$Z/\gamma^\star$ cross section computation at NNLO

Cécile Deterre, Frédéric Déliot, Slava Shary

CEA Saclay

DØ France, May 4th, 2010

Introduction

- Two codes exist to compute the $Z/\gamma^\star$ cross section at NNLO: van Neerven and FEWZ (by Melnikov and Petriello).
- The aim is to normalize $Z \rightarrow ll$ MC samples with the NNLO cross section using the latest PDF sets and taking into account the m_{inv} dependence.
- Up to now, the code from van Neerven was used to compute k-factors at NNLO per range of invariant mass of the two dileptons, with PDF sets up to CTEQ6.1 (T. Nunnemann, DØ note 5268).
- We used the FEWZ code for the $Z/\gamma^\star$ cross section calculation at NNLO with the latest MSTW and CTEQ PDF sets.

The FEWZ code

- FEWZ includes Z leptonic decays and $\gamma^\star/Z$ interference.
- A previous version was adapted for the use at DØ (H. Schellman, M. Verzocchi). In the DØ notes 5582 and 5835, comparison to the van Neerven code with PDF sets up to CTEQ6.1 .
- We used the latest available version of the FEWZ code, checked that the results obtained were consistent with the previous ones, and modified it to implement the use of LHAPDF.

Comparison with the code from van Neerven

Code	Order	PDF	$\sigma(Z/\gamma^\star).Br(Z/\gamma^\star \to ll)$ (pb)
FEWZ	NLO	MRST 2004	241.47 ± 0.20
FEWZ	NNLO	MRST 2004	254.56 ± 1.23
van Neerven	NNLO	MRST 2004	256.6

Table 1: Comparison of cross sections computed on the [60,130] GeV invariant mass range with the FEWZ and the van Neerven codes, here with $\mu_R = \mu_F = M_Z$. Only statistical errors are presented.

Parameters

- Parameters used for the calculation presented in this talk
  - Dilepton invariant mass bins of:
    - ★ 1 GeV in the [15,76] GeV range;
    - ★ 2 GeV in [76,130];
    - ★ 5 GeV in [130,250];
    - ★ 50 GeV in [250,2000].
  - No cuts on lepton pseudorapidity and p_T.
  - Factorization and renormalization scales set to the central value of the studied range:
    $\mu_F = \mu_R = m_{inv}$ in $[m_{inv} - \delta m,\ m_{inv} + \delta m]$

- PDF sets: CTEQ66 (NLO) and MSTW2008 (NLO, NNLO) for the calculations.

Estimation of the uncertainties

Uncertainties come from several sources in the cross section computation:

- the statistical uncertainty coming from integration with the Monte-Carlo method;
- the PDF uncertainties coming from the choice of a PDF set;
- the choice of factorization and renormalization scales;
- the uncertainty on the strong coupling constant α_s.

Estimation of the uncertainties

- Statistical uncertainties:
  they can be reduced by increasing the number of iterations. We set the upper limit at 0.5%.

- PDF related uncertainty:
  - computed in the 4 different mass ranges [15,75], [75,130], [130,250] and [250,1960];
  - cross sections computed with the 41 PDF members of each PDF set: central value and 40 eigenvectors.

Estimation of the uncertainties

- Renormalization and factorization scale uncertainty:
  we vary $\mu_R = \mu_F$ between $0.5 m_{inv}$ and $2 m_{inv}$ in each range [15,75], [75,130], [130,250] and [250,1960].

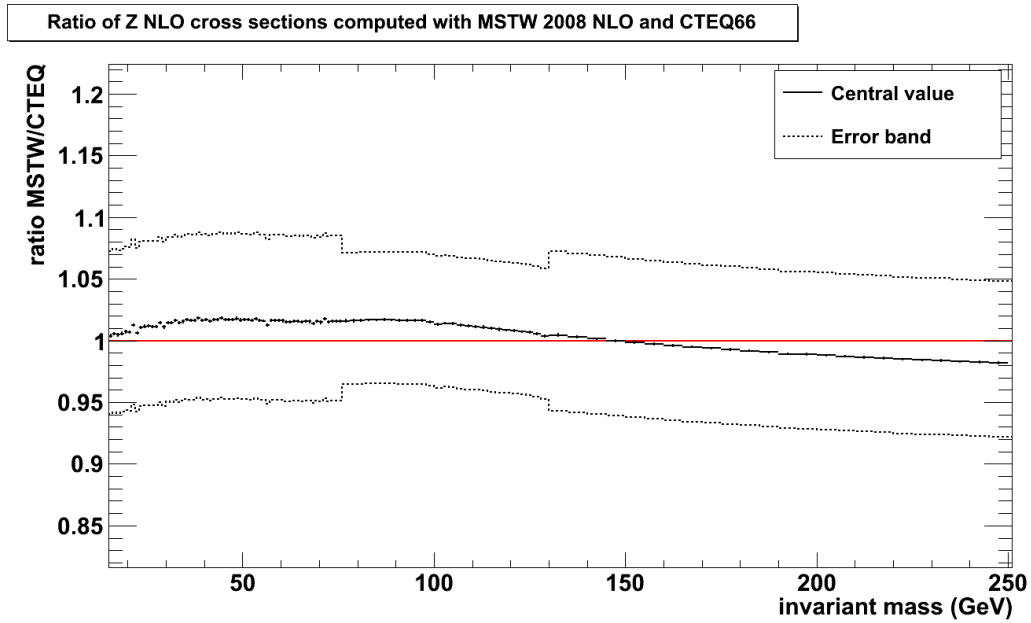
- Uncertainty on the strong coupling constant α_s:
  - CTEQ takes the PDG value: $\alpha_s(M_Z) = 0.118 \pm 0.002$;
  - MSTW takes its best-fit value: $\alpha_s(M_Z) = 0.1171 \pm 0.0014$,
    and provides a set of 22 PDF corresponding to variations of α_s around its central value.
    We use it to compute the influence of $\pm 1\sigma$ variations of α_s on the cross section.

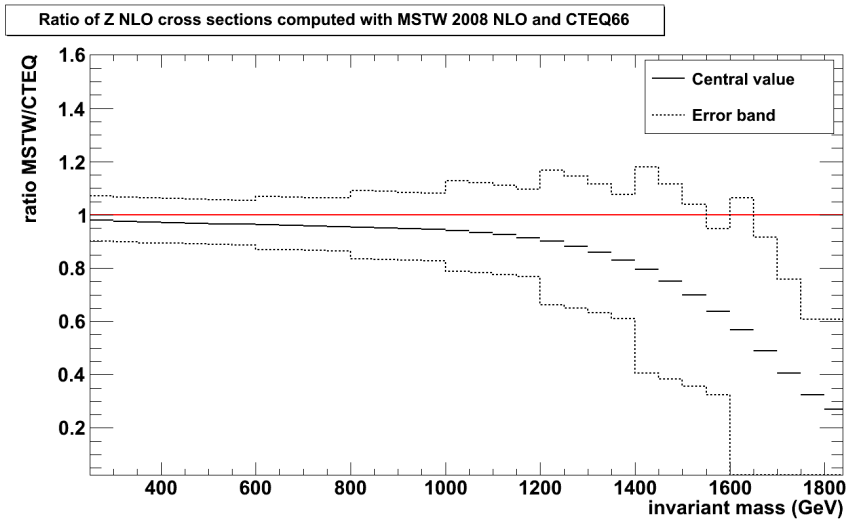
Estimation of the uncertainties: summary

Range (GeV)	Central value (pb)	stat	PDF	scale	α_S
15-75	507.50	$\pm$ 2.46	$^{+23.15}_{-18.15}$	$^{+4.02}_{-3.98}$	$^{+7.32}_{-5.47}$
75-130	242.04	$\pm$ 1.14	$^{+8.27}_{-9.89}$	$^{+0.93}_{-1.33}$	$^{+1.36}_{-1.40}$
130-250	1.8008	$\pm$ 0.0079	$^{+0.1057}_{-0.0592}$	$^{+0.0131}_{-0.0045}$	$^{+0.0108}_{-7.0.10^{-4}}$
250-1960	0.14959	$\pm$ 6.9.10^{-4}	$^{+7.31.10^{-3}}_{-10.41.10^{-3}}$	$^{+1.93.10^{-3}}_{-3.46.10^{-3}}$	$^{+0}_{-1.28.10^{-3}}$

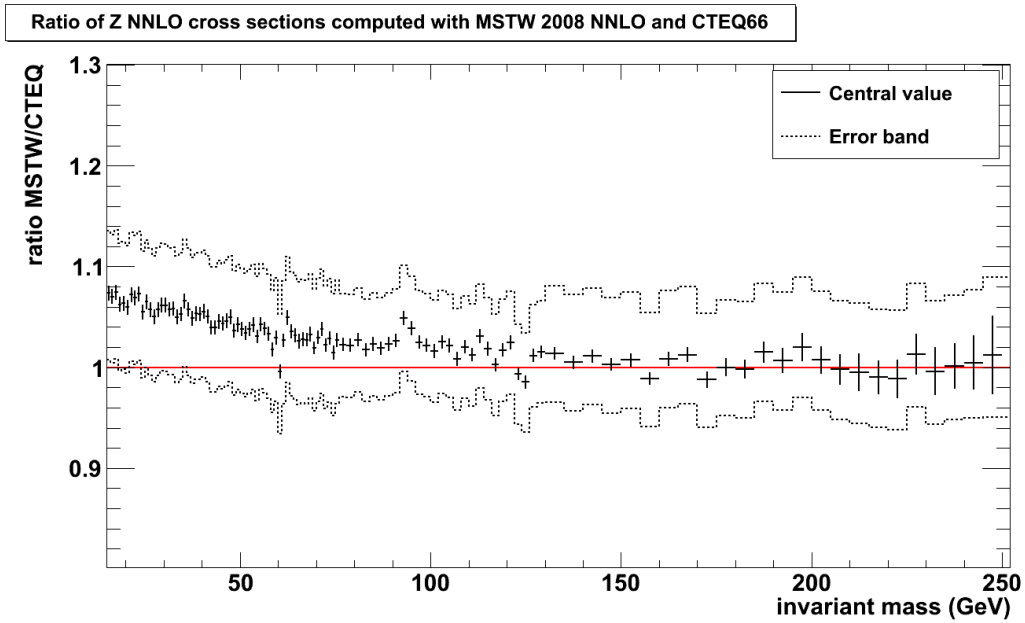
Table 2: $Z/\gamma^\star$ cross sections at NNLO computed with FEWZ using MSTW 2008 NNLO (in pb).

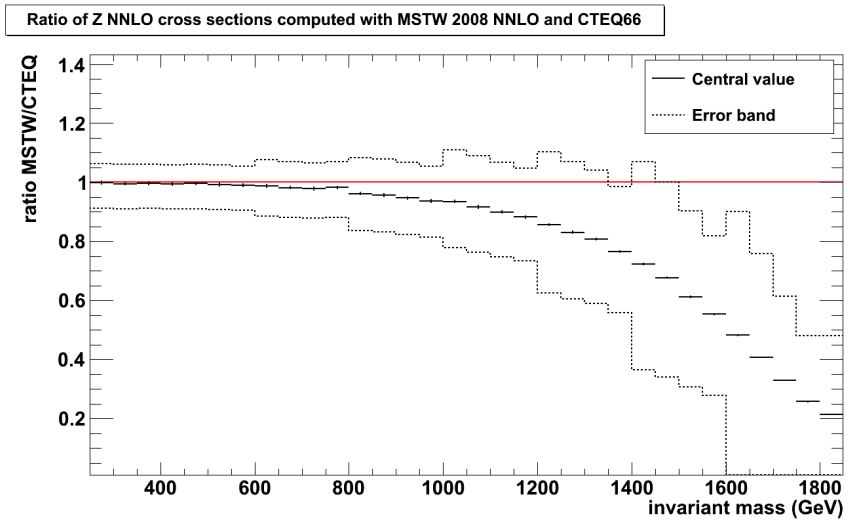
Comparison of CTEQ66(NLO) and MSTW2008(NLO) at NLO





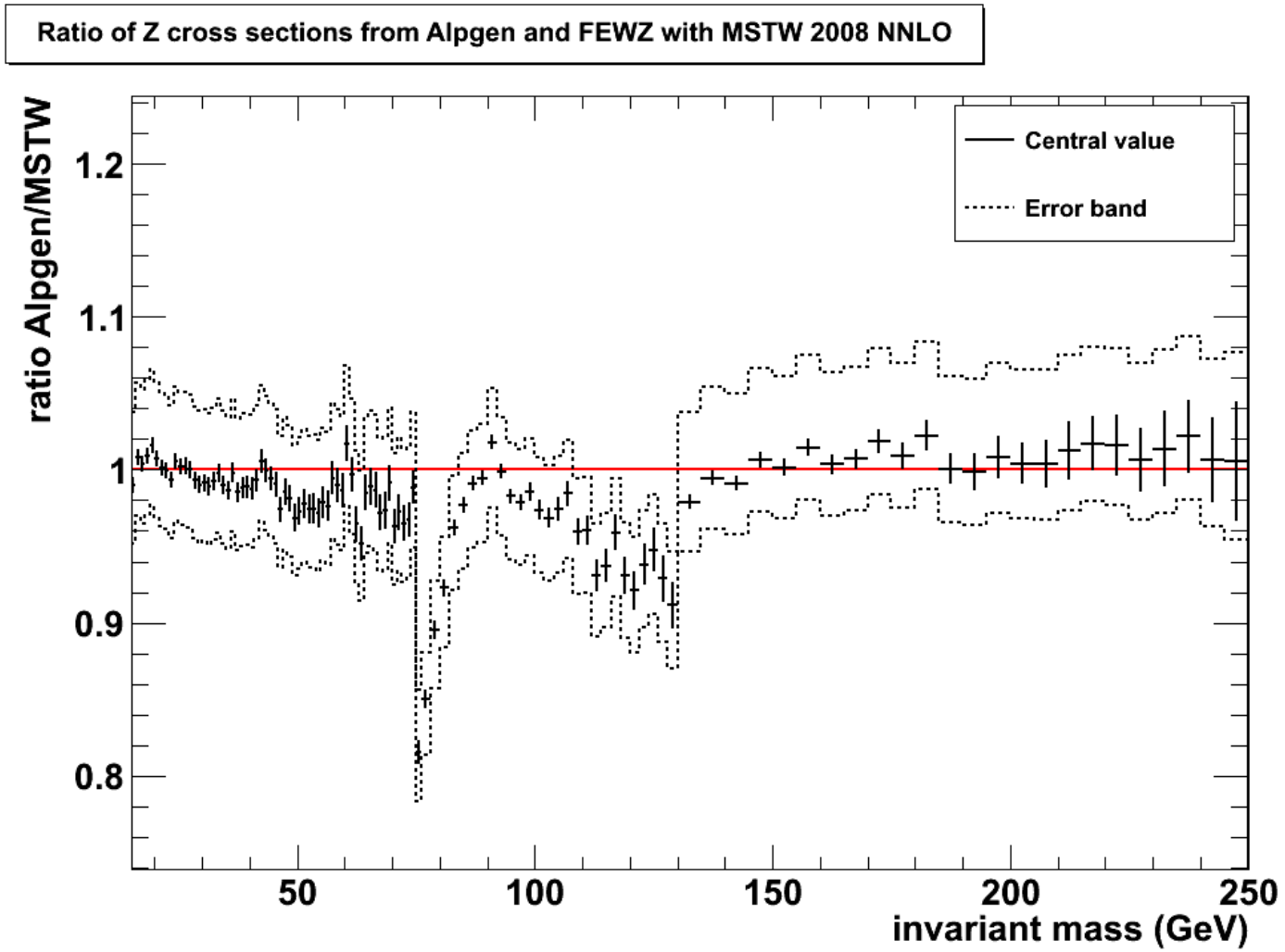
Comparison of CTEQ66(NLO) and MSTW2008(NNLO) at NNLO



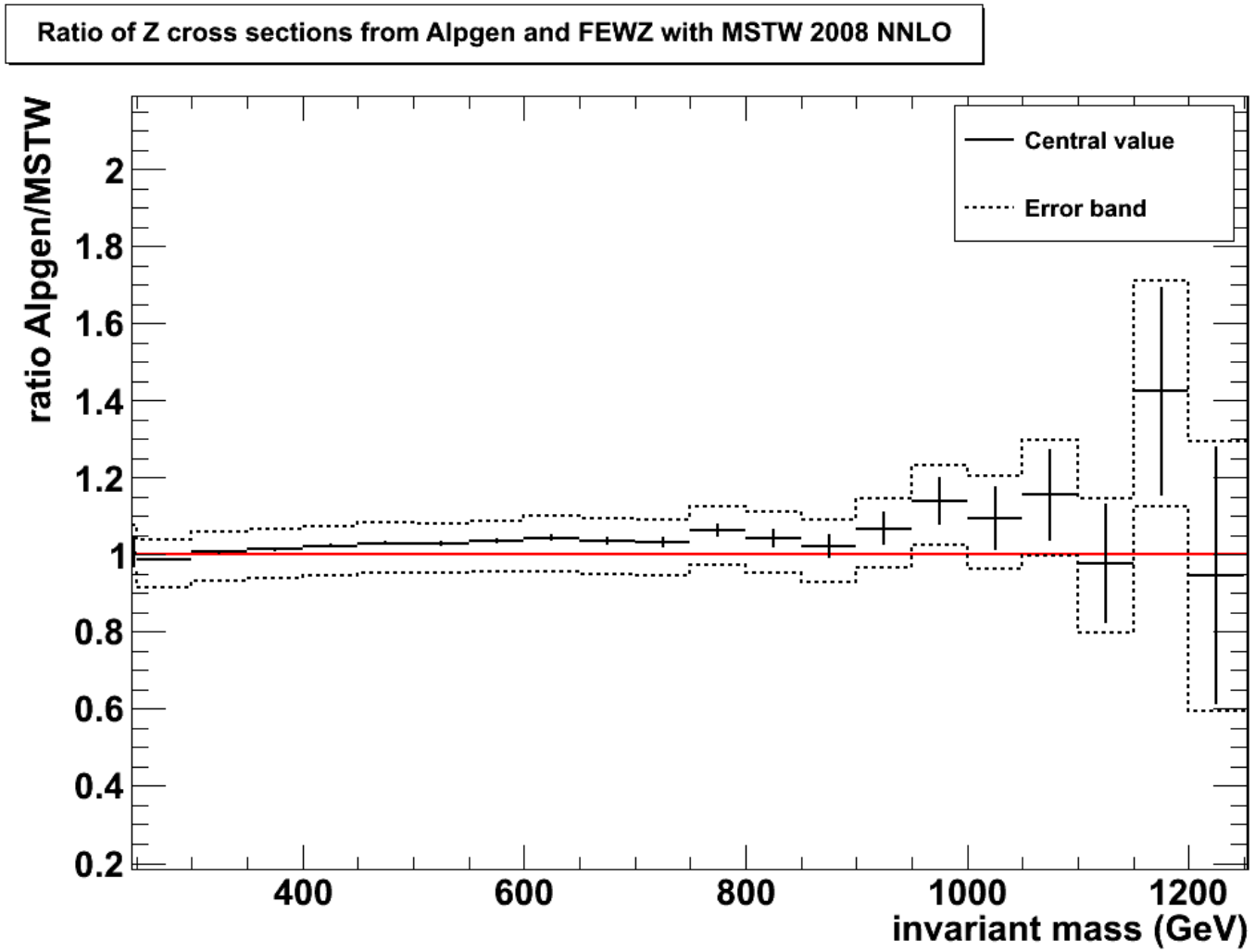


Comparison of Alpgen and MSTW (generated level)

Alpgen spectrum normalized to MSTW2008 NNLO cross section in each range ([15,75], [75,130], [130,250], [250,1960]).

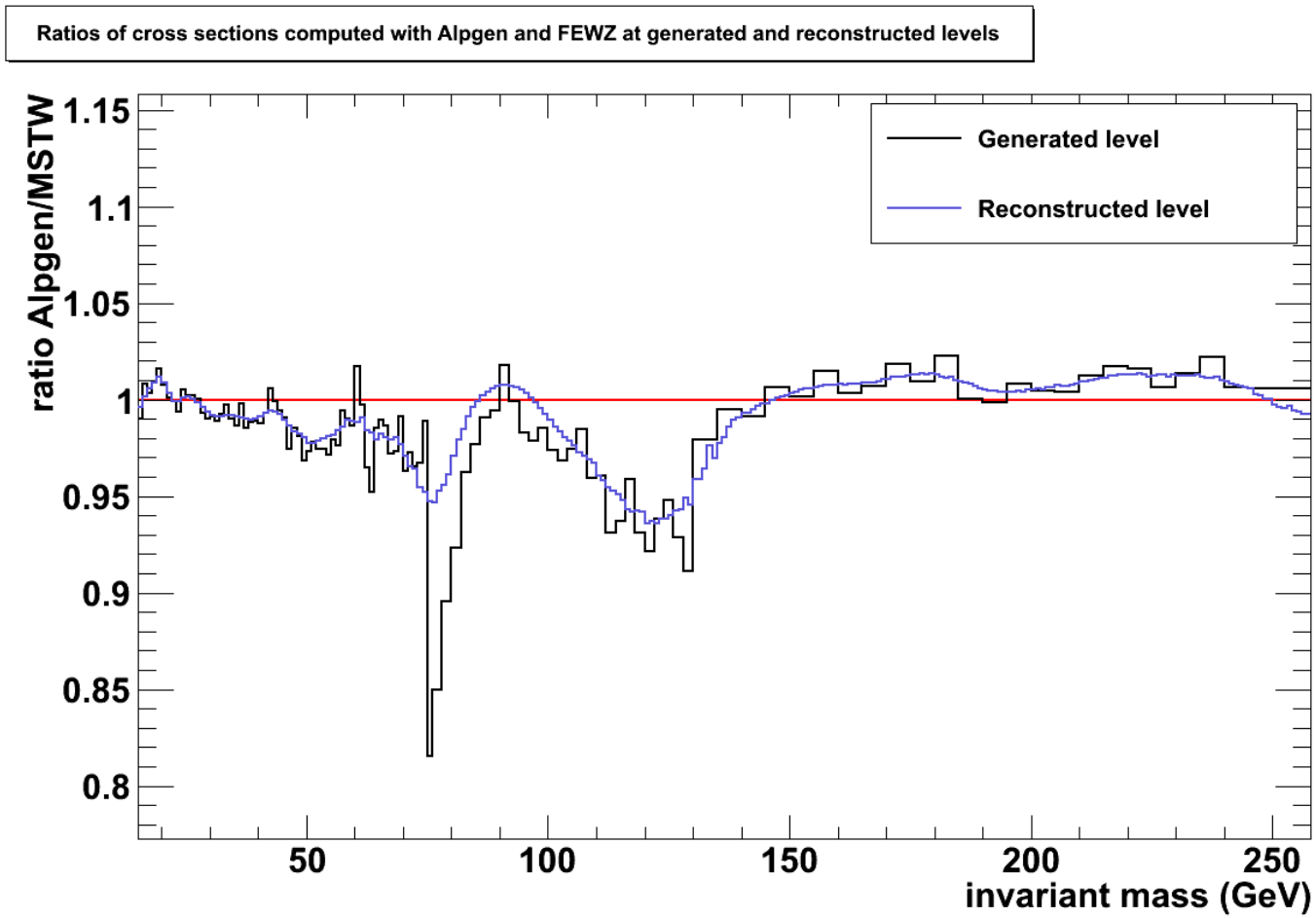


Comparison of Alpgen and MSTW (generated level)



Comparison at generated and reconstructed level

Processor ZXsecReWeighting: bin by bin normalization of the cross section (applied after the normalization per large range of invariant mass).



Conclusion

- New values implemented in *caf_mc_util* (see Table 3).
- Processor soon available for a bin by bin normalization of Z Monte-Carlo samples.
- More details: DØ Note 6050.

Range (GeV)	NNLO $\sigma(Z/\gamma^{\star}).Br(Z \rightarrow ll) \pm$ stat $\pm$ syst (pb)	current values
15-75	$507.50 \pm 2.48\ ^{+24.61}_{-19.37}$	498.13
75-130	$242.04 \pm 1.14\ ^{+8.43}_{-10.08}$	238.41
130-250	$1.8008 \pm 0.0079\ ^{+0.1070}_{-0.0594}$	1.833
250-1960	$0.14959 \pm 6.9.10^{-4}\ ^{+7.56.10^{-3}}_{-11.04.10^{-3}}$	0.154

Table 3: $Z/\gamma^{\star}$ cross sections at NNLO obtained computed with FEWZ using MSTW 2008 NNLO.