CERN 2016 SUMMER STUDENT REPORT

SPS CROSS-SECTIONAL CHANGES EXTRACTION

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ABSTRACT

The SPS particle accelerator has a circumference of 6.9km and uses different magnets with different apertures. This project work examine the changes in the various aperture both horizontally and vertically and extract the changes (as data) with respect to position of occurrence over the entire circumference.

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INTRODUCTION

The **Super Proton Synchrotron** (**SPS**) is a particle accelerator at CERN. It is housed in a circular tunnel, 6.9 kilometres (4.3 mi) in circumference, straddling the border of France and Switzerland near Geneva, Switzerland

PROJECT DESCRIPTION

Create a tool in order to extract all apertures from the SPS and the cross- sectional changes from layout database information.

PROJECT OBJECTIVE

The objective at the end of this work is to be able to design a tool to extract all the aperture changes (both horizontally and vertically) with respect to their position in the SPS.

MOTIVATION

This project work was motivated by the keen interest in knowing the aperture differences in SPS machine elements which are directly connected to the beam pipe.

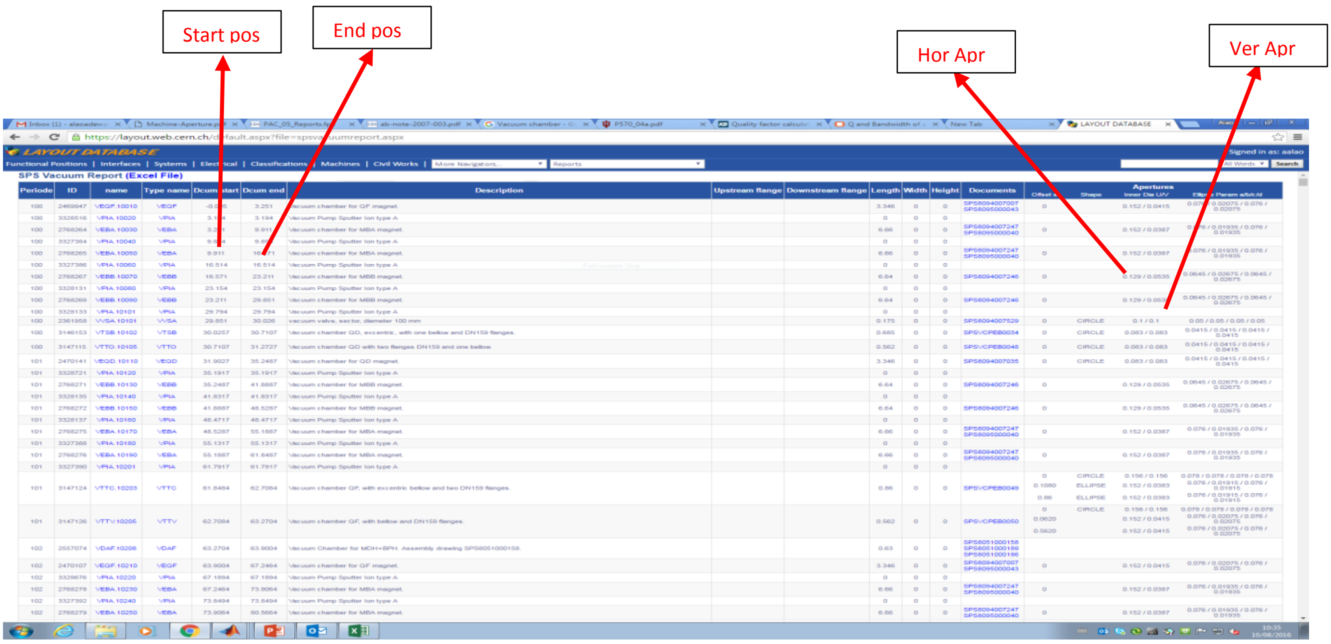
PROJECT DEVELOPMENT PROCESS

The project work was carried out using Matlab to create a tool for the extraction of the various machine elements start and end position with the horizontal and vertical aperture parameters from the database layout.

EXTRACTION OF THE RAW DATA

CSV FILE

CSV is a simple file format used to store tabular data, such as a spreadsheet or database. Files in the CSV format can be imported to and exported from programs that store data in tables, such as Microsoft **Excel** or Matlab. CSV stands for "comma-separated values". The SPS vacuum report from the database layout is saved with .csv extension. The file was then loaded into Matlab for further processes.



Layout database SPS vacuum report

MATLAB

The saved database file was loaded into Matlab where the start position, end position, horizontal aperture and vertical aperture were extracted. These four parameters contain the information about each machine element’s length and aperture values both horizontally and vertically. The output of the extraction is shown below;

Command Window

Start pos	End pos	Hor Apr	Ver Apr
-0.095	3.251	0.152	0.0415
NaN	NaN	NaN	NaN
3.194	3.194	NaN	NaN
3.251	9.911	0.152	0.0387
NaN	NaN	NaN	NaN
9.854	9.854	NaN	NaN
9.911	16.571	0.152	0.0387
NaN	NaN	NaN	NaN
16.514	16.514	NaN	NaN
16.571	23.211	0.129	0.0535
23.154	23.154	NaN	NaN
23.211	29.851	0.129	0.0535
29.794	29.794	NaN	NaN
29.851	30.026	0.1	0.1
30.026	30.711	0.083	0.083
30.711	31.273	0.083	0.083
31.903	35.249	0.083	0.083
35.192	35.192	NaN	NaN
35.249	41.889	0.129	0.0535

Start, end position and horizontal, vertical aperture

It is will be seen that the extracted data contains NaN (Not a Number), this is as a result of some machine elements which has no aperture information (such as vacuum ion sputter A etc.) and in some cases both position and aperture information were not present on the SPS vacuum report in the Layout Database because those elements were not directly connected to the beam pipe.

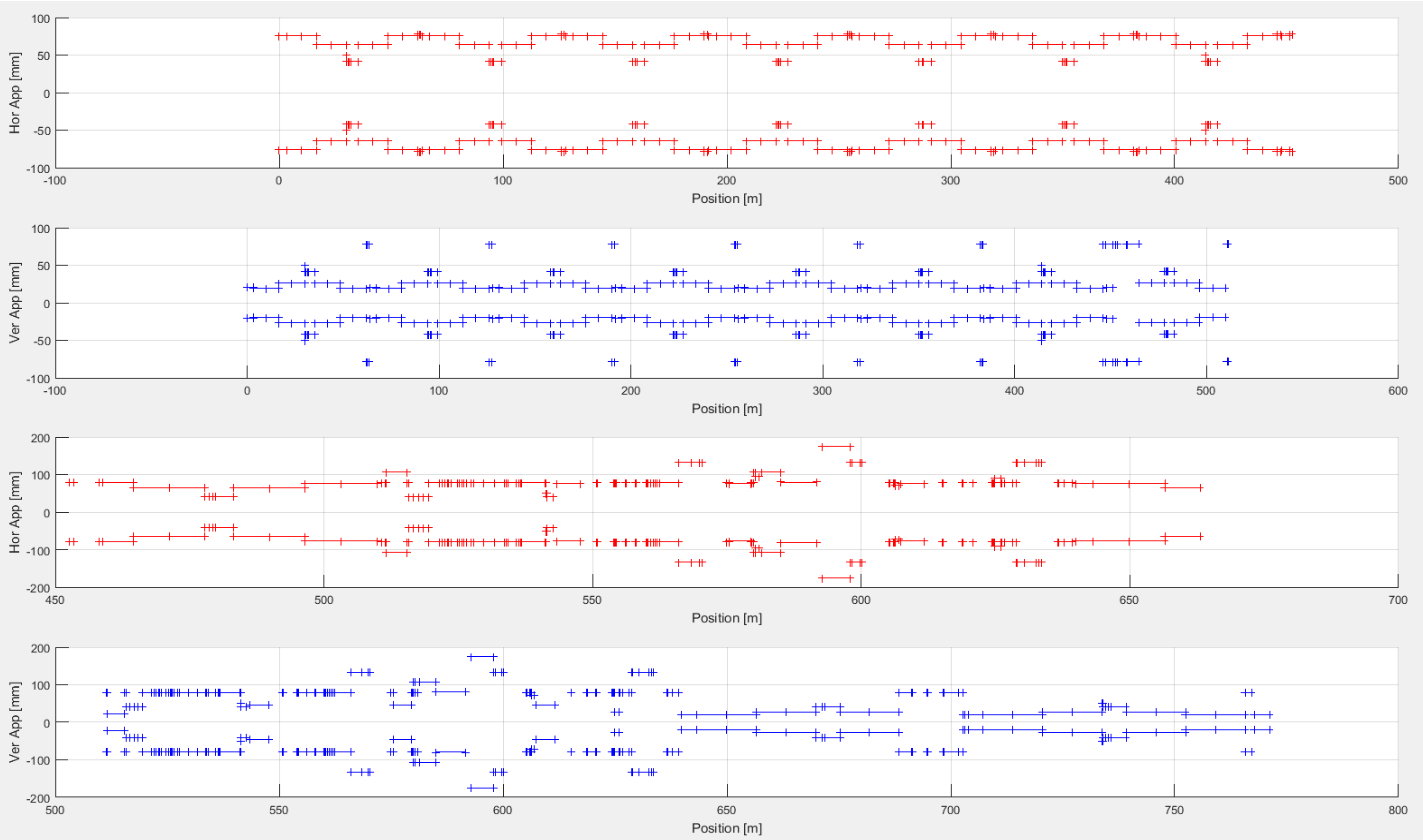
These extracted data was further filtered to remove all the NaN present in the current data. The output of the filtering is shown below:

Command Window

-0.095	3.251	0.152	0.0415
3.251	9.911	0.152	0.0387
9.911	16.571	0.152	0.0387
16.571	23.211	0.129	0.0535
23.211	29.851	0.129	0.0535
29.851	30.026	0.1	0.1
30.026	30.711	0.083	0.083
30.711	31.273	0.083	0.083
31.903	35.249	0.083	0.083
35.249	41.889	0.129	0.0535
41.889	48.529	0.129	0.0535
48.529	55.189	0.152	0.0387
55.189	61.849	0.152	0.0387
61.848	62.708	0.156	0.156
62.708	63.27	0.156	0.156
63.9	67.246	0.152	0.0415
67.246	73.906	0.152	0.0387
73.906	80.566	0.152	0.0387
80.566	87.206	0.129	0.0535

Filtered data

The above data is used to show the plot of different machine element's position and aperture both horizontally and vertically present in the SPS.



The plot showing, position and aperture of different magnet present in SPS

It will be seen that there are discontinuity along the plot with respect to position (space/gap). This is as a result of the omission of such machine element's parameters on the layout database. After examining the SPS vacuum report directly on the database, it was found that there were no parameters recorded for some elements. For example, no information was found for these positions: 453.4398 – 458.1388, 568.426 – 569.826, 570.296 – 574.996 etc.

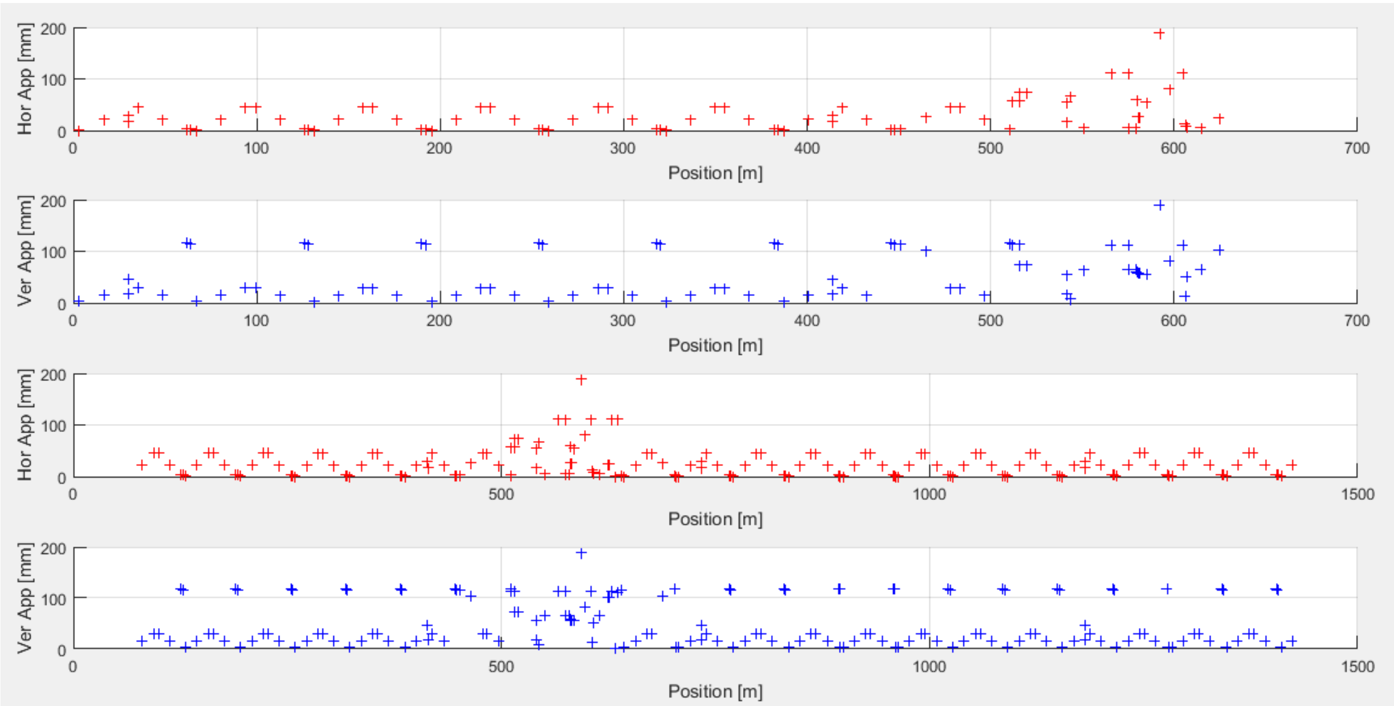
THE APERTURE CHANGES EXTRACTION

Having gotten the position and both the horizontal and vertical aperture for the various machine elements used in SPS, I was able to obtain the changes in aperture where two different machine elements were joined together by finding their absolute difference value which amount into new set of data shown in the final result shown below:

Position	Hor apr	Ver apr
3.251	0	2.8
16.571	23	14.8
29.851	29	46.5
30.026	17	17
35.249	46	29.5
48.529	23	14.8
61.848	4	117.3
63.9	4	114.5
67.246	0	2.8
80.566	23	14.8
93.846	46	29.5
99.244	46	29.5
112.52	23	14.8
125.84	4	117.3
127.9	4	114.5
131.24	0	2.8
144.56	23	14.8
157.84	46	29.5
163.24	46	29.5

Data showing the aperture changes with respect to position

The zeros in the above data was as a result of no changes in the horizontal aperture. The final data was then used to show the plot below:



The plot showing the aperture changes with respect to position

It is also worth to note that the designed tool also allow the user to view the aperture changes over a certain range of value. All that need to be done is to change the range where it is specified in the code and the corresponding data will be produced.

RECOMMENDATION

It is recommended for continuation of this work that the missing SPS machine elements parameters on the database layout should be investigated to know why those information were not available and this will better allow the designed tool to be more efficient.

CONCLUSION

In conclusion this tool is capable of providing users with general overview of SPS accelerator across its entire circumference as well as provide detail reports of changes in the various machine elements.

REFERENCES

Layout database; https://layout.web.cern.ch

APPENDIX

The Matlab codes written to achieve this project work is shown below:

```
%--------------------------------------------------------------------------------------

% program to show the aperture changes with respect to position of the diff
% material elements in Sps both horizontally and vertically

close all;
clear all
clc
format shortg;
% to load the database file into Matlab
filename = 'SPS_vac_report_30062016.csv';
[num,str,raw] = xlsread(filename);
data = [raw(3:end,5),raw(3:end,6),raw(3:end,16)];   %to extract the needed columns from
the database

position = data(:,1:2);                          % start and end position
position(cellfun(@(x) isnumeric(x) && isnan(x), position)) = {'0'};

aperture = data(:,3);                           %horizontal and vertical aperture
aperture(cellfun(@(x) isnumeric(x) && isnan(x), aperture)) = {'0 / 0'};

 % to split the aperture column into two
Mat = [];
    for i = 1:length(aperture);
      var = aperture(i,1);
      var = char(var);
      split = strsplit(var,' / ');
      Mat = [Mat;split];
    end

raw_data = horzcat(position,Mat)%the needed raw data: start pos, end pos, hor & ver apr

% to remove empty spaces from the raw data needed
fourth_column_all = raw_data(:,4);
index_zeros = find(strcmp(fourth_column_all, '0'));
raw_data(index_zeros,:) = [];

first_column_all = raw_data(:,1);
index_zeros_2 = find(strcmp(first_column_all, '0'));
raw_data(index_zeros_2,:) = [];

start_pos = str2num(num2str(cell2mat(raw_data(:,1))));
end_pos = str2num(num2str(cell2mat(raw_data(:,2))));
aper_1 = str2num(char(raw_data(:,3)));
aper_2 = str2num(char(raw_data(:,4)));
raw_data_needed = horzcat(start_pos,end_pos,aper_1,aper_2)

%--------------------------------------------------------------------------------------

% to extract the aperture changes
start_pos_mm = raw_data_needed(:,1);
end_pos_mm = raw_data_needed(:,2);
hor_apr_mm = raw_data_needed(:,3).*1000;
ver_apr_mm = raw_data_needed(:,4).*1000;
leng = length(raw_data_needed);

for i = 1:leng-1
    hor_aper_nw(i,:) = abs(hor_apr_mm(i) - hor_apr_mm(i+1));  %to find the difference
of two hor aperture
    ver_apr_nw(i,:) = abs(ver_apr_mm(i) - ver_apr_mm(i+1));  %to find the difference of
two ver aperture
 end
```

```
new_data = [raw_data_needed(2:end,1), hor_aper_nw, ver_apr_nw];  % consist of all apr
changes in hor & ver wrt position

% comparing where the apr is the same both hor & ver
location_of_zeros = find(new_data(:,2)==0 & new_data(:,3)==0);
new_data(location_of_zeros,:) = [];     %eliminating points where the aperture are same

    % note that 'new_data' contain all aperture changes across SPS entire
    % circumference wrt position

    % to display some certain range of aperture changes
    for k = 1:length(new_data)
        if new_data(new_data(k,2) >= 100 & new_data(k,3) >= 100)
            aper_chngs(k,:) = new_data(k,:);
            aper_chngs(~any(aper_chngs,2),:) = [];

        end
    end
%-----------------------------------------------------------------------------------------
```