

# $t\bar{t}Z$ xsec differentially

Differential measurement of the associated production of a top quark pair with a Z boson in pp collisions at  $\sqrt{s} = 13$  TeV with the CMS experiment

results from: CMS Collaboration, arXiv:1907.11270, submitted to JHEP

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on behalf of the CMS collaboration

Young Scientist Forum

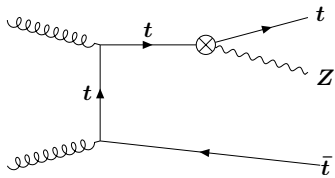
12th International Workshop on Top Quark Physics

September 22nd–27th, 2019, Beijing

**HELMHOLTZ** RESEARCH FOR  
GRAND CHALLENGES



# Why?



test of top quark–Z boson coupling

- Standard Model:

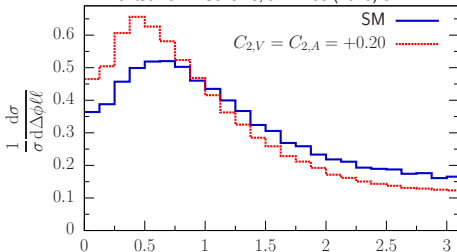
$$e \bar{t} [\gamma^\mu (C_V + \gamma_5 C_A)] t Z_\mu$$

- new physics parametrization:

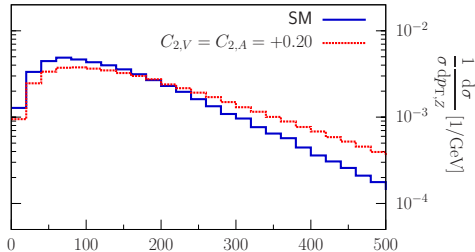
$$e \bar{t} \left[ \gamma^\mu (C_{1,V} + \gamma_5 C_{1,A}) + \frac{i\sigma^{\mu\nu} q_\nu}{M_Z} (C_{2,V} + \gamma_5 C_{2,A}) \right] t Z_\mu$$

## prediction with anomalous couplings for three-lepton channel:

R. Röntsch & M. Schulze, JHEP 08 (2015) 044



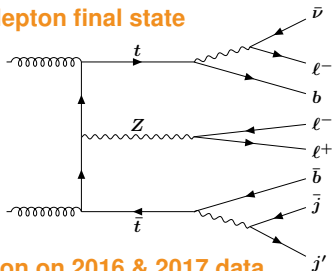
azimuthal angle between Z leptons  $\Delta\varphi(\ell\ell)$



dilepton transverse momentum  $p_T(\ell\ell)$

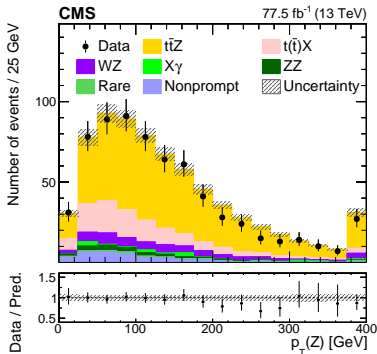
# What?

## Three-lepton final state

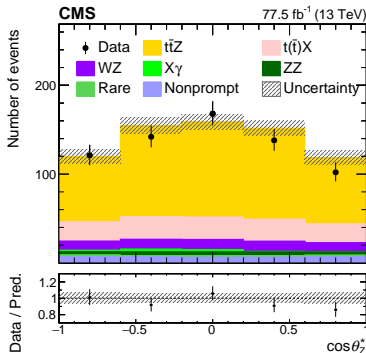


## Selection on 2016 & 2017 data

- **trigger**: one, two, or three leptons
- **exactly three isolated leptons**
  - pass dedicated  $t\bar{t}Z$  MVA ID
  - $p_T > 40, 20, 10$  GeV
- **one Z candidate**
  - OSSF pair with  $|m_{\ell\ell} - m_Z| < 10$  GeV
- **at least three isolated jets**
  - $p_T > 30$  GeV
- **at least one b-tagged jet**



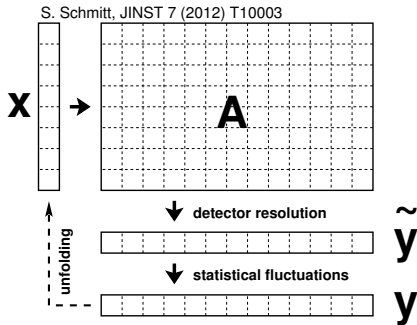
$p_T(Z)$ : dilepton  $p_T$



$\cos\theta_Z^*$ : angle between  $\ell^-$  and  $\ell\ell$ , boosted to  $\ell\ell$  rest frame

# How?

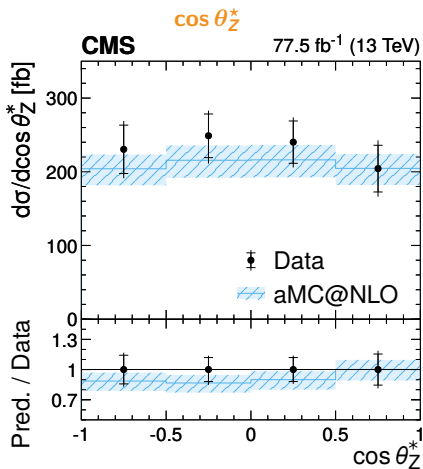
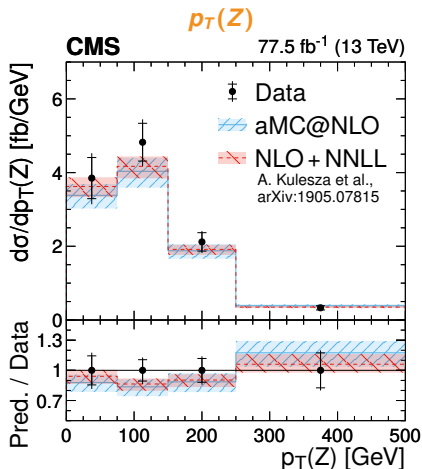
- **parton-level** distribution  $\mathbf{x}$ :  
number of events  $\bar{t}Z, Z \rightarrow \ell^+ \ell^-$   
after all radiation
- **reconstructed** distribution  $\mathbf{y}$ :  
measured events passing full event  
selection, backgrounds subtracted
- **response matrix  $\mathbf{A}$** :  
describes acceptance, efficiency,  
resolution, reconstruction, selection;  
constructed from signal MC
- **unfolding** by inversion:  $\mathbf{x} = \mathbf{A}^{-1} \mathbf{y}$ ,  
implemented with TUnfold
- here, very good resolution for leptonic  
observables  $\Rightarrow$  no **regularization** of  
statistical fluctuations needed



# Results

## Absolute cross sections at parton-level

arXiv:1907.11270

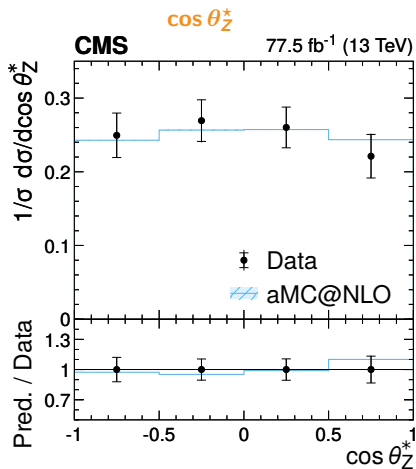
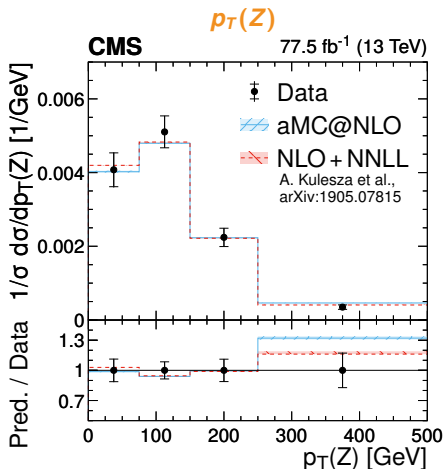


- ⇒ in agreement with standard model prediction
- ⇒ limited by statistical uncertainty

# Results

## Normalized cross sections at parton-level

arXiv:1907.11270

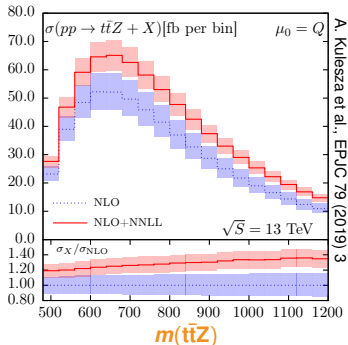


⇒ in agreement with standard model prediction

⇒ limited by statistical uncertainty, normalization uncertainties cancel

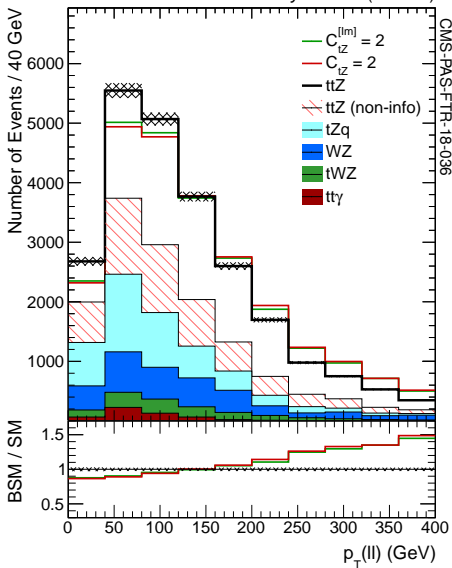
# What's next?

- CMS collaboration performed first differential measurement of  $t\bar{t}Z$  production in leptonic observables.
- Statistics limited  $\Rightarrow$  more precise results with more data.
- Aim for  $t\bar{t}$  reconstruction to measure also in hadronic observables.









## Dilepton $p_T$ at HL-LHC

CMS Phase-2 Simulation Preliminary 3 ab<sup>-1</sup> (14 TeV)



# References

-  CMS Collaboration, *Measurement of top quark pair production in association with a Z boson in proton-proton collisions at  $\sqrt{s} = 13$  TeV*, arXiv:1907.11270 (submitted to *JHEP*).
-  R. Röntsch and M. Schulze, *Probing top-Z dipole moments at the LHC and ILC*, *JHEP* **08** (2015) 044 [arXiv:1501.05939].
-  S. Schmitt, *TUnfold, an algorithm for correcting migration effects in high energy physics*, *JINST* **7** (2012) T10003 [arXiv:1205.6201].
-  A. Kulesza et al., *Associated top-pair production with a heavy boson production through NLO+NNLL accuracy at the LHC*, in *Proc. 54th Rencontres de Moriond, QCD and High Energy Interactions*, La Thuile, Italy, March 23-30, 2019 [arXiv:1905.07815].
-  CMS Collaboration, *Anomalous couplings in the  $t\bar{t}Z$  final state at the HL-LHC*, CMS-PAS-FTR-18-036, CERN 2018.
-  A. Kulesza et al., *Associated production of a top quark pair with a heavy electroweak gauge boson at NLO+NNLL accuracy*, *Eur. Phys. J. C* **79** (2019) 249 [arXiv:1812.08622].