

Measurement of the WZ inclusive cross section at 13.6 TeV with CMS

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Universidad de Oviedo



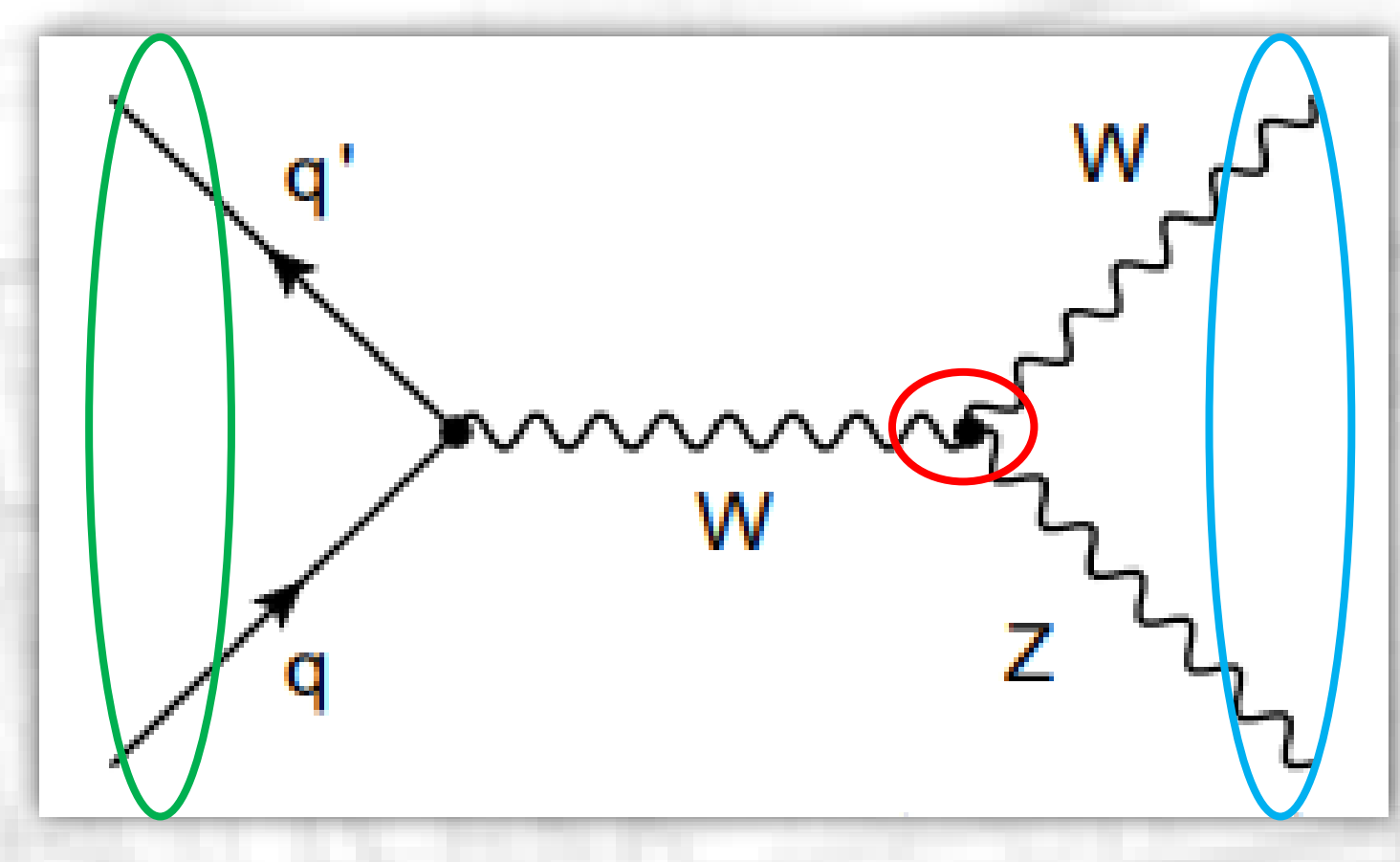
Introduction

- ▶ The WZ cross section is measured **for the first time** at the new energy frontier of 13.6 TeV
- ▶ The achieved precision is competitive with previous results and well in agreement with latest theory predictions



Physics of WZ

- ▶ The WZ process presents several interesting features
- ▶ **Theoretically:** it gives access to many sectors of the SM.
 - ▶ Sensitive to charge asymmetries.
 - ▶ Boson polarization effects.
 - ▶ Trilinear Gauge Couplings.
- ▶ **Experimentally:** in its multileptonic final state ($W^\pm \rightarrow \ell^\pm \nu, Z \rightarrow \ell^+ \ell^-$):
 - ▶ One of the cleanest channels at the LHC (85% purity of signal over background after selections).
 - ▶ Reasonably high statistical power.
 - ▶ It is known to be compatible (with excellent accuracy) with the latest NNLO QCD x NLO EWK predictions.



The analysis CMS-PAS-SMP-24-005

- ▶ Event selection is based on a **W/Z tagging algorithm**.
- ▶ **Idea:** find the pair of leptons coming from the Z. The remaining one is coming from W.
- ▶ Leptons are properly assigned to the corresponding bosons with $\sim 95\%$ efficiency.
- ▶ Selection is further optimized with kinematic requirements on the objects used in the analysis.

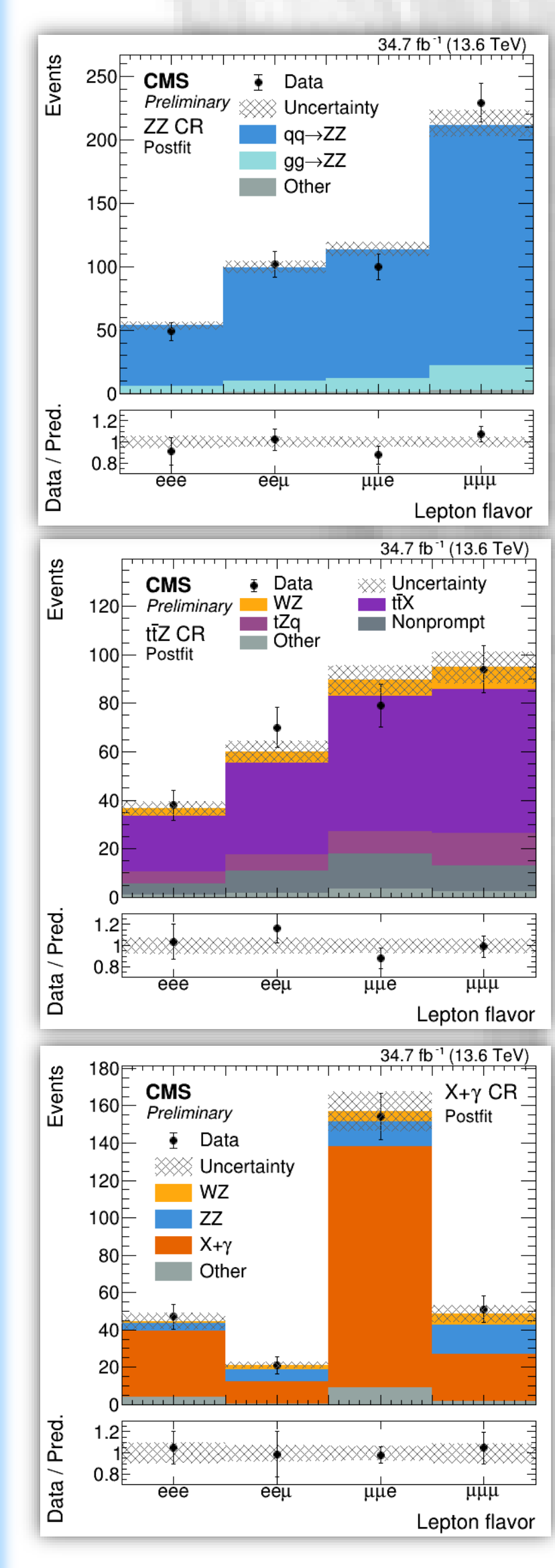
Region	N_ℓ	$p_T(\ell_Z^1, \ell_Z^2, \ell_W)$ [GeV]	N_{OSF}	$ m(\ell_Z^1, \ell_Z^2) - m_Z $ [GeV]	p_T^{miss} [GeV]	$N_{\text{b tag}}$	$\min(m(\ell\ell'))$ [GeV]	$m(\ell_Z^1, \ell_Z^2, \ell_W)$ [GeV]
SR	=3	>{25, 15, 25}	≥ 1	<15	>35	=0	>4	>100
CR-ZZ	=4	>{25, 15, 25, 15}	≥ 1	<15	-	=0	>4	>100
CR-ttZ	=3	>{25, 15, 25}	≥ 1	<15	>35	>0	>4	>100
CR-conv	=3	>{25, 15, 25}	≥ 1	-	≤ 35	=0	>4	<100

- ▶ The **signal region (SR)** selection maximises signal presence.
- ▶ The main backgrounds (ZZ, ttZ and conversions) are controlled with three additional control regions (CRs).

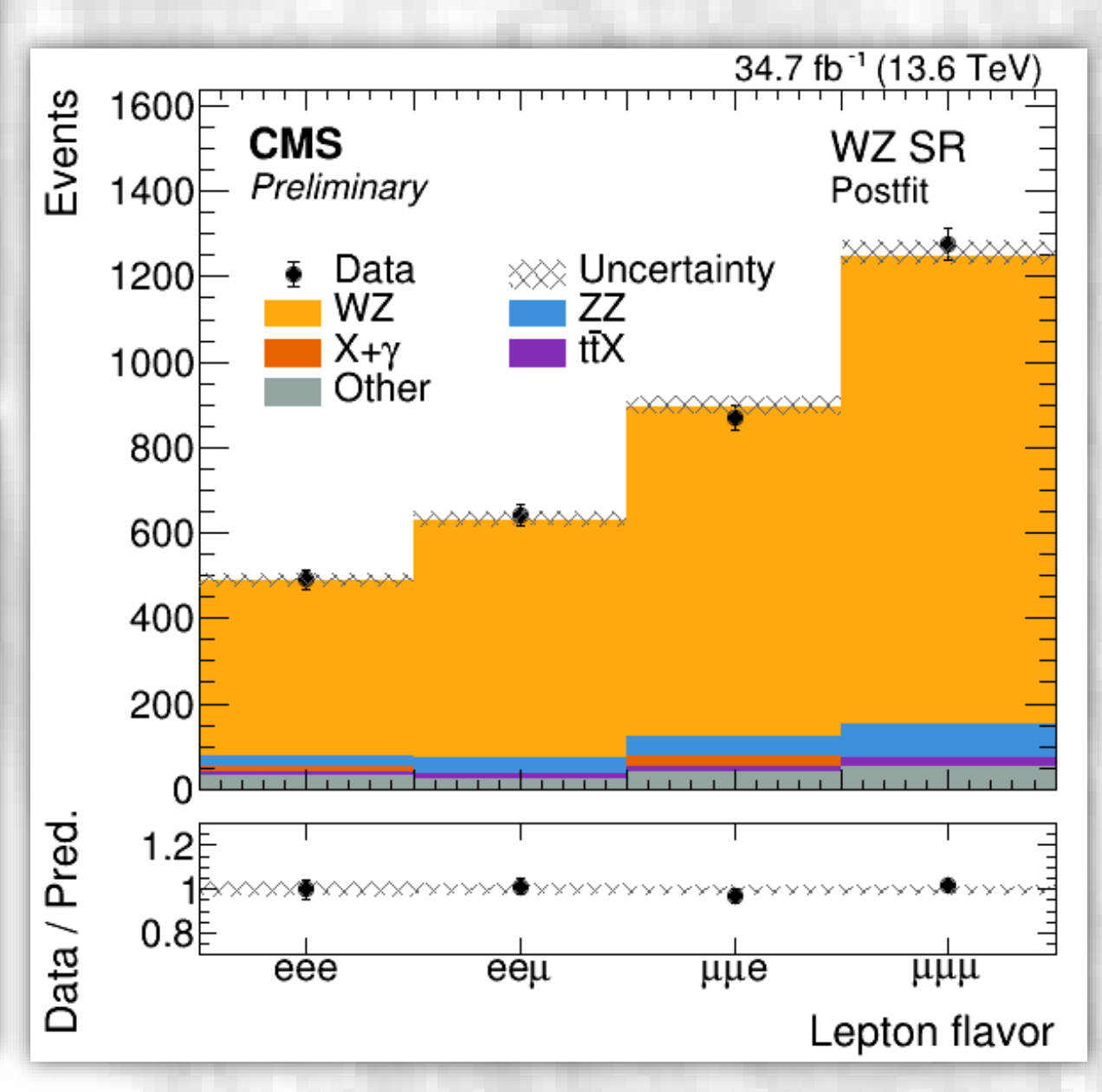
Measuring the WZ cross section

- ▶ The measurement is based on a **maximum likelihood (ML) fit** to a **distribution of interest**.
- ▶ This distribution is chosen based on the properties of WZ we want to be sensitive to.
- ▶ This distribution is the number of events in different lepton flavour categories.

▶ For each case, two cross section values are reported: a fiducial and a total cross section.



- ▶ **Four channels:**
 - ▶ eee, eeμ, μμe, μμμ
 - ▶ ML fits are performed for:
 - ▶ All the channels together.
 - ▶ Each separate bin.



Breakdown of systematic uncertainties.

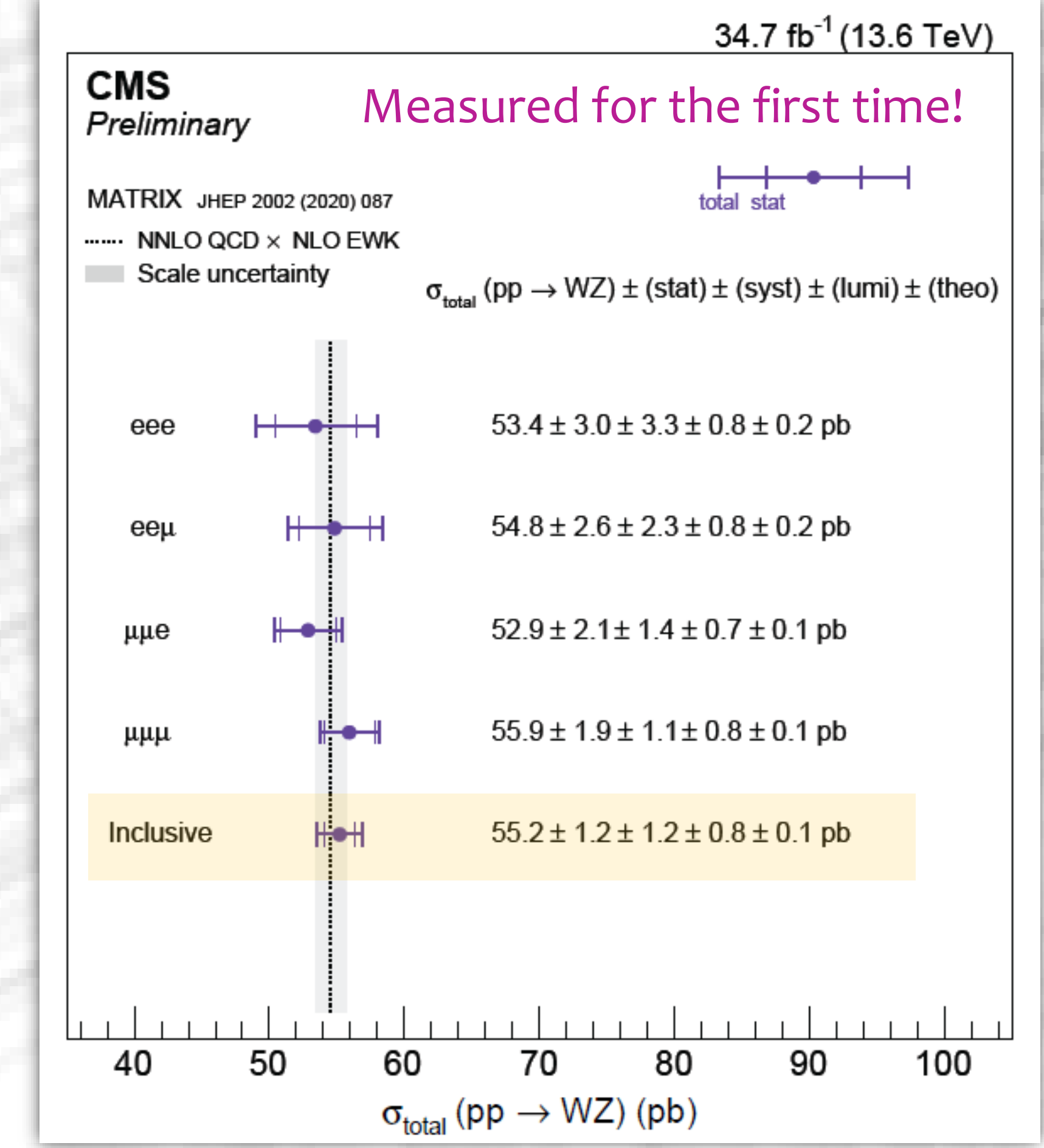
Fiducial cross sections.

Source	Inclusive	eee	eeμ	μμe	μμμ
Integrated luminosity	1.5	1.5	1.4	1.4	1.5
Trigger efficiencies	0.5	1.0	1.0	1.0	0.7
b tagging	0.1	0.1	0.1	0.1	0.1
Pileup	0.4	0.6	0.8	0.2	0.4
Jet energy scales	0.9	1.3	0.7	1.1	0.7
Electron ID efficiencies	0.7	3.6	2.4	1.1	-
Electron reconstruction	1.2	4.0	2.9	1.1	-
Electron energy scale	0.1	0.1	0.1	0.0	-
Muon efficiencies	0.7	-	0.3	0.8	1.2
Nonprompt normalization	0.7	1.6	0.5	0.7	0.7
VVV normalization	0.4	0.4	0.4	0.4	0.4
tZq normalization	0.1	0.1	0.1	0.1	0.1
ZZ normalization	0.3	0.8	0.7	0.5	0.5
ttZ normalization	0.3	0.7	0.6	0.4	0.5
Xγ normalization	0.2	0.7	0.3	0.4	0.2
VH normalization	0.2	0.2	0.2	0.1	0.2
ISR/FSR	0.3	0.5	0.2	0.4	0.3
WZ theo (μ_R, μ_F, PDF)	0.2	0.2	0.2	0.2	0.2
MC statistical	0.5	1.9	0.9	1.0	0.9
Statistical	2.0	5.3	4.6	3.8	3.3
Total	3.3	8.4	6.4	5.0	4.2

Category	Accuracy	Fiducial cross section (fb)
eee	POWHEG	$68.0^{+2.1}_{-2.1}$ (scale) ± 1.0 (PDF)
	MATRIX, NNLO QCD	$77.0^{+1.9}_{-1.9}$ (scale)
	MATRIX, NNLO QCD x NLO EWK	$75.4^{+1.7}_{-1.7}$ (scale)
	Measured	72.0 ± 6.1 (stat) ± 6.1 (syst) ± 4.0 (lumi) ± 0.5 (theo)
eeμ	POWHEG	$68.0^{+2.3}_{-2.3}$ (scale) ± 1.0 (PDF)
	MATRIX, NNLO QCD	$75.0^{+1.8}_{-1.8}$ (scale)
	MATRIX, NNLO QCD x NLO EWK	$73.4^{+1.6}_{-1.6}$ (scale)
	Measured	73.9 ± 3.5 (stat) ± 3.1 (syst) ± 1.1 (lumi) ± 0.3 (theo)
μμe	POWHEG	$68.0^{+2.3}_{-2.3}$ (scale) ± 1.0 (PDF)
	MATRIX, NNLO QCD	$75.0^{+1.8}_{-1.8}$ (scale)
	MATRIX, NNLO QCD x NLO EWK	$73.4^{+1.6}_{-1.6}$ (scale)
	Measured	71.2 ± 2.9 (stat) ± 2.0 (syst) ± 1.0 (lumi) ± 0.1 (theo)
μμμ	POWHEG	$68.0^{+2.3}_{-2.3}$ (scale) ± 1.0 (PDF)
	MATRIX, NNLO QCD	$75.0^{+1.8}_{-1.8}$ (scale)
	MATRIX, NNLO QCD x NLO EWK	$75.4^{+1.7}_{-1.7}$ (scale)
	Measured	75.3 ± 2.5 (stat) ± 1.5 (syst) ± 1.1 (lumi) ± 0.1 (theo)
Inclusive	POWHEG	$271.9^{+9.0}_{-9.0}$ (scale) ± 3.8 (PDF)
	MATRIX, NNLO QCD	$304.0^{+7.1}_{-7.1}$ (scale)
	MATRIX, NNLO QCD x NLO EWK	$298.1^{+6.3}_{-6.3}$ (scale)
	Measured	297.6 ± 6.4 (stat) ± 6.4 (syst) ± 4.2 (lumi) ± 0.5 (theo)

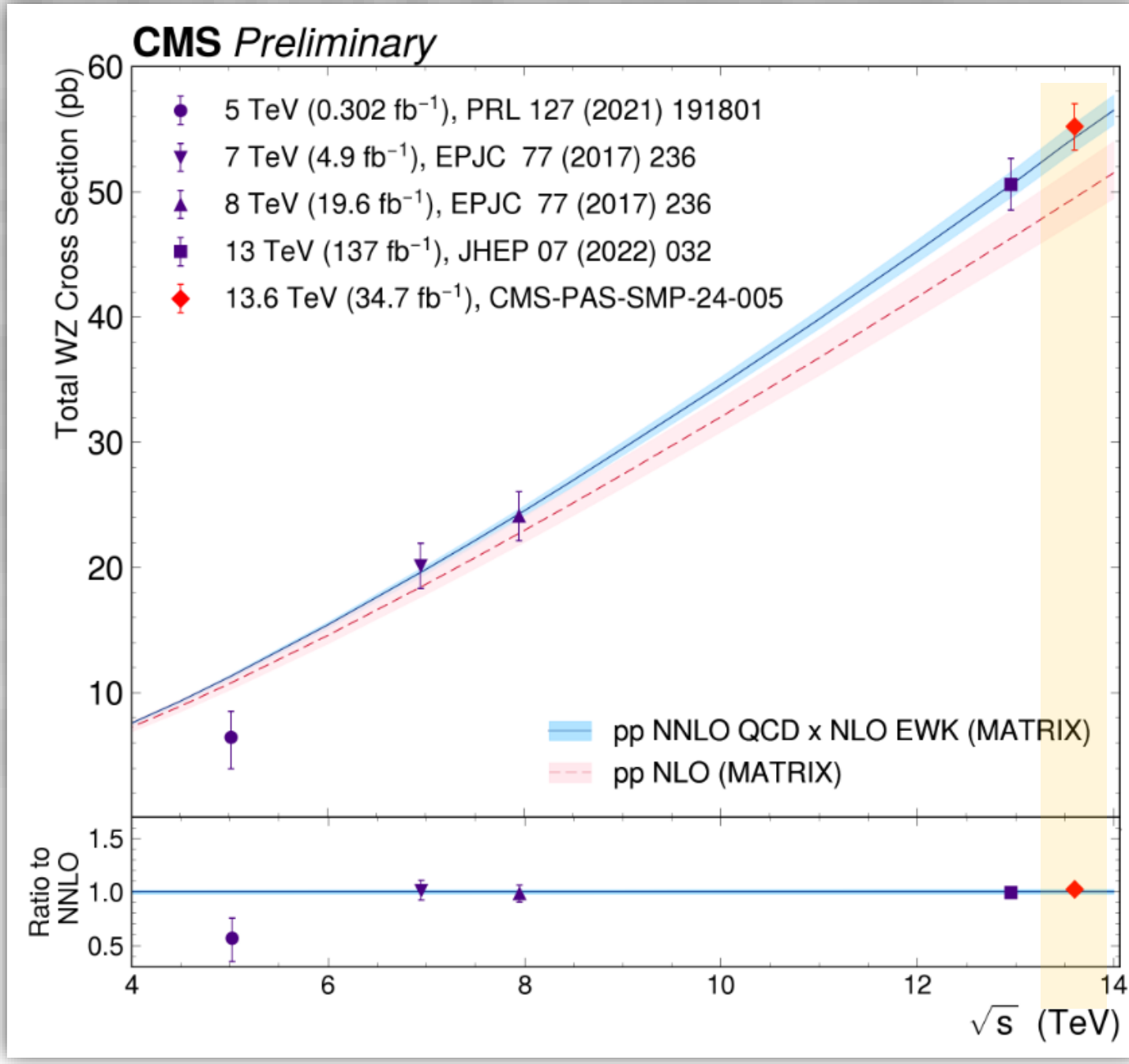
- Fiducial region**
 - 3ℓ
 - $|M_{\ell\ell} - m_Z| < 30$ GeV
 - $p_T^{\ell, \text{gen}} \in \{25, 15, 25\}$ GeV
 - $|\eta^{\ell, \text{gen}}| < 2.5$
 - $M_{3\ell}^{\text{gen}} > 100$ GeV

Total cross sections



Conclusions

- ▶ For the first time in Run 3, the WZ production cross section has been measured.
- ▶ **Latest theory prediction:** 54.7 ± 1.2 pb (NNLOxNLO EWK)
- ▶ **This measurement:** 55.2 ± 1.2 (stat) ± 1.2 (syst) ± 0.8 (lumi) ± 0.1 (theo)
- ▶ In good agreement with the latest theory predictions computed with MATRIX!
- ▶ Competitive with previous measurements in terms of total uncertainty (3.4%)



Ten years of WZ!
... and CMS has contributed with a new and very precise cross section measurement!