Maiani '70 - 21 September '11

What we have learnt so far from the LHC?

Guido Altarelli
Roma Tre/CERN

I am very glad to be here to celebrate the 70th anniversary of Luciano

and also the ~50 years of our personal and professional friendship

First, we have learnt that the LHC is working very well!

ATLAS&CMS

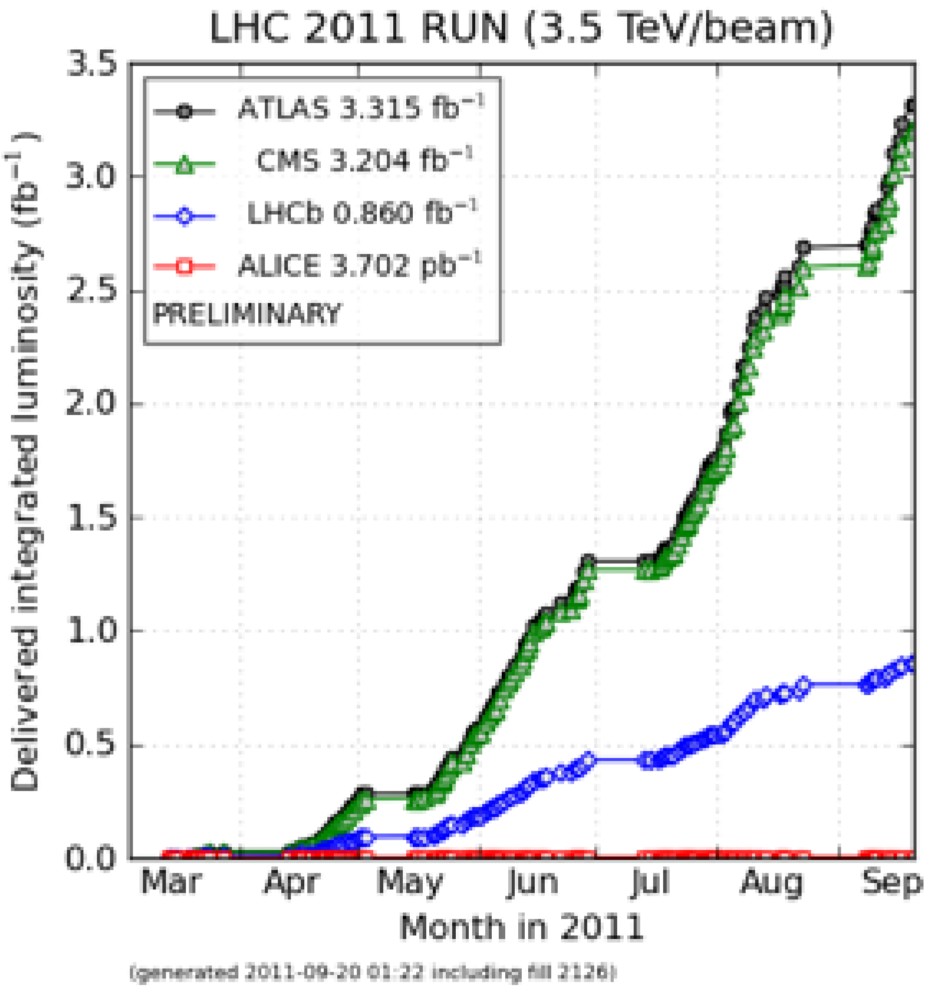
~3.2 fb^{-1} each

The target of 5 fb^{-1}
for 2011
is within sight!

LHCb

~0.9 fb^{-1}

This is great news !!



Particle physics at a glance

The SM is a low energy effective theory
(nobody can believe it is the ultimate theory)

It happens to be renormalizable, hence highly predictive.
And is well supported by the data.

However, we expect corrections from higher energies

not only from the GUT or Planck scales
but also from the TeV scale (LHC!)

In fact even just as a low energy effective theory
the SM it is not satisfactory

QCD + the gauge part of the EW theory are fine,
but the Higgs sector is so far only a conjecture

The Higgs problem is central in particle physics today

The main problems of the SM show up in the Higgs sector

$$V_{Higgs} = V_0 - \mu^2 \phi^\dagger \phi + \lambda \left(\phi^\dagger \phi\right)^2 + [\bar{\psi}_{Li} Y_{ij} \psi_{Rj} \phi + h.c.]$$

Vacuum energy
$V_{0exp} \sim (2.10^{-3}\ \mathrm{eV})^4$

Origin of quadratic divergences.
Hierarchy problem

Possible instability depending on m_H

The flavour problem: large unexplained ratios of Y_{ij} Yukawa constants

The Standard EW theory: $\mathcal{L} = \mathcal{L}_{\text{symm}} + \mathcal{L}_{\text{Higgs}}$

$$\mathcal{L}_{symm} = -\frac{1}{4}[\partial_\mu W_\nu^A - \partial_\nu W_\mu^A - ig\varepsilon_{ABC} W_\mu^A W_\nu^B]^2 +$$

$$-\frac{1}{4}[\partial_\mu B_\nu - \partial_\nu B_\mu]^2 +$$

$$+\bar{\psi}\gamma^\mu[i\partial_\mu + g W_\mu^A t^A + g' B_\mu \frac{Y}{2}]\psi$$

$$\mathcal{L}_{Higgs} = |[\partial_\mu - ig W_\mu^A t^A - ig' B_\mu \frac{Y}{2}]\phi|^2 +$$

$$+ \; V[\phi^\dagger \phi] + \bar{\psi}\Gamma\psi\phi + \text{h.c}$$

with $V[\phi^\dagger\phi] = \mu^2(\phi^\dagger\phi)^2 + \lambda(\phi^\dagger\phi)^4$

$\mathcal{L}_{\text{symm}}$: well tested (LEP, SLC, Tevatron…), $\mathcal{L}_{\text{Higgs}}$: ~ untested

After LEP **all** we knew from experiment about the SM Higgs:

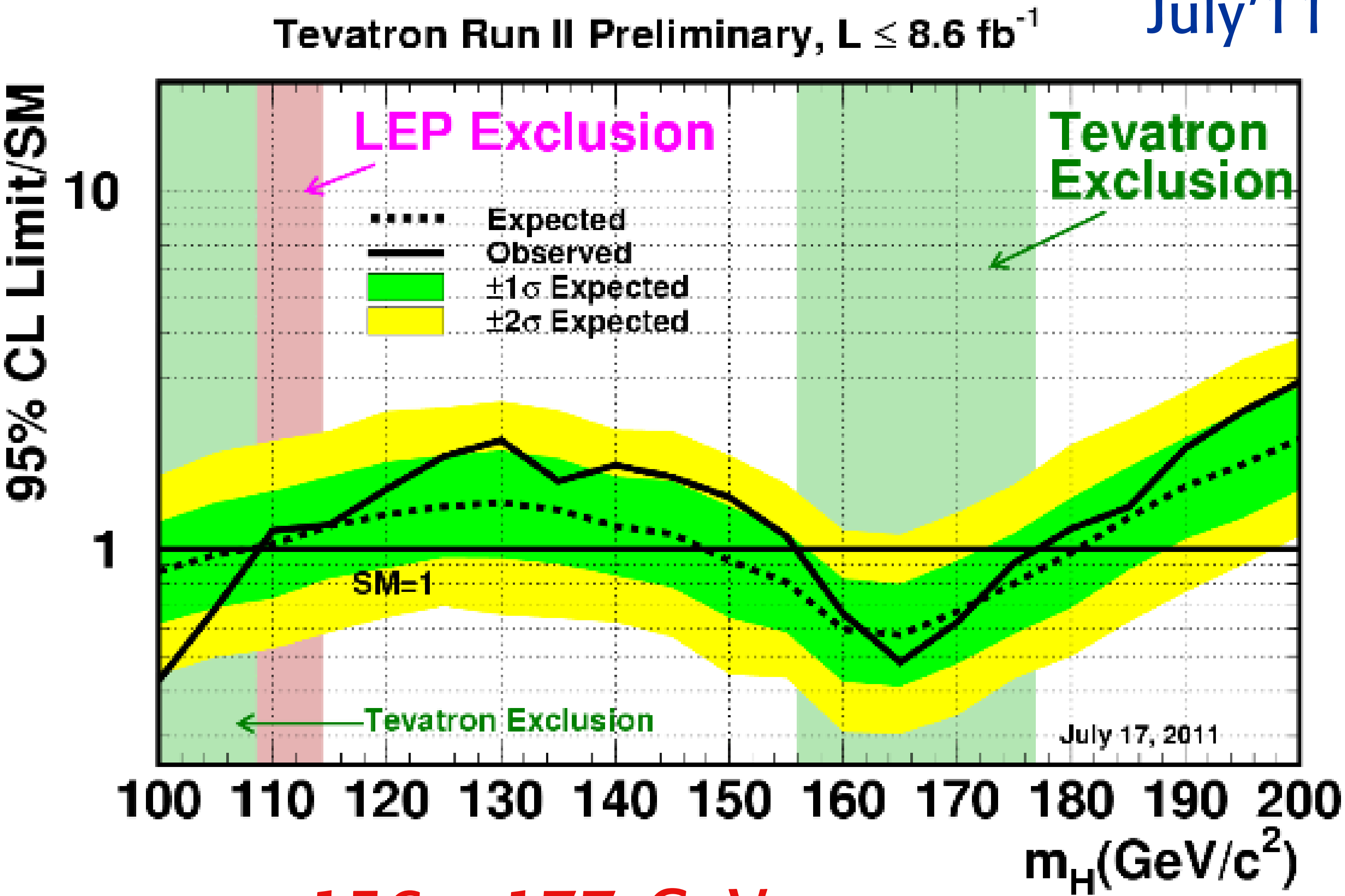
No Higgs seen at LEP2 -> $m_H > 114.4$ GeV (95%cl)

Rad. corr's -> $m_H < 186$ GeV (95%cl, incl. direct search bound)

$v = \langle\phi\rangle = \sim 174$ GeV ; $m_W = m_Z \cos\theta_W$ ⟶ doublet Higgs

After LEP, it is the hadron colliders turn

July'11

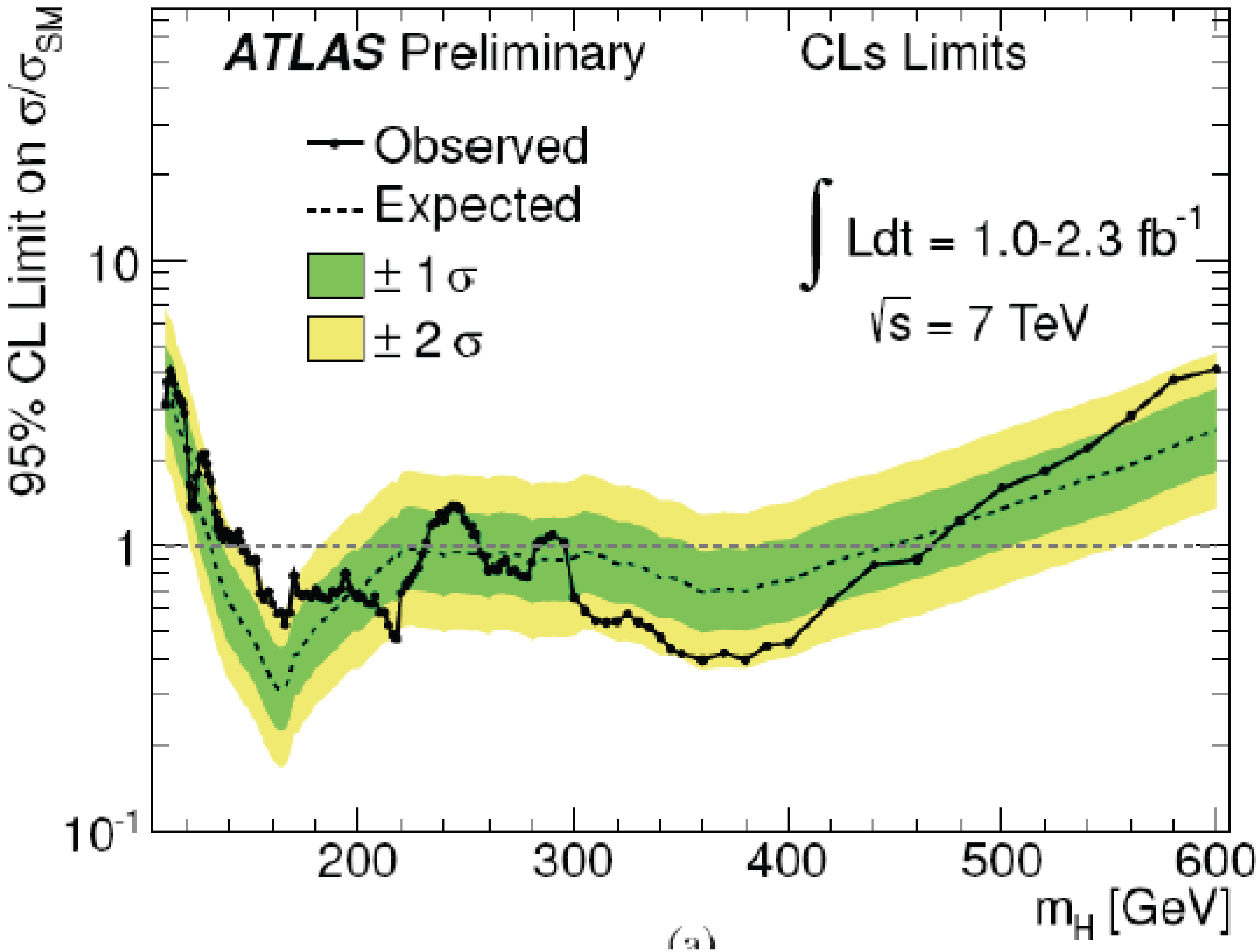


Depends on assumed pdf's, α_s errors ....

156 - 177 GeV
[and 100-109 GeV] at 95%

The present LHC m_H limits

ATLAS LP'11

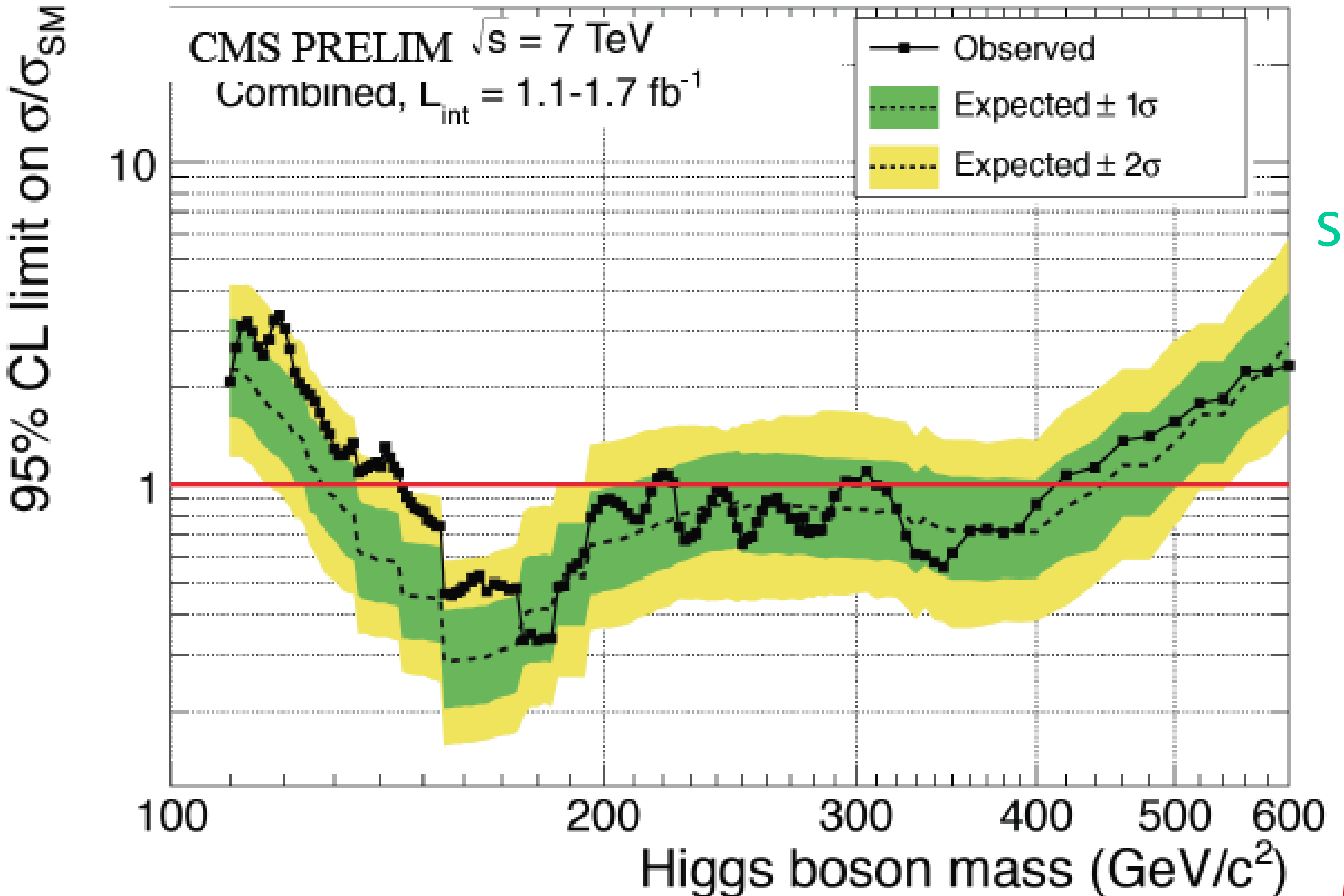


Nisati

Excl. range 95% 146-232, 256-282, 296-466 GeV

The present LHC m_H limits

CMS LP'1 1



Sharma

95%

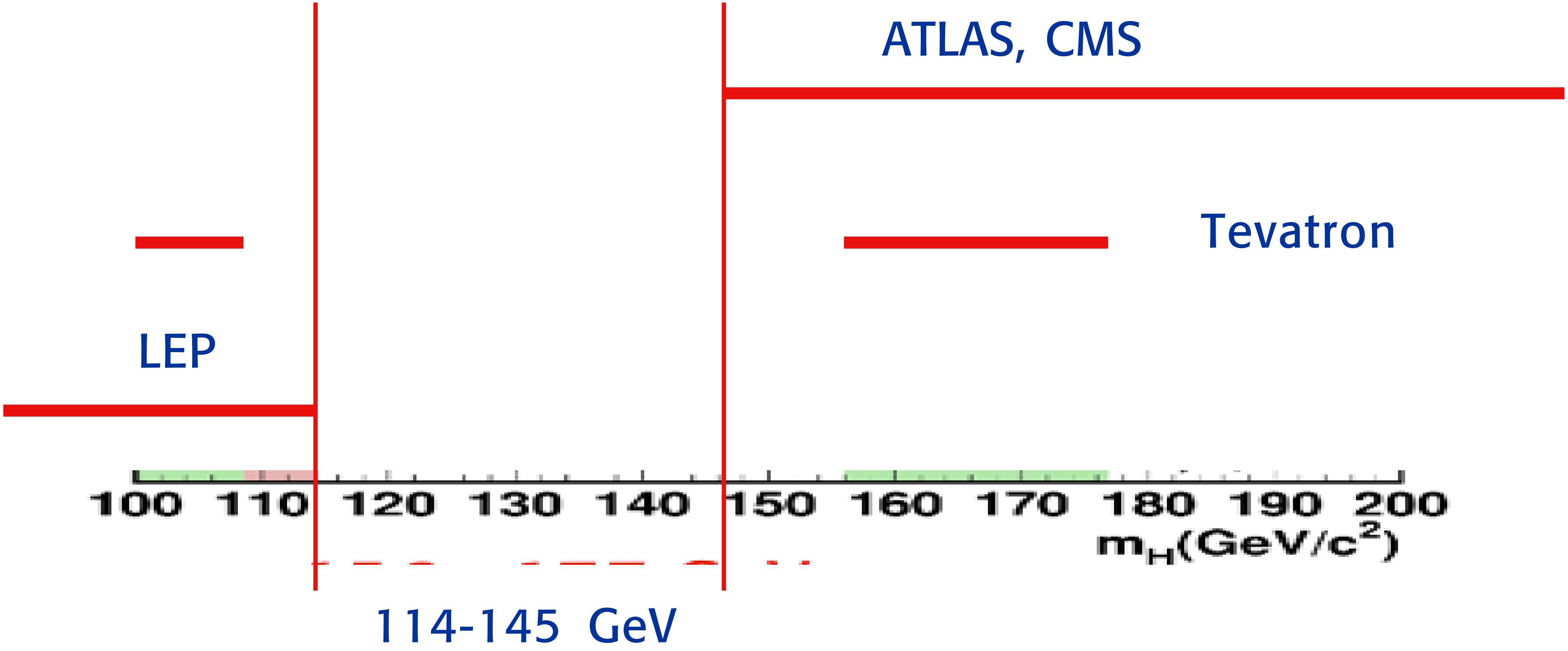
Expected exclusion mass range: 130 – 440 GeV

Observed exclusion mass range: 145-216, 226-288, 310-400 GeV

Excluded m_H range 95%, all together:

Tevatron	100-109, 156-177 GeV
ATLAS	146-232, 256-282, 296-466 GeV
CMS	145-216, 226-288, 310-400 GeV

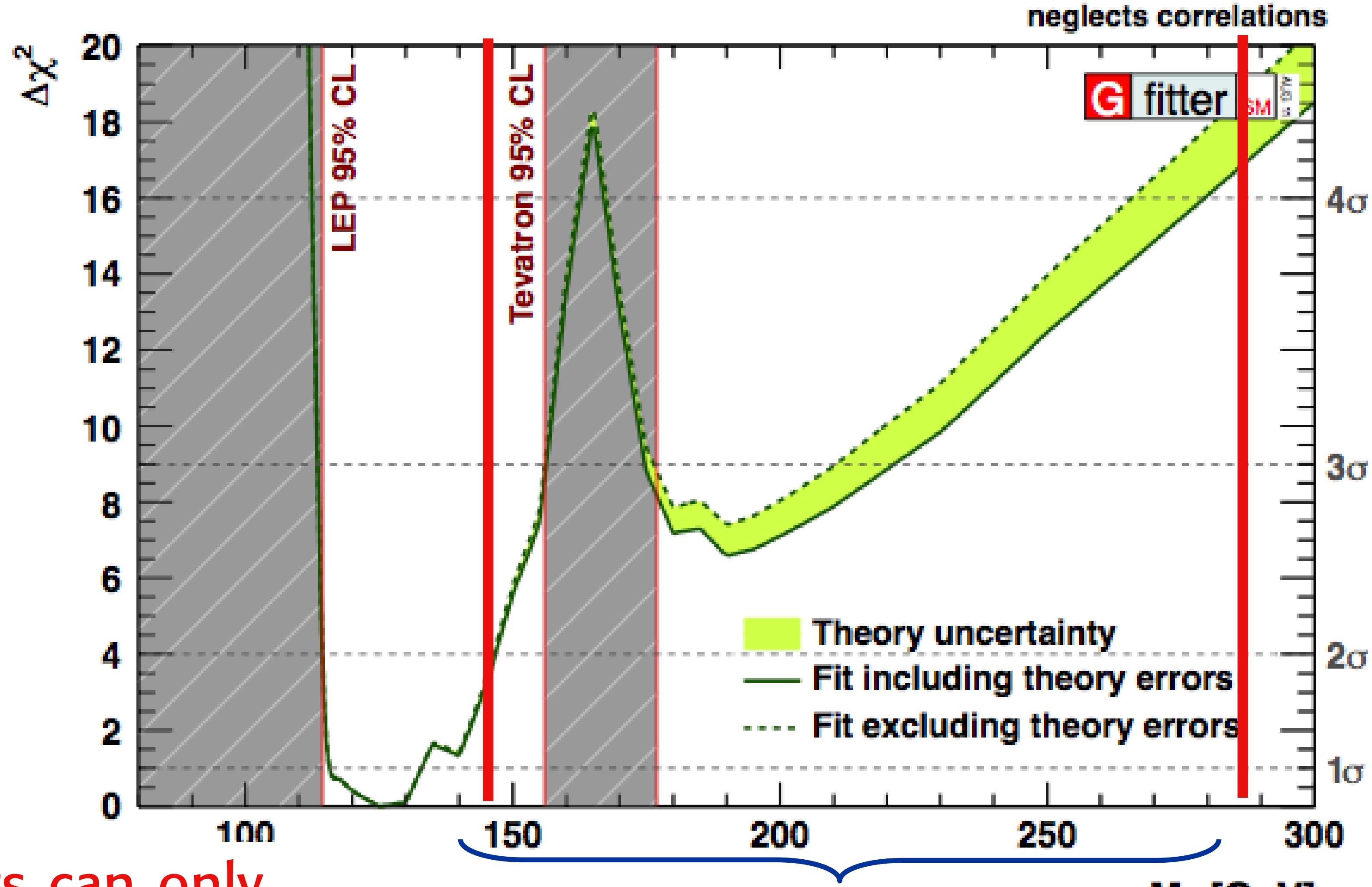
The 95% exclusion intervals for the light Higgs



The window of opportunity

A sketch of the experimental status of the Higgs search

This fig.
is a non
authorized
reproduction
of what
I understood

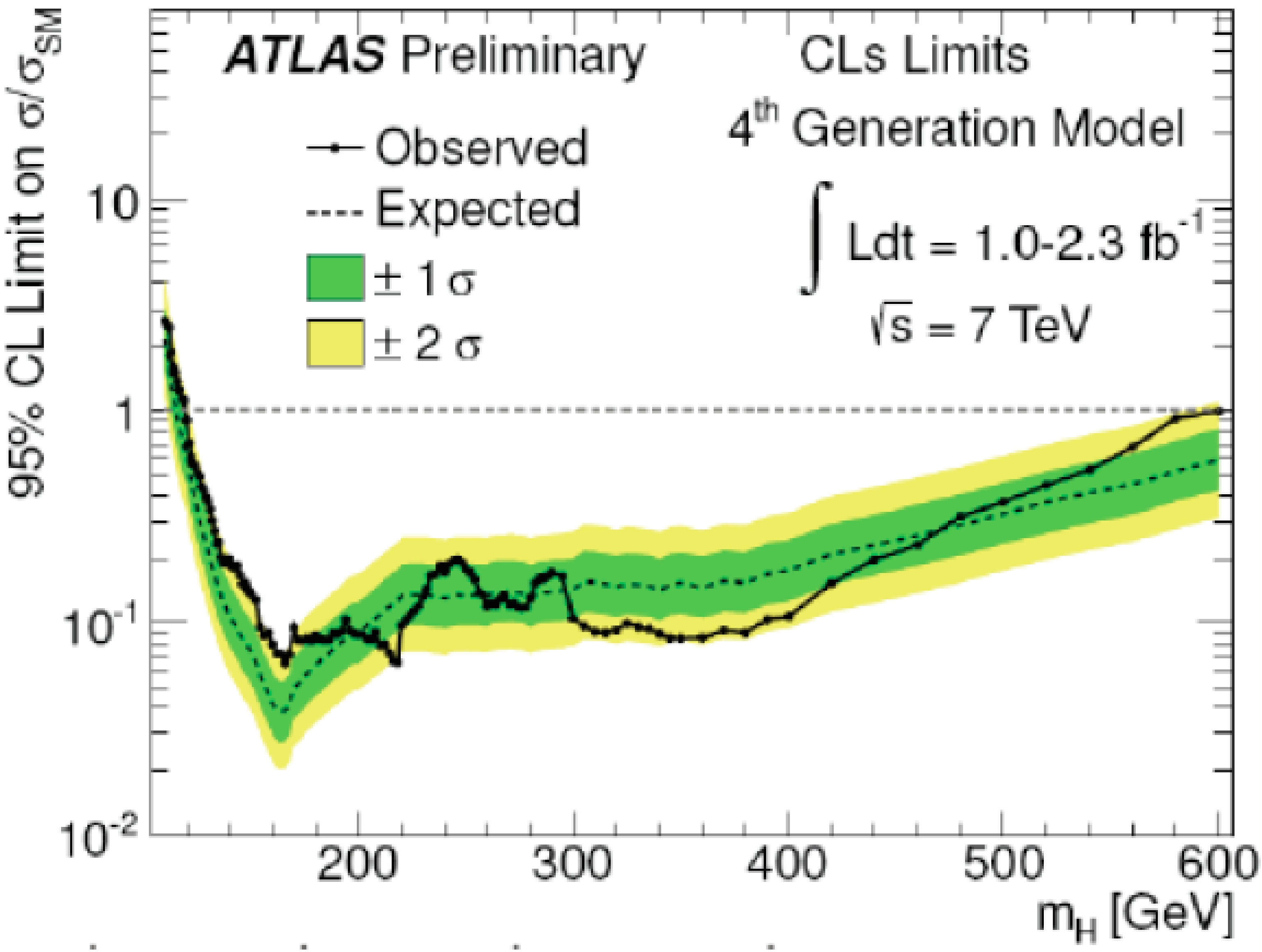


A light SM Higgs can only be in 114-145 GeV range!

Excl. by ATLAS and/or CMS

also $300 < m_H < 460$ GeV is excluded

If a 4th generation is assumed then the Higgs is excluded up to 600 GeV

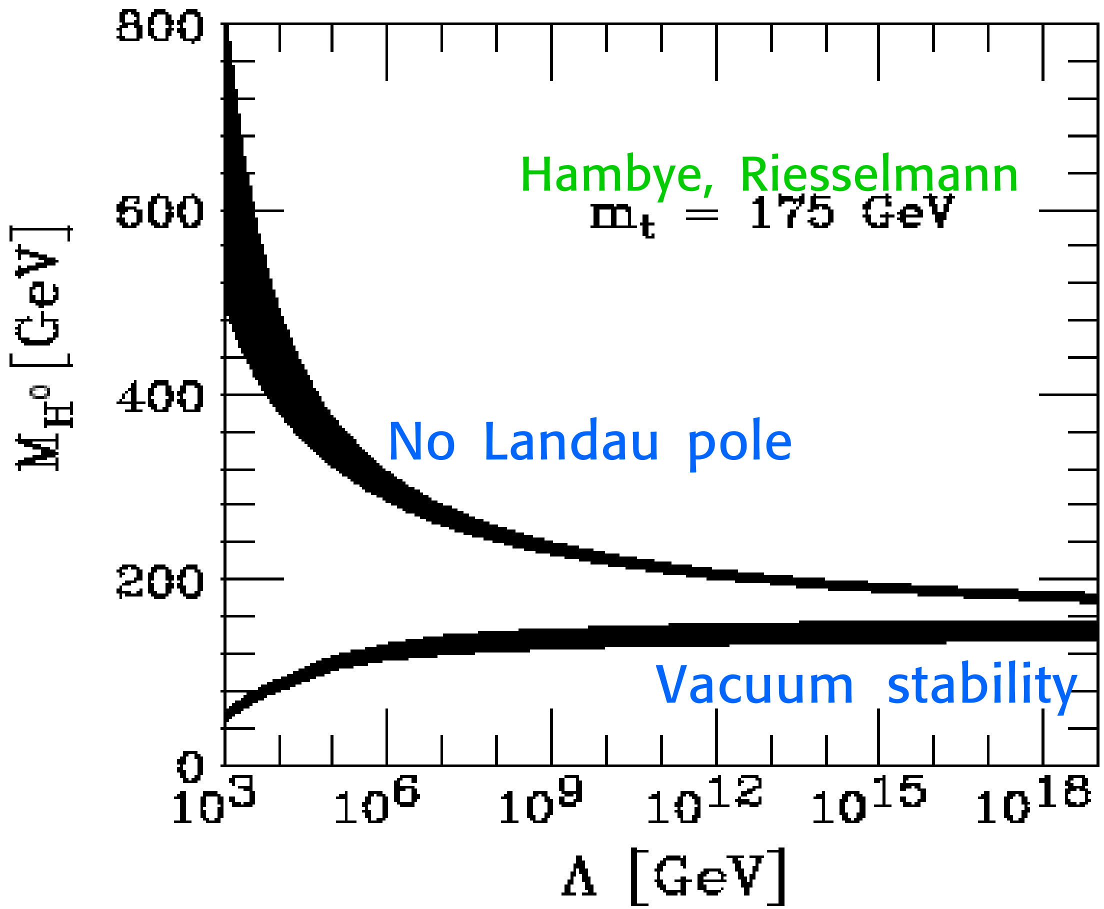


Theoretical bounds on the SM Higgs mass

Λ: scale of new physics beyond the SM

Upper limit: No Landau pole up to Λ
Lower limit: Vacuum (meta)stability

The LHC was designed to cover the whole range



If the SM would be valid up to M_{GUT}, M_{Pl} then m_H would be limited in a small range

Lower now because of m_t → $128 \text{ GeV} < m_H < 180 \text{ GeV}$

The SM Higgs is close to be observed or excluded

Either the SM Higgs is very light (114 - 145 GeV)
or rather heavy (eg > 460 GeV)

The range m_H = 114 - 145 GeV is well compatible
with the SM (and also with the SUSY extensions of SM)

Many start worry that the Higgs might not be found

What is the status of the Higgs?
Can we do without the Higgs?

That some sort of spontaneous symmetry breaking mechanism is at work has already been established (couplings symmetric, spectrum totally non symmetric)

The question is on the nature of the Higgs mechanism/particle(s)

- One doublet, more doublets, additional singlets?
- SM Higgs or SUSY Higgses
- Fundamental or composite (of fermions, of WW....)
- Pseudo-Goldstone boson of an enlarged symmetry
- A manifestation of extra dimensions (fifth comp. of a gauge boson, an effect of orbifolding or of boundary conditions....)
- Some combination of the above

Can we do without the Higgs?

Suppose we take the gauge symmetric part of the SM and put masses by hand.

Gauge invariance is broken explicitly. The theory is no more renormalizable. One loses understanding of the observed accurate validity of gauge predictions for couplings.

Still, what is the fatal problem at the LHC scale?

The most immediate disease that needs a solution is the occurrence of unitarity violations in some amplitudes

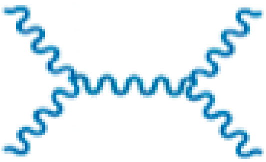
With no Higgs unitarity violations for E_{CM} ~ 1-3 TeV

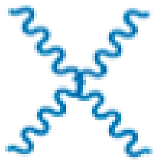
Unitarity implies that scattering amplitudes cannot grow indefinitely with the centre-of-mass energy s

In the SM, the Higgs particle is essential in ensuring that the scattering amplitudes with longitudinal weak bosons (W_L , Z_L) satisfy (tree-level) unitarity constraints
[Veltman, 1977; Lee-Quigg-Thacker, 1977; …]

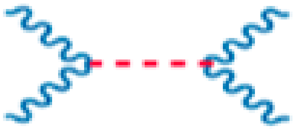
Zwirner

An example: $\mathcal{A}(W_L^+ W_L^- \to Z_L Z_L) \quad (s \gg m_W^2)$





$$i\frac{s}{v^2}$$



$$-i\frac{s^2}{v^2(s-m_h^2)}$$

$$\rightarrow \quad -i\frac{m_h^2}{v^2}\frac{s}{s-m_h^2}$$

If no Higgs then something must happen!

Can we do without the Higgs?

Suppose we take the gauge symmetric part of the SM and put masses by hand.

Gauge invariance is broken explicitly. The theory is no more renormalizable. One loses understanding of the observed accurate validity of gauge predictions for couplings.

Still, what is the fatal problem at the LHC scale?

The most immediate disease that needs a solution is the occurrence of unitarity violations in some amplitudes

To avoid this either there is one or more Higgs particles or some new states (e.g. new vector bosons)

Thus something must happen at the few TeV scale!!

A crucial question for the LHC

What saves unitarity?

- the Higgs
- some new vector boson

  W′, Z′
  KK recurrences
  resonances from a strong sector
  ......

LHC scenarios

Catastrophic: Neither the Higgs, nor new physics

Can only occur if the LHC is not enough to fully probe the EW scale: unitarity violations impose one or the other (eg new vector bosons) or both

The EW precision tests point to a light Higgs.
In most of the alternative models the Higgs is still light and the LHC sensitivity range is large

So the Higgs should not be missed at the LHC

Actually the results presented at the summer 2011 Conferences show that the search for the SM Higgs has made a lot of progress!

If a Higgs signal is observed

This would be a triumph for the LHC

The next challenge for experiment would be to measure its couplings in order to see whether it is the SM Higgs or an exotic Higgs

If a Higgs signal is excluded then some new physics must be responsible for the EW symmetry breaking

Experiments must identify it

LHC scenarios

Catastrophic: Neither the Higgs, nor new physics

Can only occur if the LHC is not enough to fully probe the EW scale: unitarity violations impose one or the other (eg new vector bosons) or both

Theorist projection: non standard Higgs and new physics

A lot of model building in this direction

The Standard Model works very well

So, why not find the Higgs and declare particle physics solved?

Because of both:

Conceptual problems

- Quantum gravity
- The hierarchy problem
- The flavour puzzle

.....

and experimental clues:

- Neutrino masses
- Coupling unification
- Dark matter
- Baryogenesis
- Vacuum energy
- some experimental anomalies: $(g\text{-}2)_\mu$, ...

Some of these problems point at new physics at the weak scale: eg
Hierarchy
Dark matter (perhaps)

insert here your preferred hints

Dark Matter

WMAP, SDSS, 2dFGRS….

Most of the Universe is not made up of atoms: $\Omega_{tot} \sim 1$, $\Omega_b \sim 0.045$, $\Omega_m \sim 0.27$

Most is Dark Matter and Dark Energy

Most Dark Matter is Cold (non relativistic at freeze out)
Significant Hot Dark matter is disfavoured
Neutrinos are not much cosmo-relevant: $\Omega_\nu < 0.015$

SUSY has excellent DM candidates: eg Neutralinos (--> LHC)
Also Axions are still viable (introduced to solve strong CPV)
(in a mass window around m $\sim 10^{-4}$ eV and $f_a \sim 10^{11}$ GeV
but these values are simply a-posteriori)

Identification of Dark Matter is a task of enormous importance for particle physics and cosmology

LHC?

LHC has good chances because it can reach any kind of WIMP:

WIMP: Weakly Interacting Massive Particle
with m ~ 10^1-10^3 GeV

For WIMP's in thermal equilibrium after inflation the density is:

$$\Omega_\chi h^2 \simeq const. \cdot \frac{T_0^3}{M_{\rm Pl}^3 \langle \sigma_A v \rangle} \simeq \frac{0.1\ \mathrm{pb} \cdot c}{\langle \sigma_A v \rangle}$$

can work for typical weak cross-sections!!!

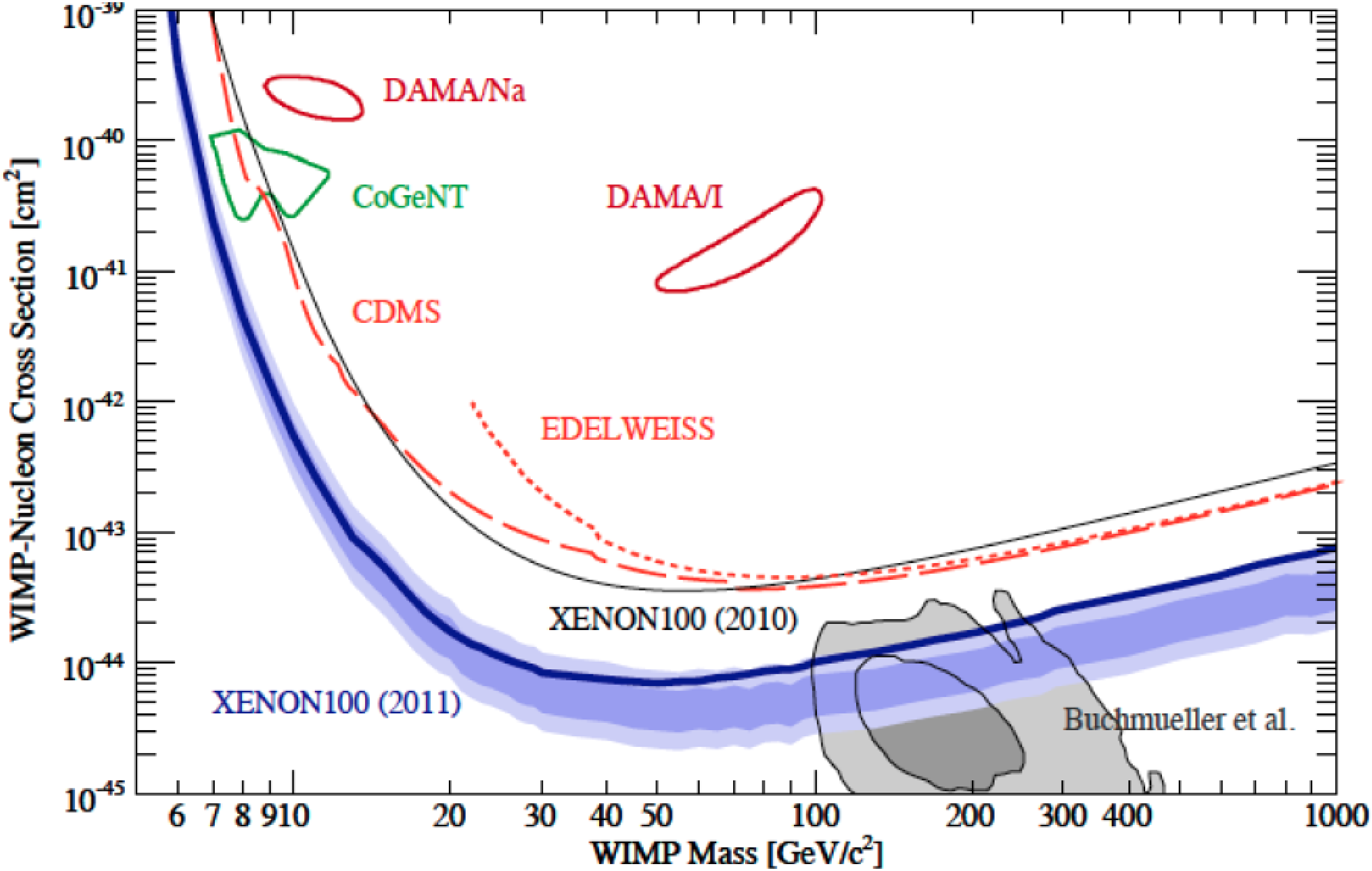
This "coincidence" is a good indication in favour of a WIMP explanation of Dark Matter

A crucial question for the LHC

Is Dark Matter a WIMP?

LHC will tell yes or no to WIMPS

Laboratory experiments on Dark Matter are also very important (including the search for axions, a non WIMP solution)

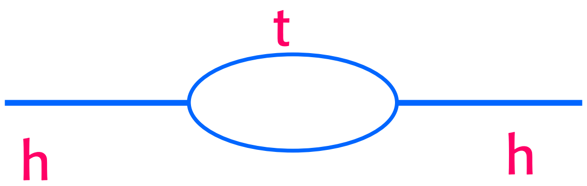


DAMA/Na
CoGeNT
DAMA/I
CDMS
EDELWEISS
XENON100 (2010)
XENON100 (2011)
Buchmueller et al.
WIMP-Nucleon Cross Section [cm²]
WIMP Mass [GeV/c²]
10⁻³⁹
10⁻⁴⁰
10⁻⁴¹
10⁻⁴²
10⁻⁴³
10⁻⁴⁴
10⁻⁴⁵
6 7 8 910 20 30 40 50 100 200 300 400 1000

The "little hierarchy" problem

e.g. the top loop (the most pressing):

$m_h^2 = m^2_{bare} + \delta m_h^2$



$$\delta m^2_{h|top} = -\frac{3G_F}{2\sqrt{2}\pi^2} m_t^2 \Lambda^2 \sim -(0.2\Lambda)^2$$

This hierarchy problem demands new physics near the weak scale

$\Lambda \sim o(1\text{TeV})$

Λ: scale of new physics beyond the SM

- $\Lambda >> m_Z$: the SM is so good at LEP
- $\Lambda \sim$ few times $G_F^{-1/2} \sim o(1\text{TeV})$ for a natural explanation of m_h or m_W

Barbieri, Strumia

The LEP Paradox: m_h light, new physics must be close but its effects were not visible at LEP2

The B-factory Paradox: and not visible in flavour physics

Precision Flavour Physics

Another area where the SM is good, too good.....

With new physics at ~ TeV one would expect
the SM suppression of FCNC and the CKM
mechanism for CP violation to be sizably modified.

But this is not the case

an intriguing mystery and a major challenge for models of
new physics

Solutions to the hierarchy problem

- Supersymmetry: boson-fermion symm.

  exact (unrealistic): cancellation of Λ^2 in δm_h^2

  approximate (possible): $\Lambda \sim m_{SUSY}-m_{ord}$ → top loop $\Lambda \sim m_{stop}$

  The most widely accepted

- The Higgs is a $\bar{\psi}\psi$ condensate. No fund. scalars. But needs new very strong binding force: $\Lambda_{new} \sim 10^3 \Lambda_{QCD}$ (technicolor).

  Strongly disfavoured by LEP. Coming back in new forms

- Models where extra symmetries allow m_h only at 2 loops and non pert. regime starts at $\Lambda \sim 10$ TeV

  "Little Higgs" models. Some extra trick needed to solve problems with EW precision tests

- Extra spacetime dim's that "bring" M_{Pl} down to o(1TeV)

  Exciting. Many facets. Rich potentiality. No baseline model emerged so far

- Ignore the problem: invoke the anthropic principle

A crucial question for the LHC

What damps the top loop Λ^2 dependence?

- the s-top (SUSY)
- some new fermion

  t′ (Little Higgs)

  KK recurrences of the top (Extra dim.)

  ......

- nothing dumps it and we accept the ever increasing fine tuning

A striking result of the 2011 LHC run (> 1 fb^{-1})
is that the new physics is pushed further away

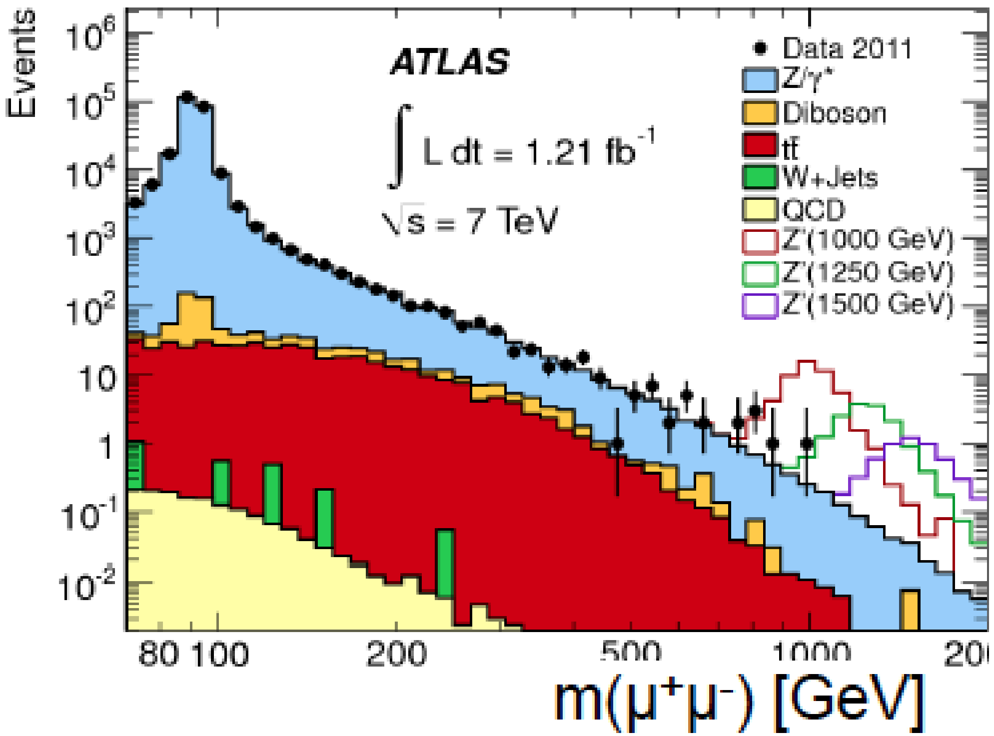
Examples:

sequential W′: $m_{W'} > 2.3$ TeV
sequential Z′: $m_{Z'} > 1.9$ TeV
axi-gluon: 2.5-3.2 TeV
gluino: $m_g > \sim 0.5 - 1$ TeV

Many generic signatures searched.
Not a single significant hint of new physics found

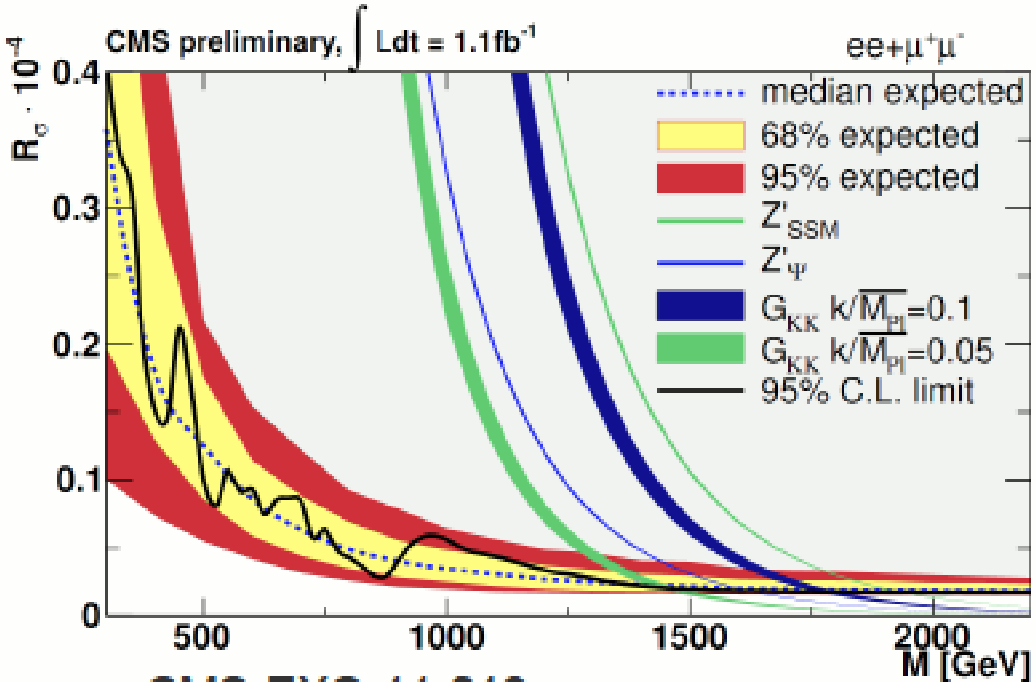
talk by H. Bachacou
LP′11 Mumbai

Di-lepton Channel



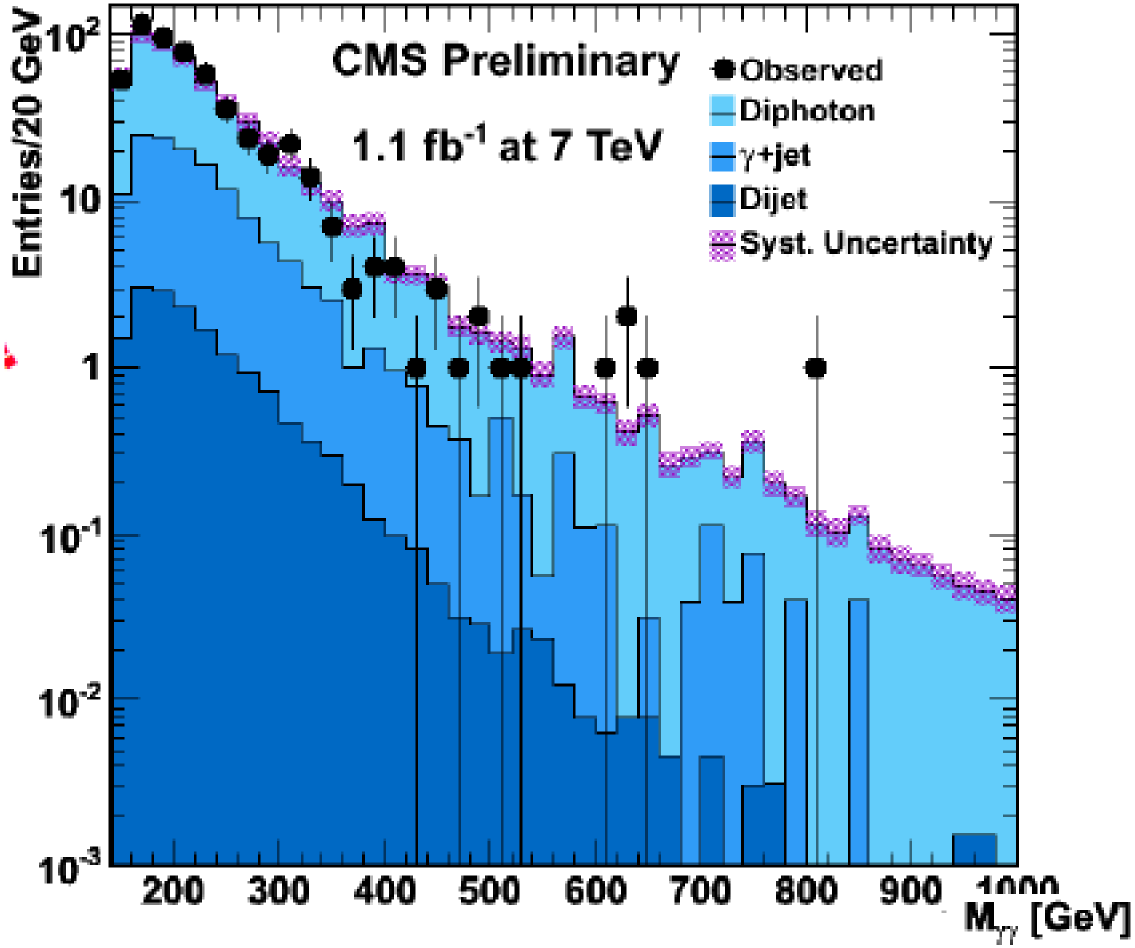
Sequential SM:
m(Z') > 1.9 TeV at 95% C.L.

RS graviton (k/M_{Pl} = 0.1):
m(G) > 1.8 TeV at 95% C.L.



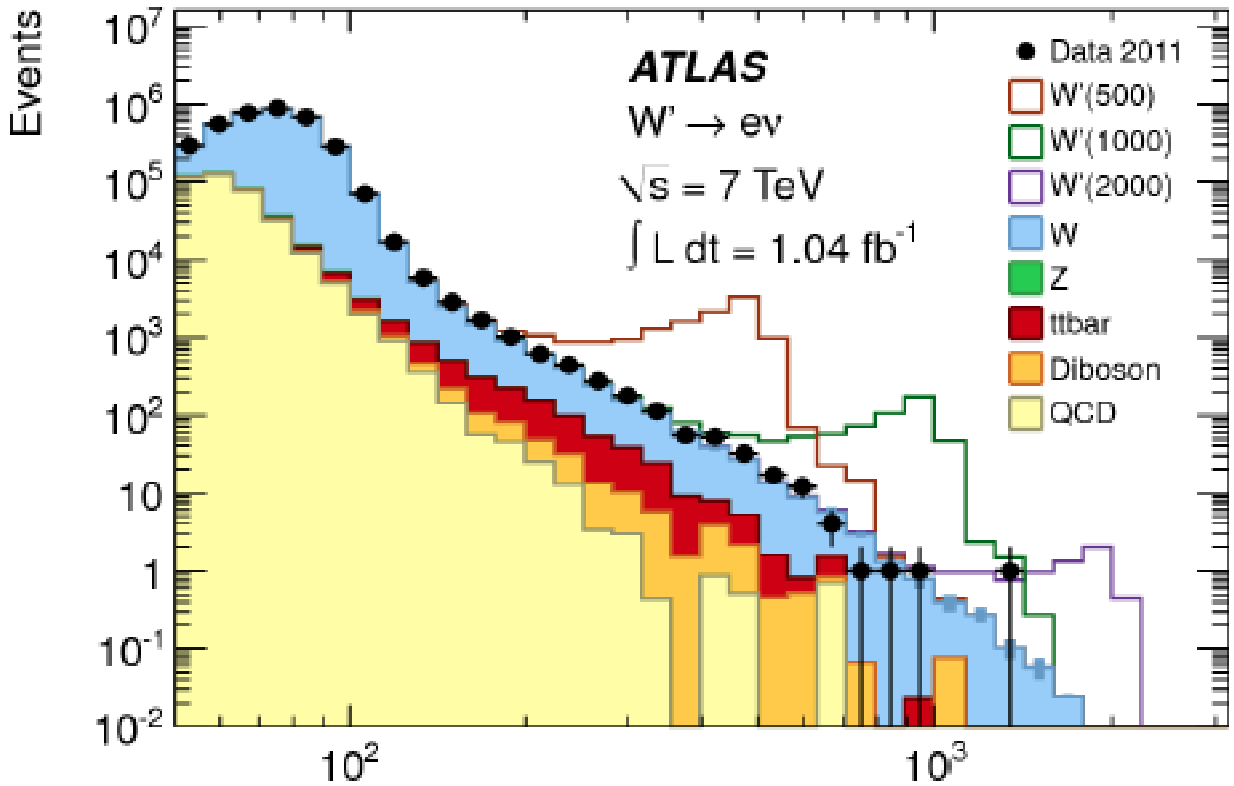
Di-photon Channel

RS graviton (k/MPl = 0.1): m(G) > 1.7 TeV at 95% C.L.



W′ -> l ν

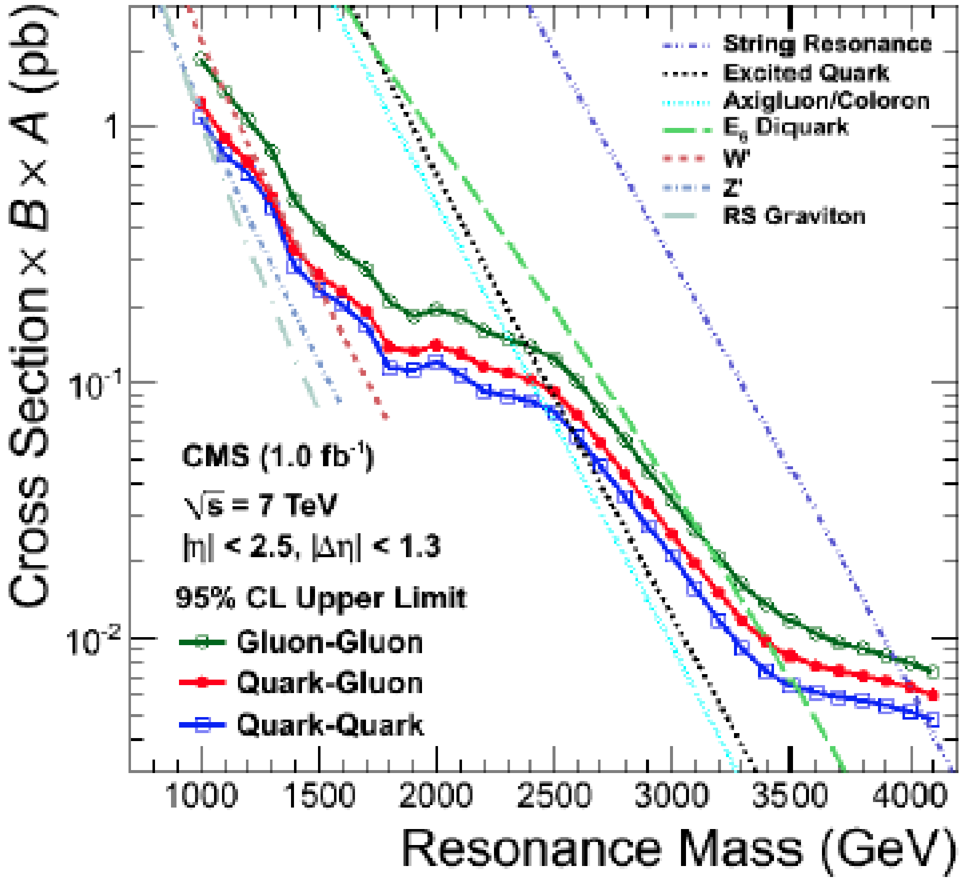
Sequential SM:
m(W') > 2.3 TeV at 95% C.L.



Dijet

Model ATL-CONF-2011-095	95% CL Limits (TeV) Expected	 Observed
Excited Quark q^*	2.77	2.91
Axigluon	3.02	3.21
Color Octet Scalar	1.71	1.91

Model CMS arXiv.1107.4771	Excluded Mass (TeV) Observed	 Expected
String Resonances	4.00	3.90
E_6 Diquarks	3.52	3.28
Excited Quarks	2.49	2.68
Axigluons/Colorons	2.47	2.66
W′ Bosons	1.51	1.40



SUSY: boson fermion symmetry

The hierarchy problem: $$\delta m^2_{h|top} = -\frac{3G_F}{2\sqrt{2}\pi^2} m_t^2 \Lambda^2 \sim -(0.2\Lambda)^2$$

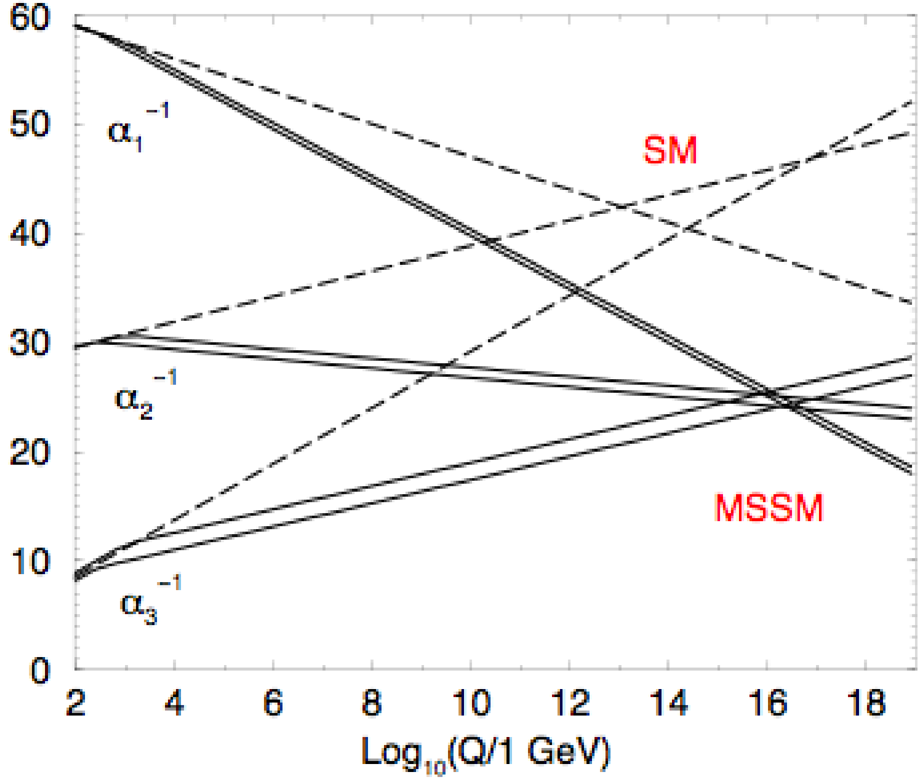
In broken SUSY Λ^2 is replaced by $(m_{stop}{}^2 - m_t{}^2)\log\Lambda$

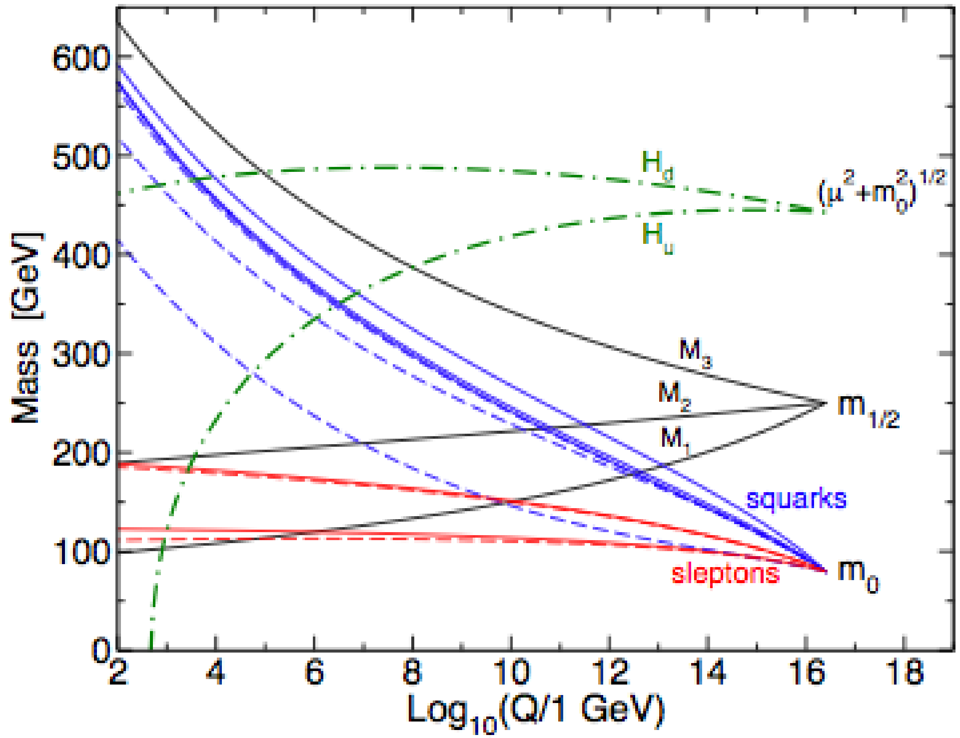
m_H>114.4 GeV, $m_{\chi+}$ >100 GeV, EW precision tests, success of CKM, absence of FCNC, all together, impose sizable Fine Tuning (FT) particularly on minimal realizations (MSSM, CMSSM…).

Yet SUSY is a completely specified, consistent, computable model, perturbative up to M_{Pl} quantitatively in agreement with coupling unification (GUT's)
(unique among NP models)
and has a good DM candidate: the neutralino (actually more than one).

⊕ Remains the reference model for NP

Beyond the SM SUSY is unique in providing a perturbative theory up to the GUT/Planck scale

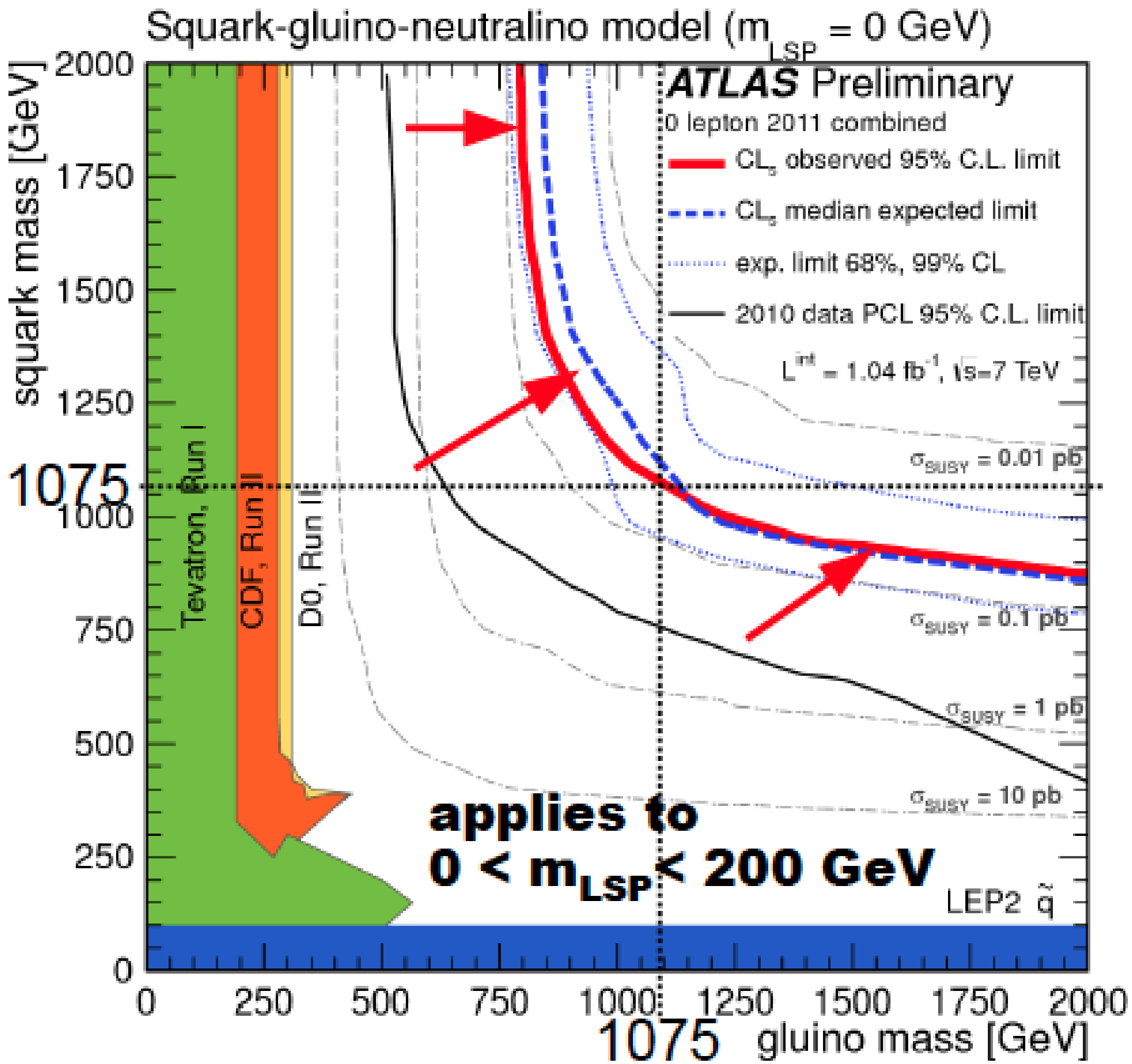


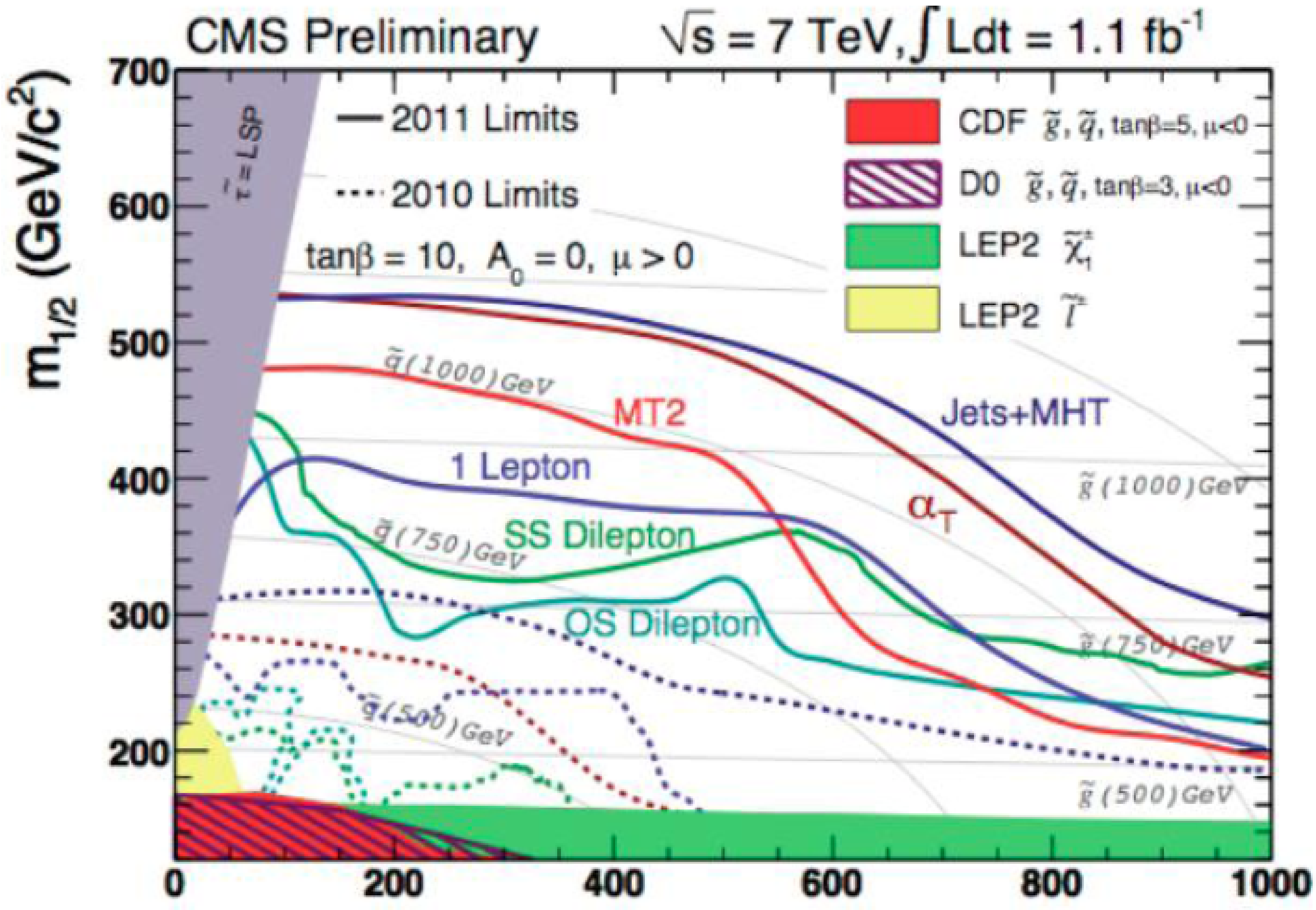


Other BSM models (little Higgs, composite Higgs, Higgsless....) all become strongly interacting and non perturbative at a multi-TeV scale

Jets + missing E_T

CMSSM (degenerate s-quarks)





Here also lepton(s)+jets+missing E_T

The MSSM has > 100 parameters

Simplified versions with a drastic reduction of parameters are used for practical reasons, e.g.

CMSSM: universal gaugino and scalar soft terms at GUT scale
5 parameters

NUHM1,2: different masses for the Higgs than for other scalars
6,7 parameters

mSUGRA: minimal supergravity model, 3 parameters

It is only these oversimplified models that are now in trouble

Input data for fits of CMSSM, NUHM1...... include

- The EW precision tests
- Muon g-2
- Flavour precision observables
- Dark Matter
- Higgs mass constraints and LHC

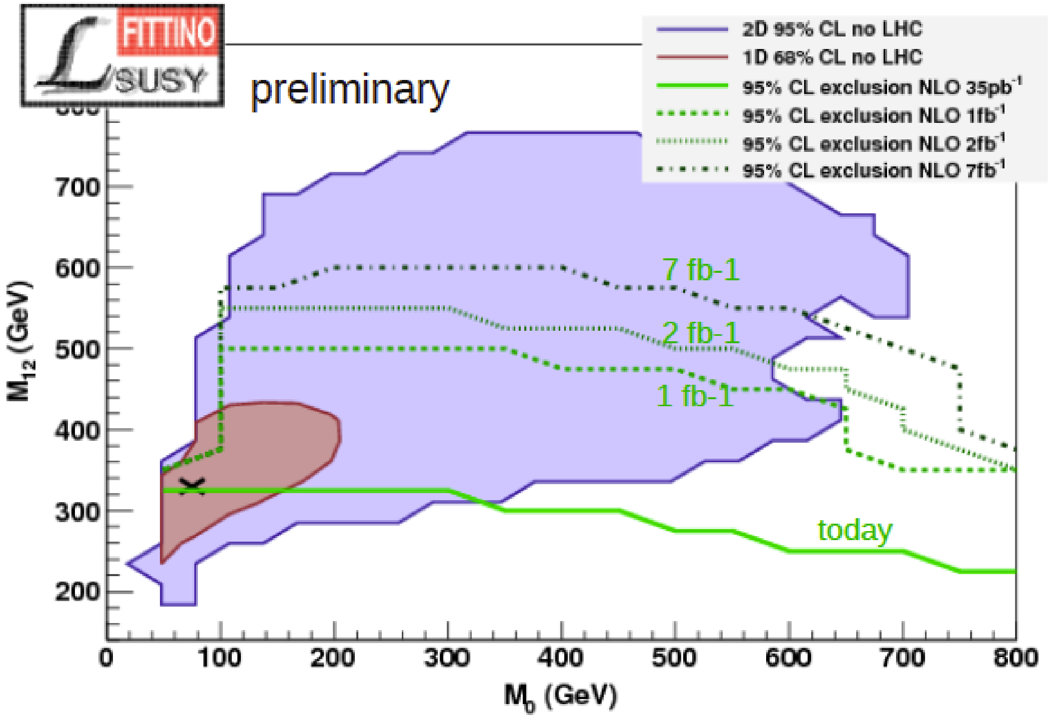
Tools to fit the data to the CMSSM

Lafaye et al

Bechtle et al

Buchmuller et al

The best fit to the data
wants light SUSY.
But the LHC
now excludes it

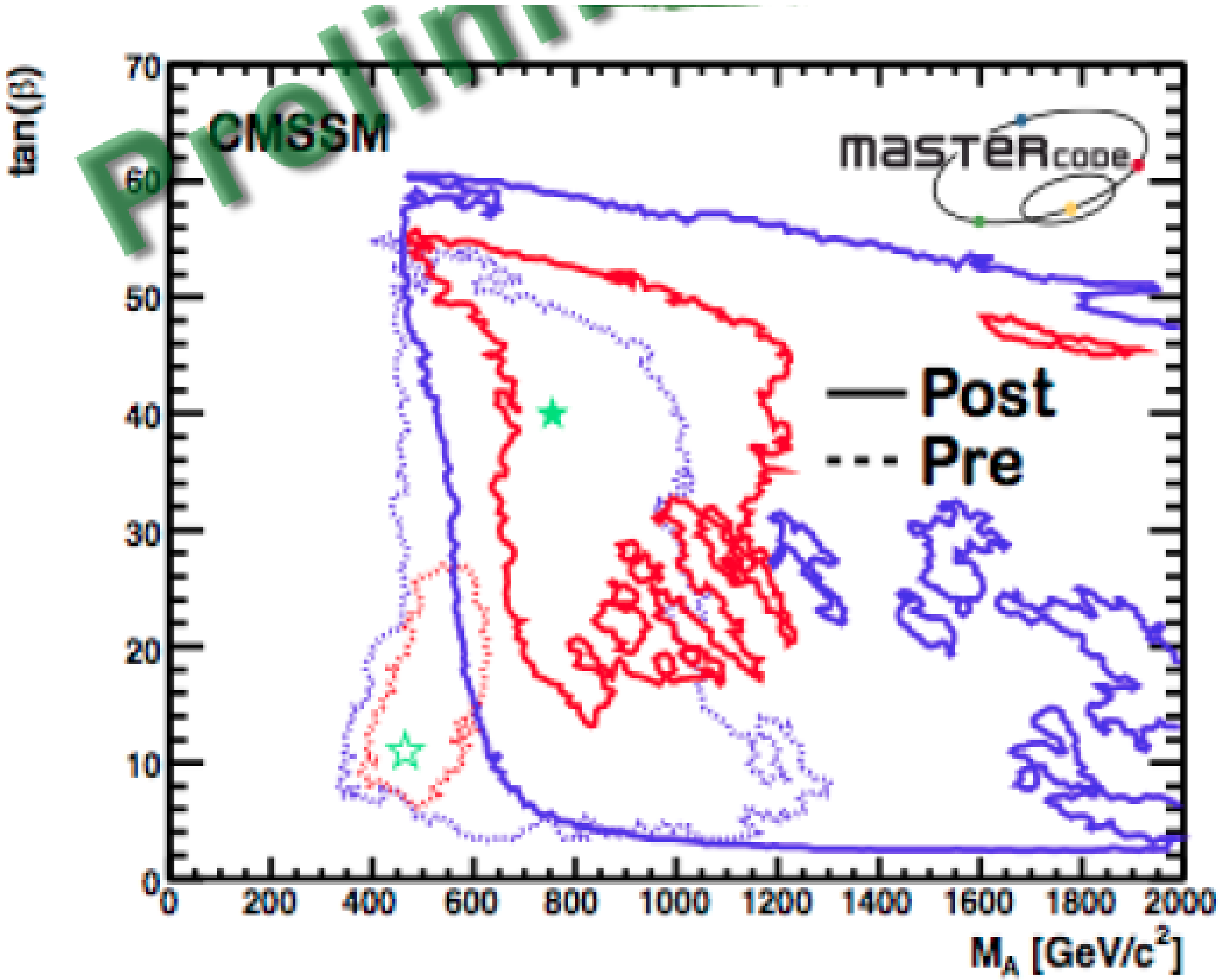


The CMSSM is increasingly disfavoured

Tension between $(g\text{-}2)_\mu$ and LHC

J. Ellis

LHC pushes best fit to larger masses, then $(g\text{-}2)_\mu$ demands larger $\tan\beta$

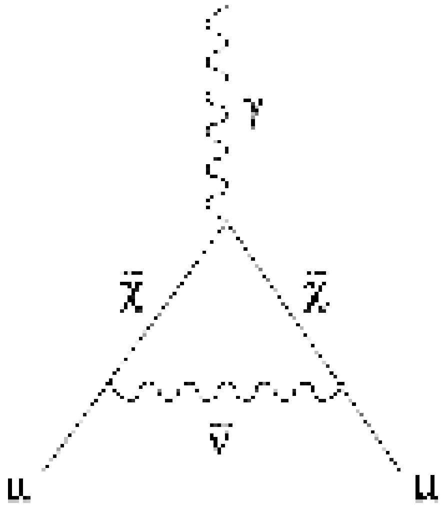


CMSSM

Muon g-2

a_μ is a plausible location for a new physics signal!!

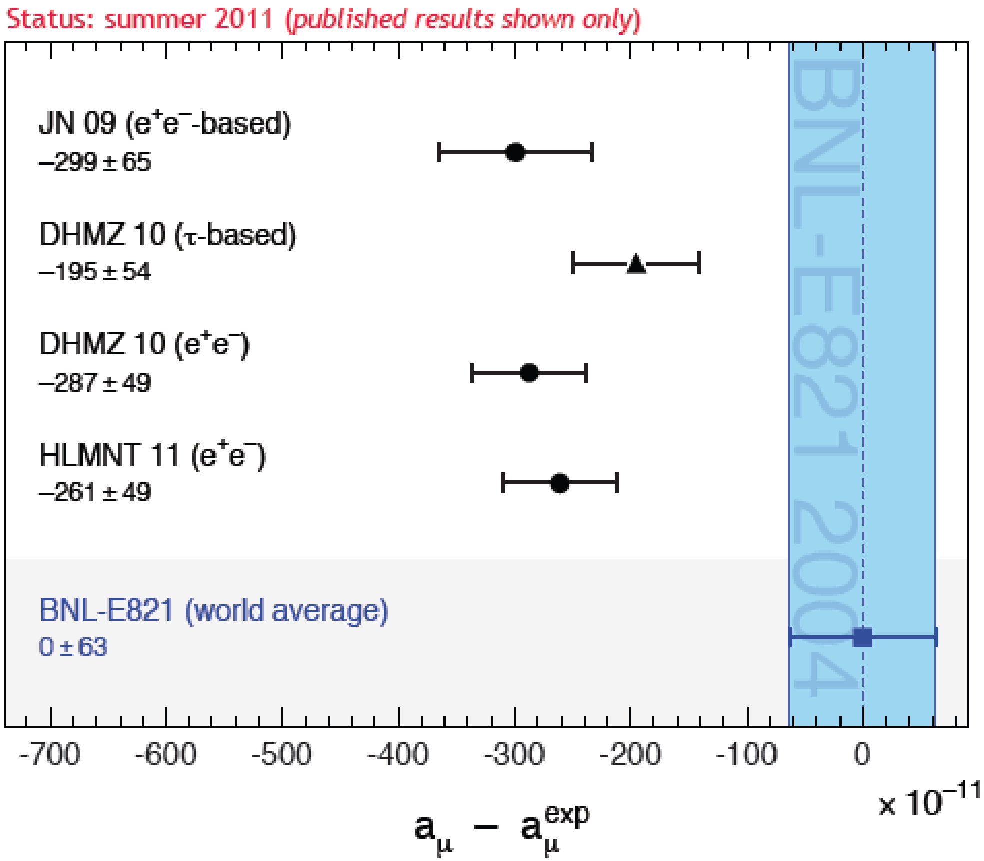
eg could be light SUSY



$$a_\mu^{exp} - a_\mu^{SM} = (28.7 \pm 8.0) \times 10^{-10}$$

- 3.6 "standard deviations" (e^+e^-)
- 2.4 "standard deviations" (τ)

$$\delta a_\mu = 13 \cdot 10^{-10} \left(\frac{100 GeV}{M_{SUSY}} \right)^2 tg\beta$$

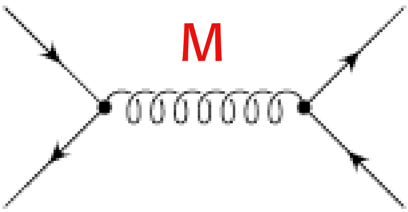


A lot of fine-tuning is imposed on us when our present theory is confronted with the data

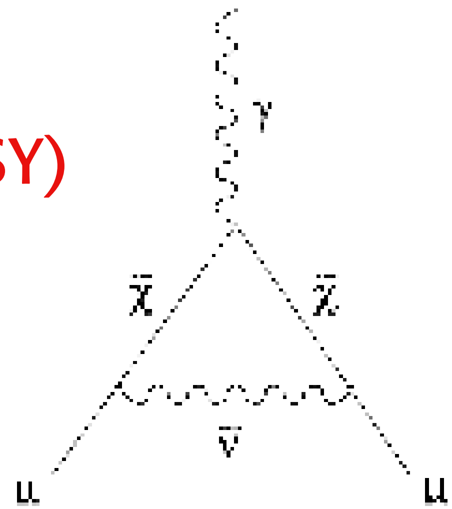
For naturalness we need new physics at ~ 1 TeV but we see no clear deviations in EW Precision Tests and in Flavour Physics and now at the LHC

Strong constraints on model building

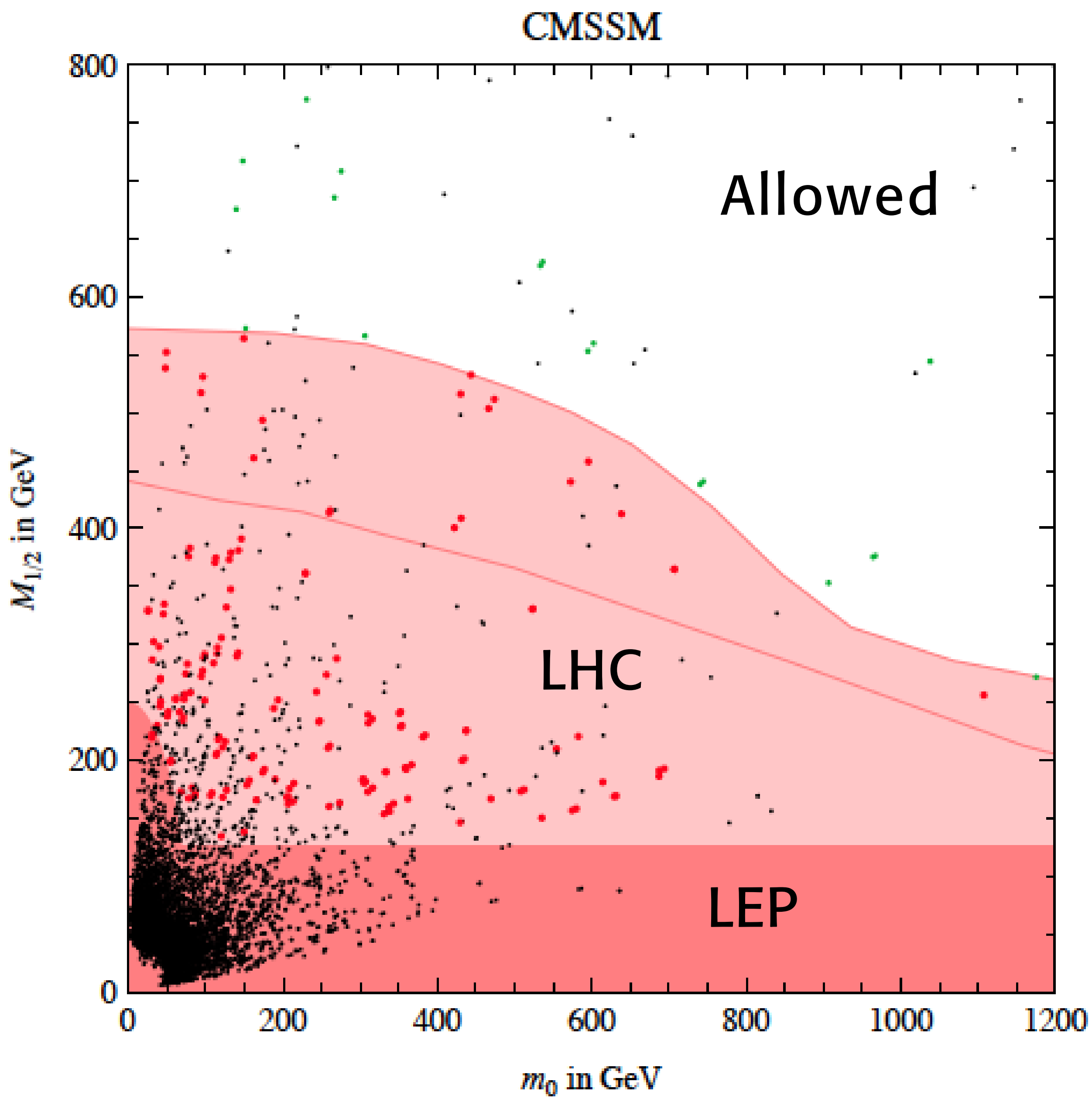
Typical tree level NP effects too large



Avoided by R-parity (SUSY)
T-parity (Little Higgs) etc



Loop effects preferred


CMSSM
Allowed
LHC
LEP
$M_{1/2}$ in GeV
m_0 in GeV
0
200
400
600
800
1000
1200

Strumia

SUSY

With new data ever increasing fine tuning

Complicating SUSY beyond the CMSSM (now disfavoured)

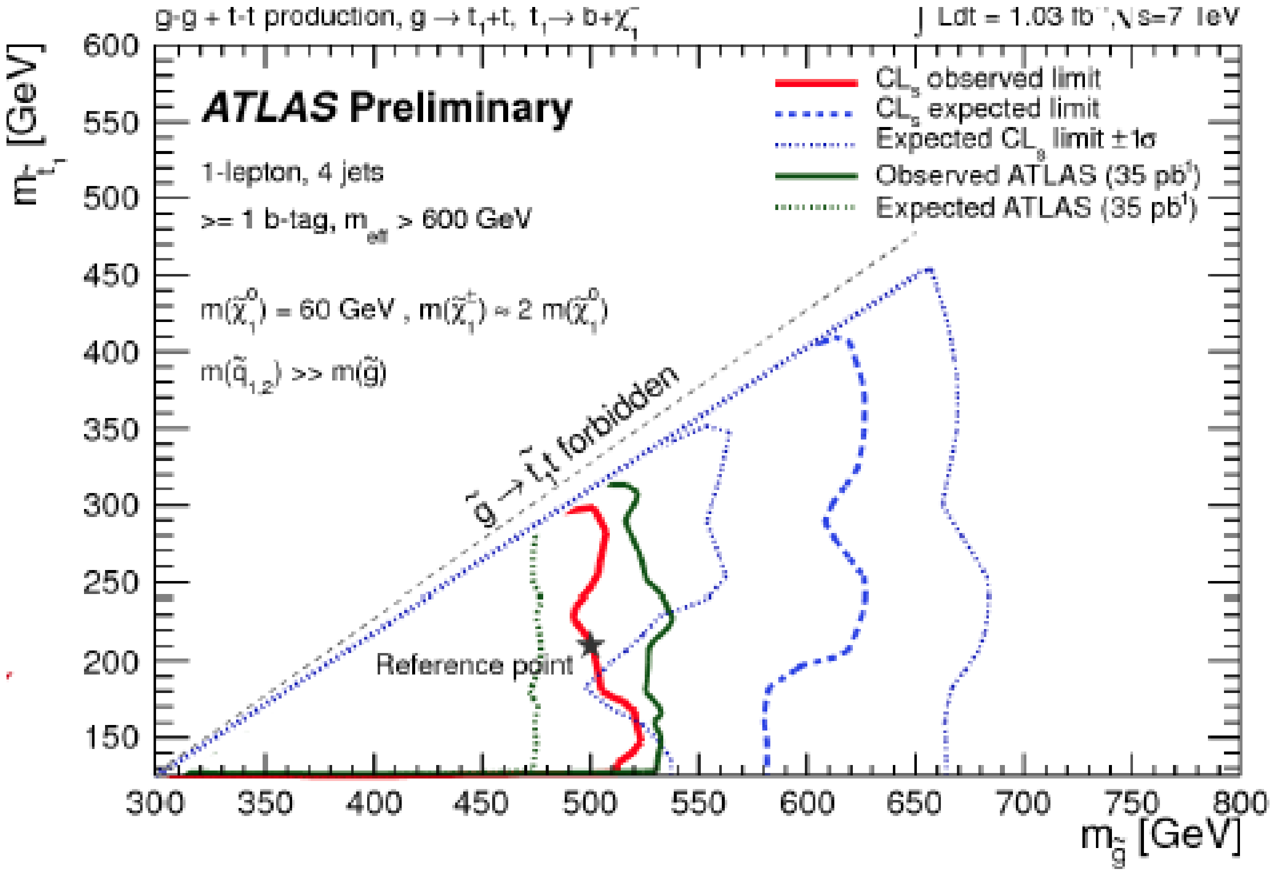
There is still room for non minimal versions

- Heavy first 2 generations
- NMSSM
- Split SUSY
- More global symmetry
- More interactions
- ...

For example, may be gluinos decay into 3-gen squarks

e.g. $\tilde{g} \rightarrow \tilde{t}_1 t$; $\tilde{t}_1 \rightarrow b\tilde{\chi}_1^{\pm}$

and $\tilde{\chi}_1^{\pm} \rightarrow W^* \, \tilde{\chi}_1^0$



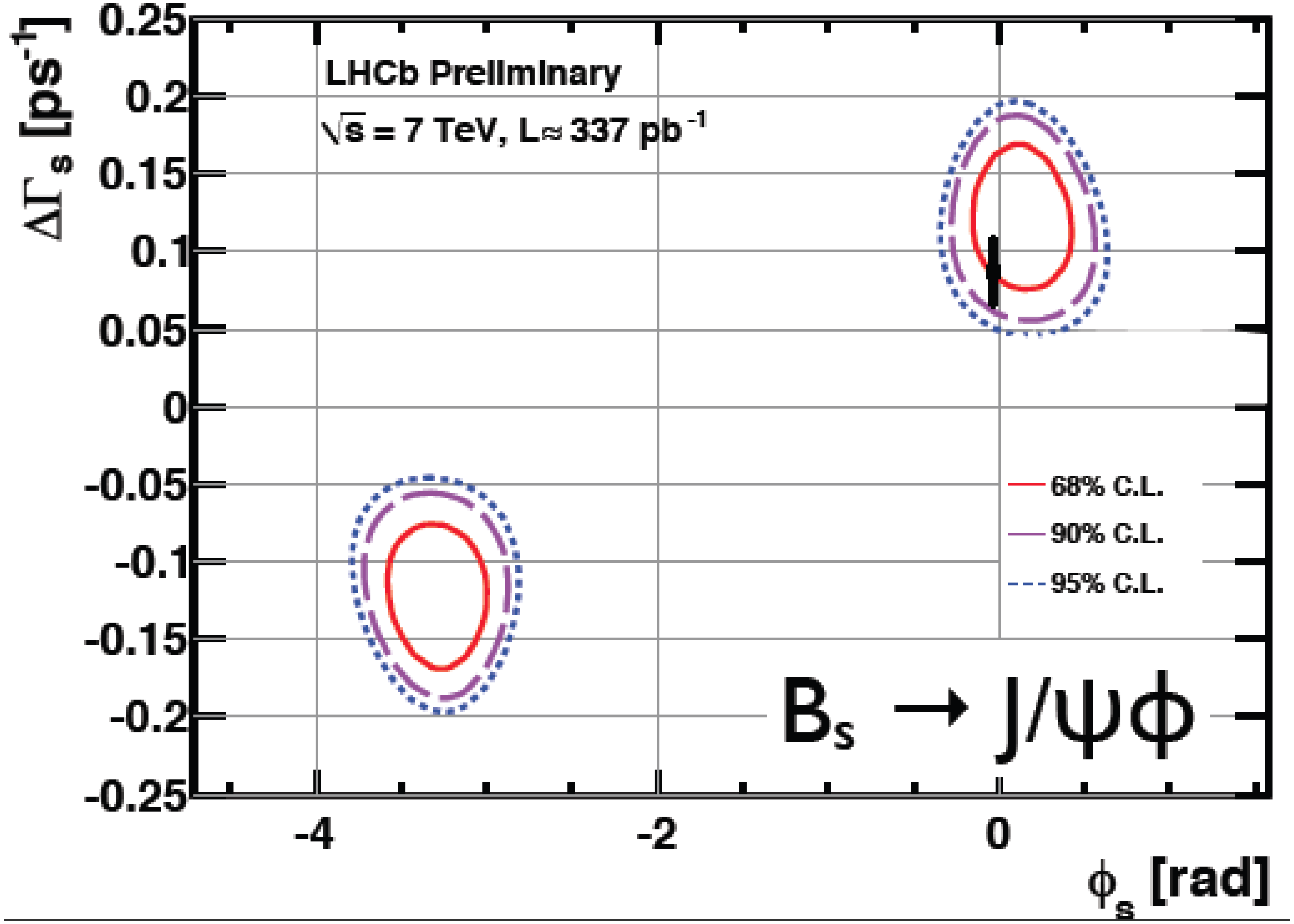
m(gluino) > 500 GeV at 95% C.L.

LHC and flavour physics

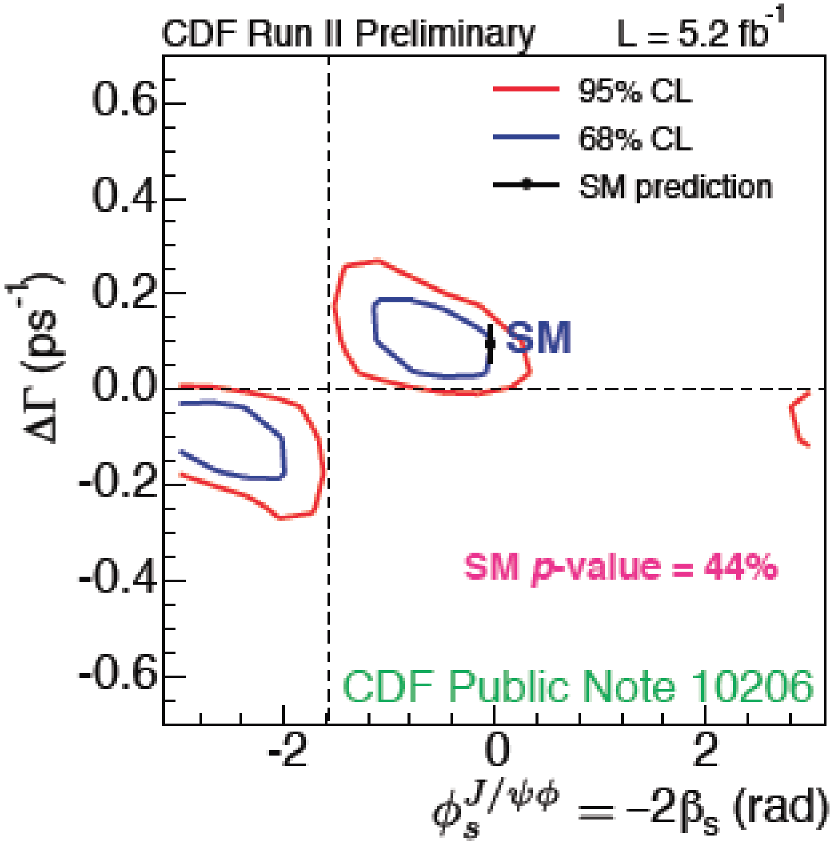
Important results from LHCb

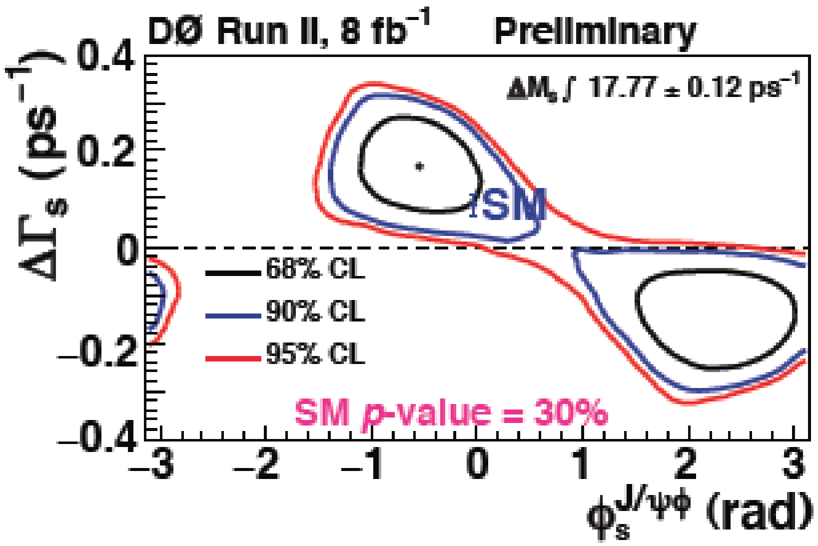
New at LP'11 $B_s \to J/\psi\varphi$:

Back into agreement with SM



Now also the Tevatron data are back into order



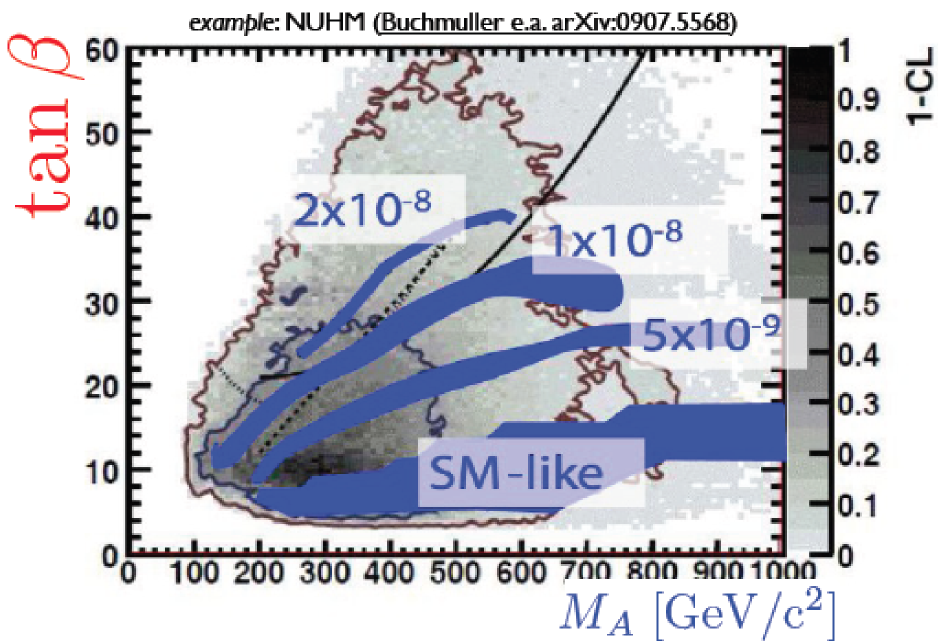


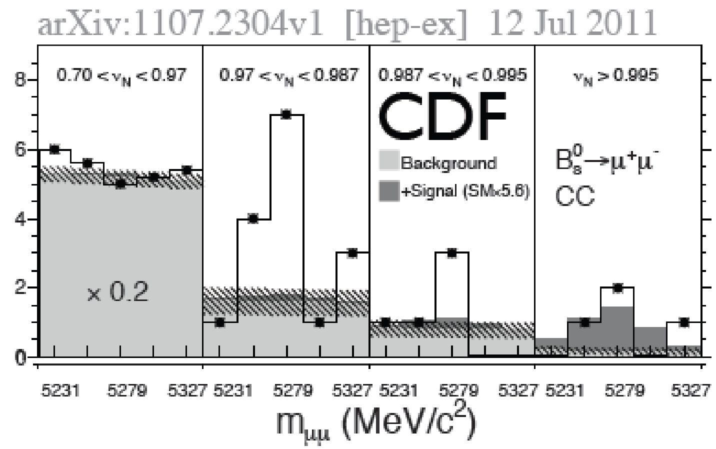
b→s: $B_s \to \mu\mu$

Raven LP'11

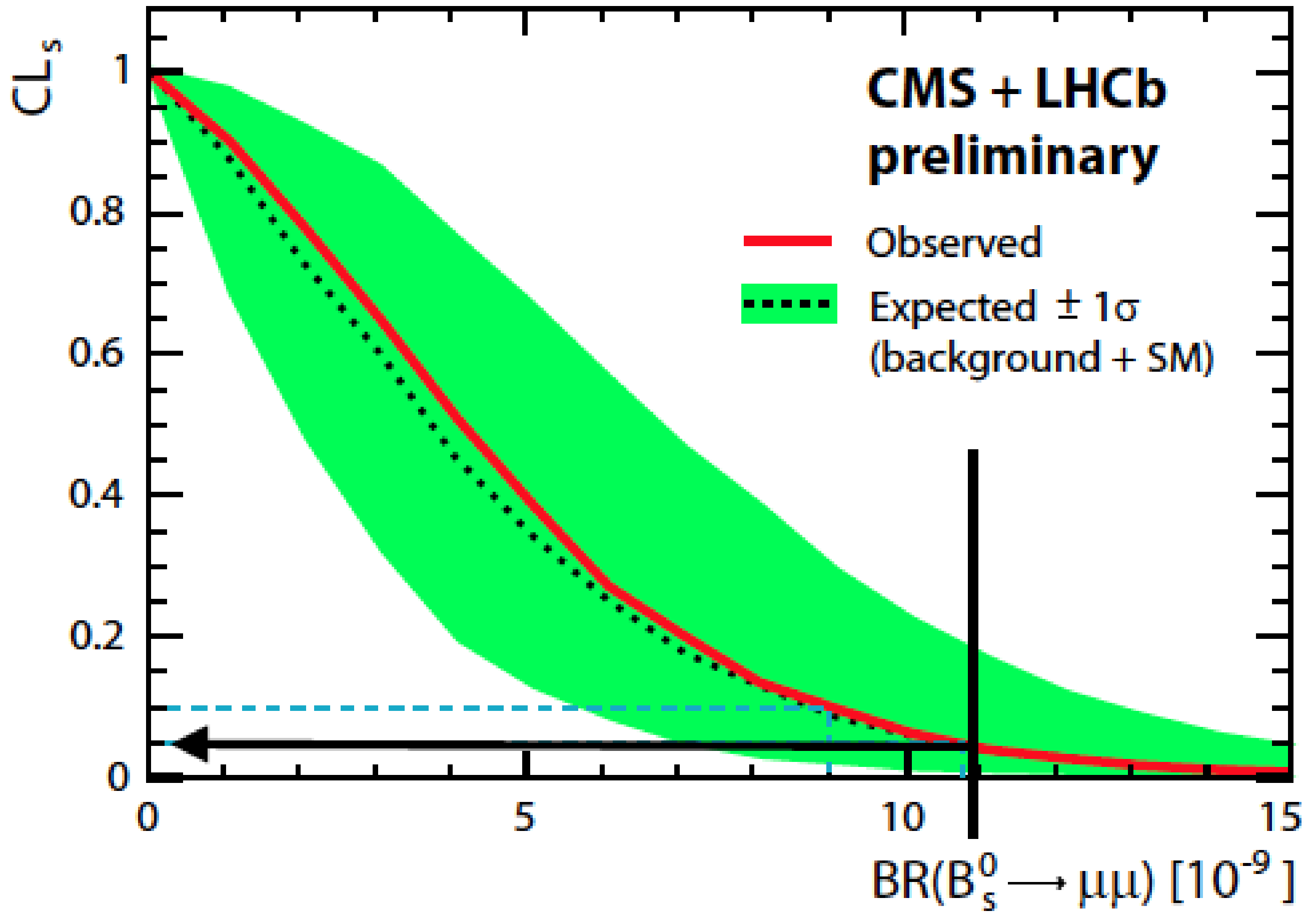
Buras et al: arXiv 1007.5291

- Predicted to be very rare in the SM due to GIM & helicity suppression:
  - $\mathrm{Br}_{SM}(B_s \to \mu\mu) = (3.2 \pm 0.2) \times 10^{-9}$
- Large sensitivity to NP, eg SUSY:
  - $\mathrm{Br}_{\mathrm{MSSM}}(B_q \to \ell^+\ell^-) \propto \frac{M_b^2 M_\ell^2 \tan^6\beta}{M_A^4}$
- Good place for synergy with direct searches
- CDF recently reported a hint of signal:
  - p-value background only: 0.3%
  - p-value background + SM Br: 1.9%
  - $\mathrm{Br}_{CDF}(B_s \to \mu\mu) = 1.8^{+1.1}_{-0.9} \times 10^{-8}$





CMS & LHCb combined (presented at EPS'11 Grenoble)

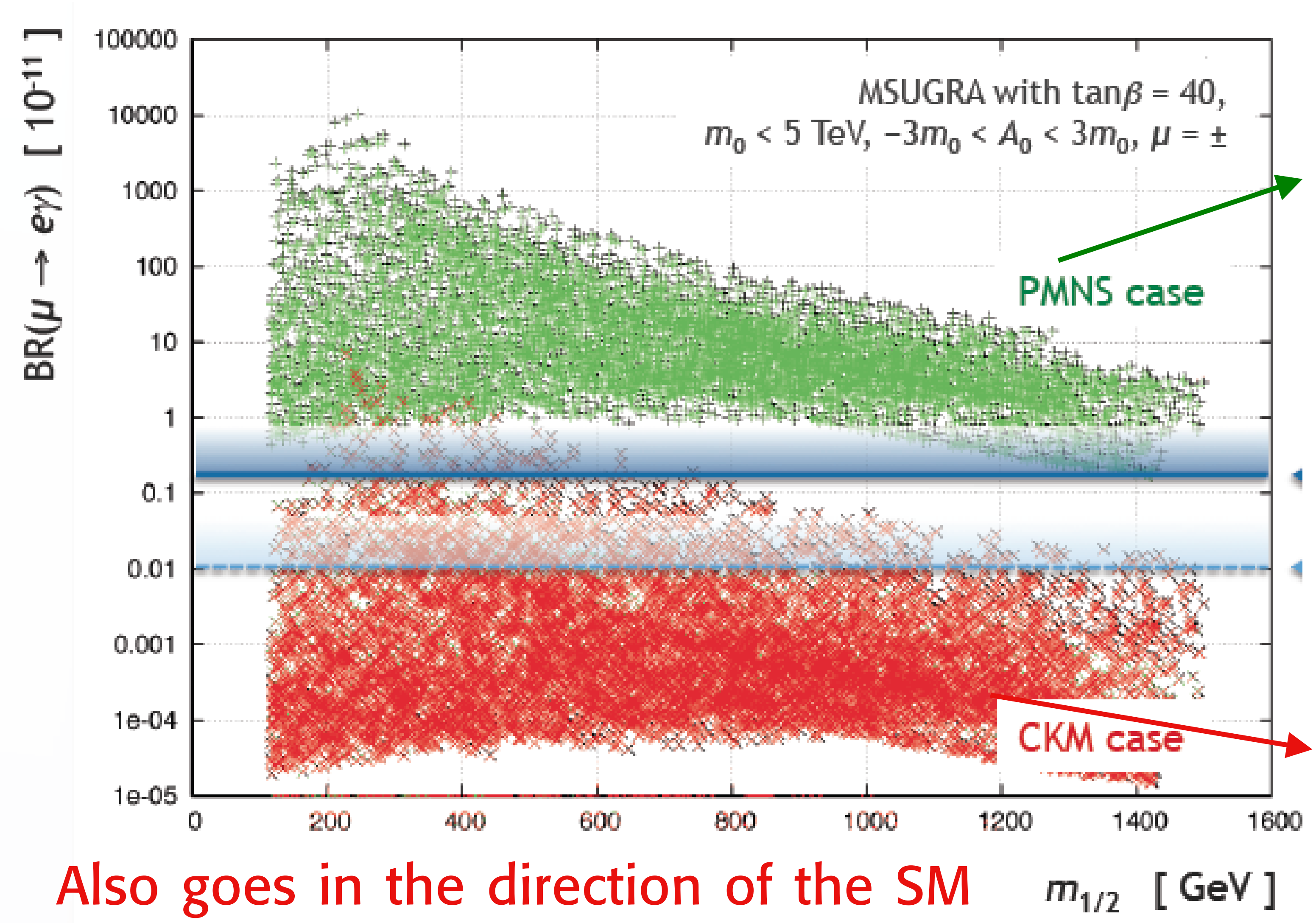


cfr
CDF 18+11-9 10^{-9}
SM 3.2±0.2 10^{-9}

$< 11 \times 10^{-9}$ @ 95% CL

A non-LHC very important result

MEG new limit on Br(μ -> e γ) < 2.4 10^{-12}



Also goes in the direction of the SM

LHC scenarios

Catastrophic: No Higgs, no new physics

Can only occur if the LHC is not enough to fully probe the EW scale: unitarity violations impose one or the other (eg new vector bosons) or both

Theorist projection: non standard Higgs and new physics

A lot of model building in this direction

Pure SM: A light scalar Higgs, no new physics at the EW scale

If so, nature does not abhor fine tuning at all

This is the paradigm that experiment must try to falsify

An enlarged SM remains an (enormously fine tuned) option

A light Higgs

SO(10) non SUSY GUT

SO(10) breaking down to $SU(4) x SU(2)_L x SU(2)_R$ at an intermediate scale

Majorana neutrinos and see-saw (-> $0\nu\beta\beta$)

Axions as dark matter

Baryogenesis thru leptogenesis

(but: $(g\text{-}2)_\mu$ and other present deviations from SM should disappear)

Some NP hints from accelerator experiments

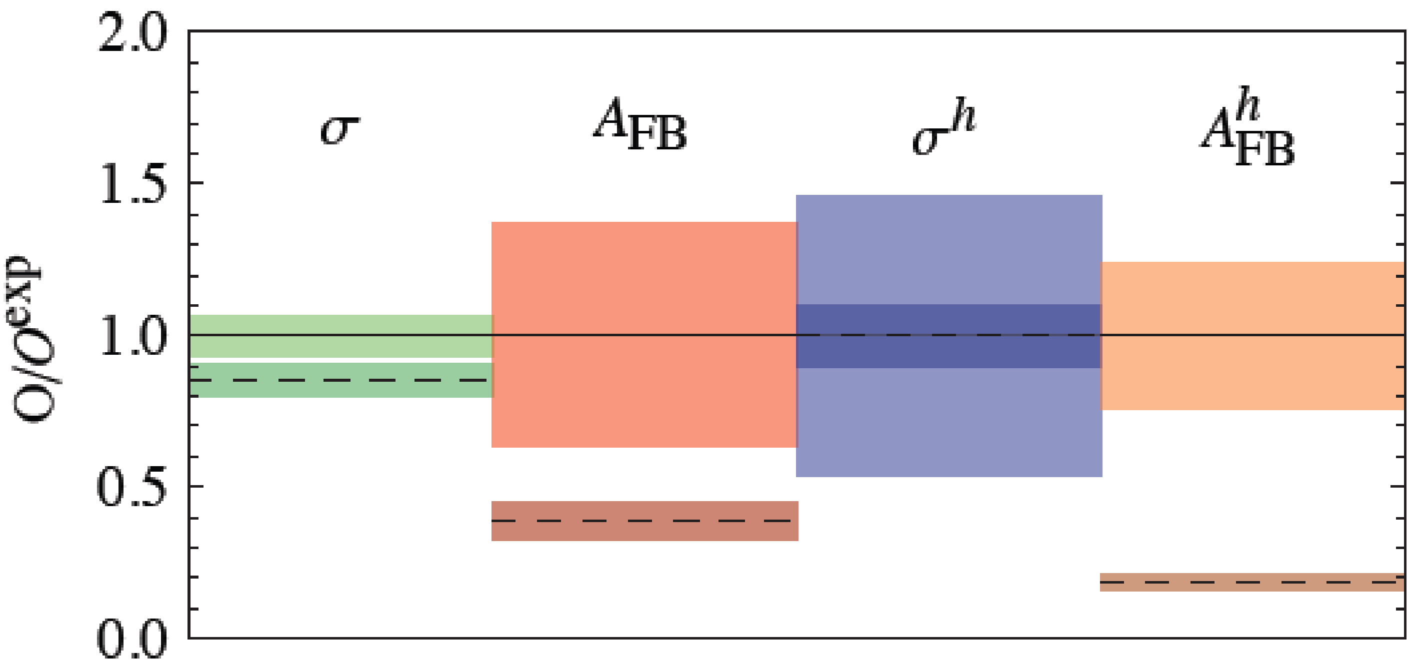
A^{b}_{FB}	LEP	$\sim 3\sigma$
$(g-2)_{\mu}$	Brookhaven	$\sim 3\sigma$
tt^{bar} FB asymmetry	Tevatron (mostly CDF)	$\sim 3\sigma$ at large M_{tt}
Dimuon charge asymmetry	D0	$\sim 3.9\sigma$
Wjj excess at $M_{jj} \sim$ 144 GeV only candidate to open prod. of NP	CDF	$\sim 3.2\sigma$ not confirmed by D0, LHC
$B_s \to J/\psi\phi$	Tevatron, LHCb	~went away
$B \to \tau\nu$	BaBar, Belle	$\sim 2.5\sigma$

•••••••

Forward-backward asymmetry in $t\bar{t}$ production

see also talk by [cut off]

- Measurements at the Tevatron



Kidonakis

Ahrens et al

also: $0.42 \pm 0.15 \pm 0.05 \quad 2\ell$

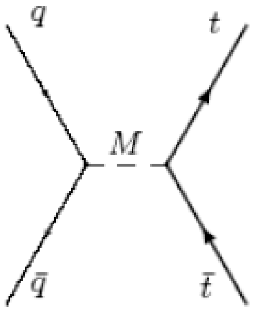
$$\sigma = (7.50 \pm 0.48)\,\mathrm{pb} \qquad A_{FB} = 0.158 \pm 0.074$$

$$\sigma^h = (80 \pm 37)\,\mathrm{fb} \qquad A^h_{FB} = 0.475 \pm 0.114$$

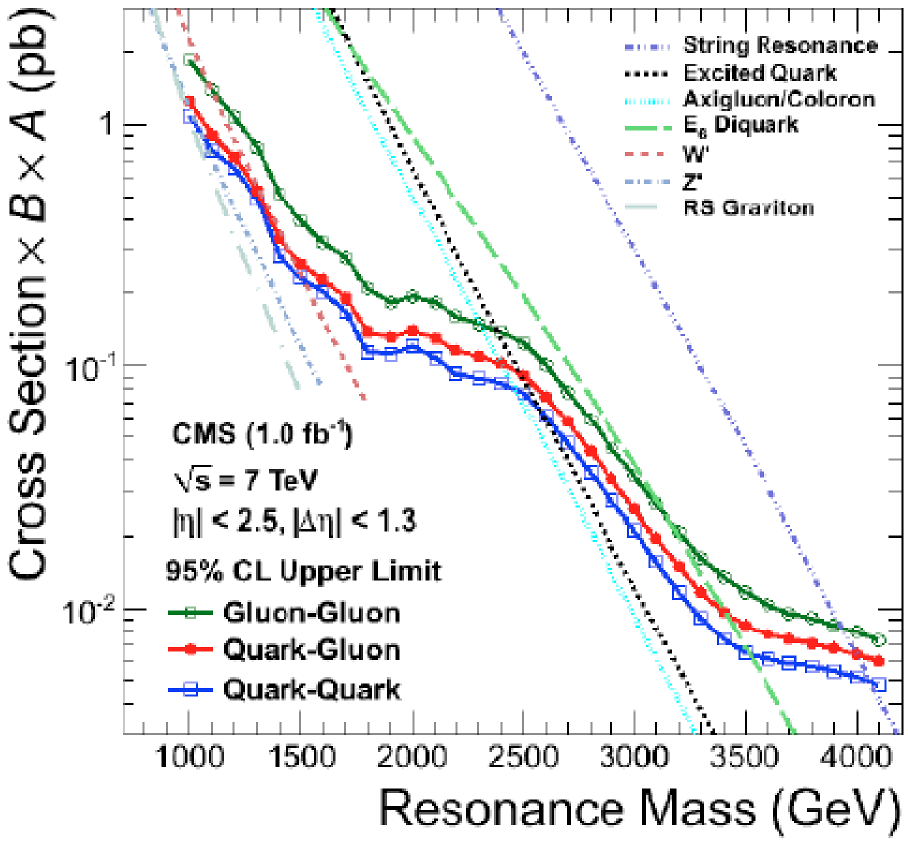
Other me[cut off]
CDF
DØ Note

CDF

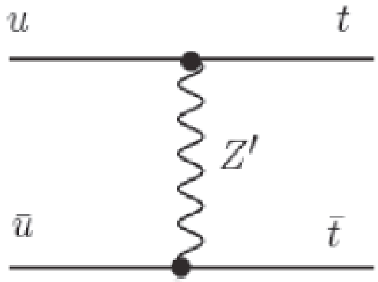
s-channel



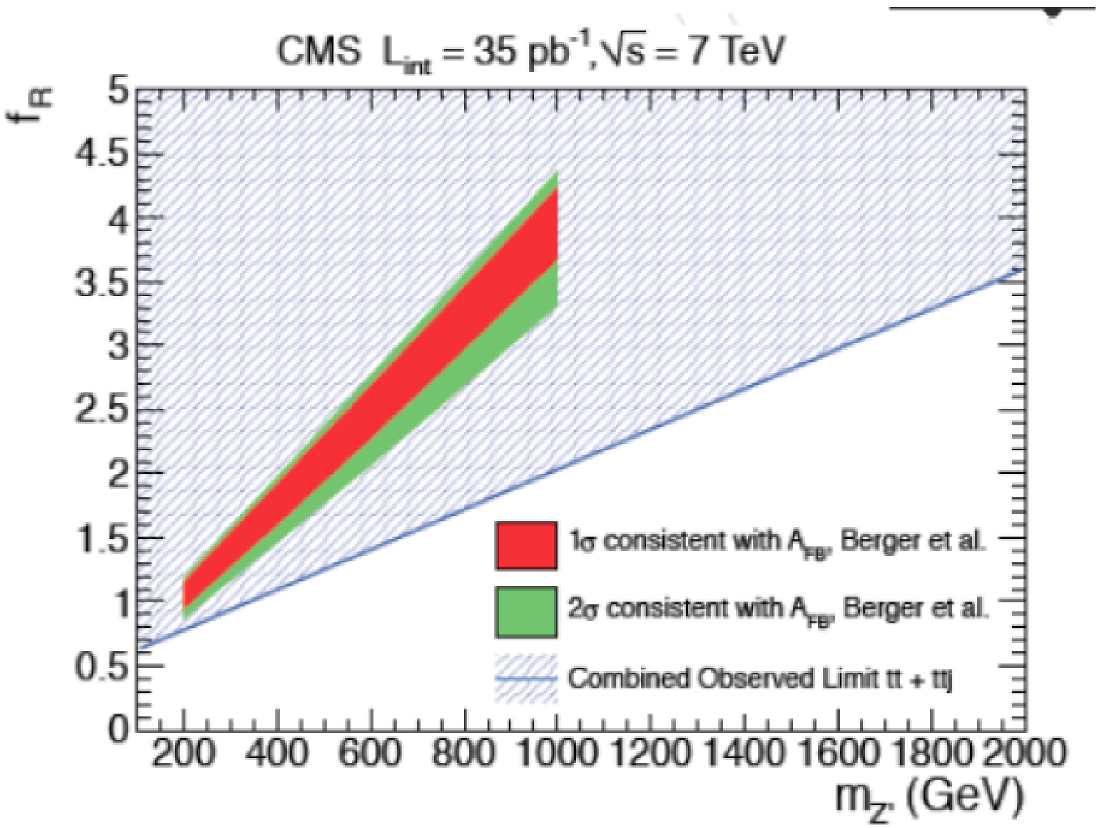
But no axigluon
or octect scalar seen



t-channel

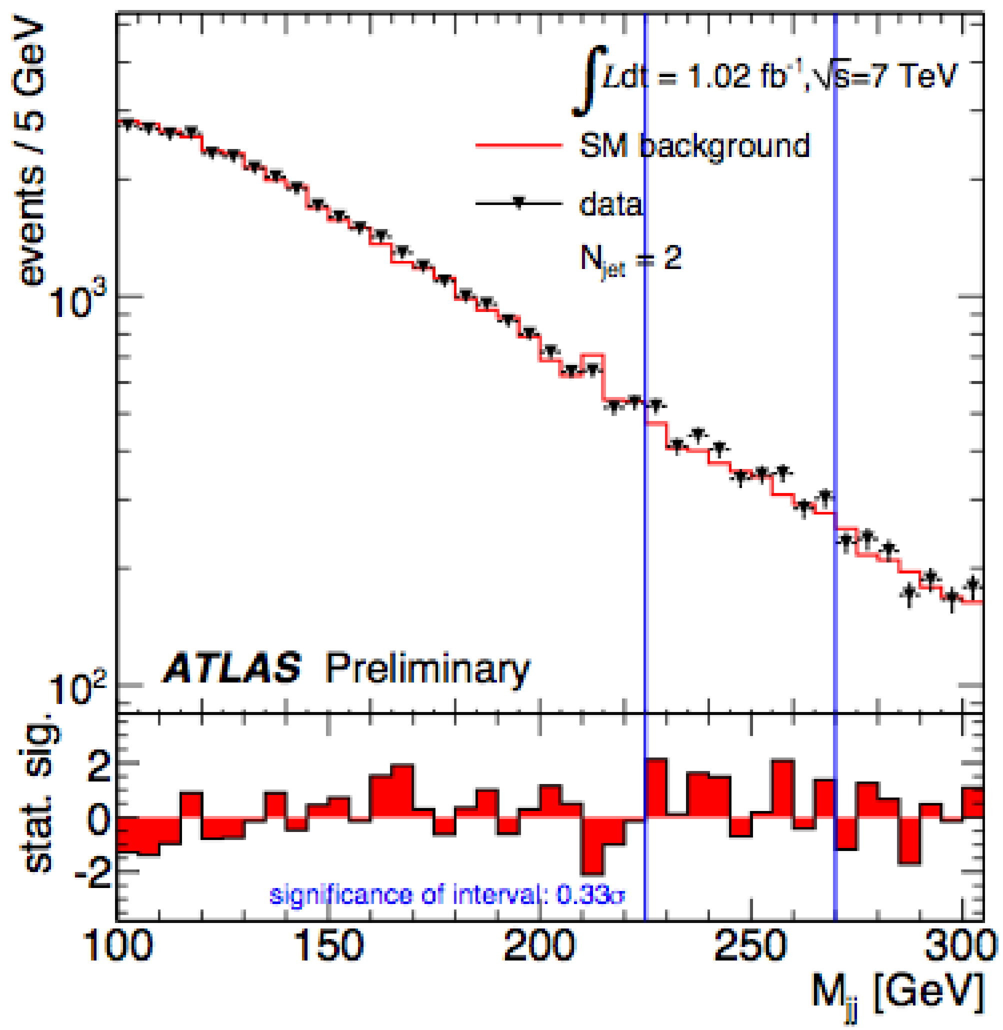


FC u-t-Z' couplings
constrained by LHC



Wjj

The CDF
Wjj excess at
M_{jj} ~ 144 GeV
is not seen
at the LHC

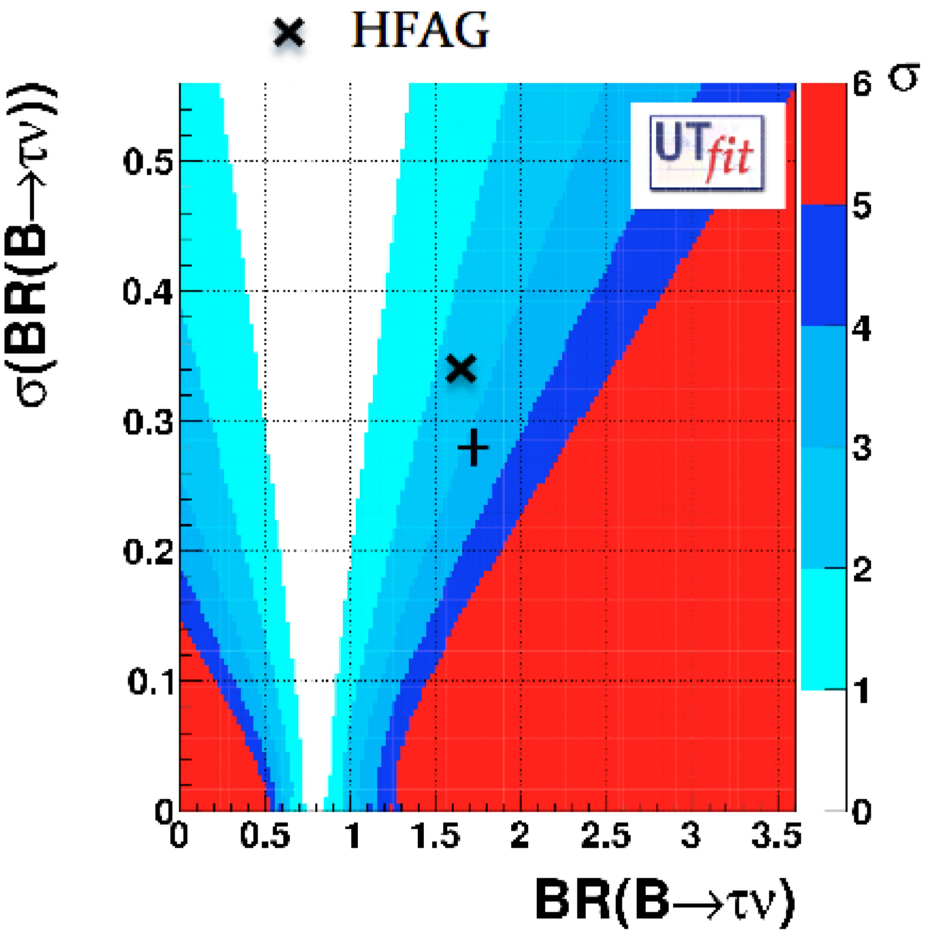


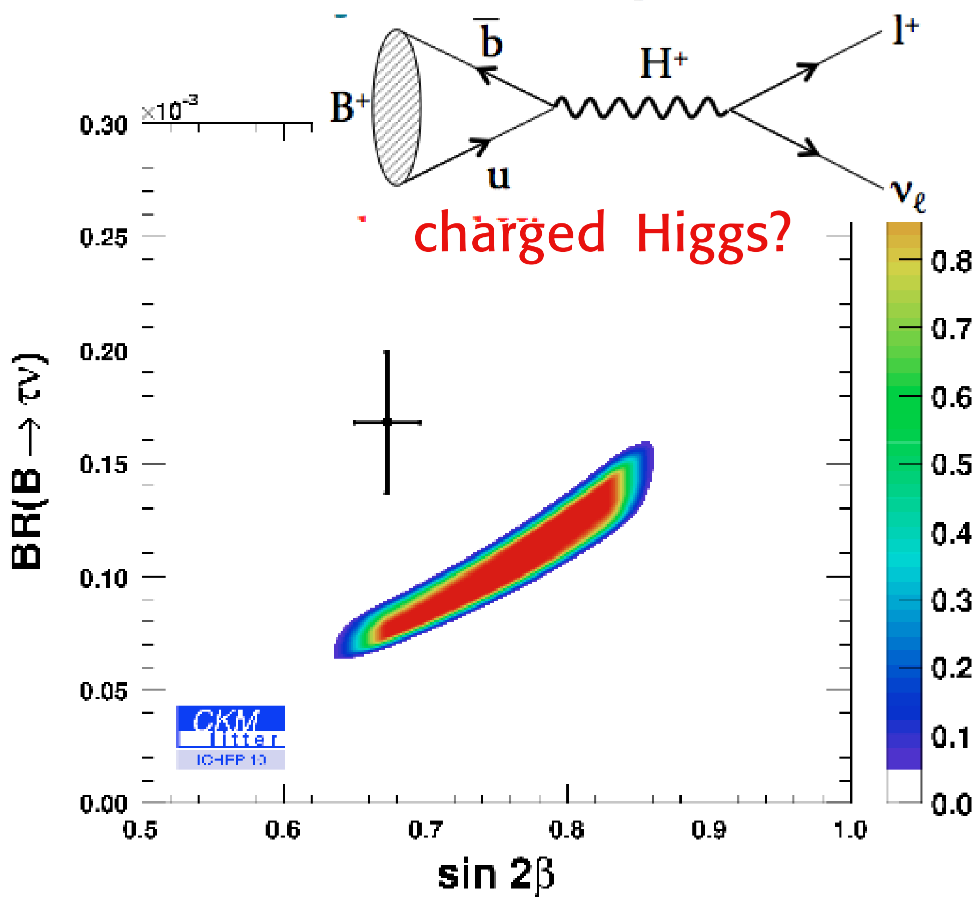
ATLAS:

The measured dijet mass spectrum shows
no significant excess over the SM expectation

HFAG average: $\mathcal{B}(B \to \tau\nu) = (1.64 \pm 0.34) \times 10^{-4}$

- Vub (exp.+theory) and f_B (theory) uncertainties dominate the SM expectation uncertainty:
  - Using $f_B = 190 \pm 13$ MeV * and $V_{ub} = (3.5 \pm 0.4) \times 10^{-3}$ **
    $BF_{SM}(B \to \tau\nu) = (0.80 \pm 0.20) \times 10^{-4}$



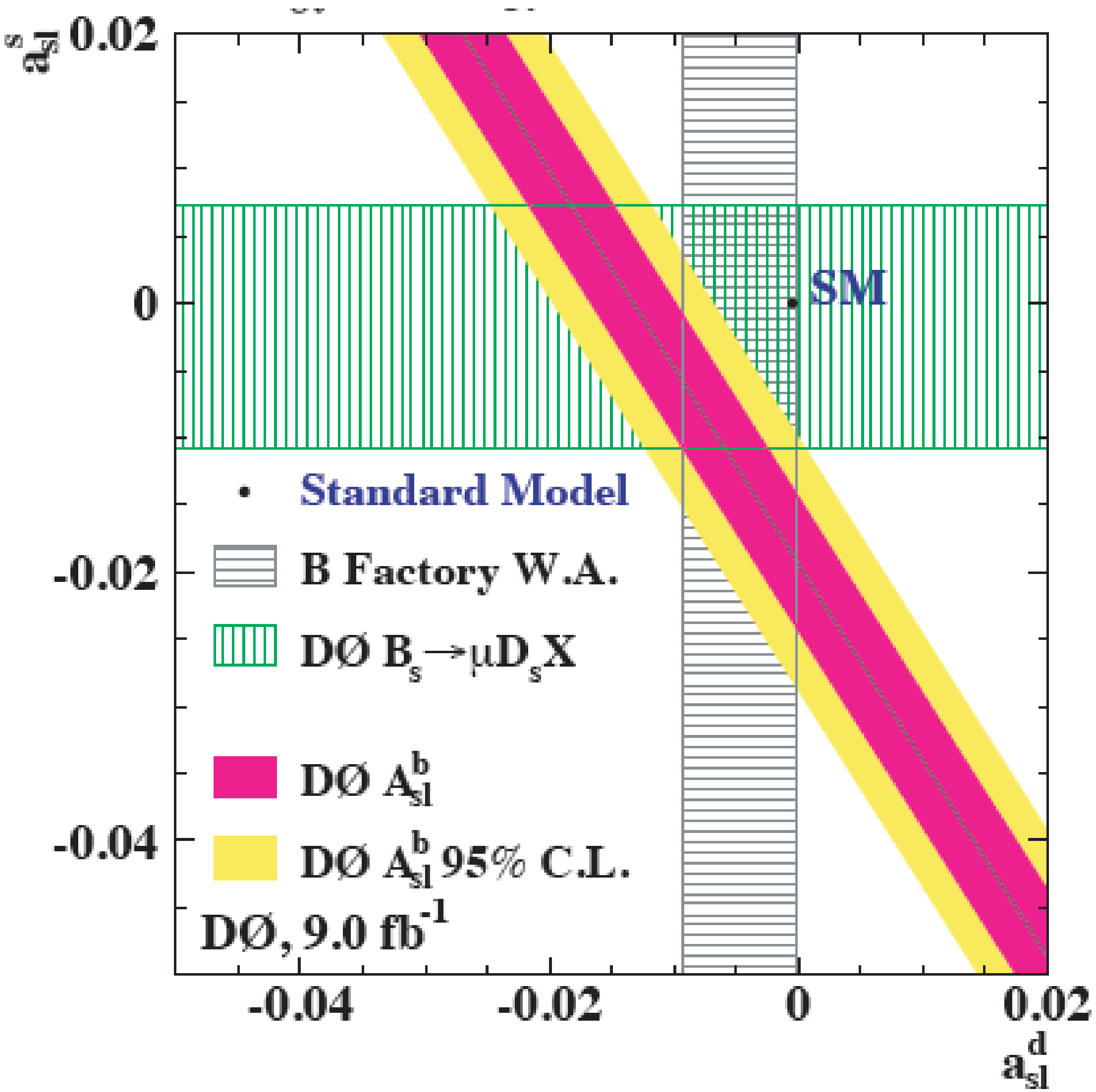


D0 dimuon asymmetry

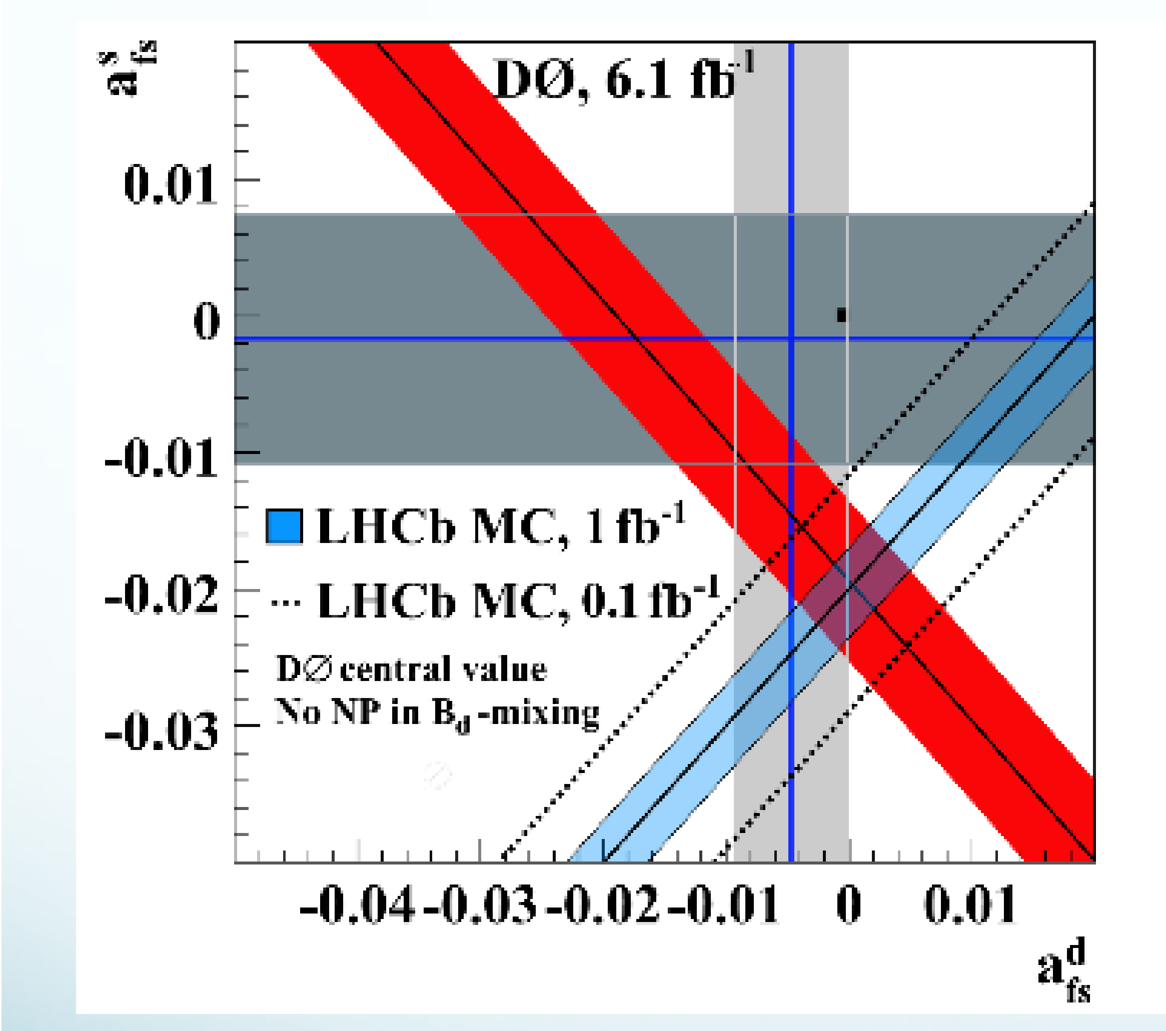
Interpreted as from semileptonic
B_d, B_s decay asymm.
a^d_{sl} , a^s_{sl}

D0 central value
larger than th possible
if Γ_{12} normal

$A < -4.8$•• $-6.1\ 10^{-3}$
$A^{D0} = -7.9 \pm 2.0\ 10^{-3}$



Probably LHCb will fix this issue



Conclusion

The Higgs comes closer, New Physics is pushed further away

The LHC experiments are just at the start and much deeper layers can be reached in the next decade

Flavour physics maintains an essential role as a precision tool

Neutrino physics is very important for the theory of flavour and as a probe into the GUT scale (some large neutrino detectors can also do p decay)

"Small" experiments like those for $0\nu\beta\beta$, m_ν, $\mu \to e\gamma$, searches for Dark Matter, ….. are still extremely important

Happy birthday, Luciano!