Z Background Formulae

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D. Colling, G. Davies P. Dunne, A.M. Magnan, A. Nikitenko and Joao Pela: Imperial with
R. Aggleton, J. Brooke: Bristol
C.Asawangtrakuldee, Q.Li: Peking
P. Srimanobhas: Chulalongkorn
S. Kumar, K. Mazumdar: Mumbai

Definitions

$$N_S(Z \to \nu\nu) = (N_C^{Data} - N_C^{Bkg}) \cdot$$
$$\frac{\sigma(Z \to \nu\nu, \mathrm{EWK}) \frac{\mathrm{N_S^{MC}(EWK)}}{\mathrm{N_{Gen}}(60 < \mathrm{m_Z^{Gen}} < 120\ \mathrm{GeV,EWK})} + \sigma(\mathrm{Z} \to \nu\nu, \mathrm{QCD}) \frac{\mathrm{N_S^{MC}(QCD)}}{\mathrm{N_{Gen}}(60 < \mathrm{m_Z^{Gen}} < 120\ \mathrm{GeV,QCD})}}{\sigma(Z/\gamma^* \to \mu\mu, \mathrm{EWK}) \frac{\mathrm{N_C^{MC}(EWK)}}{\mathrm{N_{Gen}(EWK)}} + \sigma(\mathrm{Z}/\gamma^* \to \mu\mu, \mathrm{QCD}) \frac{\mathrm{N_C^{MC}(QCD)}}{\mathrm{N_{Gen}(QCD)}}}$$

Regions

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

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

- 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:

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

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

Derivation of formula (2)

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

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

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

Formulae from paper

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

- $\epsilon_{\mu\mu} = \frac{N(\mathrm{Z}/\gamma^* \to \mu\mu, \mathrm{reco\,dimuon}, 60 < \mathrm{m}_{\mu\mu}^{\mathrm{reco}} < 120\mathrm{GeV})}{N(Z/\gamma^* \to \mu\mu, m_Z^{Gen} > 50\,GeV)}$
- $\epsilon_C^{VBF} = \frac{N_C^{MC}}{N(Z/\gamma^* \to \mu\mu, \mathrm{reco\,dimuon}, 60 < \mathrm{m}_{\mu\mu}^{\mathrm{reco}} < 120\mathrm{GeV})}$
- $\epsilon_S^{VBF} = \frac{N_S^{MC}[60{,}120]}{N(Z/\gamma^* \to \mu\mu, 60 < m_Z^{Gen} < 120\,GeV)}$
- 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 considerable as a result of the much lower ratio for 40% of the signal events

Conclusions

- Method does seem consistent
- Is there a reason not to calculate the cross-section ratio with the mass window?
  - It would remove the need for the additional event ratio.
- Preliminary results from analalysis B are compatible at at least the same level as the W estimates

Backup