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Centre for Proton therapy :: PSI

Software Framework QAClient for Measurement / Automation in Proton Therapy

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Proton Therapy at Paul Scherrer Institute

Superconducting cyclotron (2006)

PSI + Varian, 250 MeV

Experiment

Gantry 3 (Varian)

In clinical operation
since 2018

OPTIS2 (Ocular Tumors)

In clinical operation
since 2010

Gantry 2

Second generation
PSI gantry
In clinical operation
since 2013

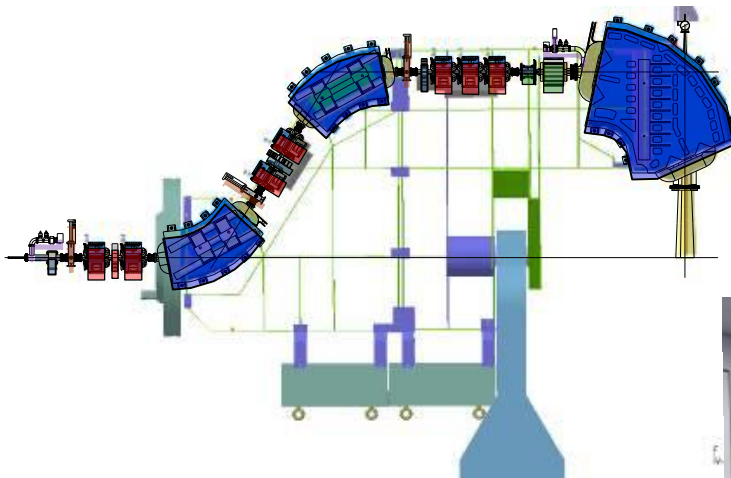
Gantry 1 (1996-2018)

First Pencil Beam
Scanning Gantry

Proton Therapy – Extensive Quality Assurance

Proton Therapy

Complexity of involved Systems used for medical patient treatment requires extensive Quality Assurance (QA)



Involved Actuators & Detectors

- Mechanical: Gantry, Nozzle, Patient Couch...
- Electromagnetic: Beam Delivery, Magnets
- Detectors: Ionization & Strip Chambers



Daily QA

Daily verification of most important proton beam, dose and position parameters has to be performed in a standardized and efficient way.

QAClient Development Started for Gantry2

- Development started in 2011
- Main Goals of QAClient:
 - Full automation of QA test procedures like daily QA
 - Integration of different control systems and measurement devices
 - Comprehensible reports and long-term QA data storage
 - Fully configurable for different projects (no programming necessary)
 - Easy to use, user interaction and visualization of data and results
 - Reduce errors and execution times of repetitive tasks
 - Less highly-specialized personnel necessary for QA
- QAClient Is now used for many other purposes:
 - Monthly QA
 - Patient Table Calibrations
 - Beam Tune Calibration
 - System Integration Tests (as test engine)
 - ...

QA Client

Reports (HTML, PDF)

email

codeBeamer QA Management

QA Database

MATLAB

LabVIEW

SpatialAnalyzer 3D Laser Scanner

Patient Safety System

Control System Gateway

VME Real Time Control Systems

VME Patient Couch Controller

RMI

UDP

EPICS

JMS

SQL

TCP-IP

TCP-IP

QAClient Technologies

- Programming Language **Java**
- requires OpenJDK 8, runs on Windows XP, 7, 10, Linux etc.
- **Swing / AWT** User Interface (uniform look on all platforms)
- **JMS** (Java Message Service) using Apache ActiveMQ
- **RMI** (Remote Method Invocation) to Gateways
- **EPICS** (Experimental Physics and Industrial Control System) to Patient Safety and Accelerator Control Systems
- **HTTP** Service
- **HTML** and **PDF** Reports
- **SMTP** (Simple Mail Transfer Protocol) using JavaMail
- different proprietary **TPC-IP / UDP** protocols
- **OJDBC** database access
- **XML** configuration



QAClient Features

- **Graphical user interface** (“expert”/”simple” mode, textures for color-blind operators)
- **XML** based application **configuration** using **standard tasks**
- Generic mechanism of **data transfer** between different tasks
- Dynamic **flow control** (conditions based on data or user decision)
- Programming **loops** and input file driven measurement loops
- Data **checks** and **validations**
- Sending **Commands** to different Control Systems, LabVIEW, MatLab
- Processing **Notifications** from Control Systems, LabVIEW, MatLab
- **Logging** framework with adjustable severity level
- **LDAP** user identification and authorization
- **Persistent** states to continue aborted tasks
- Generic **dialogs** to show/visualize data and ask for user decisions
- **Archiving** of QA data and measurement results in external database
- **Generating** and **printing** of summary **reports** (HTML, PDF)
- **Visualization** of archived QA data

QAClient Provides 228 Standard Tasks

- **System Tasks** like OpenFile, ExecuteSSHCommand etc.
- **Control System Tasks** like StartupBeamline, MoveToPosition etc.
- **QAClient Tasks** like ForEachFile, CreateData, ReceiveUDP etc.
- **LabVIEW Tasks** like DataRequest, StartVITask etc.
- **MatLab Tasks** like StatusRequest, ML_Command etc.
- **Database Tasks** like SendData, ShowDBData etc.

QAClient Tasks Configuration

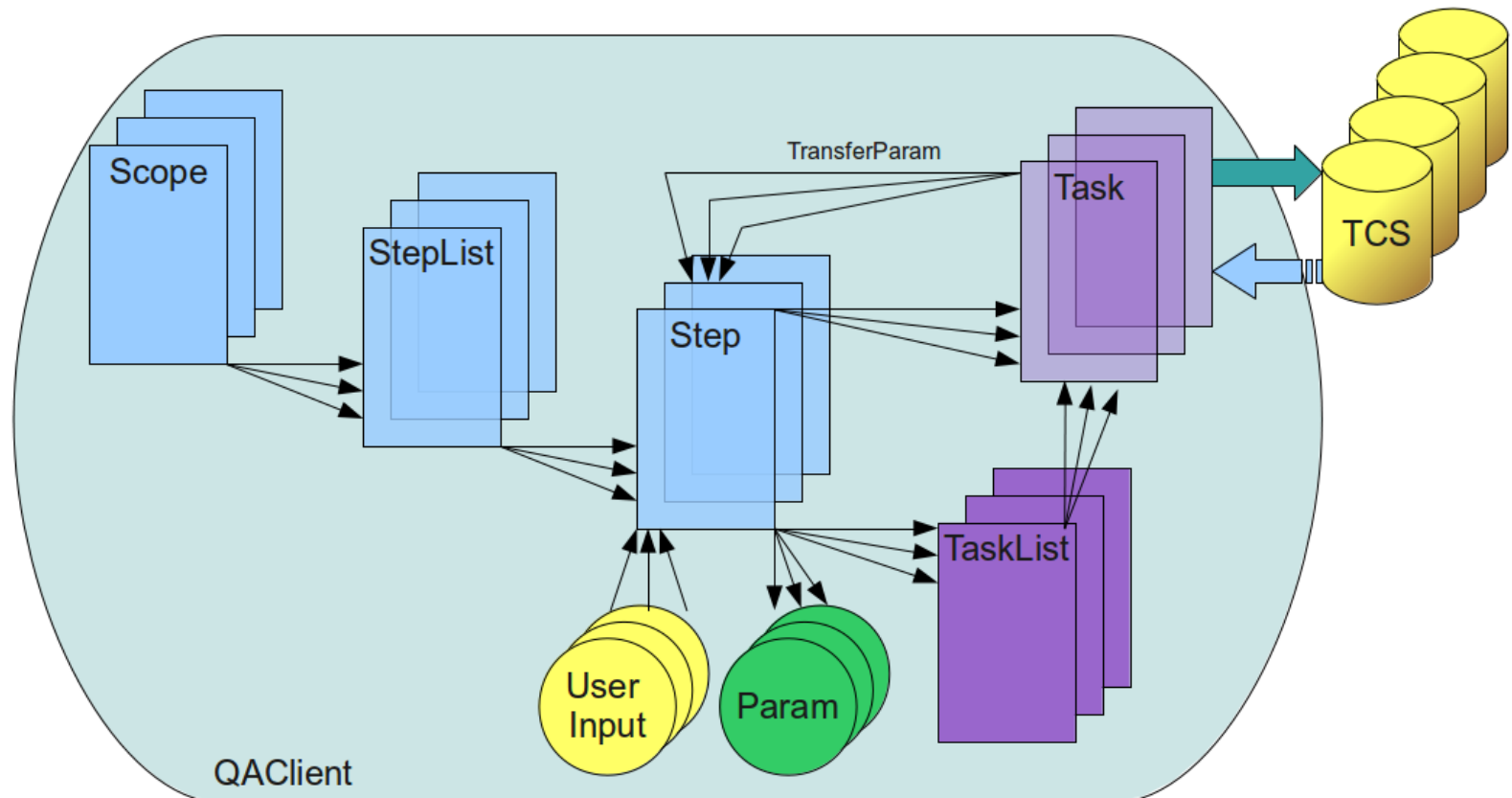
- Tasks are **defined in XML**
- Tasks can be **specialized with different parameters** to be reused
- Tasks can be **aggregated to TaskLists** to reduce complexity in project configurations

```
<Task id="TCS_PauseField" type="TCS" command="execute(TcsOpPauseField) "
  aSyncNotification="RpcNoteTcsState(sData=fieldPaused) "
  desc="Pause Field currently being applied.">
  <DefaultArg key="doNotWaitForRpcNoteRpcServer" value="true" desc="not waiting for RPC notification."/>
</Task>
```


QAClient – Application Configuration

Generic Architecture to Configure Applications

- **Scope:** QAClient application (automated measurement, daily QA etc.)
- **StepList:** Full measurement procedure
- **Step:** Smallest execution entity with all its parameters and input data
- **Task:** Standard Tasks with defined parameters, input and output data



Generic XML / Graphical Configuration

- XML configuration in external editor
- Syntax and semantic check against XSD schema and standard tasks XML
- Graphical configuration tool

```
#####
# D4.2.2 M3
# =====
#
# M3 Monitor Gain Measurement
#
# NO Mastership, NO Beam, NO Phantom: color green
#####
<StepList id="D4.2.2_M3" color="0x00FF00" desc="D4.2.2_M3 Gain Measurement" tip="Mastership: NO, Beam: NO,

<!-- Step id="D4.2.2_M3_TCS_ClosePossibleField" task="TCS_TL_CloseTcsField" ignoreErrors="true"/-->
<Step id="D4.2.2_M3_TCS_ClosePossibleField" task="TCS_Close" ignoreErrors="true"/>

<!-- TCS initialization: Mastership & Experiment -->
<Step id="D4.2.2_M3_TCS_Prepare" task="TCS_TL_SetOperationMode" desc="Request GUI Mastership and sets
  <Param key="OperationMode" value="3"/>
</Step>

<!-- Gain Measurement M3 -->
<Step id="D4.2.2_M3_TCS_MeasureGain" task="TCS_MeasureDseGain" tcsSystem="TVS" desc="Measures the gain
  <Param key="iArg1" value="-490" desc="lower limit of current range [nA]"/>
  <Param key="iArg2" value="-10" desc="upper limit of current range [nA]"/>
  <Param key="iArg3" value="49" desc="number of data points in current range"/>
  <Param key="iArg4" value="500" desc="measurement duration per data point [msec]"/>
  <Param key="iArg5" value="2" desc="DSE channel number"/>
  <Param key="sArg1" value="G2-M3" desc="DSE name"/>
  <Param key="sArg2" value="M3_UnG" desc="Monitor name"/>
</Step>

<!-- 1. Gain Measurement -->
<Step id="D4.2.2_M3_ML_AnalyseGainMeasurement" task="ML_AnalyseGainMeasurement" userDecision="false" :
  <TransferNotification dstKey="GainData" srcStep="D4.2.2_M3_TCS_MeasureGain" notificationType="RmiC
</Step>

<Step id="D4.2.2_M3_TCS_ResetInterlocks" task="TCS_ResetInterlocks" ignoreErrors="true"/>

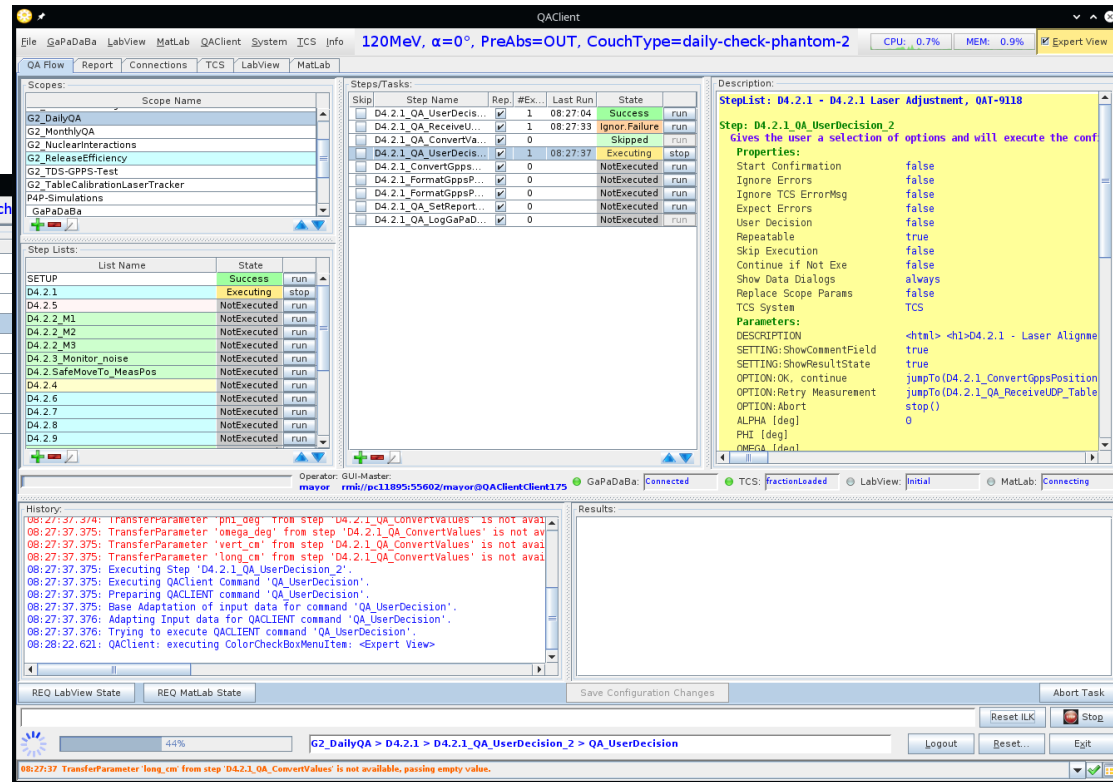
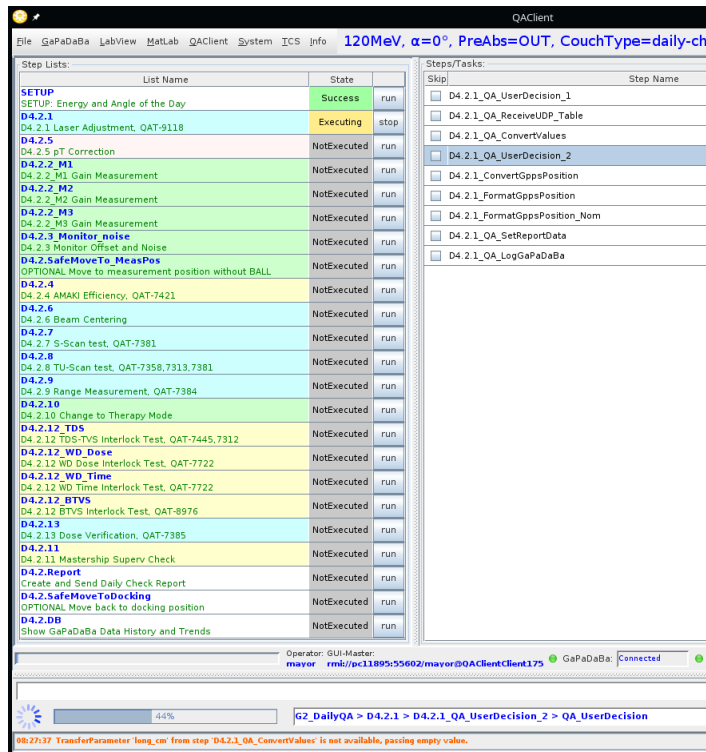
<Step id="D4.2.2_M3_QA_UserDecision" task="QA_UserDecision">
  <CDATA key="DESCRIPTION" desc="text that will be displayed at the top of the dialog">![CDATA[
    <html>
      <h1>D4.2.2 - Monitor Gain Measurement</h1>
      <p>The following values show the results as <b>analysed by Matlab</b> with the data <b>measured</b>
      <p>Please <b>confirm</b> that the analysis <b>values are reasonable</b> and can be sent to <b>Ps
      <p>Available options:
      <table border="0">
        <tr><td><b>"OK, continue" </b></td><td>sends data and Matlab report to PatBase</td></tr>
        <tr><td><b>"Retry Measurement?"</b></td><td>restarts the complete measurement at step D4.2.2_M
        <tr><td><b>"Stop" </b></td><td>stops this step list</td></tr>
      </table>
    </html>
  ]]></CDATA>
```

GUI Expert / Simple Mode

- Simple Mode: Reduced to what it is needed for daily usage
- Expert Mode: Offering full control and detailed information

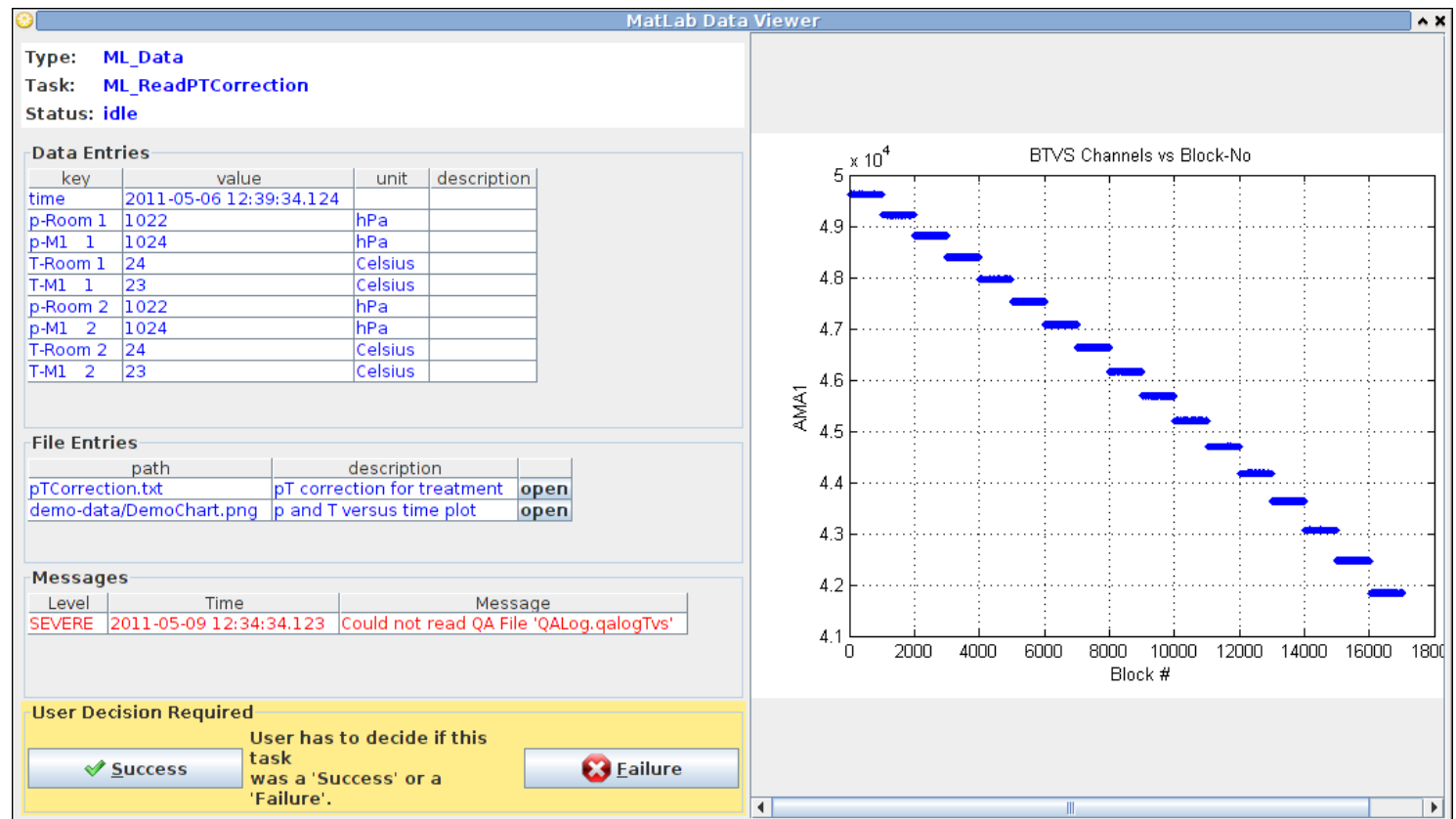
Expert Mode

Simple Mode



GUI Generic Dialogs

- showing measured/calculated data
- offering access to data files
- showing plots and messages of previous tasks
- asking for user decisions (like “continue”, “retry” or “abort”) and comments or input



Reports & Data Archiving

- Reports are saved in QA Management Tool, sent by email and printed
- Data is archived in QA Database and can be analyzed offline

G2 Daily QA Report

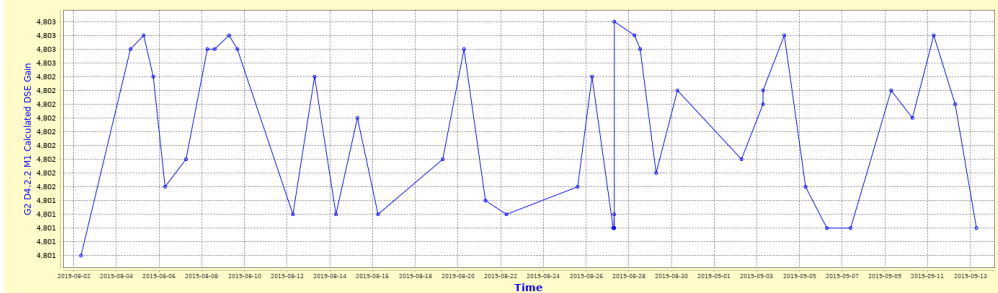
Area	G2	Responsible	Date	Signature
Scope	G2 DailyQA			
Operator	heller (Martin Heller, HA17, martin.heller@psi.ch, +41 56 310 53 23, WBBB/8131)	Physicist		
Start	2019-09-13 06:40:53			
End	2019-09-13 07:15:06	Medical Physicist		
Duration	34 min, 12 sec			
ExecTime	21 min, 21 sec			

SETUP Pre-Absorber	OUT
AcceptIncompleteScopes	true
SETUP Energy (MeV)	120
SETUP Alpha (deg)	90

Step List ID	Status	Data	Operator Comments
D4.2.1 Laser Adjustment, QAT-9118	Success	TablePos (beta=179.98, x=0.81, y=15.00, z=0.00) TablePosition (beta=180.00, x=0.82, y=15.00, z=0.00)	
D4.2.5 pT Correction	Success	Temp (CupTemp=22.7, PhatTemp=24.13) (bPa) Amb Pressure 589.5 pT correction 1.9426	
D4.2.2_M1 Gain Measurement	Success	Slope (Measured=4.89, Nominal=4.81, residualMax=0.890) Tolerance (Tolerance=0, Deviation=0.1633) (%)	
D4.2.2_M2 Gain Measurement	Success	Slope (Measured=2.29, Nominal=2.29, residualMax=0.823) Tolerance (Tolerance=0, Deviation=0.1633) (%)	
D4.2.2_M3 Gain Measurement	Success	Slope (Measured=0.57, Nominal=0.57, residualMax=0.890) Tolerance (Tolerance=0, Deviation=0.160)	
D4.2.3 Monitor Offset and Noise	Success	M1_Pos (offset=0.4, LimitLow=0, LimitHigh=0.6) (Hz) M2_Pos (offset=0, LimitLow=0, LimitHigh=0.6) (Hz) M1_Neg (offset=0, LimitLow=0, LimitHigh=200.0) (Hz) M1_Pos (offset=0.9, LimitLow=0.9, LimitHigh=0.9) (Hz) M2_Neg (offset=1191.2, LimitLow=200.0, LimitHigh=2000.0) (Hz) M3_Pos (offset=0, LimitLow=0, LimitHigh=0.6) (Hz)	
D4.2.4 AMAKI Efficiency, QAT-7421	Success	AMAKI (measureEff=0.000007, LimitHigh=0.0001)	
D4.2.6 Beam Centering	Success	Offset (measured=0.11, measured=0.11, tolerance=0.285) (cm)	
D4.2.7 5-Scan test, QAT-7381	Success	Position (residual=0.12, tolerance=0.26) (cm) Beam Size (residual=0.76, tolerance=0.80) (%)	
D4.2.8 TU-Scan test, QAT-7358,7313,7381	Success	Position (residual=0.14, tolerance=0.26) (cm) Beam Size (residual=0.30, tolerance=0.80) (%)	
D4.2.9 Range Measurement, QAT-7384	Success	Range (residual=1.20, tolerance=2.00) (mm) Energy (residual=0.98, tolerance=2.00) (MeV)	
D4.2.10 Change to Therapy Mode	Success		
D4.2.12 TDS-TVS Interlock Test, QAT-7445,7312	Success		
D4.2.12 WD Dose Interlock Test, QAT-7722	Success		
D4.2.12 WD Time Interlock Test, QAT-7722	Success		
D4.2.12 BTVS Interlock Test, QAT-8976	Success		
D4.2.13 Dose Verification, QAT-7385	Success	Chamber1 (calculated=0.988, nominal=1.000, deviation=0.014) (Gy) Chamber2 (measured=0.462, nominal=0.500)	
D4.2.11 Mastership Superv Check	Success		

✓ without issue
 🟡 minor issue(s)
 🔴 major issue(s)
 ❌ didn't pass
 ⏸ not executed or aborted

G2 D4.2.2 M1 Calculated DSE Gain



QAClient – Example: G2 Daily Check

Example Application: Gantry 2 Daily Quality Assurance

G2 Daily Check is used every morning before patient treatment to check:

- Dose delivery accuracy using ionization chambers
- Proton beam position accuracy
- Proton beam parallelism and position
- Proton beam energy / range in water
- Beam kicker magnet closing efficiency
- Base check on patient safety system
(beam on/off, beam interruptions, beam tune)



Gantry 2 Daily Quality Assurance Equipment

- Mini-strip detector
- Multi-layer ionization chamber
- Ionization chambers at different depths

Integrated Systems

- Control Systems (TDS, TVS, GPPS)
- Patient Safety System (LPaSS)
- LabVIEW: measurements
- MatLab: data analysis
- QA database (GaPaDaBa)

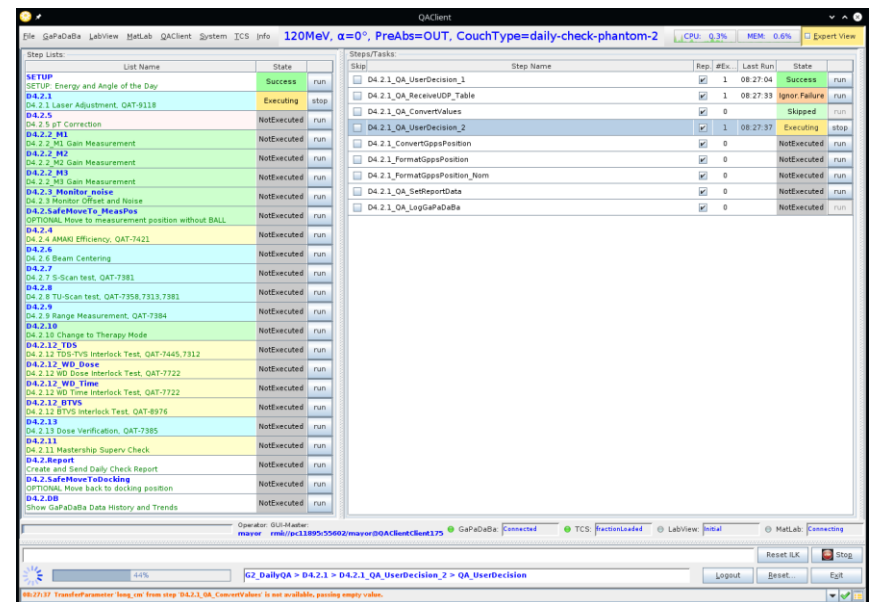
Output Produced

- Measurement/Analysis reports
- Paperwork: QA document
- Long-term storage of QA data
- Archives & mails report



QAClient - Summary

- Flexible Software Framework
- Fully Configurable
- Reliable and standardized procedures
- Reduced operator errors
- Reduced QA execution times
(Daily Check time reduction by 70%)
- Used for different applications / tasks
- Used in daily operation
- No programmer or software engineer needed to build an application
- Easy to use



Thank you for your attention

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<https://www.psi.ch/en>

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