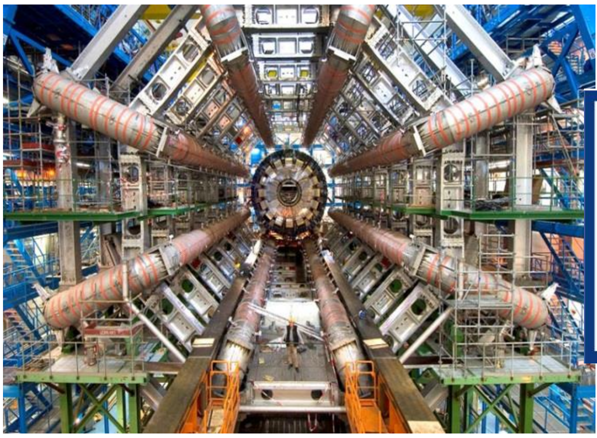
Khalifa University of Science, Technology and Research

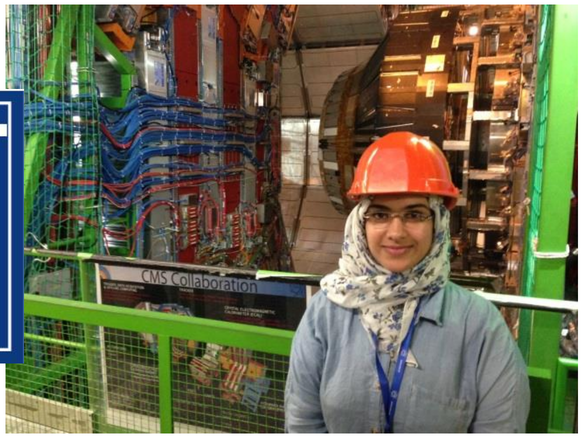
Mechanical Engineering Department

MECH 399

Mechanical Engineering Internship

Summer 2013





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Abstract:

This report discusses my summer program in CERN for summer 2013. In one of the world's leading nuclear research organization, where scientists' urge to figure out how universe was created and how it started, drive them to preform significant experiments on fundamental particles, using the most powerful particle accelerators. The report will address general information about CERN and its various departments. Moreover, it will include my personal experience as a summer student and an insight on my gas analysing project. Finally, I will conclude with the outcomes, skills, experience and knowledge gained through this unique journey.

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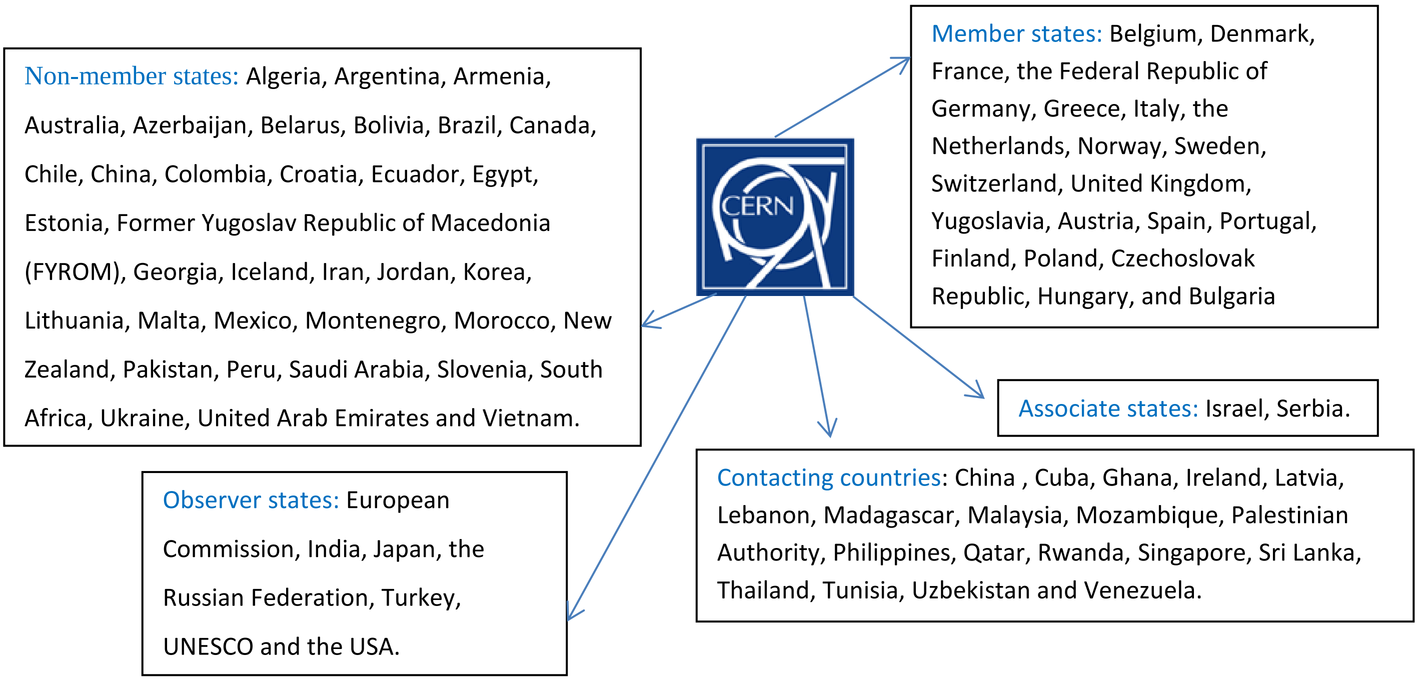
Introduction:

I still remember the first time I heard about CERN, when my physics professor was discussing the magnificent experiments to collide particles at the speed of light. I couldn't believe it at the beginning, and I kept wondering about how is it preformed? How the results are obtained? And the most important question, why? I still remember one of my quick daydreams where I would actually be there at CERN attending the great collision. Two years later, I am here at CERN as a summer student and intern from my university!

CERN:

CERN is a European Organization for Nuclear Research, established in 1954 across the Franco-Swiss borders near Geneva. The acronym CERN is derived from "Conseil Européen pour la Recherche Nucléaire". At the beginning, researches were mainly about nuclear physics. However, nowadays CERN's major focus is Particle Physics, where they concentrate their studies on the fundamental constituents of matter and the forces acting between them. This is accomplished by using the world's most complex scientific instruments to collide particles together near to the speed of light.

Here at CERN, scientific collaboration occurs from countries all over the world. The figure below shows the countries involved in this magnificent project.



Structure of CERN:

Council: which includes two official delegates from each member state. One represents his or her government's administration; the other represents national scientific interests. However, each member state has a single vote.

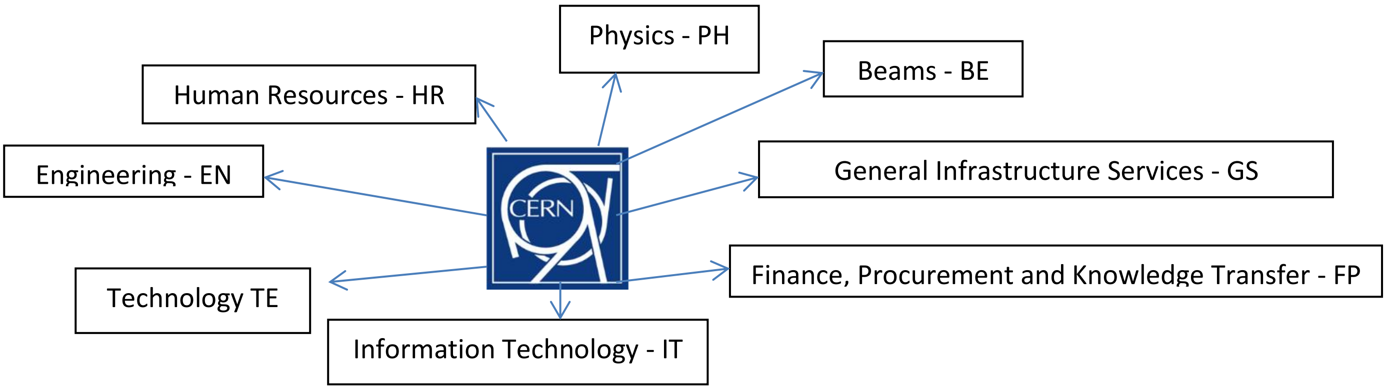
Scientific Policy Committee: which evaluates the scientific activities proposed by physicists and makes recommendations on CERN's scientific programme.

Finance Committee: which deals with all issues relating to financial contributions by the member states and to the organization's budget and expenditure.

Director-General: Which manages CERN and is selected by council, usually for five years.

International relations: Coordinator for International Relations.

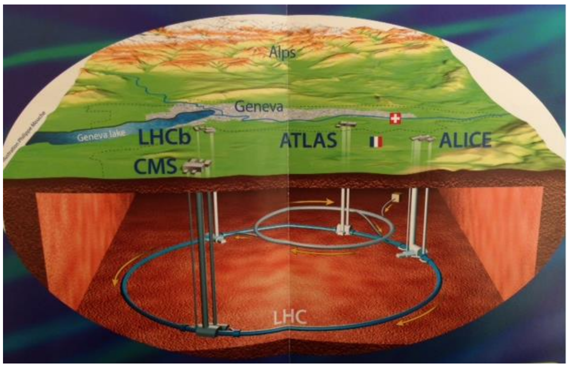
Departments: there are many departments that work co-ordinately and are illustrated in the diagram below [1].



LHC:

The large Hadron Collider is the most powerful accelerator that accelerates two beams of particles in opposite directions to 99.9% the speed of light; in order to produce showers of new particles. The LHC is surrounded by the Jura Mountain in France and Lake Geneva in Switzerland and supervised by CERN. It has 27 Km in circumference and buried 50-150 m underground.

It should be noted that the huge energies used in the LHC have never been produced in any other laboratories before. The picture below illustrates the four major experiments of the Large Hadron Collider: ALICE, ATLAS, CMS and LHCb.



Summer Student Program:

The "summer student" program is an amazing once-in-a-lifetime opportunity. You meet scientist from all over the world and gain both experience and knowledge. Moreover, you learn a lot by working in teams in different experiments, field visits, workshops and daily lectures that discuss wide range of topics in the fields of theoretical and experimental Particle Physics and computing.

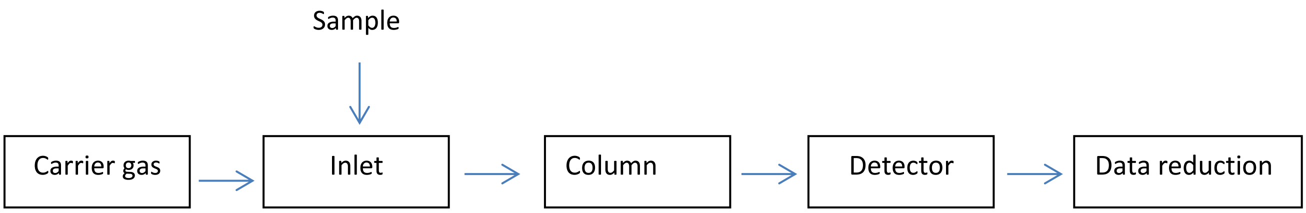
Self-Experience:

In CERN, I'm working in PH-DT department under the supervision of Dr. Roberto Guida. At the beginning I had some hand-outs and research papers which discuss particle detectors and gas analysis in details. In my opinion, this was a very important educational step especially that I lack knowledge and experience in this field.

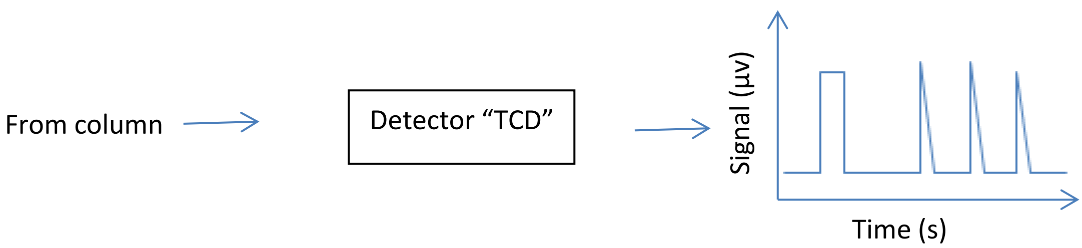
- **Gas Chromatograph**

At the moment, I'm working with gas chromatographs for the four LHC experiments, which are gas analysers that basically separate a mixture of gasses into its main components relative to time. This is done by passing the vaporized mixture through a tube containing a material that retards some components more than others. As a result, we will be able to identify the components that are already known from previous studies. In addition, we can easily measure their concentration. The picture below corresponds to a MicroGC3000.

The chromatographic system, as shown below, consists of five main parts.

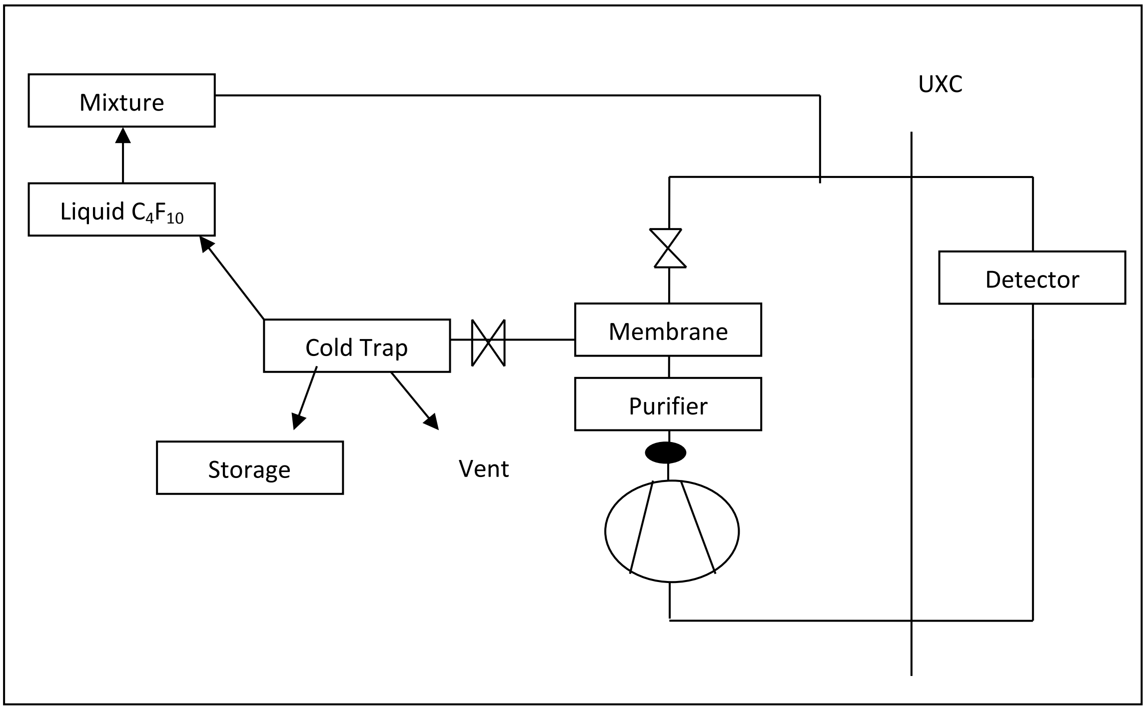


The first part is a carrier gas which “pushes” the sample through the gas chromatograph. The carrier must be of high purity to prevent any kind of contaminations, usually Argon or Helium are used. Then, the sample is moved through the inlet where it gets vaporized in case of liquid samples. There are two main types of inlet, injection ports that use liquid or gas syringes to insert the sample. While the second type is sampling valve that use a mechanical loop to flush the sample. After that, the mixture passes through the column, which is heated in a high-temperature oven. To allow the separation of the gas components, the internal surface of the column is coated with specific material depending on the gas mixture. Finally, the separated components move towards the Thermal Conductivity Detector (TDC) to give us the gas chromatogram plots. The mentioned process is illustrated in the figure below [2].

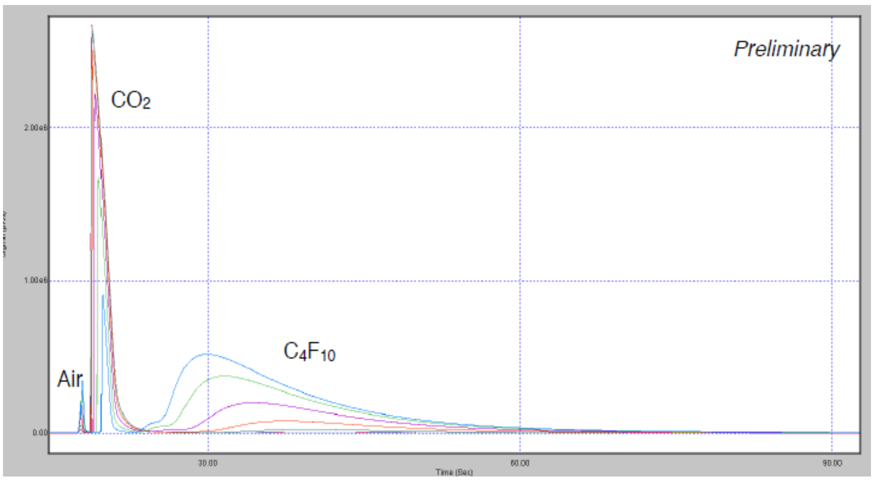


- **Gas Chromatogram analysis for the LHCb RICH detector:**

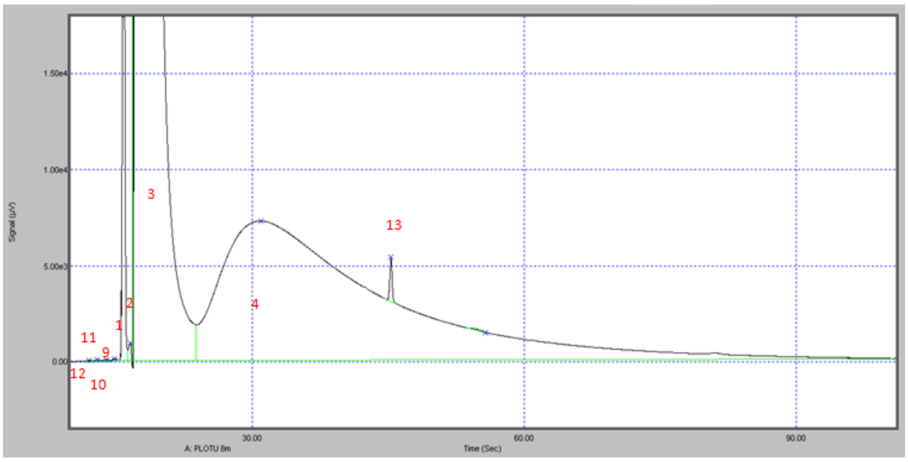
My first task as a summer student was to perform gas chromatogram analysis for the LHCb RICH detector. This detector works by measuring emissions of the Cherenkov radiation, which occurs when a charged particle passes through a certain medium faster than the light does. In this case, the medium by which the RICH detector is filled consists of 4 m^3 of C_4F_{10}. The figure below illustrates the gas circulation system.



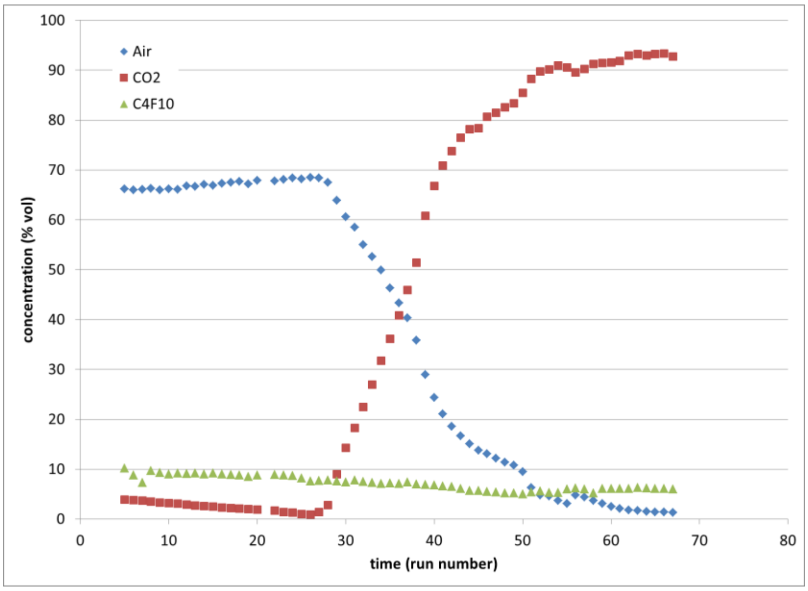
My task was to analyse this gas mixture, especially the data we acquire during the filling of RICH detector with CO_2 and the recuperation of the C_4F_{10} at the beginning of the LHC long shut down. Now, the C_4F_{10} is stored in special containers, as it is very expensive. The figure below shows the usual obtained data, where each peak indicates a certain component of the mixture, while the peak's integral is proportional to the concentration.



Of course, the figure above represents the ideal situation. However, the data obtained from the lab had more peaks; this is mainly referred to impurities or leakage. For example, the figure below has 6 peaks more than the ideal one.



The final step is to group all the data in an excel sheet and then produce a plot for the main three components representing Air, CO_2 and C_4F_{10}. The figure below shows the plot obtained. Around run 27 the CO_2 started to arrive at the cold trap in the liquefier module. This indicates that the detector is almost completely filled with CO_2. The analysis allowed also estimating the C_4F_{10} loss during the recuperation process. In fact, from the figure below, a C_4F_{10} concentration between 5-10% has been measured in the exhaust of the liquefier module.



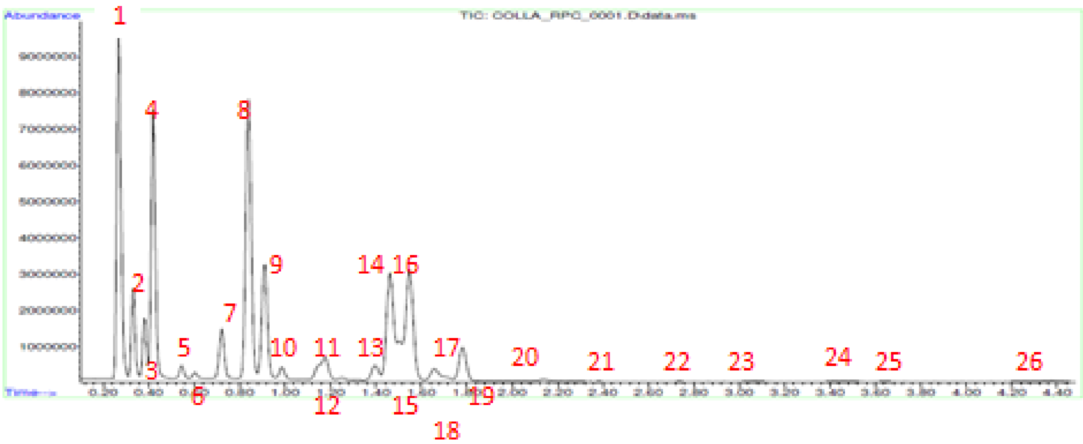
- **Mass Spectrometer Detector:**

The GC detector separates mixtures into individuals and it measures their concentration. Unfortunately, the GC cannot identify these components; as a result, a Mass Spectrometer detector ‘MS’ is needed. The picture below shows the setup of the Mass Spectrometer at CERN’s Gamma Irradiation Facility.

The MS enables the user to recognize the molecules within the sample. It actually ionizes the molecules and then the ions are separated, counted and identified. This is done by using the difference in mass-to-charge ratio (m/z) of ionized molecules, which is a unique value for each component. It is very essential to note that operations in the MS should be performed under Vacuum, in order to allow the free movements of ions [3].

- **Validation of the glue for the ATLAS RPC Detector:**

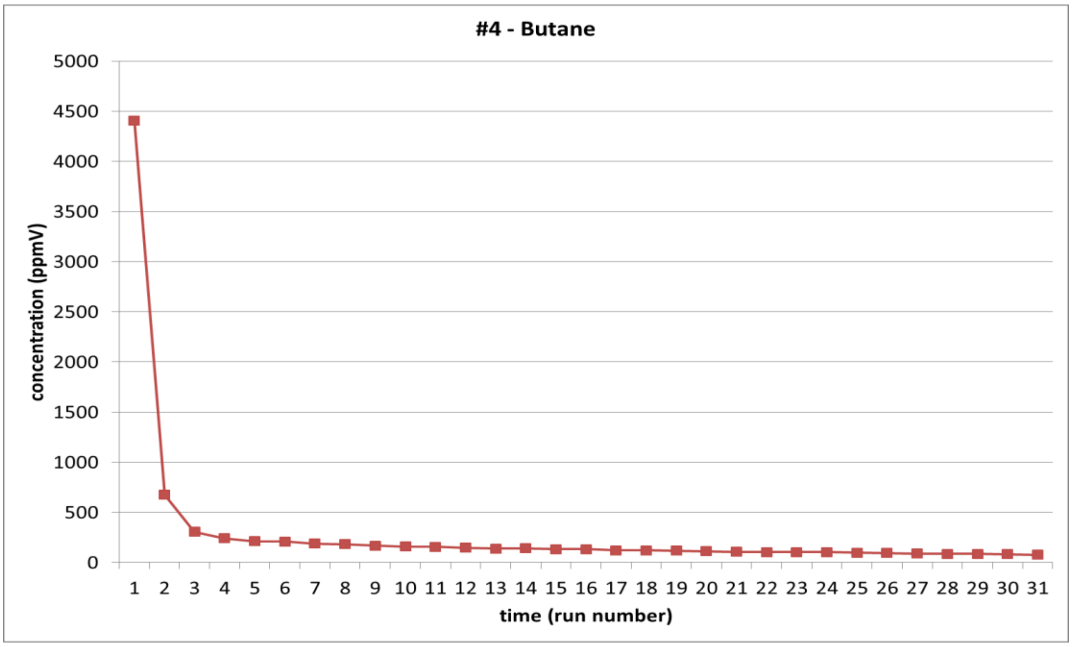
The ATLAS Resistive Plate Chamber (RPC) detector will use a new kind of glue (URETHAN71, K) to repair some of the broken gas connectors during the long LHC shut down 2013-2014. Since this glue could potentially outgas harmful components for the detector, it needs to be validated. This means that the gas will be checked to assure it is safe for the detector operation. In order to validate the gas, I performed several GC/MS gas analysis. To do so, I used gas analysis station which consists of a GC coupled with a MS. After that, we injected the glue into a plastic pipe that is connected to the inlet of the GC/MS. The Figure below shows the signals obtained from MS detector.



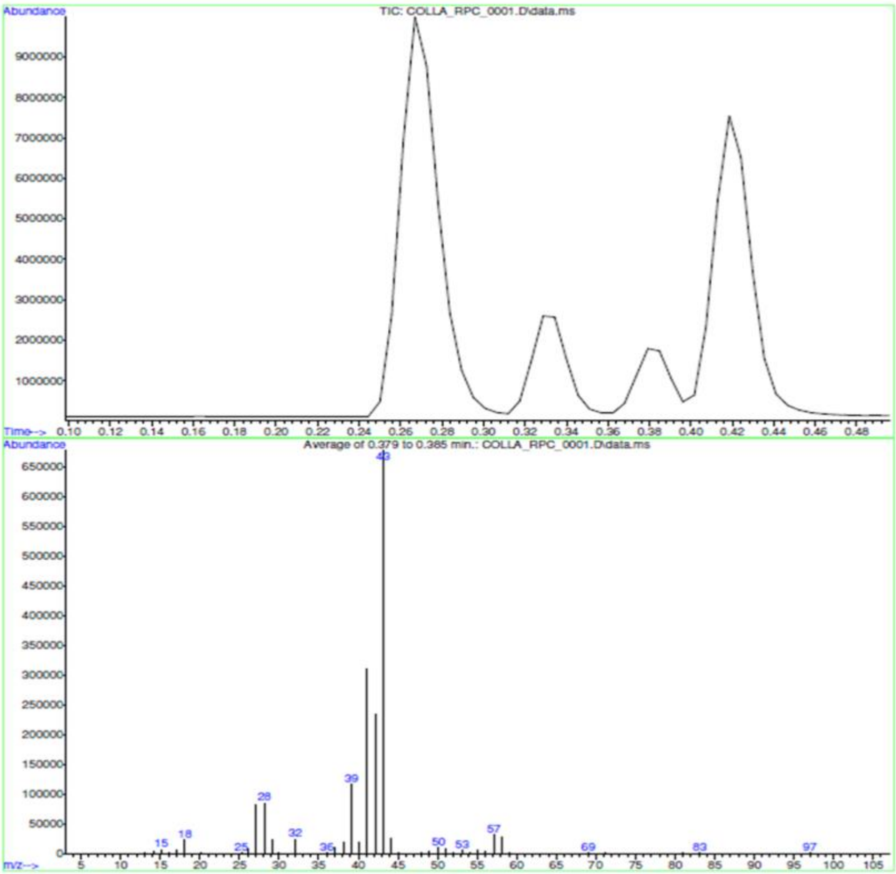
Each of the peaks shown in the figure above indicates a certain molecule.

1:Air	11: unknown	21:methyl-cyclohexane
2:Propane	12:2-methyl-Butane	22: 1,3-dimethyl-cyclohexane
3:Isobutane	13: 2,2,3-trimethyl-Butane	23:unknown
4:Butane	14: 3,3-dimethyl-Pentane	24: 1,4-dimethyl-cyclohexan
5:2-methyl-Butane	15: 3-ethyl-3methyl Pentane	25:1,4-dimethyl-cyclohexan
6: Pentane	16:unknown	26: unknown
7: 2,2-dimethyl-Butane	17:3-ethyl-Pentane	
8: 2-methyl-Pentane	18: 3-ethyl-Pentane	
9:3-methyl-Pentane	19: unkown	
10: Hexane	20: Heptane	

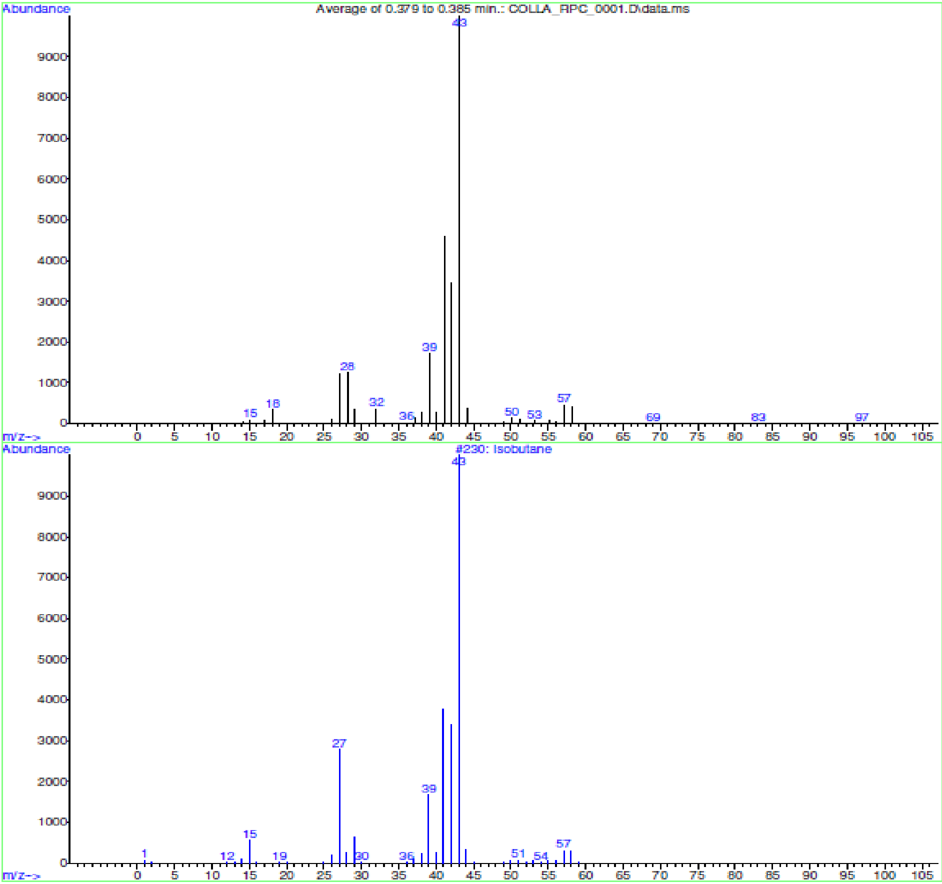
The concentration of all components is quickly decreasing with time as shown in the figure below. A further analysis was performed two days after the injection of the glue and it was found that all extra-components were not anymore present.



To illustrate an example, the figure below indicates the ions population for the first peak.



After that, the ions spectrum is compared with spectra stored in a powerful library made by the NIST institute as shown in the figure below. In this case the signal is similar to Isobutene, as shown below.



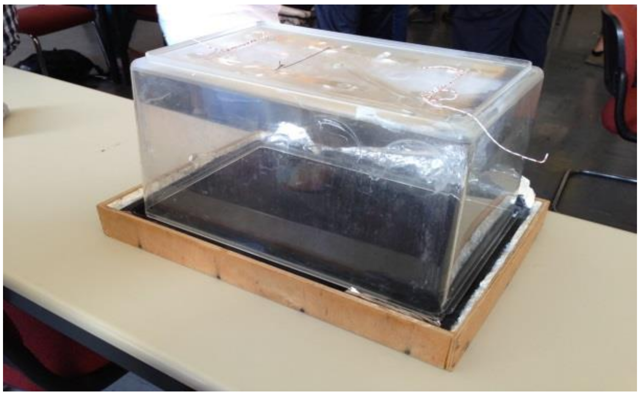
Activities:

What I love the most about my summer program that I don't only analyse data, or stay all the time in the office. I actually get the chance to visit many laboratories such as: GIF (Gamma Irradiation Facility), LHCb and CMS very often. I usually go there to take data or check the gas chambers. My supervisor Dr. Roberto always says "it is very important to have a sense of what you work on". The picture on the left side was taken in one of the CMS visits, where visitors must wear helmets and closed shoes. In addition, visitors with medical implants are prohibited from certain areas due to the high magnetic field. While the picture on the right side captures my personal dosimeter, which is used to measure the radiation and I absolutely cannot enter the GIF without it.

Here at CERN, safety is considered as a number-one priority. So, beside the strict safety procedures in labs and during visits or workshops, online safety courses play an important role too. From day-one we had the first online course, Computer Security. The course mainly addresses the do's and the don'ts while using CERN's computing resources. Later on, my supervisor suggested couple of courses like CMS Safety (Level 4C) and RP Training for CERN Supervised Radiation Areas. These courses were necessary to raise my safety awareness due to my regular visits to supervised radiation areas.

As for the lectures, I find them a very great opportunity to learn new aspects. Many of them were easy to follow, whereas, some lectures were a bit hard. I believe the reason is strongly related to my Engineering background that is a bit far from Particle Physics. Moreover, the difficulty of lectures had varied from a bachelor level to a PhD level, to suit the educational levels of all the summer students. I have to say that 'Beyond the Standard Model' was absolutely my Favourite set of lectures, as it was well explained and very interesting. In addition, I really enjoyed a multiple-sessions' seminar called 'Nuclear Physics', which was related to my nuclear engineering studies. It actually helped me correcting some of the wrong concepts I had, and understanding them in a better way. The picture below was taken in one of the seminar's sessions.

As for the workshops, I participated in the Cloud chamber workshop which allows you to see cosmic rays. The experiment requires frozen block of CO_2, 90% Alcohol, metal plate, plastic box, electrical lamp and a wooden carrier. First, the Block of CO_2 is placed in the wooden carrier and covered by the metal plate. After that, we pour the alcohol in the upper part of the plastic box, which contains foam. Later on, we place the plastic box over the metal plate as shown in the picture below.



Finally, we use the electrical lamp to see the cosmic rays.

I believe it was amazing workshop, and I recommended a lot of my friends to register for it; because it was a simple and fun group-work of the theories we have been learning so far.

Conclusion:

I have to say it was hard at the beginning to adjust to the new concepts of Particle Physics. Especially that I lack knowledge and experience in this field. However, I believe that some of the courses that I took in my university such as Nuclear 301 and Physics II were very helpful and gave me at least the basic knowledge I needed to pursue my summer program.

Something I appreciate a lot about the summer program is the various learning methods. Starting with the 45-mins daily lectures, special seminars, field trips, workshops and ending with the team projects, presentations and posters. You never stop learning, even in a short dinner discussion!

In CERN I developed many skills in research, leadership and creativity. I become more aware of what determination and hard work can achieve. In addition, I value team work more than ever, because I was in a team, and I witnessed several meeting of my supervisors, so I learnt how to respect and cooperate with teammates in a very productive way.

CERN is not only an educational organization, but also an amazing cultural enrichment. By now I know how to cook Mexican food, how to sing a Hungarian song and how to speak English with an Italian accent.

Here at CERN, every person comes with a story of determination, hope and urge to success. I had a wish two years ago of being at CERN, I'm glad it became true!

References:

[1] "www.cern.ch," CERN, [Online]. Available: http://home.web.cern.ch/about. [Accessed 21 08 2013].

[2] SRA Instruments, "Micro-ChromatographAGILENT 3000 - User manual and technical proce- dures," Agilent Technologyies Inc, USA, 2002.

[3] B. Mandelli, "Optimization of the RPC gas recirculation system for the CMS experiment," University of Pavia, Italy, 2011.