# W Mass Measurement through Hadronic Decay Channels

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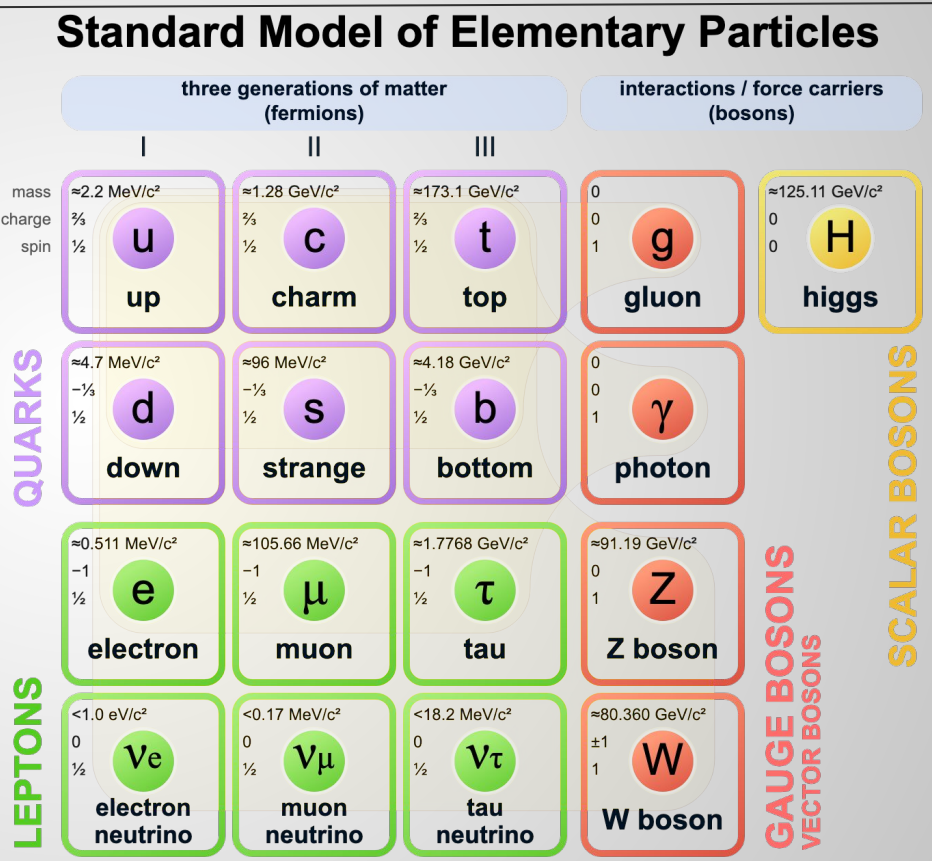
# What are W Bosons?

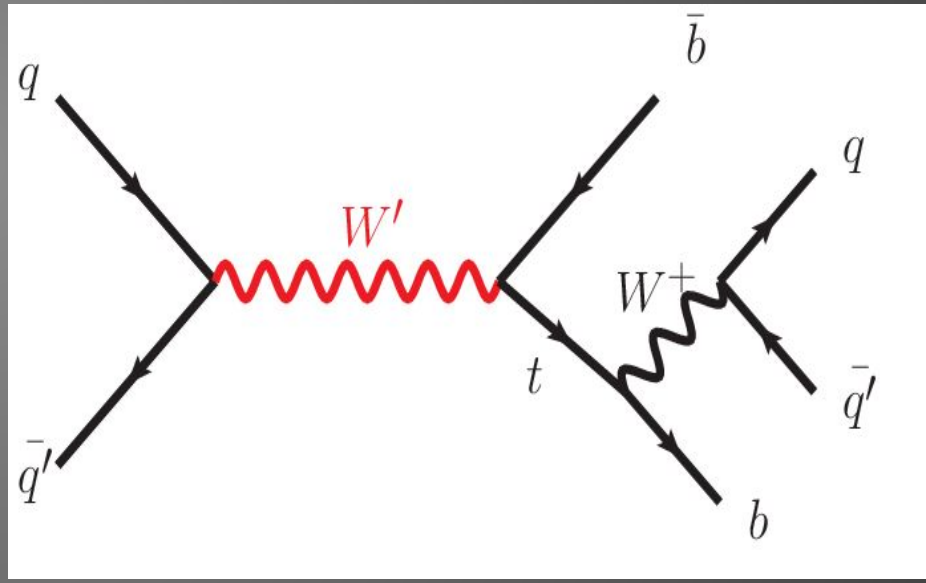
- Carriers of the Weak force
- Only Bosons that are charged (W+ , W-)
- Discovered in 1983 at CERN
- Current mass estimates at 80.379 GeV/c^2



# W Decay Channels

- Each W can either decay leptonically into a lepton and neutrino or hadronically into two quarks
- I will only look at the hadronic decay ($W \rightarrow qq$)

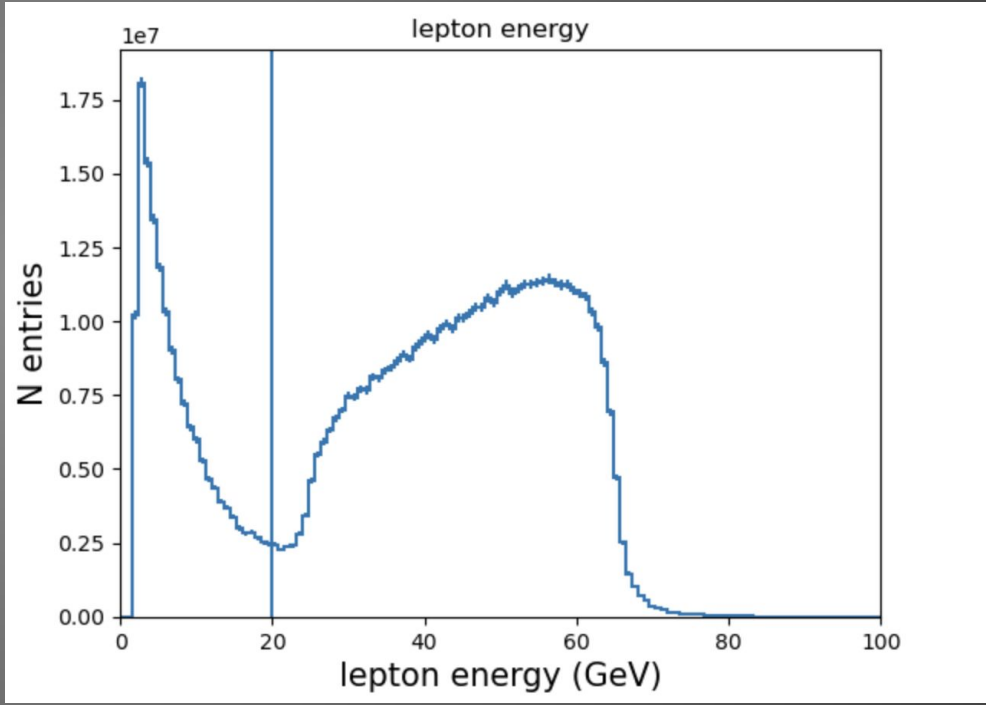
- W+ can decay into either
  - Up (u) & Anti-down ($d^-$)
  - Charm (c) & Anti-strange ($s^-$)
- W- can decay into either
  - Down (d) & Anti-up ($u^-$)
  - Strange (s) & Anti-charm ($c^-$)




- Nearly impossible to measure directly
  - quark confinement
  - hadronization

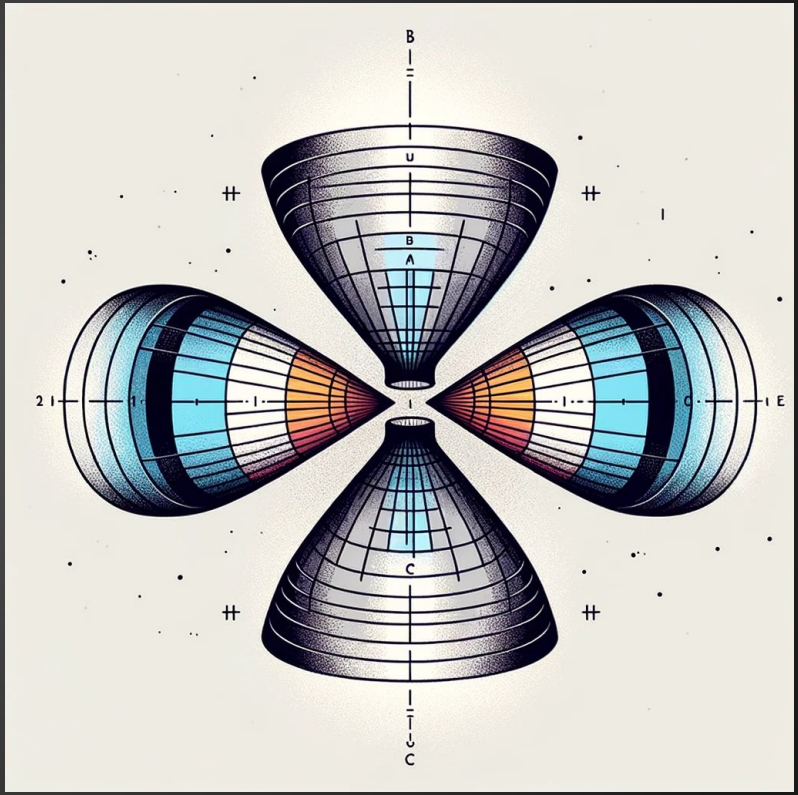
# Cuts on Leptons >20GeV

- Essential for seeing purely hadronic decays
- Completely excluding leptons significantly reduces efficiency of selecting events for purely hadronic channels.
    - This is because low-energy leptons might be produced in the event from secondary processes, such as the decay of hadrons, or could arise as detector noise or misidentification.



# Jet Clustering

- Hadronized quarks move away in different directions
- Can be clustered into conical shaped ‘jets’
- Many advanced jet clustering algorithms exist:
  - Kt, Valencia, GenKt
- These jets have measurable quantities (Mass, Energy, Momentum)
- Each W’s mass can be extrapolated by pairing the correct two jets it decays into



# Jet Pairing

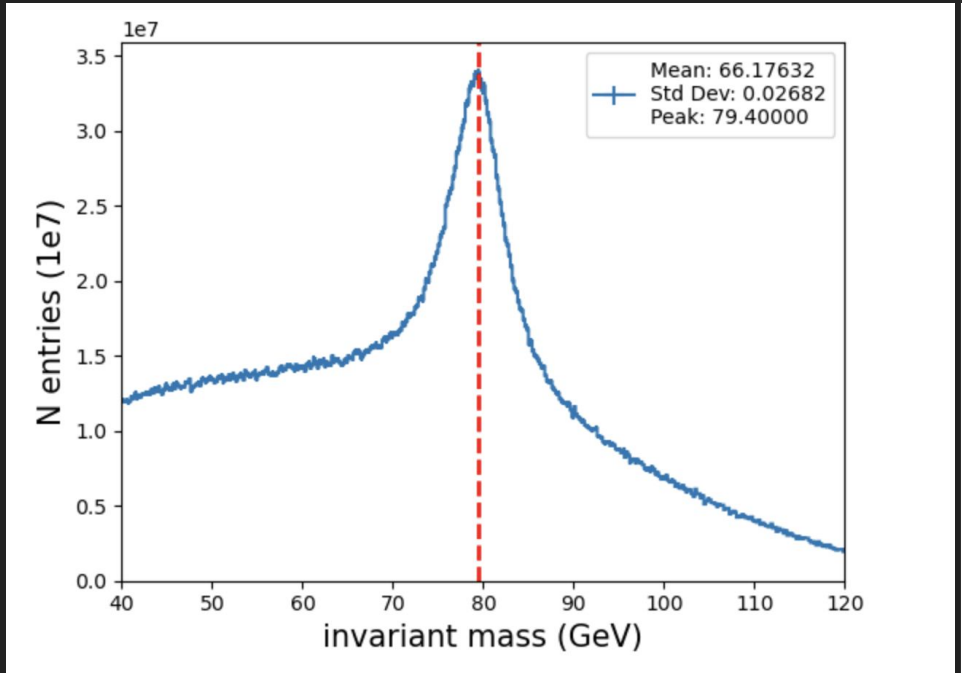
- 4 jets are paired in di-jets by selecting the jets that come from the same boson.
- Selecting these pairs is practically harder than intuition may make it seem
- I chose to pair based on minimizing the formula:

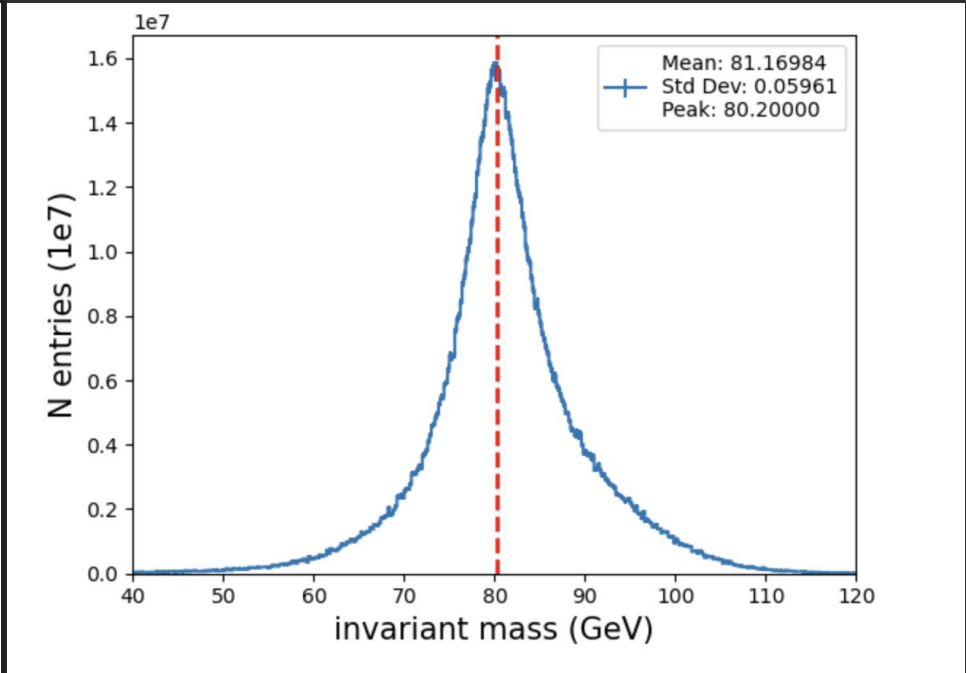
$$\chi^2 = (m_1 - m_W)^2 + (m_2 - m_W)^2$$

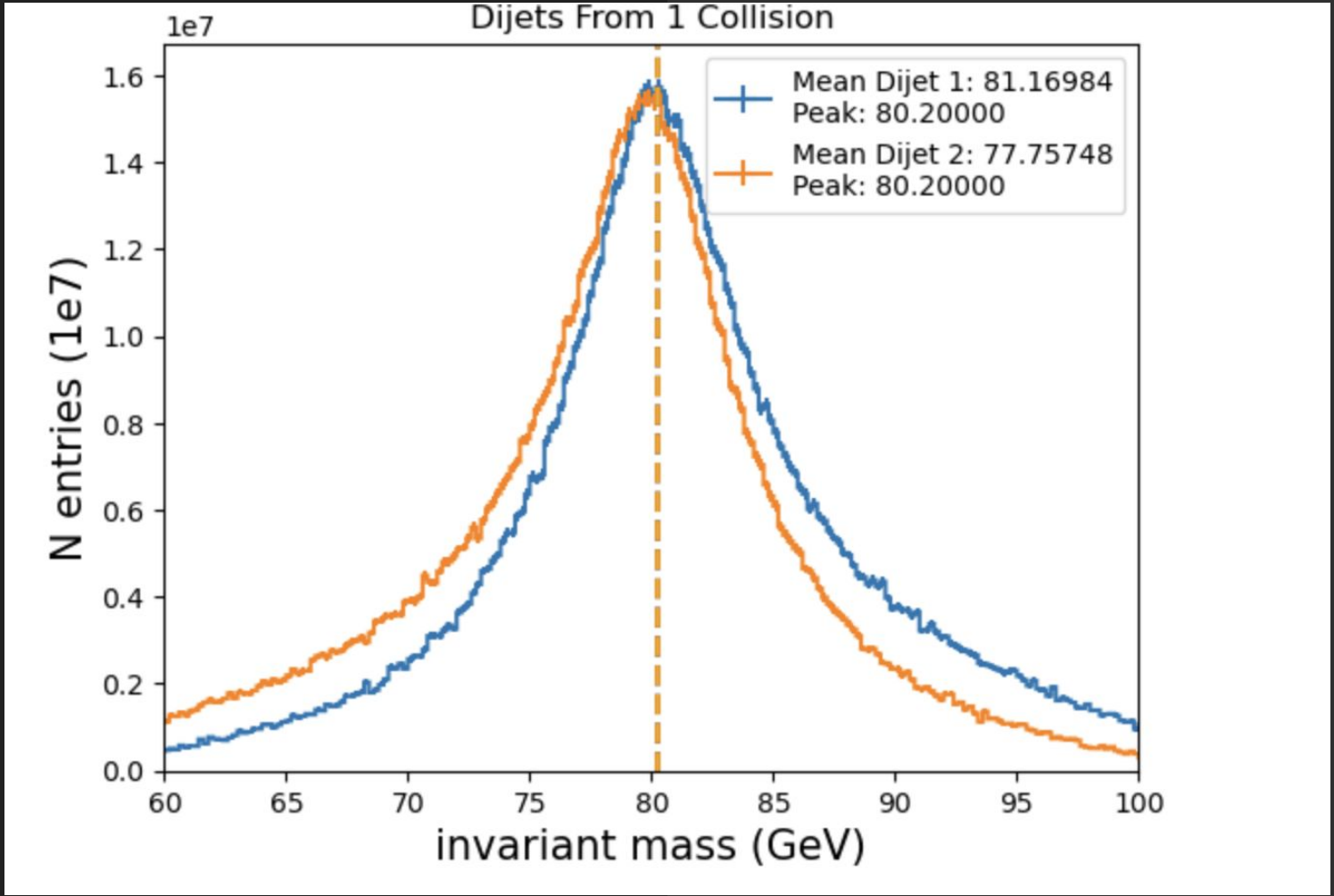
- M1 & M2 are invariant masses of the jet pairs where there are 3 unique combinations for 4 jets
- This pairing method allowed me to gain sufficiently better accuracy to discerning the W mass.

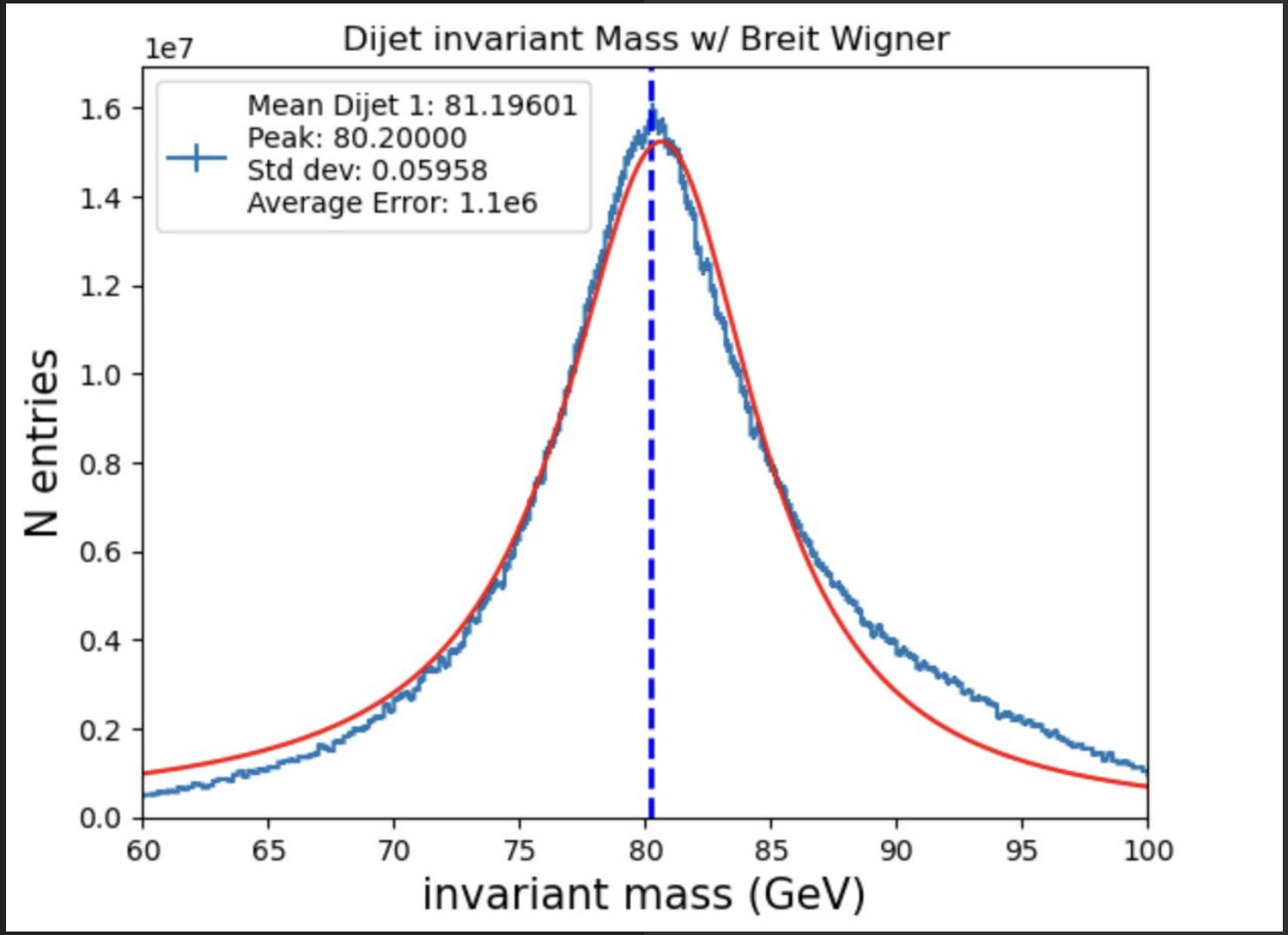
# Effects of Jet Pairing

## All Invariant Masses vs Dijet Masses after Pairing




Dijets From 1 Collision
1e7
Mean Dijet 1: 81.16984
Peak: 80.20000
Mean Dijet 2: 77.75748
Peak: 80.20000
N entries (1e7)
invariant mass (GeV)
0.0
0.2
0.4
0.6
0.8
1.0
1.2
1.4
1.6
60
65
70
75
80
85
90
95
100


Dijet invariant Mass w/ Breit Wigner
1e7
Mean Dijet 1: 81.19601
Peak: 80.20000
Std dev: 0.05958
Average Error: 1.1e6
N entries
invariant mass (GeV)
0.0
0.2
0.4
0.6
0.8
1.0
1.2
1.4
1.6
60
65
70
75
80
85
90
95
100

# Kinematic Fitting

- Simulation is not coded with laws of physics in mind

$$\sum_{i=0}^{4} E_i = \sqrt{s} \quad \text{and} \quad \sum_{i=0}^{4} \vec{p}_i = \vec{0},$$

- With this, we can only look at the events that make physical sense (positive energy, zero net momentum)

$$\begin{pmatrix} 1 & 1 & 1 & 1 \\ \beta_{x,1} & \beta_{x,2} & \beta_{x,3} & \beta_{x,4} \\ \beta_{y,1} & \beta_{y,2} & \beta_{y,3} & \beta_{y,4} \\ \beta_{z,1} & \beta_{z,2} & \beta_{z,3} & \beta_{z,4} \end{pmatrix} \begin{pmatrix} E_1 \\ E_2 \\ E_3 \\ E_4 \end{pmatrix} = \begin{pmatrix} \sqrt{s} \\ 0 \\ 0 \\ 0 \end{pmatrix},$$

- Run each jet through kinematic algorithm
  - Removes ~75% of jets

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Valid jets:   580406
Invalid jets: 1446584
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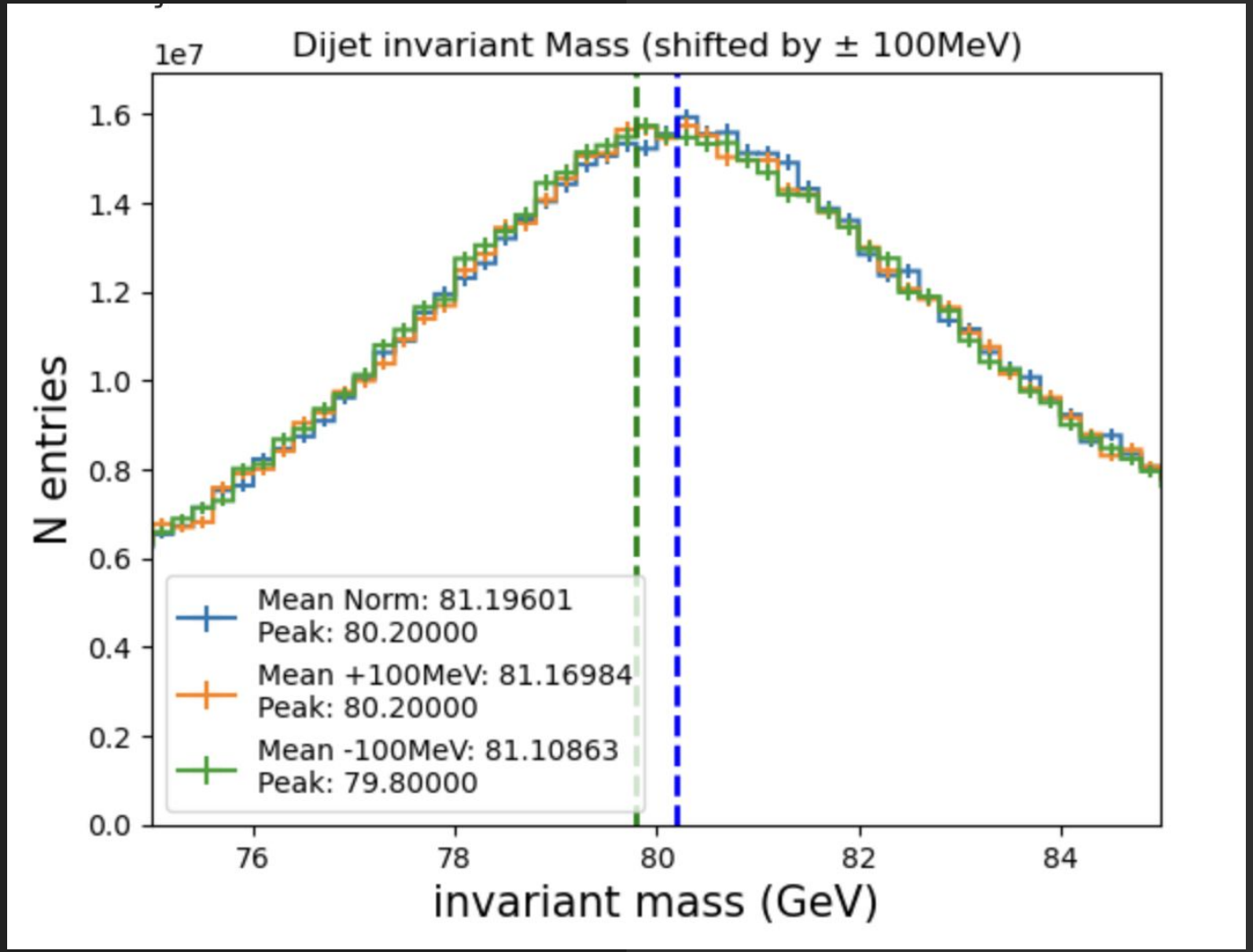
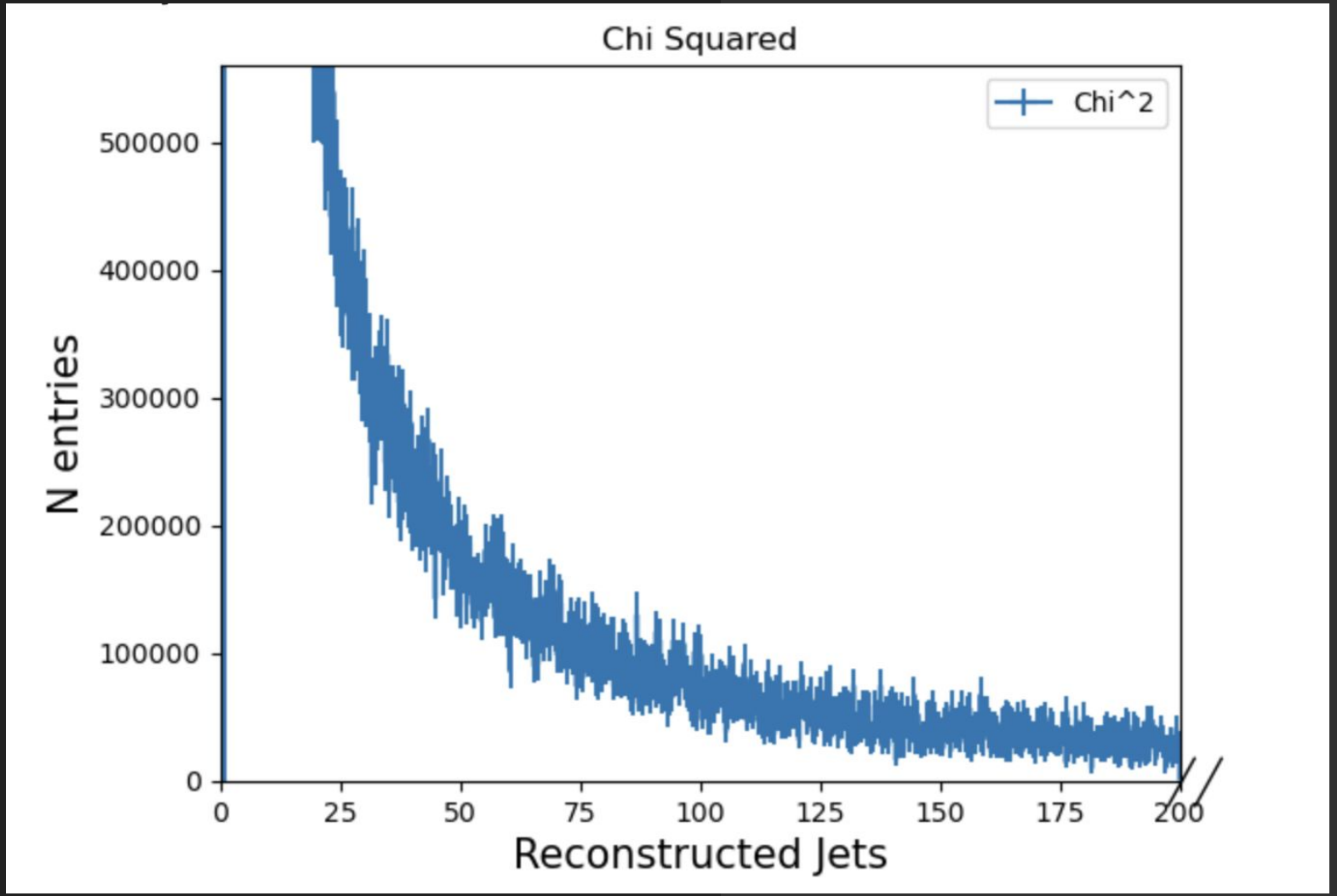

Dijet invariant Mass (shifted by ± 100MeV)
1e7
N entries
invariant mass (GeV)
Mean Norm: 81.19601
Peak: 80.20000
Mean +100MeV: 81.16984
Peak: 80.20000
Mean -100MeV: 81.10863
Peak: 79.80000
0.0
0.2
0.4
0.6
0.8
1.0
1.2
1.4
1.6
76
78
80
82
84


Chi Squared
Chi^2
500000
400000
300000
200000
100000
0
N entries
0
25
50
75
100
125
150
175
200
Reconstructed Jets

# Conclusions

- Lots of noise still remains. More filtering is still required
- Jet Clustering is not perfect
- W Mass still remains around 80.3 GeV

```
Events initial: 2215290658
Events final:   1037757339
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