Search for Contact Interactions in $\mu^+\mu^-$ and e^+e^- Final States in 13 TeV p-p Collisions at CMS

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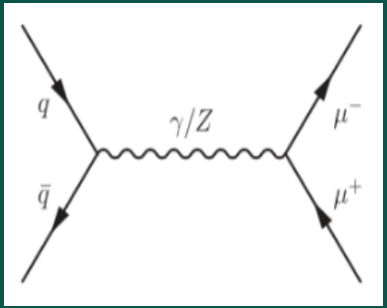
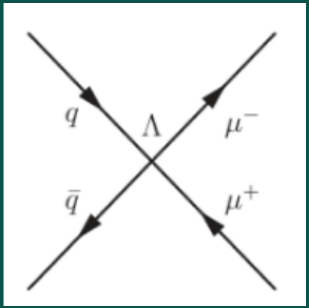
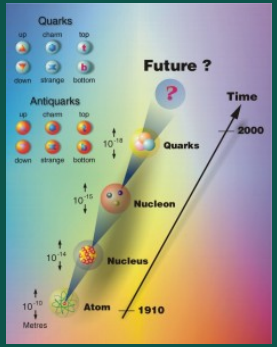
Objective





- Search for evidence of contact interactions (CI) in both dimuon and dielectron channels by comparing CI to Drell-Yan (DY)
- Will seek evidence for CI or place a lower limit on energy scale parameter Λ
- Limit on combined dilepton channel will also be set
- $\frac{d\sigma(CI)}{dM_m} = \frac{d\sigma(DY)}{dM_m} - \eta\frac{I}{\Lambda^2} + \eta^2\frac{C}{\Lambda^4}$ (η is relative sign between CI and DY)
- I and C are proportional to interference and CI amplitudes respectively

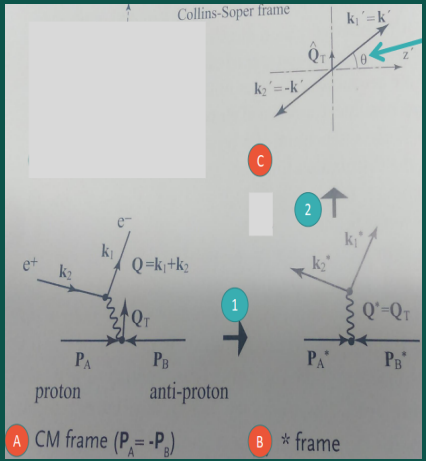
Motivation



$$\begin{aligned}\mathcal{L}_{ql} = (g_0^2/\Lambda^2)\{&\eta_{LL}(\bar{q}_L\gamma^\mu q_L)(\bar{\mu}_L\gamma_\mu\mu_L)\\ &+ \eta_{LR}(\bar{q}_L\gamma^\mu q_L)(\bar{\mu}_R\gamma_\mu\mu_R)\\ &+ \eta_{RL}(\bar{u}_R\gamma^\mu u_R)(\bar{\mu}_L\gamma_\mu\mu_L)\\ &+ \eta_{RL}(\bar{d}_R\gamma^\mu d_R)(\bar{\mu}_L\gamma_\mu\mu_L)\\ &+ \eta_{RR}(\bar{u}_R\gamma^\mu u_R)(\bar{\mu}_R\gamma_\mu\mu_R)\\ &+ \eta_{RR}(\bar{d}_R\gamma^\mu d_R)(\bar{\mu}_R\gamma_\mu\mu_R)\},\end{aligned}$$

- Evidence of CI would suggest quark or lepton substructure
- Contact interaction models with different helicity structures can be used to interpret the data: left-left(LL), left-right(LR), right-right(RR)

Collins-Soper Frame



Nagashimi, Elementary Particle Physics

- Collins-Soper (CS) frame is the rest frame of dilepton system of interest
- To get to CS frame, from CM frame boost along longitudinal direction, then boost along transverse direction
- θ_{CS} is of interest as distribution in LR model differs from those of LL and RR
- θ_{CS} defined to be angle between $q\bar{q}$ collision axis and $\ell^+\ell^-$ axis
- $$cos(\theta_{CS}) = \frac{p_z(\ell^+\ell^-)}{|p_z(\ell^+\ell^-)|} \frac{2(k_1^+ k_2^- - k_1^- k_2^+)}{m(\ell^+\ell^-)\sqrt{m^2(\ell^+\ell^-) + p_T^2(\ell^+\ell^-)}}$$

  $k_i^+ = \frac{1}{\sqrt{2}}(p_i^0 + p_i^3)$

  $k_i^- = \frac{1}{\sqrt{2}}(p_i^0 - p_i^3)$

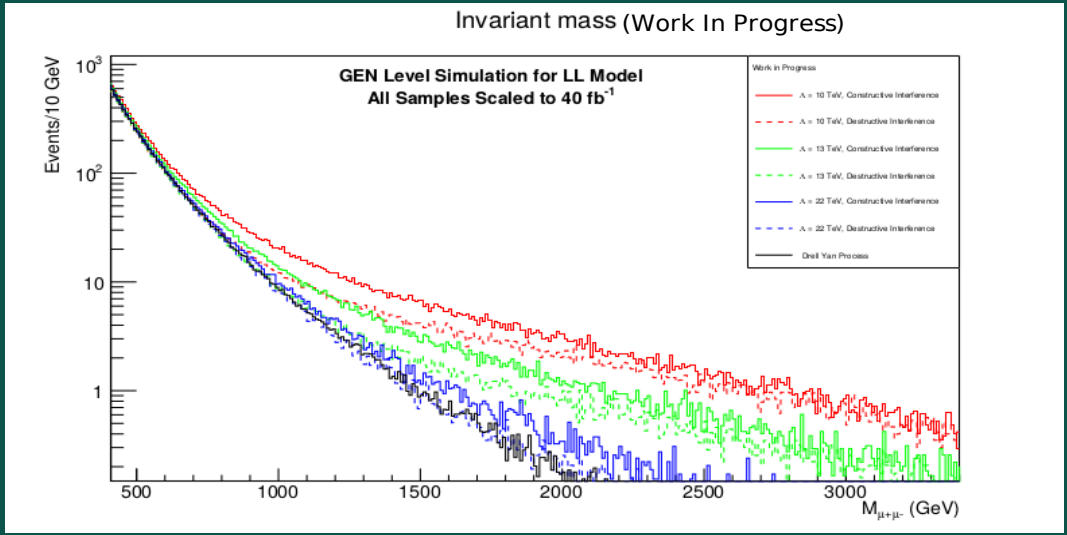
Search Method

- Compare data to SM and CI model
  - $\frac{dN}{dM_{\ell\ell}}$; θ_{CS}
- SM processes:
  - DY
  - $t\bar{t}$, tW
  - diboson (WW, WZ, ZZ)
- CI model includes interference term between DY and CI samples
- CI signal is the excess of events above SM prediction
- Find lower limits on Λ using a Bayesian method
- Use prior flat in: σ, $\frac{1}{\Lambda^2}$, or $\frac{1}{\Lambda^4}$

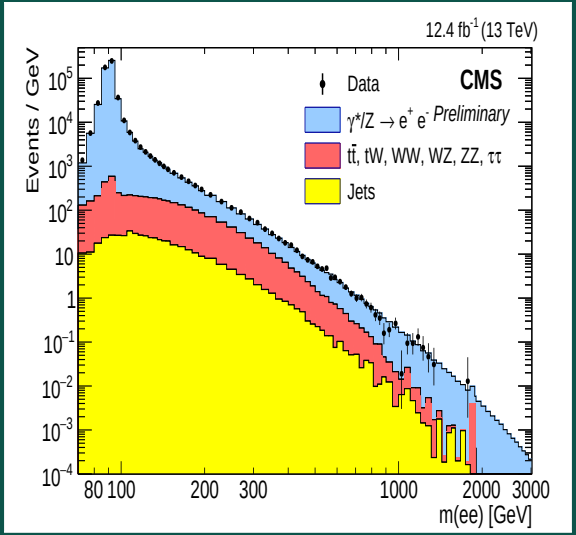
Simulation Method

- Create MC samples using Pythia8 and GEANT4 then reconstruct
- Λ = 10, 16, 22, 28, 34 TeV
- Parameterize event yield by Λ
- Λs chosen a few below and above Run I limits to better predict new limits
- Helicity models: LL, LR, RR
- Interference: Constructive and destructive
- Both dielectron and dimuon final states
- Lower mass cut at 300, 800, 1300, 2000 (LL Con Only) GeV. These will be combined for larger statistics
- Each sample has 50 k events

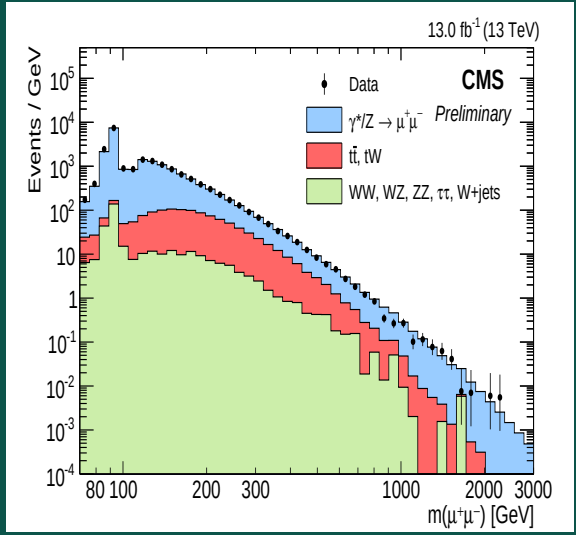
Dimuon Mass for different Λ values



Dilepton Invariant Mass

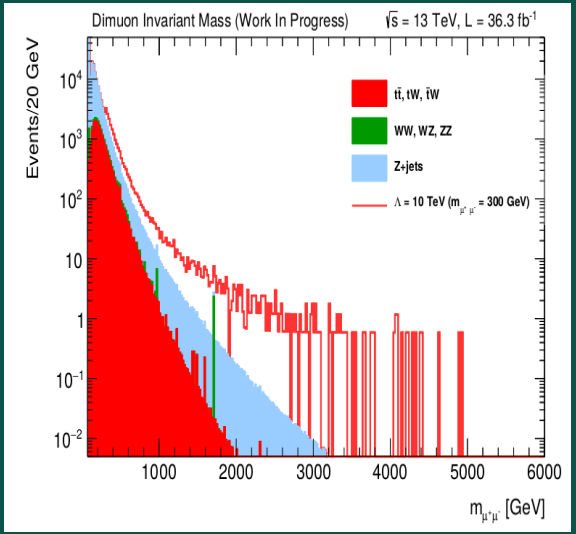


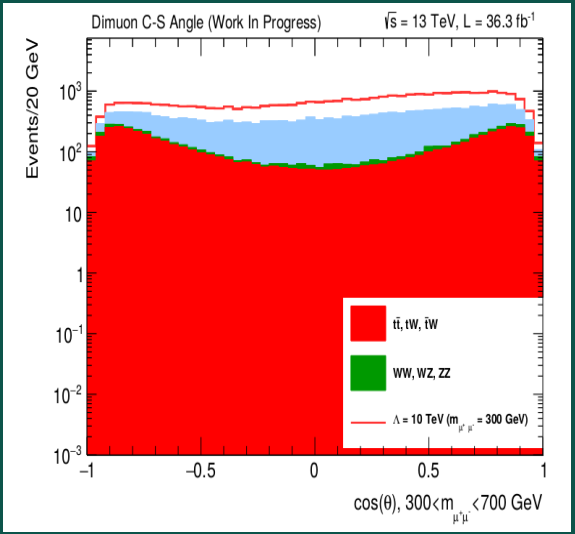
From CMS PAS EXO-16-031



From CMS PAS EXO-16-031

Dimuon CI and Background





Summary

Item	Run I	Run II
Lumi	5.7 fb^{-1} (7 TeV)	36.3 fb^{-1}
Model	LL	LL,LR,RR
θ_{CS}	no	yes

Lower Limits on Λ from Run I

Dileptons	Λ_c (TeV)	Λ_d (TeV)
e^+e^-	18.3	13.5
$\mu^+\mu^-$	15.2	12.0

Lower limits on Λ from Run 1:
CMS collaboration, Search for physics beyond the standard model in dilepton mass spectra in proton-proton collisions at $\sqrt{s} = 8$ TeV, JHEP 04 (2015) 025.

BACKUP

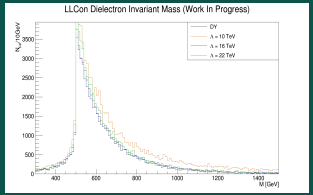
Harari Fermions

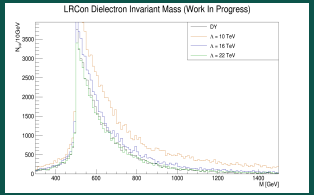
charge	preon makeup	particle
$+1$	$+++$	positron
$+\frac{2}{3}$	$++0$	u-quark
$+\frac{1}{3}$	$+00$	anti d-quark
0	000	e-neutrino
0	000	anti e-neutrino
$-\frac{1}{3}$	-00	d-quark
$-\frac{2}{3}$	$--0$	anti u-quark
-1	$---$	electron

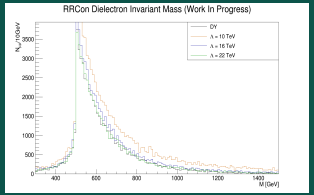
Harari Bosons

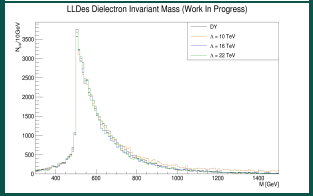
charge	preon makeup	particle
$+1$	$+++000$	W^+
-1	$---000$	W^-
0	$---+++/-+-+00/000000/-+0000$	Z_0
0	$+-$	γ

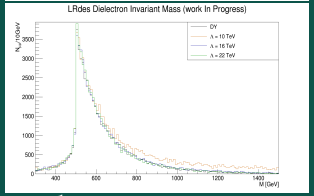
Dielectron Mass Distribution

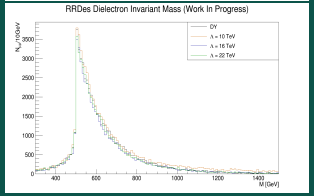






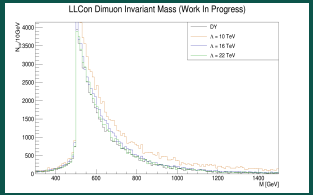


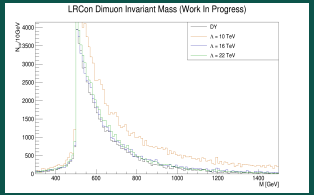


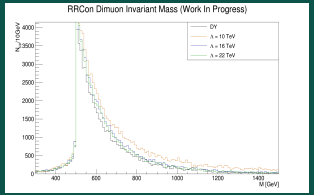


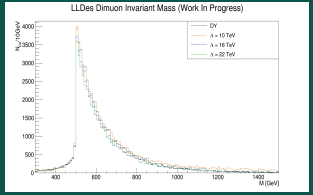
All samples scaled to $L = 37.12 fb^{-1}$

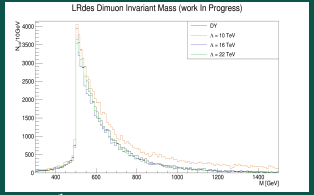
Dimuon Mass Distribution

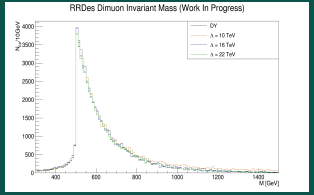






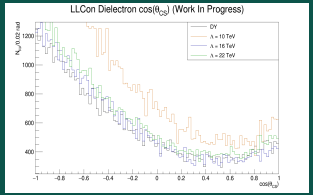


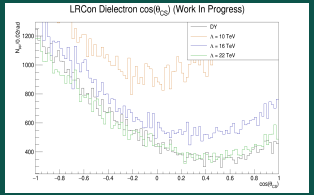


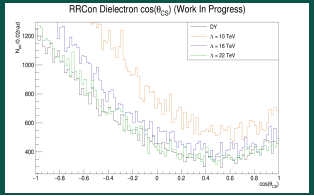


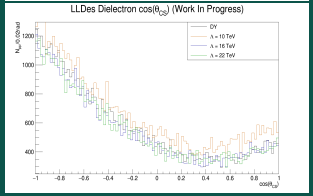
All samples scaled to $L = 37.12 fb^{-1}$

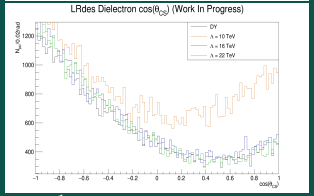
Dielectron Collins-Soper Angle Distribution

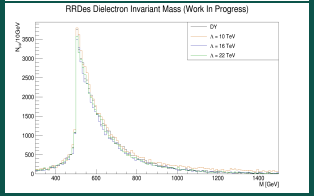






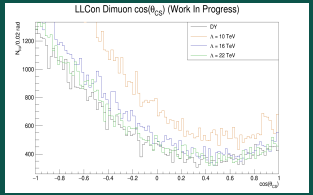


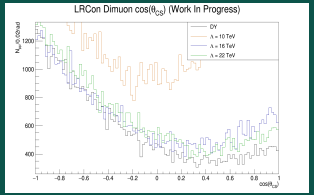


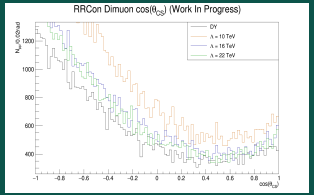


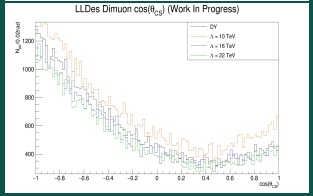
All samples scaled to $L = 37.12 fb^{-1}$

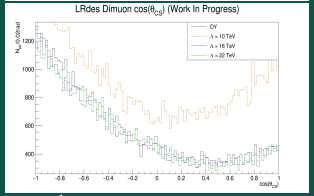
Dimuon Collins-Soper Angle Distribution

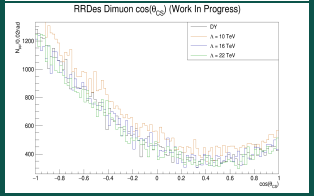






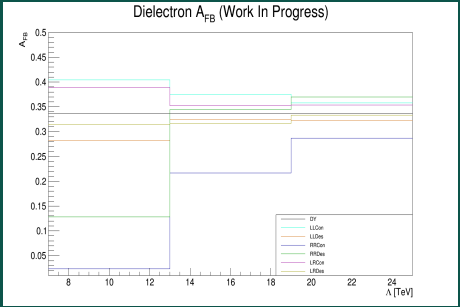


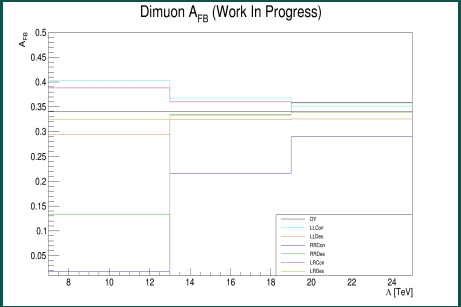




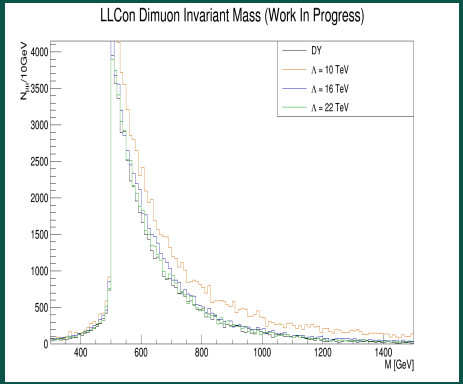
All samples scaled to $L = 37.12 fb^{-1}$

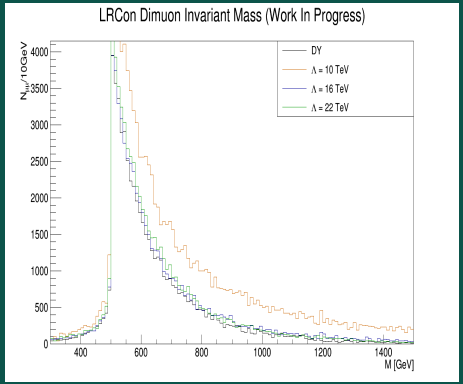
A_{FB}


Dielectron A_{FB} (Work In Progress)
A_{FB}
0.5
0.45
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
8
10
12
14
16
18
20
22
24
Λ [TeV]
DY
LLCon
LLDes
RRCon
RRDes
LRCon
LRDes


Dimuon A_{FB} (Work In Progress)
A_{FB}
0.5
0.45
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
8
10
12
14
16
18
20
22
24
Λ [TeV]
DY
LLCon
LLDes
RRCon
RRDes
LRCon
LRDes

Dimuon Mass Distribution





All samples scaled to $L = 37.12 fb^{-1}$