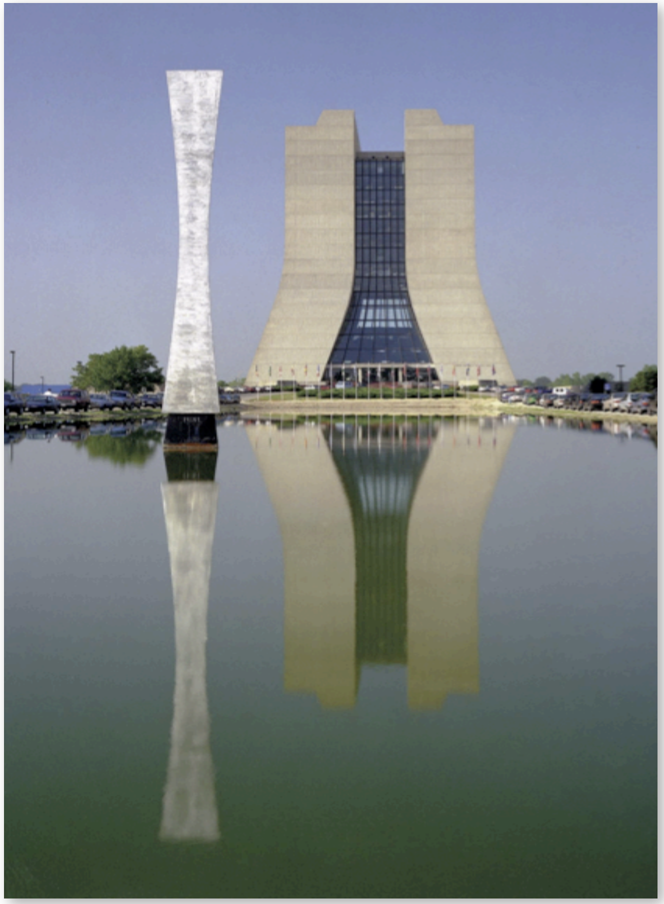
SM Higgs search at the Tevatron



MPI@LHC'08
Perugia, 27. October 2008

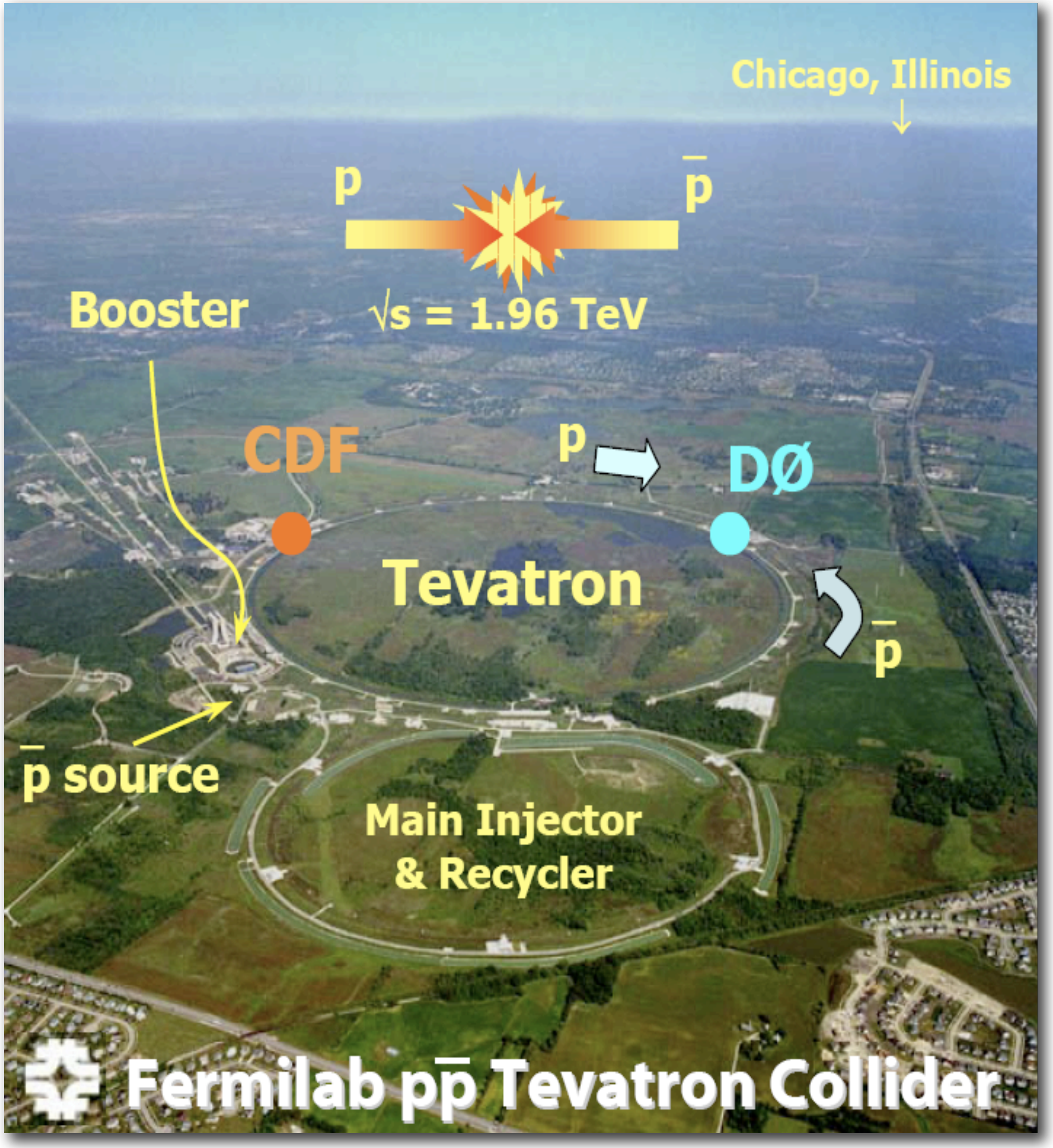
Ralf Bernhard
University of Freiburg
on behalf of DØ and CDF

Physics Department
Albert-Ludwigs-University Freiburg

Outline

- Tevatron & Detectors
- Standard Model Higgs
  - Introduction
  - Analysis
    - Low Mass
    - High Mass
  - Combination
    - CDF
    - DØ
    - Tevatron
- Prospects & Conclusions

Tevatron Facts:
- 36 x 36 bunches
- Average initial: >280 x 10^{30} /cm^2 1/s
- 40+ 1/pb per week



DØ: Integrated Luminosity

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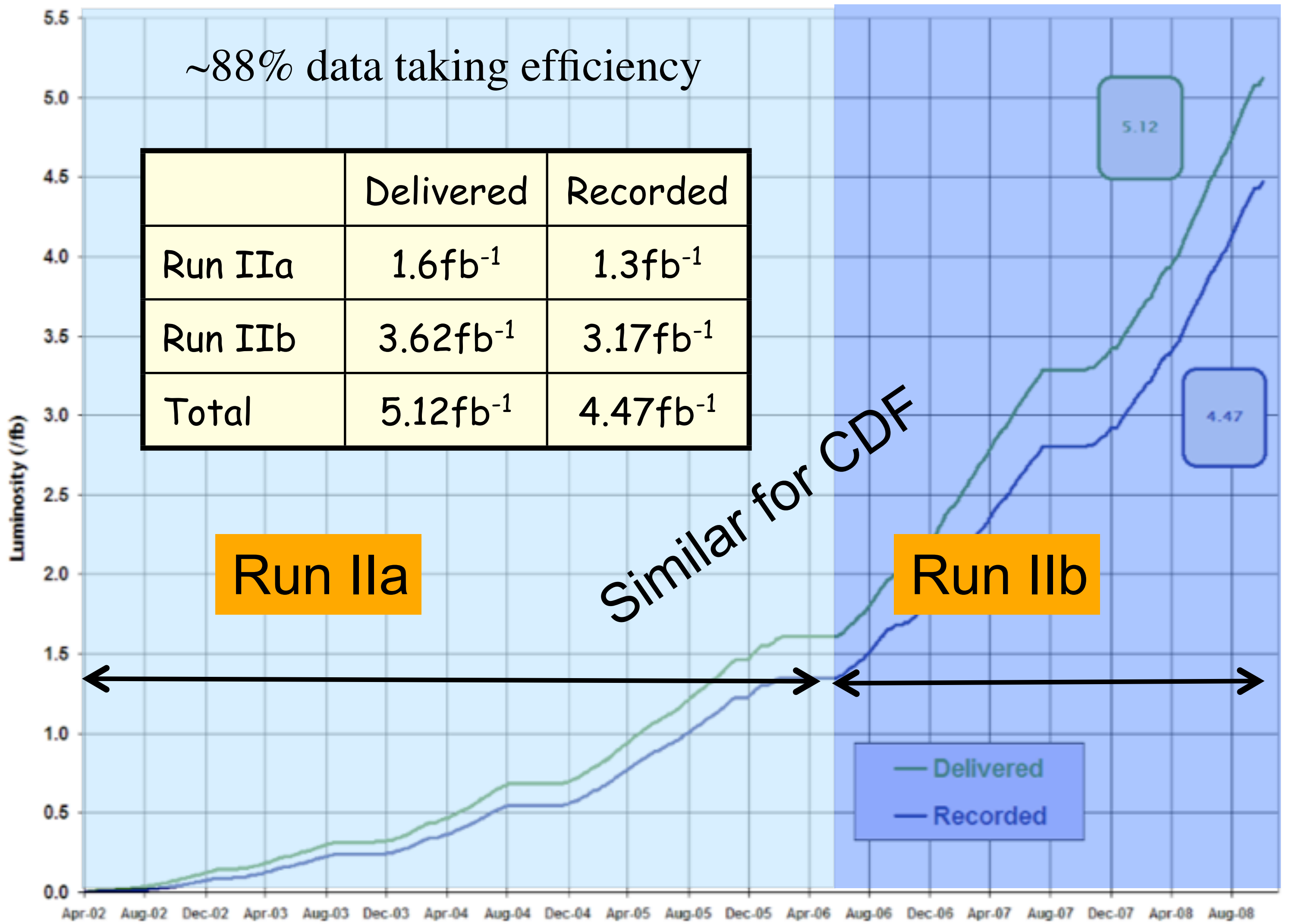

	Delivered	Recorded
Run IIa	$1.6fb^{-1}$	$1.3fb^{-1}$
Run IIb	$3.62fb^{-1}$	$3.17fb^{-1}$
Total	$5.12fb^{-1}$	$4.47fb^{-1}$

DØ: Data recorded May 31 shown at ICHEP July 31!

Up to **3.0/fb** of good data analyzed, ~14% data quality loss, ~75% overall efficiency

The DØ Detector

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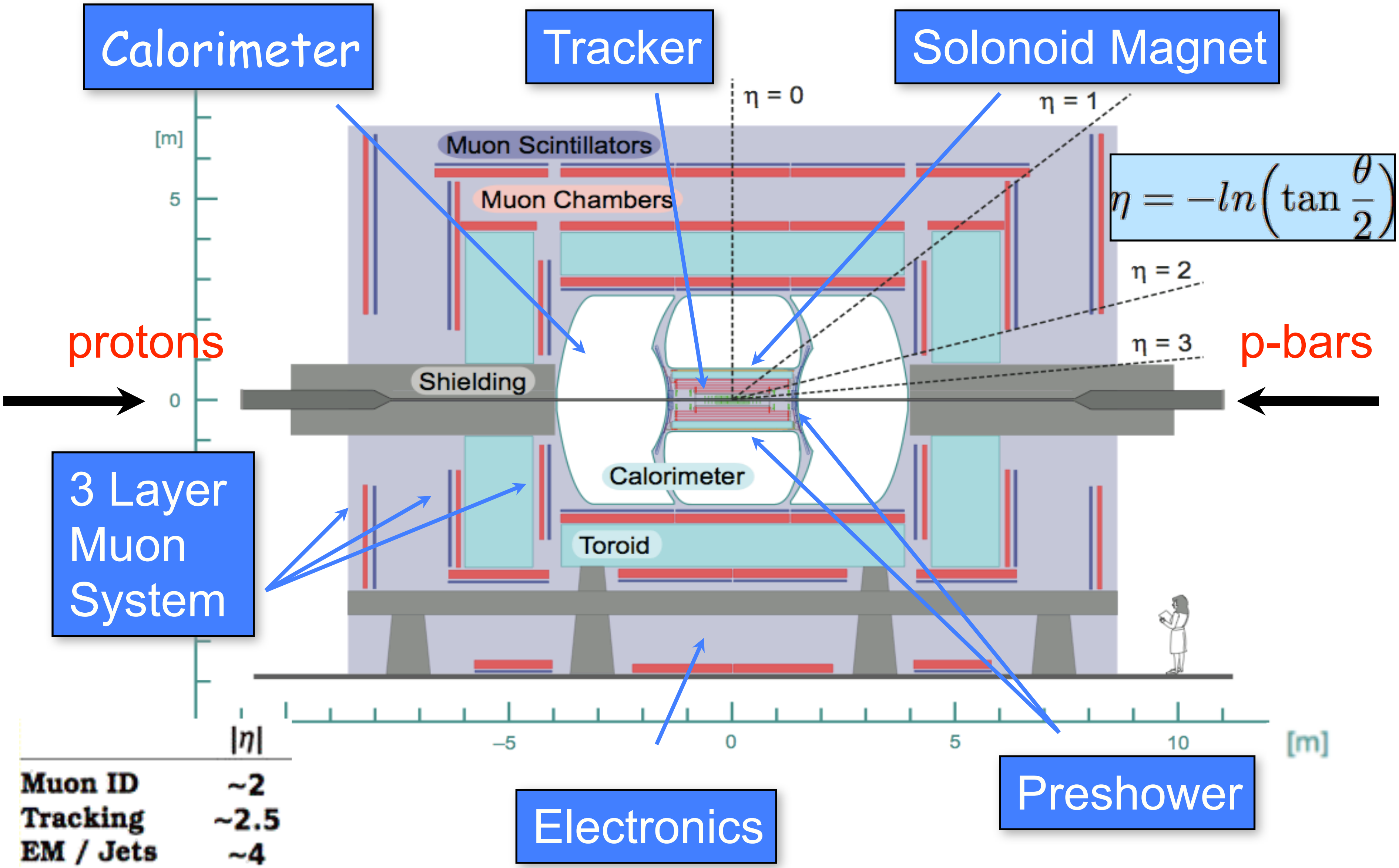
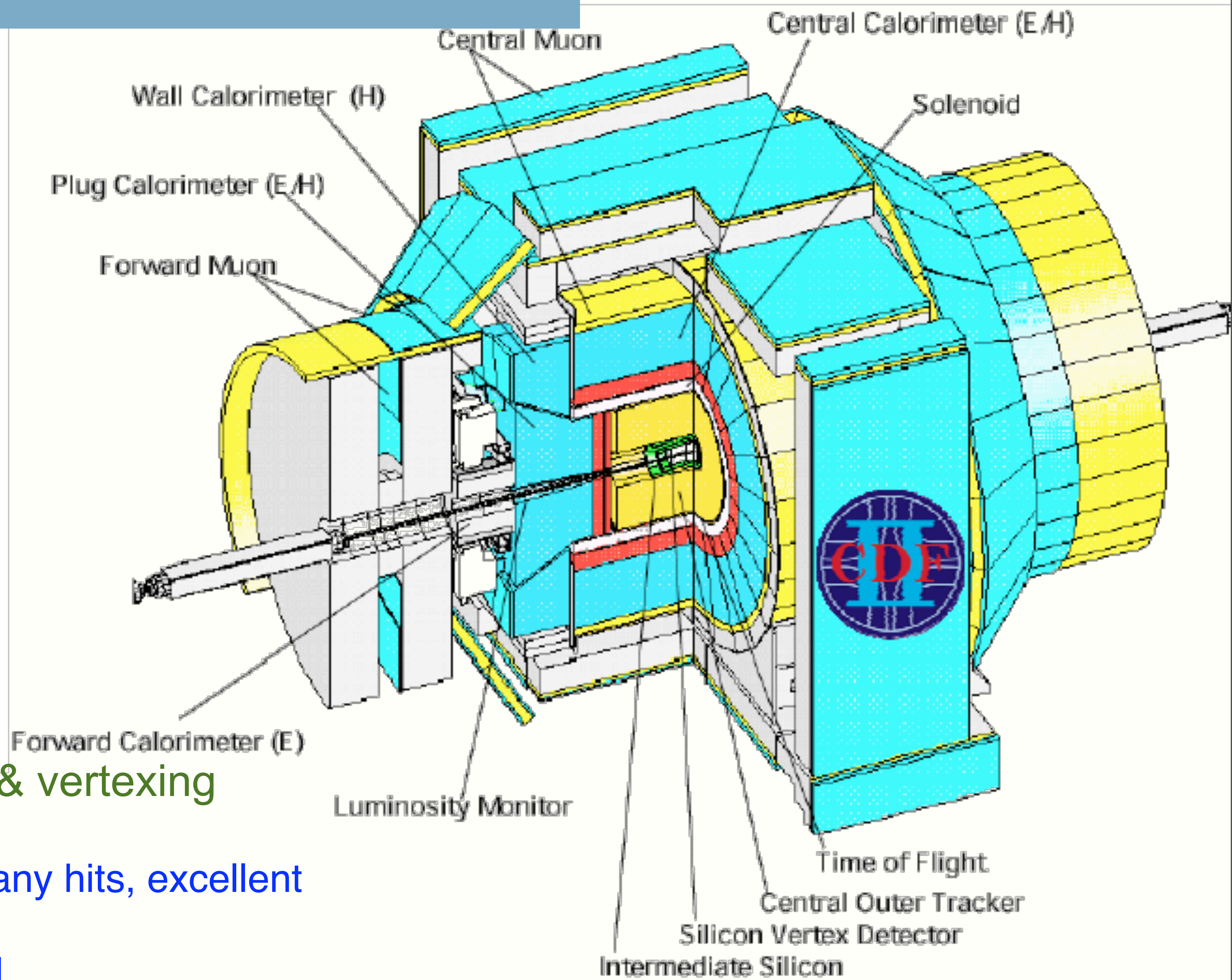


	|η|
Muon ID	~2
Tracking	~2.5
EM / Jets	~4

The CDF Detector



CDF Tracker:

excellent mass resolution & vertexing

- Silicon, Layer 00
- Large radii drift chamber, many hits, excellent momentum resolution
- dE/dx (and TOF): particle id

- Triggered muon coverage: $|\eta| < 1$
- E.g.triggers: dimuons, lepton + displ. track, two displaced tracks

Higgs in a Nutshell

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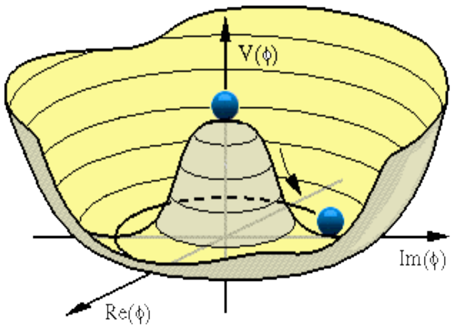
In the Standard Model, the Higgs field is a complex scalar field, $V(\phi)$:



W and Z bosons gain masses through degrees of freedom of Higgs field

Masses are generated for the fermions due to their interaction with this non-zero field

Theory preserves symmetry (gauge invariance)
Standard Model calculations no longer fail

A new particle is predicted: the Higgs boson with spin 0
The only free parameter is its mass.

Exp. constraints on the Higgs Boson

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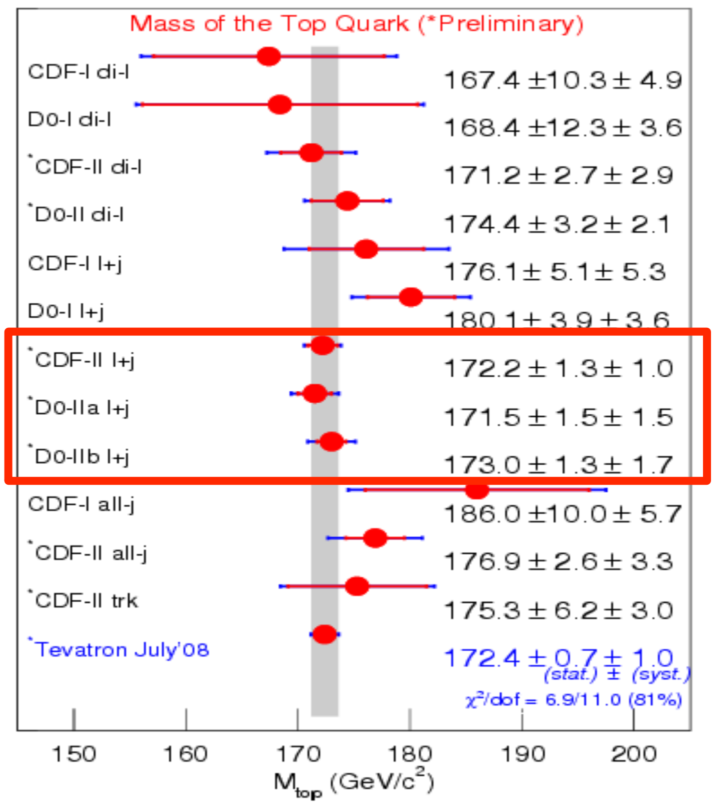
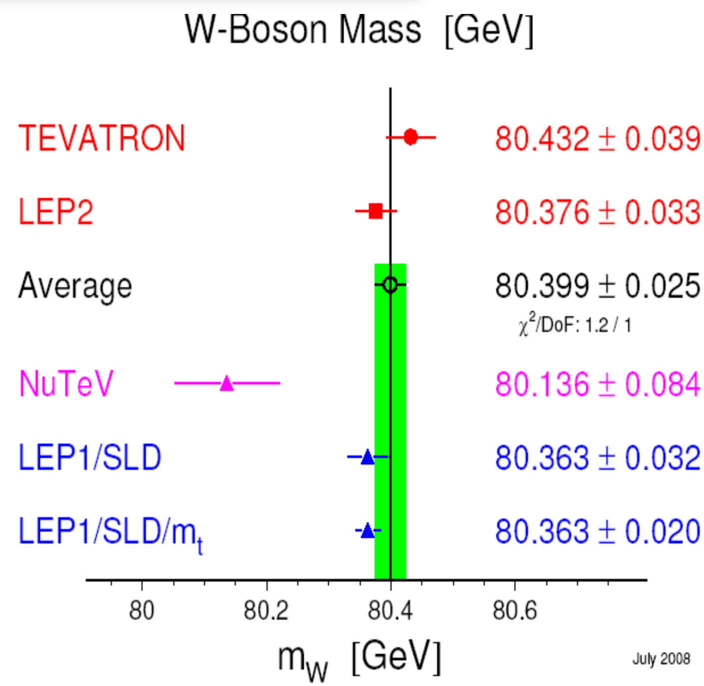
Indirect Constraints:
Top, W-boson masses

Direct searches at LEP II:
$m_H > 114.4$ GeV @ 95% CL



NB Winter 2008

$M_t = 172.6 \pm 1.4$ GeV



$\sigma M_W / M_W = 3 \times 10^{-4}$

Exp. constraints on the Higgs Boson

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Indirect Constraints:
Top, W-boson masses

Direct searches at LEP II:
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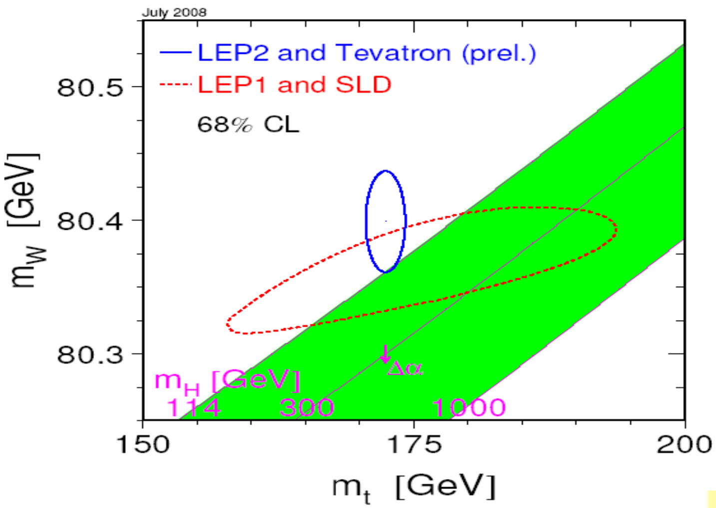
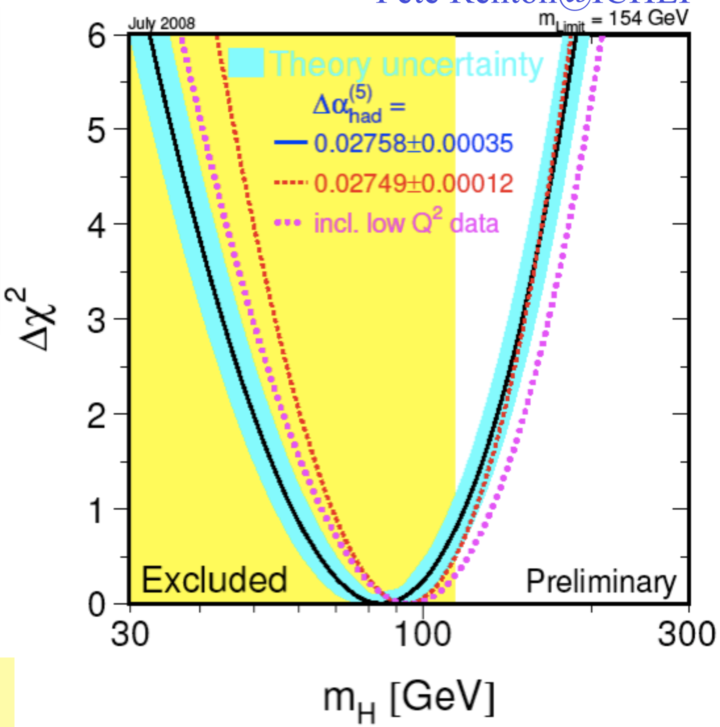


Precision EW fit:
$m_H < 154$ GeV
(<182 GeV with LEPII Limit)

$$m_H = 84^{+34}_{-26} \text{ GeV}$$

Pete Renton@ICHEP

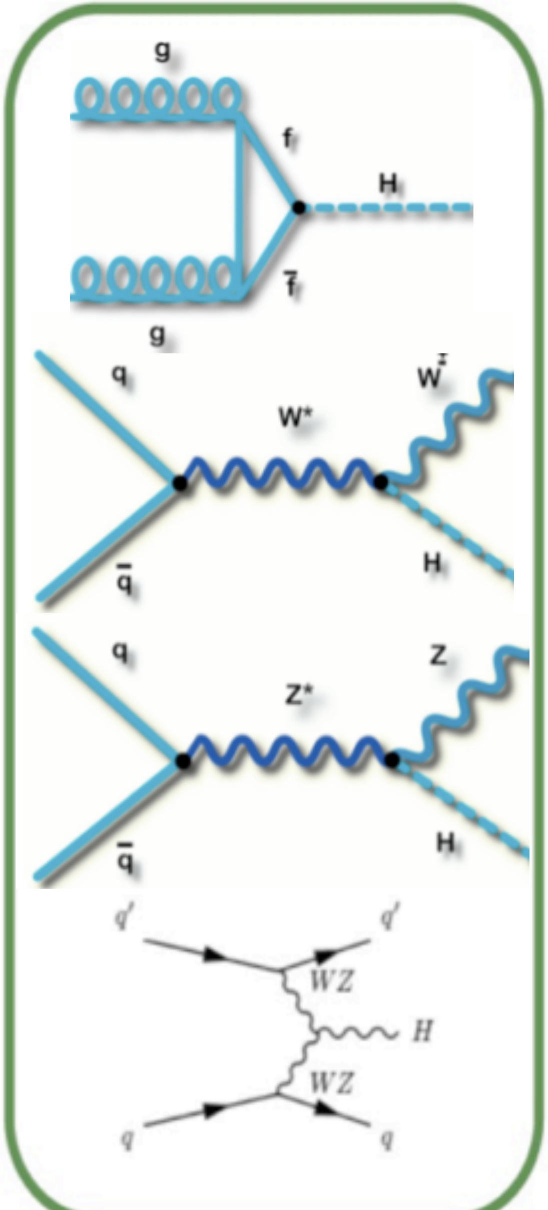


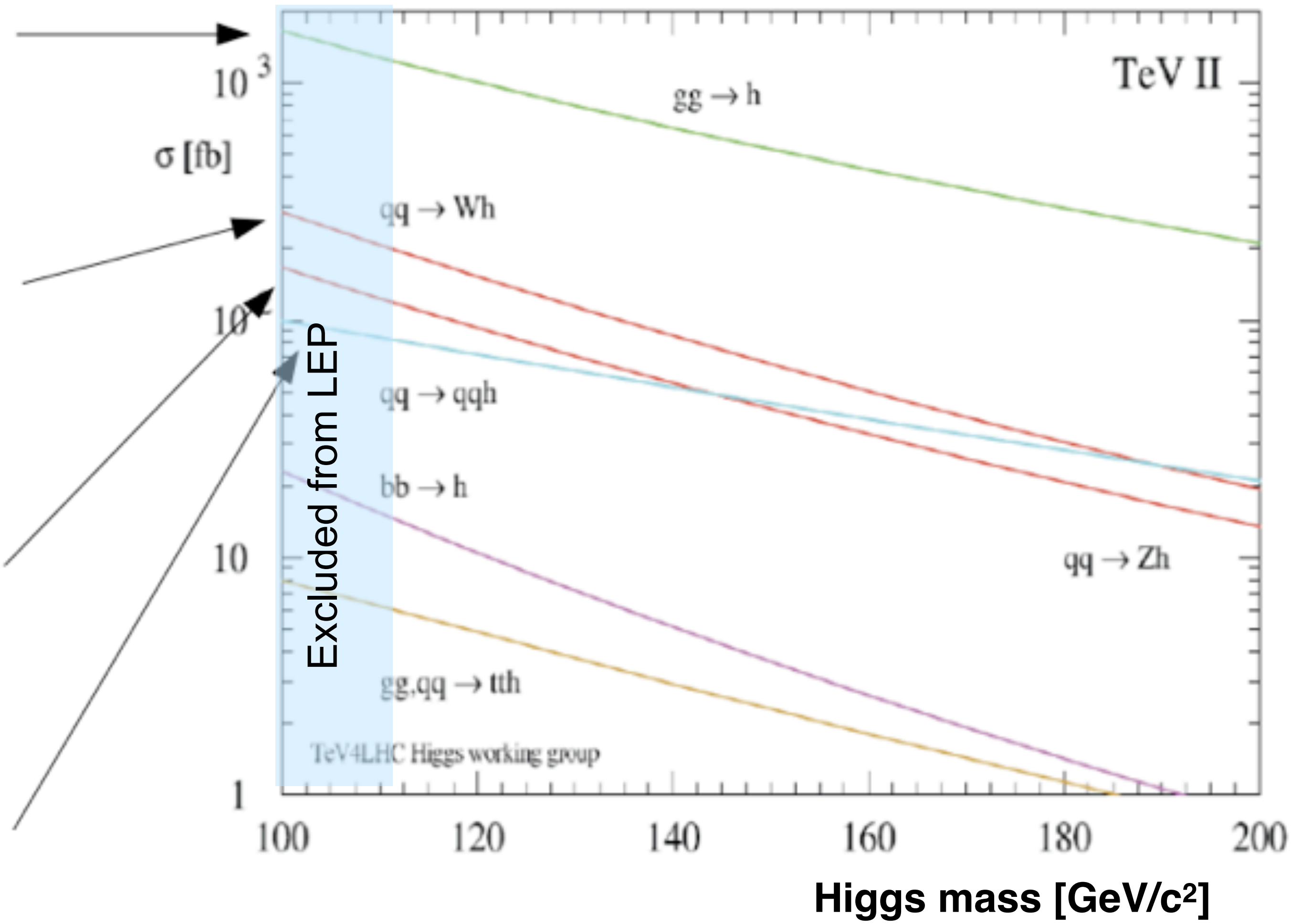
SM Higgs Production

($80 < m_H < 200$ GeV):

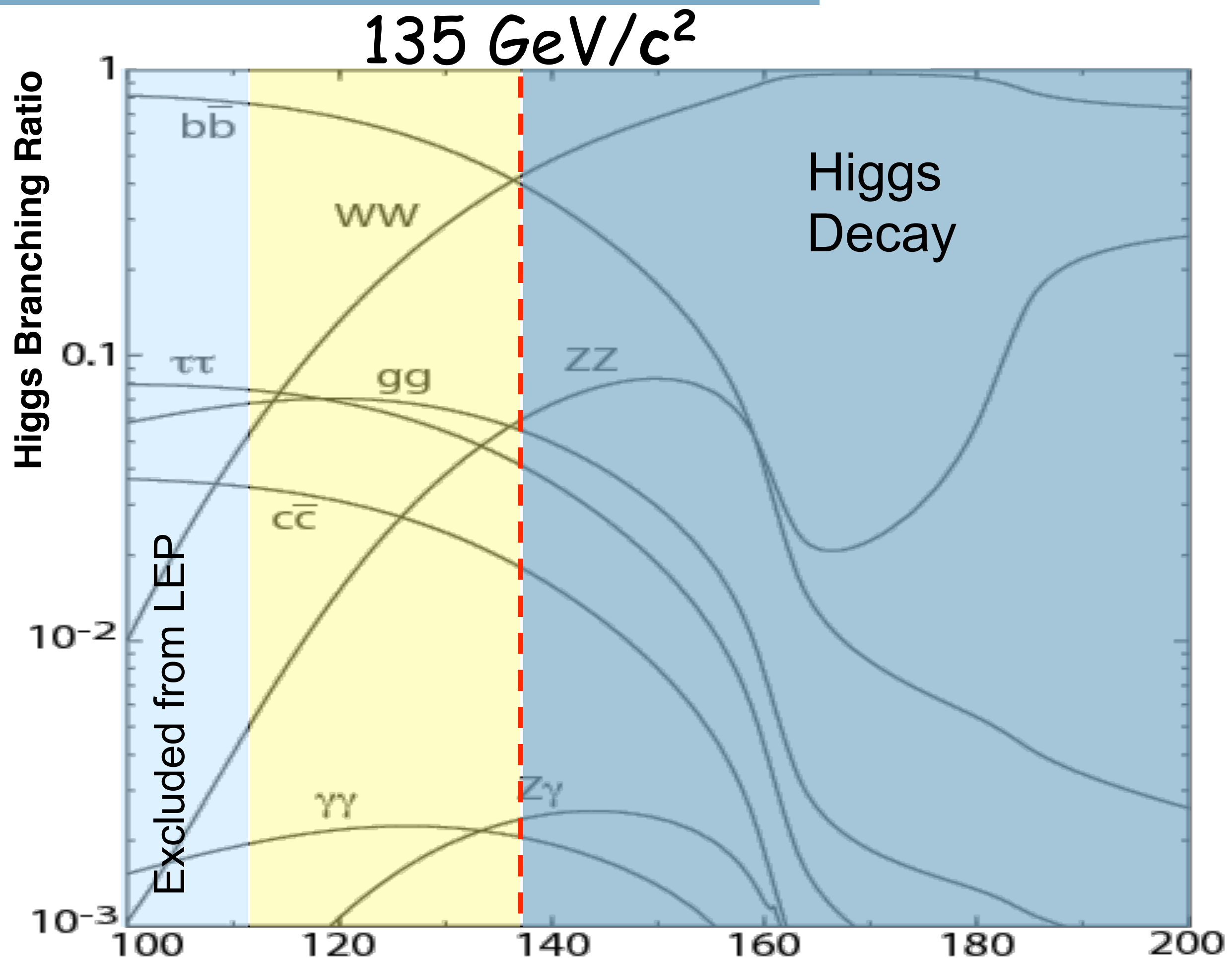
$\sigma(gg \to H) \approx 2 - 0.1\,pb$

$\sigma(qq \to HW) \approx 0.6 - 0.02\,pb$





… and Delay



$H \rightarrow b\bar{b}$

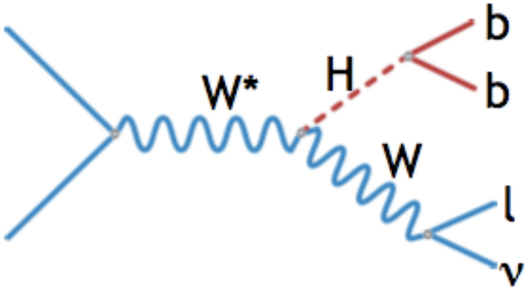
$H \rightarrow WW$

DØ: WH→lν bb (l=e,μ)

Select lepton (e,μ) + MET events -- lepton and lepton+jets triggers

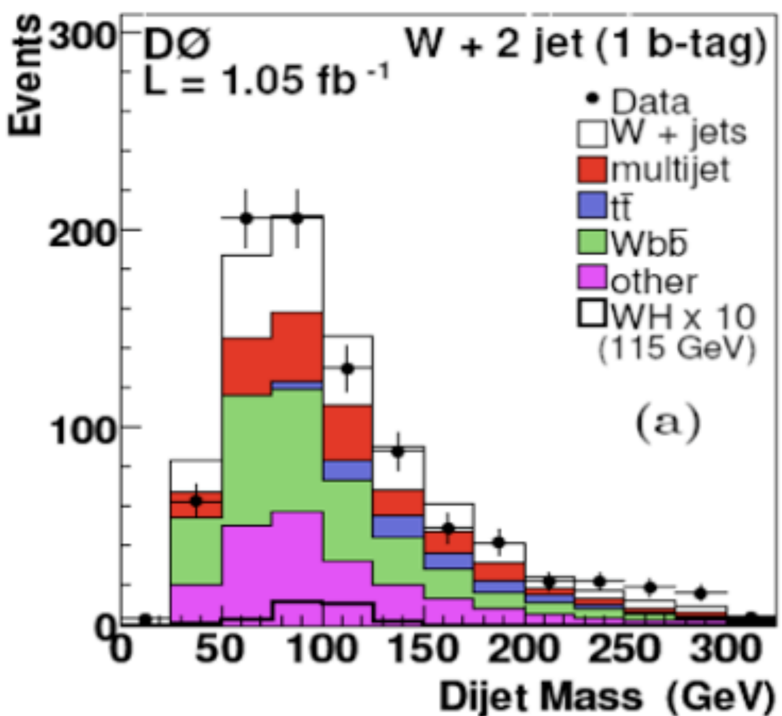
Apply b-tagging to reduce W+light-jet background

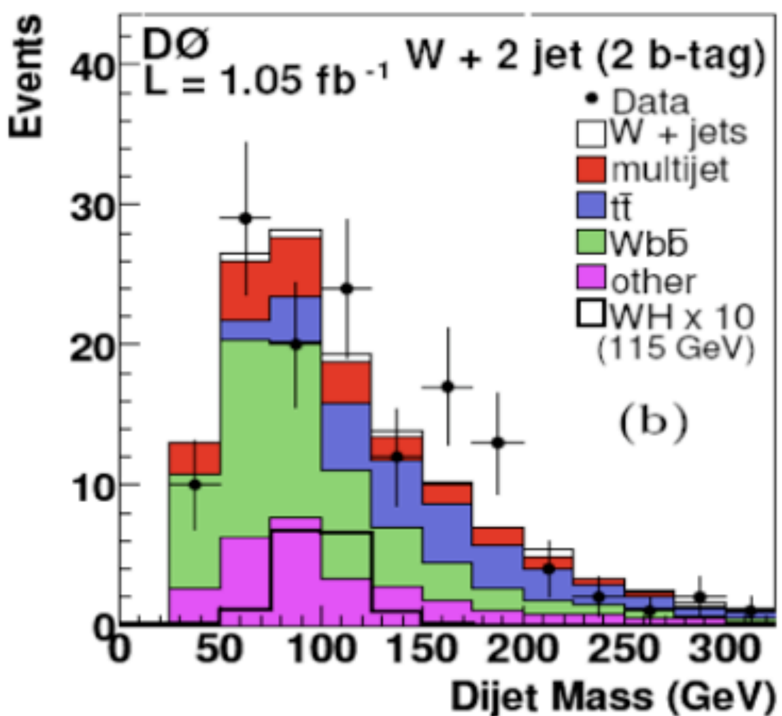
Add single-tight b-tagging to add acceptance



Single-tight tag sample (and not double-loose)

Double-loose tag sample

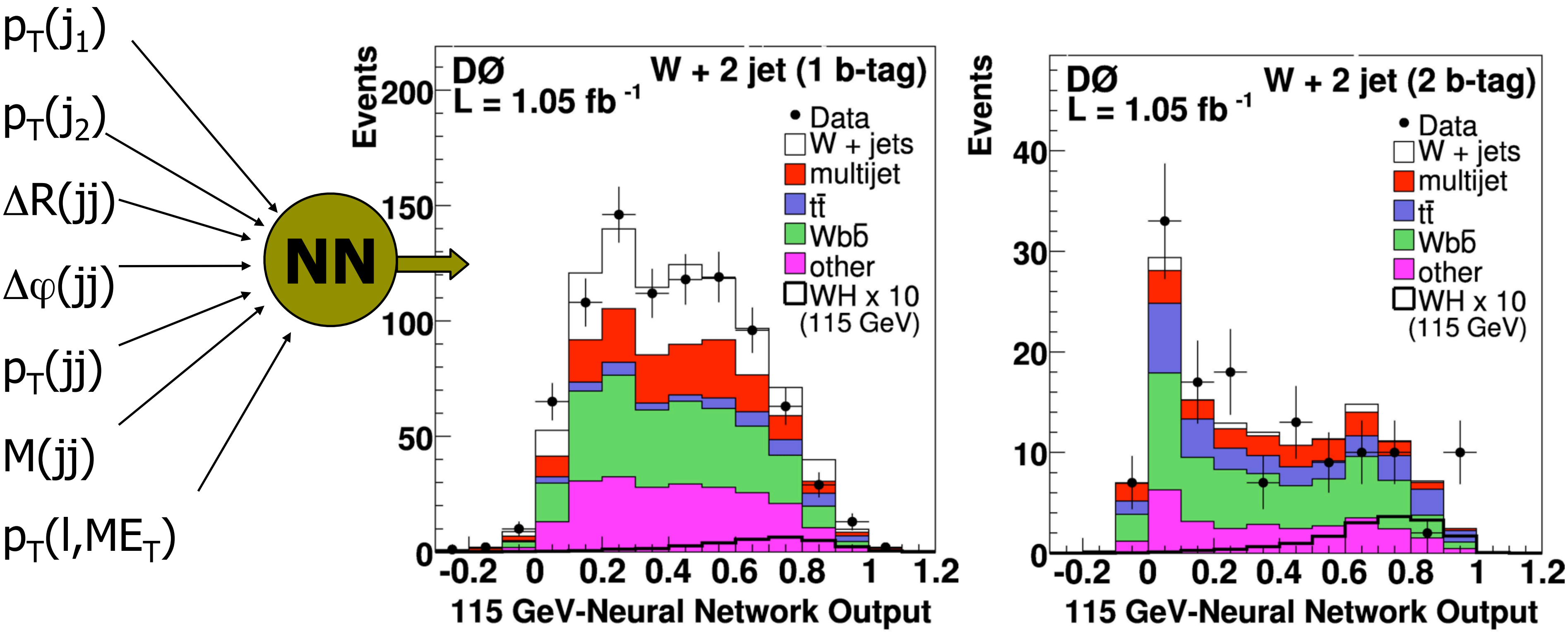




DØ: WH→lν bb (l=e,μ)

Use neural network to separate signal from background

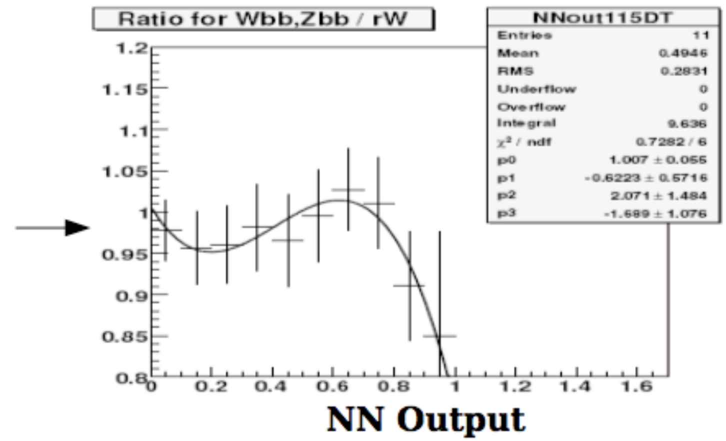
Fit the NN output



DØ: WH→lν bb (l=e,μ)

Use **NN** outputs to set limits

Full treatment of flat and shape systematics



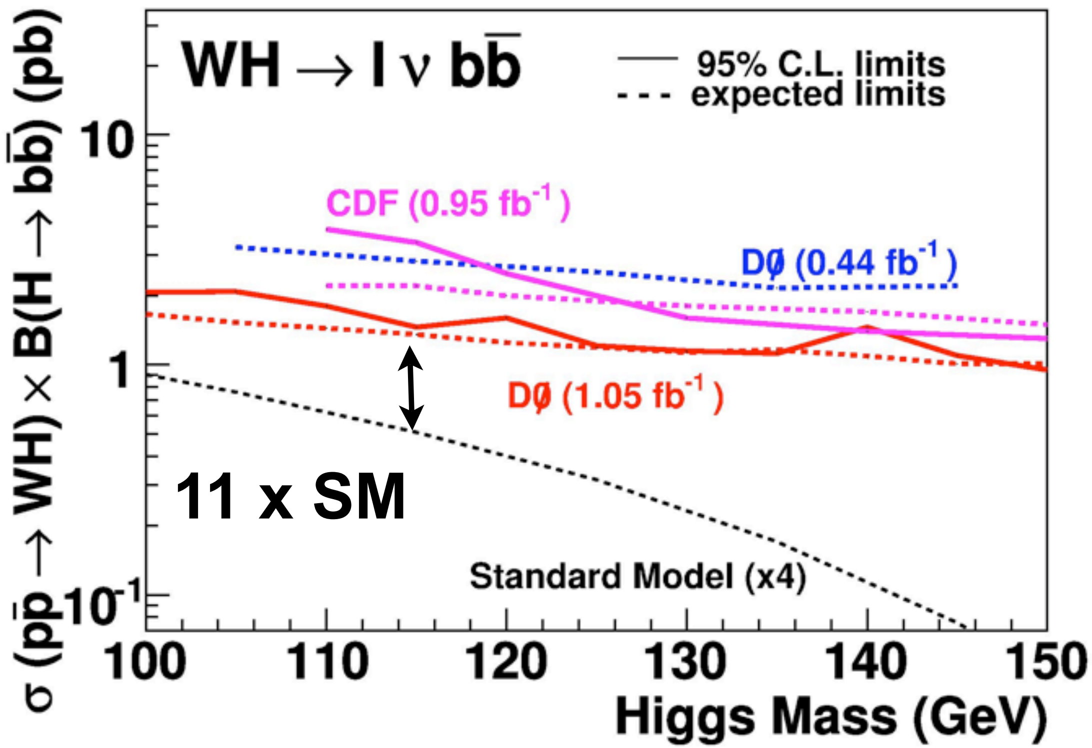
Also take advantage of better acceptance
~2x more sensitive than cut-based

Submitted for publication
arXiv:/0808.1970 [hep-ex]

Currently using **1.7/fb**

Limit is ~8.5x SM at 115 GeV

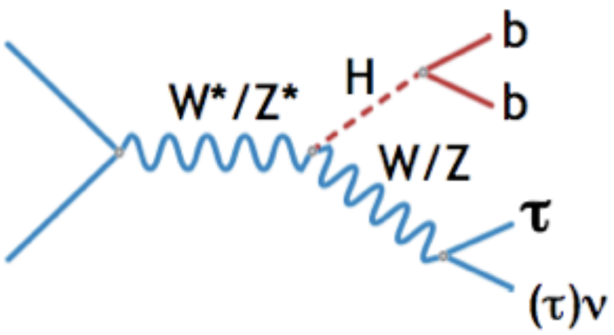
Soon extend larger 3/fb data set

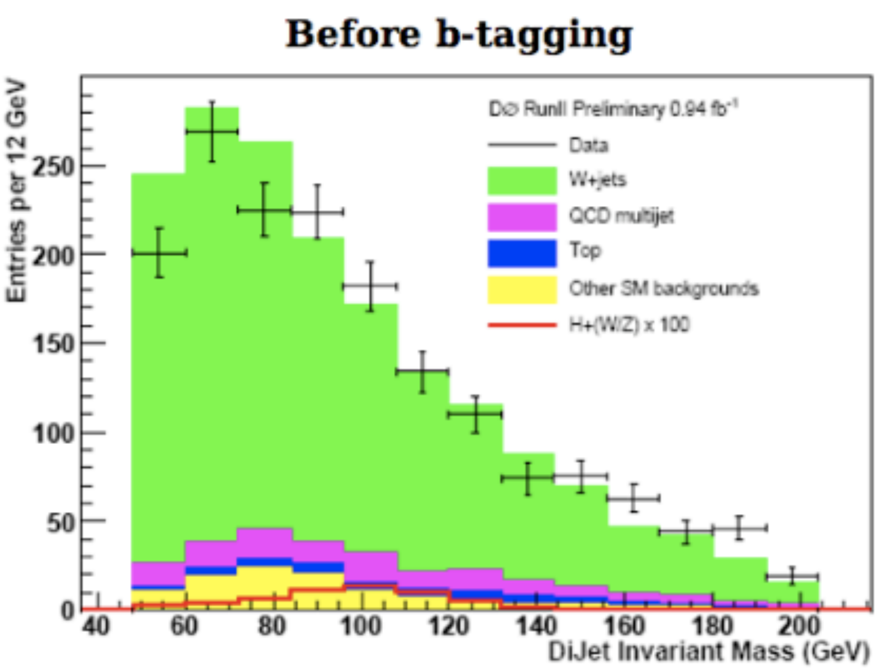


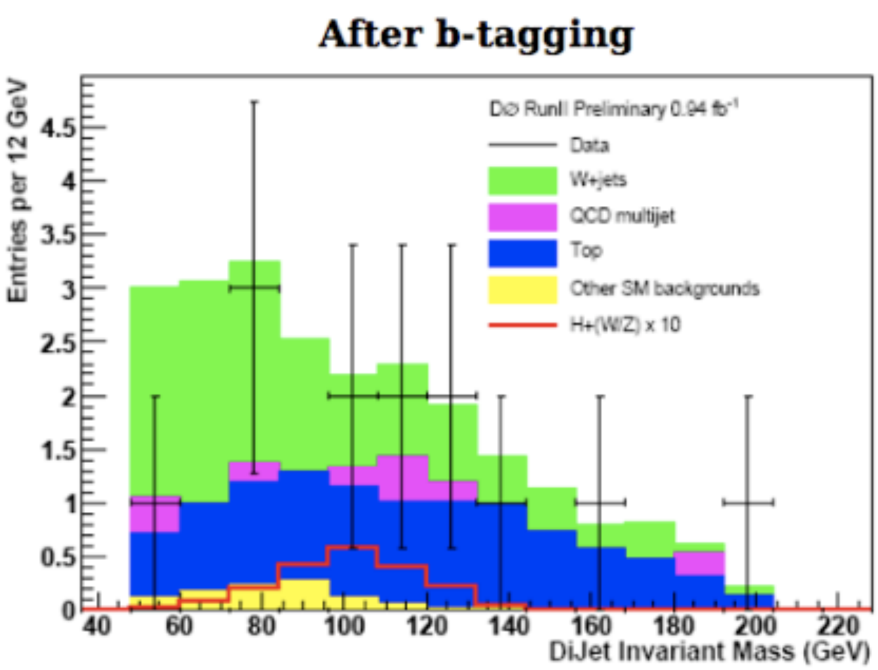
DØ: WH→τν bb

New channel!
1/fb only, trigger on jets + ME_T

Limit ~ 35x SM @115 GeV



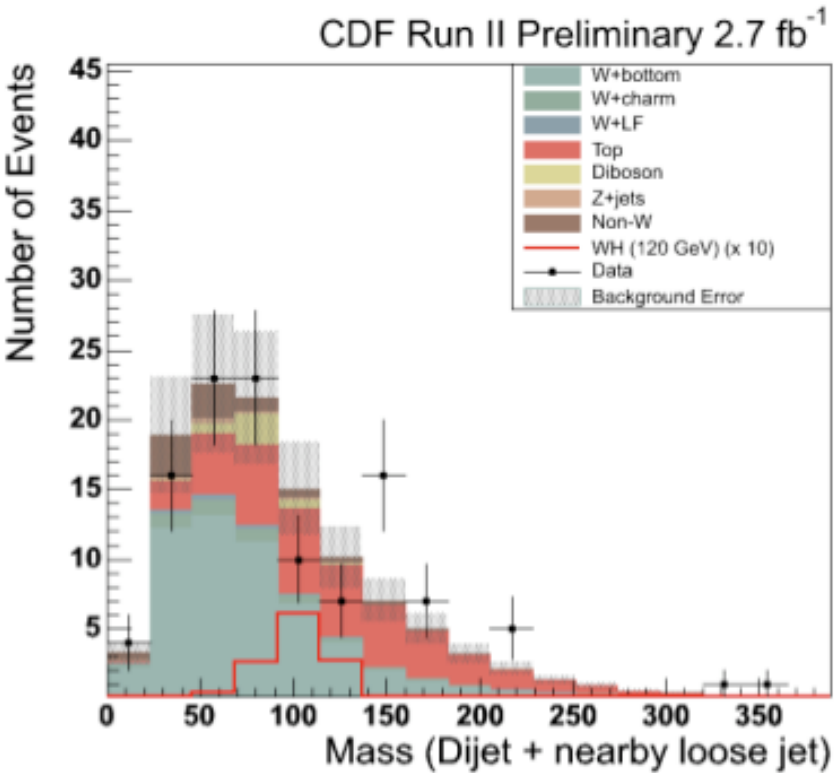




CDF: WH→lν bb (l=e,μ)

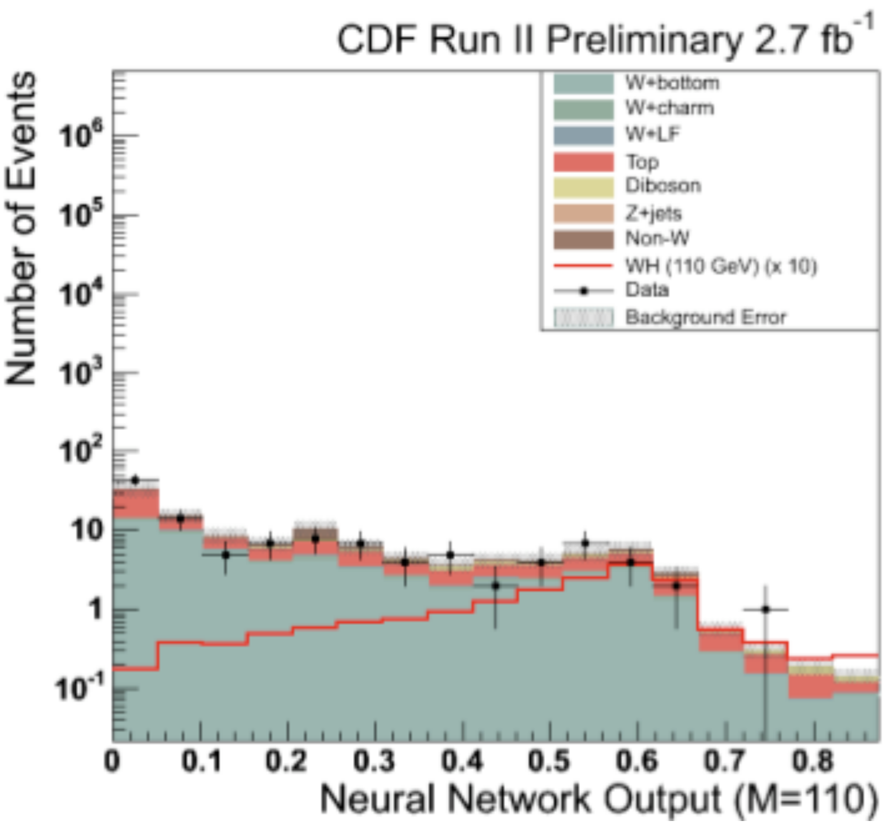
- Selection (l+MET +>=2jets + >= 1 b-tag)
  - one lepton, e or μ, $P_T > 20$ GeV
  - MET = Missing transverse energy > 20 GeV
  - >= 2 jets from bs, $E_T > 15$ GeV
  - Require jet to be b-tagged
- Experience
  - single top search
  - Similar to golden analysis for top quark pairs

    l + MET + >= 4 jets + b-tag
- Basic analysis
  - Use central high Pt lepton trigger
  - Search for resonance in dijet mass

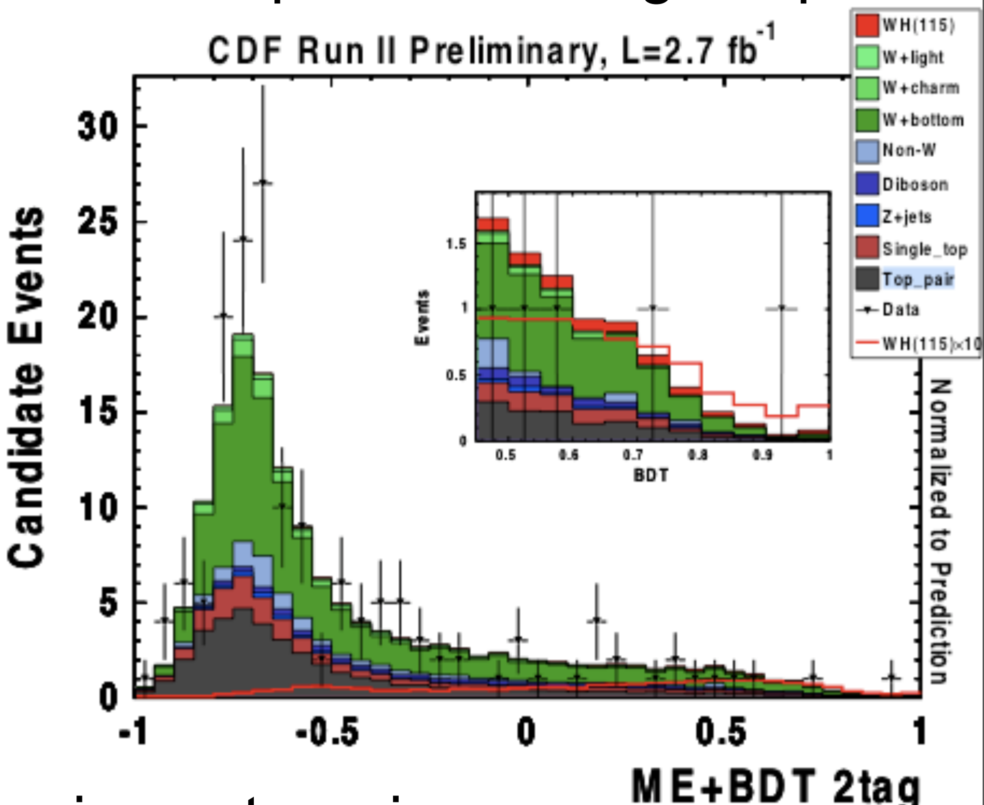


CDF: WH→lν bb (l=e,μ)

NN analysis



BDT+ME Analysis adapted from single top



Two b-tagging categories

m_H = 115 GeV 5.0 * SM (5.8 expected)

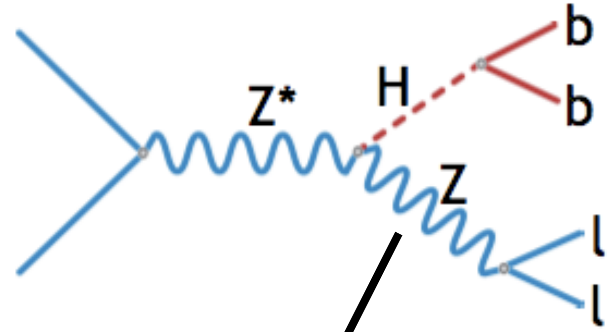
m_H = 115 GeV 5.8 * SM (5.6 expected)

DØ: ZH→ll bb

Less sensitive than WH but fully constrained final state

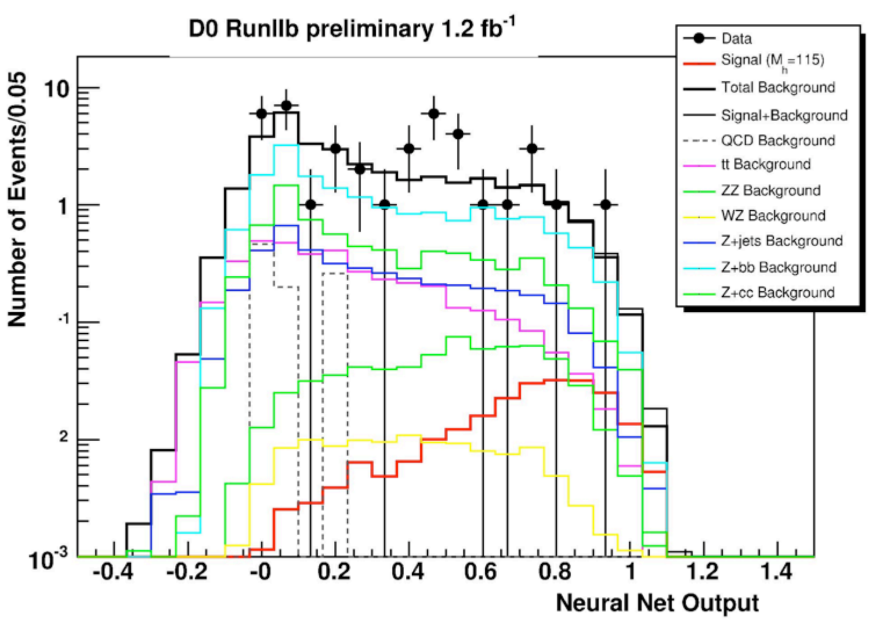
$\sigma_{ZH} < \sigma_{WH}$, Br(Z→ll)<Br(W→lν)

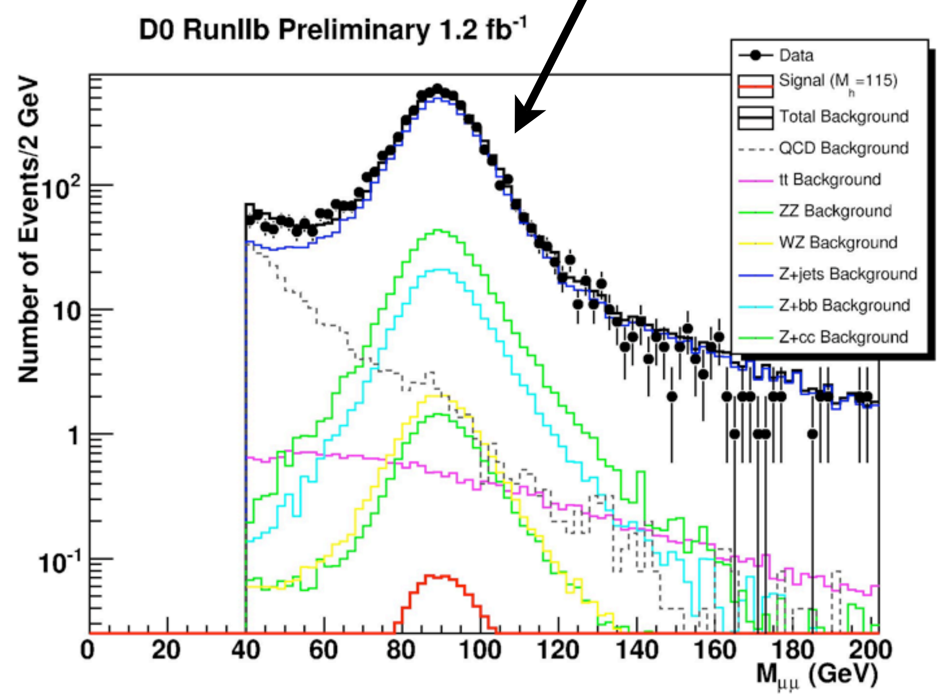
Z→ll provides a nice handle!



Recently updated analyses to 2.3/fb
Neural Network used

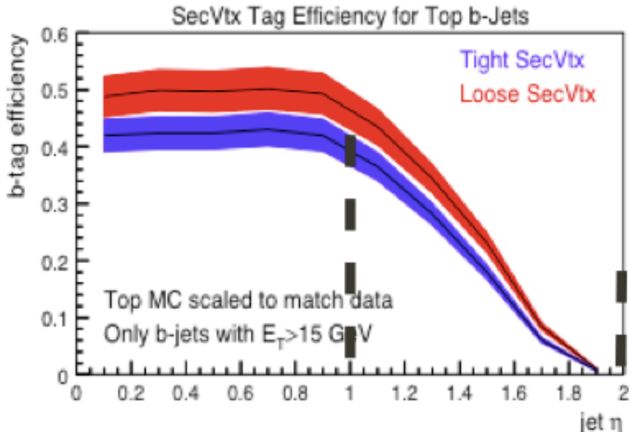
Limit ~ 12x SM @115 GeV

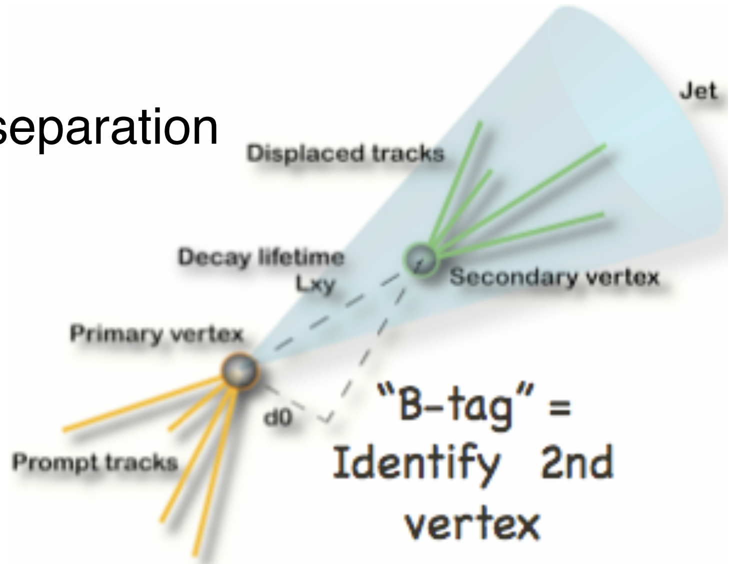




CDF: ZH→ll bb

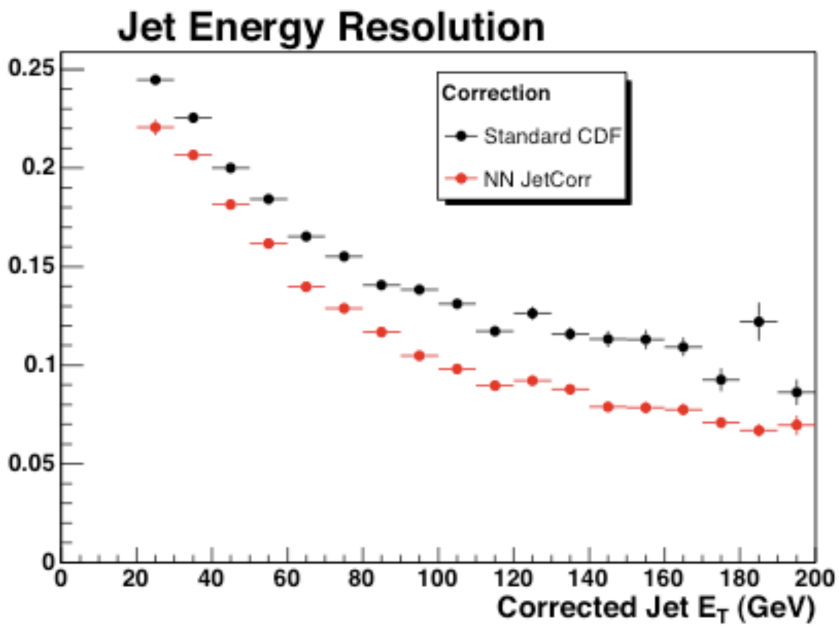
- Baseline analysis
  - Start with inclusive high P_T lepton trigger (Track + ET > 18 GeV)
  - Select two leptons ET > 18, 10 GeV, >= 2 jets ET > 20, 15 GeV
  - Fit dijet mass for an excess from H → bb
- Special techniques
  - Relax lepton requirements
    - Second muon does not require muon chamber confirmation
    - Second electron does not require track when forward in η
    - New: Dilepton categories from "no-track" trigger : two energy deposits in central or forward region
  - Use b-tagging to improve S/sqrt(B)
  - Improve dijet mass resolution
  - Employ Artificial Neural Network for improved separation

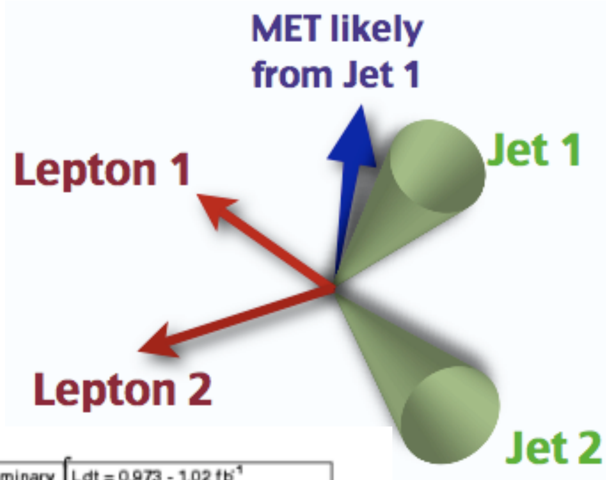




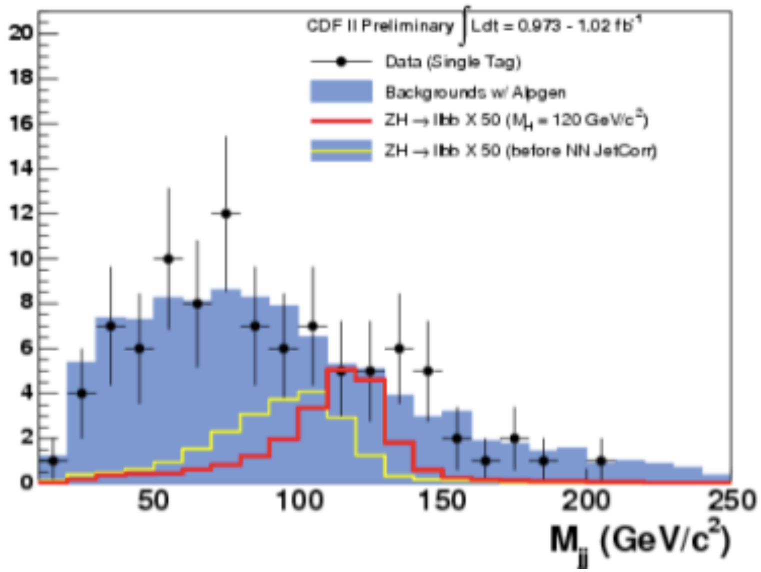
CDF: ZH→ll bb

- Correcting jets according to projection on the MET direction improves Mjj resolution





For events w/ two b tags, dijet resolution improves from 18% to 11%



CDF: ZH→ll bb

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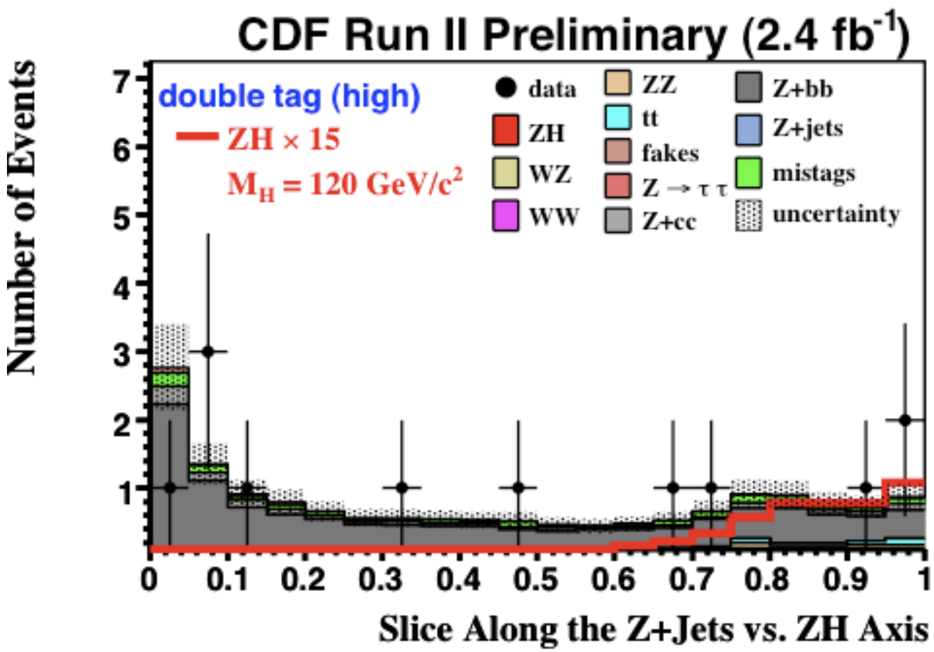
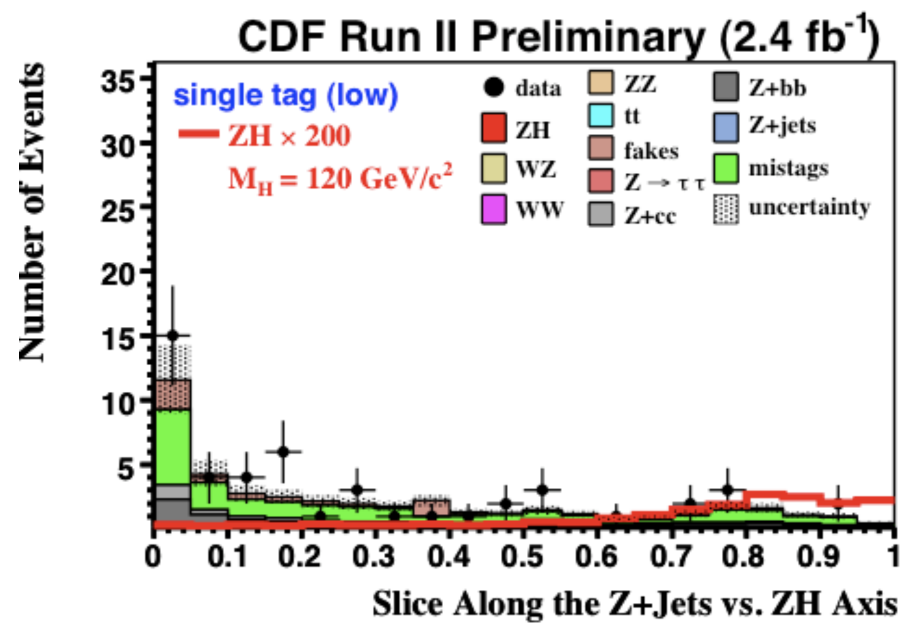
Use a 2D NN to distinguish ZH from ttbar and Z+jets

"low" purity lepton types from no-track trigger improve limit by 10%

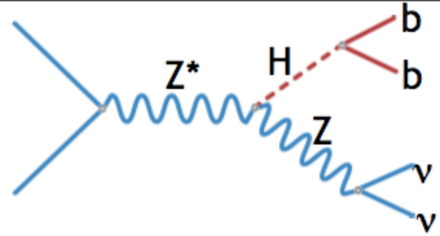




ME analysis in preparation

m_H = 115 GeV 11.8 * SM (11.6 expected)

DØ: ZH →νν bb



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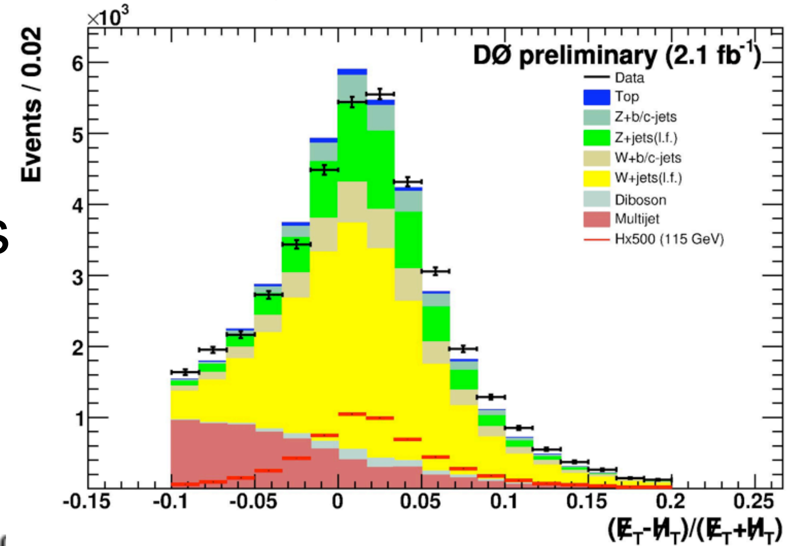
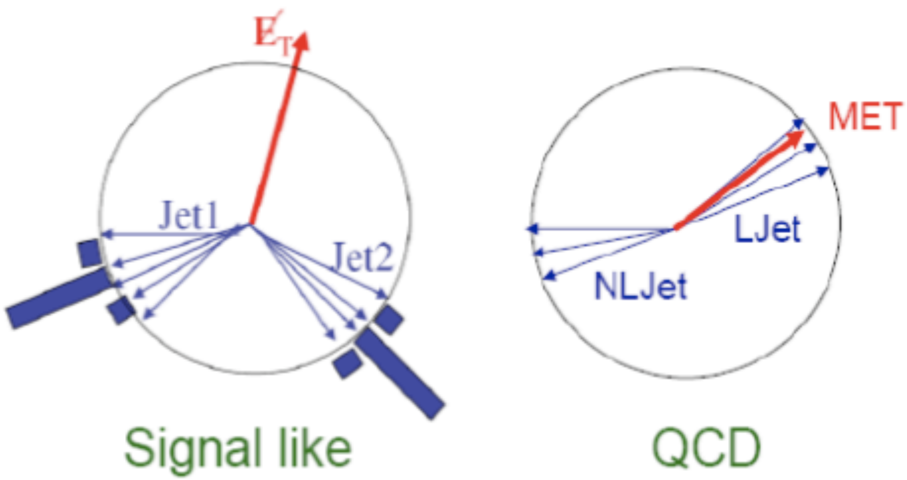
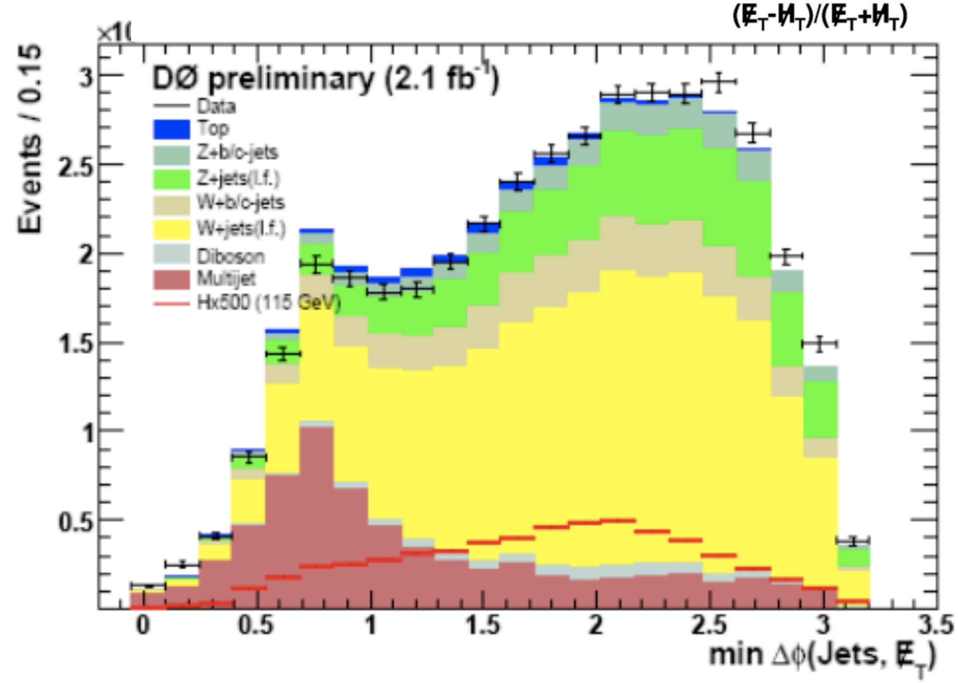
Define 2 missing energy variables

- MHT – measured with jets
- MET – direct from calorimeter cells
- Asymmetry isolates miss-measured jets







DØ: ZH→νν bb

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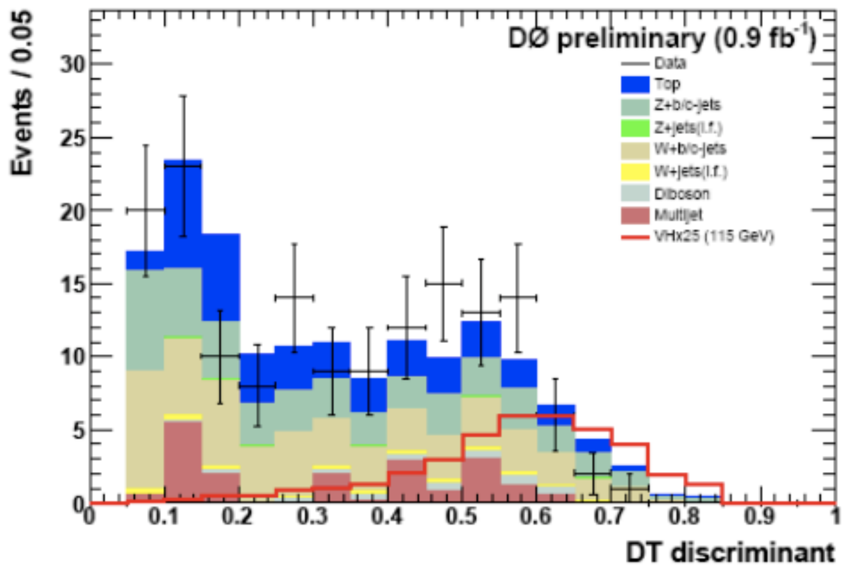
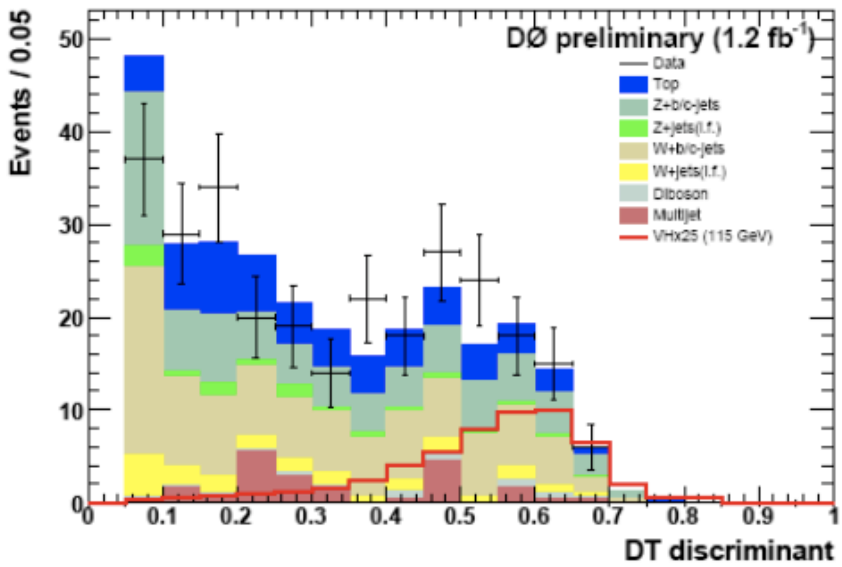
Run IIa



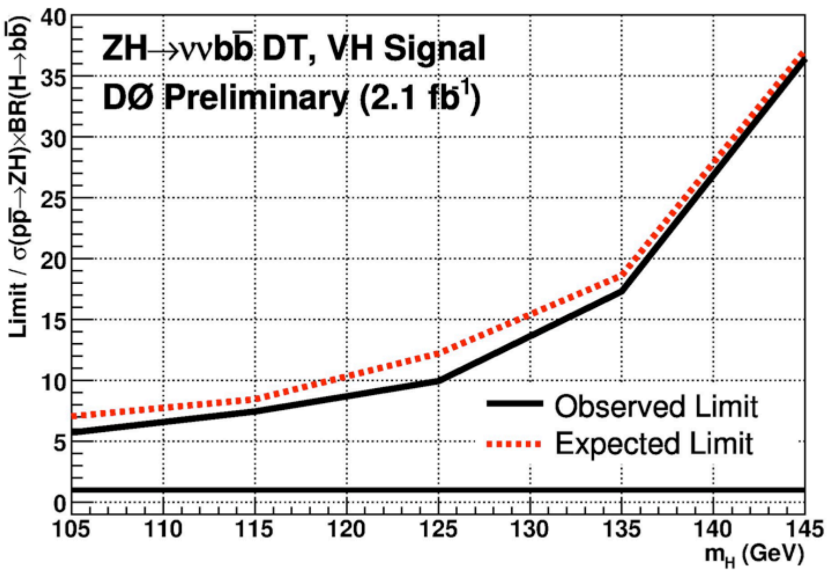
Run IIb (analyzed so far)



Use Boosted Decision Tree to separate signal from background

Also include WH signal when lepton is lost

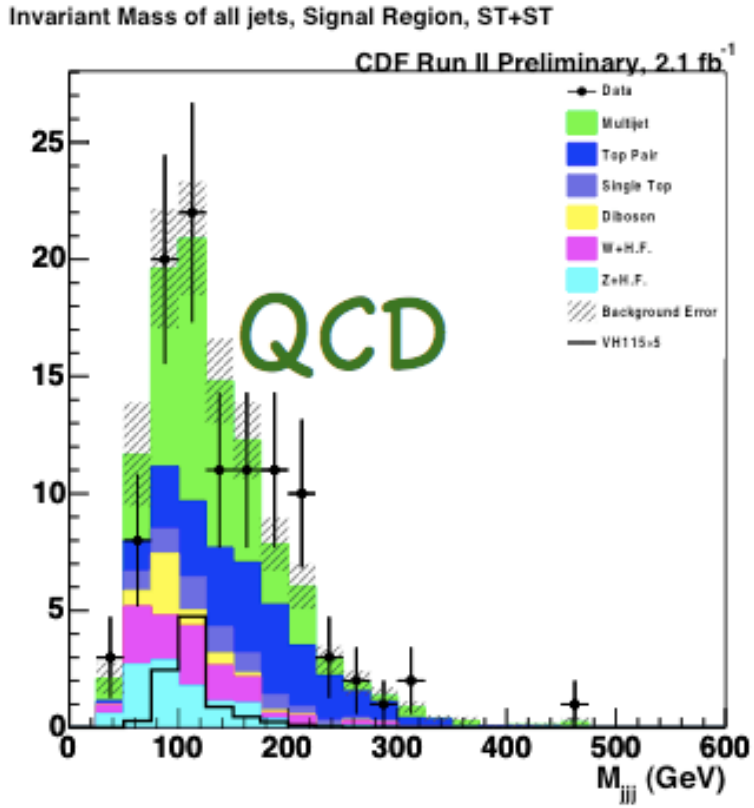
Limit ~8x SM @115 GeV



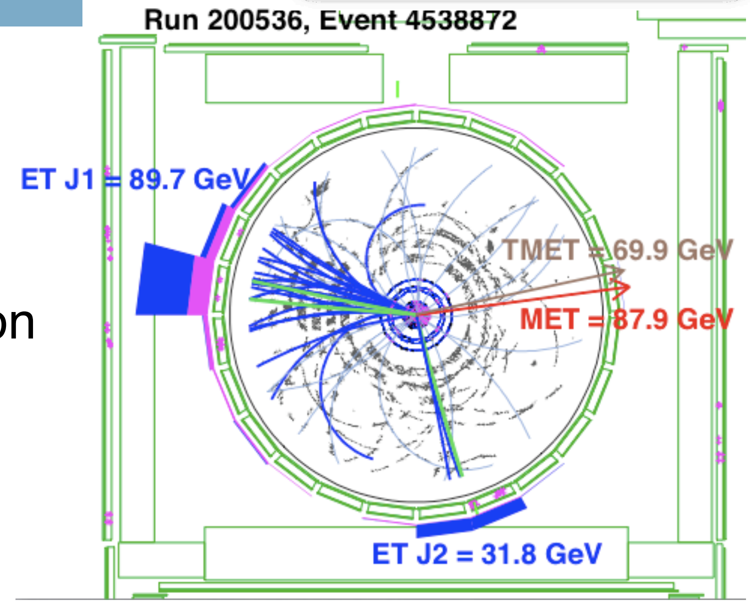
CDF: ZH→νν bb

- Signature
  - MET > 50 GeV, >= 2 jets, >= 1 b-tag
- Large total signal
  - 7.3 Higgs events in 2.1 fb^{-1}
- Baseline analysis
  - Uses MET + multi-jet trigger
  - Fit of Mjj in 2-jet data, >= 1 b-tag
- Challenge
  - Large QCD background from miss-measured jets
  - Peak in Mjj where signal

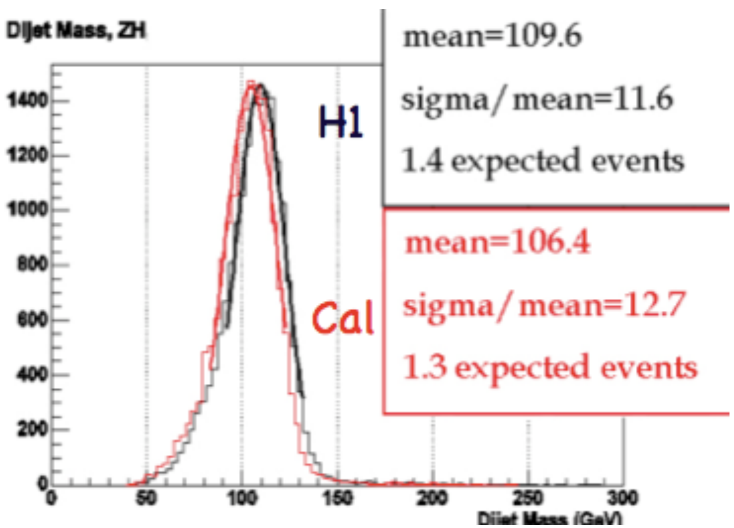
Process	Evts 2.1 fb^{-1} 2 tight b-tags
QCD	80 ± 15
Total Bkg	149 ± 20
ZH Signal	0.8
WH Signal	0.7



CDF: ZH→νν bb



- Using tracking in 2 ways
  - Tracks have excellent momentum resolution
  - 2/3 of particles in jets are charged
- Missing P_T of tracks = TMET
  - Provides confirmation of high MET measured in calorimeter
  - Helpful for reducing QCD
- Improving jet resolution
  - usage of the H1 algorithm 1st time in CDF
  - Correct calorimeter towers with matched higher P_T tracks

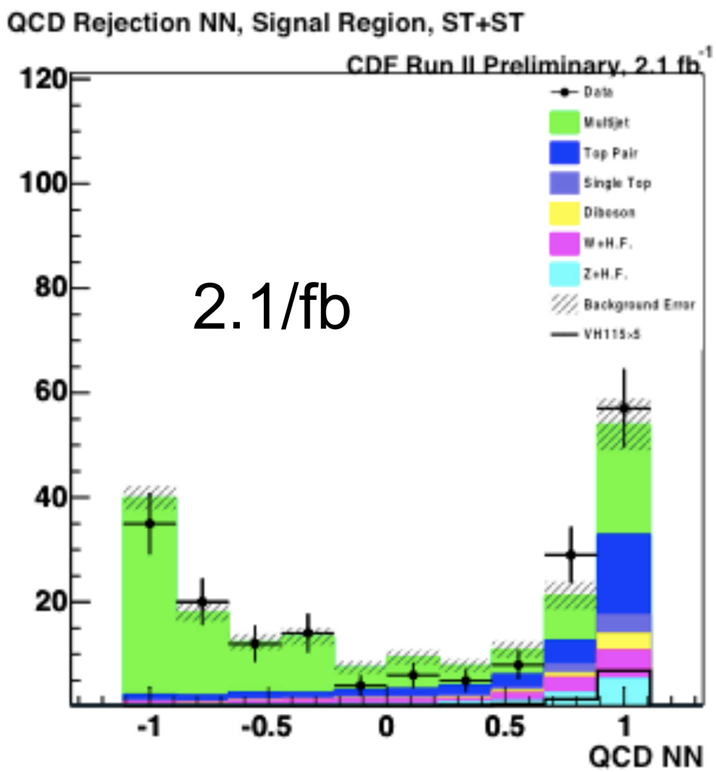


CDF: ZH→vv bb

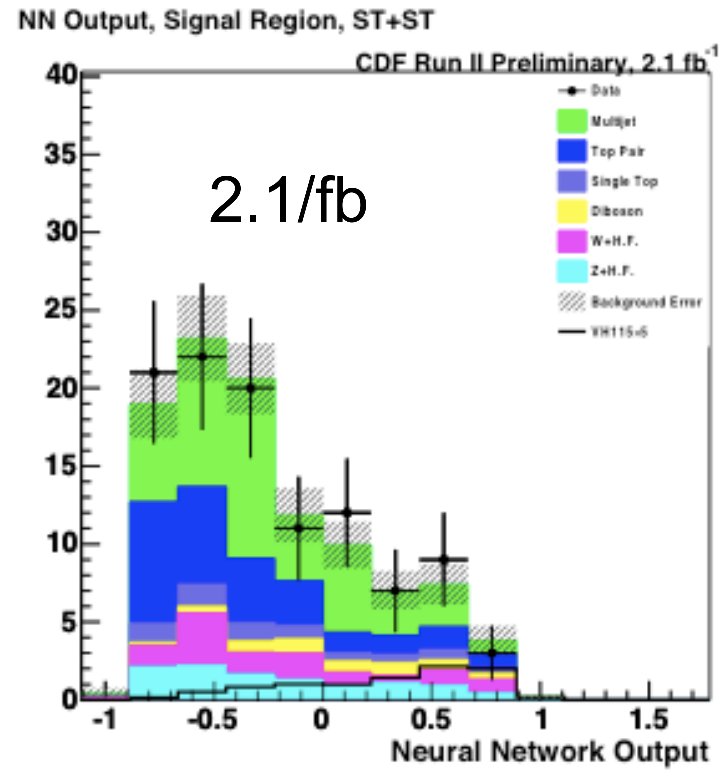
2 separate NNs

3 b-tagging categories are used for the final limit

1. Trained to remove QCD



2. Removes W/Z+jets and top



Cut removes 65% of Multijet and 5% of Signal

m_H = 115 GeV 7.0 * SM (6.3 expected)

DØ: ttH -> tt bb

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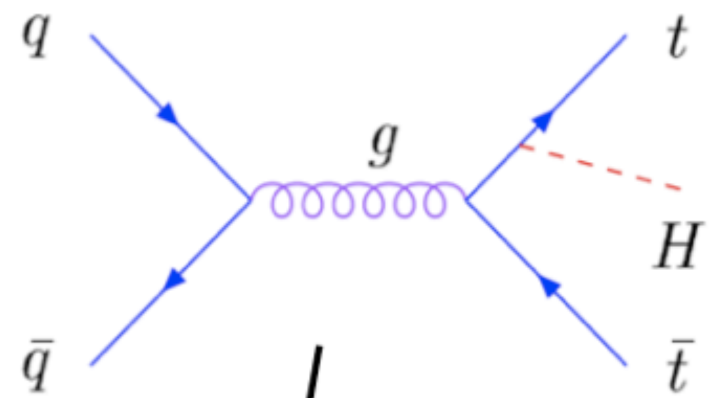
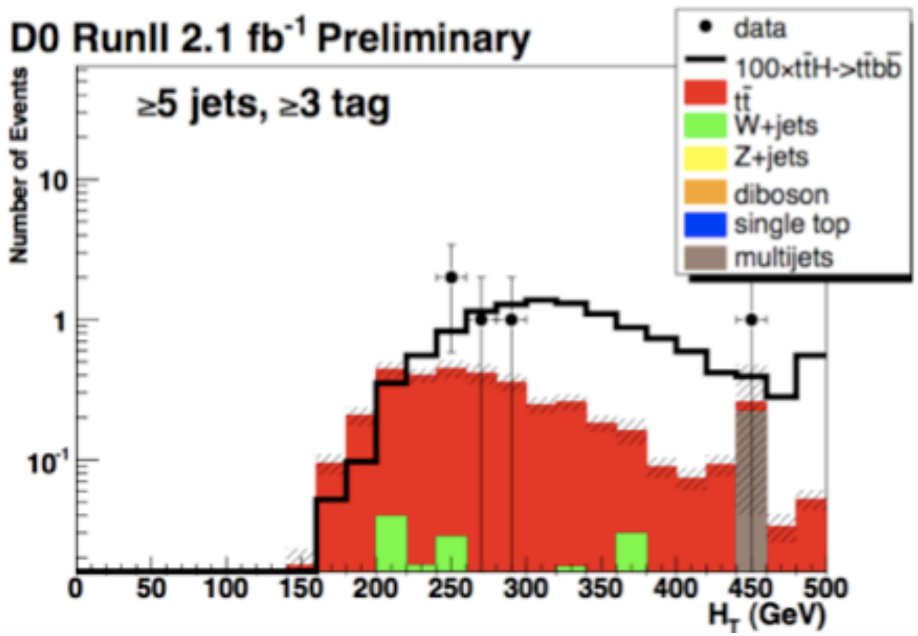
New Channel!

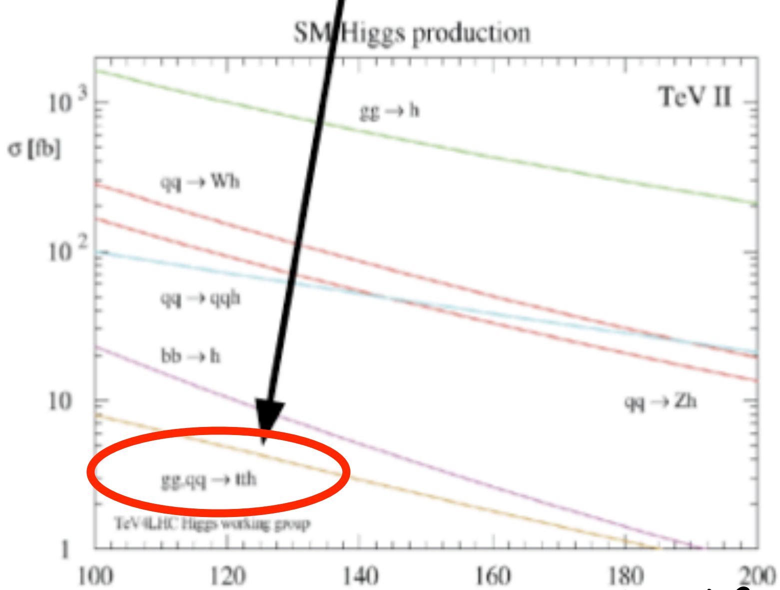
Tiny cross-section, but relatively clean

- Lepton + ME_T + jets
- 1,2, or **at least 3** b-tagged jets

Limit ~ 45x SM @115 GeV







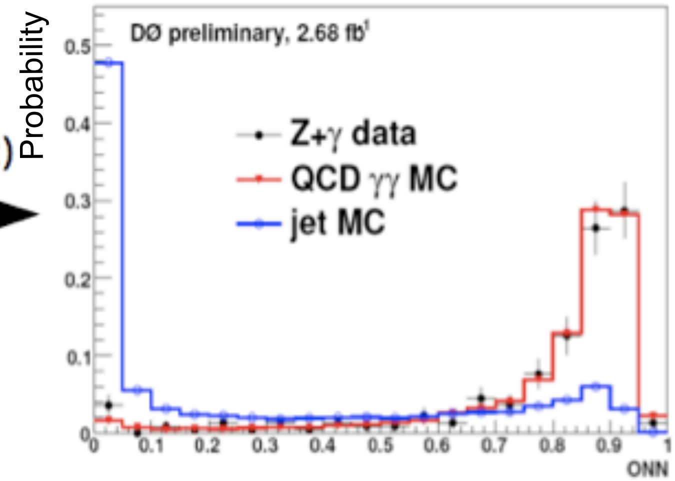
DØ: H -> γγ

Tiny cross-section, but relatively clean

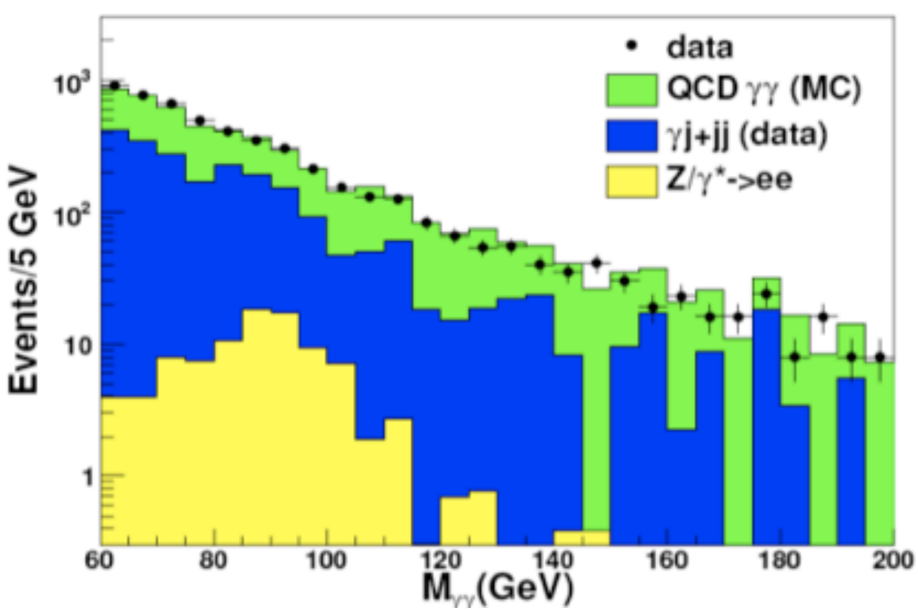
- Can be enhanced by new physics (fermio-phobic)

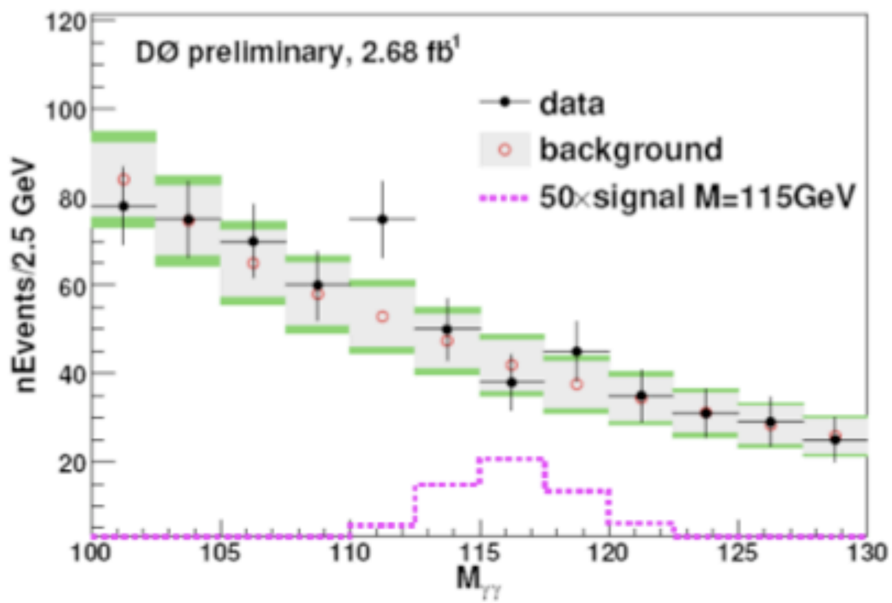
Advanced photon-ID Neural Network

Di-jet and γ+jet measured in data



Limit ~ 23x SM @115 GeV





DØ: WH→WWW*→l±l±' + X (l,l'=e,μ)

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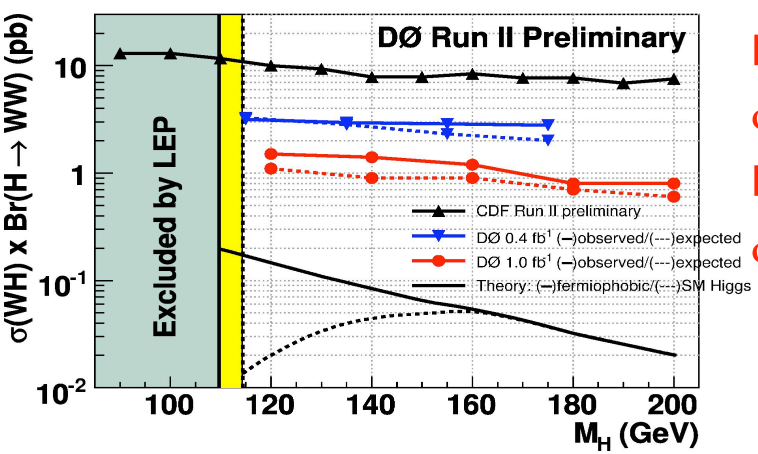
L = 1.0 fb-1

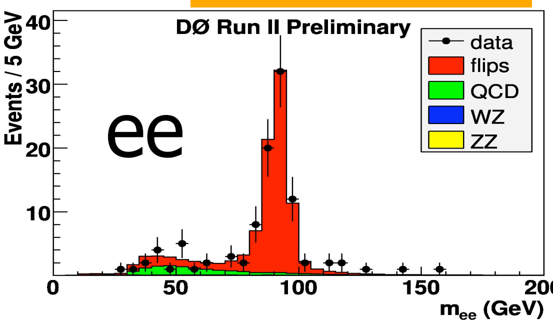
- Selection: same sign e/μ : p_T>15 GeV, |η|< 1.1(e)/2(μ) + track quality cuts
- Low, mostly instrumental background
  - charge flips: compare charge measurements in the tracker vs muon system (μ) / Δφ(tr,EM) (e)
- 3 channels (ee, eμ, μμ)

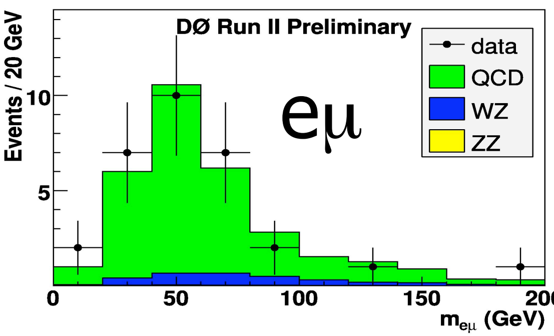
Use 2D likelihood discriminant to separate signal from background (vs instrumental background and vs dibosons)

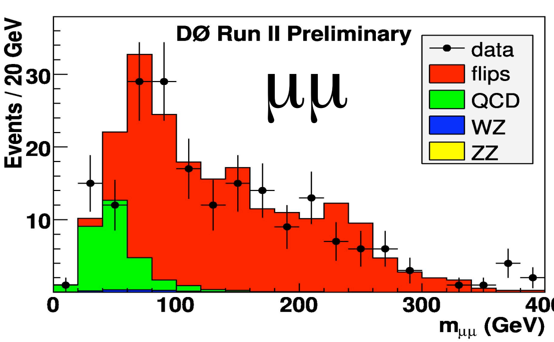
Limit setting: fit the likelihood distribution



Result @M_H=160 GeV:
σ_{95}/SM = 18(exp)/25(obs)
Result @M_H=140 GeV:
σ_{95}/SM = 21(exp)/33(obs)







High Higgs Mass

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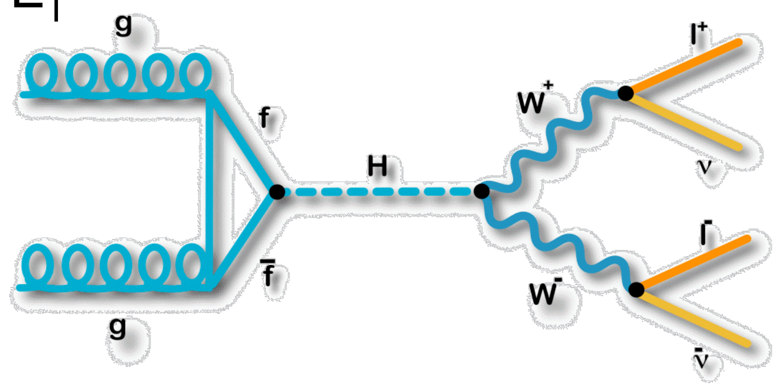
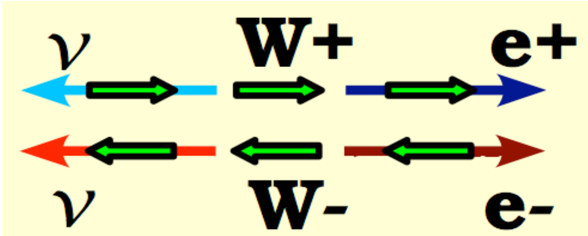
- Main mode: gg -> H -> WW* -> lν l'ν' (l, l'=e,μ)
  - two high p_T isolated leptons, missing E_T
  - three main channels (ee, eμ, μμ)
  - start probing other channels (μτ)
- Can't reconstruct the Higgs mass (escaping ν's)



H->WW* is low background mode

Di-Bosons: main background

- WW* irreducible, separate from the signal based on angular correlation Δϕ(l,l') – Higgs is a scalar !



W+jets and multijets

- need good lepton identification

Z->ττ : specific for eμ channel and channels involving taus

DØ: H -> WW* -> lv l'v'

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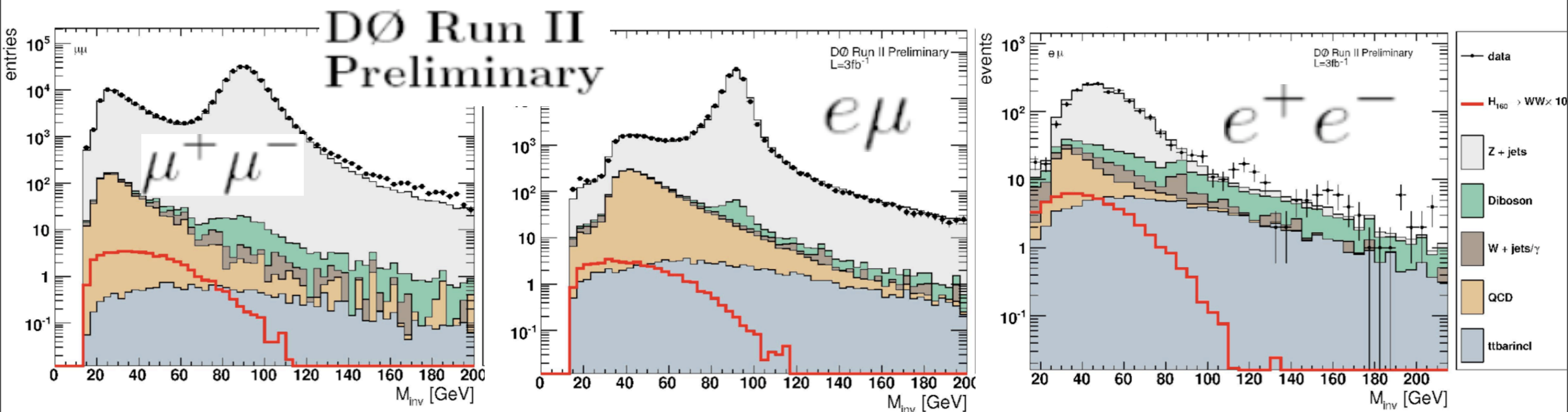


Select di-lepton events, Study and compare to Z→ee, μμ, ττ(→eμ)

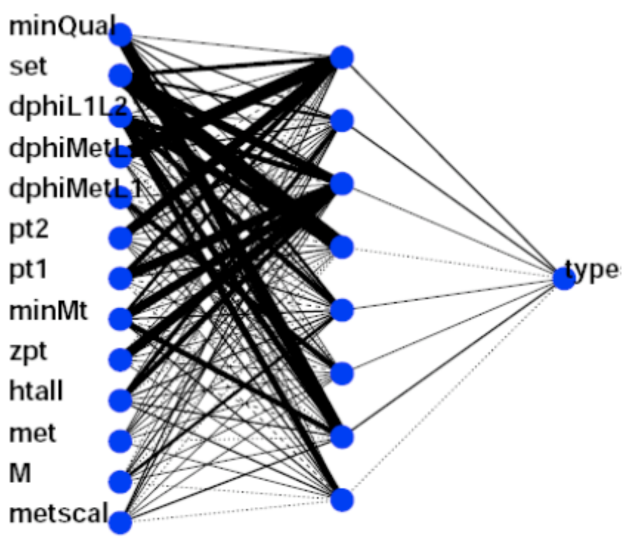
Final state	$e\mu$	ee	$\mu\mu$
Cut 0 Pre-selection	lepton ID, leptons with opposite charge and $p_T^\mu > 10$ GeV and $p_T^e > 15$ GeV invariant mass $M_{\mu\mu} > 15$ GeV $\mu\mu$: $n_{\rm jet} < 2$ for $p_{\rm T}^{\rm jet} > 15$ GeV and $dR(\mu, {\rm jet}) > 0.1$		
Cut 1 Missing Transverse Energy $\not{E}_T$ (GeV)	> 20	> 20	> 20
Cut 2 $\not{E}_T^{\rm Scaled}$	> 7	> 6	> 5
Cut 3 M_T^{min} $(\ell, \not{E}_T)$ (GeV)	> 20	> 30	> 20
Cut 4 $\Delta\phi(\mu, \mu)$	< 2.0	< 2.0	< 2.5

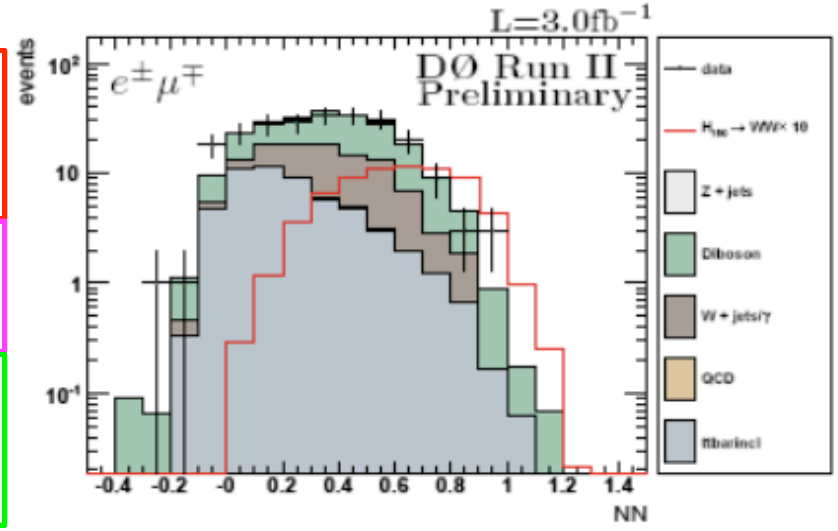
Philosophy: cut loose and use multivariate method

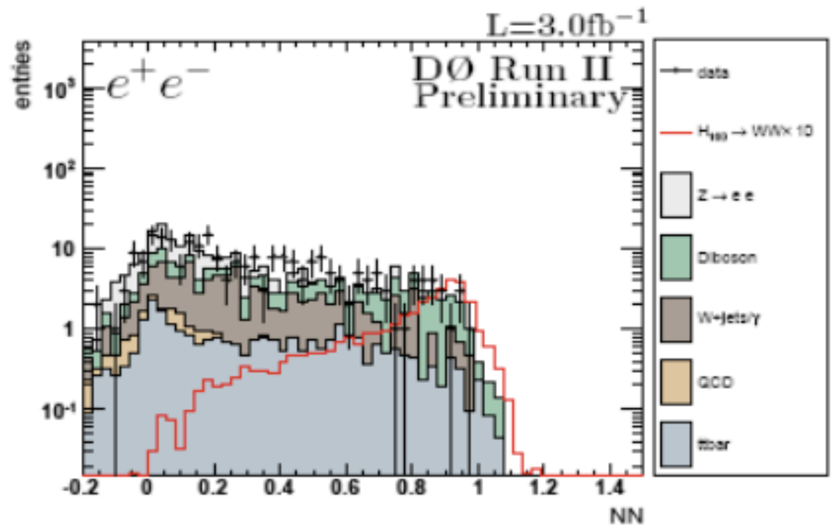
DØ: Multivariate: Neural Net (NN)

NN Analysis Variables

p_T of leading lepton	$p_T(\ell_1)$	Object
p_T of trailing lepton	$p_T(\ell_2)$	
Minimum of both lepton qualities	$\min(q_{\ell 1}, q_{\ell 2})$	
Vector sum of the transverse momenta of the leptons:	$p_T(\ell_1) + p_T(\ell_2)$	
Scalar sum of the transverse momenta of the jets:	$H_T = \sum_i \lvert p_T(\text{jet}_i)\rvert$	
Invariant mass of both leptons	$M_{\text{inv}}(\ell_1, \ell_2)$	Event
Minimal transverse mass of one lepton and $\not{E}_T$	M_T^{min}	
Missing transverse energy	$\not{E}_T$	
Scalar transverse energy	E_T^{scalar}	
Azimuthal angle between selected leptons	$\Delta\phi(\ell_1, \ell_2)$	Topo
Solid angle between selected leptons ($e\mu$ only)	$\Theta\phi(\ell_1, \ell_2)$	
ΔR between selected leptons ($e\mu$ only)	$\Delta R(\ell_1, \ell_2)$	
Azimuthal angle between leading lepton and $\not{E}_T$	$\Delta\phi(\not{E}_T, \ell_1)$	
Azimuthal angle between trailing lepton and $\not{E}_T$	$\Delta\phi(\not{E}_T, \ell_2)$	







NN trained for each Higgs test mass in 5 GeV steps, for each channel (all backgrounds). Output of NN distribution used to set limits

DØ: Multivariate: Neural Net (NN)

NN Analysis Variables

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	Vector sum of the transverse momenta of the leptons:	$p_T(\ell_1) + p_T(\ell_2)$
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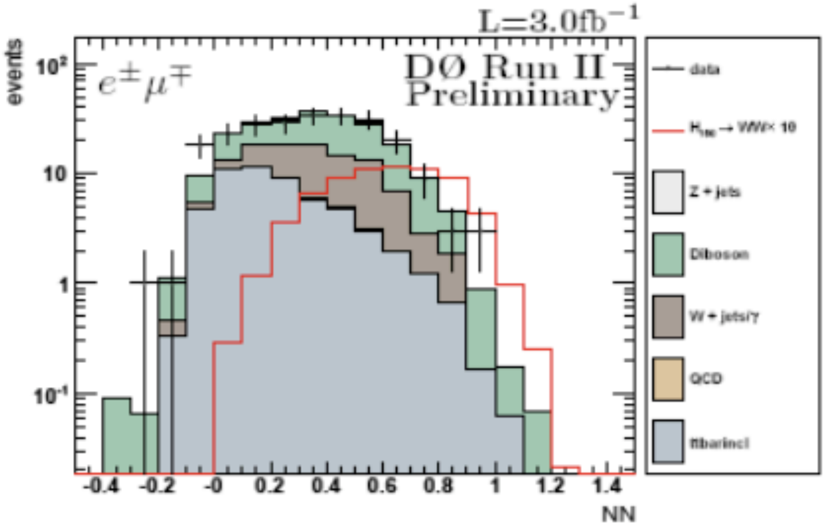
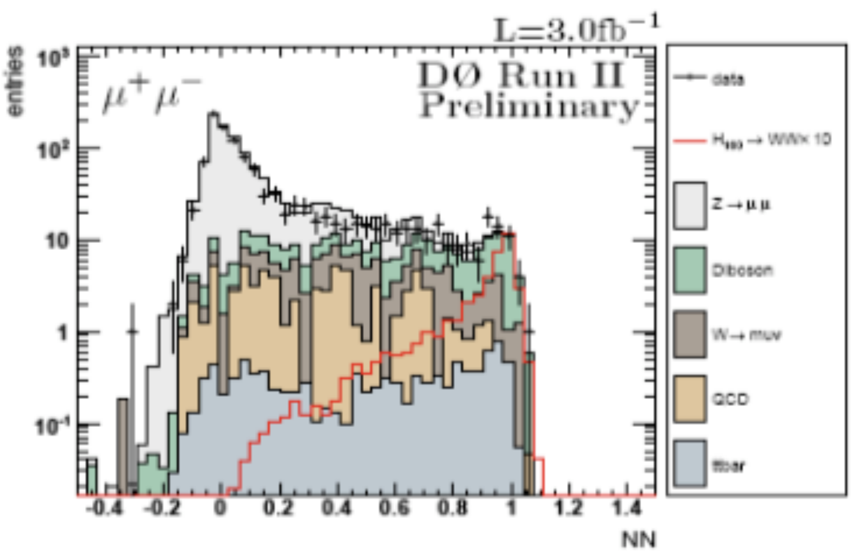
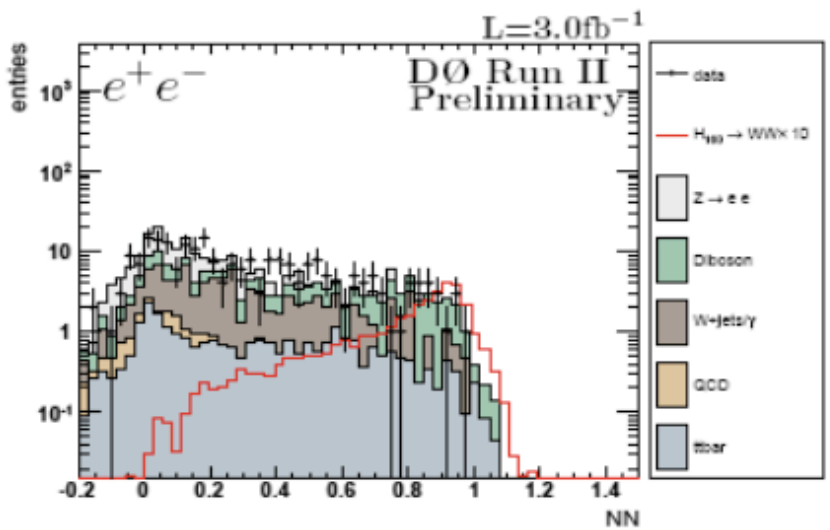
Event	Invariant mass of both leptons	$M_{\mathrm{inv}}(\ell_1, \ell_2)$
	Minimal transverse mass of one lepton and $\not{E}_T$	M_T^{min}
	Missing transverse energy	$\not{E}_T$
	Scalar transverse energy	E_T^{scalar}
Topo	Azimuthal angle between selected leptons	$\Delta\phi(\ell_1, \ell_2)$
	Solid angle between selected leptons ($e\mu$ only)	$\Theta\phi(\ell_1, \ell_2)$
	ΔR between selected leptons ($e\mu$ only)	$\Delta R(\ell_1, \ell_2)$
	Azimuthal angle between leading lepton and $\not{E}_T$	$\Delta\phi(\not{E}_T, \ell_1)$
	Azimuthal angle between trailing lepton and $\not{E}_T$	$\Delta\phi(\not{E}_T, \ell_2)$







NN trained for each Higgs test mass in 5 GeV steps, for each channel (all backgrounds).
Output of NN distribution used to set limits

DØ: Systematic Uncertainties

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Two types of systematic uncertainties:

– Type I: (flat systematic uncertainties)
  - Related to the overall normalization and efficiencies of the various contributing physical processes
  - Estimated by propagation through the cut based analysis selection and calculation of the relative fractional uncertainty

– Lepton efficiencies (2-8%)
– Lepton momentum scale (2%)
– Theoretical cross-sections (7-10%)
– Jet->lepton fake rate (10%)
– QCD normalization (30%)

– Type II: (shape systematic uncertainties)
  - Uncertainties which impact the multivariate classification of the events
  - Estimated by propagation through the cut based analysis selection and deriving fractional shape of NN output

– Jet efficiency (6%)
– Jet energy scale (7%)
– Jet energy resolution (3%)
– Inst. luminosity (0.3%)
– Interaction region (1%)
– Boson p_T (5%)

DØ: Systematic Uncertainties

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Two types of systematic uncertainties:

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– Type II: (shape systematic uncertainties)
  - Uncertainties which impact the multivariate classification of the events
  - Estimated by propagation through the cut based analysis selection and deriving fractional shape of NN output

– Lepton efficiencies (2-8%)
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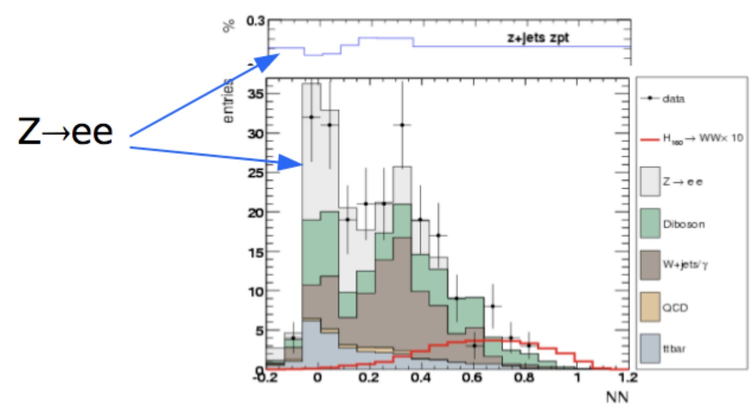
Z-P_T Systematics



DØ: All channels combined

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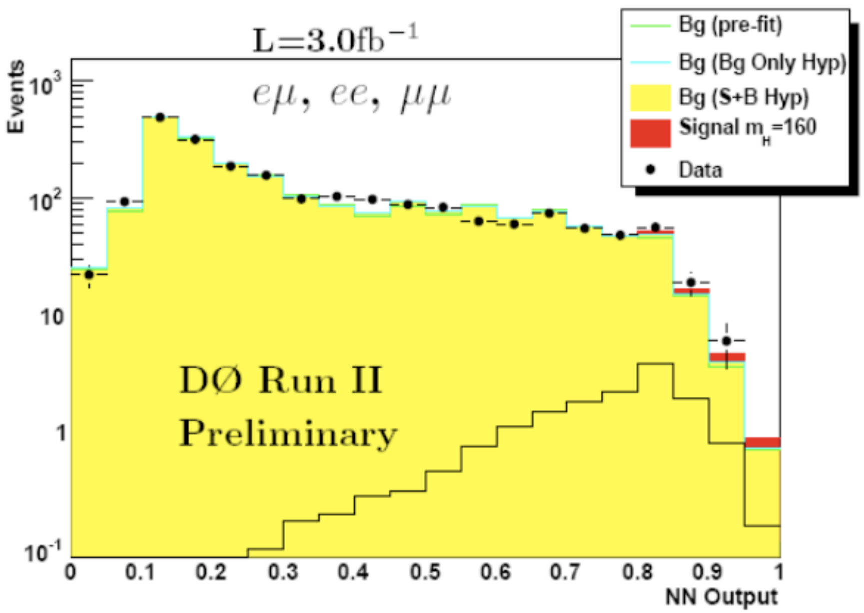
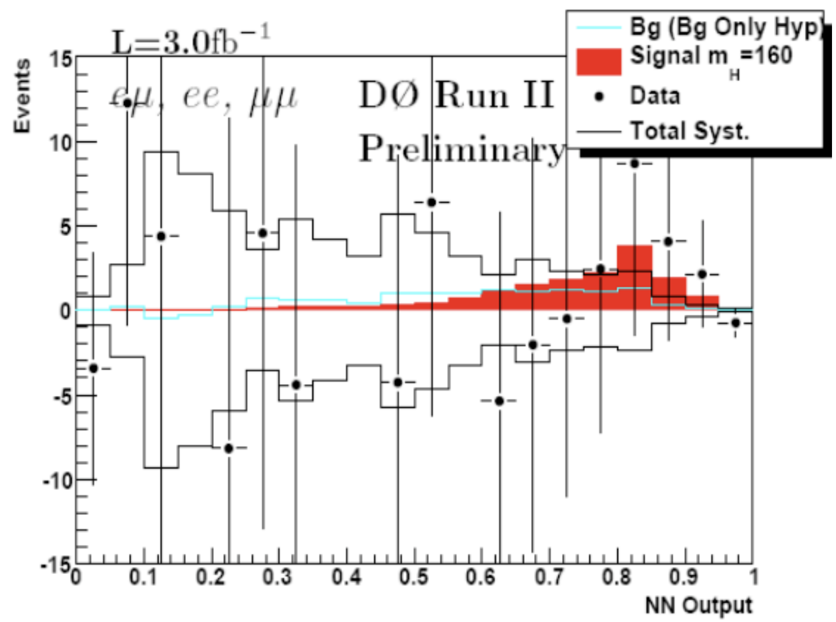
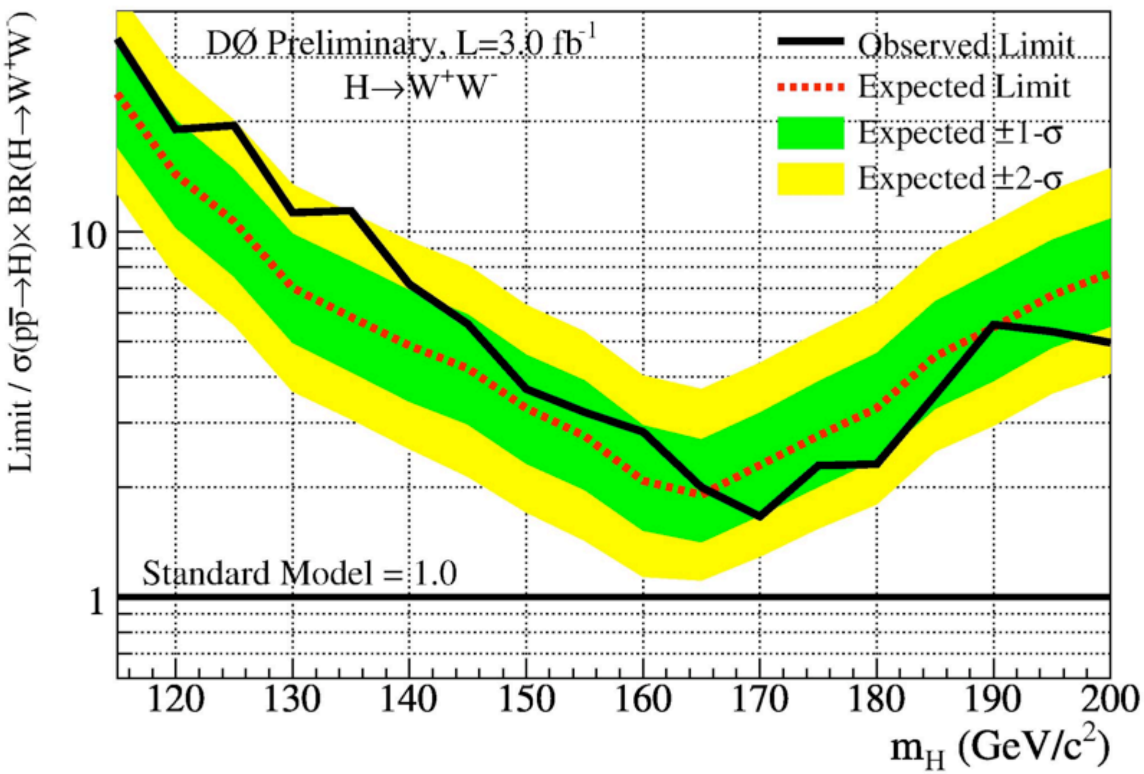
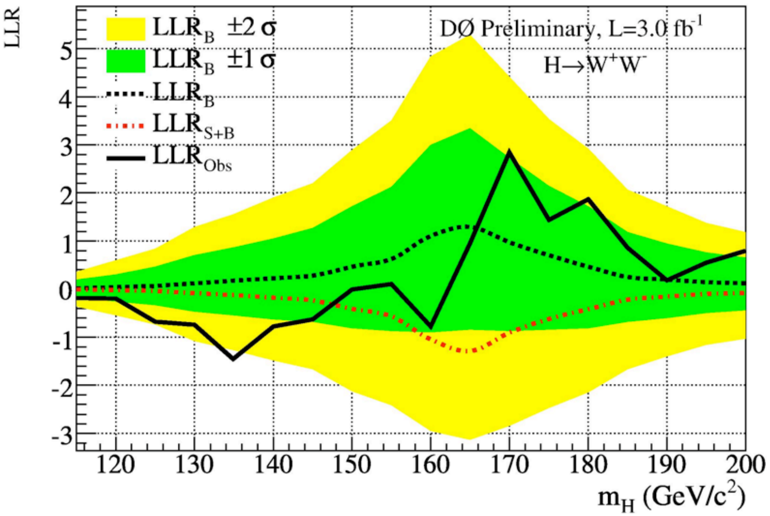
	$e\mu$ pre-selection	$e\mu$ final	ee pre-selection	ee final	$\mu\mu$ pre-selection	$\mu\mu$ final
$Z \to ee$	209.0 ± 3.0	0.72 ± 0.16	160463 ± 264	73.6 ± 5.1	–	–
$Z \to \mu\mu$	151.1 ± 0.6	2.14 ± 0.06	-	-	256432 ± 230	957 ± 14
$Z \to \tau\tau$	2312 ± 2	2.45 ± 0.05	835 ± 8	1.0 ± 0.3	1968 ± 11	5.5 ± 0.5
$t\bar{t}$	187.5 ± 0.2	54.2 ± 0.1	96.9 ± 0.2	28.5 ± 0.1	19.4 ± 0.1	10.1 ± 0.1
$W + jets$	163.4 ± 5.3	60.1 ± 3.2	174 ± 7	72.0 ± 4.3	149 ± 3	85.8 ± 2.1
WW	285.6 ± 0.1	108.0 ± 0.1	127.5 ± 0.4	45.7 ± 0.2	162.9 ± 0.5	91.3 ± 0.3
WZ	14.8 ± 0.1	4.9 ± 0.1	89.6 ± 0.8	7.6 ± 0.2	51.6 ± 0.5	16.2 ± 0.3
ZZ	3.47 ± 0.01	0.49 ± 0.01	73.5 ± 0.3	5.4 ± 0.1	43.0 ± 0.2	13.5 ± 0.1
Multi-jet	190 ± 168	1 ± 8	2322 ± 193	4.3 ± 8.3	945 ± 31	63.6 ± 8.0
Signal ($m_H = 160$ GeV)	9.0 ± 0.1	6.9 ± 0.1	4.40 ± 0.01	3.49 ± 0.01	4.7 ± 0.1	4.09 ± 0.06
Total Background	3516 ± 168	234 ± 9	164181 ± 327	238 ± 11	259770 ± 232	1242 ± 16
Data	3706	234	164290	236	263743	1147





DØ: H→WW* Limits





- For m_H=165, expected (observed) 95% CL relative to σ_{SM} = 1.9 (2.0)

- Combine results using CLS method with a log-likelihood ratio test-statistic.
- Systematics are properly correlated between channels where appropriate.
- Systematic effects are minimized using fits to data in background-rich regions.

CDF: H->WW Analysis

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m_H=160GeV

Dedicated analysis in different Jet Bins

Process	$H \rightarrow WW$ + >=2j Evts, $\mathcal{L}$ = 3fb^{-1}
$gg \rightarrow H \rightarrow WW$	1.52 ± 0.26
$WH \rightarrow WWW$	1.18 ± 0.16
$ZH \rightarrow WWW$	0.59 ± 0.08
V.B.F. $H \rightarrow WW$	0.61 ± 0.1

# jets	$H\rightarrow WW$ events	Total Bkg events	% WW	% Drell-Yan	% $t\bar{t}$	% fakes & conversions
0	8	540	52	12	0.2	30
1	5	230	32	31	11	16
2	4	130	12	22	54	8

CDF: H->WW Analysis

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- 0 Jet
  - WW background (distinguished by spin correlations)
  - Fake and conversions (difficult to model, require data validation, Control region using same sign)

CDF: H->WW Analysis

- 0 Jet
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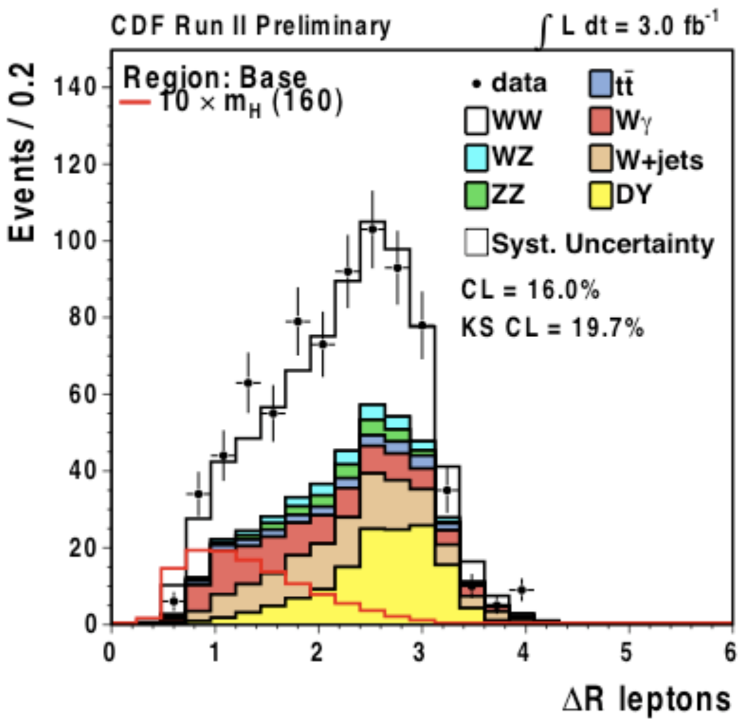

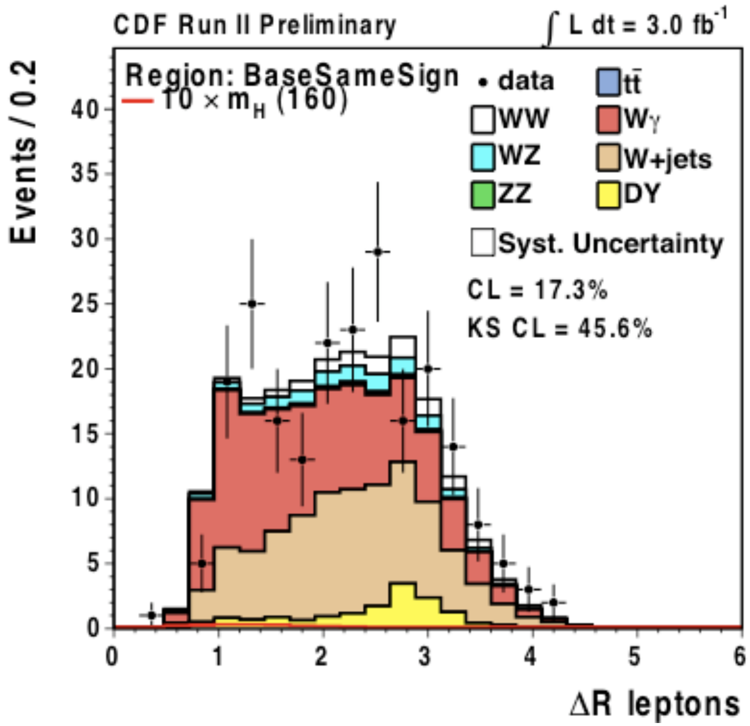

CDF: H->WW Analysis

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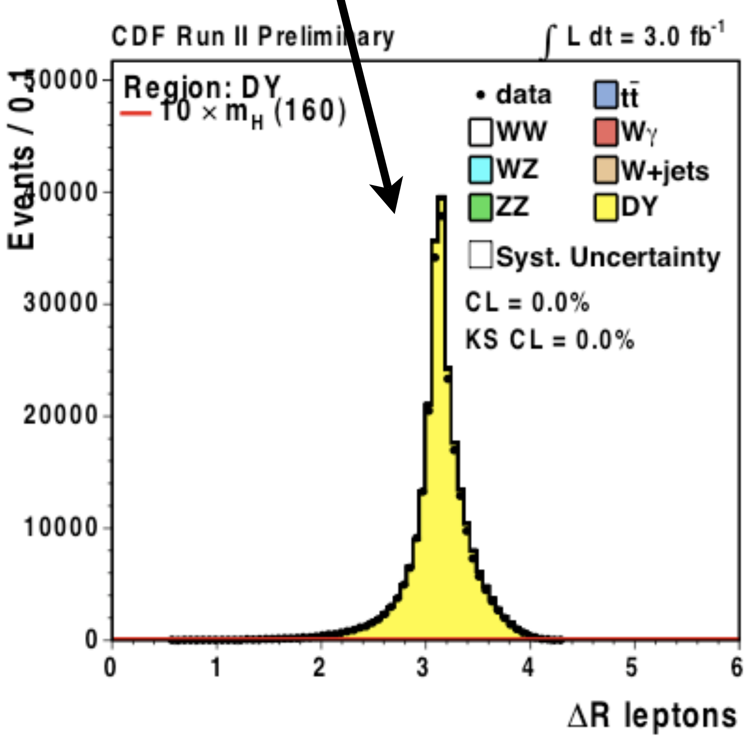
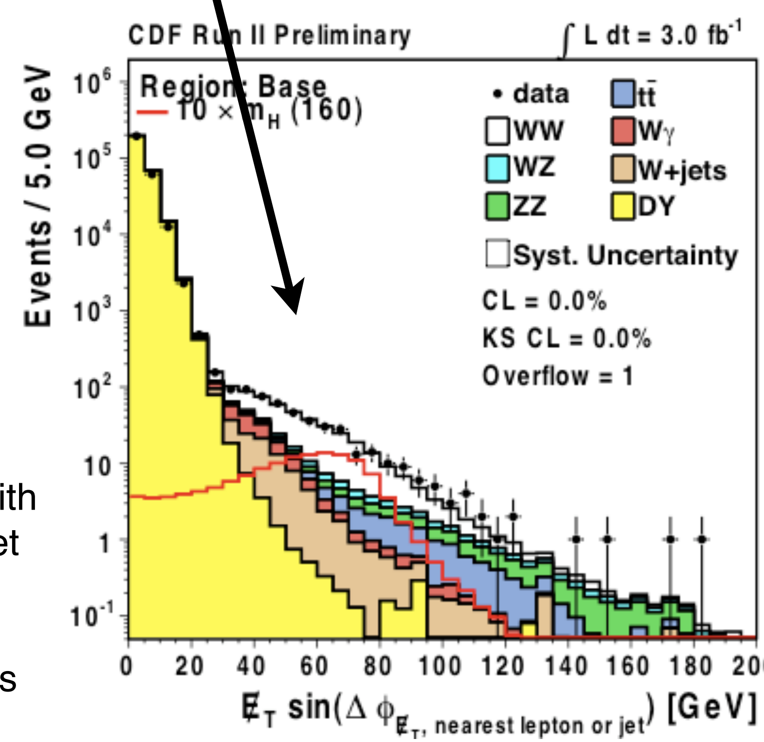
- 0 Jet
  - WW background (distinguished by spin correlations)
  - Fake and conversions (difficult to model, require data validation, Control region using same sign)

CDF: H->WW Analysis

- 1 Jet
  - Drell-Yan & WW bkgs contribute equally
    - Check Drell-Yan has proper dilepton & MET correlations
    - DY can be cleaned up with special MET calculations

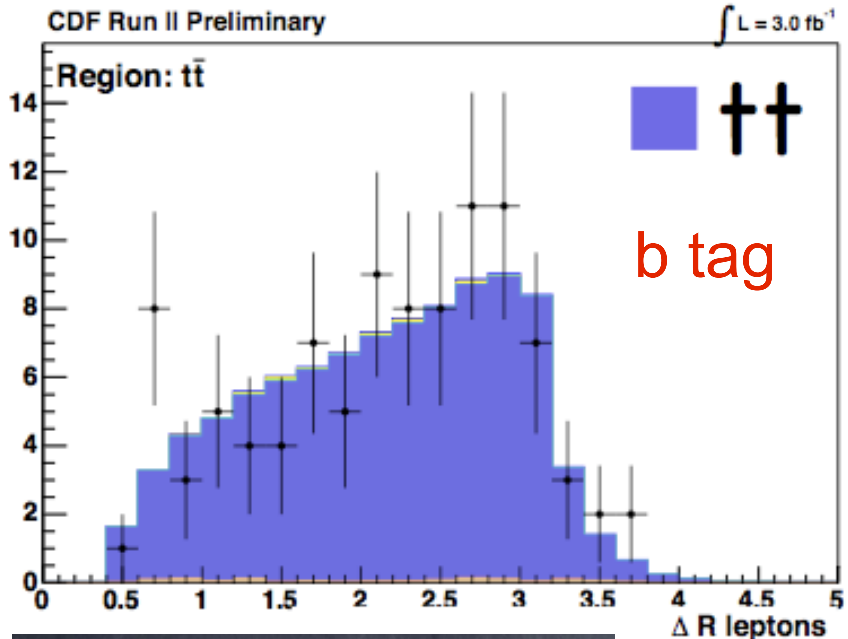


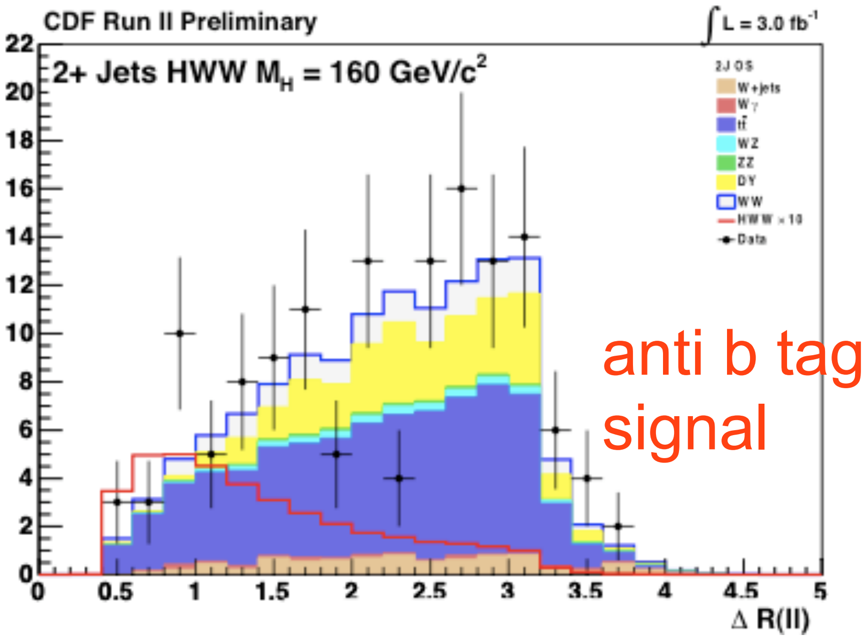
MET crossed with nearest lep or jet modeled well both in DY and WW regions



CDF: H->WW Analysis

- 2 Jet
  - Top pairs biggest bkg (tt ➞ WbWb ➞ lνlνbb)
    - Analysis requires anti-b tag to get rid of top
    - Can also examine b-tagged control region to test model



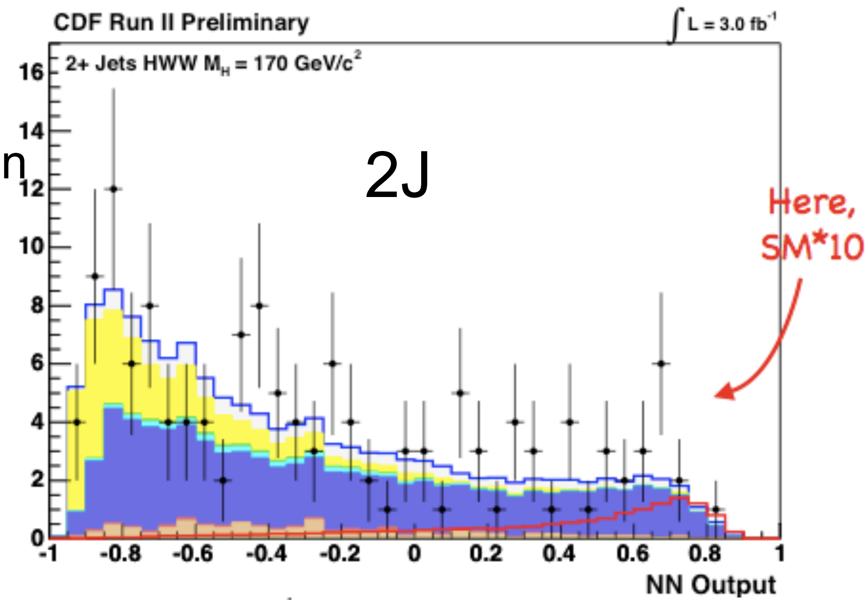


observed	tt	other
98	91 ± 17	2.3 ± 0.3

CDF: H->WW Analysis result

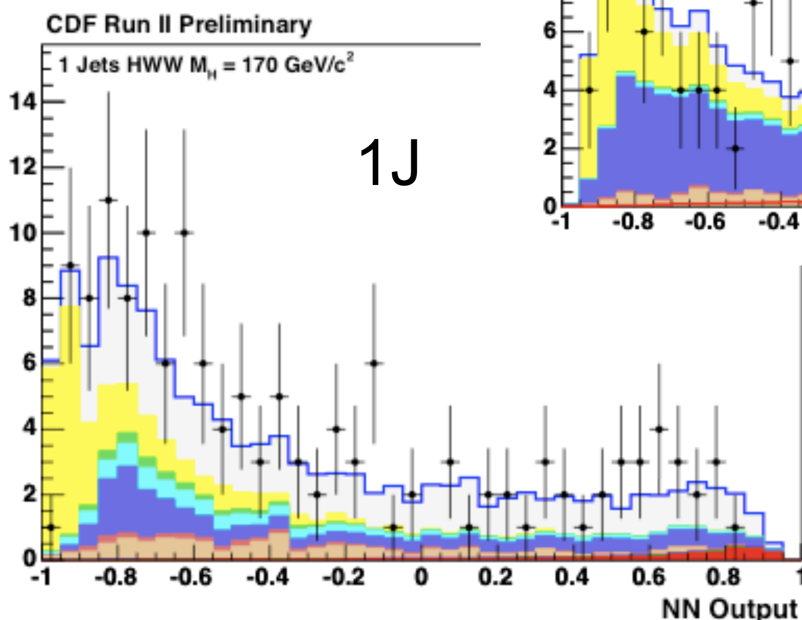
	0 J	1 J	2 J
observed	552	227	139
expected	540 ± 65	226 ± 28	129 ± 20

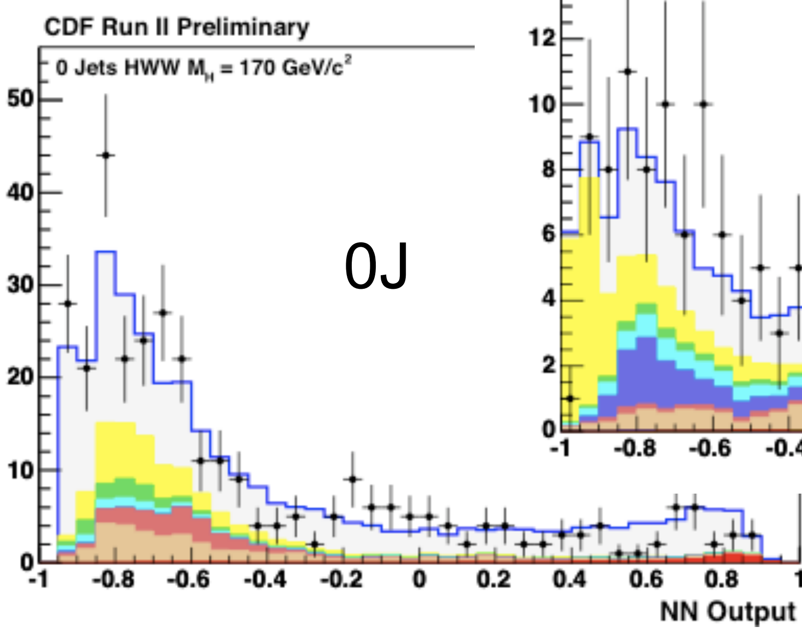
NN adds in pt of dijet system



NN adds MET cut, lepton p_Ts, no LO matrix element due to extra jet

NN using LO matrix elements probabilities. transverse energy dΦ(l1,l2), dR(l1,l2)





CDF: H->WW Analysis result

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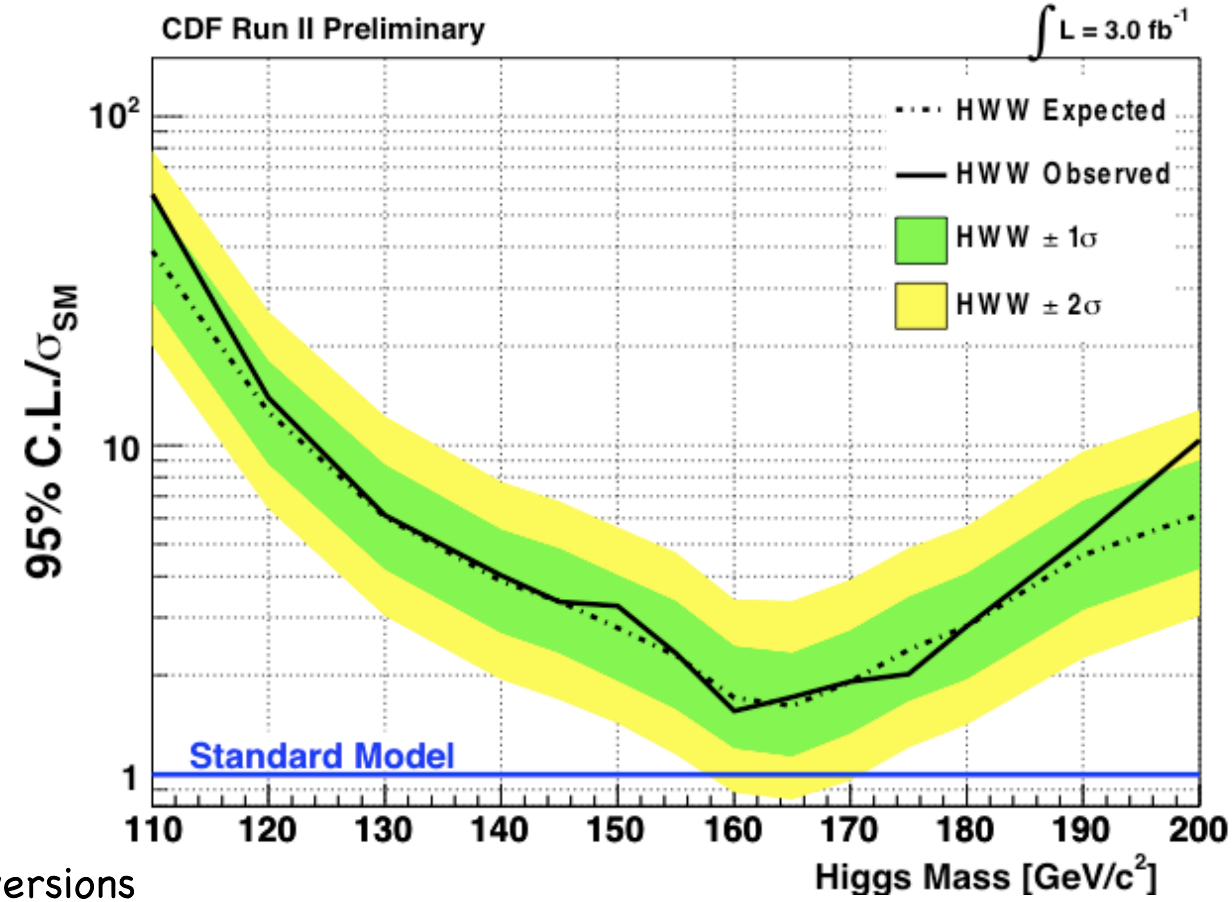
Lots of systematics uncertainties : Correlated between backgrounds, signal processes, and between 0J, 1J, 2J channels



Leading systematics :

- WW, tt, H → WW
  - 10-15% cross-section
- W+jets, W+γ
  - 20-30% jet fakes and conversions
- Drell-Yan
  - 20% MET modeling

mH	120	130	160	165
expected	13	6	1.7	1.6
observed	14	6	1.6	1.7

DØ Combination

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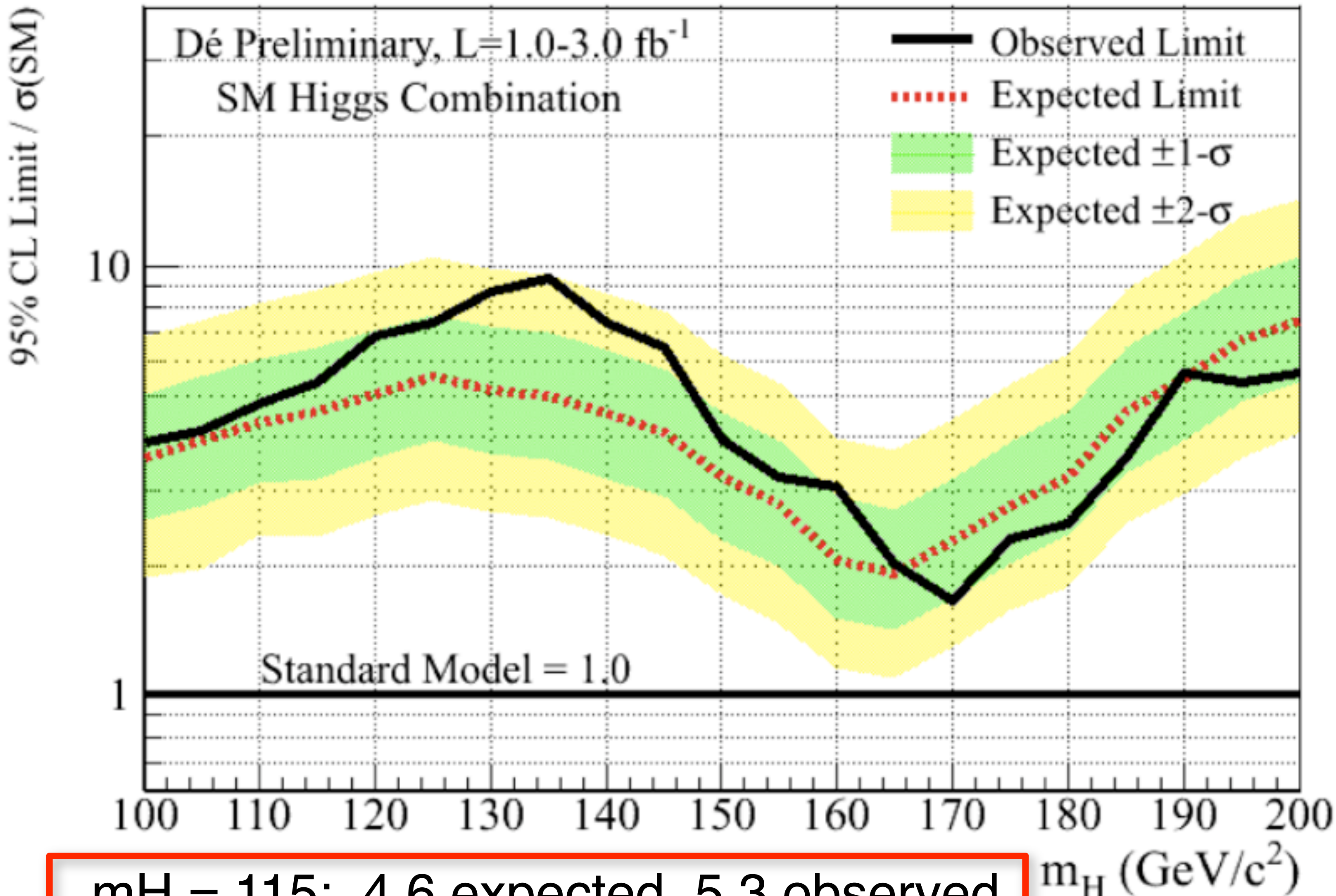
Channel	Data Epoch	Luminosity (fb^{-1})	Final Variable
$WH \to e\nu b\bar{b}$, ST/DT, W + 2 jet	Run IIa	1.1	NN discriminant
$WH \to e\nu b\bar{b}$, ST/DT, W + 3 jet	Run IIa	1.1	Dijet Mass
$WH \to e\nu b\bar{b}$, ST/DT, W + 2 jet	Run IIb	0.6	NN discriminant
$WH \to \mu\nu b\bar{b}$, ST/DT, W + 2 jet	Run IIa	1.1	NN discriminant
$WH \to \mu\nu b\bar{b}$, ST/DT, W + 3 jet	Run IIa	1.1	Dijet Mass
$WH \to \mu\nu b\bar{b}$, ST/DT, W + 2 jet	Run IIb	0.6	NN discriminant
$WH \to \ell\nu b\bar{b}$, DT	Run IIa	0.9	DTree discriminant
$WH \to \ell\nu b\bar{b}$, DT	Run IIb	1.2	DTree discriminant
$ZH \to \nu\bar{\nu} b\bar{b}$, DT	Run IIa	0.9	DTree discriminant
$ZH \to \nu\bar{\nu} b\bar{b}$, DT	Run IIb	1.2	DTree discriminant
$ZH \to e^+e^- b\bar{b}$, ST/DT	Run IIa	1.1	NN discriminant
$ZH \to \mu^+\mu^- b\bar{b}$, ST/DT	Run IIa	1.1	NN discriminant
$ZH \to e^+e^- b\bar{b}$, ST/DT	Run IIb	1.2	NN discriminant
$ZH \to \mu^+\mu^- b\bar{b}$, ST/DT	Run IIb	1.2	DTree discriminant
$WH \to WW^+W^-$ ($\mu^\pm\mu^\pm$)	Run IIa	1.1	2-D Likelihood
$WH \to WW^+W^-$ ($e^\pm\mu^\pm$)	Run IIa	1.1	2-D Likelihood
$WH \to WW^+W^-$ ($e^\pm e^\pm$)	Run IIa	1.1	2-D Likelihood
$H \to W^+W^-$ ($\mu^+\mu^-$)	Run IIa+Run IIb	3.0	NN discriminant
$H \to W^+W^-$ ($e^\pm\mu^\mp$)	Run IIa+Run IIb	3.0	NN discriminant
$H \to W^+W^-$ (e^+e^-)	Run IIa+Run IIb	3.0	NN discriminant
$H \to \gamma\gamma$	Run IIa+Run IIb	2.7	Di-photon Invariant Mass

DØ Combined Limits



mH = 115: 4.6 expected, 5.3 observed
mH = 165: 1.9 expected, 2.0 observed

CDF combined Limits

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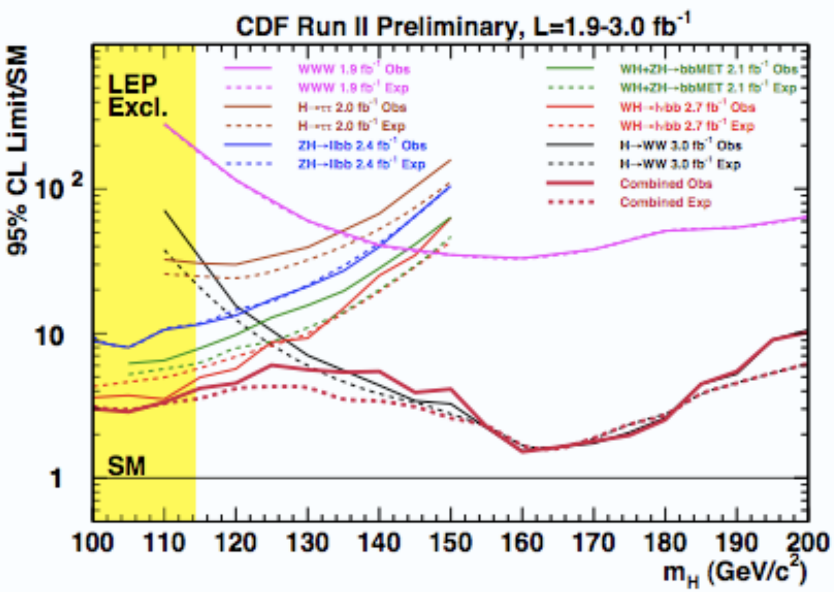

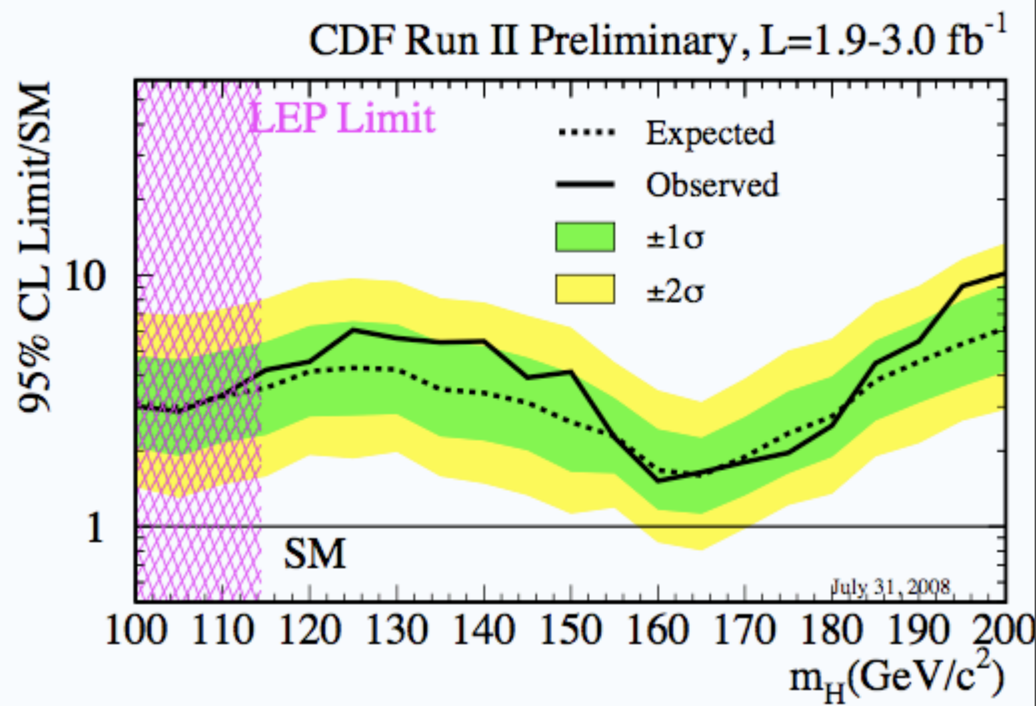

Channel	Limit @ 115 GeV
WH	5 (6)
VH → MET+bb	8 (6)
ZH → llbb	12 (12)
H → ττ + jets	26 (30)

CDF combined upper limits
m_H = 115 GeV 3.6 * SM
m_H = 165 GeV 1.6 * SM

Tevatron Combination

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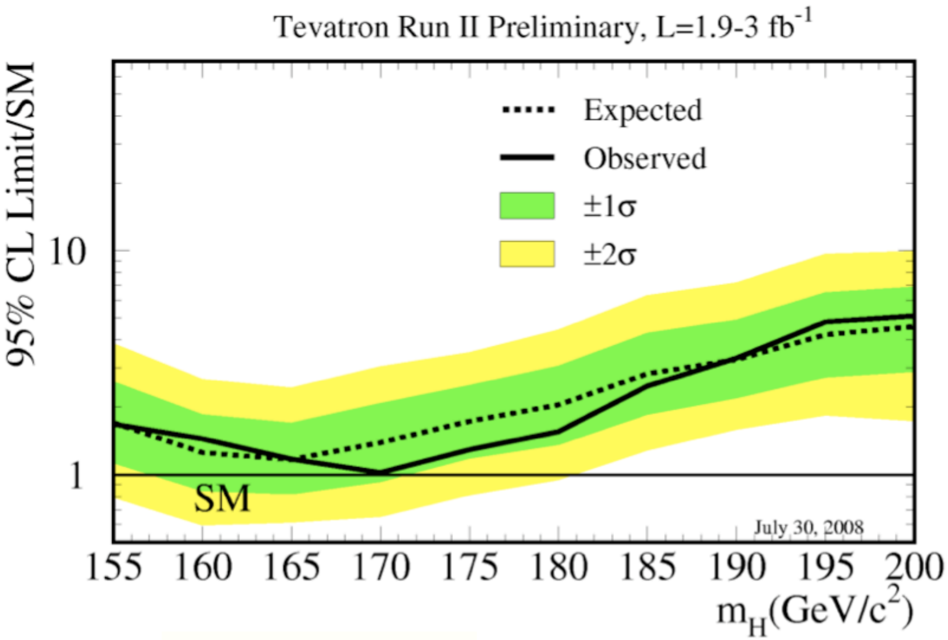
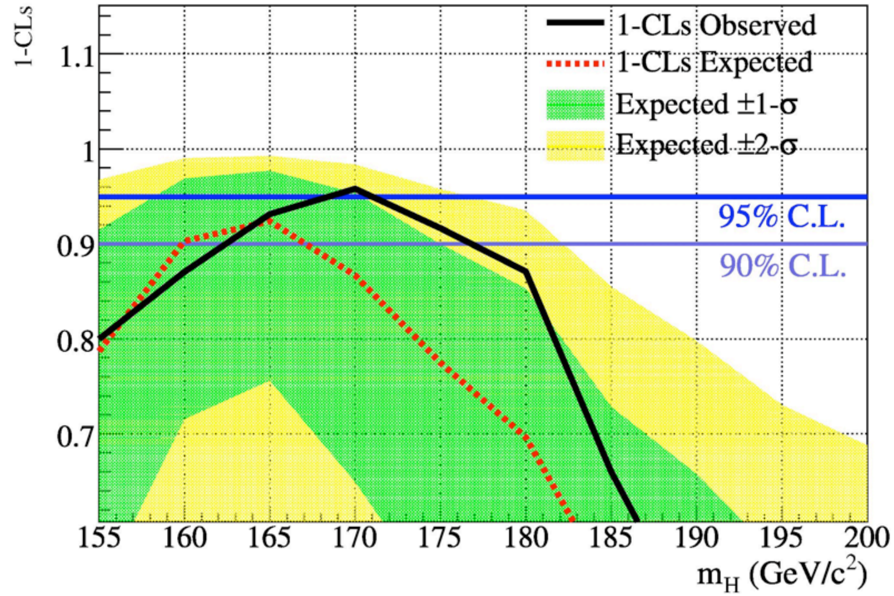
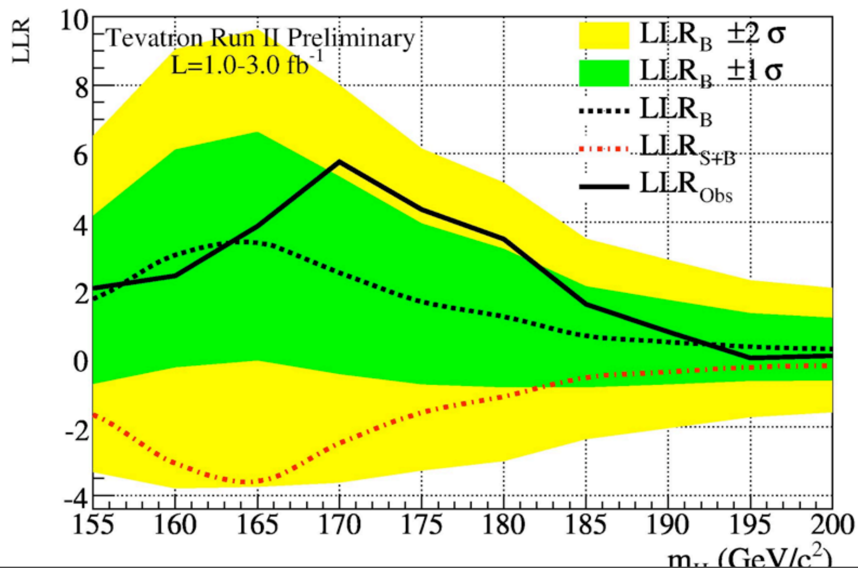




Verified using two calculations (Bayesian, CLS)

95%CL Limits/SM

M_Higgs(GeV)	160	165	**170**	175
Method 1: Exp	1.3	1.2	1.4	1.7
Method 1: Obs	1.4	1.2	**1.0**	1.3
Method 2: Exp	1.2	1.1	1.3	1.7
Method 2: Obs	1.3	1.1	**0.95**	1.2



Conclusions

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- Tevatron and CDF/ DØ experiments performing very well
- The Higgs boson search is in its most exciting era ever
- Up to 3/fb have been used per experiment, already more recorded (~4+/fb)
- Expect 6-8/fb total per experiment
- The Tevatron experiments have achieved sensitivity to the SM Higgs boson production cross section
- We exclude at 95% C.L. the production of a SM Higgs boson of 170 GeV/c^2
- Expect large exclusion, or evidence, with full Tevatron data set and improvements

Backup starts right here....

Current DØ SM Channels

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Input Channel	# Channels	Luminosity	Update Since Moriond
WH→e,μvbb, P17	8	1.1 fb^{-1}	✓
WH→e,μvbb, P20	4	0.6 fb^{-1}	
WH→τvbb	6	0.94 fb^{-1}	✓
ZH→llbb P17	4	1.1 fb^{-1}	
ZH→llbb P20	4	1.2 fb^{-1}	✓
ZH→vvbb P17	4	0.93 fb^{-1}	
ZH→vvbb P20	4	1.22 fb^{-1}	
H→WW→lvlv	3	3.0 fb^{-1}	✓
WH→WWW	3	1.0 fb^{-1}	
ttH	12	2.1 fb^{-1}	✓
H→gg	1	2.8 fb^{-1}	✓

Cut Variables

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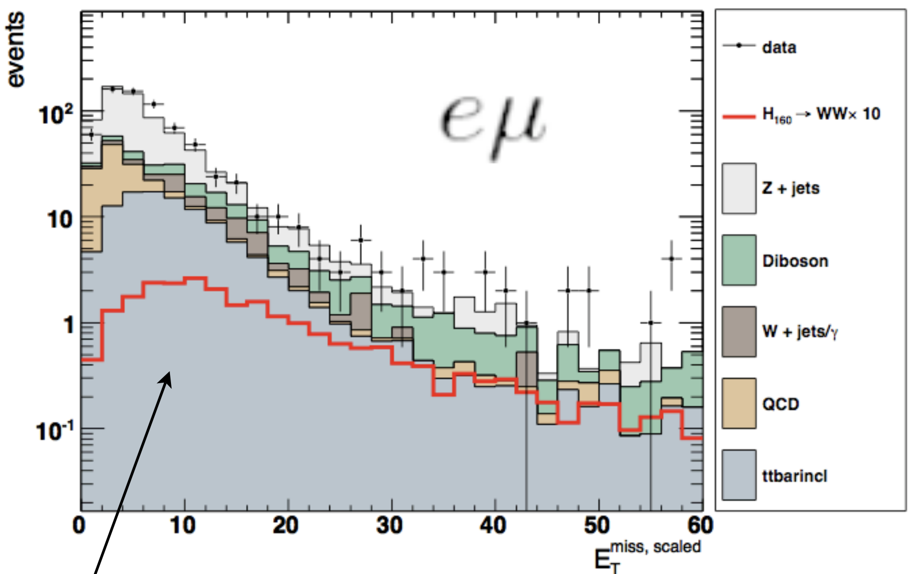
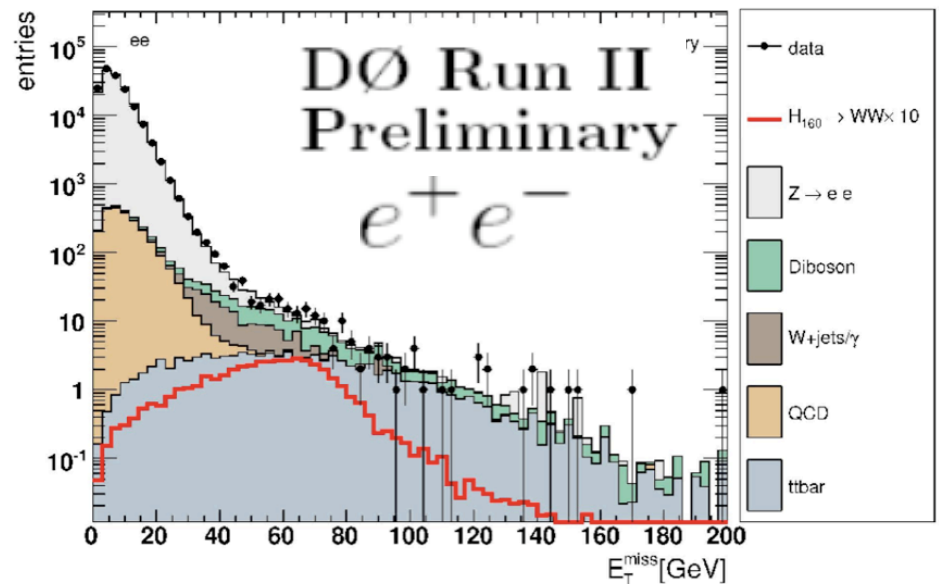
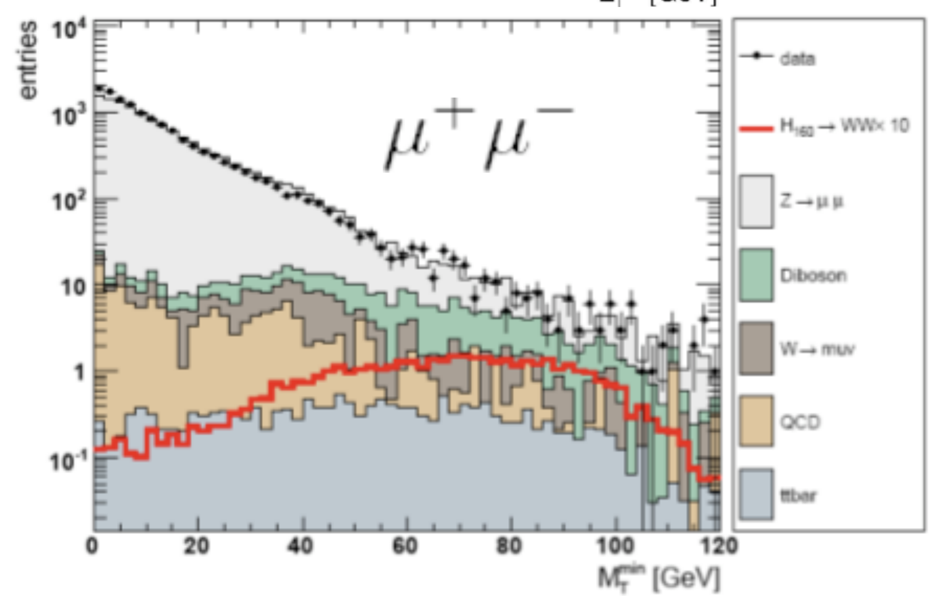
Signal has large MET and MET significance
MET is not aligned with either lepton







$$\not{E}_T^{\text{Scaled}} = \frac{\not{E}_T}{\sqrt{\sum_{\text{jets}} \left(\Delta E^{\text{jet}} \cdot \sin\theta^{\text{jet}} \cdot \cos\Delta\phi\left(\text{jet}, \not{E}_T\right)\right)^2}}$$

MET projected onto Jet axis

Angular Correlation

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- Higgs is a scalar -> leptons are more aligned
- qq->WW (spin ½ quark, spin 1 boson) -> leptons are less aligned
- Z->ll is also back-to-back -> not aligned