Alternative New Physics in CMS.

Camilo Carrillo
for the CMS collaboration

INFN - Istituto Nazionale di Fisica Nucleare
Sezione di Napoli

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The Large Hadron Collider

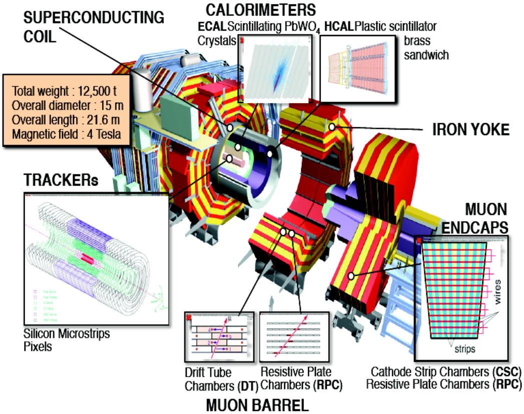
Located near Geneva city, a double proton-beam accelerator
Diameter 27km, $\sqrt{s} = 7$ TeV, Luminosity $\approx 10^{33}$ cm^{-2} s^{-1}
p-p collisions take place in four points since march 2010.

The Large Hadron Collider

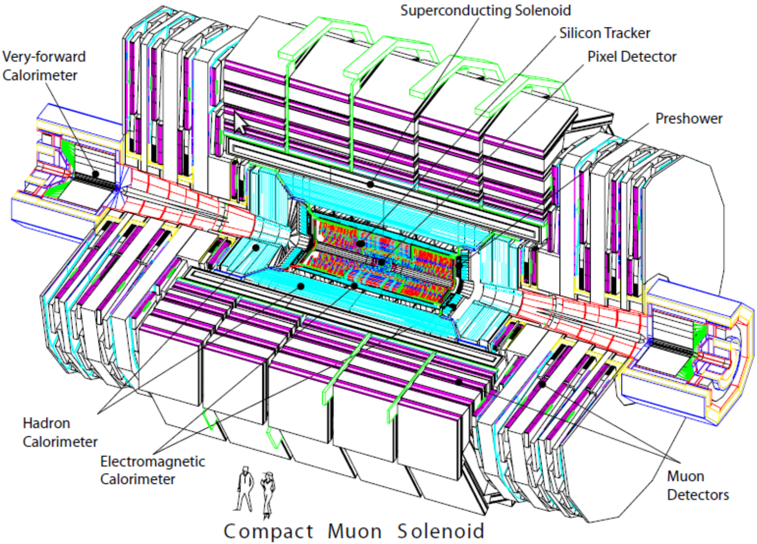
100m underground, 6 experiments: ATLAS, **CMS**, LHCb, ALICE, LHCf and TOTEM. ATLAS and CMS are general purpose experiments, looking for any kind of new physics like Higgs, SUSY and Exotica.

The CMS experiment

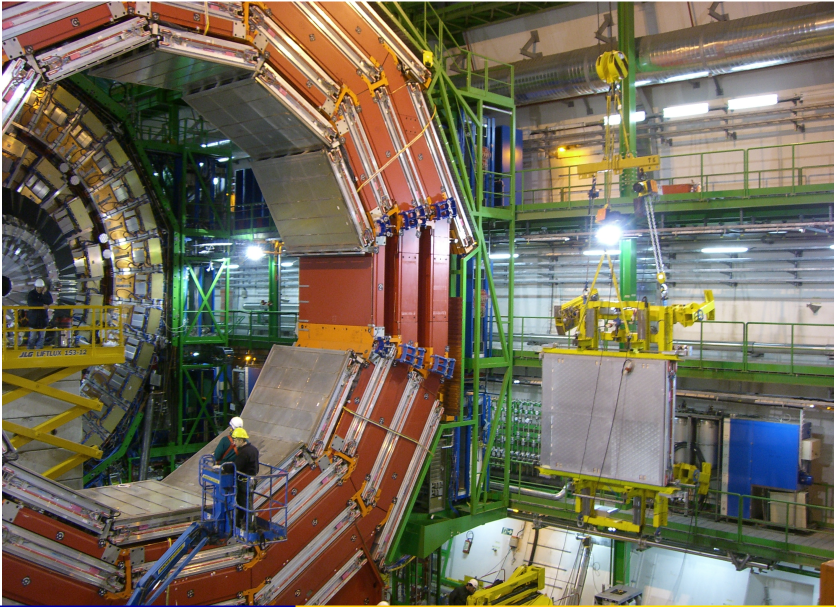
The **C**ompact **M**uon **S**olenoid, from the inner to the outer section: The Pixel detector, The Silicon Tracker, The Electromagnetic and Hadronic Calorimeter, the solenoidal magnet, and the Muon System (DTs, CSCs and RPCs) interlayed with the Iron Yoke.



The CMS experiment



The CMS experiment



The CMS experiment

The CMS experiment

The CMS experiment

The CMS Collaboration

Search for Leptoquarks

Leptoquarks are hypothetical particles predicted by different theories beyond the SM.
They are the mediators of new interactions between leptons and quarks.
They may explain the existing symmetry between the number of leptons and quarks in the nature.
In CMS we have looked for them in the following channels.

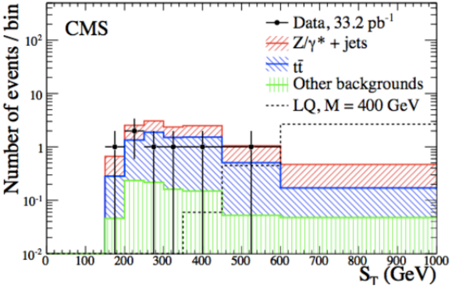
- The *eejj* channel
- The $\mu\mu jj$ channel
- The $e\nu jj$ channel

A free parameter in the models, predicting leptoquarks, is the branching ratio
β: LQ $\rightarrow \nu$ q, $(1-\beta)$: BR LQ $\rightarrow$ lq
The reconstructed variable S_T is the key of this analysis, defined as:

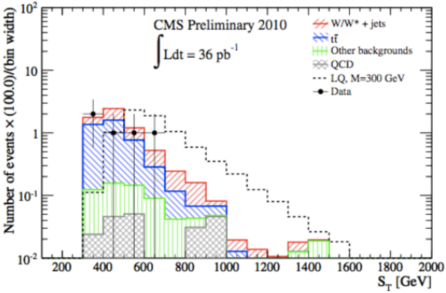
$$S_T = \begin{cases} p_T^{l1} + p_T^{l2} + p_T^{j1} + p_T^{j2} & \text{for LQ} \rightarrow \text{eejj or } \mu\mu\text{jj} \\ p_T^{l1} + MET + p_T^{j1} + p_T^{j2} & \text{for LQ} \rightarrow \text{e}\nu\text{jj} \end{cases}$$

First Generation

S_T shows an excelent ratio signal/background, and could be used for discovery and exclusions. The limits on mass depends on β when combining different channels for the first generation of leptoquarks.

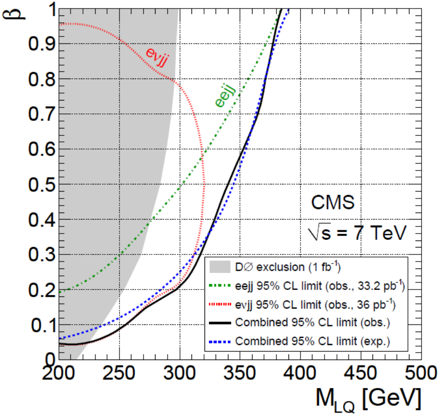


eejj channel



$e\nu jj$ channel

First Generation



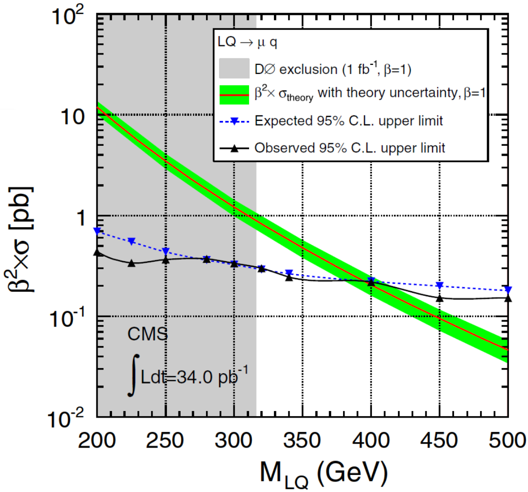
Combining both channels

$M_{LQ} > 340$ GeV for β=0.5

$M_{LQ} > 380$ GeV for β=1

arXiv:1105.5237v1 [hep-ex]

Second Generation



Just with $\mu\mu jj$

Using the same reconstructed varaible S_T

$M_{LQ} > 394$ GeV for β=1 The integration of the second channel $LQ \rightarrow \mu\nu$jj is ongoing.

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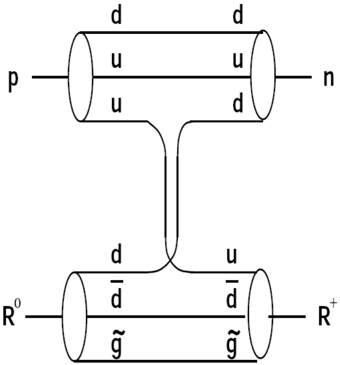
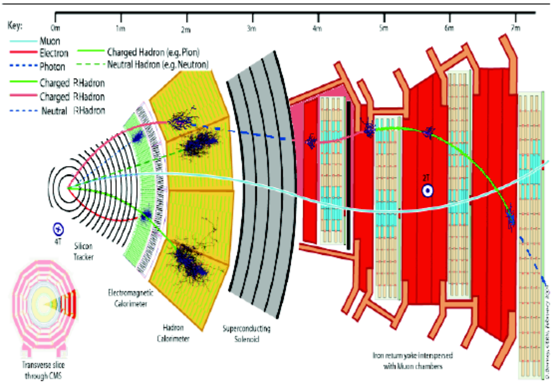
Search for Heavy Stable Charged Particles

- The HSCPs are predicted by several theoretical models like R-parity conserving SUSY, split SUSY, Universal Extra Dimensions models with Kaluza-Klein parity (KK-Parity), F-theory, etc.
- These models predict the existence of a lightest stable particle that is neutral and weakly interacting.
- In some scenarios another of the predicted states could have long life-time and electrical or color charge so that it is detectable. Usually the NLSP
- This state, called HSCP, acquires its long life-time due to constrains in its decay phase space.
- Long lived gluinos or stops will form bound states known as **R-Hadrons**. They could be R-Baryons, R-Mesons, or R-Glueballs

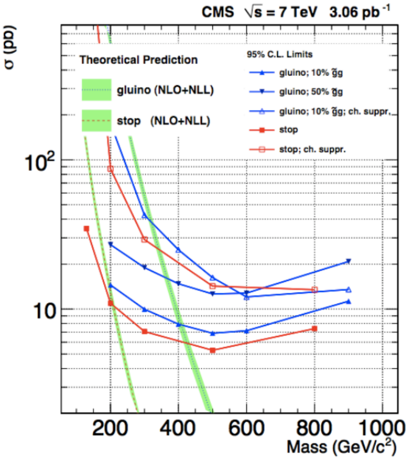




- R-Hadrons may flip their charge while crossing CMS. The identification of this particles is challenging.
- These particles could be stopped in the detector due to energy loss, decaying out-of-time w.r.t. to collisions. A dedicated search for this scenario is performed by CMS

HSCPs

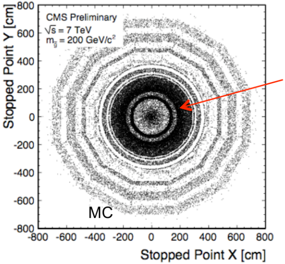
HSCPs are massive, $m_{HSCP} > 100\text{GeV}$, they will move slow when produced at $p \approx 1\ TeV$, $\beta\gamma = \frac{p}{m}$. Slow moving particles will leave a large dE/dX in silicon tracker, that could be use as a discriminator on the search for HSCPs.



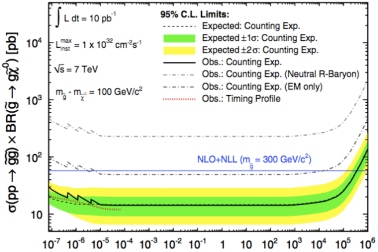
- The fraction of $\tilde{g}$ becoming a gluon ball $\tilde{g}g$ is a free parameter in the theoretical model.
- The last public result for the mass limit in the split SUSY scenario: $m_{\tilde{g}}$>311-398 GeV
- The last public result for the mass limit in the MSSM scenario: $m_{\tilde{t}_1}$>202 GeV

J. High Energy Phys. 03 (2011) 024

Stopped HSCPs



$M_{\tilde{g}} > 370$ GeV, $\tau = 10\ \mu s - 1000\ s$



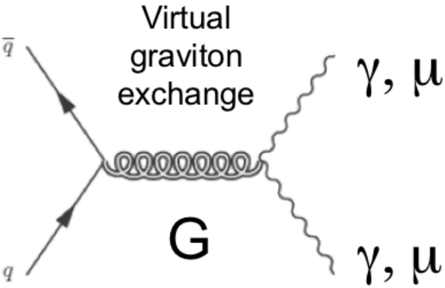
- HSCPs would be stopped with high probability in the HCAL
- A dedicated trigger was implemented to look for jet triggers in the HCAL not correlated with collisions, (in between bunch crossings or in between LHC fills)
- Mass limits for this scenario were imposed by CMS
- $M_{\tilde{g}} > 370\,\mathrm{GeV}$ for $\tau = 10\,\mu\,\mathrm{s} \rightarrow 1000\,\mathrm{s}$

Phys. Rev. Lett.106, 011801 (2011)

Search for Large Extra Dimensions

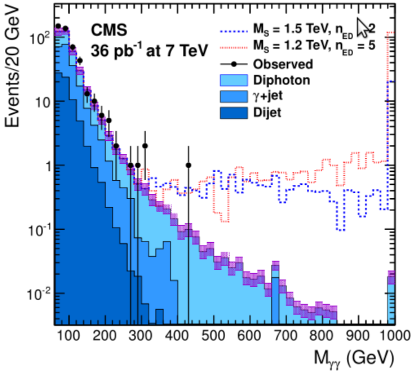
- Compact large extra dimensions (ED) are a proposed solution to the hierarchy problem of the SM.
- The fundamental scale of gravity $M_{Planck} \sim 10^{19} GeV$ is orders of magnitude higher than the electroweak symmetry breaking scale $\sim 10^3$ GeV.
- In the ADD model, the SM is constrained to the common 3+1 space-time dimensions, while gravity is free to propagate through the entire multidimensional space.
- The gravitational flux in 3+1 dimensions is effectively diluted by virtue of the multidimensional Gauss's Law.
- The Planck scale can be lowered to the electroweak scale, thus making production of gravitons possible at the LHC.

$\mu\mu$ and $\gamma\gamma$



- Searches for virtual-graviton contributions in the $\gamma\gamma$ and $\mu\mu$ have been performed.
- The studies are done in the invariant mass spectrum for the two particles system.
- The ADD signal would not appear as a narrow peak but as an overall excess of events at high values of invariant mass.

$\mu\mu$ and $\gamma\gamma$



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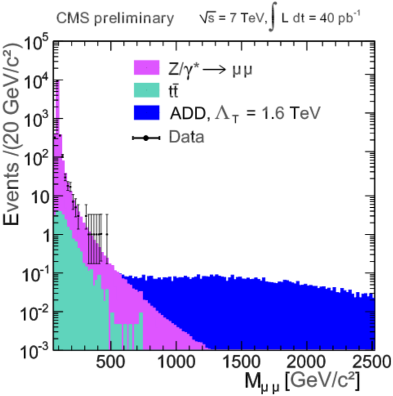
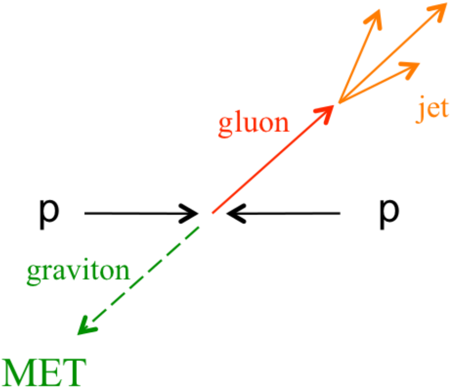


EXO-10-020

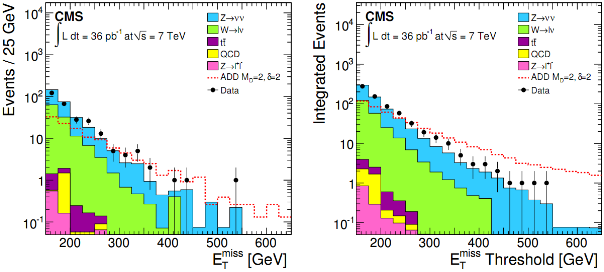
- In both $\gamma\gamma$ and $\mu\mu$ channels, the data is found to be consistent with SM expectations.
- No event observed with $M_{\gamma\gamma} > 500\,\text{GeV}$ $M_{\mu\mu} > 600\,\text{GeV}$

j+MET

- Large Extradimensions allow the production of a Graviton that will propagate in the extra-dimensions.
- pp→gG
- Then we look for: One high p_T jet + large MET + no leptons



j+MET



arXiv:1106.4775v1 [hep-ex]

- Suppress cosmic/beam halo/instrumental backgrounds, data-driven estimate for Z $\rightarrow \nu\nu$ + jets background
- Data consistent with SM, set limits on M_D ("True Plank Scale") vs δ (number of extra-dimensions)

CMS limits on M_D (36 pb^{-1})

δ	With K-Factor**	No K-Factor
2	2.37 TeV	2.16 TeV
3	1.98 TeV	1.83 TeV
4	1.77 TeV	1.67 TeV

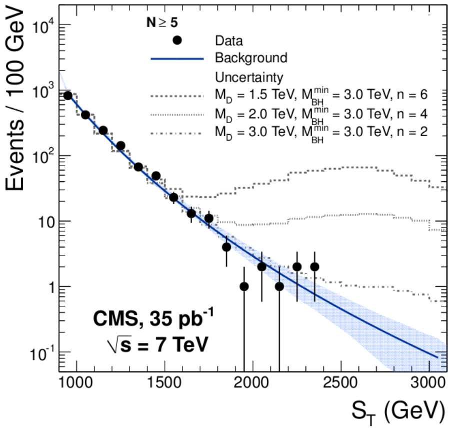
** = 1.5 (1.4) for δ=2,3 (4)

δ	CDF	LEP
2	1.4 TeV	1.6 TeV
3	1.15 TeV	1.2 TeV
4	1.04 TeV	0.94 TeV

Search for Microscopic Black Hole Signatures

- Microscopic Black Holes are predicted by models with extra dimensions.
- Multiple high-energy jets, leptons, and photons, are a typical signal expected from a microscopic black hole
- Good agreement with the standard model backgrounds is observed for various final-state multiplicities and model-independent limits on new physics in these final states are set

Search for Microscopic Black Hole Signatures



arXiv:1012.3375

- Using simple semi-classical approximation, limits on the minimum black hole mass are derived as well, in the range 3.5-4.5 TeV

Conclusions

- Many searches are performed in CMS in various physics channels and different signals.
- In many cases the limits imposed by CMS are the most restrictive at the moment.
- No significant excess has been found.
- All the results are compatible with the SM prediction.
- Good understanding of the background for differente signals (mainly data-driven).
- 2 weeks ago CMS recorded 1fb^{-1}, all these analysis will be updated.
- Looking forward to suprises.