ZZ estimate from Zγ

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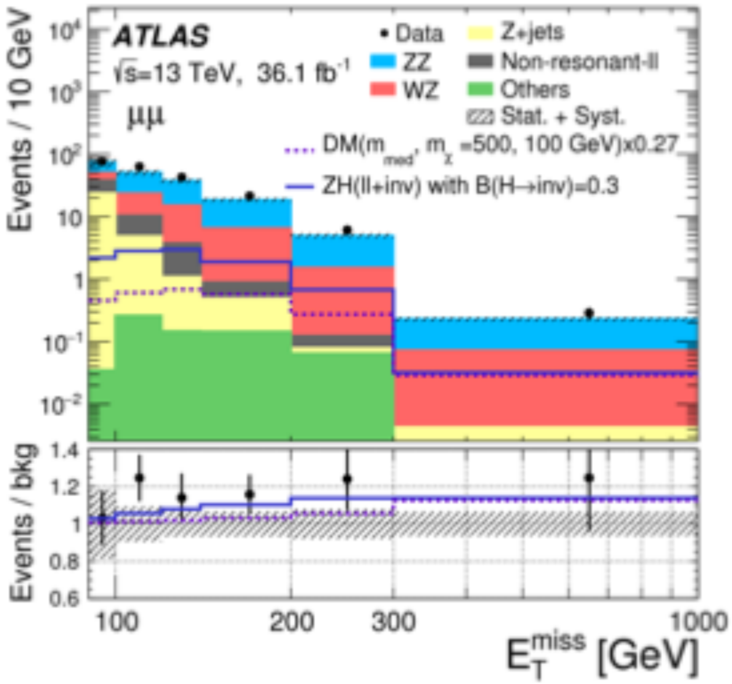
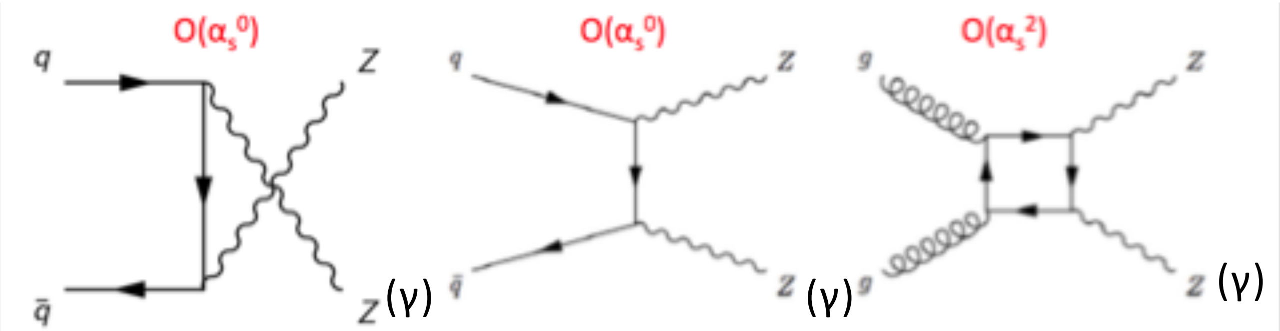
Introduction

- ZZ is the biggest background in the Z+Dark Matter search
  - Currently estimated from MC
  - Large (~10%) uncertainty
  - Also question: are all uncertainties included?
- Idea (similar to γ+jets for Z(vv) + jets):
  - Use Z(ll)+γ events in data to estimate Z(ll)+Z(vv) background
  - Same (ISR) diagrams (including gg)
    - => for pt(γ) >> MZ, kinematics γ and Z(vv) similar
    - => advantage compared to ZZ estimate from WZ
  - higher number of events expected in Zγ
  - aim for **<5%** uncertainty





Strategy

1) Select Zγ sample in data (Z cuts, photon cuts, including p_T)
2) Drop photon, reconstruct MET in event
3) Correct for photon efficiency/acceptance
   - Need photon truth-reco map, also for applying the next step
4) Reweight ZZ and Zγ MC with k-factor derived from ratio between MATRIX and NLO MC as a function of boson p_T

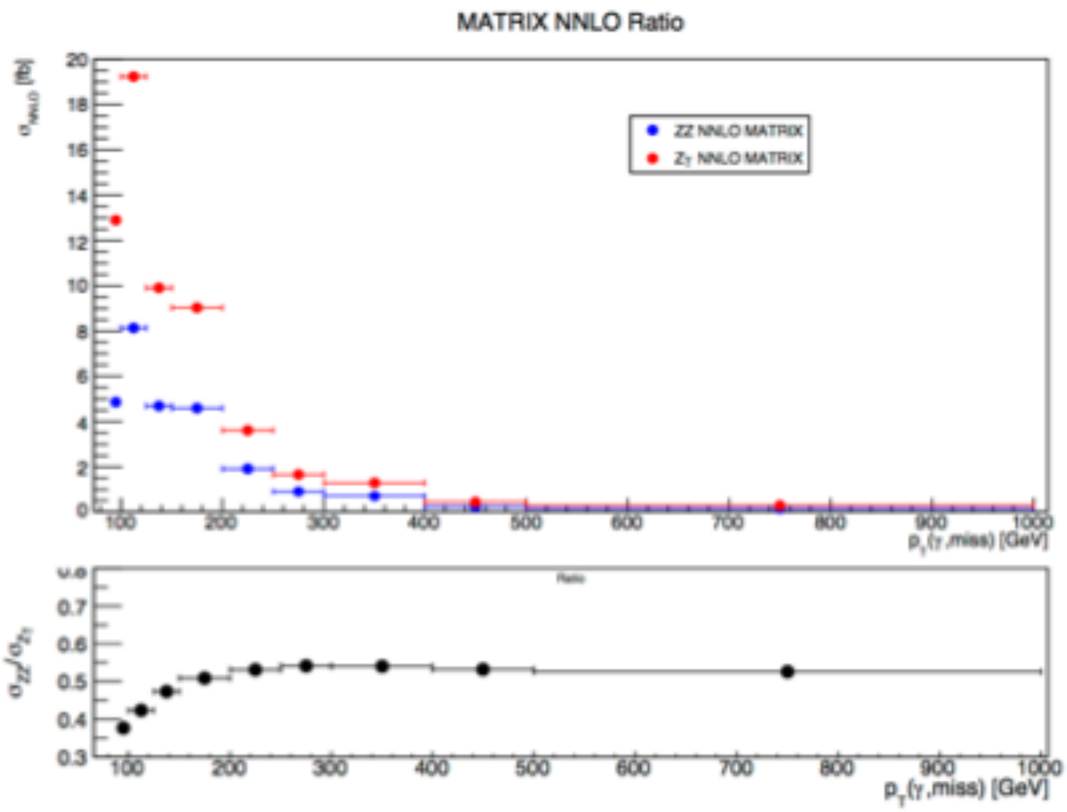
$$\frac{\mathrm{d}}{\mathrm{d}x}\frac{\mathrm{d}}{\mathrm{d}\mathbf{y}}\sigma^{(V)}(\varepsilon_{\mathrm{MC}},\varepsilon_{\mathrm{TH}}) = \frac{\mathrm{d}}{\mathrm{d}x}\frac{\mathrm{d}}{\mathrm{d}\mathbf{y}}\sigma^{(V)}_{\mathrm{MC}}(\varepsilon_{\mathrm{MC}})\left[\frac{\frac{\mathrm{d}}{\mathrm{d}x}\sigma^{(V)}_{\mathrm{TH}}(\varepsilon_{\mathrm{TH}})}{\frac{\mathrm{d}}{\mathrm{d}x}\sigma^{(V)}_{\mathrm{MC}}(\varepsilon_{\mathrm{MC}})}\right]$$

FOCUS TODAY

5) Apply remaining analysis cuts

NNLO baseline calculation

- Calculate the two processes and their ratio to NNLO using MATRIX
  - many uncertainties will drop out



Applied cuts

76 GeV $< M_{Z\rightarrow\ell\ell} <$ 106 GeV
$p_T(\ell_1) >$ 30 GeV, $p_T(\ell_2) >$ 20 GeV
$|\eta(\ell)| < 2.5$, $\Delta R(\ell,\gamma) > 0.4$,
$p_T(\gamma) >$ 60 GeV, $|\eta(\gamma)| < 2.5$

Dynamic scale

$\sqrt{M_Z^2 + pT(\ell\ell)^2} + \sqrt{M_Z^2 + pT(\nu\nu)^2}$
$M_Z^2 + p_T(\gamma)^2$

Uncertainty summary

- Total theoretical uncertainty:

$$\sigma_{total} = \sqrt{\sigma_{QCD}^2 + \sigma_{EWK}^2 + \sigma_{PDF}^2 + \sigma_{iso}^2}$$

  - σ_{QCD} is uncertainty due to missing higher order QCD corrections, estimated with k-factor method (next slide)
  - σ_{EWK} is uncertainty due to missing higher order EWK corrections, nothing in place yet
  - σ_{PDF} is the PDF uncertainty following the PDF4LHC prescription
  - σ_{iso} is the uncertainty due to the isolation definition applied to the photons, first attempt on slide 9

Missing higher-order QCD corrections

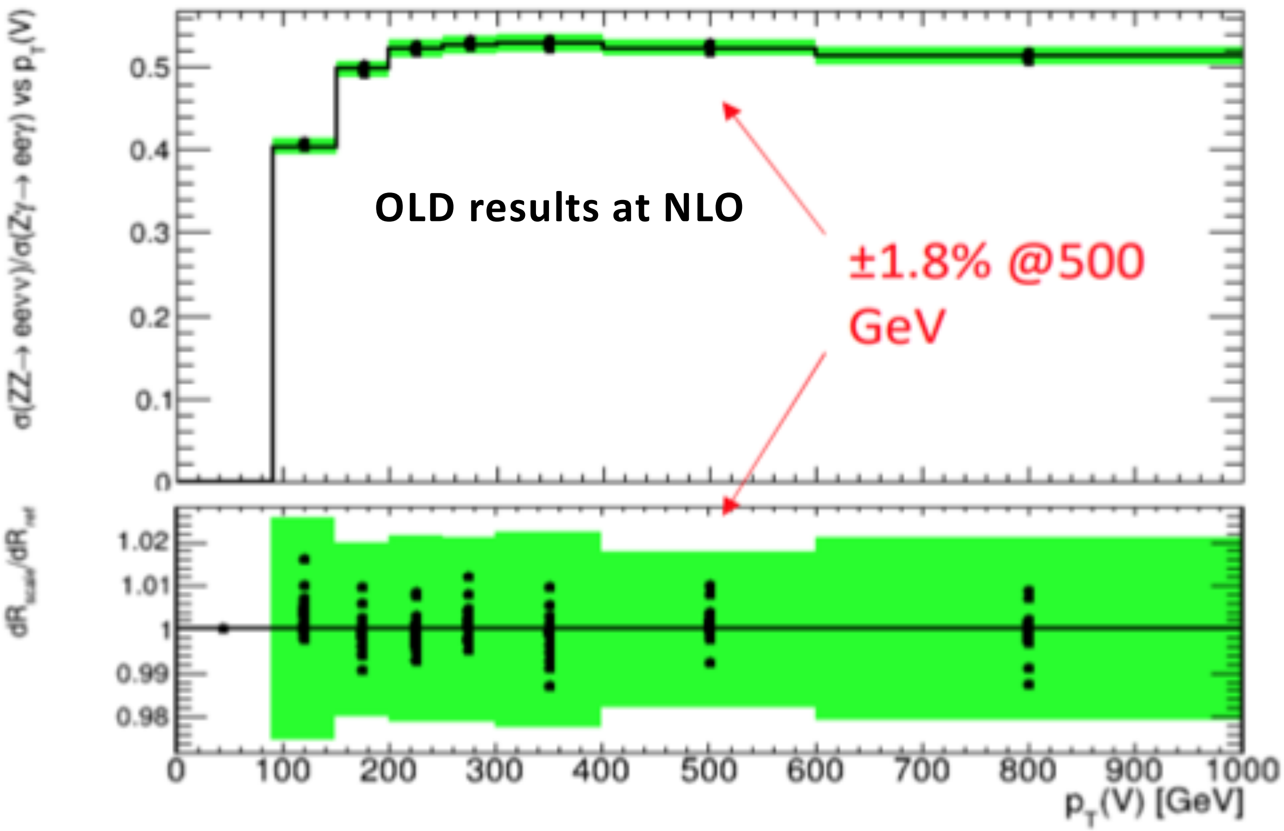
- No scale uncertainties since badly defined
- At high p_T, we expect the uncertainties to partially cancel in the ratio due to the similar production mechanisms
- Estimate uncertainties by using difference in k-factors for NLO to NNLO.
- Assumption: $\left(\frac{\sigma_{NNLO}(Z\gamma)}{\sigma_{NLO}(Z\gamma)} - \frac{\sigma_{NNLO}(ZZ)}{\sigma_{NLO}(ZZ)}\right) < \left(\frac{\sigma_{N^{\infty}LO}(Z\gamma)}{\sigma_{NNLO}(Z\gamma)} - \frac{\sigma_{N^{\infty}LO}(ZZ)}{\sigma_{NNLO}(ZZ)}\right)$
- Problems:
  1. isolation needed for γ and not for Z, introducing differences between both processes
  2. Gluon fusion process not calculated at higher order for ZZ (for $Z\gamma$ it exists inclusively) and much larger for ZZ than $Z\gamma$

Missing higher-order EWK corrections

- Similar procedure with electroweak corrections
  - Input from Stefan since there is no tool available

PDF uncertainties

- Use PDF4LHC_15_NNLO_30_as to calculate the PDF uncertainties using the standard recipe



Isolation uncertainties

- At truth level: use isolation to reject photons from hadronization/fragmentation
- Different possibilities for isolation:
  - Parton-level: sum pT of objects in a cone around photon < X, ~ ATLAS iso
  - Frixione: sum pT in cones of varying sizes < X(r) => removes fragmentation

$$\sum_{i=\text{hadrons(partons)}} p_{T,i}\, \Theta(\delta - \delta_{i\gamma}) \leq E_T^{\max}(\delta) = E_T^{\text{ref}} \left(\frac{1-\cos\delta}{1-\cos\delta_0} \right)^n \qquad \forall\, \delta \leq \delta_0$$

  - Dynamic isolation: to reduce the differences between Z and γ:

$$\delta_0 \longrightarrow R_{\text{dyn}}(p_{\text{T},\gamma}, \varepsilon_0) = \frac{M_Z}{p_{\text{T},\gamma}\sqrt{\varepsilon_0}}$$

- Varying the isolation parameters alone might not be sufficient
  - Trying to mimic parton isolation effect with Frixione isolation
    - No success so far
  - Otherwise direct comparison of parton-level isolation and Frixione isolation with MCFM or Sherpa

Jordi's talk