Search for contact interactions in the di-lepton channel with CMS

Wayne State University

P. Lamichhane ,S. Gollapinni, P. Karchin, C. Kottachchi, M. Mattson, C. Milstene

FNAL

L. Spiegel

MOTIVATION

Standard model does explain many interactions well, however, there are many mysteries which could not be explained by SM and need BSM (beyond standard model) to explain

For example : Mass acquired by quarks and leptons, 3 generations of particles , dark matter etc..

standard model → **quarks and leptons are point particles**

BSM : contact interactions → **quarks and leptons have substructure**

NEW PHYSICS

Compositeness of quarks and leptons according to contact interactions model

- Quarks and leptons are composite objects of fundamental particles called ‘preons’

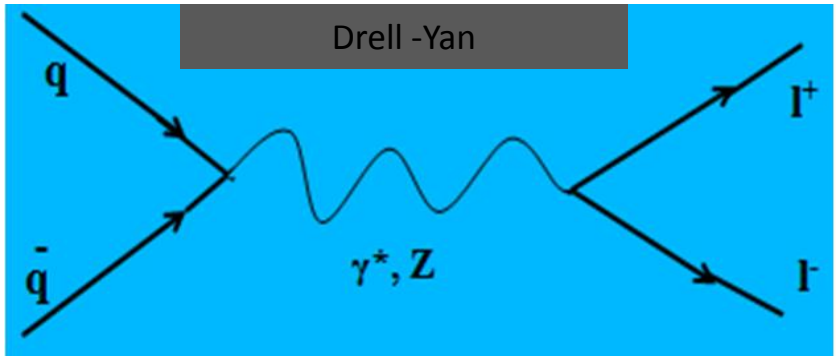
- Preons interact via new guage interaction called metacolor (similar to strong interaction via pion exchange)

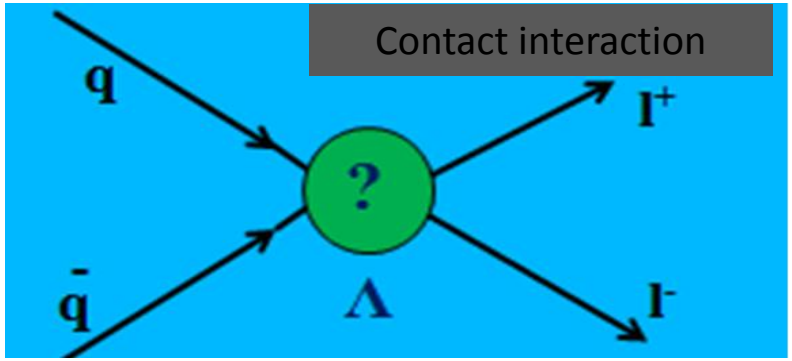
- The interaction of ‘preons’ is visible only above the characteristics energy scale Λ

- Below energy scale Λ, quarks and leptons are bound strongly, and behave point like objects

- Energy scale Λ can be visualized by physical size compositeness scale

Signature of contact interaction process





Deviation in the di-lepton mass distribution in Drell-Yan tail is a good signature of CI

Cross-section due to contact Interaction is

$$\frac{d\sigma}{dm}(\Lambda) = \frac{d\sigma}{dm}(DY) - \eta\frac{I}{\Lambda^2} + \eta^2\frac{C}{\Lambda^4}$$

Where I corresponds to the product of DY and contact amplitudes and C Corresponds to a pure contact term. Note that η = +1 corresponds to destructive interference and η =-1 to constructive interference.

Langrangian for contact interaction

$$\mathcal{L} = \frac{g^2}{2\Lambda^2}\,[\;\eta_{LL}\;\overline{\psi}_L\gamma_\mu\psi_L\,\overline{\psi}_L\gamma^\mu\psi_L + \eta_{RR}\;\overline{\psi}_R\gamma_\mu\psi_R\,\overline{\psi}_R\gamma^\mu\psi_R + 2\eta_{LR}\,\overline{\psi}_L\gamma_\mu\psi_L\,\overline{\psi}_R\gamma^\mu\psi_R\;]$$

where g is a coupling constant chosen to obey $g^2/4\pi = 1$, and $\psi_{L,R}$ are left-handed and right-handed fermion fields, respectively.

Current limit on left left model [di-lepton channel]

Model : LLIM[DI-MUON]
LUMI=1.21 fb^{-1} E_{CM}=7TeV
Λ^{+}_{LL}=7.0 TeV
Λ^{-}_{LL}=8.0TeV
ATLAS Collaboration 2011

Model : LLIM[DI-ELECTRON]
LUMI=1.08 fb^{-1} E_{CM}=7TeV
Λ^{+}_{LL}=10.1
Λ^{-}_{LL}=9.4
ATLAS Collaboration 2011

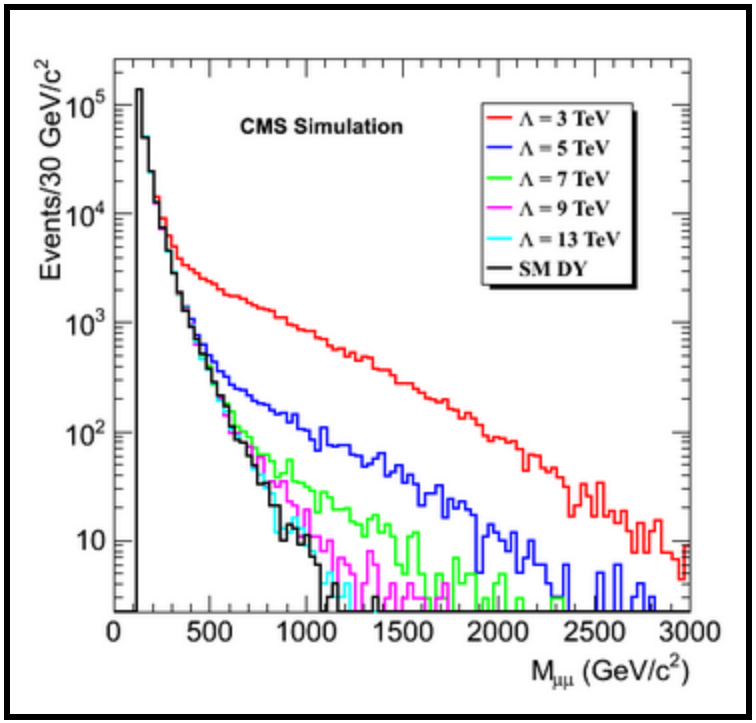
Left-Left iso-scalar model => Benchmark model

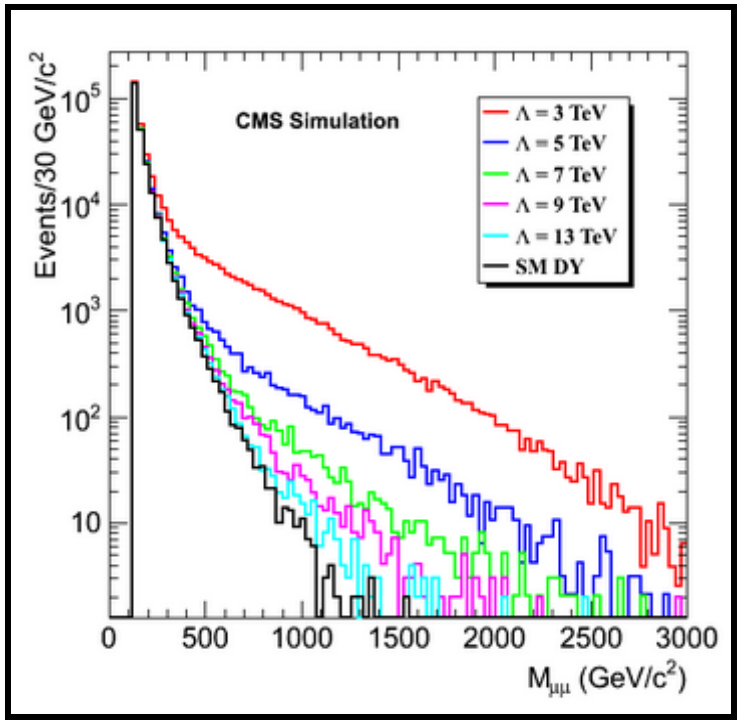
$$\mathcal{L} = \frac{g^2}{2\Lambda^2}\left[\boxed{\eta_{LL}\ \overline{\psi}_L\gamma_\mu\psi_L\,\overline{\psi}_L\gamma^\mu\psi_L} + \eta_{RR}\ \overline{\psi}_R\gamma_\mu\psi_R\,\overline{\psi}_R\gamma^\mu\psi_R + 2\eta_{LR}\,\overline{\psi}_L\gamma_\mu\psi_L\,\overline{\psi}_R\gamma^\mu\psi_R\right]$$

For our analysis, we worked on Left-Left iso-scalar model for following reason :

- **This model is one of the two models implemented in pythia MC and other is HNC model**
- **PDG limits are exclusively given for LL model**

Pythia Simulation of Left-Left isoscalar model in differrence composite scale Λ





Destructive interference η =1

Constructive interference η =-1

When Λ is ∞, The spectrum converges to DY distribution

$$\frac{d\sigma}{dm}(\Lambda) = \frac{d\sigma}{dm}(DY) - \eta\frac{I}{\Lambda^2} + \eta^2\frac{C}{\Lambda^4}$$

2011 results for di - muon channel

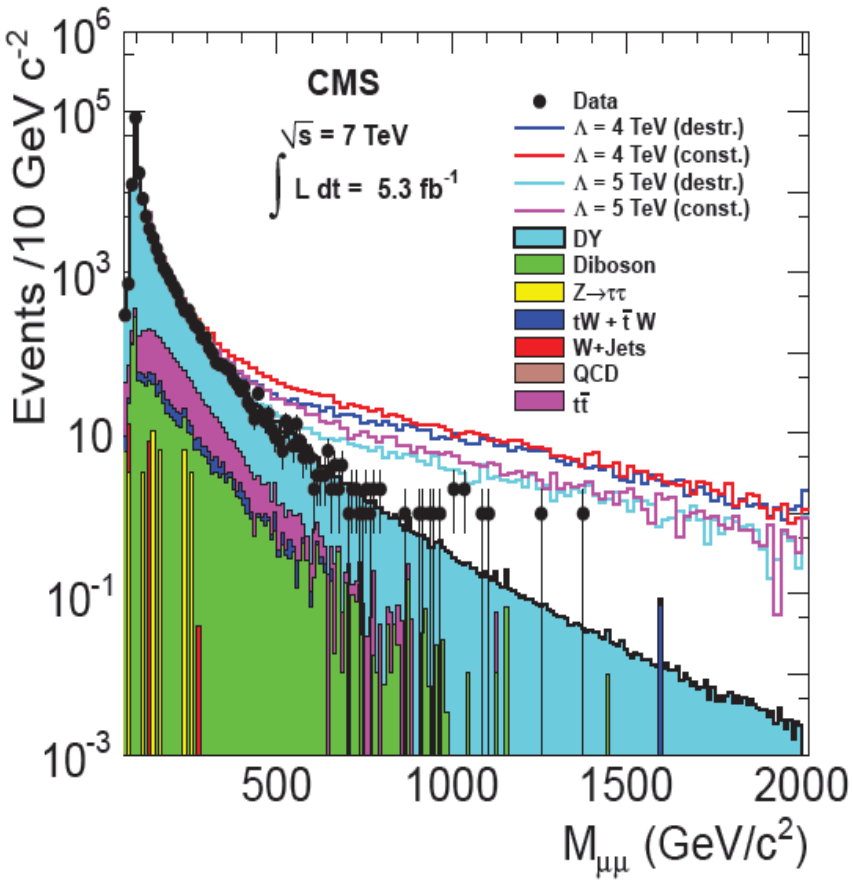
Expected signal = (CI * Acc * QCD K * QED K) + BKG

CI – generator level contact interaction signal

Acc – acceptance x migration x efficiency

BKG – background estimation

QCD K and QED K are corresponding K-factor s for NLO correction



Single muon Selection criteria

- pT > 45 GeV
- Two muons have opposite charge
- Isolated
- Both muons have a common Vertex
- Must have tracks reconstructed both in silicon tracker and muon detector
- 3D di-muon opening angle cut to suppress cosmic-ray muons
- At least one muon must match to trigger object

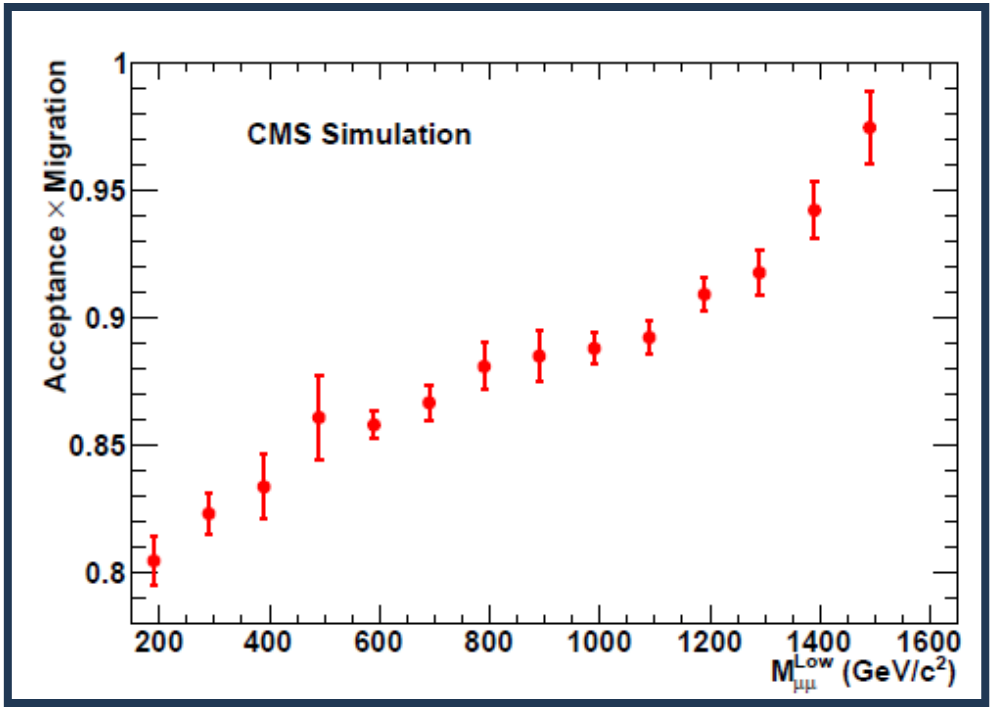
[details are in back up slides]

Acceptance × Efficiency × Migration

- Due to the momentum resolution smearing, migration effect keeps increasing from low to high di-muon mass. The shape of cross-section distribution also plays some role in this effect

- Due to the shape of cross-section is relatively flat in contact interaction , acceptance is slightly less than Drell-Yan process due to less effect of migration

- 3% systematic is assigned in acceptance due to this reason

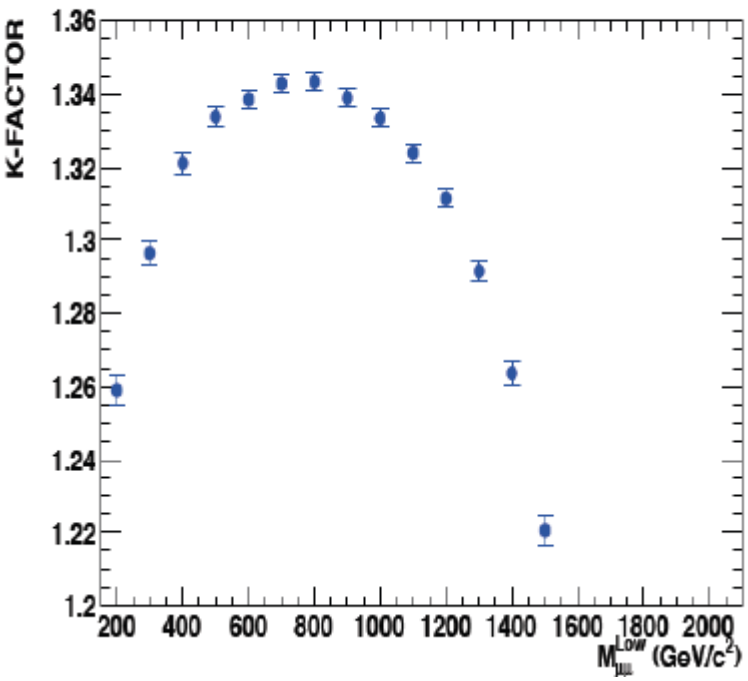


A weighted Acceptance × Migration in two pileup scenario(2011A and 2011B)

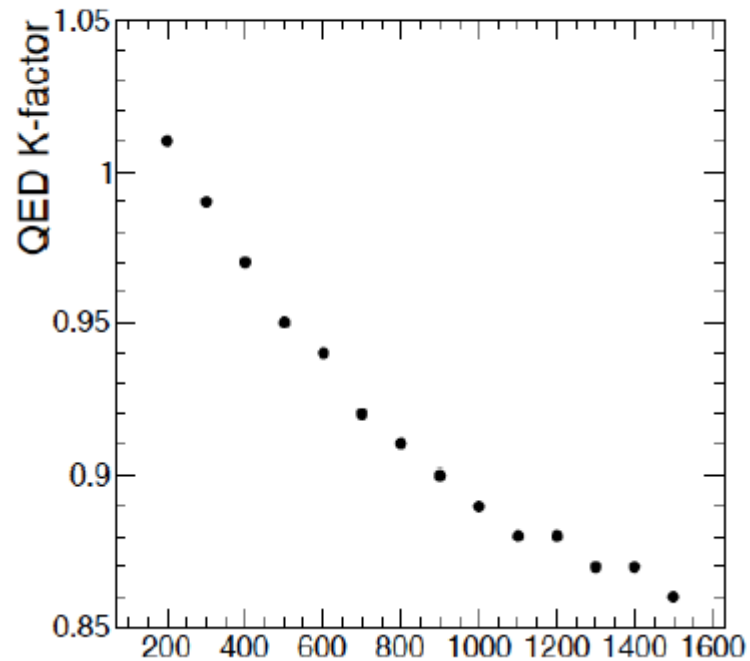
QCD and QED K-factors for NLO corrections

QCD K-factors are calculated using MC@NLO and PYTHIA generators

QCD NLO



QED NLO **



** C. C. Calame et al., "Precision electroweak calculation of the production of a high transverse momentum lepton pair at hadron colliders", J. High Energy Physics **10 (2007)109–130**

Setting limits

- Based on Modified frequentist technique (CLs technique)

(A. Read, "Presentation of search results: the CLs technique", J. Phys. G: Nucl. Part. Phys. 28 (2002).)

- Possion Statistics used for probability
- Signal only hypothesis

Expected mean = **CI * Acc * QCD K * QED K – STANDARD MODEL BKG**

- Background only hypothesis

Expected mean = **STANDARD MODEL BKG**

- Observed number of events → from LHC data recorded by CMS

Limits includes systematics coming from

- Integrated luminosity
- Acceptance and
- Expected background (DY + other standard model sources).

Systematics and results

Pdf uncertainty has the largest effect

Source	Uncertainty (%)
Integrated luminosity	2.2
Acceptance	3.0
Background estimate	14.7
PDF set variation (+)	12.3
PDF set variation (-)	9.9
DY event yield	0.8
non-DY event yield	15.0
QCD k-factor	0.2

DETECTOR	COM (TeV)	L(fb^{-1})	Λ (Des) TeV	Λ(Cons) TeV
CDF	1.8	0.11	2.9	4.2
ATLAS	7	1.21	7.0	8.0
CMS	7	5.3	9.5	13.0

Conclusion and Future Work

•The limits from this analysis are significantly better than the current published limits

•The results are available in following twikipage
https://twiki.cern.ch/twiki/bin/view/CMSPublic/PhysicsResultsEXO11009

•We have extended our search in di-electron channel in addition to di-muon channel this year using 8 TeV data

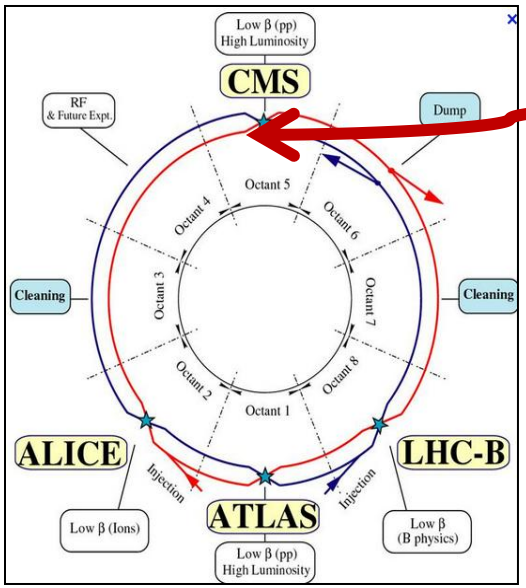
• This year we will use full simulation samples to estimate the signal

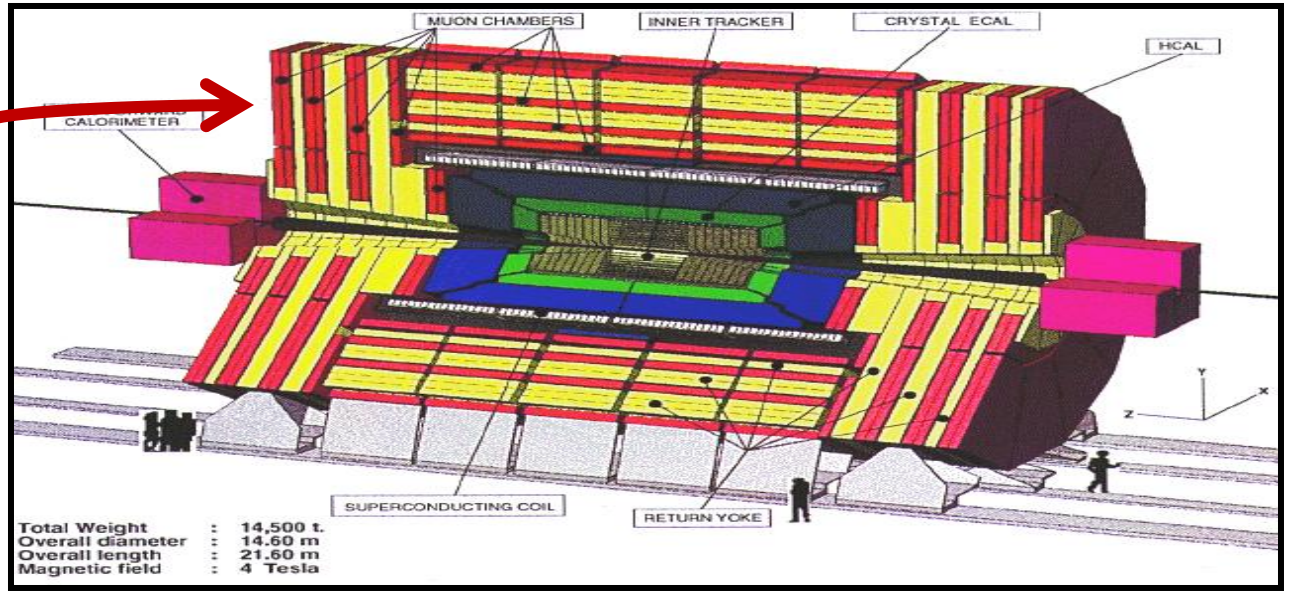
•We are hoping to get new physics or at least much better limits this year with the benefit of higher luminosity (~15 fb^{-1}) and center of mass energy(8 TeV)

Back up slides

- **Generator cuts for individual muons**
- *$pT > 40$ GeV/c*
- *$|\eta| < 2.6$*
- **Reconstruction cuts for baseline selection of events**
- *Events are required to have at least 25% of the silicon tracker tracks marked as high-purity.*
- *At least one primary vertex (PV) needs to be found in the offline reconstruction.*
- *No-scraping filter applied*
- **Reconstruction cuts for individual muons**
- *Should be both Global and Tracker*
- *$pT > 45$ GeV/c*
- *No. of valid pixel hits in silicon track > 0*
- *No. of valid strips layers in silicon track > 8*
- *No. of matches in muon chamber > 1*
- *Impact parameter < 0.2 cm*
- *Tracker relative isolation < 0.1 within an $R = 0.3$ cone radius*
- **Dimuon selection criteria**
- *The two muons are required to be oppositely charged.*
- *One of the muons must match to an trigger object of pT 40 GeV (within $\Delta R < 0.2$ cm and $\Delta pT/pT < 1$).*
- *3D angle between the two muons $< \pi - 0.02$ rad (to prevent back-to-back cosmics)*
- *Dimuon vertex $\chi 2 < 10$*

The CMS (Compact Muon Solenoid) Experiment





CMS collected ~ 5 fb^{-1} data in 2011 and planning to collect ~15 fb^{-1} in 2012.

Detector Overview

Inner detector (inside the solenoidal magnet)

- Pixel detector ($|\eta| < 2.5$)
- Silicon Tracker ($|\eta| < 2.5$)

Muon Spectrometer (outside the magnet)

- Drift Tubes (DT) in barrel ($|\eta| < 1.2$)
- Cathode Strip Chambers (CSC) in endcaps ($|\eta| < 2.4$)
- Resistive Plate Chambers (RPC) in barrel and endcaps ($|\eta| < 1.6$)