Searches at the Tevatron and the Large Hadron Collider

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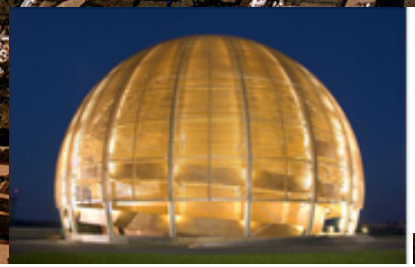
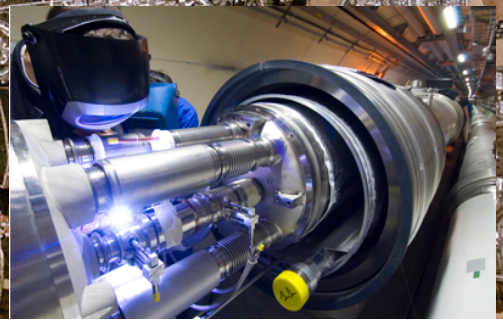
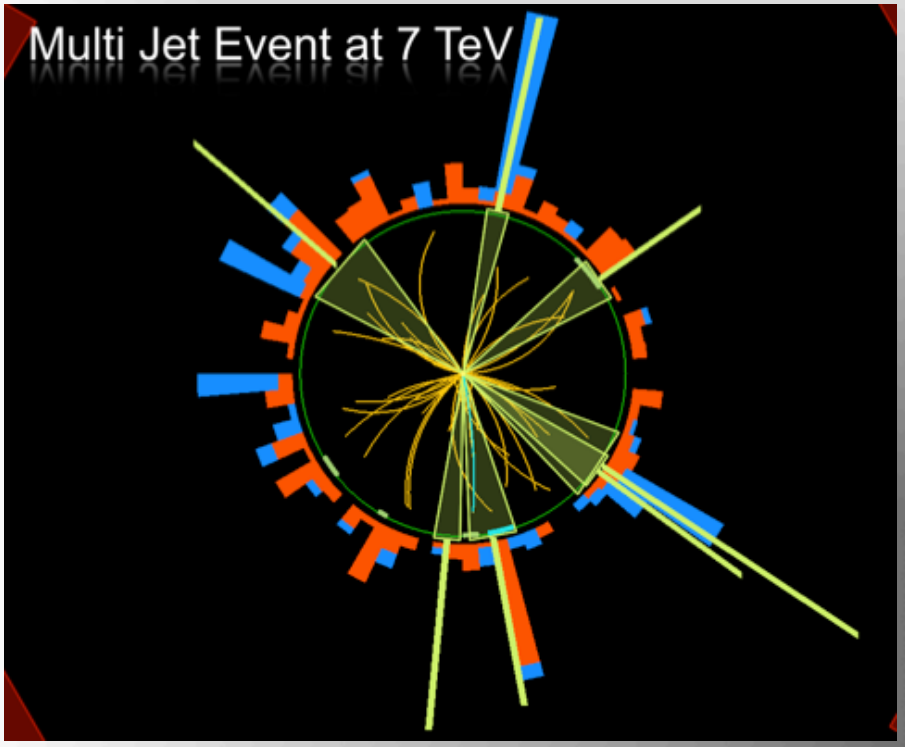
10 June 2011



The 2011 Hadron Collider Physics Summer School

CERN, Geneva, Switzerland
June 8-17, 2011

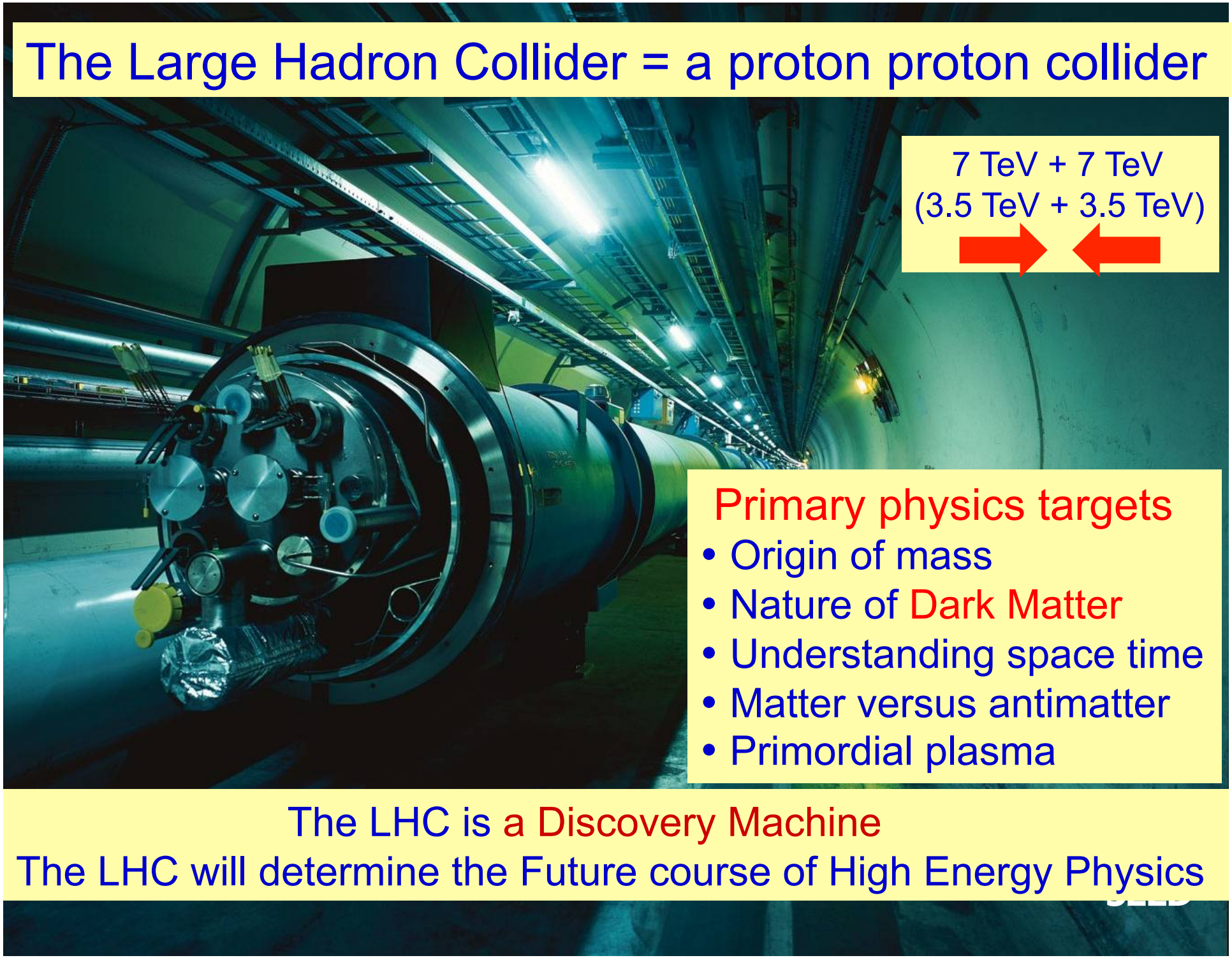




Outline

- Introduction:Discoveries
- LHC & Tevatron
- Some outstanding puzzles of the Tevatron
- First year @ the LHC
- Summary & Outlook

The Large Hadron Collider = a proton proton collider



7 TeV + 7 TeV
(3.5 TeV + 3.5 TeV)

Primary physics targets

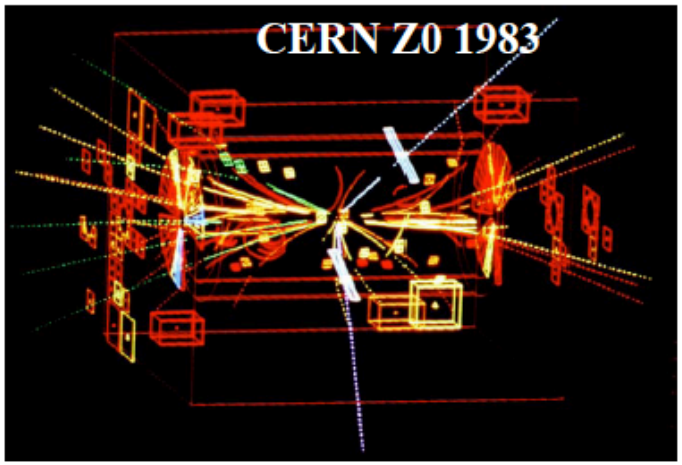
- Origin of mass
- Nature of Dark Matter
- Understanding space time
- Matter versus antimatter
- Primordial plasma

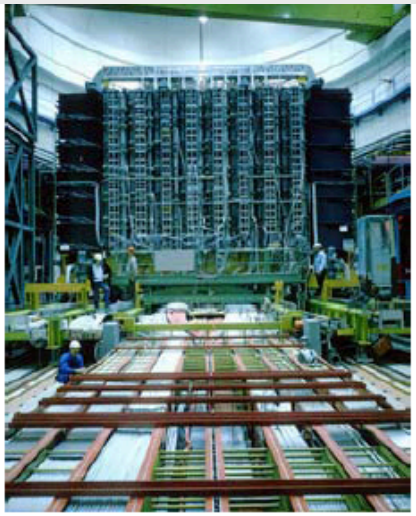
The LHC is a Discovery Machine

The LHC will determine the Future course of High Energy Physics

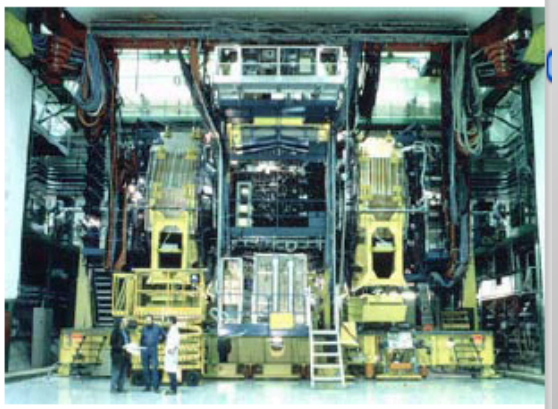
Discoveries at Recent Colliders

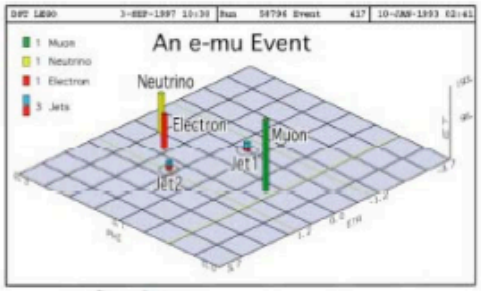
The W/Z bosons and the top quark

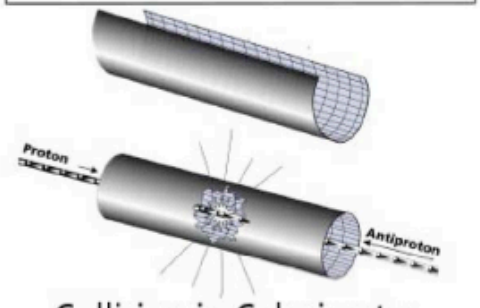




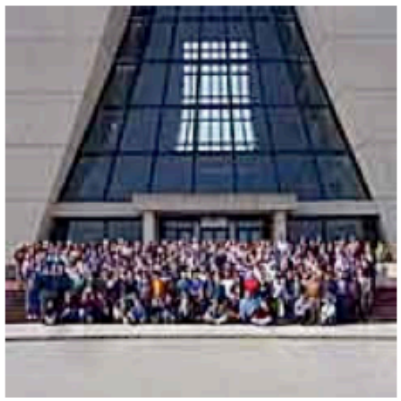
Tevatron, top, 1995







Collision in Calorimeter



“Discoveries” at Recent Colliders

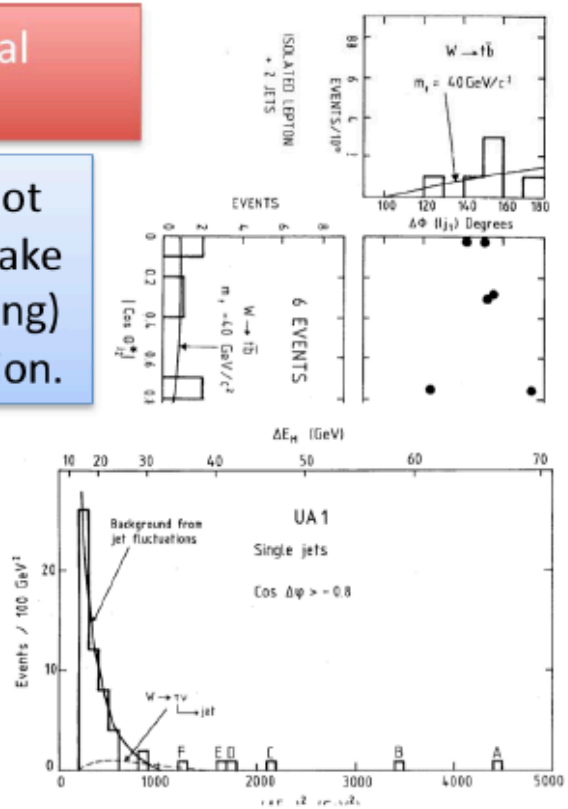
“Discoveries”

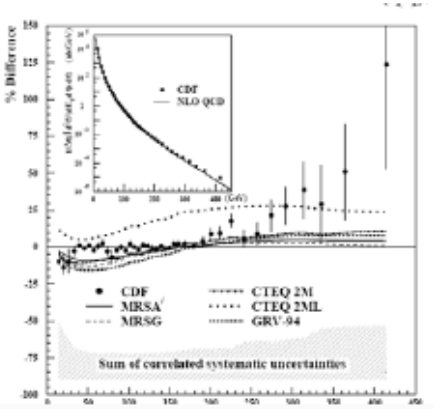
There are good reasons to be sceptical about new discoveries!

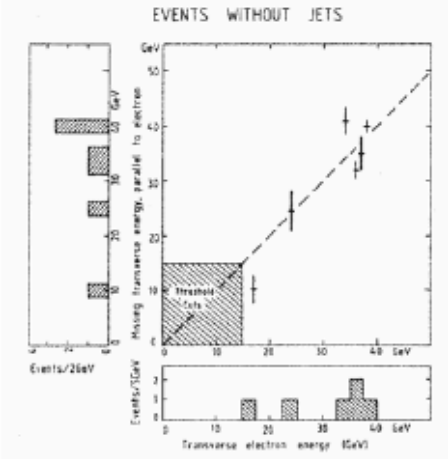
When looking for something that is not well predicted, it is much easier to make mistakes (missed systematic, cut tuning) or be mislead by a statistical fluctuation.

That went away

- contact interactions
- pentaquarks
- leptoquarks
- 40 GeV top quark
- zeta
- Mark J events
- eeγγ event



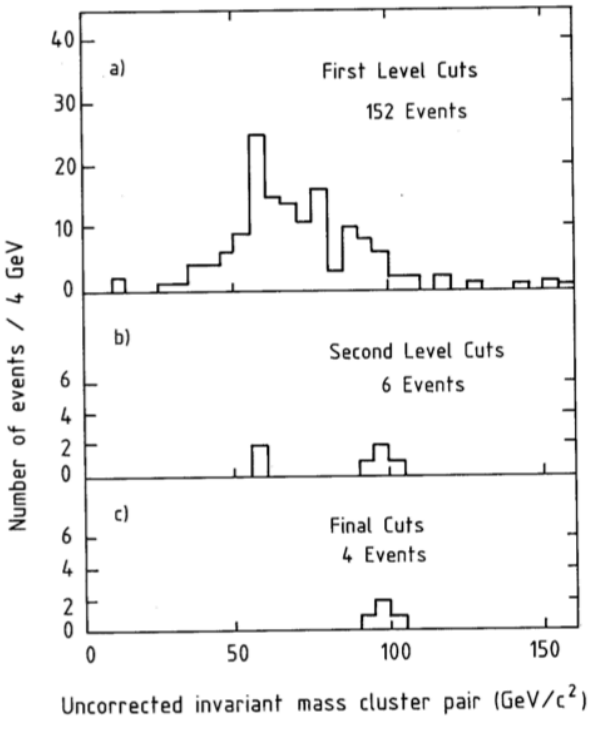




Discoveries do not always survive with time

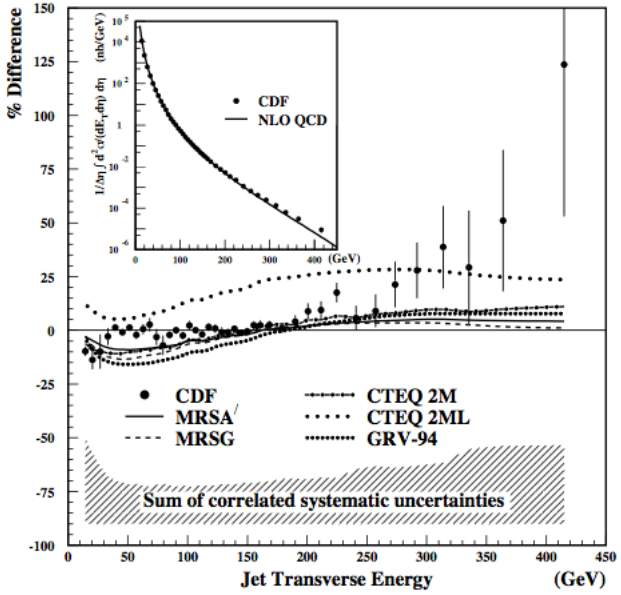
Discoveries at Recent Colliders

'83: Z bosons -> leptons
4 events/~no background



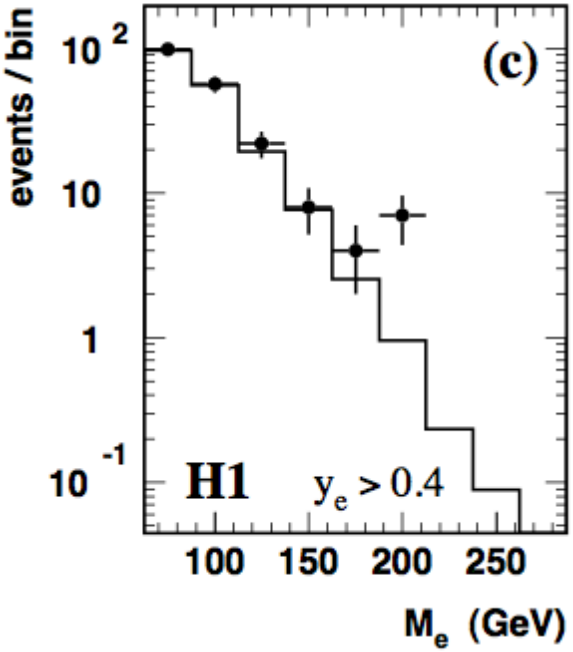
Z stayed!!
More prominent with time

'95: Compositness
Di-jet events at high E_T
Data/TH disagreement



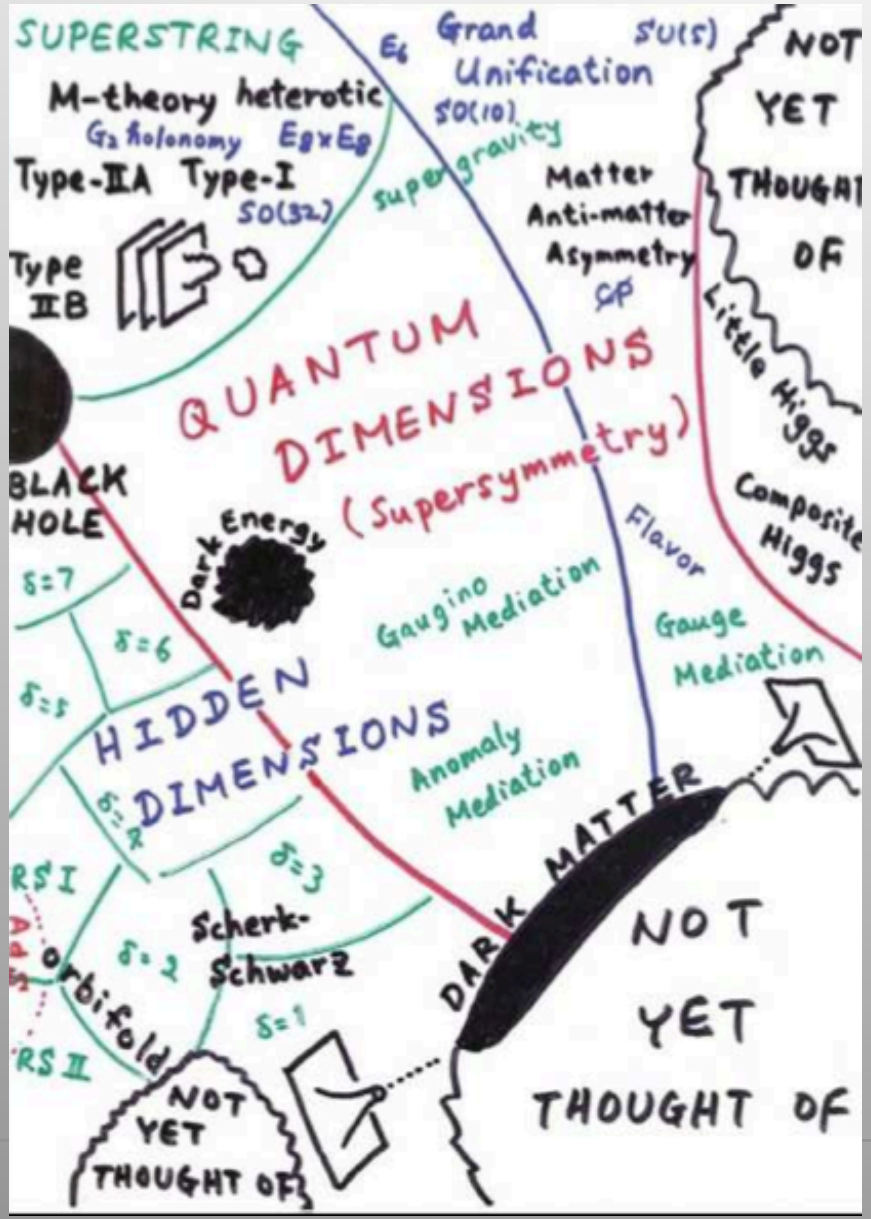
Went away:
Theory (PDFs) and exp systematic improved

'97: Leptoquarks
electron + jet @ HERA
7 events 1 expected



Went away:
Statistical fluctuation

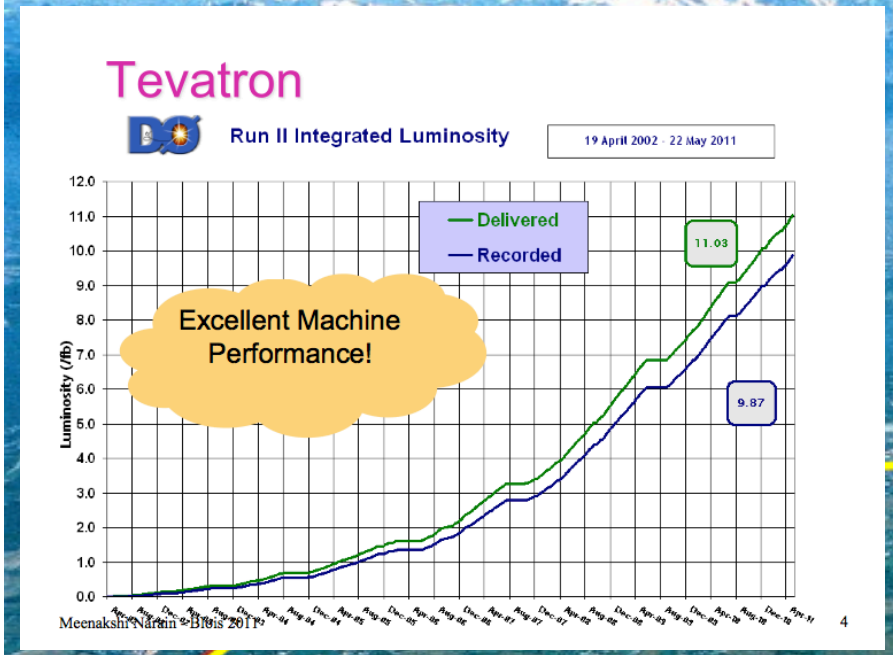
Beyond the Standard Model: No Lack of Ideas

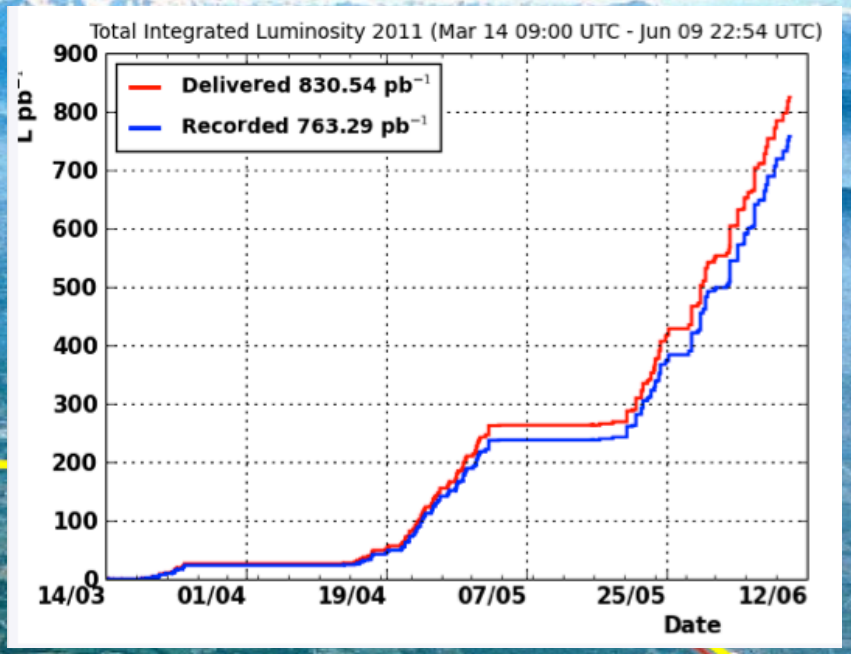


During the last 2-3 years we –LHC experimentalists- got more models to deal with than we needed…

Some theorists found it a challenge to invent a model with signatures difficult for the experiments:
heavy stable charged particles, hidden valley models, Quirks…

The Tools



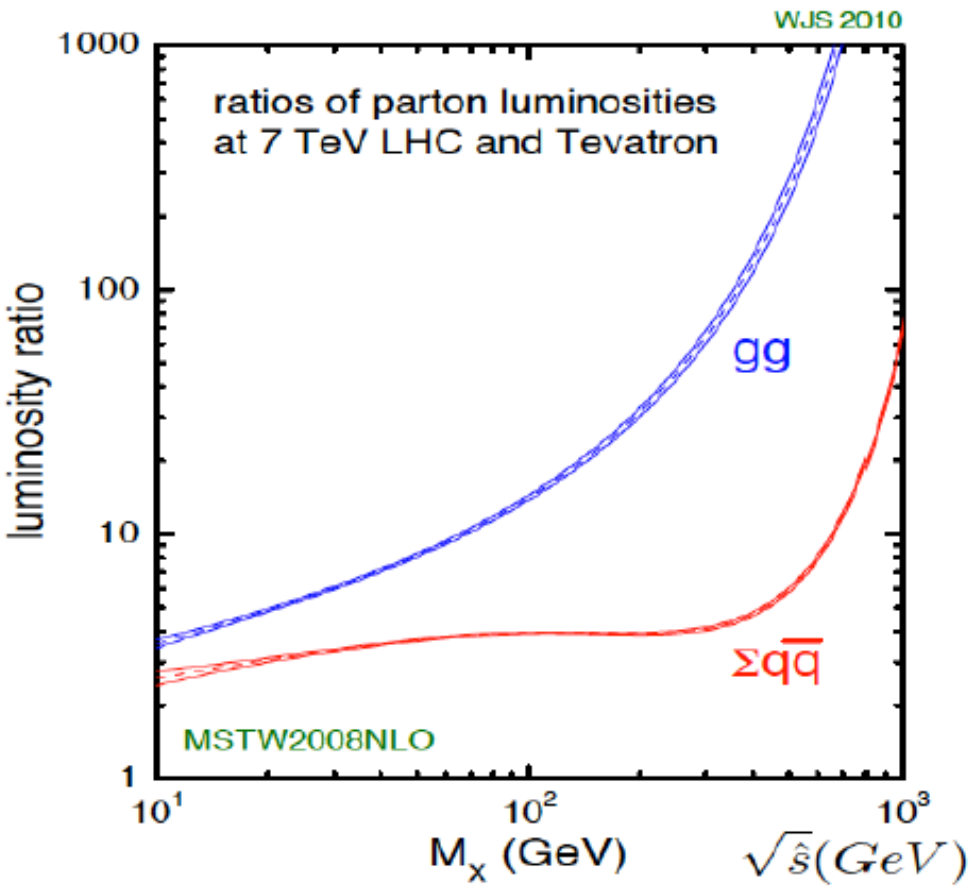


Energy 1.96 TeV
Int. Luminosity: 11 fb^{-1}
Age: ~25 years

Energy 7 TeV
Int. Luminosity: 0.045 - 0.83 fb^{-1}
Age: ~1 year

Searches for New Physics

Can LHC already compete with the Tevatron? Yes we can!



- The LHC at √s= 7 TeV offers (with respect to Tevatron):
  - Higher center-of-mass energy → access to new physics scales, even with very low luminosities
  - ~ 10 times more gluon-gluon initial state → top factory, more Higgs cross section, also larger QCD backgrounds
  - ~ 3 times more $q\bar{q}'$ initial state → larger W/Z production in general (inclusive or associated)

Recent Anomalies @ Tevatron

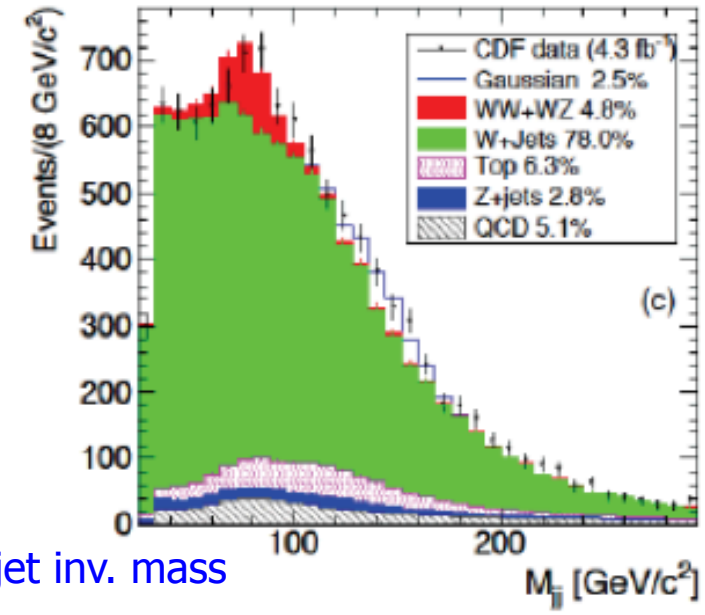
Not labelled discoveries yet.

- CDF Multi-Muon events: not observed by D0. No news from increased data sample yet.
- D0 like-sign dimuon excess: not –yet- confirmed by CDF
- Top production forward backward asymmetry: 2 sigma effect by both CDF/D0, now 3.4 sigma by CDF/D0 in preparation
- W+dijet resonance with mass 120-160 GeV in CDF: At the level of 3.2 sigma.Not –yet- confirmed by D0
- 4^{th} generation in the t'->bW? Both experiment see some excess at high mass. Difficult region for backgrounds

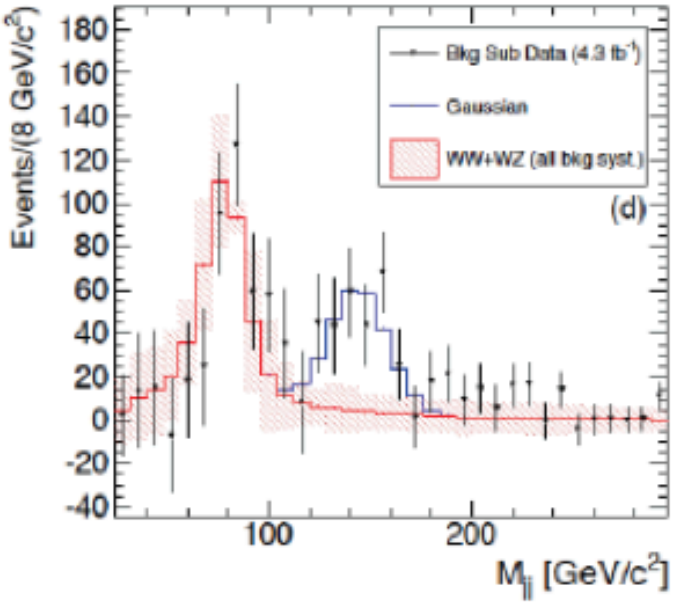
Enter also the LHC as a new referee on many of these topics very soon!

Recent Anomalies: W+jets

Study W+ 2jets (exclusive) W leptonic decay, jets > 30 GeV, P_{Tjj} > 40 GeV



Dijet inv. mass



Subtract all backgrounds except WW & WZ
Expect to see W,Z decaying into jets

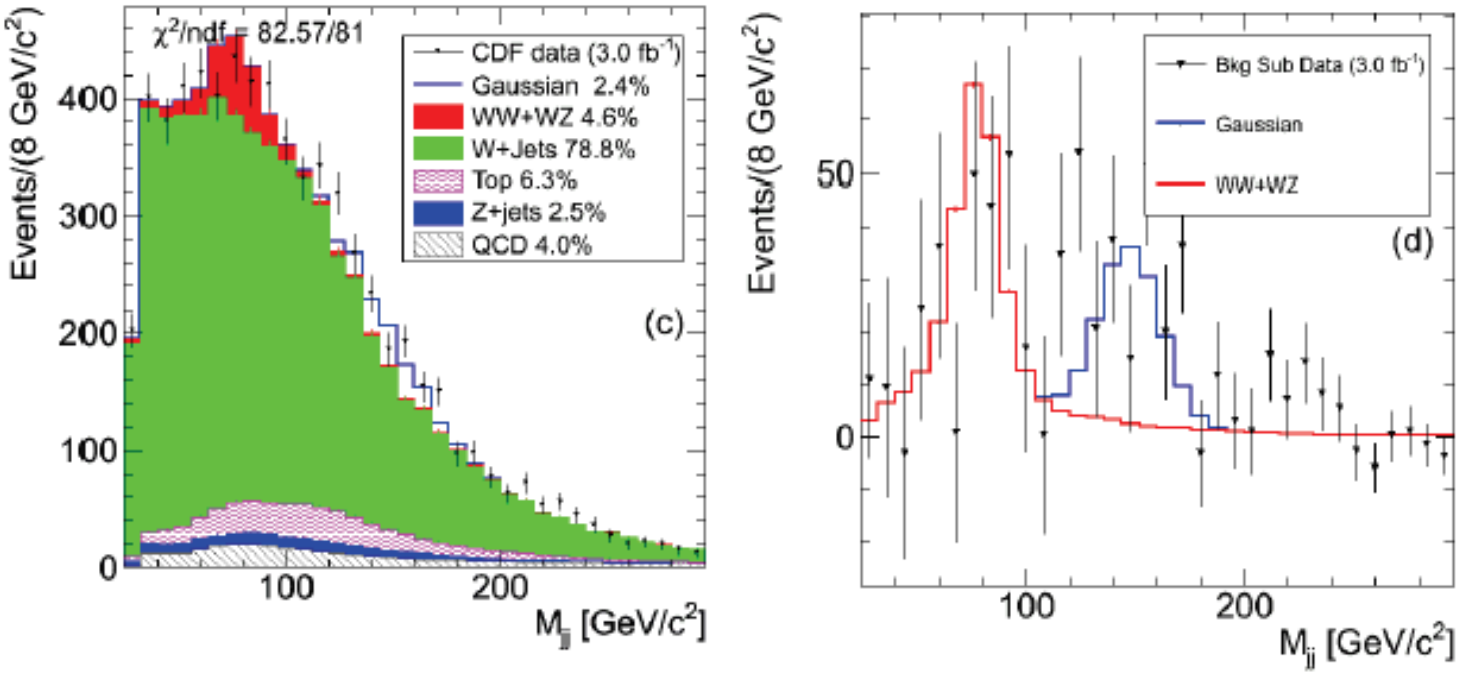
- 3.2σ excess (w/ trial factor) in Mjj spectrum in W+2jets events [PRL 106,171801 (2011)]
- Since publication, many papers cited this result and proposed possible interpretations, mostly based on NP

New physics? Ideas: technicolor, leptophobic Z', Stuckelberg Z', 2HDM color scalars, color octets, low mass strings, radion, Higgs bound state dark forces, intrinsic quarks, susy, single top production…

Recent Anomalies: W+jets update

Additional sample of 3fb^{-1} of data

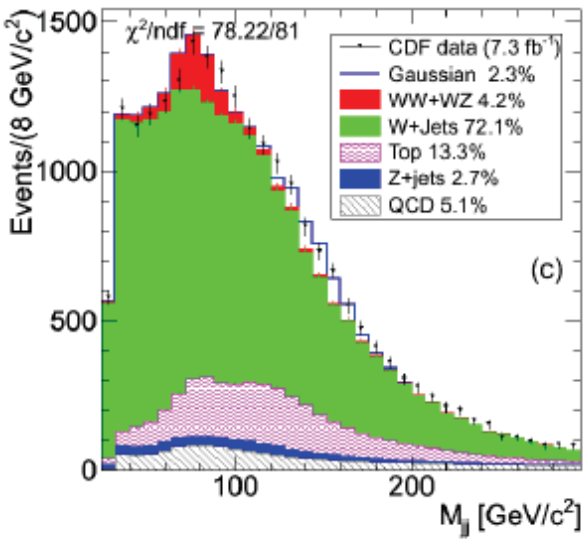
G. Punzi
Blois 2011

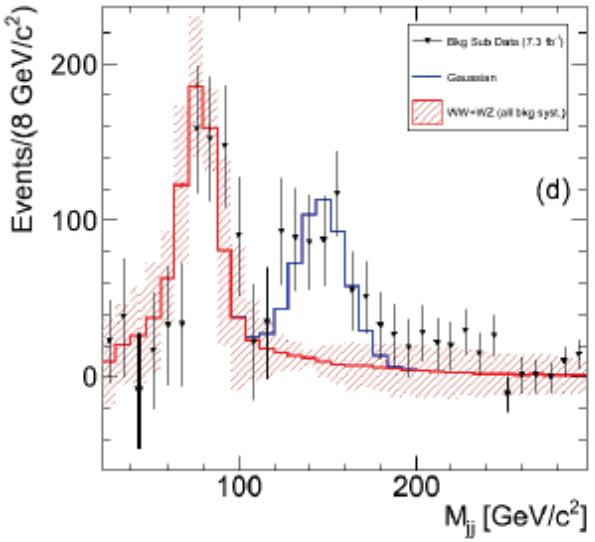


- Looks just the same as the initial 4.3fb-1
- 2.85σ excess including (unneeded) trial factor
- Fitted mass of the excess 147± 5 GeV compatible with first sample

Recent Anomalies: W+jets update

Updated W-jj with 7.3fb^{-1}



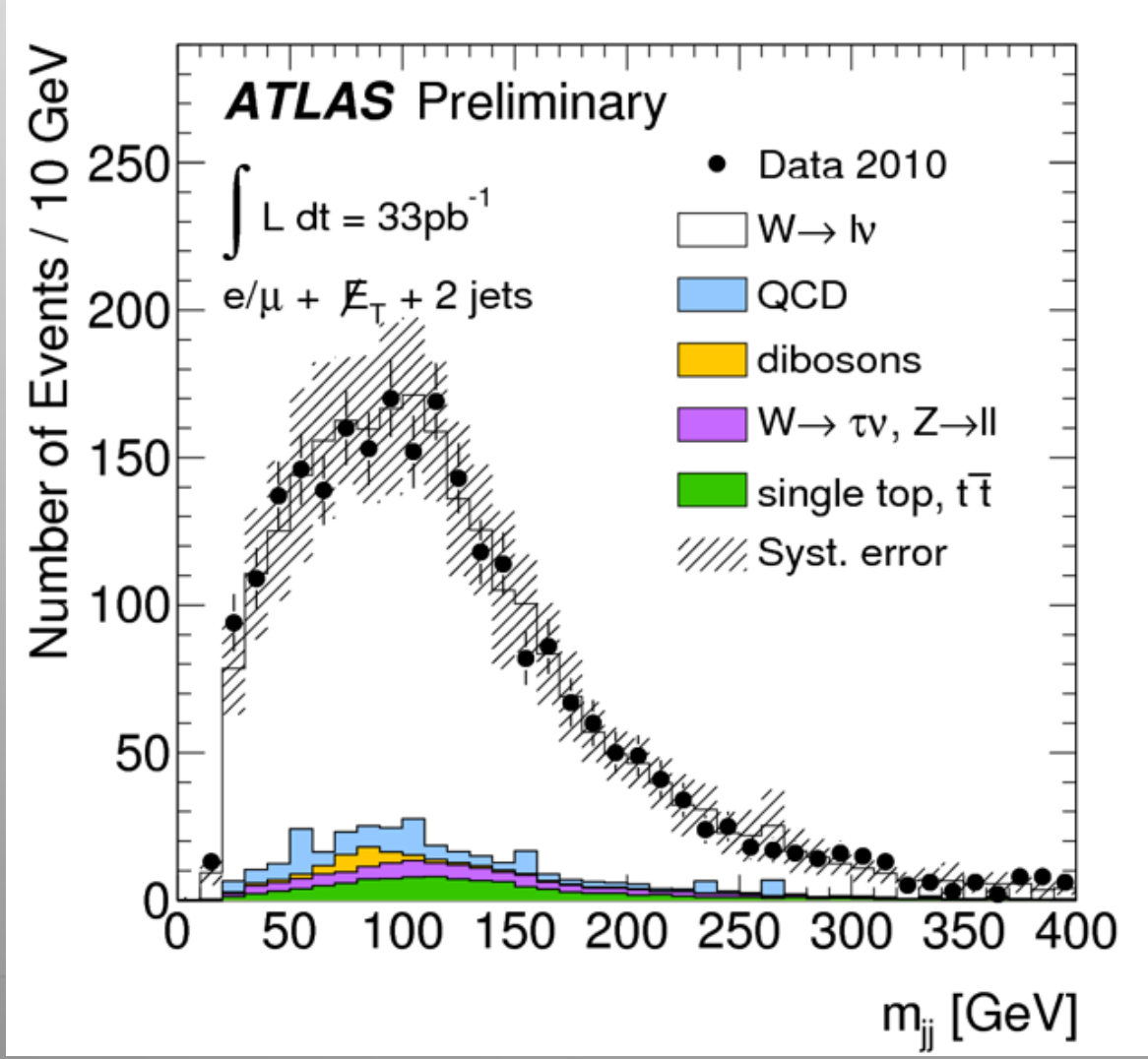


- Now closer to 5 sigma
- It was not just a statistical fluctuation
- Serious issue for CDF to understand this.
- Larger sample now allows for more detailed studies - stay tuned for updates.

Several other systematic checks made (based on criticism)
Important: what does D0 say? What do ATLAS and CMS say?
D0 result about to be released… CMS and ATLAS?

W+dijets at the LHC?

Cuts to emulate the CDF analysis

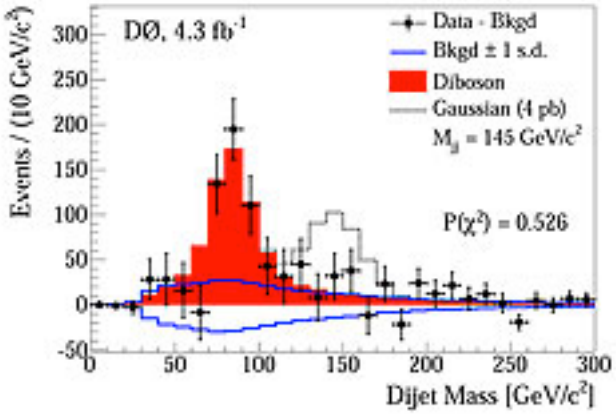


Nothing special seen in the mass range of 120-160 GeV!!

But to be competitive with the Tevatron we have to await ~1fb^{-1}, if the new process is a quark-anti-quark induced one

Hot News: D0 releases data today!

Fermilab *Today* **Friday, June 10, 2011**

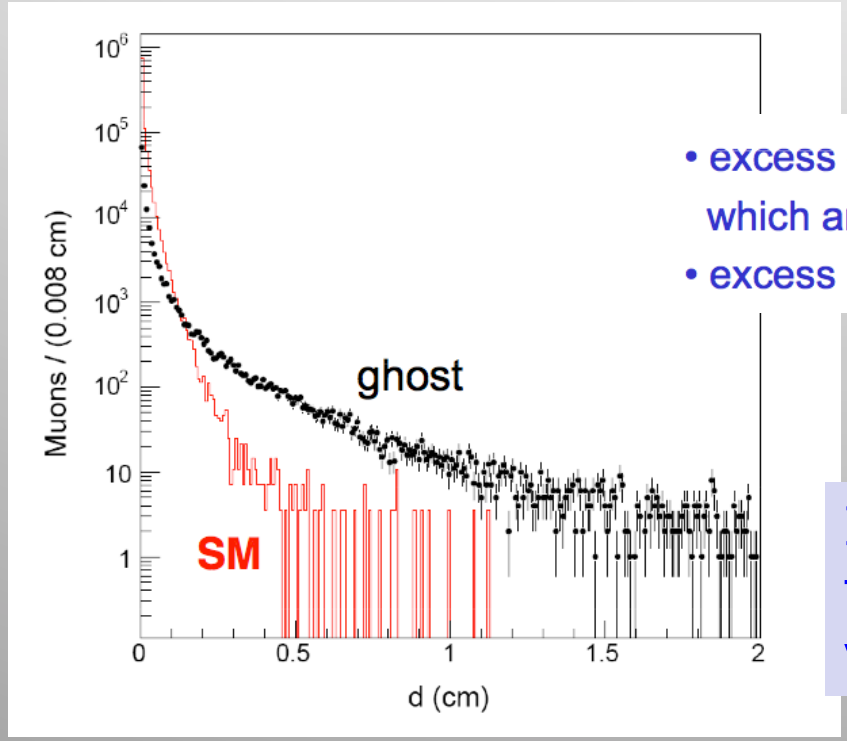


The DZero collaboration found its data for the production of a W boson and two jets to be in agreement with the predictions by the Standard Model. The red peak below 100 GeV/c^2 is a well-known Standard Model feature of the decays of W and Z bosons. If the CDF excess is interpreted as a new particle, the dotted line shows what such a particle would look like in the DZero detector. The DZero data shows no excess around 145 GeV/c^2.

D0 releases it results today in a seminar at FNAL! Paper submitted…

Anomalous Multi-Muon Events

Events with at least two muons. Look at muons that do not come form primary vertex, but are produced outside the beam pipe
CDF sees an excess which cannot be explained by the Standard Model



- excess of muons observed at large impact parameter which are not successfully explained by usual sources
- excess concentrated at low di-muon masses

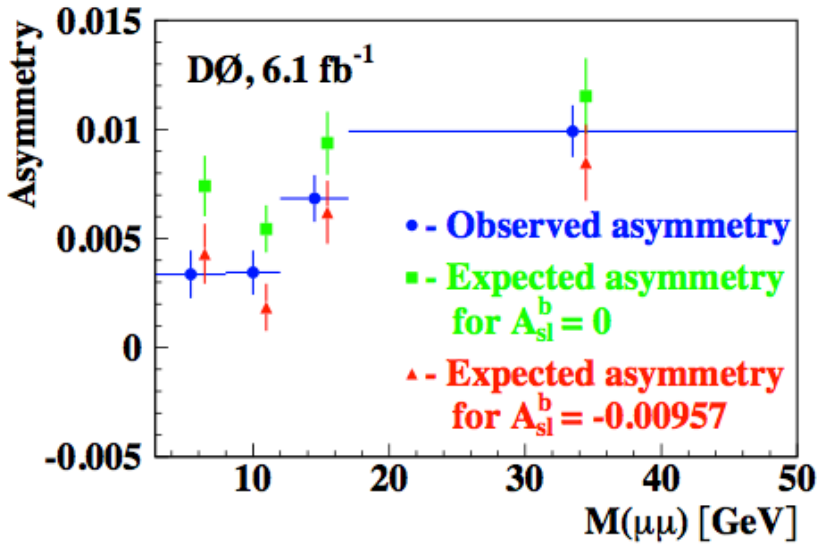
Impact parameter to the primary vertex of the muons

New Gauge bosons, NMSSM Higgs, Higgsless models, warped dimensions L-R models, B-L models, bileptons, quirks…

Anomalous Like-sign Dimuon Asymmetry

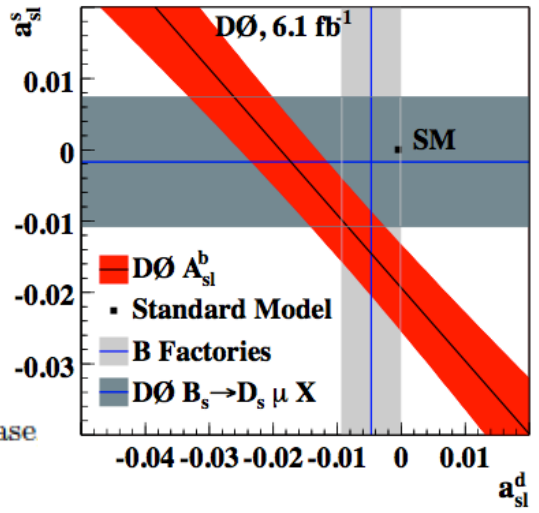
Select events with 2 muons with the same charge and construct the asymmetry
Assume these come from neutral B-mesons

$$A \equiv \frac{N^{++} - N^{--}}{N^{++} + N^{--}}$$



$$A_{\rm sl}^b = \beta_d a_{\rm sl}^d + \beta_s a_{\rm sl}^s,$$
$$a_{\rm sl}^q = \frac{\Delta\Gamma_q}{\Delta M_q}\tan\phi_q,$$

ϕ_q is the CP-violating phase



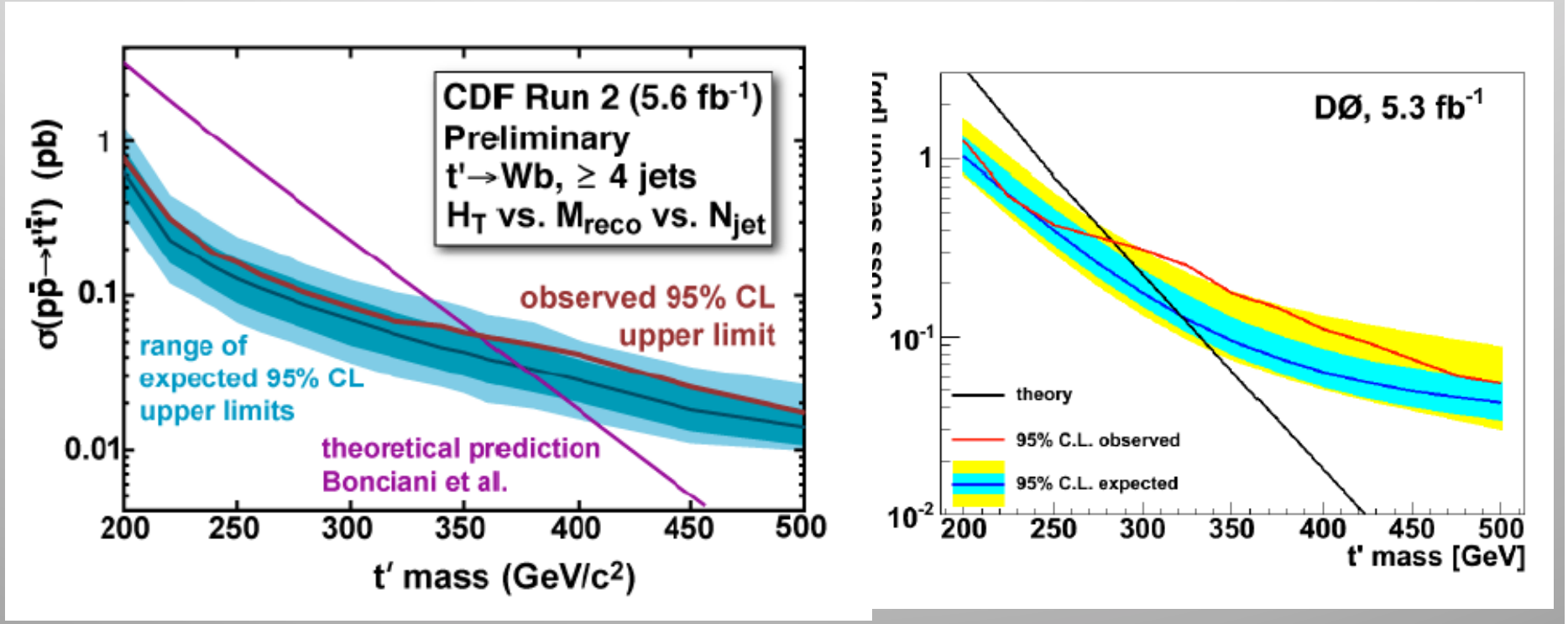
$$A_{\rm sl}^b = -0.00957 \pm 0.00251\,(\text{stat}) \pm 0.00146\,(\text{syst}).$$

$$A_{\rm sl}^b(\text{SM}) = (-2.3^{+0.5}_{-0.6}) \times 10^{-4},$$

3 sigma effect
Interpretation: Anomalous CP violation of neutral B mesons

A 4th Generation?

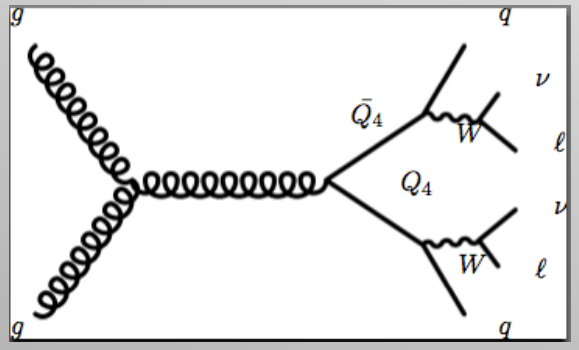
Search for a t' quark decaying into bW, like a t-quark

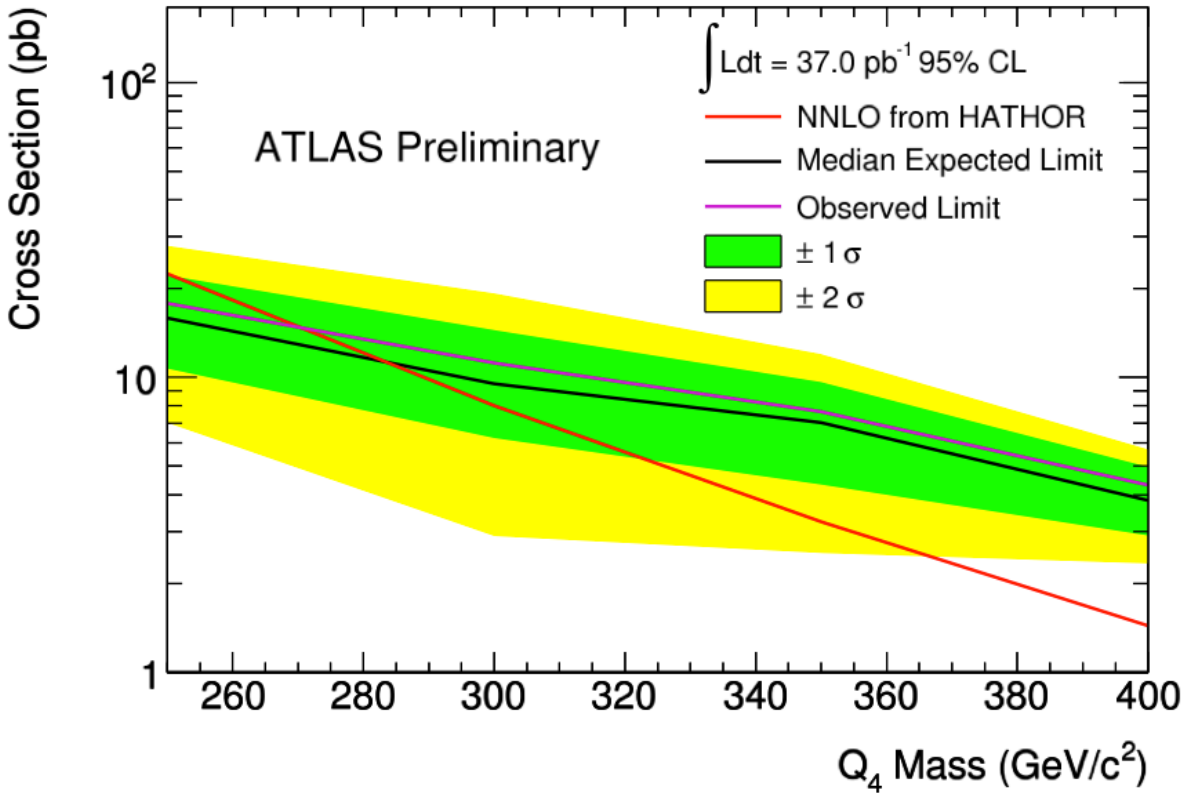


Some excess of events at large masses (used to be larger for CDF)
Is this telling us something? Pay attention at the LHC

A 4th Generation?

Search for a Q_4 quark decaying into qW





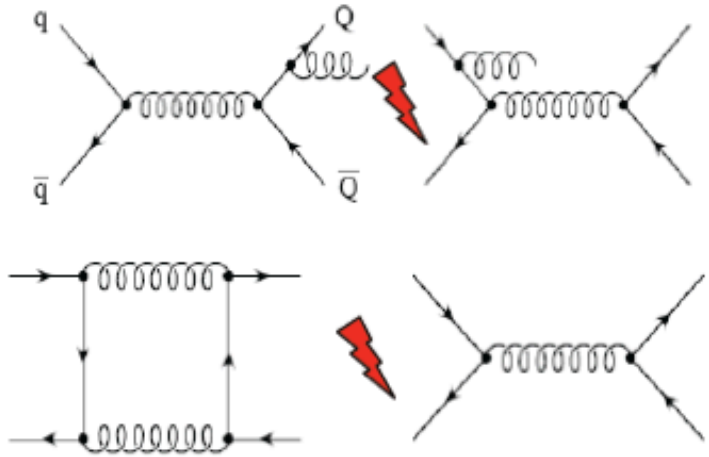
Limit around 280 GeV

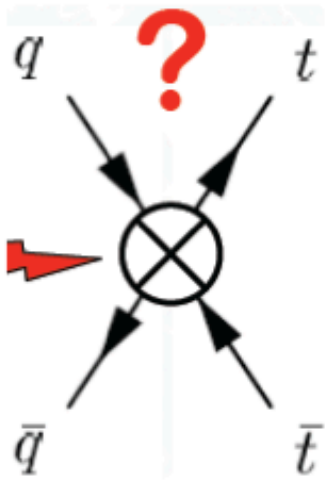
Not quite yet reaching 300 GeV but should be within reach with 2011 data

Top Forward Backward Production

color charge asymmetry A_{FB}

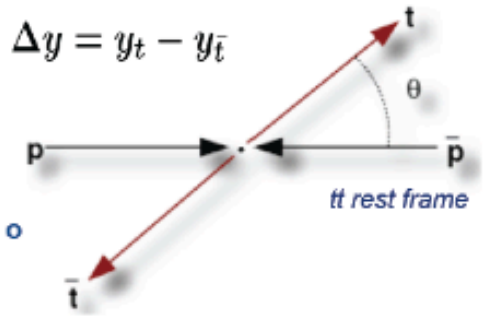
- Tevatron: at LO, completely symmetric
- At higher orders, interference terms influence t and t-bar production asymmetrically, e.g.: 4-6% expected at NLO in the parton frame
- New Physics could enhance the asymmetry.



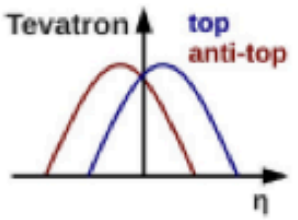


Top Forward Backward Production

color charge asymmetry A_{FB}



$$A_{fb} = \frac{N^{\Delta y>0} - N^{\Delta y<0}}{N^{\Delta y>0} + N^{\Delta y<0}}$$



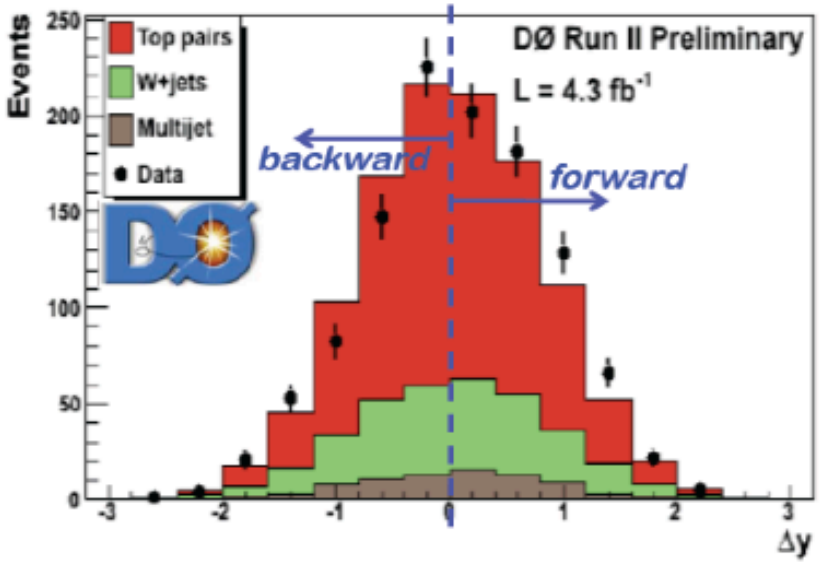
- Dzero:

  $A_{fb} = 8 \pm 4\%$ (2σ)

  Raw result (not unfolded)

- mc@nlo

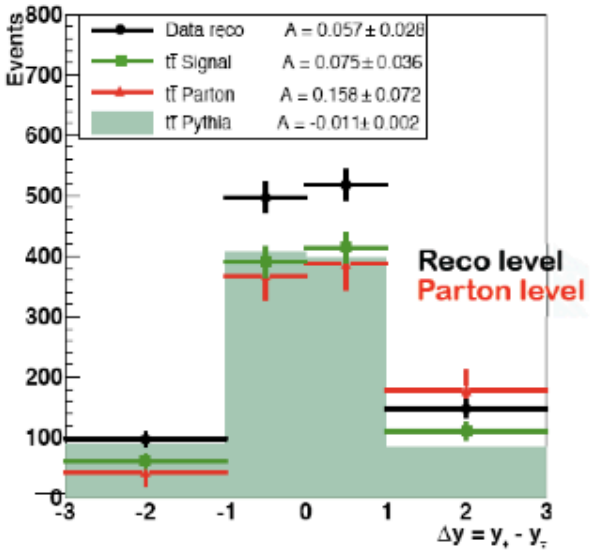
  prediction: 1 ± 2%



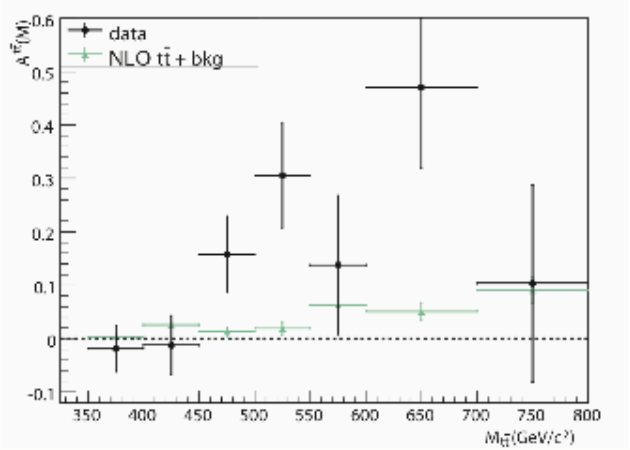
Top Forward Backward Production

color charge asymmetry A_{FB}

- CDF



- A_{FB} as a function of M_{tt}



A_{fb}=15 ± 5 % (2σ)

mc@nlo prediction: 6 ± 1%

A_{fb}=48 ± 11 % (>3σ)

8.8 ± 1.3%

(Parton Level: corrected for reconstruction)

Also a 2 σ effect in D0

Technicolor, Chiral color, top color, FCNC Z', warped extra dimensions, universal extra dimensions, color octet vector bosons…

Top Forward Backward Production

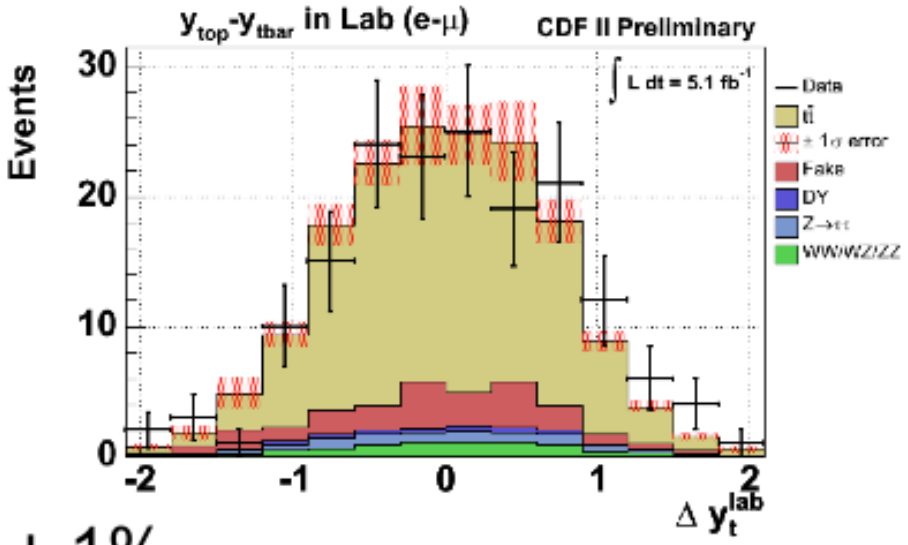
A_{FB}

- Dilepton Events:

$A_{fb}=42 \pm 16\ \%$

(2.5σ)

(Parton Level: corrected for reconstruction)

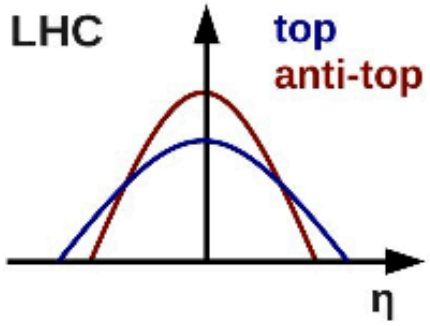


- mc@nlo prediction: 6 ± 1%

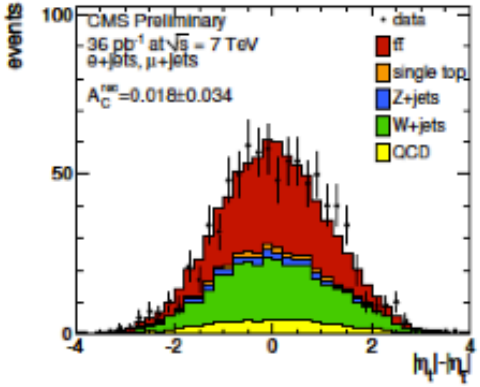
- Some tension between SM prediction and Tevatron data
- Higher order SM prediction at α_s^4?
- Soft QCD effects?
- About 2x the data is available for a closer look!

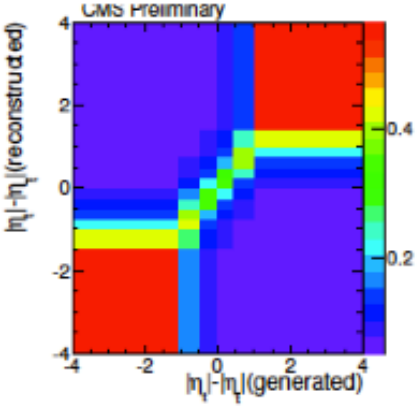
Top Forward Backward Production

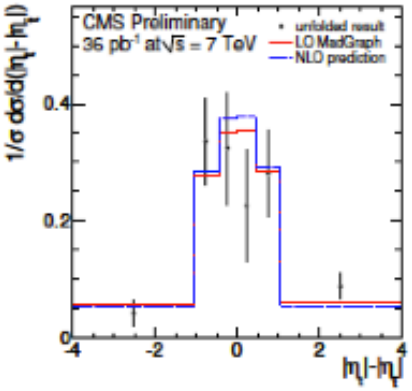
color charge asymmetry - LHC



- Initial state is symmetric
- charge asymmetry visible in $|\eta_t| - |\eta_{\bar{t}}|$
- Expected asymmetry A_C small ≈1.3%
- Z' or an axigluon could enhance the asymmetry





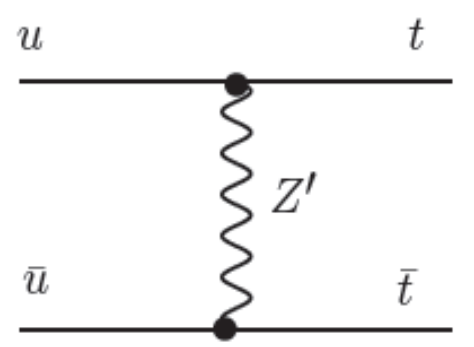


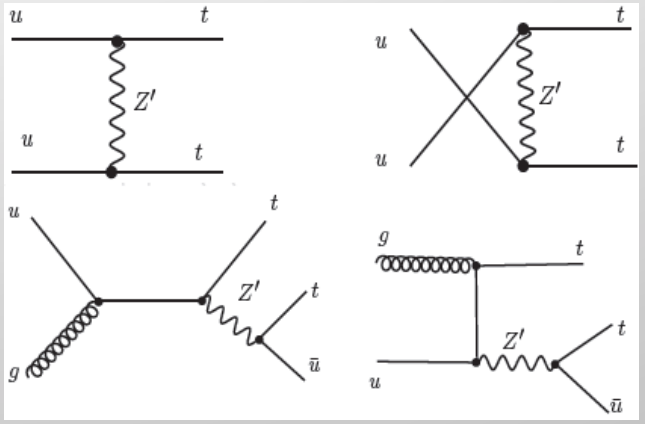
$A_C = 0.060 \pm 0.134\ (stat) \pm 0.026\ (syst)$

- First such measurement, & expect L = 1 fb^{-1} to start to compete with Tevatron

Like sign top production at the LHC

Is the Tevatron observation due to flavor changing neutral currents?



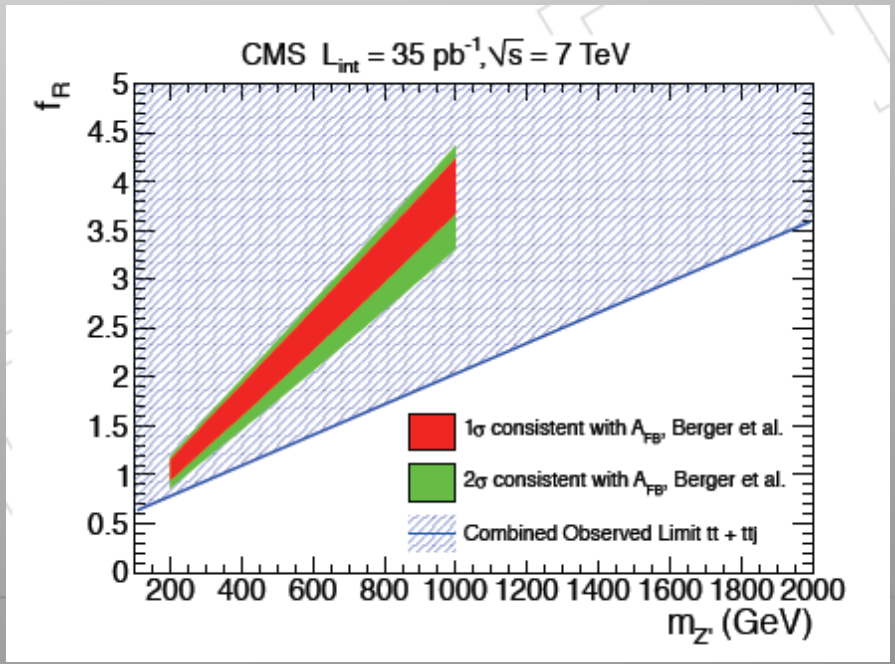


$$\mathcal{L} = g_W \bar{u} \gamma^\mu (f_L P_L + f_R P_R) t Z'_\mu + h.c.$$

This would lead to to same sign top production at the LHC

Search in CMS for like-sign leptons from top quarks

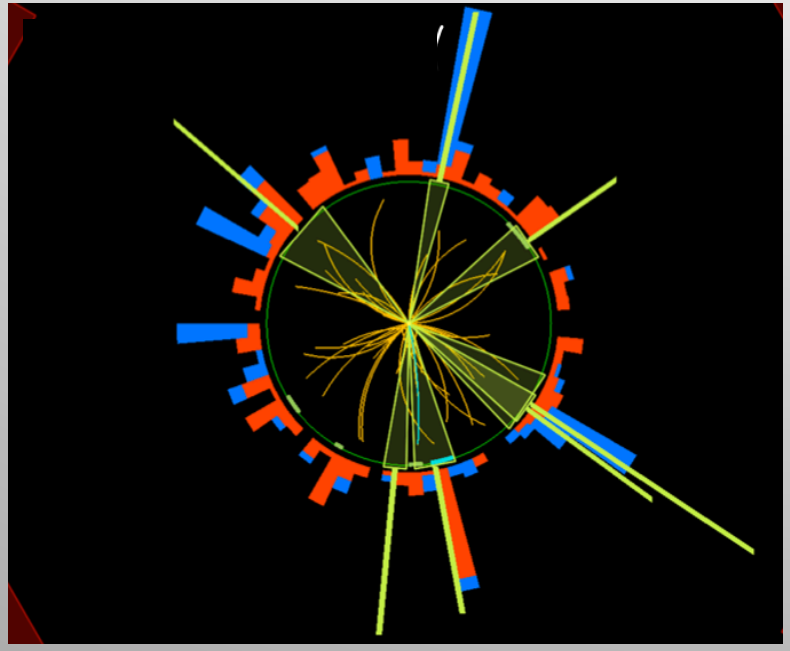
Two events found with one background event predicted
-> Exclusion limits!

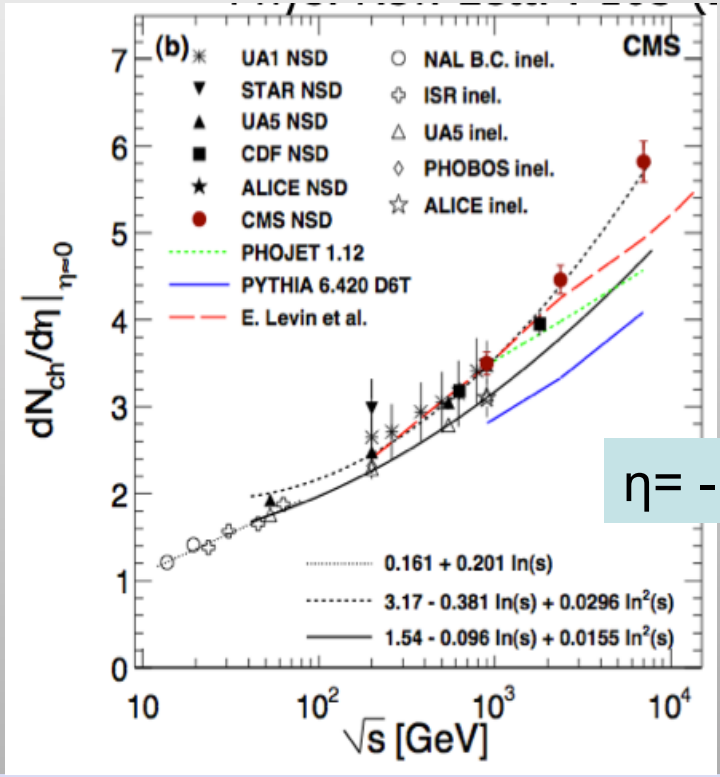


SEARCHES AT THE LHC

LHC: 7 TeV Early Analysis

We learn a lot of particle production at the highest energies!!



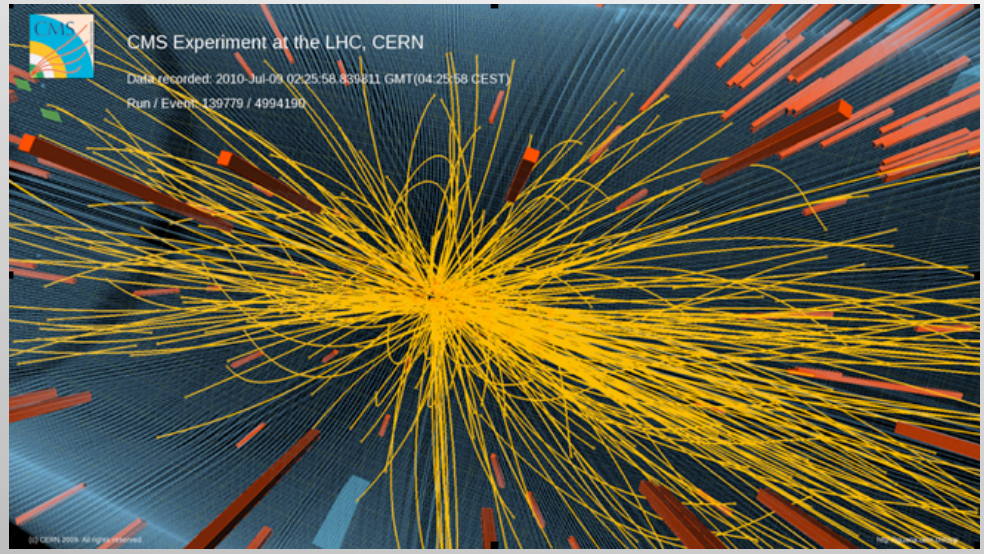


η= -ln tanθ/2

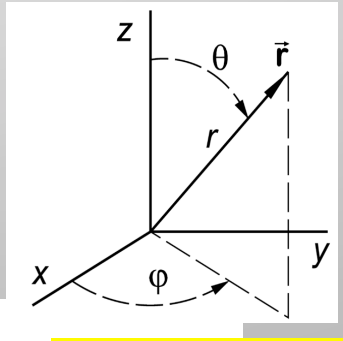
Measurement of the charged particle density in proton proton collisions at 7 TeV

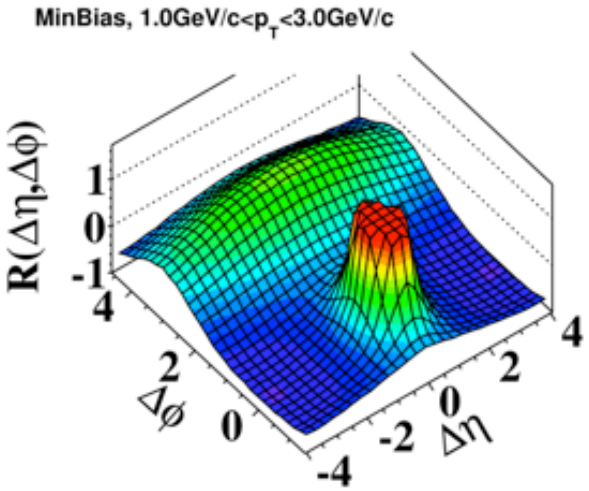
Strong rise of the central particle density with energy

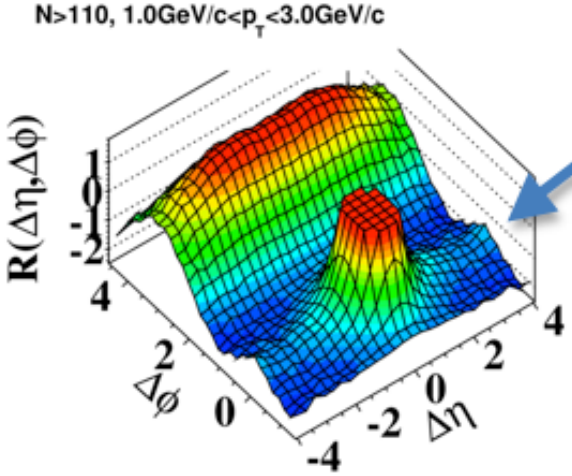
Correlations Between Produced Particles



- Select high multiplicity events
- Study the correlation between two charged particles in the angles φ (transverse): Δφ and θ (longitudinal): Δθ





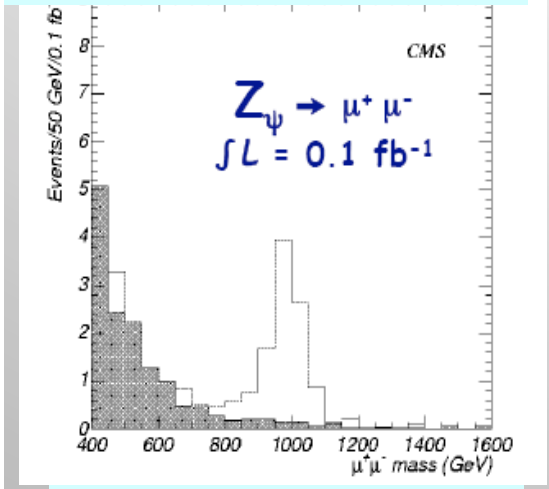


A new phenomenon in the 'stronge force' seen for the first time
But not considered New Physics

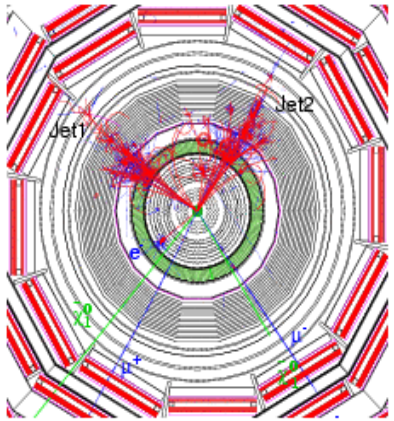
η= -ln tanθ/2

Physics Beyond the Standard Model

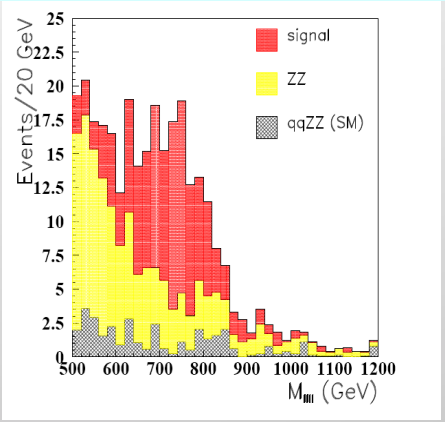
New Gauge Bosons?



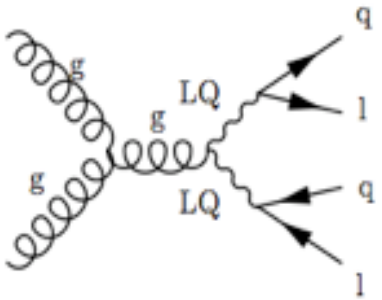
Supersymmetry



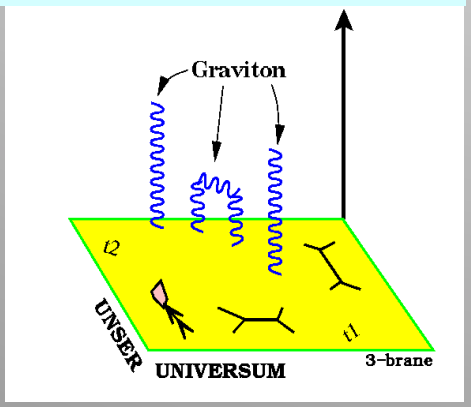
ZZ/WW resonances?



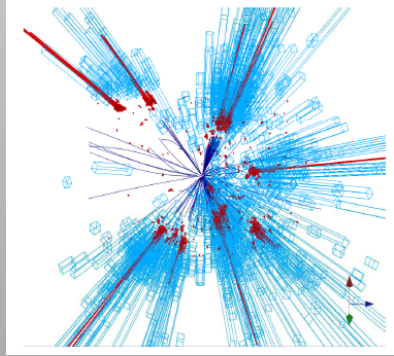
Leptoquarks?



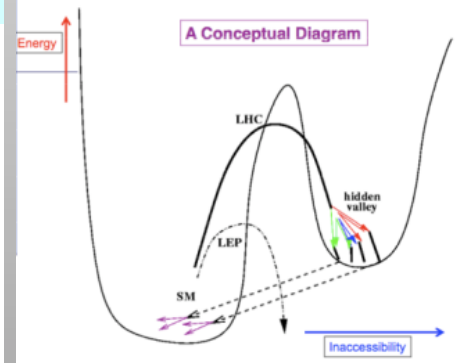
Extra Dimensions?



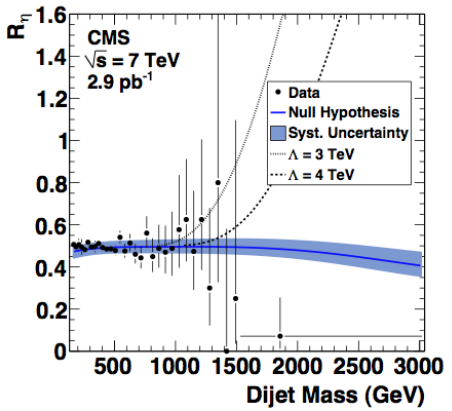
Black Holes???



Long lived particles?

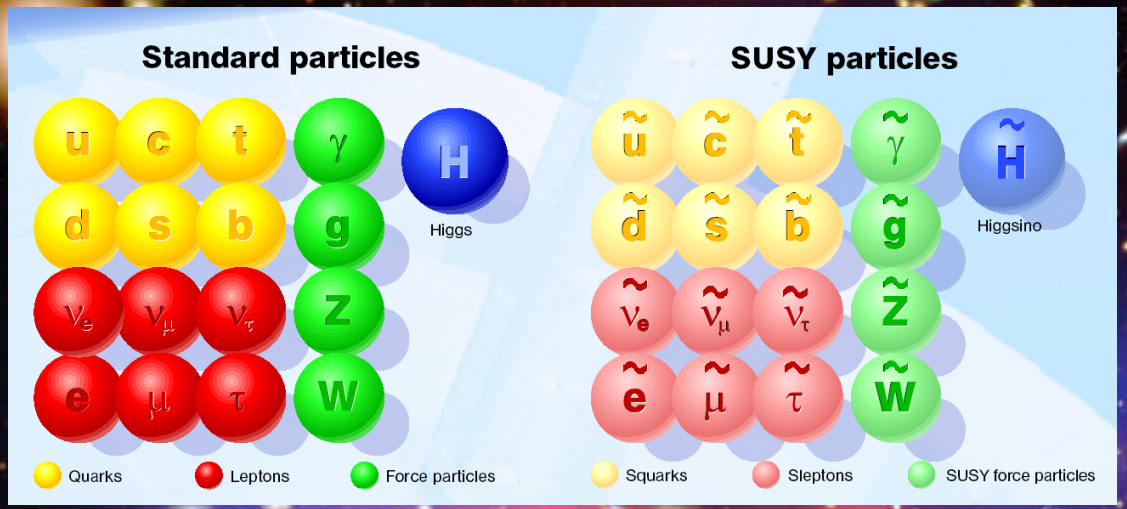


Compositness?

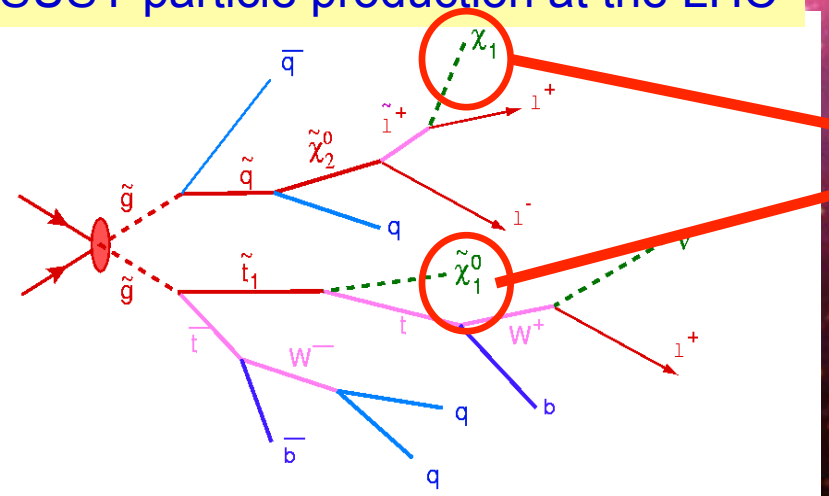


We do not know what is out there for us…
A large variety of possible signals. We have to be ready for that

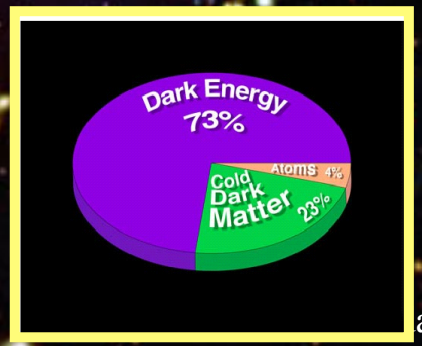
Supersymmetry: a new symmetry of Nature?



SUSY particle production at the LHC



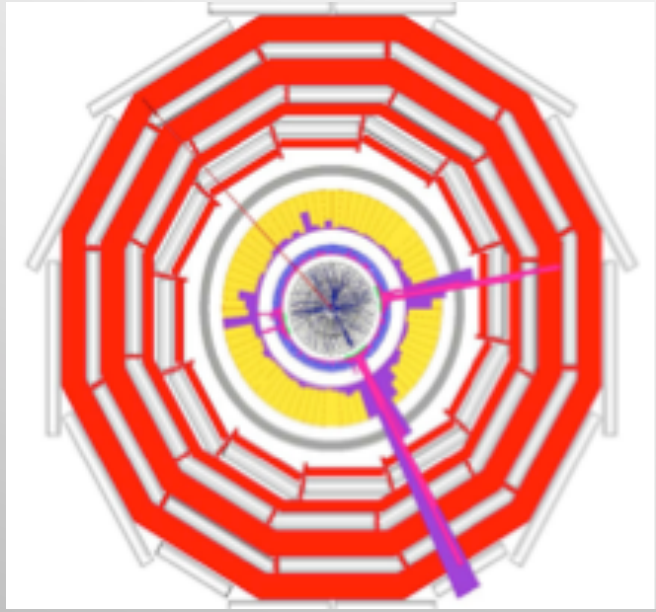
Candidate particles for Dark Matter
⇒ Produce Dark Matter in the lab

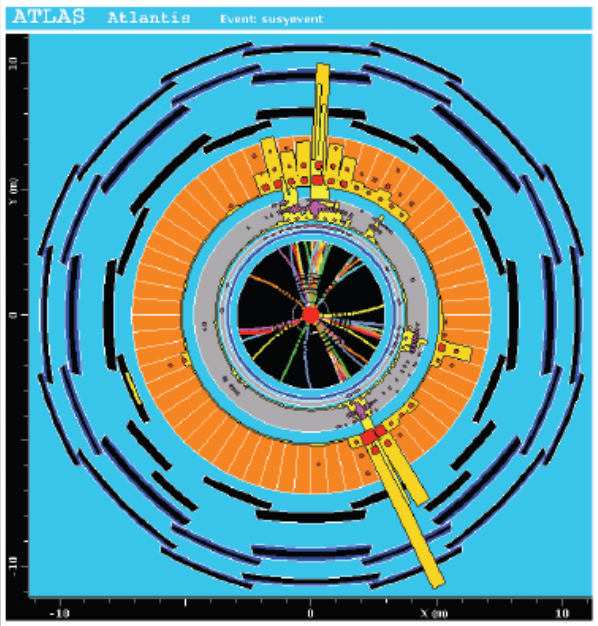


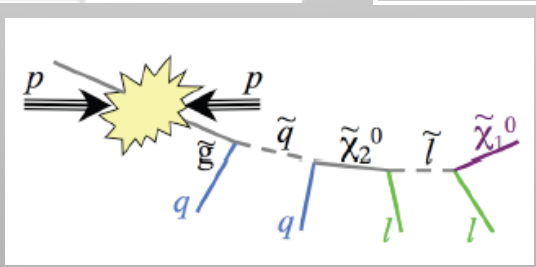
Assume "R-Parity" Conservation

+ 2 b-jets
+ 4 jets

Detecting Supersymmetric Particles







simulation

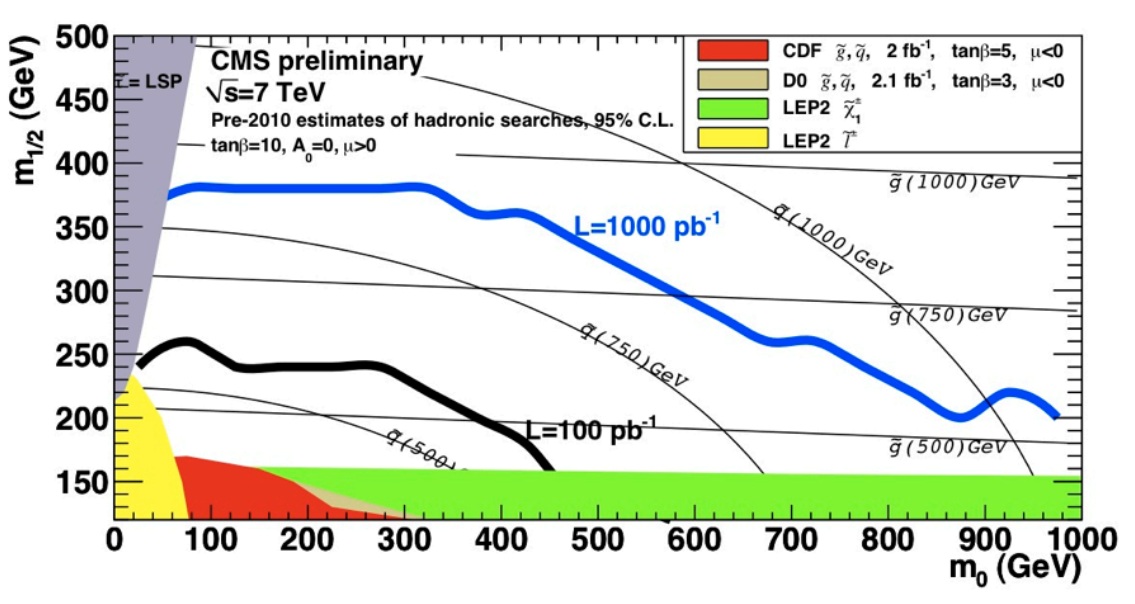
Supersymmetric particles decay and produce a cascade of jets, leptons and missing transverse energy (MET) due to escaping ‘dark matter’ particle candidates

Very clear signatures in CMS and ATLAS

SUSY Searches @ LHC

CMS-NOTE-2010-008

Prospects estimated in 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}

Usually Constrained Minimal Supersymmetric Standard Model CMSSM is 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

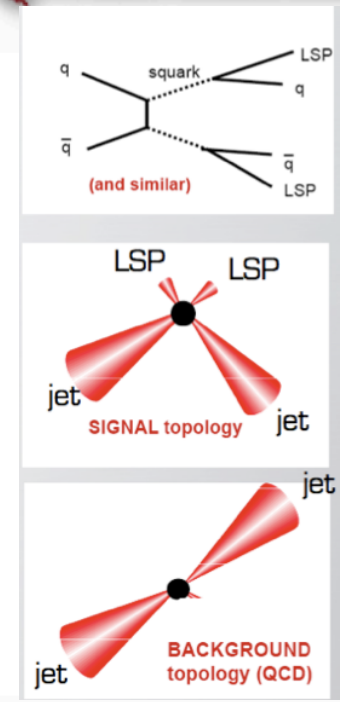
SUSY Searches at the LHC

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

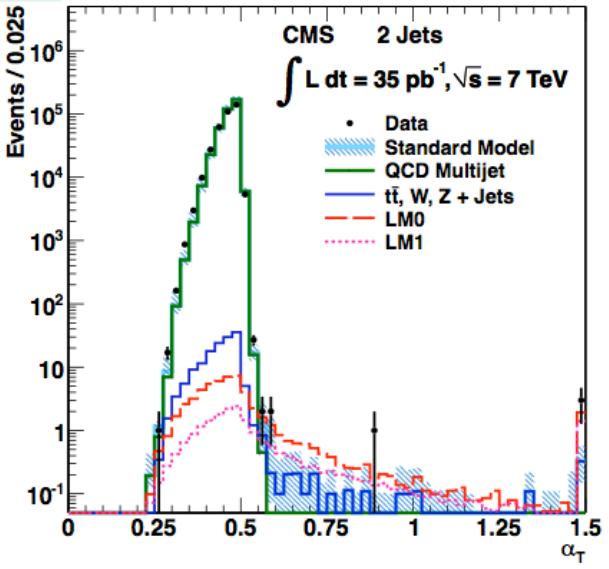
sensitivity to gauge-mediated SUSY



Example: Jets plus MET channel

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

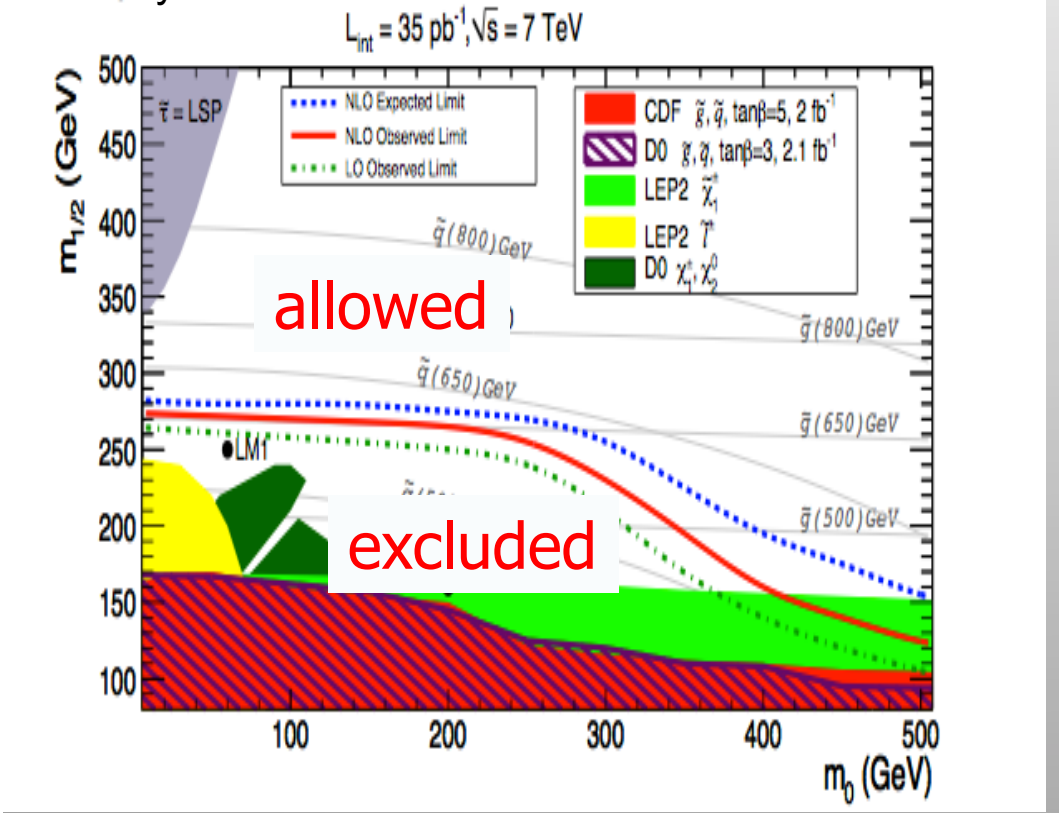
- Control jet SM background with the α_T variable
- No jet SM background expected for $\alpha_T > 0.5$



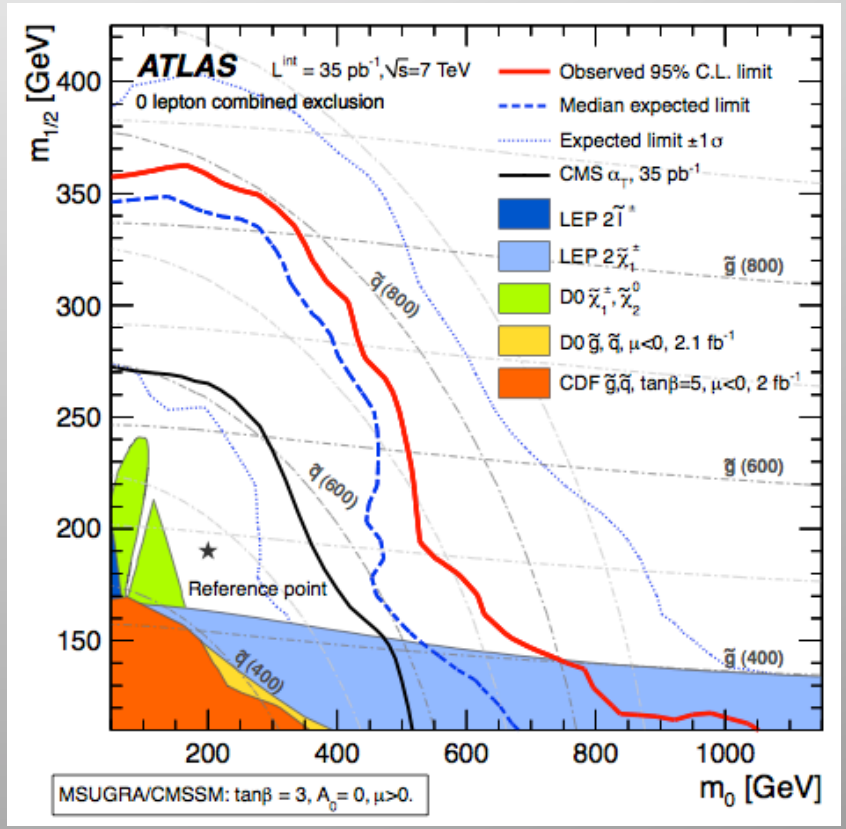
First SUSY Search Results

No discovery of supersymmetry yet… Stronger exclusion limits

Phys.Lett.B698 2011 196



arXiv:1102.5290

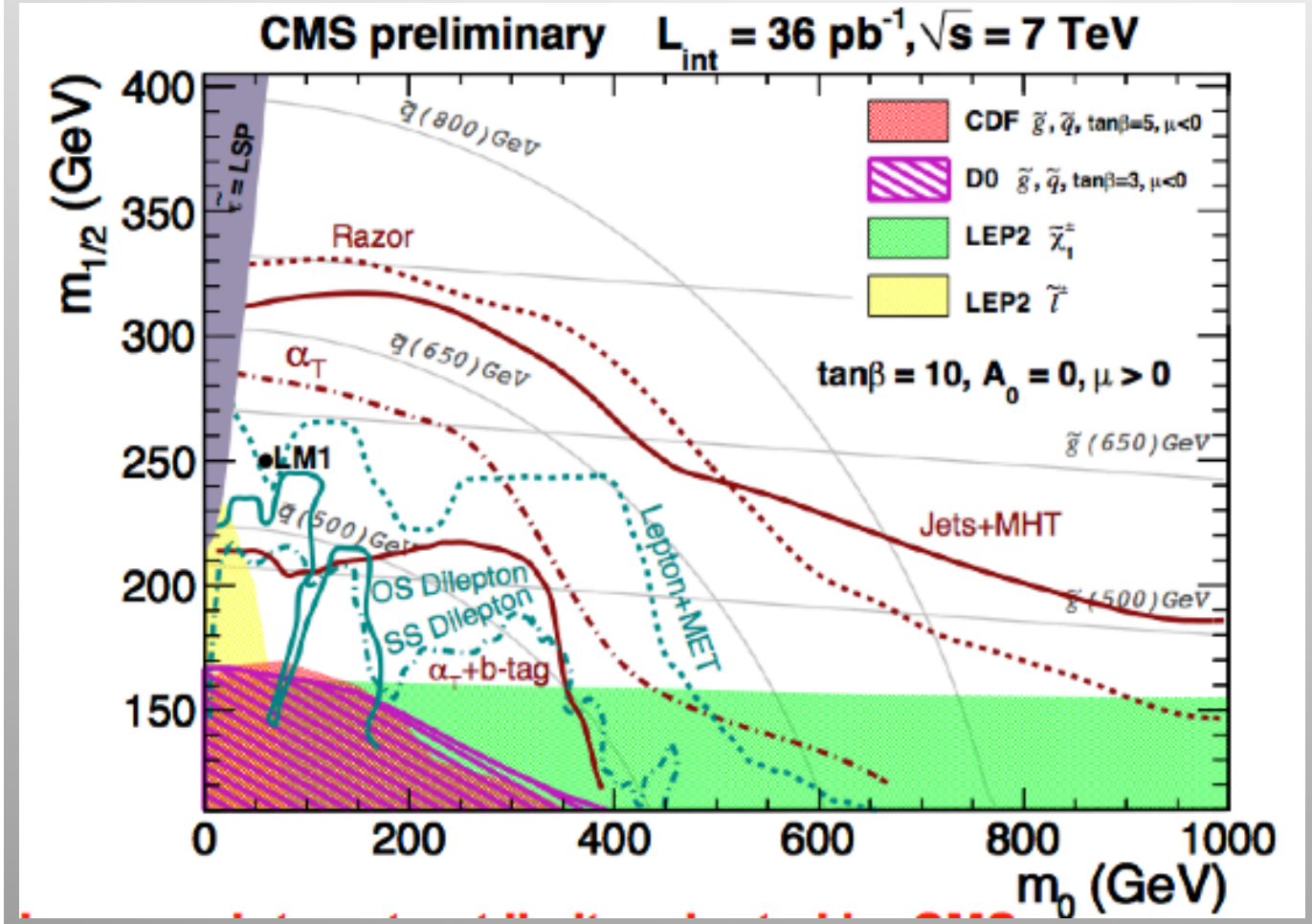


Masses of squarks/gluinos > ~600-700 GeV!!! (in the CMSSM)

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

Summary Search Channels

CMS summary of channels

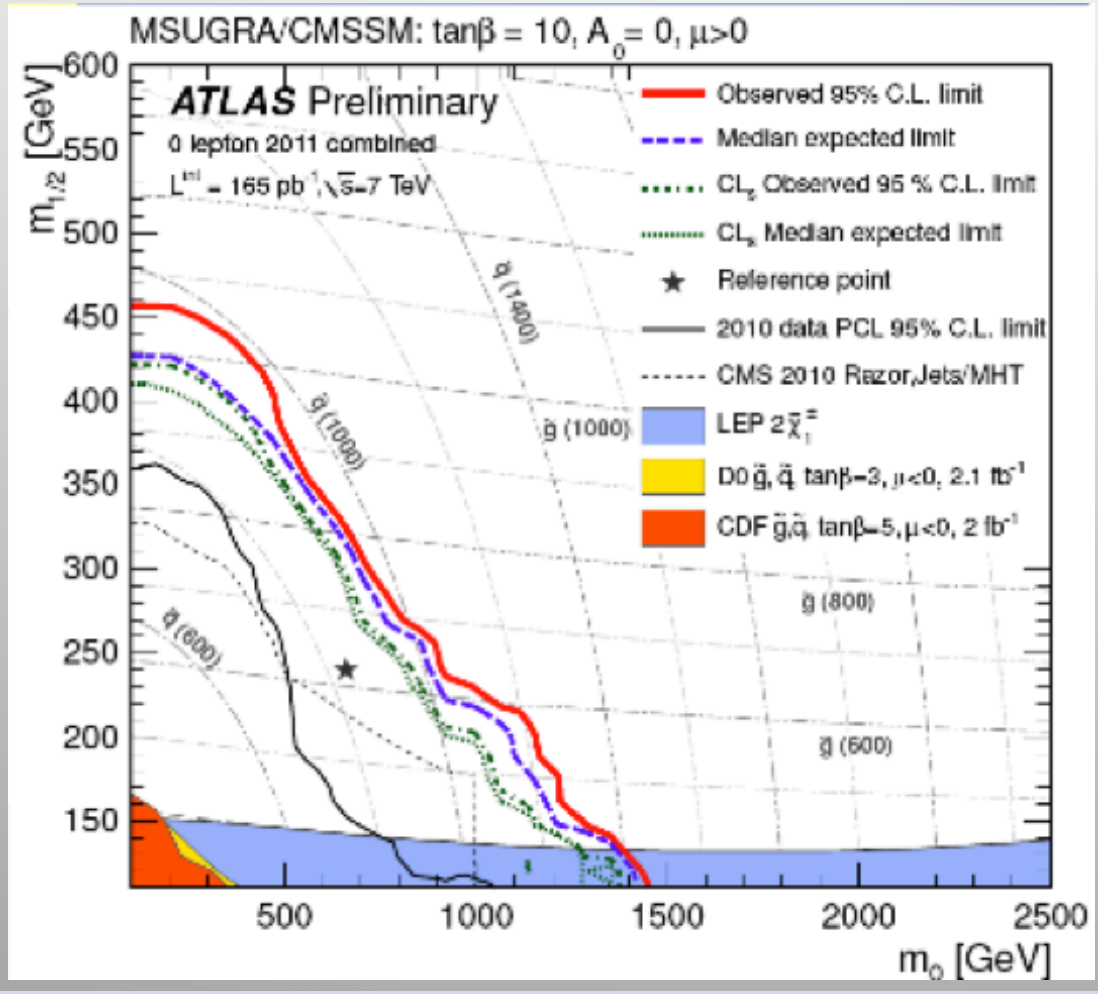


Channels with

- Jets only
- Single leptons
- Di-leptons
- Photons

Squarks/gluinos are excluded for masses below 600-700 GeV

2011 Data Search



ATLAS-CONF-2011-086

Jets plus Missing E_T

Within CMSSM Gluinos > ~950 GeV (Gluinos > 725 GeV in simpl. models)

Note: exclusion reach depends on the statistics procedure used

Where do we expect SUSY?

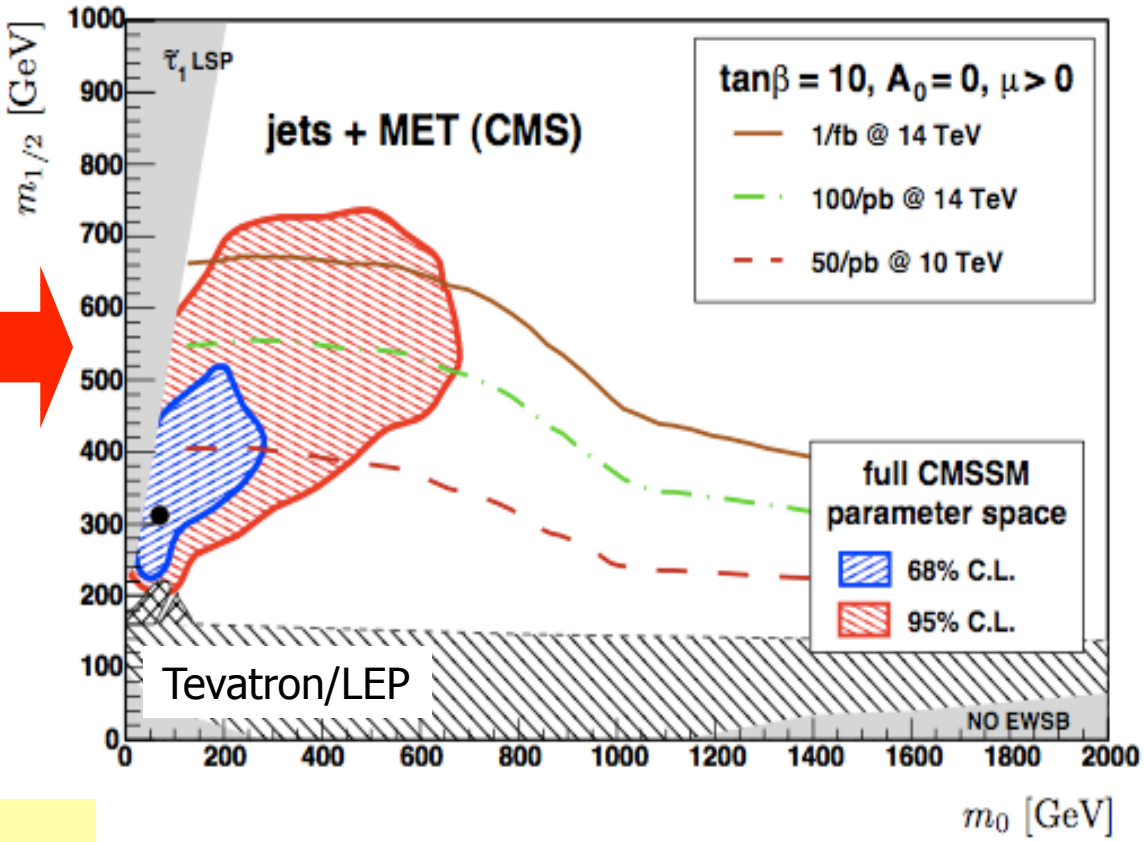
O. Buchmuller et al
arXiv:0808.4128

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"



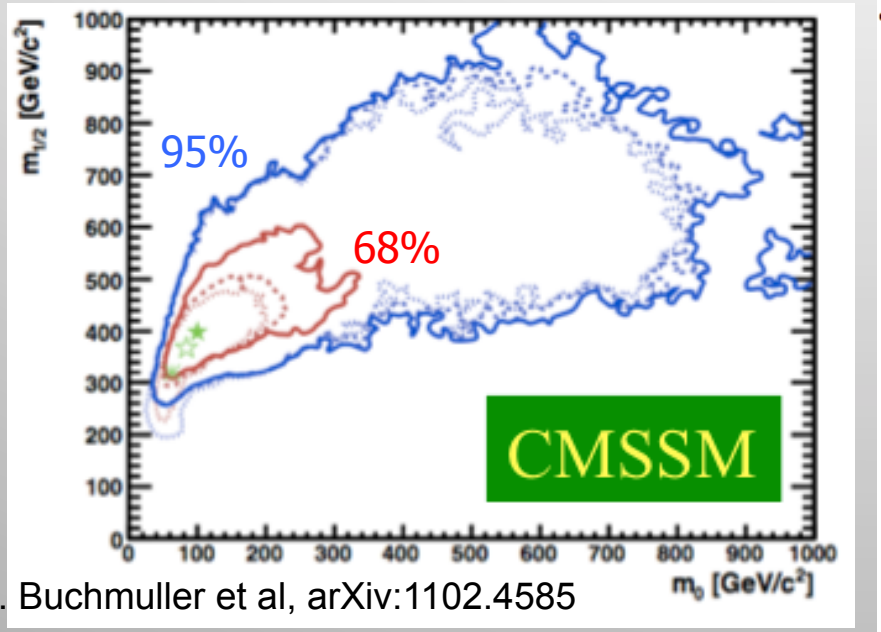
"CMSSM fit clearly favors low-mass SUSY - Evidence that a signal might show up very early?!"

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

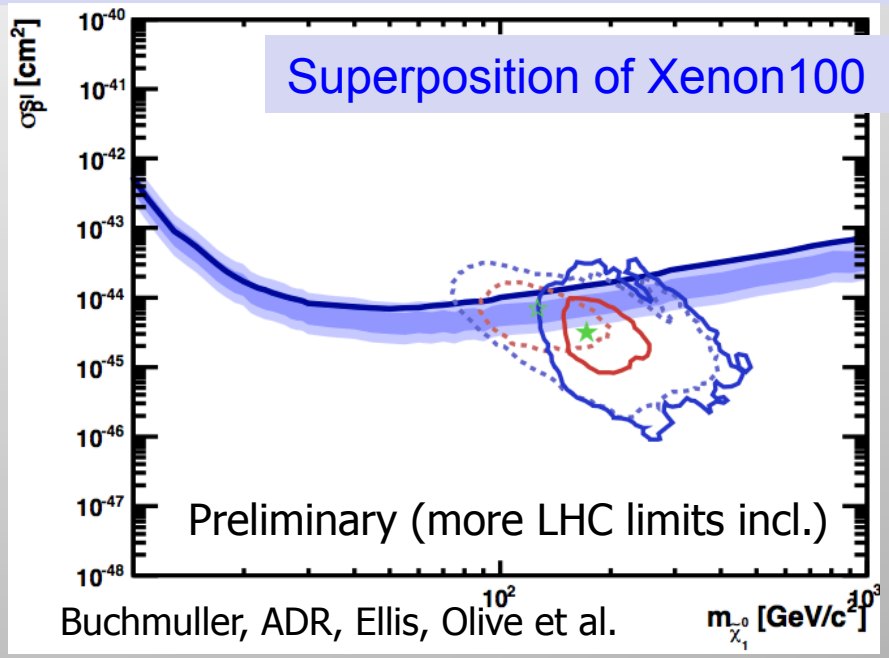
Many other groups attempt to make similar predictions

Impact of LHC Data on SUSY/DM

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



O. Buchmuller et al, arXiv:1102.4585



Buchmuller, ADR, Ellis, Olive et al.

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

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

The World is Watching

The fine-tuning price of the early LHC

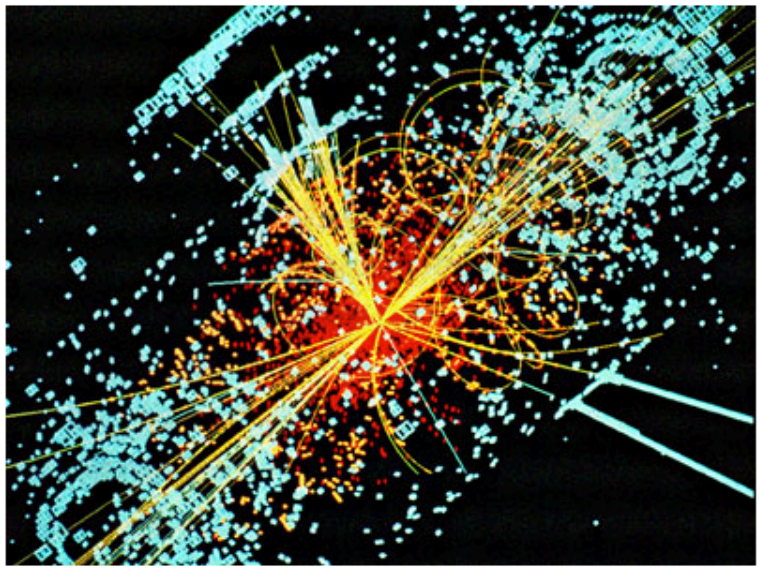
Alessandro Strumia

(Submitted on 11 Jan 2011 (v1), last revised 20 Feb 2011 (this version, v2))

LHC already probed and excluded half of the parameter space of the Constrained Minimal Supersymmetric Standard Model allowed by previous experiments. Only about 0.7% of the CMSSM parameter space survives. This fraction rises to about 2% if the bound on the Higgs mass can be circumvented.

Will the LHC find supersymmetry?

Feb 22, 2011 5 comments



Will SUSY be found lurking in LHC data?

The first results on supersymmetry from the Large Hadron Collider (LHC) have been analysed by physicists and some are suggesting that the theory may be in trouble. Data from proton collisions in both the Compact Muon Solenoid (CMS) and ATLAS experiments have shown no evidence for supersymmetric particles – or sparticles – that are predicted by this extension to the Standard Model of particle physics.

Nature

Beautiful theory collides with smashing particle data

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

Geoff Brumfiel

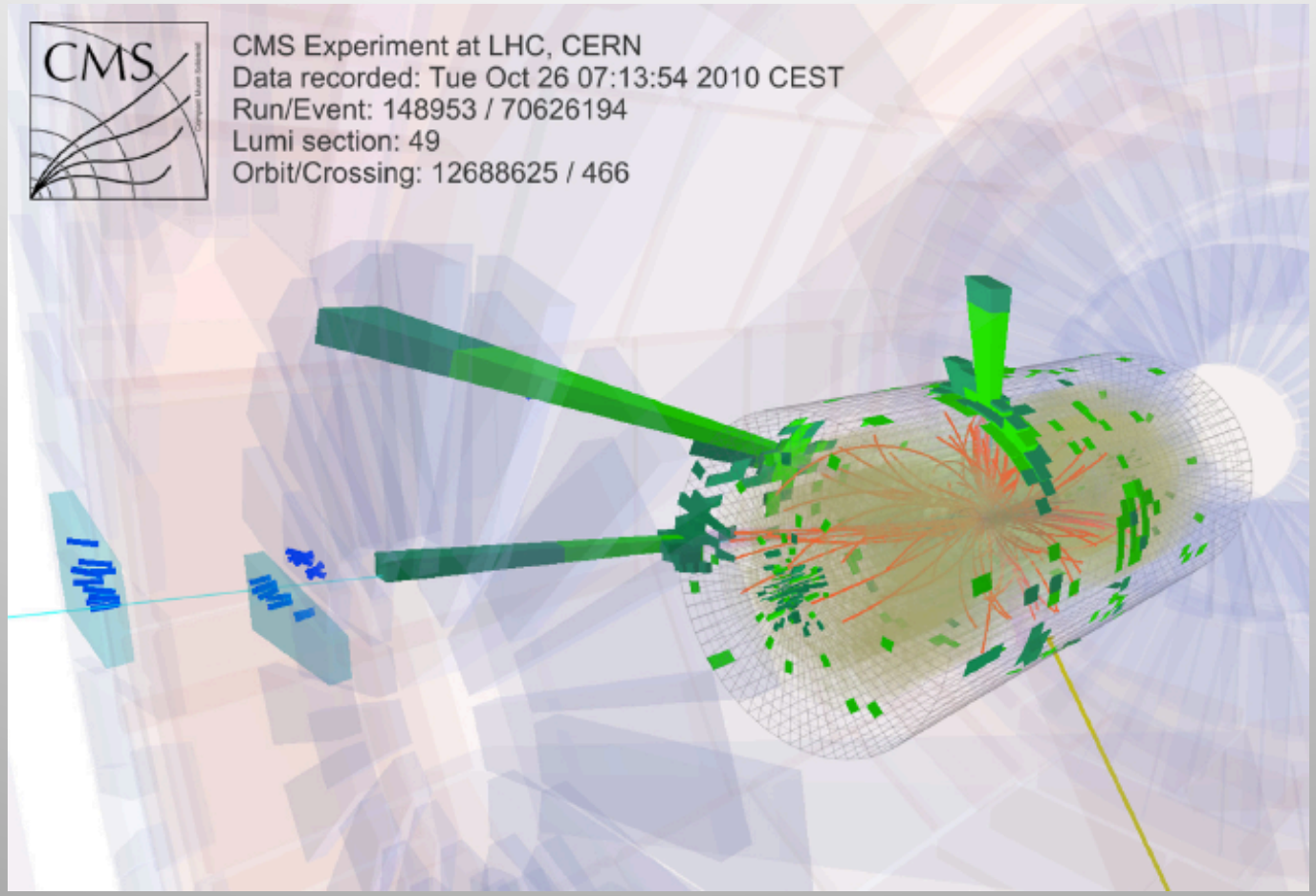
"Wonderful, beautiful and unique" is how Gordon Kane describes supersymmetry theory. Kane, a theoretical physicist at the University of Michigan in Ann Arbor, has spent about 30 years working on supersymmetry, a theory that he and many others believe solves a host of problems with our understanding of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

A slight wave of panic???
LHC just getting started..

…Some Interesting Events…



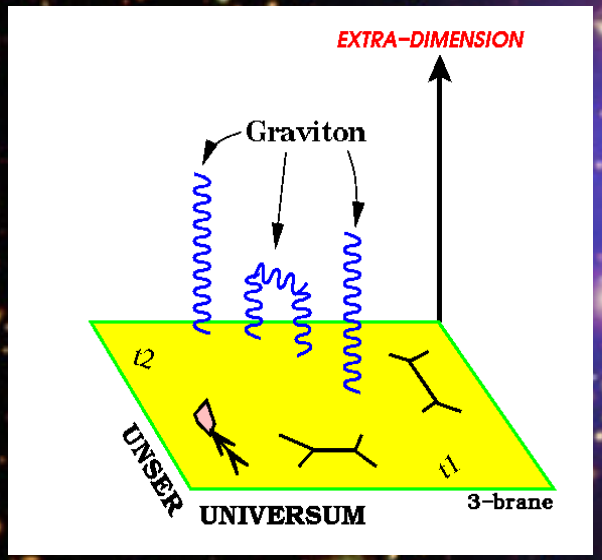
- Event with five jets and large missing transverse energy
- Total sum of transverse momentum H_T= 1132 GeV and missing transverse energy H_{TMiss} = 693 GeV

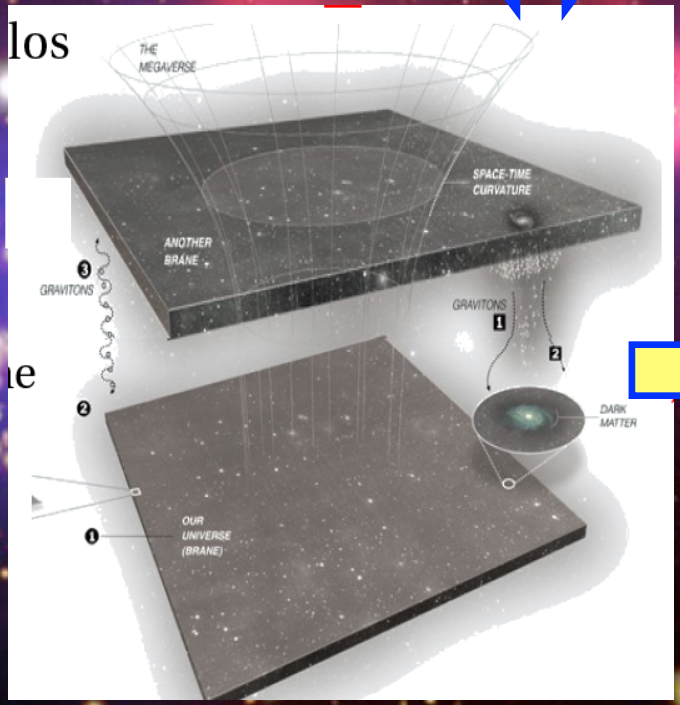
Extra Space Dimensions

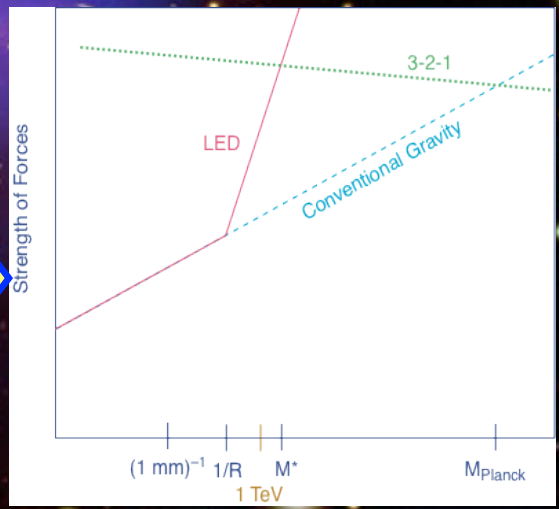
Problem:

$$m_{EW} = \frac{1}{(G_F \cdot \sqrt{2})^{\frac{1}{2}}} = 246\,\text{GeV}$$

$$M_{Pl} = \frac{1}{\sqrt{G_N}} = 1.2 \cdot 10^{19}\,\text{GeV}$$







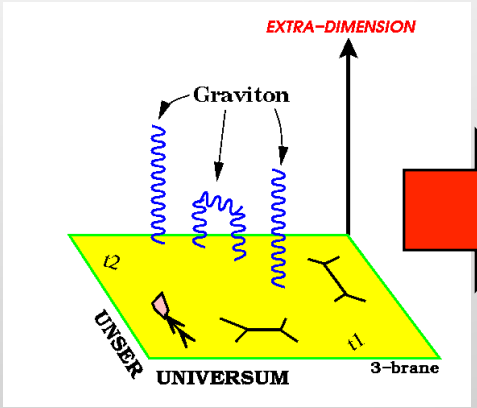
Gravity becomes strong!

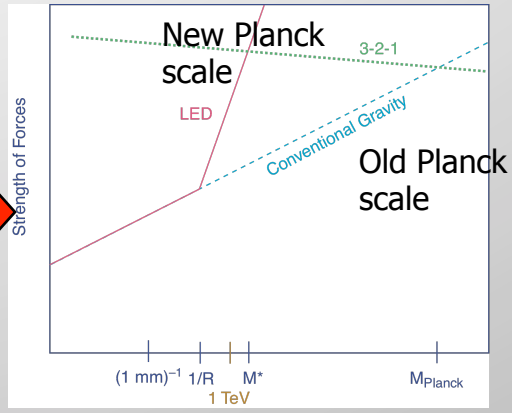
Search for Extra Dimensions

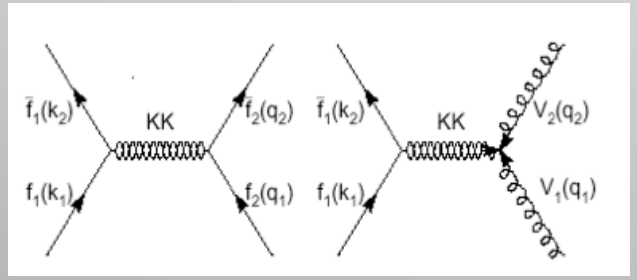
Are there extra space dimensions that open at higher energies?

Example: Experimental signature affects the di-fermion production

Study here: di-photon production





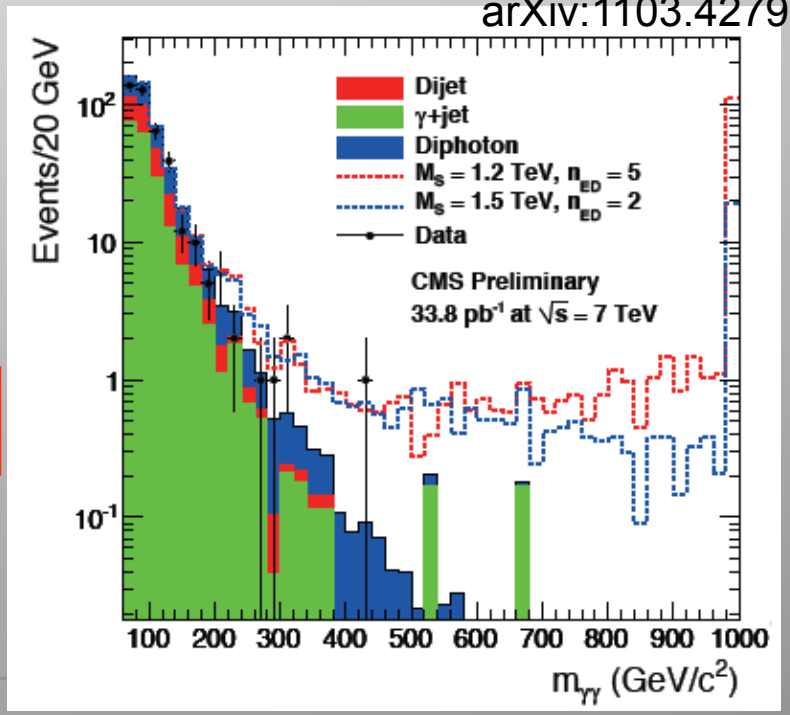


Results (TeV)

$n_{ED}=2$	$n_{ED}=3$	$n_{ED}=4$	$n_{ED}=5$	$n_{ED}=6$	$n_{ED}=7$
1.88	2.29	1.93	1.74	1.62	1.53

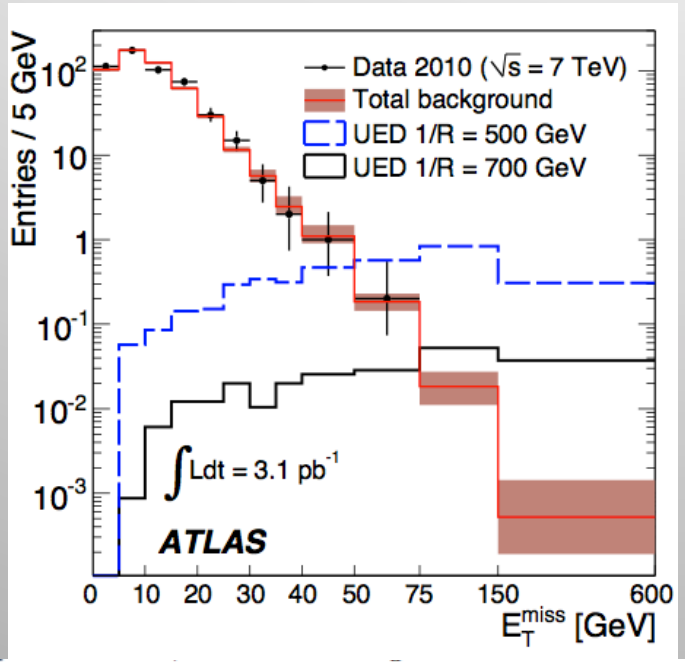
New mass scale larger than 1.5-2.3 TeV depending on the number of extra dimensions (similar in the μμ channel)
Tighter limits than from the Tevatron

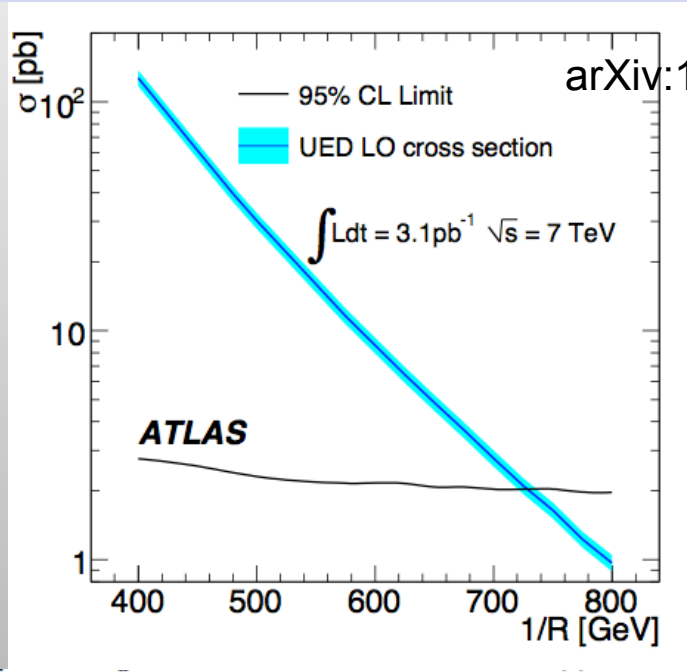
arXiv:1103.4279



Universal Extra Dimensions

Search for events with two photos and missing transverse energy
Limits set for events with two photons with E_T> 25 GeV and MET > 75 GeV



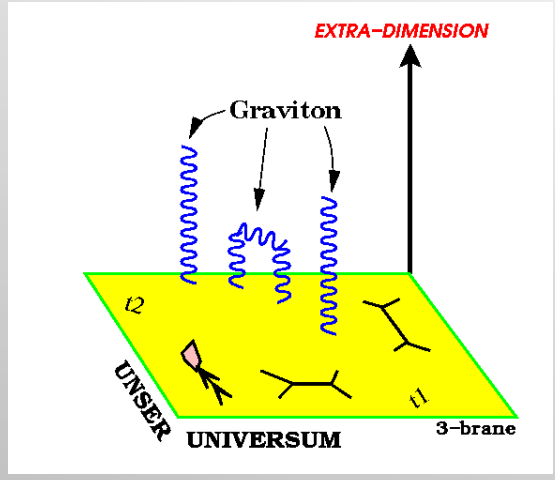


arXiv:1012.4272

E_T^{miss} range (GeV)	Data events	Predicted background events Total	QCD	$W(\rightarrow e\nu)$ + jets/γ	Expected UED signal events $1/R = 500$ GeV	$1/R = 700$ GeV
0 - 20	465	465.0 ± 9.1	465.0 ± 9.1	-	0.28 ± 0.06	0.02 ± 0.01
20 - 30	45	40.5 ± 2.2	40.41 ± 2.17	0.11 ± 0.07	0.45 ± 0.07	0.03 ± 0.01
30 - 50	9	10.3 ± 1.3	10.13 ± 1.30	0.16 ± 0.10	1.60 ± 0.12	0.08 ± 0.01
50 - 75	1	0.93 ± 0.23	0.85 ± 0.23	0.08 ± 0.05	2.84 ± 0.16	0.14 ± 0.01
> 75	0	0.32 ± 0.16	0.28 ± 0.15	0.04 ± 0.03	40.45 ± 0.62	4.21 ± 0.06

No evidence yet for Universal Extra Dimensions...

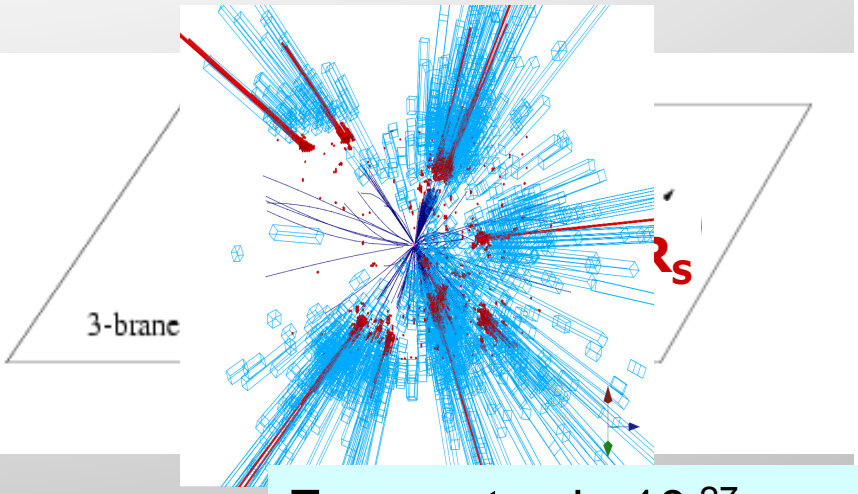
Search for Micro Black Holes



arXiv:1012.3375

Extra Dimensions!

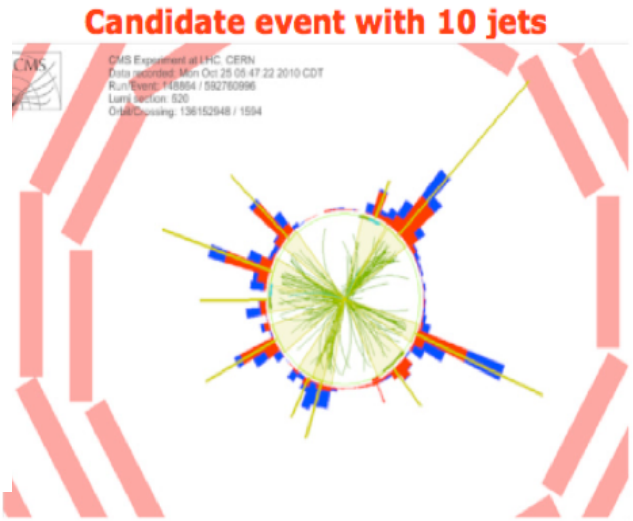
Planck scale
a few TeV?

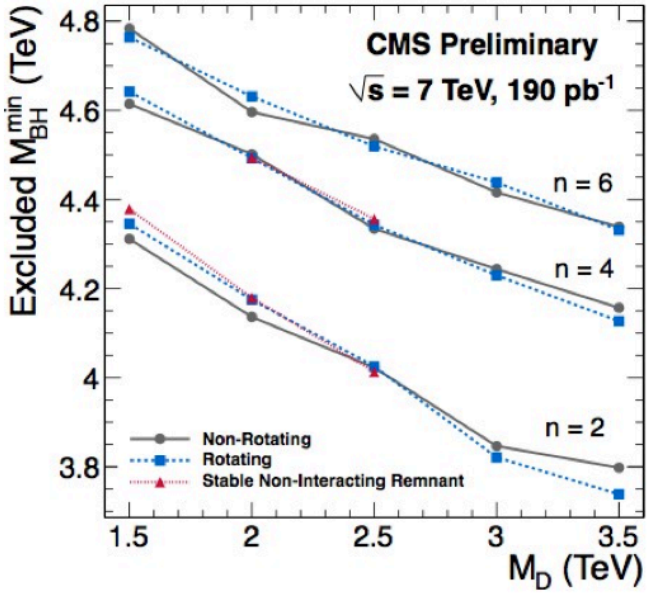


Evaporates in 10^{-27} sec

Look for the decay producs of an evaporating black hole (lifetime ~ 10^{-27} sec)

- 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



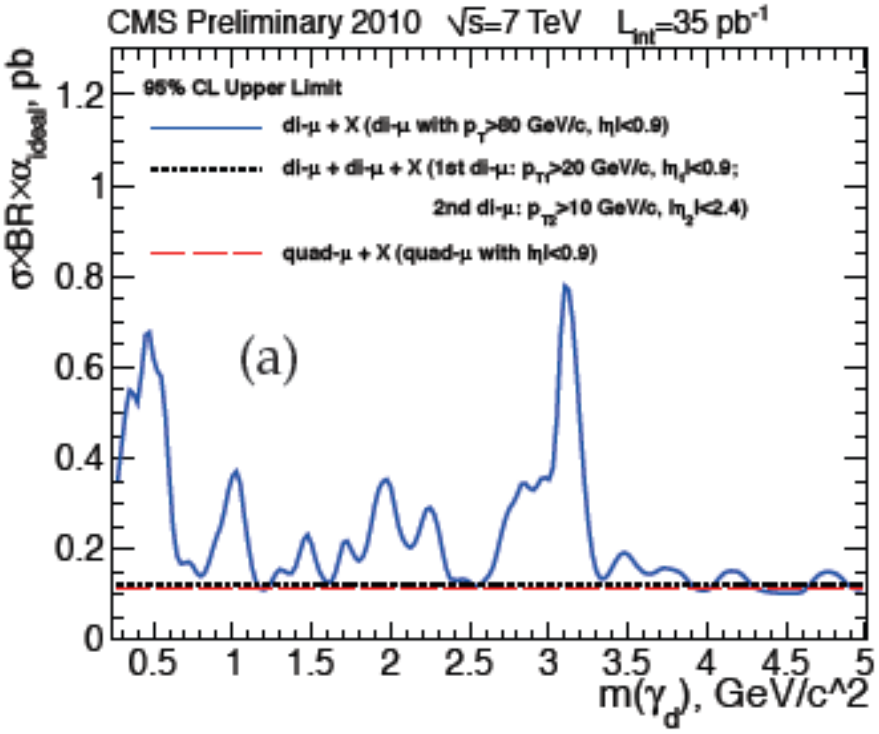


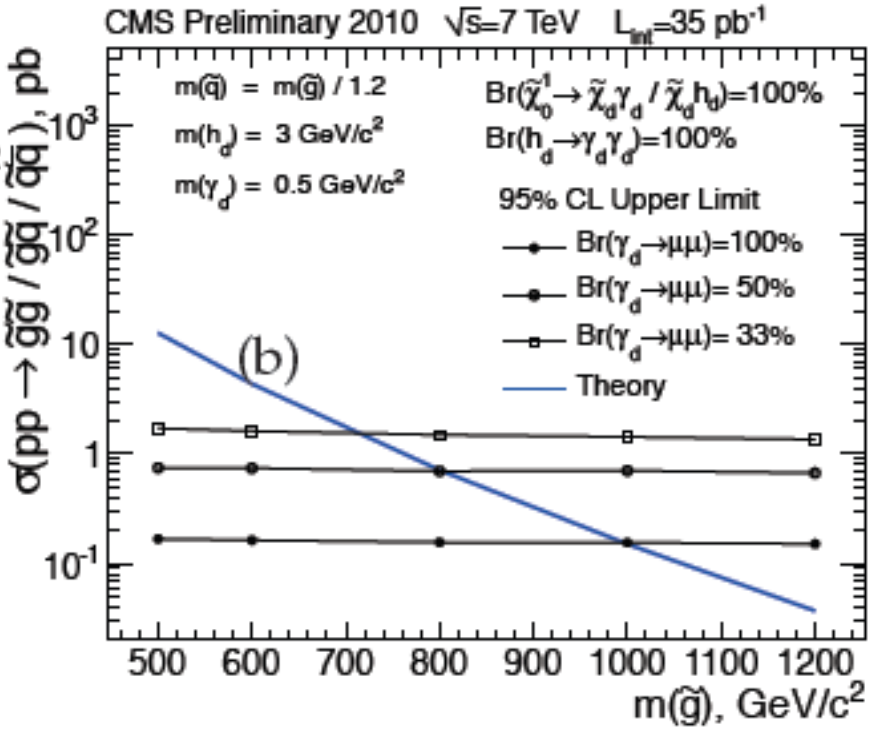
Black hole masses excluded in range 3-5 TeV depending on assumptions

Search for Dark Photons

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

Arkani-Hamed, Weiner



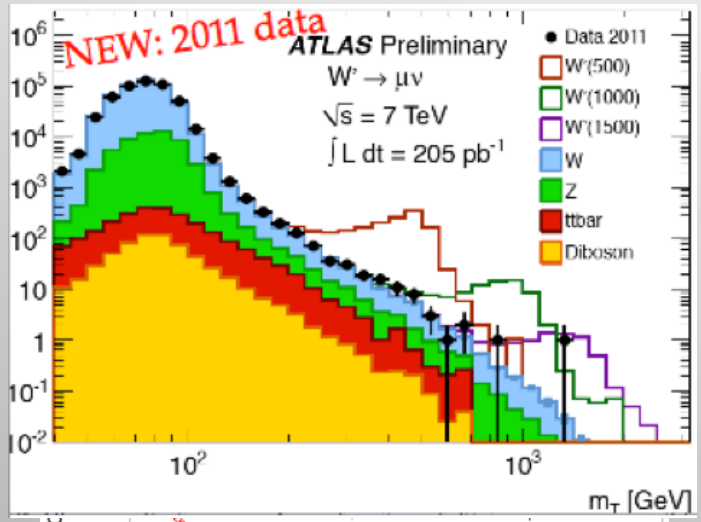


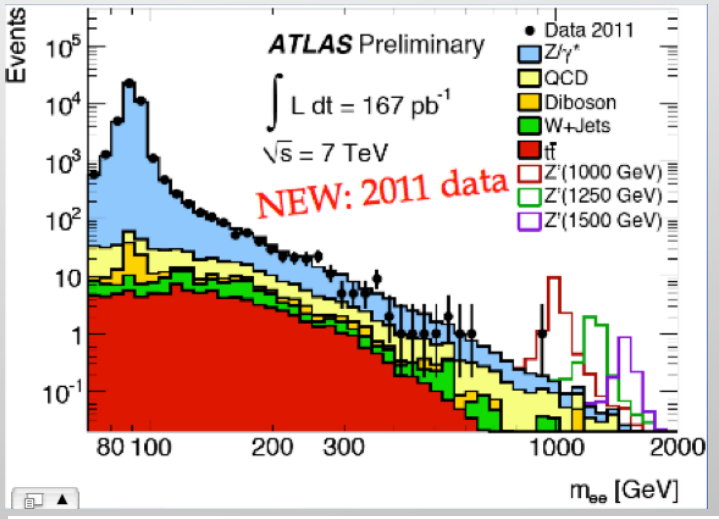
$$\tilde{\chi}_1^0 \rightarrow \tilde{\chi}_{dark}\gamma_{dark} + \tilde{\chi}_{dark}h_{dark}(\rightarrow \gamma_{dark}\gamma_{dark})$$

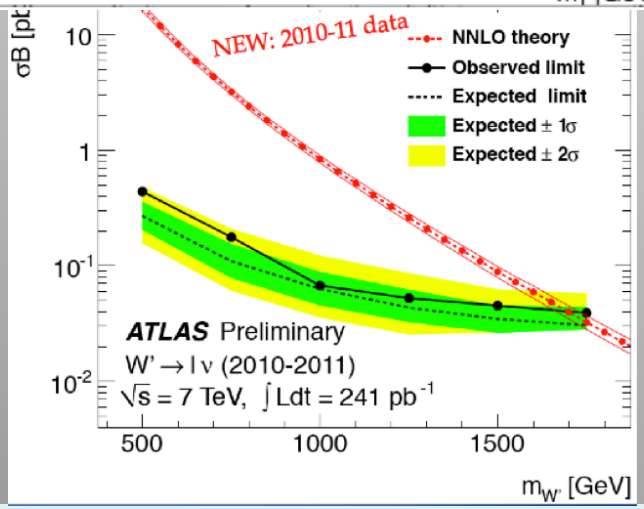
None found so far.... Limits set on production cross sections

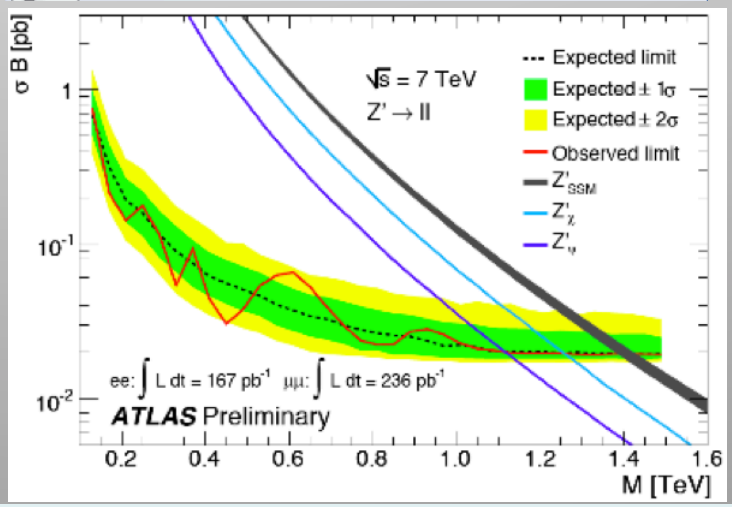
Search for New Gauge Bosons

Study of the channels W'→μν,eν and Z'→μμ, ee









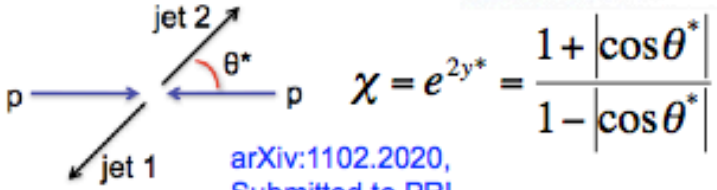
Exclude a new gauge bosons up to 1.7 TeV (W') and 1.4TeV (Z') @ 95% CL

This goes beyond the Tevatron timits of ~ 1.1 (W') and 1.0 (Z') TeV

Searches with Jets

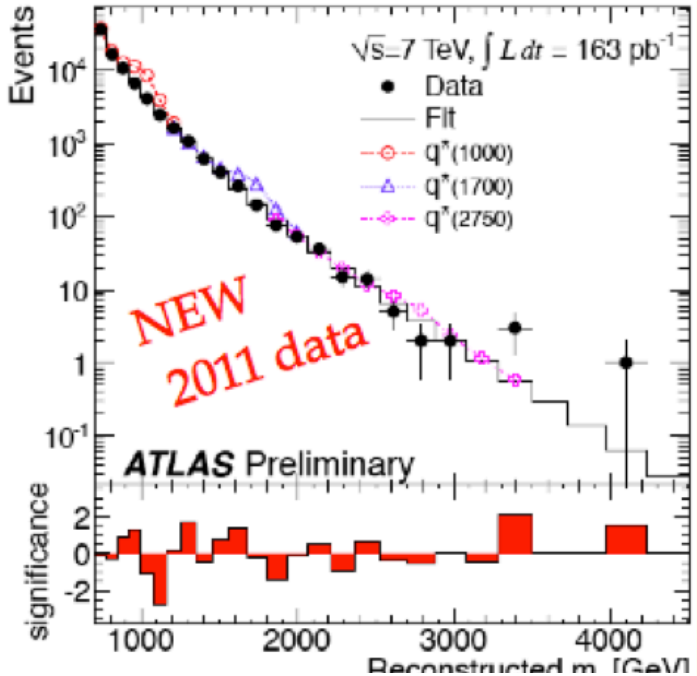
1) **Di-jet mass spectrum** (→ narrow resonances)

2) **Di-jet angular distributions** (→ contact interactions)



$$\chi = e^{2y^*} = \frac{1+|\cos\theta^*|}{1-|\cos\theta^*|}$$

arXiv:1102.2020,
Submitted to PRL

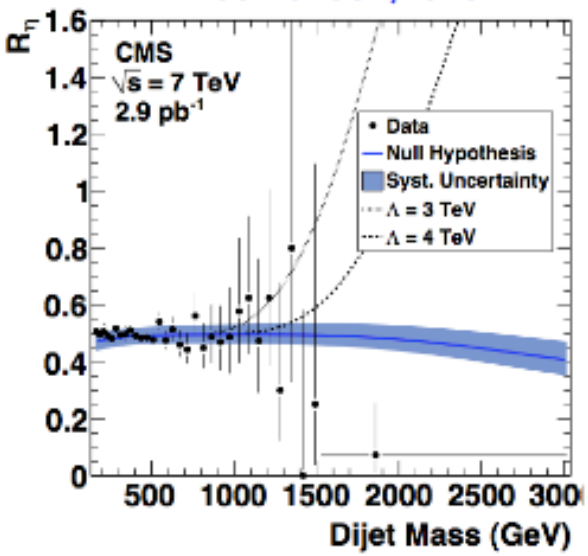


Mquark'> 2.48 TeV

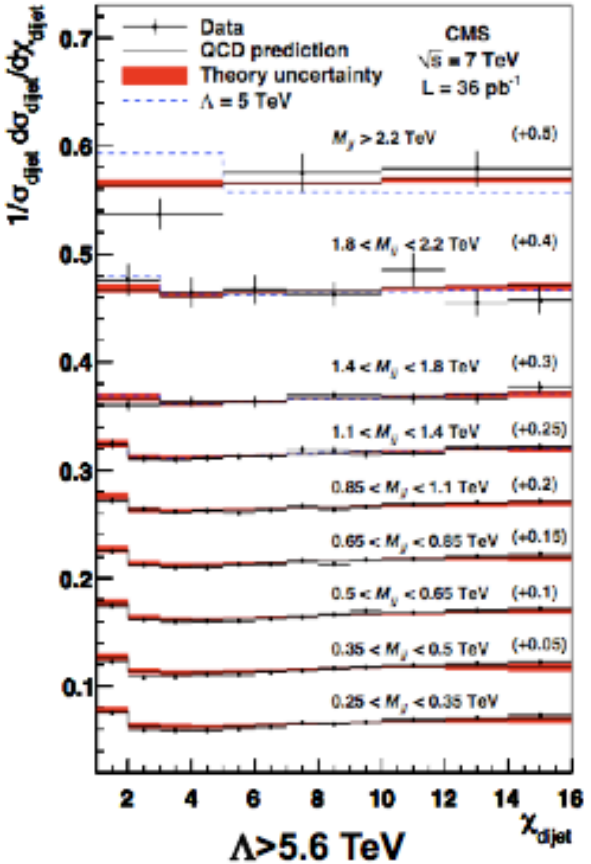
$M_{q^*} = \Lambda,\ f = f' = f_S = 1$

$$R_\eta \equiv \frac{N_{2j}(|\eta| < 0.7)}{N_{2j}(0.7 < |\eta| < 1.3)}$$

PRL 105:262001,2010

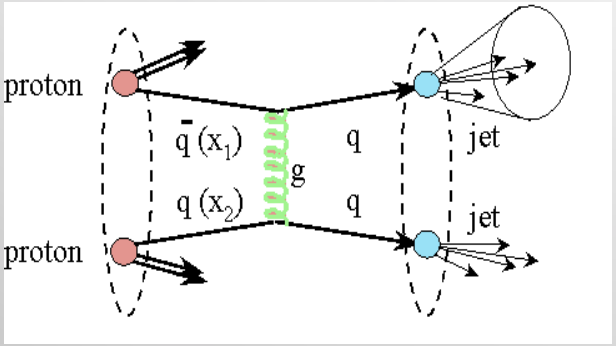


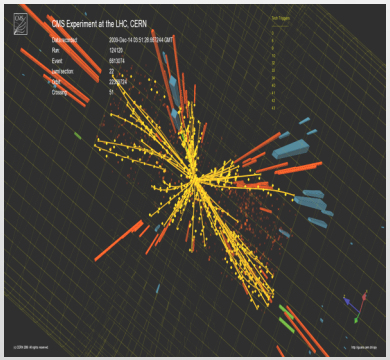
Λ>4 TeV
(expected Λ>2.9 TeV)



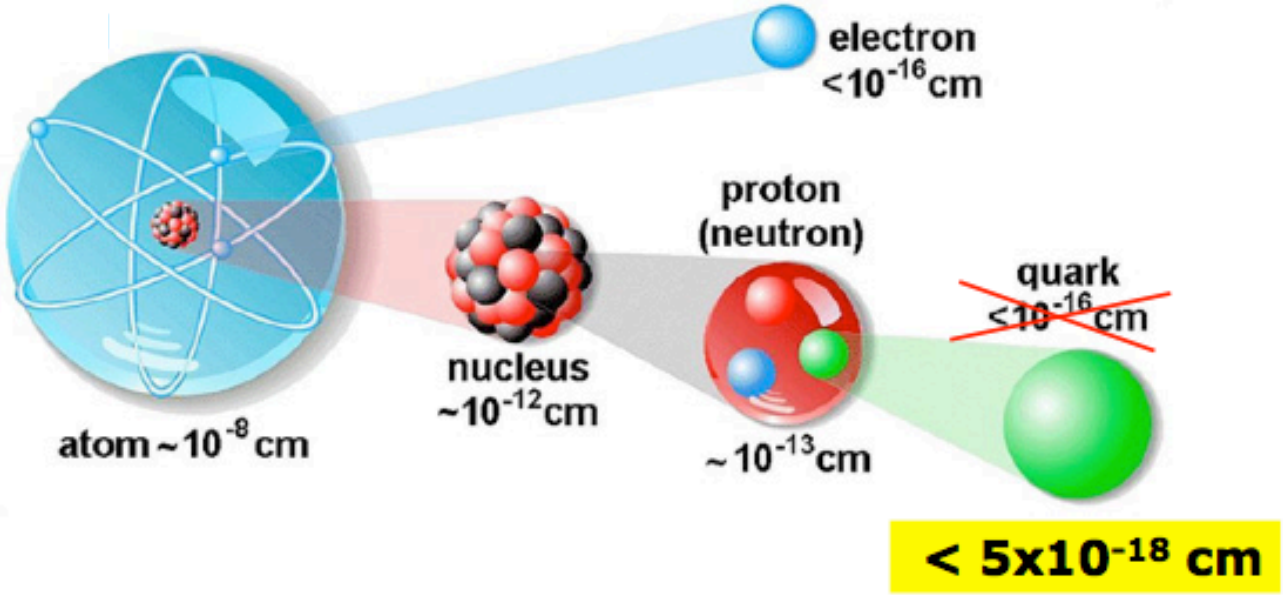
Λ>5.6 TeV
(expected Λ>5 TeV)

Limits on Quark-Compositness





Measurement of inclusive jet cross sections



Quarks remain elementary particles after these initial results

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 with a heavy gluino.

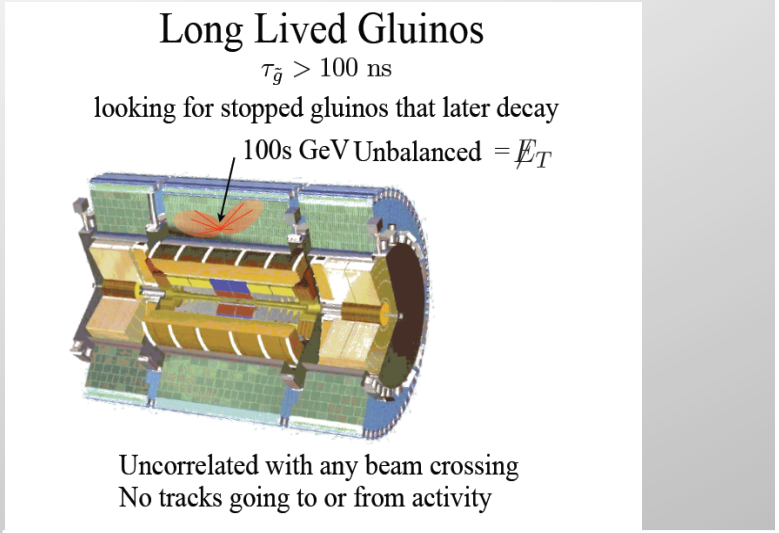
  Unusual interactions with material

  eg. with the calorimeters of the experiments!

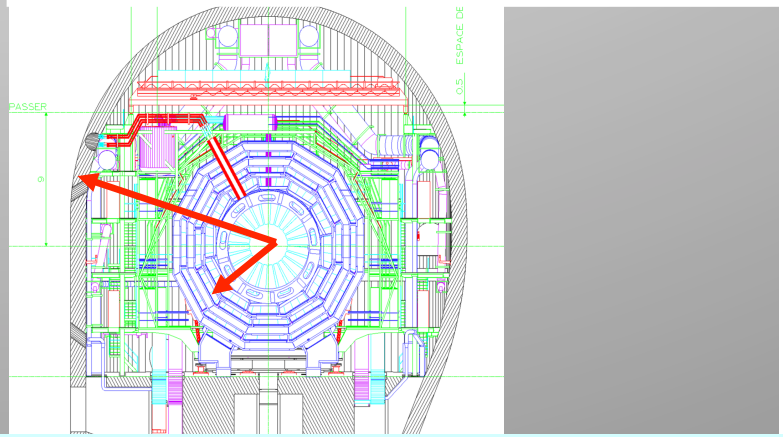
Gravitino Dark Matter and GMSB

- 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 Nijori,ADR hep-ph/0612060
ADR, J. Ellis et al. hep-ph/0508198



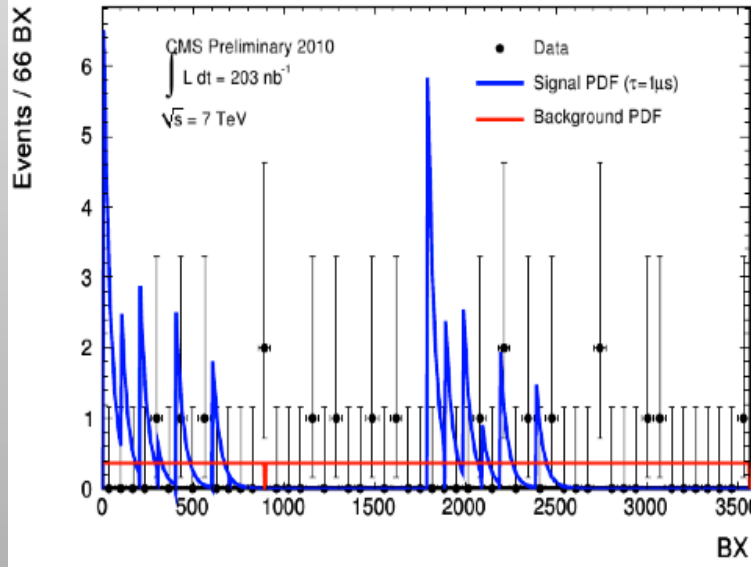
Sparticles stopped in the detector,walls of the cavern, or dense 'stopper' detector. They decay after hours---months…

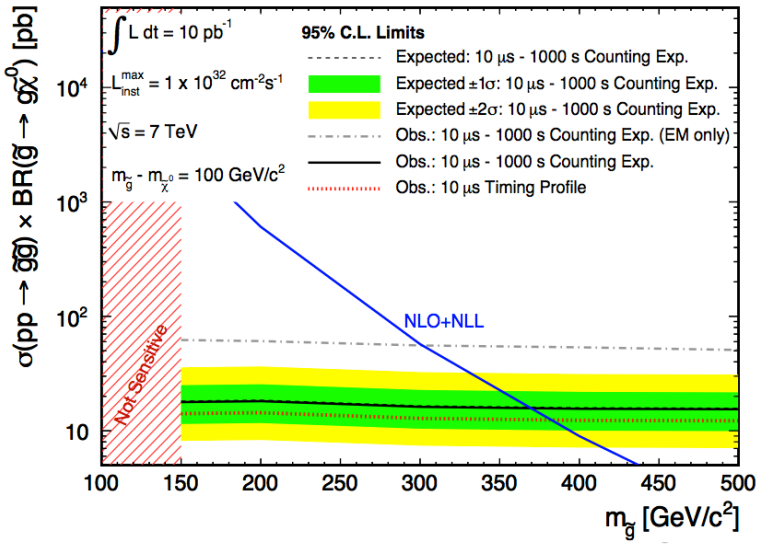
Searches: Stopped Gluinos

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

Searches for Stopped Gluino

Phys. Rev. Lett. 106 (2010) 01181





- gluino, hadronized into a charged R-hadron, can stop and decay in the calorimeter
- trigger on large "out-of-collision" energy depositions
- sensitive to the large lifetimes
- assume $BR(\tilde{g} \to g\tilde{\chi}^0) = 100\%,\ M_{\tilde{g}} - M_{\tilde{\chi}^0} > 100\ GeV$
- CMS'2010 95% CL limits on gluino lifetime $\tau_{\tilde{g}}$:
  - counting experiment excludes $\tau_{\tilde{g}}$ within [120ns, 6μs]
  - time profile analysis improves low limit down to 75ns

Gluino masses are excluded:

Time profile analysis (10 μs)
exclude $m_{\tilde{g}}$ < 382 GeV

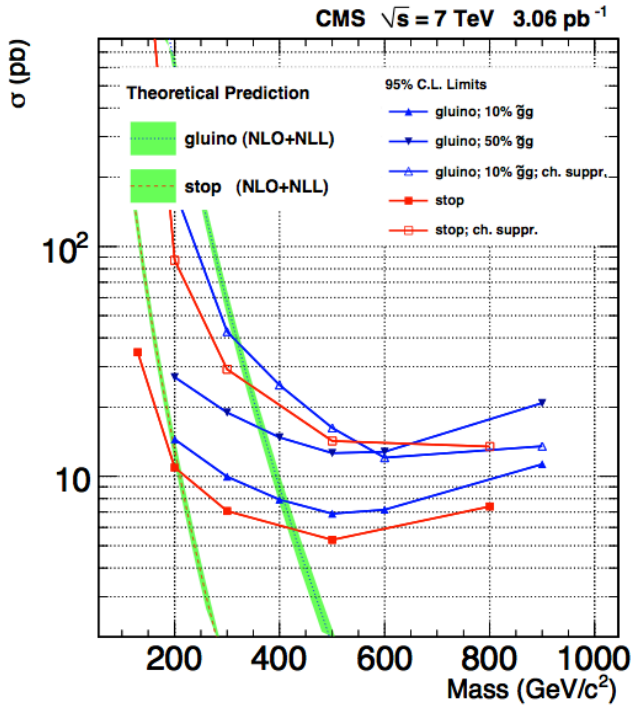
Counting experiment (10 μs - 1000s)
exclude $m_{\tilde{g}}$ < 370 GeV

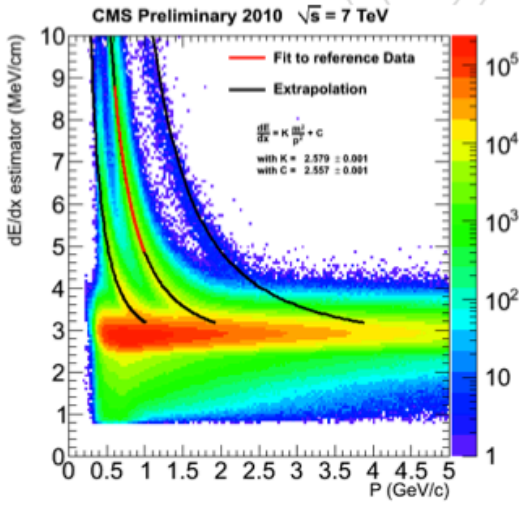
Heavy Stable Charged Particles

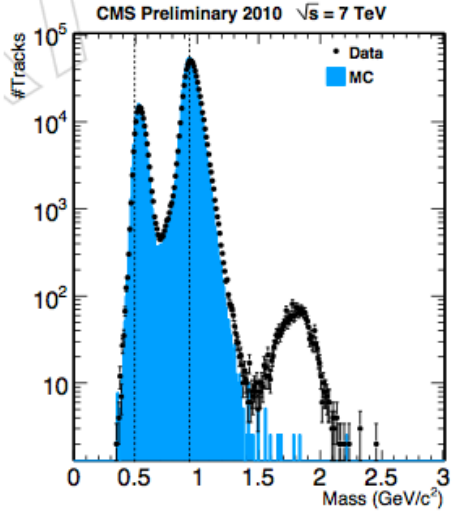
arXiv:1101.1645

Stable particles that traverse the detector

Eg heavy stable gluino (R-hadron) or stop/stau





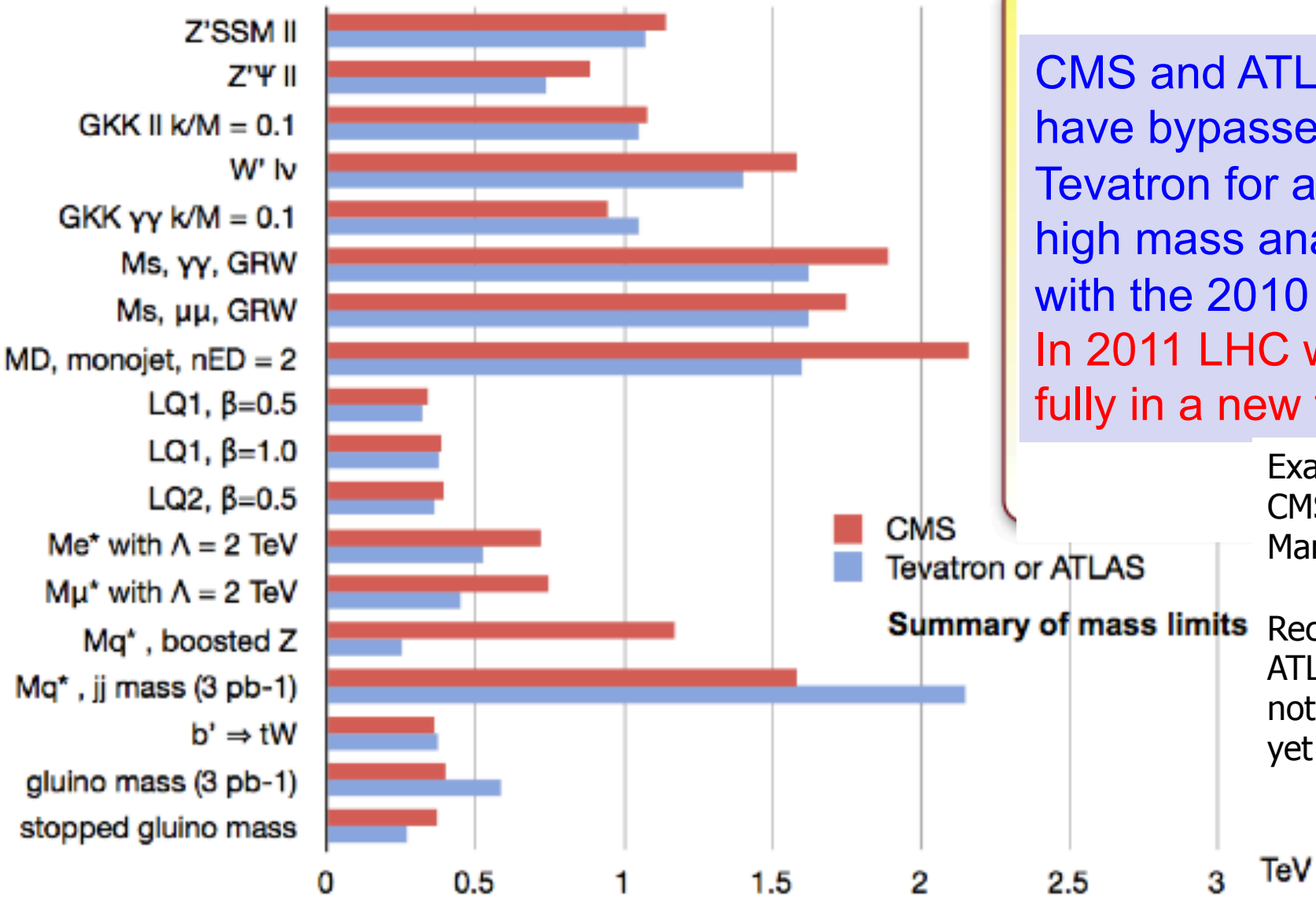


First search limits using tracker de/dx and muon identification

Result for 3.1 pb^{-1}
0 events after cuts

95% CL limits on production cross sections of a few100 pb in the 300-400 GeV mass range
Eg. Gluinos> 398 GeV

Review of Exotica Channels



CMS and ATLAS have bypassed the Tevatron for all high mass analyses with the 2010 35 pb^{-1}
In 2011 LHC will be fully in a new teritory!

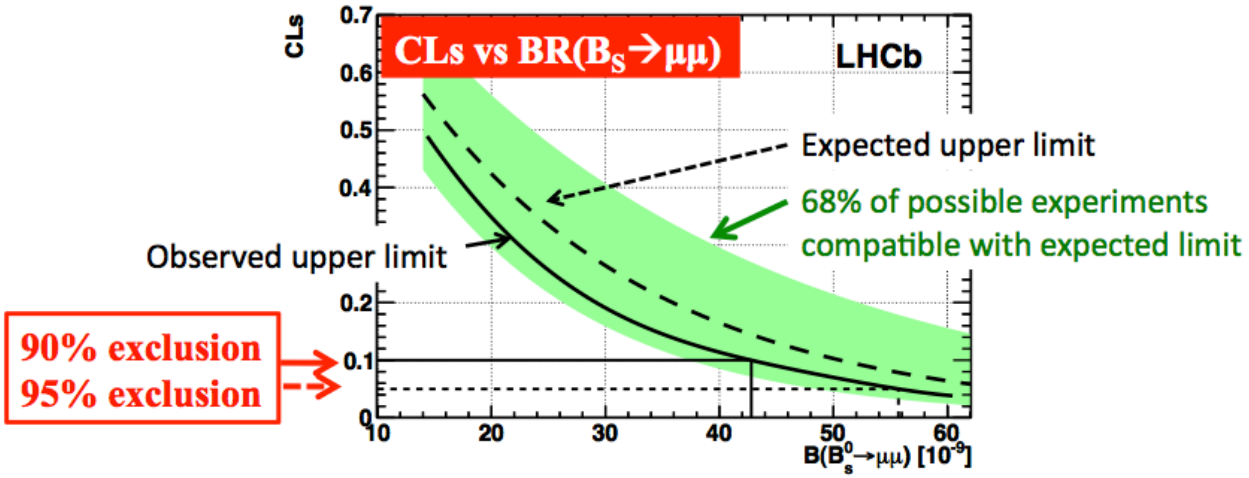
Example: CMS View March 2010

Recent new ATLAS limits not included yet

Also LHCb…

Rare Decays: a window to new physics

Results: $B_s \rightarrow \mu\mu$



		@ 90% CL	@ 95% CL
LHCb	Observed (expected), 37 pb^{-1}	< 43 (51) x10^{-9}	< 56 (65) x10^{-9}
D0	World best published, 6.1 fb^{-1} PLB 693 539 (2010)	< 42 x10^{-9}	< 51 x10^{-9}
CDF	Preliminary, 3.7 fb^{-1} Note 9892	< 36 x10^{-9}	< 43 x 10^{-9}

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Expect to bypass Tevatron into interesting New Physics regime in 2011

The Future…

When in search for the unknown, you don't know what you are going to find.

Tevatron will stop operating in fall 2011
LHC will deliver a few fb^{-1} in 2011, probably > 10 fb^{-1} in 2012

Summary: Searches for New Physics

- Tevatron has observed a number of interesting anomalies. No claimed discoveries yet, confirmation checks ongoing in the alternate experiments. Clearly two (or more) experiments at a collider are necessary! Tevatron stops this fall.
- Searches at the LHC started. In many channels the searches go beyond the Tevatron, in other channels they are approaching rapidly Tevatron sensitivity, even with 35 pb^{-1}
- LHC will be able to referee some – but not all- of the Tevatron searches (proton-proton versus proton-antiproton)
- No established new physics yet. LHC starts to cut into the 'preferred SUSY region'
- New data is coming fast. Watch also LHCb with $B_S \rightarrow \mu\mu$…
- Ready for the 'real game' ie hunting for new physics, and for the Higgs…. Which could show up already in 2011!