Early Prospects for Electroweak Physics in CMS

Ping Tan

on half of the CMS Collaboration

Fermilab

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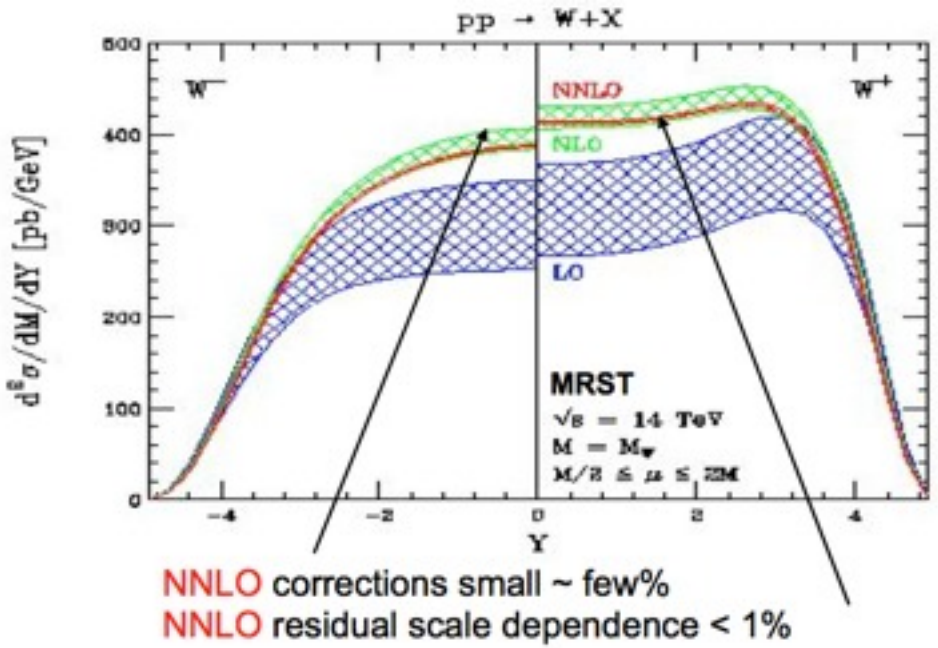
Outline

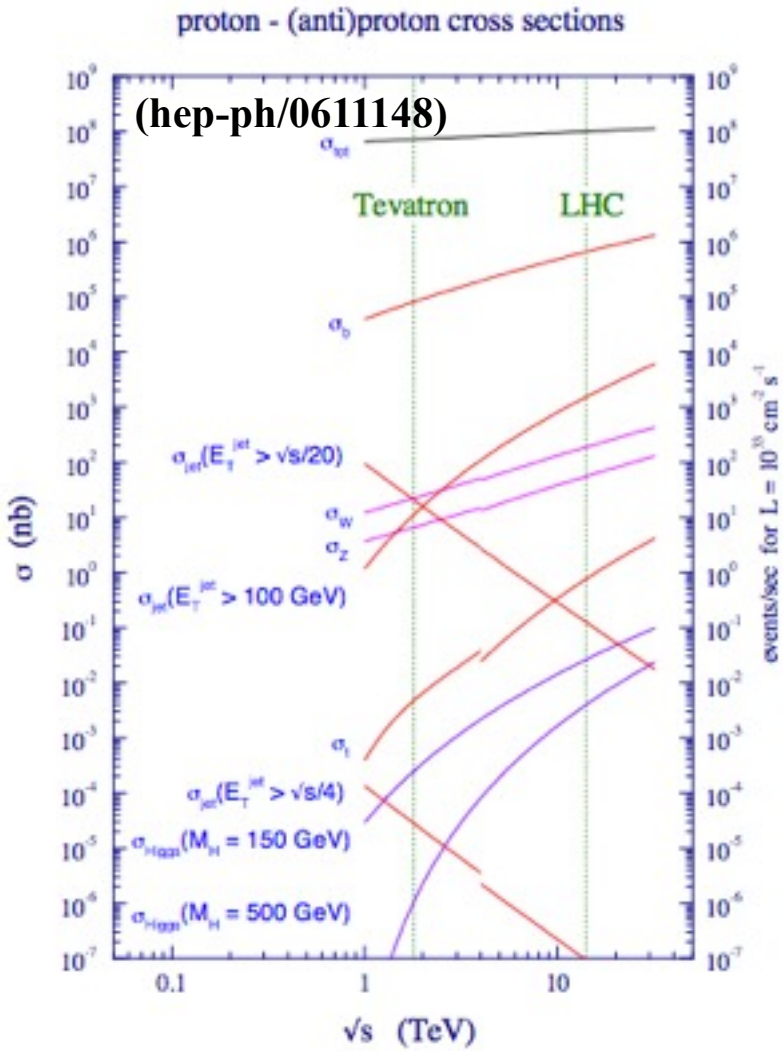
- Introduction
- The Large Hadron Collider and the CMS experiment
- Early prospects of electro-weak physics:
  - Inclusive W/Z cross sections,
  - Lepton charge asymmetry in inclusive W production,
  - Z differential cross section,
  - W/Z + jets
- Summary

Introduction

- Establish many SM candles for new physics search:
  inclusive W/Z cross sections, W/Z+jets, di-boson production, etc.
- Precision test of higher-order prediction; possibly for luminosity monitoring.



(C.Anastasiou et al., PRD 69, 094008 (2004))



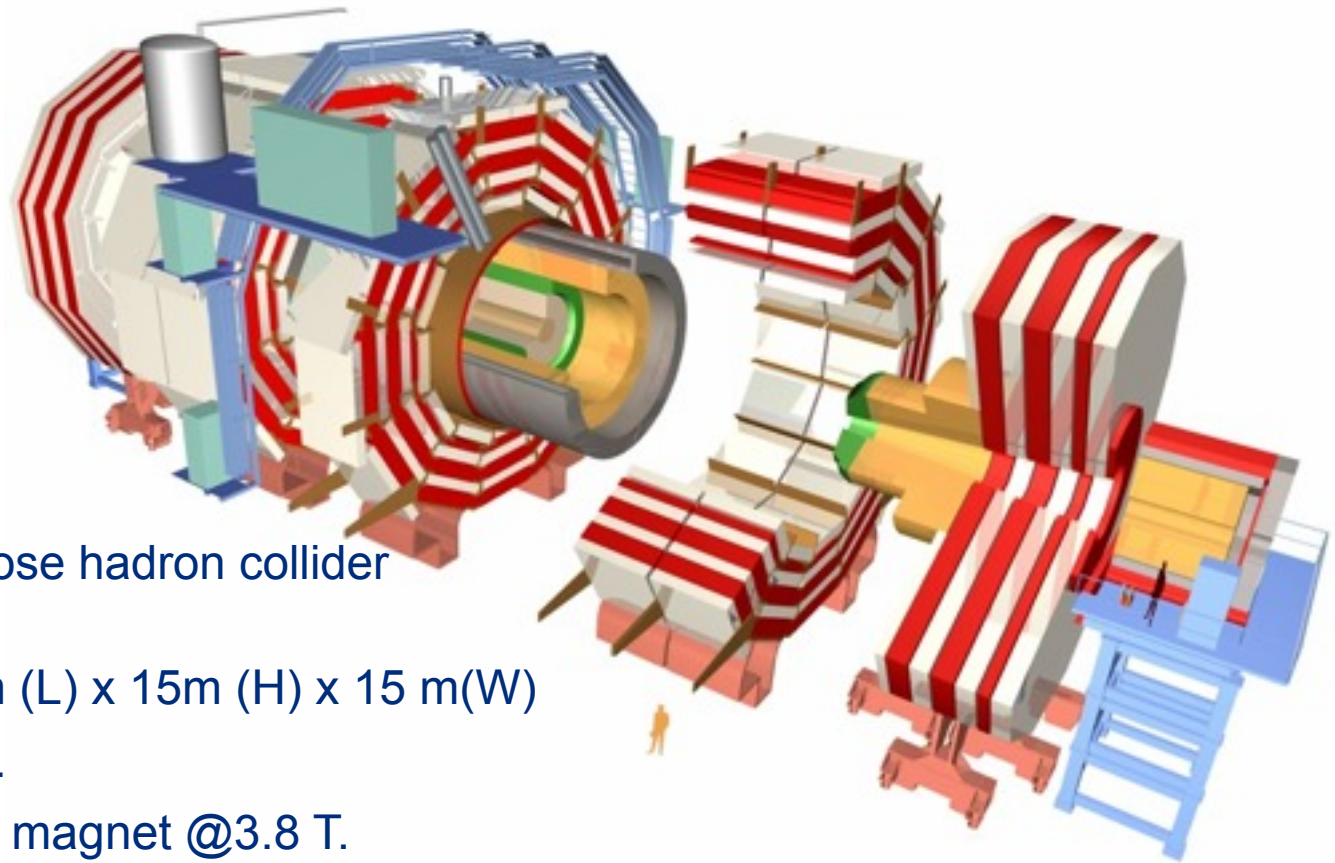
The Large Hadron Collider

- Located at the 27 km LEP tunnel.
- Proton-proton collider with designed luminosity of 10^{34} /cm^{-2}s^{-1} @ 14 TeV
- Nearly two year's running at 7 TeV initially.

First collision at 7 TeV in Mar. 30, 2010!

The CMS Experiment

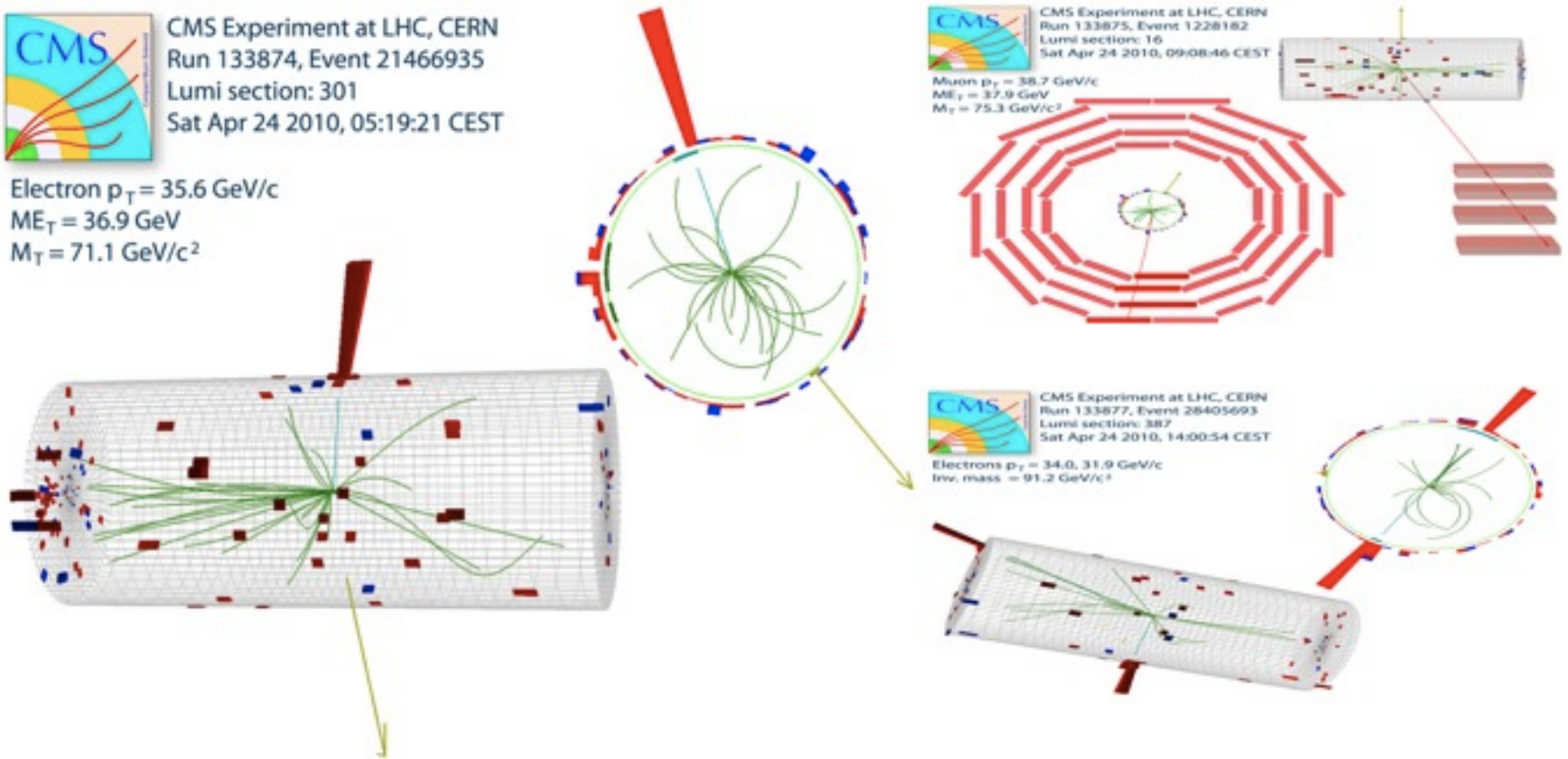
- CMS collaboration: 182 institutes in 38 countries, ~ 3000 physicists and engineers.



- 4π general-purpose hadron collider detector.
- Dimensions: 21m (L) x 15m (H) x 15 m(W)
- Weight: 12,500 T.
- Single solenoidal magnet @3.8 T.
- All-silicon tracker, ~100M channels.

Current Status of CMS Detector

- All CMS sub-systems are in excellent condition.
- Taking LHC collision data with high efficiency: > 1nb^{-1} of integrated luminosity is in tape



Inclusive W Production

- Standard candle at LHC: one of the first resonances to be observed at LHC?
- Very precise prediction in cross sections, ~2-3% level.

(About 70% decrease from 10 TeV to 7 TeV)

PDF set	$\sigma_{W+} B_{W\to l\nu}$ (nb)	$\sigma_{W-} B_{W\to l\nu}$ (nb)	$\sigma_{Z} B_{Z\to ll}$ (nb)
MSTW08	8.55±0.15	6.25±0.12	1.38±0.025
CTEQ66	8.77±0.18	6.22±0.14	1.40±0.027

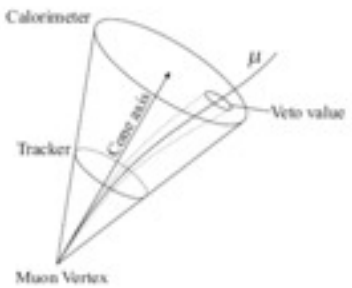
A.M. Cooper-Sarkar, PDF4LHC workshop (2009)

- Experimental signature: single electron/muon + missing transverse energy (MET).

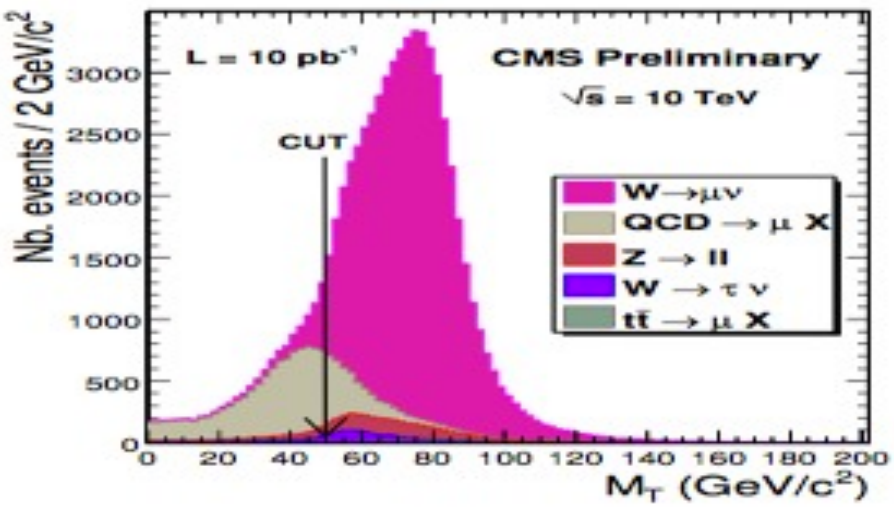
- Trigger: high-efficiency single lepton trigger,
  - ~ 97% efficient for electrons (E_T> 15 GeV, $|\eta|$ < 2.5)
  - ~ 90% efficient for muons (p_T > 15 GeV, $|\eta|$ < 2.1)

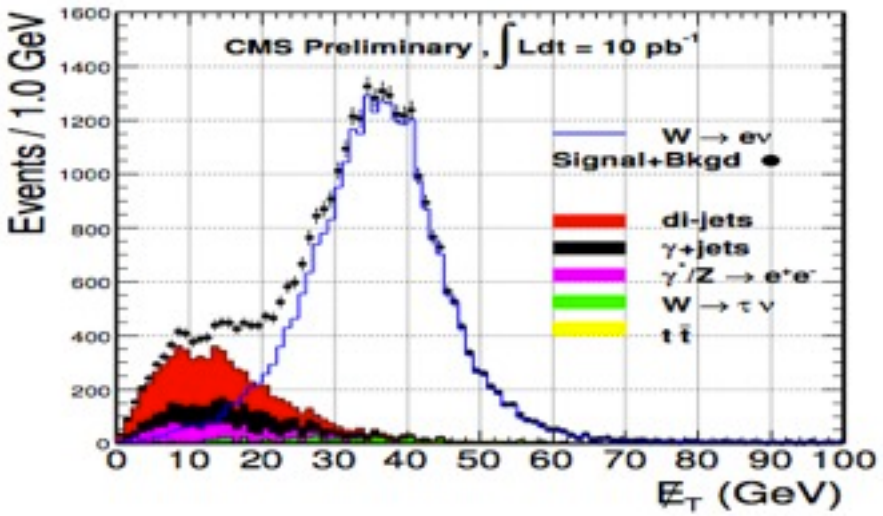
Expected Sensitivities

- Backgrounds: QCD dijets, Drell-Yan, ttbar, W(τν), photon +jets,...
- Isolation to suppress QCD background,
- Data-driven techniques to estimate rest QCD background.



$$m_T = \sqrt{2 p_T \not{E}_T (1 - \cos\Delta\phi_{\ell,\not{E}_T})}$$



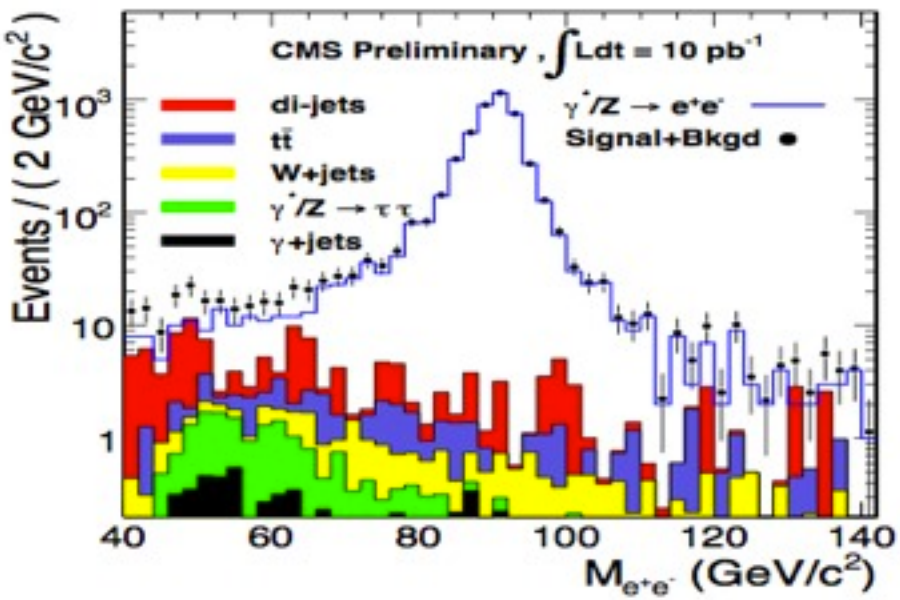


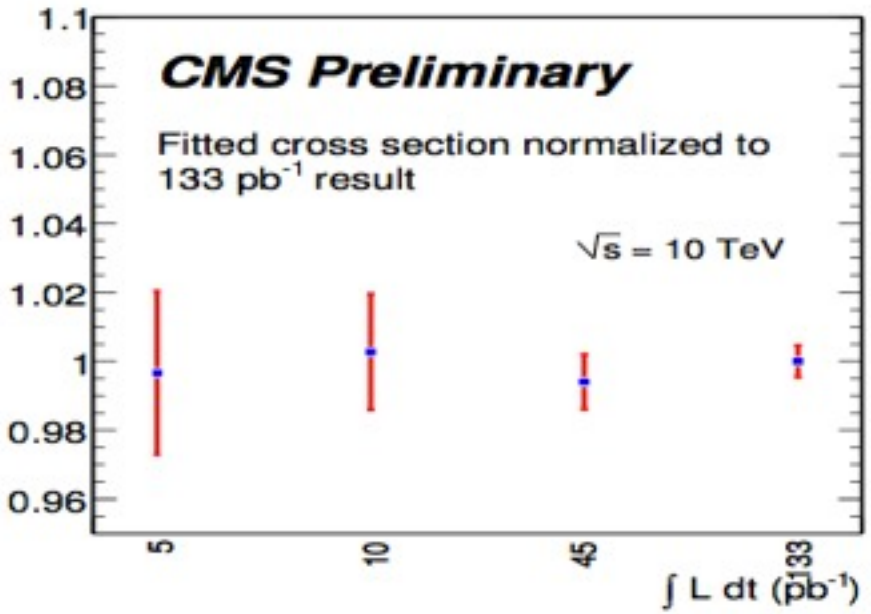
$$\sigma_W \times BR(W \to e\nu) = \frac{N_W^{pass} - N_W^{bkgd}}{A_W \times \epsilon_W \times \int Ldt}$$

: <2% statistical uncertainty@10pb^{-1}
: a few percent systematics + 10% luminosity error.

Inclusive Z production

- Another standard candle at LHC,
  $\sigma_z B_{z\to ll}$ ~1.40±0.03 (NNLO)
- Experimental signature: two high-p_T isolated leptons.
- Very little background (<1%): QCD dijets, W+jets, ttbar, Z(ττ), etc.
- < 2% statistical precision at 10pb^{-1} with systematic error dominated by 10% luminosity error.



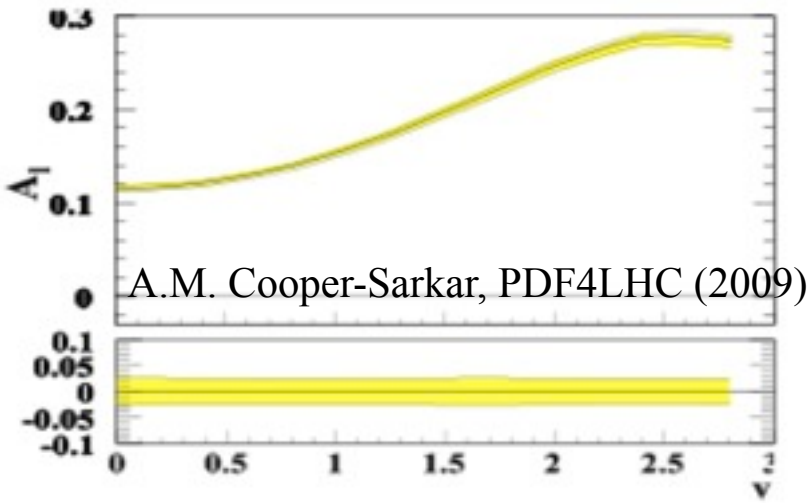


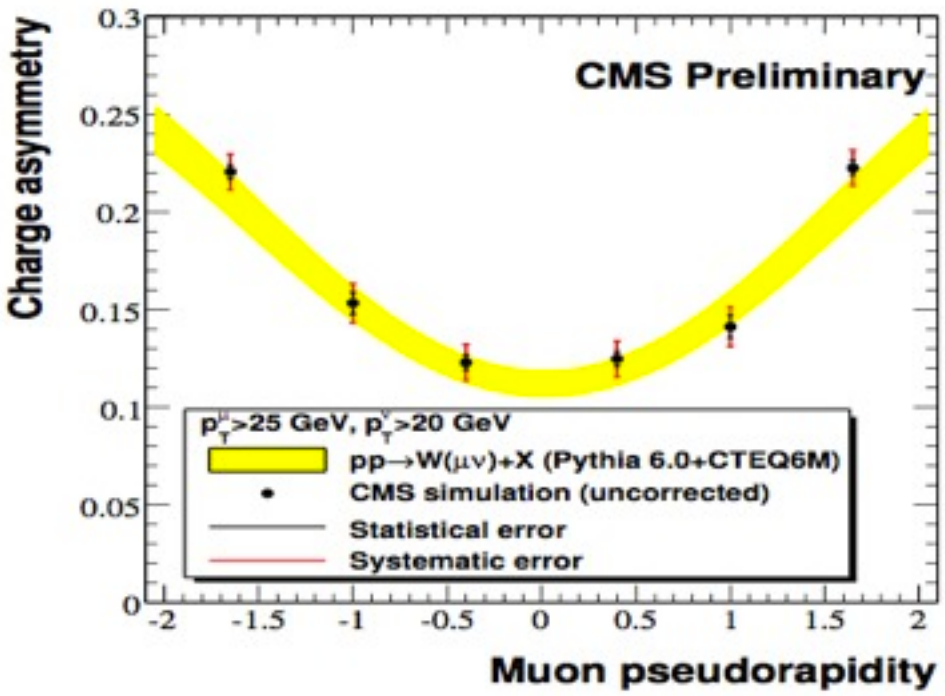
Lepton Charge Asymmetry in Inclusive W Production

- Probe the valence-sea quark ratio,

$$A_W \approx \frac{u\bar{d} - \bar{u}d}{u\bar{d} + \bar{u}d} \approx \frac{u_{val} - d_{val}}{u_{val} + d_{val} + 2\bar{q}}$$

- Understand heavy flavor contributions.





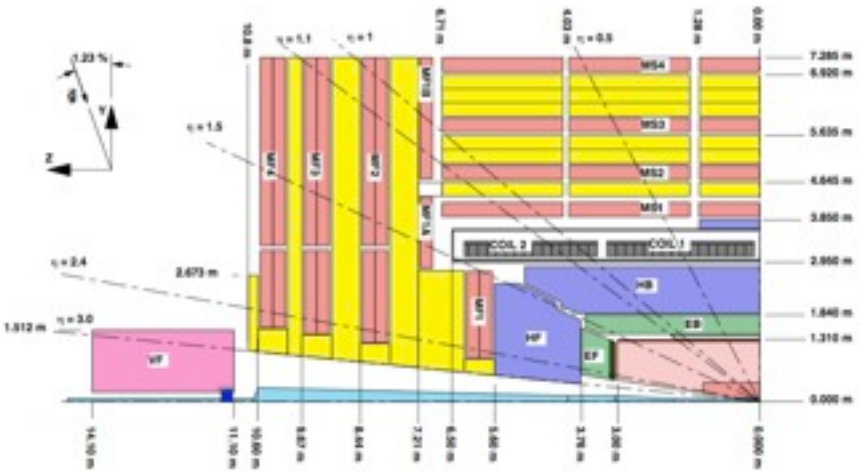
- Expected PDF error at ~4-5%,

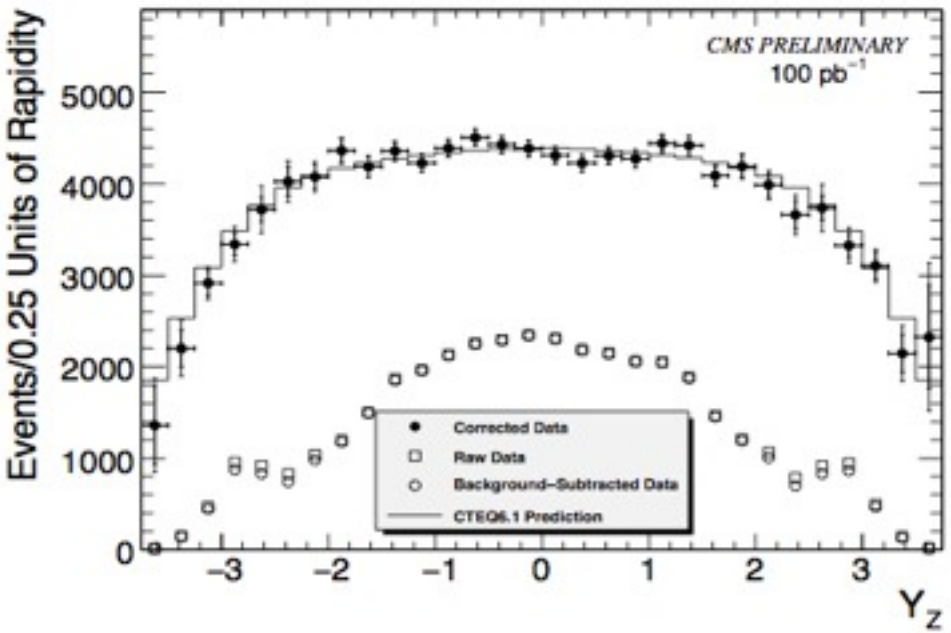
$$A(\eta) = \frac{\frac{d\sigma}{d\eta}(W^+ \to \mu^+\nu) - \frac{d\sigma}{d\eta}(W^- \to \mu^-\nu)}{\frac{d\sigma}{d\eta}(W^+ \to \mu^+\nu) + \frac{d\sigma}{d\eta}(W^- \to \mu^-\nu)}.$$

- Useful constraint to PDF models with about 10-100 pb^{-1} of integrated luminosity.
- Systematic error dominated by efficiency ratio between positive and negative leptons.

Differential Cross Section in Z(ee) Production

- Utilized Forward-Calorimeter (HF) to extend electron acceptance from ~2.4 to ~4.0.
- Signal isolated lepton trigger,
- Similar background as inclusive Z cross section measurement

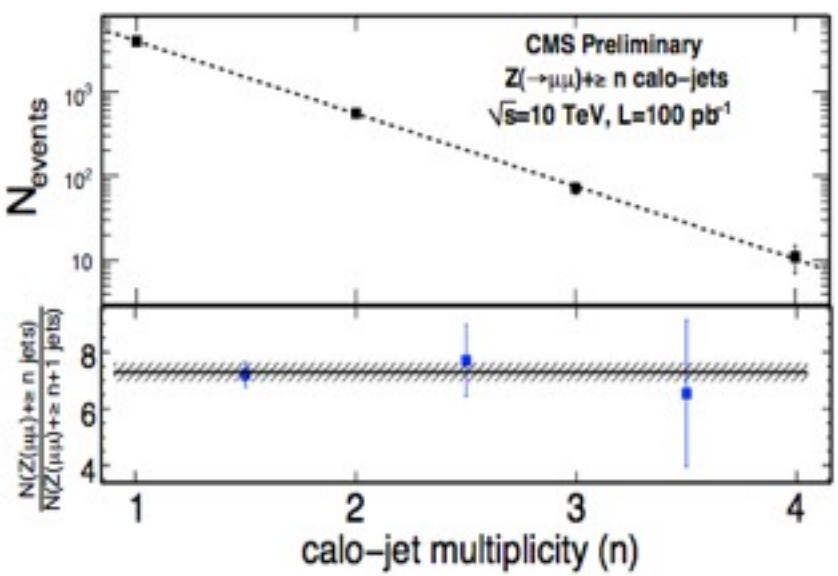


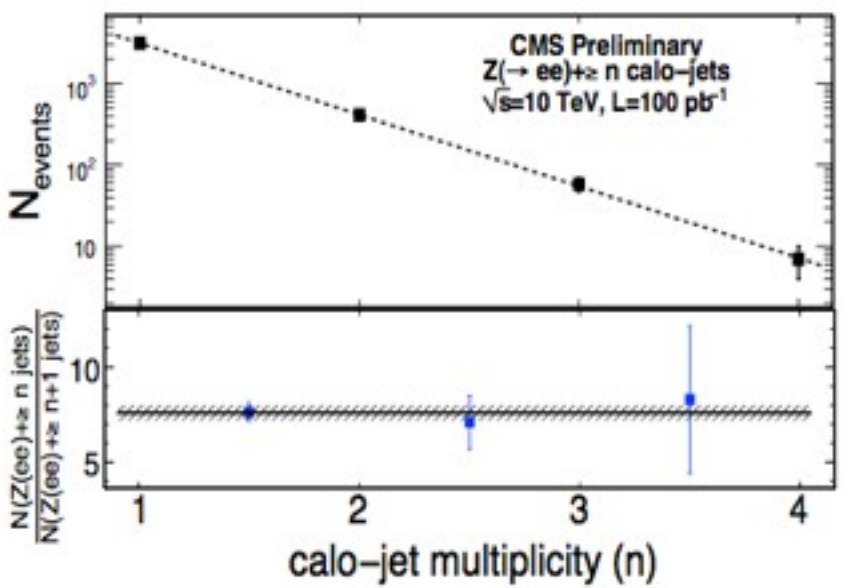


- Background in HF is under control
- Can provide constraints on different PDF models with about 100 pb^{-1} of integrated luminosity.

Z+jets

- Berends-Giele Scaling: σ(Z+(n+1) jets)/σ(Z+n jets) ~ independent of jet multiplicity.
- Test of Berends-Giele scaling, probe new physics in high jet multiplicity.
- Fit on dilepton-invariant mass to determine the signal yields for each jet multiplicity.
- With about 100 pb^{-1} of integrated luminosity, sensitivity to verify the BG-scaling up to 4 jets.



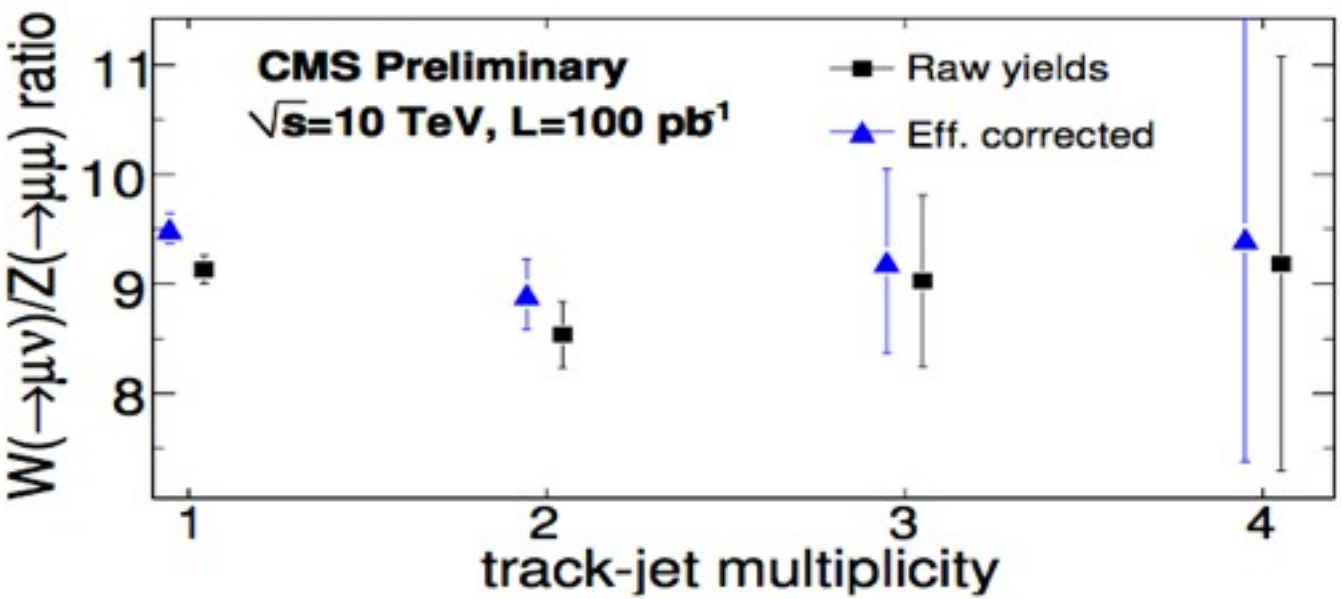


W+jets/Z+jets Ratio

- Further cancellation of experimental (e.g. jet energy scale) and theoretical uncertainties. (E. Abouzaid and H.J. Frisch)

$$C_W/C_Z \equiv \frac{W + n \text{ jets}/W + (n+1) \text{ jets}}{Z + n \text{ jets}/Z + (n+1) \text{ jets}}$$

- Can give absolute normalization for high-multiplicity W+jets production, useful for top-related physics, other physics searches.
- Additional sensitivity to new physics beyond the SM



Summary

- The first 7 TeV collision at the LHC marked the start of a nearly two-year long physics running.
- CMS is in excellent condition and taking collision data with high efficiency.
- With first 10-100 pb^{-1} LHC data,
  - Establish W/Z cross sections at a new energy regime with high precision,
  - High-precision measurement of lepton charge asymmetry and Z boson differential cross sections,
  - Be able to study W/Z+jets with great details,
  - Many physics measurements not discussed here: diboson production, W mass/width, Forward-backward asymmetry, W/Z + heavy flavor, ...
- We now have data! Stay tuned for exciting electro-weak physics results from CMS in near future.

https://twiki.cern.ch/twiki/bin/view/CMS/PublicPhysicsResults