Search for High Mass Higgs at the Tevatron

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on behalf of the CDF and DZero Collaborations

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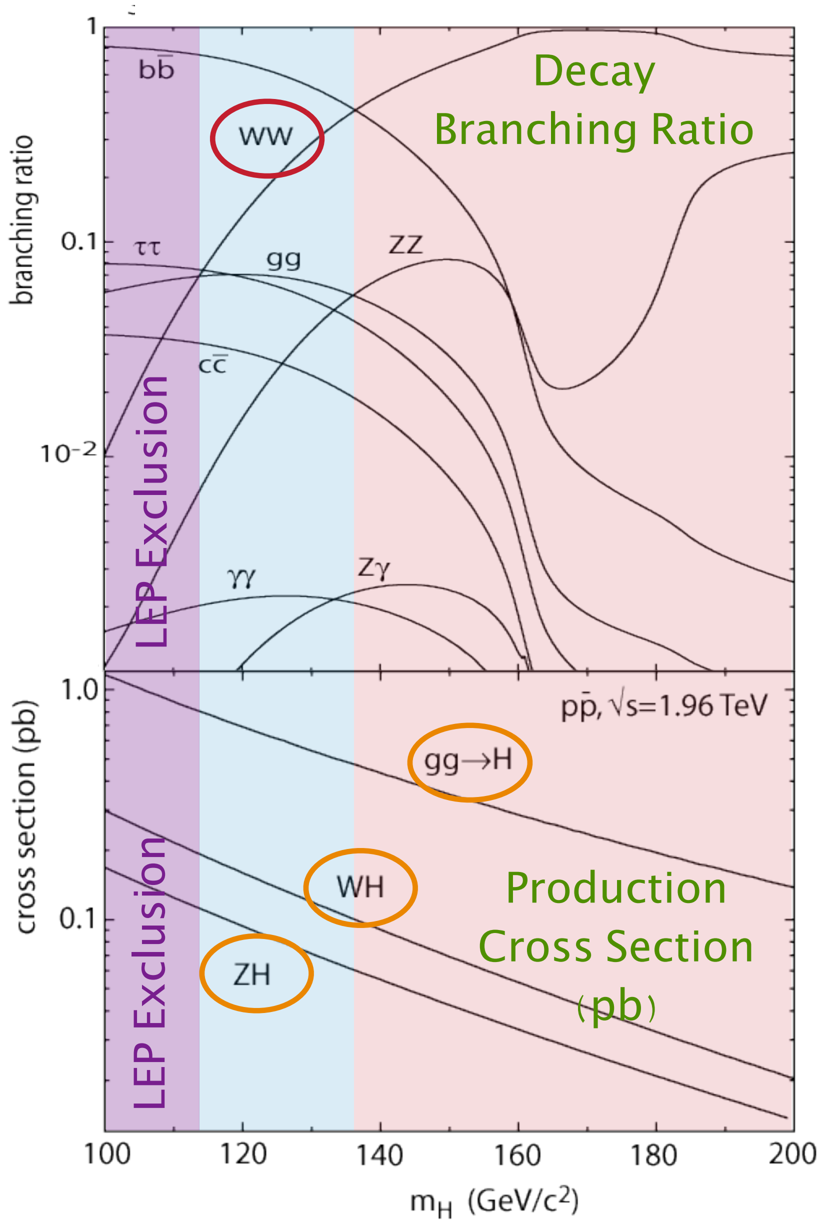
SM Higgs Boson Search

Standard Model (SM) Higgs boson searches in the high mass region

- $H \rightarrow WW$ dominant decay mode for masses above ~135GeV
- Leading production mechanism is gluon-gluon fusion

Tevatron Experiments

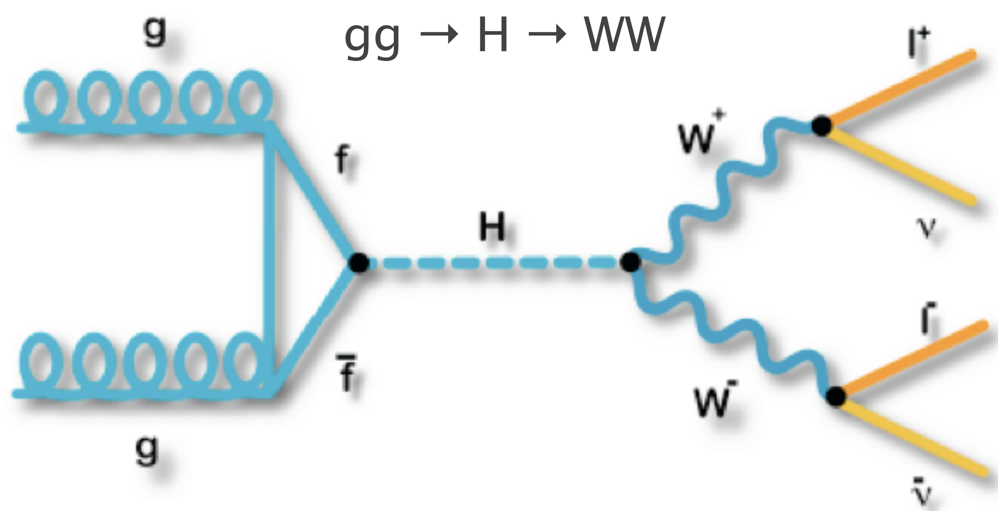
- $p\bar{p}$ collisions @$\sqrt{s}$ = 1.96TeV
- Two experiments with general purpose detectors, CDF and DØ
- Collected and analysed 4.8 – 5.4 fb^{-1} of data for high mass Higgs search

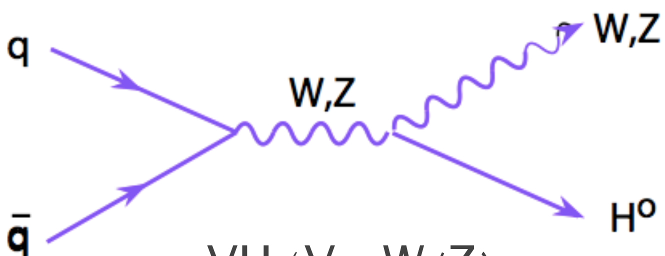


Event Signature

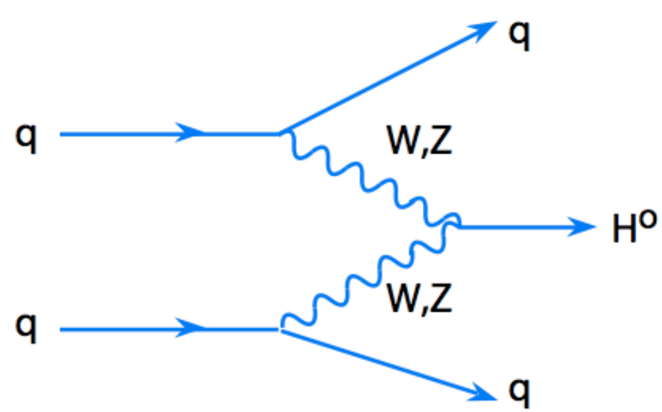
Signature from gg → H → WW

- Two high p_T isolated leptons + large missing E_T
- Relatively clean environment





VH (V = W/Z)



qqH

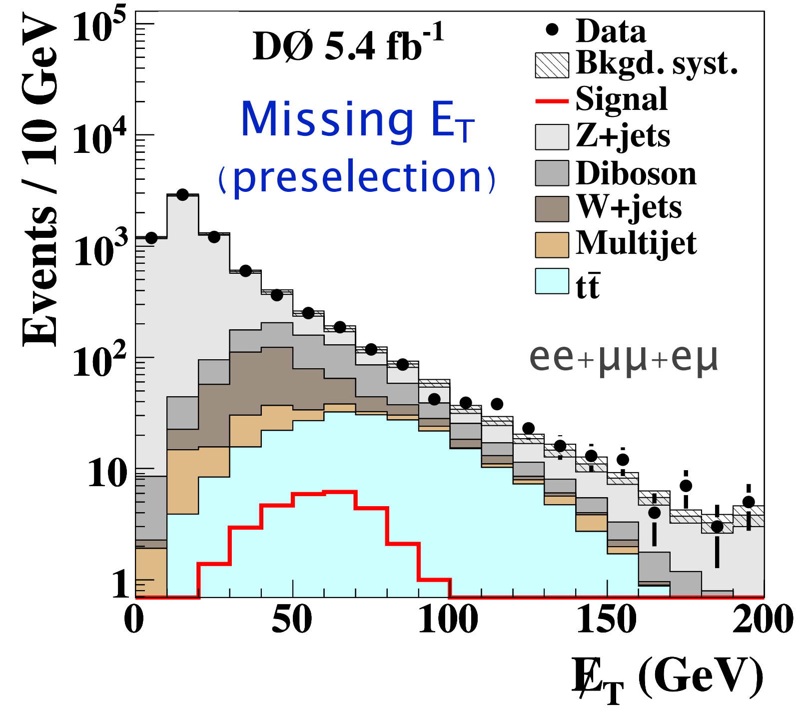
Additional sources of Higgs signals with dileptons

- Associated production (VH) and Vector Boson fusion (qqH) → ~35% more signal
- Other Higgs decay modes (e.g. H → ττ) → helps lower mass region

Background Rejection

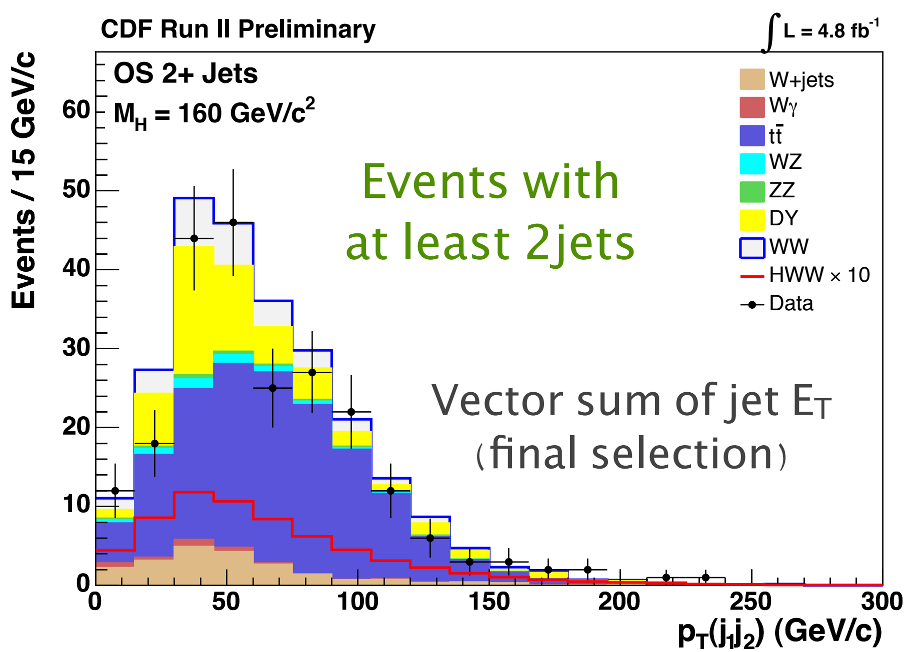
Selection based on event kinematics

- 2 high p_T leptons with η up to 2.5
- Missing E_T cut to reject a large fraction of dominant Z background



High jet multiplicity region

→ veto events with b-tagged jets to reduce tt



S/B ~ 1.5% after all selection cuts with 60 signal events (CDF + DØ) at M_H = 160GeV

Analysis Strategies I

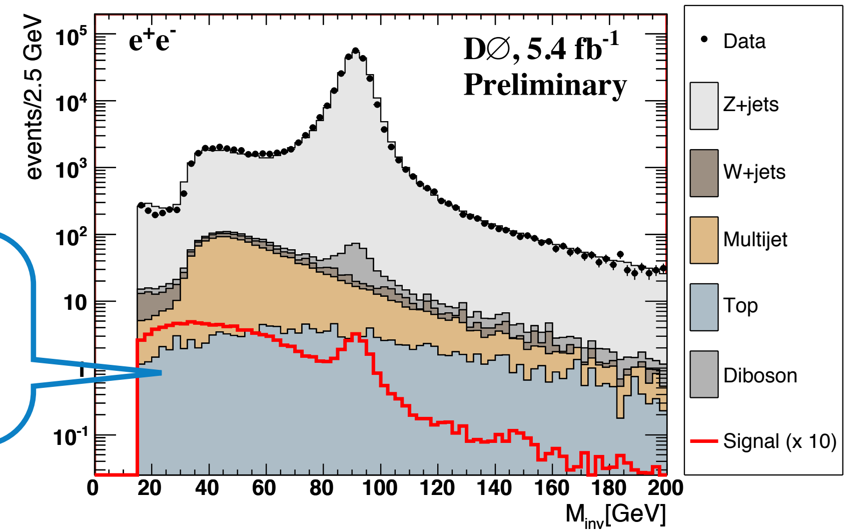
Split analysis into several orthogonal channels

→ optimise separately for different type of kinematics

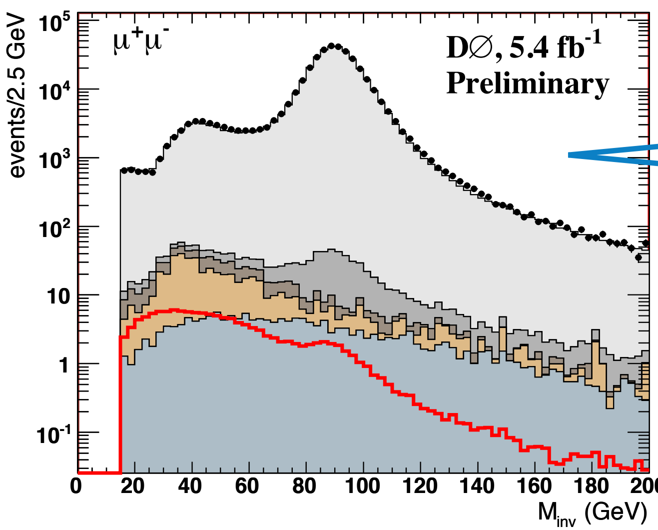
- **Lepton flavour**: different efficiency, resolution and kinematics

  DØ separate analysis into ee/μμ/eμ pairs,

  CDF into high/low S/B samples

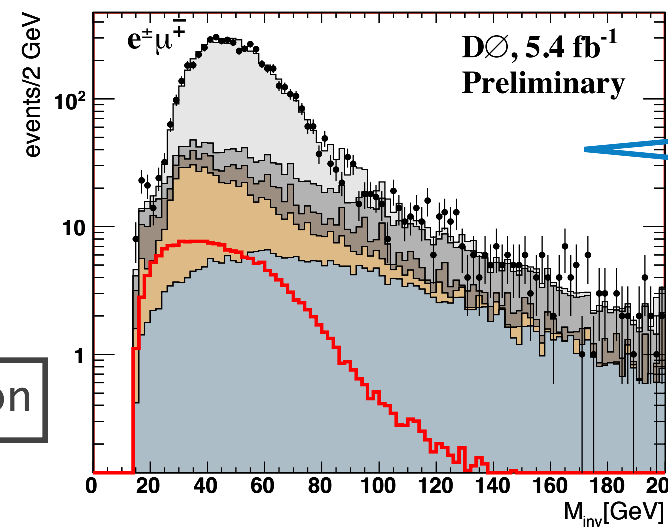


ee pair



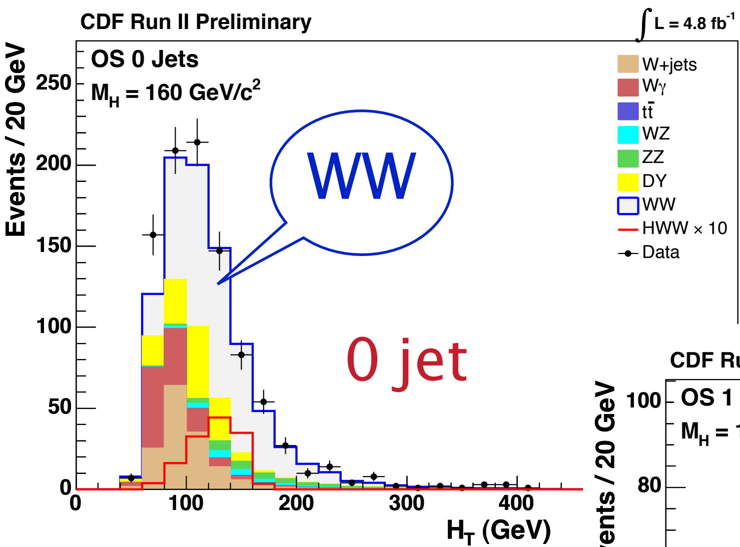
μμ pair

preselection

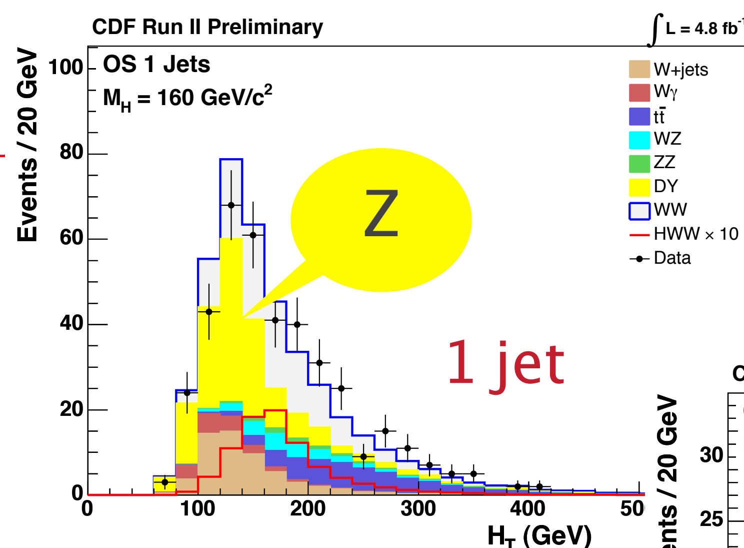


eμ pair

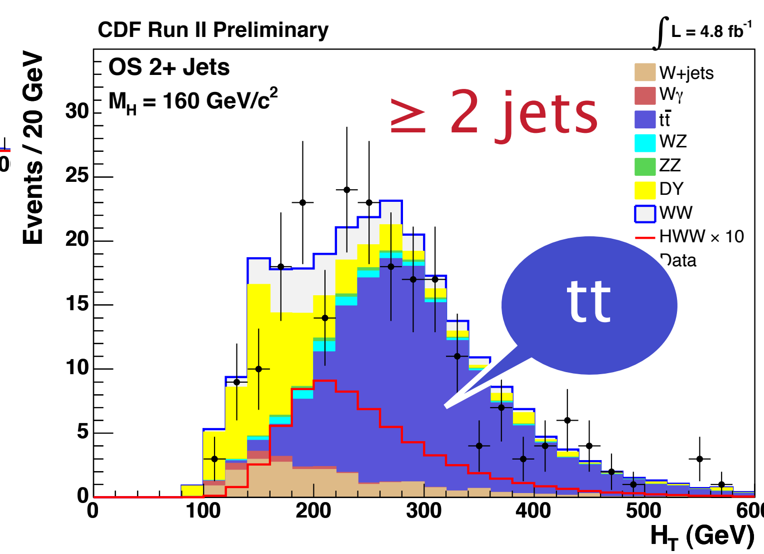
Analysis Strategies II



- Jet multiplicity (N jet): different signal and background compositions



H_T = scalar sum of lepton and missing E_T (final selection)



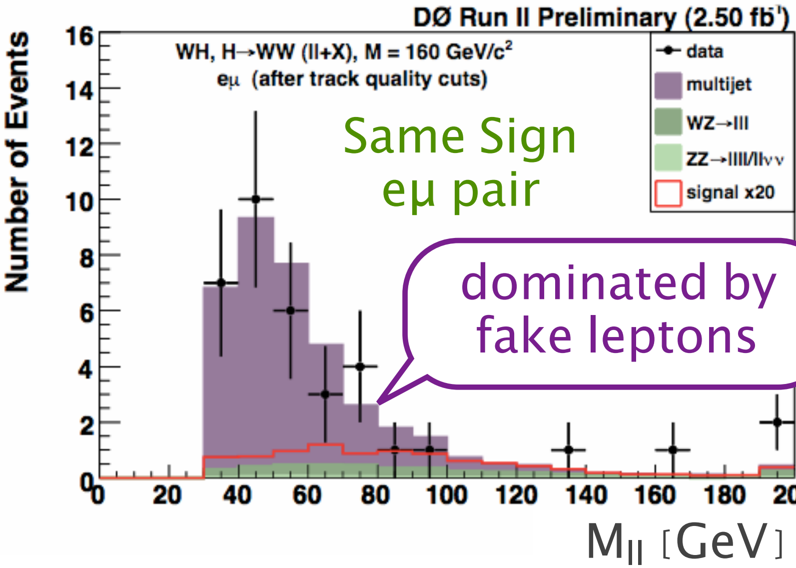
CDF separate samples into dilepton+0 jet, 1 jet and ≥ 2 jets,

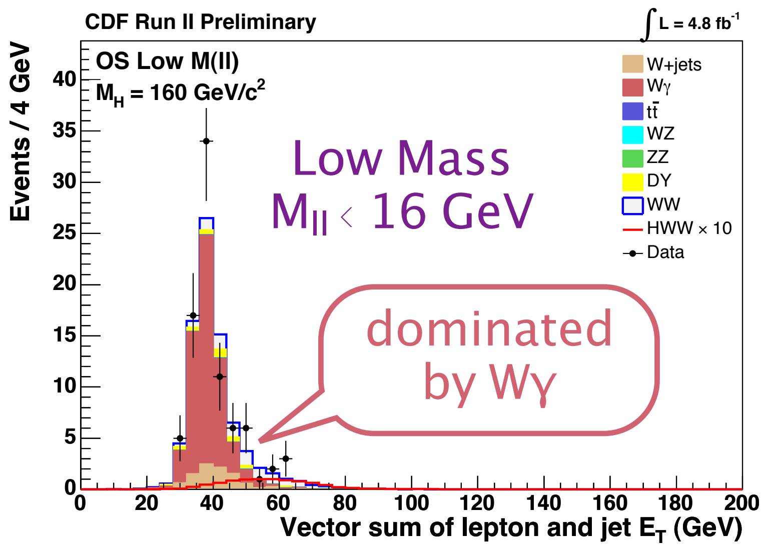
DØ uses shape of N jet distribution

Analysis Strategies III

- Charge configuration: opposite sign (OS) and same sign (SS) lepton pair

  → SS signal from VH production, physics background very small





Text

- Kinematic regions: high/low dilepton invariant mass (M_{ll}) region

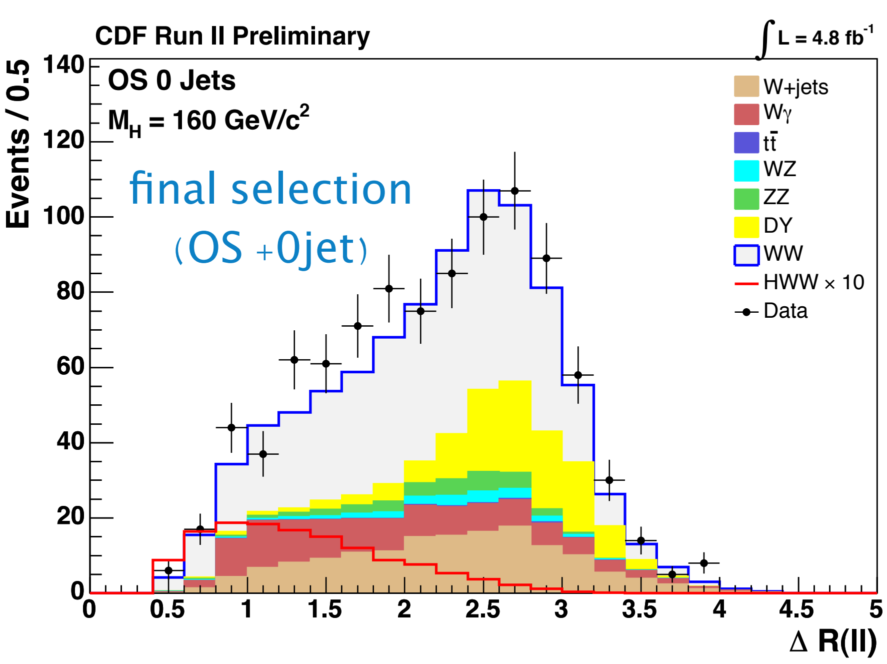
  → dedicated low M_{ll} analysis by CDF

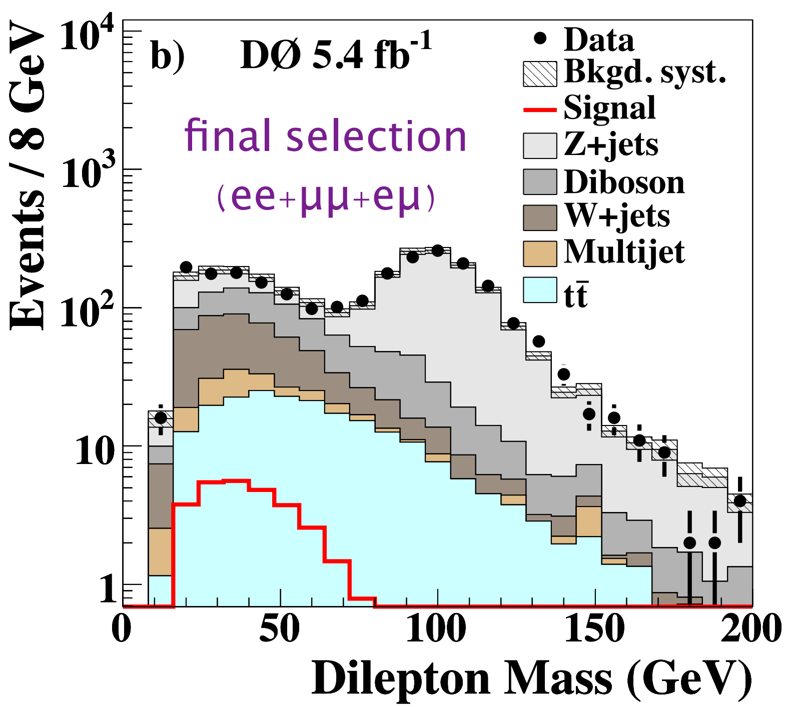
Basic cuts on kinematic variables to reduce dominant backgrounds
\+ multivariate analysis for maximum use of information

Discriminating Variables I

Variables using kinematics of two leptons

- Angular separation: powerful discriminant against WW as well as other bkgds →smaller separation angle for leptons from H decay due to spin correlation
- Invariant mass: effective against most of the physics backgrounds
- Kinematics of individual leptons and quality information

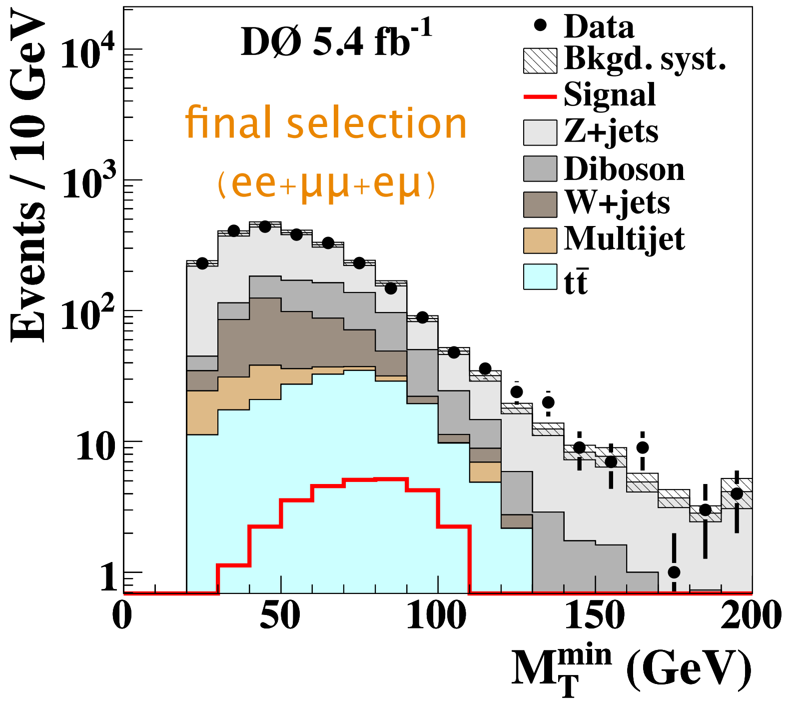


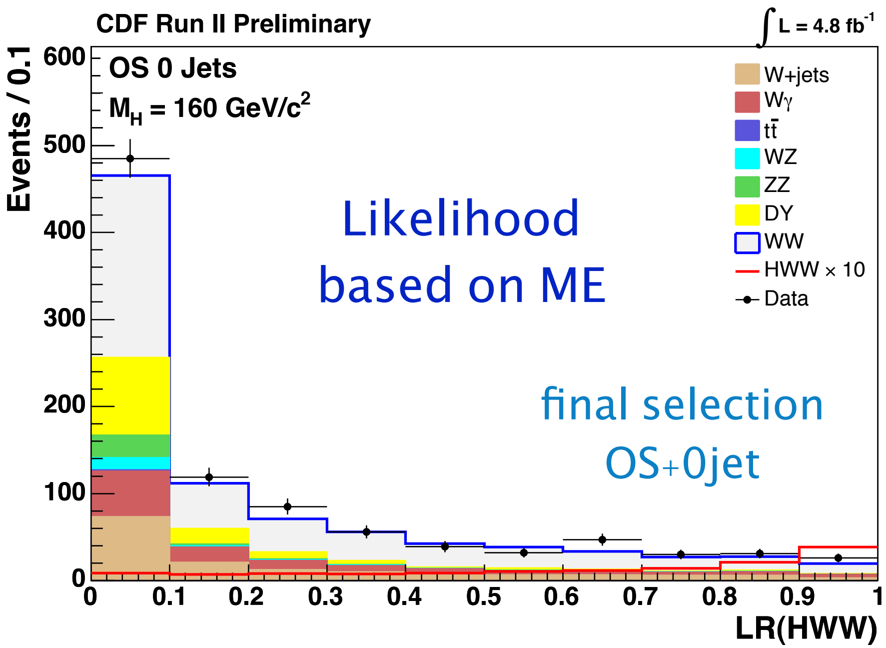


Discriminating Variables II

Variables describing event topology

- Relation between lepton and missing E_T e.g. transverse mass (M_T), angular separation, E_T sum
- Topological variables based on leptons, jets and missing E_T





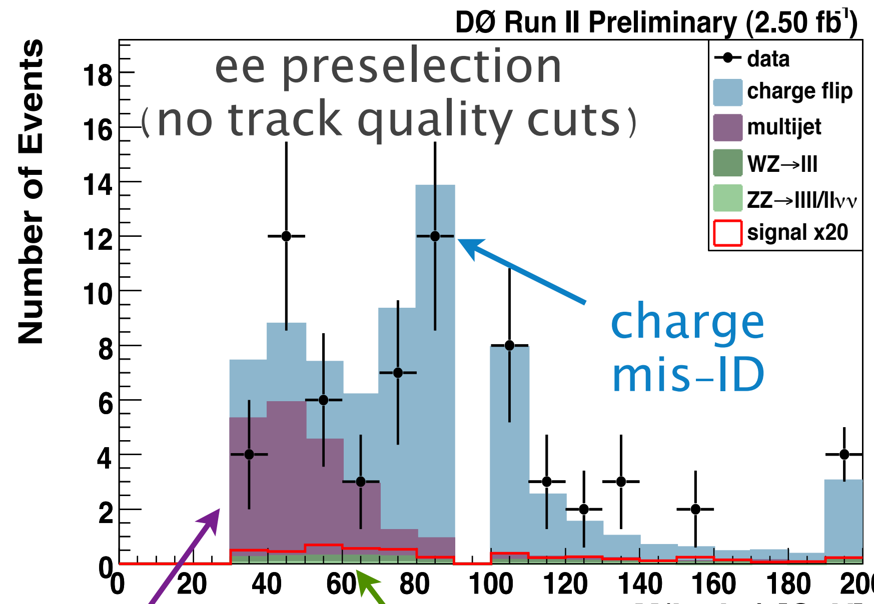
Matrix Element (ME) calculation

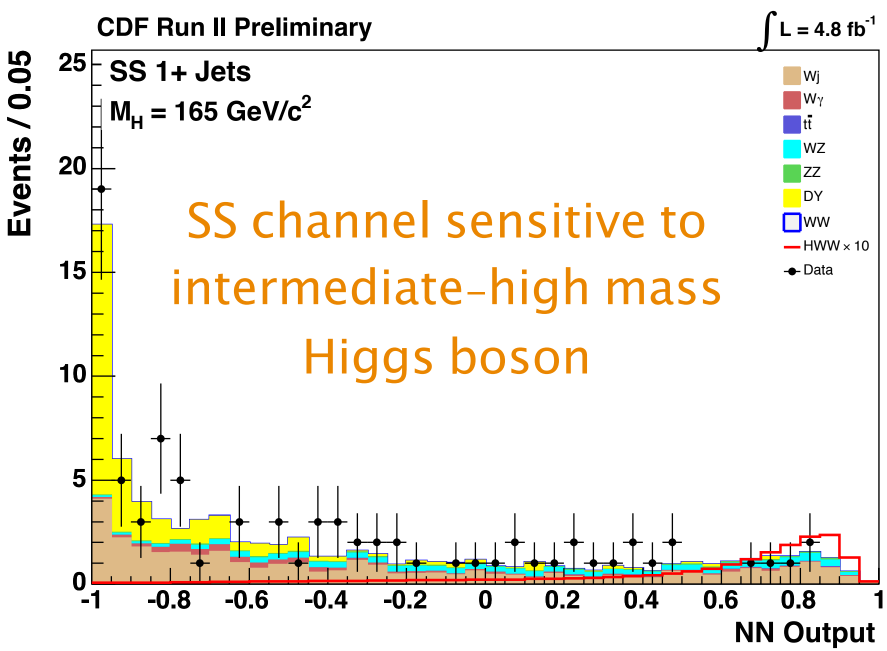
- Translate parton level kinematics into reco as probability density
- Powerful discriminant → ~10% gain in sensitivity

Same Charge DiLeptons

Same sign leptons from VH production

- Suppress Standard Model bkgds
  → true same sign from WZ and ZZ
- Fake leptons from W+jet and multijet
- Charge mis-measurement in OS
  (mostly Z → ll events)



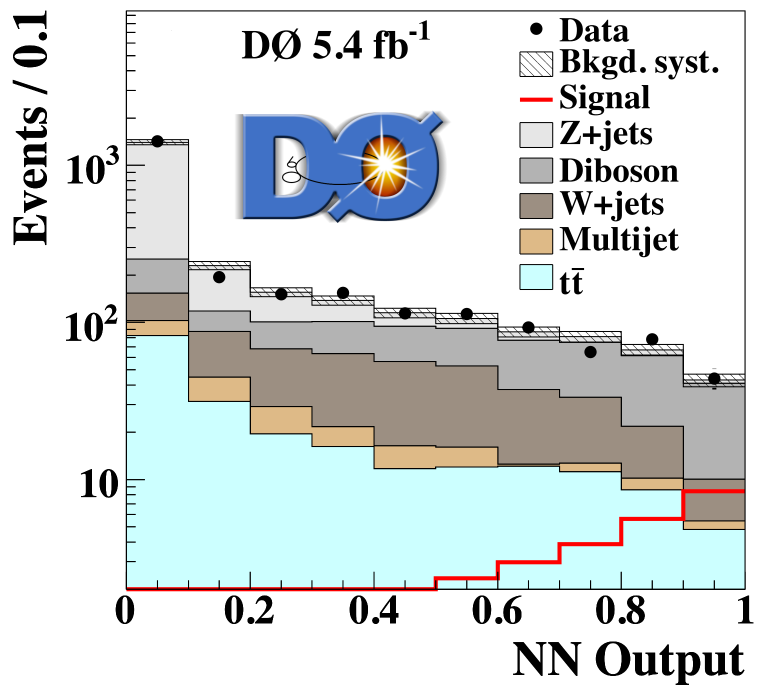


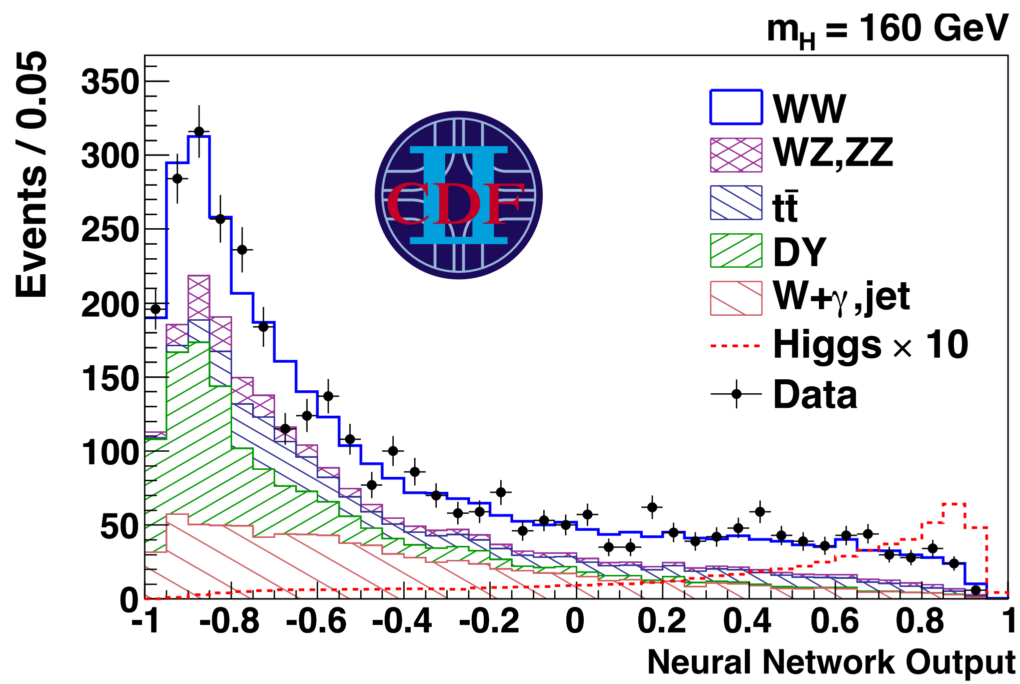
Instrumental Backgrounds

- Not well modelled by simulation
- Lepton fake rate measured in data
- Charge mis-measurement controlled by track quality cuts

Multivariate Analysis

Maximise the power of discriminating variables
using Neural Networks





All OS channels combined

All channels combined

Systematic Uncertainties

Uncertainty on estimated signal & bkgd normalisation and shape

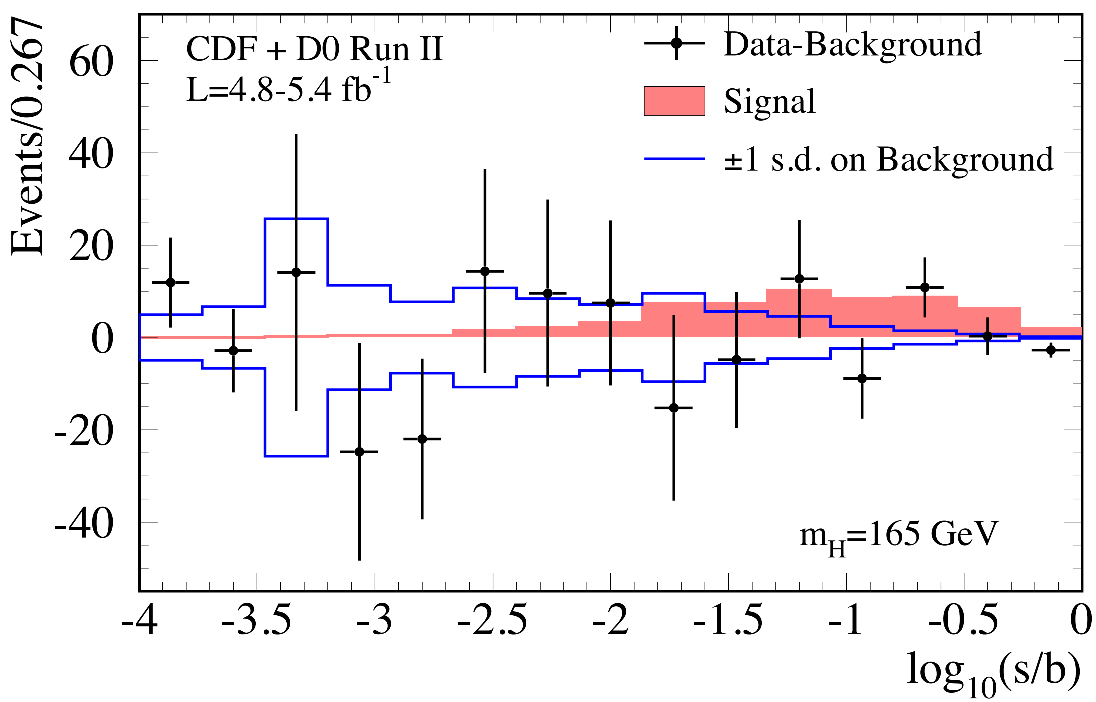
Systematics correlated between CDF and DØ

- Integrated luminosity (4% correlated out of 6% total)
- Theoretical cross sections (5-10%)

Other sources

- MC acceptance, up to 10%
- Lepton ID, 2-4%
- Jet / missing E_T modelling, 4-30% (process dependent)
- Instrumental bkgd estimate

Signal well above background uncertainty



Sensitivity

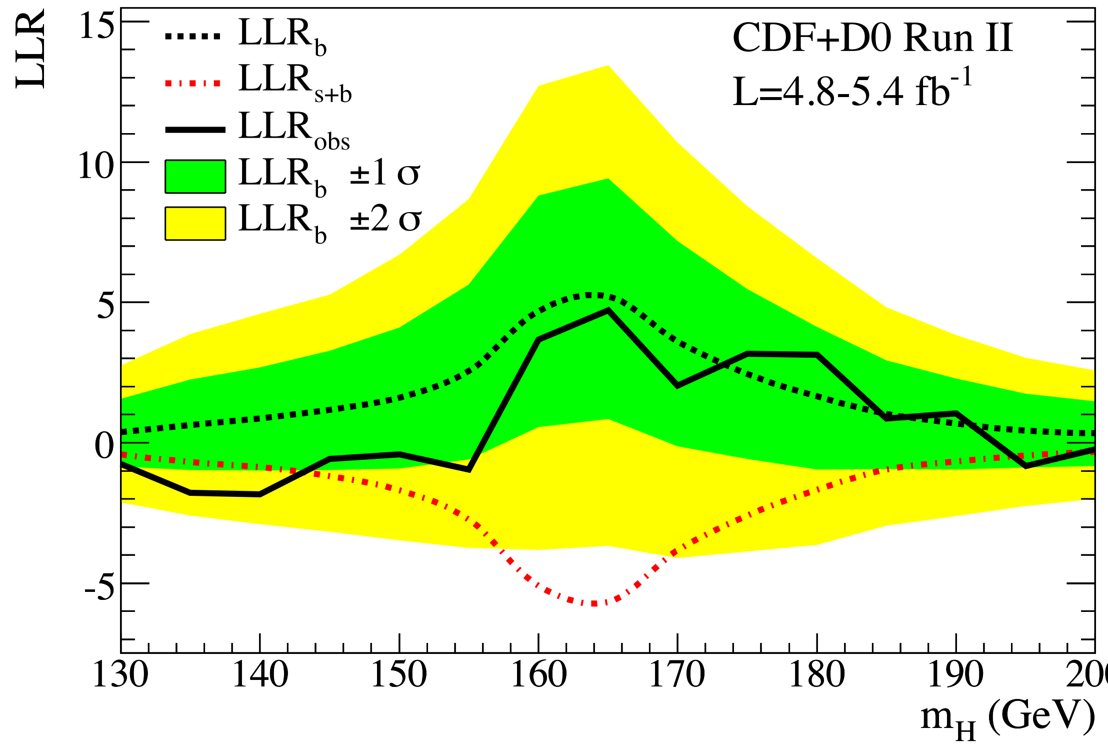
Log-Likelihood Ratio (LLR)

background only, LLR_b

background+signal, LLR_{s+b}

observed, LLR_{obs}

Uncertainty bands on LLR_b
→ include statistical & systematic uncertainties



Sensitivity of Higgs search in high mass region

- Separation between LLR_b and LLR_{s+b} translates to sensitivity of the analysis
- Maximum around ~165GeV → expected sensitivity above 2σ
- Observation consistent with background only hypothesis

Selected for a Viewpoint in *Physics*
PRL **104,** 061802 (2010) PHYSICAL REVIEW LETTERS week ending 12 FEBRUARY 2010

Combination of Tevatron Searches for the Standard Model Higgs Boson in the W^+W^- Decay Mode

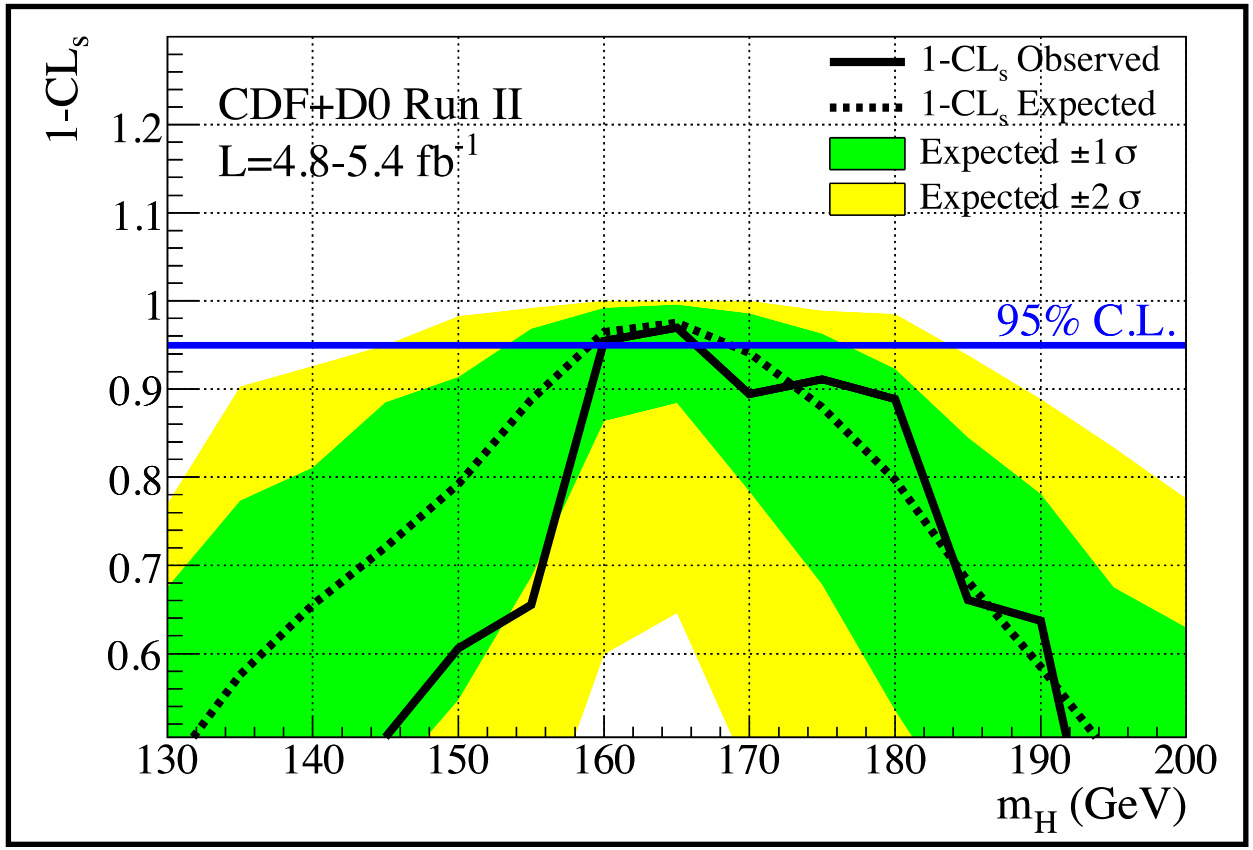
Combined dilepton results published

→ First joint CDF+DØ publication on SM Higgs search

Exclusion region

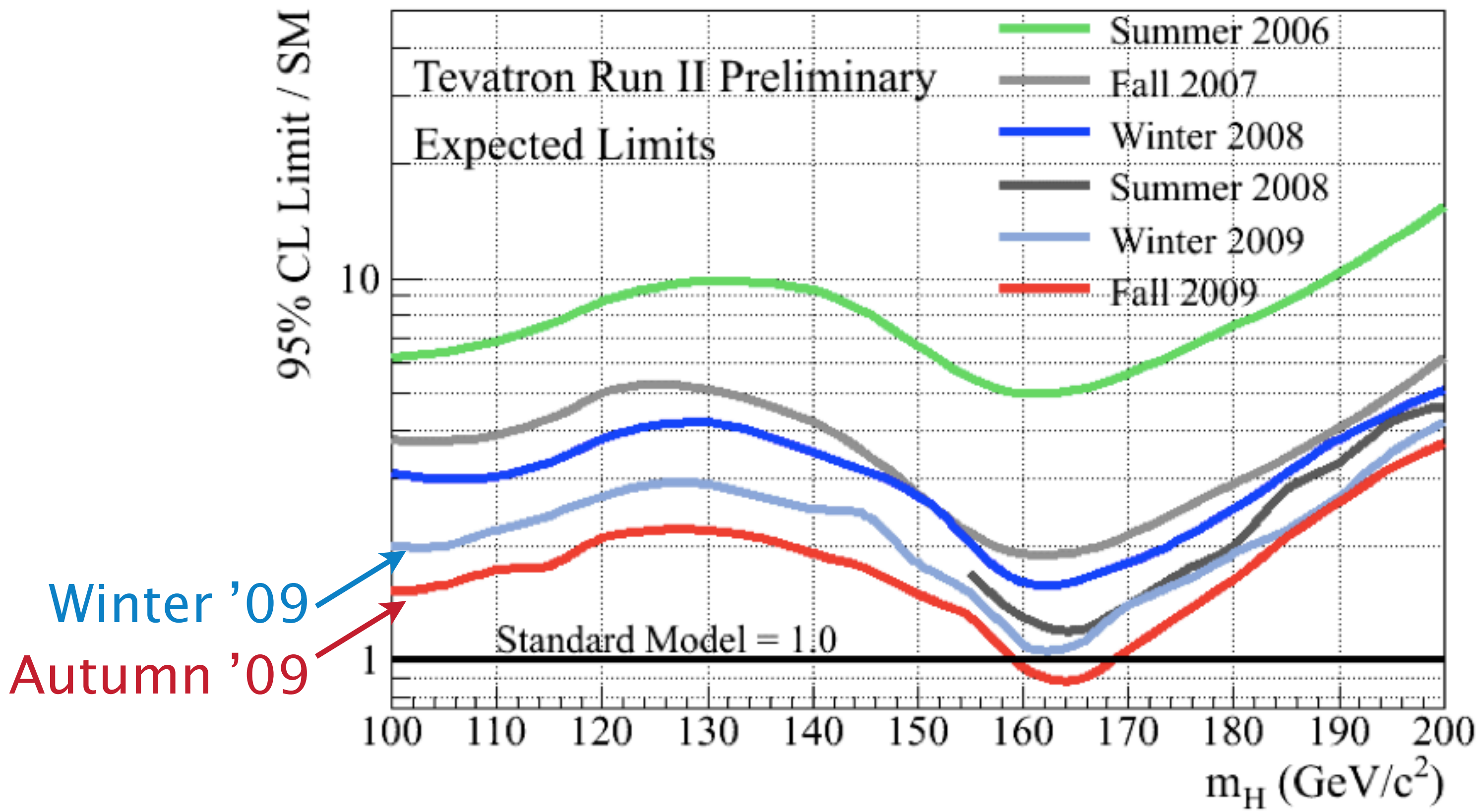
162–166 GeV @95%CL

(159–169 GeV expected)



(*CDF Collaboration)
(†D0 Collaboration)

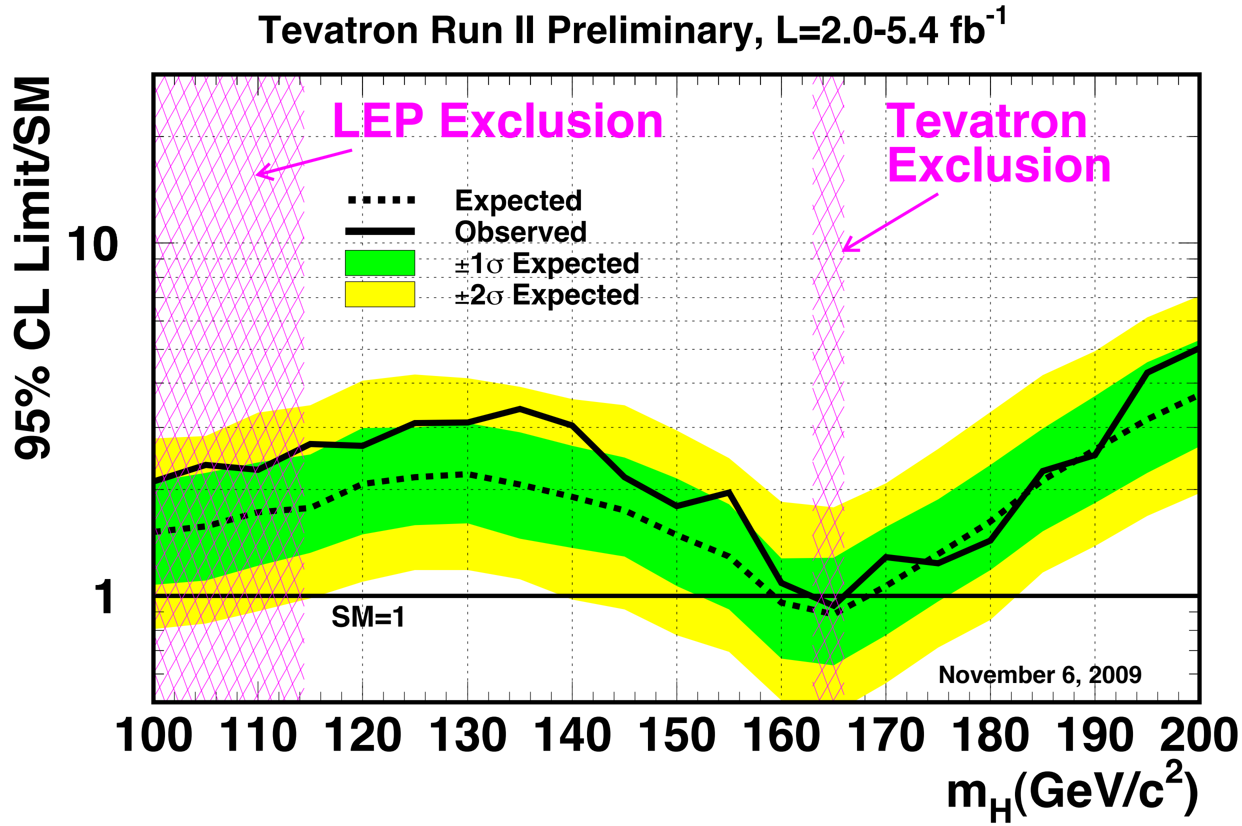
Improving Cross Section Limits



Significant improvement over the past year

All channels (low+high mass) combined, expected limits down to ~2x Standard Model prediction in most of mass region

Conclusions



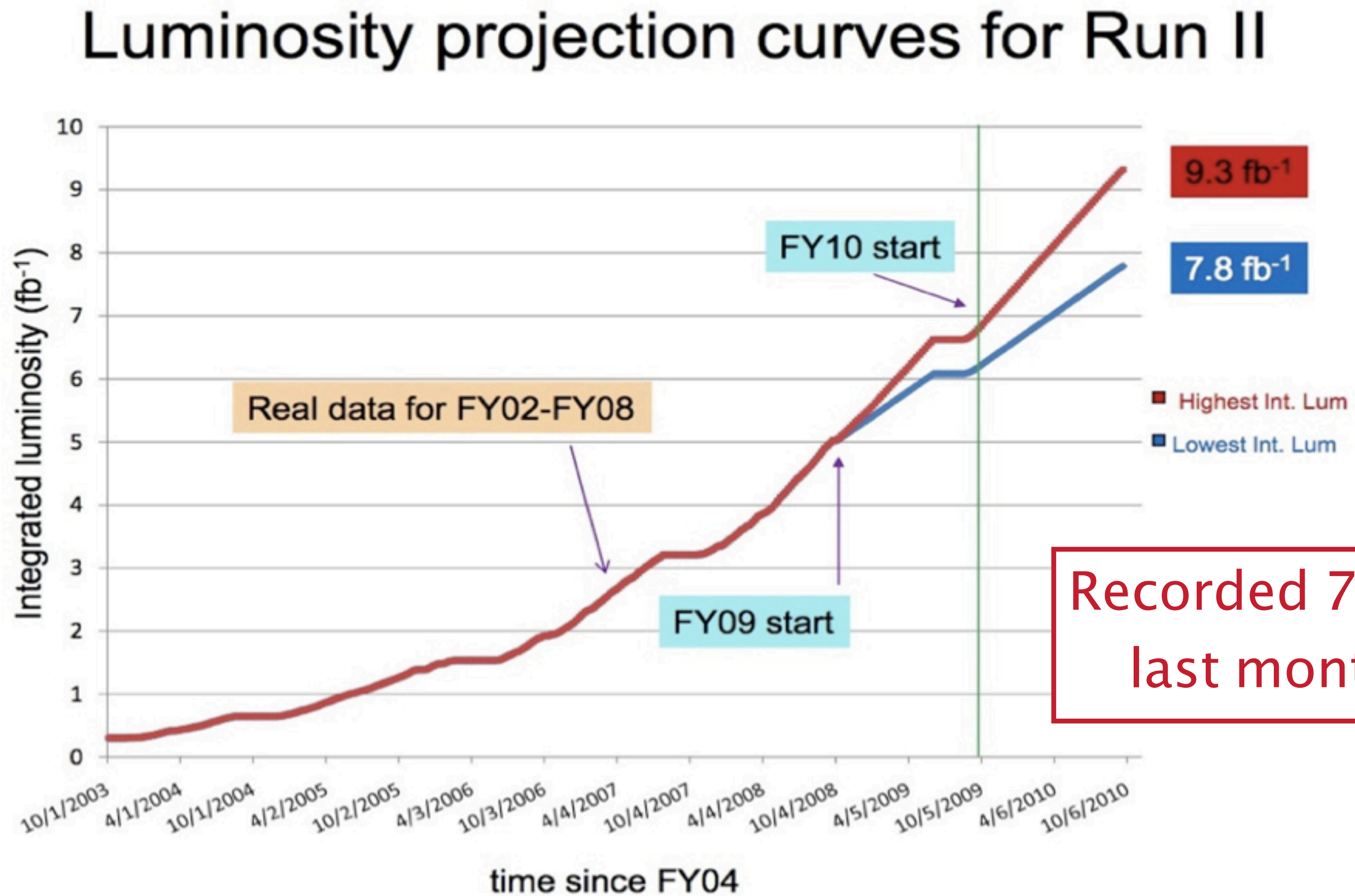
Currently excluding M_H = 162-166 GeV

With ever improving analysis techniques and increasing data, CDF and DØ experiments will be reaching the sensitivity to the Standard Model Higgs boson across a wide mass range

Back Up

back up

Tevatron Projection

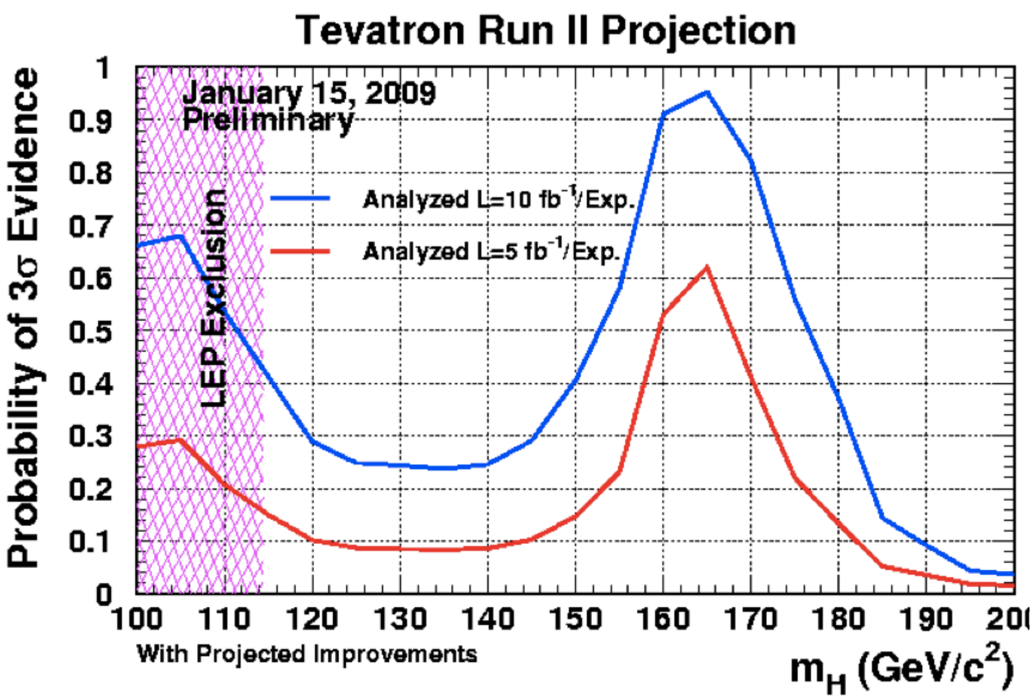


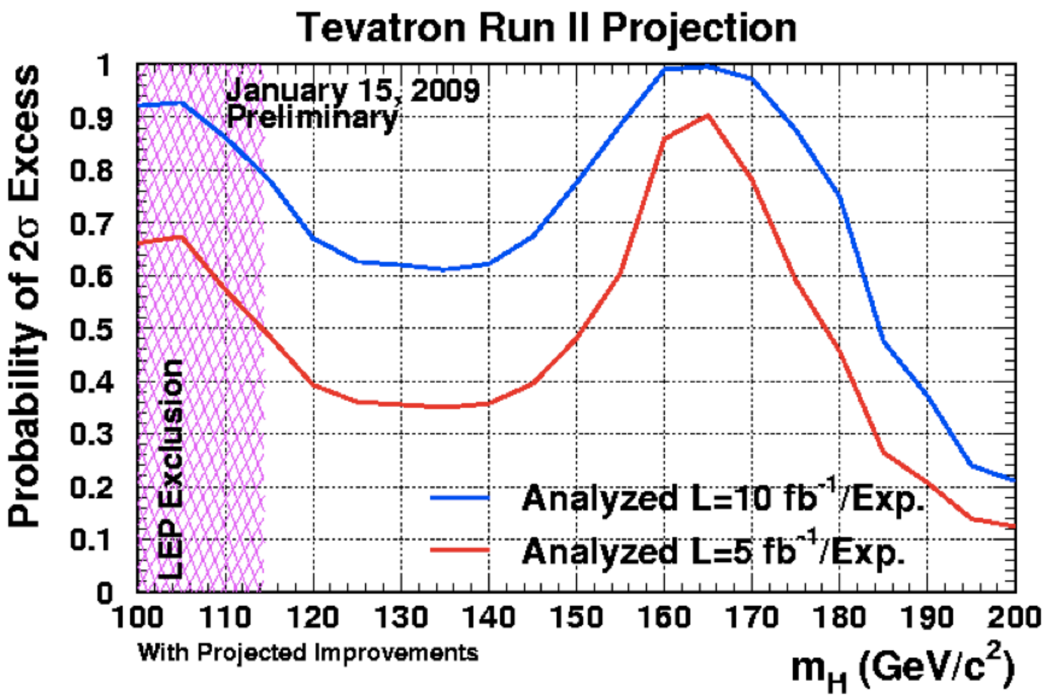
Recorded 7 fb^{-1} last month

Expecting › 9 fb^{-1} delivered by Tevatron by the end of 2010,

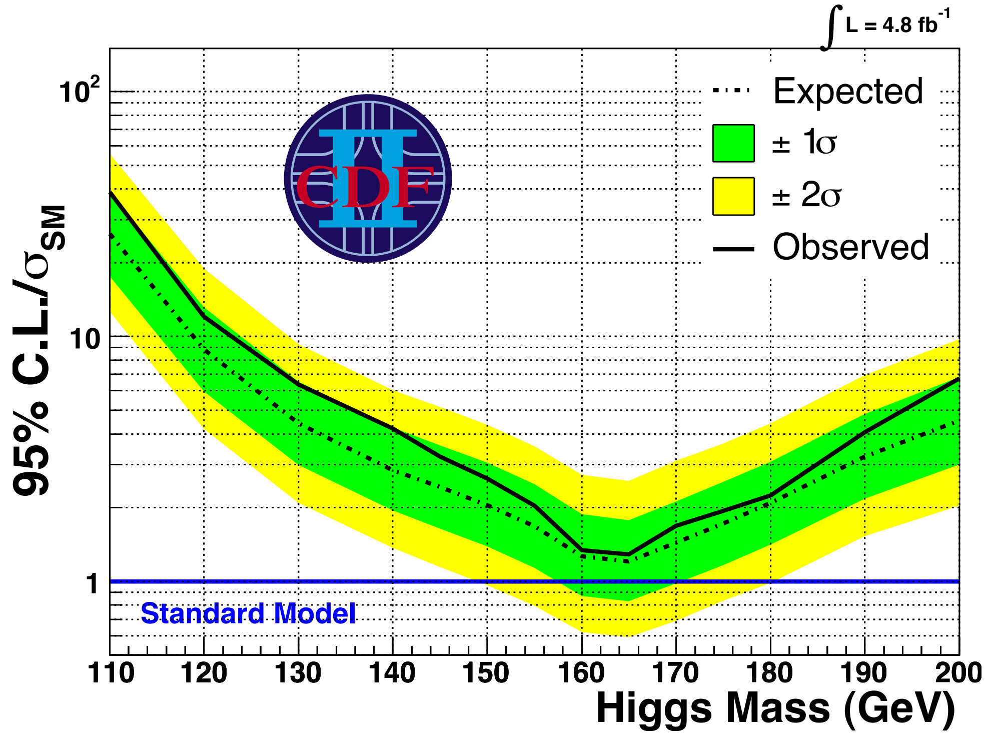
› 12fb^{-1} by the end of 2011

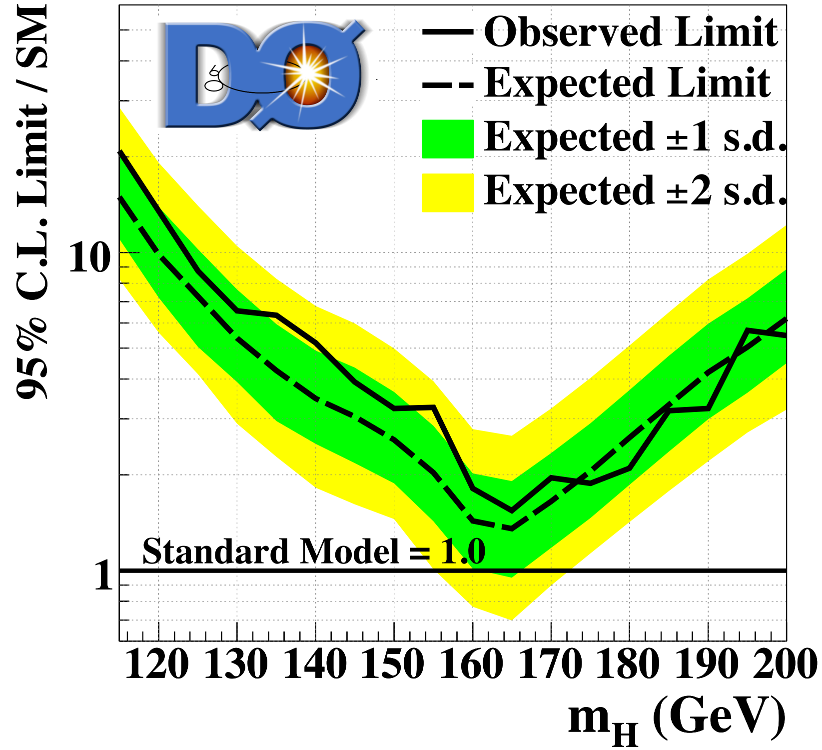
Higgs Search Projection





Cross Section Limits





High mass dilepton channels only

expected (observed) limits @95% CL in units of SM σ

	M = 120 GeV	M = 165 GeV	M = 200 GeV
CDF	8.85 (12.04)	1.20 (1.29)	4.53 (6.74)
DØ	14.9 (20.8)	1.36 (1.55)	6.23 (5.53)

Matrix Element Discriminant

Probability density P for m = 5 modes: WW, ZZ, Wγ, W+jet and H → WW

(ε = probability of a parton level object to be reconstructed as a lepton)

$$P_m(x_{obs}) = \frac{1}{<\sigma_m>} \int \frac{d\sigma_m^{th}(y)}{dy} \epsilon(y) G(x_{obs}, y) dy$$

x_{obs}	are the observed "leptons" and $\vec{\not{E}}_T$,
y	are the true lepton four-vectors (including neutrinos),
σ_m^{th}	is the leading-order theoretical calculation of the cross-section for mode m,
$\epsilon(y)$	is the total event efficiency × acceptance,
$G(x_{obs}, y)$	is an analytic model of resolution effects, and
$\frac{1}{<\sigma_m>}$	is the normalization.

Form a likelihood discriminant for S = WW or H → WW

$$LR_S(x_{obs}) \equiv \frac{P_S(x_{obs})}{P_S(x_{obs}) + \Sigma_i k_i P_i(x_{obs})},$$

k_i is the expected fraction for each background and $\Sigma_i k_i = 1$

ref: CDF public note 9887