

# An Overview of the Database Framework for GEM Detector under CMS Experiment at CERN

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In this paper, we give an overview of the database framework which we have developed for the Gas Electron Multiplier (GEM) Detector at CERN. The GEM constitutes a powerful addition to the family of fast radiation detectors; originally developed for particle physics experiments, and has spawned a large number of developments and applications. The GEM database framework comprises four components. The first component is the database itself. There are three instances of the database which have been deployed. One is for the development purpose which contains test data, other one is for the integration purposes while the last one is for the production purpose which contains real data. The database further comprises various schemas and each schema consists of different tables in it. We use separate schemas for various types of tables. The second component of the database framework is called DB Loader. The DB Loader is used to load data into database. The data is prepared in the predefined format which is in the XML form. Then the xml file is copied into a spool area of the server in which DB loader is running. Once the file is copied, the DB Loader loads the file into the database. The loader returns appropriate status codes after performing database insertion/update operation. The status of the database operations is checked against the status code which is returned by the loader. The third component of the database framework comprises graphical user interface (GUI). This is a web-based interface which can be accessed from the internet. This interface is basically used for the detector construction and to perform various quality control tests on the detector and its components. The last component of the database framework is called online monitoring system (OMS). The OMS is data visualization framework for the various detectors of the CMS experiment at CERN. It is also used to display data for the GEM. It enables users to view and retrieve database contents without having to learn database specifics.

*International Symposium on Grids and Clouds (ISGC) 2019*  
31 March 2019 to 5 April 2019  
Academia Sinica, Taipei, Taiwan

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## 1. Introduction

The Gas Electron Multiplier (GEM) is a proven amplification technique for position detection of ionising radiation such as charged particles, photons, X-rays and neutrons, in gas detectors. The GEM is a detector containing a densely pierced polymer foil coated with electrodes on both sides which is able to achieve high amplification gains and performance at low cost, even under harsh conditions. A GEM consists of a thin, metal-clad polymer foil, chemically pierced by a high density of holes. On application of a difference of potential between the two electrodes, electrons released by radiation in the gas on one side of the structure drift into the holes, multiply and transfer to a collection region. This gas detector is extensively used in High Energy Physics [1]. GEMs were invented in 1997 in the Gas Detector Development Group [2] at CERN by physicist Fabio Sauli [3]. The diagram of GEM detector is shown in Figure 1.

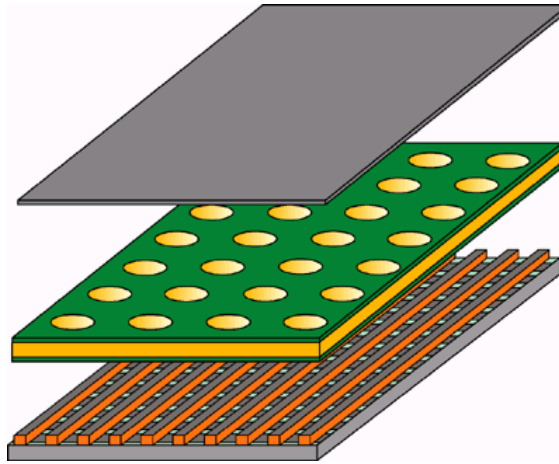


Figure 1: The Gas Electron Multiplier

The National Centre for Physics (NCP) is an academic national research institute which is located in Islamabad, Pakistan [4]. It has been established to promote research in physics and applied disciplines in Pakistan. The experimental high energy physics (EHEP) group of NCP is actively involved in various collaborative research projects, particularly related to the Large Hadron Collider (LHC) at CERN, Switzerland [5]. GEM detector is a part of the CMS which is one of the four LHC experiments at CERN. The members of the EHEP group are contributing to the analysis of LHC data. The large amount of data produced at CERN has been managed by NCP through the Worldwide LHC Computing Grid (WLCG). Software development group at NCP took the project of GEM database and its relevant web interfaces in year 2017. Currently, our group is actively involved and leading this project in collaboration with CERN.

In this paper, we give an overview of the database framework which we have developed for the GEM Detector at CERN. The GEM database framework comprises four components. The first component is the database itself. There are three instances of the database which have been deployed. One is for the development purpose which contains test data, other one is for the integration purposes while the last one is for the production purpose which contains real data. The database further comprises various schemas and each schema consists of different tables in it. We use separate schemas for various types of tables.

The second component of the database framework is called DB Loader. The DB Loader is used to load data into database. The data is prepared in the predefined format which is in the XML form. Then the xml file is copied into a spool area of the server in which DB loader is running. Once the file is copied, the DB Loader loads the file into the database. The loader returns appropriate status codes after performing database insertion/update operation. The status of the database operations is checked against the status code which is returned by the loader. The loader also accepts zip files and extracts XML files from the zip file and loads them into database for batch data upload.

The third component of the database framework comprises GUI. This is a web-based interface which can be accessed from the internet. This interface is used to generate XML files and send them to the DB Loader for data loading. This interface is basically used for the detector construction and to perform various quality control tests on the detector and its components. In the first stage, individual components of the detector are registered such as foils, electronic boards, readout boards, drift boards, VFATS, external frames, opto hybrids, cooling plate circuits, temperature sensors and radmon sensors etc. In the second stage, the chamber is constructed using these individual components. In the next step, super chamber is constructed using two chambers. The various QC tests are performed on individual components, chambers and super chambers. The GUI is used to load the data for various QC tests. Currently, the GUI has the data loading facility ranging from QC2 to QC8.

The last component of the database framework is called OMS. The OMS is data visualization framework for the various detectors of the CMS experiment at CERN. It is also used to display data for the GEM. It enables users to view and retrieve database contents without having to learn database specifics.

The remainder of the paper is organized as follows. Section 2 describes database components. Section 3 states regarding DB Loader. Section 4 presents web interface. Section 5 discusses online monitoring system. Finally we conclude in section 6.

## **2. Database**

A database is an organized collection of data, generally stored and accessed electronically from a computer system. The database is the first component of this GEM database framework. The databases for GEM detector are based on Oracle technologies. There are three instances of the database which have been deployed. One is for the development purpose which contains test data, other one is for the integration purpose and last one is for the production purpose which contains real data. The database further comprises various schemas and each schema has different tables in it. We use separate schemas for various types of tables.

The design of the database for GEM is generic and is in coherence with the design of the databases of other sub-detectors located under CMS experiment in CERN such as Pixels, HCAL, GEM, Tracker and CT-PPS etc.

### **2.1 Database Instances**

There are three instances of GEM databases deployed. The first instance is deployed in CERN IT department. This instance is used for development purposes. It consists of test data which is mainly inserted during development of new tables / functionalities. The data can be wiped out

and refreshed with data from production when needed. The second instance is deployed in point 5 (P5). The P5 is the site of CERN which physically hosts CMS detector. This instance is used for integration purposes. The data in this instance can also be wiped out and refreshed with data from production when needed. The third instance is also deployed in P5. It is used for production purposes and it consists of actual real data. The data is regularly backed up and is never deleted.

## 2.2 Types of Databases

The database is used to store various types of data i.e., detector construction data, detector configuration data and detector conditions data. The construction database is used to store detector construction data. It is a well managed central database that is globally accessible and plays a critical role in constructing and integrating the detector. This database provides track of flow of components/parts. It is also used to store various quality control tests information regarding detectors and their components.

Upon completion of detector construction, the database transitions to a configuration database. The construction DB maintains relationships between the various components and defines detector hierarchy while configuration DB is used to store configuration information. Every single detector channel is specified in database. Readout electronics hierarchy is also stored in database. Thus mapping detector to readout channels becomes straightforward. The configuration DB also consists of Tag/IOV or Config Keys and Aliases which are used to configure the detector for data taking. For example VFAT2, VFAT3, AMC and OH configuration data is used to configure detector.

The condition database is the third type of the database which is used to store detector monitoring data. For example, it can map detector components to corresponding PVSS data (where applicable). In general, it stores any type of data needed to monitor detector performance.

## 2.3 Database Schemas

The GEM database schemas are categorized into two types which are referred as core schemas and user schemas. There are five core schemas and two user schemas in GEM database.

### 2.3.1 Core Schemas

The core schemas and their purpose of usage are shown in Table 1. Each core schema consists of multiple interconnected tables. Schemas are tightly coupled. Tables in the core schemas are fixed and these cannot be altered.

Table 1: GEM Database Core Schemas

Schema Name	Purpose of Usage
CMS_GEM_CORE_CONSTRUCT	store detector components
CMS_GEM_CORE_ATTRIBUTES	store attributes of components and conditions
CMS_GEM_CORE_COND	store metadata
CMS_GEM_CORE_IOV_MGMNT	store configuration keys, IOVs, Tags, etc.
CMS_GEM_CORE_MANAGEMNT	store management info such as location, institution, etc.

### 2.3.2 User Schemas

The user schemas and their purpose of usage are shown in Table 2. New tables are added only to the user schema CMS\_GEM\_MUON\_COND as needed. Data from multiple tables are brought together and presented as views in CMS\_GEM\_MUON\_VIEW schema.

Table 2: GEM Database User Schemas

Schema Name	Purpose of Usage
CMS_GEM_MUON_COND	to store tables for all user generated data
CMS_GEM_MUON_VIEW	to store all database views

### 3. DB Loader

DB Loader is the second component of GEM database framework. It is used to load data into database. This tool was created with one main goal i.e. to upload specific XML files to Oracle DB specific schema. It was developed by another developer (Valdas Rapsevicius) and is available at GitHub Link [6].

The working mechanism of the DB Loader is very simple and it is shown in Figure 2. It has pool area in which XML / Zip files are copied. Db Loader loads these files into database. The status of the file can be checked after copying. DB Loader returns different status code for every file which shows success / failure operation.

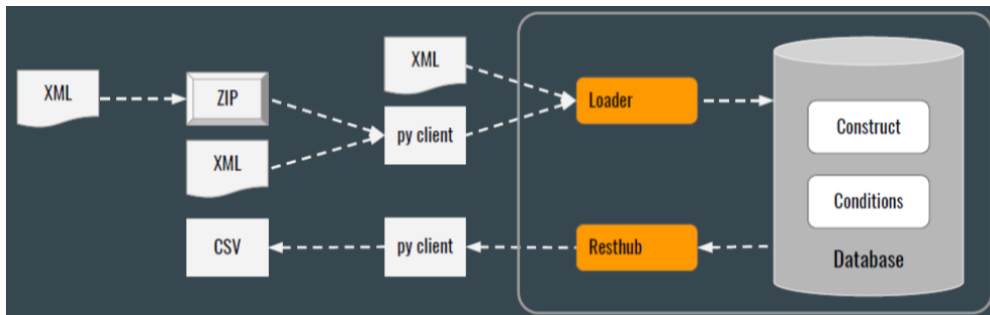


Figure 2: DB Loader

The most basic service usage is copying files into a special location and waiting for them to be processed by service running in the background. The processing can be monitored by checking the status and inspecting log files. For example, the file "somefile.xml" related to the GEM detector will be attached to the database residing on a computer named "dbloader-gem.cern.ch". The following command is used on the Linux shell environment to copy the file into specific location of DB Loader.

```
scp somefile.xml dbloader-gem.cern.ch:/home/dbspool/spool/gem/int2r
```

The user should have access to the machine to copy the files into the spool area. After the file is copied, its status can be checked using following command.

```
scp dbloader-gem.cern.ch:/home/dbspool/state/gem/int2r/somefile.xml /dev/stdout
```

The status code 0 shows success operation while any other code apart from 0 represents failure operations. Log file is also created for every file uploaded to the DB Loader. For more detailed description of the operation, the log file can be read. The following command can be used to read the log file.

```
scp dbloader-gem.cern.ch:/home/dbspool/logs/gem/int2r/somefile.xml /dev/stdout | less
```

Above example displays file copying operations for development database. The same procedure is used to upload the data into production database. However, double tunnel is required for production database as it is located under point 5 at CERN which is not accessible directly and has an extra layer of security. The machine which is used for DB Loader regarding production database is "srv-s2g18-33-01.cms". Rest of the procedure is same. Apart from the data insertion, Resthub APIs are used to read the data from the database as shown in Figure 2.

#### 4. GEM Web Interface

GEM Web Interface is the third component of the GEM Database Framework. There are two web interfaces one each for development and production environments. The web interface for development environment is accessible through URL [7] while web interface for production environment is accessible through URL [8]. The user should need to subscribe two e-groups of CERN in order to have access to these interfaces. The e-group for development environment web interface is CMS-GEM-DB-GROUP while e-group for production environment web interface is CMS-GEM-DB-PROD-GUI.

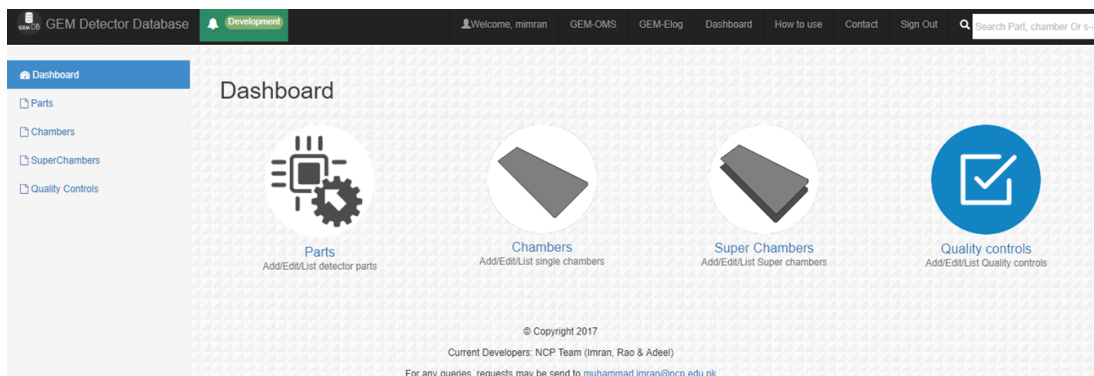


Figure 3: GEM Web Interface

The screenshot of the GEM web interface is shown in Figure 3. This interface is used for entering detector construction data. It is used to load various detector components to build chamber and super chambers. All the production sites use this interface to construct chambers. It also deals with Quality Controls (QCs).

##### 4.1 Registration of Components

In the first step, individual components are registered to the database. For example various components such as Foils, Drifts, Readouts, VFATS, GEBs, External Frames, OptoHybrids, Cooling Plate Circuits, Temperature Sensors, Radmon Sensors etc are registered to the database. The

web interface takes input from users through a form and creates relevant XML file. Then the created XML file is sent to the DB Loader for data uploading. In this way, users are not required to know exactly the template of XML file and copy file manually to the DB Loader.

#### **4.2 Registration of Chambers and Super Chambers**

Once, individual components are registered, the next step is to register the associated chamber and super chamber. There is a parent-to-child relationship between a chamber and its individual components. For example, to register a chamber we need 3 Foils, 1 Drift PCB, 1 Readout PCB, GEB Wide and GEB Narrow, 1 Optohybrid, 1 GEM External Frames, 1 Cooling Plates Circuits, 1 Temperature Sensor and 1 Radmon Sensors. Cooling Plates Circuits, Temperature Sensor and Radmon Sensors are optional components while all other components are mandatory. All these components can be attached / detached to / from chamber. VFATs are the only components that are not attached to the chambers directly. Instead these are attached to GEB Wide and GEB Narrow. 12 VFATs are attached to GEB Wide and 12 VFATs are attached to GEB Narrow. Once chambers are registered to the database, the next step is to register super chamber. Each super chamber comprises two chambers. The chambers can be attached / detached to / from the super chambers just like other components to the chambers.

#### **4.3 Quality Controls (QCs)**

GEM web interface also has the functionality to upload various data related to quality control tests of various components. These tests are conducted to test the quality of the component. There are various levels of QCs which ranges from QC2 to QC8. The procedure for various QC tests is very simple. Each QC test has its relevant template file which is in MS-Excel format. Users generate their relevant excel files according to the template. It is the responsibility of the user to make sure that their file is correct and according to the template. Users use this interface and fills relevant information for tests and upload their files. The web interface converts excel file into relevant xml files and sends them to DB Loader for uploading into database.

The hierarchy of the component i.e. parent and child relationship and relevant QC test is shown in Figure 4. It can be seen that all individual components are children of the chamber apart from VFATs which are children of GEBs. The chambers on the other hands are the children of the super chamber.

### **5. Online Monitoring System (OMS)**

The OMS is the last component of the GEM database Framework. It is the web based application to monitor the real time data from various sources. The OMS is used for data visualization. It displays data regarding the results of QCs and other stuff. URL to access old version of OMS for GEM is [9]. The users should have CERN accounts to access the URLs. The homepage of OMS for GEM is shown in Figure 5.

#### **5.1 Content Organization**

The contents in OMS are organized into three layers as shown in Figure 6. These layers are called workspace, folder and page. Workspace is a top-level object in the hierarchy of content

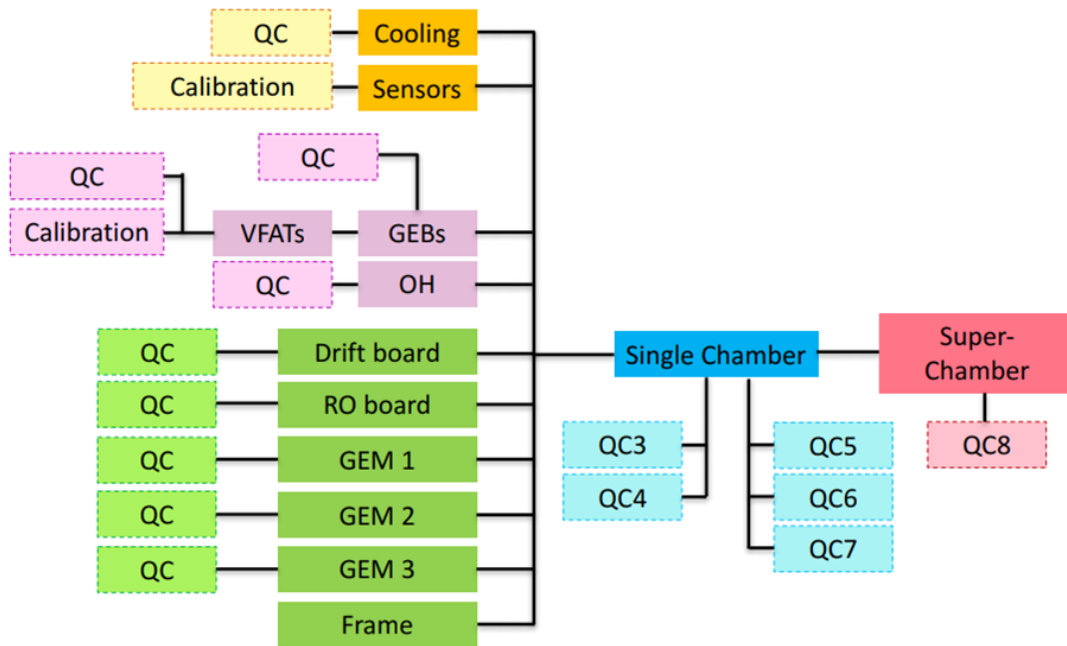


Figure 4: Components Overview

TYPE	NAME	DESCRIPTION	PARENTTYPE	PARENTNAME
GEM Detector ROOT	ROOT		GEM Detector ROOT	ROOT
GEM Foil	FOIL-B19-S-0226		GEM Chamber	GEI/1-XS-PIF-0005
GEM Foil	FOIL-B19-L-0243		GEM Chamber	GEI/1-XL-GHENT0017
GEM Foil	FOIL-B16-L-0198		GEM Chamber	GEI/1-XL-CERN-0006
GEM Foil	FOIL-B20-L-0253		GEM Chamber	GEI/1-XL-CERN-0020
GEM Foil	FOIL-B19-L-0239		GEM Chamber	GEI/1-XL-CERN-0020
GEM Foil	FOIL-B20-L-0259		GEM Chamber	GEI/1-XL-CERN-0020
GEM Foil	FOIL-B20-L-0250		GEM Chamber	GEI/1-XL-CERN-0022
GEM Foil	FOIL-B19-L-0227		GEM Chamber	GEI/1-XL-GHENT0012
GEM Foil	FOIL-B1-L-Ten-0004		GEM Chamber	GEI/1-XL-CERN-Test-0001

ID	NAME	CONDITION_TABLE	DATABASE_TABLE	DESCRIPTION
5000	VFAT3 Production Summary Data	c5000	VFAT3_PRODUCTION_SUMMARY	GEM VFAT3 Production Summary Data
5420	VFAT3 ARM DAC Lookup Table	c5420	VFAT3_ARM_DAC	VFAT3 ARM DAC Lookup Table
5440	VFAT3 Calib Pulse DAC Lookup Table	c5440	VFAT3_CAL_DAC	VFAT3 Calibration Pulse DAC Lookup Table
5460	VFAT3 Calib DAC Charge Lookup Table	c5460	VFAT3_CAL_DAC_FC	VFAT3 Calib DAC Charge Lookup Table

Figure 5: Online Monitoring System Homepage

organization. It represents a CMS detector logical or organizational units, sub-detectors, etc. For example, CMS, GEM, Pixel, Tracker, HCAL, CSC etc. Folder is the second layer in the hierarchy. It is lower-level container for Pages. For example, Quality Control, DAQ, ConfigurationDB etc. Page is the actual content container that is composed of a single Controller (optional) and one or more Portlets. For example, Run Summary, Report, etc.

## 5.2 Controller

Controller is a filtering or selection object that allows the user to apply selection on the Page, i.e. Portlets contained within the Page. Controller provides selected data object (Selection) to each Page Portlet and refreshes it. For example, Run selection, Run Range selection, Fill number etc.



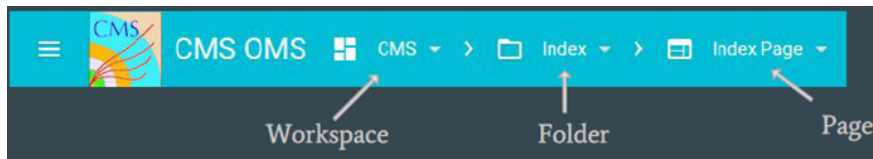


Figure 6: OMS Content Organization

### 5.3 Portlet

Portlet is a content presentation object which displays a single well-defined aspect of information, i.e. a single plot, a table. For example, Run information table, Fill Analysis plot, etc.

### 5.4 View Mode

View mode is the default portal mode. It is used to just display any information. All authenticated users (CERN Single Sign On) can browse and navigate through all the contents of the Portal. They can also use controllers and portlet functionality.

### 5.5 Edit Mode

In this mode privileged users can change the content of the page i.e. add/remove portlets, resize the portlets, change the portlet layout by dragging portlets in the desired position. Edit mode is granted to e-groups or/and individual users.

### 5.6 Manage Mode

In this mode privileged users can modify all the metadata and the structure of the workspace. It consists of three different pages i.e., Manage Workspace, Manage Pages and Manage Widgets.

## 6. Conclusion

In this paper, we presented an overview of the database framework which we have developed for the GEM Detector at CERN. The GEM database framework comprises four components. The first component is the database itself. There are three instances of the database which have been deployed. One is for the development purpose which contains test data, other one is for the integration purposes while the last one is for the production purpose which contains real data. The database further comprises various schemas and each schema consists of different tables in it. We use separate schemas for various types of tables.

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