

Why I **never** believed the Tevatron Higgs sensitivity claims for Run 2ab

Michael Dittmar 19.03.09 (CERN Phen Club)

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Search for the Higgs Particle

Status as of March 2009

90% confidence level
95% confidence level

Excluded by LEP Experiments 95% confidence level

Excluded by Tevatron Experiments

Excluded by Indirect Measurements 95% confidence level

Higgs mass values

CDF, DZero experiments constrain Higgs mass

The territory where the Higgs boson may be found continues to shrink. The latest analysis of data from the CDF and DZero collider experiments at Fermilab now excludes a significant fraction of the allowed Higgs mass range established by earlier measurements. Those experiments predict that the Higgs particle should have a mass between 114 and 185 GeV/c². Now the CDF and DZero results carve out a section in the middle of this range, excluding a mass between 160 and 170 GeV/c².

[Read more](#)

Why I never believed the Tevatron Higgs sensitivity claims for Run 2ab

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- How to judge (experimental) sensitivity claims?
- Statistical and systematic errors: optimizing the statistical significance but neglecting systematics?
- Judging (future) sensitivity estimates?
SM Higgs search with CDF and D0 as an example
 - a) associated production WH (ZH) for $M_H=100-140$ GeV
 - b) gluon gluon fusion $gg \rightarrow$ Higgs \rightarrow WW for $M_H= 160\pm 20$ GeV
- conclusion(s)

How to judge experimental claims?

- For historical reasons: new phenomena require a statistical significance of at least 5 standard deviations!
- Defined from the probability of a background fluctuation

5 sigma = probability smaller than 5.7×10^{-7} !

for large numbers ($N > 10$): $\text{excess} / \sqrt{(\text{background})} > 5$

Result: background only hypothesis is false!

If “new optimized methods of statistics and significance” are used one also should accept that old fashioned magic 5 sigma stands for more than 5 sigma in whatever “optimized” new method

Optimizing S/\sqrt{B} and S/B

Examples of simple 5 sigma (statistical) signals: $P=5.7*10^{-7}$

$S(\text{signal}) = 5000 \text{ evt}$ and $B(\text{background}) = 1 \text{ Million}$

Some other event numbers for 5 sigma statistical signals:

$S = 25$ and $B = 25 \pm 5$

$S = 5$ and $B = 0.15$! (not 1 ± 1 ! Poisson Statistics)

$S = 1$ and $B = 0$ (extremely difficult to know that $B = 0$!)

(ignore Poisson for this example) For fixed $S/B = 1$

assume that $B1 = 4 \pm 2$ (stat.) and $B2 = 16 \pm 4$ (stat.)

B1: a 2 sigma excess (or absence of) stands for about 4 excess events $S+B= 8$!

B2: a 4 sigma excess stands for 16 signal events = $S+B = 32$!

unfortunately: Significance grows with $\sqrt{\text{Luminosity}}$

1 sigma = 1 fb⁻¹ expect: 2 sigma = 4 fb⁻¹ and 5 sigma = 25 fb⁻¹!

The real problem for $S/B < 0.5-1$ how well do we know the background?

- Assume Background systematics $\pm 10\%$ ($\Delta B/B = \pm 0.1$)
for $S/B = 0.5$ and infinite statistics at best 5 sigma signal!
for $S/B = 0.2$ at best a 2 sigma signal!
if $S/B > 1$: $\Delta B/B = \pm 0.1$ is not a serious limitation!
- How to define systematic errors?
or how to “measure, constrain and believe them?”
- Always an unavoidable subjective component of systematic errors!
It does not help to ignore systematic errors (like “will be done later”)
or do black box optimizing to hide background uncertainties!

How to judge and use future sensitivity estimates?

- Judge experimental (and theoretical) systematic error claims from past experiments!
- Do luminosity and detector assumptions match the real world?
- **Attention: wrong x right x right x right = wrong!**
- Remember that (too) optimistic expectations might help to get funding! This is true,
but it is also true that this approach eventually destroys remaining confidence in science!

How to judge CDF/D0 Higgs year 2000 sensitivity estimates?

From 2000 [hep-ph/0010338] Report of the Higgs Working Group (Tevatron Run 2 SUSY/Higgs Workshop)

I. Searching in the mass range $M(H)=100-140$ GeV associated Higgs production $W(Z) H \rightarrow l \nu$ (ll) bb

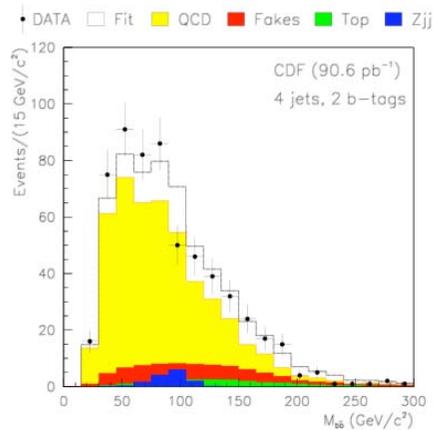


FIGURE 56. Invariant mass distribution, $M_{b\bar{b}}$, for 90.6 pb^{-1} of CDF data (points) compared to the fit prediction [135]. The solid line is the sum of the QCD, fakes, $t\bar{t}$, and $Z + \text{jets}$ components.

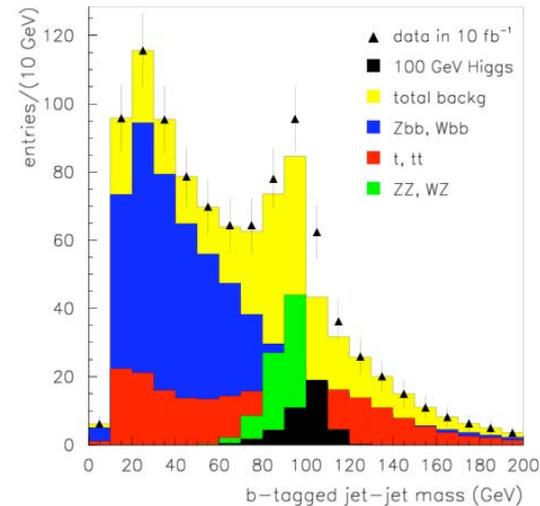


FIGURE 54. Combined $ZH \rightarrow \nu\bar{\nu}b\bar{b}, \ell^+\ell^-b\bar{b}$ channels, using the SHW analysis. The plot shows the $b\bar{b}$ dijet mass distribution for a $100 \text{ GeV}/c^2$ Higgs and background in 10 fb^{-1} .

Left plot (Run I data): deficit near Zjj peak! Could exclude existence of Zjj!

How to judge CDF/D0 Higgs year 2000 sensitivity estimates?

[hep-ph/0010338] Report of the Higgs Working Group

- $M(H) = 100\text{-}140$ GeV: significance plot with lots of hidden assumptions!
like: “a magic future method will improve bb-mass resolution by 30%”

left: lumi “single experiment”

right: combined lumi (CDF +D0)

expect with few fb-1 per experiment and both experiments combined (and using magic bb mass resolution) --> 2-3 sigma signal(!) possible!

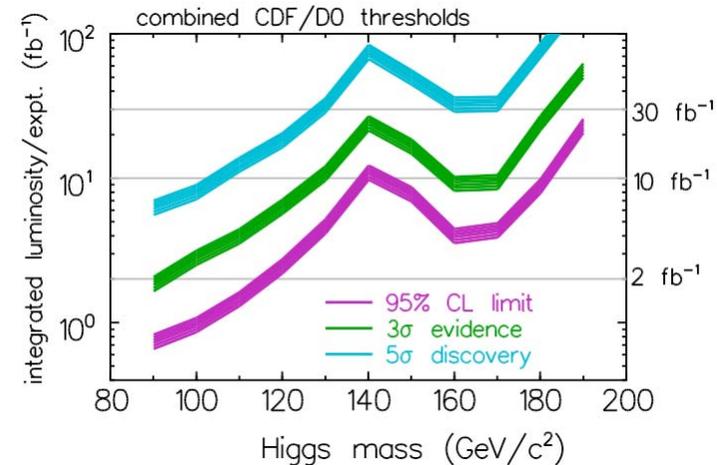
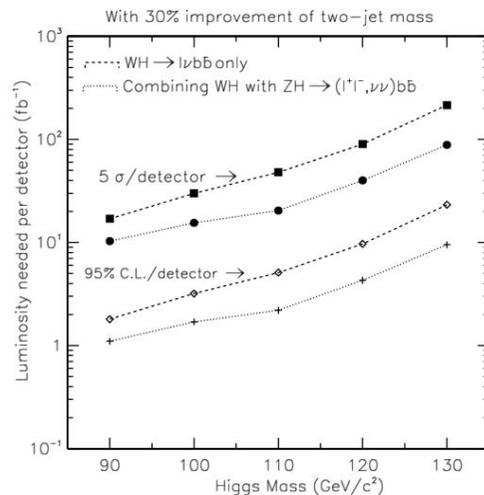


FIGURE 44. $WH \rightarrow \ell\nu b\bar{b}$ channel, QFL' analysis. The luminosity required per detector for 5σ discovery or 95% CL exclusion.

Why I never believed what was written in the 2000 report:

the $M(H)= 100-140$ GeV case:

- (1) assumed combined detector does not exist!
- (2) $b\bar{b}$ Mass resolution assumed to be Gaussian!
- (3) required mass resolution based on unknown future jet reconstruction!
- (4) b-tagging efficiency: (assumed to be 50 % or so) far higher than achieved before!
- (5) bad signal to background ratio! There is no mass peak with few events!**

TABLE 8. $WH \rightarrow \ell\nu b\bar{b}$ channel, SHW analysis. Number of events in 1 fb^{-1} after selection cuts for 12% $m_{b\bar{b}}$ resolution.

m_H (GeV/ c^2)	80	90	100	110	120	130
signal events (S)	14	10	8	5	4	3
$Wb\bar{b}$	59	54	47	38	32	28
WZ	8.6	10	8.8	7.2	6.0	4.4
$t\bar{t}$	12	16	19	21	24	26
single top	5.1	6.0	8.4	9.2	10	11
total background (B)	85	86	84	75	72	70
$S/\sqrt{(B)}$	1.5	1.1	0.9	0.6	0.5	0.4

S/B ($M_H=120$ GeV)= 4 /72! Claim 0.5 sigma with 1 fb-1!

Update D0/CDF report Oct. 2003

answer to request from DOE funding agency

M(H)= 100-140 GeV case (Fermilab-Pub-03/320-E)

- Claim that various analysis improvements were found using the first run II data!
- For $MH = 115$ GeV should see: 3 sigma excess with 3 fb⁻¹ and 5 sigma with 8 fb⁻¹.
- If no Higgs exists up to 130 GeV:
exclude Higgs up to $MH = 130$ GeV with 4 fb⁻¹!
- Quote from the paper: ***“We have not included the impact of systematics in this study. Including systematics in this study will push the luminosity thresholds higher.”***

Learned yesterday: “improvements assumed new silicon detector which has not been funded .. Its all the fault of the DOE!” (why not indicated in the plot?)

The claimed 2003 improvements!?

As shown on many follow up conferences!

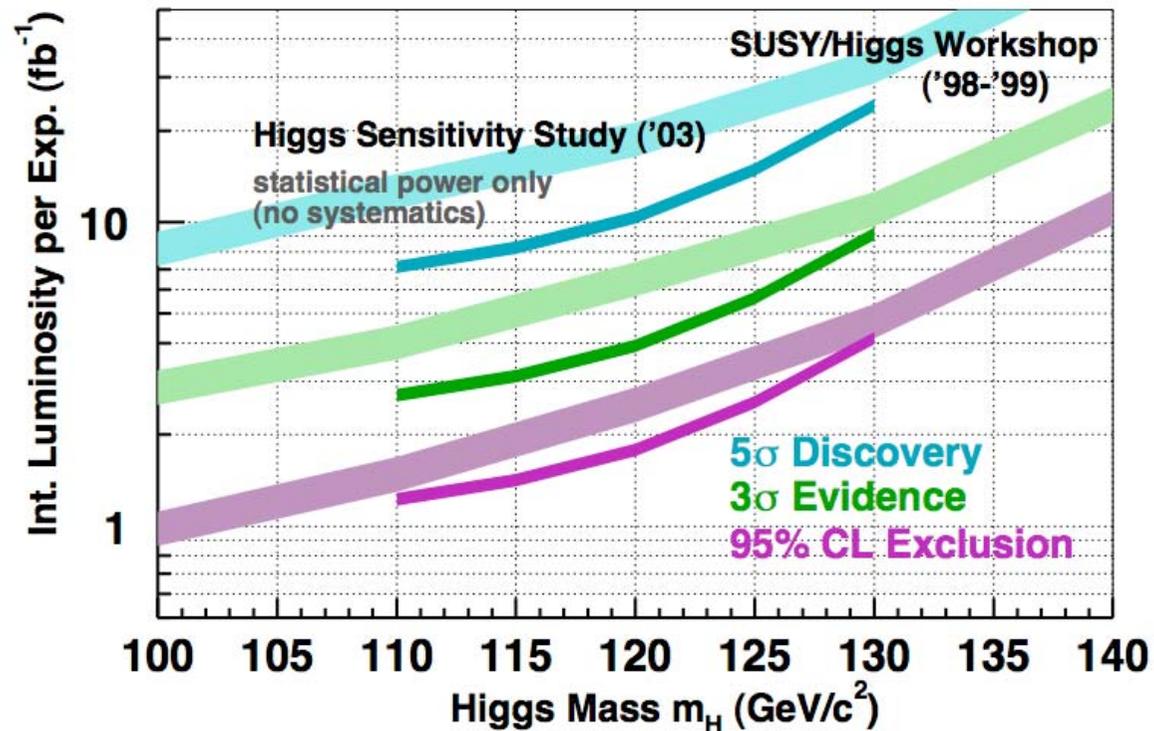


Figure 24: Integrated luminosities per experiment corresponding to the median expectations for 95% confidence level exclusion, 3 σ evidence and 5 σ discovery for $m_H = 110-130 \text{ GeV}/c^2$. The narrow curves are the updated analysis from this study (2003) and the thicker curves are the results from the previous SHWG Study (1999).

CDF/D0 Higgs 2008/9 results

SM Higgs mass with WH(Z) $M_H < 140$ GeV:

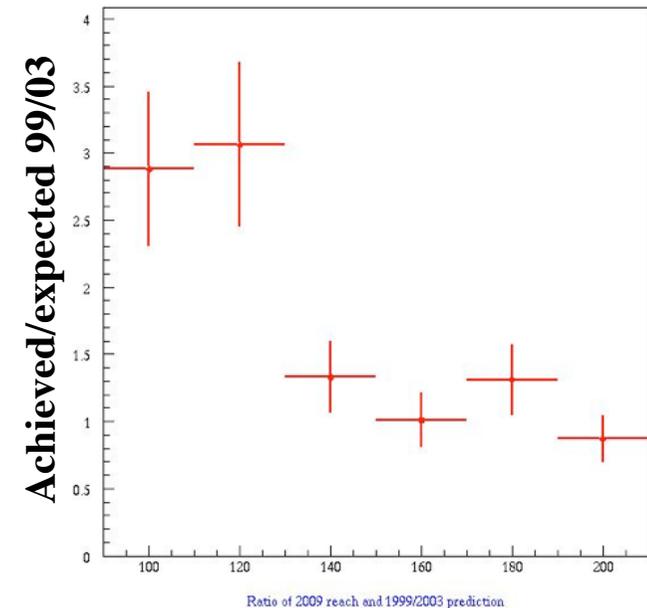
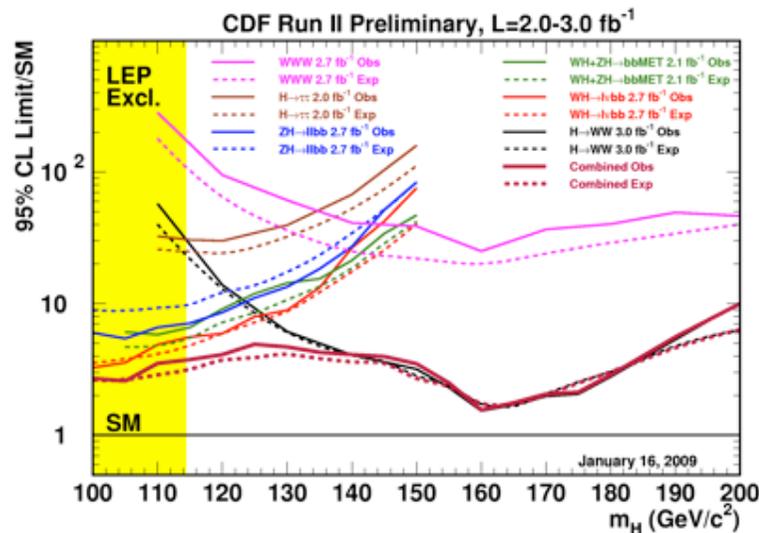
This Higgs search was, is and remains hopeless at 2 TeV!

achieved results much worse than predicted:

Real detector CDF/D0 sensitivity is at least a factor 3 times smaller!

Conclude: a factor of 9 more luminosity is needed

for 2 sigma exclusion (ignoring systematic errors!)



Plot from the T. Dorigo blog!

MH < 130 GeV (WH, ZH channel) wrong estimates!

For MH > 140 (H to WW) see next slides!

Tevatron and Higgs \rightarrow WW

$M(H) = \text{near } 165 \text{ GeV}: H \rightarrow WW \rightarrow | \nu | \nu$

great channel at the LHC (D + D 1997) $S/B \geq 1$
large signal rate and nice physics motivated signature!

Possible at the Tevatron? We had a quick look in 1997 but

Found much larger WW background for the p-anti p collider
and at best a handful signal events!!!!

My conclusion was:

if Tevatron people want to waste their time, good luck to them!

Tevatron and Higgs \rightarrow WW 2000 sensitivity estimates

From 2000 [hep-ph/0010338] Report of the Higgs Working Group (Tevatron Run 2 SUSY/Higgs Workshop)

M(H) near 165 GeV(S/B=0.4): Higgs \rightarrow WW \rightarrow $l \nu l \nu$

TABLE 29. Summary table for $h \rightarrow W^*W^* \rightarrow \ell\bar{\ell}\nu\bar{\nu}$ signal for $m_h = 140\text{--}190$ GeV and various SM backgrounds after the kinematic cuts of Eqs. (68)–(74) and the likelihood cut Eq. (77). The entry “fake $j \rightarrow e$ ” refers to the background where a jet mimics an electron with a probability of $P(j \rightarrow e) = 10^{-4}$. The backgrounds are independent of m_h .

m_h [GeV]	140	150	160	170	180	190
$gg \rightarrow h$ [fb]	2.2	2.4	1.3	0.93	0.85	0.73
associated VH [fb]	0.26	0.31	0.13	0.09	0.06	0.06
VV fusion [fb]	0.12	0.12	0.09	0.06	0.05	0.05
signal sum [fb]	2.6	2.8	1.5	1.1	0.96	0.83
SM backgrounds [fb]	39	27	4.1	2.3	3.8	7.0
fake $j \rightarrow e$ [fb]	5.1	3.4	0.34	0.15	0.08	0.45
backgrounds sum [fb]	44	30	4.4	2.4	3.8	7.5
S/B	0.058	0.094	0.34	0.45	0.25	0.11
S/\sqrt{B} for 30 fb^{-1}	2.1	2.8	3.9	3.8	2.7	1.7

**Expect for MH=170 GeV and 30 fb^{-1} : Signal = 33 events B = 69+8.3 events! (4 sigma stat. signal).
If correct and if systematics understood to $\pm 10\%$: perhaps a 3 sigma signal, but can this be done?**

Tevatron and Higgs \rightarrow WW 2008/2009 performance

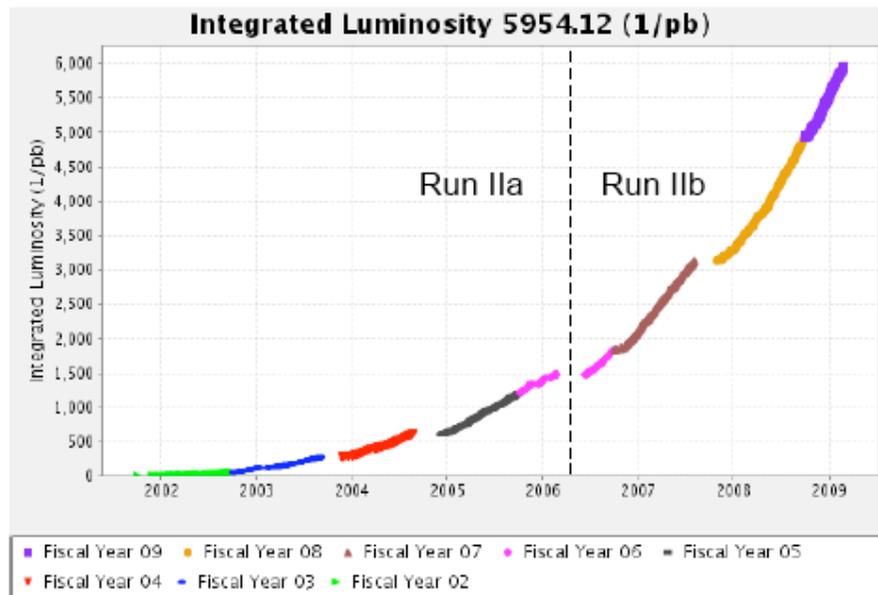
(See for example: A. Juste 2009 CERN-TH institute some of his slides follow)

So far FY09 integrated $L = 0.94 \text{ fb}^{-1}$
slope indicates perhaps $2 \text{ fb}^{-1}/\text{year}$?

2000 prediction was:

Run II a: $2 \text{ fb}^{-1}/\text{y}$ by end 2002
Peak lumi $2 \times 10^{32} / \text{cm}^2 / \text{sec}$

Run II b: $5 \text{ fb}^{-1}/\text{y}$ and up to
 15 fb^{-1} by end of 2007!
with $l = 5 \times 10^{32} / \text{cm}^2 / \text{sec}$

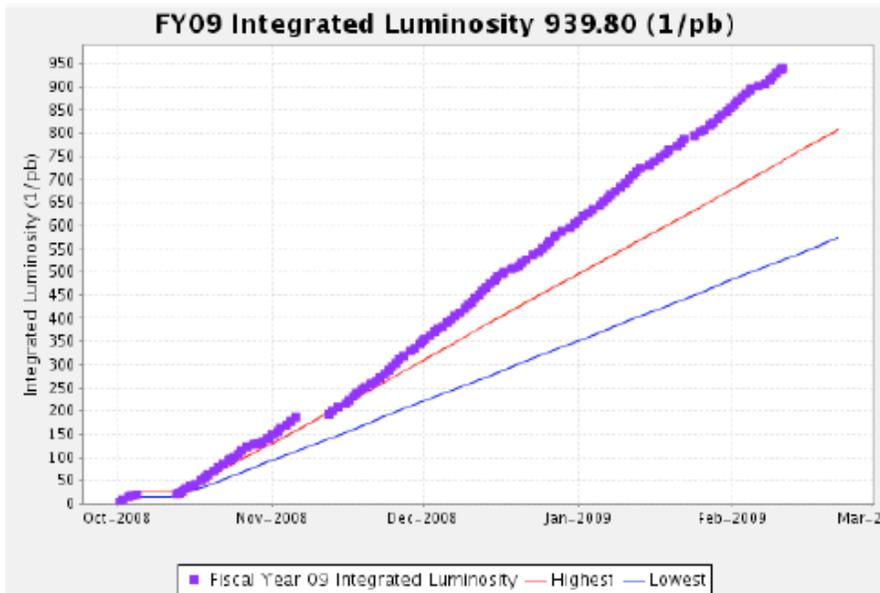
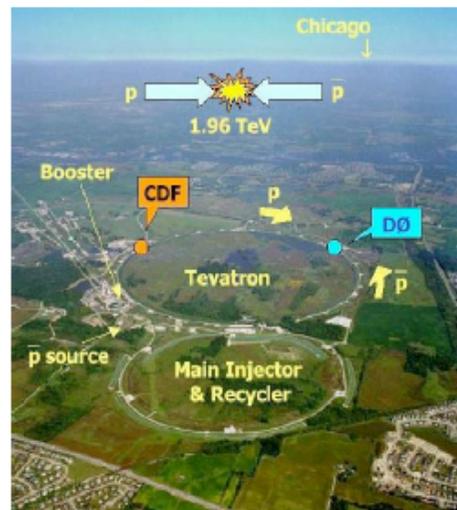


See Year 2000 report Page 37!

Source: talk from A. Juste page 5

Tevatron Accelerator

	1992-1996	2001-2006	2006-?
	Run I	Run IIa	Run IIb
Bunches in Turn	6 × 6	36 × 36	36 × 36
\sqrt{s} (TeV)	1.8	1.96	1.96
Typical L ($\text{cm}^{-2}\text{s}^{-1}$)	1.6×10^{30}	1×10^{32}	2.8×10^{32}
$\int \text{Ldt}$ ($\text{pb}^{-1}/\text{week}$)	3	15-20	50-60
Bunch crossing (ns)	3500	396	396
Interactions/crossing	2.5	2.5	7.0

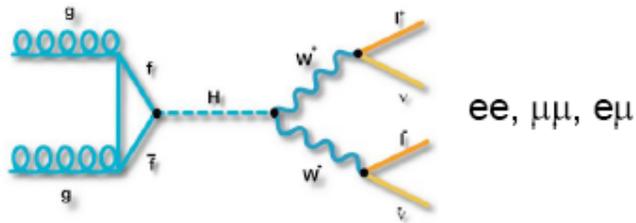


Plans:

- Shutdown: Jun 15 - Aug 23, 2009
- Planning to run in 2010.
- Project $\sim 7.7\text{-}8.8 \text{ fb}^{-1}$ by end of FY10...
...but in end of FY08 and beginning of FY09 better slope than "Highest Lum" projection!

Source: talk from A. Juste page 50 (2008 plots)
 look at CDF “signal” region NN near 0.8: observe “2 sigma deficit”

SM High Mass Higgs

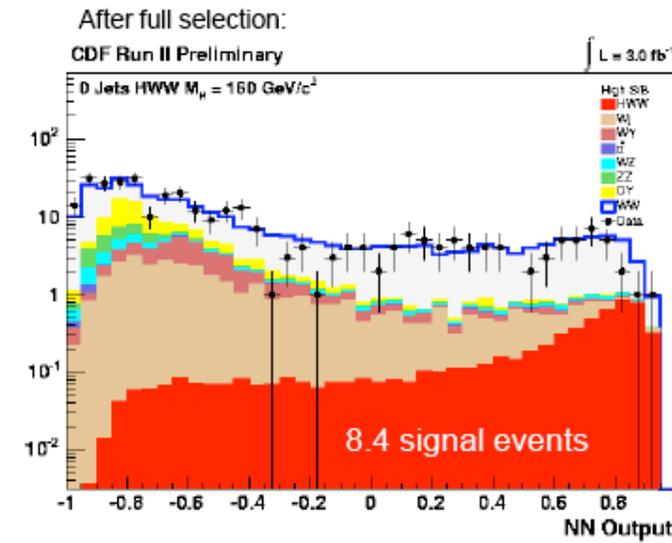
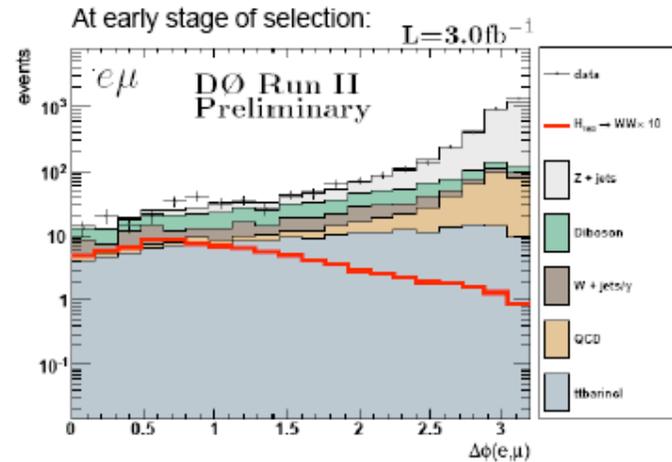


- Highest sensitivity channel for $m_H > 130$ GeV.
- Main backgrounds:
 - $m_H \sim 160$ GeV: WW
 - $m_H \sim 130$ GeV: W+jets
- Low $\Delta\phi(l,l)$ because of spin-0 Higgs.
- Capitalize on improvements in lepton identification and multivariate techniques.

95%CL Limits at $m_H = 165$ GeV

Analysis	Lum (fb ⁻¹)	Higgs Events	Limit (σ /SM)	
			Exp.	Obs.
CDF	3.0	17.2	1.6	1.7
DØ	3.0	15.6	1.9	2.0

Both experiments approaching SM sensitivity!

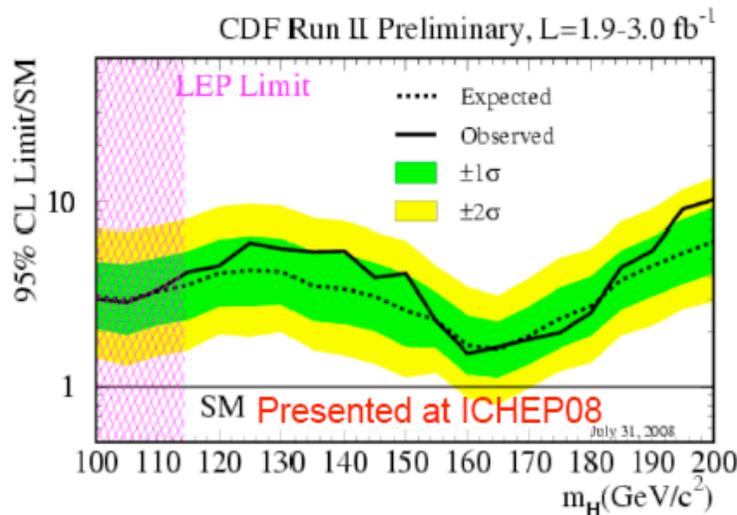


Source: talk from A. Juste page 52

CDF “160 GeV” previous plot shows “2 sigma deficit” (exclude SM Background?)
 why is this not visible at 160 GeV in the CDF limit plot?

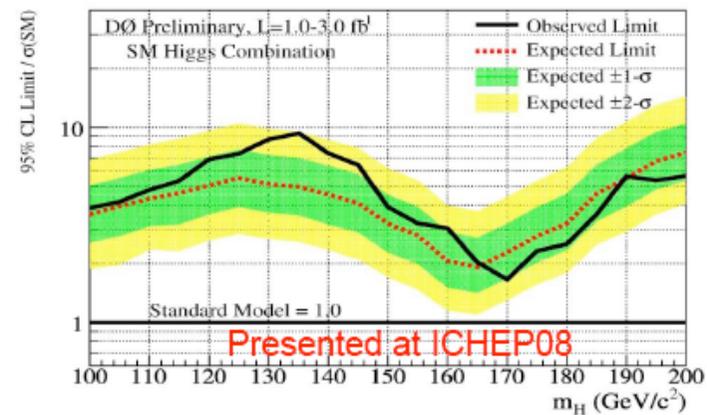
SM Higgs Combined Limits

- Calculation of limits and combination:
 - Using Bayesian and CLs approaches.
 - Incorporate systematic uncertainties (including correlations) using pseudo-experiments.
 - Some uncertainties are effectively constrained by data.



At $m_H = 115$ GeV:
 Exp. limit: 3.6 x SM
 Obs. limit: 4.2 x SM

At $m_H = 165$ GeV:
 Exp. limit: 1.6 x SM
 Obs. limit: 1.6 x SM



At $m_H = 115$ GeV:
 Exp. limit: 4.6 x SM
 Obs. limit: 5.3 x SM

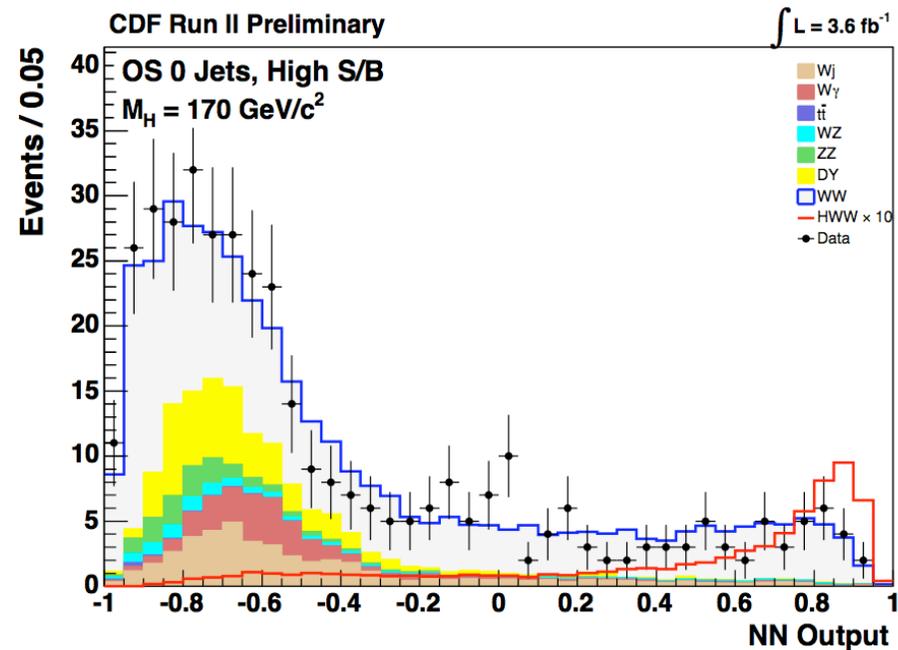
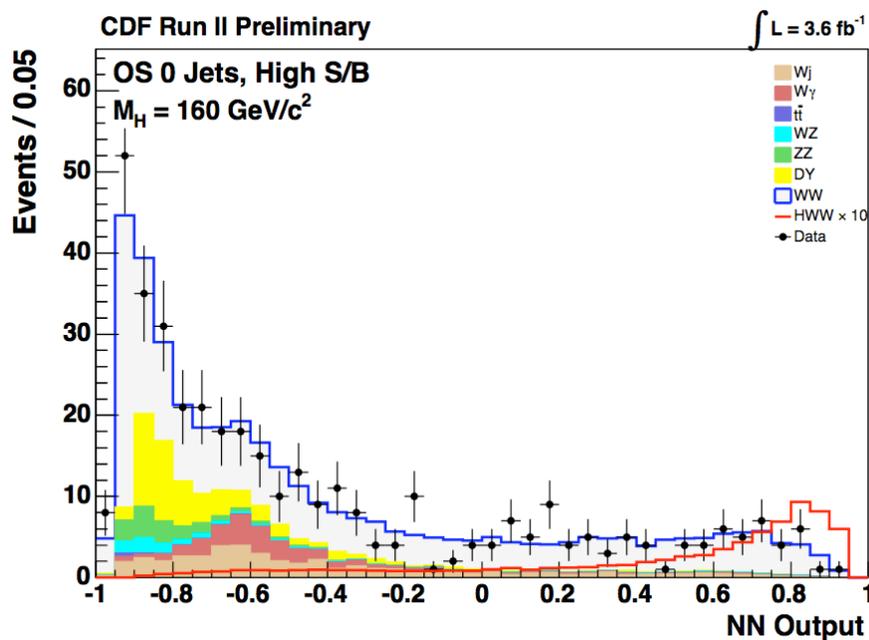
At $m_H = 165$ GeV:
 Exp. limit: 1.9 x SM
 Obs. limit: 2.0 x SM

new HWW CDF note (February 27 2009)

- Latest: “Signal” from $WH \rightarrow WWW$ like sign events .. Quote:

“In the same-sign event sample we additionally observe 41 candidate events compared with an expectation of 46.1 ± 8.0 background events and 1.4 ± 0.2 signal events.”

- 0-jet channel(High S/B?) 160/170 GeV essentially identical signals
but NN output and data look totally different! (attention signal times 10!)



Latest HWW D0 note (march 6 2009)

- right plot (linear scale) NN>0.7 numbers for S and B not given but reading from the plot one finds B=160 S=16 or S/B= 0.1! not S/B = 1/3 as from 2000 report!

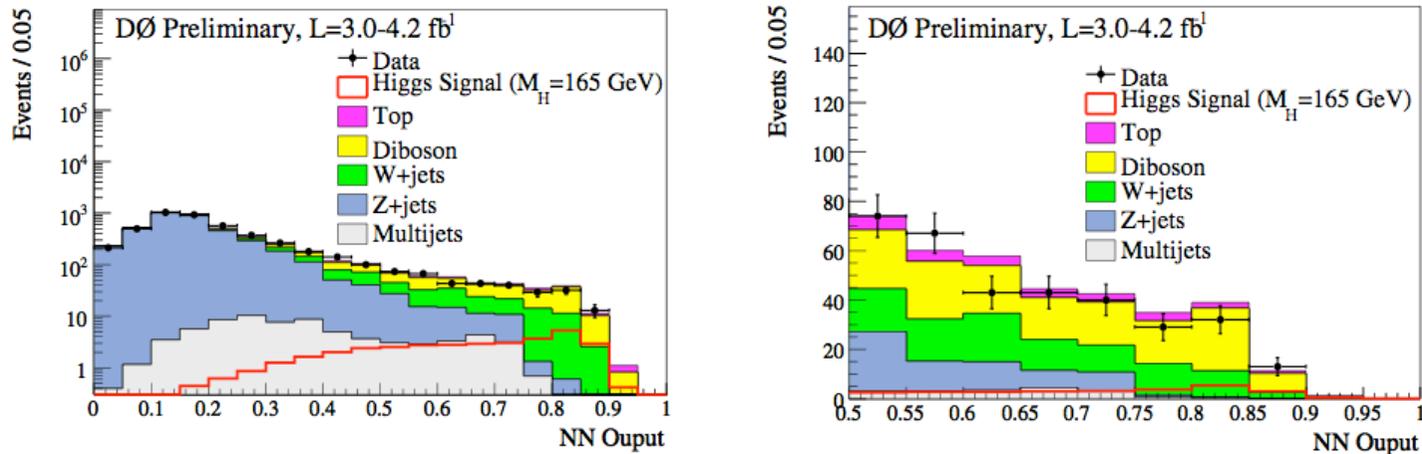
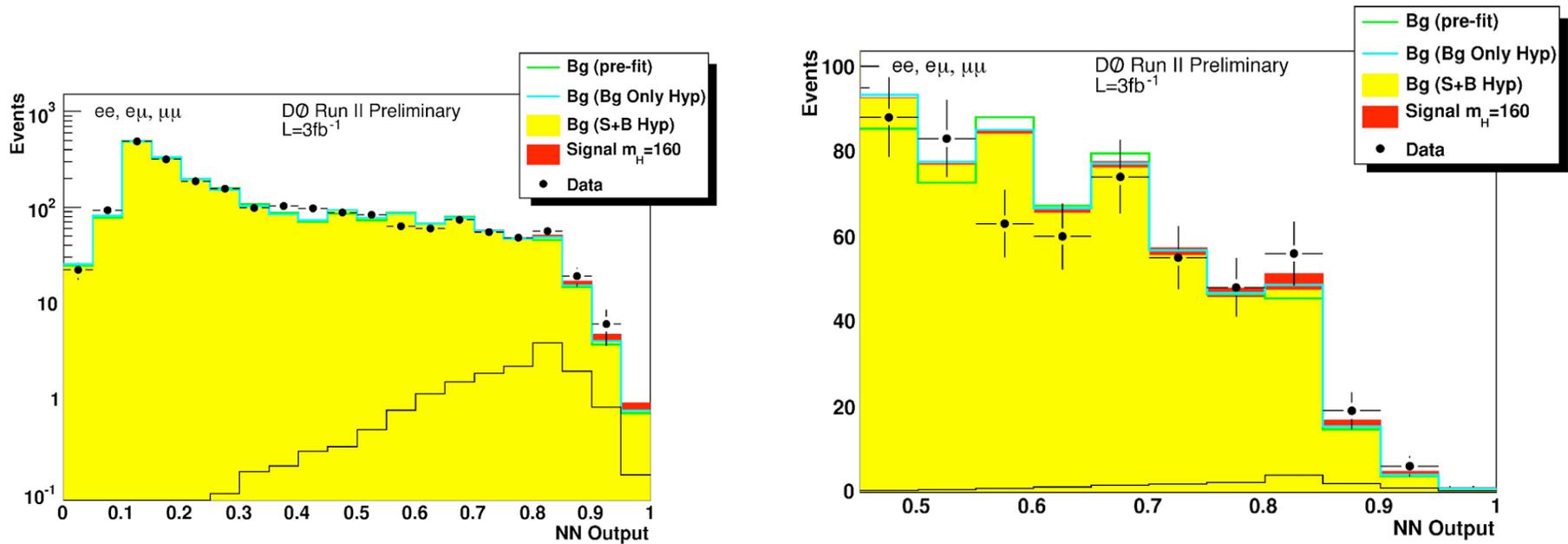


FIG. 3: Data, standard model signal expectation and backgrounds as a function of the neural net output variable. The expected standard model signal for a Higgs boson mass of $M_H = 165$ GeV is shown by the red histogram. The neural net output is shown in logarithmic scale (left) and in linear scale for the high NN region (right).

2008 HWW D0 note (July 31, 2008)

- right plot (linear scale) NN>0.8 numbers for S and B not given but looks like 3fb⁻¹ sample had some “tiny excess” for 160 GeV



Tevatron and Higgs \rightarrow WW expectation and the 2008 data: some observations

Not many details given by the experiments (preliminary Notes etc)

- Expected (year 2000) number of signal events:
MH= 160 GeV (S= 1.5 evt/fb-1 and B = 4.4/fb-1)
- CDF NN-plot (3 fb-1) shows 8.4 signal events (2.8/fb-1)!
for $NN > 0.7$: (per bin: S= 0.2-0.3 evt/fb-1 and B= 2 evt/fb-1)
if integrated $NN > 0.7$: S=1 evt/fb-1 B= 7 evt/fb-1
real Data: **S/B = 1/7 and not 1/3!**
- **CDF result not as good as expected from 2000 report!**
In addition: systematic errors not (well?) described!

Some conclusions..

- **Tevatron luminosity still much lower than predicted!**
data in FY 2009:1 fb-1/y only
- **For MH 100-140 GeV (WH, ZH channels): There is no chance!**
Time to confess: The year 2000/2003 studies were simply wrong!
- **For MH near 165 GeV (H→ WW channel)**

CDF/D0 analysis S/B roughly = $1/7 = 0.14$

in the year 2000 Higgs sensitivity report S/B = $1/3 = 0.33$

10% systematic background uncertainty kills a 2 sigma exclusion forever!

furthermore: inconsistencies exist (notes are not clear)!

CDF/D0 notes are not too clear about treatment of systematic errors!

my conclusions..

- **For MH near 165 GeV (H → WW channel)**
 - (1) today's 170 GeV MH exclusion claim is not justified by the Tevatron data!
 - (2) Tevatron Higgs sensitivity claims (even statistical error only) near 165 GeV are highly suspicious!
 - (3) Systematic errors and S/B are the key for the success or failure for this fb-1 Higgs discovery channel in a mass range 160-168 GeV at the LHC.
 - (4) For much more favorable S/B at the LHC (and H → WW) we believe:
 - a) backgrounds can be estimated from the data
 - b) with 0.5-1.0 fb-1 perhaps with an accuracy of ± 10-20%
 - c) are Tevatron people much more clever?**

“Extraordinary claims in science require extraordinary evidence!”

(Carl Sagan)

“Extraordinary claims in pseudo-science require just ordinary credulity!”

(Raphael Carreras)

For LHC Higgs search: similar bad examples exist

(for example ttH was wrong! see talk K,A.Assamagan TH Institute)

Your conclusions?

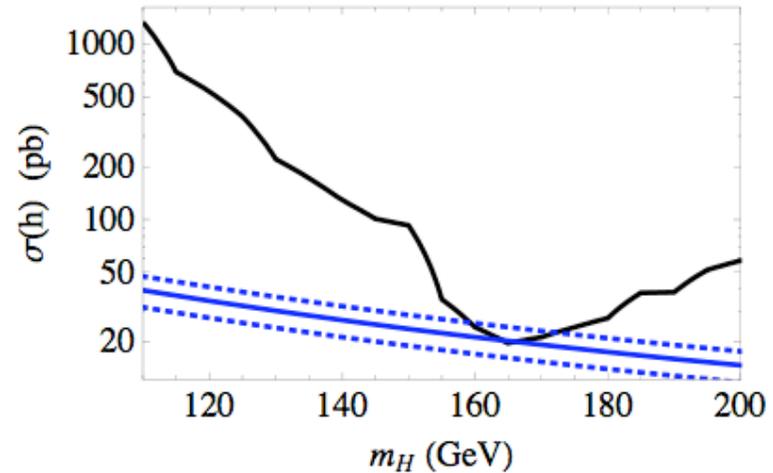
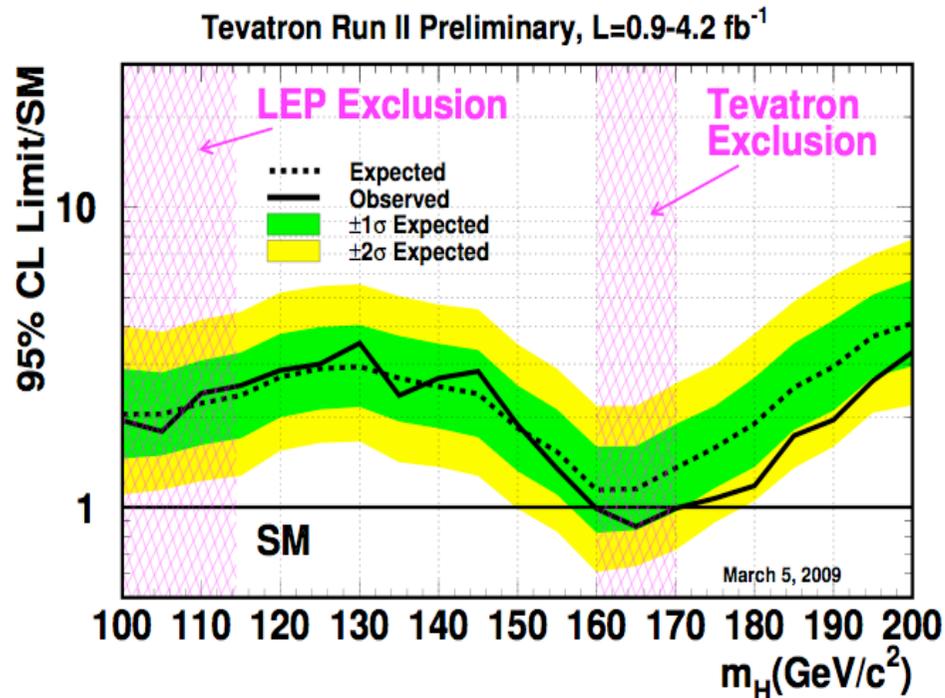
You need to judge the latest exclusion claim!

Spring 2009: 165 GeV $\text{cl}/\text{SM} = 0.86$ (expected = 1.1)
160 GeV (0.99 exp. 1.1) 170 GeV (0.99 exp 1.4)

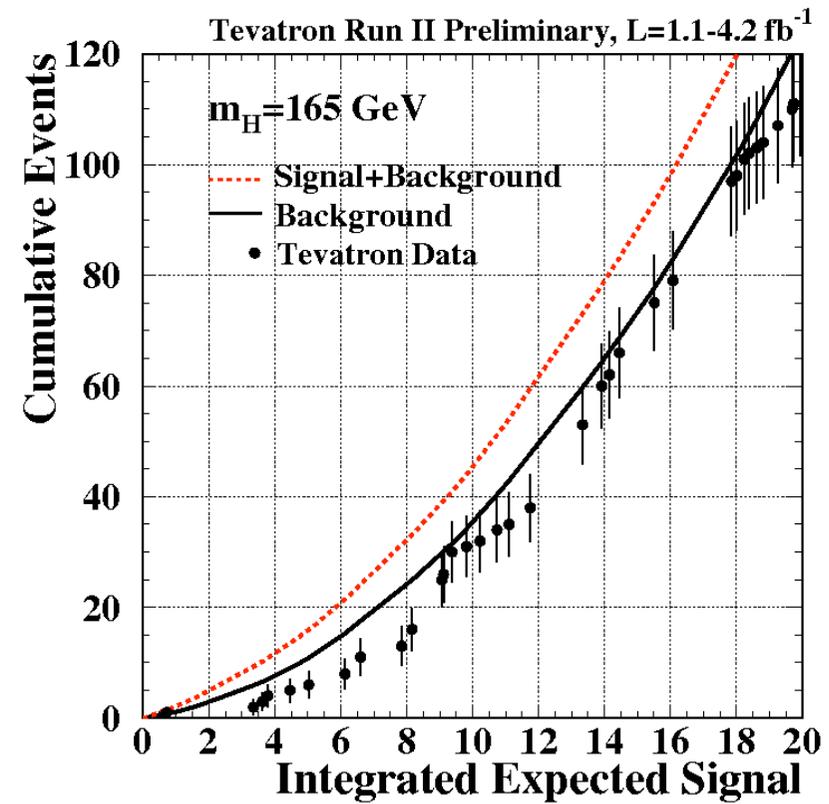
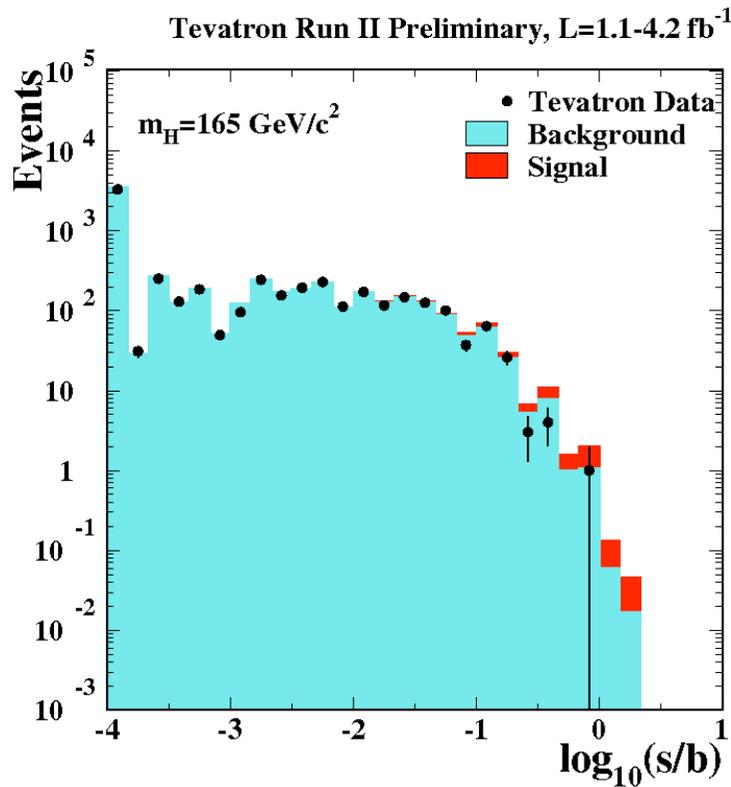
Summer 2008 (170 GeV excluded!?) With 3 fb⁻¹
170 GeV (obs 1 exp 1.4) 165 (obs 1.1 exp 1.1)

Plot shown yesterday by J.Zupan..
1 sigma cross section change and gone is
the exclusion ! (ggH at NNLO)

- should say somehow
- Spring limits thanks to
- “lucky” fluctuations only!

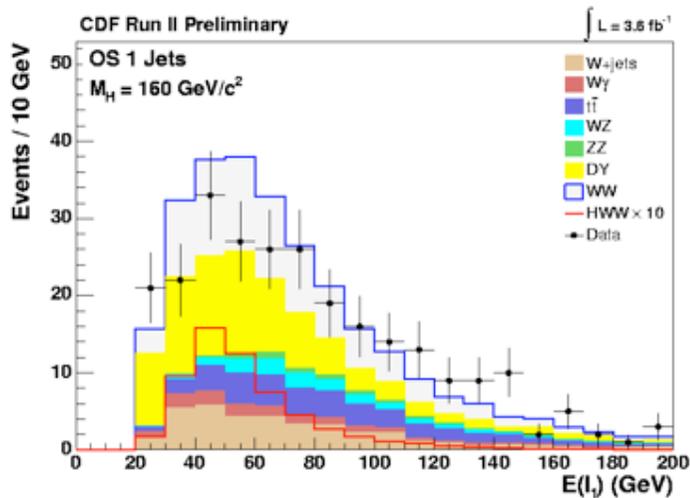


Some backup plots.. (1)

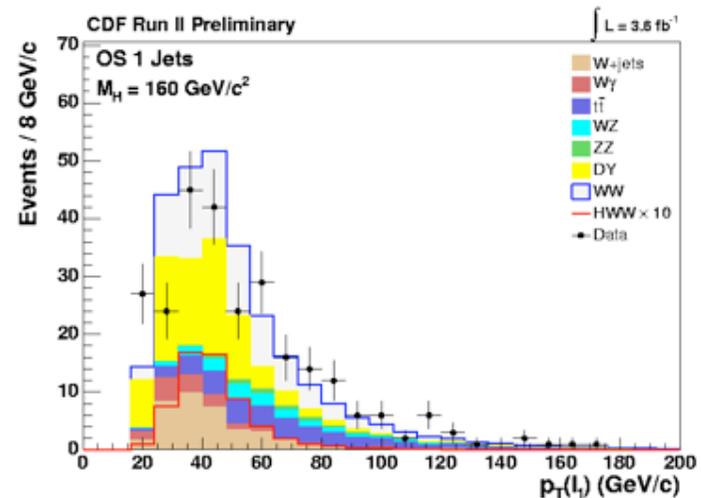


Some backup plots.. (2)

- Lepton E and pt distr. (opposite sign 1 jet)
Not the most relevant signal contribution: Data=MC ??? not too convincing!



[.eps](#) [.gif](#)



[.eps](#) [.gif](#)

2008 exclusion plot..

The ratios of the 95% C.L. expected and observed limit to the SM cross section are shown in Figure 2 for the combined CDF and DØ analyses. The observed and median expected ratios are listed for the tested Higgs boson masses in Tables IX and X, with observed (expected) values of 1.2 (1.2) at $m_H = 165 \text{ GeV}/c^2$, 1.0 (1.4) at $m_H = 170 \text{ GeV}/c^2$, and 1.3 (1.7) at $m_H = 175 \text{ GeV}/c^2$. We exclude at the 95% C.L. the production of a standard model Higgs boson with mass of $170 \text{ GeV}/c^2$. This result is obtained with both Bayesian and CL_S calculations.

