STATUS OF THE GBAR CONTROL PROJECT AT CERN

P. Lotrus[†], A. Gaget, A. Gomes, G. A. Durand, Y. Le Noa, J. F. Lecointe, J. Y. Roussé,
Institute of Research into the Fundamental Laws of the Universe , Gif-sur-Yvette, France

Abstract

One yet unanswered questions in physics today concerns the action of gravity upon antimatter. The GBAR experiment [1] proposes to measure the free fall acceleration of neutral antihydrogen atoms. Installation of the project at CERN (ELENA) began in late 2016. This research project is facing new challenges and needs flexibility with hardware and software. EPICS modularity and distributed architecture has been tested for control system and for providing flexibility for future installation improvement. This paper describes the development of the software and the set of software tools that are being used on the project.

INTRODUCTION

The GBAR experiment [1] (see Fig. 1) is a collaboration of 14 institutes to build a precise measurement of the free fall acceleration of ultracold neutral anti hydrogen atoms in Earth's gravity field. This experiment is composed of several parts (source, trap, laser, beam line) provided by member institutes.
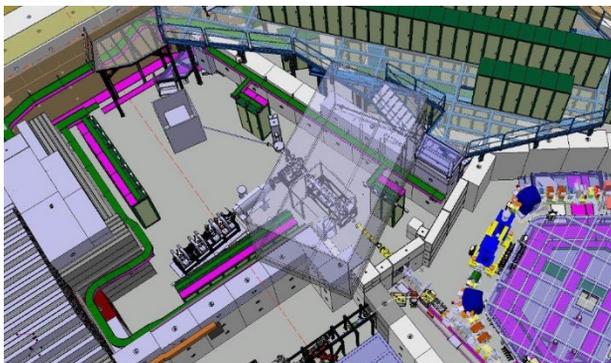
Figure 1: GBAR experiment CAO.

GBAR is currently in construction at CERN, Switzerland. More precisely, it is installed at the AD (Antiproton Decelerator) facility [2] connected to the new ELENA decelerator (Extra Low ENergie Antiproton) [3] which will provide a 100 keV antiproton beam.

To generate an antihydrogen atom, GBAR first needs two beam lines which transport a packet of positrons on one side and a packet of antiprotons on the other side.

To produce positrons, GBAR uses an electron LINAC (see Fig. 2) which will provide a 10 MeV beam at 300 Hz / 2μs. The electron beam hits a Tungsten target, many of the electrons pass through, but 0.5% of the electrons interact with the Tungsten by generating positrons.

Because we need a good amount of positrons for the reaction, the positrons will be trapped using two systems: a Buffer Gas and a Penning trap. The buffer gas is used as an injector to the high field Penning trap in order to increase

the efficiency of positrons that will be able to enter the second trap by 25%. The purpose of the second Penning trap is to accumulate 10^{10} positrons with an expected efficiency of 50%.

On the other side of the experiment, ELENA will provide a slow antiproton beam with an energy of 100 keV, which is still too fast for GBAR. For this reason, this beam will go through the decelerator which will decelerate the beam at an expected energy of 1 keV.

By synchronizing trapped positrons and antiprotons packets, both beams will interact in the reaction chamber. Several reactions will occur with the help of precise energy boost provided by a laser to increase the chance of generating few antihydrogen ion with an energy of 1 keV.

Antihydrogen ion will be transported to one trap to decelerate it at 1 to 6 eV, and move in a second trap placed in the free fall chamber to decrease its energy at 10 microK.

Now, what we want is antihydrogen ion becomes an electric neutral antihydrogen that will fall on the detectors. For that, another LASER will provide the energy to take off the ion extra positron. As we will know the distance between the trap and de detectors, plus the time at which the LASER as kick off the positron, we will be able to evaluate the effect of the earth gravity on the antimatter.
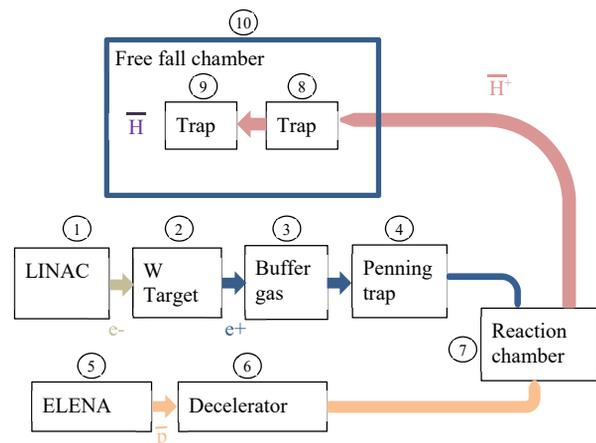
Figure 2: GBAR experiment principal.

CONTROL SYSTEM

Different part of GBAR is provided by a different institute with its own control system method and programming language like LabVIEW, Python, C++ and Siemens TIA Portal. EPICS is a good candidate for controlling all the different parts because we were able to find a communication driver for each of those languages.

IRFU is in charge of providing solutions for the main control system, and gives support to the front-end to integrate their software solutions to the EPICS [4] communication which is Channel Access.

Archive Appliance

The archive system is Archive Appliance [5]. This solution can manage large amounts of data, has easy web access and can extract information through JSON solution. For easy and rapid installation for other IRFU experiments, we have developed an Ansible [6] script to automate the installation on CentOS. This script will:

- Access Archive Appliance on the web, and its required software such as Tomcat, MySQL
- Customize the starting script and web interface
- Define the application as service.

CSS

The GUI (Graphical User Interface) software is CSS (Control Studio System). We are currently using the SNS version, but we are working on creating our own product CSS that would give us a way to add a specific plugin for a logbook electronic. GBAR will use as logbook ELOG from PSI [7]. In term of interface with CSS, this software solution provides an easy way to add information into it by using a system command.

Beast

For the alarm solution, we have chosen BEAST (Best Ever Alarm System Toolkit) from SNS/ORL [8]. The BEAST alarm server is combined with CSS (Control Studio System) [9] to display minor or major alarms. Users can configure CSS to send automatic emails and/or SMS for specific alarms.

Web Solutions

To provide information about the experiment status to the collaborators, we will install a web solution like webopi [10], webalarm and archive appliance. The experiment is composed of several high-tech parts and experts won't be able on site all the time, this set of web tools will help them to understand the state of GBAR.

NETWORK

Experiments installed at CERN can choose their software solutions but they have to follow certain network rules. CERN imposes their Ethernet manageable switches so they can create a local experiment network with possibilities to open specific doors with CERN's office network, called GPN (General Purpose Network). In the case of GBAR, the distance between the control room building and the experiment hall requires the installation of an optical fiber between the two CERN Ethernet switches.

Behind those switches, the experiment is in charge of its network. In our case, we have decided to defined two networks (see Fig. 3) called *instrument* and *GBAR*. This limits the number of IP addresses on one network, and protects the control acquisition part.

The instrument network is managed and provided by each institute. For decelerator experiment part, this network connects the different devices such as power sup-

plies, vacuum controllers and a front-end PC. This separation means that if another part of the experiment is not working well, it will not affect the decelerator part.

The second network, called GBAR, is the link between the main control system located in the control room, and the sub-systems. Each sub-system will have a front end with one Ethernet card connected on the GBAR network and another Ethernet card connected to the instrument network. This machine will be also running an IOC (Input Output Controller) which will provide information to the main control system.
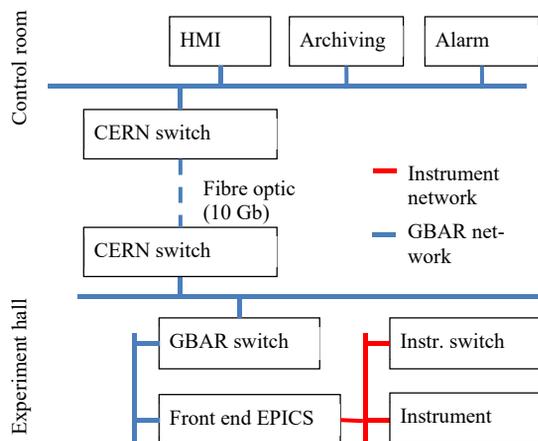
Figure 3: GBAR experiment network architecture.

CERN requires the experiment team to nominate collaborators to manage network administration and be the interface in case of dysfunction. Because the GBAR network is not completely separate from the CERN network GPN, the IT service provides a number of facilities that GBAR's administrators can configure by themselves. The configuration tool is accessible via web browser (see Fig. 4). It gives us the possibility to define specific accesses between GBAR and CERN network services, such as access to the Git server and website (GitLab), email server, backup disk and others, which is very convenient for a small experiment.
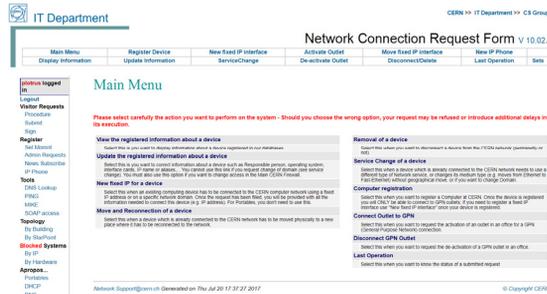
Figure 4: GBAR experiment principal.

MATERIAL PROTECTION

To protect material like vacuum and high voltage, we are using Compact RIO 9035 from National Instruments [11] in some parts of the experiment. The protection code has

been developed on the Compact RIO FPGA target. The code running on the Intel CPU (programming with Lab-VIEW RT) is in charge of the communication and other functionalities like the machine time to repair (MTTR) of a ion pump.

The Compact RIO 9035 configuration with an Intel CPU and a Xilinx FPGA has the advantage of not rebooting the FGPA program when the real-time is rebooting. As is, we can change EPICS variable names, download the new Lab-VIEW RT program without losing the protection, like for example, keep the valves in their initial states.

Research experiments like GBAR are using the system out of the predicted behaviour, this is the reason why most of the security limits can be changed through EPICS. For example, a user can modify the vacuum limit through CSS, which will send the new value to the LabVIEW RT program using Channel Access communication, then the Lab-VIEW RT program will use DMA (Direct Memory Access) functions to transfer the new value to the FPGA (see Fig. 5).
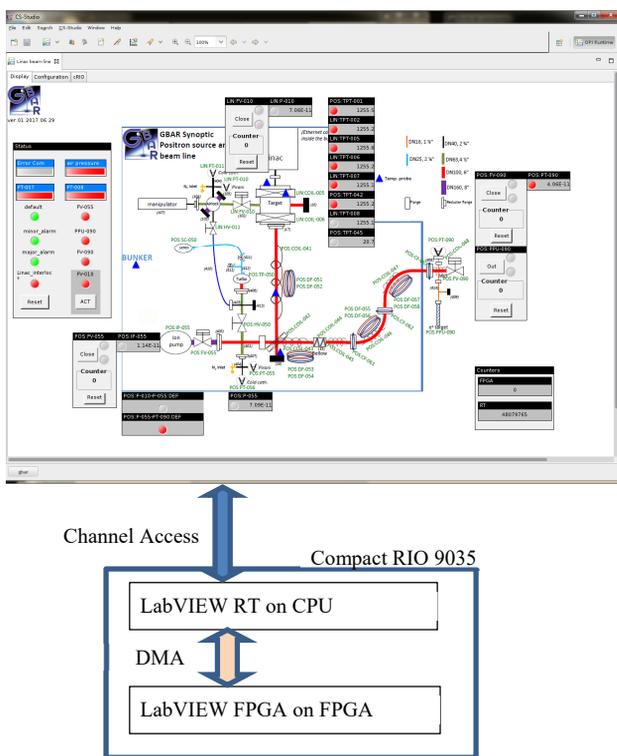
Figure 5: GBAR experiment network architecture.

EPICS server from National Instrument is used as a Channel Access server. As we use the Compact RIO for a protection system, we need to configure OSV and ZSV EP-ICS fields on certain Boolean records. Unfortunately, Lab-VIEW EPICS server doesn't provide function to change record fields others than 'VAL' field, even if they are cre-ated. A way to configure the alarm fields, is to use EPICS command caput, or creating a LabVIEW EPICS client.

SIEMENS PLC

To get information about the Siemens PLC (Program-ming Logical Controller), we will use EPICS S7PLC driver running on a PC with CentOS 7. Because moving parts and dust on a PC are the major dysfunction reasons, we will use a Nexcom NISE 3500 with no fan, SSD hard disk

CONCLUSION

GBAR experiment is under construction, the LINAC and the decelerator are physically installed, and we are ex-pecting the installation of the buffer gas and the Penning trap before the end of the year. EPICS archiving, alarm and GUI are installed and working well, but we still have work on configuring systems. LabVIEW IOC drivers have been developed for now, other languages are starting to be tested, so in a few, we will be able to purpose solutions for our partners. Main network installation is done, we are able to connect devices. Network configuration is still in pro-gress, more services need to be configured and/or tested.

ACKNOWLEDGMENT

We are grateful to CERN for their support, especially for the ability to access their software services, licences and technical support. We want to especially thank the network team for their help and patience.

REFERENCES

[1] GBAR, http://gbar.web.cern.ch/GBAR/.

[2] AD, https://home.cern/about/accelerators/antipro-ton-decelerator/.

[3] ELENA, https://home.cern/about/accelerators/anti-proton-decelerator/.

[4] EPICS collaboration, http://www.aps.anl.gov/epics/.

[5] M. Shankar, "New Archiver Appliance", *EPICS Meeting 2013*, San Francisco, USA (2013).

[6] Ansible, http://www.ansible.com/.

[7] ELOG from PSI, https://midas.psi.ch/elog/.

[8] K.-U. Kasemir, X. H. Chen and E. Danilova, "The Best Ever Alarm System Toolkit", in *Proc. ICALEPCS'09*, Kobe, Japan, October 2009, paper TUA001.

[9] Control System Studio software toolbox, http://control-systemstudio.org/.

[10] K.-U. Kasemir, X. H. Chen, E. Danilova, J. D. Purcell, "SNS Online Display Technologies for EPICS", in *Proc. ICALEPCS'11*, Grenoble, France, October 2011, paper THBHAUST01.

[11] National Instruments, http://www.ni.com/.