# Measurement of Z boson’s Mass And Optimization of Isolation Thresholds for Muon Pairs

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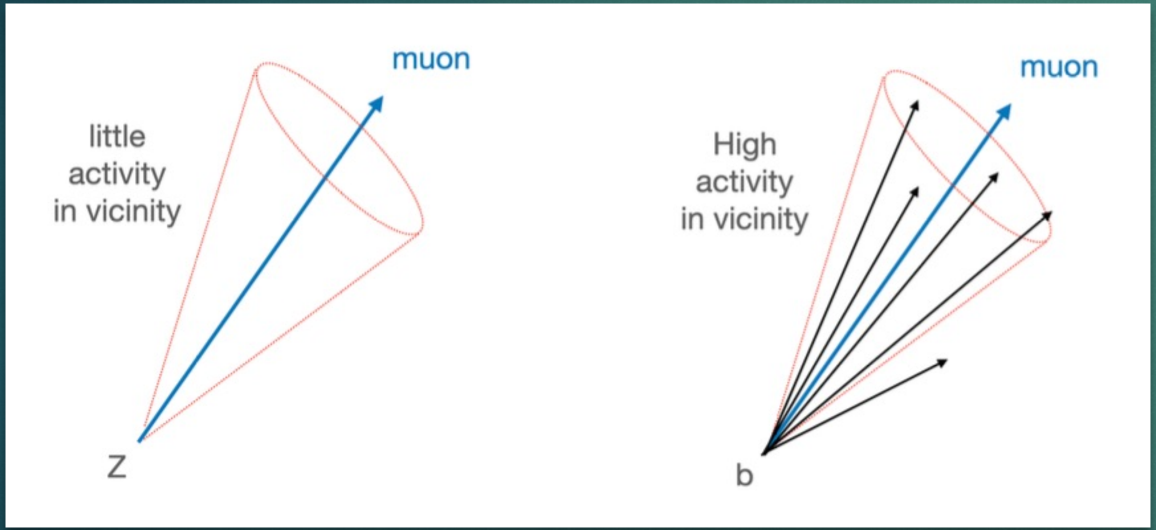
# What is the Z boson?

- Discovered in 1984 at the Large Hadron Collider
- Z boson mass: **M ≈ 91.1876±0.0021 GeV/c 2**
- Mass of nearly 100 times of a proton
- Only 10% of Z bosons decay into a lepton anti-lepton pair (Weinberg, 1993)

# Motivation & Goal

- Motivation: To test the **likelihood** of seeing a Z boson from a pair or muons to the **greatest precision** possible
- Goal:  to measure the mass and signal fraction of the Z boson and to optimize the **statistical uncertainty** of the signal fraction by searching for the threshold on the isolation that gives the smallest uncertainty.

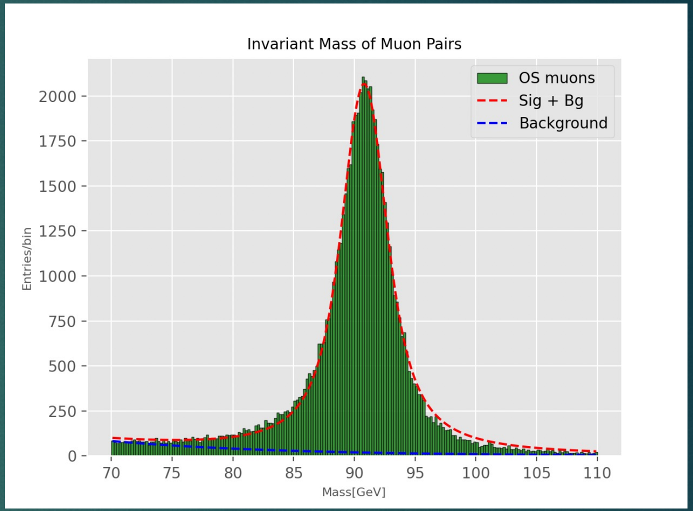
# Additional Information to Know




- $pp \rightarrow Z \rightarrow \mu^{+} \mu^{-}$
- Isolation to distinguish muons
- Constructing the mass
  - $M^2 = (E_1 + E_2)^2 - \| p \|^2$
  - $p$ is the 3-momentum vector

# Methods

- 1. Filter muon data to only muon pairs with the opposite charge
- 2. Calculate invariant mass & make histogram
- 3. Curve fit() from SciPy
- 4. Use F(x) = A[(1-s)fb(x) + s*fs] centered at x0
- 5. Obtain signal fraction and its uncertainty
- 6. Scan isolation thresholds to find minimum uncertainty



# Results

Isolation Threshold: **5.0**

Optimal Parameters:

A = 1.36784109e+04

s = **9.94234317e-01 ± 0.002156**

tau = 1.40290825e+01

X0 = 9.08103412e+01

Sigma = 9.08803422e-01

Alpha = 1.76746375e+00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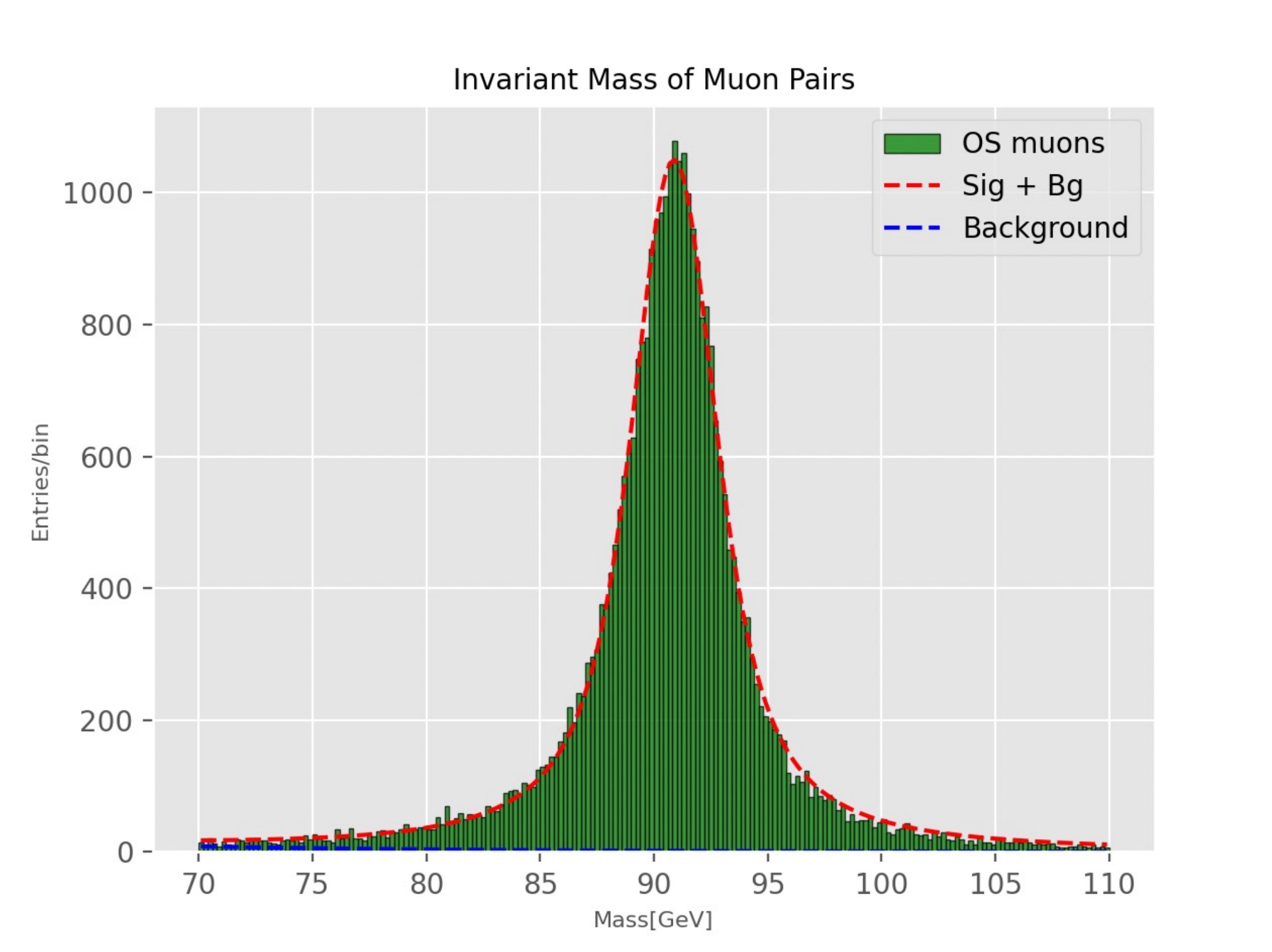
# Results After Optimization




Isolation Threshold: **<u>0.157</u>**

Optimal Parameters:

A = 6.96547340e+03

**s = 9.99046981e-01 $\pm$0.00182**

tau =1.24758570e+01

X0 = 9.08816207e+01

Sigma = 9.06484438e-01

Alpha = 1.77000598e+00

# Analysis/Implications of Results

- By decreasing the isolation, less b quark background are likely to be in the data.
- Higher signal fraction -> higher likelihood of finding a Z boson within the isolation range
- 15.5% decrease in uncertainty
- Including more data -> higher uncertainty -> more fake muons
- At isolation = 0.157, mass is 90.8816 $\pm$ 0.00994789GeV
- Better way to improve by varying threshold for each muon

# Conclusion

- Isolation Threshold = 0.157
- Within this range, probability of muons being from a Z boson is ~99%
- Signal fraction can tell us the likelihood of seeing a particle

# References


- Whiteson, D. (2022). *Physics 121W Advanced Laboratory*. ts, Irvine.
- Weinberg, S. (1993, January 1). *Dreams of a final theory : Weinberg, Steven, 1933- : Free download, Borrow, and streaming*. Internet Archive. https://archive.org/details/dreamsoffinalthe00wein

Thank you!!