Light Higgs boson searches at the Tevatron

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LANCASTER UNIVERSITY

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  - $WH \to l\nu b\bar{b}$
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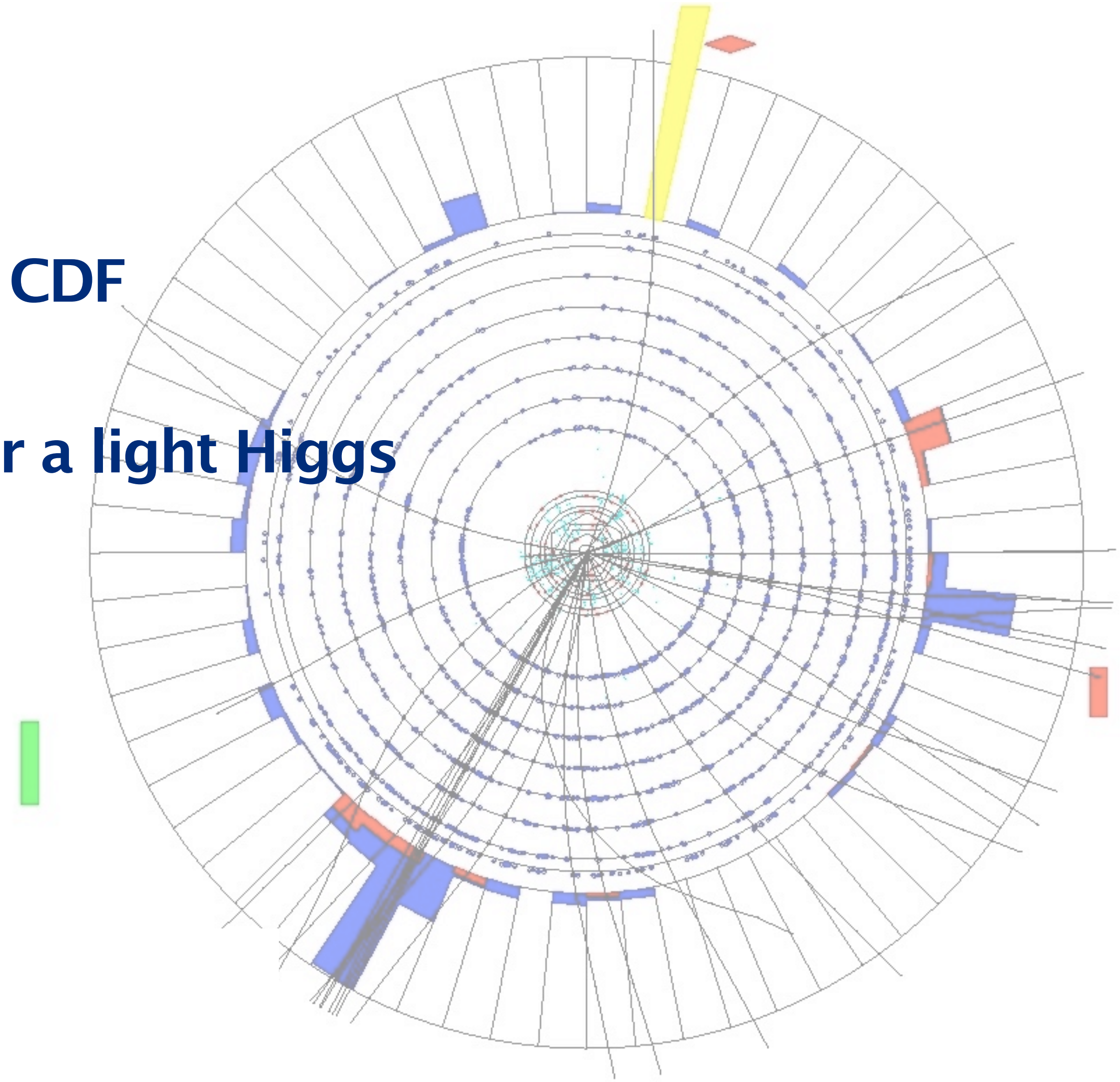
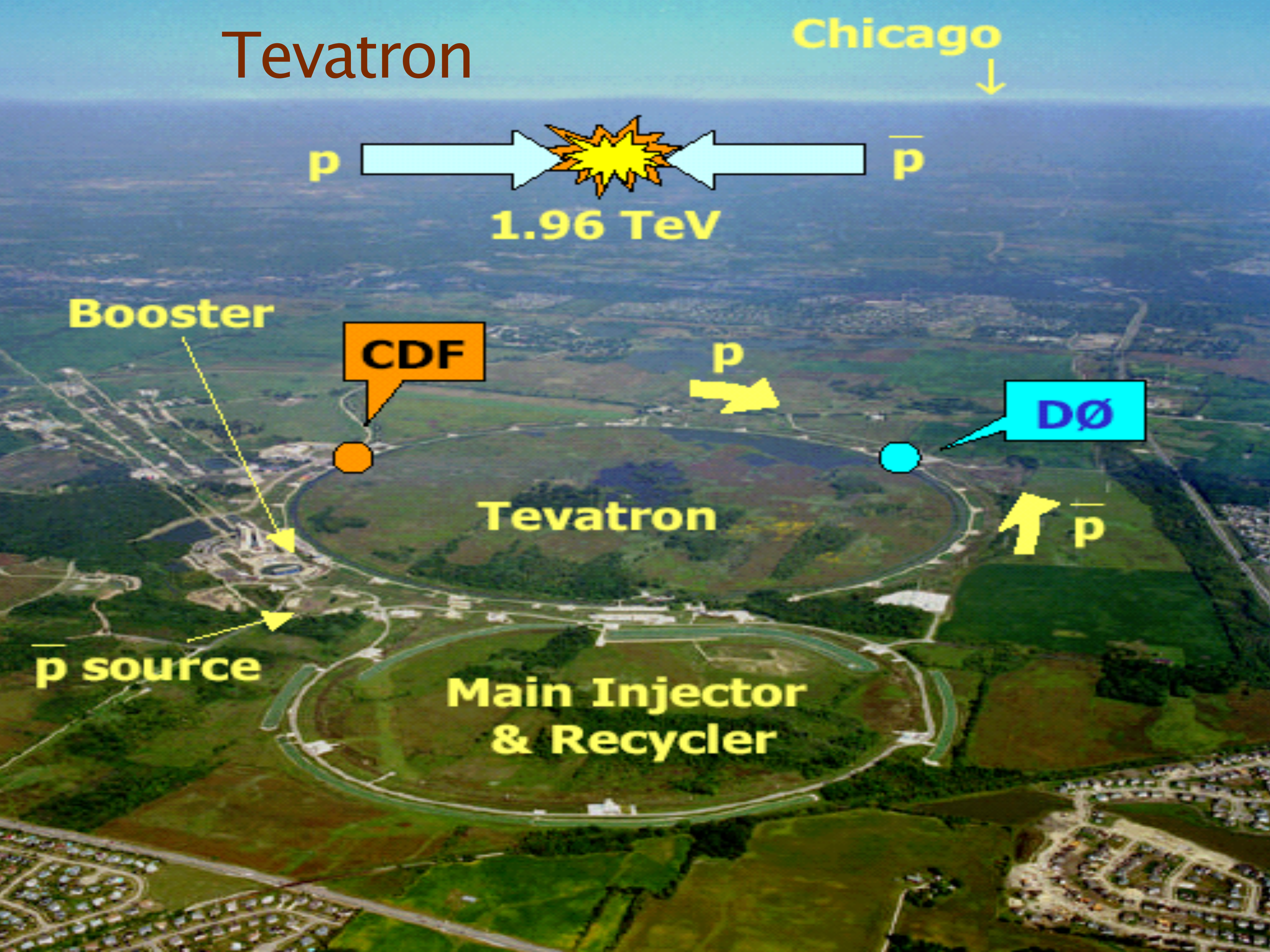
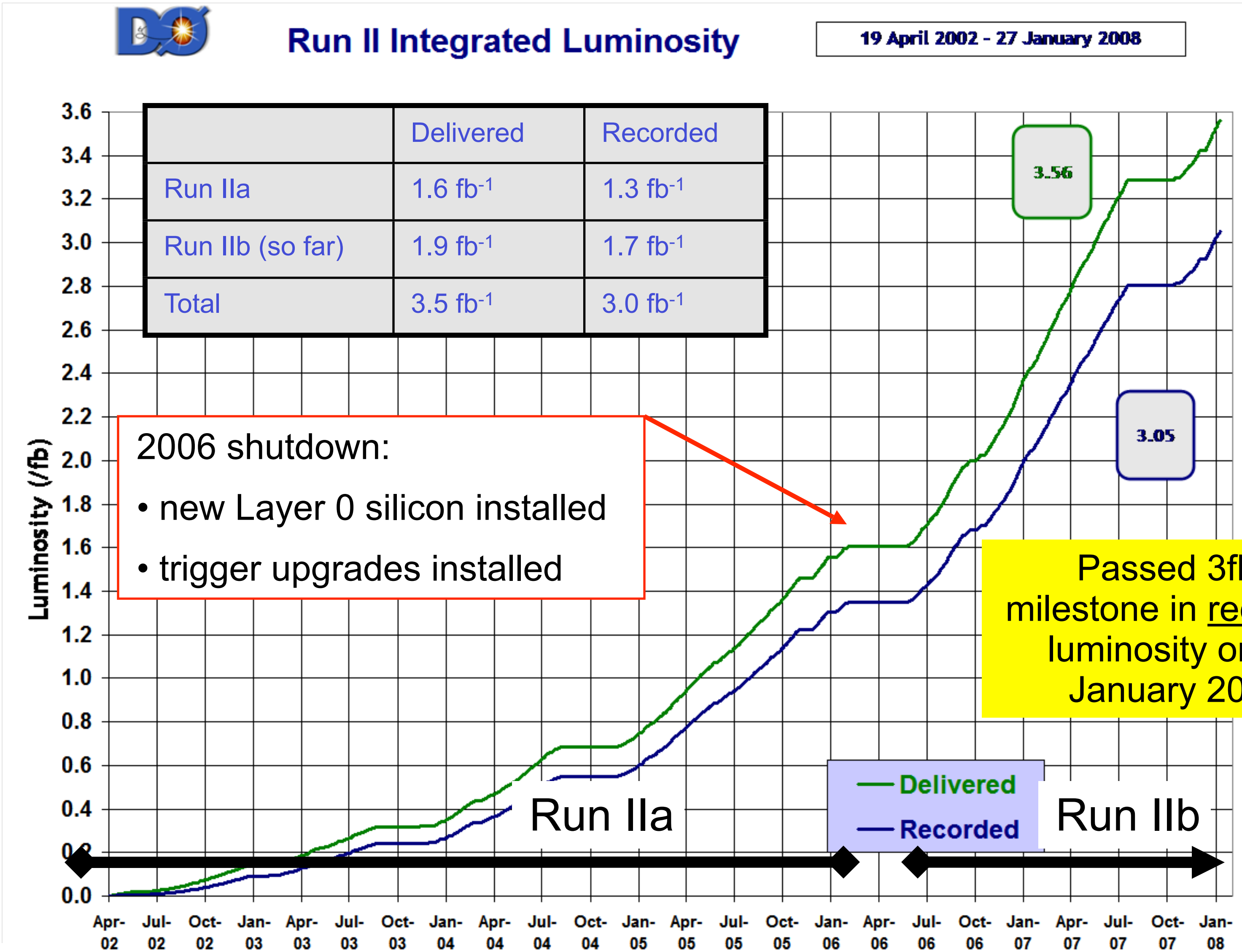
- Outlook
- Conclusion



Tevatron


Chicago
p
$\bar{p}$
1.96 TeV
Booster
CDF
p
DØ
Tevatron
$\bar{p}$
$\bar{p}$ source
Main Injector
& Recycler



	Delivered	Recorded
Run IIa	1.6 fb^{-1}	1.3 fb^{-1}
Run IIb (so far)	1.9 fb^{-1}	1.7 fb^{-1}
Total	3.5 fb^{-1}	3.0 fb^{-1}

2006 shutdown:
- new Layer 0 silicon installed
- trigger upgrades installed

Passed 3fb^{-1} milestone in <u>recorded</u> luminosity on 16 January 2008

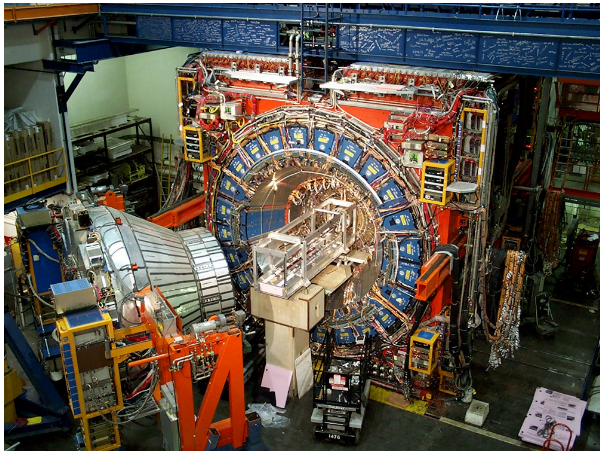
April 02

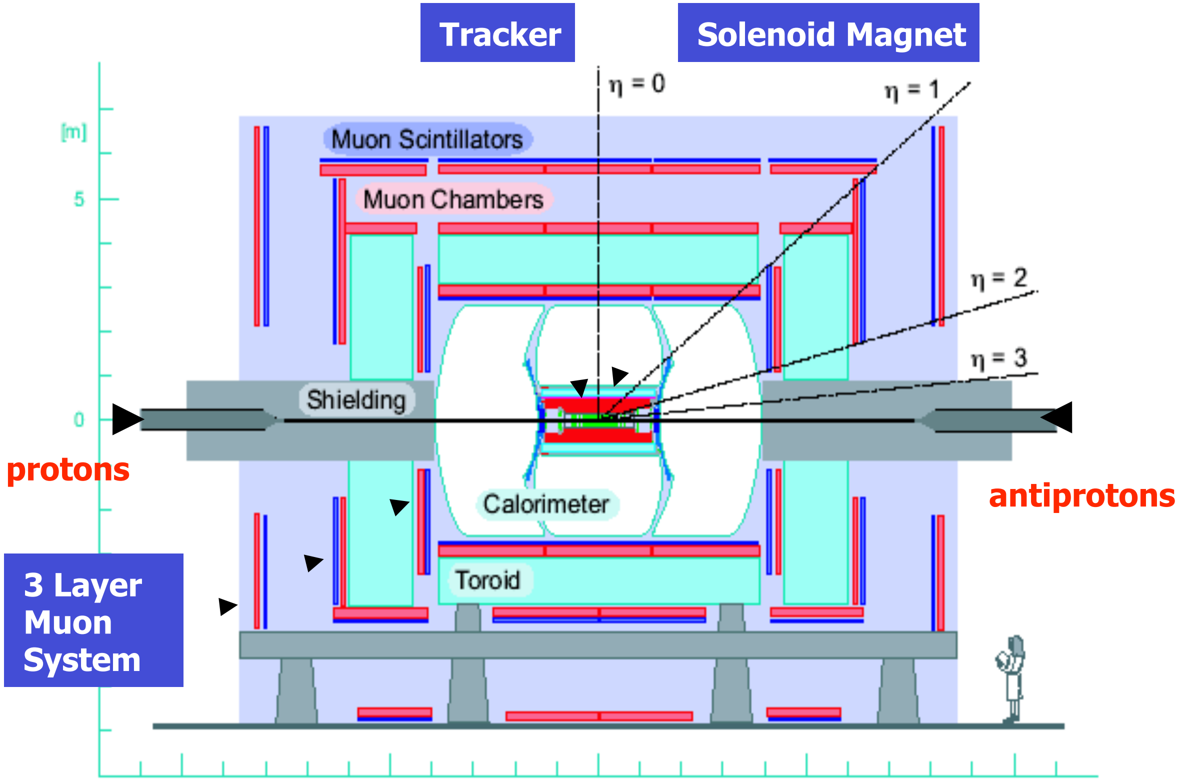
Jan 08

Two General Purpose Detectors:	CDF	DØ
Electron acceptance	$\|\eta\|<2.0$	$\|\eta\|<3.0$
Muon acceptance	$\|\eta\|<1.5$	$\|\eta\|<2.0$
Silicon Precision tracking	$\|\eta\|<2.0$	$\|\eta\|<3.0$
Hermetic Calorimeter	$\|\eta\|<3.6$	$\|\eta\|<4.2$

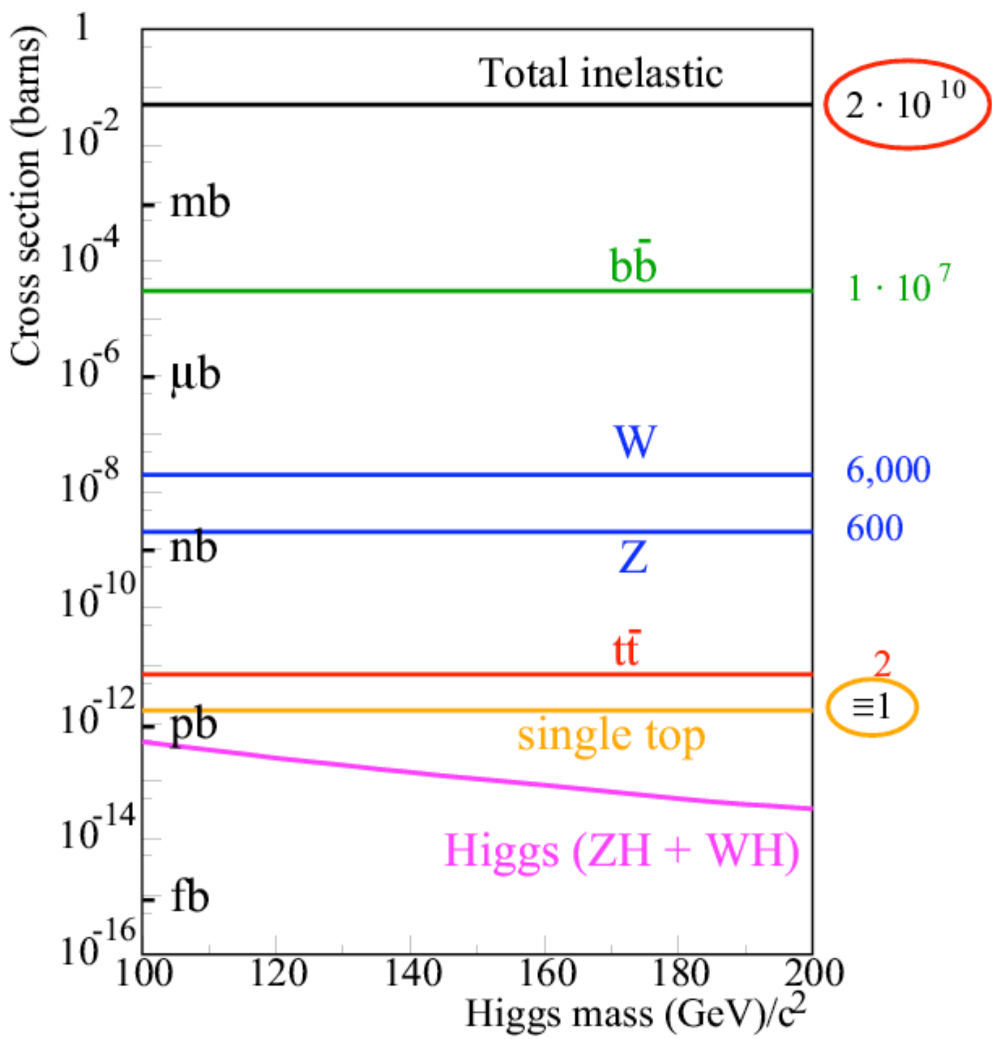
Powerful trigger systems (2.5MHz $\rightarrow$50Hz)

Dilepton triggers with p_T>4GeV

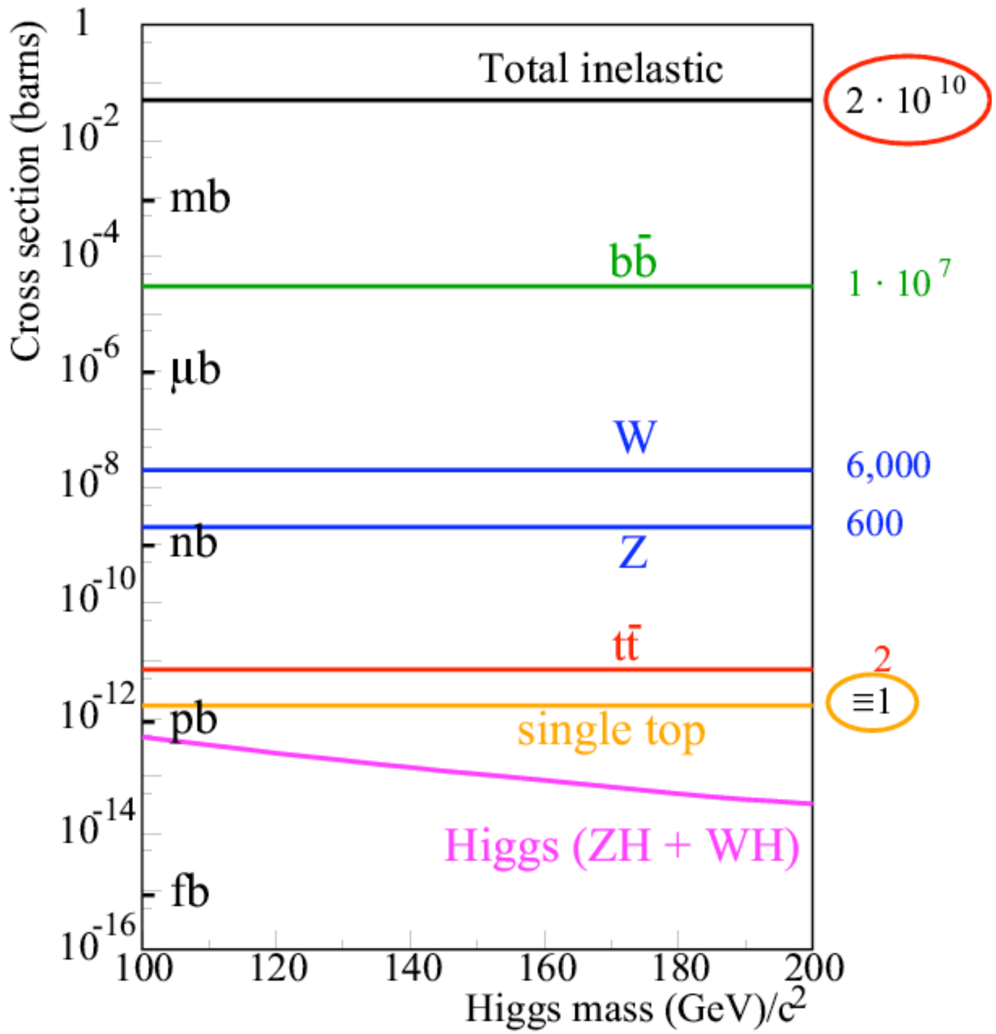




Tevatron Cross Sections

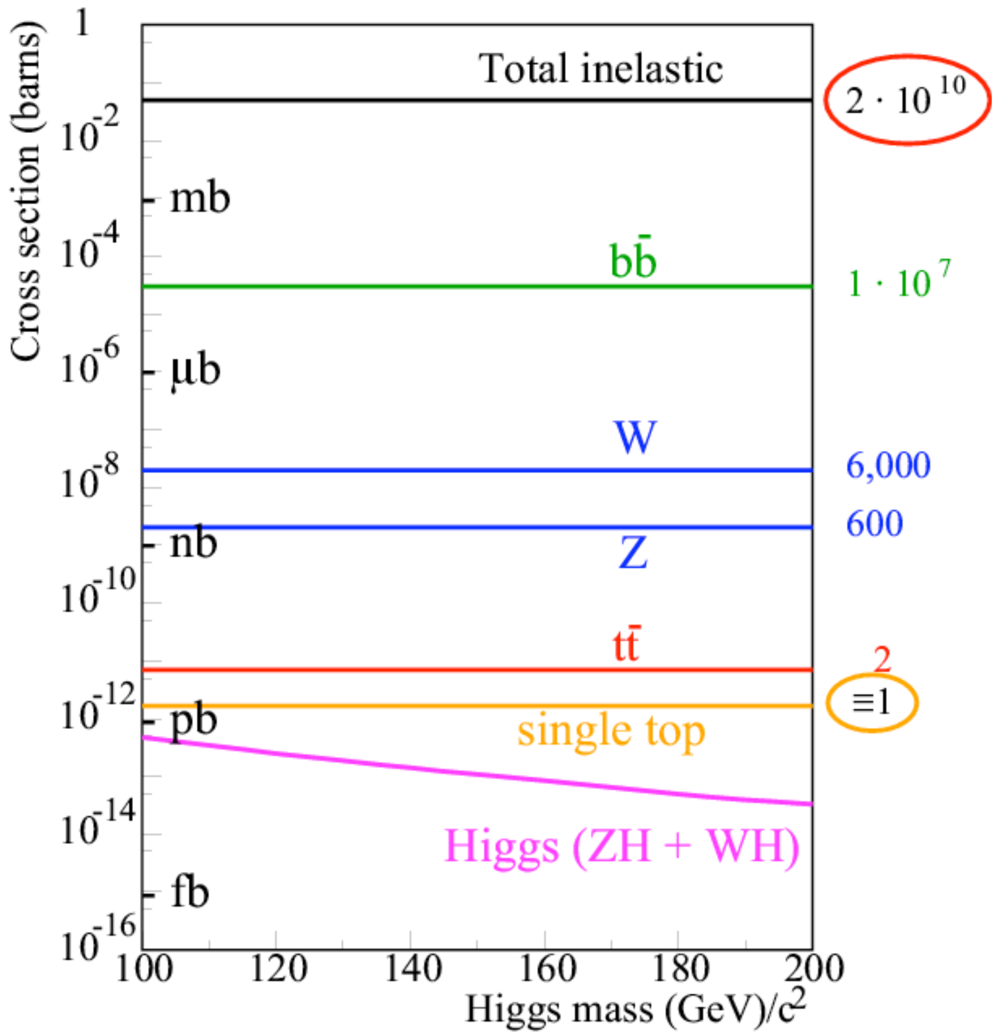


Tevatron Cross Sections



Total inelastic cross section.

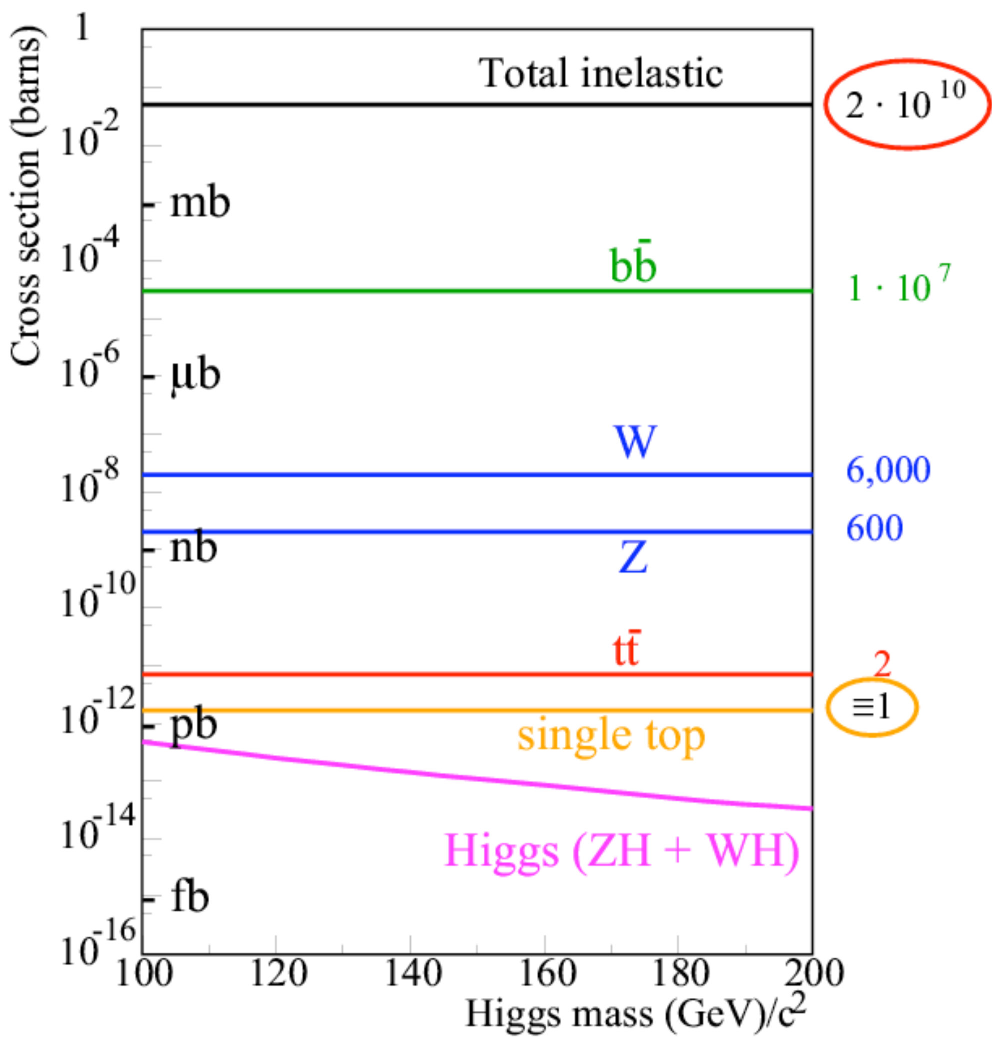
Tevatron Cross Sections



Total inelastic cross section.

Light quarks are ubiquitous.

Tevatron Cross Sections

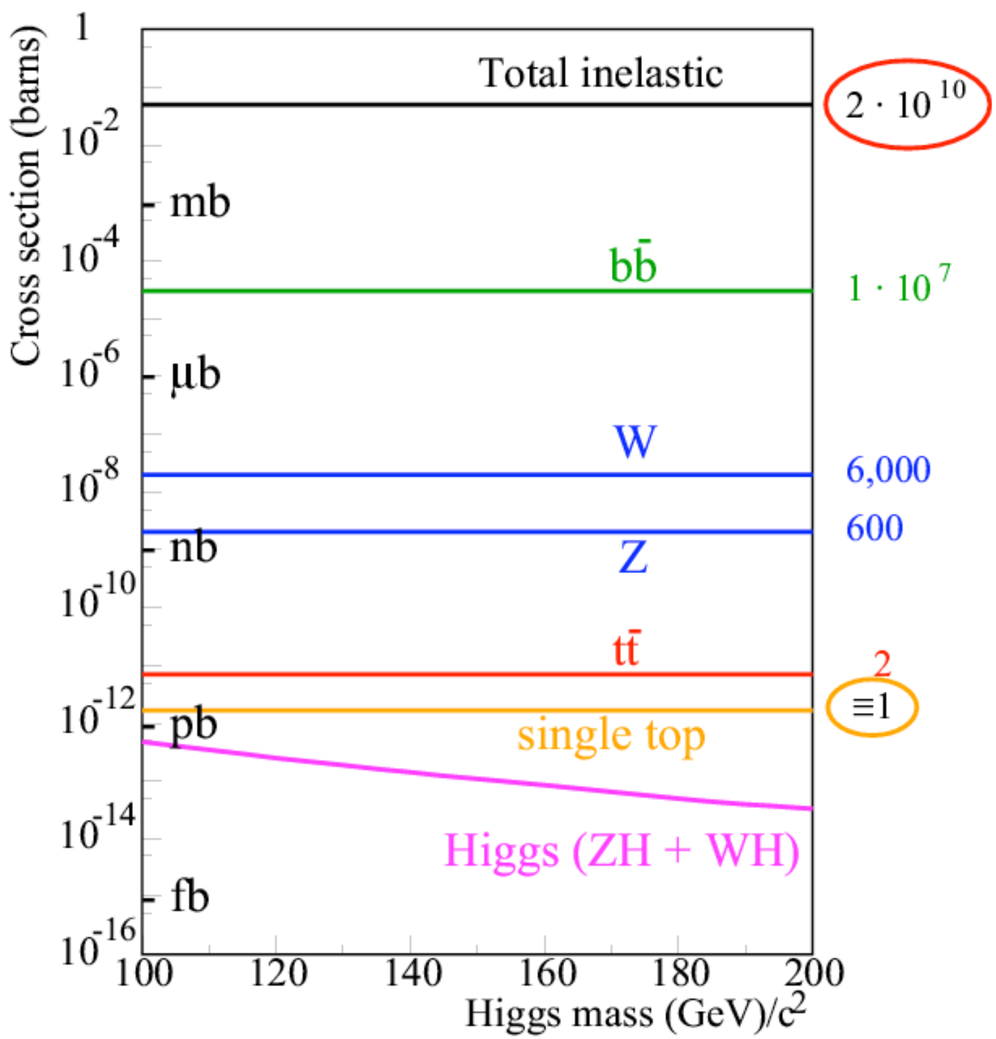


Total inelastic cross section.

Light quarks are ubiquitous.

Plenty of W and Z bosons → calibration.

Tevatron Cross Sections



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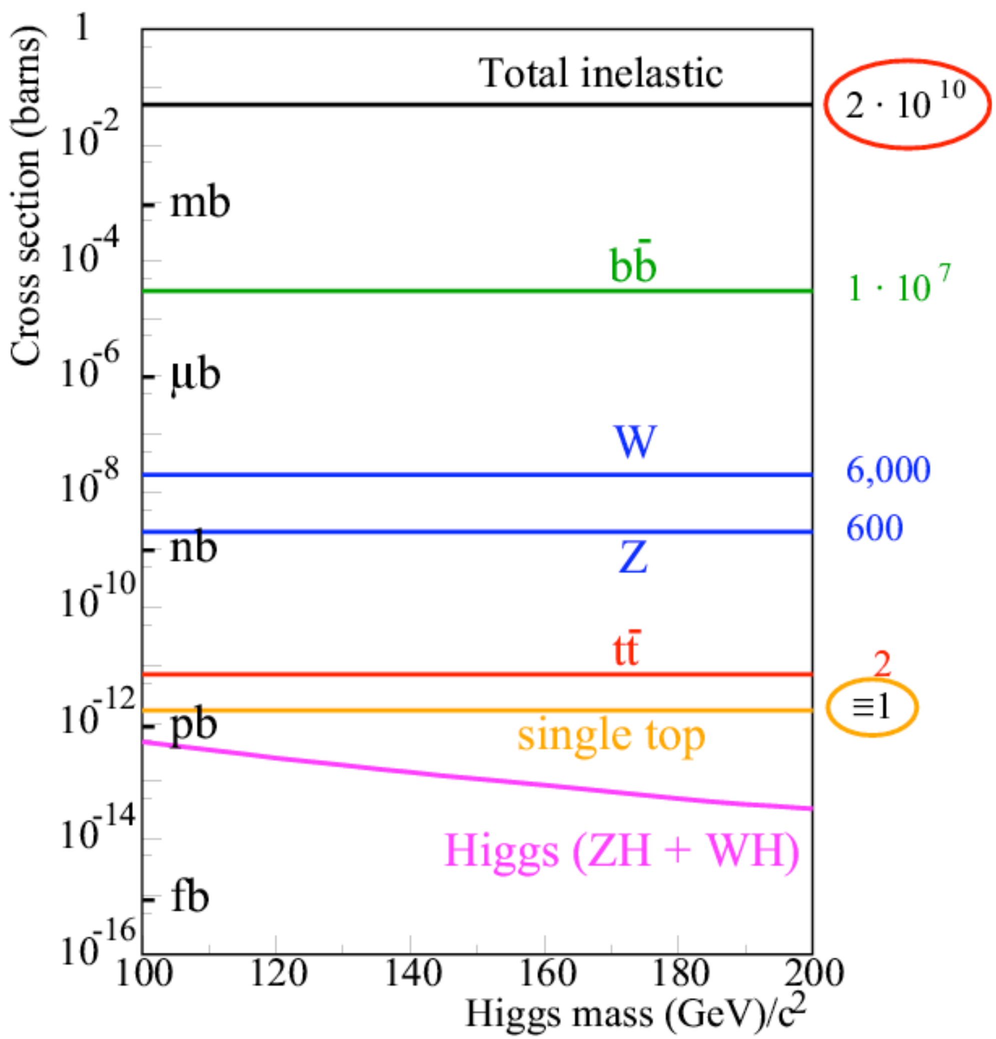
Plenty of W and Z bosons → calibration.

Evidence of single top production is an important milestone towards the Higgs boson.

Tevatron Cross Sections



Total inelastic cross section.

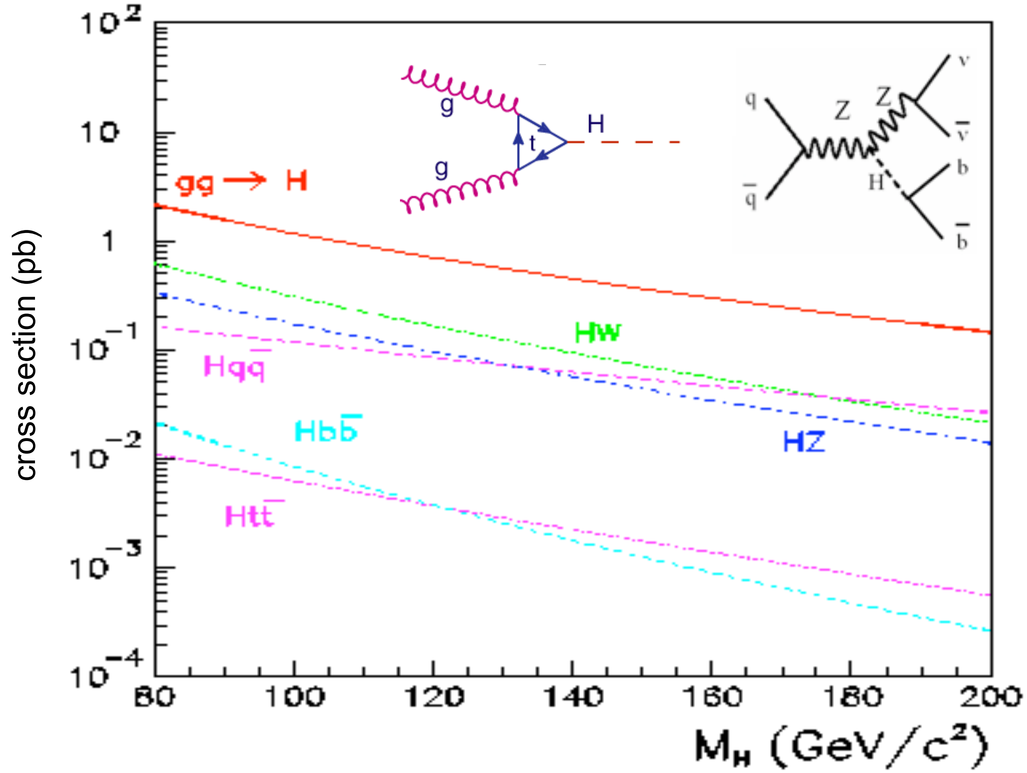
Light quarks are ubiquitous.

Plenty of W and Z bosons → calibration.

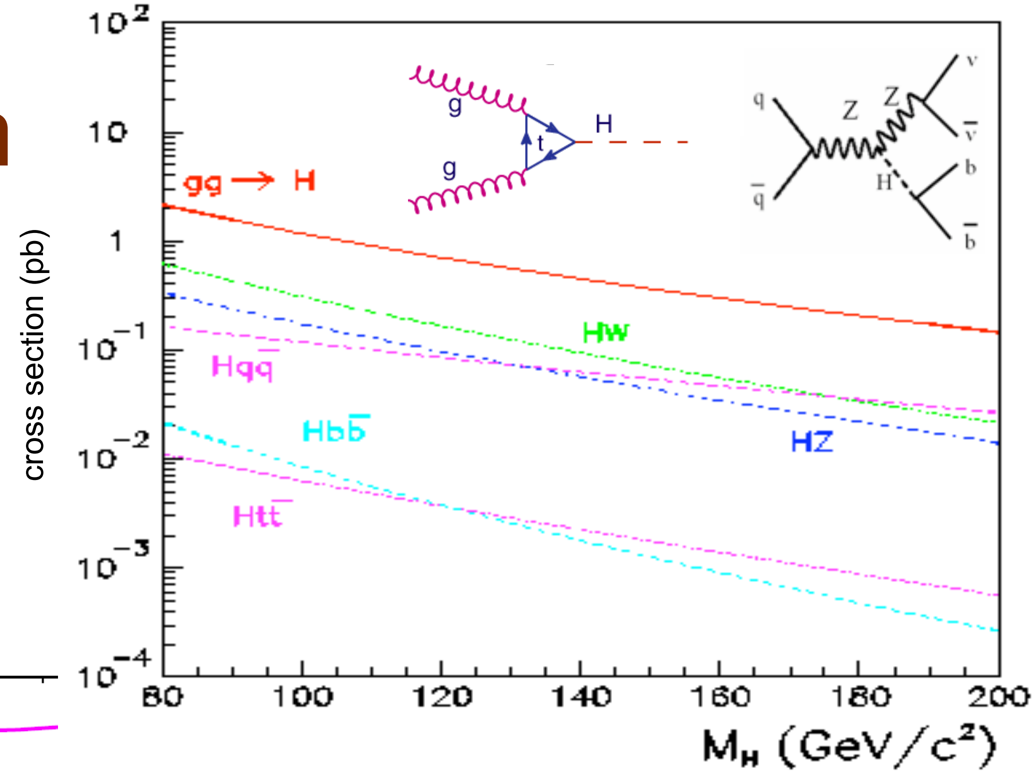
Evidence of single top production is an important milestone towards the Higgs boson.

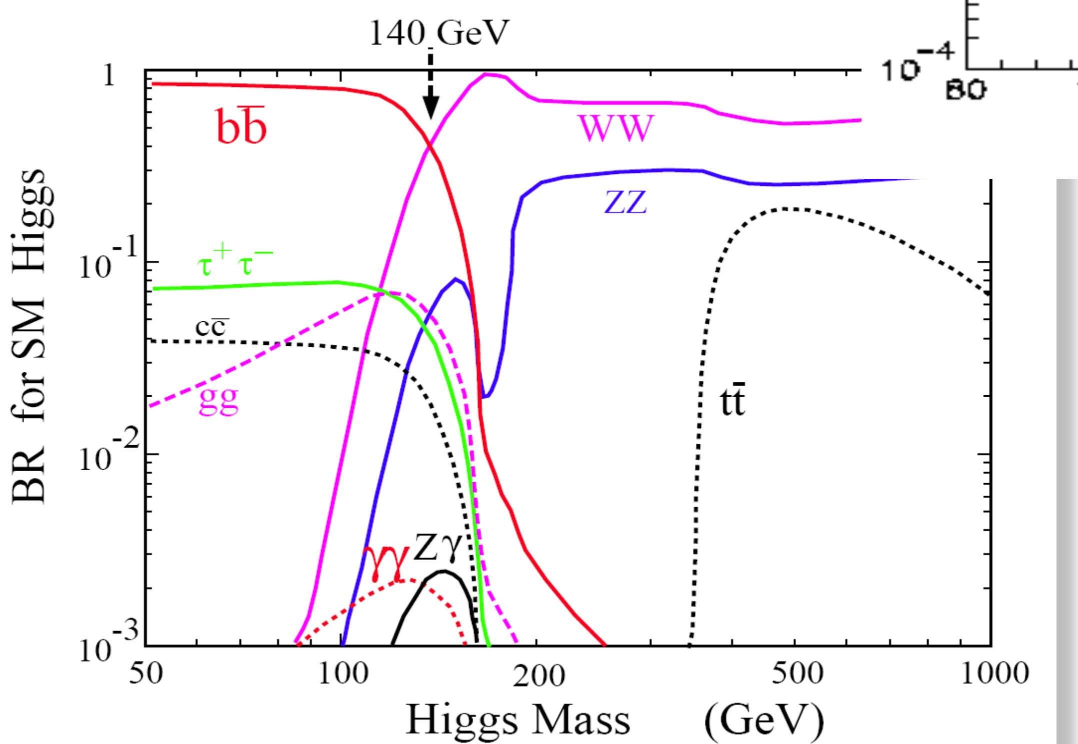
The Higgs cross section is 10-11 orders of magnitudes lower than the total inelastic cross section.

Higgs Production and Decay

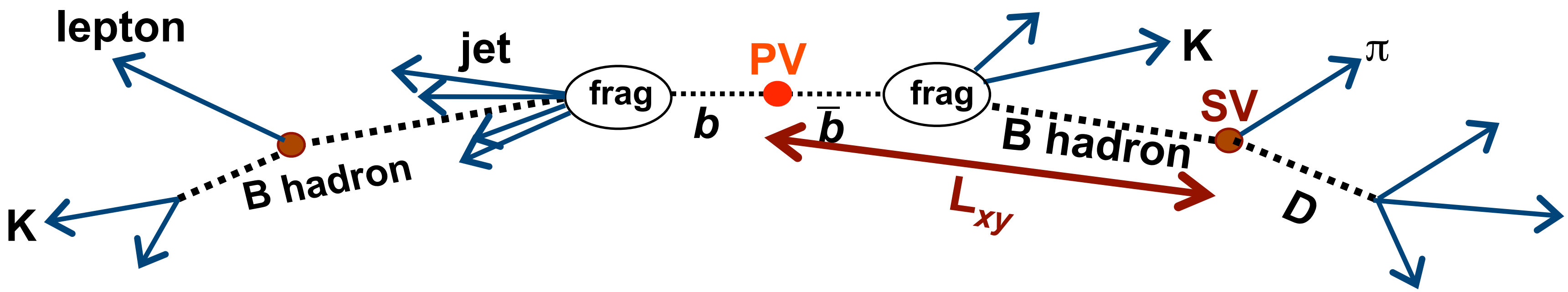


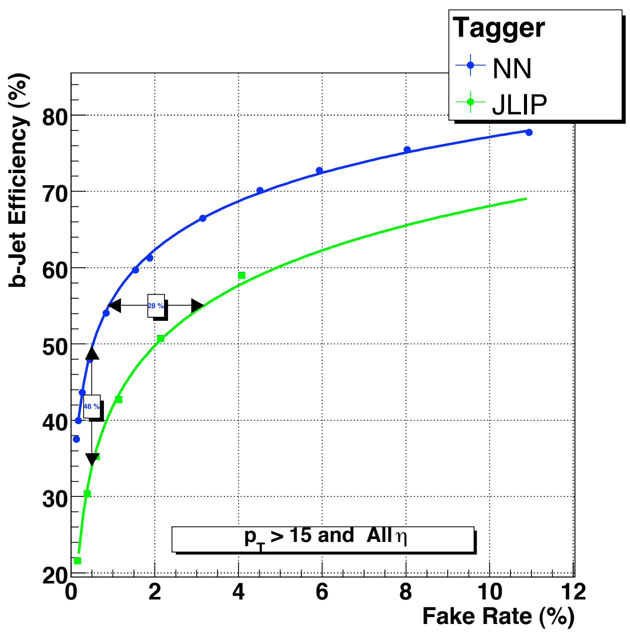
Higgs Production and Decay

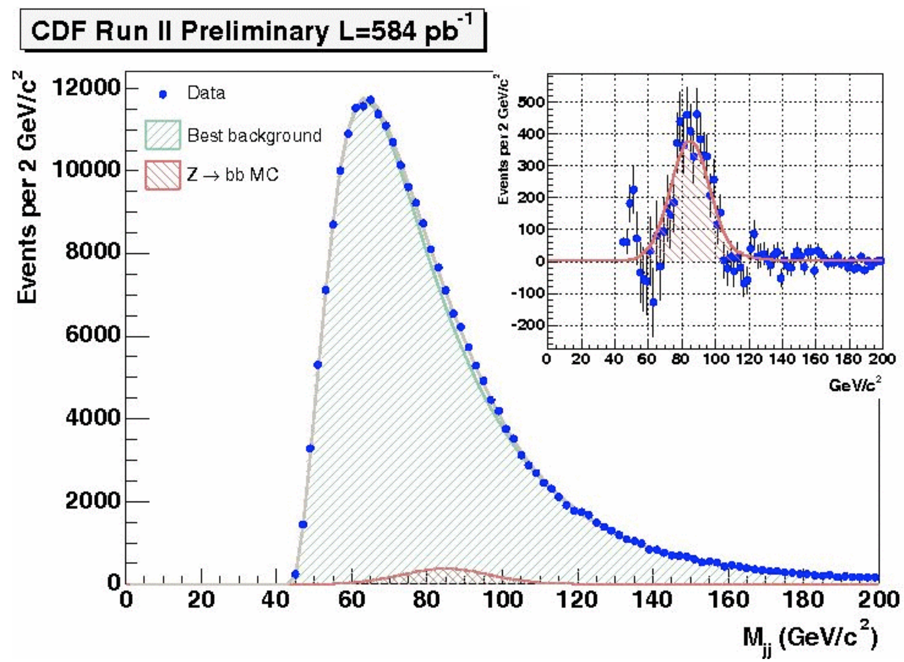




Tools: b-tagging

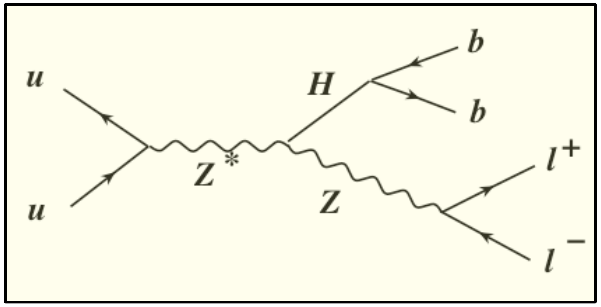






Low Mass Higgs Channels

$ZH \longrightarrow l^+l^- bb$



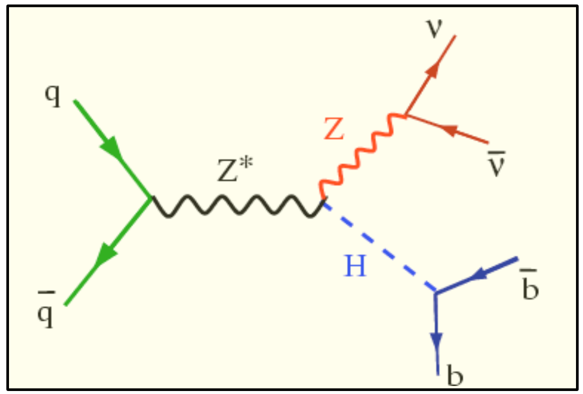
2 b jets ~ 1/2 M_H each

2 leptons ~ 45 GeV each

Z mass constraint

Cleanest signal

$ZH \rightarrow \nu\nu\ bb$



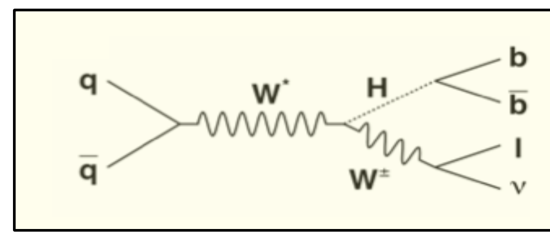
2 b jets ~ 1/2 M_H each

0 leptons

Missing E_T ~ 100 GeV

Largest expected signal

$WH \longrightarrow l\nu bb$



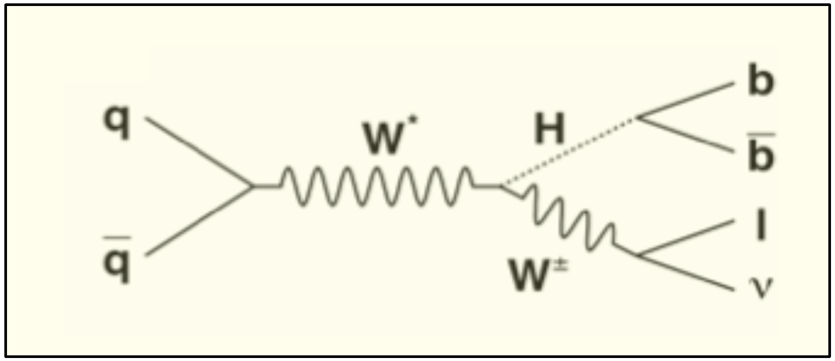
2 b jets ~ 1/2 M_H each

1 lepton ~ 50 GeV each

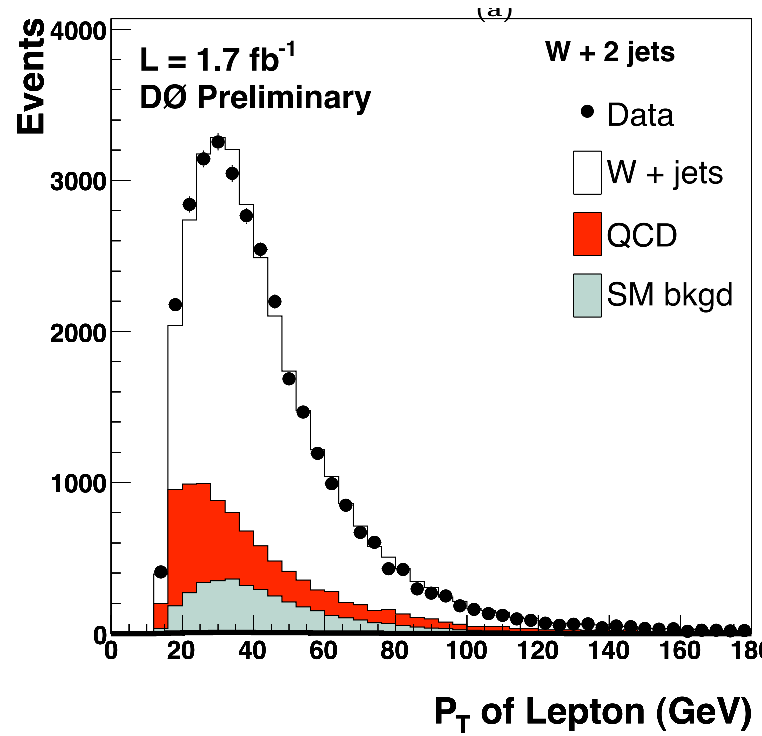
Missing E_T ~ 50 GeV

Highest production X-sec

WH → lνbb

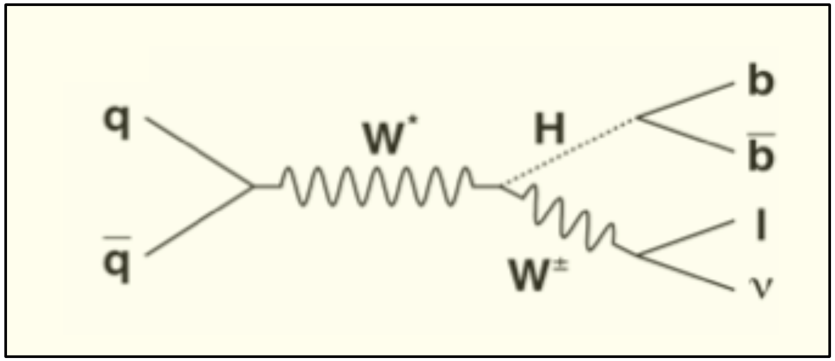


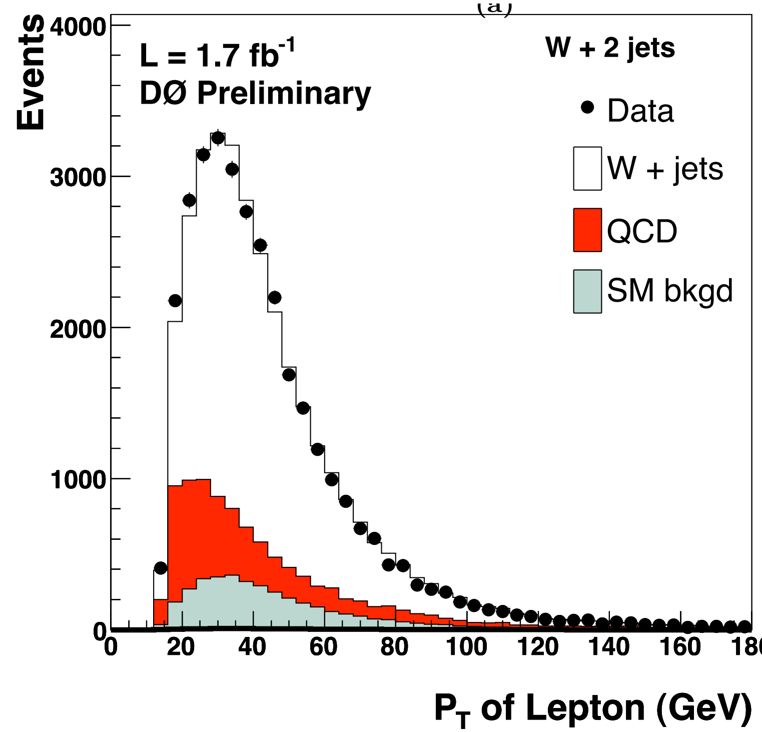
q
$\bar{q}$
W*
H
b
$\bar{b}$
W±
l
ν

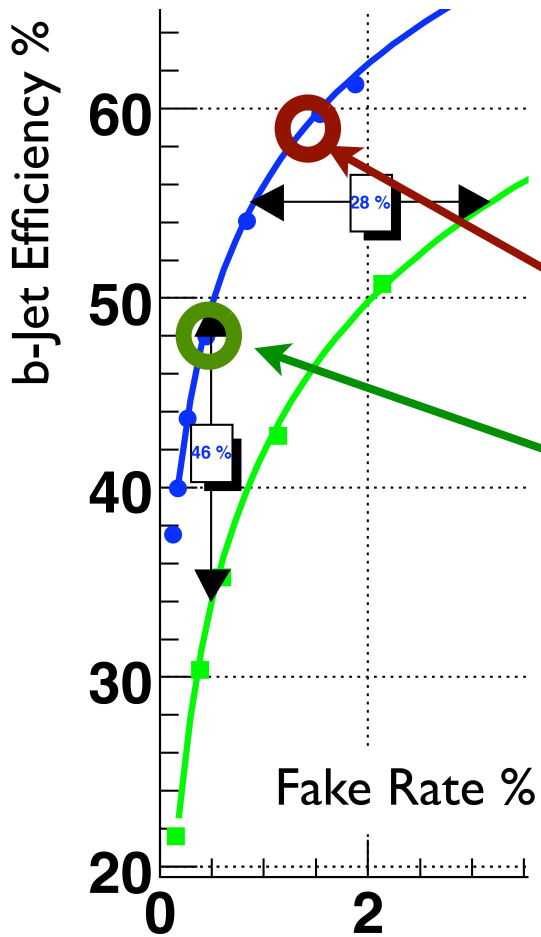


L = 1.7 fb⁻¹
DØ Preliminary
W + 2 jets
Data
W + jets
QCD
SM bkgd
Events
P_T of Lepton (GeV)

WH → lνbb



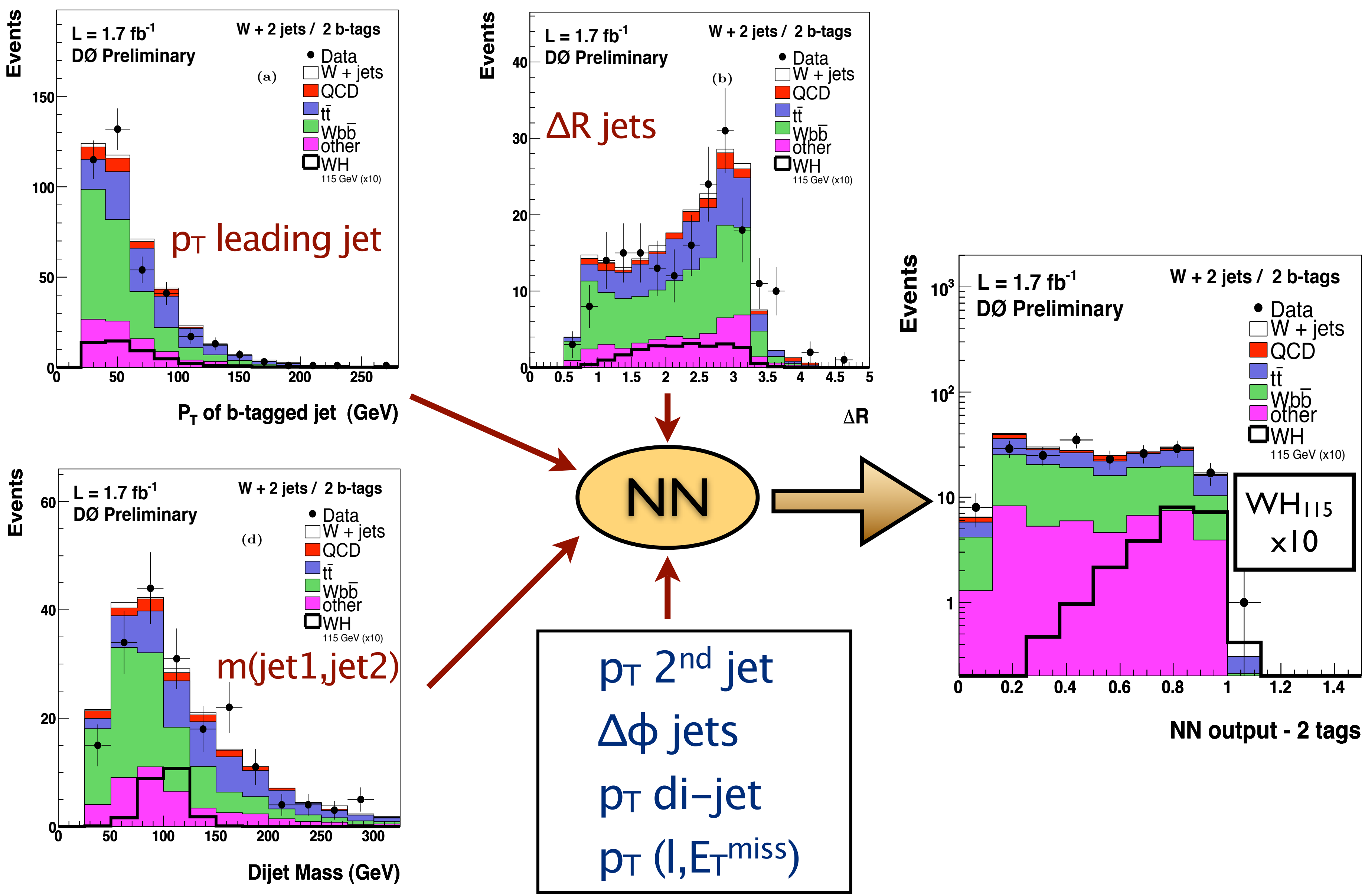




4 different analyses:

- Double b–tag (S/B ~ 2.3/204)
- Single b–tag (S/B ~ 4/1400)
- W → eν
- W → μν

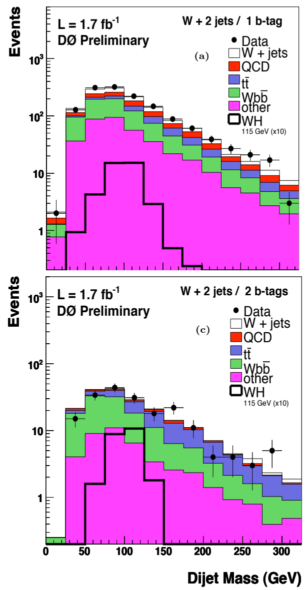
WH → lνbb̄: Neural Net



Combining WH Results

single b-tag

double b-tag



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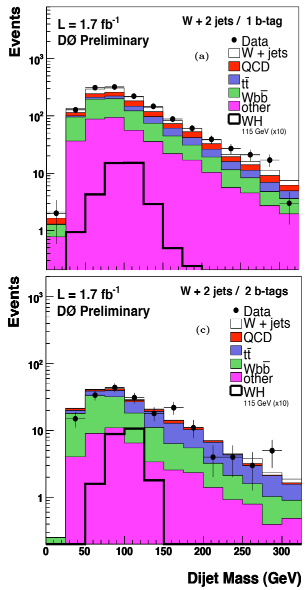
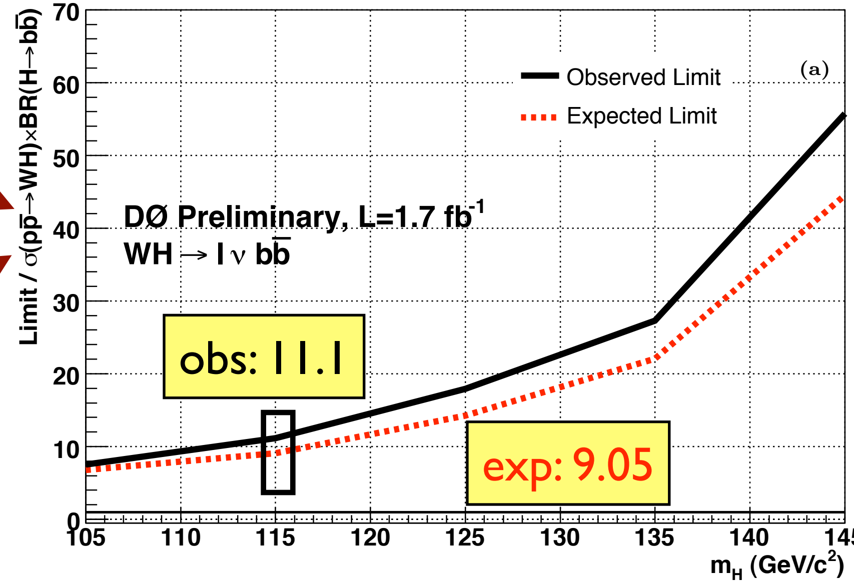


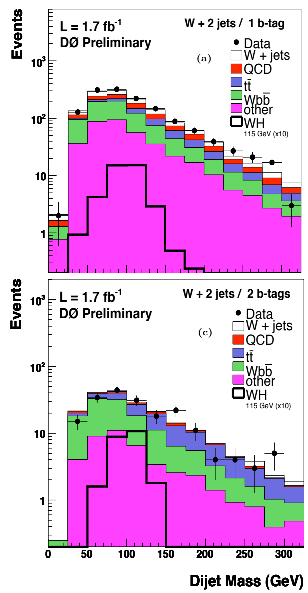


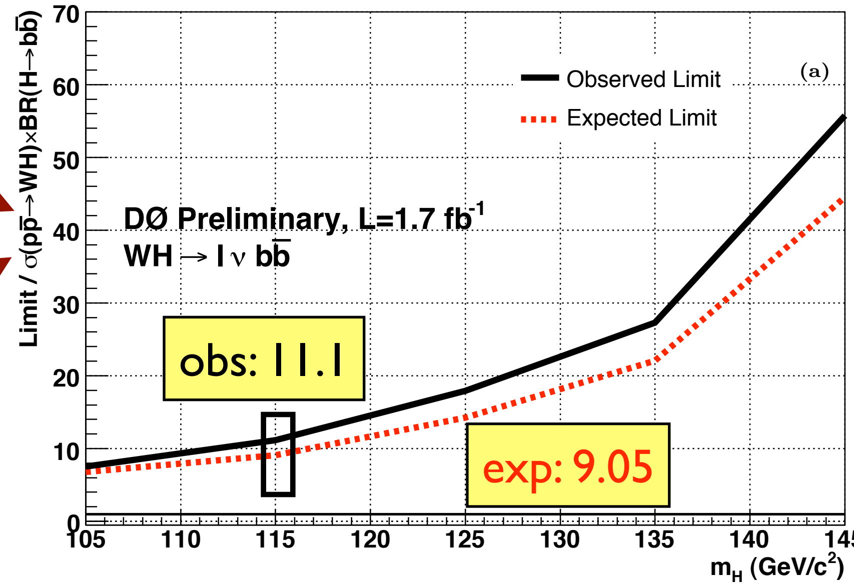
Limits relative to SM expectation

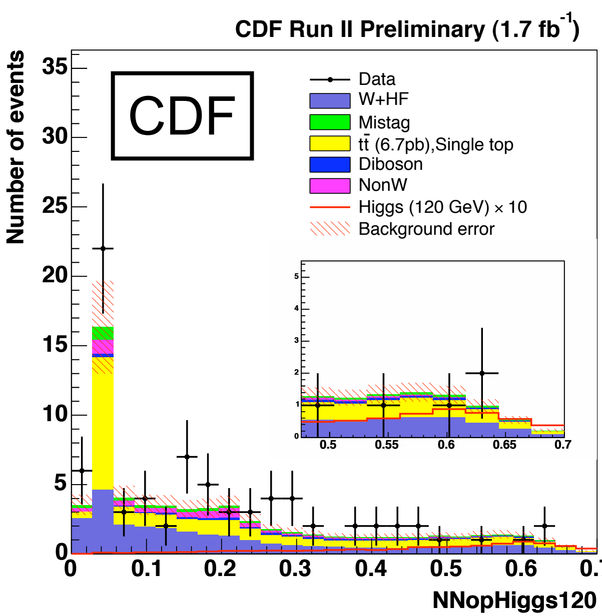
Combining WH Results

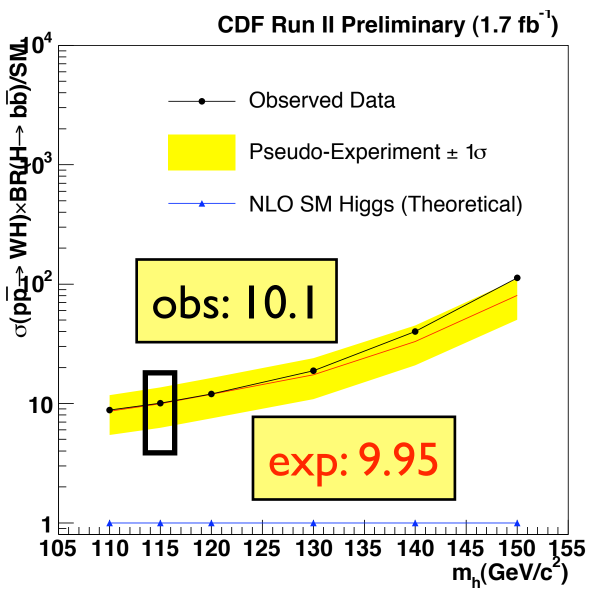
single b–tag

double b–tag



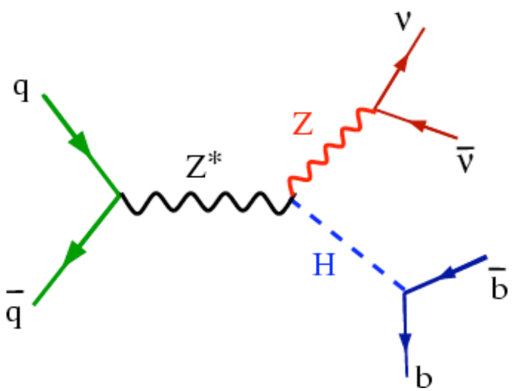




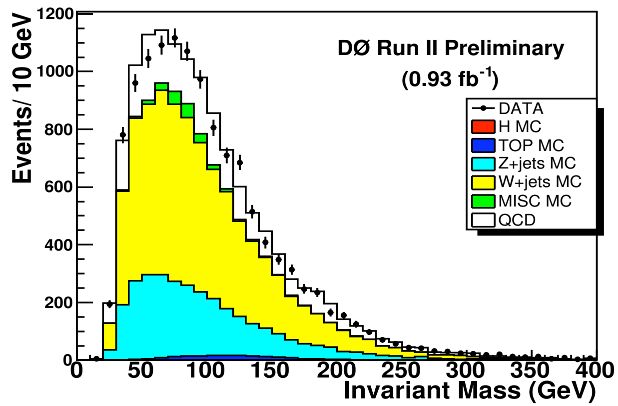


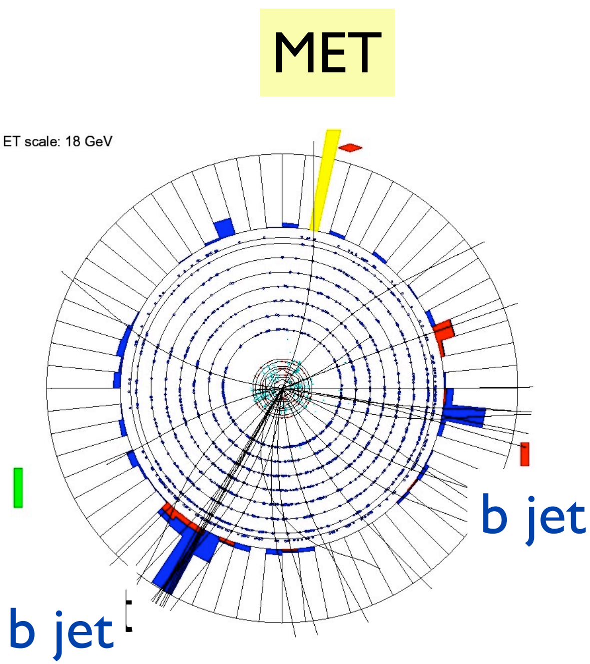
Limits relative to SM expectation

ZH → $\nu\nu b\bar{b}$

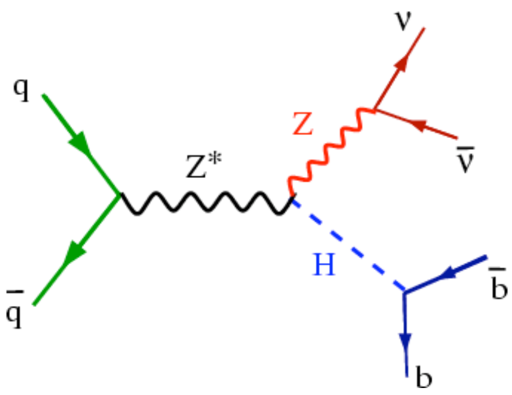


E_T^{miss} + 2 jets

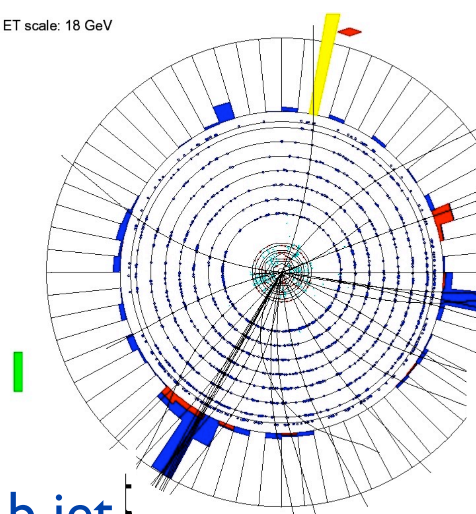




ZH → ννbb̄



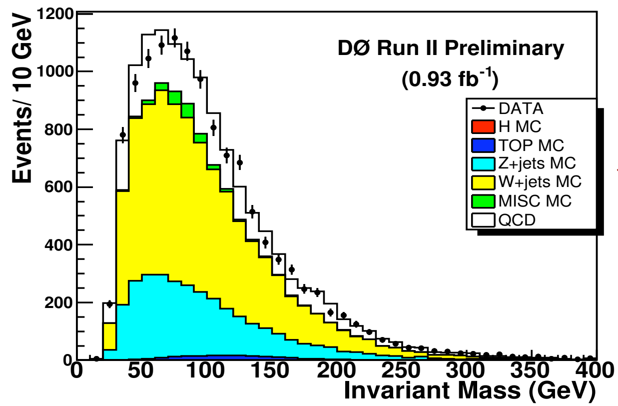
MET



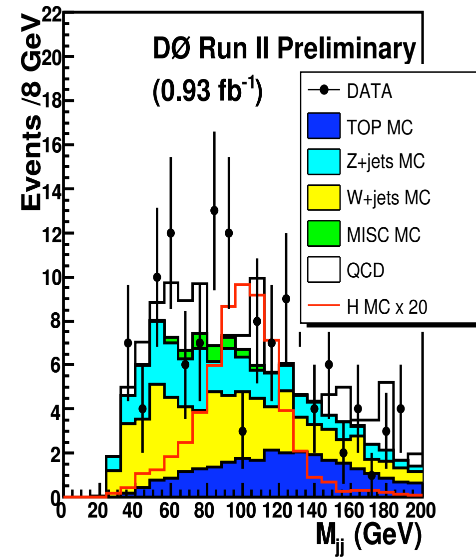
b jet

b jet

E_T^{miss} + 2 jets

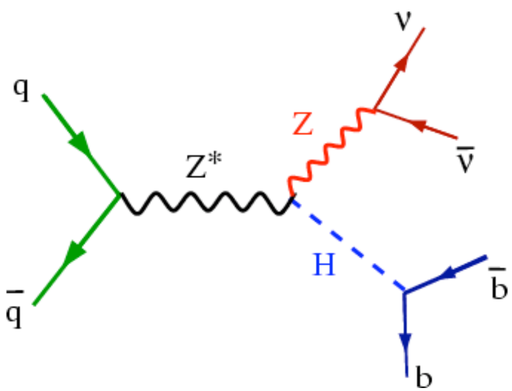


1 tight b–tag + 1 loose b–tag

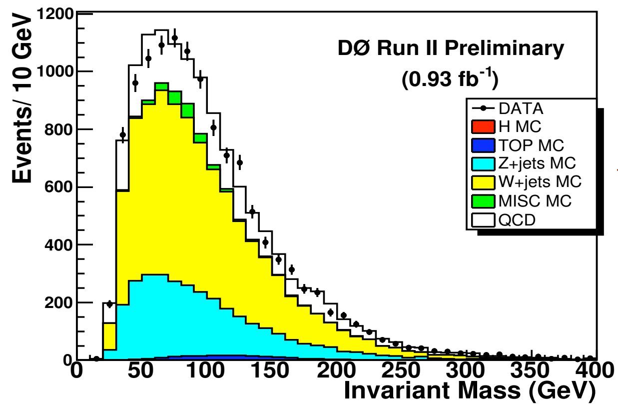


S/B ~ 1.4/134

ZH → ννbb̄



E_T^{miss} + 2 jets



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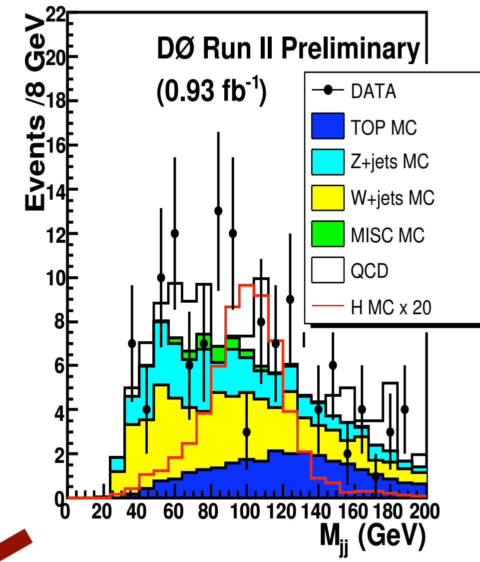
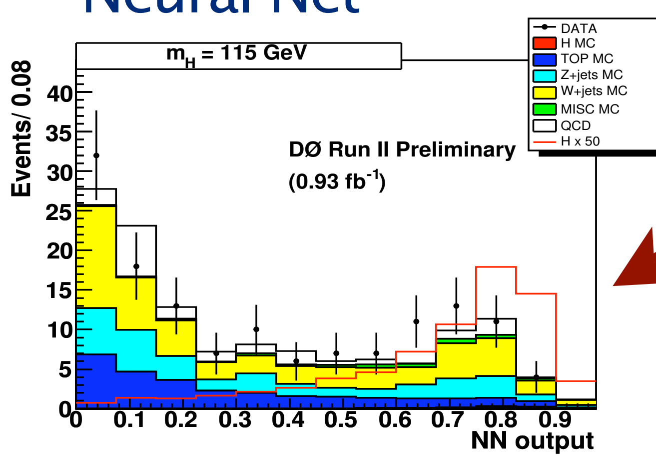
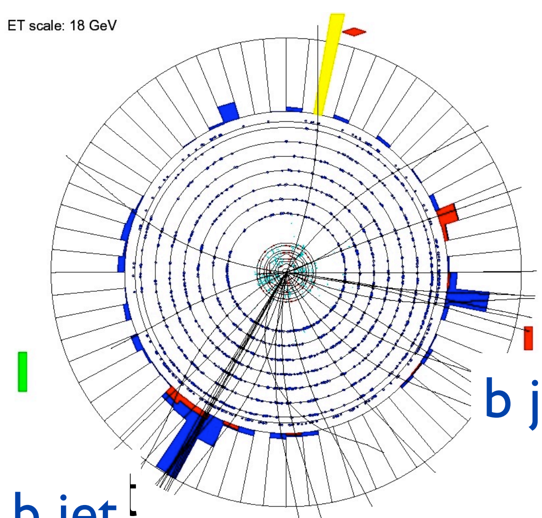


S/B ~ 1.4/134

Neural Net



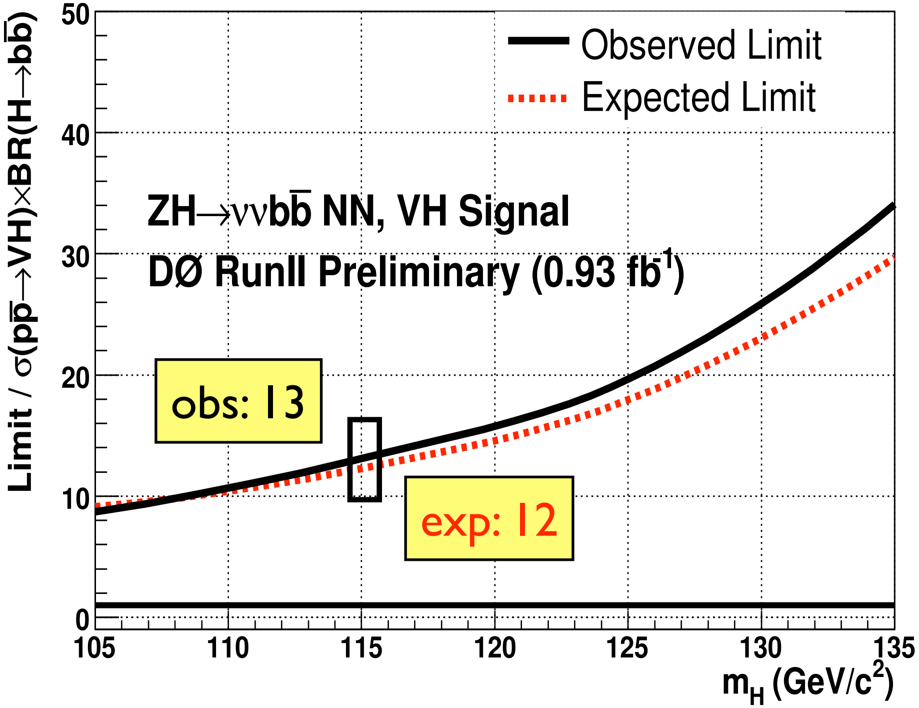
MET



b jet

b jet

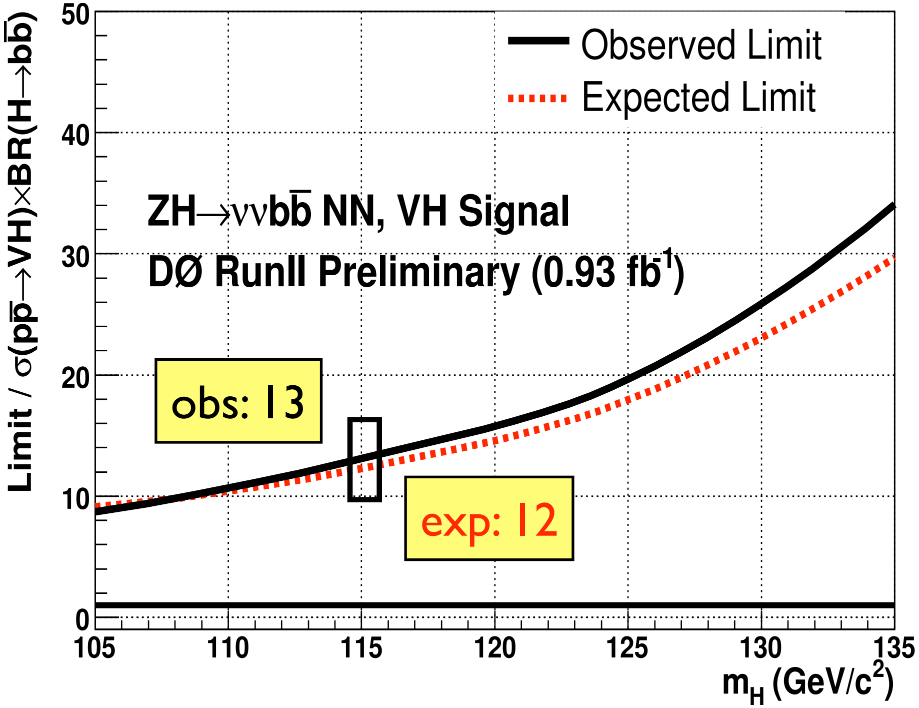
$ZH \rightarrow \nu\nu b\bar{b}$

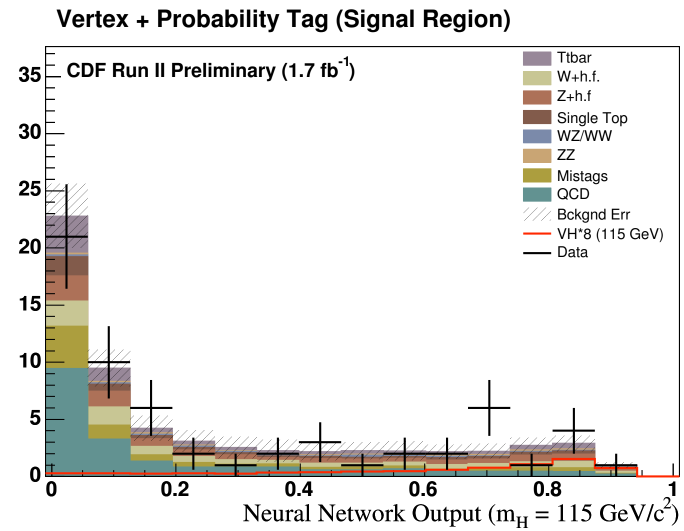


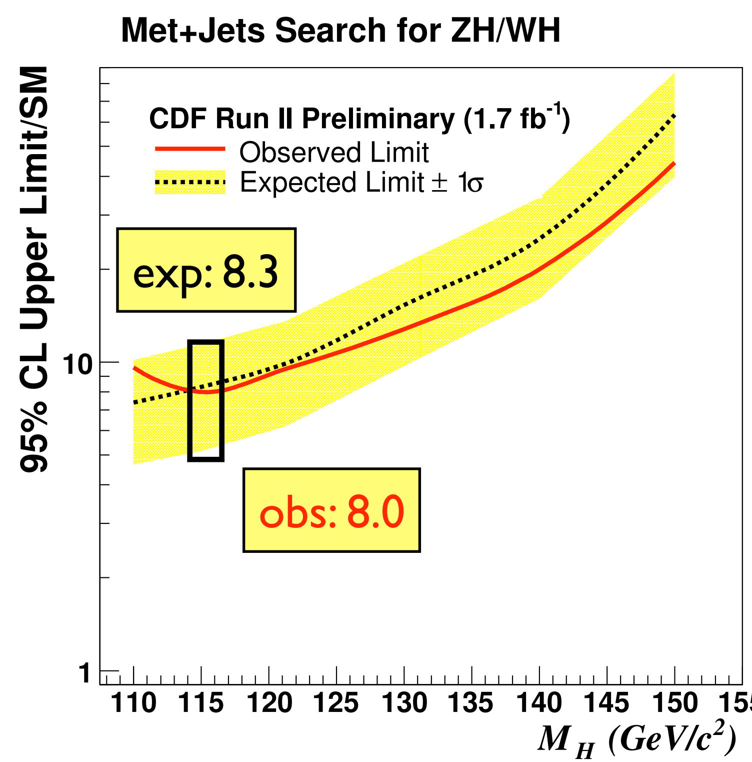
Upcoming improvements:

- Analyse complete dataset
- QCD-multijet understanding.
- Run IIb Level 1 CAL trigger upgrade.
- Include single-tag.

$ZH \rightarrow \nu\nu b\bar{b}$







Upcoming improvements:

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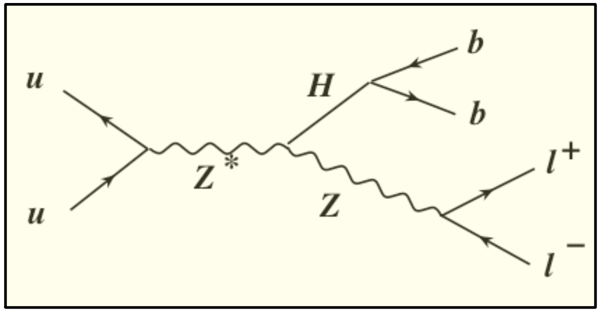
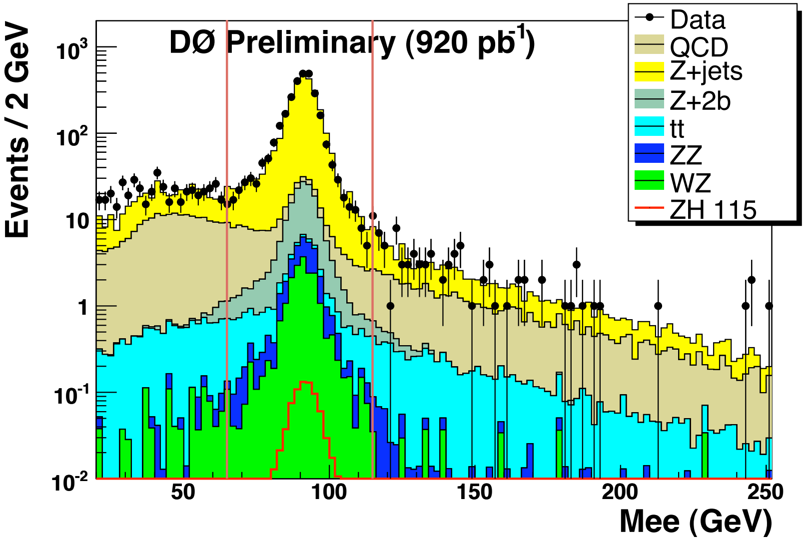
ZH → llbb̄: DØ

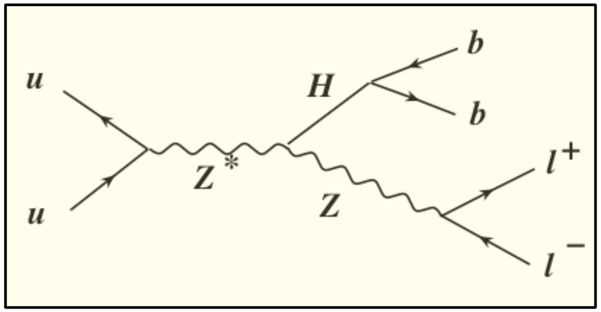


u
u
Z*
H
b
b
Z
l^+
l^-

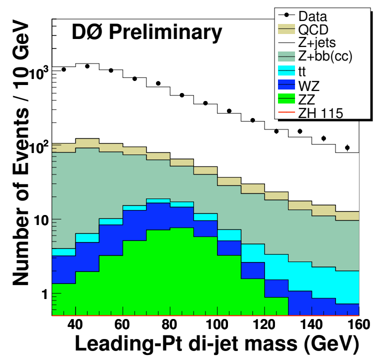


DØ Preliminary (920 pb-1)
Data
QCD
Z+jets
Z+2b
tt
ZZ
WZ
ZH 115
Events / 2 GeV
Mee (GeV)
10^3
10^2
10
1
10^{-1}
10^{-2}
50
100
150
200
250

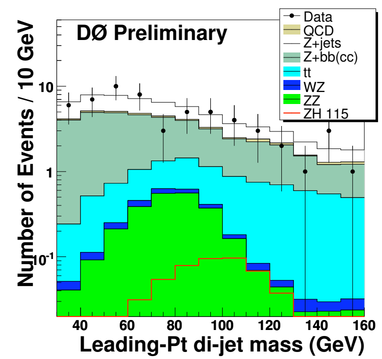
$ZH \rightarrow llb\bar{b}$: DØ



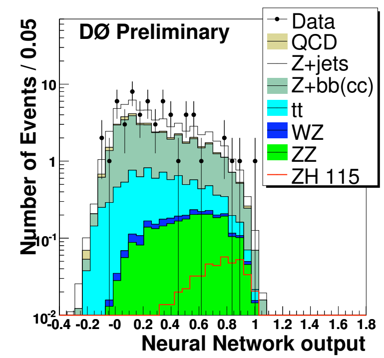
No b-tag



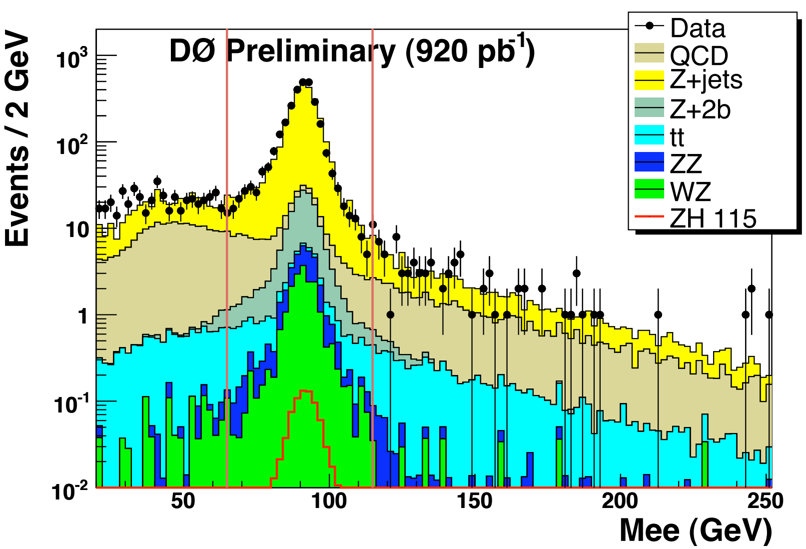
Double b-tag



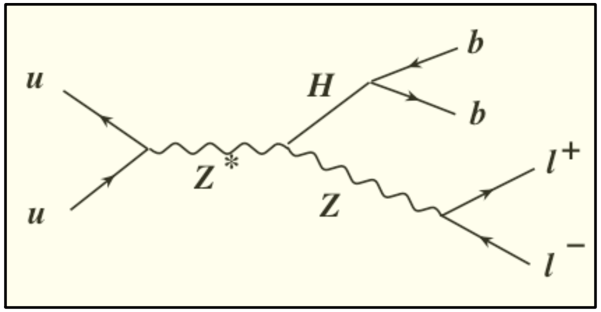
Neural Net



S/B ~ 0.53/74 before NN



ZH → llbb̄: DØ



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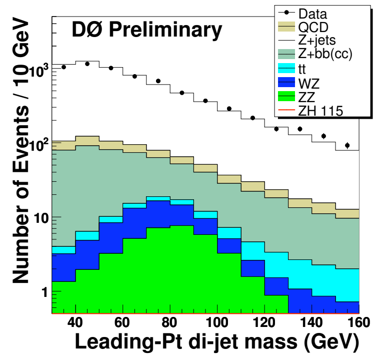
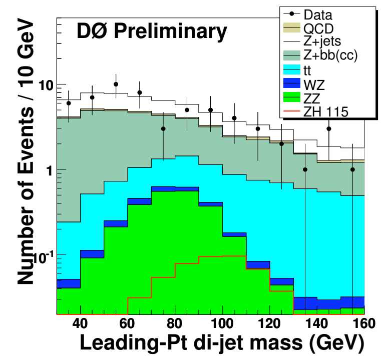
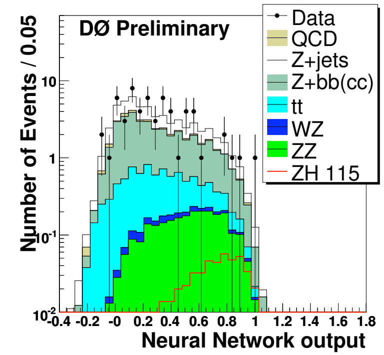


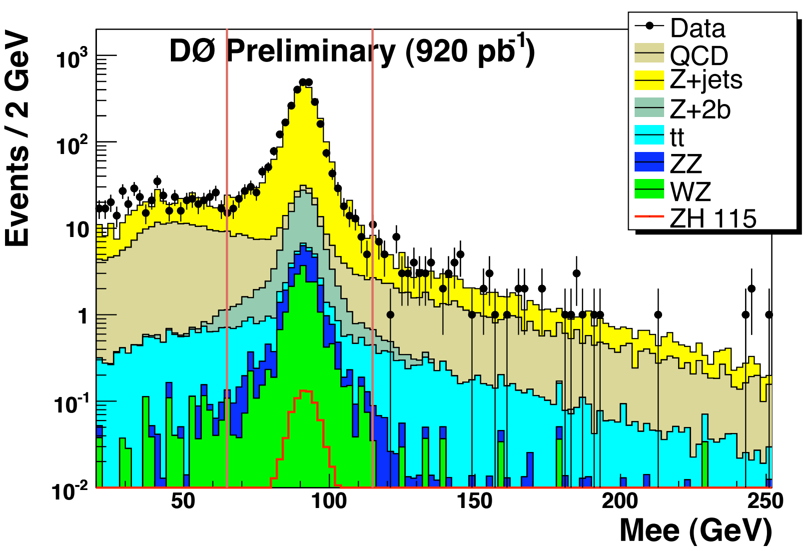
Double b-tag

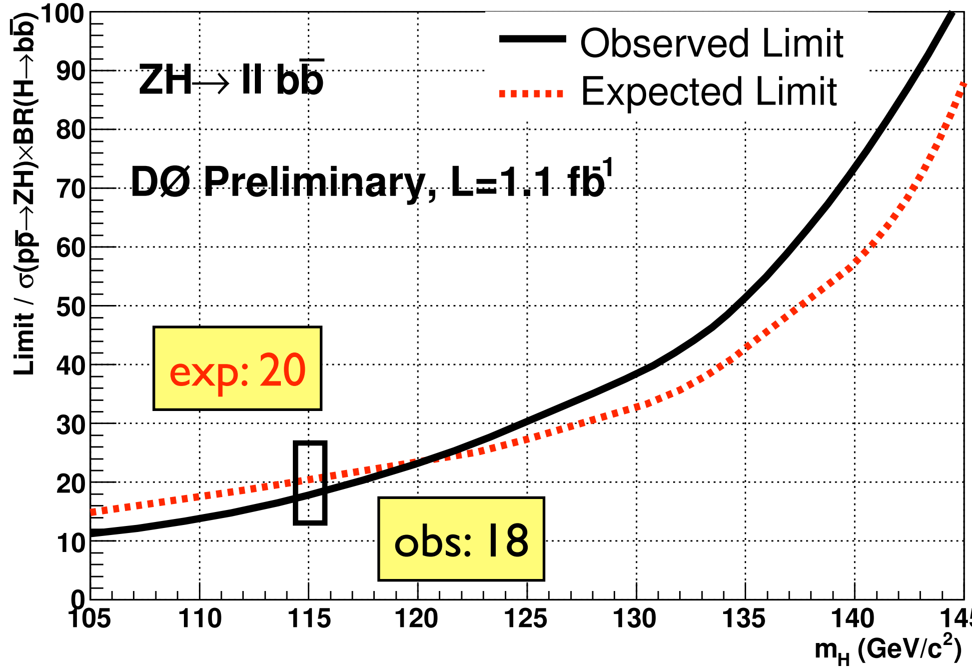


Neural Net



S/B ~ 0.53/74 before NN

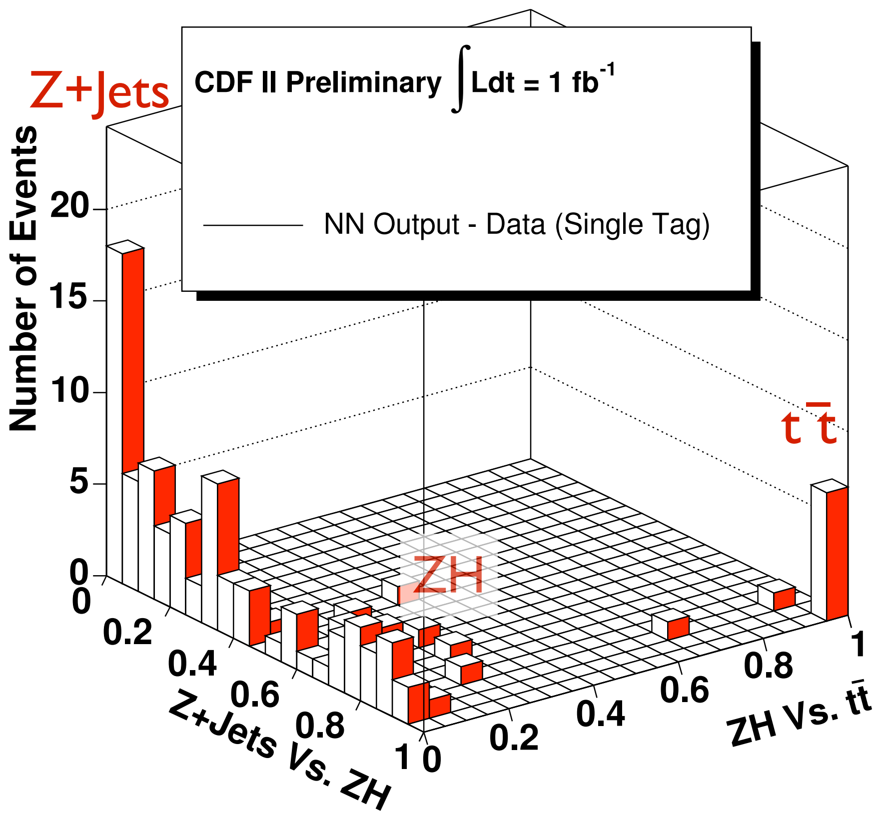


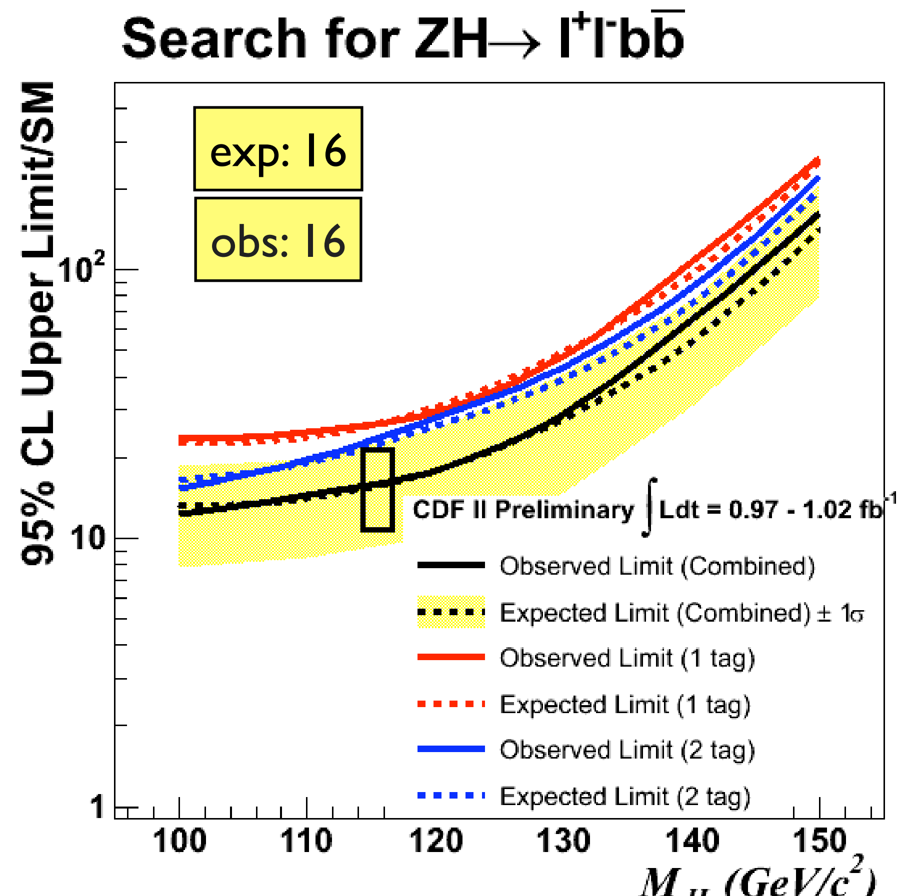


ZH → llb$\bar{b}$: CDF

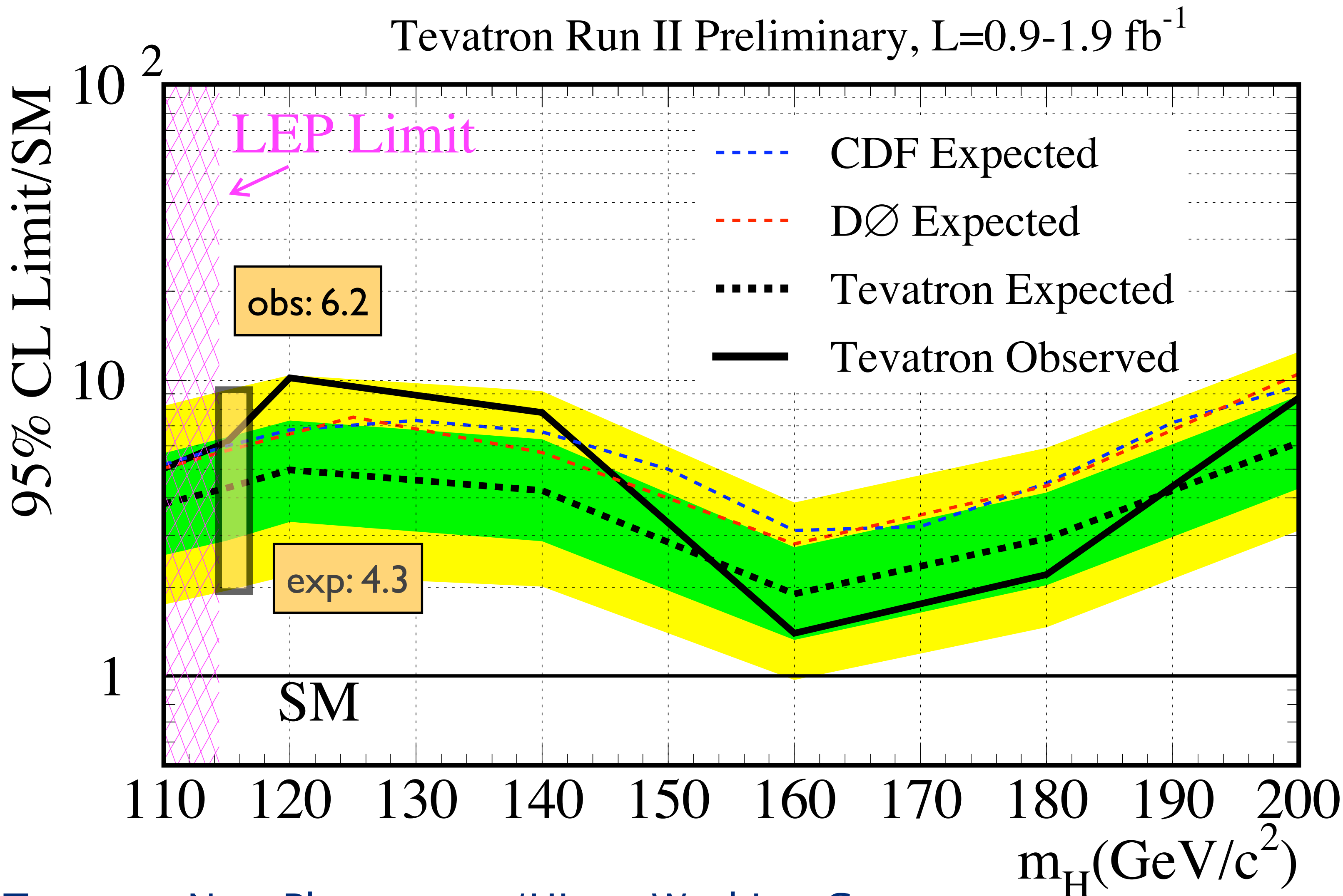
Two independent neural nets are trained to separate ZH from

- t$\bar{t}$ background
- Z+jet background





Tevatron Combination



Tevatron New Phenomena/Higgs Working Group combination **December 2007 arXiv:0712.2383**

Projecting Higgs Reach to 2010

Improvements assumed in projections

- ✦ b-tagging
  - b-tagging with Layer 0 (~8% per tag efficiency increase, DØ)
  - add semileptonic b-tags (~5% per tag efficiency increase, DØ)
  - improved usage of existing taggers (~25%, CDF)
  - add single-b-tag channel to $ZH \rightarrow \nu\nu bb$ (DØ)
- ✦ Acceptance
  - include forward electrons in WH (DØ)
  - include 3-jet sample in WH (DØ)
  - 25% trigger acceptance (CDF)
- ✦ Analysis techniques
  - improved multivariate analyses (~20% in sensitivity)
  - better usage of E_T^{miss}
  - di-jet mass resolution (from 18% to 15% in $\sigma(m)/m$, DØ)
- ✦ scaling of systematic uncertainties as a function of luminosity

Additional improvements not yet included in projection

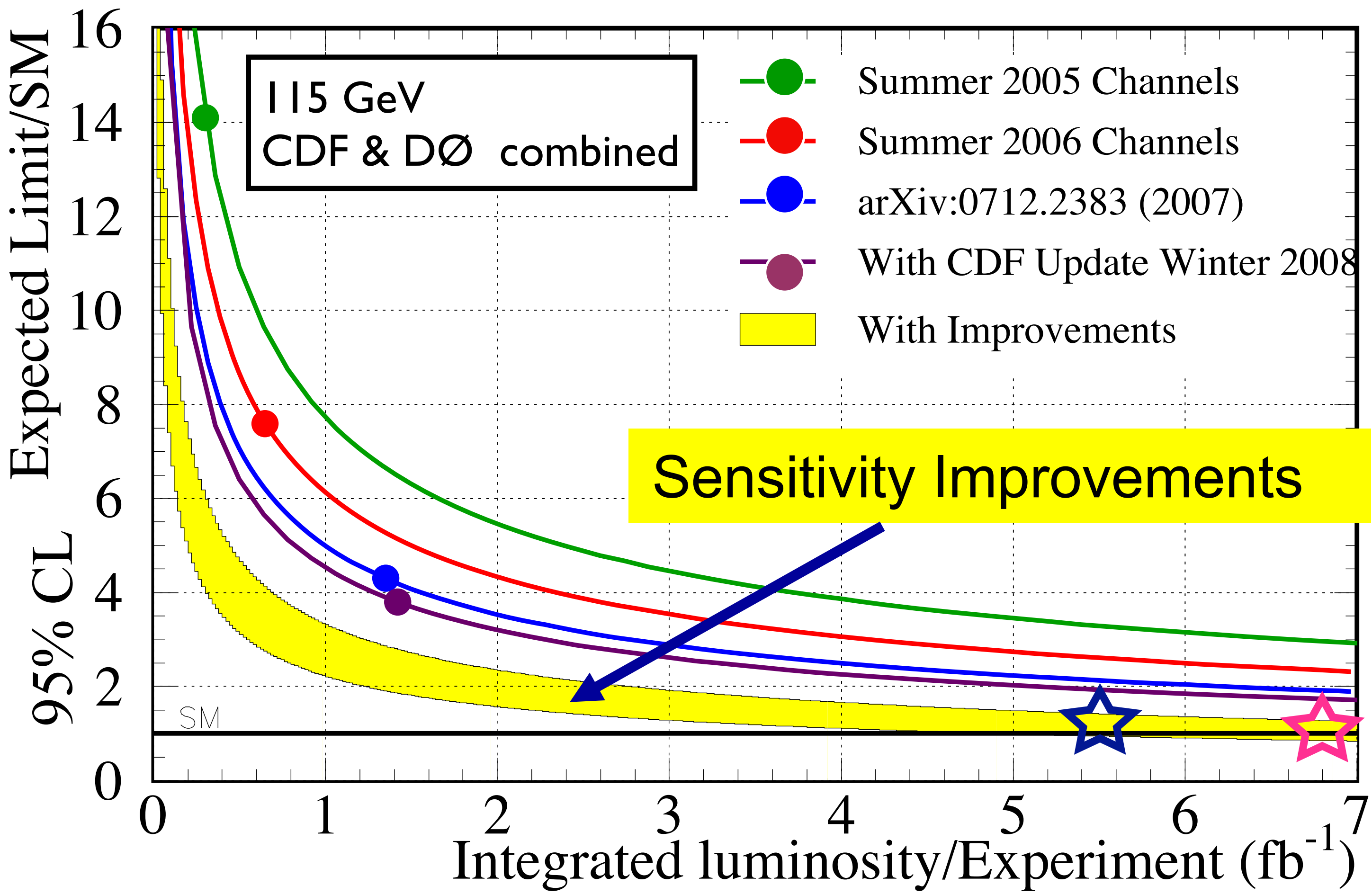
inclusion of tau channels

charm rejection in single b-tag analyses

optimizing $H \rightarrow WW$ at low mass

…

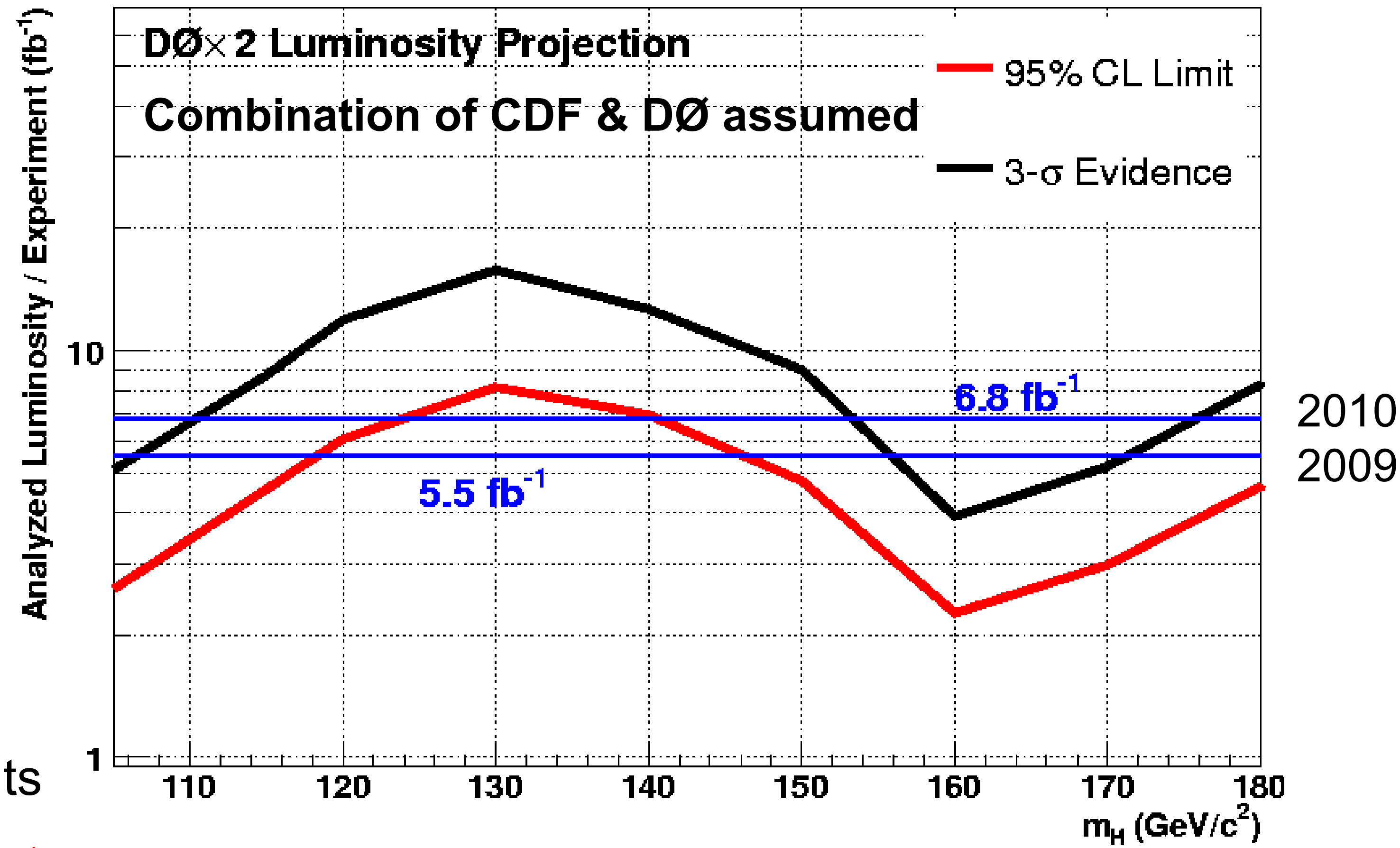
Higgs Status and Projections



2009 2010

Rob Roser, P5 Meeting, 01/02/08

Conclusion



With data accumulated by the end of 2010, we expect

- 95% exclusion possible over almost entire allowed mass range
- 3σ evidence possible at low and high ends of range

Backup Slides

Limit Setting

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

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

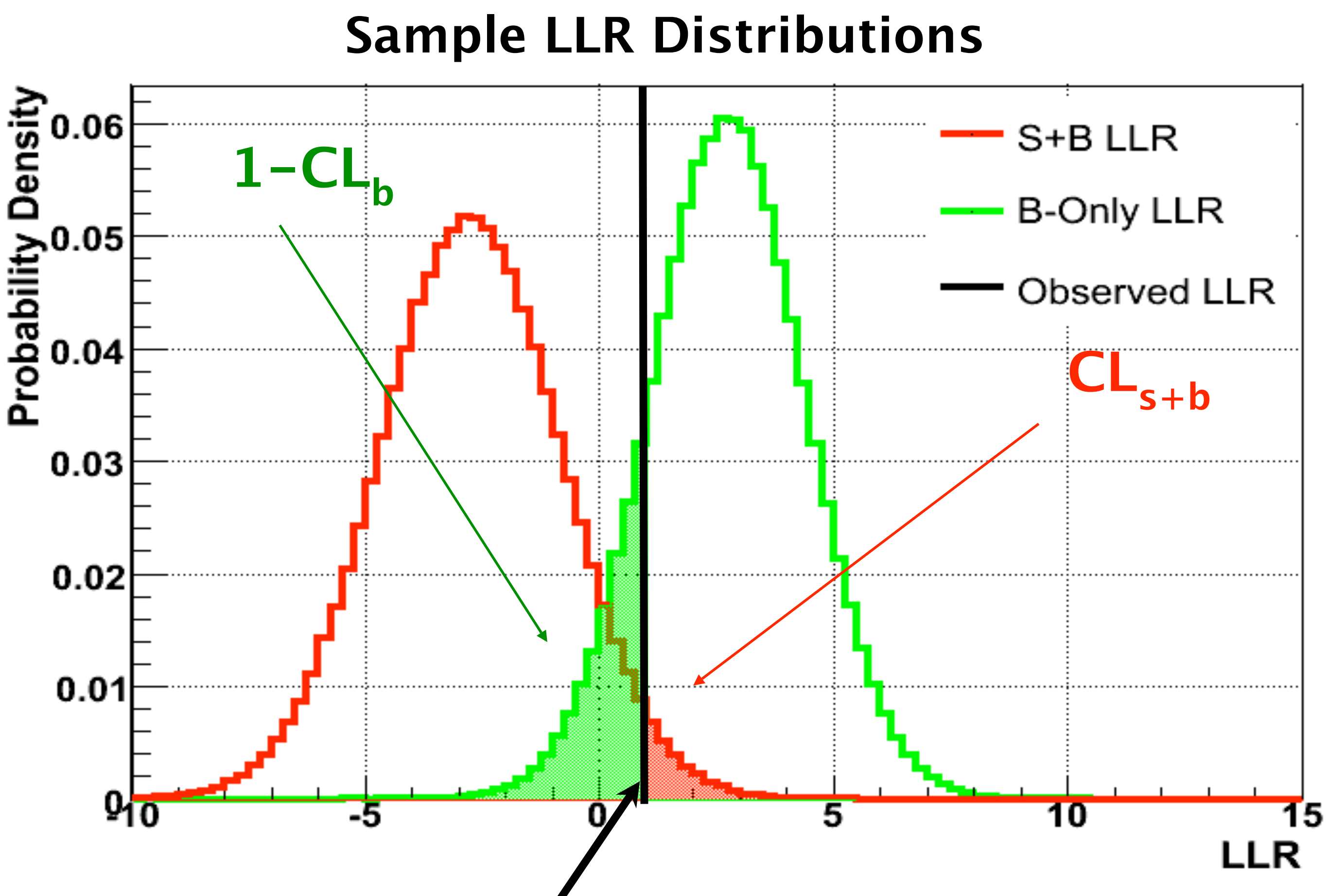
  - Using a Log-Likelihood Ratio test statistic:

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

d_{ij} refers to "data" for model being tested

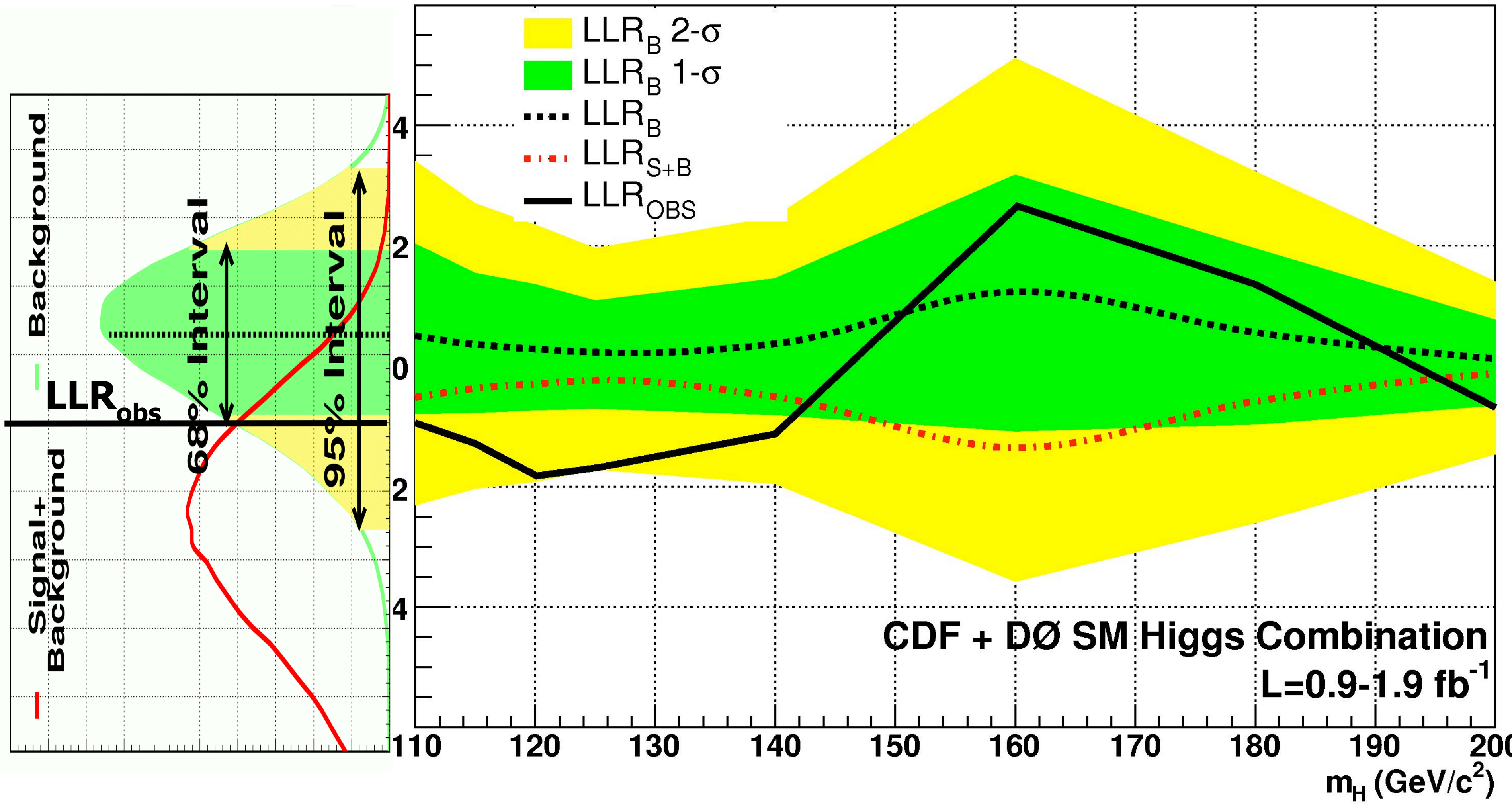
- Distributions of simulated outcomes are populated via Poisson trial with mean values given by B-only or S+B hypotheses
  - Systematics are folded in via Gaussian marginalization
  - Correlations held amongst signals and backgrounds

Limit Setting: LLR

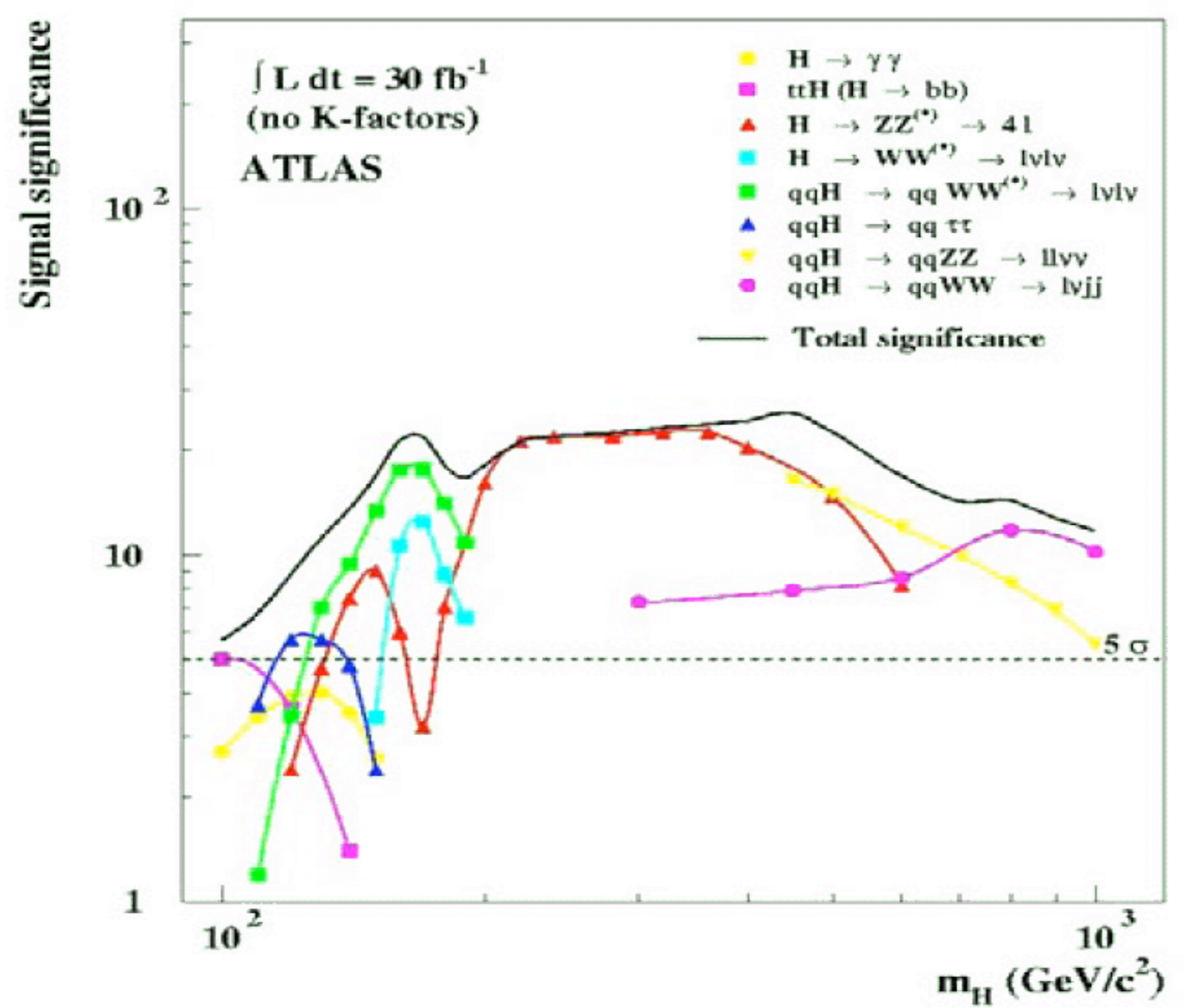


"Data excess" scenario

Tevatron Combination



Higgs @ATAS



Signal significance
∫ L dt = 30 fb⁻¹
(no K-factors)
ATLAS
H → γγ
ttH (H → bb)
H → ZZ(*) → 4l
H → WW(*) → lνlν
qqH → qq WW(*) → lνlν
qqH → qq ττ
qqH → qqZZ → llνν
qqH → qqWW → lνjj
Total significance
5 σ
10²
10
1
10³
m_H (GeV/c²)