Search for contact interactions in the di-lepton spectra in pp collisions at center of mass energy of 8 TeV

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On behalf of the CMS Collaboration

Introduction

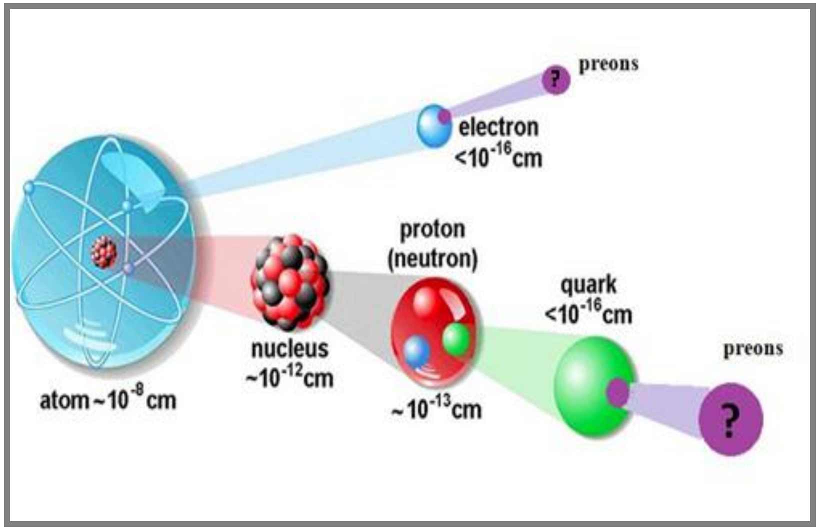
- CI is BSM which is based on the model of quark and lepton compositeness

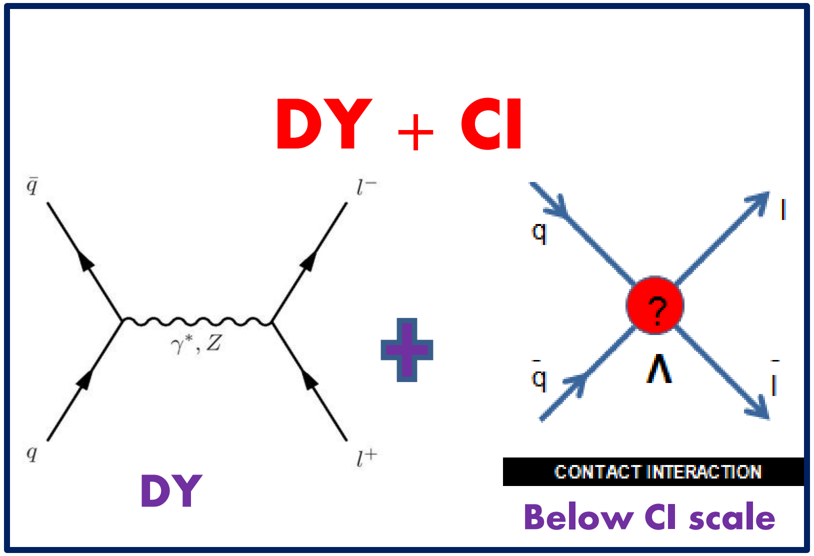
- Signature can be observed by identifying a deviation from the SM in the dilepton mass spectrum. The production cross section can be observed as :

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

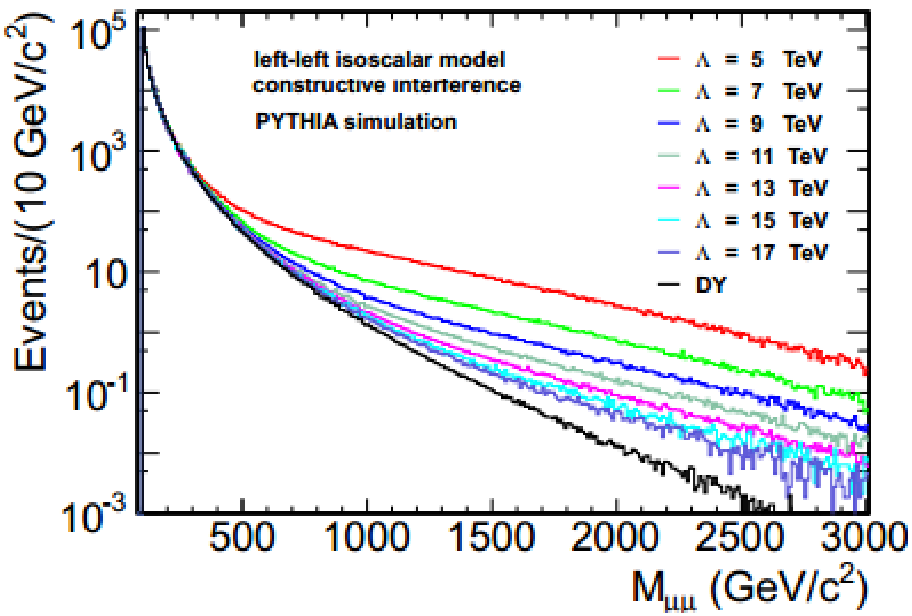
where,
$M_{l^+l^-}$ = the di–lepton invariant mass
I = product of DY and CI amplitudes
C = pure CI term.
CI/DY = CI for $\Lambda \neq \infty$ and pure DY for $\Lambda = \infty$
η = +1 and -1 for destructive and constructive interference respectively.

- The production of preons is possible only above the characteristic energy scale Λ

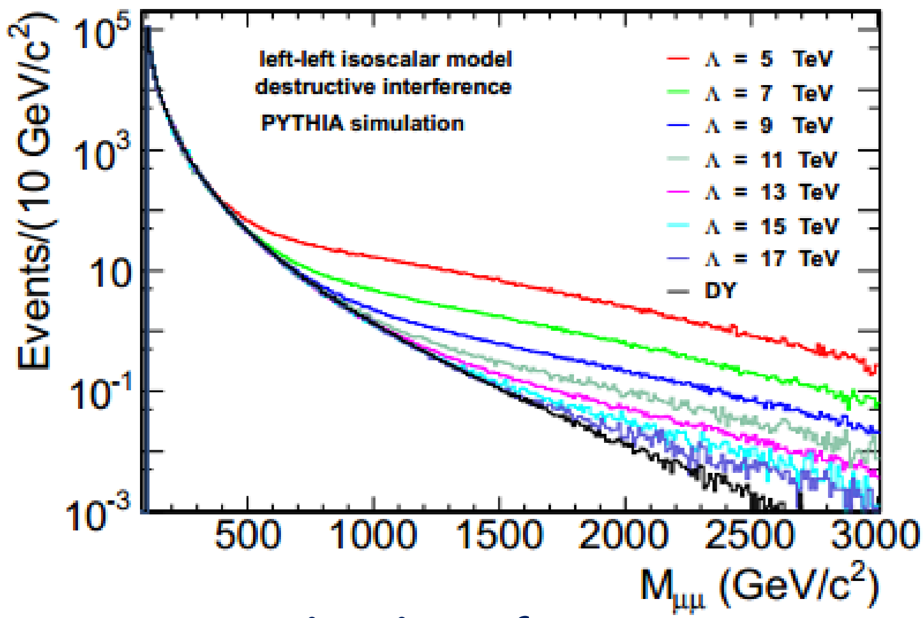




Pythia LLIM model



Constructive interference (η= -1)



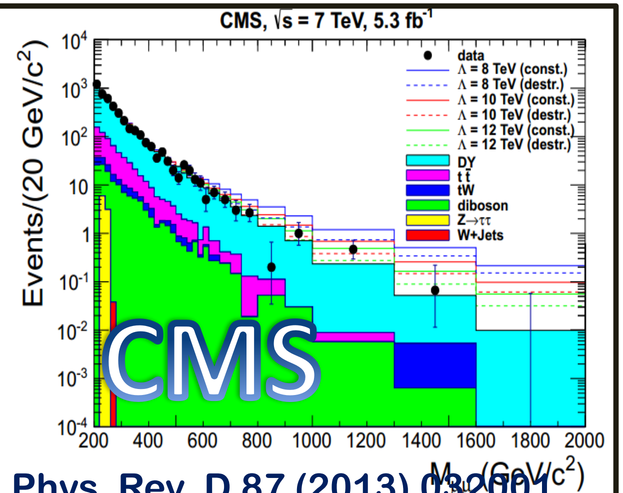
Destructive interference (η= +1)

Selection criteria used: $P_T > 45$ GeV for each μ, | η | of $\mu_1 < 2.1$ and | η | of $\mu_2 < 2.4$

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

When $\Lambda \to \infty$ The spectrum converges to DY production (SM)

Previous Searches



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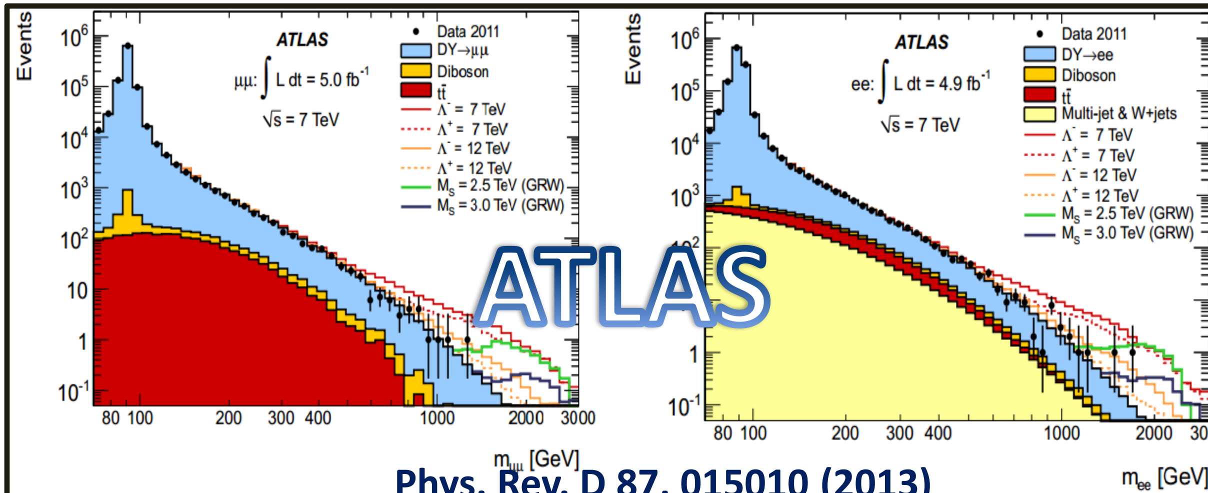


Phys. Rev. D 87, 015010 (2013)

$$L_{ql} = \frac{g_0^2}{\Lambda^2}\{\eta_{LL}(\bar{q}_L\gamma^\mu q_L)(\bar{l}_L\gamma_\mu l_L)+\eta_{LR}(\bar{q}_L\gamma^\mu q_L)(\bar{l}_R\gamma_\mu l_R)+\eta_{RL}(\bar{u}_R\gamma^\mu u_R)(\bar{l}_L\gamma_\mu l_L) + \eta_{RL}(\bar{d}_R\gamma^\mu d_R)(\bar{l}_L\gamma_\mu l_L) + \eta_{RR}(\bar{u}_R\gamma^\mu u_R)(\bar{l}_R\gamma_\mu l_R) + \eta_{RR}(\bar{d}_R\gamma^\mu d_R)(\bar{l}_R\gamma_\mu l_R)\}$$

$\sqrt{s}$ = 7 TeV			Lower Limit on Λ (TeV)	
Experiment	Channel	Luminosity(fb^{-1})	Const.	Dest.
CMS	$\mu^+ \mu^-$	5.3	13.1	9.5
ATLAS	$\mu^+ \mu^-$	5.0	12.1	9.5
ATLAS	$e^+ e^-$	4.9	12.9	9.6

Compositeness model : Left-Left Isoscalar (Currently excluded lower limits at 95 % C.L.)

Estia J. Eichten, Kenneth D. Lane, Michael E. Peskin "New Tests for Quark and Lepton Substructure",Phys. Rev. Lett. 50 (1983) 811, doi:10.1103/PhysRevLett.50.811.

Why LLIM ?

- Bench mark process (historic)
- Physics is basically similar for rest of the other terms, however, LLIM is implemented in PYTHIA

Other CMS Compositeness Searches

- Search for Contact Interactions using Inclusive Jet Events in pp collisions at $\sqrt{s}$ = 7 TeV [**CMS-EXO-11-010**] Lumi : 5 fb^{-1} Λ = 9.7 TeV (14.5 TeV) with destructive (constructive) in LLIM

- Measurement of Dijet Angular Distributions and Search for Quark Compositeness in pp Collisions at $\sqrt{s}$ = 7 TeV [**CMS-QCD-10-016**] Lumi :36 pb^{-1}
Λ = 5.6 TeV (Λ = 6.7 TeV) for destructive (constructive) interference in LLIM

- Search for Narrow Resonances using the Dijet Mass Spectrum with 19.6 fb^{-1} of pp Collisions at $\sqrt{s}$ = 8 TeV [**CMS-EXO-12-059**]
mass of excited quarks = [1.20, 3.50] TeV

- Updated Search for New Physics in Highly Boosted Z^0 Decays to Dimuon in pp Collisions at $\sqrt{s}$ = 7 TeV Lumi : 5 fb^{-1} **[CMS-EXO-11-025]**
mass of excited quarks < 2.14 TeV

- Search for new physics in the final states with a lepton and missing transverse energy at $\sqrt{s}$ = 8 TeV using 20 fb^{-1} [**CMS-EXO-12-060**]
Λ = 13.0 (10.9) TeV for the electron(muon) channel in Helicity-Non-Conserving-Model

Analysis method

- To predict observed events

  Use PYTHIA and POWHEG physics generators with full detector simulation for signal and most backgrounds

  •Expected events (SM) = DY+ Non DY

  • Expected events (CI) = CI/DY(Λ)×QCD K-factor × QED K-factor + Non DY

- Single binned counting experiment starting from dilepton minimum mass

  (M^{min} =300 GeV, 400 GeV ………… 2000 GeV)

- If data is consistent with SM prediction, set the 95 % CL lower limit in **Λ**
- To set the limit on **Λ**
  - Use modified frequentist technique commonly known as CL_s method with a profile-likelihood ratio as a test statistic
  - Choose M_{min} where expected limit peaks to get the final limit

Datasets

Data [CMS 2012 at $\sqrt{s}$= 8 TeV] :

- Di-muon channel (20.6 fb^{-1})
- Single muon trigger with PT > 40 GeV and $|\eta| < 2.1$
- Di-electron channel (19.6 fb^{-1})
- Double electron trigger with E_T > 33 GeV

Simulation

Signal :

- CI samples [Pythia 6, LLIM] with different interaction scale parameter Λ
- Λ (in TeV) of 9,11,13,15 (destructive) and additionally 17 and 19 for constructive interference

- 50 k and 25 k events for the samples in low and high mass region respectively

- Use fit functions to estimate the yields for intermediate and higher Λ values

Simulation

Backgrounds:

- Simulation (DY, ttbar, diboson, Z -> $\tau\tau$, single top)
- Using data (jets backgrounds)

Physics process	Generator
Drell - Yan	POWHEG
TT bar	POWHEG
Di- boson (WW, WZ, ZZ)	PYTHIA
Single top	POWHEG
γ +jets	PYTHIA
Z -> $\tau\tau$	POWHEG
W +jets	MADGRAPH
Incl.-μ *QCD*	PYTHIA

Selection criteria

Muon selection criteria :

❖ Momentum of muons assigned from a combined track (using tracker tracks and tracks from muon systems)

❖ $P_T > 45$ GeV

Electron selection criteria :

❖ Energy from ECAL, cluster matching with tracker, hadronic veto from HCAL

❖ $E_T > 35$ GeV

NLO corrections

K-factor = $\sigma^{NLO} / \sigma^{LO}$

Since, the Signal is generated using PYTHIA (LO) generator, QCD and QED K-factors are needed for NLO accuracy of the signal.

- A flat (mass independent) QCD K-factor of 1.3 is used for QCD NLO correction (P. Mathews et al., "Next-to-leading order QCD corrections to the Drell-Yan cross section in models of TeV-scale gravity", Nucl. Phys. B713 (2005) 333, doi:10.1016/j.nuclphysb.2005.01.051.)

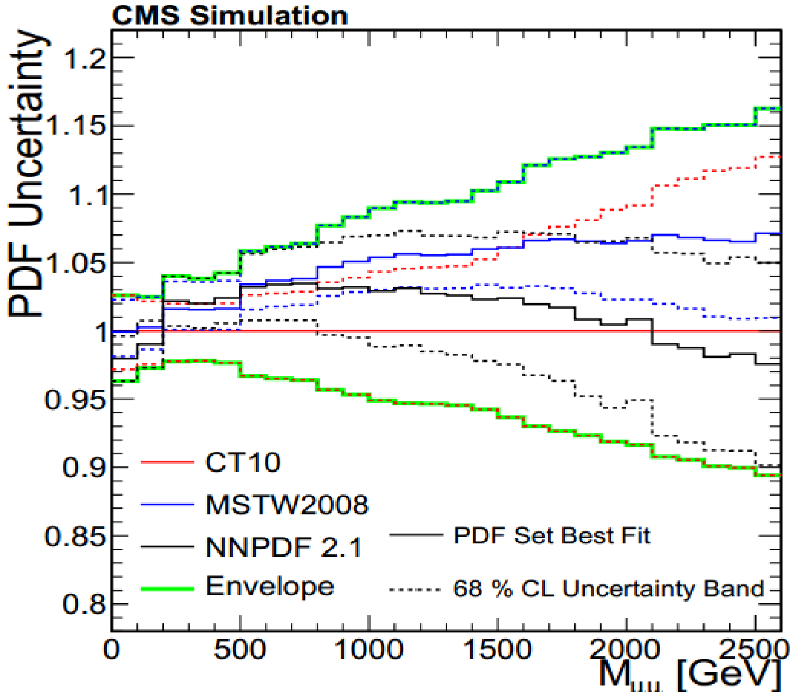
- QED NLO K-factor is estimated using HORACE 3.1 using DY simulation

- QED K-factor depends upon the di-lepton mass (0.994 at 300 GeV and 0.920 at 2 TeV)

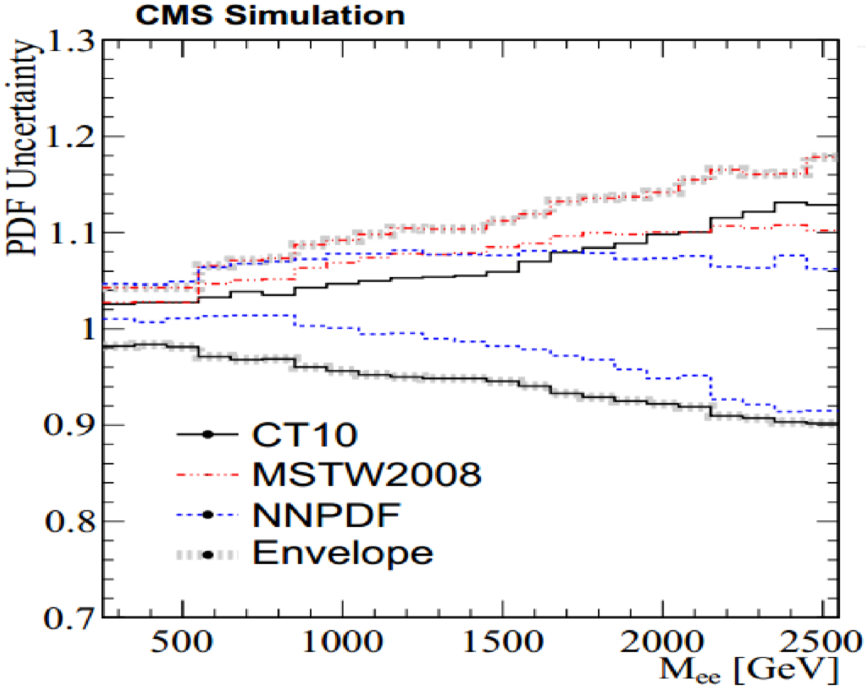
PDF Uncertainty

- Following PDF4LHC recommendations

- PDF uncertainty is estimated from the envelope of the PDF sets CT10, MSTW2008 and NNPDF2.1, using central value of CT10
- POWHEG samples of DY simulation used in both channels



CMS-EXO-12-027



CMS-EXO-12-031

PDF uncertainty shown at 68% CL

Systematic Uncertainty

Di-muon Channel:

Source	Uncertainty (%)
PDF	13.0
Trigger and reco efficiency	3.0
Momentum scale	23.0
Momentum resolution	6.0
Alignment	5.0
QED K-factor	5.0
QCD NNLO	2.0
Lumi	4.4

Given at $M_{\mu\mu}^{min} = 1.8$ TeV

CMS-EXO-12-027

Di-electron Channel:

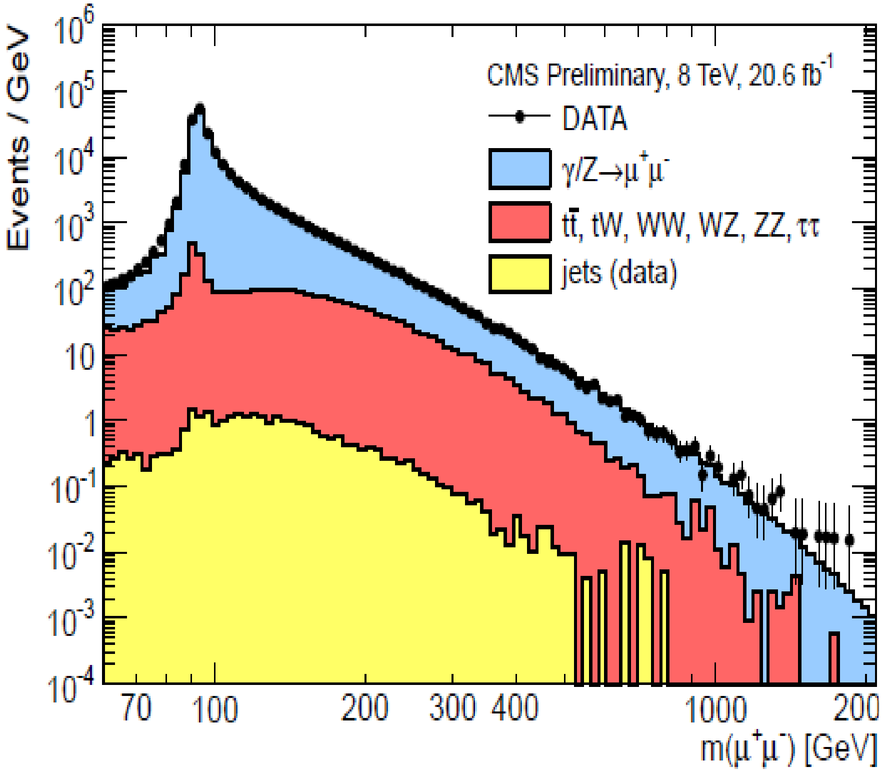
Source	Uncertainty (%)
PDF	12.0
Identification and reco	5.0
Energy scale	1.0
DY NLO correction	6.0
Lumi	4.4

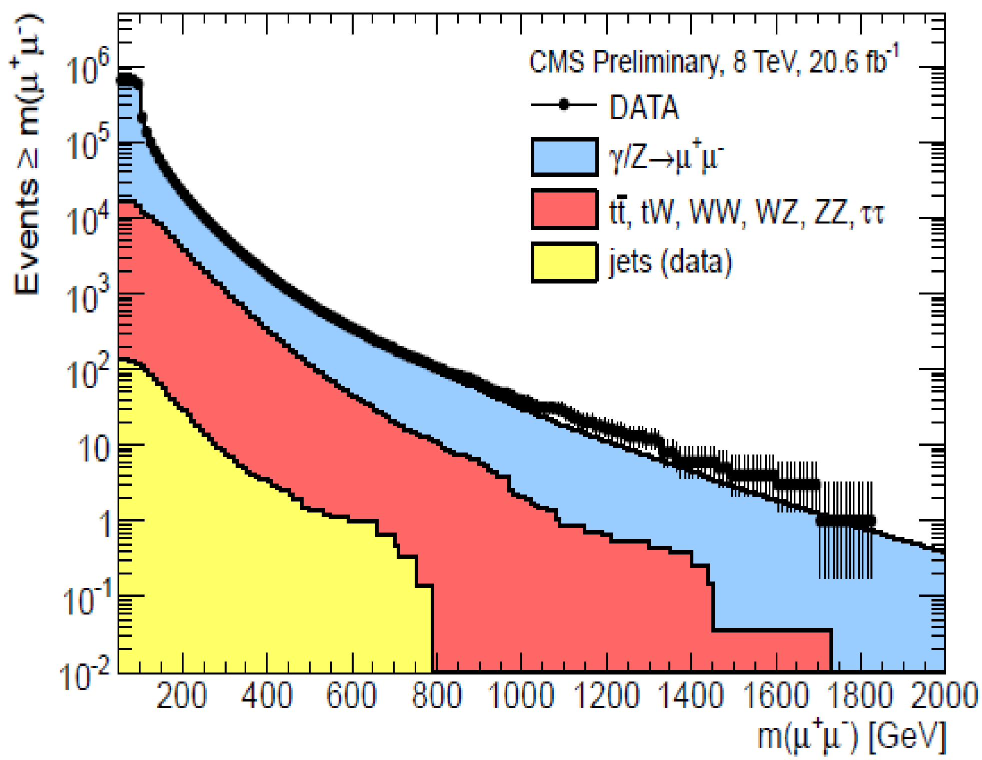
Given at $M_{ee}^{min} = 1.8$ TeV

CMS-EXO-12-031

Systematic uncertainties affecting the limit on Λ on this analysis

Data-MC comparison ($\mu^+ \mu^-$)

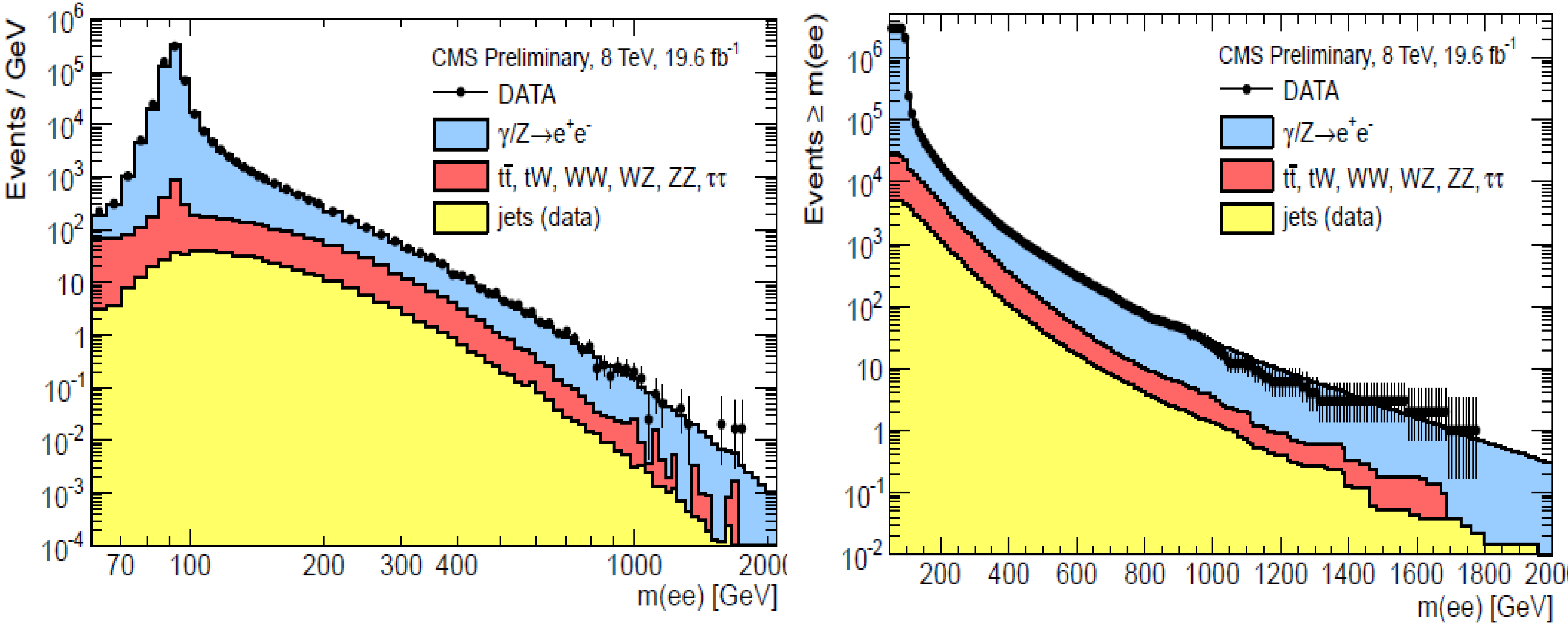




CMS-EXO-12-061

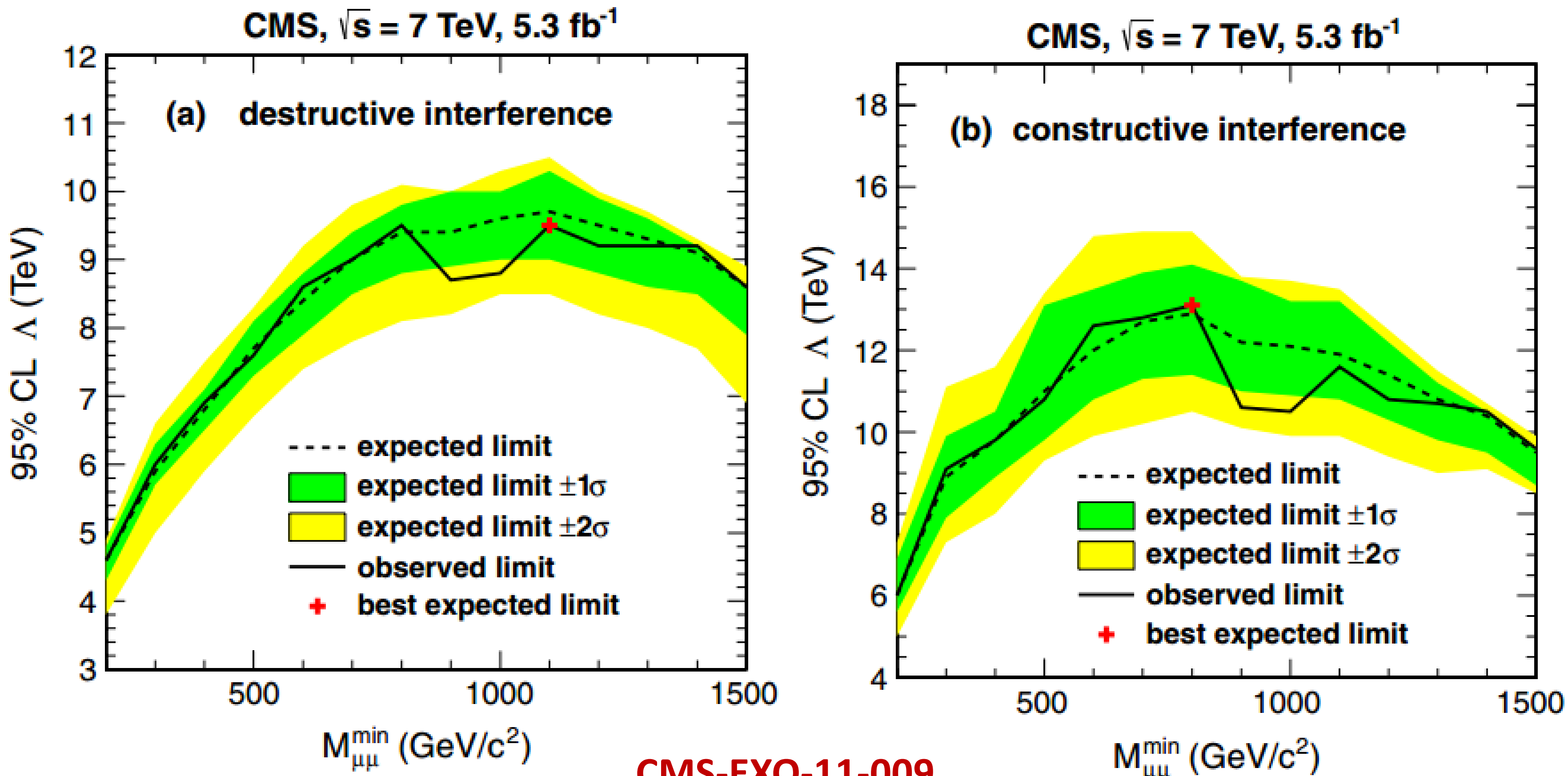
- Error bars for data show statistical uncertainty
- Data is consistent with SM expectations

Data -MC comparison ($e^+ e^-$)



CMS-EXO-12-061

$\mu^+ \mu^-$: 95% CL lower limit on Λ at $\sqrt{s} = 7$ TeV



CMS-EXO-11-009

Limits from 2011 data at $\sqrt{s} = 7$ TeV in the di-muon channel

Note : Limits from 2012 data at $\sqrt{s} = 8$ TeV are still in preparation

Conclusion

- 8 TeV dimuon and dielectron spectra are consistent with SM

- Procedure for setting 95% CL lower limits on Lambda is demonstrated with 7 TeV dimuon

- At 8 TeV, 95 % CL lower limit is set on Λ in both channels and limits are being prepared

- We expect a significant improvement in the limits in both channels at 8 TeV

THANKS!