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MULTI-USER VIRTUAL ACCELERATOR AT HEPS FOR HIGH-LEVEL APPLICATION DEVELOPMENT AND BEAM COMMISSIONING*

Xiaohan Lu†, Yi Jiao, Jingyi Li, Nan Li, Cai Meng, Yuemei Peng, Peng Zhu, Gang Xu
Institute of High Energy Physics, Chinese Academy of Sciences, Beijing, China

Abstract

To meet the beam commissioning requirements of HEPS, a new framework named PYthon-based Accelerator Physics Application Set (Pyapas) was developed for building high level applications (HLAs) for HEPS. Based on *Pyapas*, the application development for Linac was completed in June 2022. To test the HLAs before putting them online, a multi-user virtual accelerator based on *Pyapas* was developed. It provides a virtual environment of the real machine, including virtual devices, beam parameters, errors and so on. The HLAs tested on the MUVA can be seamless applied to the real beam commissioning. This paper briefly introduces the MUVA system.

INTRODUCTION

The High Energy Photon Source (HEPS) is a 6 GeV, 1.3 km, fourth-generation light source [1-3]. It began construction in Beijing, China in mid-2019 and is expected to become one of the world's smallest emittance light sources after completion. In order to meet the beam commissioning needs of HEPS, a new framework *Pyapas* was designed for developing the high-level applications (HLAs) [4]. To test the HLAs before putting them online, a virtual accelerator is necessary.

The virtual accelerator system not only provides a virtual hardware environment, but also provides real-time information on various beam parameters under different fault conditions. By performing beam commissioning simulations on a virtual accelerator before building the machine, it is possible to identify key factors that could potentially affect the performance of the machine under construction. Based on these findings, appropriate countermeasures can be formulated, greatly facilitating the timely completion of design goals. At the same time, the development of HLAs relies heavily on the support of virtual accelerators. A comprehensive virtual accelerator system can be used to test the usability of the application and the accuracy of the calculation and optimization results.

At HEPS, a multi-user virtual accelerator system has been developed for testing the HLAs and simulating the effects of various errors on the results of beam commissioning. The virtual accelerator is based on the *Pyapas* development framework for HLA and is designed using a client/server (C/S) architecture. It uses Ocelot [5] with custom multipole field models for physical calculations and supports error simulation for various magnet and beam instrumentation and diagnostics devices. Calculation results are sent externally through the EPICS PV channel. The multi-user virtual accelerator system was developed to meet the needs of different users within the same network area who need to simultaneously call the virtual accelerator for software debugging and simulation research. Each user can open a unique virtual accelerator without affecting others, and can also start different virtual accelerators for different research content. The number of virtual accelerators opened is not limited. The operation of the entire virtual accelerator system can be easily switched on and off like opening an app, greatly facilitating user use. As shown in Fig.1 in the overall control system the virtual accelerator and the low-level control system are at the same level. The HLAs are capable of connecting to either the low-level control system or the virtual accelerator

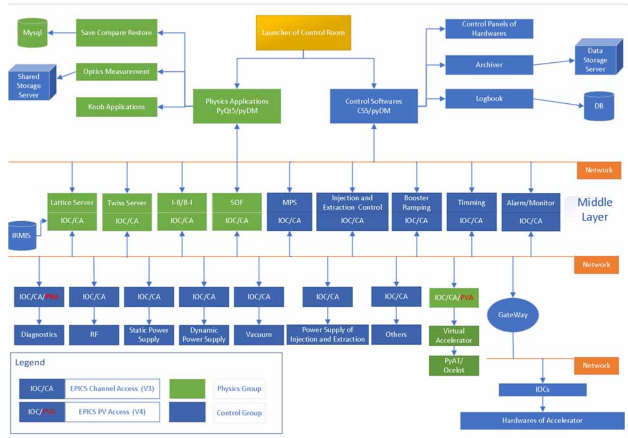

Figure 1: The control system architecture diagram of HEPS.

With the help of MUVA we completed the development of HLAs for Linac [6] and successfully applied to beam commissioning [7, 8]. This paper provides a detailed description of the design concept and implementation of the MUVA system.

FRAMEWORK DESIGN OF MUVA

The MUVA comprises of three critical components. Firstly, a set of accurate physical computation models that can effectively and promptly compute the necessary beam parameter data based on different hardware system parameters. We use Ocelot as the basic physical calculation models and develop some new models to simulate combined magnets.

Secondly, a comprehensive virtual hardware system is designed to simulate the control and interaction scenarios with the actual hardware system. The control system of HEPS are built with EPICS, thus the key component is to setup EPICS run-time database dynamically. With *Pyapas* framework, there is a lattice file to describe the real ma-

* Work supported by NSFC12005239
† luxh@ihep.ac.cn

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chine in detail, including the position, length, type, correlated EPICS PV names etc. A script was developed to setup the EPICS run-time database from the lattice file and launch the database with procServ [9] which can put the IOC in background.

Thirdly, a namespace mechanism is introduced to launch more than one virtual accelerator instance on the same cluster or same network area. EPICS PVs must be unique within the same network area, failure to ensure PVs have unique names can result in ambiguity and prevent the application from establishing connections. Thus, there can only have one virtual accelerator instance within the same network area. In fact, different developers will focus on different applications for same sequence at the same time, it is inefficient with only one virtual accelerator instance. It will be helpful if we can launch multi virtual accelerator instance and operate them independently. To address this issue, a namespace mechanism is designed to configure the independent EPICS database with same lattice.

For convenient information exchange between the HLA and the virtual accelerator, the client/server architecture is employed to function the virtual accelerator as a service on a server, thus enabling continuous operation 24/7. A dedicated client is developed to manage the virtual accelerator instance, as shown in Fig. 2.

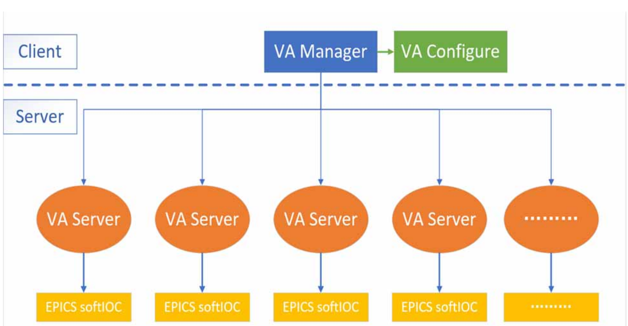

Figure 2: The framework of Multi-User Virtual Accelerator.

MUVA FOR LINAC

To meet the beam commissioning needs of the Linac, we developed corresponding HLAs based on *Pyapas*, including orbit correction, emittance measurement, energy spread and energy measurement, phase scan, and physics-based control application [7]. And a MUVA for Linac was also developed to test the HLAs, as shown in Fig. 3. The MUVA for Linac can provide the beam profile information and the beam orbit. These information are sent through the virtual diagnostics. We also can add virous types of errors to check the ability of the HLAs.

All the HLAs were fully tested on the MUVA system before going online. Figure 4 shows the result of the beam-based alignment application running on the MUVA, the result is very close to the pre-set offset. In March 9, 2023, we began the beam commissioning of the Linac. As a result of the previous comprehensive preparations, full beam transmission was achieved quickly, and the design energy was reached. The MUVA system played a crucial role in this achievement.

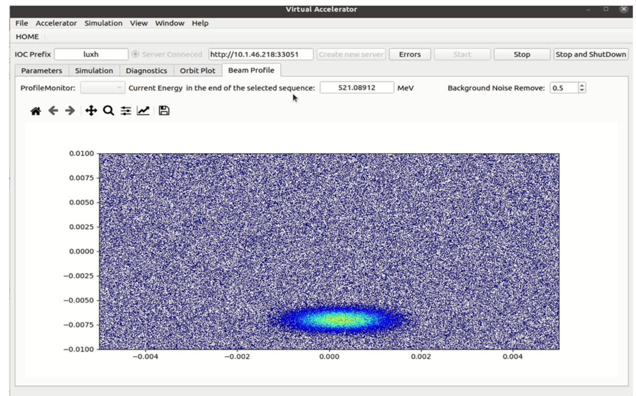

Figure 3: The MUVA for Linac.

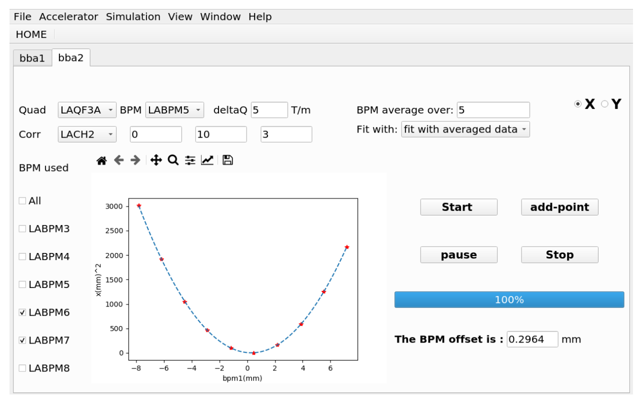

Figure 4: The beam based alignment result based on MUVA.

CONCLUSION

To meet the beam commissioning requirements of the HEPS, the new HLA development framework *Pyapas* had been designed. Based *Pyapas*, we developed a MUVA system to test the HLAs and beam commissioning. The MUVA system use Ocelot as its core calculation models and with namespace mechanism can be launched multi instances within the same network area. It is very helpful for the development team to test different applications and different contents within the same network area. For the moment, the MUVA system performs well in testing the HLAs, but it's not precise enough to forecast the beam behaviour. More physical and error models are currently being developed.

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