Spin/parity of Higgs-like particle at D0

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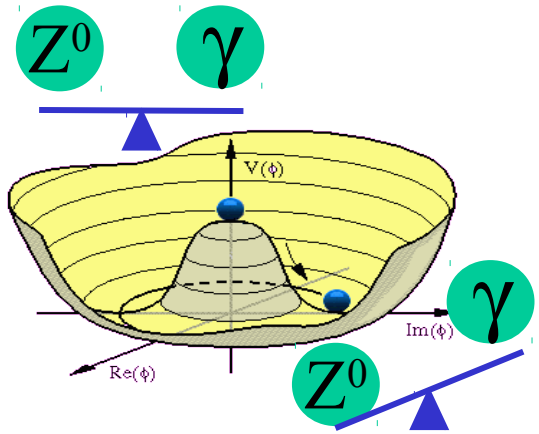
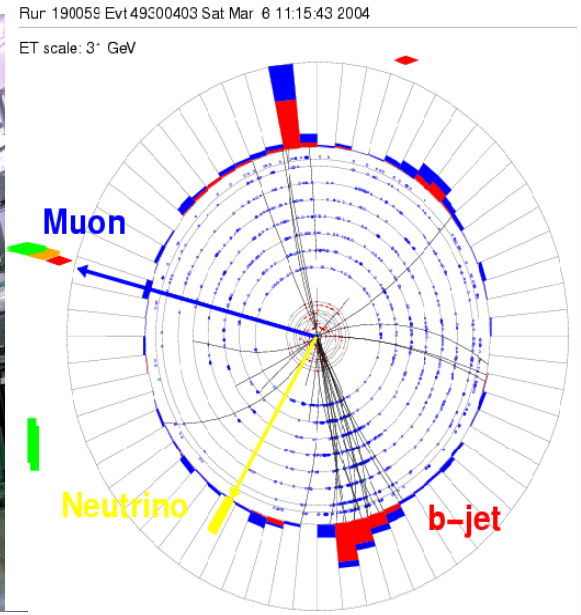
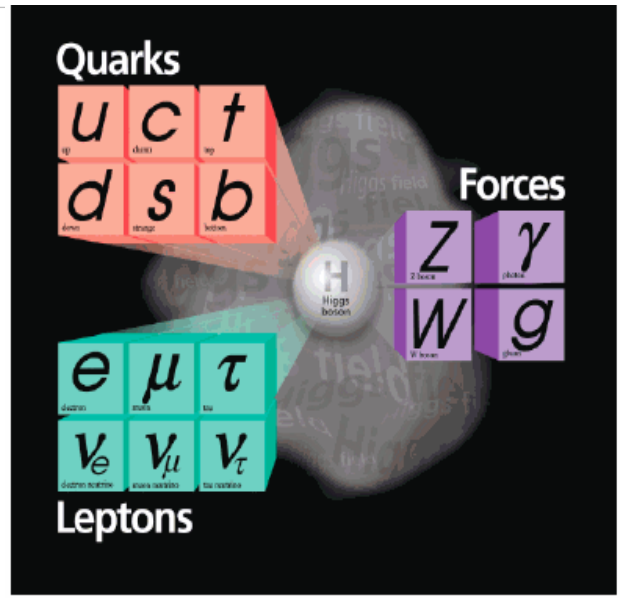
on behalf of the DØ collaboration



Special thanks to Ken Herner
for the preparation of this talk

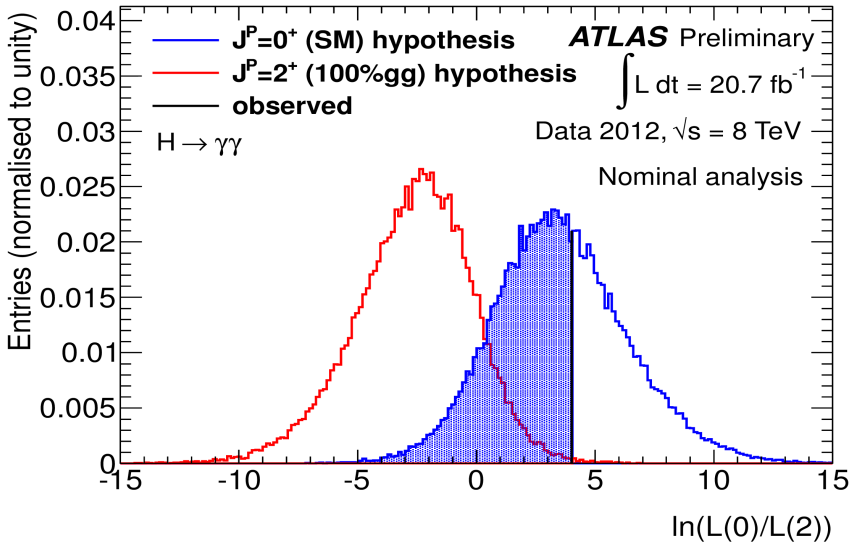


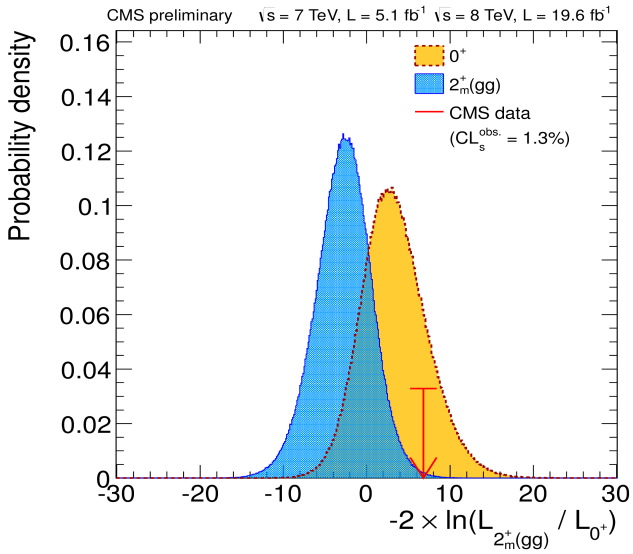


Motivation for spin-parity studies in $b\bar{b}$

- With the discovery of a new boson of mass 125—126 GeV comes detailed studies of its properties
  - What is its mass?
  - What are its spin (J) and parity (P)?
  - What are the coupling strengths?

  Extensive spin-parity studies performed at LHC
  - The di-photon decay excludes J=1 by the Landau-Yang theorem
  - Results favor $J^P=0^+$ over $2^+,0^-,..$ in $H \rightarrow ZZ$, $H \rightarrow WW$, $H \rightarrow \gamma\gamma$
    - under various hypotheses for production
  - No results yet for the $b\bar{b}$ decay mode
- Important to build a consistent picture in **all** expected Higgs boson decay modes

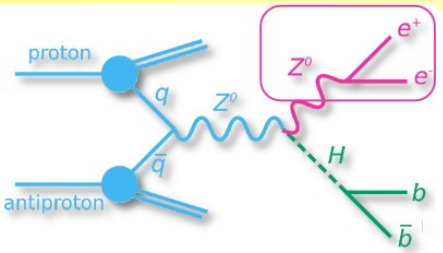




VH → Vbb̄ channels at the Tevatron

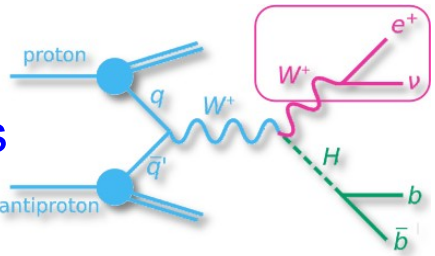
$p\bar{p} \rightarrow ZH \rightarrow \ell\ell b\bar{b}$

- 2 leptons + 2 bjets



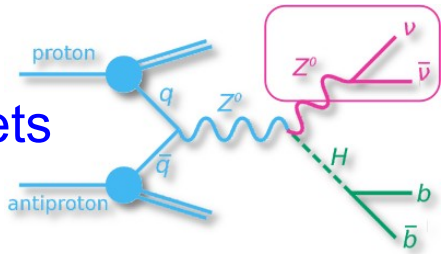
$p\bar{p} \rightarrow WH \rightarrow \ell\nu b\bar{b}$

- 1 lepton + $\not{E}_T$ + 2 bjets

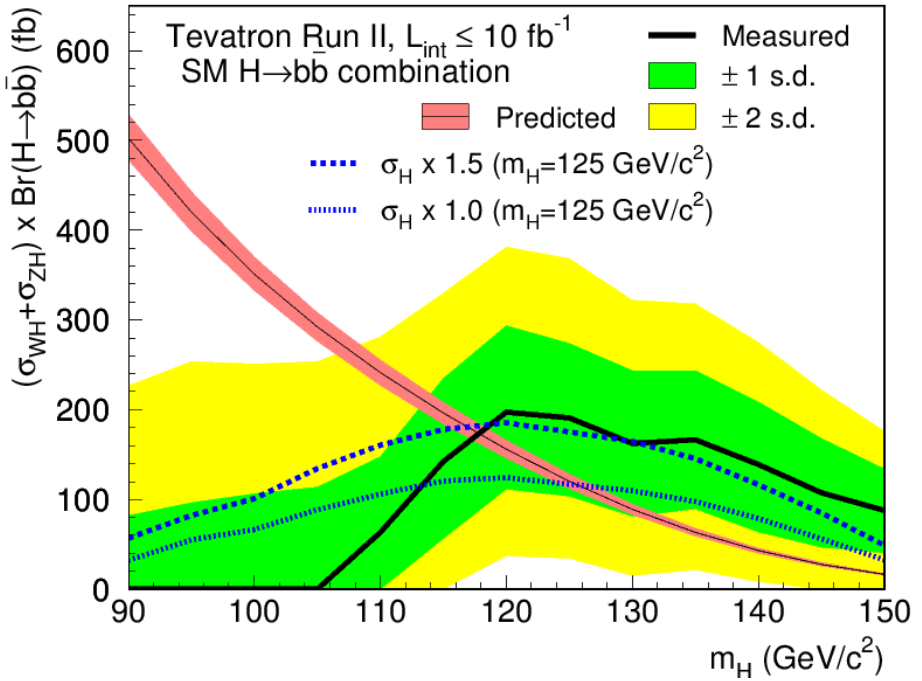


$p\bar{p} \rightarrow ZH \rightarrow \nu\nu b\bar{b}$

- 0 leptons + $\not{E}_T$ + 2 bjets



Signal strength measurement



$m_H = 125$ GeV	CDF	DØ	CDF+DØ
$R_{\text{fit}}(VH \rightarrow Vb\bar{b})$	$1.72^{+0.92}_{-0.87}$	$1.23^{+1.24}_{-1.17}$	$1.59^{+0.69}_{-0.72}$

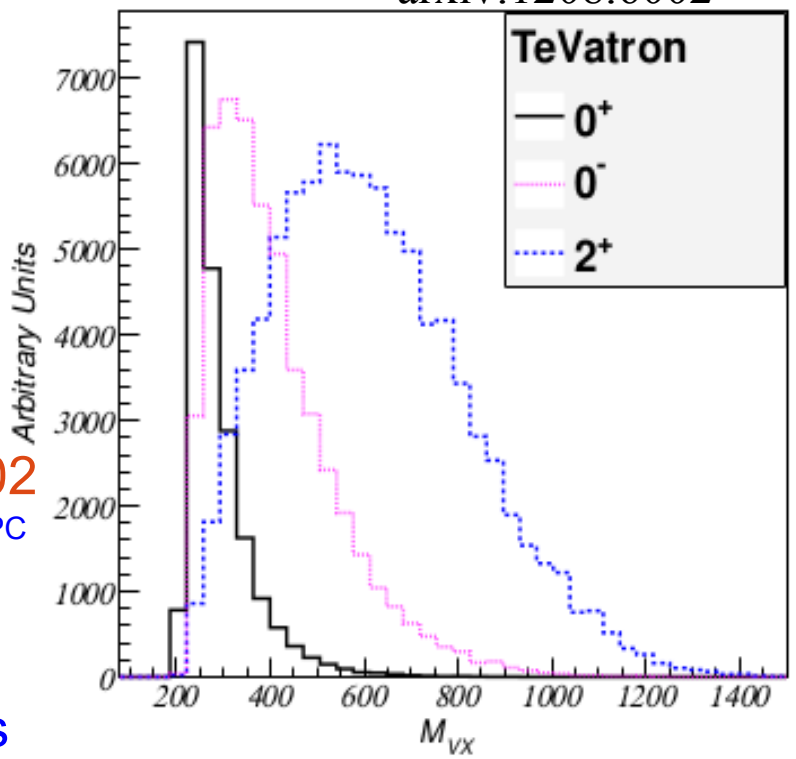
$VH \rightarrow Vb\bar{b}$ modes with full data set

- The most sensitive channels at Tevatron for M=125 GeV
- Tevatron has indication of $H \rightarrow b\bar{b}$ decay

Testing spin/parity at the Tevatron

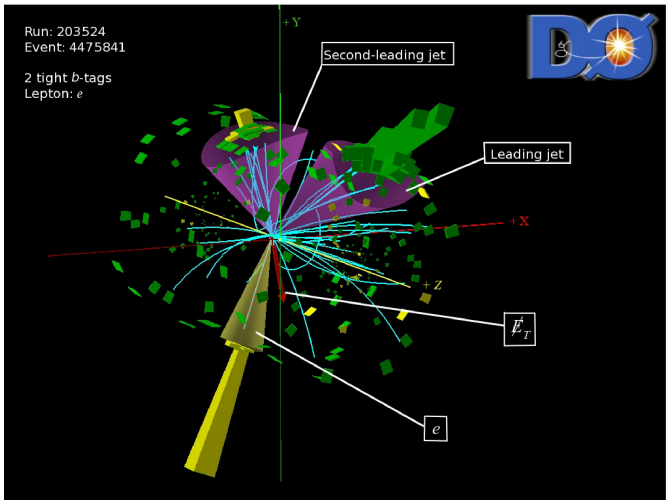
- Generally: spin/parity of particle can affect
  - Angles of decay products
  - Cross-section behavior at threshold
    - s-wave for 0^+: $\sigma \sim \beta$;
    - p-wave for 0^-: $\sigma \sim \beta^3$
    - d-wave for 2^+:$\sigma \sim \beta^5$
- $p\bar{p} \rightarrow VH$ quite sensitive to "threshold" effects
  - Paper by Ellis et al. http://arxiv.org/abs/1208.6002
  - Differential cross-sections depend strongly on J^{PC} of new particle
- Strategy
  - Re-use $VH \rightarrow Vb\bar{b}$ (published) search analyses
    - Perform the same selection as for the searches
  - Main discriminating variables at the end
    - Overall mass
    - Or overall transverse mass
    - Can use $M_{b\bar{b}}$ as a constraint to enhance S/B
- Assume σ x Br of SM Higgs boson in a first step
  - 2^+: Standard RS graviton in Madgraph
  - 0^-: Model by Ellis et al. implemented in Madgraph

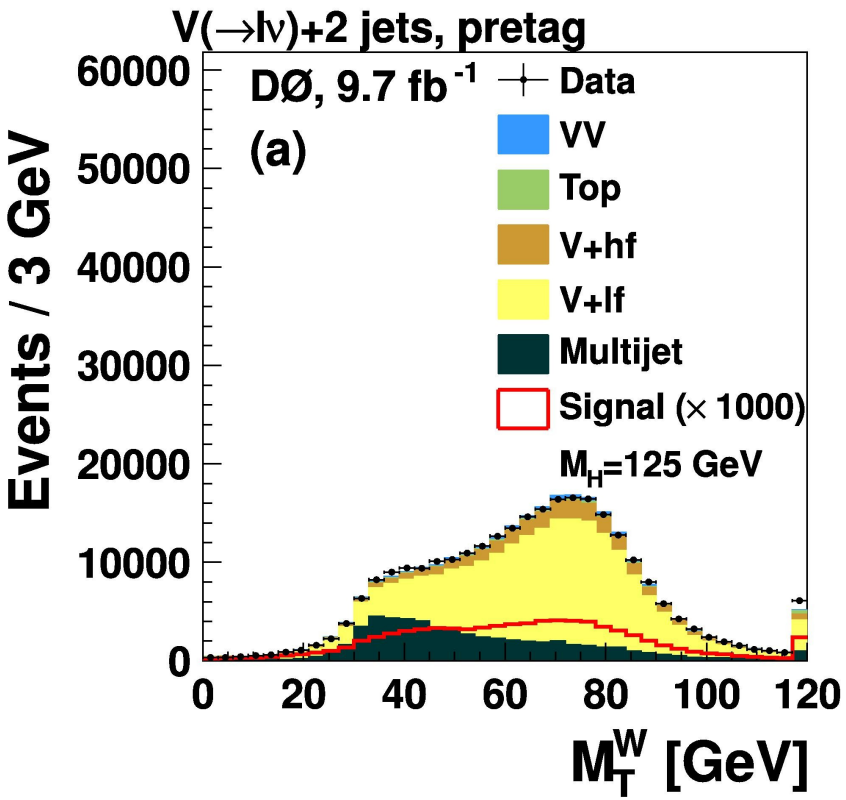
arxiv:1208.6002

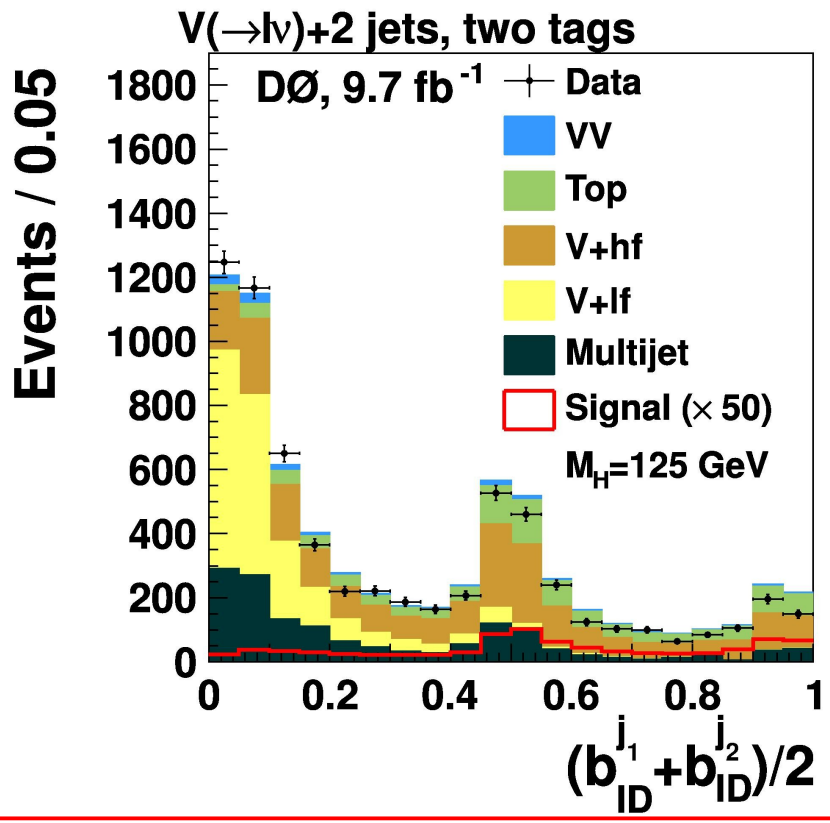


WH→ℓνbb̄ channel

- Selects isolated electron or muon, at least 2 jets, large MET
- Increase lepton acceptance with inclusive triggering
- Form 4 distinct sub-channels per lepton channel based on b-tagger outputs:
  - 1 tight, 2 loose, 2 medium, 2 tight

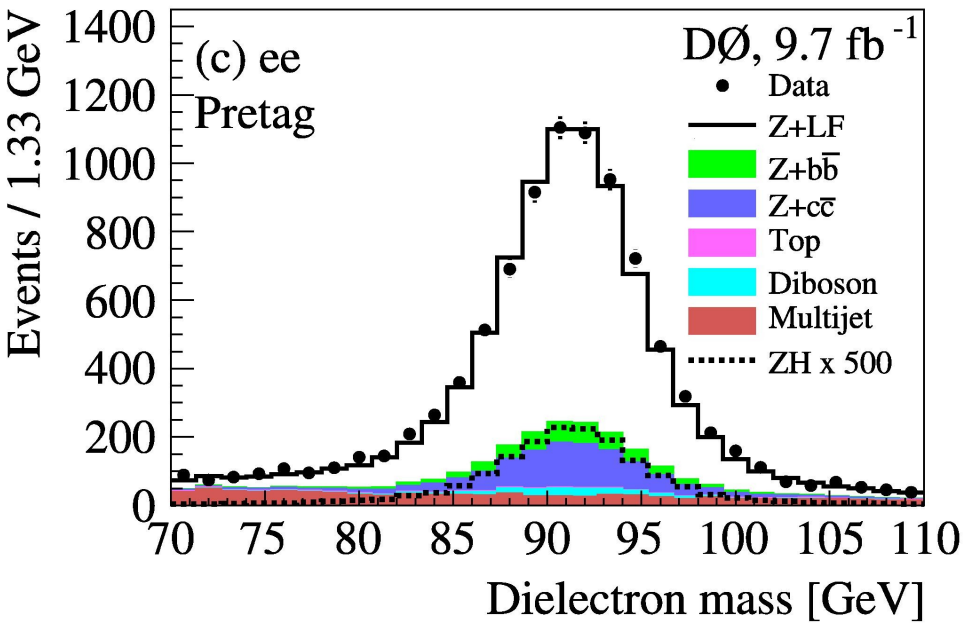


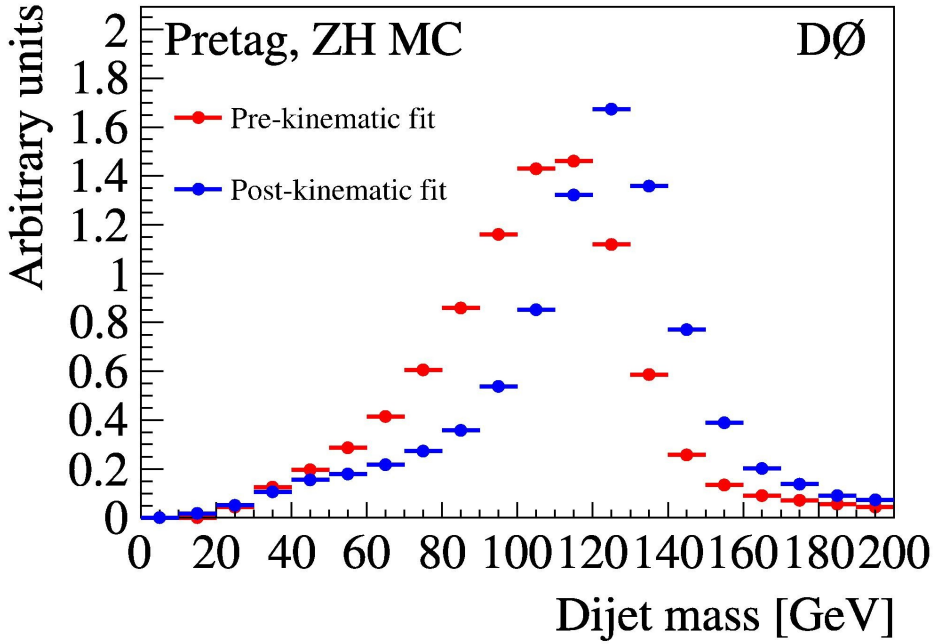




$ZH \rightarrow \ell\ell b\bar{b}$ channel

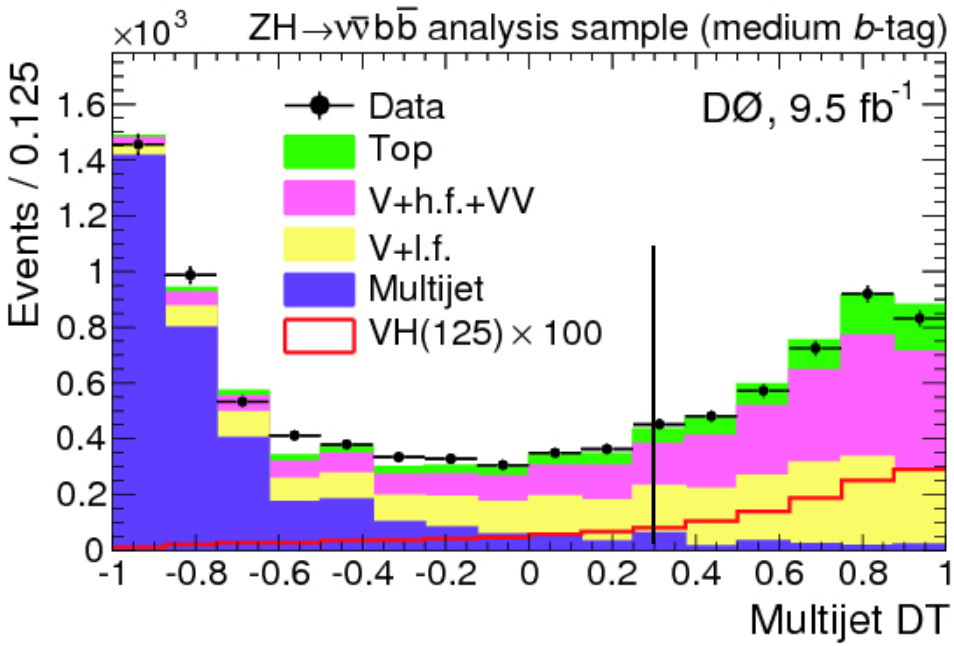
- Selects two oppositely-charged leptons, at least 2 jets
- Fully reconstructed final state allows kinematic fitting of jets
  - Shifts dijet masses closer to true value
- Recover lepton acceptance through secondary channels
  - muon+ isolated track, e+ ICR electron
- Reject top background with dedicated decision trees
- 2 orthogonal b-tag categories
  - 1 tag, 2 tag

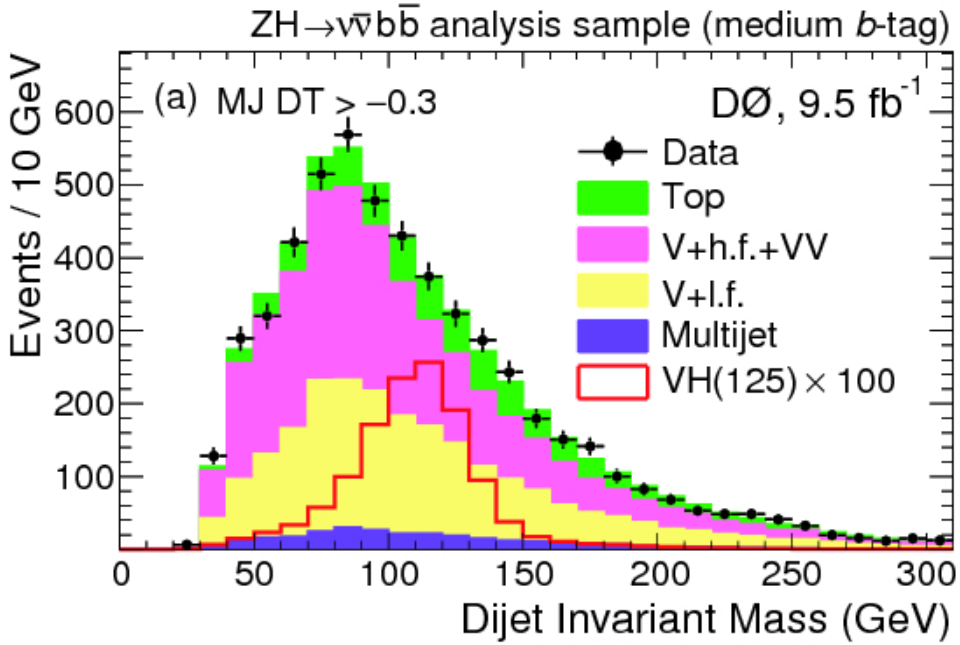




ZH→νν̄bb̄ channel

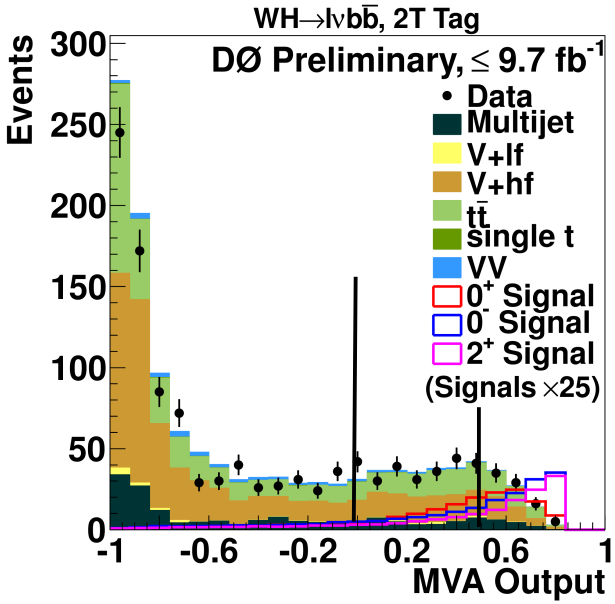
- Veto on lepton selections, select large MET, exactly 2 jets
- Sensitive to WH signal when lepton is missed
- Controlling multijet background challenging
  - dedicated multivariate discriminants employed
- Split in two b-tag categories

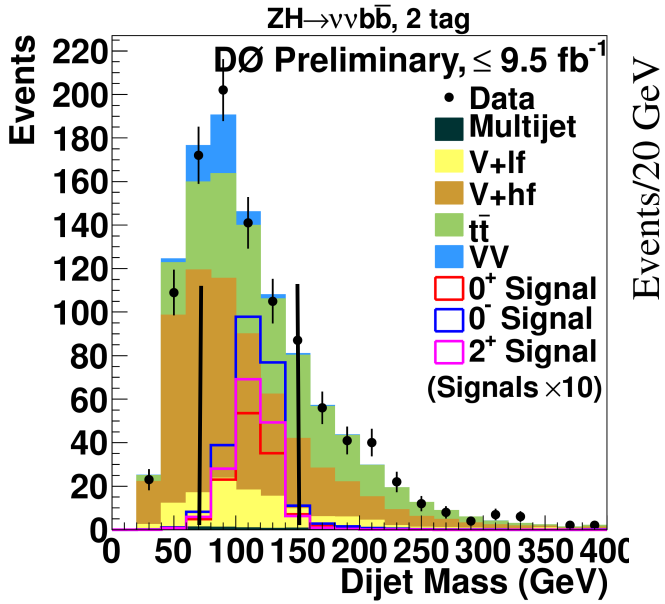


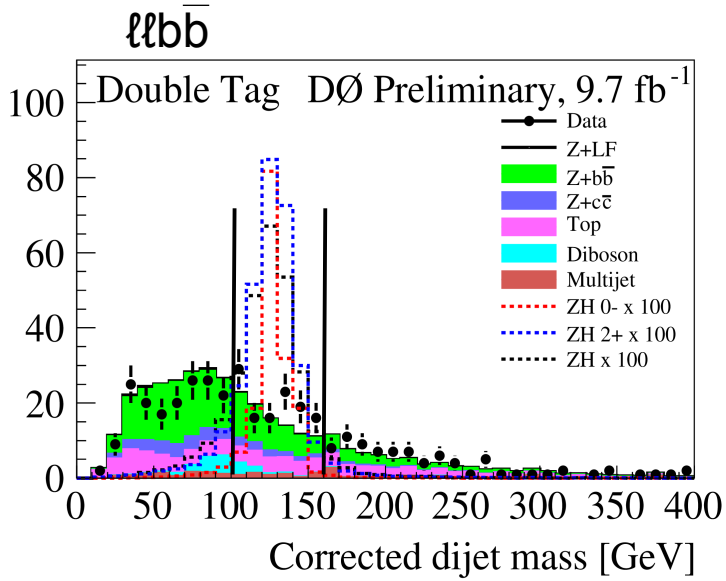


Background rejection

- Split samples into higher- and lower-purity regions according to dijet invariant mass (the mass is known now), or MVA output
  - Lower-purity regions provide additional constraints on systematics
- Include all regions in limit setting







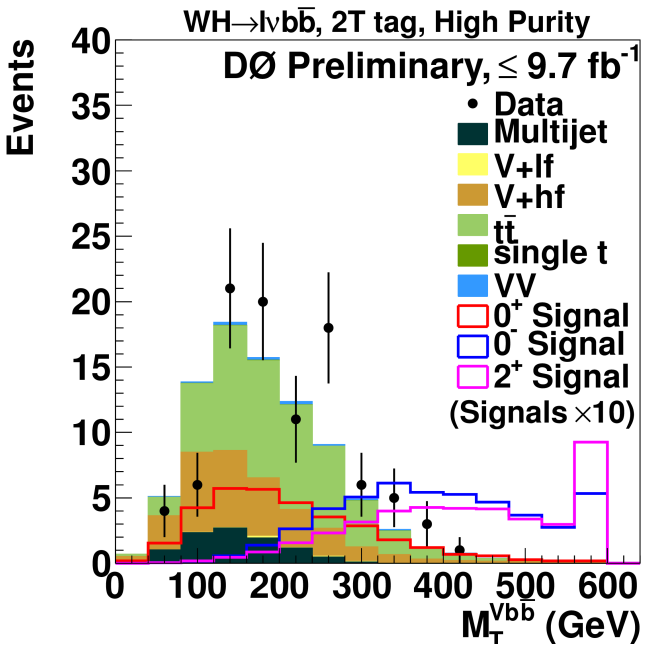
Low Purity: -1 < MVA <0
Med Purity: 0 <MVA< 0.5
High Purity: MVA > 0.5

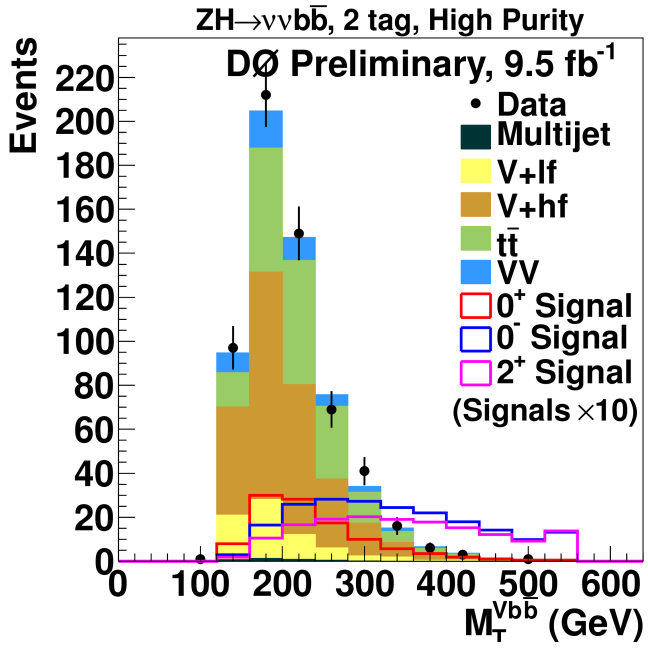
Low Purity: M_{jj}<70, M_{jj} >150 GeV
High Purity:70 < M_{jj} < 150 GeV

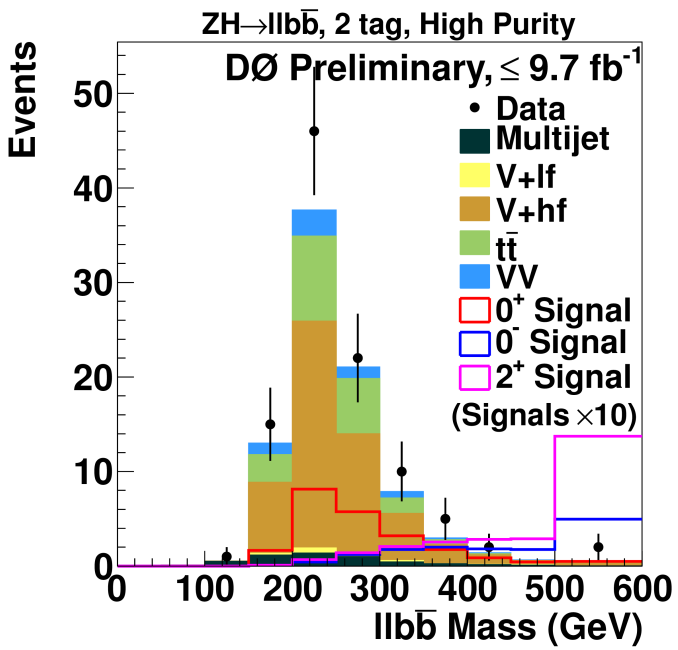
Low Purity: M_{jj}<100, M_{jj} >160 GeV
High Purity:100 < M_{jj} < 160 GeV

Final Variables

- Use total dilepton+dijet mass in $\ell\ell b\bar{b}$ analysis
- Use total transverse mass for $\ell\nu b\bar{b}$ and $\nu\nu b\bar{b}$
- See good separation
  - 2^+ vs background
  - 0^- vs background
  - 2^+, 0^- vs 0^+

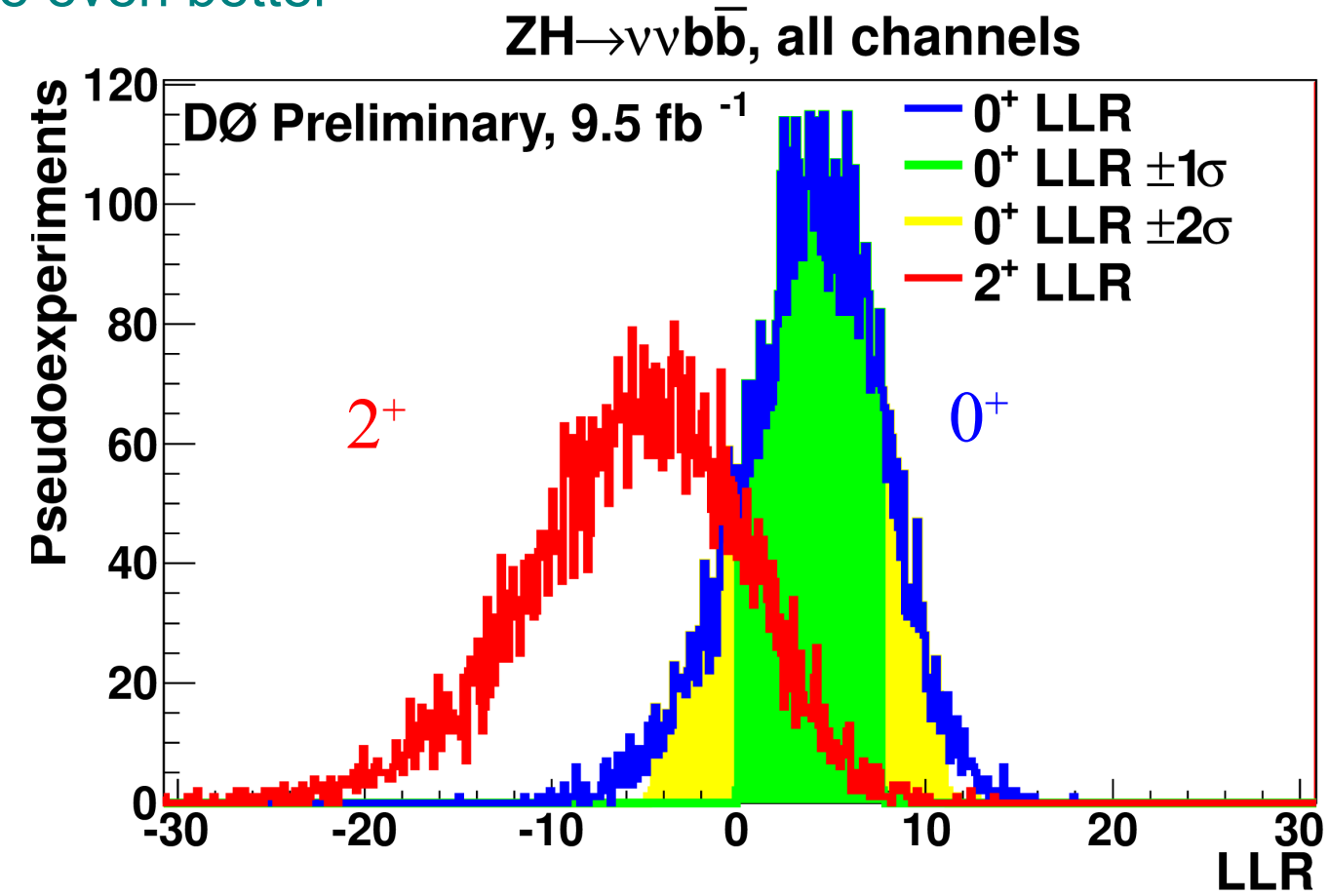






Expected Sensitivity

- Build log-likelihood ratio test: LLR= -2 log(H1/H0)
  - H0 is the SM Higgs (0^+) + Bkg
  - H1 is either 2^+ + Bkg or 0^- + Bkg
- Assume σ x Br of SM Higgs boson in a first step
- Good separation between hypotheses for one single channel
- Combination will be even better



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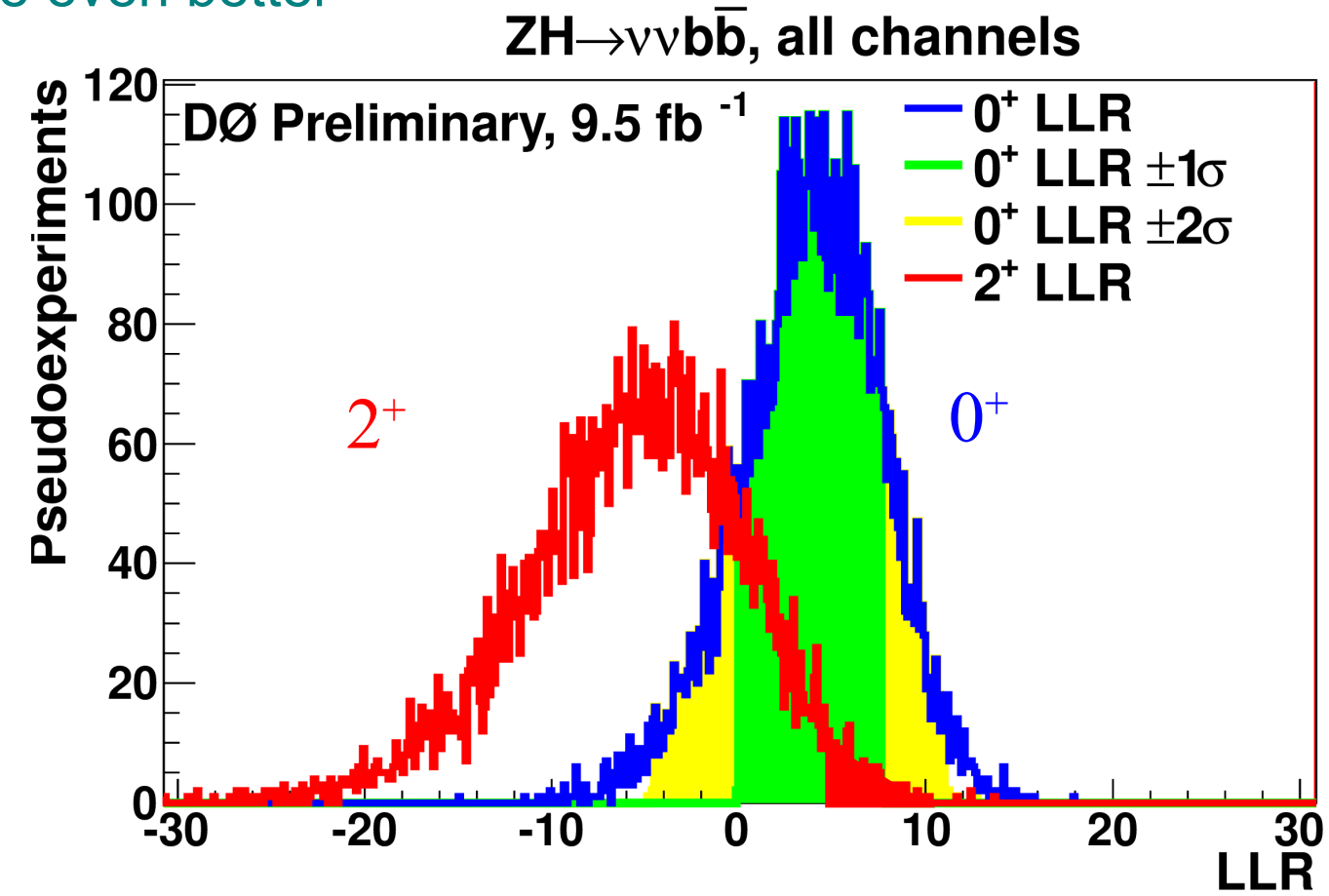
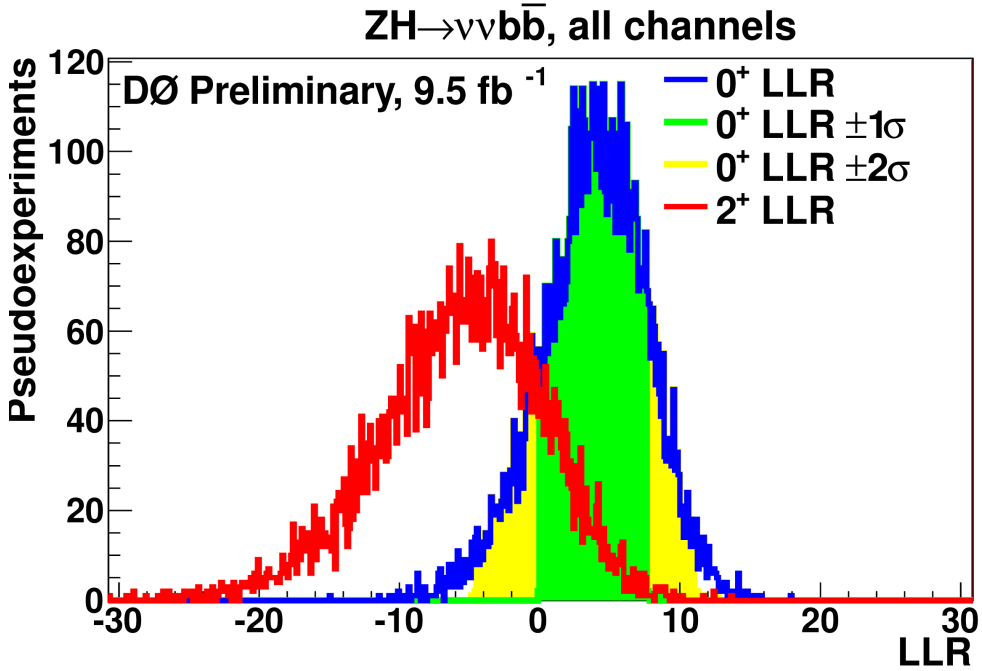


Expected if SM:
CL_{2+} = 3.5 %

Summary

- Tevatron experiments are sensitive to kinematic differences between different spin-parity hypotheses for the new boson
- Initial tests show good separating power in the D0 VH→Vb$\bar{b}$ analyses
- Should have finalized results very soon
- Plan to combine with similar analyses developed at CDF.

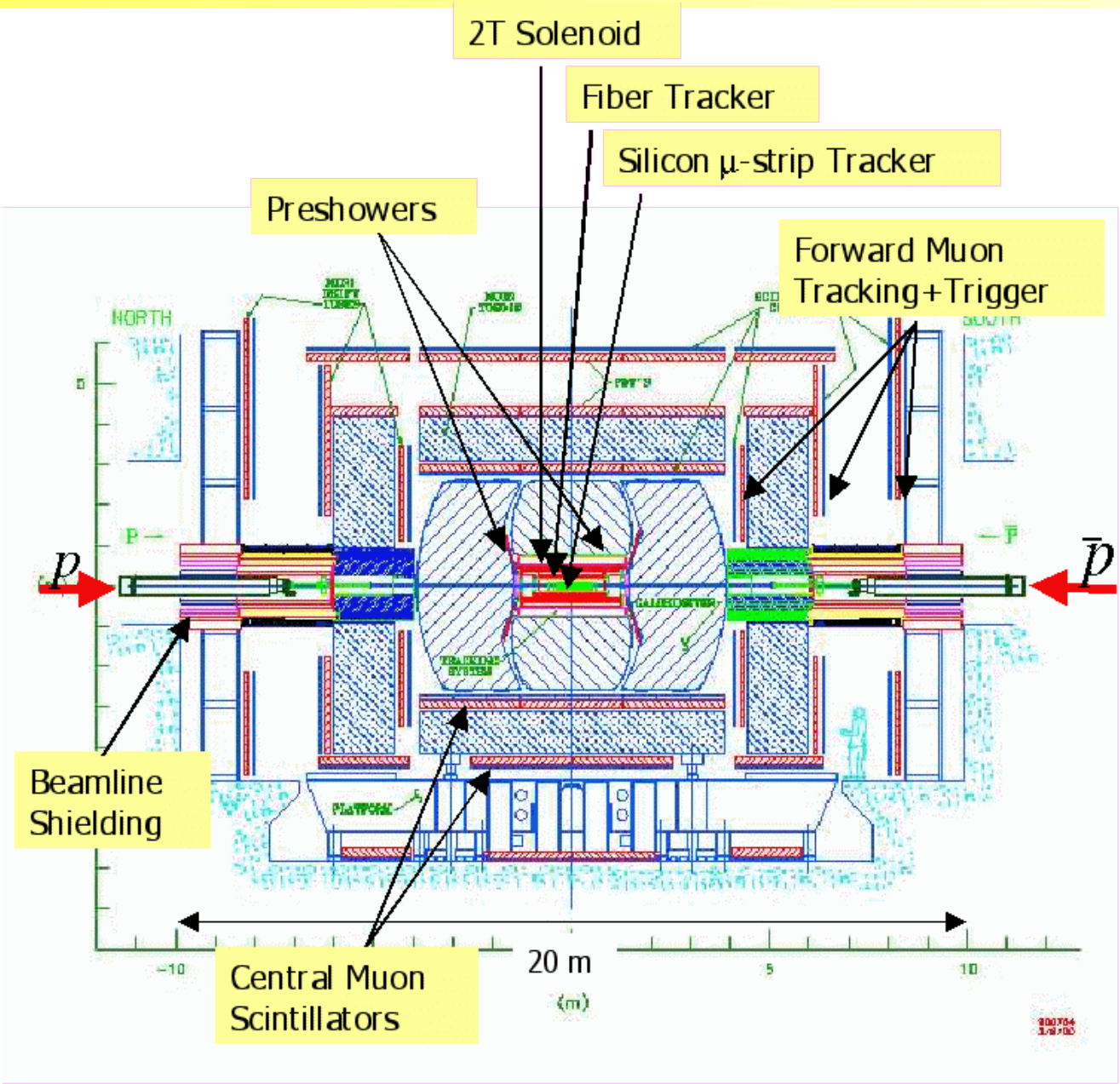


Backup

Models

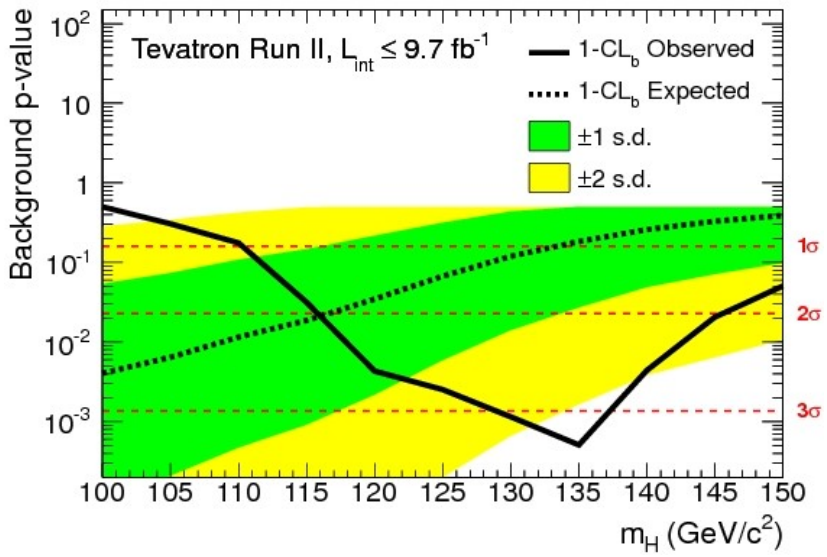
- Differences between our models and LHC JP models
- D0 Signals
  - 2+ follows Ellis et al., uses default Madgraph RS graviton
  - 0- follows Ellis et al.; model calculated by the authors, use Feynrules, and incorporate into Madrgraph
- LHC Signals
  - 2+ model has graviton-like couplings, chosen to be the “minimal couplings” scenario (Y. Gao et al., PRD **81**, 075022; S. Bolognesi et al., PRD **86**, 095031)
  - 0- model follows from similar Lagrangian as SM, but couplings are different
  - Test different mixture of production mode gg vs $q\bar{q}$
- It is also interesting to test admixtures of different spin and parity states (LHC already doing this; Tevatron will follow suit)

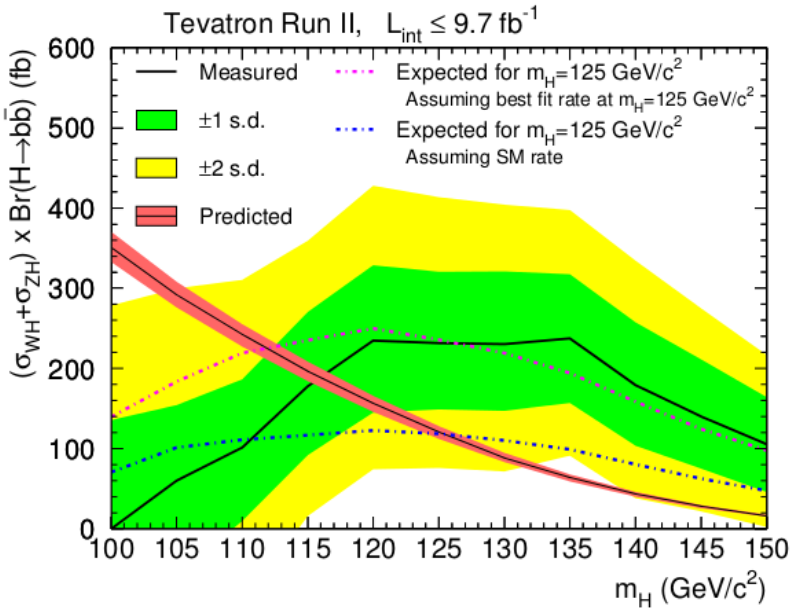
The D0 Experiments at RunII



- New in RunII
  - Tracking in B-field
  - Silicon detector
  - fiber tracker
- Upgraded for Run II
  - Calorimeter,
  - muon system
  - DAQ/trigger
- RunIIb (2006):
  - Silicon layer 0
  - Cal Trigger
- Typical coverage
  - Muons $\eta < 2$
  - Electrons
    - $\eta<1.1$
    - $1.5<\eta<2.5$
  - Jets $\eta< 2.5$

Tevatron H → $b\bar{b}$ results





July 2012 combination (PRL 109, 071804)

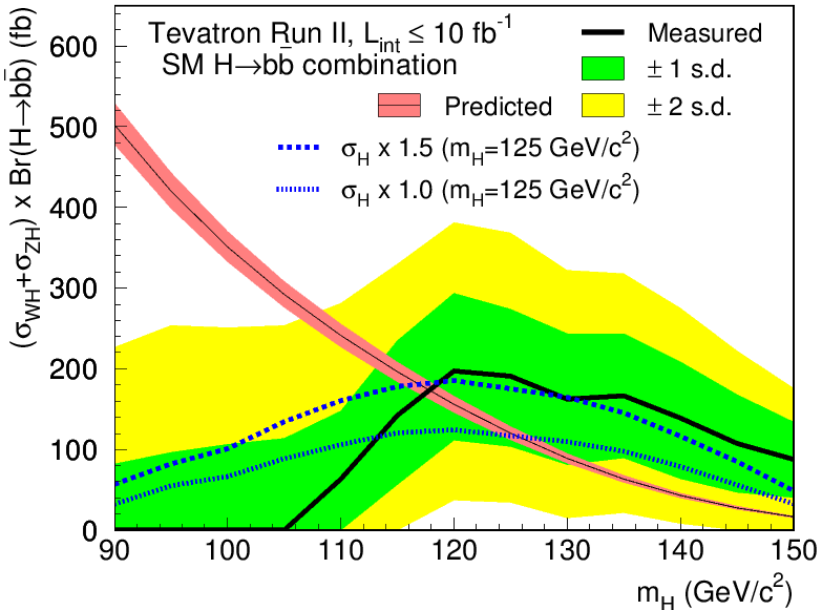
- 3.3 sigma @135 GeV
- 3.1 sigma accounting for LEE
- Measure VH → V$b\bar{b}$ yield:
  - σ=0.23±0.09 pb for M_H=125 GeV

SM prediction for VH → V$b\bar{b}$

- σ=0.12±0.01 pb for M_H=125 GeV

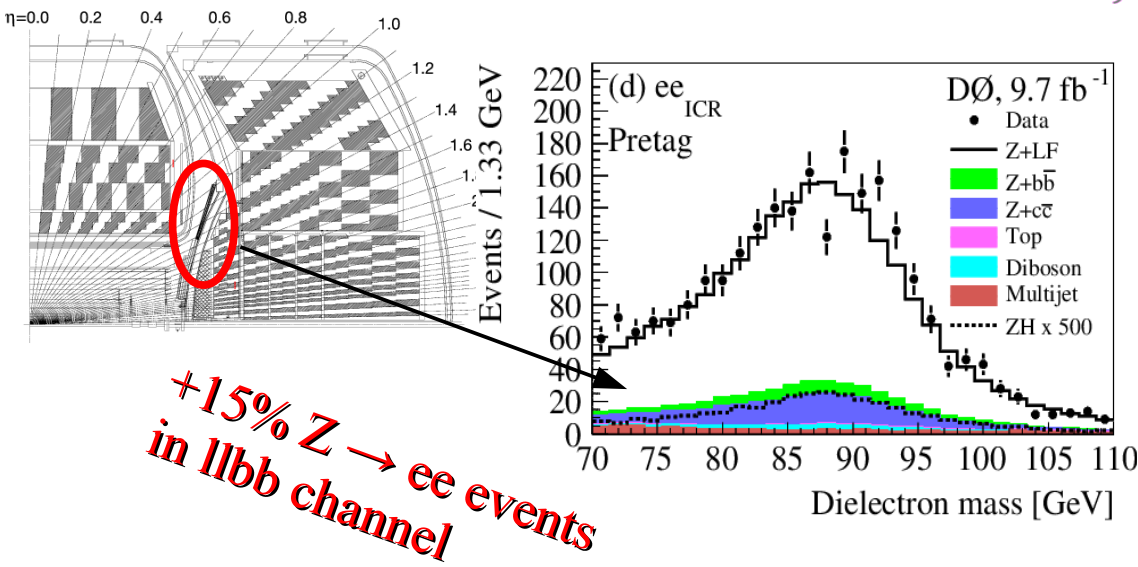
Final Tevatron combination (arxiv:1303.6346)

- σ =0.19±0.09 pb for M_H=125 GeV

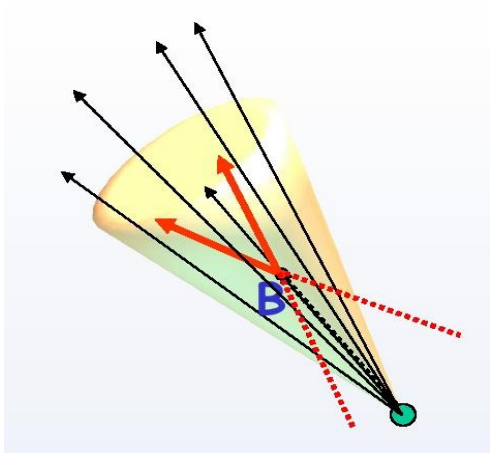


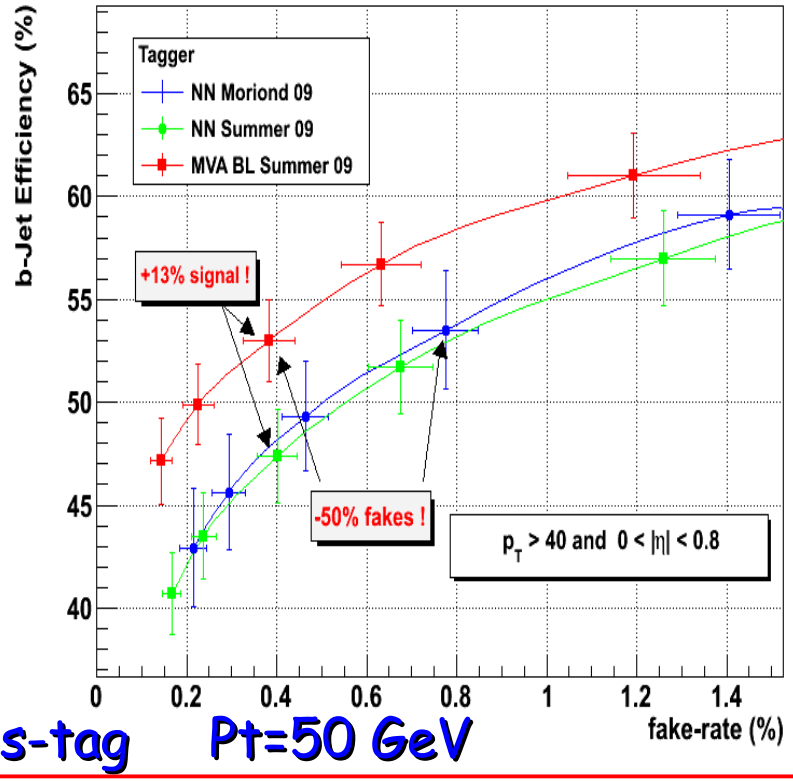
Maximize acceptance and efficiency

- Lower kinematic requirements
- Use different lepton reconstruction categories
- Inclusive triggering: accept events from all possible triggers
- Employ MVA for b-jet



+15% $Z \rightarrow ee$ events in llbb channel





ε=60% for 1% mis-tag Pt=50 GeV