Search for high-Mass Higgs Boson at the Tevatron

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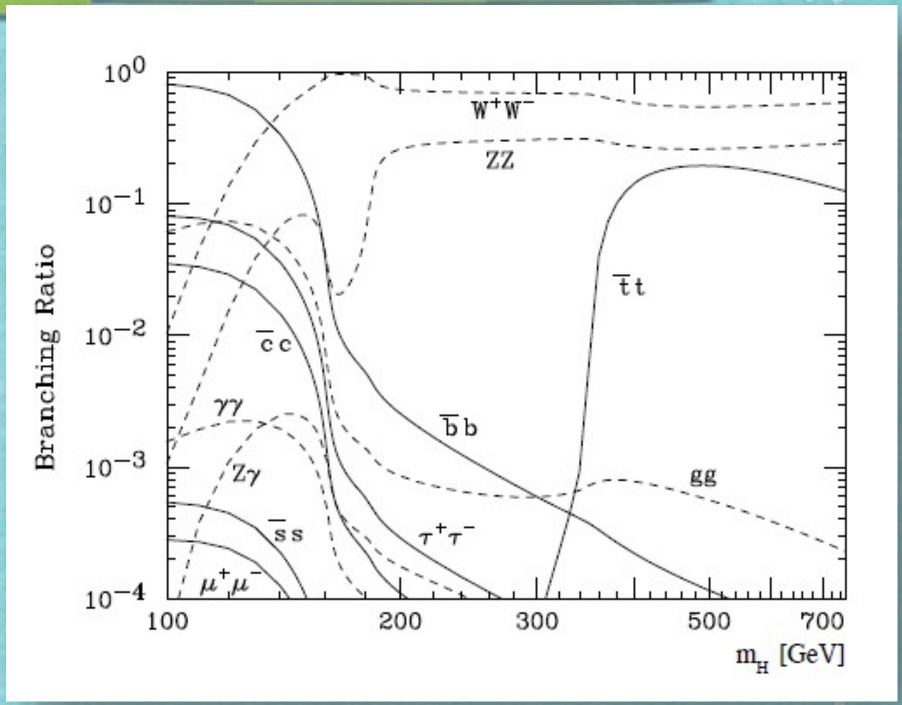
Duke University

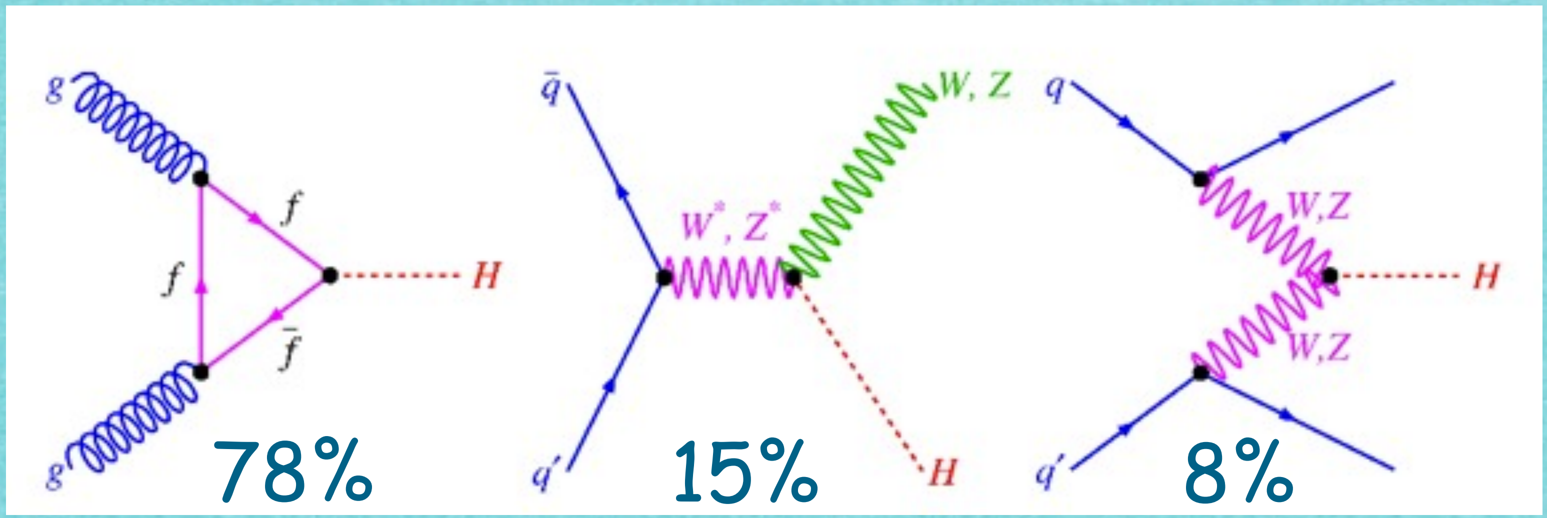
on behalf of the CDF and DØ Collaborations

23^{rd} Rencontre de Blois

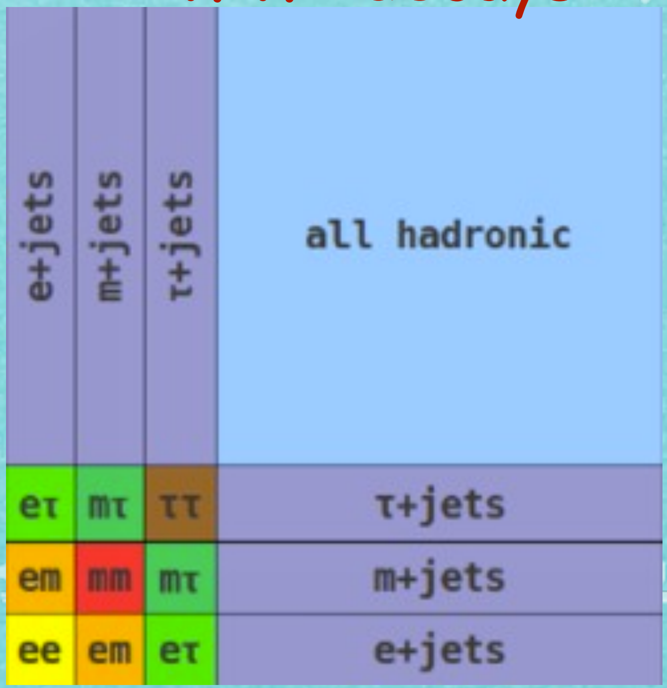
Introduction to High Mass Analysis

- Focus on $H \rightarrow WW^*$
  - Most sensitive to M(H)>~125 GeV/c²
- Consider all Higgs mechanisms
  - gg-fusion, Higgs-Strahlung, vector boson fusion
- Best sensitivity from dilepton channel





WW* decays:



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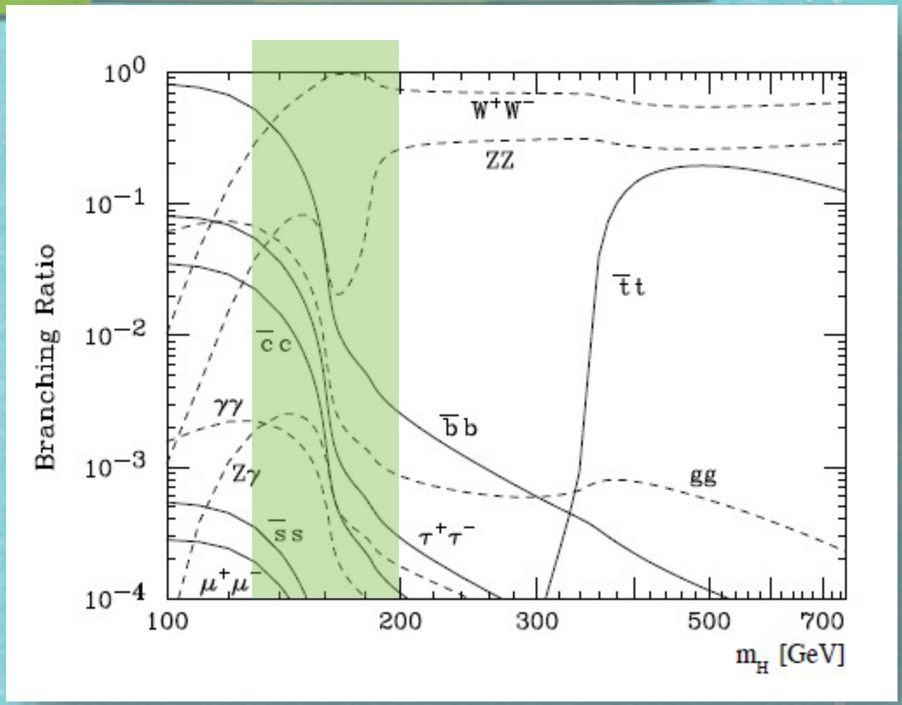

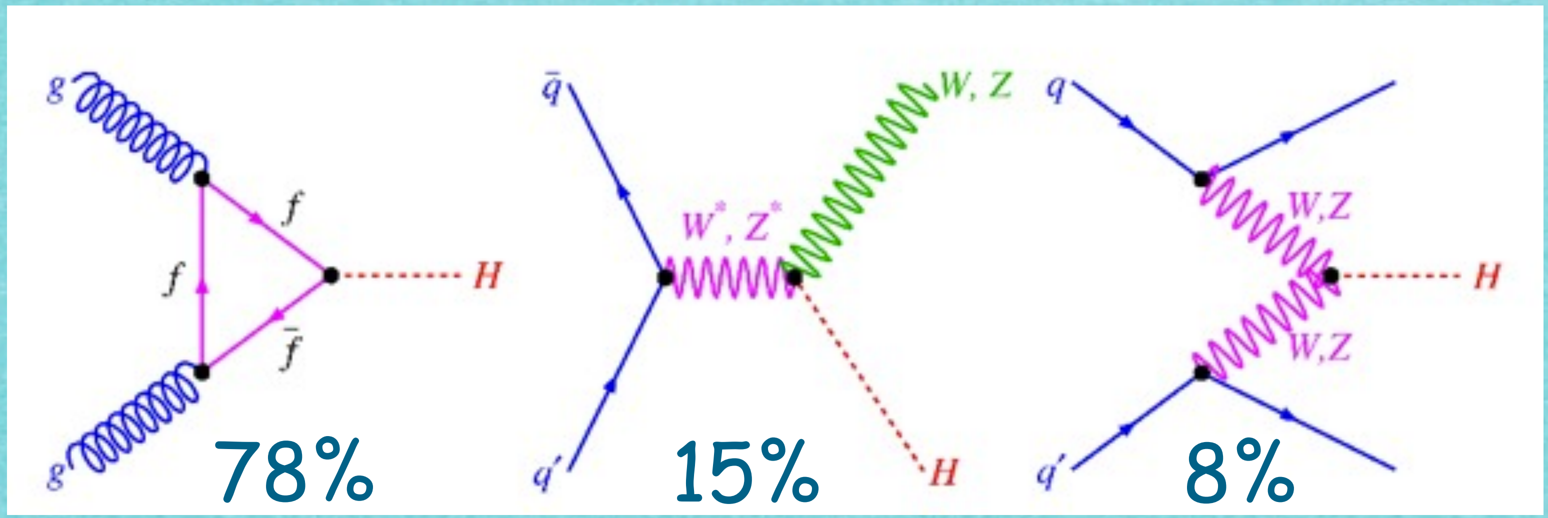

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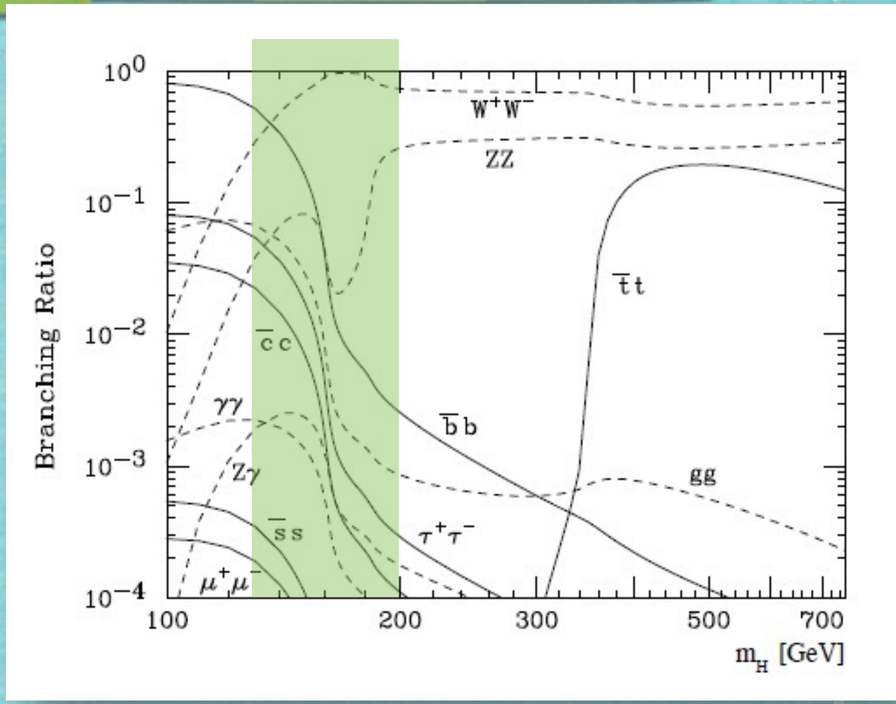

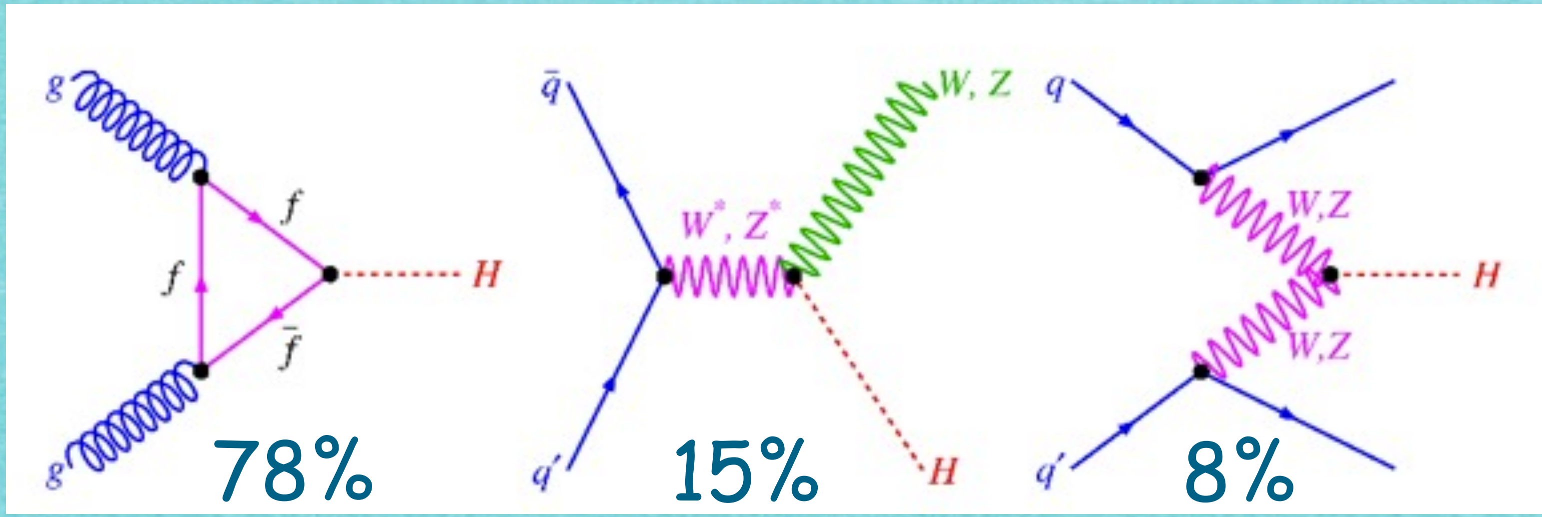

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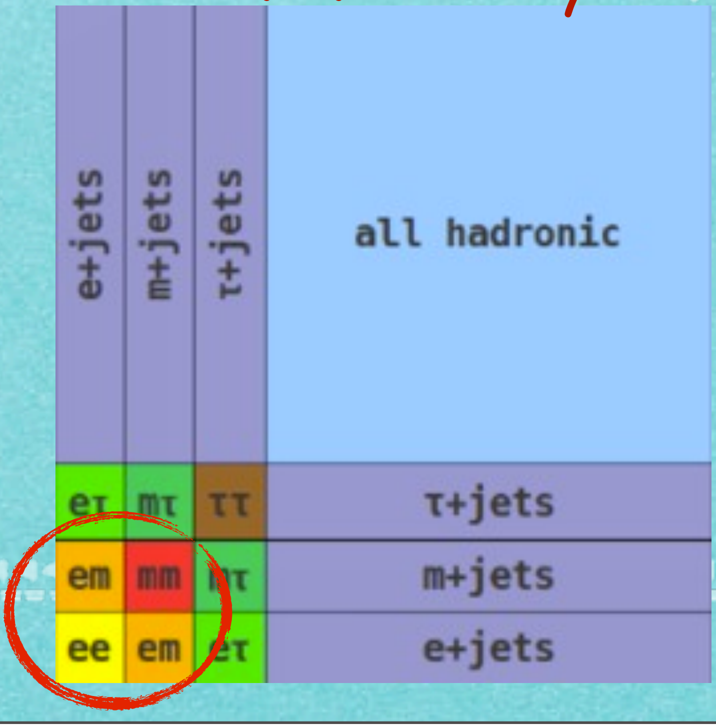


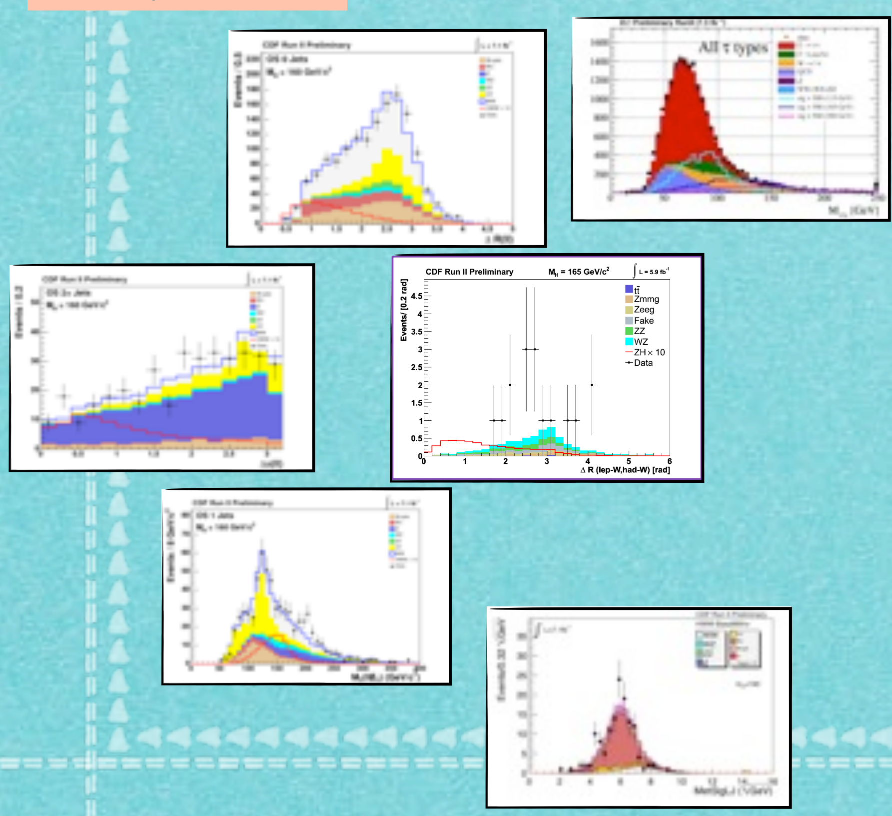
Search Strategy

1. Select objects w/ loose cuts to maximize signal acceptance

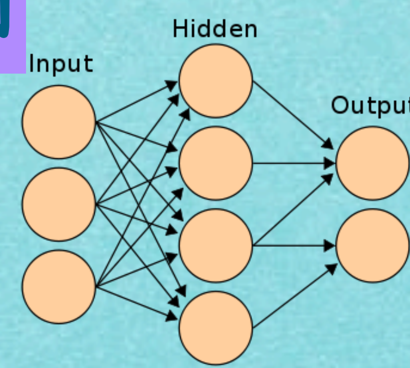
2. Use Multi-Variated Analysis techniques (Neural Network (NN) / Boosted Decision Tree (BDT)) for event discrimination

3. No excess observed? →Set limits based on the final discrimination

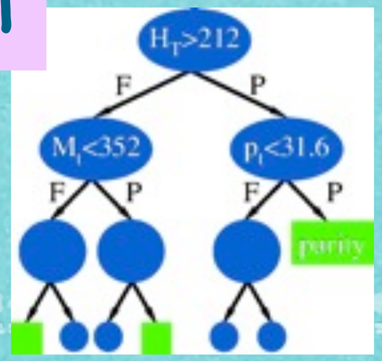
Inputs



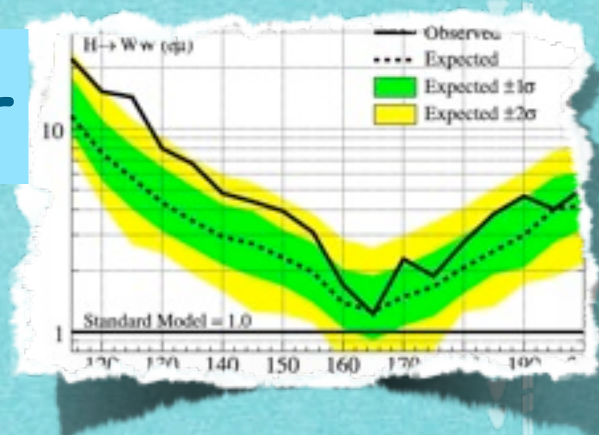
NN



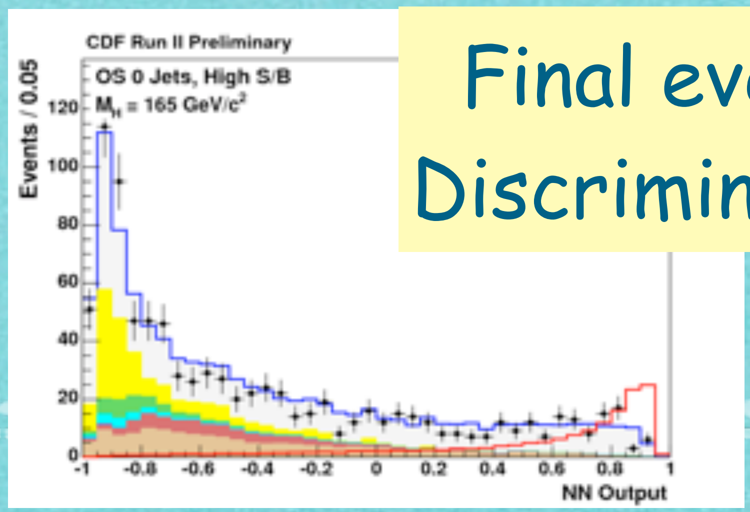
BDT



Limit



Final event Discriminator



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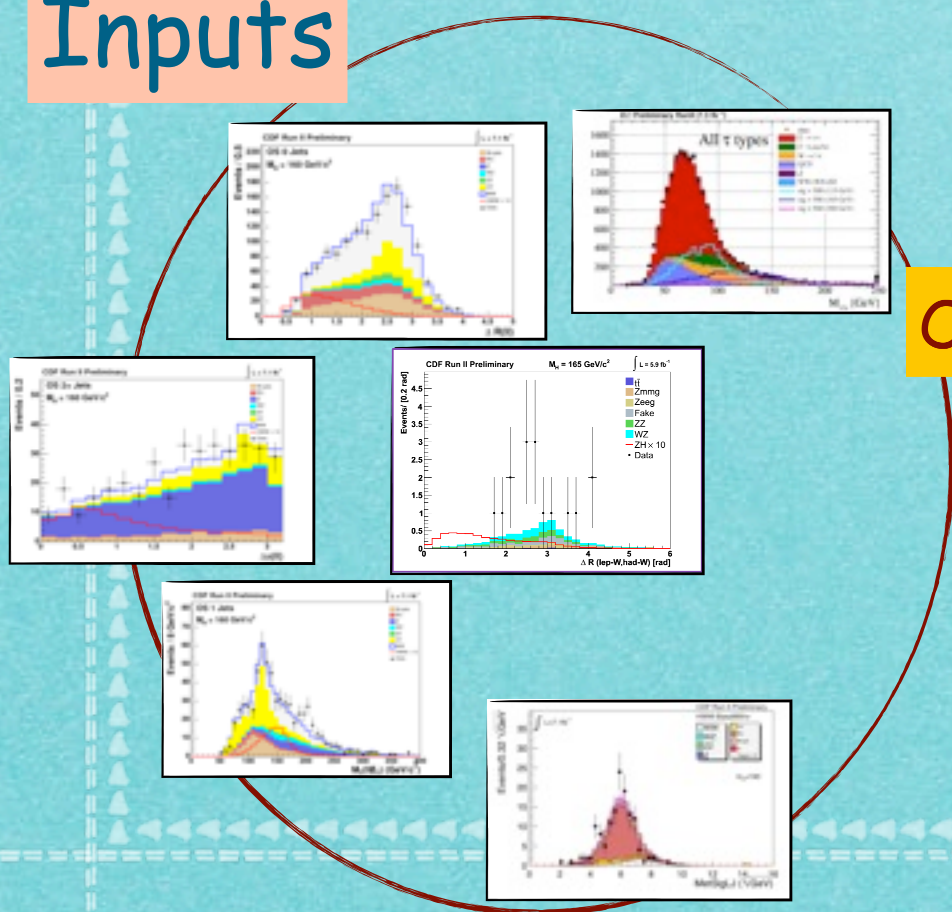
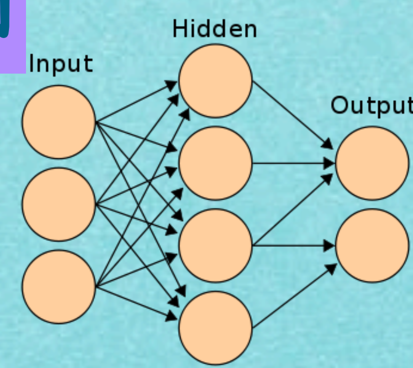
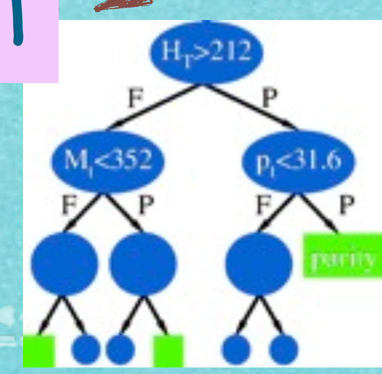


OR

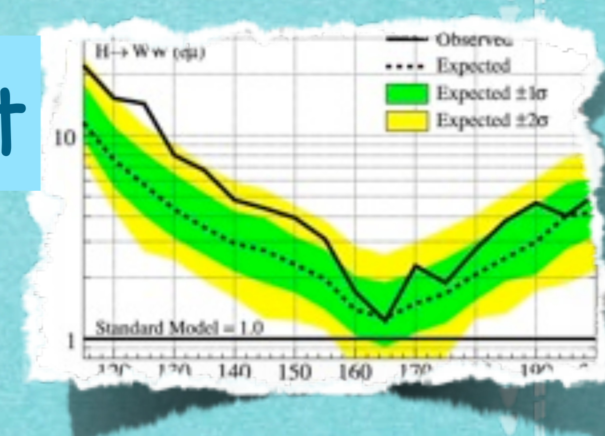
NN



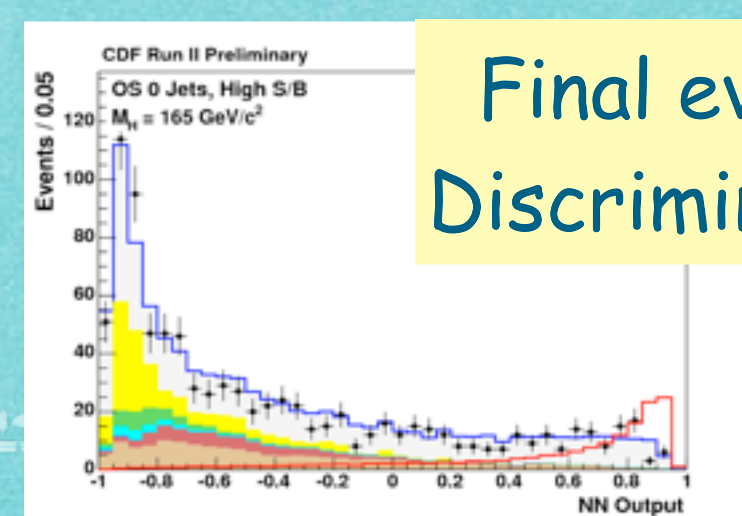
BDT



Limit



Final event Discriminator



Wednesday, June 1, 2011

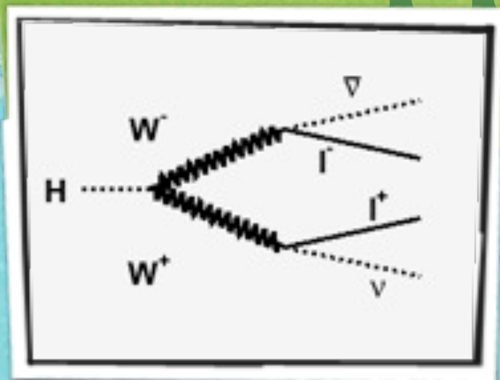
Search Channels

- Opposite-sign dilepton
  - $H \rightarrow WW^* \rightarrow l^{\mp}l^{\pm}\nu\nu$ + 0/1/2+ jets
- Same-sign dilepton
  - $W/Z+H \rightarrow W/Z+WW^* \rightarrow l^{\pm}l^{\pm}$
- Trilepton
  - $W/Z+H \rightarrow W/Z+WW^* \rightarrow l^{\mp}l^{\pm}l^{\pm}+\nu^{n}$+0/1/2+ jets
- Semileptonic decays
  - $H \rightarrow WW^* \rightarrow e/\mu+\nu+qq'$
- Hadronic tau decays
  - $e/\mu+\tau_{had}+\nu$+0/1/2 jets

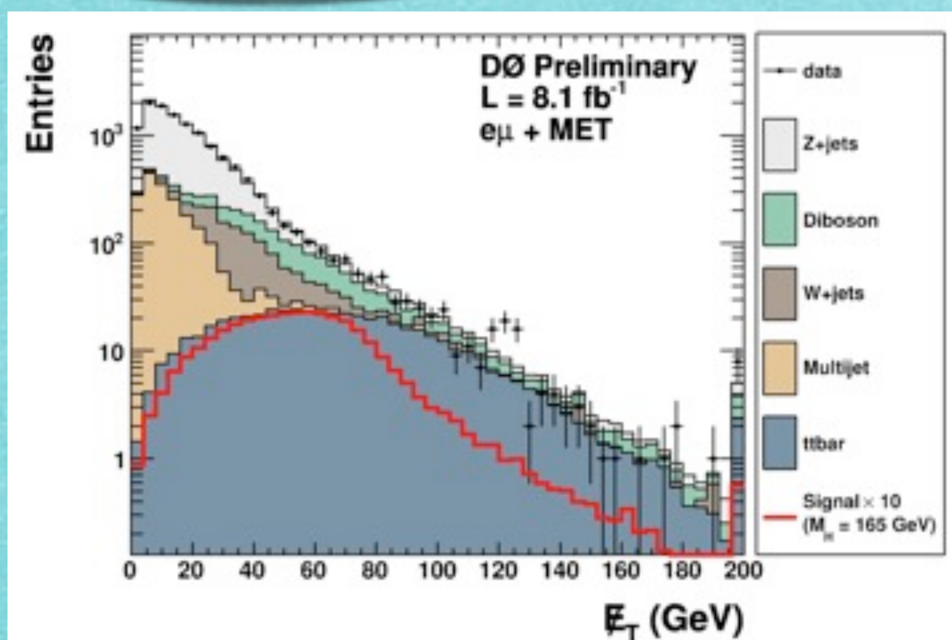
Sub-channels
CDF: 12, DØ: 35

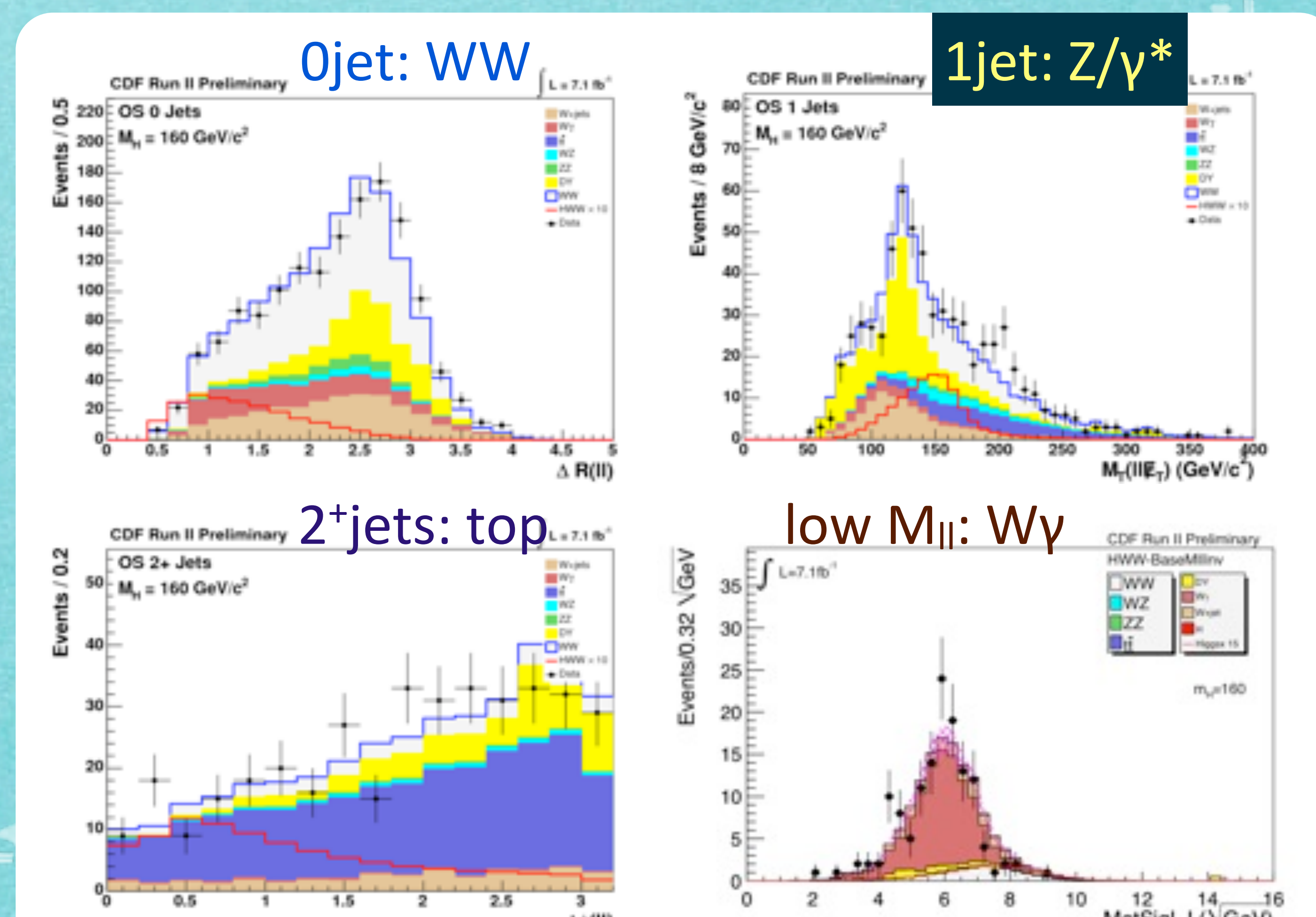
lepton(l)=e/μ

Opposite-sign Dilepton



- Multiple SM processes result in opposite-sign dilepton events
  - CDF: Use Missing E_T to suppress Z/γ^*
  - Main background: 0jet - WW, 1jet - Z/γ^*, 2^+jets - top, low M_{ll} (<16 GeV) - $W\gamma$

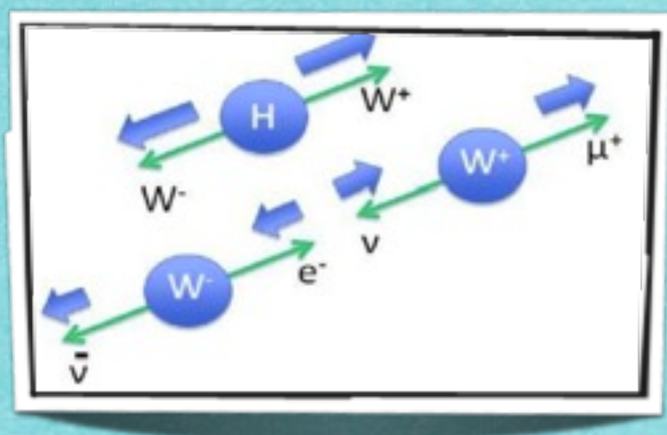




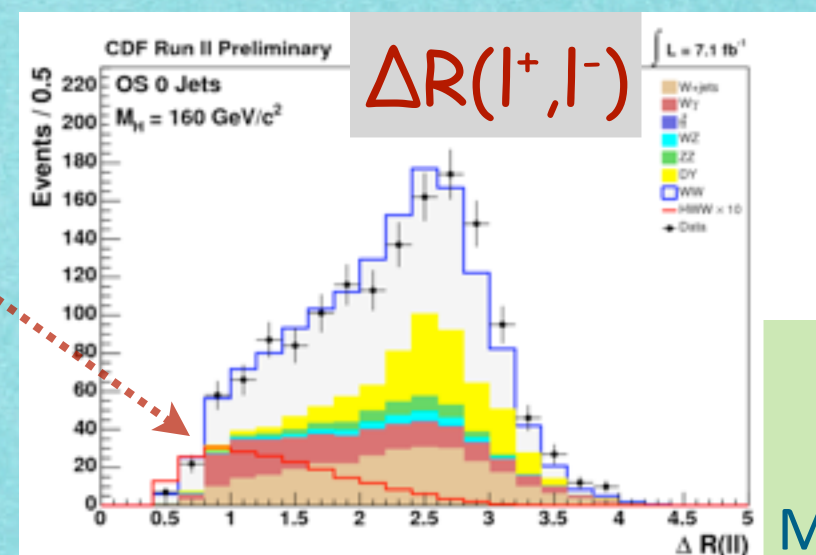
- DØ: Two rounds of BDT
  - First to reject Z/γ^*
  - Second to separate signal from all background

Opposite-sign Dilepton

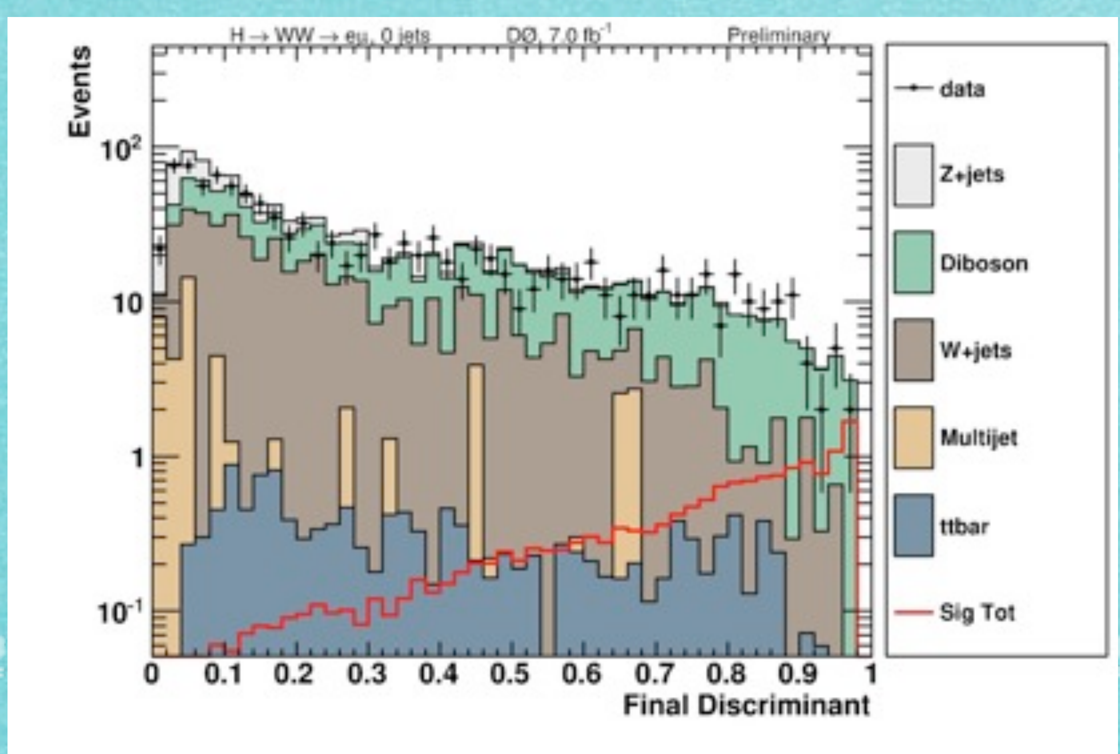
- Best signal/background discrimination from angle between reconstructed leptons

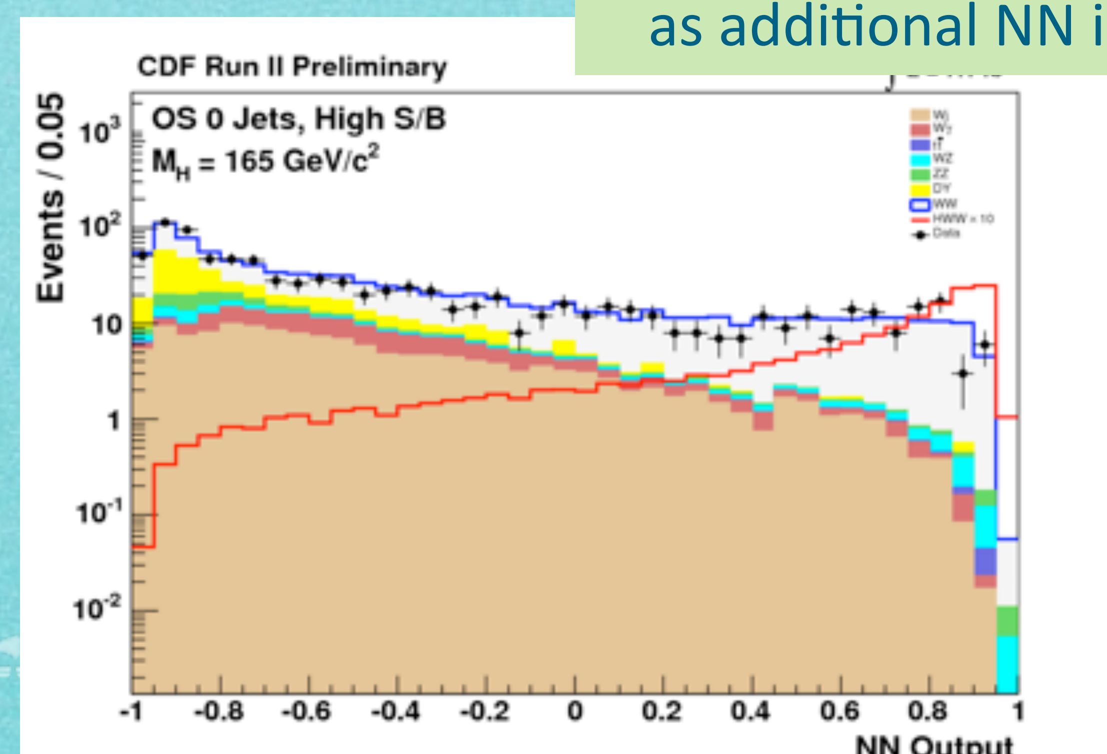


Higgs signal

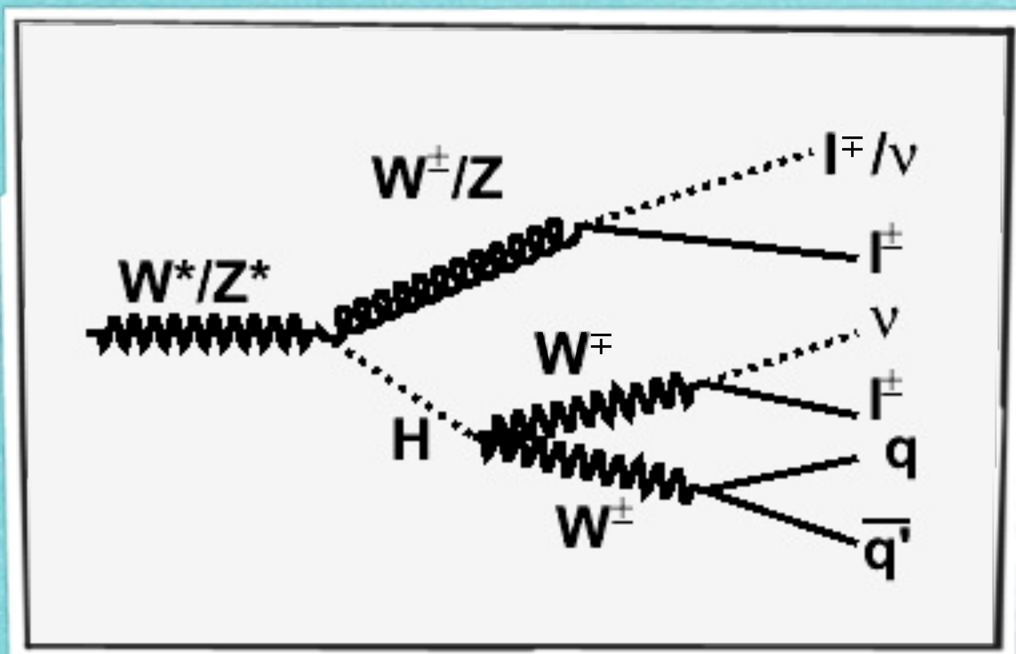


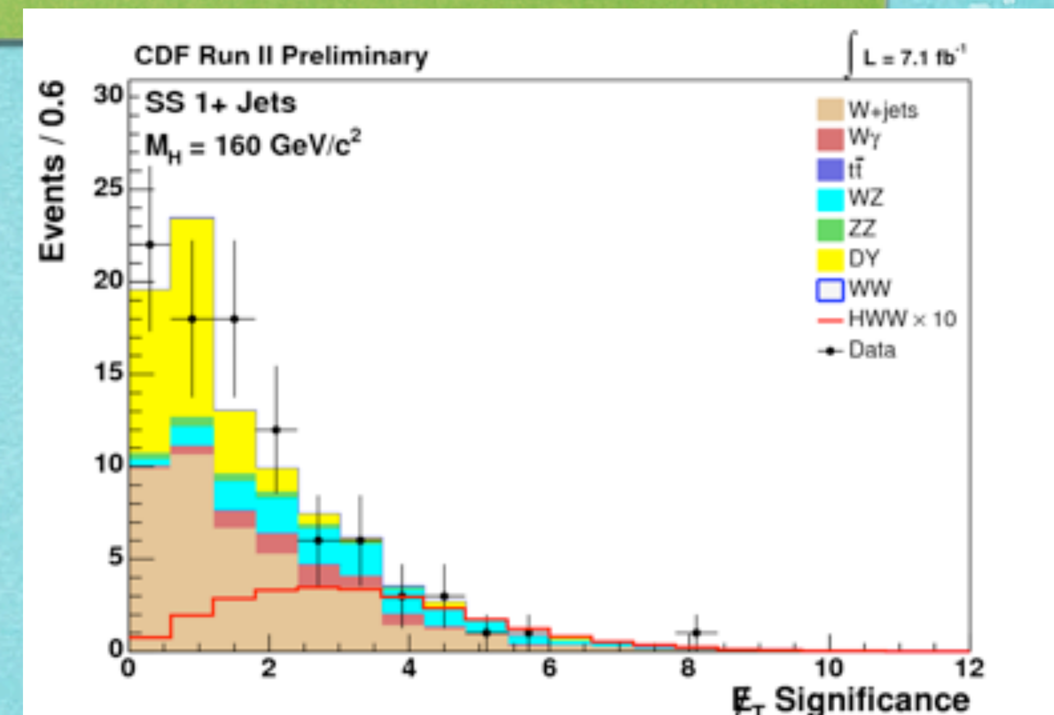
CDF ojet: incorporates likelihoods based on Matrix Element calculation as additional NN input

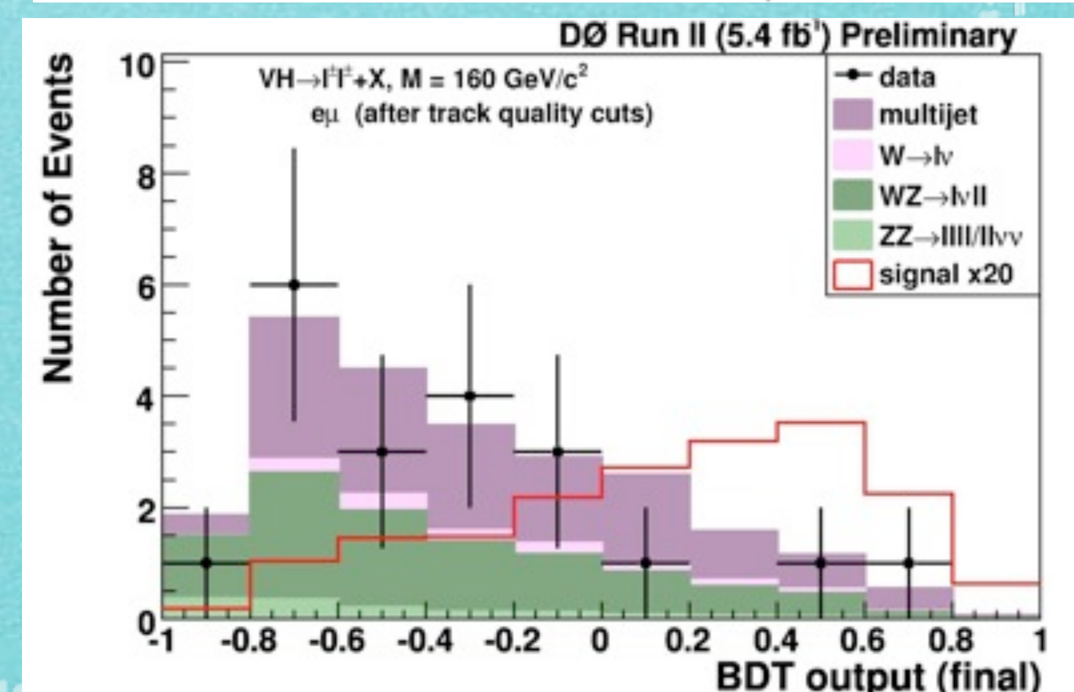




Same-sign Dilepton



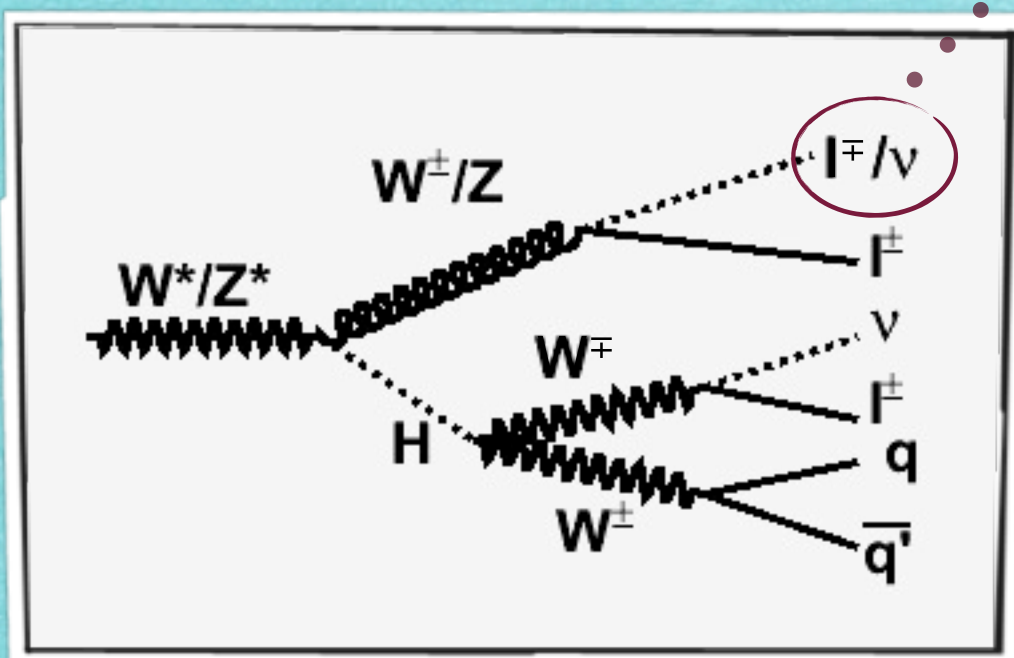


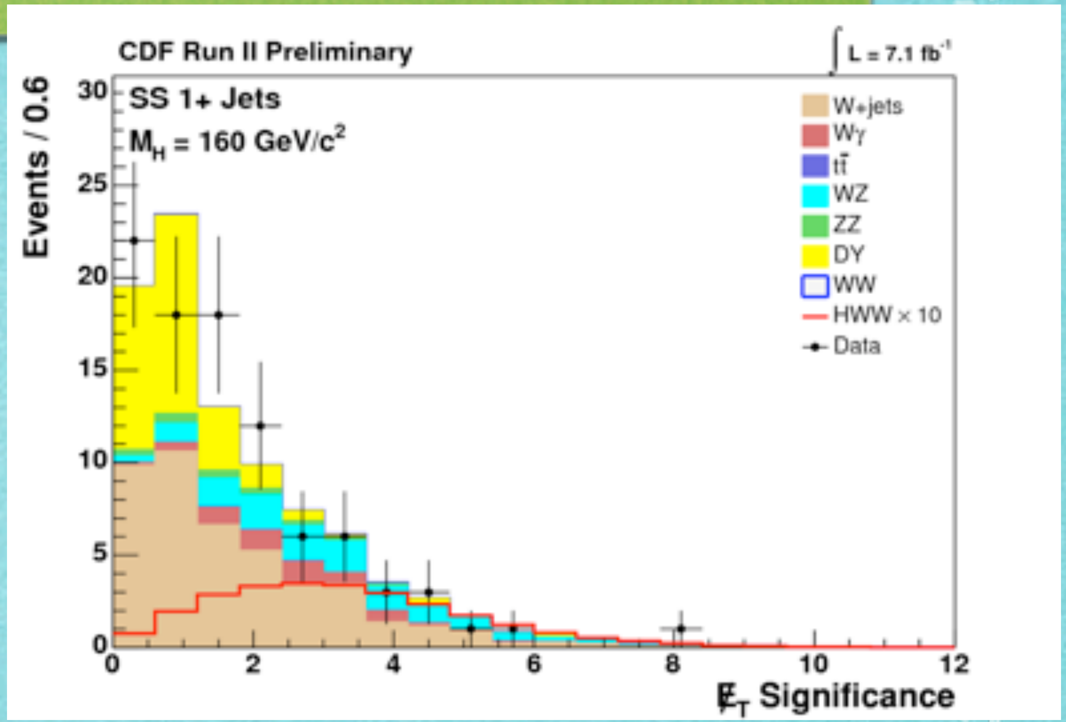


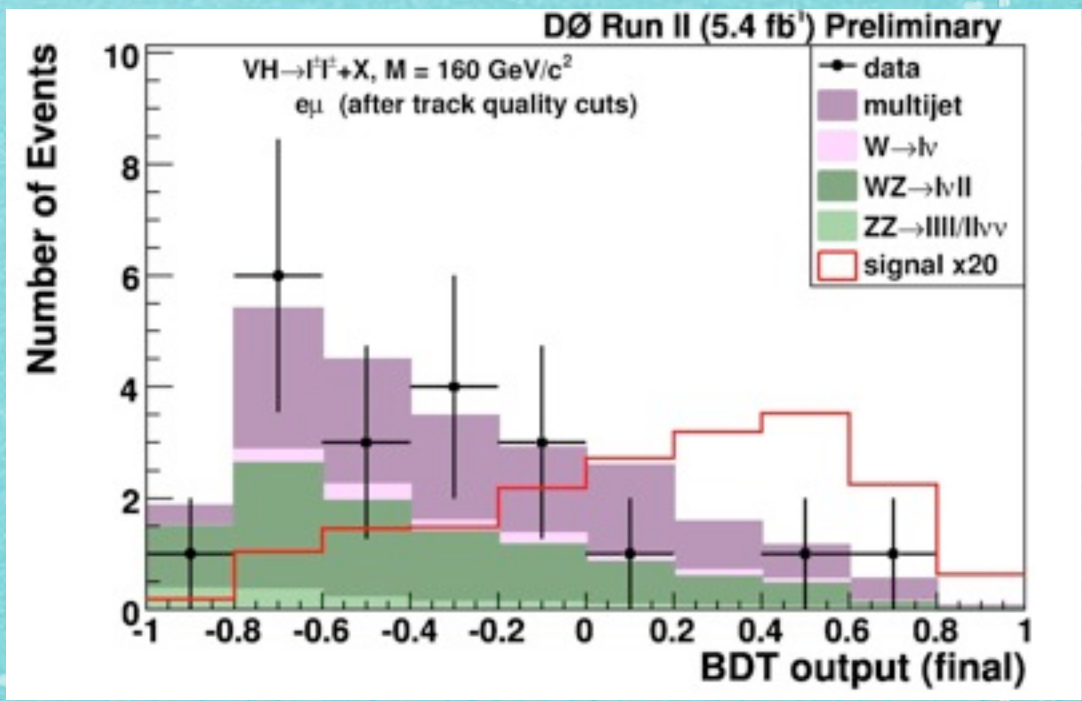
- CDF : requires 1^+ jets additionally
- DØ : ee, eμ, μμ channels
- Main Background : charge mis-id from Z/γ^*, fake lepton from W+jets

Same-sign Dilepton

missing







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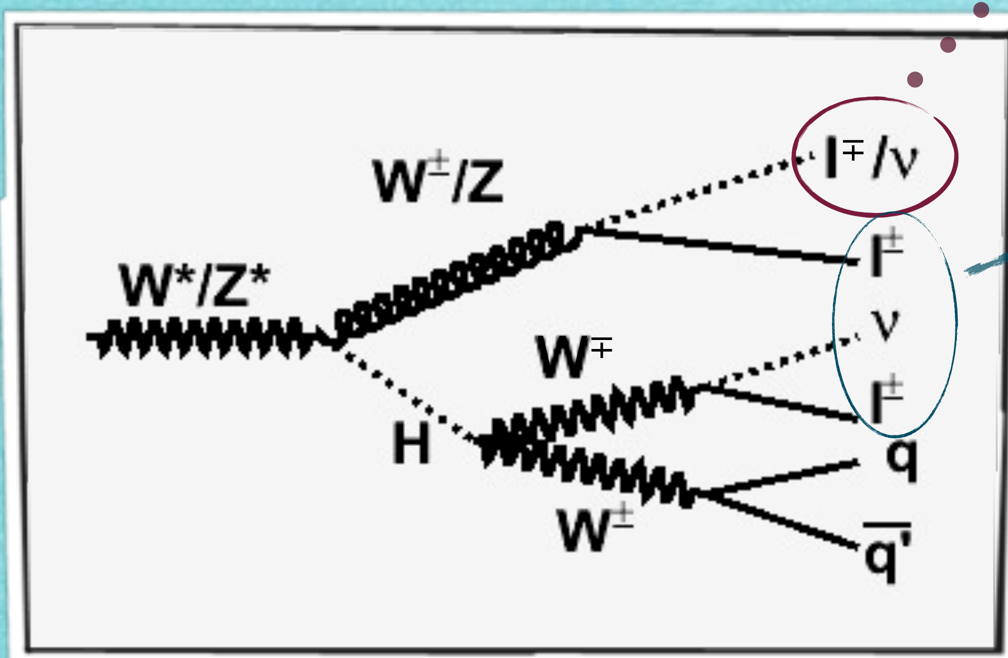
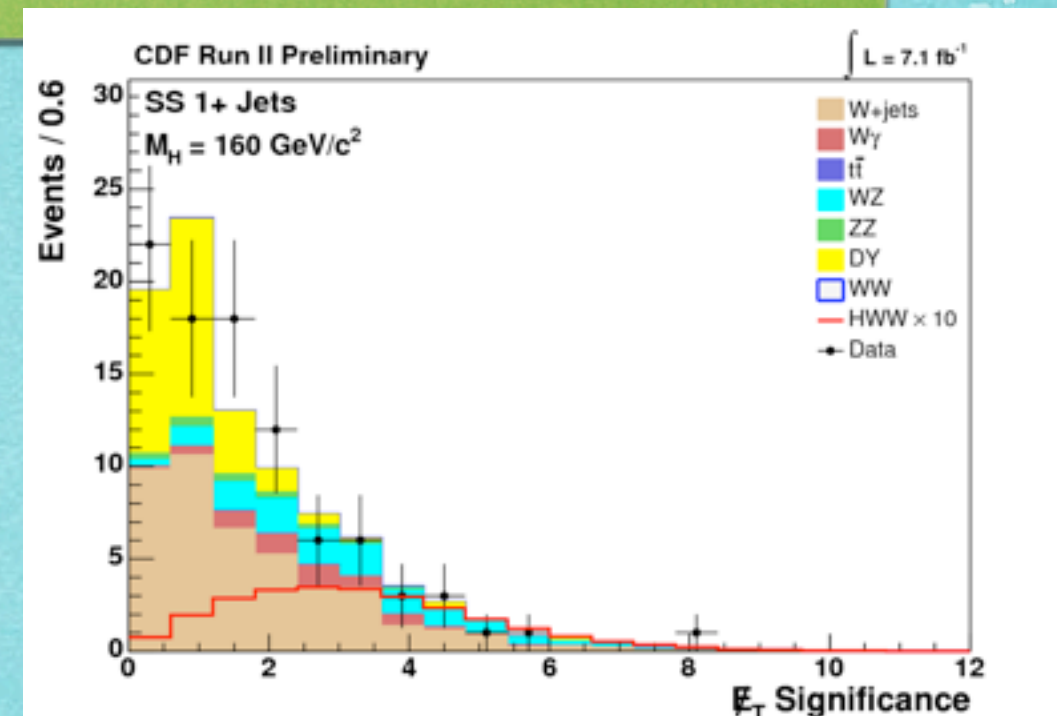
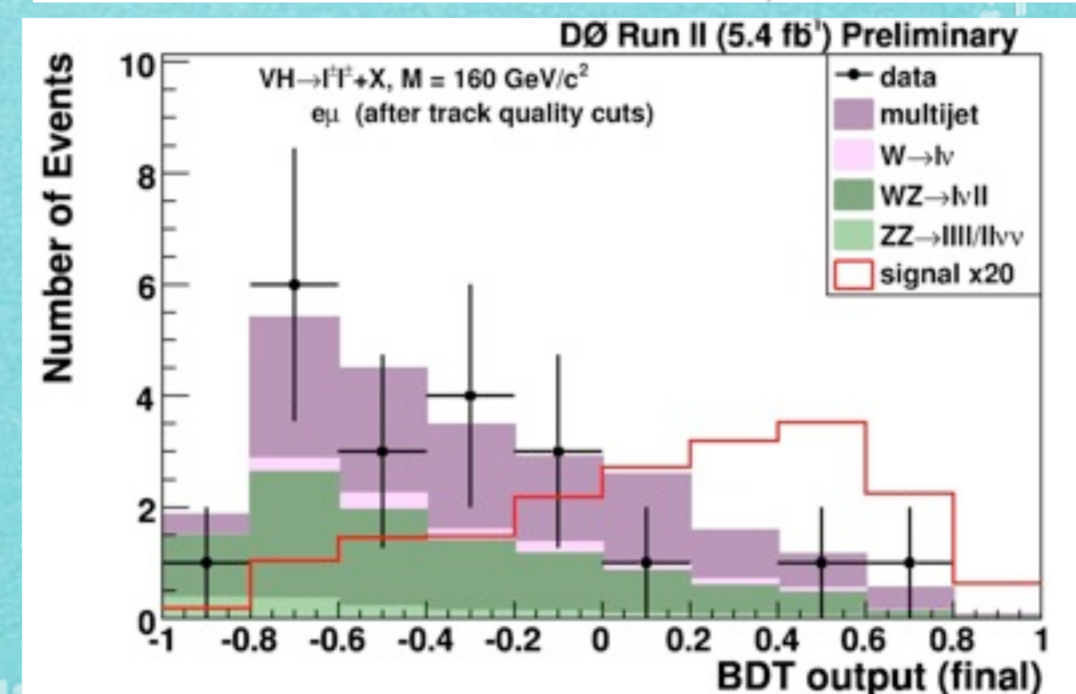


same sign dilepton





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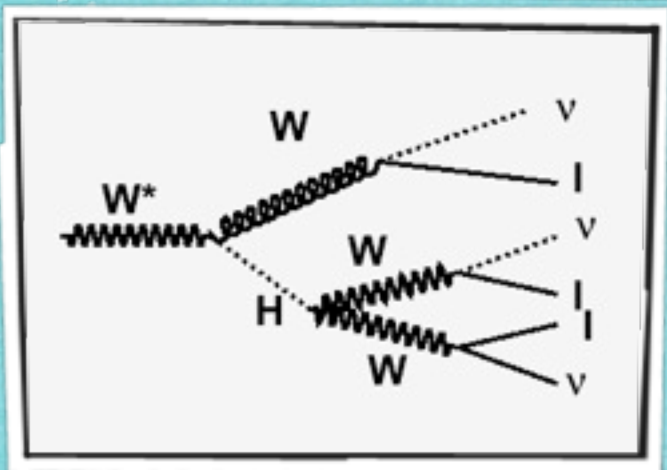
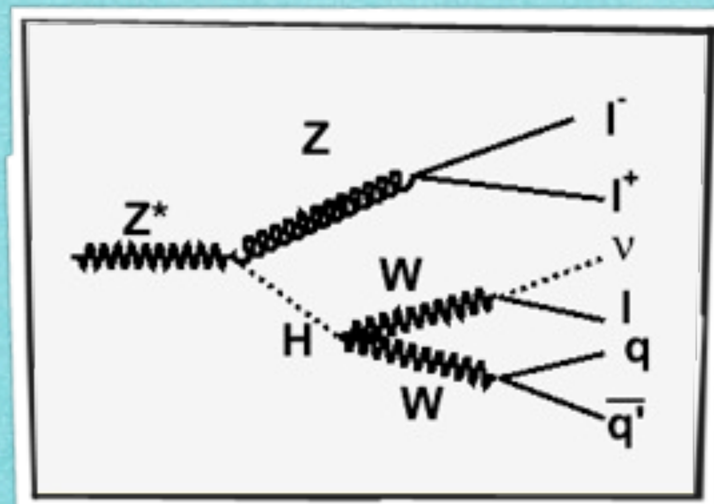
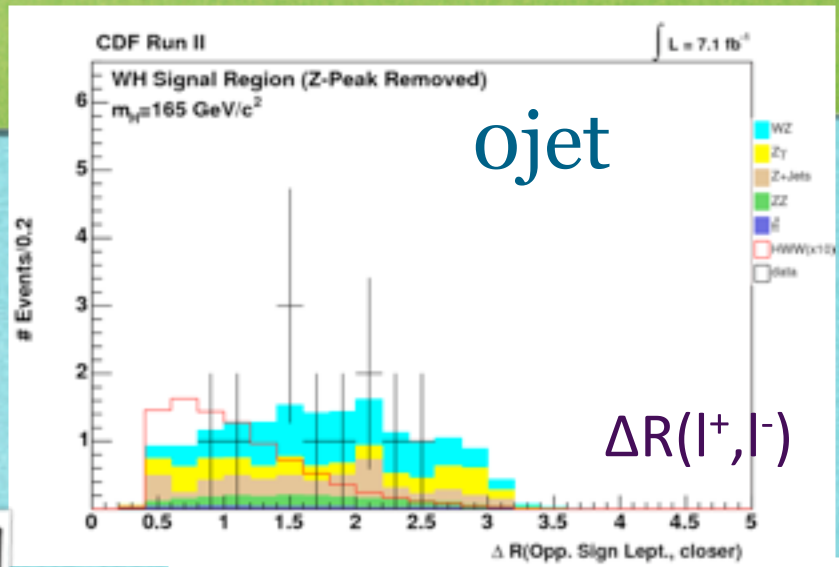
Trilepton

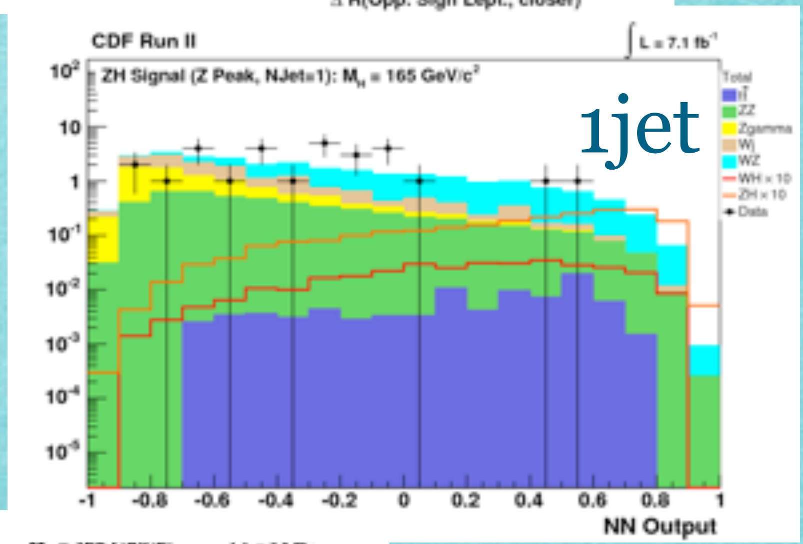


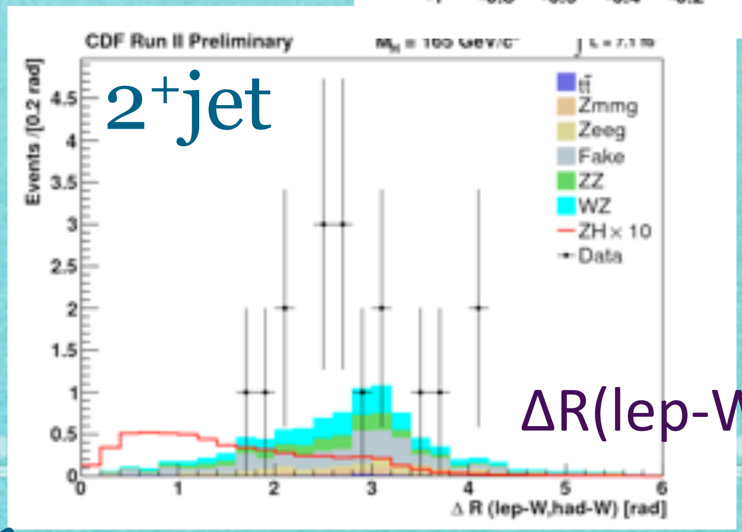
0jet: no jet req.
no Z req.
$|M(l^+l^-)-M_Z|>15$GeV



$|M(l^+l^-)-M_Z|<15$GeV
1jet: w/ 1jet missing
gain more stat.
2^+jets: full ZH recon.

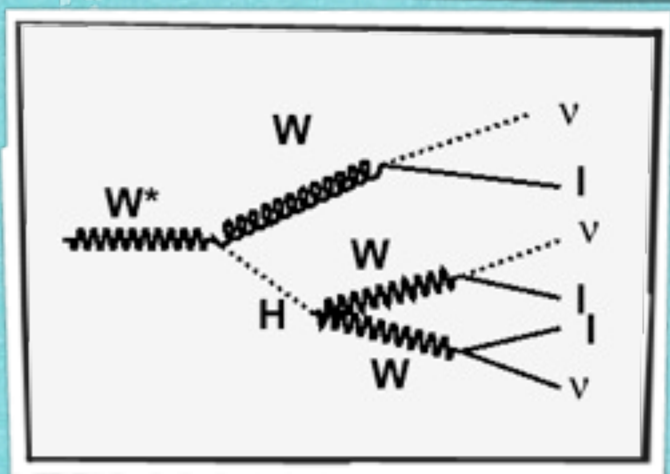






- Main Background: WZ/Zγ/Z+jets
- Clean signal but small stat.

Trilepton



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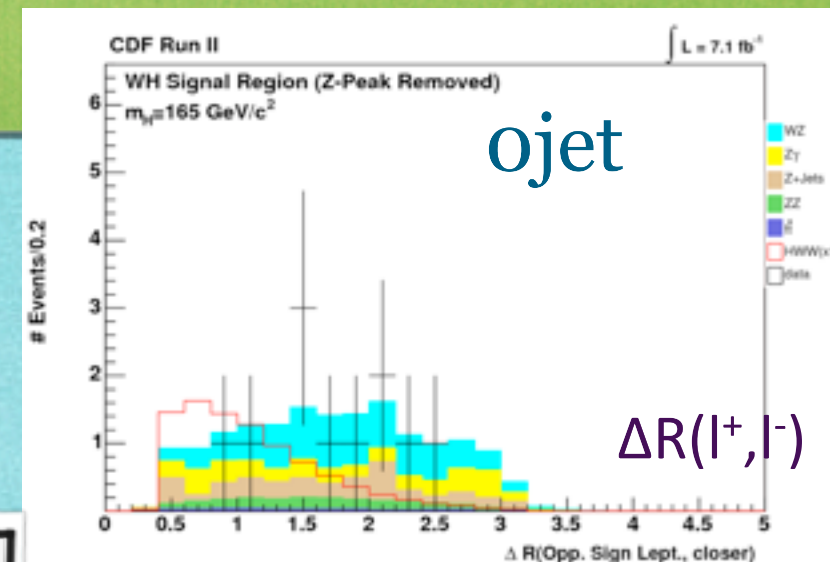

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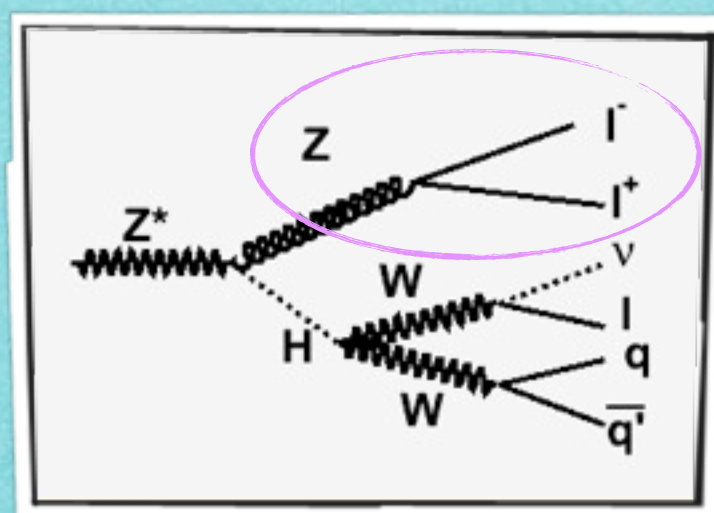

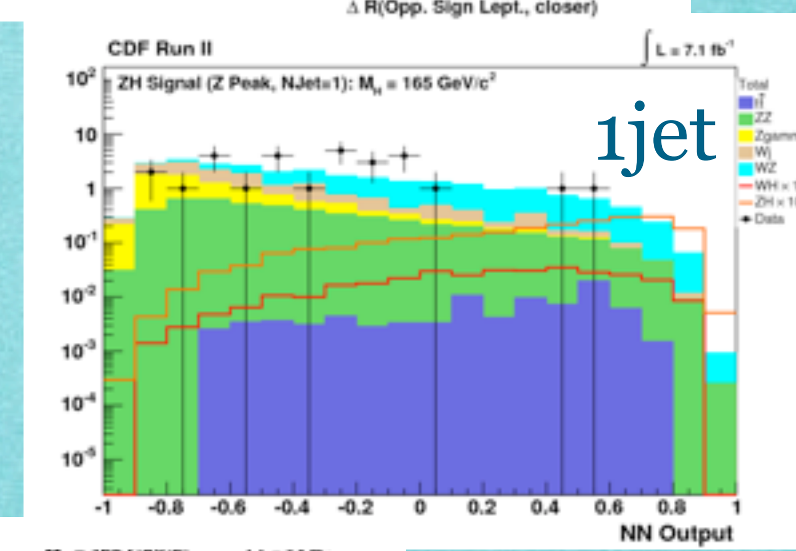

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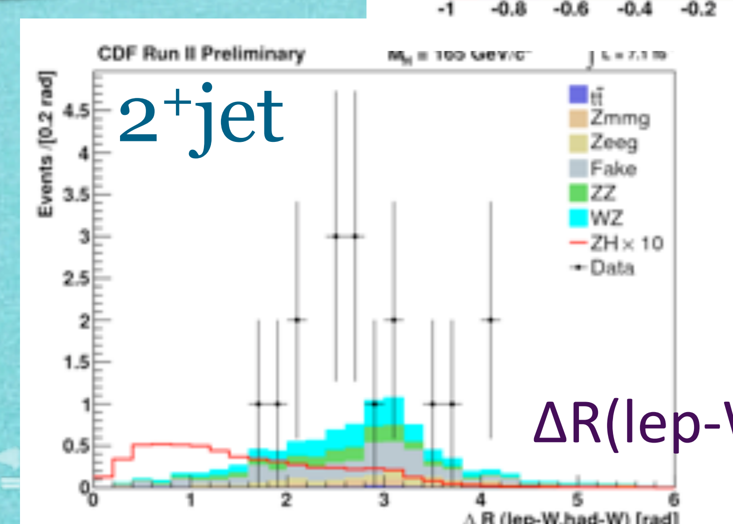
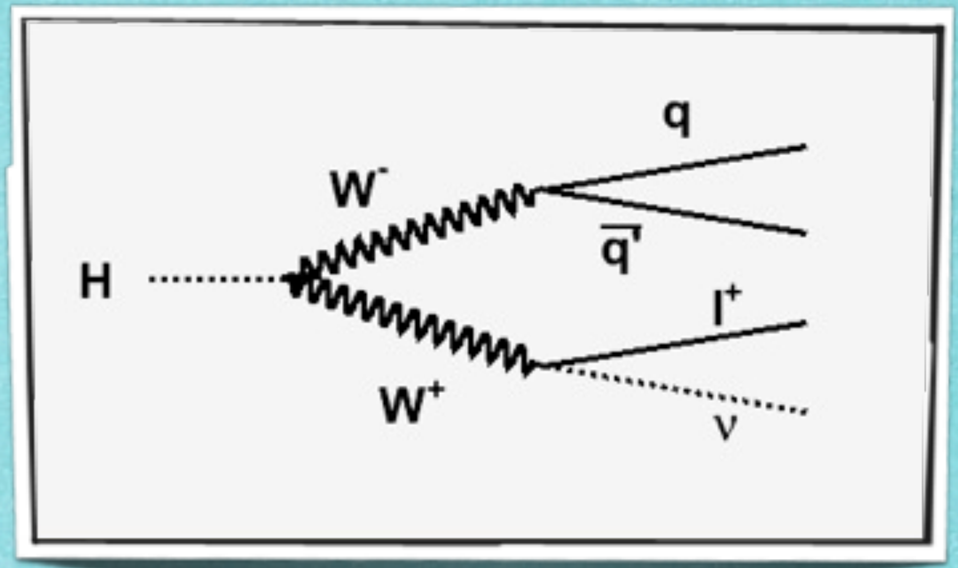
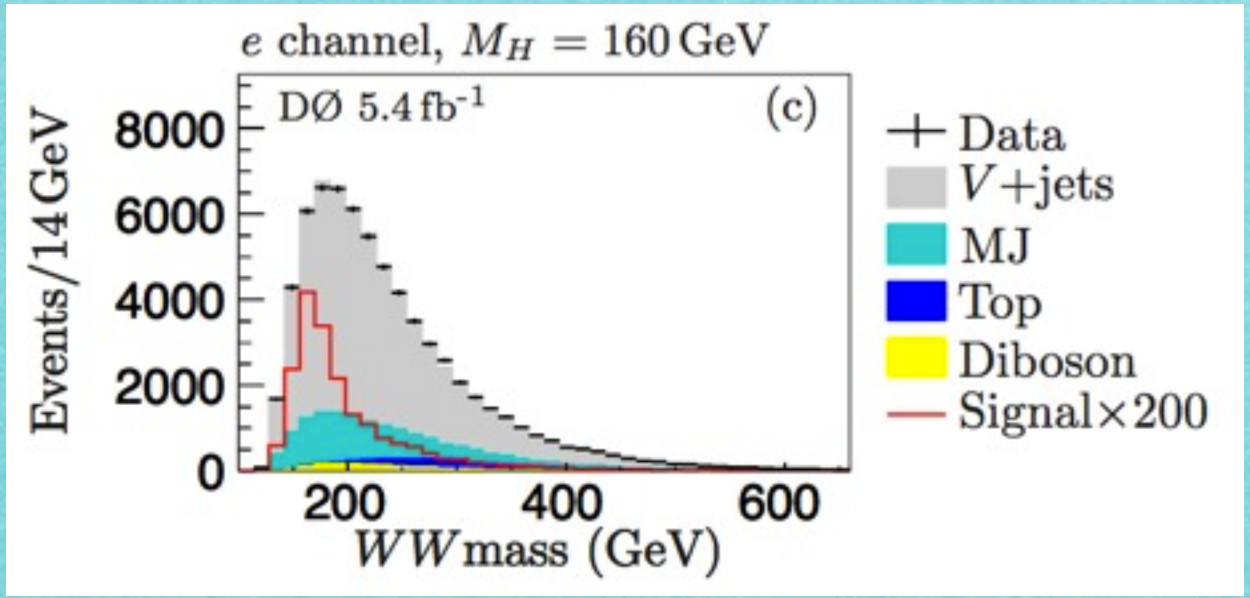
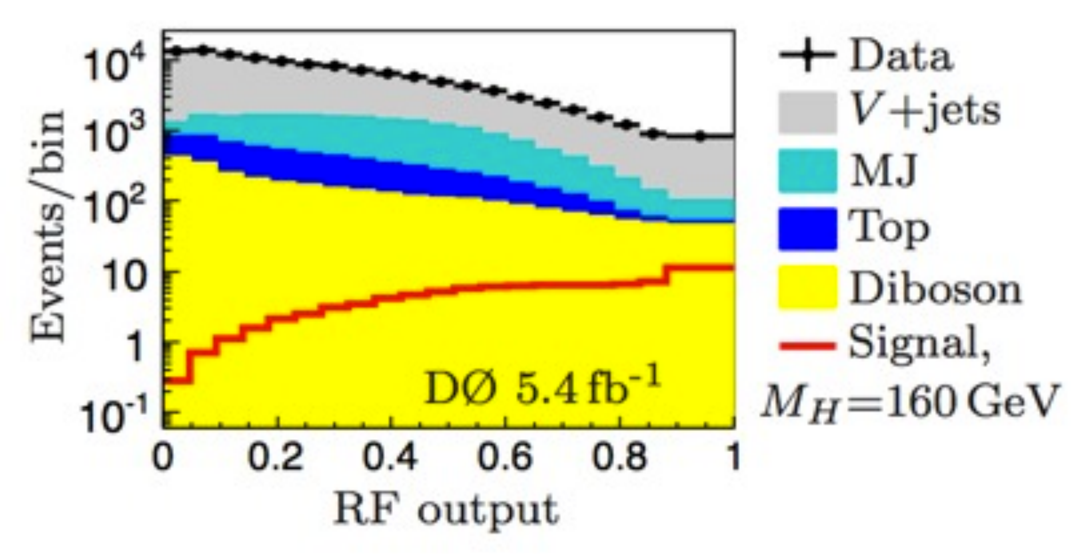


Semileptonic Decays

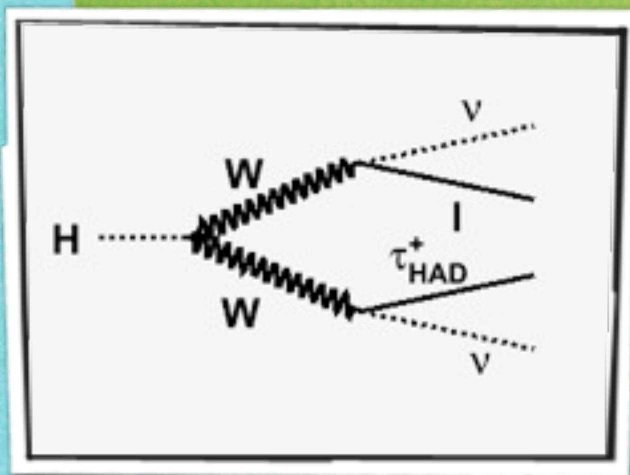
- Factor of 6 increase in signal versus dileptons
- Huge background from W/Z+jets
- Full reconstruction of the WW events





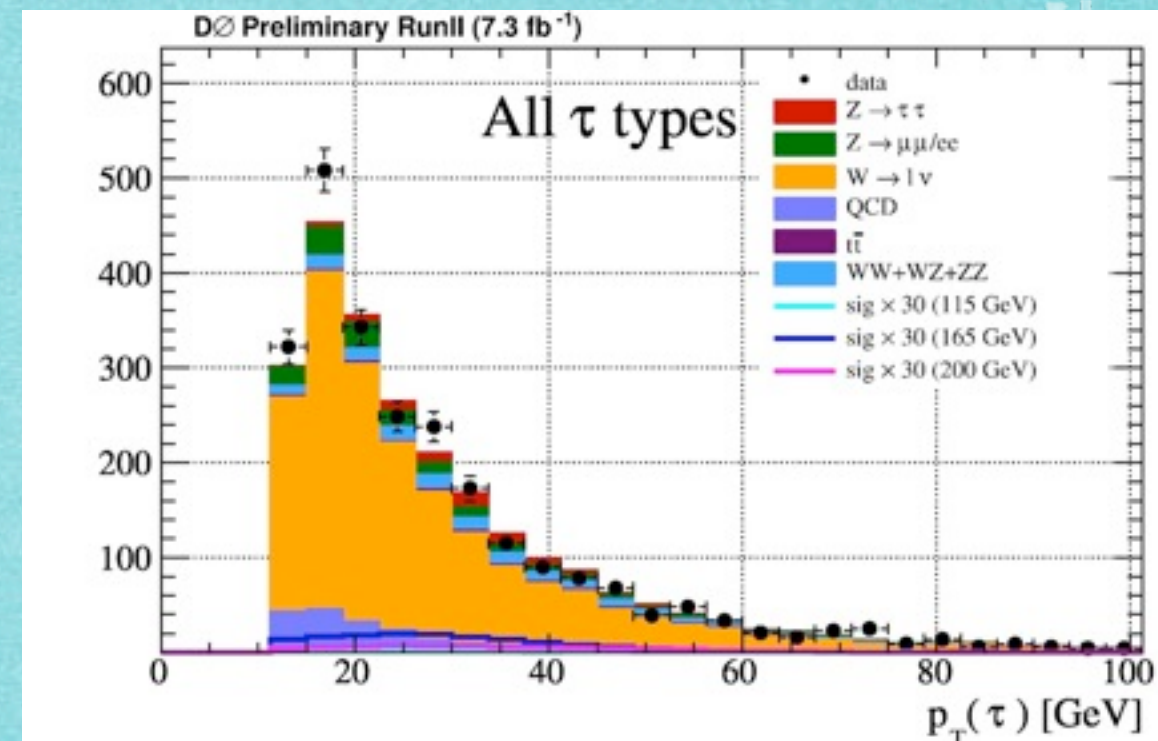


Hadronic tau lepton (τ_{had})

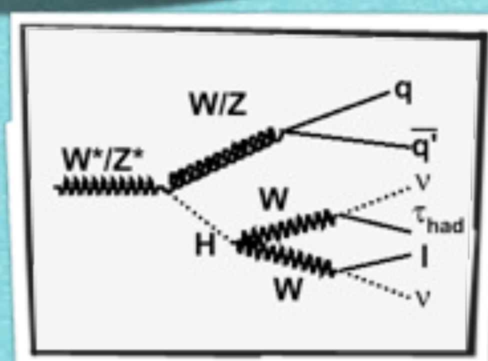


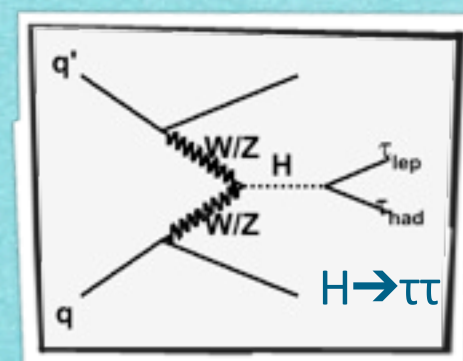
CDF: e/μ+τ_{had}, BDT

D∅: μτ_{had}+0/1jet, NN

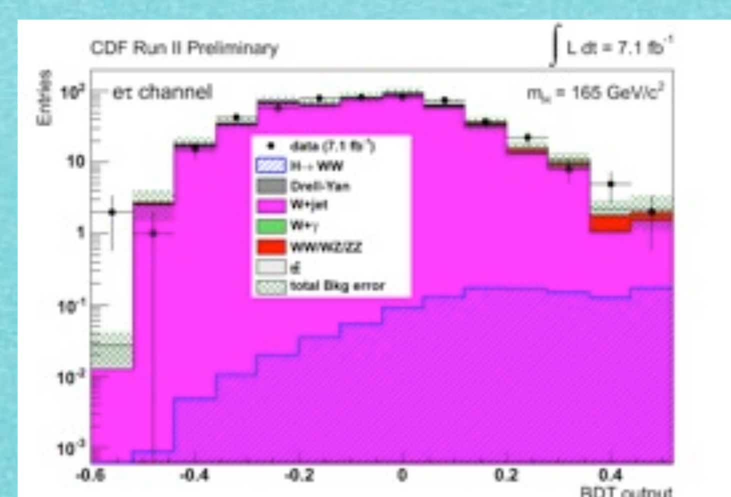


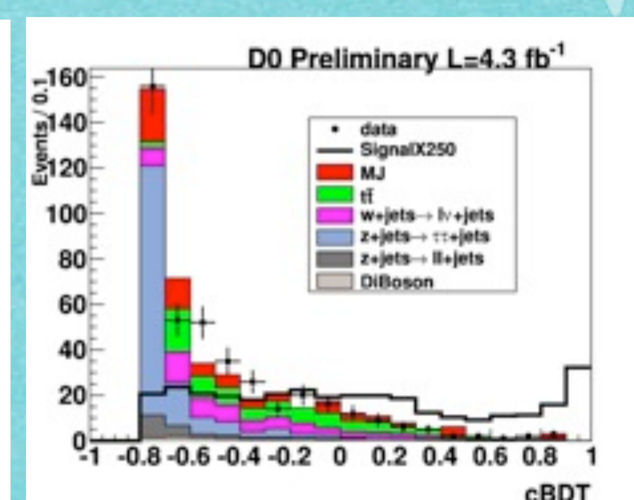
D∅: e/μ+τ_{had}
+2 jets, BDT





- Dominant background: W+jet
- Small S/B ratio

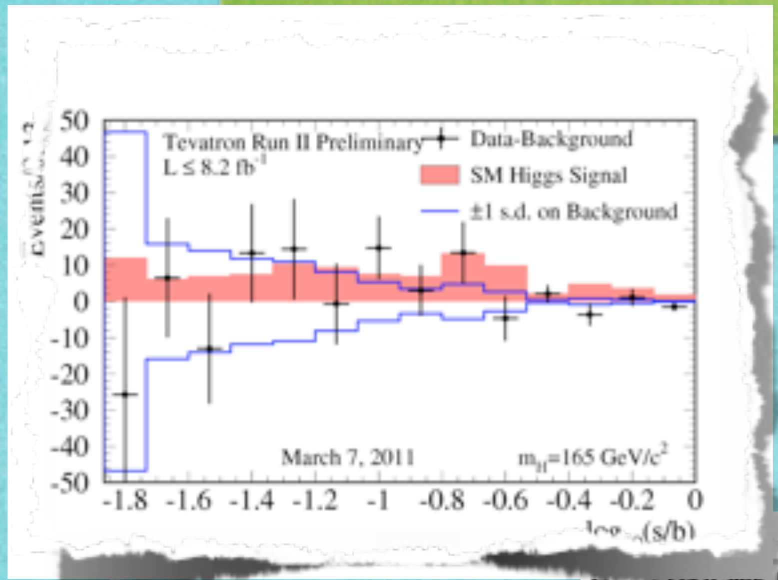


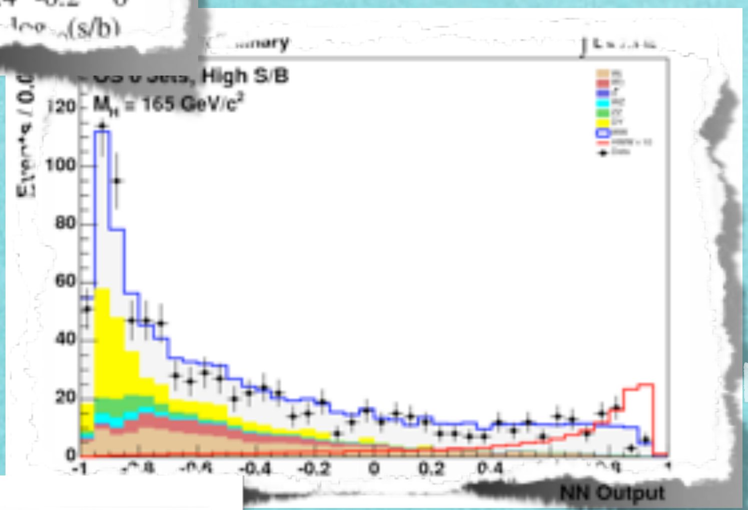


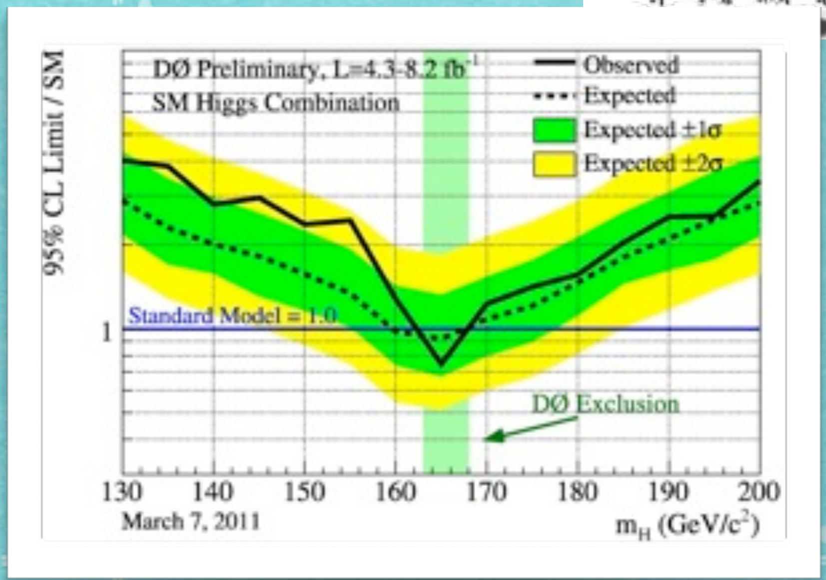
Systematic Uncertainties

- Dominant experimental uncertainties:
  - Acceptance due to higher order processes: ~10%
  - Jet Energy Scale: 3 ~ 25%
- Dominant theoretical uncertainties:
  - Cross section: 5 ~ 10%
  - $gg \rightarrow H$ case: 7~33% (Scale), 8~30% (PDF) according to jet multiplicity
- Carefully combine uncertainties
  - Correlated/uncorrelated between analysis channels and experiments

Set the Limit

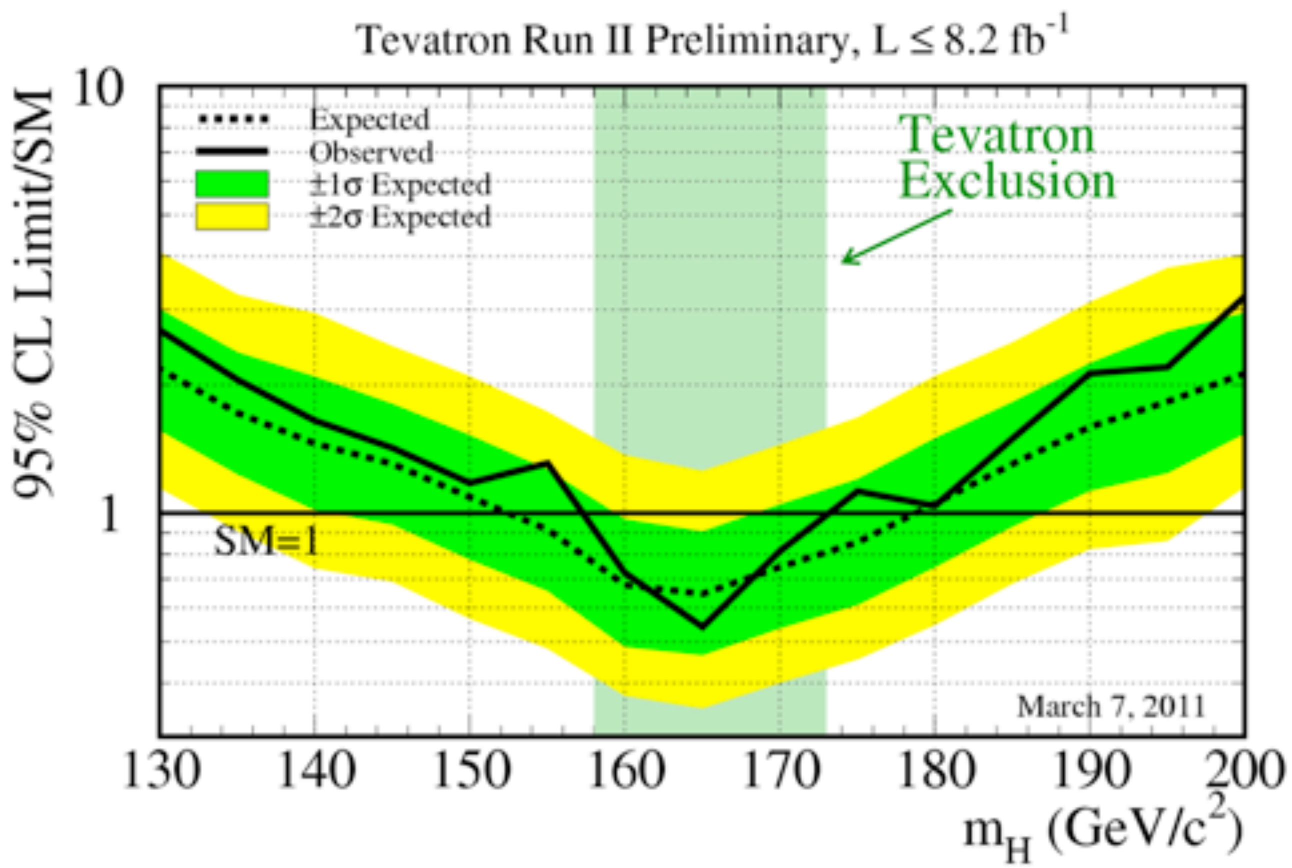




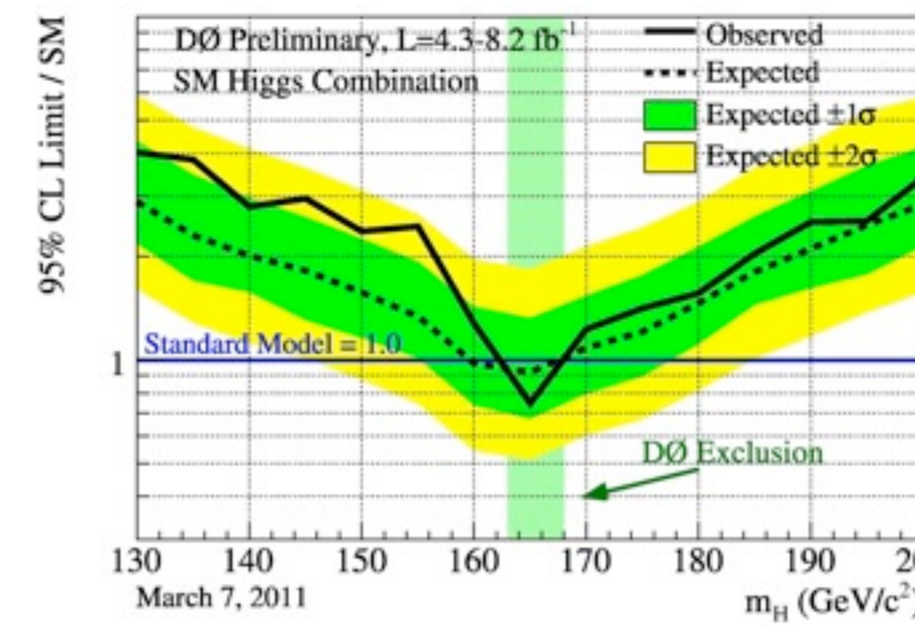


- No significant excess observed
- Systematic uncertainties are treated as nuisance parameters in the combined signal/background fit to the discriminator outputs from each channel
- Expected limits determined from background-only pseudo-experiments incorporating the systematic uncertainties
- Set upper limit on Higgs production cross section relative to SM prediction at 95% C.L.

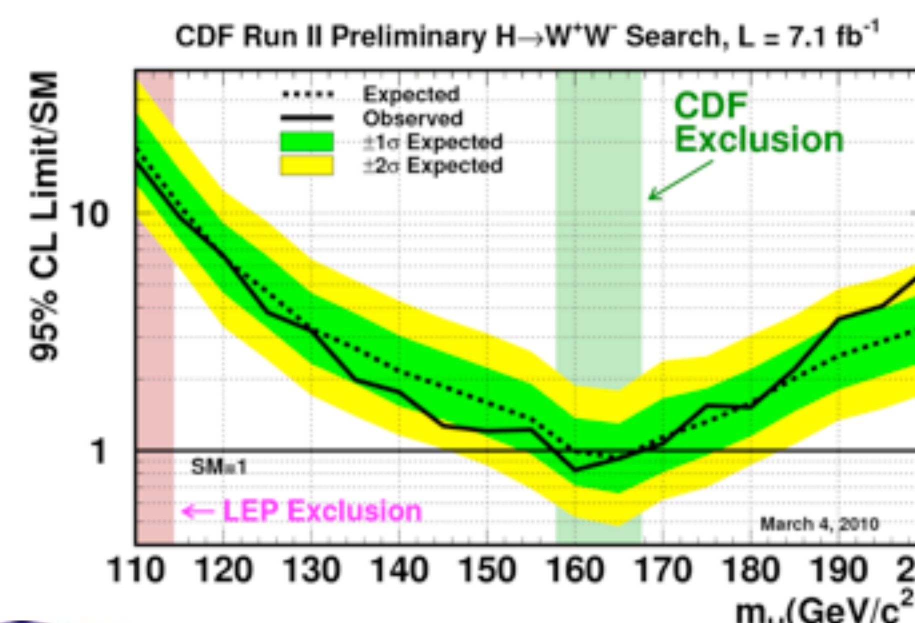
Search Result from Tevatron



Exclude $158 < m_H < 173$ GeV/c²
(expected to exclude 153-179 GeV/c²)



Observed: 163-168 GeV/c²
Expected: 160-168 GeV/c²



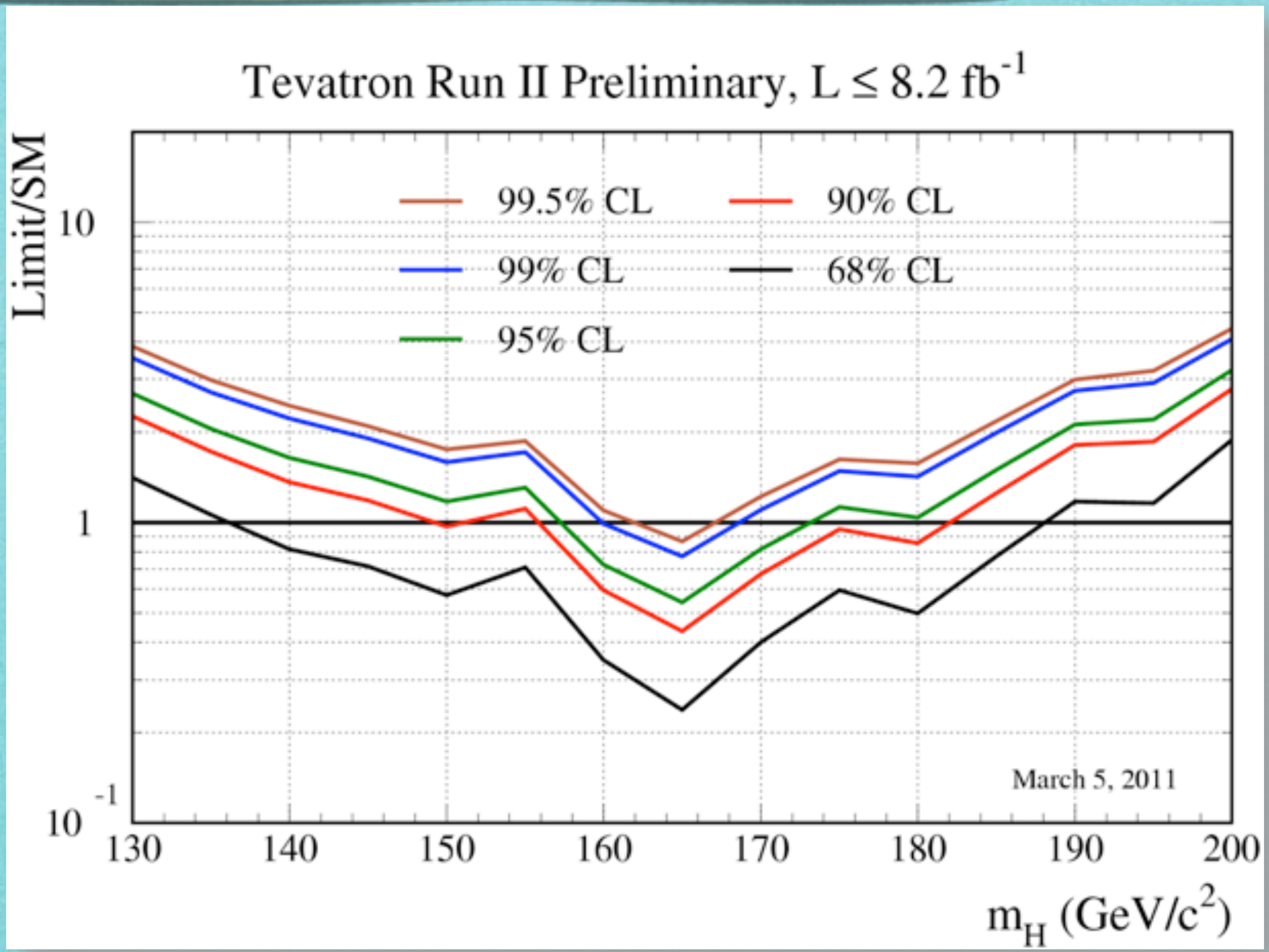
Observed: 158-168 GeV/c²
Expected: 159-168 GeV/c²

Conclusion

- For the first time this spring, CDF and D∅ were able to produce single-experiment exclusions for Higgs masses in the neighborhood of 165 GeV/c^2
- The combined Tevatron result with data up to 8.2 fb^{-1} exclude Higgs mass: 158-173 GeV/c^2
- Improvements are coming for summer
  - More search channels
  - Enlarged lepton acceptance, and so on..
- Expect the final dataset ~10 fb^{-1} by this autumn (~9.3 fb^{-1} as of May)

backup

Limits with various C.L.



Exclude $162 < m_H < 166$ with 99% C.L.

Cross sections & Branching ratios

TABLE III: The production cross sections and decay branching fractions for the SM Higgs boson assumed for the combination.

m_H (GeV/c^2)	$\sigma_{gg\to H}$ (fb)	σ_{WH} (fb)	σ_{ZH} (fb)	σ_{VBF} (fb)	$B(H\to\tau^+\tau^-)$ (%)	$B(H\to W^+W^-)$ (%)	$B(H\to ZZ)$ (%)	$B(H\to\gamma\gamma)$ (%)
130	842.9	112.00	68.5	62.1	5.305	29.43	3.858	0.2182
135	750.8	97.20	60.0	57.5	4.400	39.10	5.319	0.2077
140	670.6	84.60	52.7	53.2	3.472	49.16	6.715	0.1897
145	600.6	73.70	46.3	49.4	2.585	59.15	7.771	0.1653
150	539.1	64.40	40.8	45.8	1.778	68.91	8.143	0.1357
155	484.0	56.20	35.9	42.4	1.057	78.92	7.297	0.09997
160	432.3	48.50	31.4	39.4	0.403	90.48	4.185	0.05365
165	383.7	43.60	28.4	36.6	0.140	95.91	2.216	0.02330
170	344.0	38.50	25.3	34.0	0.093	96.39	2.351	0.01598
175	309.7	34.00	22.5	31.6	0.073	95.81	3.204	0.01236
180	279.2	30.10	20.0	29.4	0.059	93.25	5.937	0.01024
185	252.1	26.90	17.9	27.3	0.046	84.50	14.86	0.008128
190	228.0	24.00	16.1	25.4	0.038	78.70	20.77	0.006774
195	207.2	21.40	14.4	23.7	0.033	75.88	23.66	0.005919
200	189.1	19.10	13.0	22.0	0.029	74.26	25.33	0.005285

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Obs. & Exp. Limits

- Use Bayesian Limit for Tevatron Combination
  - CLs method used for double check. Consistent to each other

TABLE V: Ratios of median expected and observed 95% C.L. limit to the SM cross section for the combined CDF and D0 analyses as a function of the Higgs boson mass in GeV/c^2, obtained with the Bayesian and with the CL_s method.

Bayesian	130	135	140	145	150
Expected	2.18	1.72	1.46	1.31	1.09
Observed	2.69	2.05	1.65	1.42	1.18

CL_s	130	135	140	145	150
Expected:	2.14	1.72	1.49	1.29	1.14
Observed:	2.57	1.98	1.60	1.42	1.16

Bayesian	155	160	165	170	175	180	185	190	195	200
Expected	0.92	0.68	0.65	0.75	0.85	1.06	1.30	1.59	1.83	2.13
Observed	1.31	0.72	0.54	0.82	1.13	1.04	1.49	2.13	2.20	3.22

CL_s	155	160	165	170	175	180	185	190	195	200
Expected	0.92	0.68	0.64	0.77	0.87	1.05	1.32	1.60	1.82	2.09
Observed	1.28	0.70	0.52	0.80	1.09	1.03	1.49	2.13	2.22	3.13

Expected limits from each channel
for 165 GeV/c^2 Higgs

channel	Lum.	Exp. Limit	channel	Lum.	Exp. Limit
OS - 0jet	7.1	1.52	OS - eμ	8.1	1.26
OS - 1jet	7.1	2.13	OS - ee	8.1	2.29
OS - 2jets	7.1	2.74	OS - μμ	8.1	2.23
low M_{ll}	7.1	10.6	lνqq	5.4	5.1
SS	7.1	2.75	SS	5.4	7.0
trilepton	7.1	4.9	$e/\mu+\tau_{had}$	7.3	7.8
$e/\mu+\tau_{had}$	7.1	13.1	$e/\mu+\tau_{had}$ w/ 2^{+}jets	4.3	12.3