UNIVERSIDAD DE OVIEDO

WZ SM measurements and EWK SUSY searches

3rd Red LHC Workshop

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Why measure WZ?

⇢ Dominant process at the **3-lepton final state**.

⇢ Key process for our understanding of the SM:

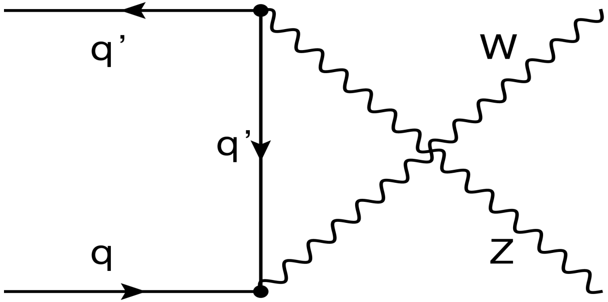
⇢ Charged final state: charge asymmetry is induced in the final state by the (ūd- ud̄) pdf imbalance.

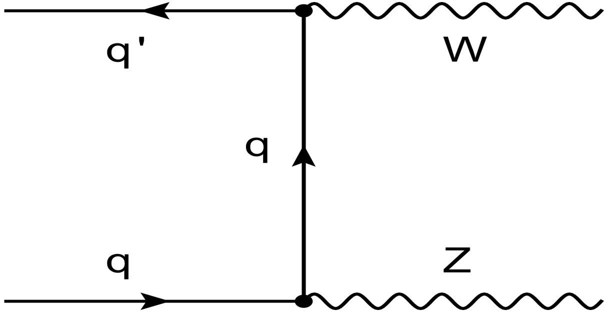
⇢ “Clean” final state: achieving very high (~85%) selection purities. Easier to check any SM deviation differentially (pointing to higher order corrections or BSM presence).

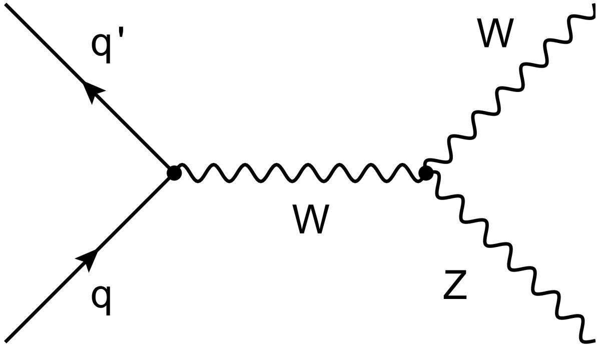
⇢ And also for BSM searches:

⇢ As a signal: unique sensitivity to variations in the **WWZ** vertex coupling.

⇢ As a background: principal SM background in the 3-lepton final state. Different BSM models predict final states with very similar behavior (typically WZ+p_T^{miss}).







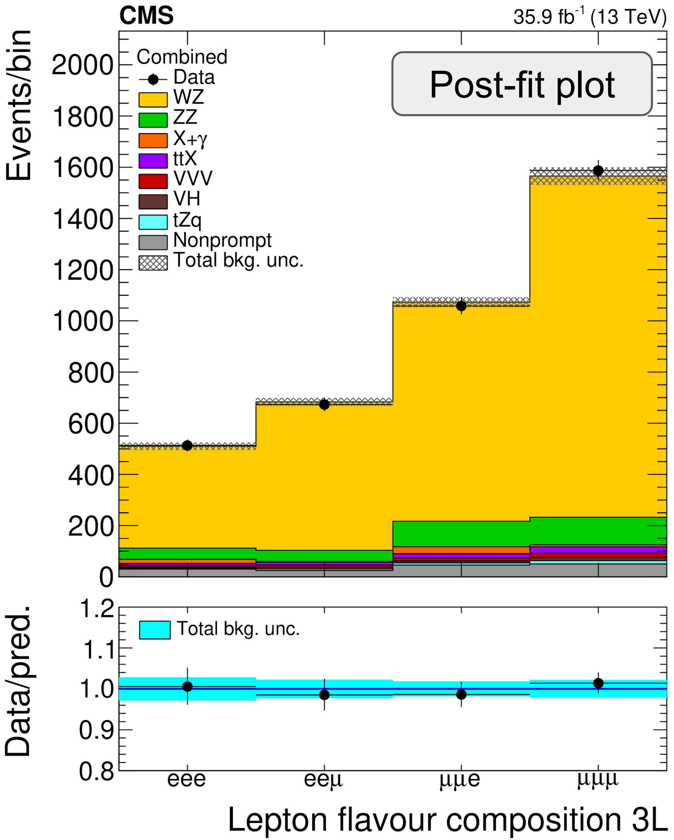
WZ Inclusive cross-section

10.1007/JHEP04(2019)122

- Cross-section measured in the 3 lepton final state:
  - Use MVA-based lepton ID to reduce non-prompt contribution.
  - p_T^{miss} > 30 GeV (to decrease DY contamination).
  - $N_{B\text{-}tag}$ = 0 (to decrease tt and ttX contamination).
  - Final selection is extremely pure (~90% WZ).

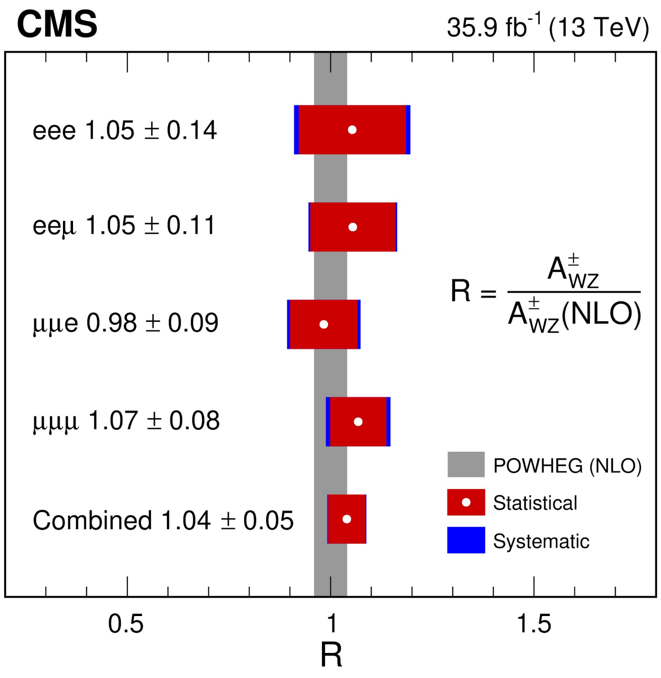
Category	$\sigma_{tot}(pp \to WZ)$ [pb]
eee	$47.11^{+5.01}_{-4.63}\,(\text{total}) = 47.11^{+2.88}_{-2.79}\,(\text{stat})^{+0.46}_{-0.41}\,(\text{theo})^{+3.89}_{-3.47}\,(\text{syst}) \pm 1.41\,(\text{lumi})$
eeμ	$47.16^{+3.87}_{-3.61}\,(\text{total}) = 47.16^{+2.31}_{-2.29}\,(\text{stat})^{+0.45}_{-0.38}\,(\text{theo})^{+2.83}_{-2.52}\,(\text{syst}) \pm 1.33\,(\text{lumi})$
e$\mu\mu$	$47.70^{+3.58}_{-3.55}\,(\text{total}) = 47.70^{+2.00}_{-1.96}\,(\text{stat})^{+0.45}_{-0.39}\,(\text{theo})^{+2.66}_{-2.61}\,(\text{syst}) \pm 1.42\,(\text{lumi})$
$\mu\mu\mu$	$49.00^{+3.18}_{-3.03}\,(\text{total}) = 49.00^{+1.57}_{-1.53}\,(\text{stat})^{+0.41}_{-0.35}\,(\text{theo})^{+2.42}_{-2.22}\,(\text{syst}) \pm 1.39\,(\text{lumi})$

- Biggest uncertainties arise from lepton and b-tag efficiencies (~2-3%).
- Measurement is closer to MATRIX $\boldsymbol{\sigma_{NNLO}}$ **= 49.9±2.5 pb** than POWHEG $\boldsymbol{\sigma_{NLO}}$**= 42.5±1.7 pb** predictions.



Grazzini *et al*, Eur. Phys. J. C 78 (2018) 537

Charge asymmetry measurements



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⇢ All flavor channels are split into +/- total charge.

⇢ Best-likelihood fit to the asymmetry parameter:

$$A_{\mathrm{WZ}}^{+-} = \frac{\sigma_{\mathrm{tot}}(\mathrm{pp} \to \mathrm{W}^{+}\mathrm{Z})}{\sigma_{\mathrm{tot}}(\mathrm{pp} \to \mathrm{W}^{-}\mathrm{Z})} = 1.48 \pm 0.06\,(\mathrm{stat}) \pm 0.02\,(\mathrm{syst}) \pm 0.01\,(\mathrm{theo})$$

⇢ Results are normalized to the expected value.

⇢ Most uncertainties “cancel out” in the + and - terms, result is driven by statistical uncertainties.

⇢ Expect uncertainties to drop significantly (~50%) with Run-II luminosity.

Differential cross-section(s) measurements

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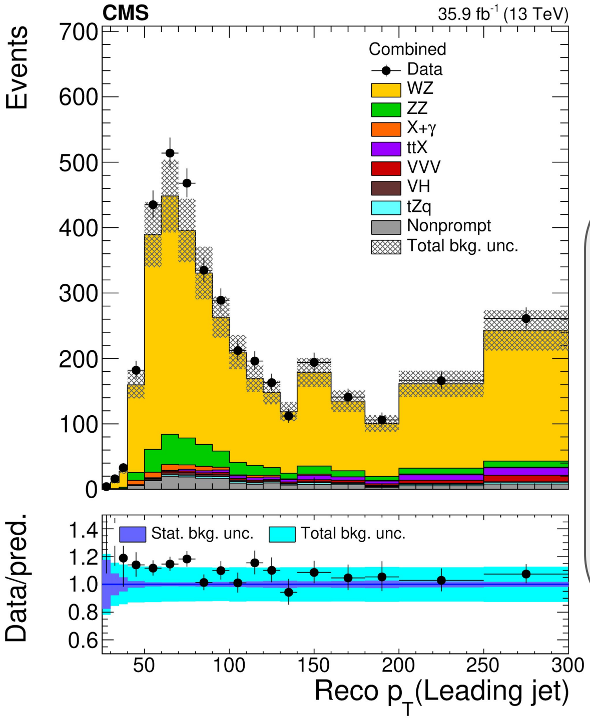
- Also providing cross-section results in differential form for:
  - p_T(leading jet): probe to recoil of the WZ system.
  - p_T(W), p_T(Z), M(WZ): typically sensitive to high energy BSM models.

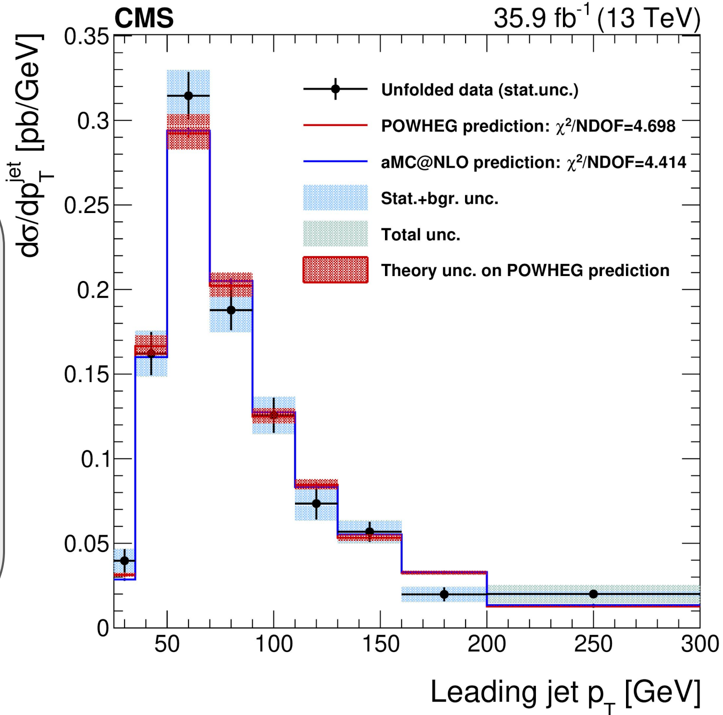


Unfolding with:

- Yields area constrain.

- Bias scale (towards measured total x-sec).

-No additional (i.e. Tikhonov) regularization terms.



Anomalous Couplings searches (I)

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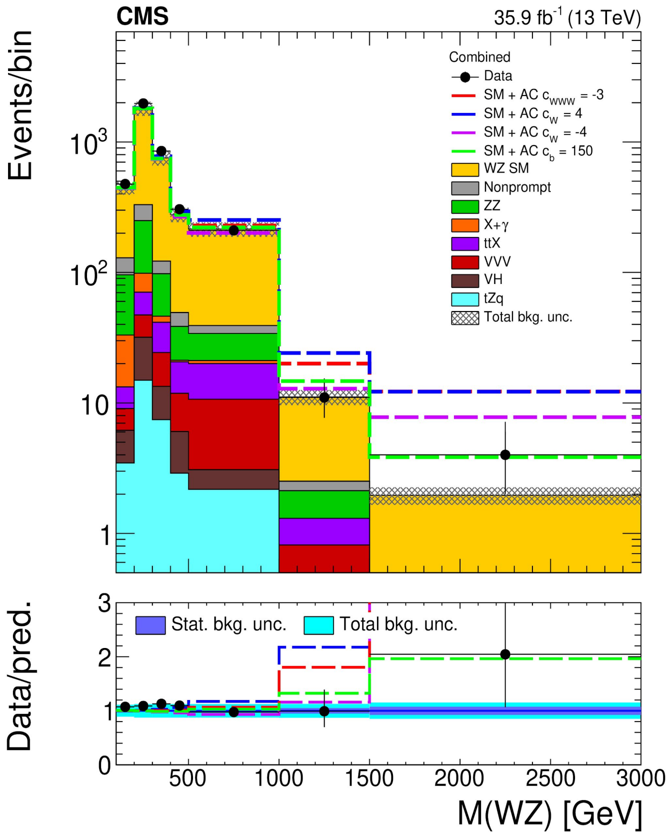
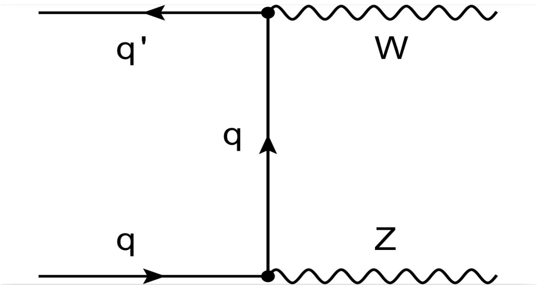
⇢ Anomalous gauge couplings based on an EFT approach:

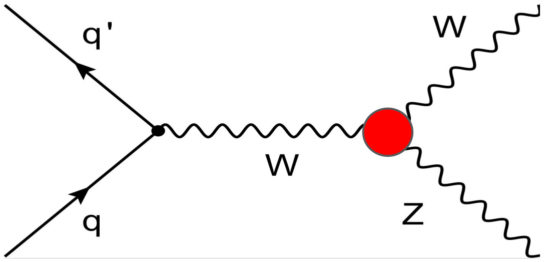
$$\delta\mathcal{L}_{AC} = c_{www}\mathrm{Tr}[W_{\mu\nu}W^{\nu\rho}W_{\rho}^{\mu}] + c_{w}\left(D_{\mu}H\right)^{\dagger}W^{\mu\nu}\left(D_{\nu}H\right) + c_{b}\left(D_{\mu}H\right)^{\dagger}B^{\mu\nu}\left(D_{\nu}H\right)$$

⇢ Signals modelled as linear (dim. 6) and quadratic (dim. 8) multiplicative terms to the cross-section (differentially).

⇢ Results extracted from likelihood fit to the shape of M(WZ) (reconstructed assuming $p_Z^{\nu} = 0$).







Anomalous Couplings searches (II)

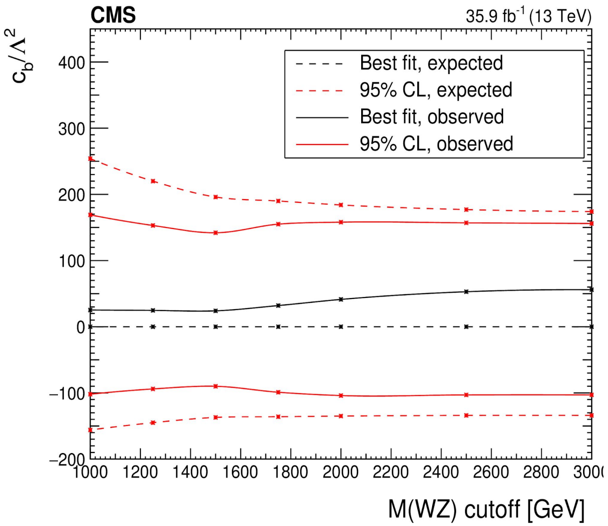
10.1007/JHEP04(2019)122

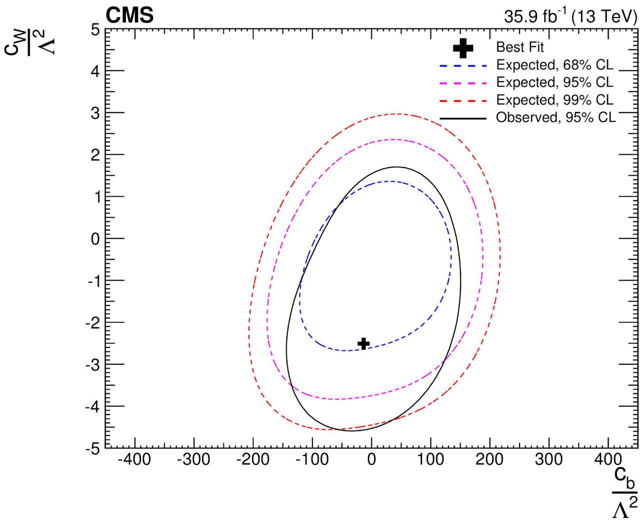
⇢ Results for 1D and 2D scans over AC parameters (both dim. 6 and dim.6 + dim.8).

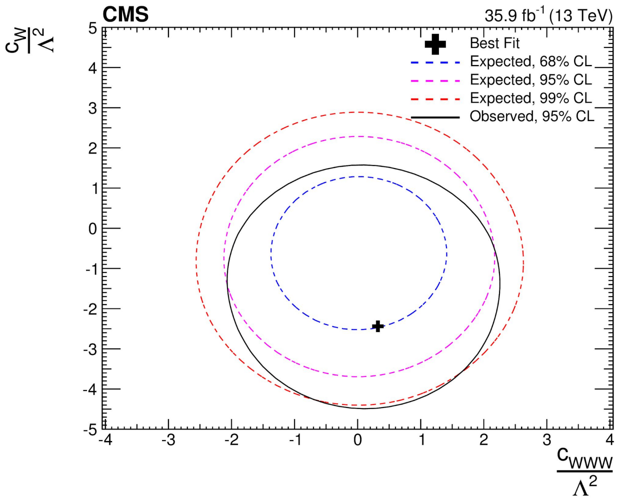
⇢ Also providing results with varying cut-off energy scale.

⇢ Measurements show very small deviations (within 1σ) of SM predictions. Driven by a fluctuation at high M(WZ) (Slide 6). Constraints are stronger than previous WZ results.

⇢ Strictly limited by statistical power at the high energy tails: improvements at Run II.







Prospects - boson polarization

⇢ Increasingly higher statistics allow for new high precision measurements.

⇢ Sensitivity is enough to study the polarization of W/Z bosons in WZ production. Typically sensitive to angles between final state leptons and its mother boson:

$$\frac{d\sigma}{\sigma d\cos\theta_3} \equiv \frac{3}{8}\left[(1\mp\cos\theta_3)^2 f_L^{W^\pm} + (1\pm\cos\theta_3)^2 f_R^{W^\pm} + 2\sin^2\theta_3\, f_0^{W^\pm}\right]$$

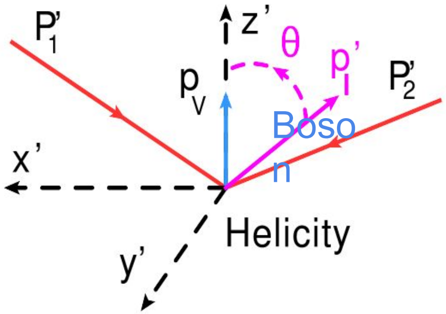
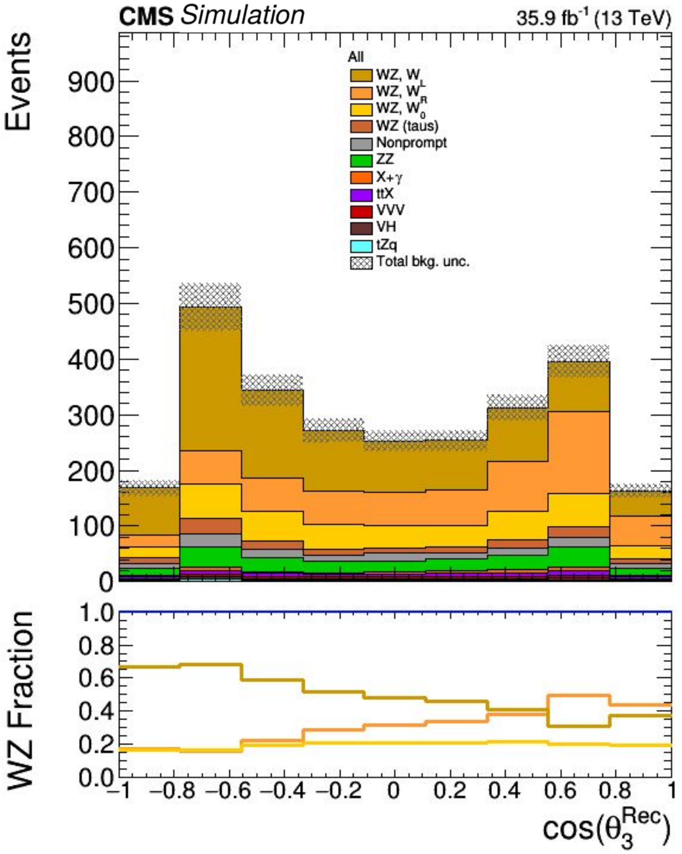
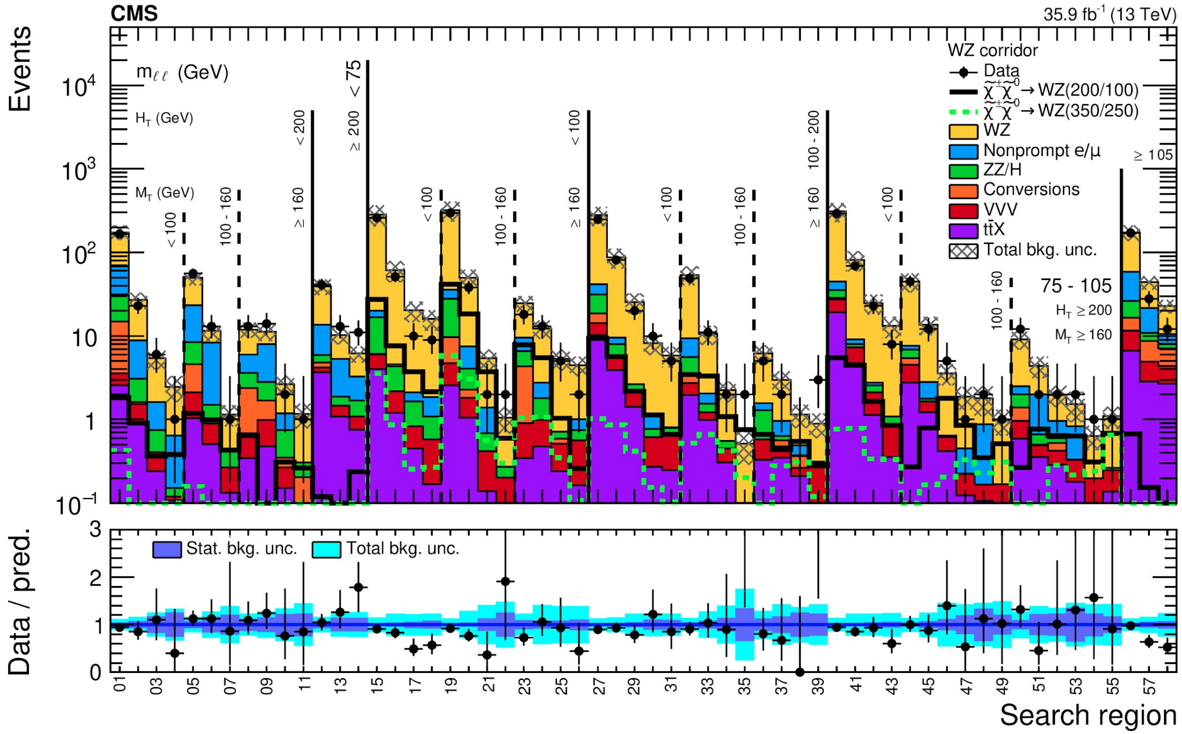


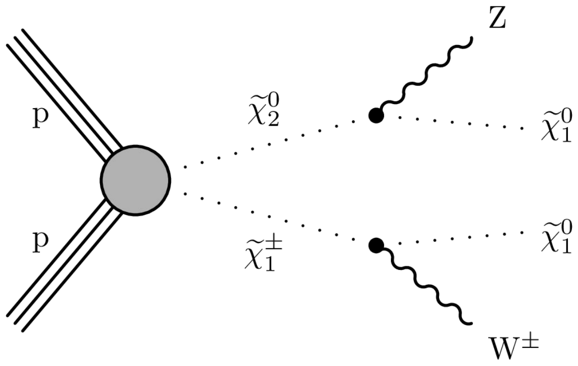
Figure from Baglio, Ninh JHEP 1904 (2019) 065



WZ-like Supersymmetric searches

10.1007/JHEP03(2018)160





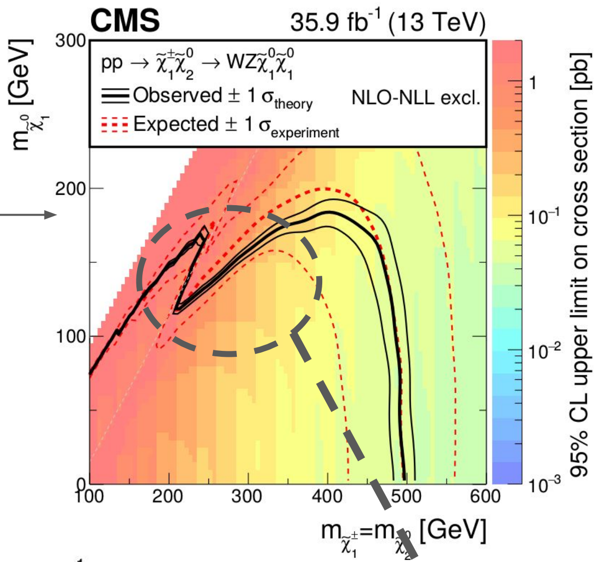
⇢ $T\chi WZ$ model predicting final states very similar to SM WZ production.

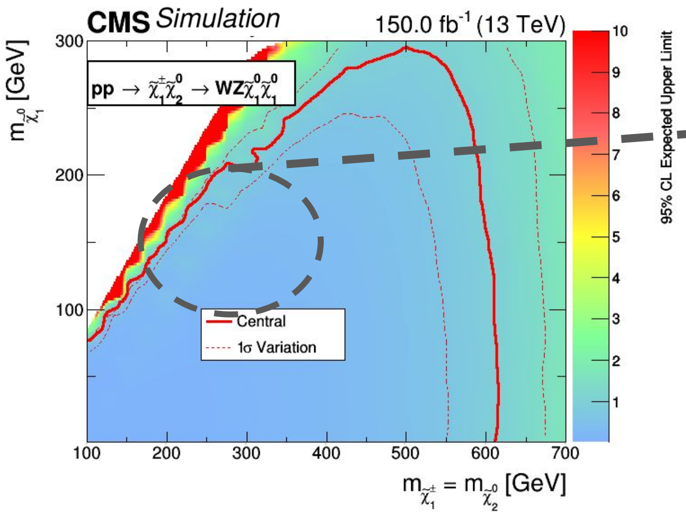
⇢ Slightly higher p_T^{miss}, m_T^W, etc.

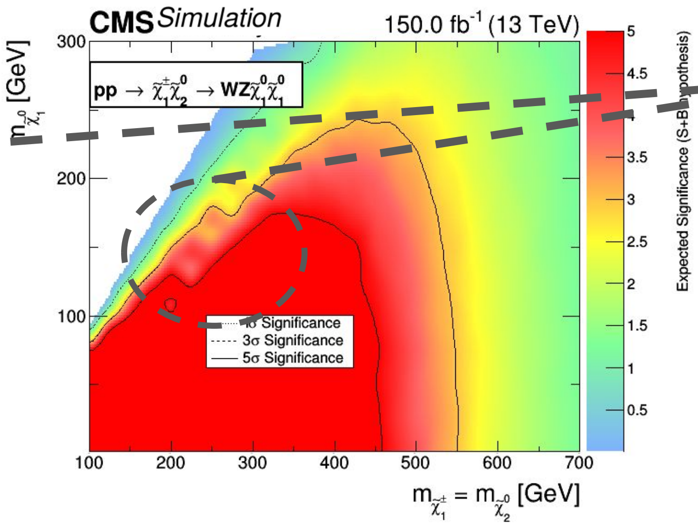
⇢ Search is limited by our knowledge of WZ differential cross-sections (enhanced p_T^{miss} tails).

Supersymmetry Prospects

- So far excluded NLSP/LSP up to ~ 500/200 GeV.
- Run II analysis driven by techniques to improve reach:
  - Increased knowledge of WZ cross-section.
  - Enhanced non-prompt background discriminance.
  - New multivariate techniques.
- Greater exclusion, but also increased discovery reach:







WZ Gap

Conclusions

⇢ New results on WZ production show overall agreement with SM expectations.

⇢ WZ Cross-sections entering the high precision era, systematics require careful assessment in Run-II analysis. Minor tensions in anomalous couplings (~1σ) to be clarified with new data.

⇢ Additional prospects: expanding into boson spin measurements, analyze boson polarization observables.

⇢ Multileptonic SUSY searches will greatly benefit by enhanced knowledge of WZ cross-section. Prospects: clarifying the status of the WZ “gap” with reach for both exclusion and discovery.

Back-Up