WW cross section measurement & MET Performance

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Motivation

- Vector boson pair production is **one of the most important electroweak processes** at hadron colliders.

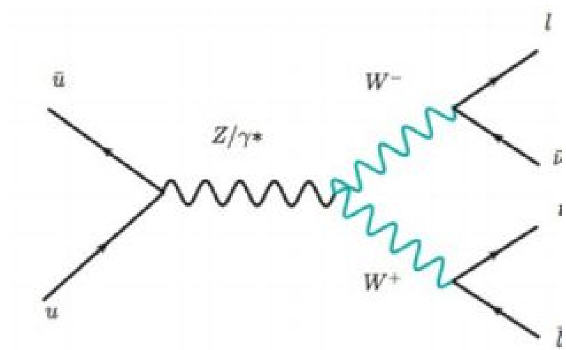
- WW production **has larger cross section** than WZ and ZZ production.
- The standard model (SM) description of electroweak interactions can be tested through **precision measurements of the WW production cross section** at hadron colliders.
- **Irreducible background** for the H→ WW process
- xs **already published at 8 TeV** = 69.9 +/- 0.7 for 5.3 fb-1

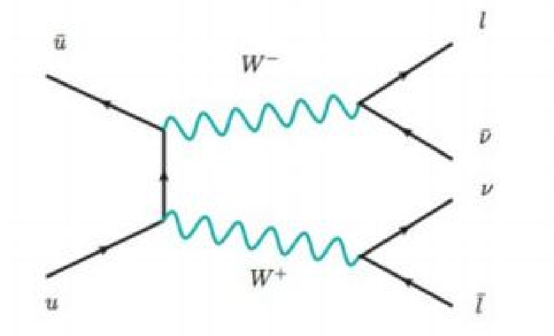
to be compared with the theoretical value $59.8^{+2.2\%}_{-1.9\%}$ pb

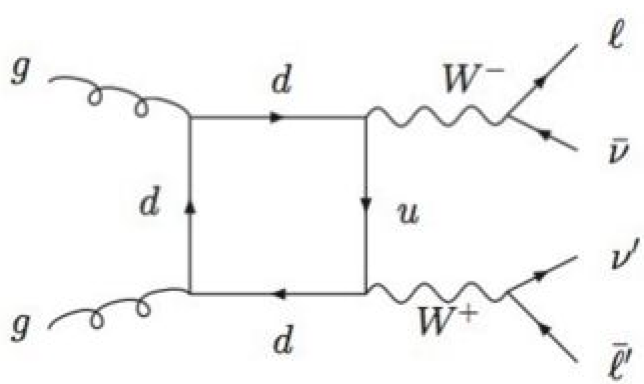
PLB 721 (2013) 190-211

WW xs measurement

Production mode:

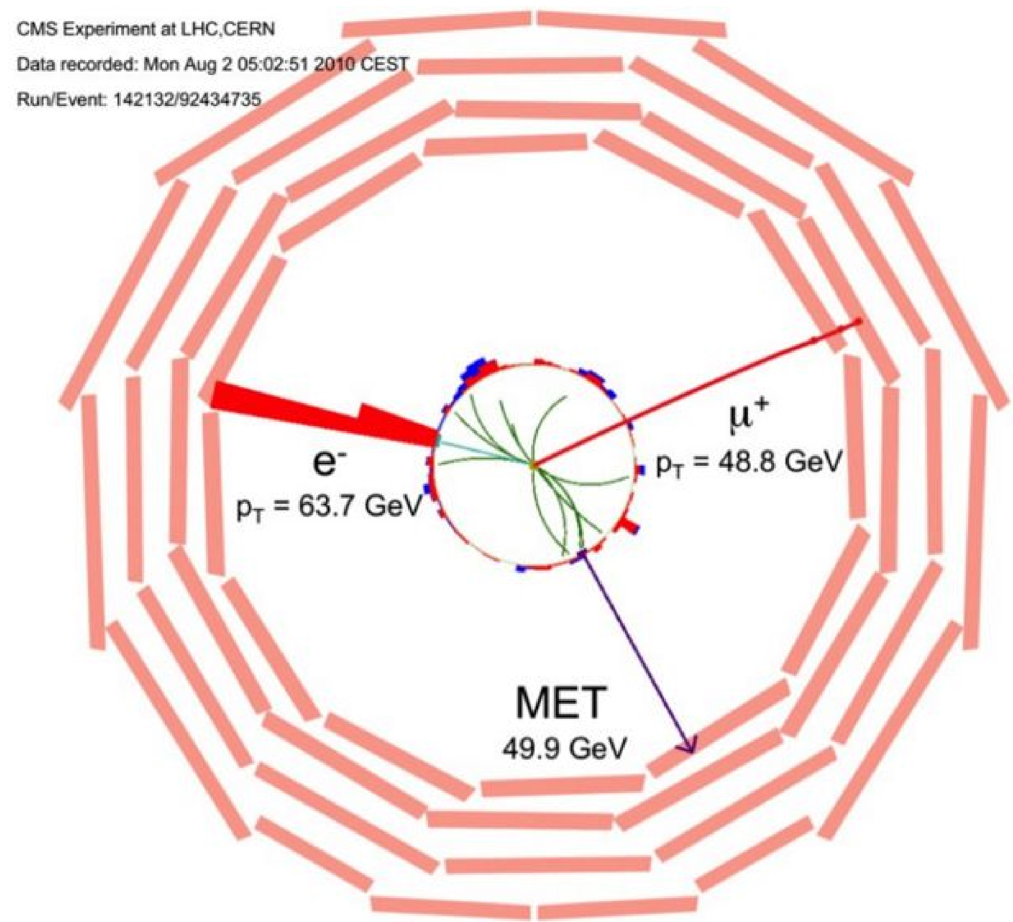






Experimental signature:

- Two high pT leptons
- Transverse missing ET
- Low hard jet activity



Selection

WW $\rightarrow$ llnunu(l=e,mu) signature

Two high pT leptons with opposite charge and tight requirements ISO/ID

Large missing transverse energy (MET)

Reject events consistent with Z decay

Veto events in Z mass window for same flavour final state

Reduce top quark decay background

Top veto based on b-tagging and soft muon tagging for low p_T jets

Reduce other diboson (WZ/ZZ) background

Veto events with a third lepton passing tight requirements

MET cuts to reduce further Drell Yan contribution

Selection

Variable	Different-flavor	Same-flavor
$q_{\ell_1} \times q_{\ell_2}$	< 0	< 0
p_T (GeV)	> 20	> 20
DY MVA	-	> 0.88 (0-jet) > 0.84 (1-jet)
$\|m_{\ell\ell} - m_Z\|$ (GeV)	-	> 15
$p_T^{\ell\ell}$ (GeV)	> 30	> 45
$m_{\ell\ell}$ (GeV)	> 12	> 12
Additional leptons ($p_T^{\ell} > 10$ GeV)	veto	veto
Top-quark veto	applied	applied

The events are analyzed in four exclusive categories:

- Separated between different- and same-flavor leptons
- Separated between events with 0 or 1 reconstructed jet with $E_T > 30$ GeV and $|\eta| < 4.7$.

Data

- We use the complete 2012 dataset corresponding to an integrated luminosity of 19.4 fb−1
- The data we use were collected with the following trigger suite:

Dataset	Trigger name	Description
DoubleElectron	HLT_Ele17_CaloIdT_CaloIsoVL_TrkIdVL_TrkIsoVL_ Ele8_CaloIdT_CaloIsoVL_TrkIdVL_TrkIsoVL_v*	$p_T > 17, 8$ GeV
DoubleMu	HLT_Mu17_Mu8_v*	$p_T > 17, 8$ GeV
	HLT_Mu17_TkMu8_v*	$p_T > 17, 8$ GeV
MuEG	HLT_Mu17_Ele8_CaloIdT_CaloIsoVL_TrkIdVL_TrkIsoVL_v*	$p_T > 17, 8$ GeV
	HLT_Mu8_Ele17_CaloIdT_CaloIsoVL_TrkIdVL_TrkIsoVL_v*	$p_T > 8, 17$ GeV
SingleEle	HLT_Ele27_WP80_v*	$p_T > 27$ GeV
SingleMu	HLT_IsoMu24_eta2p1_v*	$p_T > 24$ GeV

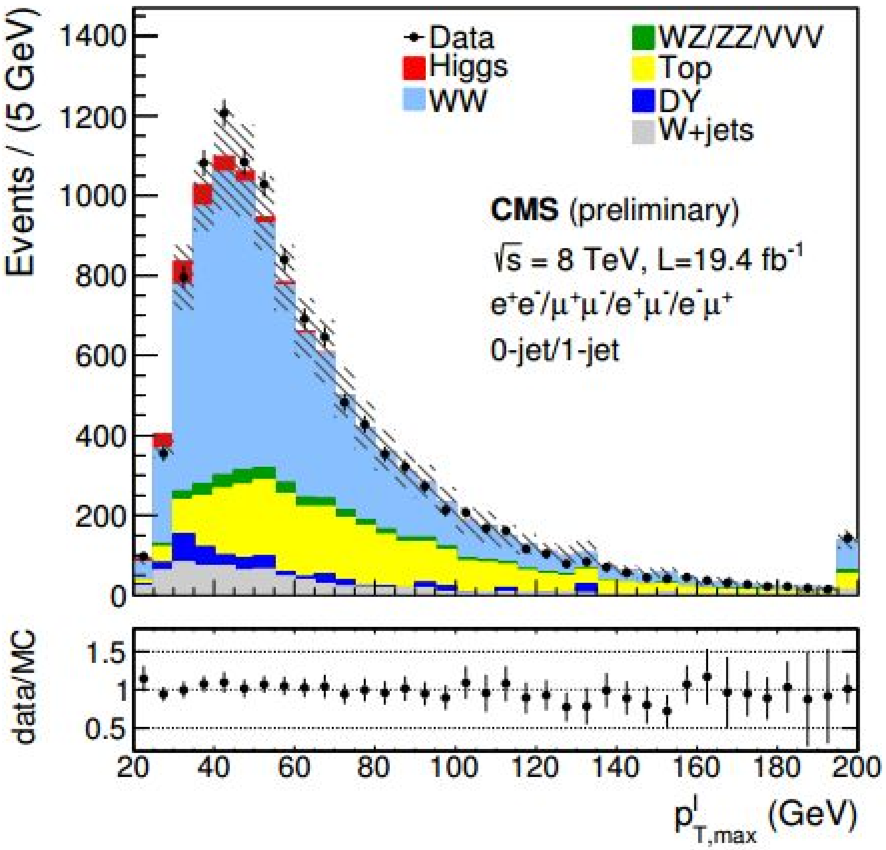
Backgrounds

- WZ, ZZ, $W\gamma$, VVV are **taken from simulation**
- ttbar and tW → data-driven estimation from control region
- W+jets **estimated from data** (with a looser selection) using a (eta, pT) dependent fake rate measured with a QCD control sample
- The DY background normalization is measured in a data control sample using the so-called **in/out method** wrt the Z mass peak
- $W\gamma^*$ is taken from MC and **normalized to a control sample** with three reconstructed leptons
- The H→ WW is **taken from MC** and considered as a **background**

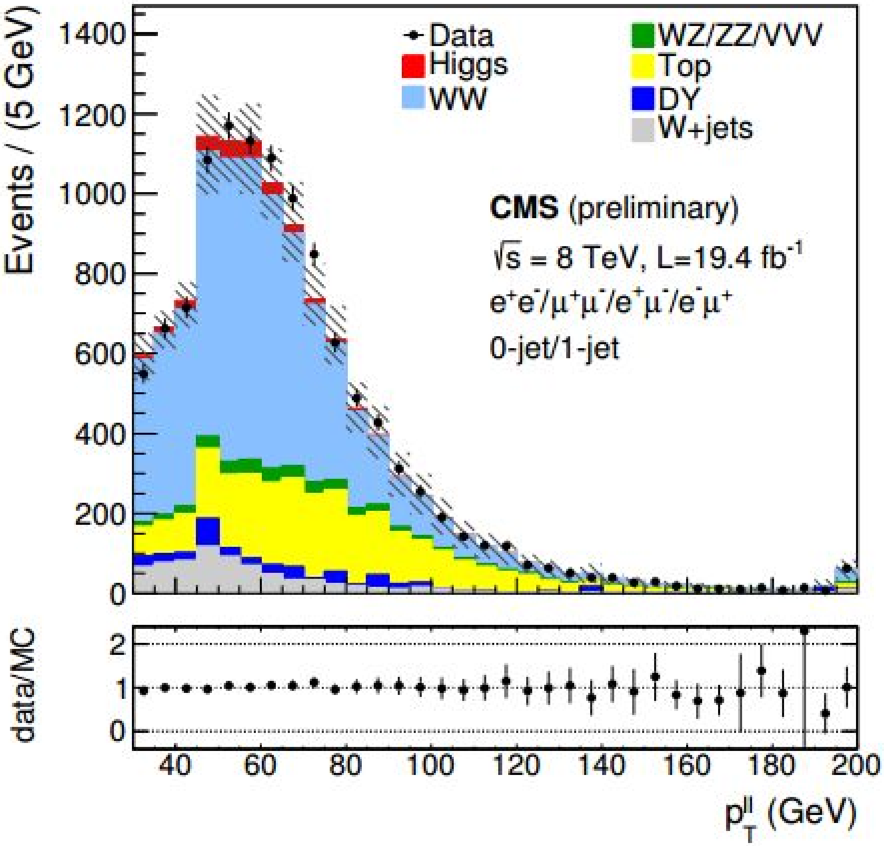
Relative Uncertainties

Source	Uncertainty (%)
Statistical uncertainty	1.5
Lepton efficiency	3.8
Lepton momentum scale	0.5
Jet energy scale	1.7
E_T^{miss} resolution	0.7
$t\bar{t}$+tW normalization	2.2
W+jets normalization	1.3
$Z/\gamma^* \to \ell^+\ell^-$ normalization	0.6
$Z/\gamma^* \to \tau^+\tau^-$ normalization	0.2
$W\gamma$ normalization	0.3
$W\gamma^*$ normalization	0.4
VV normalization	3.0
$H \to W^+W^-$ normalization	0.8
Jet counting theory model	4.3
PDFs	1.2
MC statistical uncertainty	0.9
Integrated luminosity	2.6
Total uncertainty	7.9

Results

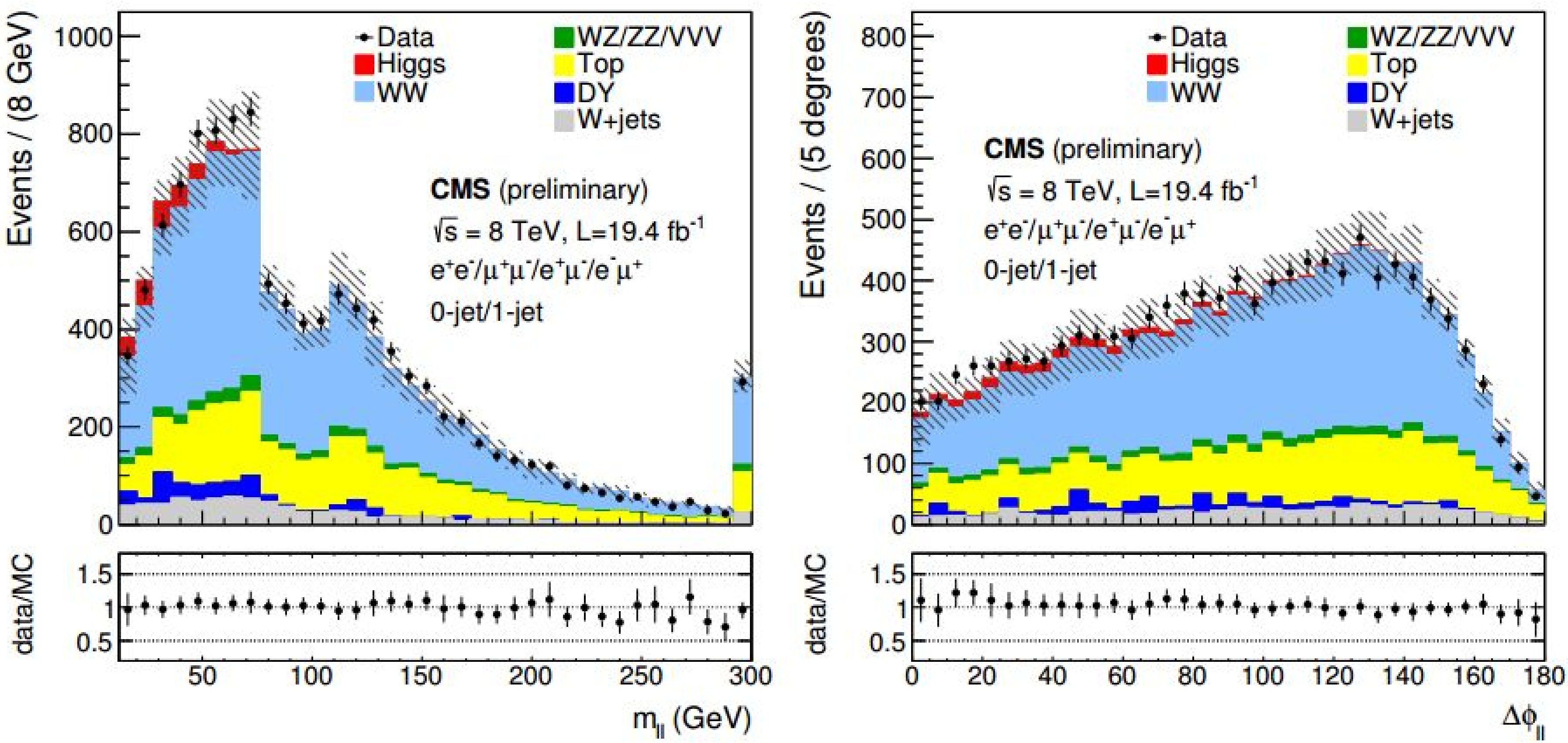


Data
Higgs
WW
WZ/ZZ/VVV
Top
DY
W+jets
CMS (preliminary)
√s = 8 TeV, L=19.4 fb-1
e+e-/μ+μ-/e+μ-/e-μ+
0-jet/1-jet
Events / (5 GeV)
data/MC
$p^{l}_{T,max}$ (GeV)



Data
Higgs
WW
WZ/ZZ/VVV
Top
DY
W+jets
CMS (preliminary)
√s = 8 TeV, L=19.4 fb-1
e+e-/μ+μ-/e+μ-/e-μ+
0-jet/1-jet
Events / (5 GeV)
data/MC
p^{ll}_{T} (GeV)

Results



Data
Higgs
WW
WZ/ZZ/VVV
Top
DY
W+jets
CMS (preliminary)
√s = 8 TeV, L=19.4 fb-1
e+e-/μ+μ-/e+μ-/e-μ+
0-jet/1-jet
Events / (8 GeV)
data/MC
m_ll (GeV)
Events / (5 degrees)
Δφ_ll

Result

$$\sigma_{W^+W^-} = \frac{N_{\mathrm{data}} - N_{\mathrm{bkg}}}{\mathcal{L}\cdot\epsilon\cdot(3\cdot\mathcal{B}(W\to\ell\overline{\nu}))^2},$$

Process	0-jet category		1-jet category	
	Different-flavor	Same-flavor	Different-flavor	Same-flavor
$qq \to W^+W^-$	3516 ± 271	1390 ± 109	1113 ± 137	386 ± 49
$gg \to W^+W^-$	162 ± 50	91 ± 28	62 ± 19	27 ± 9
W^+W^-	3678 ± 276	1481 ± 113	1174 ± 139	413 ± 50
$ZZ + WZ$	84 ± 10	89 ± 11	86 ± 4	42 ± 2
VVV	33 ± 17	17 ± 9	28 ± 14	14 ± 7
Top-quark	522 ± 83	248 ± 26	1398 ± 156	562 ± 128
$Z/\gamma^* \to \ell^+\ell^-$	38 ± 4	141 ± 63	136 ± 14	65 ± 33
$W\gamma^*$	54 ± 22	12 ± 5	18 ± 8	3 ± 2
$W\gamma$	54 ± 20	20 ± 8	36 ± 14	9 ± 6
$W + \mathrm{jets}(e)$	189 ± 68	46 ± 17	114 ± 41	16 ± 6
$W + \mathrm{jets}(\mu)$	81 ± 40	19 ± 9	63 ± 30	17 ± 8
Higgs	125 ± 25	53 ± 11	75 ± 22	22 ± 7
Total bkg.	1179 ± 123	643 ± 73	1954 ± 168	749 ± 133
W^+W^- + Total bkg.	4857 ± 302	2124 ± 134	3128 ± 217	1162 ± 142
Data	4847	2233	3114	1198

$$\sigma_{W^+W^-} = 60.1 \pm 0.9\,(\mathrm{stat.}) \pm 3.2\,(\mathrm{exp.}) \pm 3.1\,(\mathrm{th.}) \pm 1.6\,(\mathrm{lum.})\,\mathrm{pb}.$$

to be compared with the theore $59.8^{+2.2\%}_{-1.9\%}$ pb

A bit of history ...

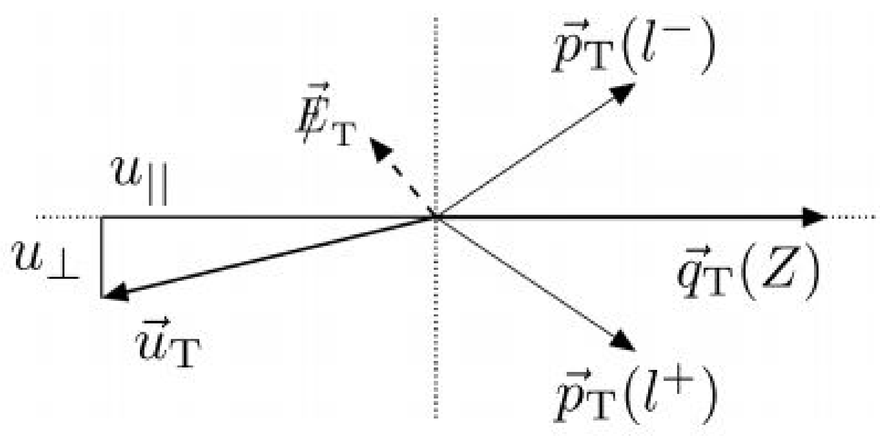
Analysis in 0-jet category	WW cross section measurement (pb)
Previous publication	69.9 ± 7.0
Full 19.4 fb^{-1} data sample	67.4 ± 5.6
Simulated signal ptWW reweighted	65.3 ± 5.6
Switched MC from MADGRAPH to POWHEG	63.3 ± 5.6
New result using DF and SF together	61.3 ± 5.4
Statistical combination of DF and SF	60.1 ± 5.2

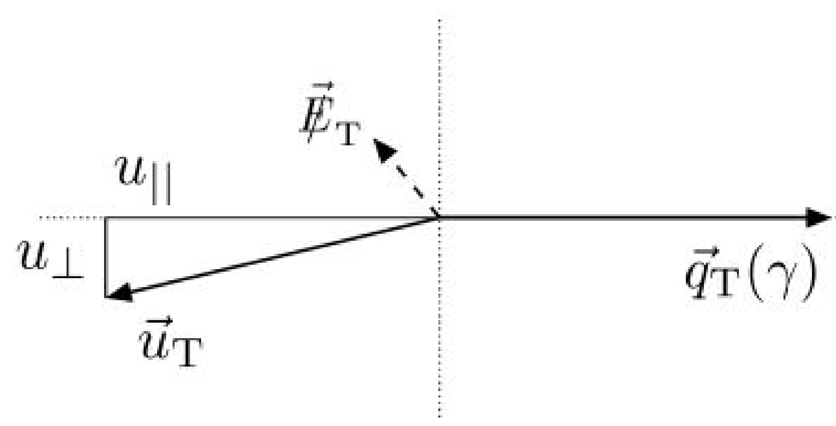
MET performance

MET

CMS-PAS-JME-12-002

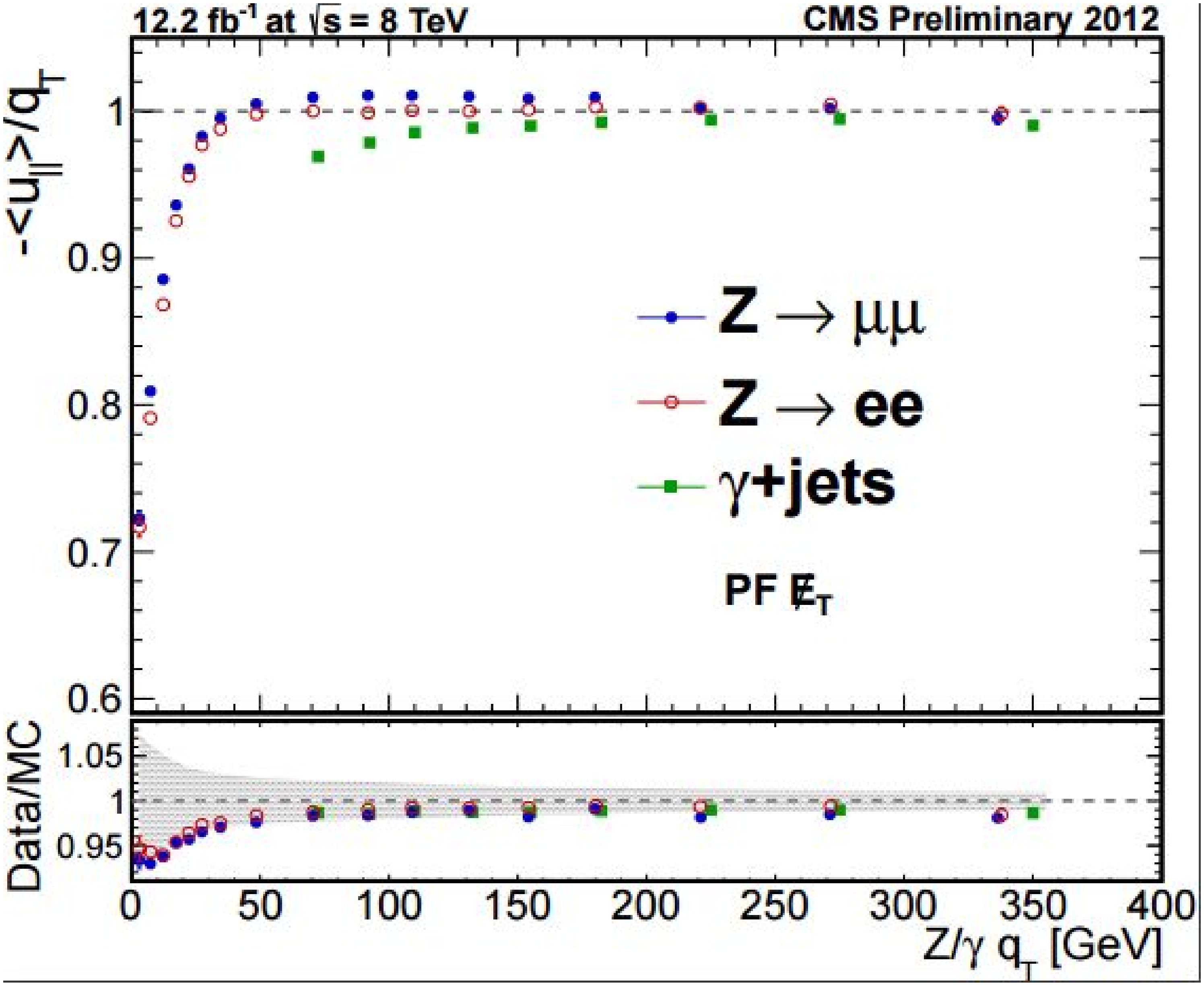
- In Z → ll and photon events we can **probe the detector response to the global hadronic system** and measure the **scale** and **resolution** of Missing Et
- Comparing the transverse momentum of the **well measured and well understood vector boson** to that of the **hadronic recoil system**.





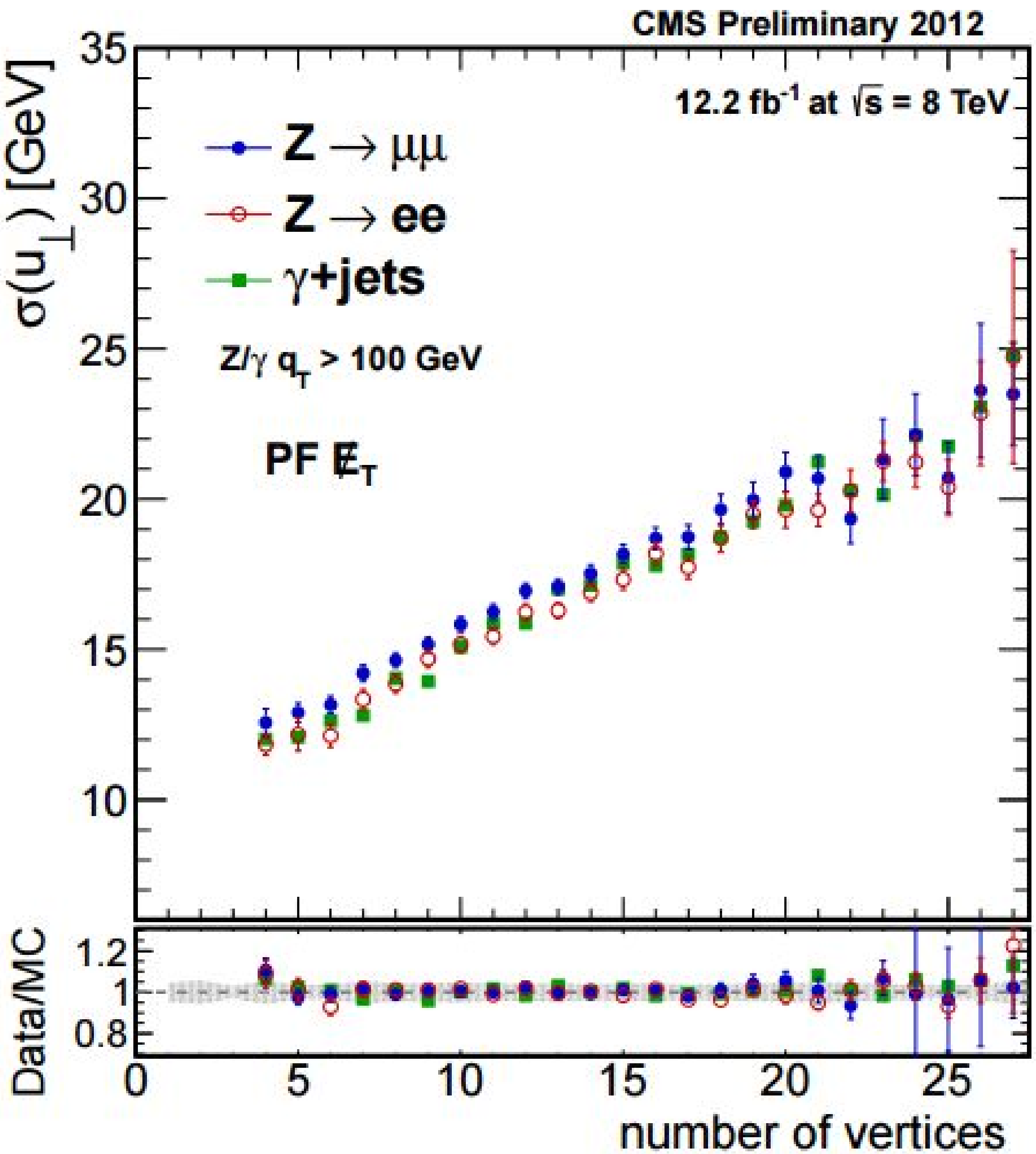
The hadronic recoil **can be projected onto the boson axis**: parallel (**u||**) and perpendicular (**u⊥**)

Scale



12.2 fb^{-1} at $\sqrt{s}$ = 8 TeV
CMS Preliminary 2012
$-\langle u_{||} \rangle / q_T$
1
0.9
0.8
0.7
0.6
$Z \rightarrow \mu\mu$
$Z \rightarrow ee$
γ+jets
PF $\not{E}_T$
Data/MC
1.05
1
0.95
0
50
100
150
200
250
300
350
400
Z/γ q_T [GeV]

Resolution



CMS Preliminary 2012
12.2 fb^{-1} at $\sqrt{s}$ = 8 TeV
Z → μμ
Z → ee
γ+jets
Z/γ q_T > 100 GeV
PF $E\!\!\!/_T$
σ($u_\perp$) [GeV]
Data/MC
number of vertices
35
30
25
20
15
10
1.2
1
0.8
0
5
10
15
20
25

Conclusions

- We measured the pp → WW cross section in the **fully leptonic channel**.
- We use the complete $\sqrt{s} = 8$ TeV data set corresponding to an **integrated luminosity of 19.4 fb−1** .
- We found $\sigma = 60.2 \pm 0.9$ (stat.) ± 4.5 (syst.) ± 1.6 (lum.) pb. **in agreement with the SM prediction** at NNLO of 59.84 +2.2% −1.9% pb.
- This is the **most precise** pp → WW production cross section measurement **at $\sqrt{s}$ = 8 TeV**.
- Result already **submitted to EPJC**
- Updated result soon at 13 TeV!
- **MET performance studies at 13 TeV to be public soon**