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ASSIGNMENT OF BACHELOR’S THESIS

Title:	Feasibility Study of Portal to Provide Knowledge about Higgs Boson to General Public and Experts
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Study Programme:	Informatics
Study Branch:	Information Systems and Management
Department:	Department of Software Engineering
Validity:	Until the end of summer semester 2020/21

Instructions

The aim of this project is to perform a feasibility study about creating a portal to provide knowledge about the Higgs boson. After its discovery in 2012 more than 1000 publications about the Higgs boson properties were released and every week new information about the Higgs boson is published.
Tasks:

1) Gaining information about the requirements for a portal from interested general public and experts in Higgs boson physics (interviews).
2) Reviewing the sources of information and developing a concept of how to transfer the information into a database.
3) Outlining of the portal design (UI, wireframe).
4) Proposal for a technical realization.
5) Evaluating the usefulness of the portal and giving an outlook for the implementation.

References

Will be provided by the supervisor.

Ing. Michal Valenta, Ph.D.	doc. RNDr. Ing. Marcel Jiřina, Ph.D.
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Prague February 14, 2020

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Bachelor's thesis

Feasibility Study of a Portal to Provide Knowledge About the Higgs Boson to the General Public and Experts

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Department of Software Engineering
Supervisor: doc. Dr. André Sopczak

June 4, 2020

Acknowledgements

First and foremost, I want to thank my supervisor, doc. Dr. André Sopczak for all the time he dedicated to helping me and for his insightful comments. I would also like to thank Natálie Klubíčková for her continuous support in my endeavors. Finally, I want to thank my friends and family for encouraging me during my studies.

Declaration

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Citation of this thesis

Kupka, Martin. *Feasibility Study of a Portal to Provide Knowledge About the Higgs Boson to the General Public and Experts*. Bachelor's thesis. Czech Technical University in Prague, Faculty of Information Technology, 2020.

Abstract

This thesis performs a feasibility study of a new web portal focused on the Higgs boson and its research. Since the particle discovery in 2012, the research has advanced greatly, while the general public is still struggling with understanding the basic concepts of particle physics and the Higgs boson. A web portal that would automatically store and categorize all the released research publications and preliminary results in the Higgs boson domain does not exist. For the scientists, keeping track of the latest discoveries and current research is unnecessarily time consuming and complicated due to the lack of a unified database. For the general public, there is a lot of information about the Higgs boson available, but there is not a website dedicated to explaining the particle and its importance. The proposed "Higgs Boson Portal" aims to solve both of these issues. In the feasibility study, some fundamental terms surrounding the Higgs boson and CERN are explained. The current resources available and the two target user groups are analyzed. User personas and user stories are formulated and the requested features for the portal are noted. A possible technical realization of the portal is suggested. Wireframes for the essential features of the proposed portal are created and presented. The development of the portal is considered feasible and possible future plans are suggested.

Keywords ATLAS, CMS, CERN, LHC, Higgs boson, feasibility study, business plan, information portal, user personas

Abstrakt

Tato bakalářská práce je studií proveditelnosti, která se zabývá informačním portálem zaměřeným na Higsův boson a jeho výzkum. Od objevu této částice v roce 2012 se její výzkum nezastavil, avšak většina veřejnosti stále nemá povědomí ani o základech částicové fyziky a Higgsově bosonu. Webový portál, který by automaticky shromažďoval a kategorizoval všechny publikované články a předběžné výsledky z výzkumu Higgsova bosonu v současné době neexistuje. Pro vědce je zbytečně časově náročné získávat všechny aktuality. Pro veřejnost je k dispozici mnoho informací o Higgsově bosonu, ale neexistuje portál zasvěcený pouze této částici a vysvětlení, proč je její objev a výzkum důležitý. Součástí této práce je návrh webového portálu „Higgs Boson Portal“, jenž řeší oba tyto problémy. Ve studii proveditelnosti jsou vysvětleny základní pojmy spojené s Higgsovým bosonem a organizací CERN. Byly zanalyzovány dostupné zdroje a dvě cílové skupiny uživatelů a následně byly vytvořeny jejich persony a uživatelské příběhy. Součástí práce je též návrh možného technického řešení, společně s drátěnými modely pro nejdůležitejší funkce portálu. Celkově je proveditelnost tohoto projektu hodnocena kladně a jsou navrženy možné budoucí rozšíření portálu.

Klíčová slova ATLAS, CMS, CERN, LHC, Higgsův boson, studie proveditelnosti, business plán, informační portal, modelování uživatelů

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Introduction

The Higgs boson is a particle that is fundamental for the Standard Model of particle physics. While its existence was first proposed in 1964, it took scientists until 2012 to first observe this elusive particle. That might sound like the end of the search, but in reality, it was only the beginning. There has been much progress since the discovery, but even more questions are yet to be answered. There are more than 1000 publications about the Higgs boson and its properties, and more information is being published every week. At the same time, 8 years after its existence was confirmed, the public is still struggling with understanding this particle.

The aim of this thesis is to conduct a feasibility study about creating a website to provide knowledge about the Higgs boson. As of now, there is no global website dedicated to the Higgs boson. There are many sites offering bits and pieces of information, but they are often outdated. The research papers from different experiments are scattered, and it is impossible to quickly search through all of them, not to mention that different portals categorize them differently. Therefore it is timely to study the feasibility of a new website which would give a comprehensive and automatically updated status of the Higgs boson knowledge.

In the first chapter, the Higgs boson is briefly introduced (its history, current research, and prospects). In the second chapter, the aim of the feasibility study is introduced and the current state of resources for Higgs boson research is analyzed. Afterward, the necessary process of getting information about the requirements for the website – both from the general public, and experts in the Higgs boson field – is explained. The process of interviewing potential users is described. Based on this the user personas and user stories are created. To finish up the analysis part, potential number of users is explored along with tips on how to advertise the portal. An estimate of how much manpower is needed to develop the portal is provided. Then a SWOT analysis if performed and advice on how to mitigate the potential risks is given. In the third chapter, it is suggested how to create such a portal to be feasible. One of the key features for experts is a complete database of publications regarding the Higgs boson. This data has to be accessible, categorized, and easy to navigate. For the public, the portal needs to be simple, engaging, and captivating. Ways to automatically update and categorize the information are suggested. In the fourth chapter, proposed design and wireframes of the portal are presented. Finally, the whole study is evaluated, the contributions are summarized, and possible future steps are described.

Chapter 1

The Higgs Boson

The Higgs boson is an elementary particle in the Standard Model of particle physics. It was first proposed in 1964 by Peter Higgs and observed for the first time in 2012. On 10th of December 2013 Peter Higgs and François Englert were awarded the Nobel Prize in Physics for their theoretical predictions. [1]

This chapter explains some of the basic terms in particle physics and introduces the CERN institute.

1.1 The Higgs Field

The Higgs field is a field that exists everywhere throughout the universe. It gives mass to certain elementary particles that interact with it. Since this concept is hard to grasp, in 1993, the Science Minister of the United Kingdom William Waldegrave wanted physicists to come up with the best explanation accessible to the general public. David Miller (UCL) [2], proposed the following analogy, which is still being used today:

Imagine a busy cocktail party. While an ordinary person could walk through the crowd easily, if someone famous came to the party they would have much more difficulty passing through. The party-goers would group up around them and slow them down. Now picture that a rumor starts to spread around the party. People near the original gossiper are going to move in closer to hear it, forming a cluster of bodies. Afterward, they pass it to people next to them, making another body cluster. Finally, they return to their starting position to discuss the rumor. Watched from above, the compression of the crowd would travel from one side of the room to the other.

In this analogy, the party-goers represent the Higgs field. A person moving through the field slowly is a particle that has been given a large mass by the field. When the Higgs field is excited, we get a Higgs boson. In the party, the excitation is the rumor and the moving compression of the crowd is the movement of the Higgs boson through the Higgs field. [3]

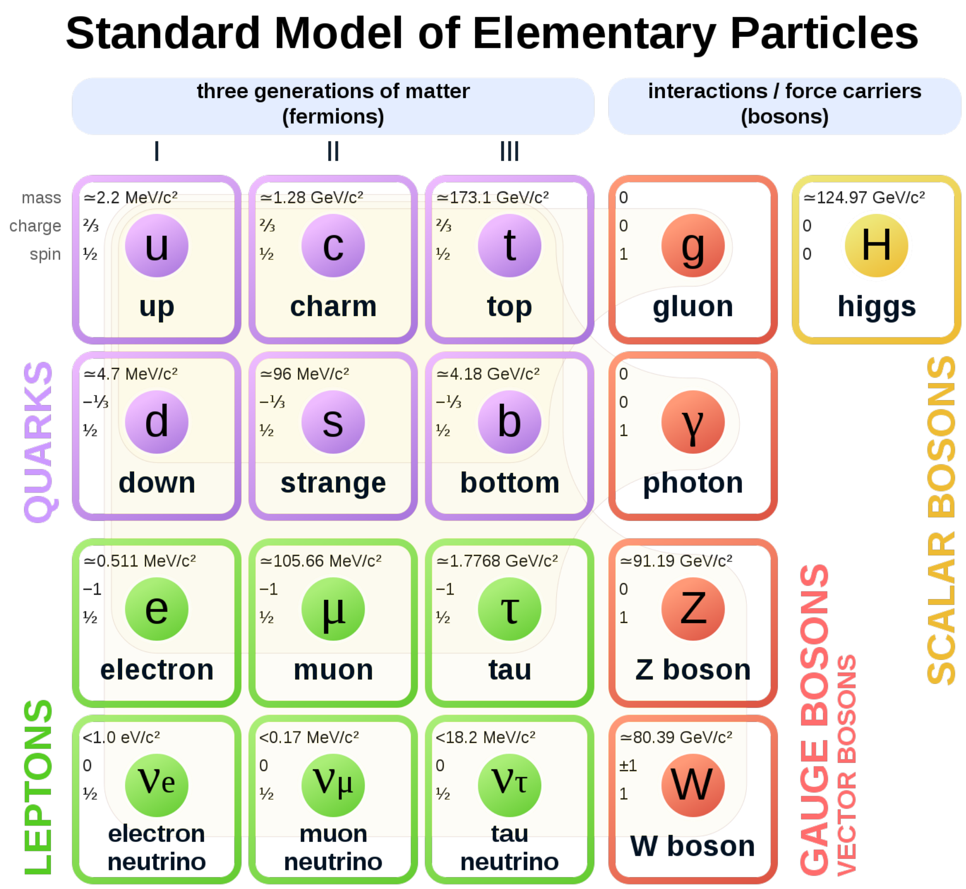

Figure 1.1: Particles of the Standard Model, Source: [4]

1.2 The Standard Model

The Standard Model of particle physics was developed in the 1970s and is still the most accurate theory explaining the very basics of particle physics [5]. When it was first introduced it explained almost all of the experimental results available at the time. More than that, it successfully predicted a lot of phenomena and even the observations and results today are in line with this theory.

In the simplest terms, we could say that: "*All known mass in the Universe is made up of six kinds of quarks, six kinds of leptons and all phenomenons that we observe can be explained by four kinds of interactions.*" [6]

While the Standard Model remains valid, there are certain issues with it:

- The Standard Model does not include gravity.
- The Standard Model cannot explain dark matter.
- The theoretical framework of the Standard Model breaks down at very high energies. [7]

Figure 1.1 shows all the particles of the Standard Model. There are also models beyond the Standard Model which predict further particles and additional Higgs bosons.

1.3 CERN and the LHC

The European Organization for Nuclear Research (CERN) was established in 1954. The CERN laboratory is located on the French-Swiss border near Geneva. CERN has built several particle accelerators and detectors, with the current Higgs boson research taking place at the Large Hadron Collider (LHC). The layout of the CERN Accelerator Complex is shown in Figure 1.3. [8]

First started in 2008, the LHC is the world's largest and most powerful particle accelerator. The main part of the LHC is a 27 kilometers long ring in which the particles are first accelerated close to the speed of light and then forced to collide. Thousand of magnets are used to steer the particles around the accelerator's oval shape. The particles travel in two separate beam pipes in opposite directions. When the two beams meet, the particles are squeezed closer together using magnets to increase the probability of collisions. This happens at four locations around the ring, corresponding to the four different particle detectors: ATLAS, CMS, ALICE, and LHCb. [9]

Before the LHC, there were the LEP-1, LEP-2 and Tevatron accelerators. For the LEP-1 and LEP-2 experiments named ALEPH, DELPHI, L3 and OPAL were conducted. For Tevatron, there are two already concluded experiments, D0 and CDF.

1.4 ATLAS and CMS

ATLAS and CMS are the names of two general purpose detectors at the LHC. They have the same range of goals, from the Higgs boson research to searching for extra dimensions or dark matter particles. However, different technical solutions and magnet system design is used for each. The experiments conducted there are named after the detectors. Both of them are amongst the biggest international scientific collaborations in history with more than 8000 scientists involved. [10, 11]

ATLAS is a particle detector of the largest volume ever constructed. It has six different detecting subsystems around the collision point to record the paths, momentum, and energy of the particles. The amount of data generated is so big, that a "trigger" system decides which events to record and which to ignore. [10]

CMS is built around a huge solenoid magnet. Its cylindrical coil of superconducting cable generates a field about 100,000 times stronger than the magnetic field of the Earth. Unlike the other LHC detectors, it was lowered into its cavern in the LHC tunnel in 15 sections and reassembled there. [11]

1.5 Current Research

As Figure 1.2 shows, the LHC is currently in Long Shutdown 2, which will last until 2021. This downtime is used to maintain and upgrade the complex. The focus is on the High Luminosity LHC (HL-LHC), which is expected to increase the luminosity by a factor of 10. Since luminosity is proportional to the number of collisions observed, this upgrade will increase the amount of data observed. Before that is completed, Run 3 will take place. However, the shutdown does not mean the research stopped – there is still an immense amount of data left to be analyzed from the previous runs. [12]

1.6 The Future

According to the LHC long term schedule [13], it is expected to run until at least 2036. After the completion of the LHC Run-3, the HL-LHC is expected to extend the discovery potential and increase the precision of the measurements. The HL-LHC is expected to hit the limits of its discovery potential in 2035. There are already studies conducted for the successor of HL-LHC, the Future Circular Collider, and the first conceptual design was proposed in 2019. [14]

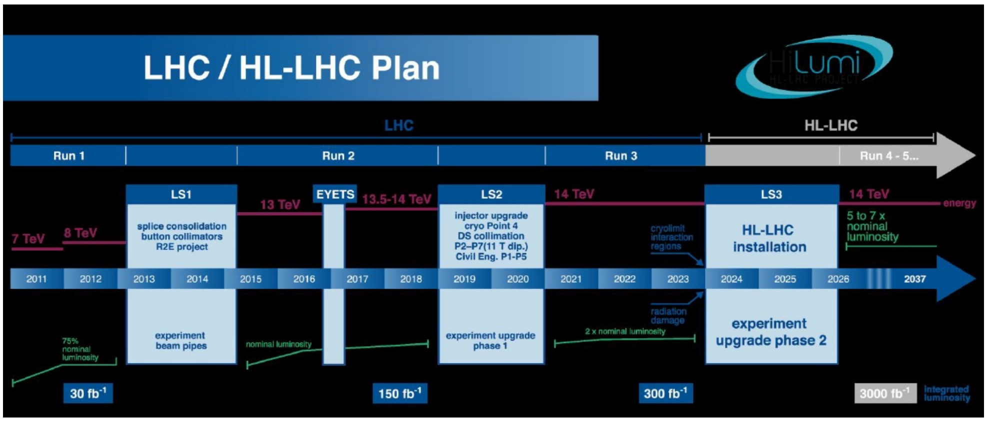

Figure 1.2: LHC/HL-LHC Plan, Source: [15]

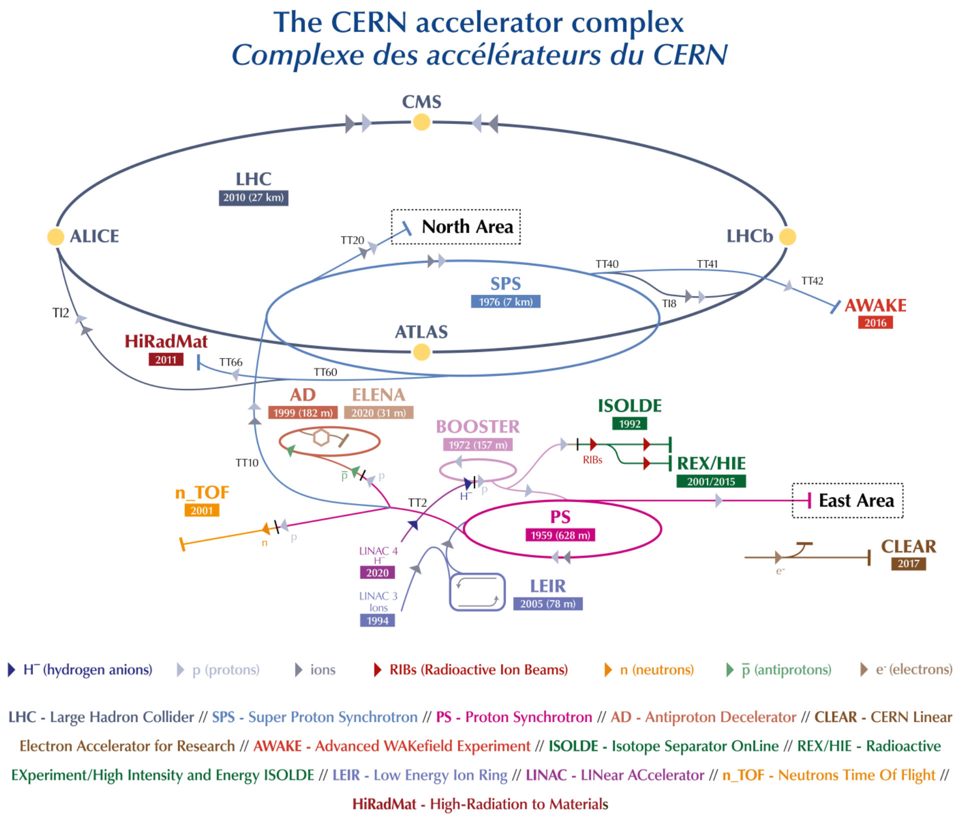

Figure 1.3: CERN Accelerator Complex, Source: [16]

CHAPTER 2

Analysis

This chapter explains the main goals of a feasibility study dedicated to the creation of an information portal about the Higgs boson. The current situation regarding the Higgs boson research is introduced, and resources that are used by the experts and the general public are analyzed. Interviews conducted with both user groups served for compiling the requested features of the portal. Afterward, user stories are created to showcase the features in the context in which they would be used. The potential number of users is examined and the best ways to advertise the portal after it is created are suggested. The number of mandays to complete the portal is estimated, and SWOT analysis is performed. Finally, ways to mitigate the potential risks are mentioned.

2.1 Portal

Throughout this thesis, the word "portal" or "Higgs Boson Portal" (HBP) is used frequently to describe the website this study aims to evaluate. Before the rise of big search engines, web portals were the doors to the internet and in a similar way, the Higgs Boson Portal aims to be the door to the world of the Higgs boson research. "*A portal is a web-based platform that collects information from different sources into a single user interface and presents users with the most relevant information for their context.*" [17] A successful portal should integrate information from different sources, with an emphasis on consistency and personalization. [17]

2.2 Feasibility Study

A feasibility study is an evaluation of the practicality of a certain project (a unique set of processes planned to achieve a particular goal). It takes all relevant factors into account – economical, technical and legal, in an objective and unbiased view. After reading the study, the reader should have a good understanding of whether it is feasible or not to begin the project before investing money and time into it. [18] A feasibility study can be completed for any kind of project, but the following points are written specifically with the creation of an information website about the Higgs boson in mind. This feasibility study aims to complete the following goals:

- Help the reader to understand all aspects of the proposed project.
- Summarize both the benefits and risks of completing the project.
- Provide an estimate of how much work is needed to complete the project.
- Propose a viable technical realization.
- Provide an outline for the website design.
- Should serve as documentation during the implementation.

Since this is a non-profit project (as CERN is a non-profit organization), there is no analysis of potential revenue.

2.3 Current State of Art

The official home page of the Higgs boson at CERN [19] offers a single article. The visitor can find a short write up about the history of the particle, how it was discovered and a mention of the Nobel prize awarded to François Englert and Peter Higgs. At the bottom of the page there is a "Latest Related News" section, which is updated only sporadically. Throughout the text, the reader is able to get to a few other pages by clicking links (such as the page for the Standard Model, W and Z bosons and several more).

This page can be useful for the public to get some basic information about the Higgs boson. However, it does not do so in a captivating manner, and it does not explain why the Higgs boson research is important.

2.3.1 The Public

For the general public, a Google search for "Higgs boson" gets many results, most of them are articles either describing the history of the discovery, or explanations of what the Higgs boson is. These pages are usually not being maintained and updated anymore and are often not interesting enough. There is not a website dedicated to spreading the knowledge about the Higgs boson to the general pubic.

Experiment	Available at	Publications
ALEPH	`https://cds.cern.ch/collection/ALEPH%20Papers?ln=en`	54
DELPHI	`https://cds.cern.ch/collection/DELPHI%20Papers?ln=en`	50
L3	`https://cds.cern.ch/collection/L3%20Papers?ln=en`	50
OPAL	`https://cds.cern.ch/collection/OPAL%20Papers?ln=en`	62

Table 2.1: Publication Data for the LEP-1 and LEP-2 Accelerators

Experiment	Available at	Publications
D0	`https://www-d0.fnal.gov/d0_publications/`	66
CDF	`https://www-cdf.fnal.gov/physics/new/hdg/Published.html`	63

Table 2.2: Publication Data for the Tevatron Accelerator

2.3.2 Experts

When the experts want to stay updated on the current progress in the Higgs boson research, there are multiple sites they have to follow and check regularly. Historically, each collider has its own, often very outdated website, and finding the results/papers is a tedious process, not to mention searching through them. In the next section, all the major resources for experts are introduced.

2.4 Scientific Resources

In this section both the finished experiments and the ongoing ones are presented. The number of published results is showcased and available categorizations are discussed.

2.4.1 Finished Experiments

There is a number of already concluded experiments, as mentioned in Section 1.3, CERN and the LHC, the data is shown in Table 2.1 and Table 2.2. Because these experiments are finished, we do not need to monitor preliminary results but only the published papers. The publication numbers count the papers withing the Higgs boson research.

However, for the ALEPH, DELPHI, L3 and OPAL some publications use combined data of the four experiments, and those papers are accounted for by each experiment. This results in some inflation of the total number of papers. The D0 experiment offers the option to list the papers by measurement topic, the remaining experiments do no offer any kind of categorization options.

2.4.2 Ongoing Experiments

There are currently two ongoing experiments researching the Higgs boson taking place at the LHC, ATLAS and CMS. Since both of these experiments constantly produce new preliminary results and publications, it is necessary to keep track of both. The data from these experiments is shown in Tables

Type	Available at	Total
Preliminary	https://twiki.cern.ch/twiki/bin/view/AtlasPublic/HiggsPublicResults	45
Published	https://twiki.cern.ch/twiki/bin/view/AtlasPublic/HiggsPublicResults	163

Table 2.3: Publication Data for the ATLAS Experiment

Type	Available at	Total
Preliminary	http://cms-results.web.cern.ch/cms-results/public-results/preliminary-results/HIG/index.html	172
Published	http://cms-results.web.cern.ch/cms-results/public-results/publications/HIG/index.html	130

Table 2.4: Publication Data for the CMS Experiment

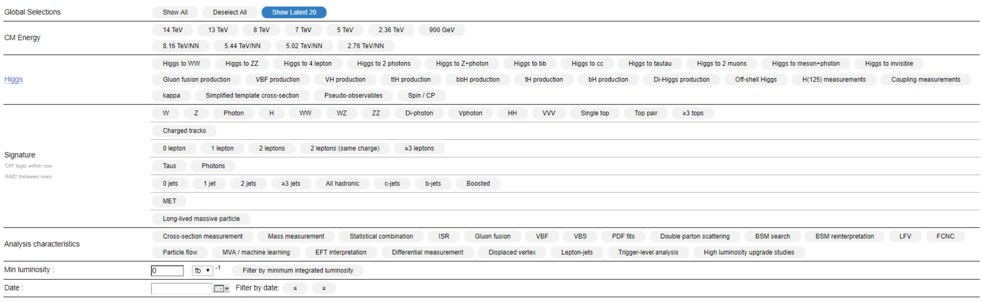

Figure 2.1: ATLAS Papers Categorization, Source: [20]

2.3 and 2.4. The data shown was collected on March 10, 2020. Once again, only the papers and preliminary results concering the Higgs boson research are counted in the tables. Both experiments offer their own categorization systems, as shown in Figure 2.1 and Figure 2.2.

There is also the LHC Higgs boson combination group, charged with producing combined Higgs boson results from LHC (ATLAS and CMS) Higgs analyses available at [21]. A summary of recent Higgs bosons research results is given for example in [22].

2.5 User Personas

Before starting to design a website it is useful to research the expected target groups. Creating user personas is a great tool for this. User persona is a fictional user created by merging common user requests and needs from real data, to represent a specific user group. Based on the research and interviews, two user personas were created. One represents the community of experts in the Higgs boson field and the second the interested public.

For the public persona a variety of people were questioned. For the expert persona, two scientists who work in the Higgs boson field were interviewed.

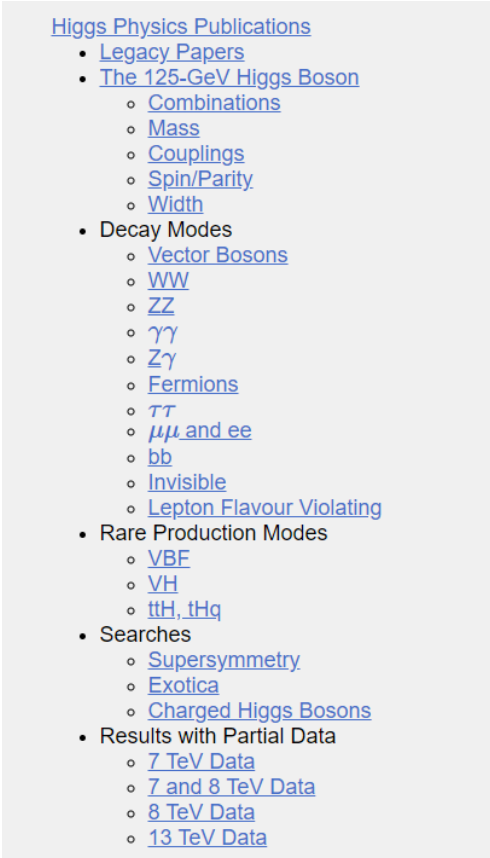

Figure 2.2: CMS Papers Categorization, Source: [23]

2.5.1 The General Public

The goal is to find out what they know about the particle, where have they learned about it, what they think about its significance and if they have any idea about the current research. Afterward, they were asked to search Google for "Higgs boson" and go through a couple of websites, their actions were observed and their feedback noted. The interviewees answered if they were satisfied with the resources they had found and what they felt was missing. Finally, the idea of a new website dedicated to the Higgs boson was proposed to them and the interviewees were asked what features would make them visit and use the portal and why.

From the interviews, the following information was gathered:

- The members of the public have very limited knowledge about the Higgs boson, usually they just know that it is a subatomic particle, that was discovered relatively recently.

- Most people have learned about it through the mainstream media coverage when it was first discovered. This was usually also the last time they heard about it.

- The majority of people assume that there is an ongoing research about the Higgs boson, but do not know anything about it nor about the progress that has been made since the discovery.

- The available resources tend to be too complicated and overwhelming. Some articles manage to explain the Higgs boson fairly well, but they are usually not engaging enough or there is a lack of some interactive/eye-catching elements.

- Generally, the idea of a website dedicated to Higgs boson was well-received.

The user persona created is Marie. She represents a member of the public, interested in learning more about the Higgs boson.

Marie is under 25 years old, and she has not finished her education yet. She is fascinated by the world around her and likes to question reality. However, she does not know much about the Higgs boson, and she would like to learn more. It is challenging to retain her attention as she is bored of reading lengthy, dull articles. She likes modern, responsive, and interactive websites that offer information in a captivating manner. She would appreciate an explanation of how a Higgs boson is produced, how it decays, and what are its properties. She likes the idea of an interactive timeline of the Higgs boson research.

2.5.2 Higgs Boson Experts

When interviewing the experts, the focus was on the biggest inconveniences they face on a daily basis and how these could be prevented. They were asked what features they would like the HBP to have and why. A list of websites they visit regularly was created, as listed in Section 2.4, Scientific Resources. Based on the interviews, the following points were obtained:

- A lot of information about the Higgs boson has accumulated since it was first proposed.

- Two main directions of the research are the Standard Model and beyond the Standard Model.

- The experts need a good structure and categorization for all the information that is available.

- The categorization system available for the ATLAS papers is preferred to the one from CMS.
- The information has to stay complete and up to date.
- Published papers and preliminary results have to be distinguished clearly.
- The experts would like to see how the precision of certain measurements developed in time.
- They would like an option to subscribe to certain topics, categories, and keywords to be notified about new developments.
- The idea of having a tool documenting how the mainstream media are talking about the Higgs boson was well-received.
- A picture gallery could be shared between both the public and expert sections.

Below is the user persona created to represent the Higgs boson experts.

Peter is over 30 years old and is a scientist. He is an expert in particle physics and he has been in this field for many years now. It is important for him to stay up to date with the latest development in research. He wants to be notified about both the finished publications relevant to his research and the preliminary results. Having an overview of how the precision of different measurements is changing would be another good feature to have. He wants to be able to access all the scientific information about the Higgs boson from one place.

2.6 User Stories

User story is an informal, short, and simple description of a feature. The feature is explained from the user's perspective. Usually, a simple template is followed: Some kind of *user* wants to accomplish some kind of *goal* for some *reason*. [24, 25]

Using these is a good way to summarize how the portal is supposed to work and how it benefits its users. Once fully developed, the portal should have all the features mentioned in the following user stories.

- High school student wants to learn what the Higgs boson is and why its discovery matters.
- College student is looking for a comprehensive overview of the Higgs boson research (how it started, a timeline of the most important events, and the future prospects) for their Physics paper.

- Scientist wants to search all Higgs boson papers for information without the need to visit multiple sites. They want to be able to search in different categories of Higgs boson research, as well as to sort and filter the results. When they find an interesting paper, they want to find more papers relevant to it.

- Particle physicist wants to see how the precision of measurements of different Higgs boson properties changed over time to get an idea of how the research is progressing.

- Higgs boson expert needs to stay updated on the ongoing research. They want to be notified when new results are published in the fields they are interested in.

- Statistician is looking for data about the Higgs boson research (how many papers have been published, how many scientists publish in this field, how often new results come out etc.) for their analysis.

- CERN employee wants to go through the finished experiments to compare some of the old results without digging through no longer updated obsolete websites.

- Higgs boson expert is looking for a specific set of preliminary results meeting their criteria. If such a result does not exist yet, they want to be notified if it appears.

2.7 Potential Number of Users

In order to get a better idea of how many users the portal could have, a few relevant websites were analyzed using SimilarWeb [26], and WikiShark [27], for Wikipedia pages. The English Wikipedia page for Higgs boson [28], is visited approximately 30,000 times per month [29]. The main page of CERN [30], is visited roughly 300,000–400,000 times per month [31]. Since the Higgs boson research is at the forefront of CERN's agenda, we can assume a high percentage of those visitors are interested in Higgs boson. The mentioned numbers show that there is a large potential target group for the Higgs Boson Portal.

For the experts, we can estimate the numbers by counting how many scientists work and/or publish in the Higgs boson field. There are more than 8,000 scientists involved with the ATLAS and CMS experiments. As about half of the working groups do research on the Higgs boson physics, about 4,000 potential experts could be estimated to be interested. According to SimilarWeb, the Cern Document Server gets roughly 300,000 to 400,000 views per month [32], and CERN wiki (which hosts the ATLAS experiment publications) around 100,000 per month [33]. Altogether, these numbers confirm that there is an interest in the Higgs boson research both from the public and from the experts and plenty of potential users for the portal.

2.8 Advertising the Portal

To make sure the portal gains traction after it is finished, CERN could utilize their websites that are already up and running to advertise it for free.

CERN's Homepage [30]

An article about the new Higgs Boson Portal could be posted and shown in the latest news section. The Higgs boson page [34], could be updated with a new paragraph about the portal and provide a link.

ATLAS Results [35]

The home of ATLAS collaboration results could add a link to the HBP to the list of resources at the top of the page.

CERN's Library [36]

The resources section could include a link to the HBP.

ATLAS and CMS collaboration homepages [37] and [38]

Both the ATLAS and CMS collaboration websites could post an article about the new HBP.

CERN's Newsletter [39]

A newsletter dedicated to updating the community about the latest news and announcements from CERN is a perfect place for the portal to be advertised. All members of the CERN community are automatically subscribed and anyone with a CERN account that can be created by anyone, even the general public, can subscribe to it as well. [40] A well put together article introducing the portal and its features would reach a high percentage of the target audience.

Following through with all of the suggestions mentioned above should create enough awareness about the portal for a successful launch.

2.9 Work Estimate

The following gives an approximate estimate of how much time and money would the development of the Higgs Boson Portal cost. Creating a Gantt chart was considered, but for a Gantt chart to be viable, it is good to already know the team of people working on the project we are trying to estimate. That is when the main advantage of the Gantt chart comes in – it is clearly visible

	Estimate
Database:	**2 MD**
Designing the database architecture	1 MD
Creating the database	1 MD
Automation scripts:	**5 MD**
Web-scraping	2 MD
Auto-categorization	3 MD
Website:	**6.5 MD**
Creating the website layout and design	3 MD
Integrating the log-in with CERN Single sign-on	0.5 MD
Implementing displaying, searching and categorization of papers and preliminary results	2 MD
Implementing an error reporting tool for the automated categorization	0.5 MD
Implementing a subscription/notification system for registered users	0.5 MD
Testing:	**4 MD**
General testing	2 MD
Testing with members of the general public	1 MD
Testing with Higgs experts	1 MD
Total:	**17.5 MD**

Table 2.5: Estimation of the Time Needed to Develop and Test the Portal

which tasks can be developed in parallel and which are dependant on each other. A critical path in the chart then shows that "*the longest sequence of dependent or floating tasks that must be completed in order to get the project done on time.*" [41]. It also shows where possible roadblocks can happen.

Since the speed of development of the HBP is not one of the main factors in analyzing its viability and there is no information about the potential developer or developers working on it, a Gantt chart is not the right tool to use. Instead, the time needed to complete different tasks is estimated in the Table 2.5. All estimates are in mandays (the amount of work one person can do in one workday, 8 hours per day).

It is assumed that the developer is already experienced and proficient in what is needed to complete the Higgs Boson Portal. This being the first estimate, we have to assume a high factor of uncertainty. Usually, that means we expect the real time spent developing the project will be within 0.25–4 times of the original estimate. As the work on the project proceeds, the cone of uncertainty gets more narrow, allowing the estimates to be more precise. [42]

This estimate only includes the work needed for building the portal and it does not account for time needed to write the content for the general public side of the portal. This is not expected to be done by the developers, but by a teacher or a Higgs boson expert with a deep understanding of the problematic. However, once the portal is built, editing or adding the content for the public can be done at any time.

2.9.1 Development

In a project like the Higgs Boson Portal, which is expected to be completed by one developer, or a small team (2–3 people), it is hard to estimate the cost, even in a very broad range. The hourly rate varies largely depending on the experience of the developer [43], or it could be done at lower costs by a student. For that matter, no cost estimation was made. The estimated mandays needed to develop the portal should provide enough information for the stakeholders.

2.9.2 Hosting the Portal

Since CERN already has a strong network infrastructure, hosting websites with hundreds of thousands of visits per month as mentioned in Section 2.7 (Potential Number of Users), hosting the HBP at CERN could be a good possibility.

2.10 SWOT Analysis

SWOT analysis is a great tool to summarize all of the previous findings. The name is an acronym for the four key elements examined.

Strengths Unique features that make the portal special. What advantage does the Higgs Boson Portal have over the already existing alternatives?

Weaknesses What could prevent the HBP from reaching its target audience? Will the benefits of developing a new website outweigh the costs?

Opportunities Factors outside of the project that could be advantageous.

Threats The exact opposite of opportunities – factors that cannot be manipulated, but could result in the portal being unsuccessful.

The SWOT analysis has the same goals as the feasibility study – determine the viability of going through with the development of the Higgs Boson Portal, but provides a much more concise and brief look on different aspects of the project. [44]

2.10.1 Strengths

- All the past research information in one place.
- Automatically updated database with new papers and preliminary results.
- One automatic categorization system across all the data.

- Easily searchable and readable information.
- Presentation of available statistics regarding the Higgs boson research.
- Depiction of the progress in measurement precision.
- Modern and responsive look.
- Option to be notified about certain developments in the Higgs field.
- Easy to understand, comprehensive information about the past, present, and future research to the general public.
- Explanation of the terms for looking further into the Higgs boson research.

2.10.2 Weaknesses

- The portal's auto-updating features will not be good enough to warrant a switch from already existing portals.
- The categorization system might not be detailed enough to satisfy the needs of experts.
- The cost of developing the portal will not outweigh the benefits.
- Portal's database will not be comprehensive enough to make users come back to it instead of the ones they were using before.

2.10.3 Opportunities

- There is not a dedicated portal to Higgs boson knowledge yet, aimed both at the experts and at the general public.
- The Higgs Boson Portal could be an alternative to well-established portals (arXive [52], for example), that have a very broad reach. It aims to coexist with them while providing a better user experience for its target group (people interested in the Higgs boson research).
- The Higgs boson research is well-estabilished and is expected to continue for many years to come.
- The awareness of the general public about the Higgs boson is expected to go up, as more research results are published.
- The current alternatives are not comprehensive enough, and are often outdated or not up to par with the current trends in web development.
- The portal could draw more interest in the research of Higgs boson.

2.10.4 Threats

- The portal will not gain enough users to make it worth maintaining.
- The maintenance costs of the portal could grow, if some of the resources being scraped undergo a transformation and the auto-scraping scripts need to be rewritten.
- Some already existing portal goes through a major overhaul before the Higgs Boson Portal is released and provides the functionalities that are currently missing.
- Some unexpected scientific discovery will halt or slow down the interest in Higgs boson research considerably.

2.10.5 Examining the Risks

Two of the mentioned weaknesses are tied to the auto-updated and auto-categorized contents of the website. Positively, the system can be improved and fine-tuned in iterations and the portal does not have to launch at a deadline. This means there can be plenty of opportunities for the experts to give feedback on it and for the developer to respond. Another potential risk is not receiving the necessary funding for the project. However, this also has a solution – developing such a portal is suited as someone's bachelor's or master's thesis, or as some form of an internship, or CERN summer school student project. CERN offers plenty of opportunities for students, available at [45]. Another risk is that after launch, the portal will not get enough attention from users. This can be prevented by carrying out the steps mentioned in Section 2.8, Advertising the Portal. In summary, the risks involved can be greatly reduced without sacrificing the benefits of the portal.

Chapter 3

Technical Realization Proposal

In this chapter, the solution on how to keep the database updated and the papers and preliminary results categorized is proposed. The goal of the solution is to be as simple as possible. One script is provided as a proof of concept to help inspire the full implementation. For the sake of simplicity, the following sections discuss gathering and categorizing the papers, but the same process can be applied for the preliminary results. A way to display the papers is proposed, along with suggested software architecture and technologies.

3.1 Filling the Database

The first step is to gather all the relevant papers (and preliminary results) into one place. This can be done by scraping the relevant websites mentioned in Section 2.4 called Scientific Resources.

3.1.1 Web Scraping

Web scraping is a technique used to extract data or files from websites automatically. The extracted data can be stored, examined, or processed further. There are many web scraping applications available (ParseHub, WebHarvy, Webscraper.io, and Apify, just to name a few), as well as many libraries (the most popular Python libraries are Requests, Beautiful Soup, Selenium, and Scrapy). Usually writing a script that does precisely what is needed is preferred over using a pre-made solution. Python 3.8 was used for the provided script, along with the open-source Scrapy library. The commented script is available in the enclosed media storage. It showcases scraping the ATLAS page for all papers published in the HIGG category and saves the information into a JSON file. Similar scripts can be written for all the resources that need to be scrapped. For the already finished experiments, the number of relevant papers is small (shown in Section 2.4 Scientific Resources), and they do not have to be checked for new publications, the relevant papers can be gathered manually as well. For ongoing experiments, these scripts can be run regularly, once every 24 hours for example. This should only take a couple of seconds and it ensures that the portal stays up to date.

3.1.2 Storing the Papers

Is it feasible to store the papers (PDF files), or should the portal just provide the links to other websites that offer the download? The advantage of storing the files is that they will always be easily available for anyone visiting the Higgs Boson Portal, even in case the original site ceases to exist, or the hyperlink becomes no longer valid. The disadvantage of saving the files is the need for the necessary storage space for it. Fortunately, the papers are usually just a few megabytes large, so even storing thousands of them is not a big problem.

What also has to be considered is the license under which the paper is published. The preprint versions are often available on arXive [52]; however, the published version is not always freely available. From October 2014 onward, all of the currently published research by CERN is under Open Access, which is a set of principles guaranteeing the research output will be accessible online, free of cost or other access barriers [46, 47]. Often the CC-BY license is also applied, defining that the work can be shared freely, as long as the original author is recognized.

This means all the research under Open Access can be safely stored and redistributed by the HBP. With the older papers, the situation can differ. The number of those papers is in the hundreds, so in case of doubts about the licensing of specific papers, a manual check can be made to ensure no mistakes are made.

3.2 Categorization

Once the complete list of papers is gathered, they need to be correctly categorized and tagged. The following categories are proposed, based on the current ATLAS and CMS categorization. This categorization can be scraped of the ATLAS and CMS website respectively. For the keywords, the other resources can be scraped (generally, the InSpire Hep provides a good list of keywords). Here are the proposed categories:

Type Clear distinction whether the results are published, or preliminary.

Experiment Can select between Current (ATLAS and CMS) or Legacy experiments (D0, CDF, ALEPH, DELPHI, L3 and OPAL). If desired, specific experiments can be selected.

Date of publication Option to select newer or older results than a chosen date.

Luminosity Option to select minimal luminosity.

Collision energy Option to select the collision energy at which the results were observed.

Decay modes Option to select the desired decay mode of the Higgs boson.

Production processes Option to select production processes (VBF, VH, ttH, tHq).

Searches Option to select papers regarding searches for Supersymmetry, Exotica or Charged Higgs bosons.

Analysis characterics Option to select the type of analysis performed.

A proposal of the categorization/search screen is shown in Figure 4.3 and Figure 4.5.

3.2.1 Relevant Papers

Since coming up with an algorithm to automatically search relevant articles is not the aim of this thesis, here is an overview of already existing solutions. The papers are available on different portals, each of them offering a slightly different set of information. All of the following sites provide an abstract of the paper.

CDS (CERN Document Server) [48]

CERN's document server provides a brief list of keywords, a list of figures and auxiliary material along with the link to arXiv.

InSpire Hep [49]

Provides abstract, automatically generated keywords, list of citations, references, and figures. If available, links to other resources are included.

HAL Archive ouverte [50]

Shows the domain of the paper along with a list of keywords.

ADS (Astrophysics Data System) Abstract Service [51]

The most interesting site of this list, along with keywords, references and citations, has the option to display similar papers to the one currently selected. It also offers papers read by those who read the current paper in the Co-reads section.

arXiv [52]

Provides references, citations and links to other resources.

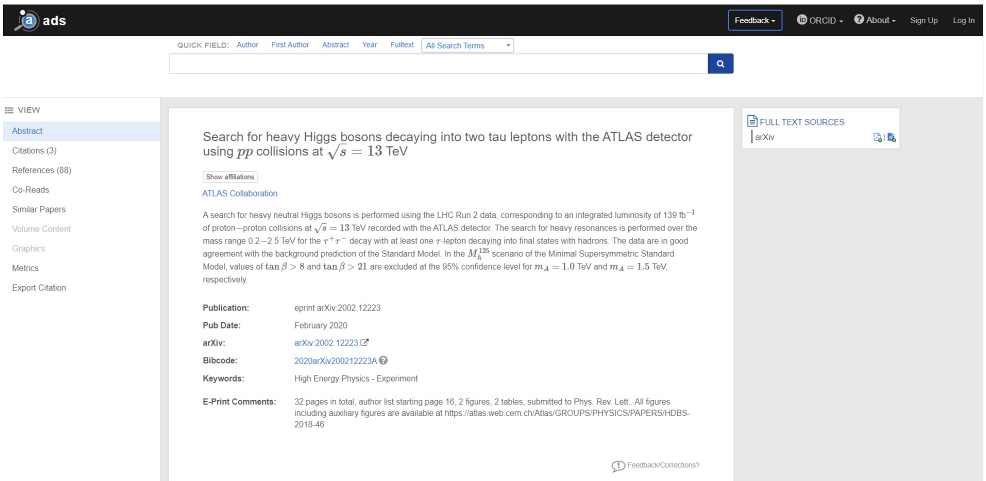

Figure 3.1: Paper Displayed in ADS Abstract Service, Source: [51]

Google Scholar [53]

Does not display the papers in the same fashion as the other portals, but after searching for the desired paper shows the citations and more importantly, offers the option to show relevant articles.

There are many ways to find relevant articles already in place. For the Higgs Boson Portal, providing the link to ADS Abstract Service (if available) would be the best solution. Another option would be to display articles with the highest matching categorization and keywords in the HBP, which is simple to achieve and could serve as an alternative to ADS.

3.2.2 Reporting Errors

In case the categorization is incorrect, the portal will offer users the option to report the mistake or suggest some other edit. The user selects the keyword/category which they deem is incorrect and picks what they think is the correct solution. These change requests are then sent to a designated person with rights to either accept or reject the proposed changes.

3.3 Displaying the Papers

All of the services mentioned earlier offer a simple and clean presentation of the paper, as shown in Figure 3.1. The name of the paper along with the abstract is the crucial info to display. Other information such as publication date, categories, keywords, and more details about the paper (page, figure, and table count) should be clearly visible.

The list of all the available links to other websites the paper is hosted on is an important feature since the goal is to be as comprehensive as possible. A metric tab similar to the one in ADS could be implemented, showing how many times the paper has been viewed, searched for, and cited. A suggestion of the paper view is shown in Figure 4.2, with more commentary in Chapter 4, Designing the Higgs Boson Portal.

3.4 Software Architecture

In this section, the two popular software architecture patterns that were considered for the Higgs Boson Portal are introduced and their pros and cons are discussed.

MVC (Model-view-controller) Figure 3.2 shows how the MVC architecture is separated into three components. The model represents the data, the view displays the data from the model and the controller reacts to events (usually an input from a user) and makes changes to the model. When the model is updated, the view is changed accordingly. Because the parts do not share responsibilities, MVC makes it easy to maintain and modify the code. The disadvantage is that navigating the code can get complex, multiple technologies are mixed together and there is usually some boilerplate code.

MVVM (Model-view-viewmodel) Figure 3.3 shows that there are a lot of similarities with MVC. The difference is that instead of the one-way, circular flow of MVC, the data-binding between the view and viewmodel provides two-way communication. That is good for quick and fluid saving and loading data from the database. However, this comes at a cost of higher memory consumption on the user's side. The MVVM model is especially good for single-page applications.

Since the Higgs Boson Portal does not require a lot of user input (mostly searching the portal or the scientific paper's database), and the users will not regularly edit the data from the models, the MVC architecture is suggested.

3.5 Suggested Technologies

There are plenty of frameworks available for the MVC architecture. The main choice comes down to the preferred programming language. Some of the most popular options are presented below, but these are just recommendations and the best framework is the one the developer is the most comfortable with.

Some of the recommended frameworks are:

Spring Framework for Java.

Django, Flask Frameworks for Python.

Ruby on Rails Framework for Ruby.

Laravel Framework for PHP.

Angular.js, React.js, Node.js, jQuery Javascript frameworks.

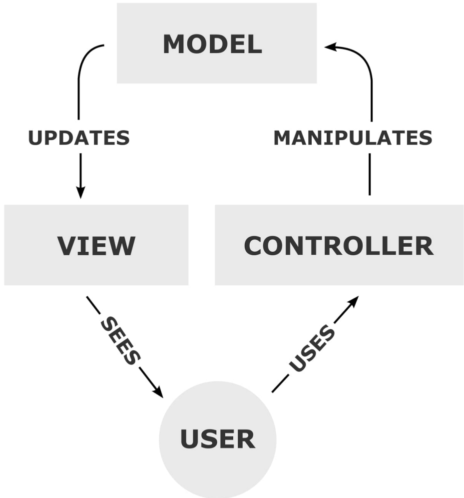

Figure 3.2: MVC Diagram, Source: [54]

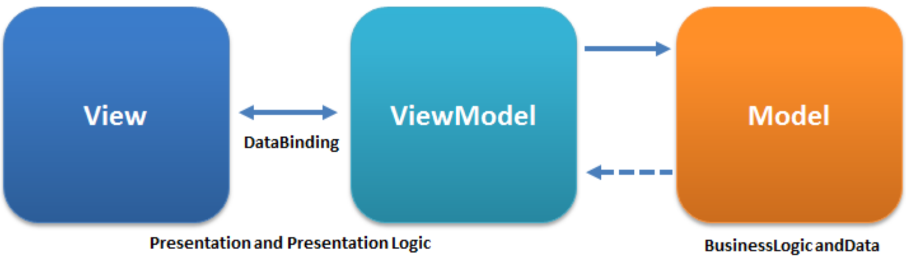

Figure 3.3: MVVM Diagram, Source: [55]

CHAPTER 4

Designing the Higgs Boson Portal

In this chapter, the created wireframes for the portal are presented, and the decision-making behind their creation is explained. The main features of the portal are showcased and suggestions for possible future developments are given.

4.1 Wireframes

Wireframes are used very often in web and application design. They provide an easy way to showcase how the individual pages of the portal are supposed to look like, along with showing the structure of the website itself. Because the wireframes can be clickable, they can mimic the final experience the user would get very well. This means that they can be used in presenting the website to the stakeholders before starting the development or to begin user testing of specific user interface (UI) elements. The main benefit is that wireframes can be changed and edited easily, based on the feedback received, so it is suitable to use them early in the development. Sometimes the wireframes are limited to a very basic black and white look, without any actual design or content shown. This serves just for testing the layout and structure of the page. However, for the Higgs Boson Portal, a more polished look using colors and some placeholder content for the wireframes was chosen. This decision makes it possible to represent the possible final look and feel of the portal better. If the real development of the portal starts, the wireframes can be used as documentation. [56]

4.2 Technology Used

For the creation of the wireframes for the HBP, Adobe XD (available for free at [57]) was chosen, because of the author's previous experiences with this software.

4.3 Layout and Theme

The whole layout of the portal is based on CERN's homepage [30]. This decision was made for the following reasons:

- The goal for the portal is to feel familiar and the users should get used to it quickly.
- CDS [48] and CERN Library [36] already use the same header and similar layout as CERN's homepage.
- Using the same layout and color scheme in multiple CERN's websites strengthens the uniformity and makes it easy to distinguish if the user is still visiting a website hosted by CERN.
- The layout used is simple and easy to use, while providing enough utility to navigate all the features of the Higgs Boson Portal.

4.4 Selected Screens

In this section, some of the important screens for the portal are presented and described. These are by no means the final design, but should provide a good enough representation of the portal for both the general public and the experts. All screenshots can be found in the attached media, along with the Adobe XD file.

4.4.1 Default Page Layout

The default layout, which is shared between all the portal pages is shown in Figure 4.1. The gray top bar displays the name of the portal along with the option to sign in. The "Sign in" button will redirect the user to CERN's Single Sign-On page [58]. This then allows the user to sign in either using their CERN account (applicable mostly to the experts), or to sign in with Facebook, Google, and other accounts. If the user wishes to do so, they can create a new account by providing their email.

The main functional component of the layout is the black horizontal navigation bar. On the left side is the switch between the general public version of the portal and the one for experts. This distinction will always be clear to the user and will make switching between the versions easy. The name of

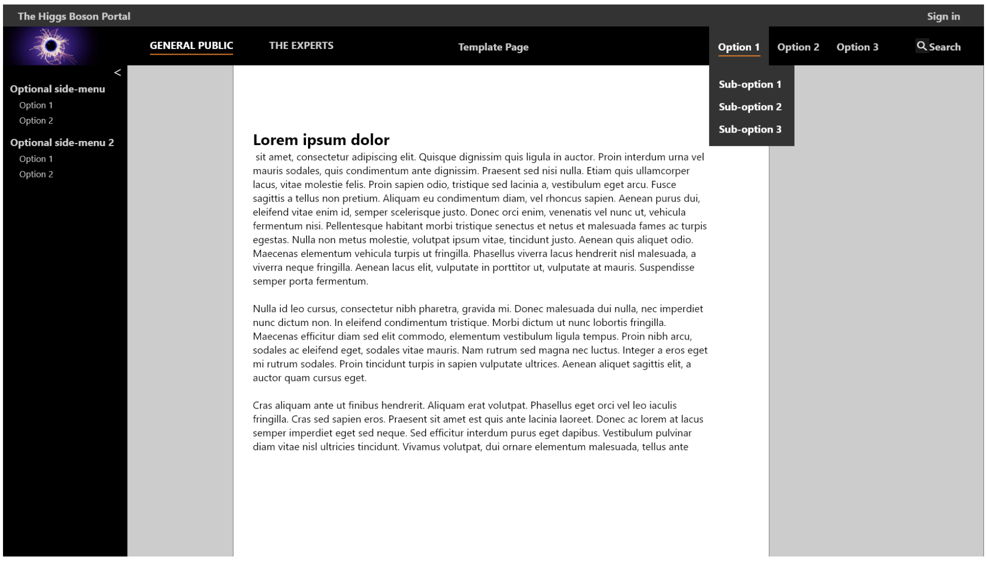

Figure 4.1: Default Layout

the page currently being visited is in the middle of the bar. The main options are on the righthand side of the horizontal navigation bar. A difference from the CERN's homepage is the optional sub-options dropdown menu displayed after hovering over an option. On the very right side of the navigation bar, there is an option to search the portal. Another new feature is a collapsible vertical navigation side-menu on the left. This menu is only displayed when needed, and it can either serve for navigation within one long page (displays where the reader is in the article and allows him to quickly move between chapters/headers), or it can display additional links. The biggest part of the page is available to display the desired content. The navigation UI is kept simple to make it easier to focus on the information displayed.

4.4.2 Displaying the Papers and Preliminary Results

An example of how the papers could be displayed is shown in Figure 4.2. The layout of the page is kept close to the looks of a physical copy on paper. For each paper, there are three sections available on the sidebar. Every section has a "Submit a correction/feedback" button in the lower right corner of the page. This allows users to report errors in categorization or in the displayed info, along with a suggestion for a fix.

Search box Enables the user to quickly search the information about the currently chosen paper and highlights them. If the searched term is on a different section than currently selected, the view switches to where the term is (for example, searching for a term that appears in the abstract while looking at the categorization page).

Figure 4.2: Displaying the Papers, "About" Section

About Shows all of the necessary information about the paper – the title, the authors, the abstract, and the publication date along with the journal name, if the results have already been published. Below is some additional info including the page-length and the number of figures and tables. This allows the user to quickly decide if he is interested in looking into the paper. If he is, they can continue to one of the portals listed underneath, or download the paper directly if it is available on the HBP. Additional features like displaying citations, references and figures or exporting citations are available from the provided resources, implementing them for the HBP would cause more work with a little added benefit – our target user group is already proficient using the provided portals for those tasks. If needed, the available resources could include a description of which features they offer.

Categorization The categorization screen, shown in Figure 4.3, allows the user to see how the paper is categorized within the portal. A quick glance at the categories gives the user more information about the results, without having to download and look into the paper itself. Clicking on "Search with this criteria" takes the user to the search page with criteria from the paper carried over. The user can search without changing it, achieving the same results as looking at the "Similar papers" option, or he can modify the searched categories.

Similar papers The third option shows similar papers stored on the Higgs Boson Portal. An example is shown in Figure 4.4. It shows the papers with the highest similarity in categorization and keywords as the cur-

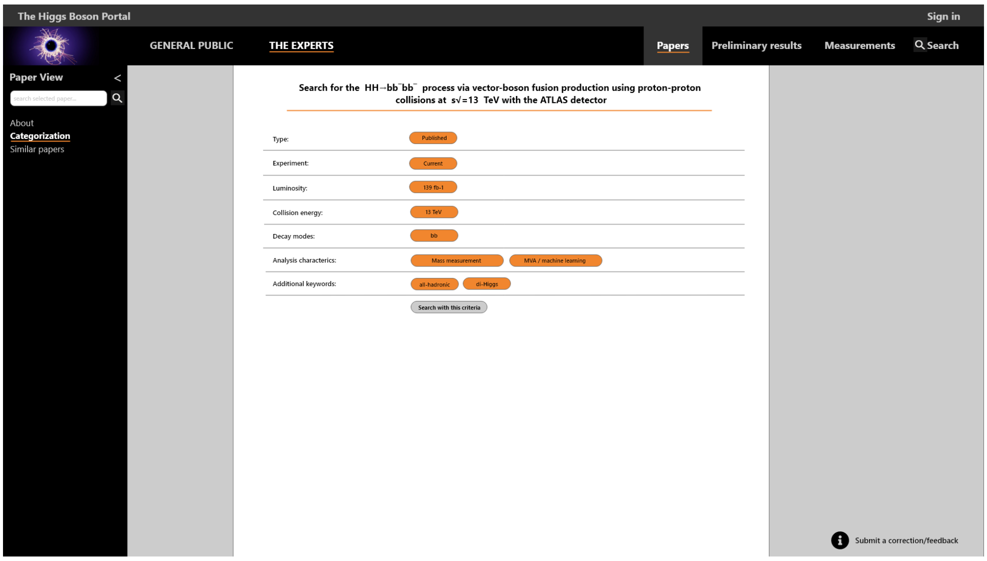

Figure 4.3: Displaying the Papers, “Categorization” Section

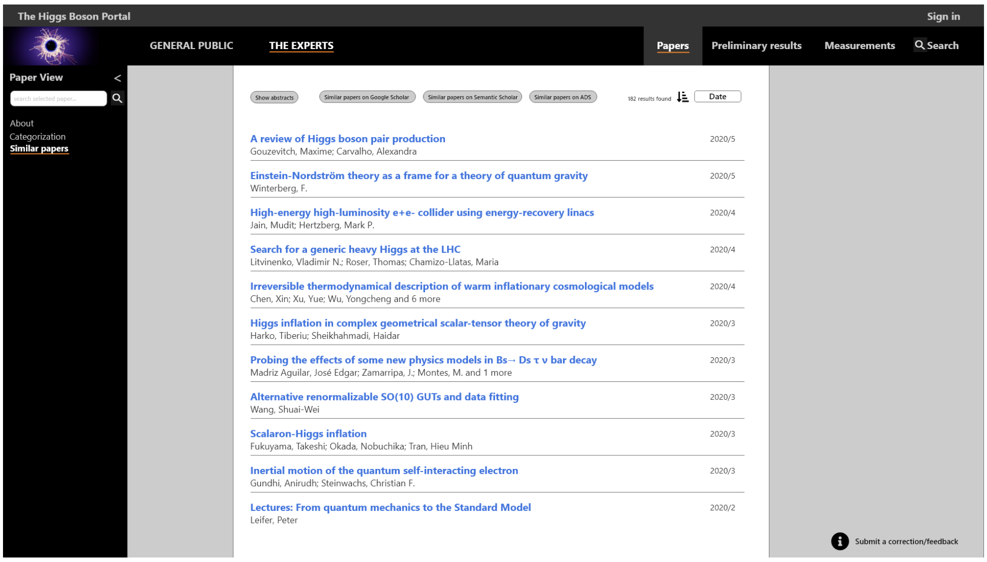

Figure 4.4: Displaying the Papers, “Similar papers” Section

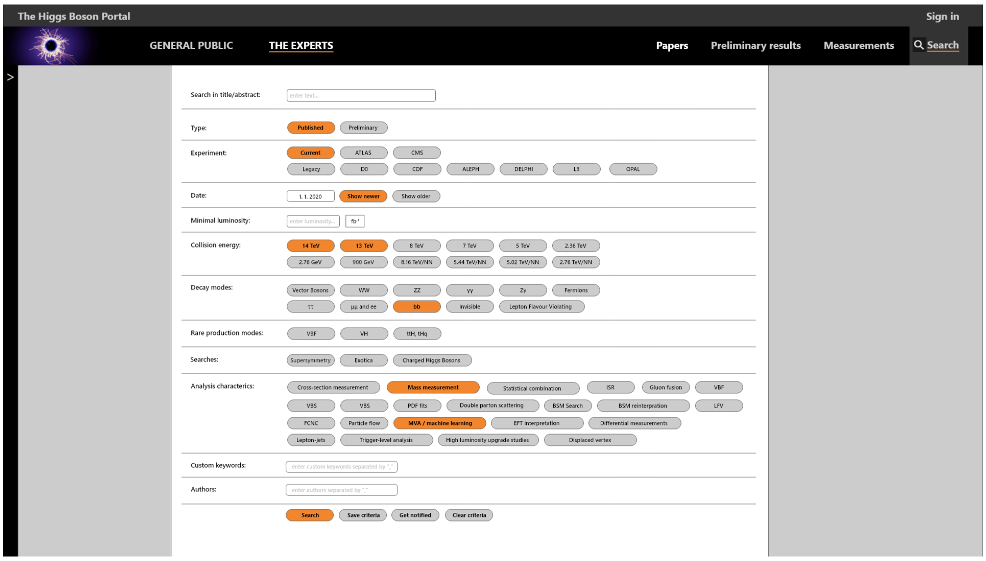

Figure 4.5: Searching the Higgs Boson Portal

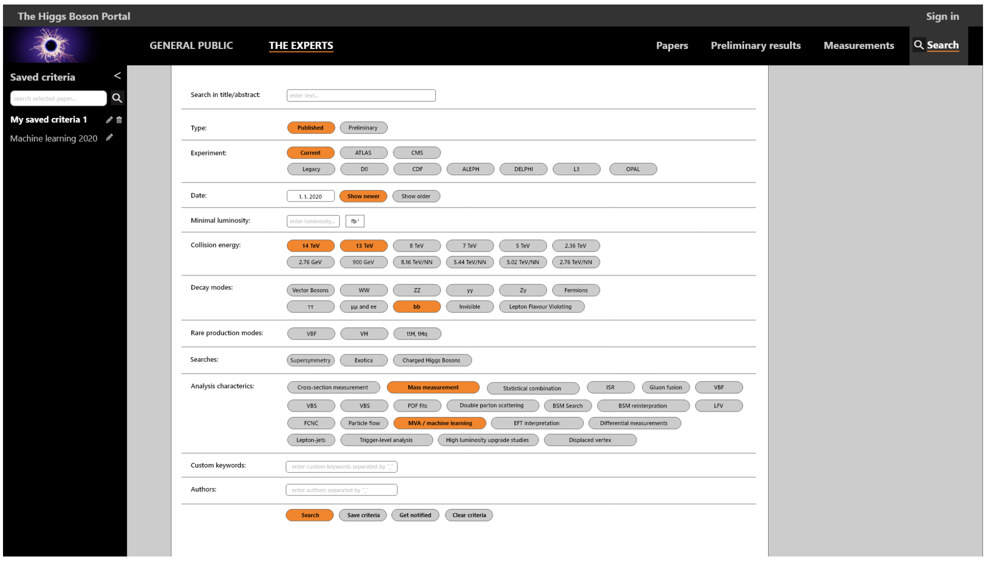

Figure 4.6: Saved Search Criteria

rently selected paper with the results sorted by the newest by default. If the paper is available on websites that have their own similar/relevant papers section, those will be accessible by clicking the buttons on the top of the page.

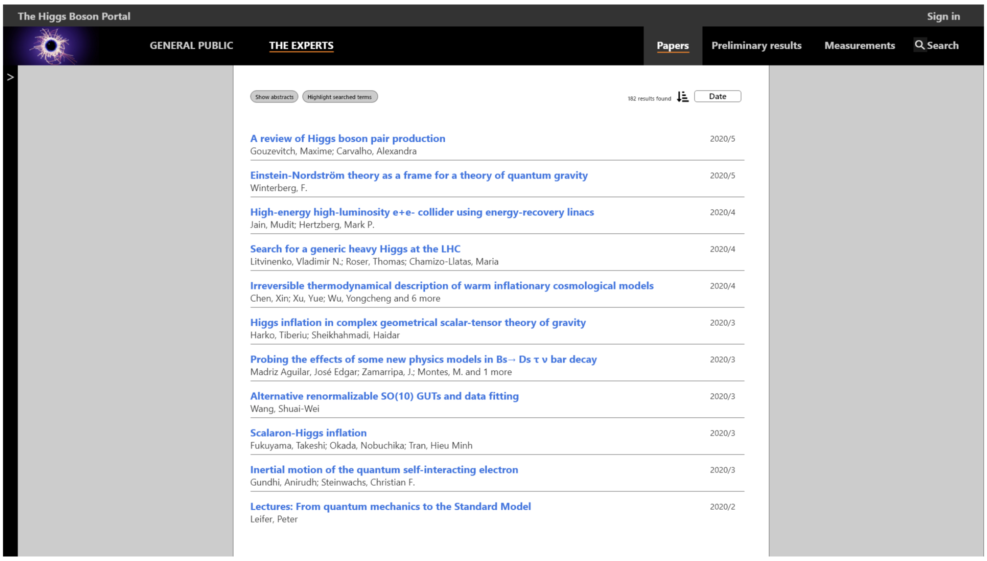

Figure 4.7: Search Results

4.4.3 Searching the Database

Figure 4.5 shows the search page. It was designed to make searching through the database quick and intuitive. Selecting multiple criteria within the same category ties them together with "OR" logic (search for results with collision energy 14 TeV or 13 TeV) while selecting criteria from multiple categories adds "AND" logic (search results with certain collision energy and certain decay mode). Searching through titles and abstracts, looking for custom keywords or specific authors is also possible. The "Save criteria" button at the bottom of the page provides the user (if he is logged in, otherwise he will be asked to do so) with an option to save and name specific search criteria to access them quickly, shown in Figure 4.6. Saved criteria can be named, edited, or deleted. Similarly, the user can select the option to be notified (by email associated with his CERN account) whenever a new result meeting the selected criteria is published. When the search button is pressed, the matching results are presented as shown in Figure 4.7. Any kind of displaying results is handled in the same fashion to prevent confusing the user. The user can choose to display abstracts along with the title for each result. The sorting can be also specified, by default the papers are sorted from the newest. In case the user searched for a specific term, the occurrences of the term in the title or abstract can be highlighted by clicking the corresponding button.

4.4.4 The Public

The most important feature for the Higgs Boson Portal version for the general public will be the content itself – the text must be captivating and easy to

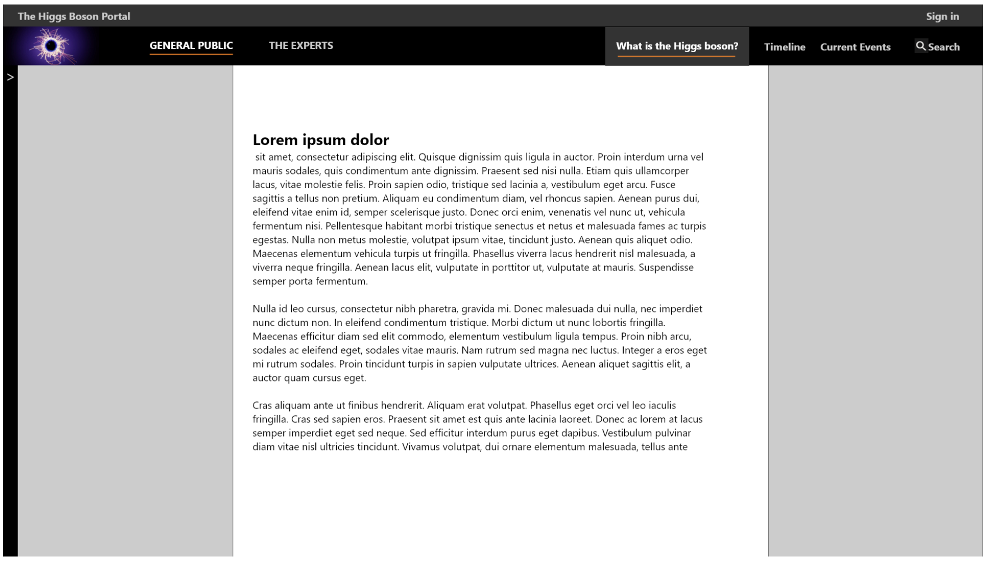

Figure 4.8: General Public Layout

grasp. The proposed layout is shown in Figure 4.8. There is no need for special navigation options or categorization in this case, so the sidebar can stay collapsed. If a longer article is posted, the sidebar can expand and show the reader the chapters and in which part of the article he currently is. The content of the main page "What is the Higgs boson?" should be short and sweet to not discourage the user from learning more. The next section "Timeline" would provide a scrollable, interactive timeline capturing all the major events in the Higgs boson research, accompanied by short descriptions of the events and pictures. In case the reader is interested in more information, the "Current Events" tab would provide a curated list of articles. Another option is an interactive section about the production and decay of the Higgs boson at the LHC. Finally, tab called "Resources" could also be added, collecting a list of educational content about the Higgs boson by CERN for kids, students, and adults. A section "For Teachers" with educational materials suited for use in classes is an another possibility to have.

4.5 Additional Features

In this section, a couple of suggested features mentioned previously but not shown in the wireframes are described.

Statistics One resource that could be interesting, especially for the general public, is an overview of all the numbers associated with the Higgs boson research. Statistics such as the total number of publications, scientists, experiments, the size of data gathered and others would provide a quick way to see how large the scale of the Higgs boson research really is.

Research terms explained A glossary explaining the important terms needed to understand the Higgs boson research would make understanding the current research development easier for the general public. Some suggested terms to explain are the different Higgs boson decay modes, search within and beyond of the Standard Model, differences between preliminary and published results, and the differences between an observation, occurrence, and exclusion.

Measurement precision development Having the opportunity to see how the precision of measurements of different Higgs boson properties has evolved over time would be a great tool to summarize the research progress both for the experts and for the general public. The data could be presented in the form of a line chart to increase the readability. However, getting the necessary data automatically would be challenging. It could probably be accomplished by a neural network trained to automatically extract the measurements and its precision from the papers. The question is if developing such a neural network is feasible – the necessary data could be also entered manually and updated periodically. This might be a better option since a carefully selected sample of data is sufficient for a description of the evolving trend.

Conclusion

The aim of this thesis to conduct a feasibility study about a new information portal dedicated to the Higgs boson and its research was achieved. The first chapter familiarizes the reader with some key terms that need to be understood before analyzing the feasibility of the portal.

In the Analysis chapter, the “Higgs Boson Portal” name is explained along with the feasibility study goals. The available resources both for the general public and for the Higgs boson experts were analyzed. Based on that and the user interviews conducted with both user groups, user personas and user stories were created to highlight the requested features for the portal, both from the experts and from the public point of view. The potential number of users was analyzed. Some advertisement possibilities for the launch of the portal were explored. The work and cost estimations are outlined. A SWOT analysis was performed, and advice on how to mitigate the potential risks is provided. Overall, the benefits of the portal outweigh the risks.

In the Technical Realization Proposal chapter, advice on how to keep the database updated and categorized is given. The recommended software architecture is discussed, and some frameworks that could be used for developing the portal are listed.

In the Designing the Higgs Boson Portal chapter, wireframes created for the main features of the portal are introduced, and the decision-making behind their creation is explained.

Overall, this thesis provides enough insight into creating the Higgs Boson Portal to prove that it is feasible and it can serve as a guideline during the development of the portal. There is also plenty of room for the future growth of the portal. After successful launch, implementing features to become less dependent on other already existing databases – such as creating an automatic keyword generation based on machine learning – is advised. There are also opportunities for completely new features, for example automatically extracting measurement precision from already written papers and graphing the results to showcase how the research has progressed in time.

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Appendix A

Acronyms

ADS Astrophysics Data System

ATLAS A Toroidal LHC ApparatuS

CDS CERN Document Server

CERN European Organization for Nuclear Research

CMS Compact Muon Solenoid

HBP Higgs Boson Portal

HEP High Energy Physics

HL-LHC High-Luminosity Large Hadron Collider

LEP Large Electron-Positron Collider

LHC Large Hadron Collider

MVC Model-view-controller

MVVM Model-view-viewmodel

PDF Portable Document Format

UCL University College London

UI User Interface

Appendix B

Contents of Enclosed USB Flash Drive

```
├── readme.txt ......... instructions on how to run the script and wireframes
├── atlas.py .............. commented proof of concept web-scrapping script
├── example_output.json ........ example output of the web-scraping script
├── wireframes.xd ...................... Adobe XD file with the wireframes
├── thesis.pdf ...................................... thesis in PDF format
└── screenshots ......... directory with exported wireframes in PNG format
    ├── Categorization.png
    ├── Displaying the paper.png
    ├── Papers displayed.png
    ├── Public.png
    ├── Saved criteria.png
    ├── Search.png
    ├── Similar papares.png
    └── Template.png
```