Latest result on SM Higgs search from Tevatron

Yuji Enari LPNHE Paris Universites VI&VII

Seminar @ CPPM

2012 March 26th

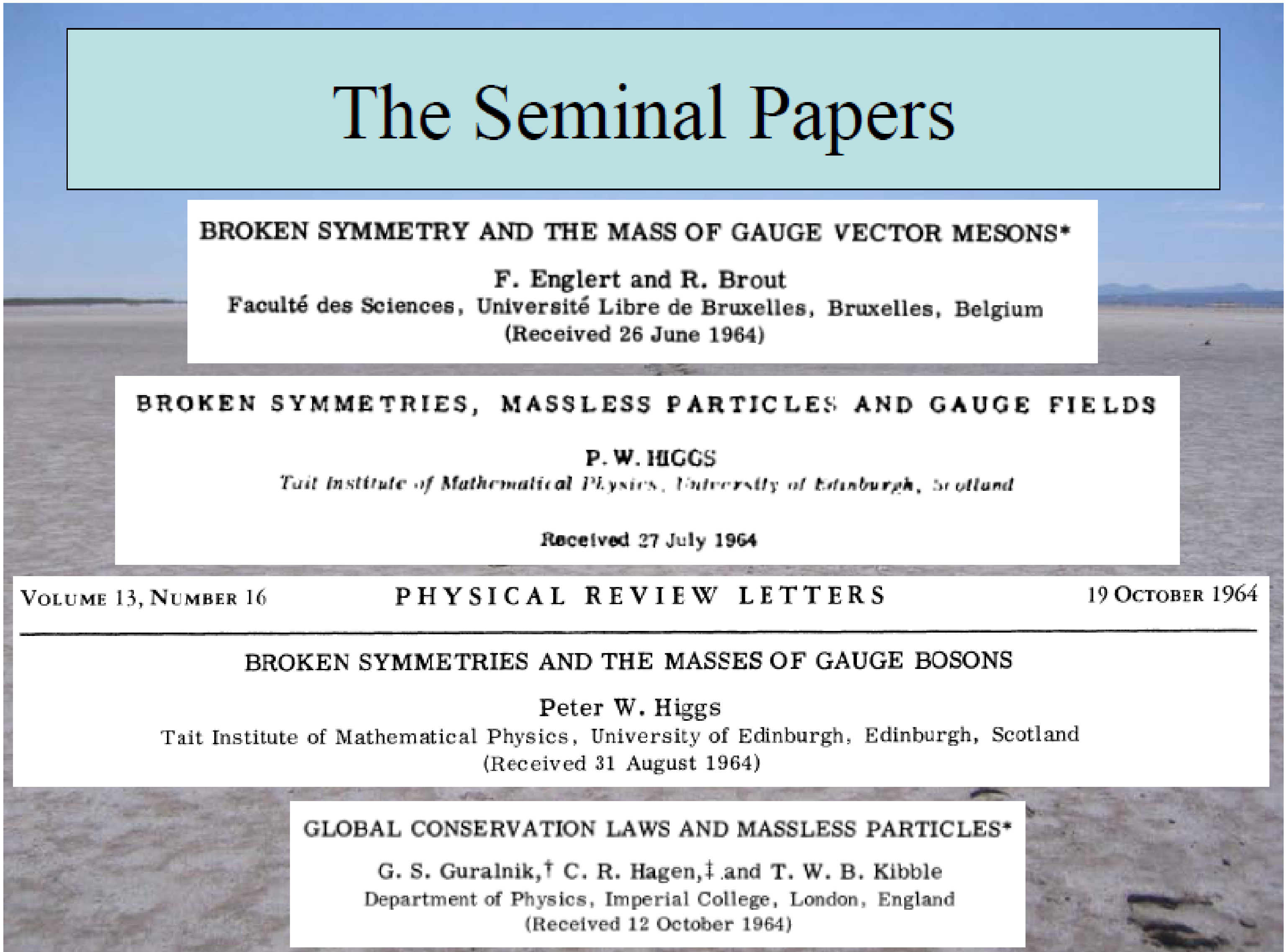
A story at U.S. airport

- Officer: Why you come to US?
- Me: I'm researcher, working on particle physics....
- Officer: ......
- Me: It's high energy experiment at Fermilab....
- Officer: **Low Mass HIGGS**?
- Me: Yes, yes, yes! That's right! Why do you know my work?!
- Officer: Ha Ha ha!

Officer wanted to know about Higgs!

Why we call Higgs boson?

- 2011 Higgs Hunting workshop by J. Ellis



The Seminal Papers

BROKEN SYMMETRY AND THE MASS OF GAUGE VECTOR MESONS*

F. Englert and R. Brout
Faculté des Sciences, Université Libre de Bruxelles, Bruxelles, Belgium
(Received 26 June 1964)

BROKEN SYMMETRIES, MASSLESS PARTICLES AND GAUGE FIELDS

P. W. HIGGS
Tait Institute of Mathematical Physics, University of Edinburgh, Scotland

Received 27 July 1964

VOLUME 13, NUMBER 16 PHYSICAL REVIEW LETTERS 19 OCTOBER 1964

BROKEN SYMMETRIES AND THE MASSES OF GAUGE BOSONS

Peter W. Higgs
Tait Institute of Mathematical Physics, University of Edinburgh, Edinburgh, Scotland
(Received 31 August 1964)

GLOBAL CONSERVATION LAWS AND MASSLESS PARTICLES*

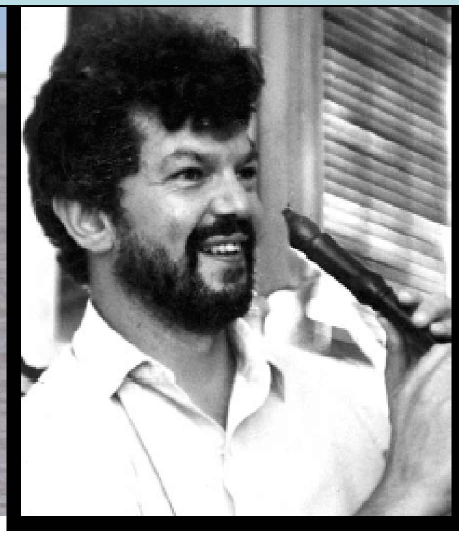
G. S. Guralnik,† C. R. Hagen,‡ and T. W. B. Kibble
Department of Physics, Imperial College, London, England
(Received 12 October 1964)

Why we call Higgs boson?

- 2011 Higgs Hunting workshop by J. Ellis

The Englert-Brout-Higgs Mechanism

Englert & Brout



(a) (b)

FIG. 1. Broken-symmetry diagram leading to a mass for the gauge field. Short-dashed line, $\langle\varphi_1\rangle$; long-dashed line, φ_2 propagator; wavy line, A_μ propagator. (a) $\to (2\pi)^4 ie^2 g_{\mu\nu}\langle\varphi_1\rangle^2$, (b) $\to -(2\pi)^4 ie^2(q_\mu q_\nu/q^2)\times\langle\varphi_1\rangle^2$.

Guralnik, Hagen & Kibble

We consider, as our example, a theory which was partially solved by Englert and Brout,[5] and bears some resemblance to the classical theory of Higgs.[6] Our starting point is the ordinary electrodynamics of massless spin-zero particles, characterized by the Lagrangian

$$\mathcal{L} = -\tfrac{1}{2}F^{\mu\nu}(\partial_\mu A_\nu - \partial_\nu A_\mu) + \tfrac{1}{4}F^{\mu\nu}F_{\mu\nu} + \varphi^\mu \partial_\mu \varphi + \tfrac{1}{2}\varphi^\mu\varphi_\mu + ie_0\varphi^\mu q\varphi A_\mu,$$

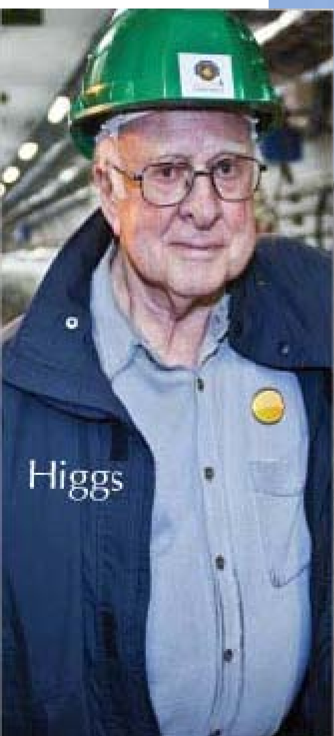
With no loss of generality, we can take $\eta_2 = 0$, and find

$$(-\partial^2 + \eta_1^{\,2})\varphi_1 = 0,$$
$$-\partial^2\varphi_2 = 0,$$
$$(-\partial^2 + \eta_1^{\,2})A_k^{\,T} = 0,$$

where the superscript T denotes the transverse part. The two degrees of freedom of $A_k^{\,T}$ combine with φ_1 to form the three components of a

Why we call Higgs boson?

- 2011 Higgs Hunting workshop by J. Ellis



The Higgs boson

- **Higgs pointed out a massive scalar boson**

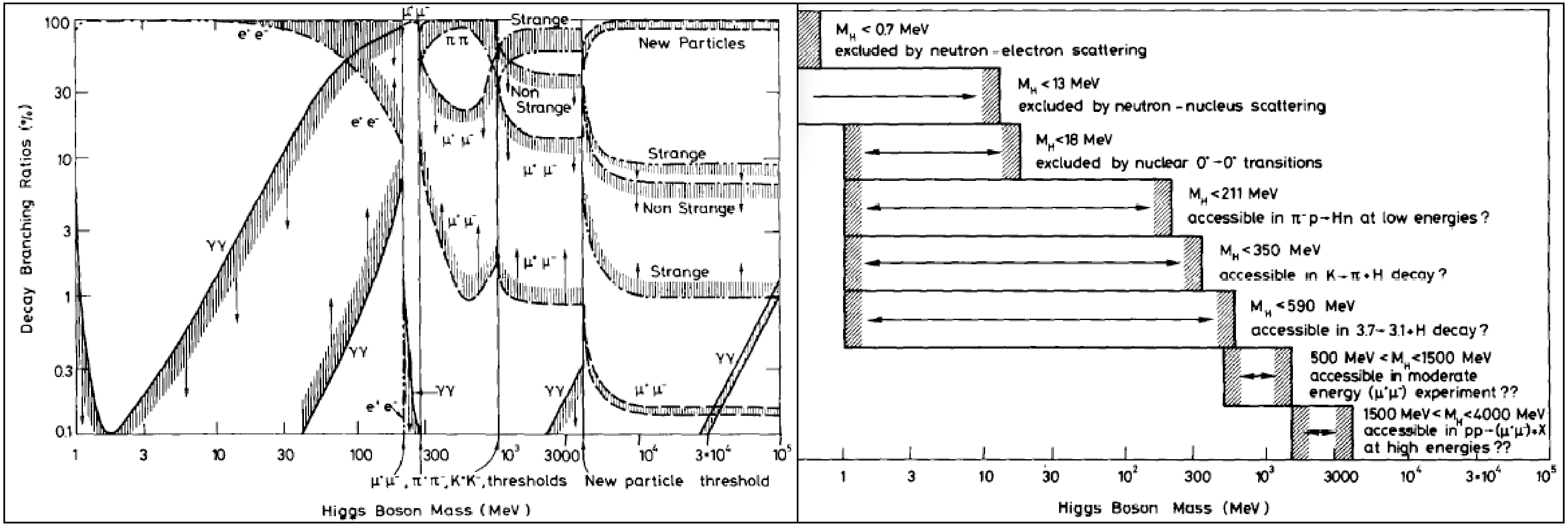
$$\{\partial^2 - 4\varphi_0^2 V''(\varphi_0^2)\}(\Delta\varphi_2) = 0, \qquad (2b)$$

Equation (2b) describes waves whose quanta have

(bare) mass $2\varphi_0\{V''(\varphi_0^2)\}^{1/2}$

- "… an essential feature of [this] type of theory … is the prediction of incomplete multiplets of vector and scalar bosons"
- Englert, Brout, Guralnik, Hagen & Kibble did not comment on its existence

History of Higgs hunting

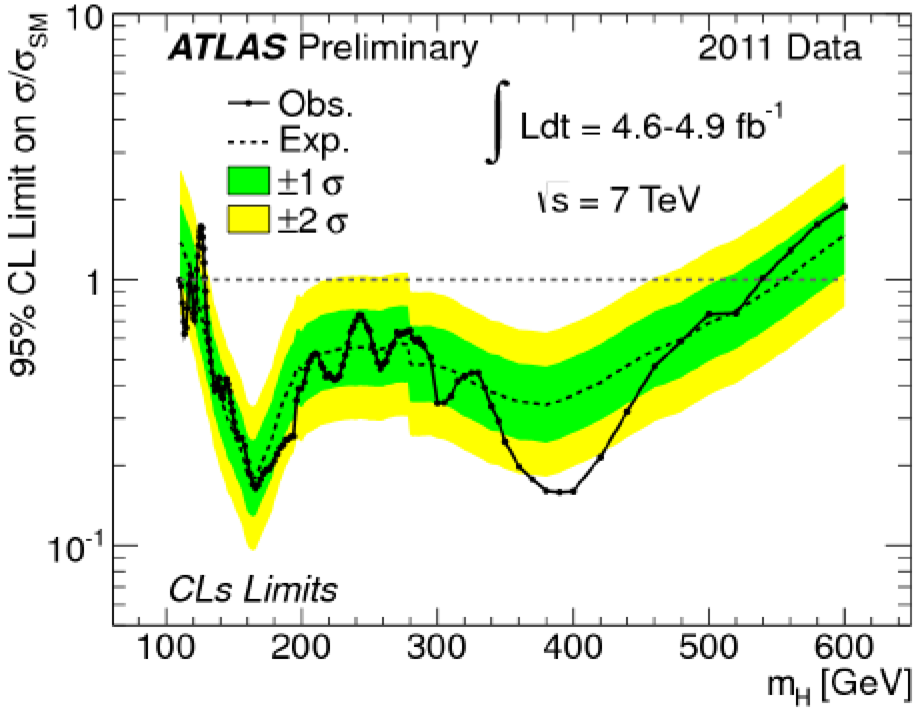


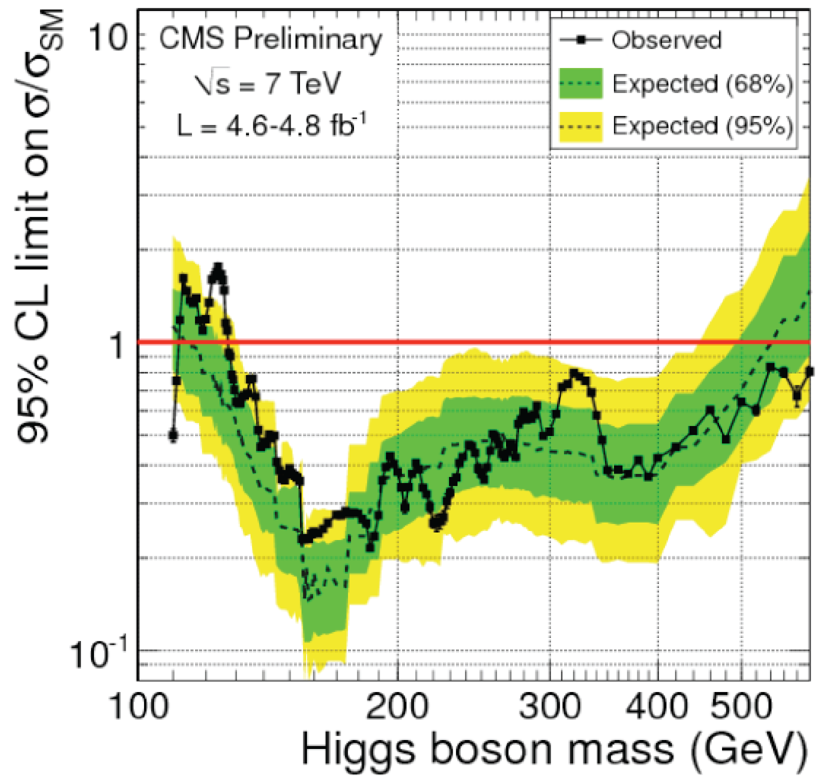
J. Ellis

We should perhaps finish with an apology and a caution. We apologize to experimentalists for having no idea what is the mass of the Higgs boson, unlike the case with charm [3,4] and for not being sure of its couplings to other particles, except that they are probably all very small. For these reasons we do not want to encourage big experimental searches for the Higgs boson, but we do feel that people performing experiments vulnerable to the Higgs boson should know how it may turn up.

- Higgs search at 1975: started from MeV scale.
- at 2012: Upto 600 GeV, start to see Higgs like boson?

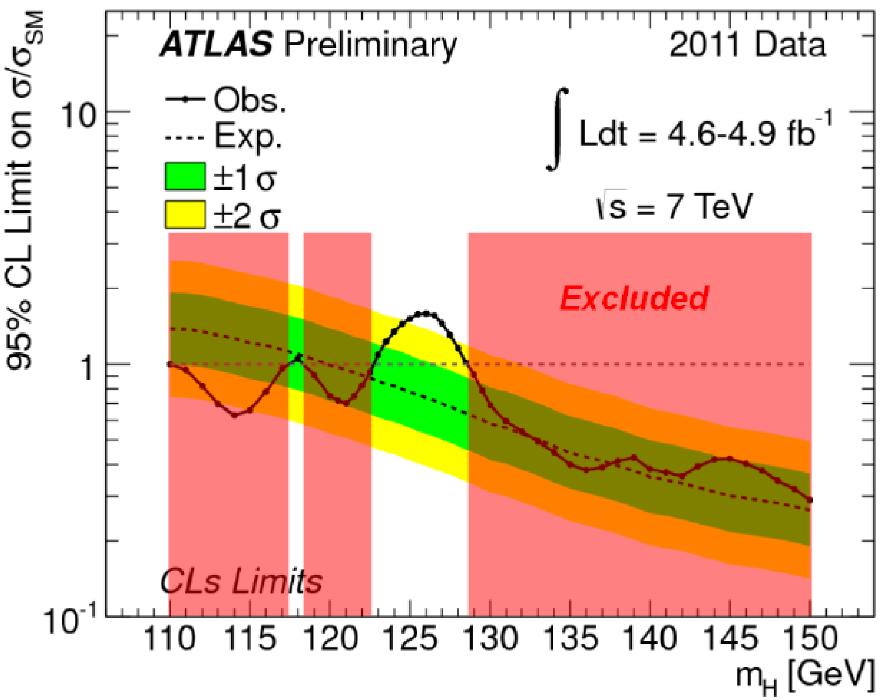
ATLAS and CMS: excluded region

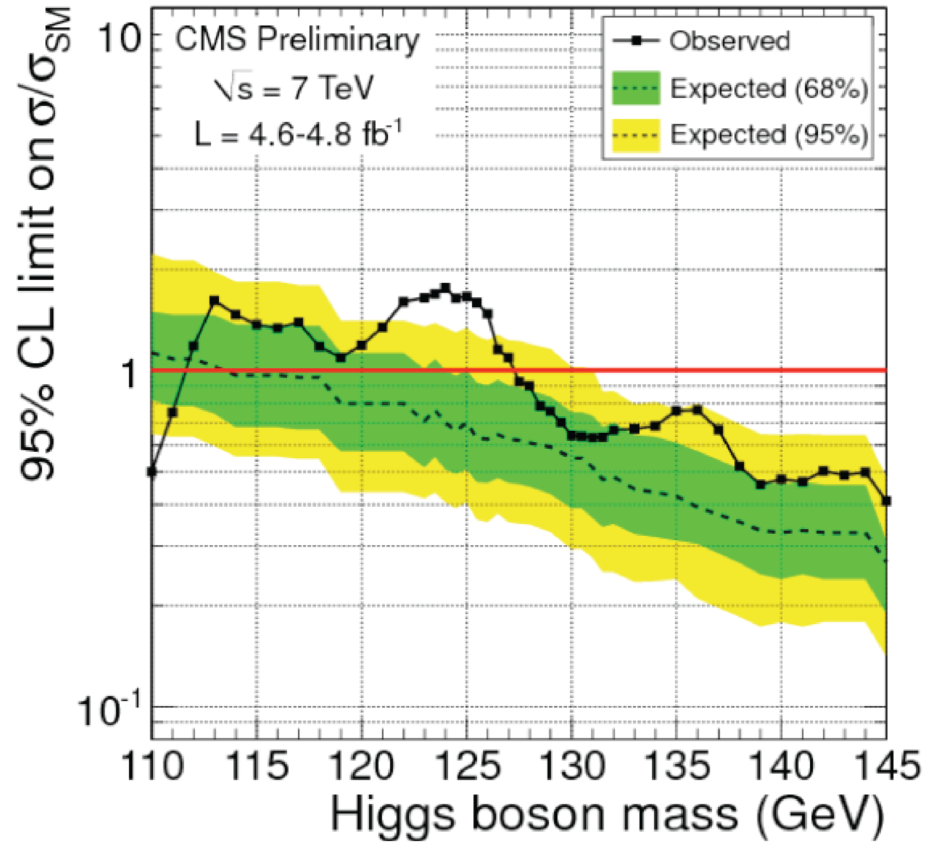




- High mass region is excluded upto 600 GeV

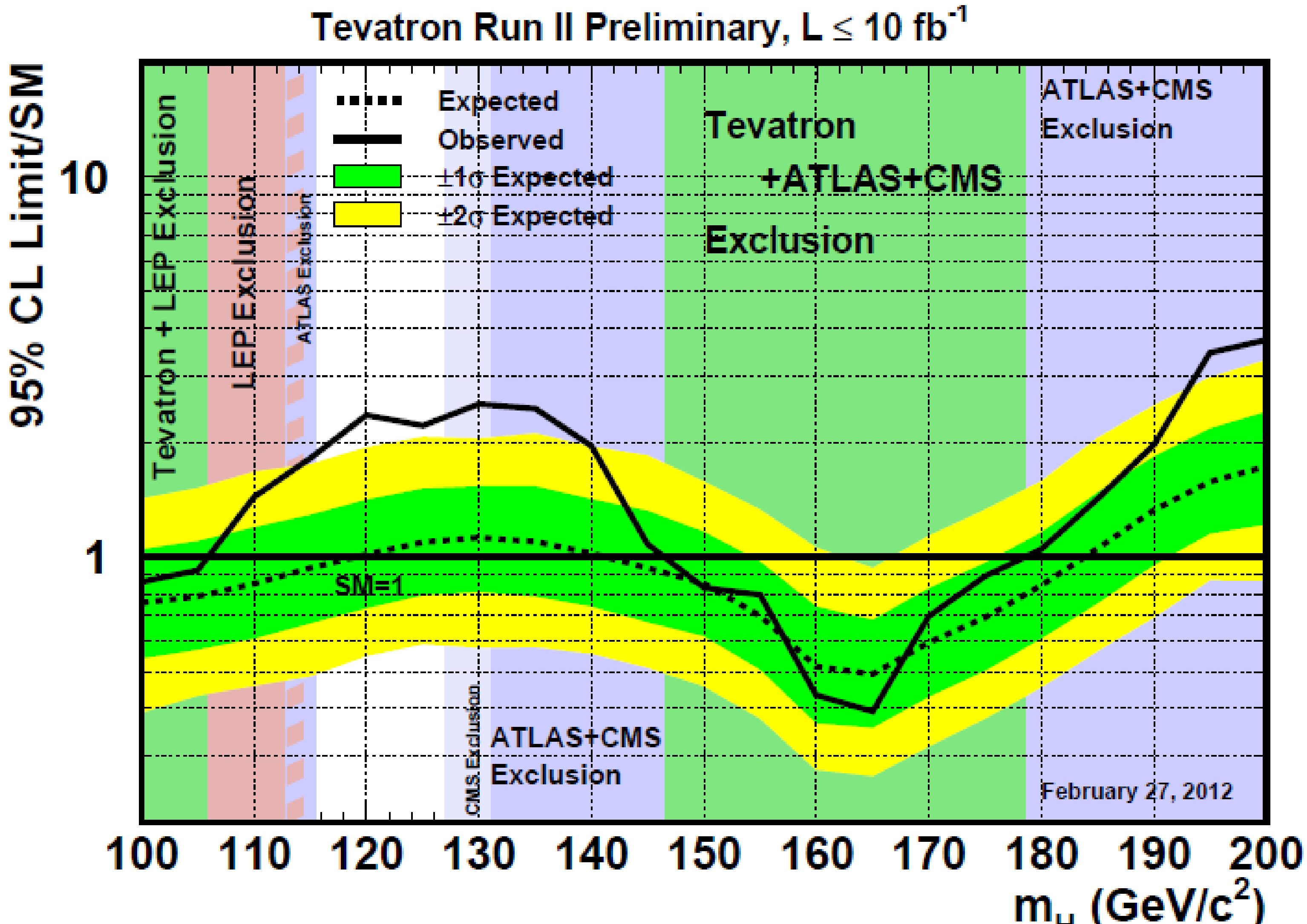
ATLAS and CMS: excluded region





- High mass region is excluded upto 600 GeV
- Both ATLAS and CMS have excess around 125 GeV.
  - Sensitive channels are $H \rightarrow \gamma\gamma$, $H \rightarrow WW$, $H \rightarrow ZZ \rightarrow 4$ leptons

Latest result from Tevatron

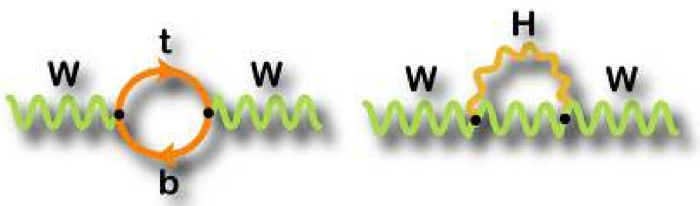


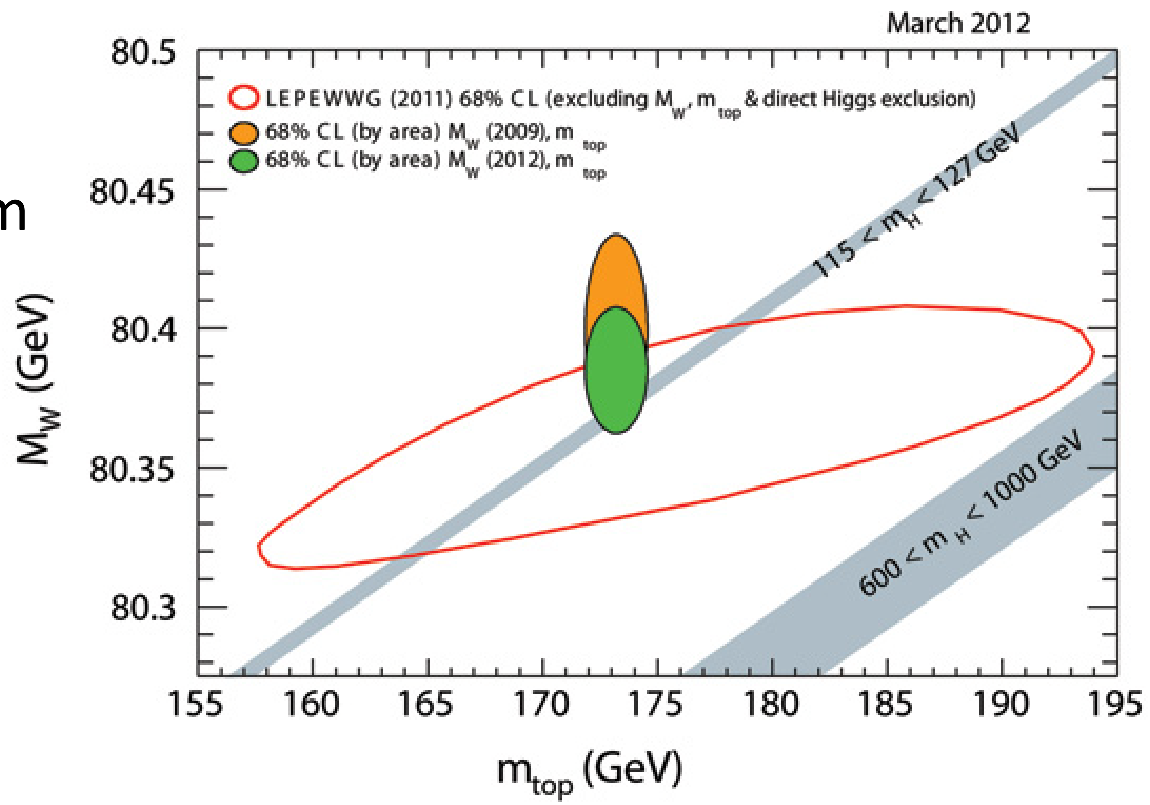
95% C.L. upper limits on SM Higgs boson production at the Tevatron

- Expected exclusion: **100 < M_H < 120 GeV** 141 < M_H < 184 GeV
- Observed exclusion: **100 < M_H < 106 GeV** 147 < M_H < 179 GeV

Indirect constraints

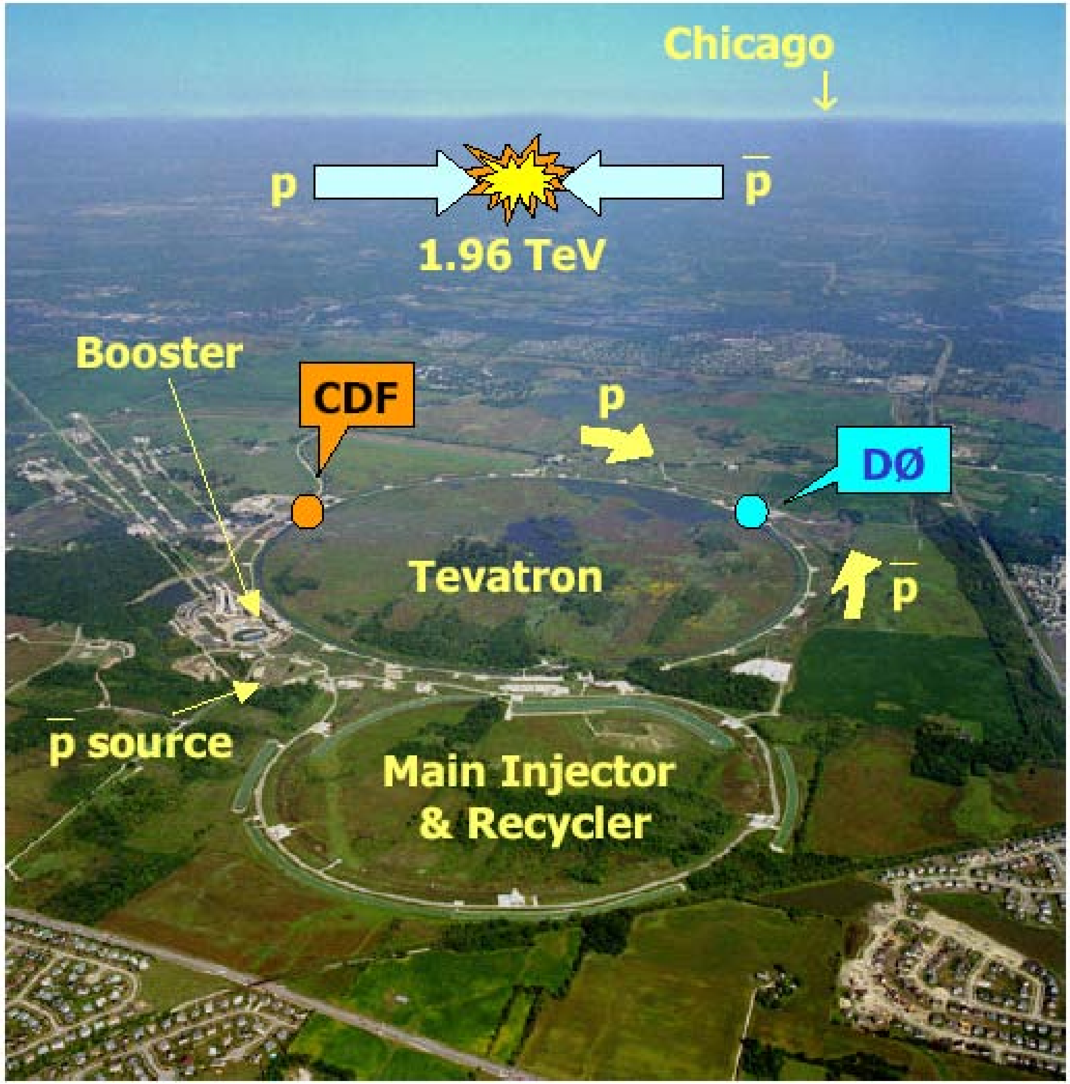
- EW global fitting
  - Main contribution from W and top mass from Tevatron





- New measurements from CDF and D0
- m_W = 80385 ± 15 MeV/c^2 (World Average @ March 2012)
- Updated SM indirect fit gives m_H < 152 GeV/c^2 at 95% C.L.

Tevatron @ Fermilab

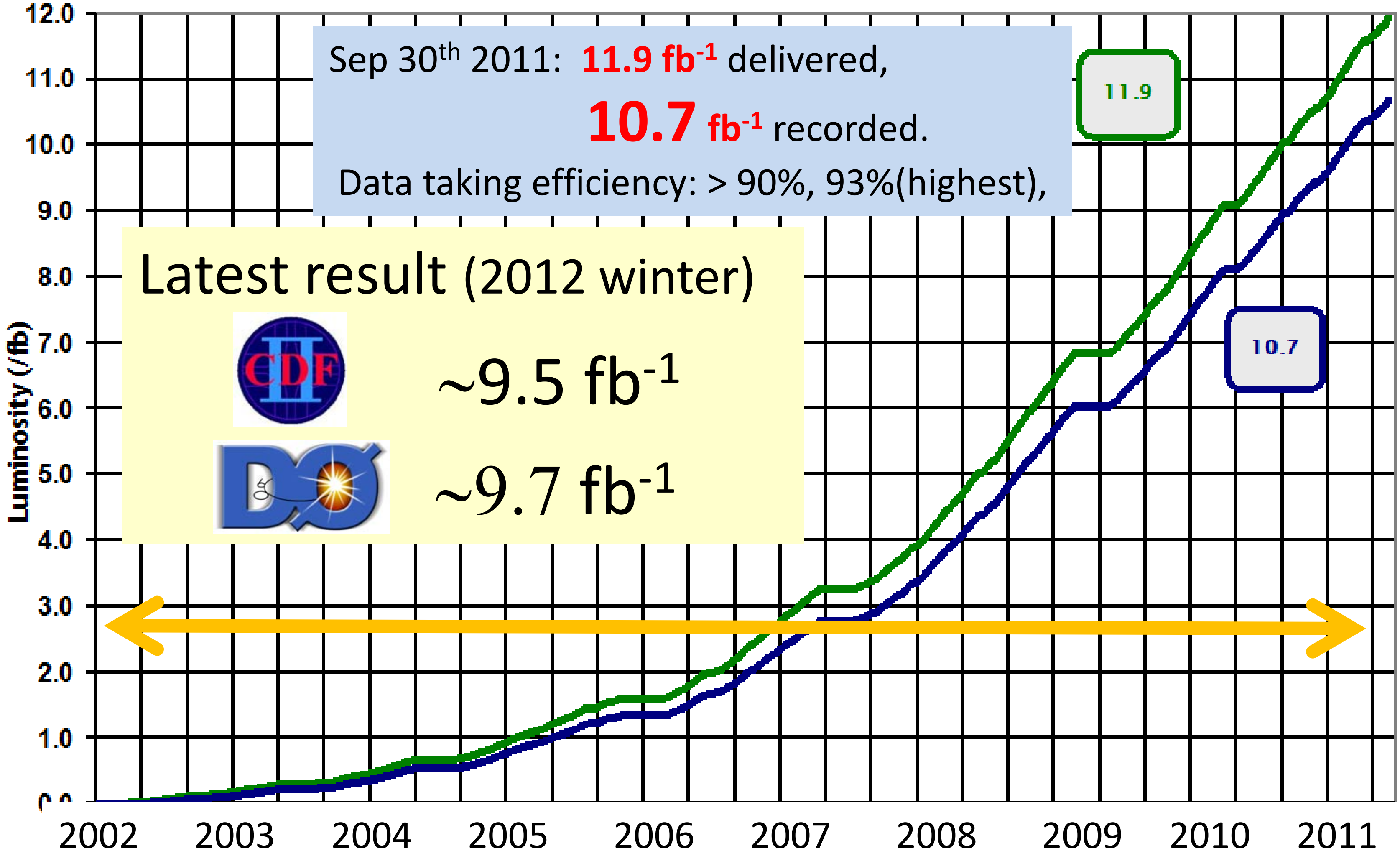


2011 Sep 30th : Tevatron terminated

Data Set

Tevatron RunII integrated luminosity

19 April 2002 -30 September 2011



Sep 30th 2011: **11.9 fb^{-1}** delivered,

10.7 fb^{-1} recorded.

Data taking efficiency: > 90%, 93%(highest),

Latest result (2012 winter)

CDF ~9.5 fb^{-1}

DØ ~9.7 fb^{-1}

Many thanks to Tevatron Accelerator group!!

D0 France

Arnaud Duperrin

Eric Kajfasz

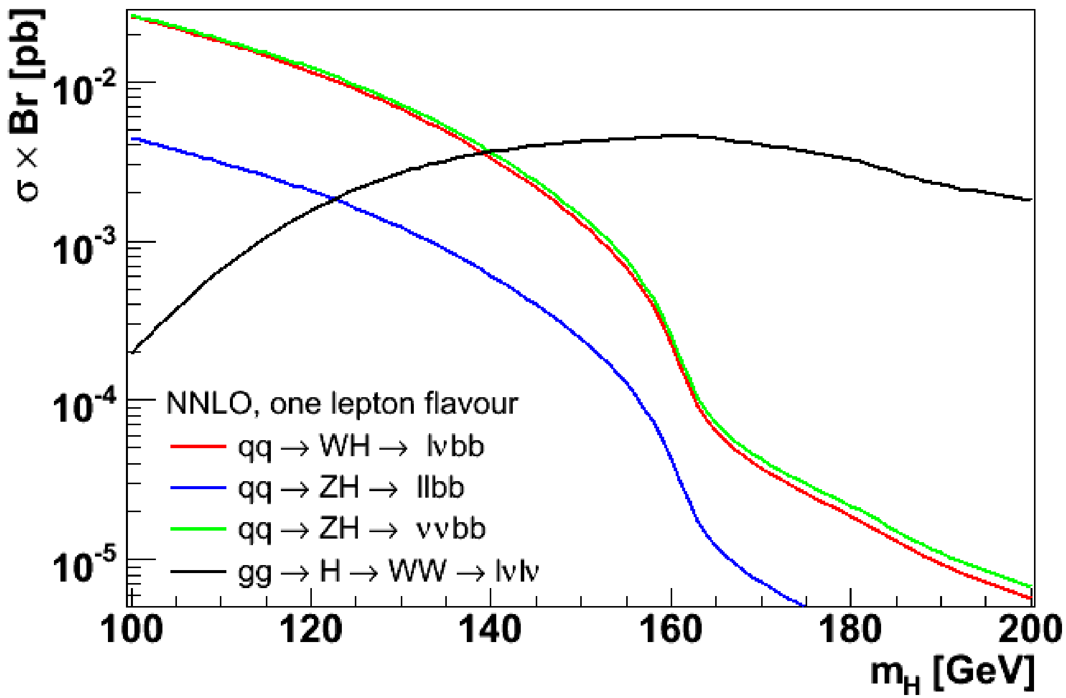
Smain Kermiche

Marie-Claude Cousinou

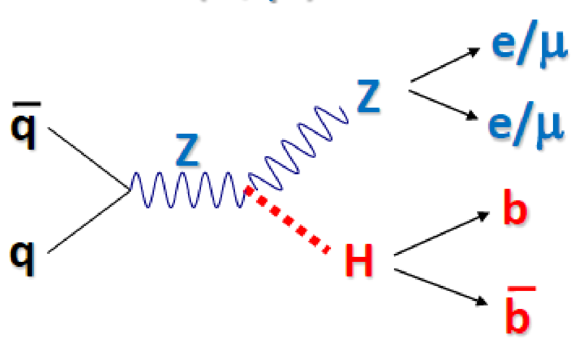
Elemer Nagy

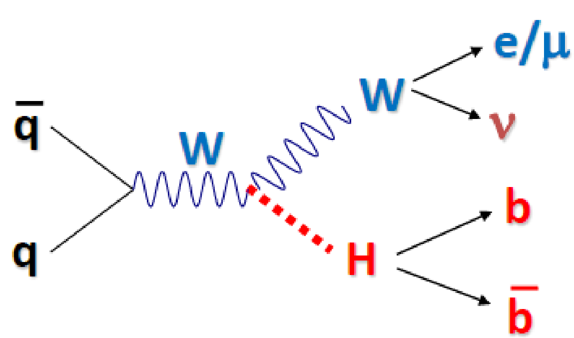
Nicolas Osman

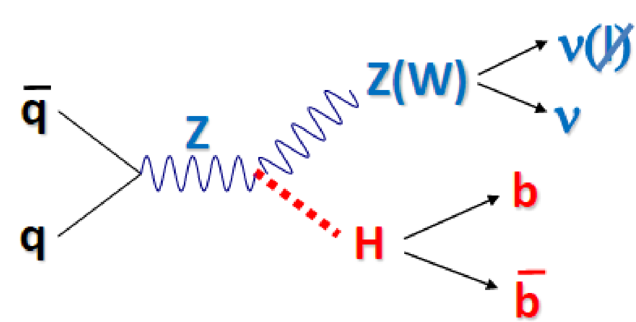
Today, focus on SM Higgs with H→b$\bar{b}$



ZH→ll bb	WH→lν bb	ZH→νν bb
2l(e/μ)+bb	l+MET+bb	MET+bb







Analysis on low mass Higgs Search

1. W or Z boson reconstruction

   $W \rightarrow l\nu$, $Z \rightarrow ll$, $Z \rightarrow \nu\nu$

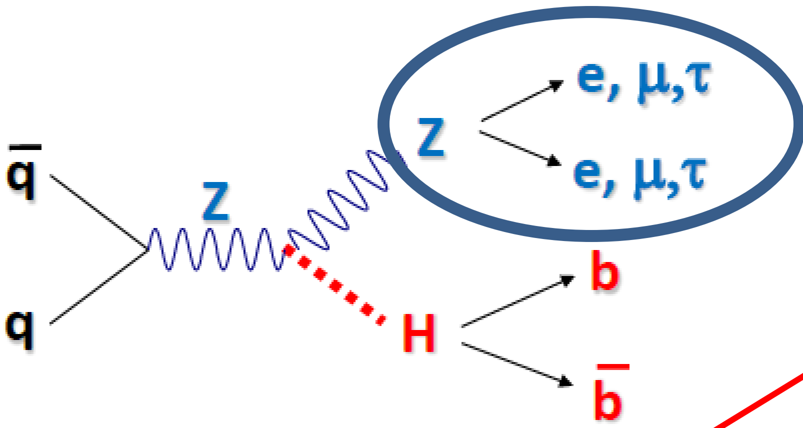
2. Higgs candidate reconstruction

   Dijet mass, b-jet tagging.

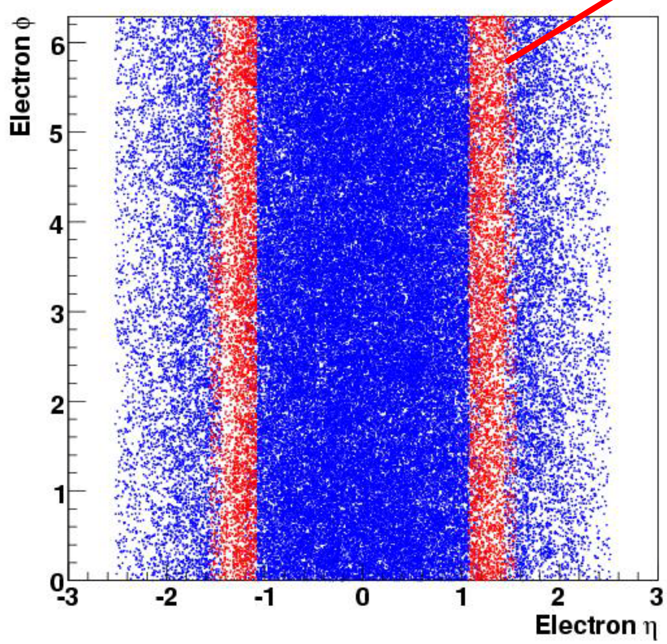
3. Build discriminant to extract signal

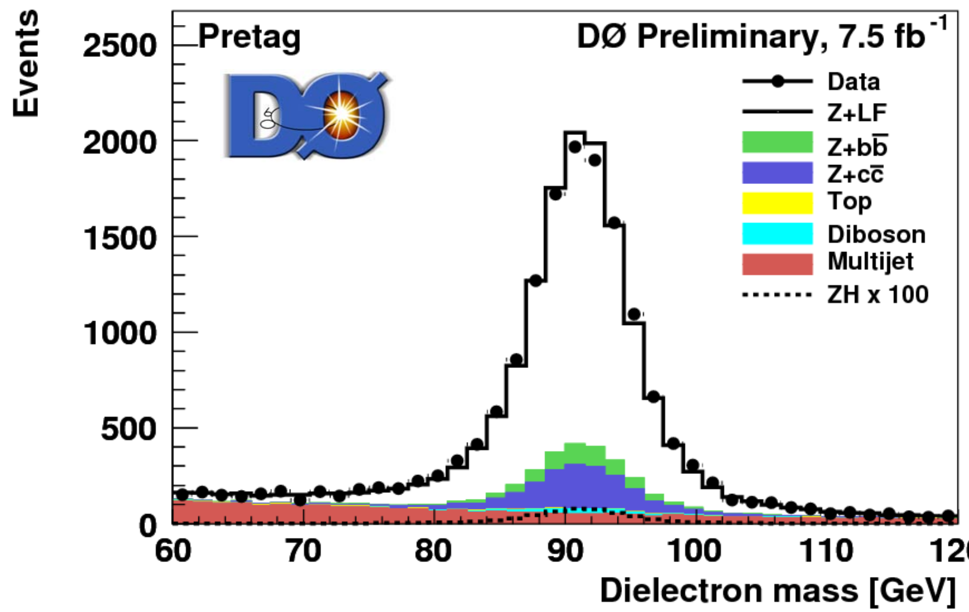
<u>Hunt for Higgs: try to improve each step!</u>

Z boson Reconstruction



- Maximize signal acceptance
  - Inclusion of isolated tracks
  - Electron in GAP,
  - Lowering pt cut on lepton pT > 10 GeV

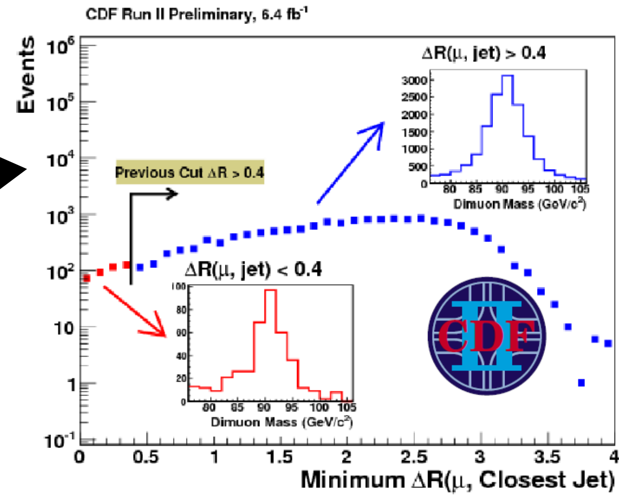


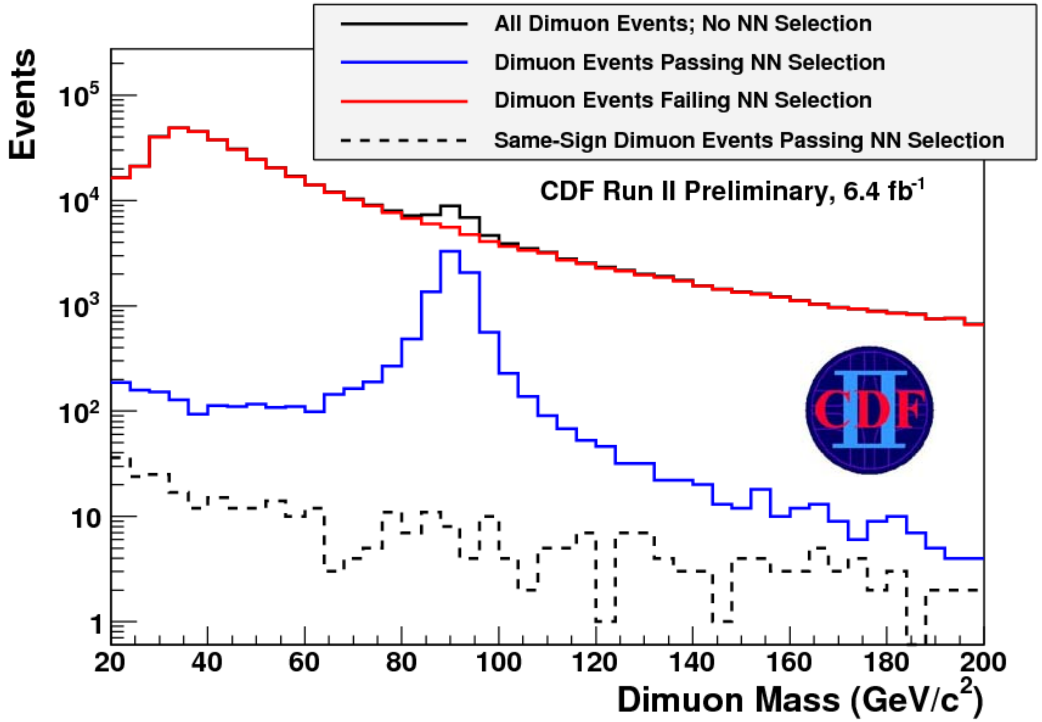


Relatively easy because of good triggering on leptons or some such low multi-jet BG
→ Already established last year.

How to get more acceptance?

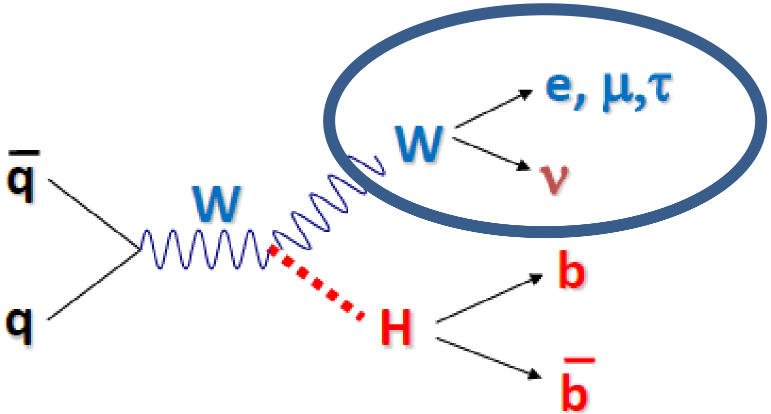
- Revisit the definition of object ID.
  - Ex: muon separation from jet
- Optimized identification by MVA





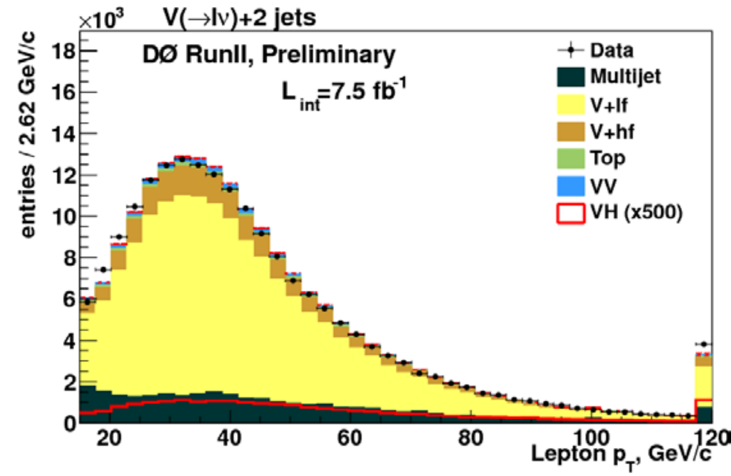
Case of CDF muon ID
Build NN with
p_T, η, ϕ, E_{EM}, E_{HAD}, $\Delta R(\mu, \text{jets})$,
Track χ^2, d0, silicon hit, isolation
→ ~ 20% improvement on llbb.

W boson Reconstruction



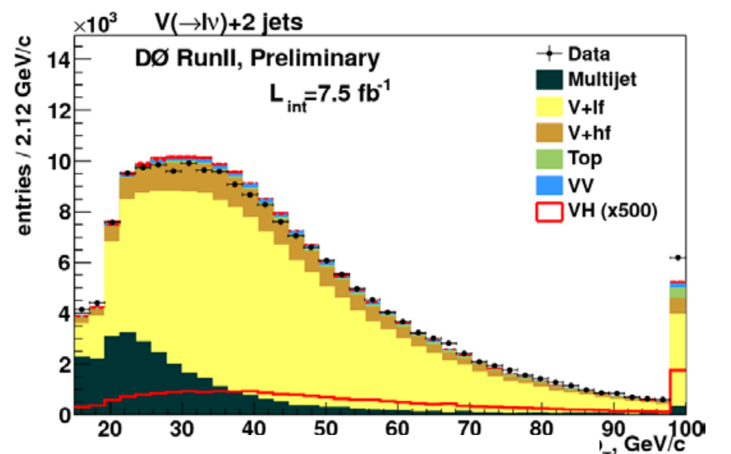
Lepton:

electron/ muon pT > 15 GeV

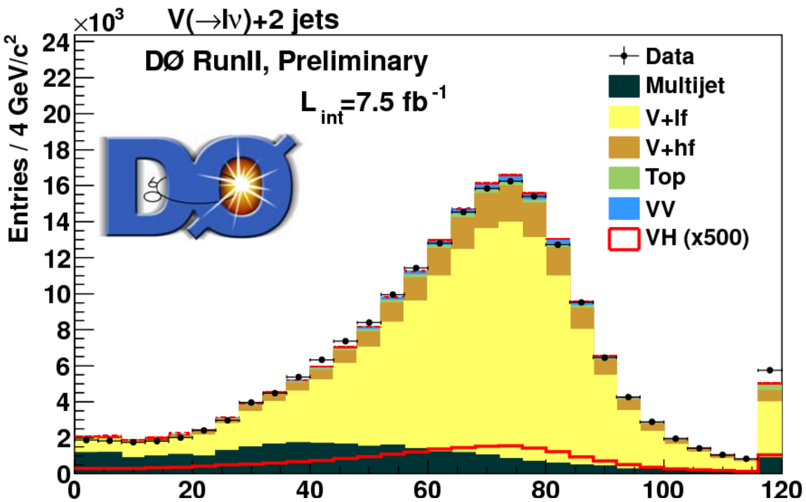


Missing E_T

MET> 15 (20) GeV for electron (muon).



Missing ET (GeV)



W Transverse Mass (GeV)

Multi-Jet Background is estimated from Data.

How to get more signal for lvbb?

- Revisit lepton ID
  - DØ muon
    - loosen muon requirement
    - Update isolation requirement
    - Use all trigger terms

      ~ 15% gain in muon efficiency.
  - DØ Electron
    - Looser criteria

      QCD veto is WtrMass > 40 – 0.5 MET

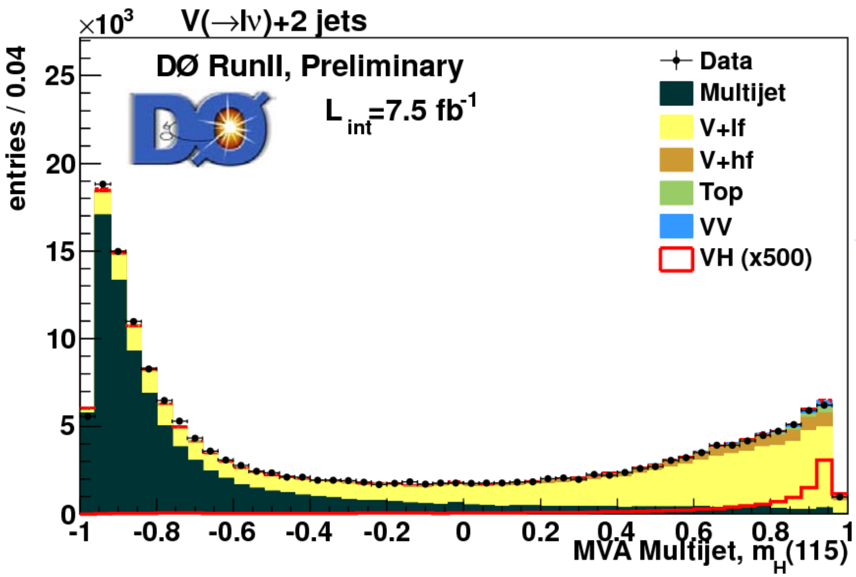
  → Use MVA(QCD) as input of Final MVA.

CDF

- isolated track.

  → include loose electron track.

  ~ 5% gain in sensitivity.



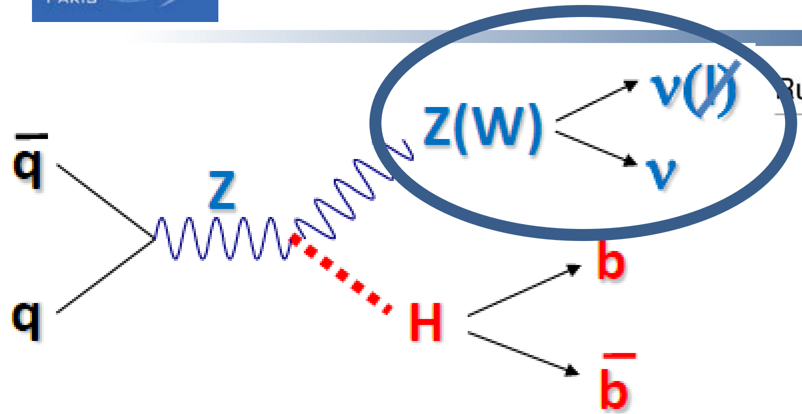
CDF

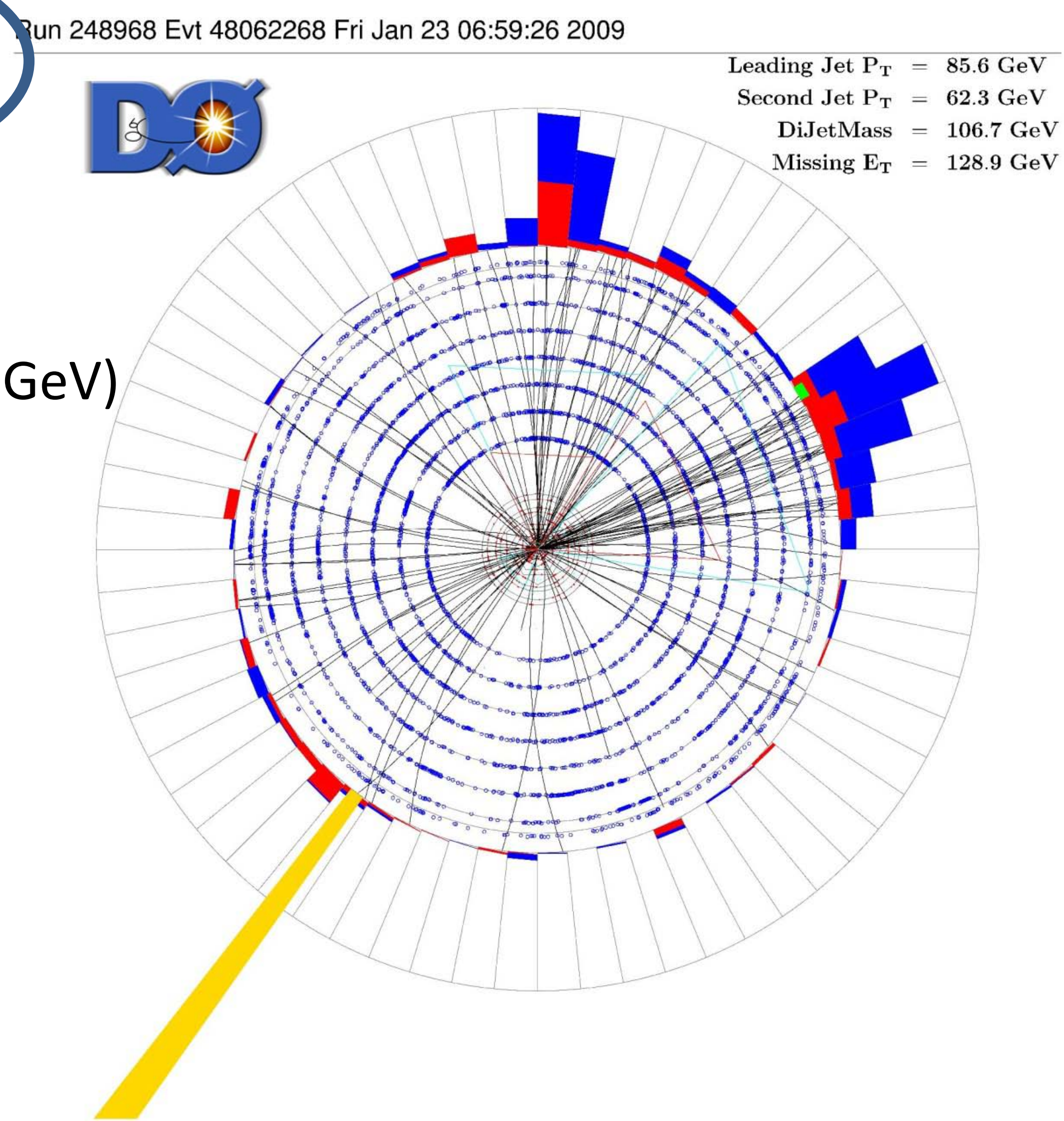
- Introduce MVA to kill MJ.

  "Support Vector Machine"

  Replaced with QCD veto.

Z→νν reconstruction



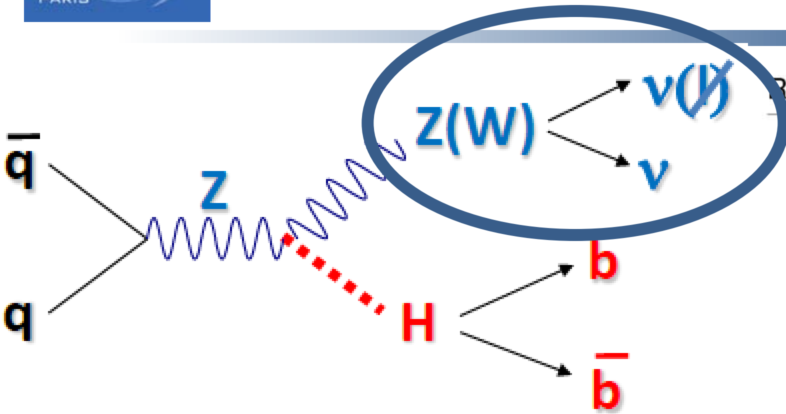


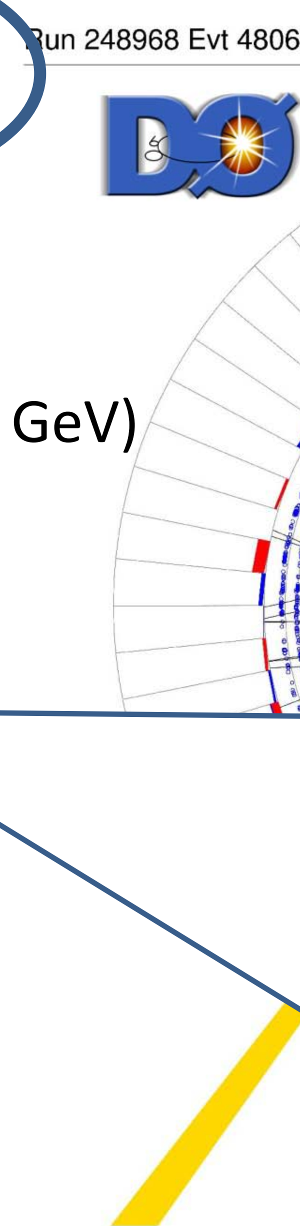
- Jets + large MET (>40 GeV)

  Expect high multi-jet Background

  - **Signal sample**
  - **Control sample**
    - **→Multi-Jet**
    - **→Electro-weak**

Z→νν reconstruction





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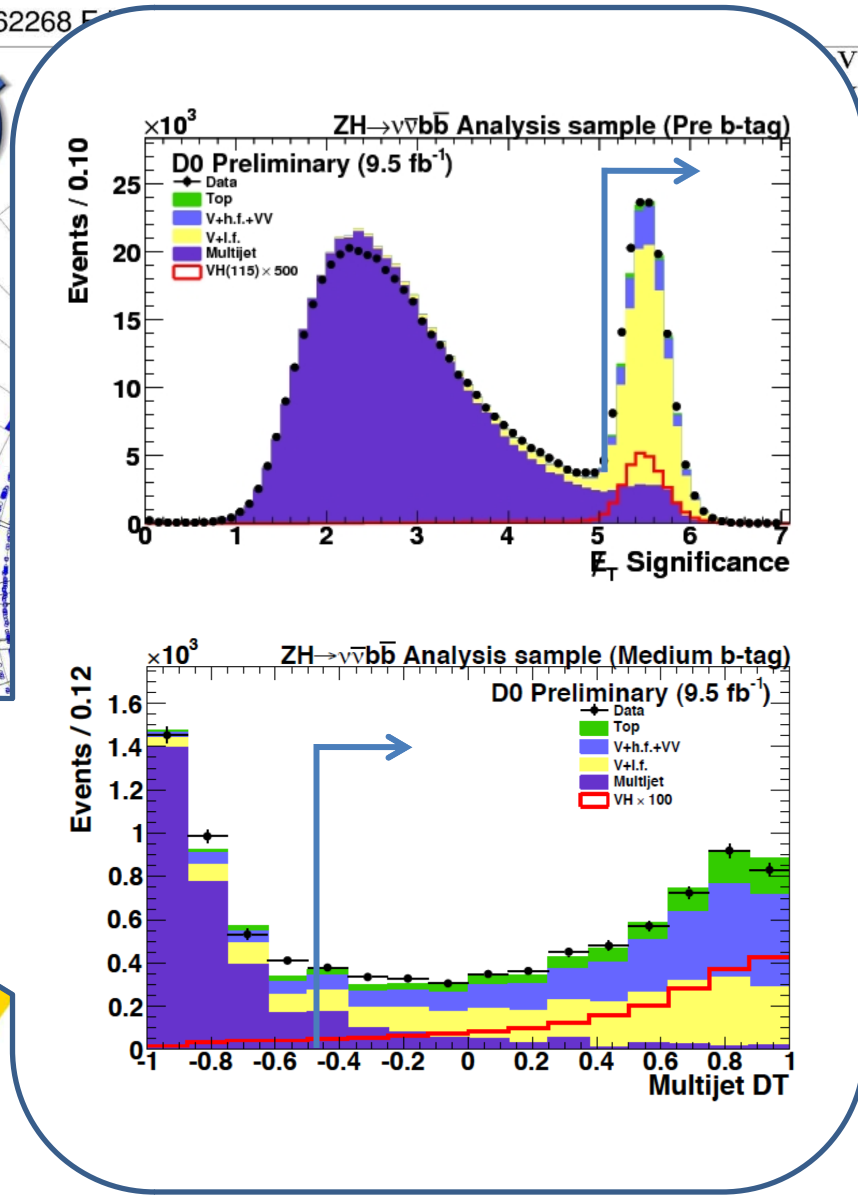
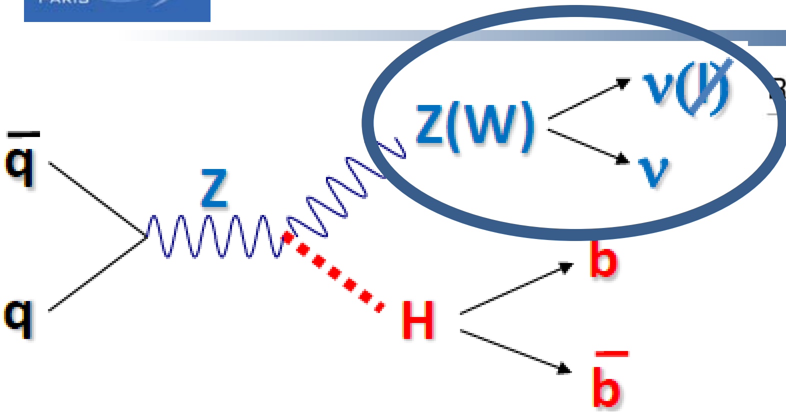


Z→νν reconstruction

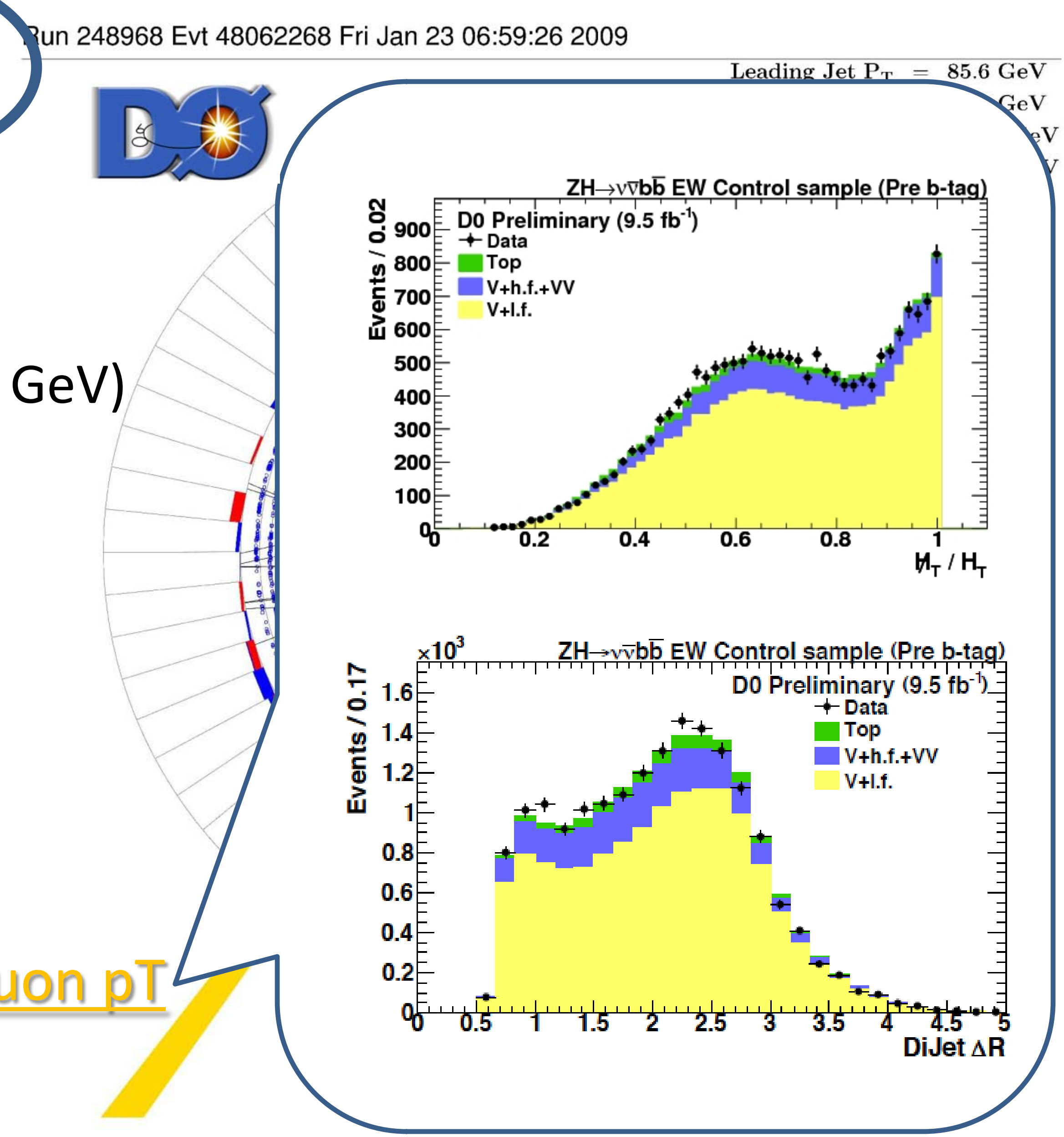


- Jets + large MET (>40 GeV)

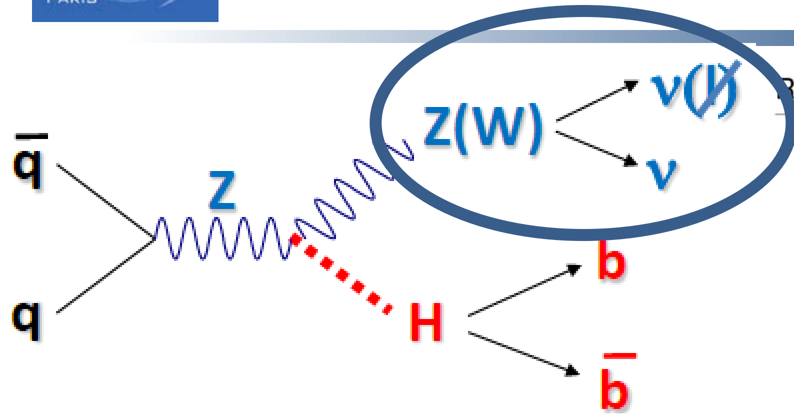
  Expect high multi-jet Background

  - **Signal sample**
  - **Control sample**
    - **→Multi-Jet**
    - **→Electro-weak**

  W→μν, subtract muon pT



Z→νν reconstruction



- Jets + large MET (>40 GeV)

  Expect high multi-jet Background

  - **Signal sample**
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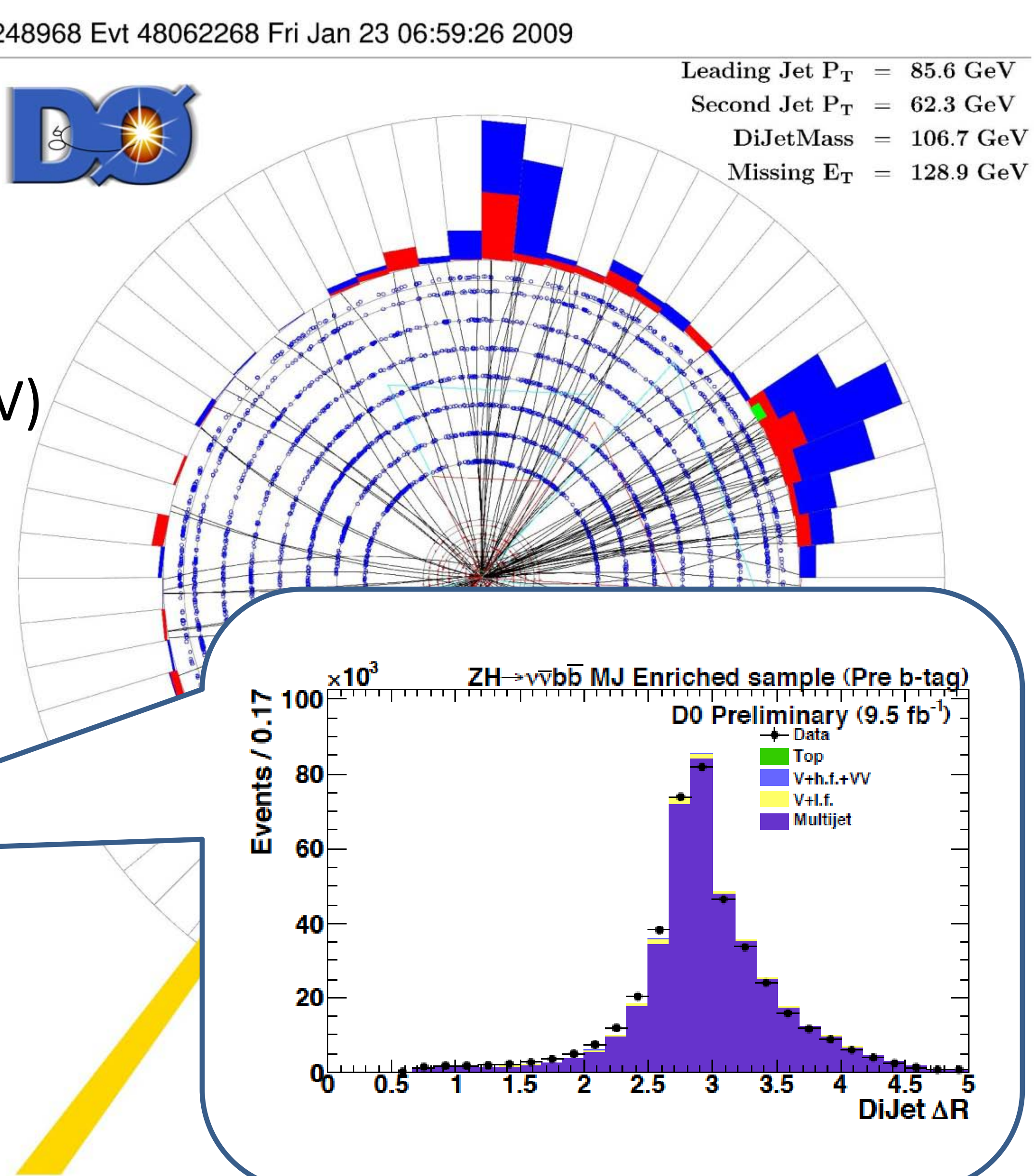
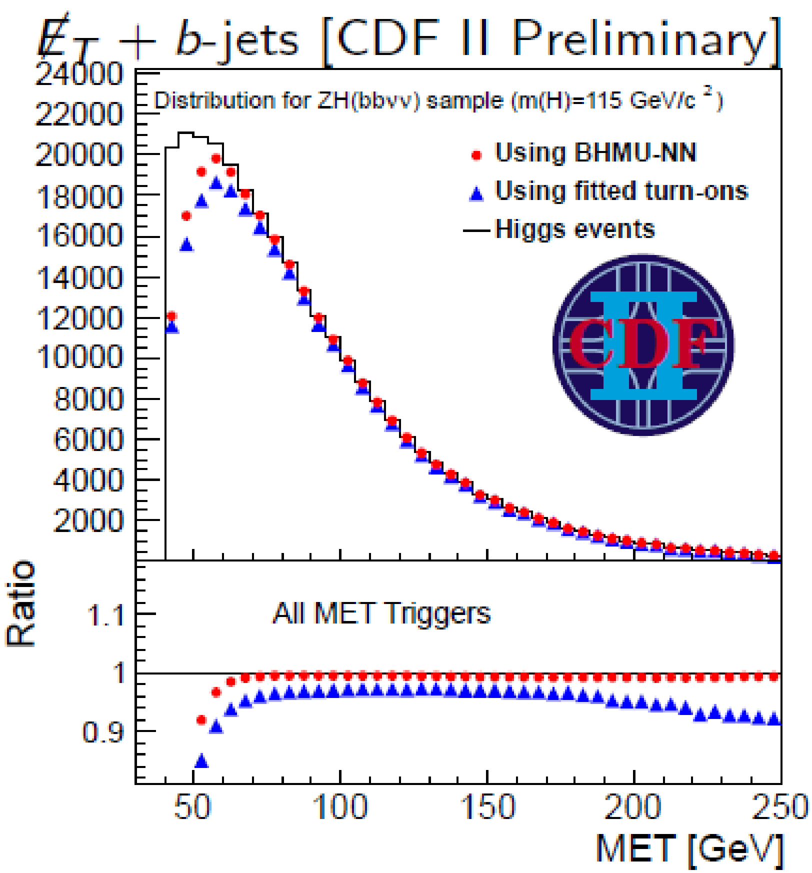
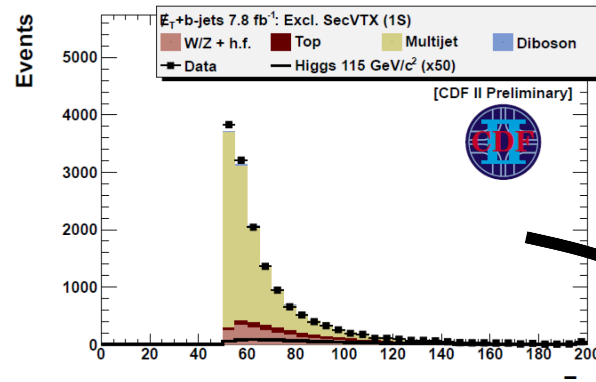
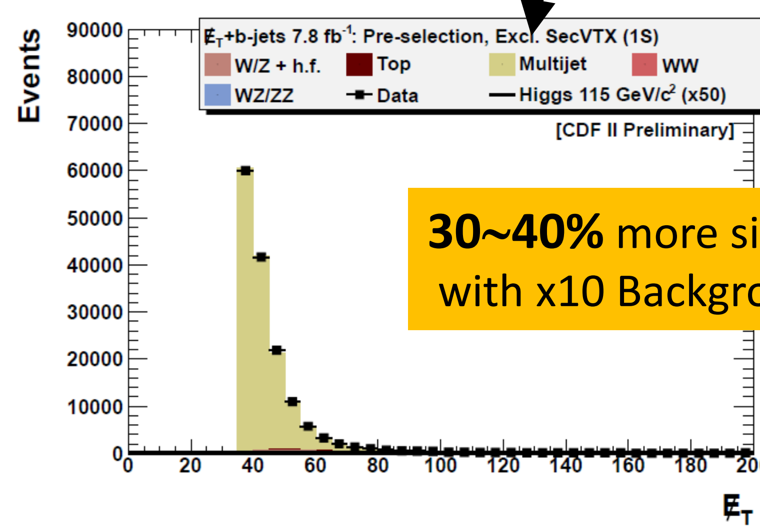


Improvement on vvb$\bar{b}$

- Additional trigger by L2 update
- Understanding of the upgraded MET trigger
  - NN function is used to parameterize complex trigger turn on.







MET selection

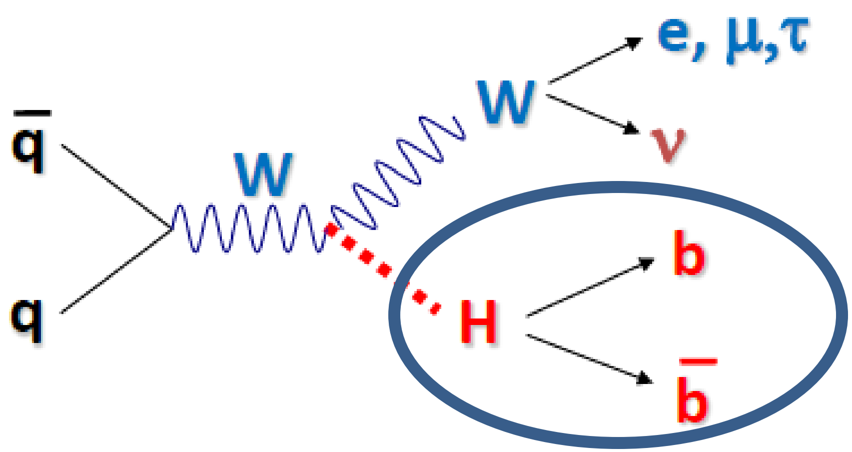
From **45** GeV

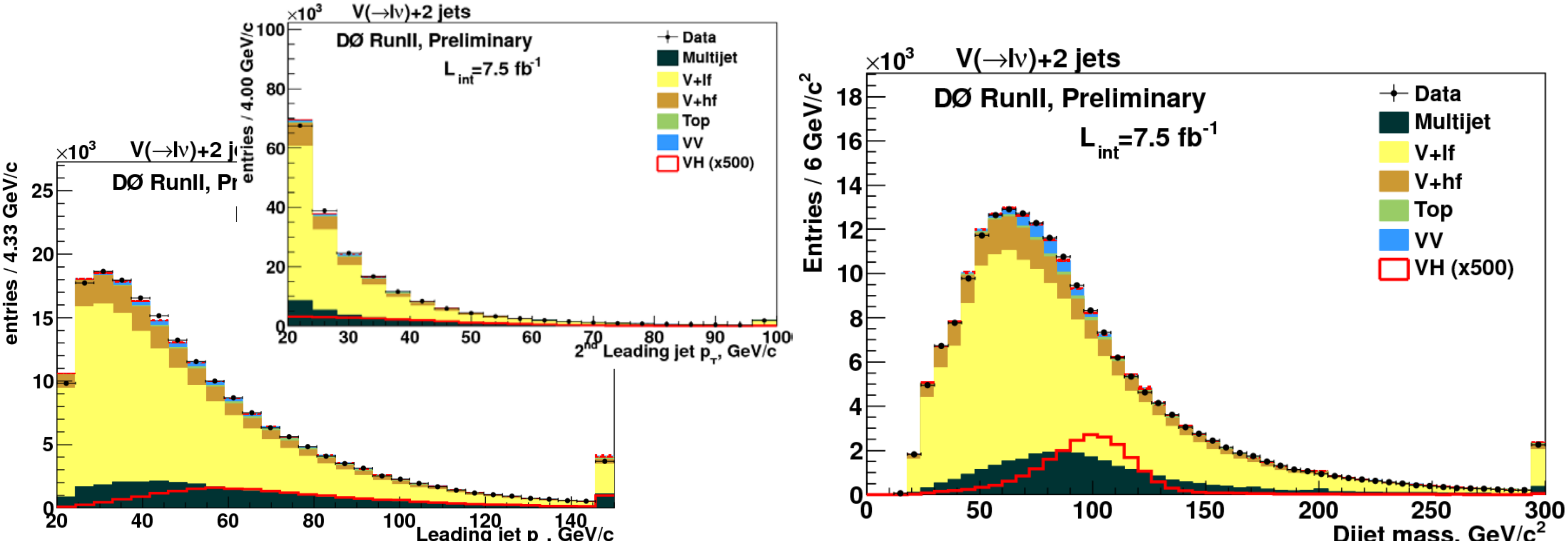
to **30** GeV

30~40% more signal with x10 Background

Applying MVA for reject QCD, obtained **2.5** better S/sqrt(B) in tagged sample

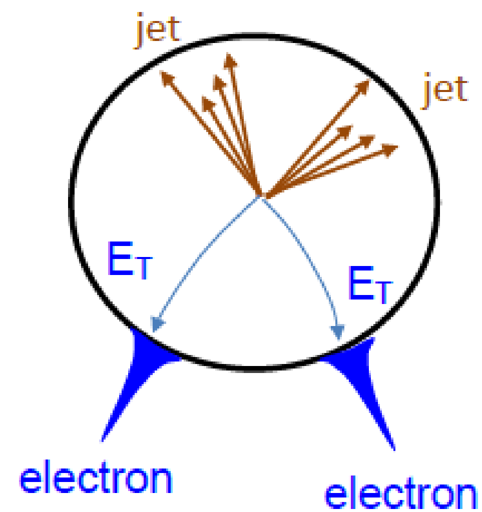
Higgs Candidates

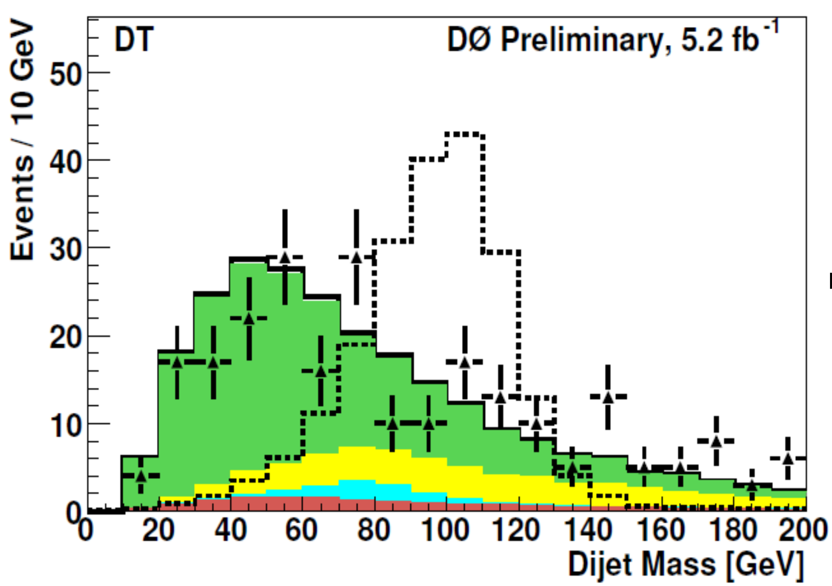


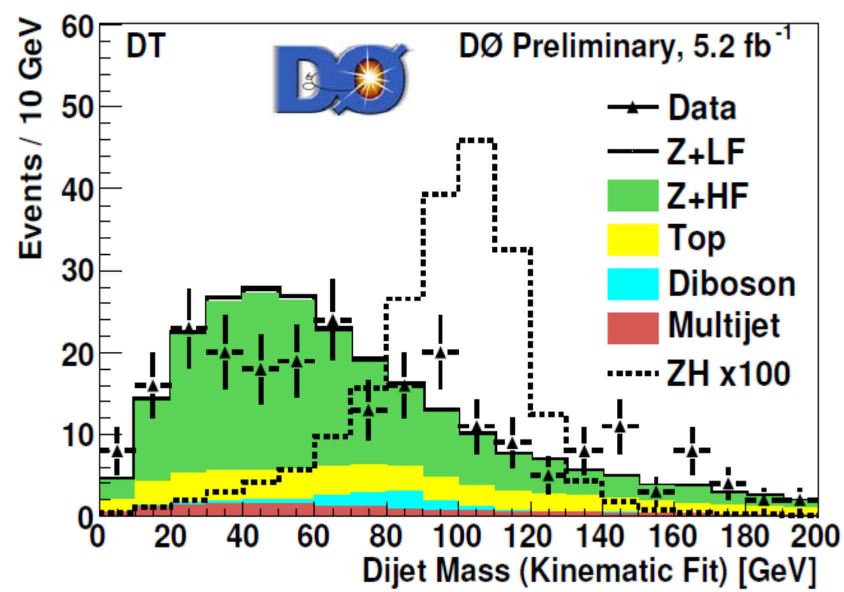


Dijet system in ZH→llbb

- ZH→llbb
  - No real missing ET
  - Use full kinematics information
    - Dijet Mass can be constrained



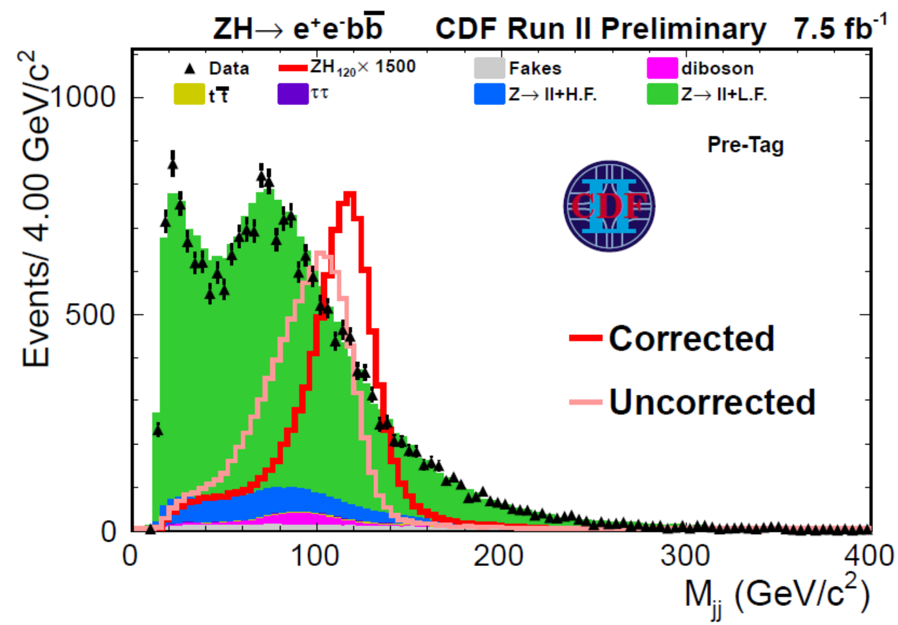




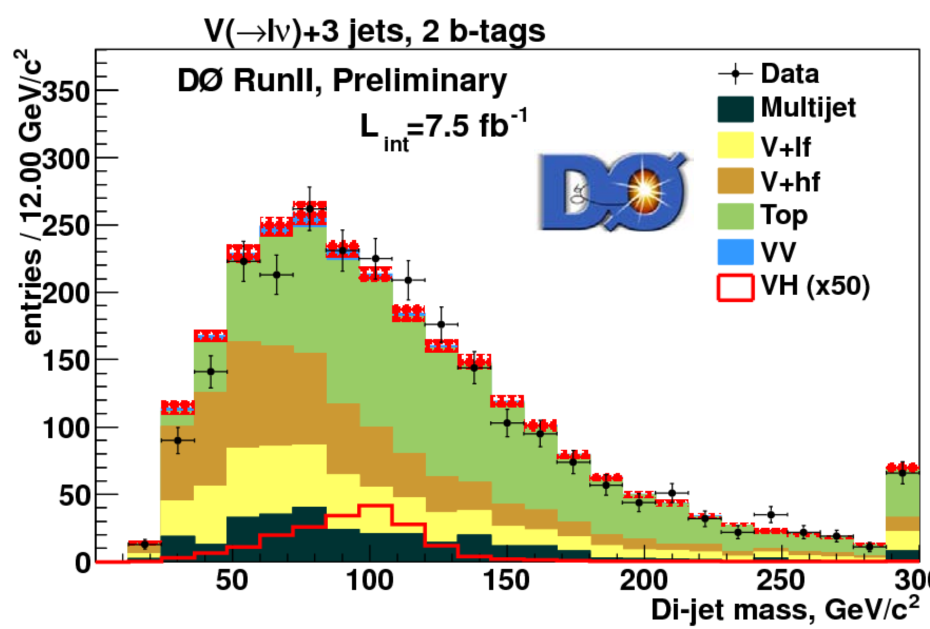
15 % improvement on Mass resolution

Dijet system

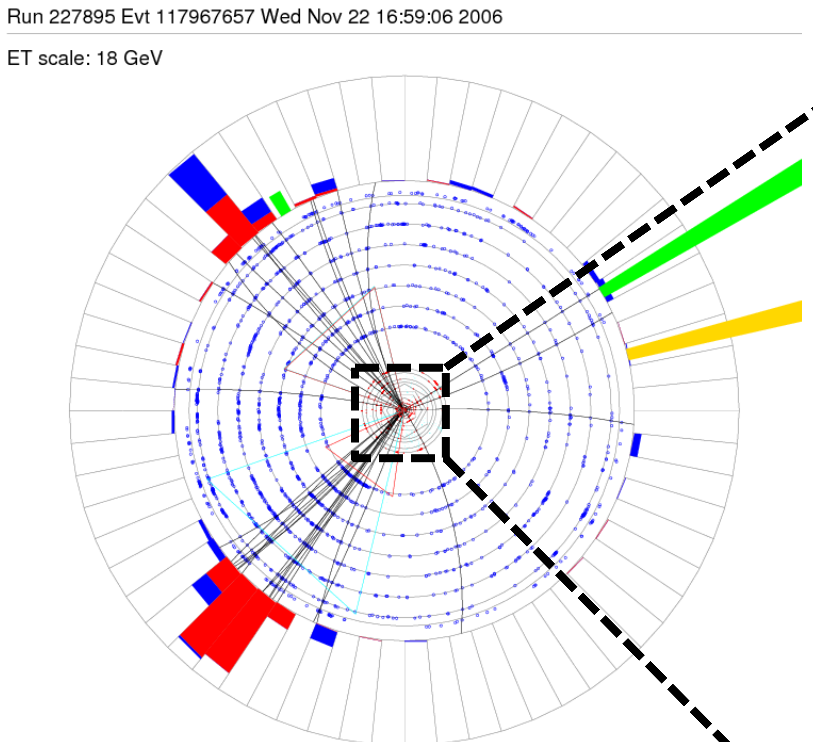
- In CDF llbb analysis, NN function is used to correct dijet system.
  ~ 15 % improvement is observed.

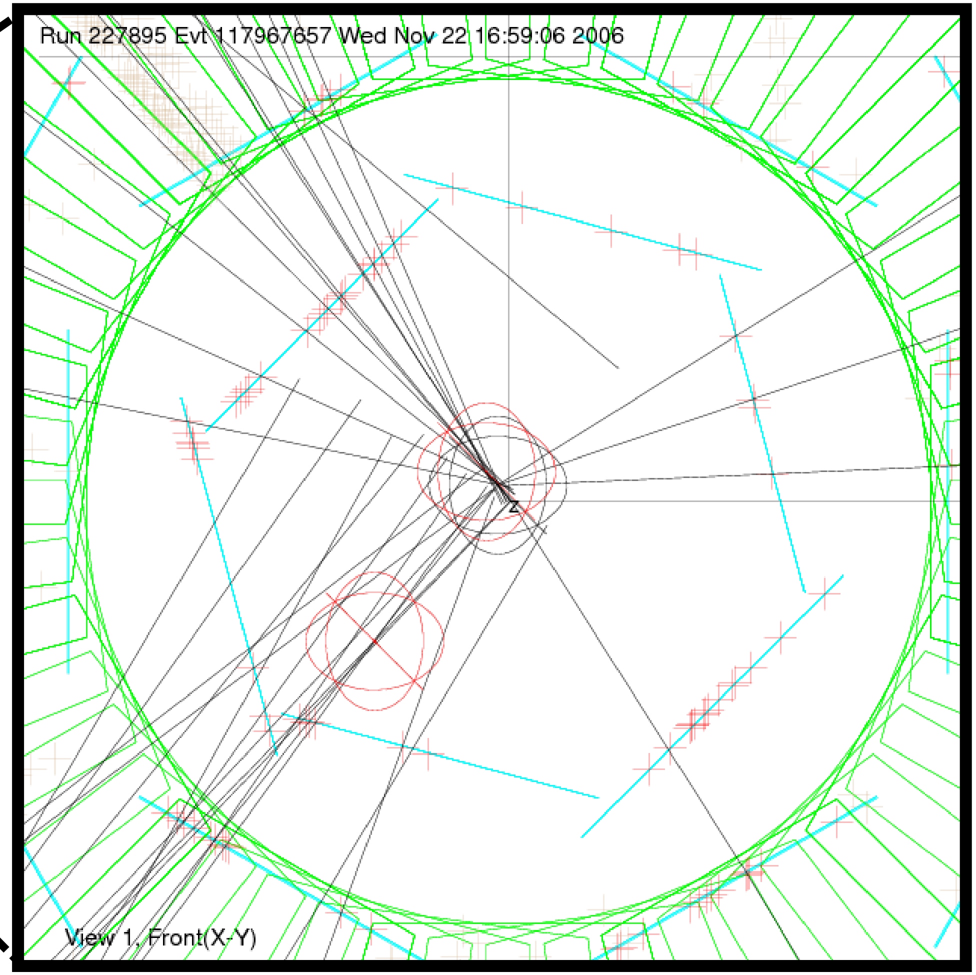


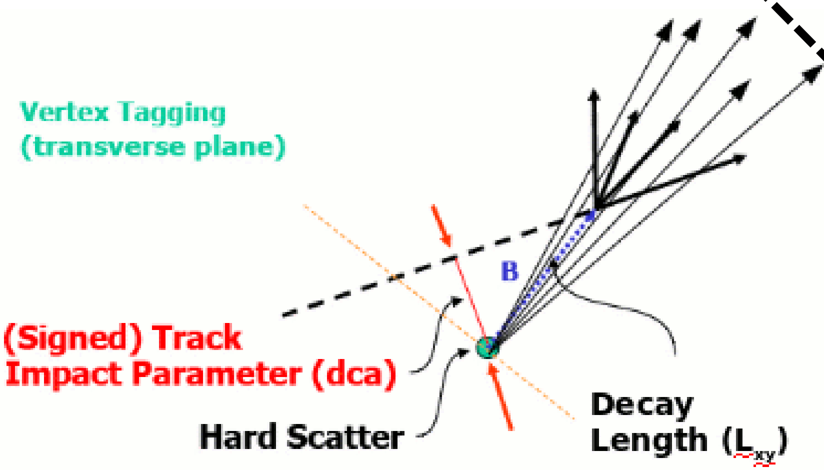
- How to choose 2jets from 3jets or more?
  - D0 lvbb
    instead of using two largest pT jets, use two most b-like jets from bID information.
    Also summing FSR jet.



b-Jet Identification



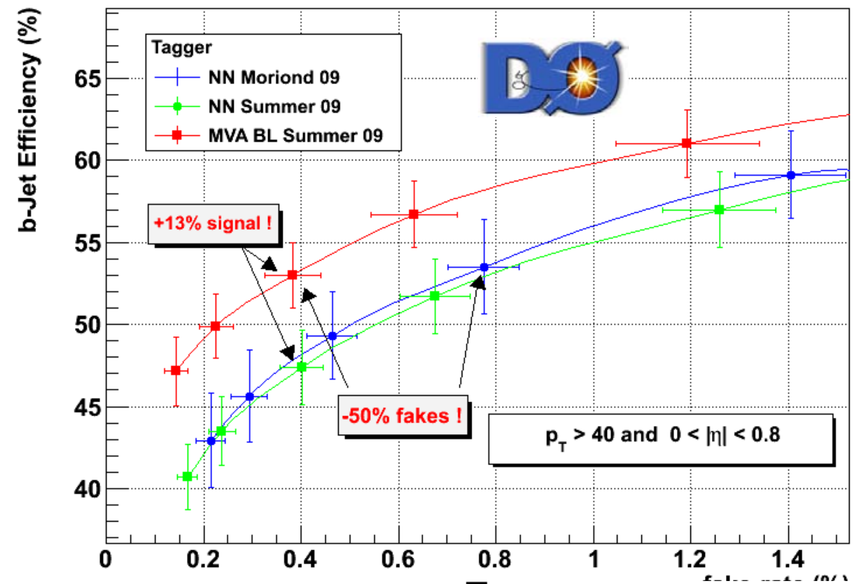


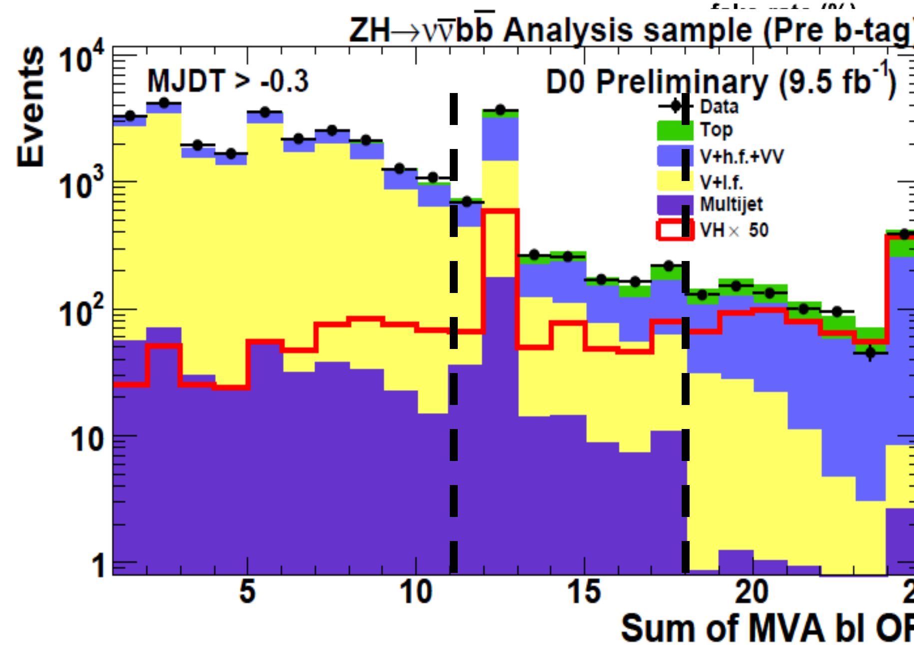


New feature on DØ b-tagging

- MVA tagger
  - Better performance
- Modeling
  - Update on TRF, Fake rate measurement
    - Systematic uncertainty reduced by 50% on fake rate.
- Usage
  - Application of TRF
  - Use all operating point.

  Use shape of bID MVA output in the final MVA





Define orthogonal sample

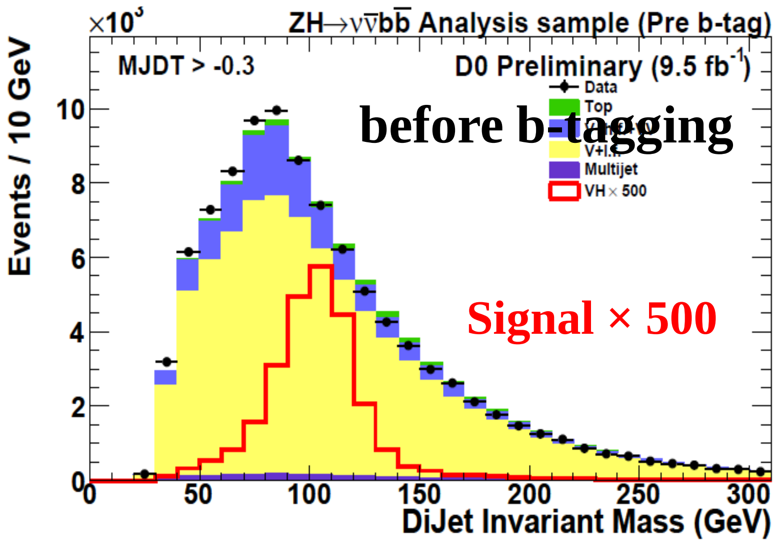
→ in order to maximise sensitivity

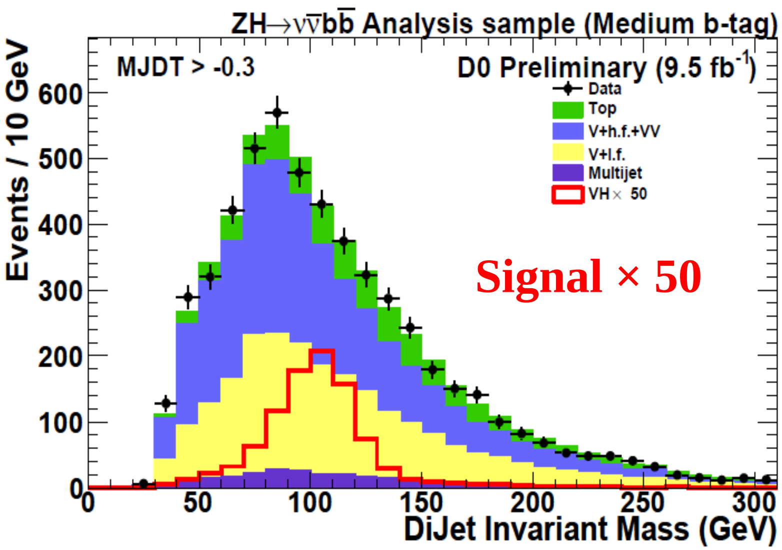
a) : MVA1 + MVA2 <= 18

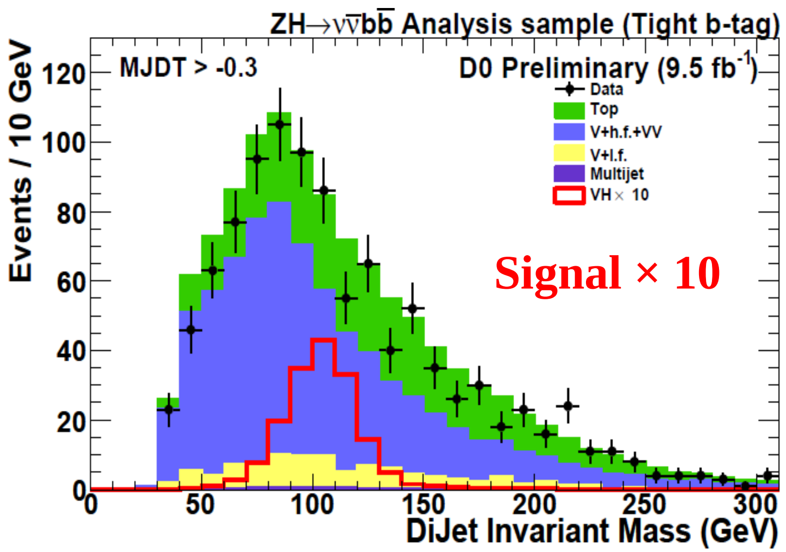
b) : 11 <= MVA1 + MVA2 < 18

c) : 0 <MVA1 + MVA2 < 11

Dijet mass after b-tagging







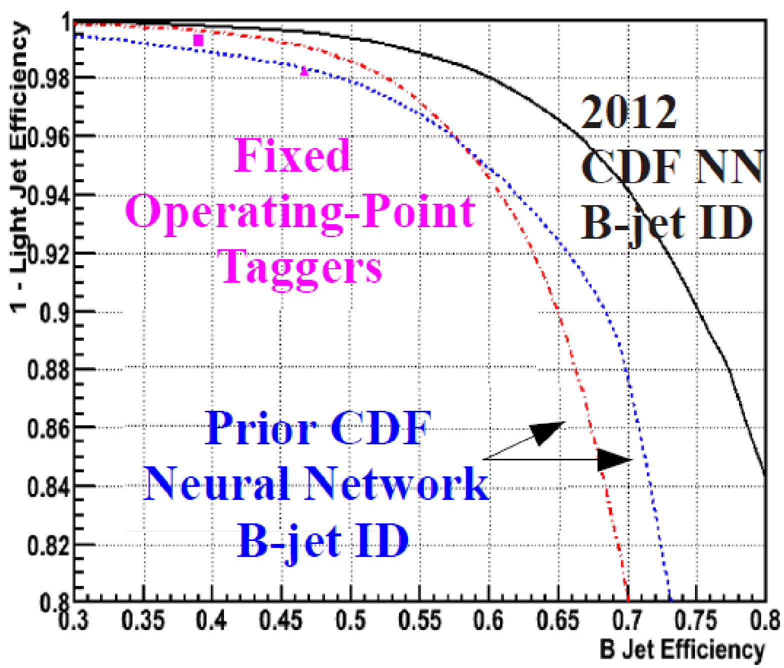
B-tagging update from CDF

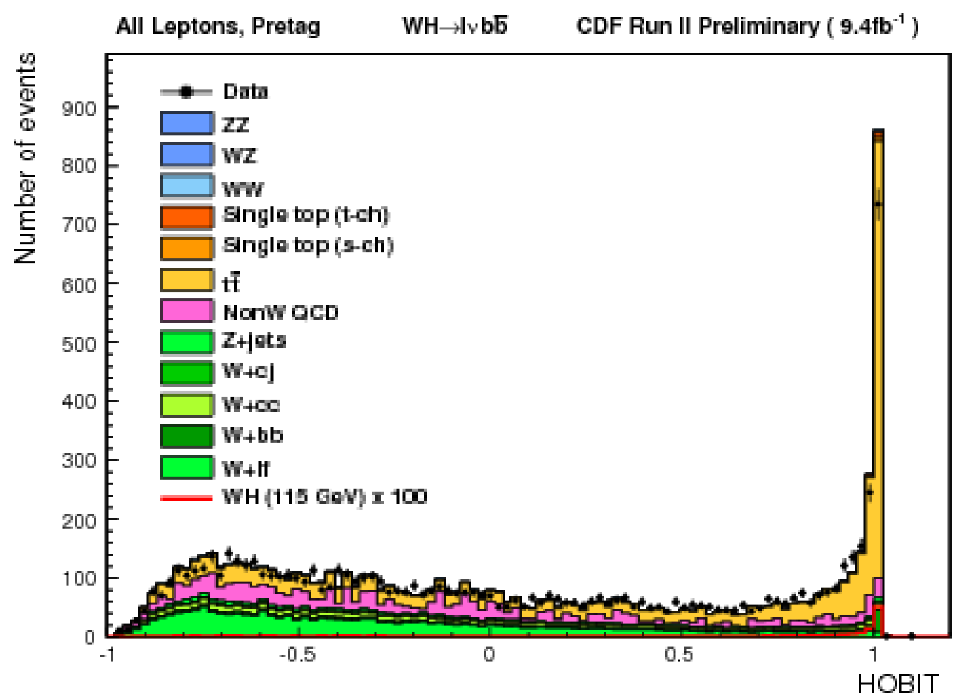
- CDF succeed to improve b-tagging performance by Multivariate technique
  - Uses most sensitive variables from previous tagger
  - Uses muon from semileptonic b-decay, jet mass, SV mass
  - Can tag jets with only one charged track

  Efficiency for Tight: 38.6 % → 53.5% @ Fake rate of 1.4%

  Efficiency for Loose: 47.1 % → 59.3% @ Fake rate of 2.8%

  → 11% gain in S/√B translates in total (lvbb)

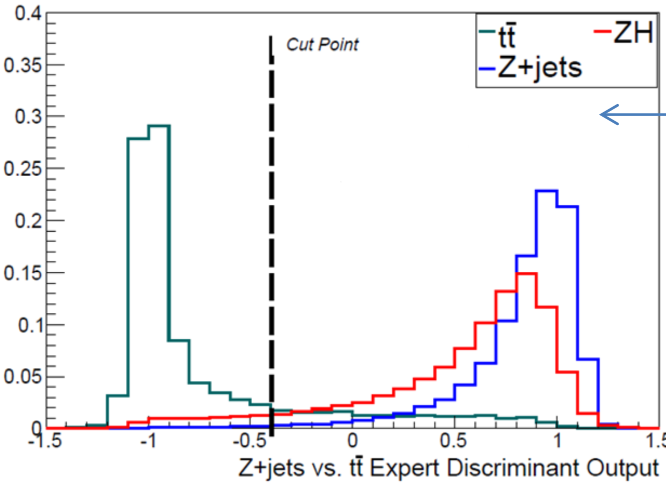


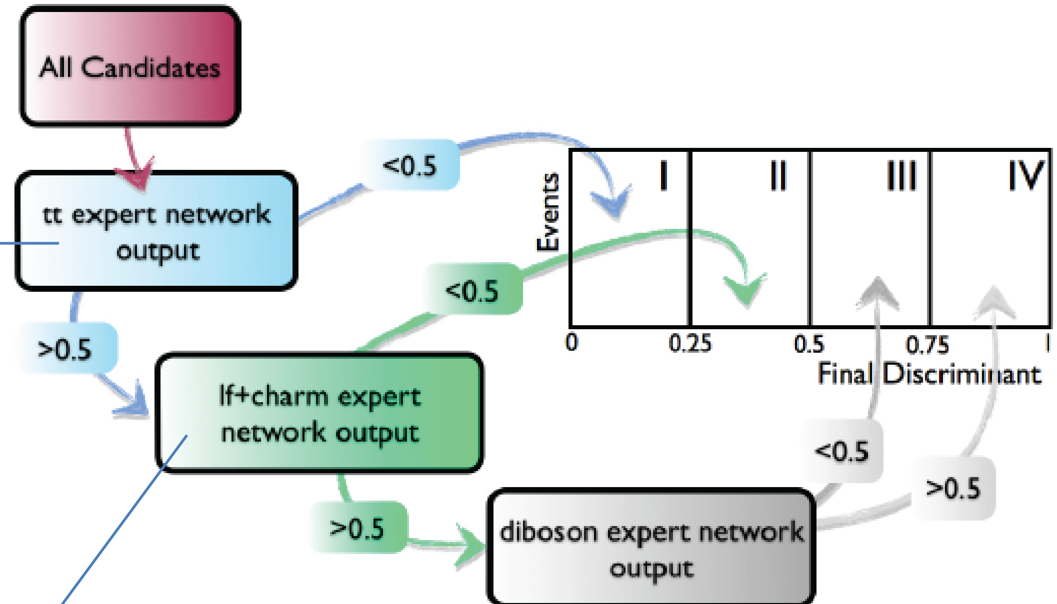


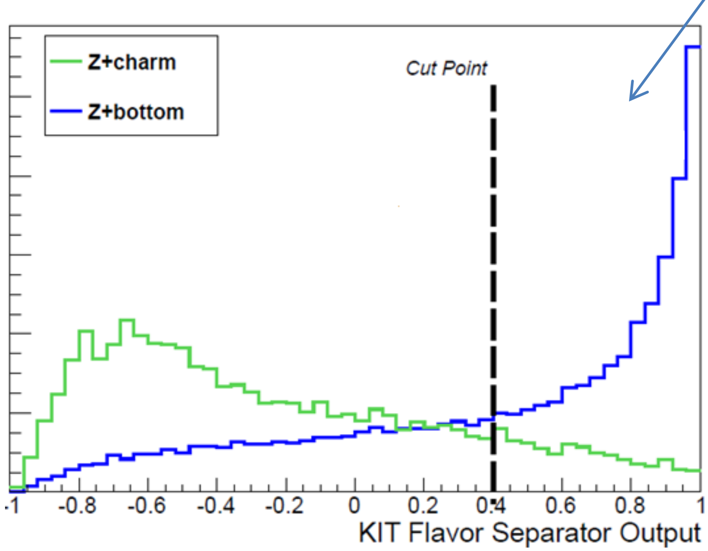
An example of MVA optimization

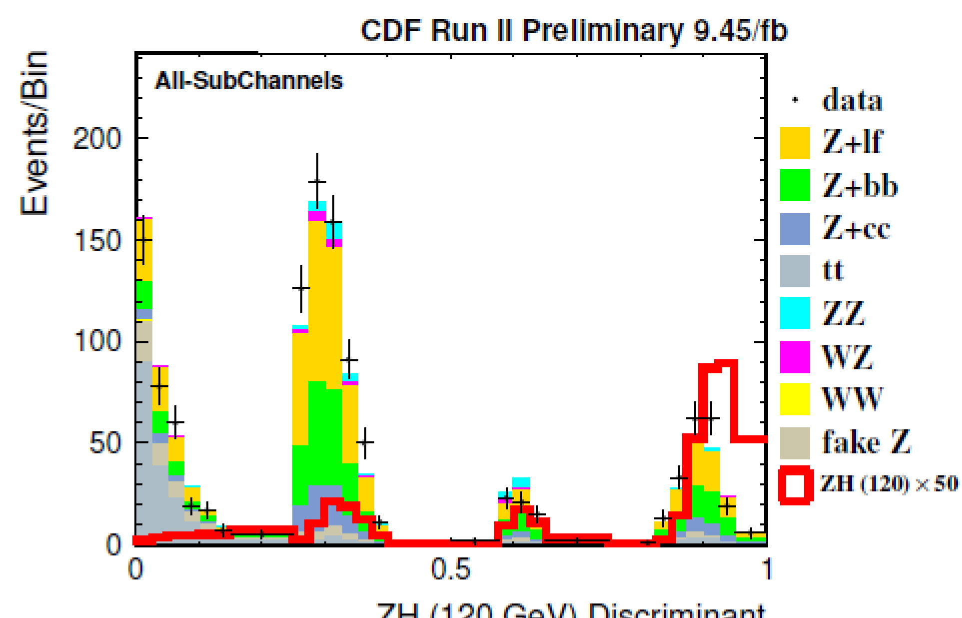
- CDF llbb

1. ttbar vs ZH









Systematic Uncertainty

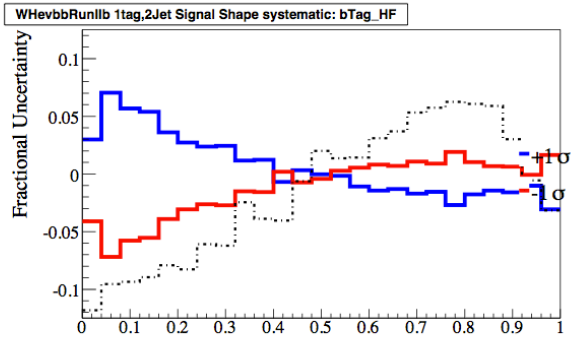
- In case of WH→lvbb (%)

Source	W→eν	W→μν
Luminosity	6.1	6.1
BG X section	6-20	6-20
Lepton ID/Trigger	2-3	3-5
Jet ID	1-2	1-2
Jet Energy Scale	2-5	2-5
b-Jet ID	9-11	9-11
Multi-Jet BG	1.0	1.0
PDF, MC Model	2-3	2-3

Flat Systematics

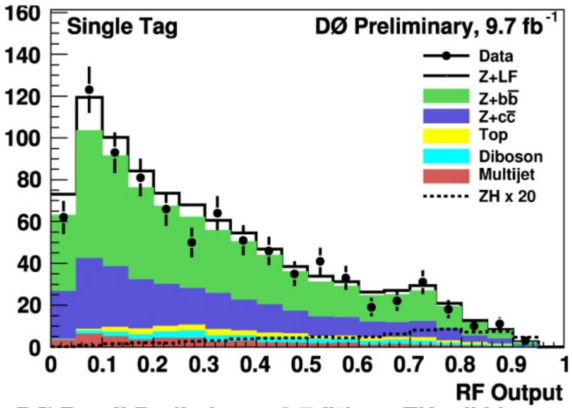
W+hf: 20%
Diboson : 6%
ttbar : 10%
Single top: 12%

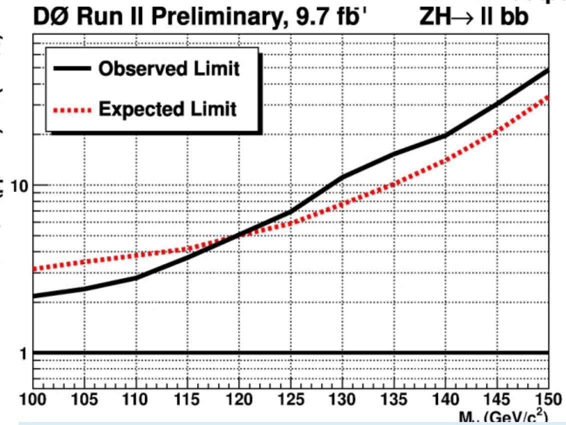
Shape Systematics



Results from DØ

ZH→llbb̄ $\int Ldt$=9.7 fb^{-1}



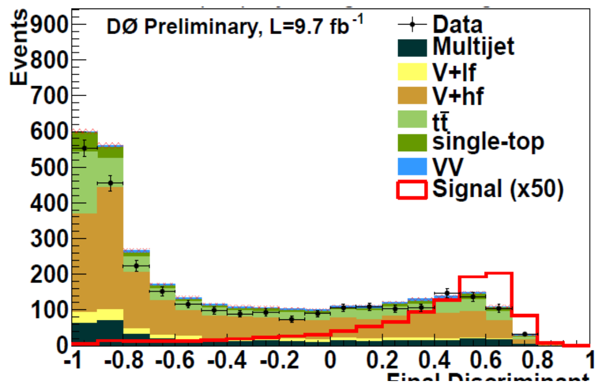


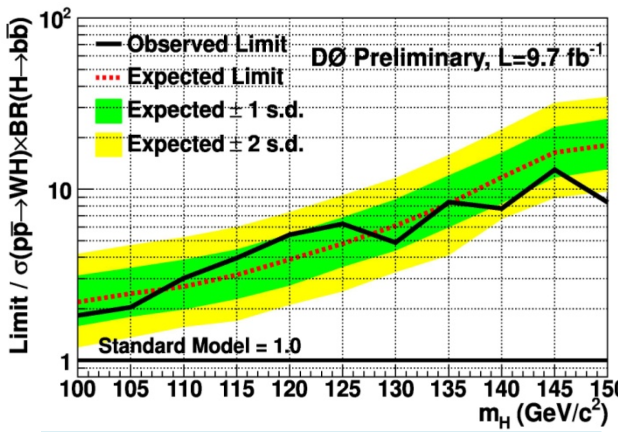
95% CL Exp (obs) Limit

4.2 (3.7) x SM

@ MH=115 GeV

WH→lνbb̄ $\int Ldt$=9.7 fb^{-1}



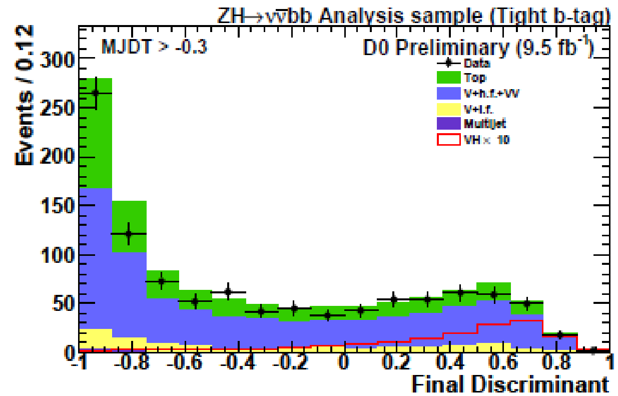


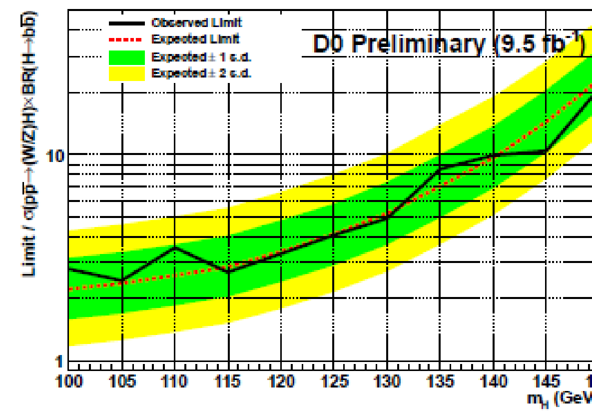
95% CL Exp (obs) Limit

3.2 (4.0) x SM

@ MH=115 GeV

VH→ννbb̄ $\int Ldt$=9.5 fb^{-1}





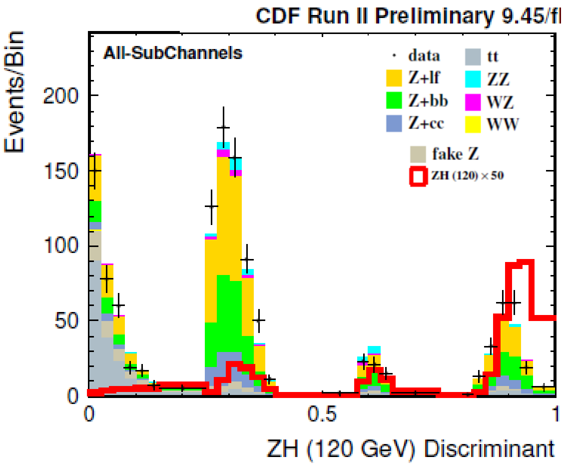
95% CL Exp (obs) Limit

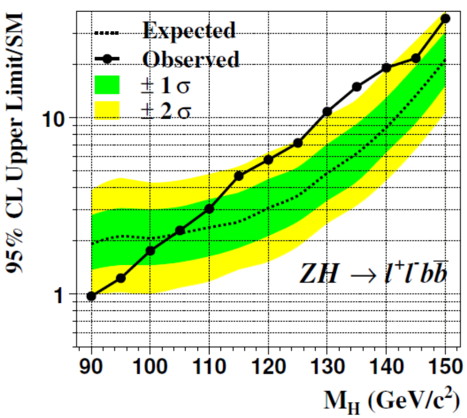
3.0 (2.5) x SM

@ MH=115 GeV

Results from CDF

ZH→llbb̄ $\int Ldt$=9.5 fb^{-1}



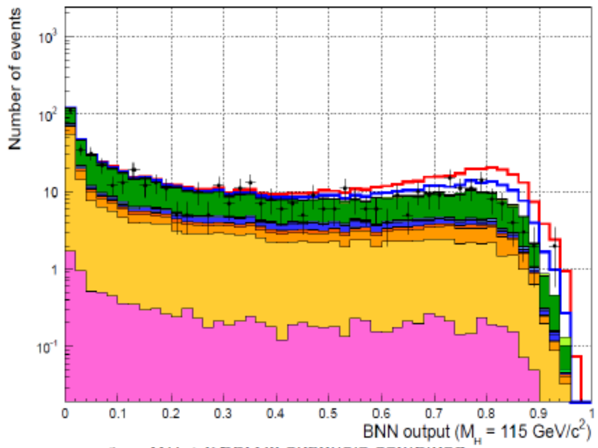


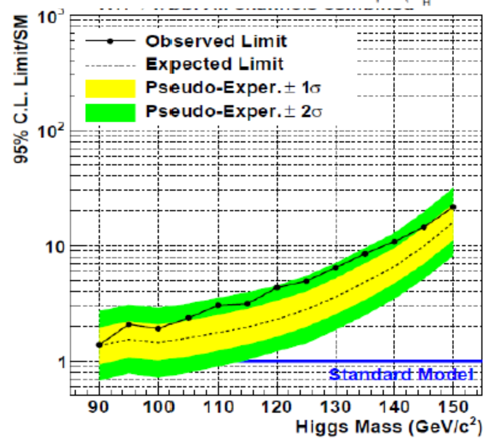
95% CL Exp (obs) Limit

2.6 (4.7) x SM

@ MH=115 GeV

WH→lνbb̄ $\int Ldt$=9.5 fb^{-1}



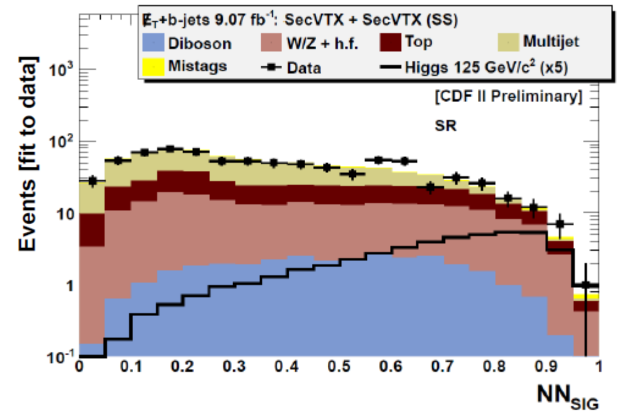


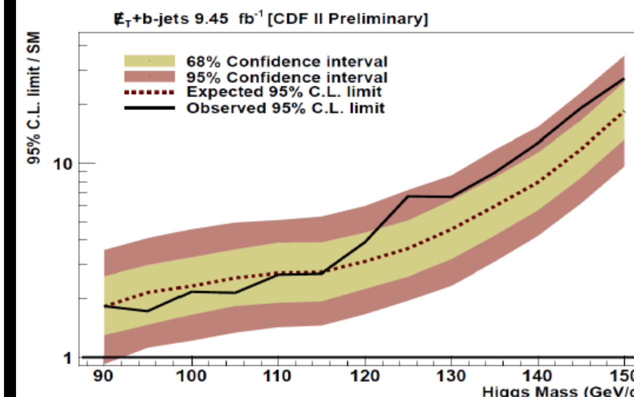
95% CL Exp (obs) Limit

2.0 (3.0) x SM

@ MH=115 GeV

VH→ννbb̄ $\int Ldt$=9.5 fb^{-1}





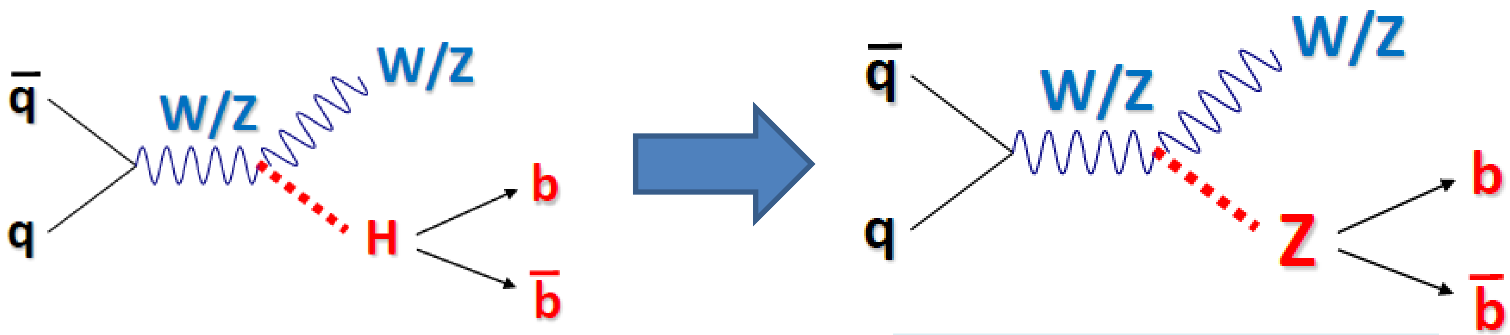
95% CL Exp (obs) Limit

2.7 (2.7) x SM

@ MH=115 GeV

What we want to confirm?

- Small signal yield in large background
  - Well tuned selection criteria and Trigger requirement
  - Advanced b-tagging tools
  - Advanced Multivariate Analysis
- Large systematic uncertainty
- Statistical analysis: Combination



<u>For m_H=115 GeV</u>
Total VH: σ = 46 fb

<u>Replace Z with H</u>
Total VZ: σ = 213 fb

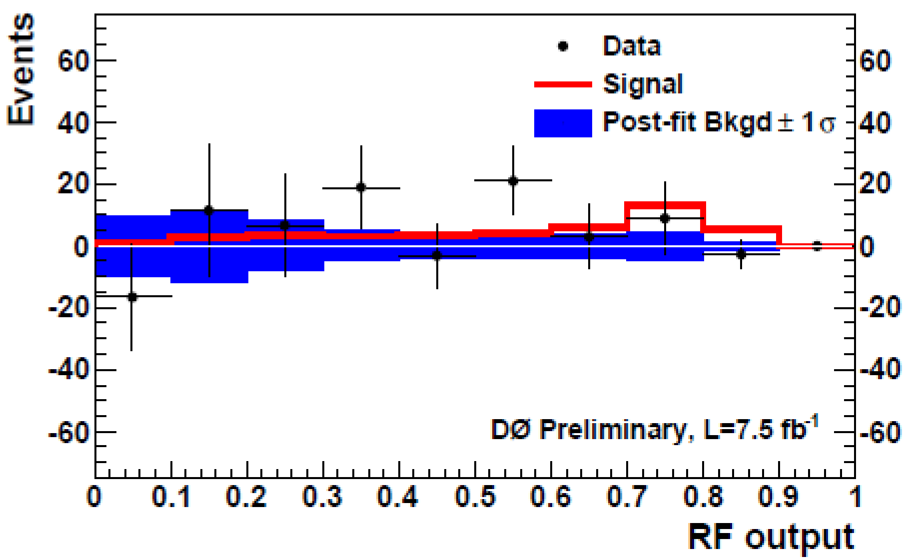
Z→bb yields is 5 times larger, but more W+jets, also there is **BG from WW**.

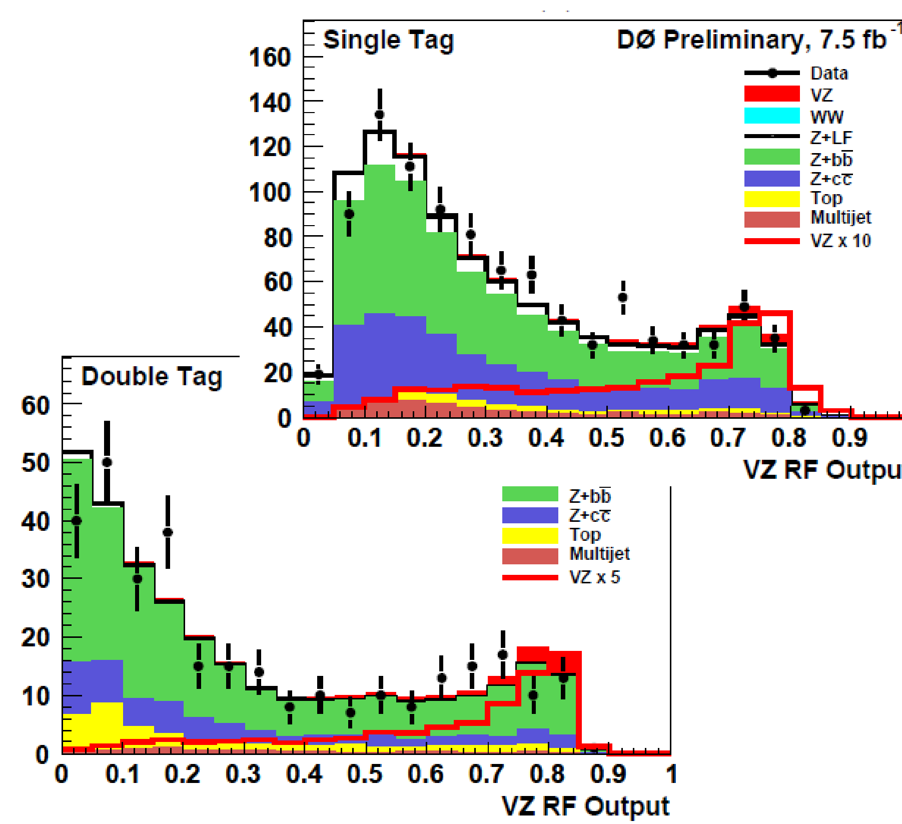
Measure diboson cross section with **exact same** analysis procedure.

VZ→llbb

- Result with 7.5 fb^{-1} of RunII data
- The same input variables as the ZH search (19 Variables)
- Measure $\sigma(VZ) = 0.4 \pm 2.8\ pb$

$\sigma(VZ)^{NLO}_{SM} = 4.42pb$

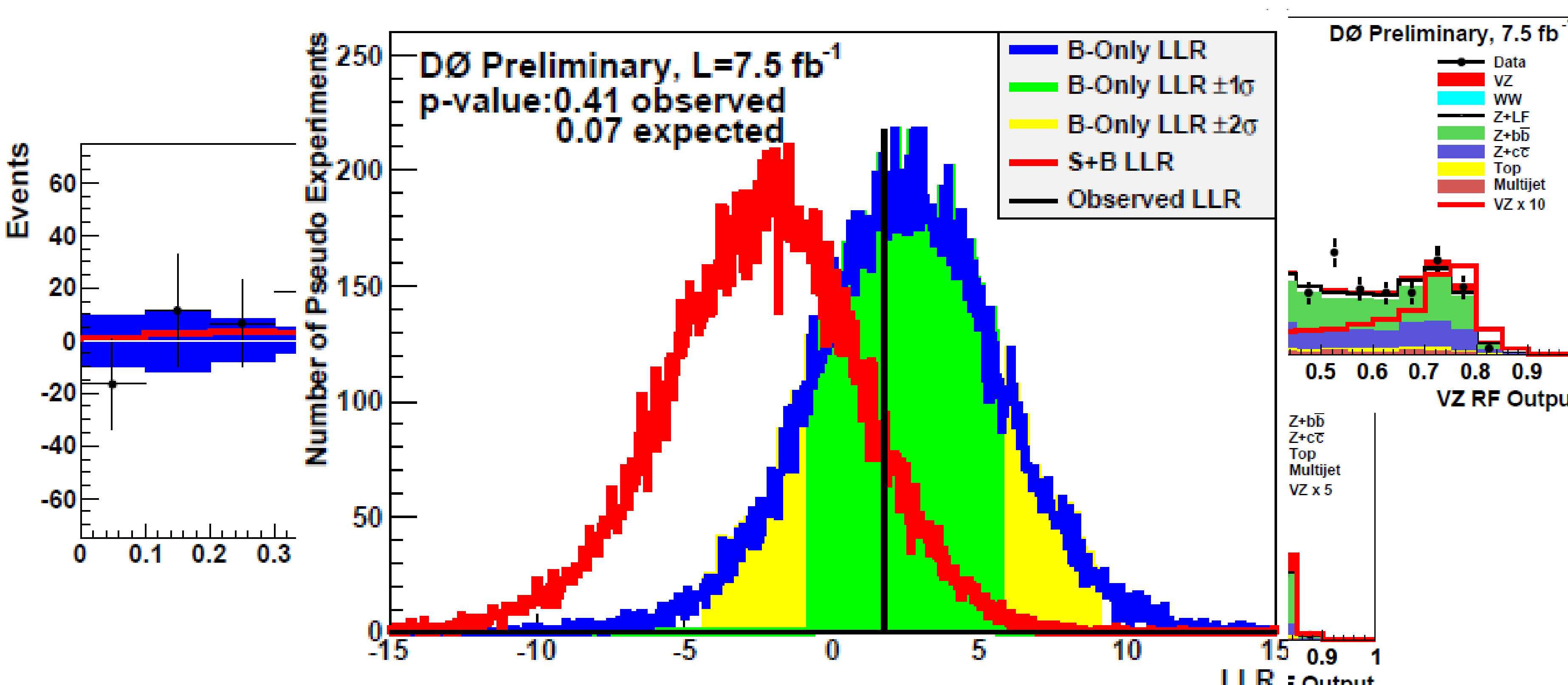




VZ→llbb

- Result with 7.5 fb^{-1} of RunII data
- The same input variables as the ZH search (19 Variables)
- Measure $\sigma(VZ) = 0.4 \pm 2.8\ pb$
- 1.5σ Expected, 0.08 σ observed significance

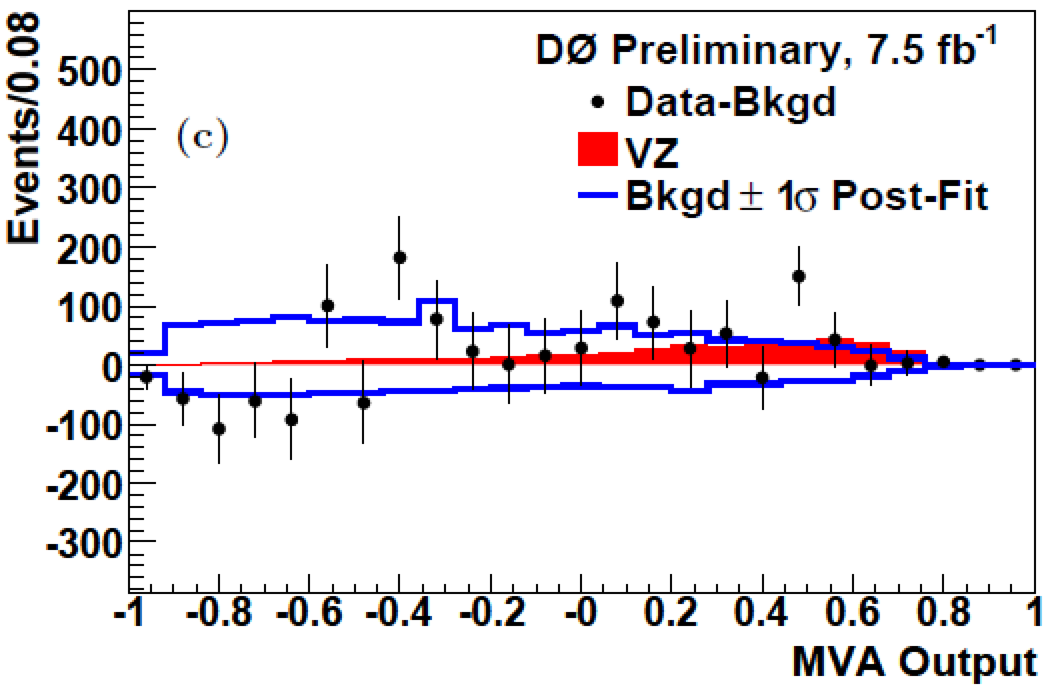
$\sigma(VZ)^{NLO}_{SM} = 4.42pb$

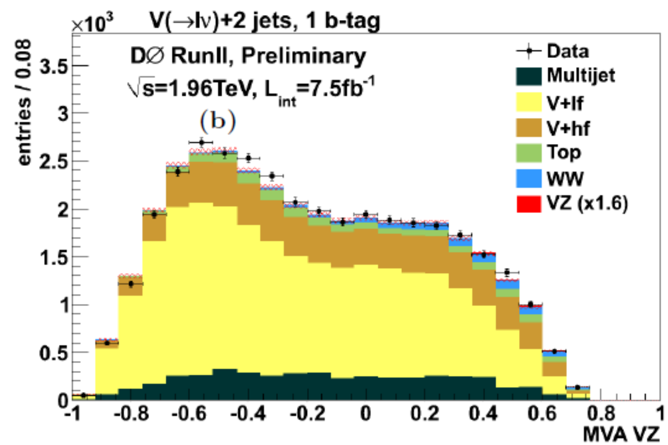


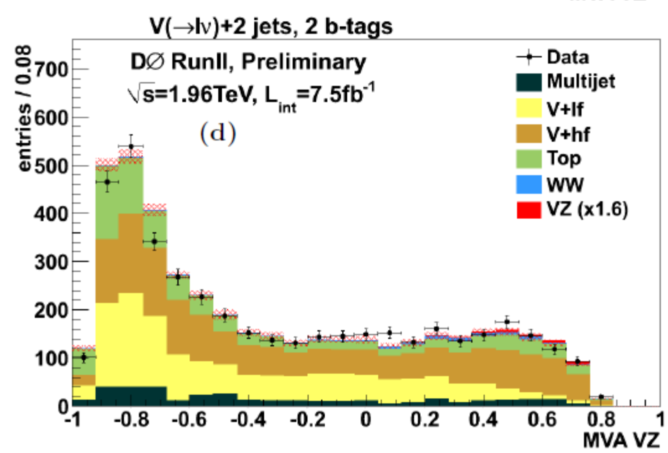
VZ→lvbb

- Result with 7.5 fb^{-1} of RunII data
- The same input variables as the WH search (14 variables)
- Measure $\sigma(VZ) = 7.2 \pm 2.03\ (stat.) \pm 2.74\ (syst.)\ pb$

$\sigma(VZ)^{NLO}_{SM} = 4.42pb$



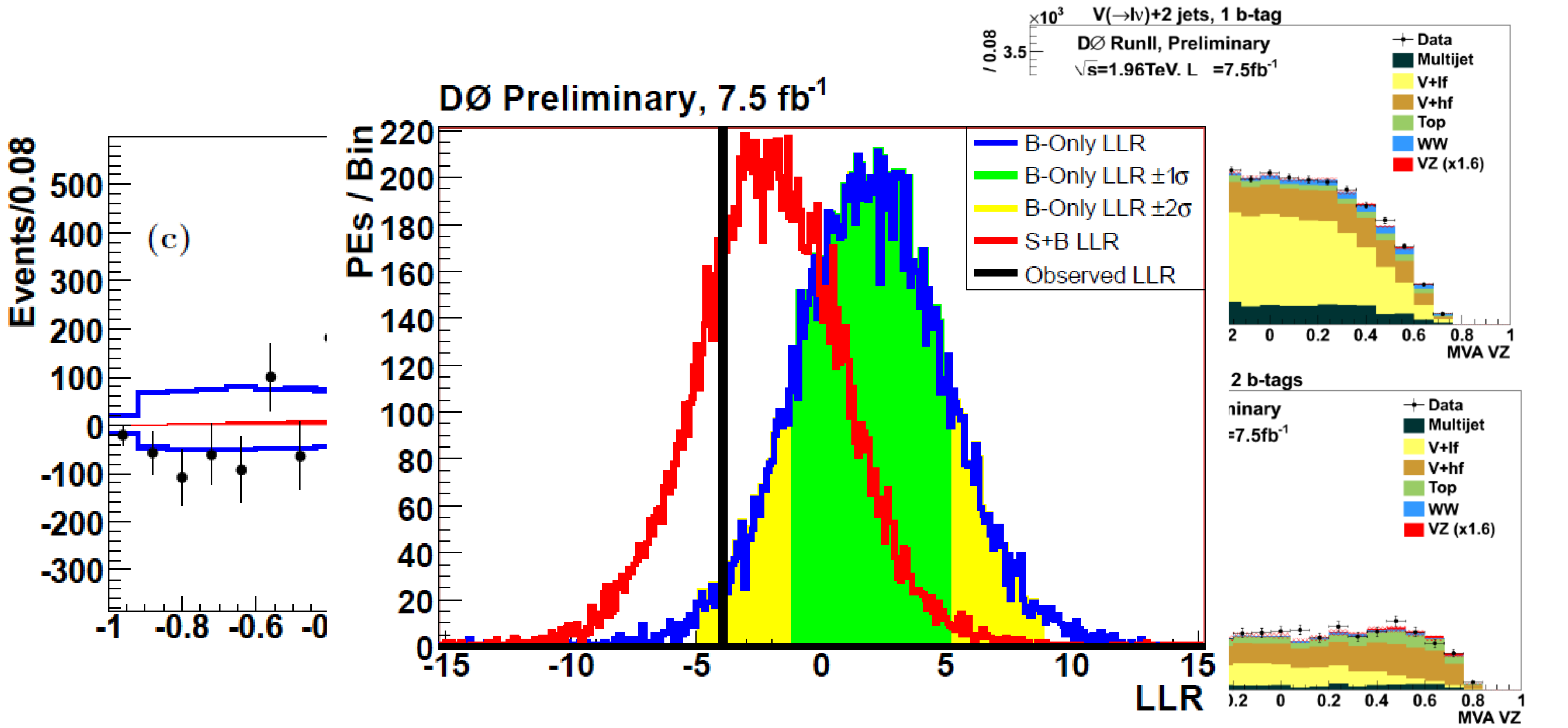




VZ→lvbb

- Result with 7.5 fb^{-1} of RunII data
- The same input variables as the WH search (14 variables)
- Measure $\sigma(VZ) = 7.2 \pm 2.03\ (stat.) \pm 2.74\ (syst.)\ pb$
- 1.4σ Expected, 2.2σ Observed significance

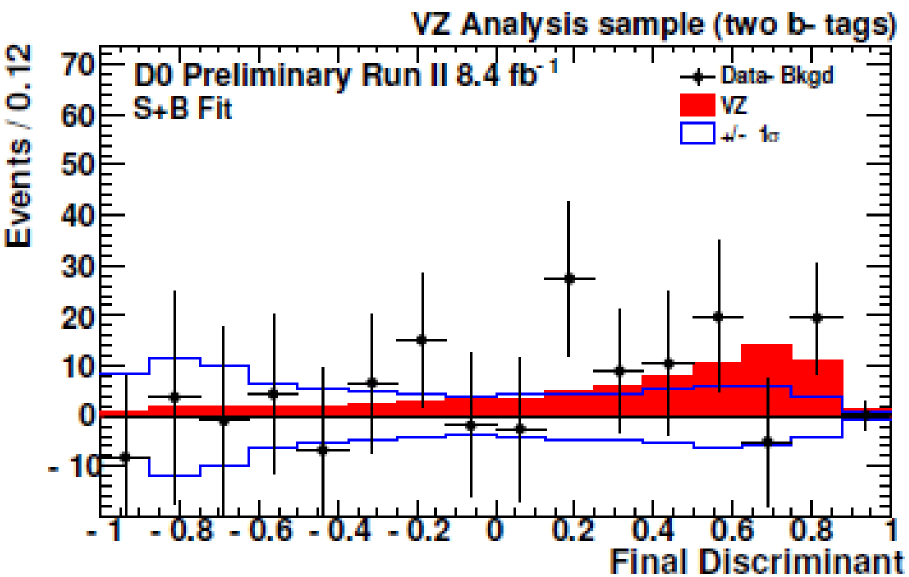
$\sigma(VZ)^{NLO}_{SM} = 4.42$pb

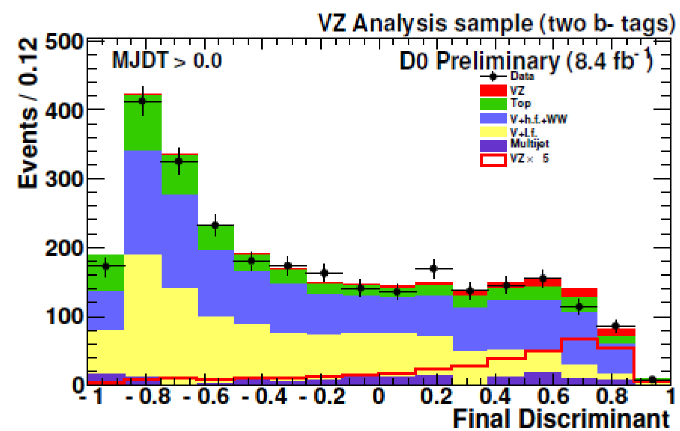


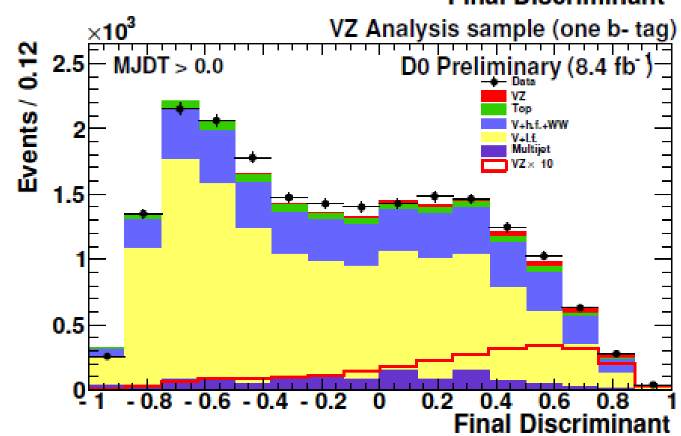
VZ→vvbb

- Result with 8.4 fb^{-1} of RunII data
- The same input variables as the ZH search (32 variables)
- Measure $\sigma(VZ) = 6.9 \pm 1.3(stat.) \pm 1.8(syst.)\ pb$

$\sigma(VZ)_{SM}^{NLO} = 4.42\text{pb}$



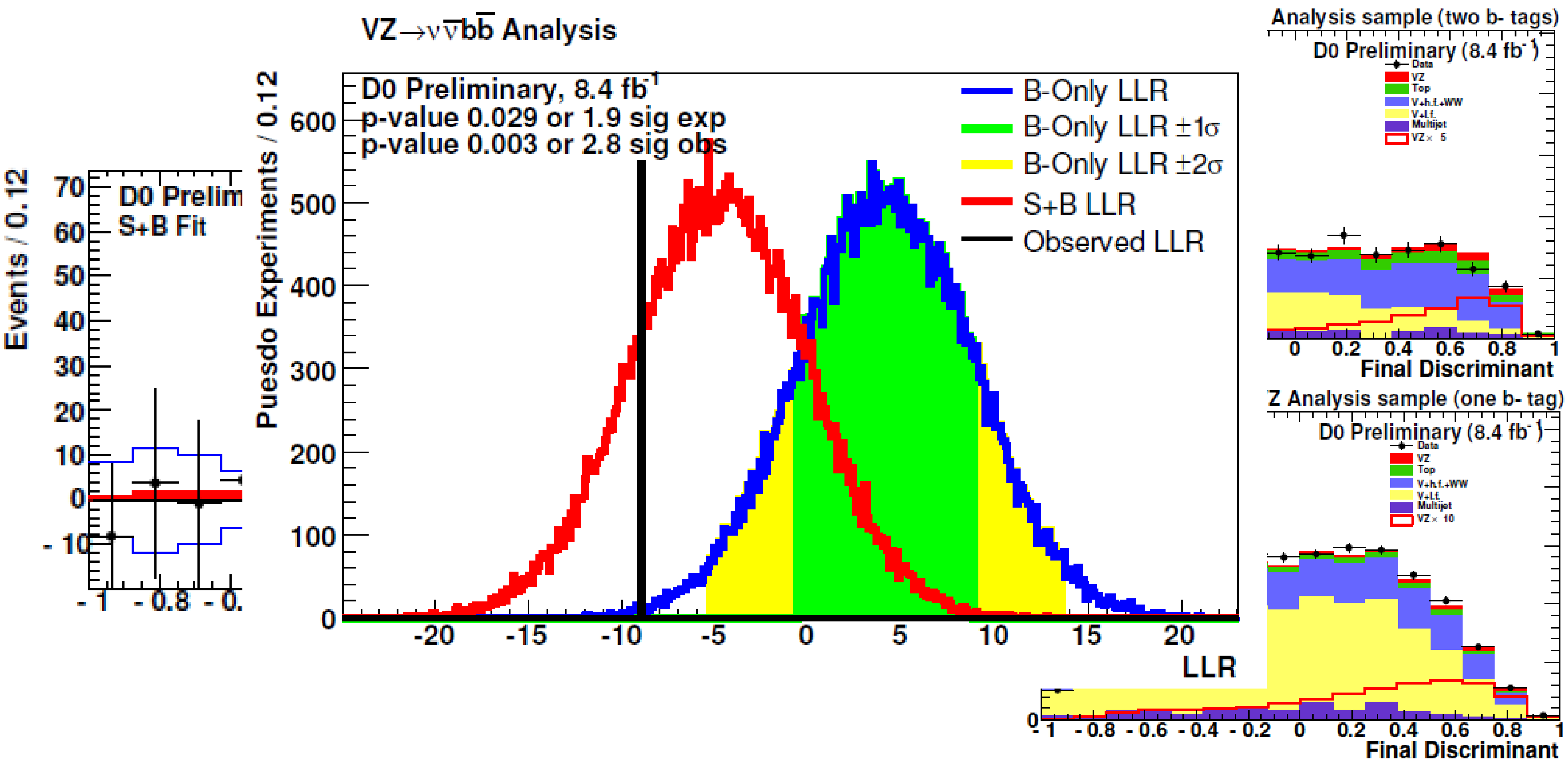




VZ→ννbb

- Result with 8.4 fb^{-1} of RunII data
- The same input variables as the ZH search (32 variables)
- Measure $\sigma(VZ) = 6.9 \pm 1.3(stat.) \pm 1.8(syst.)\ pb$
- 1.9σ Expected, 2.8σ Observed significance

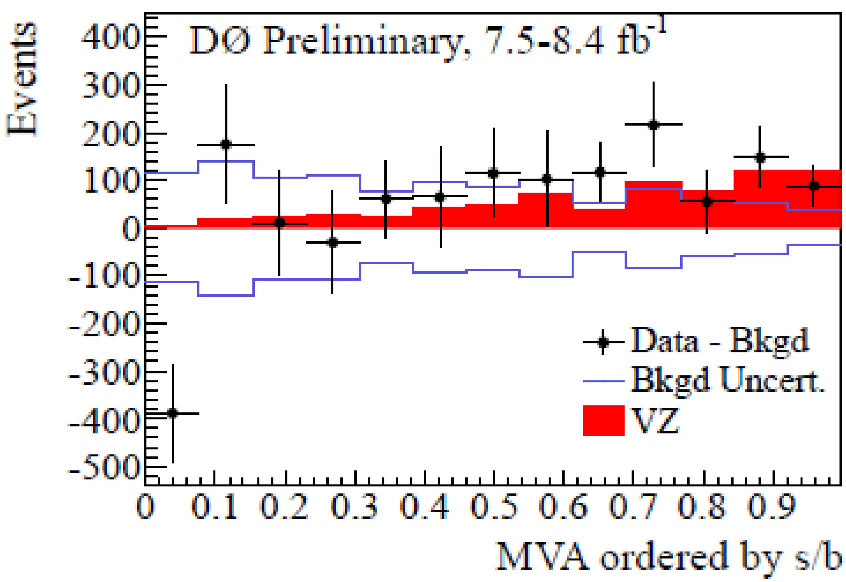
$\sigma(VZ)^{NLO}_{SM} = 4.42pb$

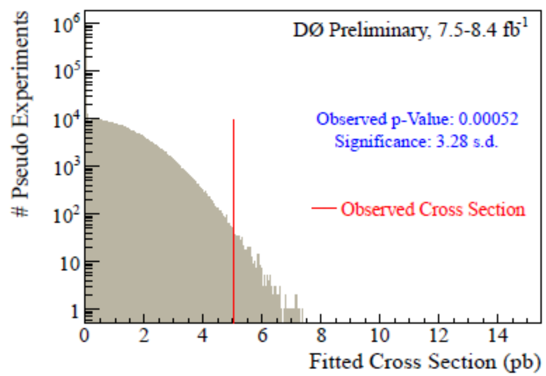


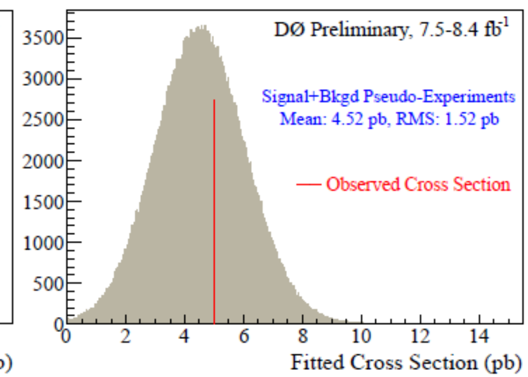
DZero Combination for VZ

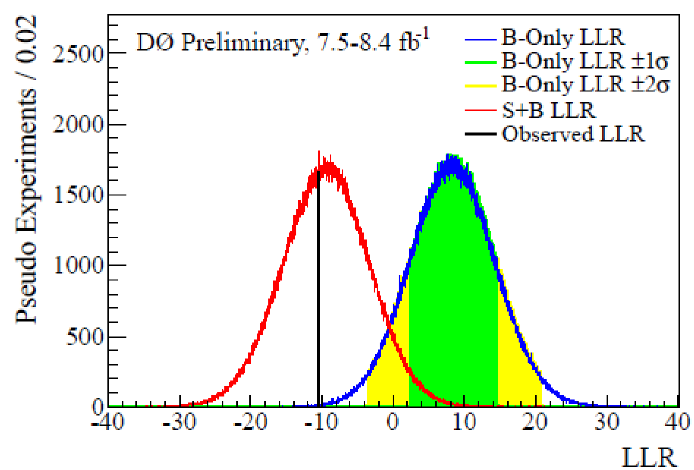
- Combine lvbb, llbb and vvbb
- Measure $\sigma(VZ) = 5.0 \pm 1.0\ (\text{stat.})\ ^{+1.3}_{-1.2}\ (\text{syst.})$ pb
- 3.3σ observed significance

$\sigma(VZ)^{NLO}_{SM} = 4.42$pb

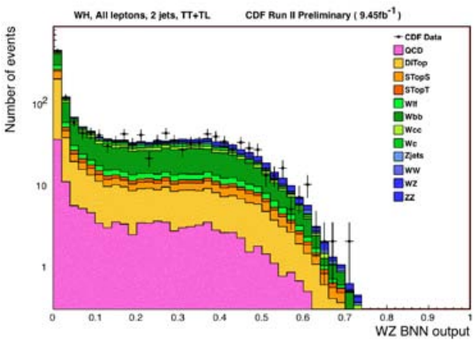


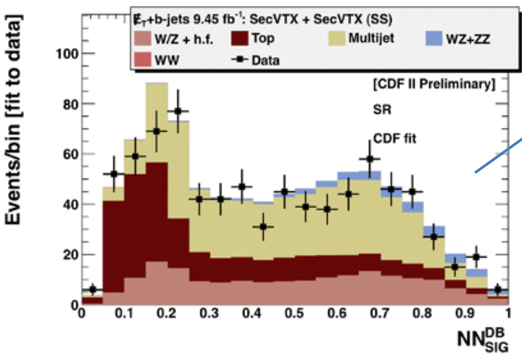


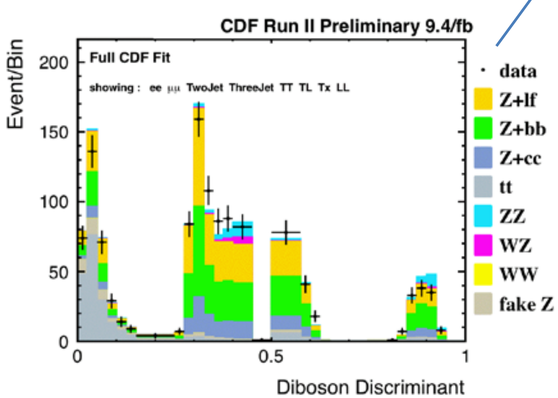


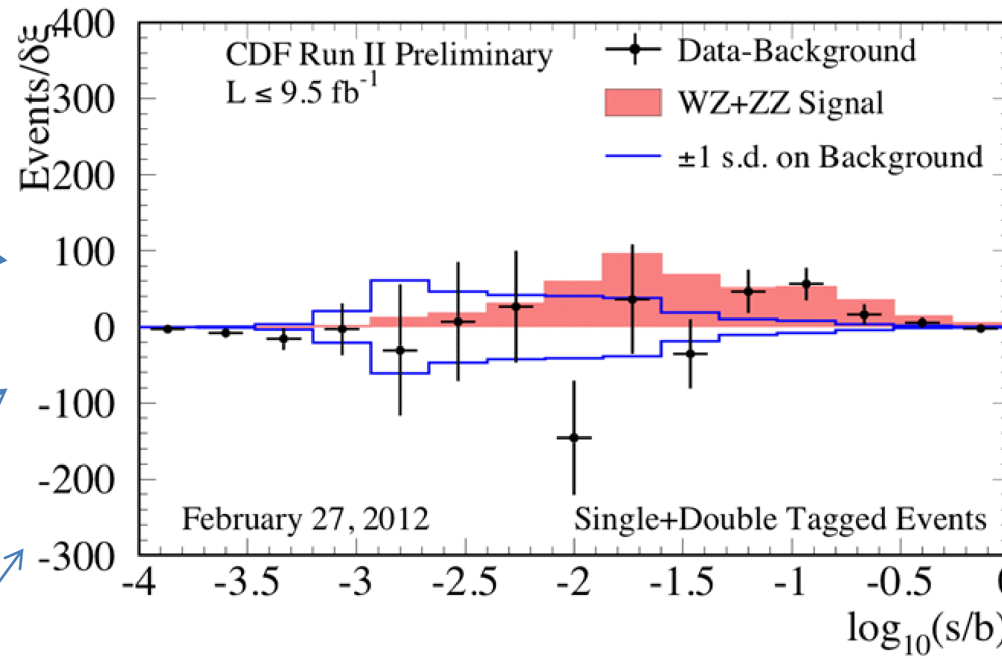


CDF Diboson VZ Result





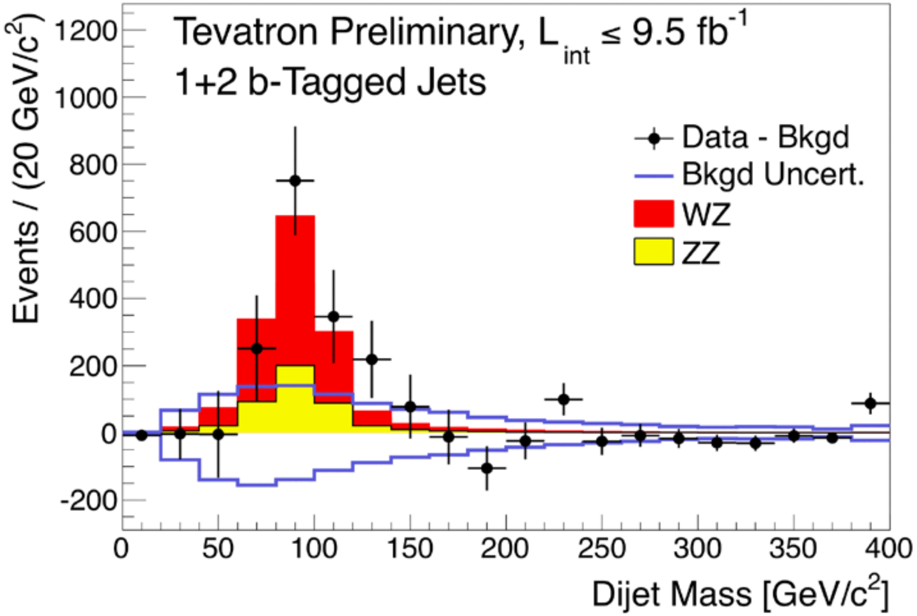


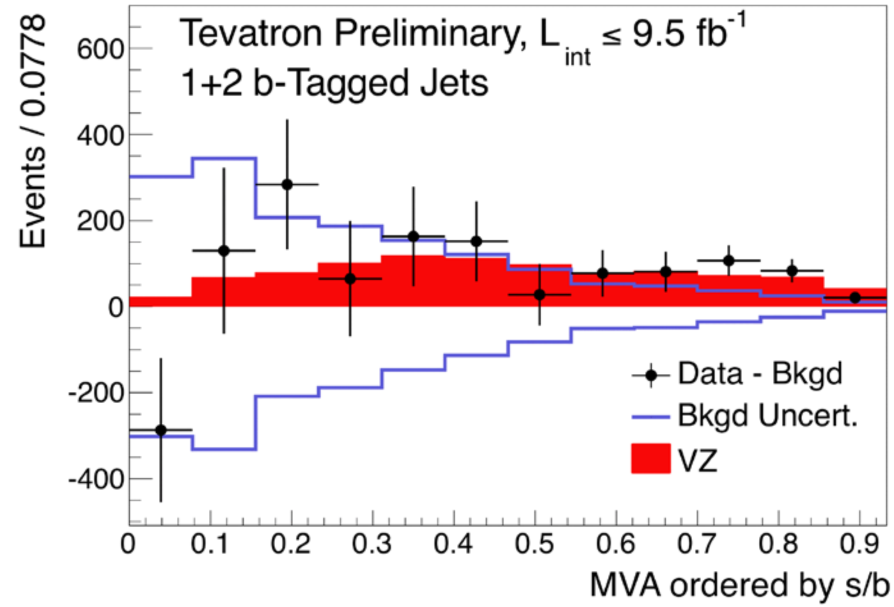


- Measure σ(WZ+ZZ)= 4.08 ± 1.32 pb
- 3.2σ observed significance

$\sigma(VZ)^{NLO}_{SM}$= 4.42pb

CDF+DZero Diboson VZ result





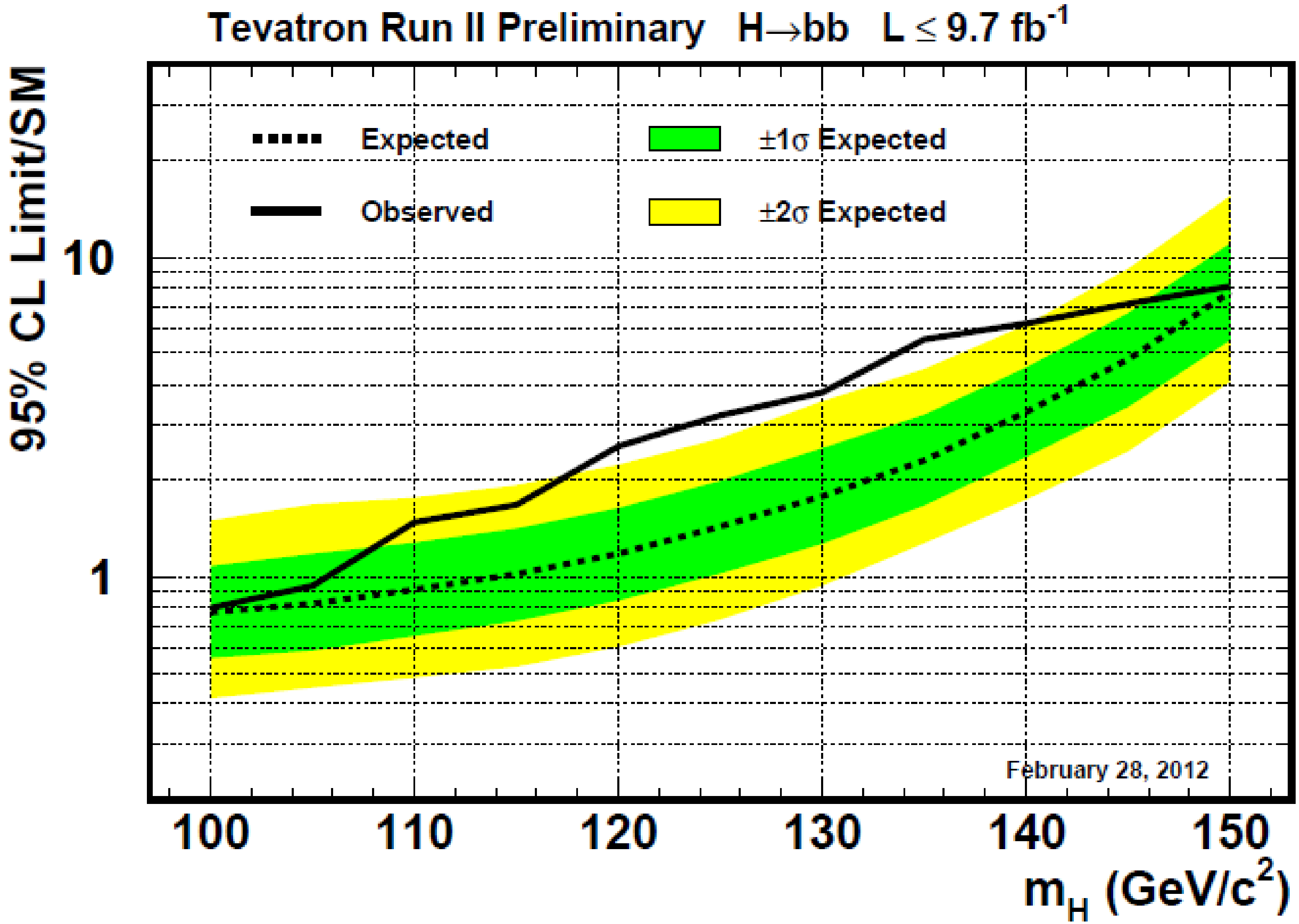
$\sigma(WZ+ZZ) = 4.47 \pm 0.64\ (stat) \pm 0.73\ (syst)\ pb$

with 4.6σ significance

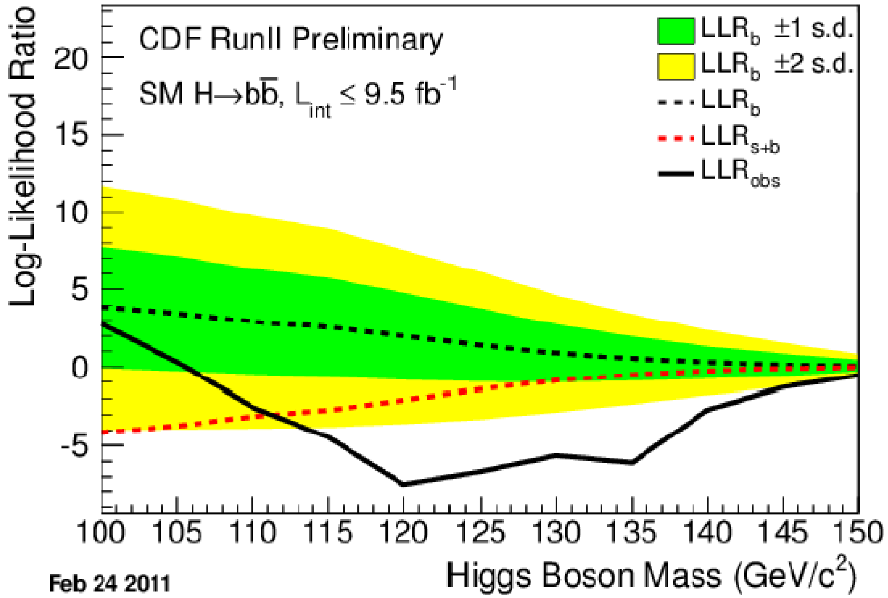
$\sigma(VZ)_{SM}^{NLO} = 4.42 pb$

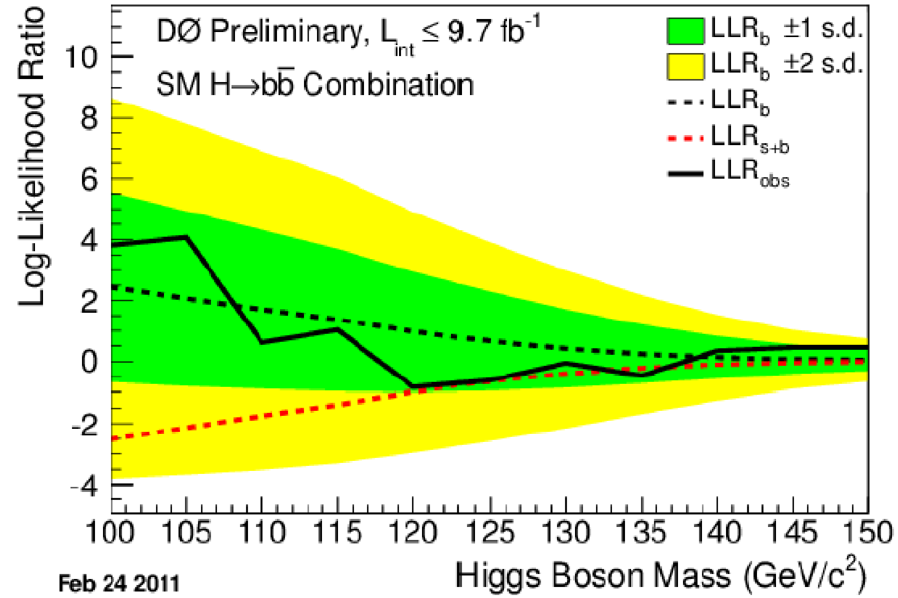
This demonstrates a capability of Higgs boson search with H→bb at Tevatron.

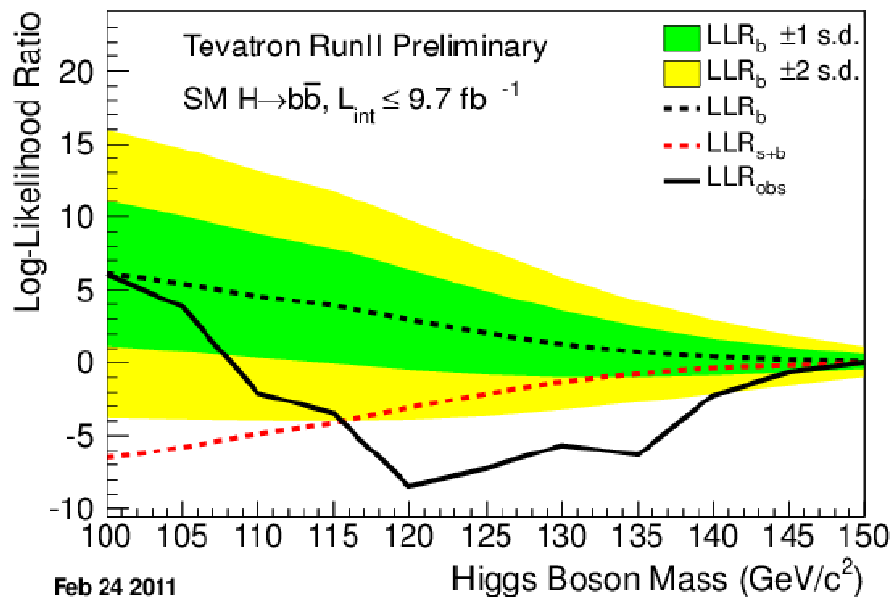
Combine all H→bb analysis (CDF+DZero)



Result on H→bb: CDF, DZero and Tevatron

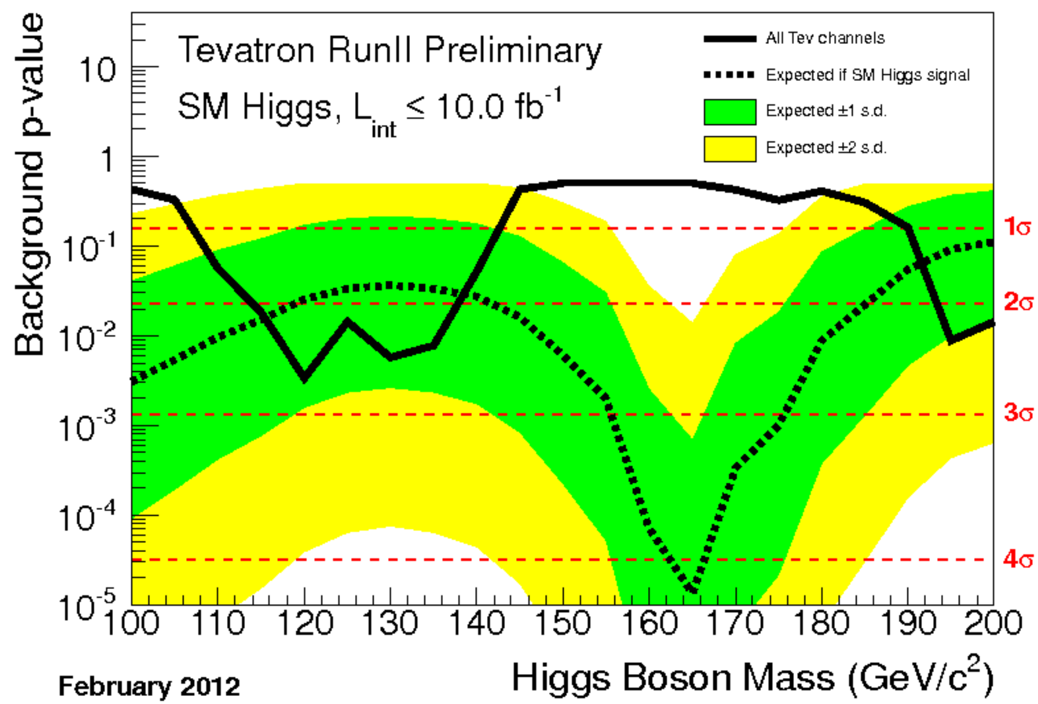






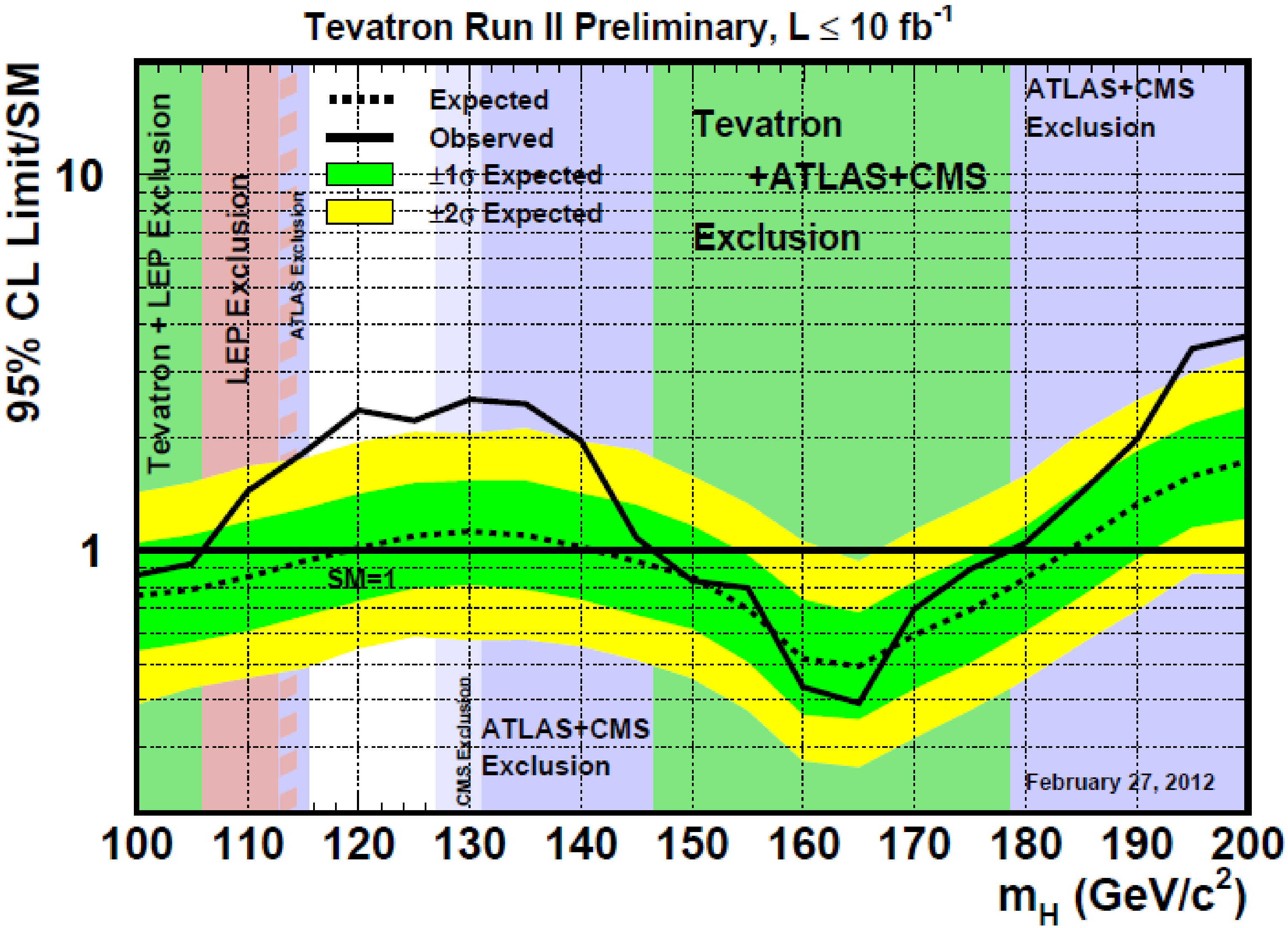
How consistent with background only

- Highest local p-value is found at m_H = 120 GeV/c^2
- Same LEE of 4 for entire SM search range from 100 to 200 GeV/c^2



SM Higgs Searches		
Experiment	Local P-value	Global P-value
CDF+D0	2.8σ	2.2σ
ATLAS	3.5σ	2.2σ
CMS	3.1σ	2.1σ

Latest result from Tevatron

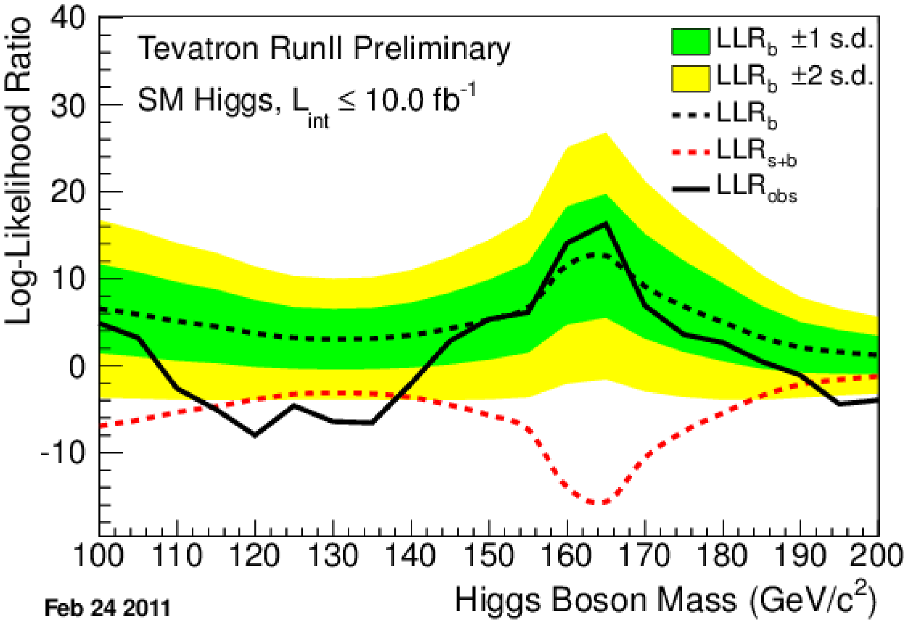


95% C.L. upper limits on SM Higgs boson production at the Tevatron

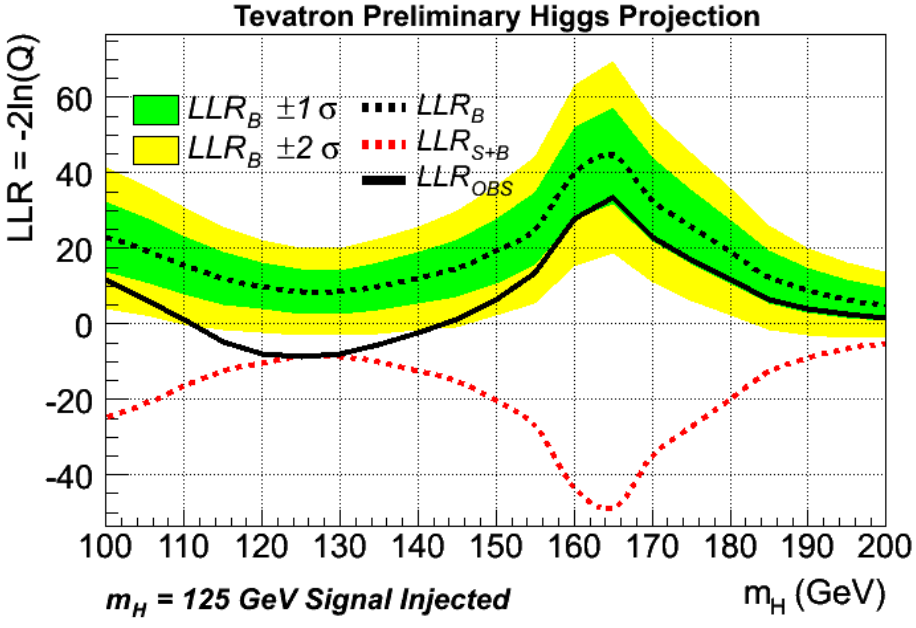
- Expected exclusion: **$100 < M_H < 120$ GeV** $141 < M_H < 184$ GeV
- Observed exclusion: **$100 < M_H < 106$ GeV** $147 < M_H < 179$ GeV

LLR in Tevatron combination

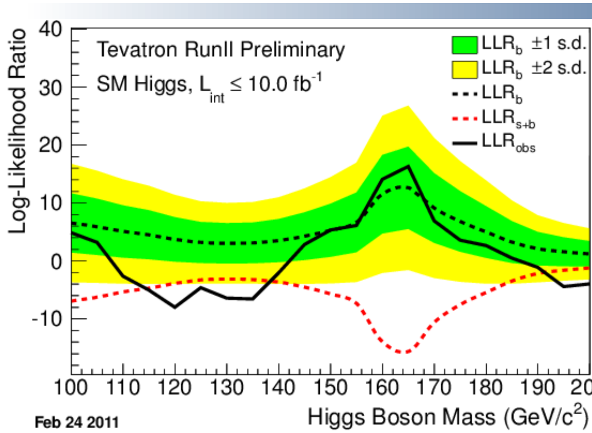
Real Data Analysis



3σ Signal Injection Study

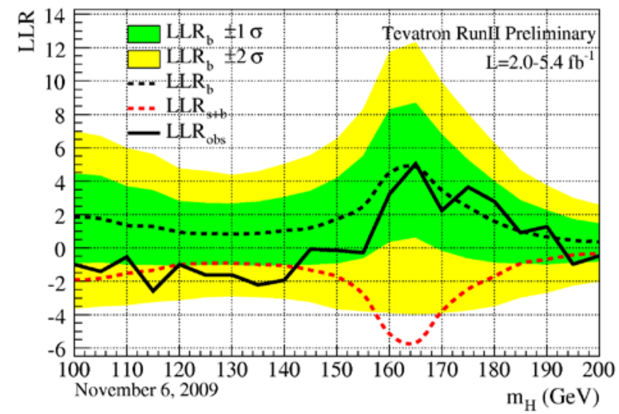


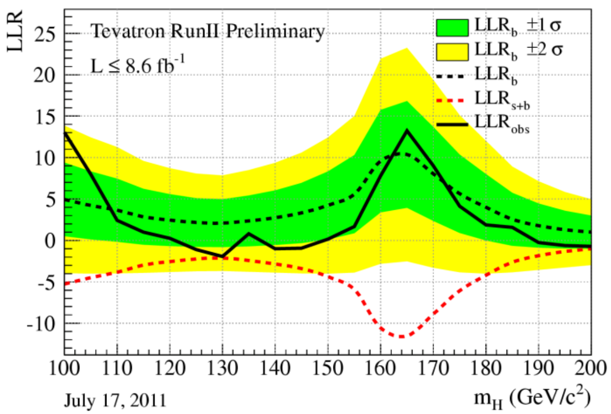
History of Tevatron Combiantion (LLR)



2012

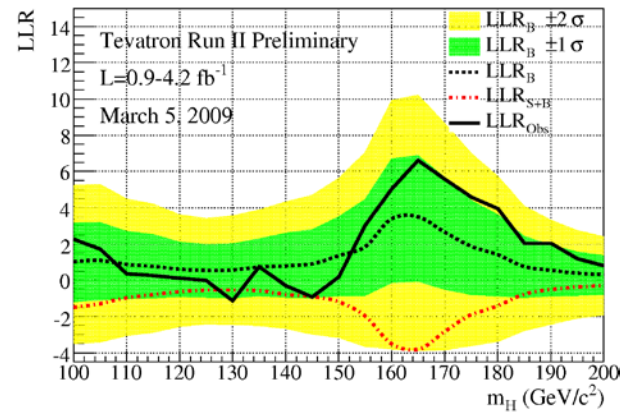
2009

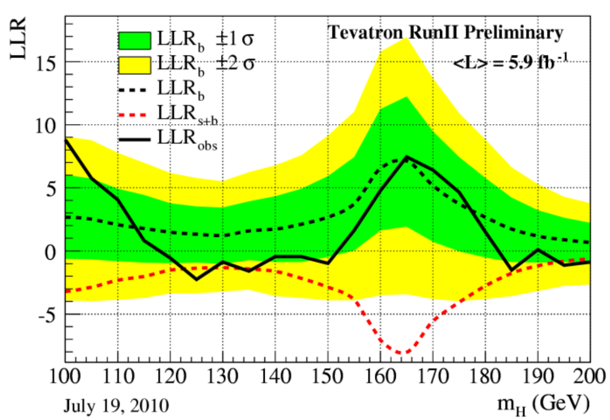




2011

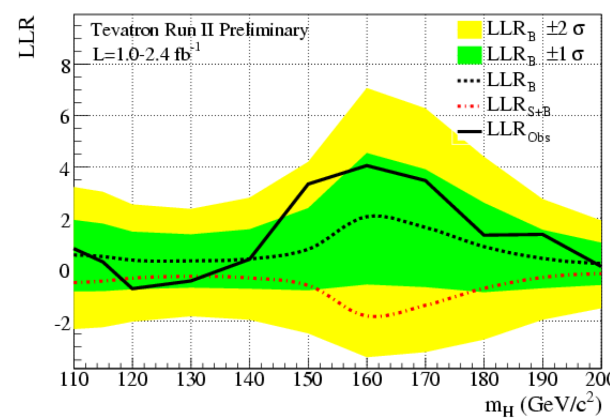
2008





2010

2007



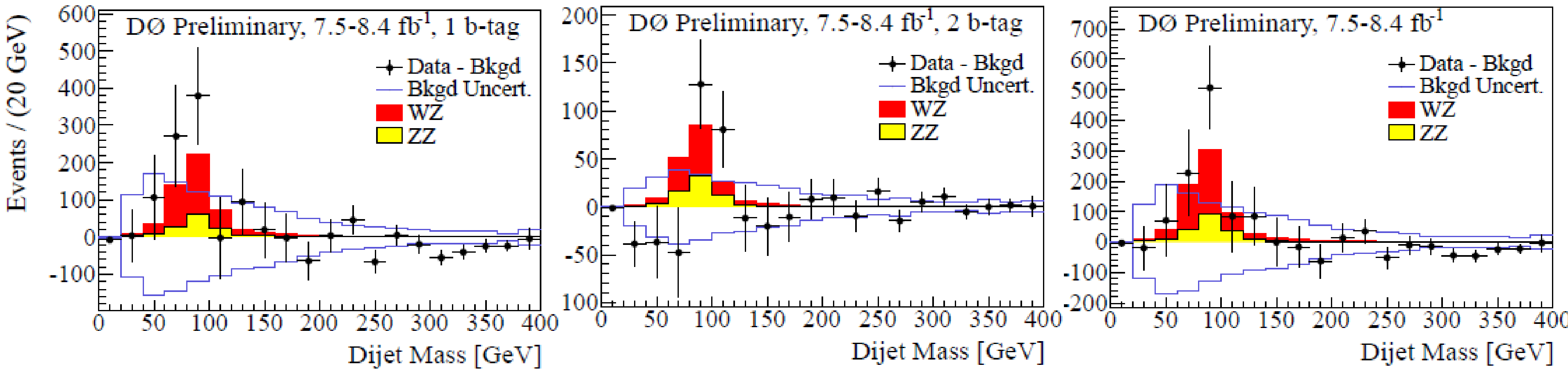
Summary

- Search for Higgs boson to prove Englert-Brout-Higgs Mechanism at Tevatron
- ATLAS and CMS excluded high mass region from 130 GeV to 600 GeV, and having excess around 125 GeV, mainly from Higgs decays into vector boson.
- Exclusion region in the Tevatron combination is

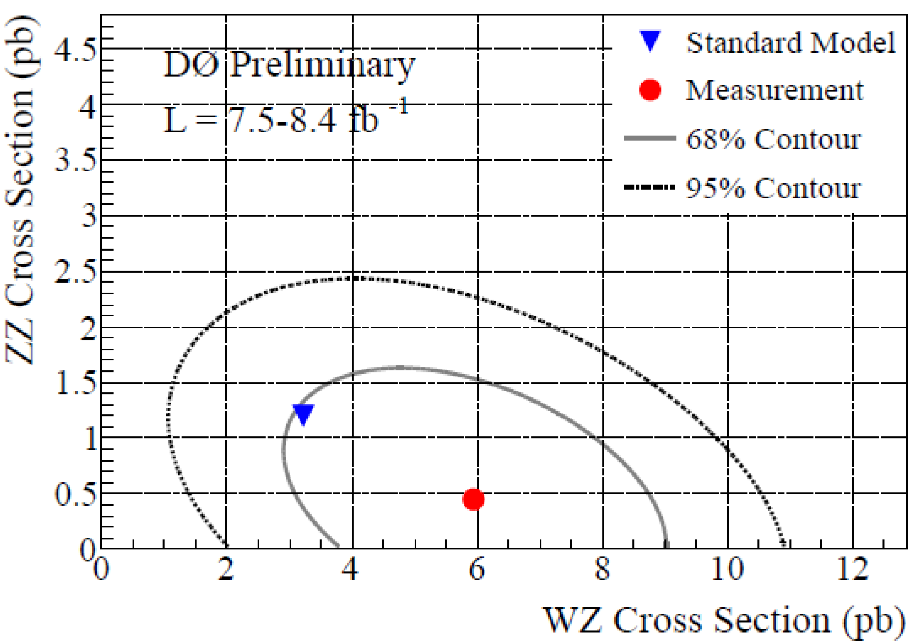
  $100 < M_H < 106$ GeV and $147 < M_H < 179$ GeV
- We observed an excess around M_H=125 GeV with significance of 2.2 σ (local 2.7 σ)
  - Largest excess is from H→bb, significance of 2.6 σ (local 2.8 σ)
- Validation with cross section measurement on Diboson VZ, Z→bb demonstrates a capability of Higgs boson search with H→bb in the Tevatron combination.
- There are still some idea to improve sensitivity.
  - Tevatron may be able to provide a measurement on Yukawa coupling! Stay tuned!

Backup

Result D0 combination



- A simultaneous fit of WZ and ZZ performed



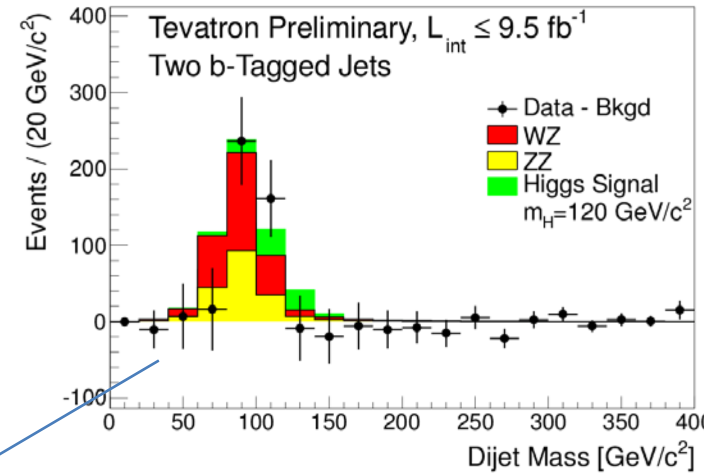
$\sigma(WZ) =$
$5.9 \pm 1.4\ (\text{stat.}) \pm 0.7\ (\text{syst.})$ pb

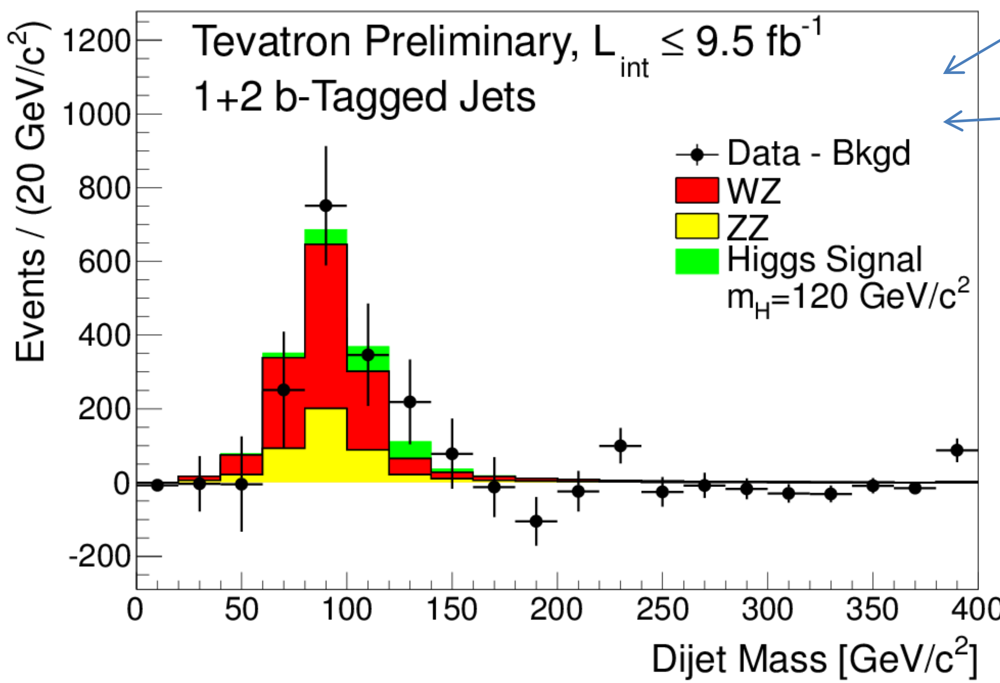
$\sigma(ZZ) =$
$0.45 \pm 0.61(\text{stat.}) \pm 1.2\ (\text{syst.})$ pb

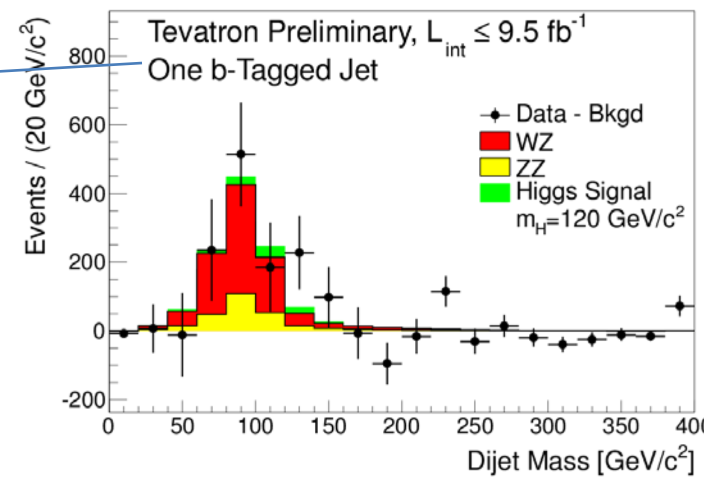
$\sigma(WZ)^{NLO}_{SM} = 3.22$pb
$\sigma(ZZ)^{NLO}_{SM} = 1.20$pb

Behavior on Dijet mass

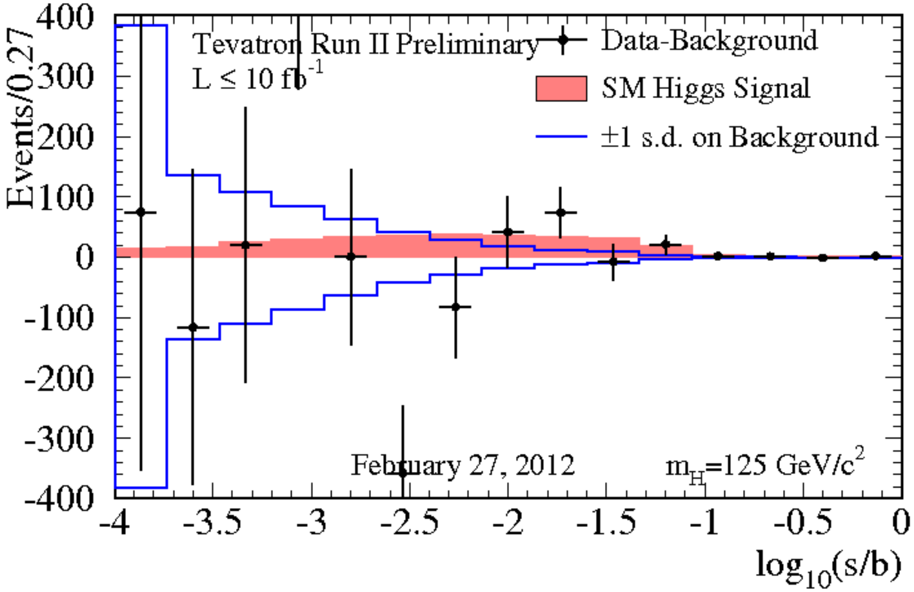
- After subtracting background
  - Expect diboson
  - Overlay Diboson and H→bb prediction

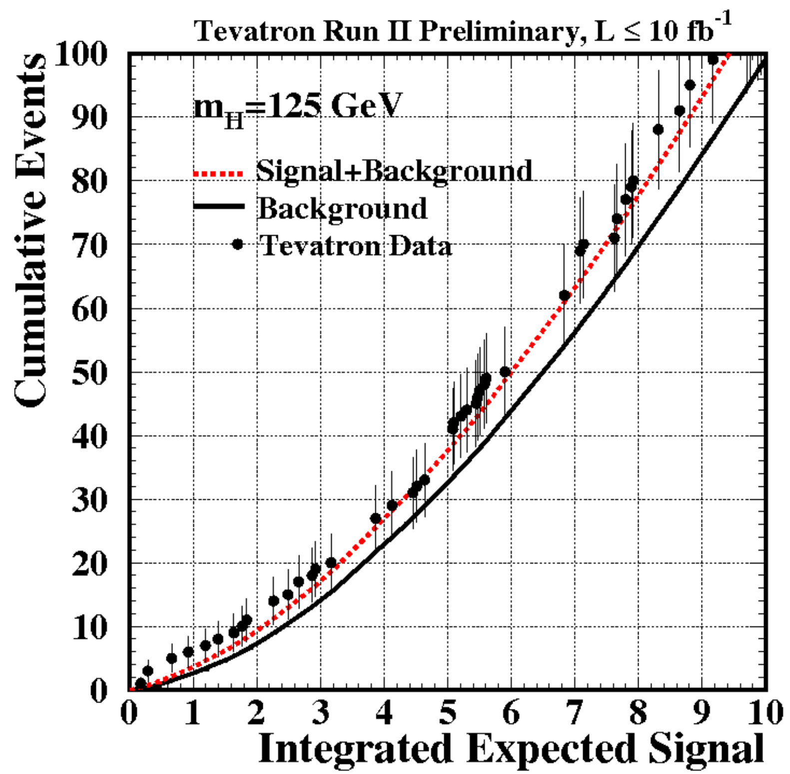




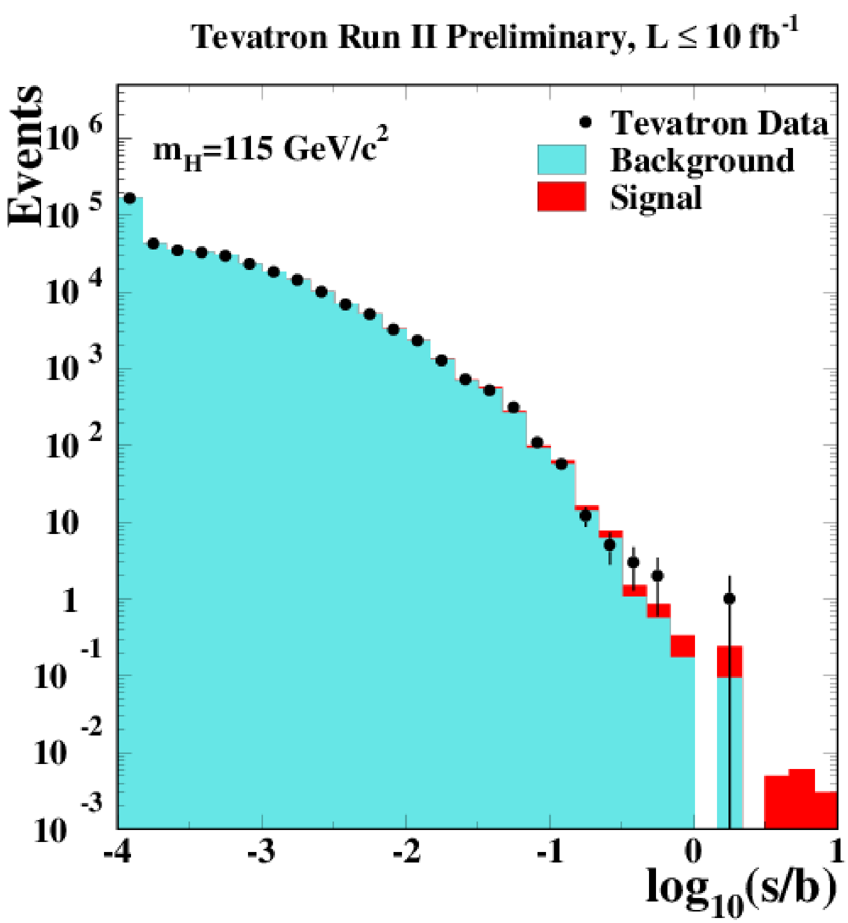


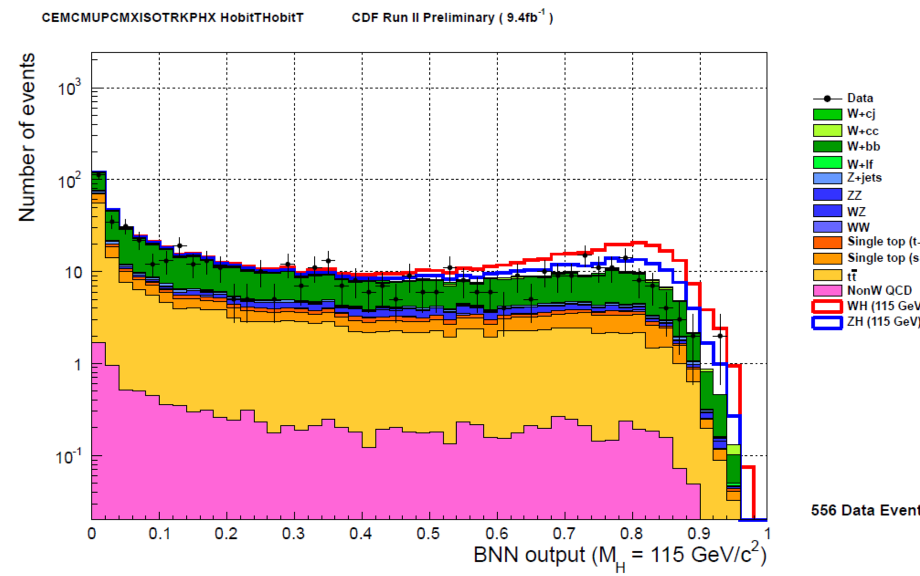
Excessness on M_H=125 GeV

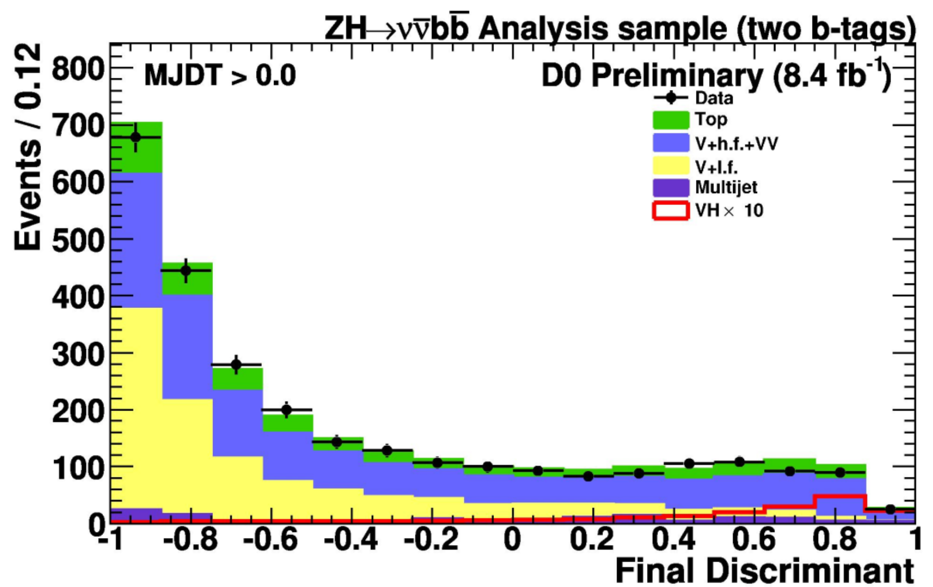


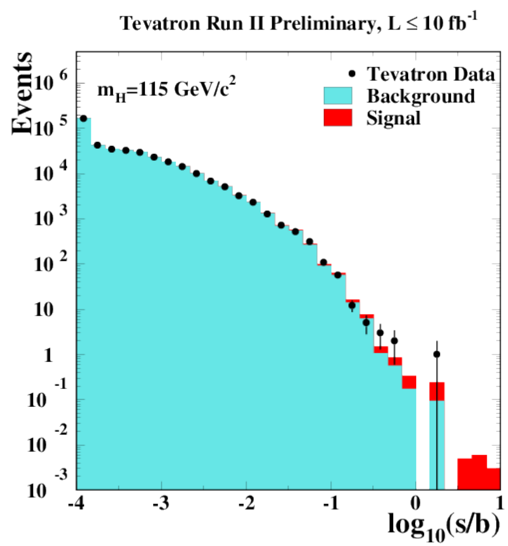


- Visualizing O(100) input distributions can be simplified by reordering bins by signal and background content
  - High s/b region is where we would expect to find an excess

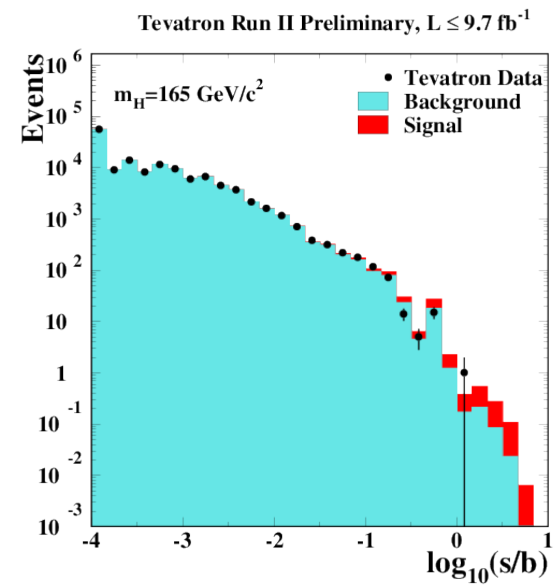


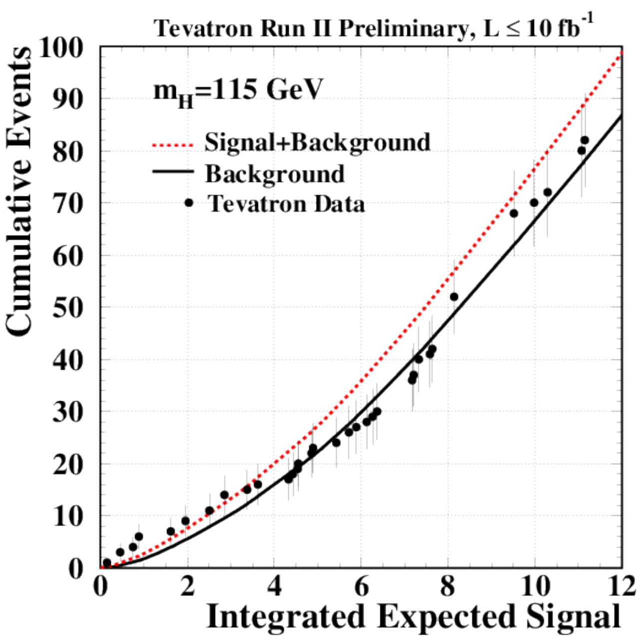


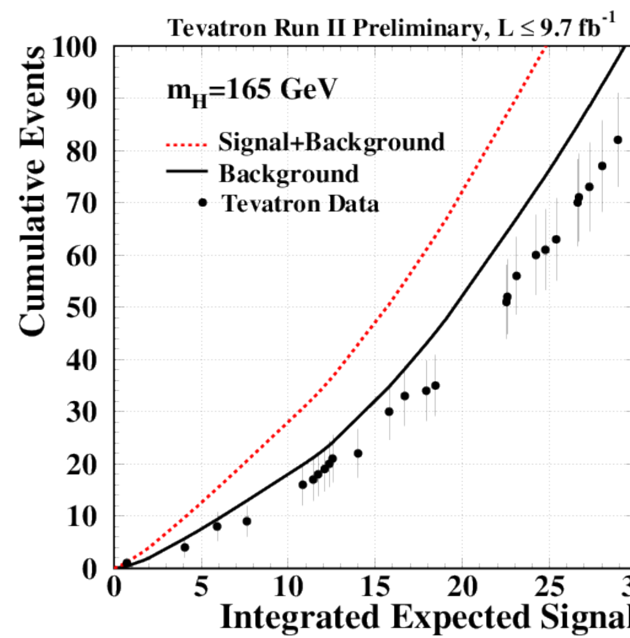


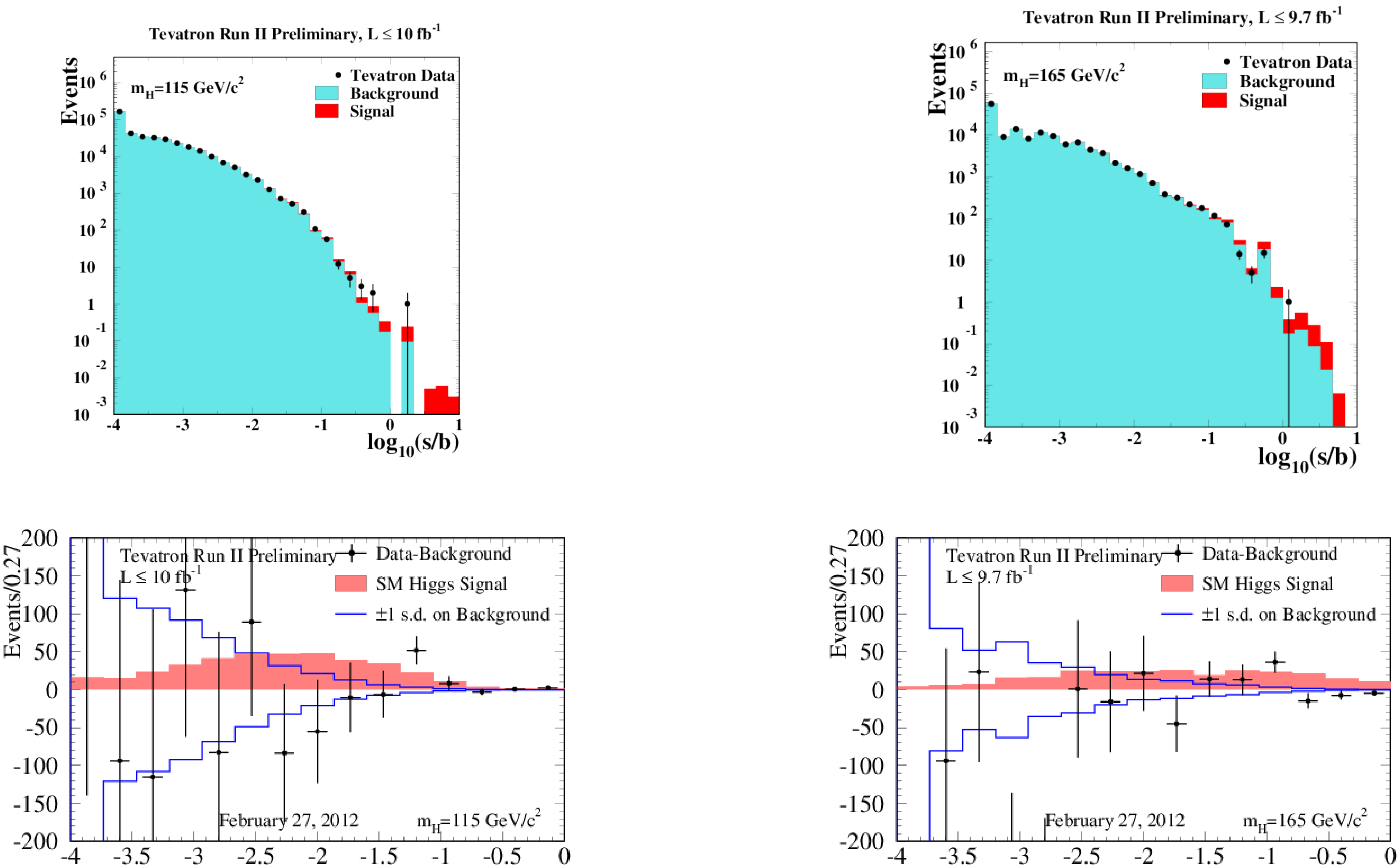


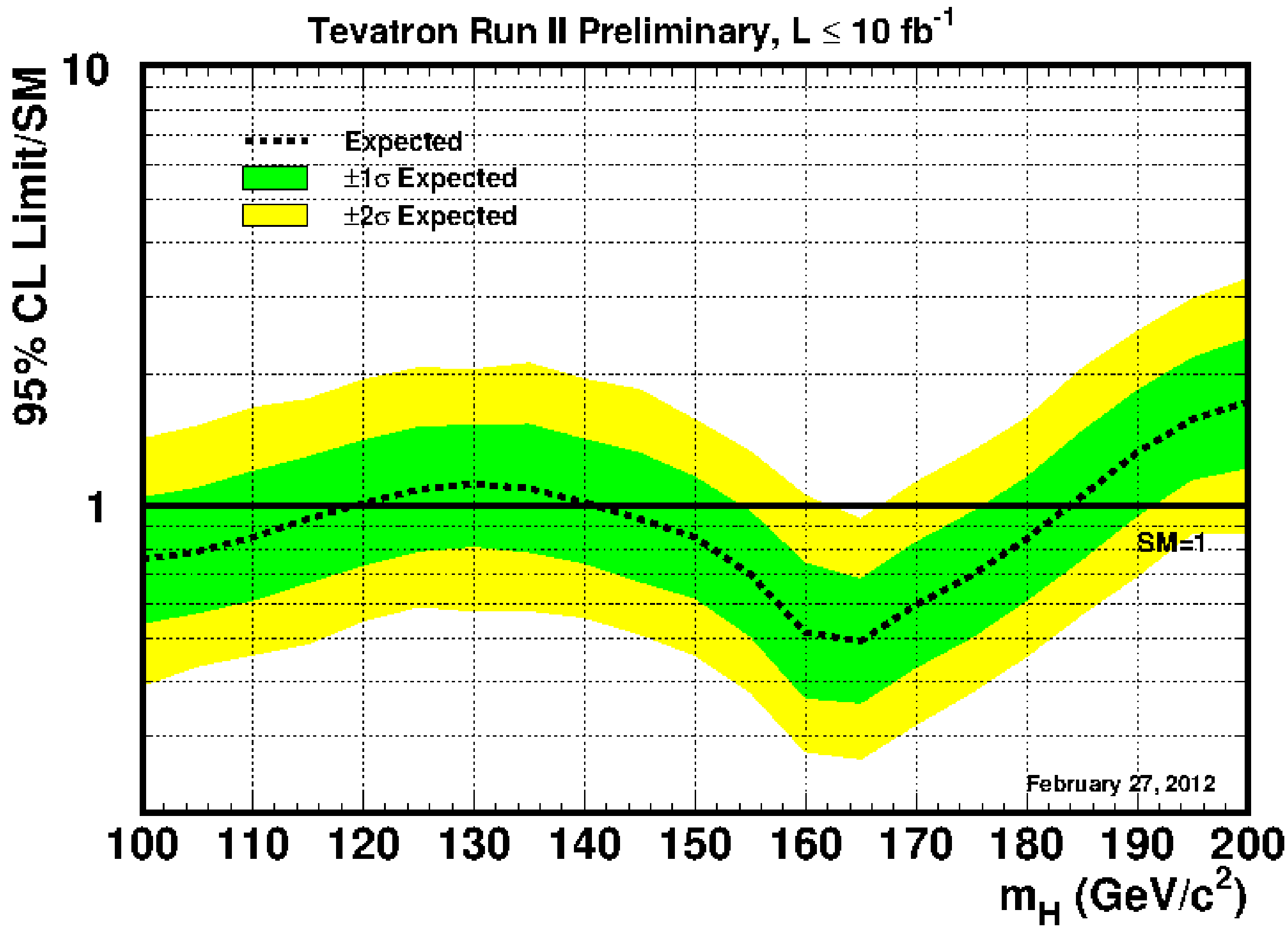
Right-to-left integral yields a means to compare data with signal and background predictions



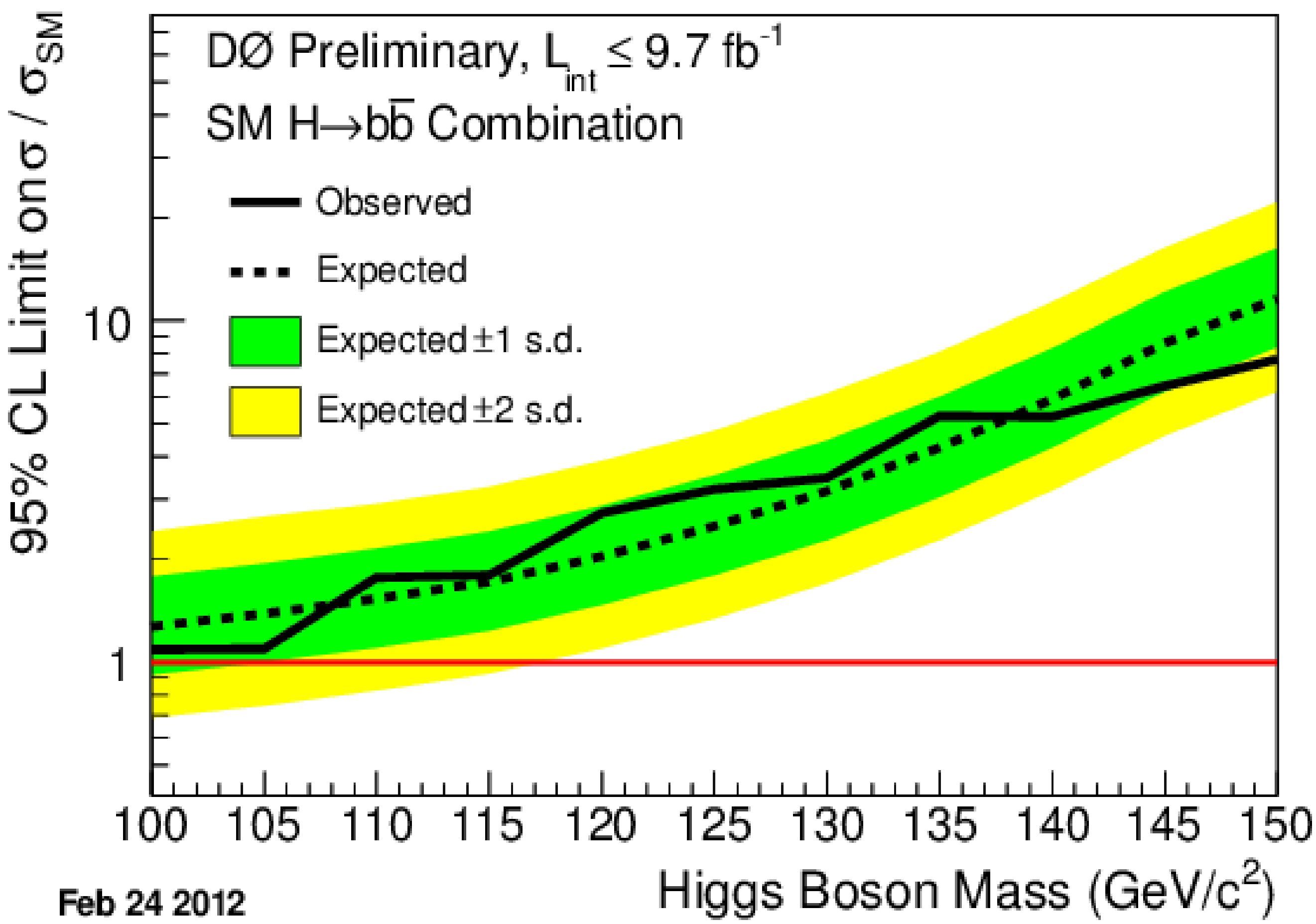





Tevatron Run II Preliminary, L ≤ 10 fb-1
Events
mH=115 GeV/c2
Tevatron Data
Background
Signal
log10(s/b)
Tevatron Run II Preliminary, L ≤ 9.7 fb-1
mH=165 GeV/c2
Events/0.27
Tevatron Run II Preliminary
L ≤ 10 fb-1
Data-Background
SM Higgs Signal
±1 s.d. on Background
February 27, 2012
mH=115 GeV/c2
L ≤ 9.7 fb-1
mH=165 GeV/c2



- 95% C.L. upper limits on SM Higgs boson production at the Tevatron

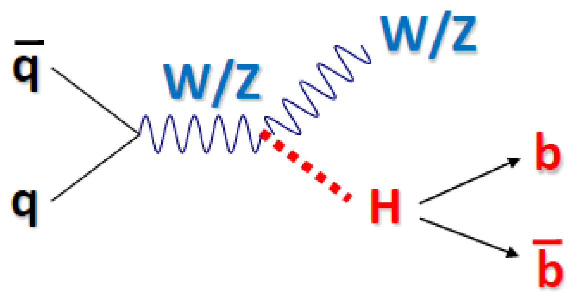


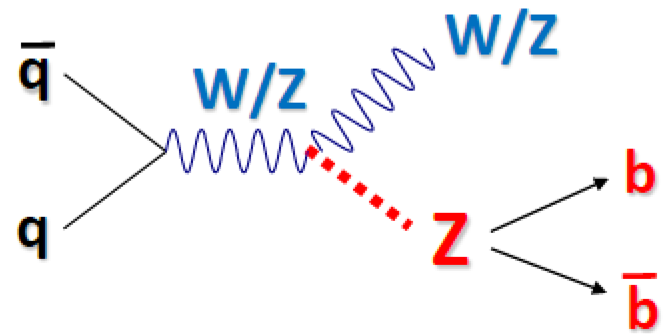
Limits for m_H = 115 GeV

- Observed: 1.79 □ σ
- Expected: 1.71 □ σ
- ~16% improvemen
from summer resul

Cross check on Diboson process

- Benchmark of H→$b\bar{b}$ searches with real data.
- VZ→leptons + heavy flavor jets





<u>For m_H=115 GeV</u>
WH→lνbb: σ = 26 fb
ZH→ννbb: σ = 15 fb
ZH→llbb: σ = 5 fb
Total VH: σ = 46 fb

<u>Replace Z with H</u>
WZ→lνbb: σ = 105 fb
ZZ→ννbb: σ = 81 fb
ZZ→llbb: σ = 27 fb
Total VZ: σ = 213 fb

  – Z→$b\bar{b}$ yields is 5 times larger, but more W+jets, also there is **BG from WW**.

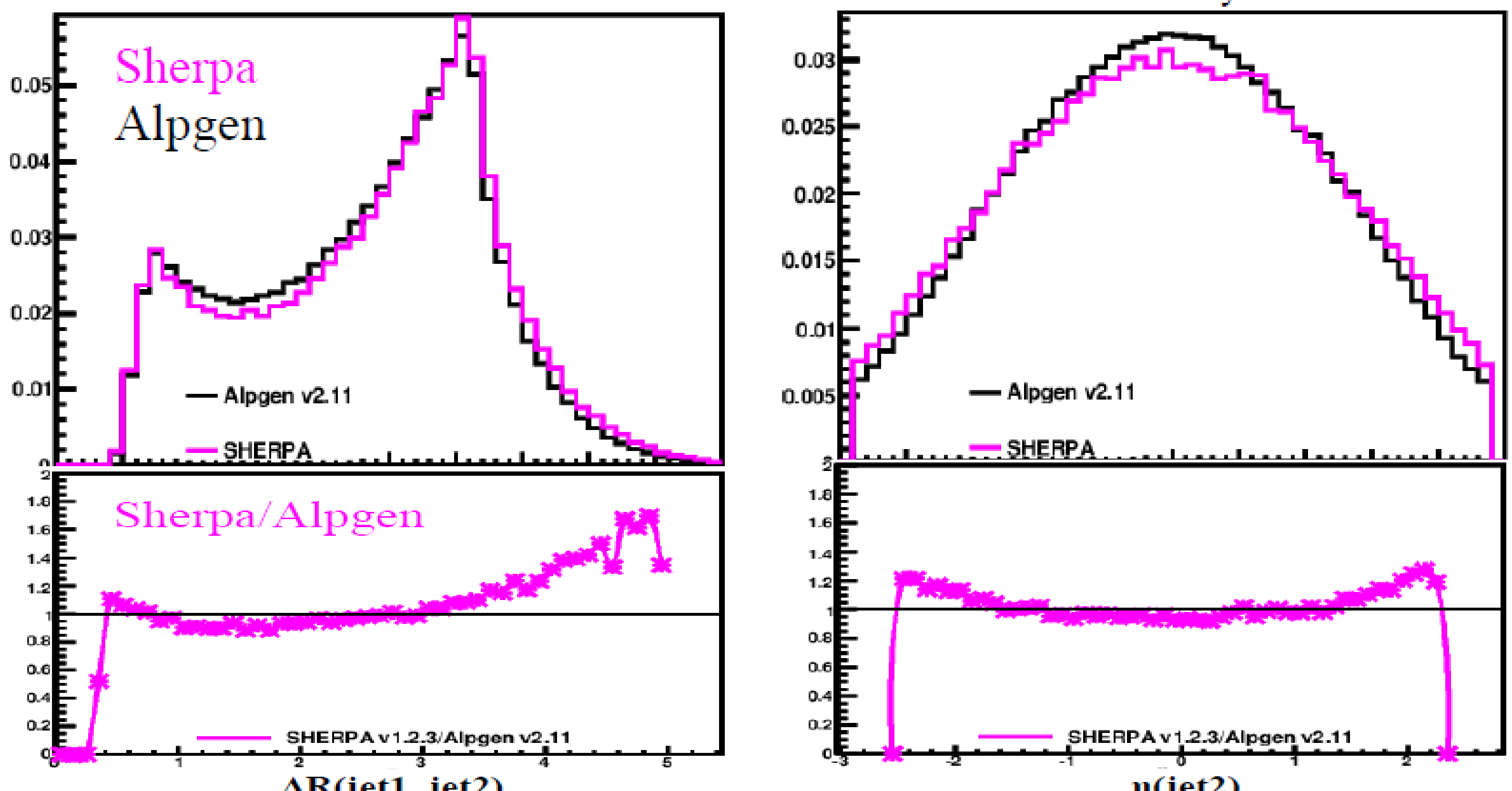
- Apply same analysis procedure with low mass H→$b\bar{b}$ analysis, and check sensitivity.

V+Jets Modeling

- ALPGEN+PYTHIA is used in both CDF and D0.
  - DØ analyses apply reweighting from extracted from data to V+Jets monte carlo.
  - Lepton η, Jet η, angle between jets, W pT

Consistency check between lepton, data epoch, final state, etc..

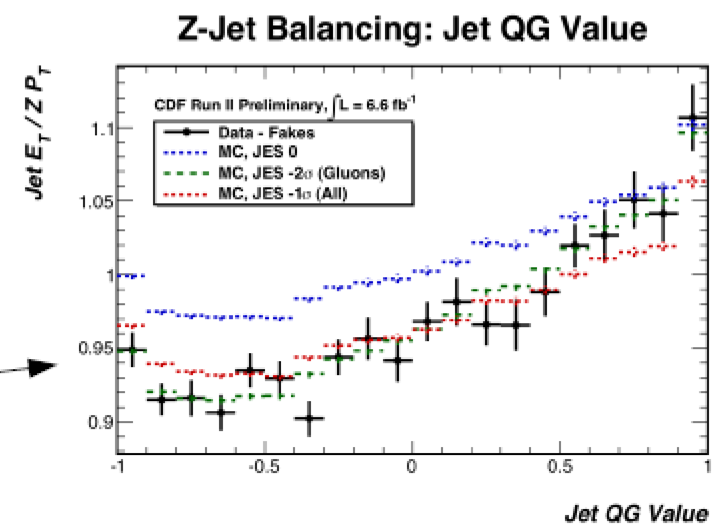
Plots courtesy of Adam Martin

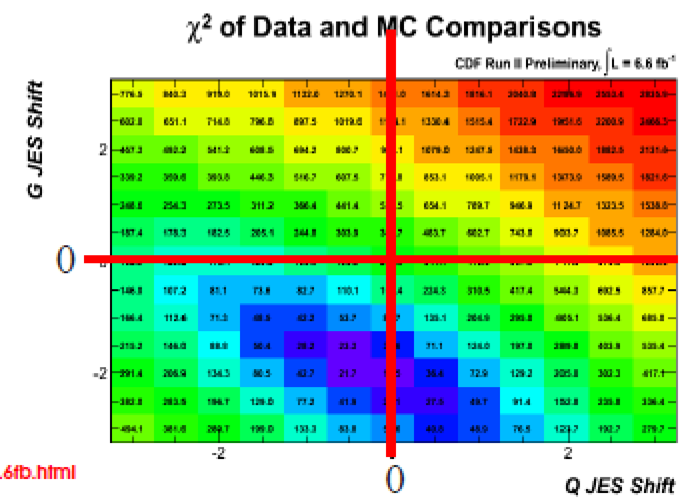


New Additional Jet Systematics

- While performing tagged WW/WZ search
  - Gluon-Quark separator
  - Z+1Jet balancing studies performed
  - Poor description of Z-jet balance seen in gluon-like jets.
    - MC gluon jets harder in ET than data by ~5% of ET
    - MC quark jets well described
  - Origin of mismodeling still under investigation
  - Affects jet energies, dijet mass spectrum of untagged jets
    - Negligible effect on tagged jets
    - For 2012 results, MC simulation has been corrected for this effect
    - Change to expected or observed limits far below other systematics
- For more information:

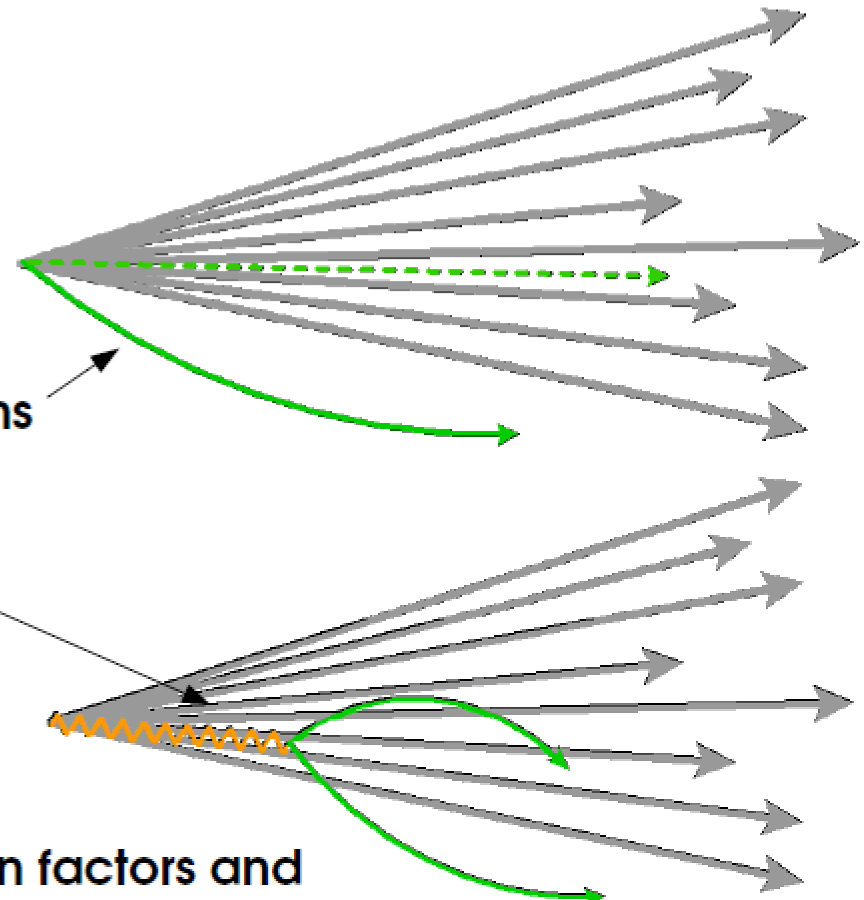
http://www-cdf.fnal.gov/physics/new/hdg/Results_files/results/wzllbb_071911/Diboson_public_6.6fb.html





New b-Jet Identification

- Calibration samples
  - Kinematic selection of W+4,5 jets events (di-top)
  - QCD dijets with low relative-pt electrons
    - Not an input to tagger
    - Semileptonic decay electrons
      - Enriched in b,c
    - Photon conversion electrons (New method)
      - Primarily u,d,s,c,g
    - Examine both e-jet and opposing side jets
- These samples produce correction factors and uncertainty estimates for simulated events
- Resulting b-jet tag-rate corrections: ~5%±4%



CDF: eebb analysis

- ZH: s:b of new events in 2012