



Image Acquisition and Analysis for Beam Diagnostics Applications of the Taiwan Photon Source

C.Y. Liao[#], C.H. Kuo, C.Y. Wu, Y.S. Cheng, K.H. Hu, Jenny Chen, K.T. Hsu
NSRRC, Hsinchu 30076, Taiwan



Abstract

Design and implementation of image acquisition and analysis is in proceeding for the Taiwan Photon Source (TPS) diagnostic applications. The optical system contains screen, lens, and lighting system. A CCD camera with Gigabit Ethernet interface (GigE Vision) will be a standard image acquisition device. Image acquisition will be done on EPICS IOC via PV channel and analysis the properties by using Matlab tool to evaluate the beam profile (sigma), beam size position and tilt angle et al. The EPICS IOC integrated with Matlab as a data processing system is not only could be used in image analysis but also in many types of equipment data processing applications. Progress of the project will be summarized in this report.

Introduction

- For optimize machine operation and diagnostics applications, the fluorescent screens convert the beam flux into a 2D beam profile images recorded by CCD cameras which have extensive information on beam parameters (beam center, sigma, and tilt angle).
- The most of machine parameters in TPS will be accessible as EPICS (Experimental Physics and Industrial Control System) process variables (PVs), Matlab was chosen as an analysis tool with ability to calculate and display results in complex ways.
- This report presents an EPICS integrated with Matlab as a data processing system, which is not only could be used in image analysis but also in other equipments data processing.

Overview of Infrastructure

Hardware

- The hardware components include a computer, Gigabit switch, and cameras. The computer system based on EPICS 3.14.10 (Linux, 2.6.18) can act as a soft IOC (Input / Output Controller) which is used to communicate to cameras and collect images data via Ethernet.
- The Prosilica GC650 VGA-resolution CCD camera with GigE Vision is used which consists of 659x493 (Cell size 7.4 μm) light-sensitive pixels. The cameras have external trigger input port which can be used to receive trigger signal from timing system (EVG/EVR) for periodic data acquisition.

Software

- The software components are constructed by EDM (Extensible Display Manager, 1.12.xx) and Matlab for cameras controlling and data analysing, respectively. All data are sent over the Ethernet network.
- The camera driver EPICS support is built by the areaDetector module which provides a general-purpose interface for area (2-D) detectors at lower-level based on asynDriver. The EDM (Fig. 2) was used to construct a client OPI for remote control the camera parameters.
- Two compiled Matlab programs were used; one is analysis program, the other display GUI.
 - ✓ The **Analysis Program** is continuously running inside the EPICS IOC's PC, through the Channel Access (CA, LabCA), it can read the raw image data from the EPICS database, analyzed it, and then store the results back to the database records.
 - ✓ The **Display GUI** acts as client OPI which can show the analysis results in multiple clients simultaneously.
- Matlab provides a familiar environment and shows easy and efficient ways to reduce the development time and effort. The compiled Matlab programs help us to develop standalone Matlab application without running it in Matlab prompt which can save budget requirement of expensive licence fee.

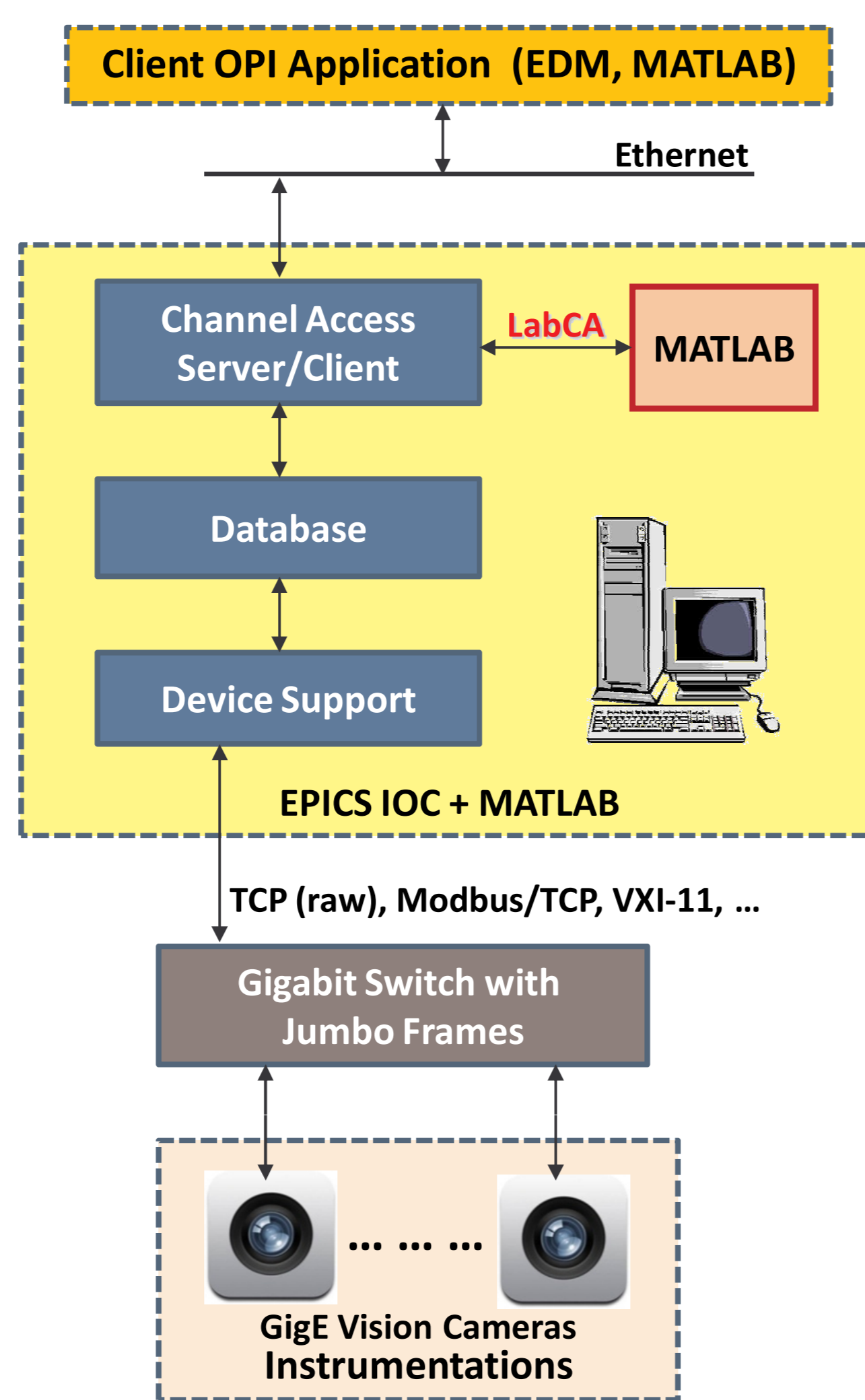


Fig 1. Overview of infrastructure.

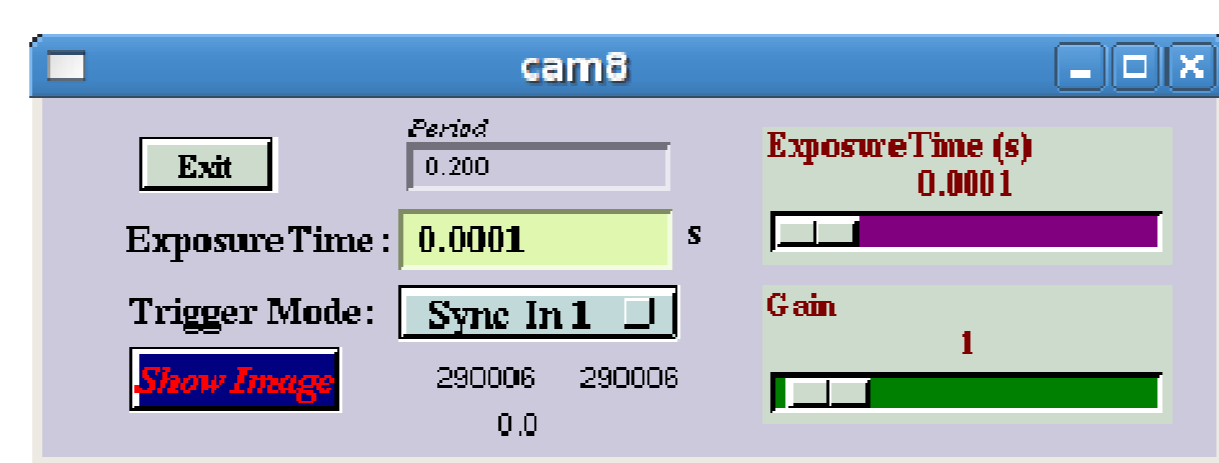


Fig 2. EDM camera control panel.

Features Development

- The Matlab analysis program runs in IOC's PC as a background task which can do a complex analytical work to analyze the beam parameters, including the beam center, sigma, and tilt angle. It can specify the region-of-interest (ROI) for clipping the image of each individual camera, and do an optional background subtraction and software multiple exposures. All the analyzed data will store into the EPICS IOC as PVs. The detail flow chart of the program is shown in Fig. 3.
- The layout of the Matlab display GUI is shown in Fig. 4. The GUI can run in multiple clients simultaneously and read the analysis results from EPICS IOC and display them in the window. The detail flow chart of the program is shown in Fig. 5.

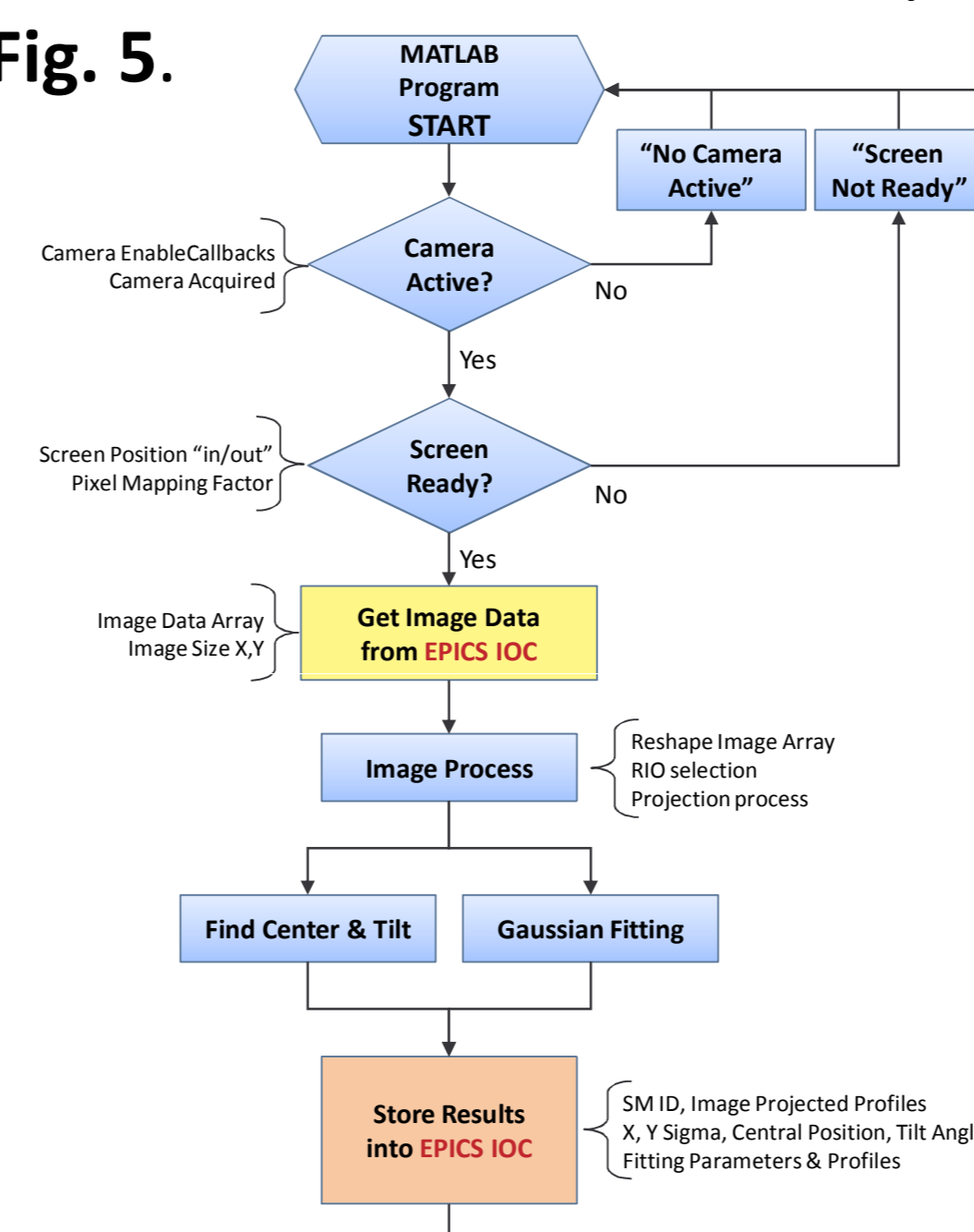


Fig 3. Flow chart of Matlab analysis program.

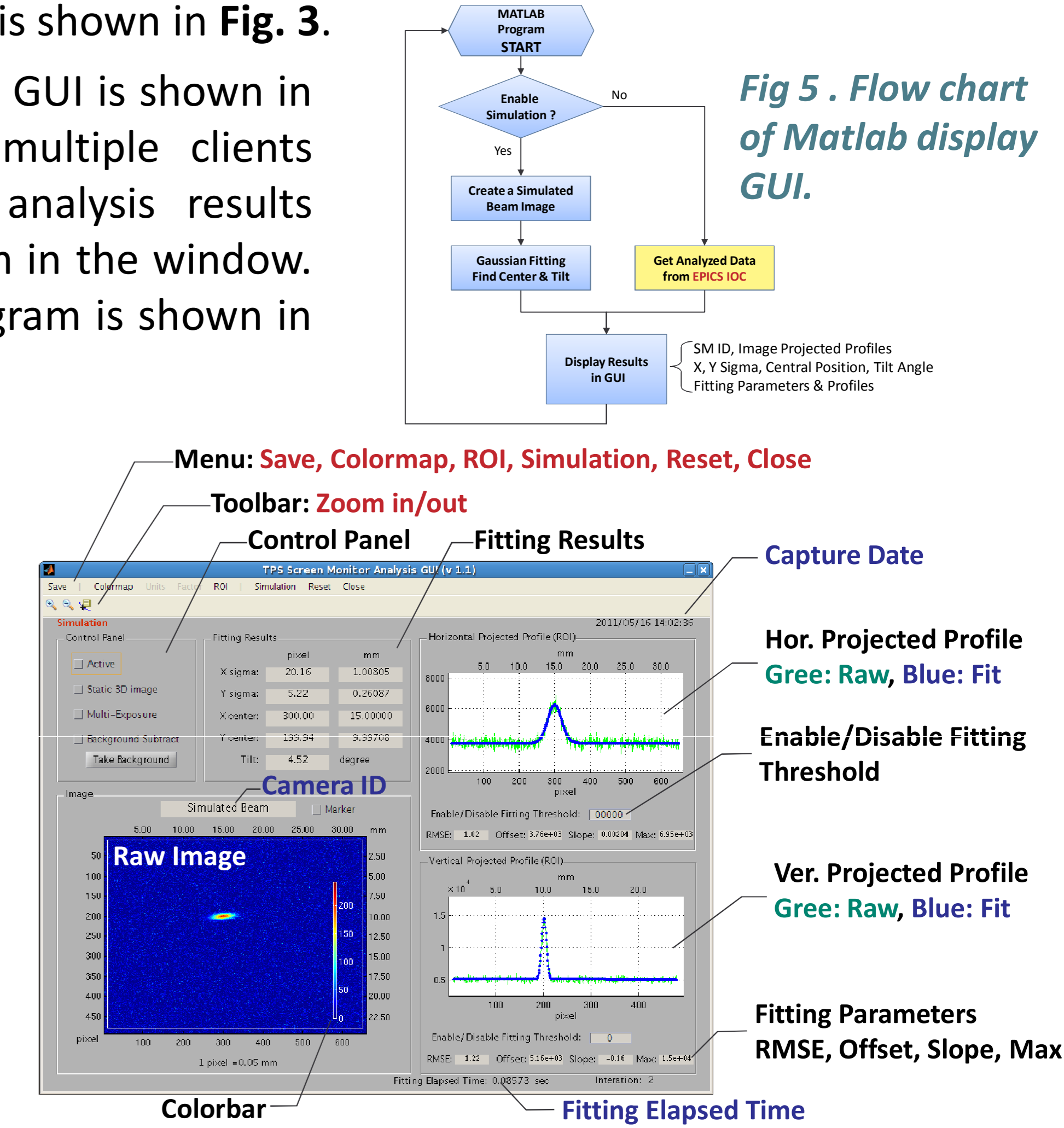


Fig 4. Layout of the Matlab display GUI.

Implementation in TPS Linac

- The beam profile of the TPS 150 MeV linac is measured by five YAG:Ce screens. The resolution of the configuration is around 60 $\mu\text{m}/\text{pixel}$, which is acceptable for TPS current beam size of ~ 0.5 mm order.
- The real beam profile (Fig. 7), on the after of gun, was analysis. The sigma of beam size is in sub-mm order, and tilt angle is also shown in the GUI. The unusual diffraction is probably a reflection due to the edge of the YAG:Ce crystal disk. Fortunately, it can be easily ignored by the ROI function. All fitted parameters will be stored as EPICS PVs such that clients can easily access it for further usage.

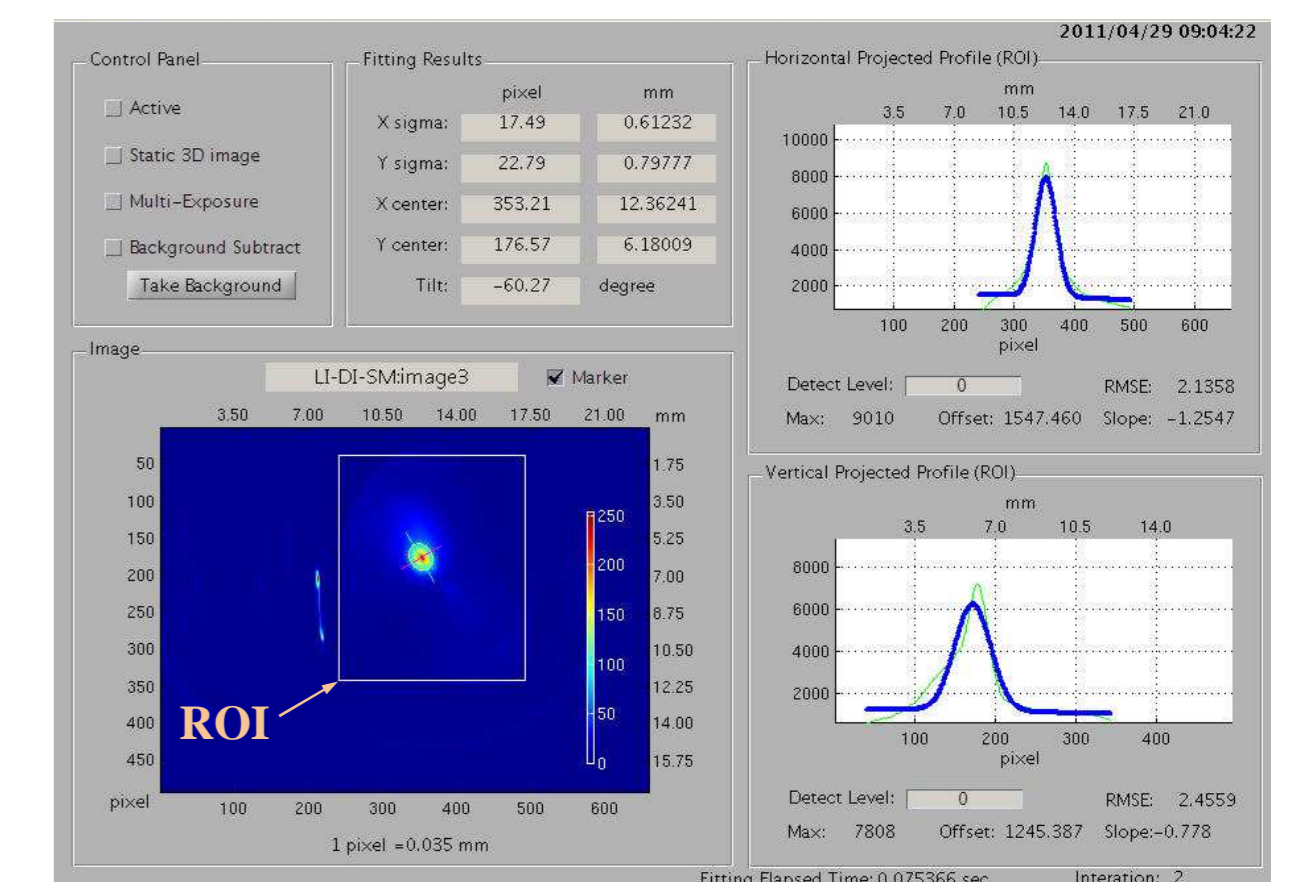


Fig 7. Screen monitor analysis GUI for real beam profile.

Timing Evaluation

- There are two key processes can affect the time required (Table 1). One is read/write data (including some conditions and raw image data array) from PVs via EPICS channel access, and the other is projected profiles analysis (including two times of fitting process (horizontal and vertical) and tilt angle recognition).
- The maxima processing rate of program can be up to 9 Hz, which is the worst case due to the computer has other tasks to handle at the same time, but this result still acceptable for TPS 3 Hz facility.
- In future the repetition rate can expect up to 10 Hz rate or higher rate by using a dedicated computer which would be beneficial for many applications.

Table 1: Timing of the analysis program.

Process	Time Required (ms)
Read/Write data from PVs	< 30
Data process	< 80
Total	< 110

Future Works

- EPICS IOC integrated with Matlab as a data processing system is a simple way to develop an application quickly, which can be extended to other applications, such as beam lifetime calculation, filling pattern measurement, real-time oscilloscope waveform analysis, and synchrotron radiation monitor image analysis etc.
- Waveform analysis will be very useful to monitoring the pulse system functionality and stability likes linac microwave system, and pulse magnets system (septa and kickers).

Summary

- A data processing system using Matlab to assist EPICS IOC to improve its calculation ability, which will become an alternative solution for complex data analysis.
- This infrastructure has been implemented and regularly used on screen monitor image analysis for TPS linac diagnostics application.
- From performance point of view, there would be no problem running the application on TPS, due to TPS injector repetition rate is 3 Hz. This solution can be extended to other applications in future.