From Van der Meer scans to precision cross section determination: the CMS luminosity and W/Z cross section measurements at √s=8 TeV

M. Zanetti (MIT)

on behalf of the CMS collaboration

Overview

$$N = L\sigma$$

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$$L = \int \mathcal{L} dt = \int \frac{R_L(t)}{\sigma_{vis}} dt \qquad \sigma = \sigma_T(\sqrt{s}) A \epsilon_{trig,rec,sel}$$

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The target physics quantity (inclusive)

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$$N = L\sigma$$

$$L = \int \mathcal{L}dt = \int \frac{R_L(t)}{\sigma_{vis}}dt$$

$$\sigma = \sigma_T(\sqrt{s})A\epsilon_{trig,rec,sel}$$

Luminosity analysis: convert rates into instantaneous luminosity by means of *constant* calibration factor

Overview

$$N = L\sigma$$

$$L = \int \mathcal{L} dt = \int \frac{R_L(t)}{\sigma_{vis}} dt \qquad \sigma = \sigma_T(\sqrt{s}) A\epsilon_{trig,rec,sel}$$

Absolute calibration:
Van der Meer scan

Overview

$$N = L\sigma + N_{bkgr}$$

$$L = \int \mathcal{L} dt = \int \frac{R_L(t)}{\sigma_{vis}} dt$$

$$\sigma = \sigma_T(\sqrt{s}) A\epsilon_{trig,rec,sel}$$

Cross section analysis: extract the signal and estimate acceptance and efficiencies

Overview

$$N = L\sigma + N_{bkgr}$$

$$L = \int \mathcal{L} dt = \int \frac{R_L(t)}{\sigma_{vis}} dt$$

$$\sigma = \sigma_T(\sqrt{s}) A \epsilon_{trig,rec,sel}$$

The target physics quantity (fiducial)

Cross section analysis: extract the signal and estimate the efficiencies

Overview

$$N = L\sigma$$

$$L = \int \mathcal{L}dt = \int \frac{R_L(t)}{\sigma_{vis}}dt \qquad \sigma = \sigma_T(\sqrt{s})A\epsilon_{trig,rec,sel}$$

Wenninger, J., *"Energy Calibration of the LHC Beams at 4 TeV"*
CERN-ATS-2013-040

$$P_{\mathrm{4TeV}} = 3988 \pm 5\,(\mathrm{stat}) \pm 26\,(\mathrm{syst})\ \mathrm{GeV/c}$$

Luminosity calibration

(determination of σ_{vis})

Disclaimer / acknowledgements

Most of the aspects discussed in the following have profited from the work and the collective effort of the “*Bunch Currents Normalization*” and “*LHC Luminosity Calibration and Monitor*” working groups that gathered experts from the machine and the LHC experiments

Measuring luminosity

- The (per BX) instantaneous lumi is a complicated function of beam parameters:

$$L = \upsilon N_1 N_2 \sqrt{(\vec{v}_1 - \vec{v}_2)^2 - \frac{(\vec{v}_1 \times \vec{v}_2)^2}{c^2}} \int \rho_1^{lab}(\vec{r} - \Delta\vec{r}, t)\,\rho_2^{lab}(\vec{r}, t)\, d^3\vec{r}\, dt \xrightarrow[\text{Gaussian beams}]{} L = \frac{\upsilon N_1 N_2}{2\pi\sqrt{\left(\sigma_{1,x}^2 + \sigma_{2,x}^2\right)}\sqrt{\left(\sigma_{1,y}^2 + \sigma_{2,y}^2\right)}}$$

- Beam measurements during physics runs not accurate enough (~10-20%)
- Exploit ***R=Lσ*** relation:
  - σ from a very accurately predicted physics process that can be very well isolated experimentally (physics candles)
    - Bhabha scattering at LEP
    - Z→$\mu\mu$ at LHC (hum, wait a moment..)
  - Perform dedicated experiment to measure L from beam parameters ➔ Van der Meer scan
- Note that in both cases σ is required to be constant!

Measuring beam parameters

- Goal is to determine luminosity from beam parameters
  - Beam current measured by dedicated beam instrumentation
    - DC Beam Current Transformer: total circulating charges
    - Fast Beam Current Transformer: fraction of charge in each bunch
  - “Affective area” assessed from rate as a function of beam separation
- Van der Meer technique, i.e. determine “effective height” of the beams (Σ):

$$R(\Delta) \propto \int \rho_1(x)\rho_2(x-\Delta)dx \quad \Rightarrow \quad \Sigma = \frac{\int R(\Delta)d\Delta}{R_0}$$

  - With F(Δ) implementing the dependency on separation, the luminosity is defined as:

$$\mathcal{L}(\Delta_x, \Delta_y) = \frac{\nu N_1 N_2}{2\pi\Sigma_x\Sigma_y}F(\Delta_x, \Delta_y) \quad \Rightarrow \quad \Sigma_x\Sigma_y = \frac{\int F(\Delta_x, 0)d\Delta_x \int F(0, \Delta_y)d\Delta_y}{F(0,0)}$$

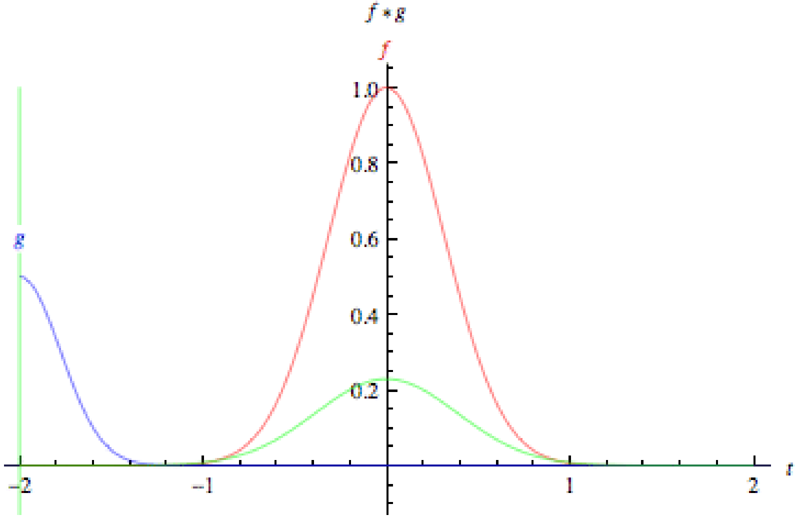
Van der Meer Scan

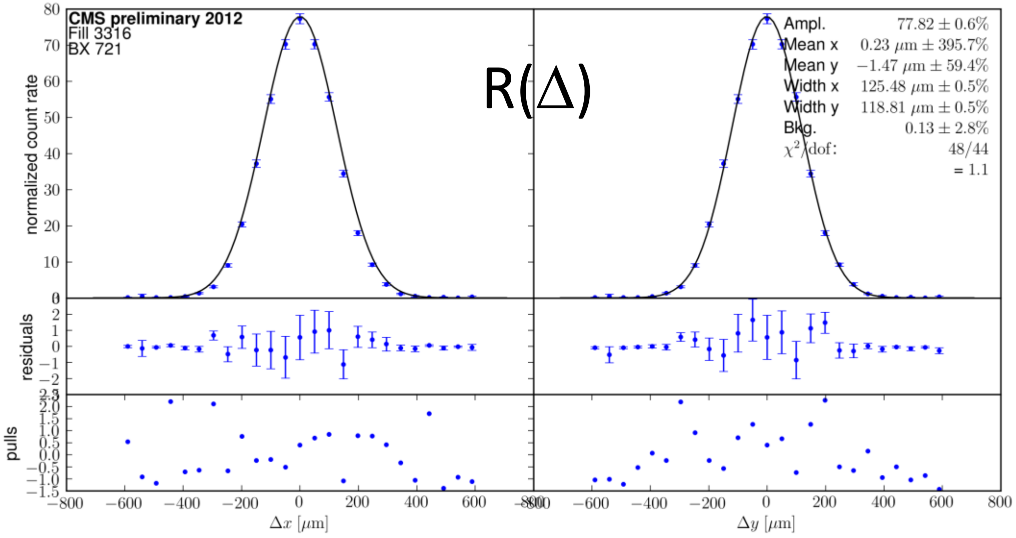
- Assuming factorizable gaussian for the beam density function (not too bad as approximation)

$$\rho(x,y) = \rho(x)\rho(y) \propto \exp(-\frac{x^2}{2\sigma_x^2})\exp(-\frac{x^2}{2\sigma_y^2}) \Rightarrow F(\Delta_x,\Delta_y) \propto \exp(-\frac{\Delta_x^2}{2\Sigma_x^2})\exp(-\frac{\Delta_y^2}{2\Sigma_y^2})$$

- The resulting "effective area" is then just:

$$\Sigma_x\Sigma_y = \sqrt{\sigma_{x,1}^2+\sigma_{x,2}^2}\sqrt{\sigma_{y,1}^2+\sigma_{y,2}^2}$$

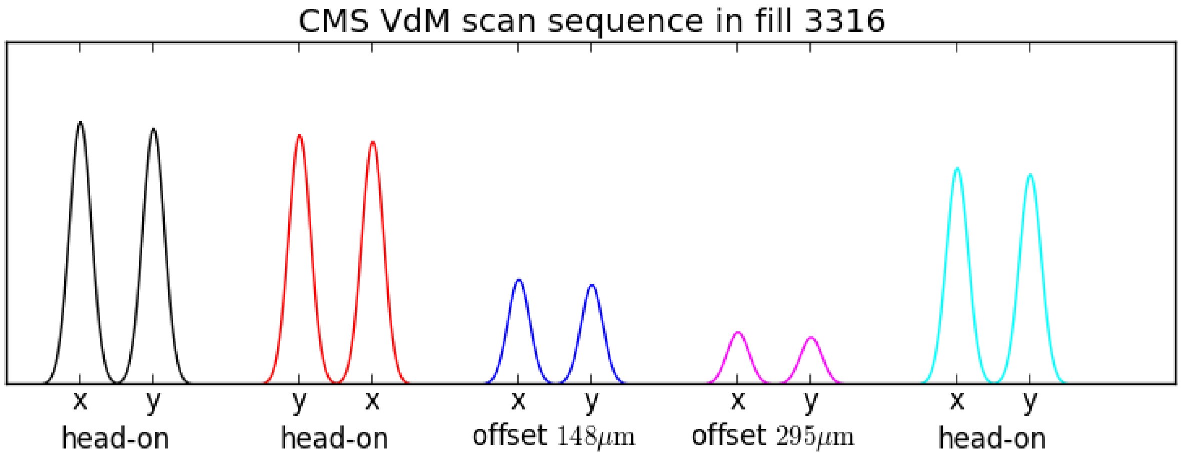




R(Δ)

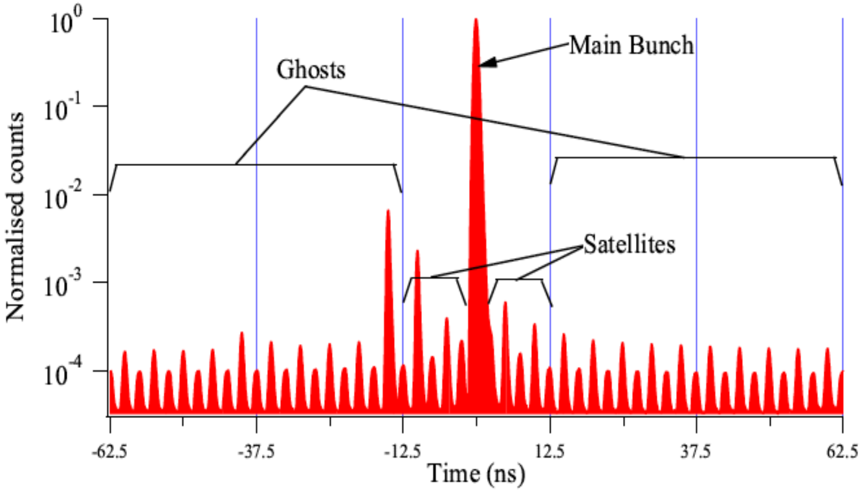
Van der Meer Scans at LHC

- Scan the beams horizontally and vertically
  - In steps of half beam width, ~25 steps, ~30 sec per step,
- Dedicated beam/machine set up (time consuming!)
  - Reduced number of bunches, reduced bunch intensity
  - Larger β^*, no crossing angle
- Conditions further and further optimized
  - Excellent results from last scan at $\sqrt{s}$=8TeV, Nov. 2012
    - H. Bartosik, G. Rumolo, CERN-ACC-NOTE-2013-0008
  - Aim at maximize validity of assumptions (factorizability and Gaussian shape)



Bunch charge

- Scale of current measurement:
  - Initially (2010), main source on uncertainty (~10%).
  - Tremendous improvements, DC BCT scale known at ~0.3%
- Bunch population:
  - O(0.1%) accuracy achieved by Fast BCT and ATLAS BPTX



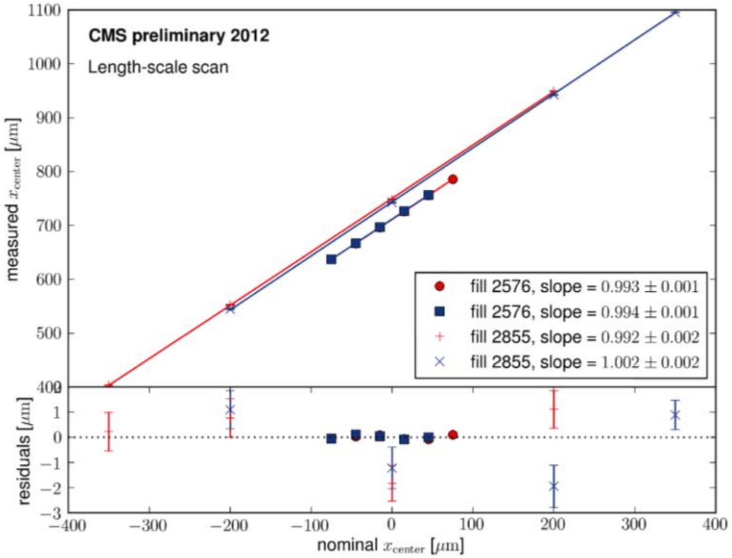
- Ghosts (charges outside main bunches) and satellites (charges outside main bucket):
  - Whatever contributes to BCT measurements but not to visible rate needs to be subtracted:

$$N^j(t) = N^j_{FBCT} \frac{N_{DC}(1 - f_{ghost})}{\sum_j N^j_{FBCT}} (1 - f^j_{sat.})$$

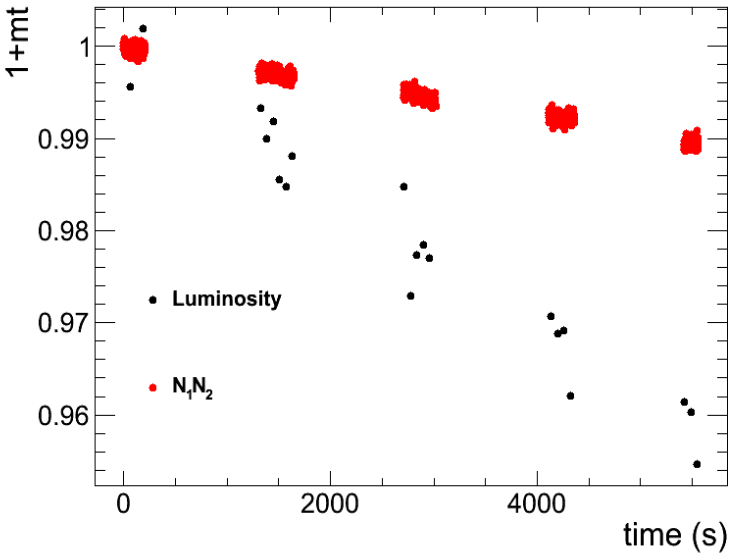
  - Spurious charges measured by experiments (e.g. LHCb SMOG, calorimetry timing) and by Longitudinal Density Monitor

Corrections to VdM analysis

- Length scale
  - Value of the separation derived from currents in the corrector magnets
  - This is calibrated against central tracking system
  - Compare luminous region information (vertices distribution) versus nominal sep.

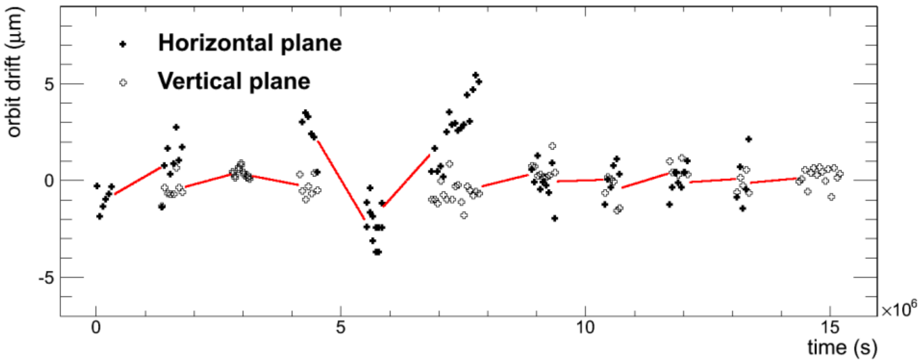


- Emittance growth
  - Beams size are known to increase in size during the fill.
  - Effect is sizable during the ~30 minutes
  - Bias almost negligible if emittance grows linearly with time and if measurement are made in between X and Y scans

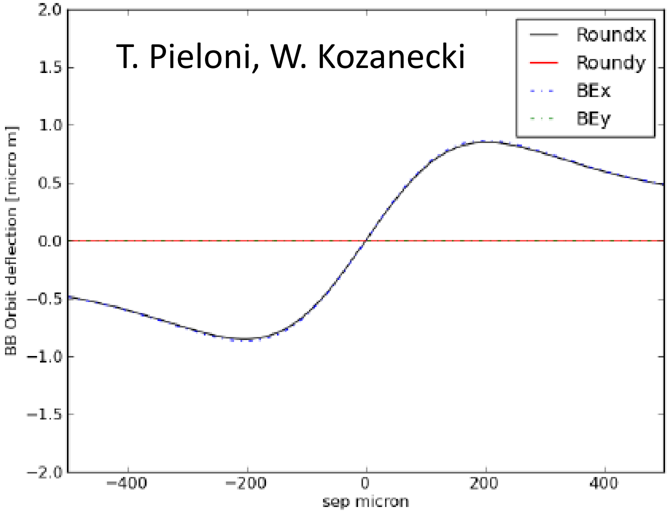


Corrections to VdM analysis

- Orbit drift
  - The beams can slowly drift in the transverse plane; effect is typically small but can be harmful in some cases
  - Drift of the orbit estimated by BPM measurements taken between scans and extrapolated to IP

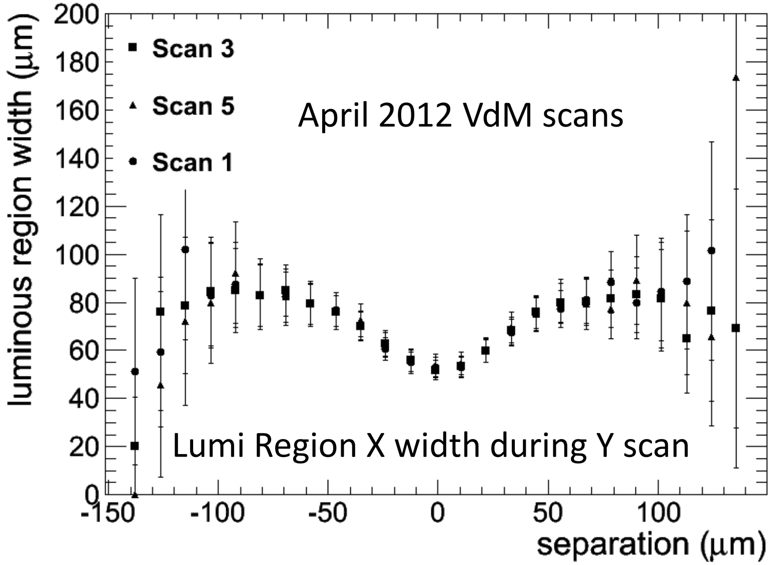


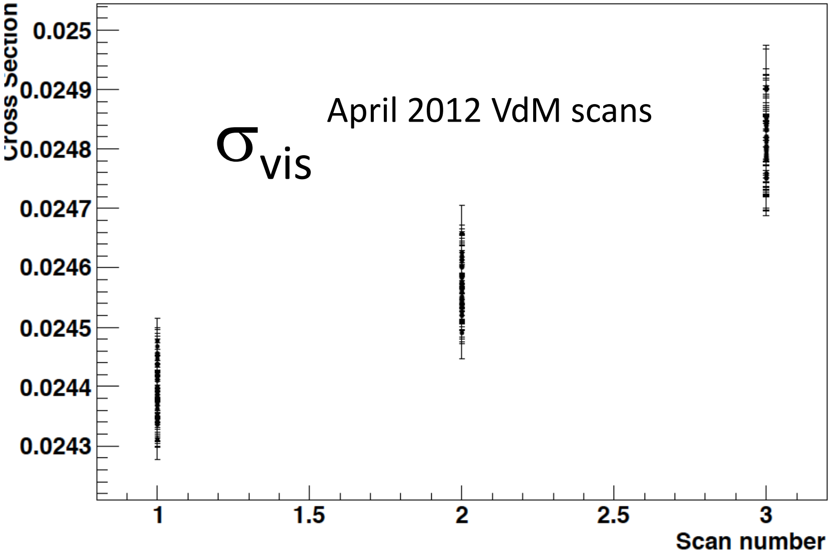
- Beam-beam effects:
  - Dipolar kick (beam-beam deflection):
    - Repulsive force deflects beams affecting nominal separation
    - depends on the separation itself, the beam width and the current
  - Quadrupolar (de)focusing (dynamic β):
    - Effective beam width modified depending on the separation
    - Peak luminosity (rate) affected


T. Pieloni, W. Kozanecki

Gaussian and Factorizable?

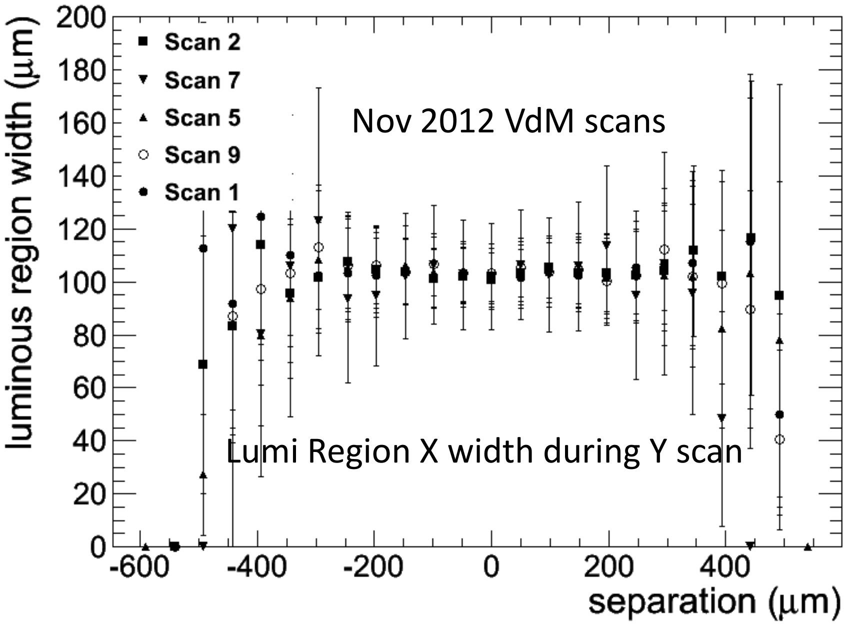
- It is convenient to take the assumption that the beam density functions can be factorized
  - E.g. the scan is performed separately along X and Y
- The Van der Meer method works for whatever shape F(Δ_x,Δ_x), but that shape needs to be known.
  - Best would be to deal with (single) gaussian distribution
- Several observations indicating that is not the case if no adequate preparation of the beam/machine setup
  - Luminous region behavior, scan to scan variation of calibration

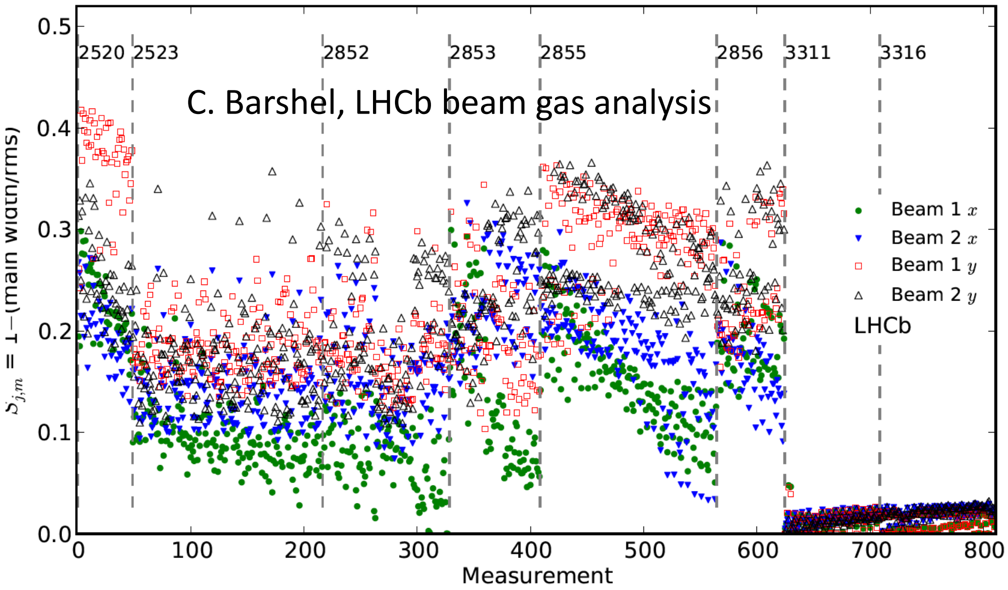




Gaussian and Factorizable?

- If beams/machine(s) are prepared such that densities are good single gaussian (Nov 2012), non-linearity and non-factorizability effects are very much reduced





- The exact functional form is however still unknown ➔ major source of uncertainty
  - A full bias study (based on Monte Carlo) is needed

Luminosity integration

Ideal Luminometer

- As for any other cross section:

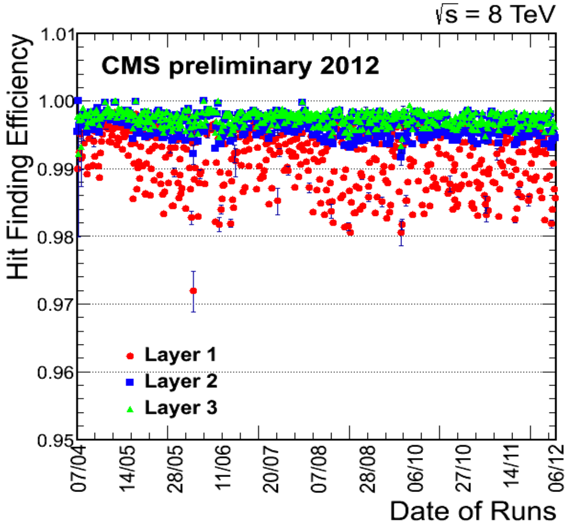
$$\sigma_{vis} = \sigma_T(\sqrt{s})A(..)\epsilon(..)$$

- Acceptance and efficiencies may depend on many things:
  - Acceptance: detector conditions (alive channels), beam positions, etc.
  - Efficiency: detector setup, pileup, filling scheme, etc.

- A perfect luminometer is a device that measures rates with constant acceptance and efficiency
- Any real implementation requires corrections
  - What to use as a reference?

CMS Luminometers

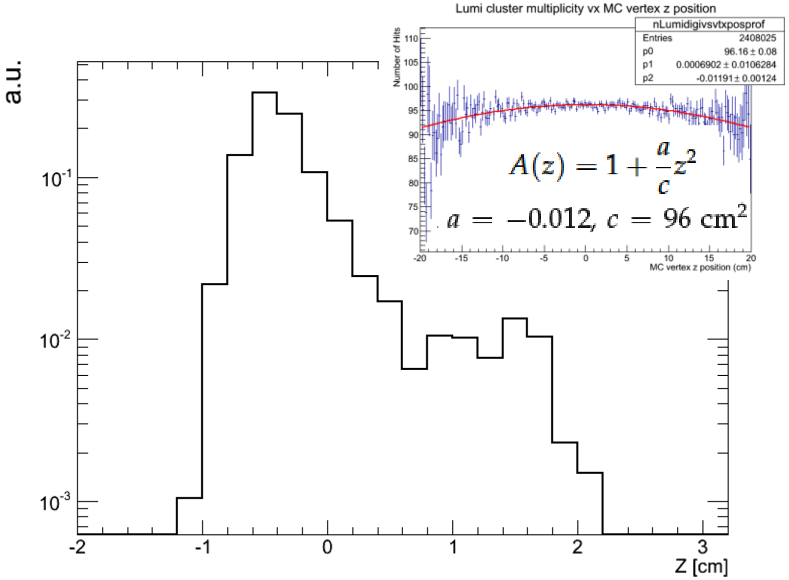
- Forward Hadronic calorimeter (HF) equipped with dedicated acquisition system used for online measurements
  - Non perfect linear response vs lumi
- Silicon Pixel detector used offline, providing the most stable luminosity measurement
  - 66M channels, 96.3% always alive, <0.1% occupancy at 10^{34} $cm^{-2}s^{-1}$
  - Luminosity from number of pixel clusters, Pixel Clusters Counting (PCC)
    - Dedicated high rate data stream triggering on Zero Bias
  - Linear response till very high pileup (1% of shared clusters at μ=200)

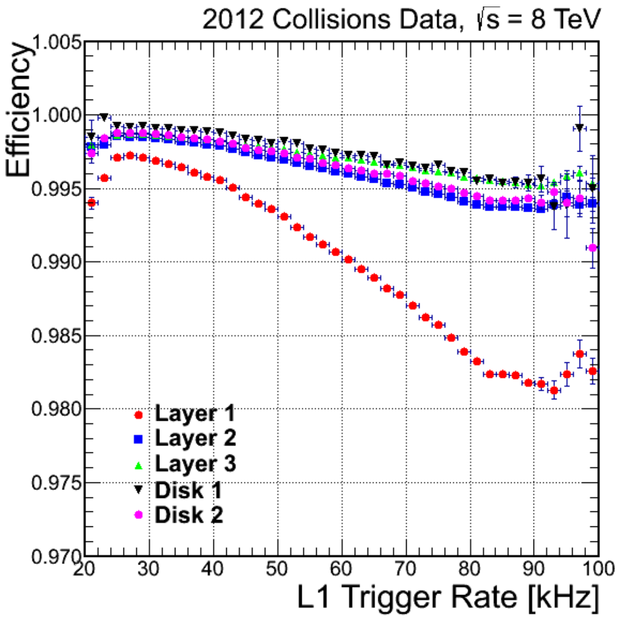


PCC: Dependencies

- Acceptance:
  - Restrict set of channels to those always alive throughout the running period
  - Beam jitter small enough not to affect geometrical acceptance

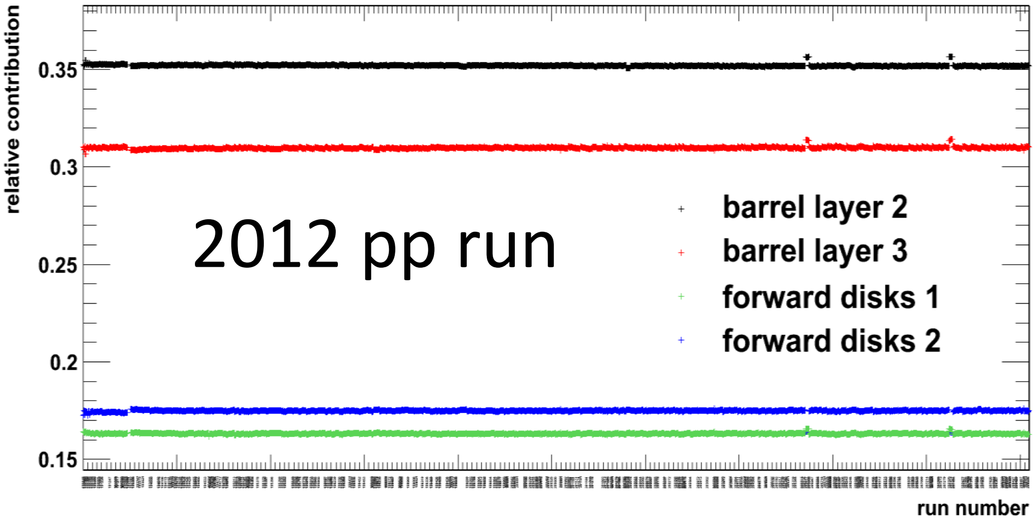
- Efficiencies:
  - Online and offline threshold such that signal efficiency insensitive to recalibration (needed to compensate effects of radiation dose)
  - Dynamic inefficiencies: filling up of the read-out buffer➔ busy state for DAQ➔ loss of efficiency. Dependency on trigger rate ⇔ luminosity

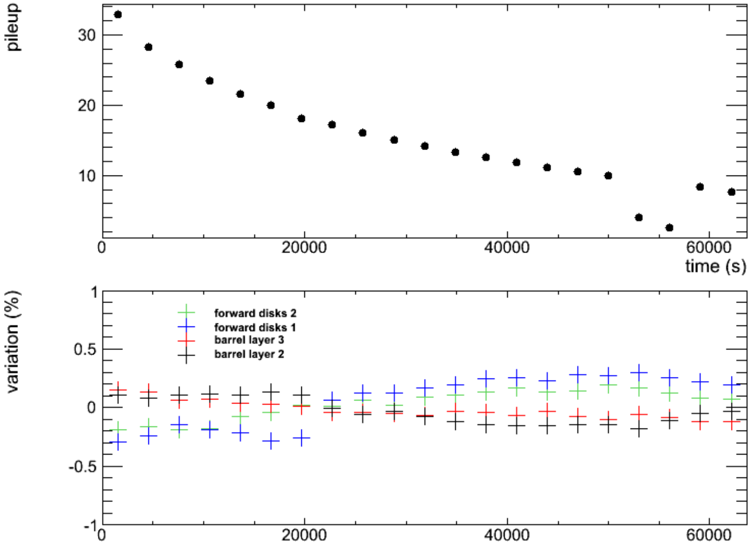




PCC: Stability check

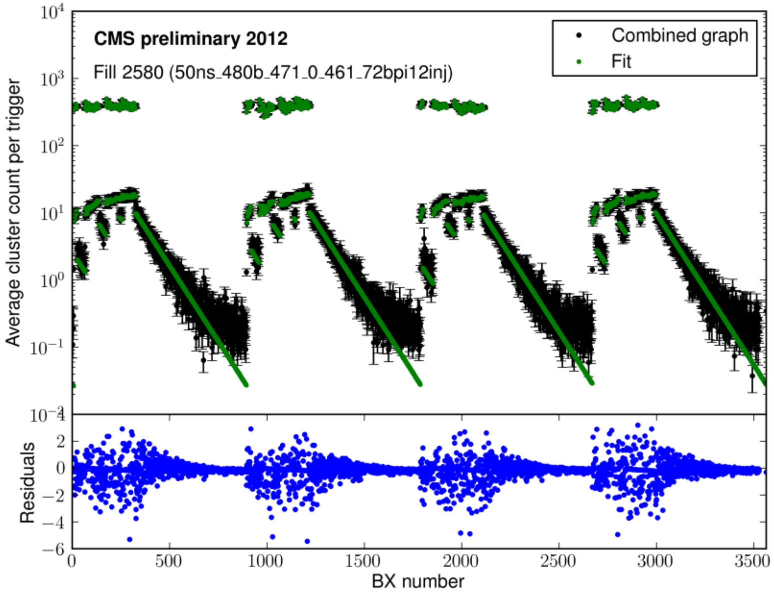
- Being the reference in terms of stability, it can only be compared with itself
- The figure of merit is relative contributions of detector components are compared
  - Fractions are stable at the 0.5% level
  - Some collective effects can be hidden (rather unlikely)
- Alternatively compare to Z->μμ rates (study ongoing)



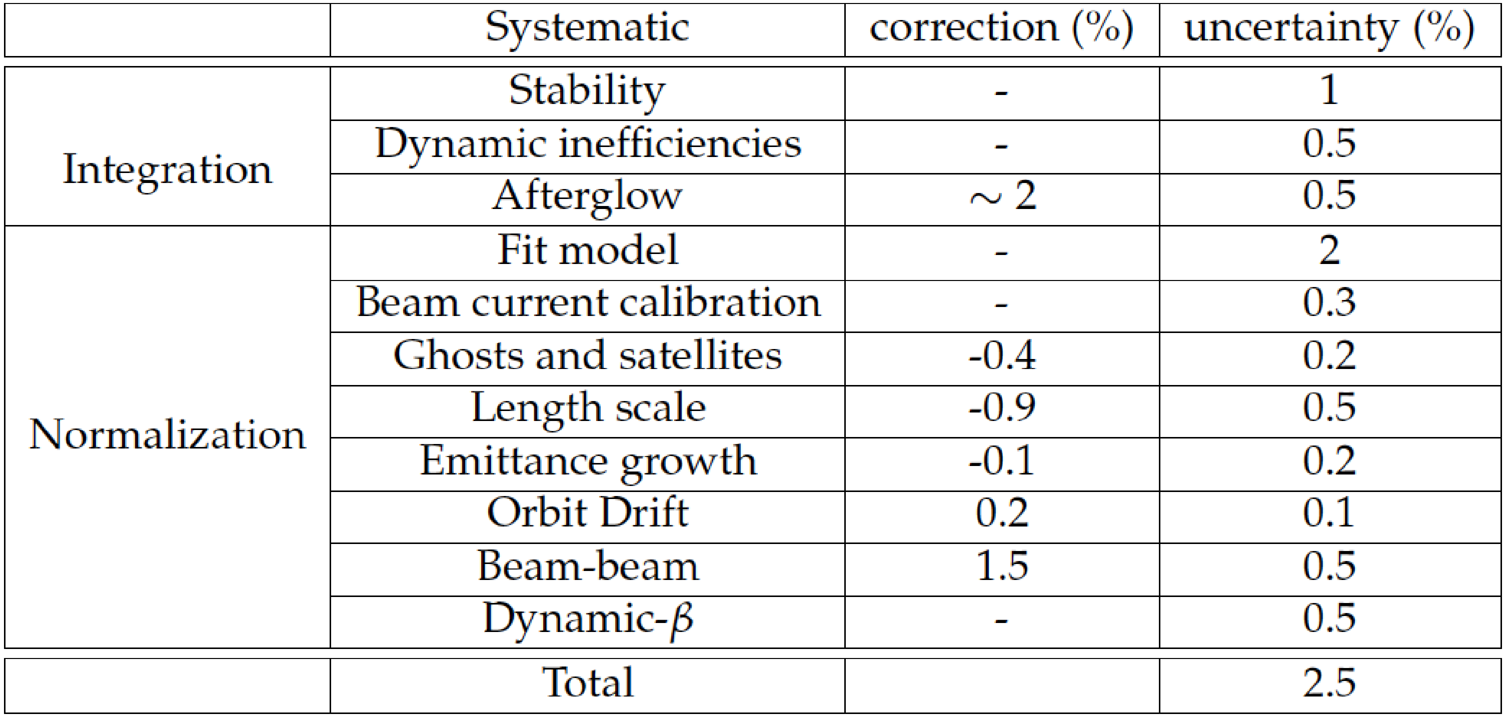


PCC: Afterglow

- “Out of time response” featured by the cluster counting method:
  - Pulse shape: not relevant for 50 ns scheme, will it be at 25 ns?
  - Mild activation of the surrounding material
- Try to model and estimate the single bunch response assuming an exponential decay
  - Does not depend on the filling scheme
- Small contribution which however sums up to a non negligible component in highly populated filling schemes, ~2% effect



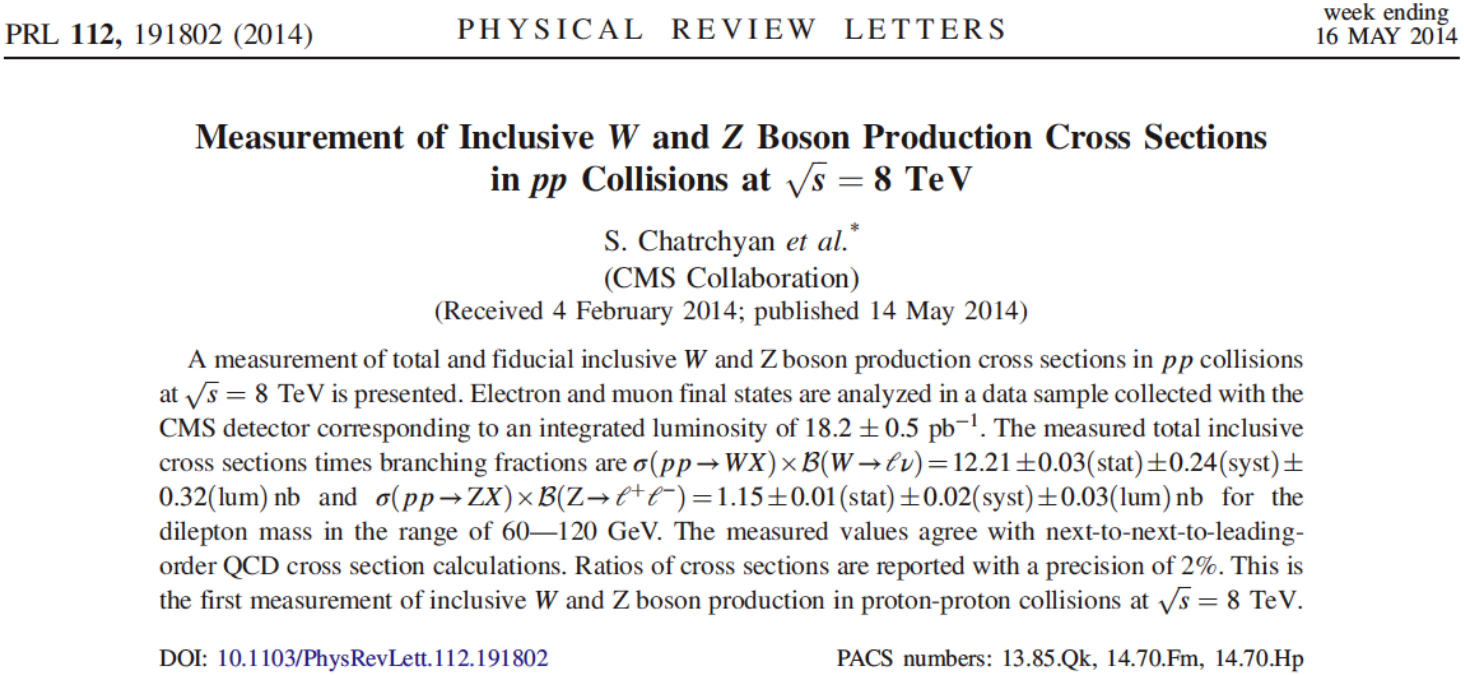
Luminosity Uncertainties



	Systematic	correction (%)	uncertainty (%)
Integration	Stability	-	1
	Dynamic inefficiencies	-	0.5
	Afterglow	~ 2	0.5
Normalization	Fit model	-	2
	Beam current calibration	-	0.3
	Ghosts and satellites	-0.4	0.2
	Length scale	-0.9	0.5
	Emittance growth	-0.1	0.2
	Orbit Drift	0.2	0.1
	Beam-beam	1.5	0.5
	Dynamic-β	-	0.5
	Total		2.5

Statistical error from rate profile fit, ~0.5%

W and Z cross section analysis



PRL **112,** 191802 (2014) PHYSICAL REVIEW LETTERS week ending 16 MAY 2014

Measurement of Inclusive *W* and *Z* Boson Production Cross Sections in *pp* Collisions at $\sqrt{s} = 8$ TeV

S. Chatrchyan *et al.*[*]
(CMS Collaboration)

(Received 4 February 2014; published 14 May 2014)

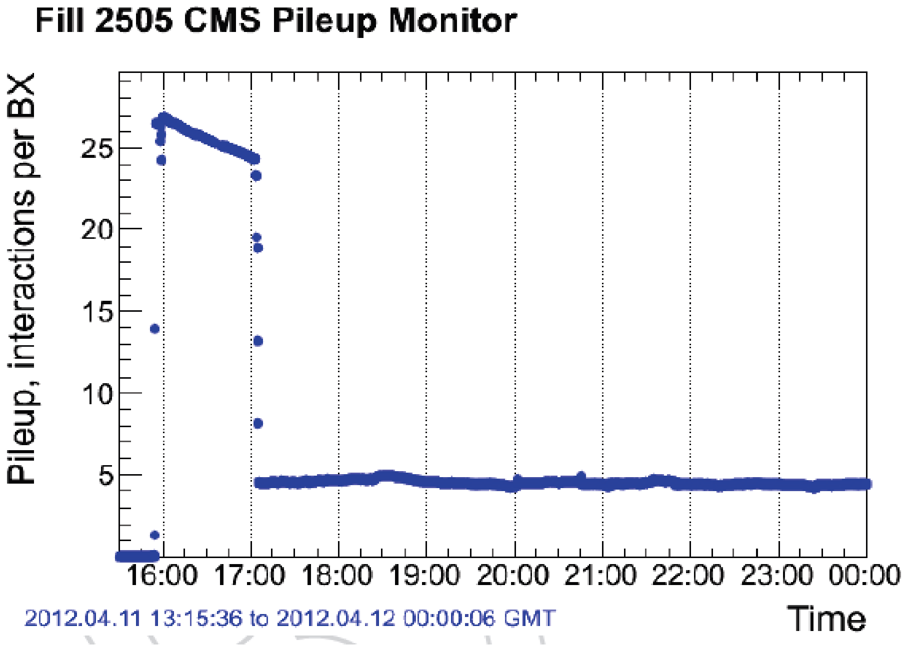
A measurement of total and fiducial inclusive *W* and Z boson production cross sections in *pp* collisions at $\sqrt{s} = 8$ TeV is presented. Electron and muon final states are analyzed in a data sample collected with the CMS detector corresponding to an integrated luminosity of $18.2 \pm 0.5\ \mathrm{pb}^{-1}$. The measured total inclusive cross sections times branching fractions are $\sigma(pp \rightarrow WX) \times \mathcal{B}(W \rightarrow \ell\nu) = 12.21 \pm 0.03(\mathrm{stat}) \pm 0.24(\mathrm{syst}) \pm 0.32(\mathrm{lum})$ nb and $\sigma(pp \rightarrow ZX) \times \mathcal{B}(Z \rightarrow \ell^+\ell^-) = 1.15 \pm 0.01(\mathrm{stat}) \pm 0.02(\mathrm{syst}) \pm 0.03(\mathrm{lum})$ nb for the dilepton mass in the range of 60—120 GeV. The measured values agree with next-to-next-to-leading-order QCD cross section calculations. Ratios of cross sections are reported with a precision of 2%. This is the first measurement of inclusive *W* and Z boson production in proton-proton collisions at $\sqrt{s} = 8$ TeV.

DOI: 10.1103/PhysRevLett.112.191802 PACS numbers: 13.85.Qk, 14.70.Fm, 14.70.Hp

Dedicated data taking

- One of the most important measurements in 2010 (7TeV, 35/pb)
- Run at 8 TeV in much harsher conditions (PU x10, $\mathcal{L}$ x30)
  - E.g. single lepton L1 trigger rate >>100kHz if same thresholds as in 2010
  - Larger uncertainties in modeling MET
- Analysis is systematically limited ➔ can tradeoff dataset size for better conditions
- Low Luminosity run yielding a dataset of ~20/pb:
  - During intensity ramp-up (minimizing loss of integrated luminosity), separate the beams and level pilup at ~5
  - Allow lowering L1 thresholds on single lepton p_T
  - Dedicated high rate HLT configuration (~300Hz for single lepton triggers)
- Basically identical analysis as in 2010 is allowed

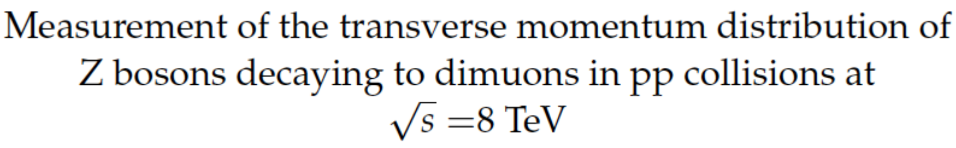
Dedicated data taking



LHC Fill	Inst. Lum. [$10^{32}\ cm^{-2}s^{-1}$]	Avg PU	# colliding bunches	Integr. Lum. [pb^{-1}]
2505	440	5	618	14.1
2509	620	5	807	5.8
2580	300	5	471	6.4

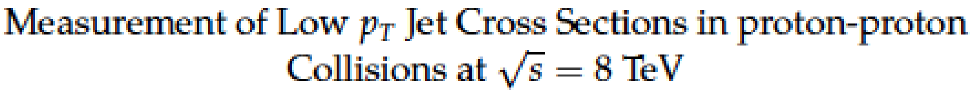
Dedicated data taking

Quite a useful dataset indeed!



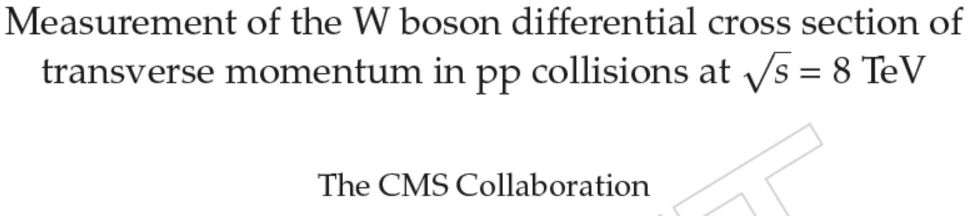
Measurement of the transverse momentum distribution of Z bosons decaying to dimuons in pp collisions at $\sqrt{s}$ =8 TeV

The CMS Collaboration



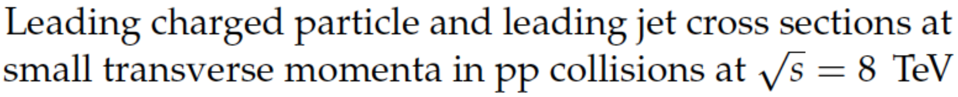
Measurement of Low p_T Jet Cross Sections in proton-proton Collisions at $\sqrt{s} = 8$ TeV

The CMS Collaboration



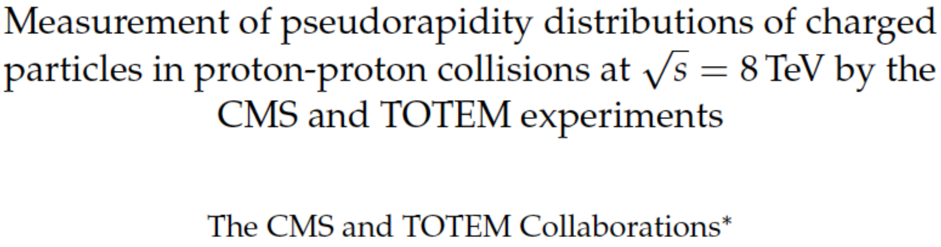
Measurement of the W boson differential cross section of transverse momentum in pp collisions at $\sqrt{s} = 8$ TeV

The CMS Collaboration



Leading charged particle and leading jet cross sections at small transverse momenta in pp collisions at $\sqrt{s} = 8$ TeV

The CMS Collaboration



Measurement of pseudorapidity distributions of charged particles in proton-proton collisions at $\sqrt{s} = 8$ TeV by the CMS and TOTEM experiments

The CMS and TOTEM Collaborations*

Selection

- Both W and Z analysis rely on single lepton triggers:

	HLT threshold (GeV) / rate (Hz)	L1 threshold (GeV) / rate (Hz)
electron	22 / 150	12 / 6000
muon	15 / 150	7 / 8000

- Offline selections
  - Electrons
    - p_T>25 GeV; $|\eta|$<1.44, 1.57<$|\eta|$<2.5
    - isolation: $\Sigma p_T^i < 0.15 p_T^{ele}$ (sum over Particle Flow candidates in cone ΔR=0.3)
  - Muons
    - p_T>25 GeV; $|\eta|$<2.1
    - isolation: $\Sigma p_T^i < 0.12 p_T^{\mu}$ (sum over Particle Flow candidates in cone ΔR=0.4)
  - W selections:
    - No MET cut, use MET to discriminate signal and background
    - MET as computed by Particle Flow reconstruction, modeled by recoil method
  - Z selections:
    - $60 < m_{ll} < 120$ GeV

Backgrounds

- Mainly affecting W analysis
- QCD:
  - Multi-jet or high Et photon (electron channels)
  - Assessed by fully data driven techniques
- Electroweak:
  - Drell-Yan (one lepton missing).
    - Veto applied ➔ small contribution
  - Leptonic decays of taus ($W\rightarrow\tau\nu$, $Z\rightarrow\tau\tau$)
    - p_T requirement on leptons suppresses it
  - Top and di-bosons (very small)
  - Use Monte Carlo to describe the shape, normalization bound to W cross section according to theoretical predictions

Acceptance

- Acceptance is estimated from simulation, corrected for efficiency
- No Monte Carlo generator combines optimal EWK and QCD predictions. Use POWHEG/CT10 for central value
- Other tools are used to estimate systematic uncertainties
  - Non perturbative QCD effects-> Resbos (NNLL)
  - Missing higher order QCD corrections -> scale variation with FEWZ
  - EWK corrections: HORACE
- PDF (dominant effect):
  - Uncertainty from nominal PDF set (CT10)

Efficiencies

- Main source of experimental uncertainties
- Tag&Probe method:
  - Tight id/isolation for the *tag* lepton that gives the Z mass together with a second lepton, the latter being an unbiased *probe* to the efficiency
  - Fit to the mass spectrum in case on non negligible background

$$\epsilon = \frac{N_{pass}}{N_{pass} + N_{fail}}$$

- Efficiency is factorized, each estimated w.r.t to previous selection
- (η,p_T) dependent scale factors are obtained and used to compensate differences between data and MC
- Systematic uncertainties computed by exploiting different models for signal and background
  - Signal: MC shape*Gaussian (default), Breit-Wigner*Cyrstal-Ball
  - Bkgr: Exponential (default), linear, ErrF*Exp, MC template from W+jets+QCD
  - N.B. statistic of the tag&probe sample affects systematic error

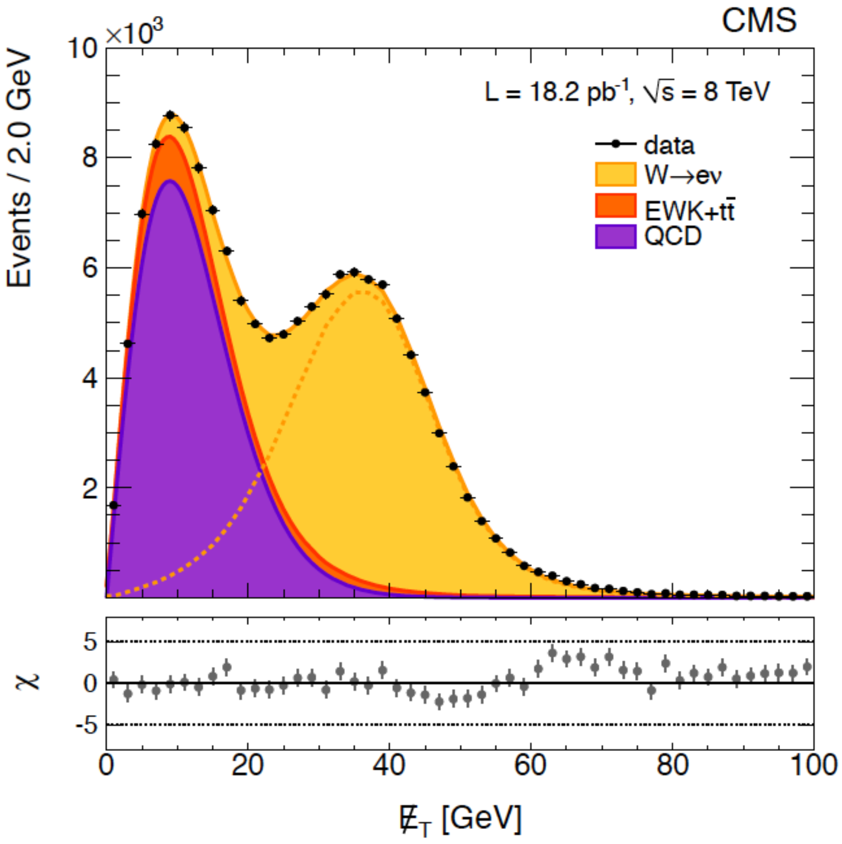
W Signal Extraction

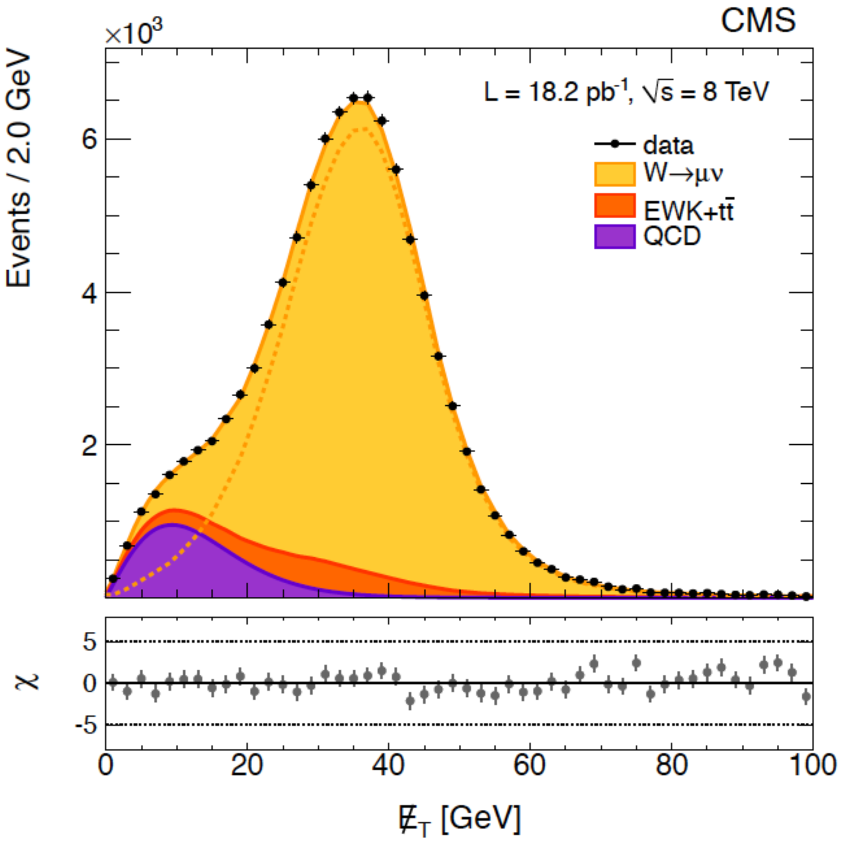
- Perform fit to MET distribution to distinguish signal over background
- Accurate MET model obtained by “recoil method”
  - Remove leptons from Z boson data and estimate recoil components (perpendicular and parallel to the boson pT) vs the boson pT
  - Data and MC are compared, corrections are applied to W simulation
- EWK bkgr at ~6% level for both *e* and μ
- QCD background is modeled by Rayleigh function

$$f_{\mathrm{QCD}}(E_{\mathrm{T}}^{\mathrm{miss}}) = E_{\mathrm{T}}^{\mathrm{miss}} \exp\left(-\frac{E_{\mathrm{T}}^{\mathrm{miss}2}}{2(\sigma_0 + \sigma_1 E_{\mathrm{T}}^{\mathrm{miss}})^2}\right)$$

  - Electrons (good S-B discrimination): σ_0 and σ_1 left free in the fit
  - Muons: simultaneous fit of signal and control region (inverse isolation) both constraining the tail parameter (σ_1)
  - Systematics assessed by adding an extra shape parameter (σ_2), and different definitions of control regions (muon isolation)

W Signal Extraction



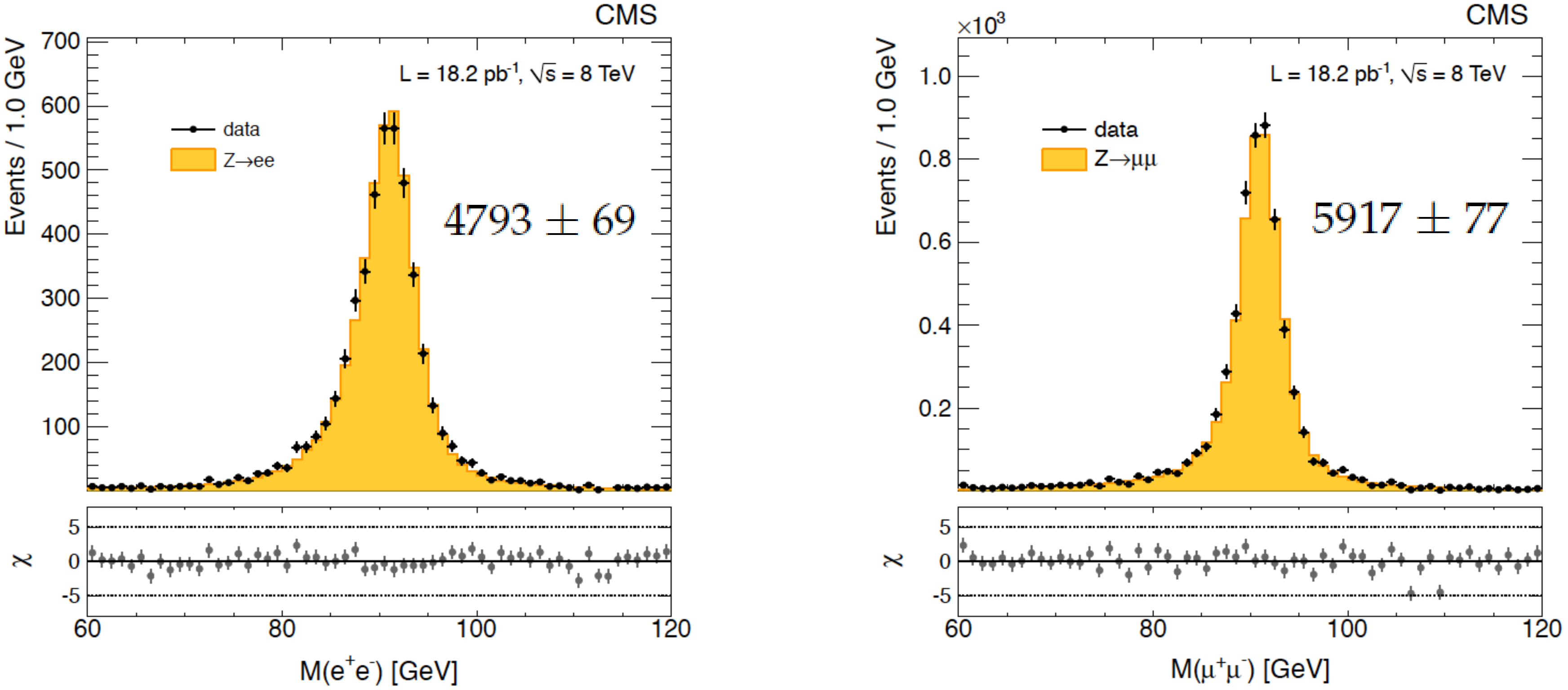


$W \to e\nu$	$W^+ \to e^+\nu$	$W^- \to e^-\overline{\nu}$
75051 ± 287	44194 ± 219	30857 ± 185

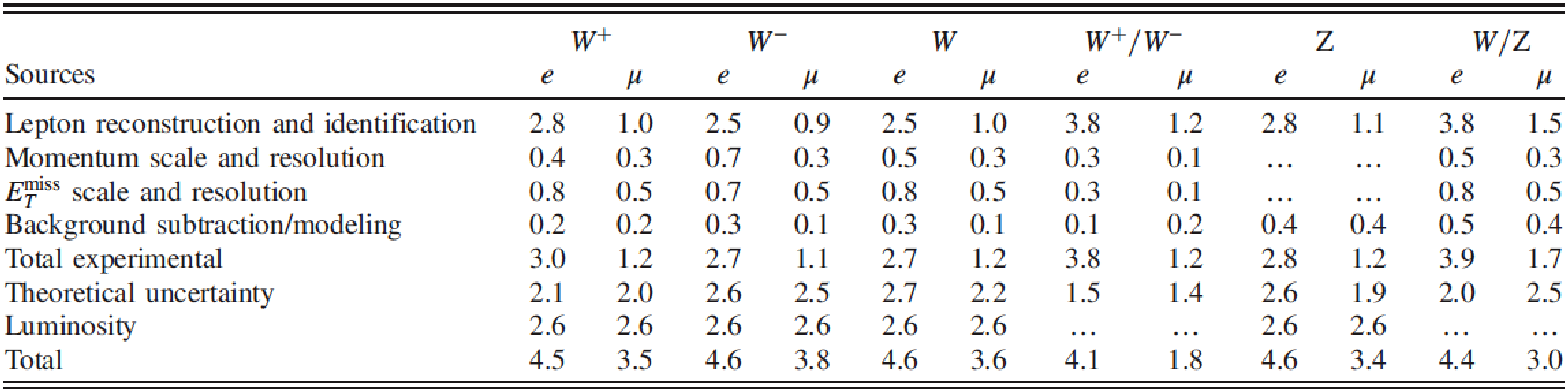
$W \to \mu\nu$	$W^+ \to \mu^+\nu$	$W^- \to \mu^-\overline{\nu}$
81473 ± 282	47637 ± 216	33836 ± 182

Z Signal Extraction

- Tiny background (0.4%), estimated from simulation
- Events yields computed by counting events in the mass window
- Systematics assessed by comparing simultaneous fit approach (cfr. 7 TeV analysis)



Systematic Uncertainties

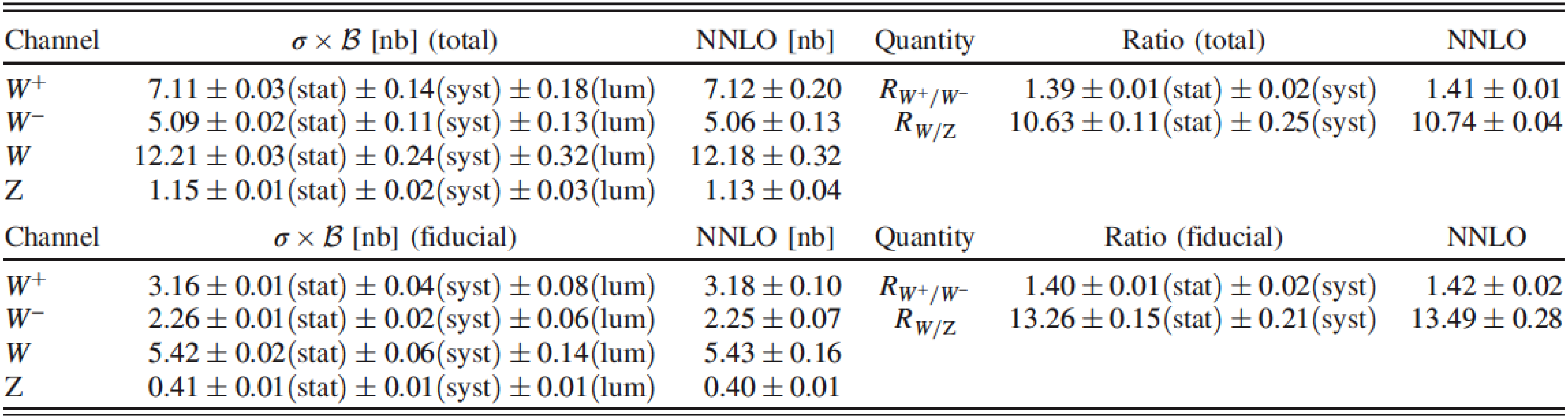


	W^+		W^-		W		W^+/W^-		Z		W/Z	
Sources	e	μ	e	μ	e	μ	e	μ	e	μ	e	μ
Lepton reconstruction and identification	2.8	1.0	2.5	0.9	2.5	1.0	3.8	1.2	2.8	1.1	3.8	1.5
Momentum scale and resolution	0.4	0.3	0.7	0.3	0.5	0.3	0.3	0.1	…	…	0.5	0.3
E_T^{miss} scale and resolution	0.8	0.5	0.7	0.5	0.8	0.5	0.3	0.1	…	…	0.8	0.5
Background subtraction/modeling	0.2	0.2	0.3	0.1	0.3	0.1	0.1	0.2	0.4	0.4	0.5	0.4
Total experimental	3.0	1.2	2.7	1.1	2.7	1.2	3.8	1.2	2.8	1.2	3.9	1.7
Theoretical uncertainty	2.1	2.0	2.6	2.5	2.7	2.2	1.5	1.4	2.6	1.9	2.0	2.5
Luminosity	2.6	2.6	2.6	2.6	2.6	2.6	…	…	2.6	2.6	…	…
Total	4.5	3.5	4.6	3.8	4.6	3.6	4.1	1.8	4.6	3.4	4.4	3.0

- Estimation of uncertainties follows closely what done in the 7 TeV analysis
- Some errors (most importantly luminosity) cancels in the ratios. Lepton efficiencies are however considered as uncorrelated (can be larger than individual measurements)

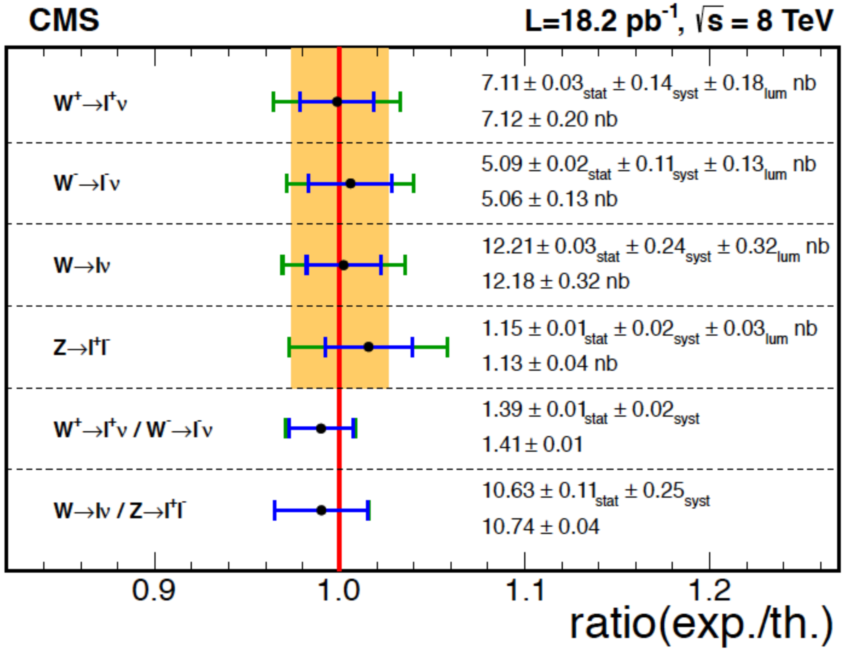
Results

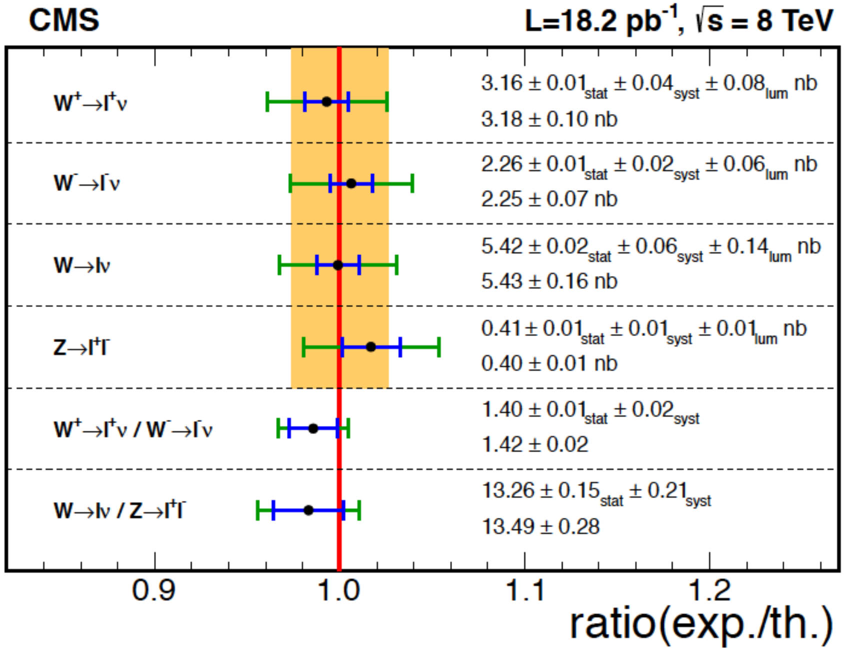
- Theoretical predictions from FEWZ and MSTW2008 PDF set
  - Uncertainties come from α_s, heavy quark masses, and missing high orders
- Results in muon and electron channel compatible (p=0.42) and thus combined assuming lepton universality
  - Correlated uncertainties for luminosity and acceptance, uncorrelated for experimental uncertainties
- Good data-MC agreement (not so good when HF based luminosity was used)



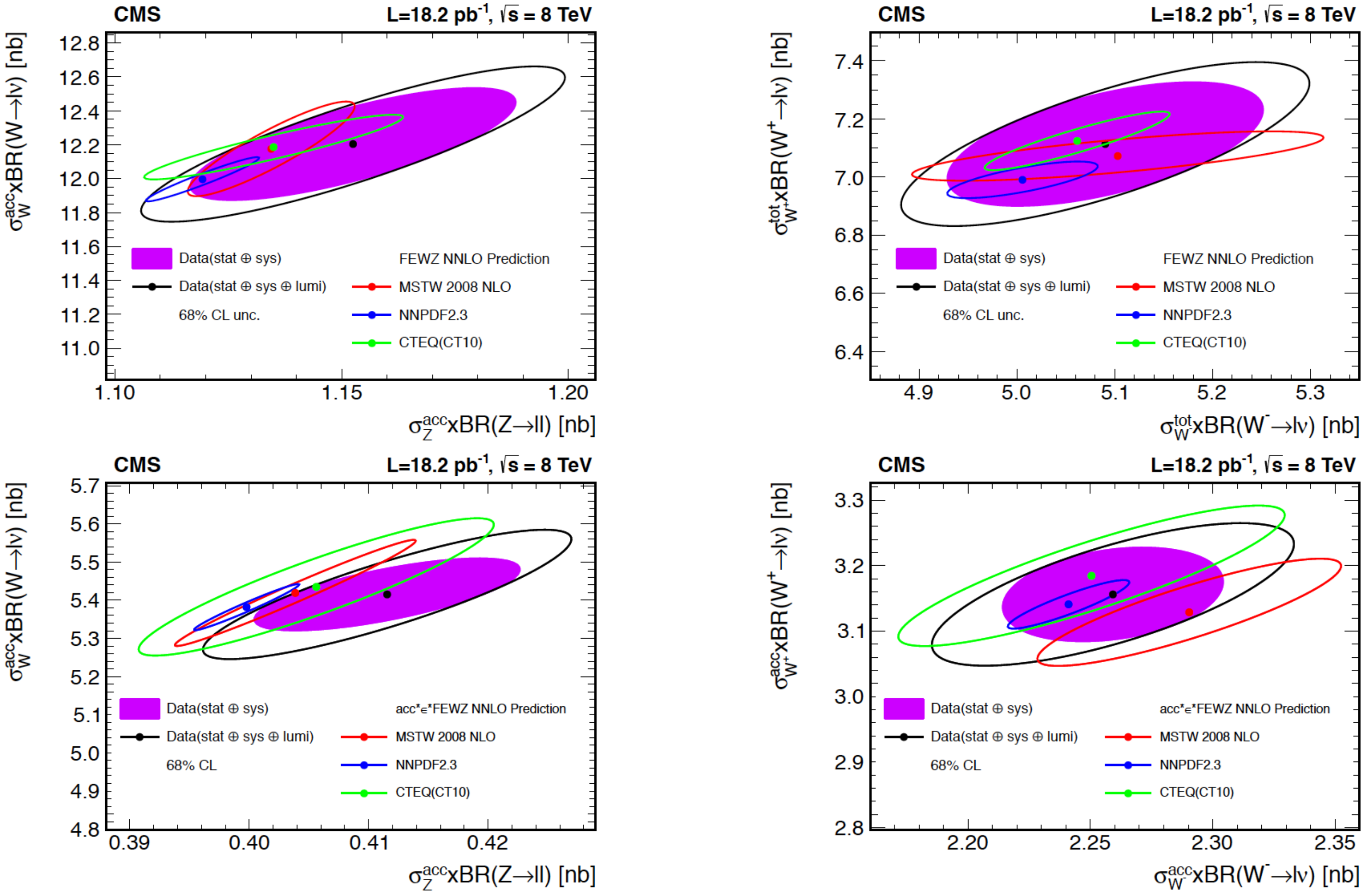
Channel	$\sigma \times \mathcal{B}$ [nb] (total)	NNLO [nb]	Quantity	Ratio (total)	NNLO
W^+	$7.11 \pm 0.03(\text{stat}) \pm 0.14(\text{syst}) \pm 0.18(\text{lum})$	7.12 ± 0.20	R_{W^+/W^-}	$1.39 \pm 0.01(\text{stat}) \pm 0.02(\text{syst})$	1.41 ± 0.01
W^-	$5.09 \pm 0.02(\text{stat}) \pm 0.11(\text{syst}) \pm 0.13(\text{lum})$	5.06 ± 0.13	$R_{W/Z}$	$10.63 \pm 0.11(\text{stat}) \pm 0.25(\text{syst})$	10.74 ± 0.04
W	$12.21 \pm 0.03(\text{stat}) \pm 0.24(\text{syst}) \pm 0.32(\text{lum})$	12.18 ± 0.32			
Z	$1.15 \pm 0.01(\text{stat}) \pm 0.02(\text{syst}) \pm 0.03(\text{lum})$	1.13 ± 0.04			
Channel	$\sigma \times \mathcal{B}$ [nb] (fiducial)	NNLO [nb]	Quantity	Ratio (fiducial)	NNLO
W^+	$3.16 \pm 0.01(\text{stat}) \pm 0.04(\text{syst}) \pm 0.08(\text{lum})$	3.18 ± 0.10	R_{W^+/W^-}	$1.40 \pm 0.01(\text{stat}) \pm 0.02(\text{syst})$	1.42 ± 0.02
W^-	$2.26 \pm 0.01(\text{stat}) \pm 0.02(\text{syst}) \pm 0.06(\text{lum})$	2.25 ± 0.07	$R_{W/Z}$	$13.26 \pm 0.15(\text{stat}) \pm 0.21(\text{syst})$	13.49 ± 0.28
W	$5.42 \pm 0.02(\text{stat}) \pm 0.06(\text{syst}) \pm 0.14(\text{lum})$	5.43 ± 0.16			
Z	$0.41 \pm 0.01(\text{stat}) \pm 0.01(\text{syst}) \pm 0.01(\text{lum})$	0.40 ± 0.01			

Results


CMS
L=18.2 pb^{-1}, $\sqrt{s}$ = 8 TeV
$W^+\to l^+\nu$
$7.11 \pm 0.03_{stat} \pm 0.14_{syst} \pm 0.18_{lum}$ nb
7.12 ± 0.20 nb
$W^-\to l^-\nu$
$5.09 \pm 0.02_{stat} \pm 0.11_{syst} \pm 0.13_{lum}$ nb
5.06 ± 0.13 nb
$W\to l\nu$
$12.21 \pm 0.03_{stat} \pm 0.24_{syst} \pm 0.32_{lum}$ nb
12.18 ± 0.32 nb
$Z\to l^+l^-$
$1.15 \pm 0.01_{stat} \pm 0.02_{syst} \pm 0.03_{lum}$ nb
1.13 ± 0.04 nb
$W^+\to l^+\nu$ / $W^-\to l^-\nu$
$1.39 \pm 0.01_{stat} \pm 0.02_{syst}$
1.41 ± 0.01
$W\to l\nu$ / $Z\to l^+l^-$
$10.63 \pm 0.11_{stat} \pm 0.25_{syst}$
10.74 ± 0.04
0.9
1.0
1.1
1.2
ratio(exp./th.)

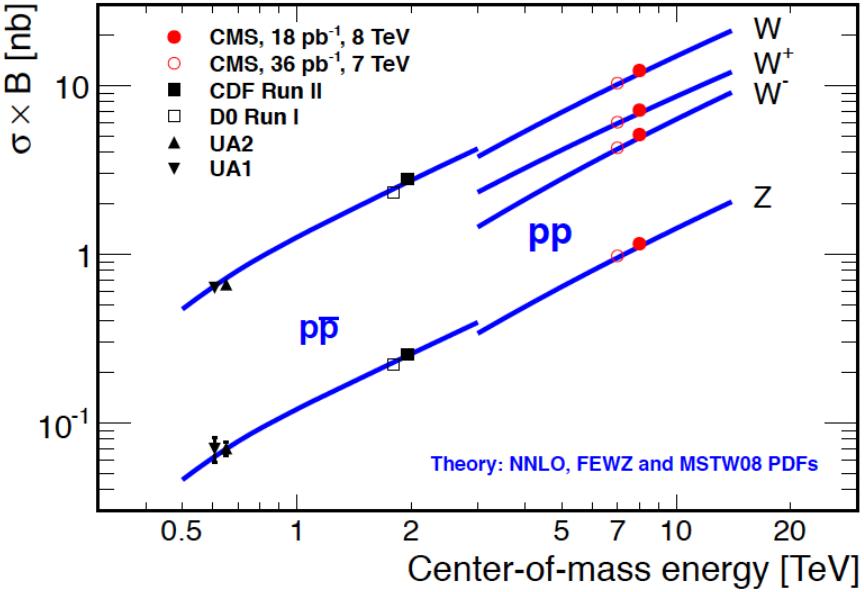

CMS
L=18.2 pb^{-1}, $\sqrt{s}$ = 8 TeV
$W^+\to l^+\nu$
$3.16 \pm 0.01_{stat} \pm 0.04_{syst} \pm 0.08_{lum}$ nb
3.18 ± 0.10 nb
$W^-\to l^-\nu$
$2.26 \pm 0.01_{stat} \pm 0.02_{syst} \pm 0.06_{lum}$ nb
2.25 ± 0.07 nb
$W\to l\nu$
$5.42 \pm 0.02_{stat} \pm 0.06_{syst} \pm 0.14_{lum}$ nb
5.43 ± 0.16 nb
$Z\to l^+l^-$
$0.41 \pm 0.01_{stat} \pm 0.01_{syst} \pm 0.01_{lum}$ nb
0.40 ± 0.01 nb
$W^+\to l^+\nu$ / $W^-\to l^-\nu$
$1.40 \pm 0.01_{stat} \pm 0.02_{syst}$
1.42 ± 0.02
$W\to l\nu$ / $Z\to l^+l^-$
$13.26 \pm 0.15_{stat} \pm 0.21_{syst}$
13.49 ± 0.28
0.9
1.0
1.1
1.2
ratio(exp./th.)

Results


CMS
L=18.2 pb^{-1}, $\sqrt{s}$ = 8 TeV
σ_W^{acc}xBR(W→lν) [nb]
σ_Z^{acc}xBR(Z→ll) [nb]
$\sigma_{W^+}^{tot}$xBR(W$^+$→lν) [nb]
$\sigma_{W^-}^{tot}$xBR(W$^-$→lν) [nb]
$\sigma_{W^+}^{acc}$xBR(W$^+$→lν) [nb]
$\sigma_{W^-}^{acc}$xBR(W$^-$→lν) [nb]
Data(stat ⊕ sys)
Data(stat ⊕ sys ⊕ lumi)
68% CL unc.
68% CL
FEWZ NNLO Prediction
acc*ε*FEWZ NNLO Prediction
MSTW 2008 NLO
NNPDF2.3
CTEQ(CT10)
12.8
12.6
12.4
12.2
12.0
11.8
11.6
11.4
11.2
11.0
1.10
1.15
1.20
7.4
7.2
7.0
6.8
6.6
6.4
4.9
5.0
5.1
5.2
5.3
5.7
5.6
5.5
5.4
5.3
5.2
5.1
5.0
4.9
4.8
0.39
0.40
0.41
0.42
3.3
3.2
3.1
3.0
2.9
2.8
2.20
2.25
2.30
2.35

Ratios

- Ratios are particularly interesting from the theoretical point of view as several uncertainties cancel out
- I.e. the cross section of other processes, e.g. V+jets, di-boson or top, can be compared to the W and Z ones
  - Work ongoing in this direction in CMS
- Cross section evolution with √s is also very interesting
  - Luminosity uncertainty doesn’t cancel though



Conclusions

- An accurate measurement of the W and Z total and fiducial inclusive cross section at √s=8 TeV have been performed for the first time.
  - A dedicated dataset of low luminosity/pileup data has been used, allowing a similar analysis as on 2010 data
  - Overall good agreement with theoretical predictions
- Luminosity measurement instrumental for this result
  - A lot of experienced gained during first LHC run especially for what concerns luminosity absolute calibration (Van der Meer scan)
  - Error down to 2.6%, comparable with other experimental uncertainties.
- Improvements to be expected for 13 TeV run

BACKUP

Factorizability