Max_Vogel_CMSDataAnalysis.mlx

This code reads dilepton files from CMS and fits bumps in dilepton mass distributions. The data are available at http://opendata.cern.ch/.

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Collaborators: John Podczerwinski, Robert Wheatley, & Jaden Sengkhammee -- helped troubleshoot during lab.

Contributions: Professor Carlsmith for the code template and the CERN lab for collecting this data and making it avaliable!

Table of Contents

Z to two electrons

Dataset URL

Initialize

```
clear;% clear variables
delete(findall(0,'Type','figure'))% close all open figure windows
```

Import & Prepare Data

We'll first import the CSV data file

```
filename='Zee.csv';A=csvread(filename,1,1);nbins=100;
filename ; %drop filename to command window for users benefit
```

Then we'll create vectors for the energy, momentum components, transverse momentum, (pseudo)rapidity, azimuthal angle, & charge in units of proton charge.

```
Event=A(:,2);
E1=A(:,3);px1=A(:,4);py1=A(:,5);pz1=A(:,6);pt1=A(:,7);
eta1=A(:,8);phi1=A(:,9);q1=A(:,10);
E2=A(:,11);px2=A(:,12);py2=A(:,13);pz2=A(:,14);pt2=A(:,15);
eta2=A(:,16);phi2=A(:,17);q2=A(:,18);
M=A(:,19); %pair mass supplied by CMS
```

We can then compute the invariant mass of each lepton

```
m1= (abs(E1.^2-px1.^2-py1.^2-pz1.^2)).^(1/2);% mass of lepton 1
m2= (abs(E2.^2-px2.^2-py2.^2-pz2.^2)).^(1/2);% mass of lepton 2
m3=(abs((E1+E2).^2-(px1+px2).^2-(py1+py2).^2-(pz1+pz2).^2)).^(1/2);
```

...and then create the vector `Nevents` for the number of entries per bin created by the `histogram` command along with `edges` which is a vector of bin edges.

```
[Nevents,edges] = histcounts(m3,nbins);
```

With this data, we can create `err` containing statistical standard error in each bin equal to the square root of the number of events in that bin (Poisson statistics)

```
err=Nevents.^(1/2);
```

Since `edges` starts at lower edge of first bin and ends at upper edge of last bin, we'll create the `mass` equal the vector of bin centers by eliminating last edge and adding a half bin size to each element.

```
mass=edges(1:end-1);
mass=mass +(edges(2)-edges(1))/2;
```

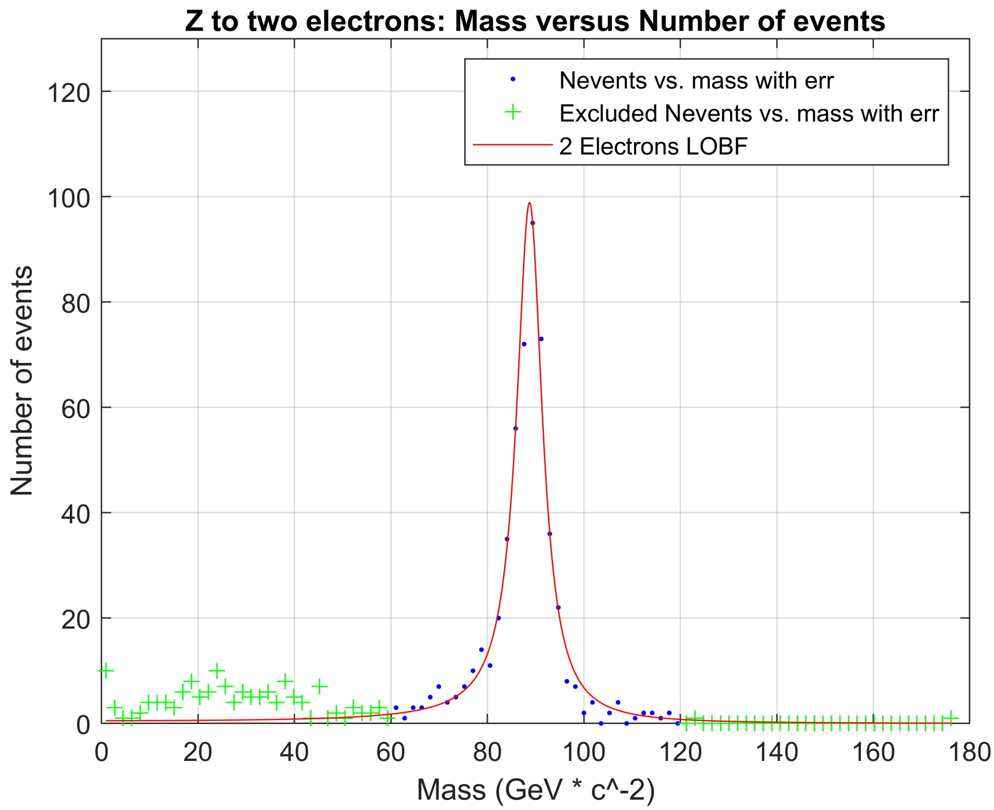
Mass distribution fit

We'll use the Relativistic Breit–Wigner distribution: $\frac{k}{(m^2 - m_Z^2)^2 + m_Z^2 \cdot \Gamma_Z^2}$ where m_z is the Z-boson mass treated as a parameter, $\Gamma_Z$is the width of the Z-boson mass, and k is a normalization constant.

```
createFitVogelZee(mass, Nevents, err)
```

```
ans = 
     General model:
     ans(x) = k * 1/((x^2 -  mz^2)^2 + mz^2 * wz^2)
     Coefficients (with 95% confidence bounds):
       k =   3.302e+07  (1.209e+07, 5.395e+07)
       mz =       88.72  (87.94, 89.5)
       wz =      -6.512  (-9.019, -4.006)
```

```
title("Z to two electrons: Mass versus Number of events")
ylabel("Number of events")
xlabel("Mass (GeV * c^-2)")
ylim([0 130]); % so table doesn't obstruct view
```



For this fit, m_z was 88.72 while the true value is 91.1876 GeV*c^-2, $\Gamma_Z$was 6.512 while the true is 2.4952 GeV*c^-2, and k was 3.302*10^7 (which was the constant.) All of the true values can be found on the PDG's site. These descripancies fall outside of two standard deviations of their resepctive measurements. The m_z value controls the center of the "spike" in the graph, so when collecting the data perhaps mass was over-estimated when being measured. Morevoer, the line of best fit only considers the lines values with a mass greater than 60 and less than 120 so perhaps those bounds were inaccurate and morphed the Γ_Z to be much higher than it should have been.

Z to two muons

Dataset URL

Initialize

```
clear;% clear variables
delete(findall(0,'Type','figure'))% close all open figure windows
```

Import & Prepare Data

We'll first import the CSV data file

```
filename='Zmumu.csv';A=csvread(filename,1,1);nbins=100;
filename ; %drop filename to command window for users benefit
```

Then we'll create vectors for the energy, momentum components, transverse momentum, (pseudo)rapidity, azimuthal angle, & charge in units of proton charge.

```
Event=A(:,2);
E1=A(:,3);px1=A(:,4);py1=A(:,5);pz1=A(:,6);pt1=A(:,7);
eta1=A(:,8);phi1=A(:,9);q1=A(:,10);
E2=A(:,11);px2=A(:,12);py2=A(:,13);pz2=A(:,14);pt2=A(:,15);
eta2=A(:,16);phi2=A(:,17);q2=A(:,18);
M=A(:,19); %pair mass supplied by CMS
```

We can then compute the invariant mass of each lepton

```
m1= (abs(E1.^2-px1.^2-py1.^2-pz1.^2)).^(1/2);% mass of lepton 1
m2= (abs(E2.^2-px2.^2-py2.^2-pz2.^2)).^(1/2);% mass of lepton 2
m3=(abs((E1+E2).^2-(px1+px2).^2-(py1+py2).^2-(pz1+pz2).^2)).^(1/2);
```

...and then create the vector `Nevents` for the number of entries per bin created by the `histogram` command along with `edges` which is a vector of bin edges.

```
[Nevents,edges] = histcounts(m3,nbins);
```

With this data, we can create `err` containing statistical standard error in each bin equal to the square root of the number of events in that bin (Poisson statistics)

```
err=Nevents.^(1/2);
```

Since `edges` starts at lower edge of first bin and ends at upper edge of last bin, we'll create the `mass` equal the vector of bin centers by eliminating last edge and adding a half bin size to each element.

```
mass=edges(1:end-1);
mass=mass +(edges(2)-edges(1))/2;
```

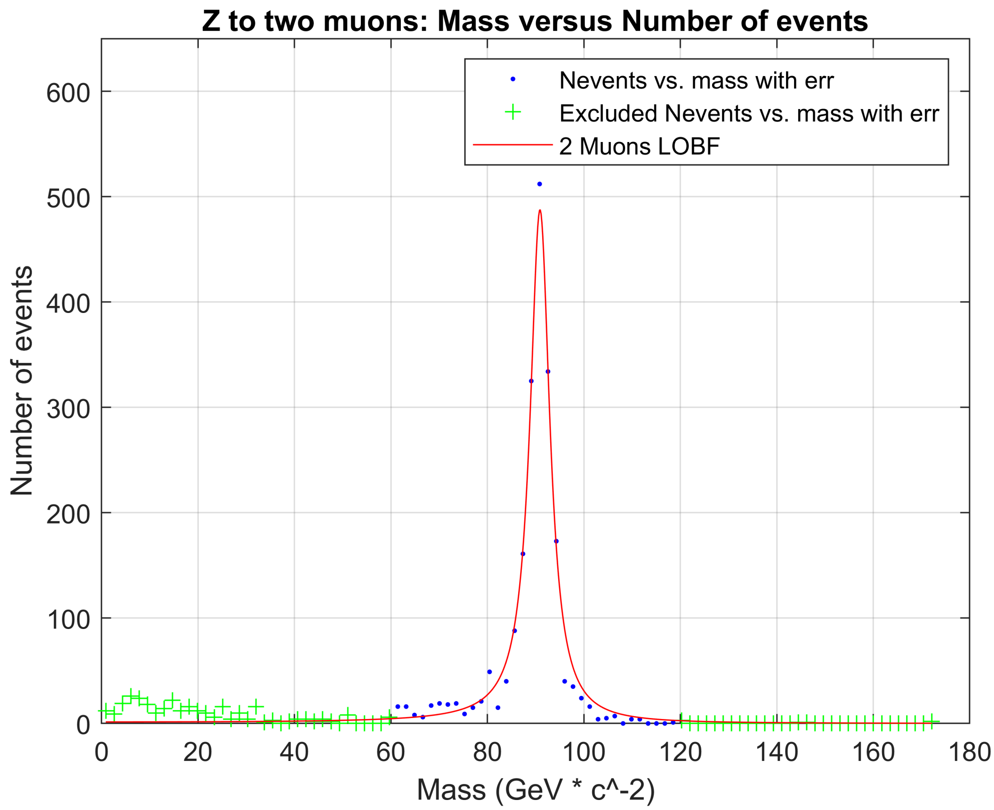
Mass distribution fit

We'll use the Relativistic Breit–Wigner distribution: $\frac{k}{(m^2 - m_Z^2)^2 + m_Z^2 \cdot \Gamma_Z^2}$ where m_z is the Z-boson mass treated as a parameter, $\Gamma_Z$is the width of the Z-boson mass, and k is a normalization constant.

```
createFitVogelZmumu(mass, Nevents, err)
```

```
ans =
     General model:
     ans(x) = k * 1/((x^2 -  mz^2)^2 + mz^2 * wz^2)
     Coefficients (with 95% confidence bounds):
       k =       1e+08  (fixed at bound)
       mz =        90.9  (90.83, 90.96)
       wz =       4.982  (4.935, 5.029)
```

```
title("Z to two muons: Mass versus Number of events")
ylabel("Number of events")
xlabel("Mass (GeV * c^-2)")
ylim([0 650]); % so table doesn't obstruct view
```



For this fit, m_z was 90.9 while the true value is 91.1876 GeV*c^-2, Γ_Z was 4.982 while the true is 2.4952 GeV*c^-2, and k was 1*10^8 (which was the constant.) All of the true values can be found on the PDG's site. Again, these descripancies fall outside of two standard deviations of their resepctive measurements. Because the k value (which is responsible for the amplitute) was fixed/limited, it could have caused the Γ_Z value (which also affects the amplitude as well as width of the spike) to be incorrectly estimated.