BSM Physics at the LHC, HERA

Few topics that could be interesting for EIC

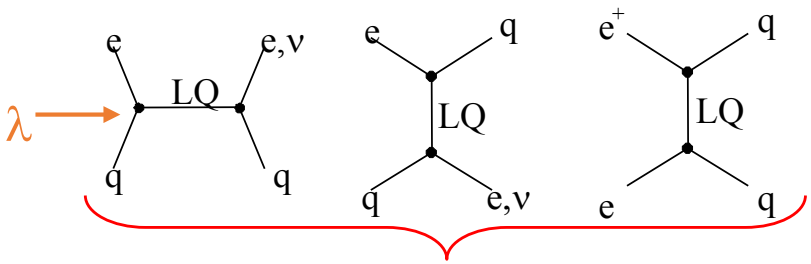
Elisabetta Gallo

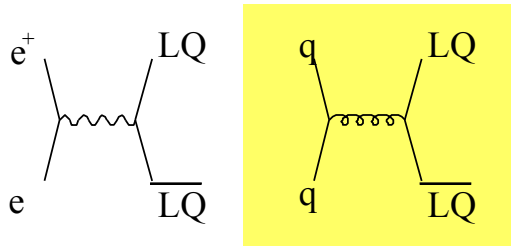
19/12/2018

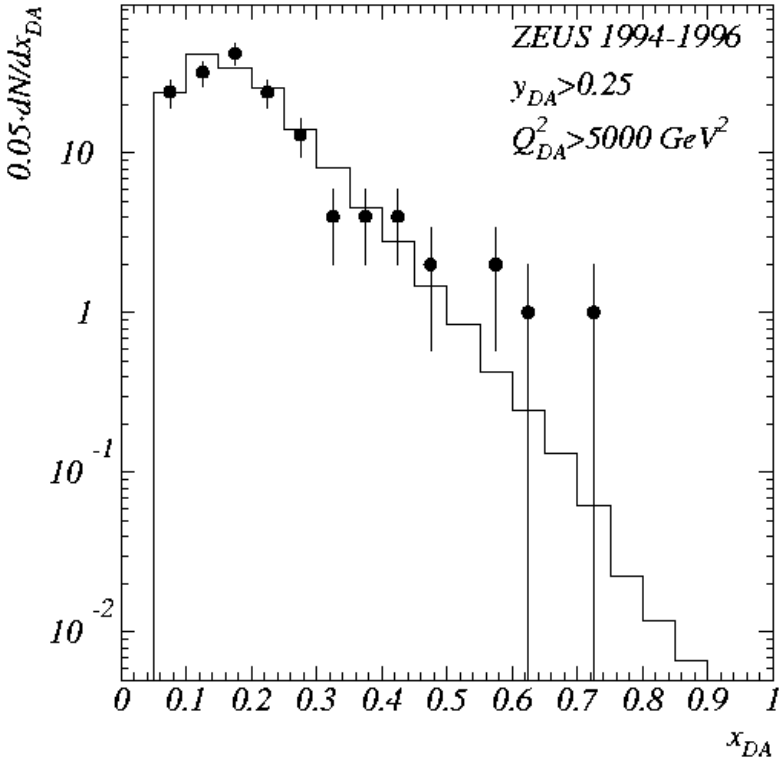
For HERA results

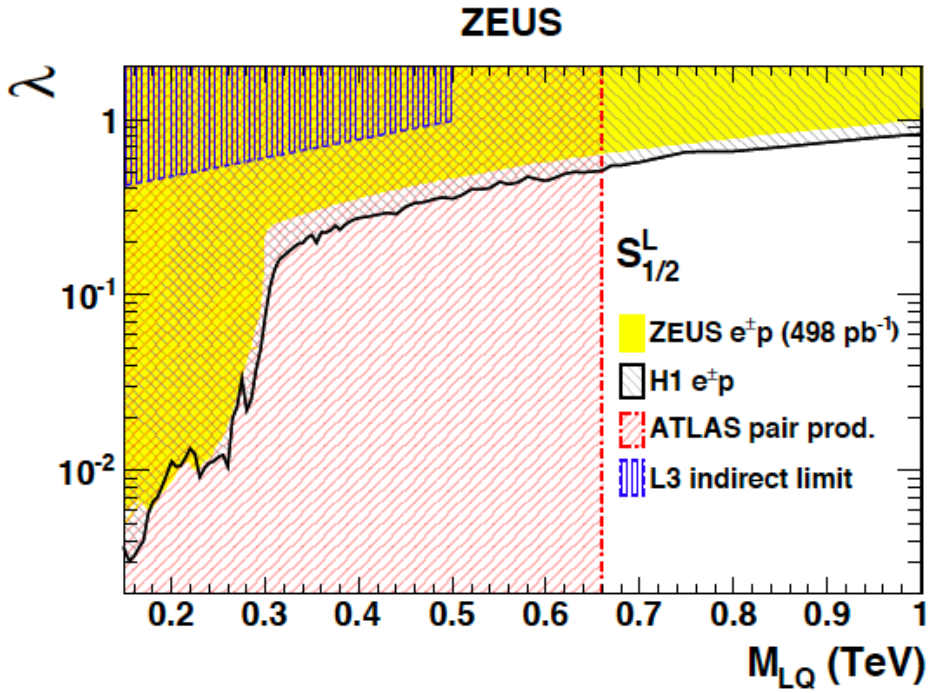
Results taken from old slides

Leptoquarks

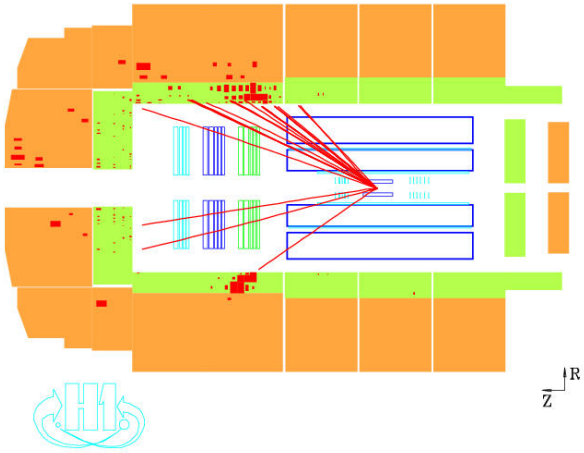


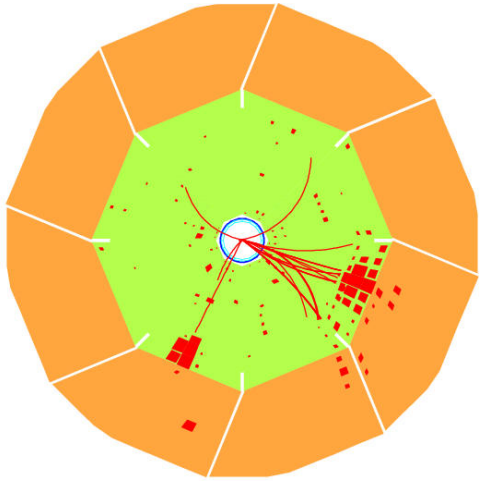


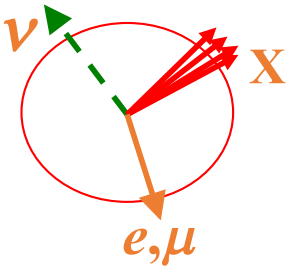


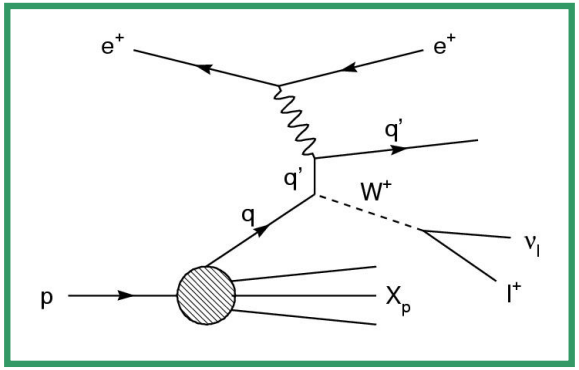


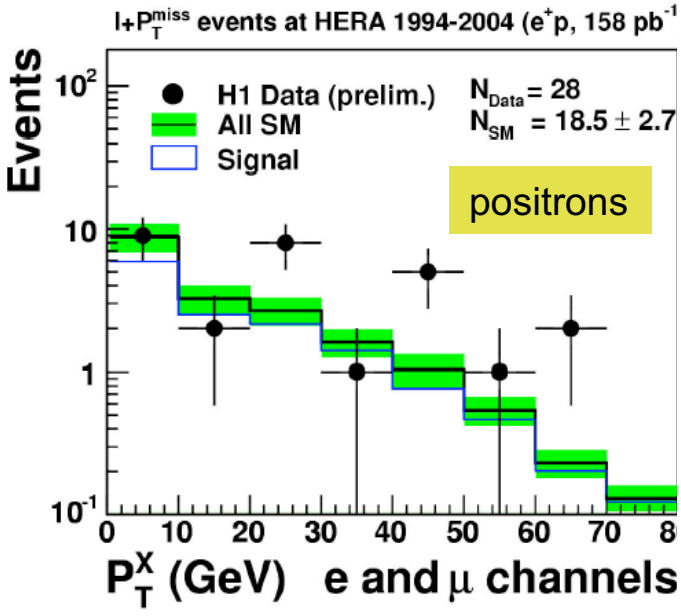
Isolated leptons at HERA

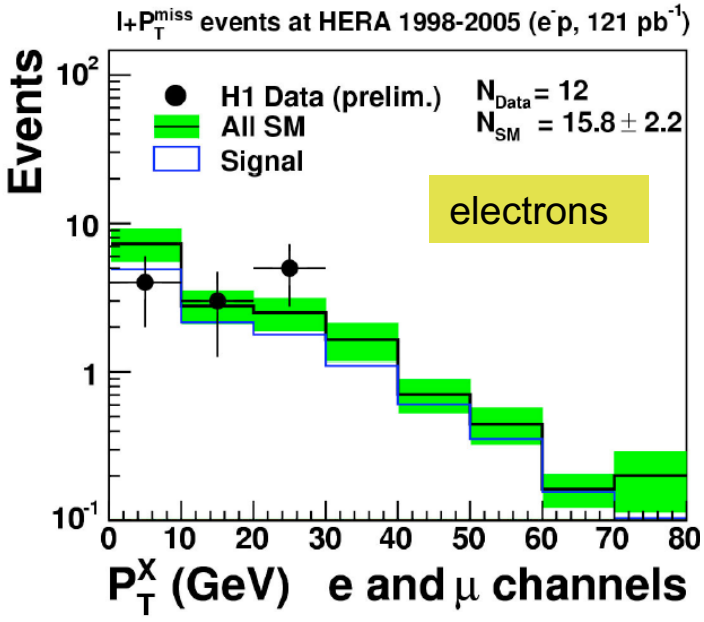










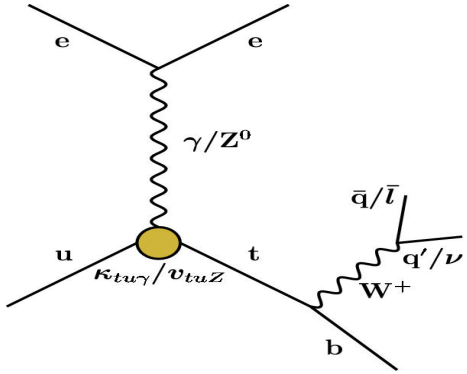


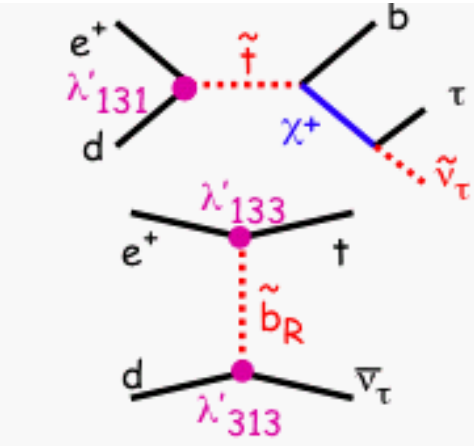
Analysis is optimized for the main SM process which is W production

Excess at high P_T^X observed by H1 in e^+p collisions

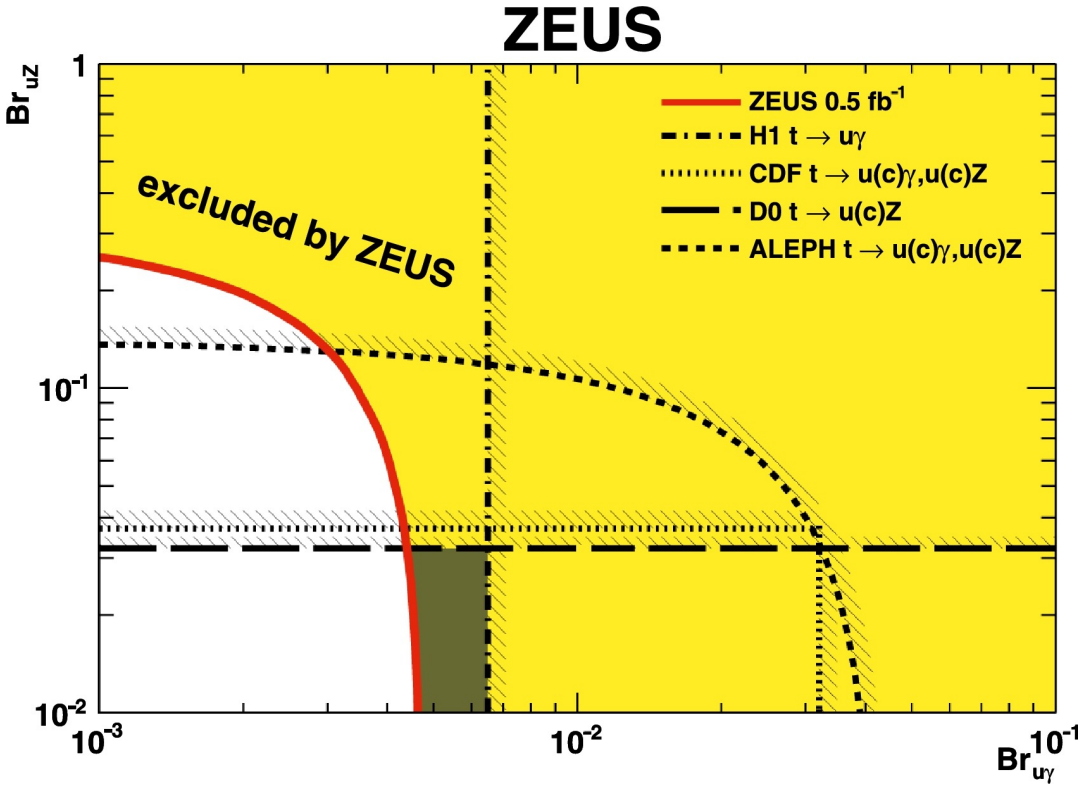
Isolated leptons at HERA

No excess seen by ZEUS, events analyzed in terms of anomalous single top production at HERA I

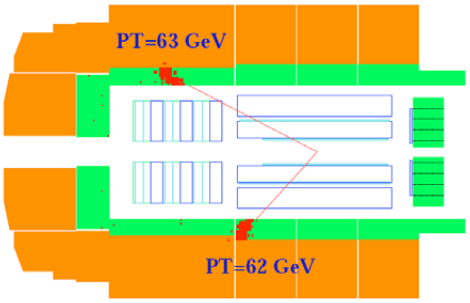


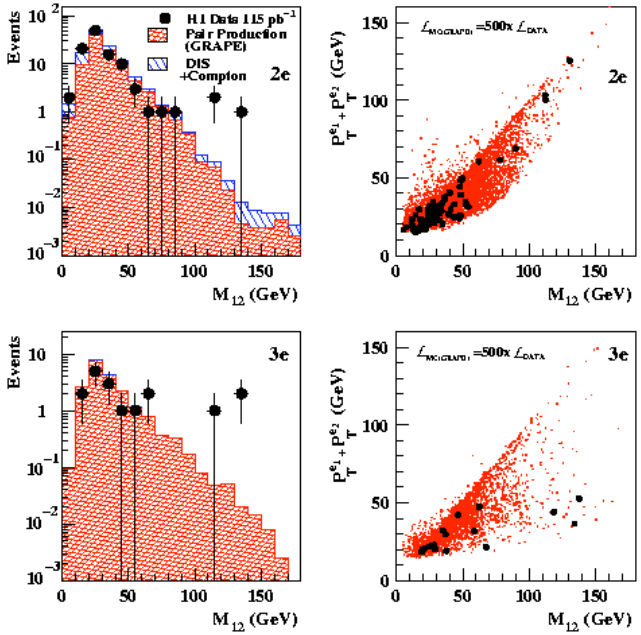


Some possible diagrams in R-parity violation SUSY to explain the H1 excess

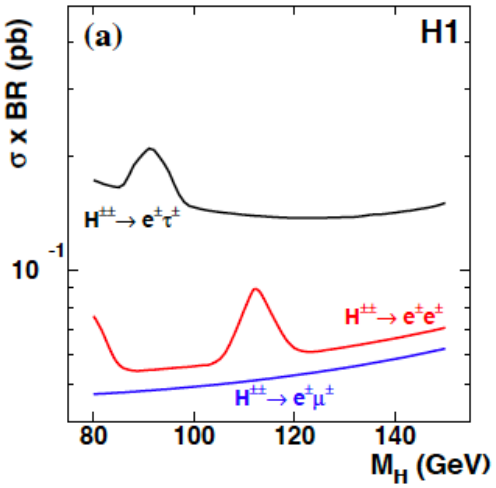


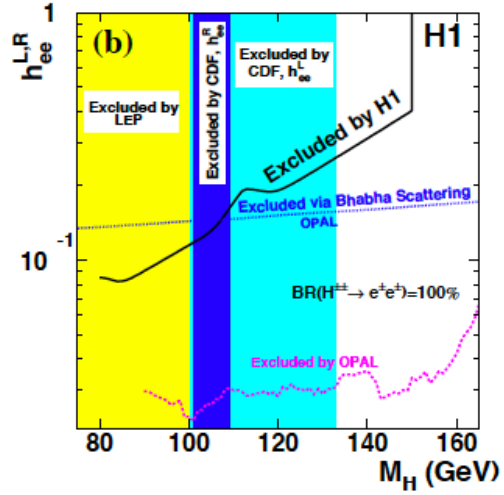
Multileptons in H1 and doubly-charged Higgs

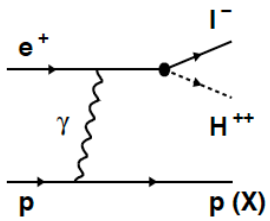


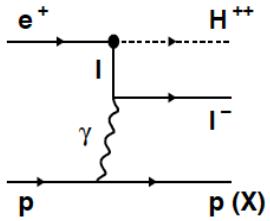


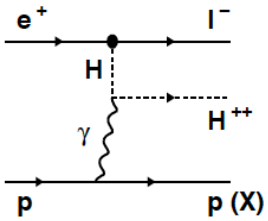
Excess of events in 2e, 3e in H1, explanation could have been doubly-charged Higgs. Limits set at the end of HERA.



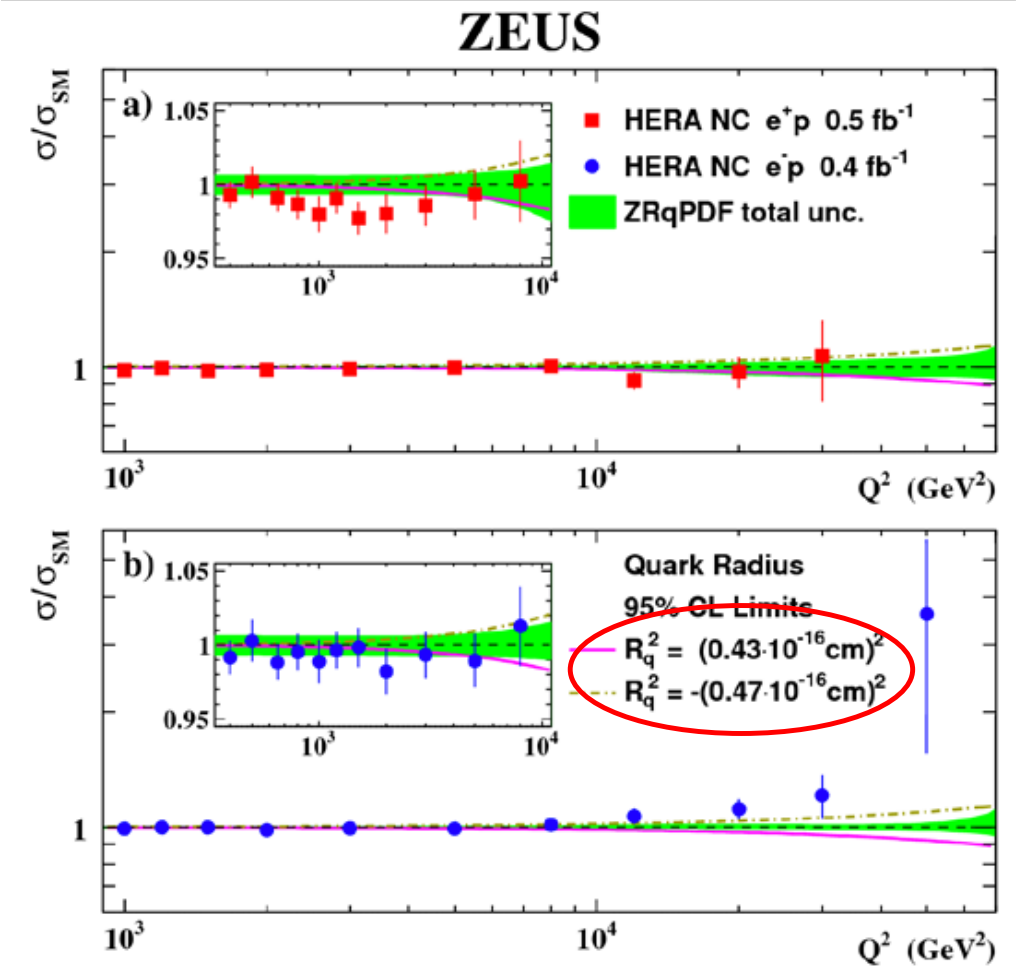


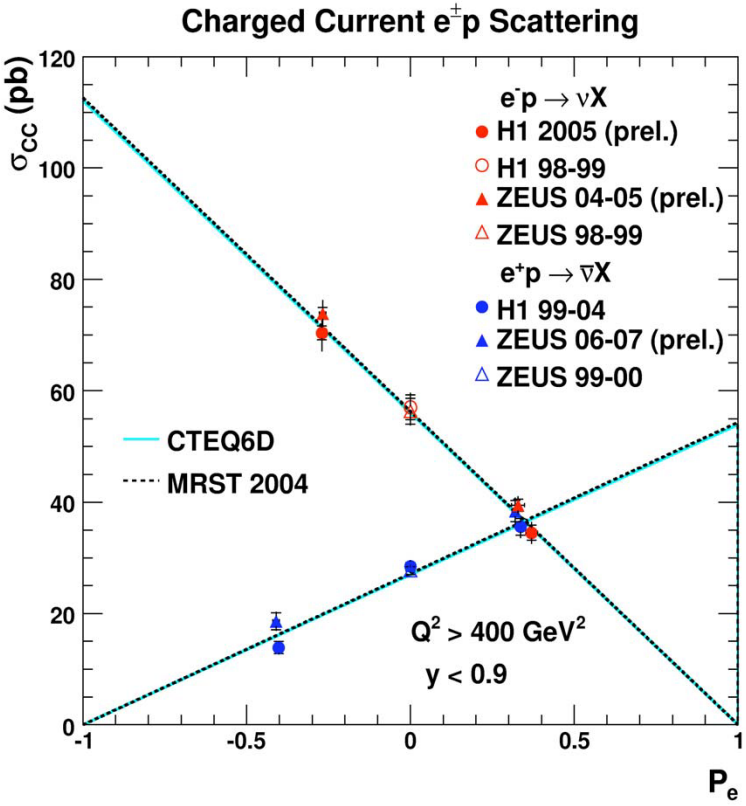






Quark radius, NC and CC cross sections





Limits on W_R around 200 GeV

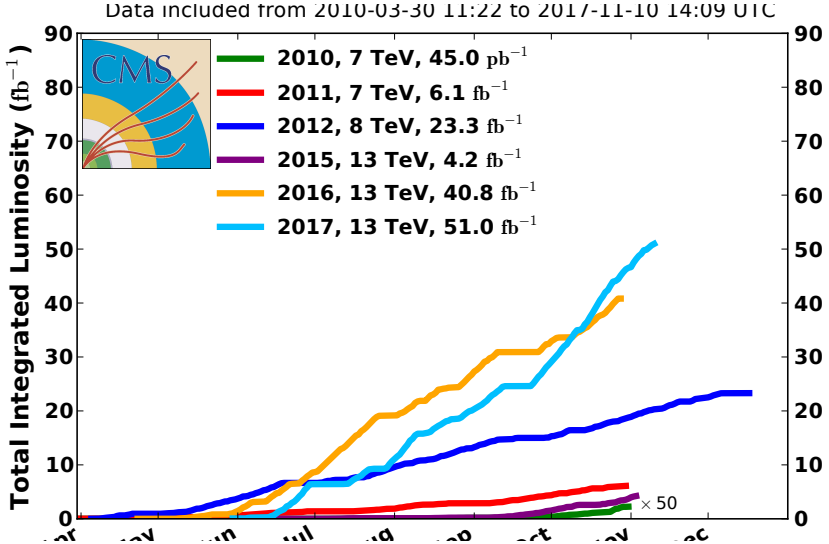
LHC results

Results taken from slides at recent conferences
on whatever is coupling to a lepton and a quark

LHC

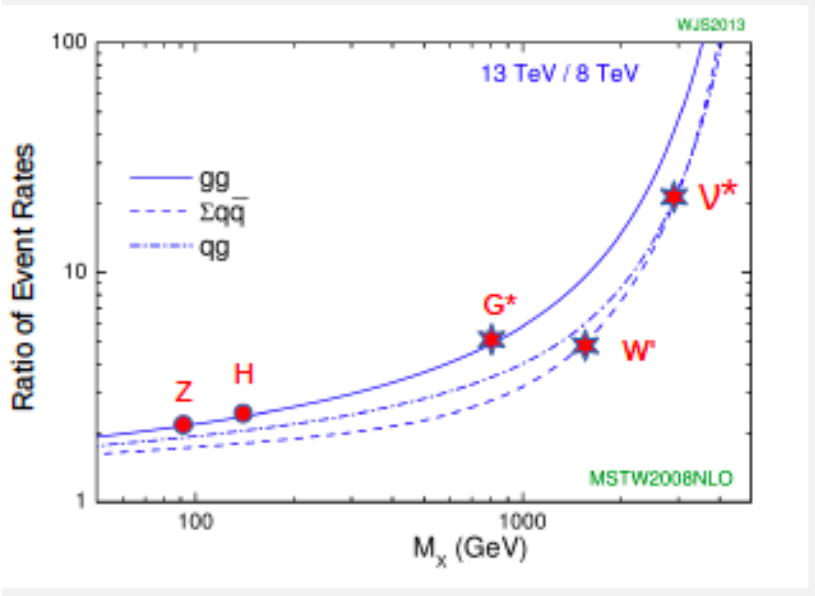
LHC luminosity

- Run 1: 2010-2012 at $\sqrt{s} = 7{,}8\ TeV$
- Run2: 2015-2018 at $\sqrt{s} = 13\ TeV$
- The increased luminosity and c.m. energy has boosted BSM searches at the LHC.
- Ratio of parton luminosities.

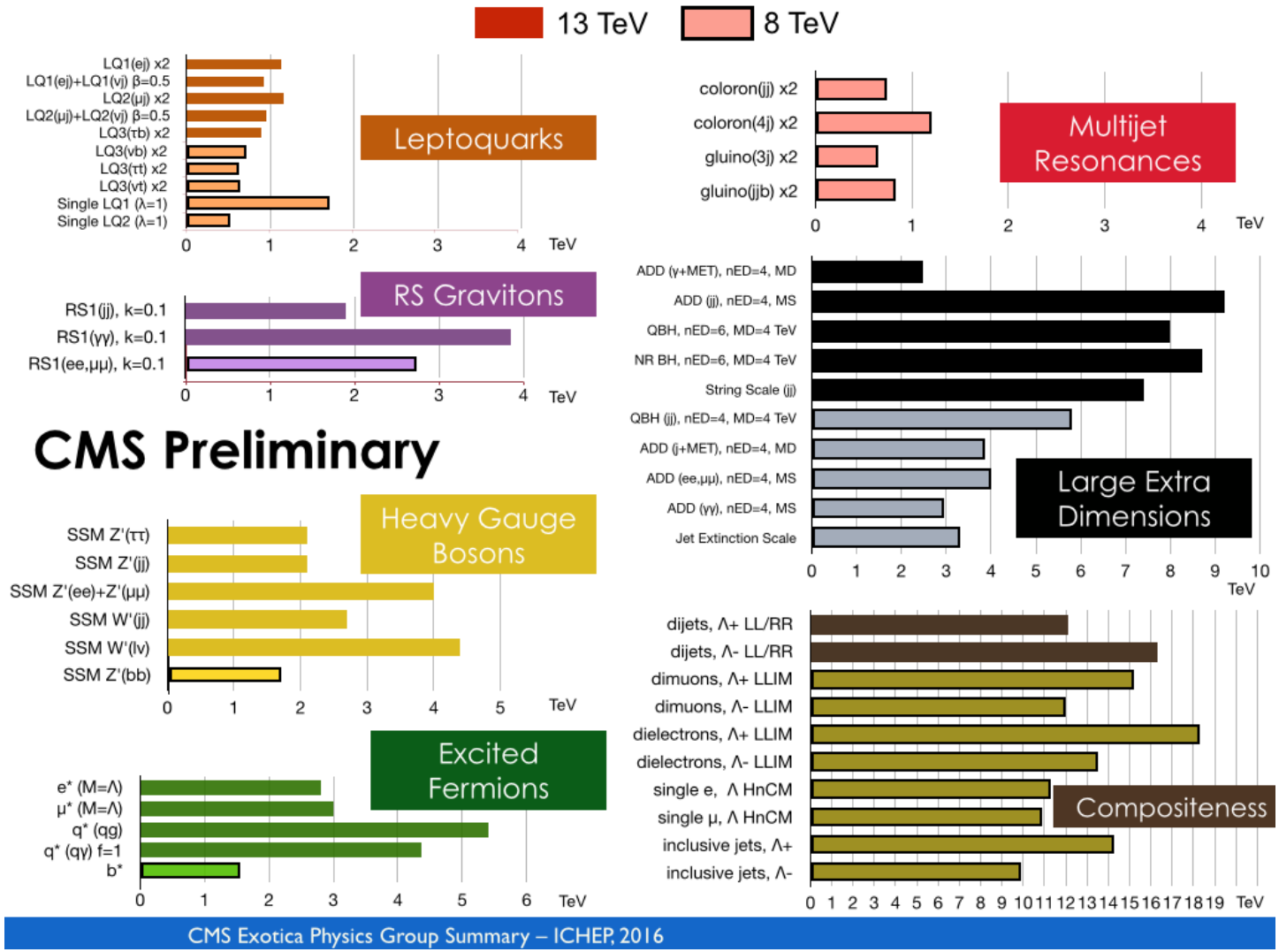


First of all I am not an expert, at DESY we do exotica, but different searches.

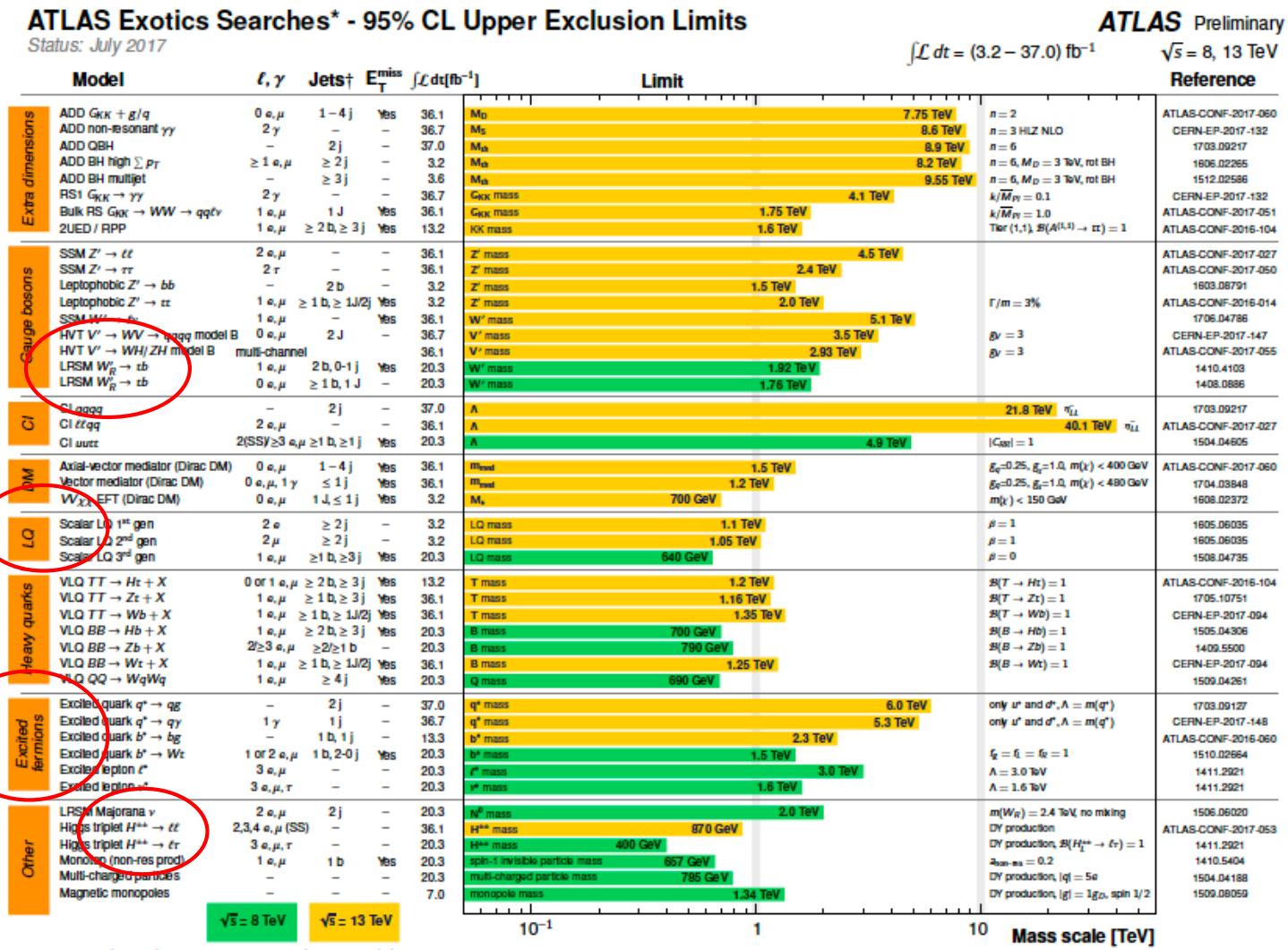
- I collected few results/slides which I thought important for ep physics.
- Many different searches, recently focused on dark matter, SUSY, heavy resonances (boosted techniques), long-lived particles.
- More than 100 Exotica papers in ATLAS/CMS only in 2016.



Searches at CMS



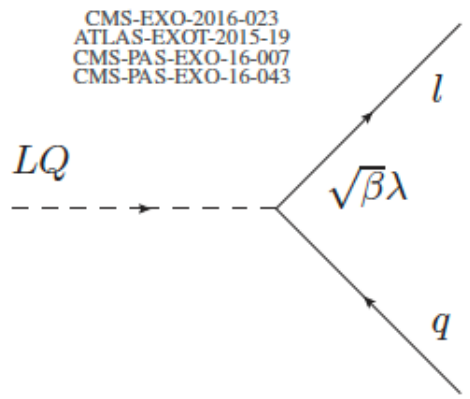
Searches at ATLAS, more recent compilation

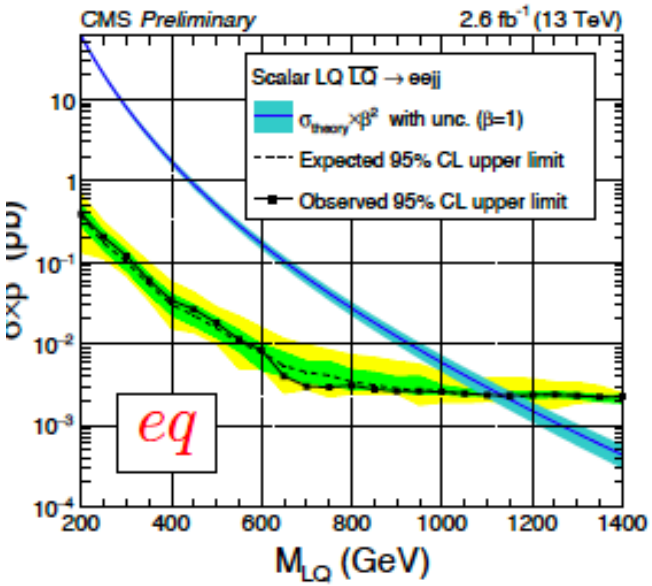


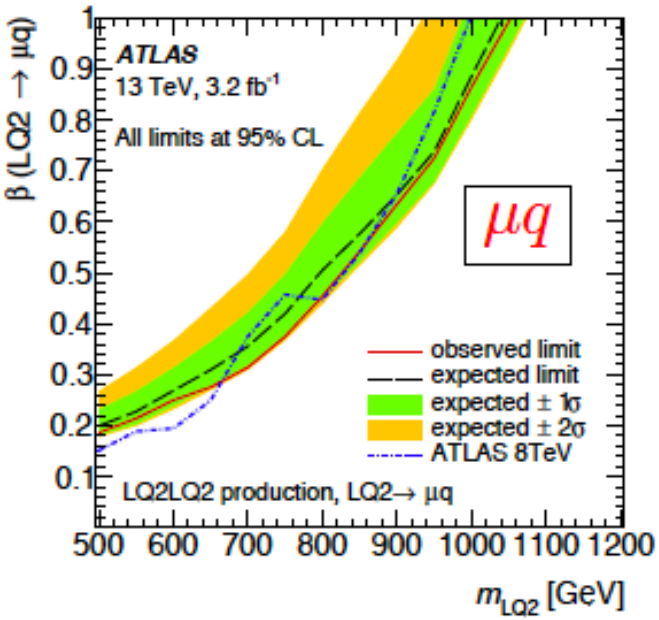
*Only a selection of the available mass limits on new states or phenomena is shown.
†Small-radius (large-radius) jets are denoted by the letter j (J).

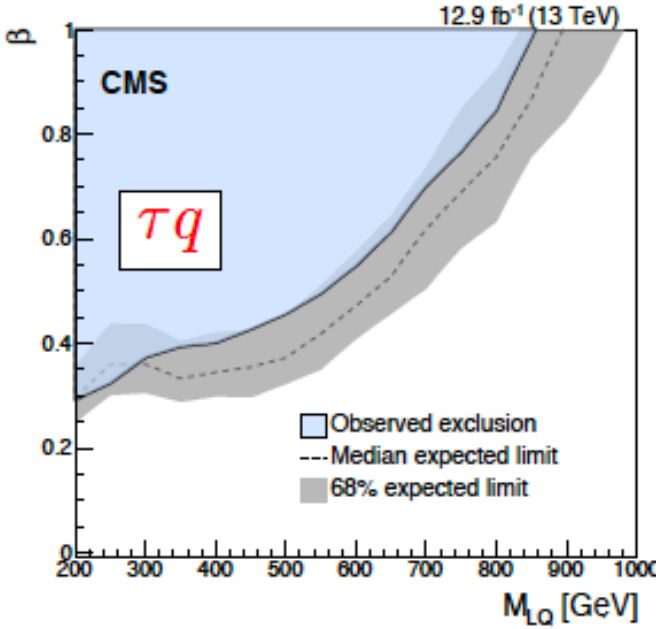
Search for Leptoquarks in pairs

Use of BRW model, assume narrow resonances.
Searches in 1st, 2nd, 3rd generation.
The limit depends on the branching ratio β, and not on the coupling to lq, λ, this is opposite to ep.







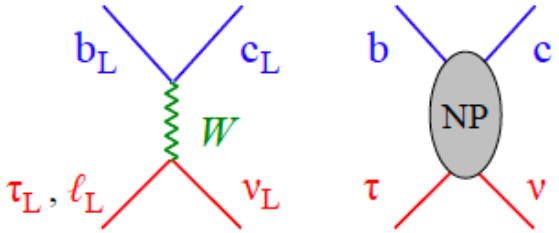


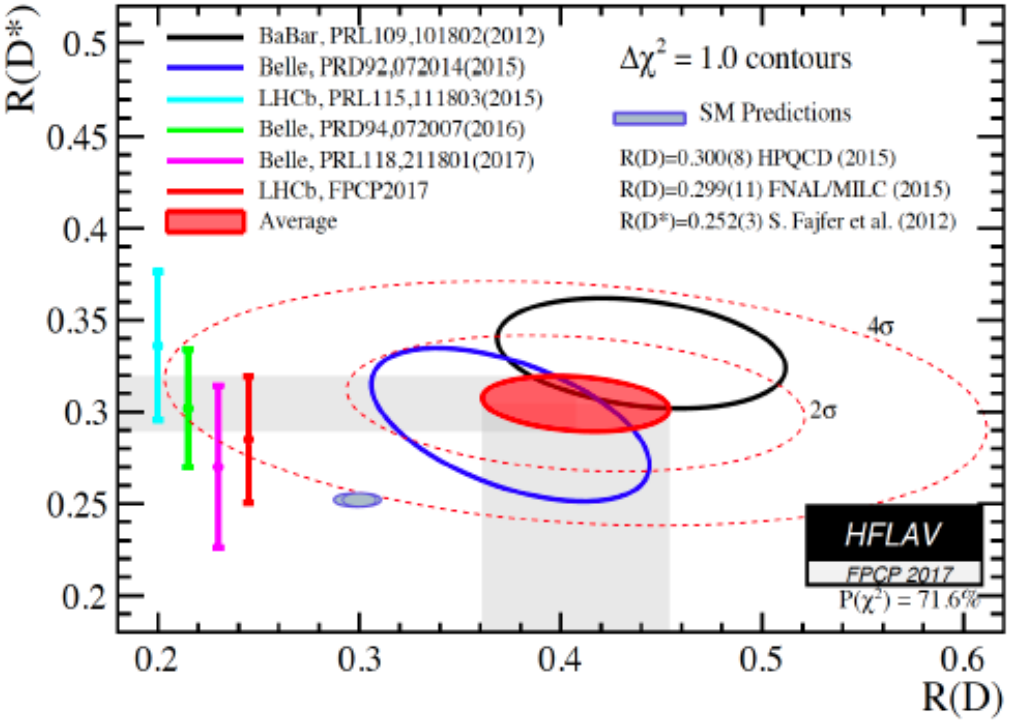
From slides at SUSY conference at Mumbai

Recently a lot of interest

Consistent set of anomalies observed recently in flavour:

1) b -> c, charged current, tau versus other lepton





$$R(X) = \frac{\Gamma(B \to X\tau\bar{\nu})}{\Gamma(B \to X\ell\bar{\nu})}$$

X = D or D*

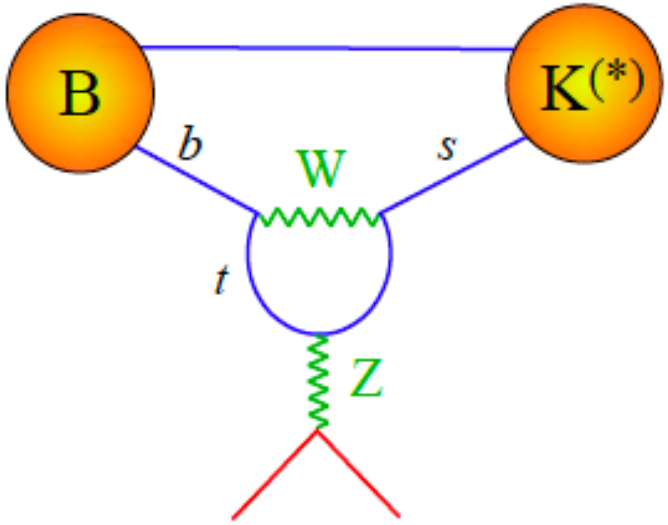
Observed by 3 experiments

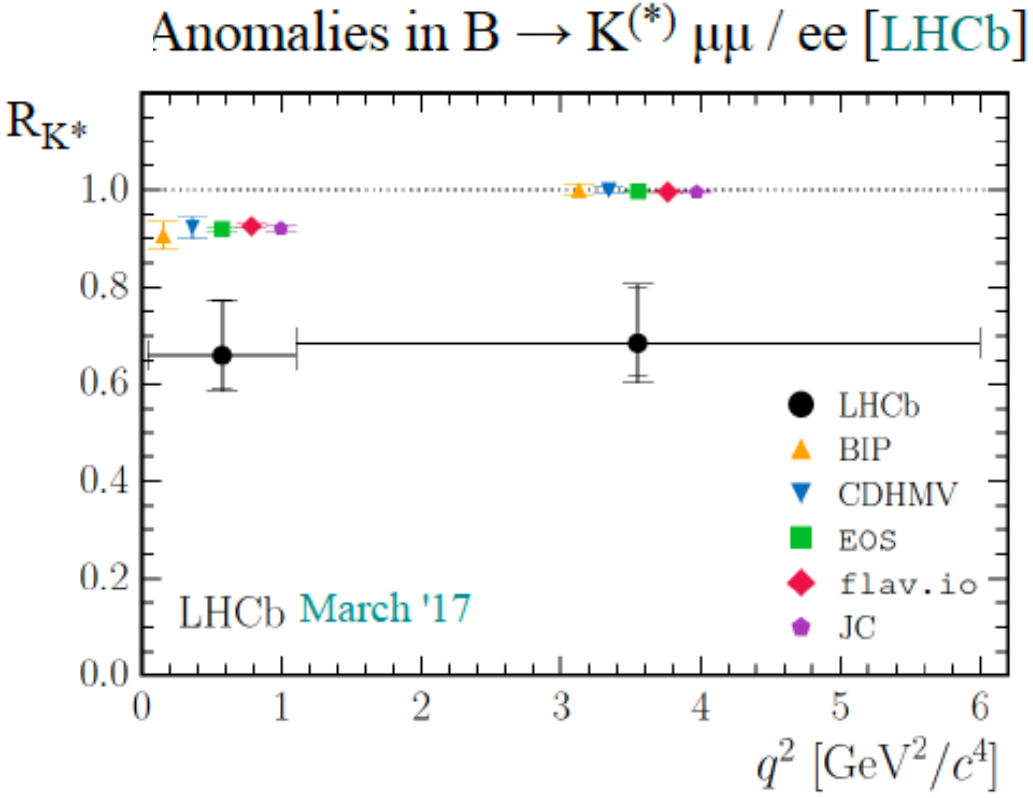
Plots taken from a seminar from Isidori at a CMS meeting

Recently a lot of interest

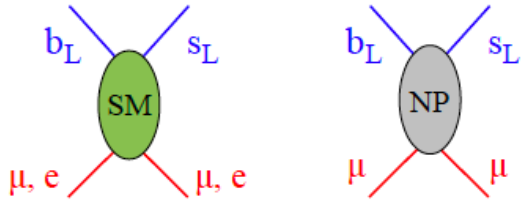
Consistent set of anomalies observed recently in flavour:

2) b -> s, neutral currents, muon versus electron





Anomalies observed in angular distributions and other observables by LHCb. Results and fits seem to point to the fact that there could be new physics in b -> s$\mu\mu$, and not in b → see



Recently a lot of interest

Quark level transition $b \to c\ell\bar{\nu}$

R_D, R_{D^*}: combined $\sim 4\sigma$ deviation (

$$R^{\tau/\ell}_{D^{(*)}} = \frac{\Gamma(\bar{B} \to D^{(*)}\tau\bar{\nu})}{\Gamma(\bar{B} \to D^{(*)}\ell\bar{\nu})}$$

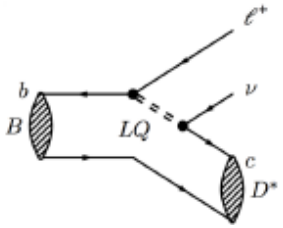
Quark level transition $b \to s\ell\bar{\ell}$

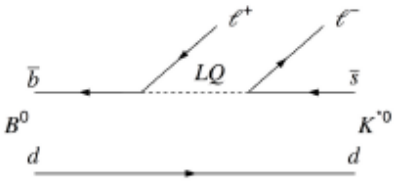
R_K, R_{K^*}: $\sim 2.5\ \sigma$ deviation (LHCb)

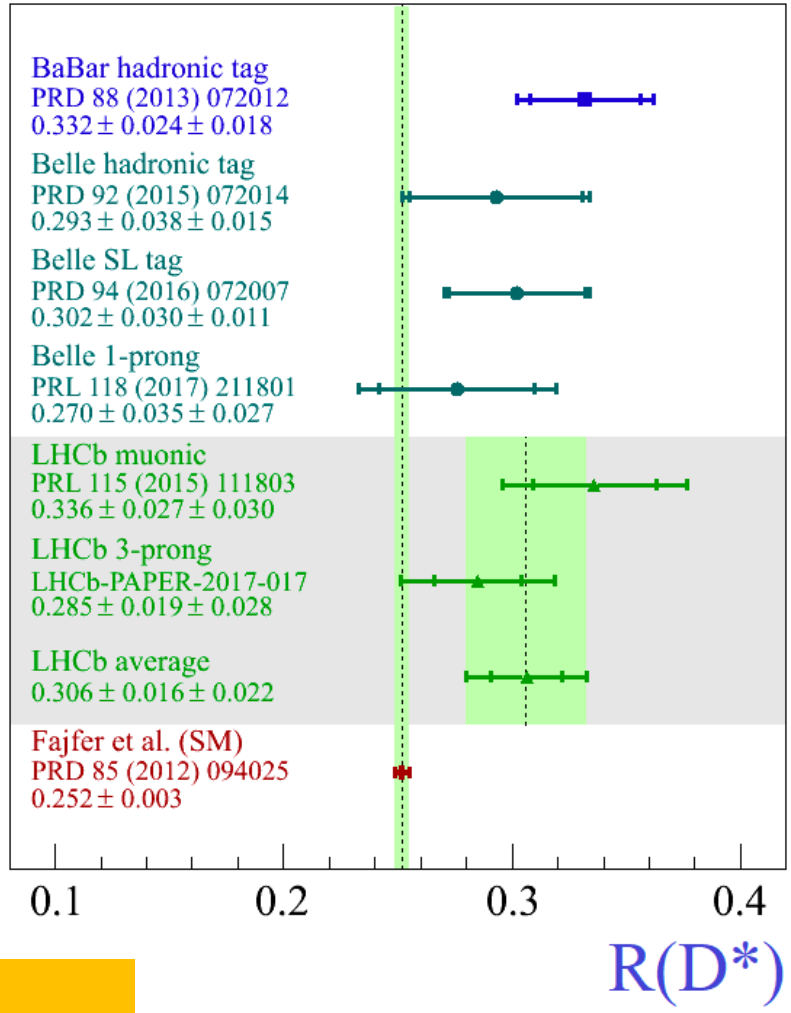
$$R_{K^{(*)}} = \frac{\Gamma(\bar{B} \to \bar{K}^{(*)}\mu^+\mu^-)}{\Gamma(\bar{B} \to \bar{K}^{(*)}e^+e^-)}$$

$B^0 \to K^{*0}\mu^+\mu-$ angular analysis:
3.4 σ deviation (LHCb) (Click Me)
(with lower precision
Belle (Click Me) , CMS (Click Me) , ATLAS

Slide taken from a CMS meeting



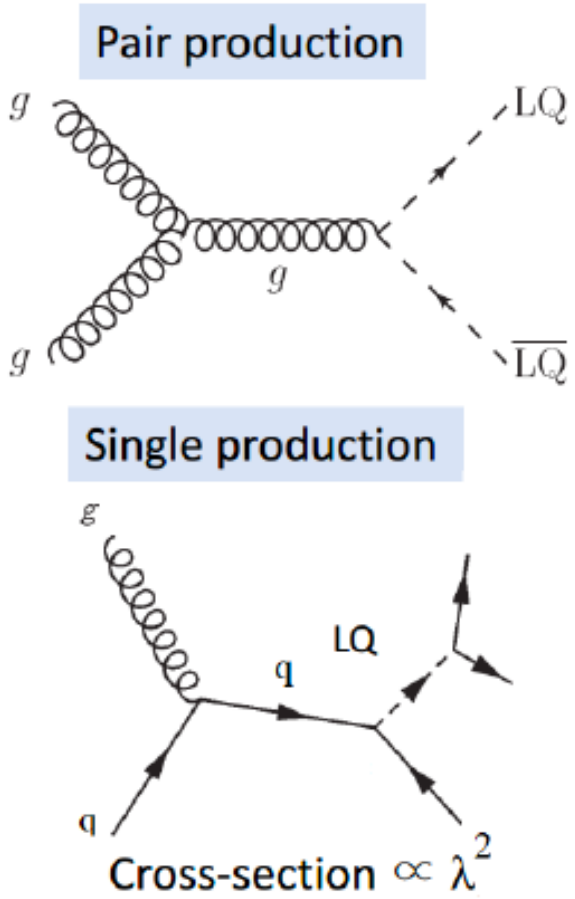




Anomalies are all seen in lepton-quark couplings.
Explanation could be a LQ coupling to 3rd generation

LQ searches, pair and single production

Slide taken from a CMS meeting, plot from arXiv:1706.07808



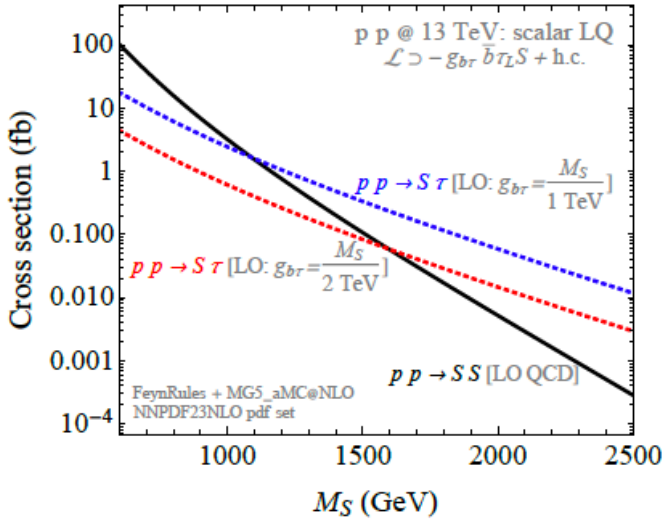
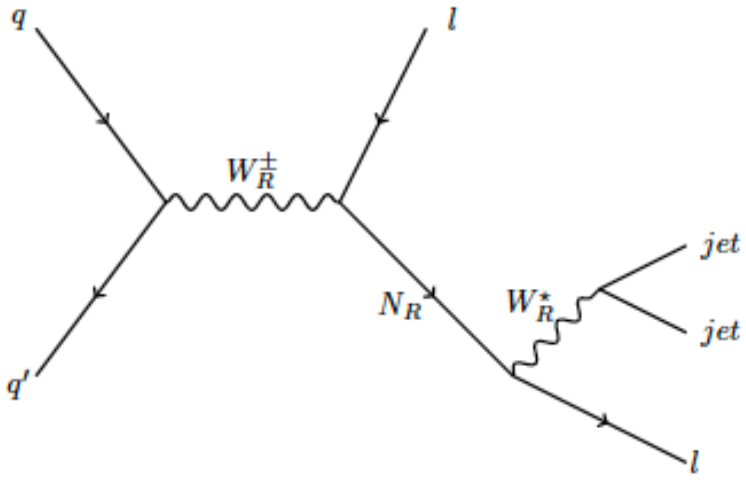
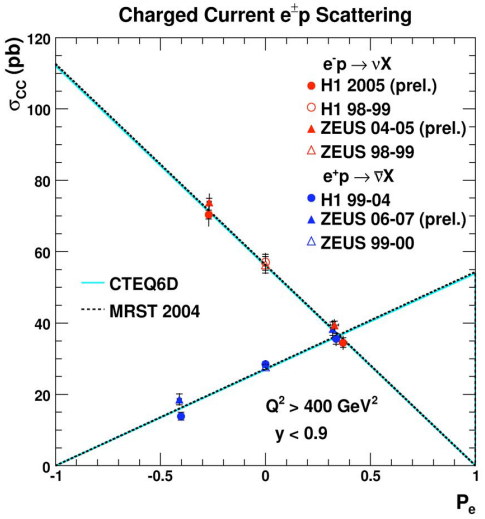


Figure 7: Cross section (in fb) at 13 TeV *pp* collider for: (a) scalar LQ pair production (solid black line), and (b) single LQ + τ production for the two coupling benchmarks motivated by the fit to low-energy data (dashed blue and red lines).

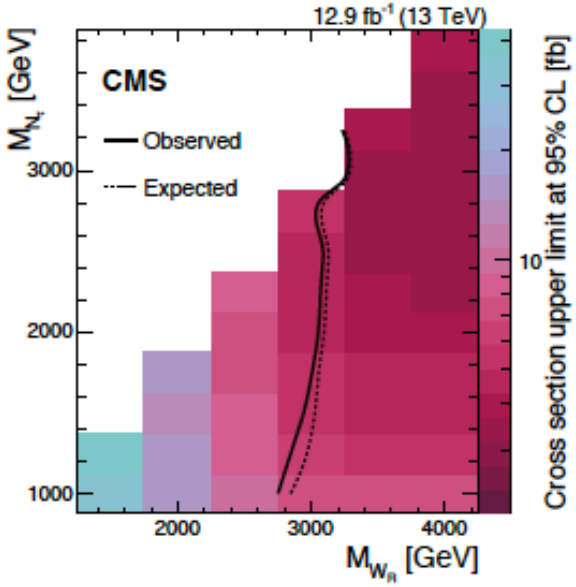
At high mass, single LQ production dominates over pair production, the crossing point depends on λ and the quark generation

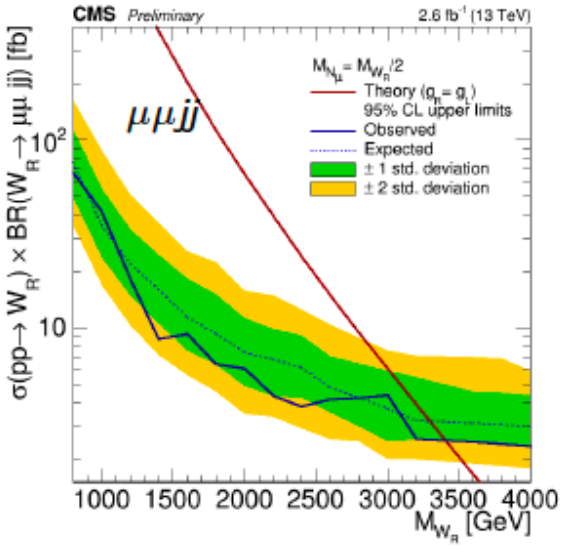
Search for heavy neutrinos N_R, W_R





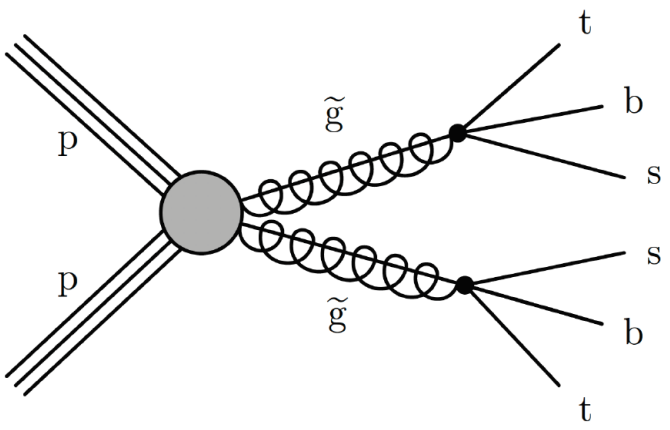
At HERA





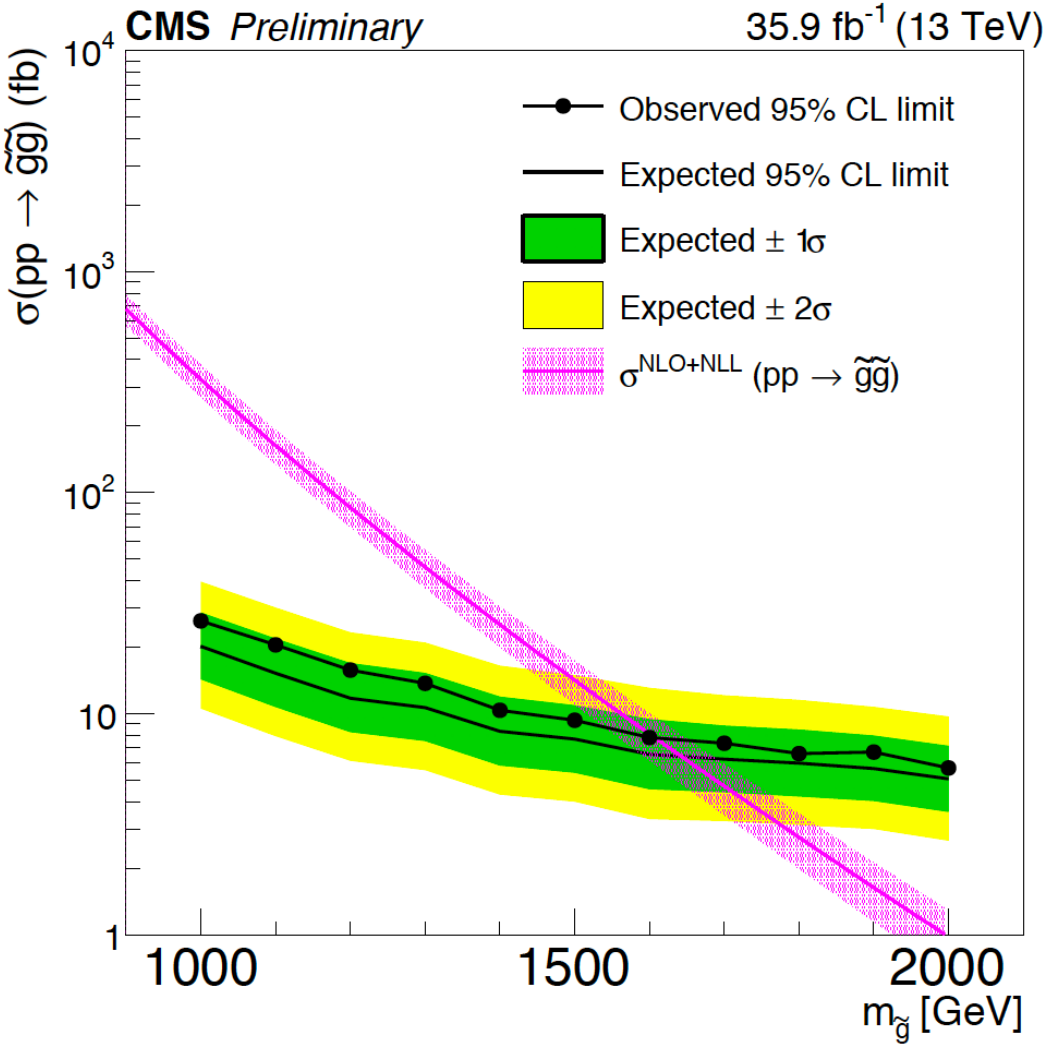
Stringent limits on W_R

SUSY R-parity violation



LHC started to look for RP-conserving SUSY, due to the very clear signature of missing transverse energy.

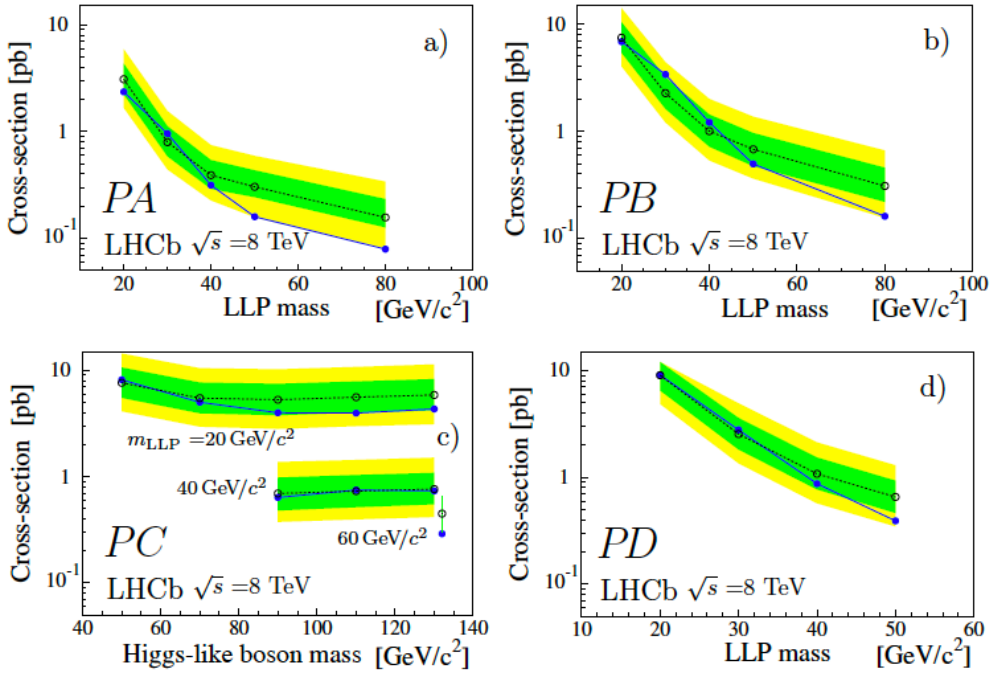
But recently they have started looking also for RPV SUSY, example here.



Search for massive long-lived particles decaying semileptonically in the LHCb detector

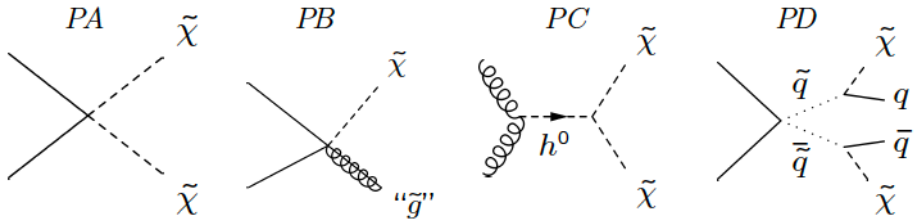
arXiv:1612.00945

Look for massive long-lived particles (LLP) in the mSUGRA model, where the neutralinos can decay in muon+jets.
Signature is a displaced vertex.
LLP mass: [20-80] GeV, lifetime: [5-100] ps

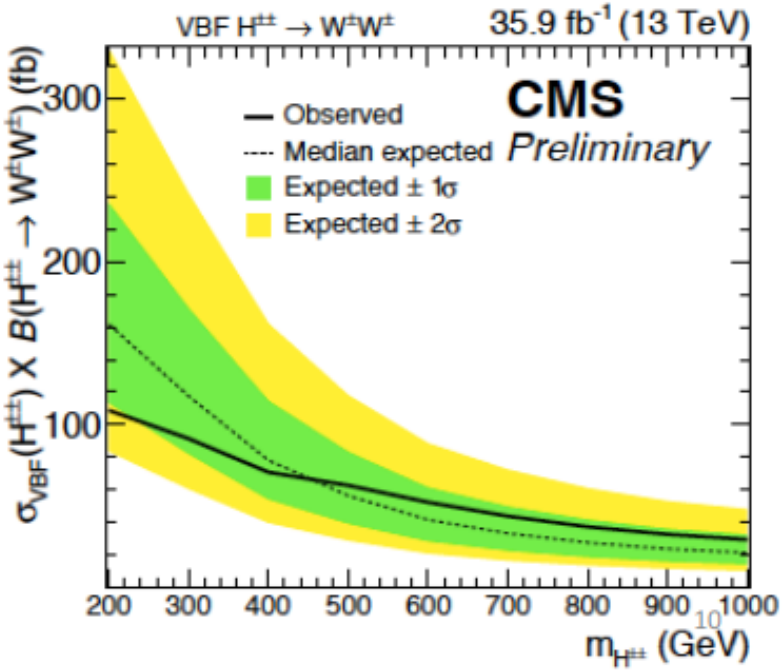


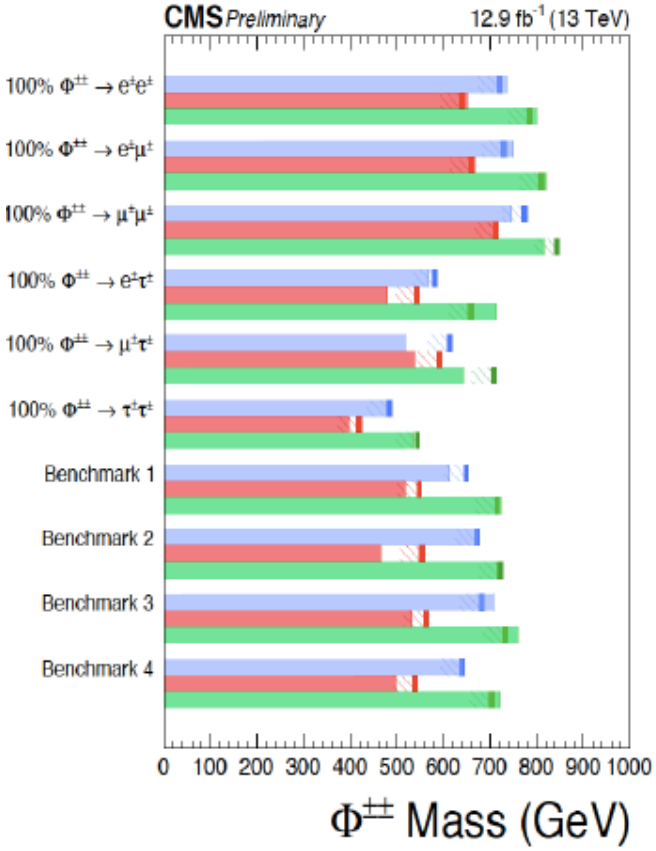
In this paper a search for massive long-lived particles is presented, using proton-proton collision data collected by the LHCb detector at $\sqrt{s} = 7$ and 8 TeV, corresponding to integrated luminosities of 1 and 2 fb^{-1}, respectively. The event topology considered in this study is a displaced vertex with several tracks including a high p_T muon. This topology is found in the context of the minimal super-gravity (mSUGRA) realisation of the MSSM, with R-parity violation [13], in which the neutralino can decay into a muon and two jets. Neutralinos can be produced by a variety of processes. In this paper

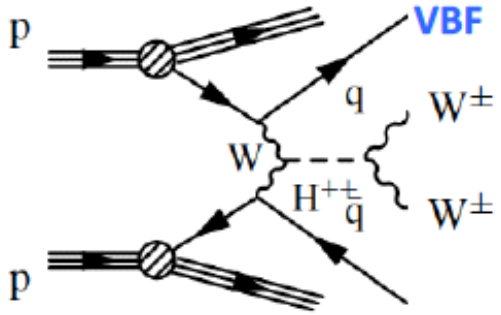
LLP not so high mass, coupling to l+quarks

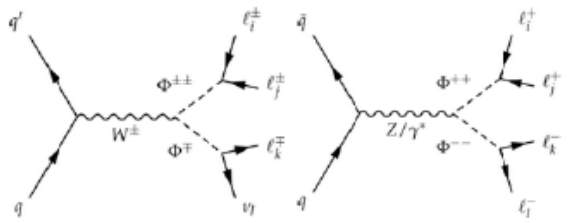


Doubly Charged Higgs







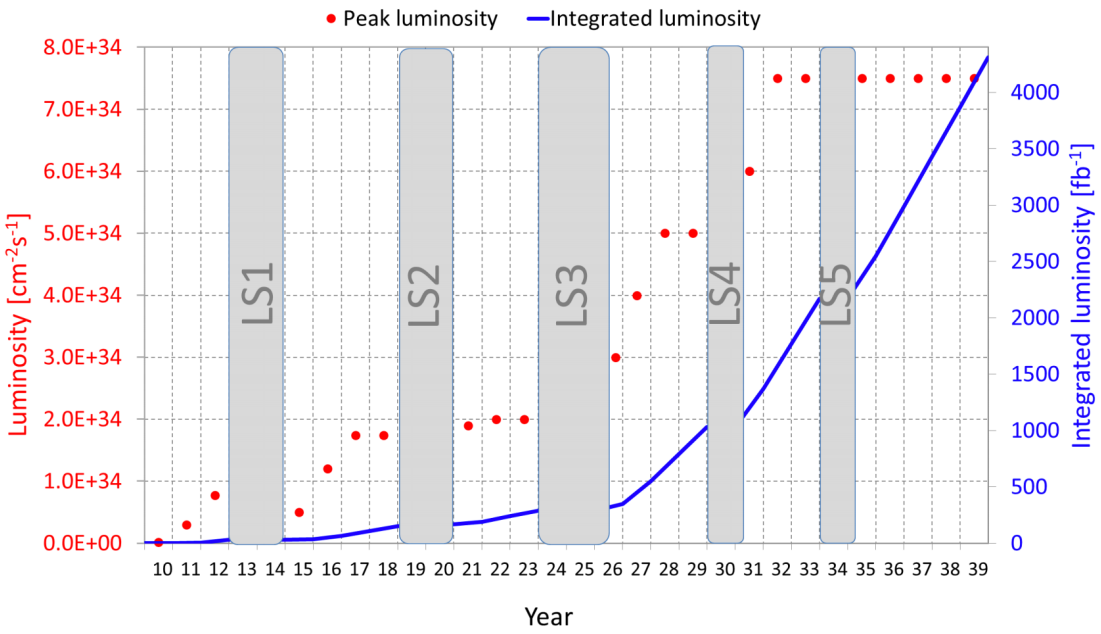


$H^{\pm\pm} \longrightarrow \ell^{\pm}\ell^{\pm}$

Slides from M. D'Alfonso at HH

Conclusion

- We have taken only 3% of whole LHC/HL-LHC data. Expect also $\sqrt{s} = 14\ TeV$ at some point.
- It is clear that LHC has put very high mass constraints on a lot of models.
- But we still look and find “strange” things also at much lower energies.
- Recent results from LHCb on LFV seems to point to a leptoquark.
- It shows that one can look for new physics also at lower energy and ep is a much “cleaner” environment compared to LHC.
- b- and c-tagging, tau reconstruction, long-lived particles important.



Also a lot of PDFs results from LHC by now. We at DESY are involved in W-charge asymmetry (u/d), W+charm (strange), jet cross sections (gluon at mid-high x), top