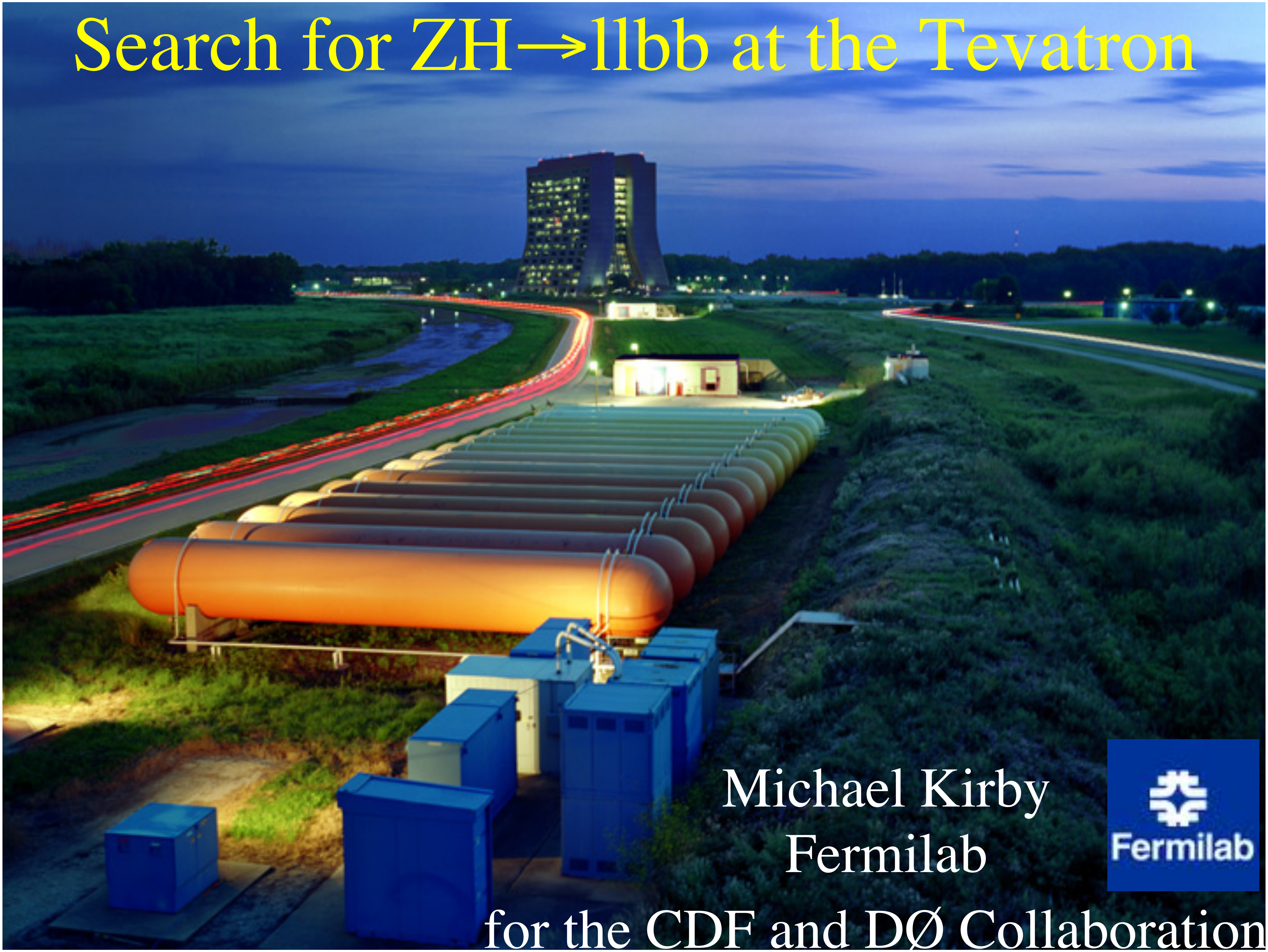
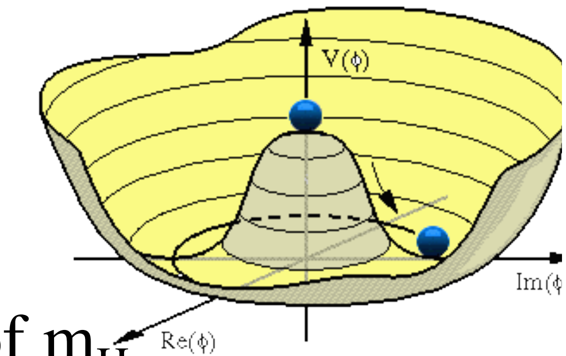
Search for ZH→llbb at the Tevatron



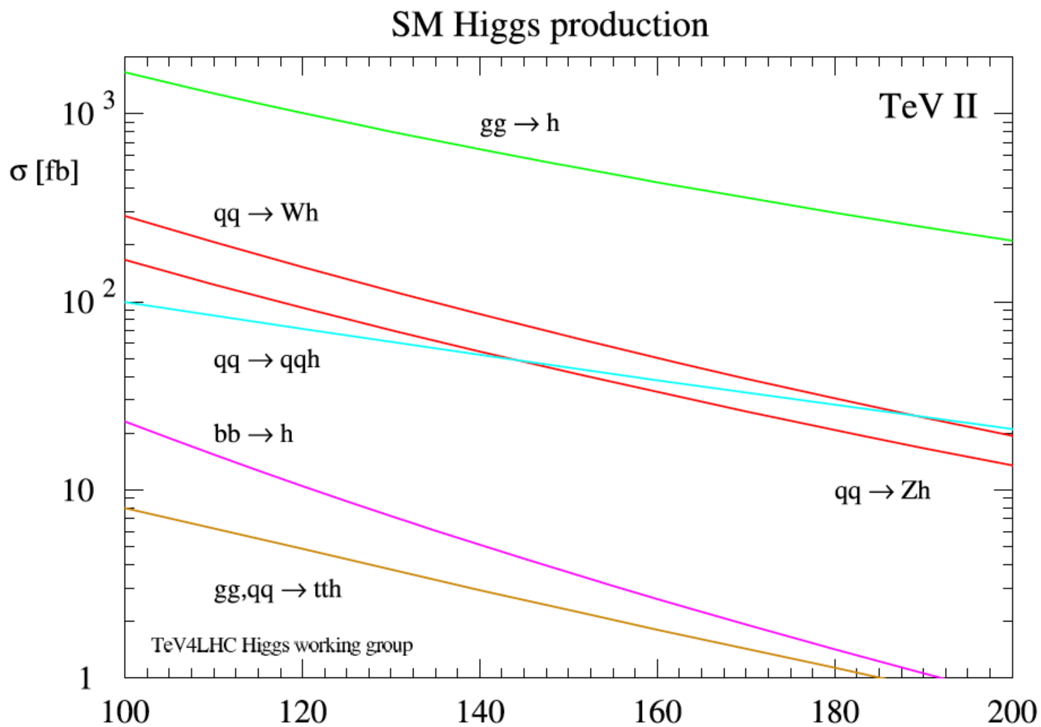
Michael Kirby
Fermilab
for the CDF and DØ Collaboration

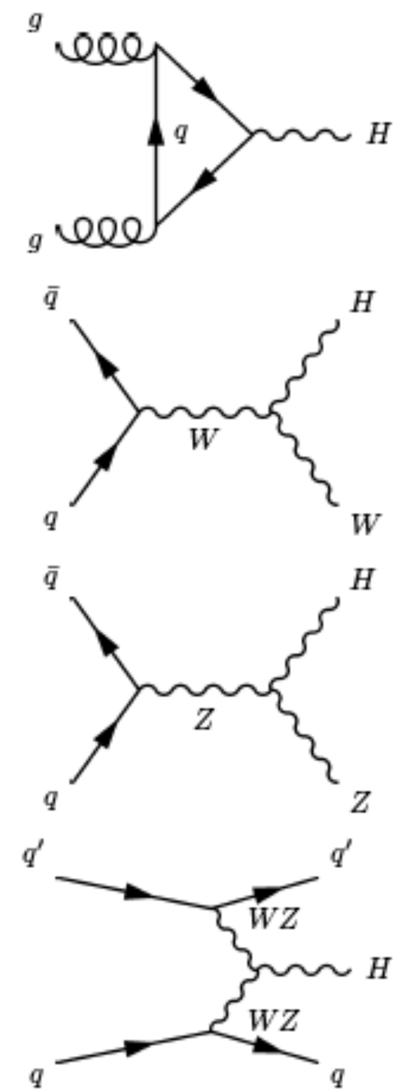
Electroweak Symmetry Breaking

- electromagnetic & weak couplings are drastically different
  - unified electroweak theory governed by one coupling constant
  - massive vector bosons suppress the Weak coupling (α/M_V)
- theorized Higgs field generates W & Z masses while leaving photon as massless
- symmetry breaking occurs at υ=246 GeV
- predict Higgs boson particle, but no prediction of m_H
- fermion masses generating by couplings to Higgs field



Higgs Production at the Tevatron



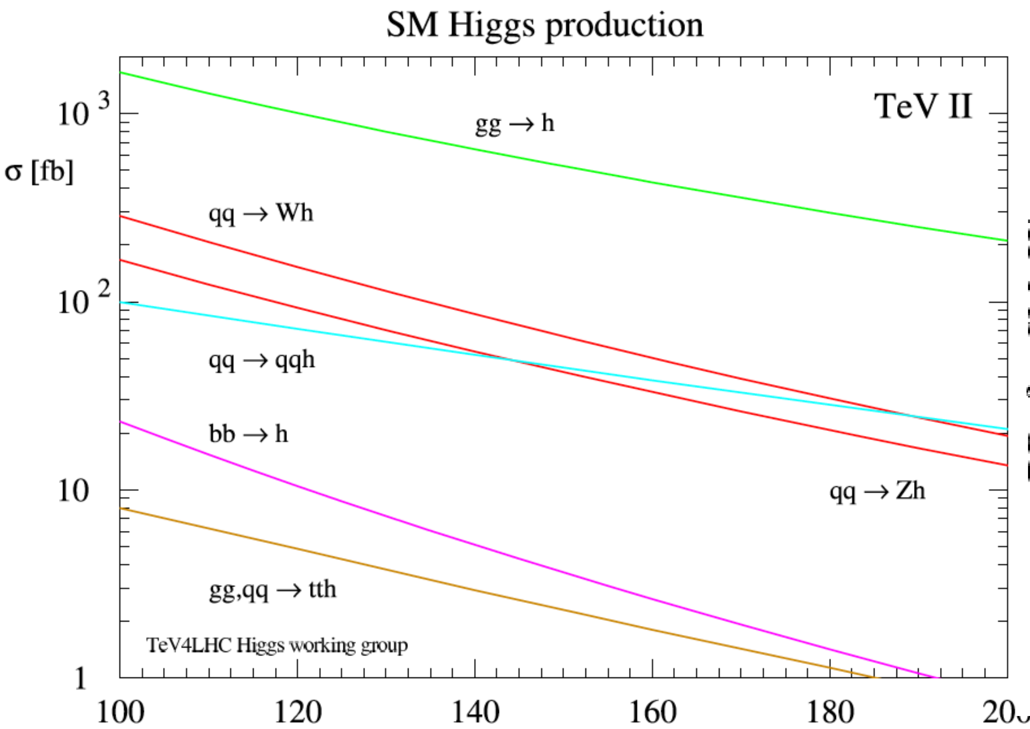


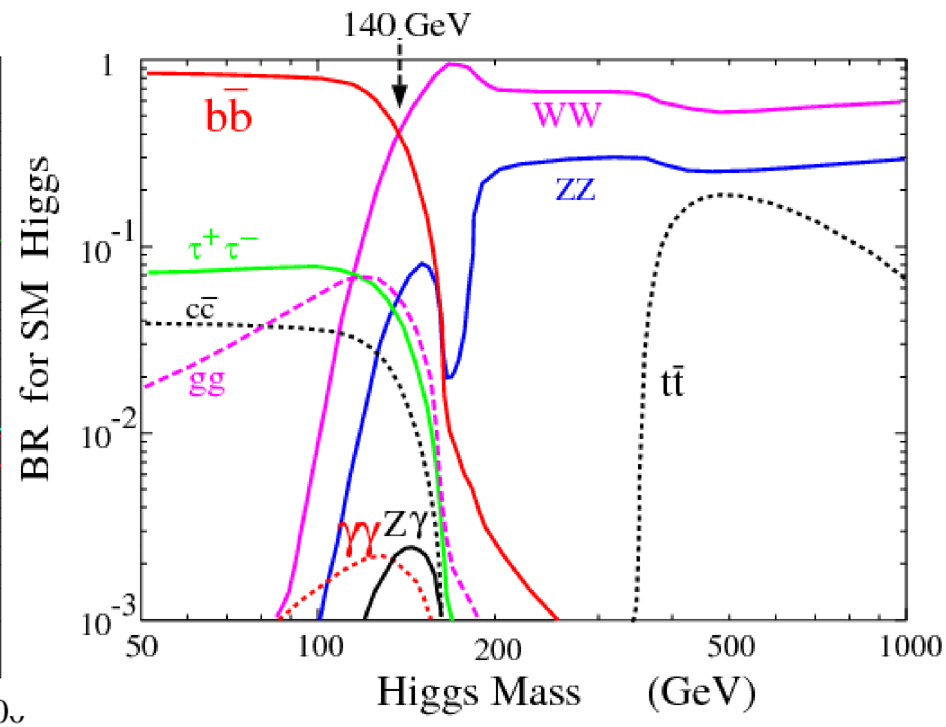
gluon fusion dominates

associated production (WH,ZH)

vector boson fusion

Higgs Production at the Tevatron





gluon fusion dominates

associated production (WH,ZH)

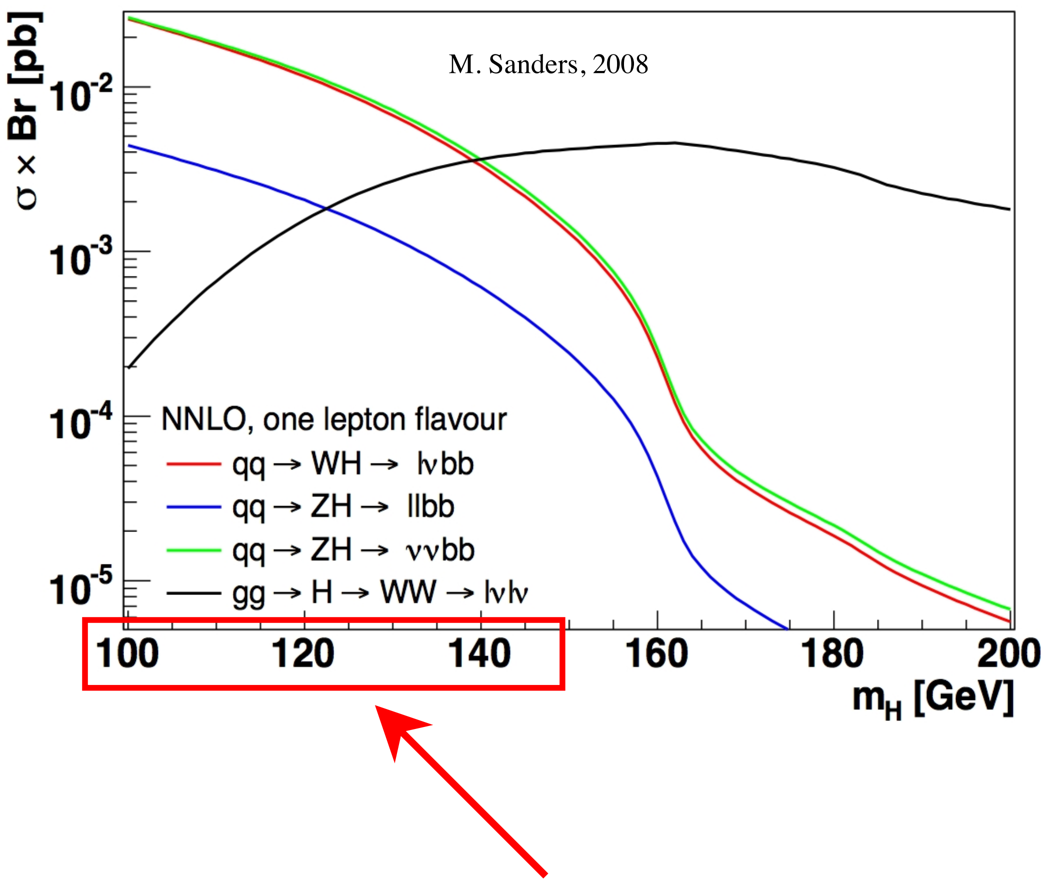
vector voson fusion

Higgs couples to mass, and so decays to heavier particles

for M_H<135, H→bb dominates

above 135, H->WW dominates

Higgs Production at the Tevatron



Low Mass Search Region

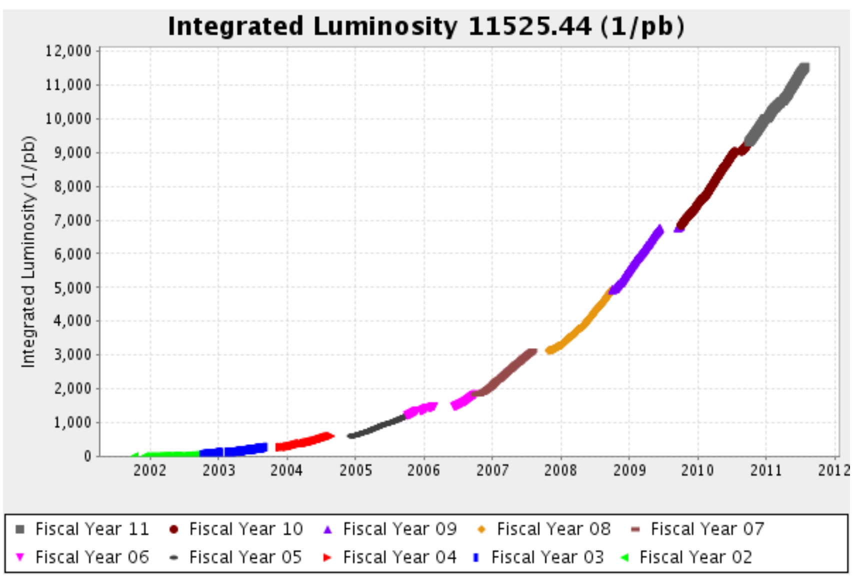
- ZH→*llbb* smallest σ×BR of major search channels
- only fully reconstructed signature
- very fertile ground for developing new techniques and discriminants

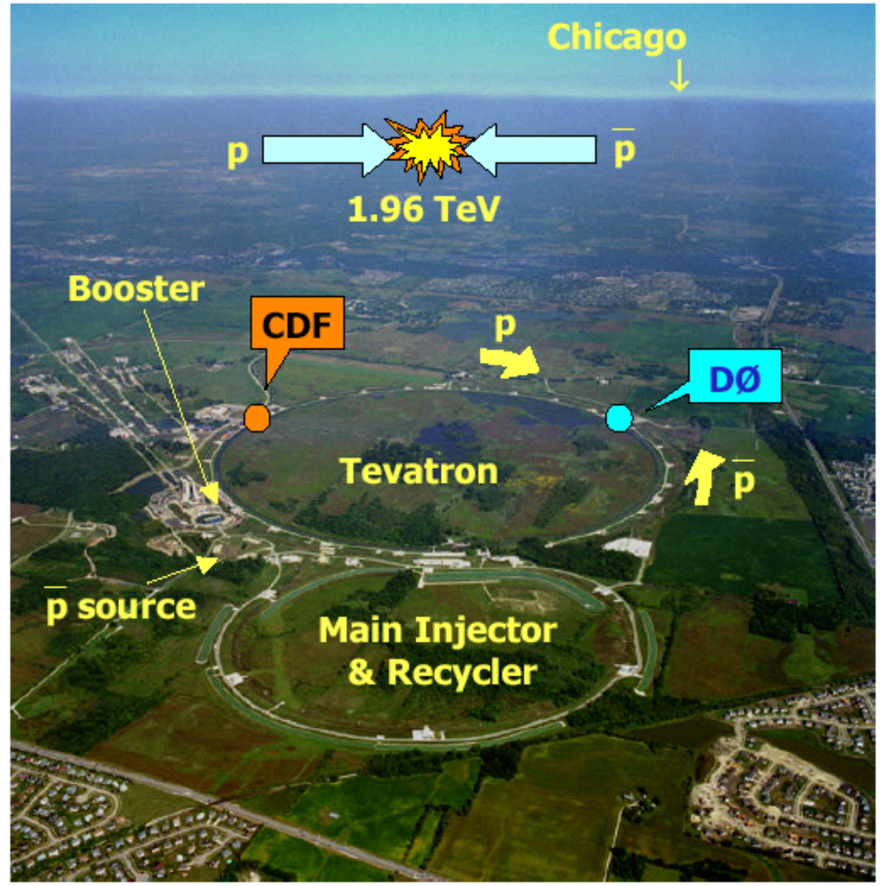
The Tevatron at Fermilab

- proton-antiproton collider at Fermilab

$$\sqrt{s} = 1.96\text{TeV}$$

- ~3x10^{32} peak lumi
- integrate ~50/pb/wk





delivered Int Lumi = 11.6/fb

meeting stretch goals and operating with excellent efficiency

The Tevatron at Fermilab

- proton-antiproton collider at Fermilab

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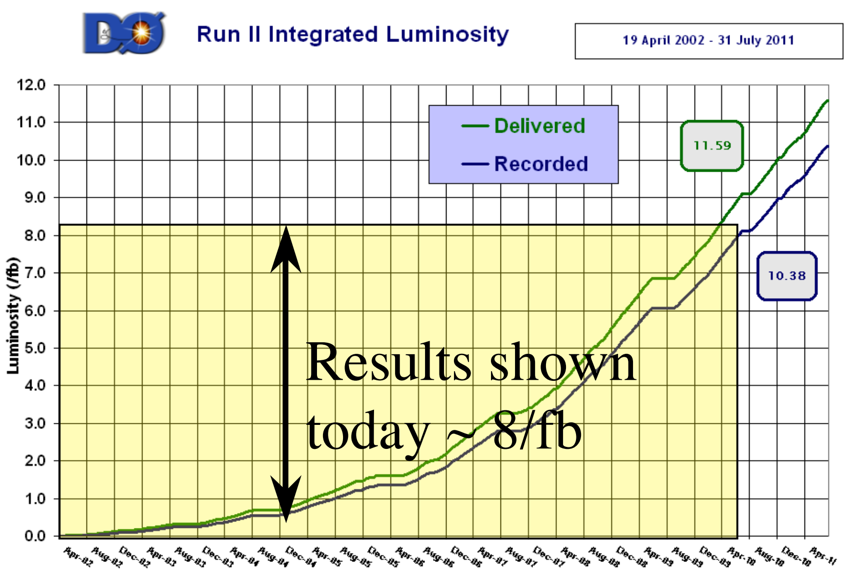

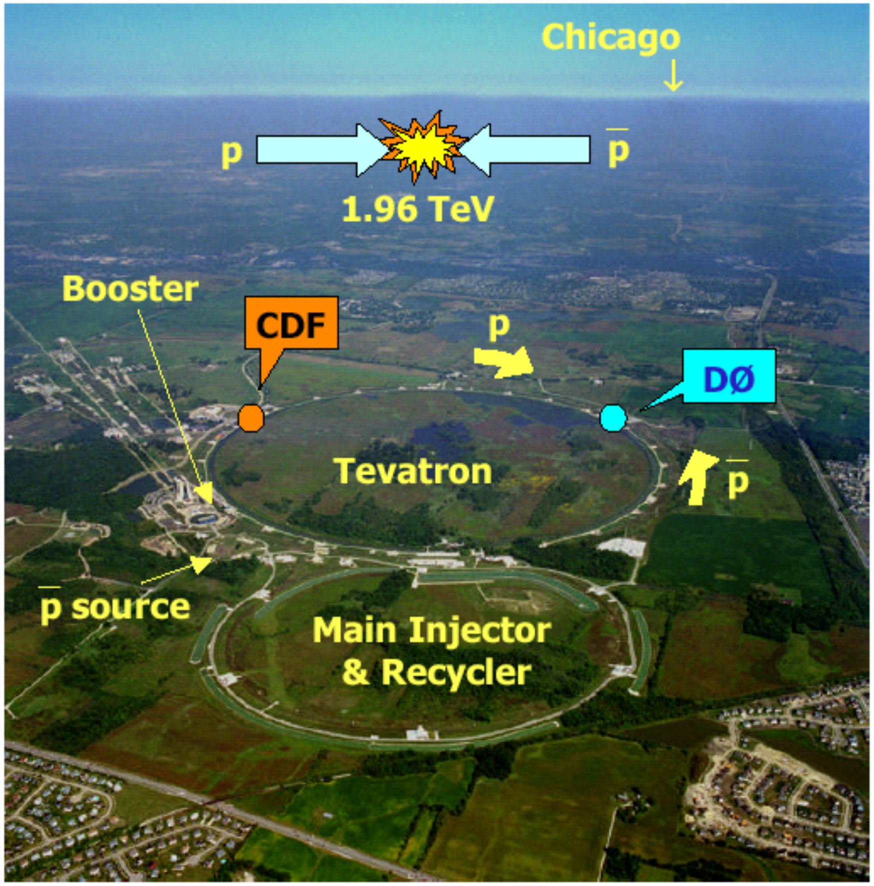

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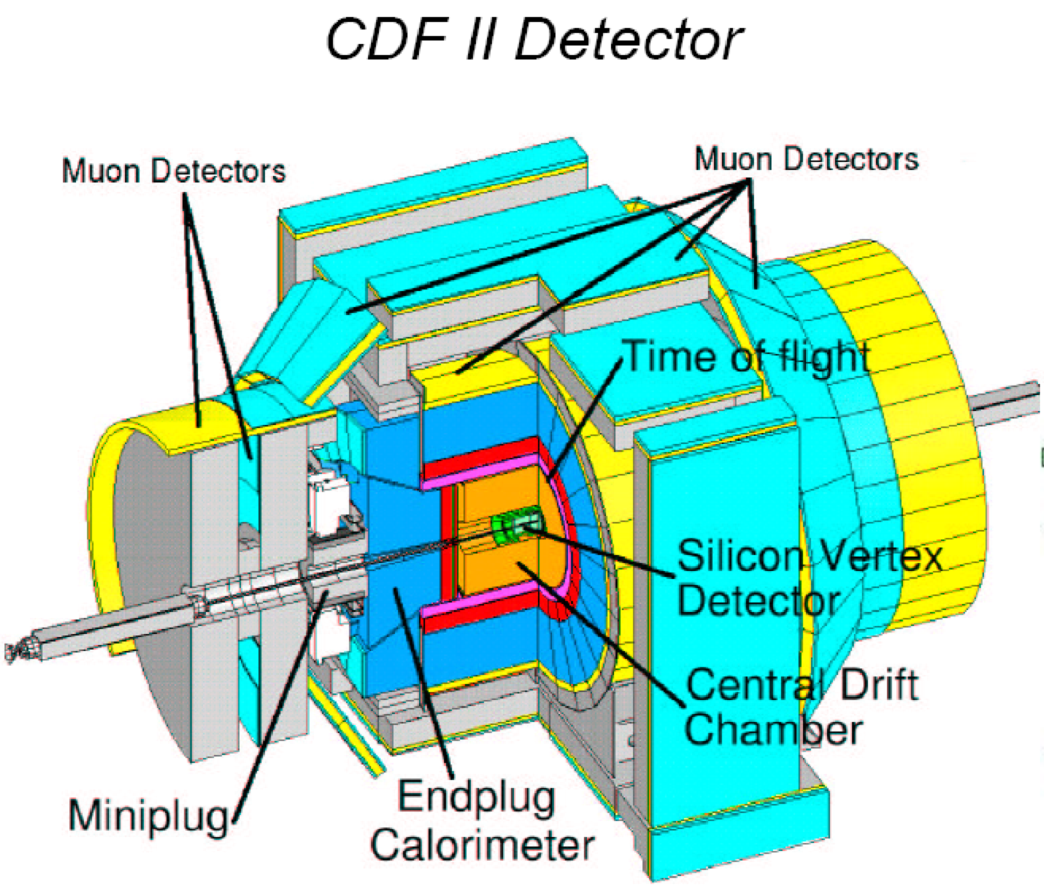
CDF & DØ Detectors

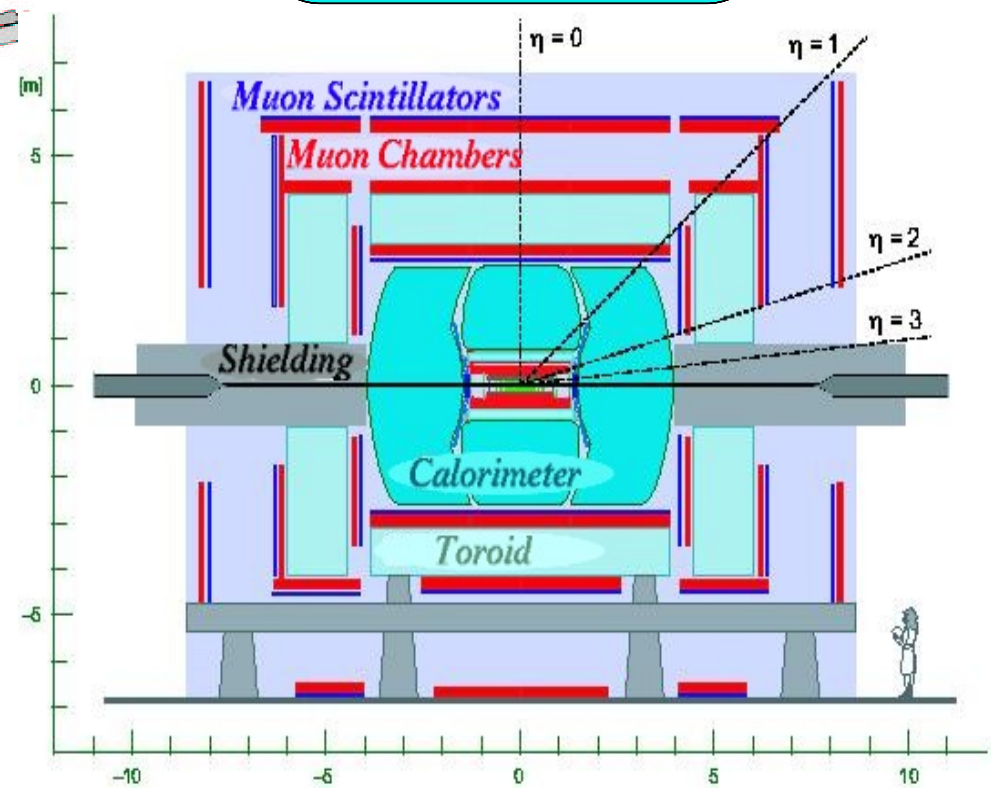


detector coverage |η|

muons ~ 2

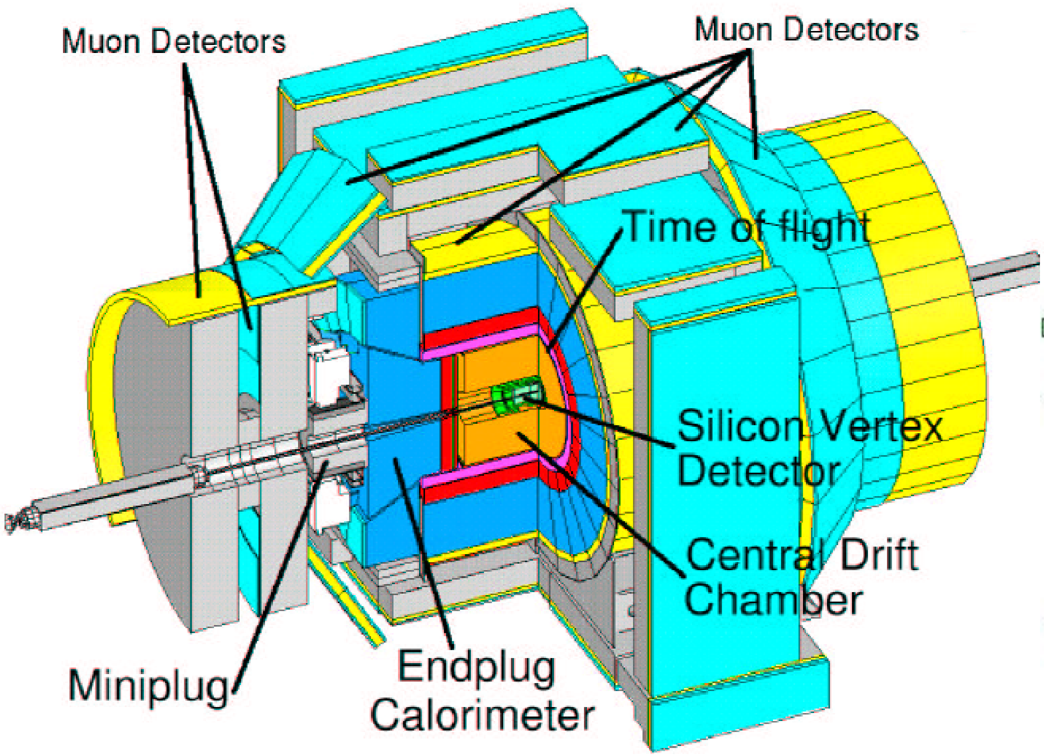
tracking ~ 2.5

EM/Jet ~ 4



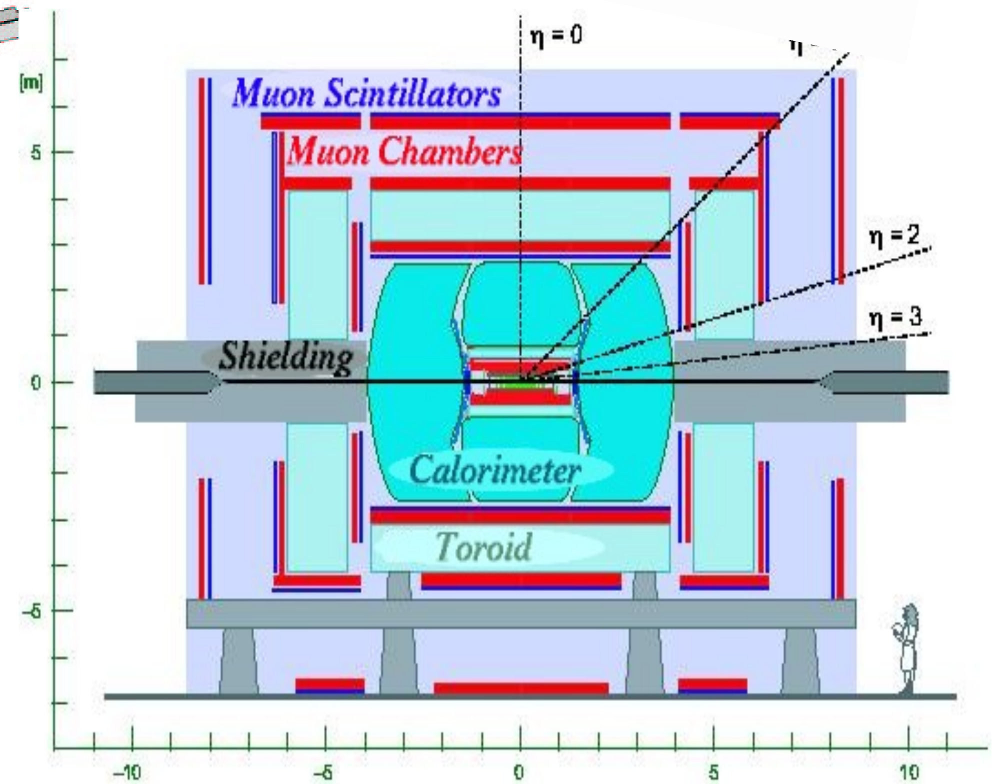
CDF & DØ Detectors

CDF II Detector



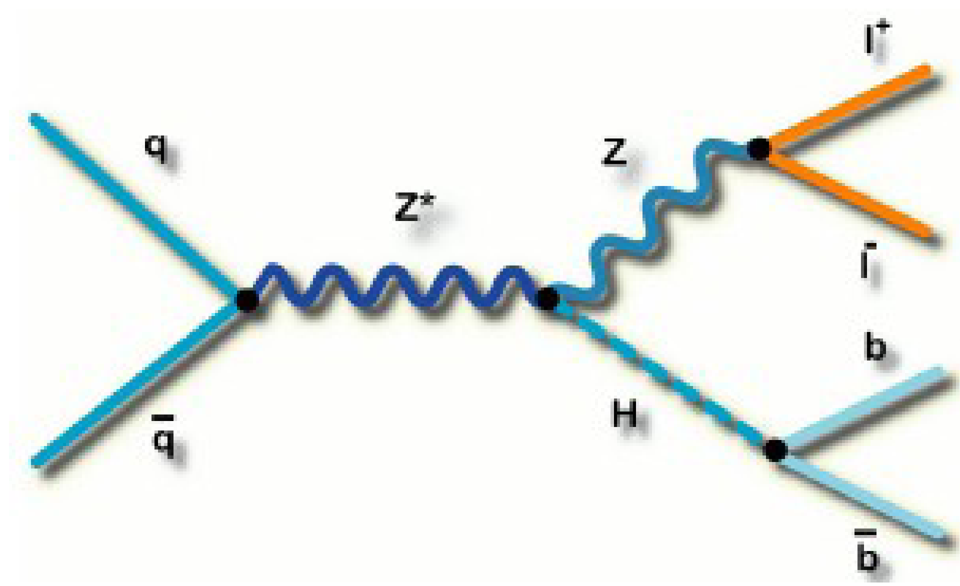
renormalized Raaf-measure

~175



ZH → *ll*bb Strategy

- reconstruct the di-electrons or di-muons from decay of Z
- require two jets, E_T > 15 GeV
  - CDF leading jet > 25 GeV
  - DØ leading jet > 20 GeV
- use b-quark identification to enhance signal
- improves acceptance using alternate lepton ID
- develop new multivariate techniques to improve sensitivity
- challenging irreducible backgrounds



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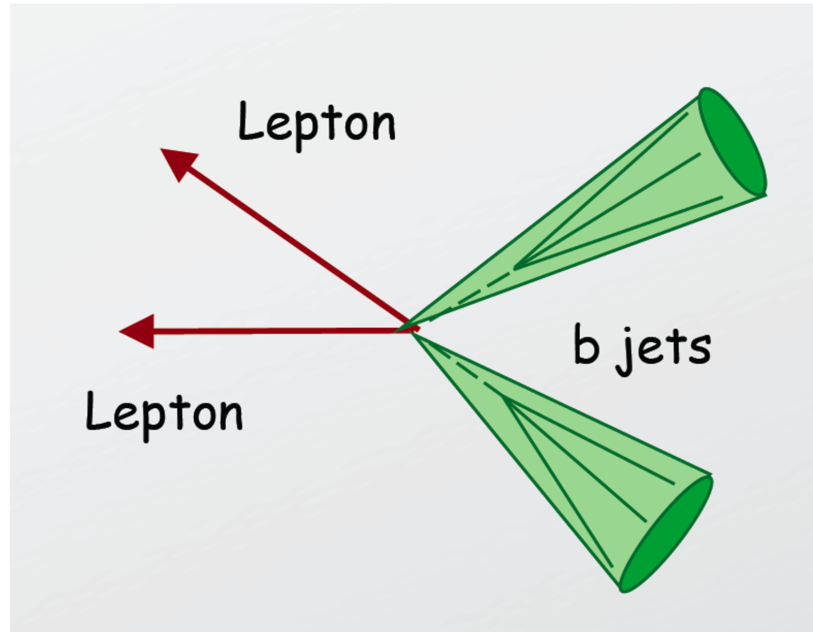

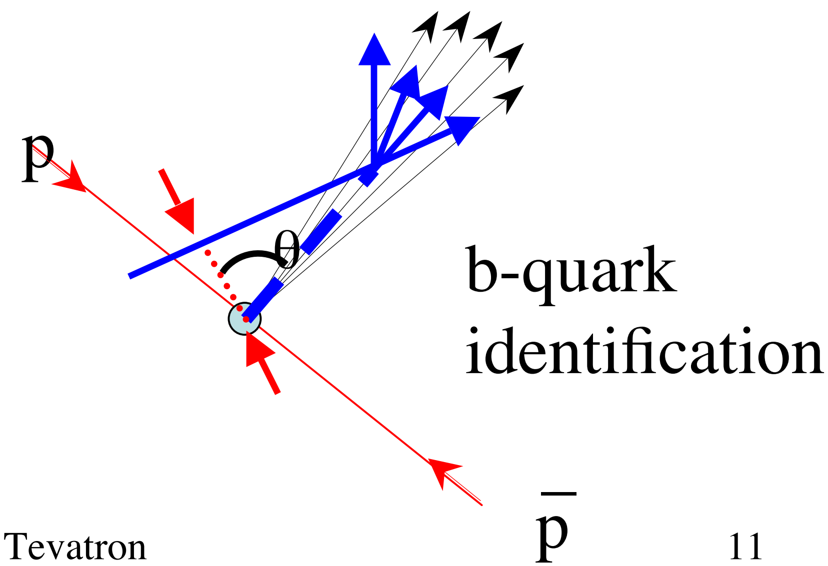

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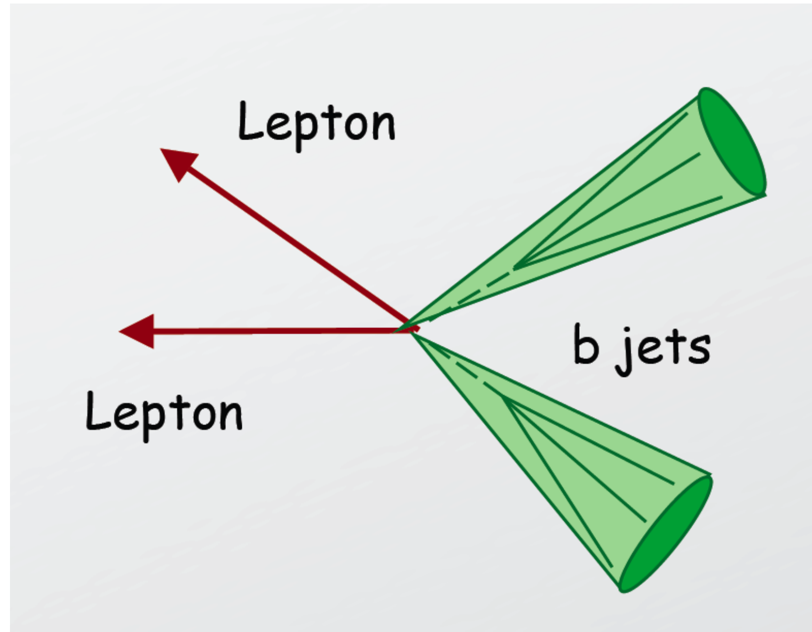
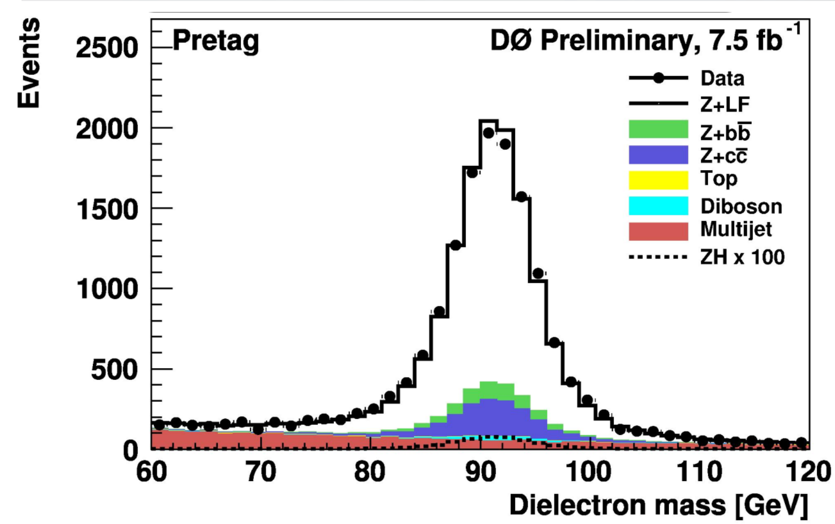
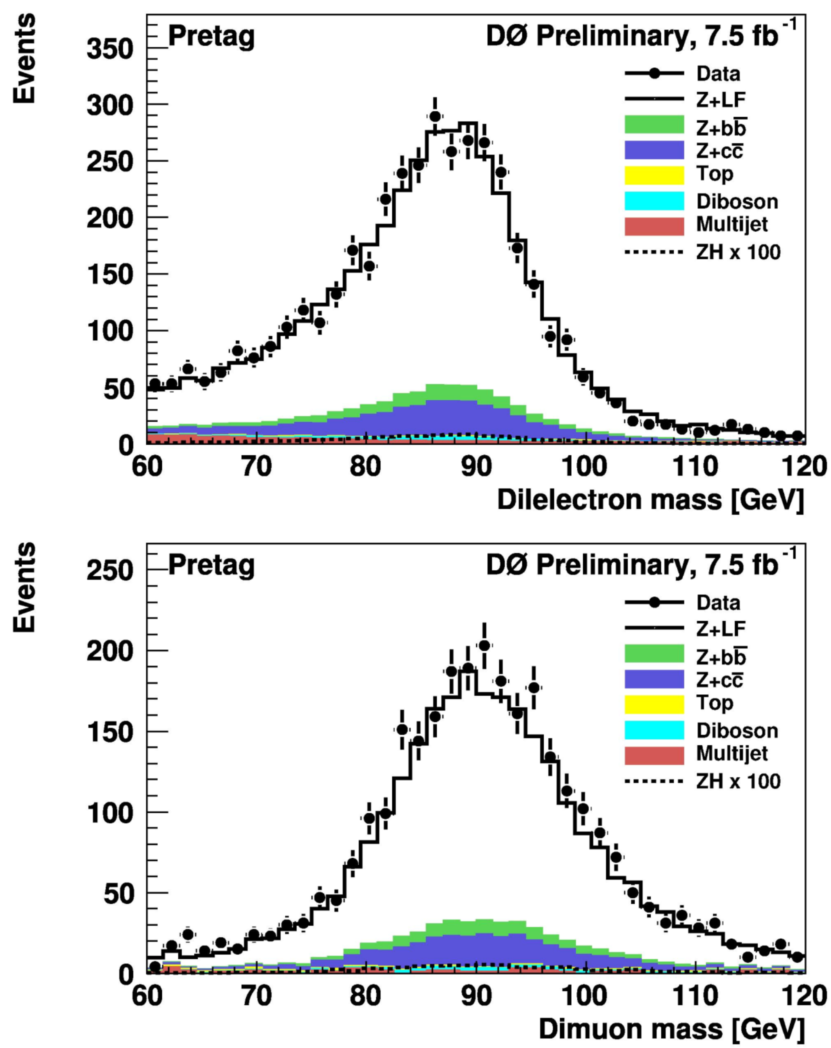




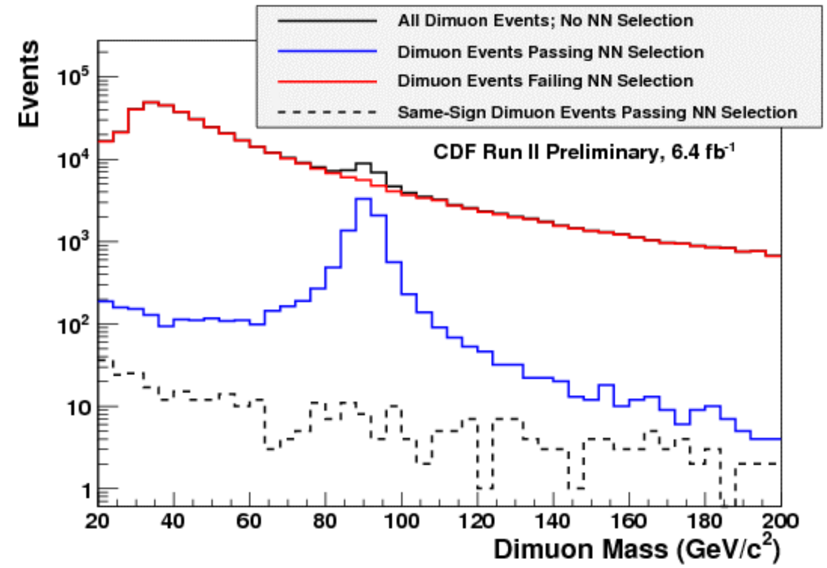
Increasing Acceptance

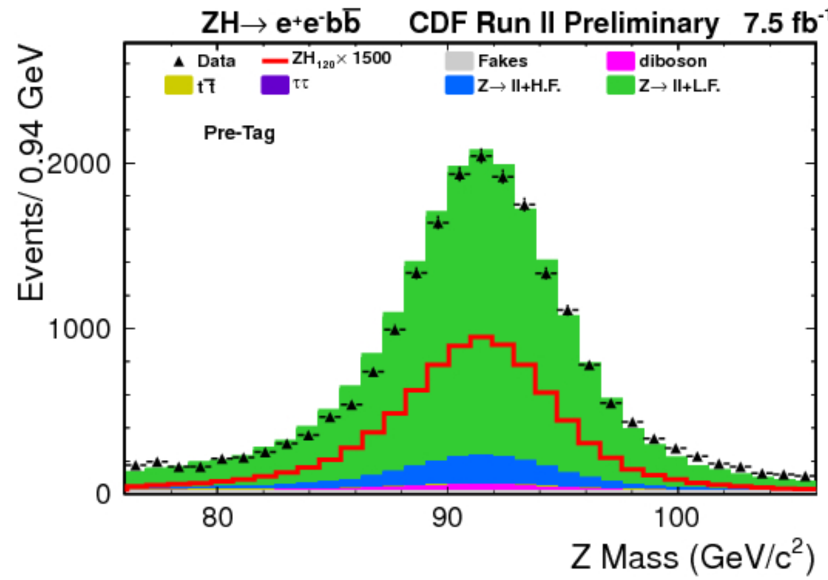


- Detector regions without full instrumentation
- Use alternate ID algorithm to reconstruct second electron or muon
    - di-electron events utilize inner-cryostat region
    - di-muon events identify track-only muons
- Additional 12% and 20% signal acceptance

Improving lepton ID

- muon identification NN
  - train using single muons in ZH Monte Carlo
  - background sample comes from same-sign data sample
- electron identification NN
  - train using combination of electrons and jets from MC and data
  - achieves similar acceptance as previous selection while improving background rejection by factor of 5

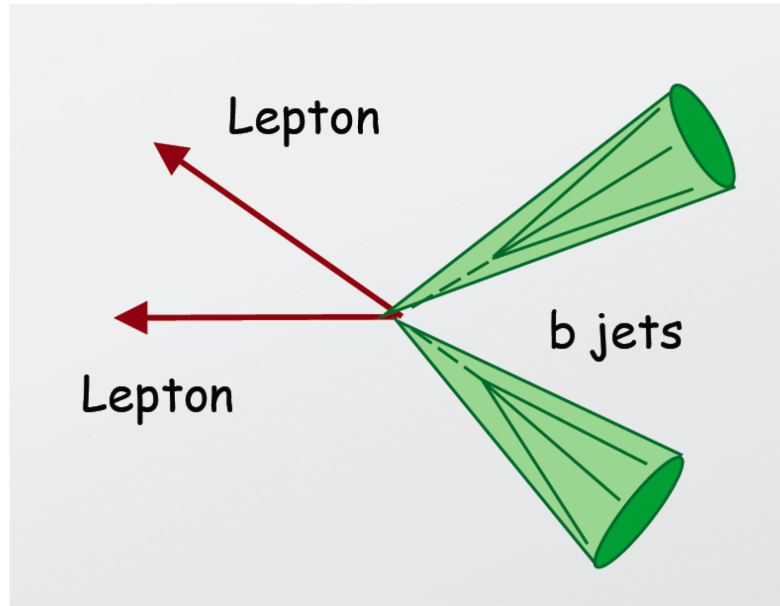




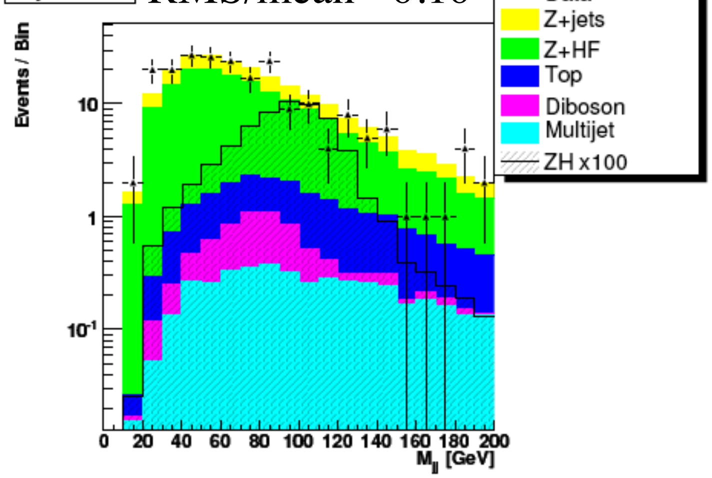
Improving dijet mass resolution ZH → *ll*bb

Kinematic fitter

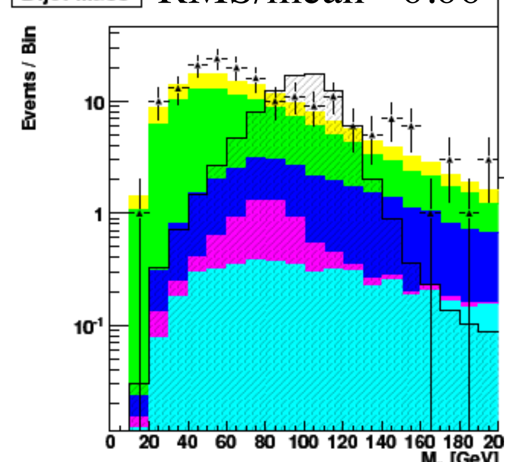
- •Introduce constraints from SM Higgs hypothesis
- •dilepton from decay of Z
- •Higgs radiated from Z
- •jets from decay of H



RMS/mean =0.10



RMS/mean =0.06

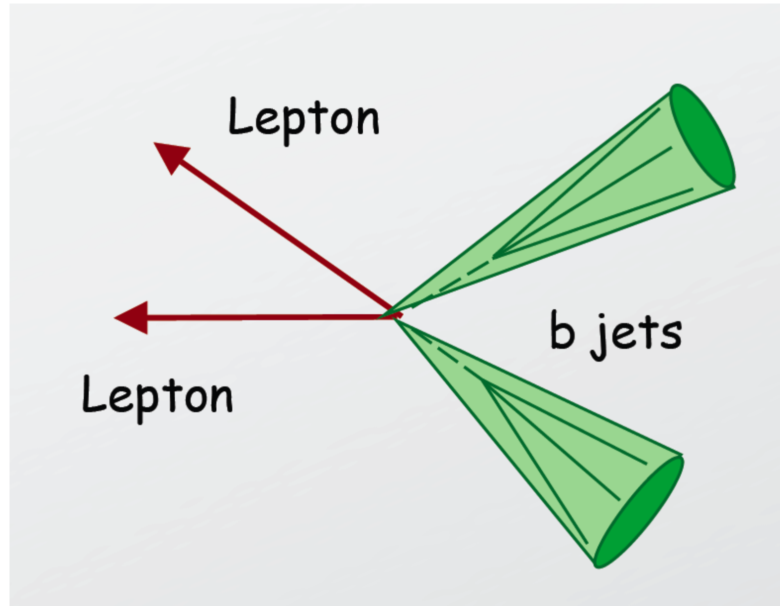


7% improvement in expected limits

Improving dijet mass resolution ZH → *ll*bb

Kinematic fitter

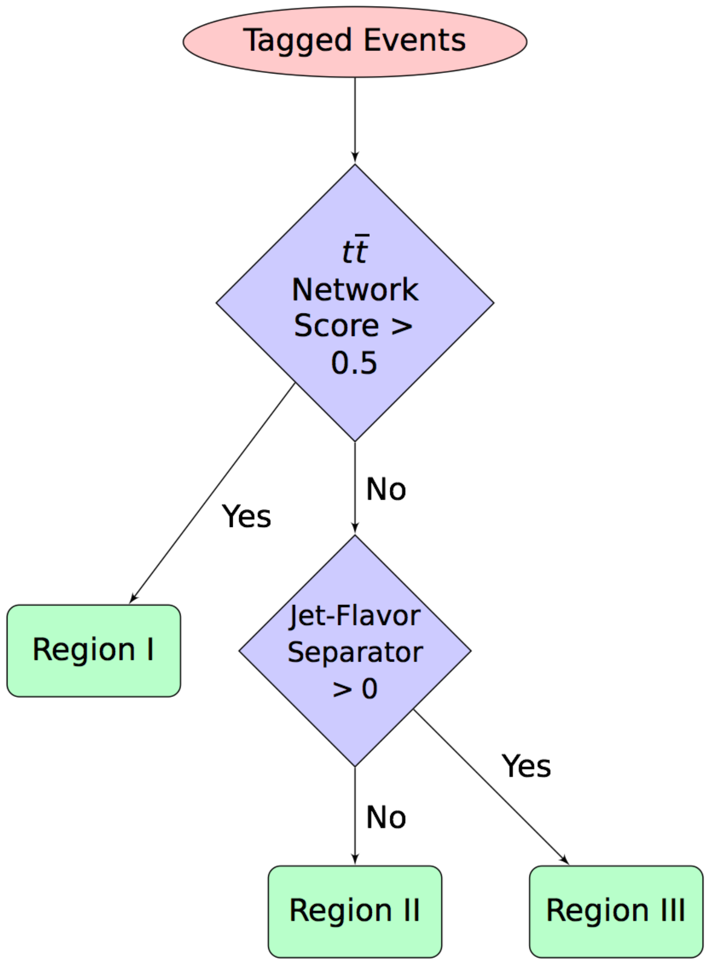
- Introduce constraints from SM Higgs hypothesis
- dilepton from decay of Z
- Higgs radiated from Z
- jets from decay of H



- train artificial NN using ZH→*llbb* events
- correct jet energies based upon projecting missing E_T onto individual jets
- provides ~8% improvement on dijet mass

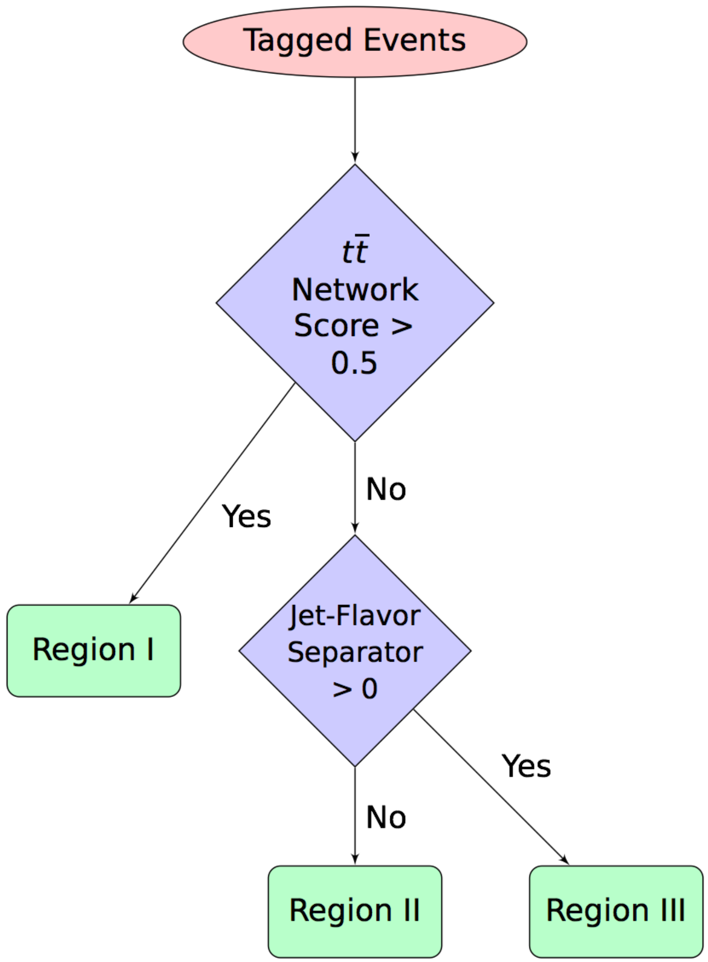
Making ZH → *ll*bb smarter

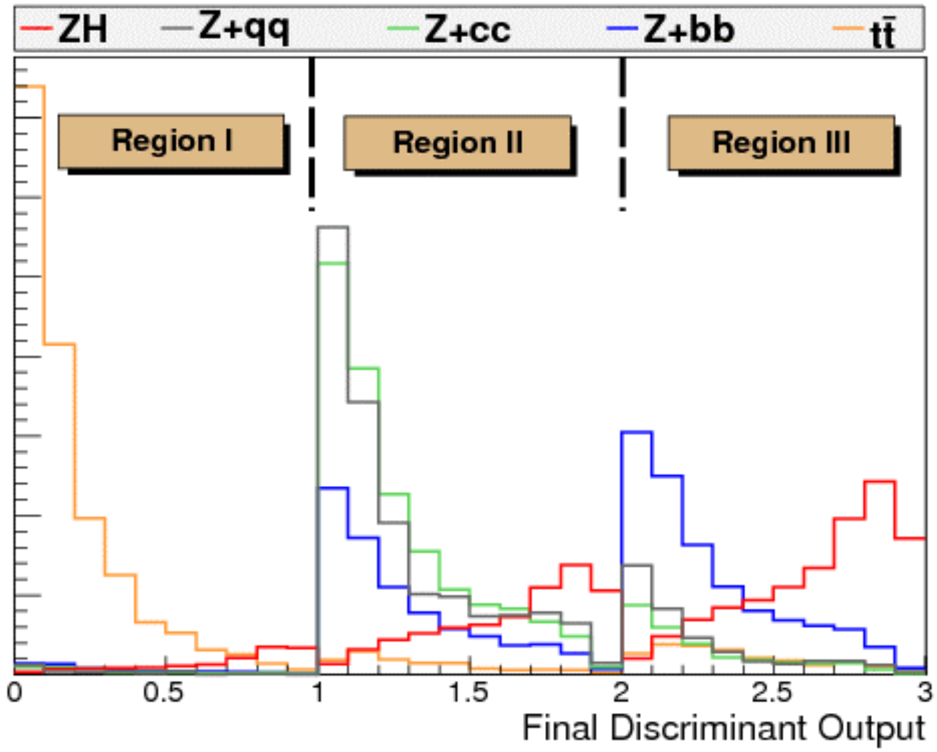
CDF Multivariate Discriminant



- Redesign previous 2D Boosted Decision Tree
- train separately for all Higgs masses
- develop discriminants for specific backgrounds
    - top discriminant
    - jet flavor separator
- Apply final NN to all samples for final search distribution

Making ZH → *ll*bb smarter



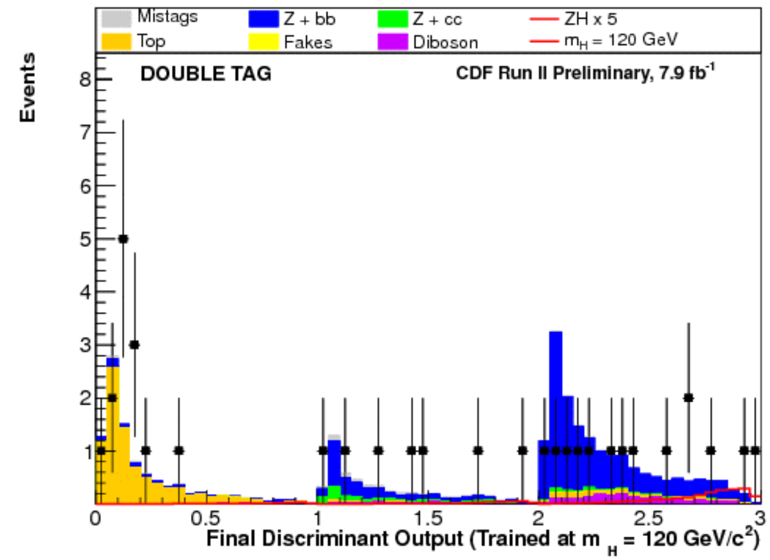


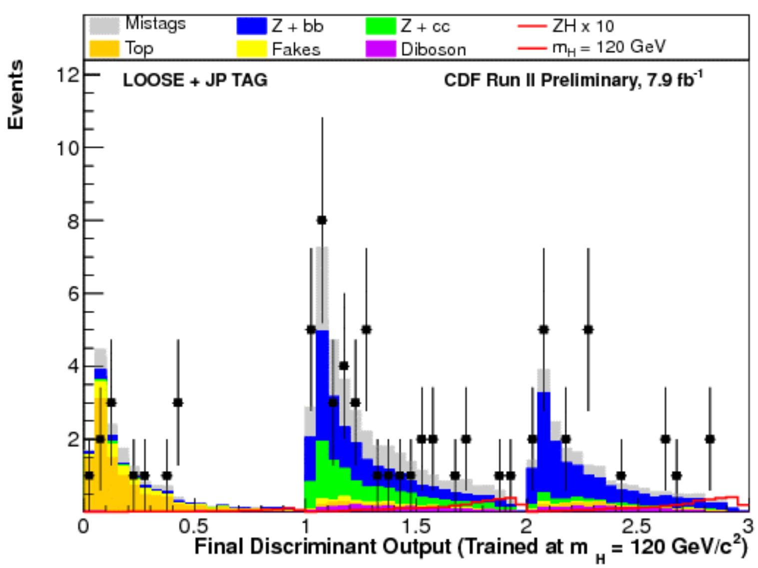
improves sensitivity by ~5%

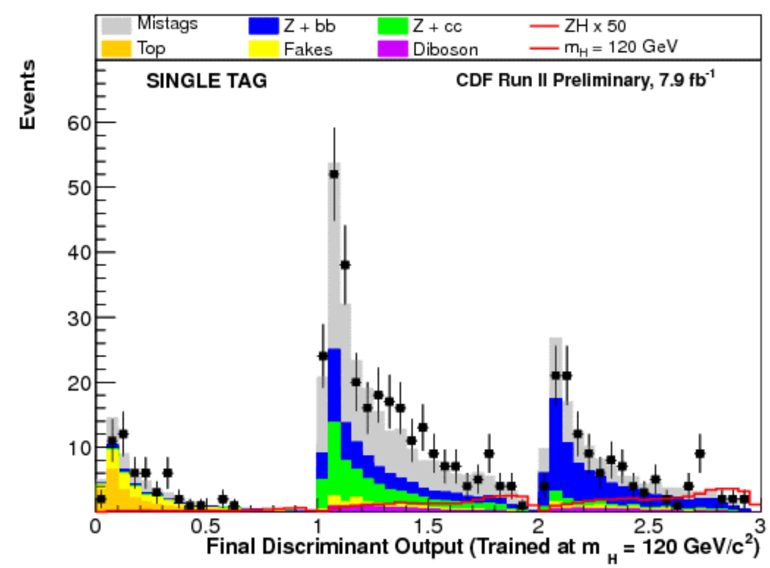
simplifies combination with other search channels

ZH→μμbb final discriminant

- Separate into 3 b-tagging channels
  - Two or more SecVtx tags
  - SecVtx tag + JetProb tag
  - Single SecVtx tag

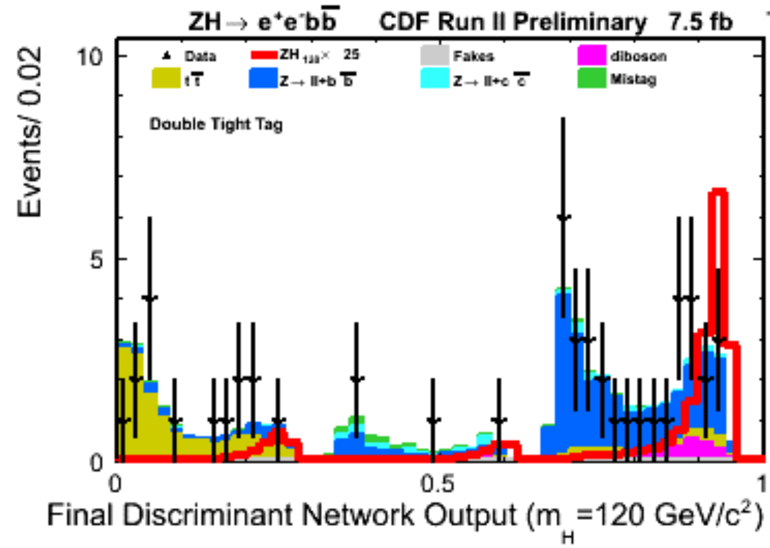


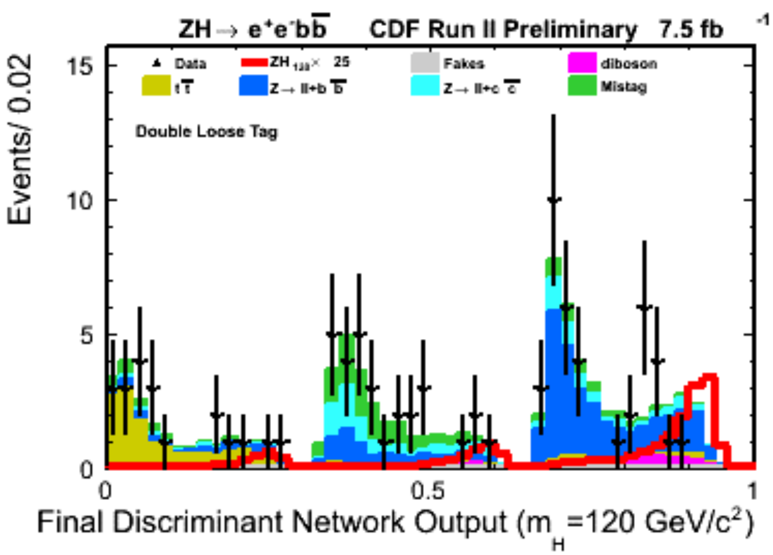


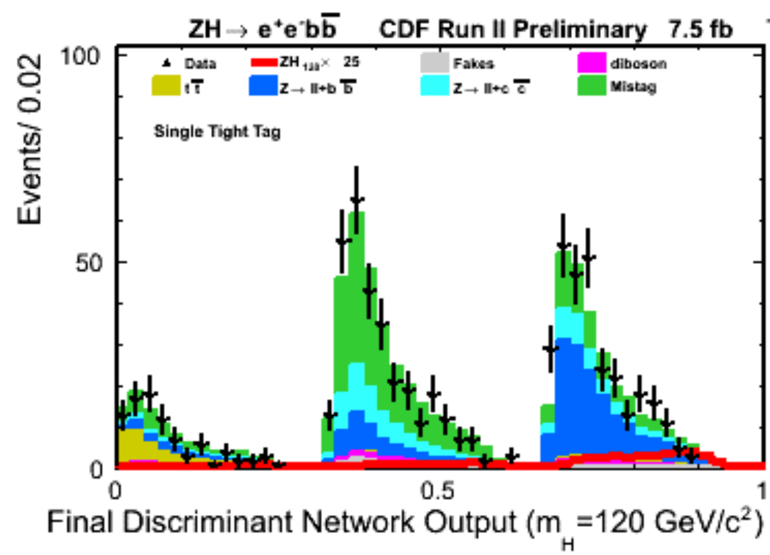


ZH→eebb final discriminant

- Separate into 3 b-tagging channels
    - Two or more SecVtx tags
    - SecVtx tag + JetProb tag
    - Single SecVtx tag

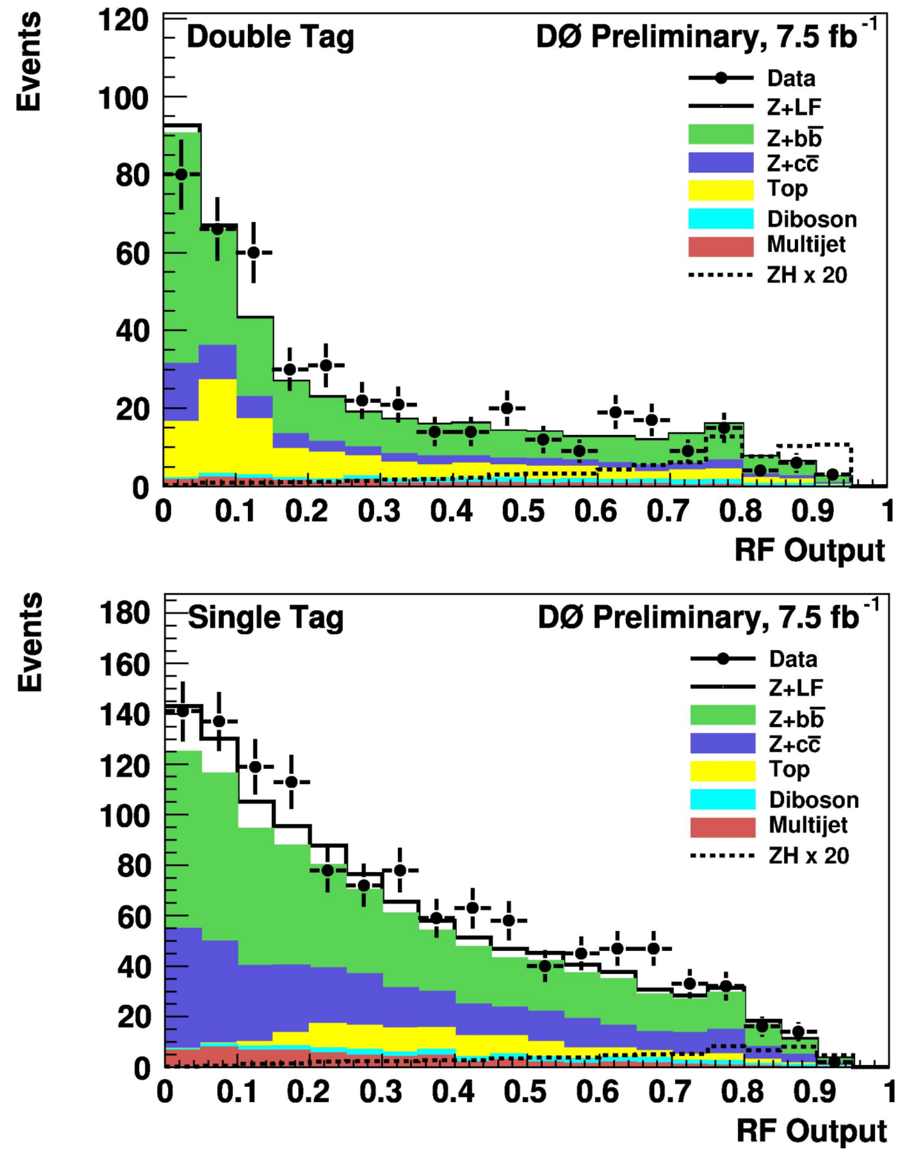




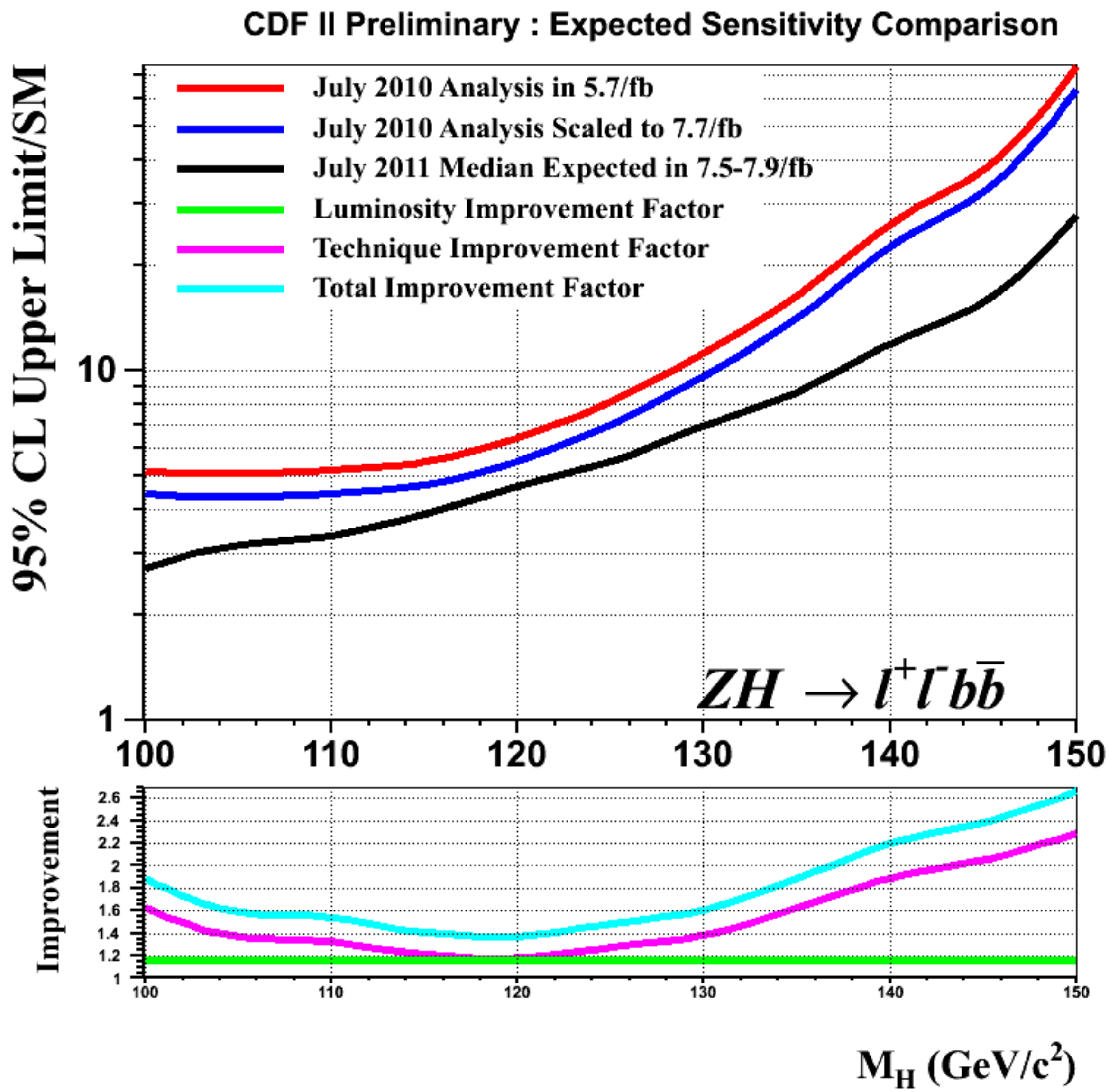


ZH→*ll*bb final discriminant

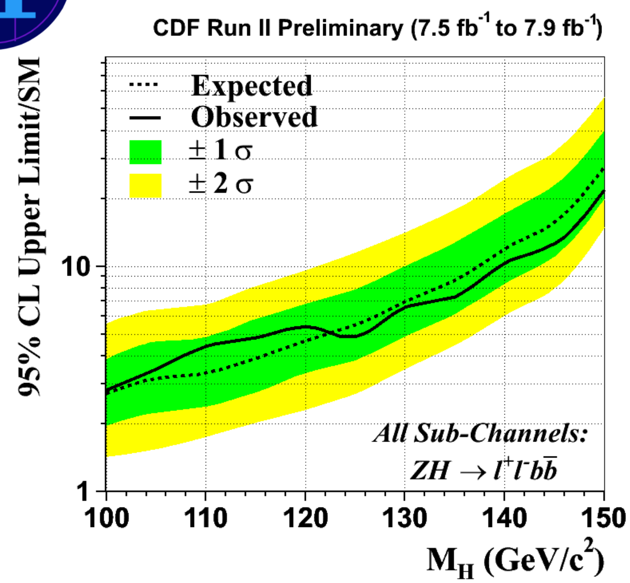
- Random Forest Boosted Decision Tree
- separate tree trained at each Higgs mass
- double b-tag and single b-tag channels
- combined with previously analyzed 1.1/fb of RunIIa data
- no significant excess is seen in the data of either experiment

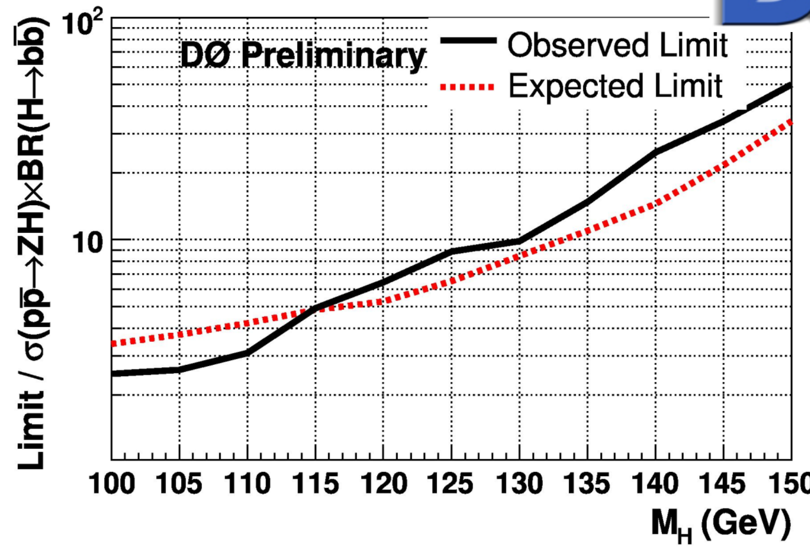


Making ZH → *ll*bb smarter



ZH → *ll*bb Results $\int \mathcal{L} \sim 8\ fb^{-1}$





CDF limit for M_H=115 GeV

limit/SM 4.8 (3.9 exp)

D∅ limit for M_H=115 GeV

limit/SM 4.9 (4.8 exp)

Conclusions

- searches for standard model Higgs in ZH→*ll*bb continue to incorporate new techniques and analysis improvements
- predicted background is in good agreement with data and shows no excess
- will continue to improve analysis sensitivity beyond increase in luminosity
- look for full Tevatron datasets soon after completion of RunII in September