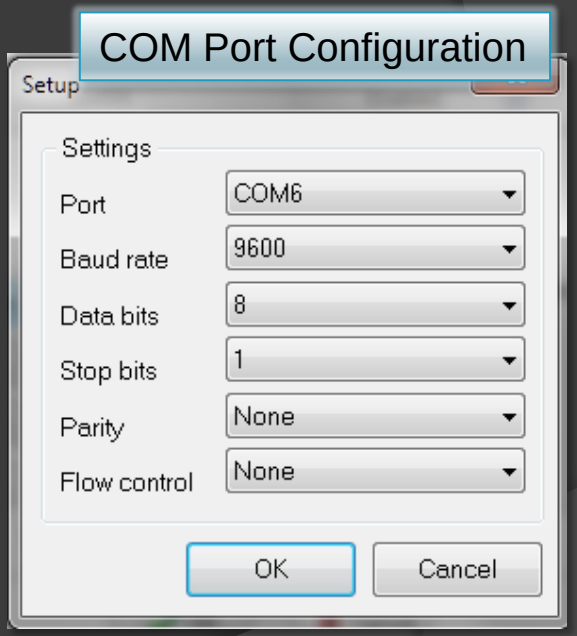
Monitor side connectors

USB – Serial adapter

ICM+ Principles

Continuous ASCII data export



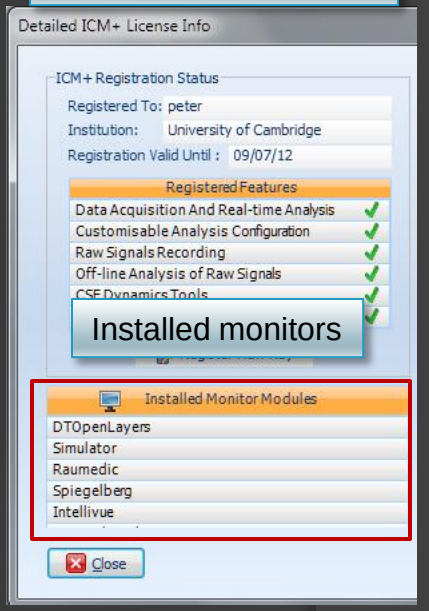


ICM+ Principles

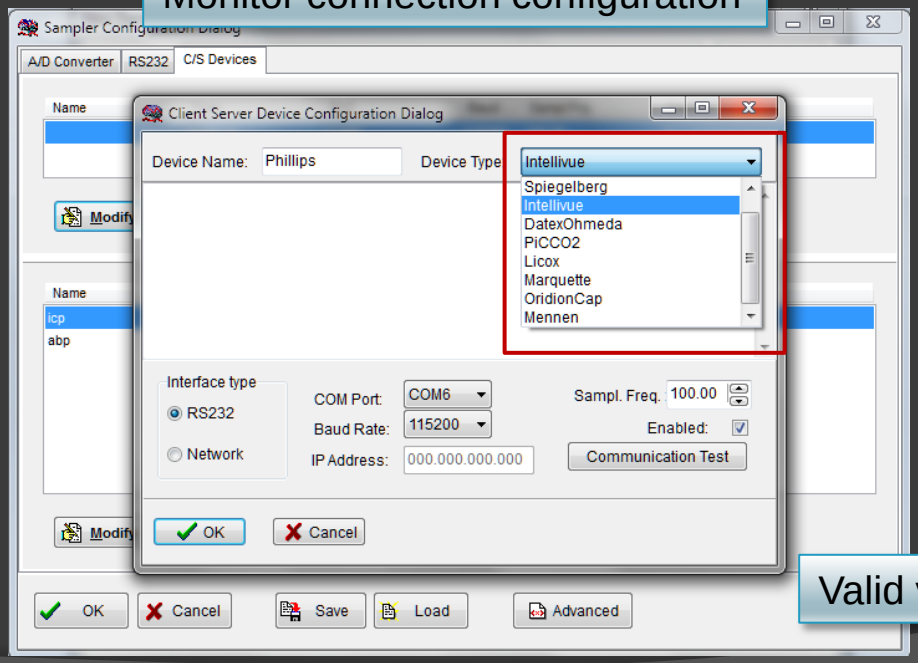
Client/server interface

Proprietary data exchange protocol

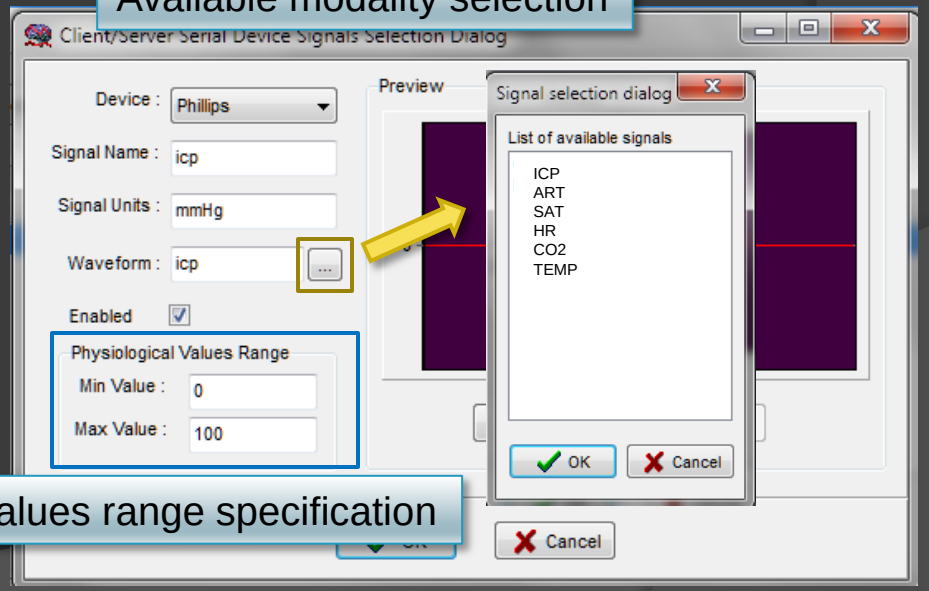
ICM+ Registration Info



Monitor connection configuration



Available modality selection



Valid values range specification

ICM+ Principles

Data collection configuration

Analogue

ASCII

Client/Server

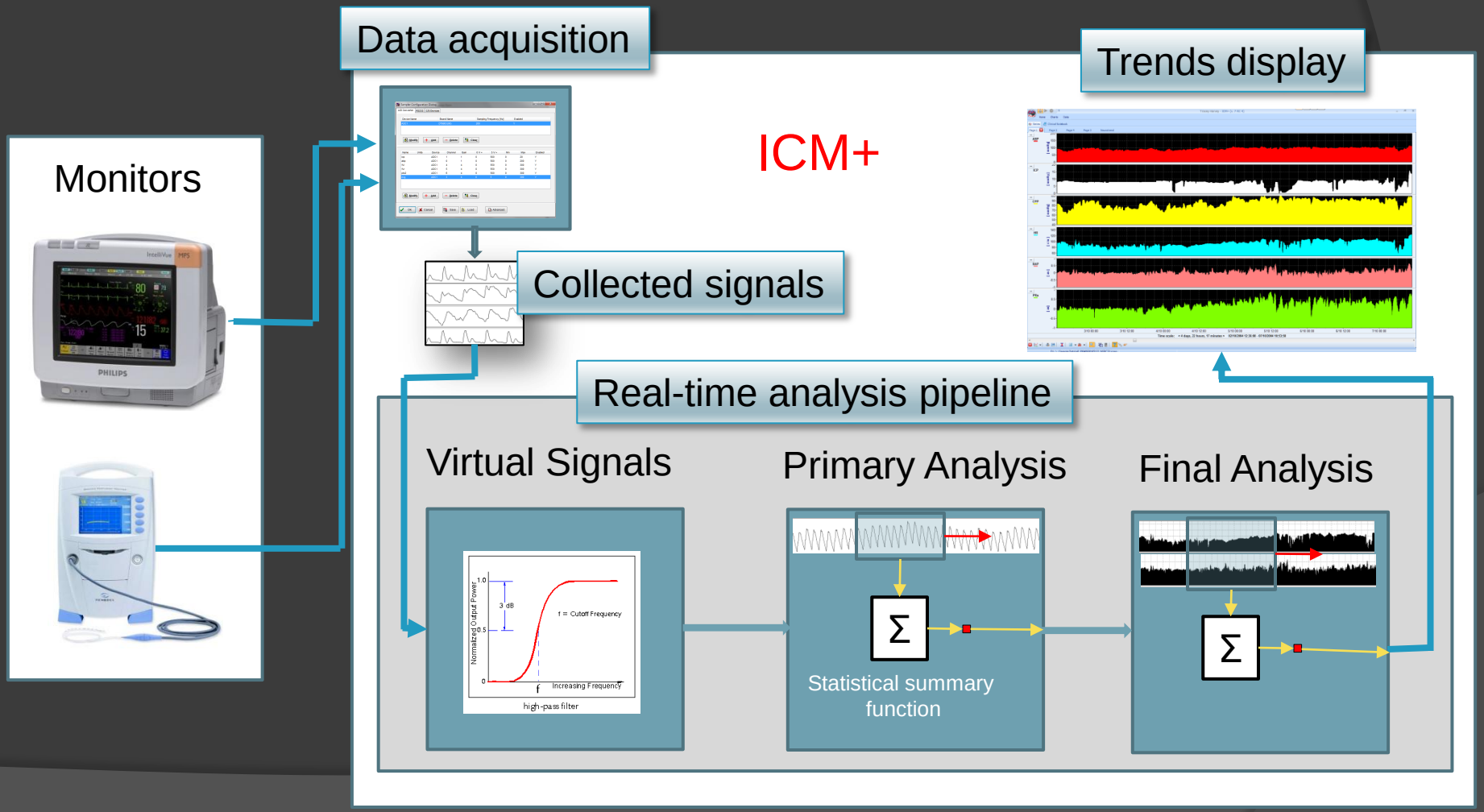
Advanced Configuration Editing

```
<?xml version = "1.0"?>

<ICMDataConfig>
   <SamplerConfig>
      <ADCDevices>
         <ADCDevice Name = "ADC1" Board = "DT9803(00)" SamplFrq = "100" Enabled = "Y">
            <ADCSignal Name = "fvl" Units = "" Channel = "1" Gain = "1" Cal0VLevel = "0" Cal5VLevel = "500" MinValue = "0" MaxValue = "20" Enabled = "Y"/>
            <ADCSignal Name = "fvr" Units = "" Channel = "0" Gain = "1" Cal0VLevel = "0" Cal5VLevel = "500" MinValue = "0" MaxValue = "200" Enabled = "Y"/>
         </ADCDevice>
      </ADCDevices>
      <RS232Devices>
         <RS232Device Name = "INVOS" Port = "COM1" BaudRate = "9600" DataBits = "8" StopBits = "1" ParityBits = "None" FlowControl = "None" StartChr = "&lt;CR>" StopChr = "&lt;LF>"
            <RS232Signal Name = "rso2l" Units = "%" Channel = "0" MinValue = "0" MaxValue = "100" Enabled = "Y"/>
            <RS232Signal Name = "rso2r" Units = "%" Channel = "7" MinValue = "0" MaxValue = "100" Enabled = "Y"/>
         </RS232Device>
      </RS232Devices>
      <CSCOMDevices>
         <CSCOMDevice Name = "raumedic" DeviceType = "Raumedic" Port = "COM2" BaudRate = "0" SamplFrq = "1" Enabled = "Y">
            <CSCOMSignal Name = "ptO2" Units = "mmHg" Waveform = "P3" MinValue = "0" MaxValue = "100" Enabled = "Y"/>
         </CSCOMDevice>
         <CSCOMDevice Name = "phillips" DeviceType = "IntelliVue" Port = "COM3" BaudRate = "19200" SamplFrq = "100" Enabled = "Y">
            <CSCOMSignal Name = "icp" Units = "mmHg" Waveform = "ICP" MinValue = "0" MaxValue = "100" Enabled = "Y"/>
            <CSCOMSignal Name = "abp" Units = "mmHg" Waveform = "ABP" MinValue = "0" MaxValue = "200" Enabled = "Y"/>
         </CSCOMDevice>
      </CSCOMDevices>
   </SamplerConfig>
</ICMDataConfig>
```

OK Cancel

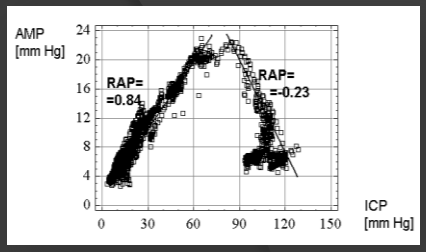
ICM+ Principles

Analysis pipeline

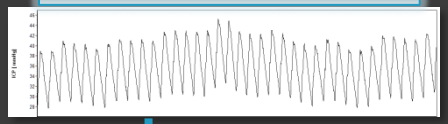


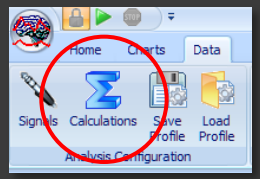
ICM+ Principles

Configuration example - RAP

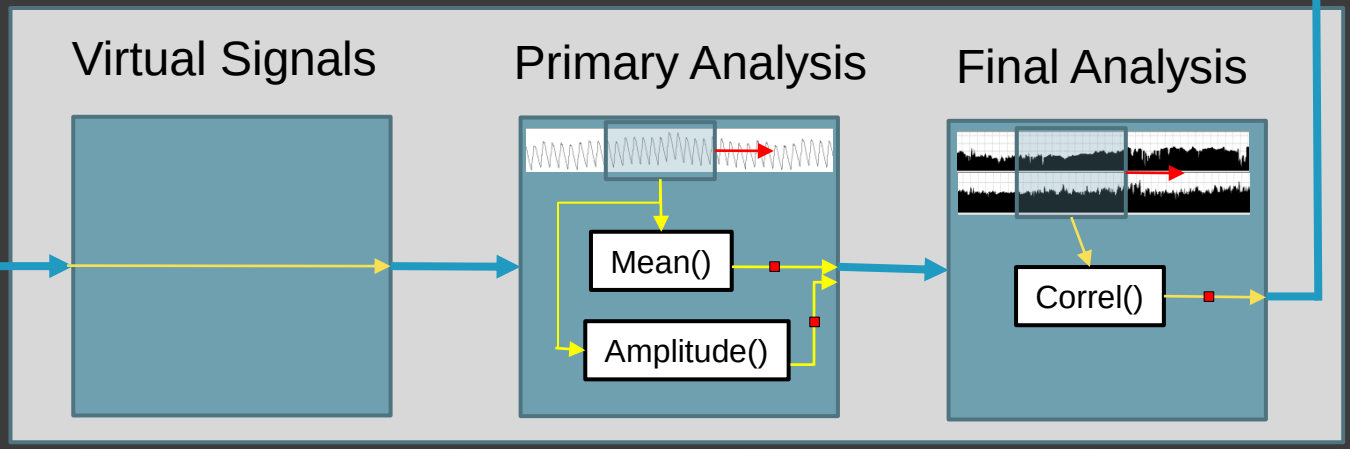


Input signal ICP



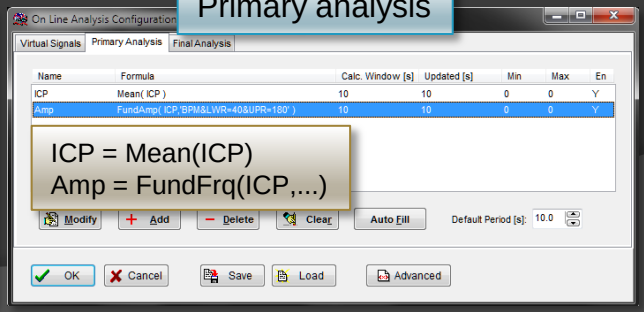


Ouput trend RAP

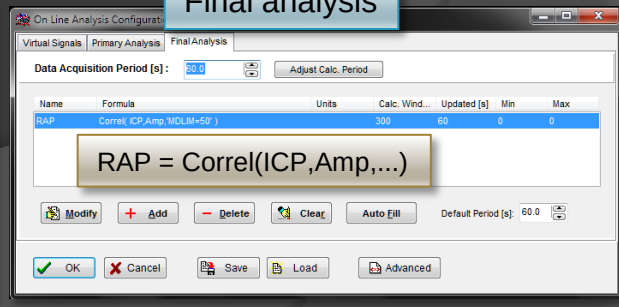


Virtual signals

Primary analysis

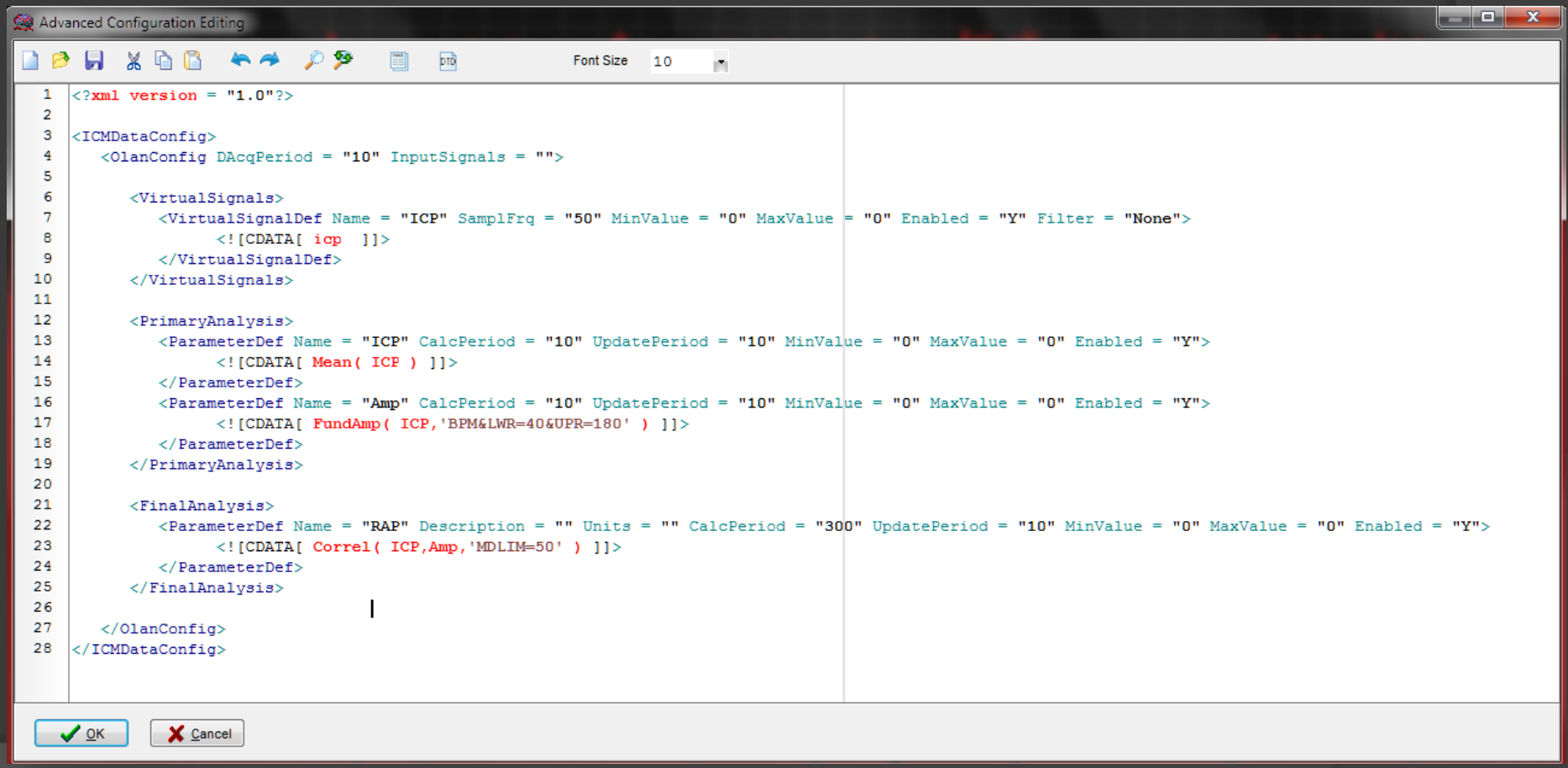


Final analysis



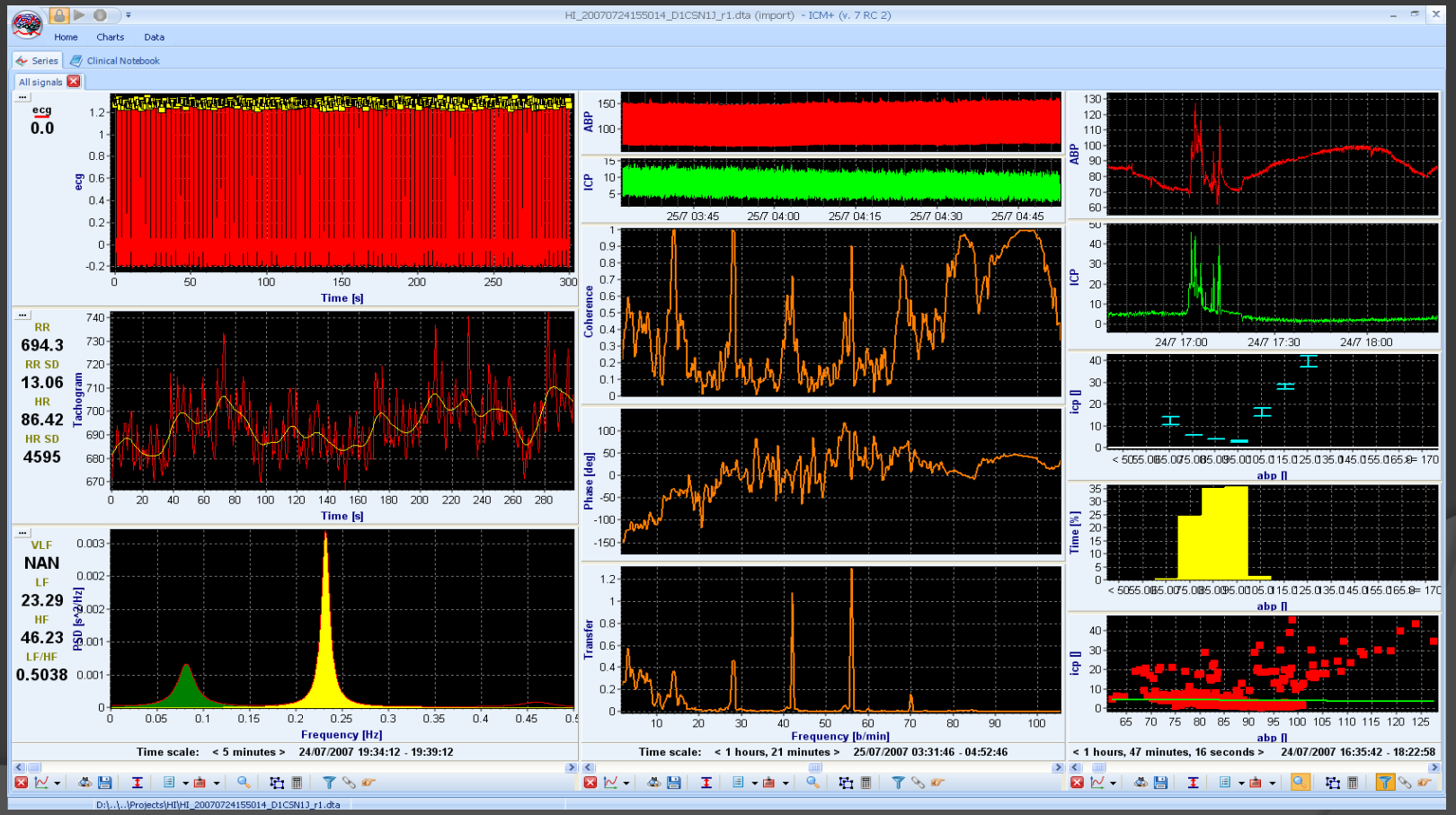
ICM+ Principles

Configuration example – Advanced mode



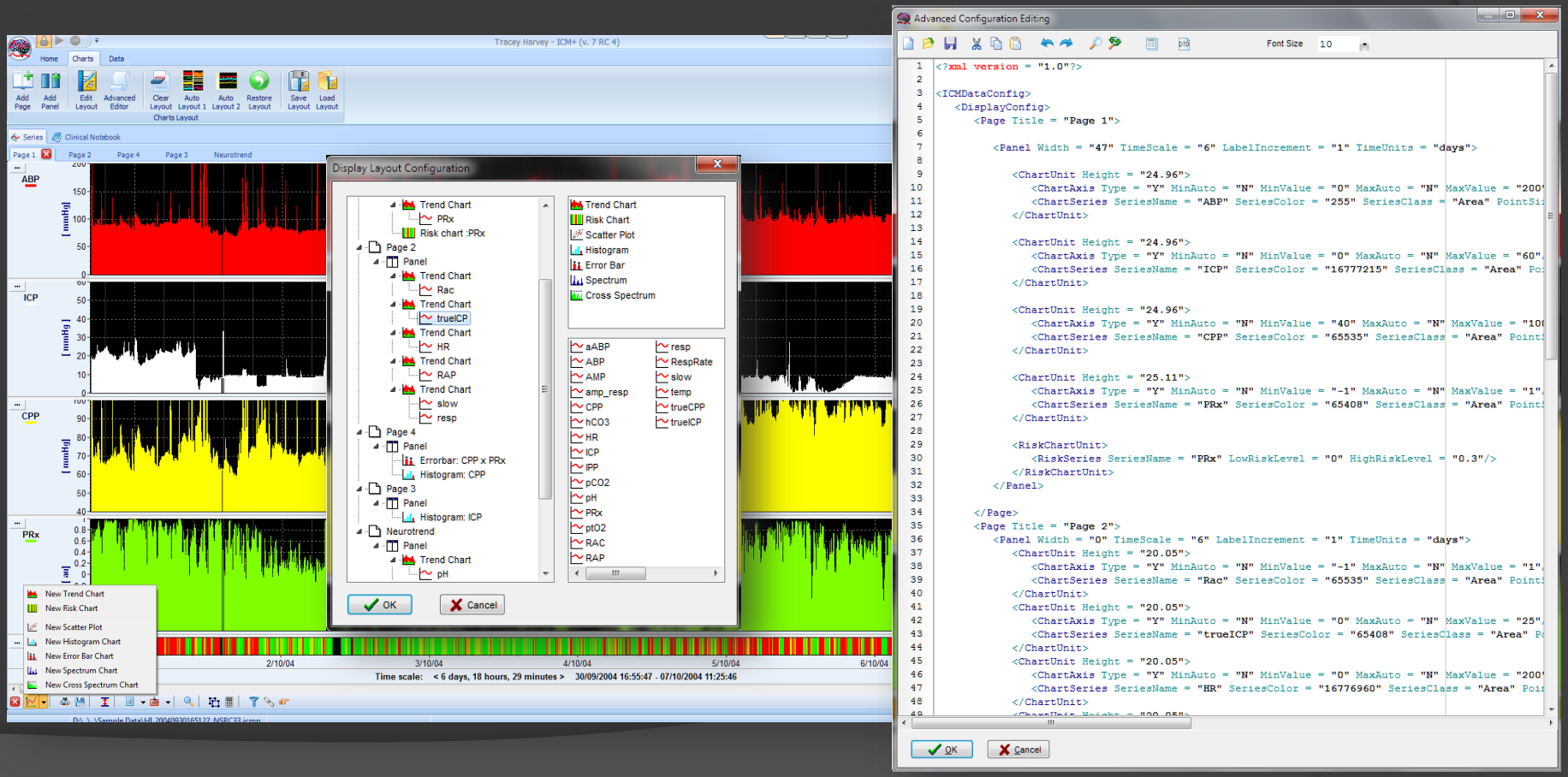
ICM+ Principles

Data display



ICM+ Principles

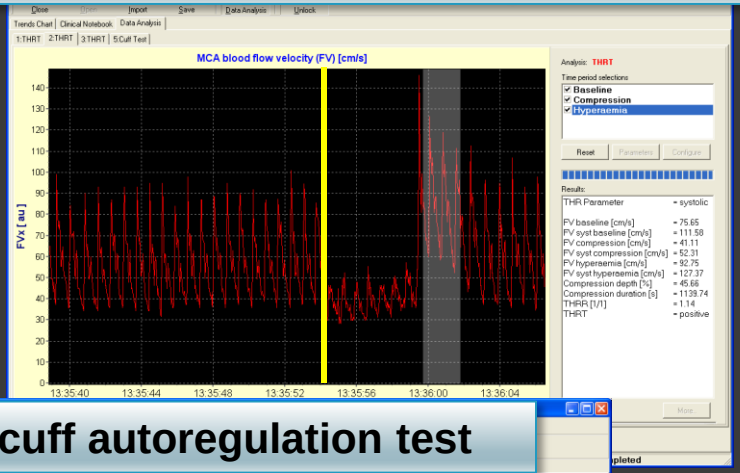
Data display - configuration



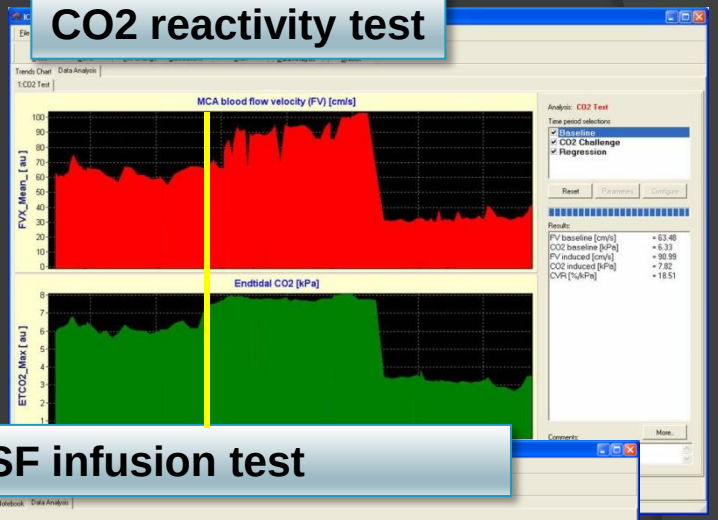
ICM+ Principles

Intervention tests analysis

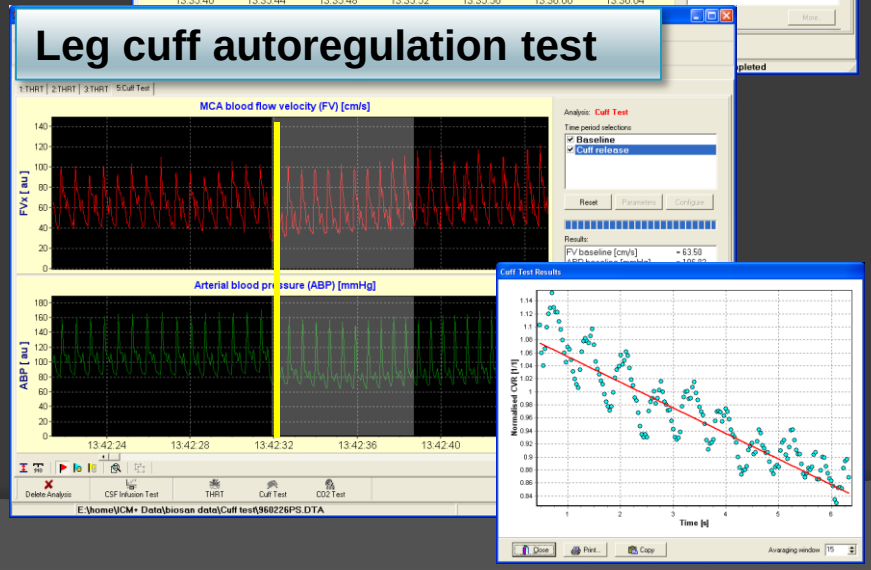
Transient Hyperaemic Response Test



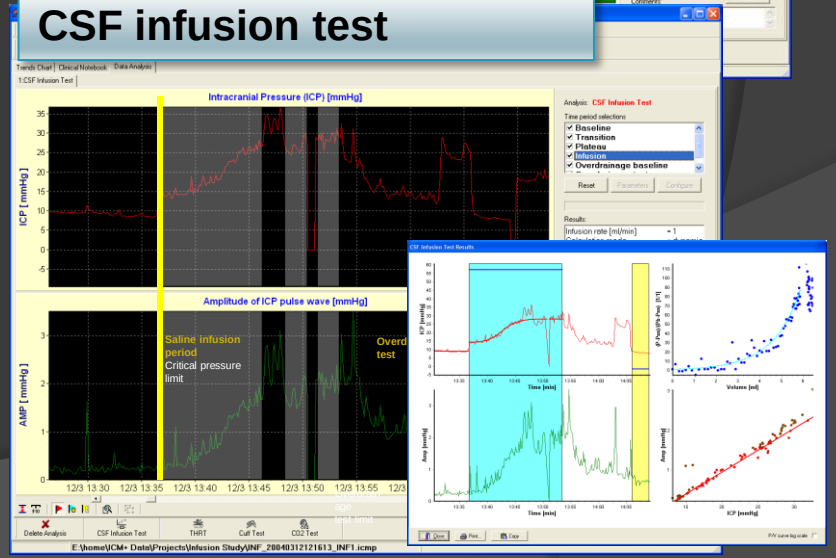
CO2 reactivity test



Leg cuff autoregulation test

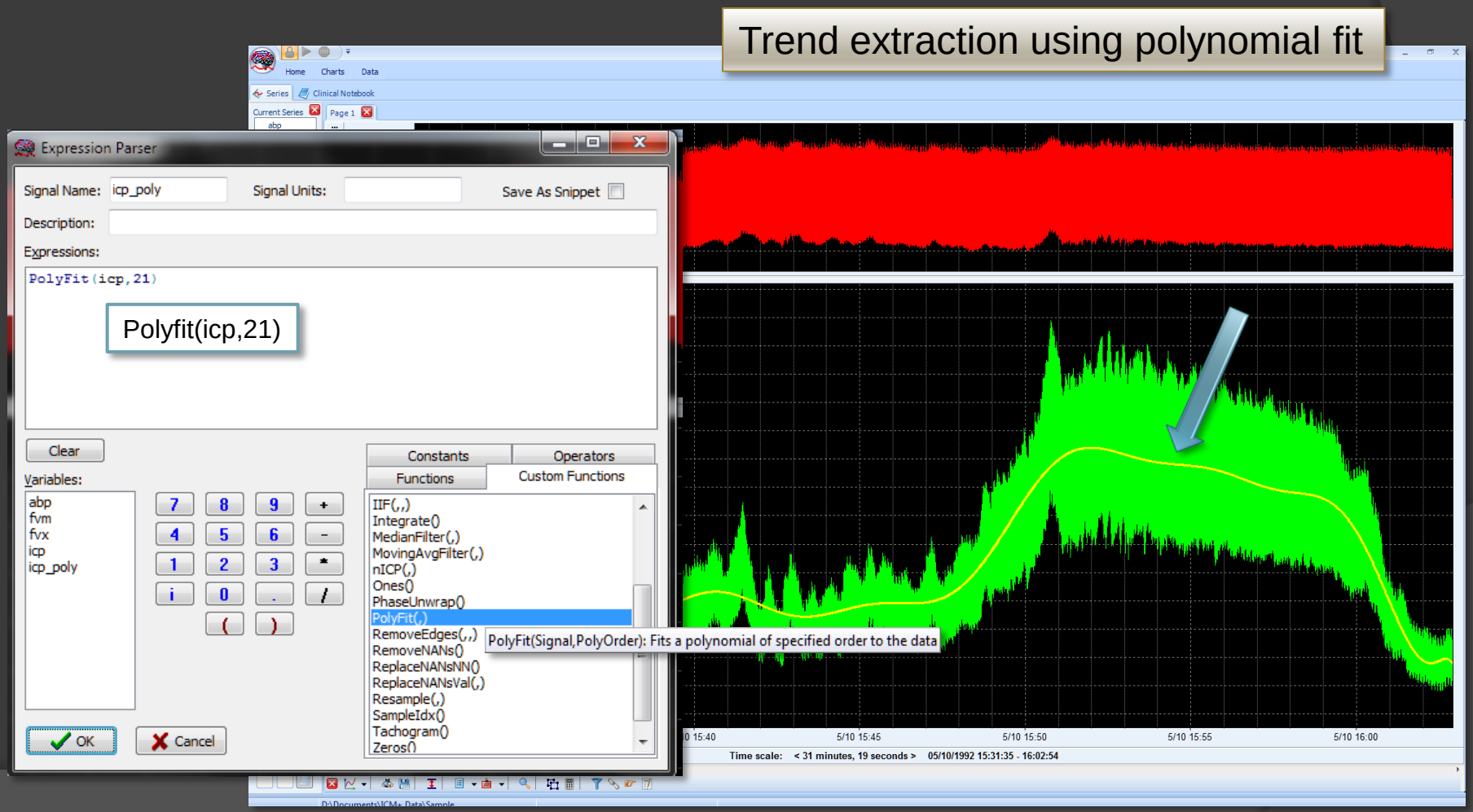


CSF infusion test



ICM+ New features

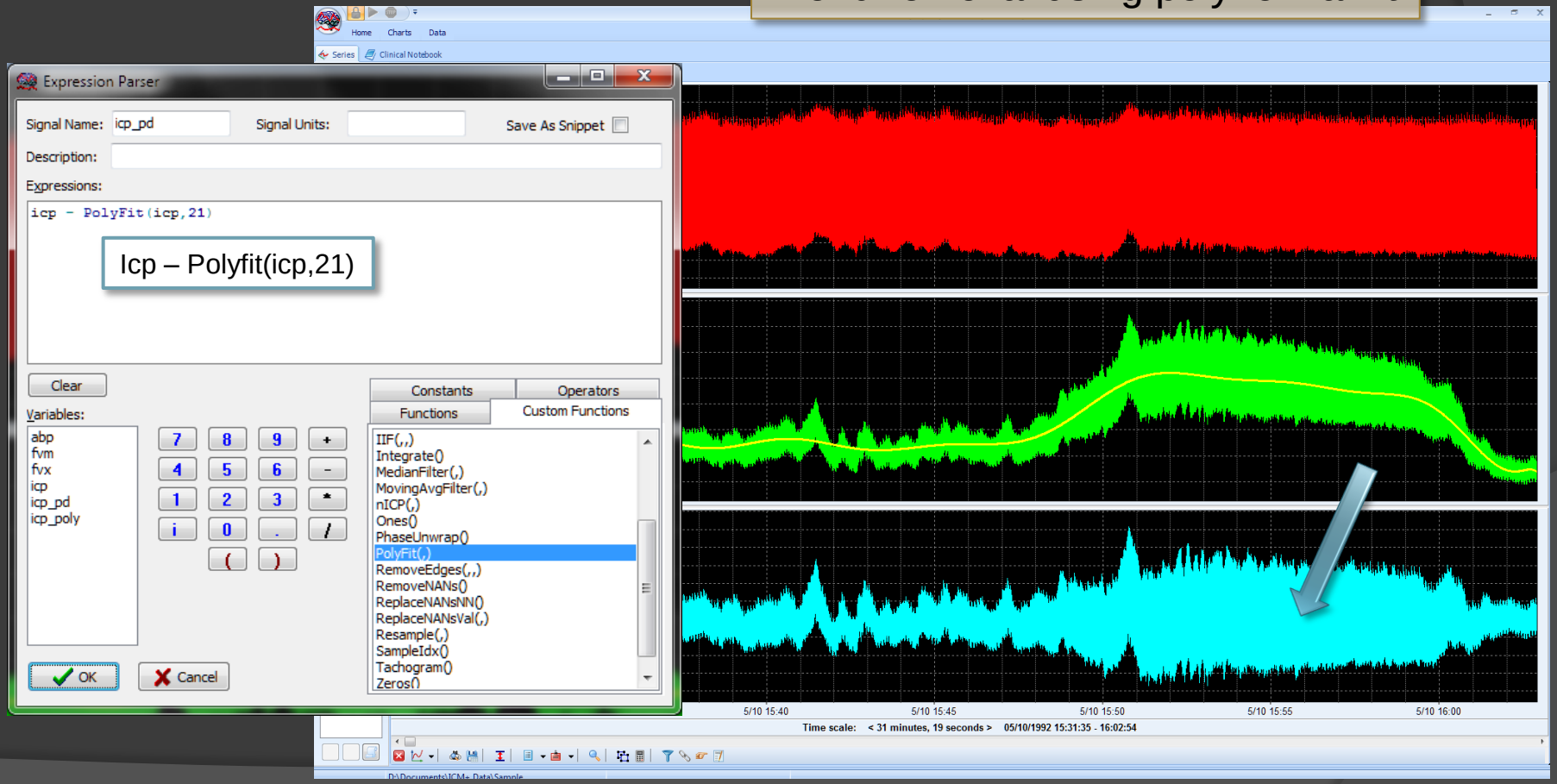
Signals calculator



ICM+ New features

Signals calculator

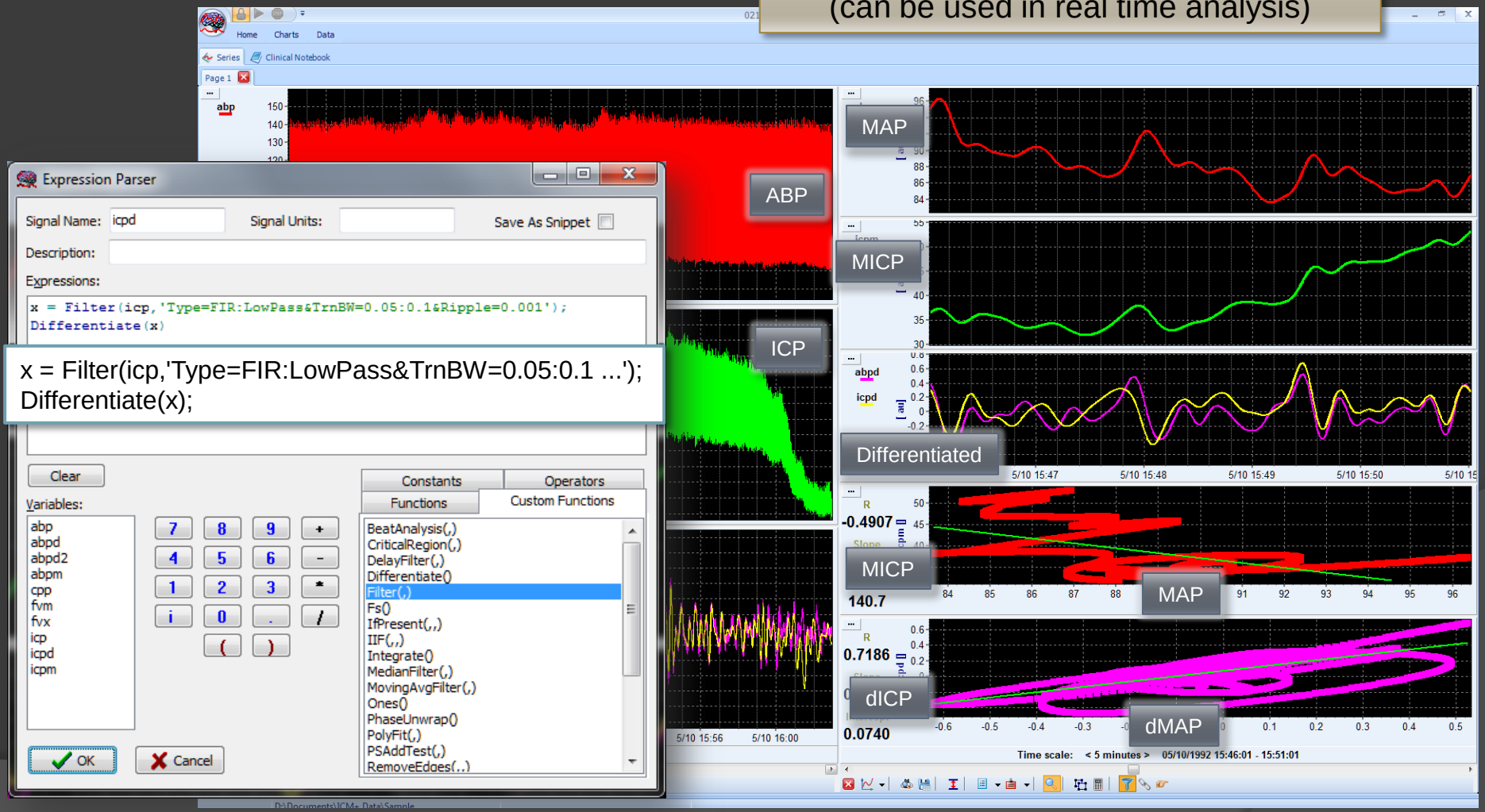
Trend removal using polynomial fit



ICM+ New features

Signals calculator

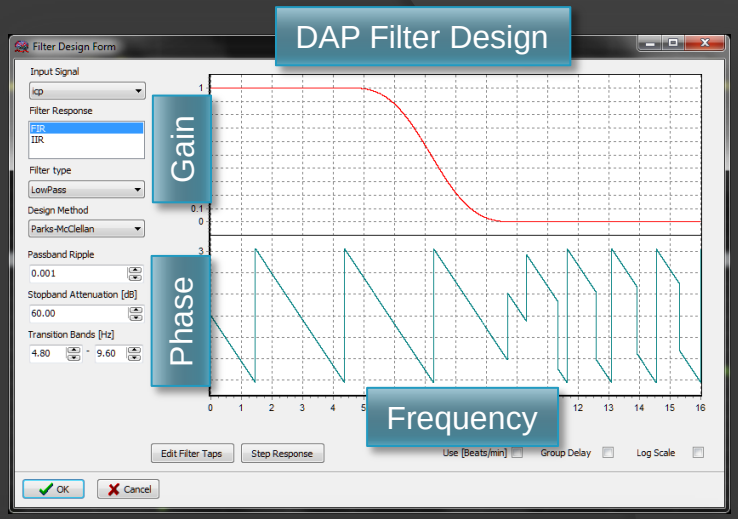
Trend removal using differentiation
(can be used in real time analysis)

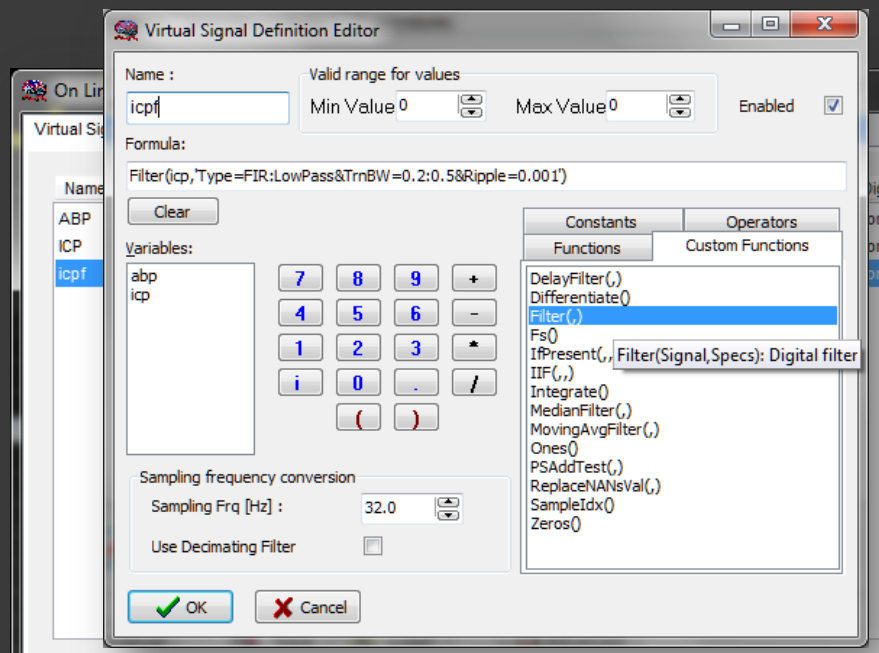


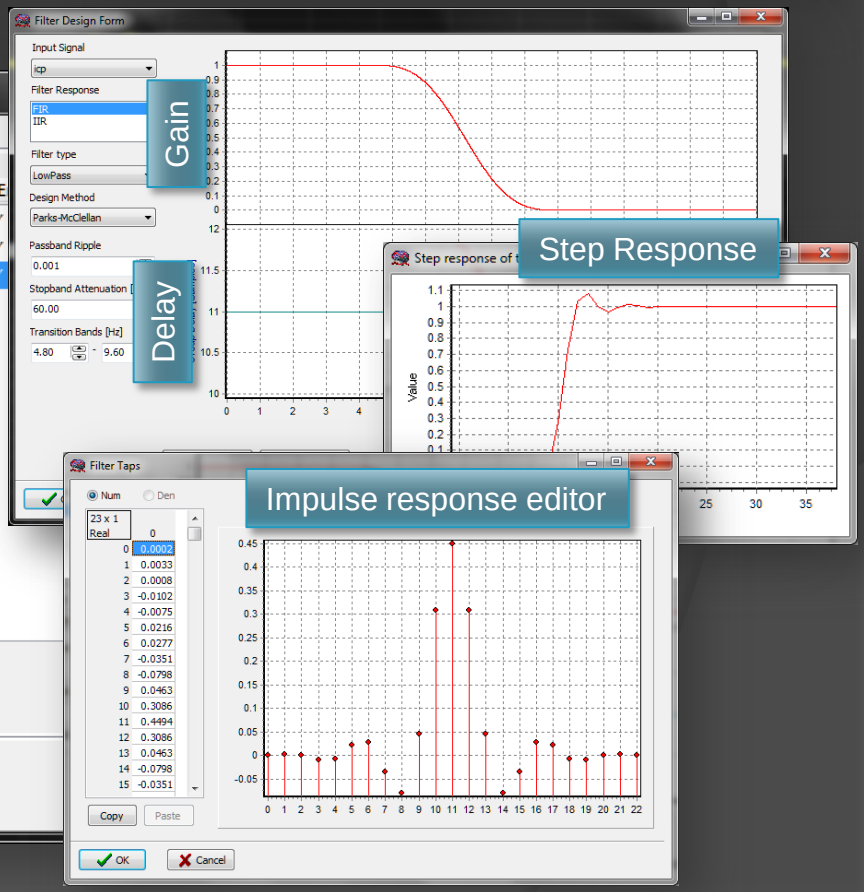
ICM+ New features

New calculation engine

‘Virtual Signals’ with DSP support



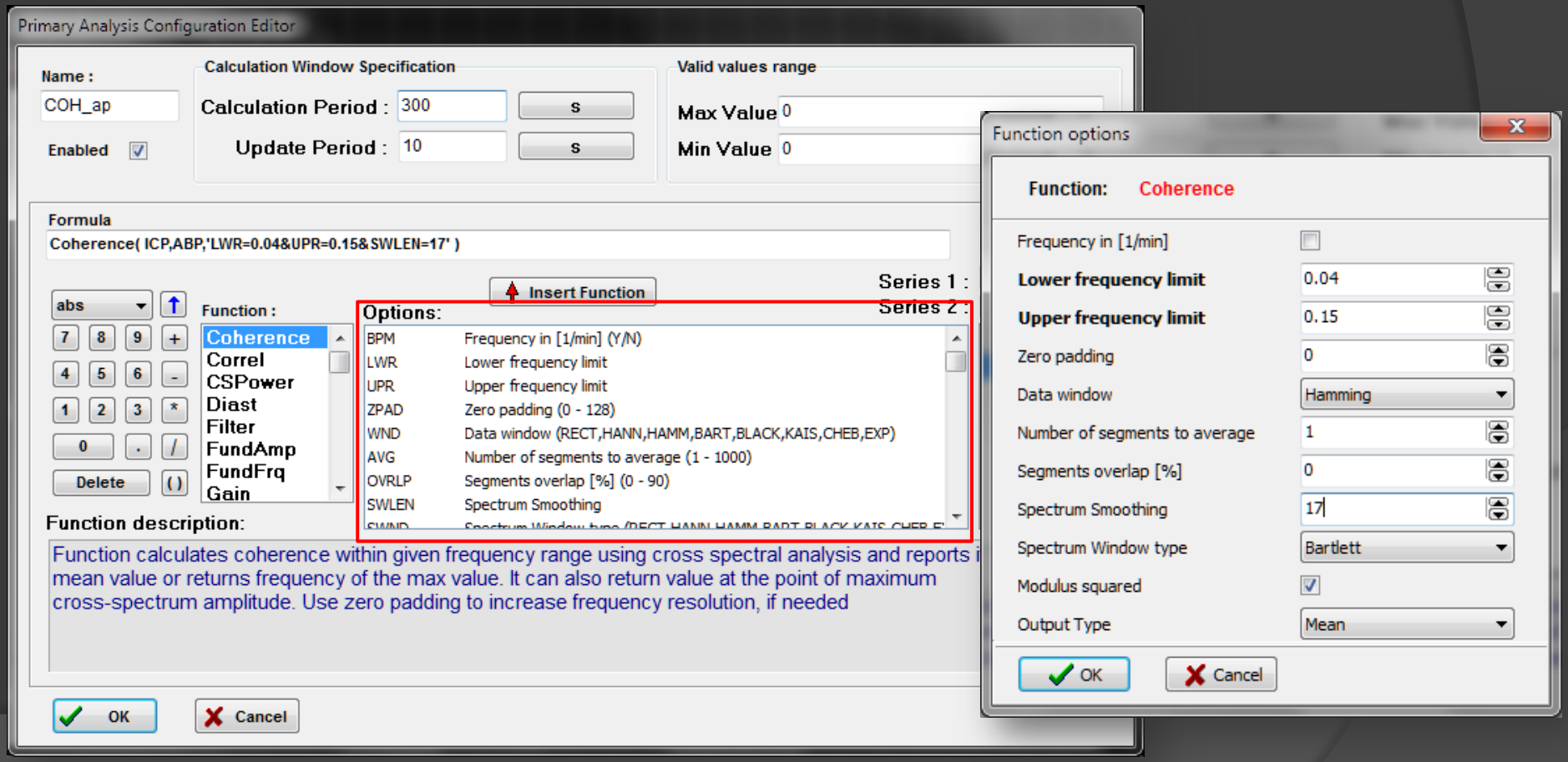




ICM+ New features

New calculation engine

'summary functions' with advanced options support

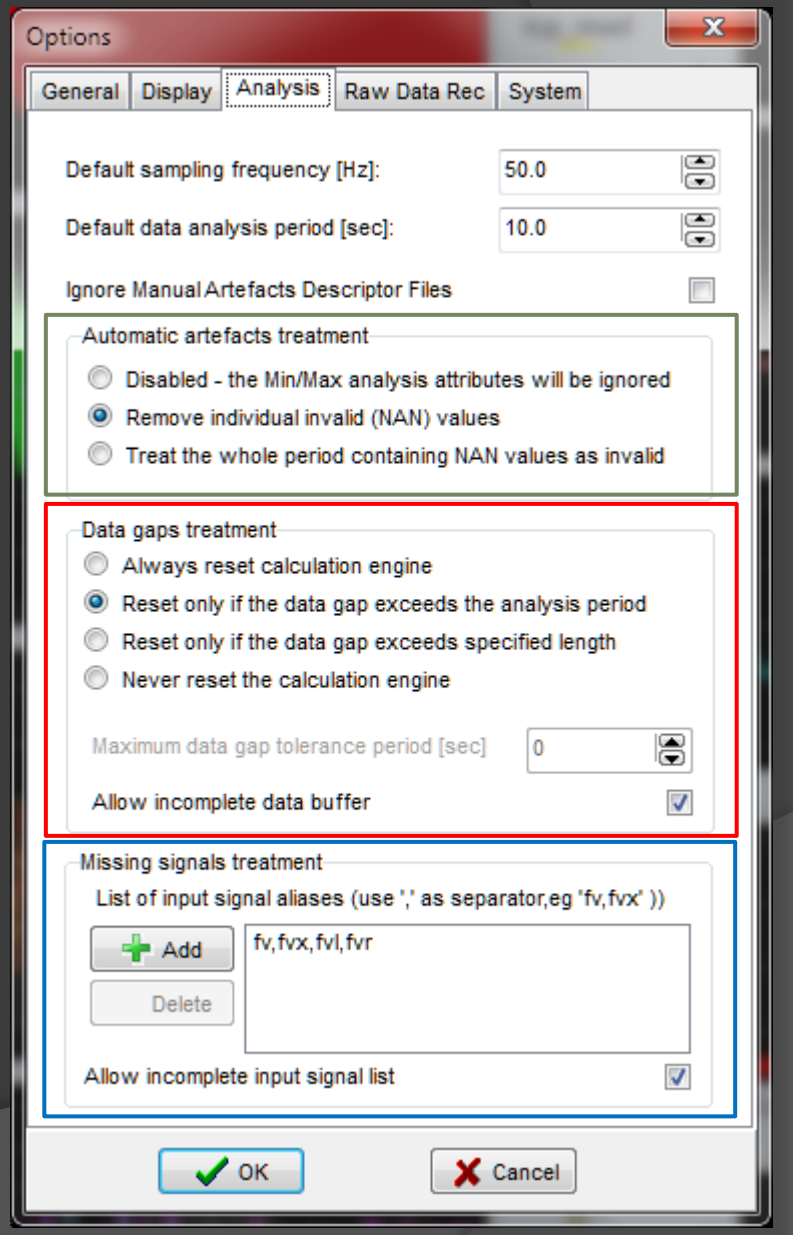


ICM+ New features

Analysis options

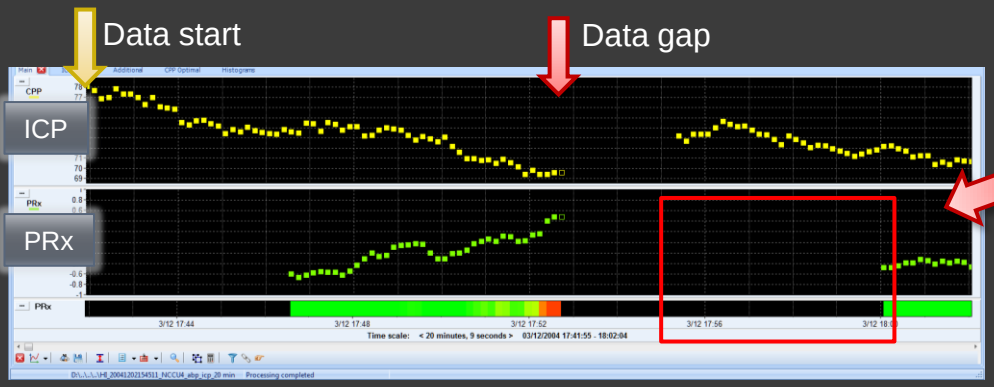
Jennifer Diedler's talk:
'Dealing with artefacts'

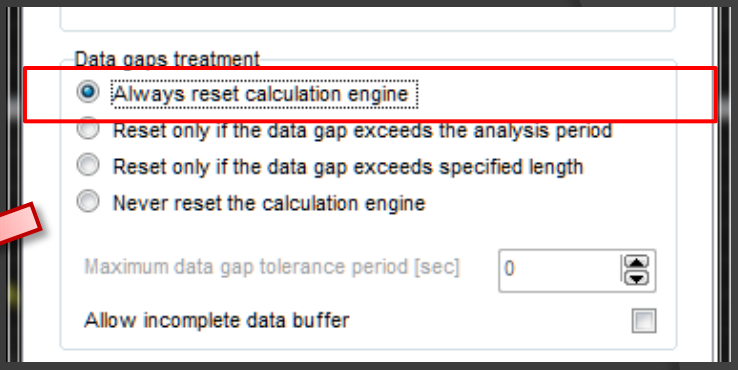
Phil Lewis' talk:
'Time series and batch data analysis'

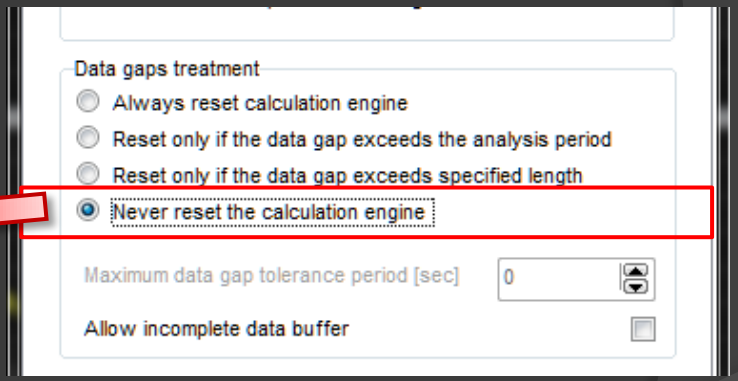


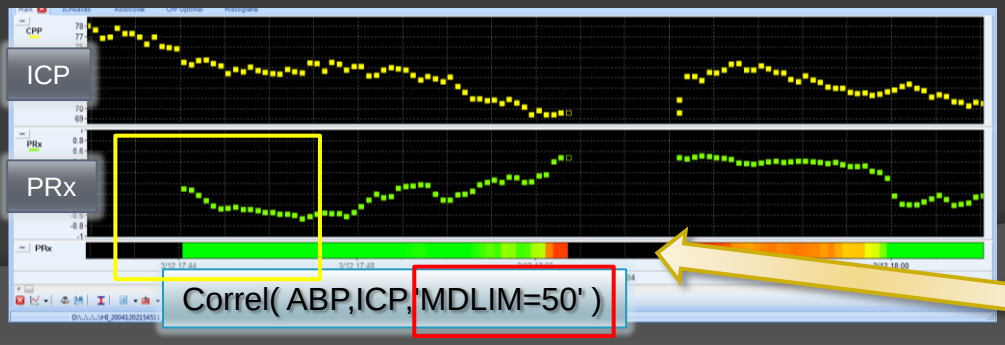
ICM+ New features

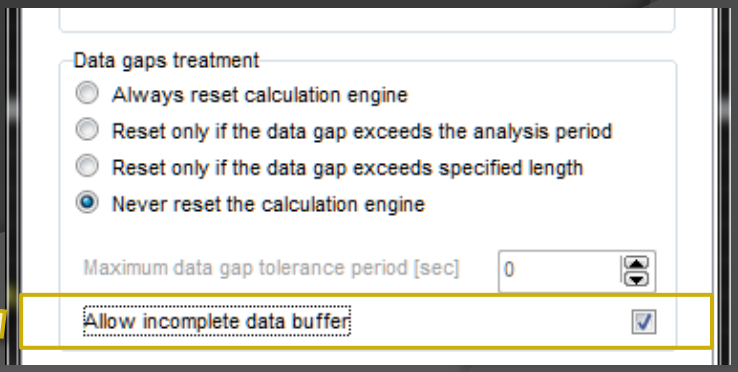
Data gaps treatment











ICM+ New features

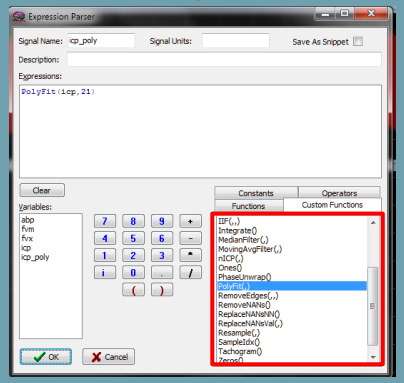
Plug-in system

DLL library Implementing **DSP** interface

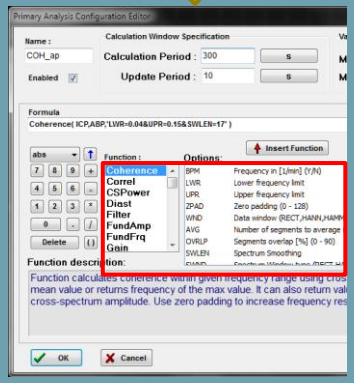
DLL library Implementing **Stats** interface

DLL library Implementing **Chart** interface

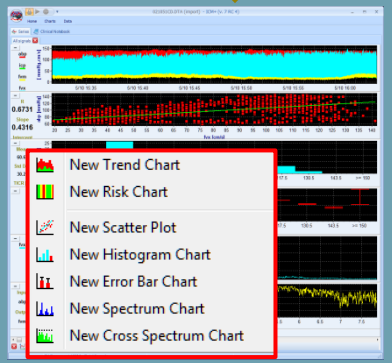
DLL library Implementing **Tools** interface



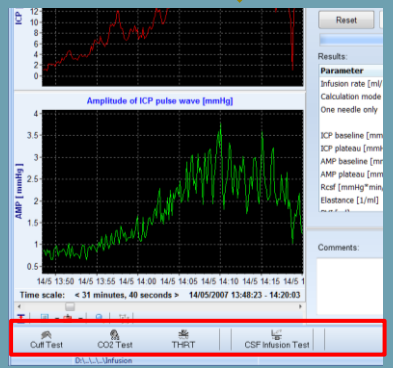
DSP
(Signal Calculator)



Stats functions
(Real-time analysis)



Charts



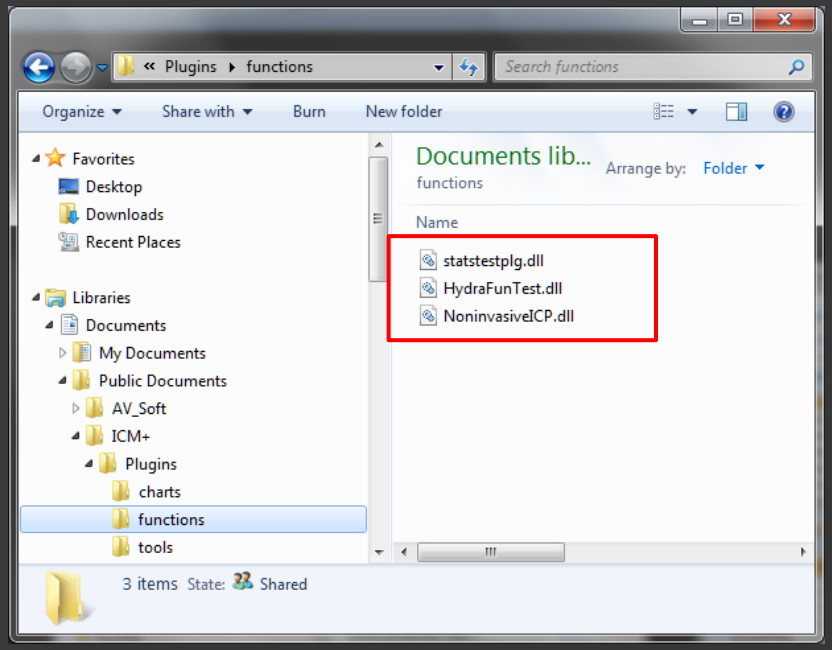
Tools
(Intervention tests)

ICM+

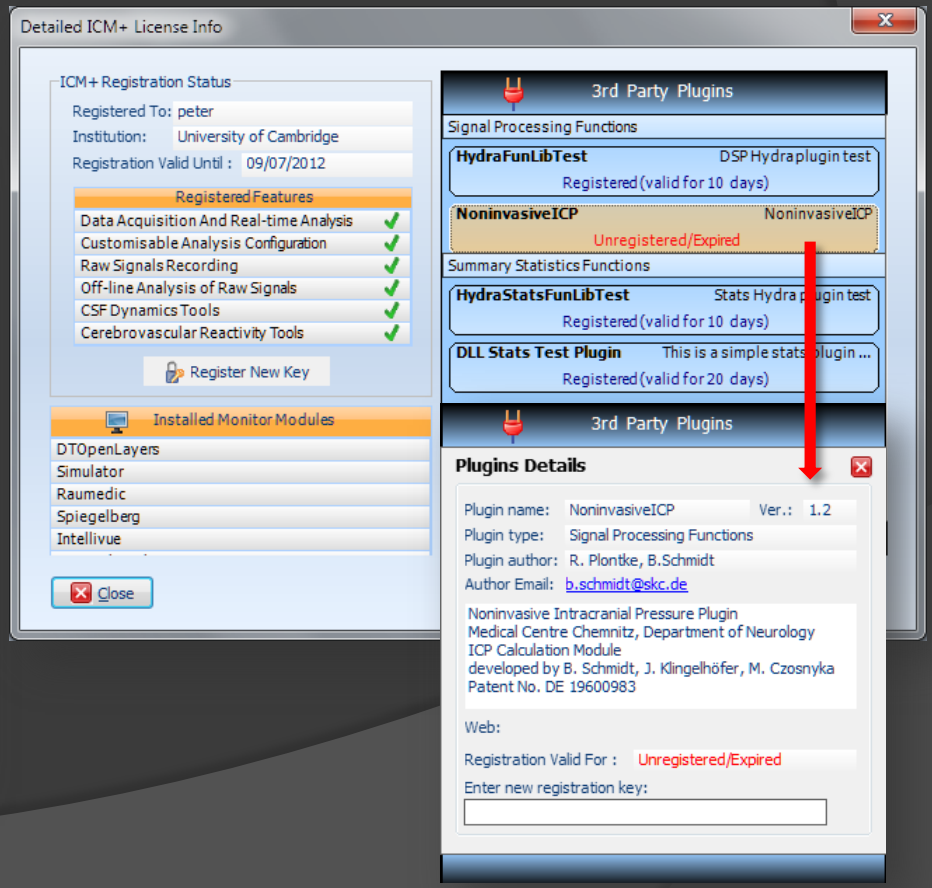
ICM+ New features

Plug-in system

Plug-ins' location in the file system



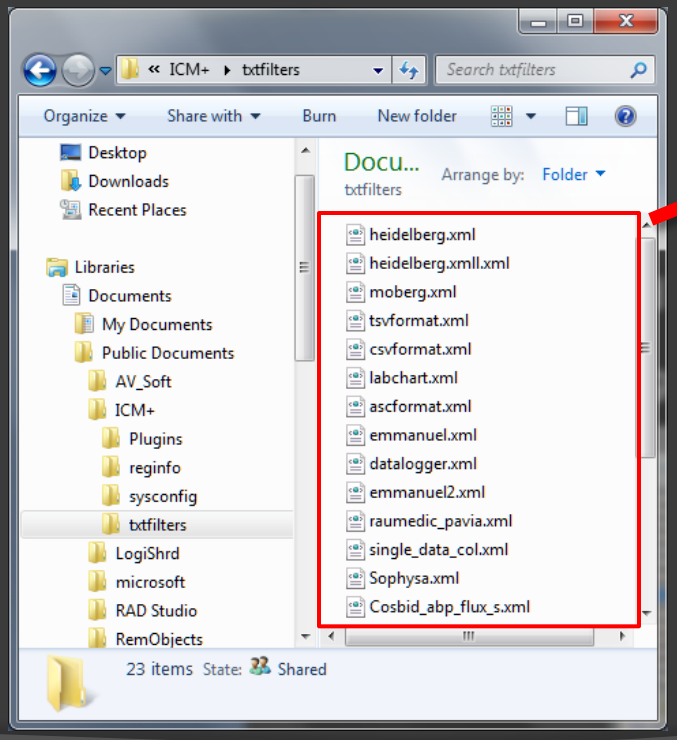
Plug-in registration (author's led)

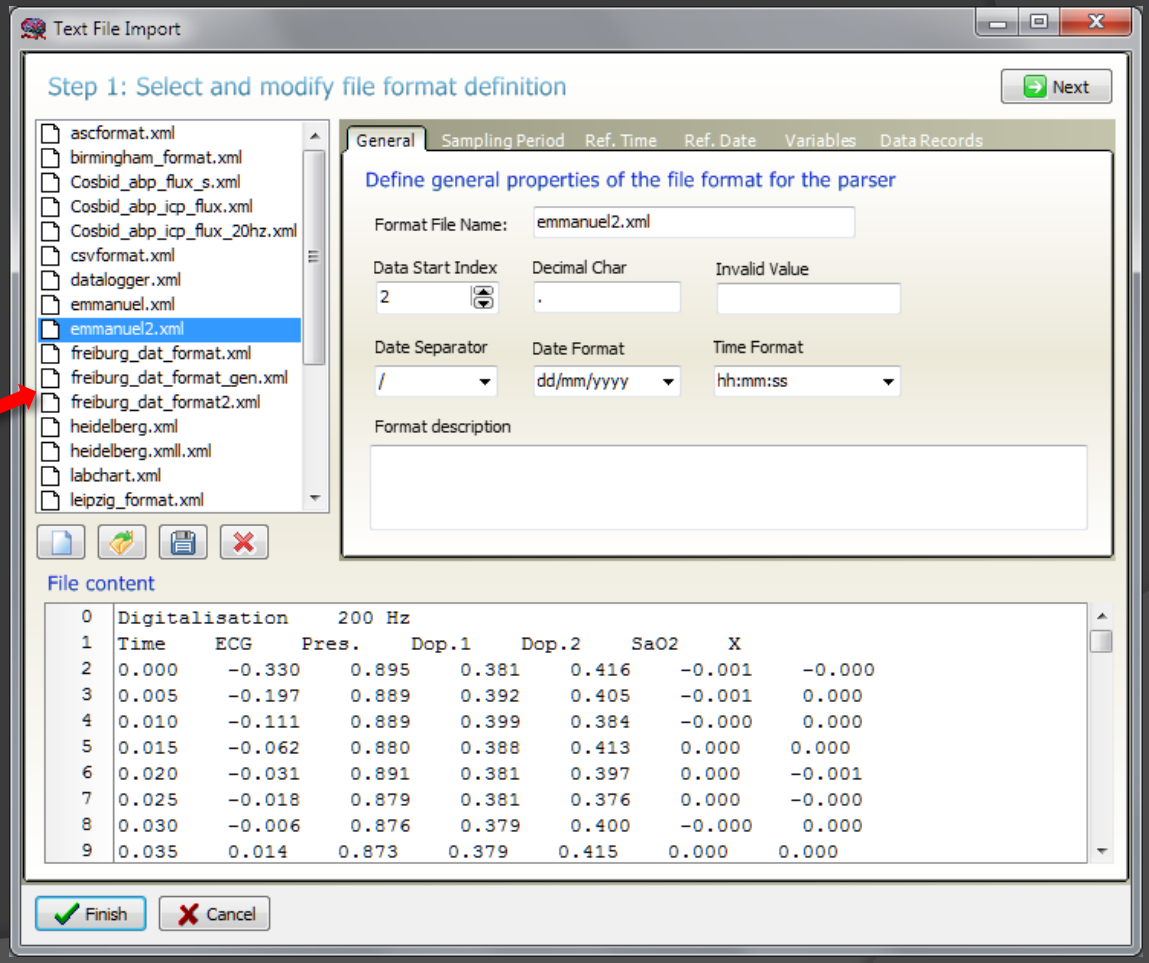


ICM+ New features

Text import configuration

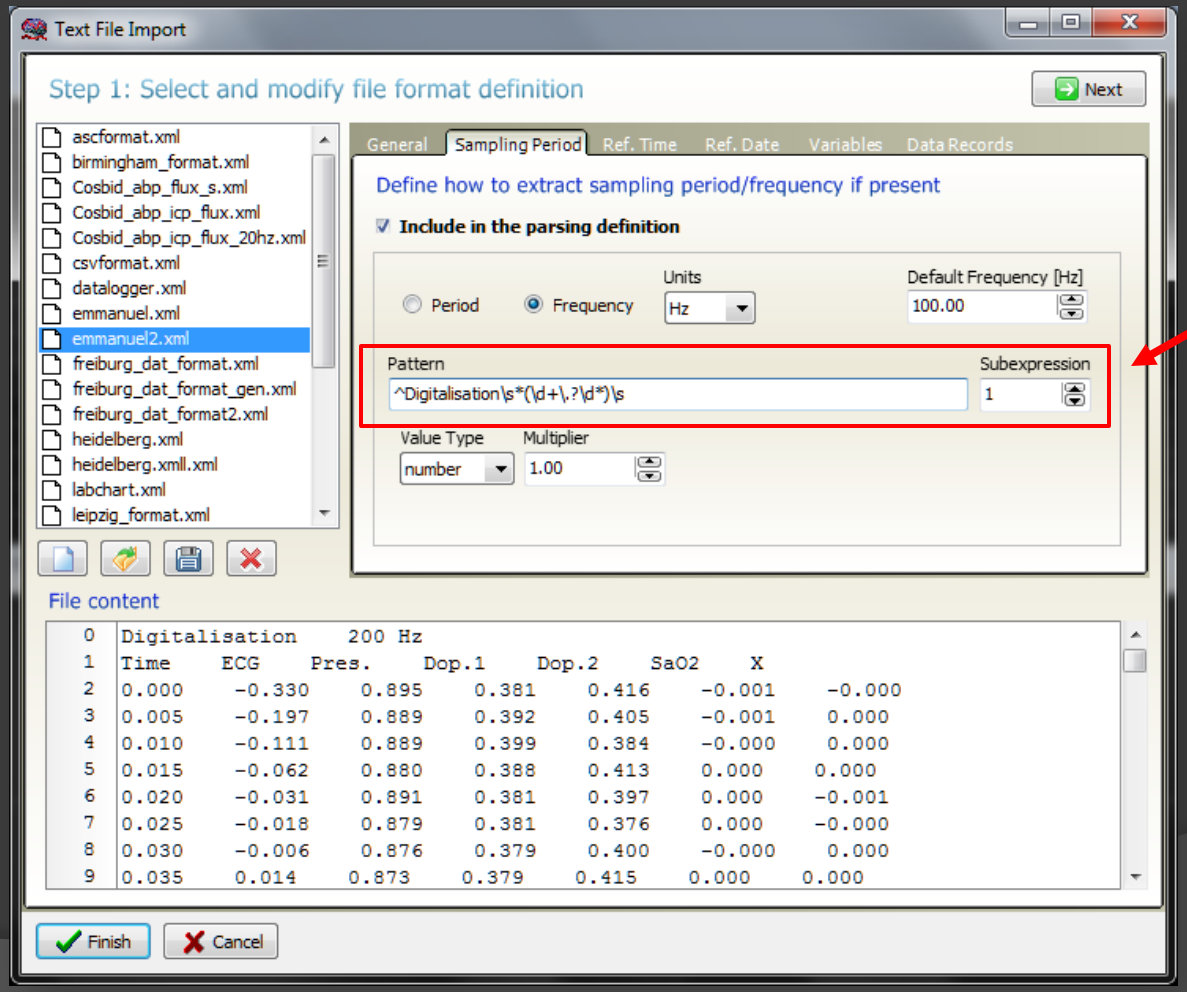
Definition files location





ICM+ New features

Text import configuration – sampling frequency parsing



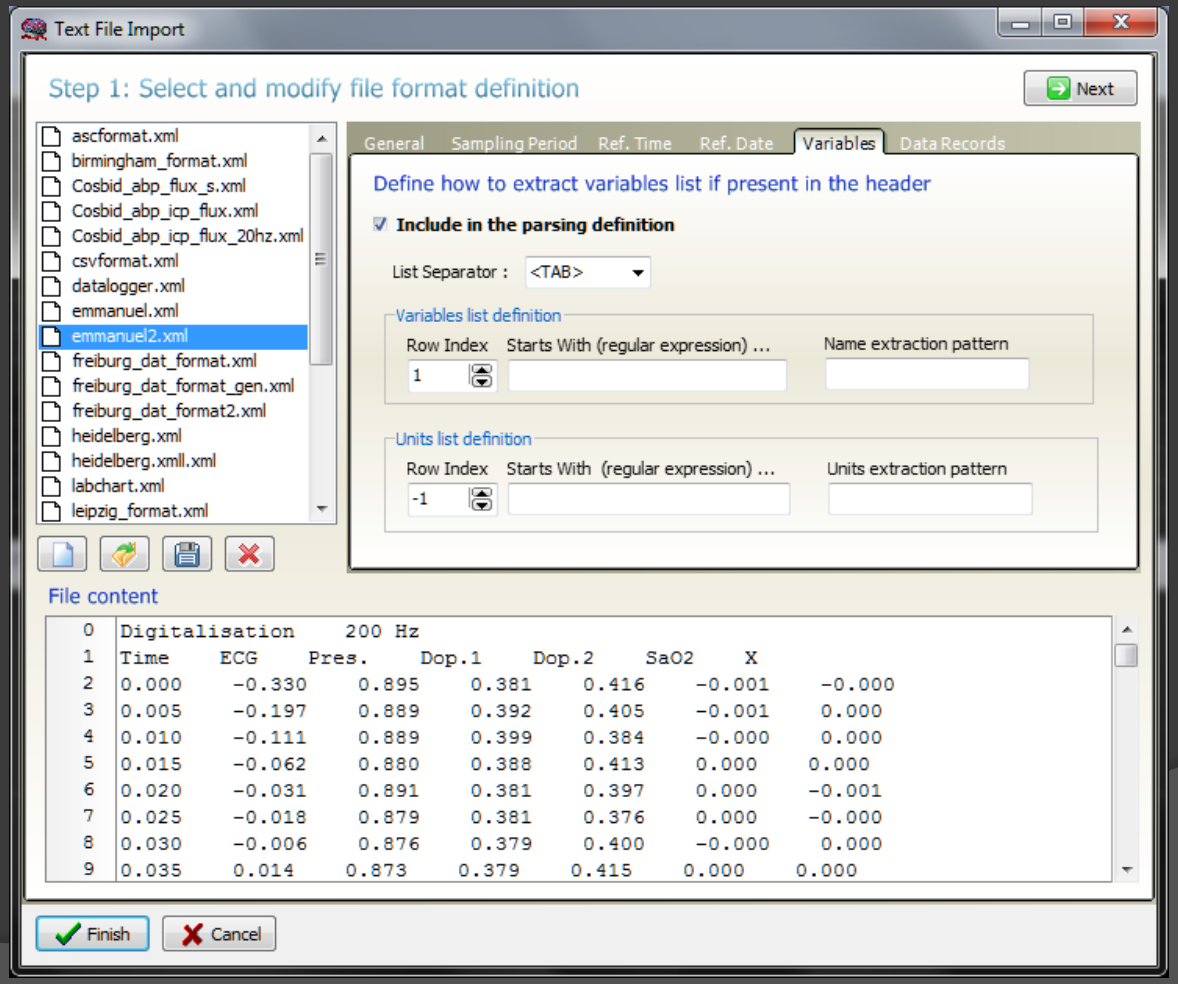
Regular Expression

The following special characters match:
. any character
\w an alphanumeric character
\W a non-alphanumeric character
\s a whitespace character
\S anything BUT a whitespace.
\d a digit
\D a non-digit
[...] any listed character.
[^...] any character except listed.
\b a word boundary.
^ the beginning of a line.
$ the end of a line.
+ the preceding element one or more times.
? the preceding element zero or one times.
* the preceding element zero or more times.

In addition:
() Groups into sub-expressions
| Separates alternate possibilities

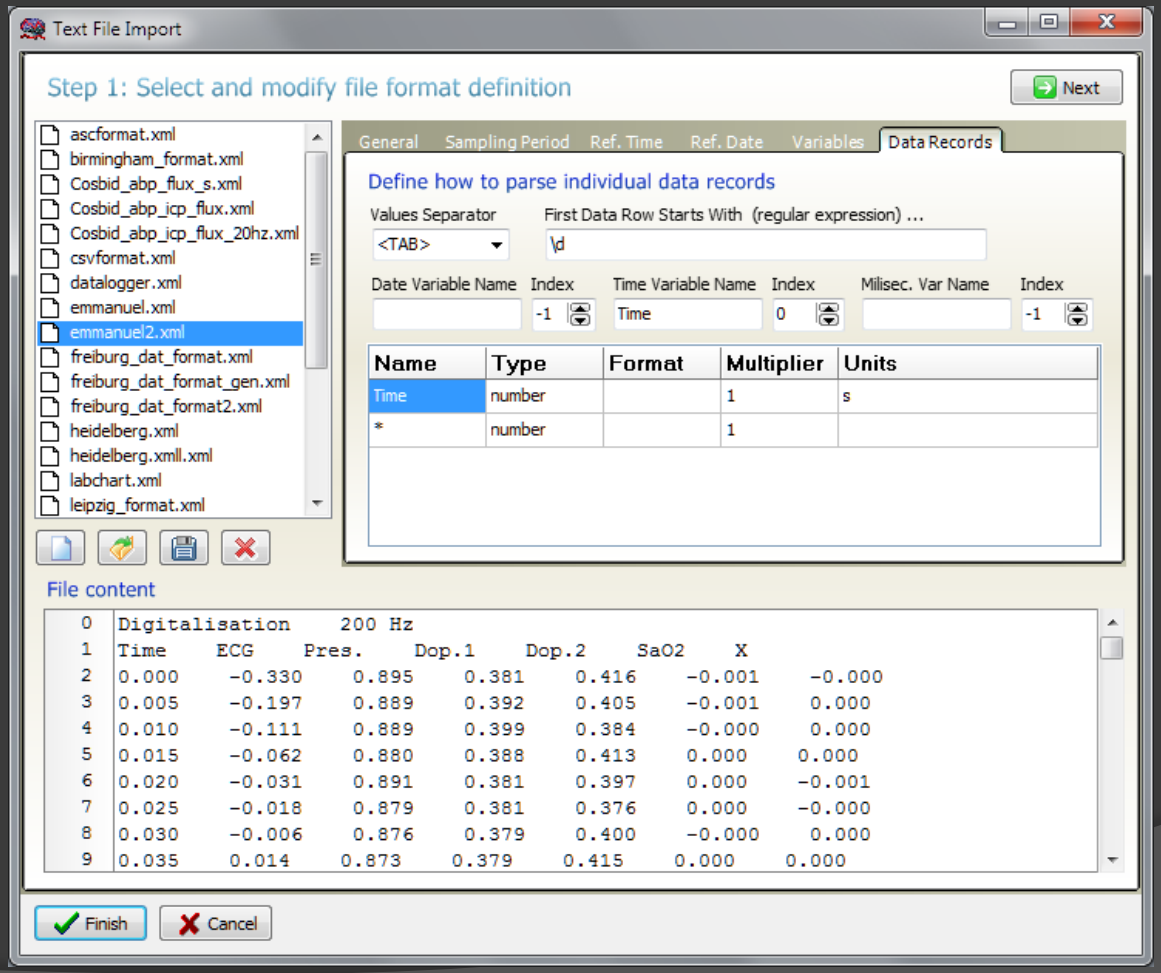
ICM+ New features

Text import configuration – variable names parsing



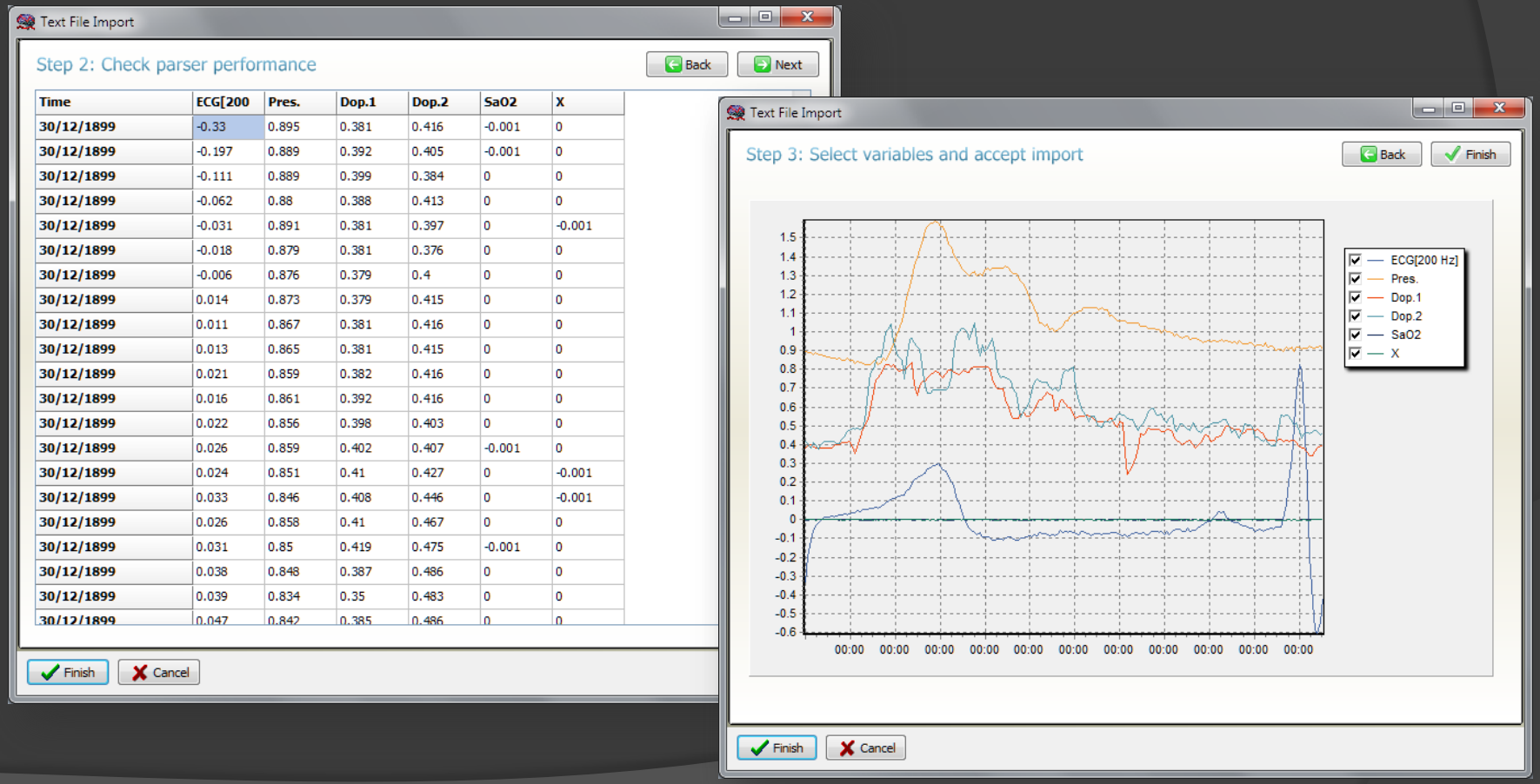
ICM+ New features

Text import configuration – data records parsing



ICM+ New features

Text import configuration – preview and signals selection



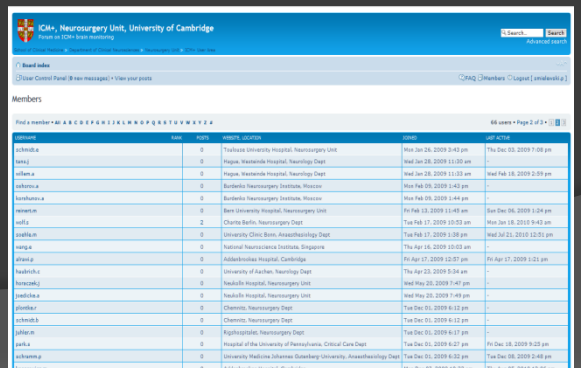
Where do we go from here?

- There are many promising methods of data analysis and display available for intensive care and more are being invented.
- Most of the methods do not see wider clinical application, usually the clinical studies presented are more of a proof of concept
- This is mostly because, at the moment, they require specialised software and/or engineering support, not widely available in clinical centres.
- Industry support is essential to incorporate new methods into general clinical practice. However this normally requires large scale studies/clinical trials to justify new investments and ensure medical governing body approval.
- Interim/hybrid solutions of integrating research orientated data analysis solutions into standard clinical monitoring might be a way of facilitating transfer of new technologies into industry supported medical practice.

Where do we go from here?

Steadily growing community

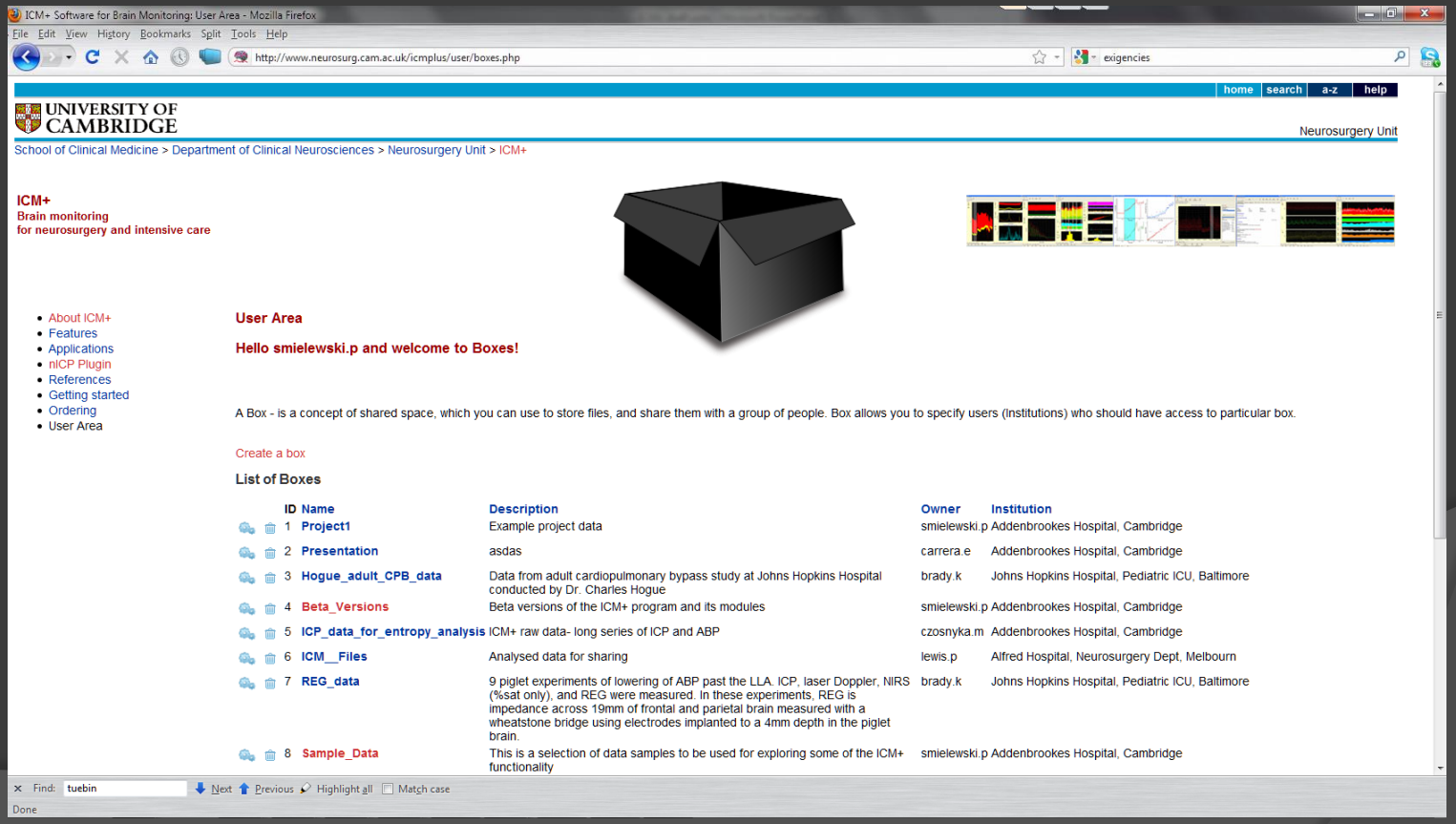
critical mass for multicentre collaborations?



Where do we go from here?

Data exchange

Boxes



Where do we go from here?

Expansion of available methods

- Artefacts detection/treatment
- Systemic variability measures (heart rate, respiration rate, pulse amplitude etc)
- Pulse morphology
- Time series complexity measure (chaos theory)

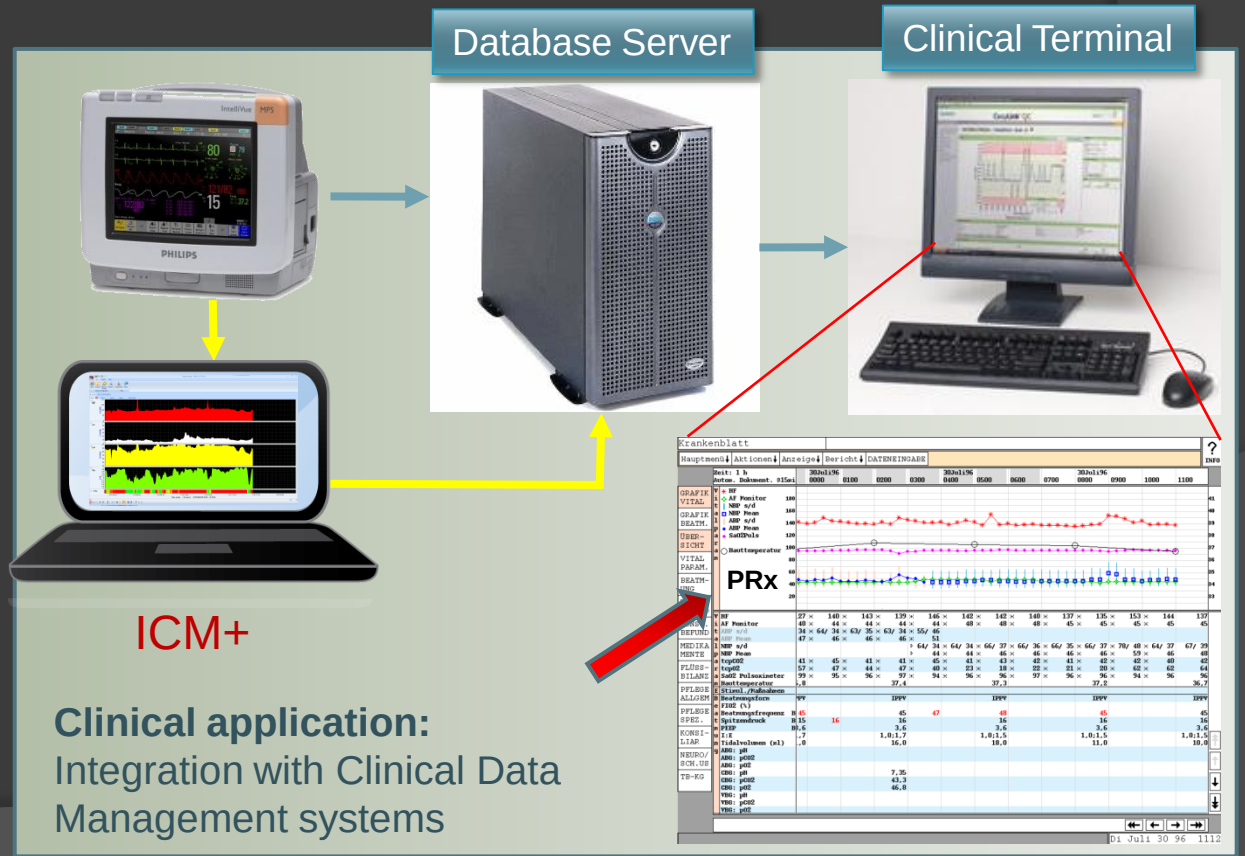
These will be done either as internal implementations or, preferably, as 3rd ‘plug-in’ solutions

Where do we go from here?

Role of ICM+ in the future ICU

ICM+ a research tool and it will remain so, but better integration with clinical systems is needed.

Research application:
laptops carried around where needed

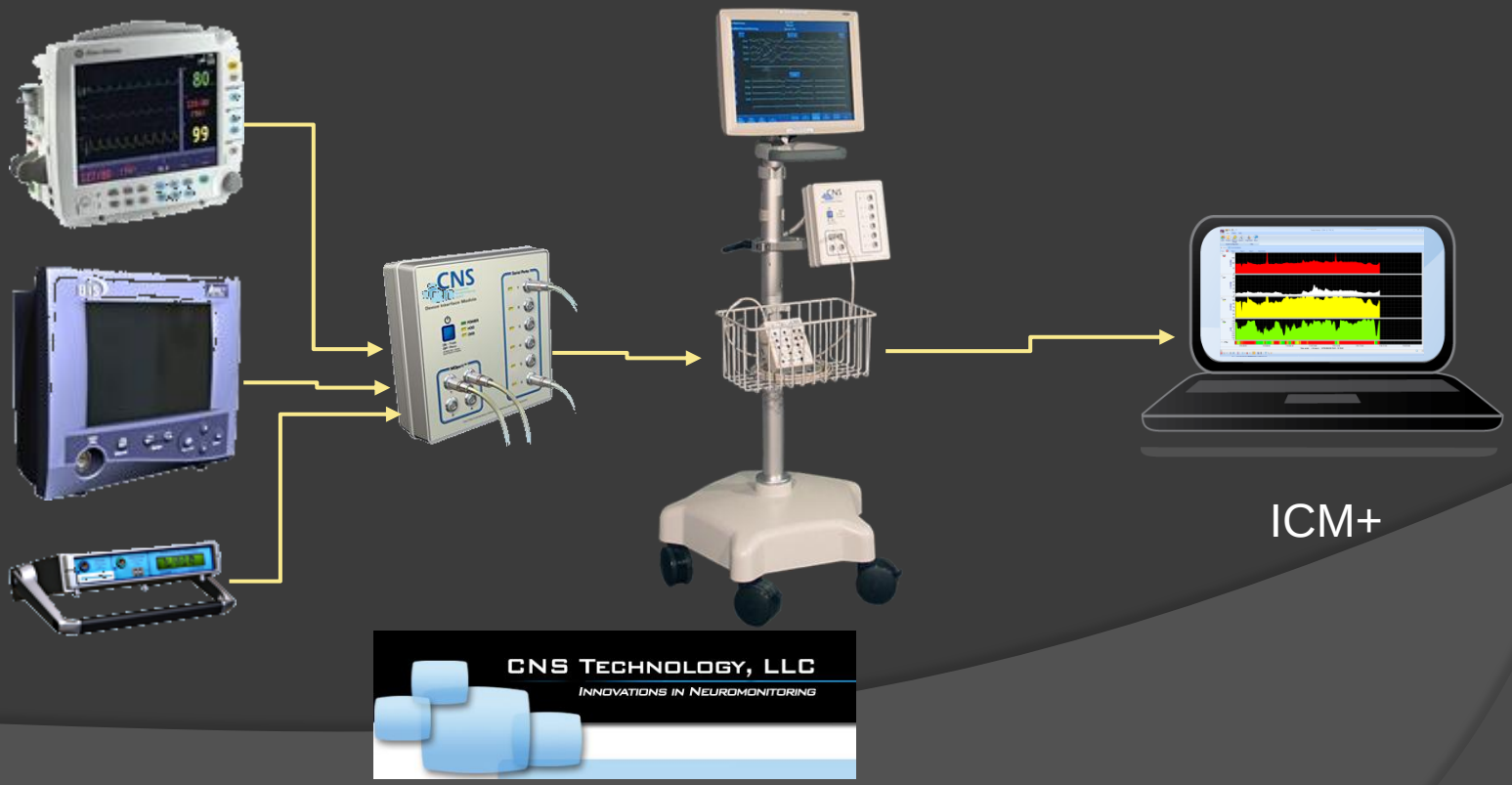


Clinical application:
Integration with Clinical Data Management systems

Where do we go from here?

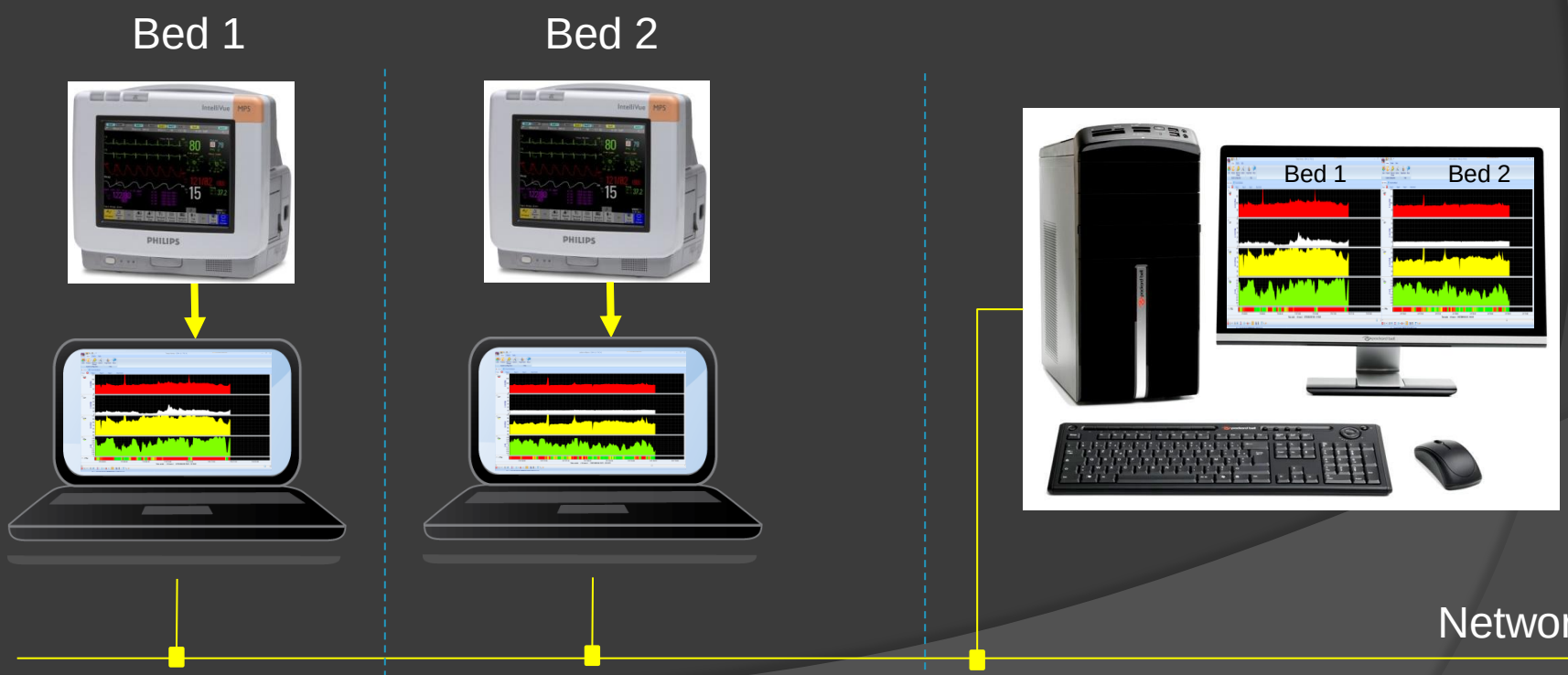
Integration with other, clinically approved, data acquisition systems

Example: CNS Technology, by Moberg Research Inc



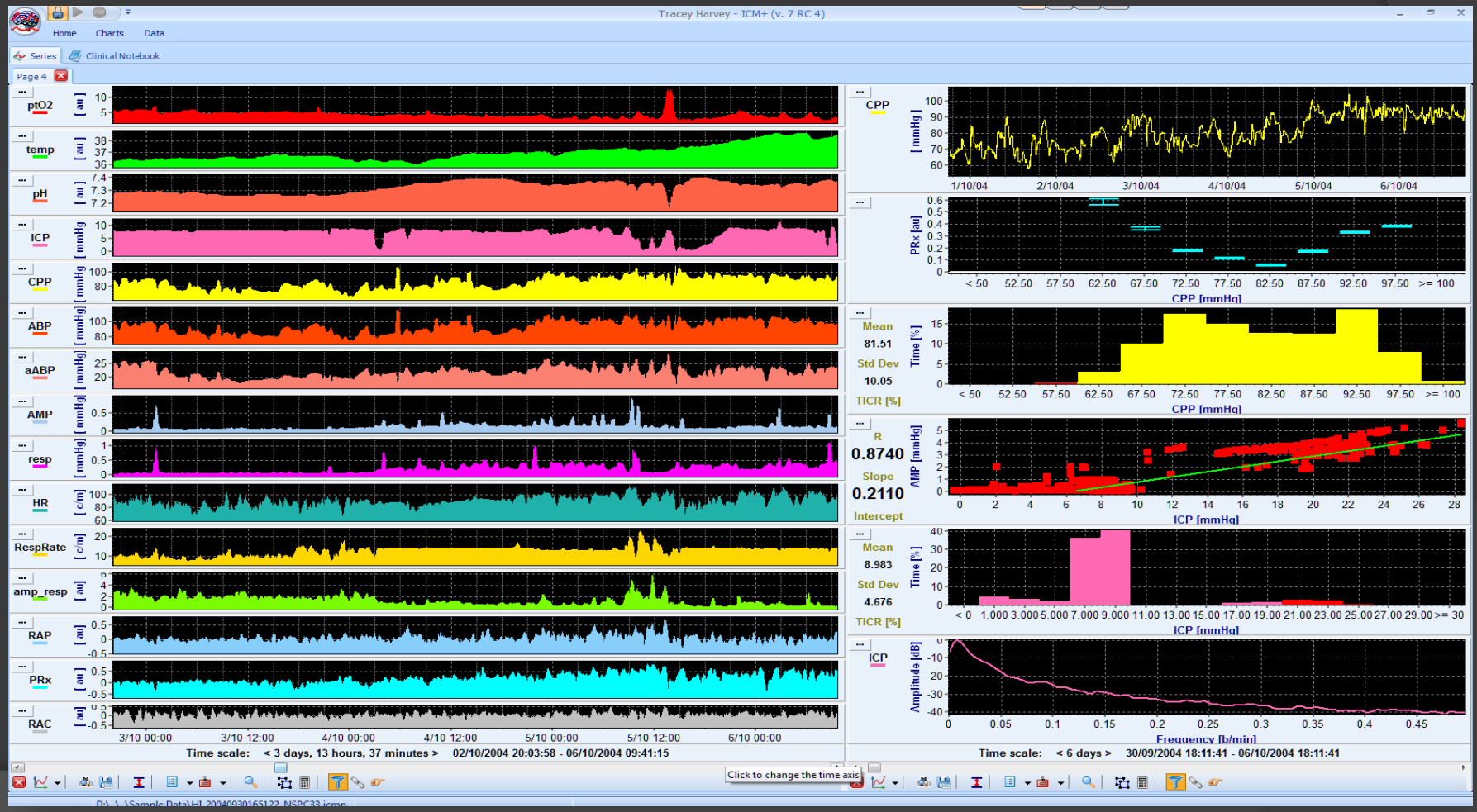
Where do we go from here?

Remote access to ICM+ monitoring



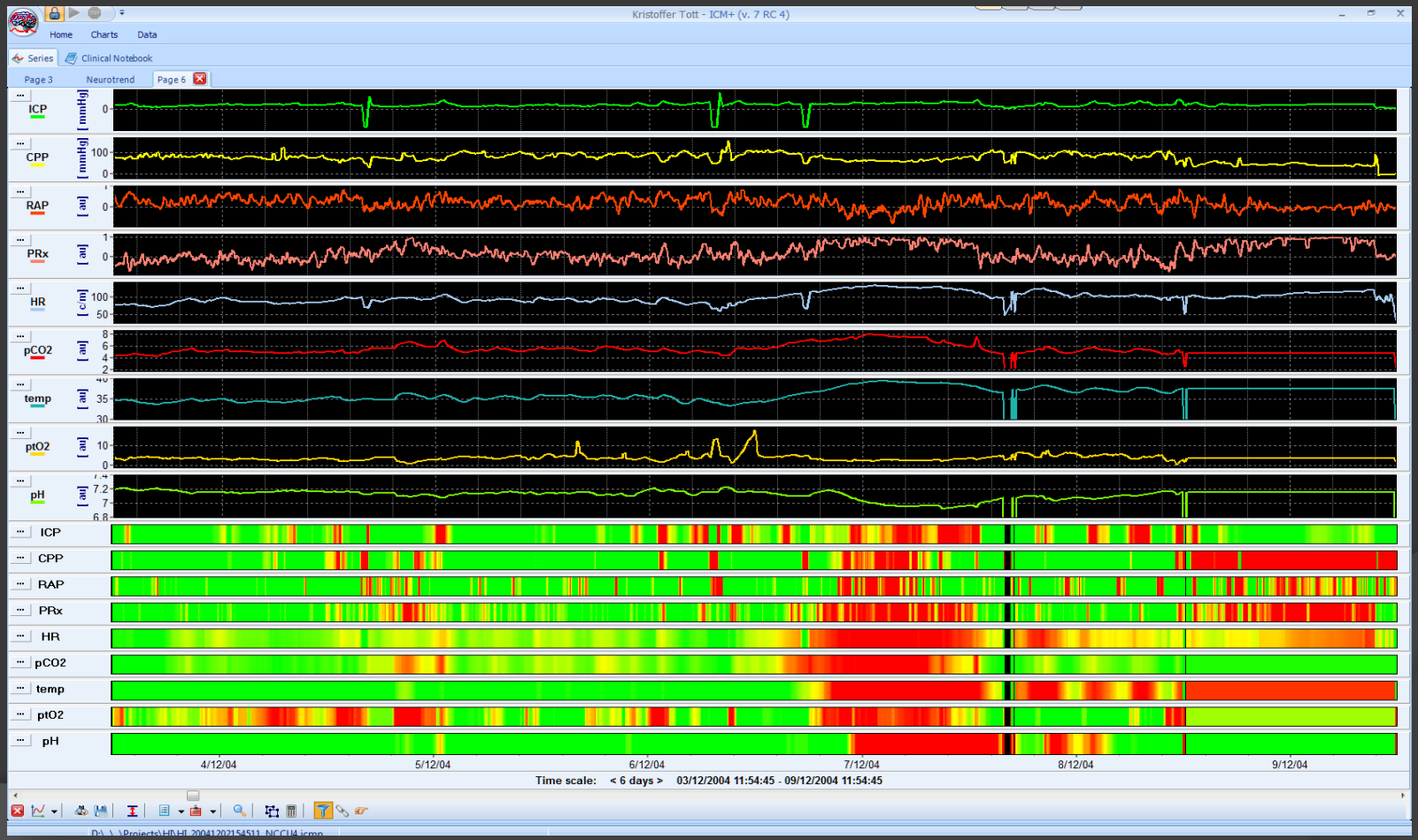
Where do we go from here?

Data visualisation improvements



Where do we go from here?

Imaging time series



Where do we go from here?

Other pending tasks

- Extended data import - synchronising data from multiple sources based on series re-sampling
- Increasing number of signals to acquire and store in raw format: NEW RAW DATA FORMAT required
- DOCUMENTATION
- New digital interface devices support – ongoing task

Acknowledgement

- Christian Zweifel, Basel, Switzerland
- Ken Brady; Johns Hopkins Medical University, USA
- Jennifer Diedler, University of Heidelberg, Germany
- Andrea Lavinio; University of Brescia, Italy
- L. A. Steiner: University of Basel, Switzerland
- M. Balestreri: University of Pavia, Italy
- M. Kasprowicz: Wroclaw University of Technology, Polar
- B. Schmidt; University of Chemnitz; Germany
- M. Reinhardt & M.Roth: University of Freiburg, Germany
- M. Jaeger & M.Schuhmann; University of Leipzig; Germa
- C. Haubrich: University of Aachen, Germany
- M. Soehle: University of Bonn, Germany
- E. Lang: University of Kiel, Germany
- A.Raabe, University of Frankfurt, Germany
- P.Lewis; University of Melbourne, Australia
- I. Gooskens: University of Maastricht, Holland
- E. A. Schmidt: University of Toulouse, France
- Z. Czosnyka: University of Cambridge, U.K
- P. Smielewski : University of Cambridge, U.K.
- Ivan Timofeyew; Cambridge , U.K.
- M.Y.Tseng; Cambridge, U.K.
- S. K. Piechnik: University of Oxford, U.K.
- B. Matta: University of Cambridge, U.K.
- D. Mennon: University of Cambridge, U.K.
- J. D. Pickard: University of Cambridge, U.K.

…. and many more

USERS' OWN EXPERIENCE WITH ICM+

Ken Brady, MD:	Laboratory vs. clinical uses of ICM+
Christian Zweifel, MD:	Multimodal signal acquisition and data processing using ICM+
Kristian Aquilina, MD:	Assessment of CSF dynamics in hydrocephalus
Christina Haubrich, MD, PhD:	ICM+ and the blood pressure - flow velocity relationship
Magdalena Kasprowicz, PhD:	How can we create and analyze new signals using ICM+?
Jennifer Diedler, MD:	Dealing with artefacts
Phil Lewis , BSc:	Time series and batch data analysis with ICM+
Martin Soehle, MD:	Options and pitfalls when using ICM+ for collecting data from Philips Intellivue- and Hemedex CBF-monitors
Bernhard Schmidt, PhD:	How to use plug-in for non-invasive ICP
Martin Schuhmann MD, PhD:	Overnight ICP monitoring
Luzius Steiner MD, PhD:	Intraoperative non-invasive monitoring of cerebral perfusion

All presentations will be available on http:\\www.neurosurg.cam.ac.uk\icmplus