Spark Chamber Project: Step by Step procedure

Andrée Robichaud-Véronneau

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Abstract

At McGill Physics Departement, a spark chamber has been developped as a muon detector. Using an acoustic method, we can reconstruct the trajectories of the particles going through the chamber. Each part of the system, from the triggering electronics to the analysis program, has to be explained in details for future users.

1 Introduction

In 1949, Keuffel first observed that a discharge was occuring between charged parallel plates after the passage of a cosmic ray and that this discharge was following the path taken by the ray. Since then, many physicists worked on this idea of a particle detector using parallel plates known as spark chamber. In the 1970's, the spark chambers were the commonly used detector in particle physics experiments. Nowadays, new technologies have taken the place occupied by the spark chamber detectors. They have been replaced by detectors of higher spatial and time resolution, such as drift chambers or silicon detectors.
Still, there is an interest in studying their working principle and to build one. In the Center for High Energy Physics in McGill University, a spark chamber has been brought to life by a team of summer students and graduate students, under the supervision of Pr. François Corriveau. Using an acoustic method, we can reconstruct the trajectories of the particles. Six piezzoelectric cells, three at the top and three at the bottom, collect the sound coming from the spark and convert it into an electric signal. This signal is used, after some modifications, to open the gates of a counter that computes the times associated with the reception of the signal. These data are then converted into trajectories.
This year, the project has been completed and the purpose of this document is to give a clear procedure on how to make it run properly. There are several parts in the system that have to be explained: the gas filling, the wiring, the triggering electronics, the acquisition system and the data analysis. In order for the reader to understand more, some sketches of the workplace have been placed in appendix.

2 Filling the chamber

The detection principle depends on the fact that gas atoms are ionized. So the chamber must be filled with a gas before hoping to get any kind of sparks. The gas we use is helium 99,5% purity. In order to get complete trajectories, the chamber has to be filled at a rate of 140 divisions on the flowmeter for a minimum of 3 hours. Depending on the humidity level, this time can easily jump to 4, maybe 5 hours. This step of the filling has to be done while the evacuation end is open (the black tape cap should be removed). For the second step, the evacuation drain has to be closed with the black tape cap. The rate has to be changed from 140 divisions to 110 divisions and will stay at this level until the end of the experiment.

3 Wiring

During the filling of the chamber, there is plenty of time to connect the piezzo amplifiers to the acquisition box via coaxial cables. The first connection to do is the +15 V/-15 V supply for the op-amps of the amplifier circuits. There is two ready-to-use cables to connect the six circuits in parallel for each voltage[1]. The power supply is located in the acquisition box and has two outputs for this purpose. Then, the output of each amplifier should be connected to their appropriate input on the acquisition box. Be careful, in order for the acquisition system to work, the last three inputs **must not** be connected in the usual order. The order must be the following: P4 = piezzo 6, P5 = piezzo 4, P6 = piezzo 4, where P* is the input of the acquisition box and piezzo * is the output of the amplifier. The last cable to connect is the T_0 cable. It is coming from the complemented output of the coincidence gate. No piezzo signal should be input in the acquisition system without the T_0 signal because it is the trigger signal of the acquisition electronics. Then, it is time to power both power bars, the one for the electronics and the other for the PC. It is important to do it before the next step. It will prevent any damage to the op-amps due to input signals without voltage supply.

4 Triggering electronics

Once the chamber is filled with helium and the connections are done, it is time to power the triggering electronics in order to get a spark. It is always possible to this first before the filling of the chamber, but the sparks won't appear until there is enough helium to be ionized. So it is preferable to this at this stage. There are different modules to power in a specific order.

4.1 Power supplies for the photomultipliers

The first thing that should be powered are the photomultipliers. Using the two HV sources at the bottom of the rack, the bottom one for the bottom PMT and the top one for the top PMT, we choose a specific voltage for each of them in order to get a good signal and a good coincidence rate. The values[2] are fixed to 1 800 V for the top PMT and 1 900 V for the bottom PMT. It is always possible to check the signals with the scope before going further in the setup. If there is something wrong at this stage, it is still possible to fix.

4.2 NIM crate modules

The signals are coming from the PMT to the inputs of the discriminators. These has to be powered by the NIM crate power supply. It is always a good thing to check the coincidence signal at this point. There is an output left on the gate to do it. It will ensure that the acquisition system is ready to go, since the T_0 signal is good. It is the last place before the acquisition where it is possible to check signals, so it is important.
The other thing to set in this part is the positive high voltage of the spark gap driver amplifier. The value is fixed at 6 300 V and it is possible to verify the value given by the knob with the high voltage monitor on the

[1] +15 V and -15 V

[2] The value of every parameters are also listed in the file c:\spark\daq\para.dat on the lab PC.

power supply. The reading at the monitor is 1 000 times smaller than the real output. **Do not** apply the input voltage for the spark gap driver amplifier right now.

4.3 Spark gap power supply and clearing field

The spark gap, which is placed under the chamber, has to be powered by a HV source adjustable via a trim resistor on the top of the box. The value is fixed at 12 kV, but it is always possible to go to 13 kV to test different voltages. To check the value of the output voltage, there is a monitor in front of the box. The conversion factor is 3 000, i.e. the real output is 3 000 times bigger than the reading.
A clearing field must be applied to the spark gap circuit. A power supply is placed under the chamber to input a 100 V field to the gap. Use the green banana terminals leads to connect it.

4.4 Spark gap driver amplifier power supply

The last step to obtain sparks is to power the spark gap driver amplifier. This is done via a similar power supply to the one used for the clearing field. We set the input voltage value to 206 V.

5 Acquisition system

Now that the sparks are going on, it is time to run the data acquisition system. The acquisition program is located in c:\spark\daq\acquire.exe on the computer PC called cardinal. The program allows the user to choose the number of events to acquire and the datafile name[3]. The acquisition part of the program as a tendency to stop or sometimes to just refuse to start. It may be due to the Lab Tender cards or to interference of other experiments going on in the lab. Don't worry, just restart the computer until it works and it will eventually! Be careful not to input signals while restarting the computer because the chips of the receiving card can be damaged since they would not be powered[4].
The datafiles can be found in c:\spark\daq*mm-dd-yy**filename*.dat. The name of the folder is the date on which the datafile was created. They can be sent to the UNIX station called plekszy-gladz by ftp[5].
After the acquisition, it is important to use the **reverse order** of the instructions to shut down the spark chamber. Also, don't forget to **close the helium valve** before leaving. An entire night of filling would make you loose a lot of precious gas. These details may seem useless, but it is exactly the kind of things someone ends up doing during the first trials.

[3]The extension is set to *.dat and it doesn't need to be typed in.
[4]They are powered by the PC power supply.
[5]The usual command in dos is ftp *stationname* but a predefined command *plekszy-gladz* exists on cardinal to do the same thing.

6 Data analysis

Once the data have been sent to plekszy-gladz, the data analysis can begin. The analysis program is located in ~\francois\20020801\spk\. But, the analysis, as well as the compiling of Fortran programs using *fol* command and CERN routines, has to be done on another computer called ullrich. In the folder mentionned earlier, there is a script that executes the program and do some more things[6]. To call the program, the files PIEZZO6.DON and SPEEDS.DON are required. The datafile is also one of the input of the program, but it has to be modified before being used. First, the heading of the datafile has to be removed and the bad events have to be deleted from the analysis. They are easy to spot since the measurements are all the same (or almost). The last thing is to had a 0 at the first line of the datafile. It is declaring to the analysis program that the data are real and not generated by a program. The output of the program is a PostScript file named *filename*.dat.ps.
The data can also be used to create some plots. They can help to find some relations between the inputs and some characteristics of the chamber. These plots are done using PAW[7]. The kumac file is located in ~\francois\20020801\paw\.
There is also another program that generates data from scratch. It has the following location ~\francois\20020801\spkmc\. Like the analysis program, it requires PIEZZO6.DON and SPEEDS.DON as inputs. The output of the program is a datafile that can be used directly without modification by the analysis program.

7 Few tricks

Here are some important details about the workspace and the experiment that I learnt over the summer and that I want to share with people to come.

- To appreciate the show, 2 black blankets can be used to cover the chamber. The sparks are then more colorful and impressive.
- The black lunch bag in the green cupboard contains spare pieces for the acquisition electronics and spare piezzoelectric cells.
- The green cupboard is filled with coaxial cables of almost any length, resistors and capacitors, spacers, a function generator[8], connectors for LEMO and BNC cables, an circular antenna[9], tons of wires, flat cables and connectors, glue, handbooks for both Lab Tender, extension cords and more.
- The acqusition card is mounted on a wire-wrapping board. In case there is some wiring to do, the wire-wrapping tool is under the tool box and the wires are in the cupboard[10] with the resistors.

[6] To know more about it, read it!
[7] Physics Analysis Workstation
[8] Useful when it's time to test a circuit!
[9] To measure the electromagnetic pickup.
[10] Not the green one, the ones all over the lab.

- The printer is working properly. You can get paper in the printing room
- A C compiler is installed on cardinal. It's a DOS version and the command is TC for the editor and TCC for the compiler. Read the Turbo C++ instructions manual for more details.
- The cover of the PC should be open **with great precautions**. There is a lot of flat cables inside and they are really tight. If there is a resistance, **don't try to force it**. Also, the cards are really close to each other. One should not try to remove them, unless there is a big problem.
- A zip disk is available to do back-ups of the data and of the programs. The disk is in the black lunch bag.
- Don't try to read the signals from the piezzoelectric cells directly. The only thing that will be read by the scope will be the electromagnetic pick-up coming from the chamber, even if the signal is good.

A Workplace Setup

As a reference, here are some sketches of the way the workplace is set so that it is easier to find the things I was talking about in this document. Figure 1 is the elctronics part and the chamber itself and figure 2 is the acqusition box and the PC.

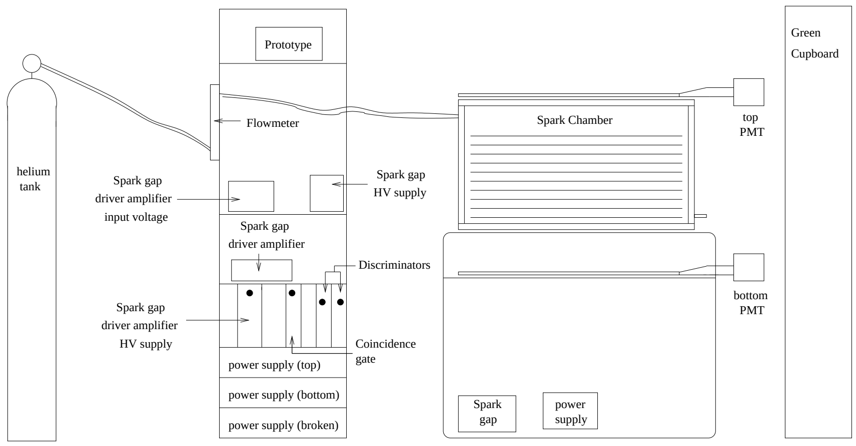

Figure 1: The chamber environment

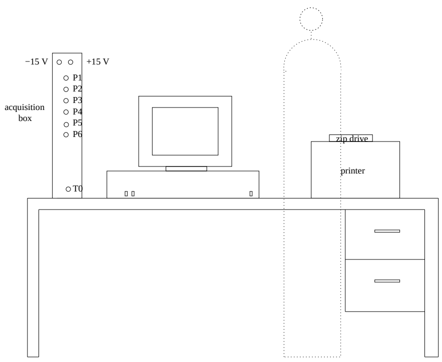

Figure 2: The PC environment