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Z Background Formulae

Paper - HIG-13-030, PASs: HIG-13-013, HIG-13-018, HIG-13-028

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Definitions

Regions

- Control Region: Reco dimuon, with $60 < m_{\mu\mu}^{reco} < 120 GeV$ passing VBF selections
  - N_C^{MC} is measured in $Z \rightarrow \mu\mu + Jets$ MC with a generator level cut of $m_Z^{Gen} > 50 GeV$
- Signal Region: VBF selections and no veto leptons
  - We use the same $Z \rightarrow \mu\mu$ sample as for N_C^{MC} and ignore the leptons to approximate a $Z \rightarrow \nu\nu$ sample, this will be denoted N_S^{MC}
  - For the efficiencies to be the same for the $Z \rightarrow \mu\mu$ and $Z \rightarrow \nu\nu$ samples a generator level mass window of $60 < m_Z^{Gen} < 120$ must be applied, this will be denoted $N_S^{MC}[60, 120]$.

Derivation of formula

- Basic formula for data driven estimate

$$N_S^{\nu\nu\ Data} = \frac{N_C^{Data} - N_C^{BKG}}{N_C^{MC}} \cdot N_S^{\nu\nu\ MC}$$

- To use $Z \to \mu\mu$ MC we use the formula:

$$N_S^{\nu\nu\ MC} = N_S^{MC}[60,120] \cdot \underbrace{\frac{\sigma(Z \to \nu\nu)}{\sigma(Z/\gamma^* \to \mu\mu,\, 60 < m_Z^{Gen} < 120 GeV)}}_{R[60,120]}$$

- The cross-section ratio that we have calculated is:

$$R[50,\infty] = \frac{\sigma(Z \to \nu\nu)}{\sigma(Z/\gamma^* \to \mu\mu,\, m_Z^{Gen} > 50)}$$

- We therefore use:

$$R[60,120] = \frac{\sigma(Z/\gamma^* \to \mu\mu,\, m_Z^{Gen} > 50 GeV)}{\sigma(Z/\gamma^* \to \mu\mu,\, 60 < m_Z^{Gen} < 120 GeV)} \cdot R[50,\infty]$$

$$= \frac{N(Z/\gamma^* \to \mu\mu,\, m_Z^{Gen} > 50 GeV)}{N(Z/\gamma^* \to \mu\mu, 60 < m_Z^{Gen} < 120 GeV)} \cdot R[50,\infty]$$

Derivation of formula (2)

- Substituting our expression for $N_S^{\nu\nu\ MC}$ into the original formula gives:

$$N_S^{\nu\nu\ Data} = \frac{N_C^{Data} - N_C^{BKG}}{N_C^{MC}} \cdot N_S^{MC}[60,120] \cdot R[60,120]$$

$$= \frac{N_C^{Data} - N_C^{BKG}}{N_C^{MC}} \cdot N_S^{MC}[60,120] \cdot \frac{N(Z/\gamma^* \to \mu\mu, m_Z^{Gen} > 50GeV)}{N(Z/\gamma^* \to \mu\mu, 60 < m_Z^{Gen} < 120GeV)} \cdot R[50,\infty]$$

Formulae from paper

$$N_S^{Data} = (N_C^{Data} - N_C^{BKG}) \cdot R[50,\infty] \cdot \frac{\epsilon_S^{VBF}}{\epsilon_C^{VBF}\epsilon_{\mu\mu}}$$

- $\epsilon_{\mu\mu} = \frac{N(\mathrm{Z}/\gamma^*\rightarrow\mu\mu, \mathrm{reco\ dimuon}, 60<\mathrm{m}_{\mu\mu}^{\mathrm{reco}}<120\mathrm{GeV})}{N(Z/\gamma^*\rightarrow\mu\mu, m_Z^{Gen}>50GeV)}$
- $\epsilon_C^{VBF} = \frac{N_C^{MC}}{N(Z/\gamma^*\rightarrow\mu\mu, \mathrm{reco\ dimuon}, 60<\mathrm{m}_{\mu\mu}^{\mathrm{reco}}<120\mathrm{GeV})}$
- $\epsilon_S^{VBF} = \frac{N_S^{MC}[60,120]}{N(Z/\gamma^*\rightarrow\mu\mu, 60<m_Z^{Gen}<120GeV)}$
- n.b. efficiencies are not defined in the paper, so the differences in the denominator between $\epsilon_{\mu\mu}$ and ϵ_S^{VBF} are not apparent

Simplifications

- Numerator of $\epsilon_{\mu\mu}$ and denominator of ϵ_C^{VBF} cancel so they should not be included in the error calculation
  - Currently stat, lepton ID, JES, JER and UES uncertainties are considered on all terms
- $\epsilon_C^{VBF} \cdot \epsilon_{\mu\mu} = \frac{N_C^{MC}}{N(Z/\gamma^* \to \mu\mu, m_Z^{Gen} > 50 GeV)}$
- $\frac{\epsilon_S^{VBF}}{\epsilon_C^{VBF} \cdot \epsilon_{\mu\mu}} = \frac{N_S^{MC}[60,120]}{N_C^{MC}} \cdot \frac{N(Z/\gamma^* \to \mu\mu, m_Z^{Gen} > 50 GeV)}{N(Z/\gamma^* \to \mu\mu, 60 < m_Z^{Gen} < 120 GeV)}$

Final formula

$$N_S^{\nu\nu\ Data} = \frac{N_C^{Data} - N_C^{BKG}}{N_C^{MC}(Z^{Gen} \to \mu\mu)} \cdot N_S^{MC}[60, 120](Z^{Gen} \to \mu\mu)$$
$$x \frac{N(Z/\gamma^* \to \mu\mu, m_Z^{Gen} > 50 GeV)}{N(Z/\gamma^* \to \mu\mu, 60 < m_Z^{Gen} < 120 GeV)} \cdot R[50, \infty]$$

- This is the same as the formula derived above

Preliminary Results - No Systematics

Components

- N_C^{Data} : $12 \pm 3.4641(stat)$
- N_C^{Bkg} : $0.225755 \pm 0.118559(stat)$
- $N_S^{MC}[60, 120]$: $40.9211 \pm 1.86195(stat)$
- $N_C^{MC}(Z^{Gen} \rightarrow \mu\mu)$: $26.4646 \pm 1.46436(stat)$
- $N(Z/\gamma^* \rightarrow \mu\mu, m_Z^{Gen} > 50GeV)$: $3.3216e+07 \pm 5763.33(stat)$
- $N(Z/\gamma^* \rightarrow \mu\mu, 60 < m_Z^{Gen} < 120GeV)$: $3.1915e+07 \pm 5649.33(stat)$

Preliminary Result

- Analysis B - $98.4151 \pm 28.41(stat.) \pm 13.6326(MCstat.)$
- Analysis A - $103.452 \pm 30.4366(stat.) \pm 14.2746(MCstat.)$

What about QCD/EWK cross-section ratio difference

- For QCD the ratio of $\nu\nu$ and $\mu\mu$ cross-sections is 5.6
- For EWK Sasha has calculated that it is 1.6
- N_S^{MC} is made up of 23 QCD events and 18 EWK events
- To my mind this means that the background estimation decreases considerably as a result of the much lower ratio for 40% of the signal events

Method

$$N_S^{\nu\nu\ Data} = \frac{N_C^{Data} - N_C^{BKG}}{N_C^{MC}(Z^{Gen} \to \mu\mu)} \cdot N_S^{MC}[60,120](Z^{Gen} \to \mu\mu)$$

$$x \frac{N(Z/\gamma^* \to \mu\mu, m_Z^{Gen} > 50\,GeV)}{N(Z/\gamma^* \to \mu\mu, 60 < m_Z^{Gen} < 120\,GeV)} \cdot R[50,\infty]$$

- Separate everything after $\frac{N_C^{Data} - N_C^{BKG}}{N_C^{MC}}$ term into QCD and EWK and redo

Numbers

nCData	$12 \pm 3.4641(stat)$
nCBkg	$0.225755 \pm 0.118559(stat)$
nSMC QCD	$23.0621 \pm 1.80889(stat)$
nSMC EWK	$17.859 \pm 0.441336(stat)$
nSMC Total	$40.9211 \pm 1.86195(stat)$
nCMCQCD Total	$13.925 \pm 1.41699(stat)$
nCMCEWK Total	$12.5396 \pm 0.369427(stat)$
nCMC Total	$26.4646 \pm 1.46436(stat)$
nGen no mass window QCD	$3.12267e+07 \pm 5588.08(stat)$
nGen no mass window EWK	$1.98928e+06 \pm 1410.42(stat)$
nGen no mass window Total	$3.3216e+07 \pm 5763.33(stat)$
nGen Z mass window QCD	$3.01797e+07 \pm 5493.6(stat)$
nGen Z mass window EWK	$1.73525e+06 \pm 1317.29(stat)$
nGen Z mass window Total	$3.1915e+07 \pm 5649.33(stat)$

Results

N^S_{Total} Equal R	$98.4151 \pm 28.41(stat.) \pm 13.6326(MCstat.)$
N^S_{QCD}	$55.7898 \pm 16.1051(stat.) \pm 8.51048(MCstat.)$
N^S_{EWK}	$11.0895 \pm 3.20125(stat.) \pm 1.47655(MCstat.)$
N^S_{Total}	$66.8793 \pm 16.4202(stat.) \pm 8.63762(MCstat.)$

Conclusions

- Original method does seem consistent between analysis A and B
- Preliminary results for equal R from analysis B are compatible with analysis A at at least the same level as the W estimates
- How to resolve different R between EWK and QCD issue?

Backup