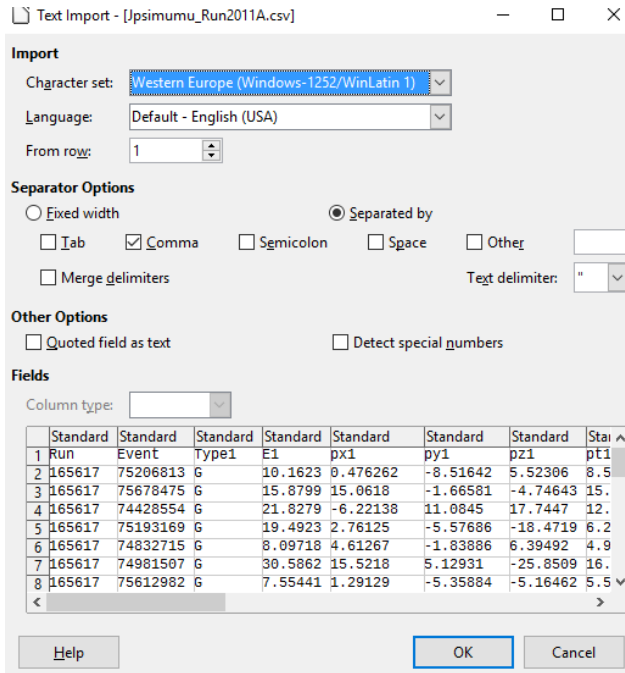


Plotting a Histogram with LibreOffice

In this tutorial, we are going to learn how to plot a histogram using LibreOffice and open data sets from CMS Experiment at CERN. The file we use is "Jpsimumu.csv". This file can be obtained from the following link: <http://opendata.cern.ch/record/545>. First, open the file with LibreOffice calc. Make sure that the option "Comma" in "Separator Options" is marked, and "Separated by" is selected.

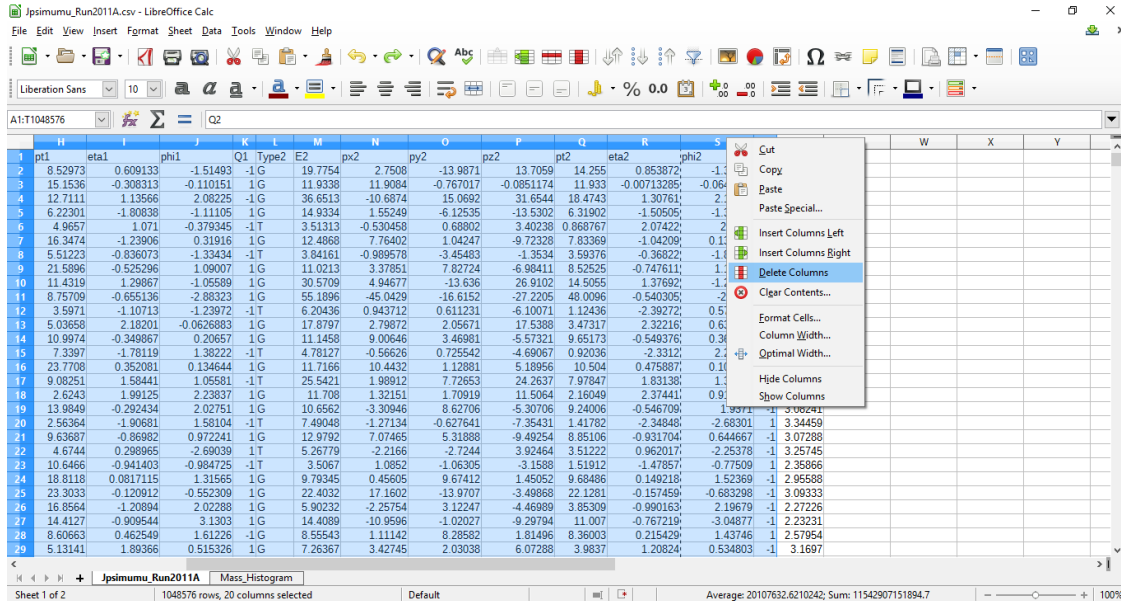


Click OK and wait for the document to load. It will look like this.

The screenshot shows the LibreOffice Calc spreadsheet with the following columns: Type1, E1, px1, E, py1, pz1, pt1, eta1, phi1, Q1, Type2, E2, px2, py2, pz2, eta2, phi2, Q2, M, and U. The data is organized in a grid with rows and columns. The first row of data is:

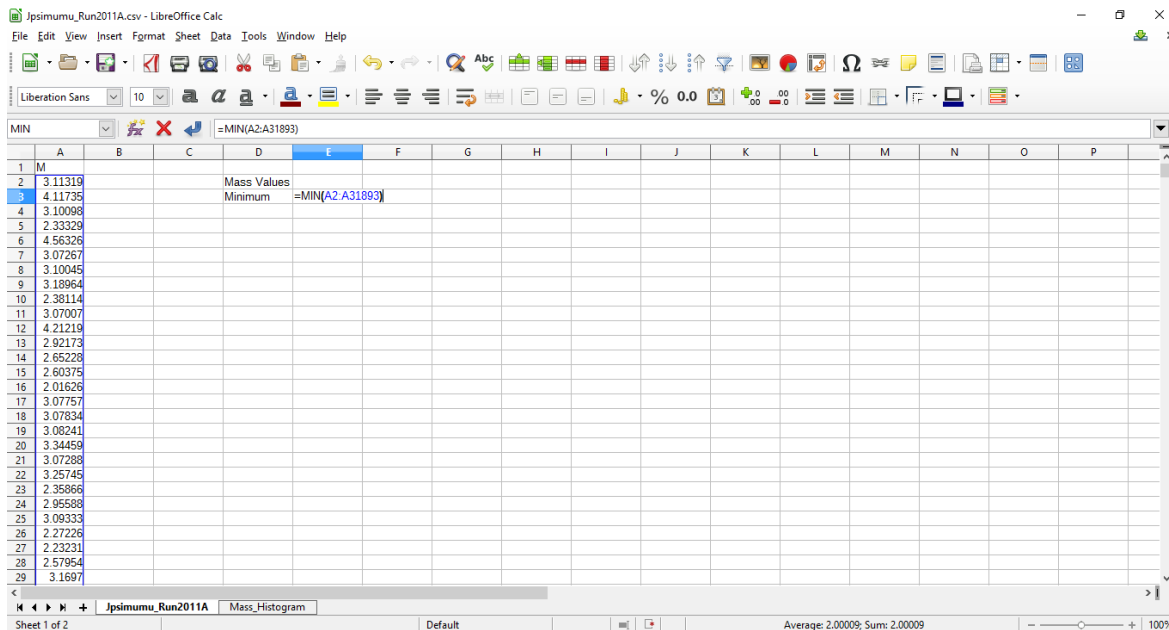
1	Type1	E1	px1	E	py1	pz1	pt1	eta1	phi1	Q1	Type2	E2	px2	py2	pz2	eta2	phi2	Q2	M	U
2	G	10.1623	0.476262	-8.51642	5.52306	8.52973	0.609133	-1.51493	-1.0	19.7754	2.7508	-13.9871	13.7059	14.255	0.853872	-1.37661	1.3113			
3	G	15.8799	15.0618	-1.66581	-4.74643	15.1536	-0.308313	-0.110151	1.0	11.9338	11.9084	-0.767017	-0.0851174	11.933	-0.00713285	-0.0643211	-1.4117			
4	G	21.8279	-6.22138	11.0845	17.7447	12.7111	1.13566	2.08225	-1.0	36.6513	-10.6874	15.0692	31.6544	18.4743	1.30761	2.18768	-1.3100			
5	G	19.4923	2.76125	-5.57686	-18.4719	6.22301	-1.80838	-1.11105	1.0	14.9334	1.55249	-6.12535	-13.5302	6.31902	-1.50506	-1.32257	-1.2333			
6	G	8.09718	4.61267	-1.83886	6.39492	4.9657	1.071	-0.379345	-1.0	3.51313	-0.530458	0.68802	3.40238	0.868767	2.07422	2.2276	-1.4563			
7	G	30.5862	15.5218	5.12931	-25.8509	16.3474	-1.23906	0.31916	1.0	12.4868	7.76402	1.04247	-9.72328	7.83369	-1.04209	0.133471	-1.3072			
8	G	7.55441	1.29129	-5.35884	-5.16462	5.51223	-0.836073	-1.33434	-1.0	3.84161	-0.989578	-3.45483	-1.3534	3.59376	-0.36822	-1.84976	-1.3100			
9	G	24.6376	9.98359	19.1426	-11.8697	21.5896	-0.525296	1.09007	1.0	11.0213	3.37851	7.82724	-6.98411	8.52525	-0.747611	1.16332	-1.3189			
10	G	22.5057	5.62963	-9.94966	19.3857	11.4319	1.29867	-1.05589	1.0	30.5709	4.94677	-13.636	26.9102	14.5055	1.37692	-1.22279	-1.2381			
11	G	10.7051	-8.46643	-2.3744	-6.15638	8.75709	-0.65136	-2.88323	1.0	55.1896	-45.0429	-16.6152	-27.2205	48.0096	-0.540305	-2.7882	-1.3070			
12	G	6.03714	1.16926	-3.40175	-4.84735	3.5971	-1.10713	-1.23972	-1.0	6.20436	0.943712	0.611231	-6.10071	1.12436	-2.39272	0.574748	-1.4212			
13	G	22.6067	5.02668	-0.315528	22.0383	5.03658	2.18201	-0.0626883	1.0	17.8797	2.79872	2.05671	17.5388	3.47317	2.32216	0.633751	-1.2921			
14	G	11.6778	10.7636	2.25561	-3.92661	10.9974	-0.349867	0.20657	1.0	11.1458	9.00646	3.46981	-5.57321	9.65173	-0.549376	0.367733	-1.2652			
15	G	22.4059	1.37594	7.20958	-21.1694	7.3397	-1.78119	1.38222	-1.0	4.78127	-0.56626	0.725542	-4.69067	0.92036	-2.3312	2.2351	-1.2603			
16	G	25.2596	23.5556	3.19093	8.54321	23.7708	0.352081	0.134644	1.0	11.7166	10.4432	1.12881	5.18956	10.504	0.475887	0.107672	-1.2016			
17	G	23.0765	4.47335	7.9045	21.2138	9.08251	1.58441	1.05881	-1.0	25.5421	1.98912	7.72653	24.2637	7.97847	1.83138	1.31883	1.3077			
18	G	9.7908	-1.62467	2.06093	9.43195	2.6243	1.99125	2.23877	1.0	11.708	1.32151	1.70919	11.5064	2.16049	2.37441	0.912626	-1.3078			
19	G	14.5875	-6.16731	12.5515	-4.14819	13.9849	-0.292434	2.02751	1.0	10.6562	-3.30946	8.62706	-5.30706	9.24006	-0.546709	1.9371	-1.3082			
20	G	8.81973	-0.0262702	2.5635	-8.43826	2.56364	-1.90681	1.58104	-1.0	7.49048	-1.27134	-0.627641	-7.35431	1.41782	-2.34848	-2.68901	-1.3344			
21	G	13.5186	5.42989	7.9615	-9.48905	9.63687	-0.86982	0.972241	1.0	12.8792	7.07465	5.31889	-9.49254	8.85106	-0.931704	0.644667	-1.3072			
22	G	4.386	-4.20659	-2.03828	1.41839	4.6744	0.298965	-2.58039	-1.0	5.26779	-2.2166	-2.7244	3.92464	3.51222	0.962017	-2.25378	-1.3257			
23	G	15.7236	5.88857	-8.86993	-11.5702	10.6466	-0.941403	-0.984725	-1.0	3.5067	1.0852	-1.06305	-3.1588	1.51912	-1.47857	-0.77509	-1.2358			
24	G	18.8749	4.74788	18.2027	1.53885	18.8118	0.0817115	1.31565	1.0	9.79345	0.45605	9.67412	1.45052	9.68486	0.140218	1.52369	-1.2955			
25	G	23.4741	19.8385	-12.2262	-2.82452	23.3033	-0.120912	-0.552309	1.0	22.4032	17.1602	-13.9707	-3.49868	22.1281	-0.157459	-0.683298	-1.3093			
26	G	30.75	-7.36353	15.1631	-25.7179	16.8564	-1.20894	2.02288	1.0	5.90232	-2.25754	3.12247	-4.46989	3.85309	-0.90163	2.19679	-1.2772			
27	G	20.7971	-14.4118	0.162709	-14.9927	14.4127	-0.909544	3.1303	1.0	14.4089	-10.9596	-1.02027	-9.29794	11.007	-0.767219	-3.04877	-1.2232			
28	G	9.54445	-0.356738	8.59924	4.12447	8.60663	0.462549	1.61226	-1.0	8.55543	1.11142	8.28582	1.81496	8.36003	0.215429	1.43746	1.2579			
29	G	17.4321	4.465	2.52885	16.6594	5.13141	1.89366	0.515326	1.0	7.26367	3.42745	2.03038	6.07288	3.9837	1.20824	0.534803	-1.316			

We're only going to use the values for the mass. Select the rest on the columns by clicking on them, then right-click and delete them using the "Delete Columns" option of the menu that appears.

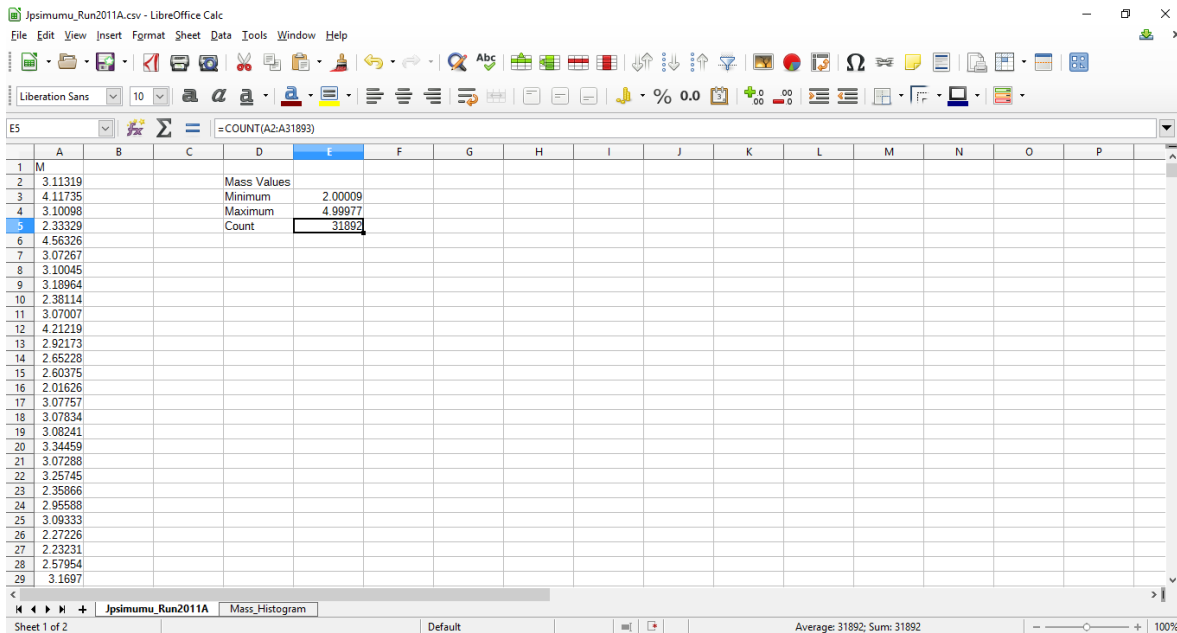


You can add a new sheet by clicking the **+** button in the lower left-hand side of the screen. Rename this sheet Mass_Histogram by double clicking on the name. There are approximately almost 32 thousand values for the invariant mass.

Now we are going to calculate the minimum and the maximum mass values in this file. You can do this by using the function MIN(), and selecting all the mass values in the file. It is easier and quicker to just write the names of the first and last cell in the parenthesis.



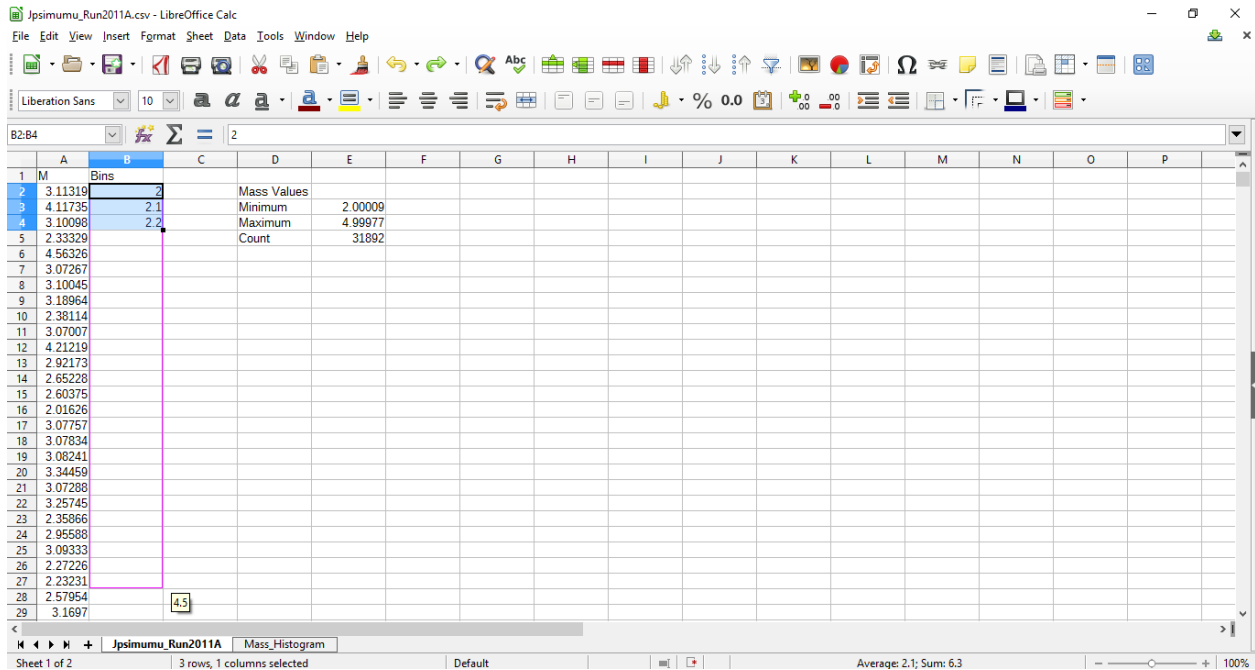
Click Enter, and the minimum value for the mass will be shown on the screen. Now we have to do the same to calculate the maximum value, but use the function MAX() instead. We also need to know the exact number of values we have in this file. For this we can use the function COUNT().



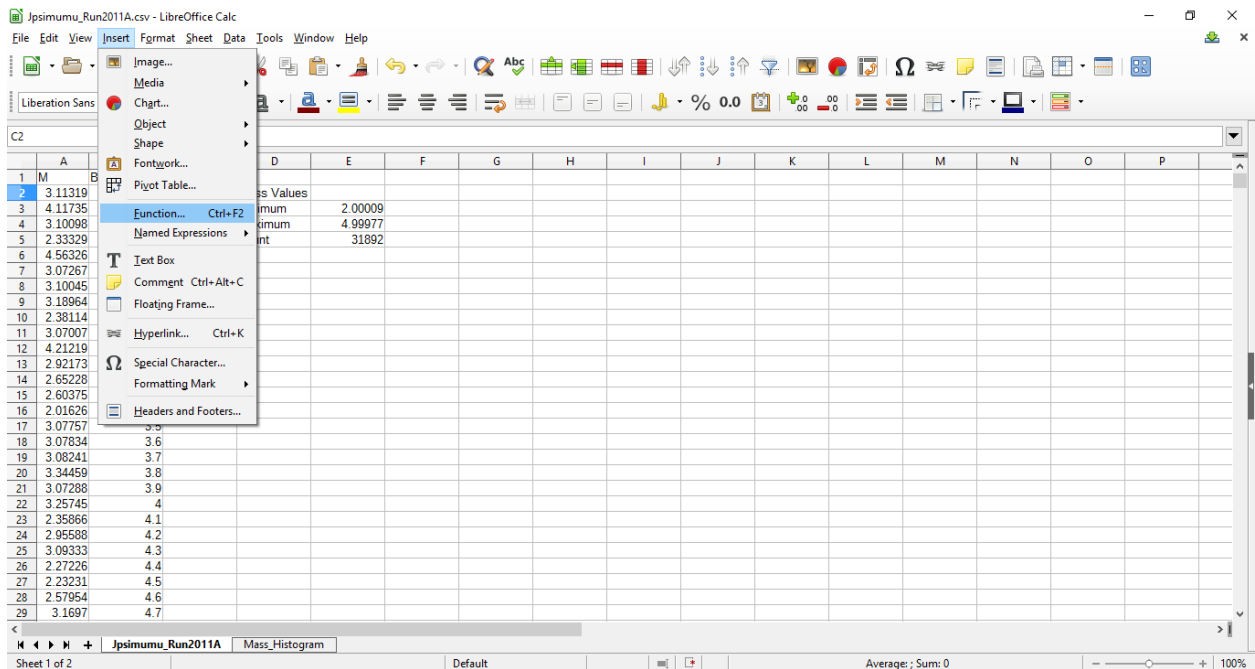
Our histogram will begin from 2.0 GeV and end in 5.0 GeV in order to include all the values that we have in our data.

We can now begin to create our classes for the histogram. In the column next to the mass column, write the heading “Bins” and then numbers going from 2.0 to 5.0 in steps of 0.10 . This will allow to better visualize the data and see what particles appear in our histogram.

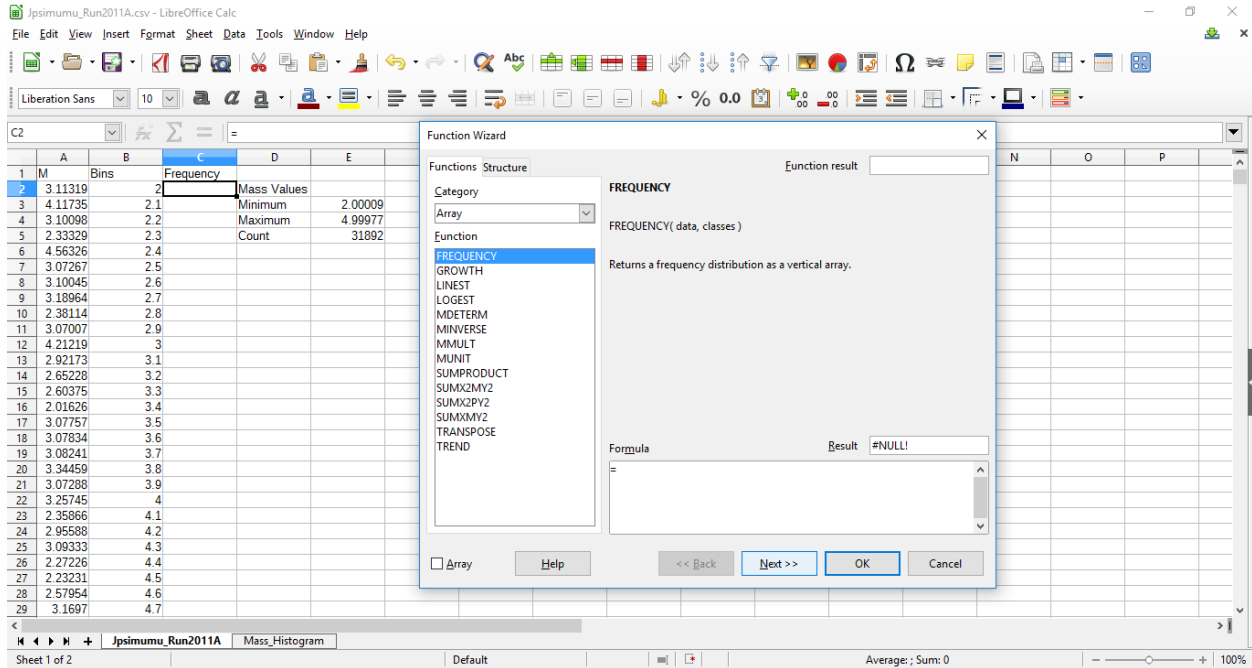
You can easily create these values by writing the first three numbers, selecting them and then sliding until we see the last value we want (5.0, shown in the picture below).



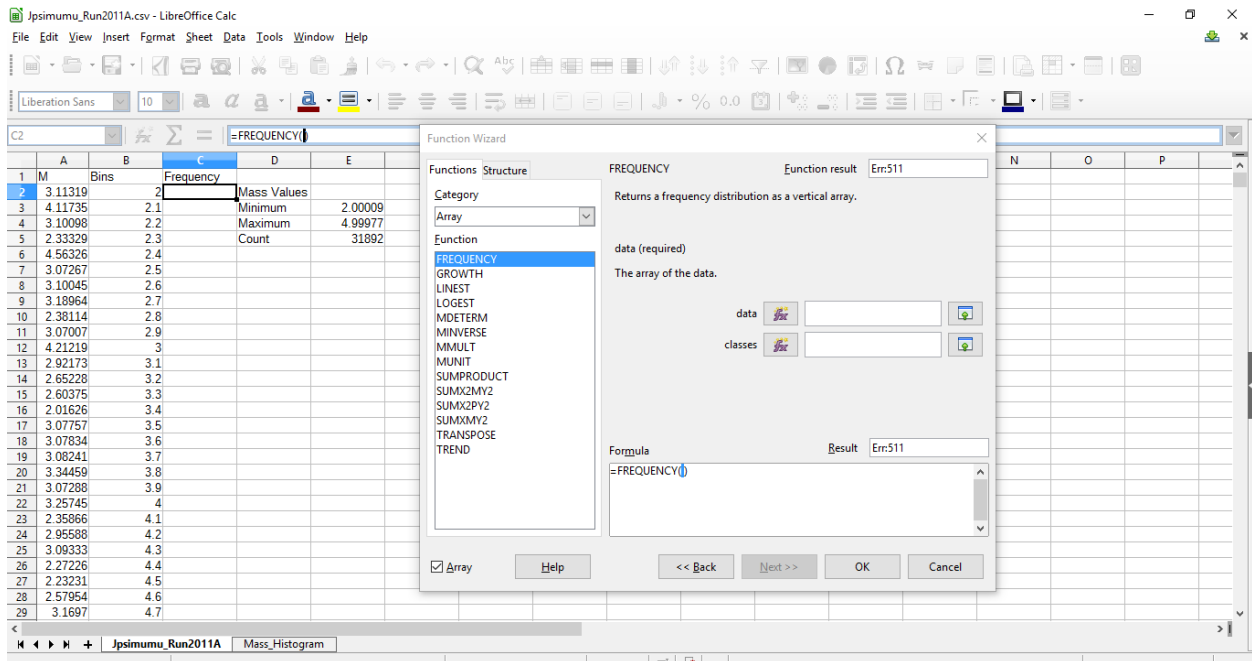
Next to the “Bins” heading now write a “Frequency” heading. Now we are going to use the Frequency function. Click on the cell below the “Frequency” heading, then in the toolbar, select “Insert”, then “Function”.




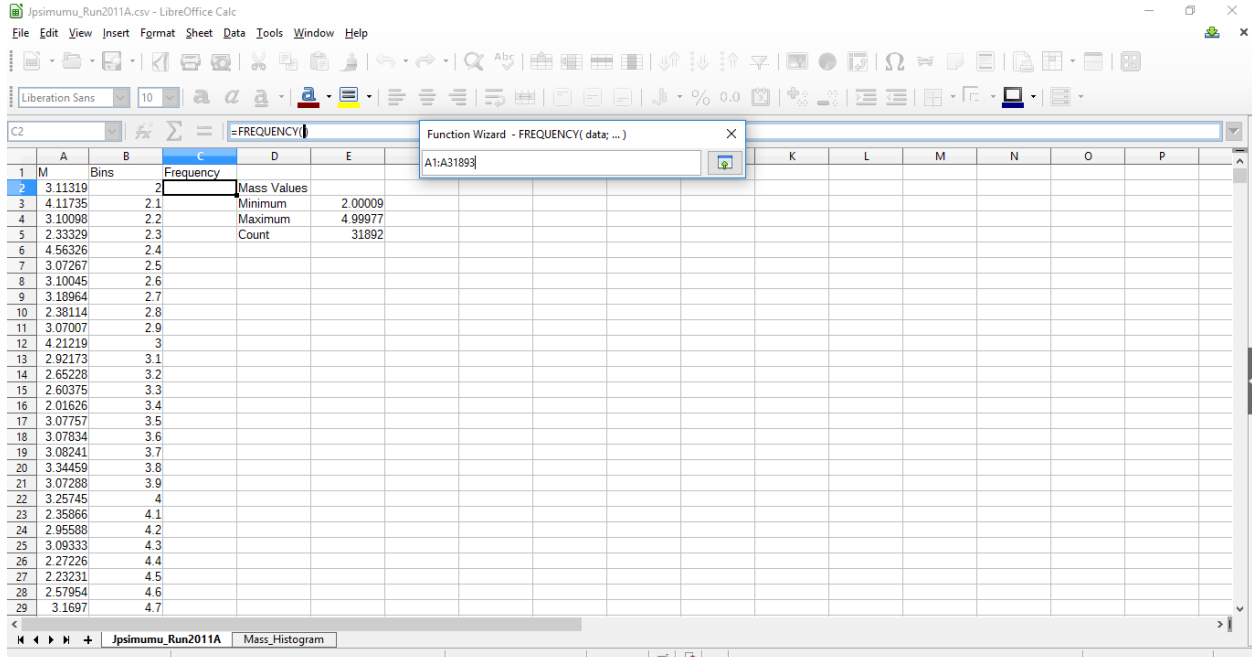
A window will pop-up. There, select the function category “Array”, and the function “FREQUENCY”, as shown in the picture below. Click on Next.



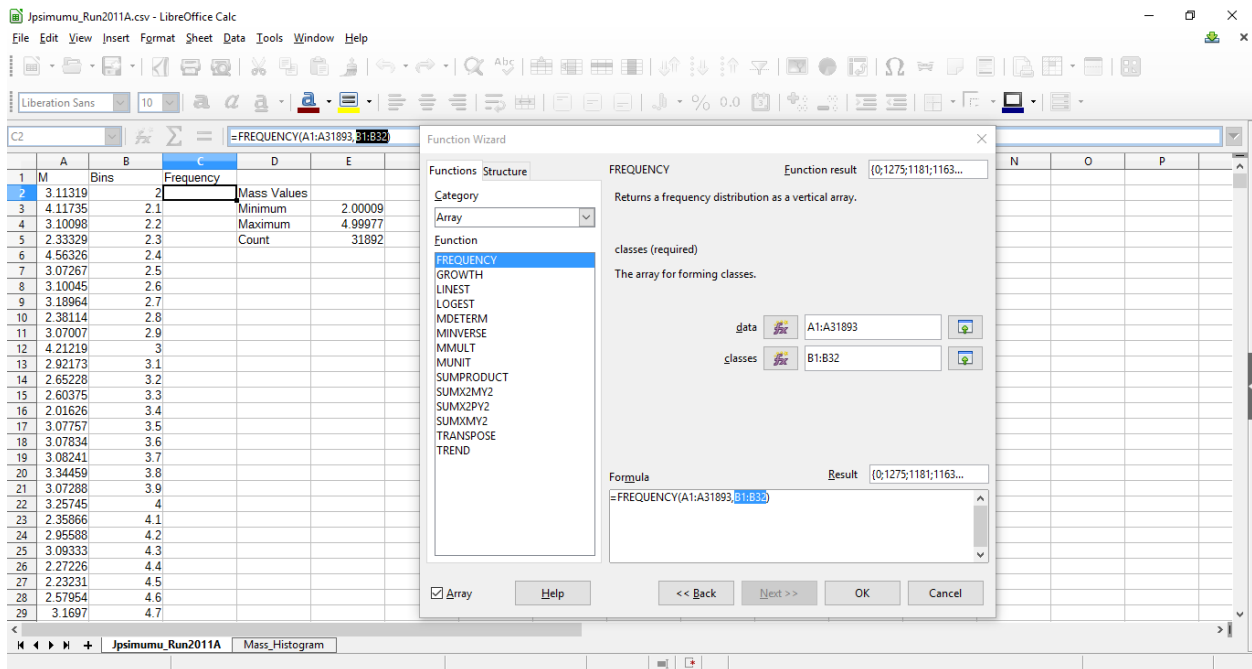
A window like this one will appear:



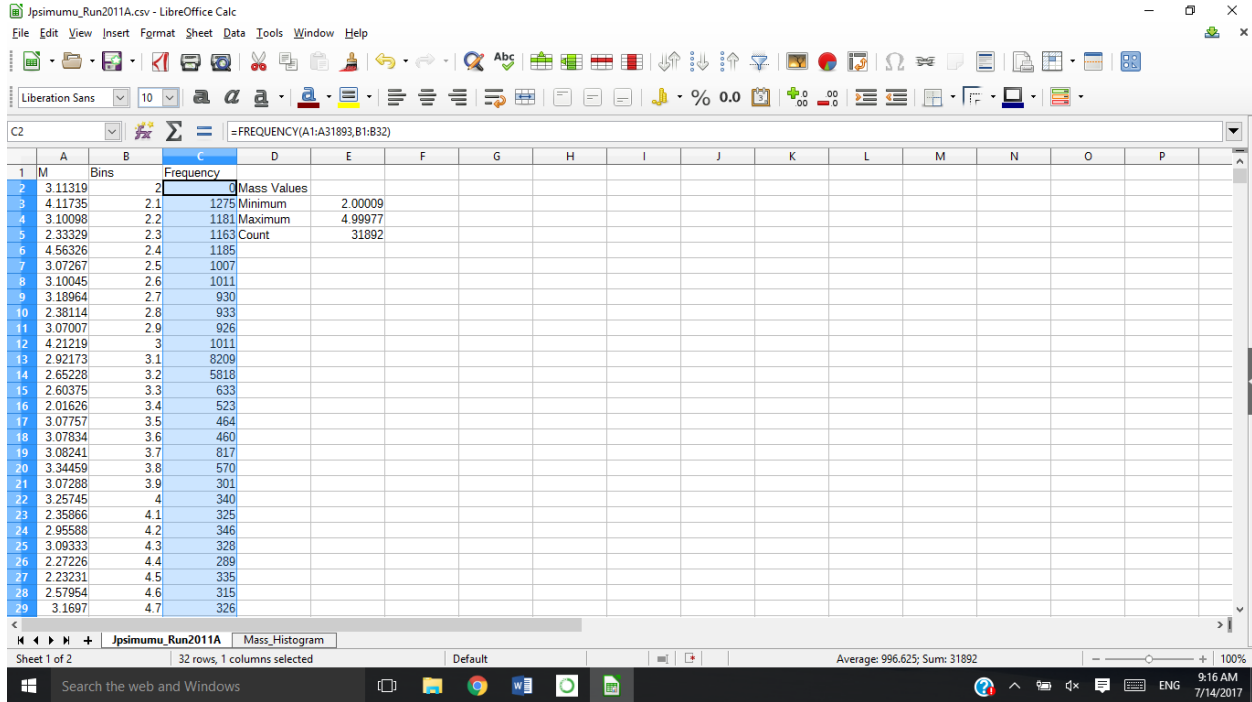
Click on the  button next “data”. From there you can select all the mass values manually with the mouse, but it is easier to write the range in the window and click Enter. You will return to the previous window. There you can do the same and include all the “Bins” values in “classes”.



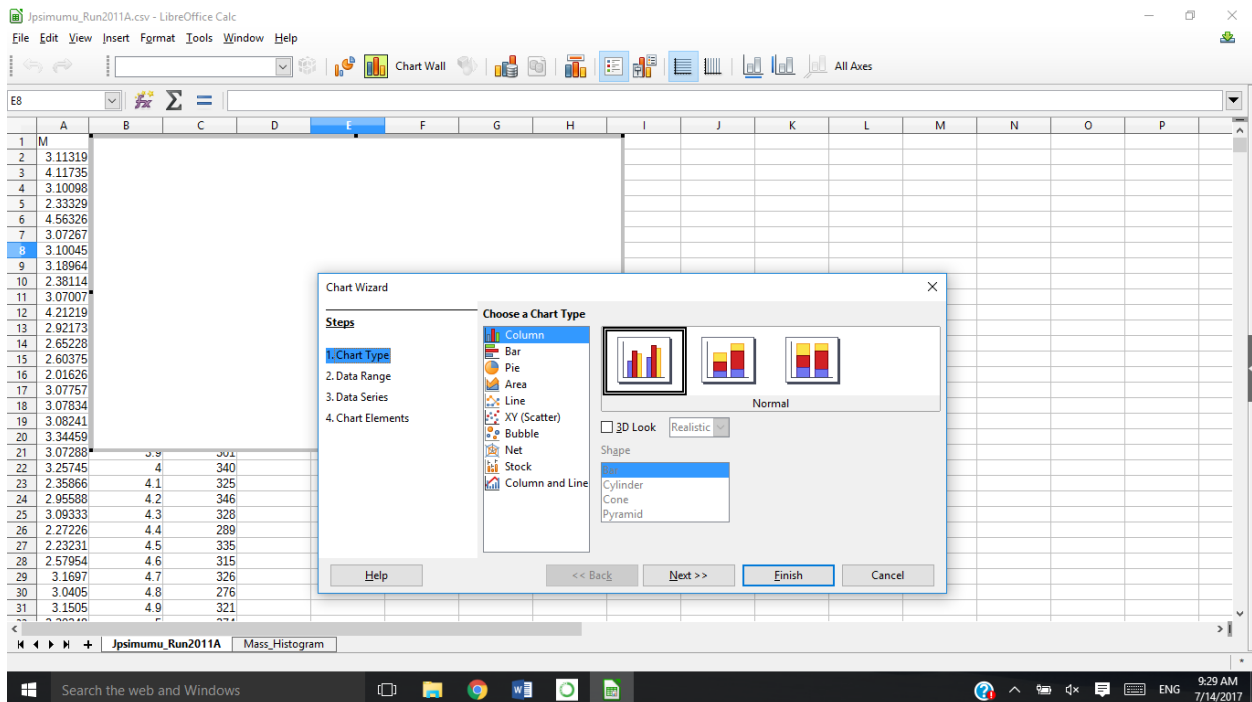
Once your screen looks like this, you can click OK. The values of the frequencies will appear.



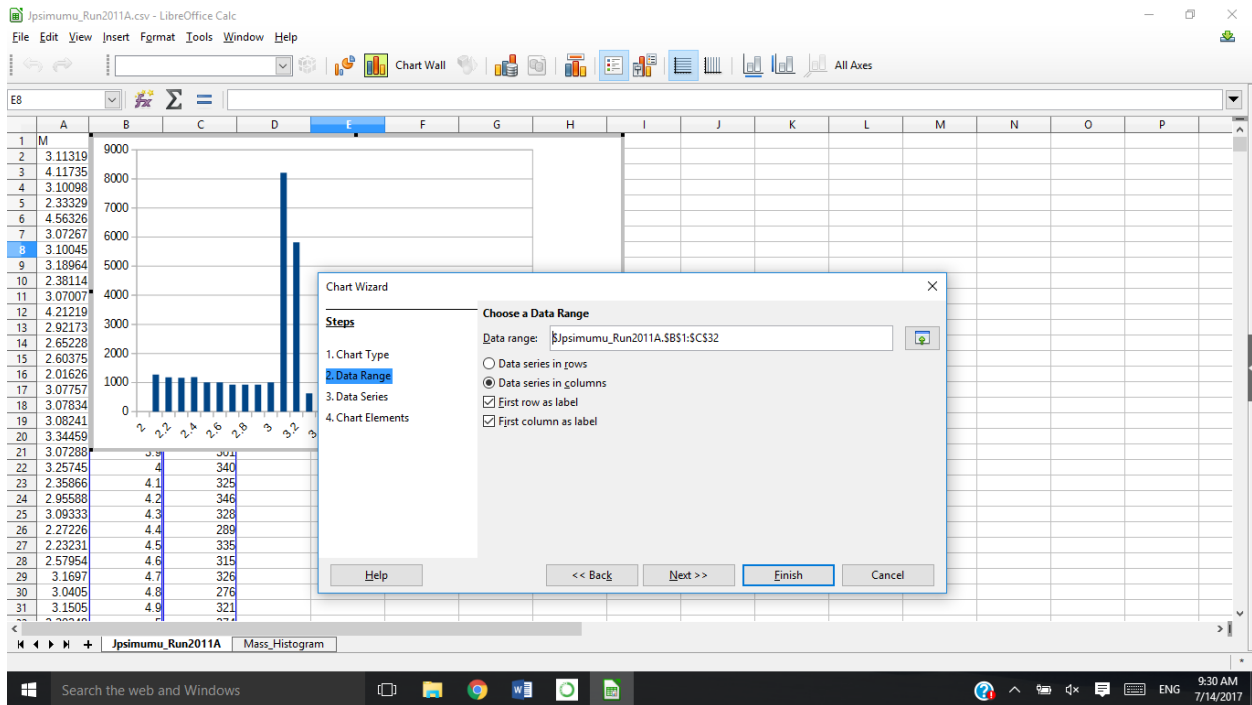
You can see that the first value of the frequency is 0. This is because the bin value to the left is the upper limit of the class, that is, the function will only count values of the mass that are less than 2.0. As we have no values of the mass that are less than 2.0, we get a frequency of 0 for this class.




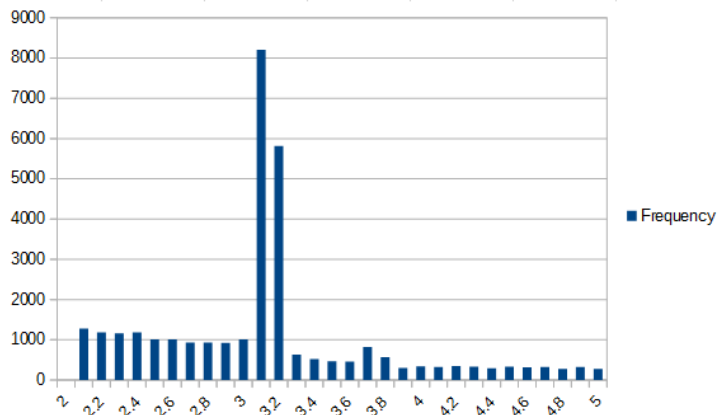
We can now make our histogram. Select in the toolbar the option “Insert”, then “Chart”. A window like this one will appear:



There, you can decide if you want to plot your values as columns or dots. We can select the column option and click next.



In this window, you can select the values that will be used for the histogram. Make sure that the options “First column as label” and “First row as label” are marked, and select the option “Data series in columns”. You can select the values for the histogram manually as explained before with the  button or you can write down the range. You can now click finish to see your histogram. It will look something like this:



Notice there’s a big peak at approximately 3.1 GeV, and there seems to be a smaller peak at 3.7 GeV. Knowing that our file contains only events where two muons have been detected, we can then find out which particle has a mass of approximately 3.1 GeV and decays into two muons.

Such particle is the J/ψ Meson. One other particle that has a mass of approximately 3.7 GeV and decays into two muons is the $\psi(2S)$ meson.

Exercise

Plot invariant mass histograms using different data sets. You can find more data sets at the following link: <http://opendata.cern.ch/record/545>.