Hiding the Higgs Boson

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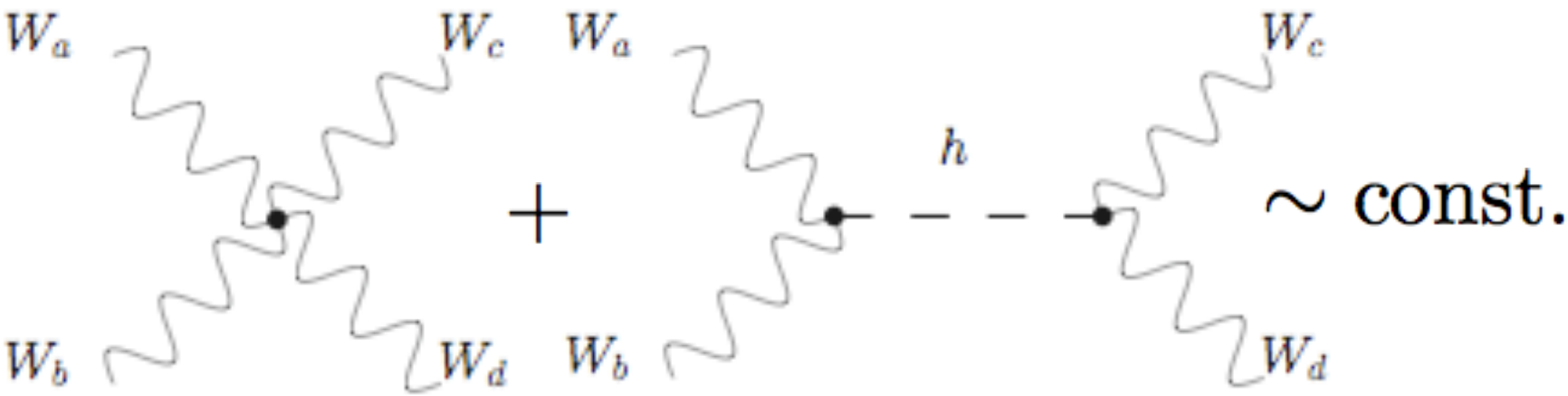
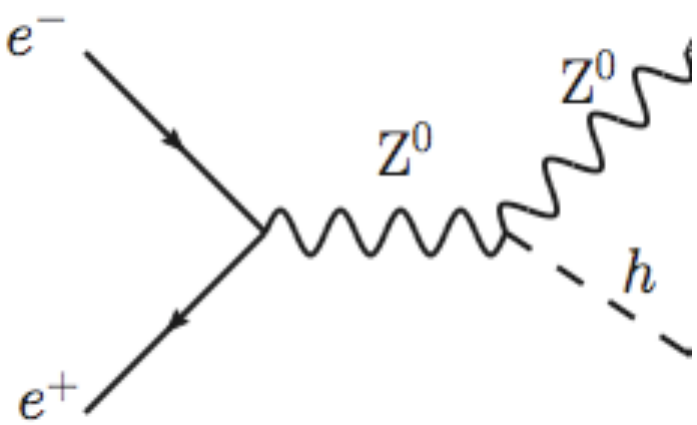
MIT

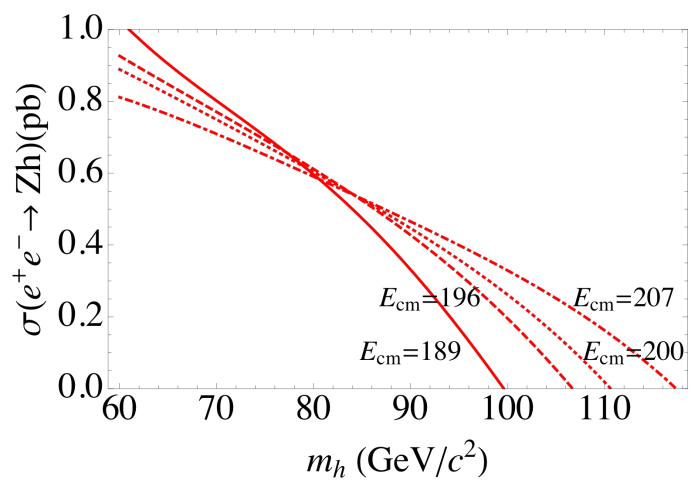
The Higgs Boson

For the purpose of this talk what I mean by “the Higgs boson” is a scalar that couples to the Electroweak vector-bosons and is responsible to the unitarization of their scattering amplitude at high energies,



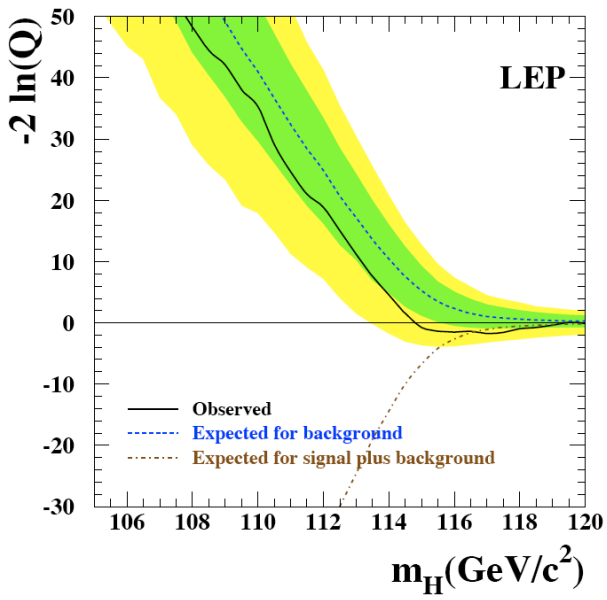
This leads to a direct and unambiguous prediction for the Higgstrahlung cross-section as a function of the Higgs mass,





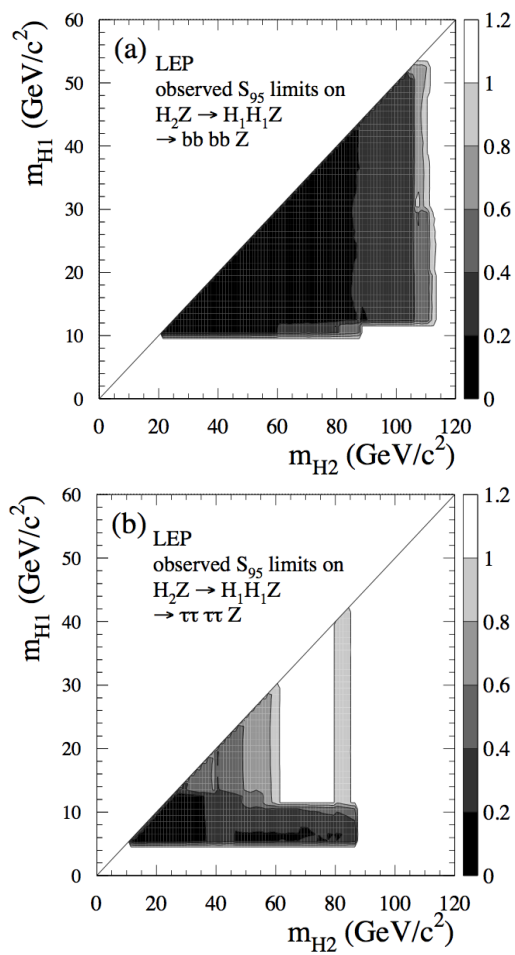
Higgs Searches at LEP2

Standard Higgs boson decay into bottoms quarks and tau leptons



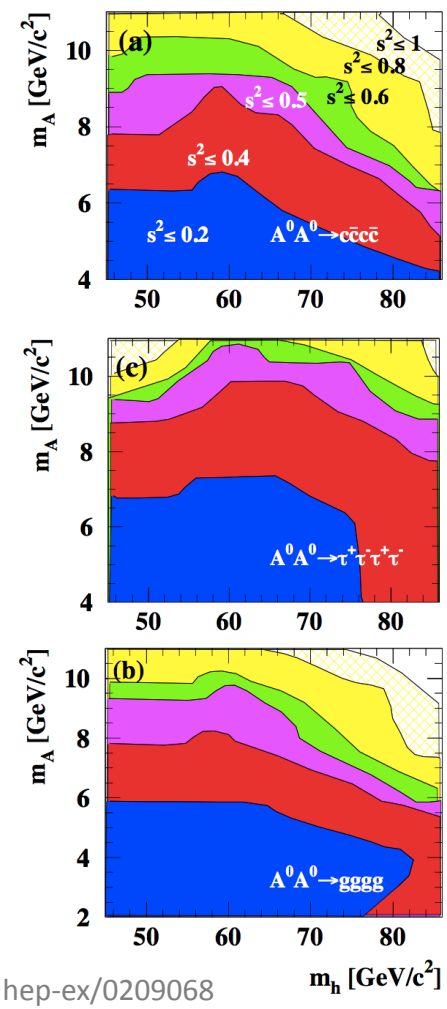
LEP combined search - hep-ex/0306033 thoroughly excluded the Standard Model Higgs up to 115 GeV/c^2

MSSM-like decays into lighter Higgses resulting in 4 bottoms or tau letpons



hep-ex/0602042

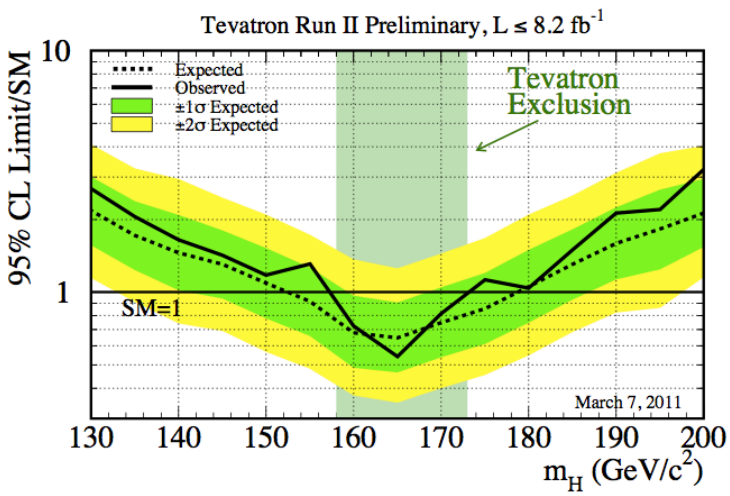
Exotic decays into lighter scalars resulting in 4-particles final state



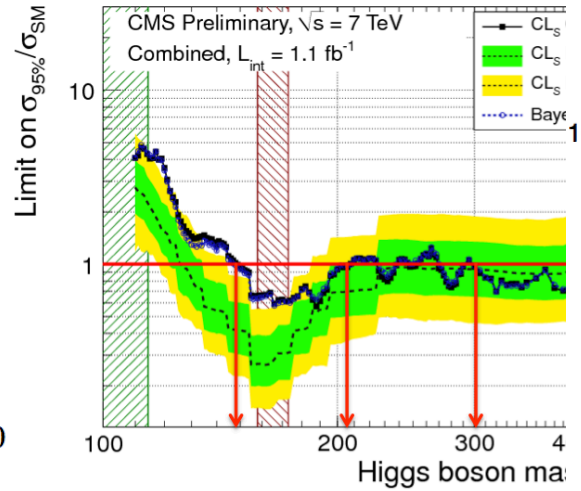
hep-ex/0209068

Higgs Searches at Tevatron and LHC

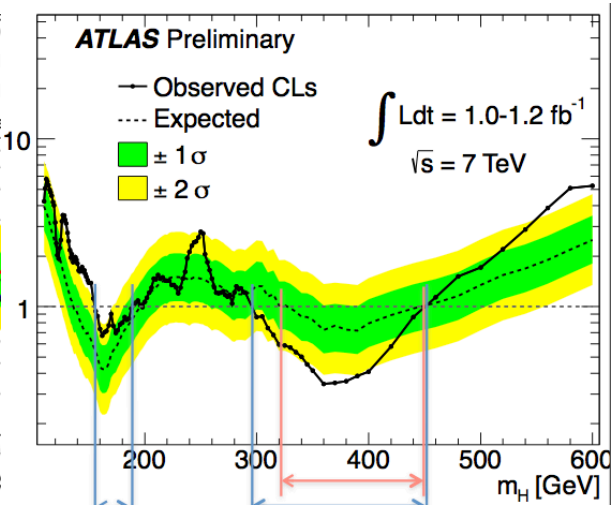
The search for low mass Higgs is in general much more difficult per luminosity for hadronic machines because of the larger backgrounds. Such searches are not hopeless, but at least for now they cannot squarely compete with the LEP2 results in that region.



Tevatron combined 1103.3233

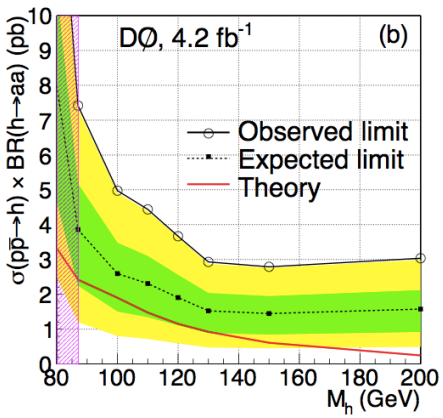


CMS result EPS meeting 2011

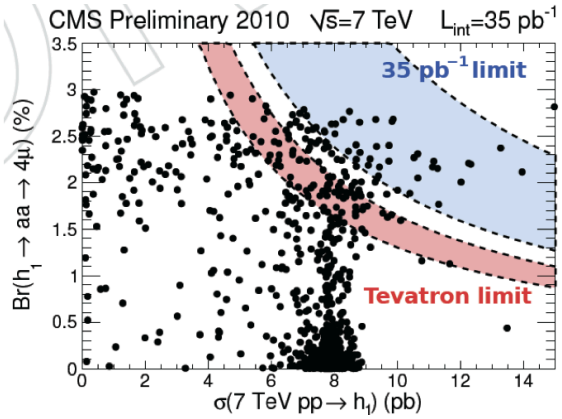


ATLAS result EPS meeting 2011

There have also been some searches for more exotic decays,

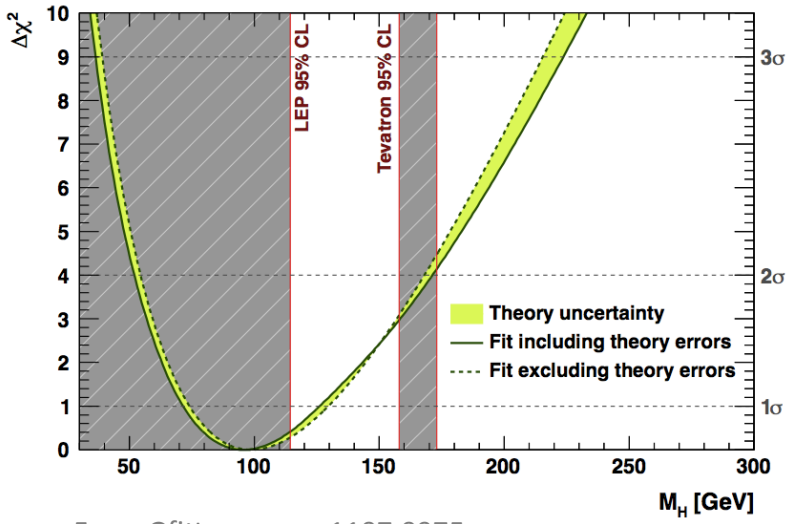


D0 search 0905.3381

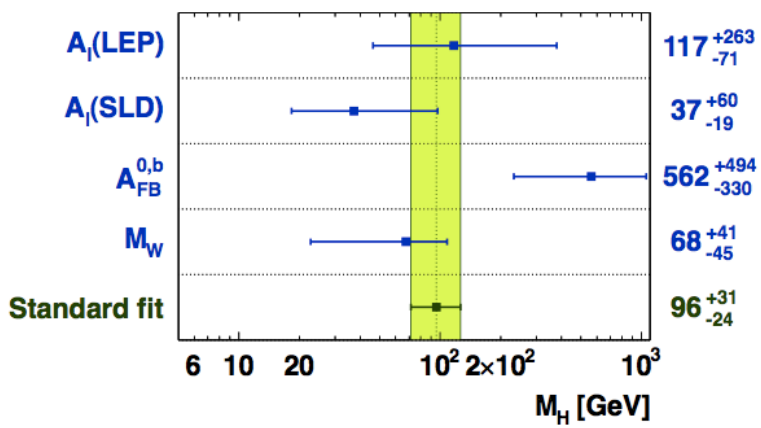


CMS Boost 2011

Maybe it has been missed?



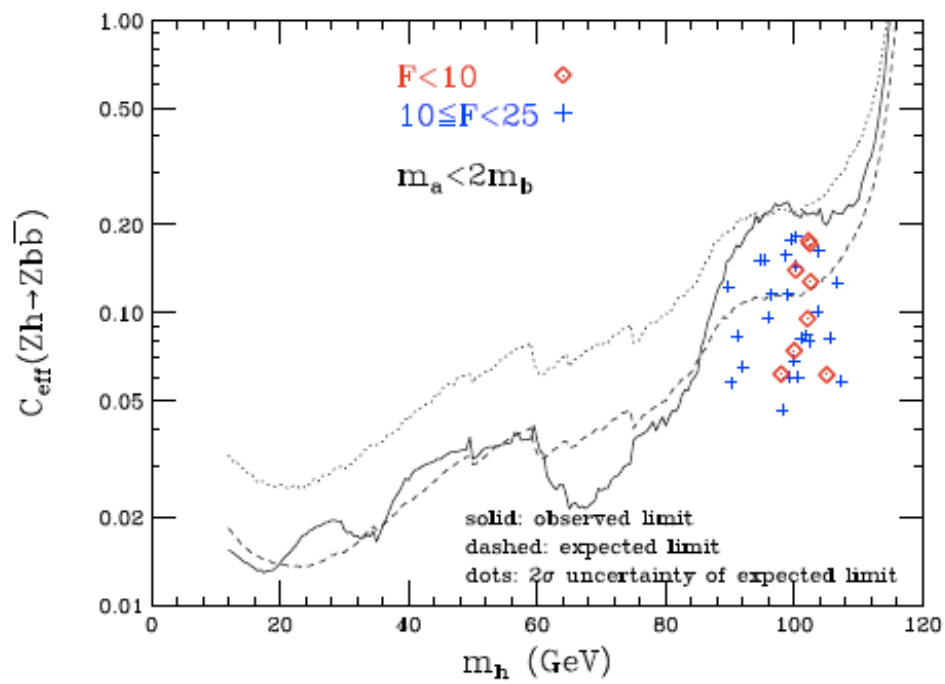
From Gfitter group, 1107.0975



Chanowitz has argued for a while now that the fit is being pulled upwards by the discrepant A_{FB} measurement in the b system.

Tree level relations in the MSSM imply a light Higgs boson

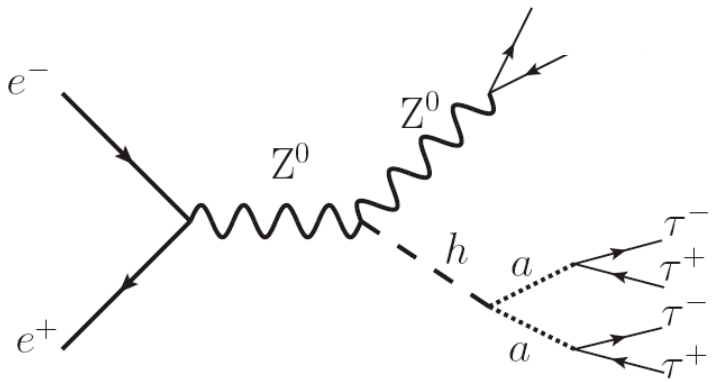
$$m_h \leq \min(m_Z, m_a)|\cos(2\beta)|$$



Excess seen by all LEP2 experiments.

Escaping the LEP2 direct searches

The original proposal by Dermisek and Gunion (hep-ph/0502105) suggested the 4τ final state as a mode which has been missed.

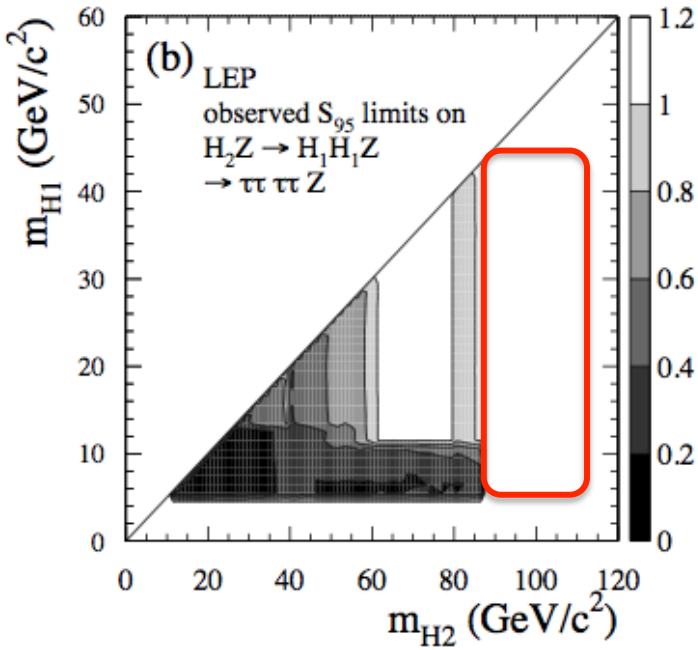


The small bottom Yukawa coupling results in a small decay width of the Higgs boson into bottom quarks

$$\Gamma(h \to b\bar{b}) \approx \frac{1}{8\pi}\left(\frac{m_b}{v}\right)^2 m_h = 10^{-5} m_h$$

… so that a different decay mode can easily dominate,

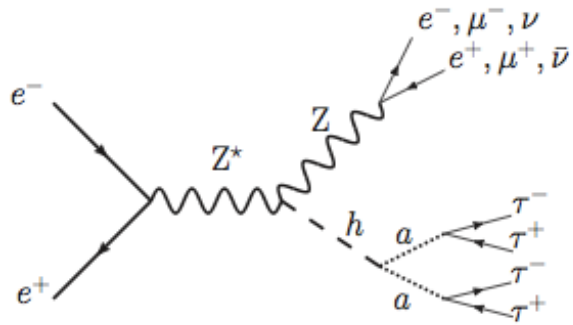
$$\frac{\Gamma(h \to aa)}{\Gamma(h \to b\bar{b})} \approx 310 \times c^2 \left(\frac{m_h}{100\ \mathrm{GeV}}\right)^2$$

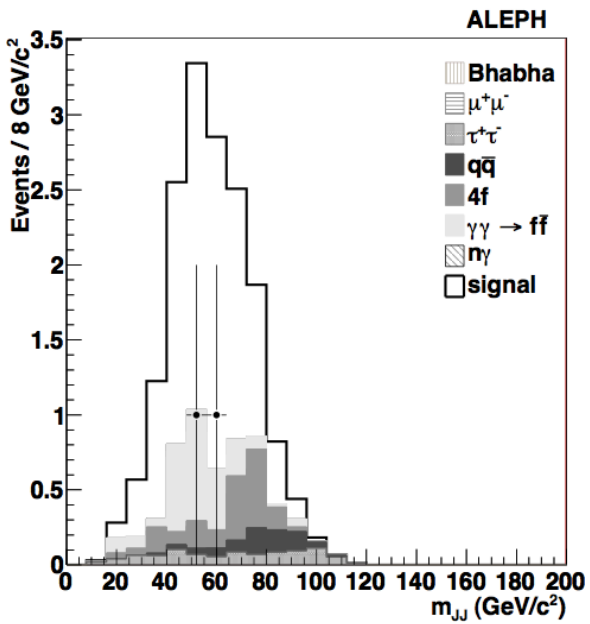


A search for this channel was made by OPAL, but fell short of excluding the entire range of interesting Higgs boson mass.

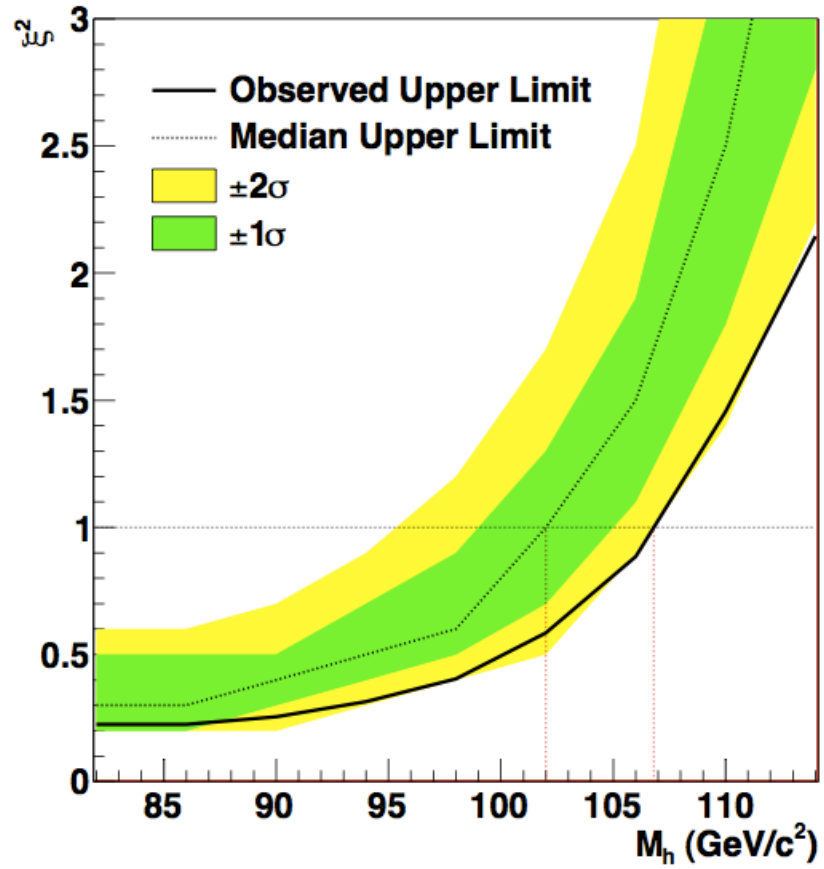
ALEPH Search for Higgs to 4 τ's

In 2010 the ALEPH collaboration published a dedicated search that excluded the possibility of an exotic Higgs boson decay into 4 τ's with archived data.



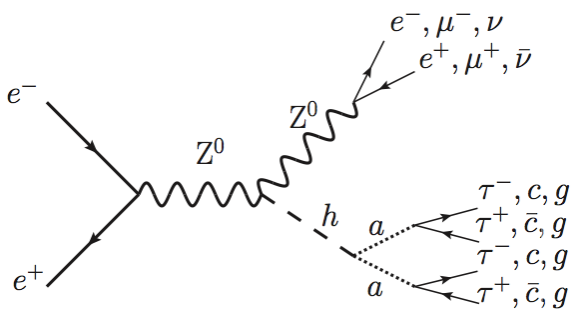


Dijet invariant mass after final selection in invisible Z boson decay channel



In JHEP 1005 (2010) 049, 1003.0705

Remaining Possibilities

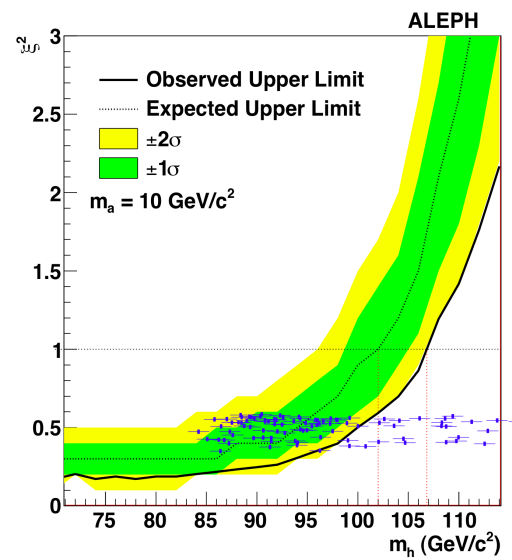


1) Charmed Higgs – Higgs to 4 charm quarks
(Bellazzini, Csaki, Falkwoski, and Weiler, 0910.3210)

2) Buried Higgs – Higgs to 4 gluons
(Bellazzini, Csaki, Falkwoski, and Weiler, 0910.3026)

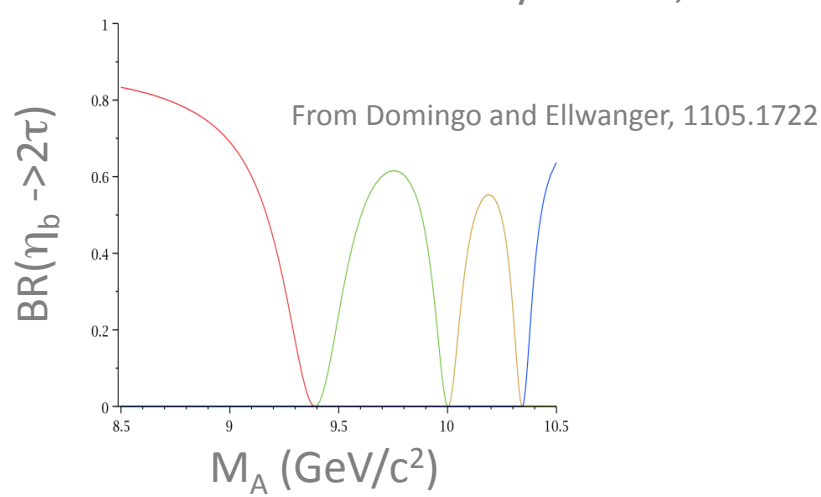
3) Higgs to Lepton Jets
(Falkwoski, Ruderman, Volanski and Zupan, 1002.2952)

4) Other analyses
(Chang, Fox, and Weiner, hep-ph/0511250)
(Chang, Dermisek, Gunion, and Weiner, 0801.4554)
(Luty, Phalen, and Pierce, 1012.1347)



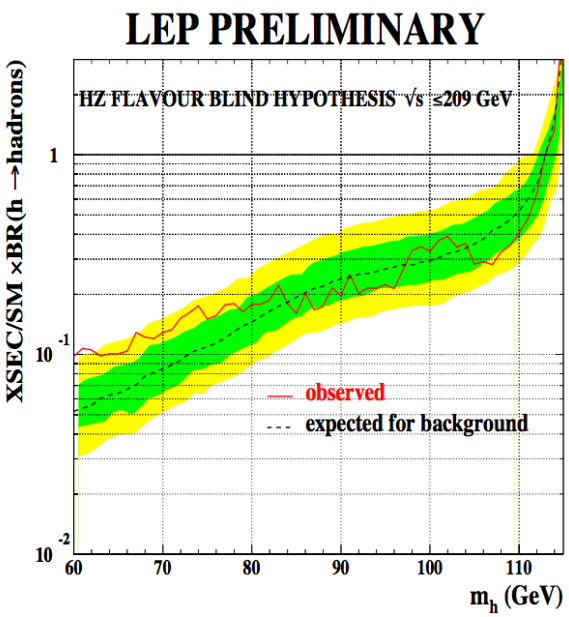
Gunion and Dermisek found additional points in the NMSSM that can escape the 4τ's search where the pseudo-scalar has a large branching ratio into charm quarks

Since the pseudo-scalars have the same quantum numbers as the bottom quark bound state η_b it can mix with it and inherit its hadronic decay modes,



Excluded Already?

Flavor Independent Searches



Some of these scenarios would have been seen in the flavor independent searches, but the efficiency of the search to these alternative scenarios is hard to estimate.

Efficiency from OPAL Thesis

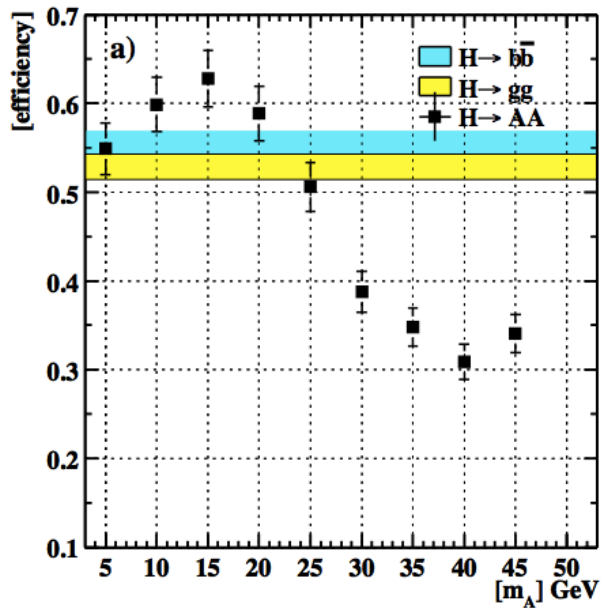
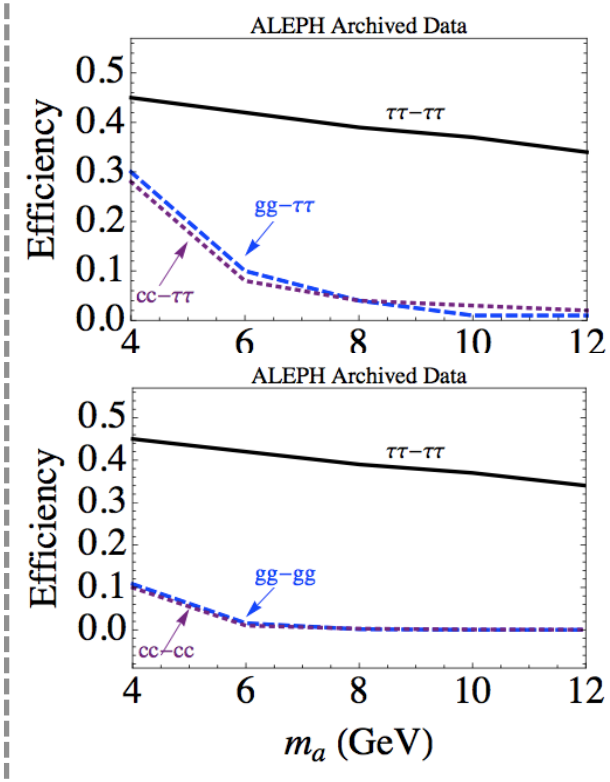


Fig. 7.20 from an OPAL thesis by Götz Gaycken. The efficiency for the alternative h -> 2A -> 4q mode is comparable to the actual search modes.

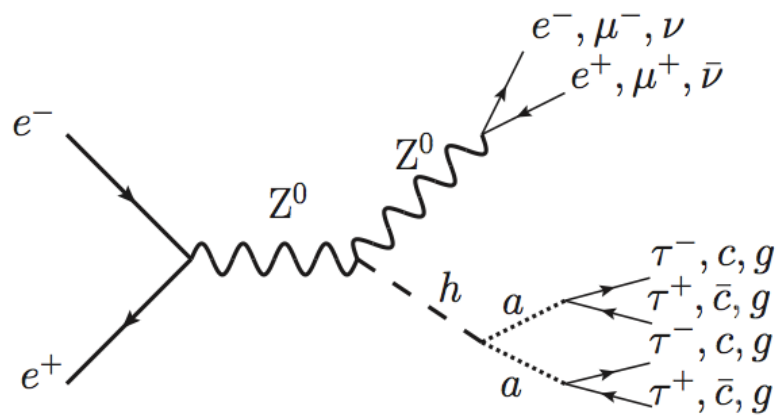
RECAST of ALEPH search

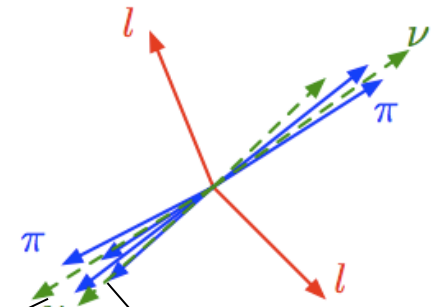


Low pseudo-scalar mass is ruled out, but need a dedicated search for higher mass values.

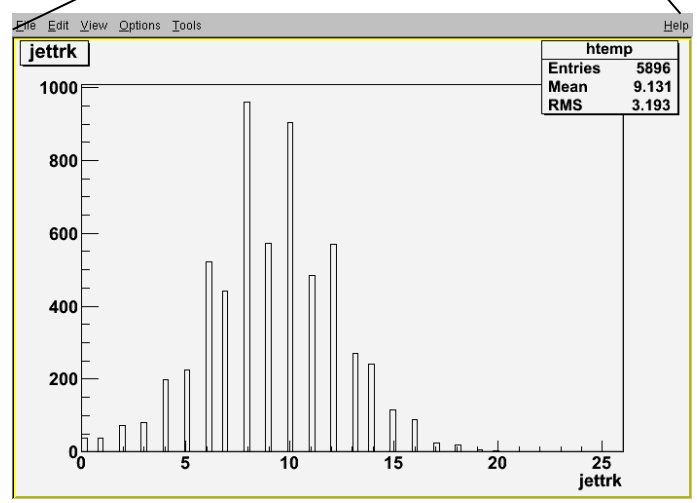
Dedicated ALEPH Search

Using ALEPH data from the LEP2 run we recently concluded a search for these alternative exotic decay modes of the Higgs boson produced in associated with the Z boson. Unfortunately, no official results can be shown at the moment.





This is a considerably more difficult analysis than the 4 tau decay case. There is a large background from QCD jets and we do not have a trained neural network at our disposal to help reject this background. We will have to rely on the detailed differences between the jets coming from the pseudo-scalar decays and the background QCD jets.



Conclusions

Some time ago, before the more recent re-analyses, there were several good reasons to wonder whether the Higgs boson might have escaped detection because of an exotic decay mode which has not be searched for properly,

1) Ease the known tension with the electroweak precision fit

2) SUSY tree-level relations demand a low mass Higgs

3) Mysterious excess at 98 GeV seen by all LEP2 collaborations

4) Very simple extensions of existing models give rise to such exotic decays

However, given everything we have learned over the last couple of years about this topic, it seems difficult to continue to entertain this possibility without admitting that it is considerably less appealing than it used to be.

We hope to soon have an official ALEPH result for the more general search we recently concluded.

Thank You