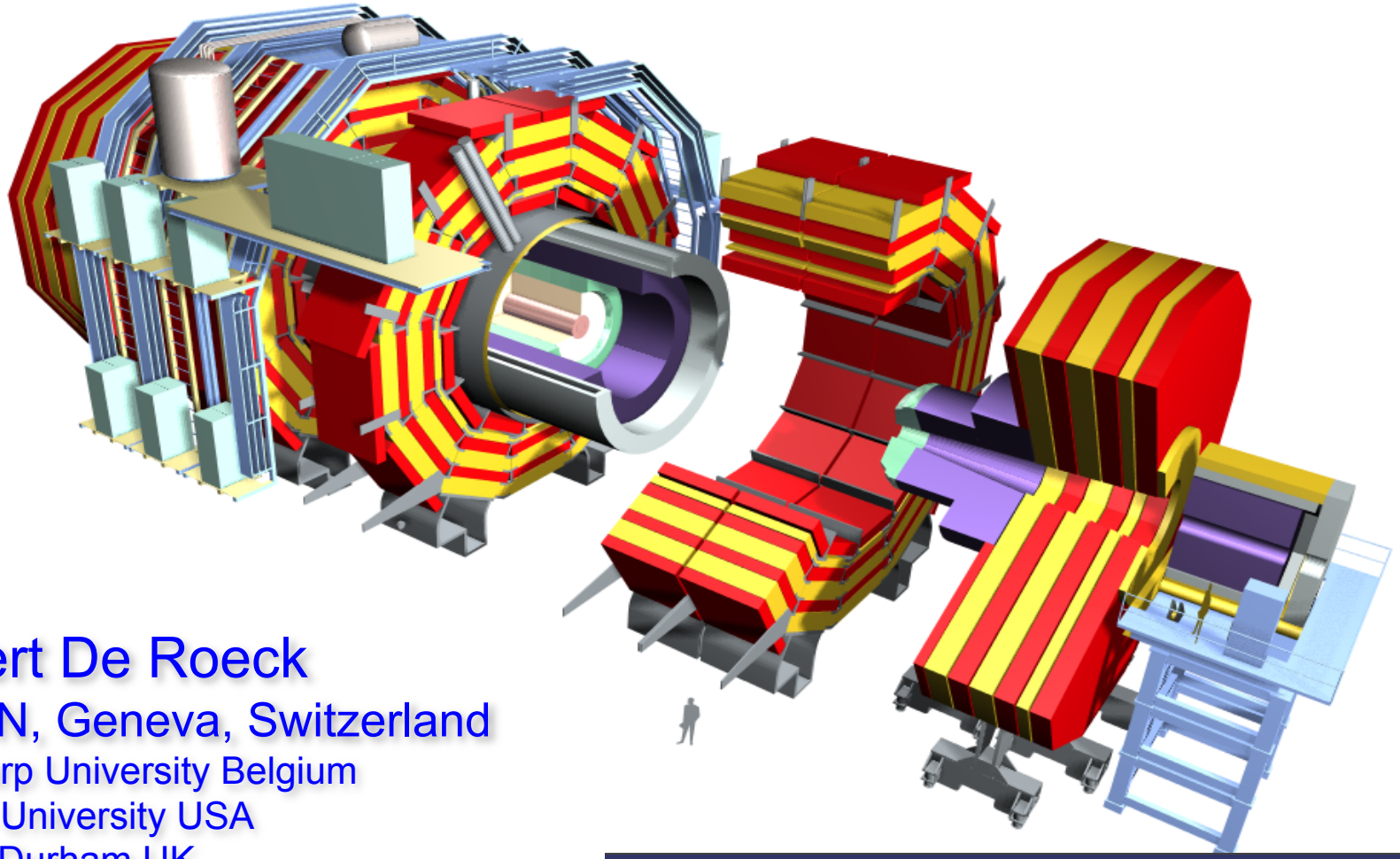
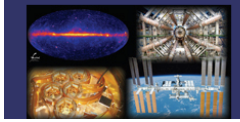
Searches at CMS and Dark Matter

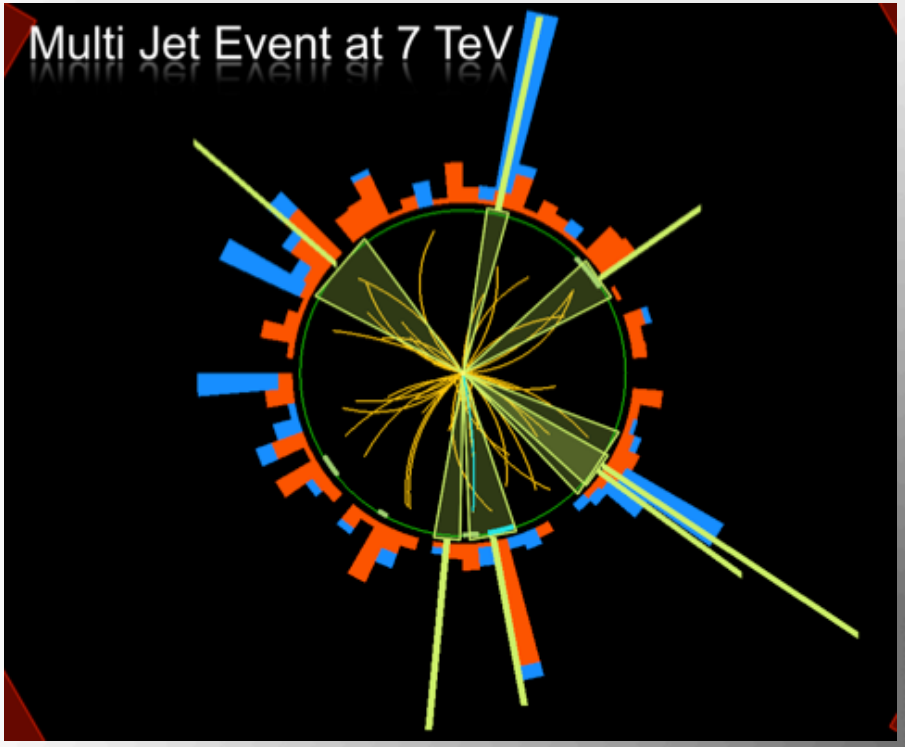


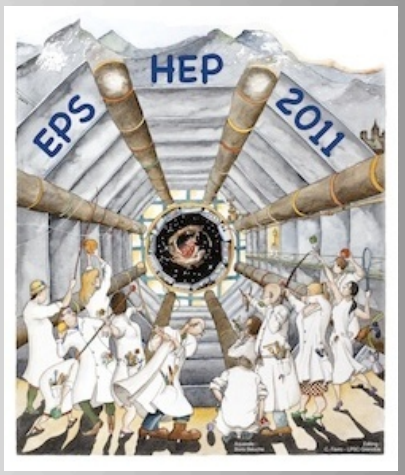
Albert De Roeck
CERN, Geneva, Switzerland
Antwerp University Belgium
Davis University USA
IPPP, Durham UK



Dark Matter underground and in the heavens - DMUH11

18-29 July 2011 *CERN*
Europe/Zurich timezone





Outline

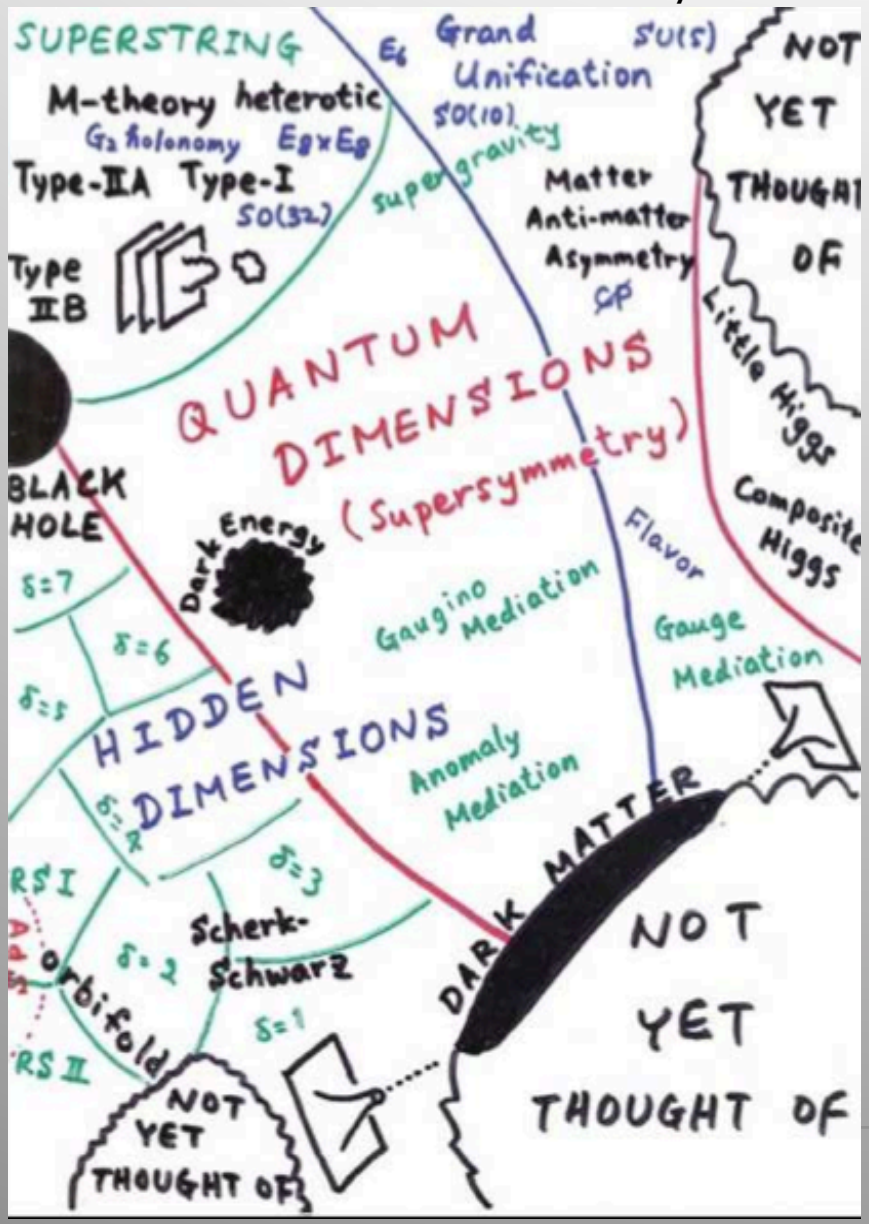
- Introduction
- Recent Physics Results at 7 TeV & The Dark Matter Connection
  - Supersymmetry
  - Higgs
  - Exotica
- Summary

Physics Results

- Studies of general characteristics of minimum bias events (our future pile-up), soft physics
- Jet physics & QCD
- Heavy ion physics
- Heavy flavor physics
- W,Z boson production at 7 TeV
- Top quark production at 7 TeV
- Searches for new physics: $\Rightarrow$ Dark Matter ??
  - Supersymmetry (Stable sparticles)
  - Other: E.g. Extra Dimensions UED (Lightest KK states)
  - Higgs Searches (Properties to calculate Ωh^2)

Beyond the Standard Model: No Lack of Ideas

H. Murayama



During the last ~10 years LHC experimentalists got more models to deal with than we needed…

Some of the latest: heavy stable charged particles, hidden valley models, Quirks, the dark sector…

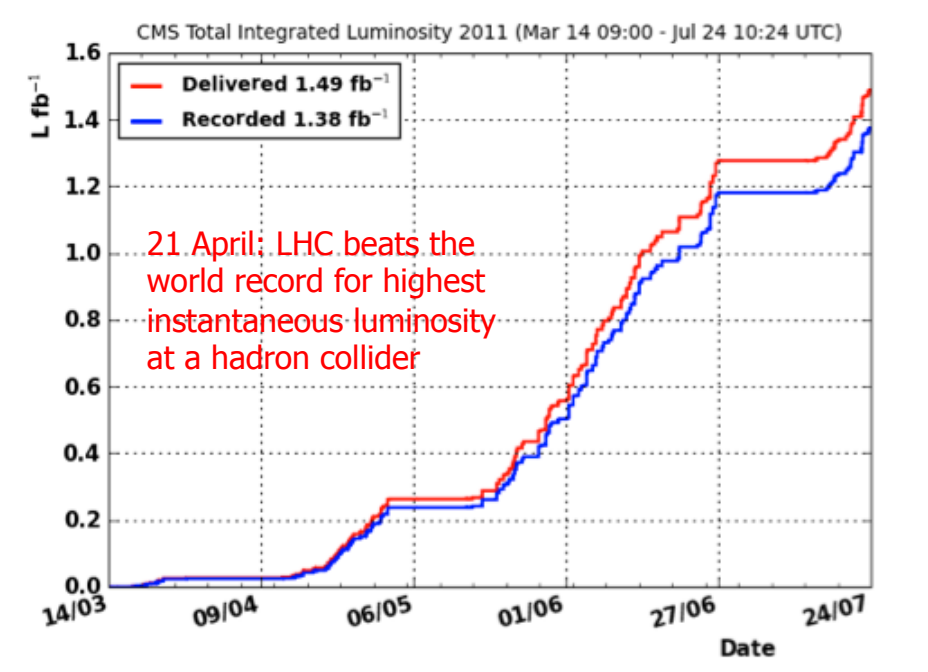
Candidates for dark matter

Many! Some interesting candidates are:

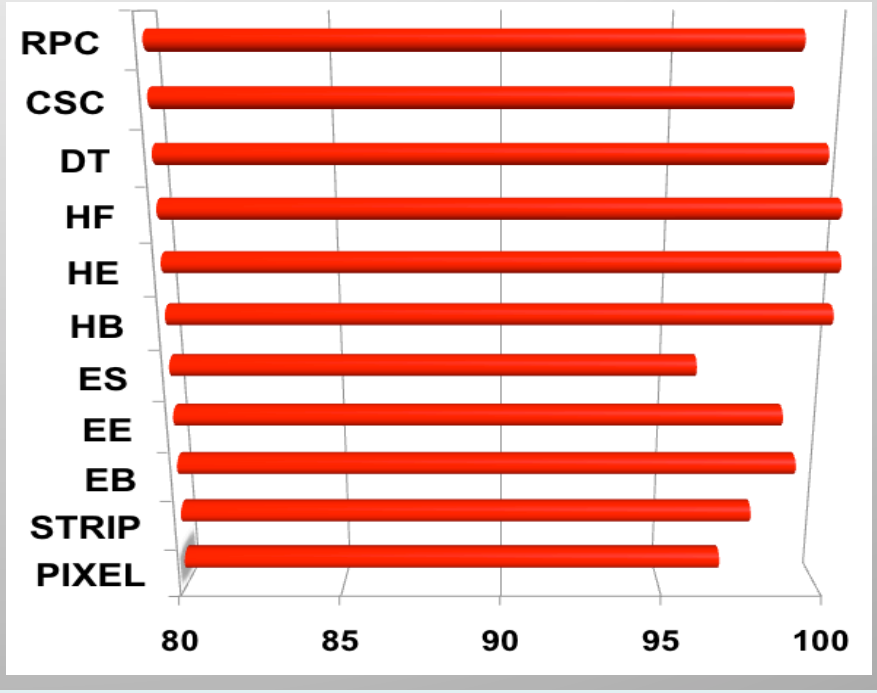
- Massive SM neutrinos (now excluded)
- Axions
- Heavy sterile neutrinos
- Neutralinos (requires R-parity conservation)
- Gravitinos
- Axinos
- Lightest Kaluza-Klein particles (B^1, KK graviton), scalar singlets, Q-balls, branons, WIMPzillas, mini-black holes, cryptons, monopoles...

Luminosity in 2011 & CMS Operation

Total luminosity



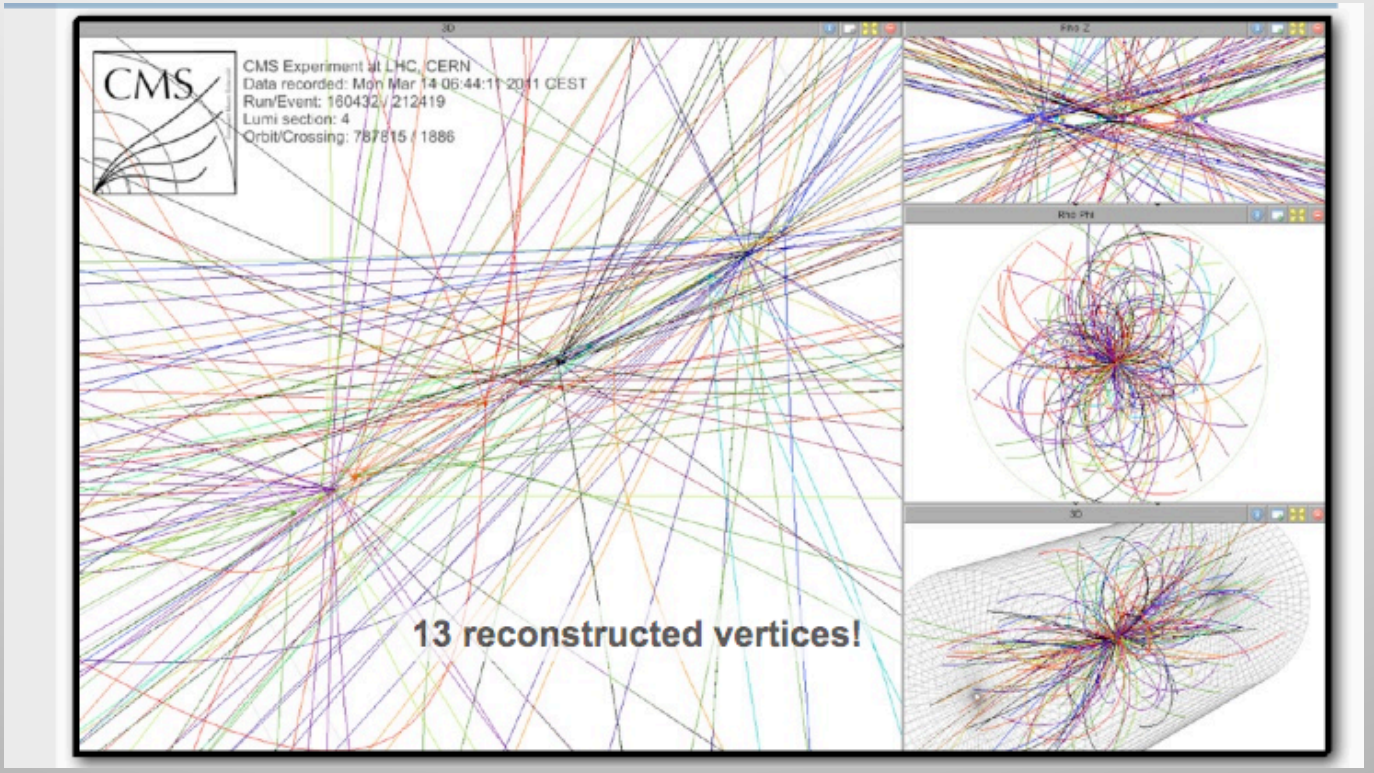
Fraction of CMS live channels



- CMS is up and running with high efficiency
- The LHC has produced already ~40 times more luminosity compared to 2010
- LHC running now with 1380 bunches and >1.5•10^{33} $cm^{-2}s^{-1}$ luminosity

-> 1 fb^{-1} now, ~5 fb^{-1} by the end of the year

New Challenges at the LHC



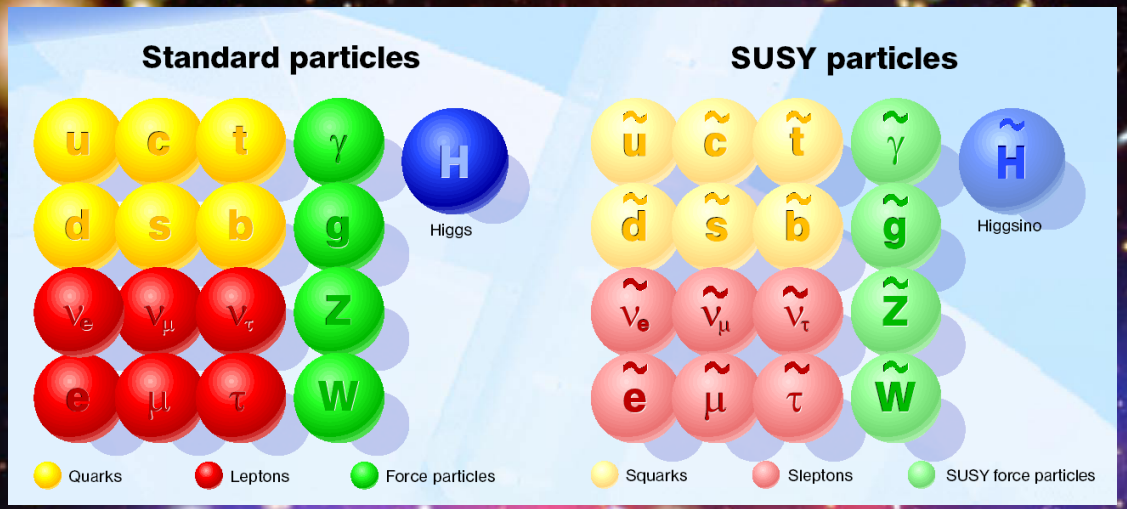
…many collisions in one bunch crossing!

On average now we have 5-8 events per bunch crossing

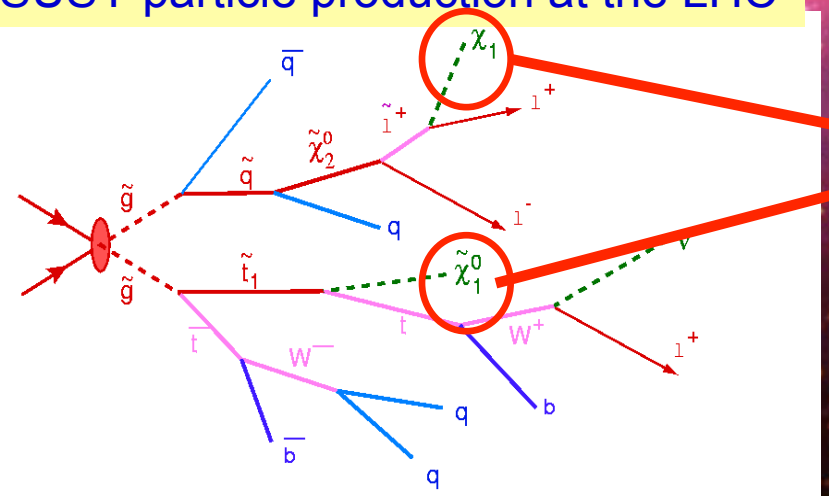
Expect this to increase to ~ 15-30 events during the year

Pile-up!!!

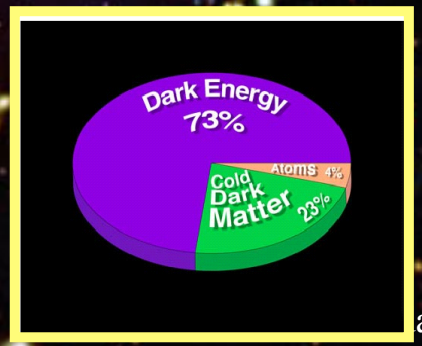
Supersymmetry: a new symmetry of Nature?



SUSY particle production at the LHC



Candidate particles for Dark Matter
⇒ Produce Dark Matter in the lab

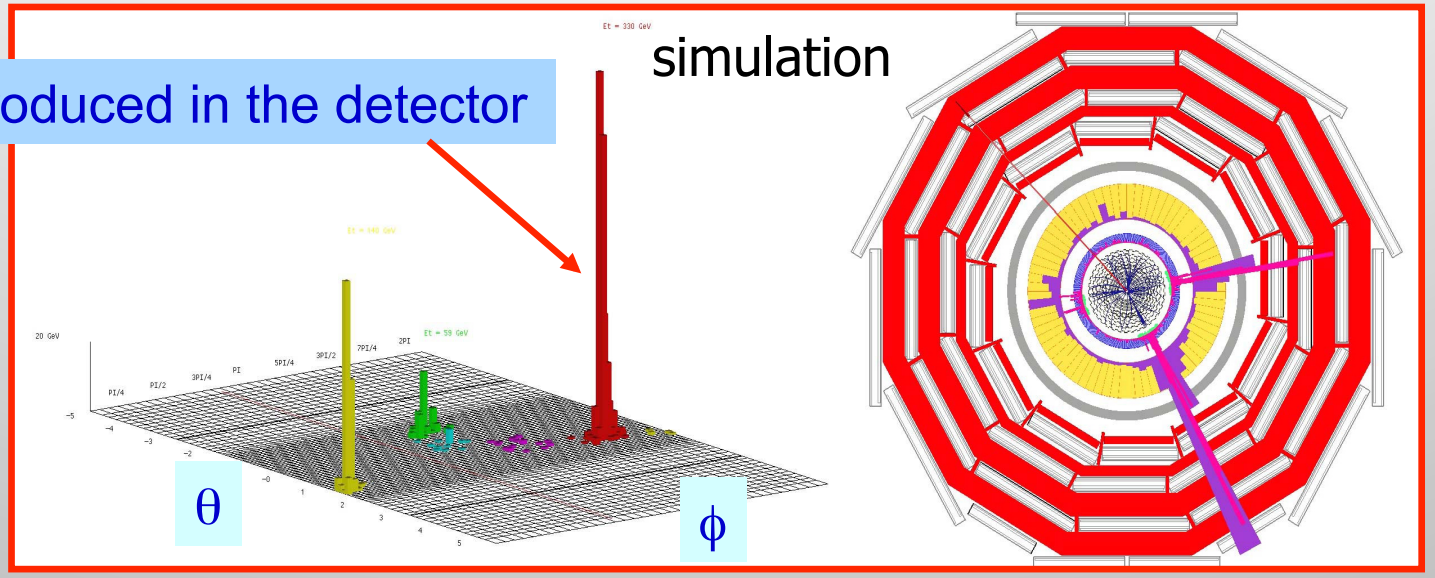


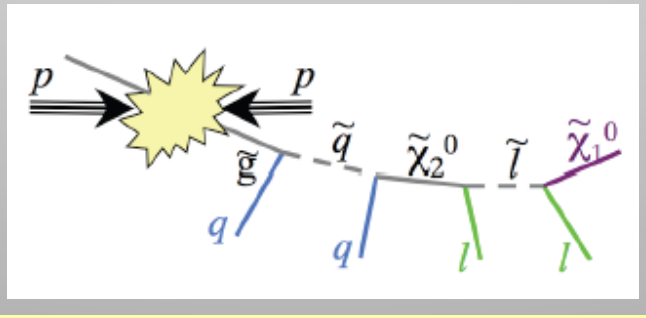
Assume "R-Parity" Conservation

+ 2 b-jets
+ 4 jets

Detecting Supersymmetric Particles

Energy produced in the detector





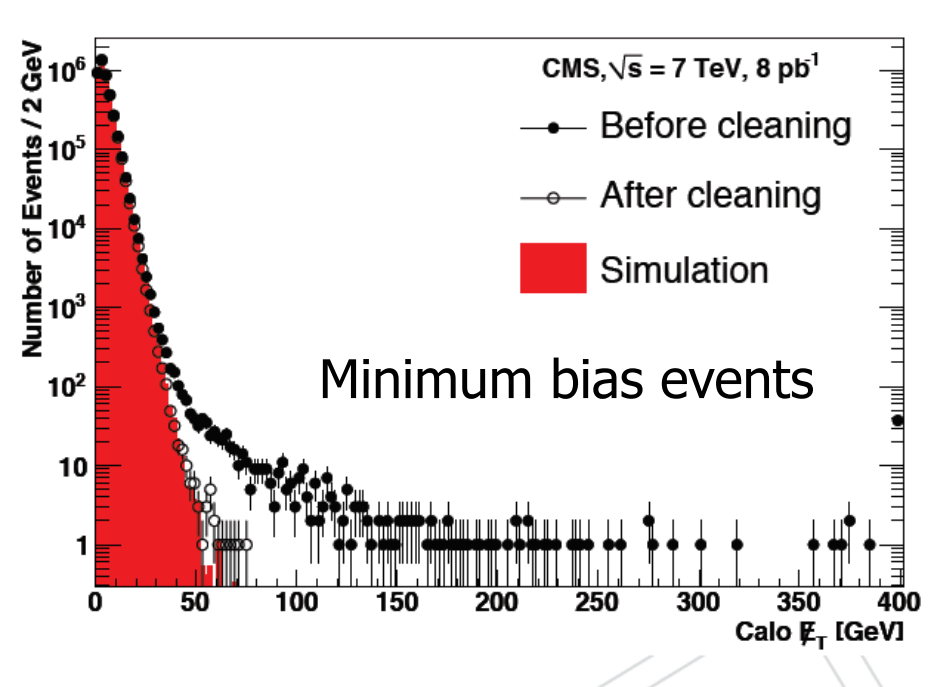
Supersymmetric particles decay and produce a cascade of jets, leptons and missing transverse energy (MET) due to escaping 'dark matter' particle candidates

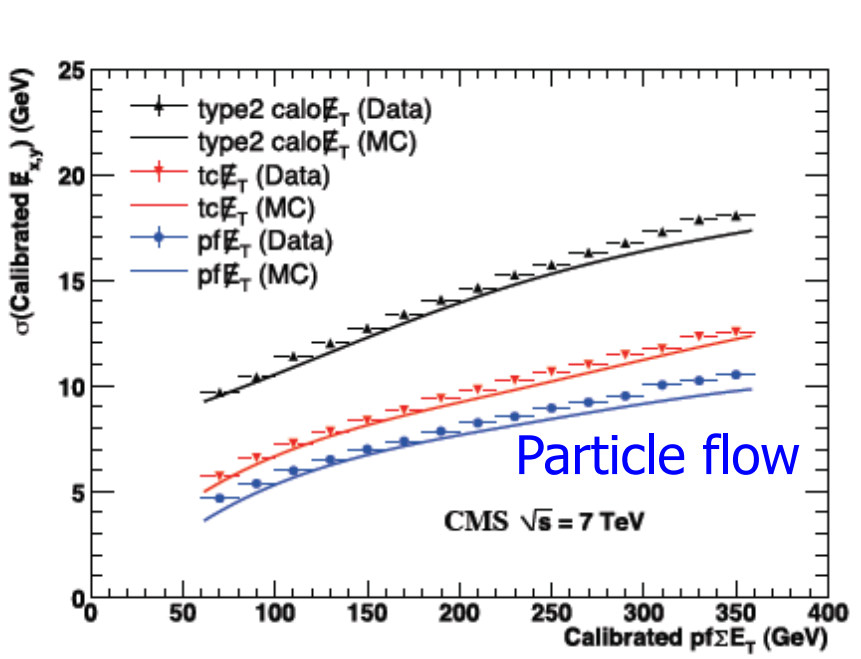
Very clear signatures in CMS and ATLAS

Missing Transverse Energy

Total transverse momentum imbalance

Generally appreciated to be a difficult quantity to measure
Very sensitive to fluctuations, miss-measurements, noise, backgrounds





CMS-JME-10-009

- In practice, rather well under control, from the start
- Good resolution using 'particle flow' ie maximally identifying particles
- More Pile-up will NOT make this simpler

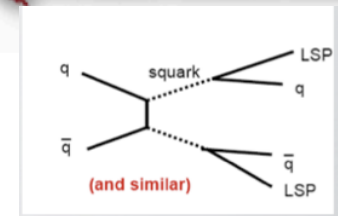
SUSY Searches in CMS

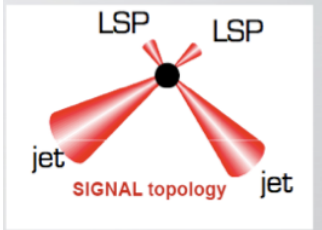
0-leptons	1-lepton	OSDL	SSDL	≥3 leptons	2-photons	γ+lepton
Jets + MET	Single lepton + Jets + MET	Opposite-sign di-lepton + jets + MET	Same-sign di-lepton + jets + MET	Multi-lepton	Di-photon + jet + MET	Photon + lepton + MET

Large SM backgrounds Low

sensitivity to strongly produced SUSY

sensitivity to gauge-mediated SUSY

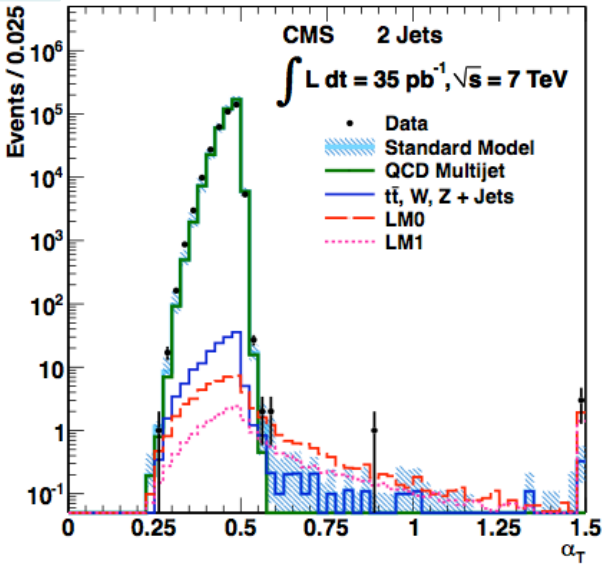




Example: Jets plus MET channel

$$\alpha_T = \frac{E_{T\,j2}}{M_{T\,j1\,j2}} = \frac{\sqrt{E_{T\,j2}/E_{T\,j1}}}{\sqrt{2(1-\cos\Delta\varphi)}}$$

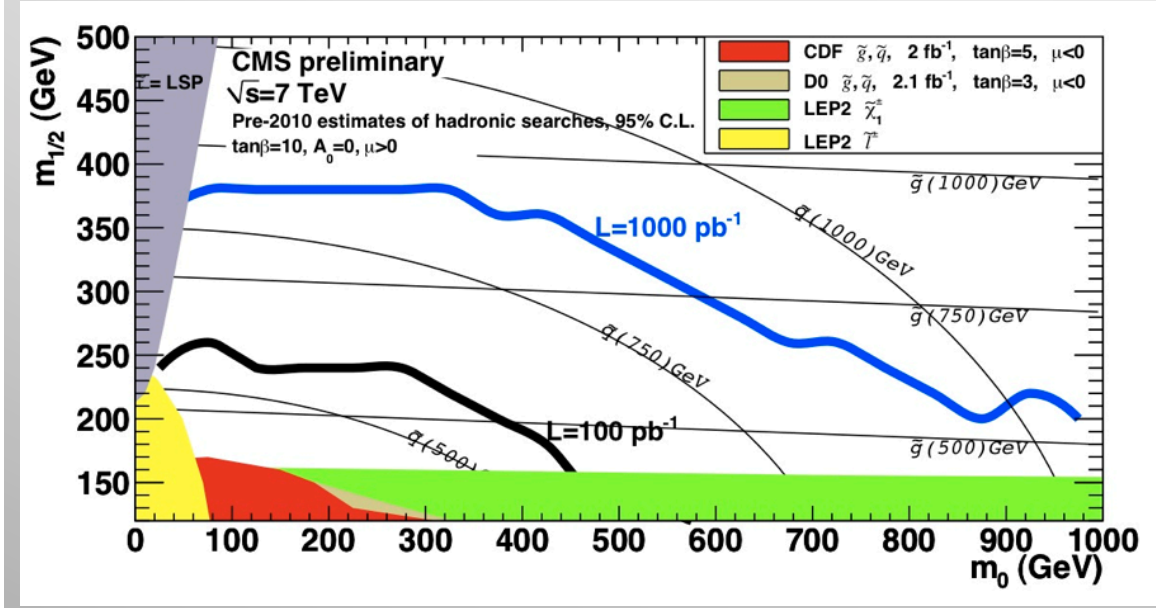
- Control jet SM background with the α_T variable
- No jet SM background expected for $\alpha_T > 0.5$



SUSY Searches @ LHC

CMS-NOTE-2010-008

Prospects 2009



- If low energy Supersymmetry exists, LHC will almost certainly observe it
- Masses up to 800-900 GeV already detectable with 1 fb^{-1}
- Squarks and Gluinos detectable up to 2.5-3 TeV mass with a ~100 fb^{-1}

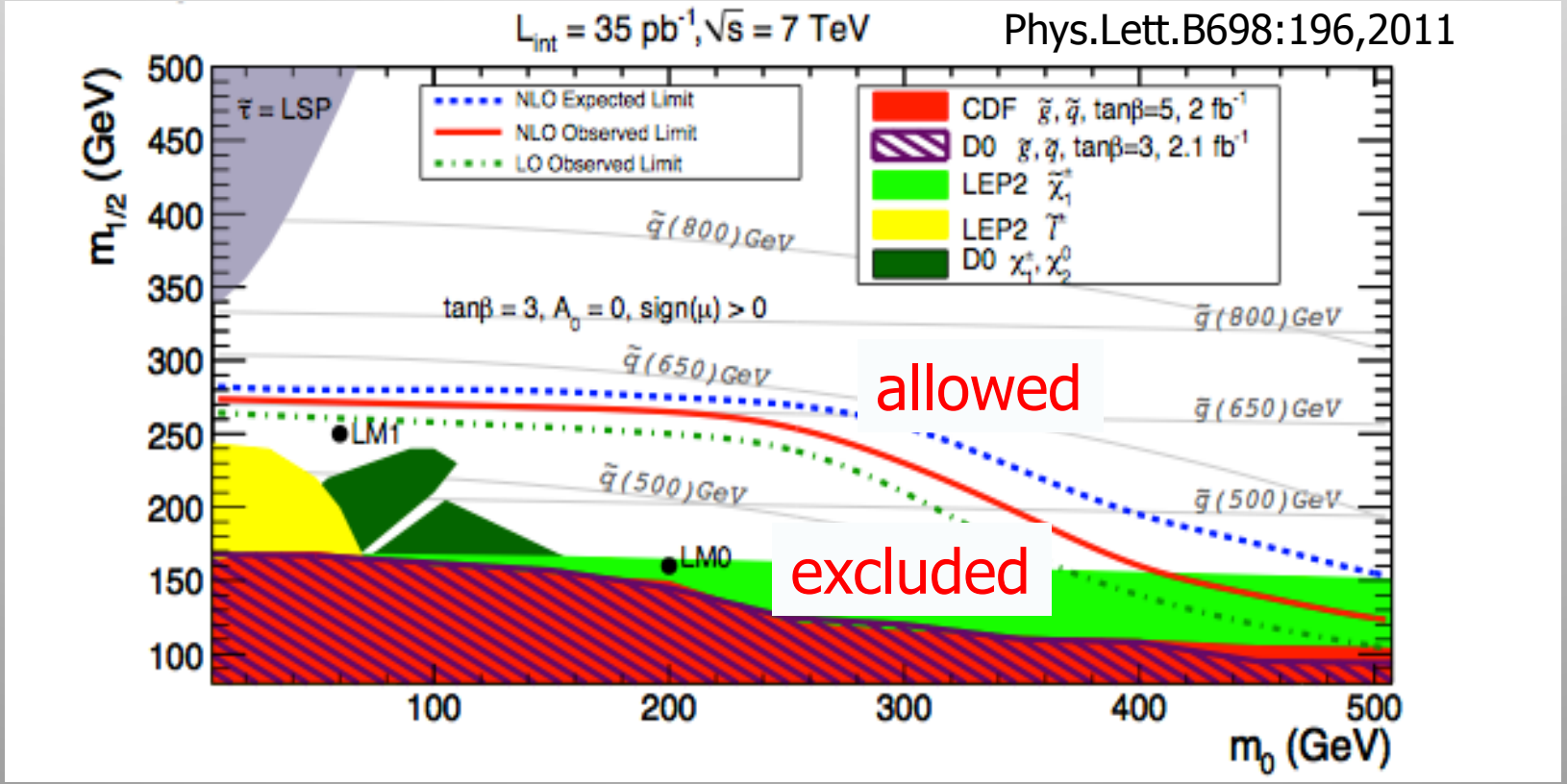
So far Constrained Minimal Supersymmetric Standard Model CMSSM is often used as a benchmark model for presenting the search results…

The CMSSM has 4 parameters
-$m_{1/2}$: universal gaugino mass at GUT scale
- m_0: universal scalar mass at GUT scale
-tanβ: vev ratio for 2 Higgs doublets
-A_0: trilinear coupling
and the sign of Higgs mixing parameter μ

First SUSY Search Result in CMS

-All 2010 data included: ~10-12 Events expected/ 13 observed

No discovery of supersymmetry yet… Stronger exclusion limits

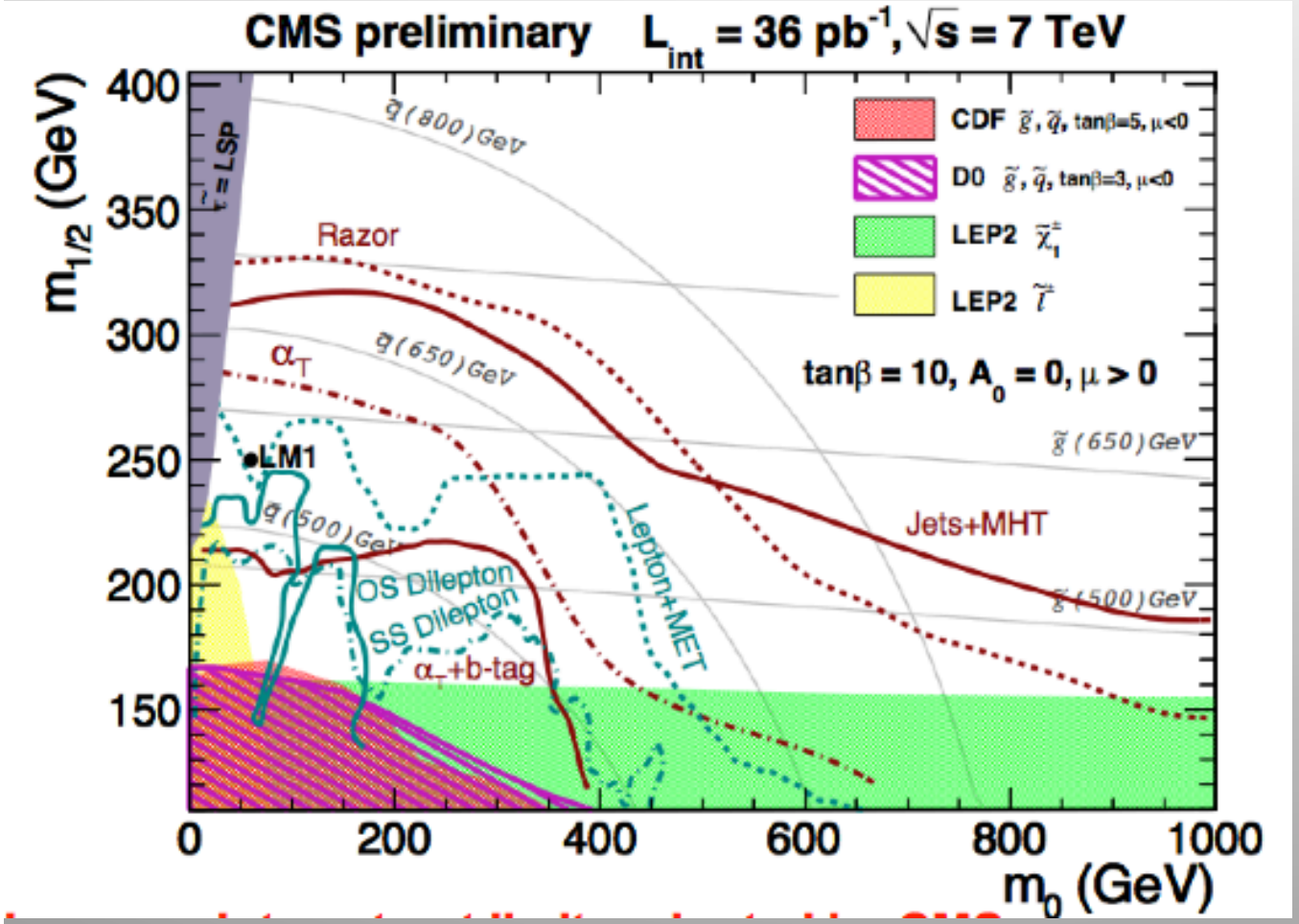


Masses of SUSY particles are larger than 600 GeV!!!

m_0 amd $m_{1/2}$ are universal scalar and gaugino masses at the GUT scale

Summary Search Channels

CMS summary of channels



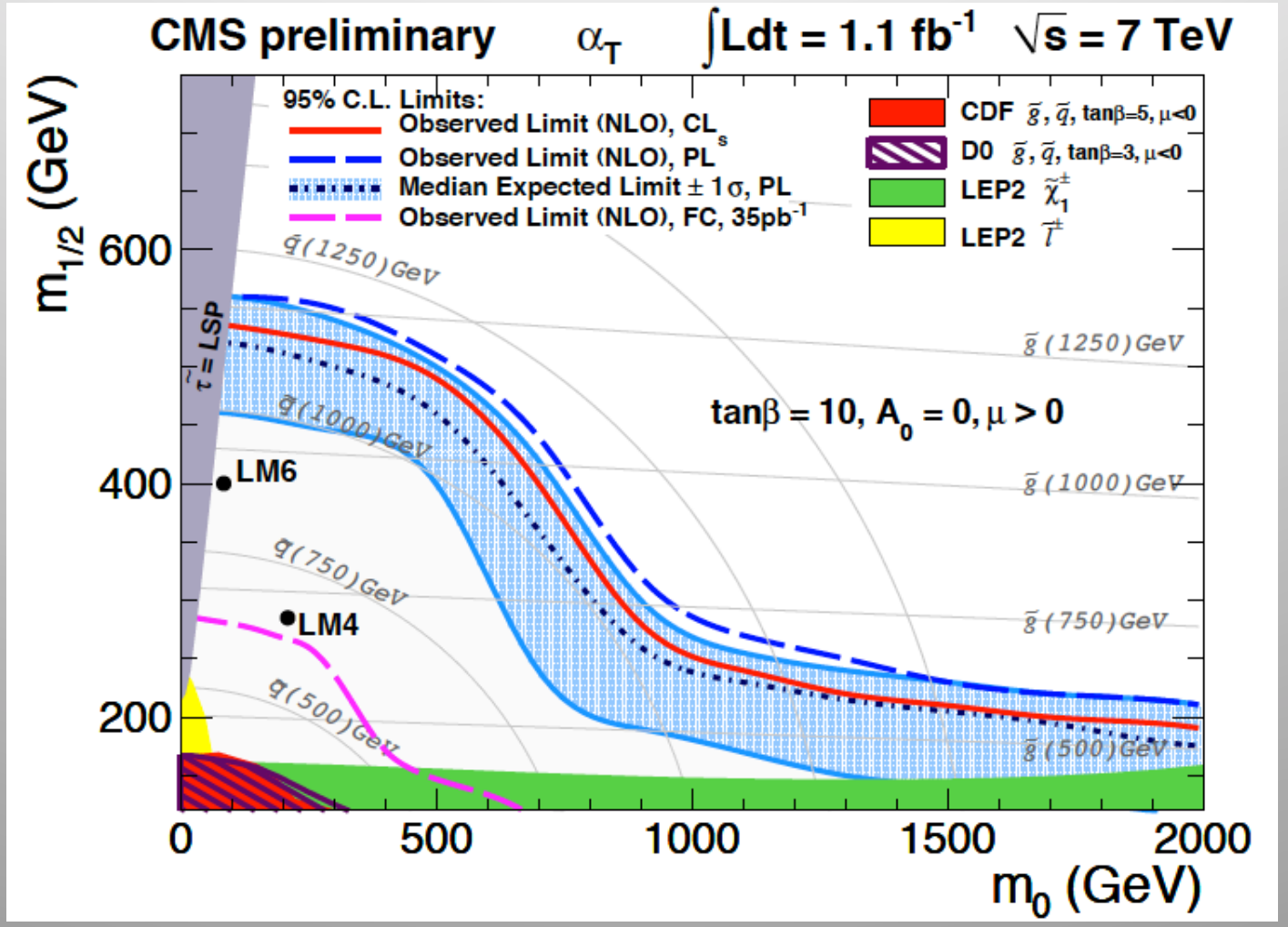
Channels with

- Jets only
- Single leptons
- Di-leptons
- Photons
- b-quarks

Squarks/gluinos are excluded for masses below 600-800 GeV in constrained models

1 fb^{-1} Search: Hadronic Channel

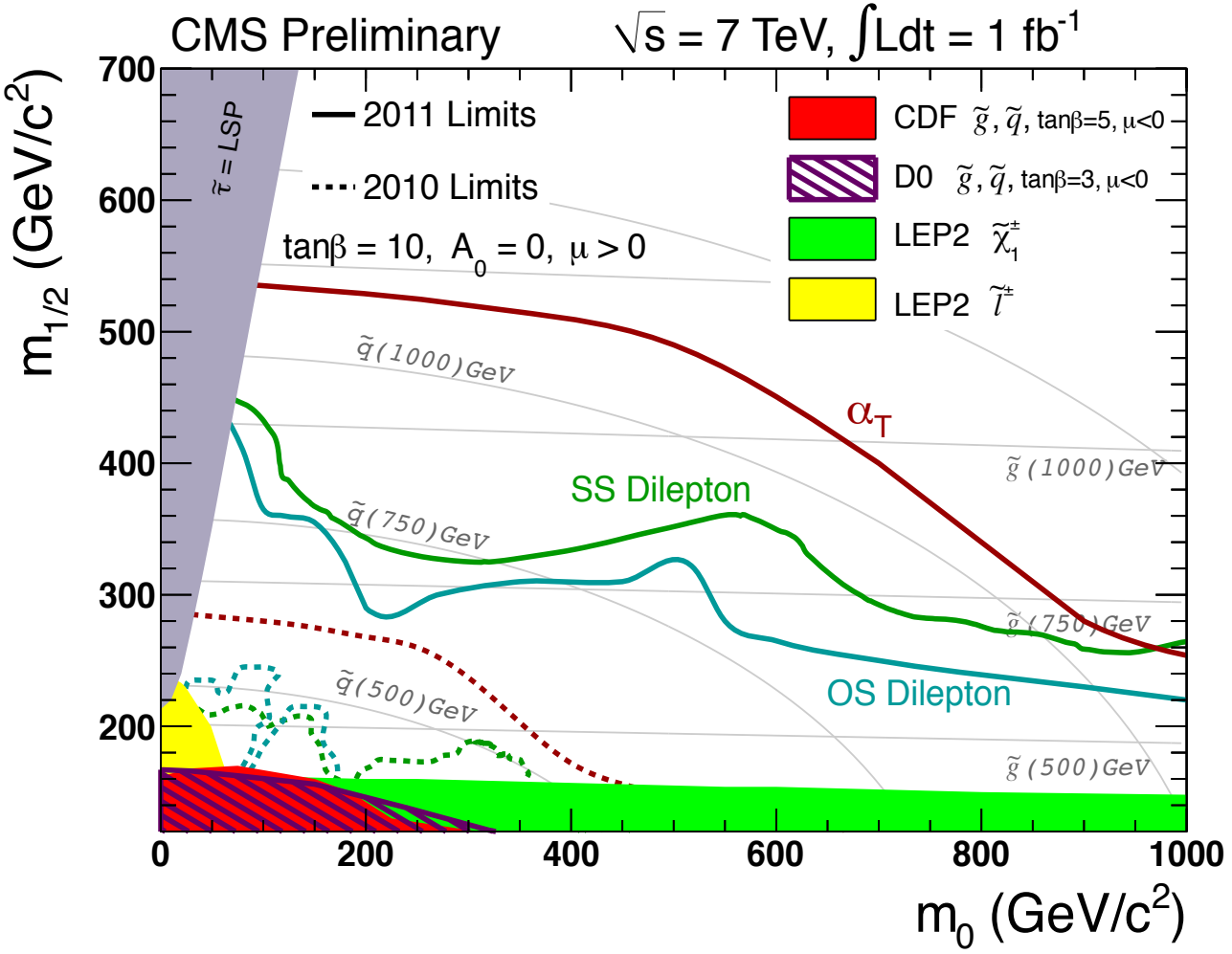
CMS-SUS-11-003



Progress on SUSY

Results of three SUSY analyses completed on 2011 data (α_T , Same Sign and Opposite Sign dileptons).

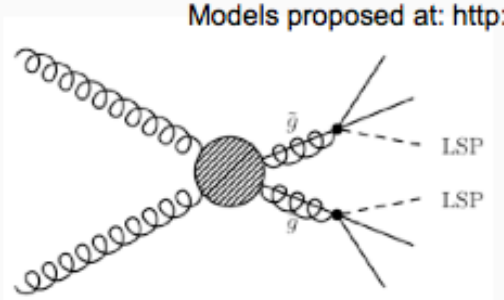
CMS-SUS-11-003
CMS-SUS-11-010
CMS-SUS-11-011

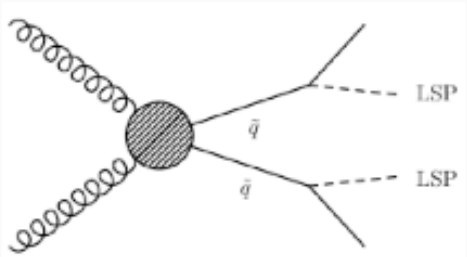


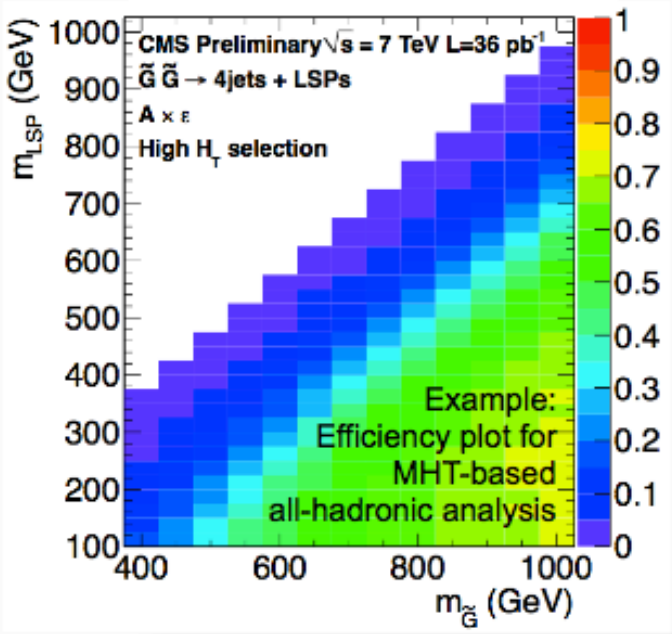
Within the Constrained MSSM model we are crossing the border of excluding gluinos up to 1TeV and squarks up to 1.25TeV

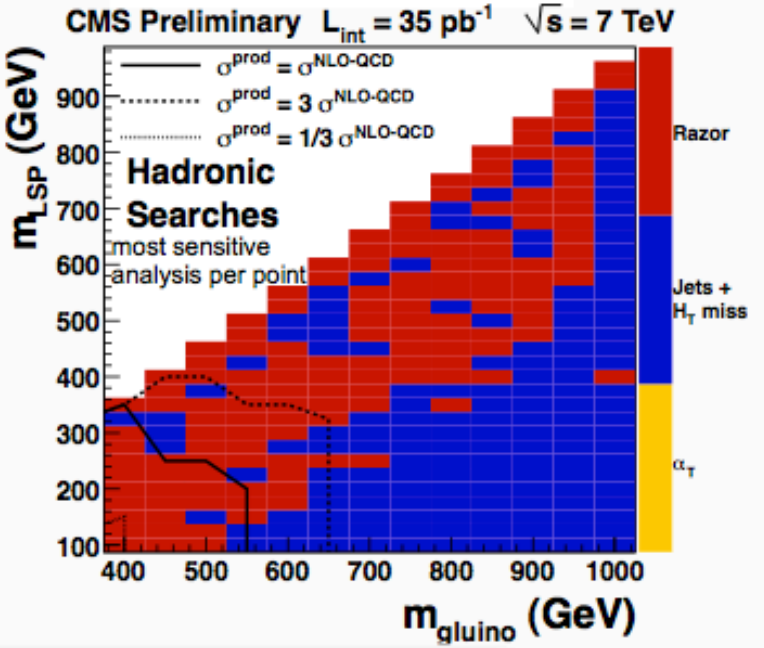
Results as Simplified Models

Models proposed at: http://www.lhcnewphysics.org





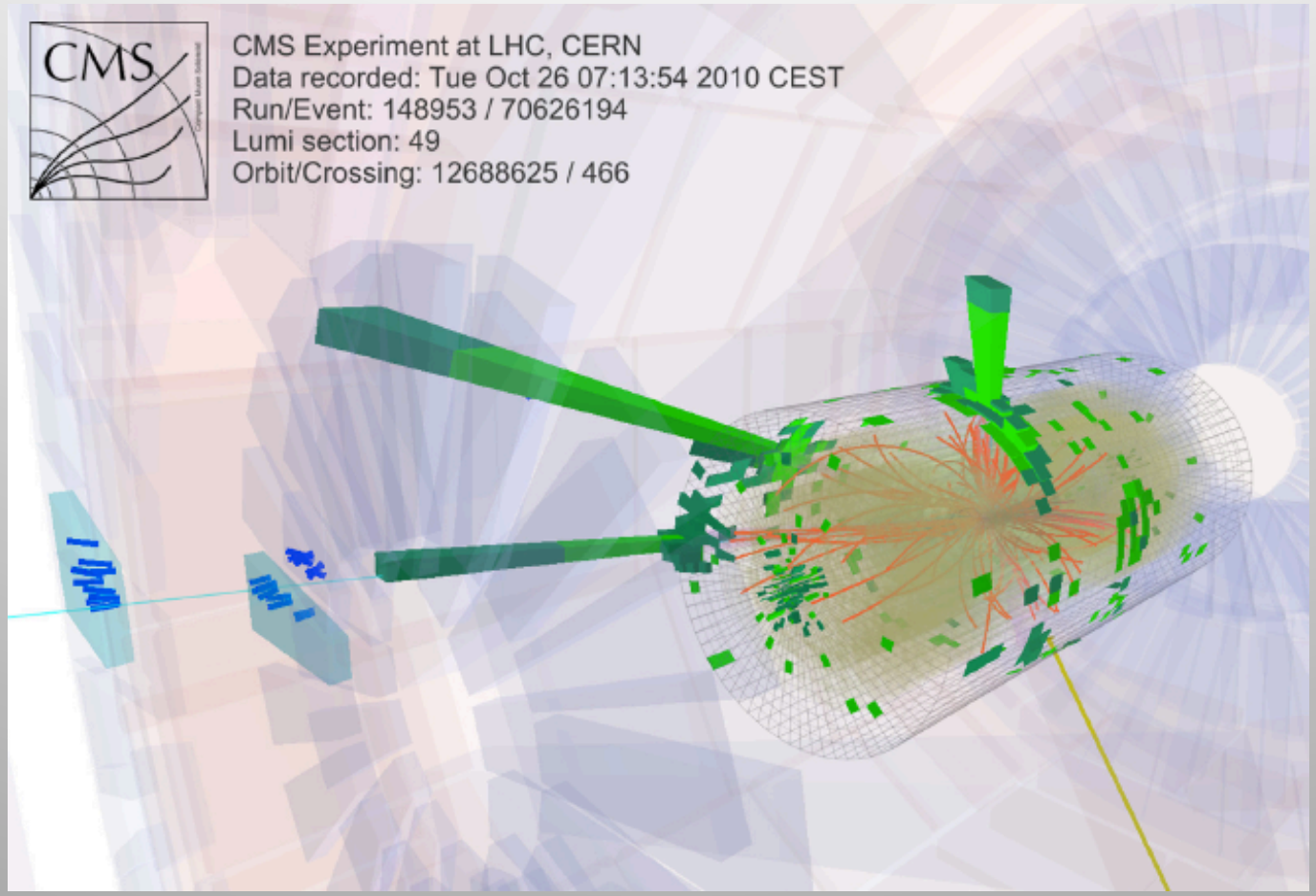




Shows complementarity of hadronic analyses.
CMS will provide these results electronically.
Feedback is welcome.

Are these result representations useful/used?

…Some Interesting Events…



- Event with five jets and large missing transverse energy
- Total sum of transverse momentum H_T= 1132 GeV and missing transverse energy H_{TMiss} = 693 GeV

Where do we expect SUSY?

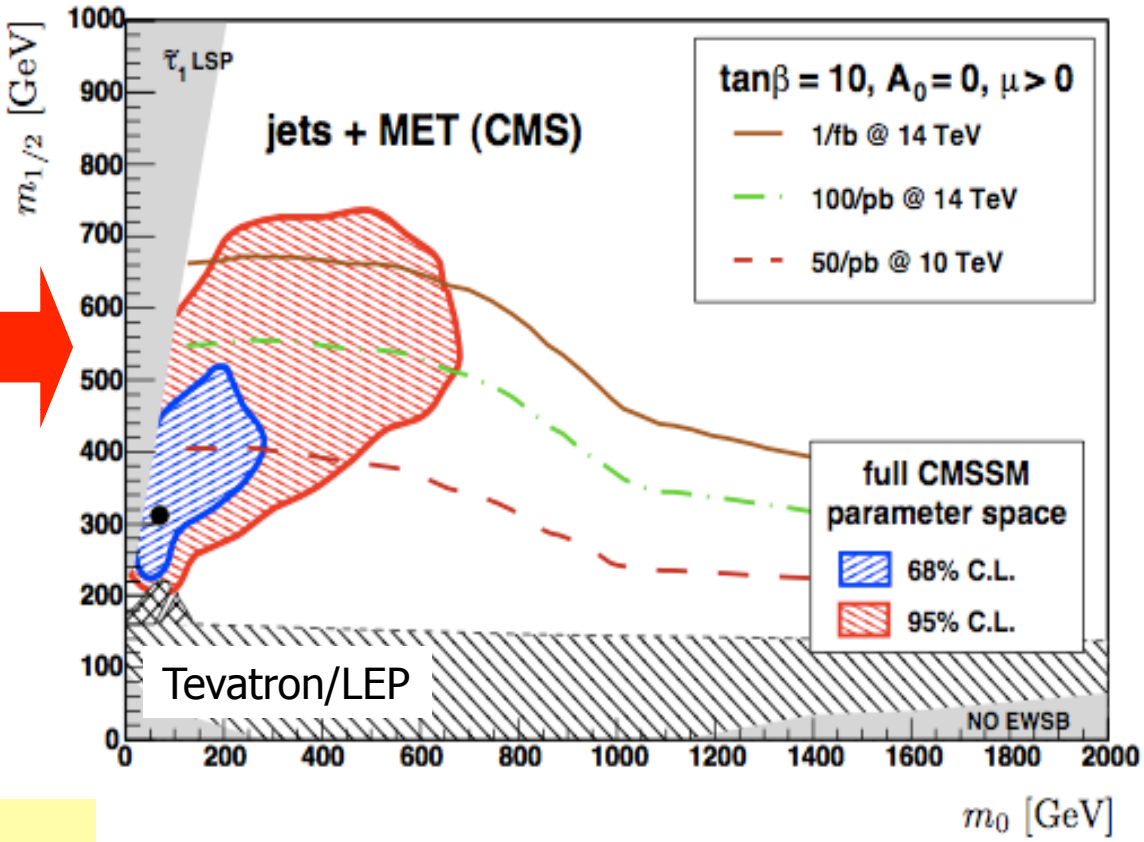
O. Buchmuller et al
arXiv:0808.4128

OB, R.Cavanaugh, A.De Roeck,
J.R.Ellis, H.~Flaecher, S.~Heinemeyer
G.Isidor, K.A.Olive, P.Paradisi,
F.J.Ronga, G.Weiglein

Precision measurements
Heavy flavour observables

Simultaneous fit of CMSSM parameters m_0, $m_{1/2}$, A_0, tanβ (μ>0) to more than 30 collider and cosmology data (e.g. M_W, M_{top}, g-2, BR(B→Xγ), relic density)

"LHC Weather Forecast"



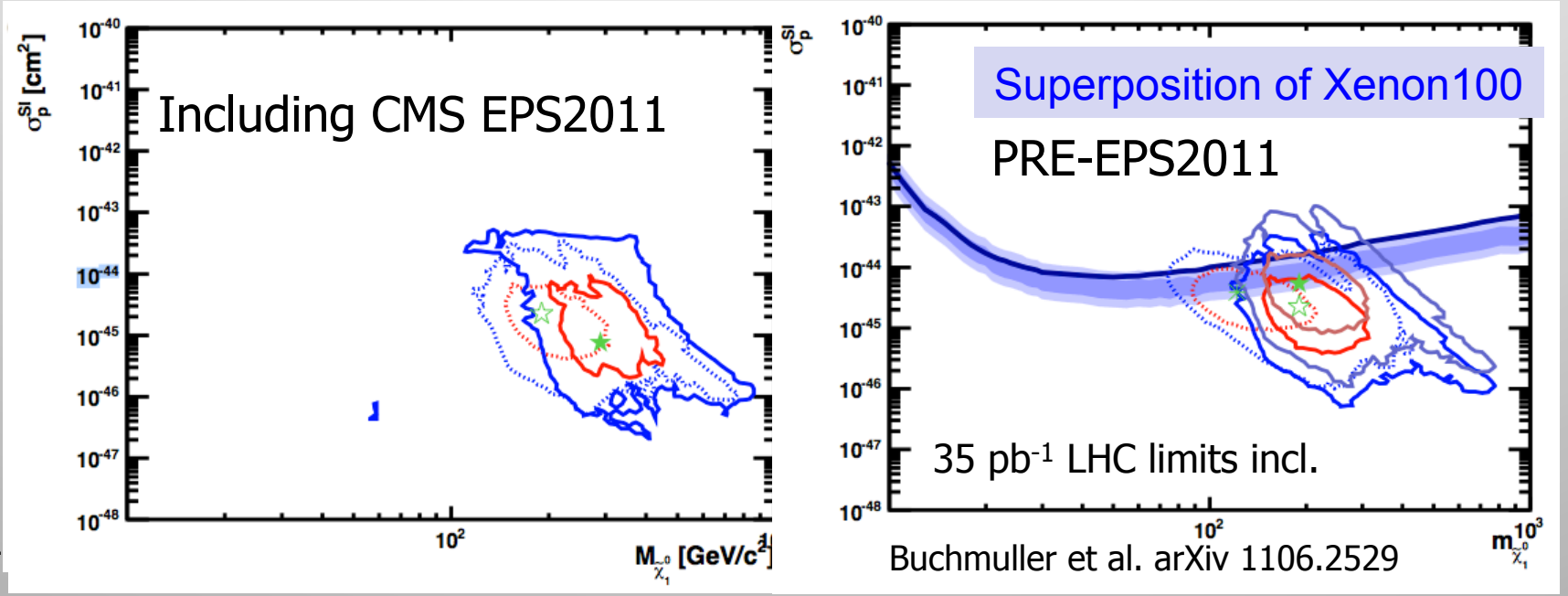
"CMSSM fit clearly favors low-mass SUSY - Evidence that a signal might show up very early?!"

"Predict" on the basis of present data what the preferred region for SUSY is (in constrained MSSM SUSY)

Many other groups attempt to make similar predictions

Impact of LHC Data on SUSY/DM

Preferred region for (CMSSM) SUSY, Including the first results from ATLAS and CMS



O.

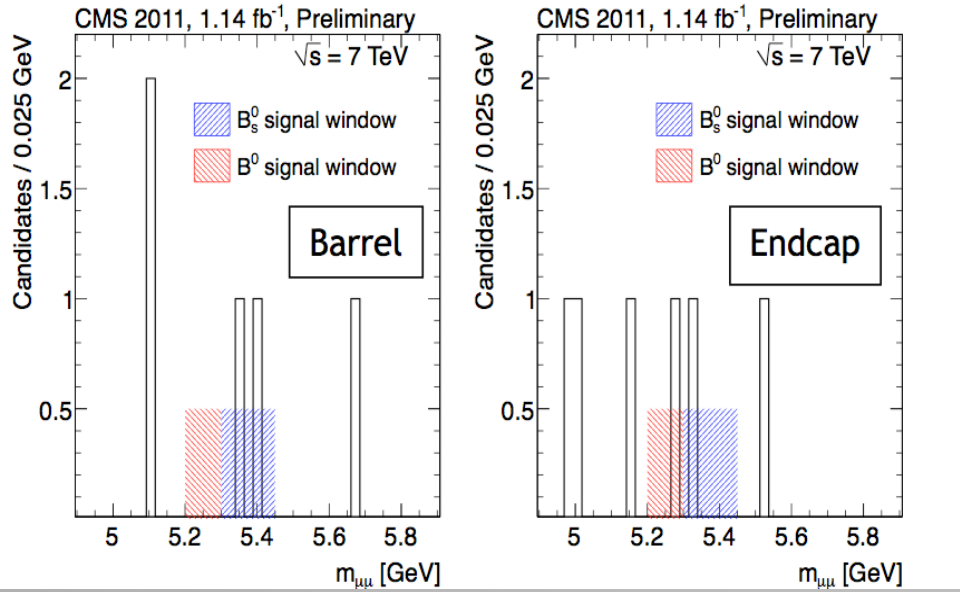
Pre-LHC: dots, ×,
post-LHC, solid ★
Original :dotted lines
+CMS: dashed lines
+ATLAS: Solid lines

New best-fit points inside previous 68% CL regions
➔No significant tension or conflict
➔More results, eg including XENON data…

D. Feldman et al., arXiv:1102.2548 : Within the framework of mSUGRA models DM neutralinos of ~ 50 GeV are about to be ruled out

$B_s \rightarrow \mu^+\mu^-$

Indirect sensitivity to new physics (MSSM:BR$\propto(\tan\beta)^6$ → sensitivity to extended Higgs boson sectors → constraints on parameter region).
$B_s \rightarrow \mu^+\mu^- = (3.2\pm0.2)\times10^{-9}$; $B_d \rightarrow \mu^+\mu^- = (1.0\pm0.1)\times10^{-10}$

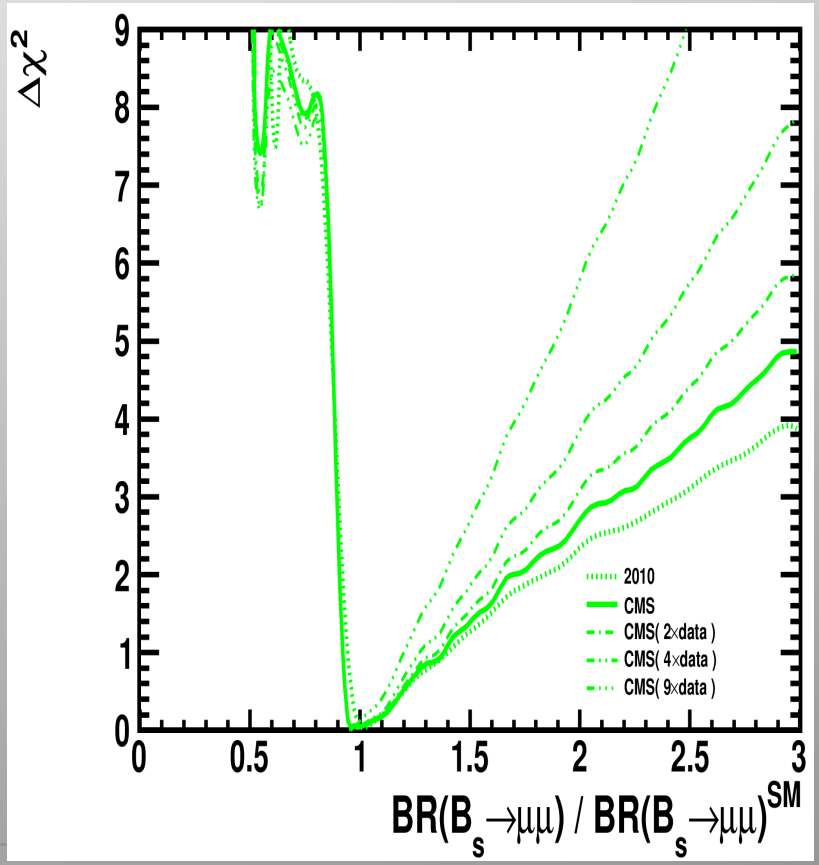


Events observed in the unblinded windows consistent with background plus SM expectations.
$B_s \rightarrow \mu^+\mu^- < 1.9\times10^{-8}$ (95% CL)
$B_d \rightarrow \mu^+\mu^- < 4.6\times10^{-9}$ (95% CL)

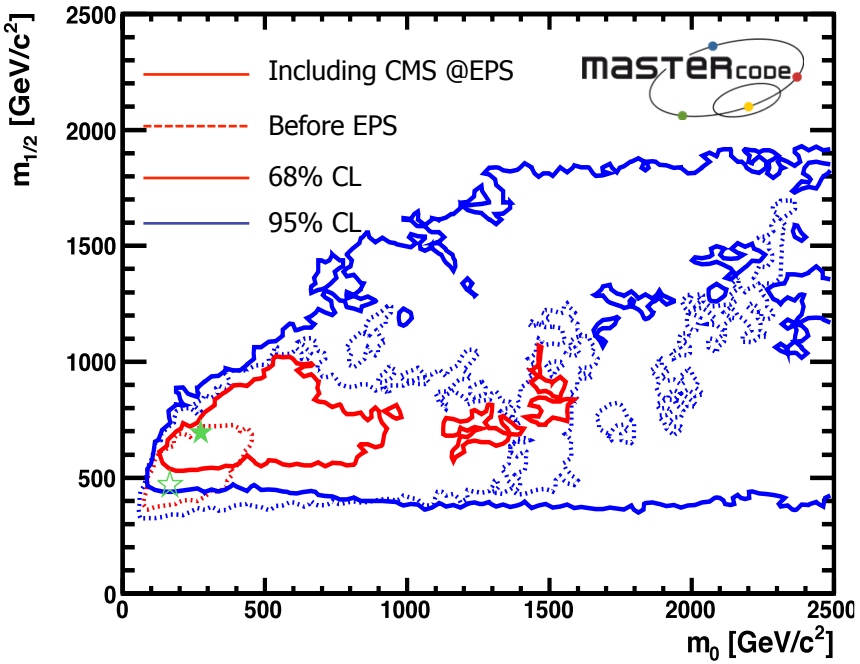
CMS PAS-BPH-11-002

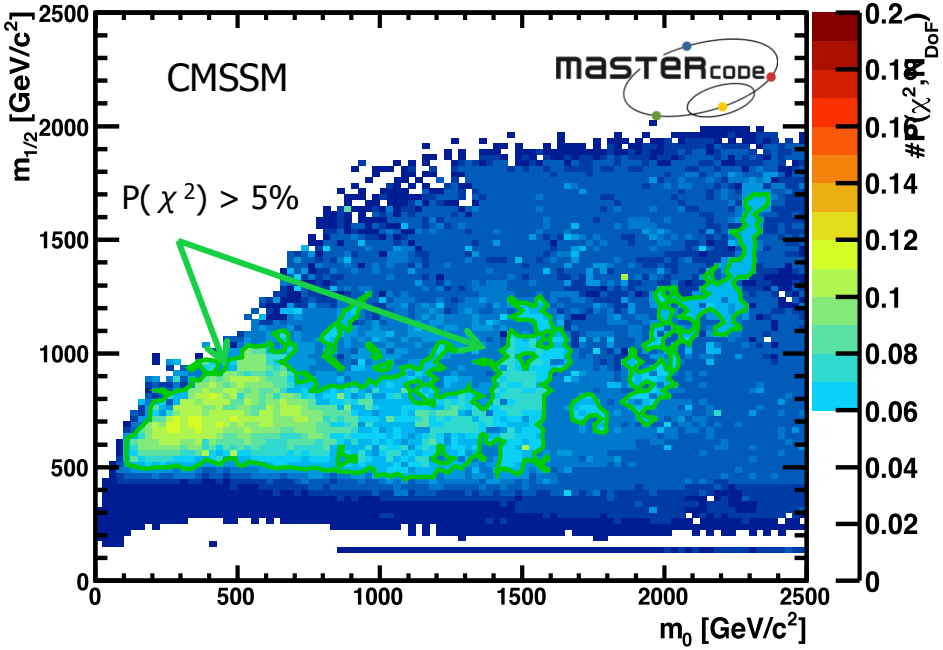
Impact on new models

arXiv:1106.2529



Impact of CMS EPS Results on SUSY





χ^2 probability: P(χ^2) for CMSSM
Before EPS: 16% Including CMS@EPS: 11%

CMS searches significantly constrain allowed SUSY parameter space.
The air is getting very thin for constrained SUSY models but it needs more data to be fully conclusive. More in the backup (incl. ATLAS)
We will know more after summer, but have to start preparing…

What is Next?

- Think beyond the simplest/ most constrianed models
  - pMSSM
  - NMSSM
  - Degenerate mass spectra
  - Light 3rd generation
  - Split SUSY
  - RPV SUSY
  - …
- May have to revise our searches for other models
- DAMA/COGENT signals? How compatible are these with our present searches?
- LPCC Workshop @ CERN August 28-September 2

Nature Feb 2011

Beautiful theory collides with smashing particle data

Latest results from the LHC are casting doubt on the theory of supersymmetry.

Geoff Brumfiel

"Wonderful, beautiful and unique" is how Gordon Kane describes supersymmetry theory. Kane, a theoretical physicist at the University of Michigan in Ann Arbor, has spent about 30 years working on supersymmetry, a theory that he and many others believe solves a host of problems with our understanding of the subatomic world.

"Any squarks in here?" The ATLAS detector (above) at the Large Hadron Collider has failed to find predicted 'super partners' of fundamental particles. *C. MARCELLONI/CERN*

Theorists starting to get a depression?? (G Altarelli EPS11)

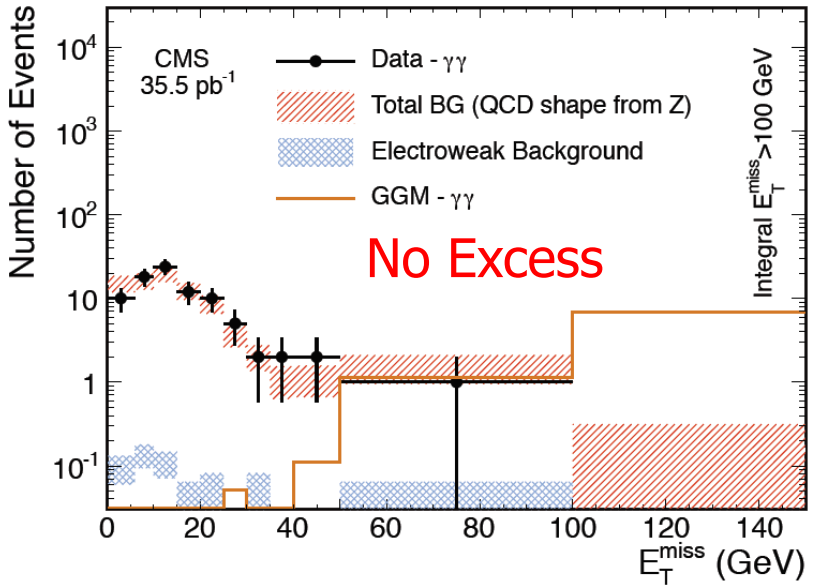
GMSB SUSY Searches

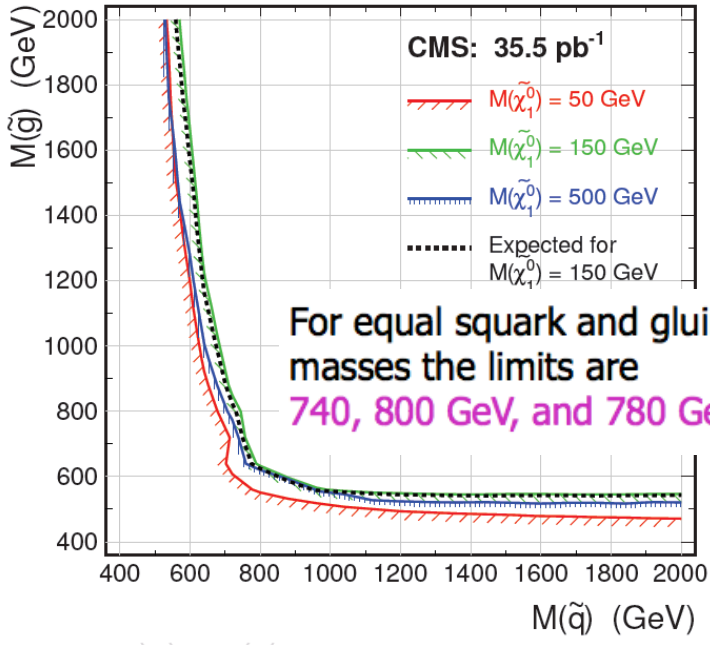
Gauge Mediated SUSY breaking: LSP is the Gravitino

- Phenomenology depends on NLSP
  - if neutralino, decays into gravitino and γ, Z^0, or h^0 (depending on neutralino mixing)

PRL.106 211802,2011

Here analyse collisions with:
two hard photons (30 GeV) , missing transverse momentum and jets

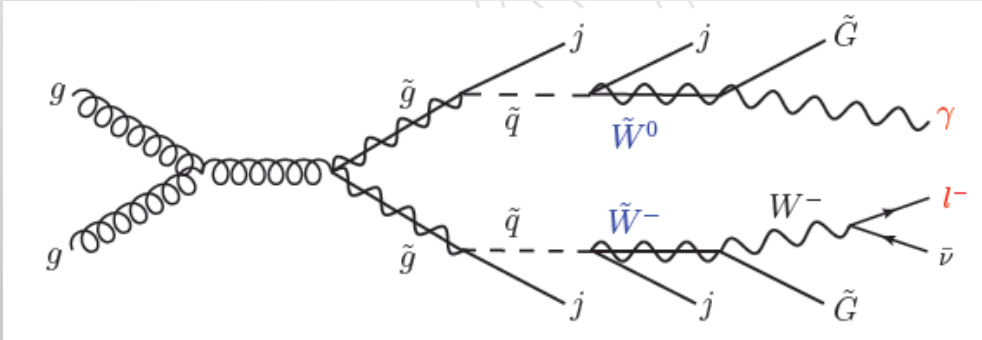




These results can be reinterpreted in Universal Extra Dimensions

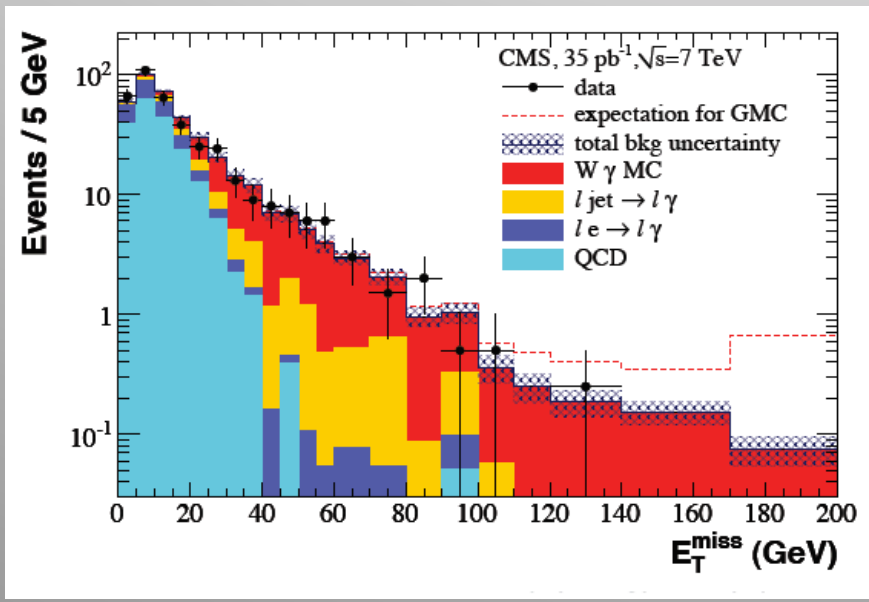
GMSB SUSY Searches

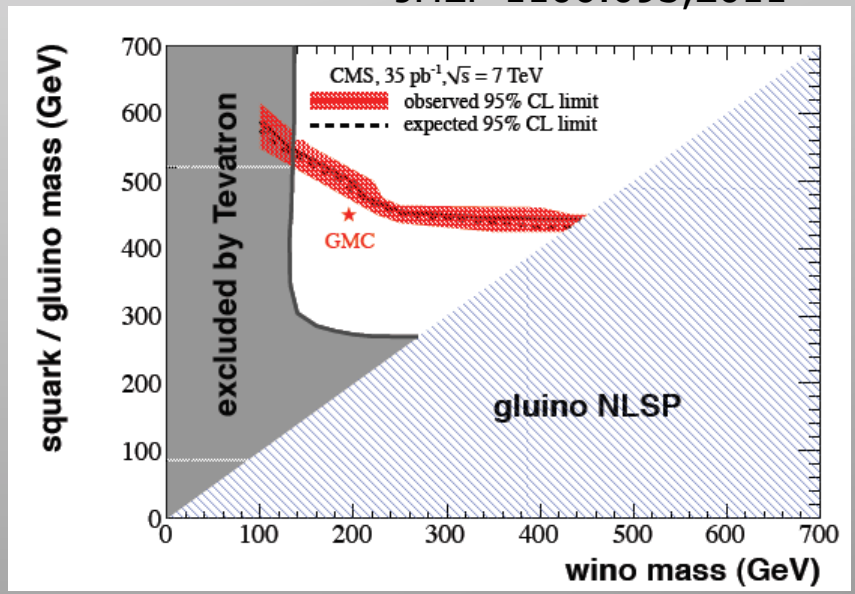
E.G. This channel: A lepton, a photon and Missing Transverse Energy



P_T lepton> 20 GeV
P_T photon > 30 GeV
MET> 100 GeV

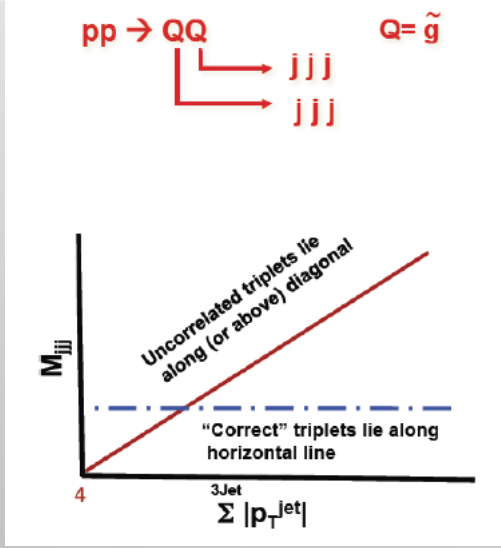
JHEP 1106:093,2011





No excess found… Exclusion in the squark/gluino wino space

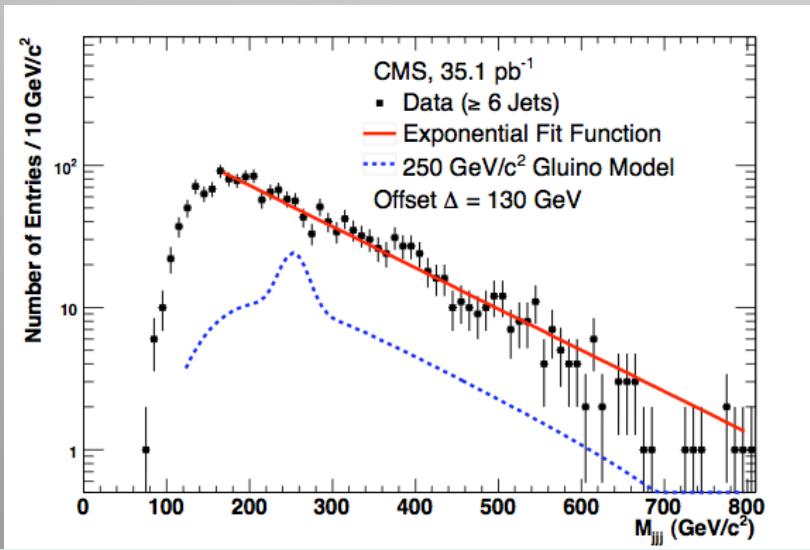
RP violating SUSY

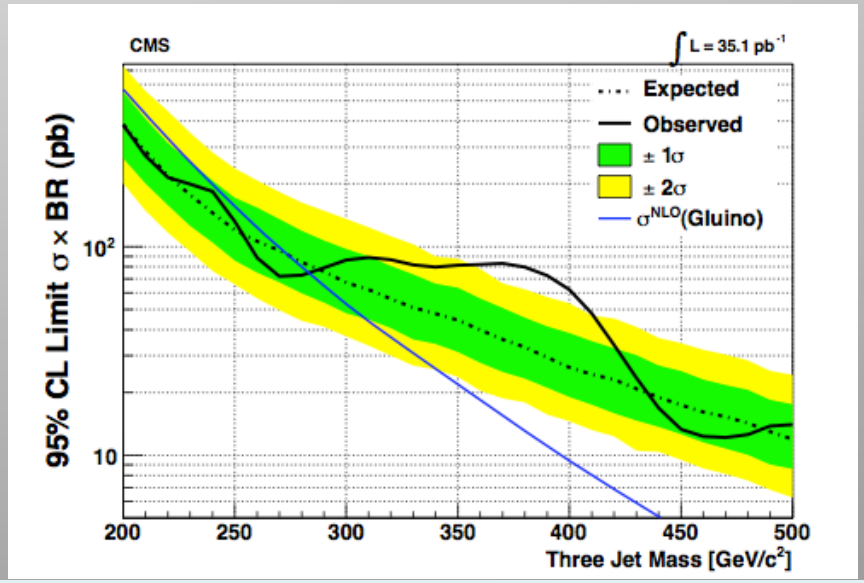


Sparticle decays into 3 jets

- Use a diagonal cut to remove combinatorial background as well as QCD background:
  - $m_{jjj} < \Sigma\ |p_T(\text{triplet})| - \alpha\ (\text{Offset})$

arXiv:1107.3084



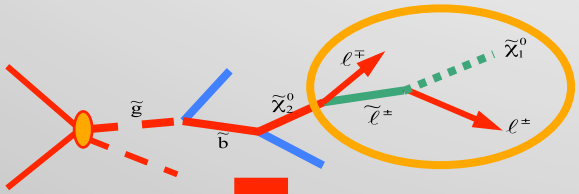


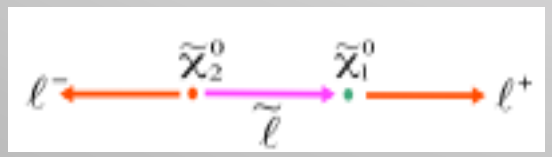
No signal for gluino masses up to 280 GeV
High mass excursion is less than 2σ taking into account look elsewhere effect

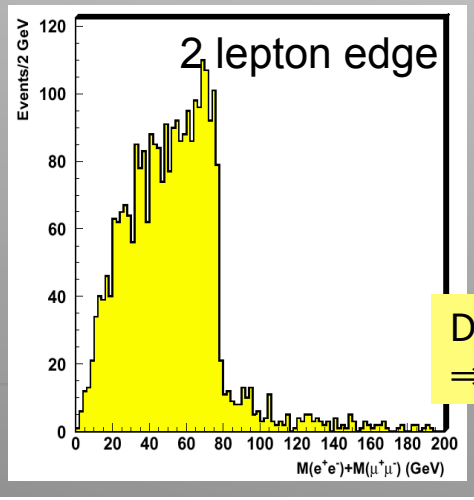
Sparticle Detection & Reconstruction

Mass precision for a favorable benchmark point at the LHC
LCC1~ SPS1a~ point B'

m_0=100 GeV
$m_{1/2}$= 250 GeV
A_0=-100
tanβ = 10
sign(μ)=+







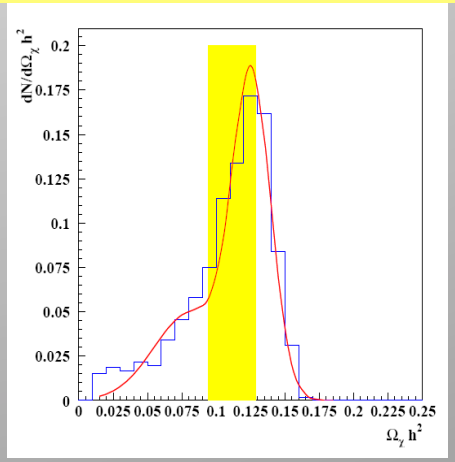
D. Miller et al
⇒Use shapes

25

hep-ph/0508198
100 fb^{-1}, 14 TeV

GeV	LHC
$\Delta m_{\tilde{\chi}_1^0}$	4.8
$\Delta m_{\tilde{\chi}_2^0}$	4.7
$\Delta m_{\tilde{\chi}_4^0}$	5.1
$\Delta m_{\tilde{l}_R}$	4.8
$\Delta m_{\tilde{\ell}_L}$	5.0
$\Delta m_{\tilde{\tau}_1}$	5-8
$\Delta m_{\tilde{q}_L}$	8.7
$\Delta m_{\tilde{q}_R}$	7-12
$\Delta m_{\tilde{b}_1}$	7.5
$\Delta m_{\tilde{b}_2}$	7.9
$\Delta m_{\tilde{g}}$	8.0

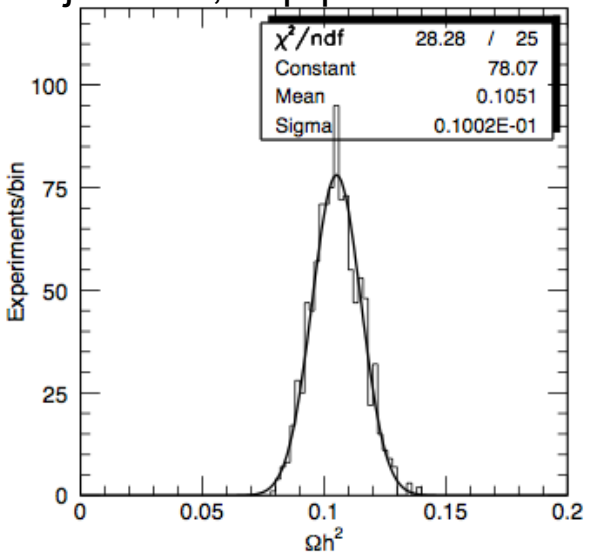
Lightest neutralino → Dark Matter?
Fit SUSY model parameters to the measured SUSY particle masses to extract $\Omega\chi h^2$ ⇒ O(10%) for LCC1



This point and much more of the CMSSM space is ruled out
What can LHC still say on DM?

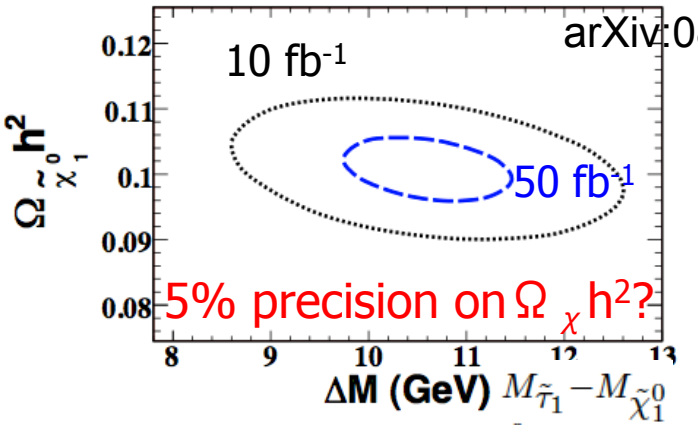
LHC Related Dark Matter Studies

Nojiri et al., hep-ph/0512204



Precision on Ωh^2 using tau lepton data

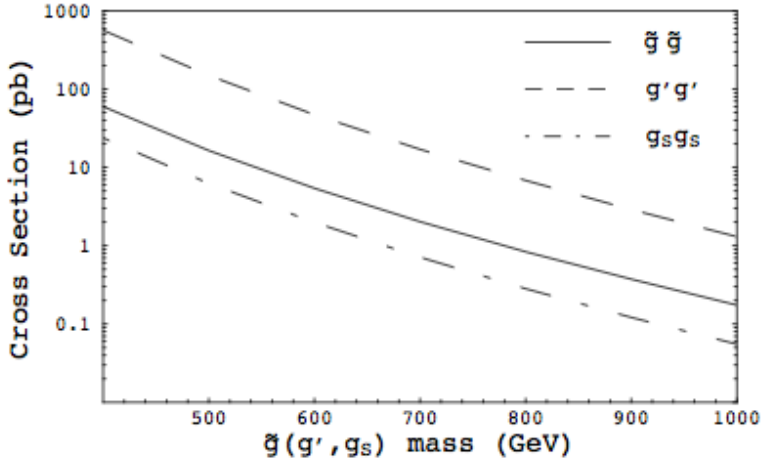
Arnowitt et al., arXiv:0802.2968



Several case studies in the past years to relate particle properties we can measure at the LHC (masses, mixing parameters) to Dark Matter properties (mass, annihilation cross section spin independent cross section, $\Omega_\chi h^2$)

Kane et al., arXiv:0805.1397

Spin versus production cross section



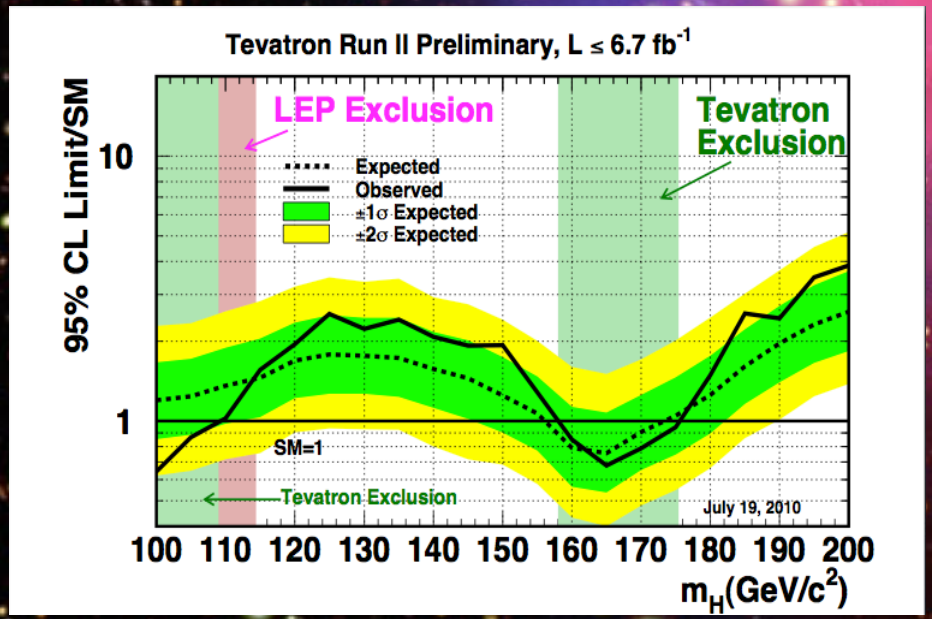
Outcome will depend on the specific SUSY realization in Nature...

The Hunt for the Higgs

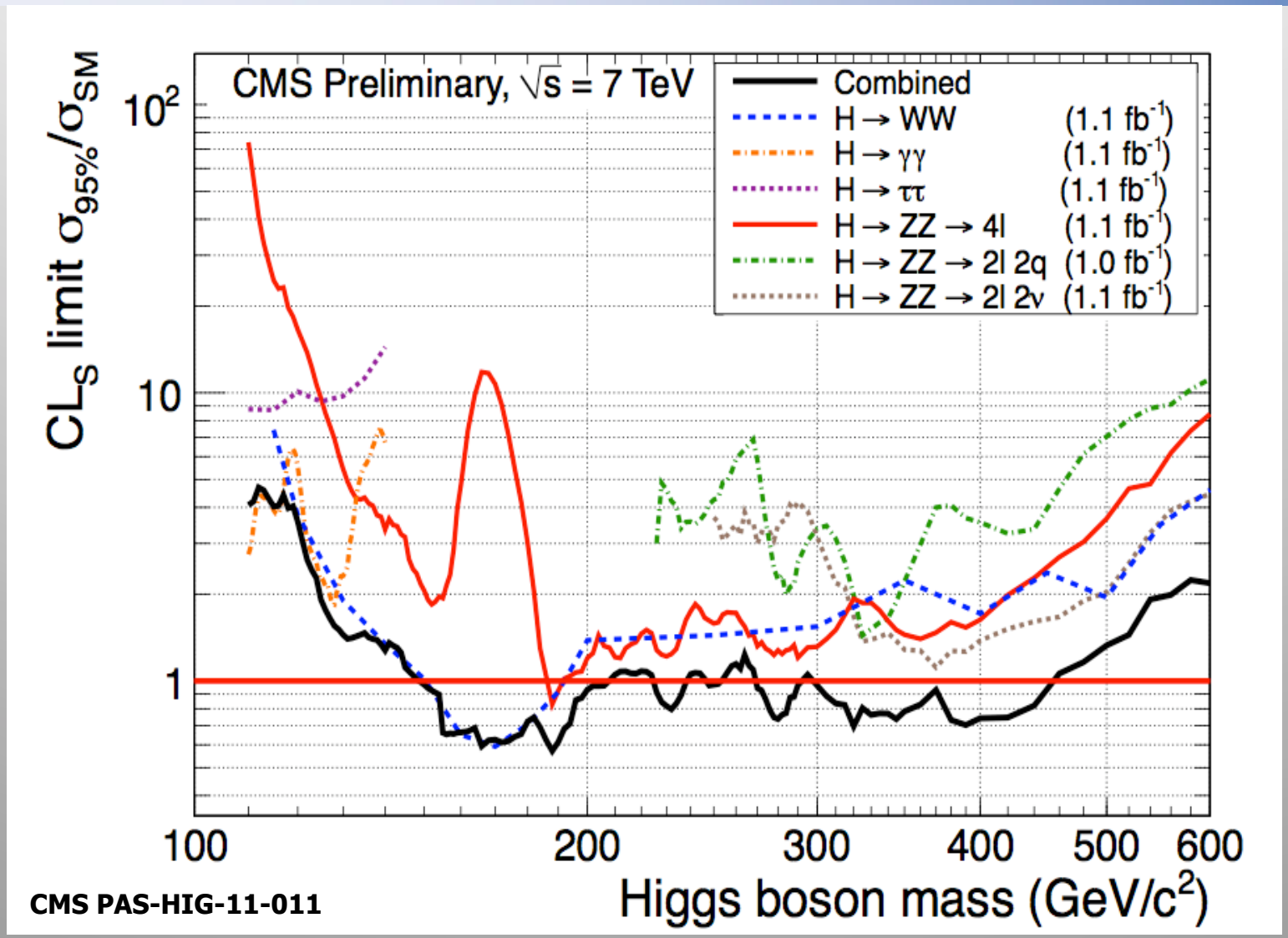
This has been for the last years the hunting ground for the Tevatron

P. Higgs, R. Brout en F. Englert
⇒ A new field and particle

The key question (since '64): Where is the Higgs?



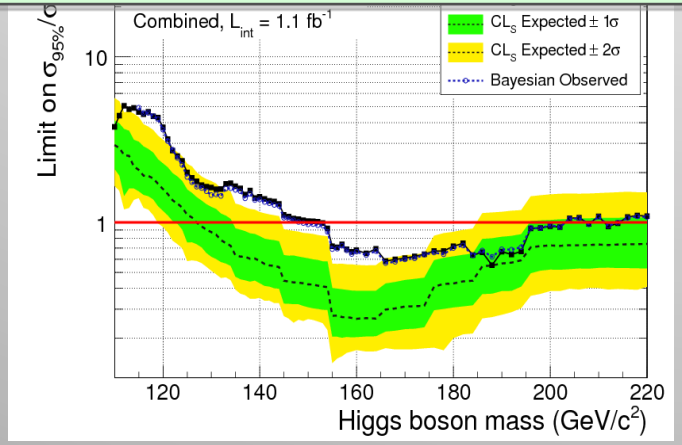
Search for the SM Higgs Boson

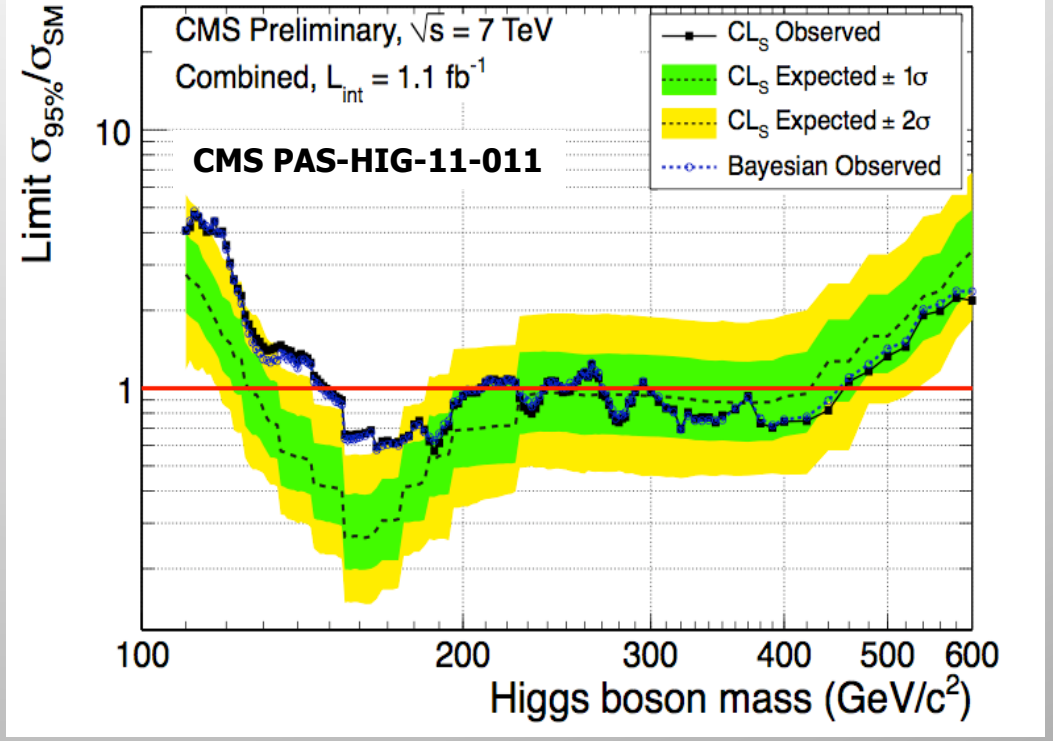


From now on: the LHC is the main player in town

SM Higgs Exclusion Limits

Expected exclusion: 127-420 GeV
Observed exclusion: 149-206 GeV + 300-440 GeV + parts in between





In the low mass part (114-149 GeV) we see a couple of interesting regions showing excesses. Further study with new data will give us hopefully a better understanding.

Breaking news

24 July 2011 Last updated at 14:57 GMT

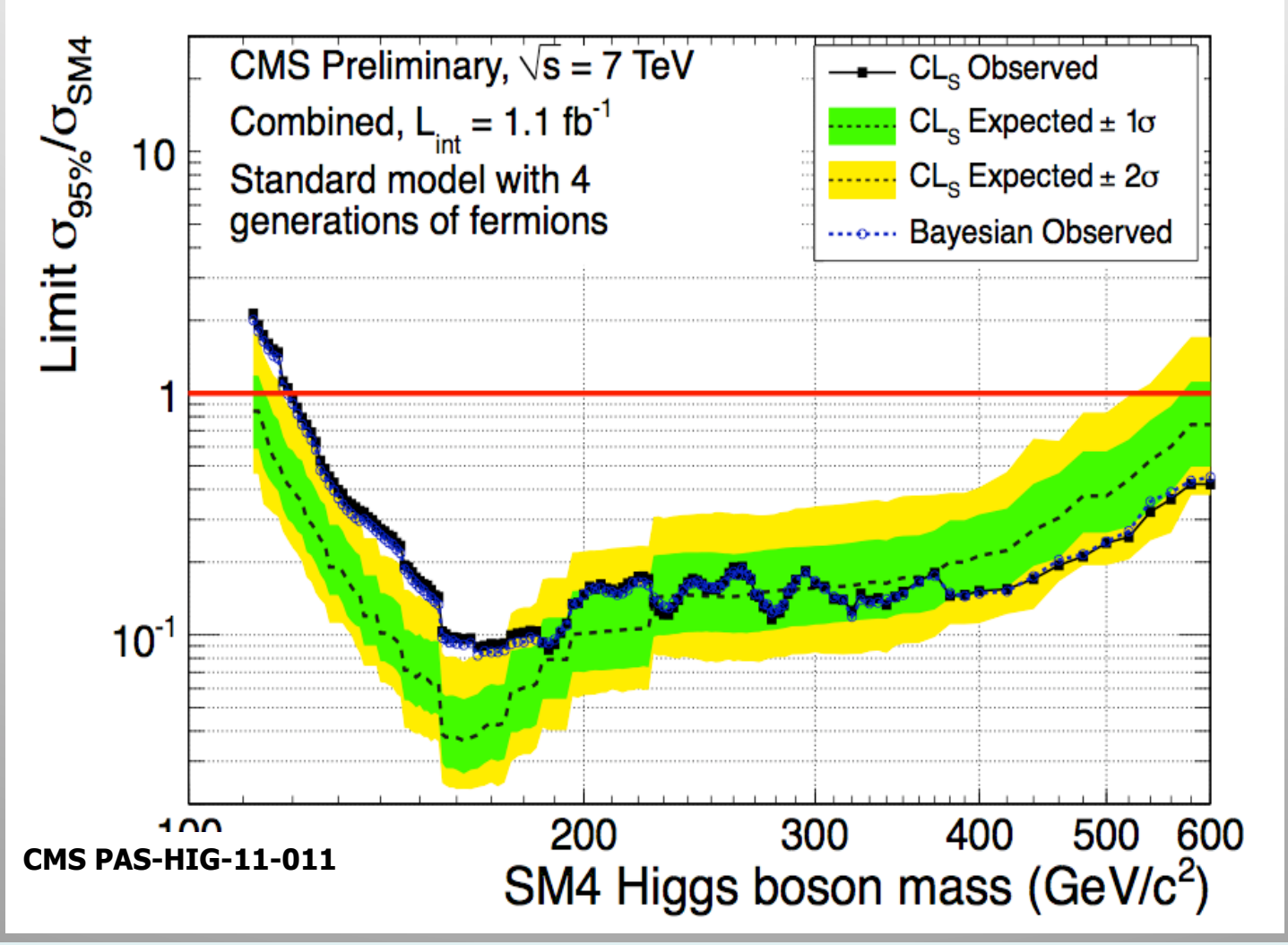
221 Share

Higgs boson 'hints' also seen by US lab

By Paul Rincon
Science reporter, BBC

Now, the US DZero and CDF experiments have also seen hints of something at about 140GeV.

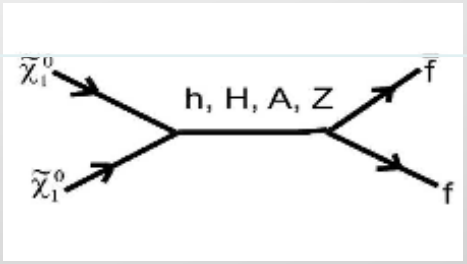
4th Generation Exclusion Limits



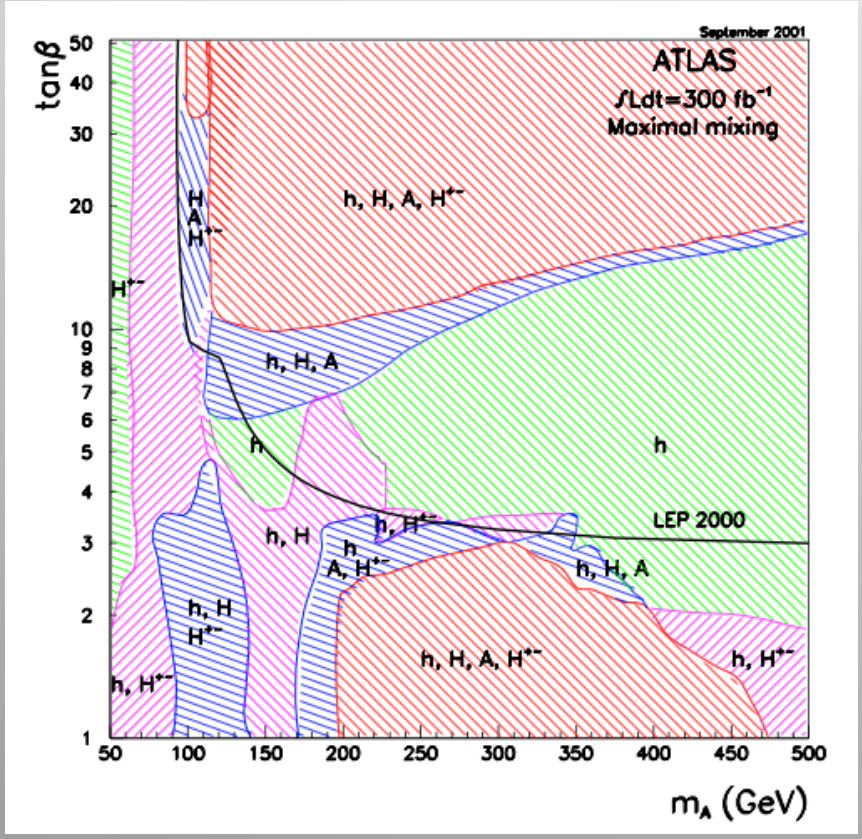
CMS data exclude at 95%CL a SM4G Higgs with a mass between 120 and 600GeV

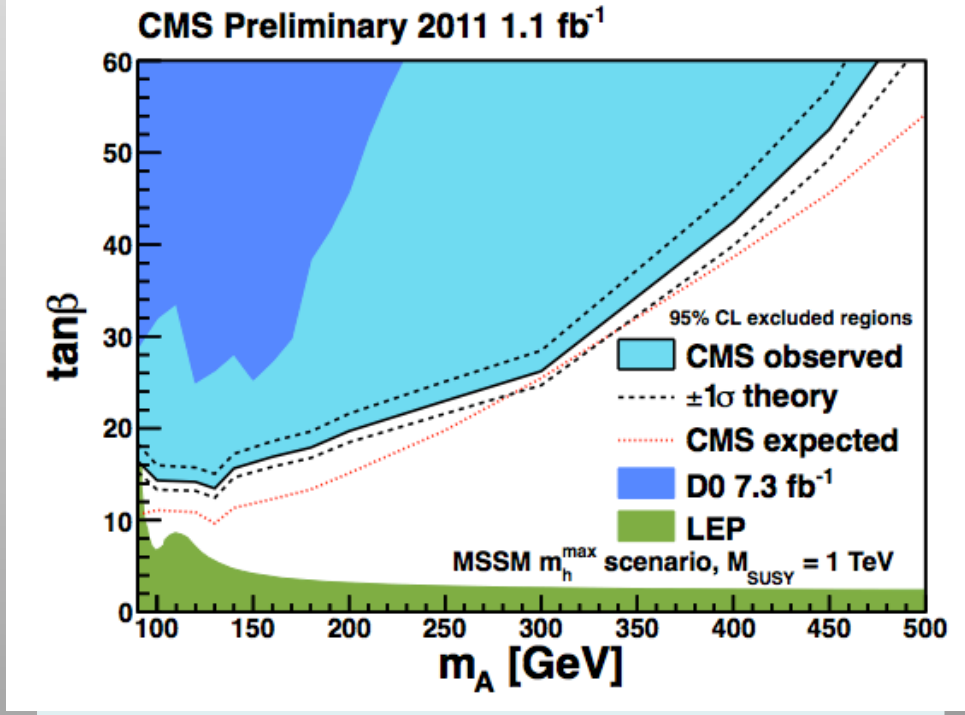
Prospects for the MSSM Higgs

The properties of particularly the CP-odd A Higgs are important for calculating the relic density



CMS-HIG-11-008

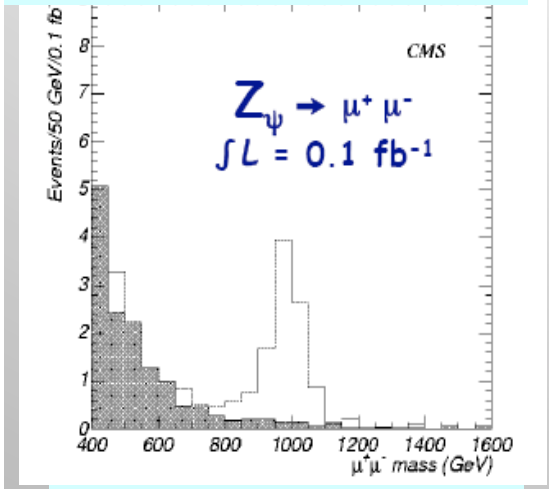




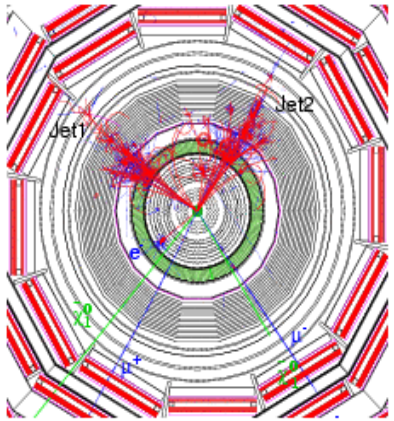
This may be difficult if tan β is small

Physics Beyond the Standard Model

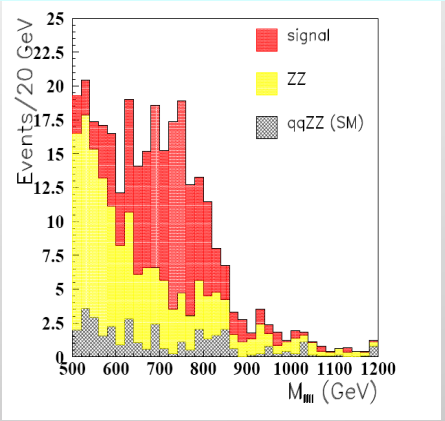
New Gauge Bosons?



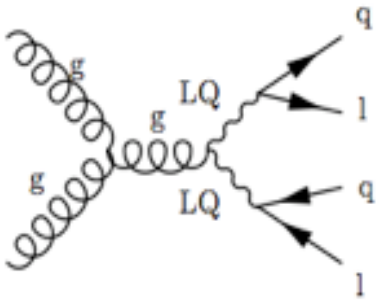
Supersymmetry



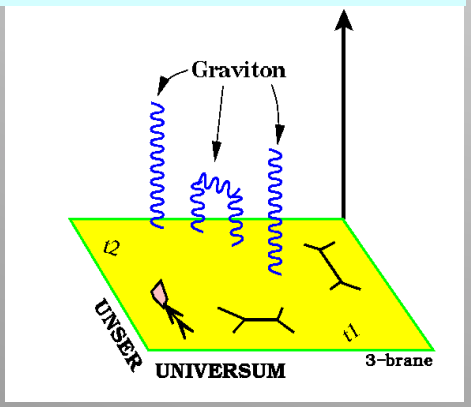
ZZ/WW resonances?



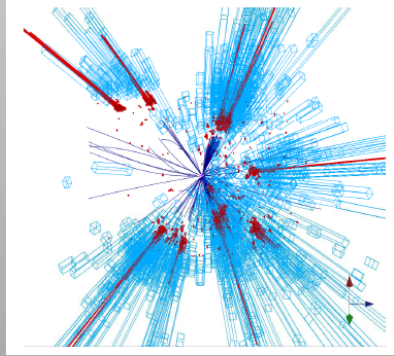
Leptoquarks?



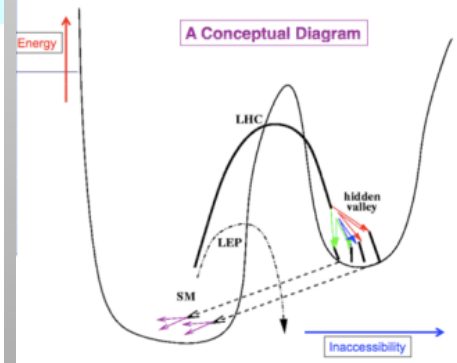
Extra Dimensions?



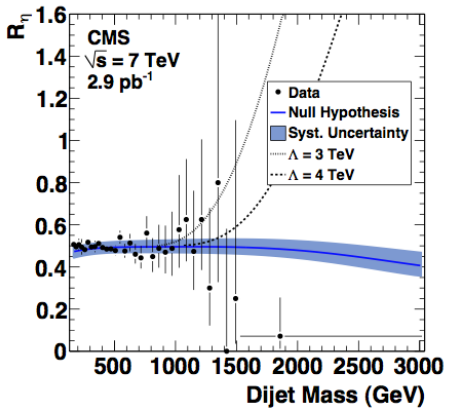
Black Holes???



Long lived particles?



Compositness?

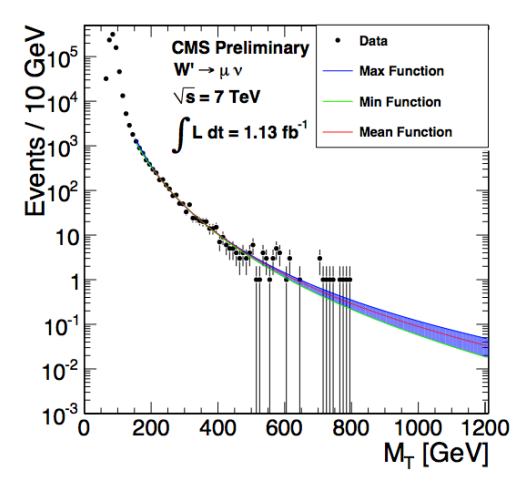


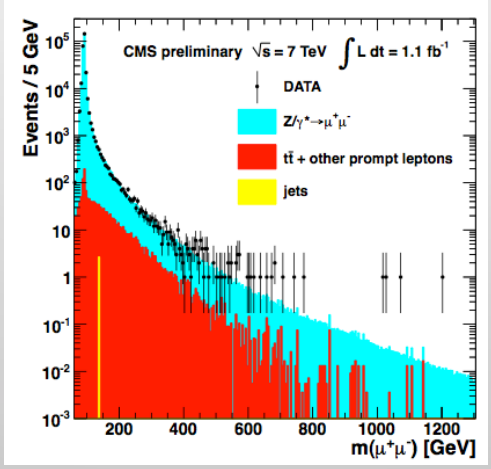
We do not know what is out there for us…
A large variety of possible signals. We have to be ready for that

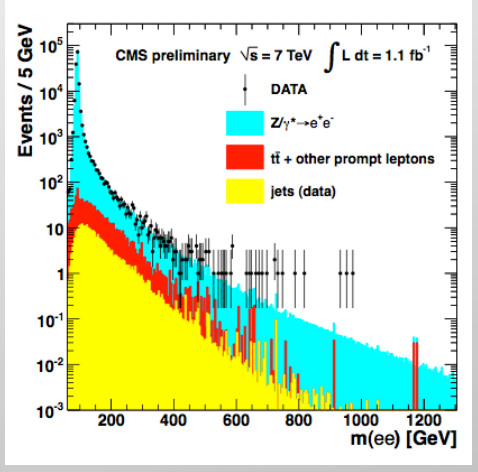
Search for New Gauge Bosons

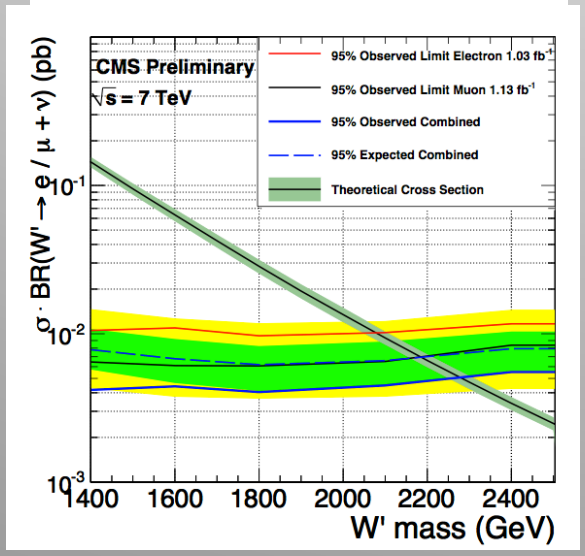
CMS-EXO-11-024
CMS-EXO-11-019

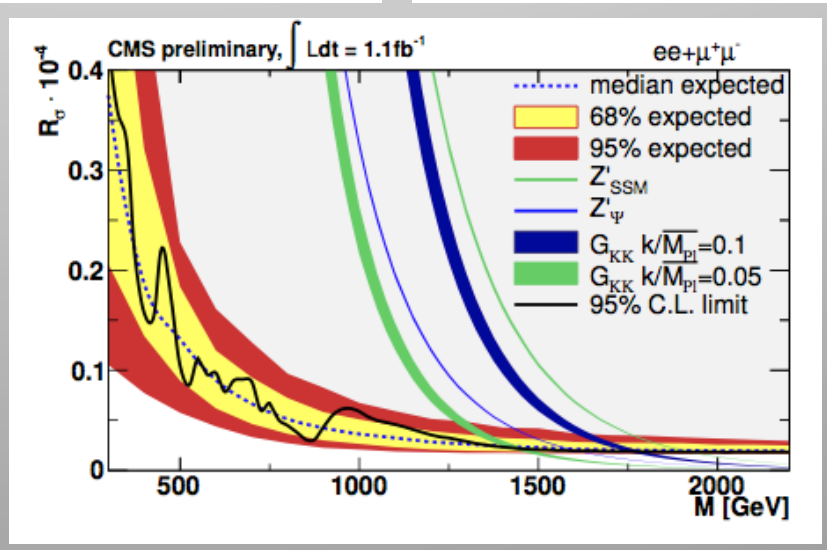
Study of the channels $W' \to \mu\,\nu$, $e\,\nu$ and $Z' \to \mu\,\mu$, ee







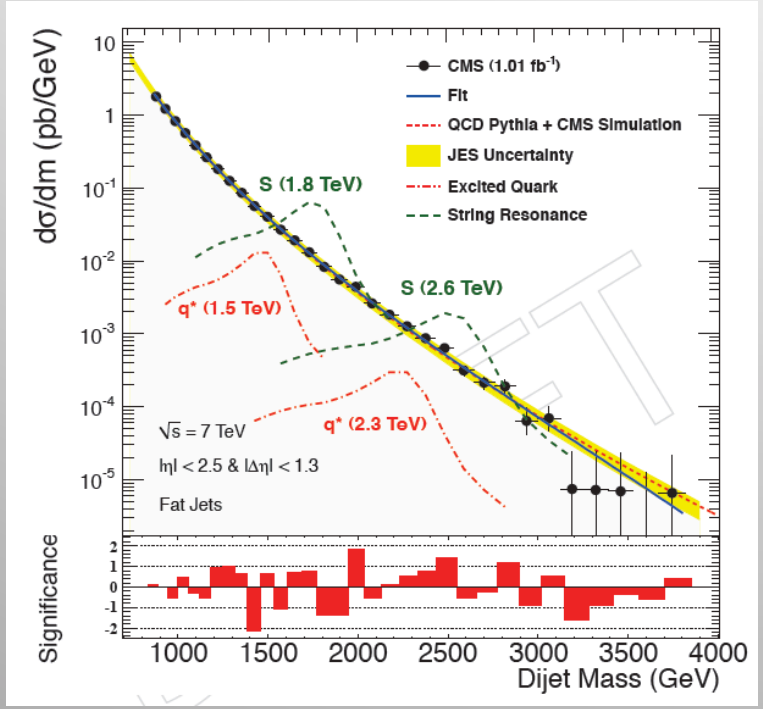


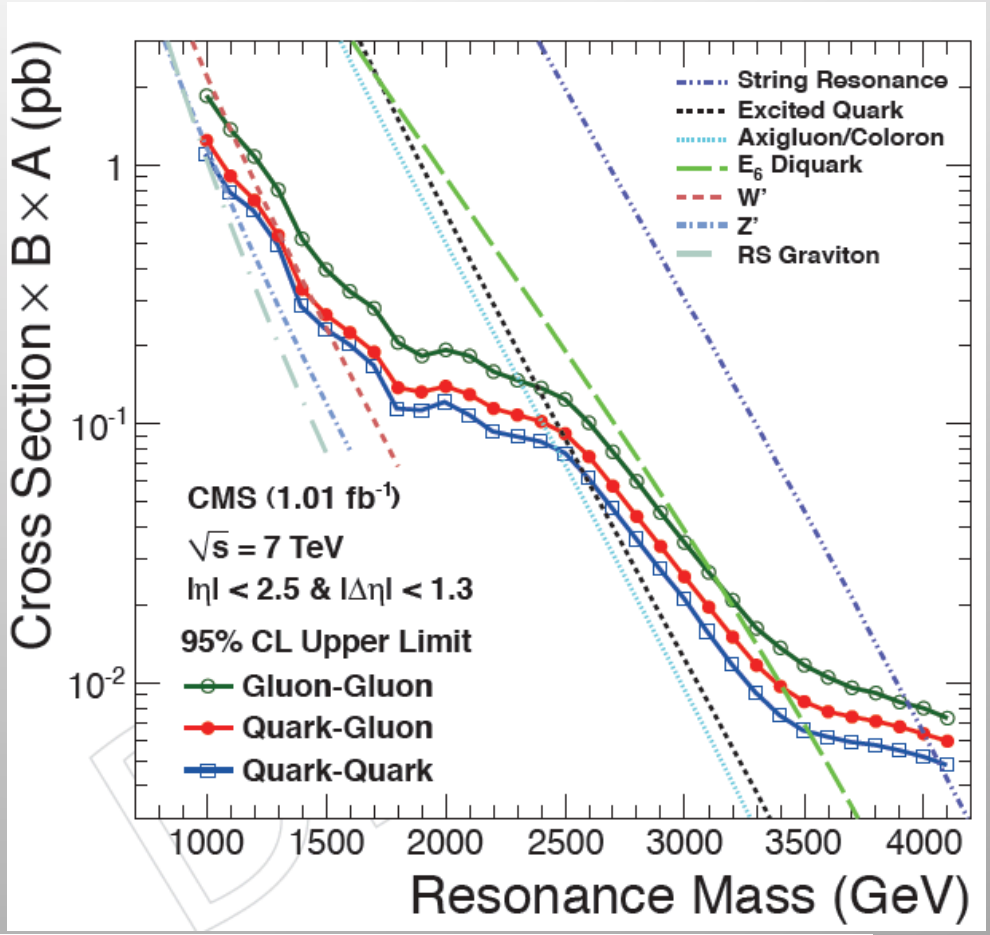


Exclude new gauge bosons up to ~2.27 TeV (W') and 1.94TeV (Z') @ 95% CL

Dijet Resonance Search

CERN-PH-EP-2011-119 Submitted to PLB



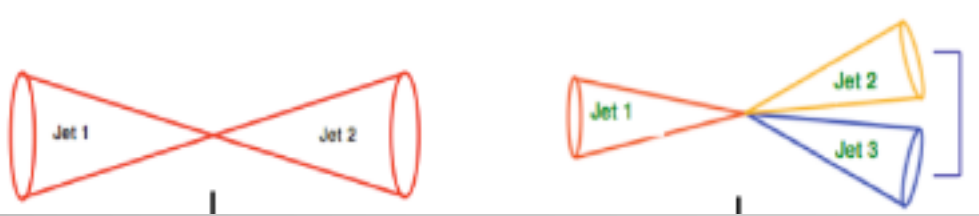


Model	Previous CMS Excluded @95% w/ 3 pb⁻¹ (TeV)	Excluded @95% CL w/ 1fb-1 (TeV)	Expected limit (TeV)
String Resonance	0.5–2.5	1.0 – 4.00	3.90
Excited Quark	0.5–1.58	1.0 – 2.49	2.67
Axigluon/Coloron	0.5–1.52	1.0 – 2.47	2.66
E_6 Diquark	0.5–0.58,0.97–1.08,1.45–1.6	1.0 – 3.52	3.28
W'	N/A	1.0 – 1.51	1.42

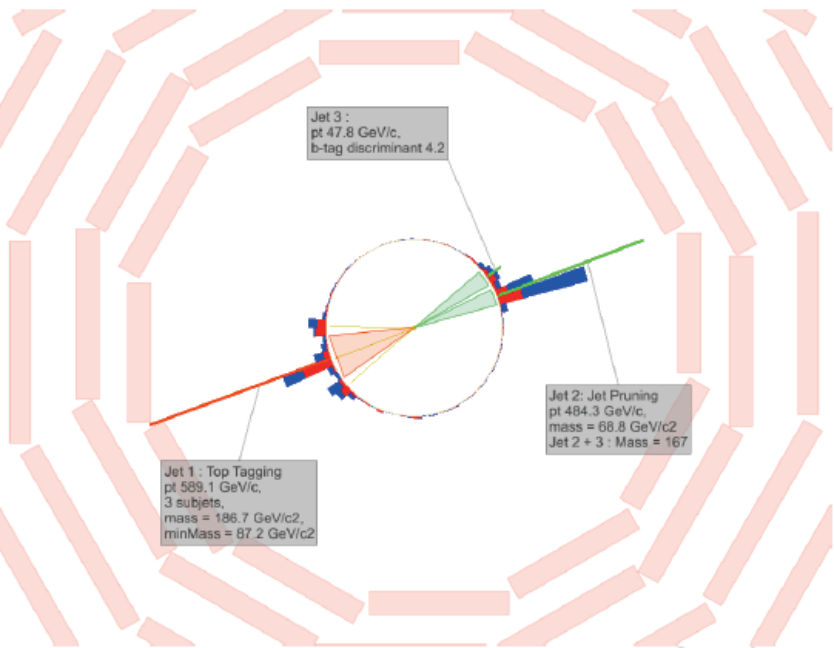
Z' → tt Search

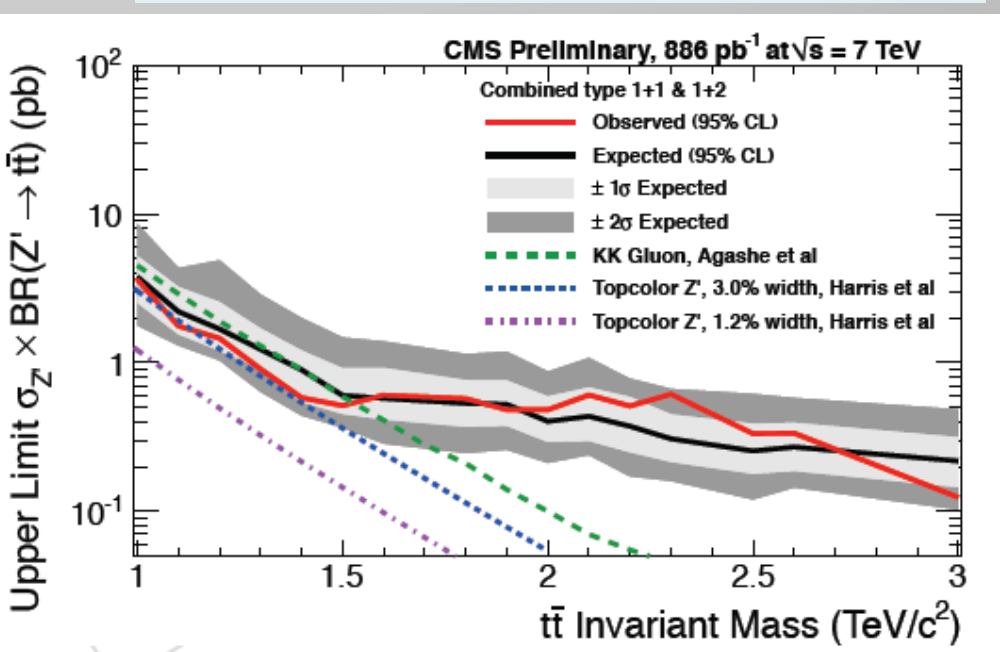
Search in the all hadronic decay channel for the tops
Tops are boosted for high mass Z', jets merge
Start from Cambridge-Aachen fat jets and apply jet pruning to find sub-jets
QCD background estimate from data (mistag method)

CMS-EXO-11-006



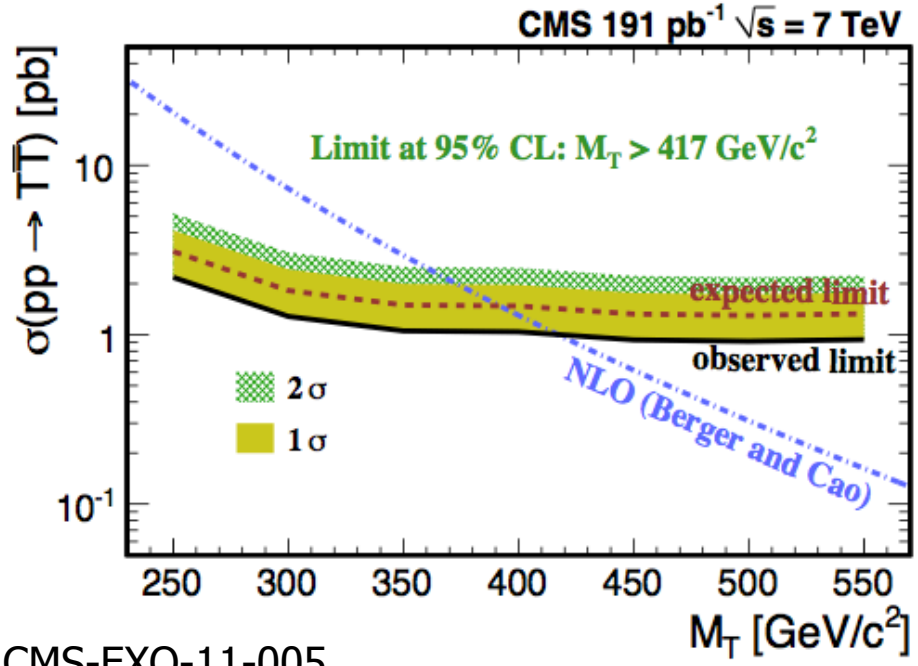
Exclude KK-Gluons 1<M<1.5 GeV





4th Generation: Top partners

$T \to tZ$

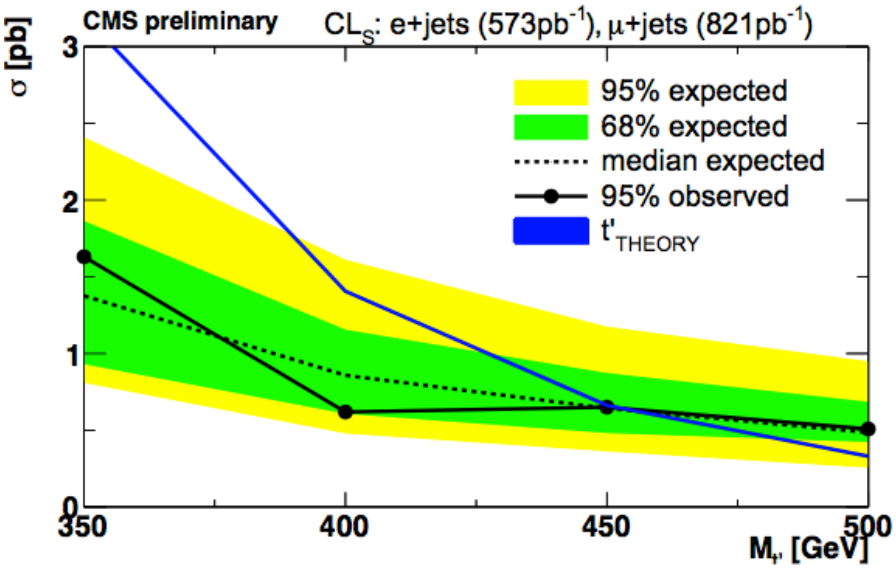


CMS-EXO-11-005

$M(T)$ [GeV/c^2]	250	300	350	400	450	500	550
Observed limit [pb]	2.18	1.28	1.05	1.04	0.93	0.91	0.94

No top-like quark with tZ decay found with mass < 417 GeV at 95% CL

$t'\bar{t}' \to WbW\bar{b} \to \ell\nu bq\bar{q}\bar{b}$



CMS-EXO-11-0051

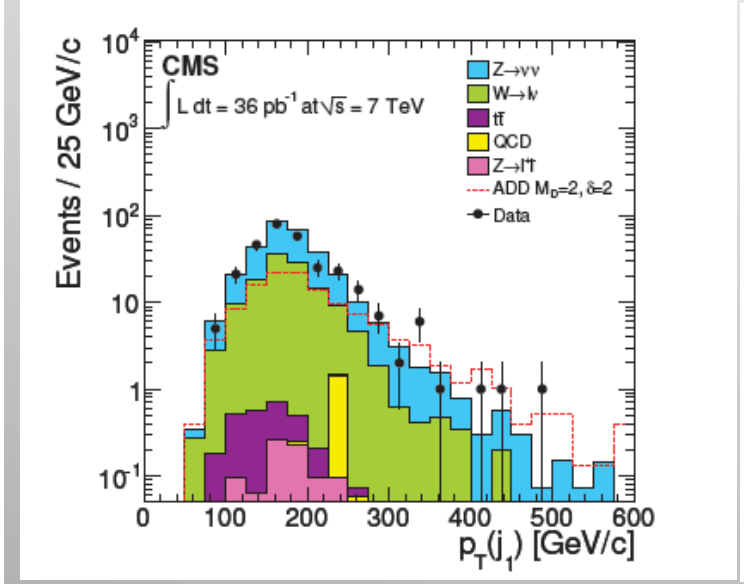
No t' with found in the region of mass < 450 GeV at 95% CL

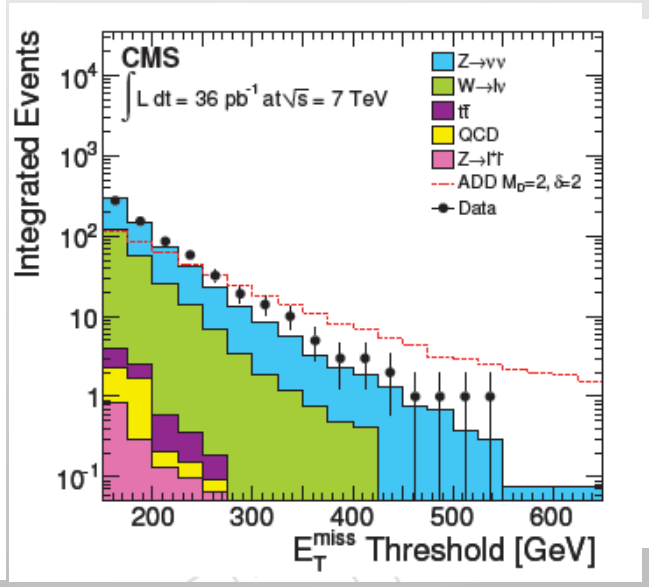
$b'\bar{b}' \to tW^-\bar{t}W^+ \to bW^+W^-\bar{b}W^-W^+$

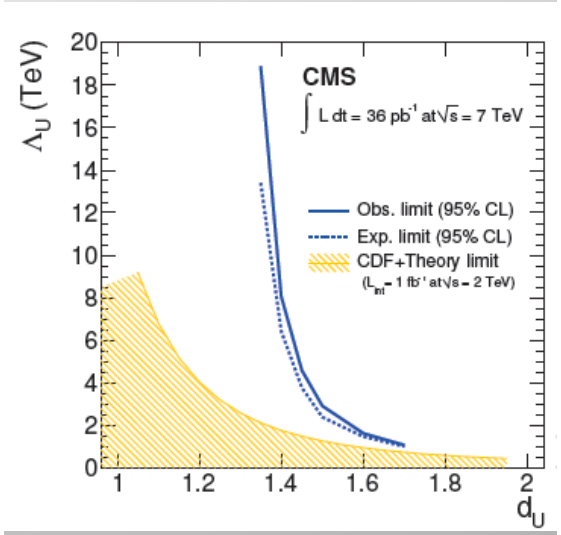
No b' with 255<mass< 361 GeV

Monojets: ADD Extra Dimensions

Selection: max 2 jets in the event: 1 jet > 110 GeV, MET> 150 GeV





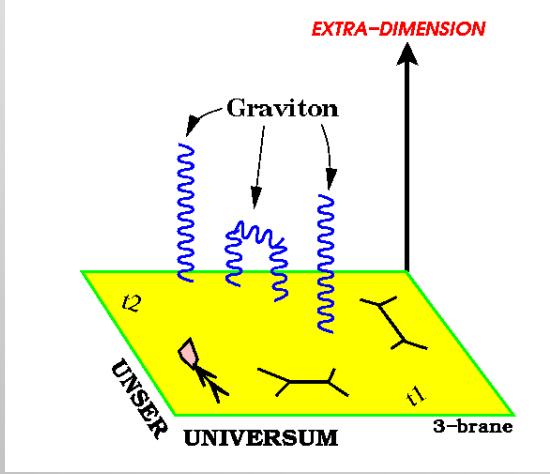


CMS-EXO-11-003

Results for ADD scale (with/without K-factor)

δ	K factor	LO Exp.	LO Obs.	NLO Exp.	NLO Obs.
2	1.5	2.17	2.29	2.41	2.56
3	1.5	1.82	1.92	1.99	2.07
4	1.4	1.67	1.74	1.78	1.86
5	1.4	1.59	1.65	1.68	1.74
6	1.4	1.54	1.59	1.62	1.68

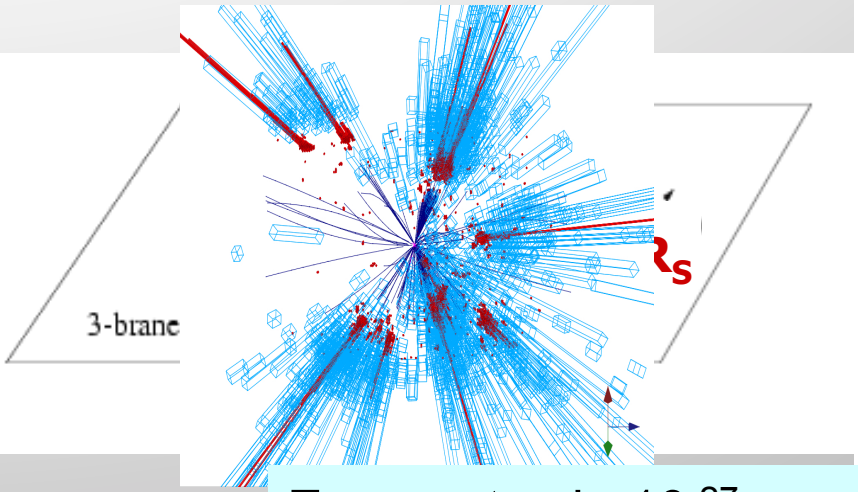
Search for Micro Black Holes



CMS-EXO-11-071

Extra Dimensions!

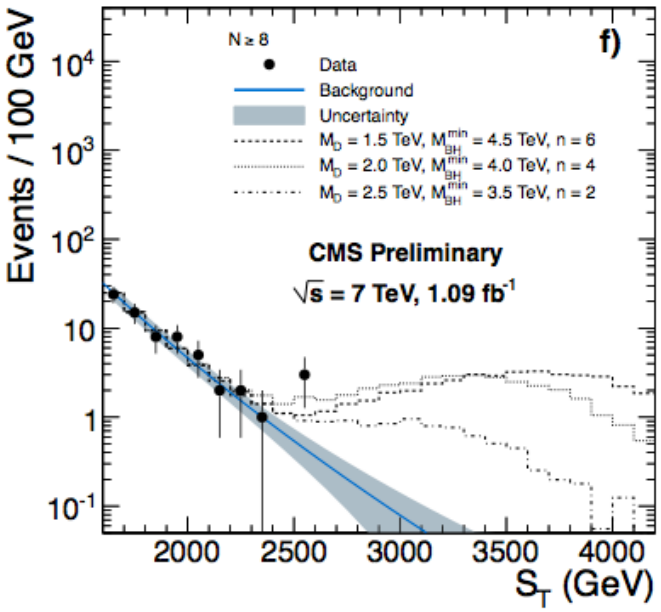
Planck scale
a few TeV?

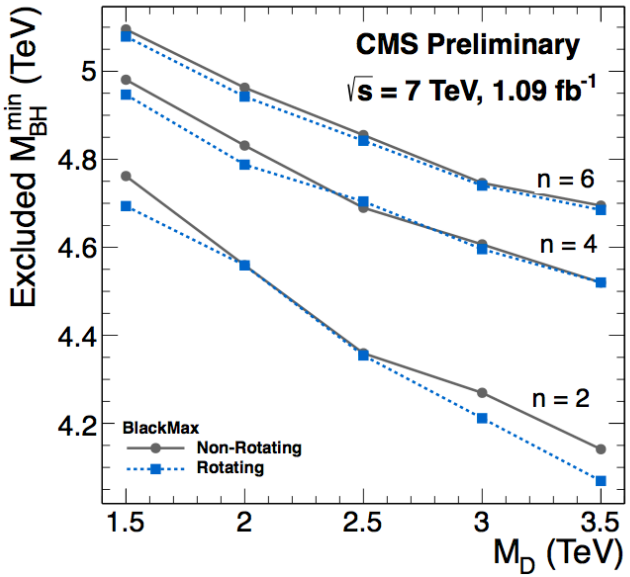


Evaporates in 10^{-27} sec

Look for the decay producs of an evaporating black hole

- Define S_T to be the scalar sum of all high p_T objects found in the event
- Look for deviations at high S_T



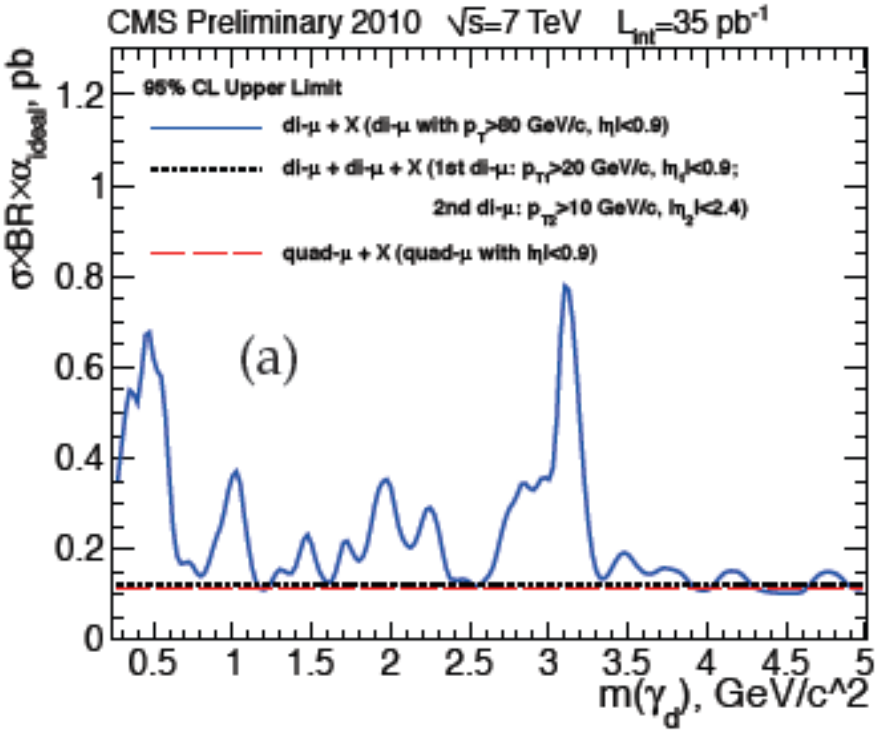


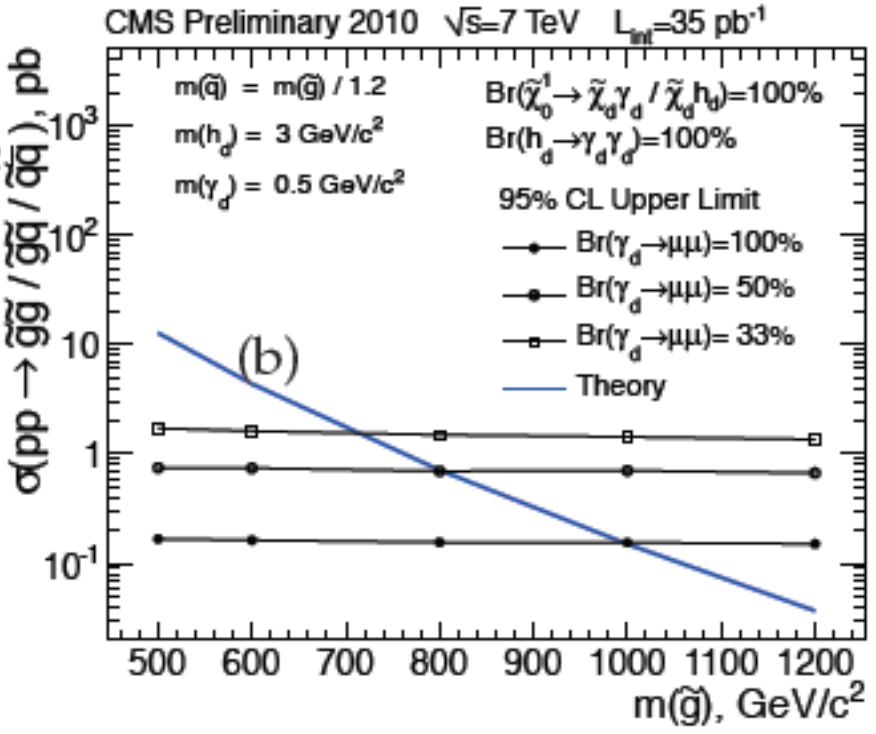
Black hole masses excluded in range ~5 TeV depending on assumptions

Search for Dark Photons

Dark photons decaying into muons. Look for muon jets events in data

Arkani-Hamed, Weiner





$$\tilde{\chi}_1^0 \rightarrow \tilde{\chi}_{dark}\gamma_{dark} + \tilde{\chi}_{dark}h_{dark}(\rightarrow \gamma_{dark}\gamma_{dark})$$

None found so far.... Limits set on production cross sections

Long Lived Particles

Split Supersymmetry

- Assumes nature is fine tuned and SUSY is broken at some high scale
- The only light particles are the Higgs and the gauginos

- Gluino can live long: sec, min, years!

- R-hadron formation (eg: gluino+ gluon): slow, heavy particles

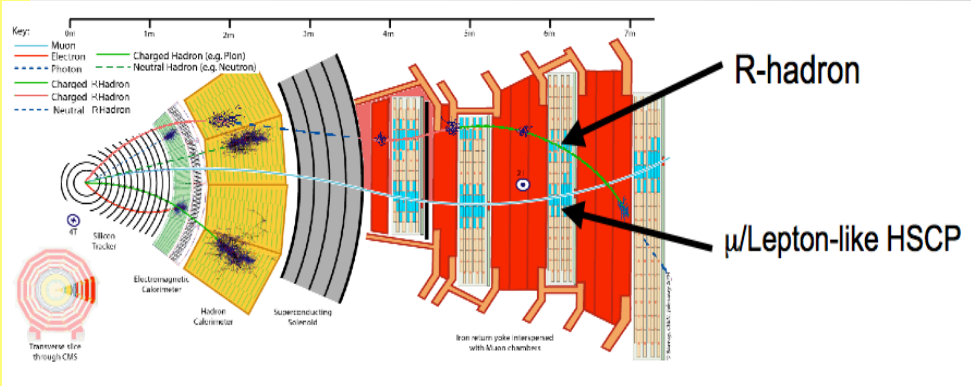
Unusual interactions with material

eg. with the calorimeters of the experiments!

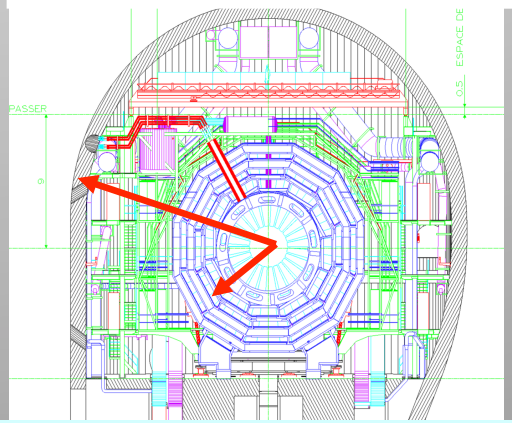
Gravitino Dark Matter and GMSB

- In some models/phase space the gravitino is the LSP
- ⇒ NLSP (neutralino, stau lepton) can live 'long'
- ⇒ non-pointing photons

⇒Challenge to the experiments!



K. Hamaguchi,M Nojiri,ADR hep-ph/0612060
ADR, J. Ellis et al. hep-ph/0508198



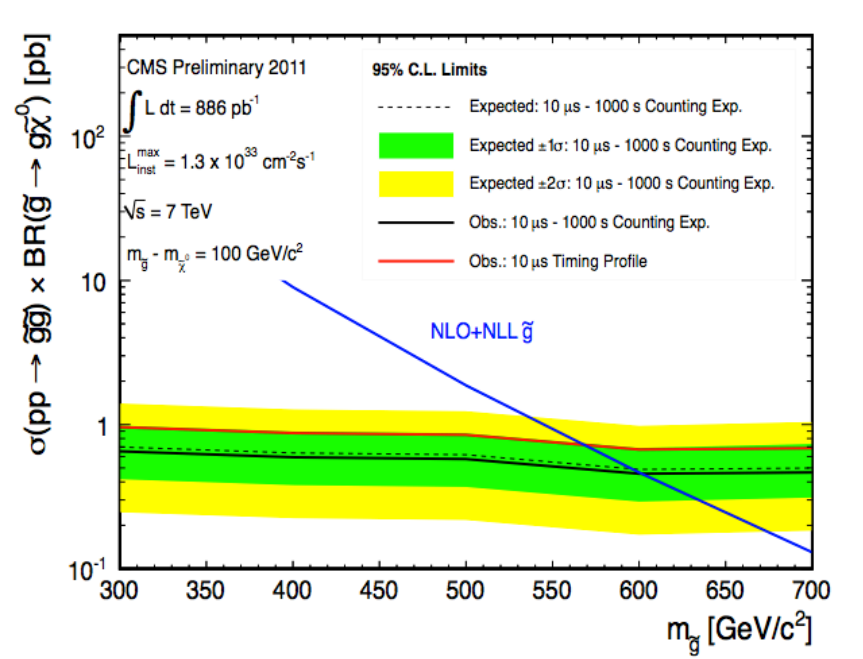
Sparticles stopped in the detector,walls of the cavern, or dense 'stopper' detector. They decay after hours---months…

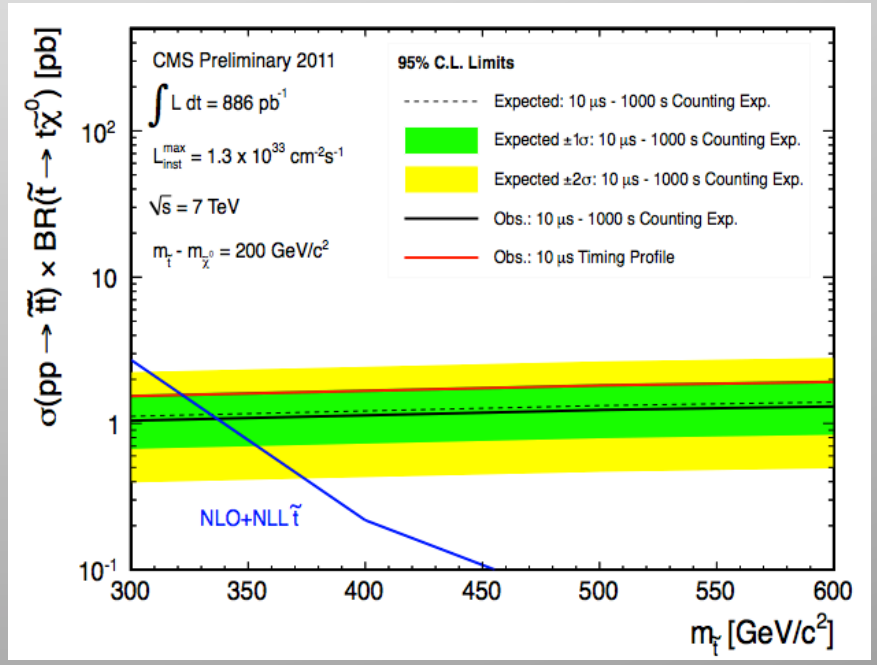
Searches: Stopped Gluinos

Search for Heavy Stable Charged Particles that stop in the detectors and decay a long time afterwards (nsec, sec, hrs…)

Special data taking after the beams are dumped and during beam abort gaps

CMS-EXO-11-020

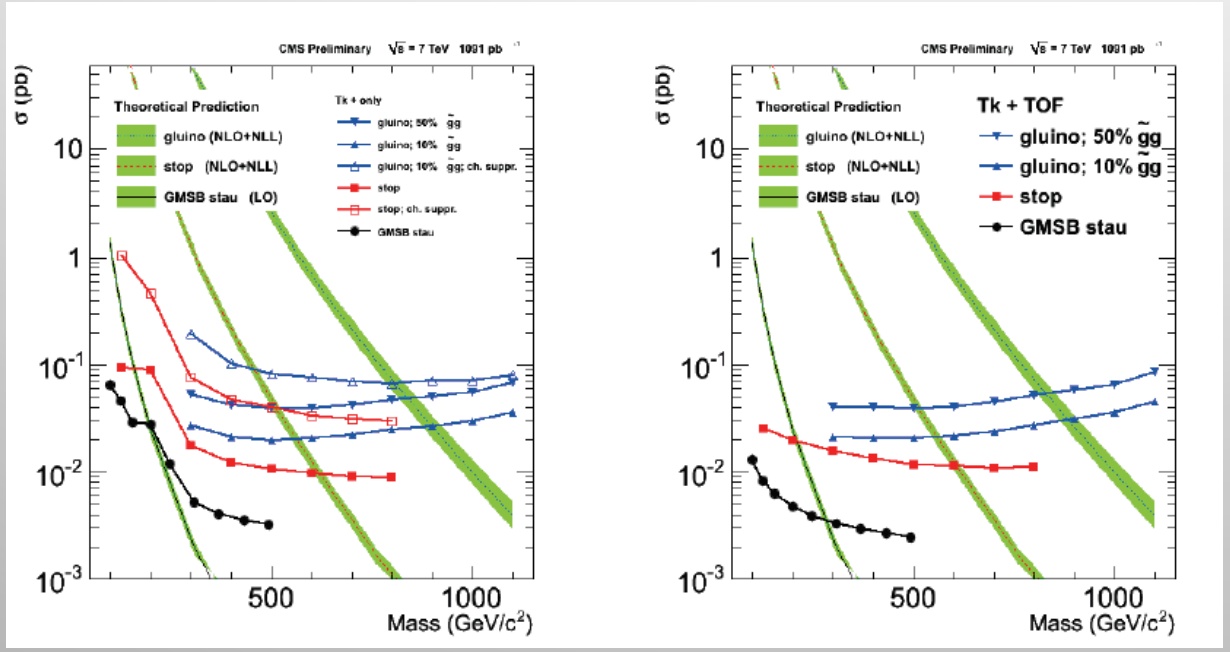




95% CL Limits: Stopped Gluinos > 600 GeV, Stopped Stop quarks> 337 GeV

Heavy Stable Charged Particles

CMS-EXO-11-022



Stable particles that traverse the detector, and move slowly

Eg heavy stable Gluino or stop/stau

Search limits using tracker de/dx and Muon TOF information

Result for 1 fb^{-1}:
0 events after all cuts

95% C.L. mass limits are set for

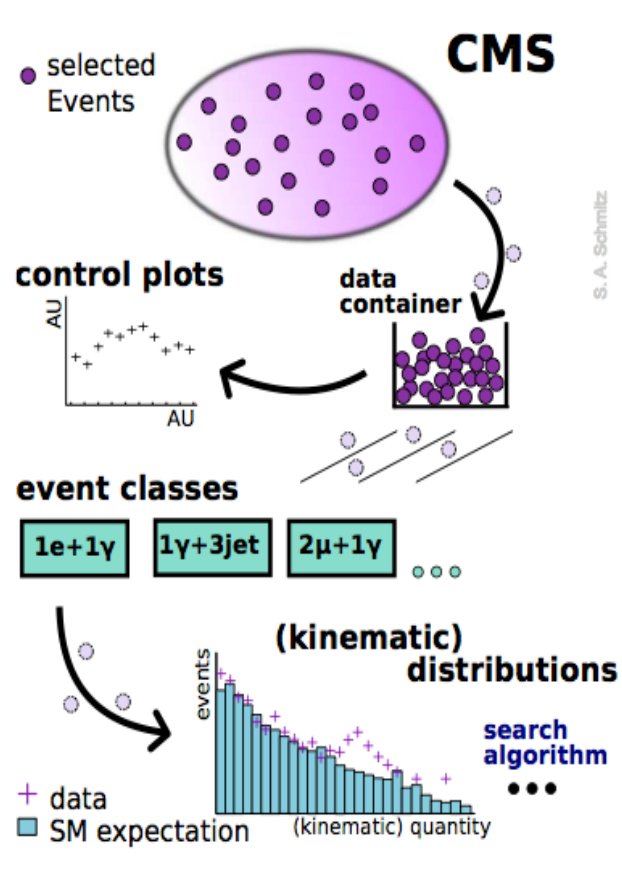
- Cloud model interaction scenario
  - Gluino (10% ~gg): 899 GeV, Gluino (50% ~gg): 839 GeV
  - Stop: 620 GeV GMSB Stau:293 GeV ← NEW Addition
- Charge suppression interaction scenario
  - Gluino(10% ~gg): 808 GeV, Stop: 515 GeV

Summary of the Exotica searches

	Limits in TeV	
	Heavy Bosons	
Z'_{SSM} ll	1.94	2011
Z'_{Ψ} ll	1.62	2011
G_{KK} ll k/M = 0.1	1.78	2011
W' lν	2.27	2011
W' dijet	1.51	2011
G_{KK} γγ k/M = 0.1 (2010)	0.945	2010
	4th Generation	
$M_{b'}$, b' ⇒ tW (2010)	0.361	2010
$M_{t'}$, t' ⇒ tZ (100%)	0.417	2011
$M_{t'}$, t' ⇒ bW (100%), l+jets	0.45	2011
	Heavy Stable Particles	
M_{gluino}, HSCP	0.899	2011
M_{gluino}, Stopped Gluino	0.601	2011
M_{stop}, HSCP	0.620	2011
M_{stop}, Stopped Gluino	0.337	2011
M_{stau}, HSCP	0.293	2011
	Large Extra Dimensions	
M_S, γγ, GRW (2010)	1.89	2010
M_S, μμ, GRW (2010)	1.75	2010
M_D, monojet, n_{ED} = 2 (2010)	2.56	2010
M_D, monojet, n_{ED} = 6 (2010)	1.68	2010
M_{BH}, rotating, M_D=3.5 TeV, n_{ED} = 2	4.1	2011
M_{BH}, non-rot, M_D=1.5 TeV, n_{ED} = 6	5.1	2011
String Ball M, M_D=2.1, M_s=1.7, g_s=0.4	4.1	2011
	Compositeness and Contact Interactions	
String Resonances	4.0	2011
E_6 diquarks	3.52	2011
Axigluon/Coloron	2.47	2011
q* , dijet	2.49	2011
q* , boosted Z	1.17	2010
e*, Λ = 2 TeV	0.720	2010
μ*, Λ = 2 TeV	0.745	2010
C.I. Λ , dijet mass (3 pb^{-1})	4.0	2010
C.I. Λ , X analysis	5.6	2010
	LeptoQuark	
LQ1, β=0.5 (2010)	0.340	2010
LQ1, β=1.0 (2010)	0.384	2010
LQ2, β=1.0 (2010)	0.394	2010

Can we miss something?

CMS-EXO-10-021

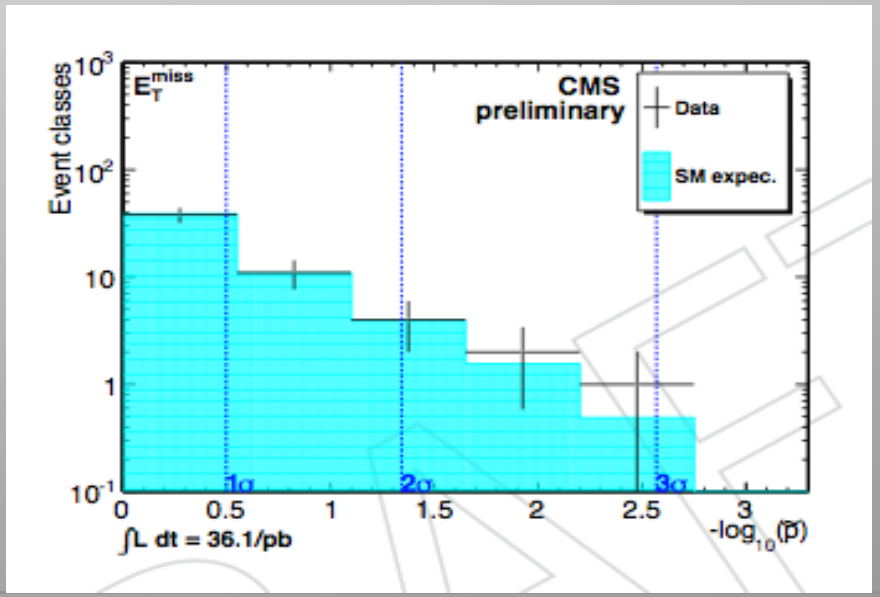


Model independent search

- Divide events into exclusive classes
- Study deviations from SM predictions in a statistical way

Distributions in each class

- $\sum p_T$ - Most general
- $M_{inv}^{(T)}$ - Good for resonances
- MET - Escaping particles



Probability distribution as expected for 35 pb^{-1}

Look at & watch the outliers…

Summary: The Search is on!

- Dark Matter is closely connected with the searches for new physics at the LHC. The most popular example is SUSY, but many other NP models have a dark matter candidate.
- No sign of new physics yet – hence no sign of Dark Matter candidates yet. Starts to cut into the 'preferred SUSY region'. The air for constrained models is getting very thin.
- The present results have impact on the Dark Matter interpretation within models. No conflict yet with direct searches (but check DAMA/COGENT "SUSY scenarios")
- We need to prepare to tackle the next, more difficult, cases experimentally. Guidance and ideas welcome! Will have to reassess what detail on DM study the LHC can contribute.
- The LHC is did its part so far with a great first half in 2011