Status of the Physics Report for the DBD

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KILC12
Apri 2012

The DBD will consist of four parts:

A common introduction on experimentation at the ILC
Design and benchmarking report from ILD
Design and benchmarking report from SiD
Report on physics opportunities at the ILC

Three documents should be prepared for LC input to the European Strategy Study:

CLIC CDR and Physics Report
A common ILC/CLIC document on future e+e- experiments
An ILC-specific physics report

The Physics Chapter of the DBD is intended to fill both of these roles.

We are planning a report of 80-100 pages. At the moment, most of the work is being done by the small team of convenors.

It is not the purpose of this report to redo the Physics volume of the RDR. Rather, our intention is

to update the RDR Physics report where necessary
to incorporate the results of studies done for the LOIs and DBD
to incorporate new information from the LHC

Here is the outline of the report and the names of the convenors:

Introduction -- Jae Yu, Michael Peskin

W boson physics -- Tim Barklow, Juergen Reuter

2-fermion processes -- Yuanning Gao, Maxim Perelstein

Standard Model Higgs -- Keisuke Fujii, Heather Logan

Extended Higgs -- Aurore Savoy-Navarro, Shinya Kanemura

Top Quark -- Andrei Nomerotski, Andre Hoang

Supersymmetry -- Jenny List, Howard Baer

Connection to Cosmology -- Geraldine Servant, Tim Tait

For further details, see the web page:
http://www.slac.stanford.edu/~mpeskin/PhysicsChapter.html

Our report should make a clear physics case for the ILC.

Rolf Heuer (in Granada) / Jon Bagger (+ FALC) (today) :

The case for the next accelerator should be based on the knowledge we have gained from the LHC.

A problem is that we have not yet gained much knowlege from the LHC.

In 2005, we expected that, by now, we would have a 100 fb-1 luminosity sample at 14 TeV. What we have is a 5 fb-1 sample at 7 TeV.

Counting energy and the possibility of luminosity upgrades, we have seen less the 0.1% of the eventual LHC data set.

Nevertheless, there is a clear physics case for the ILC, if we are willing to anticipate the discovery of the Higgs boson.

There is now considerable excitement in the community generated by the observation of small signals of a possible resonance in $\gamma\gamma$ and ZZ^* near 125 GeV. These are the channels in which a Standard Model-like Higgs boson is first expected to appear.

At 5fb-1, the signals of a Standard Model Higgs boson are not yet expected to be significant. At 20 fb-1, we should have 5 σ signals and corroboration in other channels.

There are good reasons why a Standard Model-like Higgs boson is expected at masses well below 150 GeV, even if there is new physics at the TeV scale.

So, our attitude is that we should take the presence of the Higgs boson near 125 GeV as an assumption that guides our work.

Obviously, we cannot go to the world today and sell the ILC on this basis.   It is up to ATLAS and CMS to give criteria for the discovery of the Higgs and to assess whether those criteria are satisfied.

But, if the assumption should prove true, we would argue as follows:

(Our report will provide detailed support for points 1 and 3 below.)

1. The Higgs boson must be studied in e+e- annihilation.

The Higgs boson is expected to be Standard Model-like in most viable models of new physics. However, the deviations from the definite Standard Model predictions are a window into the new sector.

The expected deviations are at the 10% level or smaller in branching fractions. Such accuracy is inaccessible at the LHC.

The deviations predicted can be of order

$$v^2/M^2 \text{ or } m_t^2/M^2$$

Thus, they access new particles in the TeV mass range. These particles can be discovered at the LHC only after 2105, even if they couple to QCD.

There is more. Come to my lecture tomorrow in the Physics session.

I would like to show you a picture that illustrates the improvement of accuracy in Higgs couplings from LHC to ILC.

We must insist on model-independent results. Only these test the widest variety of theoretical proposals.

However, it is not possible to make model-independent statements about Higgs couplings at the LHC. Some modes of HIggs boson decay are not measurable.

For LHC, I will make the (mild?) assumption that the physical Higgs is a linear combination of I = 0, 1/2 fields. Then it follows that

$$g(hWW)/g(hZZ) = \cos^2\theta_w$$

$$\Gamma(h \to WW) \leq \Gamma(h \to WW)|_{SM}$$

I will assume that the decay $h^0 \to b\bar{b}$ can be seen in both of the reactions

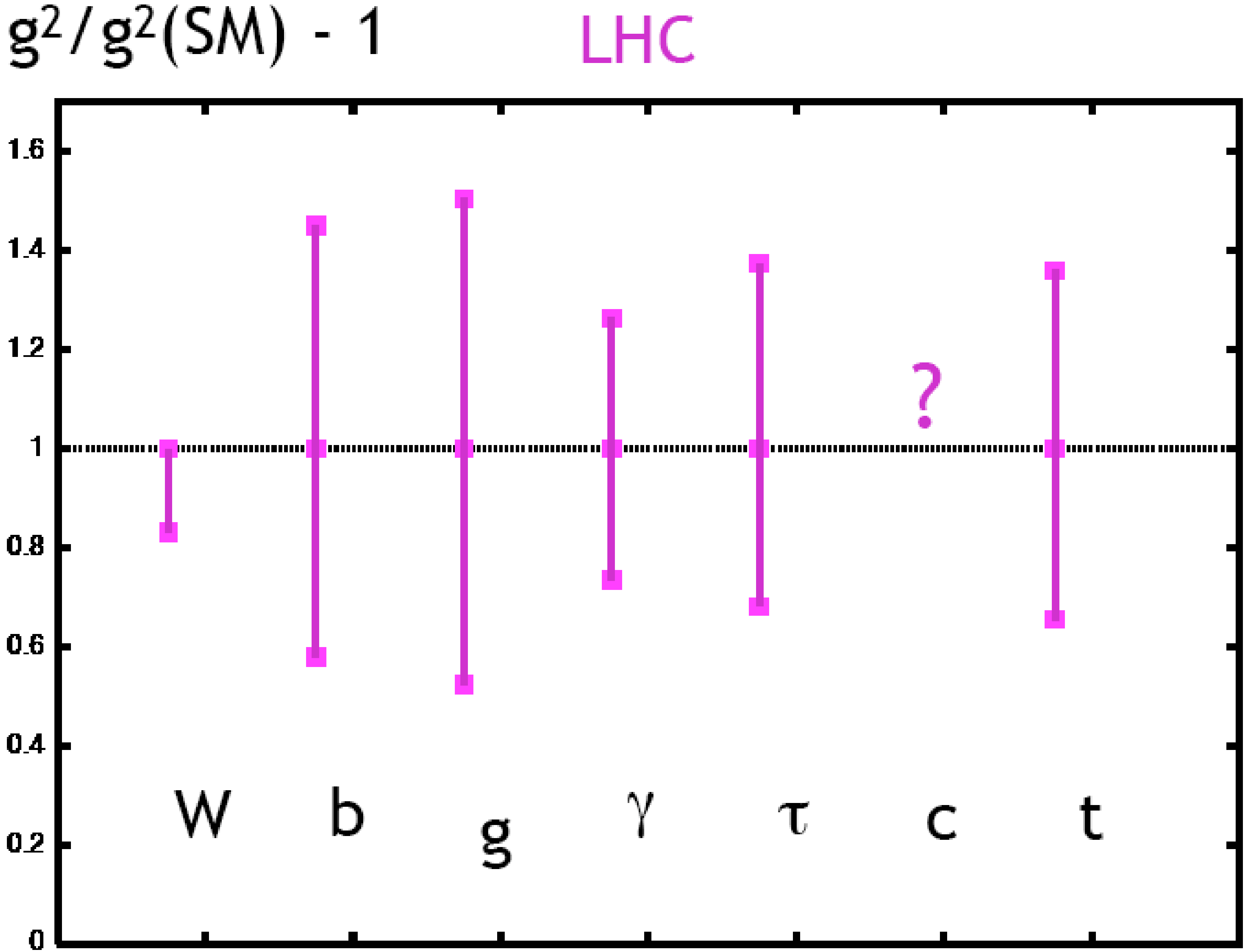
$$pp \to W, Z + h^0 \qquad\qquad pp \to t\bar{t}h^0$$

using "boosted Higgs" techniques. This is a promising but unproven method. I assume errors of 20% and 30% respectively, in measuring the $\sigma \times BR$. These estimates are wildly optimistic.

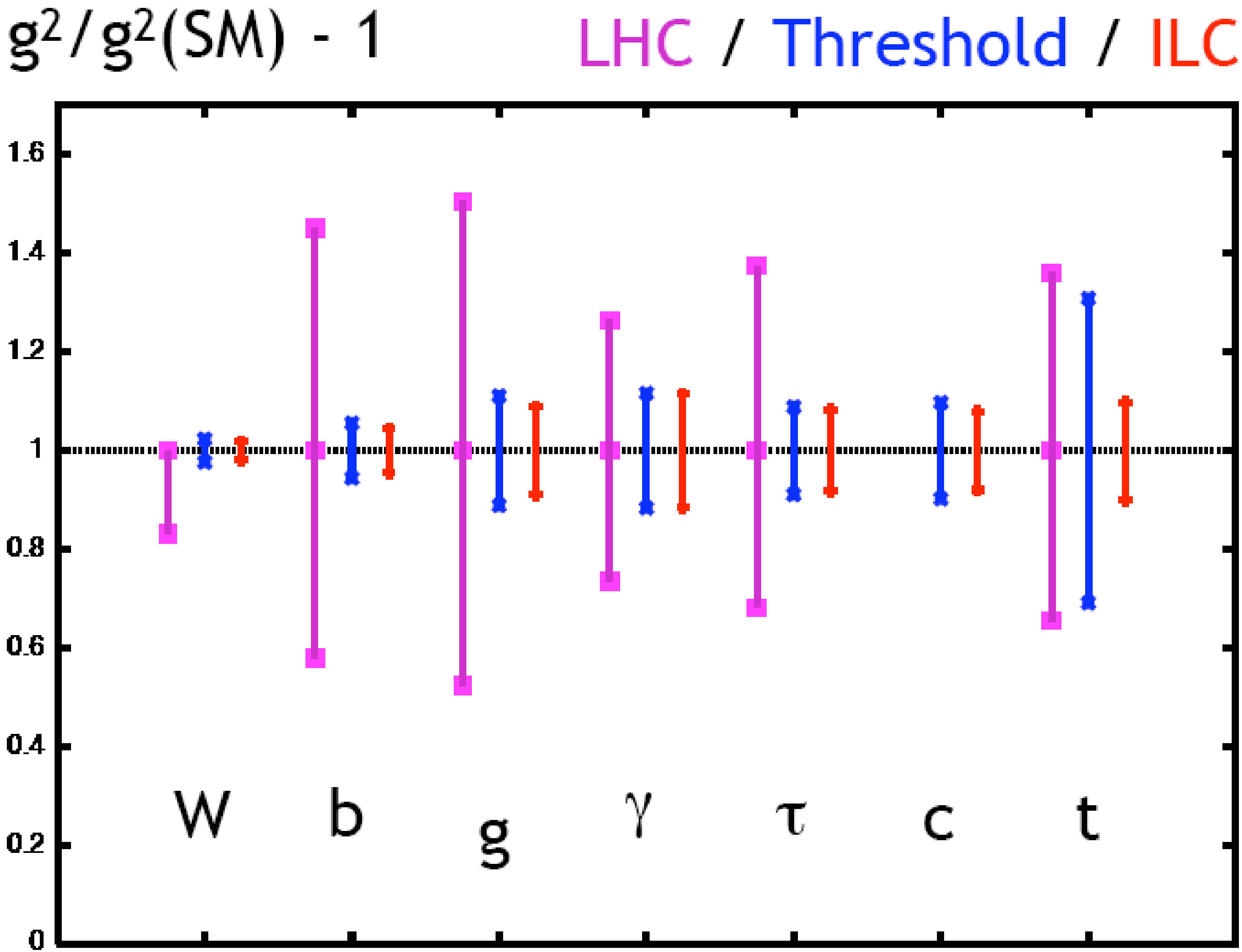
I have taken into account the theoretical errors on production cross sections of the Higgs boson at hadron colliders. Most Higgs measurements require jet vetos. These increase the theoretical systematic errors.

I have accepted pre-LHC estimates on WW fusion measurements. It is not clear that these estimates will stand up in the presence of high pileup.

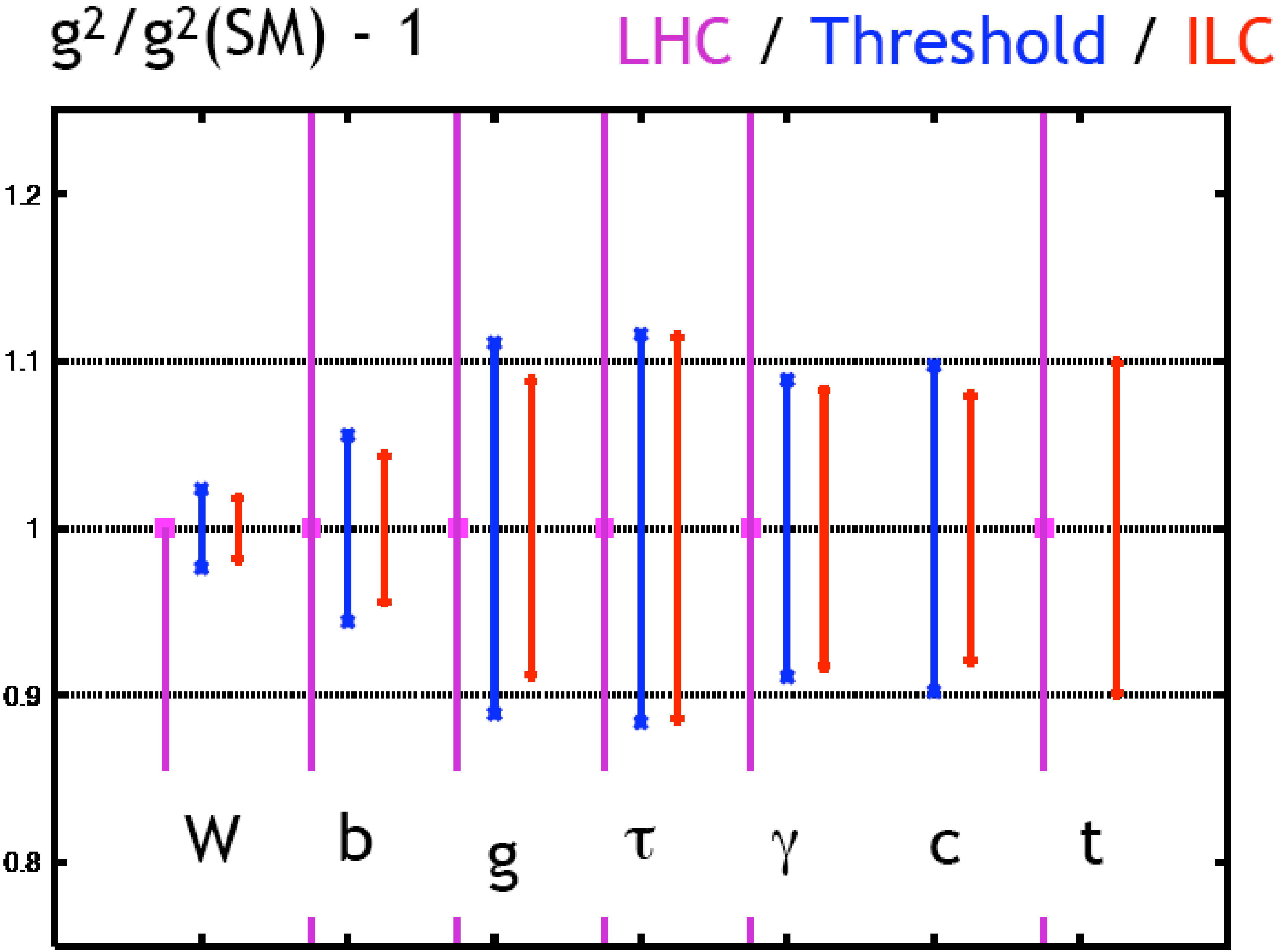
These figures are preliminary.



g²/g²(SM) - 1
LHC
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
?
W
b
g
γ
τ
c
t

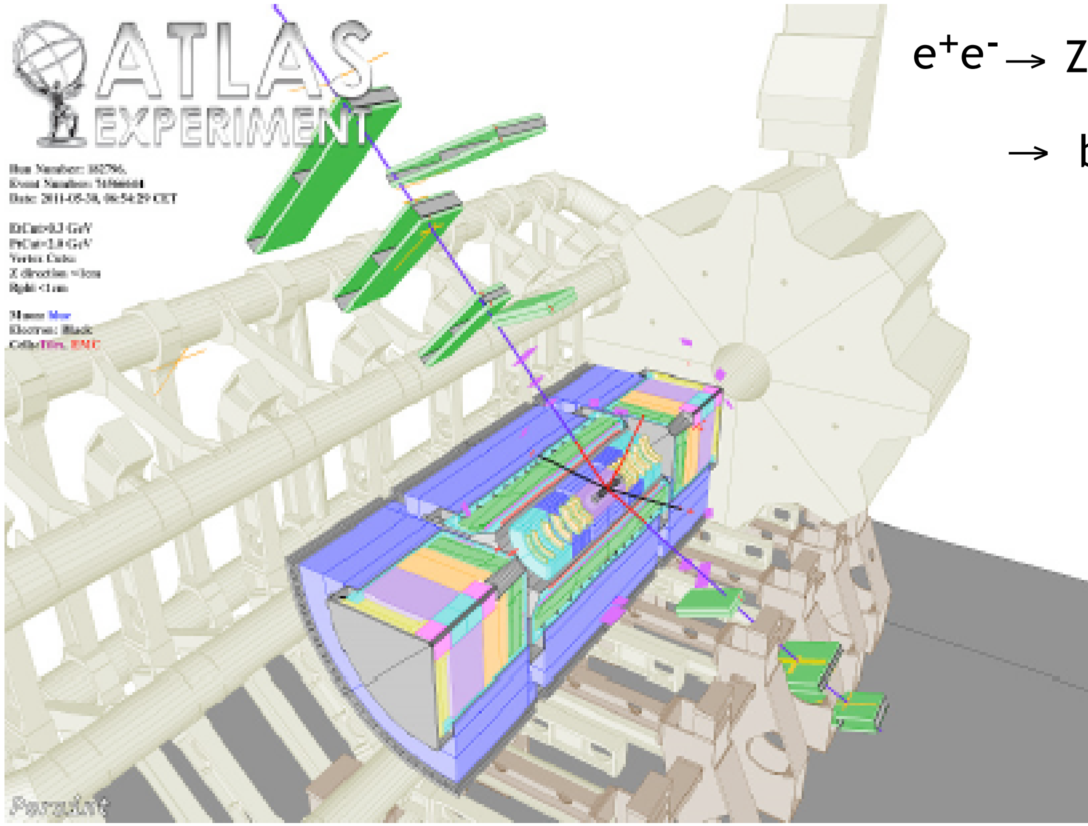


g²/g²(SM) - 1
LHC / Threshold / ILC
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
W
b
g
γ
τ
c
t

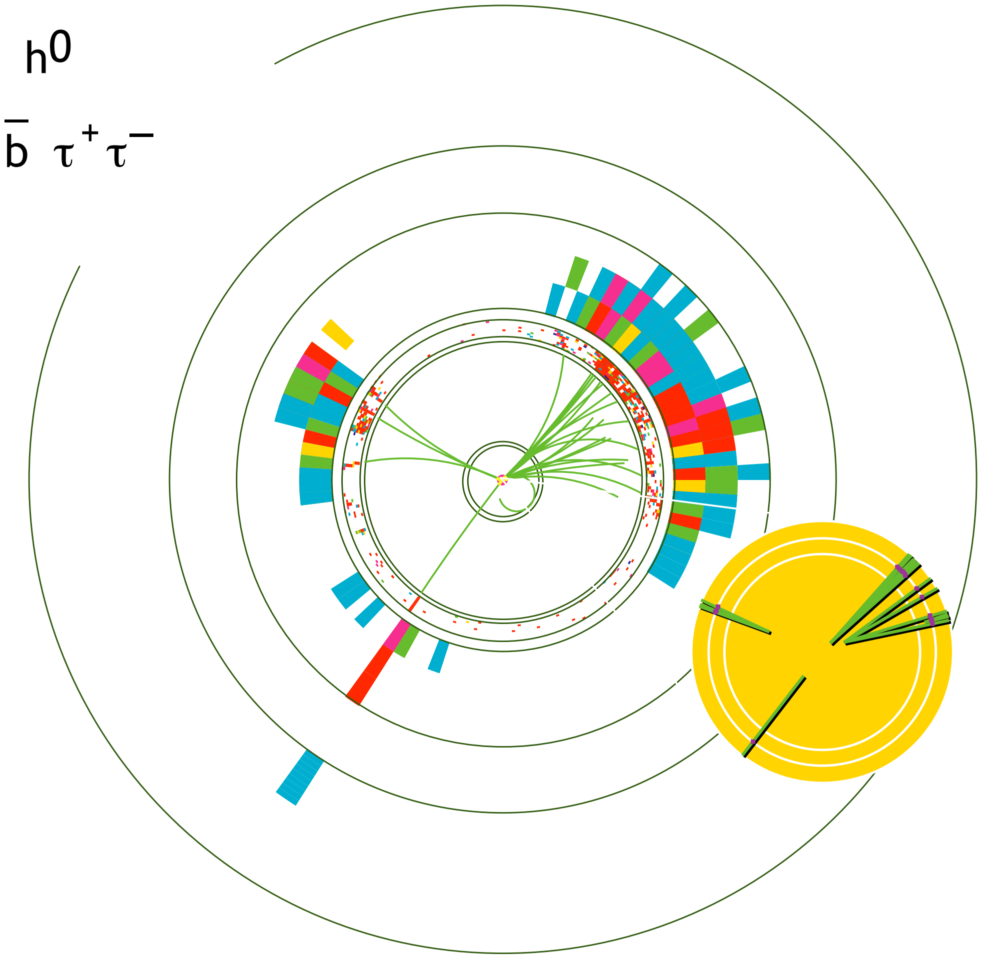


g²/g²(SM) - 1
LHC / Threshold / ILC
1.2
1.1
1
0.9
0.8
W
b
g
τ
γ
c
t

comparison of Higgs events at LHC and ILC



$$e^+e^- \rightarrow Z^0\ h^0$$
$$\rightarrow b\,\bar{b}\ \tau^+\tau^-$$



2. This experimental program should be started urgently.

The moment of the discovery of the HIggs boson will be a watershed for high-energy physics. It will the culmination of a 30-year search for this elusive particle. At the same time, this discovery will not solve the mystery of electroweak symmetry breaking. What it will do is to bring into focus a path to the resolution of this mystery.

Will there be a better moment to propose the next machine ?

"Urgency" is a relative term in Big Science. Projects like LHC, ITER, Planck take more than a decade to realize. If we start today, we can have the precision study of the Higgs boson in the late 2020's. Otherwise, perhaps, never ...

3. More paths to new physics could be found at the LHC. We need a plan that gives us flexibility to pursue these.

The programs that are hardly begun at the LHC include

searches for the supersymmetric partners of top and bottom

searches for the supersymmetric partners of Higgs bosons

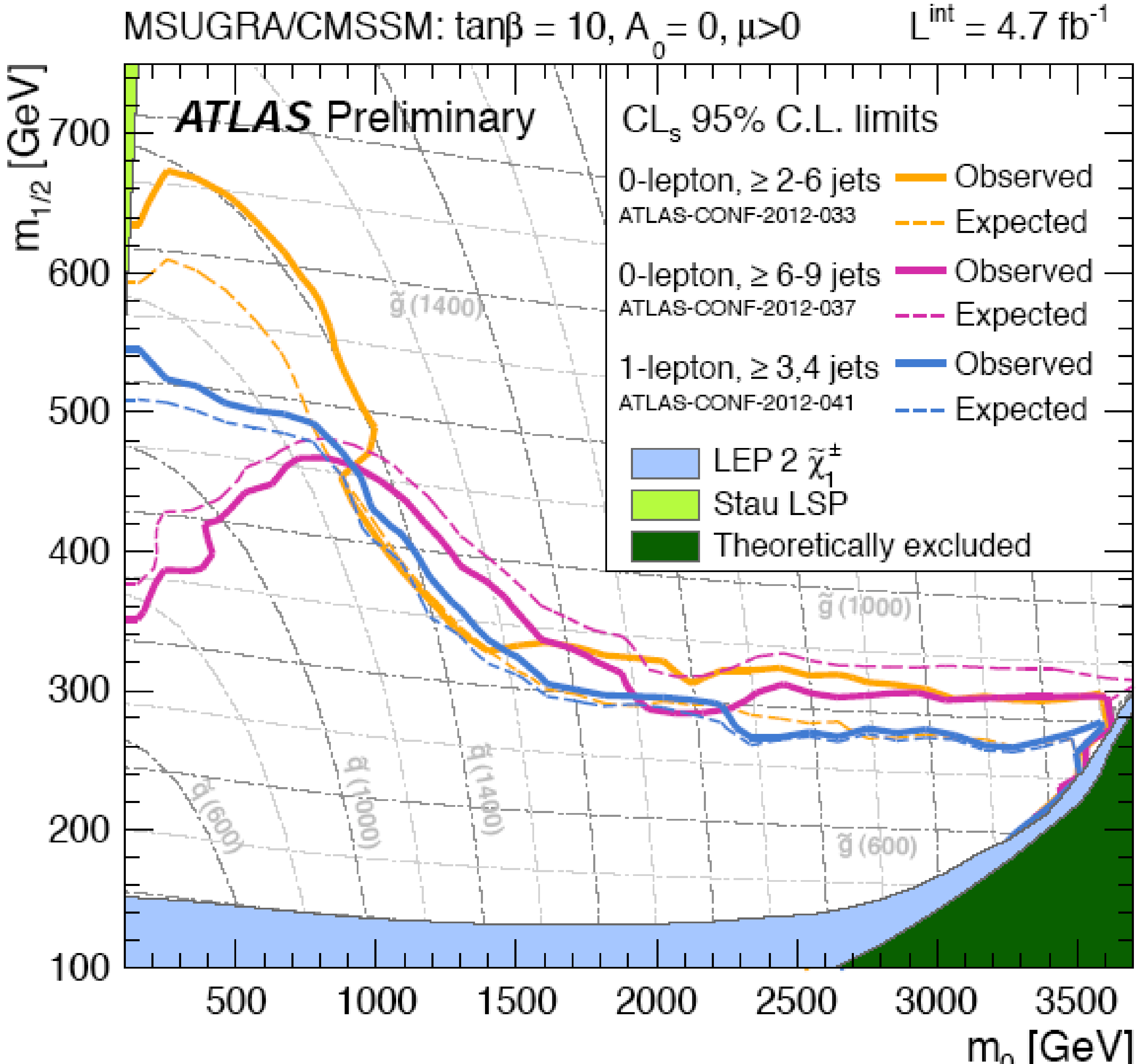
searches for the supersymmetric partners of leptons

searches for vectorlike heavy quarks

searches for new gauge bosons that are not sequential Z, W

searches for exotic couplings of the top quark

All of these programs potentially lead to signatures at the ILC at 500 GeV.


MSUGRA/CMSSM: tanβ = 10, A0 = 0, μ>0
Lint = 4.7 fb-1
ATLAS Preliminary
CLs 95% C.L. limits
0-lepton, ≥ 2-6 jets
ATLAS-CONF-2012-033
Observed
Expected
0-lepton, ≥ 6-9 jets
ATLAS-CONF-2012-037
Observed
Expected
1-lepton, ≥ 3,4 jets
ATLAS-CONF-2012-041
Observed
Expected
LEP 2 χ̃±1
Stau LSP
Theoretically excluded
g̃ (1400)
g̃ (1000)
g̃ (600)
q̃ (600)
q̃ (1000)
q̃ (1400)
m1/2 [GeV]
m0 [GeV]
100
200
300
400
500
600
700
500
1000
1500
2000
2500
3000
3500

The first two years of the LHC have led to very strong constraints on the constrained Minimal Supersymmetry Standard Model.

However, this has not caused theorists to give up on SUSY. There is no theoretical literature on how to replace SUSY.

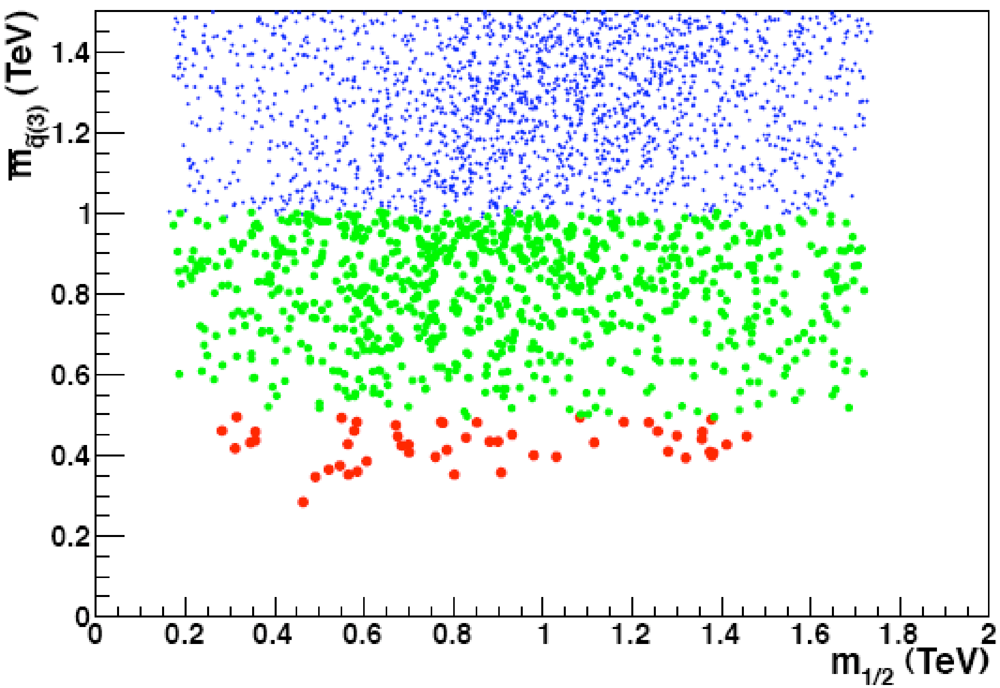
Rather, theorists have emphasized that the primary criterion for the naturalness of the electroweak scale is for the μ parameter to be small.

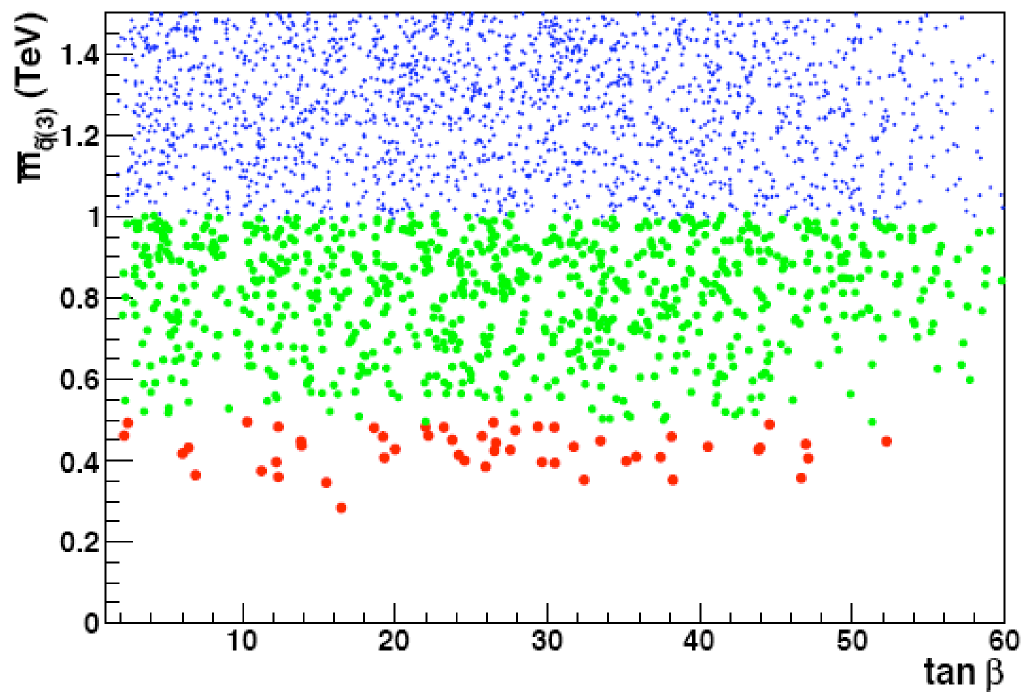
This leads to a spectrum in which

Higgsinos are the lightest charginos and neutralinos. These automatically have small mass splittings

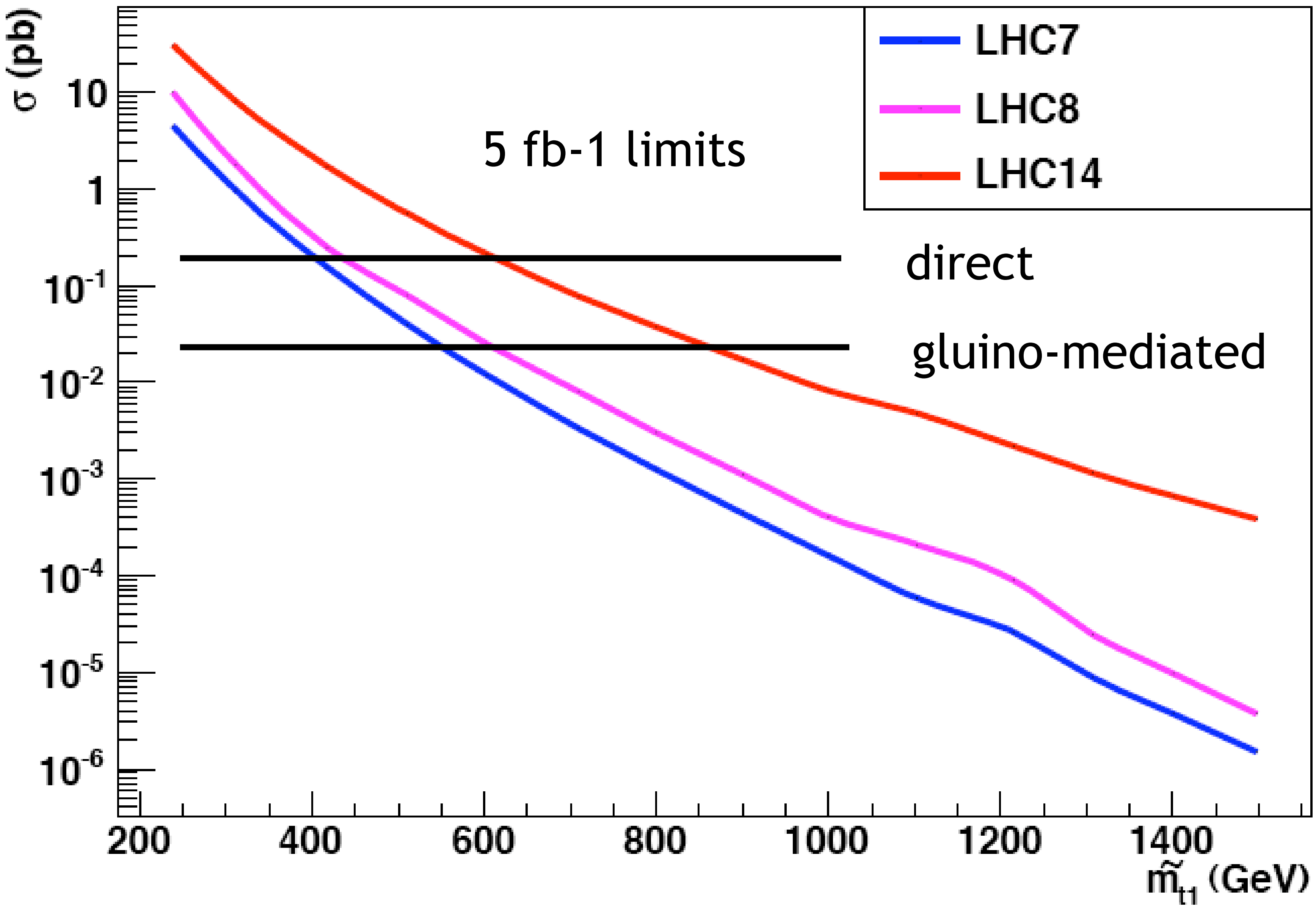
the only light colored SUSY particles are top (and maybe bottom) squarks

Cohen-Kaplan-Nelson ... Pappucci, Ruderman, Weiler

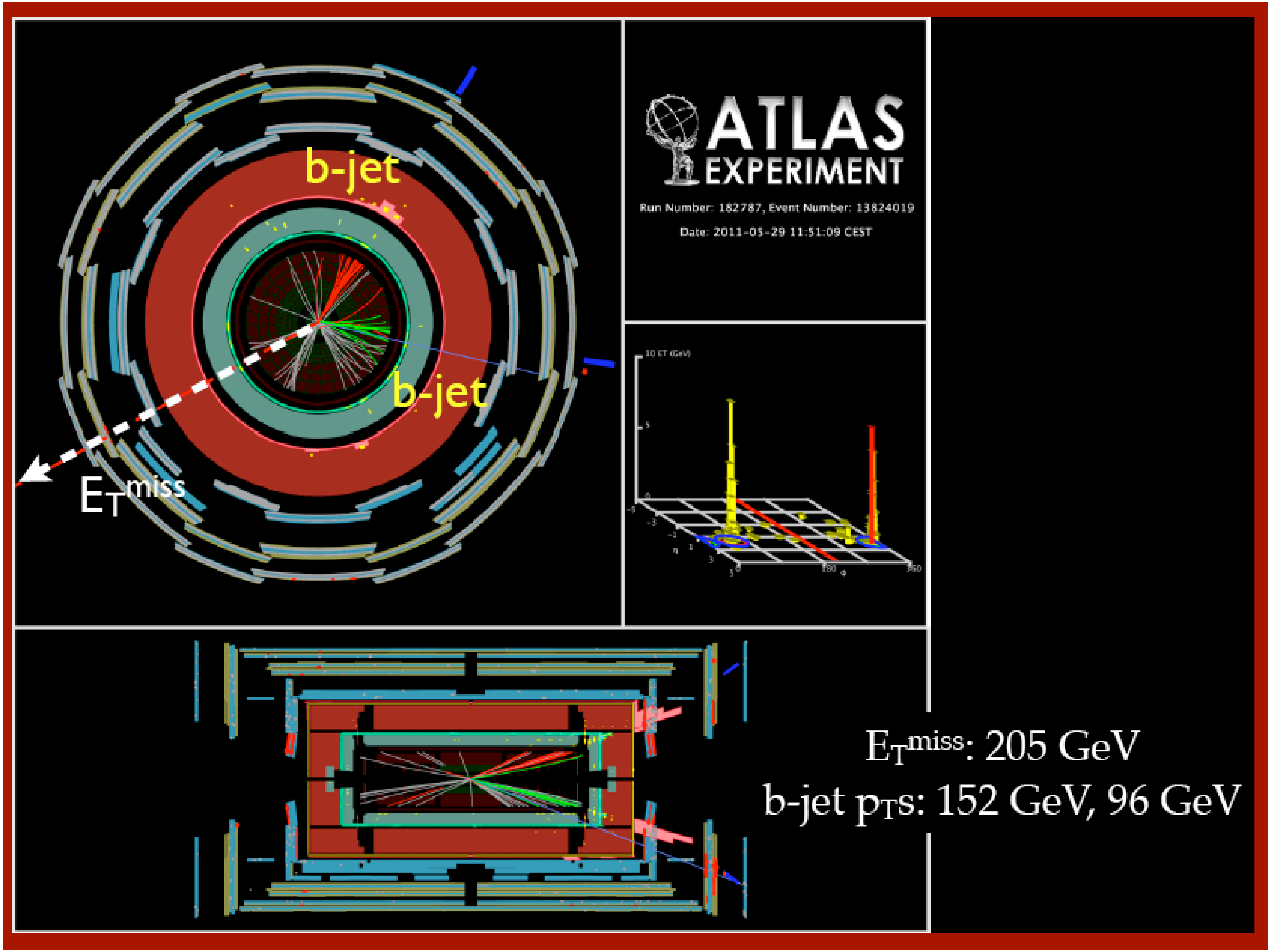




Baer, Barger, Huang, and Tata



Baer, Barger, Huang, and Tata


b-jet
b-jet
E_T^{miss}
ATLAS EXPERIMENT
Run Number: 182787, Event Number: 13824019
Date: 2011-05-29 11:51:09 CEST
E_T^{miss}: 205 GeV
b-jet p_Ts: 152 GeV, 96 GeV

Another possibility is that SUSY decays are more complicated than we expect.

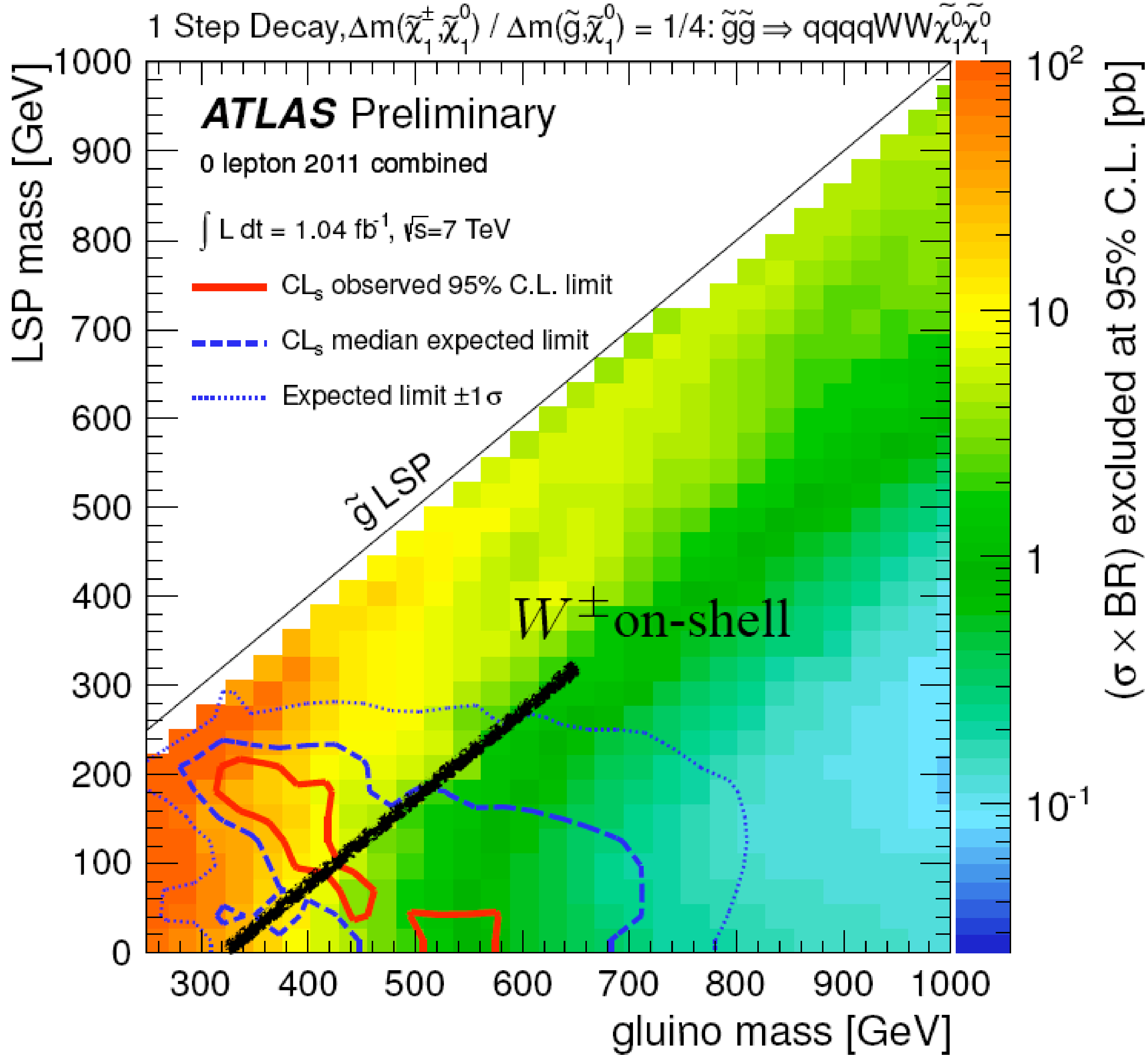
Assuming that the dominant decay mode for (accessible) squarks is

$$\widetilde{q} \to q + \widetilde{W}, \widetilde{Z} \to q + \widetilde{\chi}^0 + (q\overline{q}),\ (\ell\nu),\ (\ell\ell)$$

dramatically weakens the current limits.

Alves, Izaguirre, and Wacker

The most obvious strategies for finding SUSY do not work, but many other strategies are still left to pursue.



1 Step Decay, Δm($\tilde{\chi}_1^{\pm}$,$\tilde{\chi}_1^0$) / Δm($\tilde{g}$,$\tilde{\chi}_1^0$) = 1/4: $\tilde{g}\tilde{g} \Rightarrow qqqqWW\tilde{\chi}_1^0\tilde{\chi}_1^0$
ATLAS Preliminary
0 lepton 2011 combined
$\int L\,dt$ = 1.04 fb^{-1}, $\sqrt{s}$=7 TeV
CL$_s$ observed 95% C.L. limit
CL$_s$ median expected limit
Expected limit ±1σ
$\tilde{g}$ LSP
$W^{\pm}$ on-shell
LSP mass [GeV]
gluino mass [GeV]
(σ × BR) excluded at 95% C.L. [pb]
0
100
200
300
400
500
600
700
800
900
1000
300
400
500
600
700
800
900
1000
10^{-1}
1
10
10^2

Schedule of the report:

The convenors are current collecting material and references. Anyone who would like to help is invited to contact the relevant convenors. See the web page on slide 4.

We cannot get ahead of the LHC experiments, especially as to the evidence for the Higgs boson. However, the schedule is challenging:

July 4-10 ICHEP 2012 - first results from 2012 LHC running

July 31 deadline for submission of materials to the European Strategy Study meeting in Cracow

This dictates the following schedule:

We will release a public draft of our report just after ICHEP.

We will ask for comments and signatures from the ILC collaborations and the theory community.

We will submit a revised draft by the Cracow deadline July 31.

We will submit an updated version to the arXiv in early September, before the actual Cracow meeting Sept. 11-13.

The final version will be completed by December for the DBD.