Search for Exotic Physics with the CMS detector at LHC

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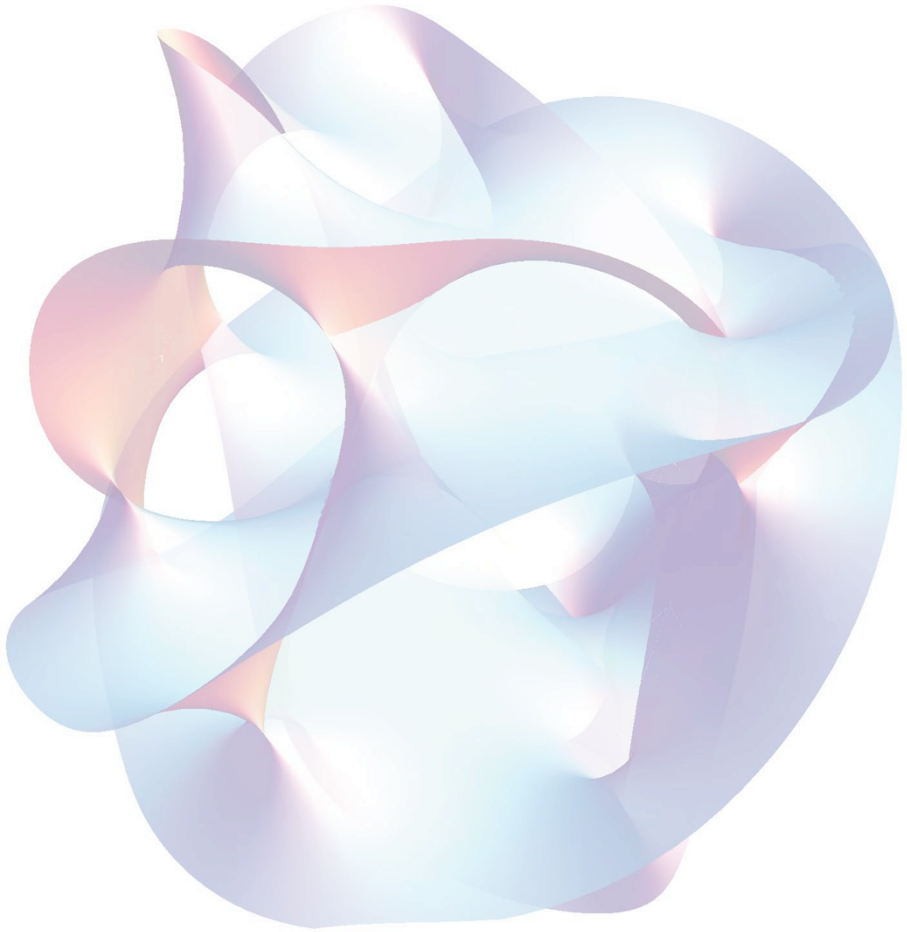
Outline

- 8TeV results:
  - Black Holes
  - W' leptonic decays
  - Dilepton resonances
  - Dijet resonances
  - Heavy neutrino
- 7 TeV results:
  - Heavy quarks
  - Z' decaying to $t\bar{t}$
  - Slow HSCP
- Results summary



8 TeV Results

Microscopic Black Holes

Assuming that n extra dimensions are compacted on an n-dimensional torus or sphere of radius r, and gauge interactions are localized on 3+1 space-time membrane, gravitational coupling is enhanced at distances smaller then r.

Planck scale in 4+n dimensions M_D is much lower then M_{Pl} seen by 3+1 dim. observer.

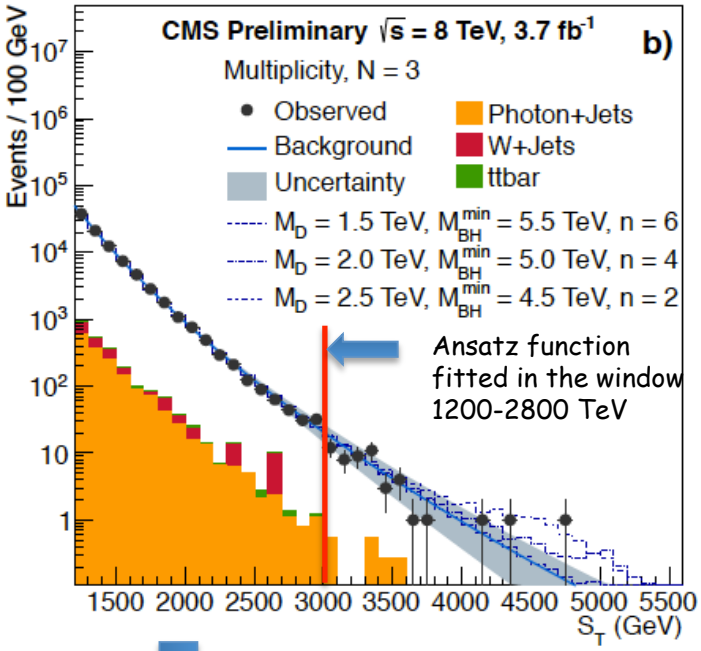
Black Holes can be created at energies > M_D. They decay thermally via Hawking radiation, democratically to all SM degrees of freedom, so mainly to quarks (75%).

Picture from QueryOnline.it

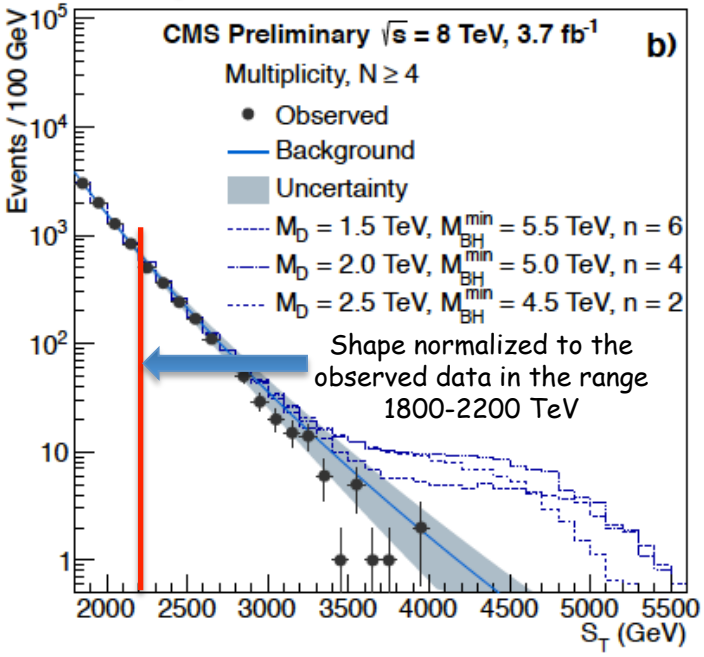
Microscopic Black Holes

CMS-PAS-EXO-12-009

- Signature: multiple energetic jets, leptons, γ
- S_T - scalar sum of the transverse momenta of all jets, leptons and γ with p_T > 50 GeV, passing all the selection criteria and not overlapping with each other. MET is also included if larger then 50 GeV.
  - largely model-independent variable
  - used to separate black hole candidate events from backgrounds
- N – final state multiplicity, number of objects used to calculate S_T, not counting MET
- Background:
  - dominated by QCD multijet events,
  - < 1% from vector boson + jet and $t\bar{t}$,
  - estimated from data basing on the independence of the shape of S_T spectrum on the number of final-state objects N.



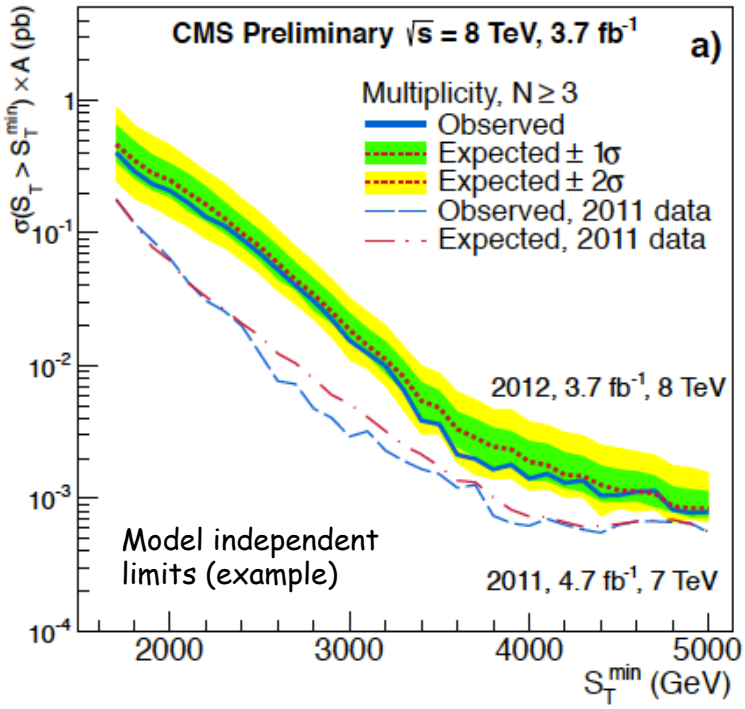
Fit result of the background prediction for the inclusive samples with high object multiplicity

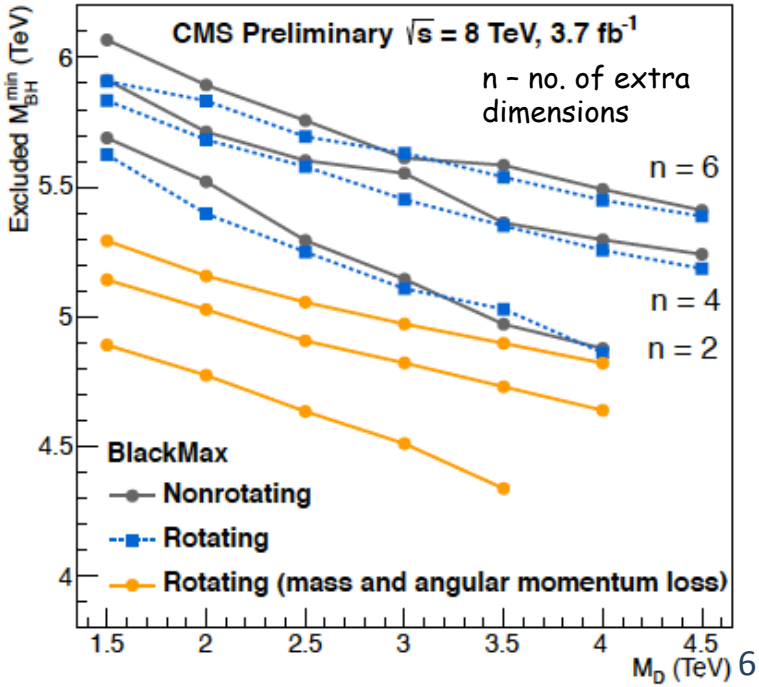


Microscopic Black Holes

CMS-PAS-EXO-12-009

- The results are presented separately for six different values of the minimum final state multiplicity
- The data agree with the background shapes from the low multiplicity samples and do not exhibit evidence for new physics
- Limits:
  - ~750 different MC signal samples used, covering only small part of the parameter space of the models, scaling the number of samples up very impractical,
  - Model-independent limits on the cross-section times acceptance for new physics production in high-S_T inclusive final states
  - Model-specific indicative limits, excluding semiclassical black holes with a minimum mass varying from 4.1 to 6.1 TeV for $M_D < 4.5$ TeV and $n \leq 6$.





W' leptonic decays

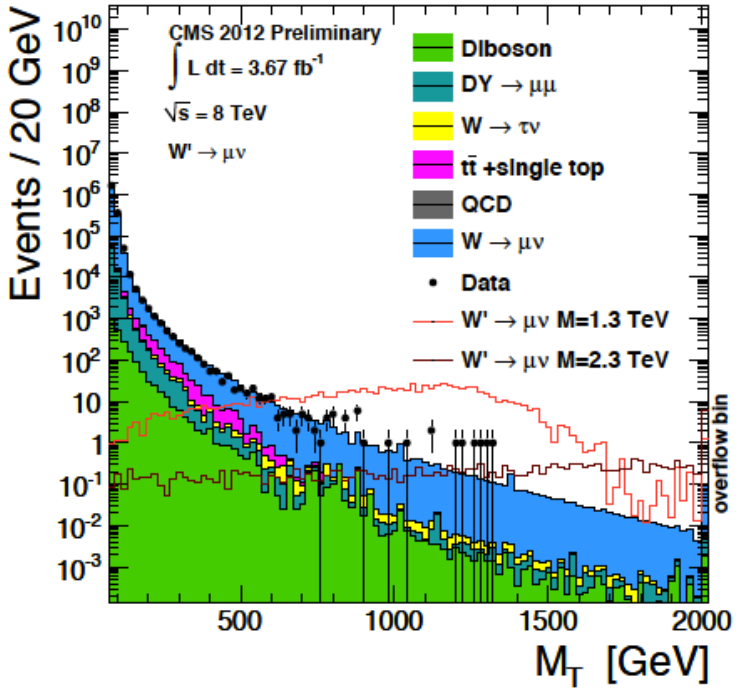
CMS-PAS-EXO-12-010

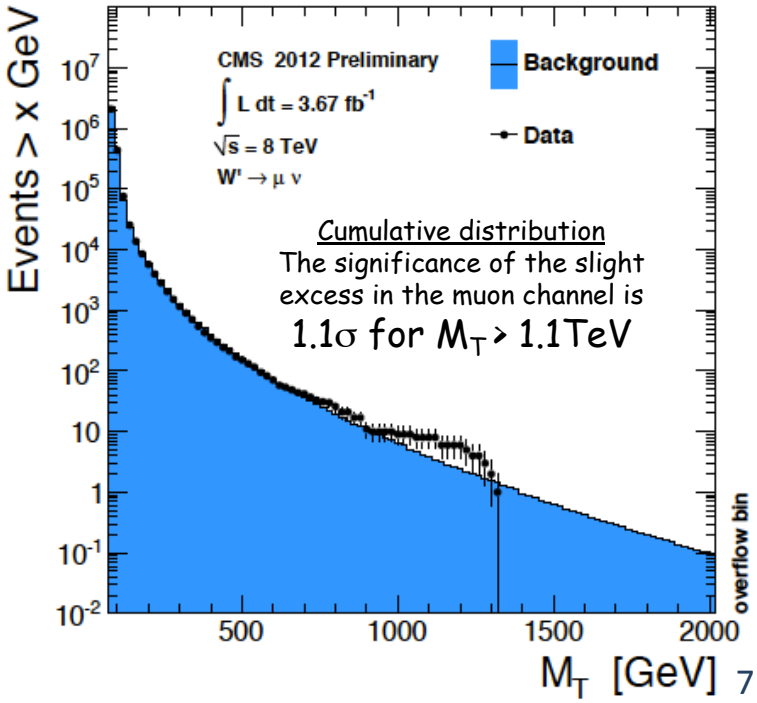
- Search for a new heavy gauge boson W' decaying to an electron or muon and a low mass neutrino
- The main observable – transverse mass of the lepton-MET system, calculated as:

$$M_{\mathrm{T}} = \sqrt{2 \cdot p_{\mathrm{T}}^{\ell} \cdot E_{\mathrm{T}}^{\mathrm{miss}} \cdot (1 - \cos \Delta\phi_{\ell,\nu})}$$

azimuthal opening angle between lepton p_T and MET

- Backgrounds:
  - W->lν high transverse mass tail,
  - QCD multijet, $t\bar{t}$, Drell-Yan
  - Diboson leptonic decays
- No significant excess of events with final state consisting of a charged lepton and significant MET over expected SM background

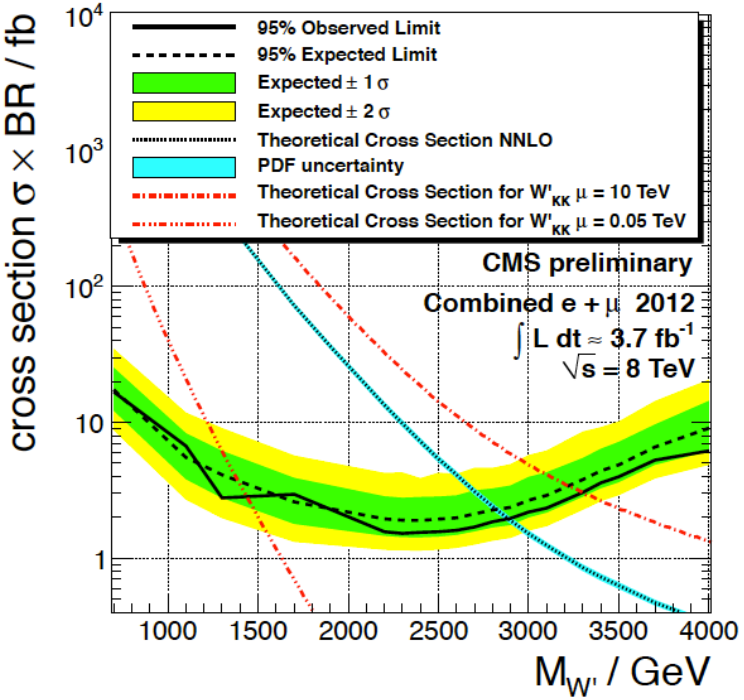


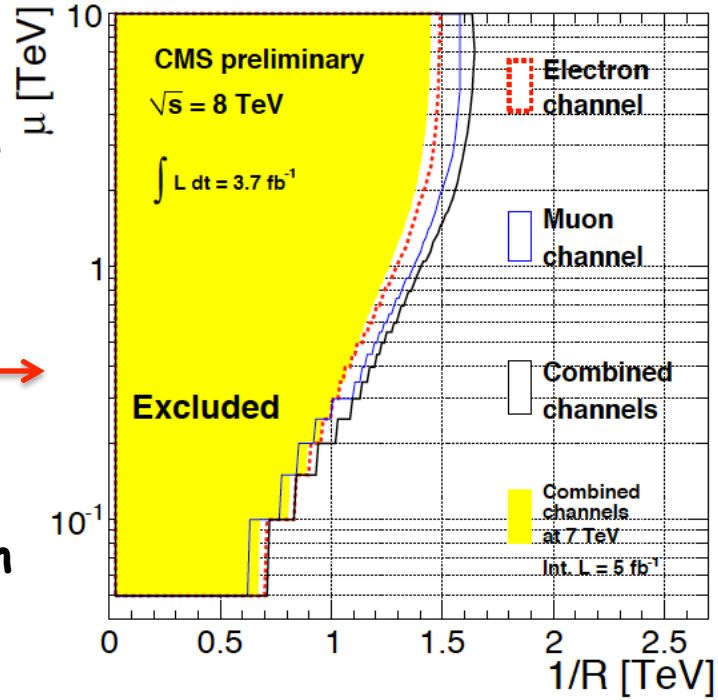


W' leptonic decays

CMS-PAS-EXO-12-010

- The results interpreted in the frameworks of **3 theoretical models**:
  - **Sequential Standard Model (SSM)** predicting W' as a heavy analogue of W – narrow resonance with decay modes and branching fractions similar to W.
    Excluded SSM W' with mass < 2.85 TeV.
  - **Split-UED** – additional compact dimension of radius R, SM particles have KK partners like W^n_{KK}, where n denotes n-th KK excitation mode. The UED parameter space is defined by two parameters [1/R, μ], where μ is the bulk mass parameter of the fermion field in 5 dimensions. Limits →
  - **Compositeness** of fermions (fundamental constituents - preons) manifested at $E \ll \Lambda$ (preon binding energy scale) by **four-fermion contact interaction** (2q, l, ν).
    Excluded Λ < 8.7 TeV.

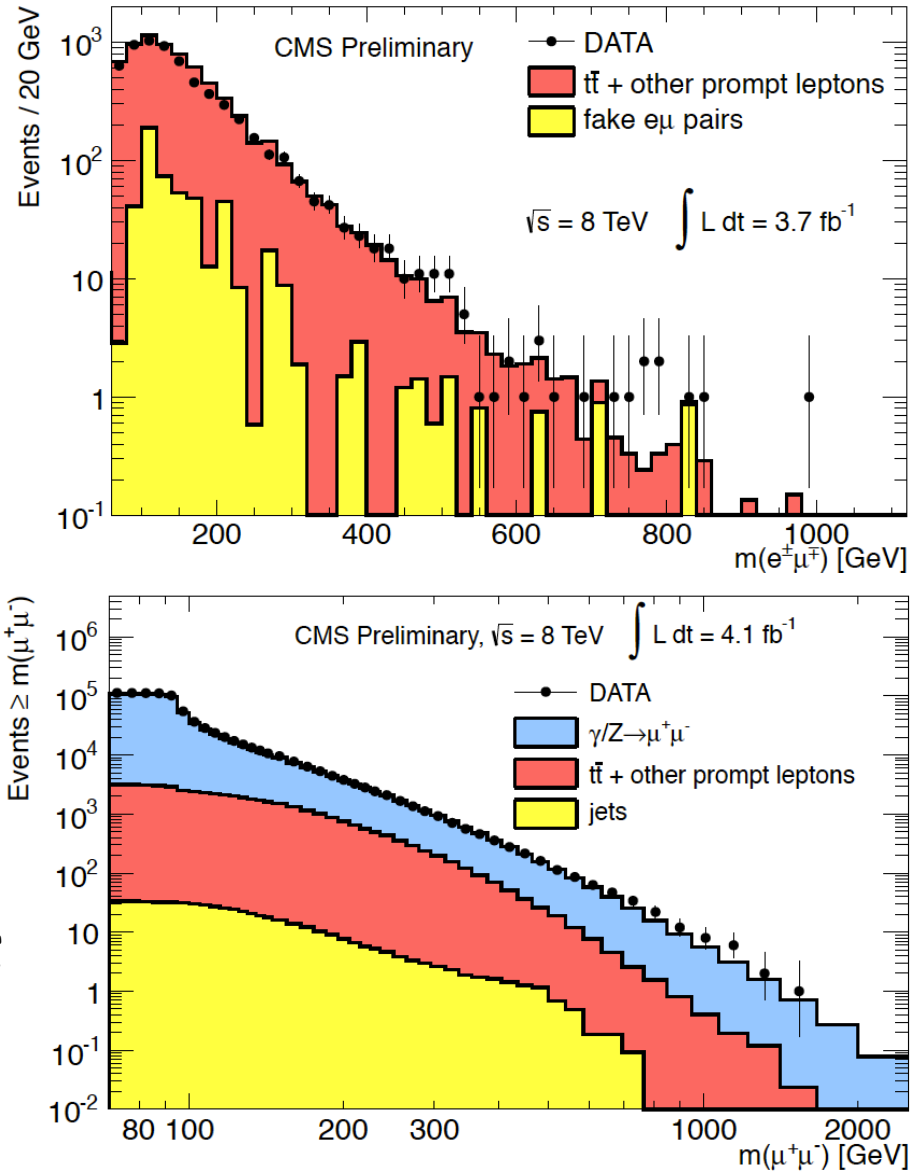




Dilepton resonances

CMS-PAS-EXO-12-015

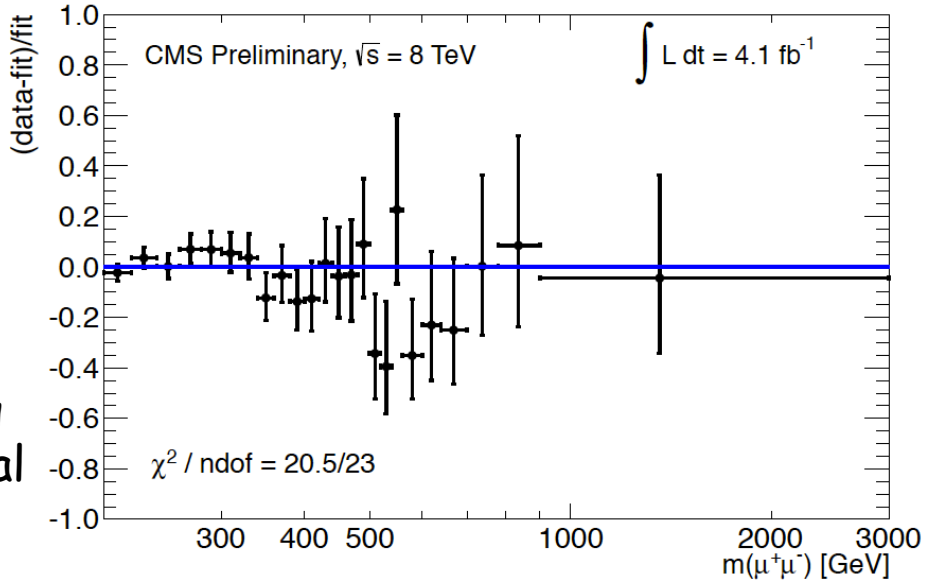
- Search for narrow dilepton Z′ resonances decaying to electron or muon pairs
- Based on a shape analysis of the dilepton mass spectra – to be robust against uncertainties in the absolute background level,
- Event selection: two isolated same-flavour leptons originating from the same vertex: opposite sign muons with p_T > 45 GeV, electrons with E_T > 35 GeV,
- Backgrounds: Drell-Yan, $t\bar{t}$, tW, diboson, jets misidentified as leptons - multijet and vector boson + jets, diphotons misidentified as dielectrons,
- Background due to non-Drell-Yan prompt leptons is flavor symmetric – compare MC simulation with data using opposite sign eμ spectra

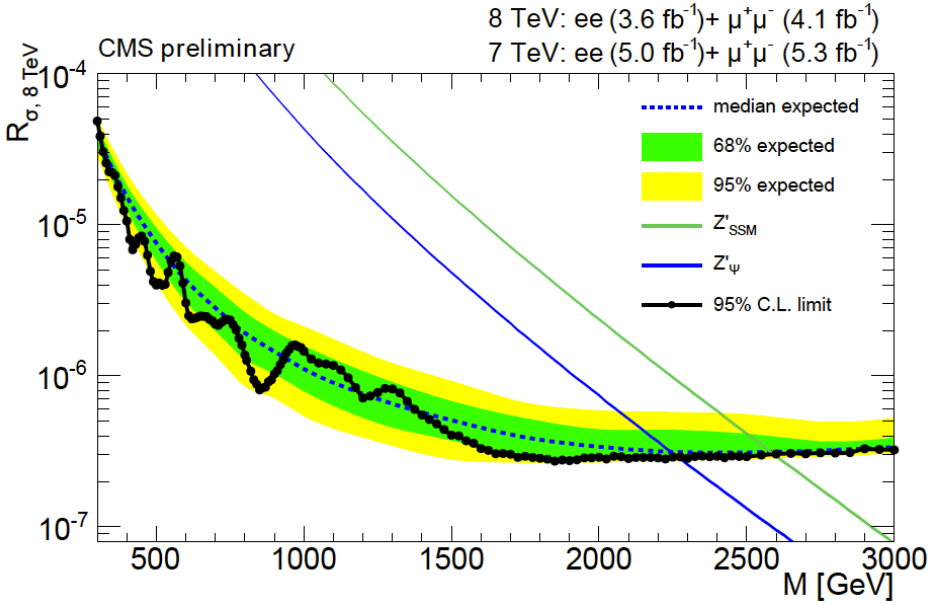


Dilepton resonances

CMS-PAS-EXO-12-015

- Background is estimated fitting an appropriate function, obtained from MC simulations to the data, the result of the fit is in good agreement with the observed data
- Limits are set on the ratio R_σ of the production cross section times branching fraction to that for Z => many theoretical and experimental uncertainties common to both measurements cancel and the dependence on experimental acceptance, trigger and offline efficiencies is reduced,
- The results are interpreted in the context of two Z' models, and the limits are following:
  - SSM with standard model-like couplings Z'_{SSM}- 2590 TeV
  - Superstring-inspired grand unified theory Z'_{ψ} - 2260 TeV

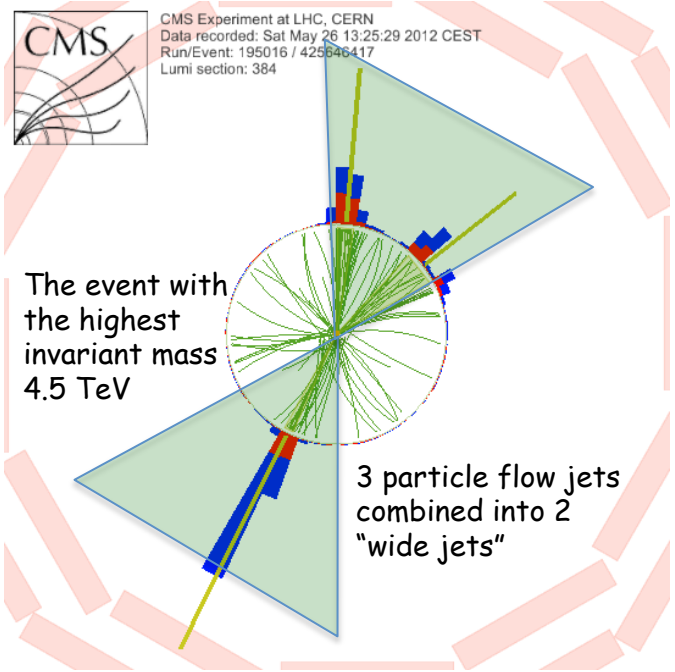


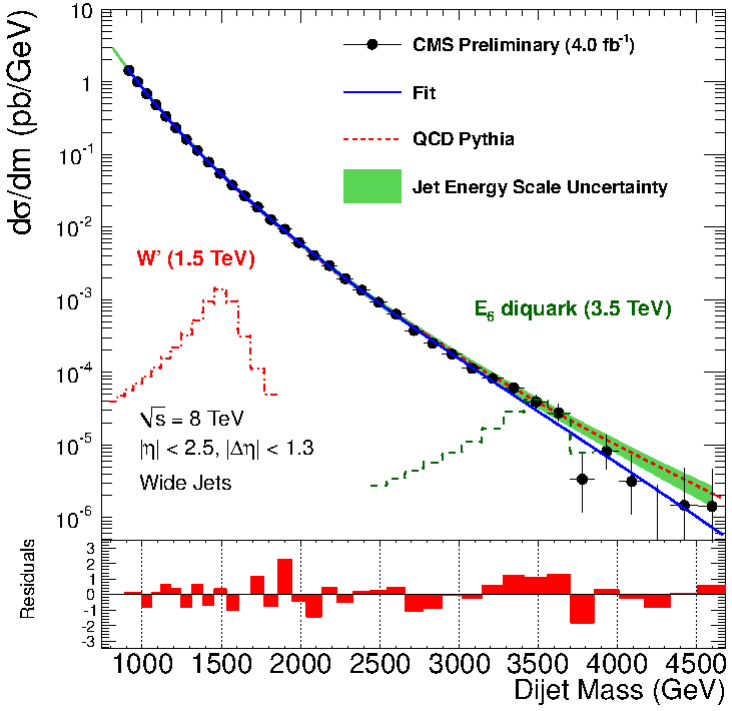


Dijet resonances

CMS-PAS-EXO-12-016

- Search for new massive objects that couple to quarks and gluons, resulting in resonances in the dijet mass spectrum
- Event selection: two particle flow jets with $p_T > 30$ GeV and $|\eta|<2.5$ are required,
- Particle flow jets are combined into "wide jets", which are used to measure the dijet mass spectrum:
  - two jets of the highest p_T are selected
  - Lorentz vectors of all other jets are added to the closest of these two jets, if within $|\eta|<1.1$, the particles belonging to the jets can extend further up to 1.6
  - Two "wide jets" must be separated by $\eta > 1.3$, each jet inside the region $|\eta|<2.5$
- The algorithm is intended to reduce sensitivity to gluon radiation.

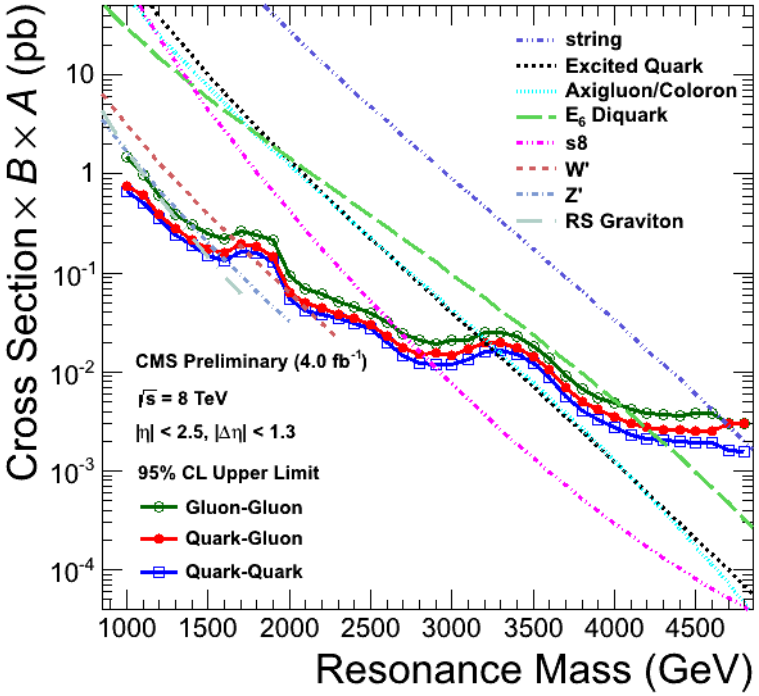


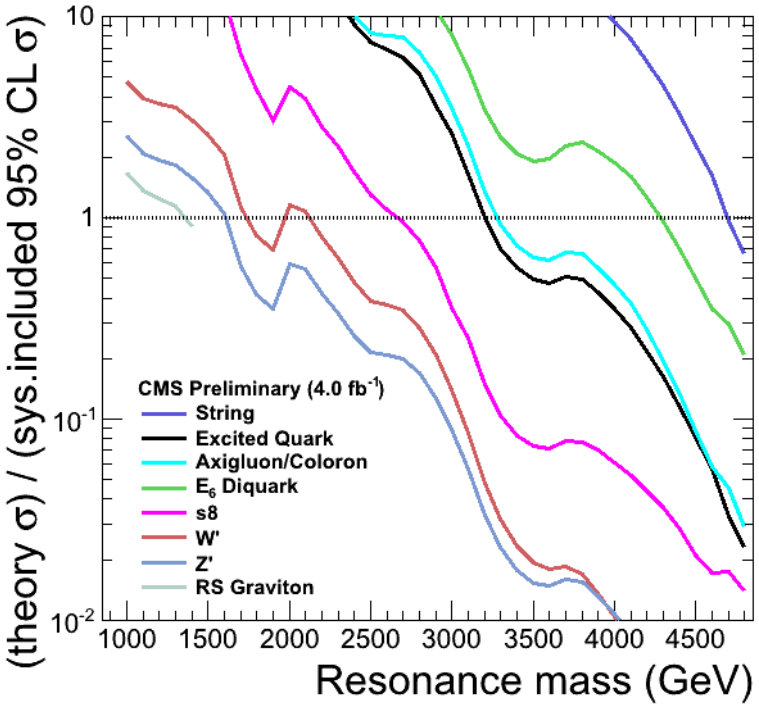


Dijet resonances

CMS-PAS-EXO-12-016

- Measured dijet mass spectrum is fitted with a smooth, empirical parameterization which well describes the prediction from simulated QCD dijet events
- A lot of theoretical new physics models, including:
  - string resonances,
  - scalar diquarks,
  - excited quarks,
  - axial-vector particles called axigluons,
  - color-octet colorons,
  - the s8 resonance,
  - W', Z',
  - RS gravitons
- Specific lower limits are set on the masses of exotic objects in the 1 - 4.7 TeV range

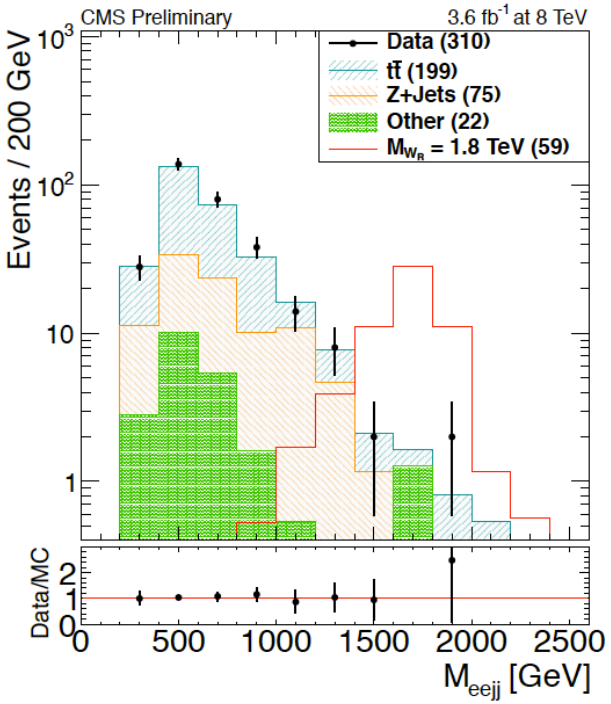


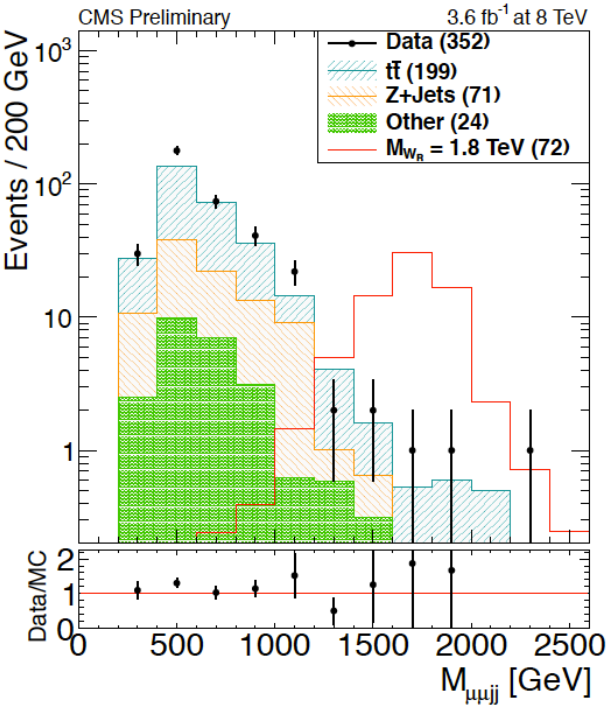


Heavy neutrino

- Heavy right-handed neutrino states are naturally introduced in Left-Right Symmetric Extensions (LRSM) to the SM $SU_C(3)\otimes SU_L(2)\otimes SU_R(2)\otimes U(1)$. They explain the origin of parity non-conservation in weak interactions. They also introduce three additional gauge bosons $W_R^{\pm}$, Z'
- The following reactions are considered:
  - $pp \to W_R + X \to N_\ell + \ell + X$
  - $W_R \to \ell_1 N_\ell \to \ell_1 \ell_2 W_R^* \to \ell_1 \ell_2 q q' \to \boxed{\ell_1 \ell_2 jj}$
- A unique feature of the heavy neutrino production is that it has a two-dimensional resonance structure, the distributions of M_{lljj} and M_{l_2jj} should exhibit narrow peaks
- Event selection:
  - Two isolated electrons or muons, leading (subleading) lepton p_T > 60(40) GeV, M_{ll} > 200 GeV
  - Two jets p_T > 40 GeV
  - M_{lljj} > 600 GeV

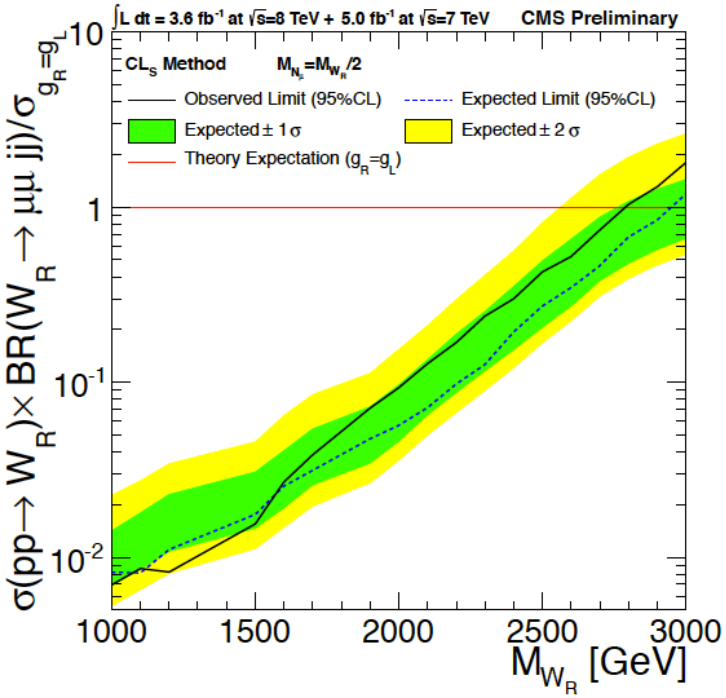
[CMS-PAS-EXO-12-017]

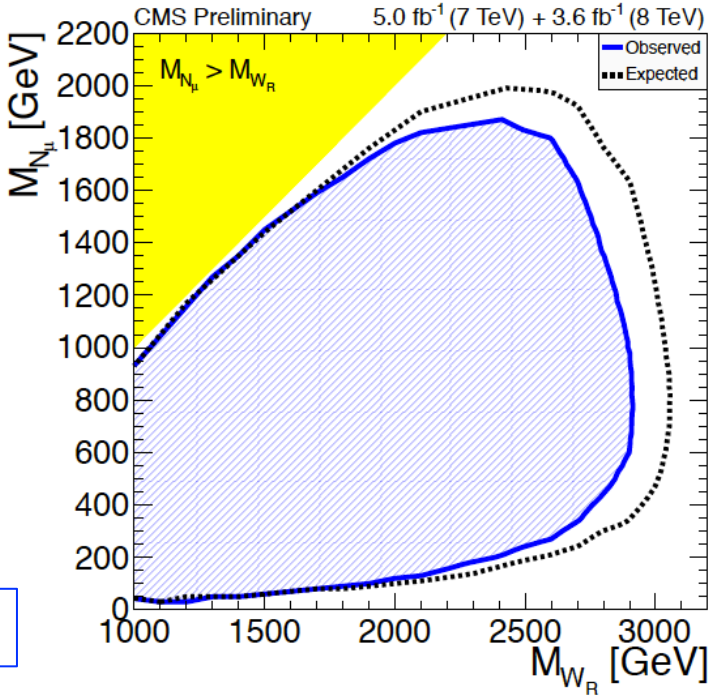




Heavy neutrino

- Main source of background are SM processes with two real leptons, such as $t\bar{t}$ and Z+jets (estimated from data), additional background processes (W+jets, diboson, single top) are modeled using MC,
- No excess over expectations from SM processes is observed, exclusion limits in the two-dimensional parameter (M_{W_R}, M_{N_l}) space were obtained by comparing the observed (expected) cross section for each mass point.
- The limits extend to roughly M_{W_R}=2.5 TeV in each channel and exclude a wide range of heavy neutrino masses for W_R mass assumptions below this maximal value.
- Limits are also presented as a function od ER mass for a right-handed neutrino with $M_{N_l} = \frac{1}{2} M_{W_R}$
- Good agreement is seen between observed and expected limits





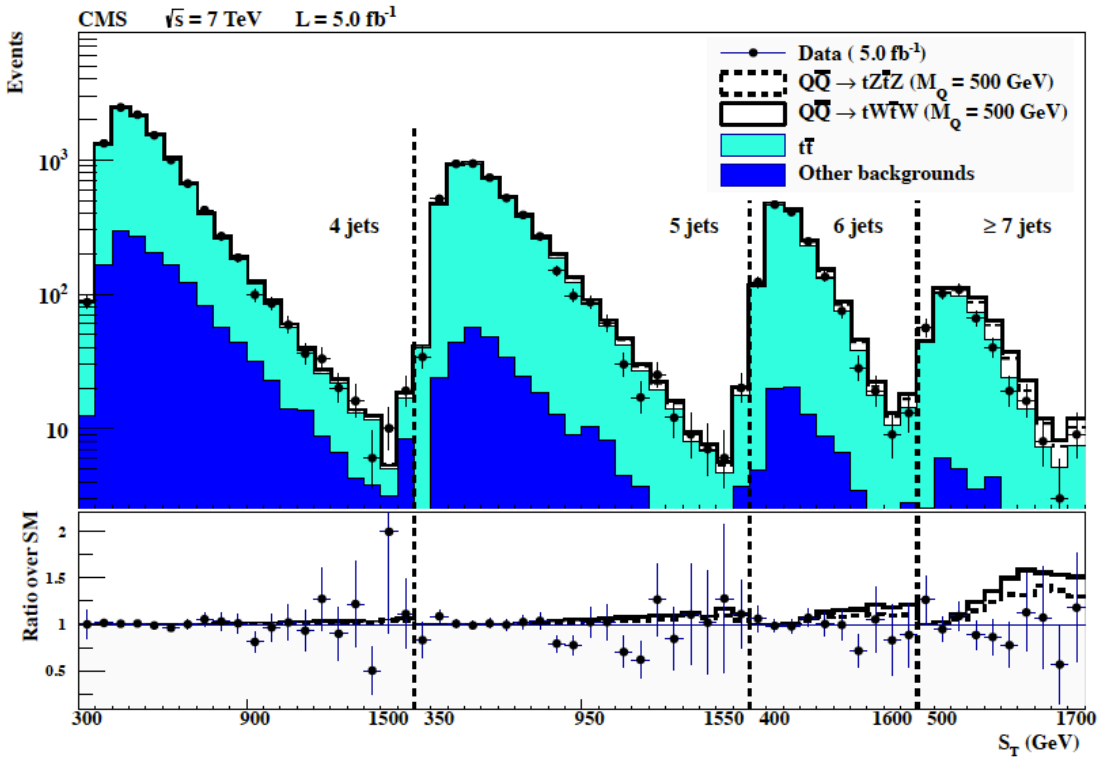
CMS-PAS-EXO-12-017

7 TeV Results

Heavy quarks

arXiv:1210.7471

- Search for strong pair production of heavy quarks $Q\bar{Q}$ (down and up type), that decay exclusively into a top quark and a W (sequential four generation model) or Z boson (models including non-chiral heavy quarks with vector-like coupling to bosons),
- The search is performed by classifying events based on jet multiplicity N_j, for each N_j the data are fitted to the distribution of the scalar sum S_T of lepton, jets and missing p_T.
- The distributions for different N_j are combined after maximum-likelihood fit to data.



- Decay chains:
  - down type Q:

$$Q\bar{Q} \rightarrow tW^{-}\bar{t}W^{+} \rightarrow bW^{+}W^{-}\bar{b}W^{-}W^{+}$$

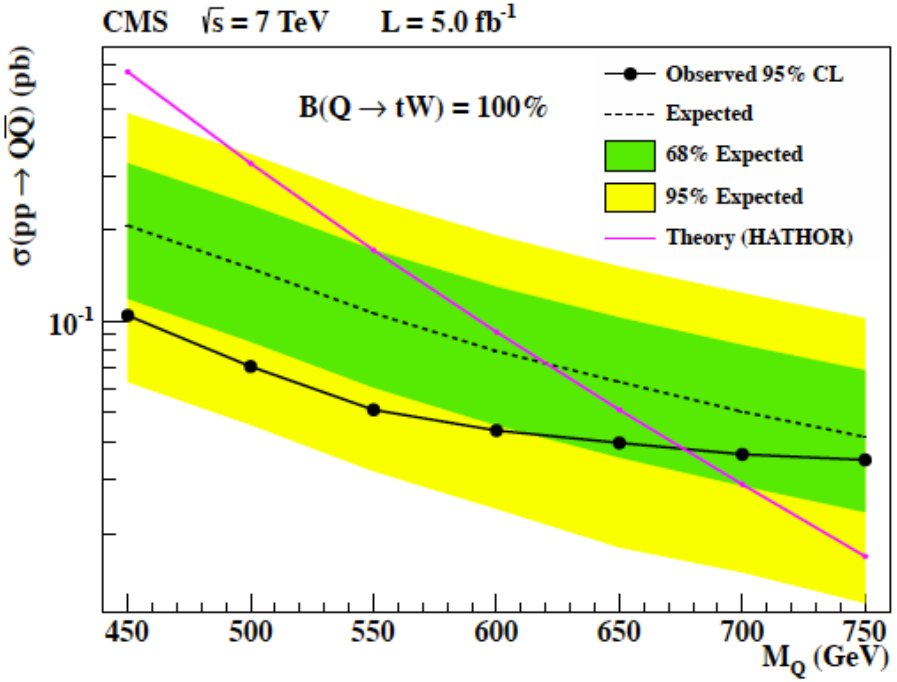
  - up type Q:

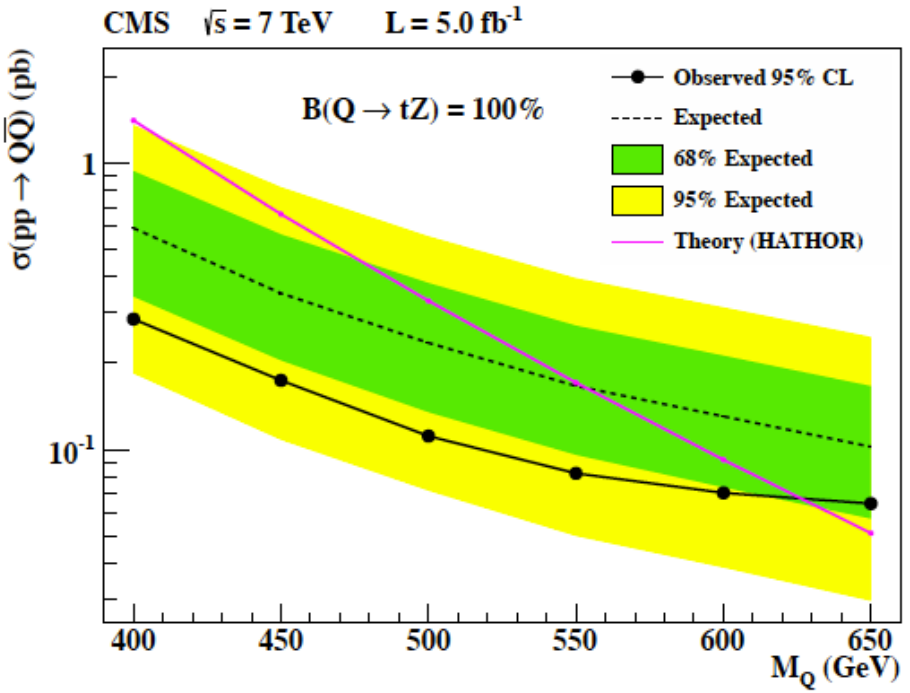
$$Q\bar{Q} \rightarrow tZ\bar{t}Z \rightarrow bW^{+}Z\bar{b}W^{-}Z$$

Heavy quarks

arXiv:1210.7471

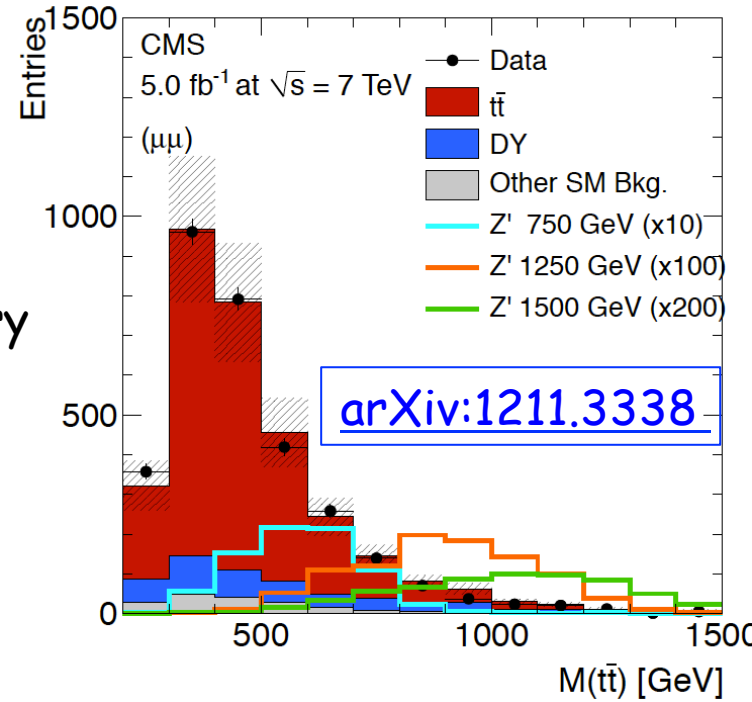
- Event selection:
  - one e or μ with p_T > 35 or 42 GeV,
  - missing p_T >20 GeV,
  - minimum four jets with p_T > 100, 60, 50, 35 GeV, at least one b-tagged
- Dominant SM background: $t\bar{t}$ production and W+jets – smaller lepton and jet p_T and lower jet multiplicities then in $Q\bar{Q}$ events.
- Other backgrounds: single top, W+jets, Z+jets, diboson, multijet
- Number of expected background events evaluated from MC, with exception of multijet – estimated from data.
- No excess over predicted background is observed, the limits are set on the $Q\bar{Q}$ cross section.

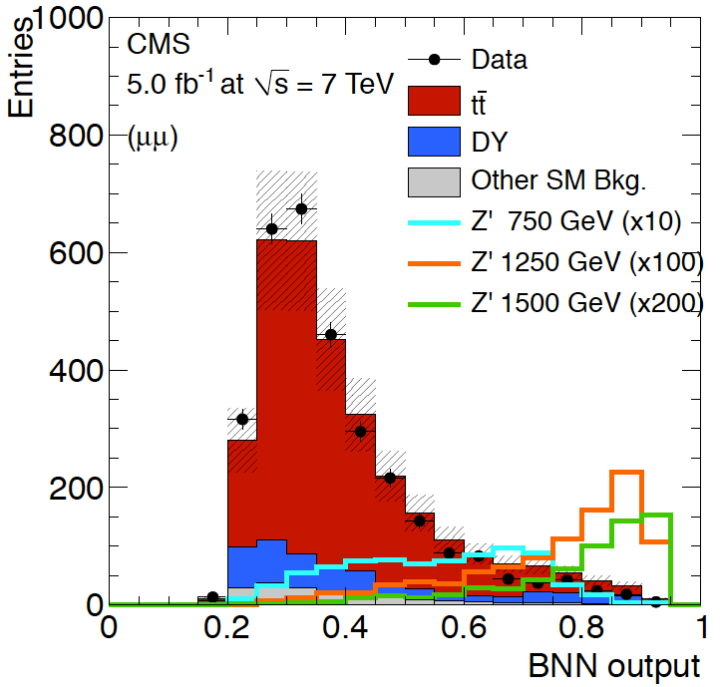




Z′ decaying to $t\bar{t}$

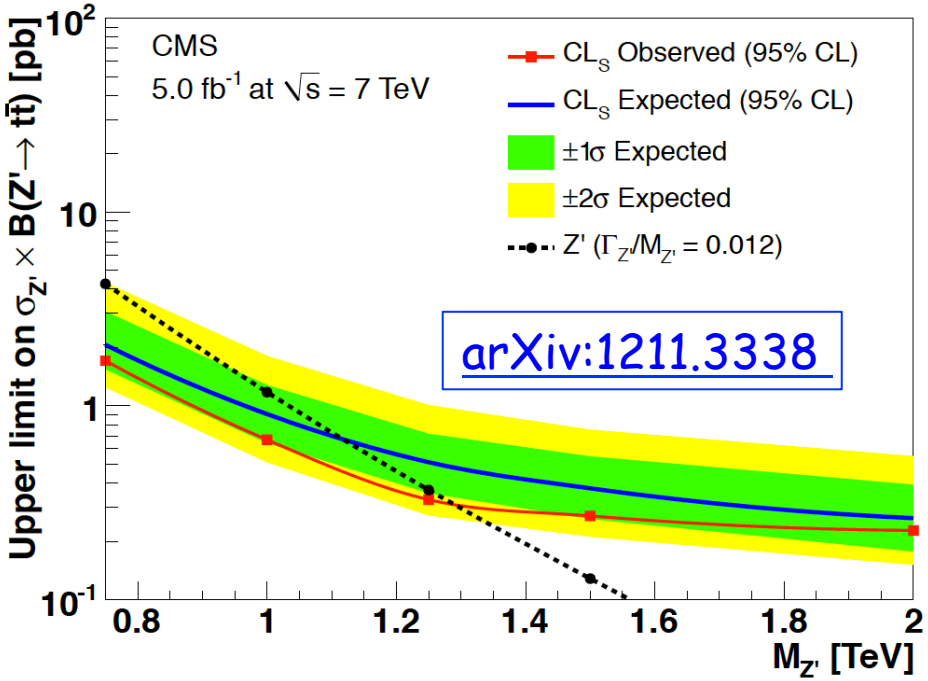
- Z′ decaying to $t\bar{t}$ pairs is predicted by topcolor-assisted technicolor model (TC2), which provides a dynamical explanation for electroweak symmetry breaking and flavor symmetry breaking, giving masses to the weak gauge bosons and fermions
- A heavy Z′ boson is predicted with preferential coupling to the 3rd quark generation, and no significant couplings to leptons (leptophobic)
- Search for Z′->$t\bar{t}$ resonance, where each top quark decays to a W boson and a b quark, and each b quark decays into a lepton and a neutrino (2l+2ν+jets final state, where l = e,μ)
- Event selection:
  - 2 isolated opposite sign leptons, p_T > 20 GeV,
  - MET > 30 GeV due to undetected neutrinos,
  - at least 2 jets, p_T > 30 GeV
  - M_{ll} > 12 GeV to suppress low-mass resonances,
  - 76 < M_{ll} < 106 GeV, to suppress Z bosons (only in ee and μμ channels)

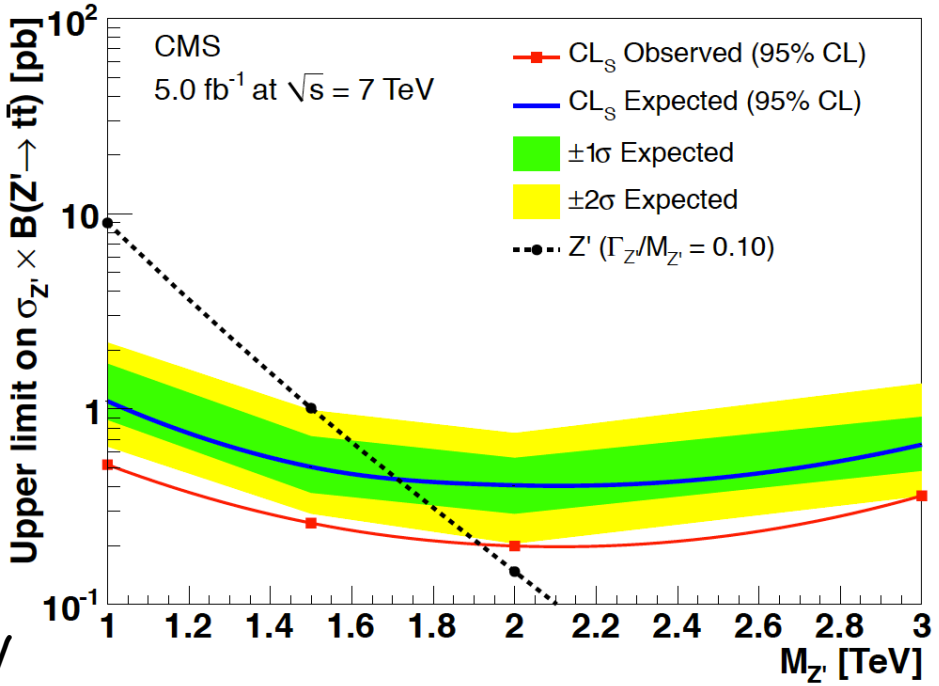




Z′ decaying to $t\bar{t}$

- The principal sources of background: $t\bar{t}$, DY, single top, diboson,
- Minor background contributions: W->lν, multijet production,
- The signal efficiency and background rejection are determined from simulation studies augmented where necessary by corrections based on data control samples,
- Good agreement is observed between data and the sum of all SM backgrounds,
- A multivariate analysis based on Bayesian neural networks (BNN) has been carried out to provide more powerful discriminant between backgrounds and signal then that based on invariant mass alone,
  - Expected limit improved by 29%
- Excluded Z′ with masses $M_{Z'}$ <1.3(1.9) TeV for a width $\Gamma_{Z'} = 0.0012(0.10)M_{Z'}$

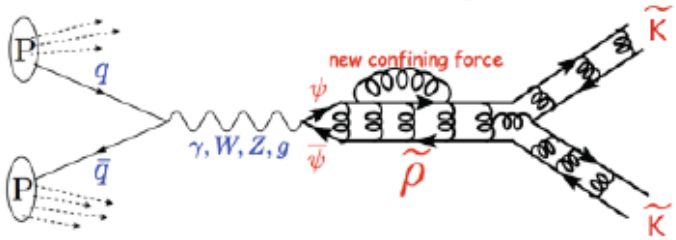


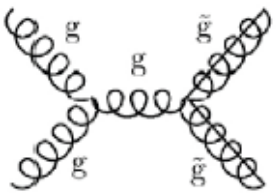


Slow HSCP

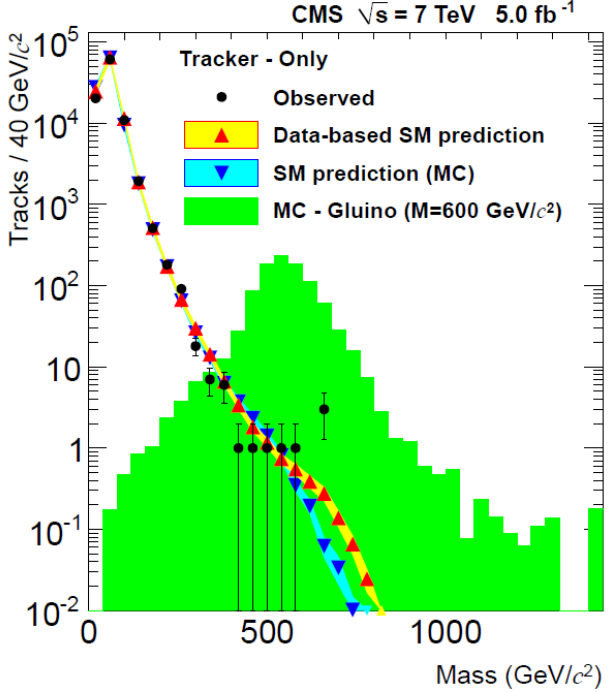
Physics Letters B, Volume 713, Issues 4–5, 18 July 2012, Pages 408–433

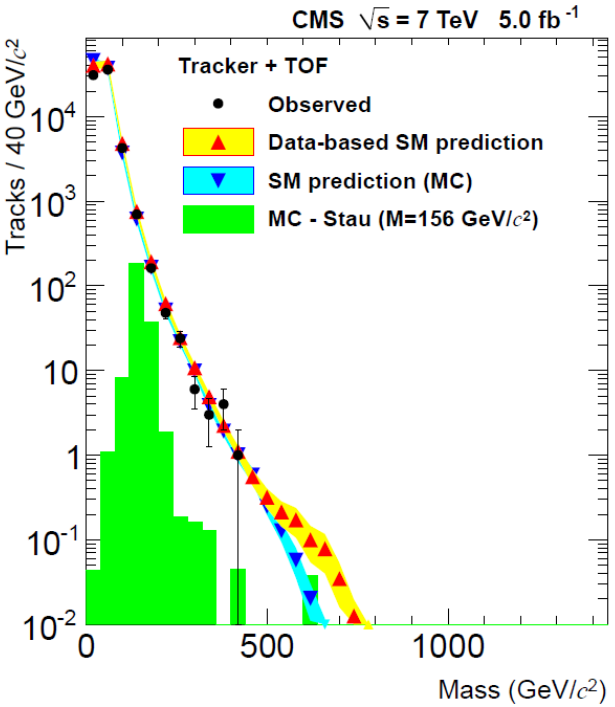
- R-hadrons: gluino, stop:
  - Two interaction models: cloud and conservative charge suppression
  - R-gluonball fractions: 0.1, 0.5
- Lepton-like:
  - Stau (direct pair production, GMSB)
  - Pair produced Hyper-kaon (through DY + hyper-ρ resonance)





- Two selection strategies:
  - Tracker-only: large dE/dx + large p_T
  - Tracker+TOF: Tracker-only + μ-like + long time-of-flight (β^{-1} from μ system)





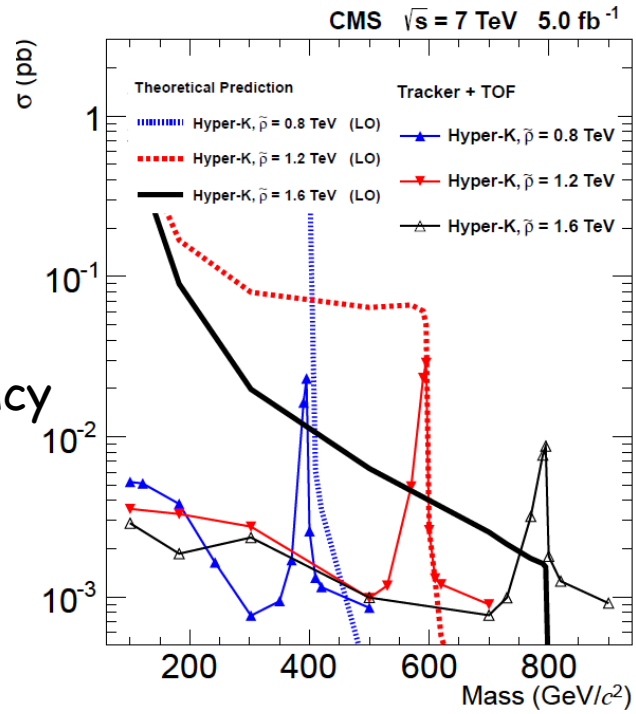
Slow HSCP

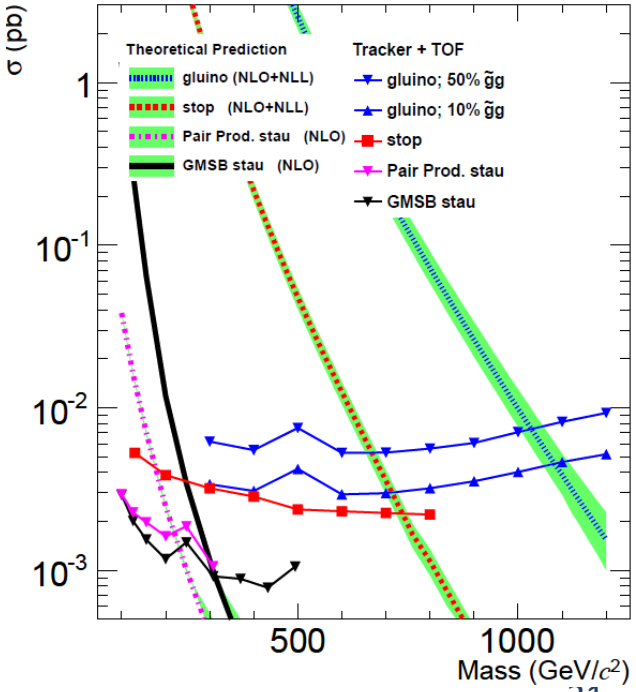
Physics Letters B, Volume 713, Issues 4–5, 18 July 2012, Pages 408–433

- Triggers:
  - Single μ, MET (for charge suppression models),
  - HSCP dedicated RPC trigger - 75% (10%) efficiency for staus with β = 0.6 (0.45)
- Data-driven background estimation:
  - Utilizing the non-correlation between β^{-1}, dE/dx MIP-compatibility (I_{as}) and p_T. Mass prediction using p, I_h and β^{-1} PDF from non-signal region
- Limits:
  - Cloud model interaction scenario:

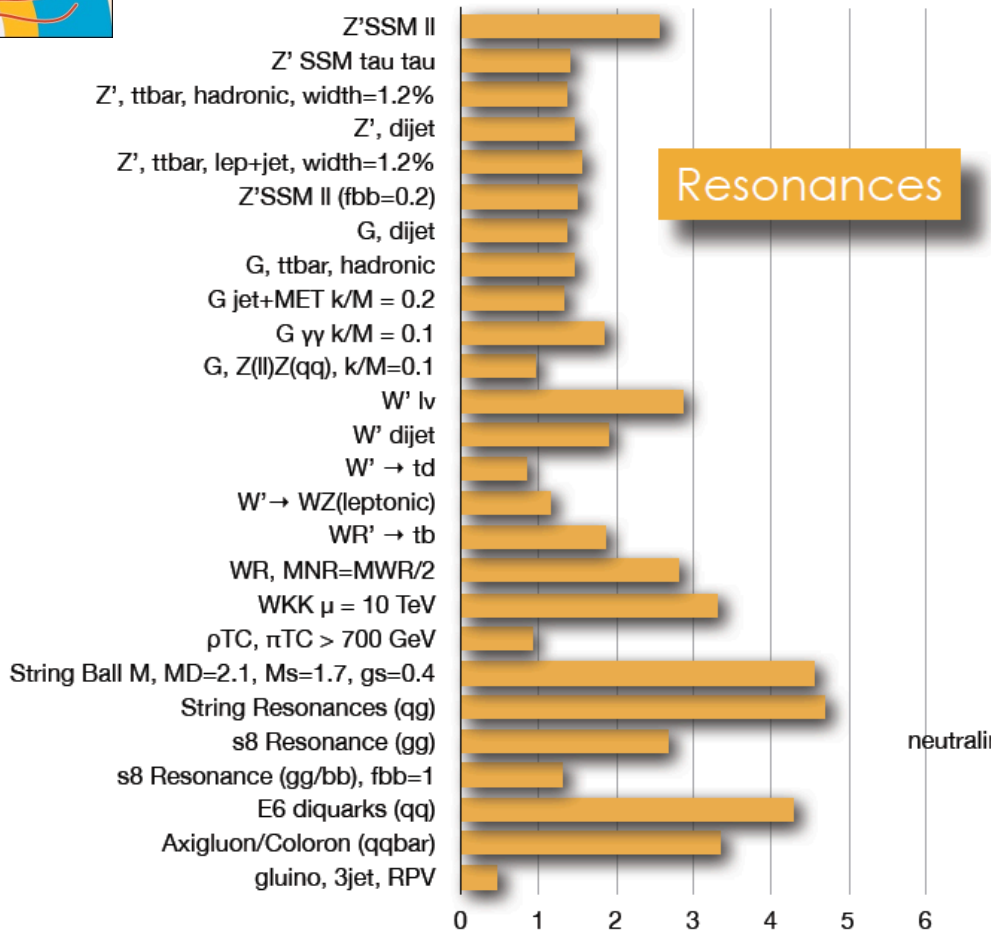
    Gluino (10% gg): 1098 GeV, Stop: 737 GeV
  - Charge suppression interaction scenario

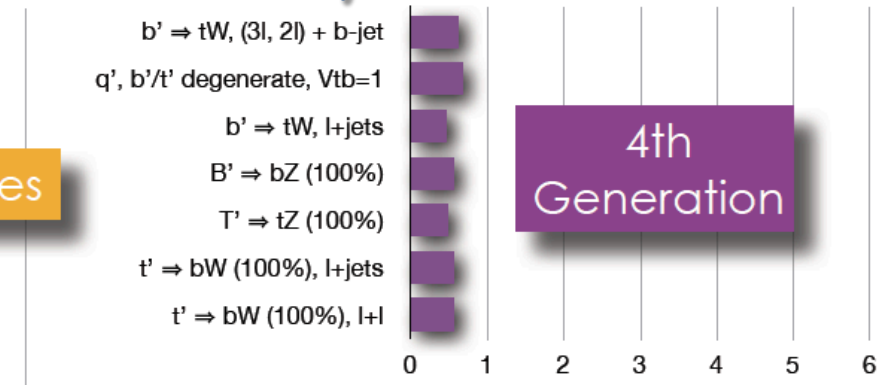
    Gluino(10% gg): 928 GeV, Stop: 626 GeV
  - Direct pair produced stau: 223 GeV
  - Hyper-kaon: 484, 602 and 747 GeV for hyper-p masses of: 800, 1200 and 1600 GeV

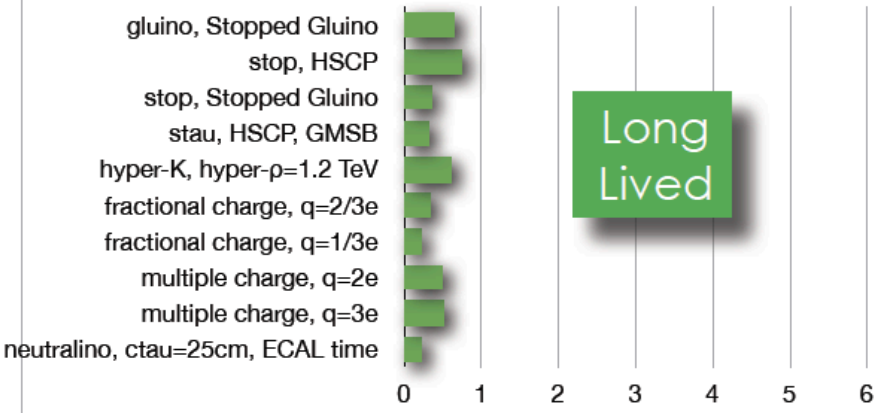


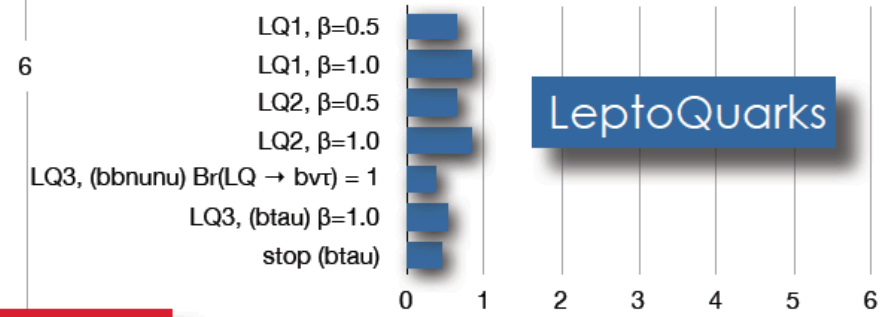


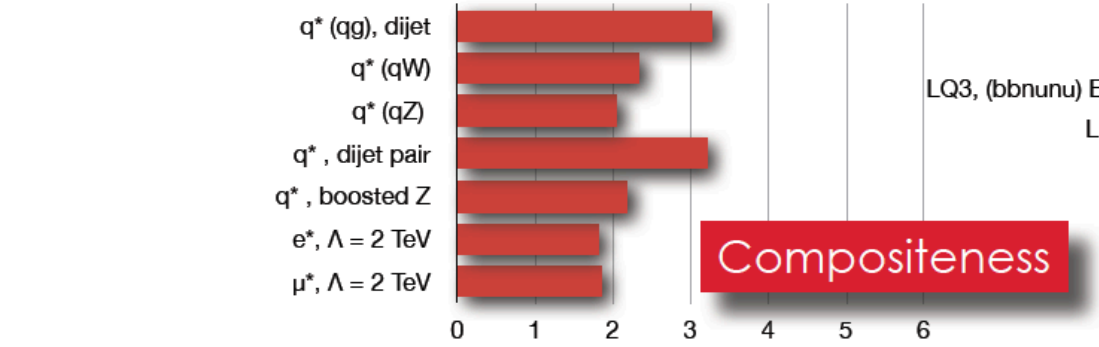
Results summary





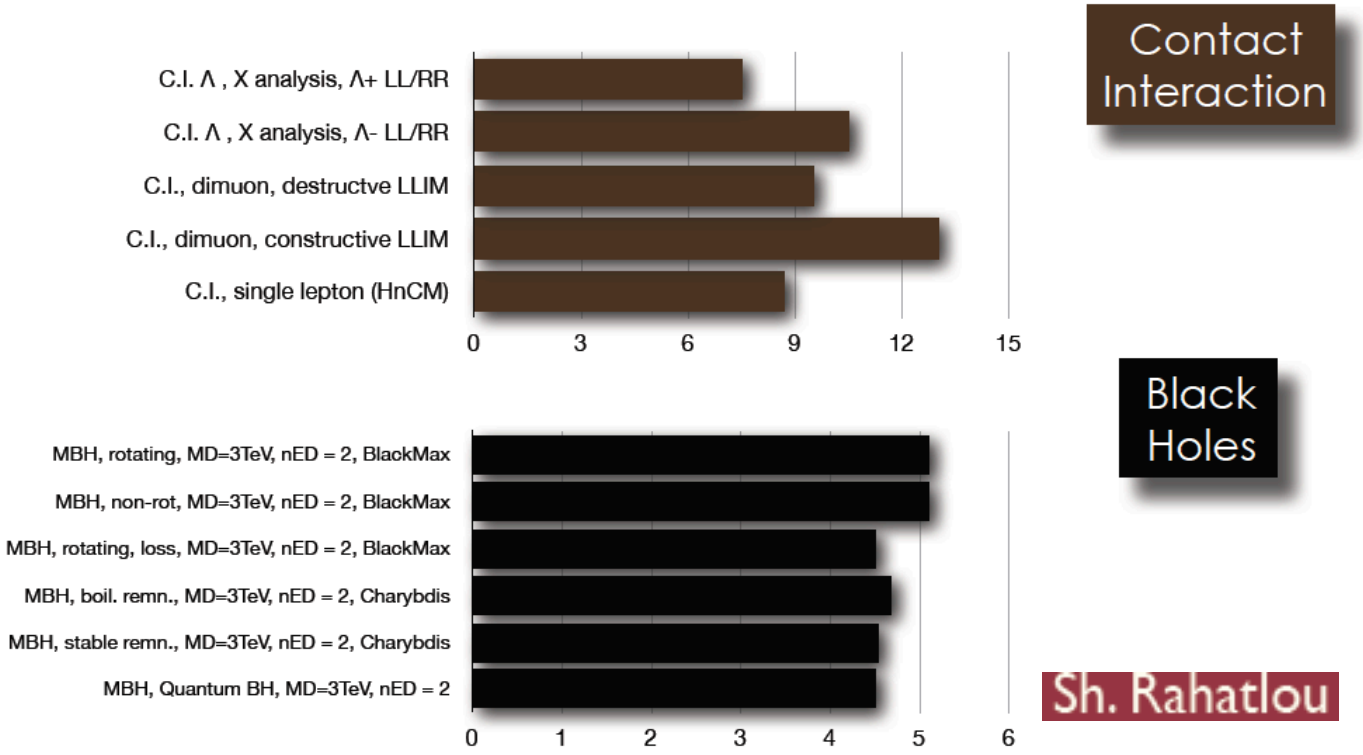






Sh. Rahatlou

Results summary



- Seven fresh CMS Exotic results have been presented
- Still no sign of physics Beyond Standard Model
- Stay tuned for the new results coming soon!

Results summary

Preliminary Results - 2012 Run

Analysis	Approved Plots	CDS Entry	Luminosity
Search for dijet resonances	EXO12016	PAS EXO12016	4/fb
Search for black holes	EXO12009	PAS EXO12009	4/fb
Search for dilepton resonances	EXO12015	PAS EXO12015	4/fb
Search for W' with lepton+MET	EXO12010	PAS EXO12010	4/fb

Complete list of results:

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

Journal Publications - 2011 Run

Analysis	ArXiv Entry	Luminosity	Publication Status	Approved Plots
Search for Evidence of Contact Interactions in Dimuon Mass Spectrum NEW	arXiv:1212.4563	5.3/fb	accepted by PRD	EXO11009
Search for qW/qZ/WW/WZ/ZZ-Resonances in the W/Z-tagged Dijet Mass Spectrum NEW	arXiv:1212.1910	5/fb	submitted to PLB	EXO11095
Search for Long-Lived Particles using Displaced Photons NEW	arXiv:1212.1838	4.9/fb	submitted to PLB	EXO11035
Search in leptonic channels for heavy resonances decaying to long-lived neutral particles NEW	arXiv:1211.2472	5/fb	submitted to JHEP	EXO11101
Search for new light bosons from Higgs boson decays using multi-muon events NEW	arXiv:1210.7619	5/fb	submitted to PLB	EXO12012
Search for Third-Generation Leptoquarks and Scalar Bottom Quarks NEW	arXiv:1210.5627	5/fb	submitted to JHEP	EXO11030
Search for third generation leptoquarks in tau+b NEW	arXiv:1210.5629	5/fb	submitted to PRL	EXO12002
Search for New Physics in Highly Boosted Z0 Decays to Dimuon NEW	arXiv:1210.0867	5/fb	submitted to PLB	EXO11025
Search for pair produced fourth-generation up-type quarks in pp collisions at 7 TeV with a lepton in the final state	arXiv:1209.0471	5/fb	10.1016/j.physletb.2012.10.038	EXO11099
Search for a heavy neutrino and right-handed W	arXiv:1210.2402	5/fb	submitted to PRL	EXO11091
Search for fractionally charged particles	arXiv:1210.2311	5/fb	submitted to PRL	EXO11074
Search for Excited Leptons	arXiv:1210.2422	5/fb	submitted to PLB	EXO11034
Search for narrow resonances and quantum black holes in inclusive and b-tagged dijet mass spectra	arXiv:1210.2387	5/fb	accepted by JHEP	EXO11094
Search for Type III seesaw from pp collisions at 7 TeV	arXiv:1210.1797	5/fb	accepted by PLB	EXO11073
Search for a narrow, spin-2 resonance decaying to a pair of Z bosons in the q qbar l+ l- final state	arXiv:1209.3807	5/fb	accepted by PLB	EXO11102
Inclusive search for quarks of a sequential fourth generation	arXiv:1209.1062	5/fb	accepted by PRD	EXO11098

Results summary

Journal Publications - 2011 Run

Search for Three-Jet Resonances	arXiv:1208.2931	5/fb	10.1016/j.physletb.2012.10.048	EXO11060
Search for W' -> t b in lepton + jets	arXiv:1208.0956	5/fb	accepted by PLB	EXO12001
Search for 1st or 2nd generation LQ	arXiv:1207.5406	5/fb	10.1103/PhysRevD.86.052013	EXO11027,EXO11028
Search for Heavy Majorana Neutrinos with same sign dileptons	arXiv:1207.6079	5/fb	10.1016/j.physletb.2012.09.012	EXO11076
Search for new physics with long-lived particles decaying to photons and missing energy	arXiv:1207.0627	2.1/fb	accepted by JHEP	EXO11067
Search for Stopped HSCPs	arXiv:1207.0106	5/fb	10.1007/JHEP08(2012)026	EXO11020
Search for Dark Matter and Large Extra Dimensions in Monojet Events	arXiv:1206.5663	5/fb	10.1007/JHEP09(2012)094	EXO11059
Search for W' decaying into t and d quarks	arXiv:1206.3921	5/fb	10.1016/j.physletb.2012.09.048	EXO11056
Search for Resonances to Dileptons	arXiv:1206.1849	5/fb	10.1016/j.physletb.2012.06.051	EXO11019
Search for resonances decaying into ditaus	arxiv:1206.1725	5/fb	10.1016/j.physletb.2012.07.062	EXO11031
Search for Search for W' (or techni-rho) to WZ	arxiv:1206.0433	5/fb	10.1103/PhysRevLett.109.141801	EXO11041
Search for HSCPs	arXiv:1205.0272	5/fb	10.1016/j.physletb.2012.06.023	EXO11022
Search for Anomalous Production of Multilepton Events and R-Parity-Violating Supersymmetry	arXiv:1204.5341	5/fb	10.1007/JHEP06(2012)169	EXO11045
Search for W' to lepton+MET	arXiv:1204.4764	5/fb	10.1007/JHEP08(2012)023	EXO11024
Search for Z' to ttbar (boosted tops)	arXiv:1204.2488	5/fb	10.1007/JHEP09(2012)029	EXO11006
Search for t' to bW (dilepton channel)	arXiv:1203.5410	5/fb	10.1016/j.physletb.2012.07.059	EXO11050
Search for Heavy Bottom-like Quarks	arXiv:1204.1088	5/fb	10.1007/JHEP05(2012)123	EXO11036
Search for Dark Matter and Large Extra Dimensions in the γ+MET Final States	arXiv:1204.0821	5/fb	10.1103/PhysRevLett.108.261803	EXO11096
Search for Quark Compositeness in Dijet Angular Distributions	arXiv:1202.5535	2.2/fb	10.1007/JHEP05(2012)055	EXO11017
Search for Black Holes	arXiv:1202.6396	4.7/fb	10.1007/JHEP04(2012)061	EXO11071
Search for Large Extra Dimensions in Dielectron and Dimuon Events	arXiv:1202.3827	2.2/fb	10.1016/j.physletb.2012.03.029	EXO11087
Search for signatures of extra dimensions in the diphoton mass spectrum at the Large Hadron Collider	arXiv:1112.0688	2.2/fb	10.1103/PhysRevLett.108.111801	EXO11038
Search for a Vector-like Quark with Charge 2/3 in t + Z Events from pp Collisions at √s = 7 TeV	arXiv:1109.4985	1.1/fb	10.1103/PhysRevLett.107.271802	EXO11005
Search for Resonances in the Dijet Mass Spectrum from 7 TeV pp Collisions at CMS	arXiv:1107.4771	1/fb	10.1016/j.PhysLetB.2011.09.015	EXO11015