Recent CMS Results of Searches for Physics Beyond Standard Model

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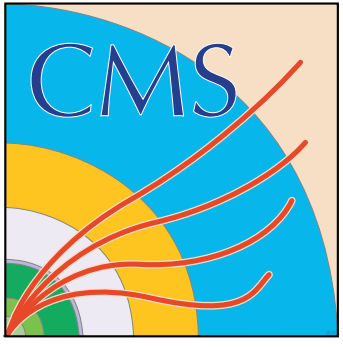
on behalf of the CMS Collaboration

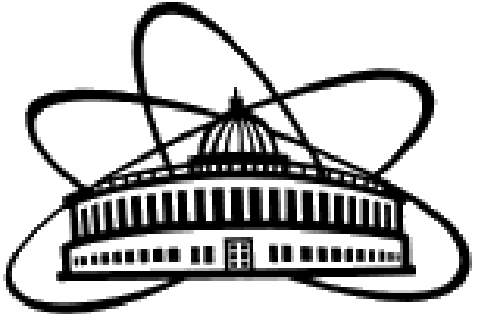
ICSSNP-13

International Conference–Session
of the Section of Nuclear Physics
of the Physical Sciences Division
of the Russian Academy of Sciences



Protvino, Russia

November 6, 2013

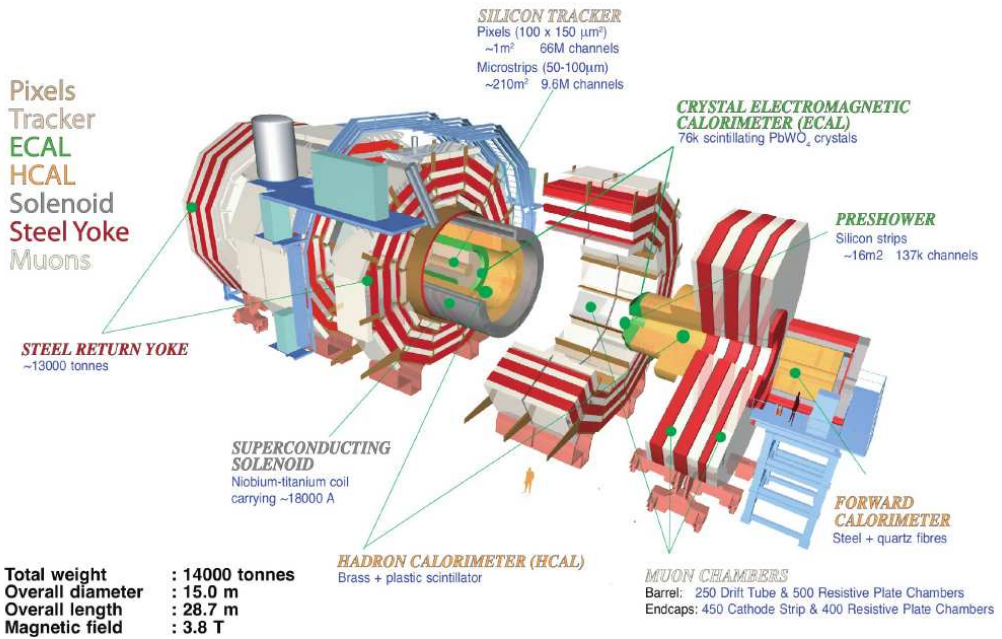


CMS Public Physics Results:

https://twiki.cern.ch/twiki/bin/view/CMSPublic/PhysicsResults

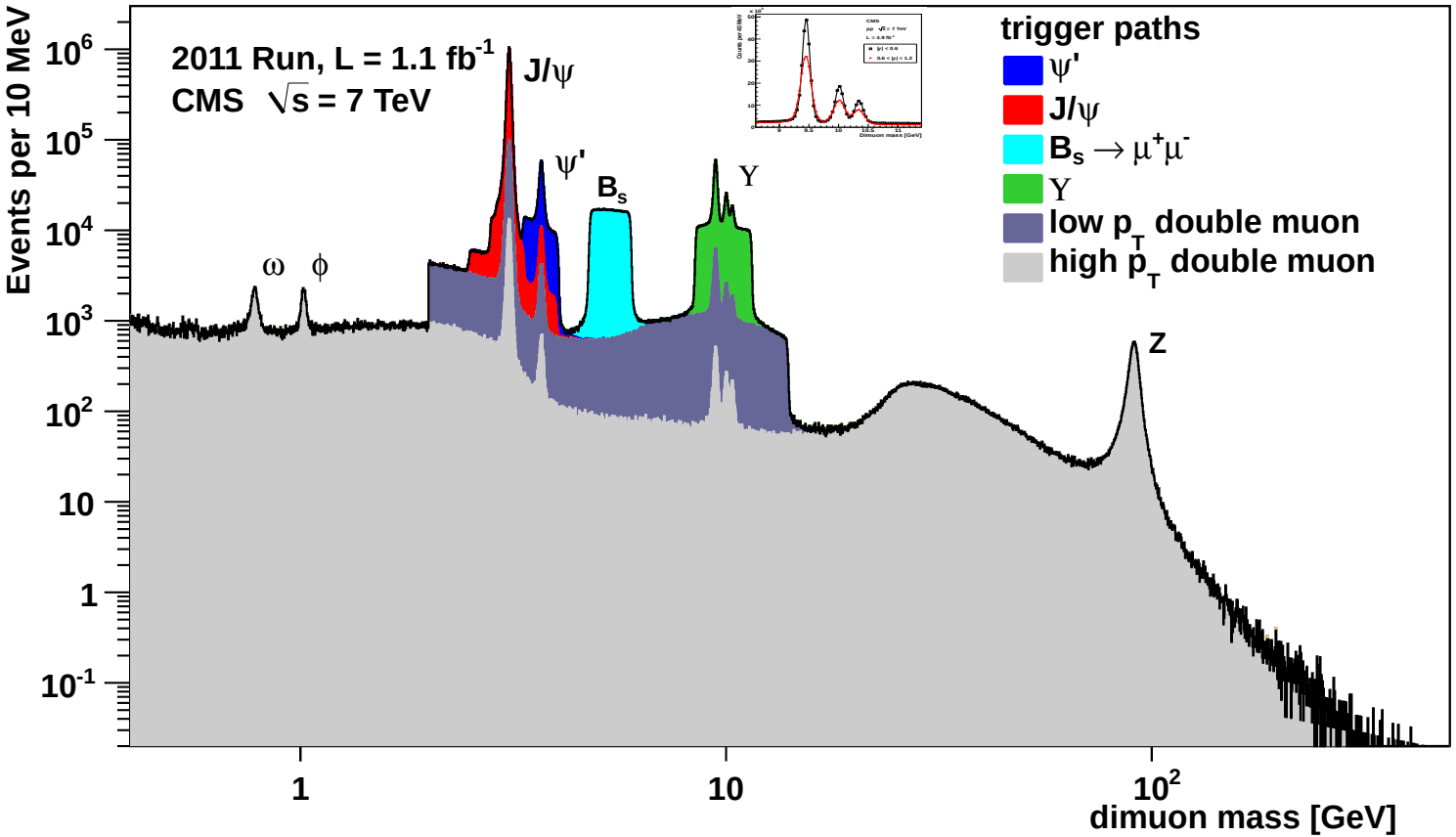
Outline:

- Heavy Resonances (extended gauge models, extra dimensions)
  $\Longrightarrow$ dileptons, dijets, diphotons, $t\bar{t}$, dibosons, etc.
- Non-Resonant Signals
- Leptoquarks
- 4th Generation particles
- Supersymmetry
- Conclusions



Dimuon Mass Spectrum

Dimuon mass distribution from several trigger paths



Excellent performance of the CMS detector

Models Beyond Standard Model for Dilepton Production

Extra gauge bosons appear naturally in various extensions of Standard Model:

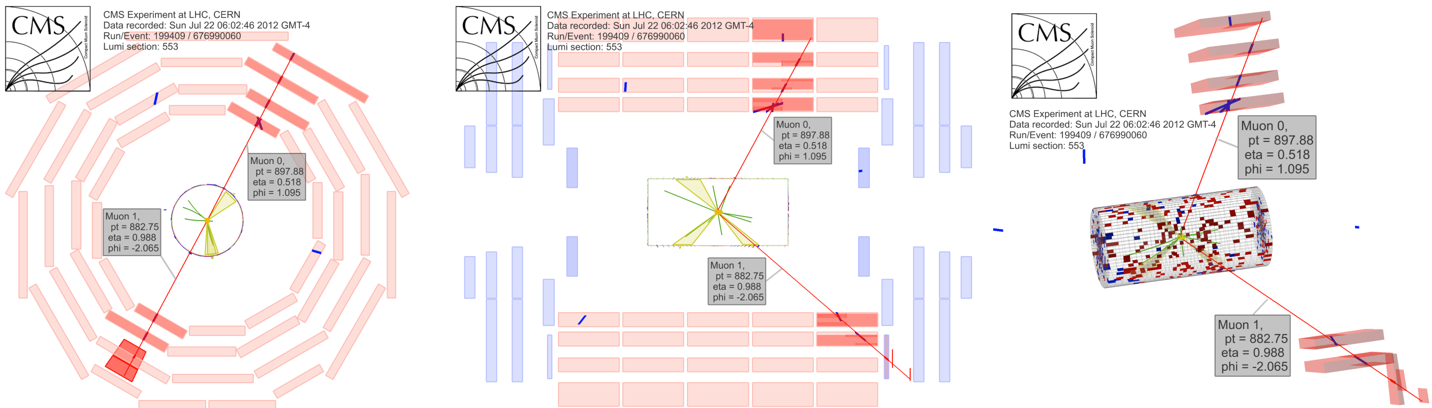
- E_6 models: Z'_χ, Z'_η, Z'_ψ arise in different ways of breaking E_6 symmetry group
  Implemented in Pythia according to J. Rosner, Phys.Rev. D35 (1987) 2244
  $E_6 \to SO(10) \times U(1)_\psi$; $SO(10) \to SU(5) \times U(1)_\chi$; $Q_{Z'} = Q_\psi \sin(\theta_6) + Q_\chi \cos(\theta_6)$
- SSM (Sequential Standard Model) or "reference" model —
  The same coupling constants for Z' as for the SM
- Heavy graviton resonances are predicted by RS1 (Randall-Sundrum) model of TeV-scale gravity with one additional warped extra dimension:
  coupling constant $c = k/\bar{M}_{Pl}$

  Non-resonant models such as ADD and Contact interactions:
- ADD (Arkani-Hamed–Dimopoulos–Dvali) model — large flat extra dimensions,
  $N_{ED} = 2 - 7$, string scale M_s
- Contact interactions model comes from idea of quark and lepton compositeness.
  Conventional benchmark — 4-fermion interaction model $\mathcal{L} \sim \frac{4\pi}{\Lambda^2}(\bar{q}_L\gamma^\mu q_L)(\bar{l}_L\gamma_\mu l_L)$.
  Λ — the energy scale parameter for the contact interaction.

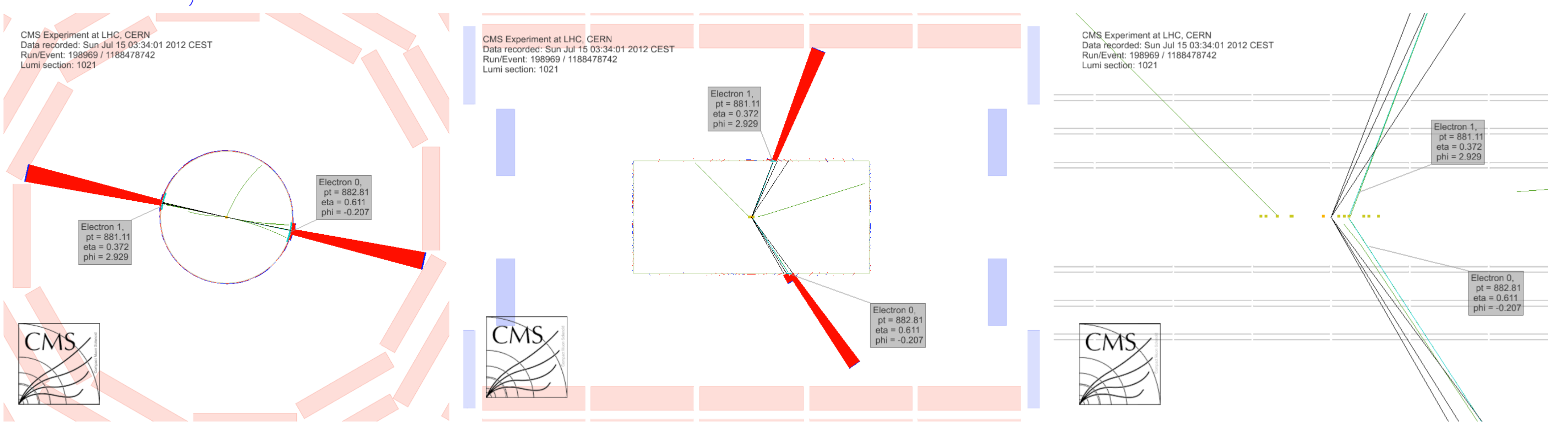
There exist also other models in which heavy dileptons appear.

Dimuon, $M = 1.824$ TeV

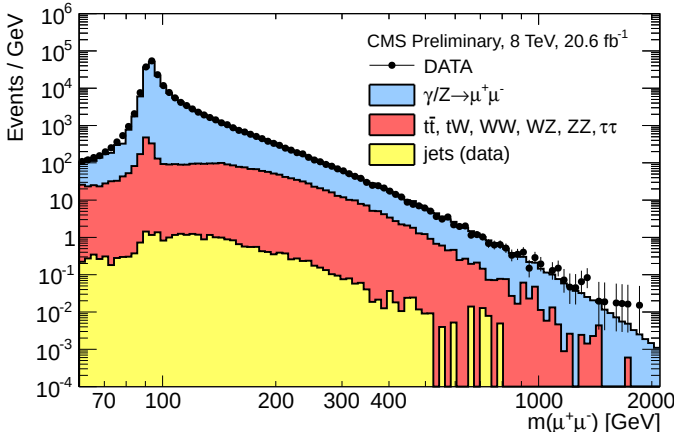
At $\sqrt{s} = 8$ TeV $\int L\,dt \approx 20$ fb^{-1}



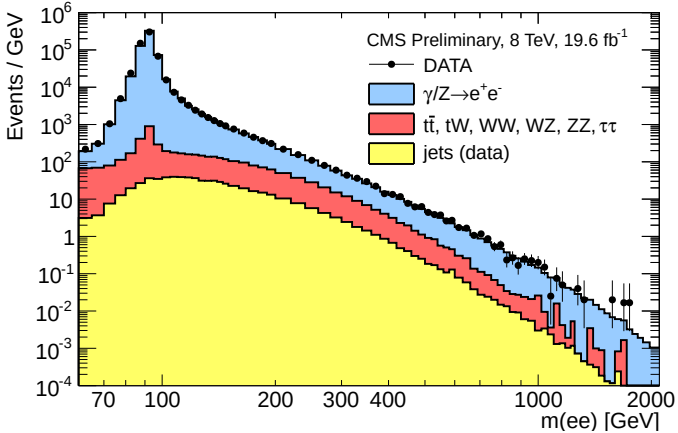
Dielectron, $M = 1.776$ TeV

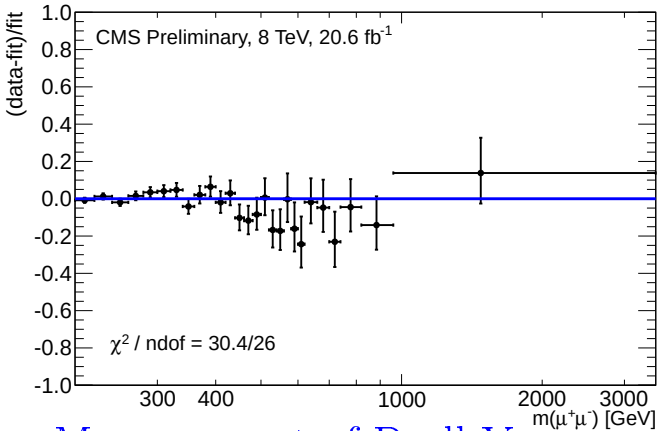


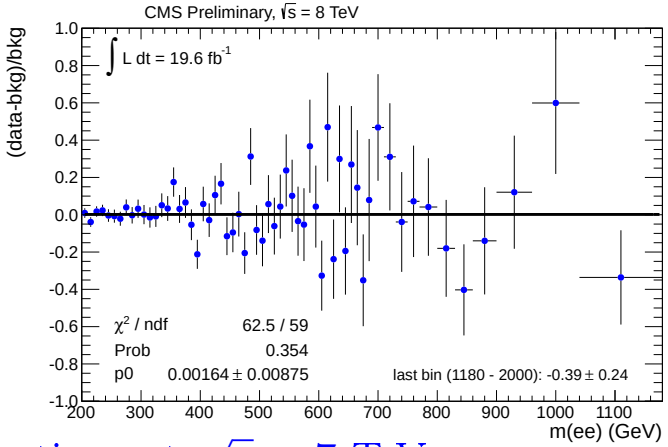
$\mu^+\mu^-$



e^+e^-

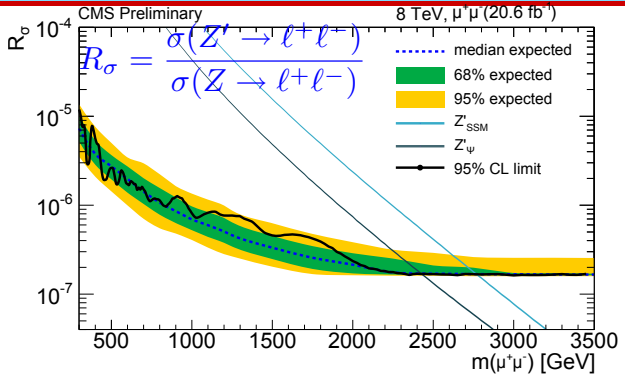


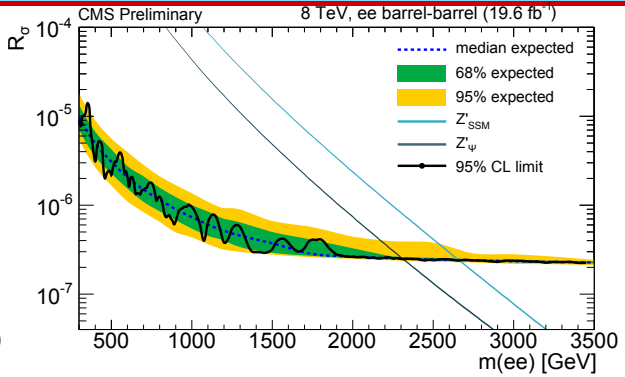


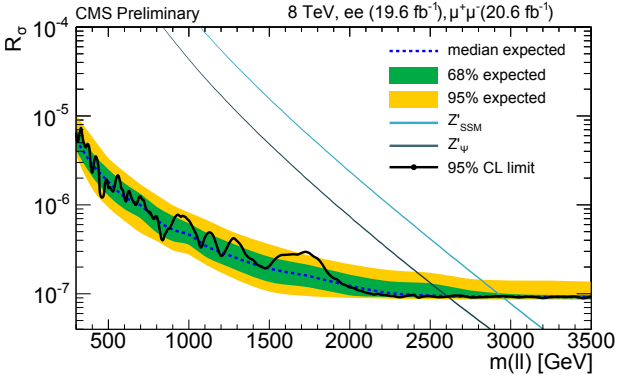


Measurement of Drell-Yan cross sections at $\sqrt{s} = 7$ TeV: $\frac{d\sigma}{dM}$, $\frac{d\sigma}{dM\, d|Y|}$ (arXiv:1310.7291)

Search for Narrow Heavy Resonances in Dilepton Spectra (EXO-12-061)







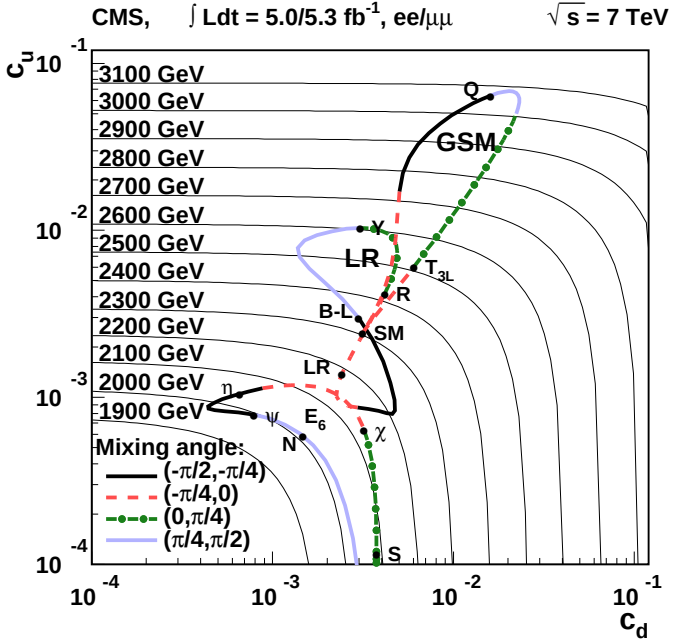
The lower dilepton mass limits at 95% CL:

2950 GeV — $Z'_{\rm SSM}$ model

2600 GeV — Z'_{ψ} model

CMS limits are more restrictive than those previously obtained with similar direct searches by the Tevatron experiments or indirect searches by LEP-II experiments.

Generalizing to Other $Z' \to l^+l^-$ Models — Plot c_u–c_d



Z' cross section can be expressed in terms of quantity $[c_u w_u + c_d w_d]$ (Phys. Rev. D83 (2011) 075012):

$$\sigma^{Z'}_{l^+l^-} = \frac{\pi}{48s}\left[c_u w_u(s, M^2_{Z'}) + c_d w_d(s, M^2_{Z'})\right]$$

c_u, c_d contain information from the model-dependent couplings to fermions in the annihilation of charge 2/3 and -1/3 quarks, respectively.

w_u, w_d contain information about PDFs for the annihilation at a given mass.

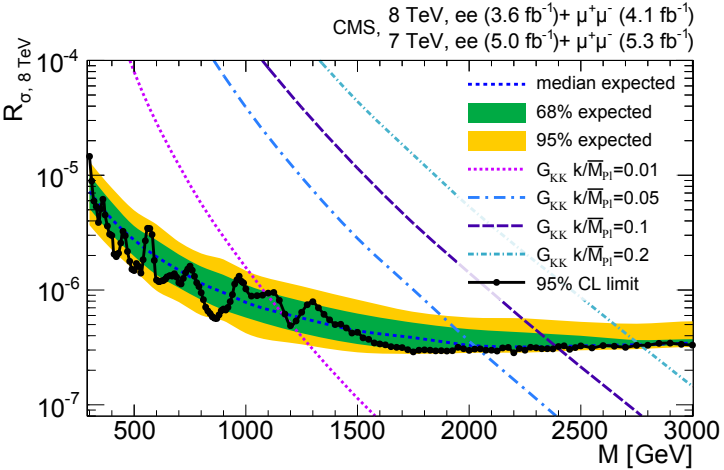
$Z'_{\rm SSM}$ is a special case of generalized sequential standard models (GSM), Z'_ψ is one of the E_6 models, generalized L-R models can also be included.

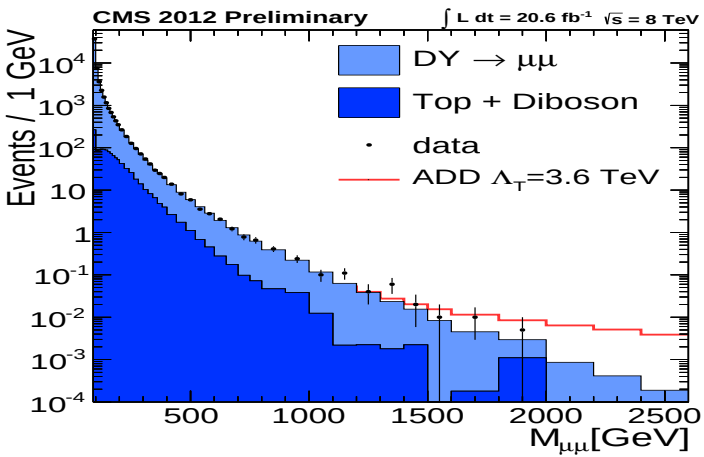
Plot show iso-contours of cross section with constant $c_u + (w_d/w_u)c_d$.

Changing this combination (or $\int L\,dt$) by 1 order of magnitude moves the mass limits by ≈ 500 GeV.

CMS Collaboration, Phys. Lett. B714 (2012) 158 — for $5\,\text{fb}^{-1}$ at $\sqrt{s} = 7\,\text{TeV}$

Search for RS1 model in Dilepton Mass Spectrum (Phys. Lett. B720 (2013) 63)





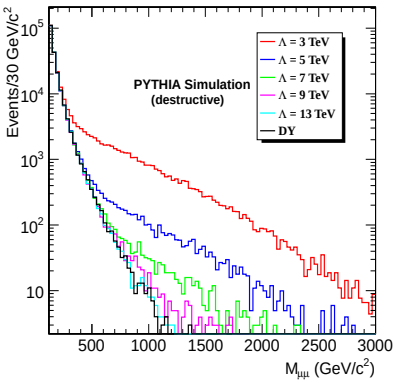
The measured dilepton mass spectra are consistent with predictions from SM.
An RS1 graviton with coupling constant $c = 0.10$ is excluded below 2.39 TeV.
An RS1 graviton with coupling constant $c = 0.05$ is excluded below 2.03 TeV.

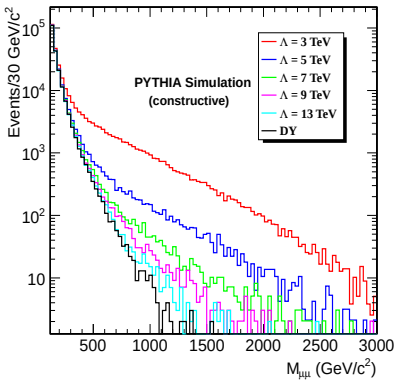
For search in diphoton mass spectrum (Phys. Rev. Lett. 108 (2012) 111801)
An RS1 graviton with coupling constant $c = 0.10$ is excluded below 1.84 TeV.
An RS1 graviton with coupling constant $c = 0.05$ is excluded below 1.50 TeV.

For ADD model, values of the model parameter M_S up to 4.94 TeV are excluded at 95% C.L. (EXO-12-027, EXO-12-031)

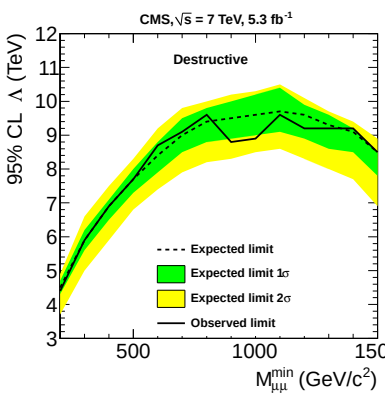
See talk by M. Savina

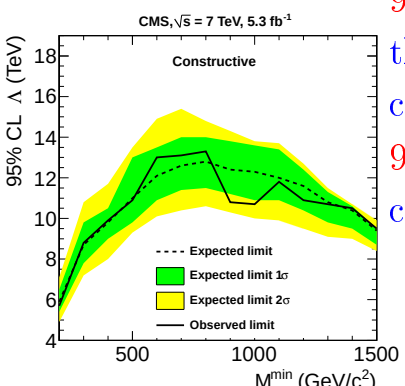
Contact interactions (Phys .Rev. D 87 (2013) 032001)





Samples with 5 fb^{-1} at $\sqrt{s} = 7$ TeV





CI model comes from idea of quark and lepton compositeness.

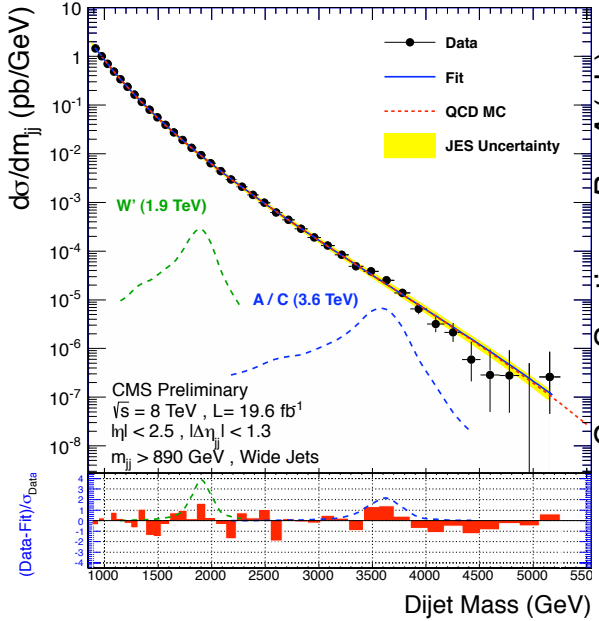
Conventional benchmark for CI in the dilepton channel:

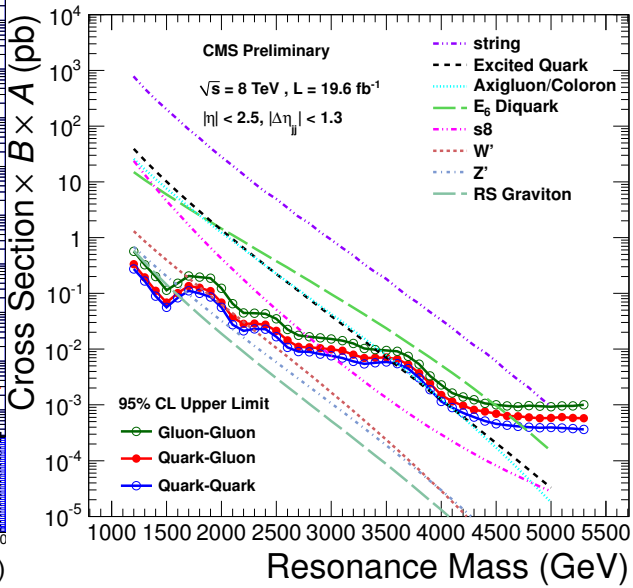
Left-left isoscalar model (Eichten et al.):

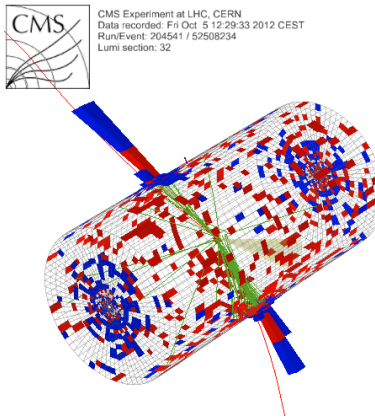
$$\mathcal{L} = \eta \frac{4\pi}{\Lambda^2}(\bar{q}_L\gamma^\mu q_L)(\bar{l}_L\gamma_\mu l_L), \quad \eta = \pm 1$$

95% C.L. lower limits are set on Λ, the energy scale parameter for the contact interaction:

9.5 and 13.1 TeV for destructive and constructive interference.







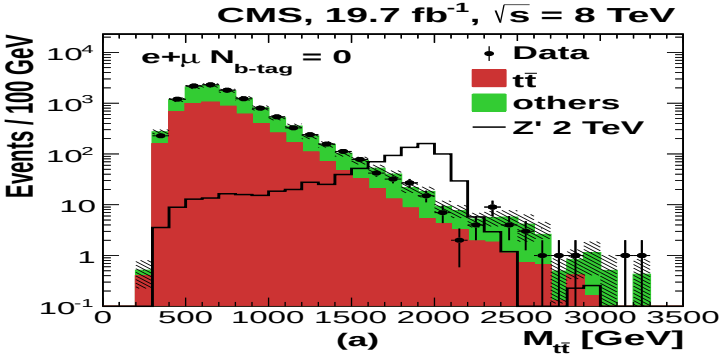
Lower limits on the masses of different types of exotic resonances are set in the range 1.2–5.1 TeV.

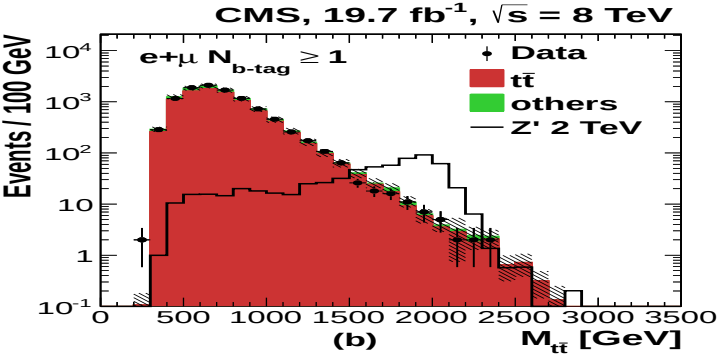
Many of them extend the previous exclusions from the dijet mass search.

Model	Final State	Obs. Mass Excl. [TeV]	Exp. Mass Excl. [TeV]
String Resonance (S)	qg	[1.20,5.08]	[1.20,5.00]
Excited Quark (q*)	qg	[1.20,3.50]	[1.20,3.75]
E_6 Diquark (D)	qq	[1.20,4.75]	[1.20,4.50]
Axigluon (A)/Coloron (C)	$q\bar{q}$	[1.20,3.60] + [3.90,4.08]	[1.20,3.87]
Color Octet Scalar (s8)	gg	[1.20,2.79]	[1.20,2.74]
W′ Boson (W′)	$q\bar{q}$	[1.20,2.29]	[1.20,2.28]
Z′ Boson (Z′)	$q\bar{q}$	[1.20,1.68]	[1.20,1.87]
RS Graviton (G)	$q\bar{q}$+gg	[1.20,1.58]	[1.20,1.43]

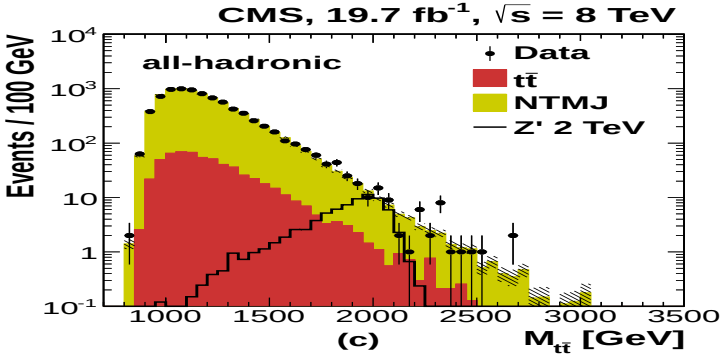
JHEP 01 (2013) 013

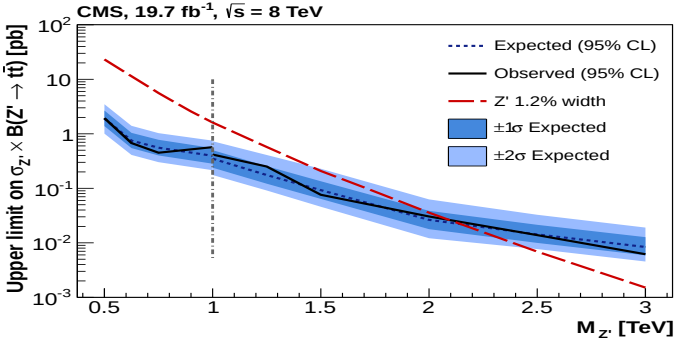
Semileptonic Top decays + ≥ 2 jets





Full hadronic Top decays





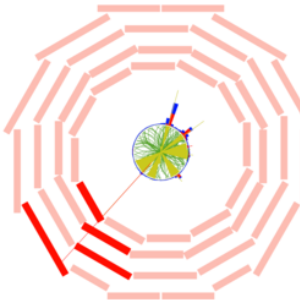
95% C.L. lower limits on the masses of new particles in specific models:

Model	Observed Limit	Expected Limit
Z' ($\Gamma_{Z'}/M_{Z'} = 1.2\%$)	2.1 TeV	2.1 TeV
Z' ($\Gamma_{Z'}/M_{Z'} = 10\%$)	2.7 TeV	2.6 TeV
RS KK gluon	2.5 TeV	2.4 TeV

Non-resonant BSM $\sigma(t\bar{t}) < 0.2 \times$ SM $\sigma(t\bar{t})$ at the 95% C.L. (for $M_{t\bar{t}} > 1$ TeV)

These exclusion limits represent significant improvements to the existing results.

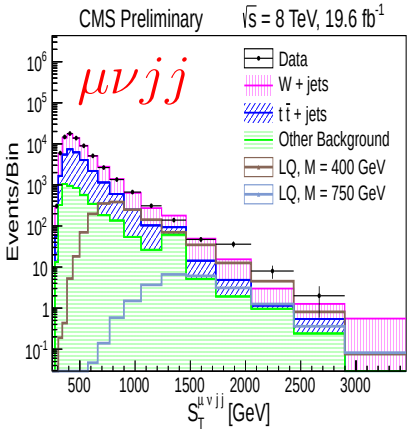
Search for 2nd-generation scalar leptoquarks (PAS EXO-12-042)

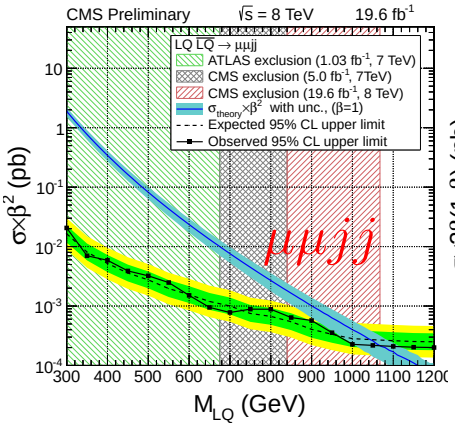


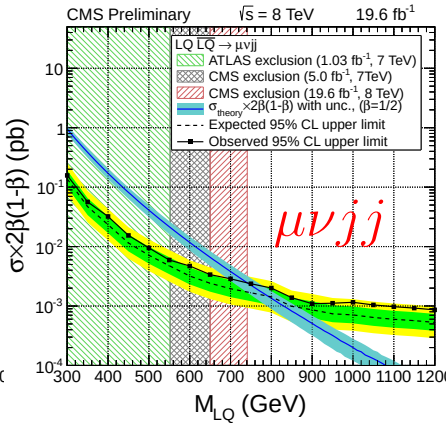
$M_{LQ} = 850$ GeV

$S_T = 2170$ GeV

$LQ \to lq$







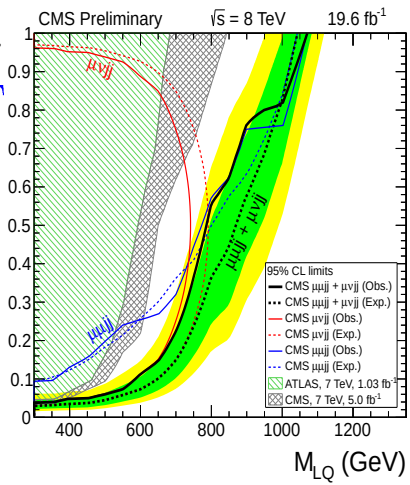
Search for 2nd-generation scalar leptoquarks, pair-produced

Signature: $(\mu\mu jj)$ Two high p_T muons and at least two jets

Or $(\mu\nu jj)$ one high p_T muon, at least two jets + MET

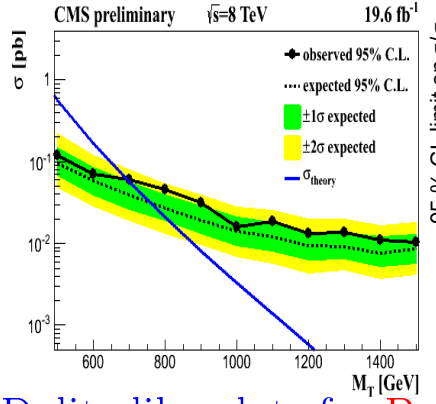
A small excess in data in the $\mu\nu jj$ channel (still well within calculated systematic and statistical uncertainties) $\Longrightarrow$

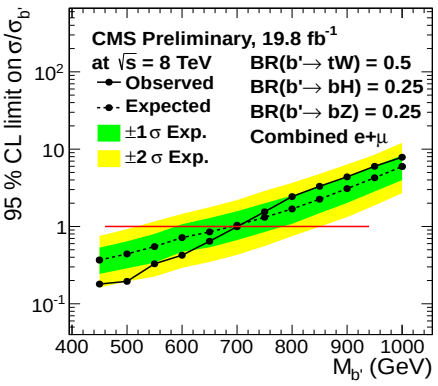
A higher-than-expected cross-section upper limit is visible.

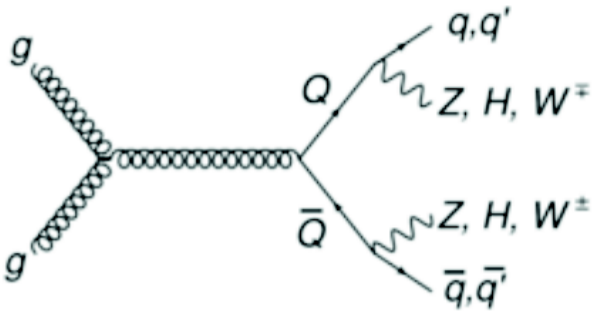


Second-generation scalar leptoquarks with masses less than 1070 (785) GeV are excluded for $\beta = 1\,(0.5)$, where $\beta = \mathrm{Br}(\mathrm{LQ} \to l^{\pm} q)$.

Vector-like T′ quark $(+\frac{2}{3})$ Vector-like B′ quark $(-\frac{1}{3})$



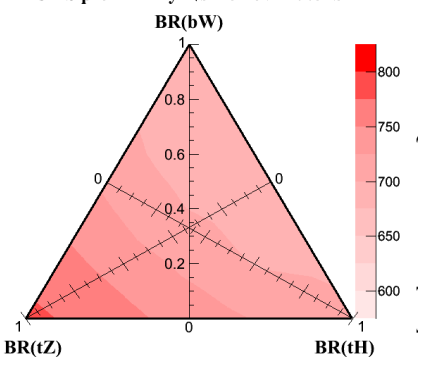


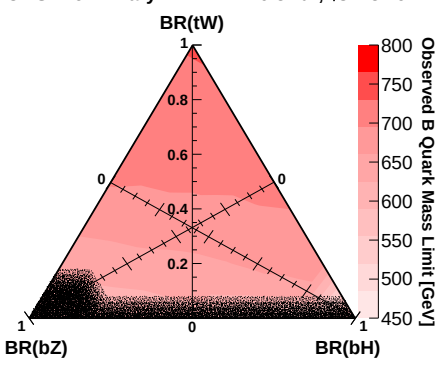


Signature: 1–3 leptons + MET
+ jets with large p_T

Dalitz-like plots for Branchings to Final states:

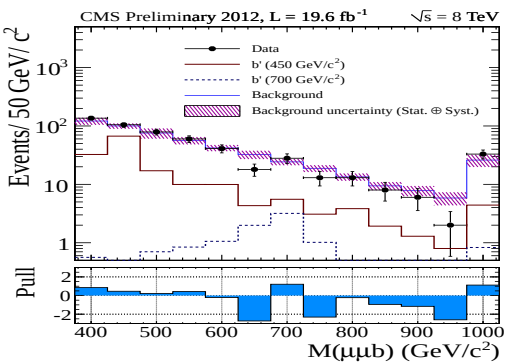
$T' \to bW, tZ, tH$ $B' \to tW, bZ, bH$





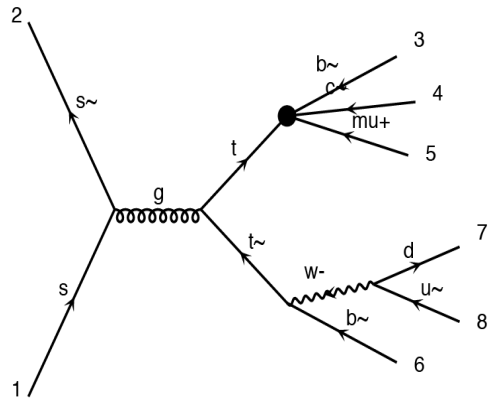
Limits 687–782 GeV 95% C.L. Limits 582–732 GeV

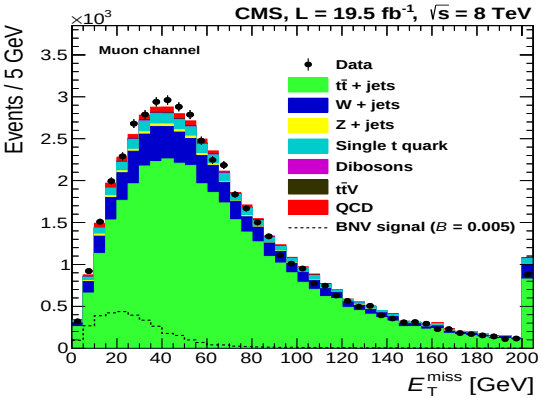
Additional search for decay $B' \to bZ$:
(mode: Z dilepton decay + b-tagged jet).
Mass limit = 700 GeV at 95% C.L.
(assuming $\mathrm{Br}(b' \to bZ) = 1$)

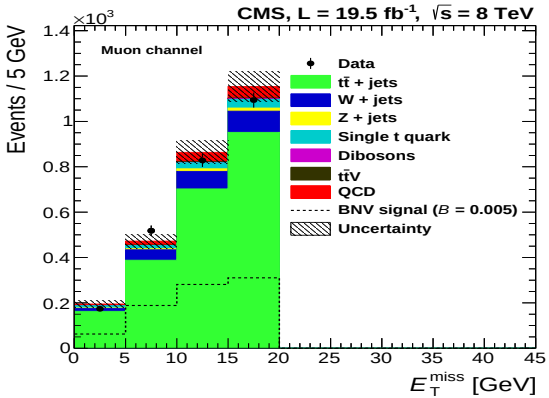


This is the first search that considers all 3 final states.
The limits place the most stringent constraints on the existence of such quarks to date.

Search for Baryon Number Violation (BNV) in Top Quark Decays (arXiv:1310.1618)







- Strong Baryon Number Violation (BNV) effects predicted in many BSM models
- BNV is a necessary condition for the observed baryon asymmetry in the Universe
  — А. Д. Сахаров, Письма ЖЭТФ, 5 (1967) 32
- BNV in top quark system suggested in Z. Dong et al., Phys. Rev. D85 (2012) 016006
  BNV could be probed at quark level, with top flavor clearly identified

Signature: One t quark having BNV decay $(t \to \bar{b}\,\bar{c}\,\mu^+)$
One t quark having SM hadronic decay to 3 jets $(\bar{t} \to W^-\,\bar{b} \to d\,\bar{u}\,\bar{b})$

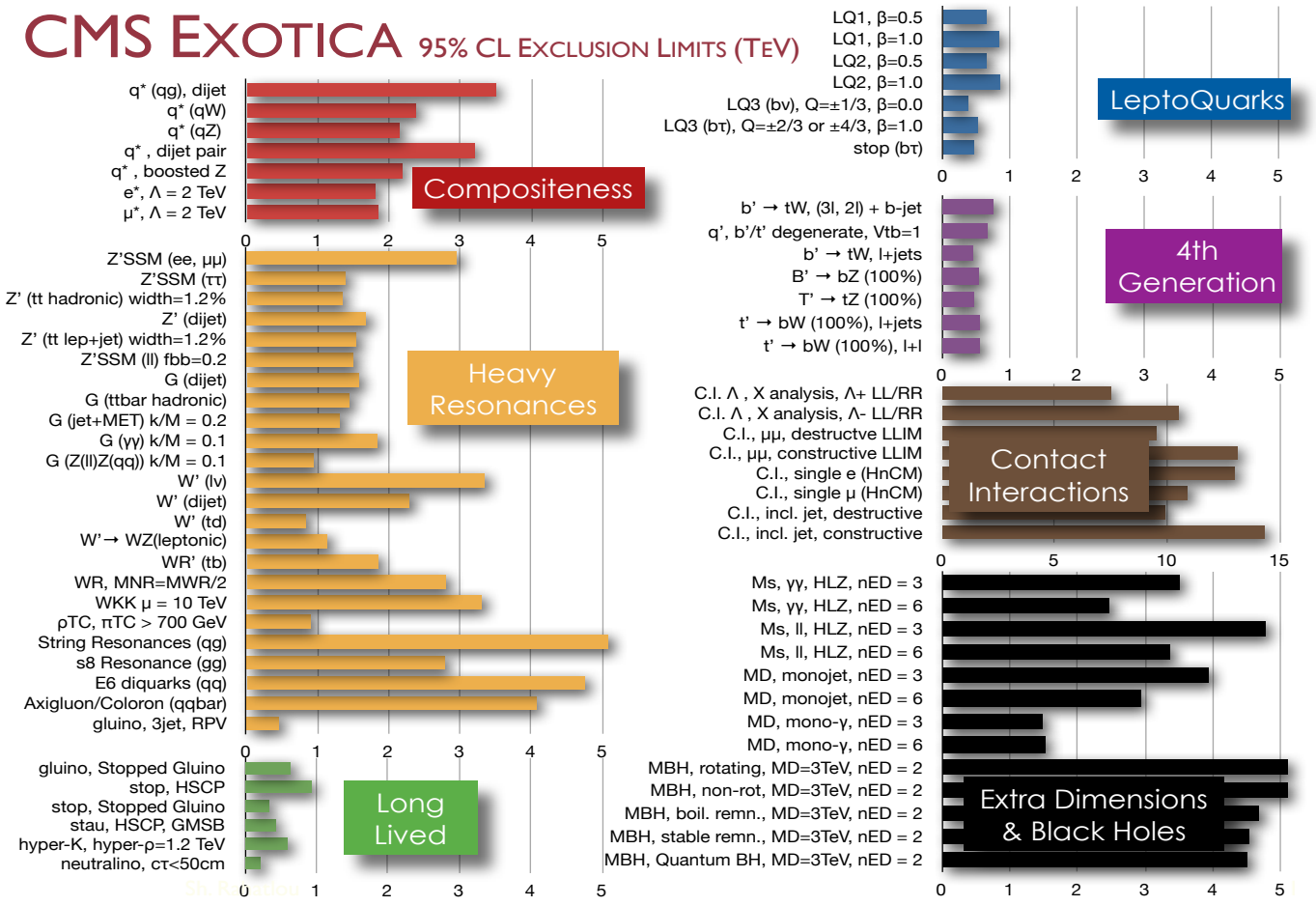
$\Longrightarrow$ Events with 1 isolated lepton (μ or e) + at least 5 jets (at least one b tagged) + low MET

No significant excess of events over the expected yield from SM processes
$\Longrightarrow$ **Upper limit of 0.0015** at 95% C.L. on branching of a hypothetical BNV decay $t \to l + 2j$

The first results on a BNV process involving the top quark

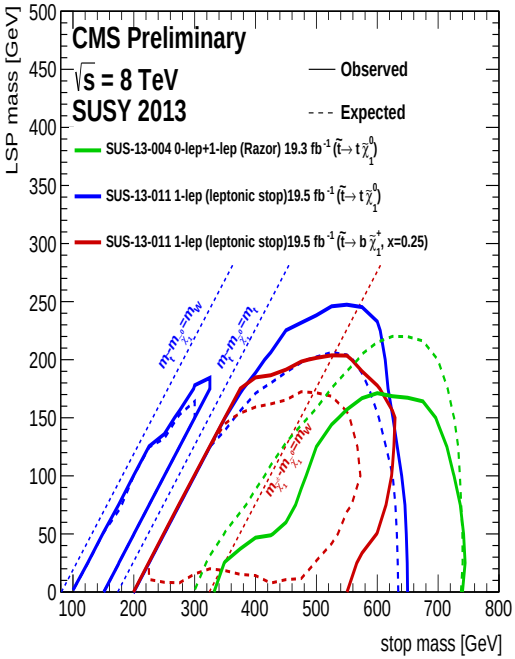
Exotica 95% CL Limits

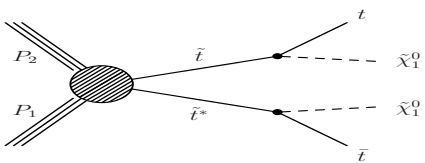
Many other searches of Exotica at CMS has been performed. Limits have been set. https://twiki.cern.ch/twiki/bin/view/CMSPublic/PhysicsResultsEXO



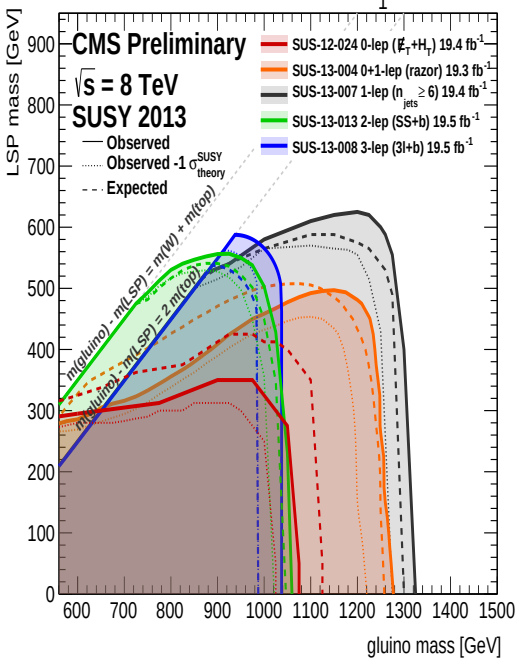
Summaries for Supersymmetry Limits

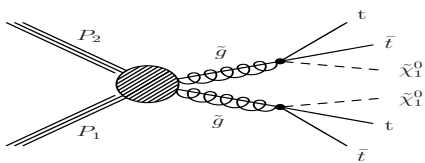
Direct stop searches



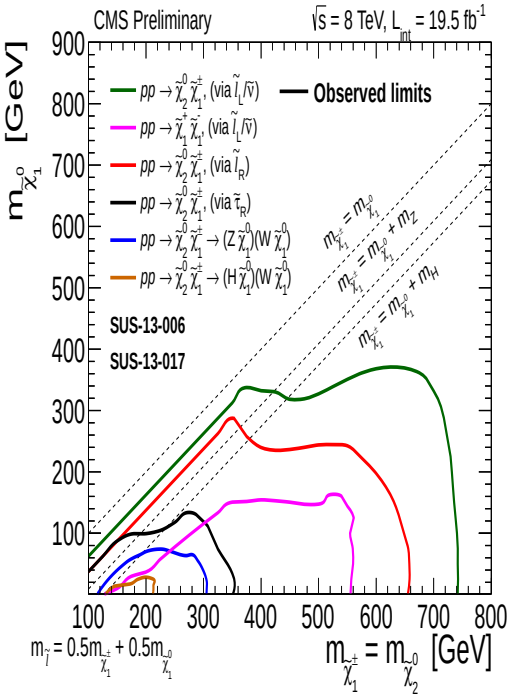


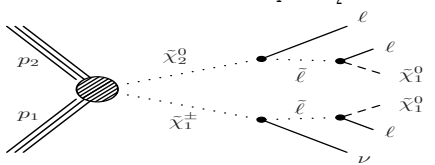
Gluino pair production





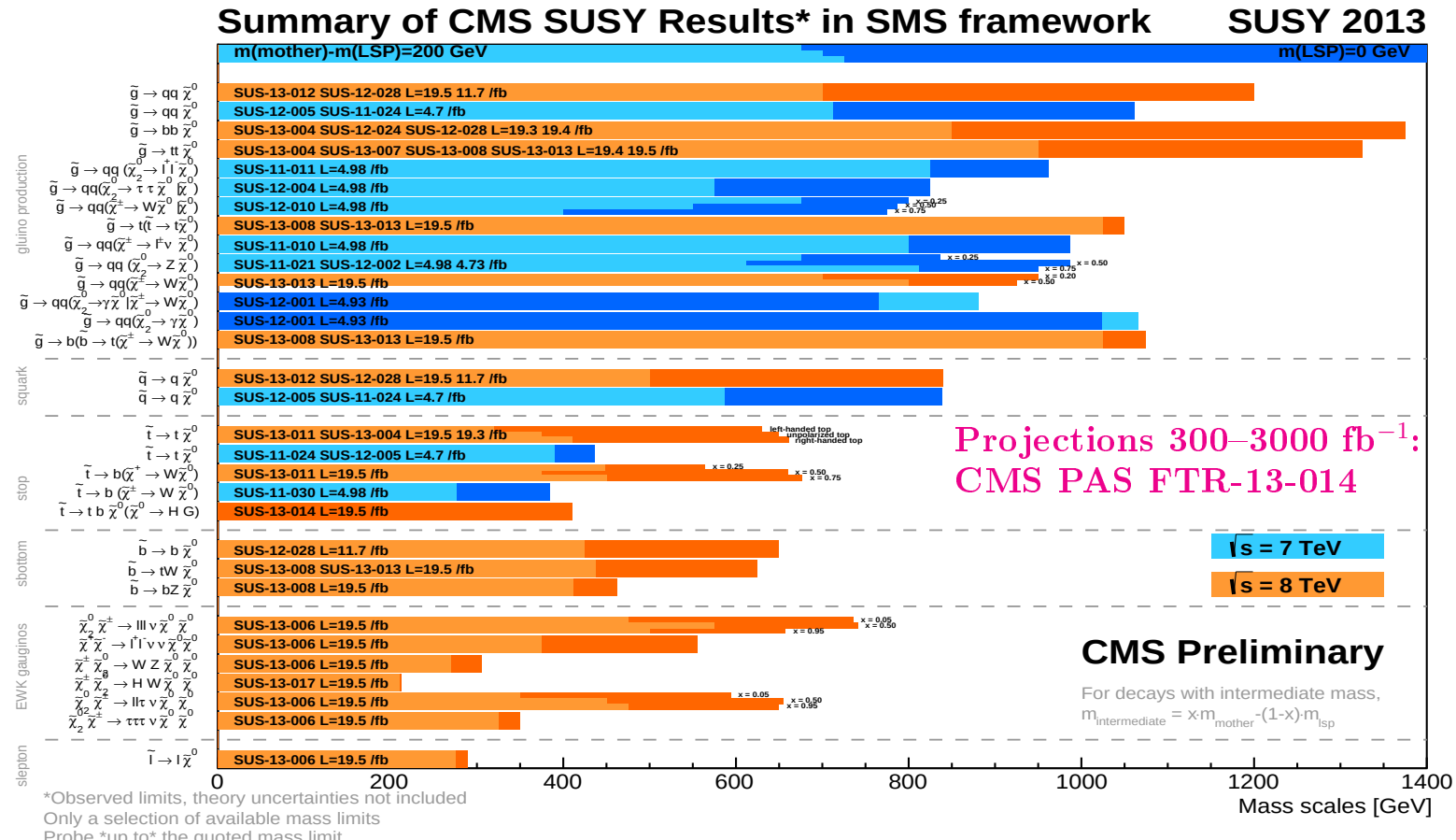
Limits for EWKino models





https://twiki.cern.ch/twiki/bin/view/CMSPublic/PhysicsResultsSUS

Supersymmetry 95% CL Limits

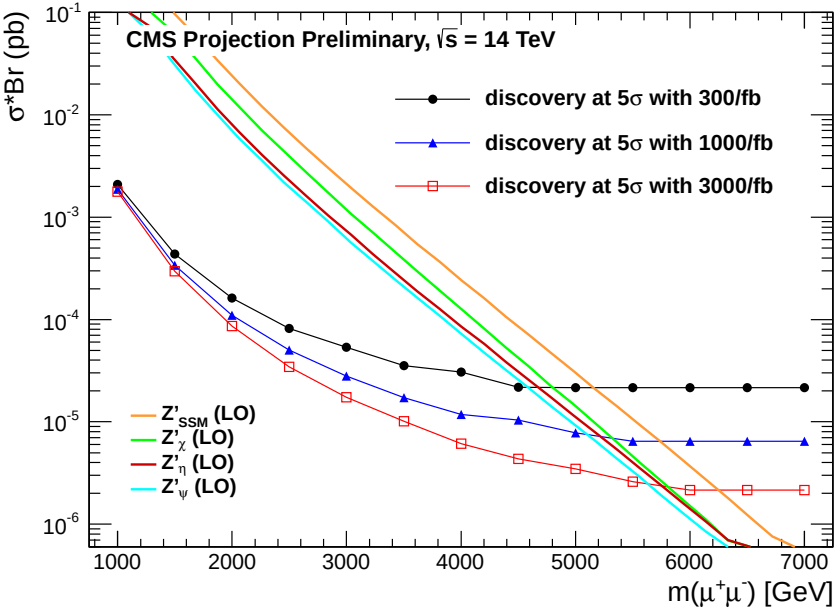


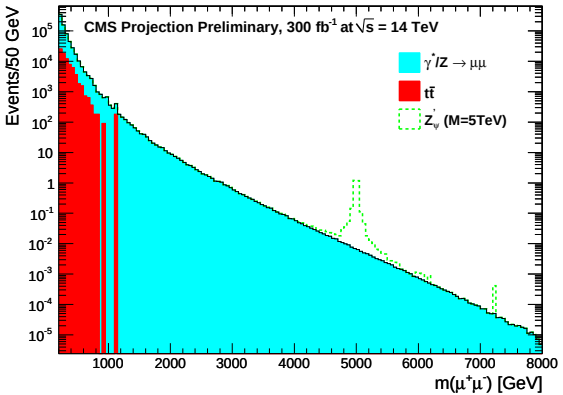
*Observed limits, theory uncertainties not included
Only a selection of available mass limits
Probe *up to* the quoted mass limit

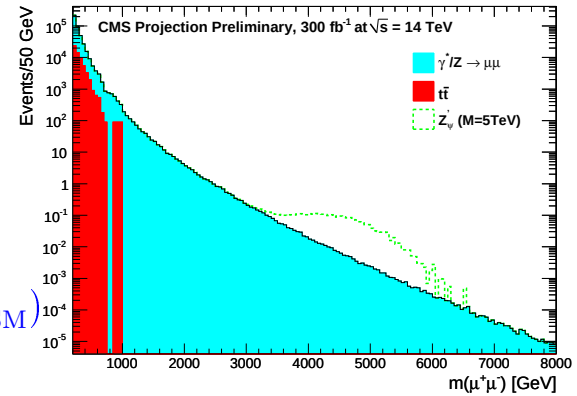
Many searches of Supersymmetry at CMS has been performed. Limits have been set.

https://twiki.cern.ch/twiki/bin/view/CMSPublic/PhysicsResultsSUS

Projections for $Z' \to \mu\mu$ at $\sqrt{s} = 14$ TeV (ArXiv:1307.7135)







Projections for dimuons at $\sqrt{s} = 14$ TeV:

- at $\int L\,dt = 300$ fb^{-1} — up to 4.6–5.2 TeV (Z'_ψ–$Z'_{\rm SSM}$)
- at $\int L\,dt = 3000$ fb^{-1} — up to 5.6–6.2 TeV.

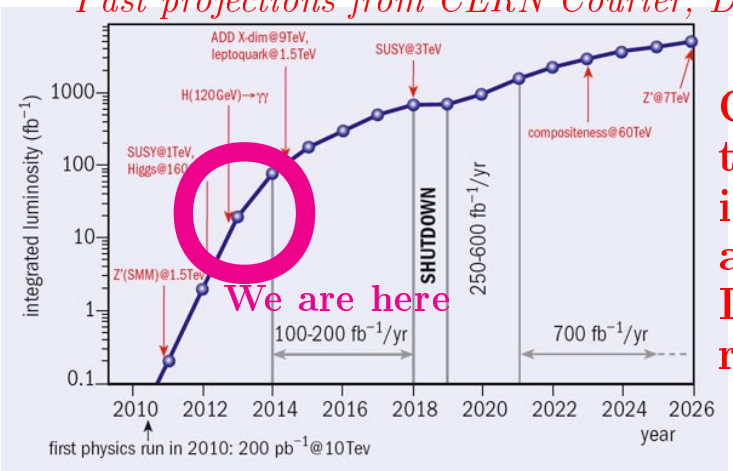
Other projections can be found in CMS White paper at Snowmass'2013 (arXiv:1307.7135). See also results reported at ECFA HL LHC Experiments Workshop (in Aix-Les-Bains, Oct 1–3).

https://indico.cern.ch/conferenceDisplay.py?confId=252045

Conclusions

- CMS detector performance is excellent,
  new results are produced at very high rate.
- Many papers in Exotica at CMS – around 70, impossible to mention all.
  https://twiki.cern.ch/twiki/bin/view/CMSPublic/PhysicsResults
- Impressive agreement of the data with the Standard Model.
  Many searches for new physics have been performed, limits are set.
- New physics can hiding in very interesting final states that demonstrate the capability of the detector.
- CMS is well situated
  to continue to probe nature
  for new physics models.
- Stay tuned...

Past projections from CERN Courier, Dec. 2009

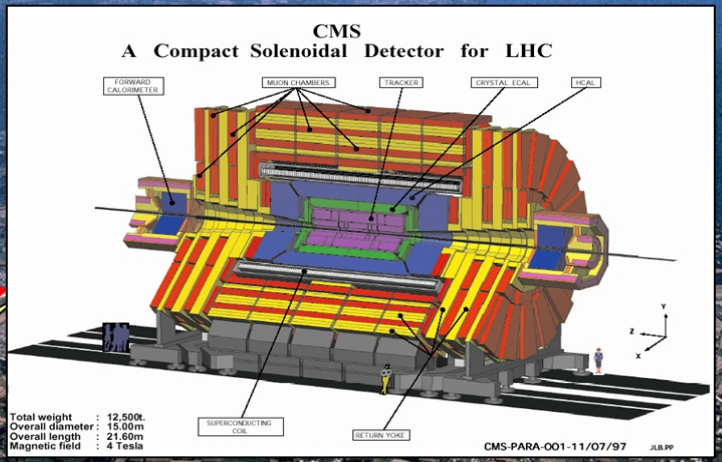


One of these items at next LHC run ..?

Thank you

Backup slides

CMS Detector

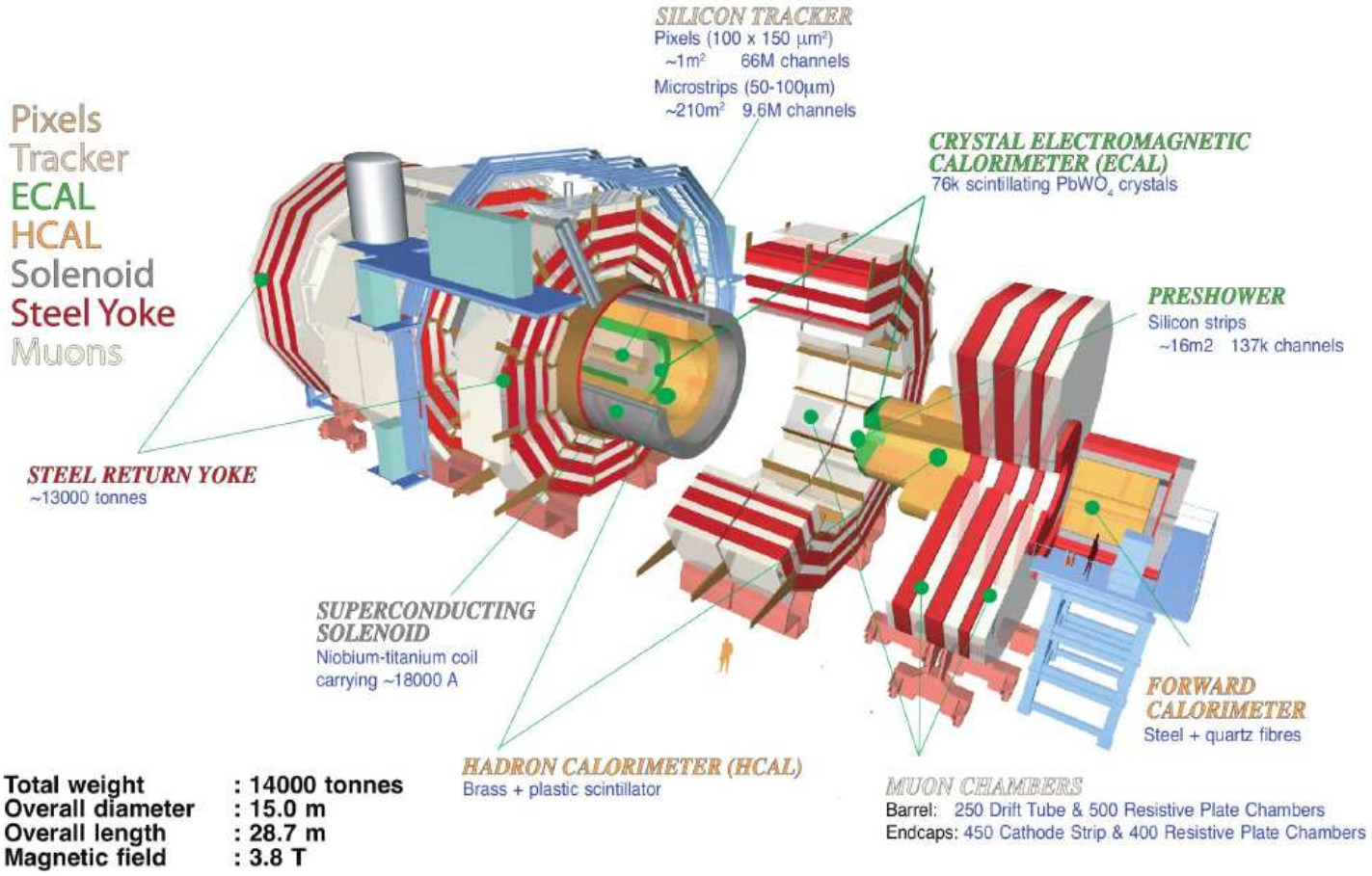


CMS

14 km

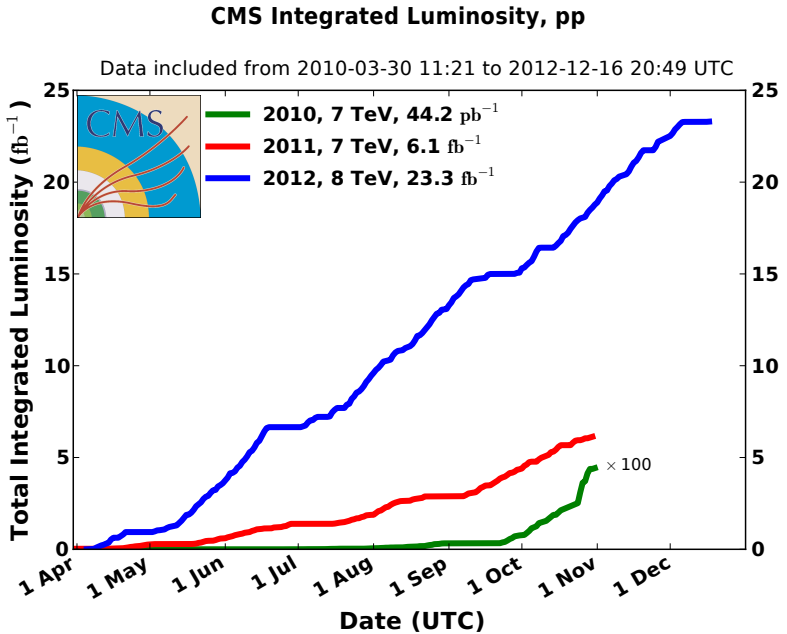
CERN, Meyrin

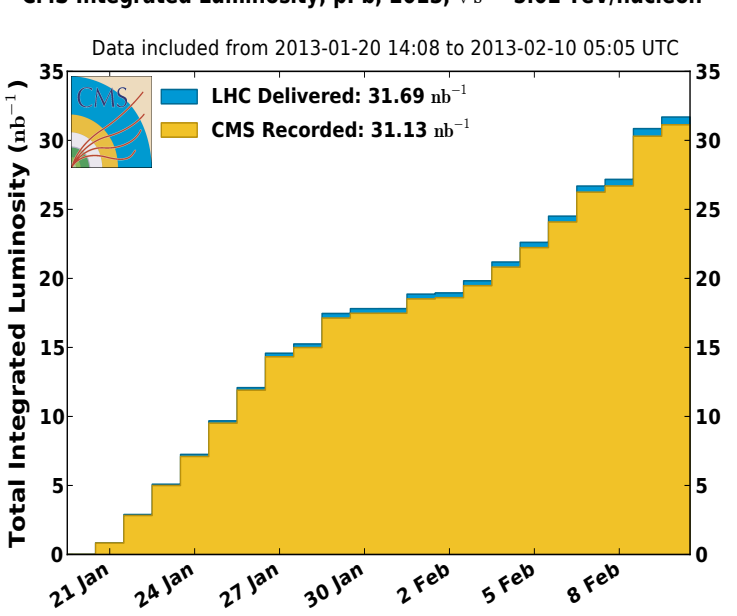
Detector: Compact Muon Solenoid (CMS)

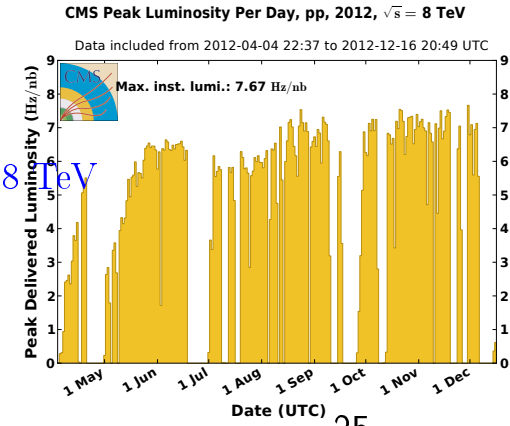


Total weight	**: 14000 tonnes**
Overall diameter	**: 15.0 m**
Overall length	**: 28.7 m**
Magnetic field	**: 3.8 T**

Statistics of Integrated Luminosity

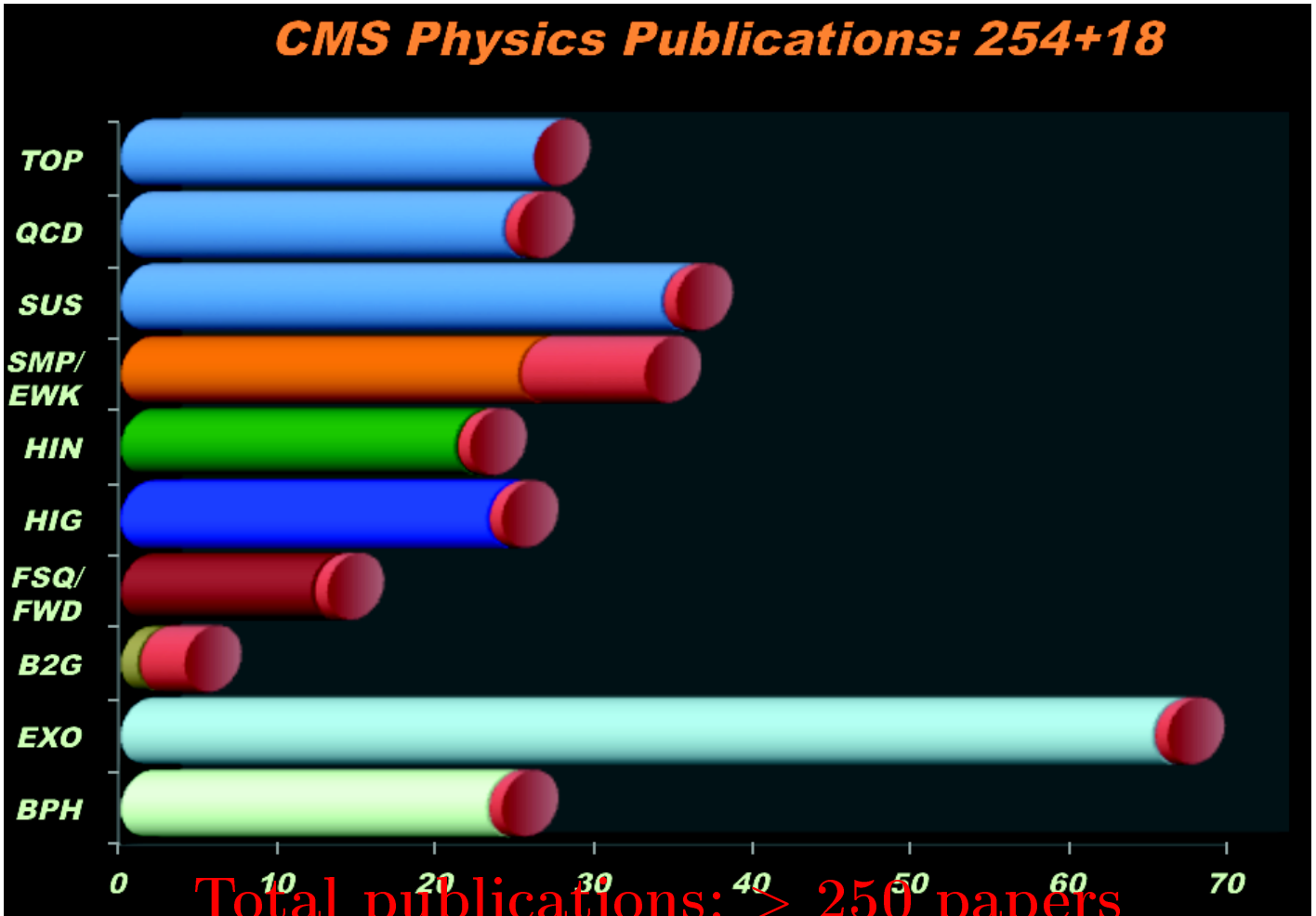






- Excellent performance of LHC and CMS in 2011 and 2012
- $\int \mathcal{L}\, dt = 6.1 + 23.3\,\mathrm{fb}^{-1}$ in pp collisions collected at $\sqrt{s} = 7$ and 8 TeV
- Peak luminosity $7.6 \times 10^{33}\,\mathrm{cm}^{-2}\,\mathrm{s}^{-1}$
- Data taking efficiency $> 90\%$

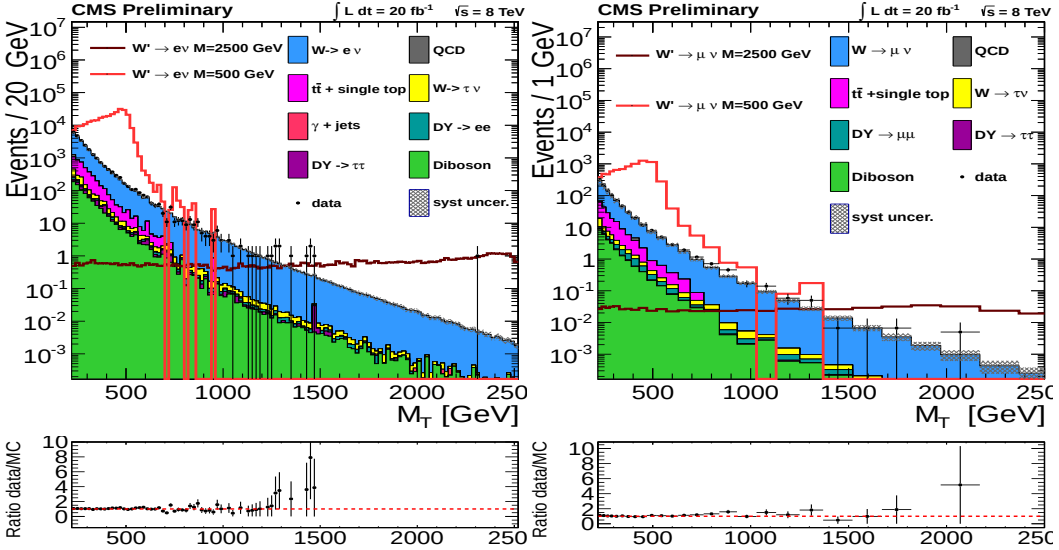
CMS Publications

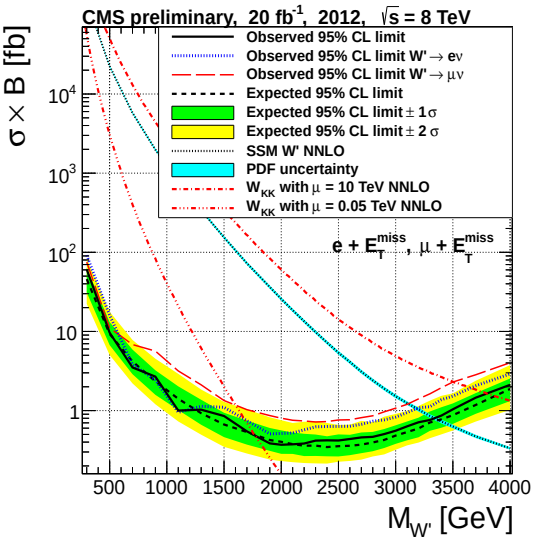


Total publications: > 250 papers

Search for leptonic decays of W' bosons (EXO-12-060)

$W' \to \ell\nu$ Lepton-MET system: $M_T = \sqrt{2 \cdot p_{\mathrm{T}}^{\ell} \cdot E_T^{\mathrm{Miss}} \cdot (1 - \cos\Delta\phi_{\ell,\nu})}$



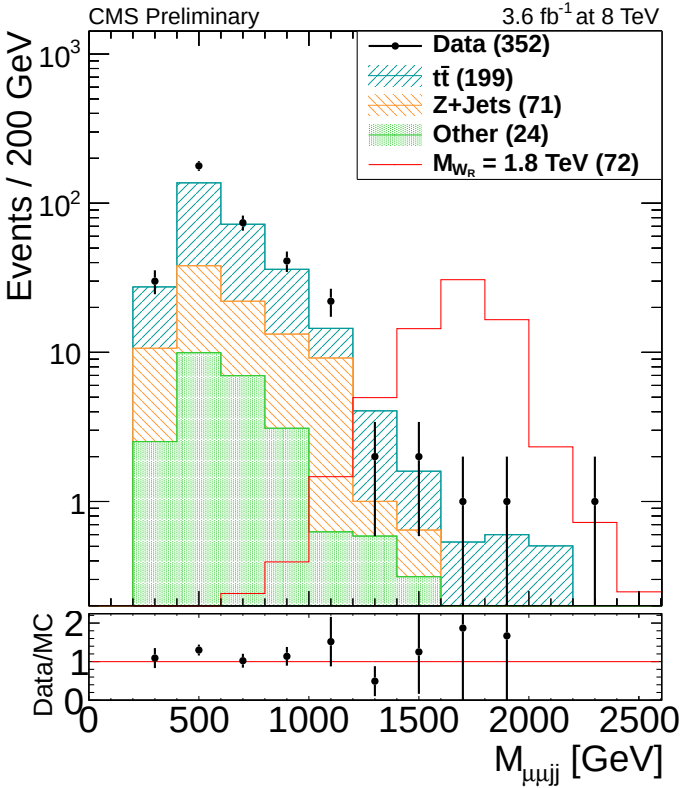


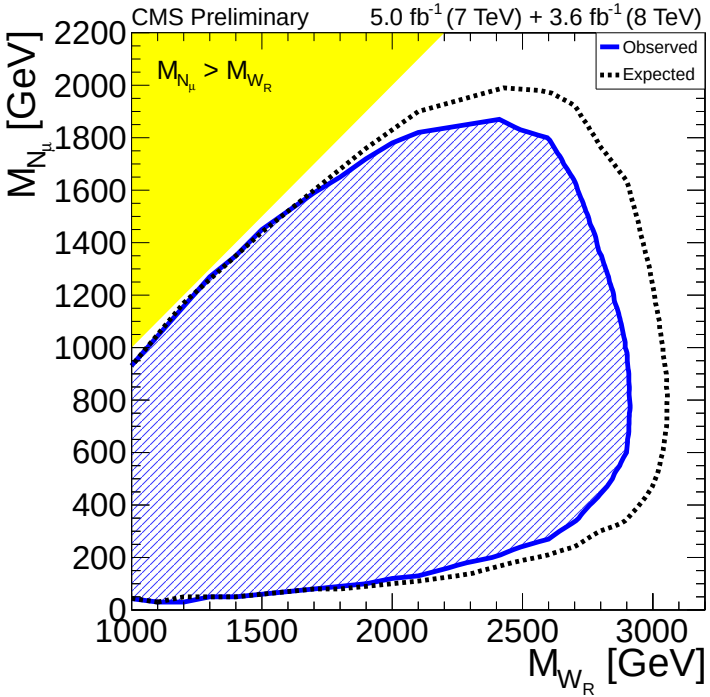
SSM W' with $M < 3.35$ TeV was excluded at 95% C.L.

These results are also interpreted in the framework of split universal extra dimensions and exclusion limits on Kaluza–Klein W^2_{KK} states are set:
$M_{W^2_{\mathrm{KK}}} < 1.7 - 3.7$ TeV for bulk mass parameter $\mu = 0.05 - 10$ TeV.

Another reinterpretation is performed in terms of compositeness, which would manifest itself as a four-fermion contact interaction, setting a limit on the new contact interaction scale Λ of 13.0 (10.9) TeV for the electron (muon) channel.

Search for a heavy neutrino and right-handed W of the left-right symmetric model (EXO-12-017)



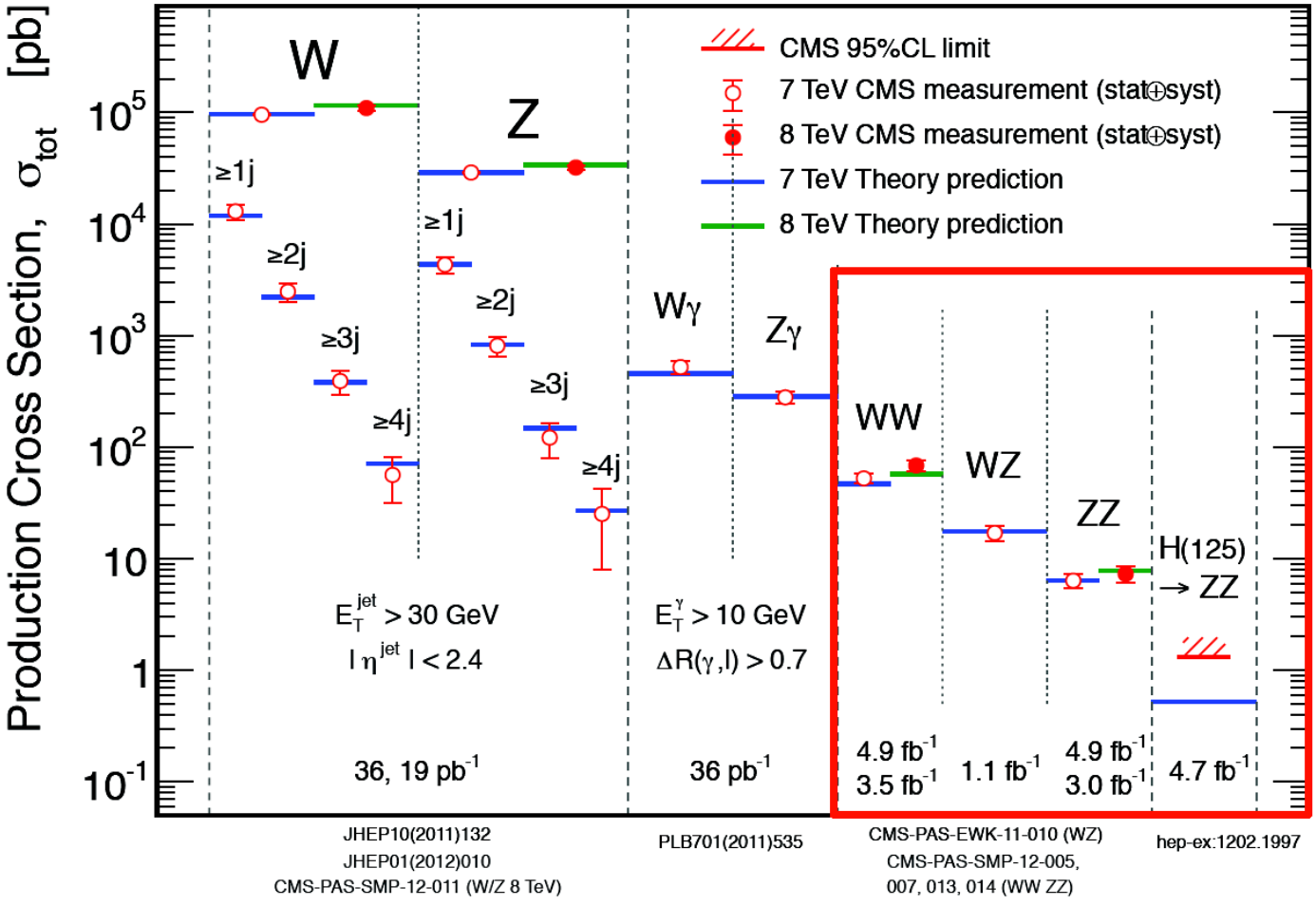


No excess over expectations from standard model processes is observed.

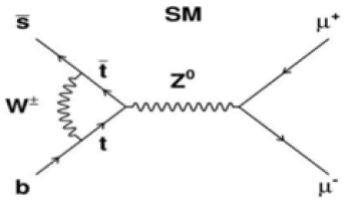
Combining 7 + 8 TeV data and electron + muon channels,

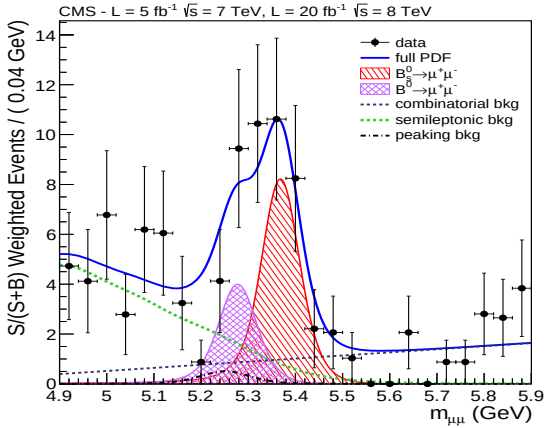
We exclude the region in the two-dimensional parameter (M_{W_R}, M_{N_ℓ}) space that extends beyond $M_{W_R} = 2.9$ TeV.

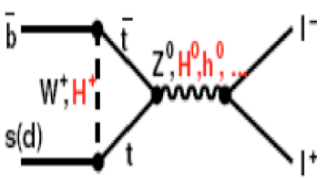
Summary of Electroweak Physics Results

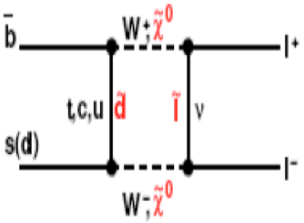


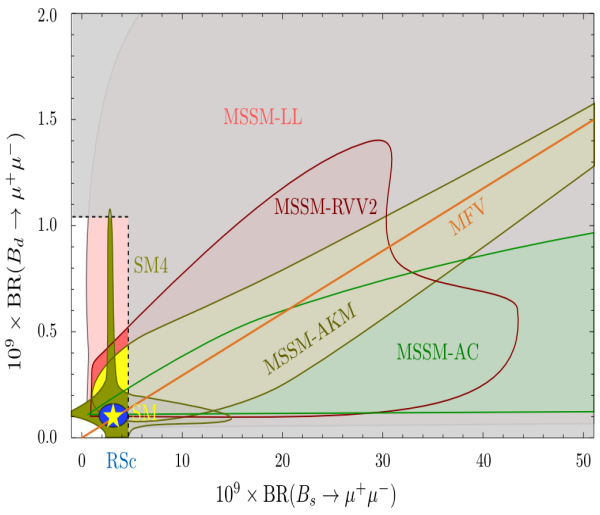
Discovery of $B_s \to \mu^+\mu^-$ (Phys. Rev. Lett. 111 (2013) 101804)











SM predicts $\mathrm{Br}(B_s \to \mu\mu) = 3.6 \pm 0.3 \times 10^{-9}$

At the EPS HEP conference in Stockholm CMS (and LHCb) reported results for $B_s \to \mu^+\mu^-$.

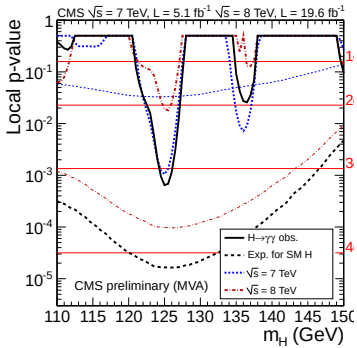
$\mathrm{Br}(B_s \to \mu\mu) = (3.0^{+1.0}_{-0.9}) \times 10^{-9}$ (significance of $4.3\,\sigma$).

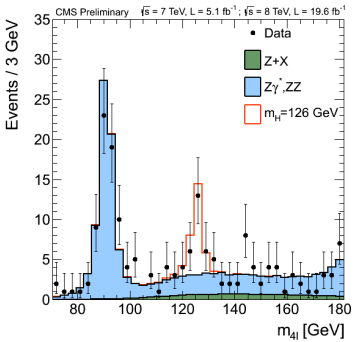
Upper limit for $B_0 \to \mu^+\mu^-$
$\mathrm{Br}(B_0 \to \mu\mu) < 1.1 \times 10^{-9}$
at the 95% C.L. is determined.

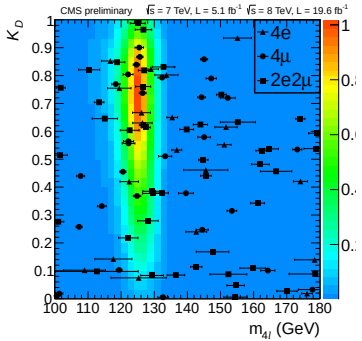
These processes are sensitive to search for BSM physics.

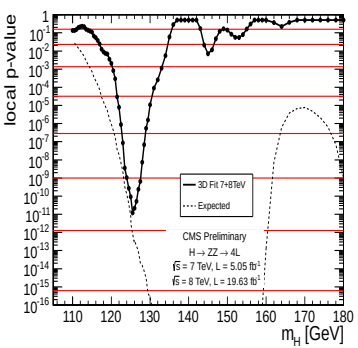
Both results are in agreement with the expectations from SM.

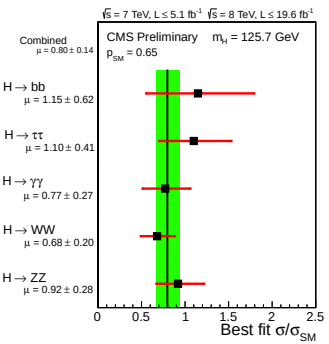
Discovery of Higgs

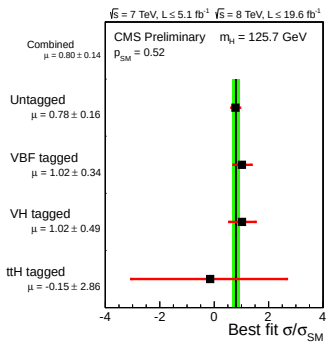


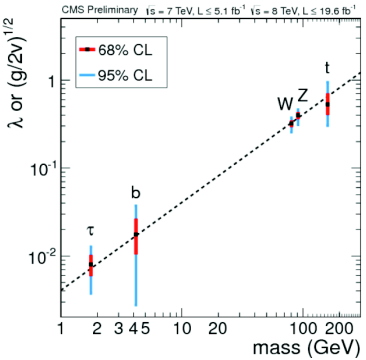


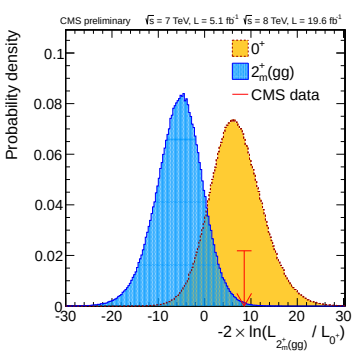












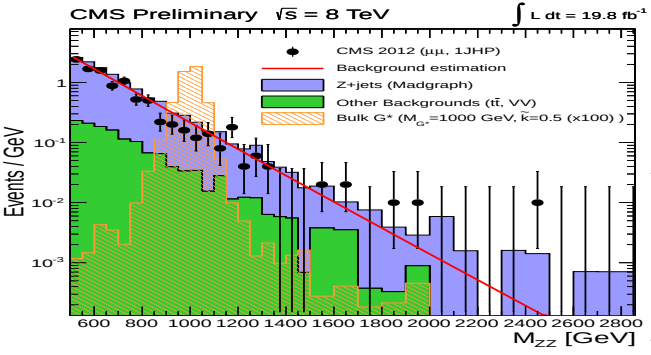
Higgs-like boson has been discovered, $M_H = 125.7 \pm 0.3 \pm 0.3$ GeV.

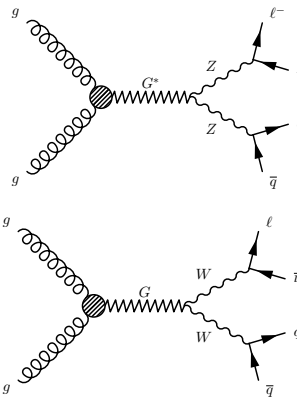
Many its properties are studied, they resemble, up to now, the Standard model.

What's next?

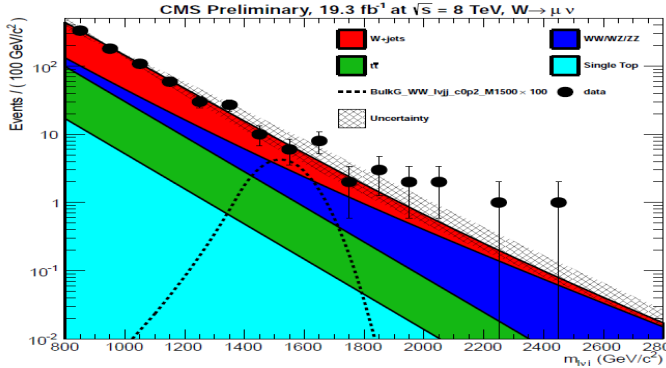
Search for Di-Boson Resonances (EXO-12-021, EXO-12-022)

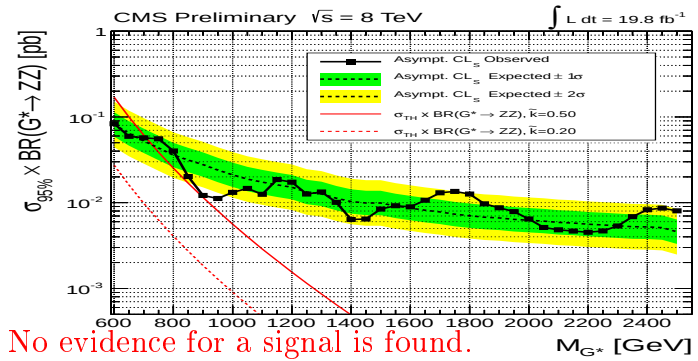
ZZ



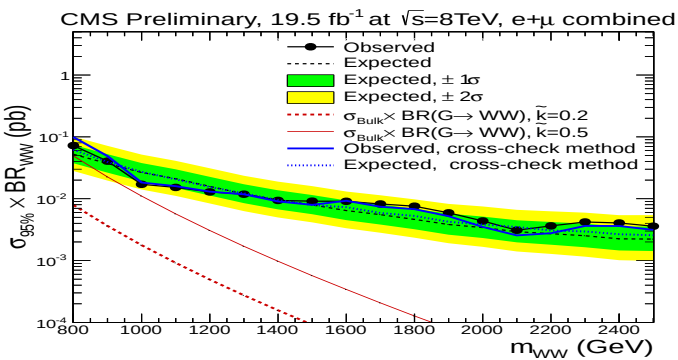


WW





No evidence for a signal is found.



ZZ: Signature: dilepton + recoiled jet with mass compatible with Z mass.

Additional information from jet substructure is used to reduce the background from SM.

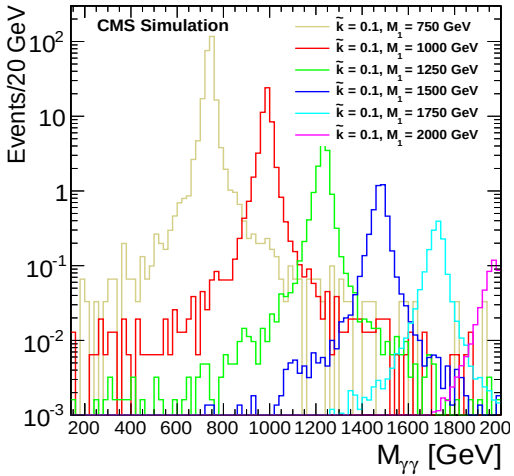
Limits on a narrow-width bulk RS graviton model with $\tilde{k} = 0.5$ and mass smaller than 710 GeV are excluded at 95

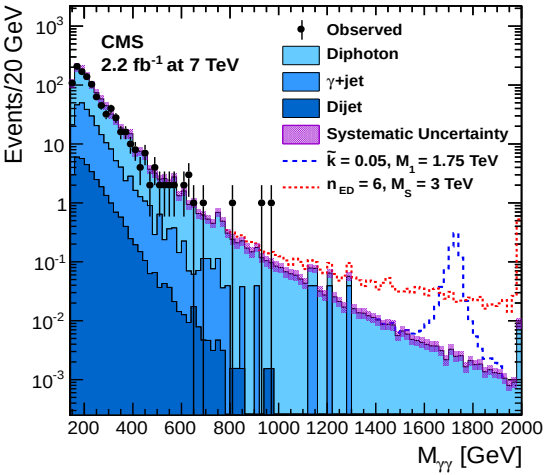
WW: Signature: one lepton + large MET + recoiled jet with mass compatible with Z mass

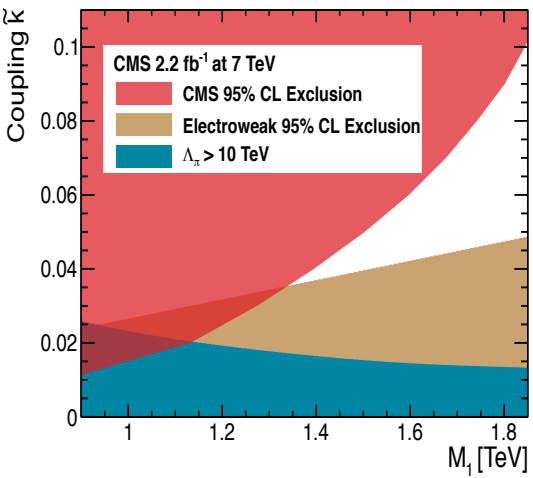
Upper limits are set on bulk graviton production cross section times branching ratio to WW in the range from 70 fb to 3 fb for resonance masses between 0.8 and 2.5 TeV, respectively.

WZ: SSM: $M_{W'} > 1.143$ TeV (Phys. Rev. Lett. 109 (2012) 141801 at $\sqrt{s} = 7$ TeV)

Search for RS1 model in Diphoton Mass Spectrum (Phys. Rev. Lett. 108 (2012) 111801)







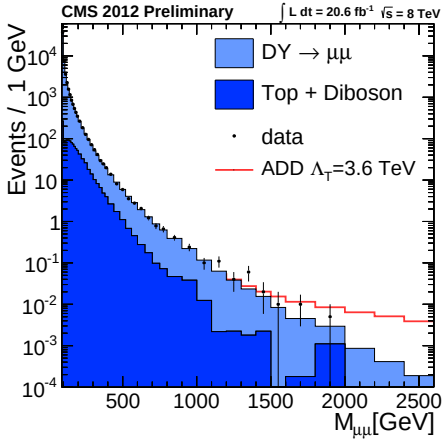
We observe no excess in diphoton production above the rate predicted from SM background.

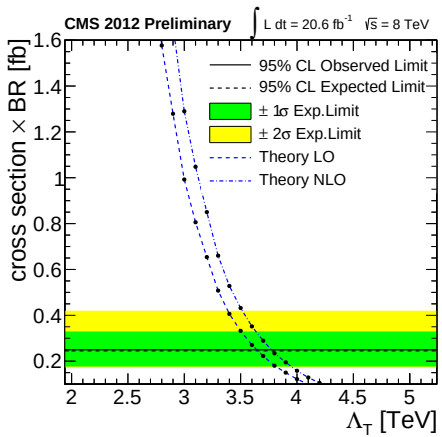
We exclude at 95% CL resonant graviton production in the RS1 model with values of M_1 less than 0.86–1.84 TeV depending on the normalized coupling strength, $\tilde{k}$.

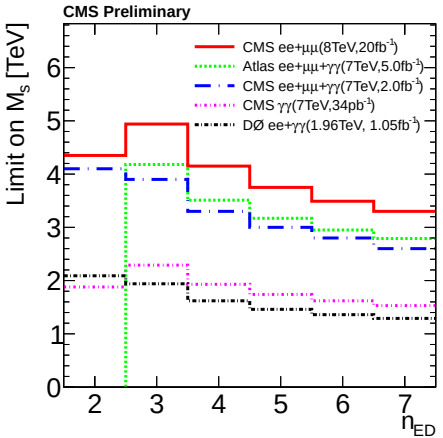
$\tilde{k}$	0.01	0.02	0.03	0.04	0.05	0.06	0.07	0.08	0.09	0.10
M_1 [TeV]	0.86	1.13	1.27	1.39	1.50	1.59	1.67	1.74	1.80	1.84

For ADD models, values of the effective Planck scale M_S less than 2.3–3.8 TeV are excluded at 95% C.L., depending on the number of extra dimensions n_{ED}.

Search for ADD in Dilepton Spectra (EXO-12-027, EXO-12-031)







Search for the effects of ADD — large extra dimensions in dilepton invariant mass spectrum

The SM expectation is found to be consistent with the measurement.

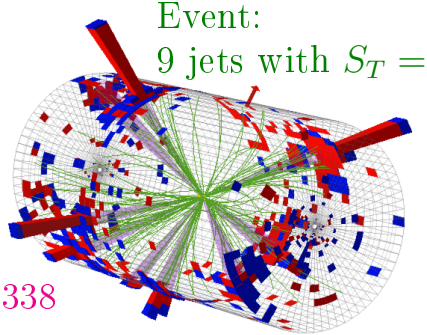
CMS set limits on the model parameter M_s up to 4.94 TeV at 95% C.L. for $\mu\mu + ee$, depending on the number of extra dimensions n_{ED}.

The observed 95% C.L limits on ADD models significantly improve
the previous limits evaluated with 2011 data
and provide the best limits based on dilepton events to date.

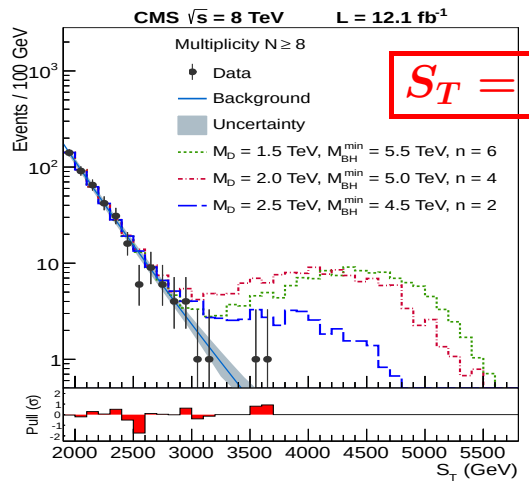
Search for Microscopic Black Holes (JHEP 07 (2013) 178)

Microscopic Black Holes can manifest themselves as multiparticle final state with large $S_T = \sum E_T$

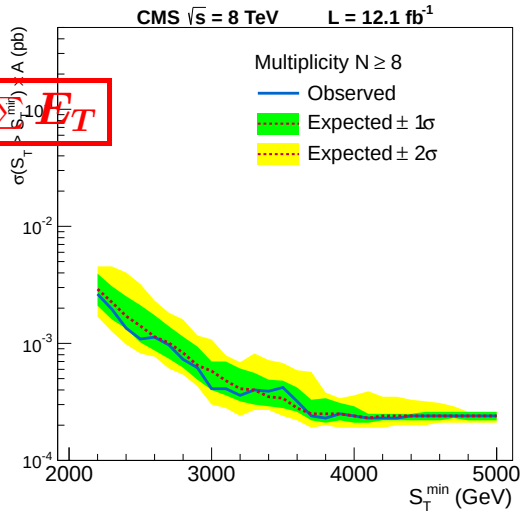
The CMS analyses:
2010, 35 pb^{-1} at 7 TeV: Phys. Lett. B697 (2011) 434;
2011, 4.7 fb^{-1} at 7 TeV: JHEP 1204 (2012) 061;
2012, 3.7 fb^{-1} at 8 TeV: CMS-PAS-EXO-12-009;
NEW 2013, 12 fb^{-1} at 8 TeV: JHEP 07 (2013) 178 = arXiv:1303.5338

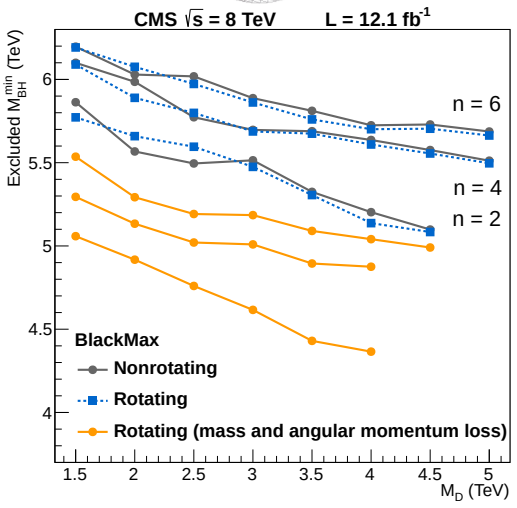


Event:
9 jets with $S_T = 2.6$ TeV



$S_T = \sum E_T$

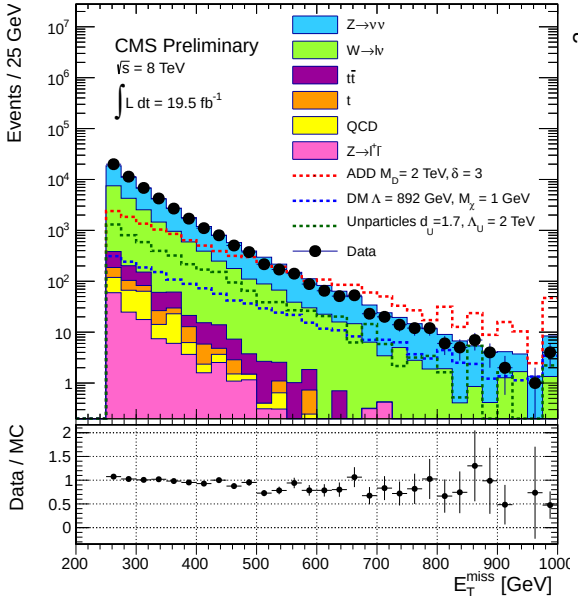


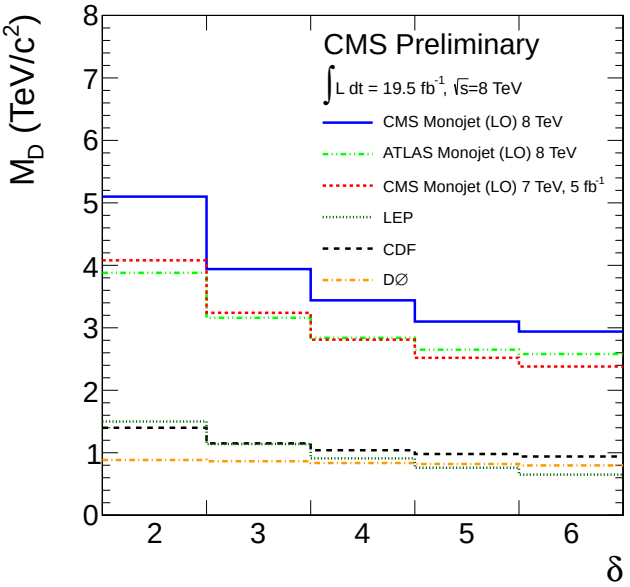


CMS set limits on the minimum Black Hole mass of 4.3–6.2 TeV.

The last analysis at $\sqrt{s} = 8$ TeV has a substantially increased sensitivity compared to previous searches.

Search for Monojet + MET (PAS EXO-12-048)





Search for events with an energetic jet and MET.

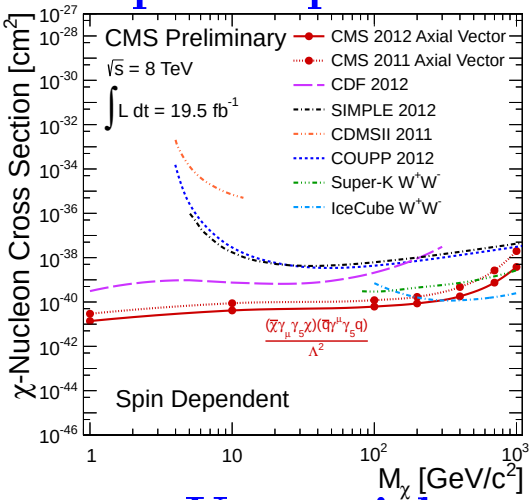
Limits are placed on ADD model parameter M_{D} as a function of number of extra dimensions δ.

Yet another interpretation: DM...

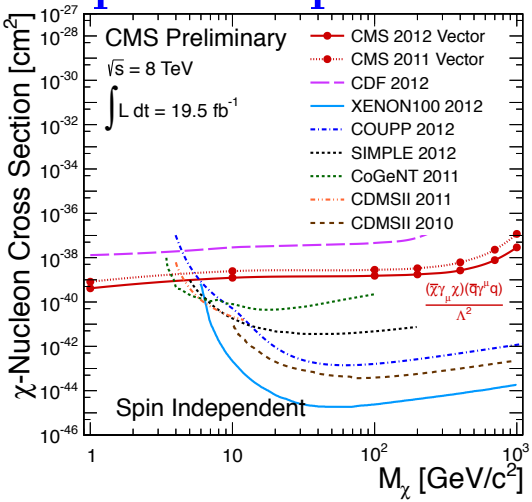
Event yields for representative signal points from ADD, dark matter and Unparticles after passing the full selection criteria and various MET thresholds, corresponding to an integrated luminosity of 19.5 fb^{-1}.

MET (GeV) →	> 250	> 300	> 350	> 400	> 450	> 500	> 550
ADD LO $M_D = 3$ TeV, $\delta = 3$	4496	2888	1885	1265	881	603	422
ADD LO $M_D = 4$ TeV, $\delta = 3$	1071	685	454	310	210	150	108
DM $\Lambda = 850$ GeV, $M_\chi = 1$ GeV	1774	1103	693	454	297	202	137
DM $\Lambda = 950$ GeV, $M_\chi = 1$ GeV	1137	707	444	291	190	129	88
Unparticles $d_U = 1.7$, $\Lambda_U = 2$ TeV	4328	2220	1237	700	378	218	141
Unparticles $d_U = 1.7$, $\Lambda_U = 3$ TeV	1859	905	478	247	158	103	60

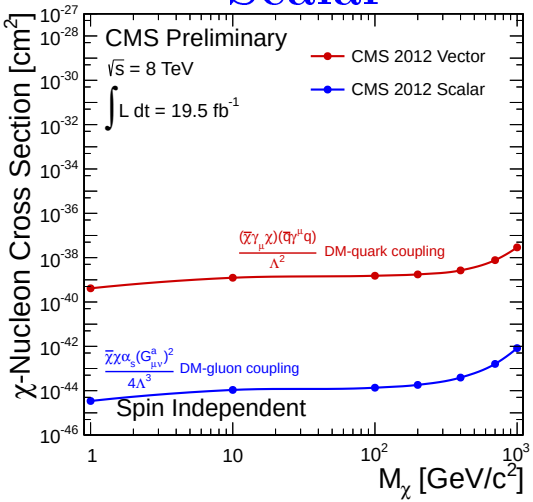
Spin Dependent



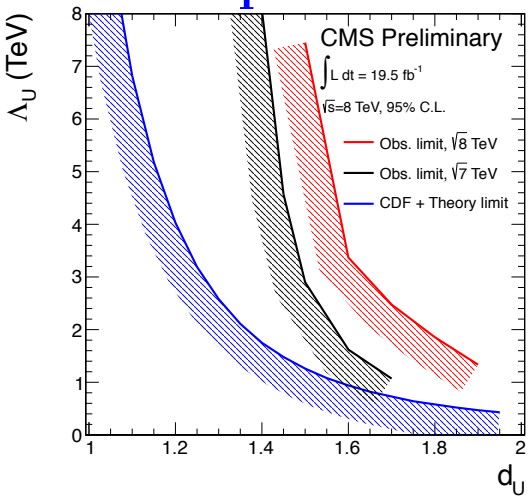
Spin Independent



Scalar



Unparticles



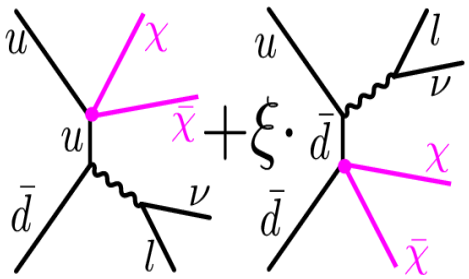
Search for events with an energetic jet and MET.

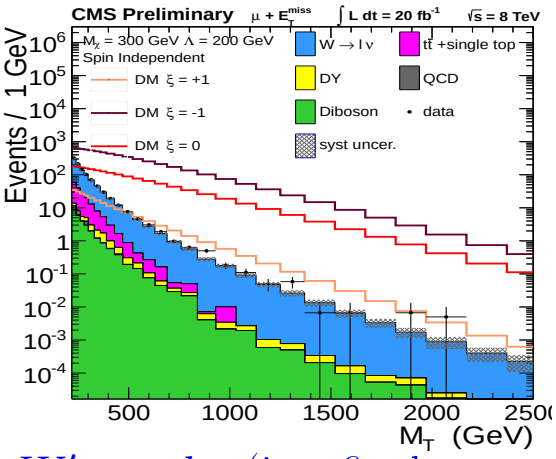
Event number is consistent with SM expectation.

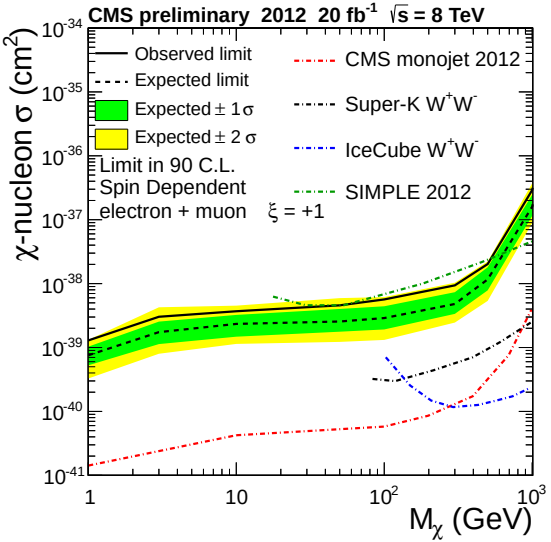
Constraints on Dark matter–Nucleon scattering cross sections determined for both spin-independent and spin-dependent interaction models.

Also limits on the production of Unparticles.

Search for Dark Matter — Monolepton + MET (PAS EXO-13-004)





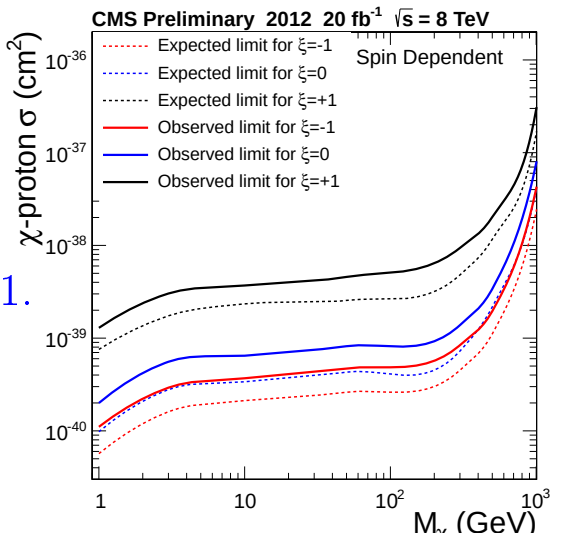


The results of search for $W' \to l\nu$ (i.e. final state lepton+MET) can be re-interpreted in terms of the cross section of a W-boson recoiling against a pair of dark matter particles.

No indications of a DM signal are seen $\Longrightarrow$

Excluding $\Lambda < 1000/700/300$ GeV for $\xi = -1 \ / \ 0 \ / \ +1$.

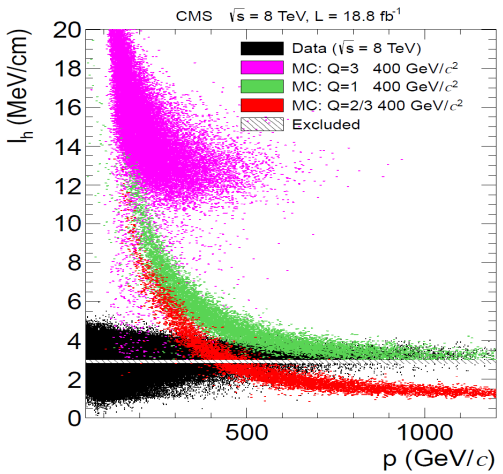
The χ-proton cross section has to be smaller (in terms of 10^{-39} cm^2) than 0.4, 0.7, 5 (0.1, 2, 90) for axial-vector (vector) coupling for $\xi = -1 \ / \ 0 \ / \ +1$.

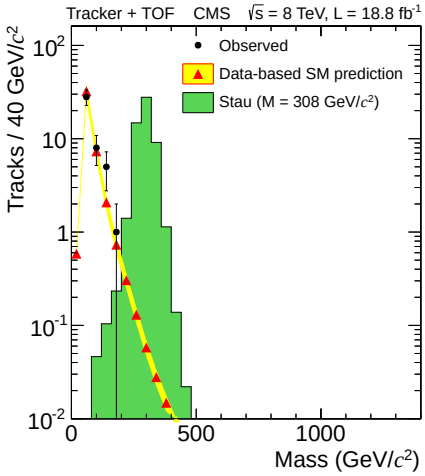


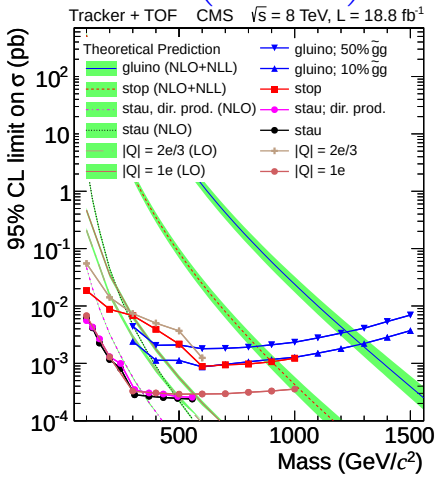
Search for Heavy Stable Charged Particles (JHEP 07(2013) 122)

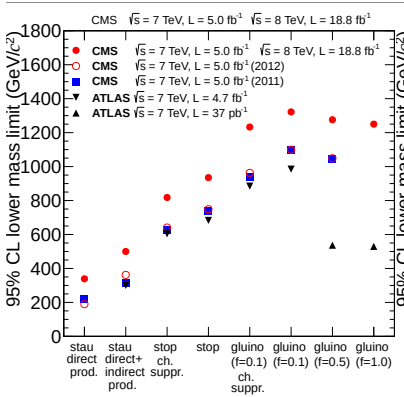
Detector Signatures: — Long time-of-flight (TOF) to the Muon detector $1/\beta = 1 + \frac{c\delta_t}{L}$;

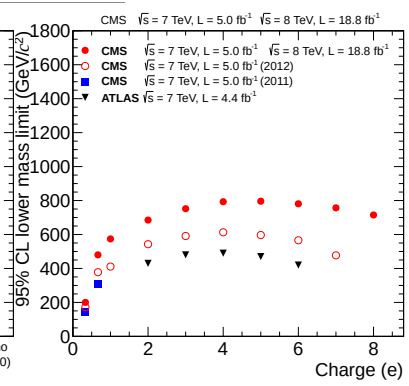
Or anomalously high (or low) energy deposition in the Inner tracker, $I_h = \left\langle \frac{dE}{dx} \right\rangle = \left(\frac{1}{N} \sum_i c_i^{-2} \right)^{-1/2}$







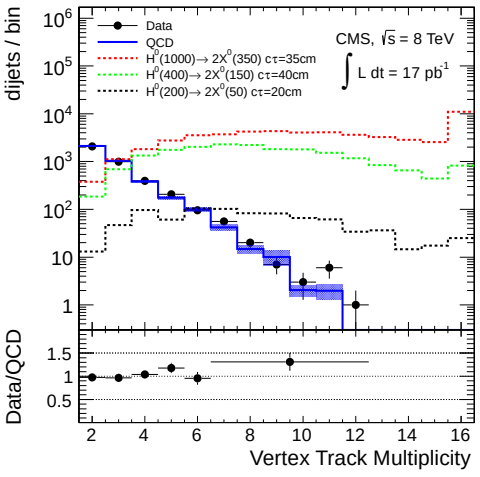




Strong limits on long-lived gluinos, stops, staus, and pair-produced long-lived leptons from the combination of tracker+TOF and tracker-only analyses.

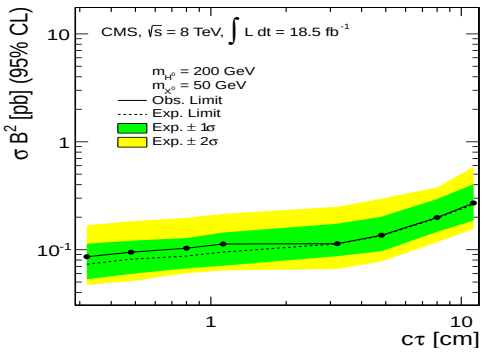
Corresponding lower mass limits, ranging up to 1322 GeV for gluinos, are the most stringent to date.

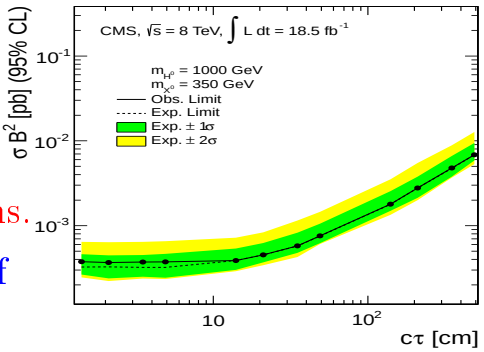
Long-lived neutral particles decaying to dijets (PAS EXO-12-038)



Search for long-lived massive neutral particles decaying to $q\bar{q}$ pairs. $\Longrightarrow$ Dijets

Signature: pair of jets originating at a secondary vertex ($> 8\sigma$ in transverse plane);
$p_T^{\text{Jets}} > 60$ GeV, $|\eta| < 2$,
$H_T > 300$ GeV.





No significant excess is observed above standard model expectations.

Upper limit is set with 95% C.L. on the production cross section of a heavy scalar particle H^0 in the mass range 200—1000 GeV, decaying into a pair of long-lived neutral X^0 particles with mass range 50—350 GeV.
For X^0 mean proper lifetimes 0.1–200 cm the upper limits are typically 0.3—300 fb.

Additionally, the results are interpreted for a supersymmetric model containing long-lived neutralinos that decay through an R-parity violating coupling into two quarks and a muon.

For a pair production of squarks that decay to long-lived neutralinos, we exclude squark masses up to 1000 GeV for the neutralino mean lifetimes between 0.1—10 cm.