Status Report

2015. 10. 07

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Action Item

- Paper Review
  - Flow of Measurement of Inclusive W and Z Boson Production Cross Sections in pp Collisions at $\sqrt{s} = 8$ TeV
- ROOT
  - THstack

Introduction

- Production of W and Z is prominent examples
- Theoretical prediction : NNLO in perturbative QCD
- Calculation limited:
  - uncertainties in PDFs
  - missing higer-order QCD effects
  - weak EW radiative corrections
- Previously mesured at $\sqrt{s}$ = 7TeV
- Luminosity = 18.2 ± 0.5 pb^{-1}
- CMS features
  - 3.8T solenoid
  - silicon pixel and strip tracker
  - ECAL (electrons, photons), HCAL (hadrons)
  - Muon detector

Electron and Muon Candidates

- Z boson decays to 2 leptons
- Energetic, isolated, same flavor, opposite charge
- Reconstructed dilepton mass of between 60 and 120 GeV
- Looser requirements: estimate efficiencies
- Triggers
  - muon : pT > 15GeV, $|\eta| < 2.1$
  - electron : pT > 22GeV, $|\eta| < 2.5$
- ECAL
  - $E_T > 25$GeV, $|\eta| < 1.44$(barrel), $1.57 < |\eta| < 2.5$ (end cap)
  - $\Delta R = 0.3$
- Muon global fit
  - reconstructed tracks from muon detector + silicon strip and pixel
  - pT > 25GeV, $|\eta| < 2.1$, $\Delta R = 0.4$ is selected

Acceptance, Efficiency

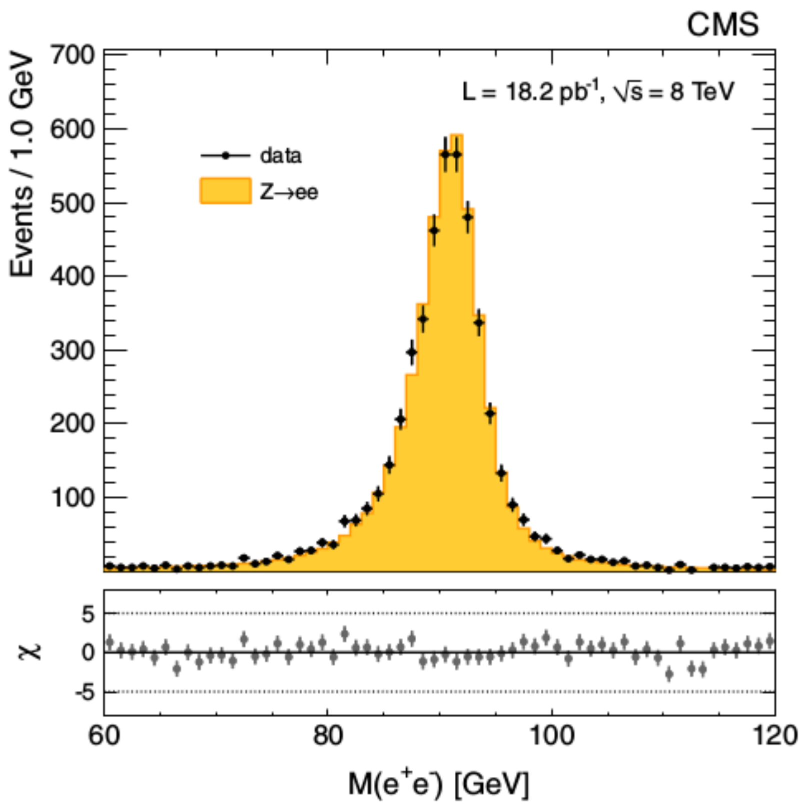
- Acceptance
  - Fraction of generated events for which the leptons satisfy the restrictions
- Efficiency
  - Fraction of events selected
- eg. $1.44 < |\eta| < 1.55$
- Crystal boundaries
- Separate experimental from theoretical uncertainties

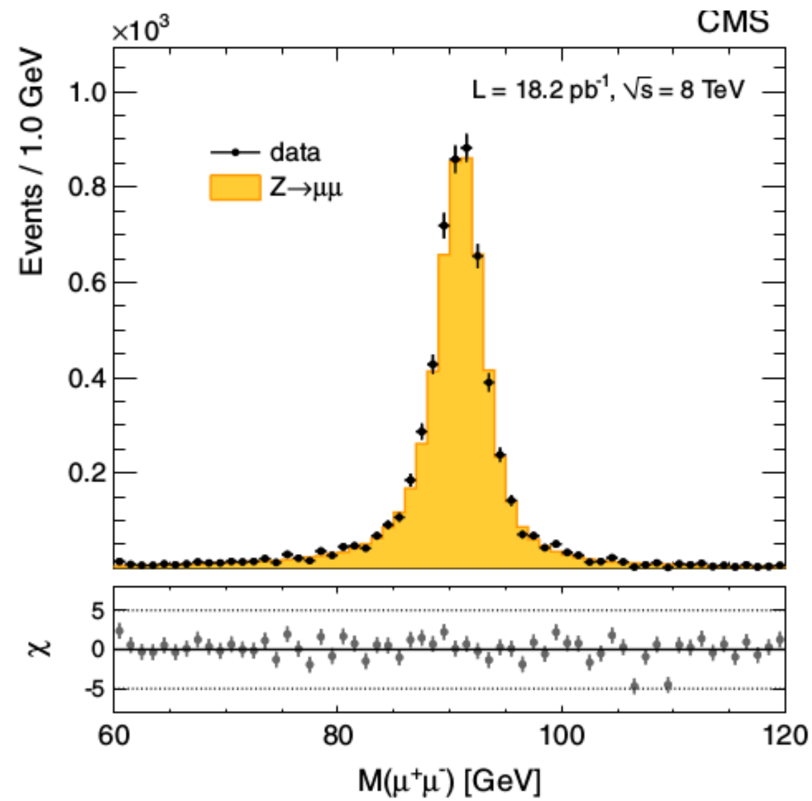
Z boson yield

- Events in the dilepton mass window are counted
- Yield constain contribution of 3% from ɣ*-mediated processes
- Background contamiination is estimated form simulation to be about 0.4%

Source	$Z \to e^+e^-$	$W \to e\nu$	$W^+ \to e^+\nu$	$W^- \to e^-\overline{\nu}$
Yields	4793 ± 69	75051 ± 287	44194 ± 219	30857 ± 185
Acceptance	0.399 ± 0.010	0.479 ± 0.013	0.484 ± 0.011	0.471 ± 0.013
Efficiency	0.585 ± 0.016	0.695 ± 0.019	0.687 ± 0.021	0.708 ± 0.019
Source	$Z \to \mu^+\mu^-$	$W \to \mu\nu$	$W^+ \to \mu^+\nu$	$W^- \to \mu^-\overline{\nu}$
Yields	5917 ± 77	81473 ± 282	47637 ± 216	33836 ± 182
Acceptance	0.346 ± 0.007	0.440 ± 0.010	0.441 ± 0.009	0.439 ± 0.011
Efficiency	0.809 ± 0.010	0.839 ± 0.010	0.843 ± 0.010	0.831 ± 0.009

Dileption Mass Distributions for Z boson





Uncertainties

- Leading experimental uncertainty comes from measurement of the lepton reconstruction and identification efficiency
- Others from integrated luminosity of the data sample
- Theoretical uncertainties dominated by the PDF uncertainties

TABLE I. Systematic uncertainties in percent for the electron and muon channels; "…" means that the source either does not apply or is negligible.

	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

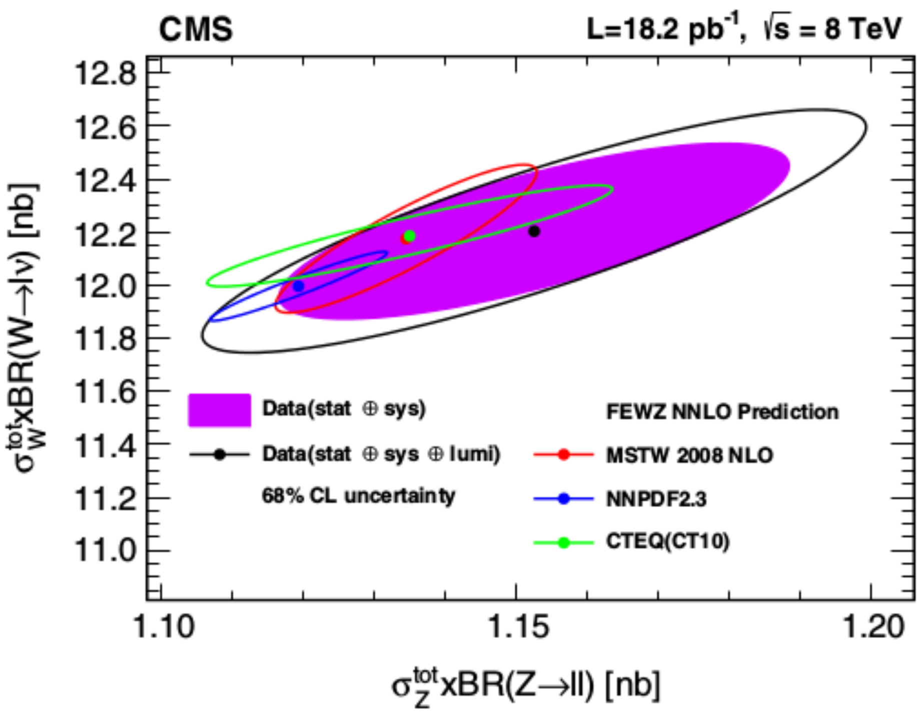
Cross Section Result

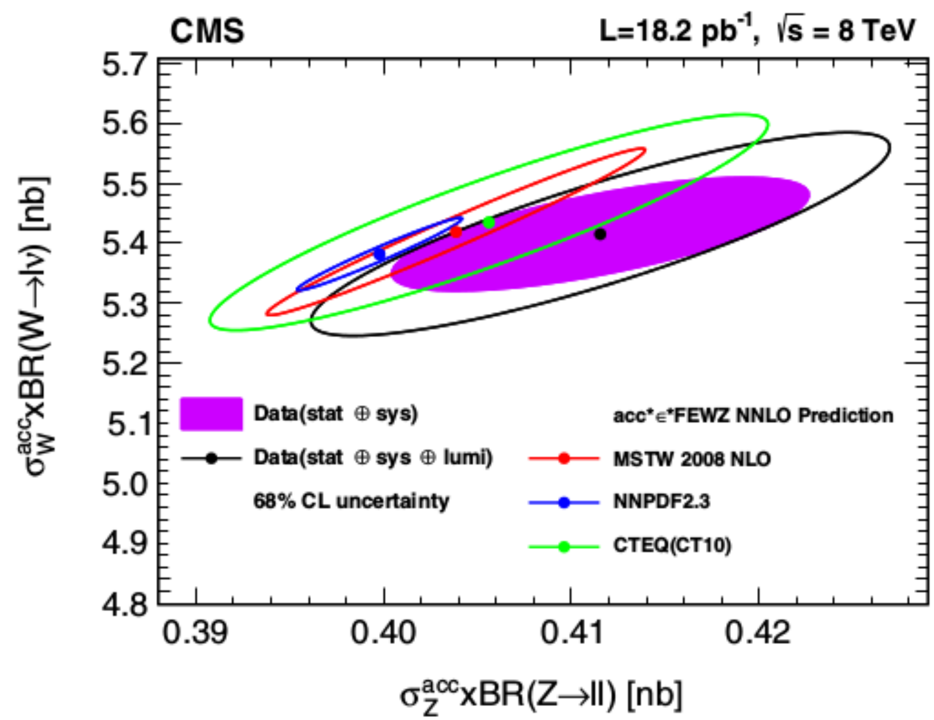
- Theoretical predictions computed at NNLO
- Total Cross Section x Branching Fractions = 1.13 ± 0.04 nb for Z
- Electron and muon decay channels
- combined by calculating average cross section value weighted by uncertainties
- Assuming fully correlated uncertainties for the acceptance and luminosity

TABLE II. Summary of total and fiducial W^+, W^-, W, and Z production cross sections times branching fractions, W to Z and W^+ to W^- ratios, and their theoretical predictions.

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			

W vs Z Cross Sections





THStack

- Histogram Stack
- THStack(“name”, “title”)

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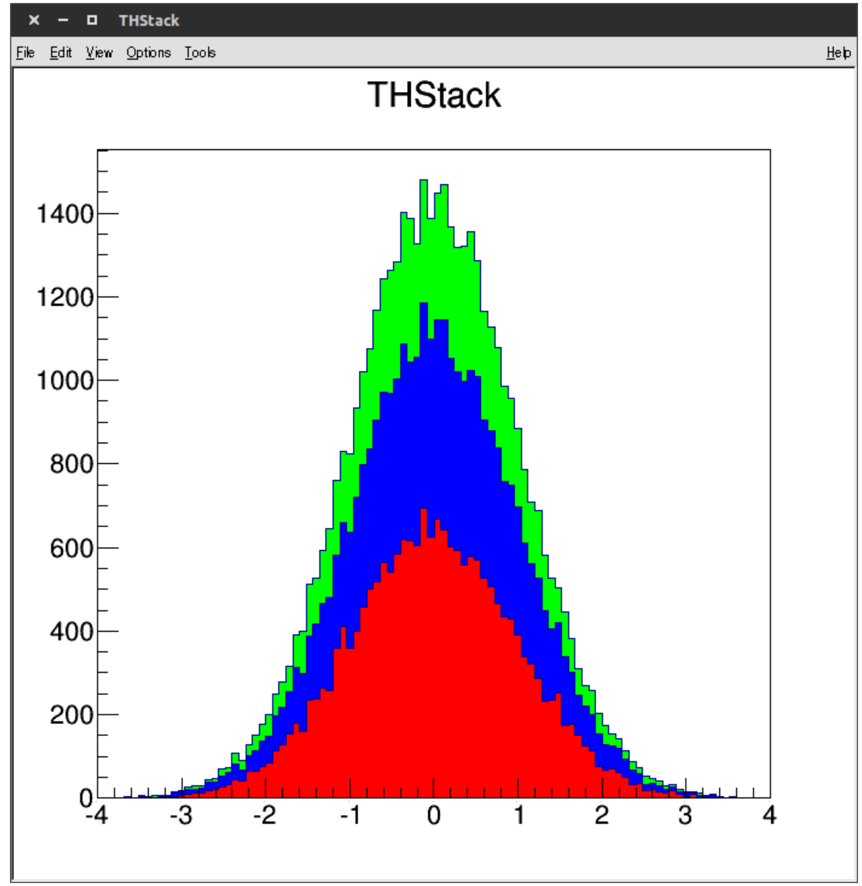
THStack *hs = new THStack ("hs", "THStack");

TH1F *h1 = new TH1F ("h1", "test hstack", 100, -4, 4);
h1->FillRandom("gaus", 20000);
h1->SetFillColor(kRed);
hs->Add(h1);

TH1F *h2 = new TH1F ("h2", "test hstack2", 100, -4, 4);
h2->FillRandom("gaus", 15000);
h2->SetFillColor(kBlue);
hs->Add(h2);

TH1F *h3 = new TH1F ("h3", "test hstack3", 100, -4, 4);
h3->FillRandom ("gaus", 10000);
h3->SetFillColor(kGreen);
hs->Add(h3);

hs->Draw();
```



- THStack *hs
- hs->Add(h1);
- hs->Add(h2);
- ……. hs->Draw();

- 3 stacked Gaussian histograms