



Search for Standard Model

$$ZH \rightarrow l^+ l^- b \bar{b} \text{ at D}\text{\O}$$



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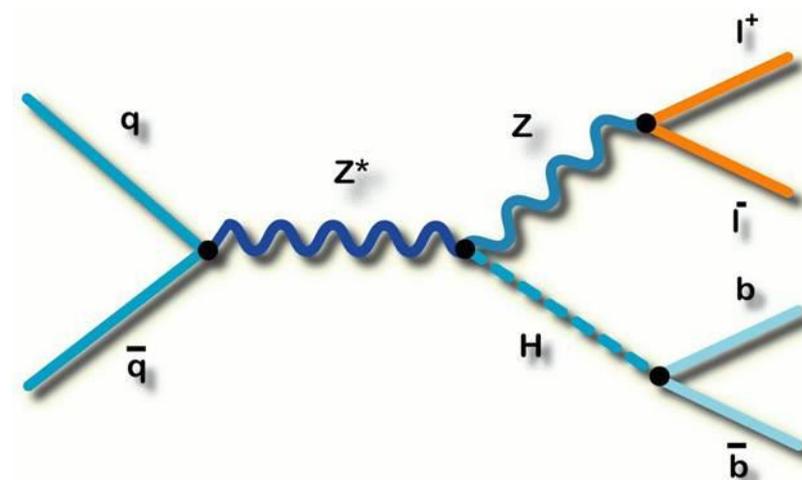
On behalf of the DØ Collaboration

DIS2014



Outline

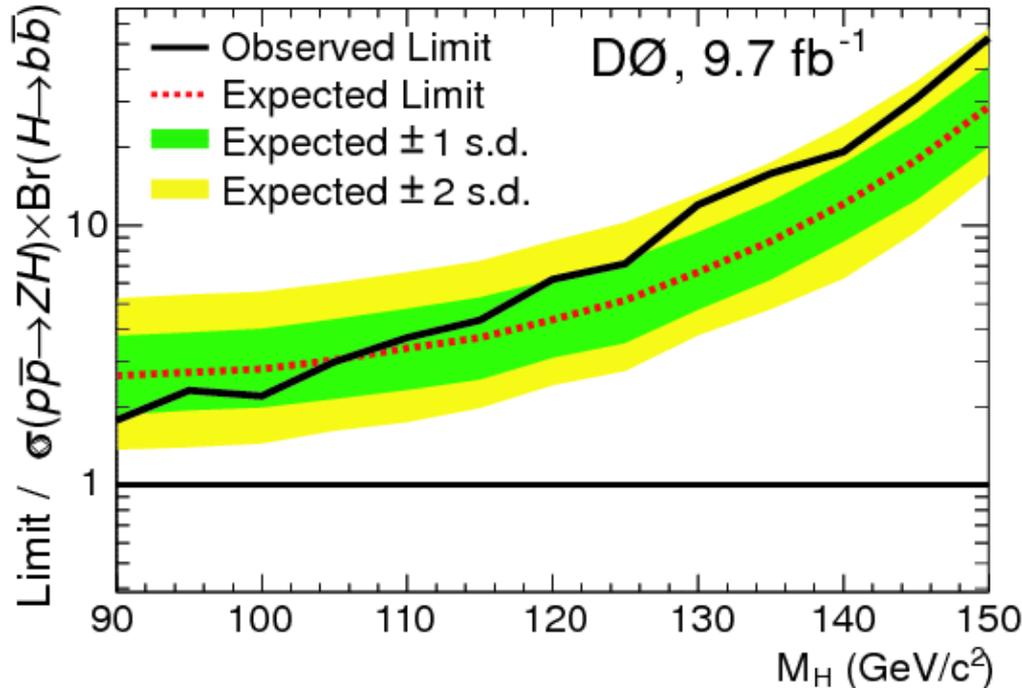
- Publication Results
- Reprocessed Data
- Event Selection & SM Background
- b-Tagging Optimization
- Kinematic Fit & Multivariate Analysis
- Results & Summary





Publication Results

Higgs Search in $ZH \rightarrow llbb$ channel



- Two publications with 9.7 fb^{-1} data:
 - [Phys. Rev. D 88, 052010 \(2013\)](#)
 - [Phys. Rev. Lett. 109, 121803 \(2012\)](#)

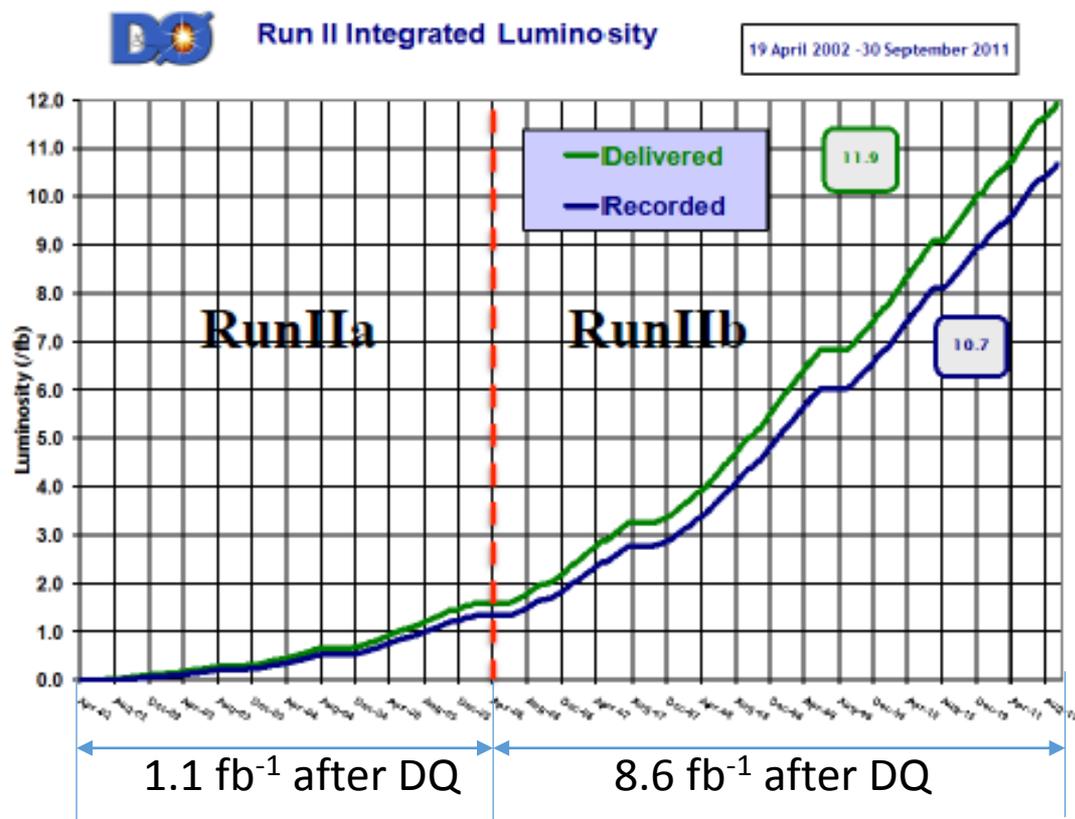
- Higgs discovered at LHC July 2012 through $\gamma\gamma$, ZZ and WW channels with mass of $125 \text{ GeV}/c^2$.
- Evidence from Tevatron in $H \rightarrow b\bar{b}$ in July 2012
 - ◆ DØ combination
[Phys. Rev. Lett. 109, 121802 \(2012\)](#)
 - ◆ Tevatron combination
[Phys. Rev. Lett. 109, 071804 \(2012\)](#)



Reprocessed Data

- RunIb reprocessed data

- Total 8.6 fb^{-1} , after data quality(DQ) requirements
- Analysis improvements from reprocessing:
 - Better vertexing algorithm.
 - Improved alignment for inner tracking detectors, reduce track impact parameter resolution by up to 15%
 - New Track-in-Road, improving the lepton efficiency in reconstruction.

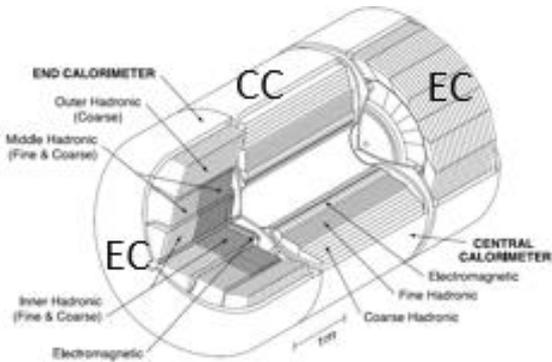




Event Selection

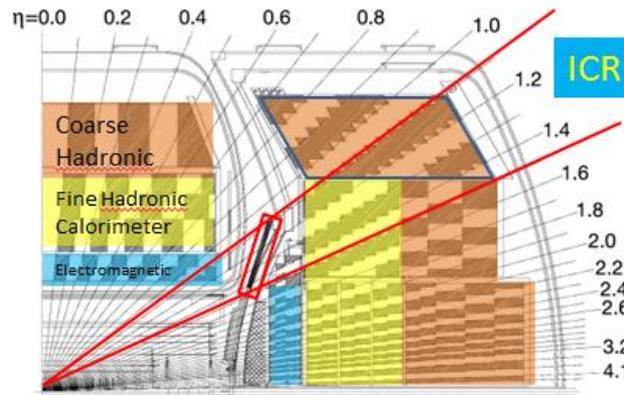
ee channel:

Two Electrons, CC-CC and CC-EC, leading electron $p_T > 15$ GeV, second CC electron $p_T > 10$ GeV, second EC electron $p_T > 15$ GeV with looser EMID quality cuts.



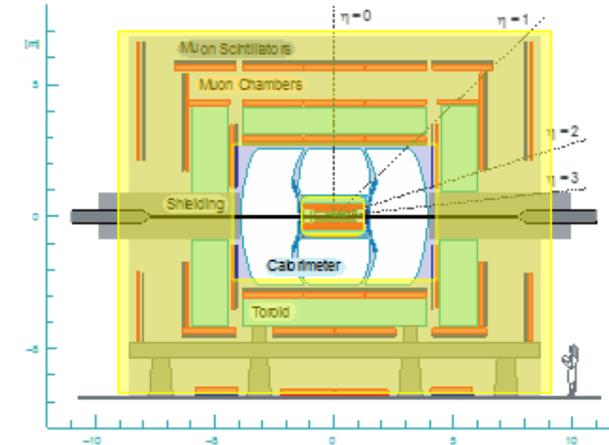
ee_{ICR} channel:

Two Electrons with $p_T > 15$ GeV, one in CC, one in ICR Region (between red lines)



$\mu\mu$ channel:

Two muons with $p_T > 10$ GeV, $|\eta| < 2.0$, at least one with $p_T > 15$ GeV, $|\eta| < 1.5$

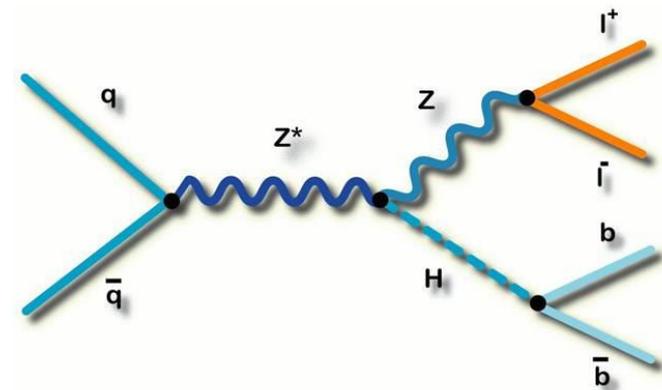


• Z candidate

- Mass window cut: 70-110 GeV
- $dZ(PV, e) < 1$ cm for electron has trackmatch.

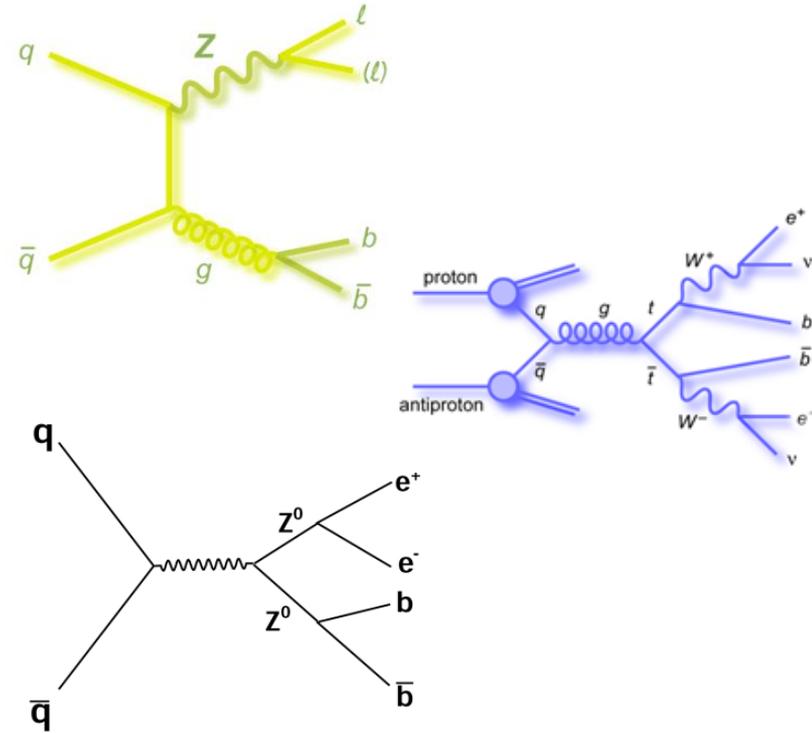
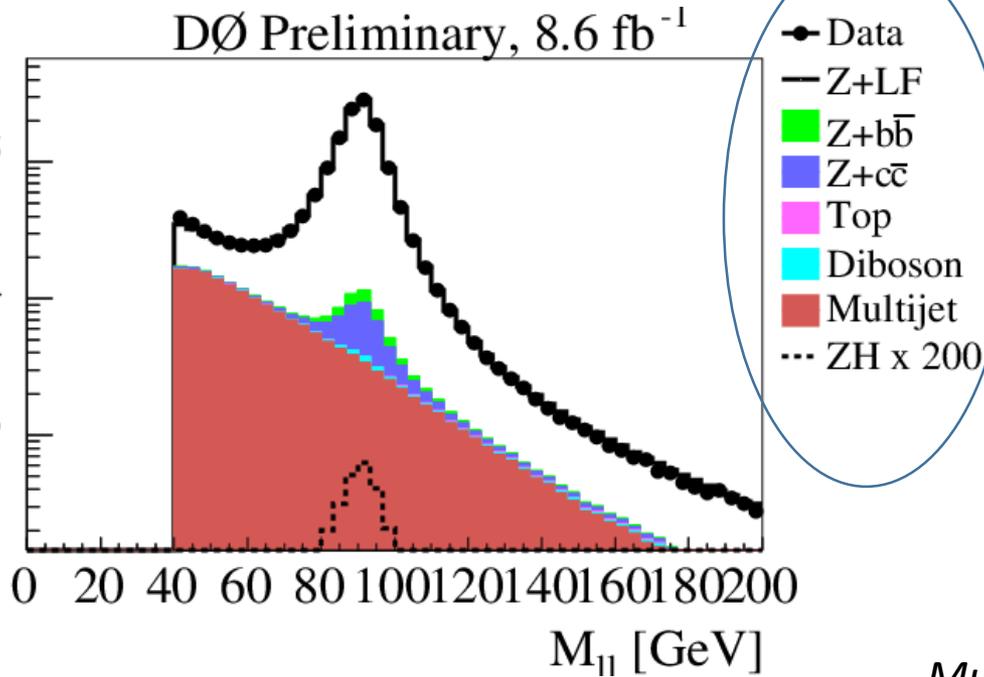
• Jets:

- At least two jets $p_T > 20$ GeV and $|\eta| < 2.5$
- At least two tracks match primary vertex, $dR(e, j) > 0.5$





SM backgrounds



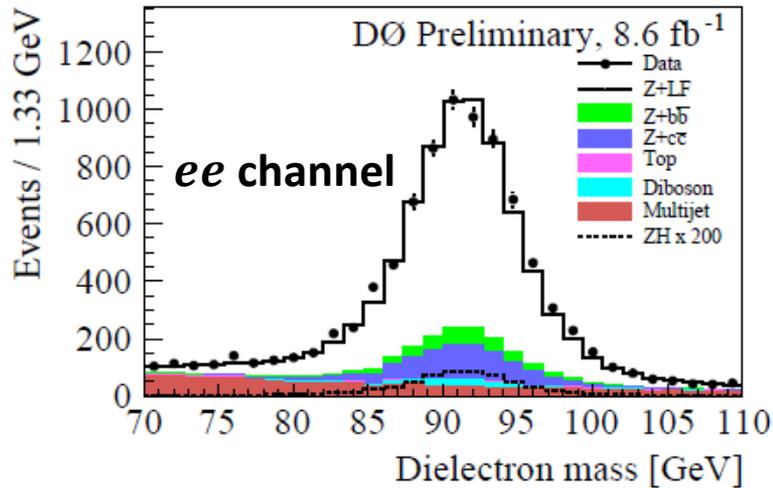
Multijet backgrounds are estimated from data.

➤ Background Normalization:

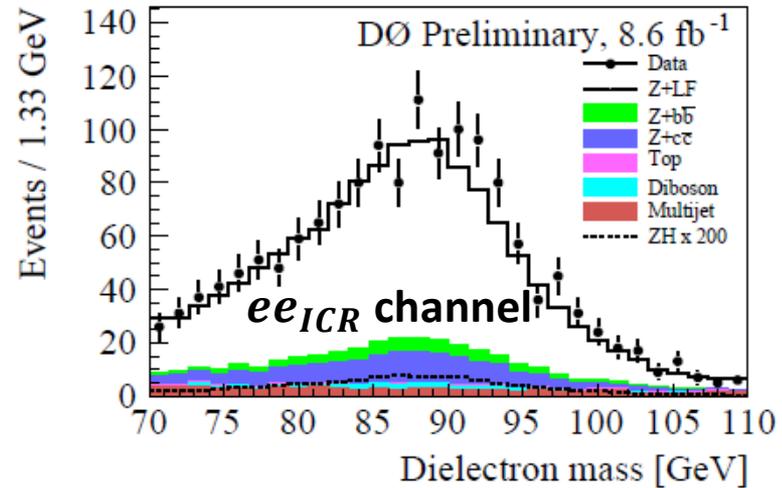
- Fit to the dilepton invariant mass
- Multijet samples normalized in the low-mass tail
- MC backgrounds normalized in the Z peak region



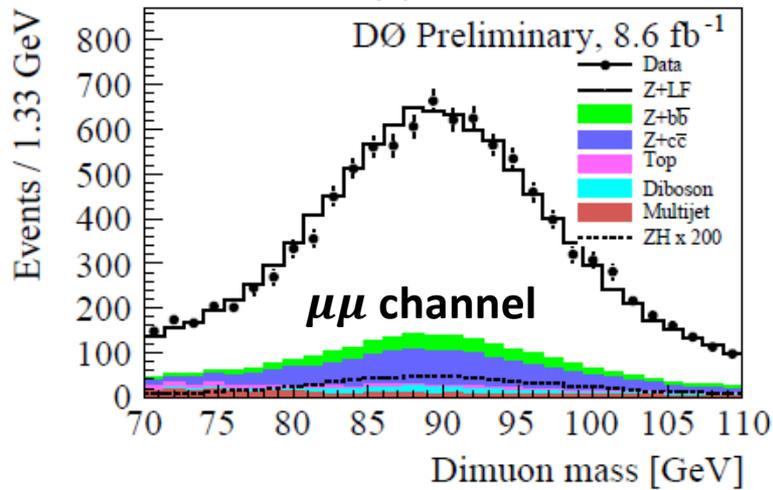
Dilepton and Dijet Invariant Mass



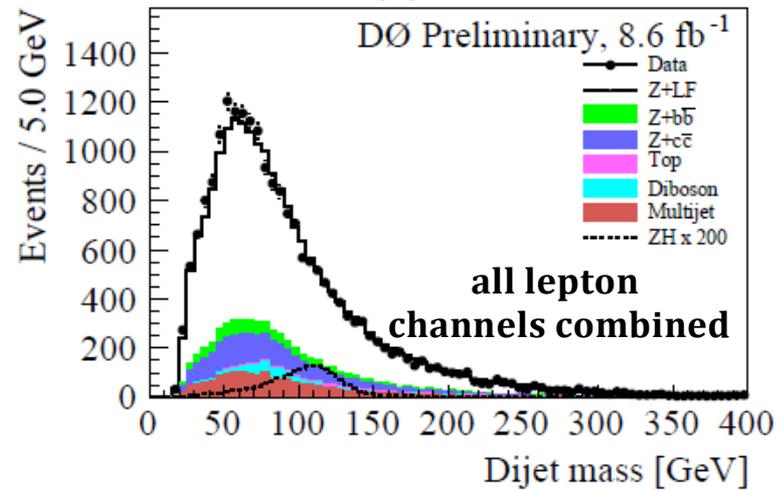
(a)



(b)



(c)



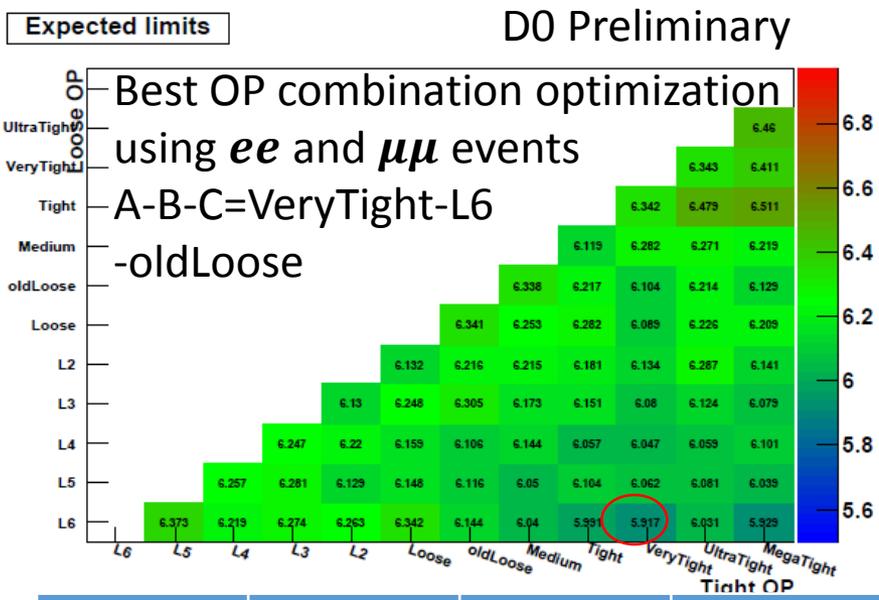
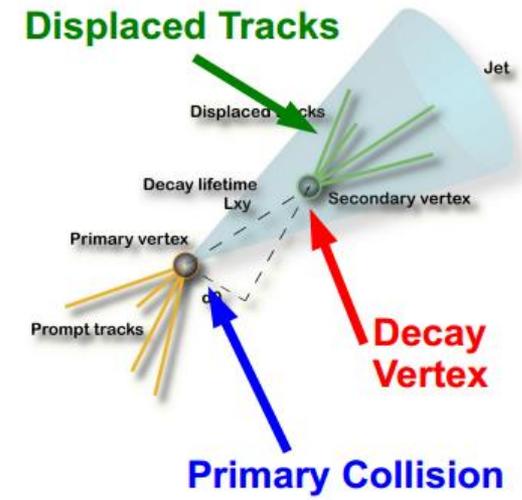
(d)



b-Tagging Optimization

- Improved MVA b-tagging tool
 - Impact parameter
 - Reconstructed decay vertex

Super new



OP name	VeryTight	L6	oldLoose
Efficiency	60%	80%	70%
Fake Rate	1%	8%	2%

- Loose-Tight (LT) sample:
 - One b-tagged jet satisfy tight operating point A
 - Another b-tagged jet satisfy loose operating point B.
- Single-Tight(ST) sample:
 - Not in the LT sample
 - At least one b-tagged jet satisfy a tight operating point C.

Note: Efficiency/Fake Rate vary for different pT and η



Kinematic Fit

Before Kinematic Fit

After Kinematic Fit

- Three Constraints:

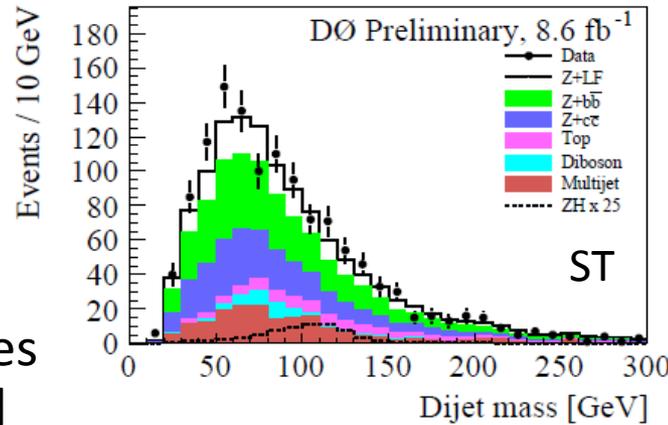
$$M_{di-electron} = M_z,$$

$$\sum P_x = 0,$$

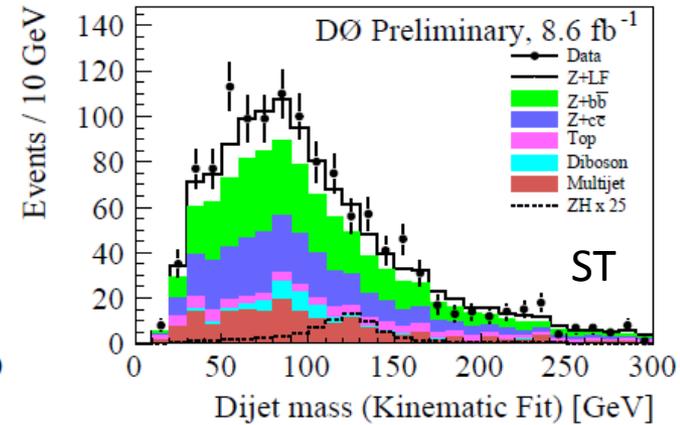
$$\sum P_Y = 0$$

- The energies and angles of the two leptons and the two jets are allowed to vary within their experimental resolutions in the fit.

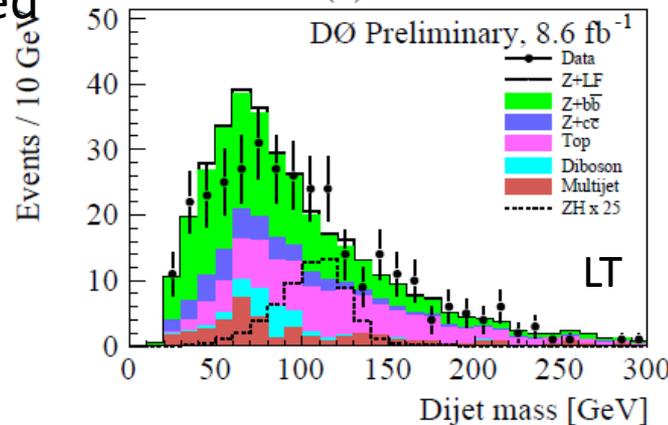
- Improving the dijet mass resolution $\sim 12\%$ for $M_H=125$ GeV



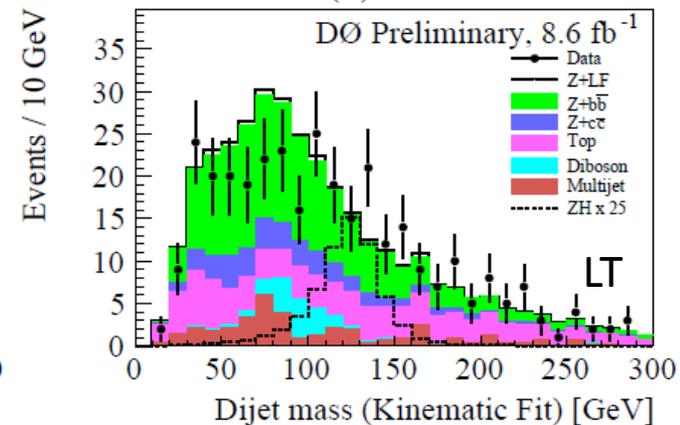
(a)



(b)



(c)



(d)



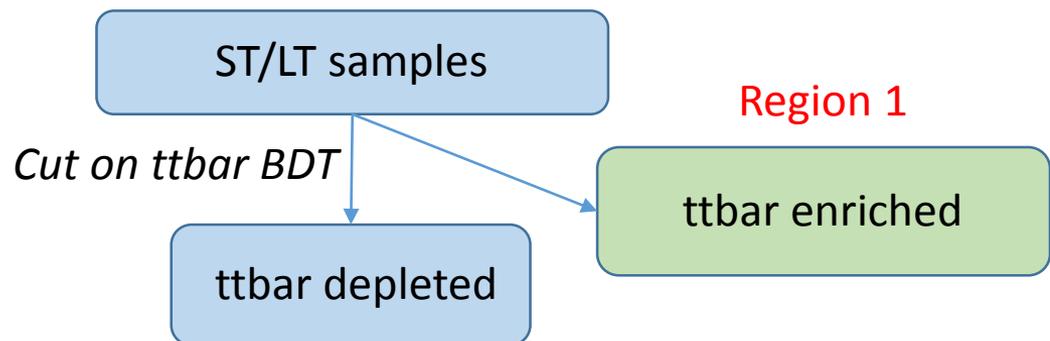
Second Step

Multivariate Analysis

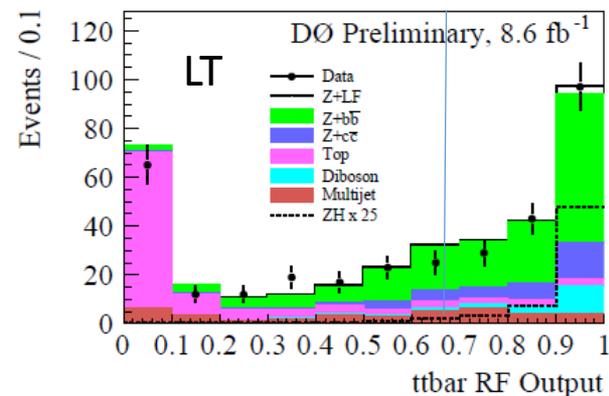
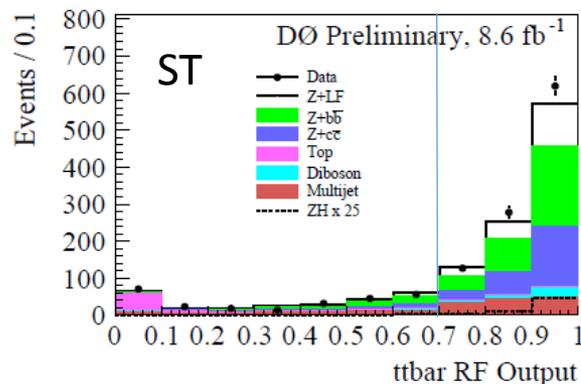
First Step

- Four intermediate BDTs:
 - $t\bar{t}b\bar{b}$ VS ZH
 - Z+bb VS ZH
 - Z+cc/LF VS ZH
 - Diboson VS ZH
- Training using all ST/LT samples for four intermediate BDTs.
- Best cut value read from TMVA for highest significance.

- Final discriminant trained for five separated regions(all background VS ZH)



ttbar BDT

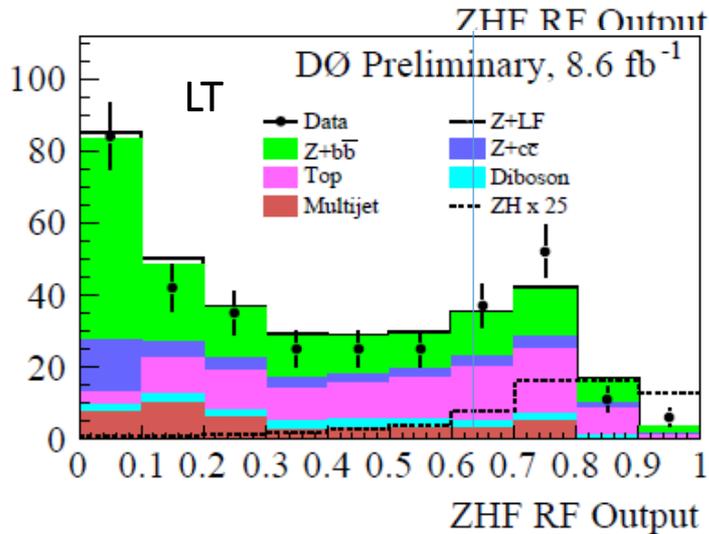
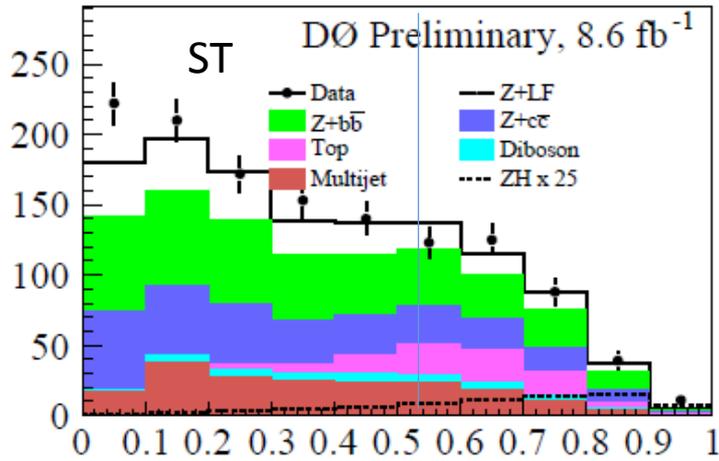




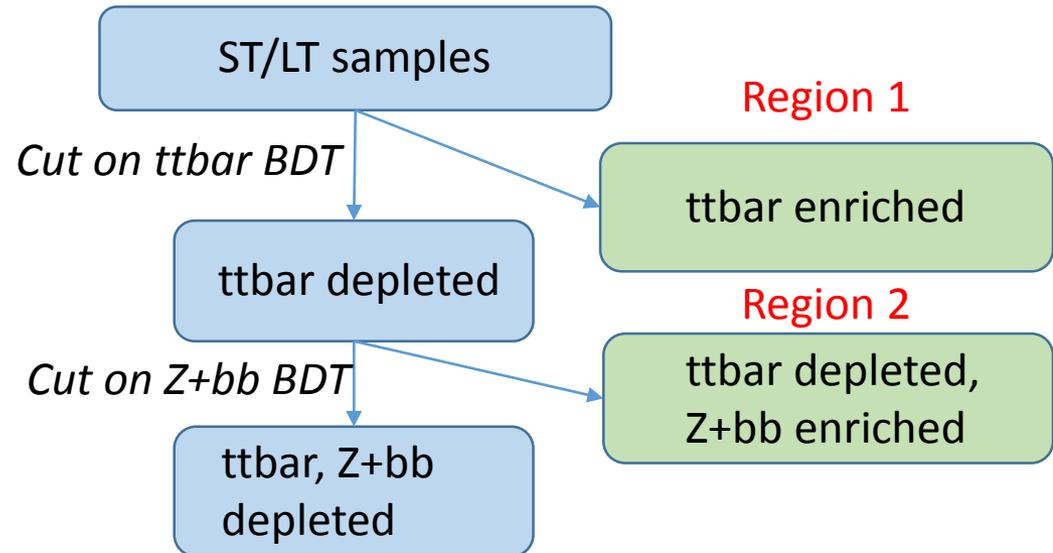
Second Step

Multivariate Analysis

Z+bb BDT



- Final discriminant trained for five separated regions (all background VS ZH)



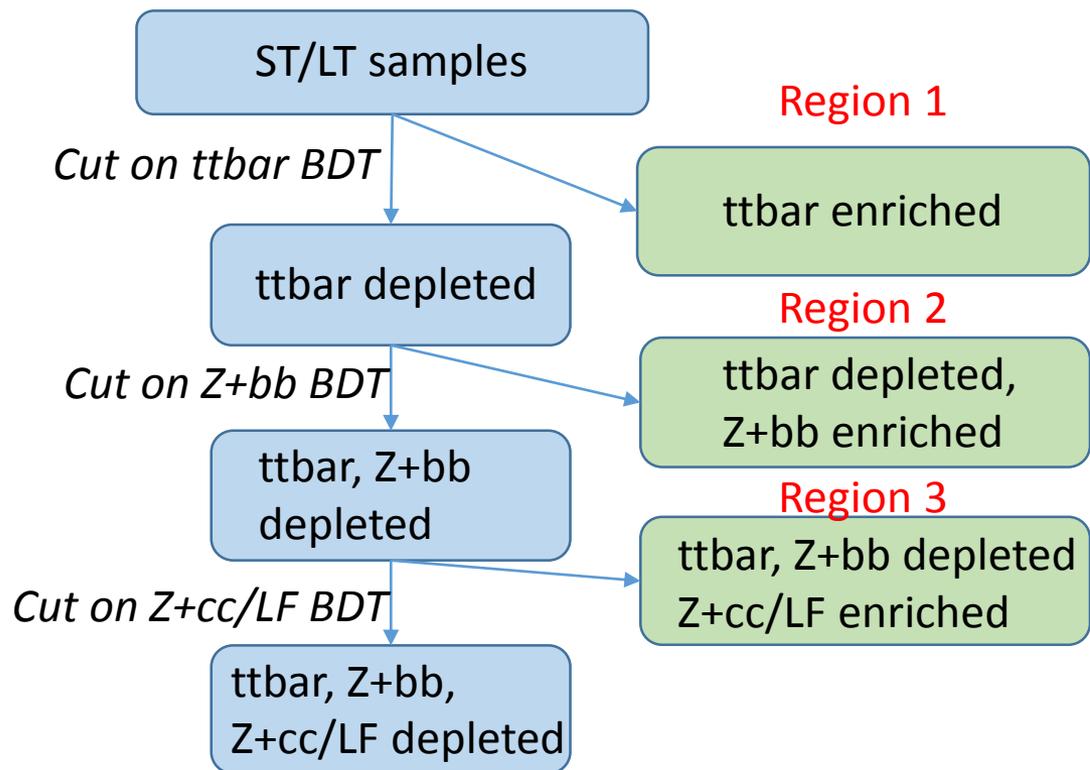
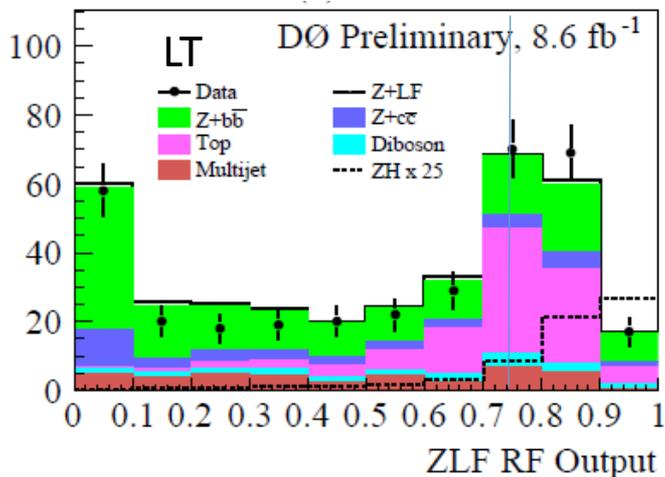
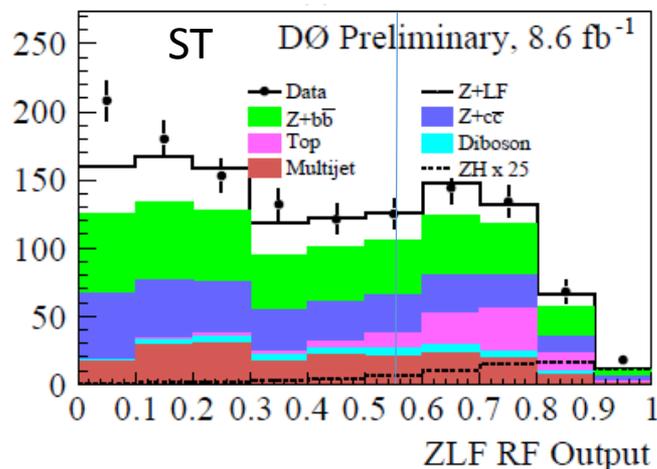


Second Step

Multivariate Analysis

- Final discriminant trained for five separated regions (all background VS ZH)

Z+cc/LF BDT

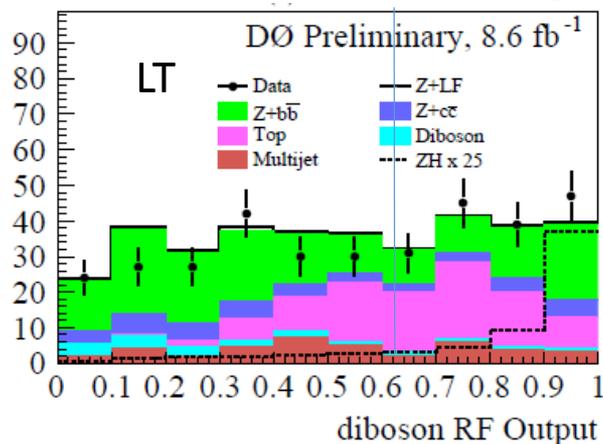
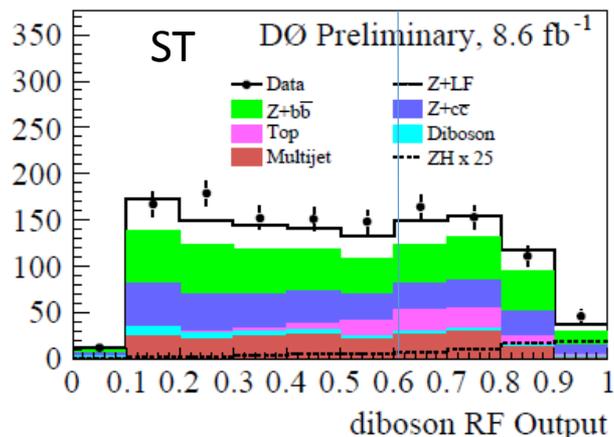




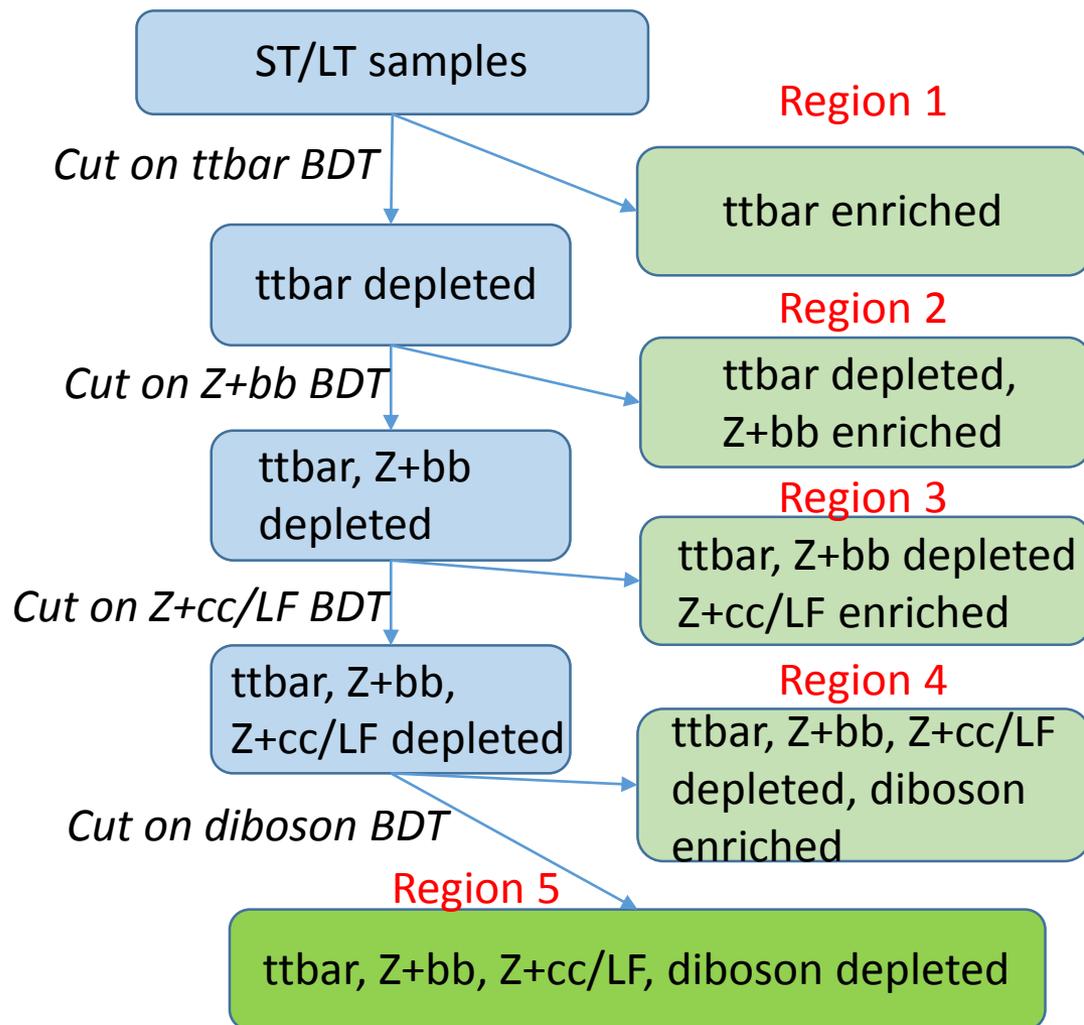
Second Step

Multivariate Analysis

diboson BDT



- Final discriminant trained for five separated regions (all background VS ZH)



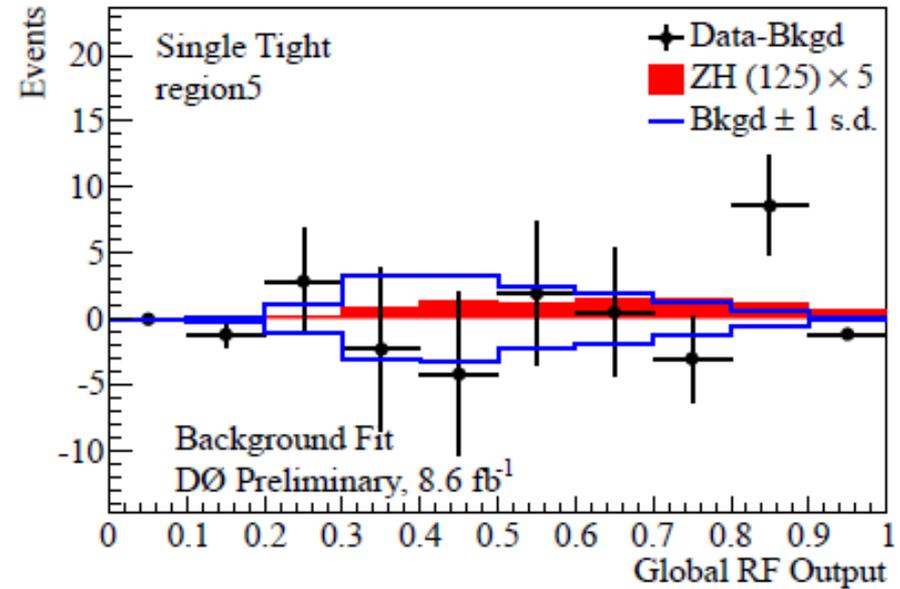
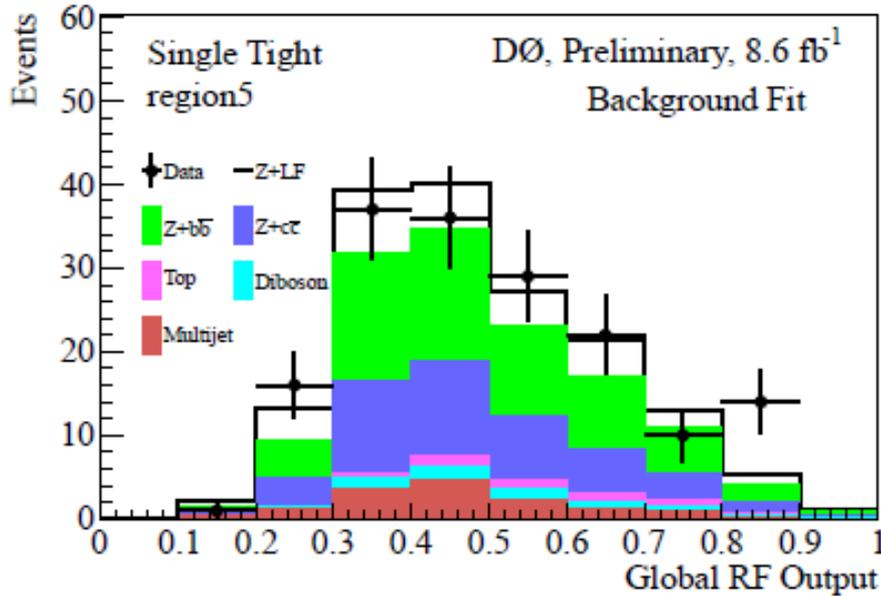


Final discriminant and expected limits

e.g. ST Region5

After fit to background-only hypothesis

Background-subtracted



MH=125GeV 95% C.L.	Non-reprocessed Analysis	Reprocessed Analysis
AWW Approximation Expected Limits (8.6fb ⁻¹)	5.64	5.38 (improved by ~5%)

Note: Limit are quoted over SM cross section time branching ratio.



Summary

- ZH- \rightarrow llbb analysis with 8.6 fb^{-1} reprocessed data:
 - Better reconstruction algorithm in reprocessing
 - Revised the events selection
 - New b-tagging optimization
 - New multivariate analysis strategy
- Comparing with non-reprocessed analysis, we estimate that the expected limits from this analysis are improved by about 5%.
- This analysis confirms that the results of publication are close to optimum.



Thank you!