CMS searches in 2010

Piotr Zalewski

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on behalf of the CMS Collaboration

CMS searches in 2010

outline

- Direct Search for New Physics
- After Paris (~0.2/pb) before Moriond (~40/pb)
  - All hadronic (SUSY in Jets + MET @ 35/pb)
  - All hadronic (compositeness & dijet resonances @ 2.9/pb)
  - W' in electron + MET (36/pb)
  - Microscopic Black Holes (35/pb)
  - Leptoquarks (2 leptons + 2 jets @ 33-34/pb)
  - Stopped Gluinos (10/pb)
- Conclusions

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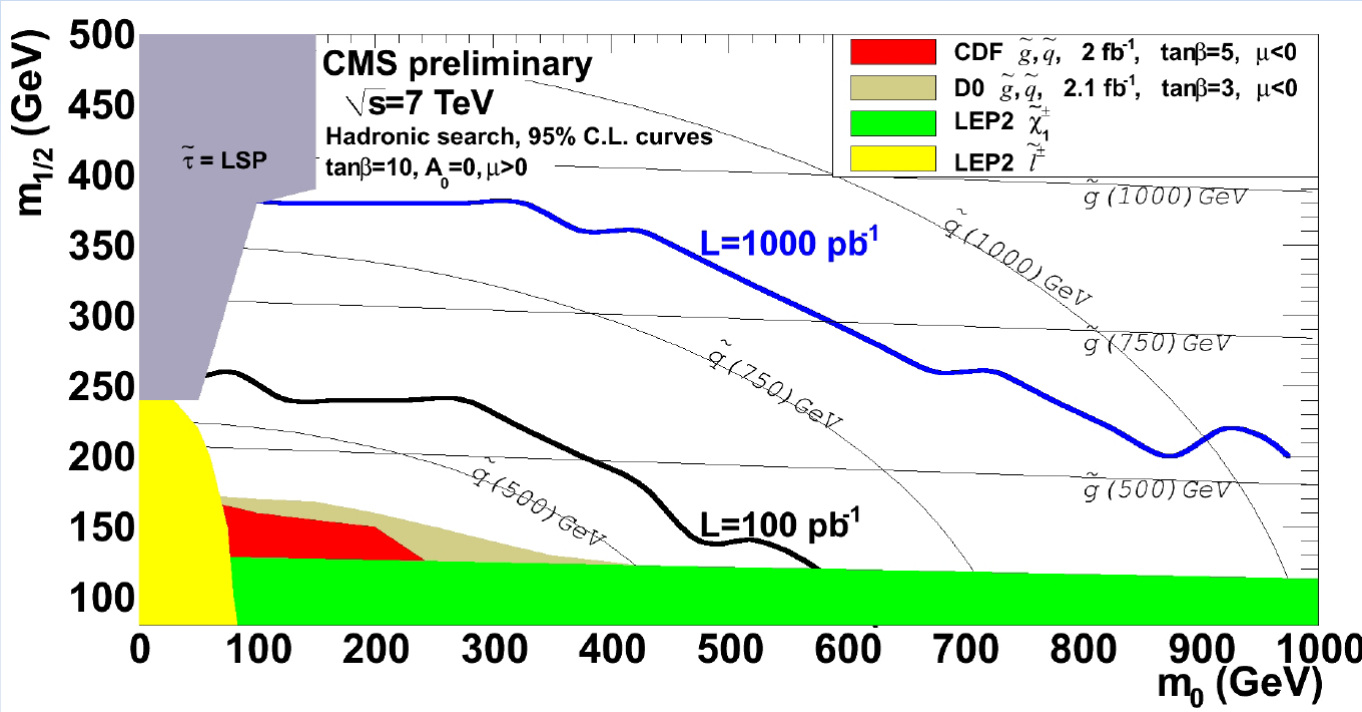
Direct Search for New Physics

Direct search for New (Beyond SM) Physics, together with the search for SM Higgs boson, are the main scientific goals of the CMS [1]*. We look for heavy objects that could be visible in proton-proton collisions in many different final states. All search topologies are based on hard (high transverse energy E_T) jets, leptons, photons and/or large missing transverse energy (MET, E_t^{miss}).

One of the most elaborated frameworks for New Physics is mSUGRA scenario, for which we were not yet sensitive at Paris.

Early data were used for the first data driven background estimates at 7 TeV [3] and performance evaluations on data [4].



mSUGRA "all hadronic" reach with 100/pb and 1/fb [2]

A bulk of results with full 2010 statistics is being prepared for Moriond.

In this talk I will present already published or submitted to publication post-ICHEP2010 results.

* References to the CMS publications are listed in the last slide.

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Search for Supersymmetry in the Jets and MET Final State (all hadronic) [5]

Dominant production channels at the LHC are squark-squark, squark-gluino and gluino-gluino.
Final states (R-parity conserved): several hadronic jets and large missing transverse energy due to escaping neutralinos (LSP).

Analysis design to be robust against energy mismeasurements. Backgrounds levels estimated using data.

(see → next slides)

The search is model independent, but the results are interpreted using CMSSM.

Sample	m_0 (GeV/c^2)	$m_{1/2}$ (GeV/c^2)	A_0	$\tan\beta$	sign(μ)	σ LO (pb)	lightest $\tilde{q}$ (GeV/c^2)	χ_1^0 (GeV/c^2)
LM0	200	160	-400	10	+	110	207	60
LM1	60	250	0	10	+	16.1	410	97

Hadronic final state selection:

trigger: H_T > 150 GeV (scalar sum of jets E_T)

offline jets: anti k_T algorithm with $R = 0.5$;
p_T and η dependent corrections (JES 3-5%);
$E_T^{jet} > 50$ GeV; $|\eta^{jet}| < 3$; $|\eta^{leading\ jet}| < 2.5$;
E_T (2 leading jets) > 100 GeV

Events with
(i) "problematic" jets
(ii) isolated high p_T leptons or fotons
(iii) dead ECAL cells MET are VETOed.

H_T and H_T^{miss} : |vector sum| are calculated also offline
H_T^{miss} / E_T^{miss}(calo towers) < 1.25 to reject spurious MET due to omission of low E_T jets

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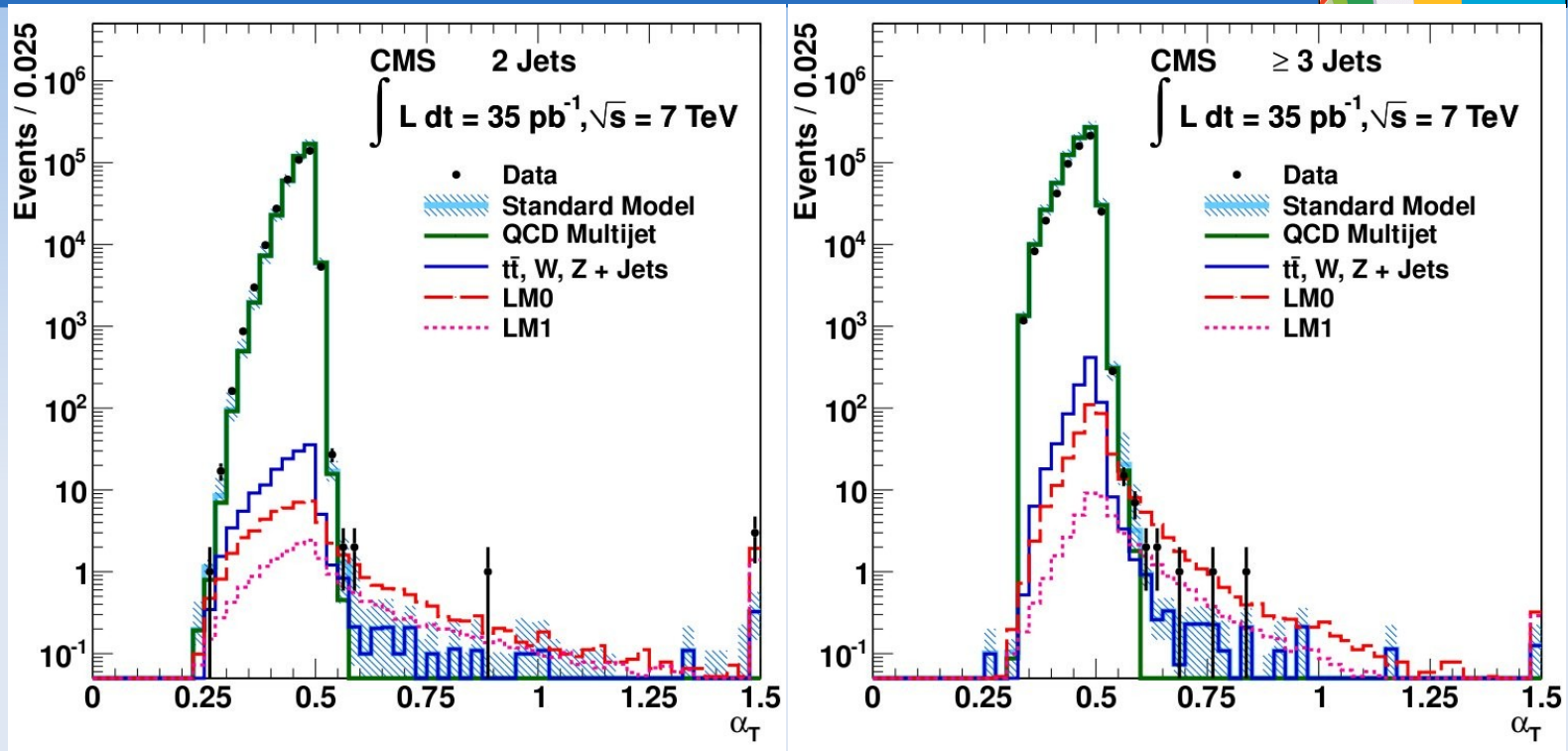
Search for Supersymmetry in the Jets and MET Final State (all hadronic)

Analysis design to be robust against energy mismeasurements.
Backgrounds levels estimated using data.

$$\alpha_T = E_T^{jet\,2} / M_T$$

M_T → transverse mass



For perfectly measured dijet α_T=0.5.
Jet mismeasurements diminish α_T, whereas genuine MET enlarges it (any deviation from back to back system do).

For greater number of jets pseudo dijet system is constructed with minimal E_T imbalance.

$\alpha_T > 0.55$ reduces QCD background by more than 4 orders of magnitude.
After final selection less than one QCD background event is expected.

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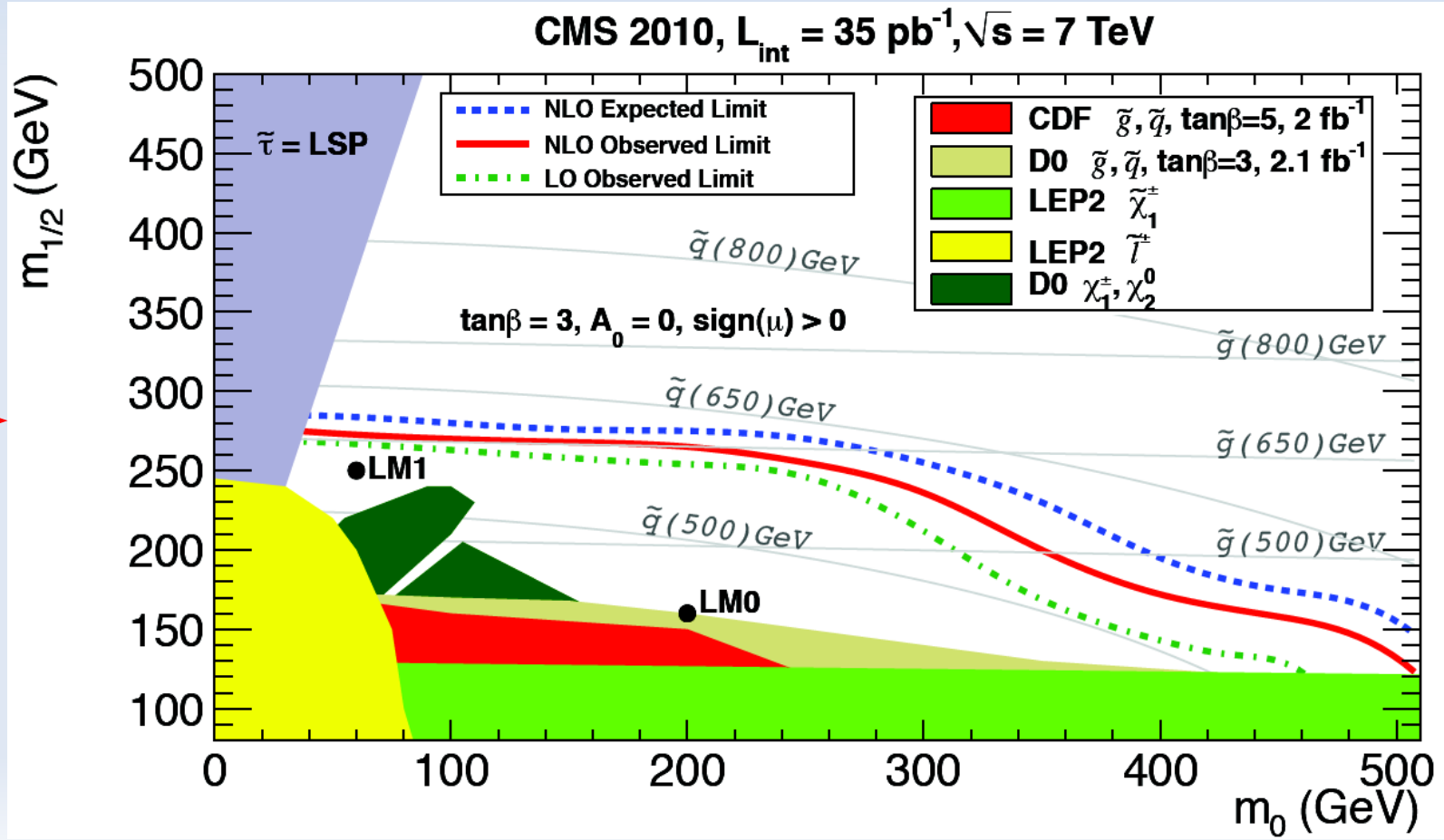
Search for Supersymmetry in the Jets and MET Final State (all hadronic)

The SM background in the signal region is estimated directly from data.
(1) Use of the control regions at lower H_T to estimate the total background.
(2) $W \rightarrow \mu\nu$ + jets and γ + jets for EW and ttbar backgrounds.

Analysis design to be robust against energy mismeasurements.
Backgrounds levels estimated using data.

95% CL exclusion contour at NLO in the CMSSM



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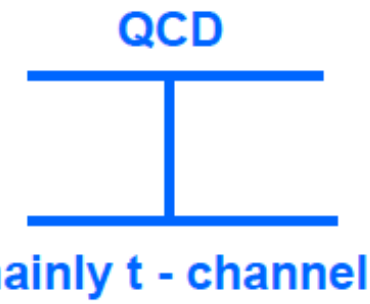
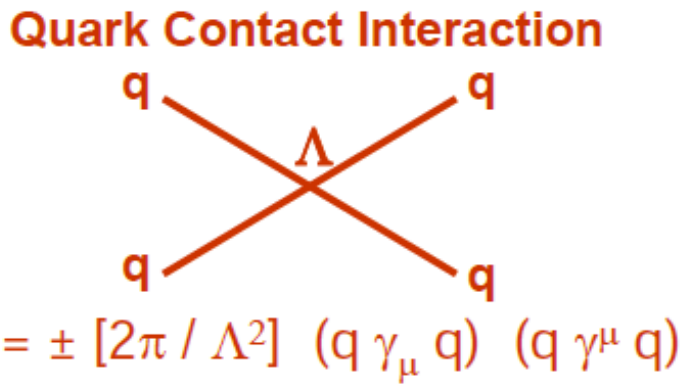
Search for Quark Compositeness with Dijet Centrality Ratio (all hadronic)

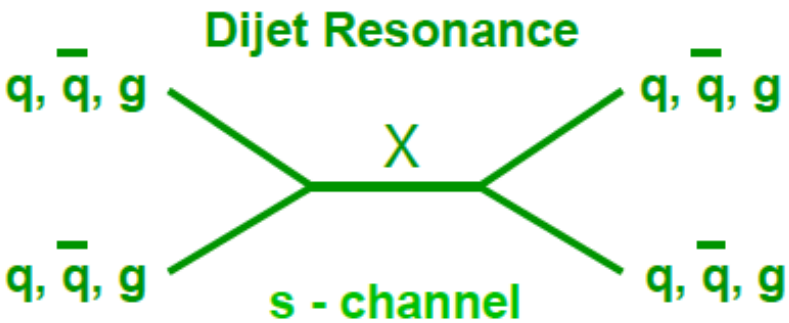
- Jets are produced predominantly by QCD processes
  - When we measure jets, we primarily study QCD.



- Signatures of new physics with jets
  - Contact interactions
    - e.g. from quark compositeness
    - Would produce in jet data
      - **Excess of events at high jet p_T.**
      - **Different angular distribution than QCD**



  - Dijet resonances
    - Excited quarks (q^*)
    - Z′ and Randall-Sundrum Gravitons
    - Many other models.



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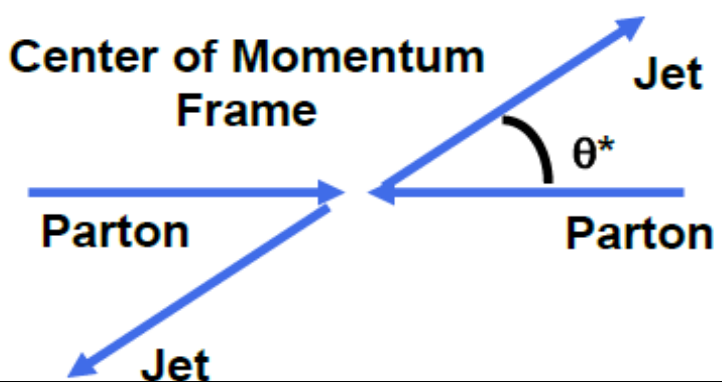
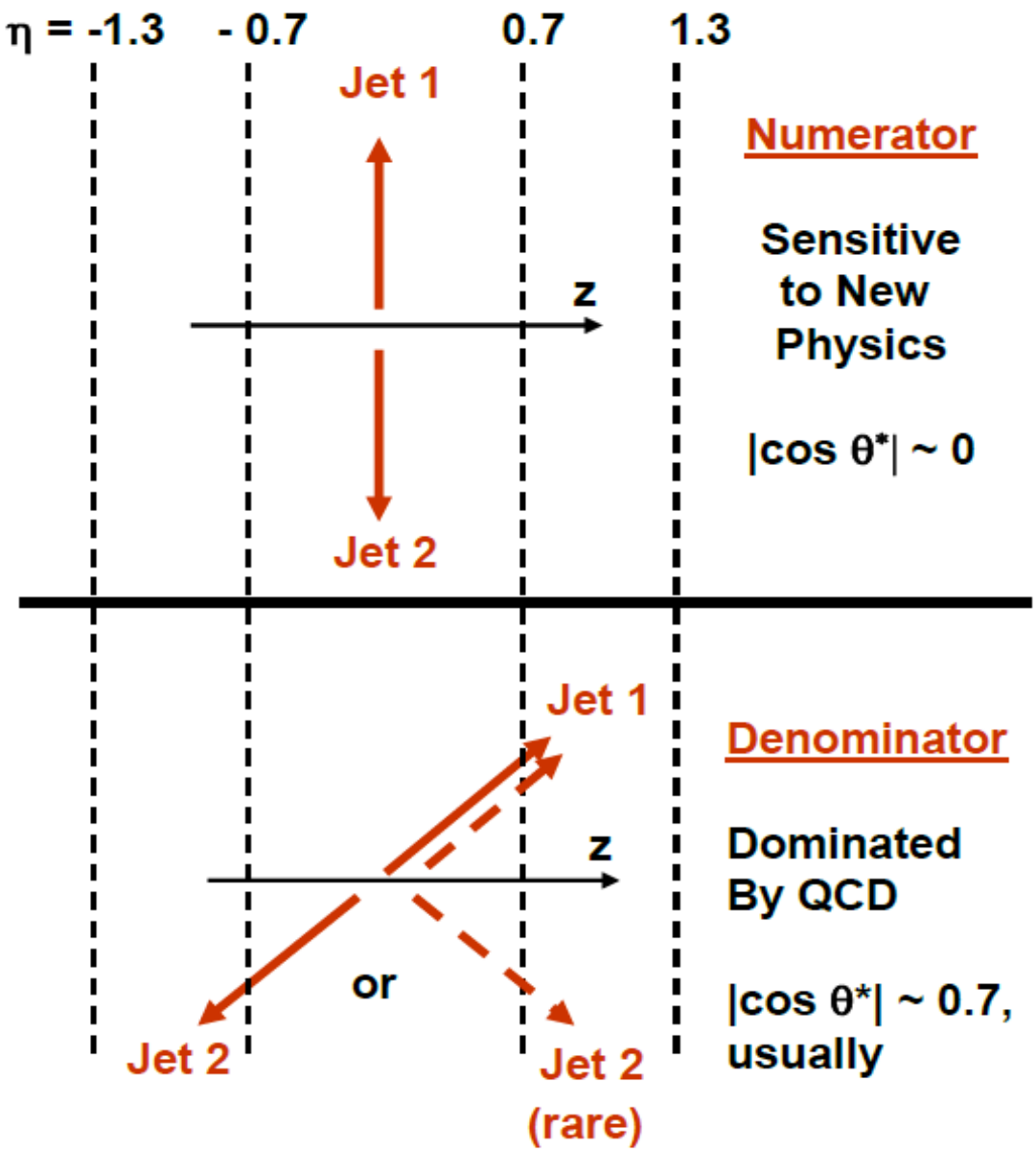
Search for Quark Compositeness with Dijet Centrality Ratio (all hadronic)

- **Dijet Centrality Ratio is sensitive to new physics**
  - Contact Interactions & Resonances
- **Dijet Centrality Ratio = R_η =**

  $N(|\eta|<0.7) / N(0.7<|\eta|<1.3)$
  - Number of events in which both leading jets have $|\eta|<0.7$, divided by the number in which both leading jets have $0.7<|\eta|<1.3$
  - Numerator is sensitive to new physics at low $|\cos\theta^*|$.
  - Denominator is dominated by QCD at high $|\cos\theta^*|$.





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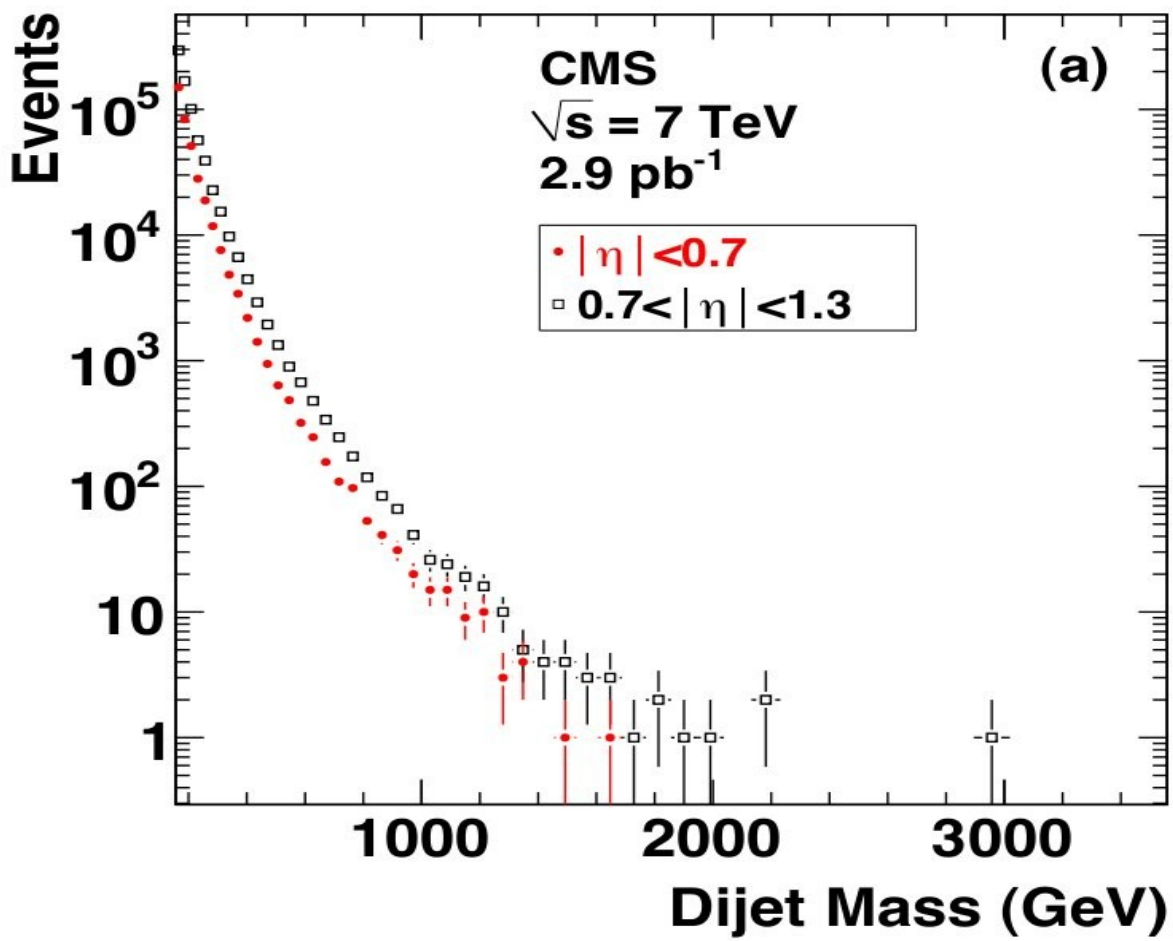
Search for Quark Compositeness with Dijet Centrality Ratio (all hadronic) [6]

Jets reconstructed with anti-k_T (R=0.7) algorithm. p_T- and η- dependent corrections applied.

$|\eta|<0.7$ – inner events
$0.7<|\eta|<1.3$ – outer events

Since many systematics effects cancel in the ratio, R_η provides an accurate test of QCD and, as a probe of the angular jet distribution, is sensitive to new physics → next page



Event counts corrected for trigger prescales

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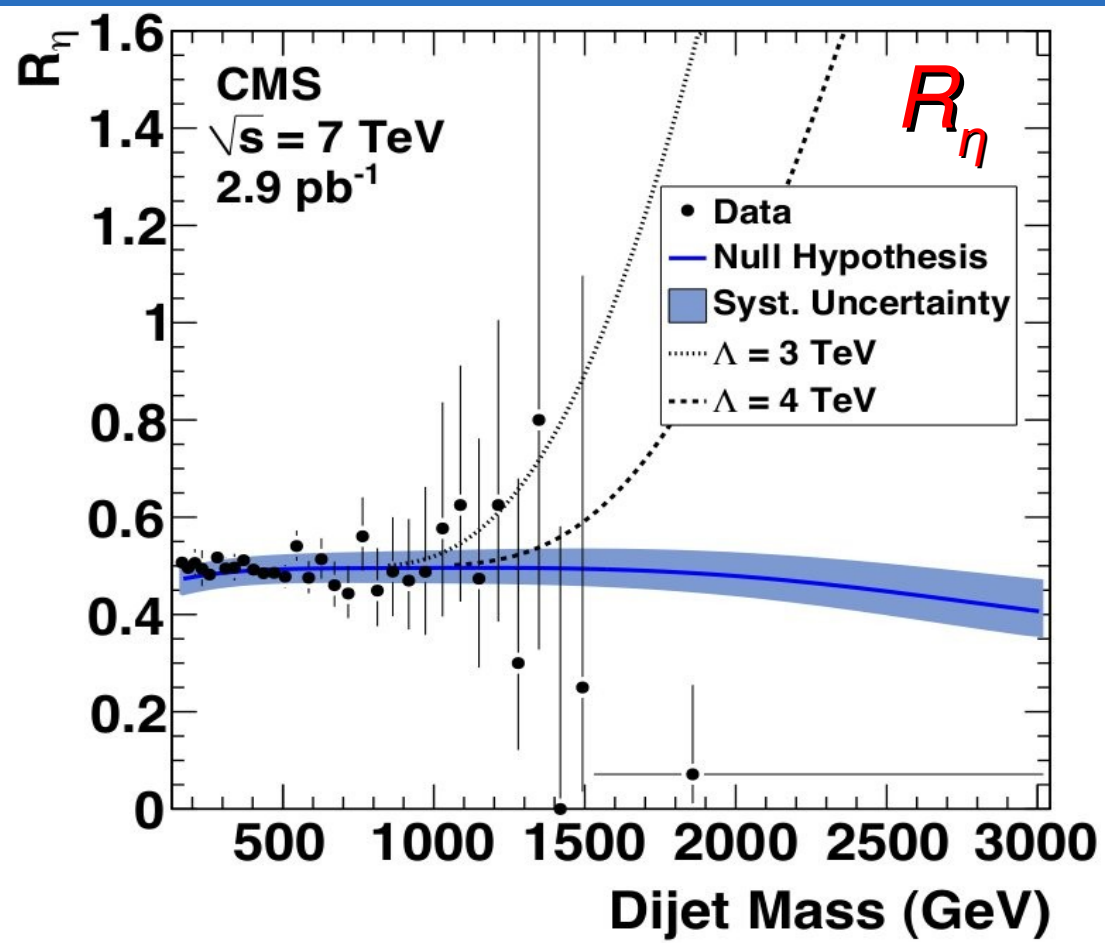
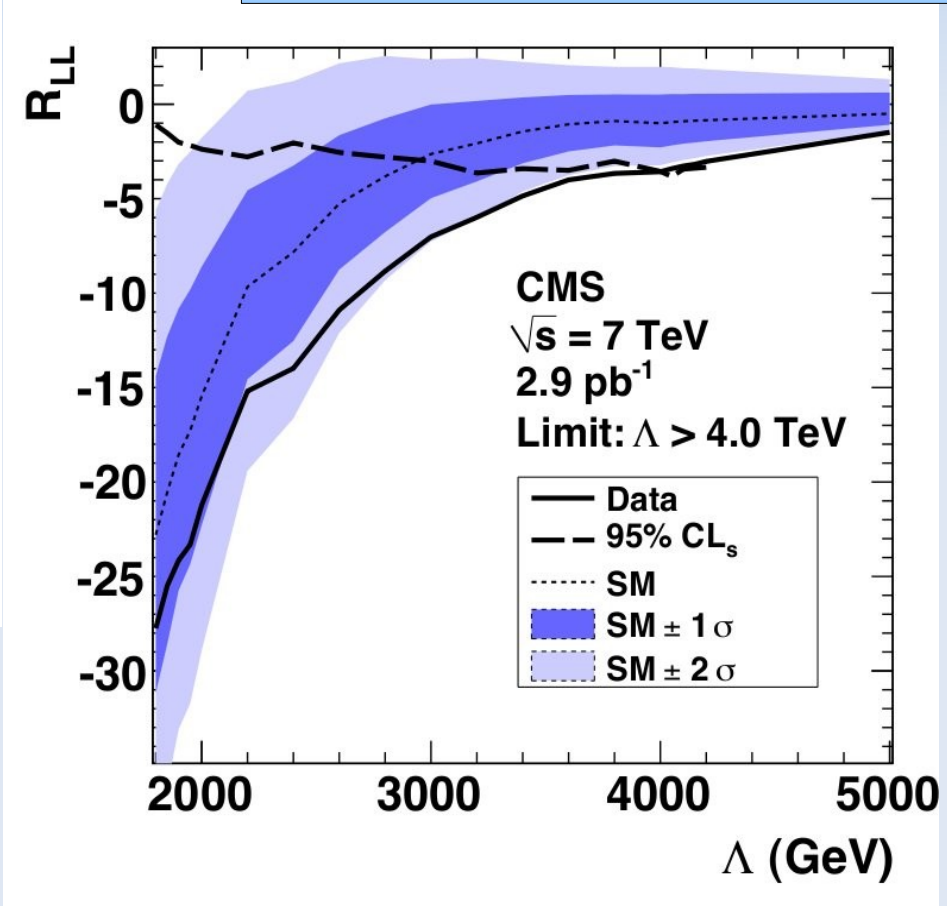
Search for Quark Compositeness with Dijet Centrality Ratio (all hadronic)



Exclusions for contact interaction
Expected: Λ < 2.9 TeV
Observed: Λ < 4.0 TeV

$$R_{LL} = \ln\mathcal{L}_{alt} - \ln\mathcal{L}_{QCD}$$



The observed centrality ratio compared to null (QCD) and Λ=3, 4 TeV hypotheses

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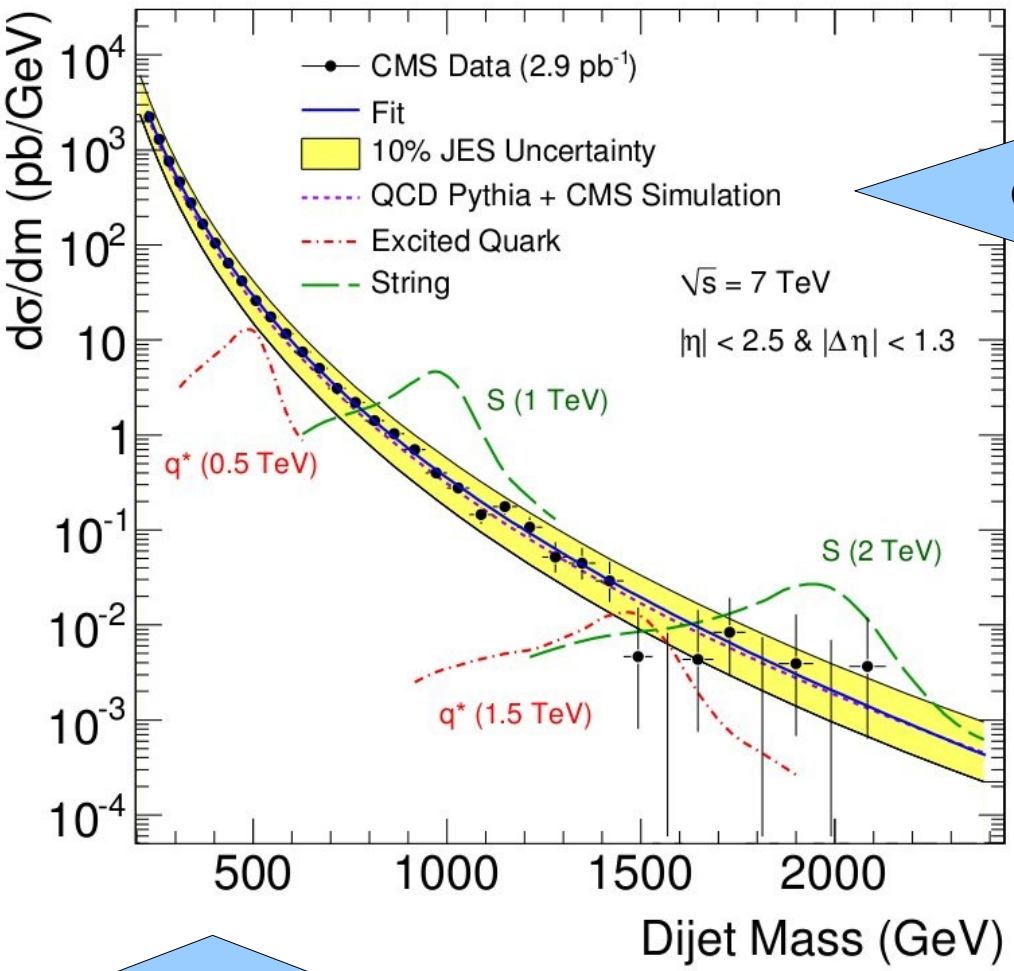
Search for Dijet Resonances (all hadronic) [7]

Dijet system: $|\Delta\eta|<1.3$ & $|\eta|<2.5$
dijet mass $m > 220$ GeV

dijet mass for pp → 2 leading jets +X

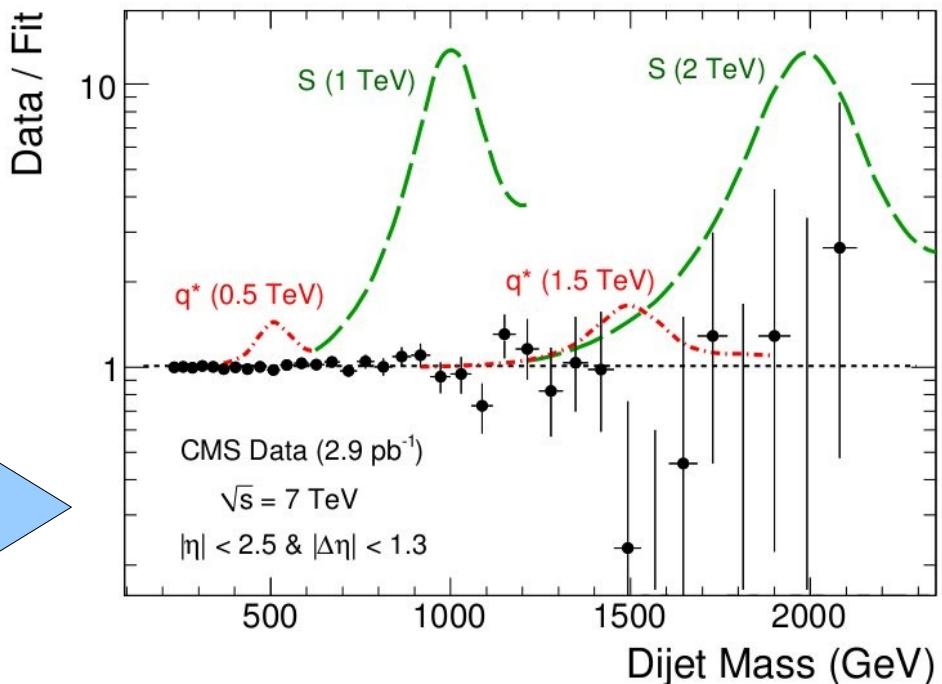


$$\frac{d\sigma}{dm} = \frac{P_0(1-m/\sqrt{s})^{P_1}}{(m/\sqrt{s})^{P_2+P_3\ln(m/\sqrt{s})}}$$

Fit with parameterization (used by CDF and ATLAS)

Signals and QCD shown separetely

Ratio: data/fit for QCD and signals + QCD



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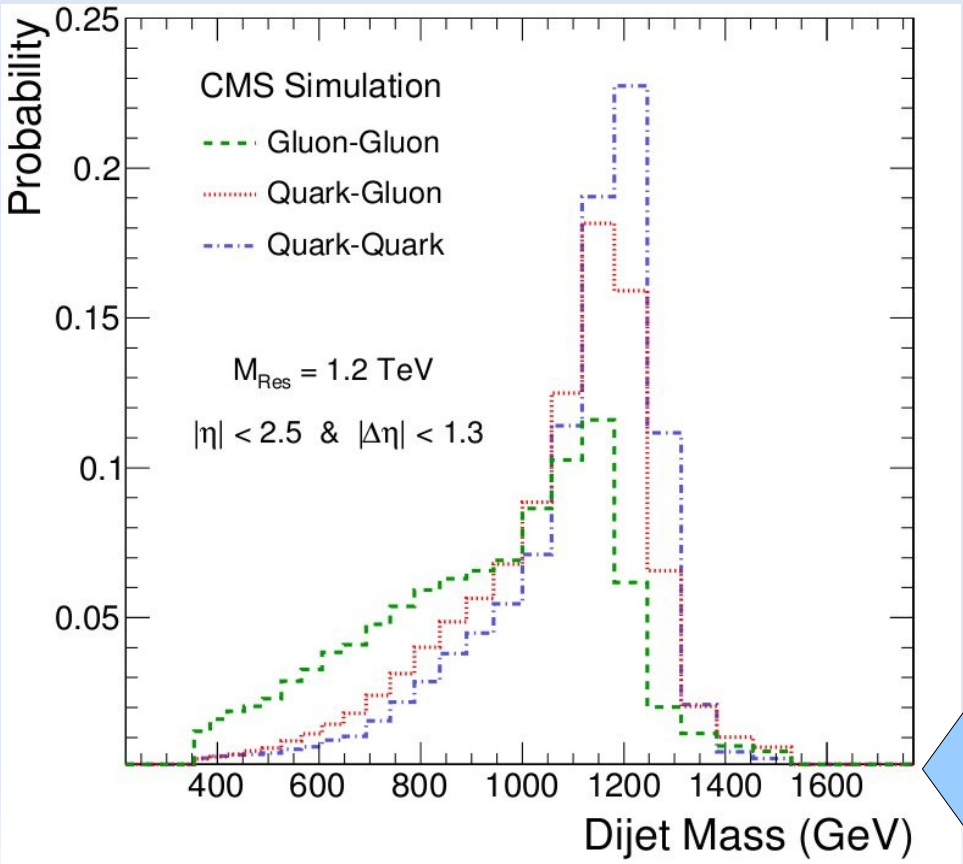
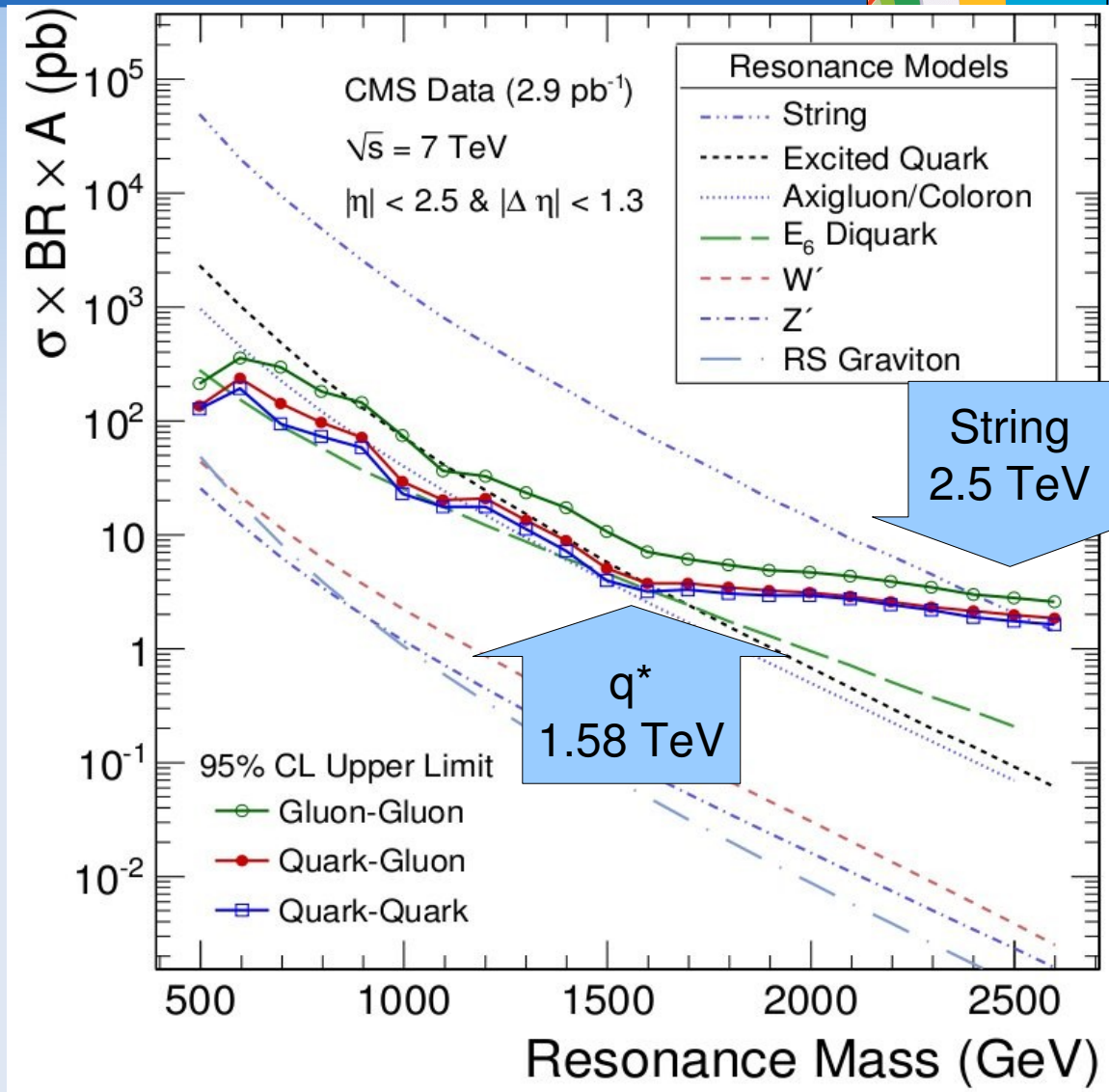
Search for Dijet Resonances
(all hadronic)

Exclusion limits depend on the model but also on the resonance decay mode, because the increase of the width and the shift toward lower masses are enhanced with number of gluons in the final state.





Dijet mass distribution dependence on the decay mode for 1.2 TeV narrow resonance

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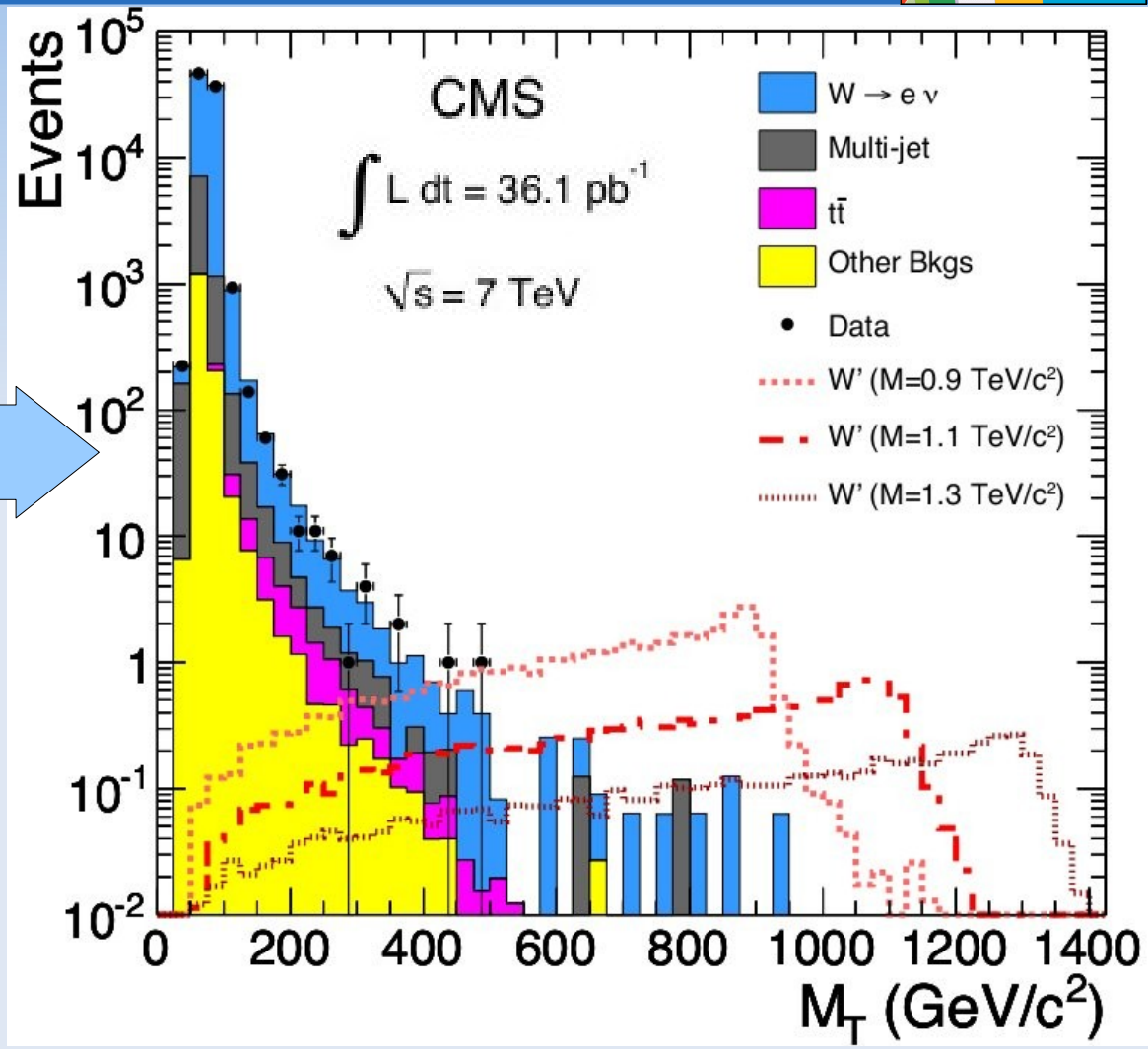
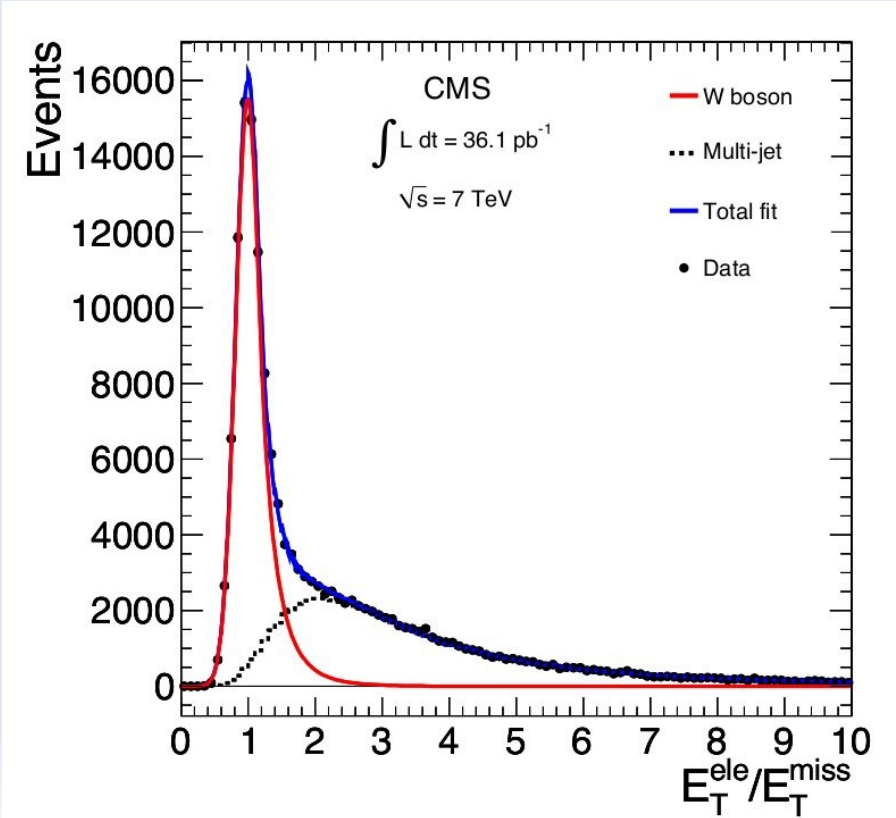
Search for W' in the final state with an electron and large MET [8]

W' decays like W decays (except W'→tb). Electron identification with brem recovery, efficiency evaluated with Z candle.

Electron vs MET balance required:
$0.4 < E_T^{ele} / E_T^{miss} < 1.5$; $\Delta\varphi > 2.5$ rad.

Transverse mass M_T distribution





W → eν vs. Multi-jet normalization fitted.

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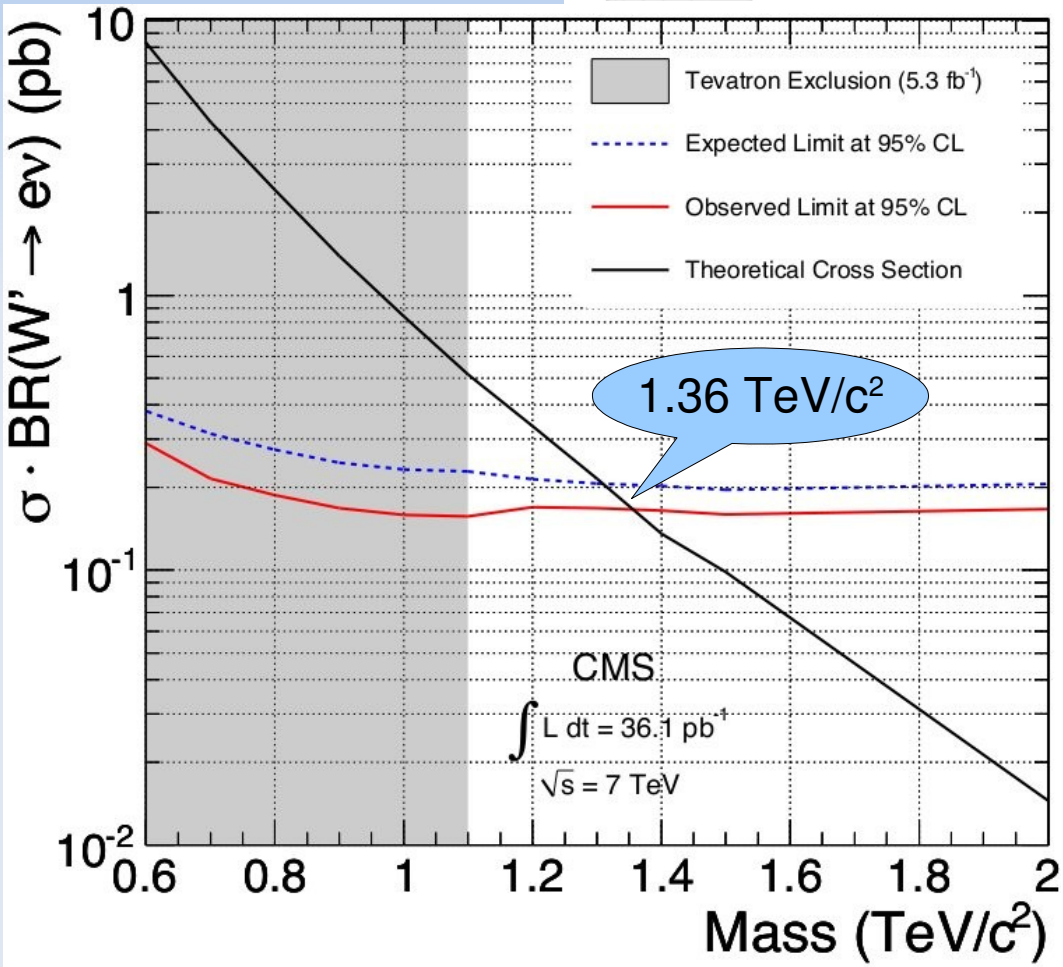
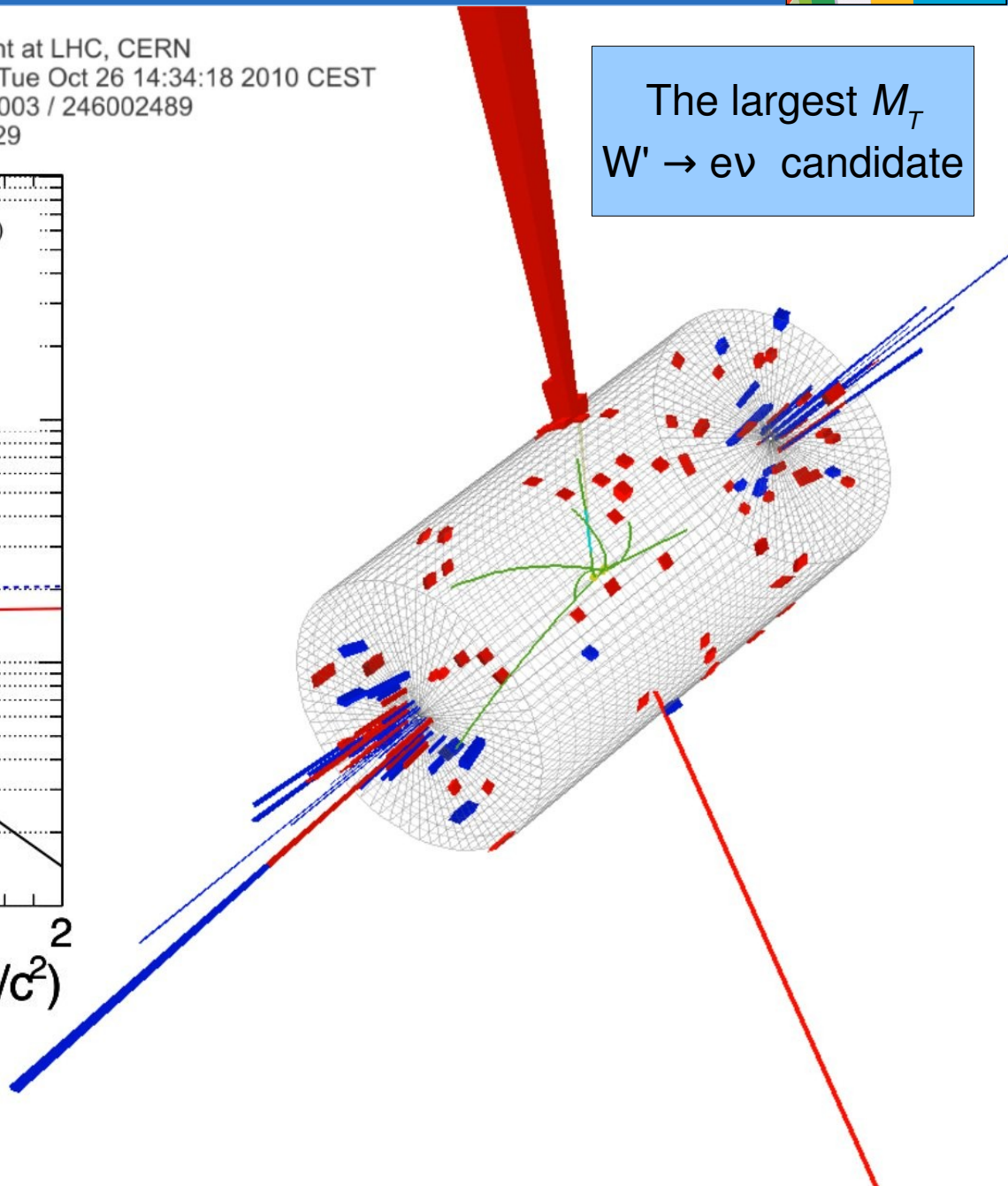
Search for W' in the final state with an electron and large MET



The largest M_T
W' → eν candidate



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Search for Microscopic Black Hole Signatures [9]

The possibility of production of microscopic black holes in particle collisions has been predicted in models with low-scale gravity.

The lowering of the scale is achieved by adding extra spatial dimensions to the SM, which are compactified.

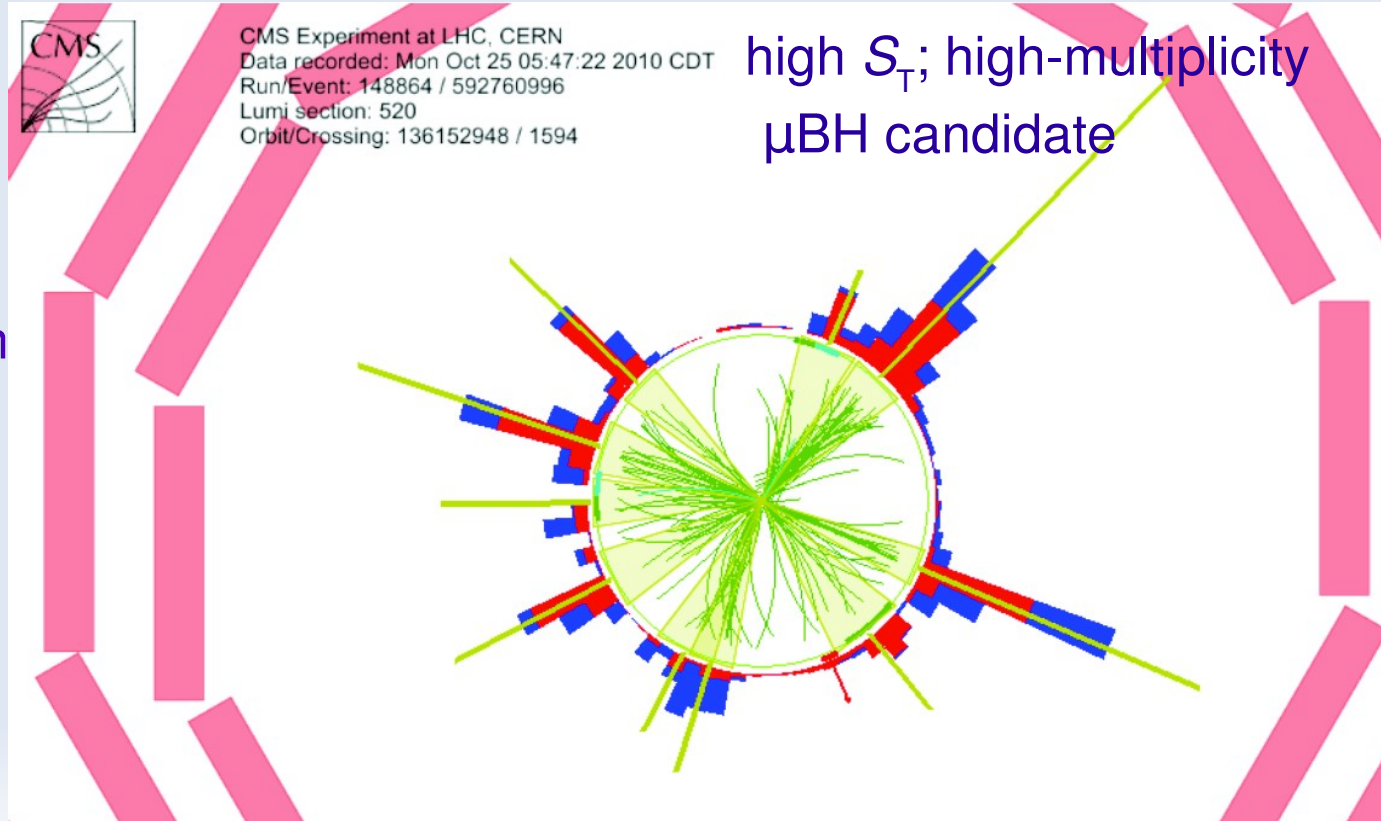
While all the SM particles are contained within a 3D membrane embedded in the multidimensional “bulk” space, gravity permeates the entire space.

As a result, gravitational interaction is “diluted”.

If the “true” Planck scale M_D is in the 1 TeV range, parton collisions with energy exceeding M_D, may collapse in a microscopic black hole.

X-section for µBH production is proportional to to the Schwarzschild radius squared.

Once produced, the µBH evaporate almost instantaneously by emitting energetic particles.



high S_T; high-multiplicity µBH candidate

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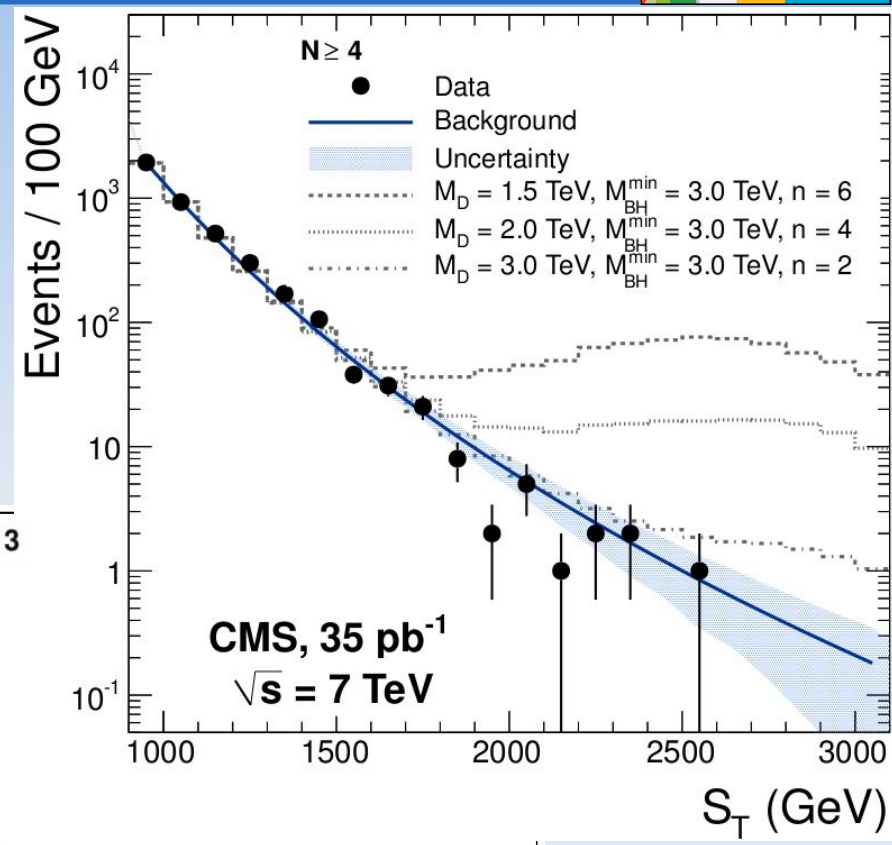
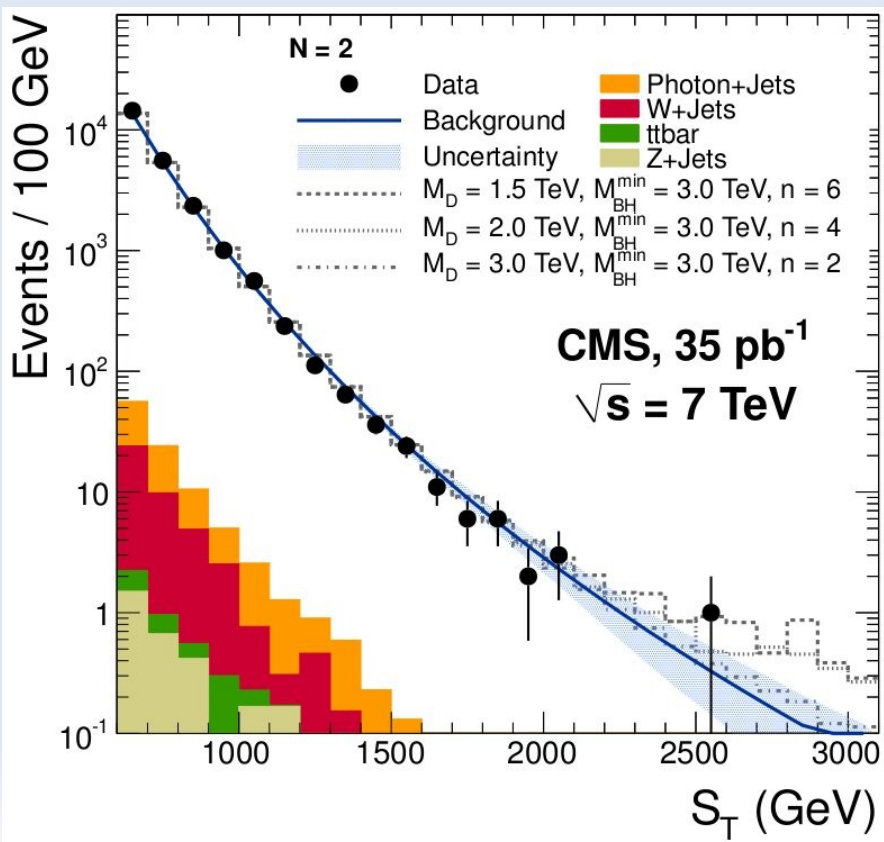
Search for Microscopic Black Hole Signatures

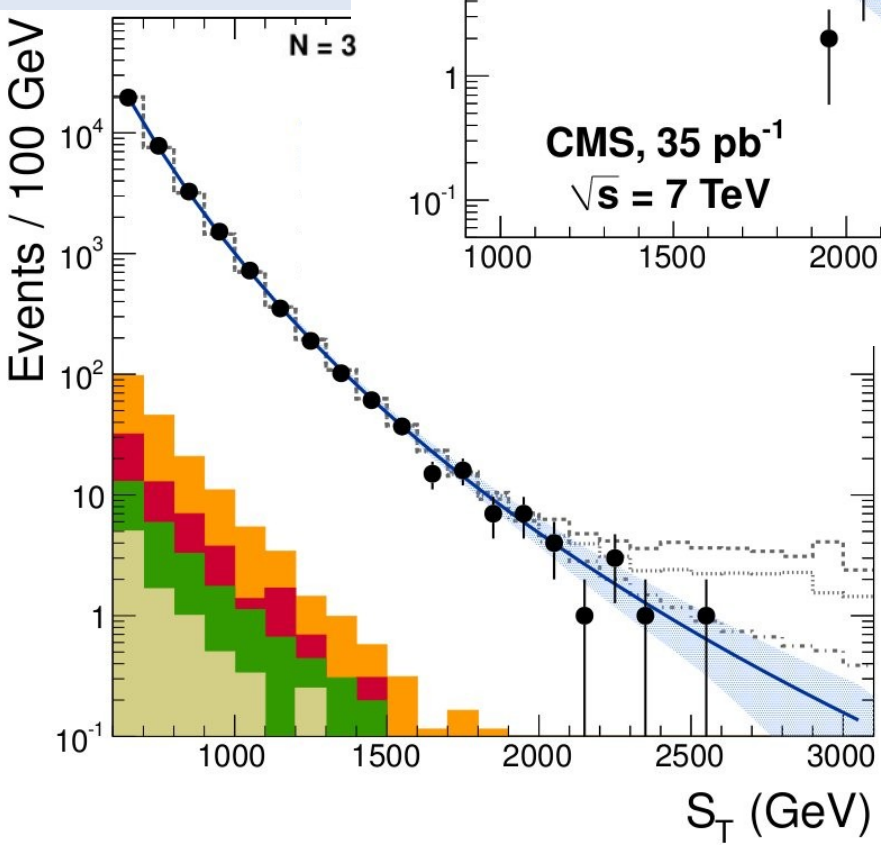
Dedicated trigger on total jet activity H_T

Separation (jet, lepton, photon) $\Delta R > 0.3$

S_T – scalar sum of the E_T of all N individual objects passing selection and with $E_T > 50$ GeV, to which missing E_T^{miss} is added (if > 50 GeV).







S_T is almost independent of the final state mult. N

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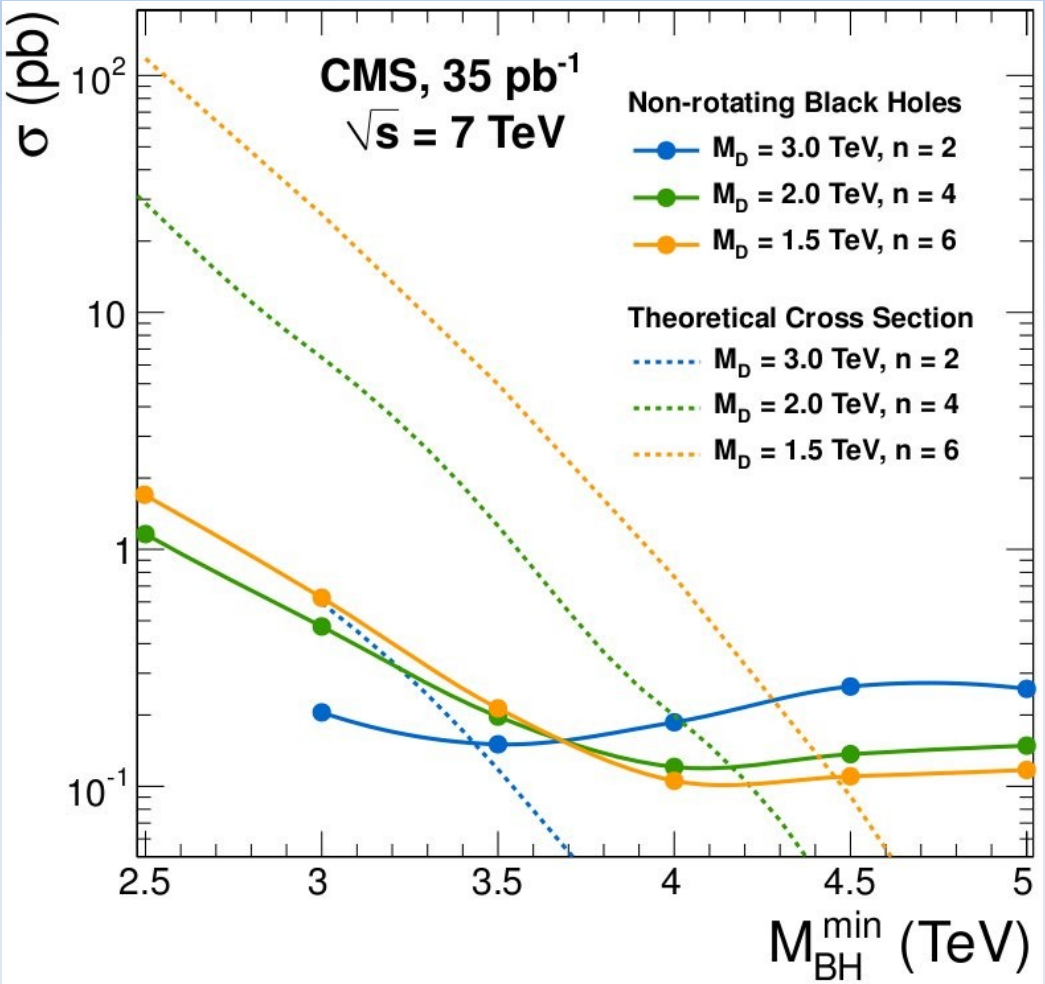
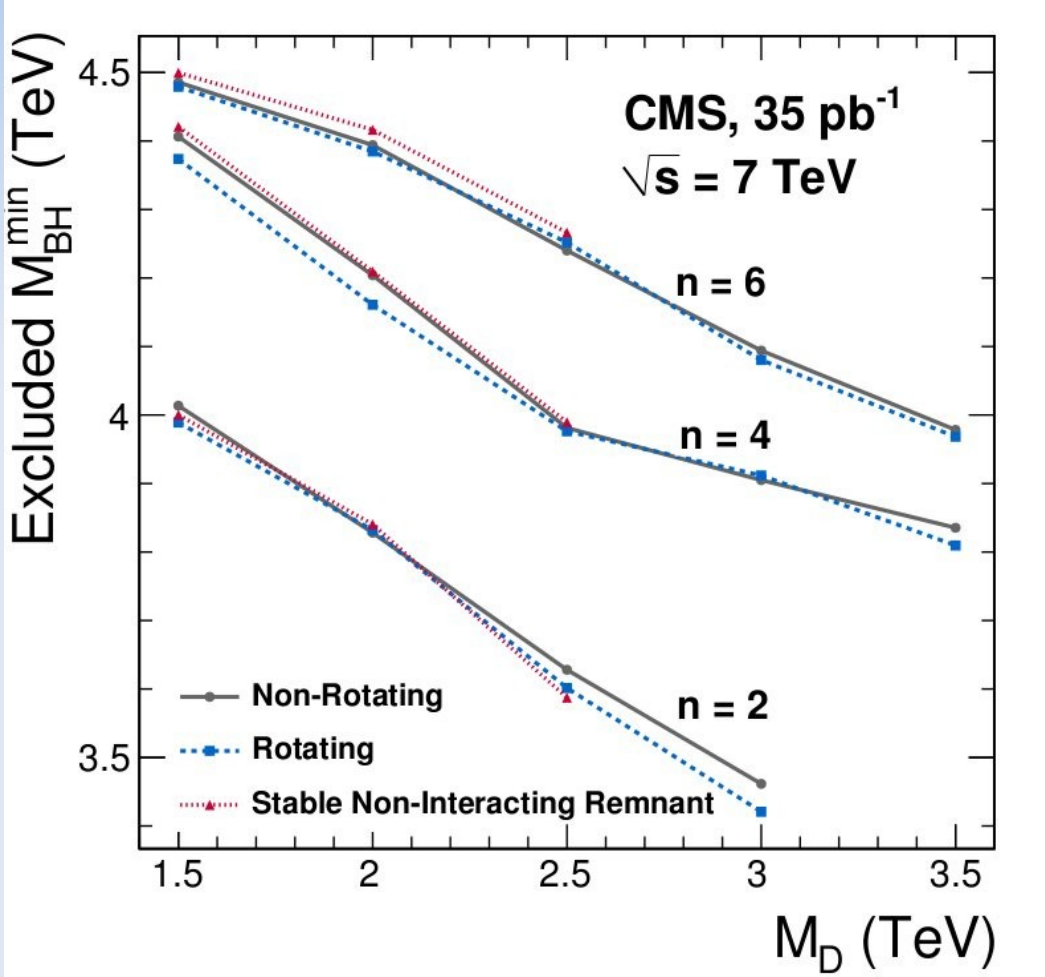
Search for Microscopic Black Hole Signatures

The 95% CL upper limits on the black hole →





→ X-section as a function of black hole mass

→ black hole mass as a function of multidimensional Planck scale M_D

Search for Pair Production of Leptoquarks in 2 leptons + 2 jets final states

Some well-motivated theories of physics beyond the SM, including grand unified theories, composite models , technicolor , and super-string inspired E6 models, postulate the existence of a symmetry, beyond that of the SM, relating quarks and leptons and implying the existence of new bosons, called leptoquarks (LQ).

An LQ carries colour, has fractional electric charge, can have spin 0 (scalar) or spin 1 (vector), and couples to a lepton and a quark with coupling strength λ.

An LQ would decay to a charged lepton and a quark, with an unknown branching fraction β, or a neutrino and a quark, with branching fraction $1-\beta$.

At LHC LQs are predominantly produced in pairs via gluon-gluon fusion and quark-antiquark annihilation with a cross section that depends on the strong coupling constant but is nearly independent of λ.

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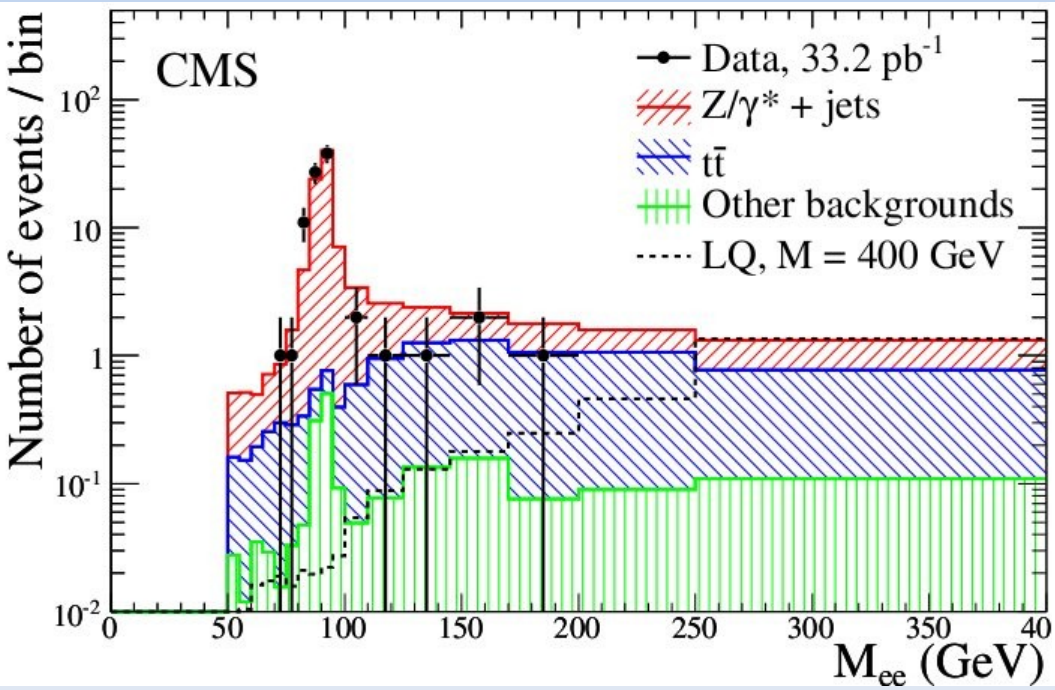
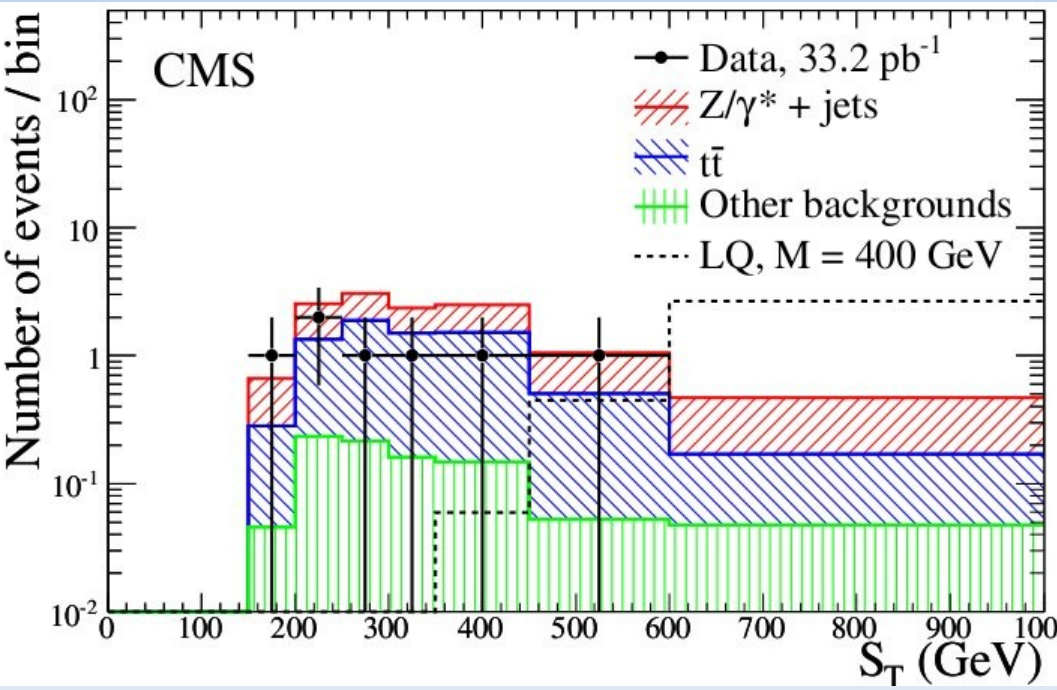
Search for Pair Production of 1st-Generation Scalar Leptoquarks [10]

A search for pair production of first generation leptoquarks is performed in the final state containig two electrons and two jets.





M_{ee} distribution for events after preselection.

S_T distribution for events after preselection (except $S_T > 250$ GeV) and after $M_{ee} > 125$ GeV.

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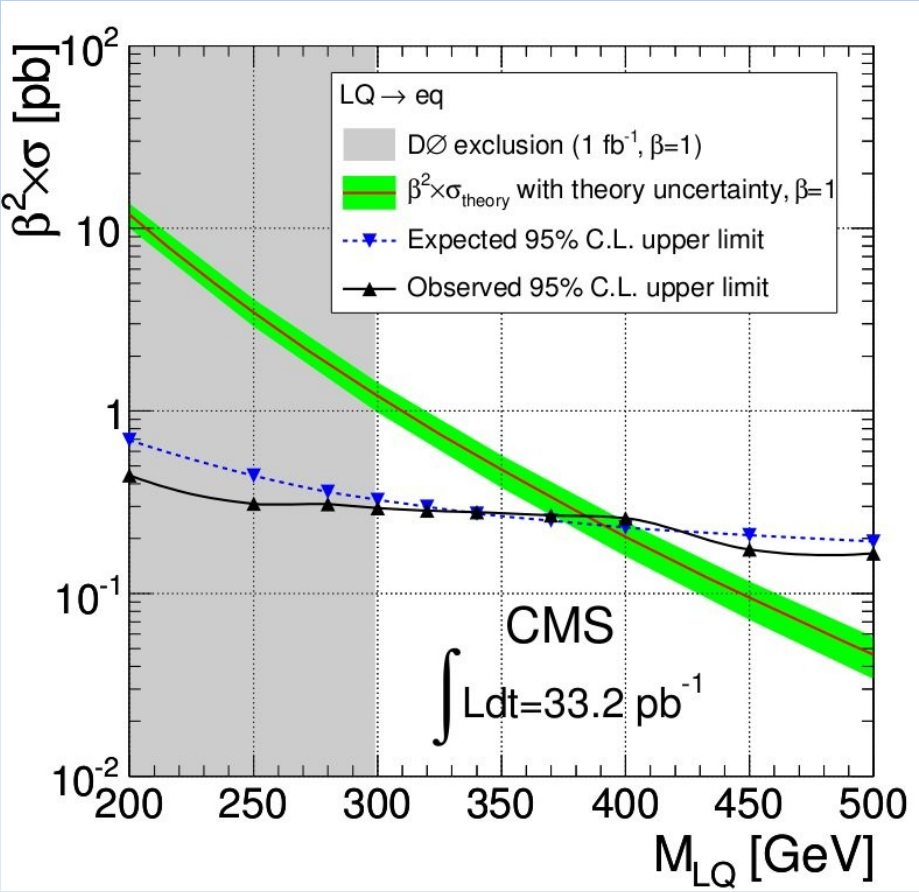
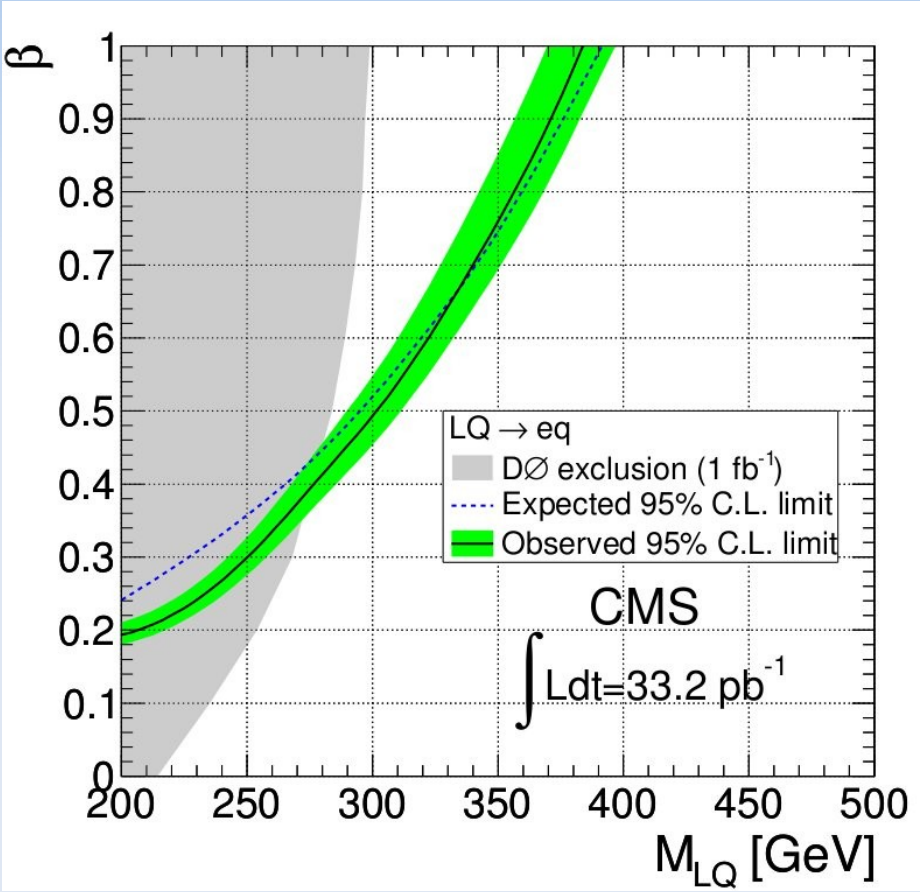
Search for Pair Production of 1st-Generation Scalar Leptoquarks

Parameter β is the branching fraction of the leptoquark decay into lepton and quark



Limits on X-section times β^2



Minimal β for 95% exclusion.

Green bands correspond to LQ X-section uncertainty due to PDF and renormalization/factorization scales.

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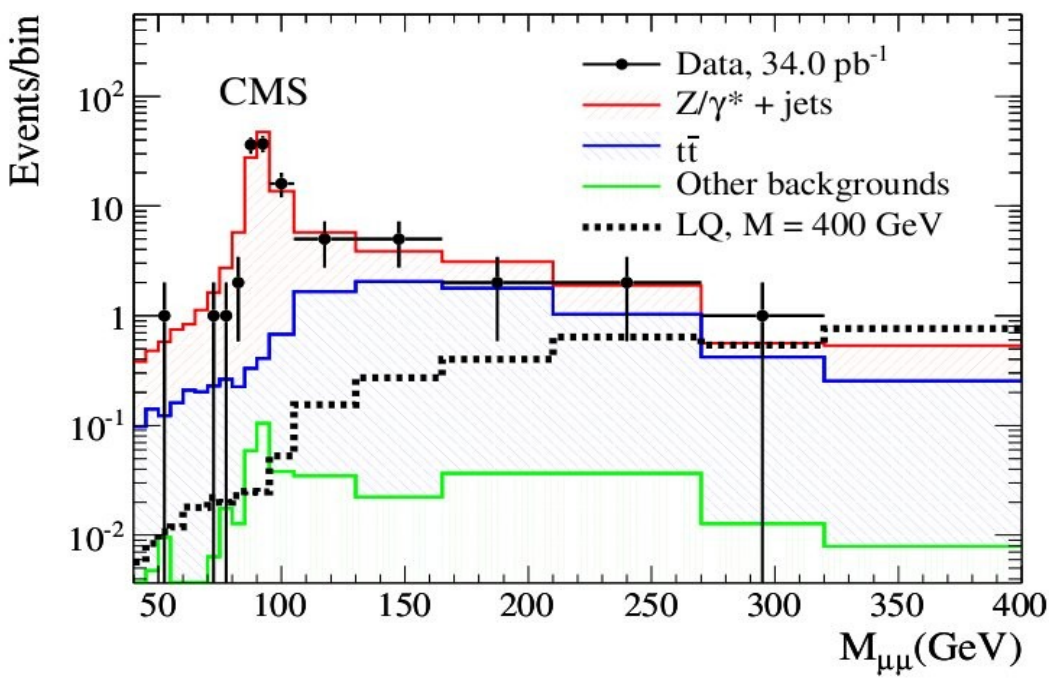
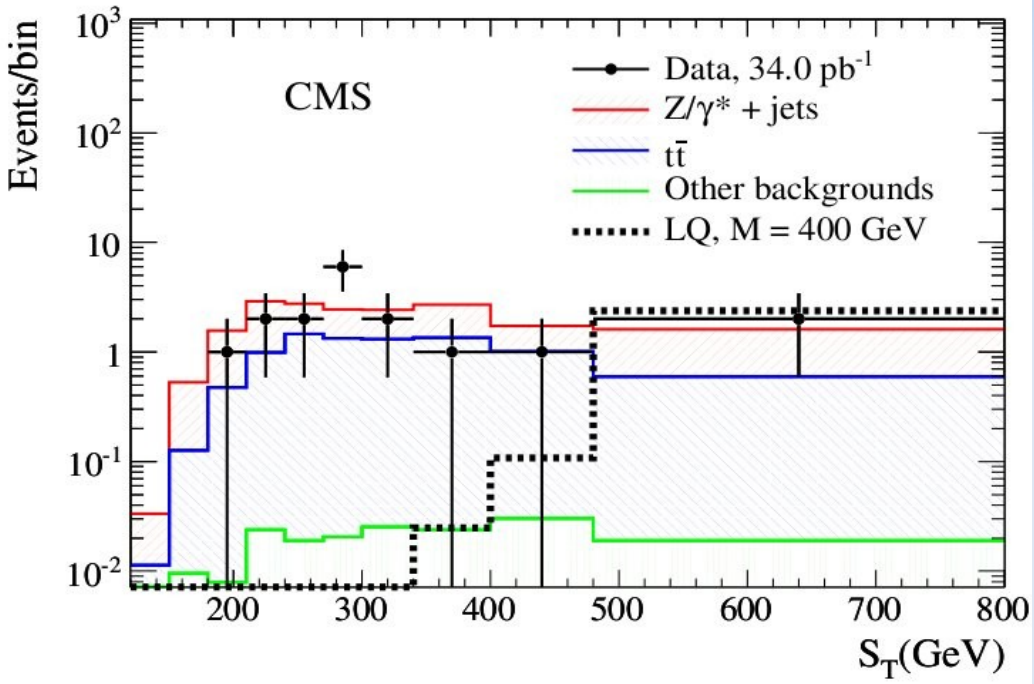
Search for Pair Production of 2nd-Generation Scalar Leptoquarks [11]

A search for pair production of first generation leptoquarks is performed in the final state containig two muons and two jets.





$M_{\mu\mu}$ distribution for events after requiring at least 2 muons and at least 2 jets with p_T > 30 GeV and S_T > 250 GeV

S_T distribution for events after requiring at least 2 muons and at least 2 jets with p_T > 30 GeV and $M_{\mu\mu}$ > 115 GeV

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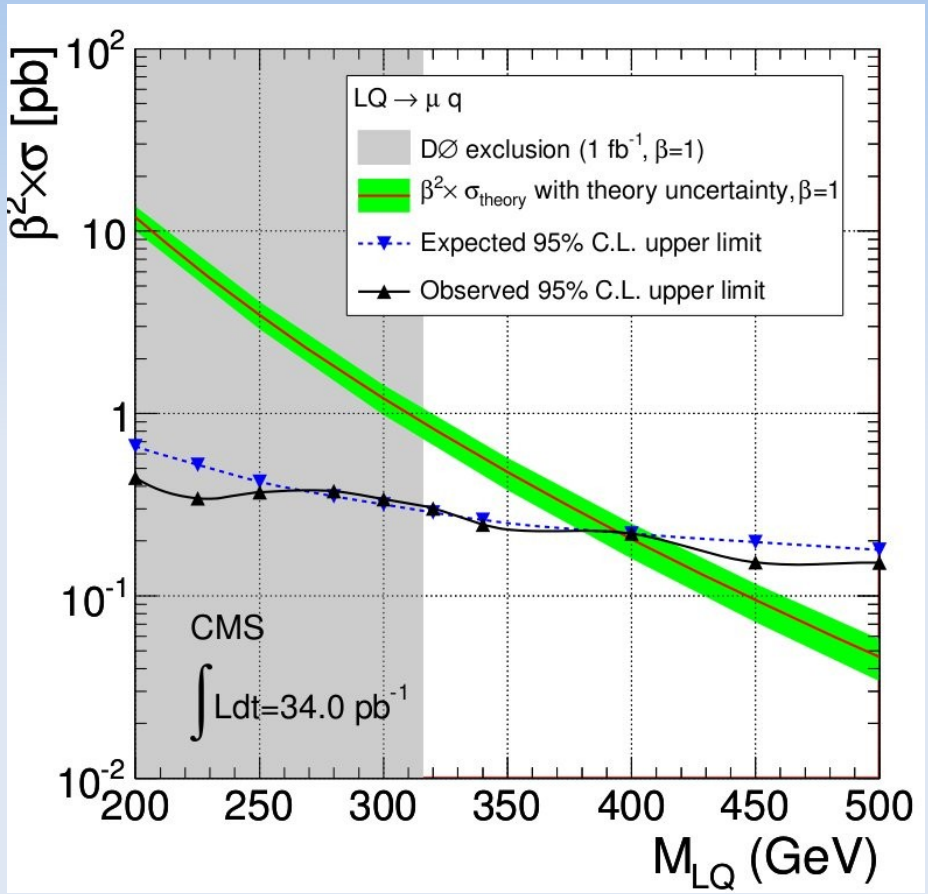
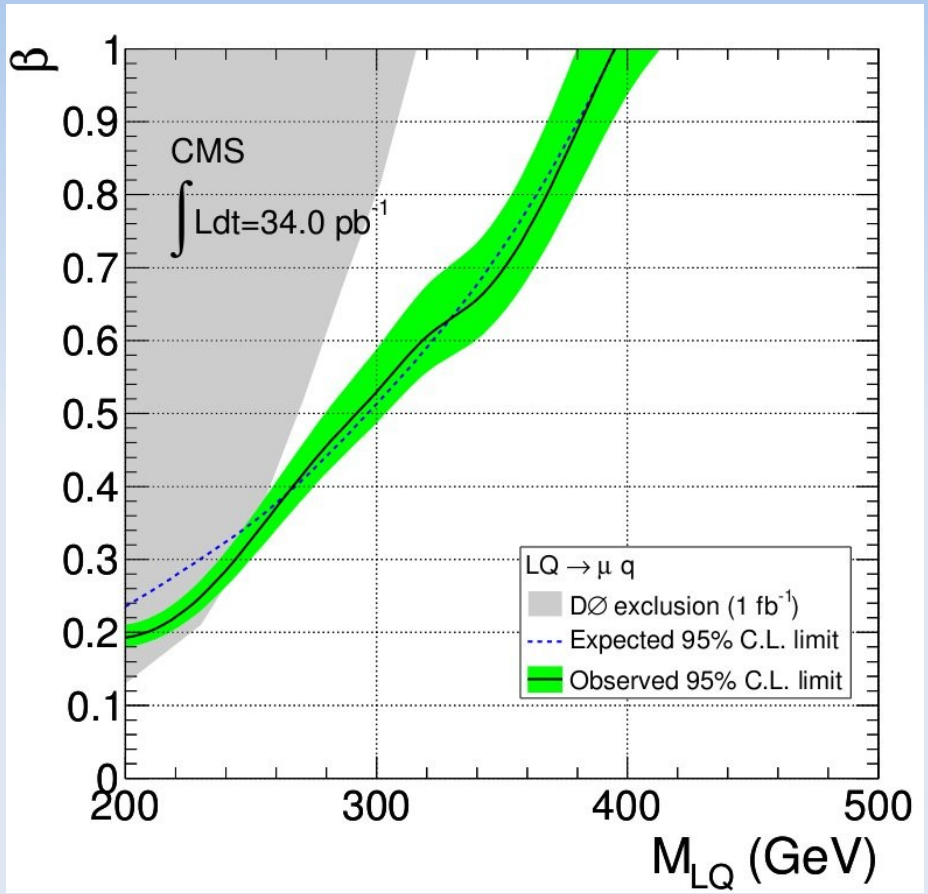
Search for Pair Production of 2nd-Generation Scalar Leptoquarks



Limits on X-section times β^2



Minimal β for 95% exclusion.

Green bands correspond to LQ X-section uncertainty due to PDF and renormalization/factorization scales.

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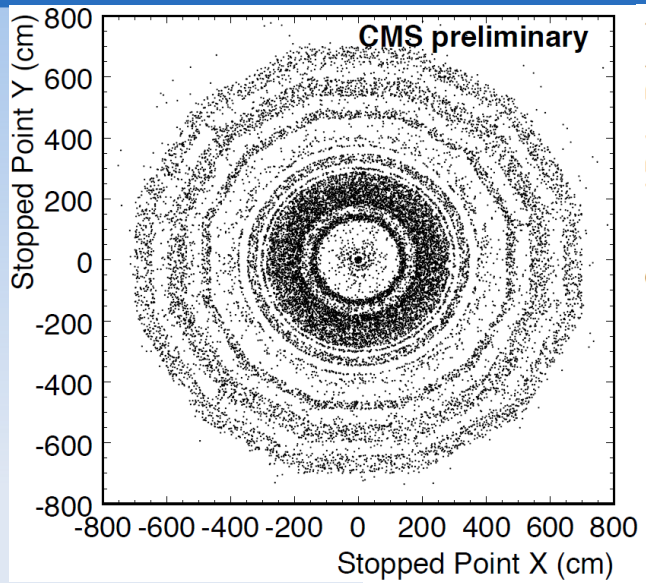
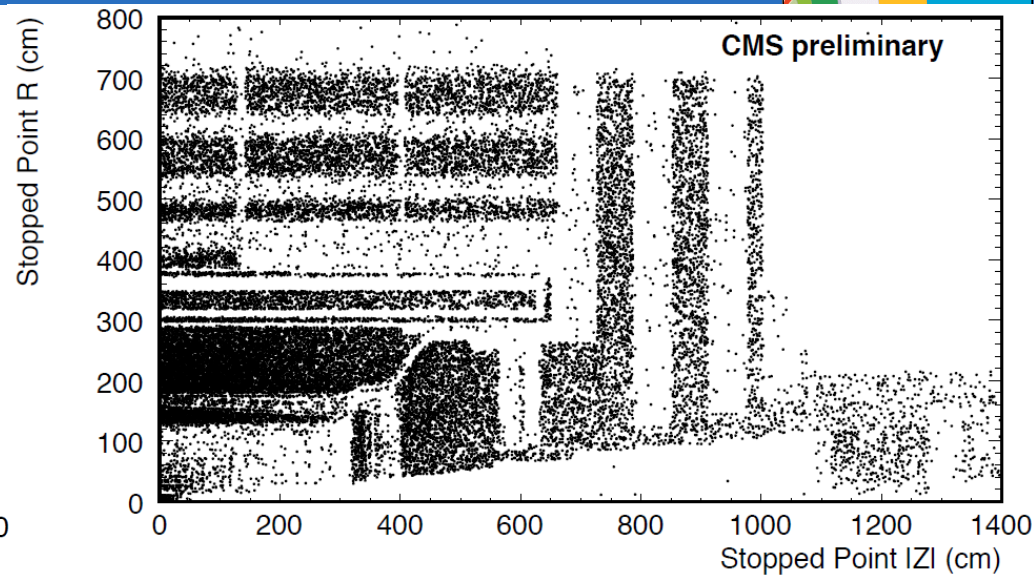
Search for Stopped Gluinos [12]

Published last Friday in the PRL

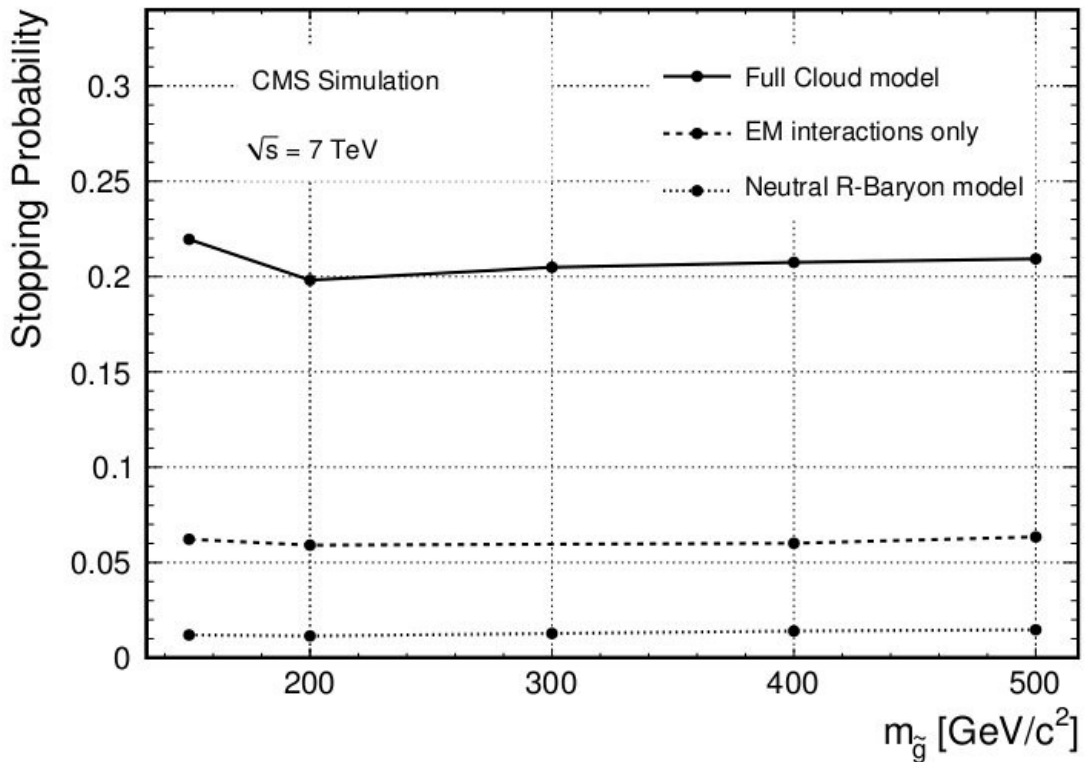
Look for evidence of long-lived particles that stop in the CMS and decay in the quiescent periods between beam crossings.





Many extensions of the SM predict the existence for such particles. With 10/pb the search is sensitive to models with large x-section and large stopping power like gluino which hadronize into R-hadrons.

The trigger aspects of the search were already described yesterday by M. Kazana.



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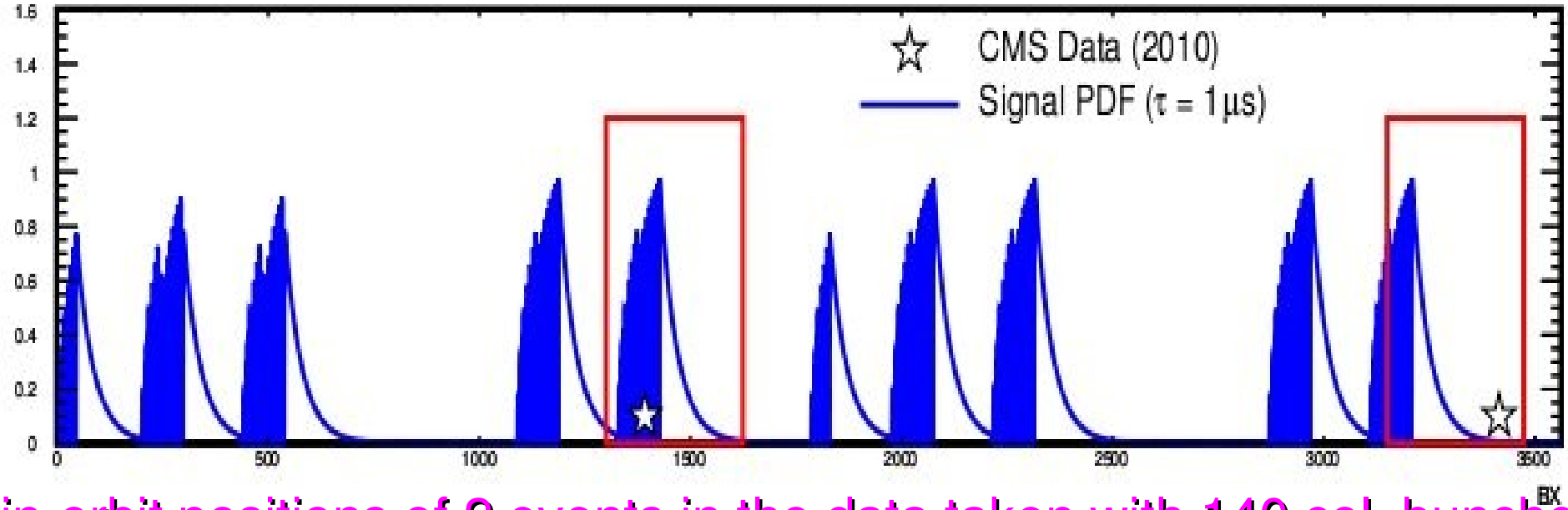
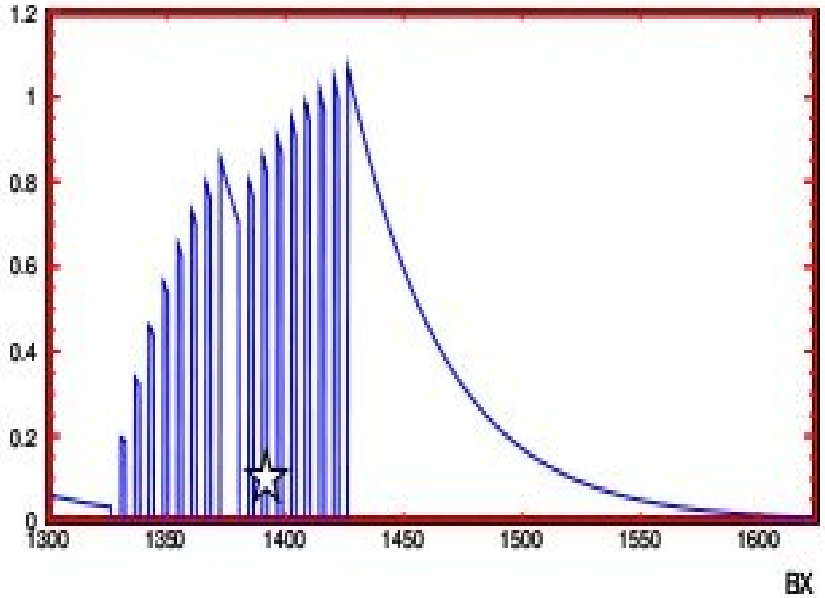
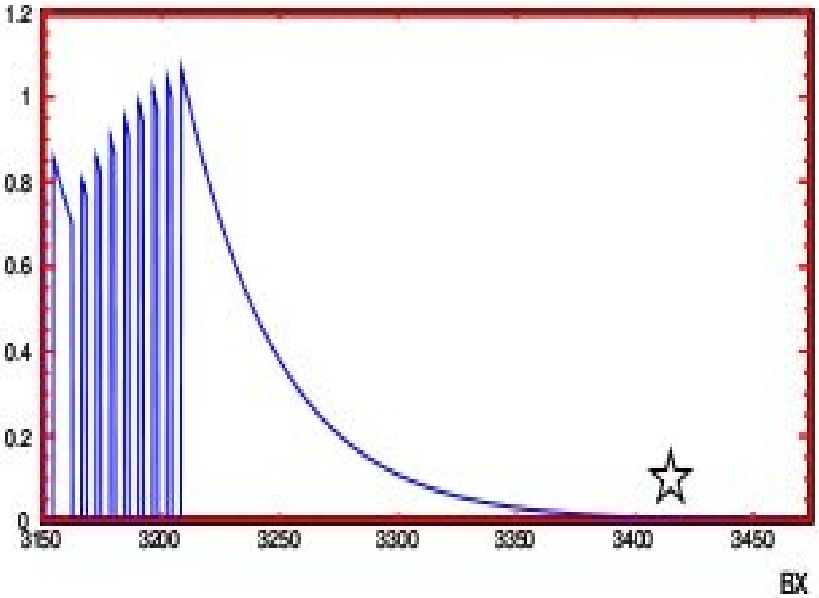
Search for Stopped Gluinos



The in-orbit positions of 2 events in the data taken with 140 col. bunches





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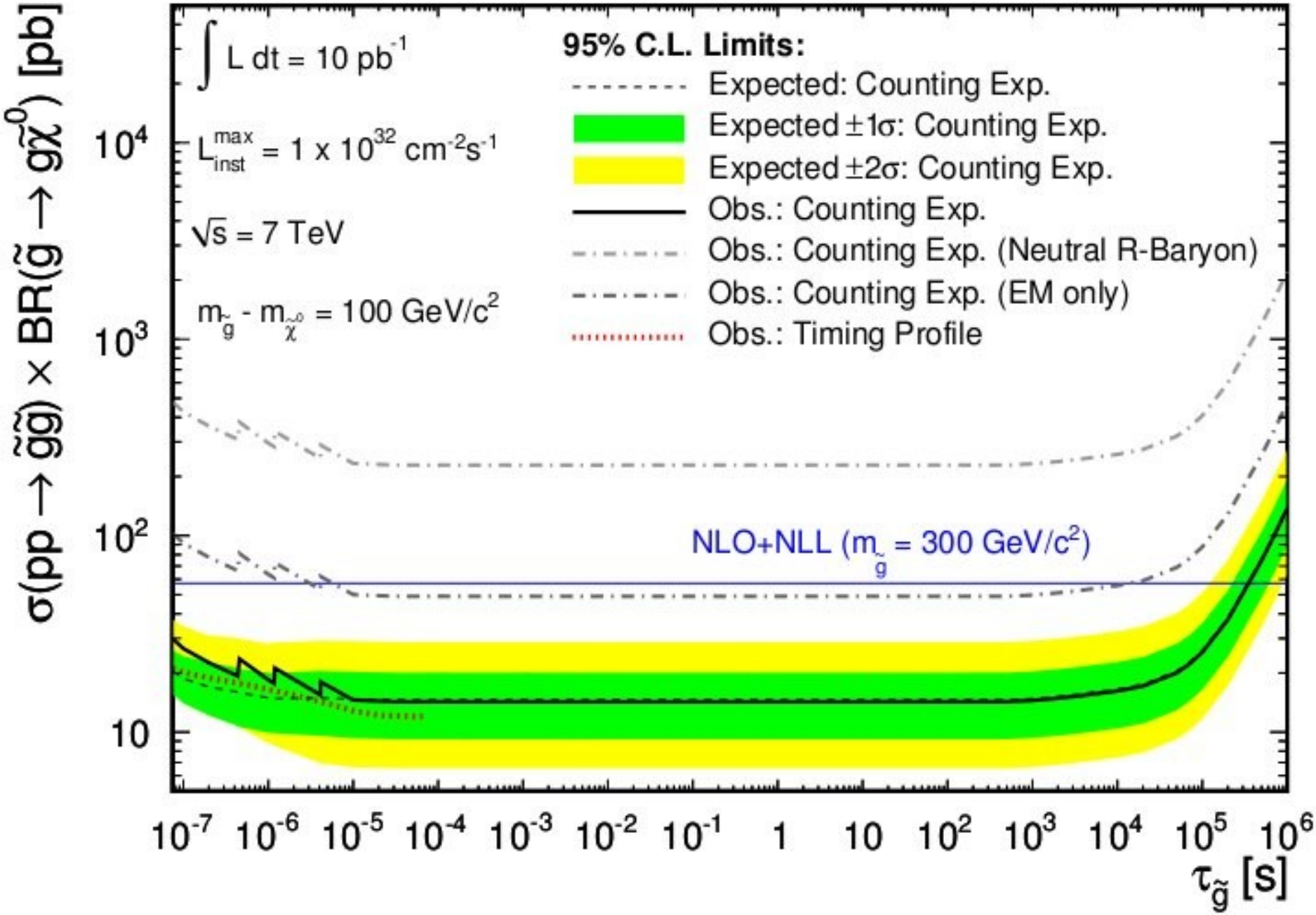

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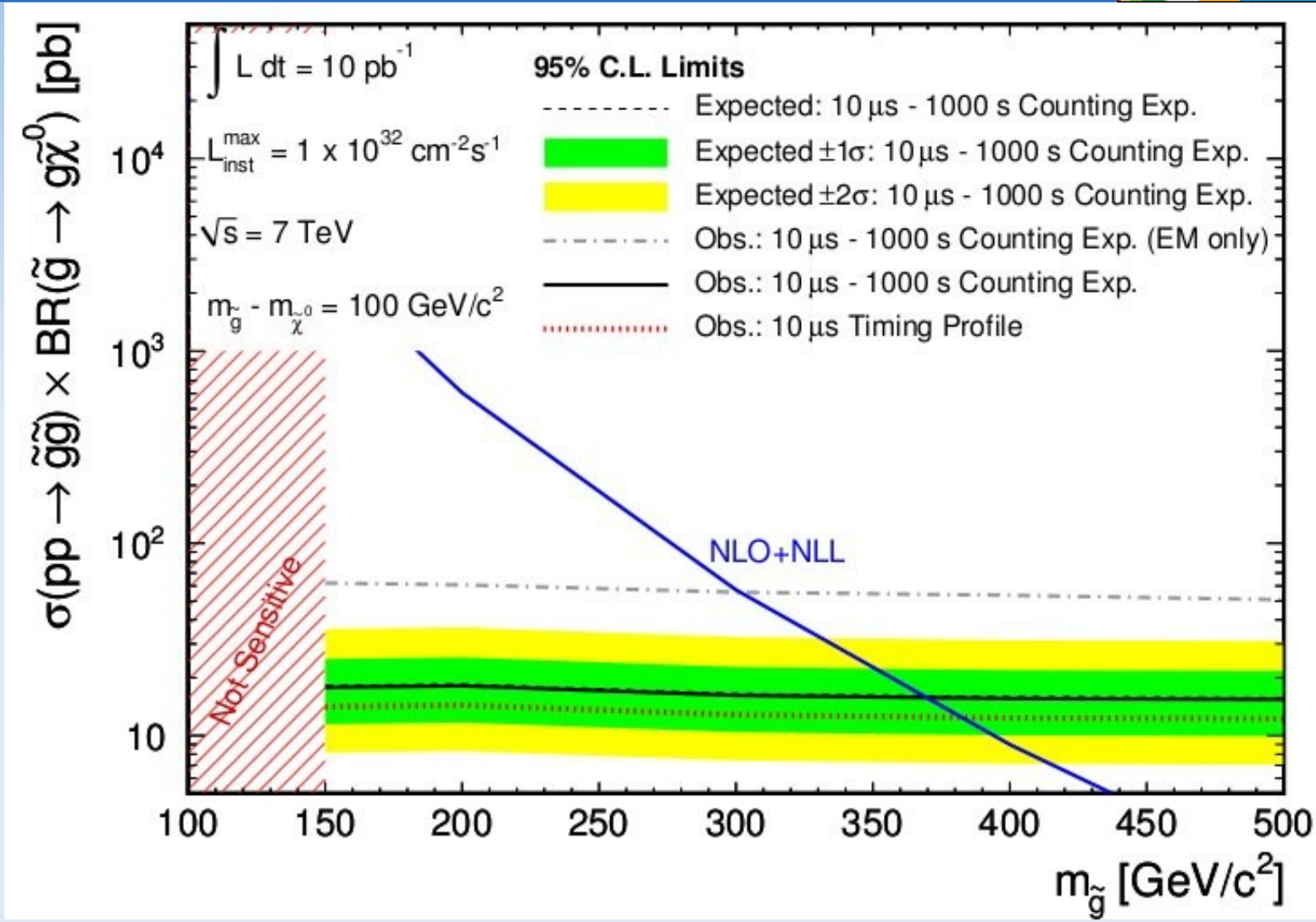
Search for Stopped Gluinos

We looked for Subsequent decays of gluinos, that have stopped in the CMS, during time intervals without pp collisions.

In the data with istant. lumi. 10^{32} $cm^{-2}s^{-1}$ and int. lumi. 10/pb no significant excess above backg. was observed.

This allow to exclude Gluino mass below 370 GeV/c^2 for lifetimes from 10^{-5} s to 10^3 s with a counting experiment



And below 382 GeV/c^2 for 10^{-5} s lifetime with a time-profile analysis.
These limits are the most restrictive to date.

Conclusions

Excellent performance of the LHC machine and effective operation of the CMS detector allowed for accumulation of ~40/pb of data at 7 TeV during 2010.

Early data were used to tune and understand detector response to physics objects produced in proton-proton collisions.

Acumulted statistics turned out to be sufficient to extend exclusions of some new physics models.

Even more search for new physics analyses will be accomplished before Moriond conferences.

We are ready to record and proces 2011 data.

We hope that the era of exclusion limits is comming to its end.

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