Plans for Diffractive Inclusive Z Analysis in CMS detector at LHC

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Outline

① **Physics motivation**
② **CMS detector**
③ **Diffractive W/Z analysis in the CMS**
④ **Future plans: is this analysis easier at $\sqrt{s}$ = 7 or 14 TeV ?**
⑤ **Analysis discussions**
⑥ **Final remarks**

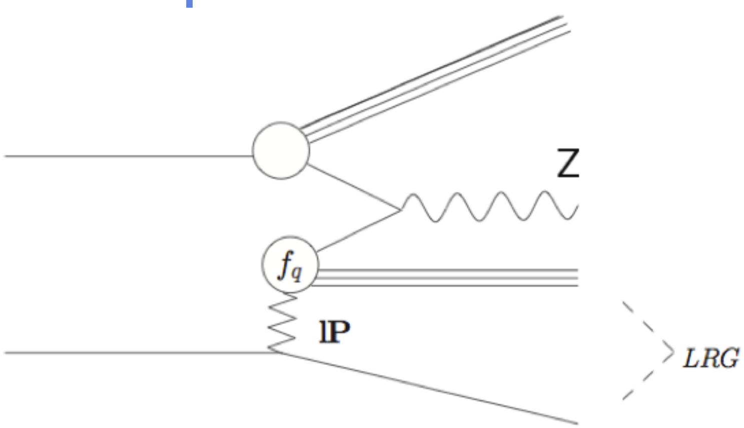
Phys Rev Lett 78, 2698 (1997)

Phys Rev D82:112004 (2010)

Physics Motivation

- Z bosons are produced via leading order (**LO**) annihilation of quark-antiquark pair (*Drell-Yan process*):

- **The diffractive production mode is sensitive to the diffractive structure function of the proton, notable its quark component since bosons originate from quark fusion.**



Channels:

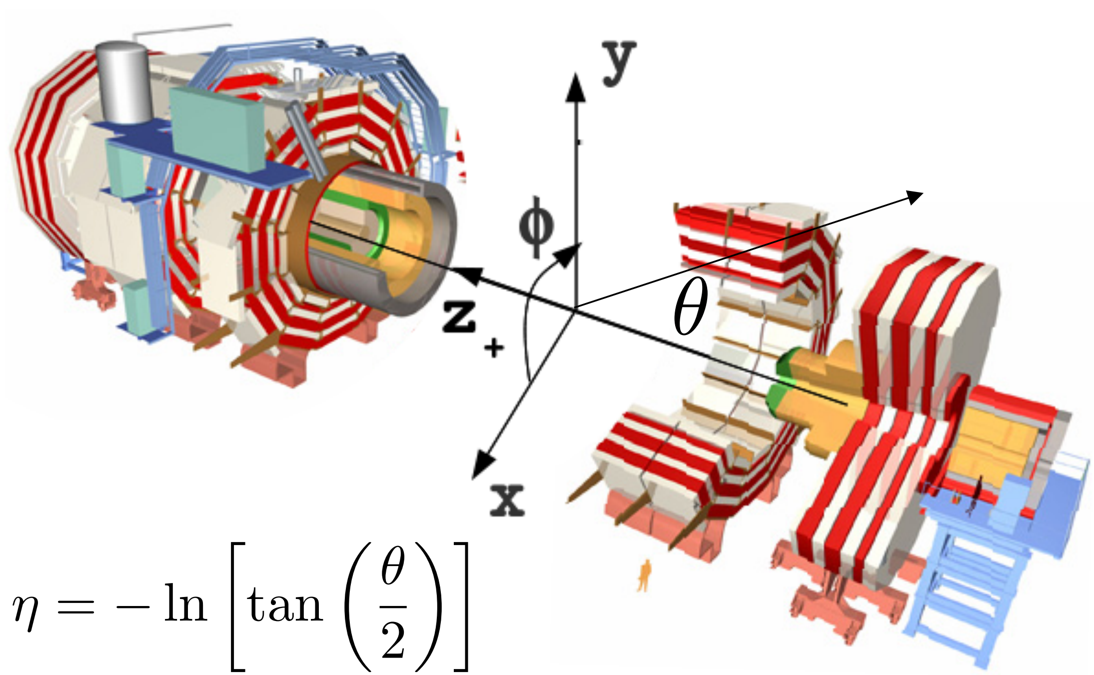
$\mathrm{Z}(\mu^+\mu^-)$

$\mathrm{Z}(\mathrm{e}^+\mathrm{e}^-)$

- Experimental observable is $d\sigma/d\xi$ cross section:

$$\xi^{\pm} = \frac{1}{\sqrt{s}} \sum_{i}^{N} E_{T,i} e^{\pm\eta_i}$$

Some definition

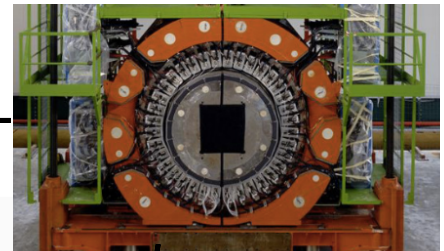


$$\eta = -\ln\left[\tan\left(\frac{\theta}{2}\right)\right]$$

Coordinate System

CMS Detector

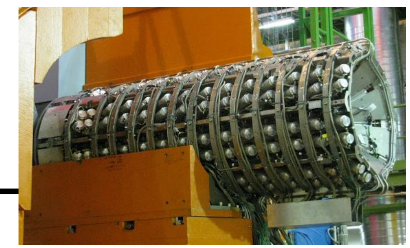
$3 < |\eta| < 5.2$

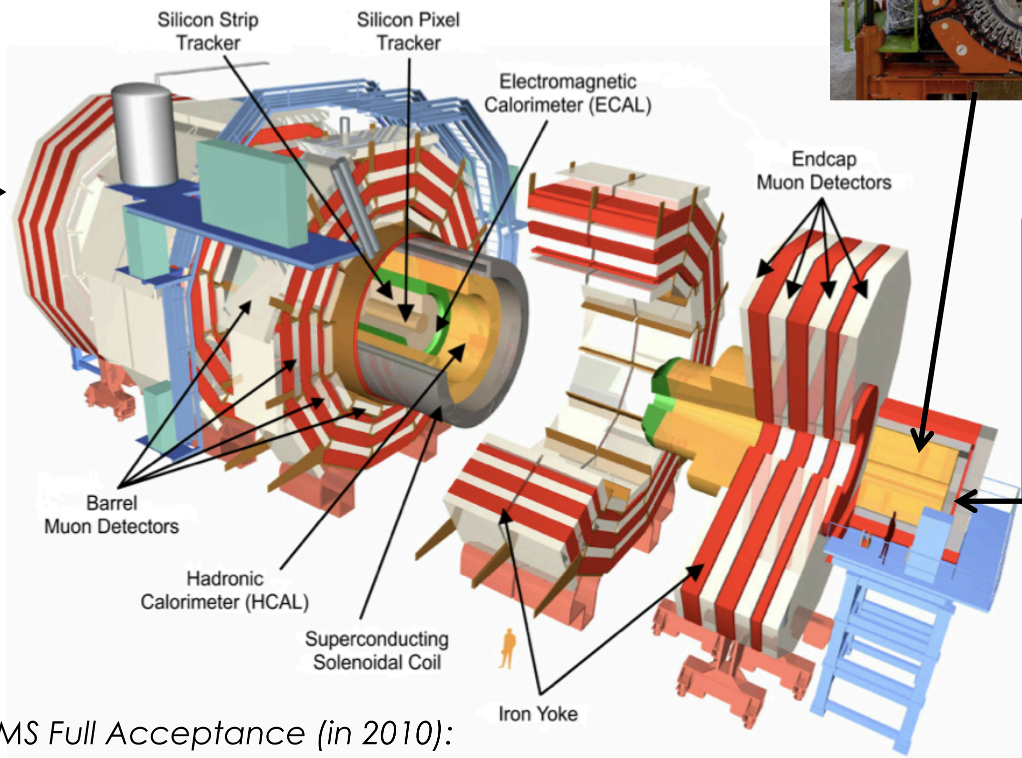


HCAL-HF

HCAL-CASTOR

$-6.6 < \eta < -5.2$





Subdetector	Acceptance
Tracking	$\mid \eta \mid < 2.5$
Muon System	$\mid \eta \mid < 2.4$
EM Calorimeter (ECAL)	$\mid \eta \mid < 3$
HAD Calorimeter (HCAL)	$-6.6 < \eta < 5.2$

CMS Full Acceptance (in 2010):

$$-6.6 < \eta < 5.2$$

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First analysis of diffractive W and Z Boson in the CMS (2010 data): learning with first measurements

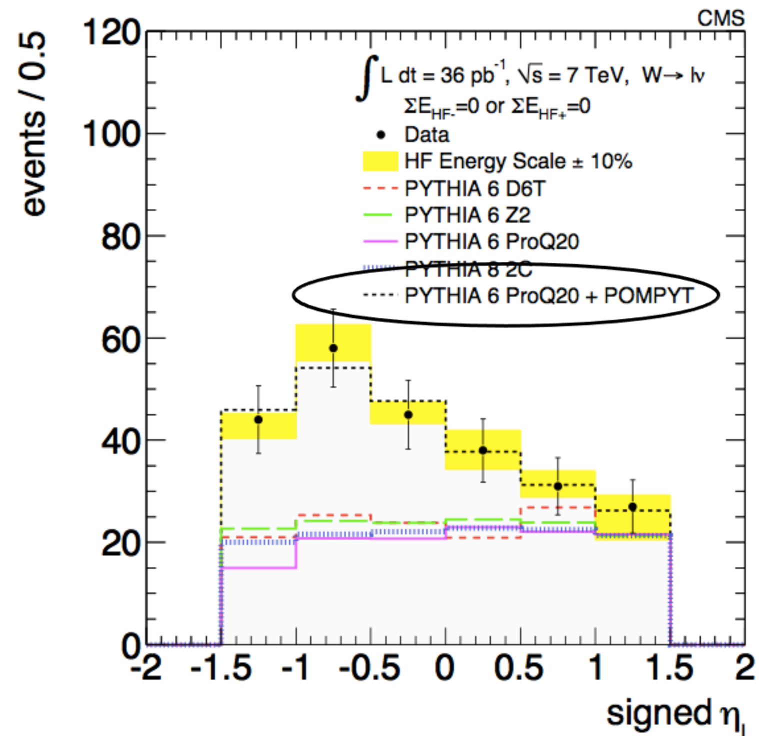
1) **Analysis of the underlying event structure and of events with a *pseudorapidity gap* of more than 1.9 units**

➔ $\mathrm{pp} \rightarrow \mathrm{W(Z)X} \rightarrow \mathrm{l}\nu\mathrm{(ll)X}$

2) Selection:

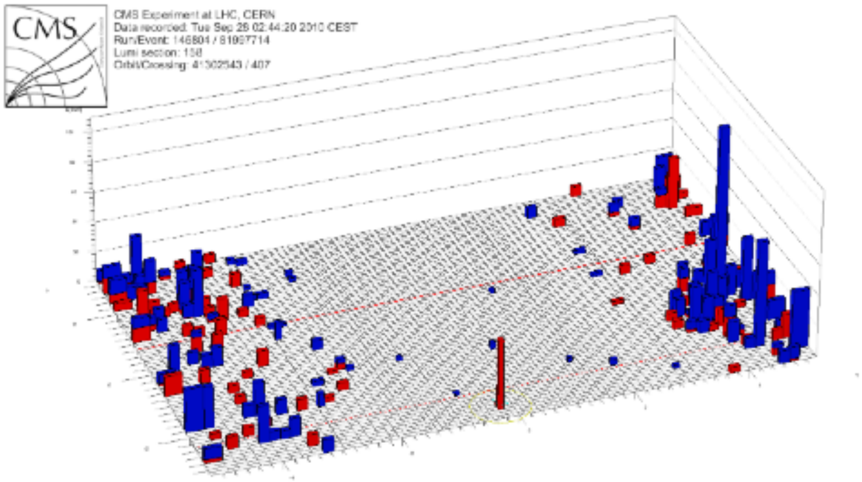
➔ Boson W (isolated lepton and missing E_t) and Z (dilepton events). Invariant mass cut.

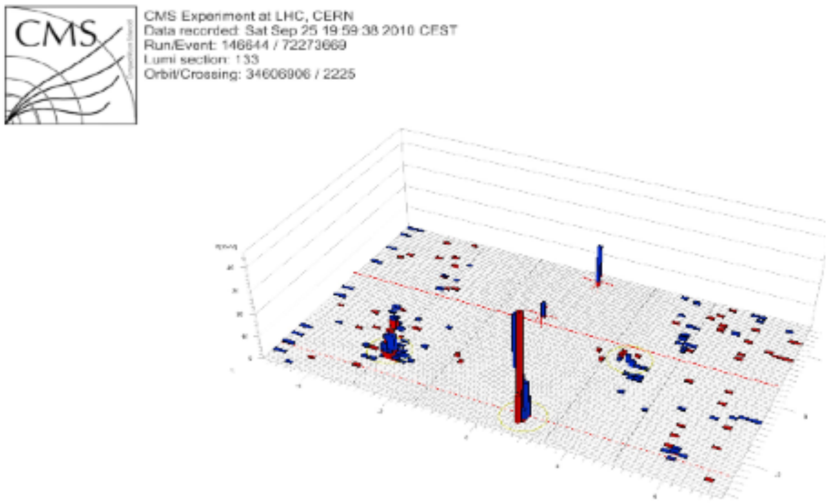
➔ No energy deposit in HF (LRG, threshold of tower energy > 4 GeV)

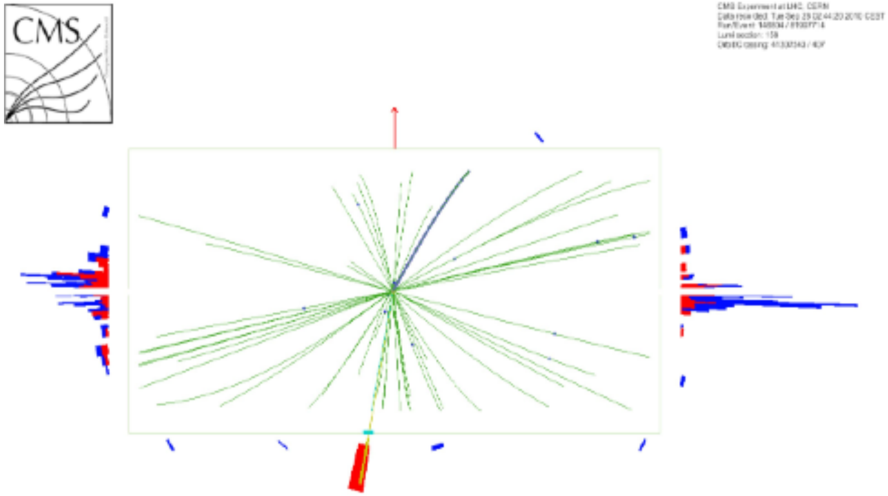


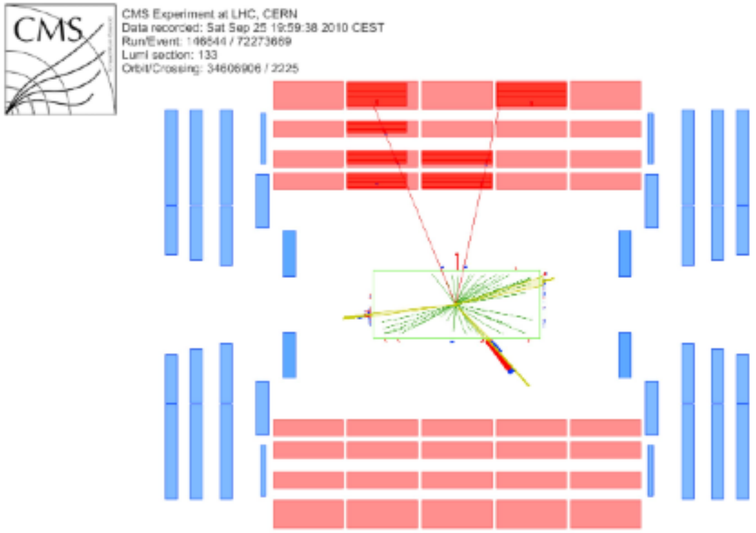
The sign is defined to be **positive** when the **gap and the lepton are in the same hemisphere** and negative otherwise. The data show that charged leptons from W decays are found more often in the hemisphere opposite to the gap

Non-diffractive W/Z Event display



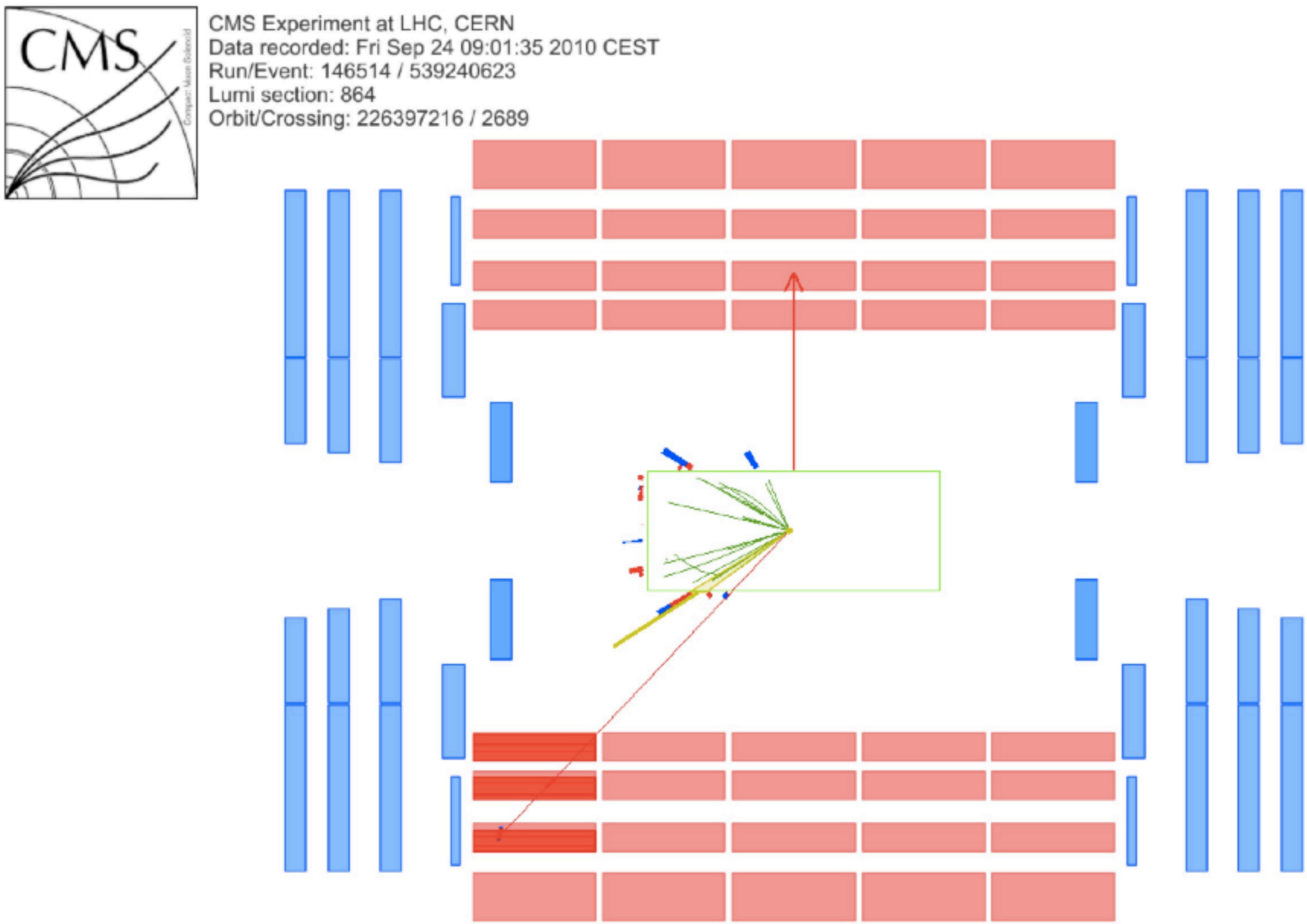






Diffractive boson W Event display

http://cds.cern.ch/record/1328359/files/DP2011_001.pdf



Future plans: is this analysis easier at $\sqrt{s}$ = 7 or 14 TeV ?

Increase LHC energy is a hard game…

1) **To reach more energy, a significant increase in luminosity can be achieved:**

➔ While more quantity of data will be delivered, **number of pile-up (PU) events will increase**. Some examples:

For 7 TeV data (2010): ~15 % single vertex events of ~25 pb^{-1}.

For 8 TeV data (2011): ~< 2 % single vertex events of ~ 4 fb^{-1}. No low PU Runs.

For 8 TeV data (2012): ~ 21 PU per event. Few runs with low luminosity.

Estimation for 14 TeV: 50 pile up events as baseline operation. These events will fill the gap and without forward detectors, we hardly ever can control our background. Solution: forward detectors + special low luminosity runs.

So, for 14 TeV scenarios, proton tagger detectors are the key!

CMS Timeline of data taking

2010: forward gap measured with CASTOR, 25 pb^{-1}

2011: No low pile-up runs

2012: No CASTOR, ~ 10 pb^{-1} low pile-up runs (to be explored yet)

2012: ~ 50 nb^{-1} of data taken together with TOTEM, too few for this study

➔ **2015: CMS – TOTEM data taking. 1 – 10 pb^{-1} will be perfect**

Currently using the data taken in 2010, using CASTOR as gap tagger

Future plans: analysis techniques using CASTOR (2010)

1) Define "golden" events:

➔ Look for events with gap in CASTOR and HF ($-3 < \eta < -6.5$)

➔ Small acceptance, high purity sample. Do we have enough luminosity only for Z channels?

➔ Look for correlation in the golden events using global event variables:

- Z direction
- Energy flow direction
- Trust, sphericity, multiplicity….

2) Use higher statistical sample

➔ Use only HF^- to tag the gap ($-3 < \eta < -5.2$)

➔ Higher acceptance, lower purity

Is the gap too small?

➔ Combine a smaller gap with global event variables

➔ Multivariate analysis?

Analysis hurdles for Diffractive Z with CASTOR. A new measurement (2010)

1) **Forward energy flow:**
   - Very difficult to simulate, data and MC still do not agree very well in HF and CASTOR.
   - **What is a gap? 0 GeV Energy? 1, 5, 10 GeV? Can we trust the MC gaps?**

2) **One vertex requirement:**
   - The analysis requires "**only one vertex**", otherwise the rapidity gap is always filled.

     ➔ Possible problem with pile-up events that don't make a visible vertex. If present, **they fill the gap**

3) **Beam gas, particles in the beam**
   - Simulation only tracks particles from the primary vertex.

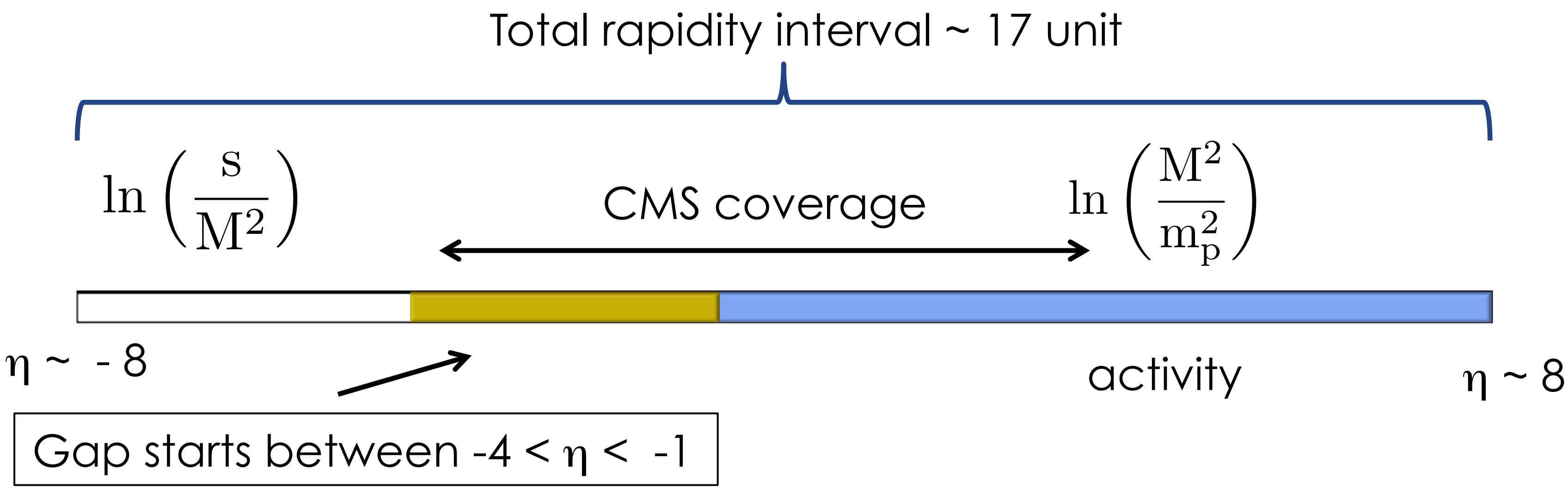
     ➔ How do we account for extra activity? **It fills the gap...**

Final Remarks

- 2010 data are being analyzed for diffractive Z bosons;
- CASTOR detector response studies are being performed. Detector thresholds has been defined with no bunch crossing;
- Non-diffractive Z boson has been detected. Compatible results with other studies;
- Diffractive Monte Carlo are being studied (POMPYT) as well as observables to extract signal from background.

Backup

Why do we need forward detectors ?



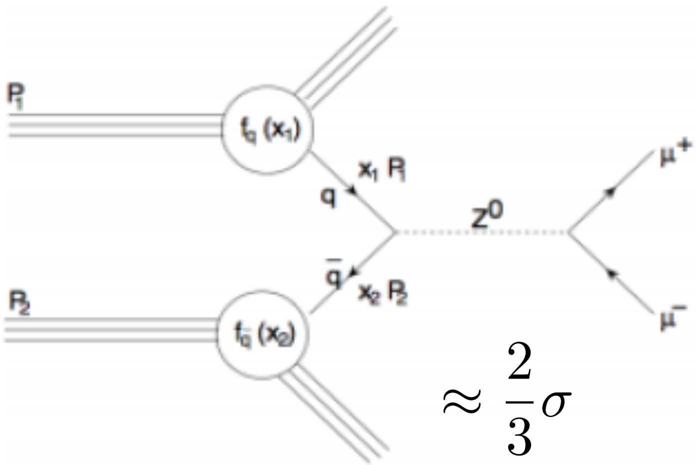
M^2 is large, and it covers from 9 to 12 units of rapidity

The gap starts at the limit of the CMS central detector coverage

The gap is normally outside the reach of central CMS

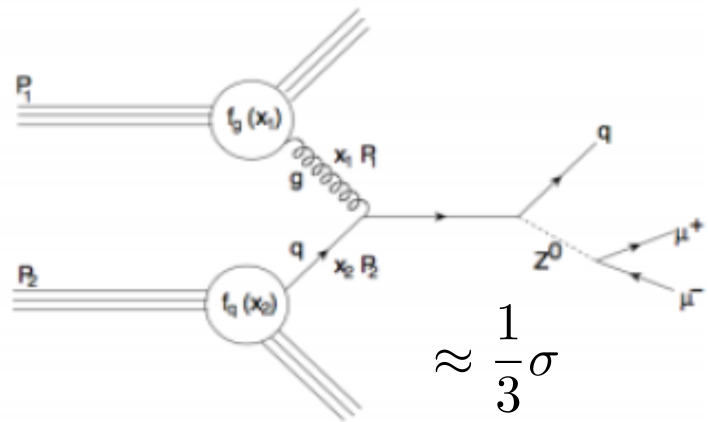
Drell-Yan LHC

- Z bosons production at LHC proceeds via Drell-Yan process.



$\approx \frac{2}{3}\sigma$

LO diagram

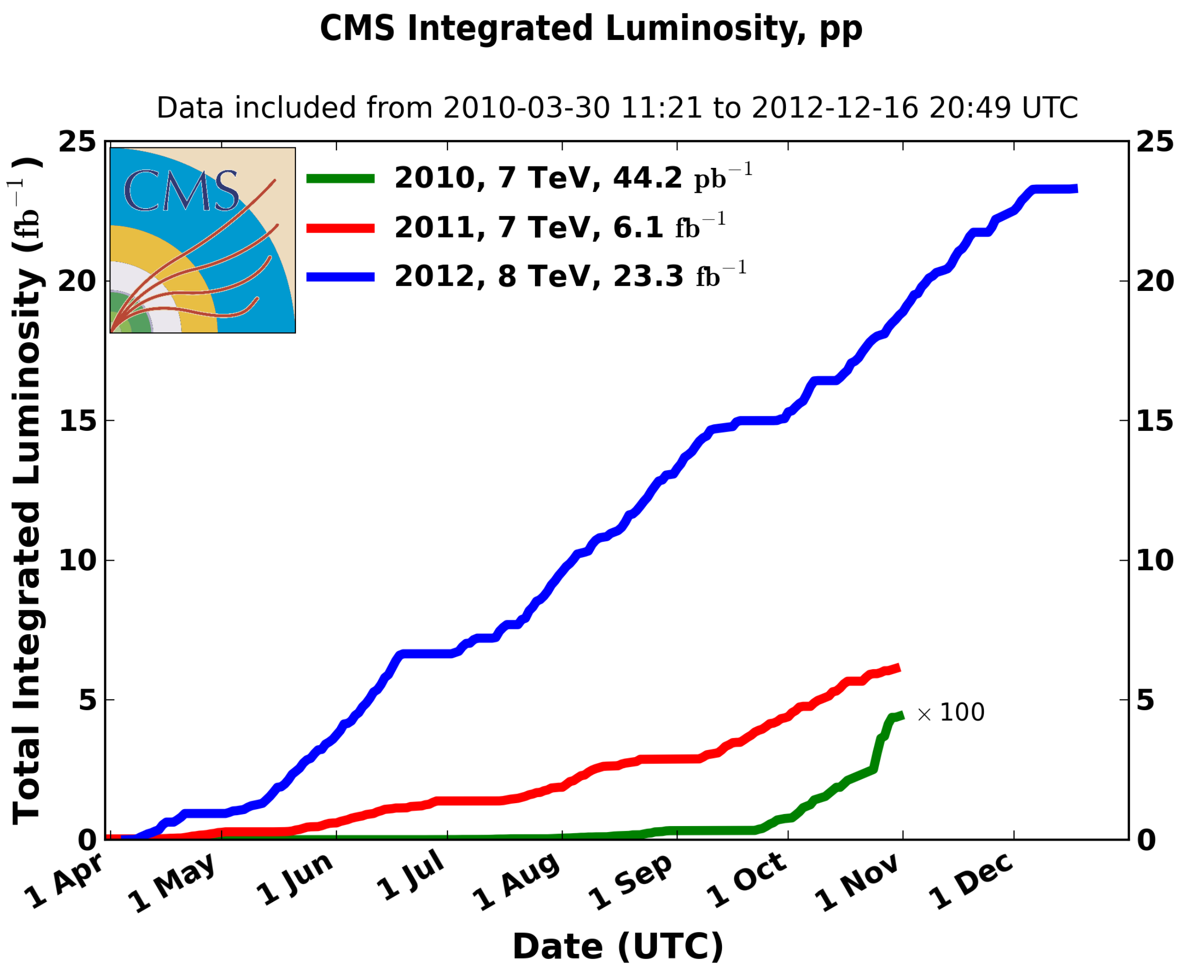


$\approx \frac{1}{3}\sigma$

NLO diagram

- The backgrounds arise from isolated leptons from other electroweak boson production (QCD jet or jet + γ process).

CMS recorded data



CMS recorded data