SOCIEDADE BRASILEIRA DE FÍSICA

Métodos Experimentais

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Lafex

(2009-1)

- Perspectiva histórica
- Quarks, leptons, flavor
- Aceleradores, detetores
- Experimentos contemporâneos

Higgs Searches (S.M.)

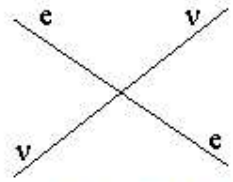
- **Tevatron: mass region exclusions, or evidence (with luck)**
- **LHC: observation ability over the full mass range, plus property studies.**

The Higgs Boson

"Must" Exist

- Or, something *Higgs-like*...
- The current "Holy Grail" of HEP

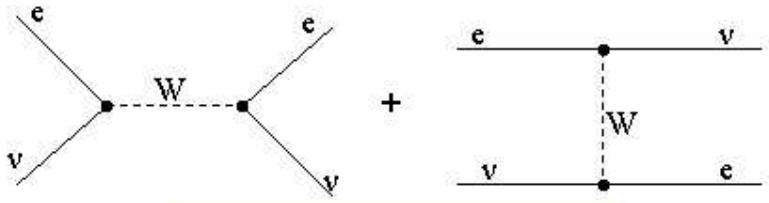
A Bit of History (W.I.)



Fermi Theory (~1935)
Point interactions violate unitarity at high energies

$(s \to \infty) \to \sigma(\nu e \to \nu e) \to (1/\pi)\, G_F^2\, s$

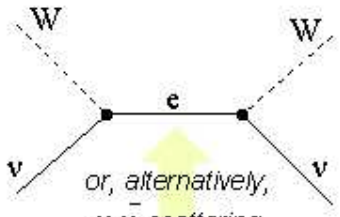
Problem avoided (~1955) with EM analogy, and introduction of a charged & massive vector boson

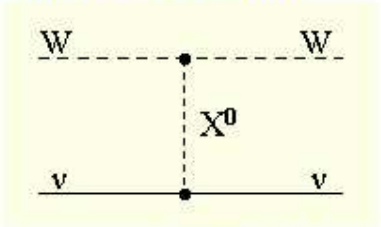


$\sigma(\nu e \to \nu e) \to (1/\pi)\, G_F^2\, M_W^2$

(has an upper bound)

But problem returns *e.g.* with ν-W scattering;



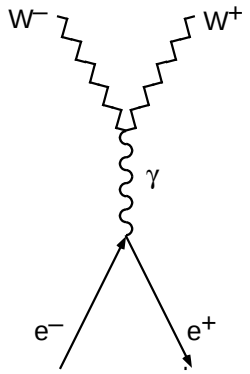


$\sigma(\nu W \to \nu W) \to (1/(3\pi))\, G_F^2\, s$

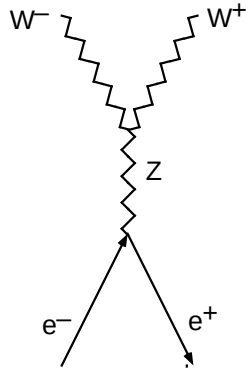
"cure" (~1960) with added neutral vector boson "X⁰"

- **And, jumping over the 70's (S.M.)**

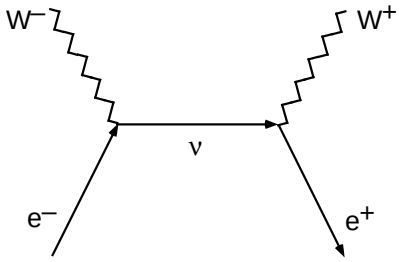
  consider now $e^+e^- \longrightarrow W^+W^-$



(a)



(b)

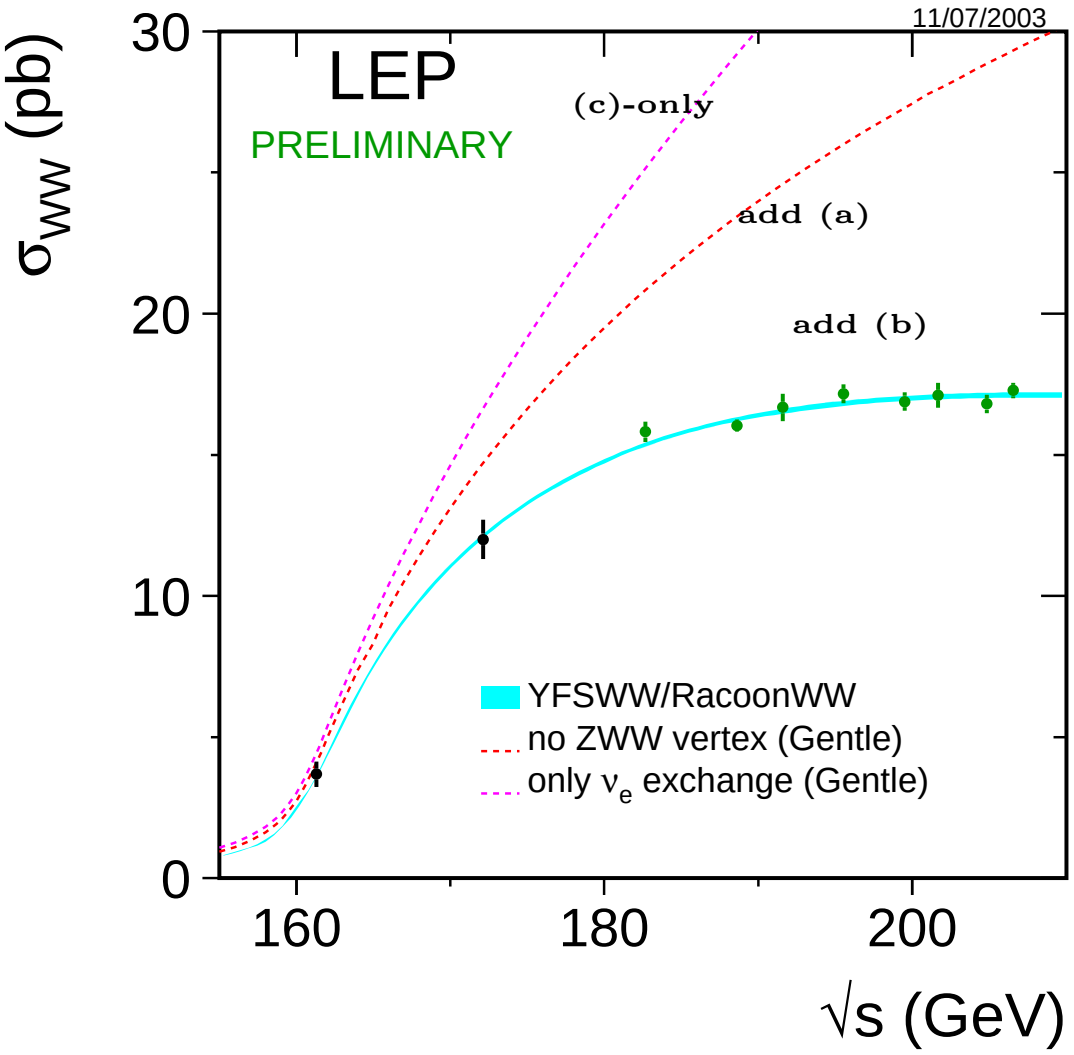


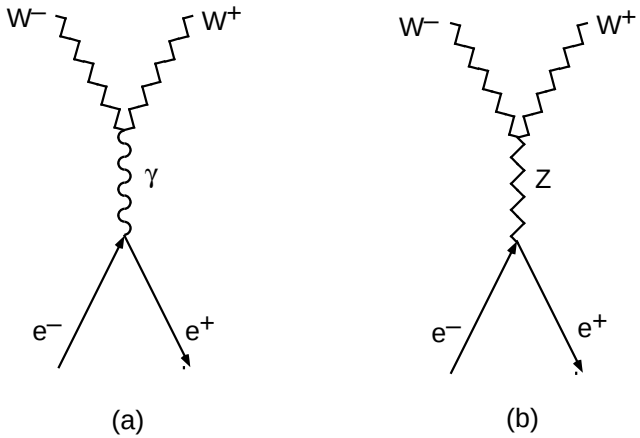
(c)

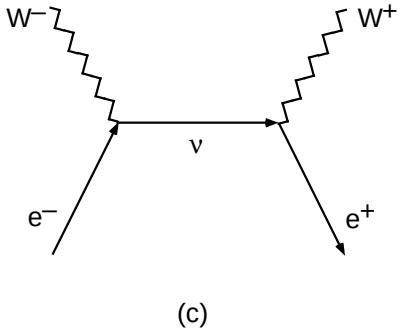
The *Standard Model* view

... and trilinear gauge couplings at work ...

And it Works Beautifully...







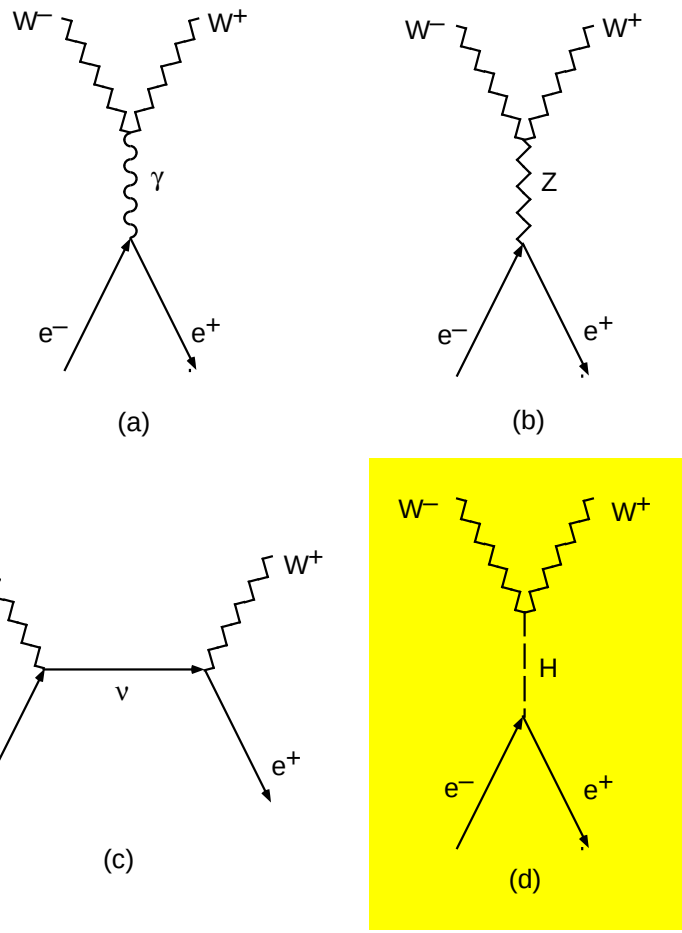
But... the original problem still persists... and is connected with MASS

Mass "Creates" a Problem

- **Because electrons have mass (and therefore exist in mixtures of (e_L) and (e_R) components), a $J = 0$ partial wave exists**
  - **which diverges as $\sqrt{s}$ for the production of longitudinally polarized boson pairs $(e^+e^- \longrightarrow W_\ell^+ W_\ell^-)$,**
  - **and again will break the unitarity bounds, only slower, at much higher energies (∼a few TeV).**

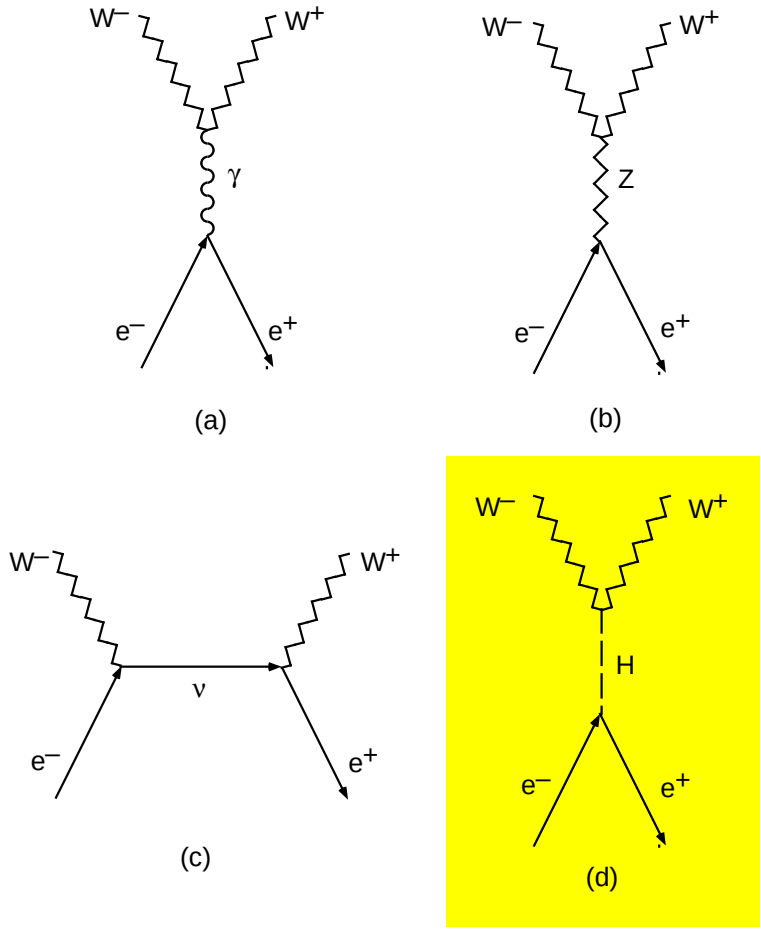
- **This divergence is *precisely cancelled* by an added neutral scalar boson exchange (d), *provided its couplings are proportional to the masses of the particles to which it couples.***

- **In other words, it *must* be a Higgs-like scalar boson.**



The Higgs Boson is the "Cure"

- **Fermion helicity flips (mixings) are proportional to the fermion masses and it is therefore necessary that the *S*-wave "cure" also be proportional to mass.**
- ***Electroweak Symmetry Breaking* (EWSB) is such that the potential problems created by the addition of a scalar Higgs boson are cured by its own coupling properties.**
- **This is a general result: the only theories of massive vector bosons with acceptable high energy limit behaviour are those that result from "spontaneously broken gauge theories".**



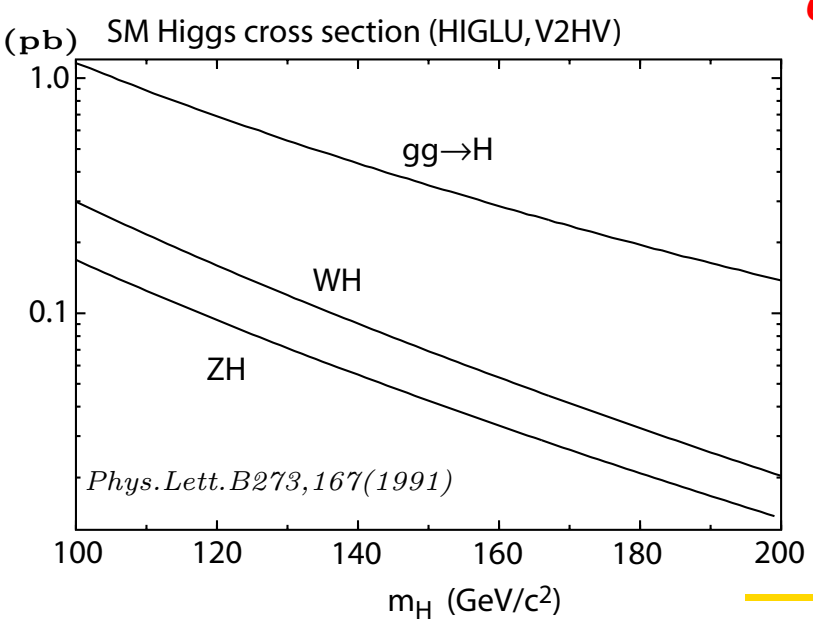
See the full $e^+e^- \to W^+W^-$ calculation in Peskin&Schroeder, p.157

Higgs Boson Searches

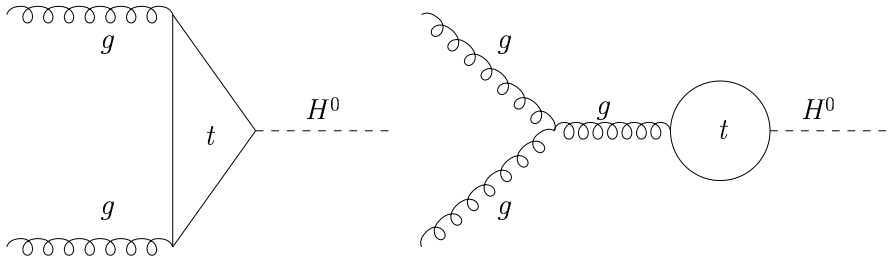
(mostly within the SM)

(I) Tevatron

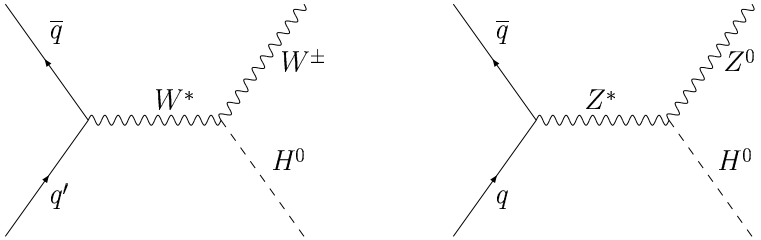
SM Higgs Production ($\overline{p}p$)



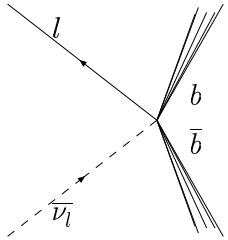
Gluon fusion, not visible for the low mass Higgs



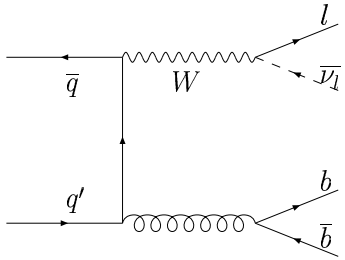
- ***Gluon Fusion*** *is the dominant cross section and roughly compares with inclusive* $t\bar{t}$ *production;*
  (light H); $\sigma_{gg\to H^0} \sim 1pb$ $\sigma_{t\bar{t}} = 7.6pb$



- *Gauge boson associated production is next highest, and provides a lepton signature*

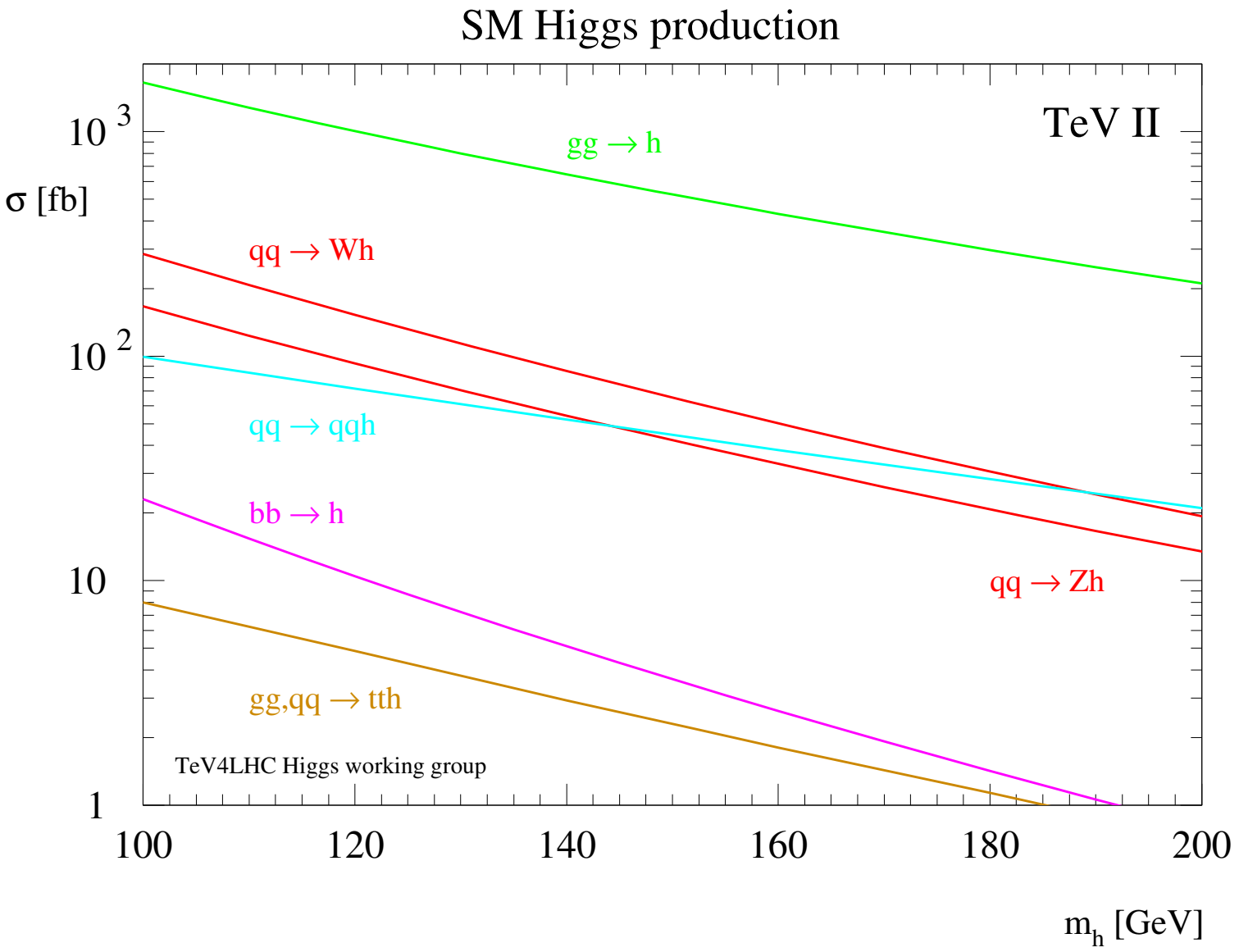


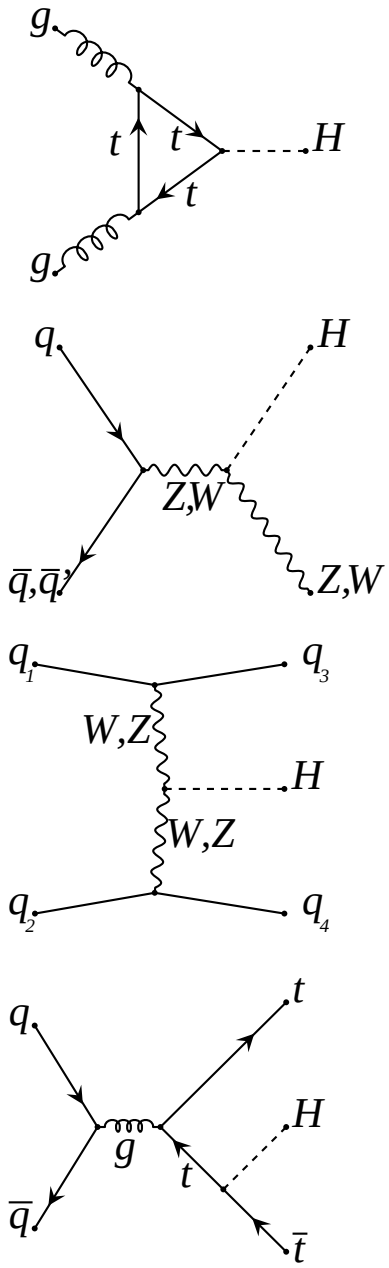
"signature"



example of irreducible background. $\sigma \sim 10^3$ *above*

SM Higgs Production ($\bar{p}p$) - more...





Two Distinct Strategies

- The "low mass" Higgs: $M_H < 135GeV$

  observation through

  $q\bar{q} \longrightarrow WH(ZH)\ ,\ H \rightarrow b\bar{b}$

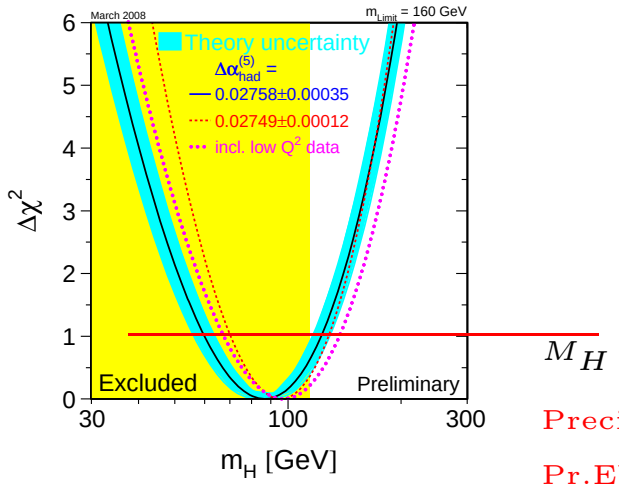
- The "high mass" Higgs: $M_H > 135GeV$

  observation through

  $gg \longrightarrow H$ with $H \rightarrow WW(ZZ)_{cleaner}$

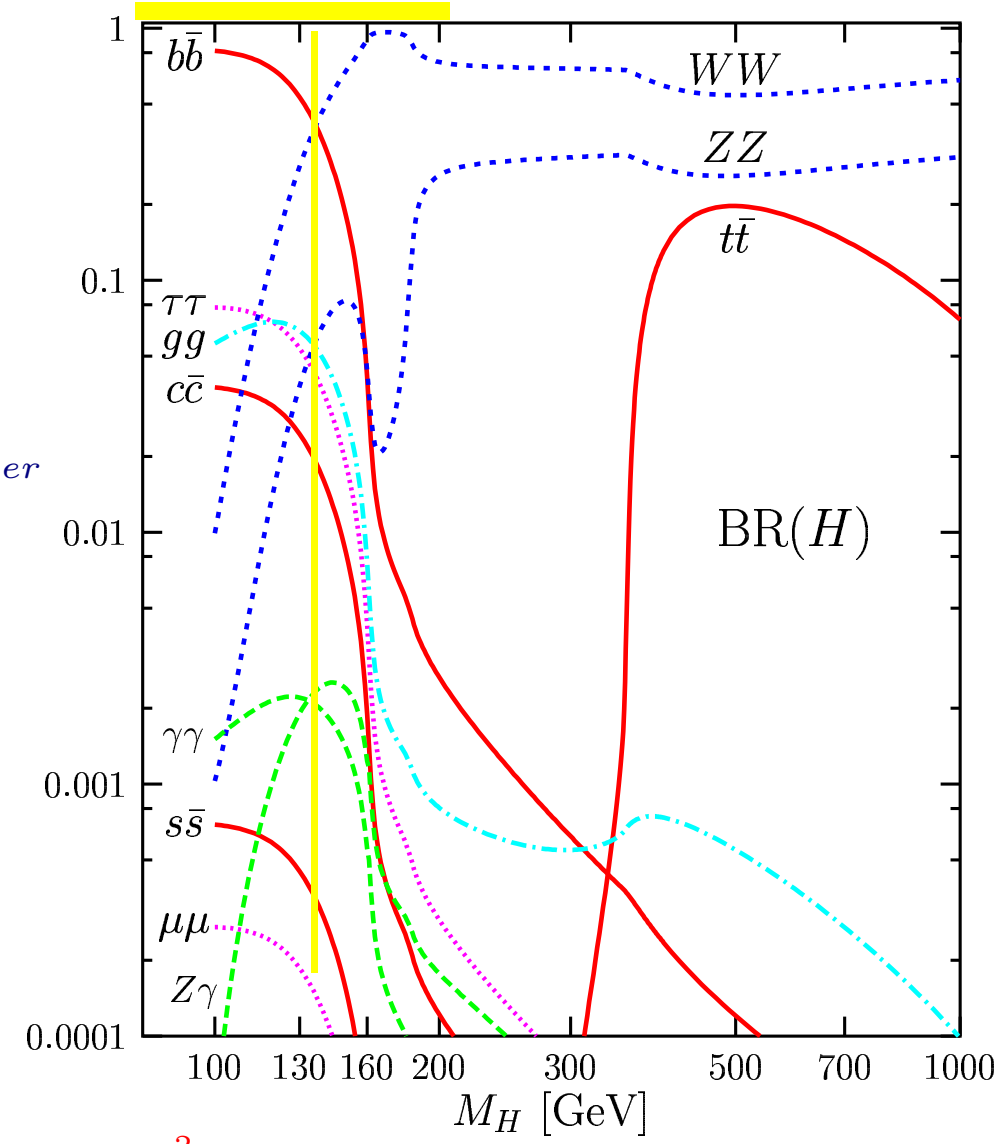
  $q\bar{q} \longrightarrow W^{\pm}H \longrightarrow W^{\pm}W^{+}W^{-}$

- The "low mass" option is preferred by EW precision measurements



LEPEWWG:
March 2008
at 68% CL;

$M_H = 87 + 36 - 27GeV$



Precision EW: $M_H < 160$ GeV/c^2 at 95% C.L.

Pr.EW+LEPlim: $M_H < 190$ GeV/c^2 at 95% C.L.

Panorama of DØ Analyses

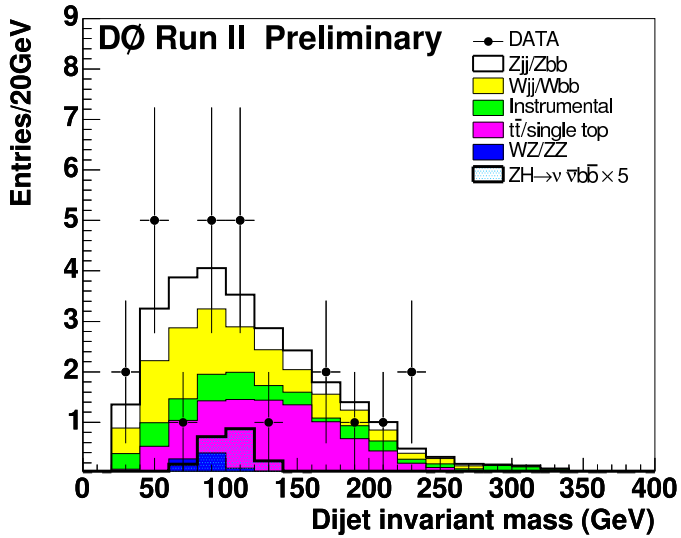
- The search range is $105 < M_H < 200$ GeV/c^2
- 15 final states, belonging to specific production and decay modes, to be combined. Samples are mutually exclusive after analysis selections. Contributing processes are:

production	**decay**		**obs.**
assoc: $W/Z + H$	$H \to b\bar{b}$	$\ell\nu, \not\ell\nu$ $\ell\ell, \nu\nu$	**NN b-tag** **(S & D)**
assoc: $W + H$	$H \to W^+W^-$	$\ell\nu + \ell\nu$	**SS lepton +** $\not\!\!E_T$
gluon fusion	$H \to \gamma\gamma$		**(mass peak)**
also V.B. fusion	$H \to W^+W^-$		**OS lepton +** $\not\!\!E_T$

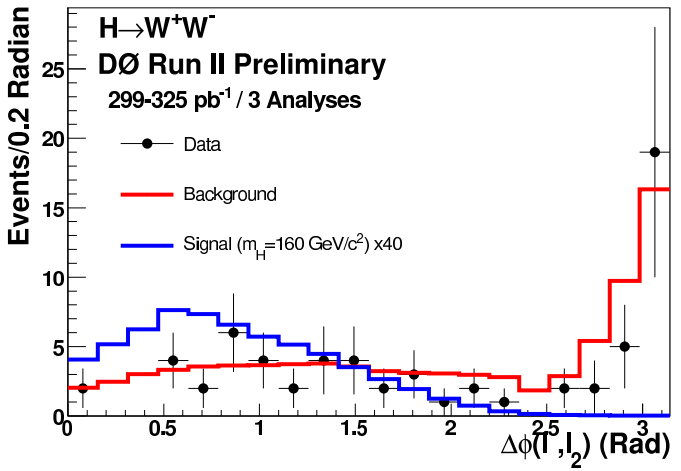
- Two epochs (different detectors, Runs IIa and IIb) are separately analyzed: a total of 25 individual analyses !!
- For each analysis, a "final variable" (normally a NN or DT) is built from discriminants, and measures the *higgsness* of the sample

Example Discrimination Variables

- "Low Mass" ($H \to b\bar{b}$)
  - isolated lepton(s)
  - two jets + $\not\!\!E_T$
  - single/double b-tags
  - NN b-tagging
    - track IP in jet
    - 2nd Vtx in jet
    - lepton in jet
  - discrimination variable: (b-)dijet mass

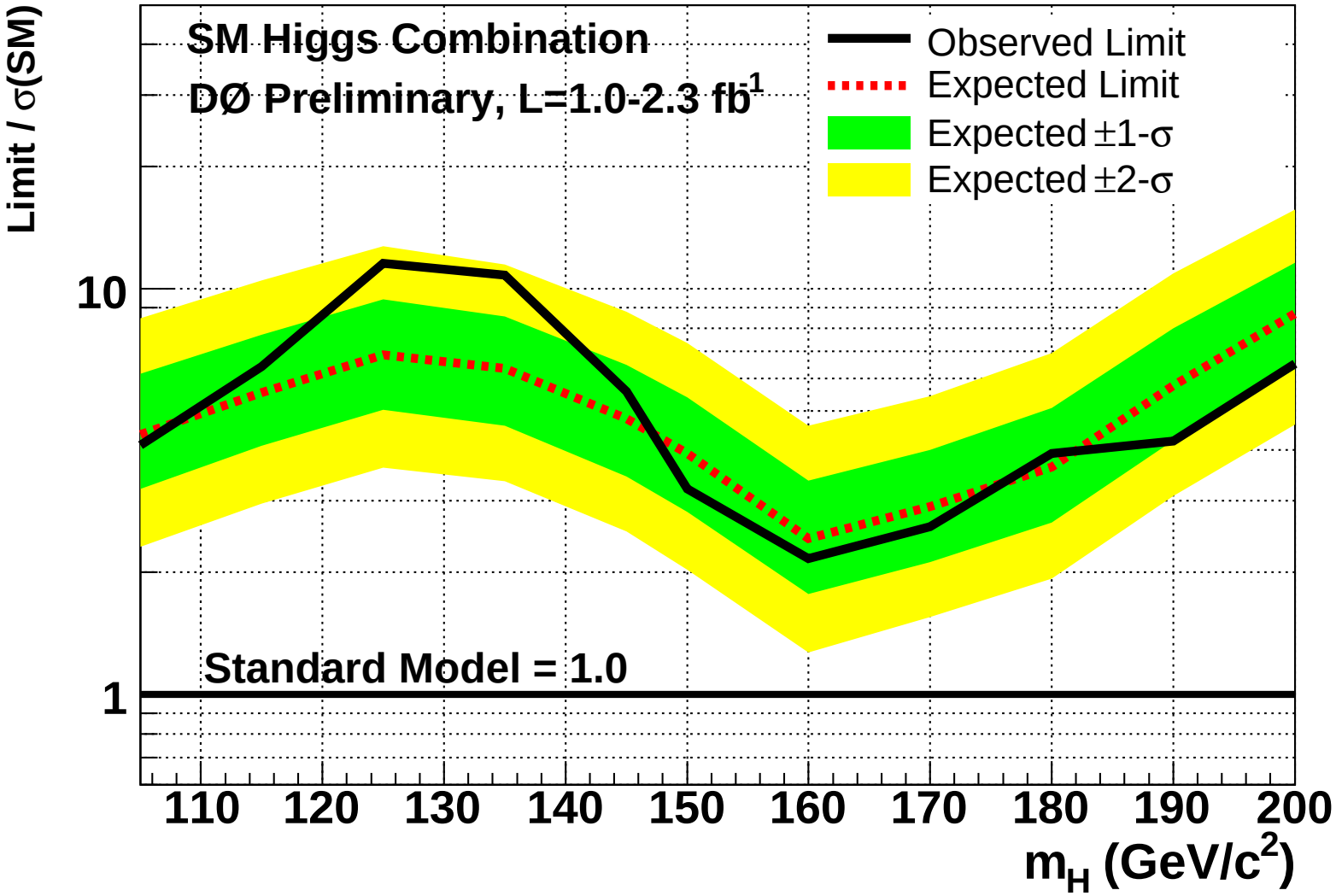


- "High Mass" ($H \to W^+W^-$)
  - high $\not\!\!E_T$
  - two OS isolated leptons
  - discrimination variable: azimuthal $\Delta\phi(\ell^+\ell^-)$



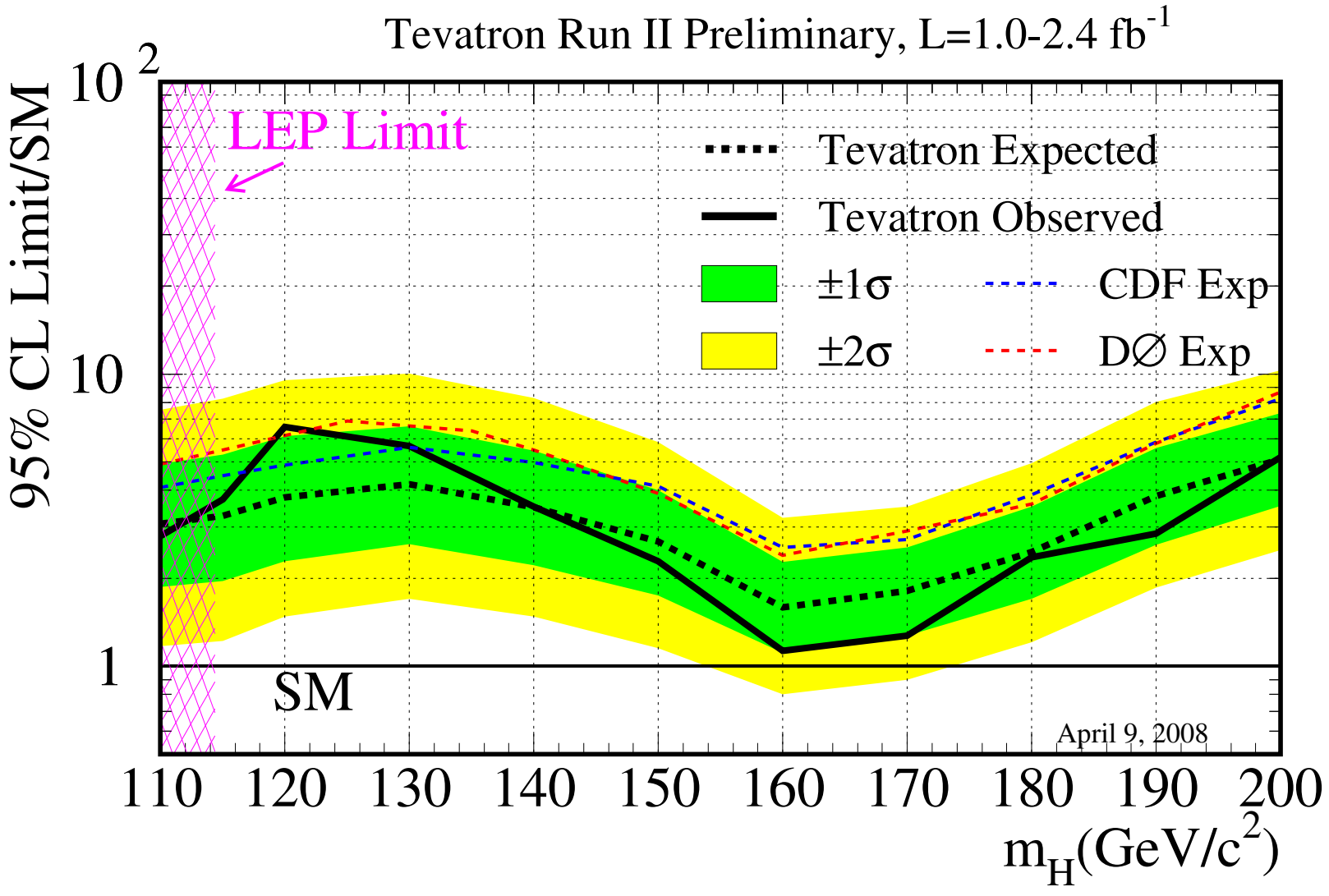
Tevatron Search Results – March'08, DØ-only

The SM prediction will be excluded at the 95% C.L. whenever the observed limit line falls below unity.



Tevatron Search Results - April'08, DØ+CDF

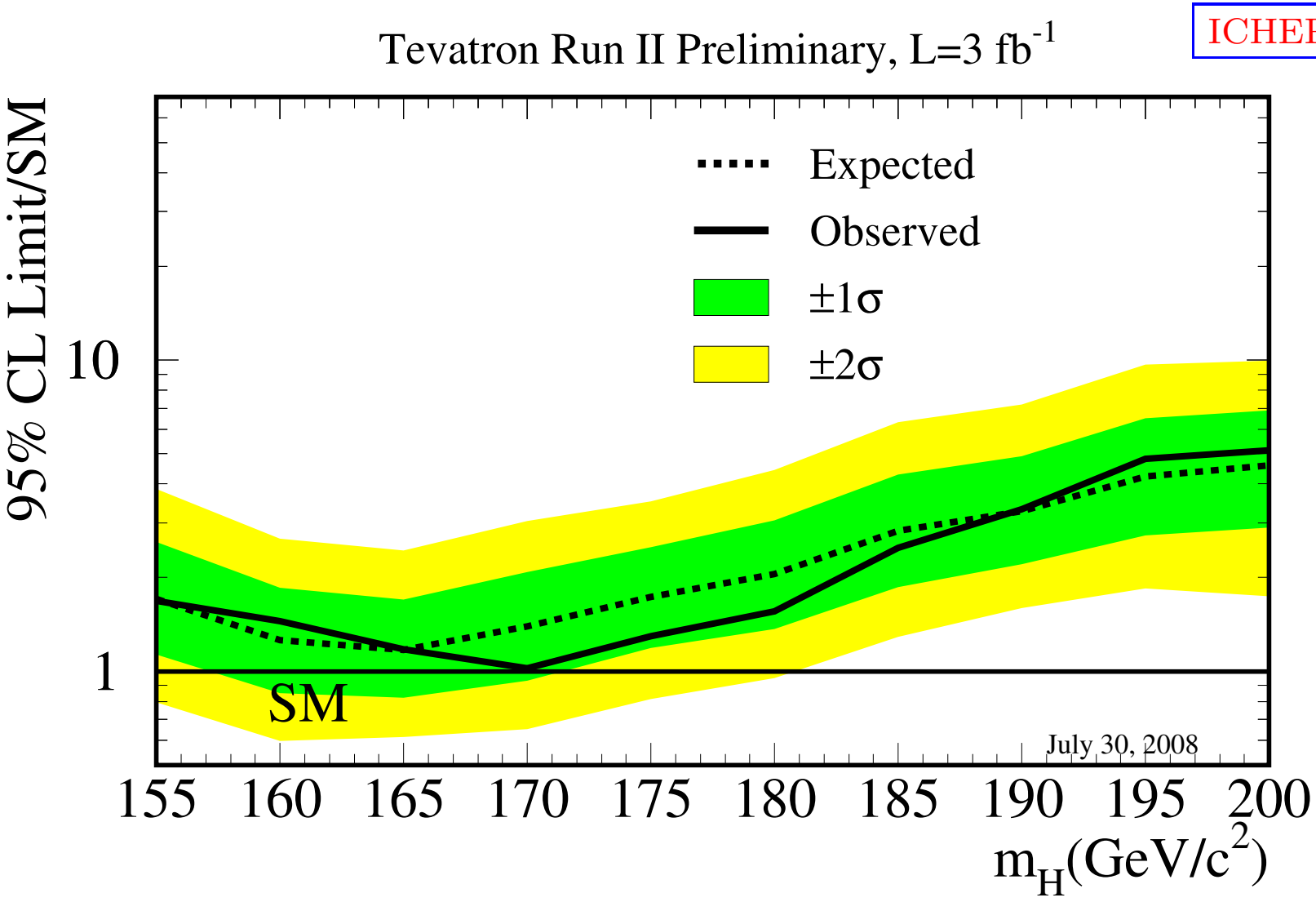
Both experiments have the same sensitivity
– an effective doubling of the data sample.



Tevatron Search Results – July'08, DØ+CDF

http://tevnphwg.fnal.gov/ **the "high mass" end; $H \to W^+W^-$**

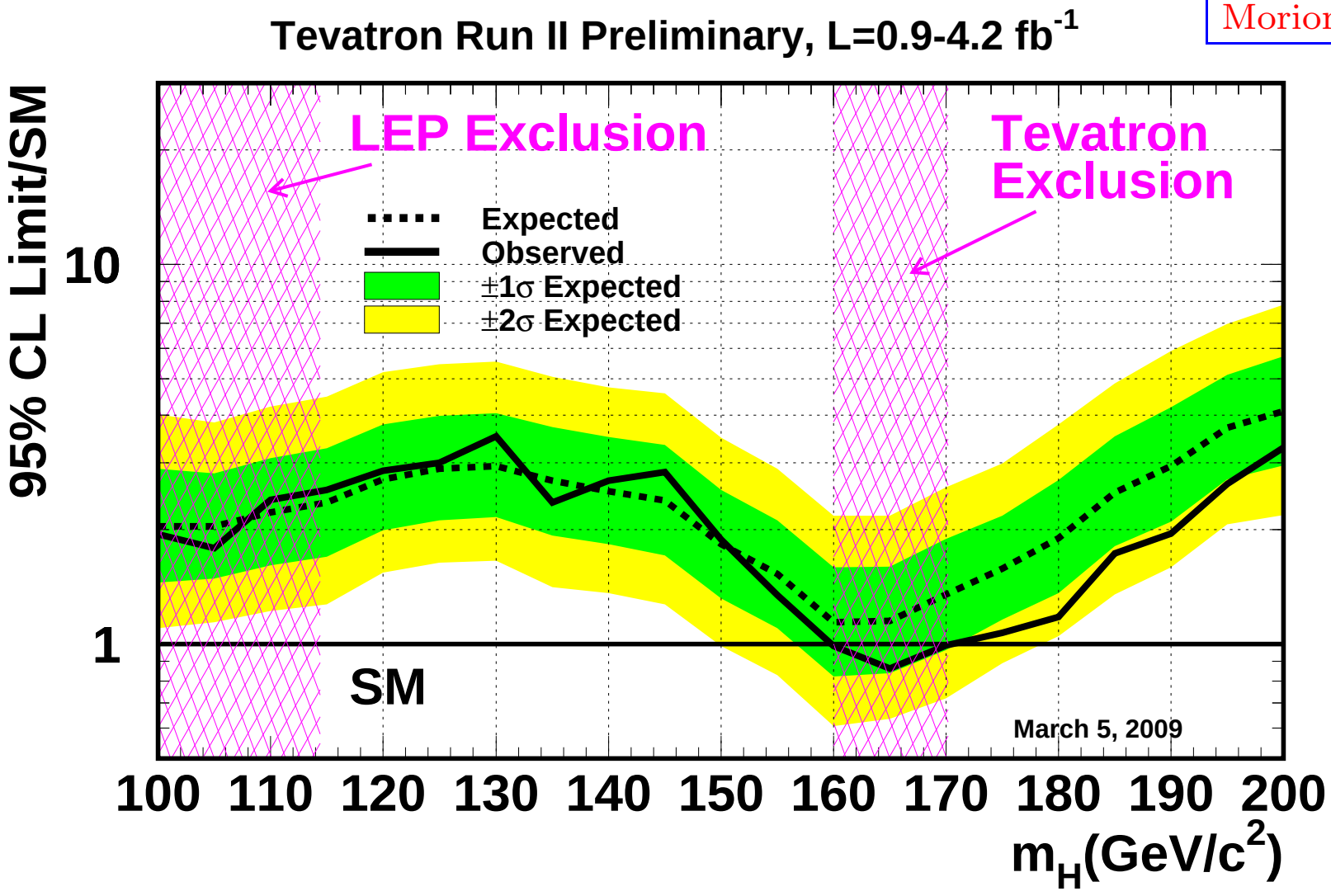
ICHEP-2008



Tevatron Search Results – March'09, DØ+CDF

arXiv:0903.4001

Moriond-2009

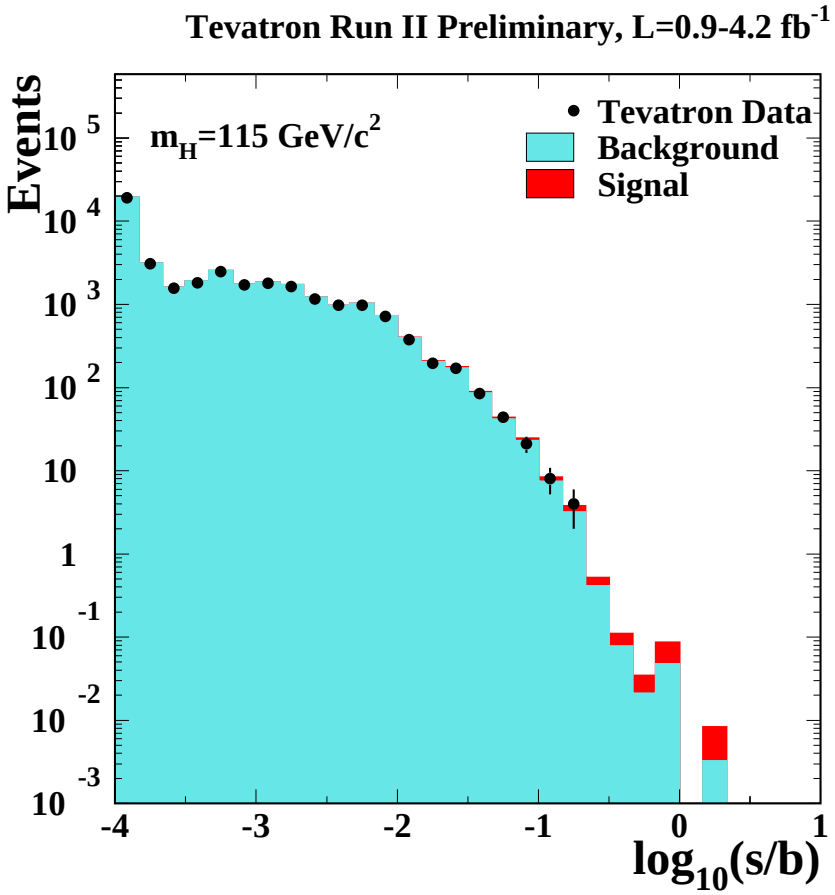


Overall Log-Likelihoods – March'09, DØ+CDF

arXiv:0903.4001

Moriond-2009

the "low mass" end; $H \to b\bar{b}$



the "high mass" end; $H \to W^+W^-$