



CERN SUMMER STUDENT REPORT

CERN SUMMER STUDENT 2024

Web Visualization of ATLAS Data

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Introduction

The **ATLAS Experiment** is one of CERN's four main scientific experiments, and as one of the detectors in the **Large Hadron Collider** (LHC), ATLAS is investigating everything from the Higgs boson to dark matter particles, generating a huge amount of data that needs to be processed and analysed.

The **Liquid Argon (LAr) Calorimeter** surrounds the inner surface of the ATLAS detector and measures the energy of electrons, protons and hadrons, allowing physicists to determine the original energy of the particle colliding with the detector. The **LAr Operations Team** is responsible for monitoring, storing and analysing all this data in various databases. These databases, together with various analysis scripts, are run to produce summary plots as part of a daily process.

Previously, the LAr team was using a basic, non-responsive and not very user-friendly website developed in PHP with many limitations to display this data on different screen resolutions, including laptops, in a non-intuitive way, making it difficult to track this data and causing the **loss of critical information**.

In order to overcome these limitations and improve the user experience of the LAr Operations Team, it was decided to develop a new web application from scratch using more modern technologies to cover the current needs of the team. This technical report documents the entire development process of this new website, including several technologies and enhancements that were implemented.

Description of the Project

This project consists of the development of a **new website** from scratch to support the LAr Operations Team of the ATLAS experiment at CERN. This new website will replace a previous one, developed in PHP, which had usability, functionality and data loss limitations.

The motivation for this project came from the necessity to solve the various problems and limitations that the previous website had, as it did not satisfy the needs of the team and was difficult to use on laptops and mobile devices due to its non-intuitive and non-responsive design, complicating web browsing and data analysis.

The main objectives of the project are:

- Improve usability by creating a modern, intuitive and responsive interface that would allow the team to **efficiently monitor** and manage data on any device.
- Optimise loading speeds by improving the performance of the site's basic functions.
- Implement **new functionalities** to display updated data in real time.
- Develop **advanced search filters** to allow the team to filter by year, board name, run execution, ATLAS status, etc. to facilitate access to information.
- Design a platform that is **easy to modify** and update, enabling the team to make changes and improvements to the website without advanced web development skills.
- Ensure **compatibility** with mobile devices to avoid loss of information due to design.
- Implement various **security measures** using Django's features, such as security middleware against Cross-Site Request Forgery (CSRF) and protection against code injection in database queries (SQLi).

Requirements

Functional requirements describe the specific capabilities and behaviors that the web application must provide including all the functionalities and features that must be fulfilled to perform the intended tasks.

On the other hand, non-functional requirements define system characteristics that affect performance, security, usability and maintainability and although they are not directly related to specific system functions, they are critical to ensure that the web application functions efficiently.

The functional and non-functional requirements for the development and implementation of the new web application are detailed below.

3.1 Functional Requirements

- **Data visualization**

- The application must allow the visualization of data in the form of **updated graphs** and tables in real time.
- Data must be **updated in real time** without the need to reload the entire page.
- The application must support the display of different data types including “Lights/Temperature”, “Errors”, “ADC Shift”, “ADC Shift DB”, “RD Used” and “LTDB Replacement”.

- **User interface**

- The interface of the application must be modern, intuitive and **responsive** ensuring its usability on devices of different resolutions such as mobiles, tablets and laptops.
- The interface must provide a navbar for quick access to the different sections that are part of the application.

- **Search filters**

- The application should implement **advanced filters** to allow searches by run number, board name, year and ATLAS status.
- The filters should be applied **dynamically** allowing real time updating of the views that are part of the application.

- **Dynamic database queries**
 - The application must allow the execution of **dynamic queries** to DCS, COOL and MySQL databases.
- **Customization and administration**
 - The application must allow the creation, modification and deletion of tabs **without** the need for **advanced knowledge** in web development.
 - The application must allow the creation, modification and deletion of tabs to display data through an administration interface.
- **Data export**
 - The application should provide options to **export data** in CSV, Excel and PDF format from the data display tables.

3.2 Non-Functional Requirements

- **Performance**
 - The application must be able to handle **large volumes of data** without affecting performance.
- **Security**
 - The application must implement **security measures** such as CSRF and SQLi protection to avoid common vulnerabilities.
 - The application should only be accessible to **authenticated** and **authorized users** belonging to CERN.
- **Maintainability**
 - The application code should be well documented to facilitate future modifications and upgrades.
- **Continuous Integration**
 - The application development must integrate a **CI/CD system** to ensure continuous delivery of new features in an efficient and secure manner.
 - The deployment system must use **OKD** to manage the orchestration and scalability of the application in the production environment.

Technology Stack

In the development of this web application, several technologies have been used for both the frontend and the backend, as well as various connections to databases.

4.1 Frontend

The web design is based on three main technologies: **HTML** (HyperText Markup Language) to structure the web content, **CSS** (Cascading Style Sheets) to apply styles and a nice visual design, and **JavaScript** to add interactivity to the web by manipulating the DOM (Document Object Model). To provide a better user experience, **AJAX** has been used to allow parts of the site to be updated asynchronously, allowing data to load quickly and providing a smoother experience without having to reload the whole page. In addition, the **Bootstrap** web design framework was used to facilitate the creation of a responsive interface that adjusts to any device size.

4.2 Backend

For the application logic and database management, **Django** was used as a web development framework based on **Python**, following an **MVC** (model-view-controller) structure that separates the business logic from the presentation and user interaction. As a data model, **SQLite** and the **ORM** (Object-Relational Mapping) offered by Django were used to define the data models related to the tabs and configurations, defining the BaseTab, AtlasTab, Tab, PageView and ErrorConfig classes in such a way that each model is automatically mapped to a database table.

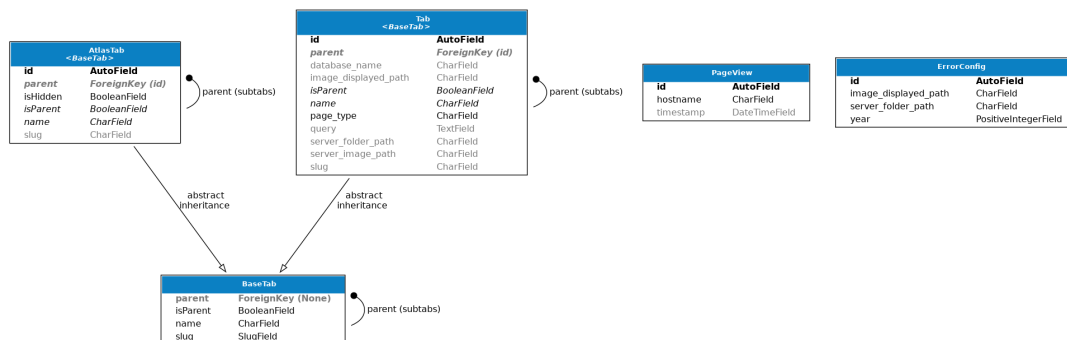


Figure 4.1: Data Model Diagram Class

4.3 Databases

Changes to the database schema were managed through a **migration system** to make changes to the data models without losing information, and a context processor was created to provide tab-related data to all application templates to improve flexibility and efficiency. In addition, the `apps.py` file was configured to initialise default data, in this case the tabs that are already configured by default (Lights/Temp, Lights Latome, Lights Latome-Upod, Lights LTDB, Errors, ADC Shift, ADC Shift DB, RD Used, LTDB Replacement, EMF Status and Admin Site), so that this default data is added to the application each time a migration is performed, creating the default tabs and the necessary configurations. Within each tab, different database connections are made, such as:

- **DCS** (Distributed Control System) databases used to manage data related to the distributed control of the sensor system.
- **COOL** (Condition of Operation) databases used to store data on the operating conditions of the system with a historical record.
- **MySQL** databases used to get information from the data models defined in the application.

4.4 Integration and Deployment

During the development of this project, a **GitLab** repository linked to CERN has been used for the version control of the code, which facilitates the tracking of changes and the continuous integration. For the deployment of the application, this repository has been integrated with **OKD**, an orchestration platform based on **Kubernetes**, to deploy and manage the application in the production environment in an efficient and secure way.

Previous Website

The previous website used by the LAr Operations Team to visualise and analyse the data generated was developed in **PHP** with the main objective of providing a platform to visualise and analyse the information, but this site had several design and **efficiency limitations** that resulted in **data loss**. It was not designed to be responsive, so the navbar containing access to the rest of the web tabs did not adapt to different screen sizes, making it difficult to use on mobile devices and even on computers, and causing the loss of information stored on the site.



Figure 5.1: Previous website

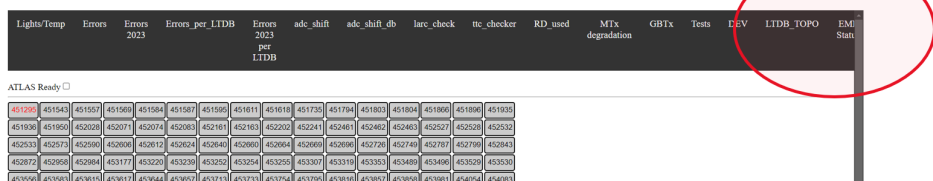


Figure 5.2: Navbar of previous website

The design and web interface was **unfriendly** and difficult to use, as some options were not clear enough and complicated the user experience especially for those who were not familiar with the structure of the site. In addition, the loading of data on the website in some sections was **slow**, which had a negative impact on the user experience when dealing with large amounts of data, and it did not implement security measures and was **vulnerable** to common attacks such as SQLi and other security issues by not checking fields in forms and causing various errors.

Results

The main page consists of a navbar where you can access the different sections of the site such as "Errors", "ADC Shift", "ADC Shift DB", "RD Used", "LTDB Replacement", "EMF Status" and "Lights/Temp" which includes the Lights Latome, Lights Latome-Upod and LTDB sections. There is also a final tab, "Admin Site", to manage the tabs and modify the existing information, allowing a high level of **customisation** and the possibility of adding new tabs.



Figure 6.1: Main page of new website (laptop view)



Figure 6.2: Main page of new website (mobile view)

The web application implements an **authentication system** directing users to the official **CERN authentication platform** before allowing access to the application ensuring that only authenticated and authorized users can access. Authentication is managed through the standard OAuth security protocol guaranteeing a high level of security. Regarding data management, database connections are used with the corresponding permissions and, in addition, protections against **CSRF** (Cross-Site Request Forgery) attacks are used using security middleware validating form requests and protections against **SQL Injection**.

The design of the web application has been based on the official [ATLAS design guide](#), using the official Open Sans font, the ATLAS blue colour and the official images as the official ATLAS logo with transparent background.

The following colours have also been used:



Figure 6.3: Colour palette 1

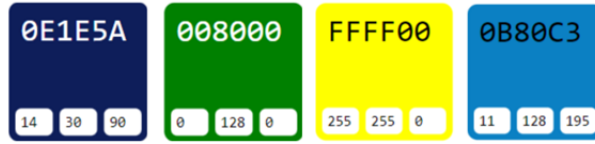


Figure 6.4: Colour palette 2

Below is an analysis of the main sections of the web application, such as "Lights/Temperature", "Errors", "ADC Shift DB", "LTDB Replacement" and "Admin Site", highlighting the functionalities and improvements that have been implemented to facilitate data management.

6.1 Lights/Temperature

This section of the website presents all the data in the form of plots related to 'Lights Temperature'. For this purpose, the "Lights/Temp" tab groups the "Latome", "Latome-Upod" and "LTDB" sections, each of which displays a new page of related plots. These plots allow a clear and **detailed visualisation** of the different data collected, making it easier to analyse the data.

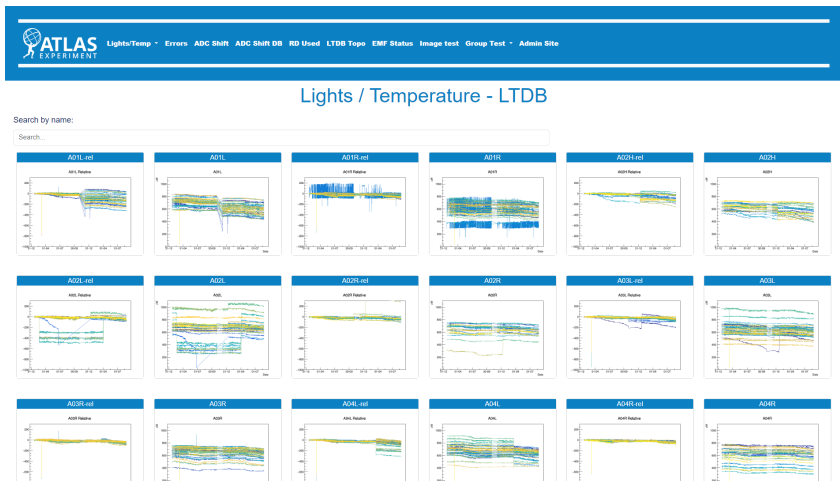


Figure 6.5: Lights LTDB page

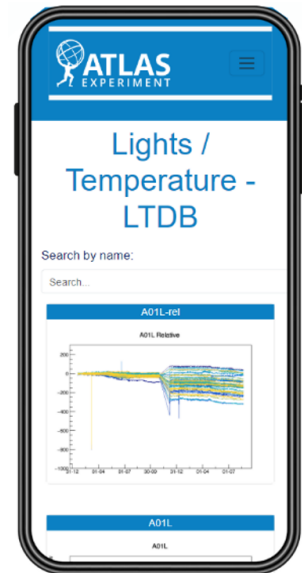


Figure 6.6: Lights LTDB page (mobile view)

To improve the accessibility and quick search of the information, a **search filter by name** has been incorporated to quickly find the required plots.

In addition, clicking on one of the plots opens a modal that enlarges the selected plot allowing a better visualisation of the data in more detail.

Compared to the previous website, **three** different sections have been created for each button that appeared on the old website (latome, latome-upod, ltdb) grouping them in the same category "Lights/Temp" as three new subtabs (latome, latome-upod, LTDB). In addition, the design has been improved making it **adaptable** to any screen resolution and device.

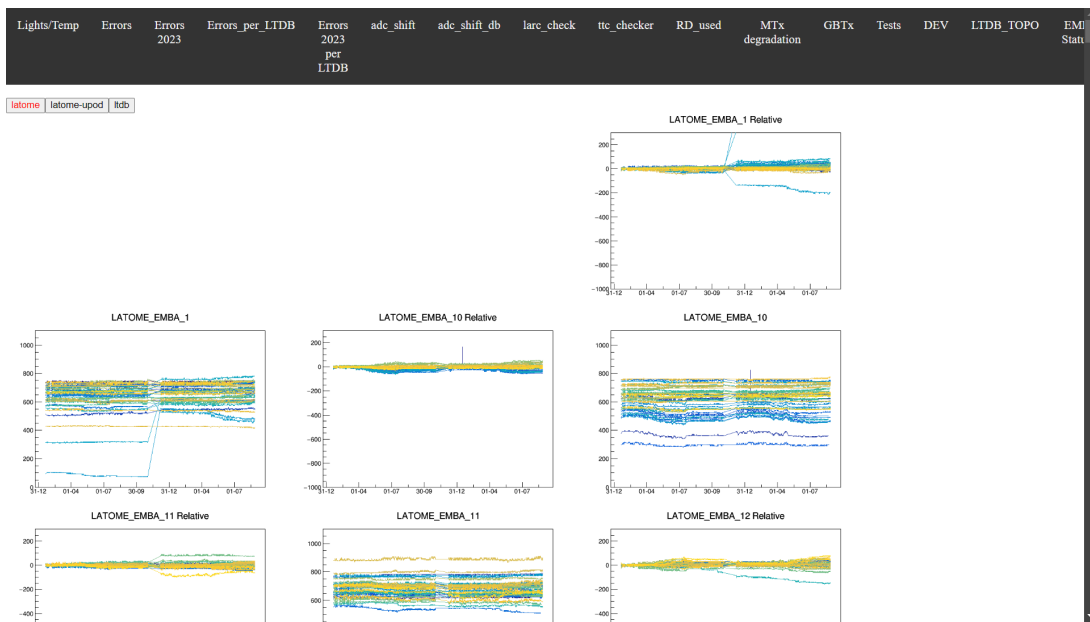


Figure 6.7: Lights latome page (previous website)

6.2 Errors

In this section of the website all the run numbers are presented in the form of buttons for each of the runs made. Each button has an associated colour that changes according to the filters applied: **yellow** for the run numbers that have suffered an error and contain plots, and **green** for the runs that have not suffered an error and therefore do not contain plots. These buttons allow a clear visualisation of the executions that have suffered an error and show all the plots available, making it easier to **trace the errors** in the executions.

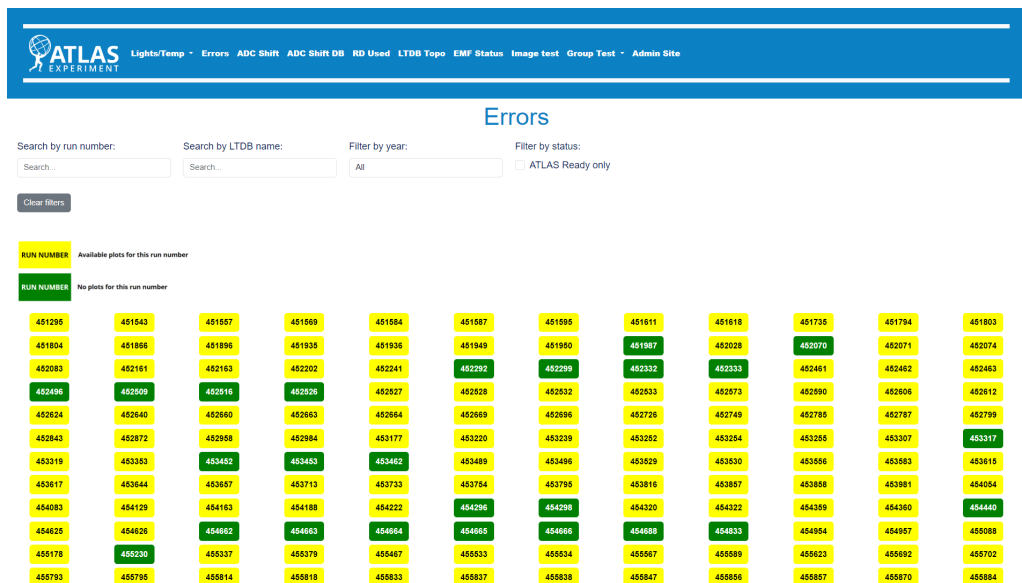


Figure 6.8: Errors page

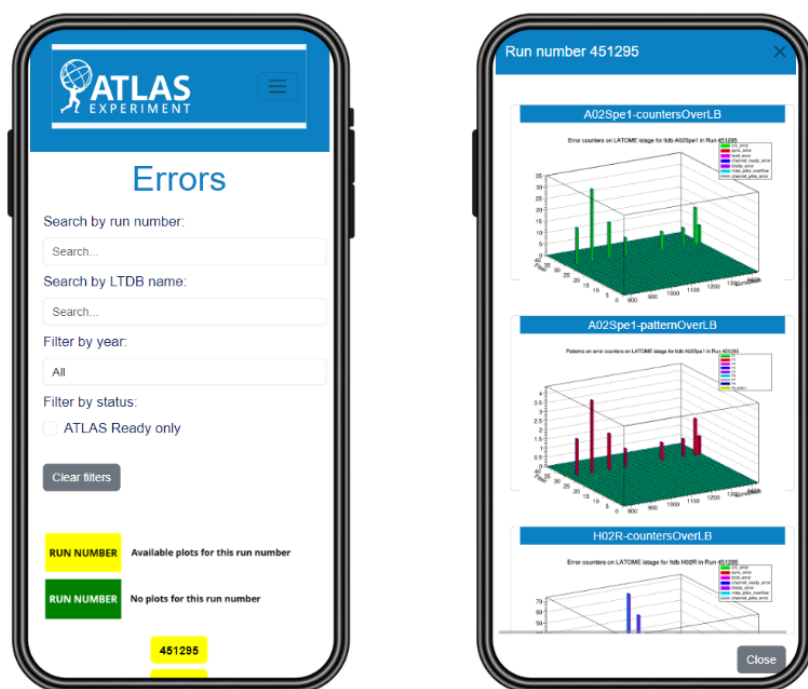


Figure 6.9: Errors page filters (left) and enlarged plot after clicking on it (right) (mobile view)

To improve the accessibility and quick search of the information, several **advanced filters** have been incorporated, a search filter **by run number**, **by board name** (LTDB name), **by year** and a filter according to the **ATLAS ready status** by making a query in the database allowing a more personalised search. In addition, by clicking on one of the yellow run number buttons, you can see all the plots associated with that run that

meet the applied filters. In addition, the design has been improved making it **adaptable** to any screen resolution and device.

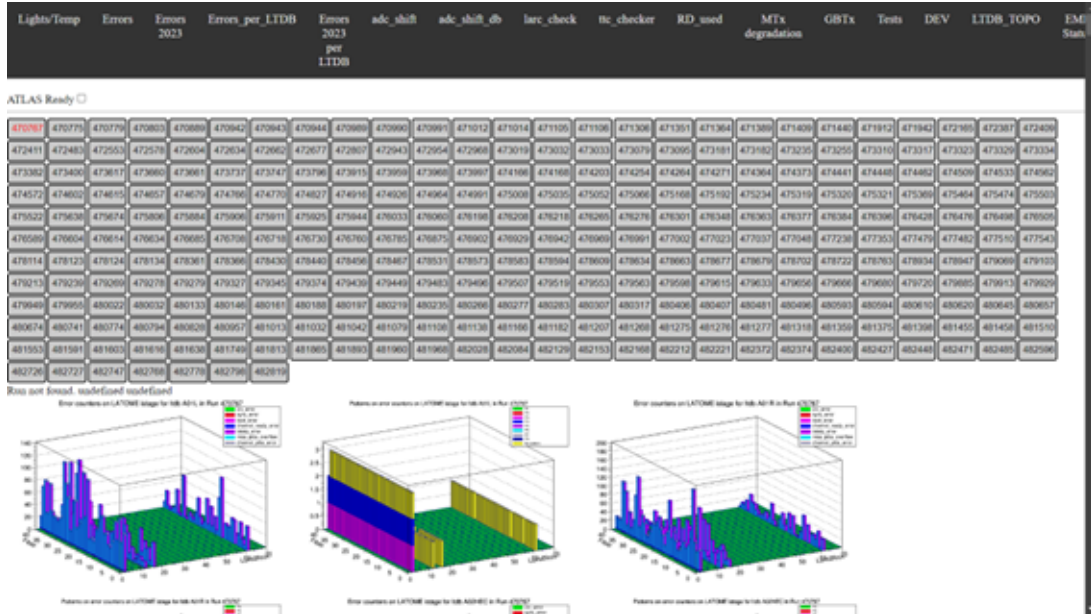


Figure 6.10: Errors page of previous website

Compared to the previous website, the four tabs "Errors", "Errors 2023", "Errors per LTDB" and "Errors 2023 per LTDB" have been combined into **one tab** called "Errors". Several **advanced search filters** have been added to allow searching by run number, board name (LTDB name), year and ATLAS status. In addition, the design has been improved to adapt to any screen resolution and device.

6.3 ADC Shift DB

In this section of the website, all the analysed run numbers are presented in the form of **buttons** for each of the runs performed. Each button contains graphs of each run with information such as the distribution of the reading percentage with shift or the luminosity.

On the other hand, this section allows to **execute queries** to two databases related to ADC Shift (AdcShift and AdcShiftPerLB). Depending on which database is chosen, the data that can be added to the query will be indicated **dynamically**. In the case of the ADC Shift database option, preferences such as search by ADC, add LB and add mapping will appear. In addition to these preferences, you can indicate the run number, the threshold and the scId. On the other hand, if you choose the ADC Shift per LB database, you can only indicate the run number and LB in the query.

When executing a query in any of the databases, a **table** will be displayed with all the information obtained, and in addition, in ADC Shift queries the scId will be indicated which, if pressed, will give more information in the form of a graph on the percentage of executions in shift for that scId.

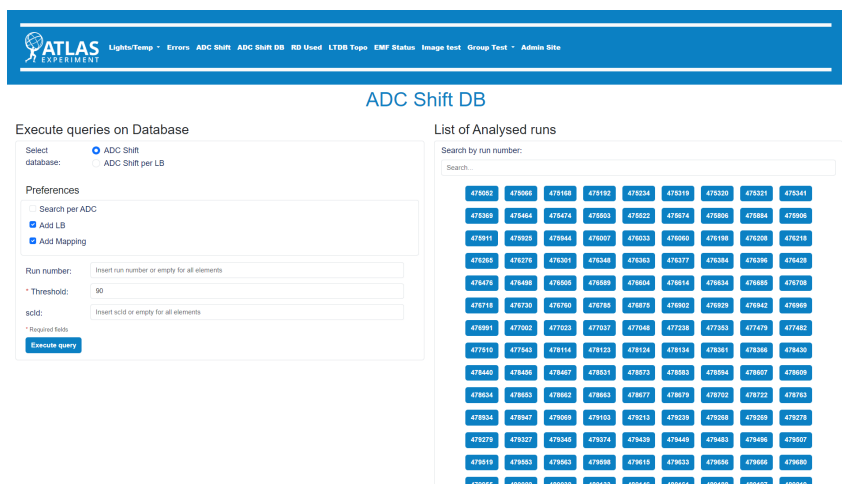


Figure 6.11: ADC Shift DB page

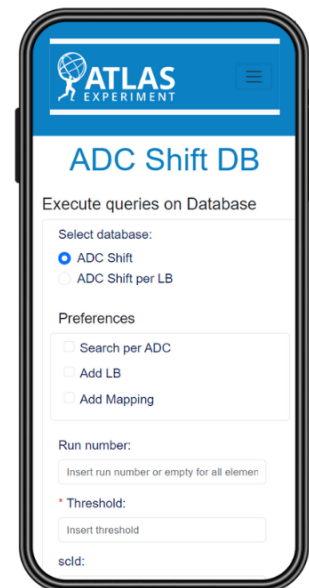


Figure 6.12: ADC Shift DB page (mobile view)



Figure 6.13: ADC Shift DB plots of run number 475474

In order to improve accessibility and a quick search for information, a **search filter** has been incorporated by run number for the section of runs

analysed and, in addition, a **dynamic form** has been added for queries to the database, providing all the information obtained in a table **adaptable** to any device.

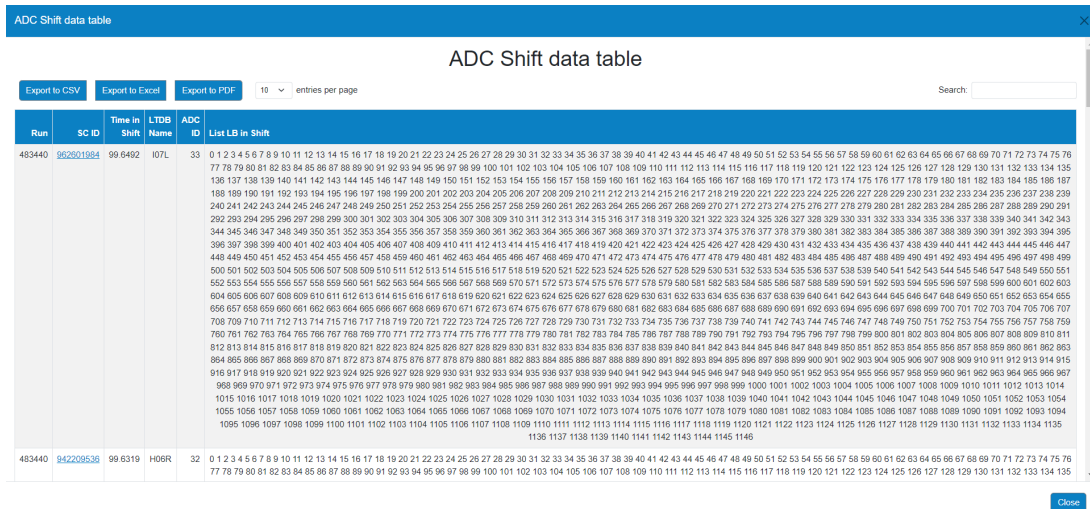


Figure 6.14: ADC Shift DB query executed with LB and Mapping added to the preferences and a threshold of 90

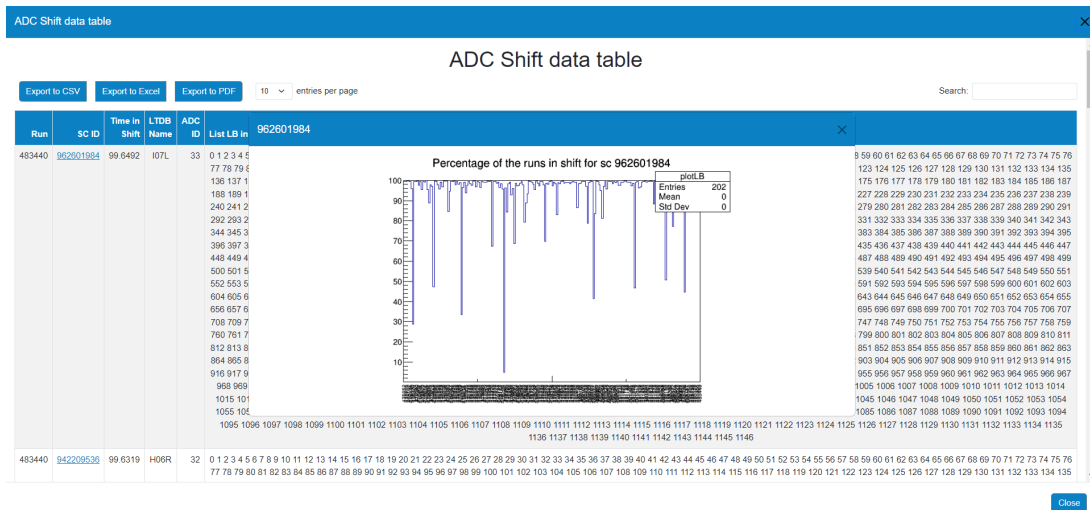


Figure 6.15: ADC Shift DB query executed plot of scID 962601984

Compared to the previous website, both parts have been divided into two different columns, facilitating the organisation and visualisation of the content. A **dynamic form** has been implemented that allows queries to be made to the databases in a more **intuitive** way and, in addition, the design has been improved, making it **adaptable** to any device with a better appearance, improving accessibility and user experience.

Lights/Temp	Errors	Errors	Errors_per	Errors	adc_shift	adc_shift_db	lare_check	tte_checker	RD_used	MTx	GBTx	Tests	DEV	LTDB_TOPO	EMF
	2023	2023	LTDB	2023						degradation					Stat
				per											
				LTDB											

List of analysed runs:

475053	475066	475168	475192	475234	475310	475320	475321	475341	475369
475464	475474	475503	475522	475674	475896	475898	475906	475911	475925
475944	476033	476060	476108	476208	476218	476265	476376	476381	476348
476363	476377	476384	476396	476428	476476	476498	476505	476589	476604
476614	476634	476685	476708	476718	476730	476760	476785	476874	476902
476979	476942	476969	476991	477002	477023	477037	477048	477238	477353
477479	477482	477510	477543	478114	478123	478124	478134	478361	478366
478430	478440	478456	478467	478531	478573	478583	478594	478607	478609
478634	478653	478662	478663	478677	478679	478700	478729	478763	478934
478947	479069	479103	479213	479239	479269	479278	479279	479327	479345
479374	479439	479449	479483	479496	479507	479510	479553	479563	479598
479615	479633	479656	479666	479680	479955	480024	480032	480133	480146
480161	480188	480197	480219	480225	480266	480277	480282	480407	480417
480436	480447	480481	480496	480523	480592	480610	480630	480645	480647
480674	480741	480774	480794	480828	480952	481012	481021	481042	481079
481108	481138	481166	481182	481207	481268	481275	481276	481277	481218
481359	481375	481398	481510	481553	481591	481601	481616	481638	481749
481813	481865	481893	481960	481968	482028	482088	482129	482152	482153
482168	482212	482221	482377	482374	482400	482427	482448	482471	482484
482596	482726	482727	482747	482768	482778	482798	482819	483370	483398
483409	483440								

Run/Empty for all:

☐ Search per ADC

scId/Empty for all:

Threshold(Must contain a value):


☐ Add LB

☐ Add Mapping

Figure 6.16: ADC Shift DB page of previous website

6.4 LTDB Replacement

In this section of the website, all the data is presented in **table** form after performing several queries to the ‘*MTx_Exchange*’ and ‘*LTDB_Exchange*’ databases on the topology of the LTDB (LAr Trigger Digitizer Board), organising the data in a clear way to facilitate analysis and understanding. Additionally, the functionality to **export the data** in **CSV**, **Excel** or **PDF** format has been added, as well as a **search by fields** and **pagination**, improving the accessibility and management of the information in each table.



Lights/Temp

Errors

ADC Shift

ADC Shift DB

RD Used

LTDB Replacement

EMF Status

Admin Site

LTDB Replacement

MTx Exchange table

Export to CSV

Export to Excel

Export to PDF

5 entries per page

Search

LTDB Name	LTDB Serial Number	MTx ID	Date of Exchange	MTx Old Serial Number	MTx New Serial Number
C06Spe0	148	2	2024-01-30T00:00:00	0	0
C06Spe0	146	7	2024-01-30T00:00:00	0	0
C06Spe0	146	8	2024-01-30T00:00:00	0	0
I15L	9	2	2024-01-30T00:00:00	2267	3647
C03R	91	16	2024-01-24T00:00:00	1083	3620

Showing 1 to 5 of 22 entries

<

1

2

3

4

5

>

LTDB Exchange table

Export to CSV

Export to Excel

Export to PDF

5 entries per page

Search

LTDB name	LTDB Old Serial Number	LTDB New Serial Number	Date of Exchange
A01R	101	111	2024-02-02T00:00:00
A01L	132	117	2023-12-07T00:00:00
H08R	69	45	2023-01-06T00:00:00
A13R	117	139	2023-01-06T00:00:00
C03R	124	112	2022-12-18T00:00:00

Showing 1 to 5 of 15 entries

<

1

2


3

4


5

>

Figure 6.17: LTDB Replacement page



ATLAS
EXPERIMENT



LTDB Replacement

MTx Exchange table

Export to CSV

Export to Excel

Export to PDF

5

 entries per page

Search:

LTDB Name	LTDB Serial Number	MTx ID
▶ C06Spe0	146	2
▶ C06Spe0	146	7
▶ C06Spe0	146	8
▶ I15L	9	2
▶ C03R	91	16

Showing 1 to 5 of 22 entries

Figure 6.18: LTDB Replacement page (mobile view)

Compared to the previous website, new functionalities have been incorporated, such as options for filtering and exporting information, improving the **efficiency** of data analysis and management. In addition, the design has been improved, making it **adaptable** to any device and with a better appearance.

Lights/Temp	Errors	Errors 2023	Errors_per_LTDB	Errors 2023 per LTDB	adc_shift	adc_shift_db	larc_check	ttc_checker	RD_used	MTx degradation	GBTx	Tests	DEV	LTDB_TOPO	EMI Statu
LTDB Name	LTDB Serial Number	MTx ID	Date of Exchange	Old Serial Number	New Serial Number										
I15L	9	2	2024-01-30 00:00:00	2267	3647										
C06Spe0	146	8	2024-01-30 00:00:00	0	0										
C06Spe0	146	7	2024-01-30 00:00:00	0	0										
C06Spe0	146	2	2024-01-30 00:00:00	0	0										
C03R	91	16	2024-01-24 00:00:00	1083	3620										
A03L	120	1	2024-01-23 00:00:00	664	3619										
C04L	196	8	2024-01-18 00:00:00	1086	3616										
C04L	196	11	2024-01-18 00:00:00	1065	3614										
C04L	196	12	2024-01-18 00:00:00	1071	3615										
C09Spe1	150	5	2024-01-18 00:00:00	976	3617										
C12Spe0	147	17	2024-01-17 00:00:00	3309	3618										
A02Spe1	151	15	2024-01-12 00:00:00	953	3612										
A02Spe0	141	3	2024-01-12 00:00:00	1392	3610										
A02H	179	7	2024-01-12 00:00:00	3376	3613										
H01L	10	6	2024-01-12 00:00:00	1102	3609										
A06Spe0	143	12	2023-12-20 00:00:00	3560	3607										
A09Spe1	154	7	2023-12-12 00:00:00	1330	3606										
A12H	175	15	2023-12-11 00:00:00	0	0										
A01L	117	20	2023-12-08 00:00:00	2689	3601										
A01L	117	2	2023-12-08 00:00:00	3502	3605										
I01L	35	18	2023-11-30 00:00:00	0	0										
I16L	38	19	2023-11-30 00:00:00	0	0										
LTDB Name	LTDB Old Serial Number	LTDB New Serial Number	Date of Exchange												
A10R	101	111	2024-02-02 00:00:00												
A01L	132	117	2023-12-07 00:00:00												
H06R	69	45	2023-01-09 00:00:00												
A13R	117	139	2023-01-06 00:00:00												
C05R	124	112	2022-12-16 00:00:00												
A09H	177	176	2021-12-14 00:00:00												
C09Spe0	0	149	2021-12-07 00:00:00												

Figure 6.19: LTDB Replacement page of previous website

6.5 Admin Site

This section of the website presents the administration menu of all the tabs present in the web application and some settings. It offers the options to **create** a new tab in the application or to **manage** the default ones (Lights/Temp including latome, latome-upod and LTDB, Errors, ADC Shift, ADC Shift DB, RD Used, LTDB Replacement and EMF Status).

In the case of creating new tabs, the creation of three different types of tabs (images, folders, data) is allowed. Furthermore, these can be grouped in a group as in the case of the "Lights/Temp" group and its sub-tabs "latome", "latome-upod" and "LTDB". The predefined tabs in the web application can be hidden and some can even be modified. For example, in the Errors tab you can add a new year with its corresponding path or modify existing years.

This administration section has been created with the aim of allowing changes to be made and new data sources to be added to the website **without** the need for **advanced knowledge** of web development in a

simple and accessible way. Thanks to this functionality, the LAr Operations team can manage and update the content of the application with greater **flexibility**, making it easier to adapt to changes.

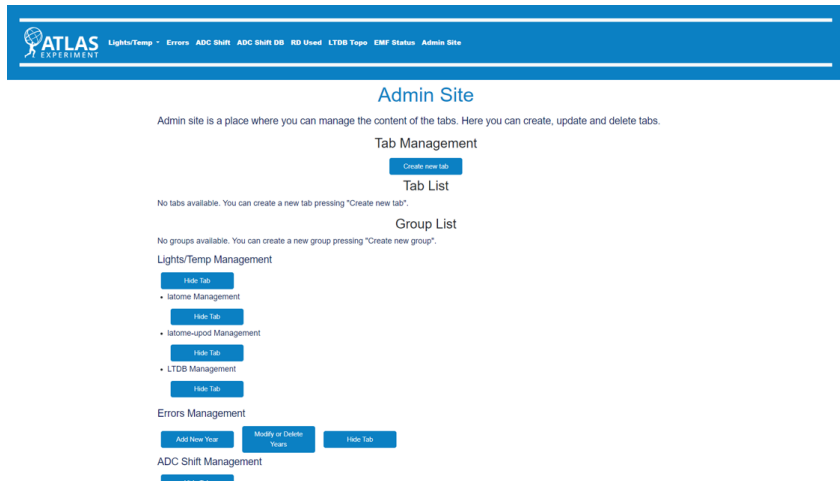


Figure 6.20: Admin Site page

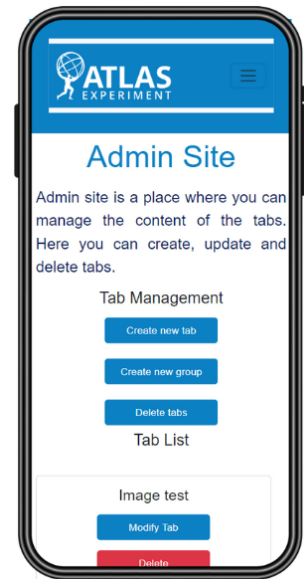


Figure 6.21: Admin Site (mobile view)

Compared to the previous website, this customisation functionality **did not exist** and to make any changes it was necessary to access the **PHP code** of the website and make modifications **manually**. This made the task of modification difficult because it required advanced knowledge and could be prone to errors.

Conclusions

In conclusion, the development of this new web application for the LAr Operations team in the ATLAS experiment has been important to overcome the limitations of the previous website. Modern technologies have been implemented to improve **usability** and **efficiency** in data visualization and management, facilitating the team's analysis with a more **intuitive** interface and new **advanced functionalities**. In addition, it guarantees **adaptability** and **maintenance** ensuring that the needs of the equipment are covered in the long term avoiding the loss of information and helping to **prevent future problems**.

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