Higgs to Strange

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$Z \to \mu\bar{\mu}$ Reconstruction

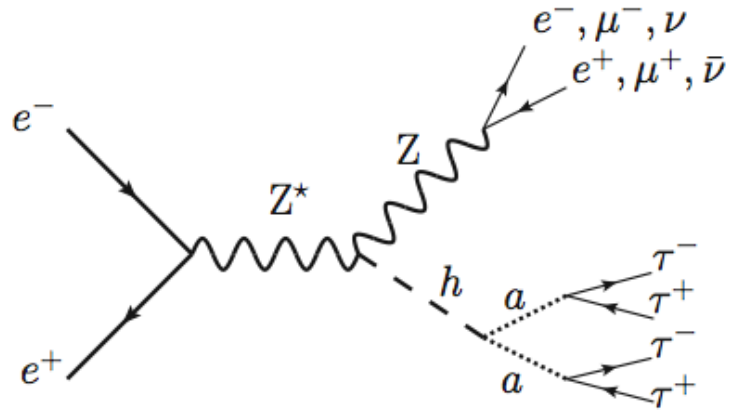

Figure: Feynman diagram for $H \to Z \to \mu\bar{\mu}$, amoung other channels [1].

Table: Cross section of the background from $H \to Z \to \mu\bar{\mu}$ at 250 GeV ILC Yan et al. [2].

$\sqrt{s} = 250$ GeV	σ		N_{Gen}	
polarization	left	right	left	right
$\mu^+\mu^-\mathrm{H}$	10.4 fb	7.03 fb	17.1k	11.0k

- $Z \to \mu\bar{\mu}$ is a considerable source of background for $H \to s\bar{s}$

$Z \to \mu\bar{\mu}$ Reconstruction

$\mu\bar{\mu}$ invariant mass sum: $m_{\mu\bar{\mu}} = \sqrt{(E_\mu + E_{\bar{\mu}})^2 - (p_\mu + p_{\bar{\mu}})^2}$

- In each event, we select the pair of final state particles reconstructed as muons such that their mass sum is closest to m_Z.
- We expect this method to yield an efficiency of about 80, given an expected efficiency of about 90 for both charged particle reconstruction and muon reconstruction.

$Z \to \mu\bar{\mu}$ Reconstruction

- Purity is calculated as the proportion of reconstructed Z muons that are matched to MC Z muons.
- The 2 PFO/2 MC is the proportion of events with two MC muon reconstructed as well as two from the PandoraPFO reconstruction.
- MC Efficiency is the proportion of events where a muon pair is reconstructed from MCParticle.
- This verifies that the algorithm to find the correct muon pair from MCParticle works.

Event Type	Purity	2 PFO/2 MC	MC Efficiency	nEvents
$s\bar{s}$	1.0	1.0	1.0	96500
$b\bar{b}$	0.998	1.0	1.0	95500
$c\bar{c}$	1.0	1.0	1.0	50000
gg	1.0	1.0	1.0	96500

$Z \to \mu\bar{\mu}$ Reconstruction: Efficiency

- The following is the efficiency as defined by the proportions of events with two reconstructed muons
- The right column is the proportion of MC Truth muons that get reconstructed by PandoraPFO.

Event Type	**Reco Efficiency**	**Optimal Efficiency**
$s\bar{s}$	0.589	0.816
$b\bar{b}$	0.588	0.816
$c\bar{c}$	0.582	0.814
gg	0.587	0.817

$Z \to \mu\bar{\mu}$ Reconstruction: Z Mass Validation

- For initial validation of our reconstruction, we checked the difference of m_Z as reconstructed from true muon pair and that of the PandoraPFOs algorithm.

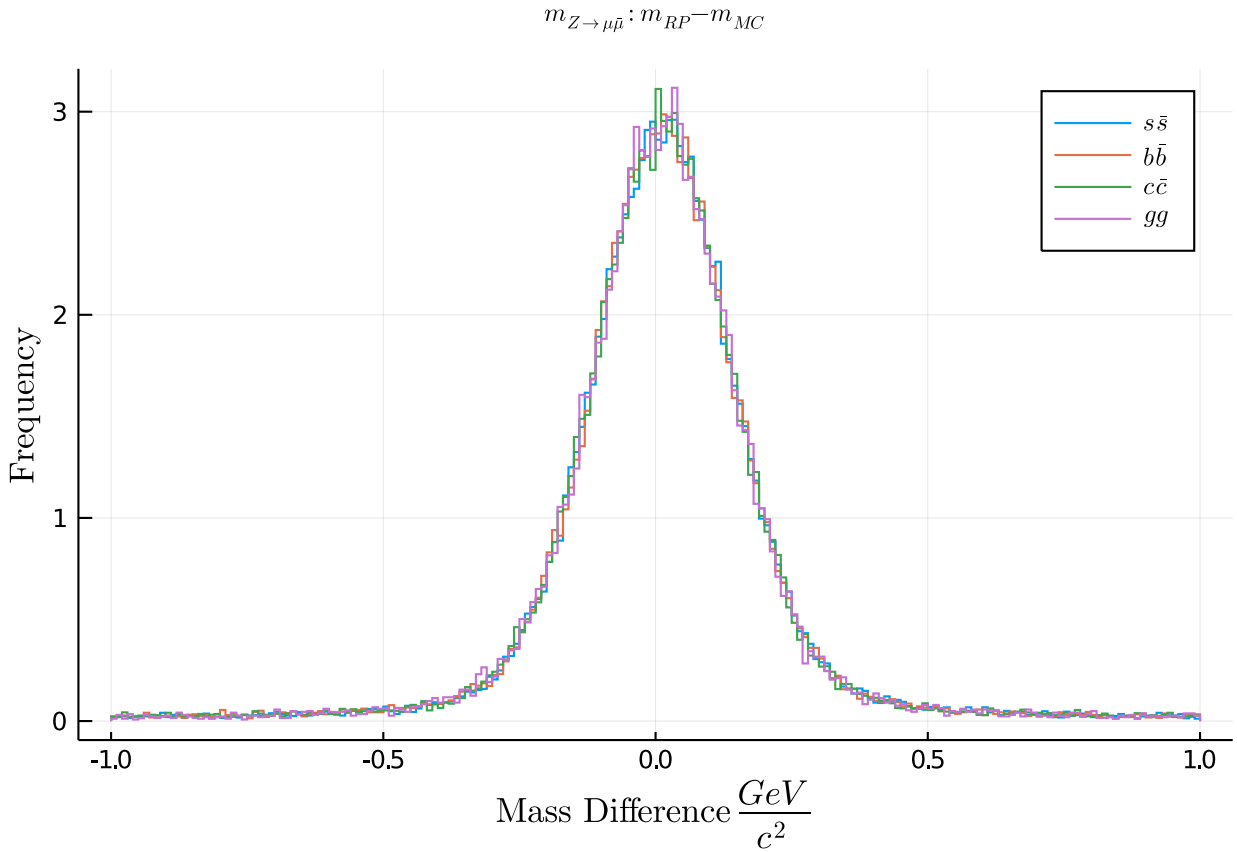

Figure: Difference in reconstructed m_Z between the true muon daughters and the reconstructed pair.

$Z \to \mu\bar{\mu}$ Reconstruction: Recoil Mass Validation

- $m_{recoil} = \sqrt{(E_0 - E_\mu - E_{\bar{\mu}})^2 - |\vec{p_0} - \vec{p_\mu} - \vec{p_{\bar{\mu}}}|^2}$, where E_0 and p_0 is the initial energy and momentum, respectively.
- As another check of the reconstructed, we considered the recoil mass of the selected muons. Based on these two plots, we expect the reconstruction to be effective.

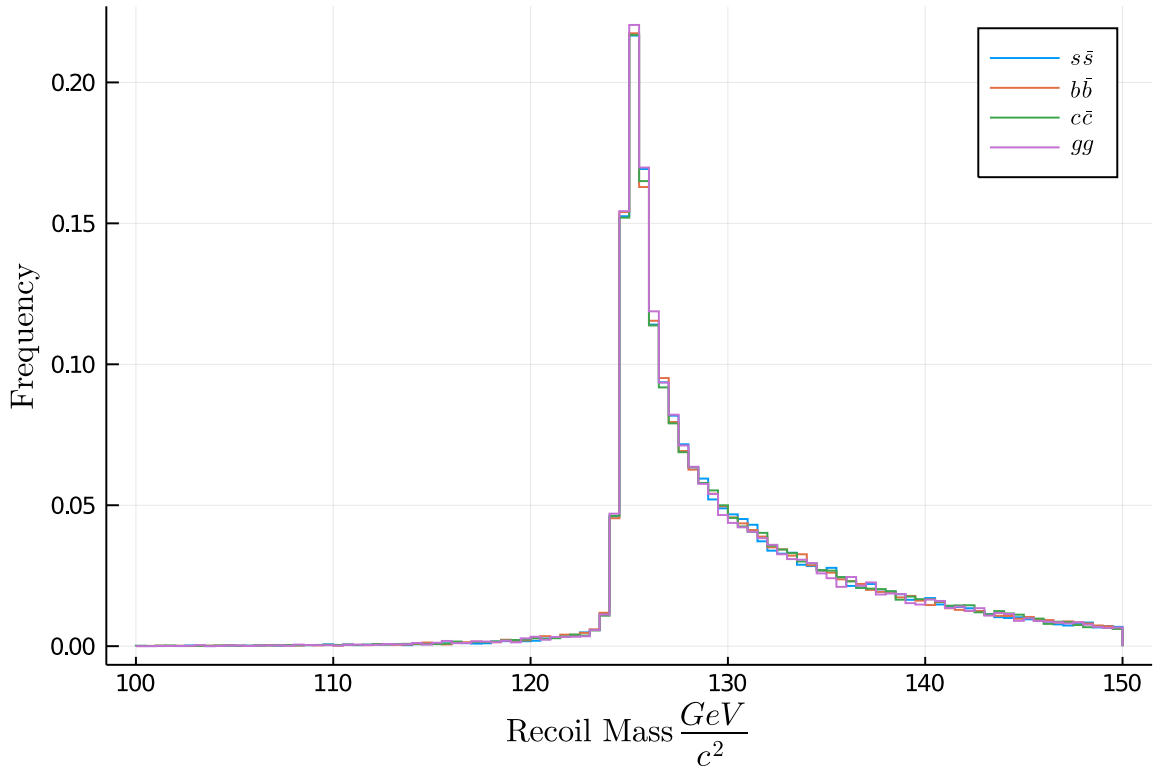

Figure: Recoil mass of reconstructed muon pair in considered samples

$Z \to \mu\bar{\mu}$ Reconstruction: Pion Misidentification

- Based on the validation from m_Z and m_{recoil}, we considered a PandoraPFO may be labelling some muons as pions. The following is the cut efficiency (e) where the algorithm could match to muons or pions.
- With the algorithm reconstructing two muons, we expect an total efficiency of about 64%
- Purity is still determined by comparing to just MCTruth muon.

Event Type	Pair e	Muon e	Expected e	Purity
$s\bar{s}$	0.64	0.800	0.816	0.978
$b\bar{b}$	0.632	0.795	0.816	0.992
$c\bar{c}$	0.626	0.791	0.814	0.995
gg	0.635	0.797	0.817	0.986

Lead Particle Analysis - Overview

- To filter out background from $H \to b\bar{b}, c\bar{c}$ and gg we considered the difference in jet properties between a signal sample and the three background samples.
- The earlier strange Hadron SH analysis does not include K_L. This considers K_L^0, K_S^0, K^+, and Λ. When K_L are included, all proportions increase, though the difference between the proportion for our signal and background samples is greater, thus should be concluded in the final analysis.

Event Type	SH in Event	SH in Jet
$s\bar{s}$	0.974	0.42
$b\bar{b}$	0.968	0.385
$c\bar{c}$	0.969	0.397
gg	0.953	0.336

Lead Particle Analysis - Strange Hadron Analysis

- The following are the proportions of events based on strange hadrons being found in an event, in one of two jets, or is the highest momentum particle in one or two jets.
- Assuming 100% efficiency for our SH reconstruction, the values on the this and the previous slide are are the efficiency for their respective cuts.

Event Type	**>0 SH is High $\|\vec{p}\|$**	**Both SH are High $\|\vec{p}\|$**
$s\bar{s}$	0.383	0.025
$b\bar{b}$	0.196	0.006
$c\bar{c}$	0.278	0.014
gg	0.156	0.004

Going Forward

- To integrate the various cuts made, we will create a multivariate classifier for $H \to s\bar{s}$ classification. This will further inform weather the cuts made thus far are effective.
- If this analysis is to be successfully conducted for the ILC, the bug that labels reconstructed muons as pions will need to be resolved.
- Furthering parameterizing the jet clustering, such as looking into shower shape, should give more discriminatory power between considered each sample.

References


ALEPH Collaboration et al. "Search for neutral Higgs bosons decaying into four taus at LEP2". In: (2010). DOI: 10.1007/JHEP05(2010)049. eprint: arXiv:1003.0705.


Jacqueline Yan et al. "Measurement of the Higgs boson mass and $e^+e^- \to ZH$ cross section using $Z \to \mu^+\mu^-$ and $Z \to e^+e^-$ at the ILC". In: *Phys. Rev. D* 94.11 (2016), p. 113002. DOI: 10.1103/PhysRevD.94.113002. arXiv: 1604.07524 [hep-ex].