(W/Z)Z with Z→bb using the DØ Higgs Framework

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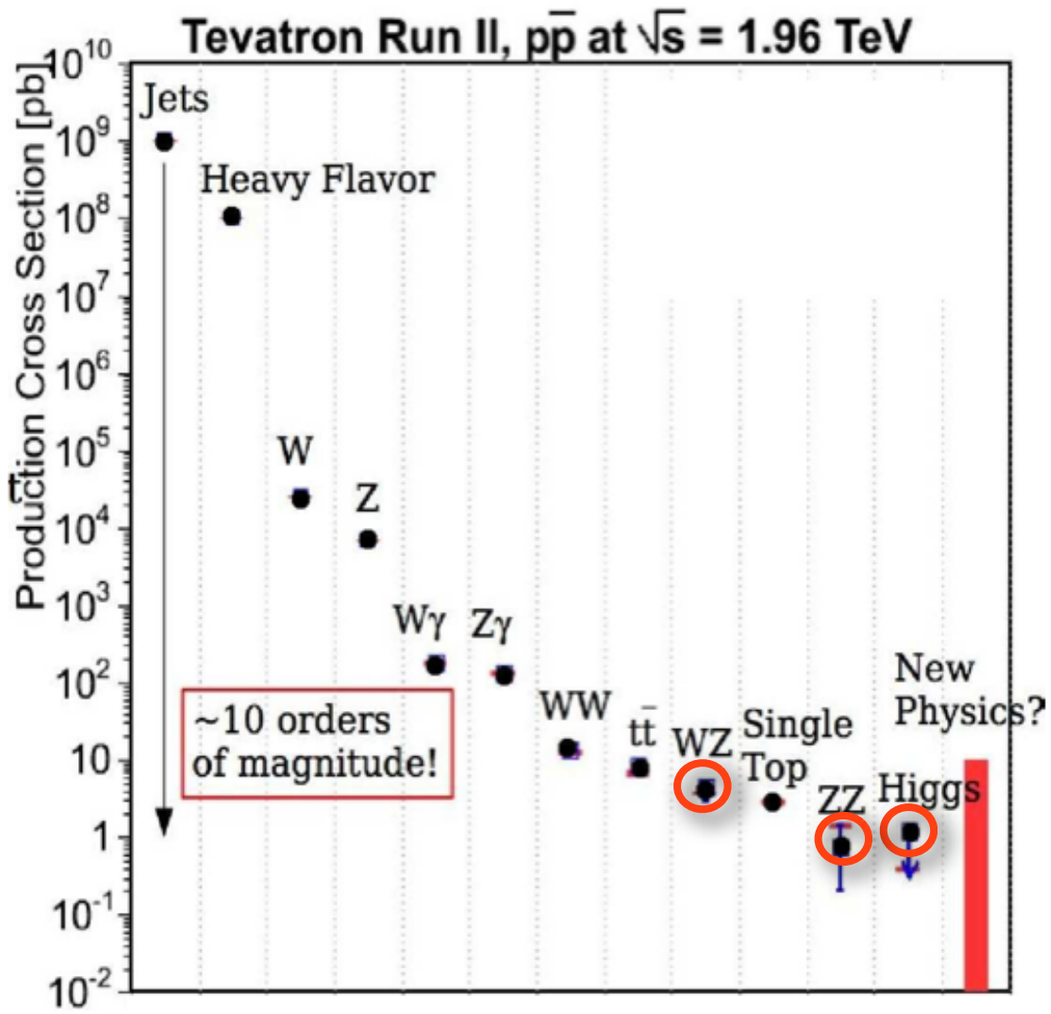
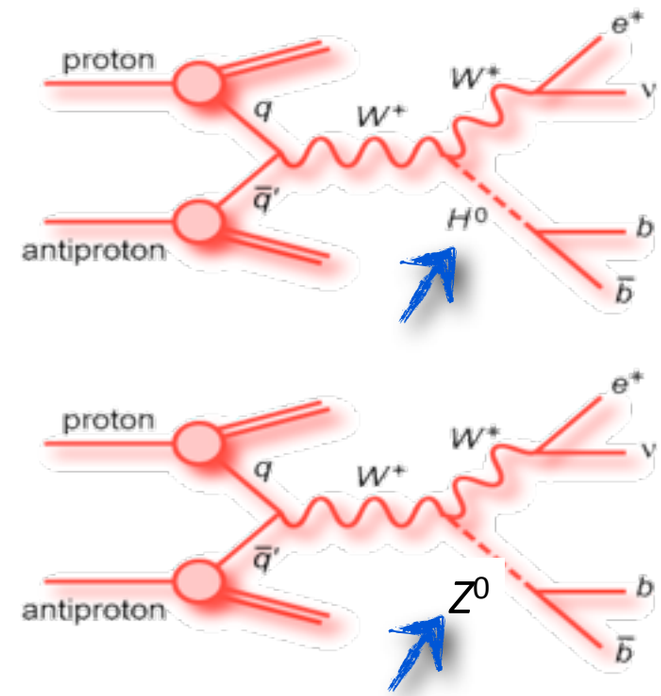
Fermilab

(W/Z)Z at Tevatron

- Probe of the EWSB mechanism
  - Test of SM
  - Indirect searches for New Physics (xsec, kinematic, couplings)





$$\sigma(W^{\pm}Z^0) = 3.22^{+0.20}_{-0.17}(\text{scale})^{+0.11}_{-0.08}(\text{PDF})\ \text{pb}$$

$$\sigma(Z^0Z^0) = 1.20^{+0.05}_{-0.04}(\text{scale})^{+0.04}_{-0.03}(\text{PDF})\ \text{pb}$$

- Ultimate test of experimental and statistical techniques used in the Higgs searches

VZ with Z→bb as Higgs Test

(W/Z)H (mH=115GeV)	
WH→lνbb	27fb
ZH→llbb	5fb
ZH→ννbb	15fb
Sum	46fb

→

(W/Z)Z	
WZ→lνbb	105fb
ZZ→llbb	24b
ZZ→ννbb	73fb
Sum	202fb

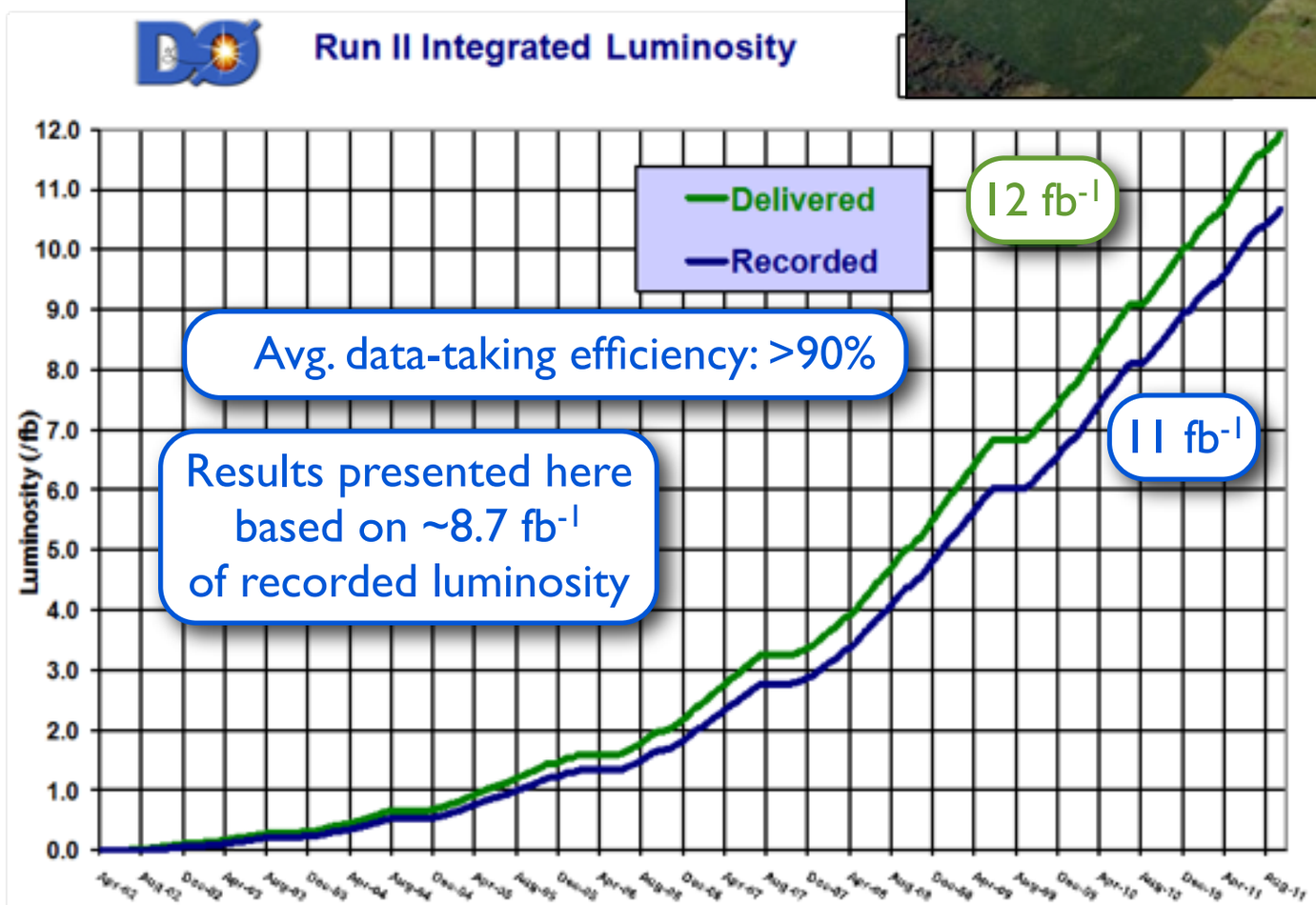
- σ(VZ) ~4.5 times larger than σ(VH)
- Lower masses
  - Dijet mass resolution doesn't allow to separate dijets from W and Z decays: WW(→lνcs) becomes large background
  - Background rates and systematics increase at lower masses
  - Larger Z→cc contribution than H→cc

The Tevatron and DØ

$\sqrt{s}$ =1.96 TeV
Δt = 396 ns

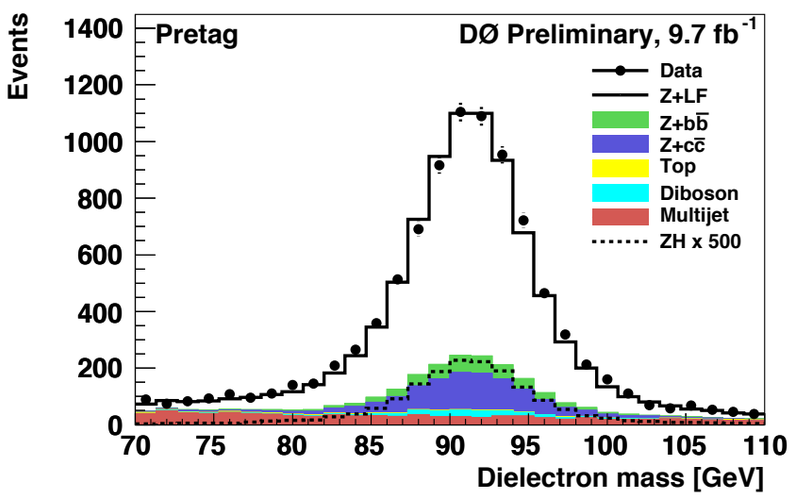
Run I 1987 (92)-95
Run II 2001-11: 75x larger dataset
increased energy

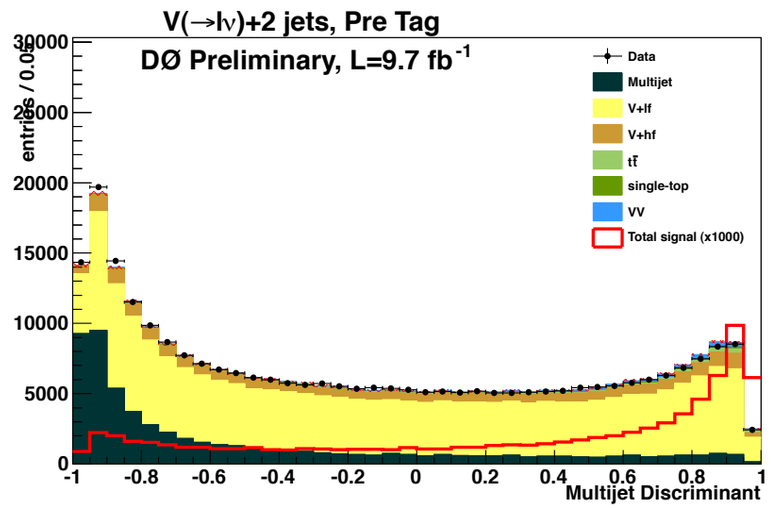
Typical average Luminosity:
>300 x 10^{30} cm^{-2} sec^{-1}
~50pb^{-1} per week

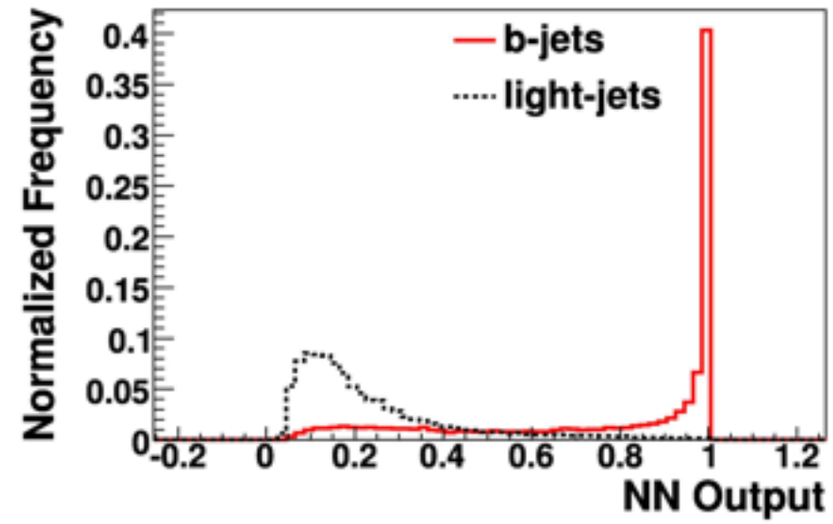


- **Central tracking:**
  silicon vertex detector and fiber tracker in 2T field
- **Calorimeter:**
  hermetic coverage |η|<4.2, LqAr Calorimteter
- **Muon System:**
  excellent purity and coverage: |η| < 2

Validation of Higgs-Methods

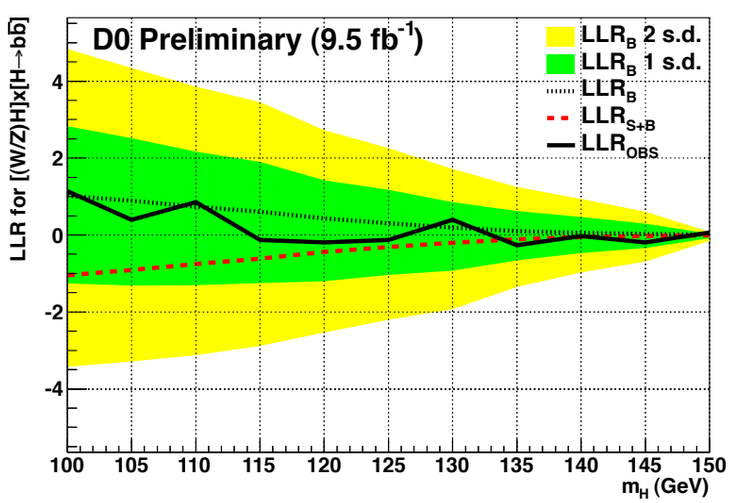




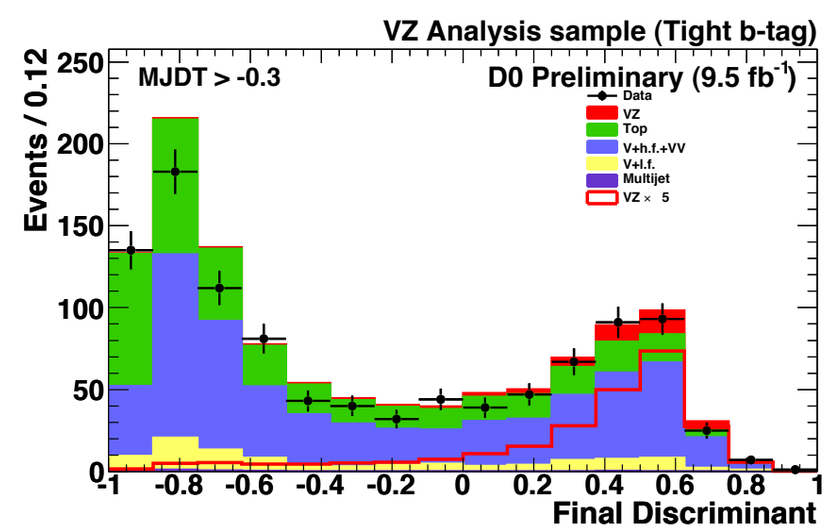


kinematic selection → multijet removal → b-tagging

final discriminant

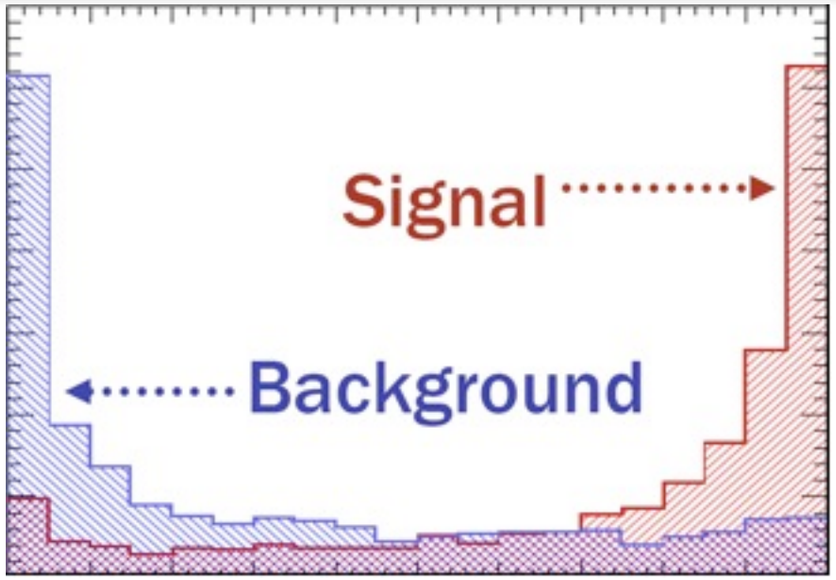


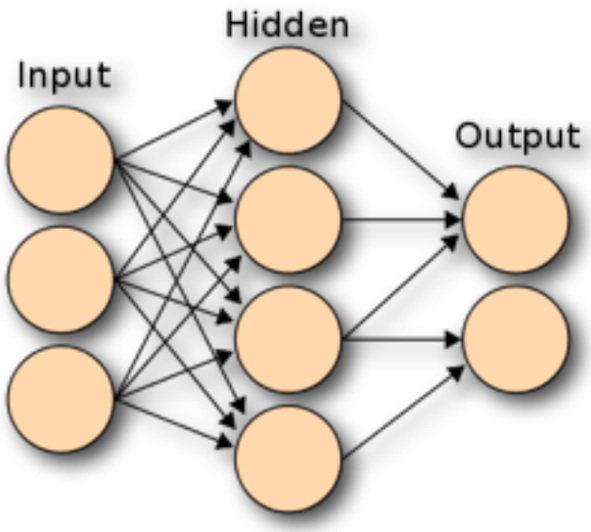
statistical analysis



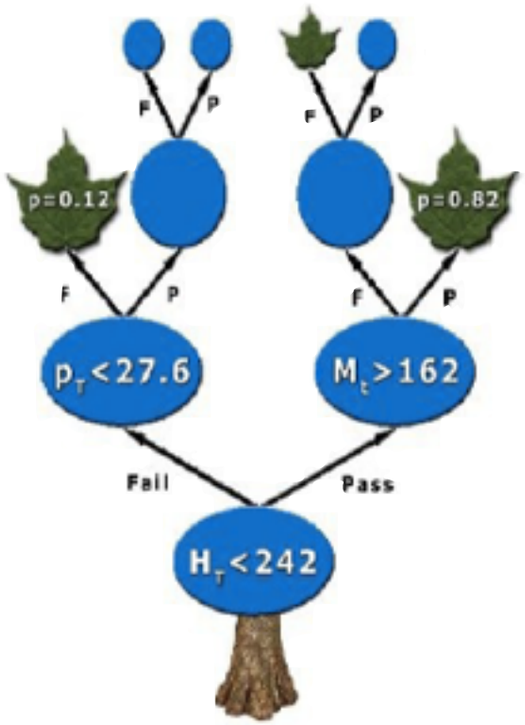
Multivariate Methods

- Look at many variables simultaneously
- Choose well modeled, separating variables
- Neural Networks (NN) , Decision Trees (DT)
- DT arboretum: Random Forest (RF)
- Typically see > 20% sensitivity improvement w.r.t. single best variable

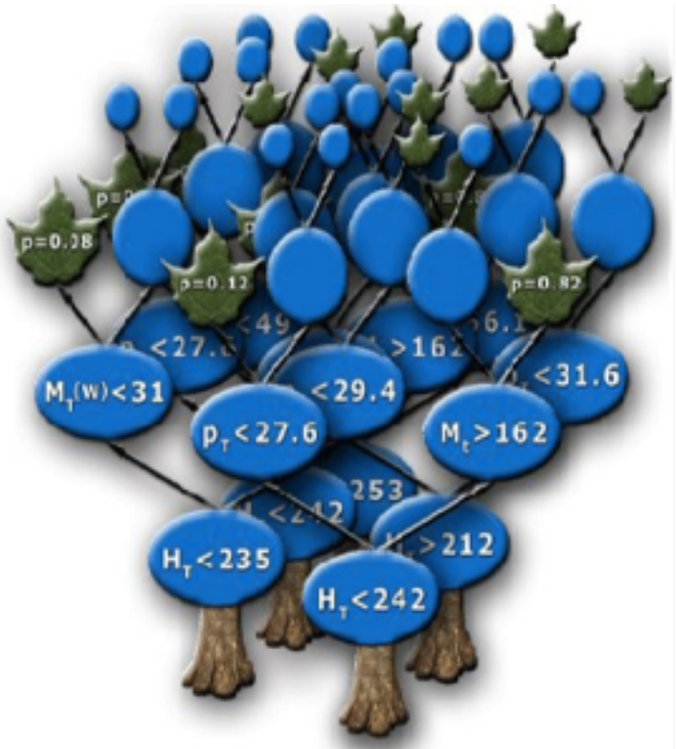




NN



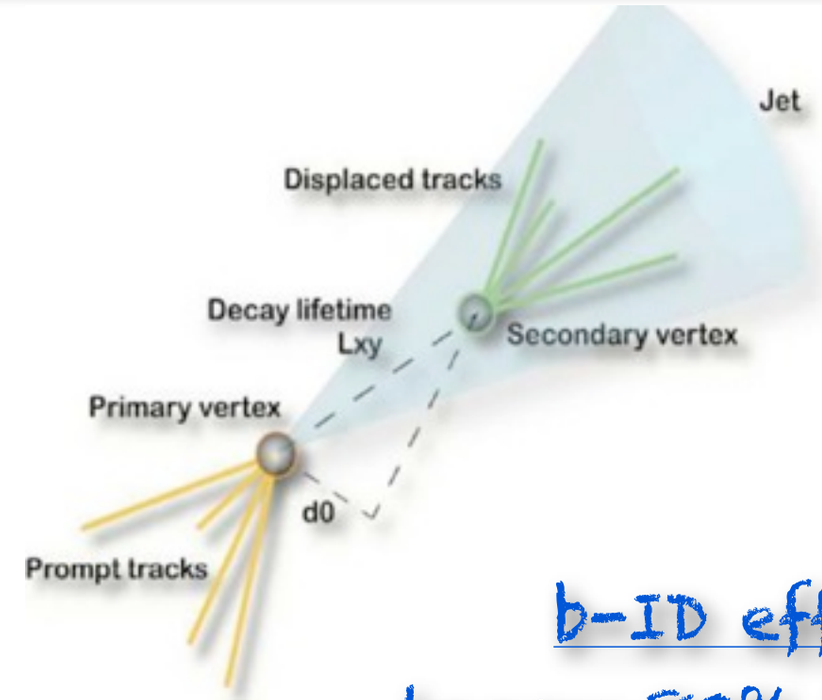
DT



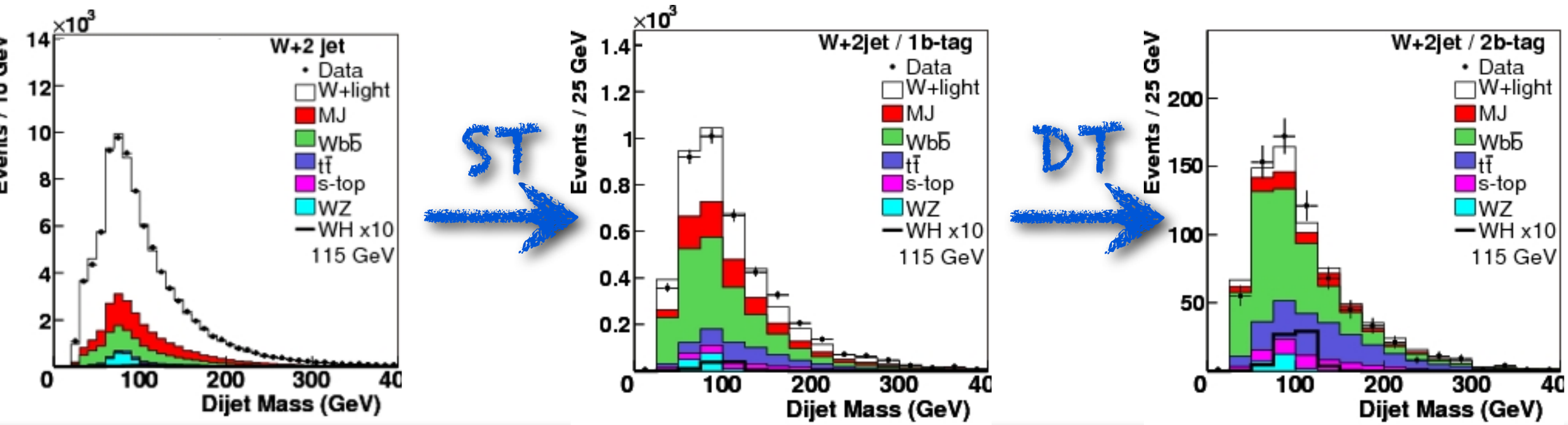
RF

b-tagging

- Long life-time of b-hadrons → displaced vertex
- DØ uses MVA, exploiting
  - information of displaced vertex, track impact and PV association probability
- Typically two orthogonal samples
  - Double Tag (DT)
  - Single Tag (ST)



b-ID eff:
loose: 80% (10%)
tight: 50% (0.5%)



The observation of (W/Z)(Z→bb), using the same techniques as for the Higgs searches, is validation of the Higgs searches at the Tevatron

Only change:
MVAs retrained using (W/Z)Z as signal,
WW still background

Diboson Channel

Diboson lνbb

- high p_T e,μ
- E_T^{miss}
- 2,3 jets
- BDT: 14 inputs

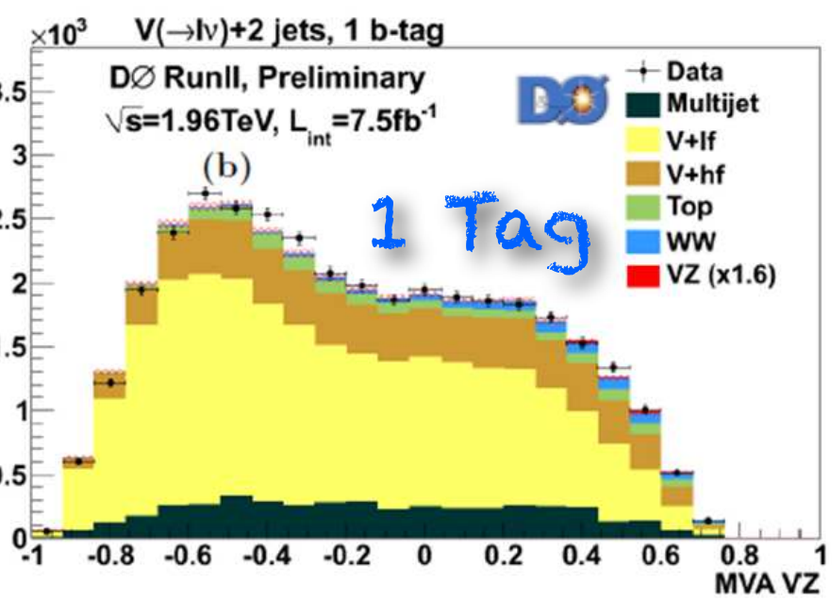
Diboson llbb

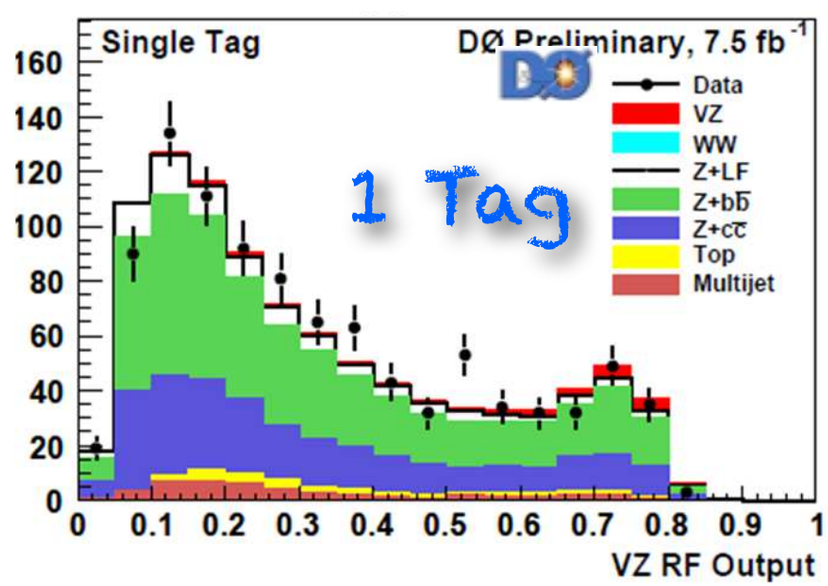
- lepton pair ~M(Z)
- kinematic fit
- 2,3 jets
- RF: 19 inputs

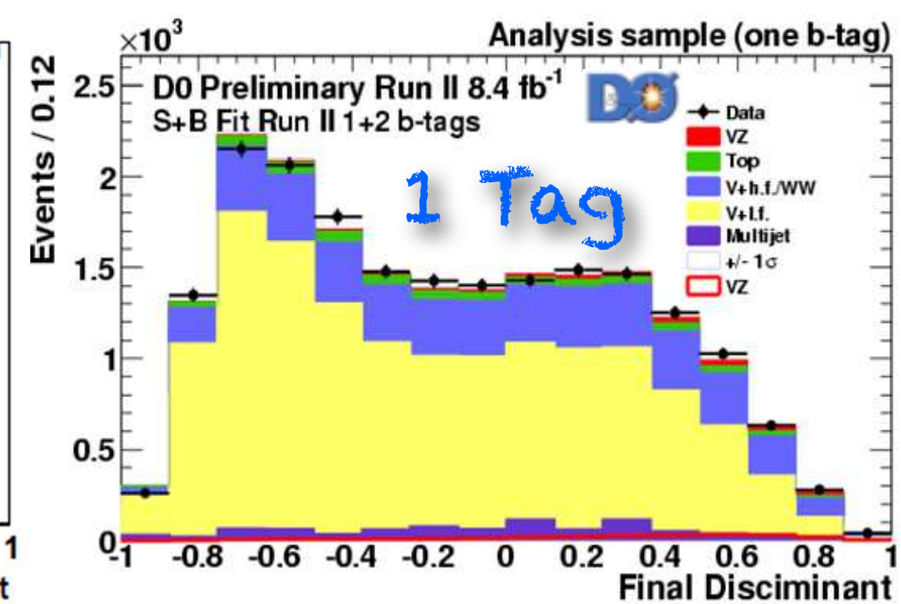
Diboson ννbb

- large E_T^{miss}
- E_T^{miss} signific.
- ≥2 jets
- BDT: 32 inputs

Discriminating Variables

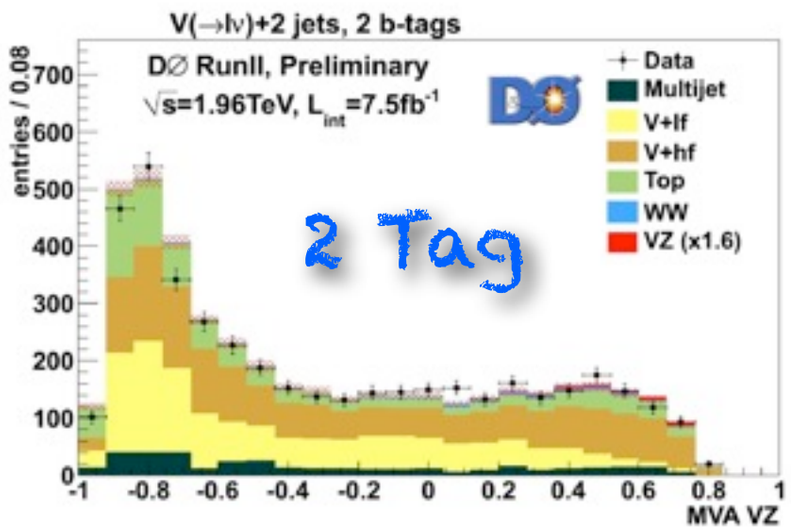




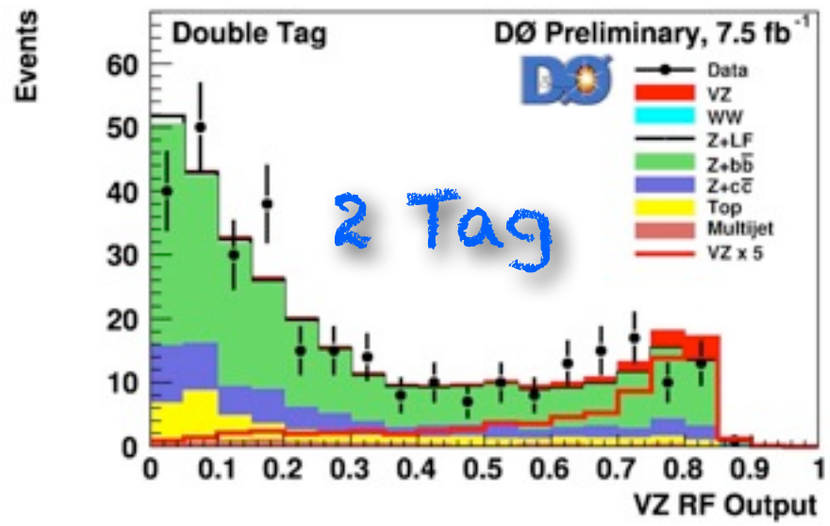


Diboson Channel

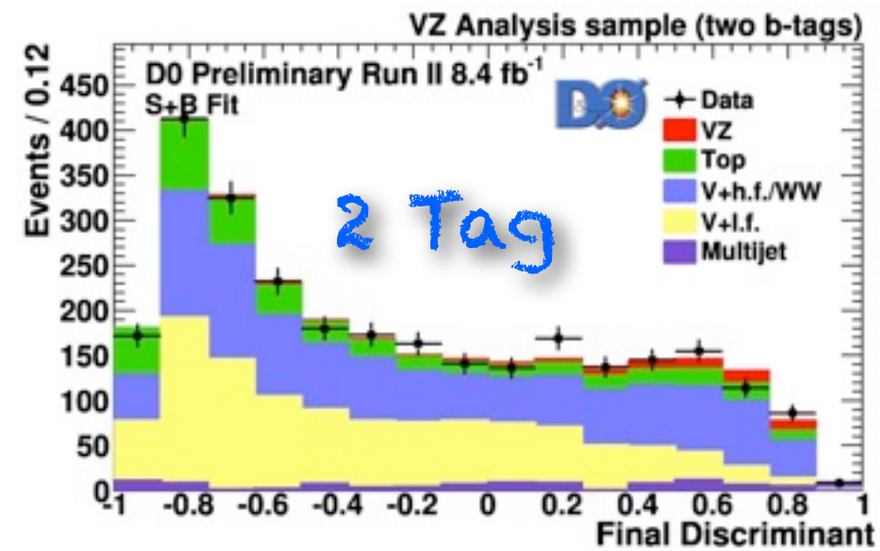
Diboson lvbb



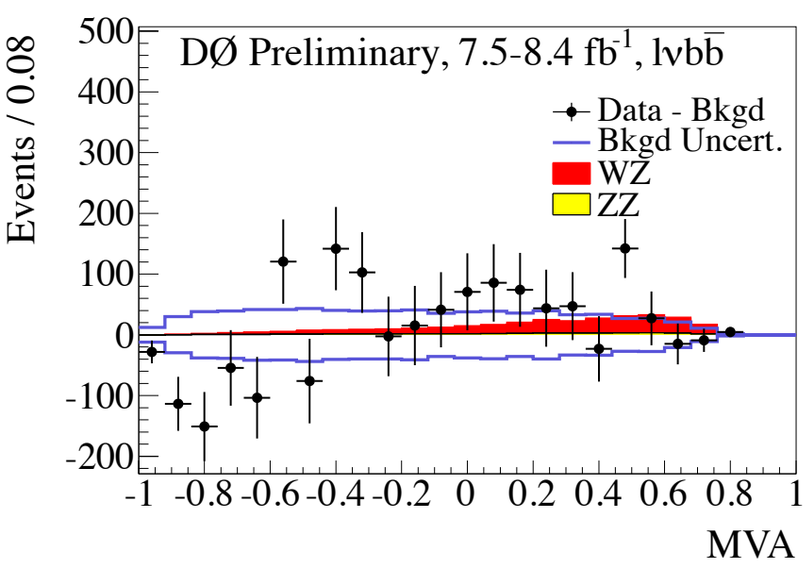
Diboson llbb

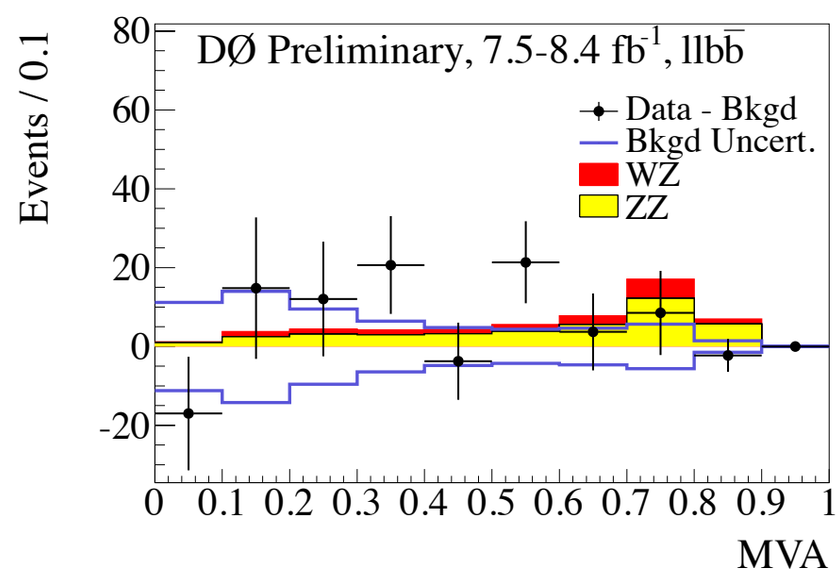


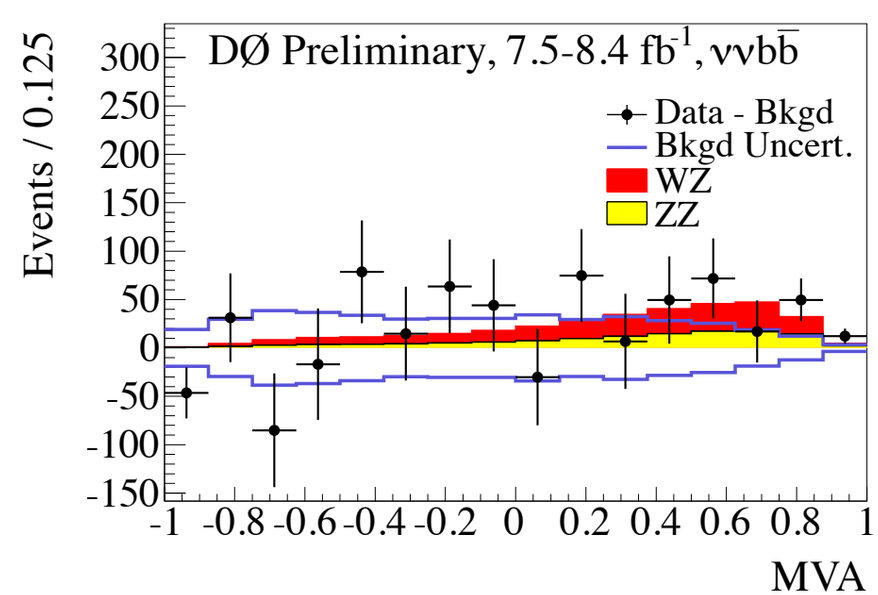
Diboson vvbb



Background Subtracted Distribution

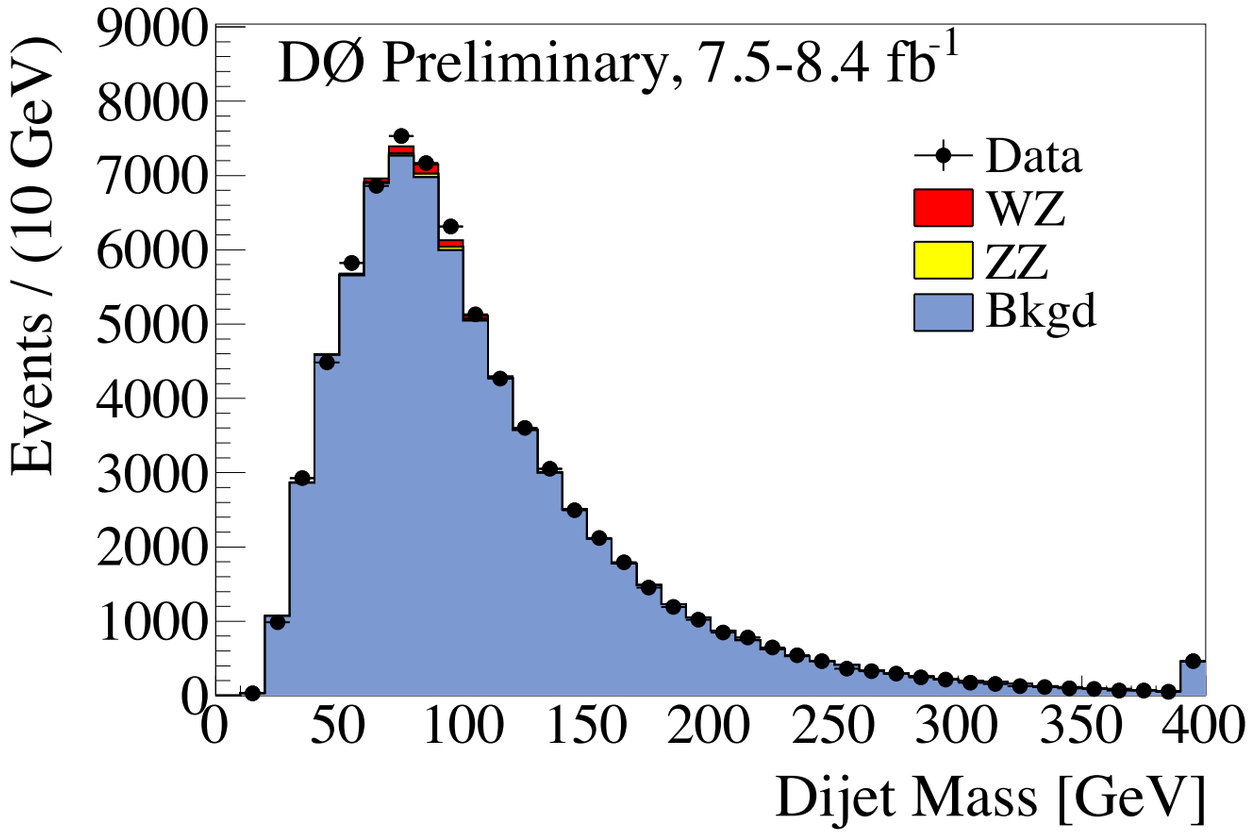






Combination

- Identical to Higgs searches too
- Global fit to final discriminants in all sub-channels
  - Theoretical uncertainties correlated
  - Experimental uncertainties (un-)correlated
- Main uncertainties: b-tagging, Jet Energy Scale and Resolution, heavy/light flavor ratio



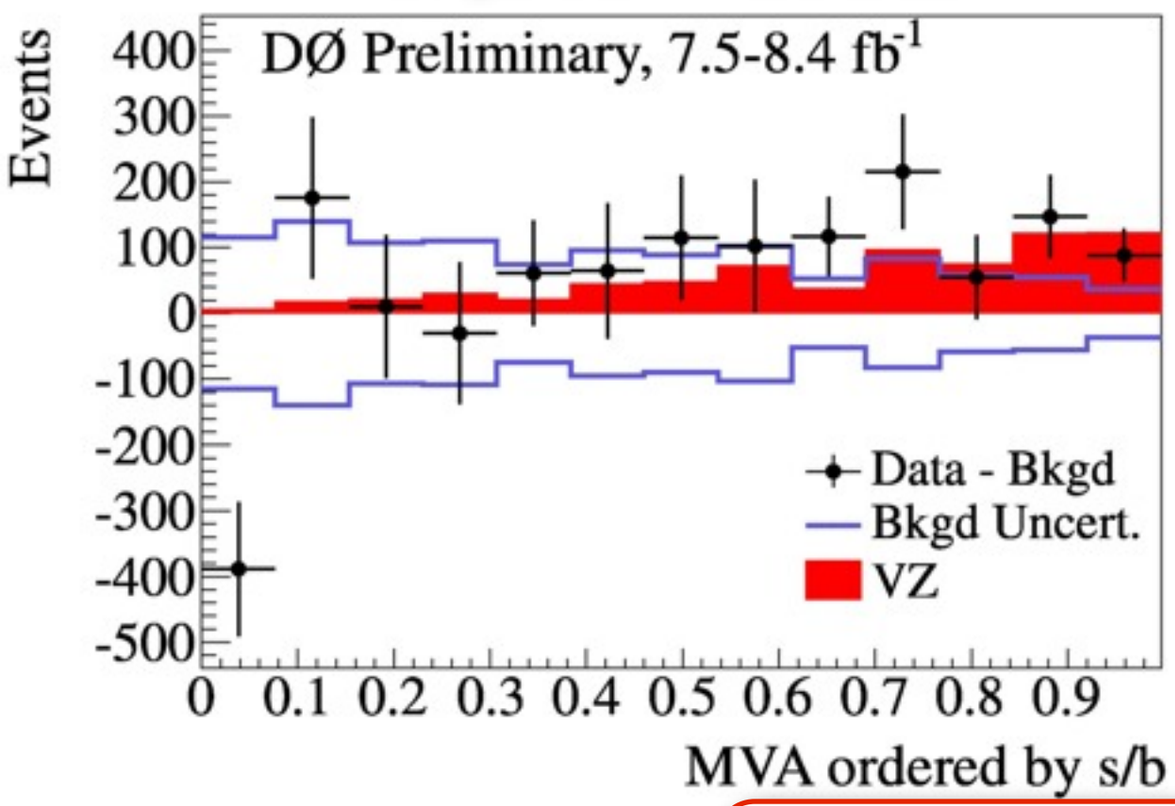
Combined analyses: M(jj)

Combination

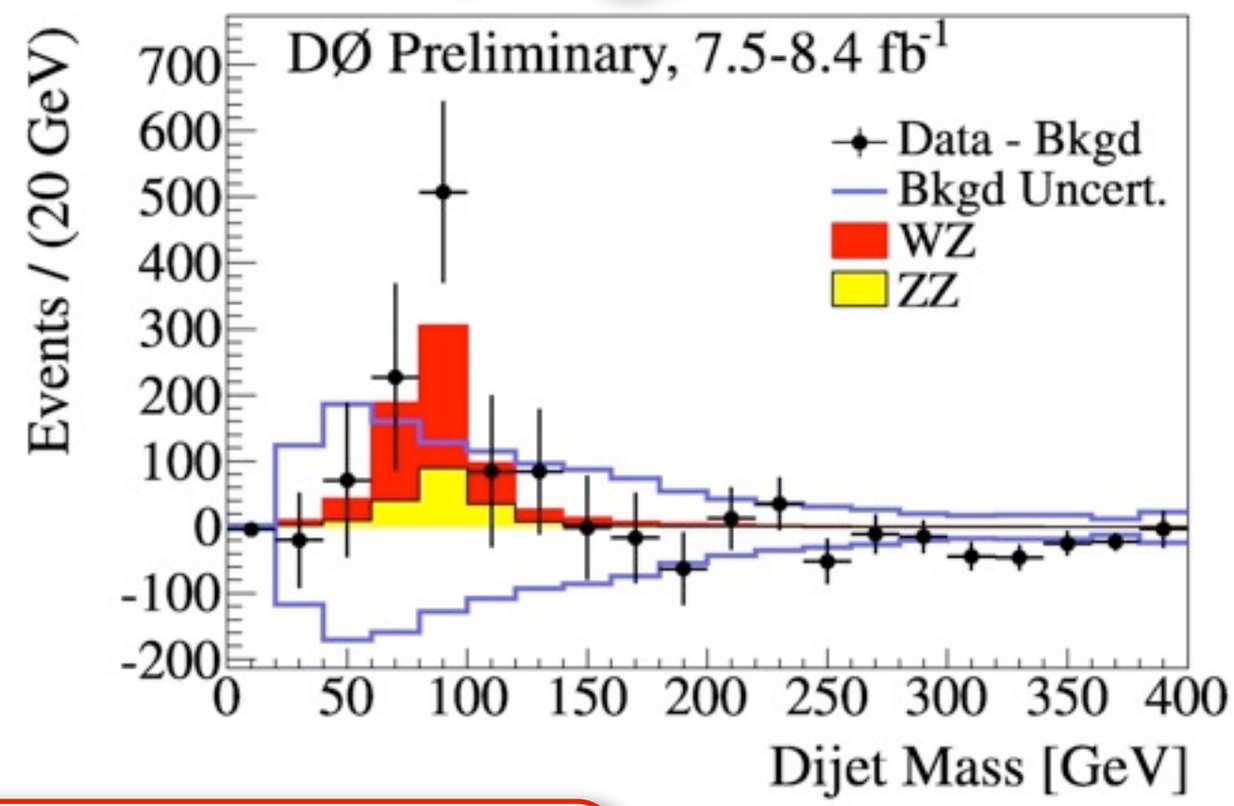
arXiv:1204.4496v1

- Combining all three channels
- Maintaining proper correlation among channels

Post fit MVA distribution



Post fit M(jj) distribution



$\sigma^{MVA}_{(WZ+ZZ)} = (1.13 \pm 0.36) \times \sigma_{SM}$

3.3σ Evidence (exp. 2.9σ)

SM@NLO :
σ (WZ + ZZ) = 4.4 ± 0.3 pb

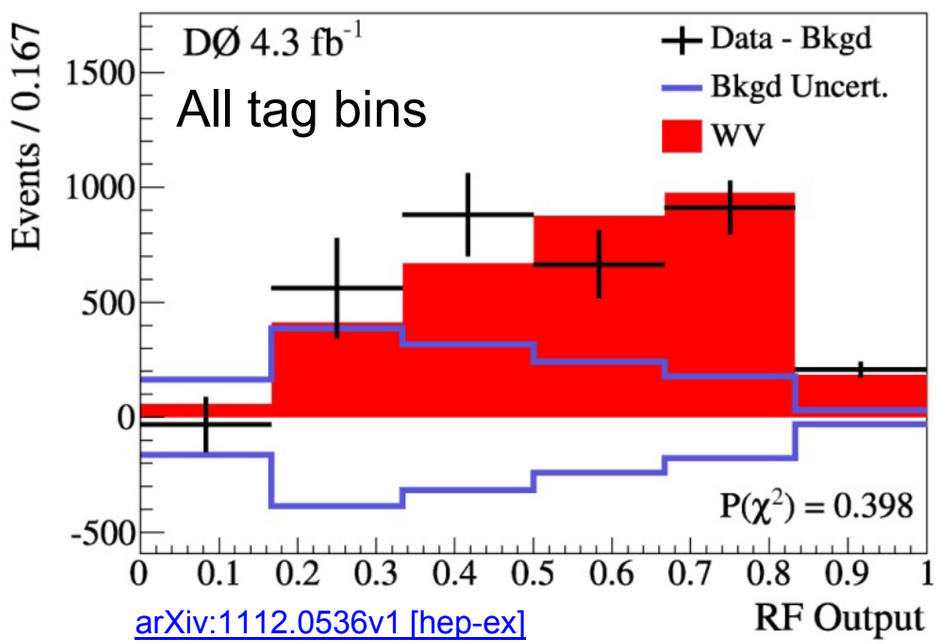
Summary

- Looking (W/Z)Z with Z→bb provides ultimate test for our Higgs searches
- Very 'Higgs-like' final state with comparable σ
- Using identical techniques as Higgs searches in validation of procedures and techniques
- Evidence for (W/Z)Z with Z→bb production

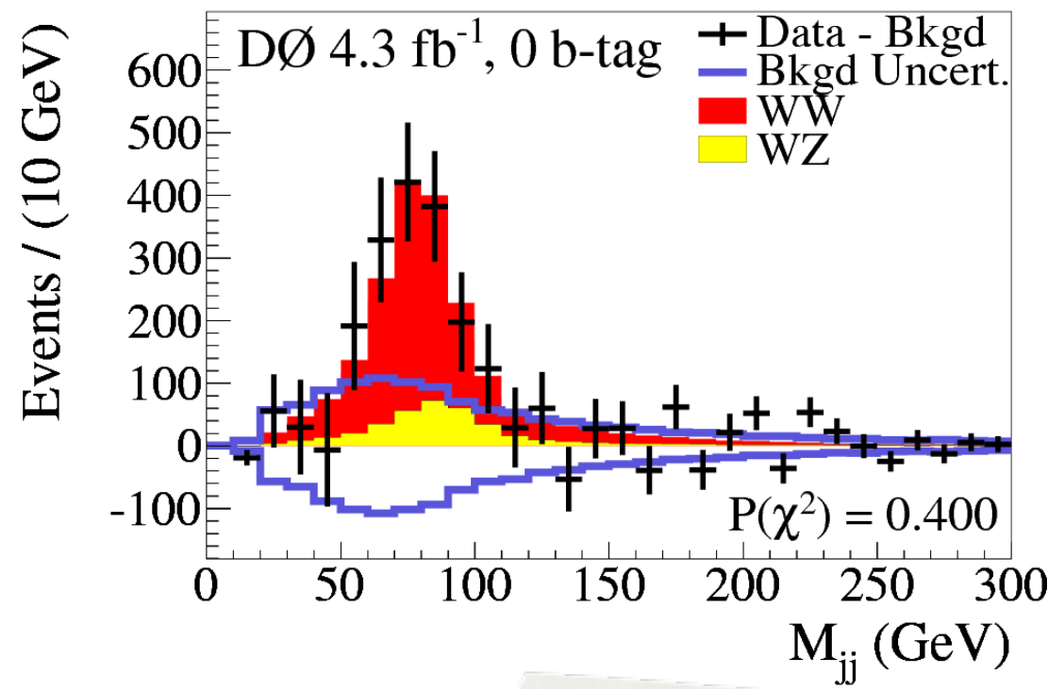
Backup

Towards Today's Measurement

- High p_T muon/electron $+E^T_{miss}$+2/3 jets
- b-tagging to enrich heavy flavor contributions
- Perform fit to Random Forest and Mjj distribution
- Cross section measured in NT, ST, DT channels

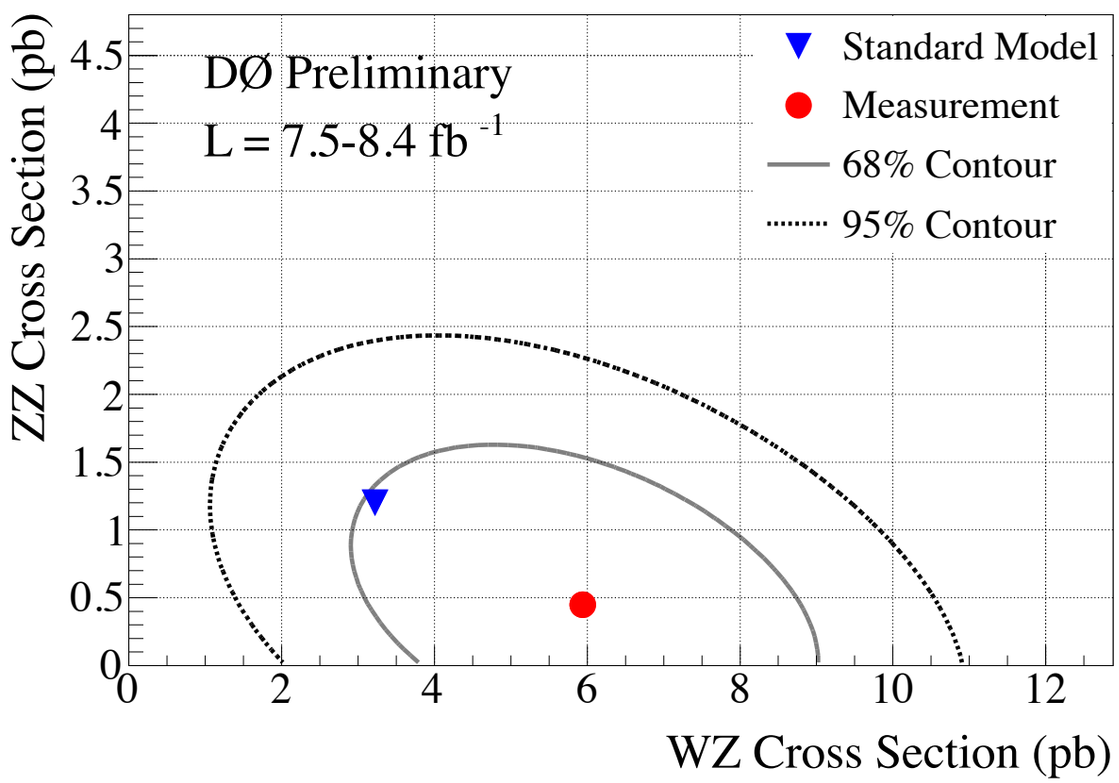


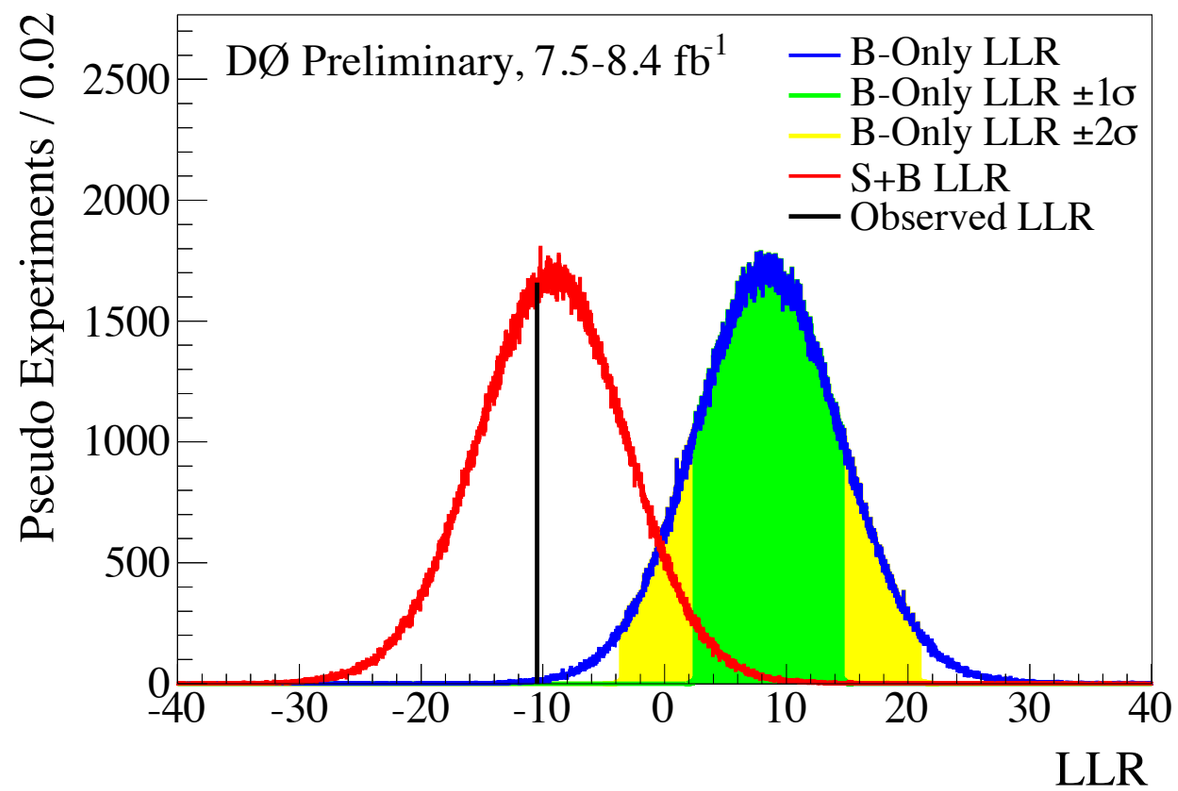
arXiv:1112.0536v1 [hep-ex]



$\sigma^{RF}_{(WW+WZ)} = 19.6^{+3.2}_{-3.0}$pb
$\sigma^{jj}_{(WW+WZ)} = 18.3^{+3.8}_{-3.6}$pb

$\sigma^{RF}_{(WW+WZ)} = 15.9^{+3.7}_{-3.2}$pb
$\sigma^{jj}_{(WW+WZ)} = 3.3^{+4.1}_{-3.3}$pb


DØ Preliminary
L = 7.5-8.4 fb -1
Standard Model
Measurement
68% Contour
95% Contour
ZZ Cross Section (pb)
WZ Cross Section (pb)
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
0
2
4
6
8
10
12


DØ Preliminary, 7.5-8.4 fb-1
B-Only LLR
B-Only LLR ±1σ
B-Only LLR ±2σ
S+B LLR
Observed LLR
Pseudo Experiments / 0.02
LLR
0
500
1000
1500
2000
2500
-40
-30
-20
-10
0
10
20
30
40