Exotica in CMS

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Claudia-Elisabeth Wulz
CMS Collaboration
Institute of High Energy Physics, Vienna

Overview

Selected recent results:

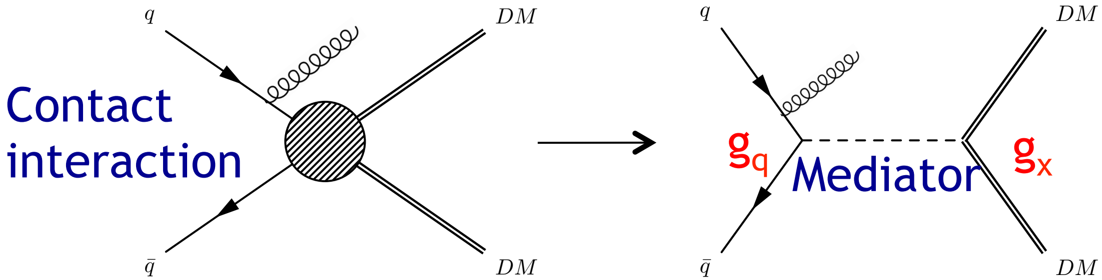
- Dark matter searches — *EXO-14-004, EXO-12-054, EXO-12-048, EXO-12-047*
- Searches with boosted objects — *EXO-14-010, EXO-14-009, EXO-13-007*
  - Weak bosons, tops, Higgs in final state
- Long-lived signatures — *EXO-12-038, EXO-12-036, EXO-12-034, EXO-12-026, EXO-13-006, EXO-14-012, EXO-14-017*
- Classic narrow resonance searches — *DP-15-017, EXO-14-010, EXO-13-007, EXO-12-059, EXO-12-052, EXO-12-050, EXO-12-049, EXO-12-046, EXO-12-045, EXO-12-024*

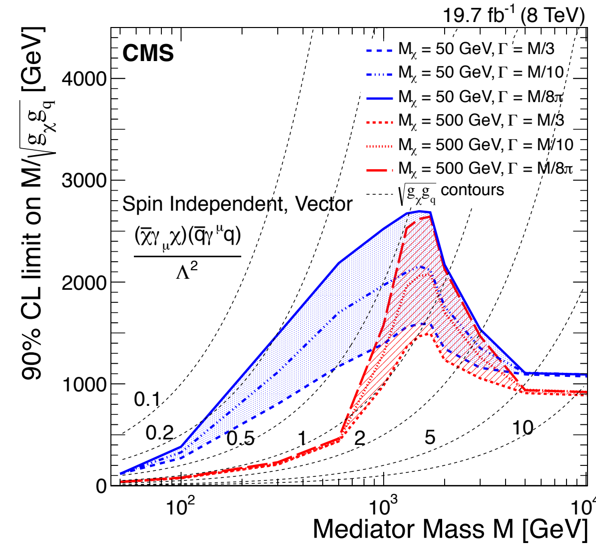
All CMS public BSM physics results:

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

https://twiki.cern.ch/twiki/bin/view/CMSPublic/PhysicsResultsB2G

Dark Matter Searches

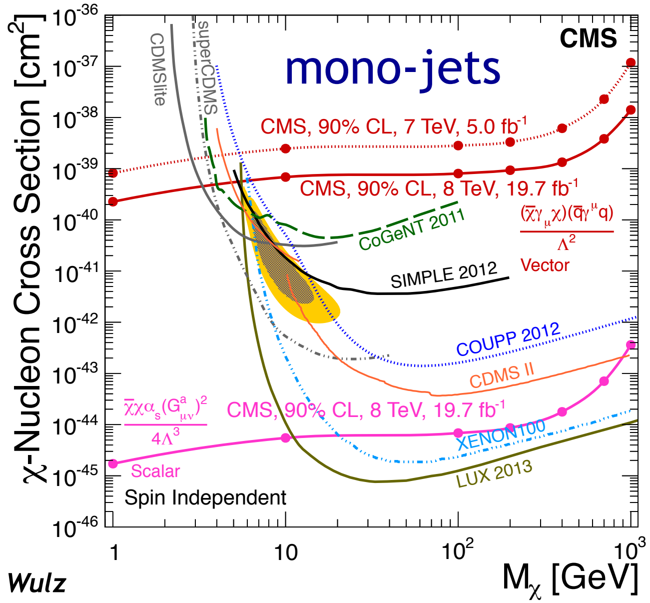


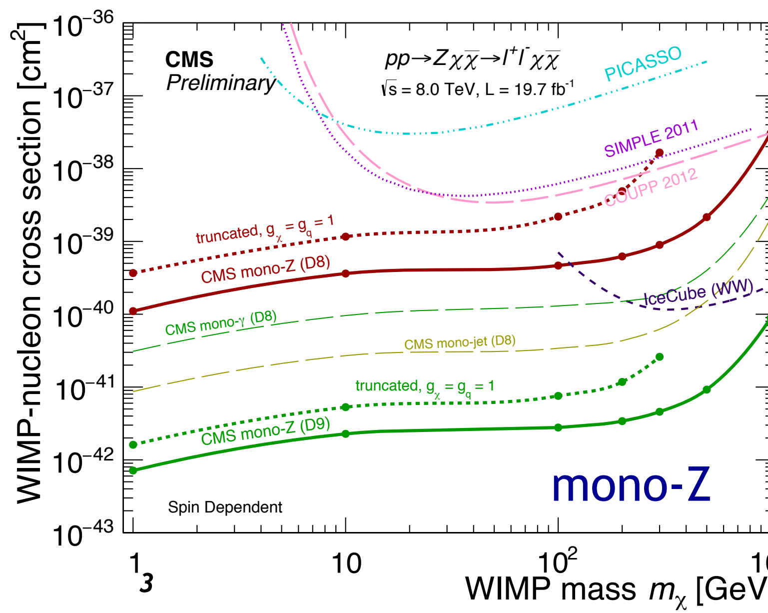


Complementary to direct/indirect searches, best for low DM mass and spin-dependent couplings

CMS-EXO-12-048, EPJC 75 (2015) 235

Select events with ISR -> mono-objects, e.g. mono-jets, mono-Z, mono-γ

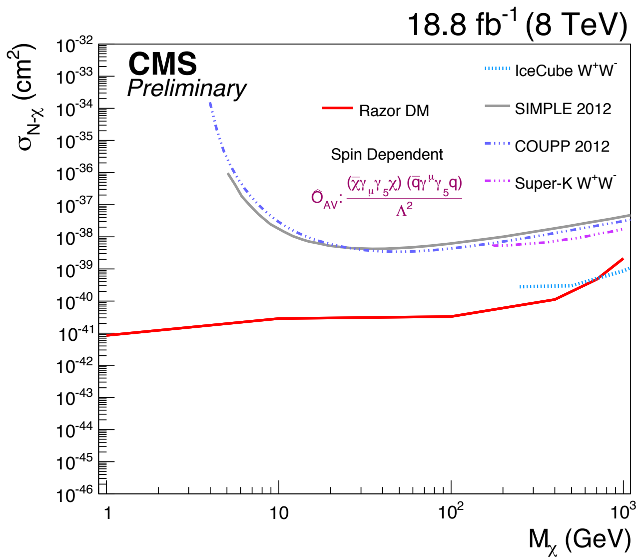


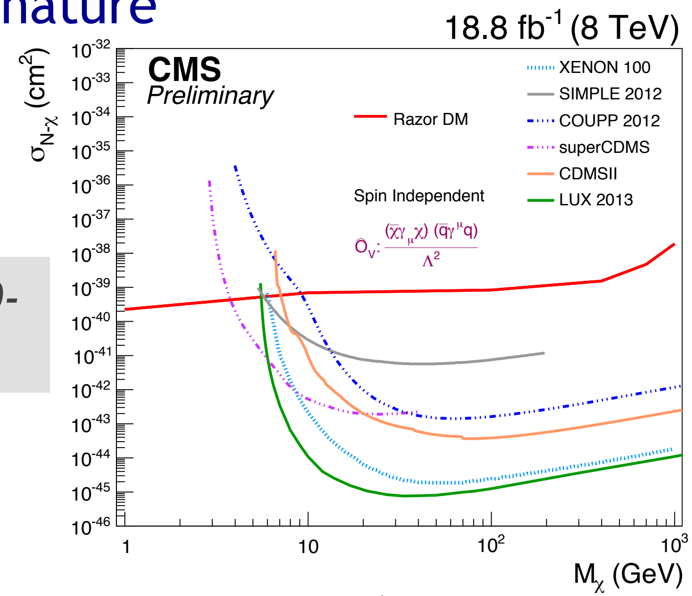


CMS-EXO-12-054

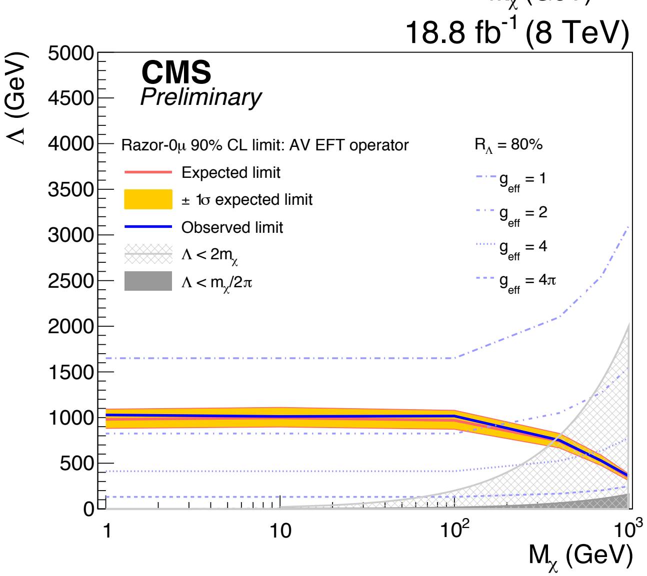
Dark Matter Searches

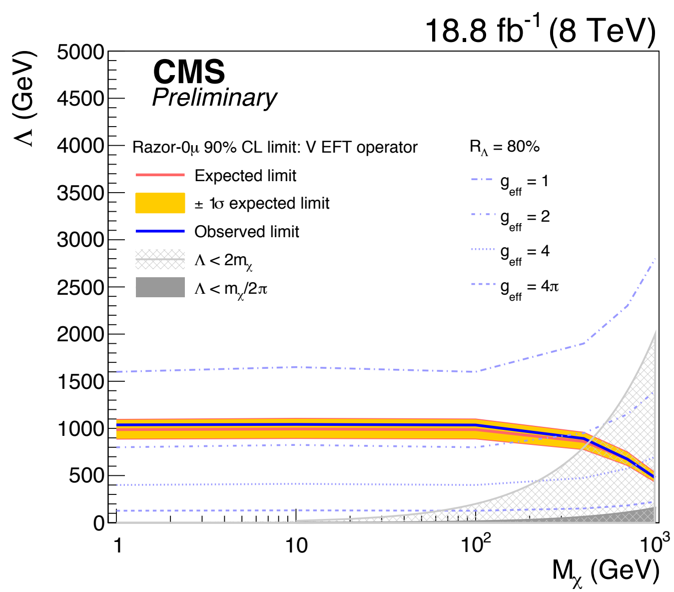
Recent razor analysis of dijet + E_T^{miss} signature





CMS-EXO-14-004





R_Λ quantifies fraction of events for which EFT hypothesis is still valid

$$g_{eff} = \sqrt{g_q g_x}$$

Long-lived Particle Signatures

Long-lived particles are predicted in many BSM scenarios

SUSY: GMSB, AMSB, split SUSY, RPV SUSY

Hidden valley scenarios

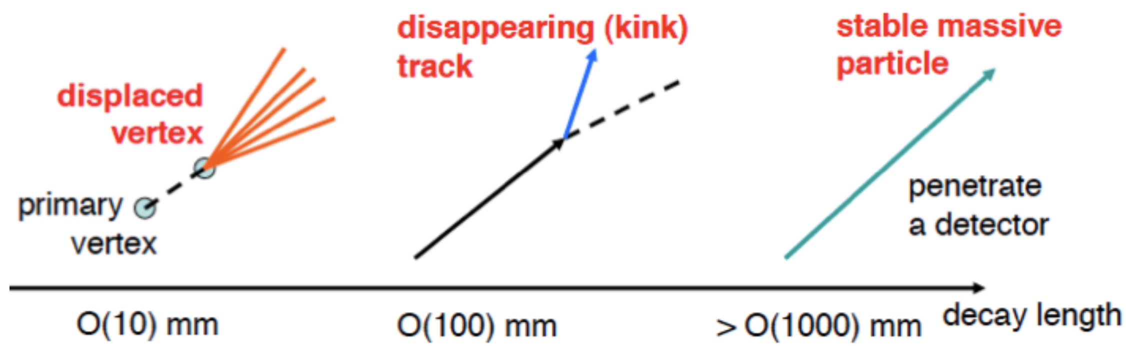
Signatures:

Displaced objects

Delayed objects

Disappearing or kinked tracks

Lepton jets



Recent examples of searches:

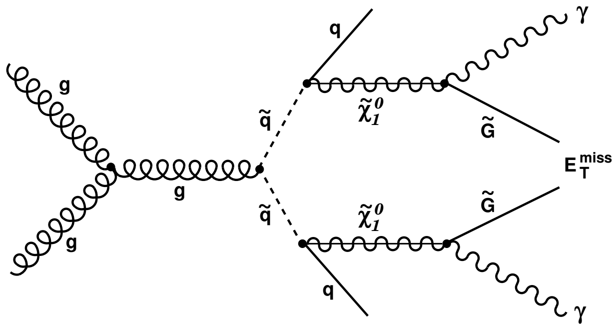
Neutral particles decaying to photons (CMS-EXO-14-017)

Neutral particles decaying to muons (CMS-EXO-14-012)

Heavy stable charged particles (CMS-EXO-13-006)

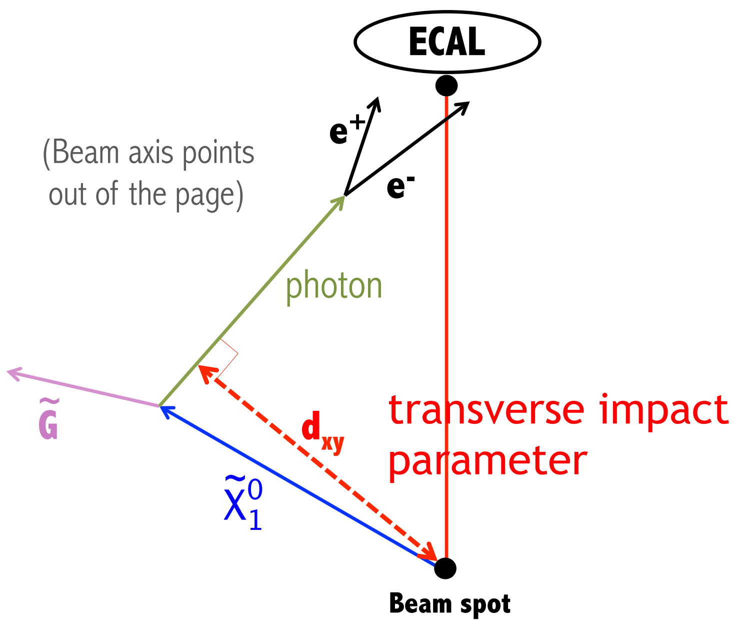
Long-lived Neutral Particles Decaying to Photons

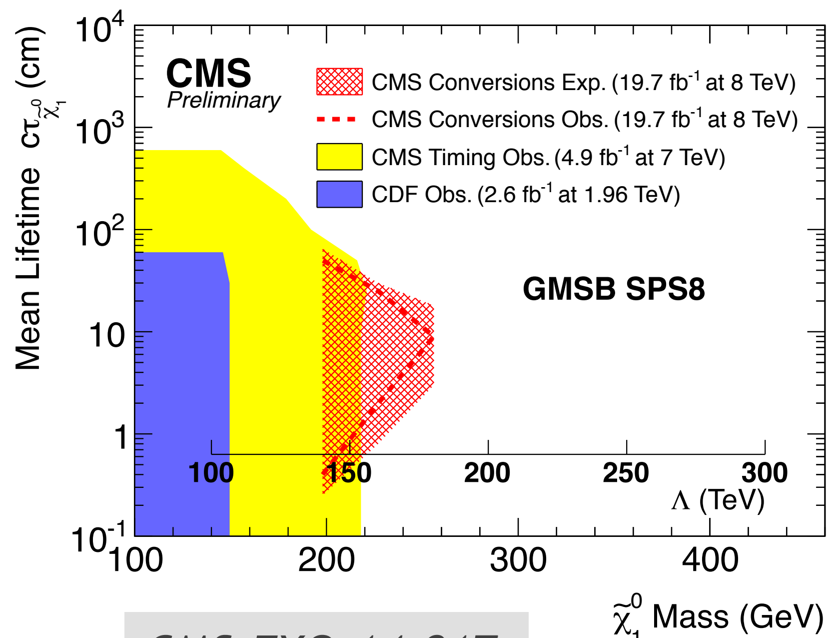
Model with GMSB: long-lived lightest neutralino decays to gravitino and photon



Event selection: 2γ, with one converting to e^+e^-, at least 2 jets, and E_T^{miss}

Scenario: 0.4 cm ≤ cτ ≤ 100 cm





CMS-EXO-14-017

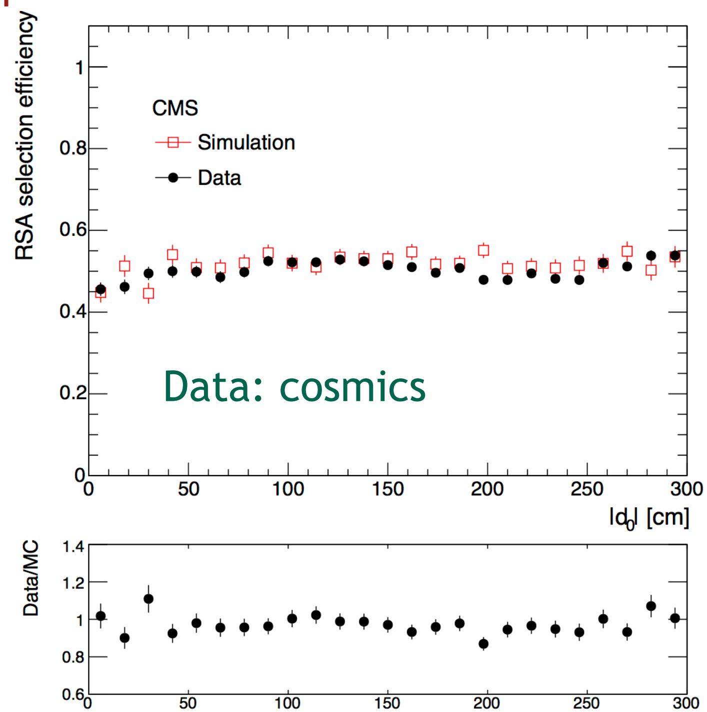
Long-lived Neutral Particles Decaying to Muons

Topology: Two muons originating from displaced secondary vertex, detected in muon chambers only

Limits derived for two specific models:

1) H^0 -> XX -> 4μ (H^0 … non-SM Higgs boson, X … long-lived boson with spin 0)
2) 2 squark pairs, with $\tilde{q}$ -> $q\tilde{\chi}^0$, long-lived $\tilde{\chi}^0$ -> μμν (R-parity violated)

μ reconstruction and selection efficiency



d⁰: transverse impact parameter

CMS-EXO-14-012

Signal systematic errors

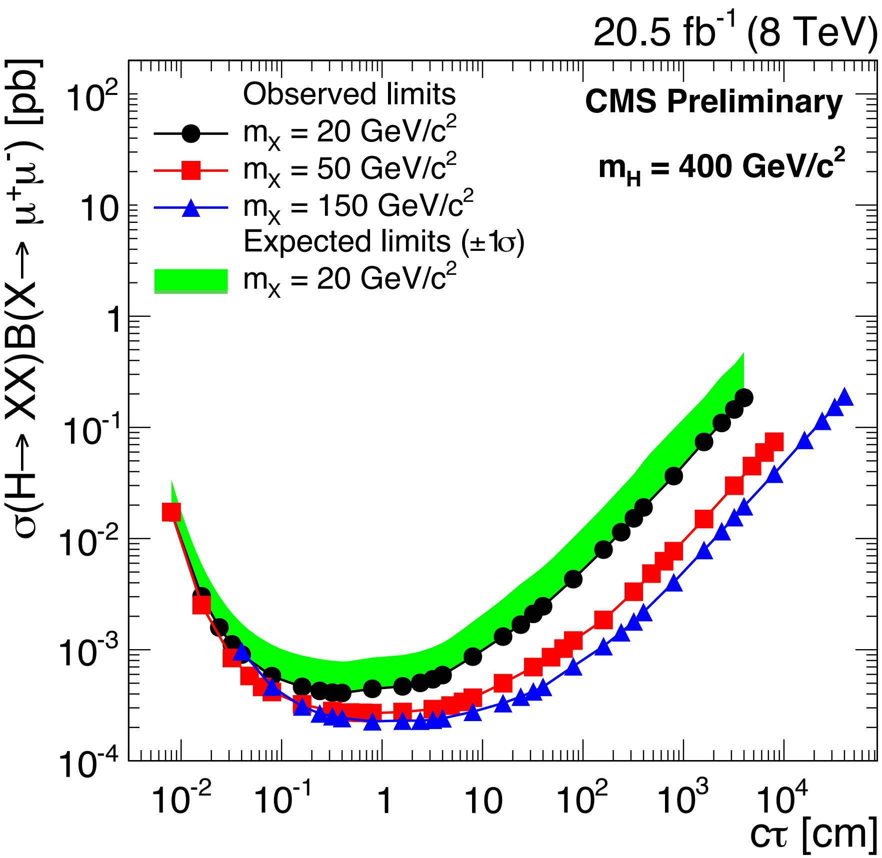
Source	Uncertainty
Pileup modelling	2%
Tracking efficiency from cosmics	3%
Trigger efficiency	15%
Parton distribution functions	$< 1\%$
Renormalisation and factorisation scales	$< 0.5\%$
NLO effects	$5-7\%$

This analysis is orthogonal to a previous one that used only the tracker (arXiv: 1411.6977) – the two analyses have been combined to improve limits

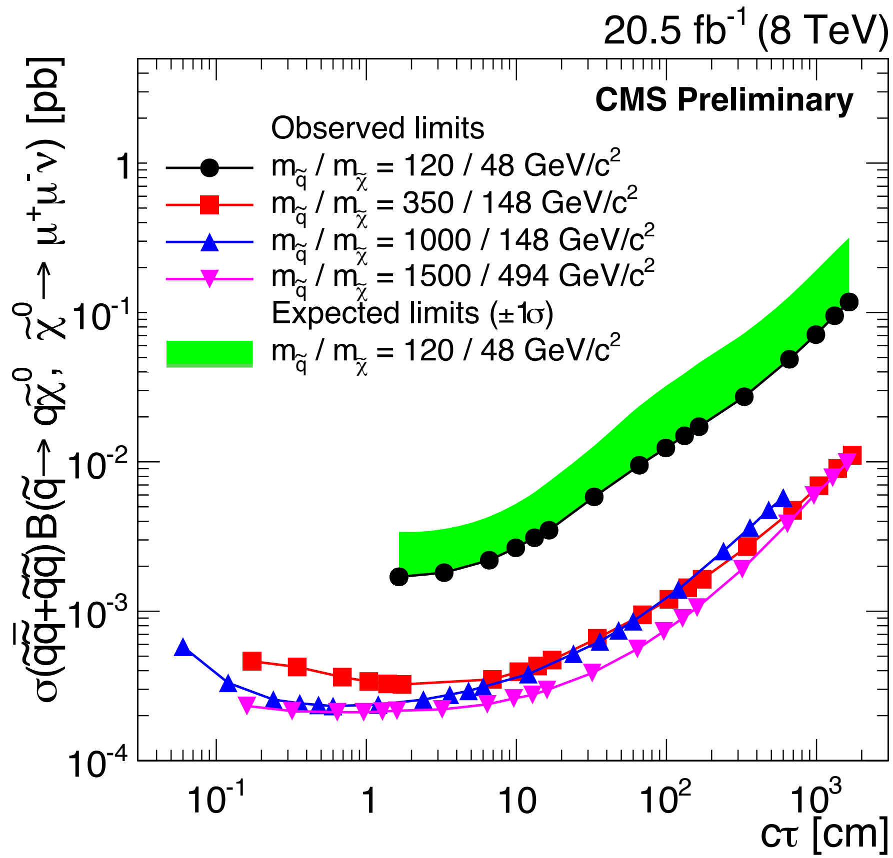
Long-lived Neutral Particles Decaying to Muons

Combined 95% CL upper limits for muon chamber and tracker analyses

$H^0 \to XX \to 4\mu$



$\tilde{q} \to q\tilde{\chi}^0,\ \tilde{\chi}^0 \to \mu\mu\nu$

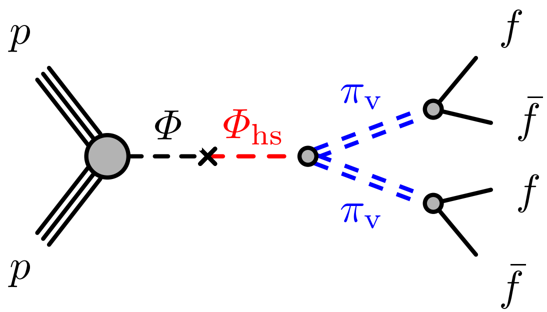


Displaced Jets

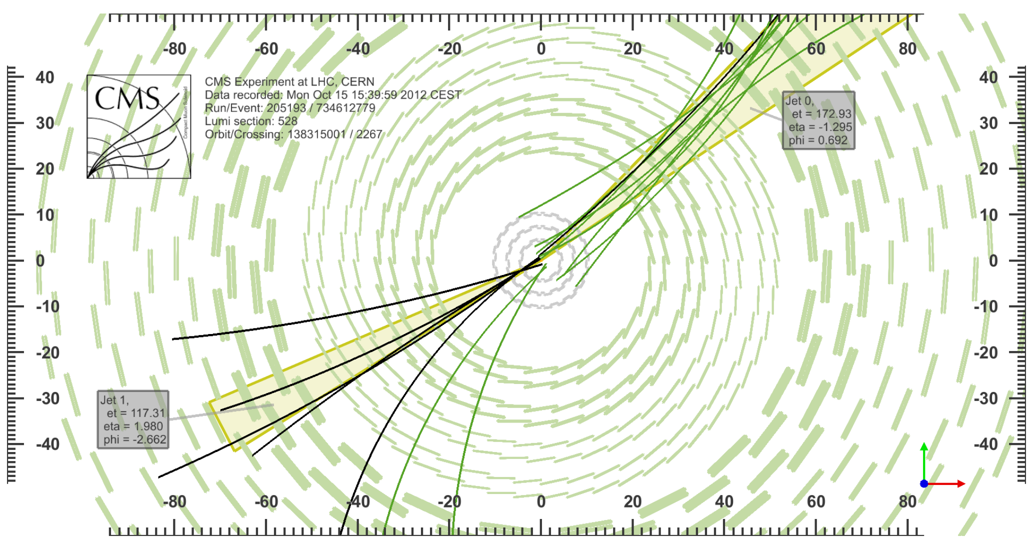
Hidden valley benchmark model: $H/\Phi \rightarrow \Phi_{hs} \rightarrow \pi_v \pi_v$ with $\pi_v \rightarrow jj/ll$

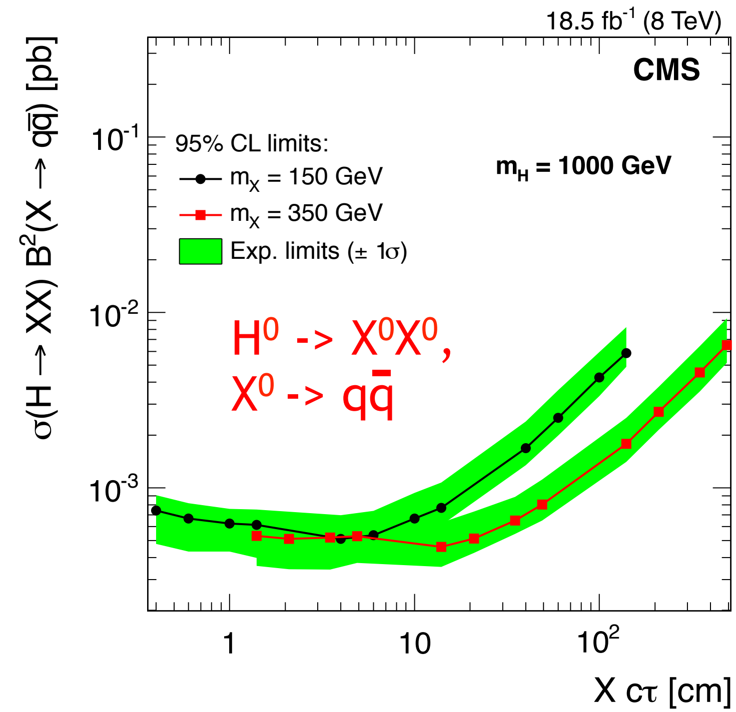
Decays of v-particles must occur via hidden sector mediator as they do not couple directly to SM particles.

Topology studied: 2 hadronic jets originating from same displaced vertex.



CMS-EXO-12-038, PRD 91 (2015) 012007



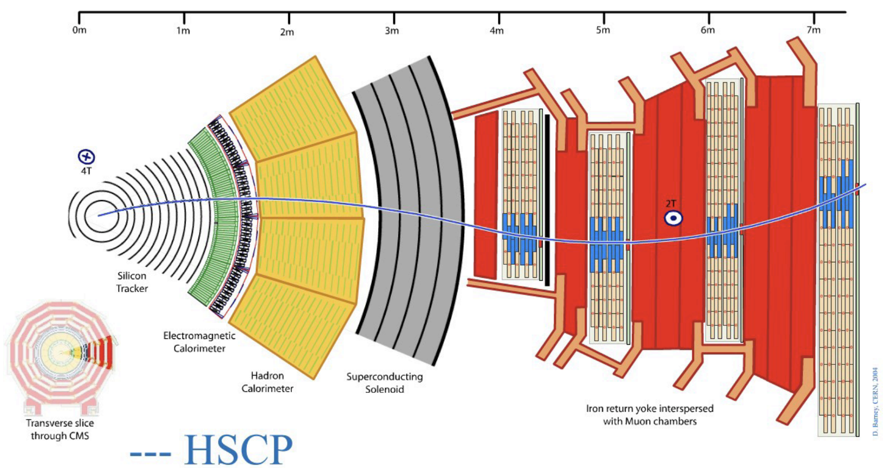


Long-lived Heavy Charged Particles

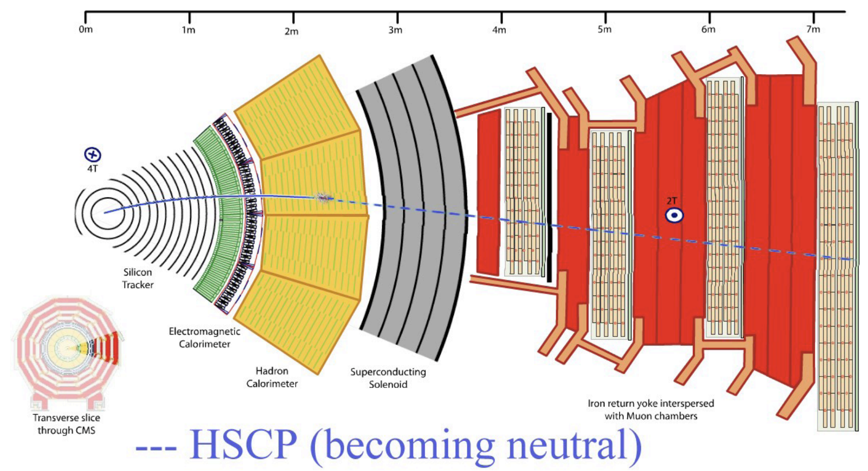
R-hadrons: long-lived gluinos could hadronize to e.g. $\tilde{g}$-g, $\tilde{g}$-q$\bar{q}$, $\tilde{g}$-qqq states

Stable chargino or stau, etc.

If mass greater than about 100 GeV: β < 0.9.
Nuclear interactions may lead to charge exchange.



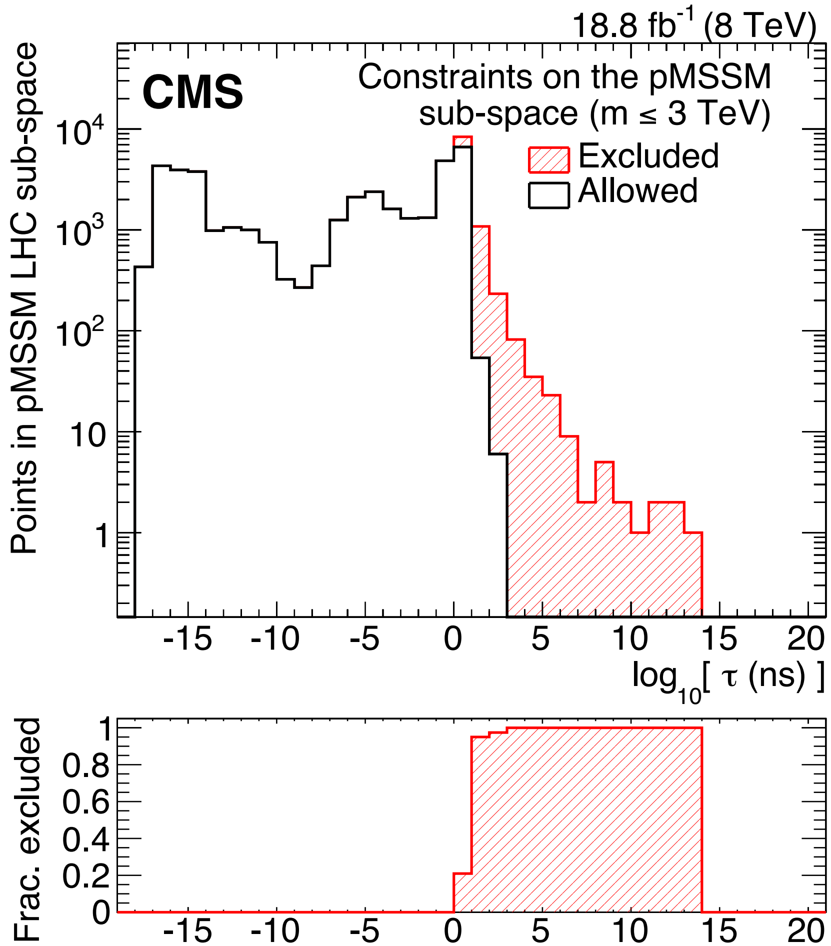
Tracker (high dE/dx) + μ system (long TOF)



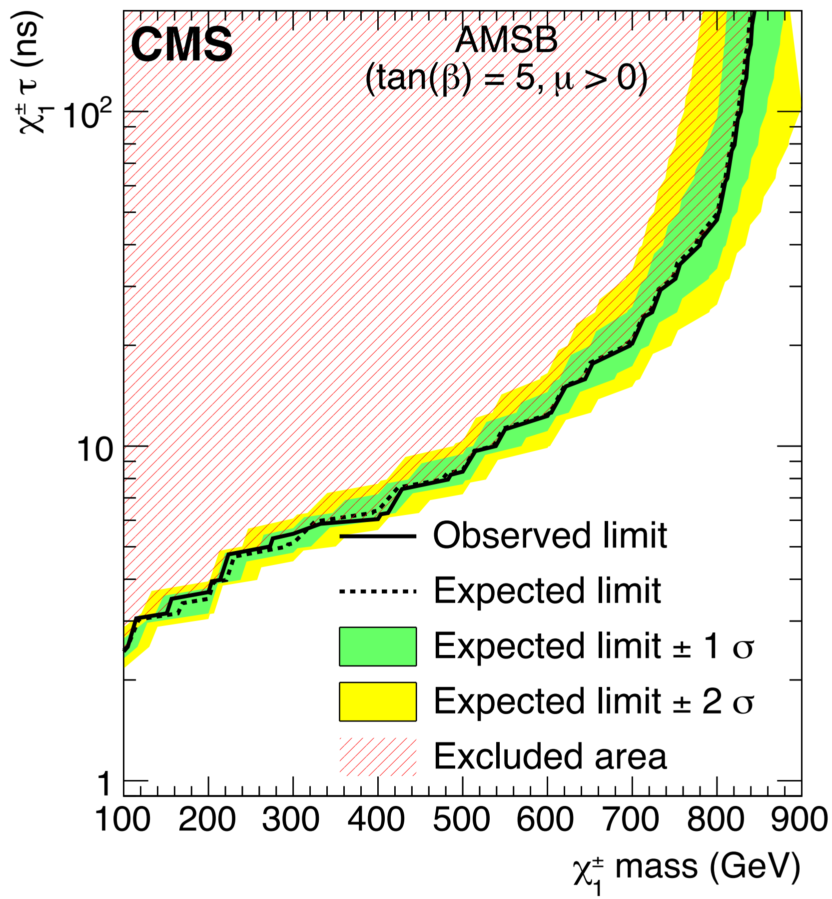
Tracker only (charge exchange)

Long-lived Heavy Charged Particles

Reinterpretation of previous results on long-lived chargino production [JHEP 07 (2013) 122] in context of pMSSM (first constraints at the LHC) and AMSB models, based on highly-ionizing and penetrating particles



CMS-EXO-13-006

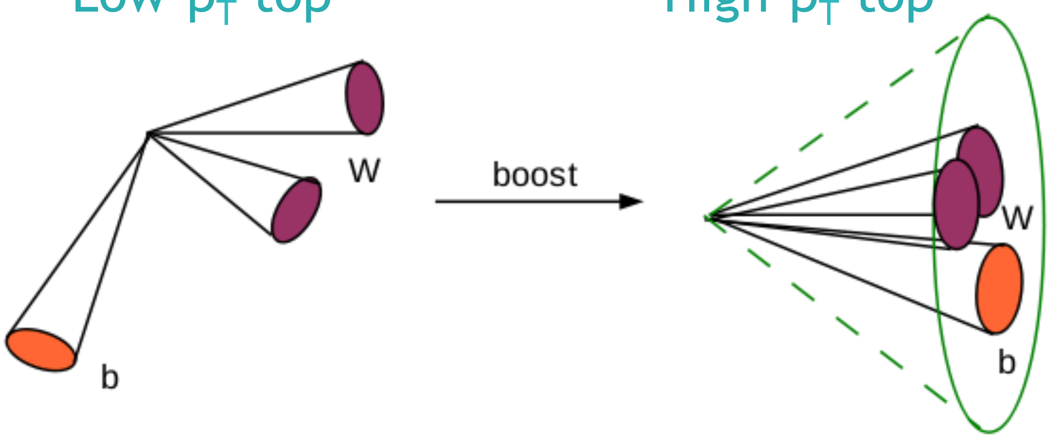


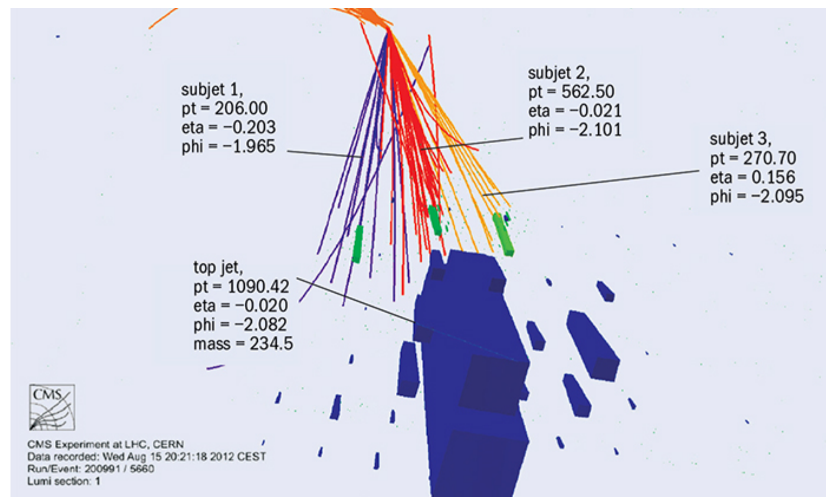
Boosted Objects

Massive final-state particles (m_X > 1 TeV mass) with high Lorentz boost (γ > 2)
- overlapping jets
- jet substructure
- non-isolated leptons

New analysis techniques to improve high-mass sensitivity (up to factor ~10)
- grooming (remove noise and pile-up)
- pruning (remove soft, large-angle particles from jets)
- tagging (b, t, W/Z, …)
- subjettiness, mass-drop

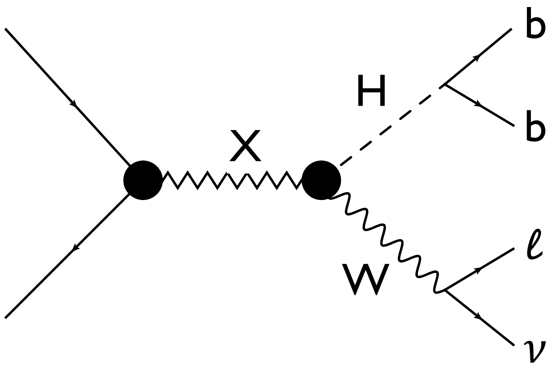
Low-p_T top High-p_T top





Boosted Objects: X -> WH

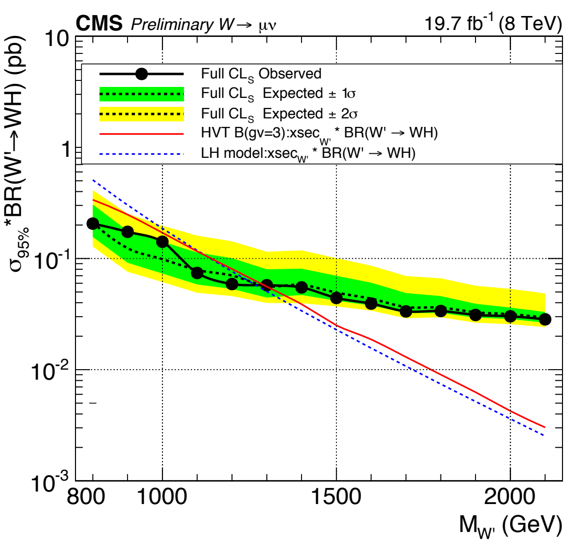
First search in semi-leptonic WH final state

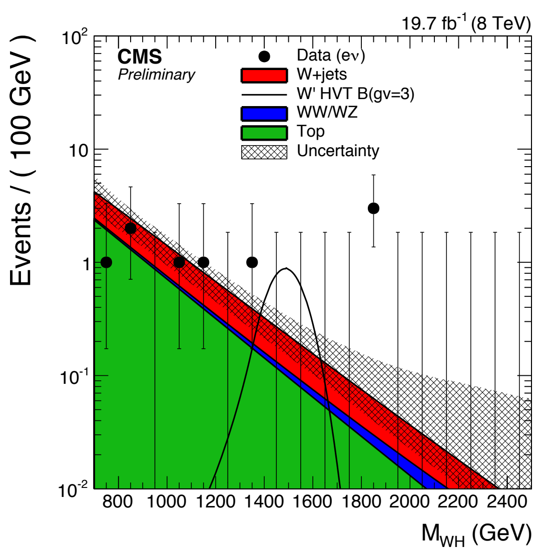


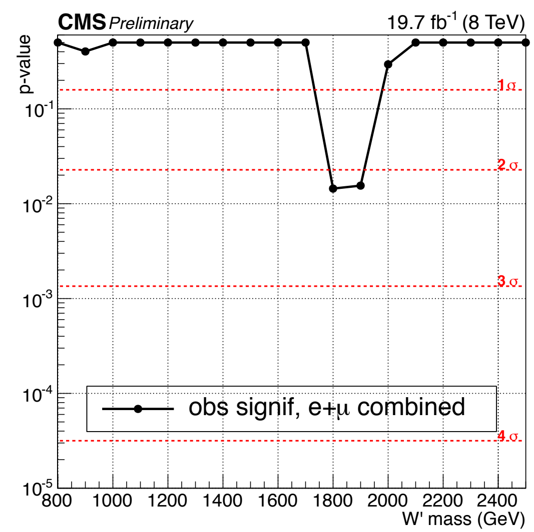
Search strategy close to one for high-mass WW resonances in lνq$\bar{q}$ final state, with additional b-tag requirements

Main backgrounds: W+jets, WW/WZ, t$\bar{t}$

CMS-EXO-14-010

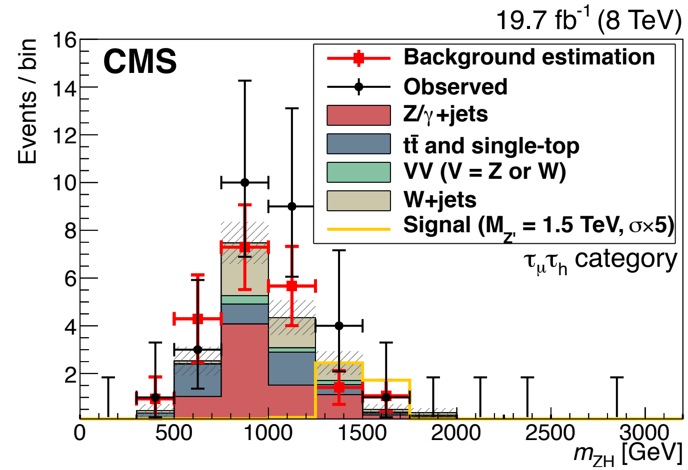


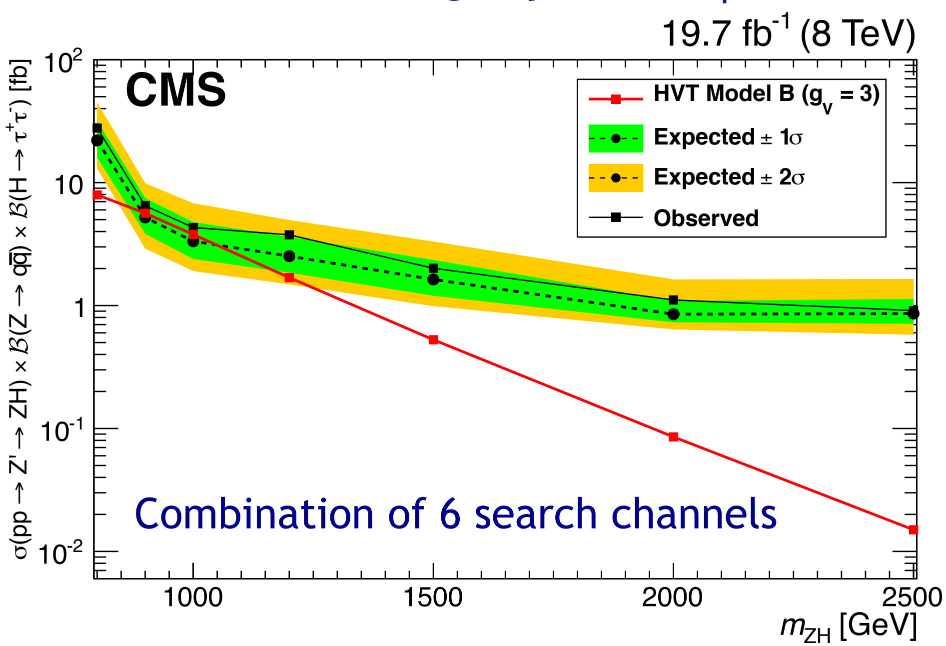


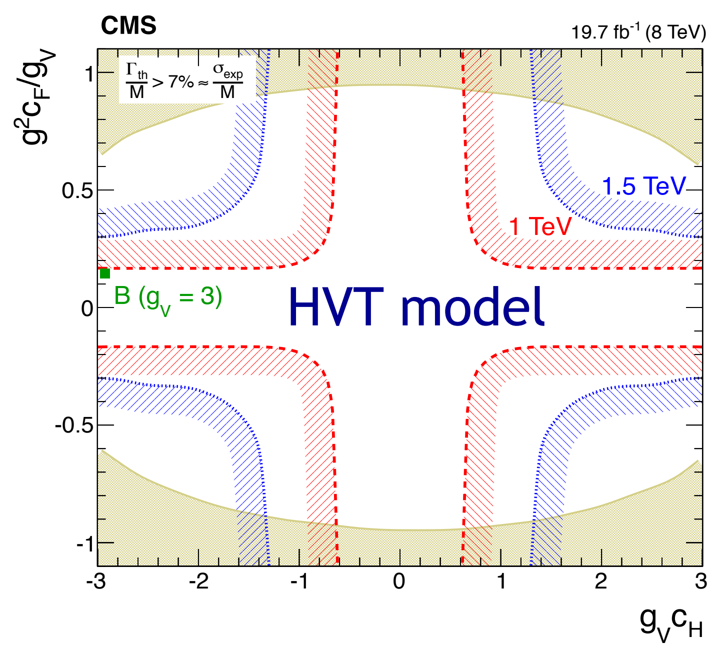


Boosted Objects: X -> ZH -> qqττ

Novel analysis feature: τ pair in boosted regime
Six search channels: leptonic($\tau_e\tau_e$, $\tau_e\tau_\mu$, $\tau_\mu\tau_\mu$), semi-leptonic($\tau_e\tau_h$, $\tau_\mu\tau_h$), all-hadronic ($\tau_h\tau_h$)
Different backgrounds according to search channels : Z/γ+jets for leptonic channels, for $\tau_e\tau_h$, $\tau_\mu\tau_h$ $t\bar{t}$ and W+jets, for $\tau_h\tau_h$ QCD
Event selection: single jet or H_T

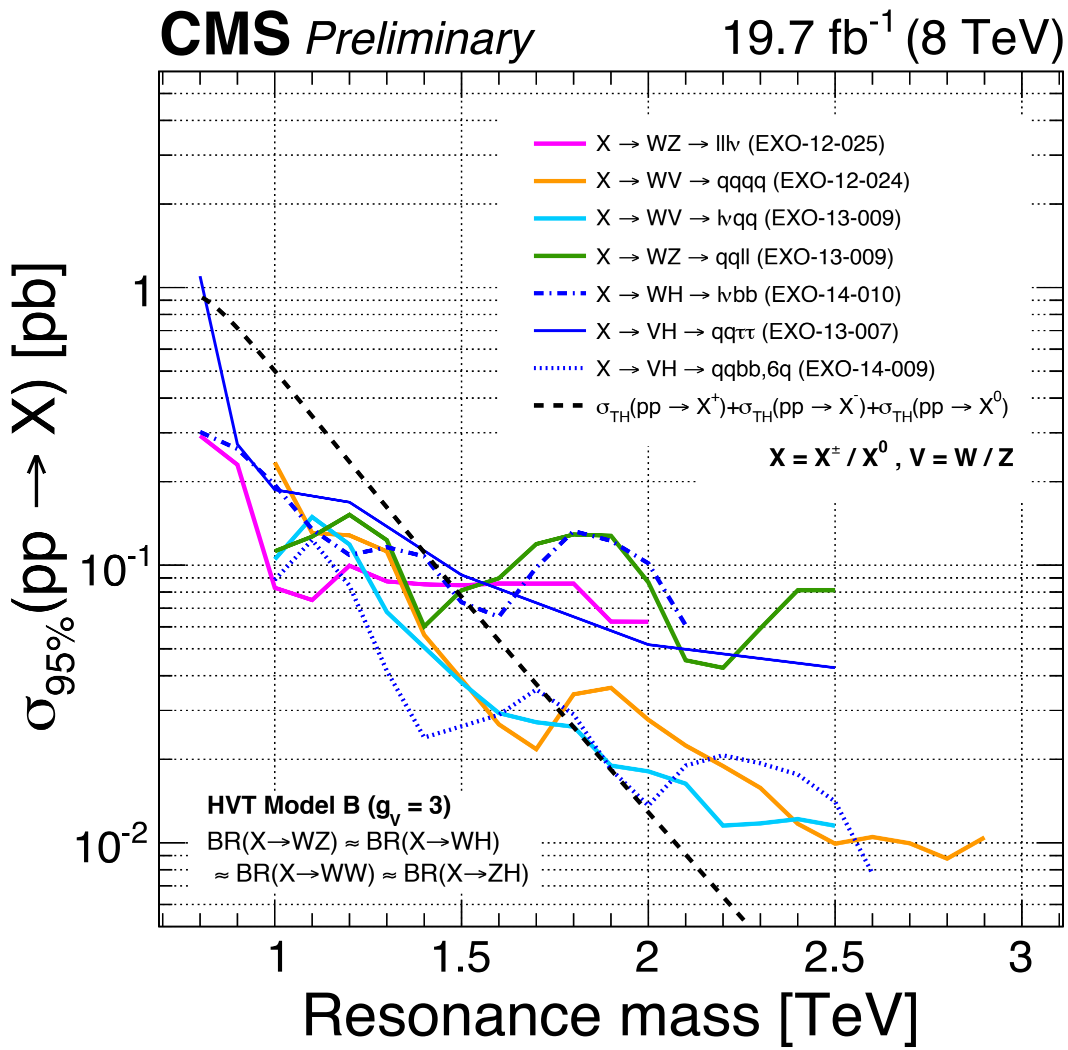




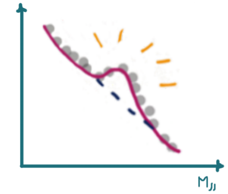


PLB 748 (2015) 255, CMS-EXO-13-007

Boosted Objects: X -> WH, VH, VV



Classic Narrow Resonance Searches



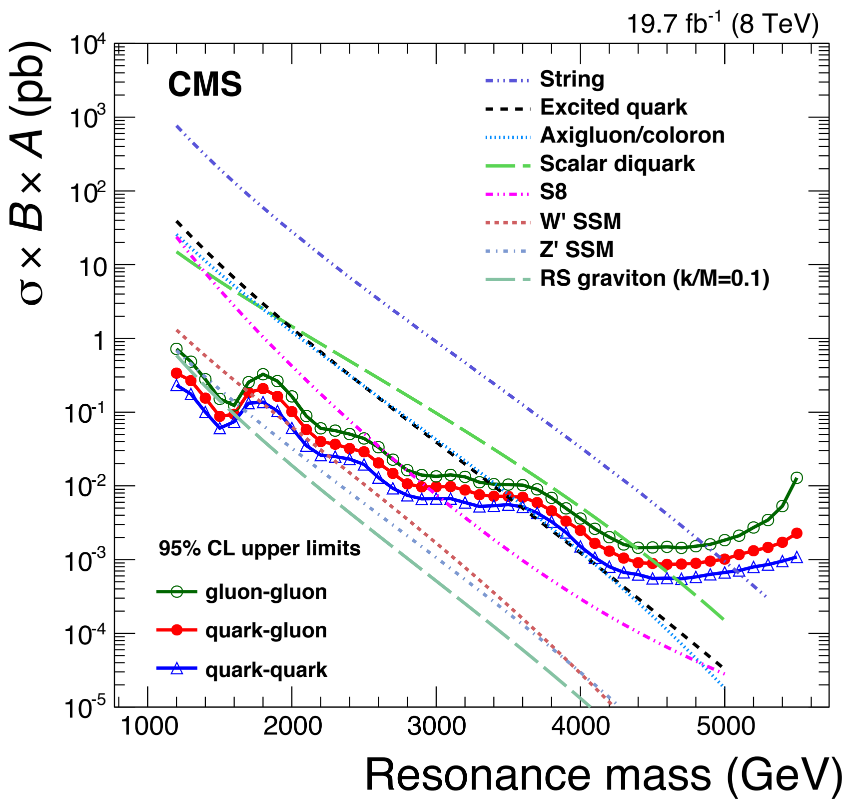
Example: Dijet spectrum

Background estimation: data-driven, parameterization by smooth function

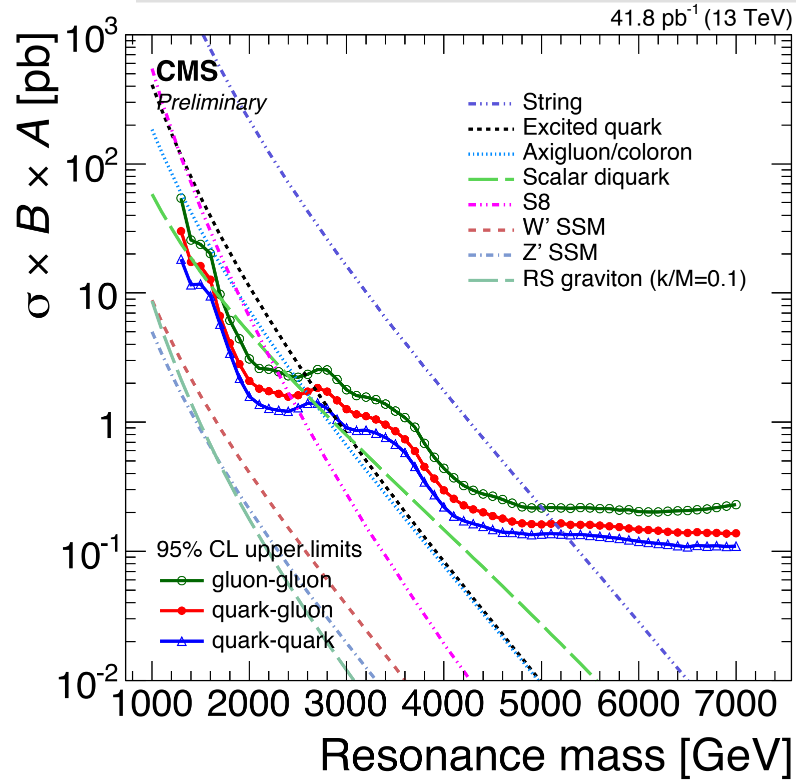
Interpretation possible for many exotica scenarios

Sensitive beyond the Run I reach for resonances with M > 5 TeV

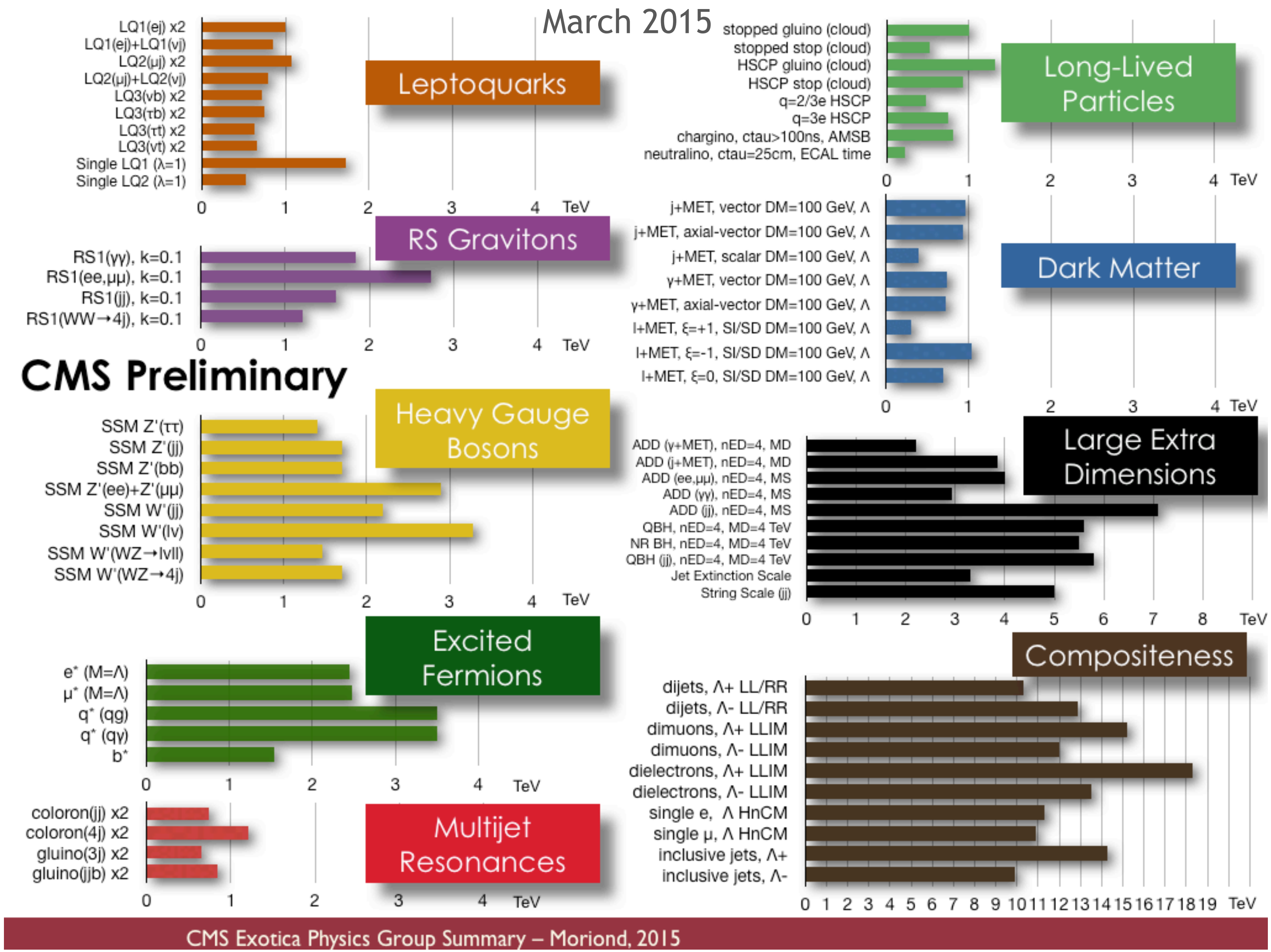
CMS-EXO-12-059, PRD 91 (2015) 052009



CMS-DP-2015-017, cds.cern.ch/record/2037378



Exotica Limits



Conclusions

- CMS has studied a plethora of Exotica signatures with $\sqrt{s}$ = 7 TeV and $\sqrt{s}$ = 8 TeV data and has derived limits for many scenarios.

- Interesting excesses have been seen – stay tuned for more results at $\sqrt{s}$ = 13 TeV !

- Sensitivity for New Physics is expected to grow fast during Run II.