Higgs Results from the Tevatron

quark - lepton
Vancouver, Canada, 28August-1September 2011

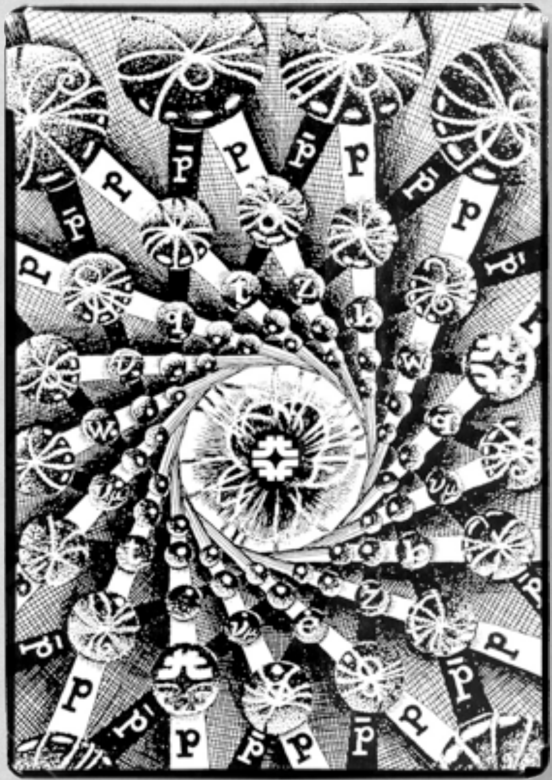
Jacobo Konigsberg
Univ. of Florida

Outline

- Today
- How did we get here
- What's next

Preamble

- The Tevatron will shut down on September 30th
- After 10 & 1/2 years of continuous running
  - 26 years since 1st collisions...
- It has been an incredibly rich program
  - Elucidating the top quark
  - Discovery of Bs-oscillations,
    new B-baryons, rare B-meson decays
  - Stringent tests of CP-violation & asymmetries
  - Precision EWK and QCD measurements
  - Myriad of tests for new physics
- An then there is the Higgs...



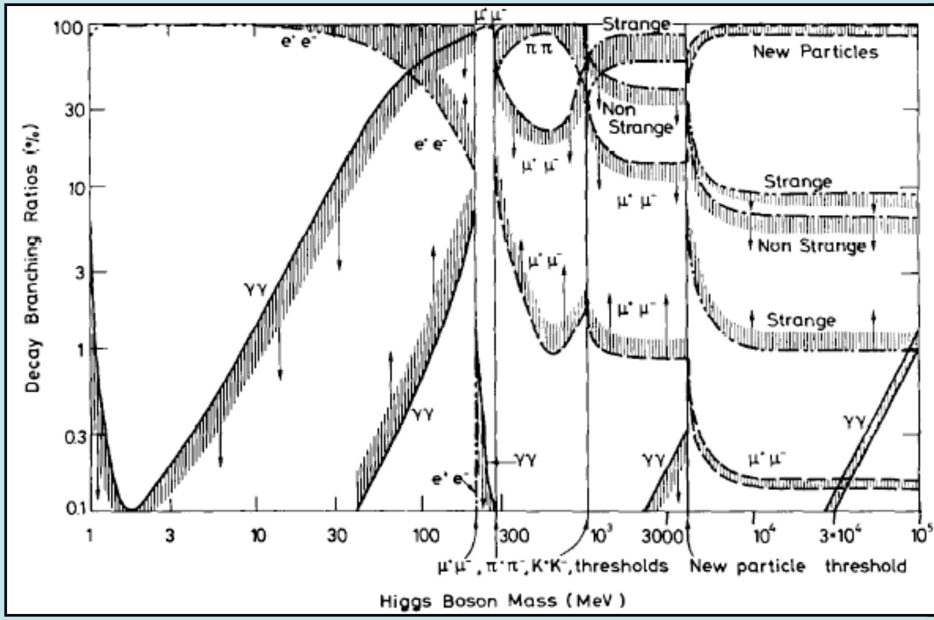
A PHENOMENOLOGICAL PROFILE OF THE HIGGS BOSON

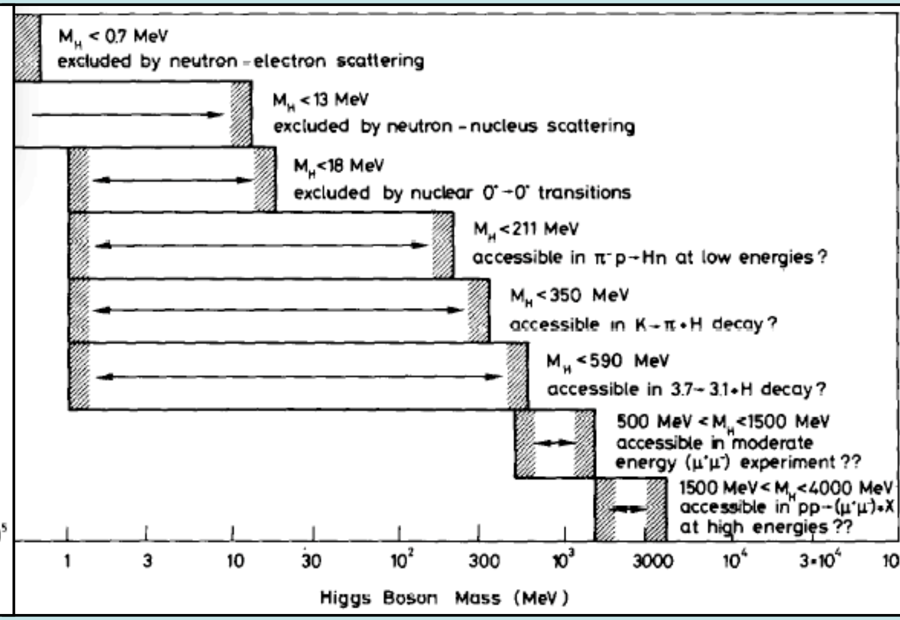
John ELLIS, Mary K. GAILLARD * and D.V. NANOPOULOS **
CERN, Geneva

Received 7 November 1975

From J. Ellis @
Higgs Hunting Workshop

- Higgs decay modes and searches in 1975:

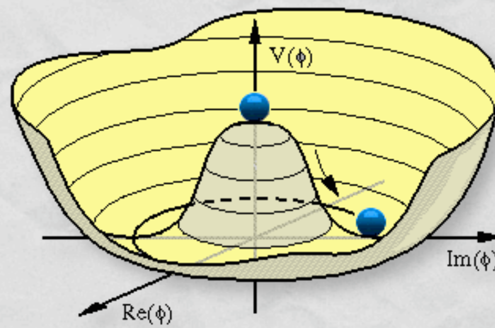


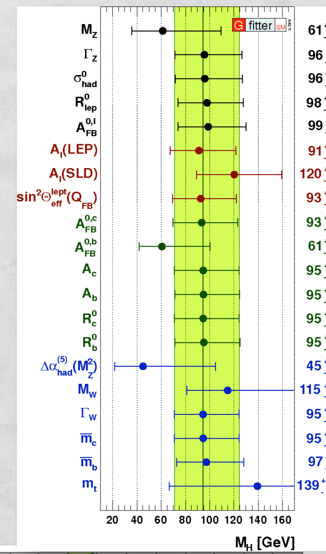


We should perhaps finish with an apology and a caution. We apologize to experimentalists for having no idea what is the mass of the Higgs boson, unlike the case with charm [3,4] and for not being sure of its couplings to other particles, except that they are probably all very small. For these reasons we do not want to encourage big experimental searches for the Higgs boson, but we do feel that people performing experiments vulnerable to the Higgs boson should know how it may turn up.

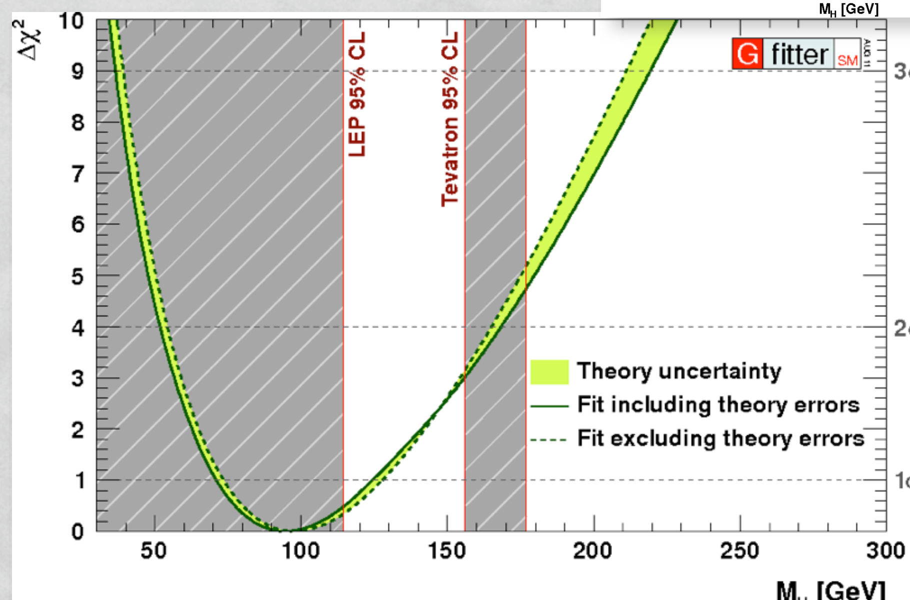
The SM Higgs today

- EWK symmetry breaking darling. Mass generating scalar field.
- Couplings proportional to particle mass

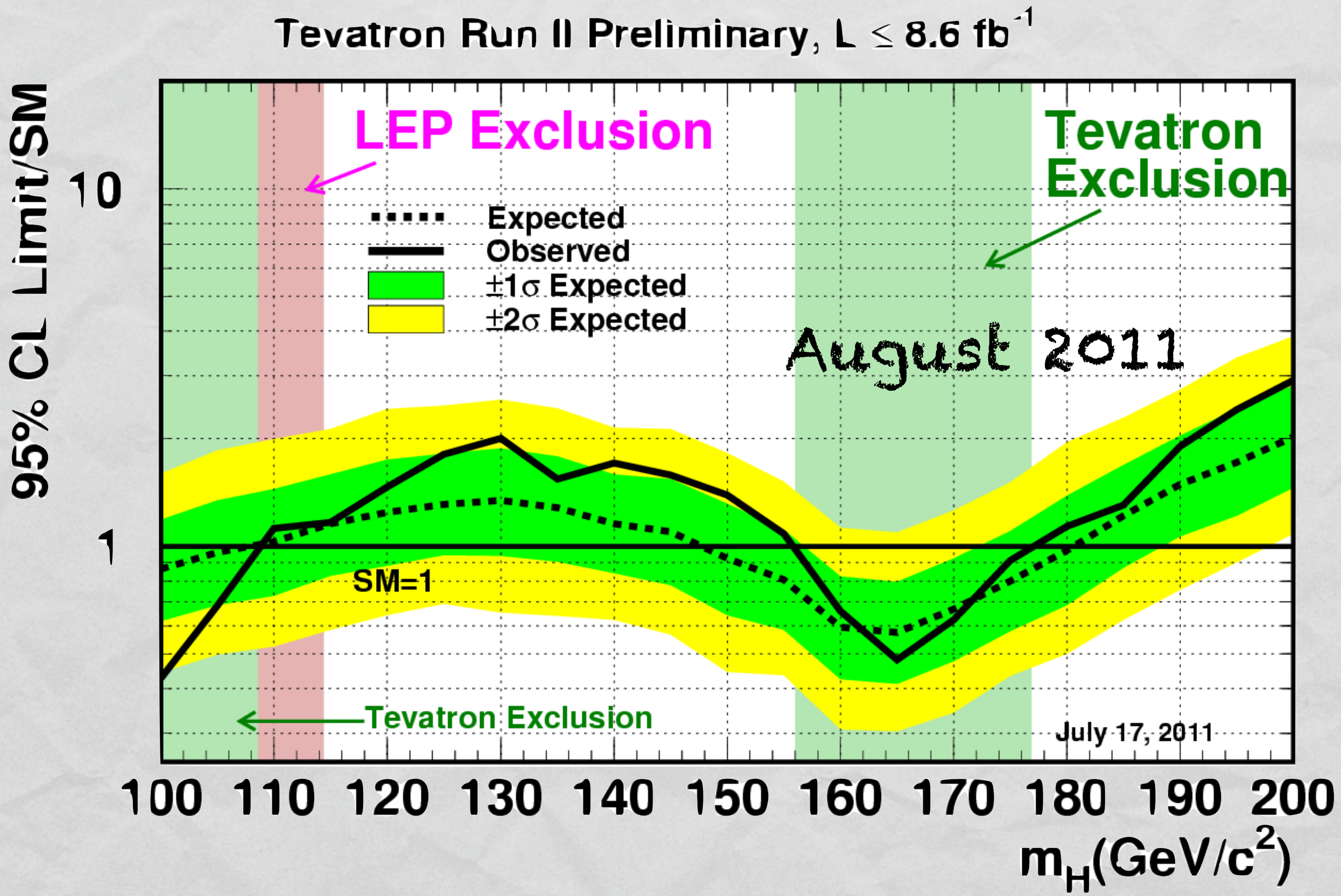




- Higgs mass still unknown but strongly constrained
- Yes, a couple of “big experimental searches” are ongoing...



Let's start at the end...



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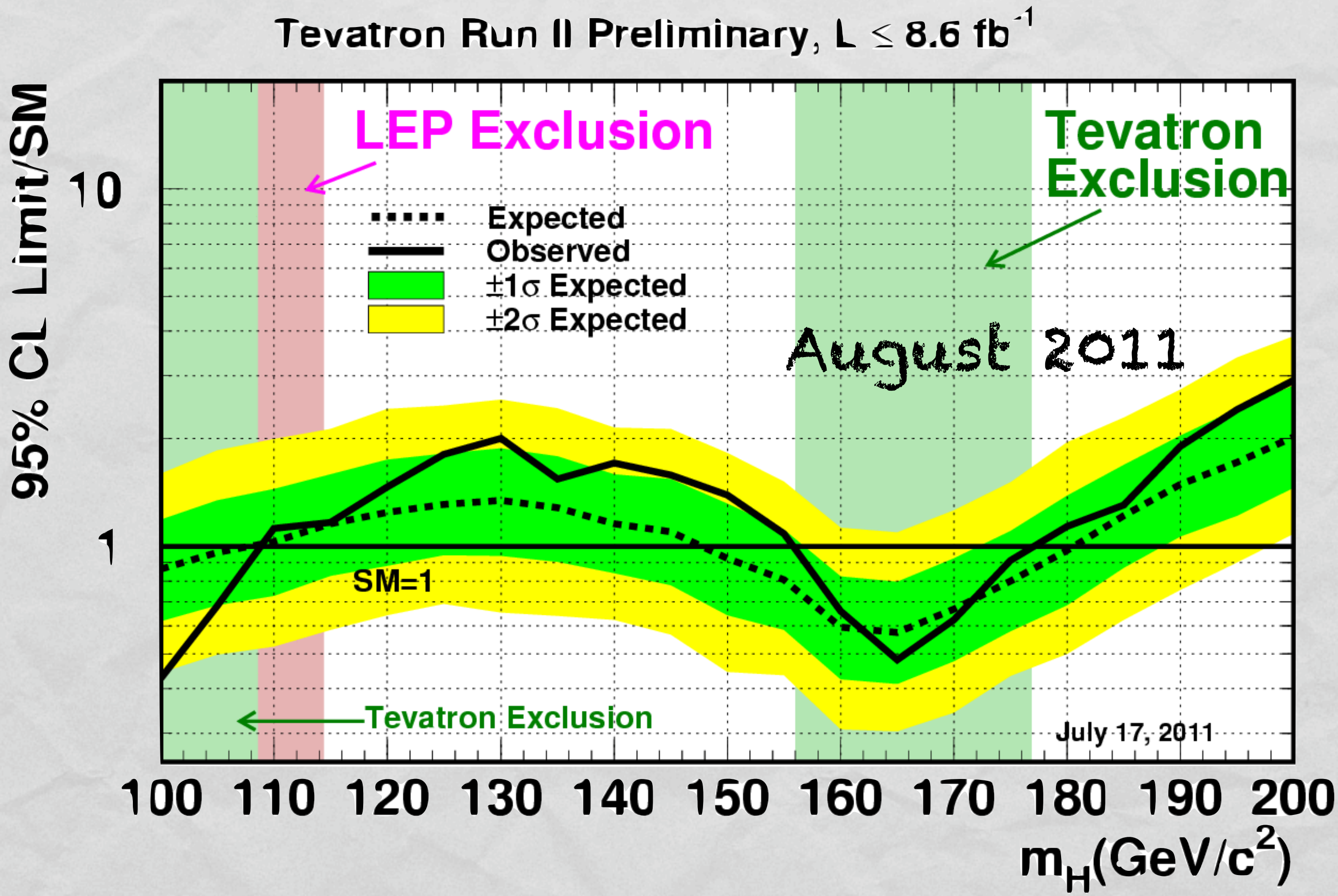


The first exclusions of Higgs mass values since the LEP era came from the Tevatron

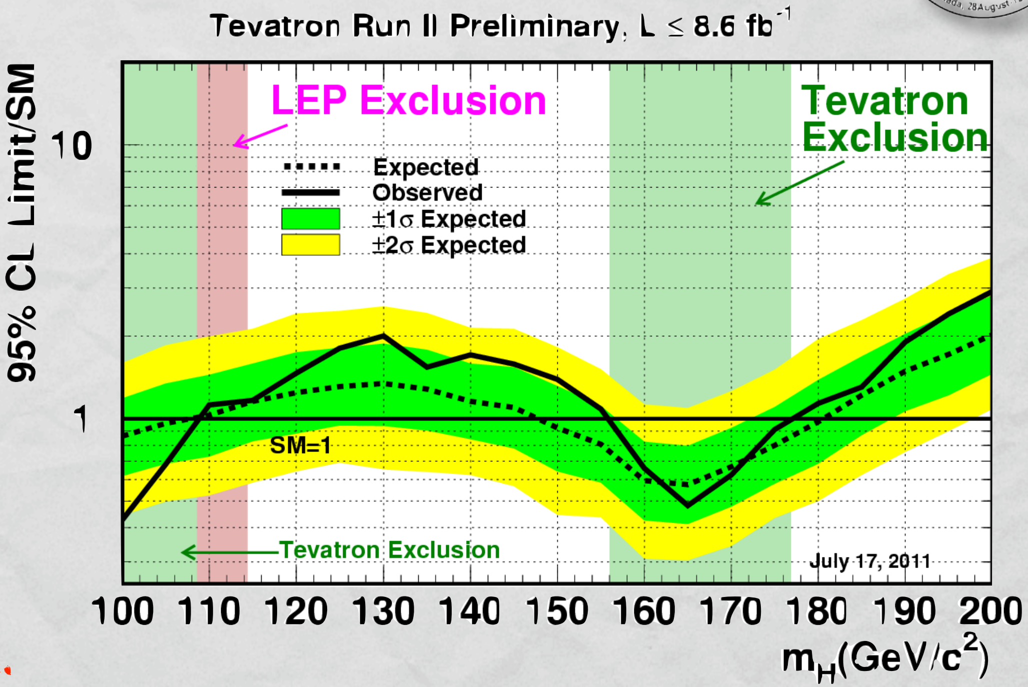
Deconstruction

95% CL upper cross section limit, relative to the SM cross section; vs. Higgs mass.

If R<1.0 the SM cross section value is excluded for those masses

---- is the "expected sensitivity", the median over many simulated experiments. The green/yellow bands are the 1/2-sigma in the distribution.

—— is the observed limit from the one experiment performed



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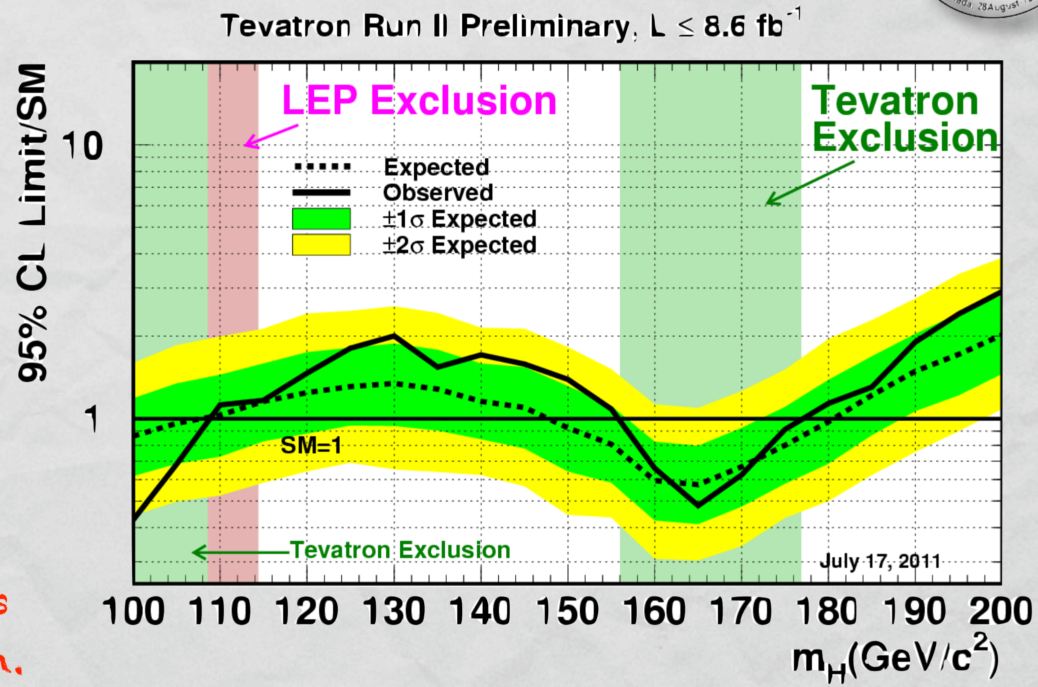

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100-109 and 156-177 GeV

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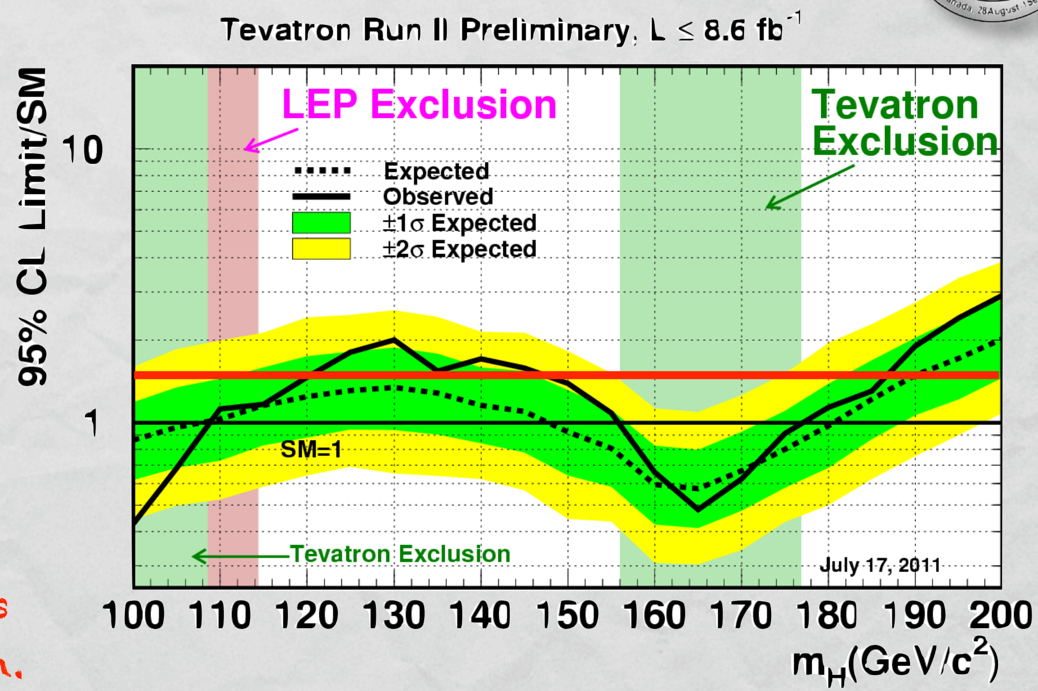

Observed exclusion:
100-109 and 156-177 GeV

Current sensitivity is below x1.5 SM from 100-190 GeV !

At MH=115 GeV
R @ x1.1 SM cross section

Deconstruction

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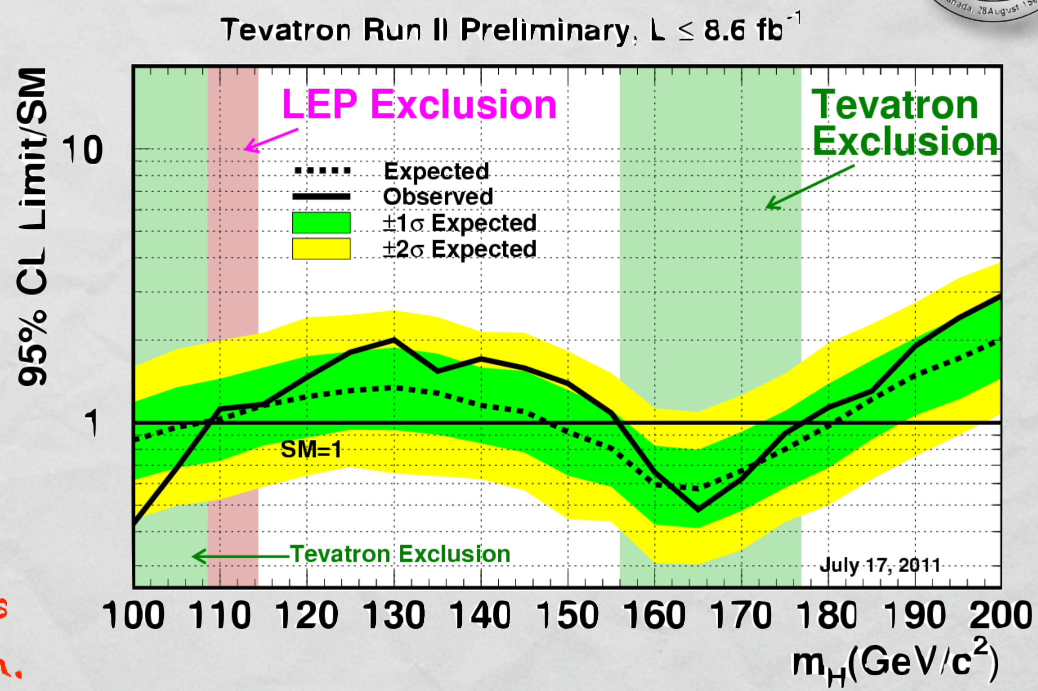

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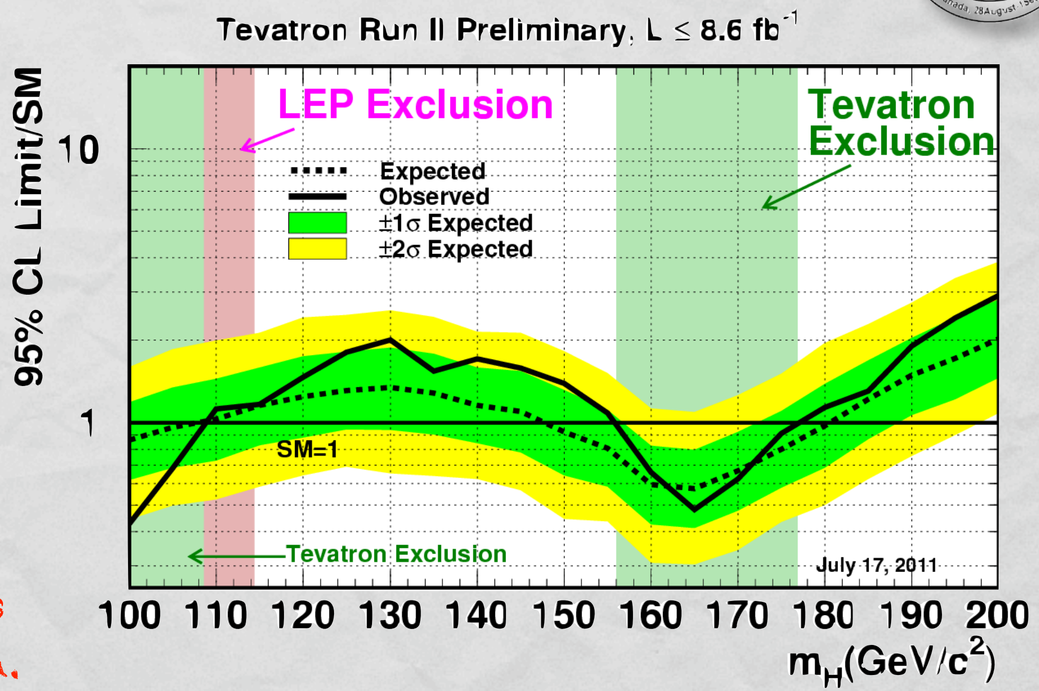
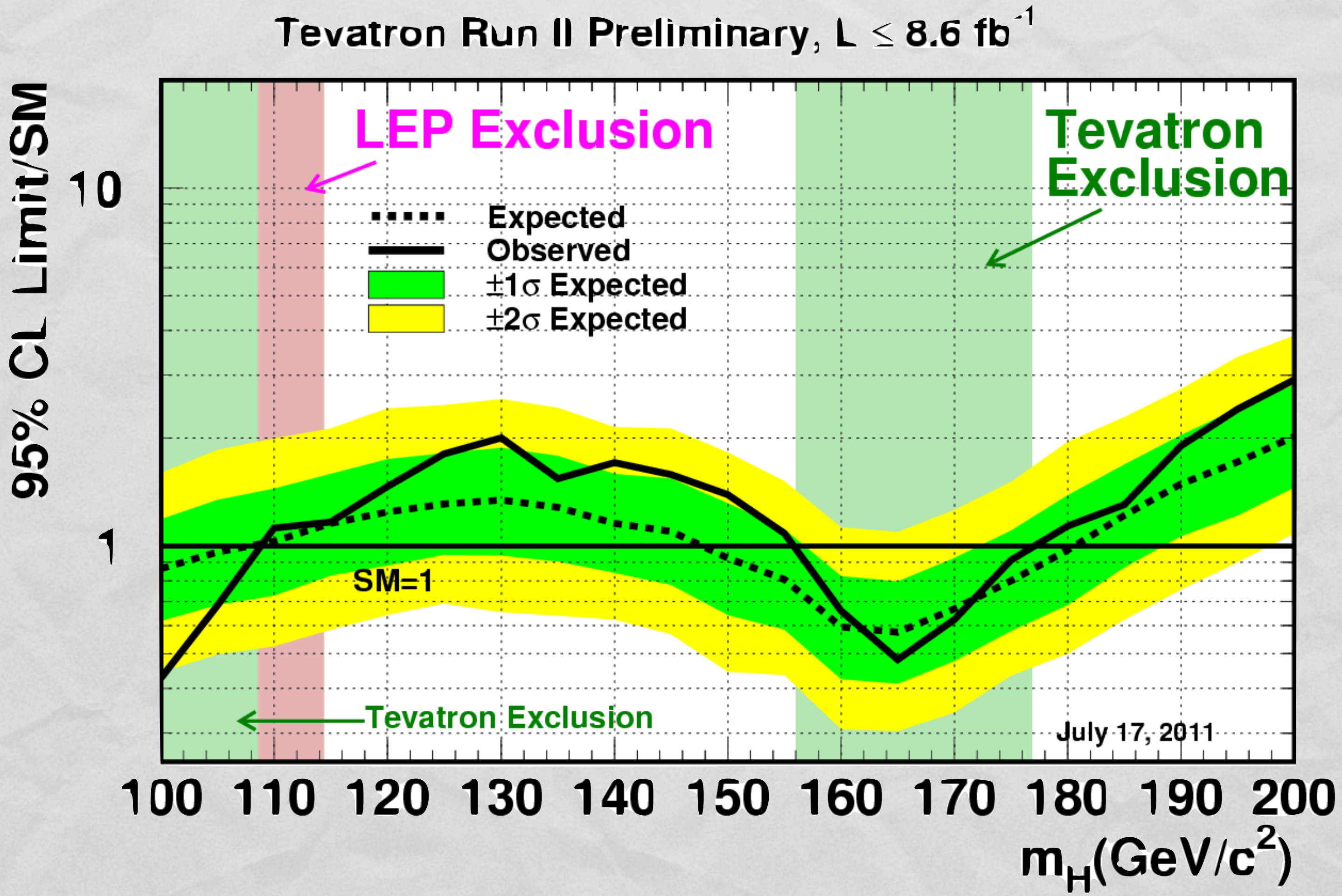


Observed exclusion:
100-109 and 156-177 GeV

A remarkable realization: given enough luminosity, the Tevatron could have fully explored the SM Higgs territory

How did we even get here ?



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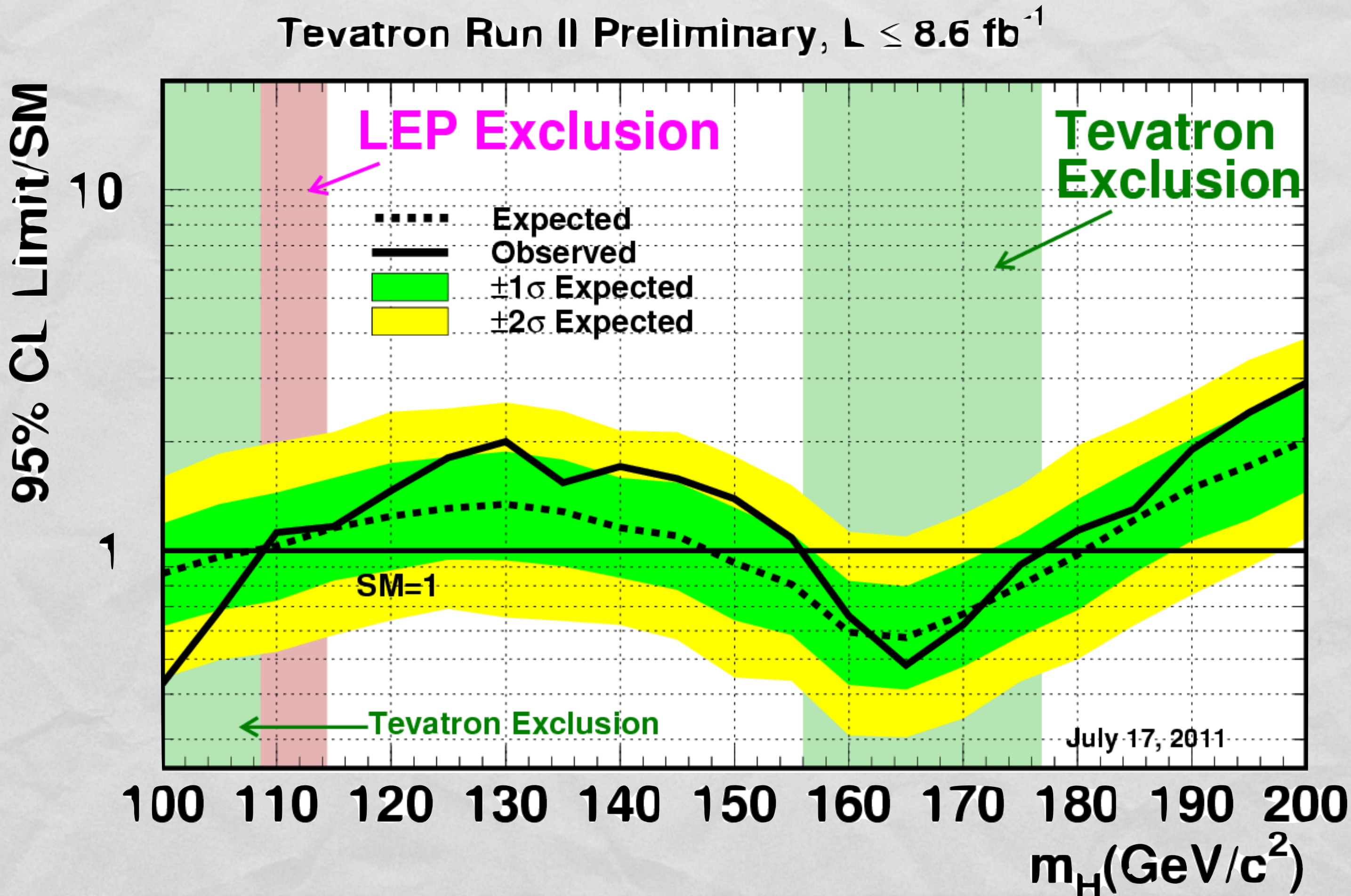
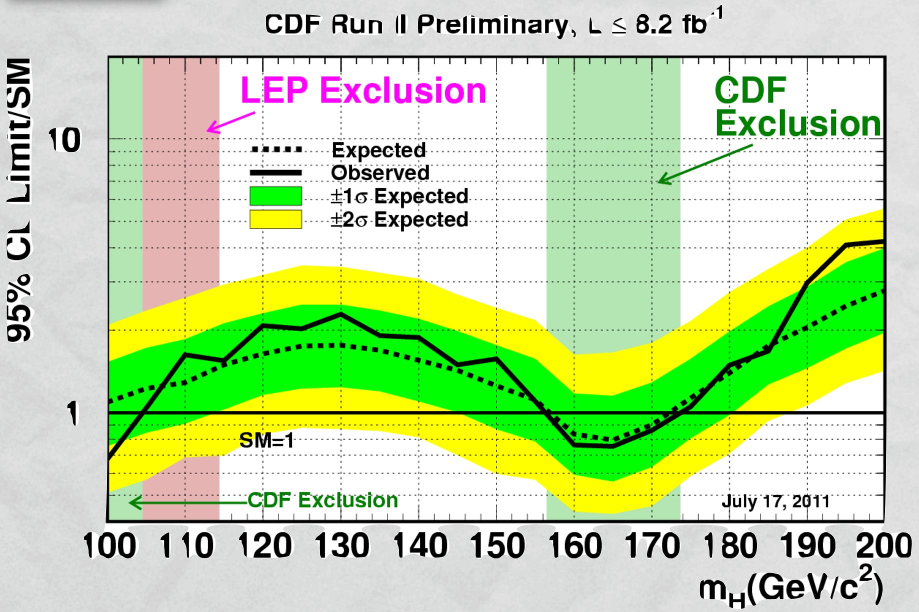


Several key factors

Key: combination of CDF & DO results



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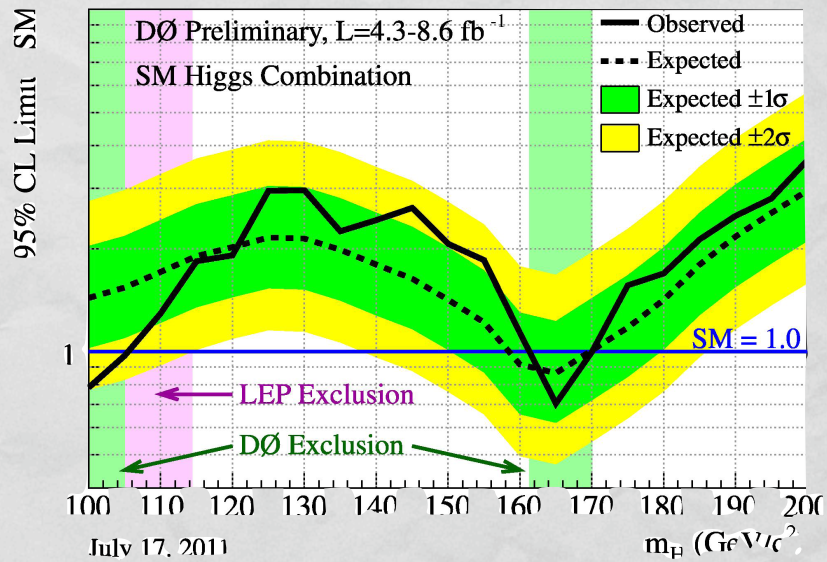

Similar sensitivities & similar observations

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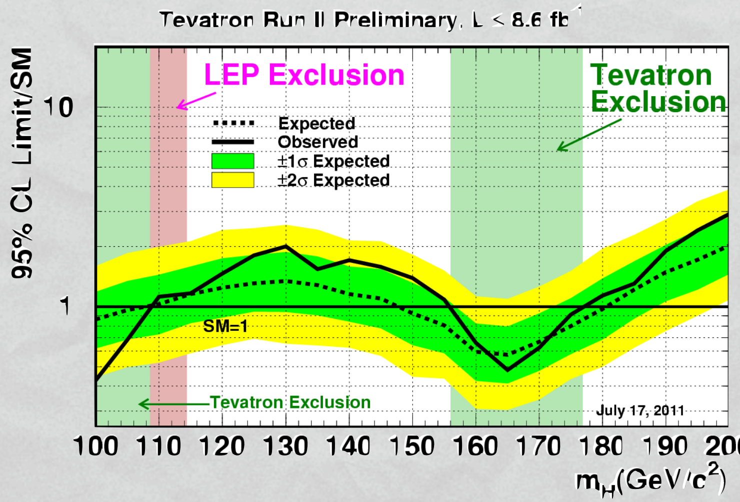

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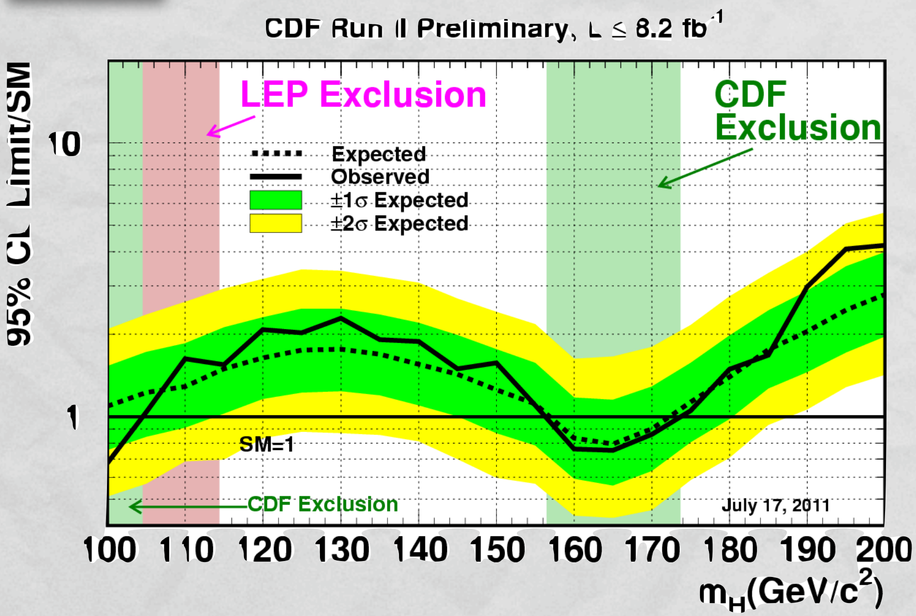

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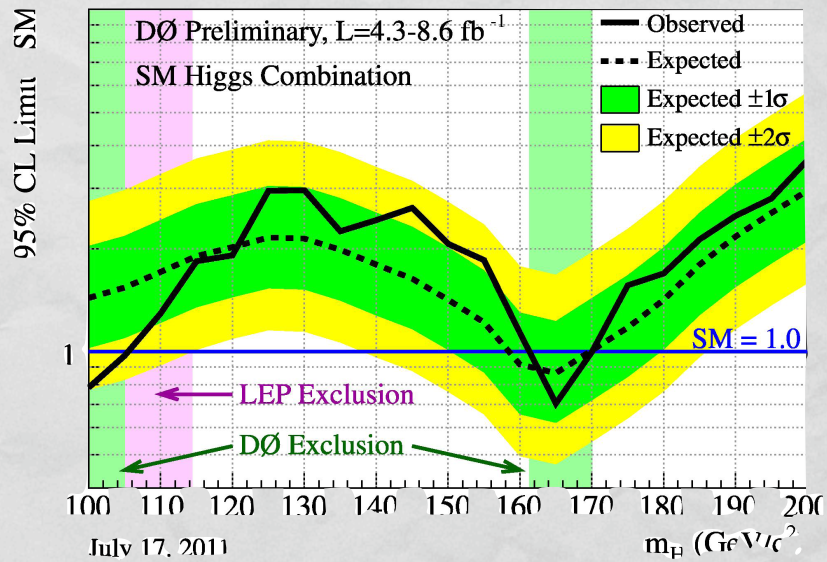

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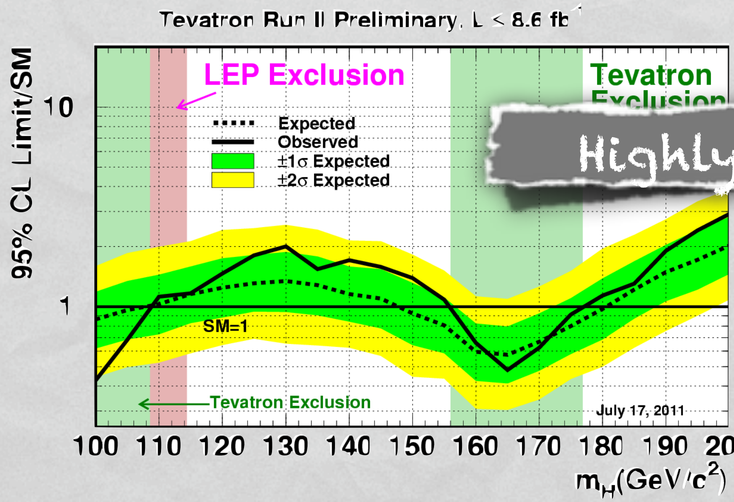
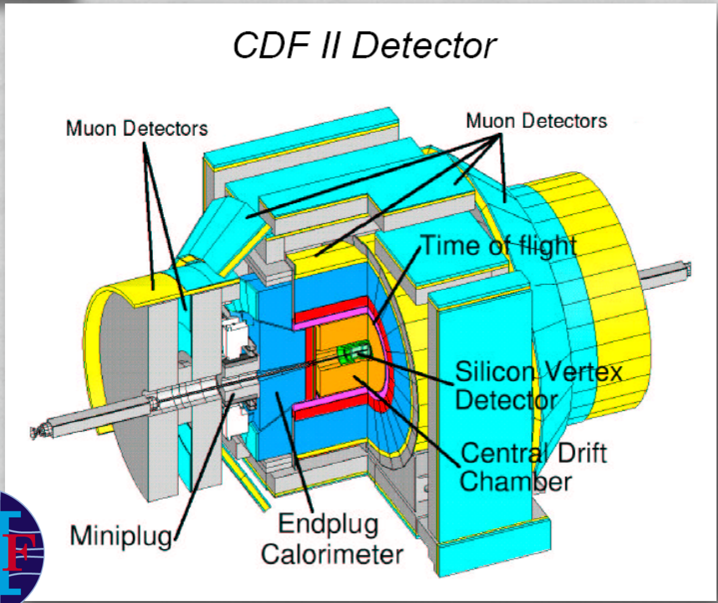


Highly non-trivial

Key: two multi-purpose detectors



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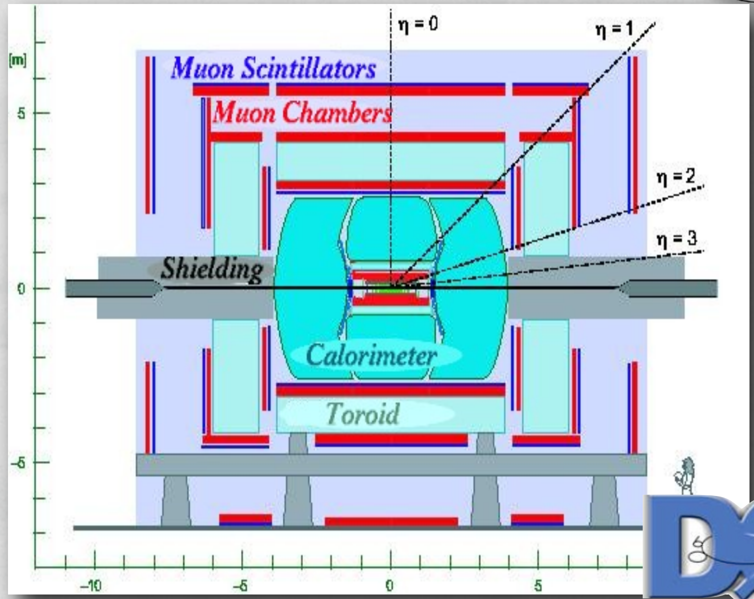

Precision measurement: trks, e, mu, tau, photons, jets, hf, met

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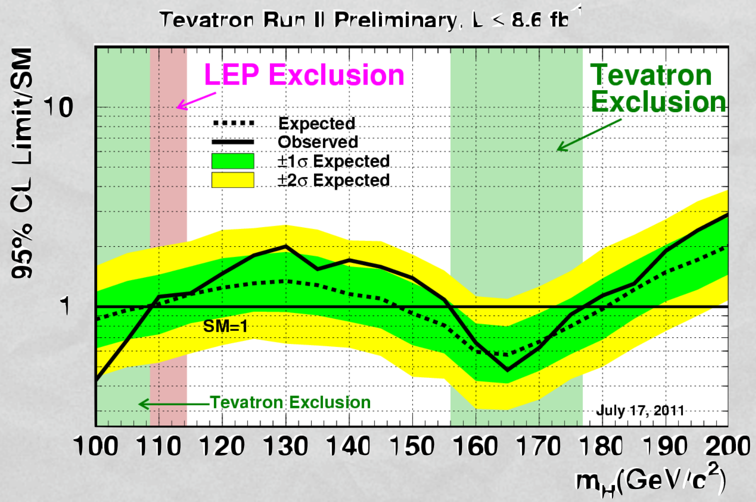
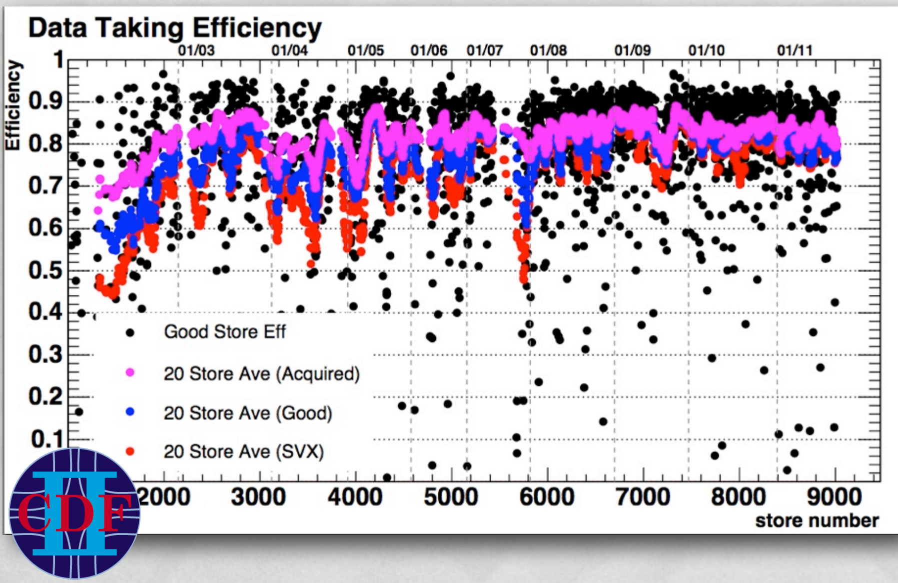


Key: long term operations



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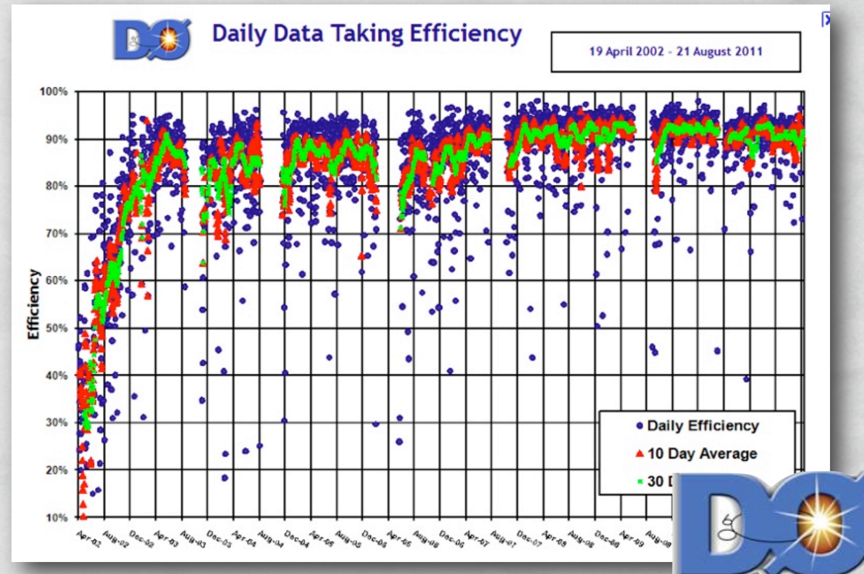

10.5 years of stable operations @ ~85% efficiency

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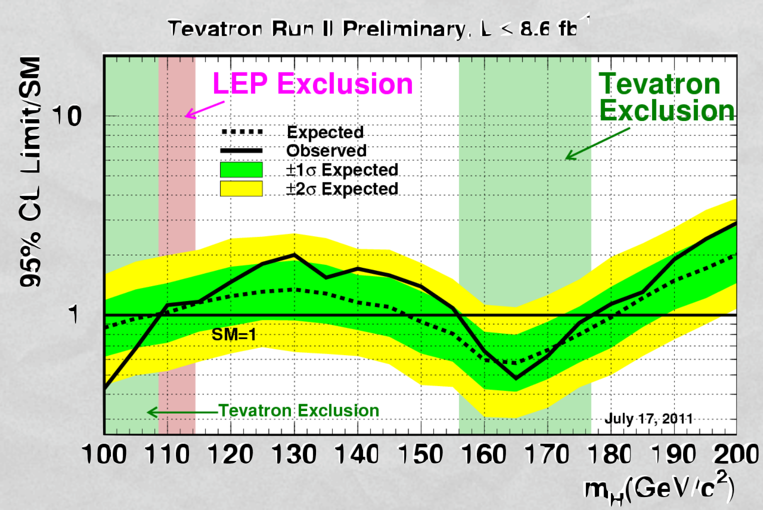
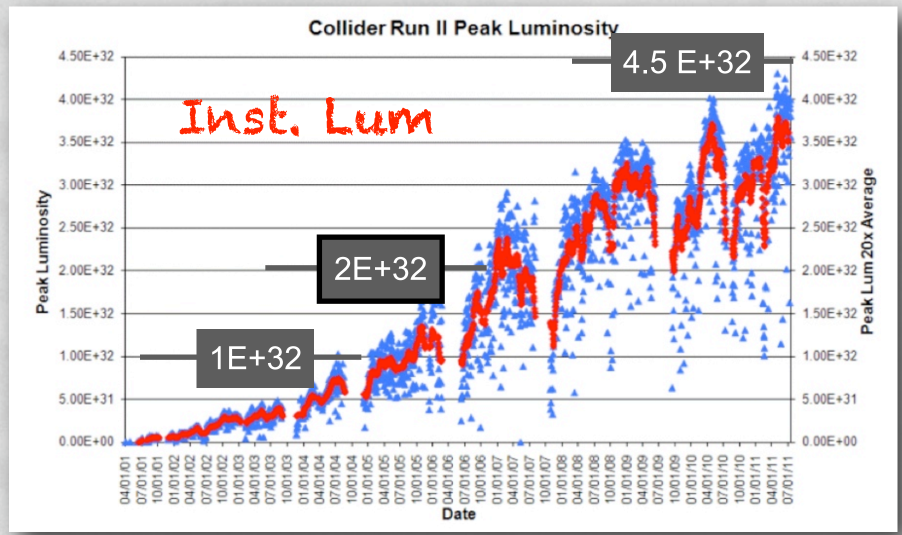


Key: luminosity



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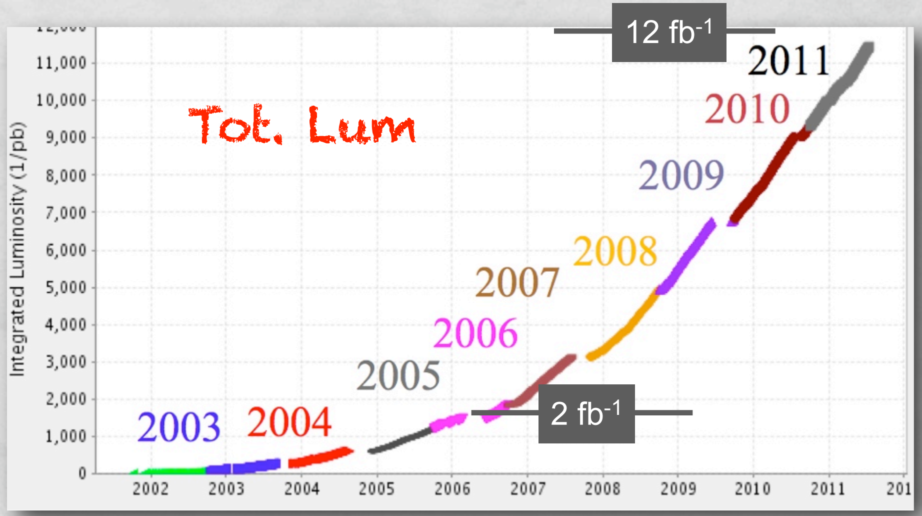

10.5 years of lum improvements, inst & total

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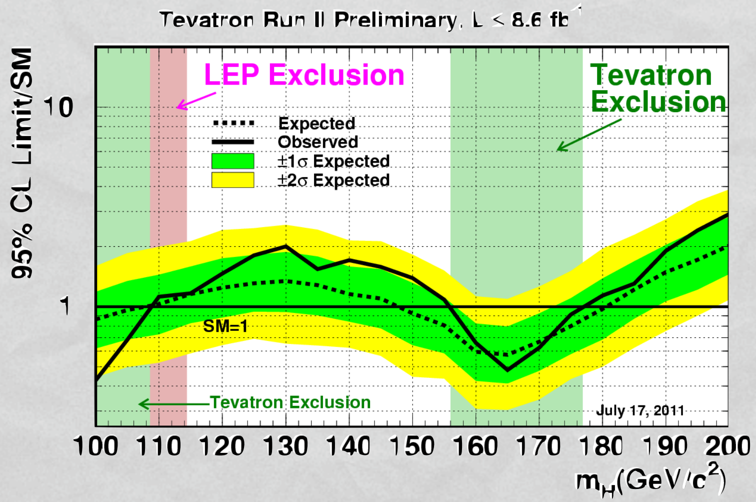
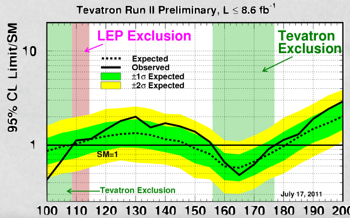
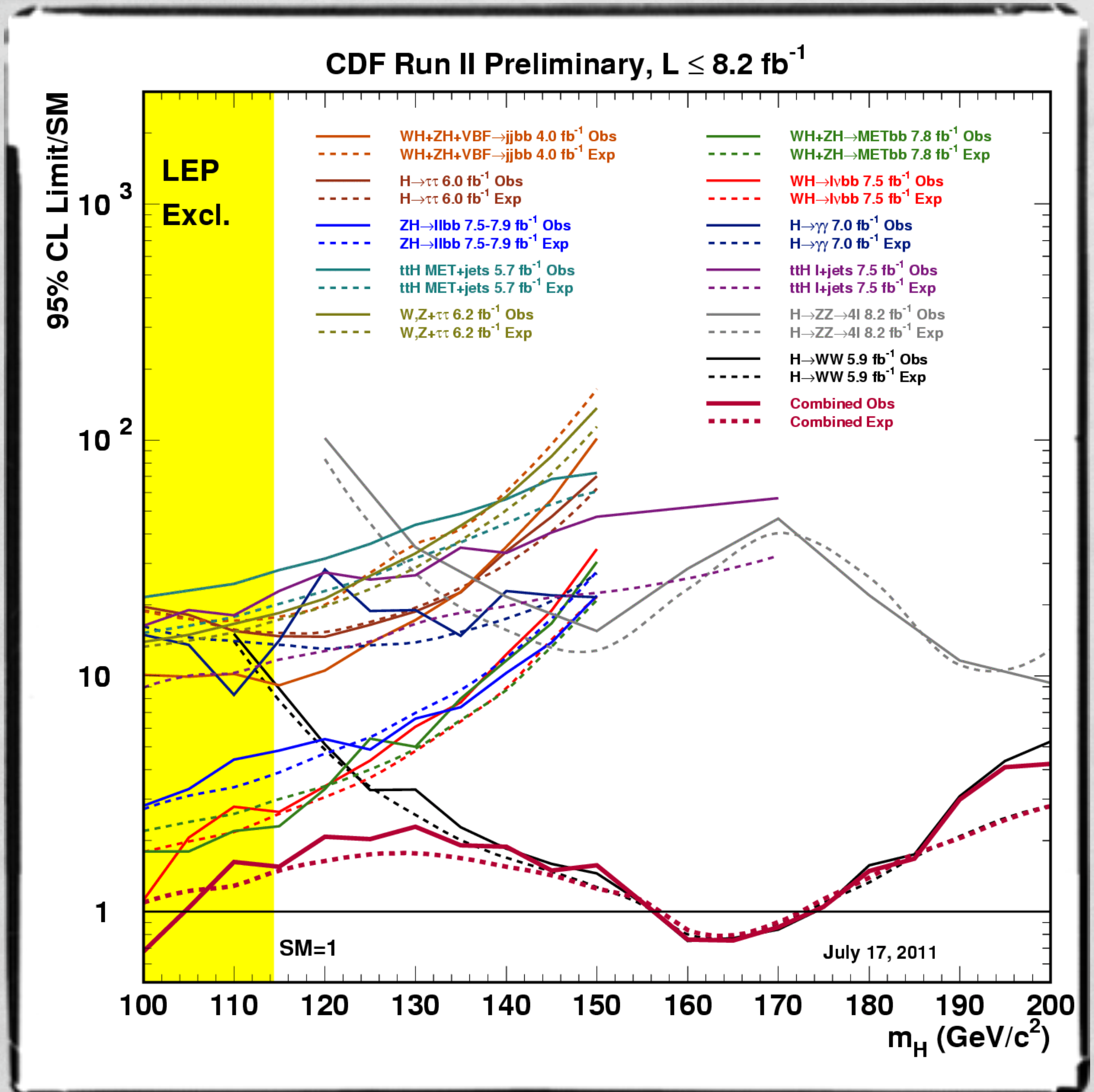


Key: address all channels





WH→lνbb
ZH→ννbb
ZH→llbb
WH/ZH→jjbb
ttH→WbWbbb
H→γγ
H→ττ
WH→lνττ / ZH→llττ
H→WW→lνlν
H→WW→lνjj
WH→WWW / ZH→ZWW
H→ZZ

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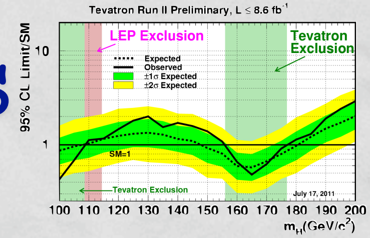

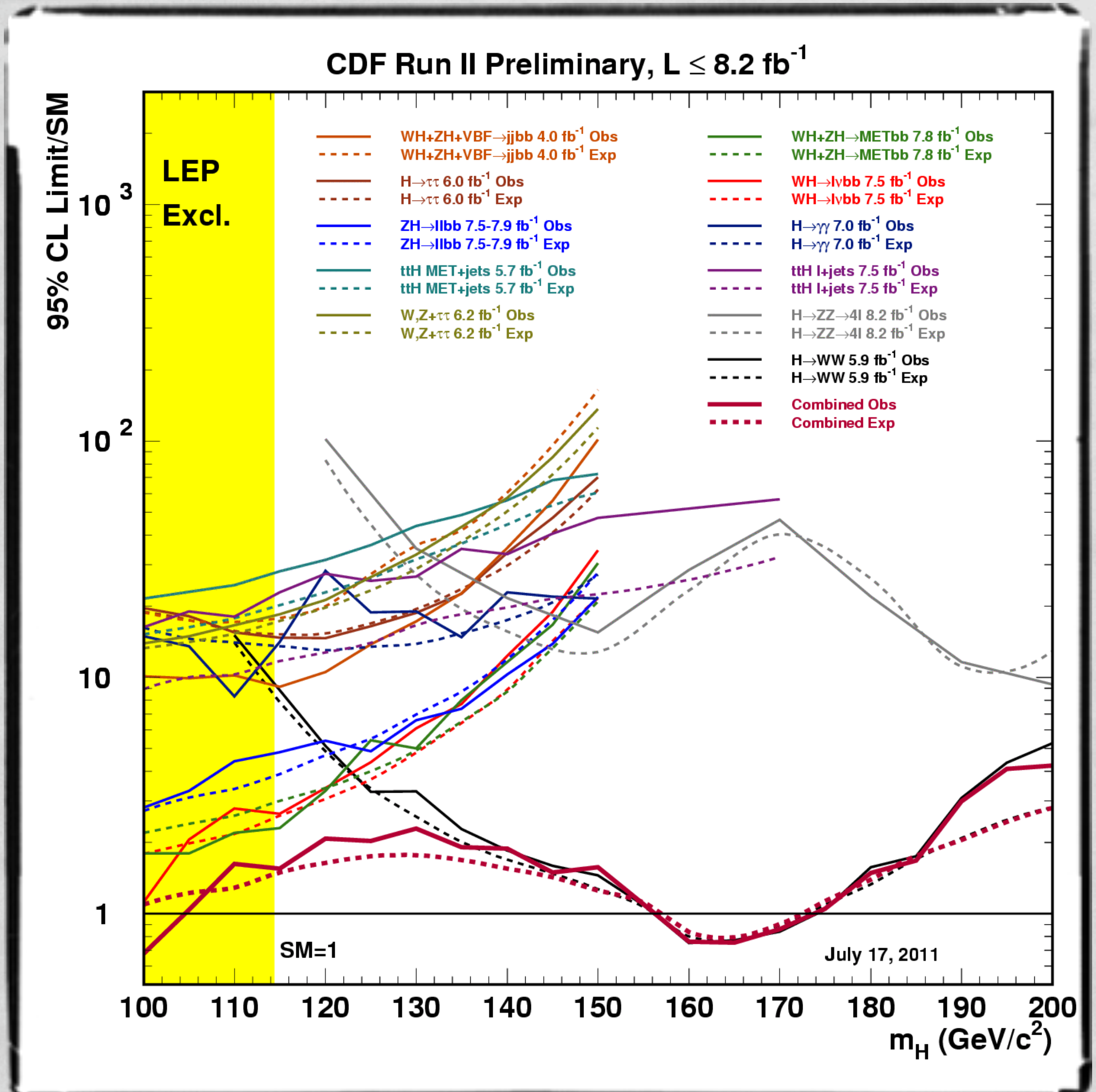

15 different process topologies

X

e, mu, tau

X

Nlept, Njets

X

diff. b-tagging, MVA

X

detector regions

=

O(100) different analyses !

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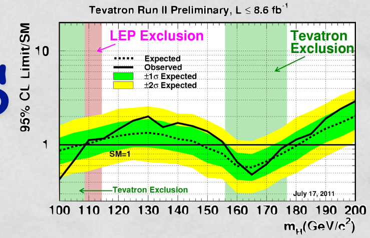

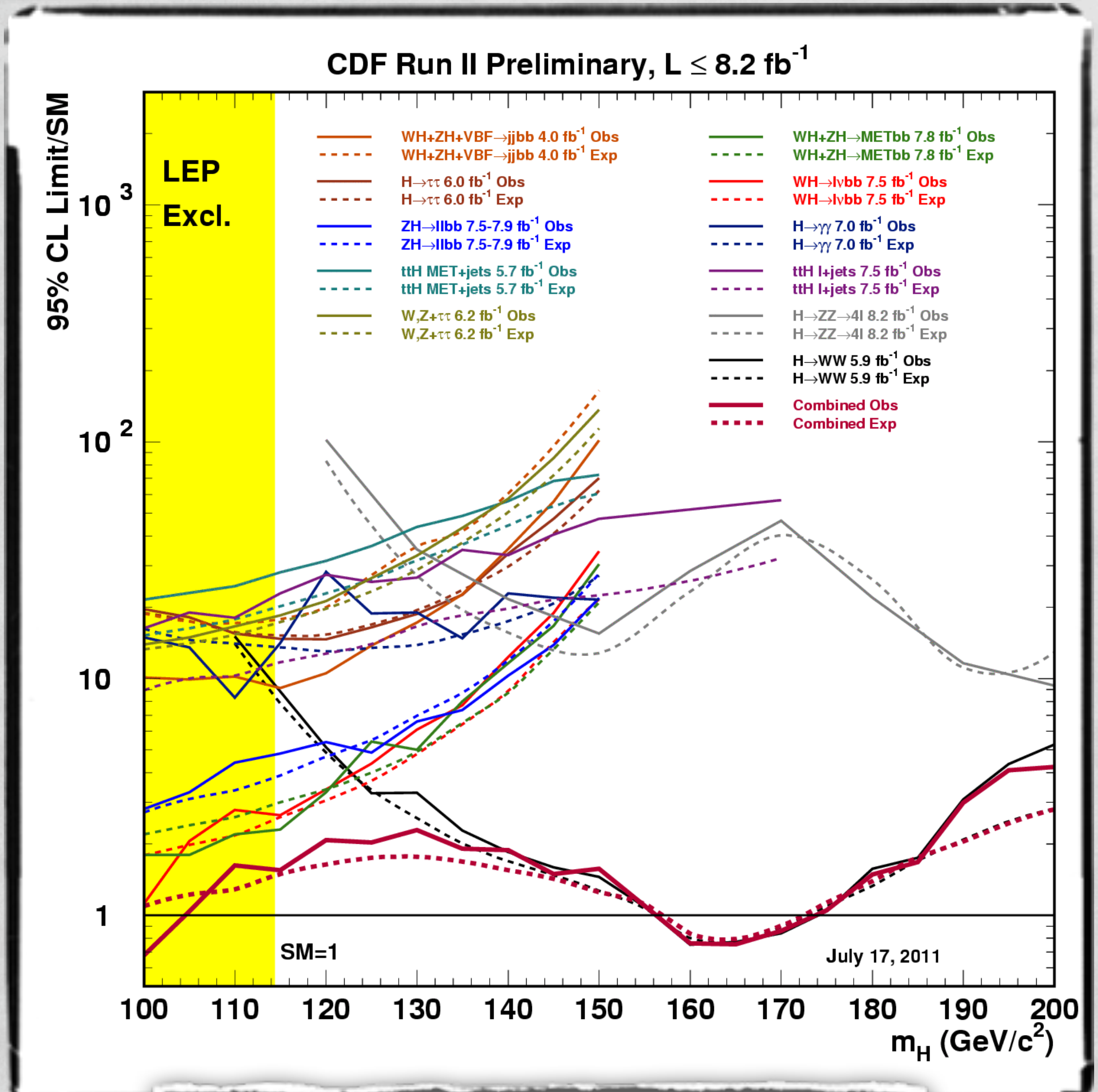

A monumental effort

15 different process topologies

x

e, mu, tau

x

Nlept, Njets

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diff. b-tagging, MVA

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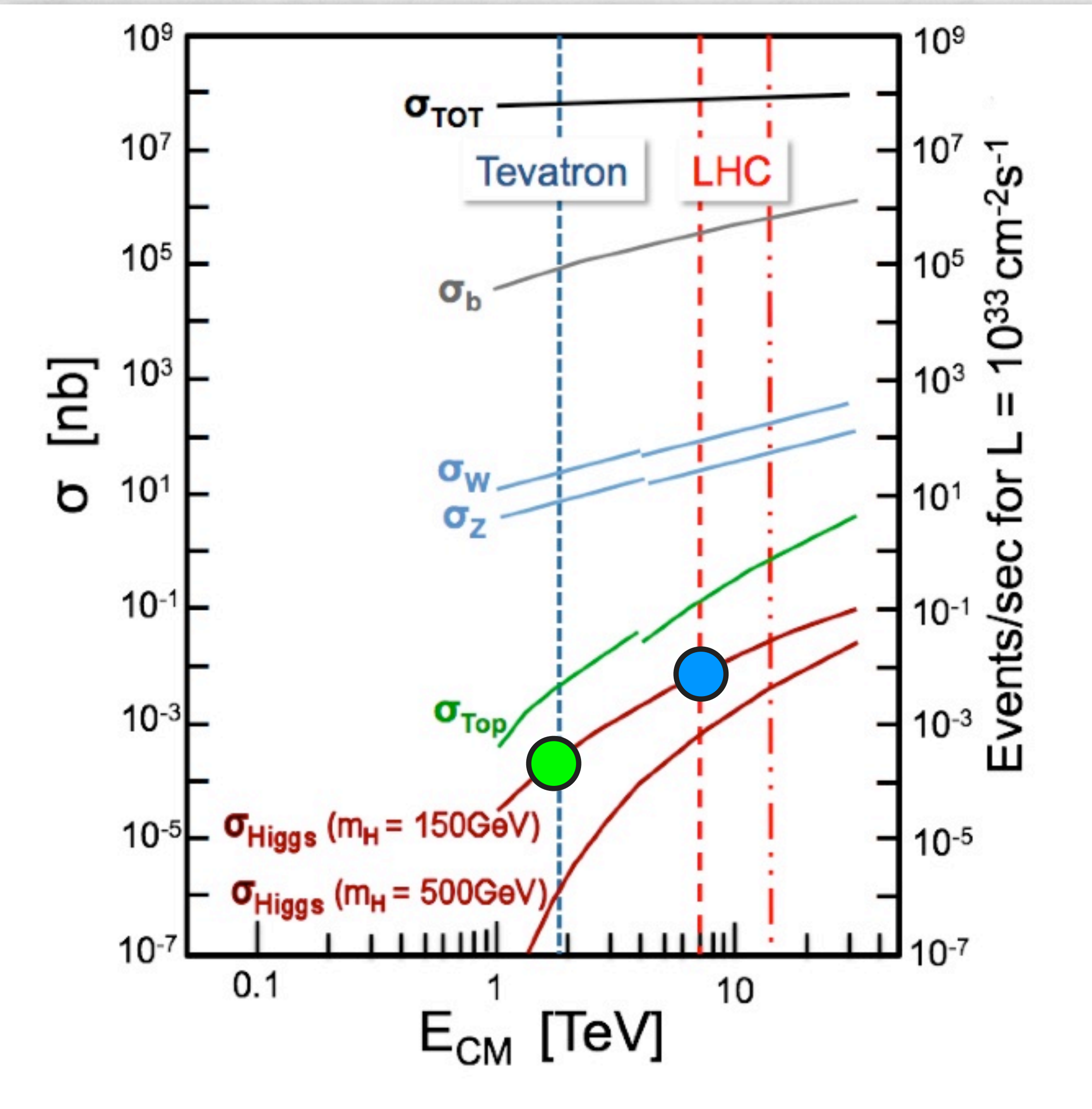
O(100) different analyses !

And then there are backgrounds



@ Tevatron

Top quarks/10^{10} collisions

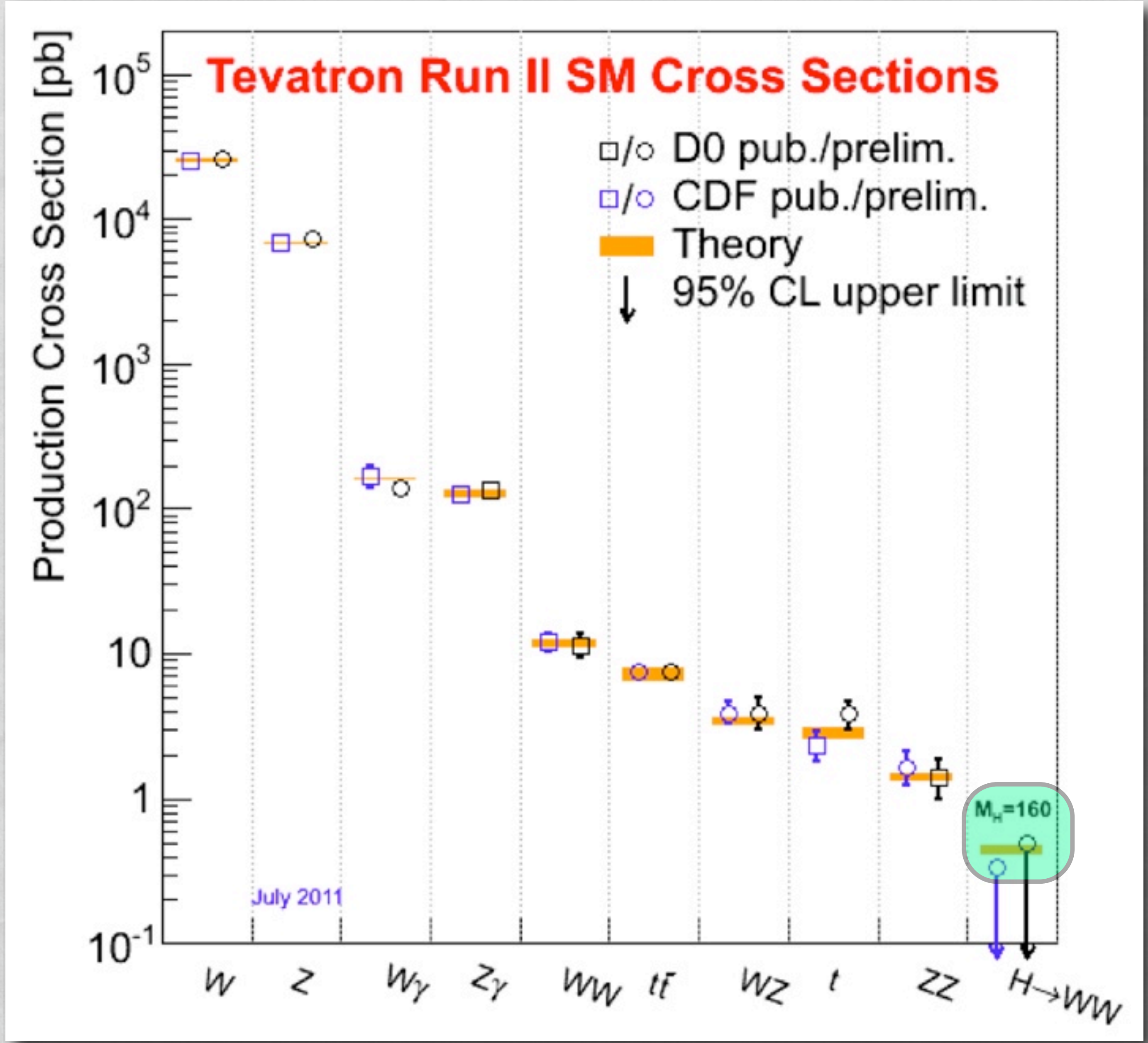
Higgs/10^{11} -10^{12} collisions

@ LHC

Top quarks/10^7 collisions

Higgs/10^9 -10^{10} collisions

Key: dig through the backgrounds...



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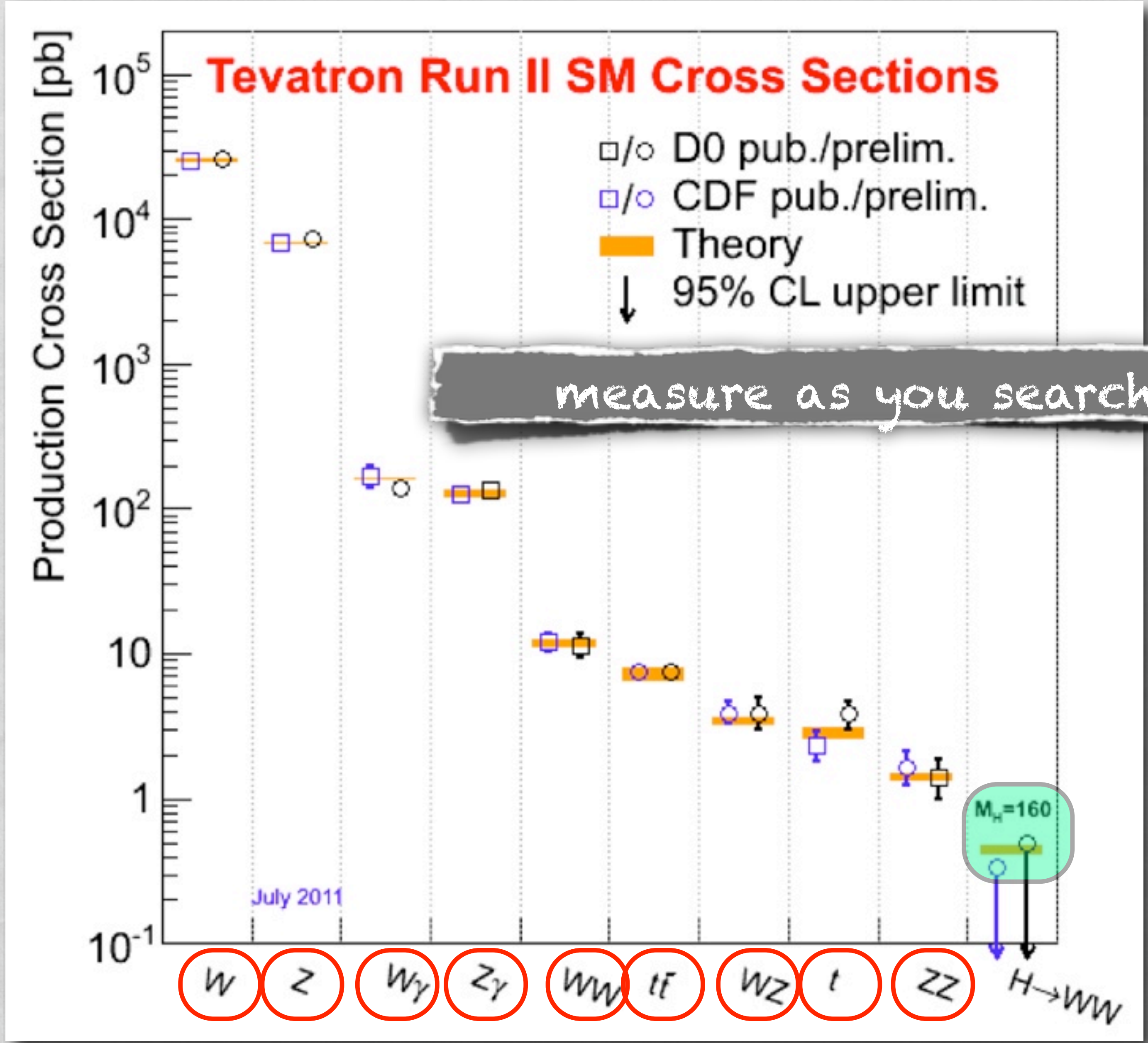
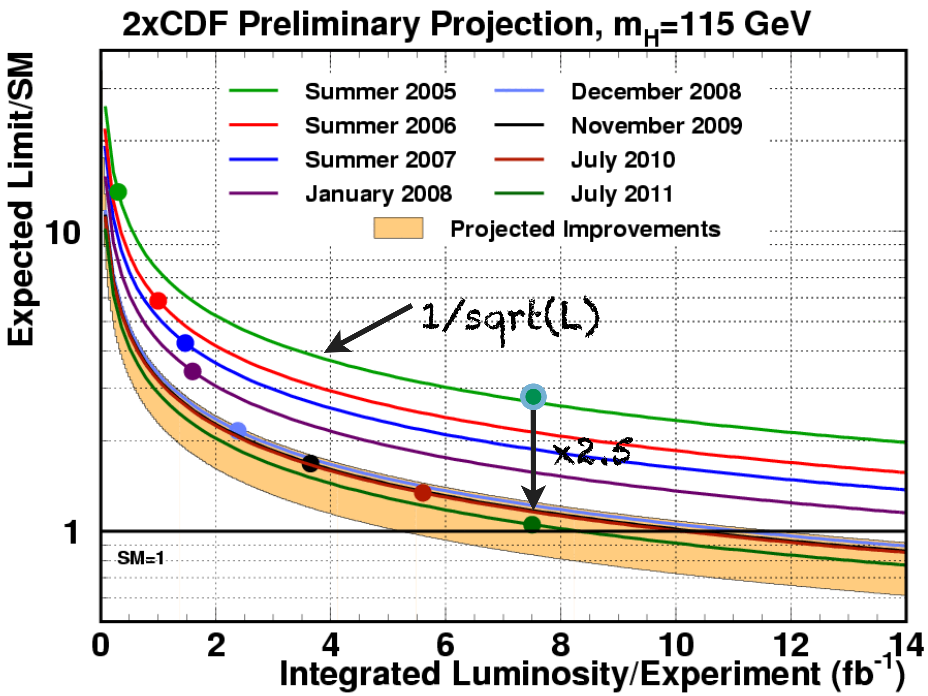


measure as you search

Key: analysis improvements



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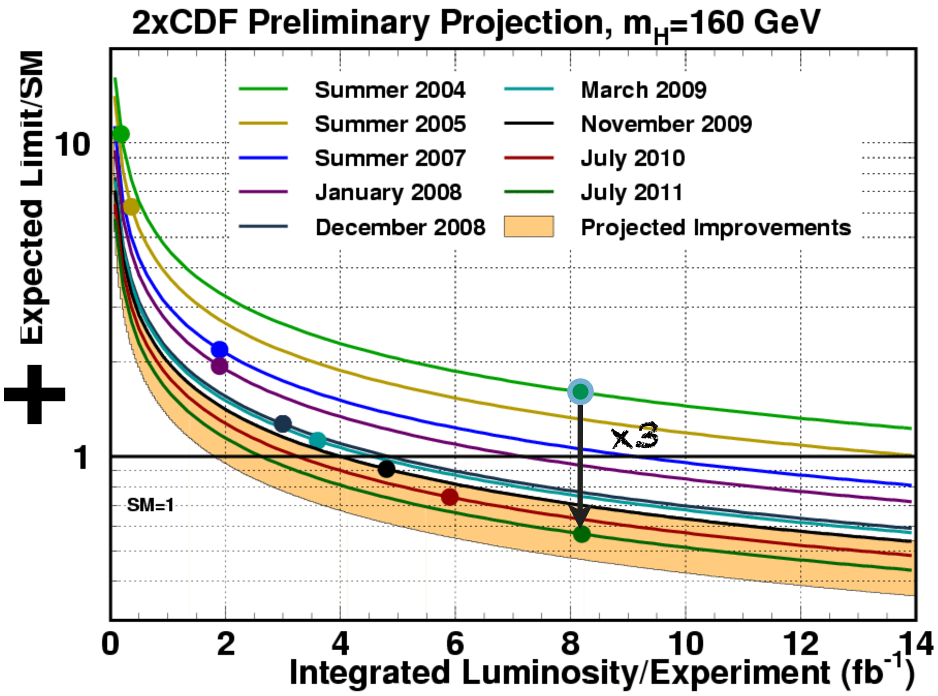

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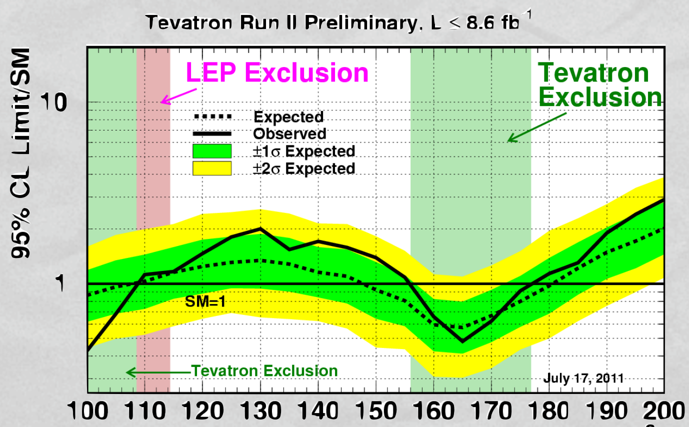
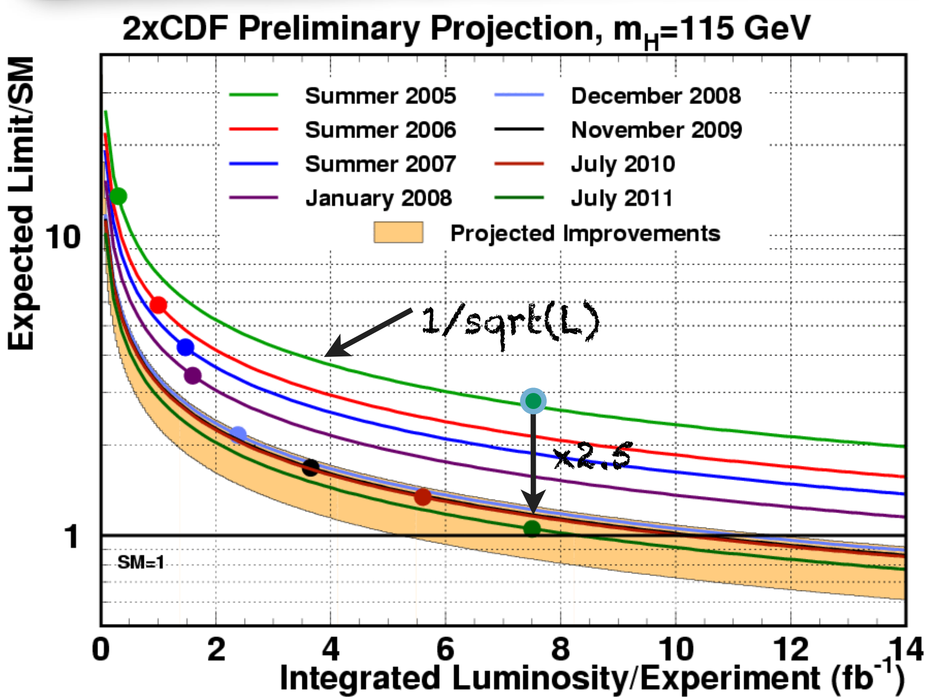


Key: analysis improvements

Improvements: x2.5-3 in sensitivity => x6-9 in Luminosity !



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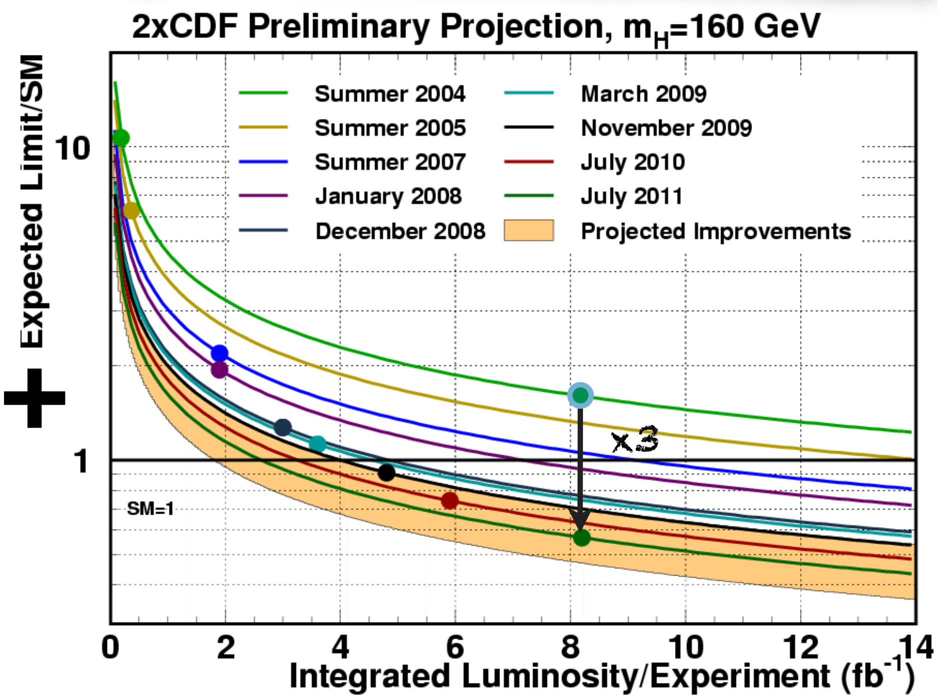

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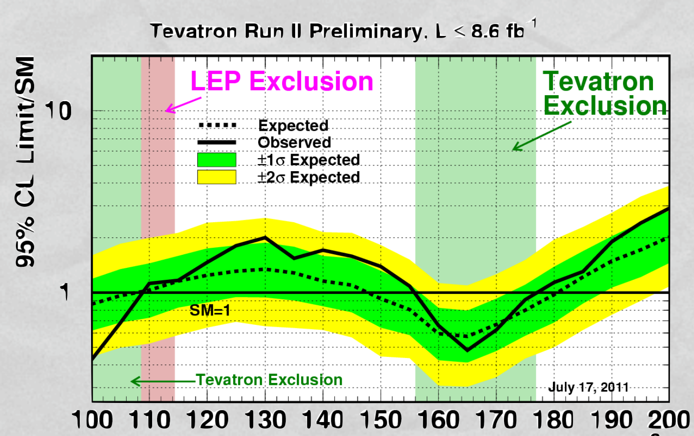

Key: analysis improvements

- Acceptance
  - Incorporate as many channels as possible
  - Trigger, fiducial, lepton-id efficiency, b-tag efficiency, taus
- Signal/background separation
  - Split channels by different s/b content: # jets, # b-tags
  - Improve M_{bb} resolution
  - Multi-variate analysis [mva]: exploit correlations between final state objects: BDT, NN, matrix-element etc.
- Background modeling
  - Improved event generators
  - Cross checks using control regions in data
  - Measure cross sections for relevant SM processes

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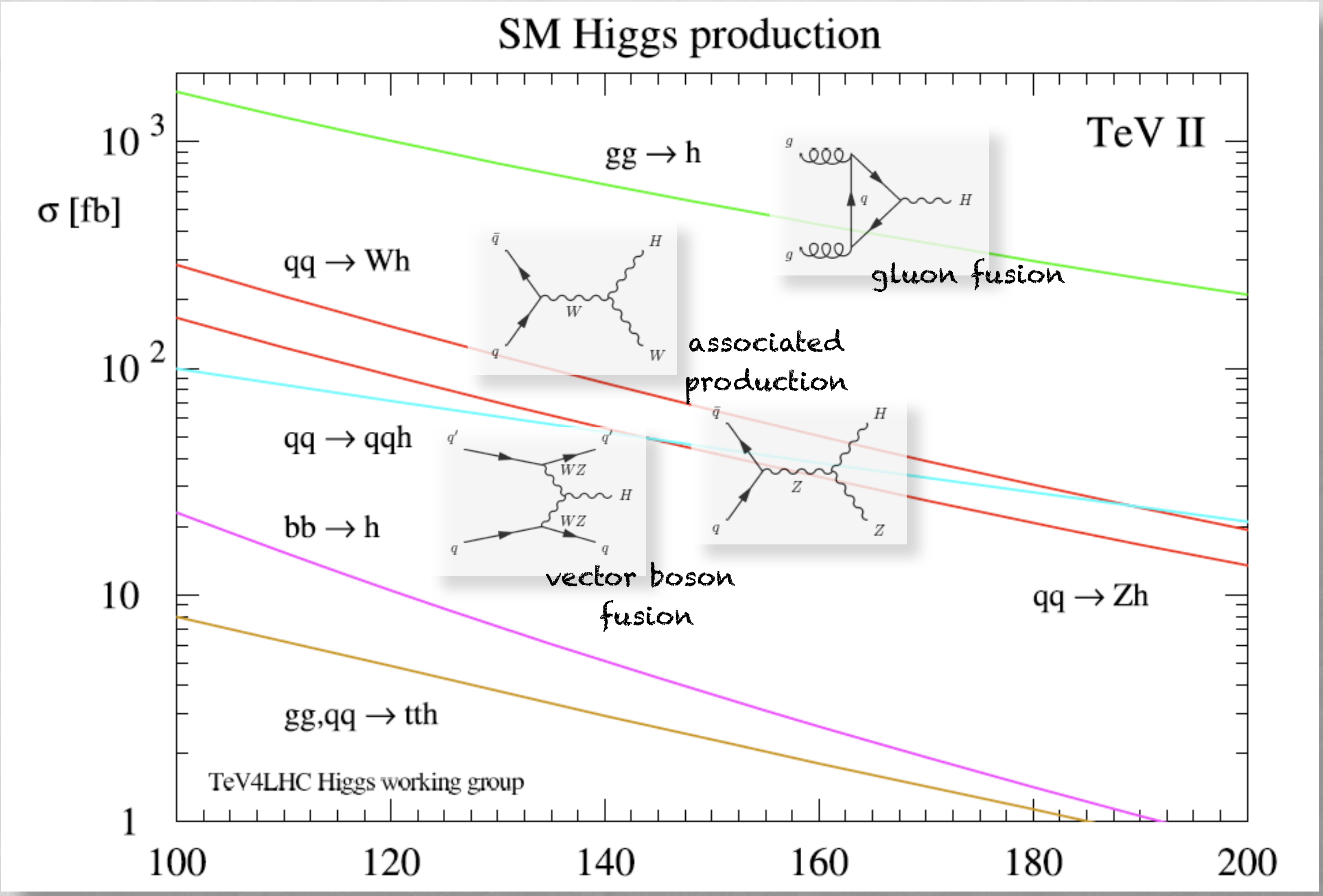
Note: $(1.10)^{10} \sim 2.5$

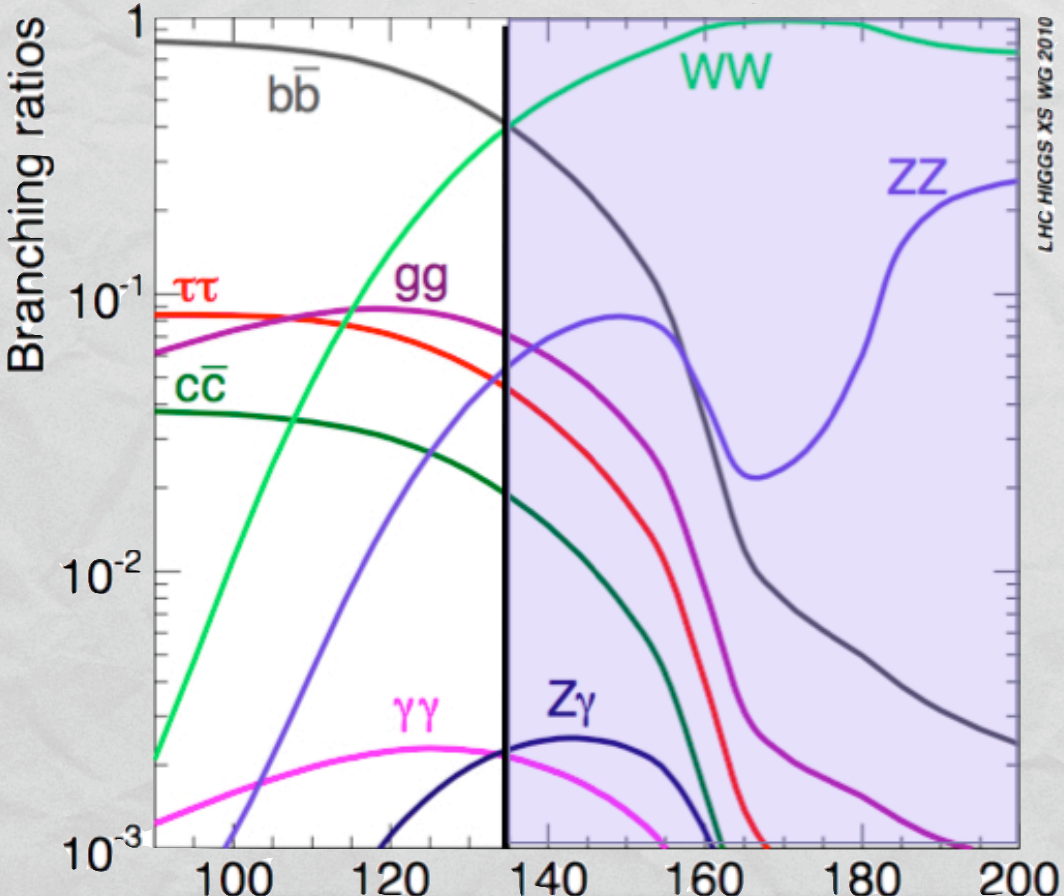
Analysis & Results

- An overview only...
  - focus on SM Higgs
- Details at:
  - CDF public physics pages
  - Dzero public physics pages
- Latest Higgs presentations at:
  - EPS
  - Lepton-Photon

Higgs production



Higgs decays: high and low



low H mass

high H mass

@ low mass

Main decay H => bb

also H => ττ and H => γγ

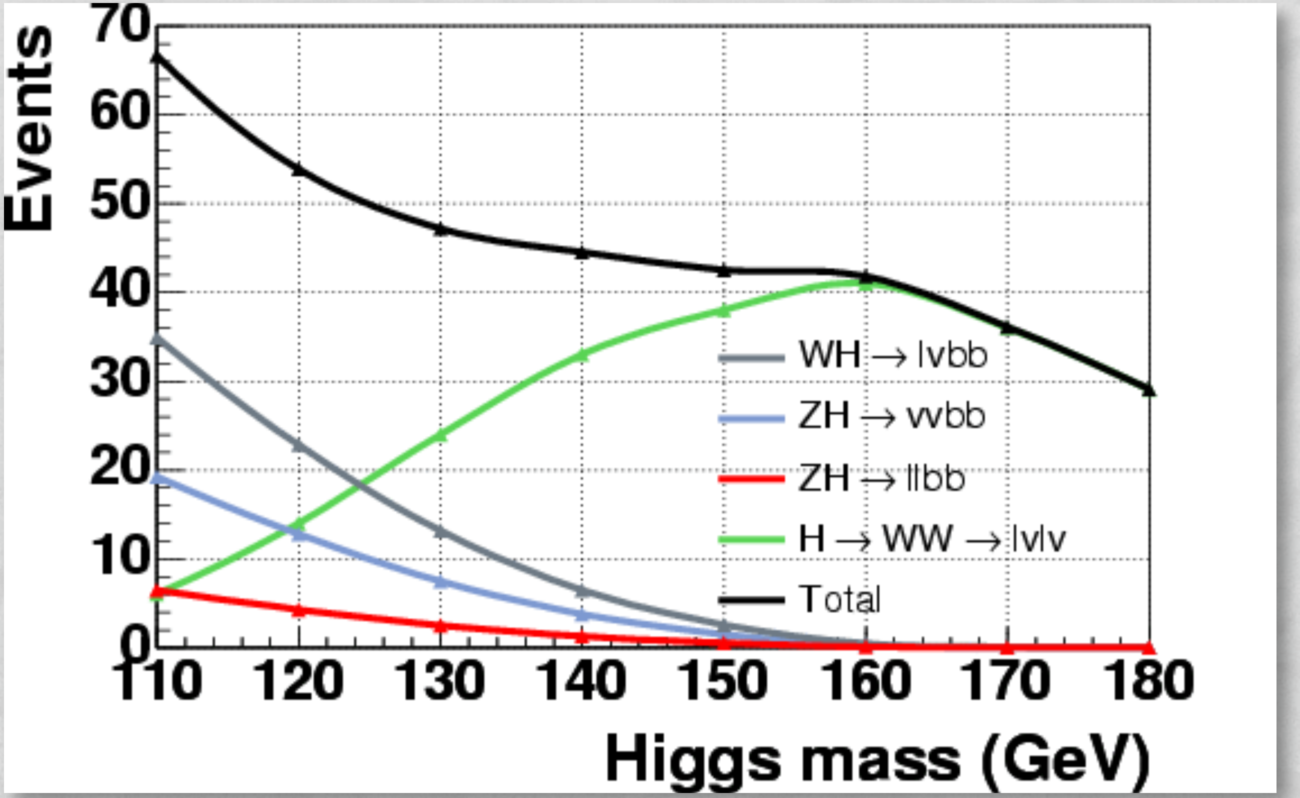
@ high mass

Main decay H => WW

also H => ZZ

Yields

of events produced per fb^{-1}, per experiment

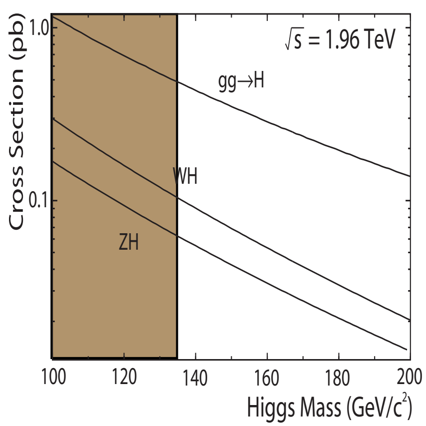


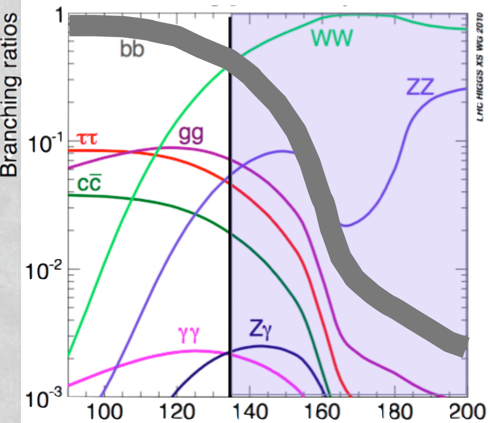
trigger/reconstruction/selection efficiency:

~10% for H=>bb channels

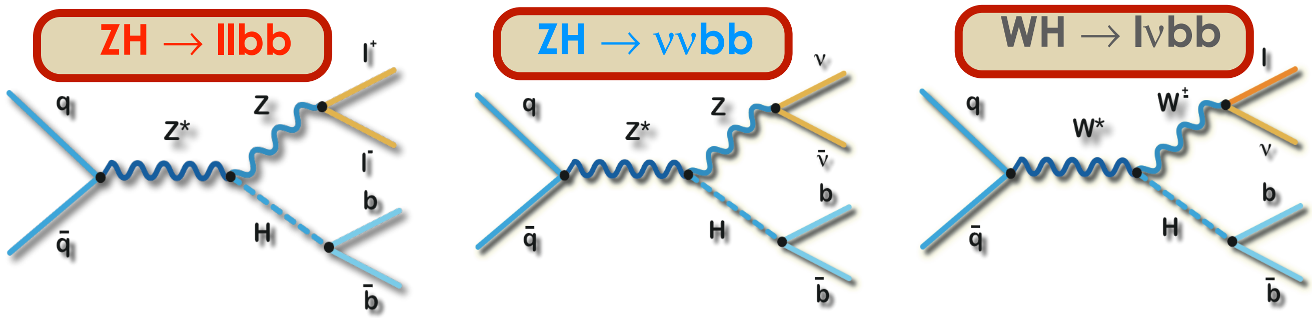
~25% for H=> WW channels

Low mass search



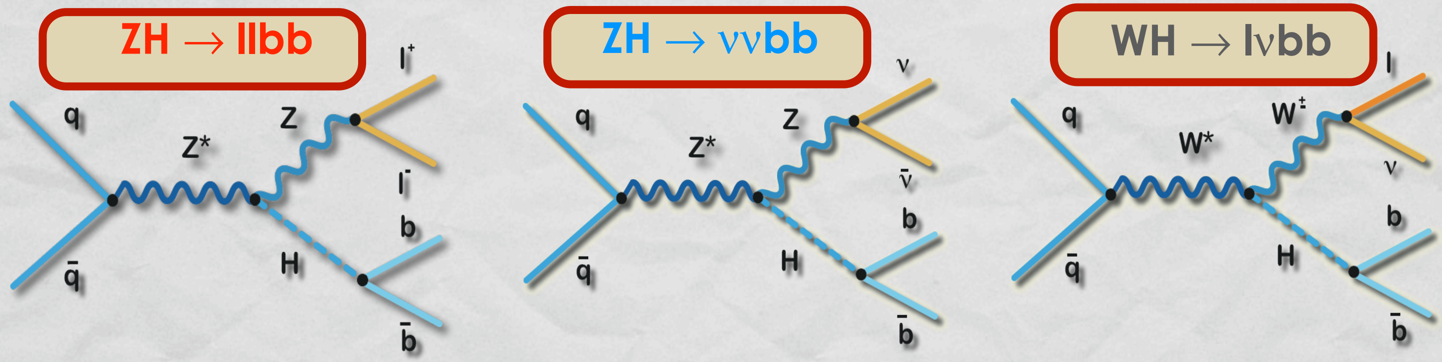


- $\sigma(H) \times B(H \to b\bar{b}) \approx 0.5$ pb
  - Final state overwhelmed by QCD
  - Other rare decay modes less sensitive
- $\sigma(VH) \times B(H \to b\bar{b}) \approx 0.1$ pb
  - Extra vector boson helps reducing backgrounds
- **Associated production**: main low mass channel



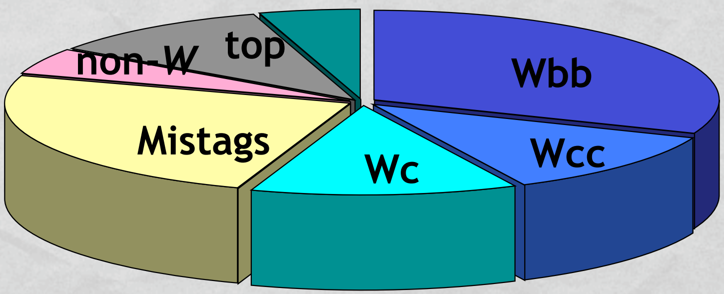
- **Direct production**: using other decay modes
  - $H \to \tau\tau$, $H \to \gamma\gamma$, $H \to WW$, $t\bar{t}H \to \ell\nu q\bar{q}b\bar{b}b\bar{b}$

Associated production



− $\sigma \cdot BR \lessgtr N_B$ +

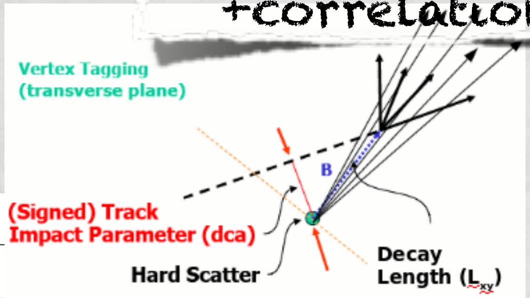
- Analysis flow:
  - W and Z reconstruction
  - H=>bb reconstruction
  - MVA "fever"
    - improvements on every piece in every analysis round

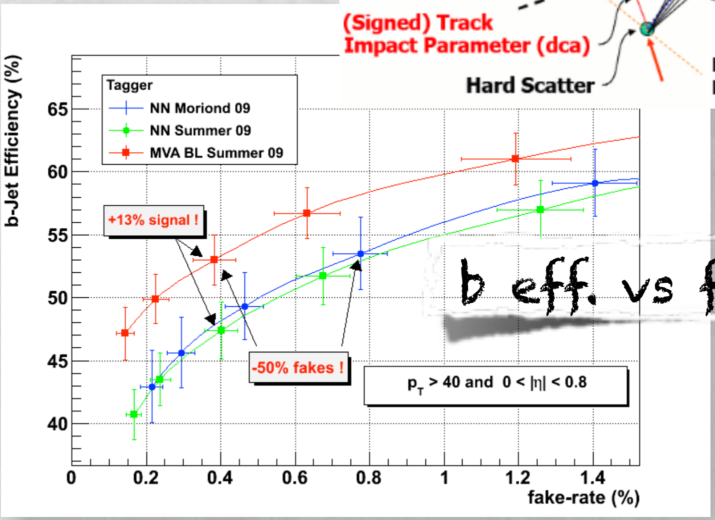


Backgrounds

b-tagging

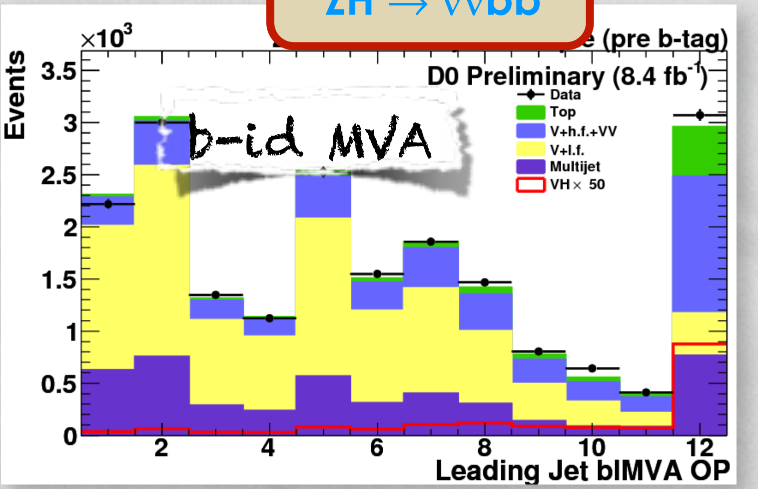
+correlations



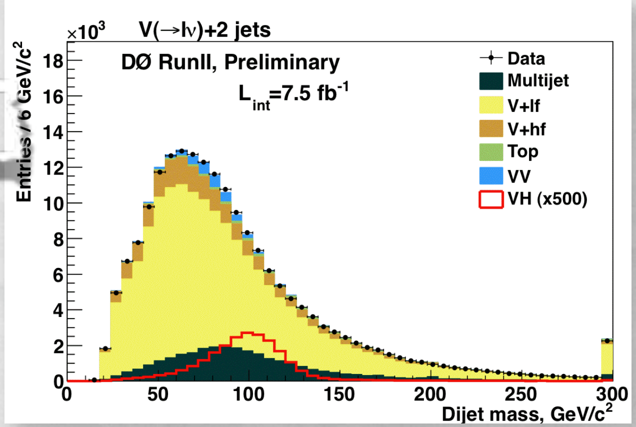


b eff. vs fake rate

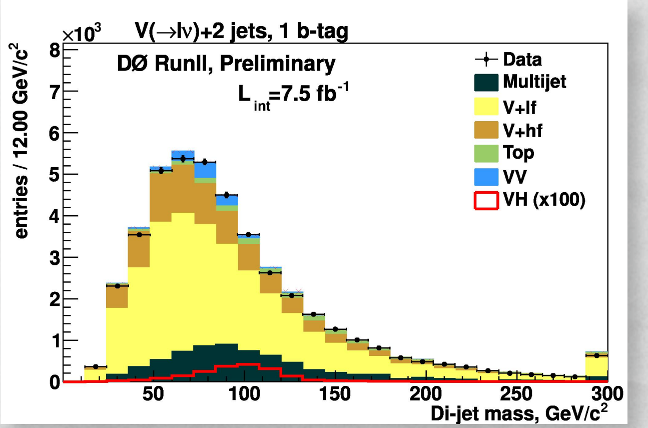
ZH → ννbb



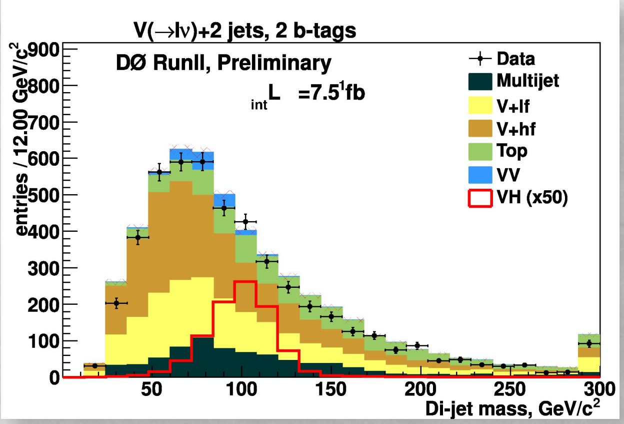
b-id MVA



no tags



1 tag



2 tags

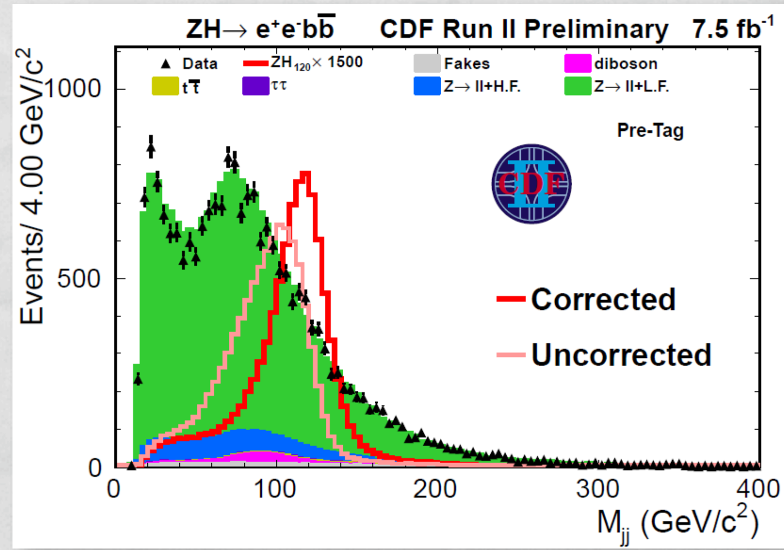
Mass resolution

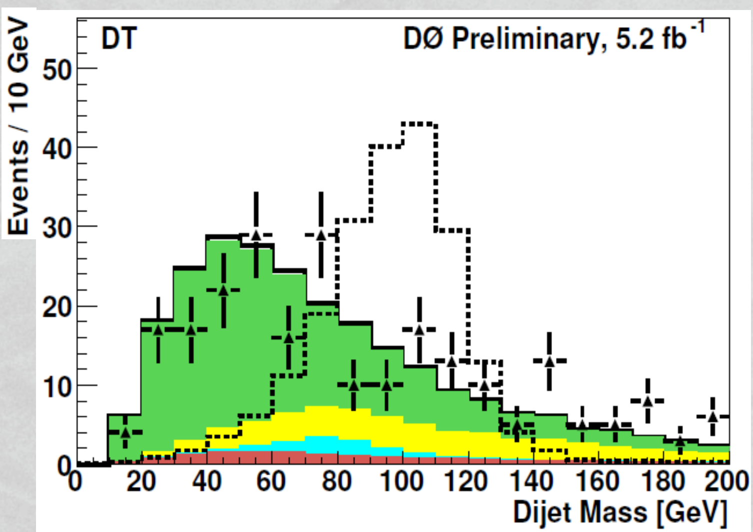
ZH → llbb

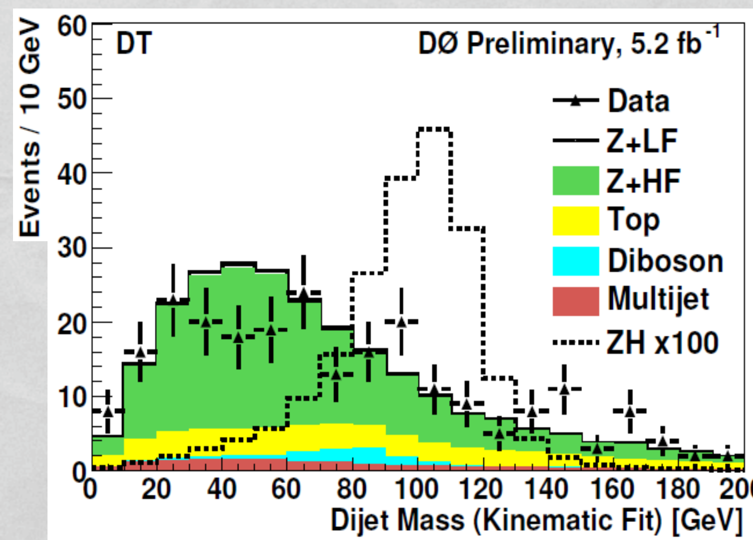
Dzero: use kinematic constraints [MET=0, Zmass] to fit jet energies

CDF: via NN function [tracks, calor]

~15% mass resolution improvements.

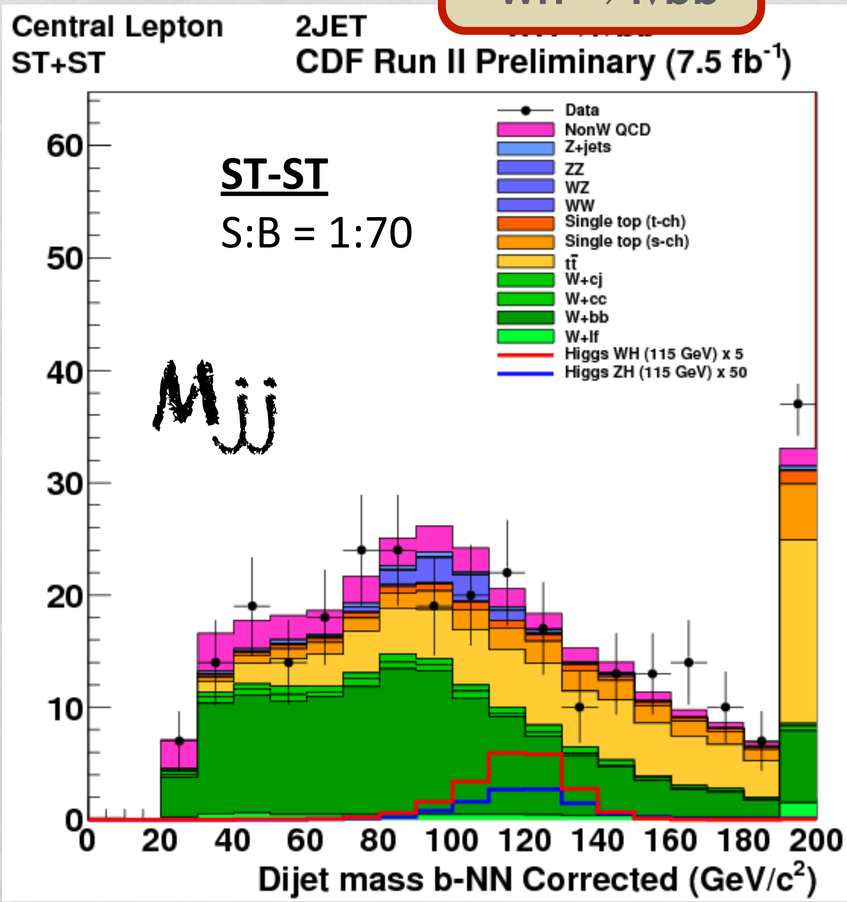


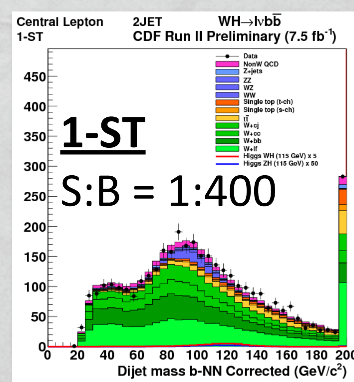


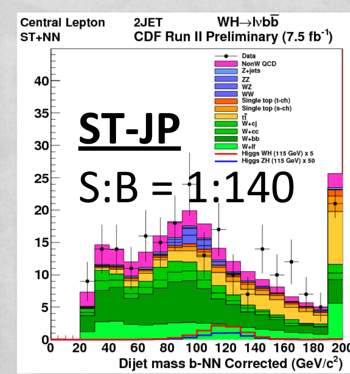


Sample composition

WH → lνbb



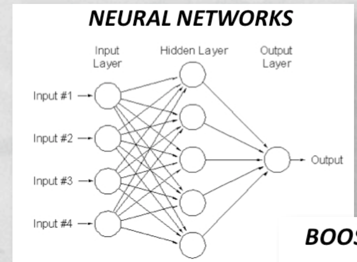


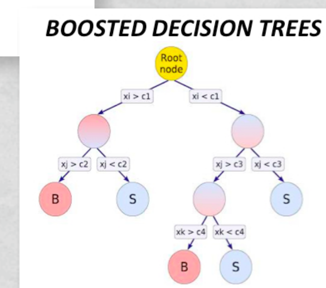


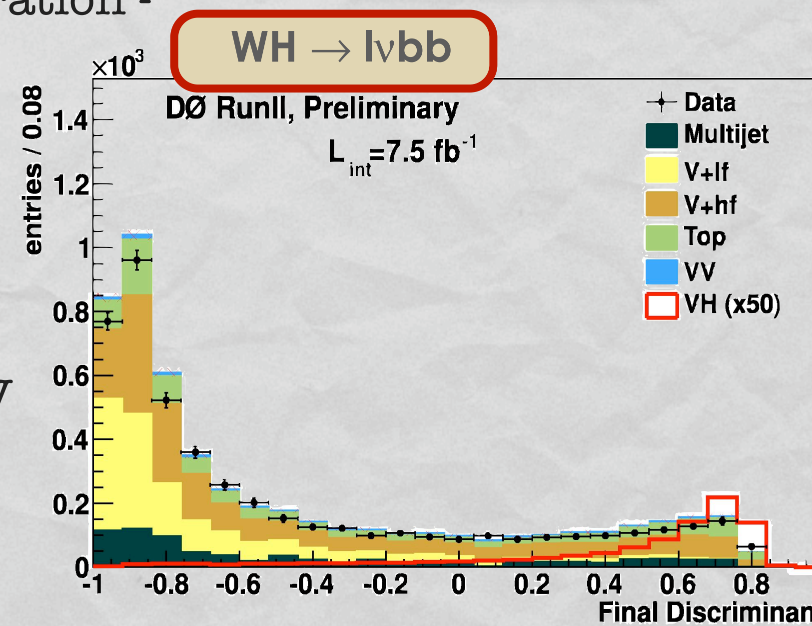
using different b-taggers
=> orthogonal samples
powerful technique

Multivariate fever

- MVA's now used everywhere
  - e, mu, tau-ID
  - b-tagging and HF separators
  - modeling trigger turn-on's and for jet-E corrections
  - Signal to background kinematical separation - specific and global
  - And as inputs to other MVA's !
- A lot of validation work behind them
- Typical gains of 10-20% in sensitivity



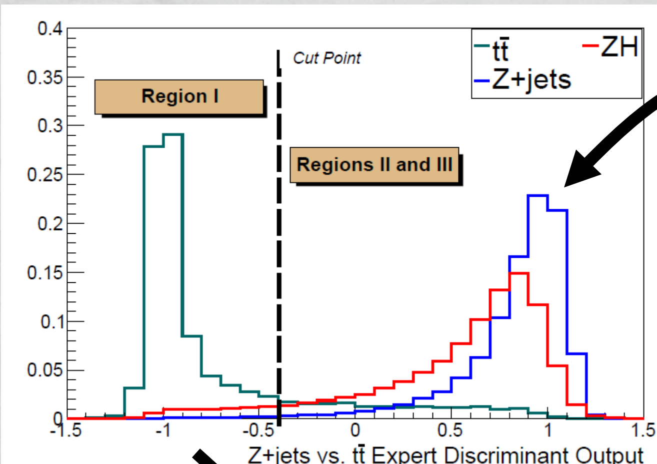


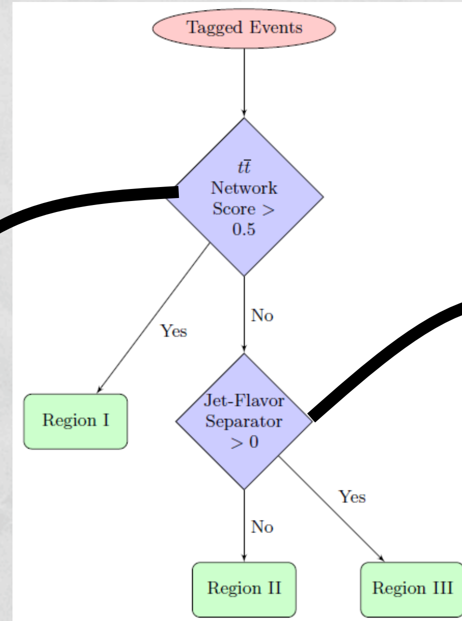


An example of MVA optimization

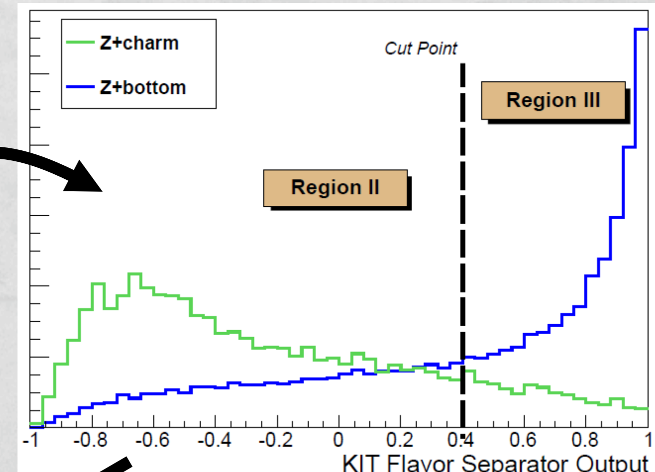
CDF's ZH → llbb

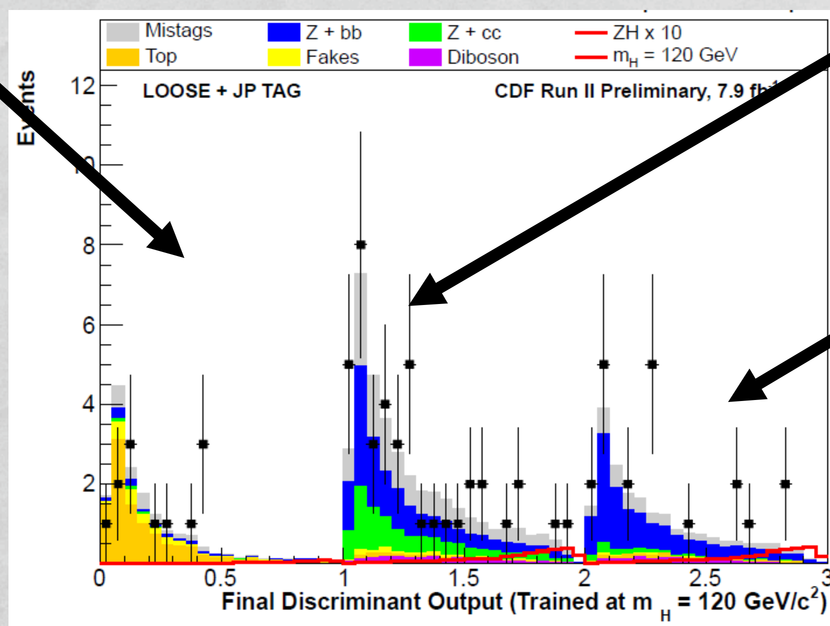
1. ttbar vs ZH





2. Charm vs bottom

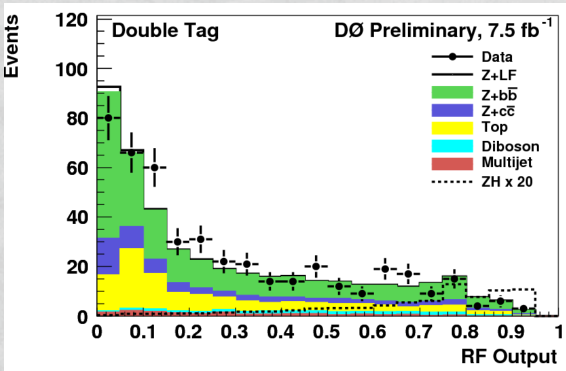


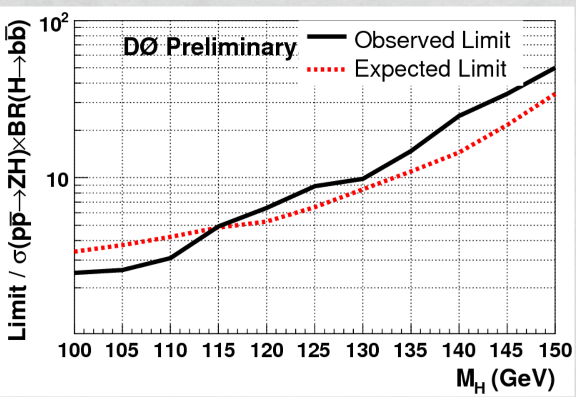


8 % gain over original network.

Results from DØ

ZH→llbb̄ ∫Ldt=8.6 fb^{-1}



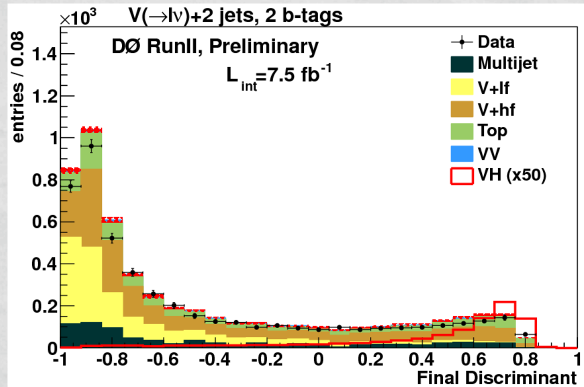


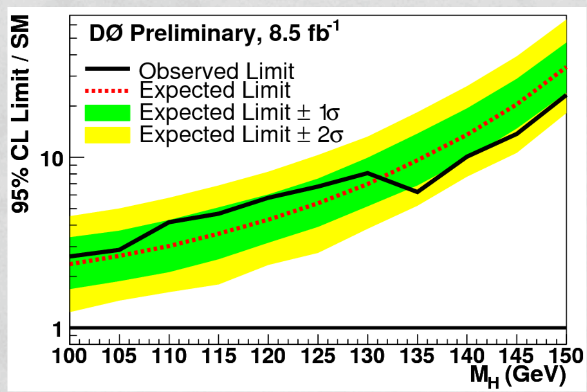
95% CL Exp (obs) Limit

4.8 (4.9) x SM

@ MH=115 GeV

WH→lνbb̄ ∫Ldt=8.5 fb^{-1}



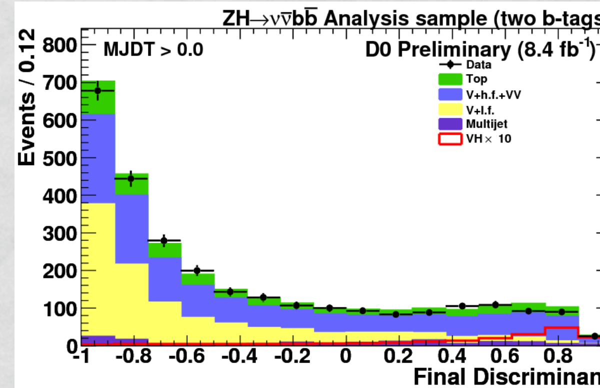


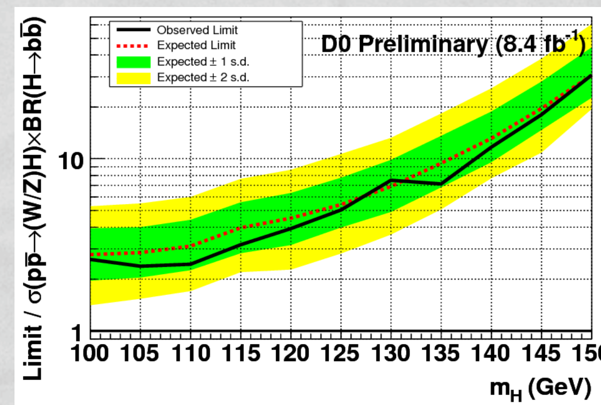
95% CL Exp (obs) Limit

3.5 (4.6) x SM

@ MH=115 GeV

VH→ννbb̄ ∫Ldt=8.4 fb^{-1}





95% CL Exp (obs) Limit

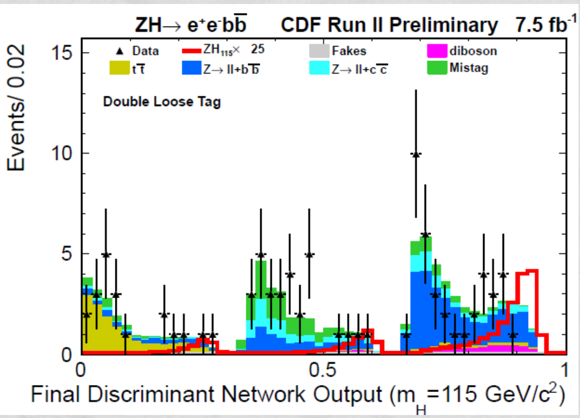
4.0 (3.2) x SM

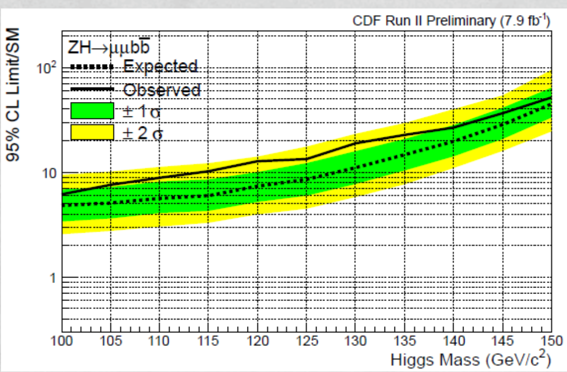
@ MH=115 GeV

10% gain on top of Lumi

Results from CDF

ZH→llbb̄ ∫Ldt=7.9 fb^{-1}





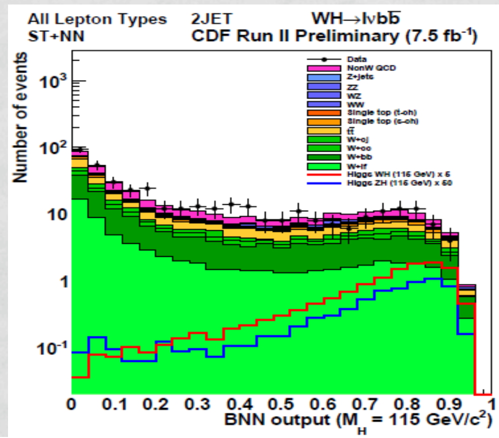
95% CL Exp (obs) Limit

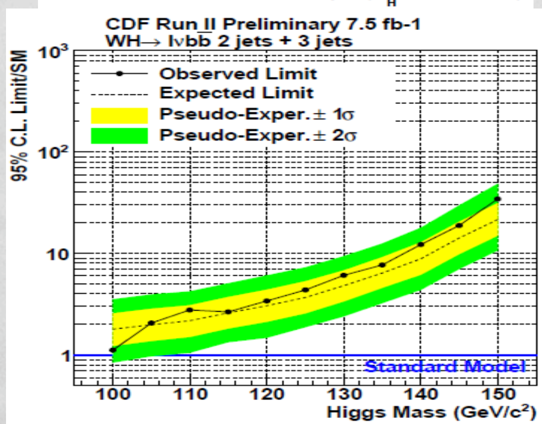
3.9 (4.8) x SM

@ MH=115 GeV

20% gain on top of Lumi

WH→lvbb̄ ∫Ldt=7.5 fb^{-1}





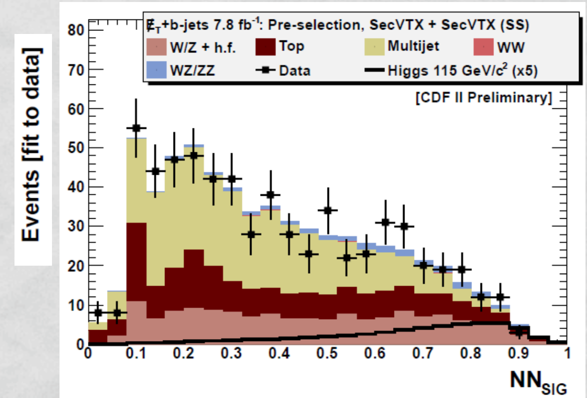
95% CL Exp (obs) Limit

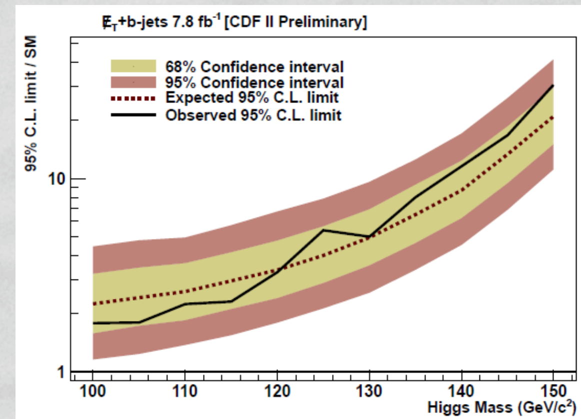
2.7 (2.6) x SM

@ MH=115 GeV

13% gain on top of Lumi

VH→vvbb̄ ∫Ldt=7.8 fb^{-1}





95% CL Exp (obs) Limit

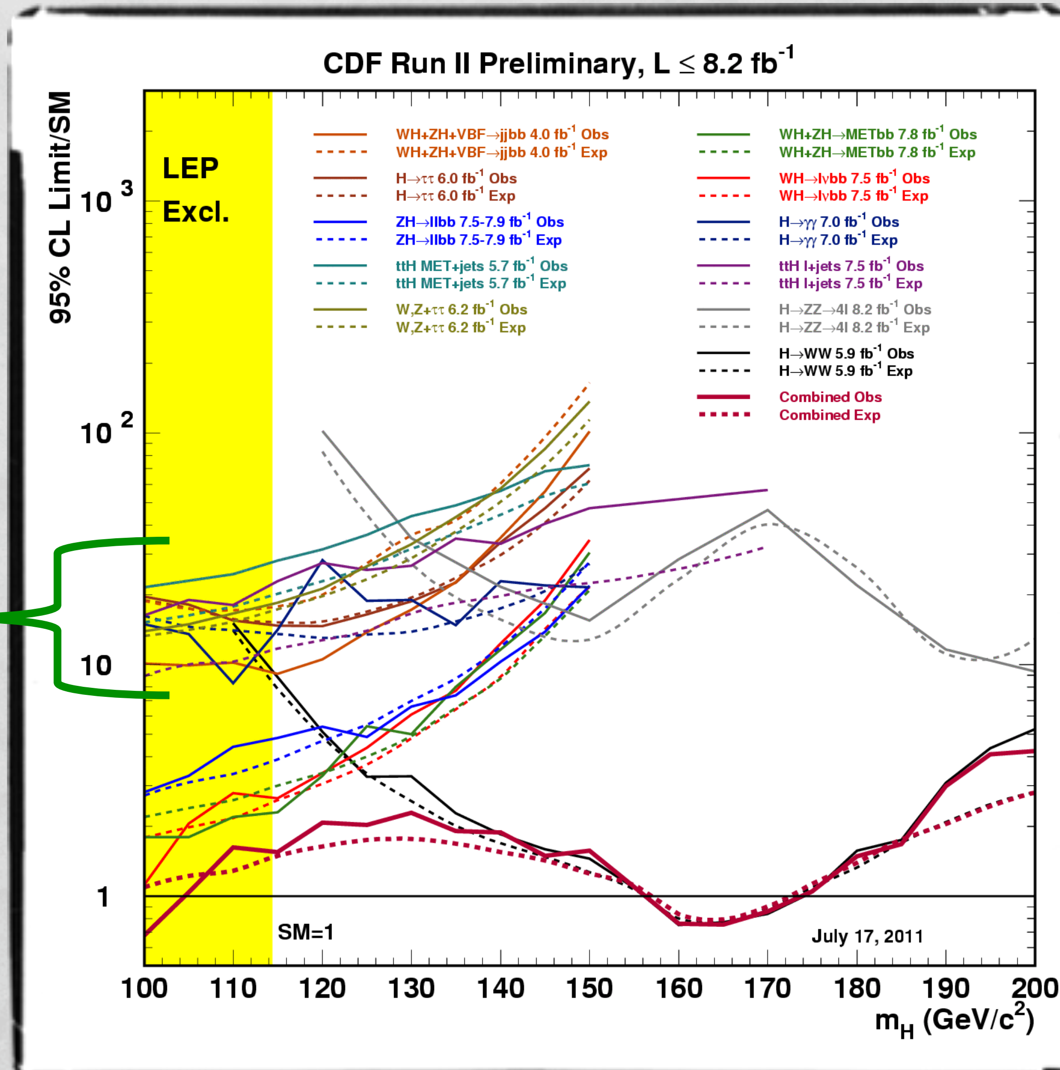
2.9 (2.3) x SM

@ MH=115 GeV

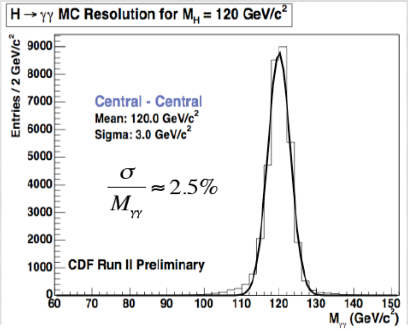
18% gain on top of Lumi

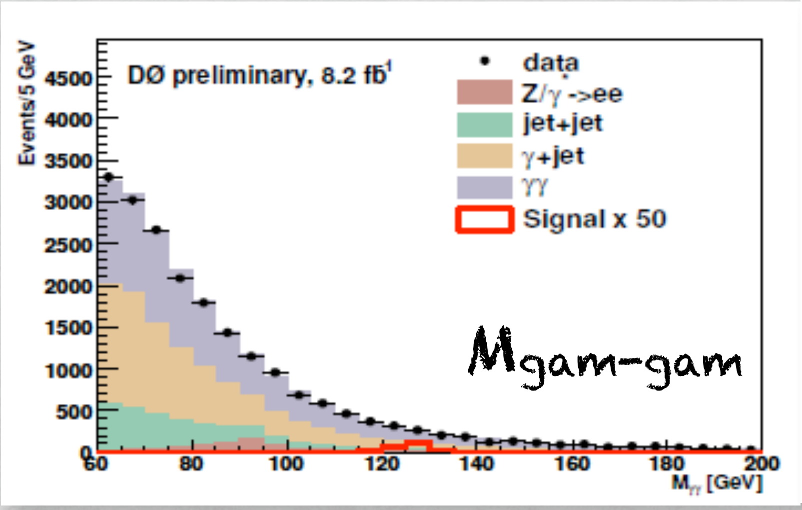
LOW mass - secondary channels

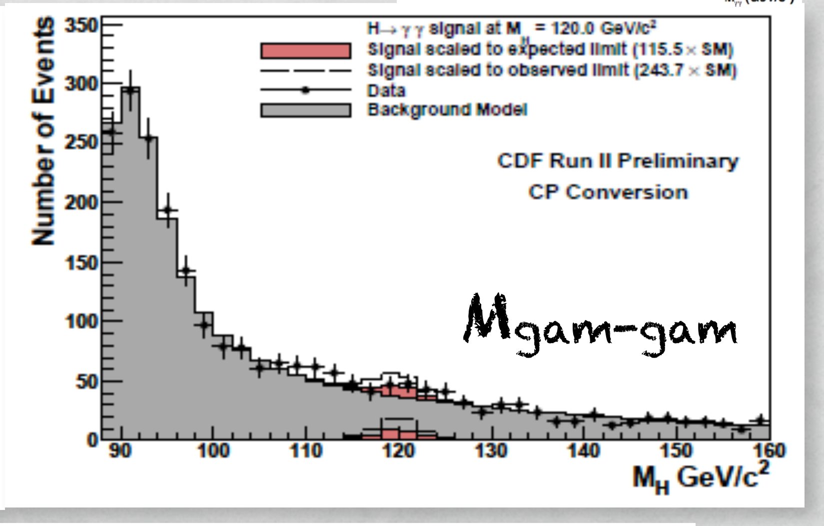
Their combined contribution is very relevant to the ultimate sensitivity

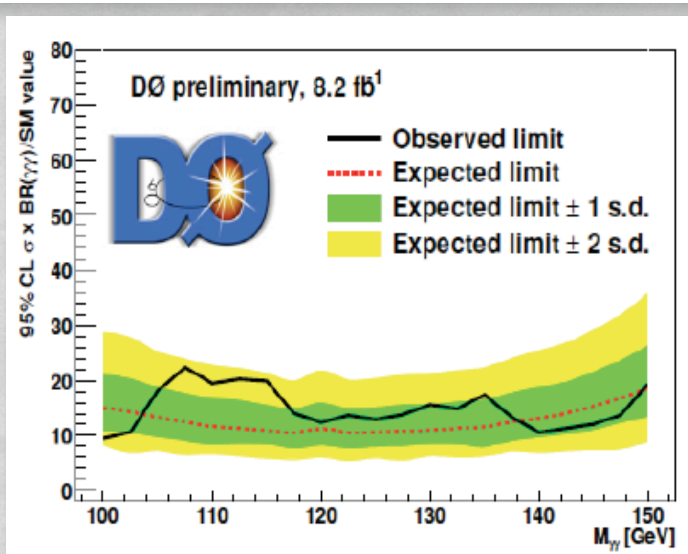


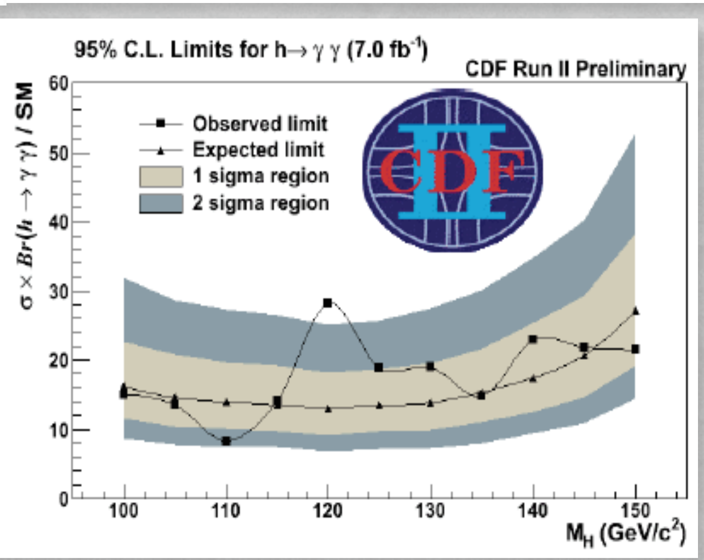
H=> gamma-gamma



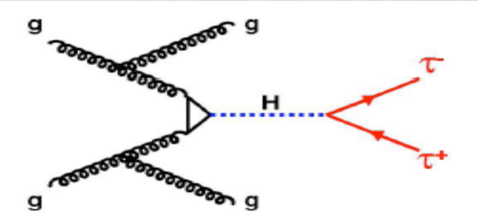




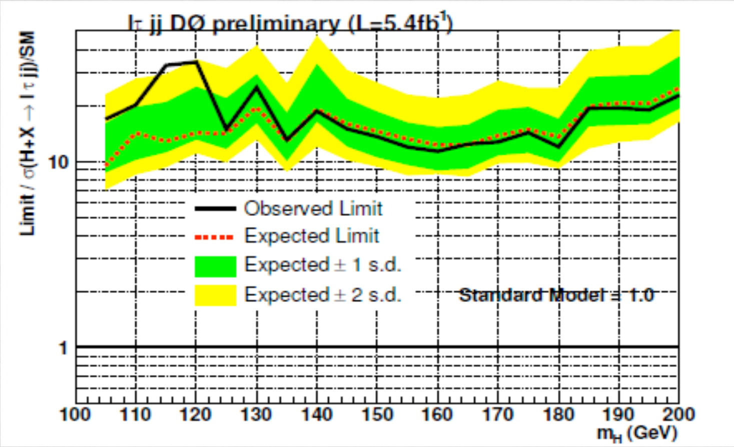


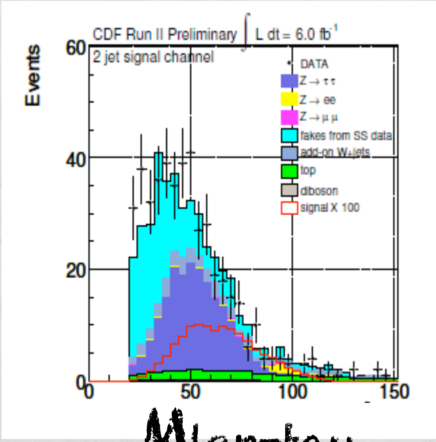


H=> tau-tau



final states considered below:
1 hadronic tau + 1 leptonic tau + jets
=> ggH, VH, VBF - all covered

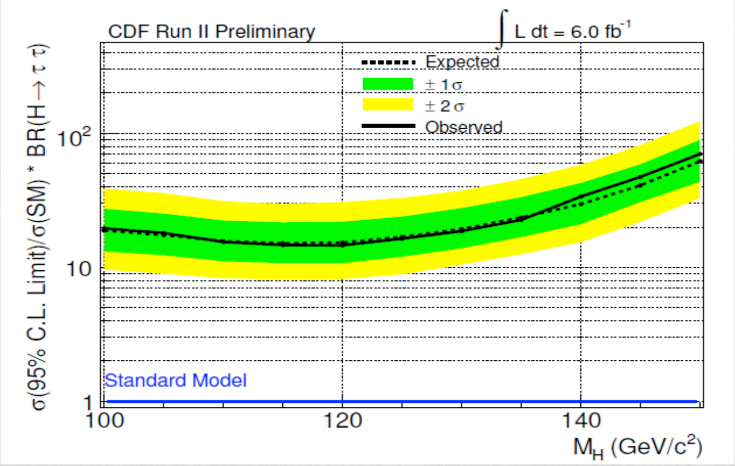


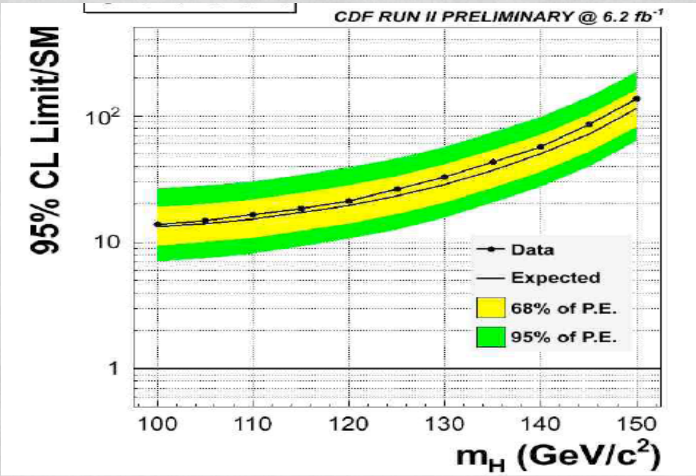


Mlep-tau

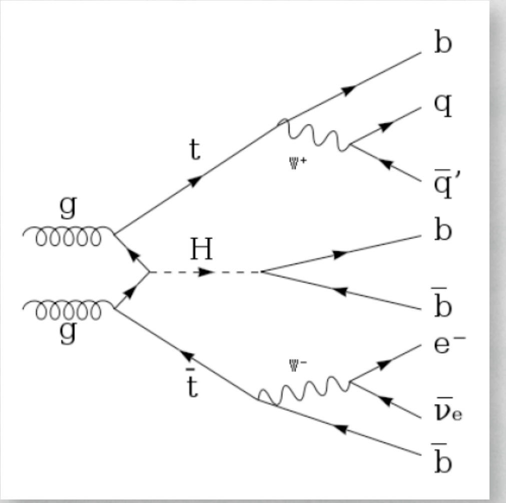
Newest, w/all tau decays modes !

ZH → llττ/WH → lνττ

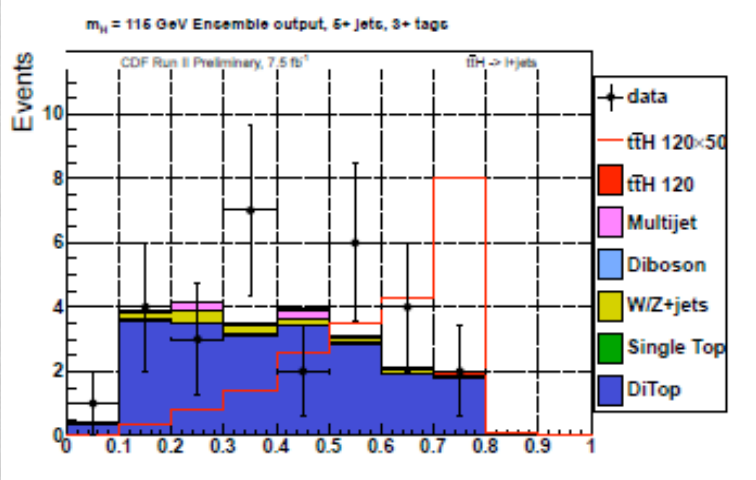




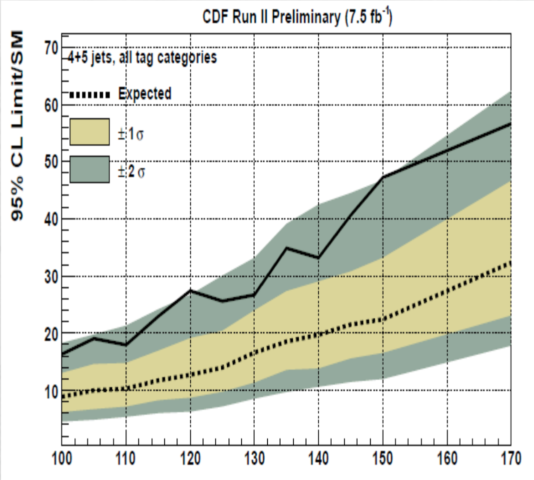
ttH searches



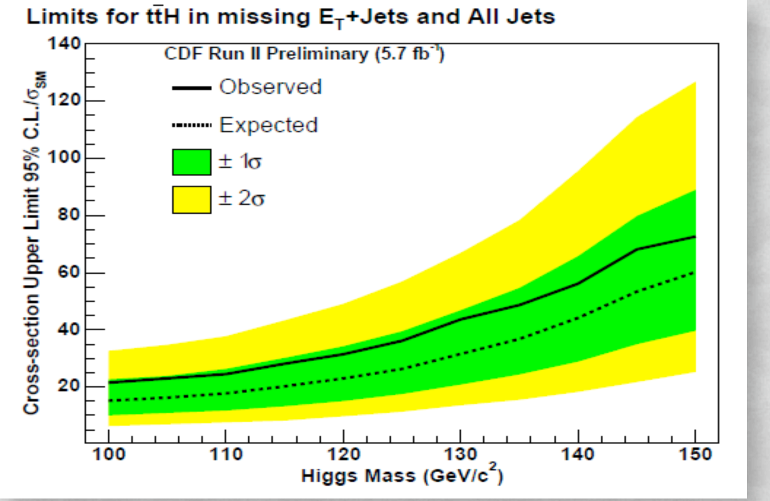
jets, #b-tags + NN kin discriminants



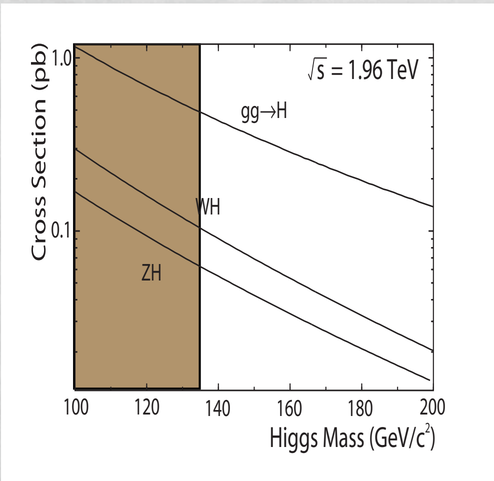
l+jets channel

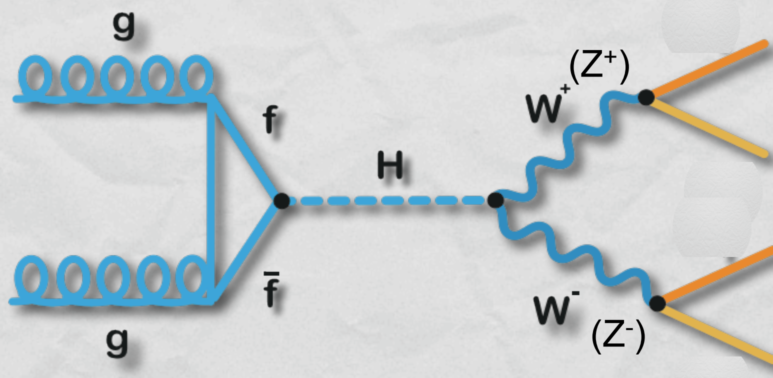


all-hadronic channel



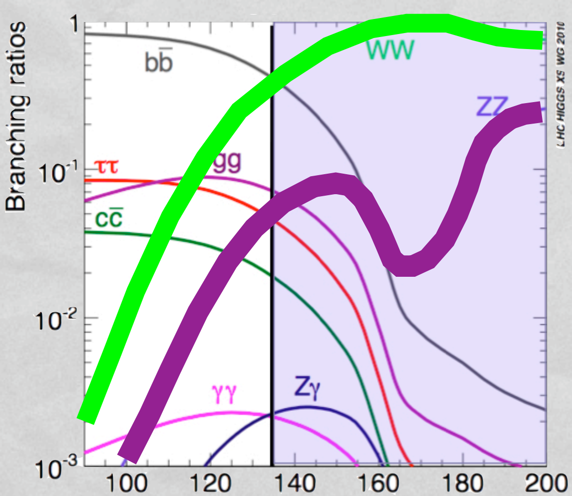
High mass searches

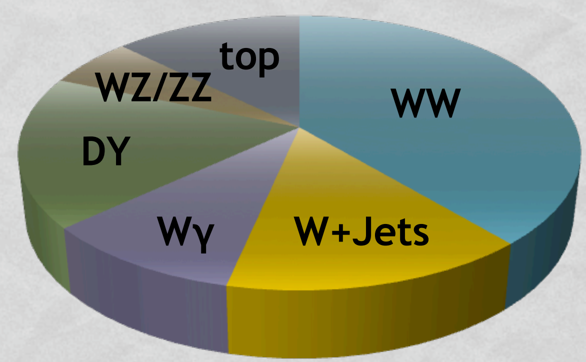




$H \to WW \to l\nu l\nu$

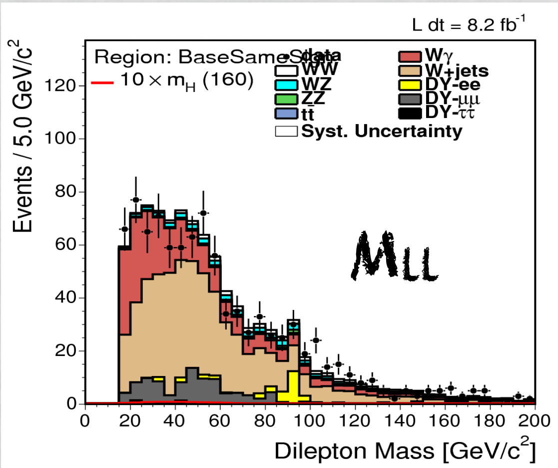
$H \to ZZ \to l\nu l\nu$



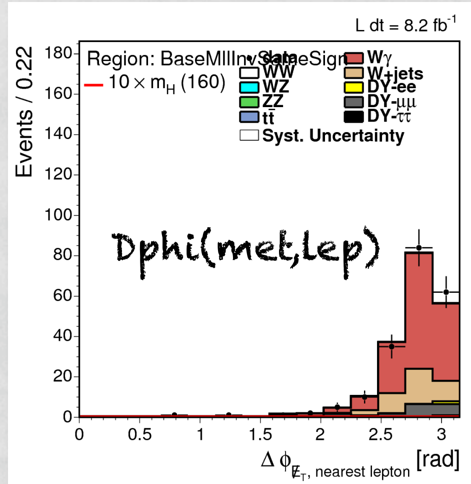


Backgrounds

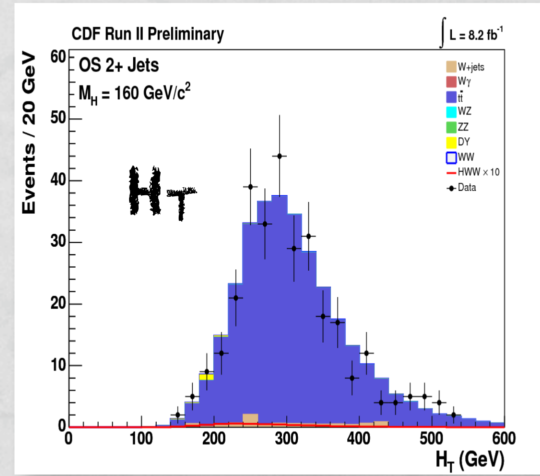
Background checks



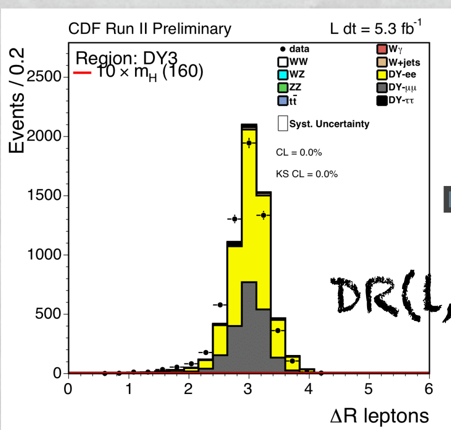
W+jet: same sign dileptons



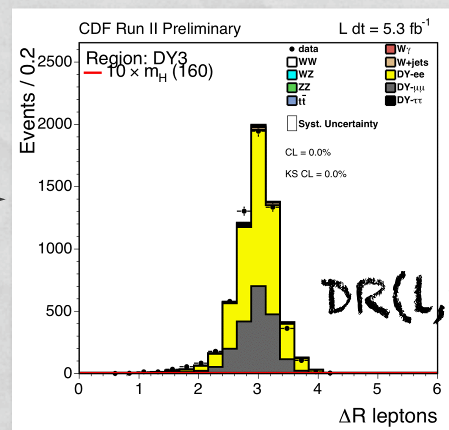
W+photon: same sign dileptons (low Mll)



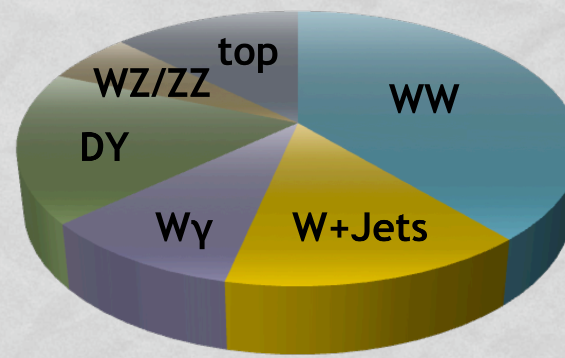
t-tbar: opposite sign dileptons, >2 jets, b-tag



tunning



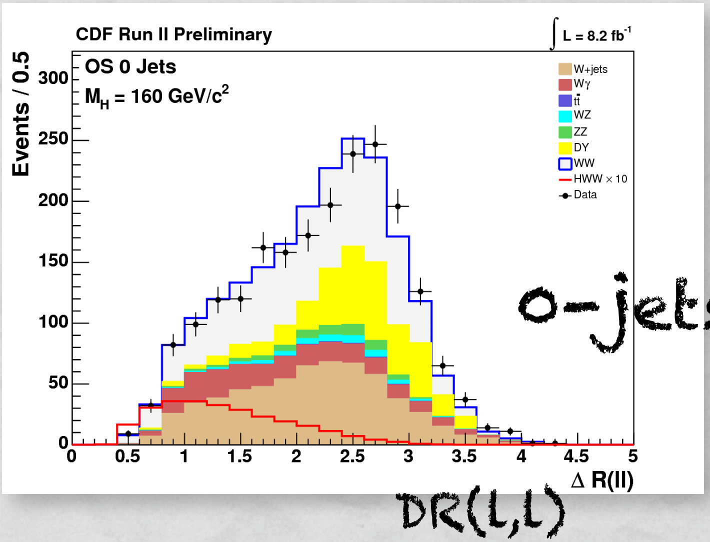
DY: intermediate met region

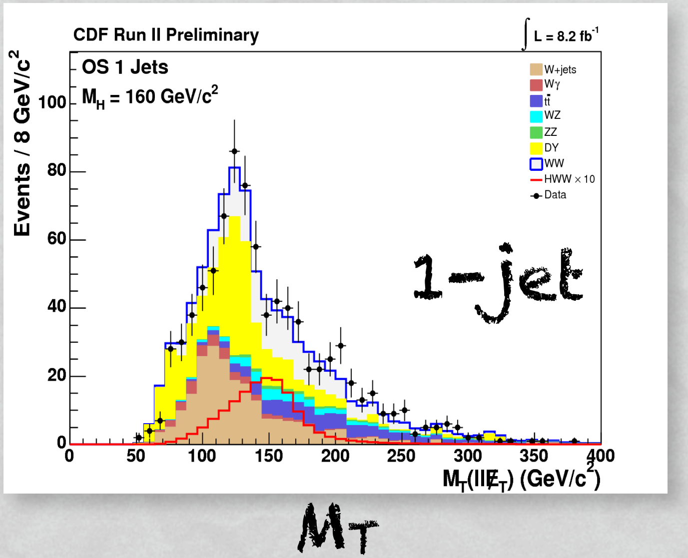


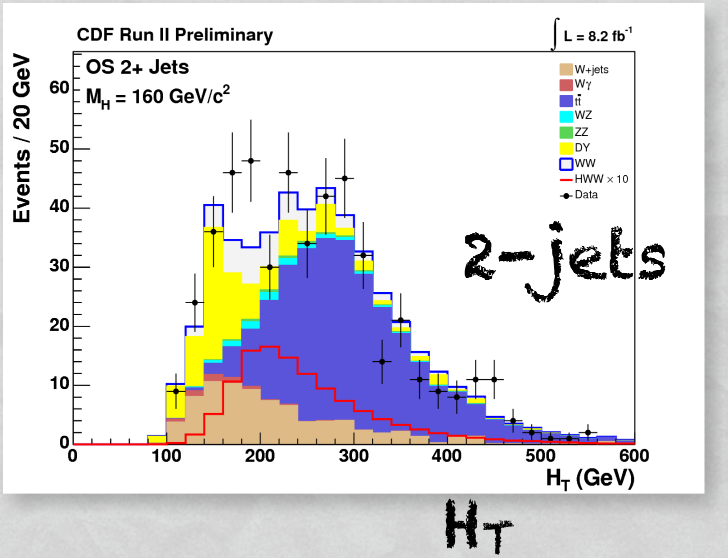
Backgrounds

Divide and conquer

- Optimize search sensitivity by dividing events into multiple analysis channel
- Use separately optimized discriminants for each channel based on:
  - specific signal contributions
  - specific background contributions
  - specific event kinematics

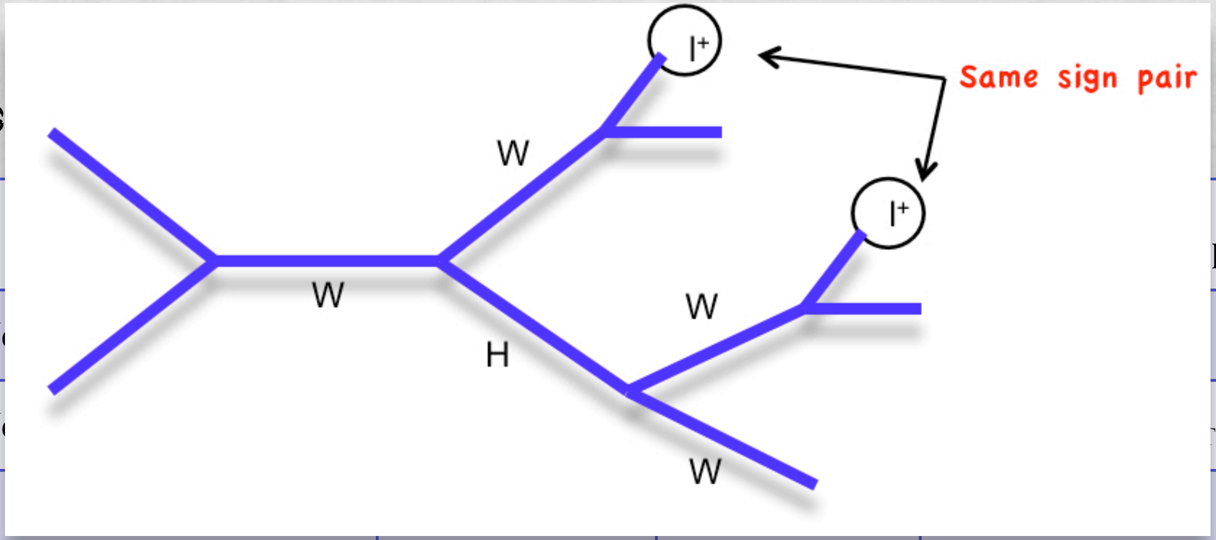






Leave no Higgs behind

High-mas



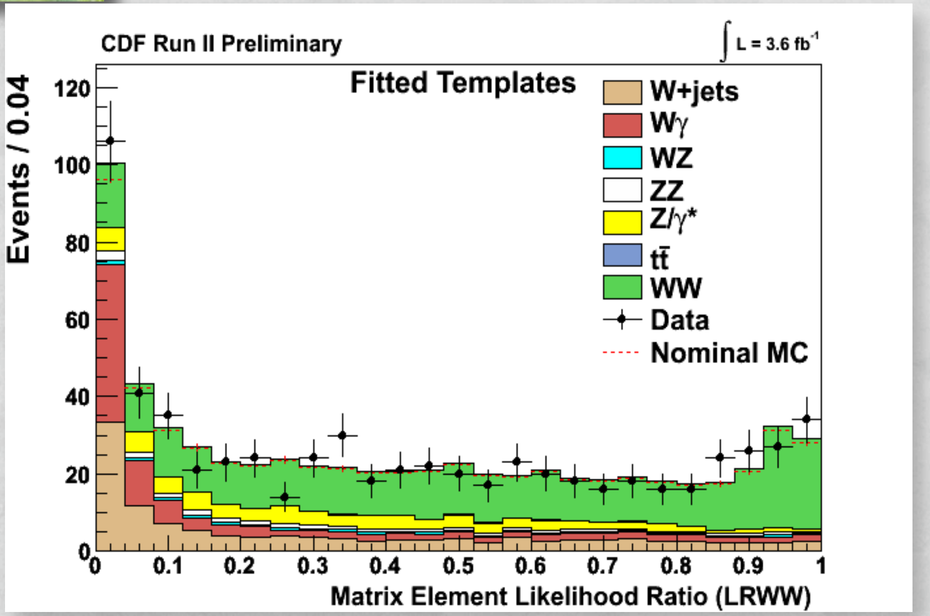
Channel			les
OS dileptons, 0 Je			
OS dileptons, 1 Je			
OS dileptons, 2+			
OS dileptons, low M_{ll}, 0 or 1 Jet	gg→H	W+γ	p_T(l2), p_T(l1), E(l1)
SS dileptons, 1+ Jet	WH→WWW	W+Jets	E_T, $\sum E_T^{jets}$, M_{ll}
Tri-leptons, no Z candidate	WH→WWW	WZ	E_T, ΔR_{ll}^{close}, Type(lll)
Tri-leptons, Z candidate, 1 Jet	ZH→ZWW	WZ	Jet E_T, ΔR_{lj}, E_T
Tri-leptons, Z candidate, 2+ Jets	ZH→ZWW	Z+Jets	M_{jj}, M_T^H, ΔR_{WW}
OS dilepton, electron + hadronic tau	gg→H	W+Jets	$\Delta R_{l\tau}$, τ id variables
OS dilepton, muon + hadronic tau	gg→H	W+Jets	$\Delta R_{l\tau}$, τ id variables

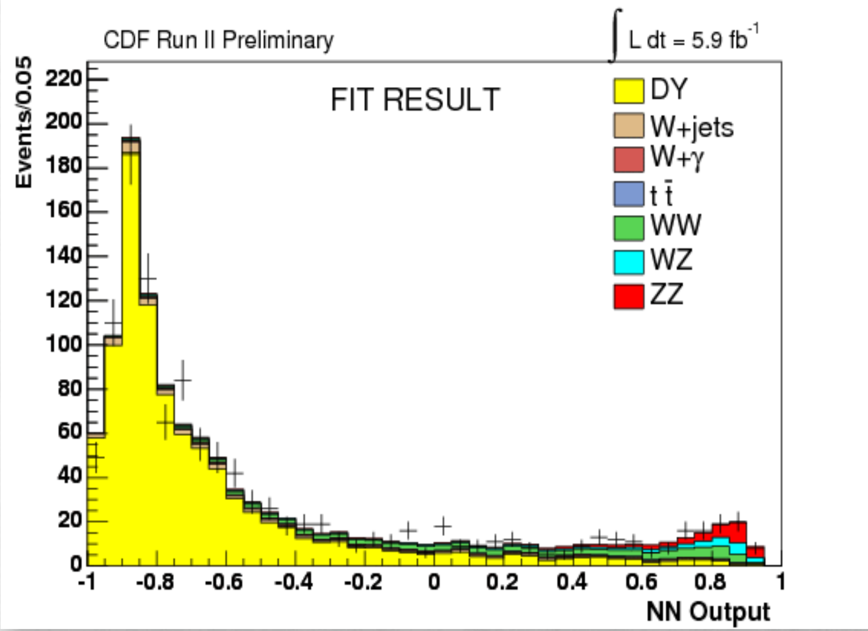
Leave no Higgs behind

High-mass searches: by Nlept, Njet, SS, OS, Z/no-Z, tau

Channel	Main Signal	Main Background	Most Important kinematic variables
OS dileptons, 0 Jets	$gg \to H$	WW	LR_{HWW}, ΔR_{ll}, H_T
OS dileptons, 1 Jet	$gg \to H$	DY	ΔR_{ll}, $m_T(ll,E_T)$, E_T
OS dileptons, 2+ Jets	Mixture	t-tbar	H_T, ΔR_{ll}, M_{ll}
OS dileptons, low M_{ll}, 0 or 1 Jet	$gg \to H$	$W+\gamma$	$p_T(l2)$, $p_T(l1)$, $E(l1)$
SS dileptons, 1+ Jet	$WH \to WWW$	W+Jets	E_T, $\sum E_T^{jets}$, M_{ll}
Tri-leptons, no Z candidate	$WH \to WWW$	WZ	E_T, ΔR_{ll}^{close}, Type(lll)
Tri-leptons, Z candidate, 1 Jet	$ZH \to ZWW$	WZ	Jet E_T, ΔR_{lj}, E_T
Tri-leptons, Z candidate, 2+ Jets	$ZH \to ZWW$	Z+Jets	M_{jj}, M_T^H, ΔR_{WW}
OS dilepton, electron + hadronic tau	$gg \to H$	W+Jets	$\Delta R_{l\tau}$, τ id variables
OS dilepton, muon + hadronic tau	$gg \to H$	W+Jets	$\Delta R_{l\tau}$, τ id variables

SM cross section measurements





$WW \to l\nu l\nu : \sigma(WW) = 12.1^{+1.8}_{-1.7}$ pb

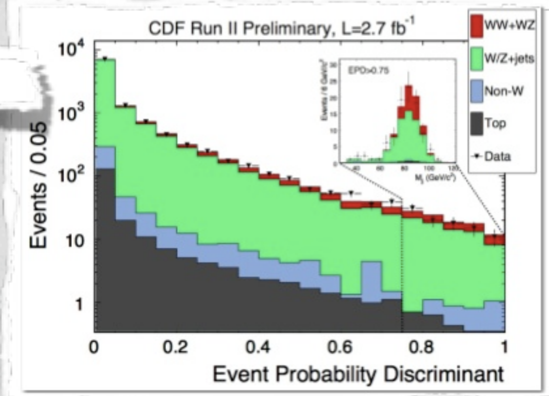
$ZZ \to ll\nu\nu : \sigma(ZZ) = 1.45^{+0.60}_{-0.51}$ pb

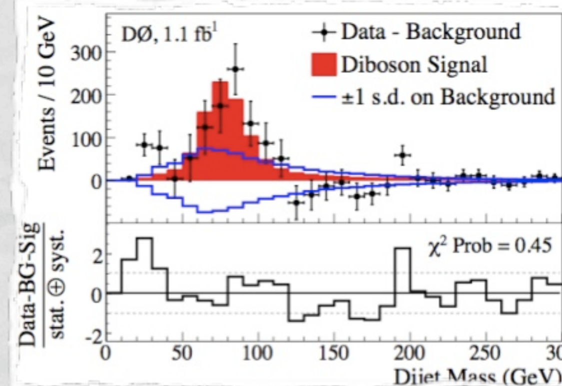
consistent with expectations

- Using same tools and data samples
- Important validation for background modeling and analysis techniques

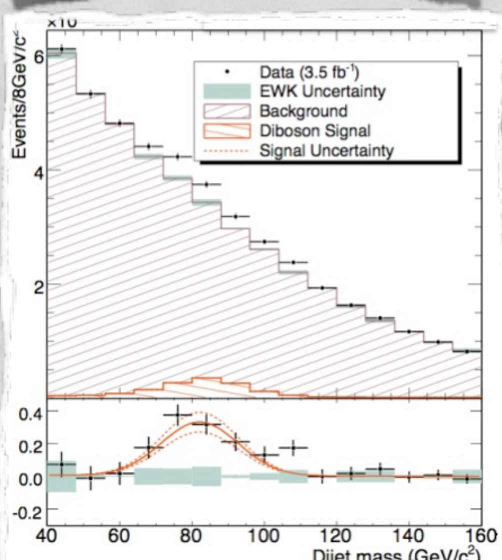
"Dibosons pave the road to the Higgs"

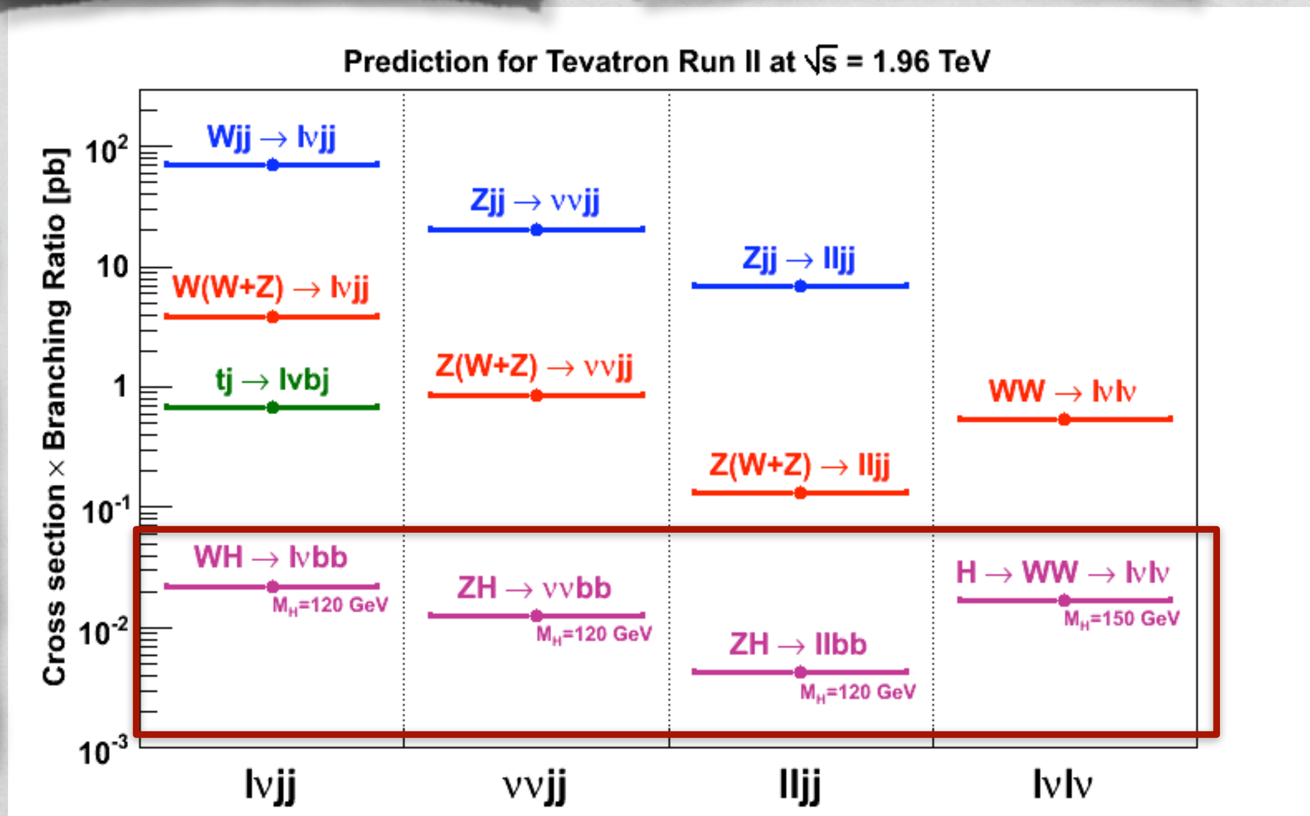
WW/WZ=>l,nu,jj



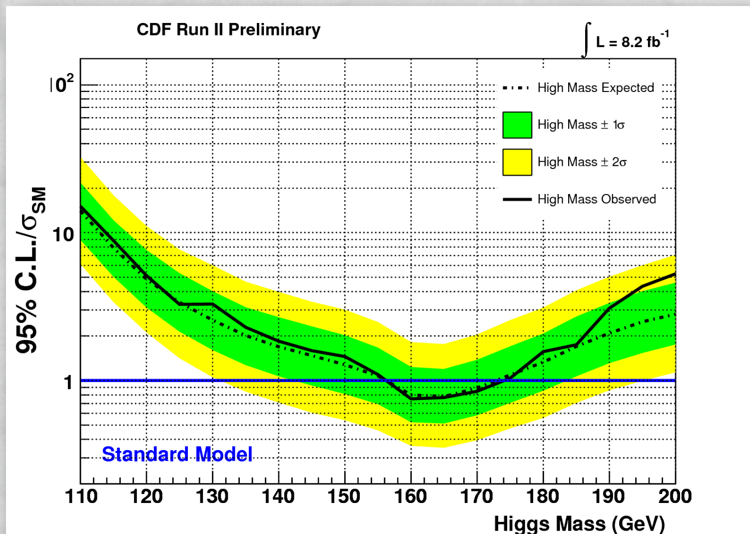


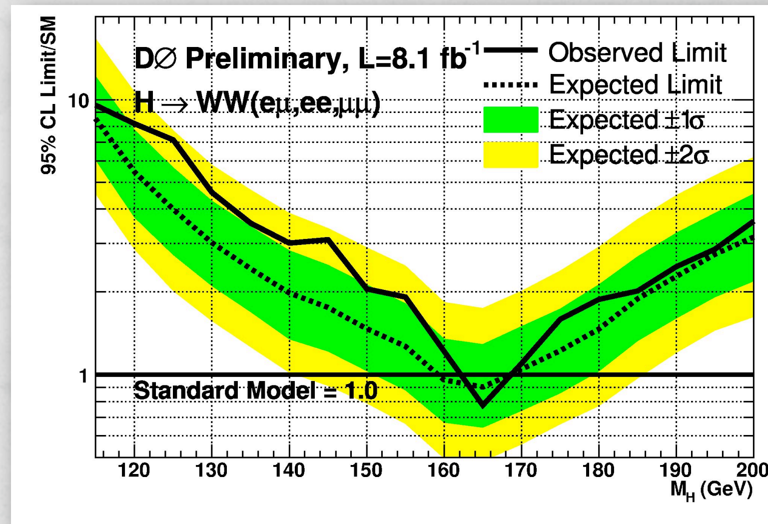
WW/WZ=>met+jj



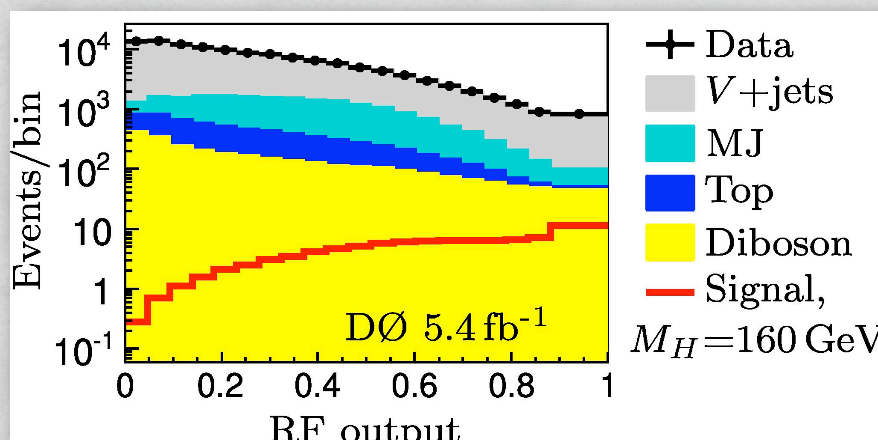


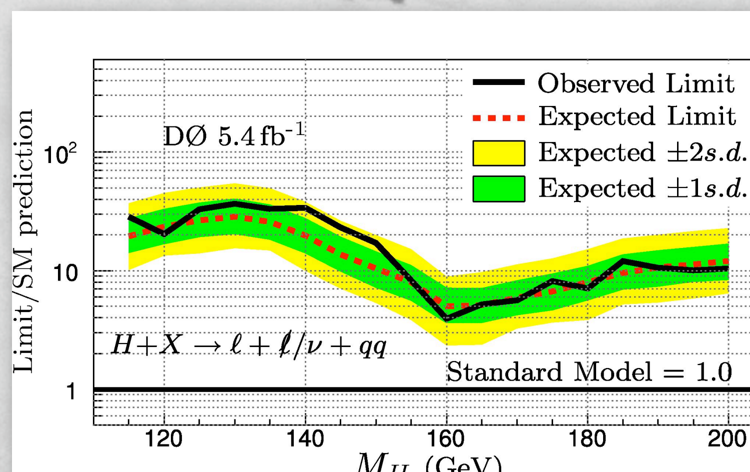
H=>WW search results





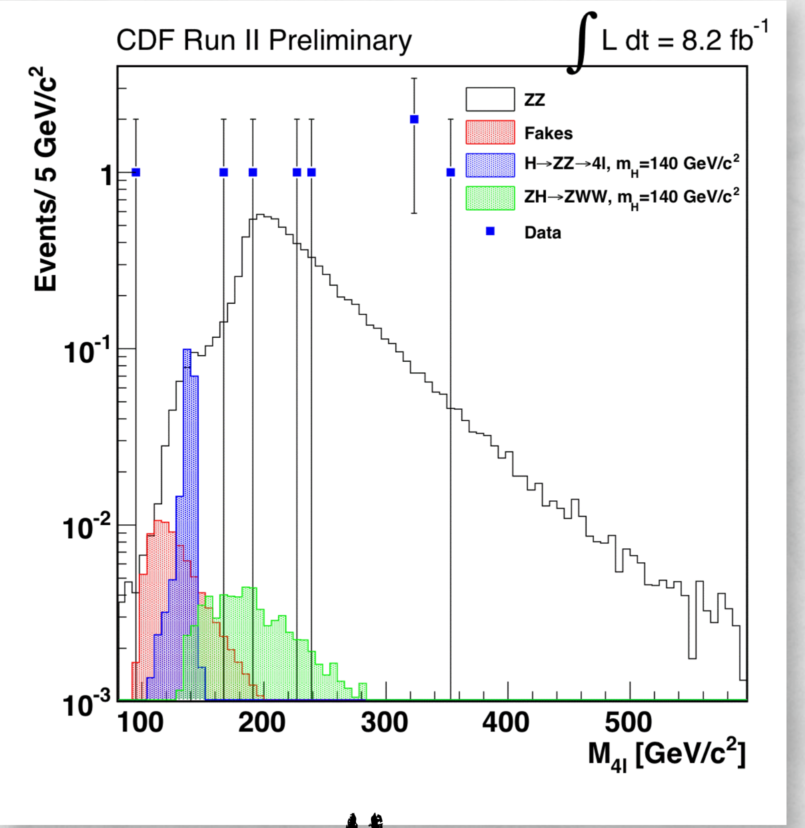
CDF & DO H→WW→lνlν



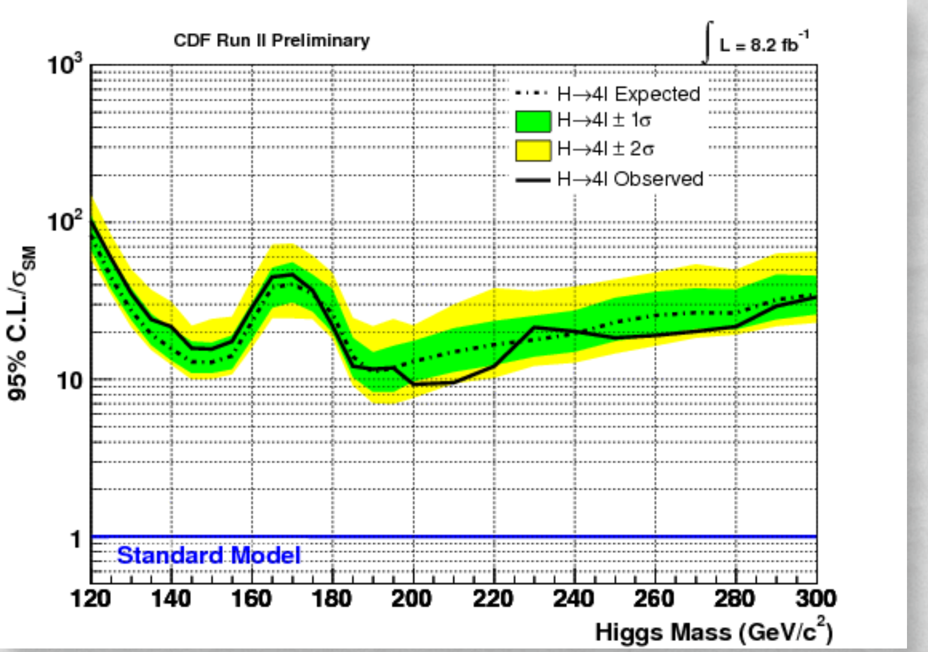


DO H→WW→lνjj

Results on inclusive H=> 4-lepton search



M4L

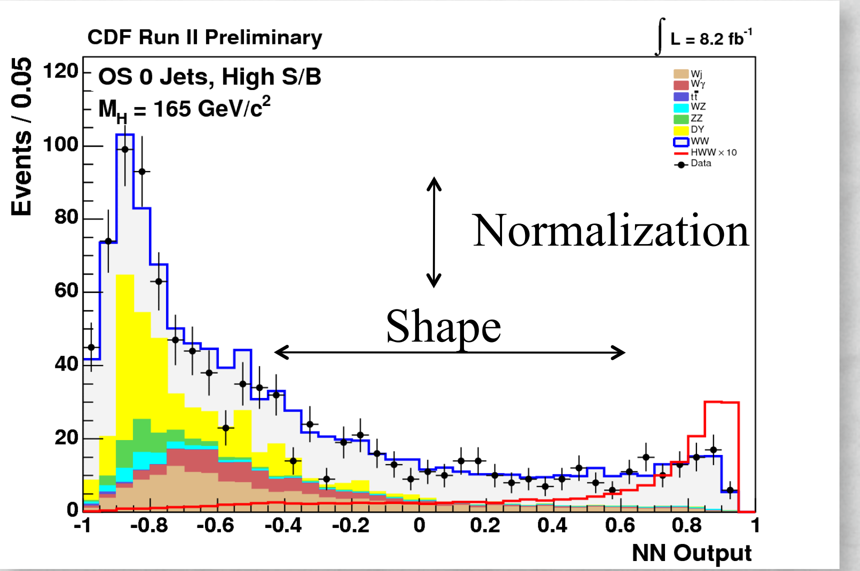


Systematic uncertainties

For each signal/background process:

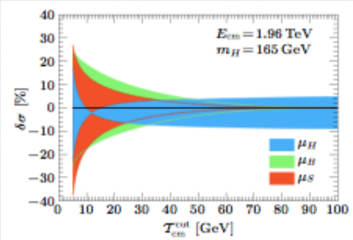
> **normalization** and **shape** of the discriminant templates.

> **cross section** signal uncertainties
- special care of scales and also of sample splits by # of jets



channel	scale 0	scale 1	scale 2
0 jet	13.4%	-23.0%	-
1 jet	-	35.0%	-12.7%
2+ jets	-	-	33.0%

Stewart and Tackmann, arXiv:1107.2117v1

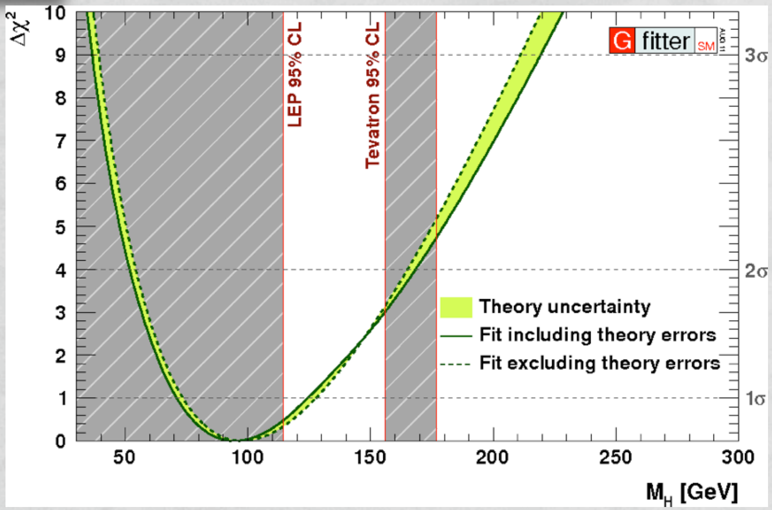


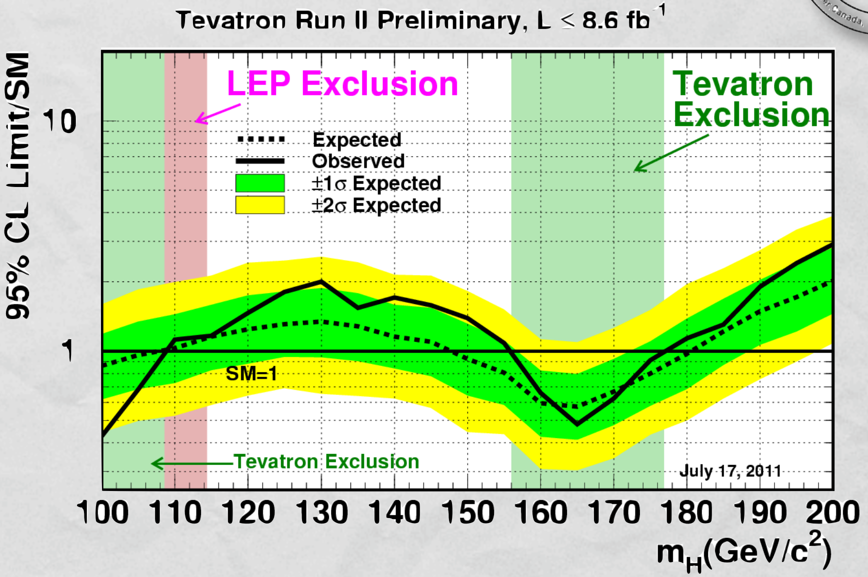
Berger et al., arXiv:1012.4480v2

✦ In the limit-setting procedure systematics are included as nuisance parameters, taking into account the correlations between different channels.

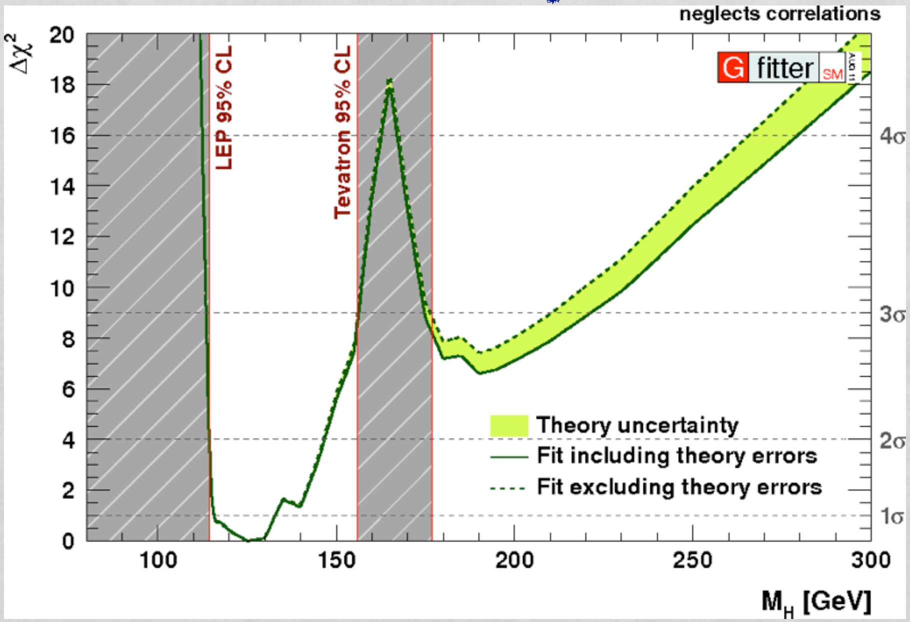
✦ With this approach we are able to further constrain our background uncertainties directly from the data

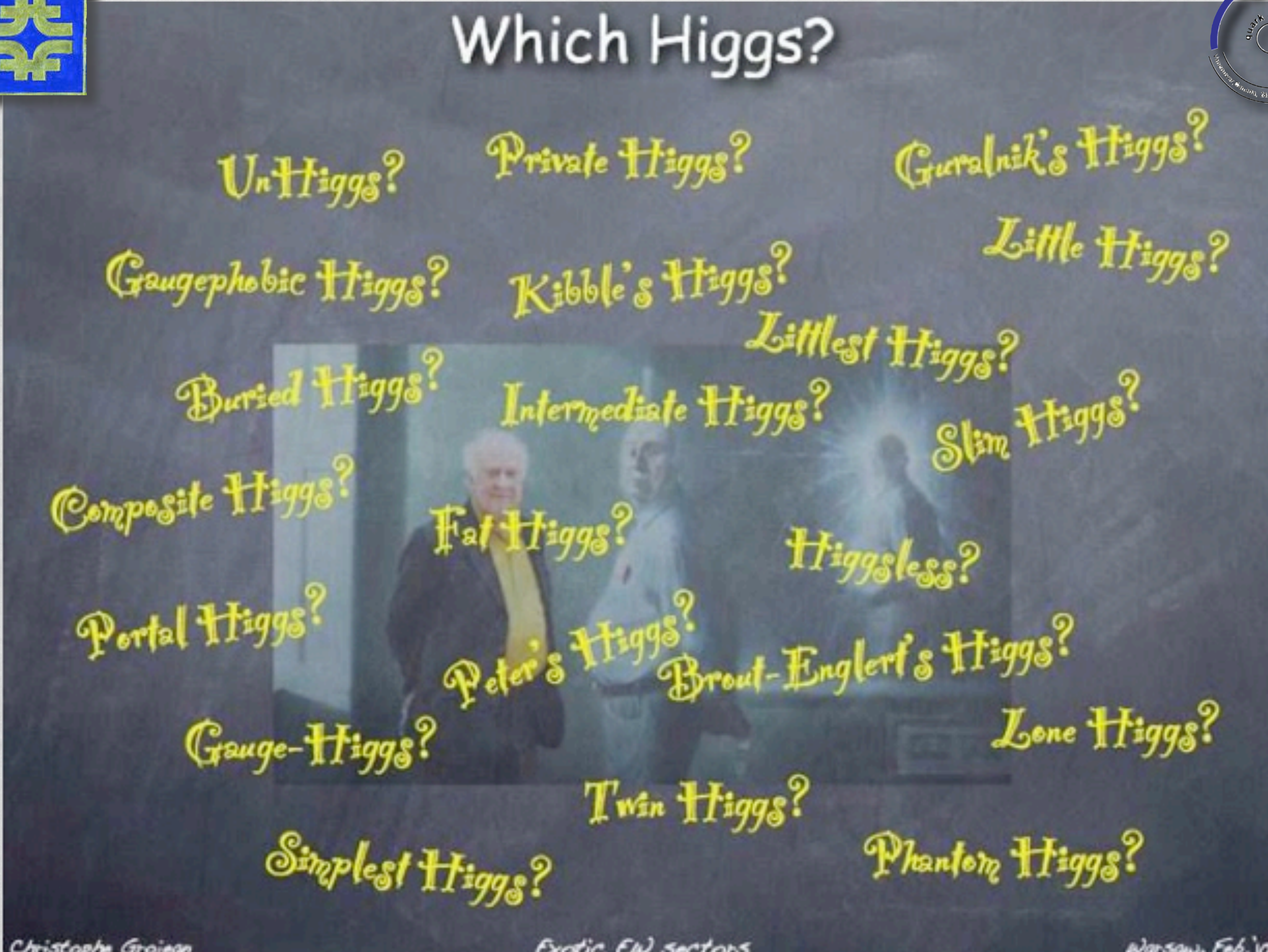
Back to the end





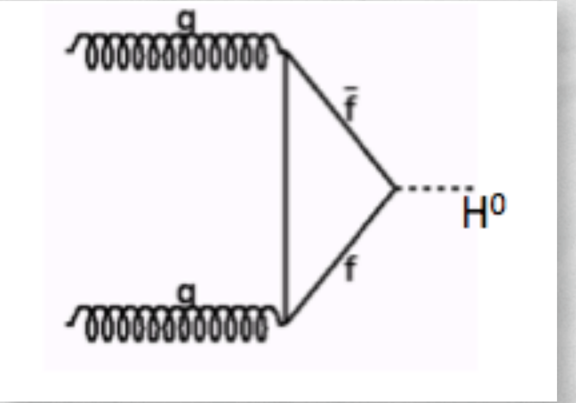
Higgs mass likelihood -modified by the Tevatron searches

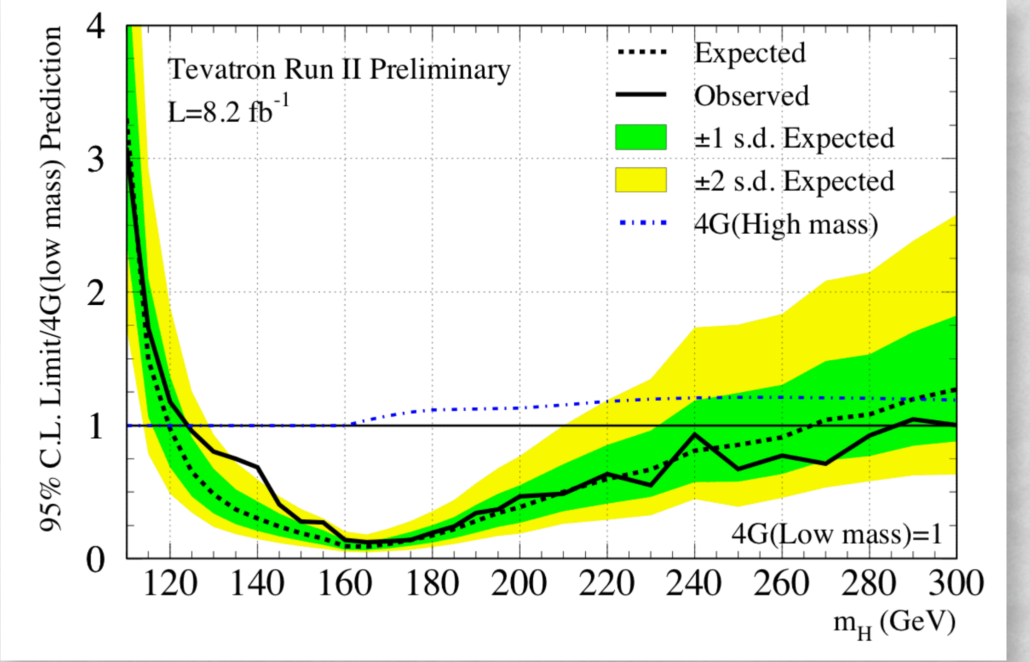



Which Higgs?
UnHiggs?
Private Higgs?
Guralnik's Higgs?
Little Higgs?
Gaugephobic Higgs?
Kibble's Higgs?
Littlest Higgs?
Buried Higgs?
Intermediate Higgs?
Slim Higgs?
Composite Higgs?
Fat Higgs?
Higgsless?
Portal Higgs?
Peter's Higgs?
Brout-Englert's Higgs?
Gauge-Higgs?
Lone Higgs?
Twin Higgs?
Simplest Higgs?
Phantom Higgs?
Christophe Grojean
Exotic EW sectors
Warsaw, Feb.'10

Fourth Generation

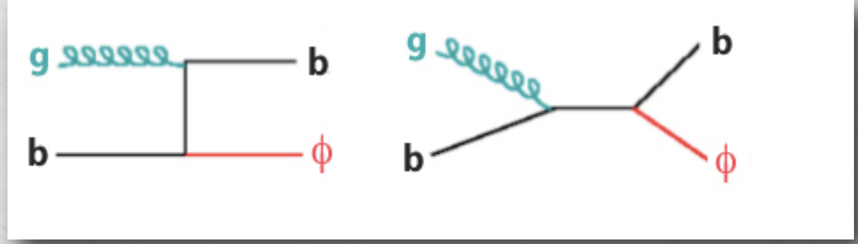
- Can interpret our high mass search results in terms of a fourth generation model
- Presence of additional quarks enhances $gg \rightarrow H$ production by as much as a factor of nine - also modifies Higgs branching ratios
- Observed exclusion : $124 < m_H < 286$ GeV

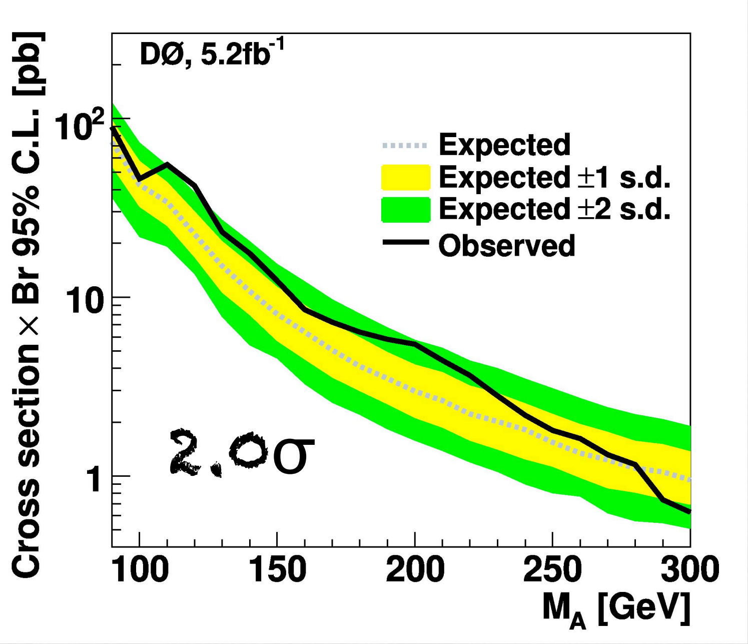


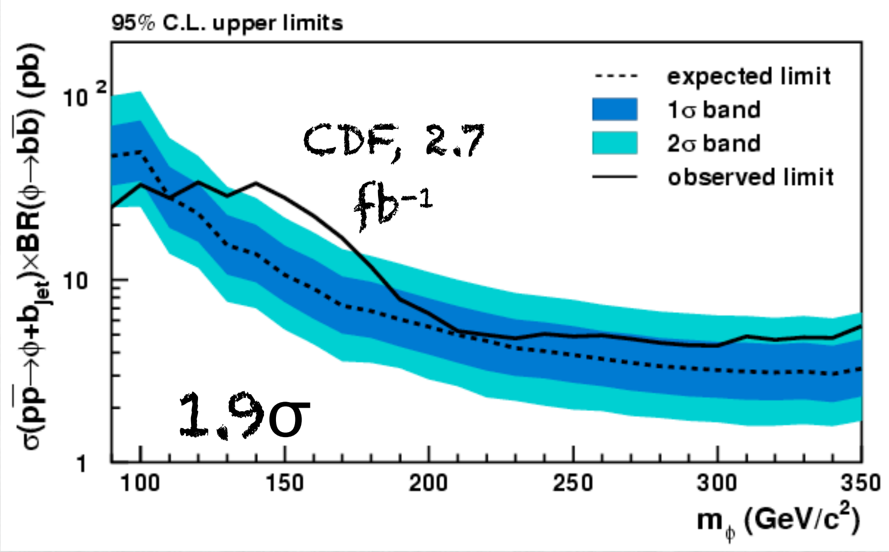


MSSM-like Higgs

- Inclusive production cross section
- $\sigma(pp \rightarrow h/H/A)$ is enhanced
  - enhancement depends on $\tan\beta$
- General limits applicable to any
- narrow scalar with bb final states
- produced in association with b-jet



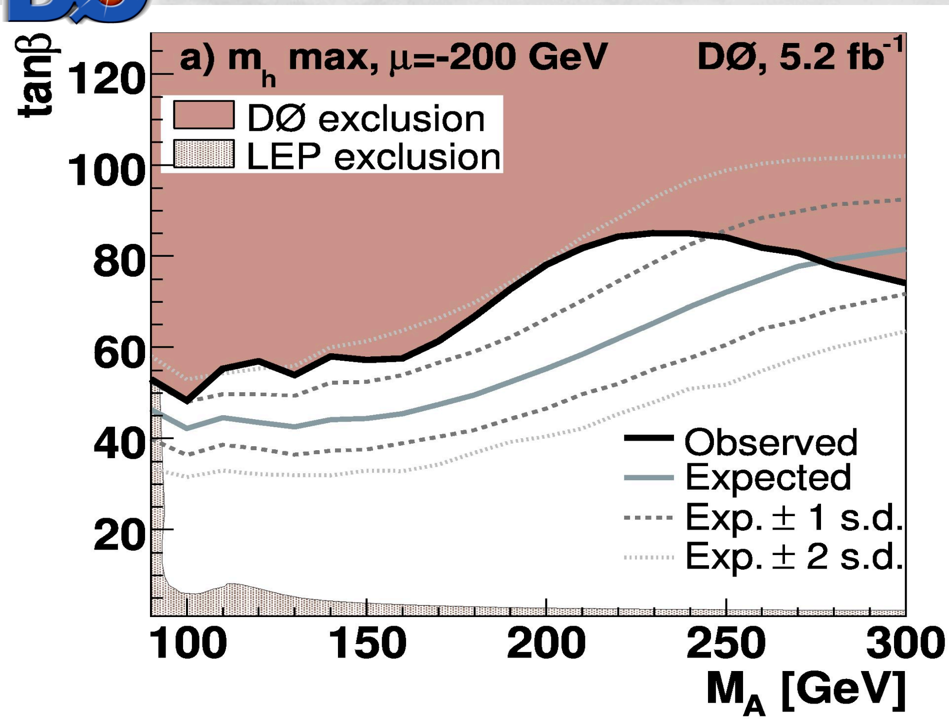


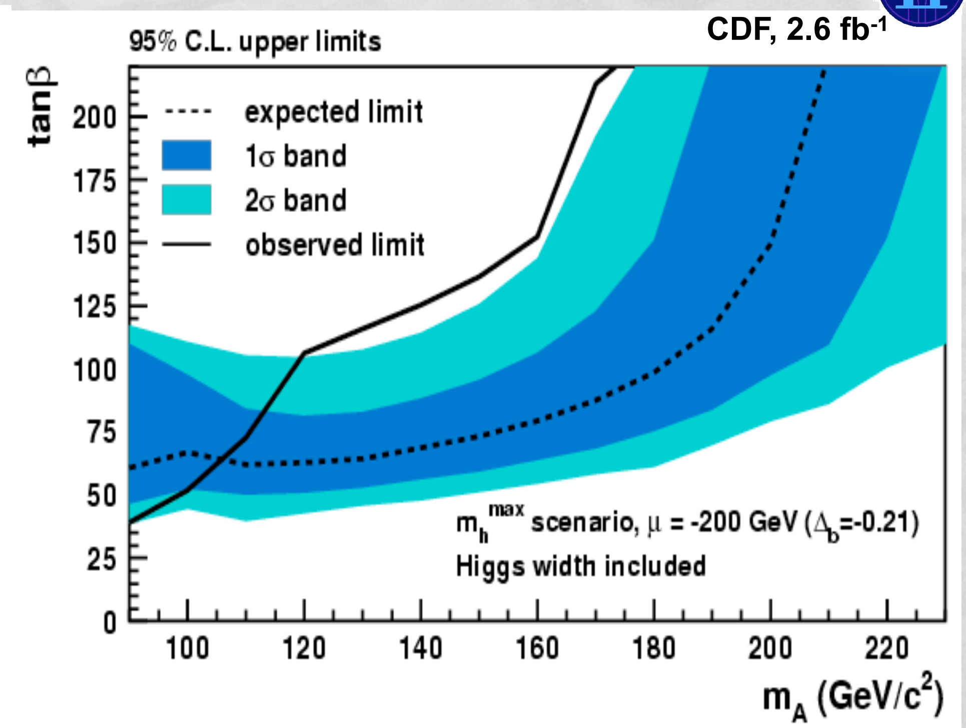


broad excesses observed by CDF and D0 in $b\phi \rightarrow bbb$

$\phi b \rightarrow bbb$: MSSM interpretation

MSSM Exclusions in (M_A, tanβ) Parameter Space

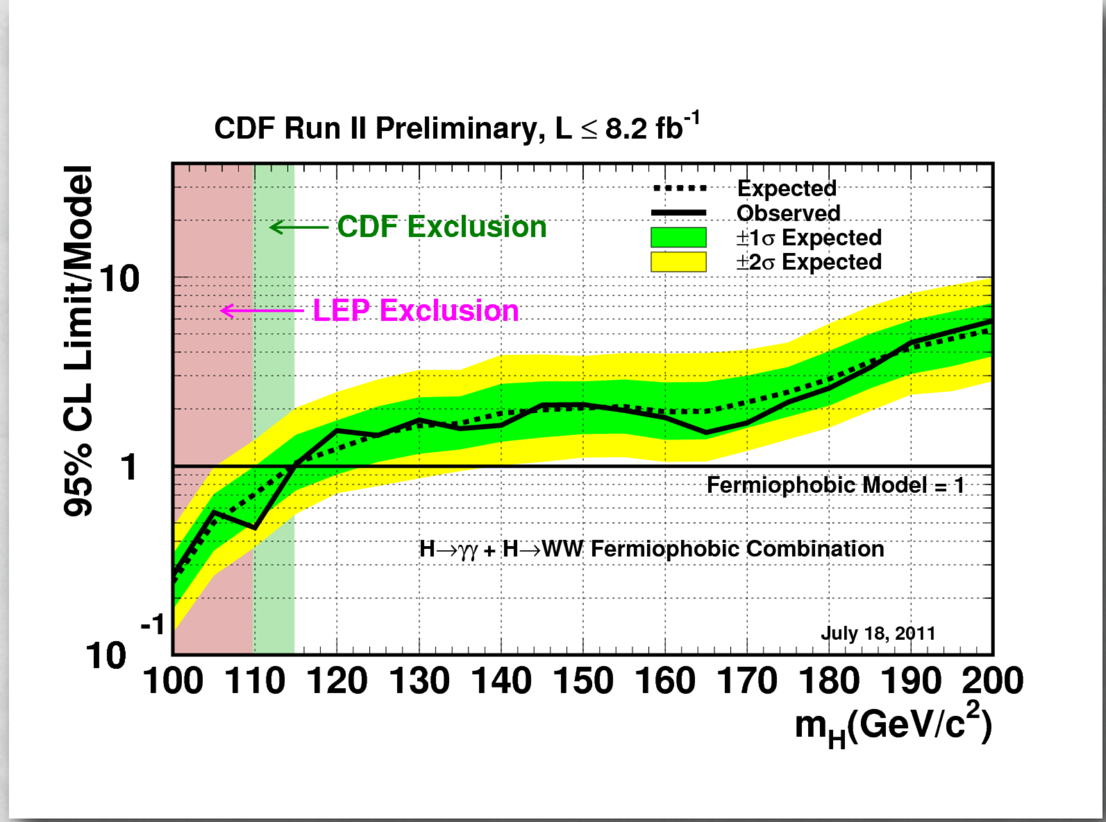




Higgs mass term, $\mu < 0$ $\Rightarrow$ enhanced production for 3b at large tanβ
enhances the bbH coupling as well as increases width of the Higgs

Fermiophobic Higgs

- Fermiophobic Higgs is not accessible though the dominant gluon fusion production mode
- CDF sets world-best lower mass limit of 114.8 GeV/c² pending soon to be completed combination with D0

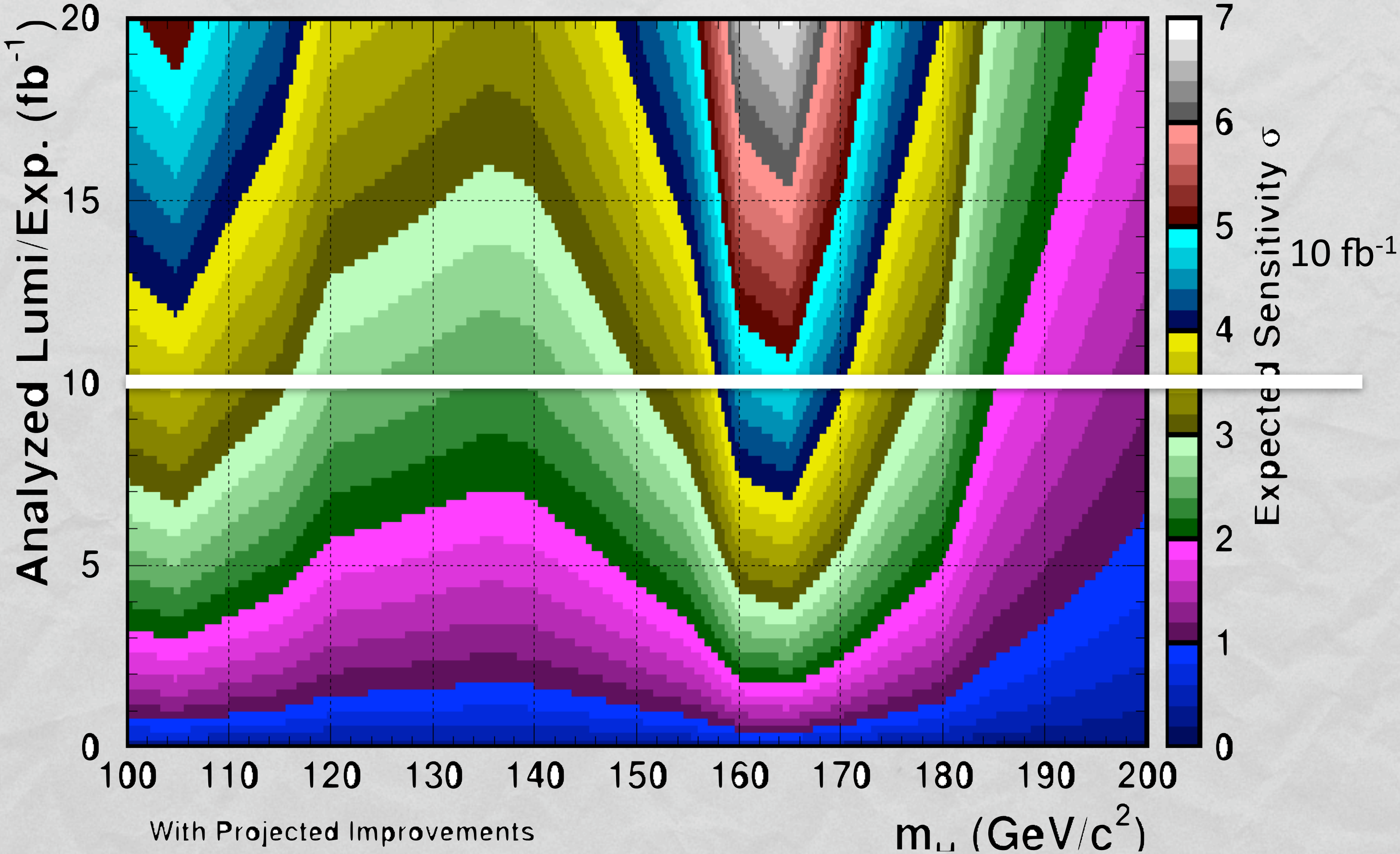


What's next

Tevatron's expected sensitivity vs Higgs mass vs lum

The run will end with about 10 fb-1 analyzable lum

2-3 sigma sensitivity up to 185 GeV



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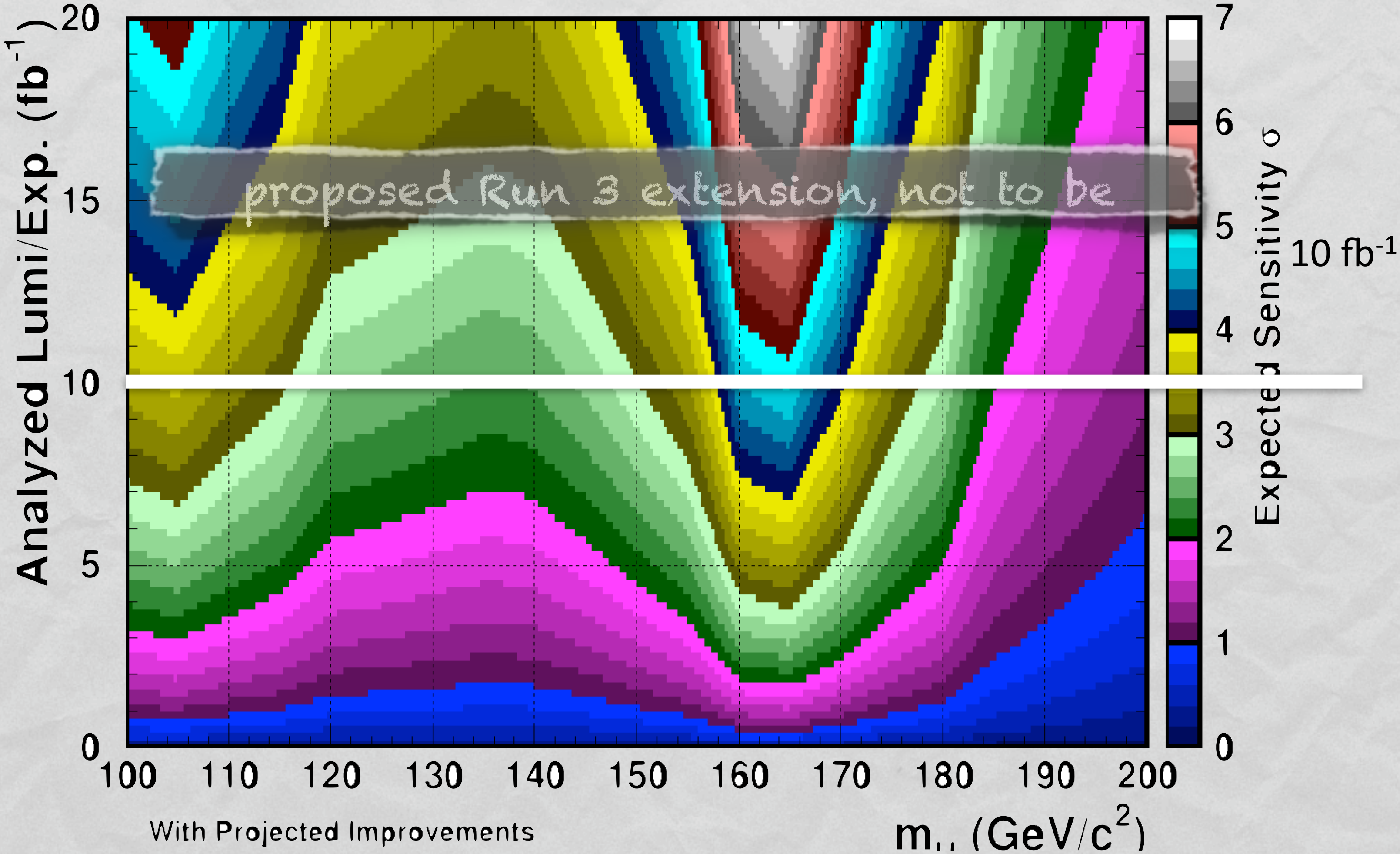


Still work to do..

Improvements (e.g. DØ)

Type	Projected Improvement	WH→lvbb	ZH→llbb	ZH→vvbb	H→WW	Other Channels
Lepton ID	MVA Electron ID	1%	5%	-1%	3%	3%
	Improved MuonID/tracking	4%	3%	-2%	Done	3%
	Add Isolated Tracks	2%	Done	-1%	3%	2%
	Add ICR Electrons	2%	Done	-1%	3%	2%
	Add EC Electrons	Done	Done		Done	2%
	Improved energy scale	1%	2%		2%	5%
Trigger / Reco	Trigger/Reconstruction Efficiency	5%	3%	Done	Done	5%
Jet Selection	Di-jet Mass Resolution	10%	10%	10%		
	MVA B-ID	5%	5%	5%		
	MVA Bottom vs Charm	4%	4%	4%		
MVA Analysis	Enhanced Techniques	10%	10%	10%	10%	10%
	New signal separation variables	5%	5%	5%	5%	5%
	MVA QCD Rejection	3%	1%	Done	3%	3%
	Matrix Element Discriminants	5%	5%	5%	5%	3%
	Kinematic Fitting	5%	Done			3%
Optimization	Track Variables	5%	3%	Done	5%	5%
	Optimized B-ID Usage	3%	3%	3%		
	Optimized Jet Treatment	3%	8%	Done		
New Channels	H→WW→e/mu+tau				5%	
	VH→etau+jj					3%
	H→ZZ					3%
	VH→VVV→trileptons					3%
	Additional Decay Modes	5%	5%	Done	5%	5%
	Existing Improvements:	57%	70%	29%	41%	
	Planned Improvements:	36%	27%	20%	18%	

- Yellow cells are existing improvements to be propagated to final analysis.
- White cells with numbers are the areas the experiment is actively working on.

Summary

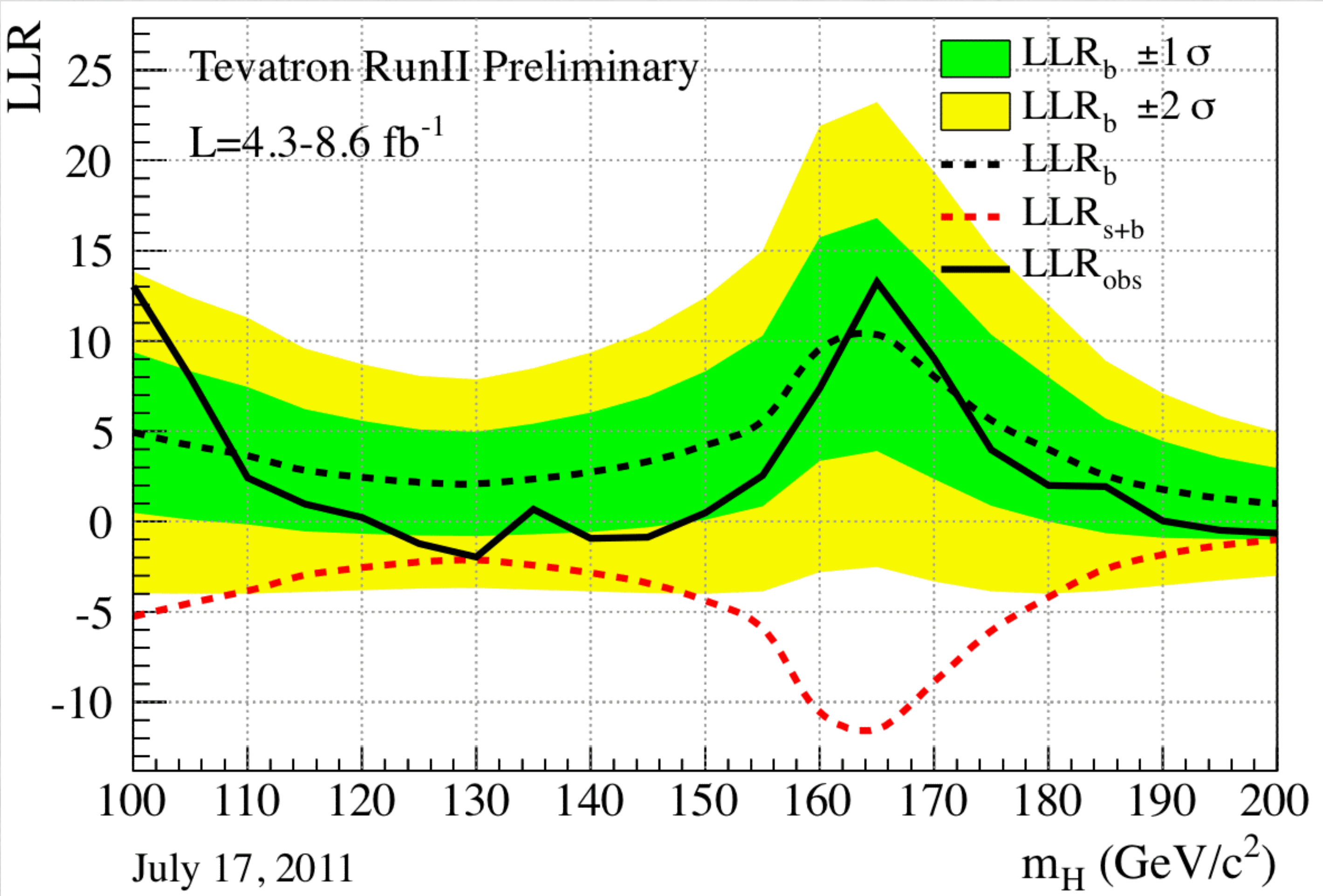
- The Tevatron Higgs searches broke new ground
  - great advances in data understanding and in analysis techniques at hadron colliders
- Goal remains to reach 95% CL exclusion sensitivity over the allowed SM mass range [100:185 GeV]
- LHC is well into the game [see P. Meridiani's talk]
  - It's effort fueled by the Tevatron's success and aided by the assortment of tools developed by CDF and Dzero
- For H=>bb the Tevatron remains well ahead
  - M_H~115 limits at 1.1 xSM ! [might rule out LEP's hints]
- Aside from Higgs - vast physics phase space examined

Many thanks to:

- The CDF and DO Higgs teams for their perseverance, passion and creativity
- The FNAL accelerator teams for never giving up and delivering ever more luminosity
- The HEP funding agencies for continued support of this magnificent program
- J. Ellis, E. James, M. Verzocchi, B. Kilminster, E. Pianori, K. Potamianos, Y. Enari, A. Patwa - for “slides support”
- **The PIC organizers & hosts !**

BACKUP

S+B versus B-only Hypotheses



CDF's modes

cdf15 <> CDF VH->MET bb 1S 7.8 fb-1
cdf16 <> CDF VH->MET bb SS 7.8 fb-1
cdf17 <> CDF VH->MET bb SJ 7.8 fb-1
cdf28 <> CDF HWW 8.2fb HighSB0J
cdf29 <> CDF HWW 8.2fb LowSB0J
cdf30 <> CDF HWW 8.2fb HighSB1J
cdf31 <> CDF HWW 8.2fb LowSB1J
cdf32 <> CDF HWW 8.2fb 2JOS
cdf56 <> CDF WH WWW 8.2 fb-1 like-sign
cdf57 <> CDF H->WW 8.2 fb-1 low-mll
cdf64 <> CDF WH ME 5.6 fb-1 3J SVJP
cdf65 <> CDF WH ME 5.6 fb-1 3J SVJP loose
cdf66 <> CDF WH ME 5.6 fb-1 3J SVnoJP
cdf67 <> CDF WH ME 5.6 fb-1 3J SVnoJP loose
cdf68 <> CDF WH ME 5.6 fb-1 3J SVSV
cdf69 <> CDF WH ME 5.6 fb-1 3J SVSV loose
cdf84 <> CDF H->WW Trilepton NoZ 8.2 fb-1
cdf85 <> CDF H->WW Trilepton InZ 1jet 8.2 fb-1
cdf86 <> CDF H->WW etau 8.2 fb-1
cdf87 <> CDF H->WW mutau 8.2 fb-1
cdf88 <> CDF H->WW Trilepton InZ 2jet 8.2 fb-1
cdf101 <> CDF Htautau 2jets 6.0 fb-1
cdf102 <> CDF Htautau 1jet 6.0 fb-1
cdf103 <> CDF jjbb SS 4fb-1
cdf104 <> CDF jjbb SJ 4fb-1
cdf105 <> CDF jjbb VBF SS 4fb-1
cdf106 <> CDF jjbb VBF SJ 4fb-1
cdf112 <> CDF H->gammagamma 7.0 fb-1 CC
cdf113 <> CDF H->gammagamma 7.0 fb-1 CP
cdf114 <> CDF H->gammagamma 7.0 fb-1 CC Conv
cdf115 <> CDF H->gammagamma 7.0 fb-1 CP Conv
cdf116 <> CDF Vtautau lll 6.2 fb-1
cdf117 <> CDF Vtautau lltau 6.2 fb-1
cdf118 <> CDF Vtautau emutau 6.2 fb-1
cdf119 <> CDF Vtautau ltautau 6.2 fb-1
cdf120 <> CDF Vtautau llll 6.2 fb-1
cdf121 <> CDF ttH MET+jets 2btag 5.7 fb-1
cdf122 <> CDF ttH MET+jets 3btag 5.7 fb-1
cdf123 <> CDF ttH All 2btag 5.7 fb-1
cdf124 <> CDF ttH All 3btag 5.7 fb-1

cdf125 <> CDF mumubb ST 7.9 fb-1
cdf126 <> CDF mumubb LJP 7.9 fb-1
cdf127 <> CDF mumubb DT 7.9 fb-1
cdf128 <> CDF eebb ST 7.5 fb-1
cdf129 <> CDF eebb LJP 7.5 fb-1
cdf130 <> CDF eebb DT 7.5 fb-1
cdf131 <> CDF WHAM NN 7.5 fb-1 SVTSVT TIGHT with BNN
cdf132 <> CDF WHAM NN 7.5 fb-1 SVTJP05 TIGHT with BNN
cdf133 <> CDF WHAM NN 7.5 fb-1 SVTnoJP05Roma TIGHT with BNN
cdf134 <> CDF WHAM NN 7.5 fb-1 SVTnoJP05noRoma TIGHT with BNN
cdf135 <> CDF WHAM NN 7.5 fb-1 SVTSVT PHX with BNN
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cdf137 <> CDF WHAM NN 7.5 fb-1 SVTnoJP05Roma PHX with BNN
cdf138 <> CDF WHAM NN 7.5 fb-1 SVTnoJP05noRoma PHX with BNN
cdf139 <> CDF WHAM NN 7.5 fb-1 SVTSVT ISOTRK with BNN
cdf140 <> CDF WHAM NN 7.5 fb-1 SVTJP05 ISOTRK with BNN
cdf141 <> CDF WHAM NN 7.5 fb-1 SVTnoJP05Roma ISOTRK with BNN
cdf142 <> CDF WHAM NN 7.5 fb-1 SVTnoJP05noRoma ISOTRK with BNN
cdf155 <> CDF WH NN 7.5 fb-1 2JET SVTSVT LOOSE ISOTRK
cdf156 <> CDF WH NN 7.5 fb-1 2JET SVTJP05 LOOSE ISOTRK
cdf157 <> CDF WH NN 7.5 fb-1 2JET SVTnoJP05Roma LOOSE ISOTRK
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cdf159 <> CDF HZZ mLLLL 8.2 fb-1
cdf160 <> CDF ttH l+5J STSTST 6.3 fb-1
cdf161 <> CDF ttH l+5J STSTJP 6.3 fb-1
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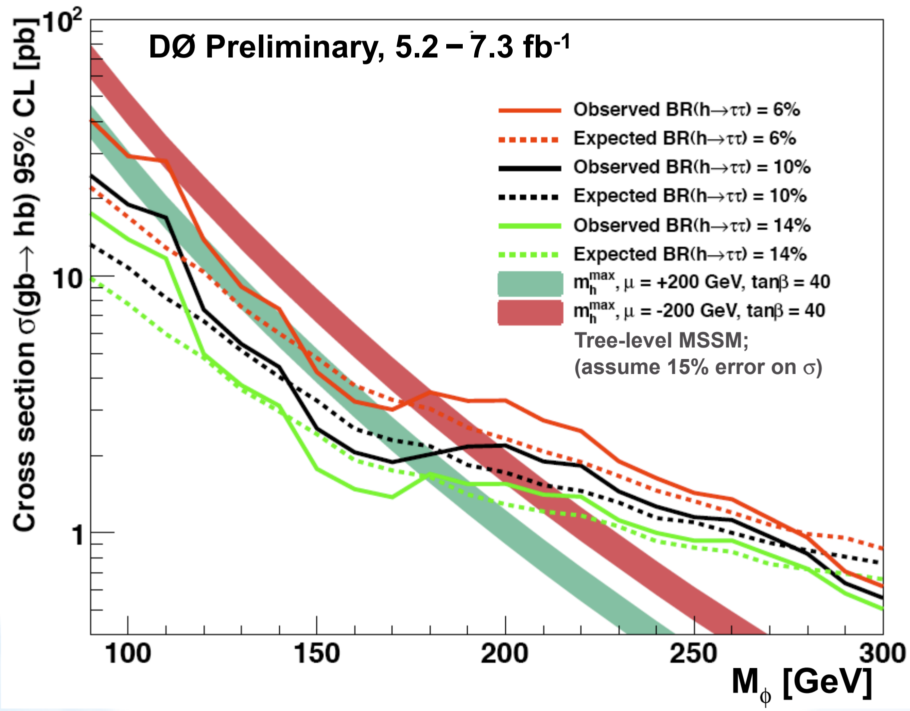
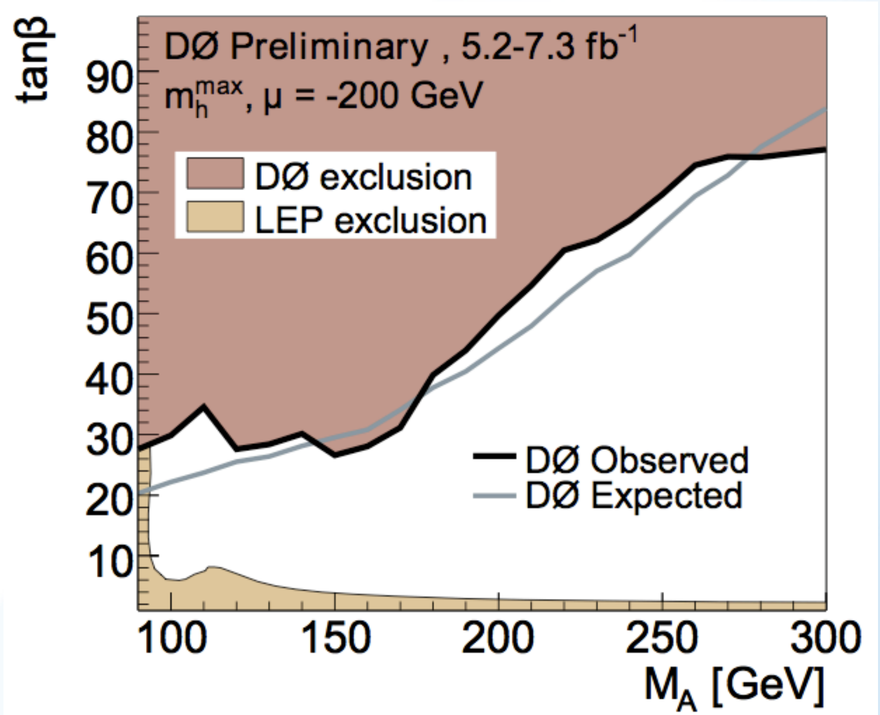
cdf168 <> CDF ttH l+5J STJPJP 6.3 fb-1
cdf169 <> CDF ttH l+5J STJP 6.3 fb-1

DØ Combined Limits: $\phi b \to \tau\tau b, \phi b \to 3b$

- **[New for Summer 2011] DØ MSSM Higgs combination**
- **Inputs to limits: 5.2 fb^{-1} $\phi b \to b\bar{b}b$ and 7.3 fb^{-1} $\phi b \to \tau_\mu \tau_{had} b$**
  - assume narrow Higgs and sum rule: BR($\phi \to bb$) + BR($\phi \to \tau\tau$) = 1
    - for BR($\phi \to \tau\tau$) = 0.06, 0.10, and 0.14
  - correlate b-tag efficiency and jet modeling systematics between channels
  - up to M_ϕ ~ 180 GeV: $\phi b \to \tau\tau b$ dominates limits; $\phi b \to 3b$ at higher mass as dependencies on the limit from tau BR decreases
- **Translate to exclusions in (M_A, tanβ) plane**



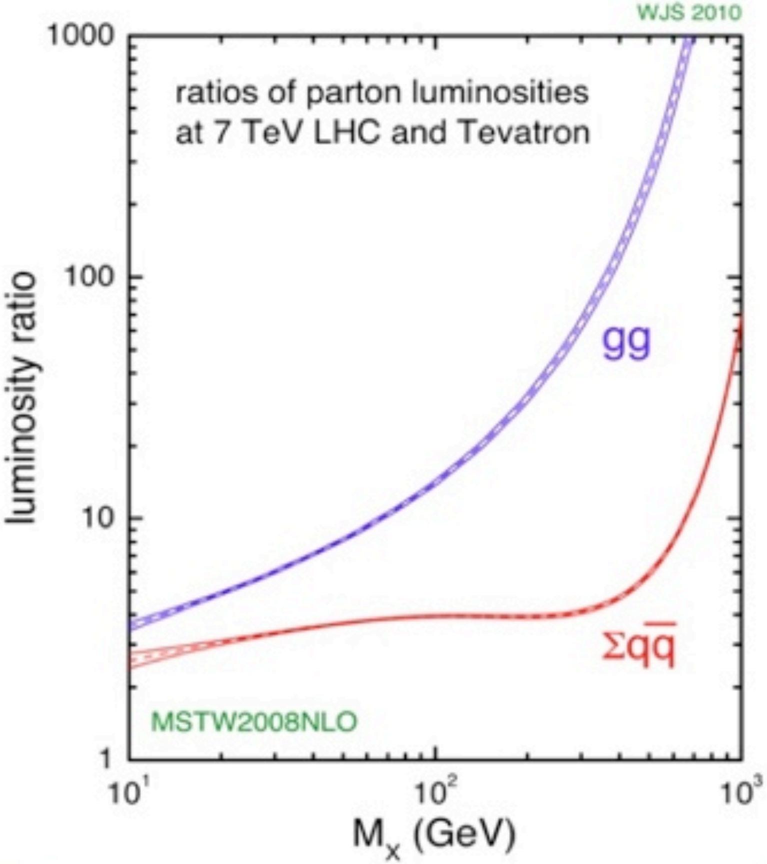


Tevatron combination from MSSM Higgs searches expected imminently…

Comparison to Higgs Production at the Tevatron

Depending on the production mechanism and the dominant backgrounds, there is a larger/smaller advantage for the LHC relative to the Tevatron

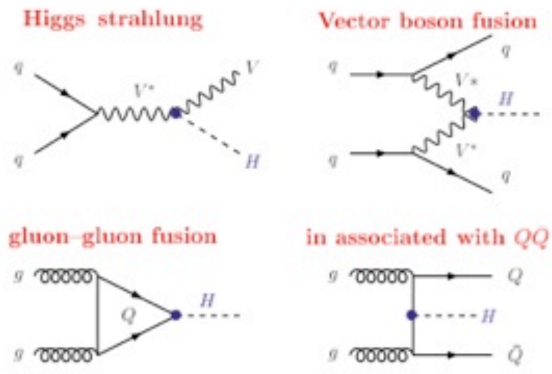
- $m_H < 130$ GeV/c²
  - pp→VH only 3x larger at LHC
  - Dominant backgrounds from W/Z+bb and top production which increase more due to the rise in gg cross section
- $m_H > 140$ GeV/c²
  - gg→H ~15x larger at LHC
  - Dominant backgrounds from WW and ZZ production, from qqbar production which increases by a smaller factor

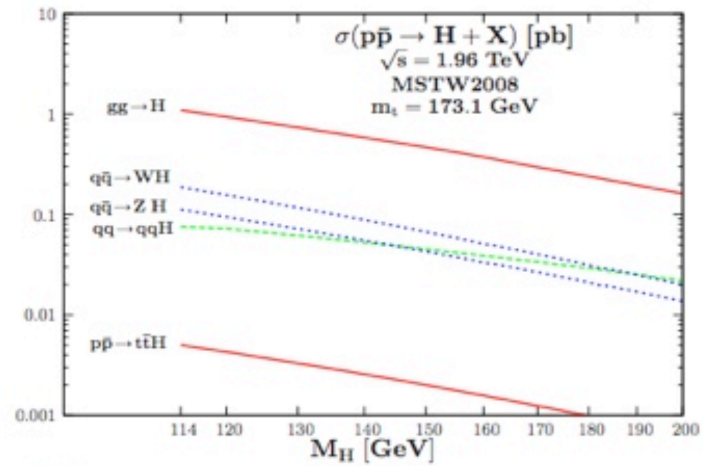


cross sections

2. The Higgs at hadron colliders

Main Higgs production channels





Large production cross sections

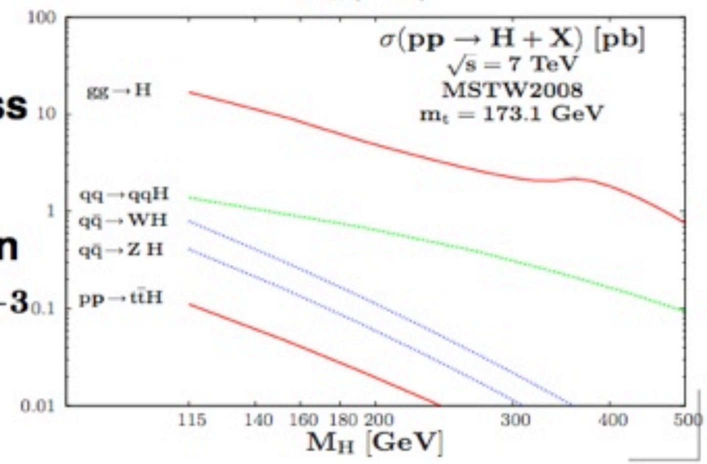
with gg→ H by far dominant process

1 $\text{fb}^{-1} \Rightarrow \mathcal{O}(10^4)$ **events@lHC**

$\Rightarrow \mathcal{O}(10^3)$ **events @Tevatron**

but eg BR(H$\rightarrow \gamma\gamma, ZZ \rightarrow 4\ell) \approx 10^{-3}$

... a small # of events at the end...



Lepton–Photon Mumbai 22/08/2011 Higgs: Theory – A. Djouadi – p.6/20

Higgs width vs mass