Tango based software development for the diagnostics of longitudinal bunch parameters in synchrotron

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Acknowledgement

I would like to express my appreciation to Dr. Grigory Vladimirovich Trubnikov, my practice supervisor and vice-director of Joint Institute for Nuclear Research for giving me an opportunity to participate in Student Summer Program.

I also wish to thanks for the help provided by Evgeny Valerievich Gorbachev, head of group Scientific and Technical Department of beams and Georgy Sedykh for their valuable and constructive recommendations on this project.

Summer Student Program at Joint Institute for Nuclear Research took place in Veksler and Baldin Laboratory of High Energy Physics (VBLHEP). The challenge of this practice was to develop a device on the system TANGO and the user application for diagnostics of longitudinal bunch parameters in synchrotrons and calculate depending on the period of revolution of the particles to the time. Servers and user applications development on the C++ program language and programs as well as QT Creator, Microsoft Visual Studio and others.

Introduction

Device servers have been developed at the European Synchrotron radiation Facility (ESRF) in order to solve the main task of Control Systems viz provide read and write access to all devices in a distributed system. The problem of distributed device access is only part of the problem however. The other part of the problem is providing a programming framework for a large number of devices programmed by a large number of programmers each having different levels of experience and style.

To solve these problems has been established object - oriented system TANGO. It is the standard to build a NICA accelerator complex control system. Device servers on this system have been written for a large variety of different devices. It is easy to use and is well adapted to solving simple and complex distributed problems.

The aim of this project was to develop a program complex allowing to process the data obtained from the synchrotron to provide diagnostics of longitudinal bunch parameters.

TANGO

What is a TANGO

TANGO control system is an object oriented control system based on CORBA for Windows, Linux and Unix . It is a free open source controls toolkit for controlling any kind of hardware or software and building SCADA systems. This system used for controlling various kind lasers, synchrotrons, physics experiments. It is being actively developed by a consortium of research institutes as well as JINR.

TANGO is a distributed control system. It is used on a single machine as well as hundreds of machines. TANGO uses two network protocols - the omniorb implementation of CORBA and Zeromq. The basic model of communication is the client-server model. Communication between clients and servers can be asynchronous, synchronous or event driven. CORBA is used for asynchronous and synchronous communication and Zeromq is used for event-driven.

TANGO is based on the concept of Device Servers. Devices implement service oriented and object oriented approaches to software architecture.

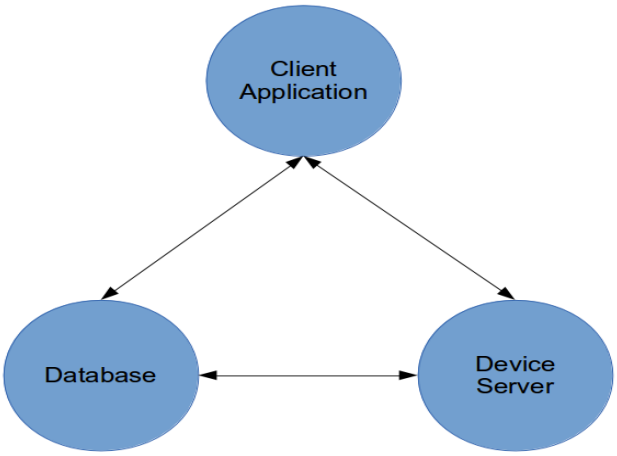
The Device Server model in TANGO implements commands (methods), attributes (data fields) and properties for configuring Devices.

TANGO Device Server model

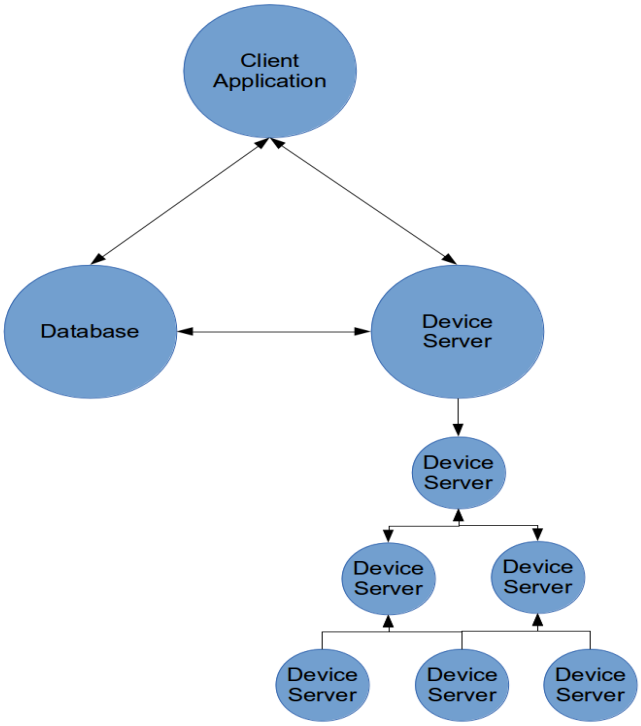
TANGO control system is software for construction of control systems which need to provide network access to hardware. Hardware can range from single system of digital input/output up to sophisticated synchrotron systems or plant control systems (SCADAs). Hardware access is programmed in a process called Device Server. This Device Server implements Device Classes which that provide the hardware access. Also this Device Server creates instances of Device Classes which that display logical instances of hardware in the control system in the process. The client communicates with devices using TANGO protocol. Clients should import the Device Servers via a database and send requests to the devices using this protocol Devices can store setup values and configuration in a Mysql database permanently.

Many types of Device Classes have been written by the community. This Classes we can used to develop your application or Device Server.

TANGO manages complexity using hierarchies.



All solutions in Tango Control System include 3 based processes



TANGO uses hierarchies of devices. This solution to manage complexity simply

How to use TANGO based software

TANGO Control System has been used to build solutions for:

1. Distributed Control Systems (DCS) in which devices are controlled and monitored in a local distributed network.
2. Supervisory Control And Data Acquisition (SCADA) systems in which remote devices are controlled and monitored centrally.
3. Integrated Control Systems (ICS) in which different autonomous control systems are integrated into a central one.
4. Interface Devices that run on small embedded platforms into a distributed control system.
5. Internet of Things (IoT) applications in which arbitrary devices are controlled through the Internet.
6. Machine to Machine (M2M) applications in which devices communicates with each other.
7. System Integration Platforms in which different kind of software applications and systems are integrated into a central one.
8. TANGO Controls is operating system independent and supports C++, Java and Python for all of the components.

The main components of TANGO

To simplify the management of Device Servers TANGO used in such programs:

Tools for development and deployment application

1. JIVE - independent Java application designed for viewing and editing database TANGO. JIVE written on Swing and to run it requires a Java Virtual Machine above version 1.4.0.
2. POGO - code generator for device servers TANGO.

Tools for run and manage the system TANGO

1. Astor - is program manager for the system TANGO. Astor can:
    1. Manage hosts;
    2. Start / Stop Device Servers;
    3. Send a simple command to the Device Server.

Archiving system

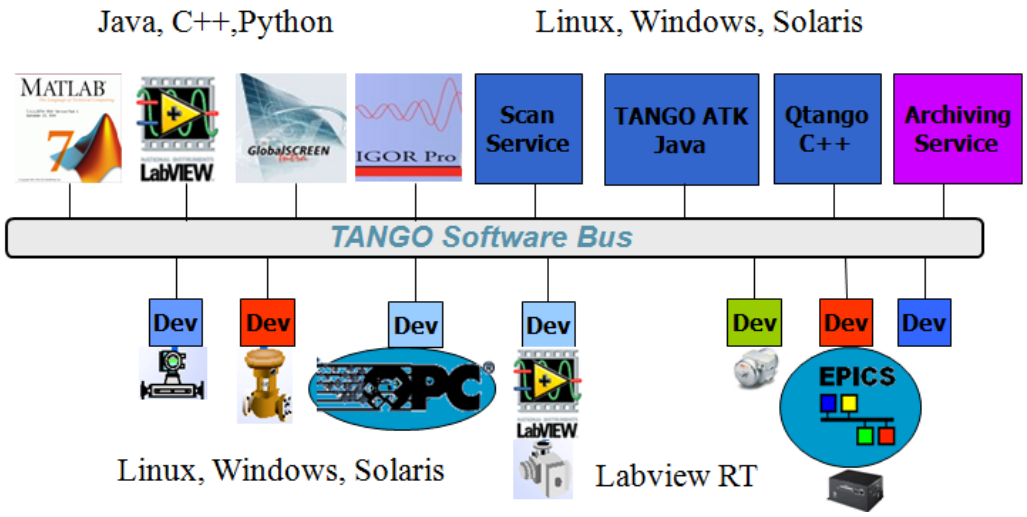
TANGO system contained a built backup system, which that uses MySQL or Oracle database. Archiving system allows storing the necessary data from the devices.

Bindings

TANGO Control system supports bindings to the following languages:

C, C++, Python, Java, LabVIEW, MATLAB.

TANGO is a software bus for distributed objects:



About TANGO project and Licensing

TANGO is an Open source project. Anyone can download and use TANGO.

TANGO is distributed under 2 licenses. The libraries are licensed under the GNU Lesser General Public License (LGPLv3). Tools and device servers are (unless otherwise stated) under the GNU General Public License (GPLv3). The LGPL licence allows the TANGO libraries in products which are not GNU GPL.

Digital Diagnostics of Longitudinal Bunch Parameters in Synchrotrons

People use different encoders for diagnostics bunch parameters in synchrotrons. The simplest and most widely used device is a multi-electrode sensor for measuring the position of the center of gravity of the bunch. The sum signal from the electrodes of such a device depends on the number of particles in the bunch. It is used to detect the intensity of the longitudinal profile of the bunch, that is, to identify the dependence *n(t)* - the number of particles in successive time-of-flight sensor sections of the bunch. The measured analog signal is typically converted into a sequence of digital samples *n(i)*, corresponds to the time t = i * Tclk constant sampling period Tclk.

We use method of moments for digital distribution function to calculate phases of a bunch concerning a phase of accelerating voltage, root-meansquare longitudinal dimensions of a bunch, intensities of a bunch and a beam as sets of circulating bunches. The calculated characteristic bunches in the present method allows identify important patterns of evolution in the process of acceleration.

Also, we used this method to build a digital differential distribution function of particles in the bunch in accordance with the digital signal from the measuring sensor to the longitudinal beam and the intensity of the digital signal to the accelerating voltage.

This method allows you to fully analyze form of the bunch, phase fluctuations, the intensity, the root-meansquare and center of gravity. These settings allow you to adjust the amplitude and phase of the accelerating voltage, to change the current value of the accelerated particles. Because, I have used this method for processing a digital signal from the sensor and receive depending on the period of revolution of the particles on the time.

Software complex is based on TANGO for diagnostics longitudinal bunch parameters in synchrotrons

Our software complex consists of two Tango based Device Servers and user application to display depending on the period of revolution of the particles to the time. Let's take a closer look at each device.

Writing TANGO devices for extracting and processing data obtained from pickup electrode

As I said before the system Tango was not chosen randomly, because the system is distributed and allows you to create devices on different machines, which is convenient for large projects. This allows you to create a modular system and a malfunction of the device does not deduce the entire system is in operation.

Management of project NICA develops on the basis of system TANGO. It is the standard to build a NICA accelerator complex control system.

My program complex consists of two Device Servers: BeamParamExtractor and BeamParamProcessor.

The first Device Server obtain digital data array. TANGO system is built on the principles of object model and support methods, attributes and properties. Our device BeamParamExtractor consist of 5 commands/methods (init, Process, ProcessFile, State and Status), 4 attributes (Data, DataRF, State and Status) and 1 properties.

Method is a piece of code associated with a class or object to perform a task. Our methods associated with a BeamParamExtractor class. Let's take a look more detailed each commands:

- Init – it is command for making initialization our device. Method creates, activate, prepares for operation and defines the parameters.
- Process – it is command, which obtain address file, open this file and write array for data set. This method can be operated when file with data array is placed on a machine where operate Device Server.

- ProcessFile – it is command, which obtain string data array. Using this command we can receive data from other machines. This method I used to obtain data array from client application.
- State and Status – it is commands, which allows you to set the state and status of device. This methods are the most important key device informations. Nearly all client software dealing with Tango device needs device(s) state and/or status. In order to simplify client software developper work, it is possible to get these two piece of information in three different manners :

1. Using the appropriate CORBA attribute (state or status);

2. Using command on the device. The command are called State or Status;

3. Using attribute. Even if the state and status are not real attribute, it is possible to get their value using the read attributes operation. Nevertheless, it is not possible to set the attribute configuration for state and status. An error is reported by the server if a client tries to do so.

Process and ProcessFile make our device independent for input data. We can call the appropriate method depending on the form of data.

Our first device server consists of 4 attributes. . Let's take a look more detailed each attributes:

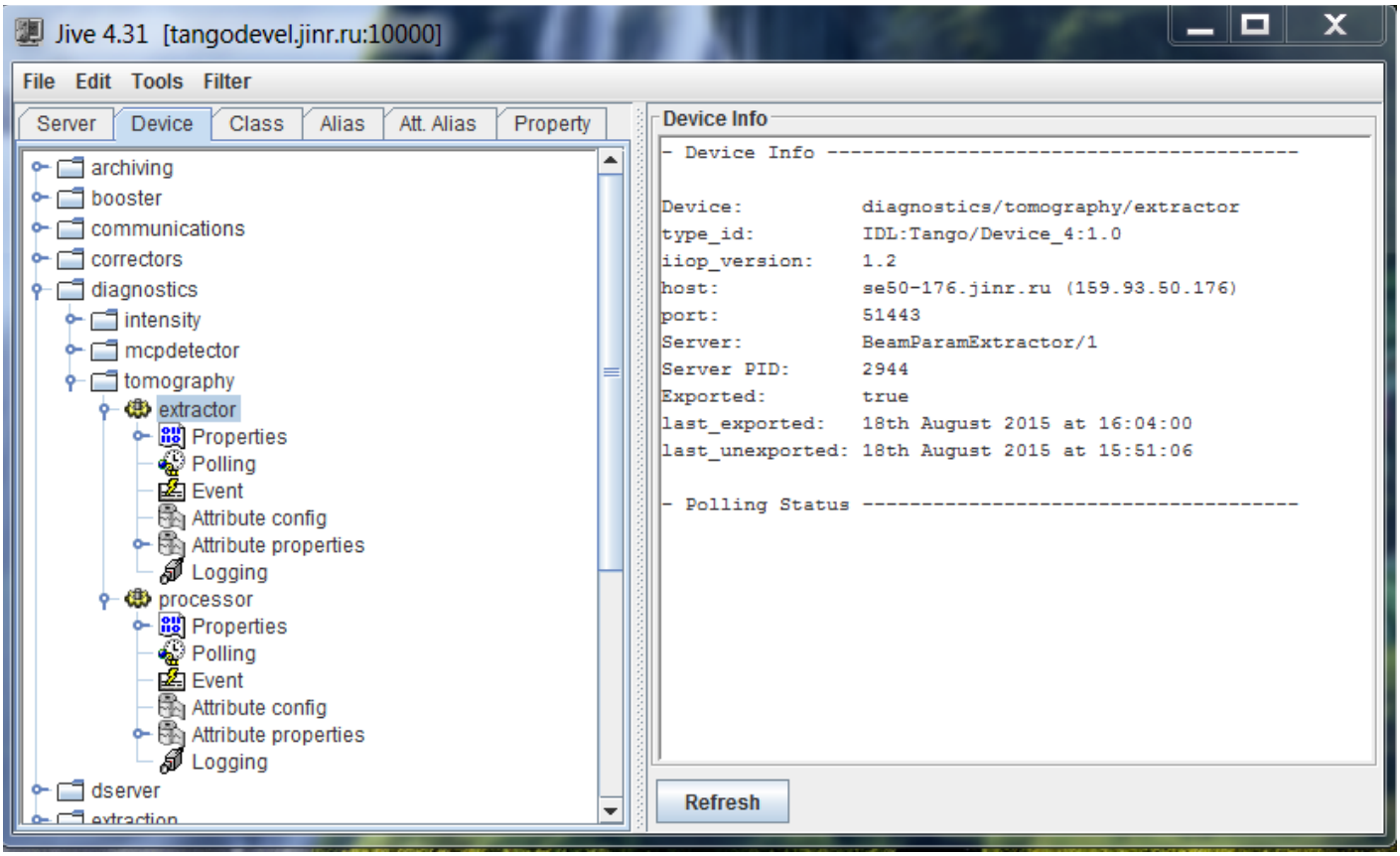
- Data and DataRF – it is each attributes consists of a DevDouble data array. These attributes obtain half of the data from file array.
- State and Status - it is attributes which get their value using the read parameters operation.

Also BeamParamExtractor consist of one property, which has the address of the file. This property used, which our device call the appropriate Process command. It allows you to specify only the name of the file substituting in command of the path to the file, and the file must be based on this way.

So, the first Device Server receive and divides array on two part. Further these data takes second Device Server BeamParamProcessor.

The second Device Server BeamParamProcessor consists of 4 commands (init, Process, State and Status), 4 attributes (T, Trev, State and Status) and 4 properties (Extractor, Hrf, Tclk and Trev. Methods in these Device operate as in the first Tango Server.

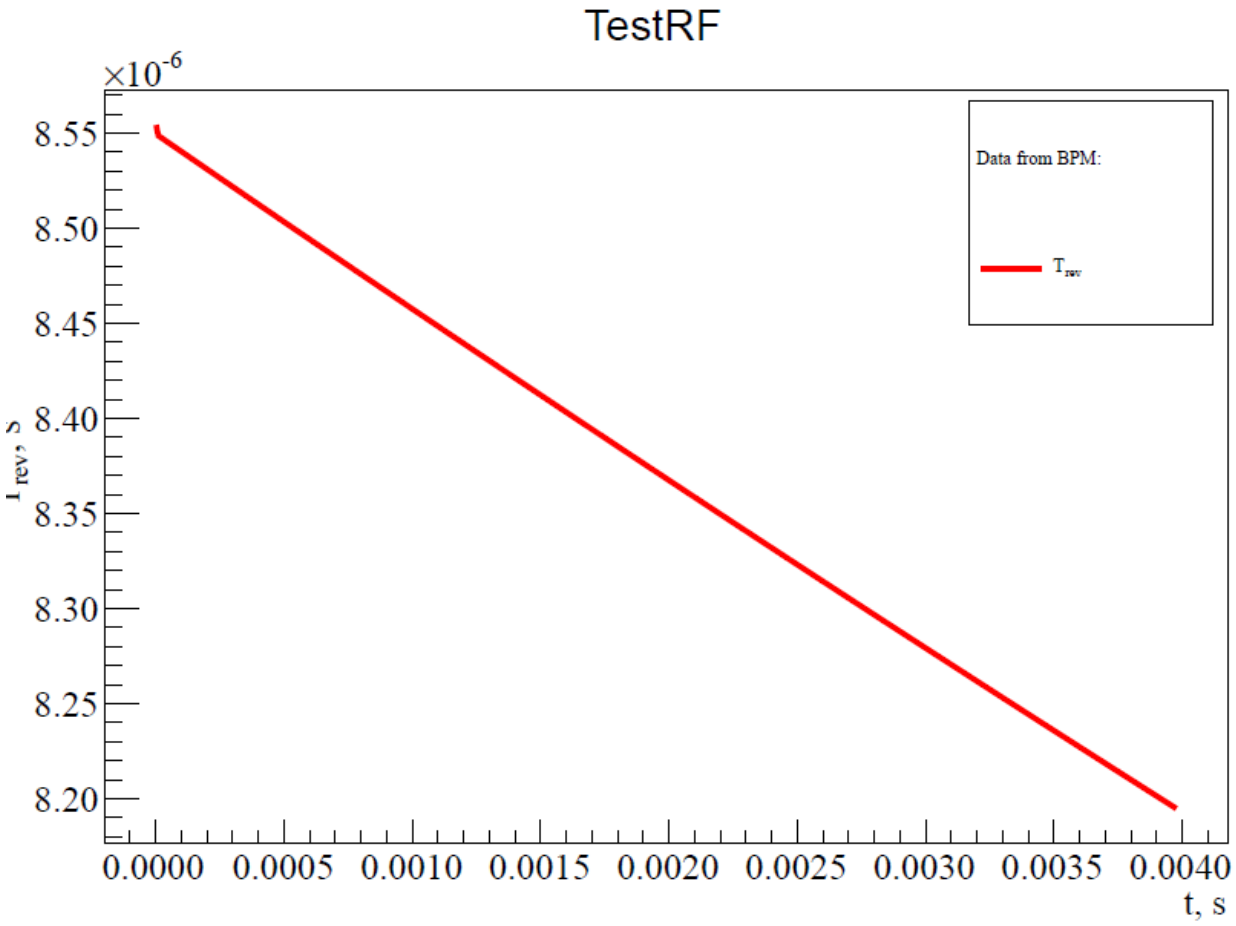
This device describes digital methods of Longitudinal Bunch Parameters in Synchrotrons. Dr. Vyacheslav Mikhailovich Zhabitsky described these methods. I used his code and static library in my project. This code allows process the data received from the first Device and to provide data for the period of revolution of the particles depending to the time. The obtained data is written to attributes T and Trev. The method of Dr. Zhabitsky uses constant which are incorporated in the properties of Device Server. At the end of the data attributes T and Trev are transmitted to the client application which generated graph.



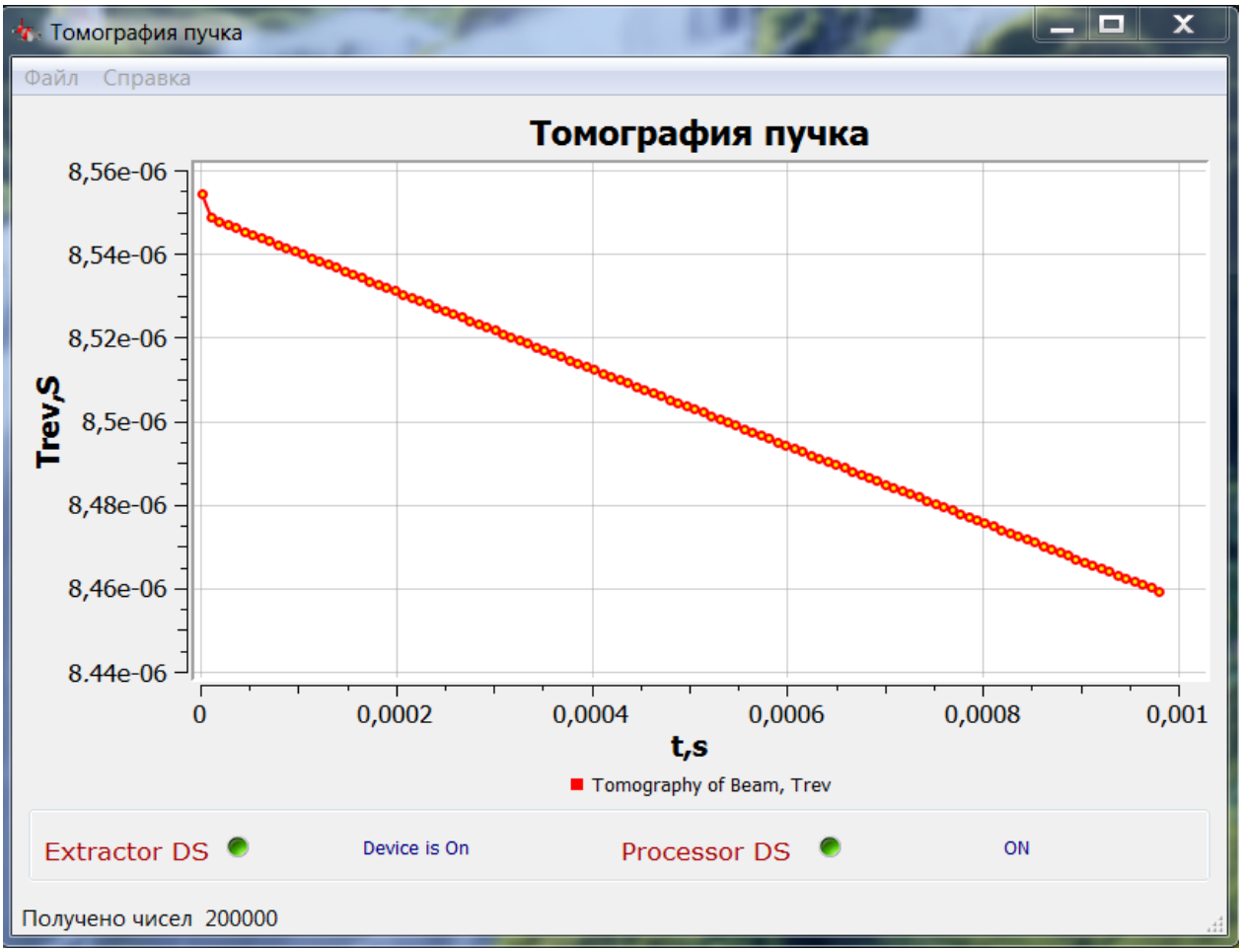
Jive displays information about the device

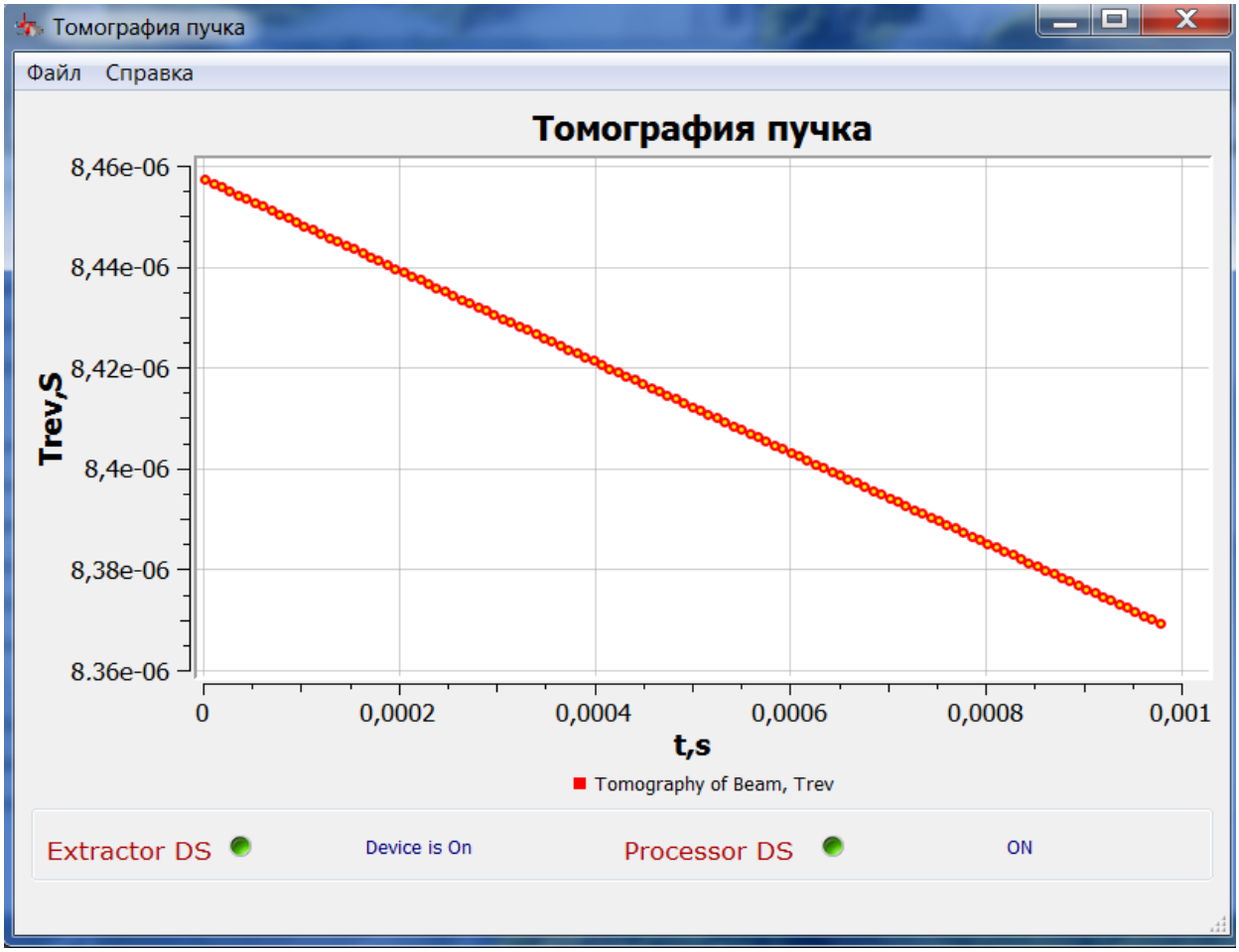
Implementing a custom client application to display depending on the period of revolution of the particles to the time

Client application built using the program QT Creator. Qt Creator is a cross-platform C++, JavaScript and QML integrated development environment. My program is written on C++ program language. QT Creator is a good tool for the development of programs of various complexities. My program is designed to use Graphical user interface (GUI). All the methods of implementation are described in one class MainWindow. Client application connects to Tango Device Servers BeamParamExtractor and BeamParamProcessor. We open the file in program and pass this data array in the first Device Server. After processing the data in the second Tango Device we have two data array from the attributes. These data array forming depend on the period of revolution of the particles to the time. Using the QWT library I display of graphic on the client application.



The dependence obtained by Dr. Zhabitsky





Dependences obtained in the client application

Conclusions

The main goal of the practices was to learn about C++ program language and programs as well as QT Creator, Microsoft Visual Studio and others. The task was to develop a program complex allowing to process the data obtained from the synchrotron to provide diagnostics of longitudinal bunch parameters. Results of work have been presented in these paper.

During the Summer Student Program at Joint Institute for Nuclear Research, I have analyzed a many systems to control large devices and enterprises. TANGO is the best system to control synchrotrons, lasers, physics experiments. This system has considerable advantages against existing. One of them, TANGO is a distributed control system. It is the standard to build a NICA accelerator complex control system.

During 8 weeks there was opportunity to work with one of the best programs to C++ programming – QT Creator.

As a result, I received invaluable experience which can be applied in any area.

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