

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.

Start pos

End pos

Hor Apr

Ver Apr

SPS Vacuum Report (Excel File)																
Periodo	ID	name	Type name	Down start	Down end	Description	Upstream Range	Downstream Range	Length	Width	Height	Comments	Cycles	Apertures	Elements	
100	2460447	VEOP 10010	VEOP	40.75	3.251	Vacuum chamber for QP magnet.			3.345	0	0	SPS0004000247	0	0.152 / 0.0415	0.0776 / 0.076 / 0.02975	
100	330516	VPA 10020	VPA	5.1	5.154	Vacuum Pump Spigot for Type A.			0	0	0	SPS0004000247	0	0.152 / 0.0367	0.0776 / 0.076 / 0.02975	
100	2760264	VEBA 10030	VEBA	10.1	9.951	Vacuum chamber for MBB magnet.			0.66	0	0	SPS0004000247	0	0.152 / 0.0367	0.0776 / 0.076 / 0.02975	
100	3307384	VPA 10040	VPA	5.1	5.154	Vacuum Pump Spigot for Type A.			0	0	0	SPS0004000247	0	0.152 / 0.0367	0.0776 / 0.076 / 0.02975	
100	2760265	VEBA 10050	VEBA	9.951	10.1	Vacuum chamber for MBB magnet.			0.66	0	0	SPS0004000247	0	0.152 / 0.0367	0.0776 / 0.076 / 0.02975	
100	3307386	VPA 10060	VPA	10.114	10.114	Vacuum Pump Spigot for Type A.			0	0	0	SPS0004000246	0	0.129 / 0.0536	0.0645 / 0.05275 / 0.0645 / 0.05275	
100	2760267	VEBA 10070	VEBA	10.071	10.211	Vacuum chamber for MBB magnet.			0.64	0	0	SPS0004000246	0	0.129 / 0.0536	0.0645 / 0.05275 / 0.0645 / 0.05275	
100	3308131	VPA 10080	VPA	23.154	23.154	Vacuum Pump Spigot for Type A.			0	0	0	SPS0004000246	0	0.129 / 0.0536	0.0645 / 0.05275 / 0.0645 / 0.05275	
100	2760268	VEBA 10090	VEBA	23.211	29.851	Vacuum chamber for MBB magnet.			0.64	0	0	SPS0004000246	0	0.129 / 0.0536	0.0645 / 0.05275 / 0.0645 / 0.05275	
100	3308133	VPA 10101	VPA	29.764	29.764	Vacuum Pump Spigot for Type A.			0	0	0	SPS0004000246	0	0.129 / 0.0536	0.0645 / 0.05275 / 0.0645 / 0.05275	
100	2361958	VSA 10101	VSA	29.851	30.026	Vacuum valve, auto loc, diameter 100 mm.			0.175	0	0	SPS0004000226	0	CIRCLE	0.1 / 0.1	0.05 / 0.05 / 0.05 / 0.05
100	3146153	VTSB 10102	VTSB	30.0267	30.7107	Vacuum chamber G2, accretion, with one bellows and CH150 Ranges.			0.685	0	0	SPS0004000304	0	CIRCLE	0.063 / 0.063	0.0415 / 0.0415 / 0.0415 / 0.0415
100	3147115	VTTD 10105	VTTD	30.7107	31.2727	Vacuum chamber G2 with two Ranges CH150 and one bellows.			0.562	0	0	SPS0004000304	0	CIRCLE	0.063 / 0.063	0.0415 / 0.0415 / 0.0415 / 0.0415
101	240141	VEOP 10110	VEOP	31.9027	35.2487	Vacuum chamber for QP magnet.			3.345	0	0	SPS0004000305	0	CIRCLE	0.063 / 0.063	0.0415 / 0.0415 / 0.0415 / 0.0415
101	3308721	VPA 10120	VPA	35.1917	35.1917	Vacuum Pump Spigot for Type A.			0	0	0	SPS0004000305	0	CIRCLE	0.063 / 0.063	0.0415 / 0.0415 / 0.0415 / 0.0415
101	2760271	VEBA 10130	VEBA	35.2487	41.8867	Vacuum chamber for MBB magnet.			0.64	0	0	SPS0004000246	0	0.129 / 0.0536	0.0645 / 0.05275 / 0.0645 / 0.05275	
101	3308135	VPA 10140	VPA	41.8317	41.8317	Vacuum Pump Spigot for Type A.			0	0	0	SPS0004000246	0	0.129 / 0.0536	0.0645 / 0.05275 / 0.0645 / 0.05275	
101	2760272	VEBA 10150	VEBA	41.8867	48.5267	Vacuum chamber for MBB magnet.			0.64	0	0	SPS0004000246	0	0.129 / 0.0536	0.0645 / 0.05275 / 0.0645 / 0.05275	
101	3308137	VPA 10160	VPA	48.4717	48.4717	Vacuum Pump Spigot for Type A.			0	0	0	SPS0004000246	0	0.129 / 0.0536	0.0645 / 0.05275 / 0.0645 / 0.05275	
101	2760275	VEBA 10170	VEBA	48.5267	55.1507	Vacuum chamber for MBB magnet.			0.66	0	0	SPS0004000247	0	0.152 / 0.0367	0.0776 / 0.076 / 0.02975	
101	3307388	VPA 10180	VPA	55.1317	55.1317	Vacuum Pump Spigot for Type A.			0	0	0	SPS0004000247	0	0.152 / 0.0367	0.0776 / 0.076 / 0.02975	
101	2760276	VEBA 10190	VEBA	55.1607	61.8467	Vacuum chamber for MBB magnet.			0.66	0	0	SPS0004000247	0	0.152 / 0.0367	0.0776 / 0.076 / 0.02975	
101	3307390	VPA 10201	VPA	61.7917	61.7917	Vacuum Pump Spigot for Type A.			0	0	0	SPS0004000247	0	0.152 / 0.0367	0.0776 / 0.076 / 0.02975	
101	3147124	VTTD 10205	VTTD	61.8464	62.7084	Vacuum chamber G2, with accretion bellows and two CH150 Ranges.			0.56	0	0	SPS0004000305	0	CIRCLE	0.063 / 0.063	0.0415 / 0.0415 / 0.0415 / 0.0415
101	3147126	VTTD 10206	VTTD	62.7084	63.2704	Vacuum chamber G2, with bellows and CH150 Ranges.			0.562	0	0	SPS0004000305	0	CIRCLE	0.063 / 0.063	0.0415 / 0.0415 / 0.0415 / 0.0415
102	2507074	VDAF 10208	VDAF	63.2704	63.9004	Vacuum Chamber for M2CH150A Assembly drawing SPS00051000108.			0.63	0	0	SPS00051000108	0	ELLIPSE	0.152 / 0.0415	0.0776 / 0.076 / 0.02975
102	2470107	VEOP 10210	VEOP	63.9004	67.2464	Vacuum chamber for QP magnet.			3.345	0	0	SPS0004000305	0	0.152 / 0.0367	0.0776 / 0.076 / 0.02975	
102	330876	VPA 10220	VPA	67.1904	67.1904	Vacuum Pump Spigot for Type A.			0	0	0	SPS0004000305	0	0.152 / 0.0367	0.0776 / 0.076 / 0.02975	
102	2760279	VEBA 10230	VEBA	67.2464	73.9004	Vacuum chamber for MBB magnet.			0.66	0	0	SPS0004000247	0	0.152 / 0.0367	0.0776 / 0.076 / 0.02975	
102	3307392	VPA 10240	VPA	73.8464	73.8464	Vacuum Pump Spigot for Type A.			0	0	0	SPS0004000247	0	0.152 / 0.0367	0.0776 / 0.076 / 0.02975	
102	2760279	VEBA 10250	VEBA	73.9004	80.5604	Vacuum chamber for MBB magnet.			0.66	0	0	SPS0004000247	0	0.152 / 0.0367	0.0776 / 0.076 / 0.02975	

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;

Start pos	End pos	Hor Apr	Ver Apr
Command Window			
-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

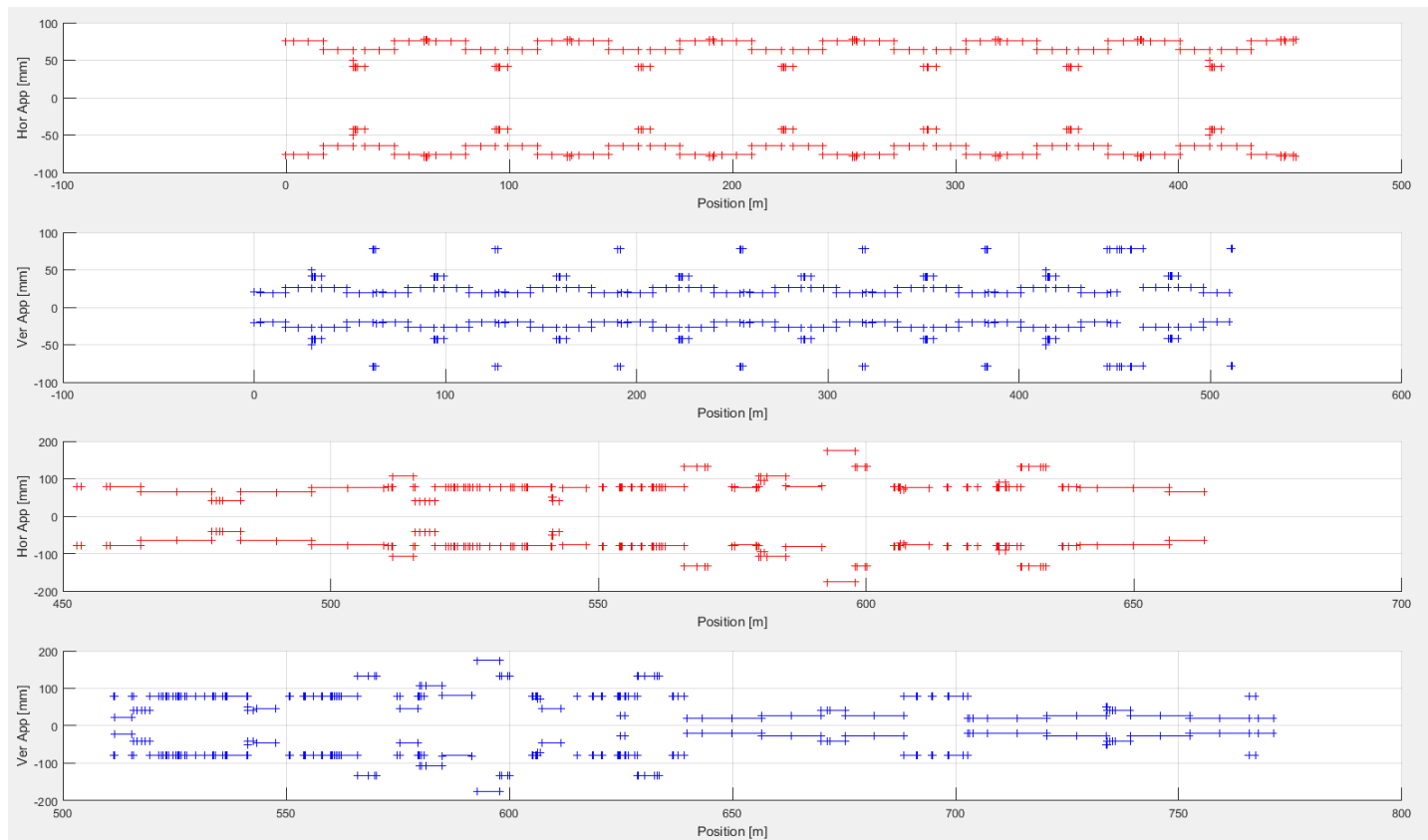
It is will be seen that the extracted data contains NaN (Not a Number), this is as a result of some machine elements which has no aperture information (such as vacuum ion sputter A etc.) and in some cases both position and aperture information were not present on the SPS vacuum report in the Layout Database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

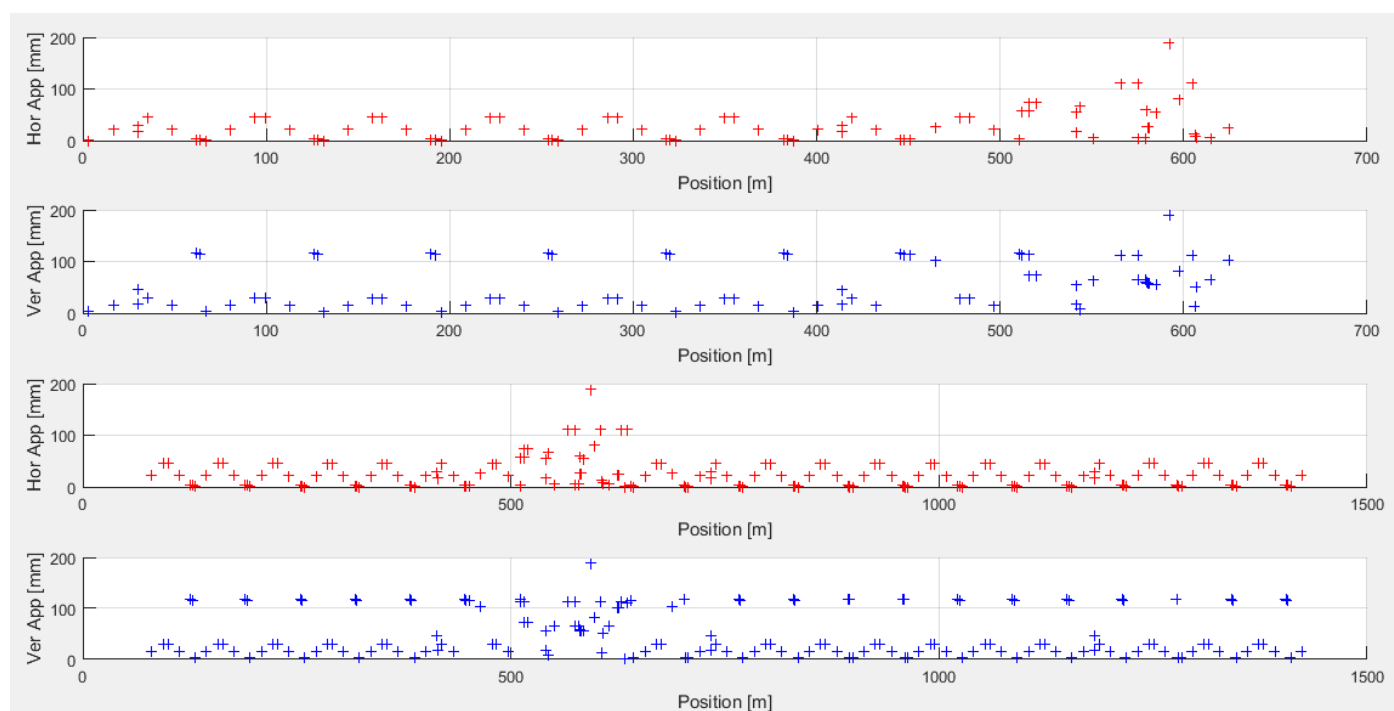
THE APERTURE CHANGES EXTRACTION

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,row] = xlsread(filename);  
data = [row(3:end,5),row(3:end,6),row(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_apr_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
%-----

```