Z Background Synchronisation

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Outline

- A synchronisation has been carried out between analysis A and B Z estimates
- A couple of bugs were found in the preliminary analysis B number
- Two main changes were made to the analysis A Z background estimate
  - Correction of efficiency definitions
  - Updates to EWK cross-sections
- The two analyses now produce consistent estimates of the Z background

Corrections to efficiency formulae from paper draft

$$N_S^{Data} = (N_C^{Data} - N_C^{BKG}) \cdot \frac{\sigma(Z \rightarrow \nu\nu)}{\sigma(Z/\gamma^* \rightarrow \mu\mu)} \cdot \frac{\epsilon_S^{VBF}}{\epsilon_C^{VBF}\epsilon_{\mu\mu}}$$

- For the number in the paper the following form was used for efficiencies:
  - $\epsilon = \frac{\sigma(QCD) \cdot N_{Sel}^{MC}(QCD) + \sigma(EWK) \cdot N_{Sel}^{MC}(EWK)}{N_{Gen}^{MC}(QCD) + N_{Gen}^{MC}(EWK)}$
- This is not quite right and has been corrected to:
  - $\epsilon = \frac{\sigma(QCD) \cdot \frac{N_{Sel}^{MC}(QCD)}{N_{Gen}^{MC}(QCD} + \sigma(EWK) \cdot \frac{N_{Sel}^{MC}(EWK)}{N_{Gen}^{MC}(EWK}}{\sigma(QCD) + \sigma(EWK)}$
- $\epsilon_C^{VBF} \cdot \epsilon_{\mu\mu}$ is also now calculated as one number, due to cancellations between the numbers used in each efficiency

Updates to EWK cross-sections

- In addition to the efficiency correction the EWK cross-sections have been updated
- For the paper we used LO EWK cross-sections
- Sasha has calculated NLO cross-sections:
  - $\sigma_{NLO}(Z/\gamma^* \rightarrow \mu\mu, EWK) = 304fb$, $\sigma_{LO}(Z/\gamma^* \rightarrow \mu\mu, EWK) = 288fb$
- Also for the paper $\frac{\sigma(Z \rightarrow \nu\nu)}{\sigma(Z/\gamma^* \rightarrow \mu\mu)}$ was taken to be the same for QCD and EWK
- Sasha has calculated that the cross-section ratio is very different for EWK:
  - Ratio(EWK)=1.480, Ratio(QCD)=5.616

Other differences between analyses A & B

- Analysis A use the inclusive DY+Jets sample with a cut of $Z_{pT}^{Gen} < 100$ GeV and the high Z pt DY+Jets sample
  - No events pass from the inclusive DY+Jets sample with the p_T cut
- Analysis B previously used the inclusive DY+Jets sample and the DY+1/2/3/4 Jets samples correctly weighted
  - Similarly to in the W estimate
- This was changed to using the 5 weighted p_T inclusive samples with a cut of $Z_{pT}^{Gen} < 100$ GeV and the high Z pt DY+Jets sample
- This changed the result by 9% for an MC stat error of 18%
  - There is very little overlap between the events used in the two estimates as few inclusive sample events pass the Z_{pT}^{Gen} cut

New Results

Analysis	Paper draft	$\sigma(Z/\gamma^* \rightarrow \mu\mu, EWK)$ & ϵ formula corrected	Ratio $\sigma(EWK)$ corrected
A	$104 \pm 30(stat.)$	$105 \pm 31(stat.)$	$92 \pm 27(stat.)$
B	N/A	$102 \pm 30(stat.)$	$88 \pm 25(stat.)$

- Efficiency formula and $\sigma(Z/\gamma^* \rightarrow \mu\mu, EWK)$ corrections go in opposite directions
  - Hence small change in middle column
- The two analyses are consistent
- There is a 12% decrease in the analysis A Z background estimate

Backup

Numbers

Number	Analysis B	Analysis A
nCData-nCBKG	$12 \pm 3(stat)$	12
nSMC QCD	$30 \pm 3(stat)$	32
nSMC EWK	$6.0 \pm 0.2(stat)$	6.0
nSMC Total	$36 \pm 3(stat)$	38
nCMCQCD Total	$20 \pm 3(stat)$	21
nCMCEWK Total	$4.2 \pm 0.2(stat)$	4.3
nCMC Total	$24 \pm 3(stat)$	25
nGen QCD	$2.3e + 07 \pm 7000(stat)$	2.3e+07
nGen EWK	$5800 \pm 6(stat)$	5800
nGen Total	$2.3e + 07 \pm 7000(stat)$	2.3e+07
nGenZMassFiltered QCD	$2.2e + 07 \pm 7000(stat)$	2.2e+07
nGenZMassFiltered EWK	$5000 \pm 6(stat)$	5000
nGenZMassFiltered Total	$2.2e + 07 \pm 7000(stat)$	2.2e+07

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

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

- $\epsilon_{\mu\mu} = \frac{N(\mathrm{Z}/\gamma^* \to \mu\mu, \mathrm{reco\,dimuon}, 60 < \mathrm{m}_{\mu\mu}^{\mathrm{reco}} < 120\mathrm{GeV})}{N(Z/\gamma^* \to \mu\mu, m_Z^{Gen} > 50 GeV)}$
- $\epsilon_C^{VBF} = \frac{N_C^{MC}}{N(Z/\gamma^* \to \mu\mu, \mathrm{reco\,dimuon}, 60 < \mathrm{m}_{\mu\mu}^{\mathrm{reco}} < 120\mathrm{GeV})}$
- $\epsilon_S^{VBF} = \frac{N_S^{MC}[60{,}120]}{N(Z/\gamma^* \to \mu\mu, 60 < m_Z^{Gen} < 120 GeV)}$
- 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