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การฝึกงานวิศวกรรม (ENGINEERING PRACTICE)

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ภาควิชาวิศวกรรมไฟฟ้า

คณะวิศวกรรมศาสตร์

จุฬาลงกรณ์มหาวิทยาลัย

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<u>ช่วงระยะเวลาการฝึกงาน</u> ตั้งแต่วันที่ 4 มิถุนายน 2561

ถึงวันที่ 3 สิงหาคม 2561

<u>รวมระยะเวลาการฝึกงาน</u> 8 สัปดาห์ 5 วัน 0 ชั่วโมง

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Preface

For Mr. Jiraphon Yenphraphai, the 8-week internship at CERN is a valuable chance for me to develop and improve the skills I never had. My daily work is to see the beam profile in the Proton Synchrotron. I love my workplace, CERN control center. It would be great to have more time here at CERN, being surrounded by physicists and engineers having the same passion.

In this report, it consists of 4 main parts. The first point is introduction to summer student at CERN. For the second point, I will about CERN background information. The third part is the key of this report since I will tell the readers thoroughly about the things that I have done during my summer here such as beam document and inspector project. Ultimately, the problem and benefits would be presented.

Last but not least, I would love to appreciate for my supervisor, Piriya Chaichanasiri, who always not only teach me about the PS, but also take care of me. Moreover, I like to send my thankful to PS operators, Raul Valera Teruel, Oliver Hans, and much more people for helping me without I didn’t ask. It would be pleasuring to work in Proton Synchrotron again.

Jiraphon Yenphraphai

CERN 2018 summer student

Contents

1.1Objectives of an internship program

I have studied electrical engineering for 3 years, and I do believe that learning in the classroom is completely distinct from working in real situations. After working at CERN for almost 2 months, I have learned tons of things I have ever known before. Even though CERN principal's ideas are based on Physics, they need engineers to build accelerators, designed by physicists. Both physicists and engineers need each other. Nevertheless, there is more job developing CERN such as computer science, technicians and so forth. To discover new particle or breakthrough, it needs everyone's helping to move on the organization. Like the idiom, Rome wasn't built in a day.

Since I got an internship abroad, I have met a lot of new people coming from the different country, department. It is a good chance to meet someone who has the same inspiration, passion for Physics. Finally, we had bond our friendship via the lectures, activities and working. You perhaps find your soulmate here like my colleague who is also summer student 5 years ago.

The place that I worked at is CERN control center, which is the room controlling the beam in booster, PS, SPS, and LHC. The atmosphere is friendliness because every operators and fellow are willing to help me every time I got stuck with the problems. Moreover, they also offer some croissant, chocolate, pie, barbeque which makes everyone get closer even though I had a hard time talking to them because they mostly speak French.

1.2 Period of summer student program

I had arrived in Geneva on the third of June since the first day of working was on the 4th of June. I stayed at CERN for 2 months, which implies that I will finish my program on the 3rd of August. By working every day from Monday to Friday will create 40 days of working.

1.3 Condition at working

The atmosphere is warm. Every time, I have problems. My supervisor and his colleagues are helping me willingly. The condition at work is relaxing. Everyone works hard allday long. Because accelerators are operating 24/7, I can clearly see that people working at night shift are

1.4 My supervisor

My supervisor's name is Piriya Chaichanasiri, and his nick name is Win. He is working as PS operator. He is so generous and friendly to me and my friends. Not only did he teach me about work, but he also devoted his free time to have lunch, bring us to an Asian market, drinking with us and so on.

Sometimes, I had Afternoon shift, working during 1pm to 9pm. Since I worked at Prevessin, it was not easy to go to work. The only way to go to Prevessin is by car, so waiting for CERN shuttle bus is the only option for me. However, CERN shuttle bus is only available for daytime. Fortunately, my supervisor dropped me off at the hostel after working.

As we knew, CERN's accelerators are operating 24/7. This means he must work at night shift, as well. This means I haven't met him much. With his sacrifice, he still took care of me via the e-mail and his colleagues. I am pretty sure that working at CERN will be the most memorable summer of my life.

2.1 CERN Address:

As CERN is on the border between France and Switzerland it has two official addresses, one French and one Swiss.

Here is the address of the CERN Switzerland site (Meyrin) : Route de Meyrin, 1211 Genève, Suisse.

Here is the address of the CERN French site (Prevessin) : Organisation Européenne pour la Recherche Nucléaire, F-01631 CERN Cedex, France

2.2 CERN telephone:

For general enquiries speak to reception on +41 (0)22 76 784 84 or +41 (0)22 76 776 76 or send them an email.

2.3 CERN opening hours:

Opening hours: Monday - Friday from 8am to 5.45pm, Saturday 8.30am to 5.15pm.

2.4 CERN website: https://home.cern/

2.5 CERN history

The European Organization for nuclear research is known as CERN. Founded in 1953, CERN is the largest particle physics laboratory in the world. CERN is funded by all 22-member states, which are almost every European country. Nowadays, CERN employs around 2500 people, but in total, almost 11000 scientists and engineers are using the CERN's experiment and facilities. The main goal at CERN is to study the fundamental structure of the universe; however, there are other things that CERN are studying such as medical research by using accelerator, isotopes and so on.

There are several of scientific achievements discovered at CERN:

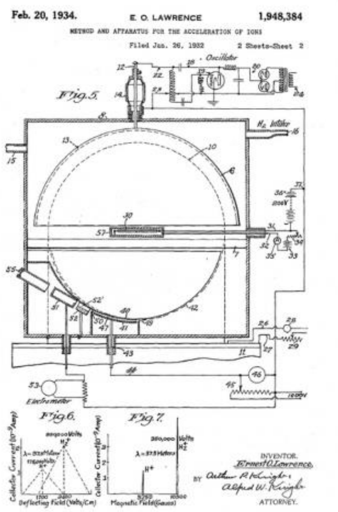
- 1983: The discovery of W and Z bosons in the UA1 and UA2 experiments;
- 1991: First World Wide Web

- 2012: A boson with mass around 125 GeV/c^2 consistent with the long-sought Higgs boson.

Although the most well-known accelerator at CERN is LHC, there are other accelerators that are still used for example: booster, proton synchrotron, super proton synchrotron.

CERN timeline:

Ernest Lawrence, the professor of physics, invented the cyclotron, a device for accelerating nuclear particles to high velocities. This cyclotron can speed up the electron's energy to the levels of mega electron volt



CERN's first accelerator

Built in 1957, Synchrocyclotron was CERN's first accelerator. It provided beams for CERN's first experiments in particle and nuclear physics. In 1964, this machine started to concentrate on nuclear physics alone, leaving particle physics to the newer and much more powerful Proton Synchrotron (PS).

In 1967, it started supplying beams for a dedicated unstable-ion facility called ISOLDE; however, in 1990, ISOLDE was supplied the beams by another accelerator, and the synchrocyclotron was closed and became the tourist attraction at CERN.

Proton Synchrotron (PS)

In 1959, Proton Synchrotron (PS) was the most complex accelerator, which was able to accelerate proton bunch's energy up to 25 GeV with the 8 main magnets, DHZ, DVT, FOC, DOC. Nowadays, PS supplies proton to Super proton synchrotron.

Luckily, with my supervisor's help, I had a chance to visit PS during the technical stop. Normally, we can't enter PS because of radiation.

Super Proton Synchrotron (SPS)

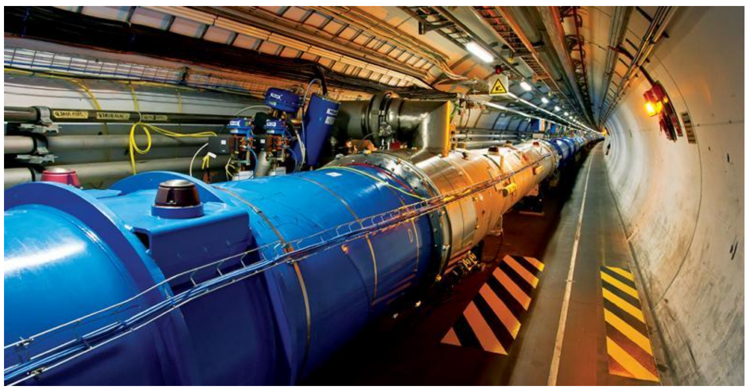
With the 7-kilometer circumference, SPS is the second enormous accelerator at CERN. It takes proton from PS and sends them to LHC. Moreover, it will also soon feed the AWAKE which aims to test new techniques for accelerating particles.

With the room temperature magnets, RF, it can speed up the proton's energy to 450Gev. It is, additionally, able to handle other elements such as electron, antimatter.

Large Hadron Collider (LHC)

LHC was started in 2008 and became the world most powerful accelerator since then. With the 27-kilometer superconducting magnets, LHC can handle the proton's energy up to 7 TeV.

Inside the LHC tunnel, the two-high energy protons are made to collide with each other, but a small number of protons are collided.



2.6 Overall job at CERN

There is always one question coming to our mind is what is the universe made of? how did it start? Physicists at CERN are seeking answers, using some of the world's most powerful particle accelerators.

Mainly, CERN are studying what consists of all the elements. In 2012, CERN had discovered Higgs boson; somehow, we have a long way ahead of us to understand the simplest elements.

2.7 **CERN administration**

The CERN council is the highest authority of the Organization and has responsibility for all-important decisions. It controls CERN's activities in scientific, technical and administrative matters. It approves programmes of activity, adopts the budgets and reviews expenditure. The council is assisted by the Scientific Policy Committee and the Finance Committee. The Director-General, appointed by the council, manages the CERN laboratory. The Director-General is assisted by a directorate and runs the laboratory through a structure of departments.

Council

CERN is run by 22-member states, each of which has two official delegates to the CERN council. One represents his or her government's administration; the other represents national scientific interests. Each member state has a single vote and most decisions require a simple majority, although in practice the council aims for a consensus as close as possible to unanimity.

Scientific Policy Committee

The Scientific Policy Committee evaluates the scientific merit of activities proposed by physicists and makes recommendations on CERN's scientific programme. Its members are scientists elected by their colleagues on the committee and appointed by council based on scientific eminence without reference to nationality. Some members are also elected from non-member states.

Finance Committee

The Finance Committee is composed of representatives from national administrations and deals with all issues relating to financial contributions by the member states and to the Organization's budget and expenditure.

Director-General

Appointed by council, usually for five years, the Director-General manages CERN. A directorate assists the Director-General, who proposes its members to council. The Director-General reports directly to the council and can also propose to council any adjustment deemed necessary to meet the evolving needs of the research programme.

DIRECTORATE

DIRECTOR-GENERAL	Fabiola Gianotti
DIRECTOR FOR ACCELERATORS AND TECHNOLOGY	Frédérick Bordry
DIRECTOR FOR RESEARCH AND COMPUTING	Eckhard Elsen
DIRECTOR FOR FINANCE AND HUMAN RESOURCES	Martin Steinacher
DIRECTOR FOR INTERNATIONAL RELATIONS	Charlotte Warakaulle

HEADS OF DEPARTMENTS

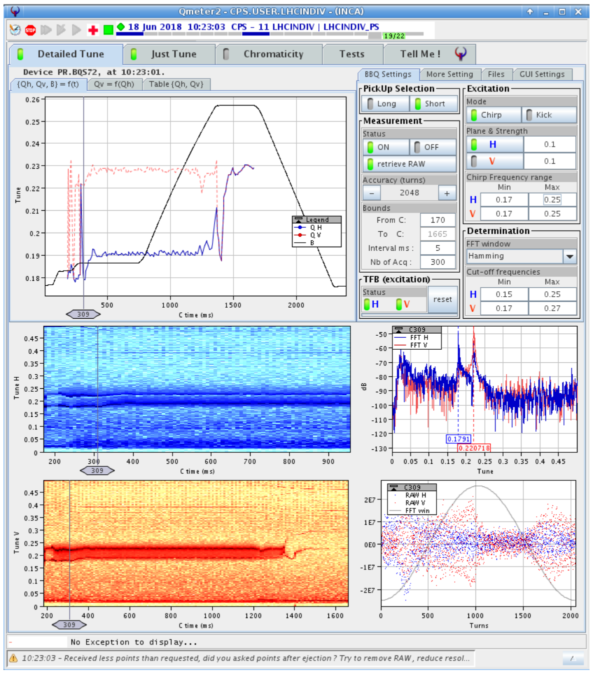
BEAMS	Paul Collier
ENGINEERING	Roberto Losito
EXPERIMENTAL PHYSICS	Manfred Krammer
FINANCE AND ADMINISTRATIVE PROCESSES	Florian Sonnemann
HUMAN RESOURCES	James Purvis
INDUSTRY, PROCUREMENT AND KNOWLEDGE TRANSFER	Thierry Lagrange
INFORMATION TECHNOLOGY	Frédéric Hemmer
SITE MANAGEMENT AND BUILDINGS	Lluis Miralles
TECHNOLOGY	José Miguel Jiménez
THEORETICAL PHYSICS	Gian Francesco Giudice

3.1 LHCINDIV document

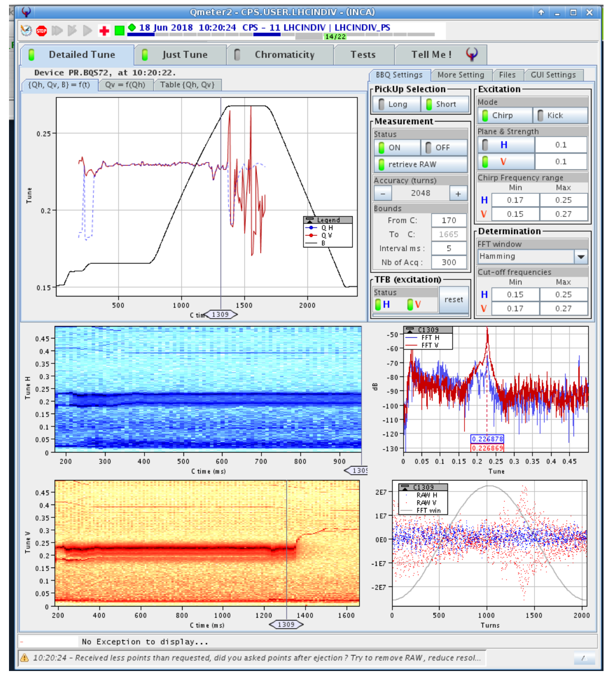
Firstly, the work, which I have got, is the LHCINDIV beam document. The main goal of this beam is commissioning filling patterns for the LHC. The beam characteristics is already be ready from the PS Booster. Therefore, it is important that we should know the beam profile before ejection to the SPS (Super proton synchrotron) and LHC (Large hadron collider), respectively. Moreover, all accelerators will be close for 2 years for LIU “LHC Injector Upgrade” project . This means we will lack of the information of the beam during upgrade of machine, so the beam information, compared in the future beam, should be backed up in the system. That is the main reason why the beam document is considerable and assigned to me.

LHCINDIV is the beam that is injected with timing 170ms, transited at 825ms, and finally ejected at 1650ms. PS is the machine that can speed up the proton’s energy to 26GV.

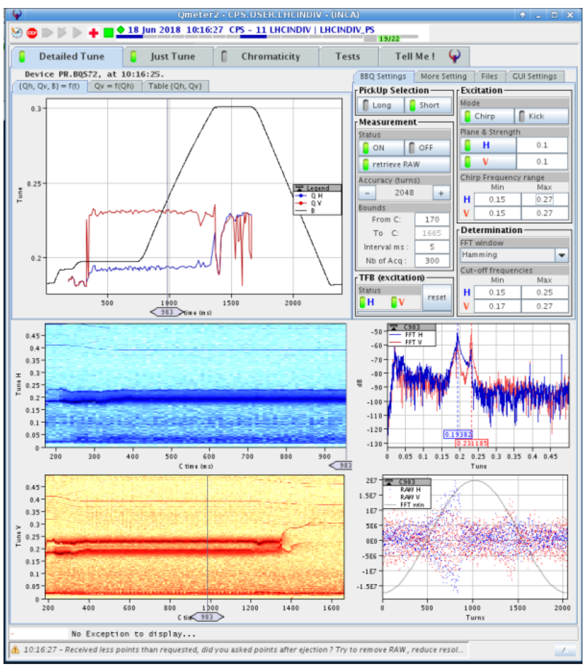
The first thing that I measured is Tune. of the PS accelerator. The method being behind this measurement is kicking the beam with a TFB “transfer feedback”. By using TFB, the beam trajectory is oscillating getting bigger as the time passed. However, there is one point that the beam is getting the biggest. That point is the point that we can see the resonance of our accelerator. Normally, we don’t take measurement of this thing, but we only measure when there is a problem occurred in the PS. In the excitation section, there are 2 modes: chirp and kick, mentioned to below picture. Both chirp and kick mode are using the same mechanism, kicking the beam; however, chirp is much more practical because of the small usage of electric current. Furthermore, there are also 2 options kicking the beam: horizontal and vertical.



Tune Horizontal

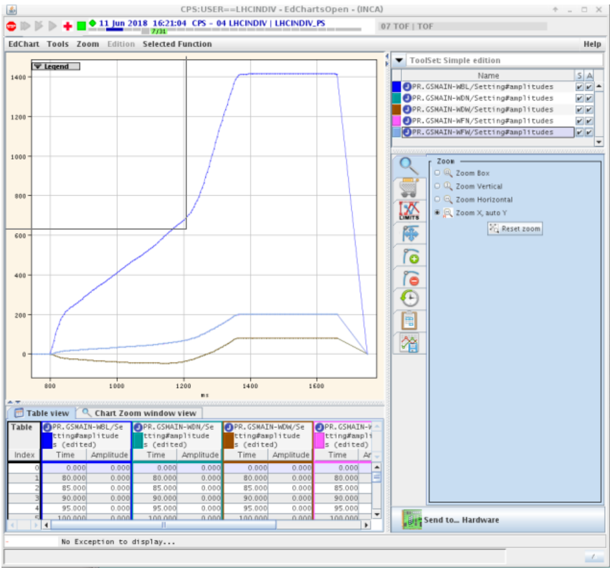


Tune Vertical

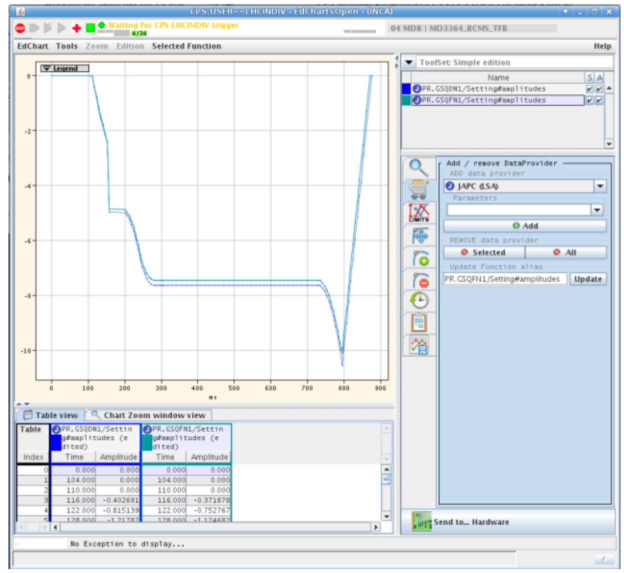


Tune Both

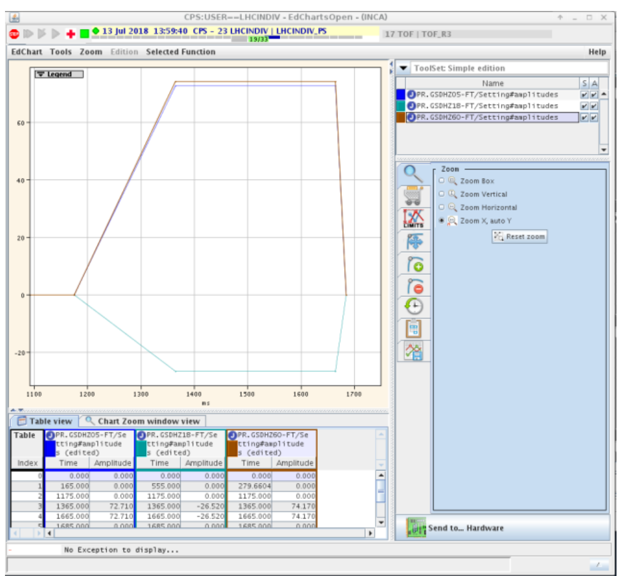
PS has a long history since it was beginning its operation in 1959. PS has 628-meter-long circumference. Most of the cost of building PS is magnet because magnetic fields are used to manipulate the beam's trajectory and accelerated proton via radiofrequency cavities. There are 7 types of magnets inside of main magnet using in PS main effect is for dipole horizontal magnet, Focusing magnet (FO and so on. Since the PS is antique and 628-meter-long, there are no enough space to install the auxiliary magnets. The solution to solve this problem is combining all magnets together, called main magnets. The picture below, GSMAIN, GSQFN shows the electric current that's supplied to the main magnet. In the last picture, GSDHZ, shows the electric current during the proton has a near of light speed, approximately around 99.99% the speed of light.



GSMAIN

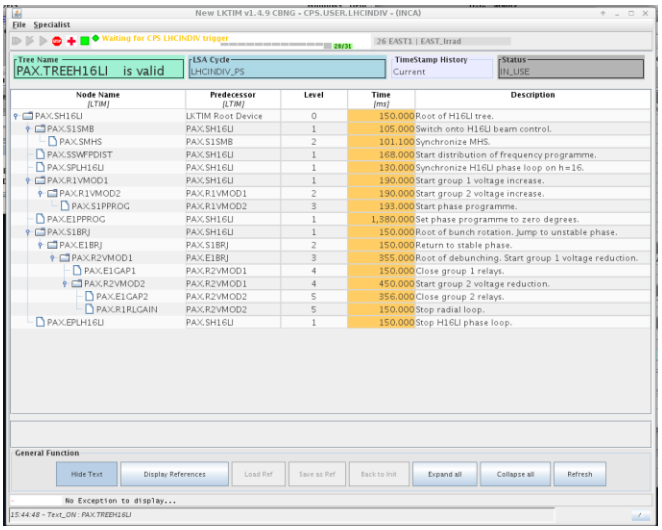


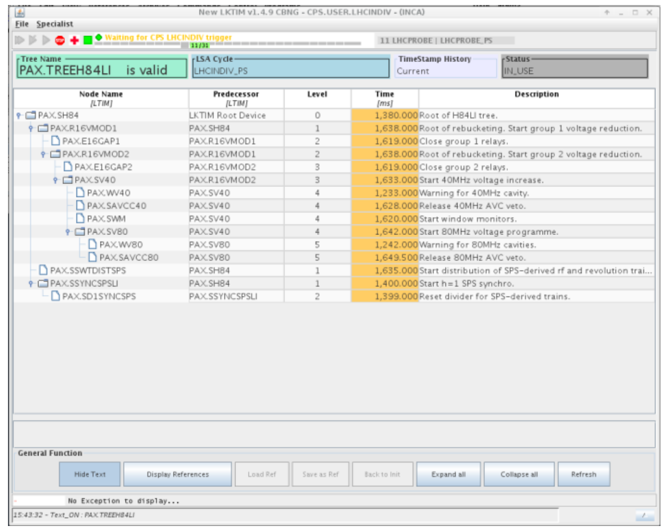
GSQFN



GSDHZ

To quicken the proton bunch, radio frequency cavities are used in varieties of ranges. However, 10MHz radio frequency cavities are used to accelerate the proton bunch. After getting enough speed, Radio frequency cavities are controlled by electronic cards, the 40MHz and 80MHz RF are the timing PAX.SV40 andPAX.SV80 for shorter the length bunch less than 4ns. because the smaller the bunch is, the more possibilities of proton collide with others are. . Why these protons bunches must be shorter than 5ns? It is because the buckets in LHC and SPS (Super proton synchrotron) is 5 ns. This means if the protons are ejected with the size larger than 5ns, SPS can't keep in the machine.

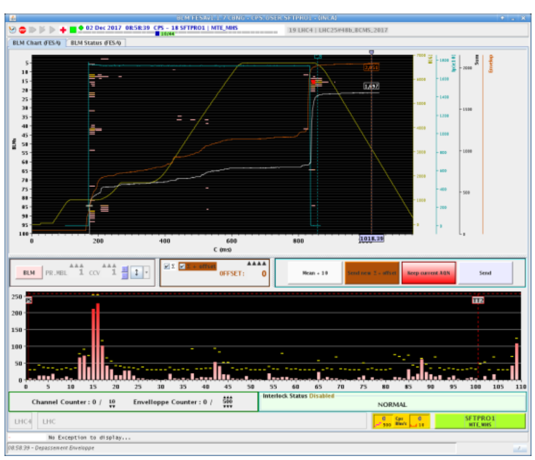




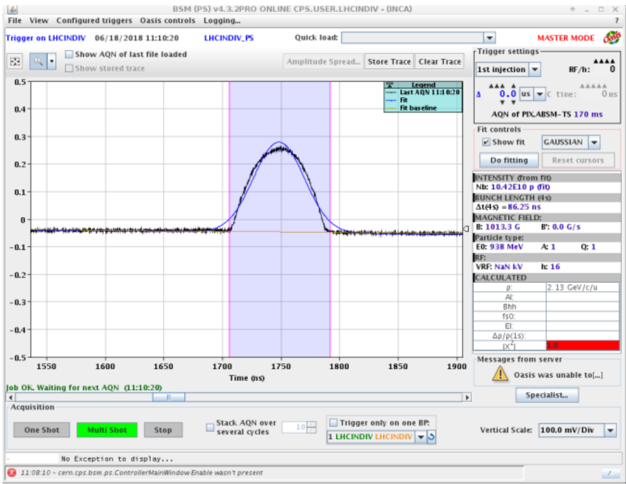
40MHz RF

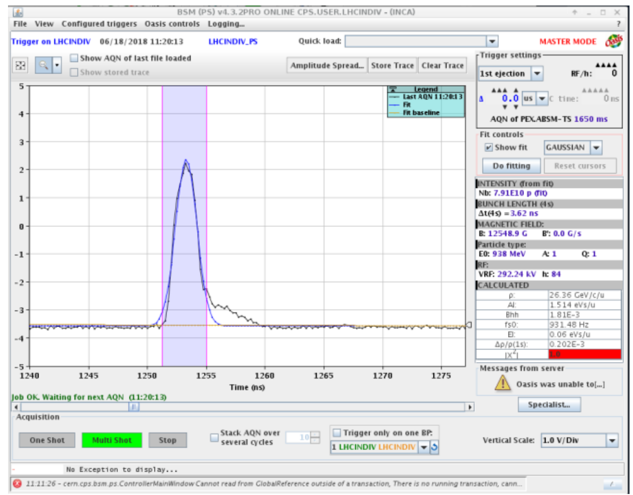
80MHz RF

The next thing is intensities and beam losses. Practically, the beams' trajectory doesn't stay in the center of the pipe because the protons are oscillating along their way in accelerators. Consequently, the beam perhaps collides with the wall of the pipe. These events could lead to radiation, dropping in beam intensities and even explosion in the LHC. It is so important that in the CERN Control Center, which I have been working, has one BLM "Beam Lose Monitor" that shows beam losses for every beam in each cycle.



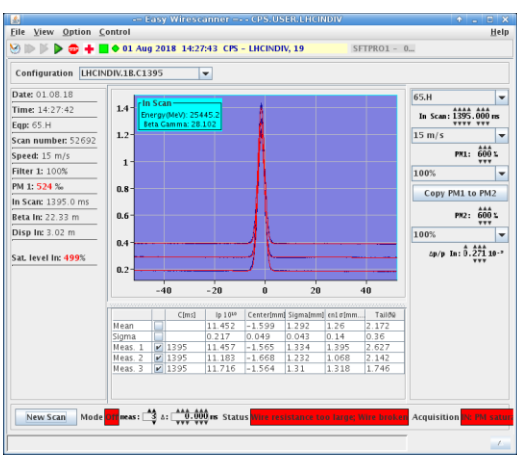
Bunch shape measurement is the program we use to see the bunch shape such as bunch length as longitudinal plan. According to the picture, during the injection the bunch length is approximately around 90ns. As the result of RF cavities, the proton beams split creating the bunch length to become around 4 ns, during ejection to SPS.

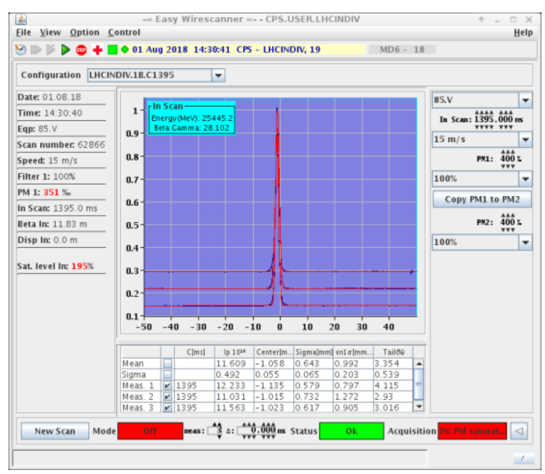




Bunch shape measurement during injection and ejection, respectively.

There are several ways to see the beam profile as transvers plan such as putting the screen into the beam, rotating the wire passing the beam, injection the gas into the pipe, etc. Wirescanner is one of them by rotating the wire passing through the beam. After the beam collides with the wire, it will radiate in the forms of light (Electromagnetic waves). By analyzing this produced light will lead to the beam profile such as delta p over p, intensities, etc.

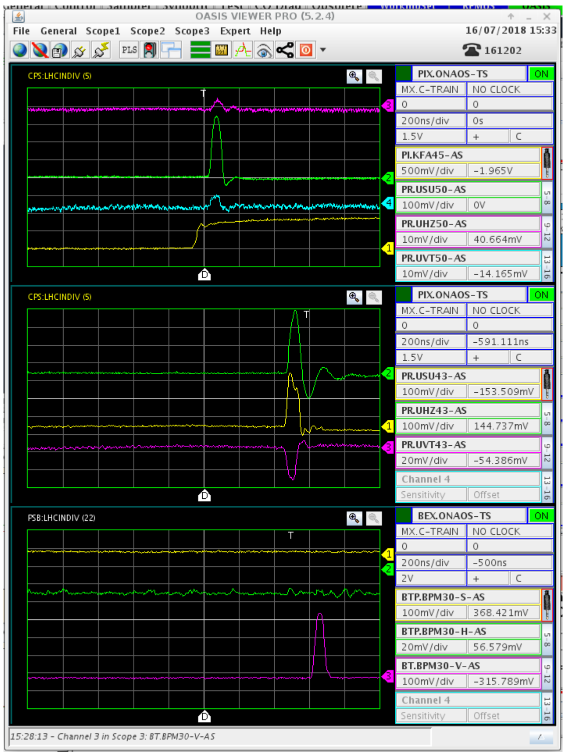


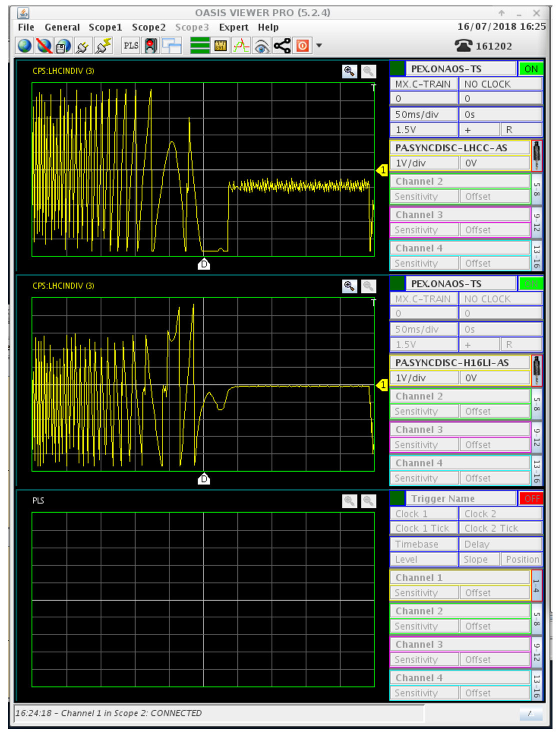


Wirescanner

Normally, in electronic laboratory, we use oscilloscope to measure many electrical things such as voltage, frequency, current, etc. At CERN, we use OASIS in the same way as

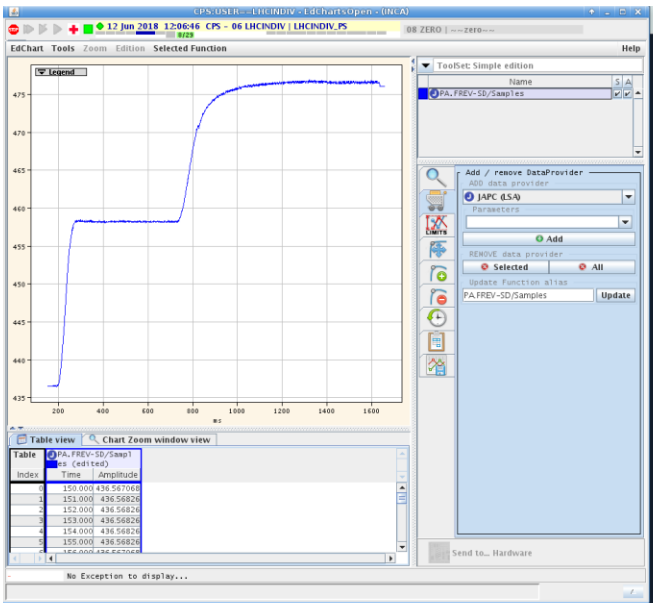
a digital oscilloscope. However, OASIS needs triggers to operate, and there is the timing where we want to analyze the graph. For injection, we use left trigger to see the graph; however, for ejection, we use right trigger instead. In the second picture, we will see that after triggering in the center, the graph seems smooth and steady. It means PS synchronize with SPS.

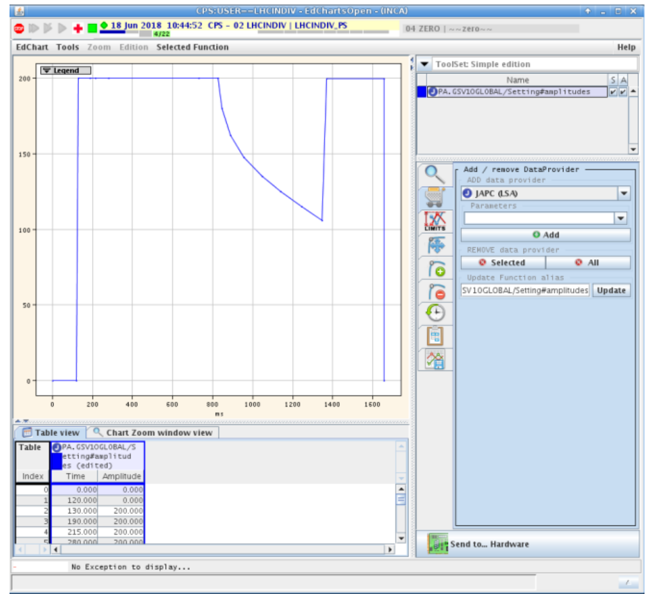




OASIS

Function Editor is also the program that functions. However, I use Function Editor to see the power supplied to RF cavities, frequency of the proton, gain of the signal, etc.

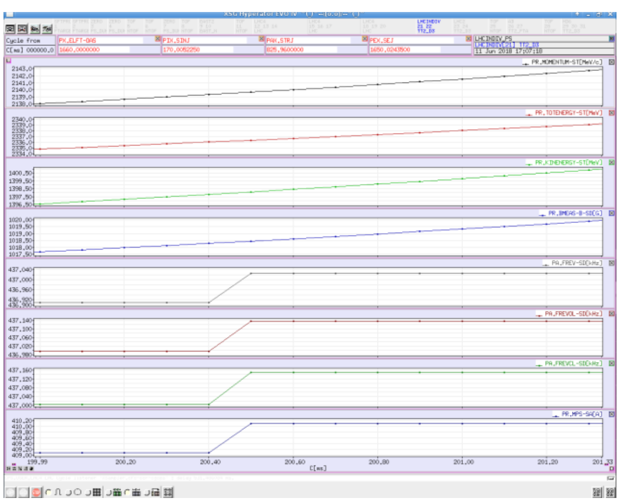


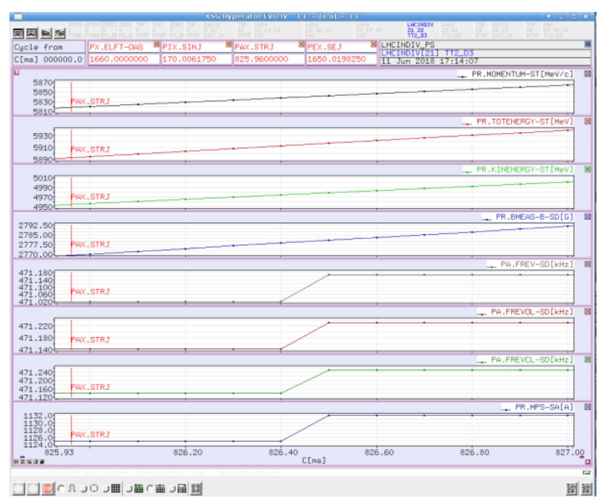


Revolution frequency of the proton

Voltage Electric current

Sampler is the program that we can measure the beam for instance momentum, energy, kinetic energy, magnetic field and much more things.





Sampler at C200

Sampler at transition state

3.2 Inspector Project

In PS, there are 100 main magnets called section as well, installed on the 628-meter-long tunnel. Every of these main magnets are containing many kinds of magnets, one of which are magnets for radiofrequency cavities. Therefore, there are 100 magnets along the PS tunnel. There are 101 magnets, but the 101th magnet is using for measuring the beam, instead. The project I have got is to find the phase difference C11, C46, C51, C56, C66, C76, C81, C86, C91, C96Rf compared to c36 magnet.

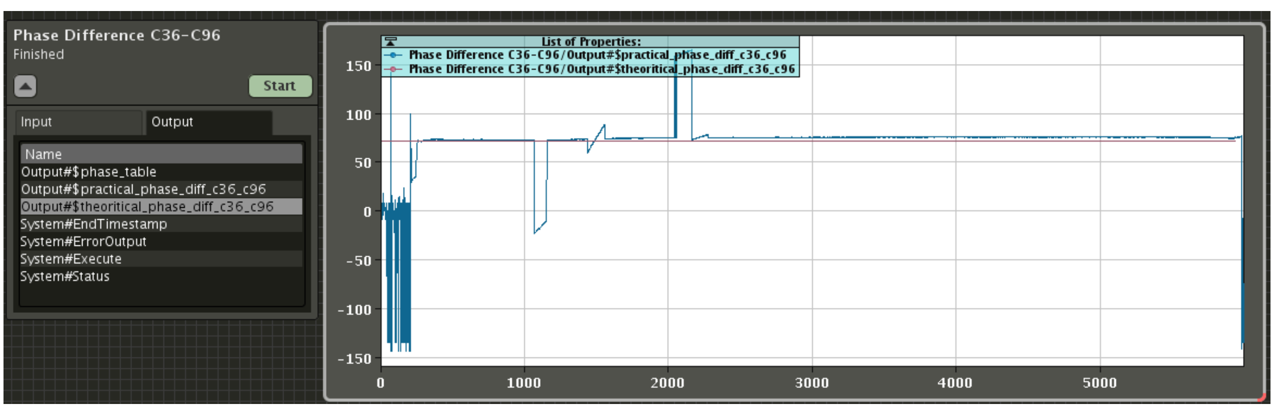
Since TOF beam is a harmonic 8 beam, all 8 bunches proton should see the same phase so as to accelerate steadily. This means for every 12.5 main magnet ($\frac{100}{8}$), radio frequency should have the same phase. Straightforwardly, the phase difference between section 1 magnet and section100 magnet is 2880° (360°x8). By interpolate, we can calculate the phase difference for every magnet.

For example: Find the phase difference between C46-C56 magnet.

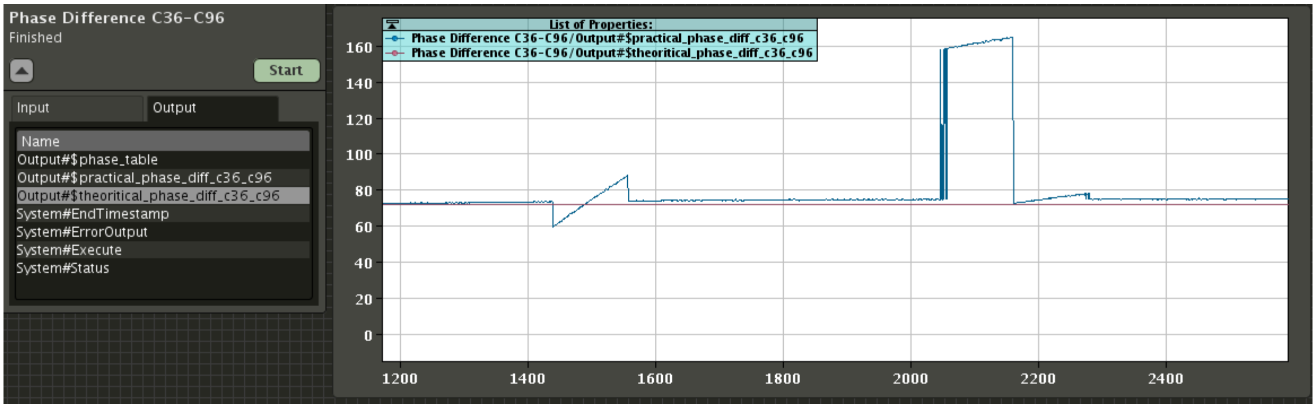
We know that 100 sections have the phase difference 2880°

If it is difference 10 section of magnet, the phase difference will be $\frac{10}{100}x2880° =$ 288° which is -72° (C56 lags C46 72°)

By using inspector, it is possible to show the graph of practical and theoretical phasing.

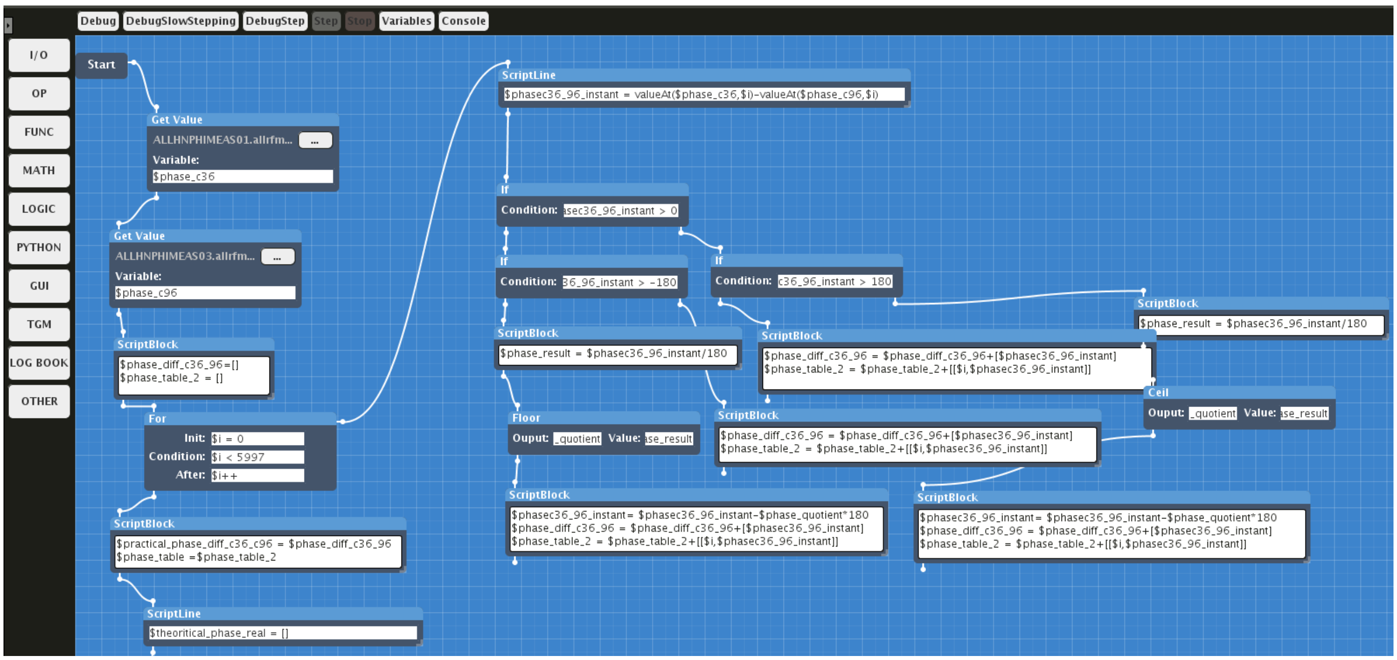


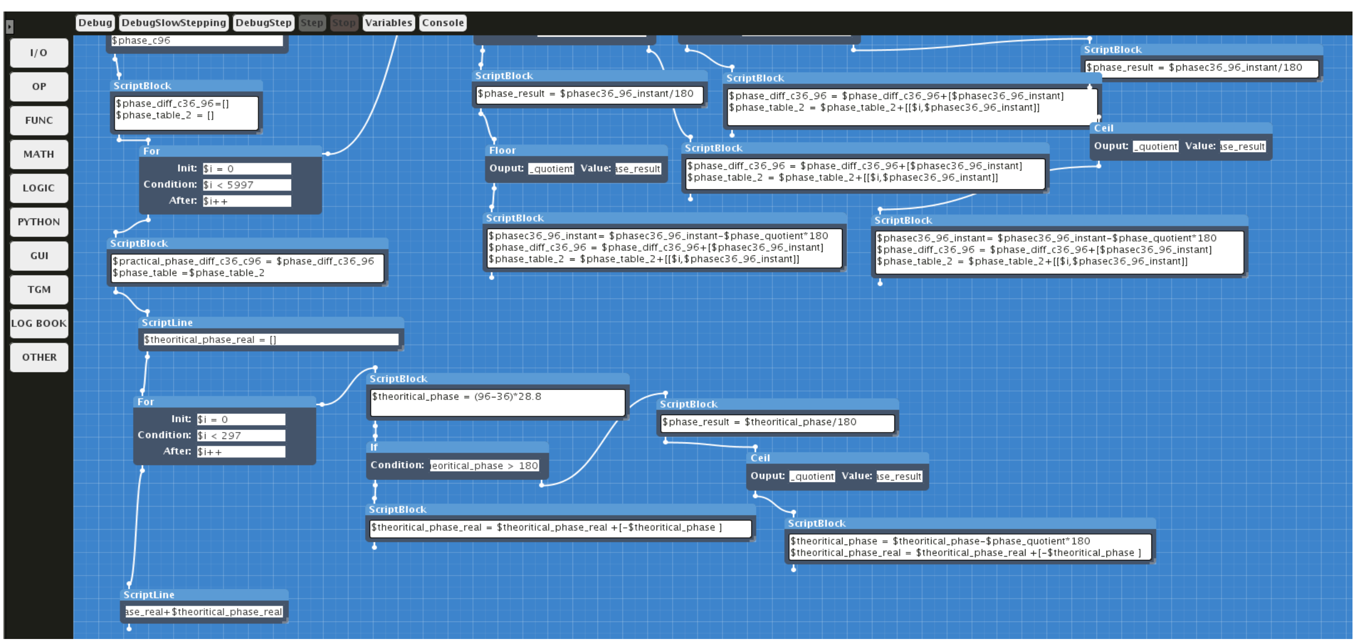
The graph shows the phase difference between C36 and C96 in practical (blue) and theoretical (pink) ways.



There are slight difference between reality and theory.

Here is the code for blueprint





The idea that is behind this code is simple. We use For loop to subtract every data from C96 to C36. The next thing that I tried to do is making the modulo function, since modulo function doesn't exist in this program, If-else blocks are used so that the phasing value will be between -180° and 180°. Ultimately, the last for loop is used for calculating the phase in theoretical way, the principal of which are already told in the previous page.

FTA&FTN LINE

The second project that my super advisor and his colleague Raul Valera Teruel assigned to me is drawing the magnetic lines, which are FTA and FTN line. Both are the lines ejected from PS. The drawing that I said early is not the drawing of the pipes, but I drew only important things controlling the beam. For instance, the dipole horizontal and vertical magnet controls the proton's trajectory in the horizontal and vertical plane, respectively. Quadruple focus magnets use to focus the beam in the horizontal and defocus the beam in another plane.

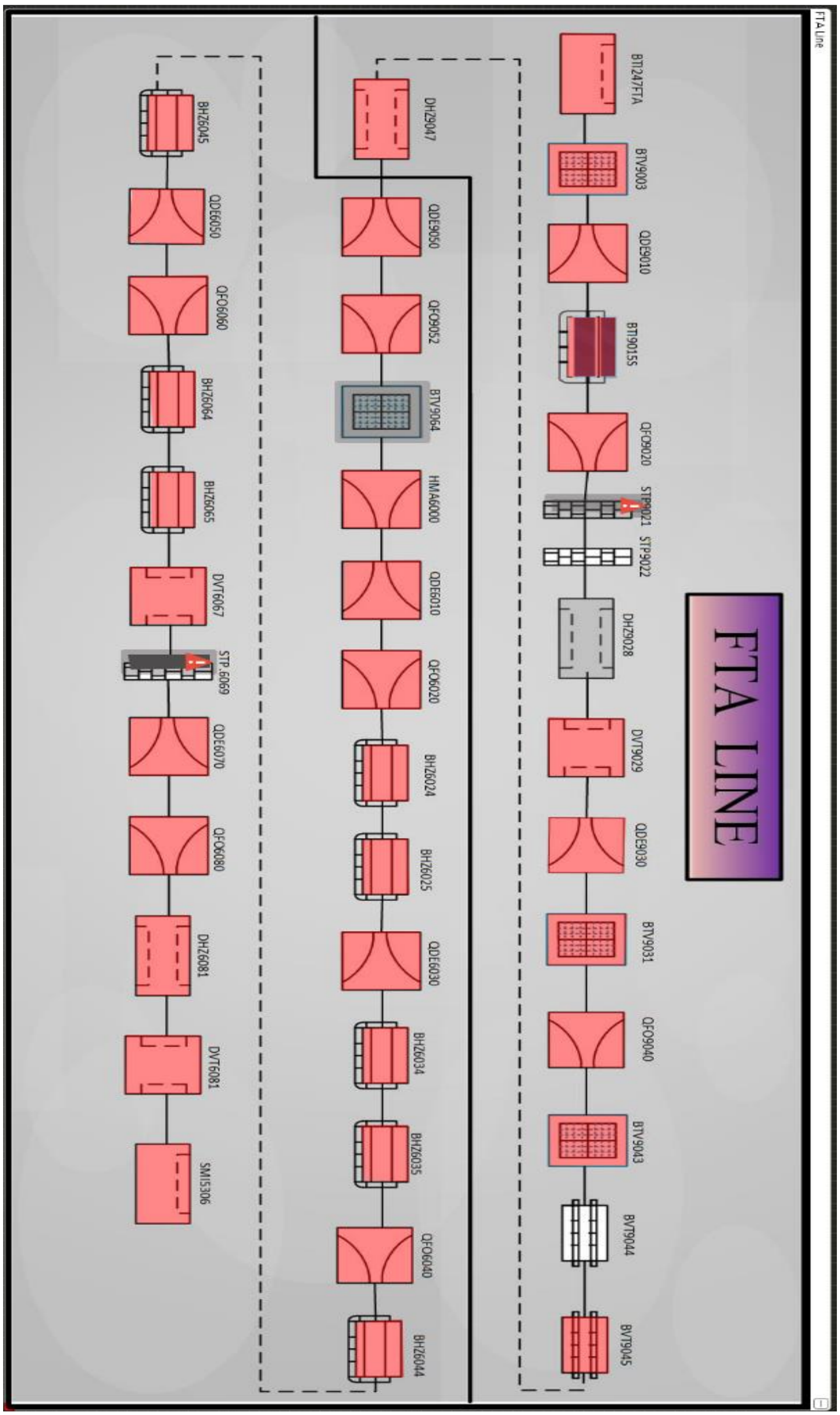
FTA line is the line that was sent by PS to Antiproton decelerator (AD). The main job of the AD is to produce low-energy antiproton and send them to different experiments. By firing the proton beam into the target will create high-energy antiprotons, which is not useful. Consequently, in the AD, there are strong electric fields to slow down the antiproton.

The FTA drawing will show status of magnets, beam stoppers, screens which are the machine that are along the way from PS to AD. The following page will show FTA line drawing. The green box indicates everything is alright. The red box indicates something is wrong. The yellow box indicates warning. According to the name convention for all accelerator at CERN.

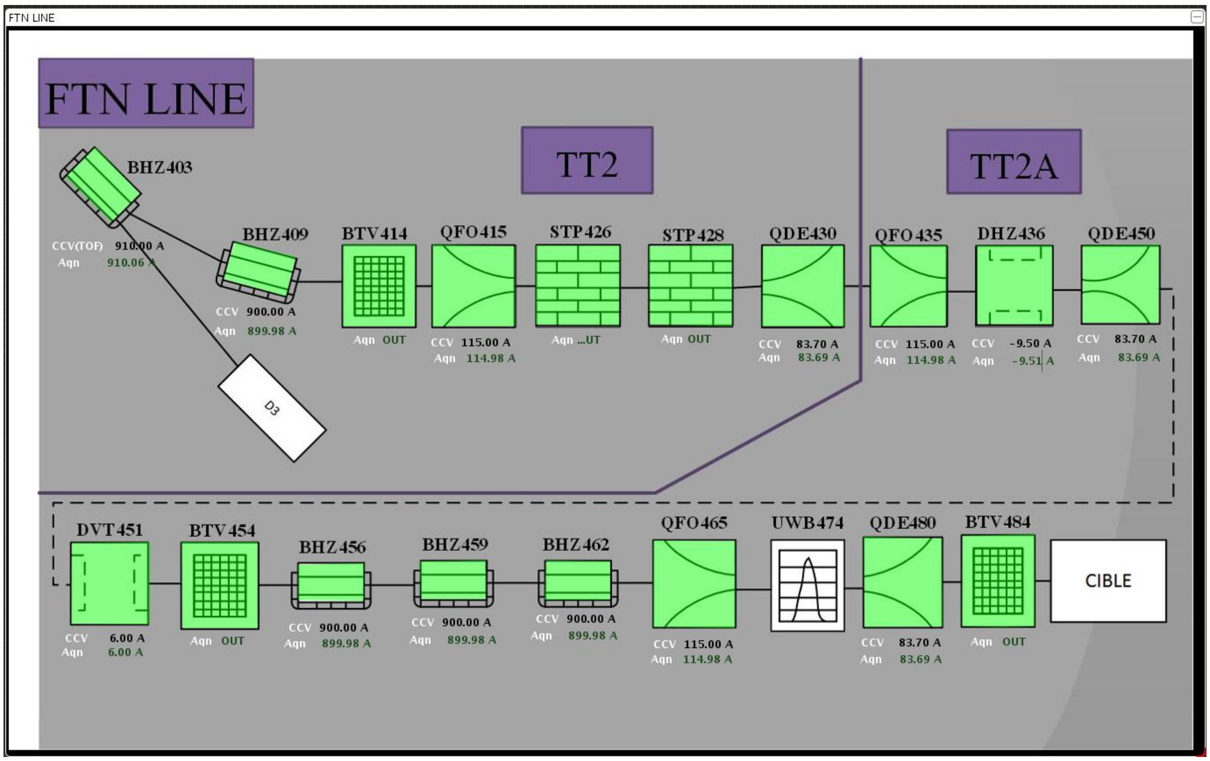
- QDE (Defocusing quadruple magnet) using for defocusing the proton bunch size
- QFO (Focusing quadruple magnet) using for focusing the proton bunch size
- STP (Beam stopper) using to stop the beam in case of emergency
- DHZ (Dipole horizontal magnet) controlling the beam's trajectory
- DVT (Dipole vertical magnet) controlling the beam's trajectory

- BTV is the screen to see the beam profile
- BHZ (Bending) is used to bend the beam during injection and extraction

As you can see from the below picture, all of the machines are red (alert mode) because there is no beam in the AD, due to some technical problems.



FTN line is located between PS and SPS. This line will end at neutron time-of-flight facility, nTOF, target. Its main job is to study the nuclear interaction by firing the proton at the lead target. Here is the picture of FTN line. This picture also indicates the electric current supplied to the magnet creating magnetic fields.



4.1Benefits of summer student program

CERN is one of the biggest, high reputation scientific organization in the entire world. By working at CERN makes my dream come true because you are being a part of the coolest history. You can't find the atmosphere of working anywhere else like CERN for instance, working among the physicists, engineers having the same passion, working with one of the highest technology equipment in the world, and so on.

Meeting new people coming from a different country, department makes your social skills become stronger. Even though some of their cultures are completely distinct, you slightly adapt yourself to the new environment such as greeting others by touching each other's cheek, food and lifestyles.

4.2 Problem

I strongly agreed that 2-month of summer student program is not enough for learning about proton synchrotron. Perhaps, a year of internship is suitable to work in PS.

In summer student program, they offered lectures about the things related to CERN such as standard model, accelerator, cosmology, quantum field theory etc. I can say that I barely understood about the physics lecture because it was too hard to catch up in the small amount of time. I believed that only the person who already had that course would follow the lectures.

Though the route between my hostel and CERN control center is not far, 20-minute walk, it is unsafe to walk or ride a bike along the highways. This leads to the only option, taking CERN shuttle bus. However, this bus is only available in limited time. This restricts the working hours for those who don't have a personal car.