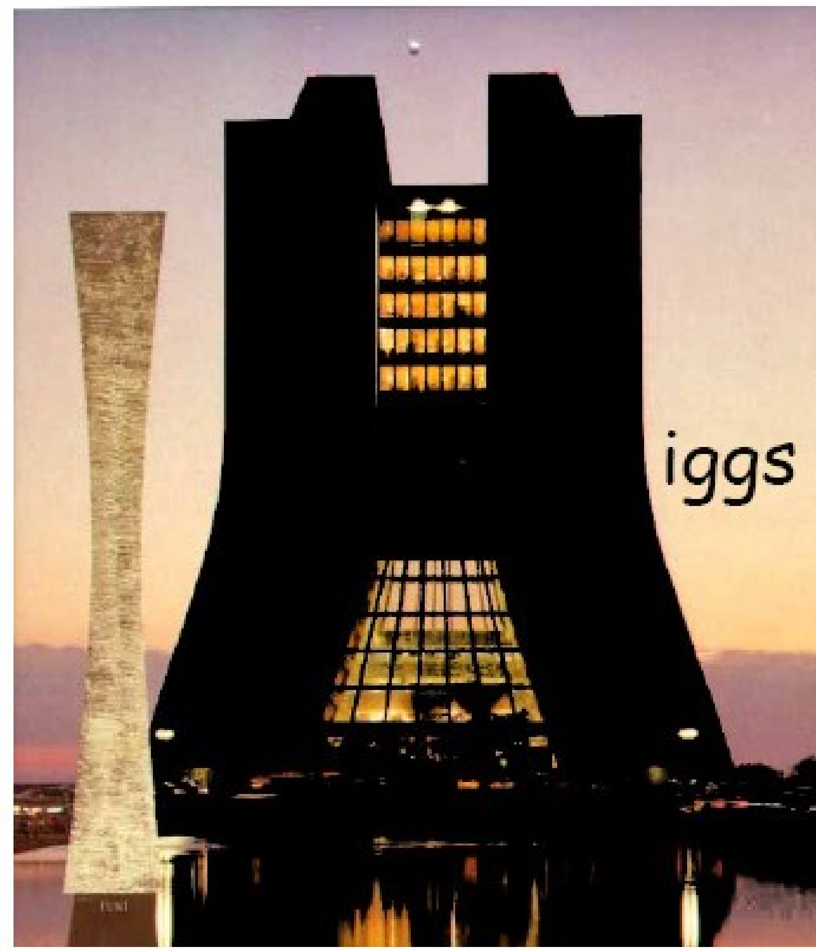
Latest Results and Prospects for Higgs Searches at the Tevatron

Andy Haas
DØ / ATLAS
Columbia University

with results from the
DØ and CDF Collaborations*

Saclay/Orsay Seminars
March 10-11, 2008



**Mostly from Moriond EW 2008 (last week)*

Outline

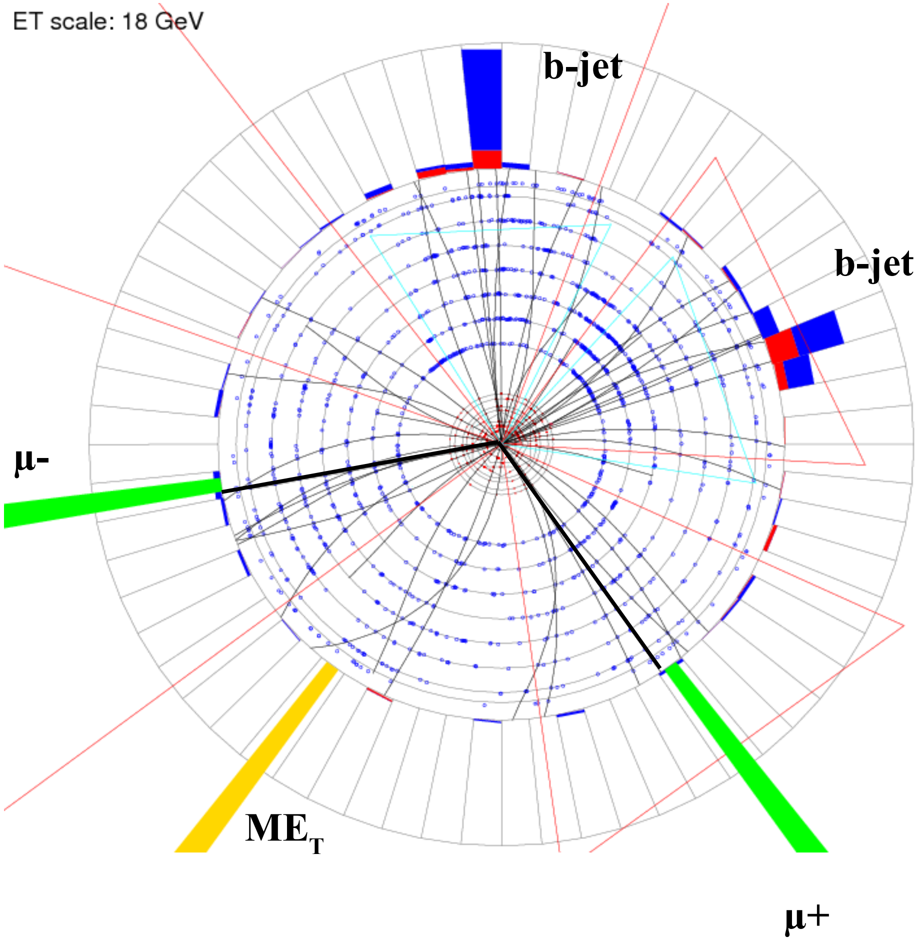
Standard Model Higgs searches

- Low mass
- High mass

- Improvements
- Prospects

MSSM Higgs searches

Other Higgs searches

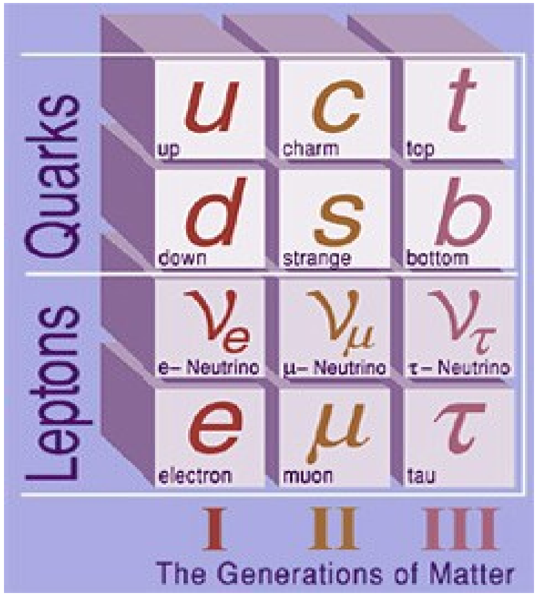


The Standard Model

3 families of matter

3 forces

- "gauge symmetries": $U(1)_Y \times SU(2)_L \times SU(3)_C$



Massive W,Z gauge bosons

Scalar Higgs field, non-zero VEV

- W,Z get masses through "Higgs mechanism"
- Fermions can get Yukawa masses:

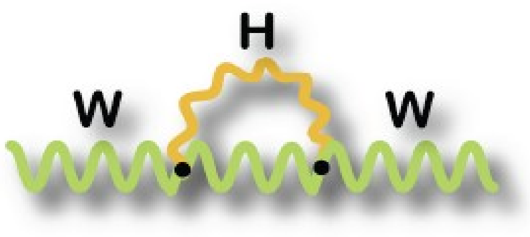
$$-\frac{1}{v} m_f \bar{\psi}_f \phi_h \psi_f$$

Higgs boson: excitation of the Higgs field

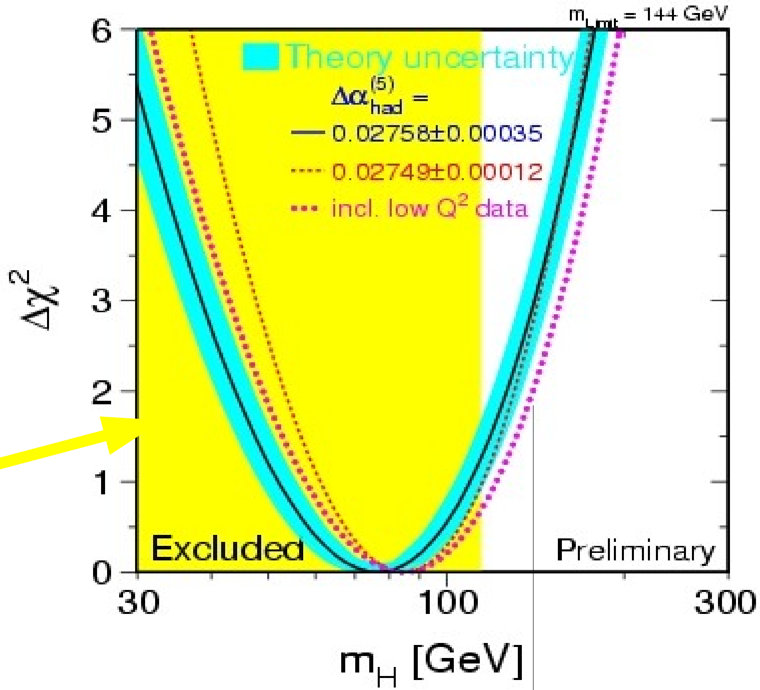
- Scalar boson
- Couplings specified
- Unknown mass: m_H

Higgs Mass Constraints

EW variables sensitive to m_H via radiative corrections:

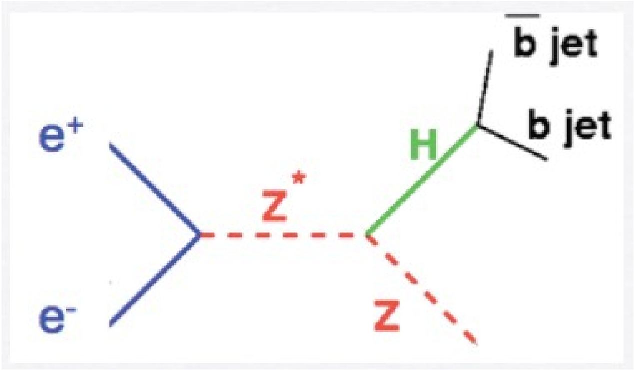


$$\log \frac{m_H}{m_Z} \longrightarrow$$



m_H<144 GeV (at 95% CL)

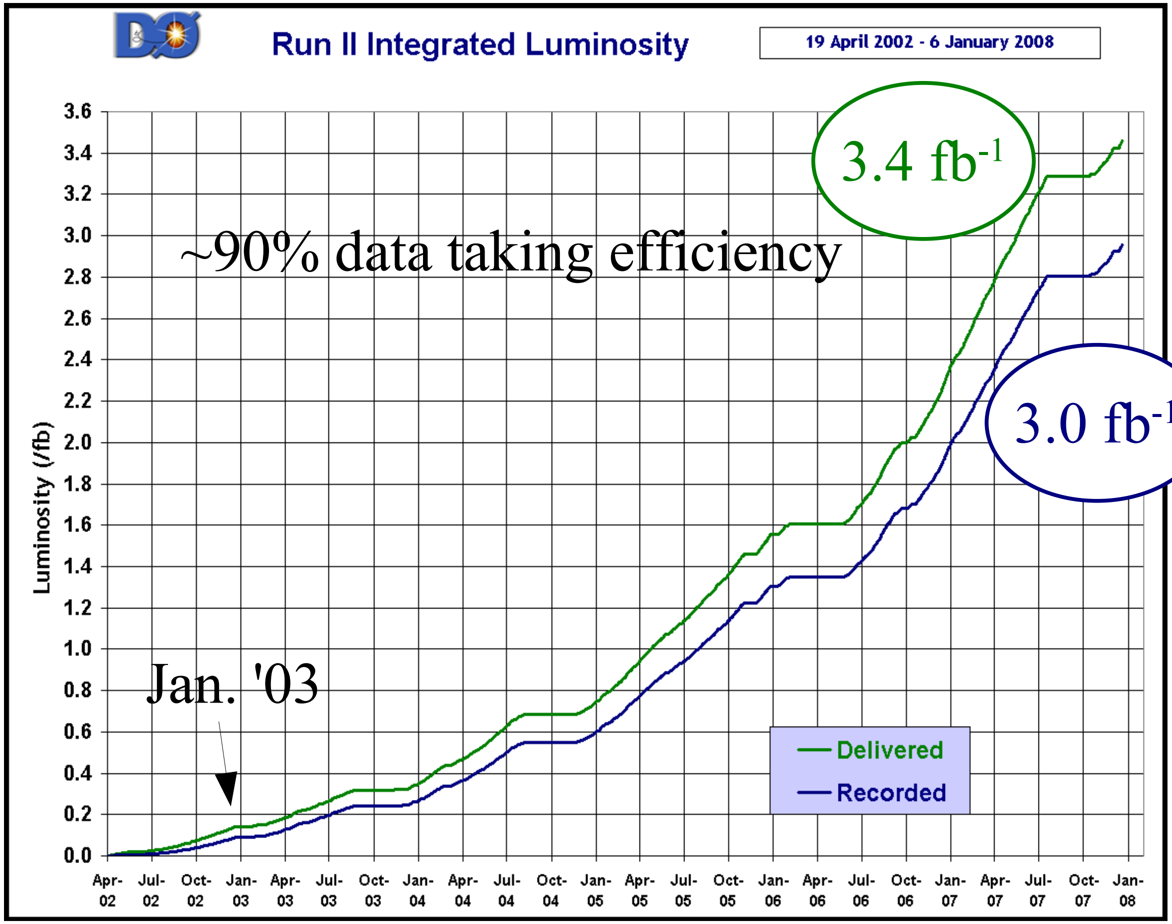
LEP II direct: m_H>114.4 GeV

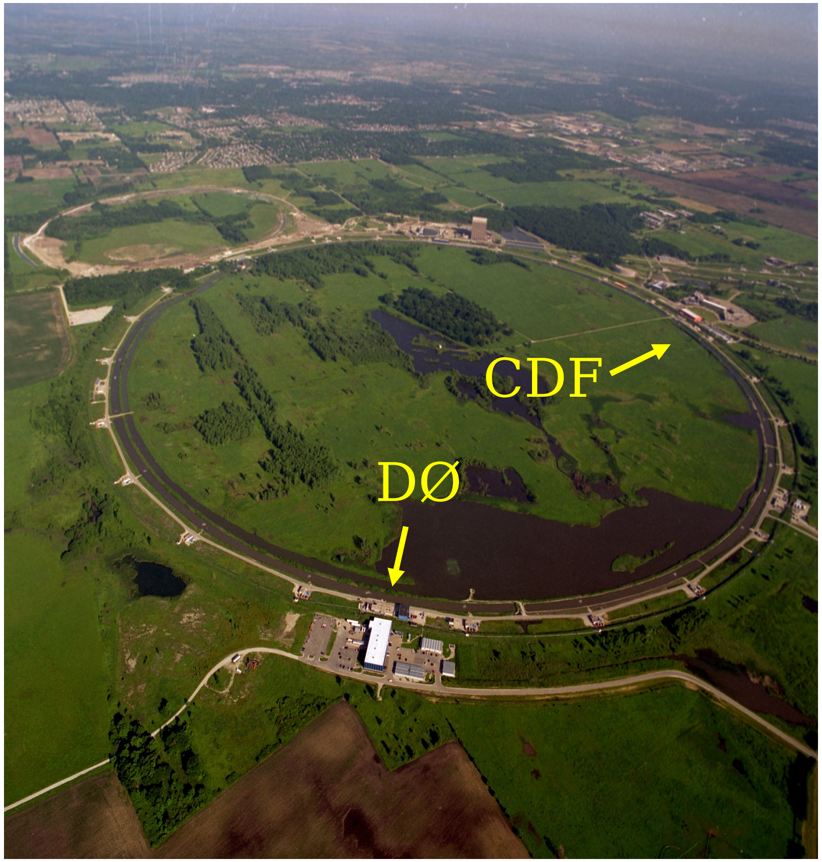


m_H<182 GeV (including direct limit)

The Tevatron at Fermilab

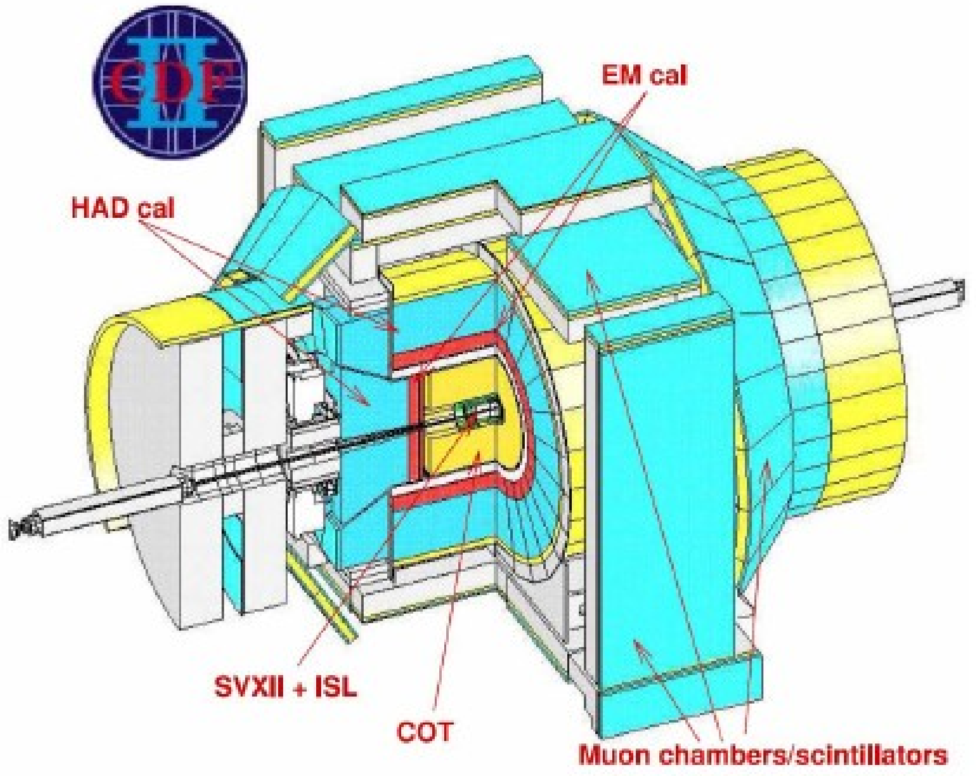
Running (again) since ~2003
p-pbar, sqrt(s)=1.96 TeV
Record luminosity: 2.9e32 $cm^{-2}s^{-1}$!
Expect 6 fb^{-1} by '09 *(maybe 8 fb^{-1} by '10)*

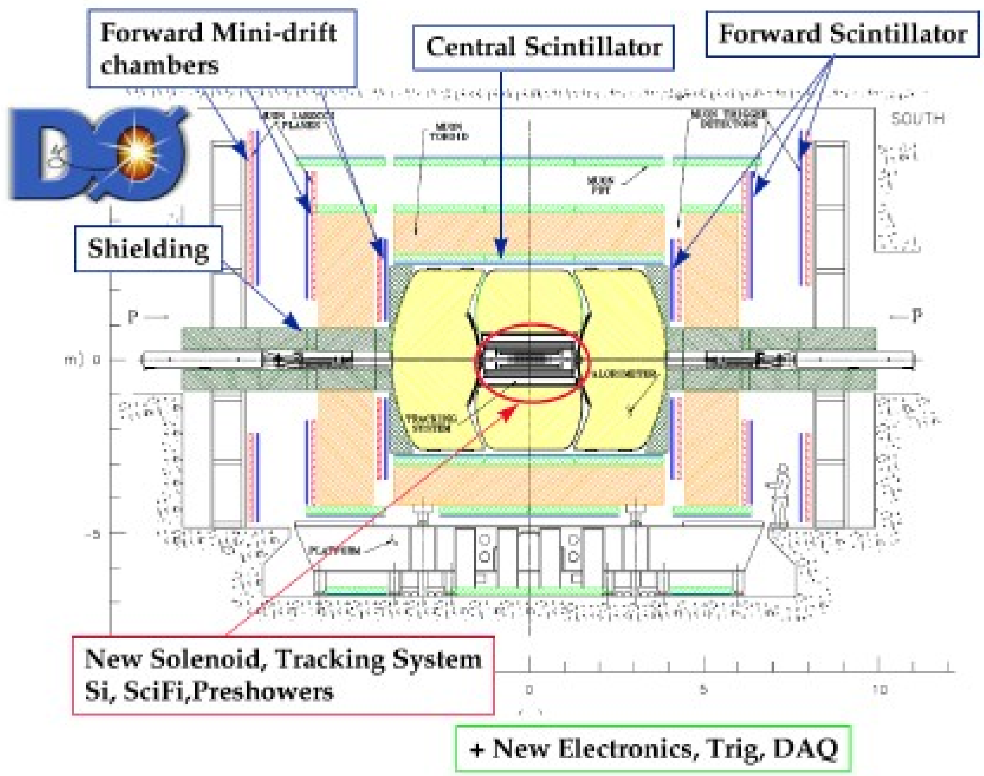




CDF and DØ experiments in RunII

- Both detectors are highly upgraded in RunII
  - New silicon micro-vertex tracker
  - New tracking system
  - Upgraded muon chambers





- CDF: new Plug Calorimeters, new TOF
- DØ: new solenoid, new pre-showers, LØ for SMT in RunIIb, new L1Cal trigger

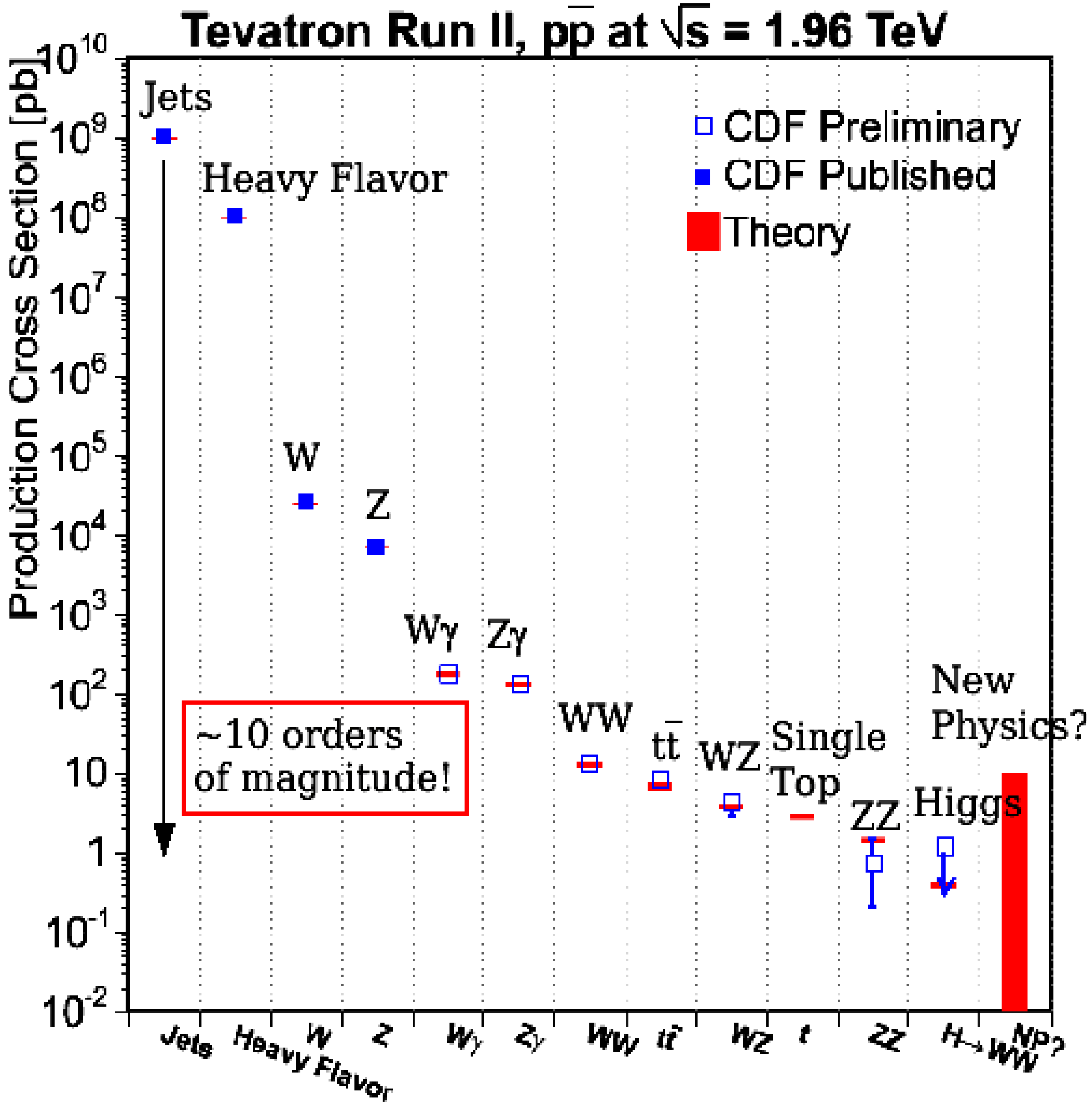
Needle in a Haystack

Higgs has small cross-section at the Tevatron

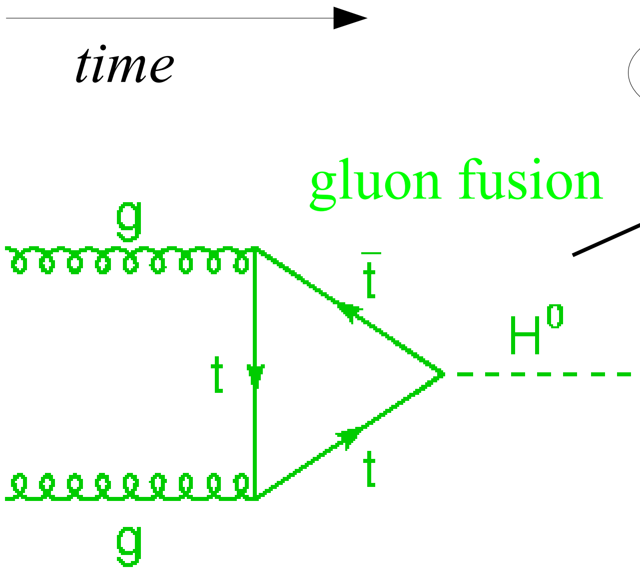
- Couples weakly to light quarks in the proton!

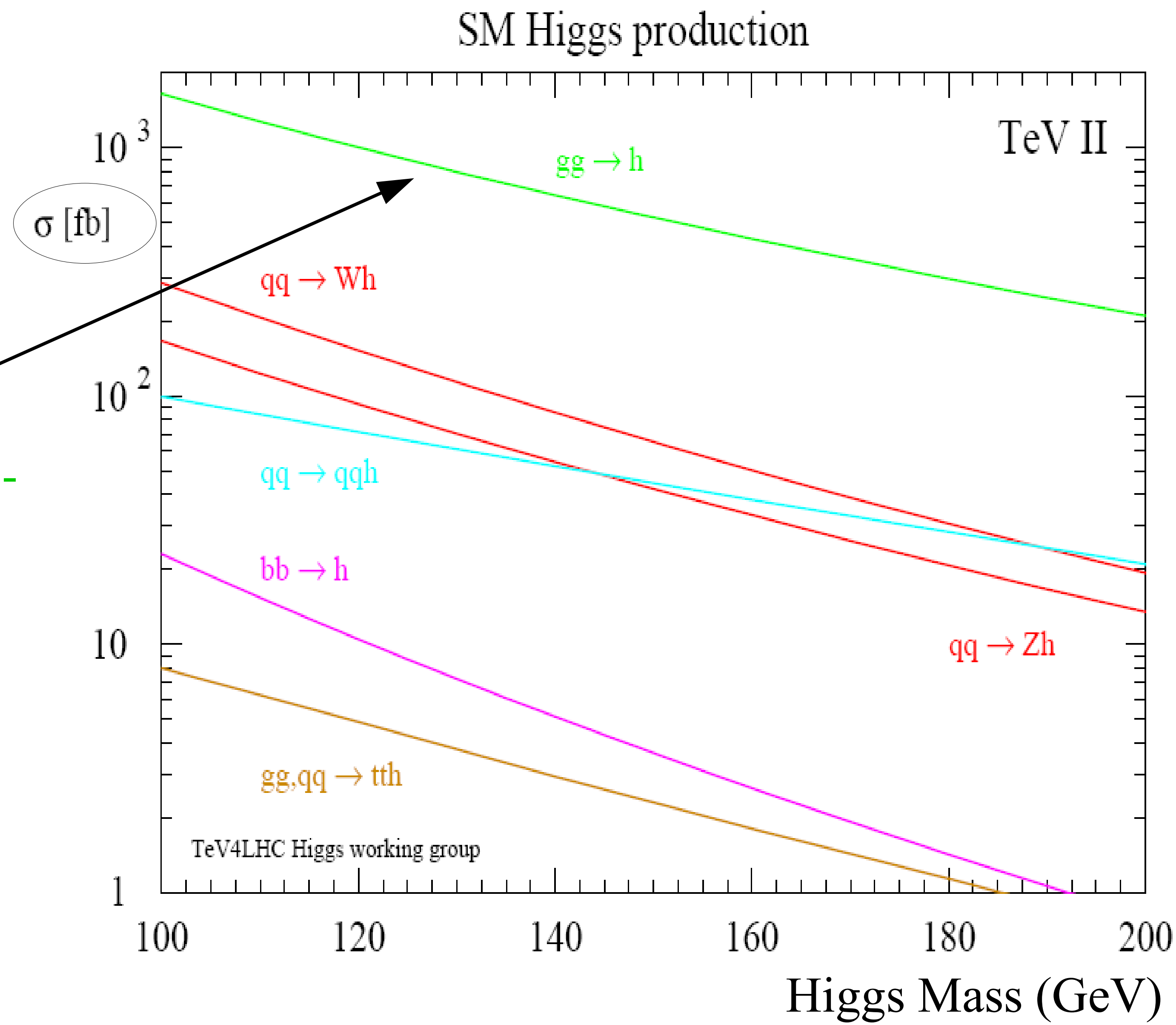
Large backgrounds from

- Jets
- W,Z + jets
- ttbar
- WW, WZ, ZZ

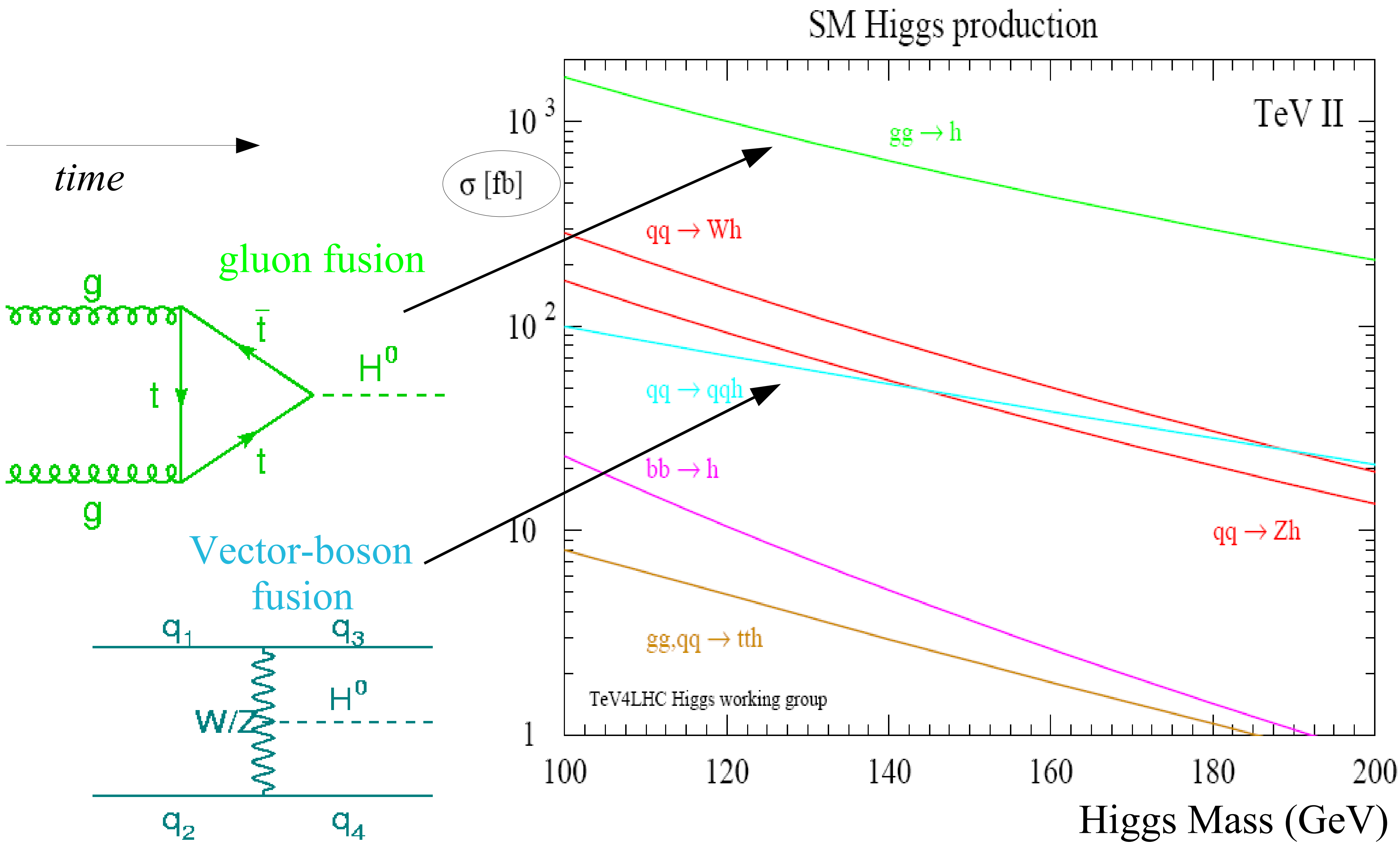


Higgs Production at the Tevatron

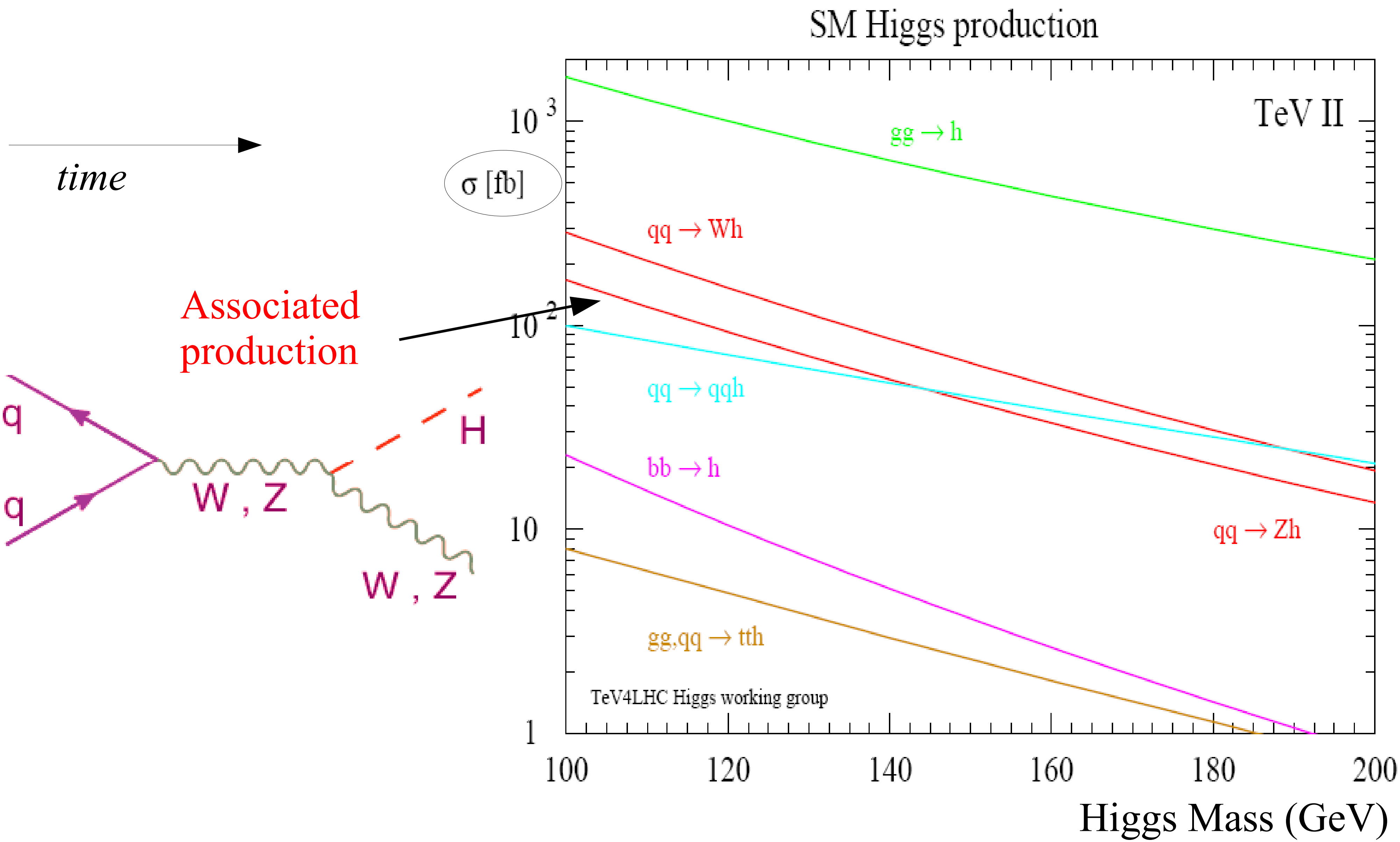




Higgs Production at the Tevatron



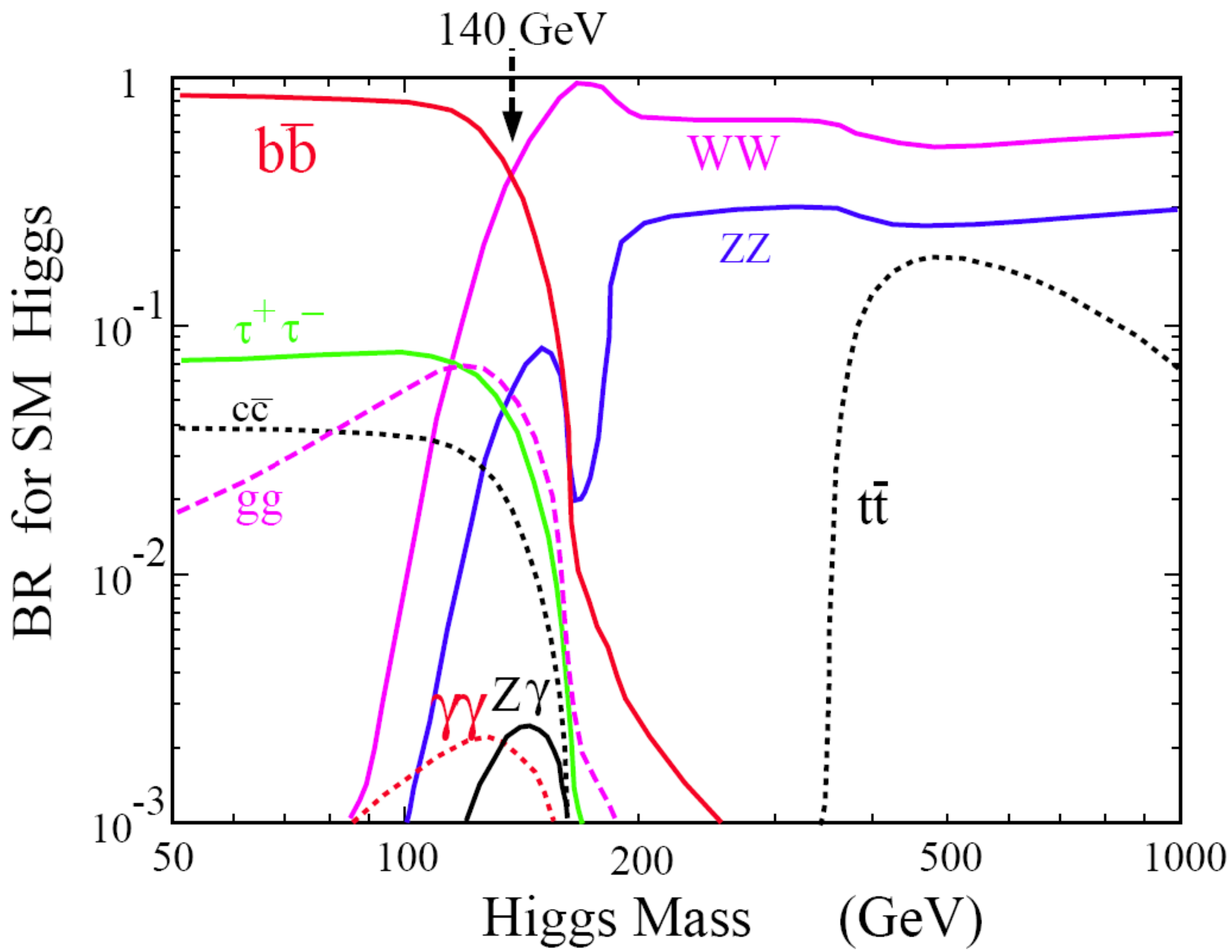
Higgs Production at the Tevatron



Higgs Decays

Coupling ∝ fermion mass

$$-\frac{1}{v} m_f \bar{\psi}_f \phi_h \psi_f$$



Main channels:

WW* (high mass)

bb, ττ (low mass)

Need good b-jet tagging!

Main Higgs Analyses

	$H\rightarrow bb$, $\tau\tau$ (low mass)	$H\rightarrow WW^*$ (high mass)
$p\bar{p}\rightarrow H$	~~$H\rightarrow bb$~~	**$H\rightarrow WW^*\rightarrow$ ee/eμ/μμ+MET**
$p\bar{p}\rightarrow WH$	**$WH\rightarrow Wbb\rightarrow$ e/μ+bb**	$W/Z+H\rightarrow W/Z+WW^*\rightarrow$ $l^+l^-l^+$ / l^+l^+jj + MET
$p\bar{p}\rightarrow ZH$	**$ZH\rightarrow Zbb\rightarrow$ ee/μμ+bb MET+bb**	

Main Higgs Analyses

	H→bb, ττ (low mass)	H→WW* (high mass)
$p\bar{p}$→H	~~H→bb~~	**H→WW*→ ee/eμ/μμ+MET**
$p\bar{p}$→WH	**WH→Wbb→ e/μ+bb**	W/Z+H→W/Z+WW*→ $l^+l^- l^+$ / l^+l^+jj + MET
$p\bar{p}$→ZH	**ZH→Zbb→ ee/μμ+bb MET+bb**	

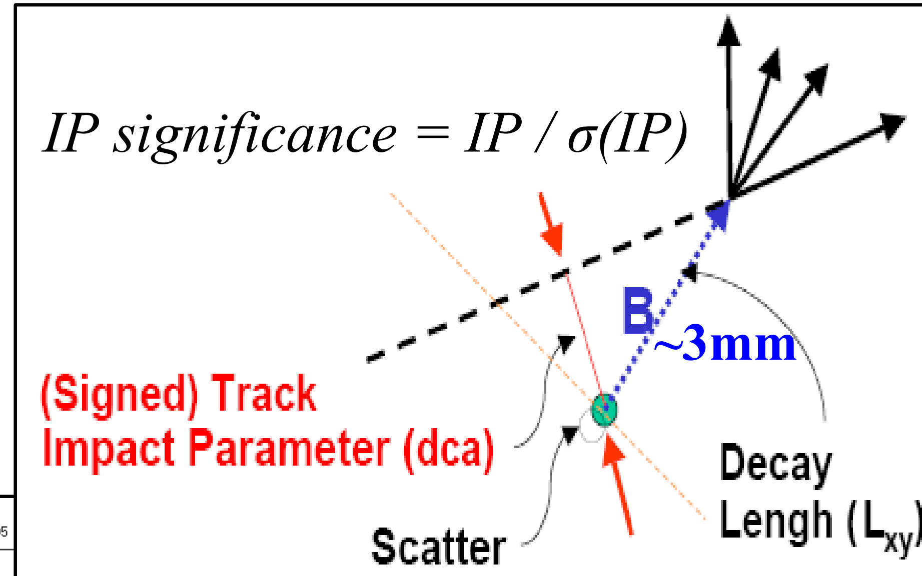
b-Jet Tagging

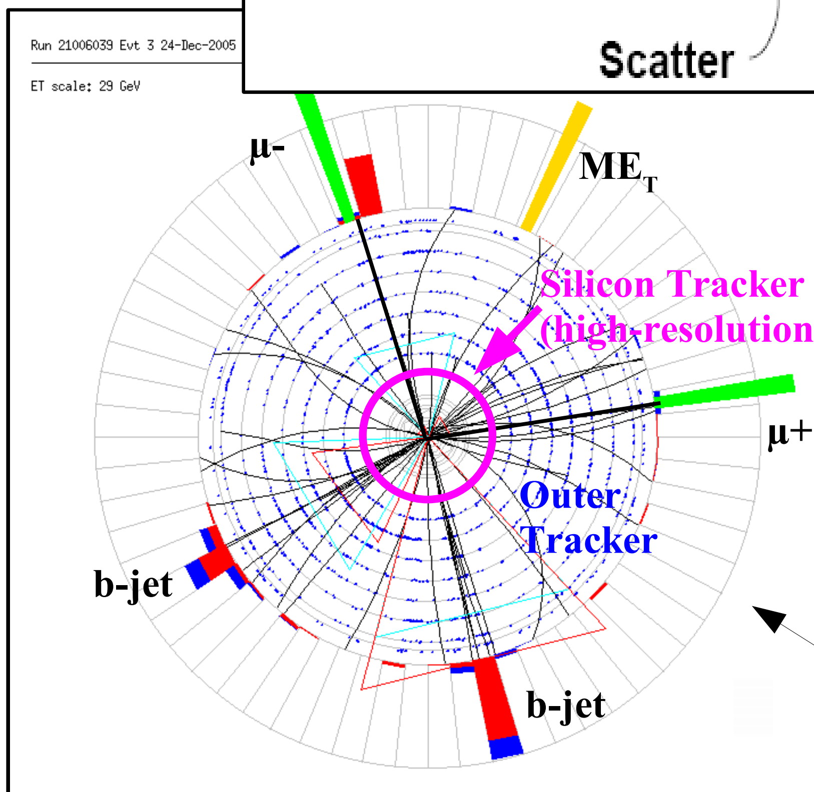
B hadrons are "long"-lived

- Reconstruct charged particles tracks
- Reconstruct "vertices" where tracks overlap

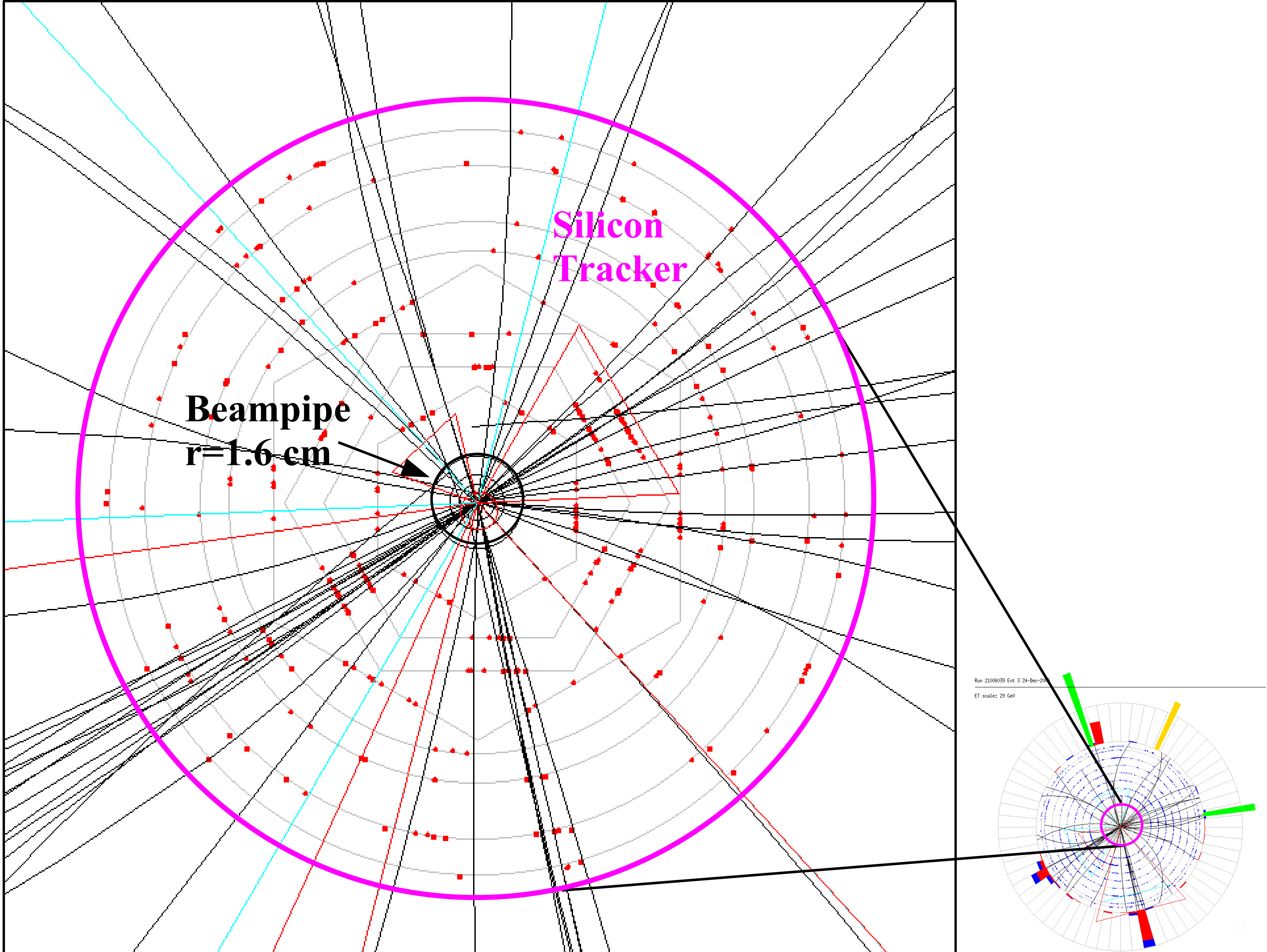
Identify jets with:

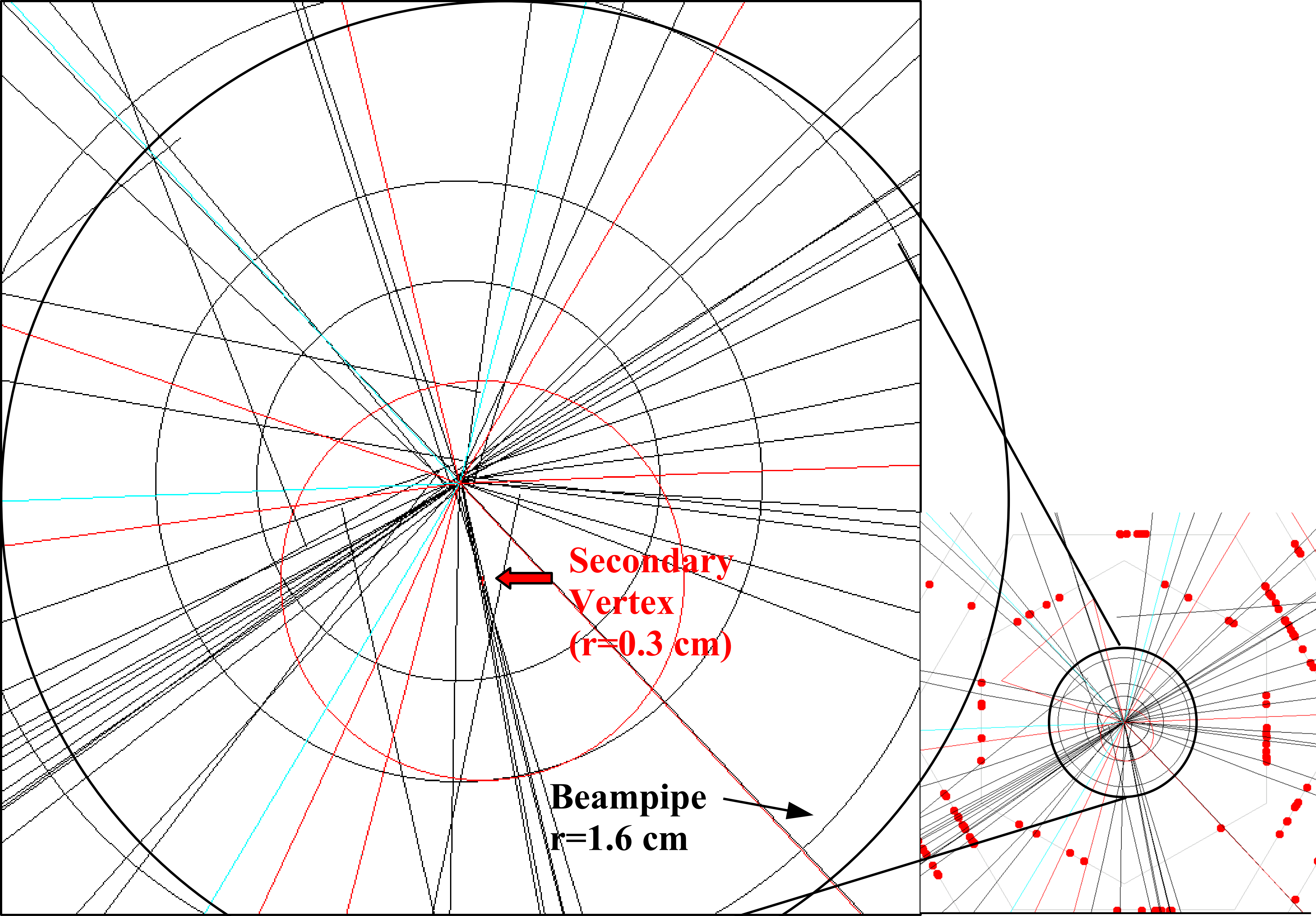
- Large impact parameter significance tracks
- Large decay length significance vertices





Simulated ZH→μμbb event


Silicon Tracker
Beampipe r=1.6 cm


Secondary
Vertex
(r=0.3 cm)
Beampipe
r=1.6 cm

b-Jet Tagging

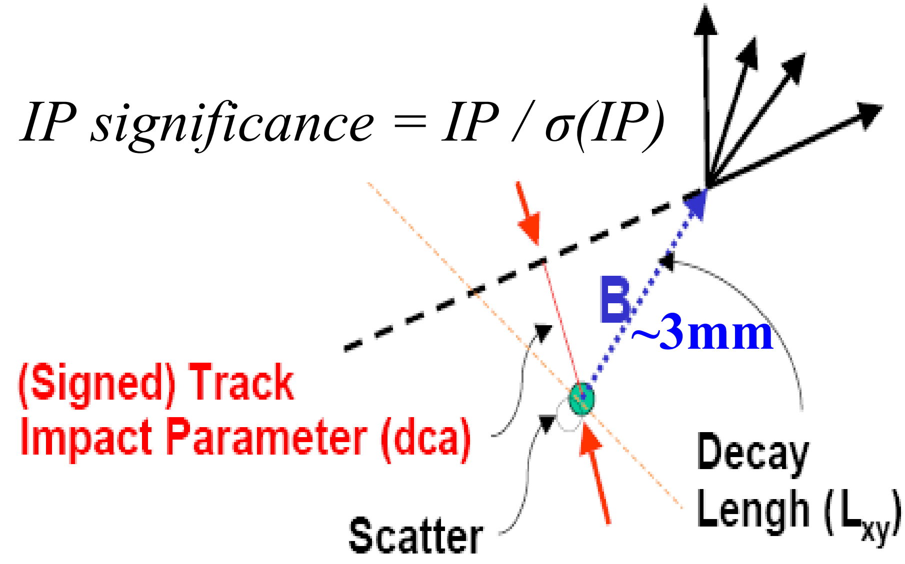
Many variables with separation power:

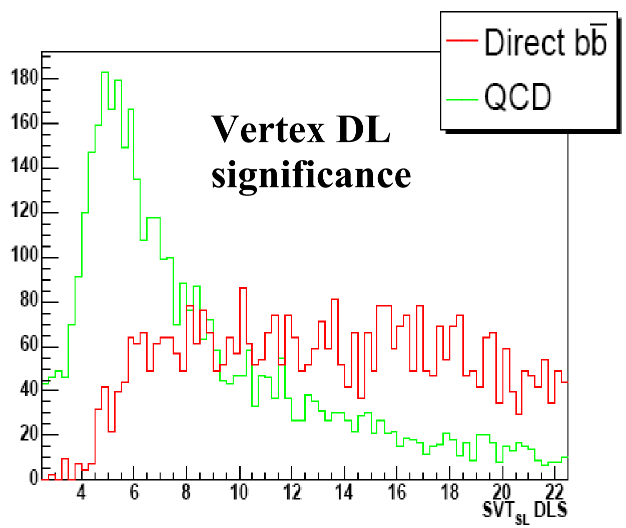
- <u>Secondary vertex:</u>

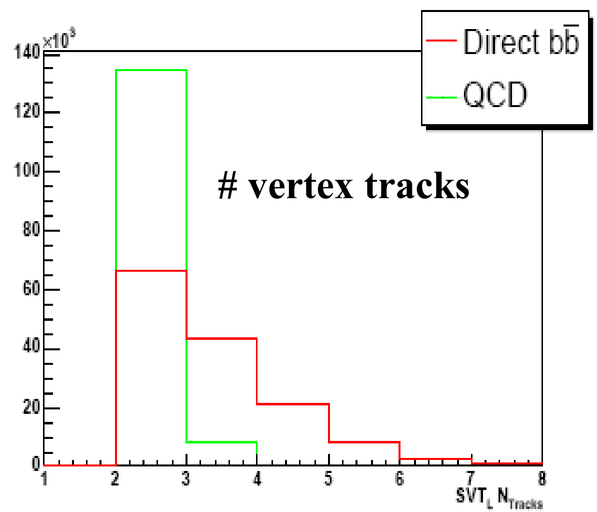
  Decay-length significance
  # tracks on vertex
  # vertices
  mass
  chi^2/dof

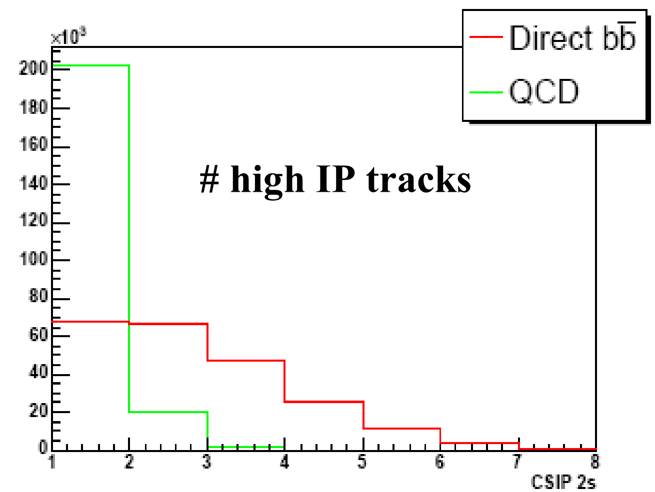
- <u>Jet:</u>

  # high IP sig. tracks
  combined light-jet probability









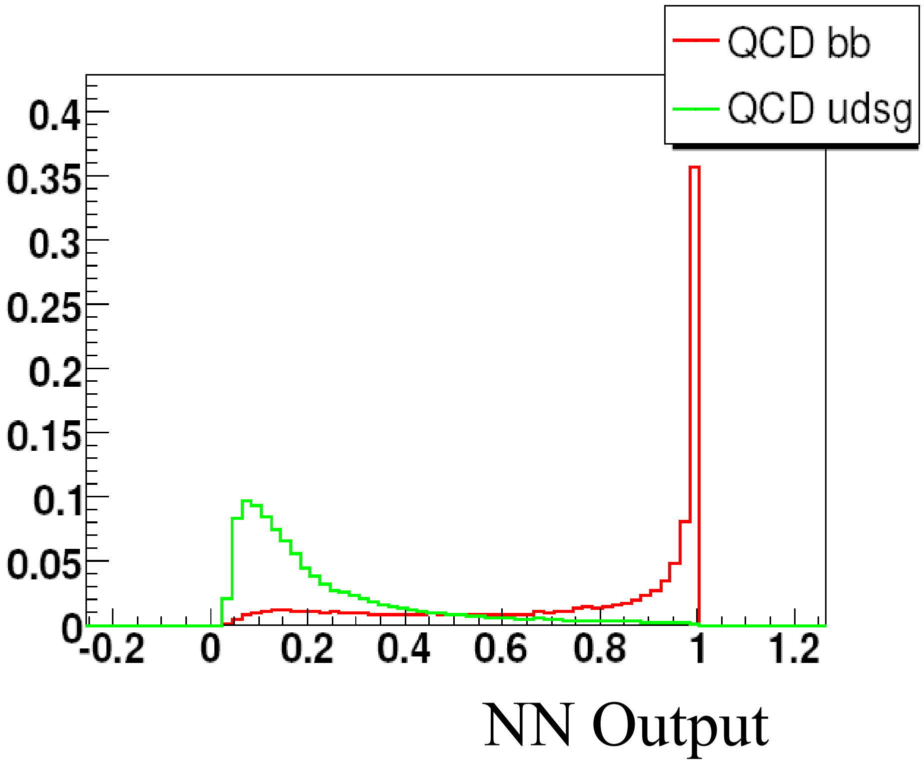
...

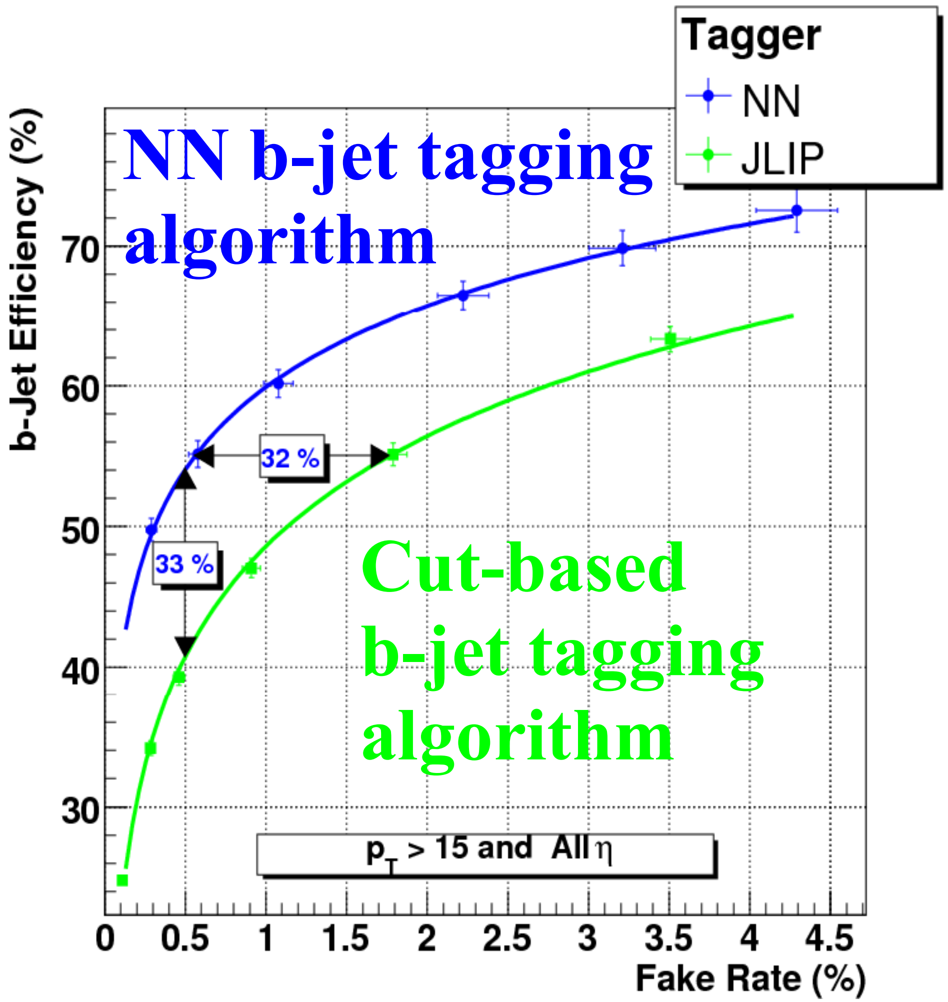
Neural Network b-Jet Tagging

Train NN on simulated events

- Optimized inputs, training method, network topology

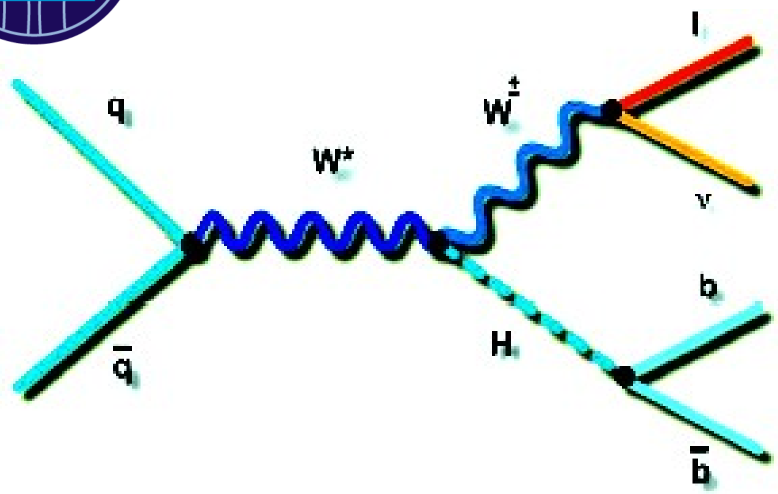
Test NN eff. and fake rate using data





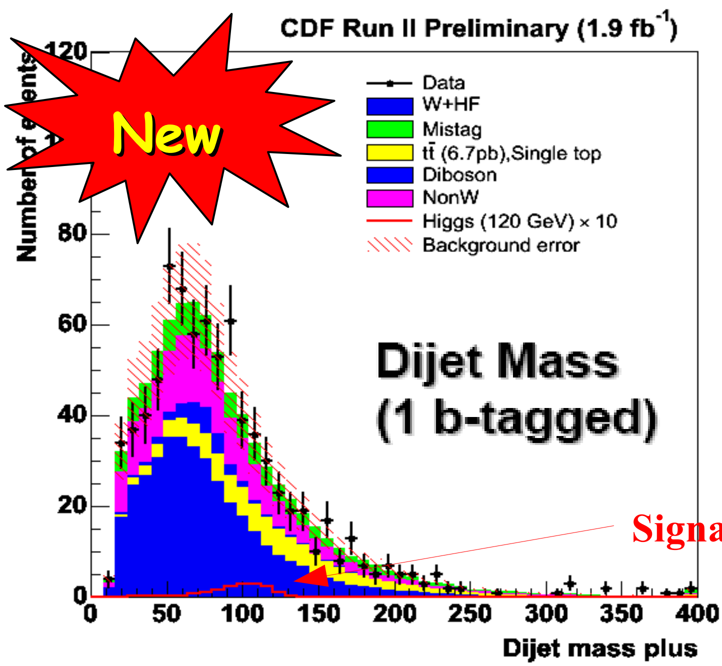
Equivalent to 2.5x as much data for a double-b-tag analysis!

WH-> l nu b b (l=e,mu)



- e or μ P_T > 20 GeV
- ME_T > 20 GeV

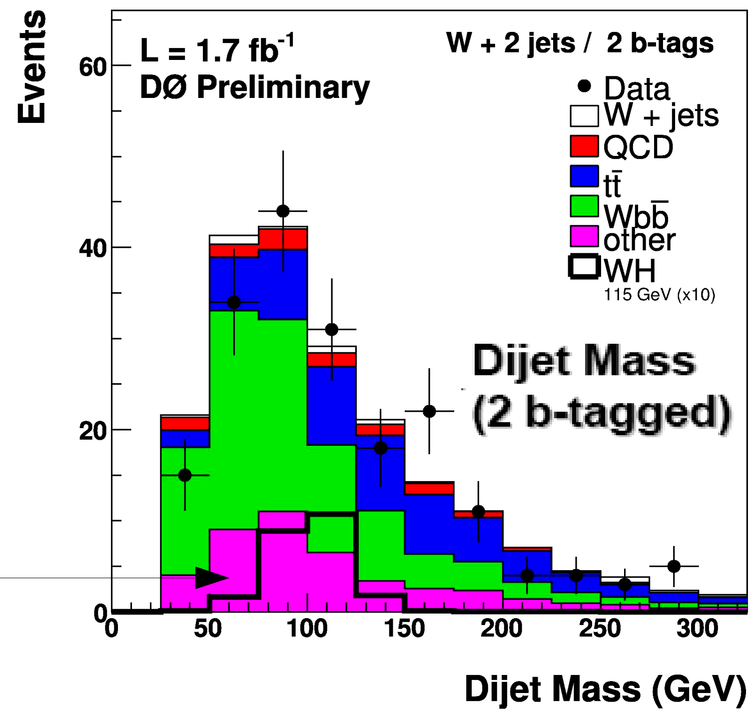
- 2 jets, with 1 or 2 b-tagged
- Main backgrounds:
  W+bb, QCD, ttbar



CDF updates:

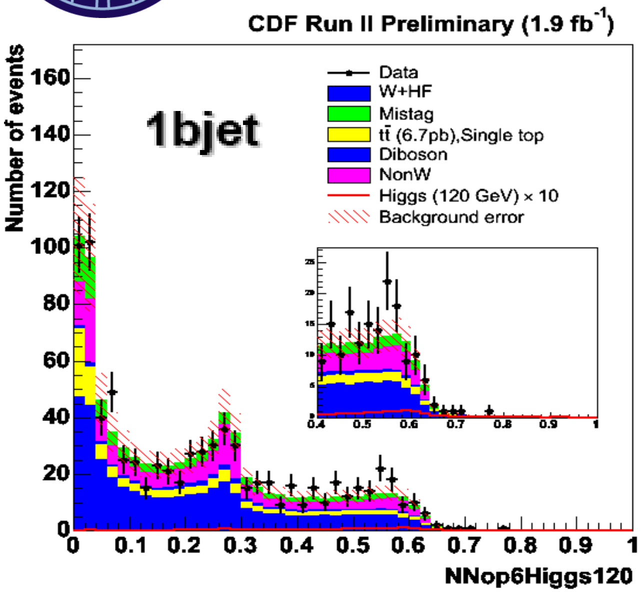
- Added 1 b-tagged events with NN flavor separation
- Included forward electrons

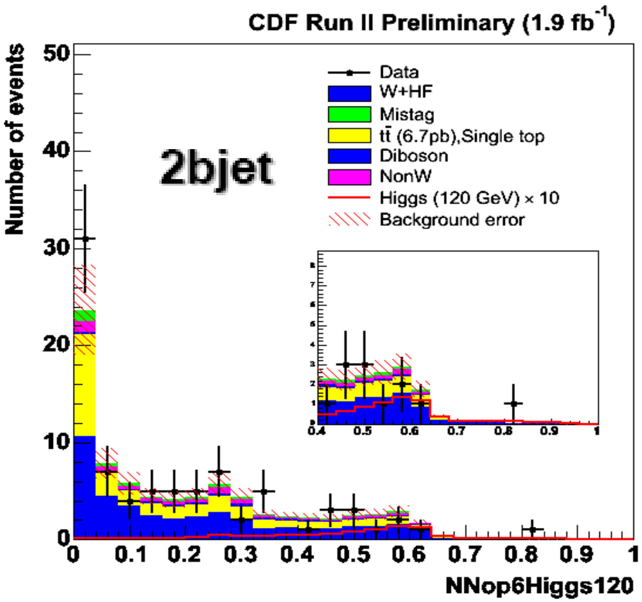
Signal (x10)



Dijete mass+: Inv. mass plus an extra loose jet (E_T>12,|η|<2.4) if within ΔR<0.9 of one of the tight jets

WH-> l nu b b (l=e,mu)



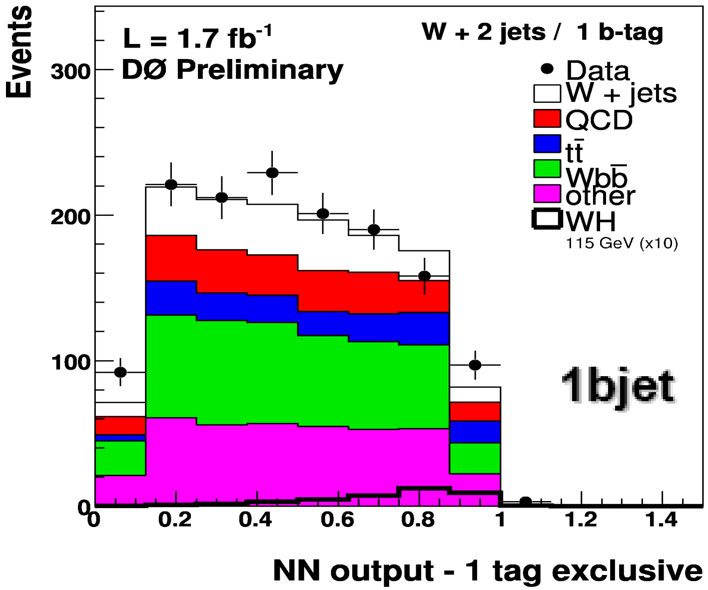


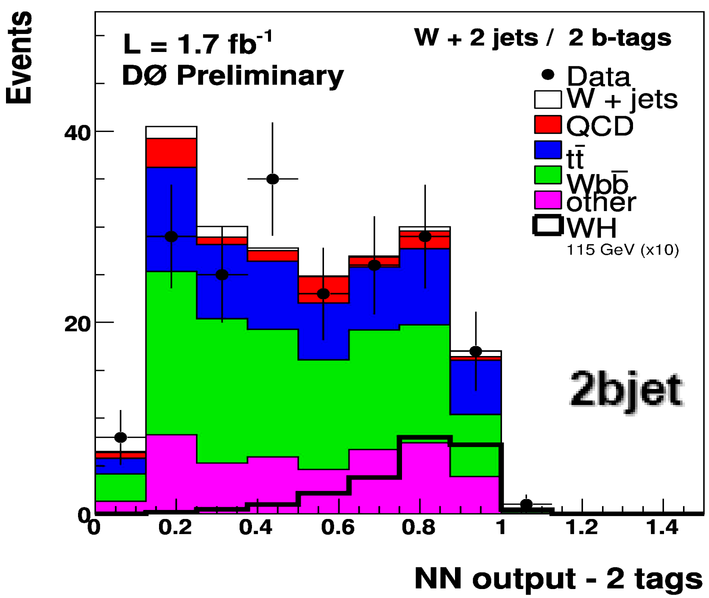
Use NN trained on MC to separate signal from background:

Signal $\rightarrow$ 1
Background $\rightarrow$ 0

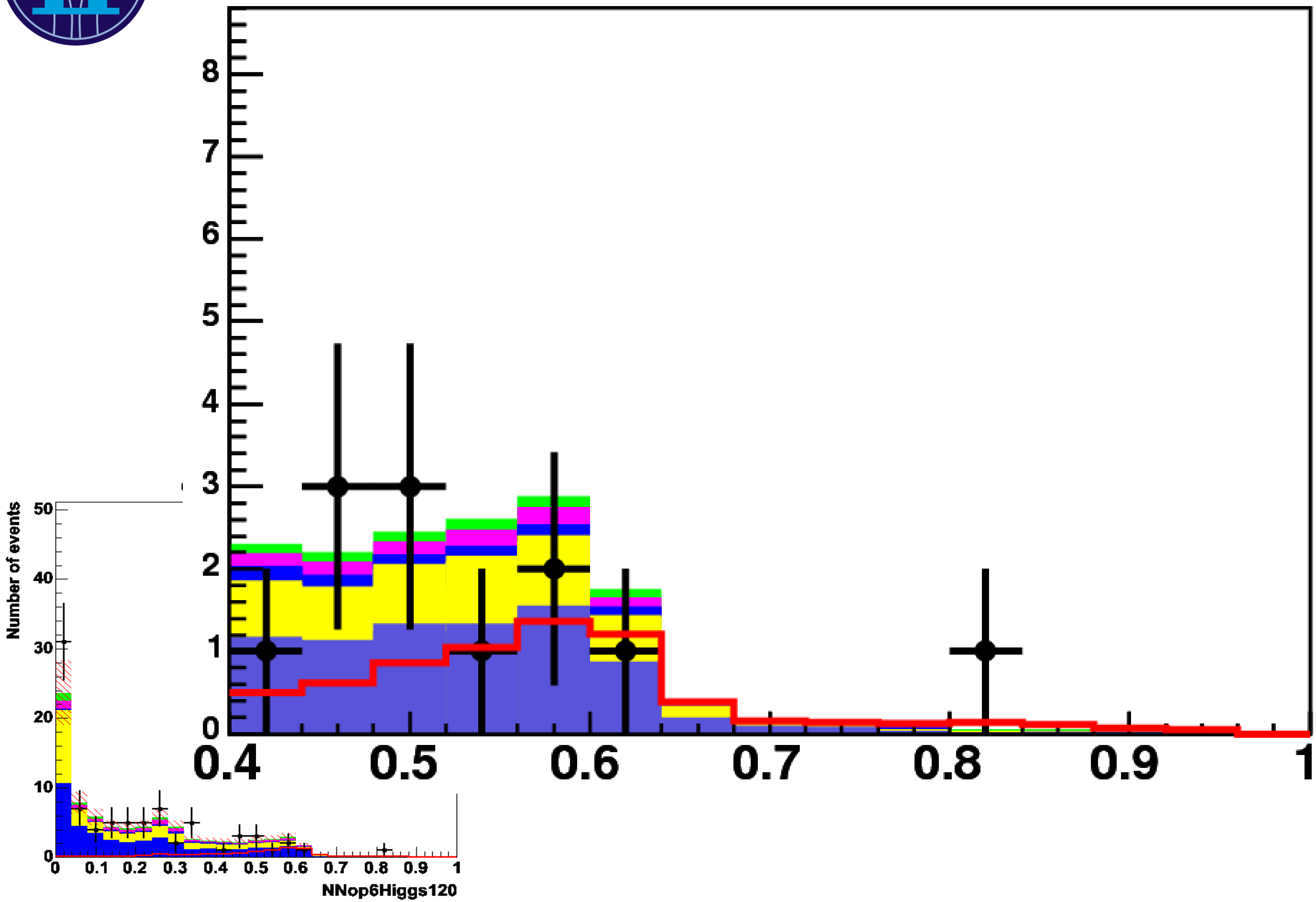
No significant excess in signal region for either CDF/DØ

-> Set limits for exclusion!



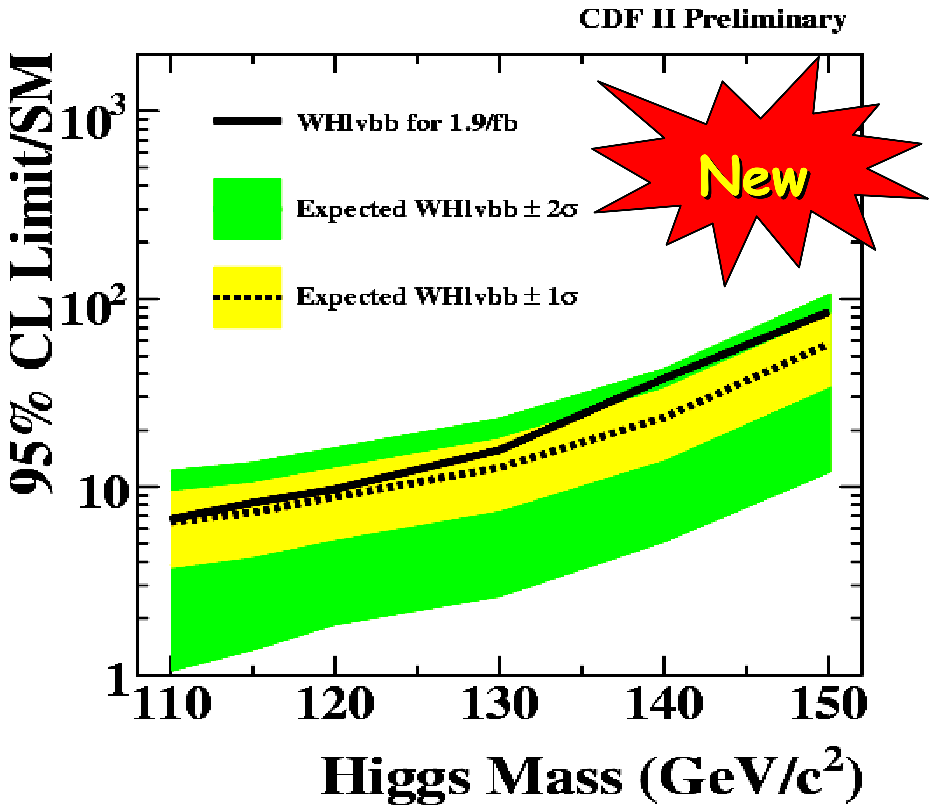


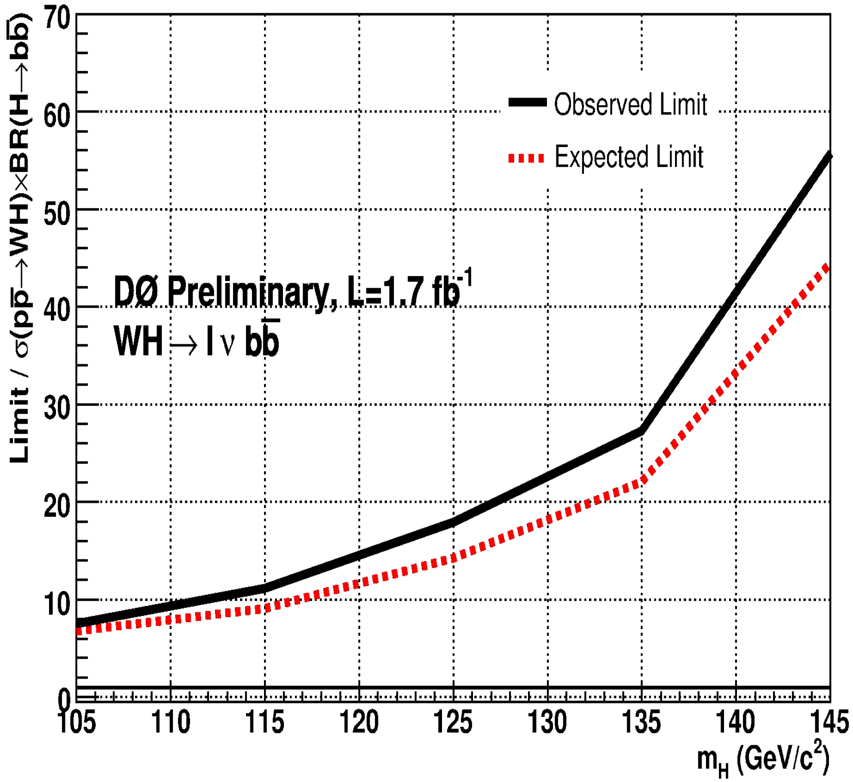
WH-> l nu b b (l=e,mu)



WH-> l nu b b (l=e,mu)

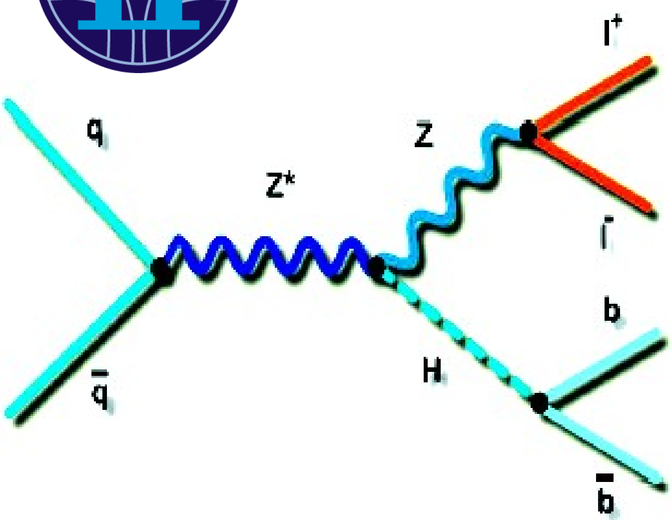
- 95% Confidence Level Upper limit is set by binned likelihood method.
  -> Showing σ(limit)/σ(SM) Ratio (i.e. If reached 1, it is excluded)





- CDF: (at M_H=115 GeV)
  σ(limit)/σ(SM) = 8.2/7.3 (obs./exp.)
- DØ: (at M_H=115 GeV)
  σ(limit)/σ(SM) = 11/9 (obs./exp.)

ZH-> l l b b (l=e,mu)

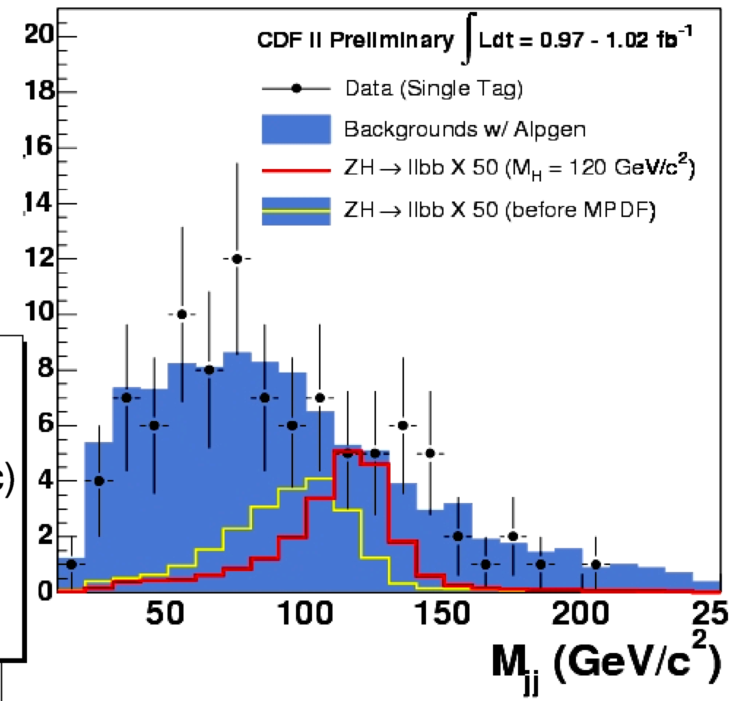


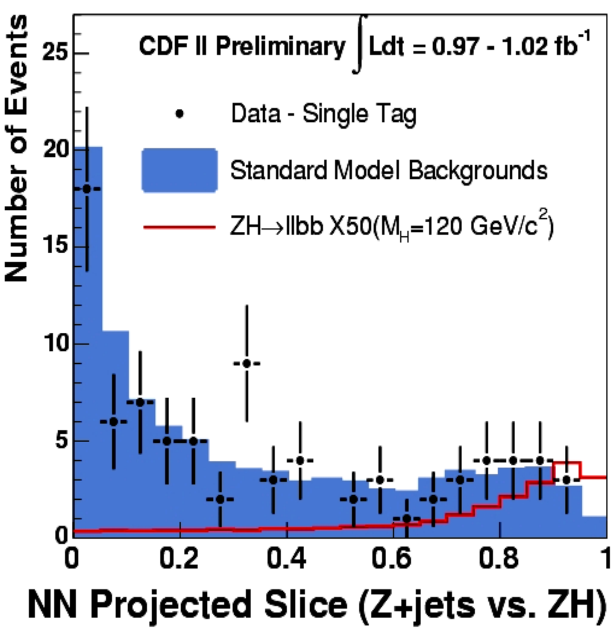
- 2 high P_T leptons from Z
  -> Clean signature !

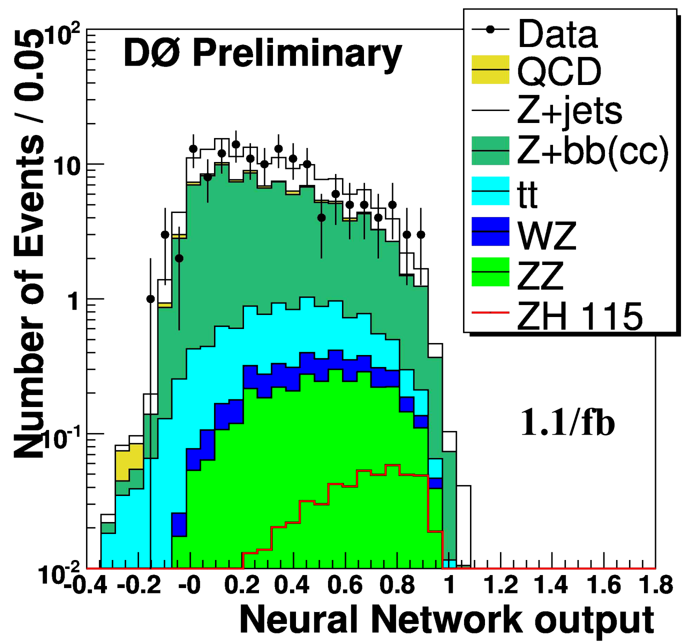
*Summer 2007 results

CDF: improve dijet mass resolution with ME_T projection

- Optimized by NN







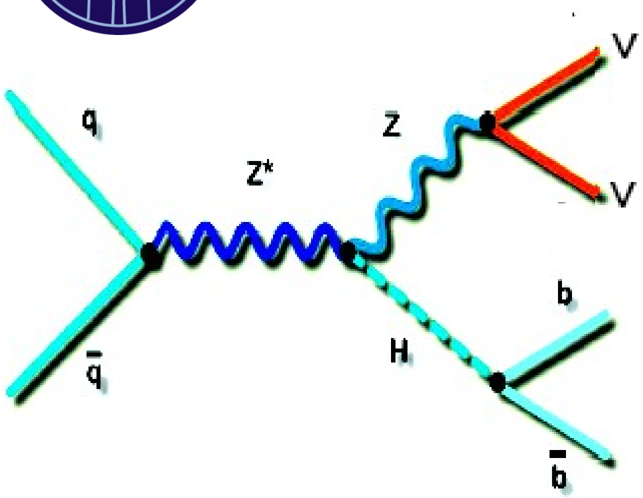
95% CL Limit (relative to SM) at M_H=115 GeV:

CDF: 16/16 (obs./expected)

DØ: 18/20 (obs./expected)

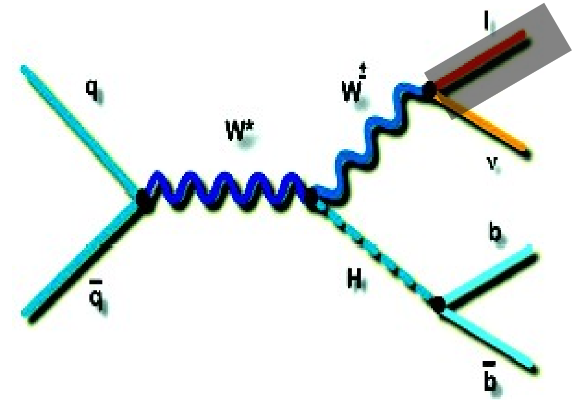
ZH-> nu nu b b

New

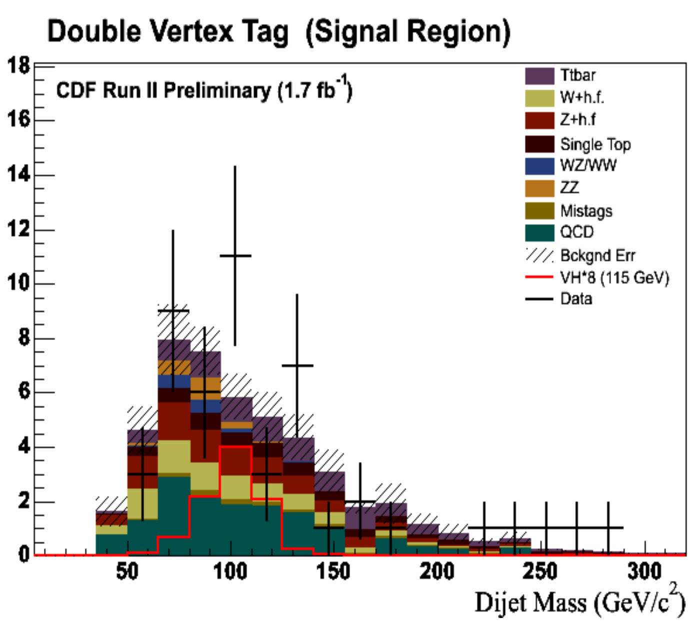


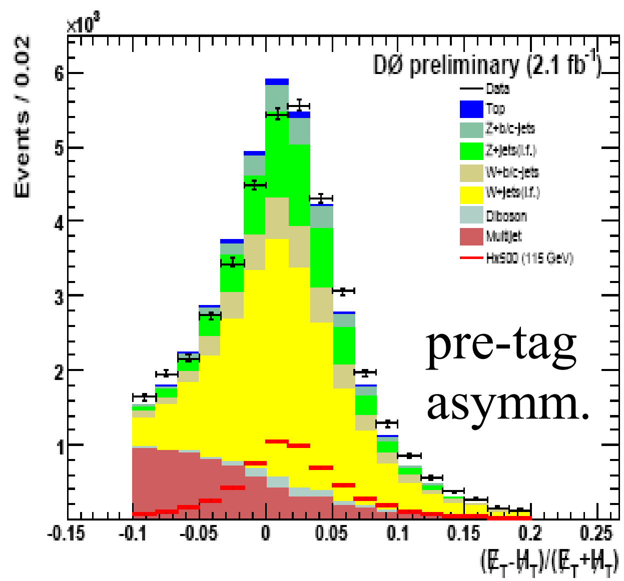
- ME_T >50 GeV, 2 b-jets
- Data driven QCD estimate:
  CDF: NN with track-based ME_T
  DØ: Asymmetry between ME_T and $SumE_T$

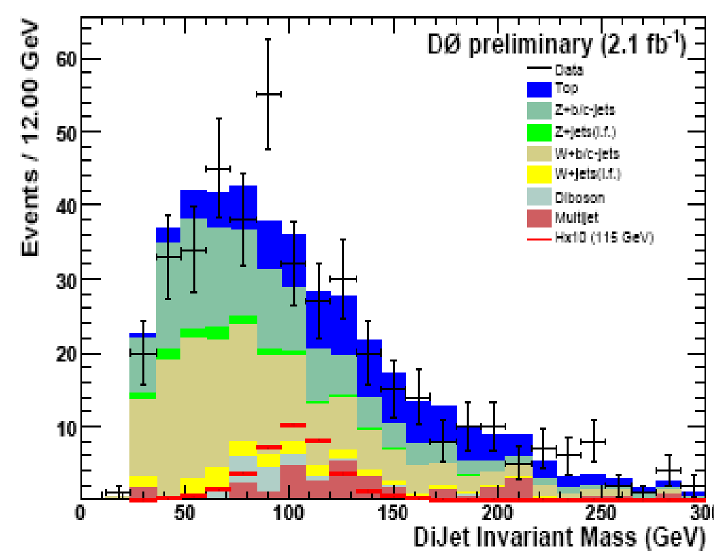
Recovered WH→lvbb



New DØ result: Boosted Decision Tree, 2.1/fb

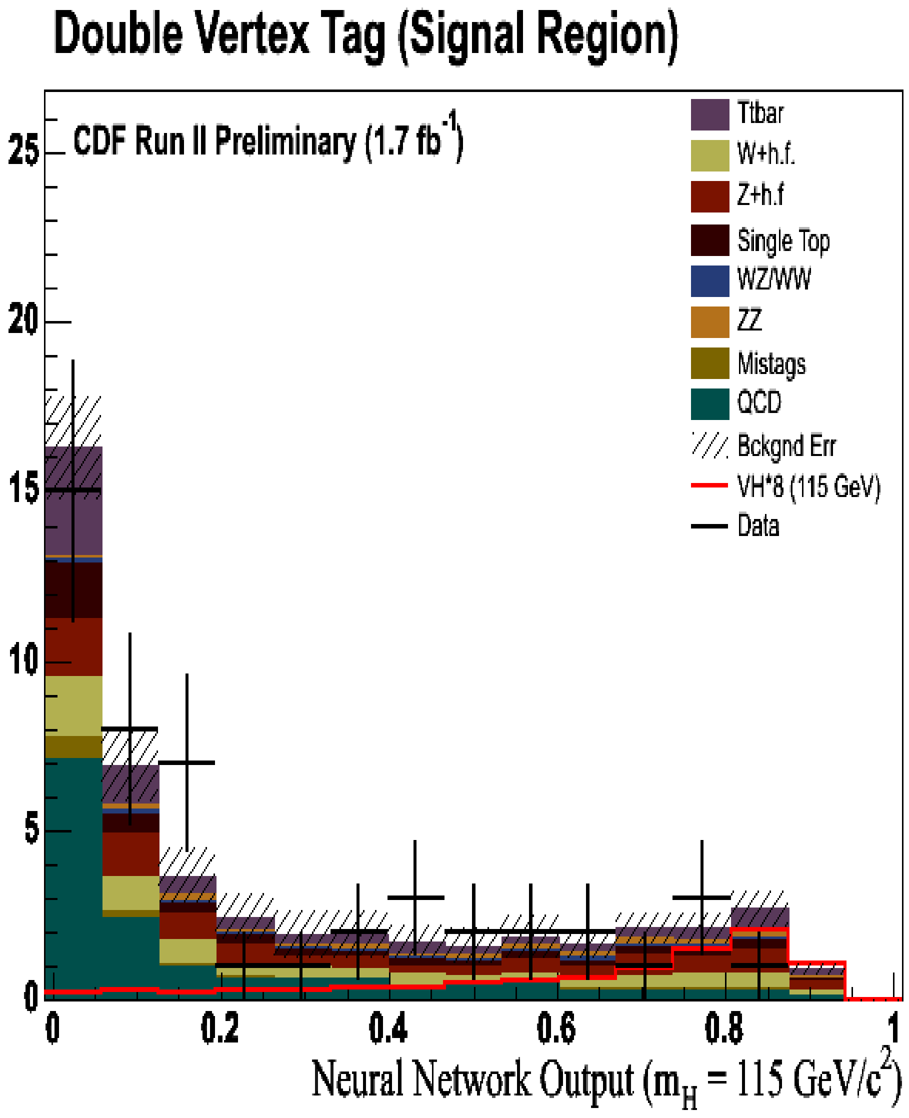


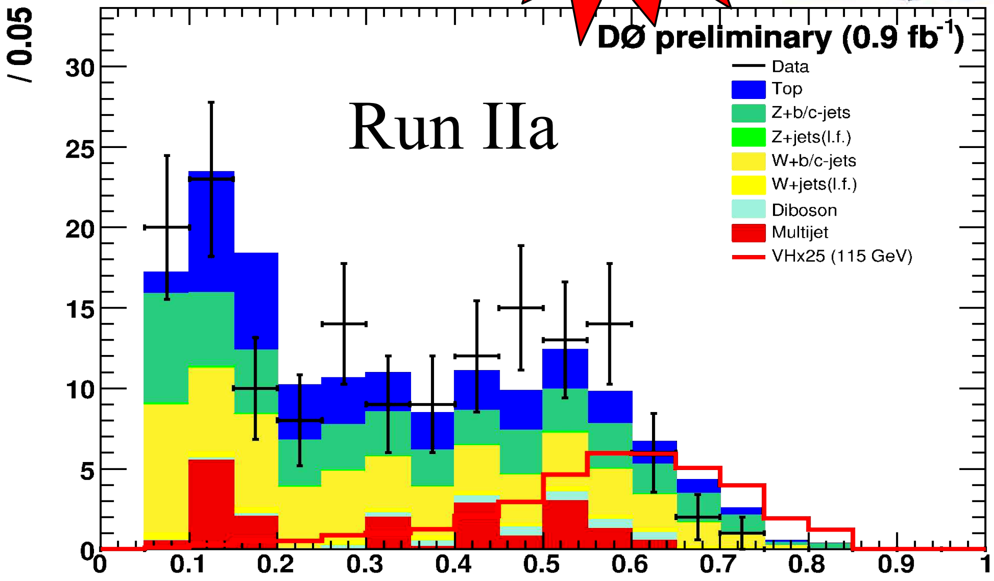


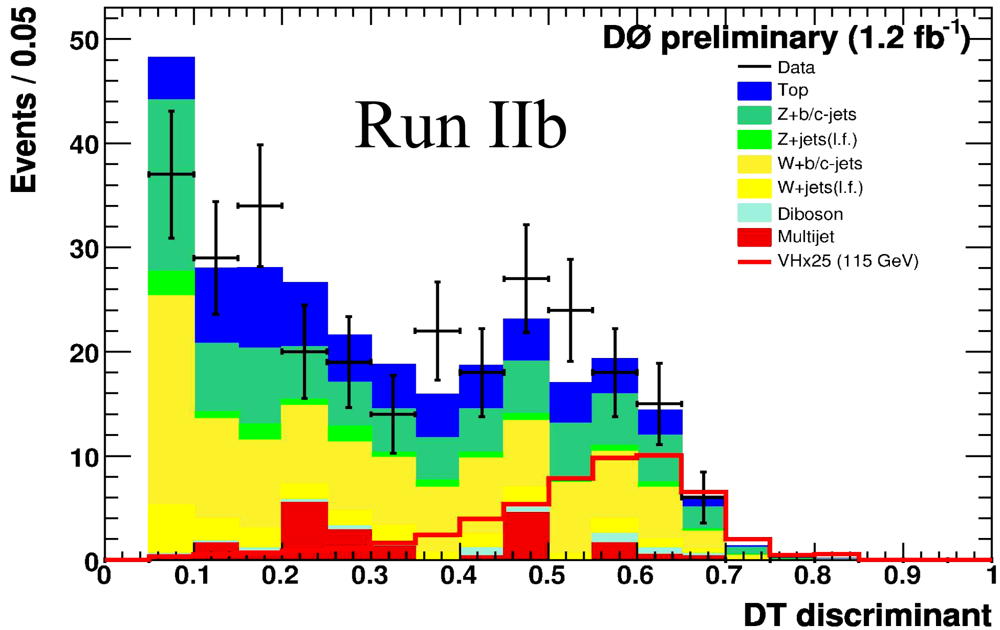


ZH-> nu nu b b

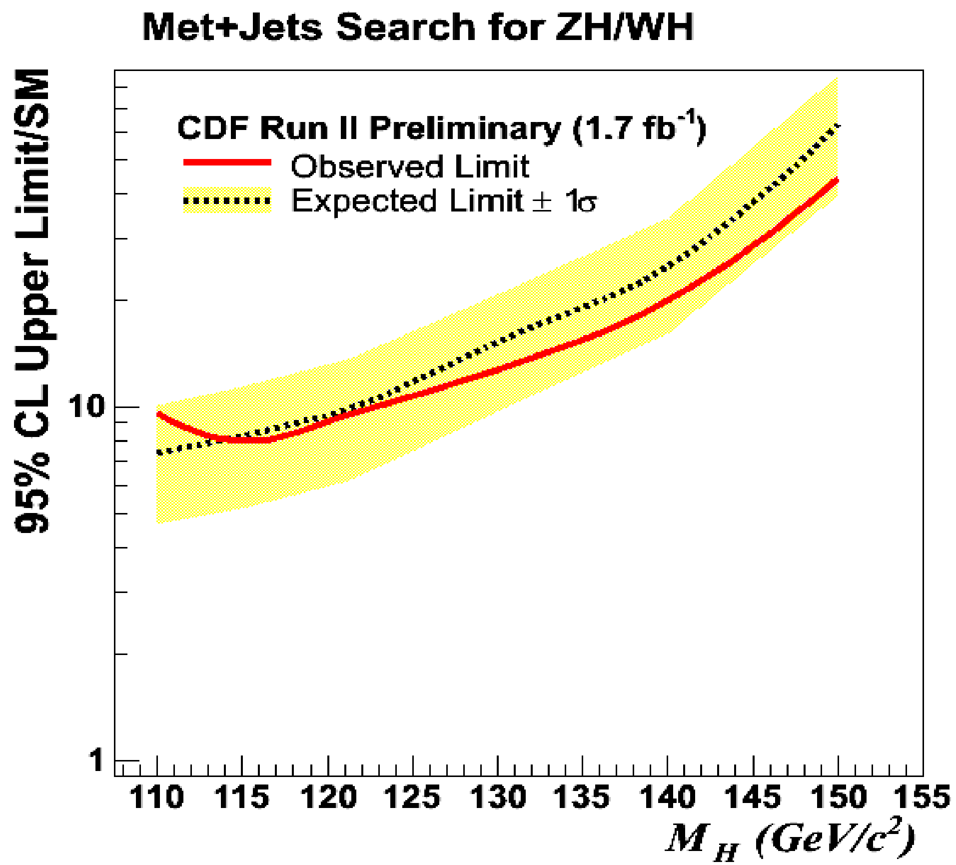
New

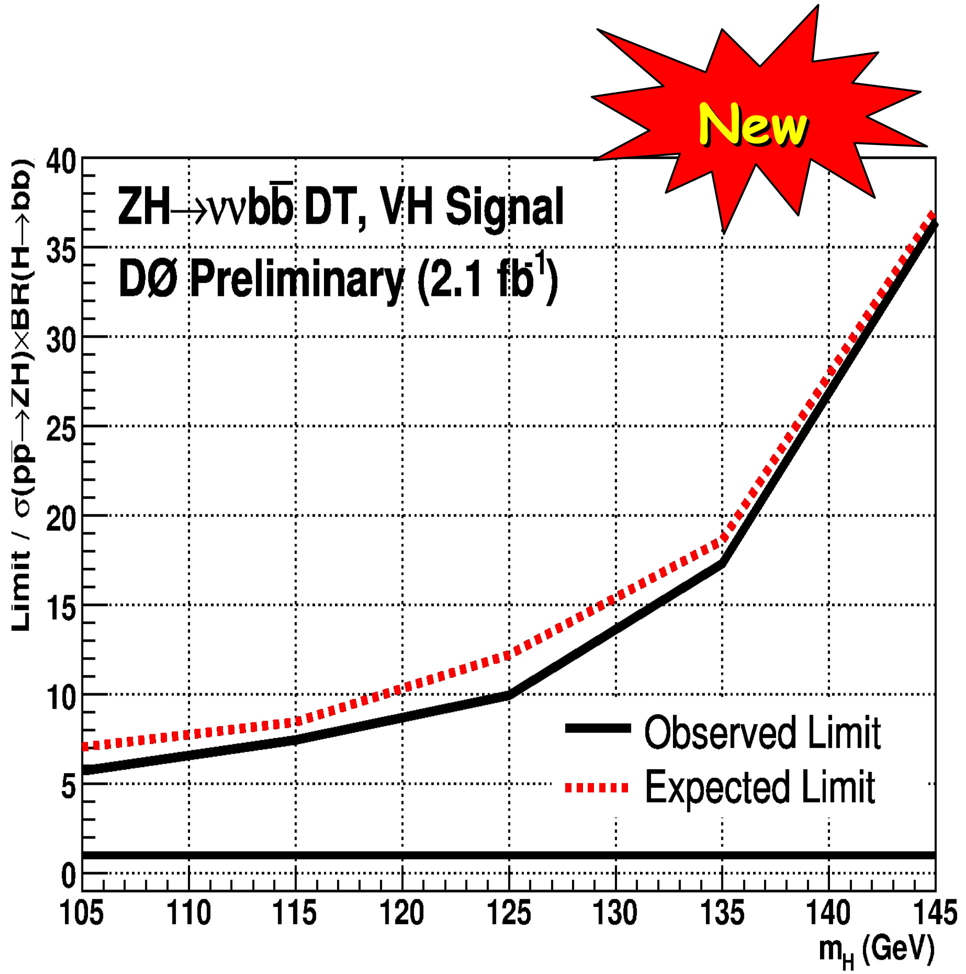






ZH-> nu nu b b



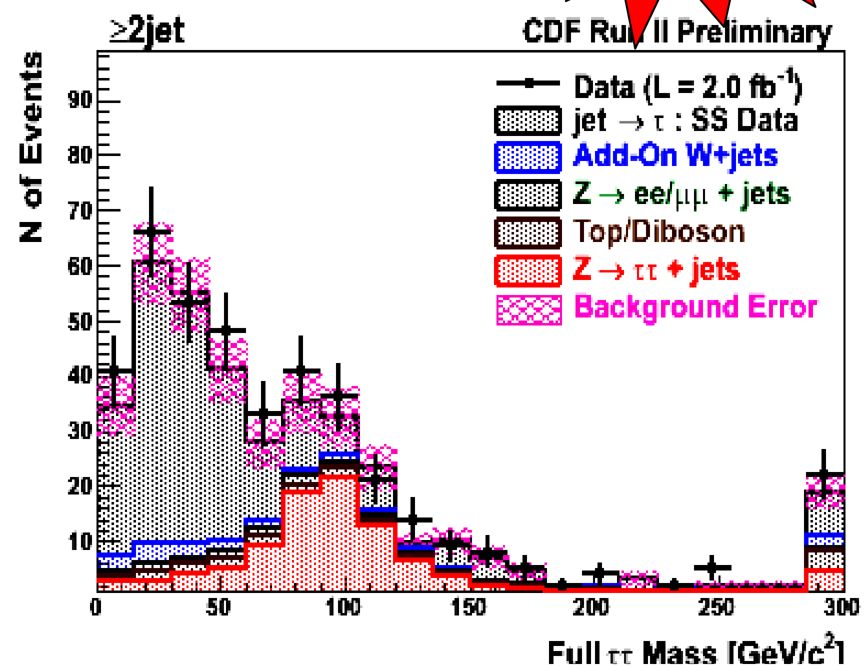


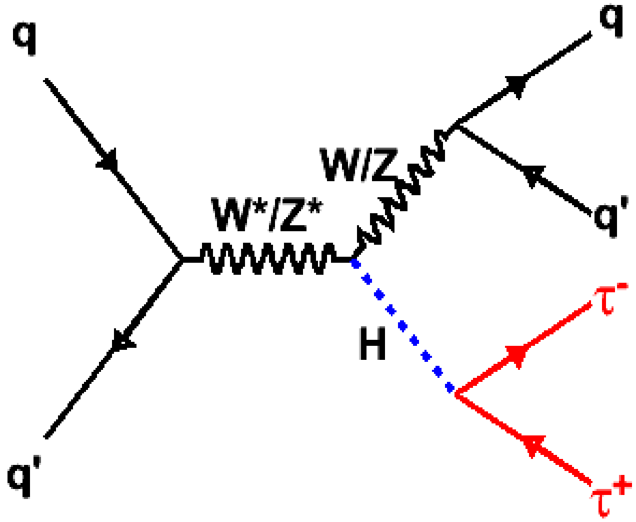
- CDF: (at M_H=115 GeV)
  σ(limit)/σ(SM) = 8/8.3 (obs./exp.)
- DØ: (at M_H=115 GeV)
  σ(limit)/σ(SM) = 7.5/8.4 (obs./exp.)

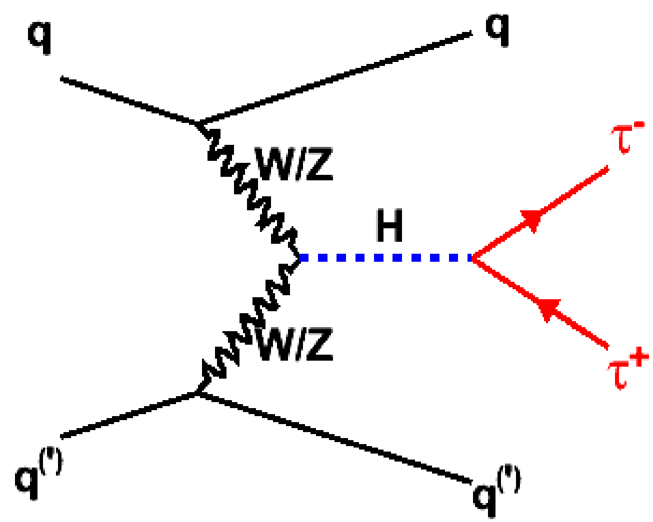
WH/ZH/VBF/ggH -> ττ + 2 jets

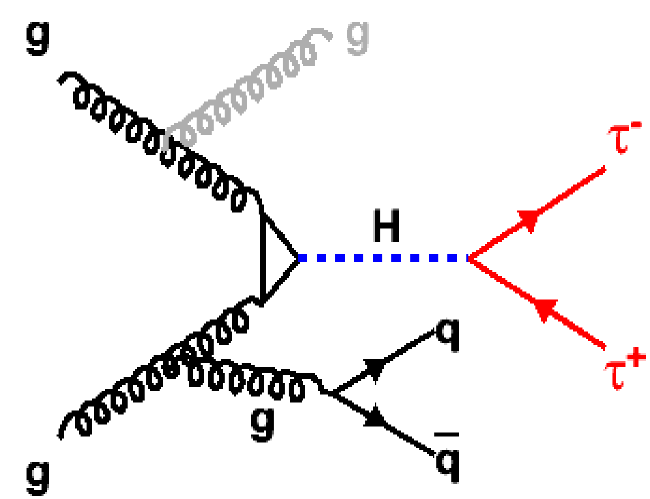
NEW!

- $H \rightarrow \tau\tau$ is hard due to small BR (10% of bb)
- But not impossible! Ideas are:
  1. Recover BR by looking at W/Z->2 jets:
     - $W \rightarrow l\nu(22\%)$, $Z \rightarrow ll(6\%)$, $Z \rightarrow \nu\nu(20\%)$
     - $W \rightarrow jj\ (67\%)$, $Z \rightarrow jj(70\%)$
  2. Add all possible channels:
     - Simultaneous Search for WH+ZH+VBF+ggH
  3. Many good kinematic variables to separate signal from backgrounds(dijet mass, dη(j,j) etc.)





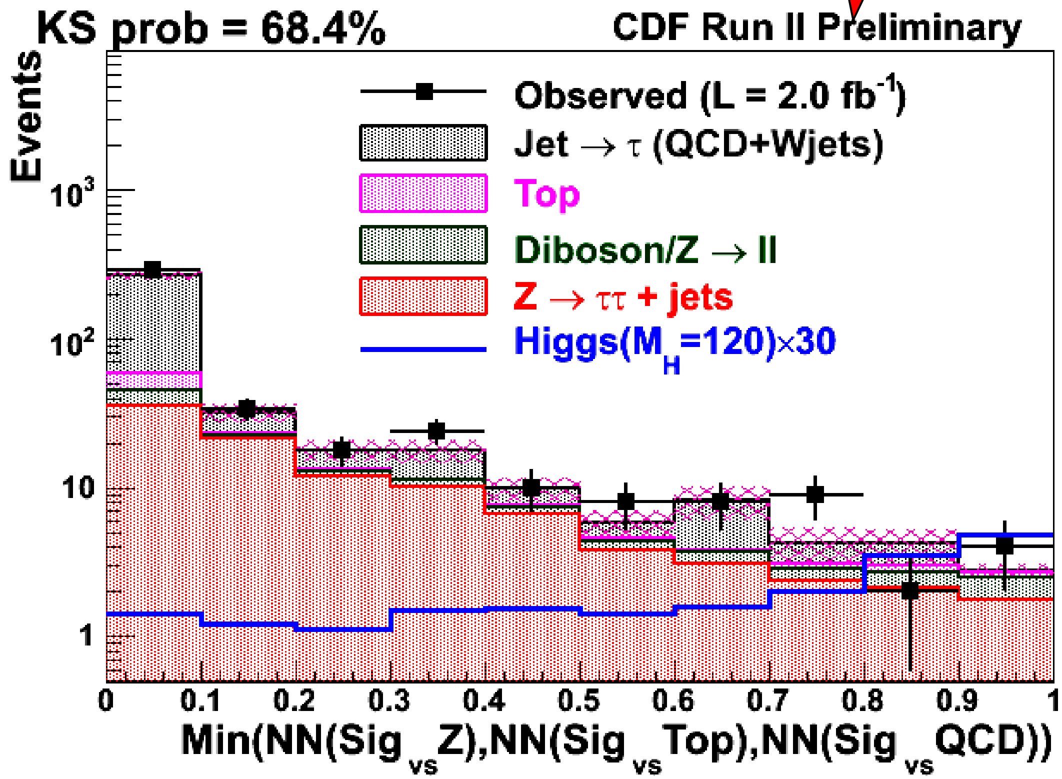


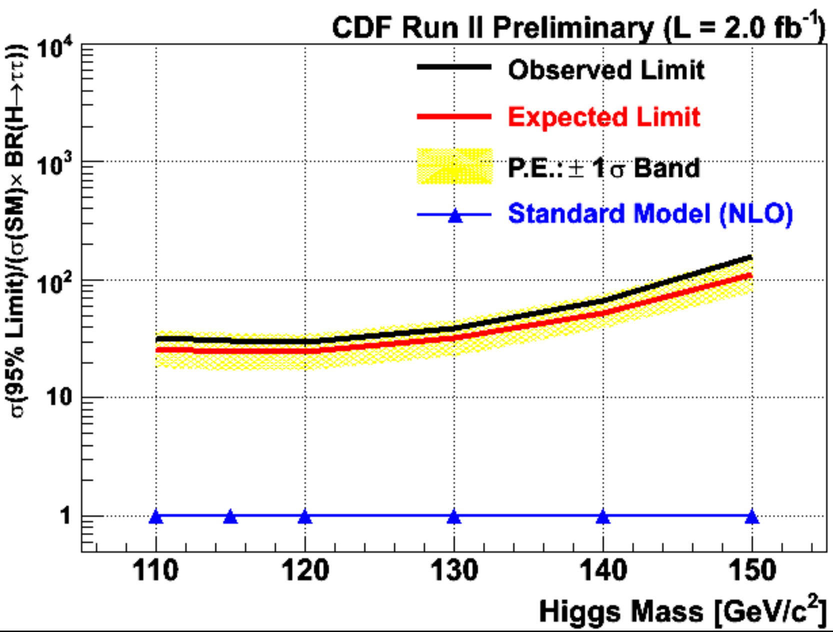


WH/ZH/VBF/ggH -> ττ + 2 jets

NEW!

- Use $\tau_{lep}\tau_{had}$ mode.
  - Lepton P_T > 10 GeV
  - Hadronic τ P_T > 15 GeV
- 3 Neural Nets are trained:
  - Signal vs Z-> ττ + jets
  - Signal vs ttbar
  - Signal vs QCD
- Select *minimum* of 3 NN scores





- CDF: (at M_H=120 GeV)
  σ(limit)/σ(SM) = 30/24 (obs./exp.)

* Established background estimate & modeling
* Further improvement by adding 0j/1jet events
* Becomes more interesting at LHC

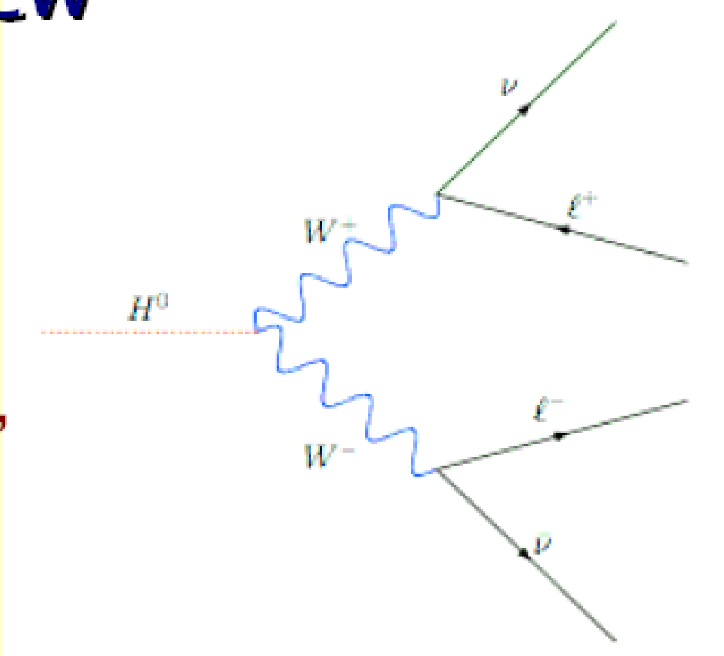
Main Higgs Analyses

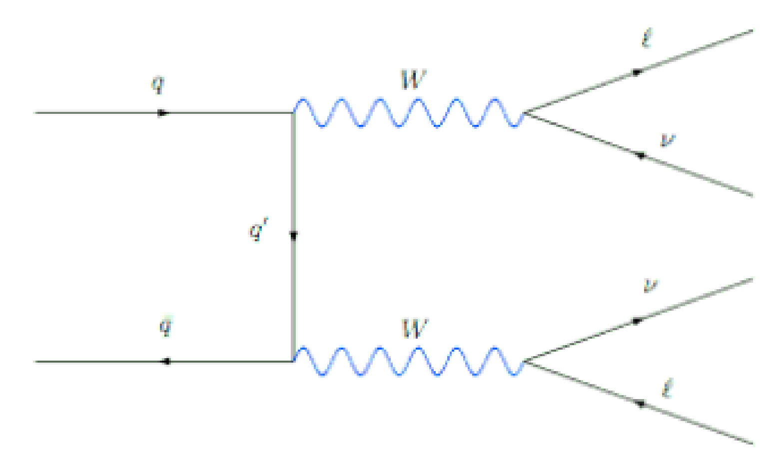
	$H\to bb$, $\tau\tau$ (low mass)	$H\to WW^*$ (high mass)
$p\bar{p}\to H$	~~$H\to bb$~~	**$H\to WW^*\to$ $ee/e\mu/\mu\mu$+MET**
$p\bar{p}\to WH$	**$WH\to Wbb\to$ $e/\mu+bb$**	$W/Z+H\to W/Z+WW^*\to$ $l^+l^-\ l^+$ / l^+l^+jj + MET
$p\bar{p}\to ZH$	**$ZH\to Zbb\to$ $ee/\mu\mu+bb$ MET+bb**	

H -> WW* -> l l (l=e,mu)

Analysis overview

- To suppress hadron backgrounds we look into final states where both W decay to leptons, i.e. ee, μμ and eμ
- Major backgrounds: Diboson (mainly WW), Drell-Yan, Multijets, tt, W+jets
- Signature:
  - Two energetic isolated leptons with opposite charge
  - Large missing transverse energy

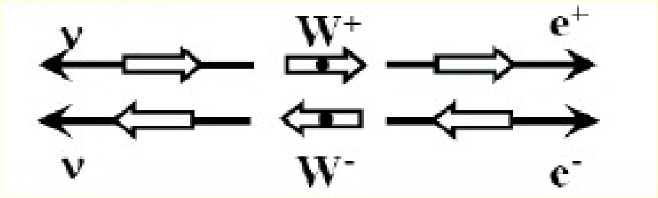




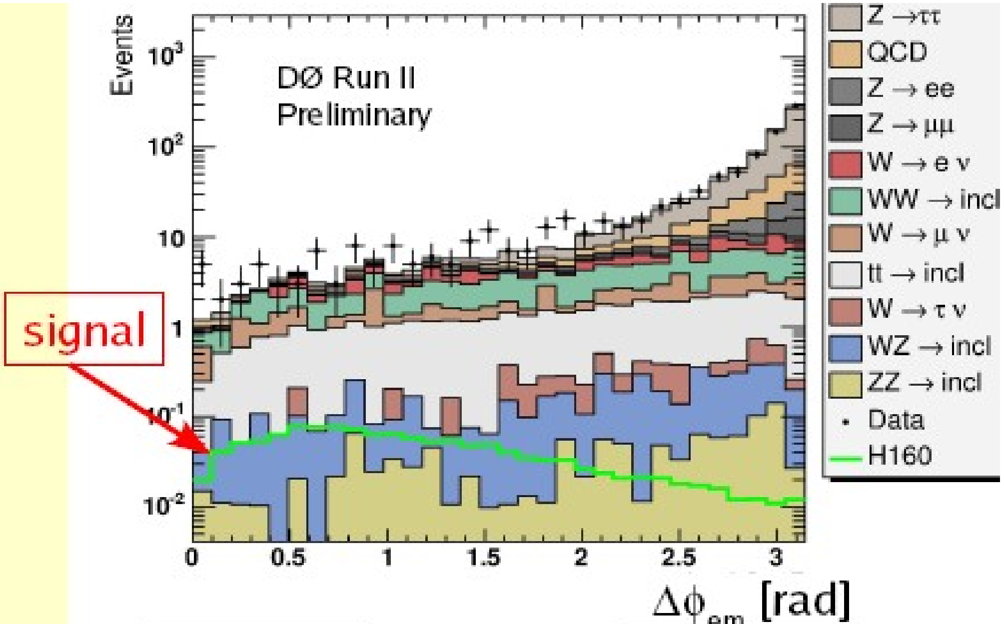
H -> WW* -> l l (l=e,mu)

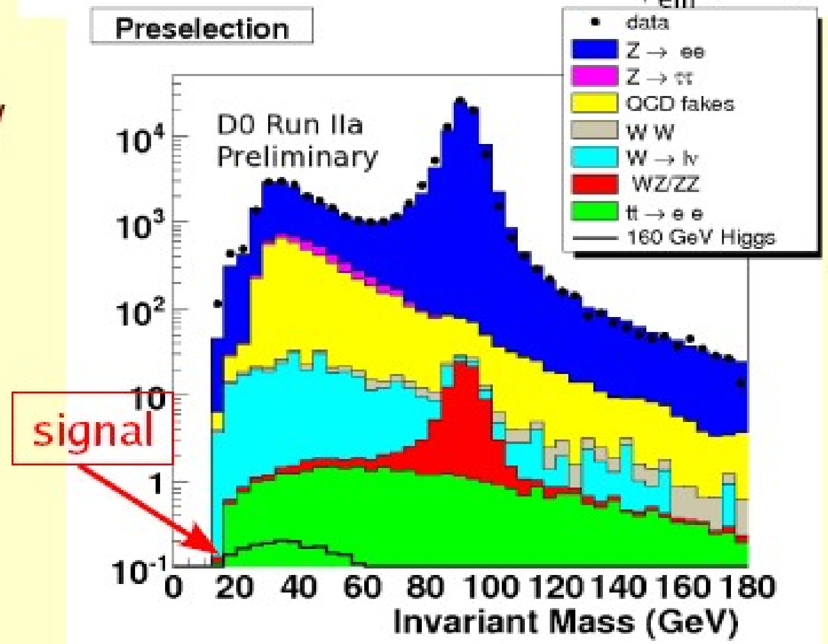
Characteristics:

- In signal WW pair is coming from spin 0 Higgs boson
  - Leptons prefer to point in same direction



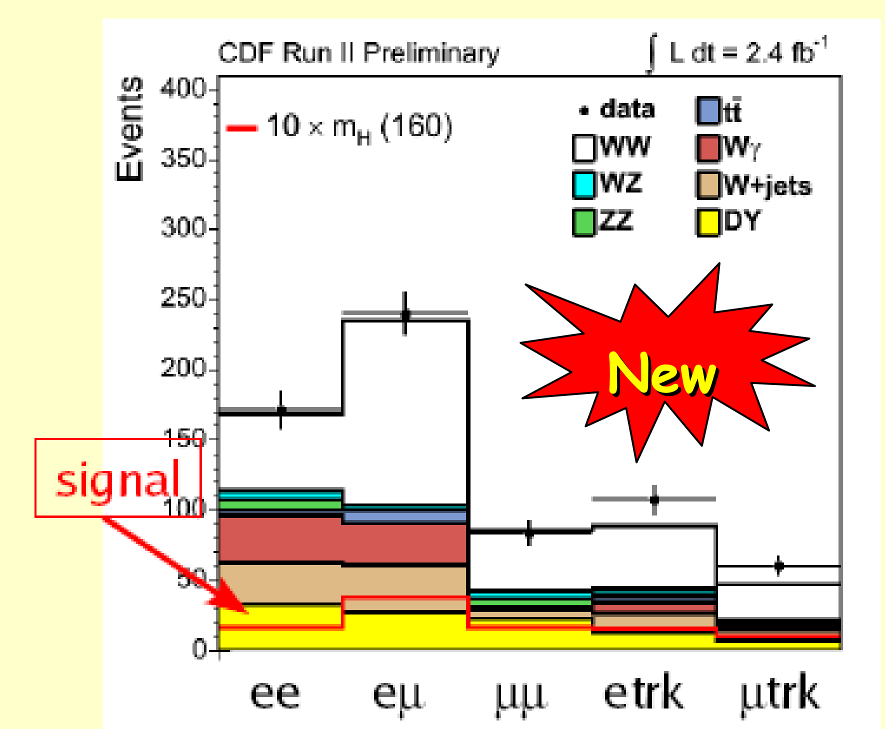
  - Di-lepton opening angle $\Delta\phi_{ll}$ discriminates against dominant WW background.
- Dilepton mass is small and broad
  - Discriminates against Drell-Yan





H -> WW* -> l l (l=e,mu)

NEW!



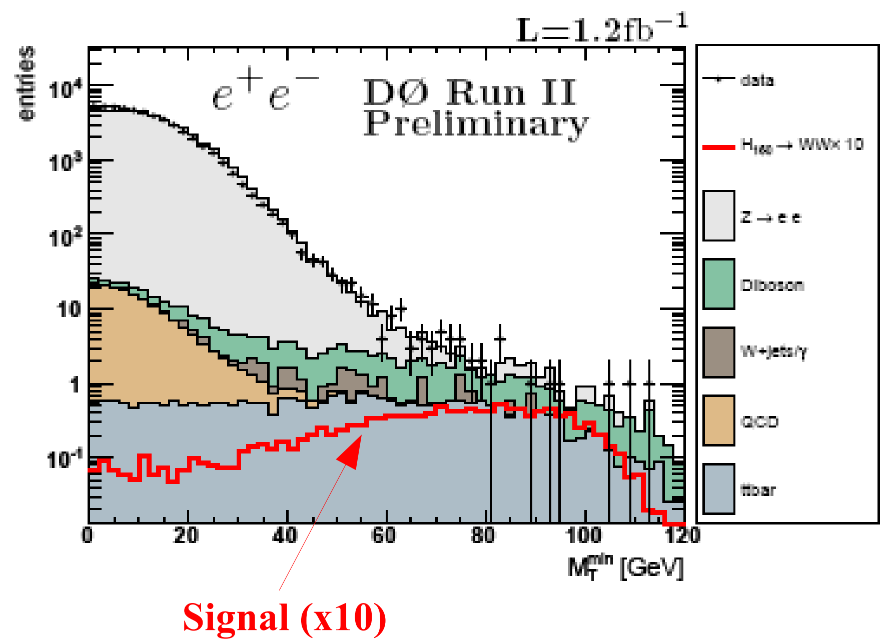
Selection criteria	$m_H = 115$ GeV	$m_H = 160$ GeV	$m_H = 200$ GeV
Cut 0 Pre-selection	lepton ID, leptons with opposite charge and $p_T^{e_1} > 20$ GeV and $p_T^{e_2} > 15$ GeV invariant mass $M_{ee} > 15$ GeV		
Cut 1 Missing Transverse Energy $\not{E}_T$ (GeV)	> 20	> 20	> 20
Cut 2 $\not{E}_T^{\text{Scaled}}$	> 6	> 7	> 7
Cut 3 $M_T^{min}(\ell, \not{E}_T)$ (GeV)	> 35	> 50	> 50
Cut 4 Sum of $p_T^{\ell} + p_T^{\ell'} + \not{E}_T$ (GeV)	80-120	90-160	120-200
Cut 5 Invariant mass M_{ee} (GeV)	< 40	< 70	< 75
Cut 6 H_T (GeV)	< 50	< 80	< 80
Cut 7 $\Delta\phi(e_1, e_2)$	< 2.5	< 2.0	< 2.0

Lepton trigger selection

Several categories of lepton(track) pairs with opposite charge divided into two groups – high signal to background and low signal to background

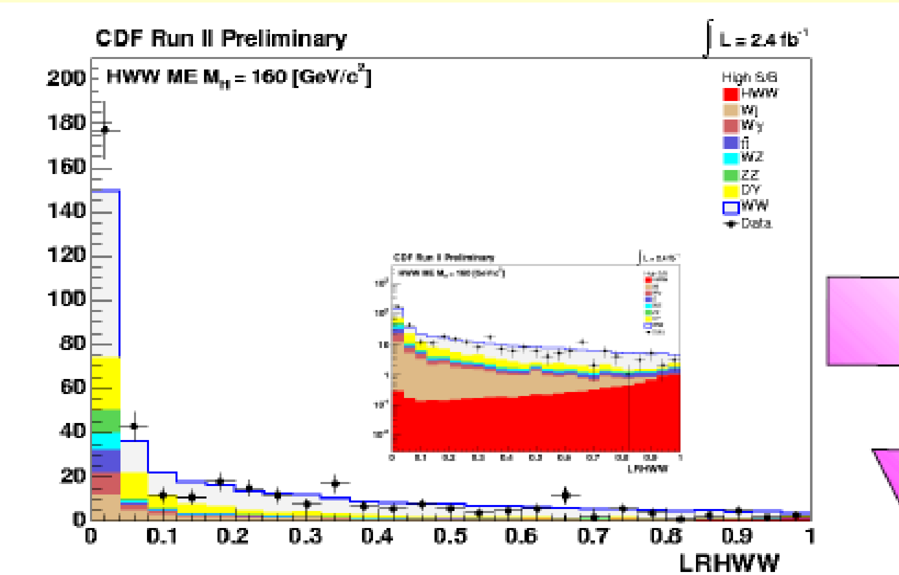
Lepton and missing E_T cuts applied to reduce backgrounds:

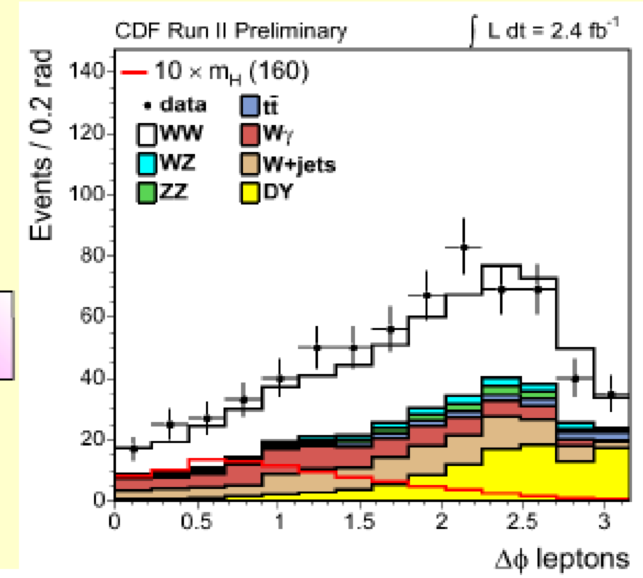
$p_T(l_1) > 20$ GeV, $p_T(l_2) > 10$ GeV, $\not{E}_T \cdot \sin(\min(\pi/2, \Delta\phi(\not{E}_T, l \text{ or jet}))) > 25$ GeV, $n_{jets} < 2$ ($p_T(\text{jet}) > 15$ GeV, $|\eta| < 2.5$), $m_{ll} > 16$ GeV, trilepton veto

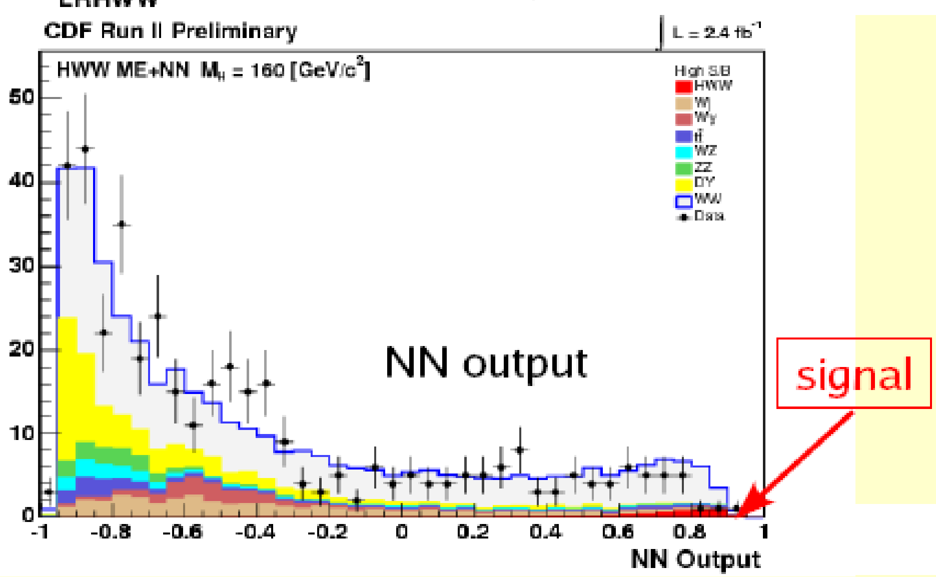


H -> WW* -> l l (l=e,mu)

- ME calculated from lepton 4-vectors and missing transverse energy is used as an input to NN together with several kinematic distributions







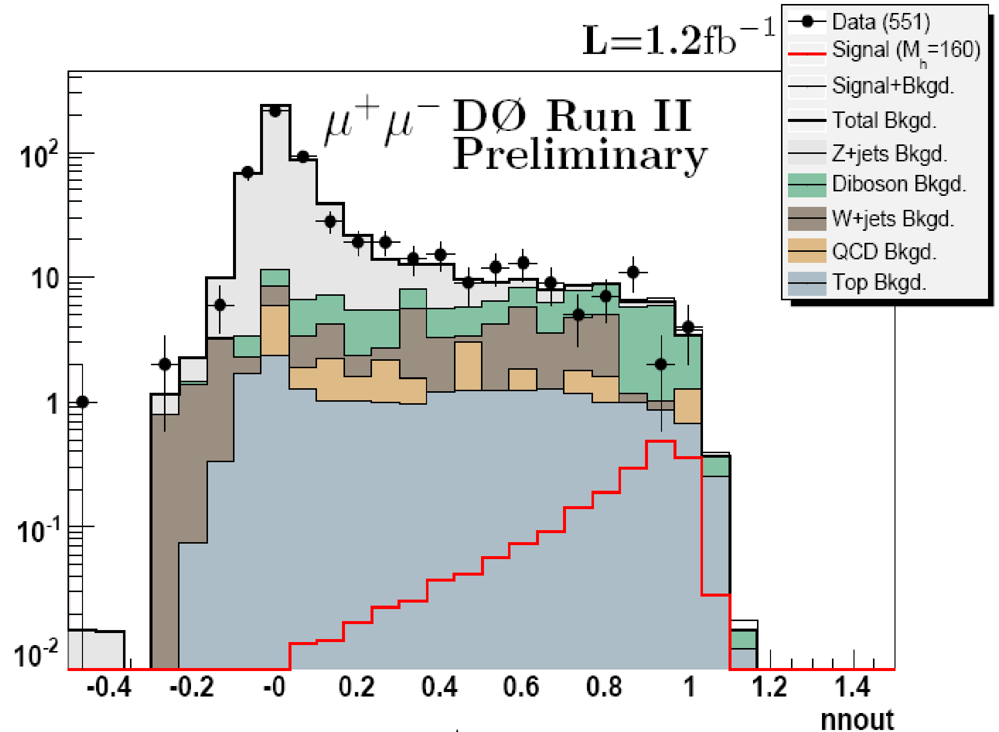
NEW!

H -> WW* -> l l (l=e,mu)

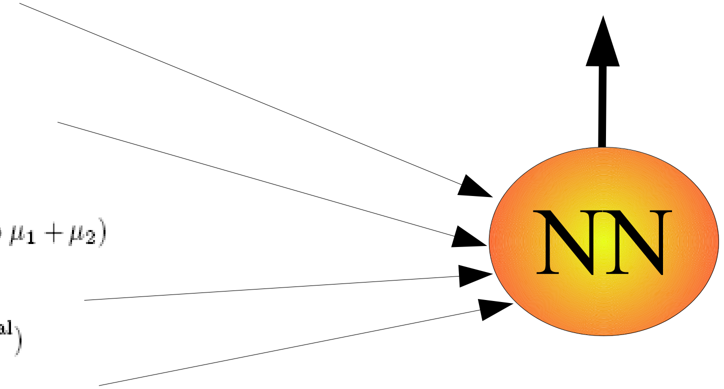
Now also using H->WW vs. WW ME calculation as input to NN

NN trained for each Higgs mass in 5 Gev steps, for each channel

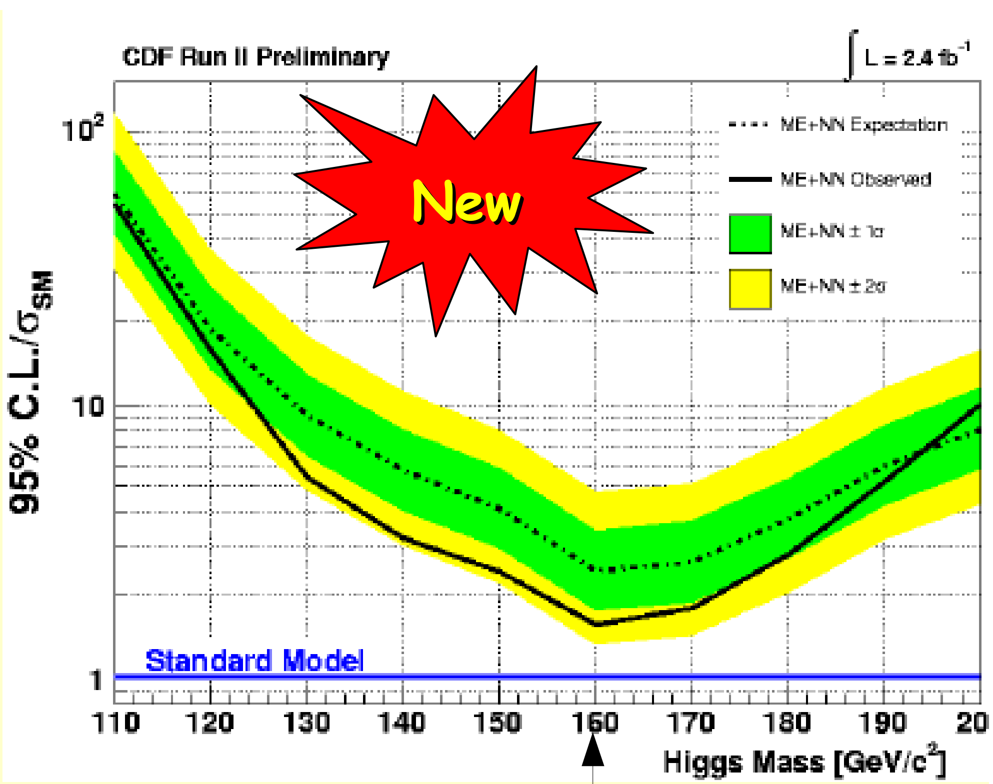
Full output used for setting limits

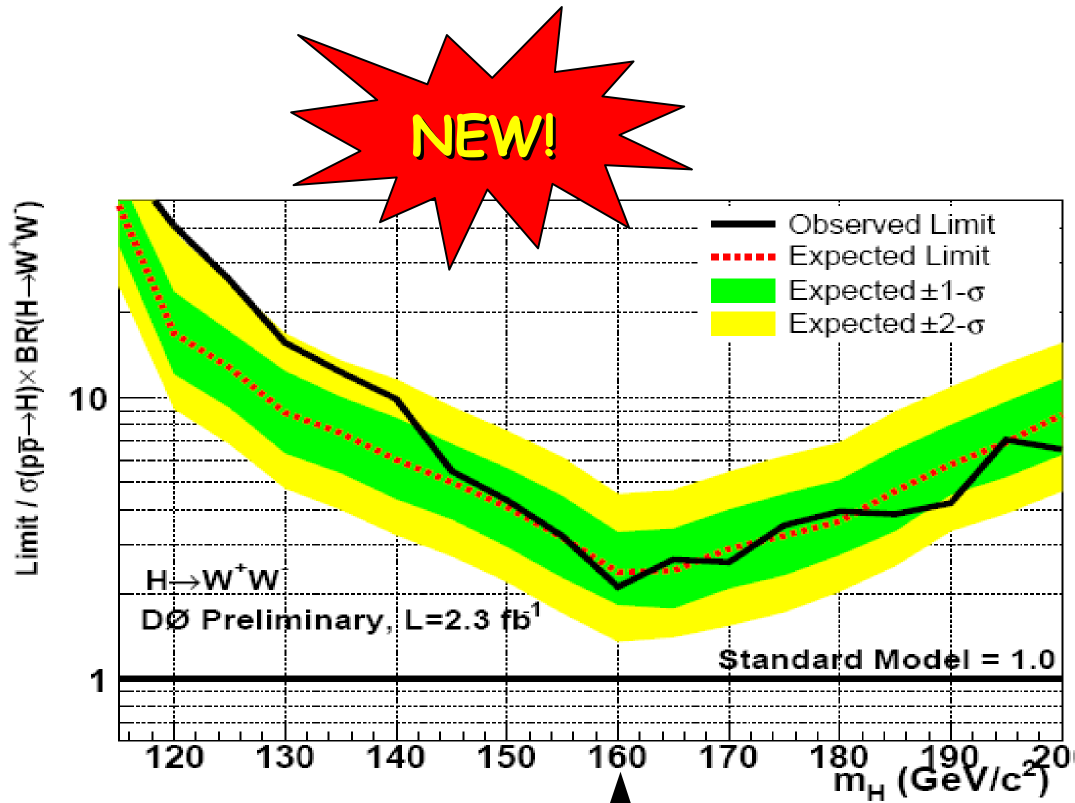


$\mu\mu$ NN Analysis Variables	
Scaled $\not\!\!E_T$	$\not\!\!E_T^{\text{Scaled}}$
Invariant mass of the two muons	$M_{\mu\mu}$
Missing E_T	$\not\!\!E_T$
Sum of the p_T's of all 0.5 cone jets with $p_T > 6$ GeV	H_T^{all}
$H \to WW$ vs. WW ME discriminant	ME_{disc}
p_T of the $\mu\mu$ system	$p_T(\mu_1 + \mu_2)$
Smaller of the two muon-$\not\!\!E_T$ transverse masses	M_T^{min}
p_T of the leading p_T muon	$p_T(\mu_1)$
Azimuthal angle between the $\not\!\!E_T$ and the second-leading p_T muon	$\Delta\phi(\mu_2, \not\!\!E_T)$
$\log_{10}$ of the sum of the muon scaled (track+cal) isolations	$\log_{10}(\text{scalediso } \mu_1 + \mu_2)$
Event scalar E_T	SE_T
Azimuthal angle between the two muons	$\Delta\phi(\mu_1, \mu_2)$
Worst of the two muon qualities (loose,medium,tight)	$\min(\mu_1^{\text{qual}}, \mu_2^{\text{qual}})$
Azimuthal angle between the $\not\!\!E_T$ and the leading p_T muon	$\Delta\phi(\mu_1, \not\!\!E_T)$
p_T of the second-leading p_T muon	$p_T(\mu_2)$



H -> WW* -> l l (l=e,mu)

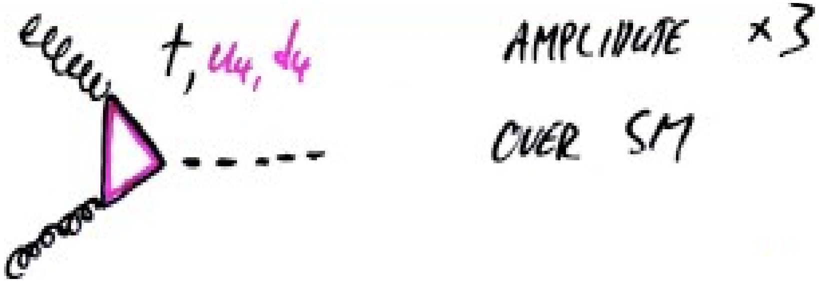




Observed Limit/σ_{SM} (NNLL) ~ 1.6
Expected Limit/σ_{SM} (NNLL) ~ 2.4

Observed Limit / SM ~ 2.1
Expected Limit / SM ~ 2.4

4th Generation

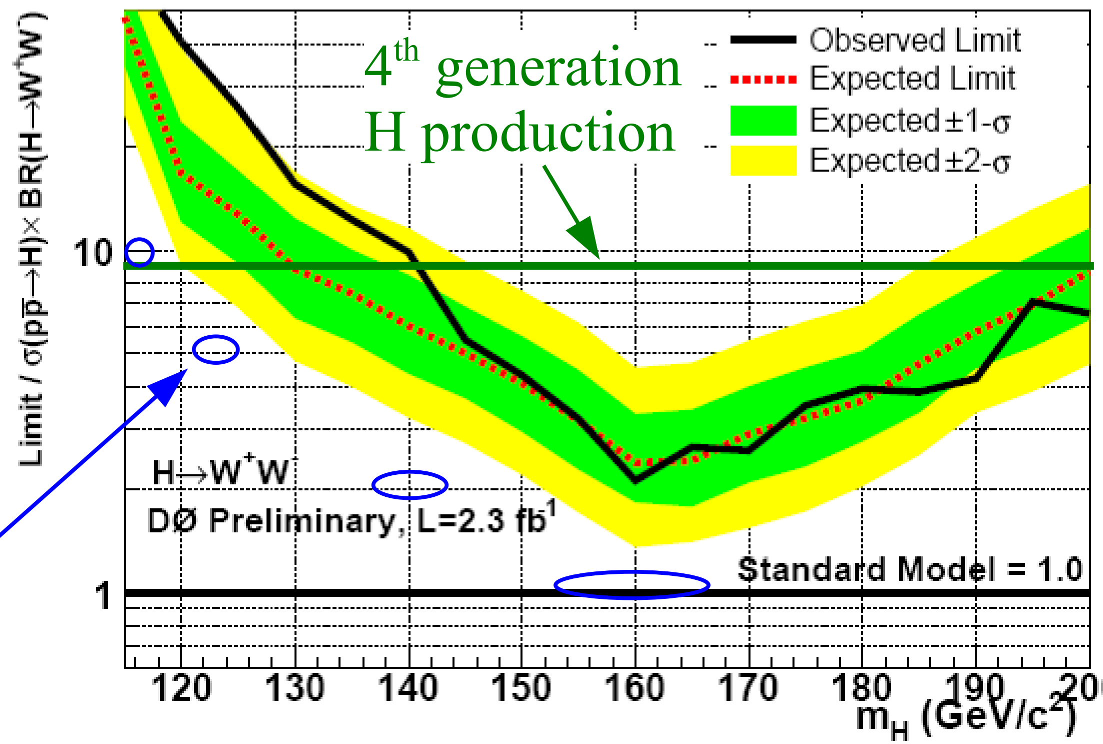


9x more gg->H production!

NEW!

DØ excluding from 140-200 GeV

Sensitive up to ~260 GeV by 2010



(Also will be sensitive to fermiophobic Higgs...)

WH -> W WW* -> l± l± +X (l=e,mu)

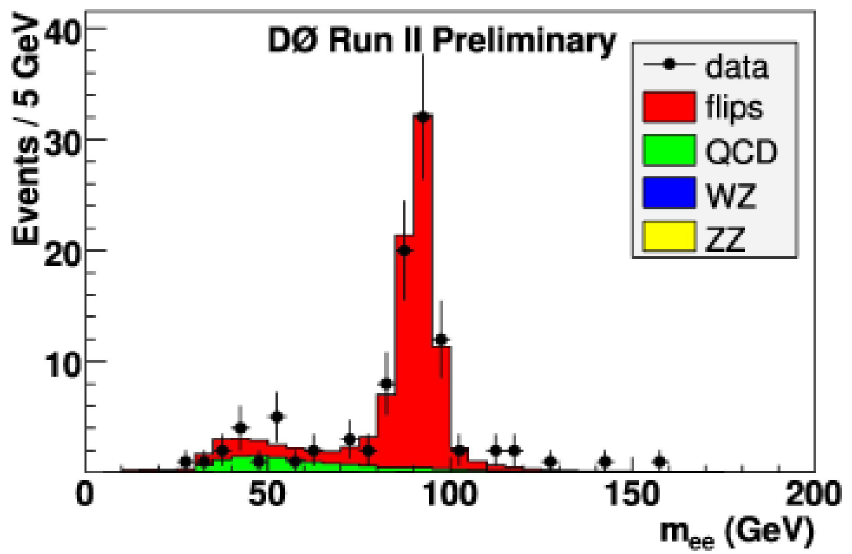
Basic selection requires two same charge leptons with p_T > 15 GeV

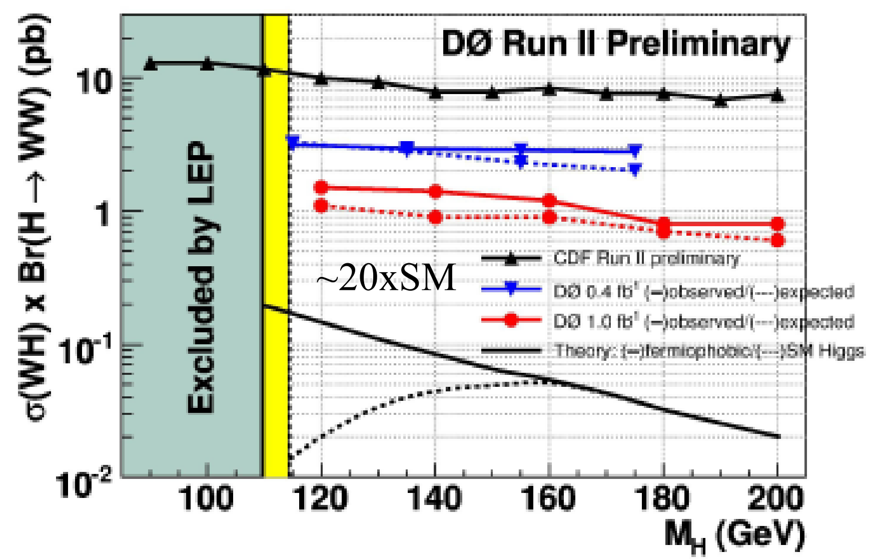
Two main types of backgrounds:

- With two real same charge leptons like WZ→lνll
- Instrumental – measured from data:
  - "QCD" with misidentified lepton
  - "flip charge" when charge of the lepton is mismeasured

Main source of systematic uncertainty is coming from instrumental background (~30%)

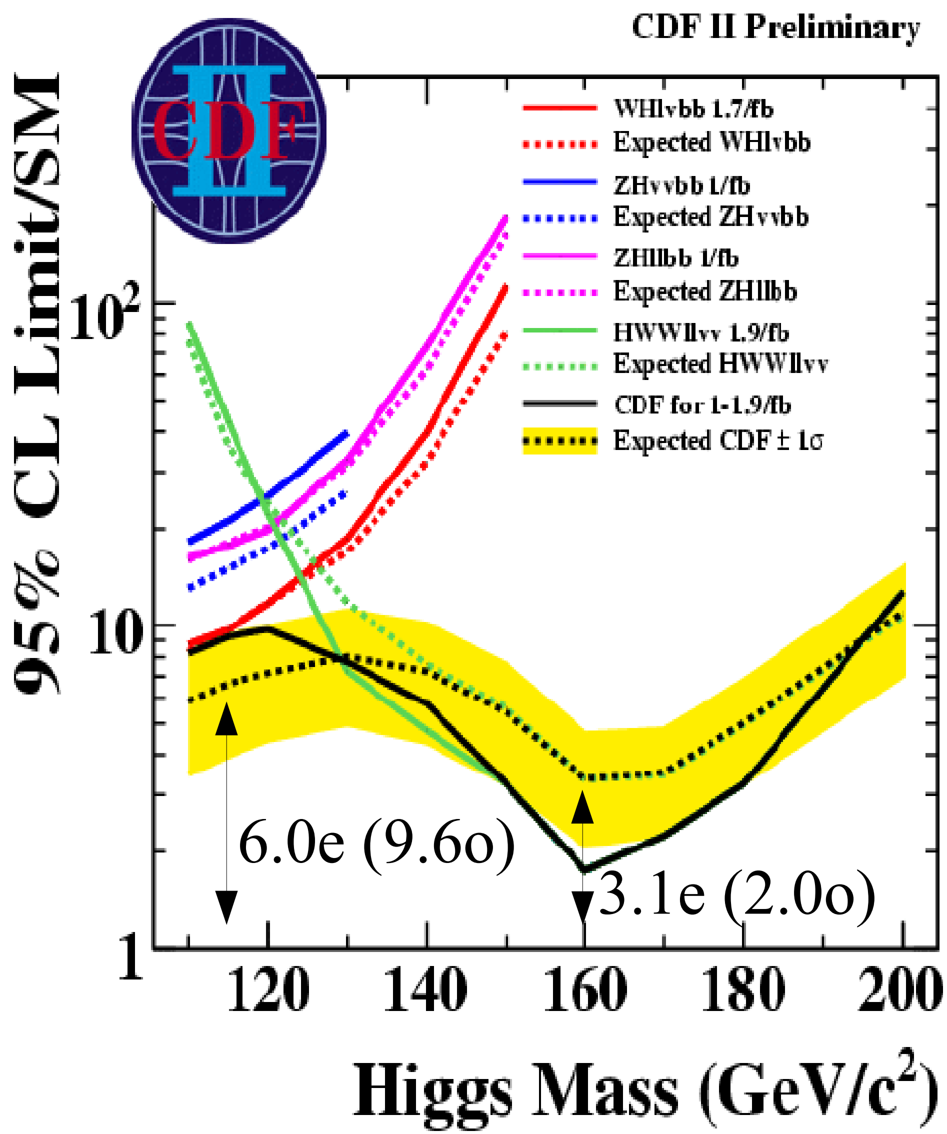
Limit: 0.9 pb at 95% CL for m_H=160 GeV





SM Higgs Combinations

NEW!

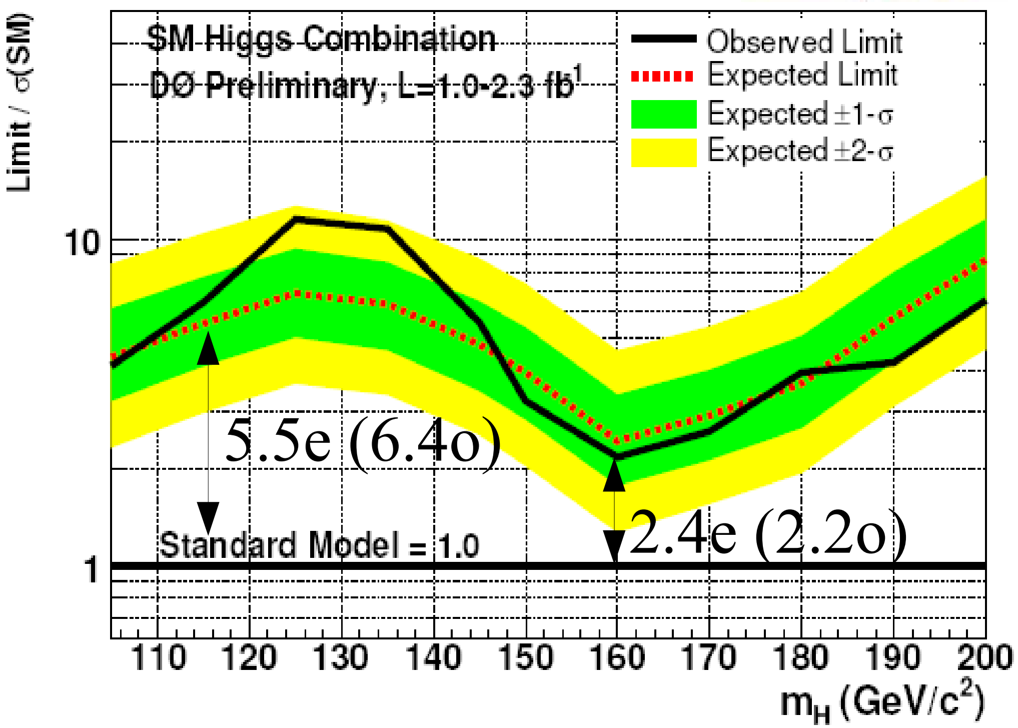


New things not in CDF combination yet:

WH -> lvbb: +200pb^{-1}, 1tag improvement, forward electrons

ZH -> vvbb: data driven QCD

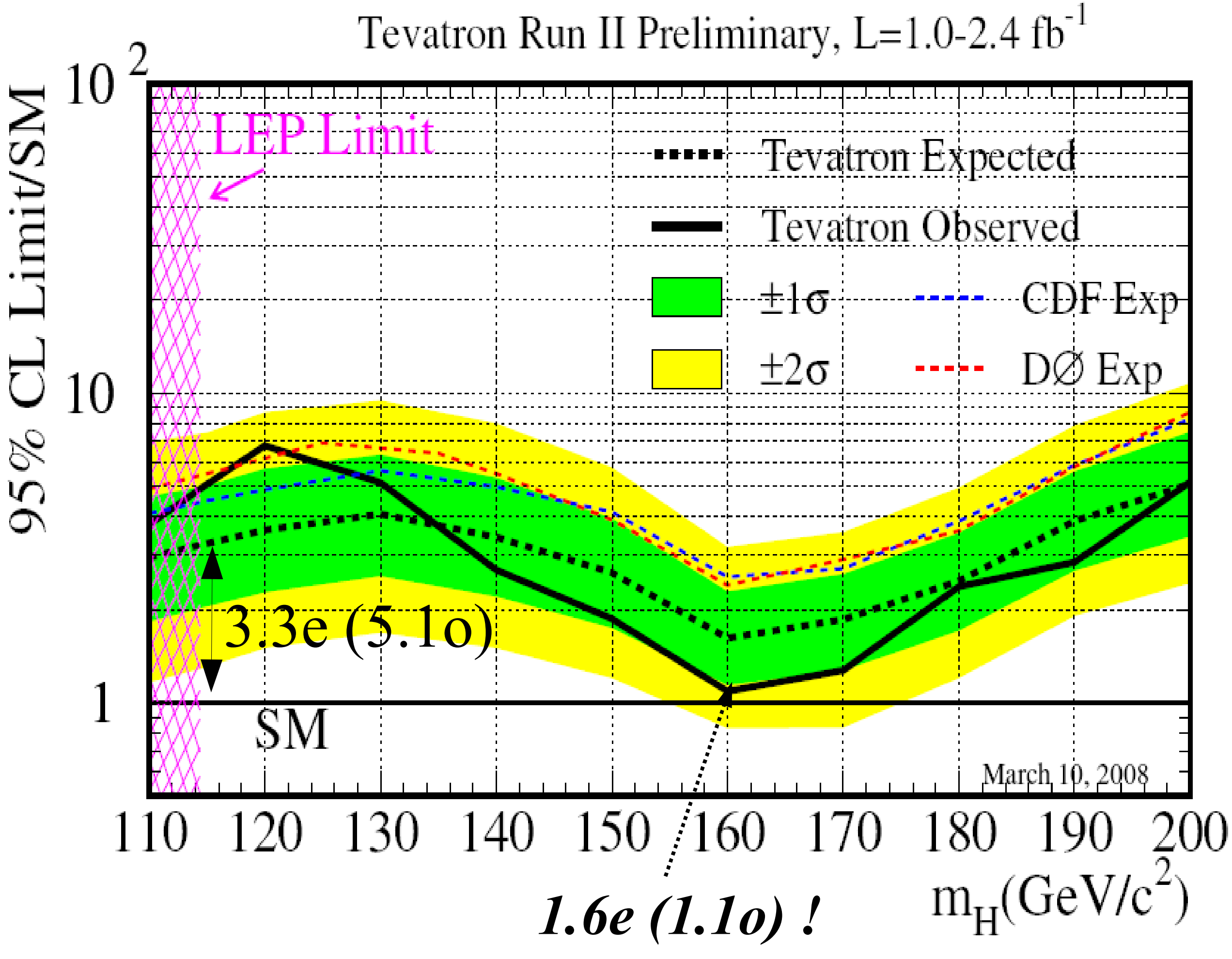
H -> ττ: 2.0fb^{-1}



D0/CDF SM Higgs Combination

Improvements underway:

- **Di-jet mass resolution**
- **Lepton efficiency**
- **Further improvements in analysis technique**
- **Better multivariate techniques**
- **Better b-tagging**

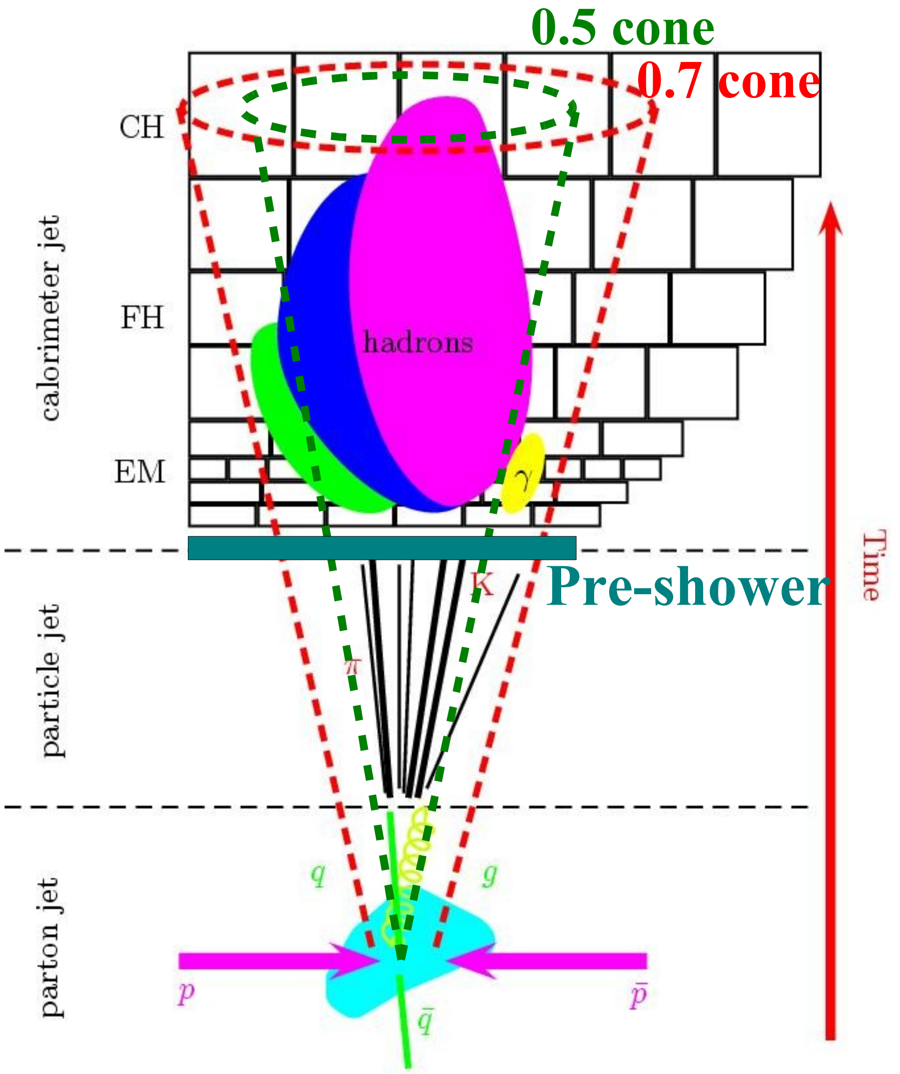


Di-jet Mass Resolution

Undertaking a major effort to improve jet energy resolution

- Add "pre-shower" energy
- Correct for jet "width"
- Track-based corrections
- (H1-style) cell energy weighting

- Multiple jet-cone sizes
  - 0.5 less sensitive to noise, pileup, overlap
  - 0.7 captures more jet energy
  - *Jet-by-jet showering / FSR correction*

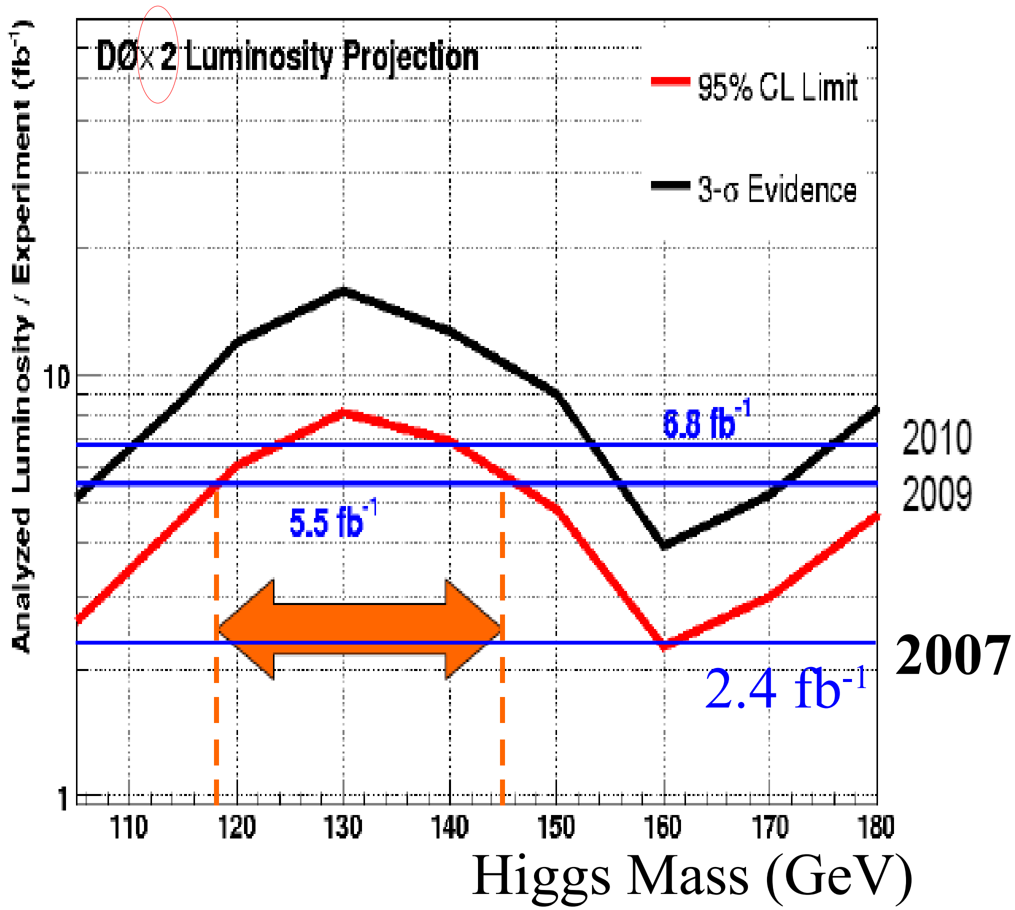


Sensitivity Estimates

Di-jet mass resolution (20%)
Lepton efficiency (10% / lepton)
Improved analyses (20%)
Matrix Element (20%)
Better b-tagging

- Semi-leptonic tagging (5%)
- Silicon Layer-0 (8%)

Should be sensitive to m_H=160 GeV ~now

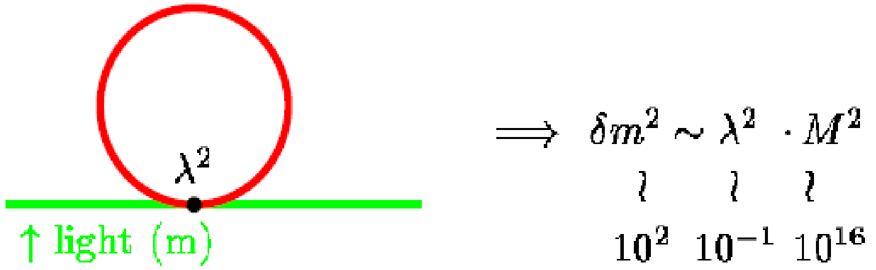


<u>Sensitive to SM Higgs up to 200 GeV by 2010</u>

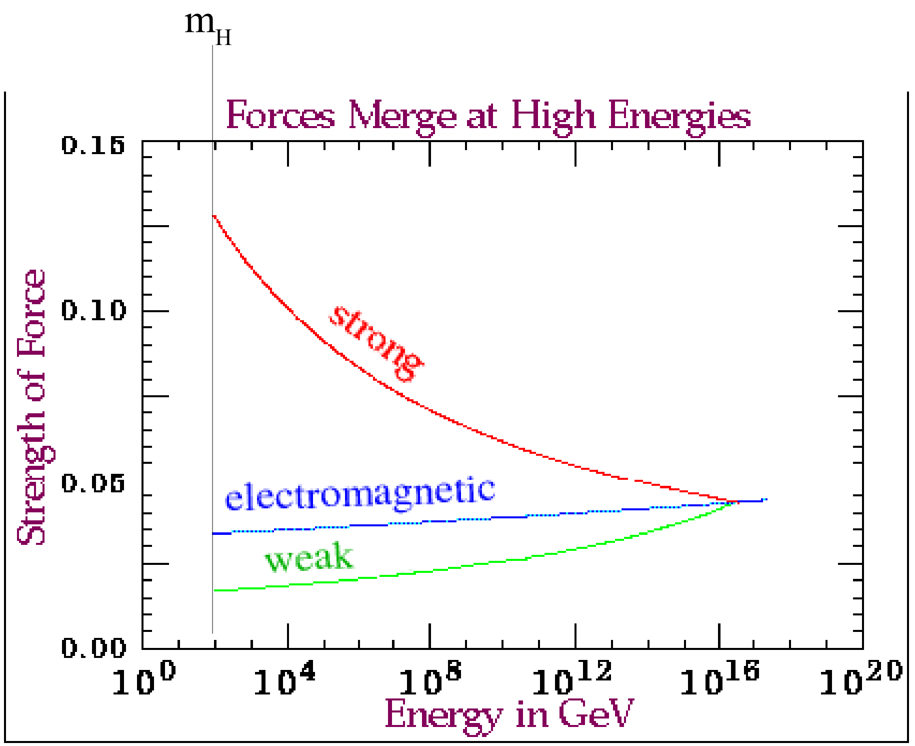
Why is the Higgs so Light?

The Higgs mass is *unstable*

- Large radiative corrections (it's a scalar)



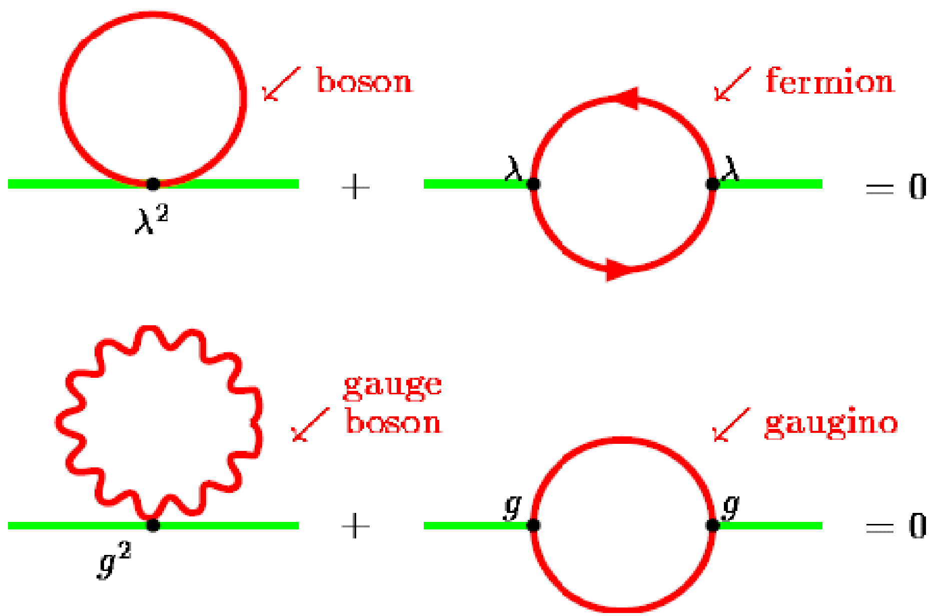
Hierarchy problem:
$m_H << m_{GUT}$



Why is the Higgs so Light?

New physics: Supersymmetry !

- Particles come in fermion-boson pairs
- Corrections to Higgs mass nearly cancel, if boson and fermion masses are similar



Higgs Bosons in the MSSM

Two Higgs doublet fields

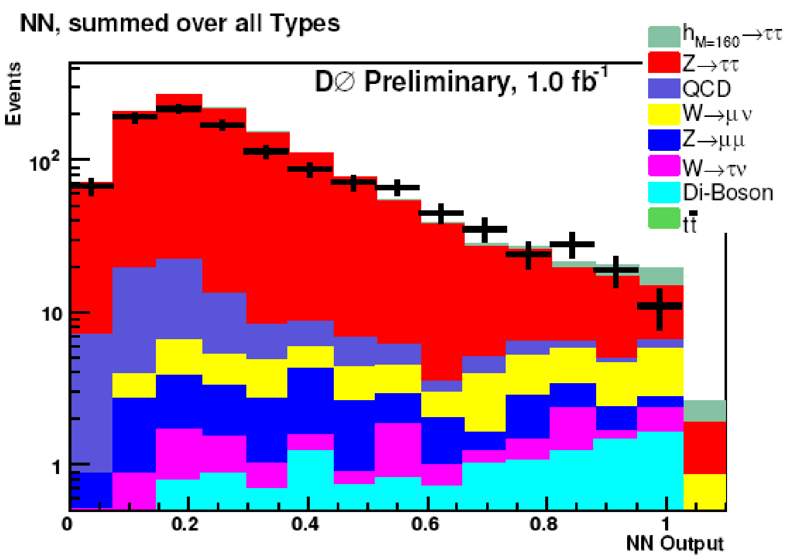
- $H_u(H_d)$ couple to up(down)-type fermions
- $\tan\beta = \langle H_u \rangle / \langle H_d \rangle$
- 5 particles after EWSB
  - h, H, A, H^+, H^-
- h must be light, <~135 GeV

At large $\tan\beta$, coupling of A, h/H to down-type fermions (b, τ) is enhanced

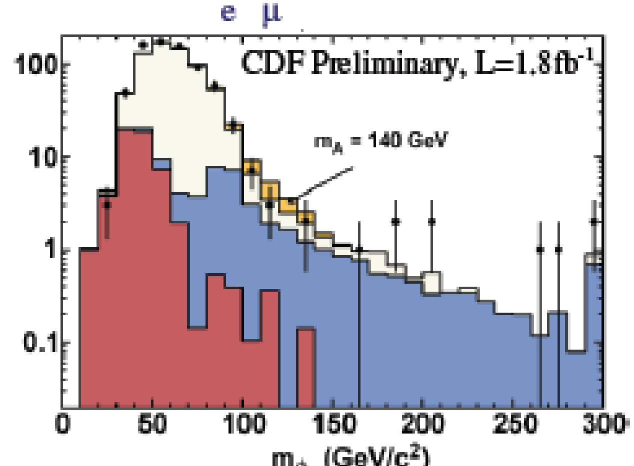
- *Cross-section proportional to $\tan^2\beta$*
- Branching ratio: bb~90%, $\tau\tau$~10%

Neutral MSSM Higgs $\rightarrow \tau_l \tau_{had}$

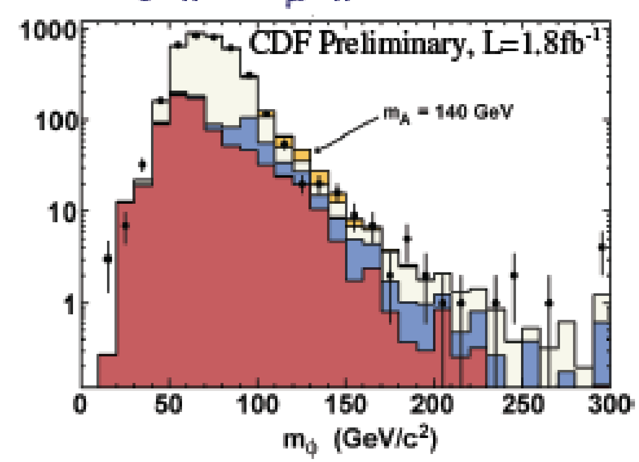
- Main backgrounds: Z→ττ (irreducible), W+jets, Z →ee,μμ, multijet, di-boson
- DØ (μ channel only): Selection:
  - only one isolated μ separated from the hadronic τ with opposite sign
  - set of NNs to discriminate τ from jets
  - cut on M_W(visible) < 20 GeV removes most of the remaining W boson backgr.
- Optimized NNs to separate signal from background
- CDF (e, μ, e+μ channels): Selection:
  - isolated e or μ separated from the hadronic τ with opposite sign
  - variable-size cone algorithm for τ discrimination
  - jet background suppressed by requiring: $|p_t^l| + |p_t^{had}| + |\not{E}_T| > 55$ GeV
  - remove most of the W background by a requirement on the relative directions of the visible τ decay products and $\not{E}_T$



$\tau_e \tau_\mu$ channel



$\tau_e \tau_h + \tau_\mu \tau_h$ channels



b(h/H,A)→bbb

(h/H,A)→bb swamped by QCD background

- Look for *associated* b production

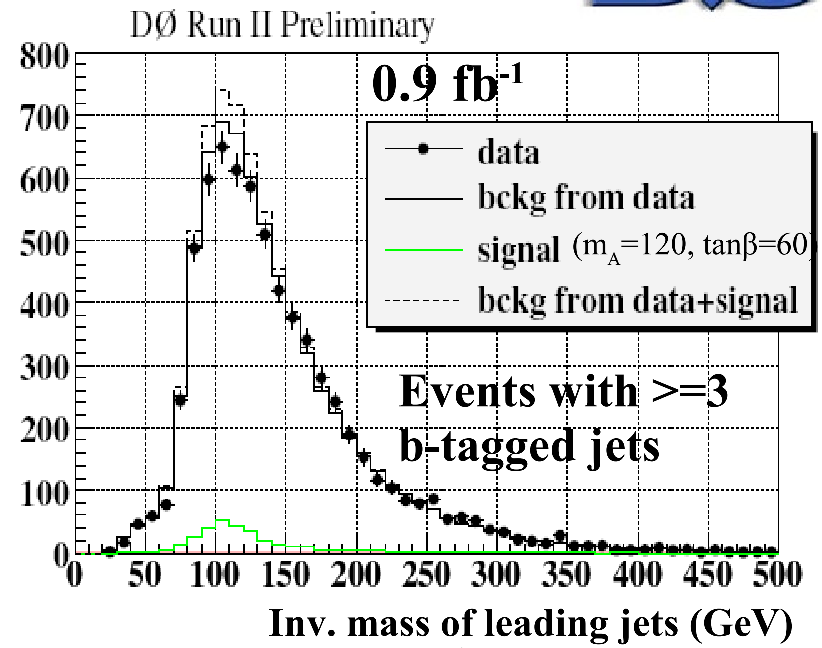
Require at least 3 *b-tagged* jets

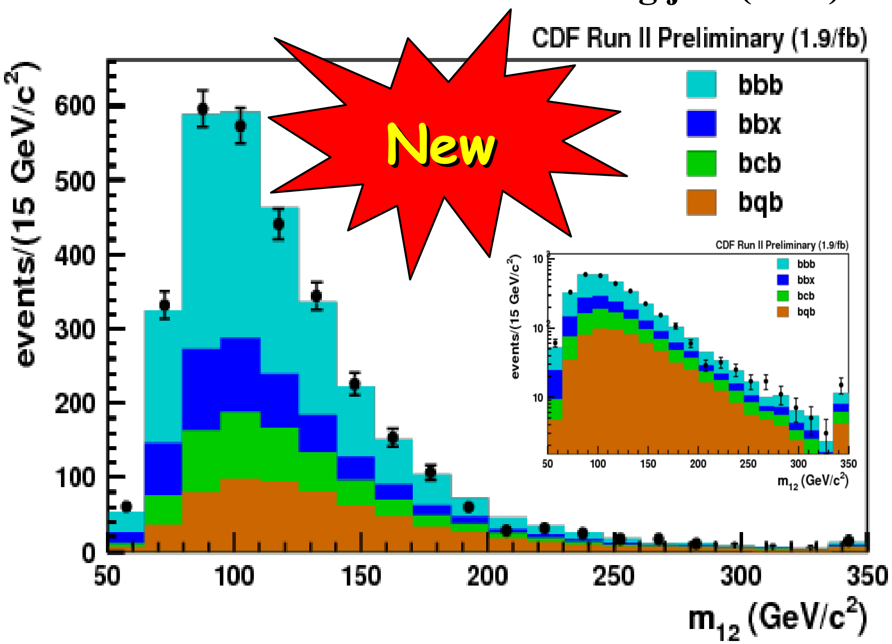
Signal:

- Invariant mass of leading jets is peaked at m_A

Backgrounds (determined from data):

- Shape based on the *double* b-tagged data sample
- Corrected for kinematic bias from the 3rd b-tag

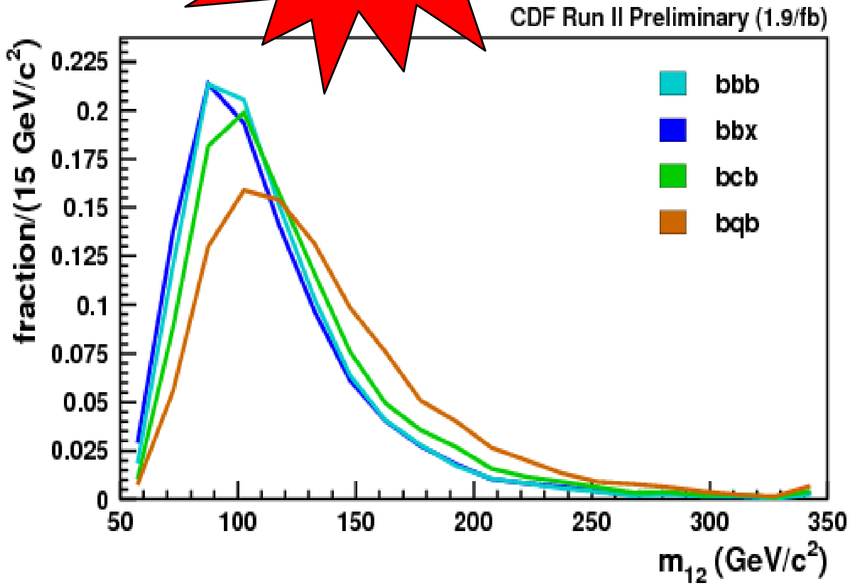


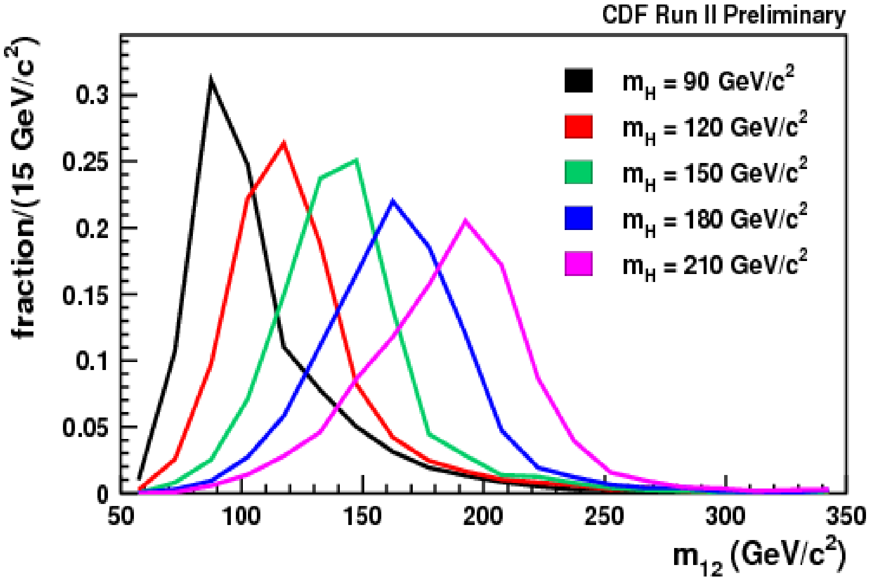


b(h/H,A)→bbb

New

- New result for Moriond QCD 08, using 1.9 fb^{-1}
- Search in mass of two lead jets, m_{12}
- Backgrounds are events with two true b-tags, and a b/c/fake tag
- Characteristic m_{12} spectra for each
- Start from bb+jet sample (corrected double-tags), weight events by flavor hypothesis
- Correct bbb and bcb shapes for double/triple-tag selection bias
  - Largest systematic error
- Fit the observed m_{12} spectrum with the backgrounds and a Higgs shape





b(h/H,A)→bττ

344 pb^{-1} *(update in progress!)*

Best S/B of all three MSSM analyses, but lowest cross-section x BR

Select ττ(→μ) events, normalize to Z→ττ peak
Require >=1 *b-tagged* jet, with p_T>15 GeV

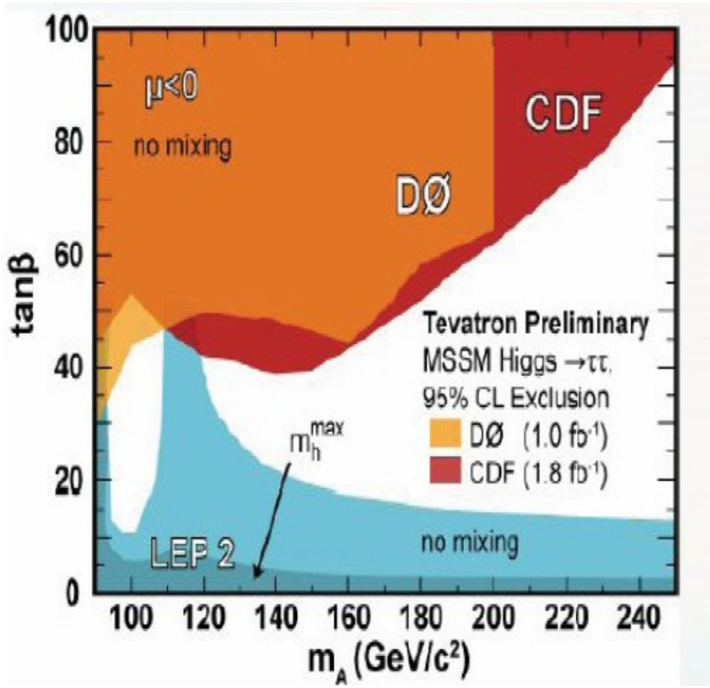
Multijet (QCD) background measured using like-sign data

(for M_H = 120 GeV and tanβ = 80)

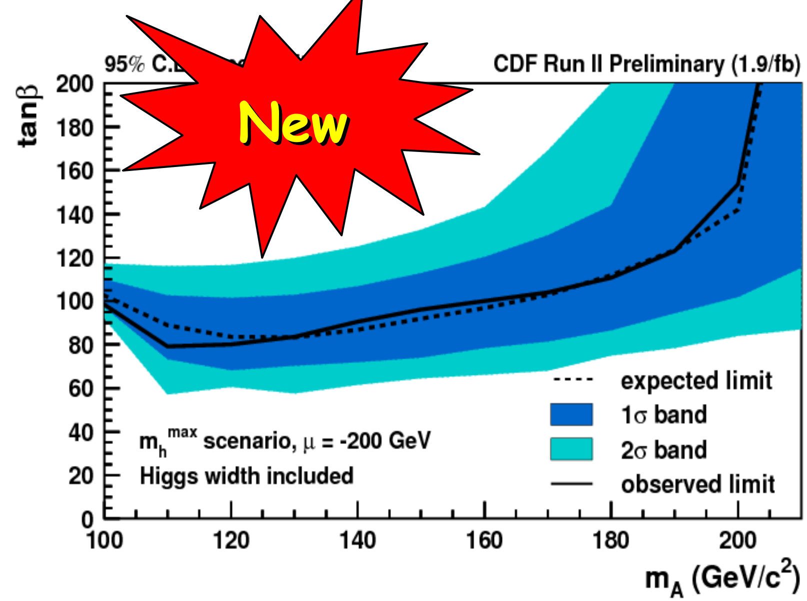
	single-π-like τ	rho-like τ	3-prong τ
Signal Accept. (%)	0.15 ± 0.03	0.87 ± 0.11	0.30 ± 0.04
Expected Signal	0.6 ± 0.1	3.5 ± 0.5	1.2 ± 0.2
QCD	0.62 ± 0.22	0.51 ± 0.14	1.45 ± 0.18
Z+jet	0.34 ± 0.09	1.6 ± 0.3	0.35 ± 0.10
$t\bar{t}$ (di-l)	0.18 ± 0.03	0.50 ± 0.11	0.007 ± 0.0013
$t\bar{t}$ (l+jet)	0	0.008 ± 0.008	0.15 ± 0.04
W+jj	0.005 ± 0.005	0.05 ± 0.02	0.40 ± 0.14
Total Background	1.2 ± 0.2	2.6 ± 0.3	2.5 ± 0.2
Observed	0	1	2

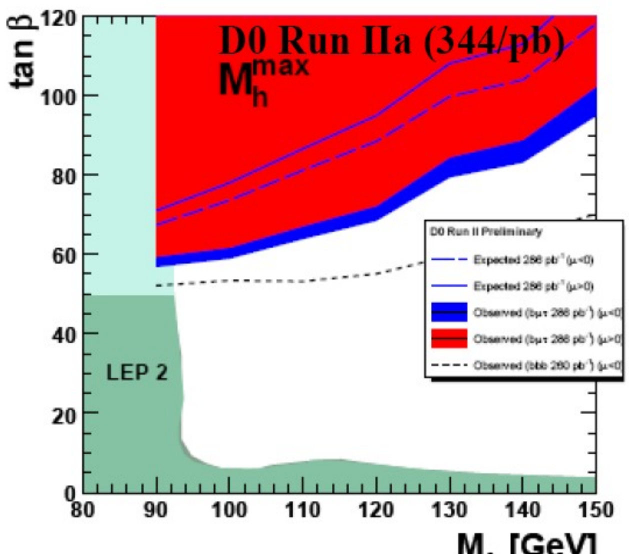
MSSM Higgs Limits

H→ττ



bH→bbb





bH→bττ

New D0 result soon!

MSSM Prospects

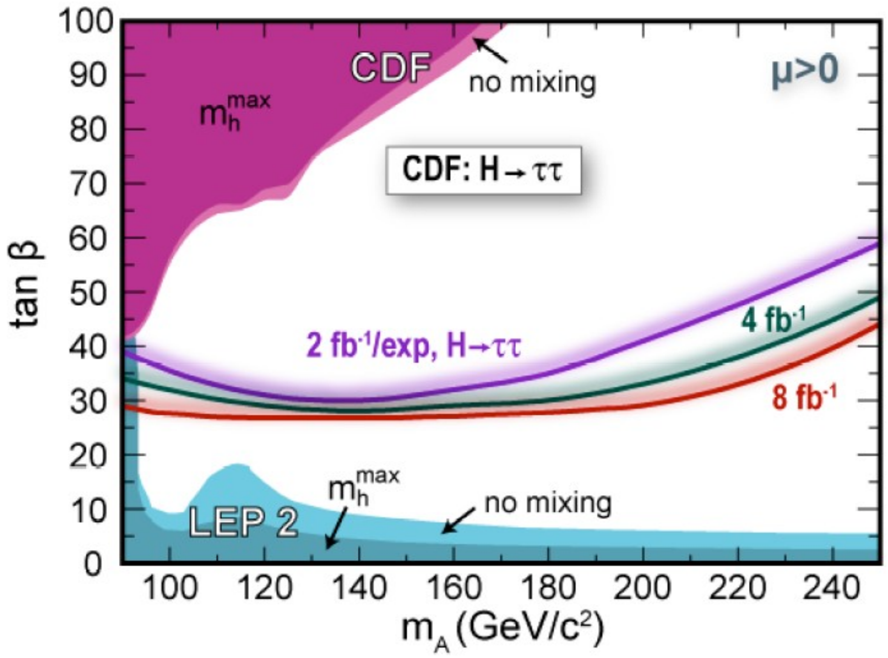
Results from the first 1-2/fb of data show very promising sensitivity

By 2010...

Exclude

- up to m_A~300 GeV for high tanβ
- down to tanβ~30 for low m_A

Or make a discovery!



New results on H^+ coming soon!

Other Higgs Searches

Showing results 1 through 47 (of 47 total) for ti:(Higgs AND Decay) and year 2008

4. arXiv:0801.4554 [ps, pdf, other]
Title: **Nonstandard Higgs Boson Decays**

5. arXiv:0801.3456 [ps, pdf, other]
Title: **Higgs boson decays to four fermions through an abelian hidden sector**

13. arXiv:0711.3361 [ps, pdf, other]
Title: **Higgs Boson Decays into Single Photon plus Unparticle**

18. arXiv:0710.5331 [ps, pdf, other]
Title: **Higgs boson decays in the Complex MSSM**

19. arXiv:0710.4923 [ps, pdf, other]
Title: **Di-photon Higgs Decay in SUSY with CP Violation**

21. arXiv:0710.4591 [ps, pdf, other]
Title: **Nonstandard Higgs Decays with Visible and Missing Energy**

24. arXiv:0710.0340 [ps, pdf, other]
Title: **Di-photon Higgs decay in the MSSM with explicit CP violation**

31. arXiv:0708.1939 [ps, pdf, other]
Title: **Effect of Charged Scalar Loops on Photonic Decays of a Fermiophobic Higgs**

34. arXiv:0708.0248 [ps, pdf, other]
Title: **Higgs decays in supersymmetric models with light neutralinos**

36. arXiv:0707.3152 [ps, pdf, other]
Title: **New Physics Effects in Higgs Decay to Tau Leptons**

37. arXiv:0707.1591 [ps, pdf, other]
Title: **Invisibly decaying Higgs boson in the Littlest Higgs model with T-parity**

39. arXiv:0706.1732 [ps, pdf, other]
Title: GeV Seesaw, Accidentally Small Neutrino Masses, and **Higgs Decays to Neutrinos**

Other Higgs Searches

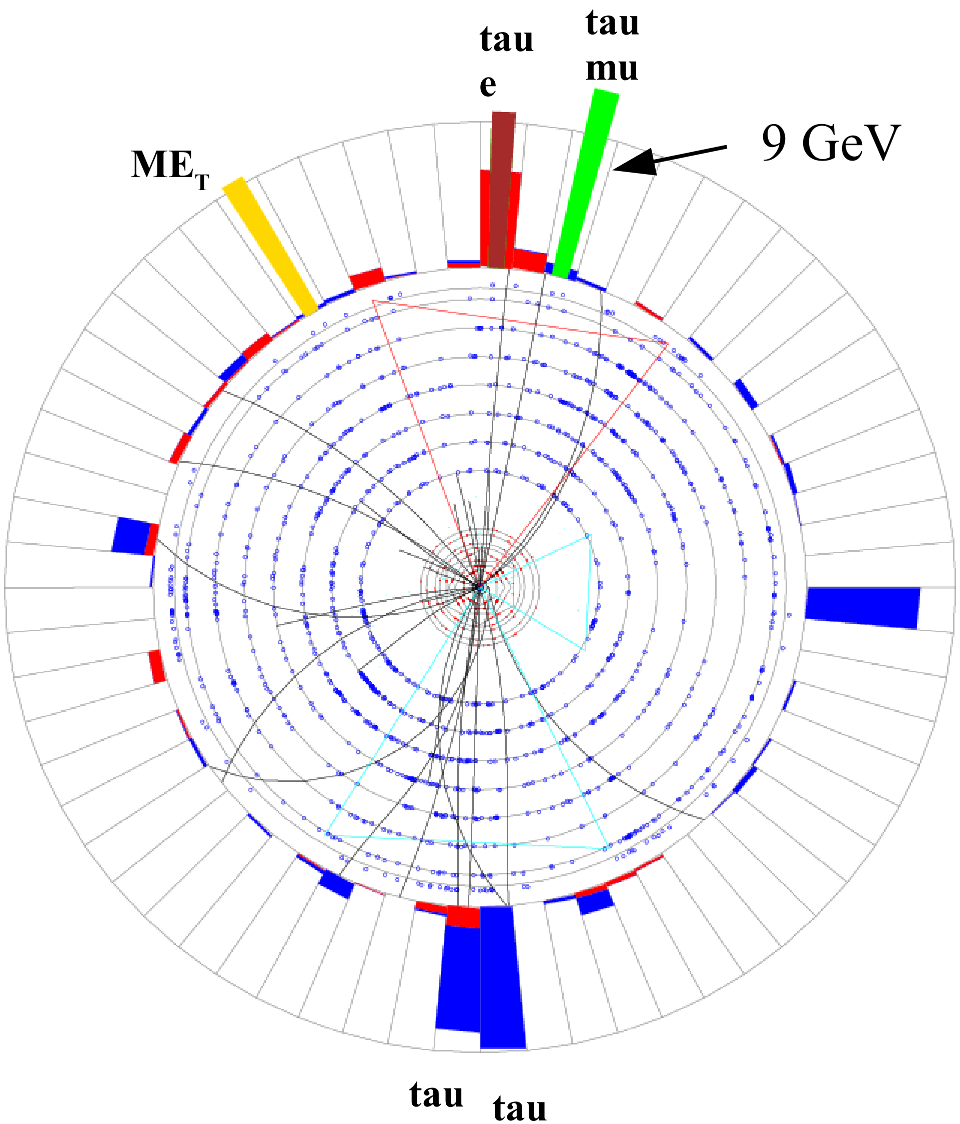
No shortage of new models!

Cover some general signatures we are sensitive to:

- Doubly charged Higgs
- Enhanced decays to photons

Others are harder, but on the way:

- Invisible Higgs
- CP-violating Higgs
- Higgs->aa->4τ
- …

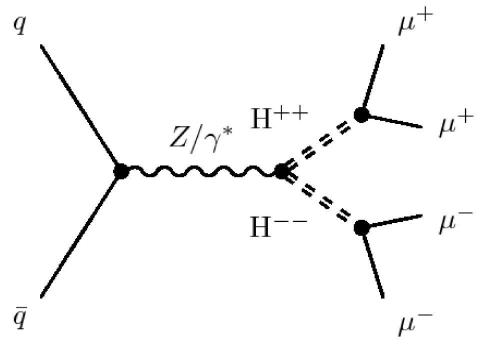


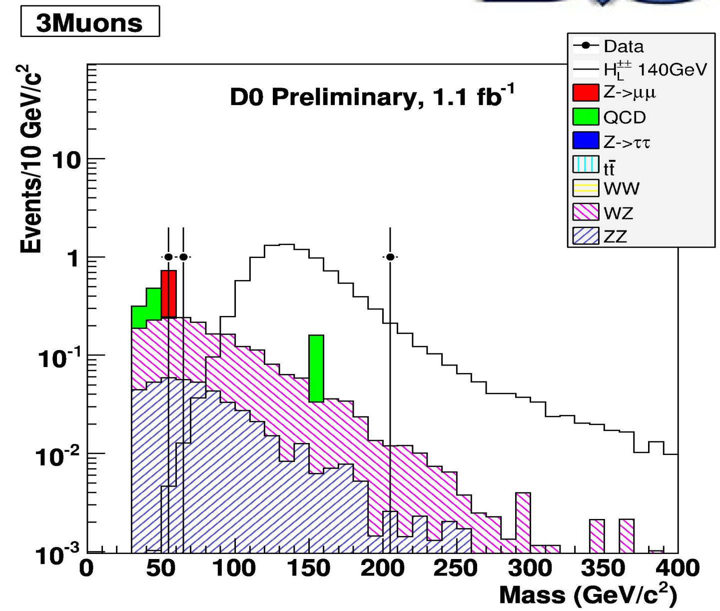
H++

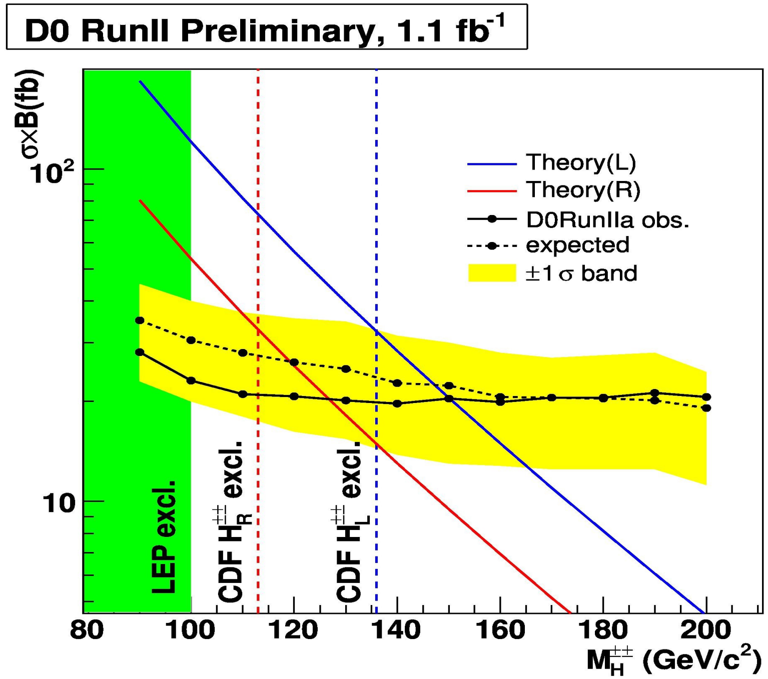
Models with H++
- Left-right symmetric models
- Higgs triplet
- Little Higgs

Analysis Overview
- 1.1 fb^{-1}
- 3 μ's with:
  P_T>15 GeV
  |η|<2.0
- >=1 μμ pair with:
  M>30 GeV/c^2;
  Δφ<2.5 rad

Results
- Background: 3.1±0.5
- Data: 3 events







Result:
H_R > 127 GeV
H_L > 150 GeV

H→γγ

Could be large H→γγ BR: "fermiophobic"

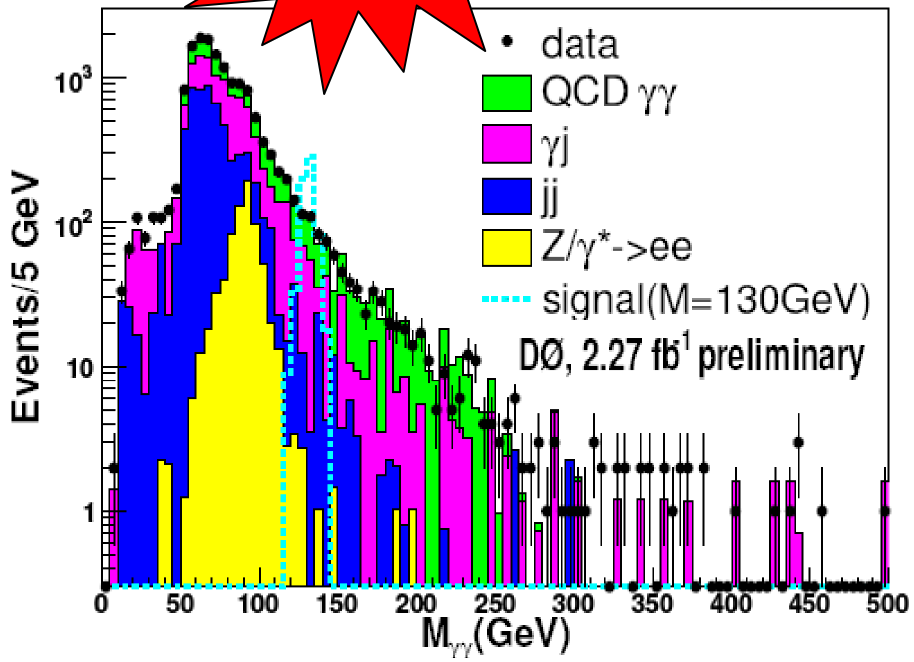
- Top-color models
- LED theories
- MSSM: H→bb suppressed by 1-loop corrections

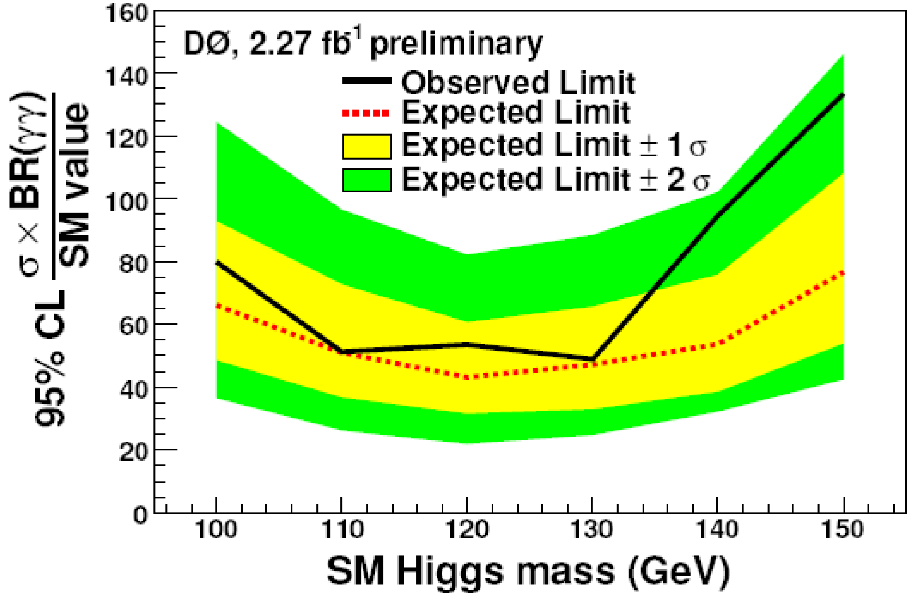
Select 2 isolated photons, E_T>25 GeV

QCD jet fakes estimated using the shower-shape correlations between the 2 photons ("matrix method")

Also contributes to SM Higgs search!

data	13827
$Z/\gamma* \rightarrow ee$	740.9 ± 102.3
jet+jet	4778.6 ± 1264.6
γ+jet	4677.2 ± 1245.8
QCD $\gamma\gamma$	3400.5 ± 711.0
total background	13597.2 ± 2548.5





Conclusions

The Tevatron is closing in on the SM Higgs

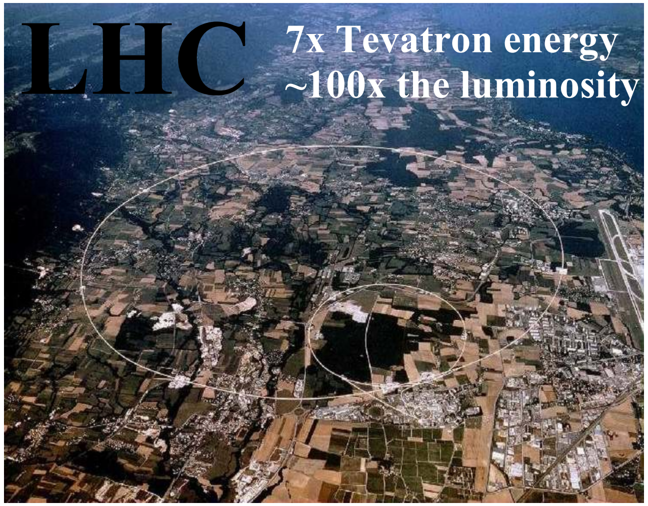
- **Sensitive at 160 GeV *this summer***
- **Sensitive to SM Higgs up to 200 GeV by 2010**

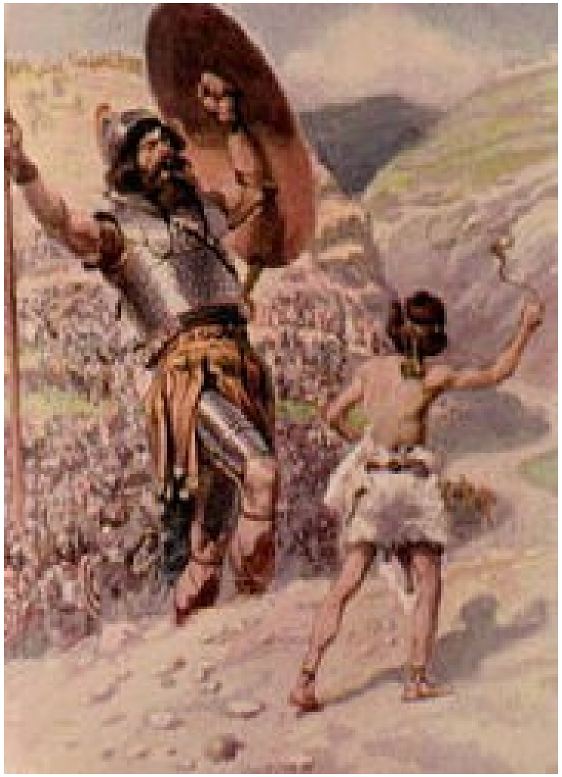
Also looking for Higgs in the MSSM and other plausible models

- **Already exploring new parameter space**

The LHC starts this year (?!)

- **SM Higgs boson by ~2011?**





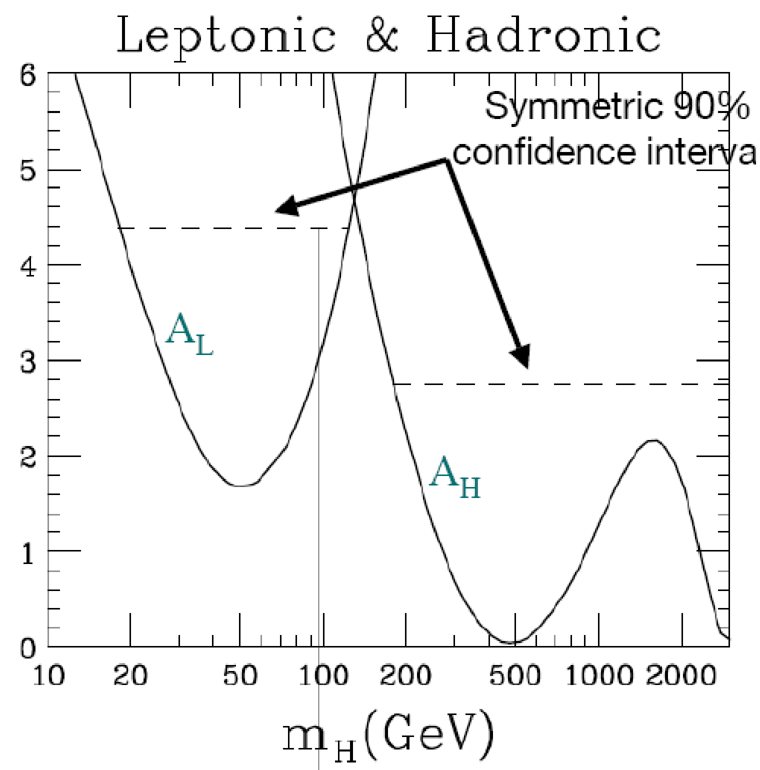
Backup

Precision EW Constraints

EW variables sensitive to m_H via radiative corrections:

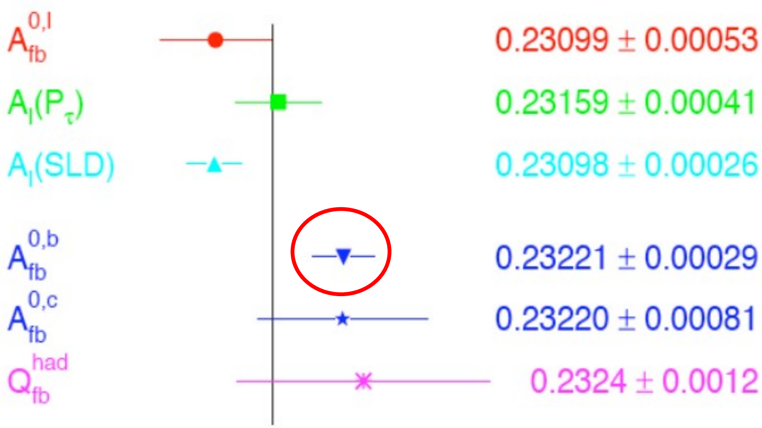
$$\log \frac{m_H}{m_Z}$$

LEP II: $m_H > 114.4$ GeV



$m_H < 97$ GeV
(at 95% CL)
(leptonic only)

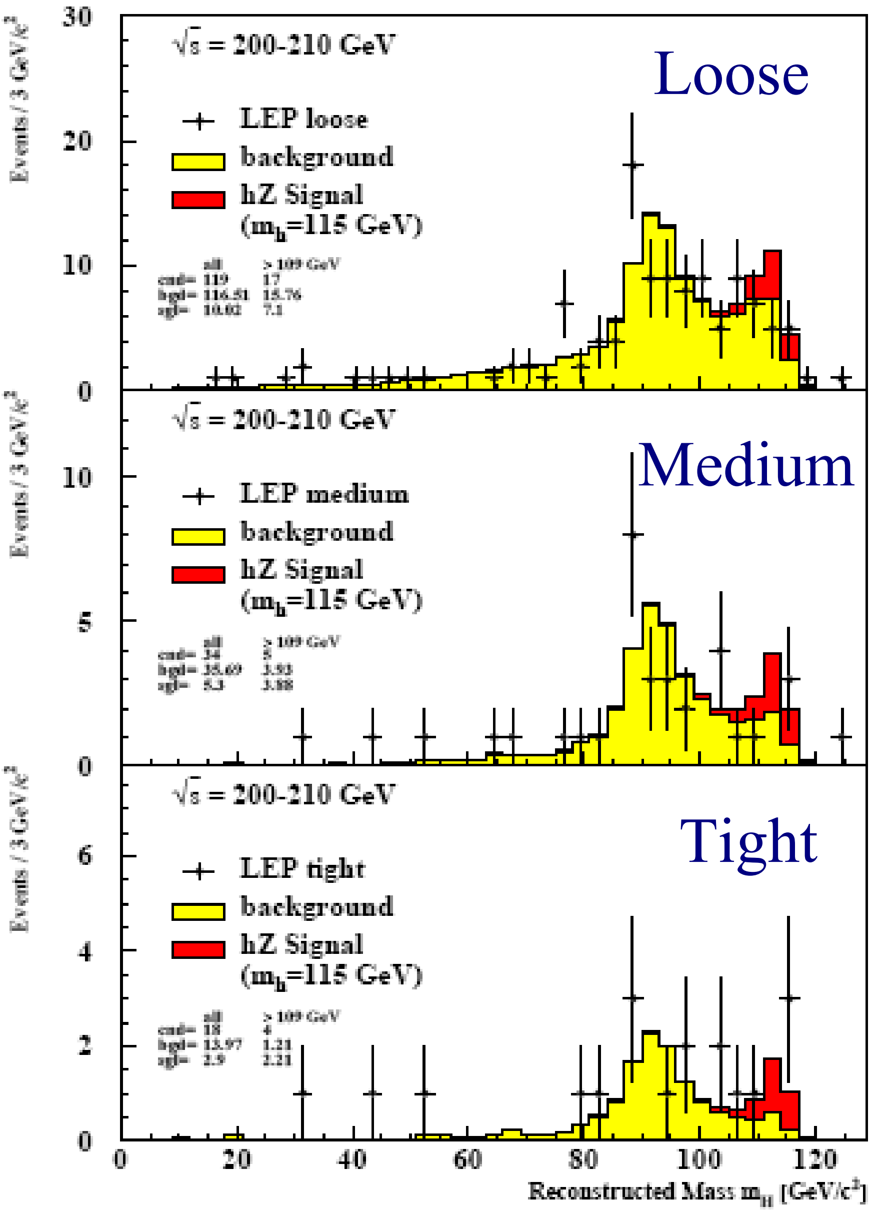
$\sin^2\theta_{eff}^{lept}$: **most important observable for m_H fit**



LEP @ CERN in 2000

Circular e$^+$ e$^-$ collider
Maximum E of 200-210 GeV

A good, but not the only variable...



Look for e$^+$ e$^-$ -> Z+H(->bb)
Slight excess around 115 GeV
Higgs mass > 114.4 GeV

Limit Setting

- In the absence of signal, we set limits on Standard Model Higgs boson production
  - We calculate limits via the CLs prescription:

$$CL_s = \frac{CL_{s+b}}{CL_b}$$

  - Using a Log-Likelihood Ratio test statistic:

$$Q(\vec{s},\vec{b},\vec{d}) = \prod_{i=0}^{N_{Chan}} \prod_{j=0}^{N_{bins}} \frac{(s+b)_{ij}^{d_{ij}} e^{(s+b)_{ij}}}{d_{ij}!} \Big/ \frac{b_{ij}^{d_{ij}} e^{b_{ij}}}{d_{ij}!} \qquad LLR = -2 \times LogQ$$

d_{ij} refers to "data" for model being tested: **Observed events, or expected Background or Signal+Background**

- Distributions of simulated outcomes are populated via Poisson trial with mean values given by B-only or S+B hypotheses
  - Systematics are folded in via Gaussian marginalization
  - Correlations held amongst signals and backgrounds

6

Systematic Uncertainties

Luminosity, 6.1%

Lepton ID, 2%

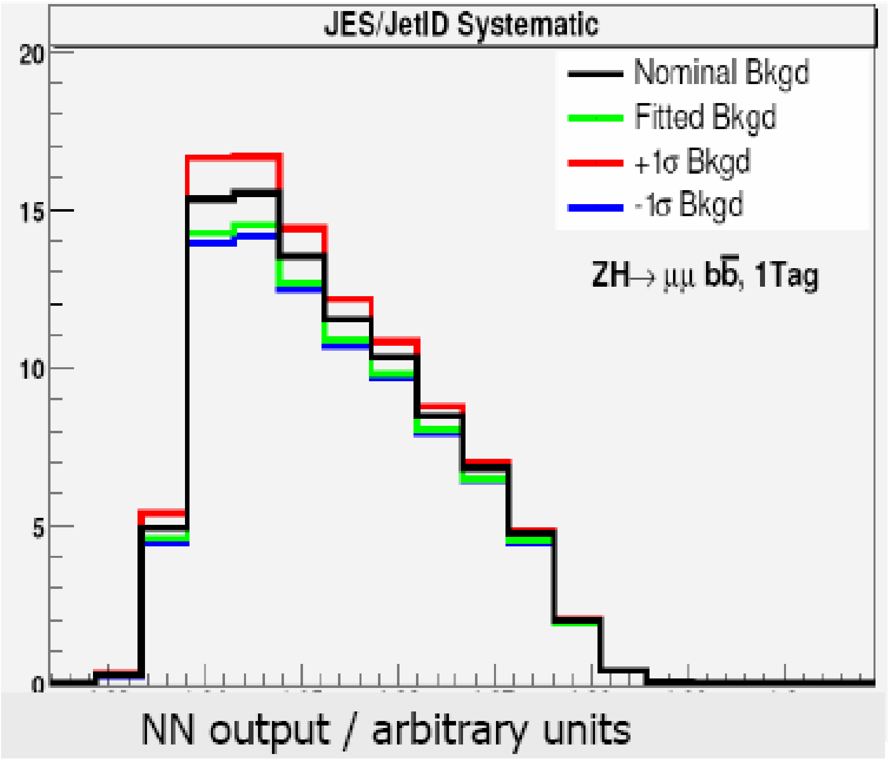
Background cross-sections, 5-30%

QCD estimation, 20%

Jet-energy scale*

b-tagging*

**Affects shape of NN output as well as normalization*

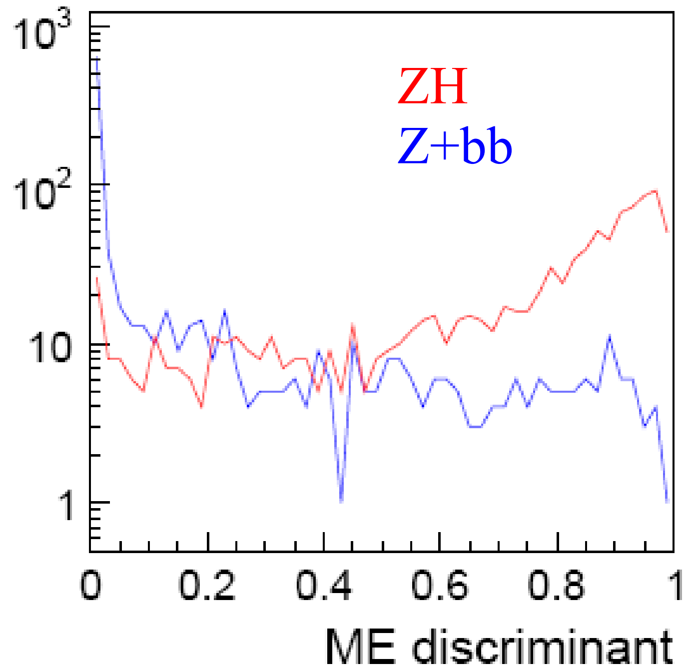


Matrix Elements

Calculate "cross-section" for an observed event to be from Z+bb or Z+(H->bb)

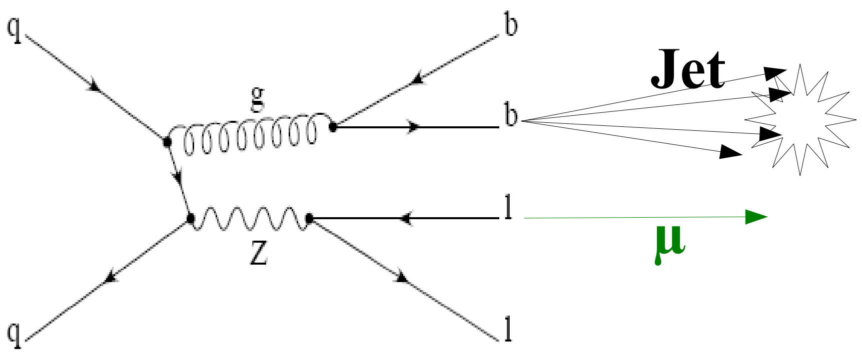
Use MC integration methods

Include as inputs to NN



$$p(m) = \int dx\ f_\Phi \cdot \sum_{a,b} f_a f_b \left|M_{ab}(k(m,x))\right|^2 \cdot T(k(m,x),m)$$

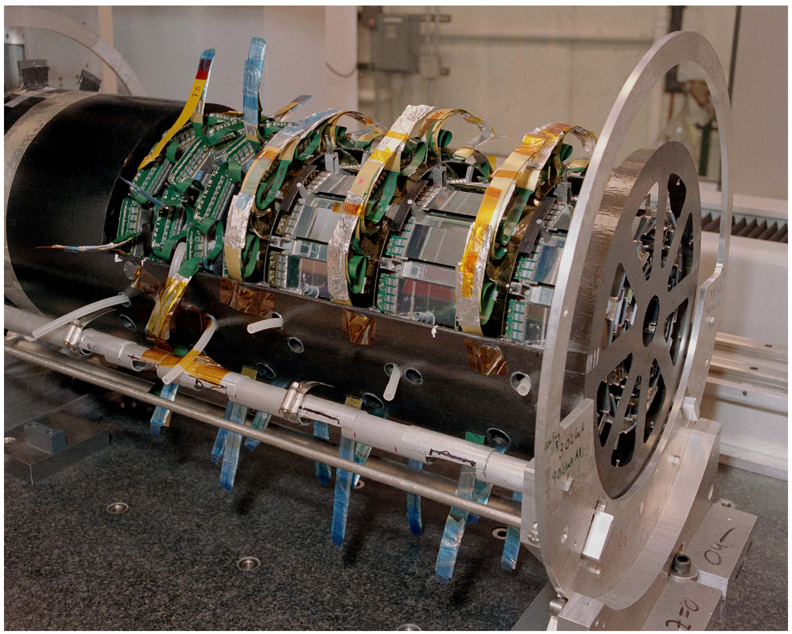
- m: detector measurement of event.
- x: integration parameters
- $k(x,m)$: parton solution given m and x.
- f_Φ: phase-space factors.
- $f_a f_b$: PDFs from MCFM.
- M_{ab}: matrix element from MCFM.
- T: transfer functions

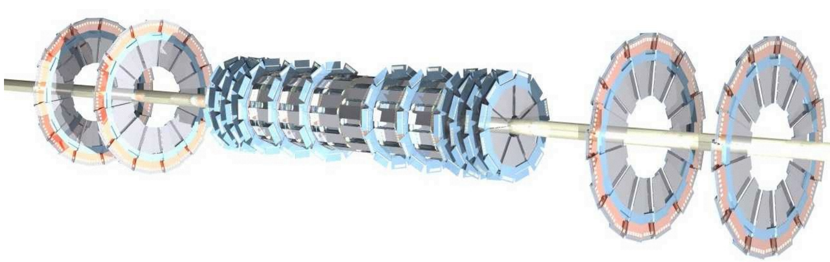


MET = μ1+μ2+j1+j2+σ(MET)

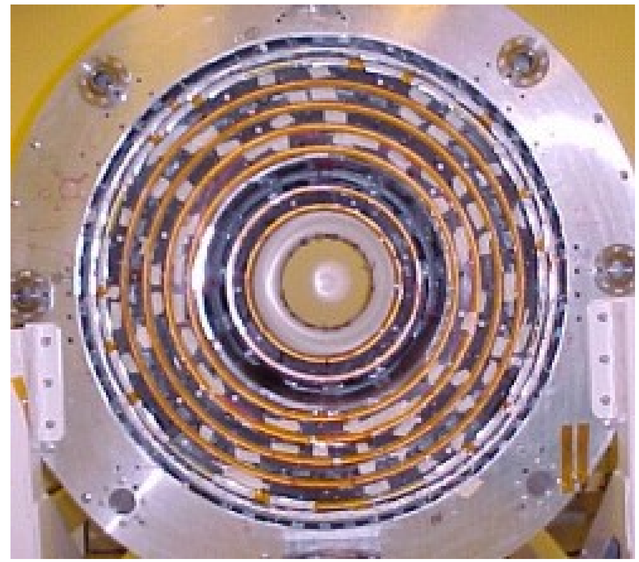
Tracking

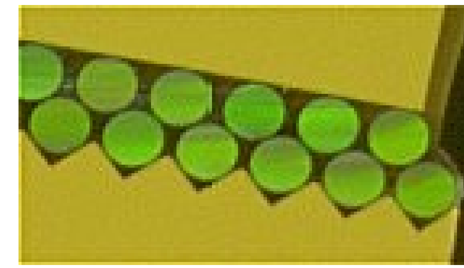
Silicon Microstrip Tracker

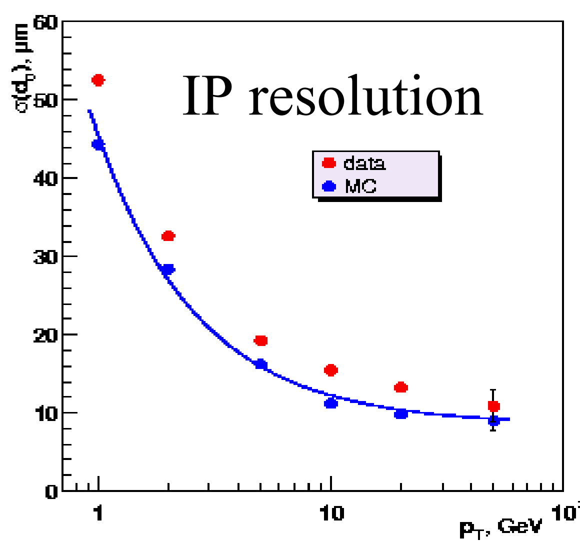


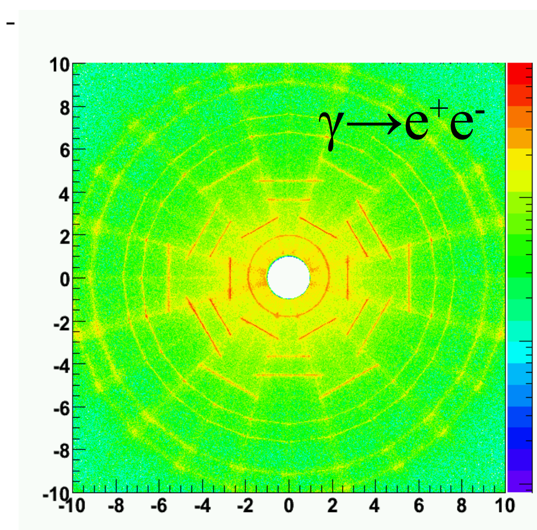


Central Fiber Tracker







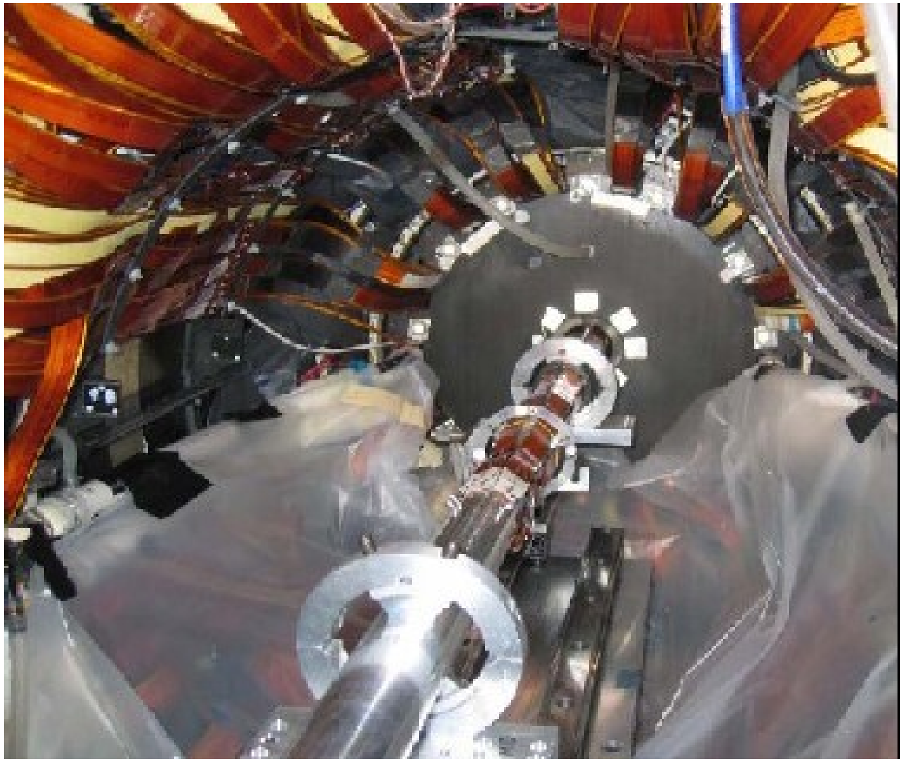


Layer 0 of Silicon Tracker

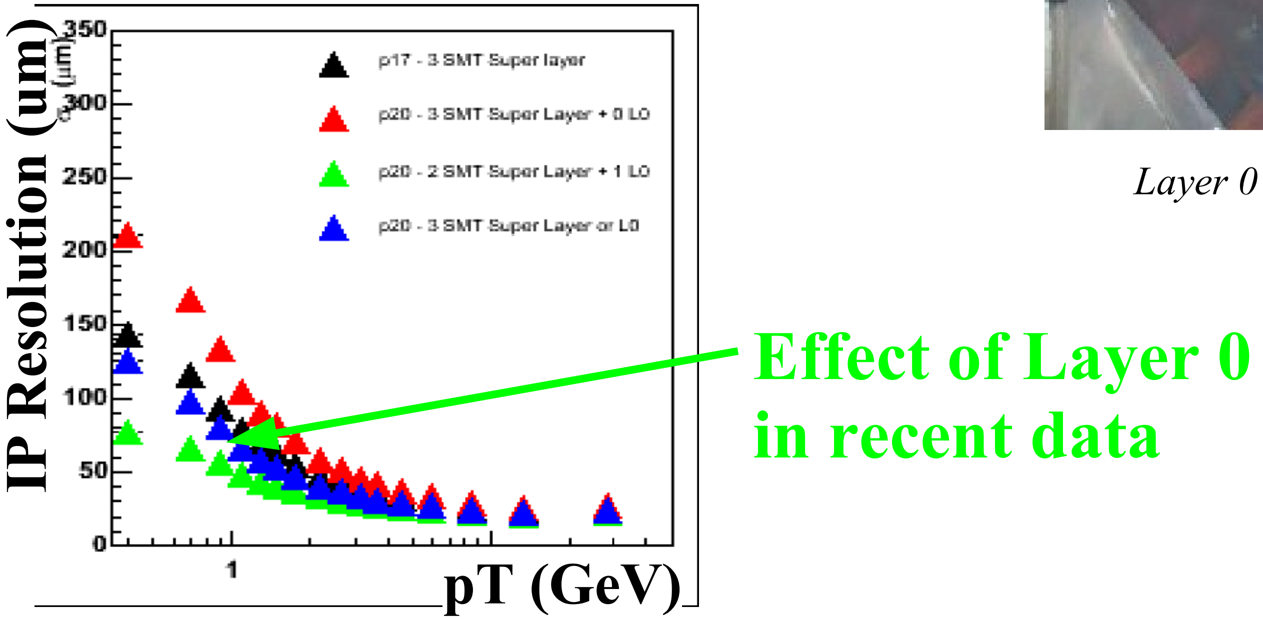
Silicon detectors mounted just outside the beampipe

Installed fall '06

Better track impact-parameter resolution
-> Better b-jet tagging



Layer 0 being inserted into the silicon tracker



b-Tagging Measurement

System 8 method:

$$
\begin{aligned}
n &= n_b + n_{udsgc} \\
p &= p_b + p_{udsgc} \\
n^{SLT} &= \varepsilon_b^{SLT} n_b + \varepsilon_{udsgc}^{SLT} n_{udsgc} \\
p^{SLT} &= \varepsilon_b^{SLT} p_b + \varepsilon_{udsgc}^{SLT} p_{udsgc} \\
n^{NN} &= \varepsilon_b^{NN} n_b + \varepsilon_{udsgc}^{NN} n_{udsgc} \\
p^{NN} &= \beta\varepsilon_b^{NN} p_b + \alpha\varepsilon_{udsgc}^{NN} p_{udsgc} \\
n^{SLT,NN} &= \kappa_b \varepsilon_b^{SLT} \varepsilon_b^{NN} n_b + \kappa_{udsgc} \varepsilon_{udsgc}^{SLT} \varepsilon_{udsgc}^{NN} n_{udsgc} \\
p^{SLT,NN} &= \kappa_b \beta \varepsilon_b^{SLT} \varepsilon_b^{NN} p_b + \kappa_{udsgc} \alpha \varepsilon_{udsgc}^{SLT} \varepsilon_{udsgc}^{NN} p_{udsgc}
\end{aligned}
$$

- Correlation coefficients, measured in MC:

  α - Ratio of the *udsc*-tagging efficiencies in the two samples.

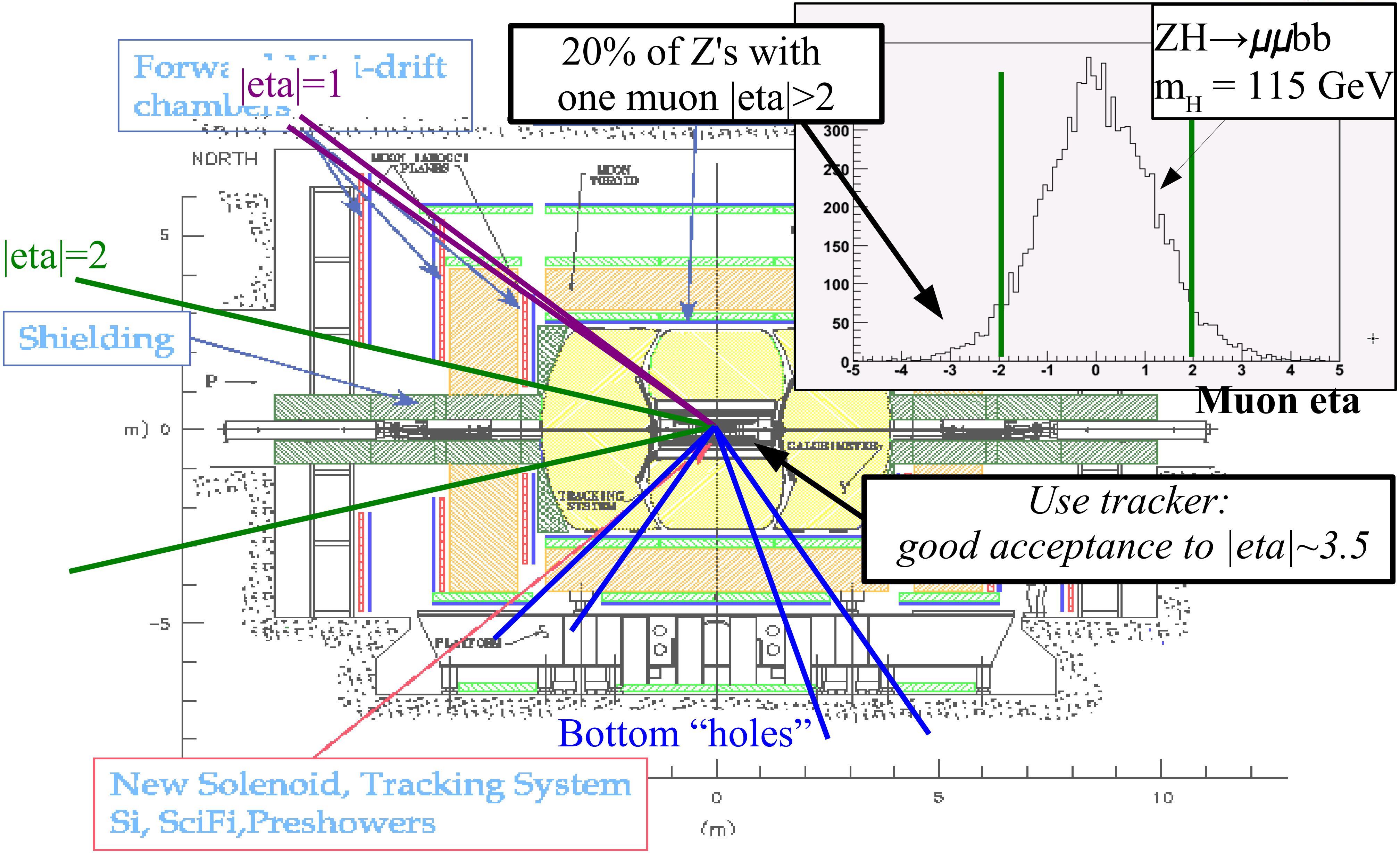
  β - Ratio of the *b*-tagging efficiencies in the two samples.

  κ_b - Correlations between the NN tagger and the SLT tagger on *b*-jets.

  κ_{udsc} - Correlations between the NN tagger and the SLT tagger on *udsc*-jets.

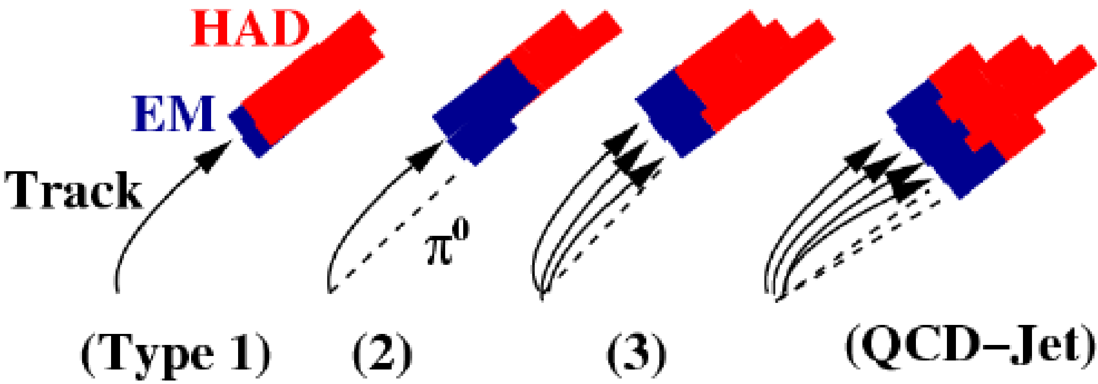
  $p_{T\,Rel}$ - Ratio of the SLT tagging efficiencies on *c* and *uds*-jets.

Muon Acceptance

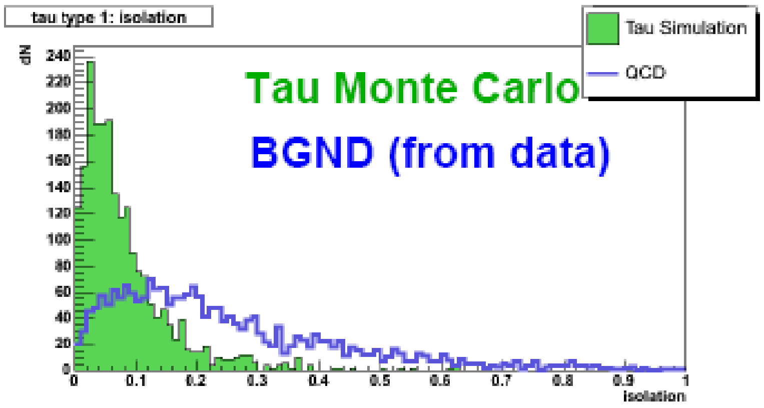


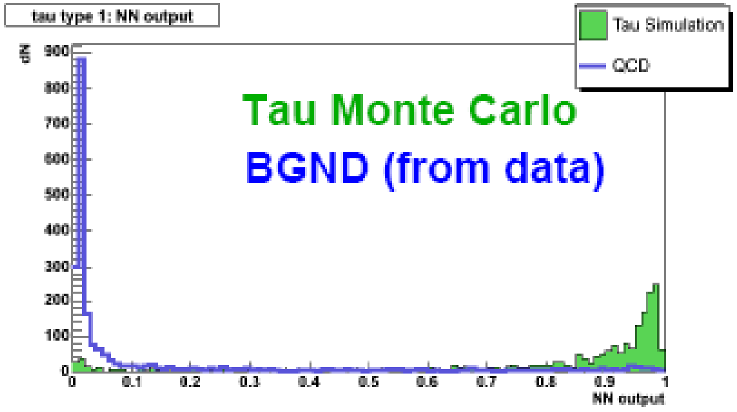
Tau ID

- Tau = narrow isolated jet with low track and π^0 multiplicity
- Taus decay inside detector:
  - $BR(\tau \to e/\mu + \nu)$ ~17%
  - $BR(\tau \to hadrons + \nu)$ ~65%



- DØ uses one Neural Network per tau type to discriminate taus from jets

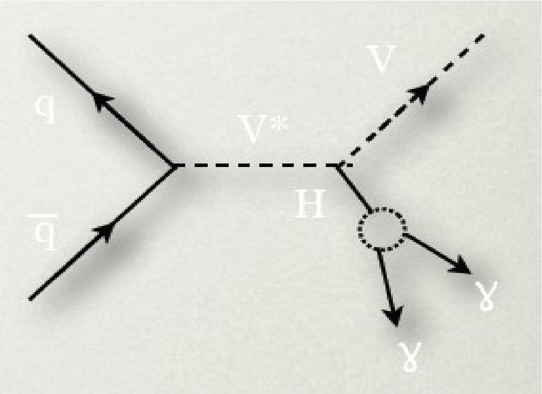




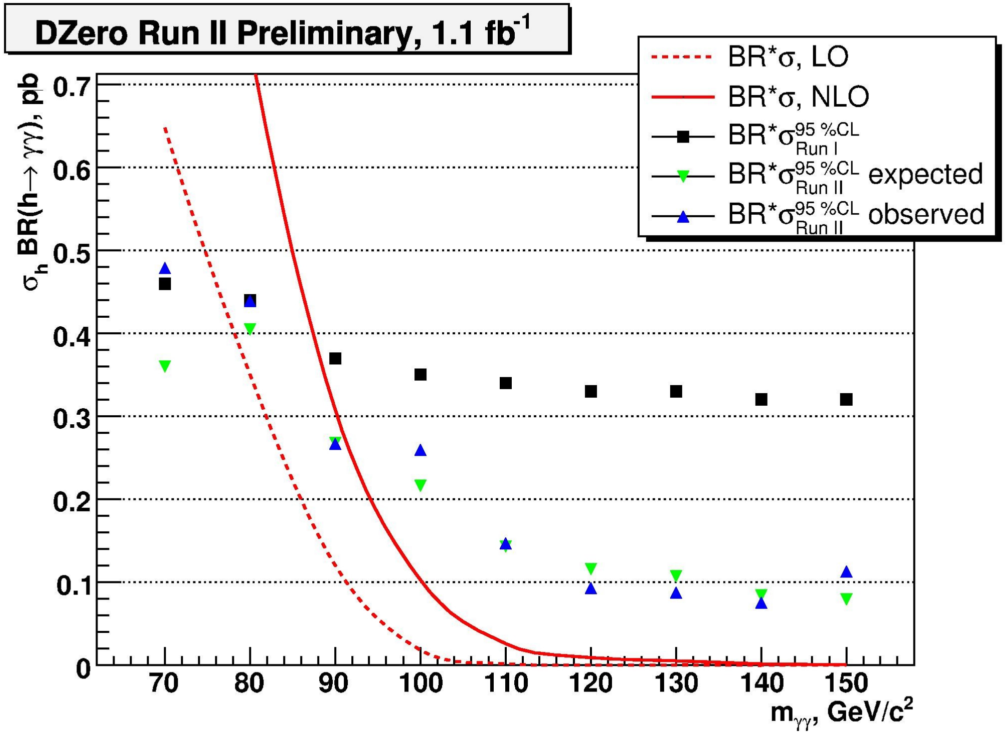
H+V→γγ+X

- Associated Fermiophobic Higgs

$$p\bar{p} \to VV \to h_f \to \gamma\gamma + X$$
$$p\bar{p} \to h_f W^{\pm}(Z) \to \gamma\gamma + X$$



- Analysis overview
  - 1.1 fb^{-1};
  - 2 γ's with: E_T>25 GeV, |η|<1.1, $M_{\gamma\gamma}$>65 GeV
  - Two regions
    - Signal: q_T>35 GeV
    - Control: q_T<35 GeV
  - Backgrounds: γγ, γj, jj



- LEP: m_H>109.7 GeV

Fermiophobic Higgs $\rightarrow 3\gamma + X$

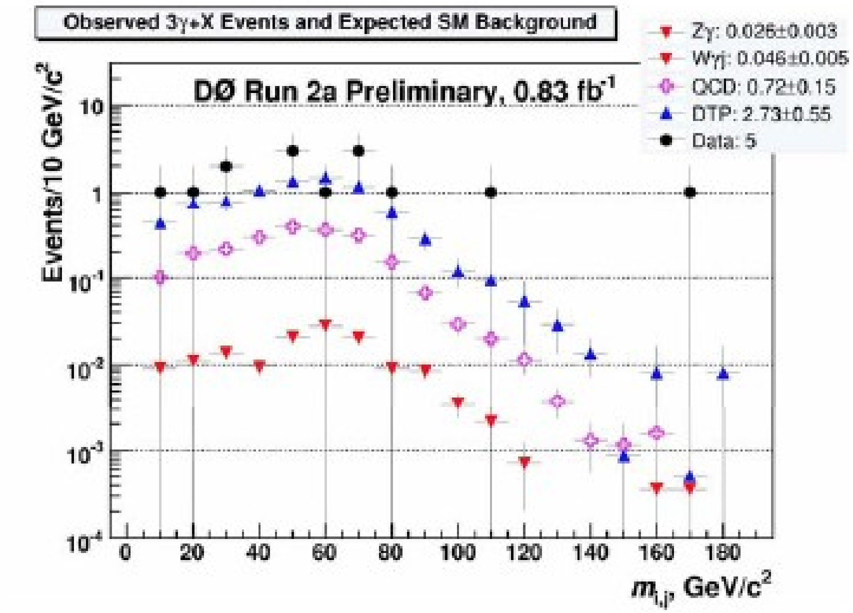
- In various extensions of the SM (also MSSM) the coupling of h might be suppressed to Fermions
- Search for the channel:

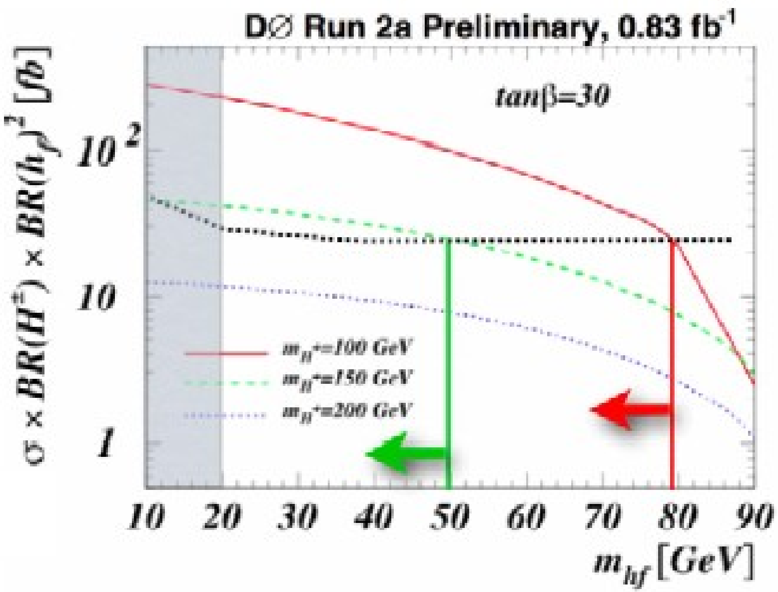
$$p\bar{p} \rightarrow h_f H^{\pm} \rightarrow h_f h_f W^{\pm} \rightarrow \gamma\gamma\gamma(\gamma) + X$$

- Good photon identification is crucial
- Cuts: 3γ within $|\eta|<1.1$
  $E_T^{1,2,3} > 30, 20, 15$ GeV
- Backgrounds: Jets or electrons misidentified as γ and direct 3γ prod.
- Background is estimated from data with efficiencies ε^{γ}, $P(j\rightarrow\gamma)$, $P(e\rightarrow\gamma)$

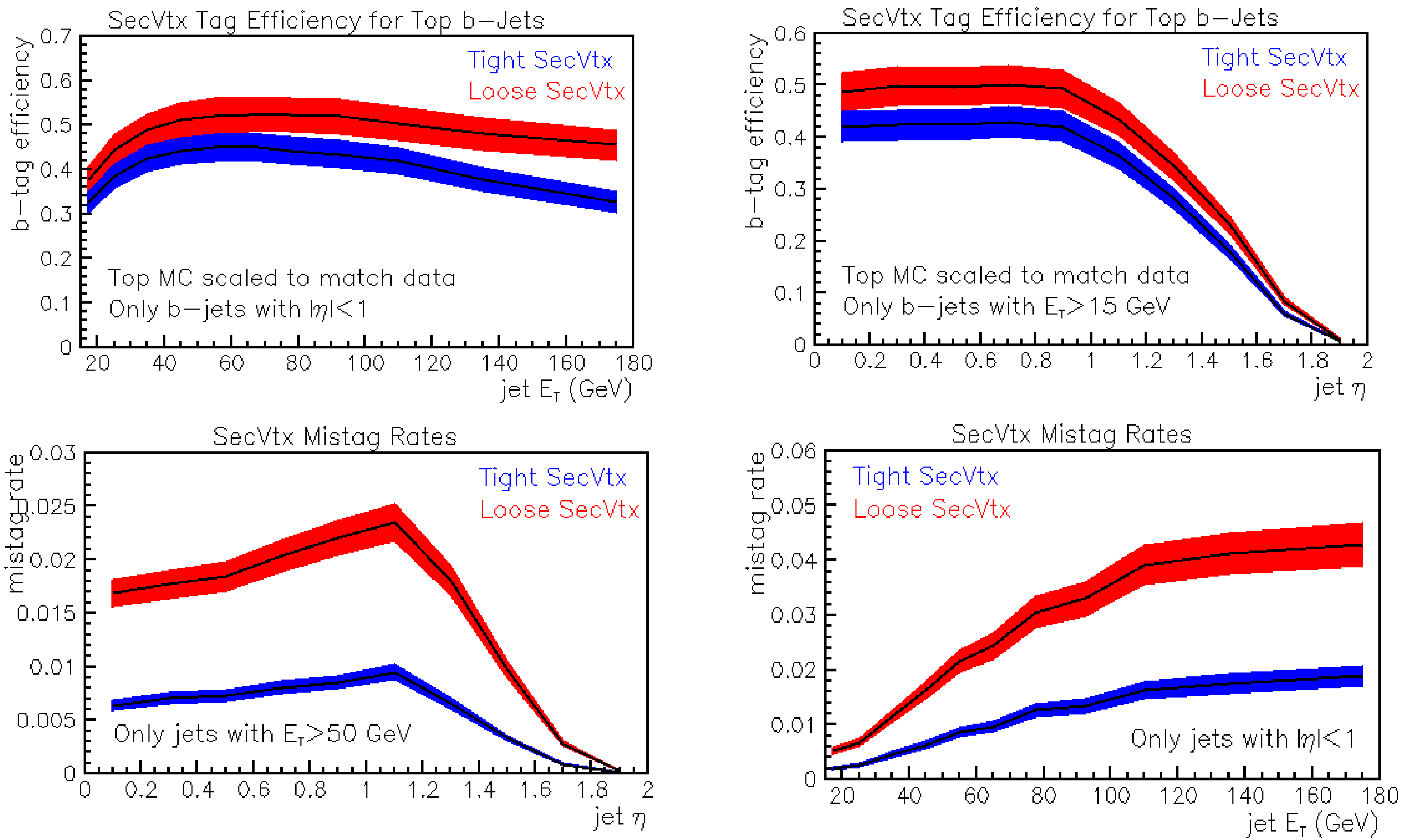
  3γ prod.: $N^{3\gamma} = \frac{N_{\gamma\gamma\gamma}(MC)}{N_{\gamma\gamma}(MC)} N_{\gamma\gamma}(Data) * \rho$

- Cut on $p_T^{3\gamma} > 25$ GeV gives 1.1 events in background and 0 in data
- Upper limit: $\sigma = 25.3\ fb\ (95\%\ CL)$

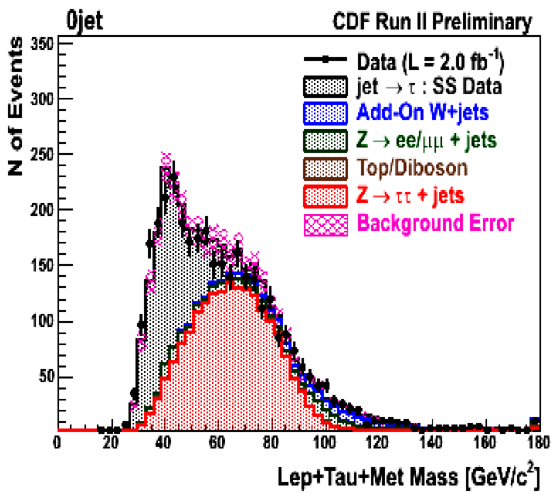


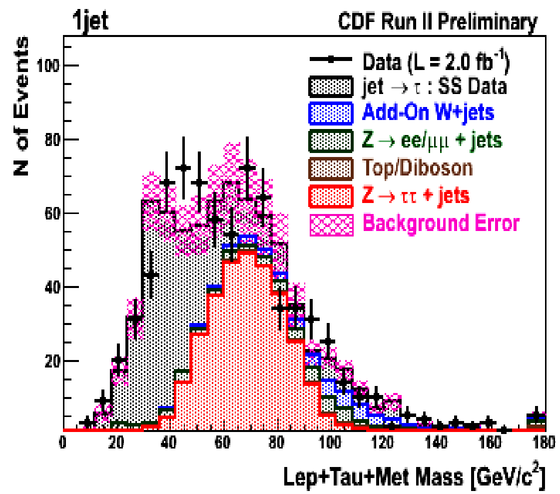


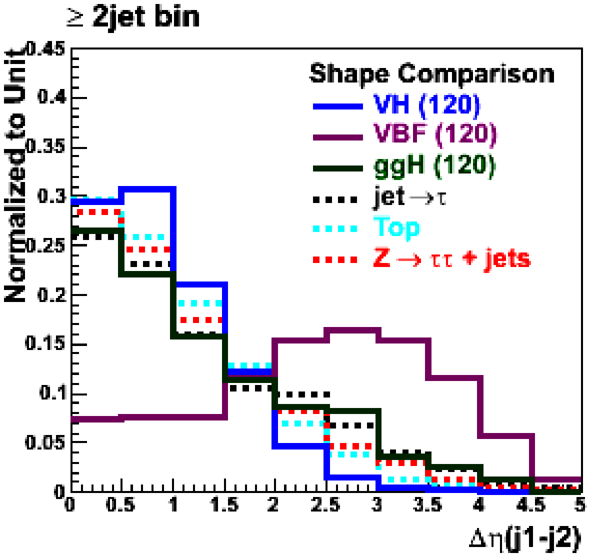
Ref.) CDF SECVTX btag

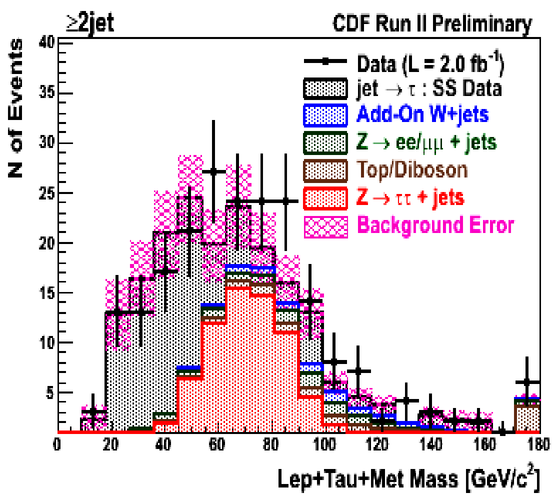


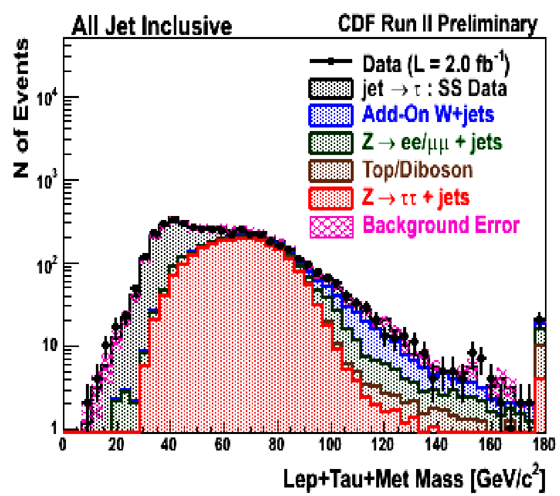
More Plots : H → ττ Channel

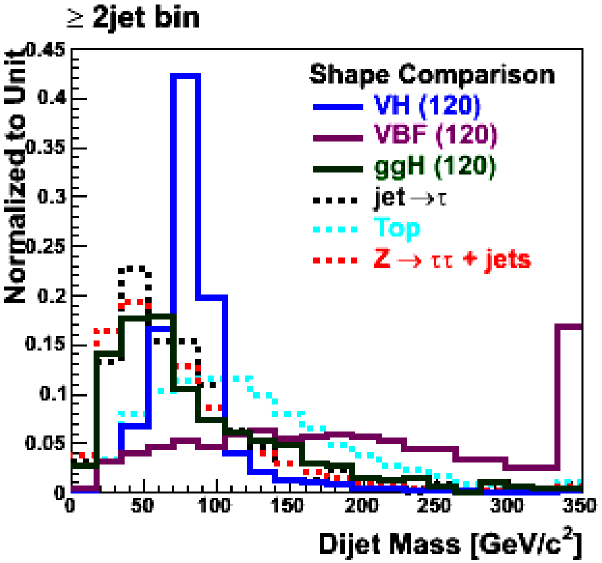




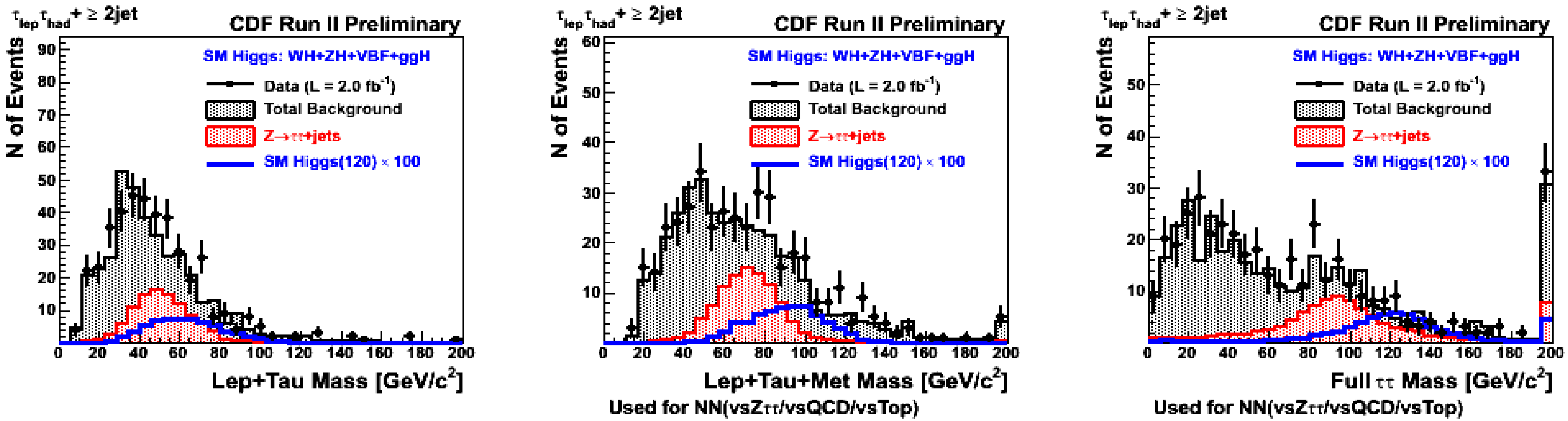




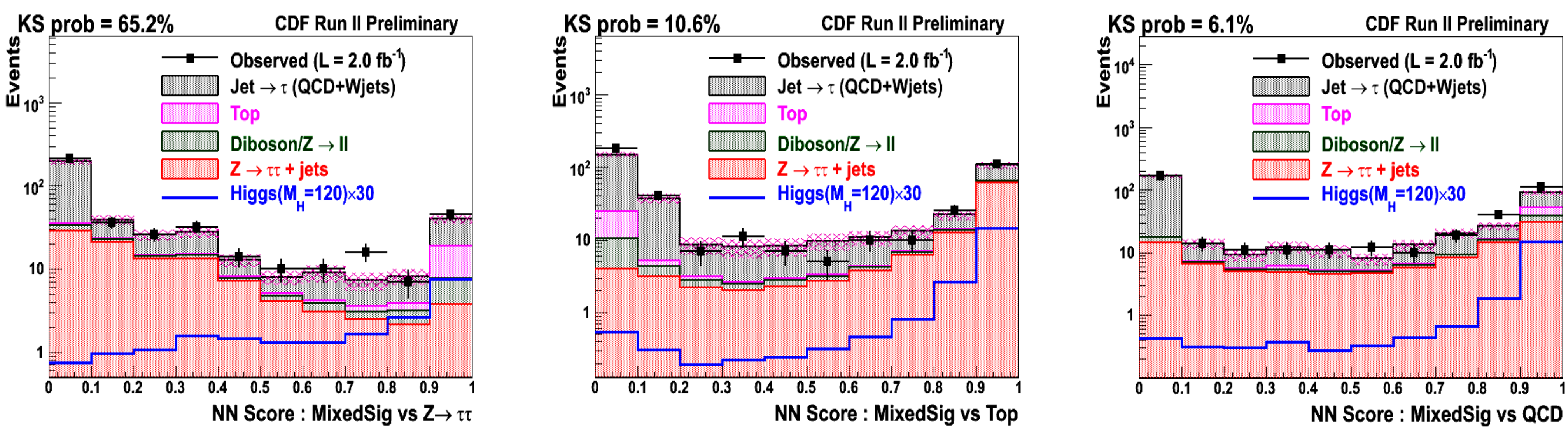




More Plots : H → ττ Channel

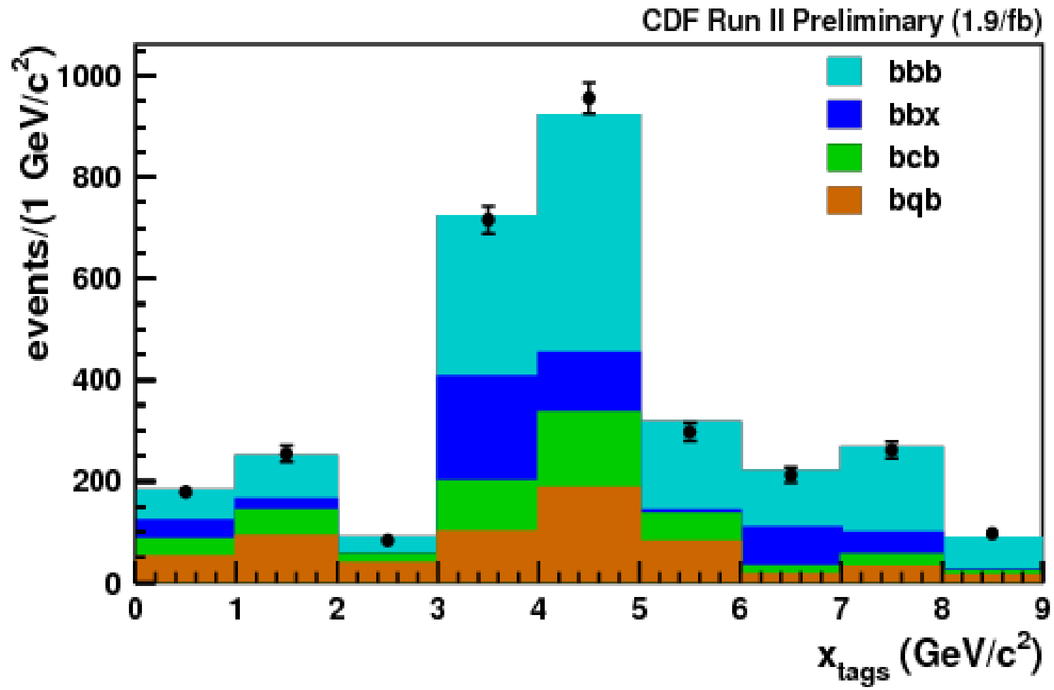


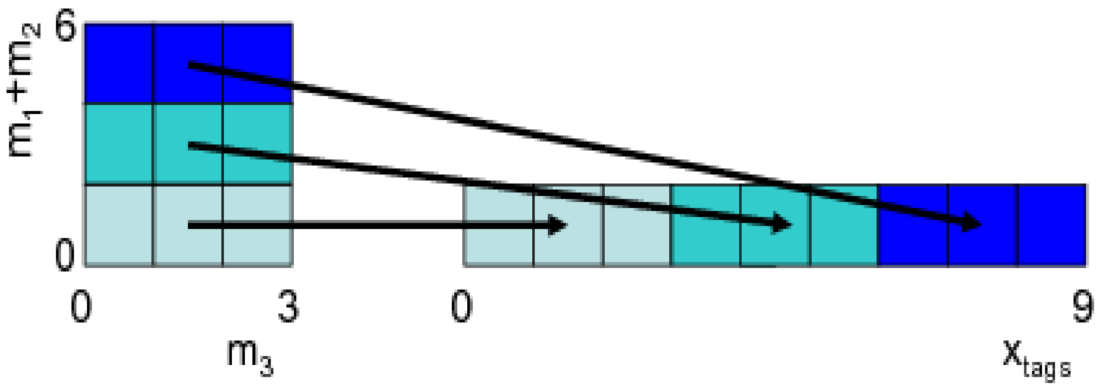
> 3 Neural Nets Distributions:

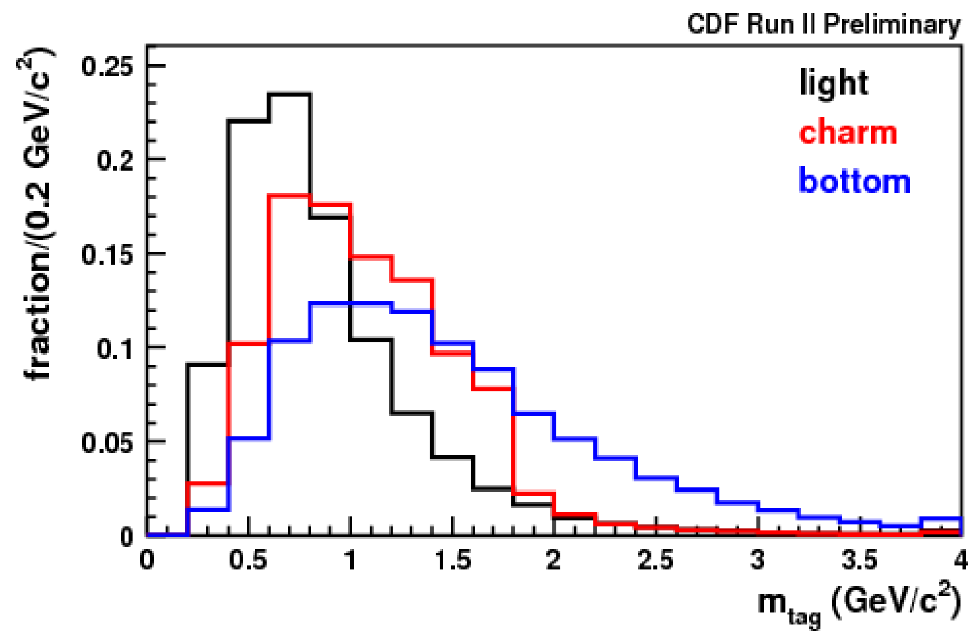


CDF 3b Channel

- Improve prediction of total background m_{12} using tag properties
  - Invariant mass of tracks in each vertex m_j
- m_1+m_2 : bbb+bbx / bcb+bqb
- m_3 : bbx / bbb+bcb+bqb
- Unstack into 1D variable "x_{tags}" for plotting/fitting
- Fits are 2D - m_{12} vs x_{tags}
  - Four backgrounds
  - Higgs signal template

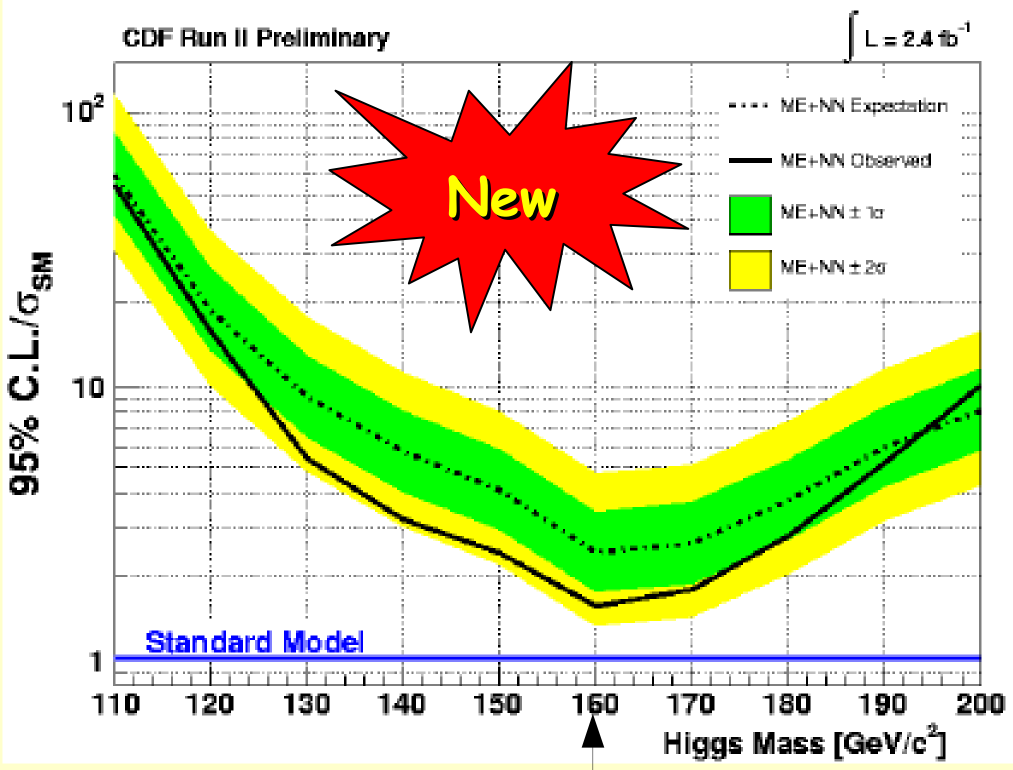


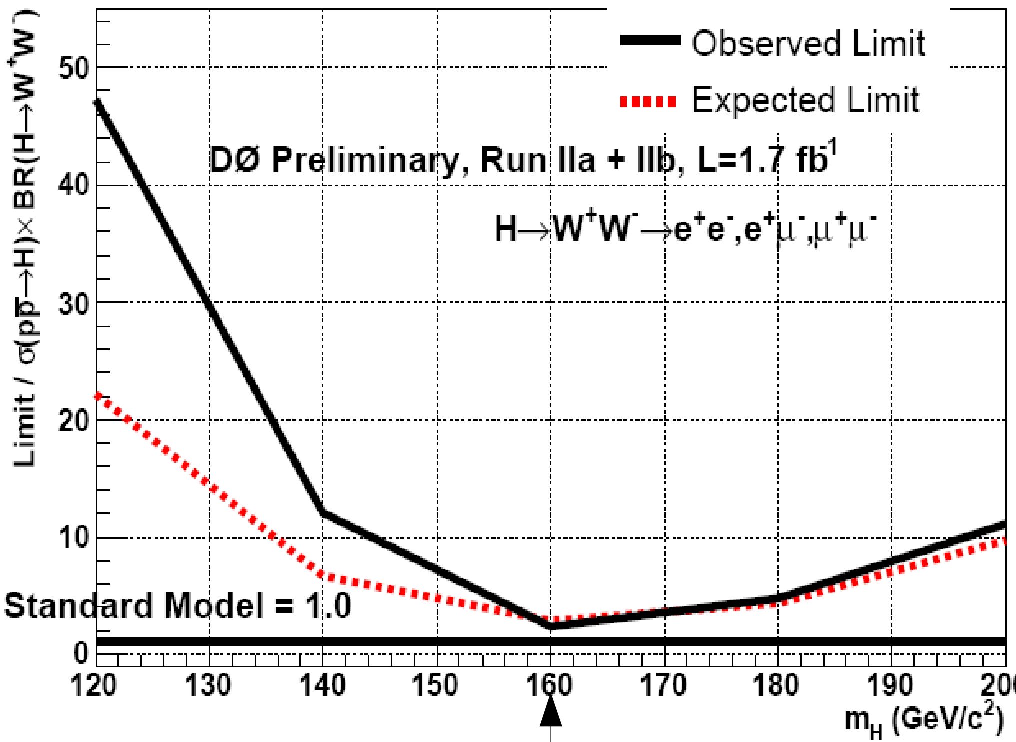




Old Combinations

H -> WW* -> l l (l=e,mu)





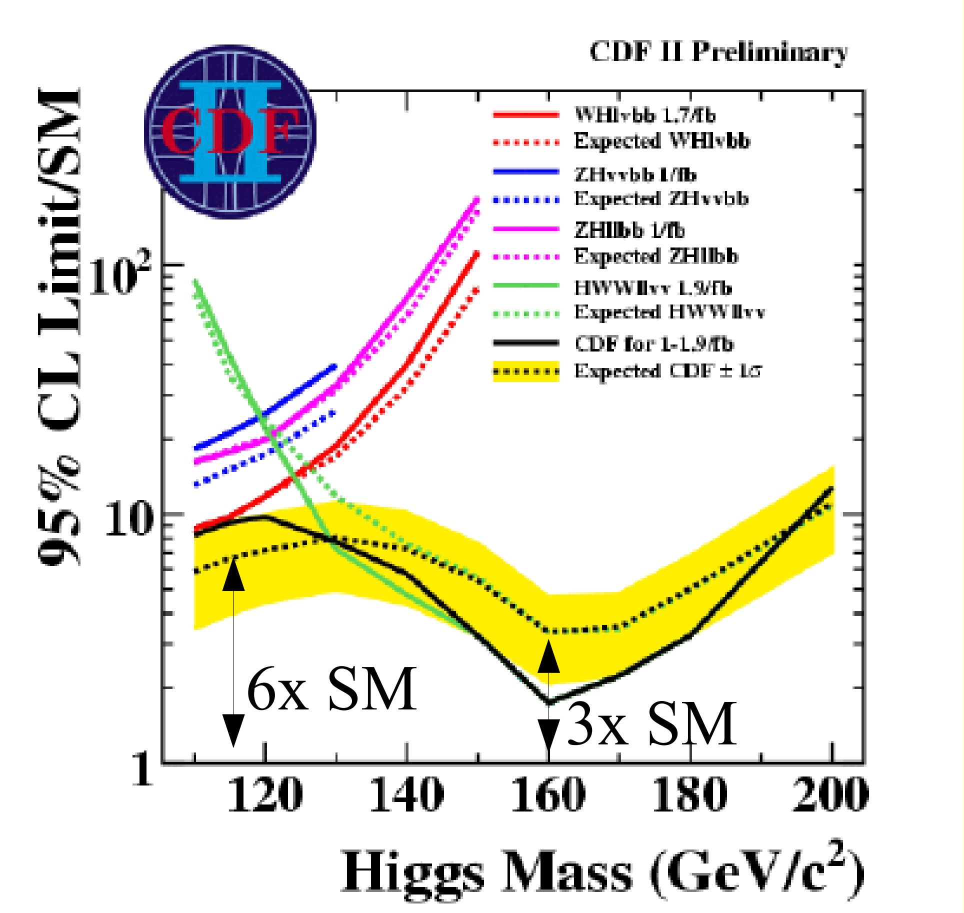
Observed Limit/σ_{SM} (NNLL) ~ 1.6
Expected Limit/σ_{SM} (NNLL) ~ 2.4

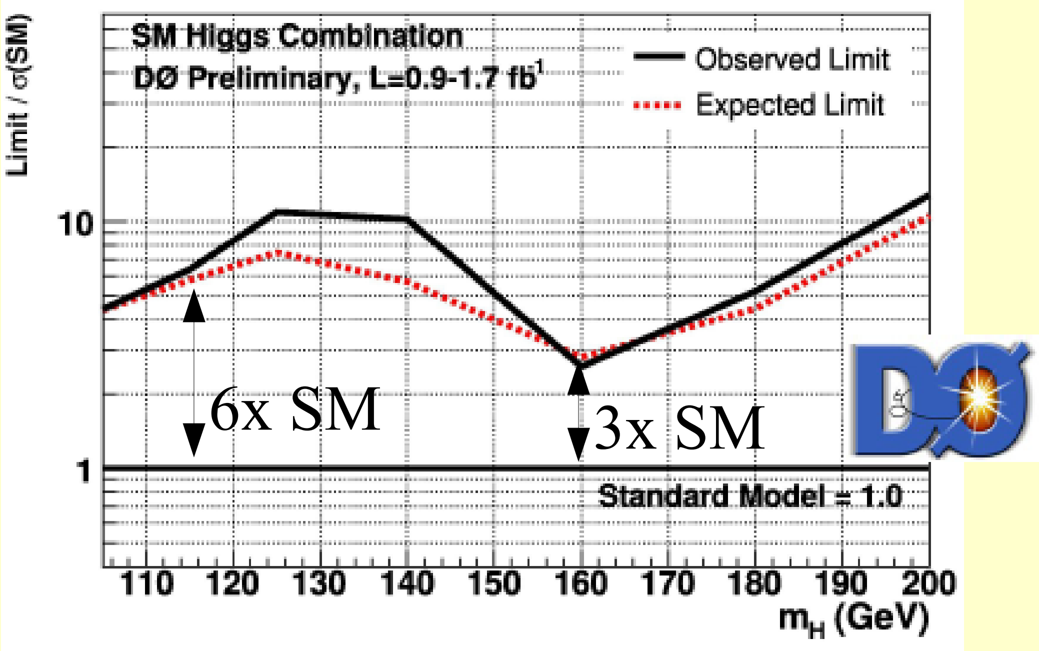
Observed Limit/σ_{SM} (NNLL) ~ 2.4
Expected Limit/σ_{SM} (NNLL) ~ 2.8

SM Higgs Combinations

- Combined limits from December 2007
  - New results shown today not yet included!
- Expect both experiments to show improved limits next week

	m_H [GeV]	CDF	DØ
expected	115	6	5.7
	160	3.1	2.8
observed	115	9.6	6.4
	160	2	2.5



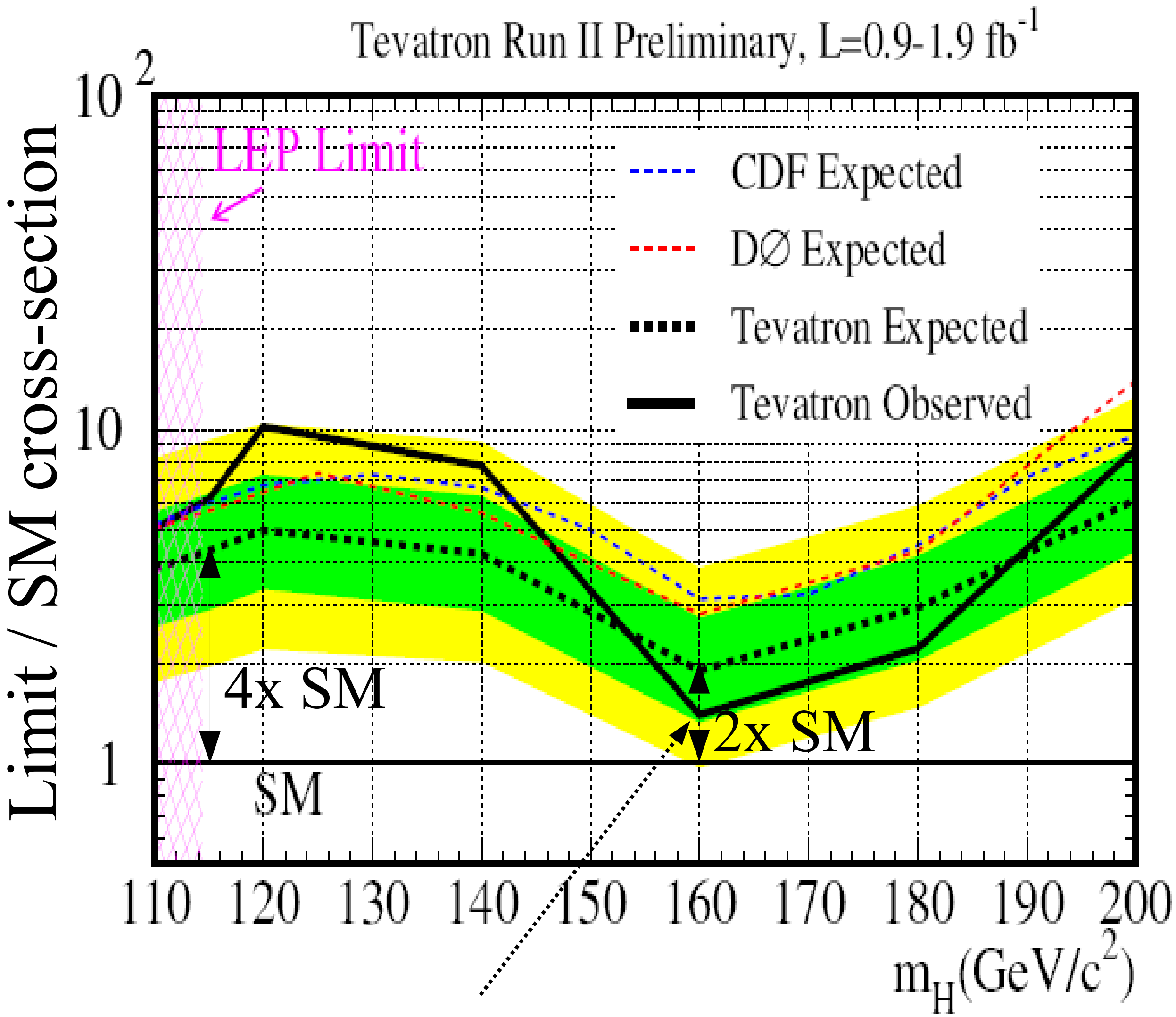


D0/CDF SM Higgs Combination

New Tevatron combination coming very very soon!

Improvements underway:

- Di-jet mass resolution
- Lepton efficiency
- Further improvements in analysis technique
- Better multivariate techniques
- Better b-tagging



Observed limit: 1.4x SM !