The Search For The Brout-Englert-Higgs Boson With Up To 10/fb With CDF

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Rencontres de Moriond
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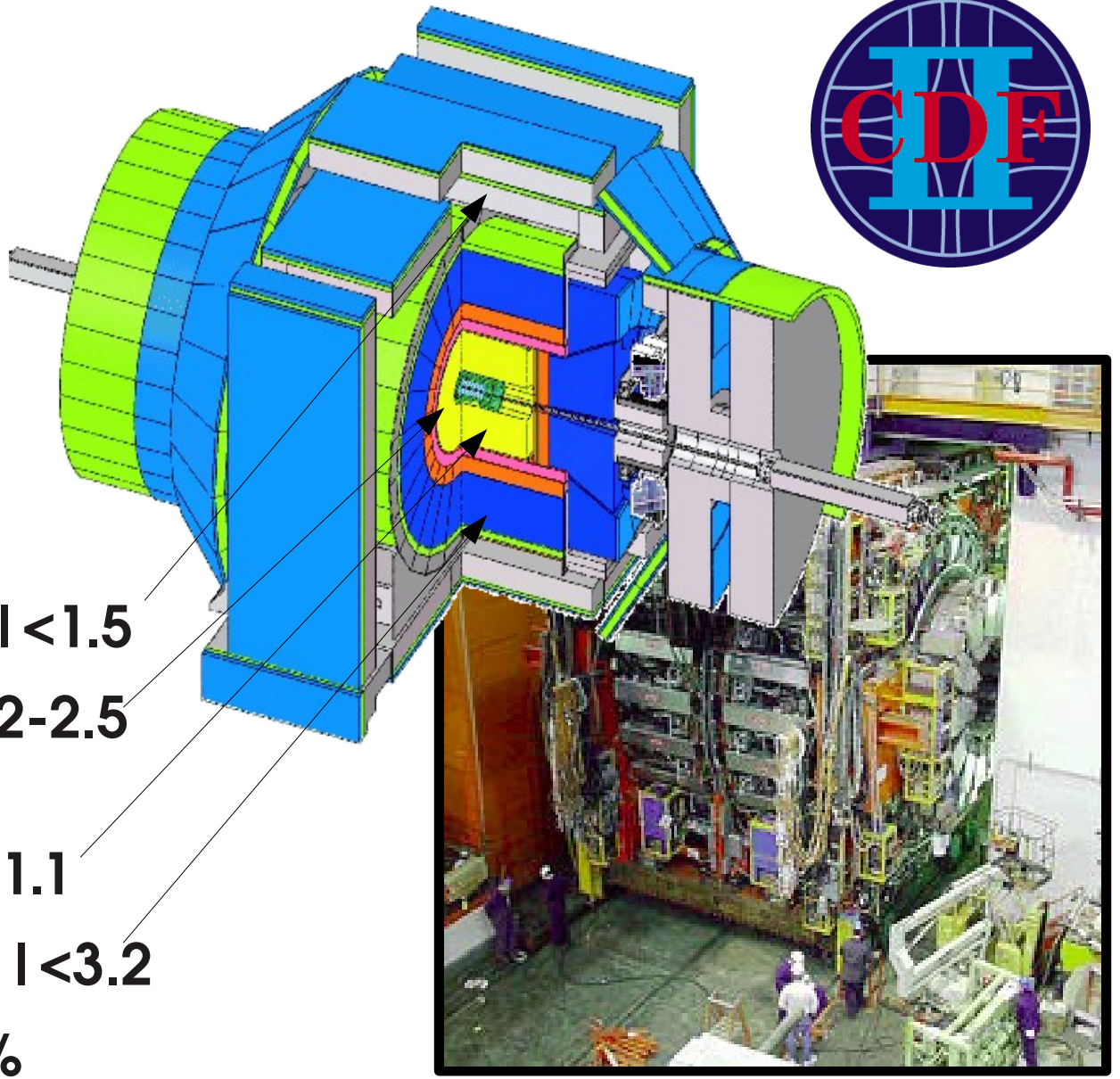
Overview

- Goal: Direct evidence for or exclusion of the SM Higgs boson
- Overview of new results
- The CDF experiment
- Overview of searches
- Recent advancements in search Techniques
- Full dataset results
- Conclusions/ prospects

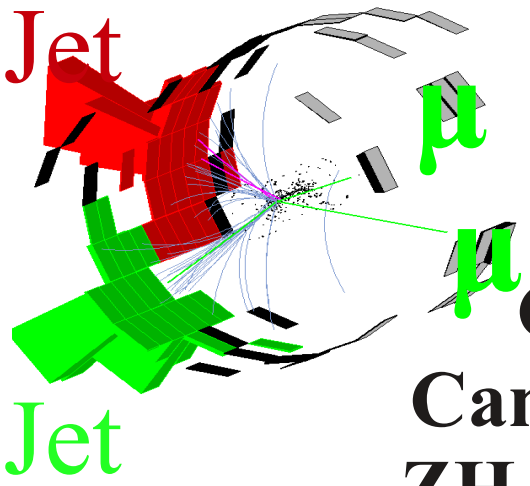
CDF: A General Purpose Experiment

- ~5K tons
  (~2.5K central only)
- ~10 m each direction
- ~100 Hz readout
- ~720 K silicon tracker readout channels

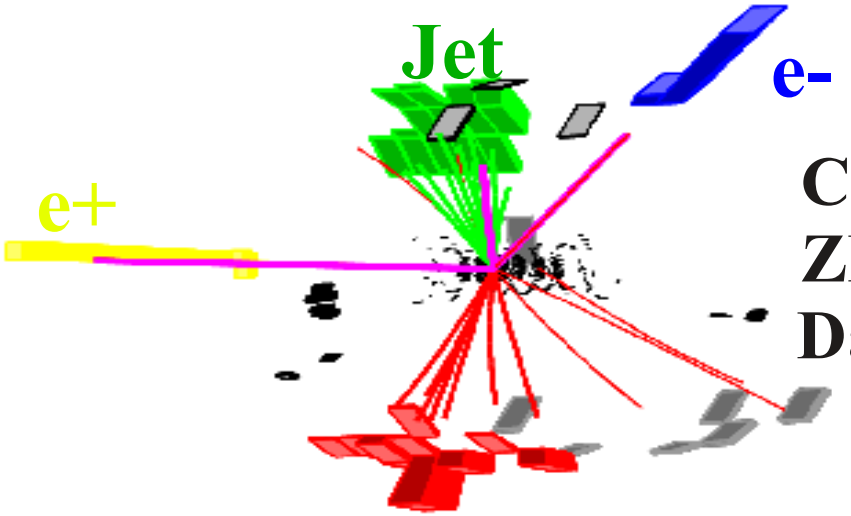
- Muon chambers: $|\eta|<1.5$
- Silicon tracking $|\eta|<2$-2.5
- Drift cell tracker
  1.4 Tesla B field, $|\eta|<1.1$
- Pb/Cu/scint calor. $|\eta|<3.2$
  - JES uncertainty 2-3%



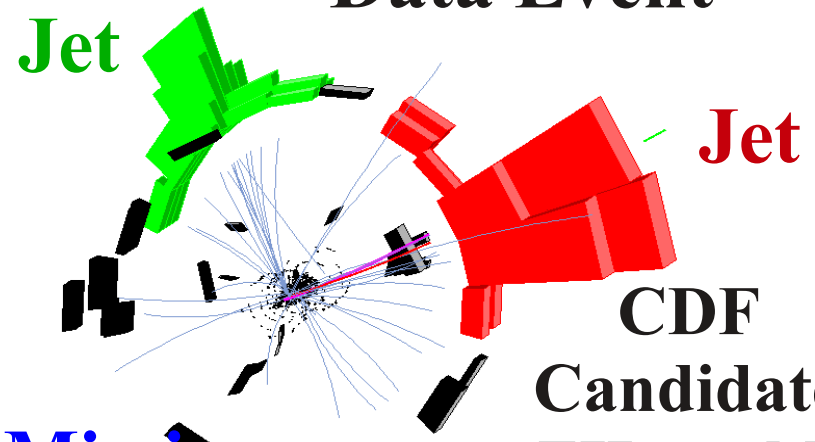
Candidate VH Events at CDF



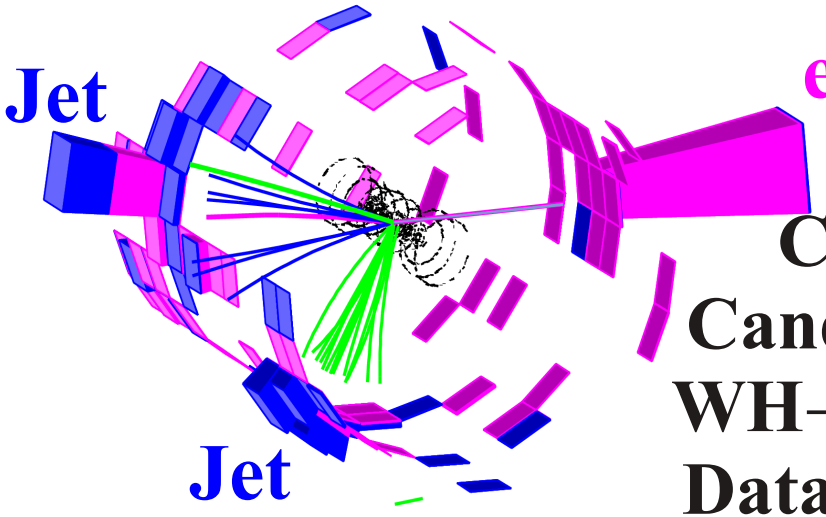
CDF Candidate $ZH \rightarrow \mu\mu bb$ Data Event



CDF Candidate $ZH \rightarrow eebb$ Data Event



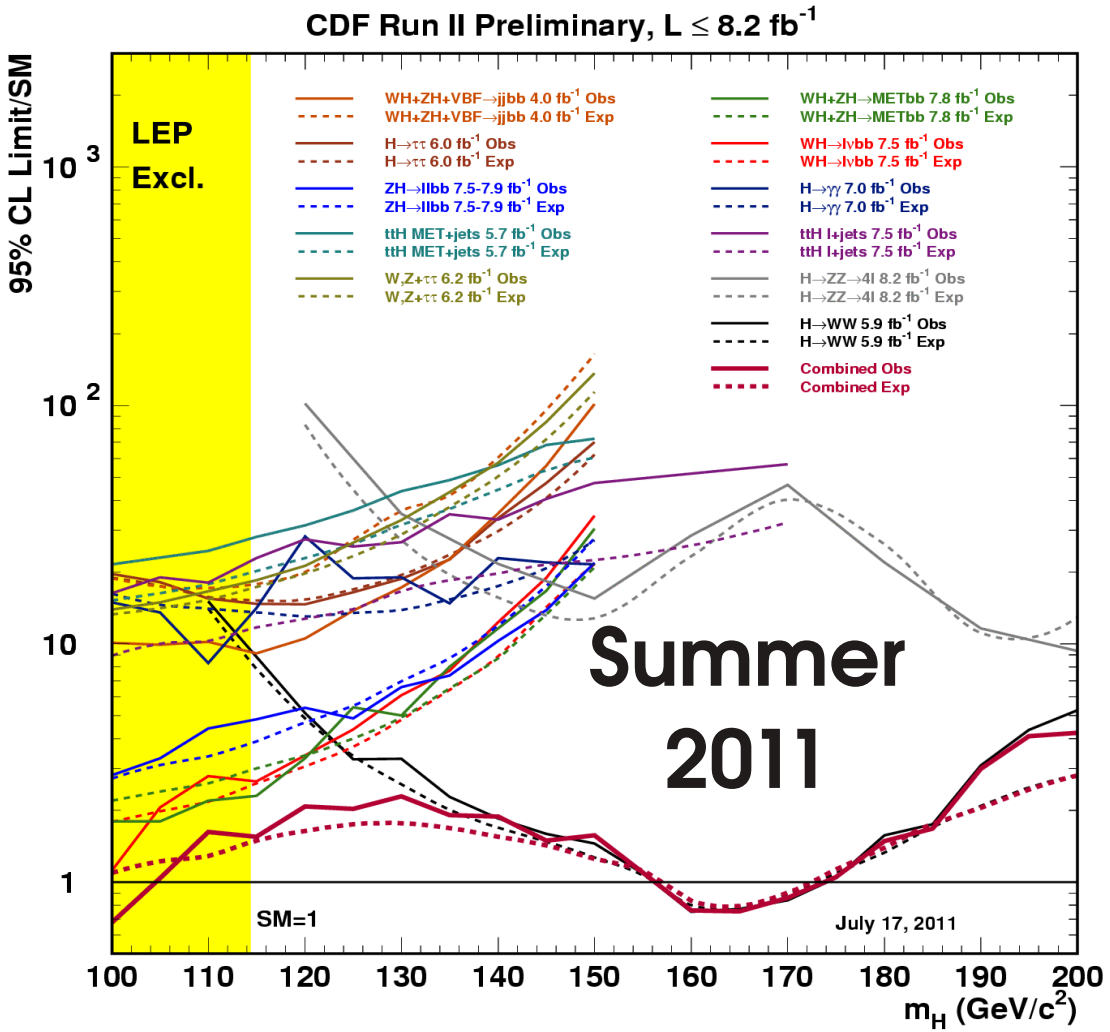
CDF Candidate $ZH \rightarrow \nu\nu bb$ Data Event



CDF Candidate $WH \rightarrow e\upsilon bb$ Data Event

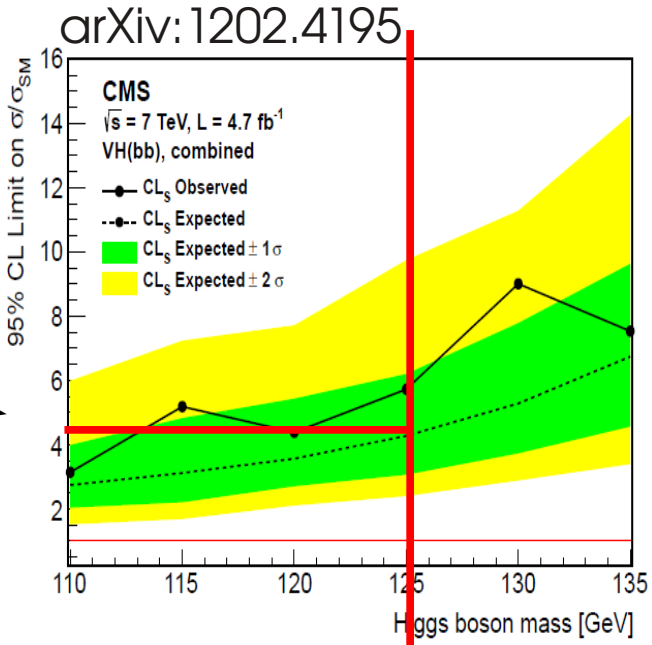
The CDF Higgs Search

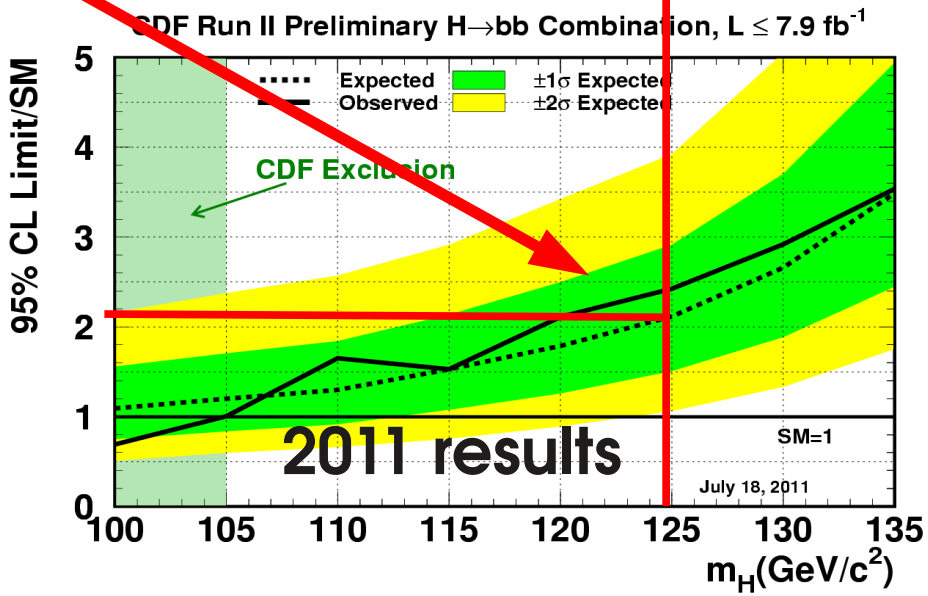
- For the 2012 CDF Winter results:
  - SM predicts ~167 Higgs (125 GeV) events *reconstructed and selected*
  - SM background of ~200K
- Small signal on diverse background
  - Maximize signal acceptance
  - Maximize signal significance
- Partitioned over many final states
  - Low (<150 GeV) mass
    - WH, ZH, METbb, ttH, γγ, VBF→bbjj
  - High (>150 GeV) mass
    - WWW, WWZ, WW, ZZ, τ-decays, full/semi-leptonic...
- 16 CDF analyses:
  - 93 orthogonal sub-channels.
- In non-excluded region, associated production and WW contribute ~90% of total weight.



Comparing Search Channels

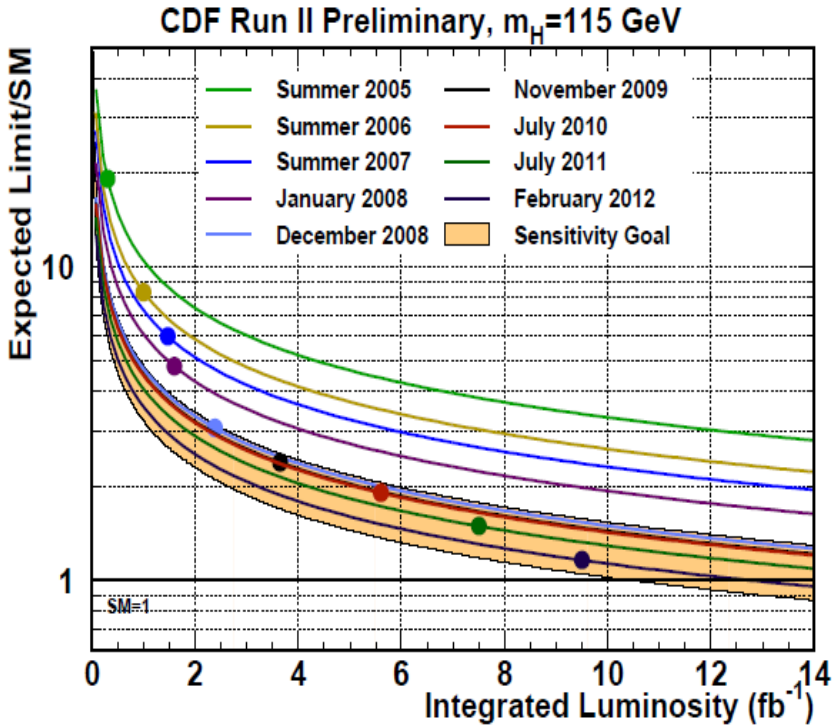
- **Expected Sensitivities (January 2012, 125 GeV):**
  - **VH, H→bb:**
    - ATLAS,CMS: ~4.3xSM
    - CDF, D0: ~2xSM
  - **H→γγ:**
    - ATLAS,CMS: ~1.5-2xSM
    - CDF, D0: ~10-13xSM
  - **H→WW:**
    - ATLAS,CMS: ~1-2xSM
    - CDF, D0: ~3.5xSM
- **Tevatron's strength in the light-SM-Higgs scenario is the branching fraction of H to bb!**

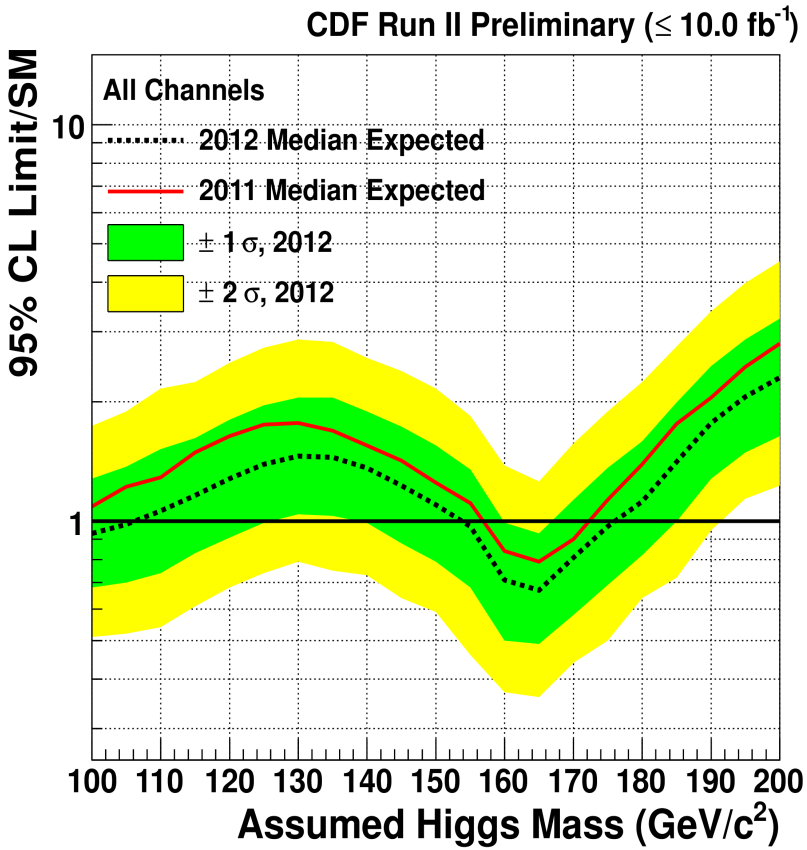




Massive Search Strategy Improvements

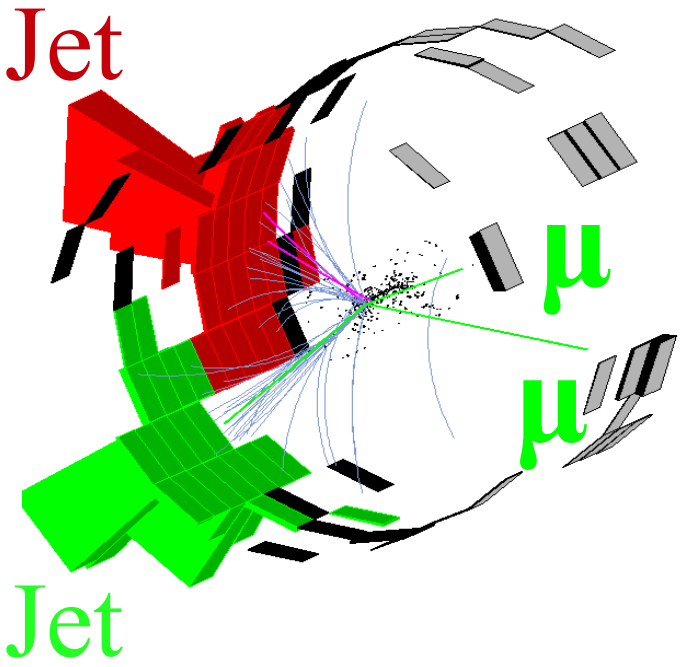
- The combined CDF Higgs search:
  - Sensitivity improvements:
    ~2X beyond dataset increases since 2007
  - 2012: ~30% more sensitive at low-mass than summer 2011
  - 1.46*SM or better from 115 to 180
  - This talk outlines how





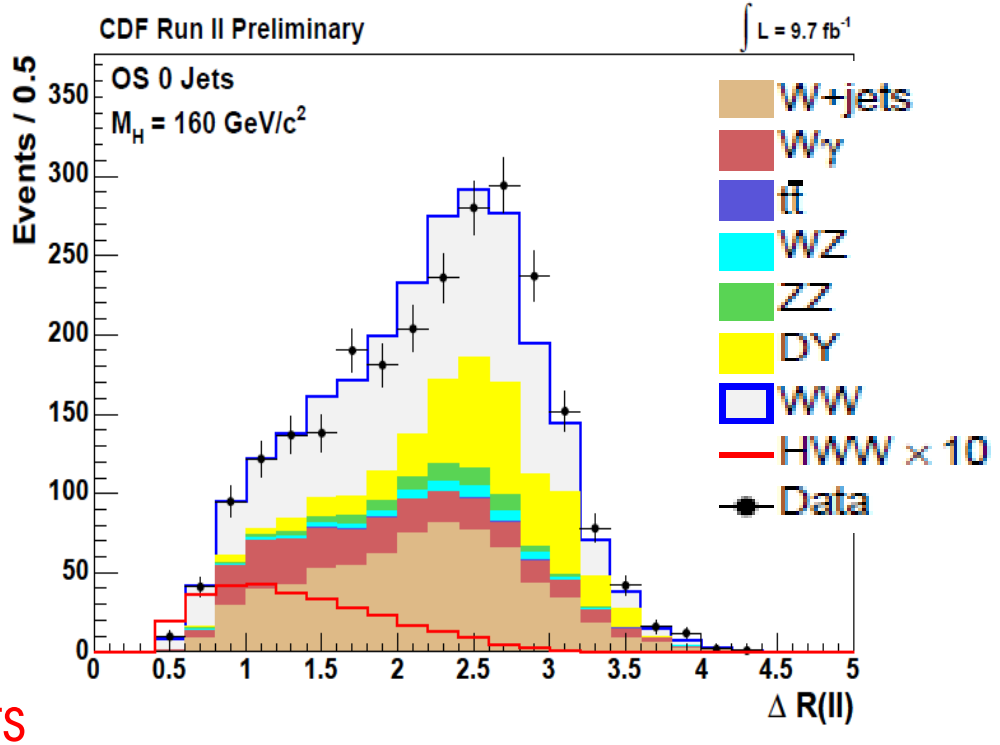
Online Event Selection

- Tevatron bunch crossing rate: ~MHz
  - CDF data taking rate: ~100 Hz
  - Triggers select most interesting events
- To maximize the number of recorded candidates
  - Optimized generic single-object triggers
  - Triggers designed specifically for SM Higgs searches
- 2010-2012: Inclusive Triggering:
  - Resulting gain was >20% more signal acceptance in ZH→μμbb
    - Trigger on "MET" at trigger level caused by muons
    - Utilize MET+jets triggers originally intended for Z→νννbb
    - Accept events with muons non-fiducial to muon chambers used for triggering
- ~30% signal gain seen in METbb, 5% in WH Analyses.



Reconstruct Events

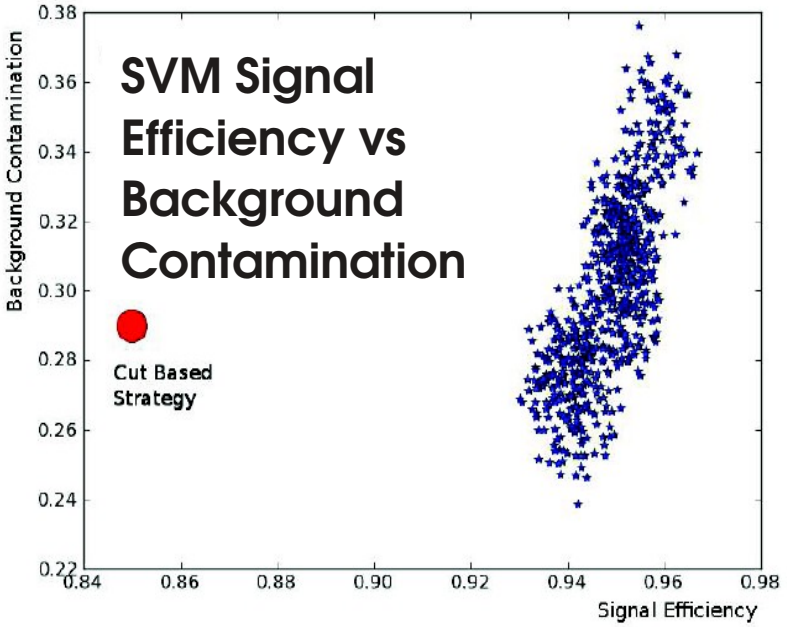
- Original CDF definitions of leptons were designed for purity and efficient triggering, not acceptance
  - WW→lνlν analysis: uses small opening angle of two leptons to identify signal
    - Spin of Ws correlated in Higgs decays
    - Two nearby leptons spoil each other's track isolation, flagged as background
    - 2011: WW-specific event selection retains these events

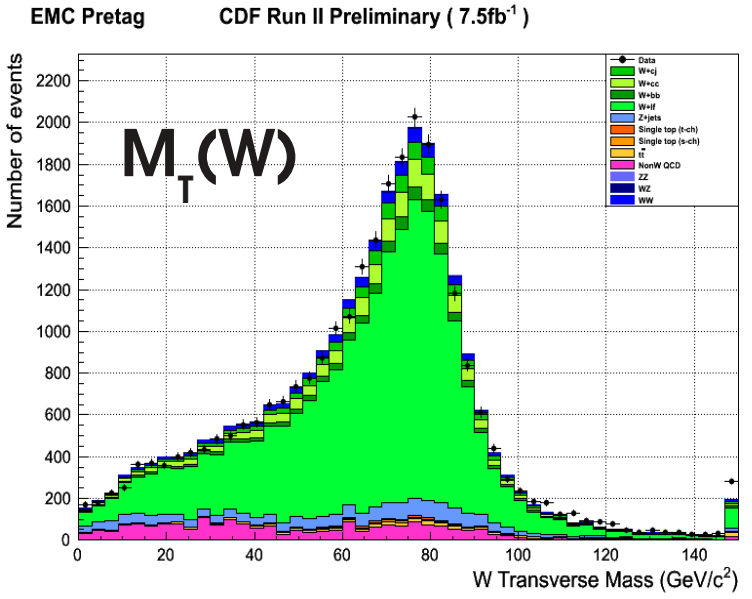


- 2010-2012: WW, WH, ZH Analysis:
  - Employ multivariate lepton identification

Select Events Offline, Reject Background

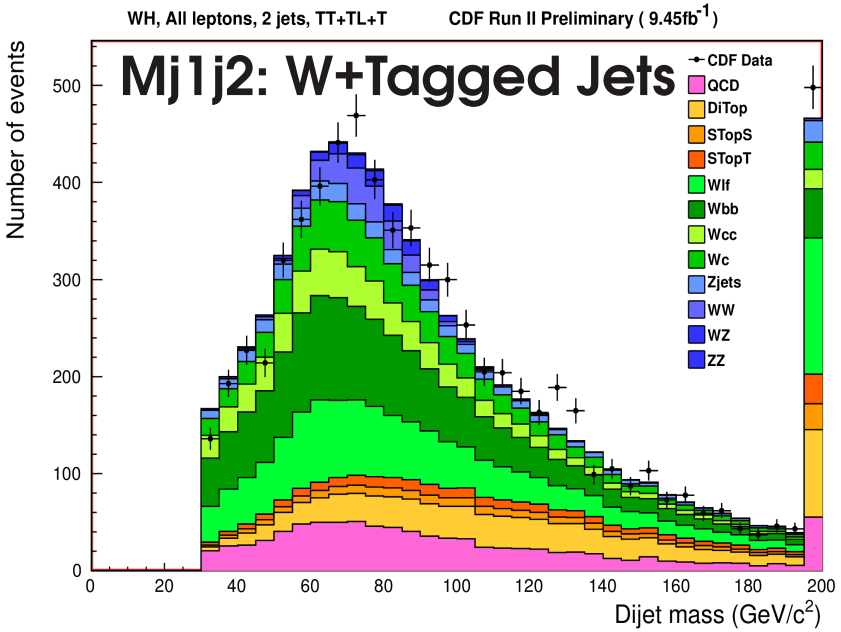
- To maintain high efficiency, with good simulation, multivariate rejection of difficult backgrounds is performed
  - 2011-2012: WH Analysis:
    - Reject instrumental background via a Support Vector Machine:
    - Retains
      95% EWK, 24% Instrumental
    - Compare to previous cut- based instrumental rejection:
      84% EWK, 29% Instr.

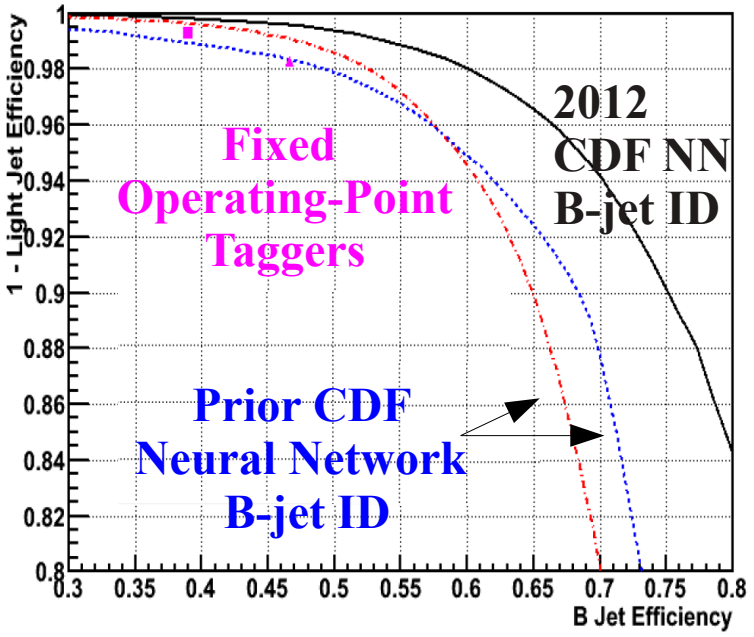




New b-Jet Identification

- 2011: CDF WH,ZH,VH used 2 or 3 different b-taggers in orthogonal series
- 2012: New CDF Neural Network b-tagger
  - More jets are taggable
  - For identical false-positive rates of previous taggers, b-jet efficiency:
    - Tight: 38.6→53.6%
      - False Positive: 1.4%
    - Loose: 47.1→59.3%
      - False Positive: 2.8%
- Calibrated on multiple sideband samples of varying flavor composition
  - Adjustments to simulation in each sample are comparable
  - Differences taken as systematic
  - Adjustments for true bs: 5%±4%

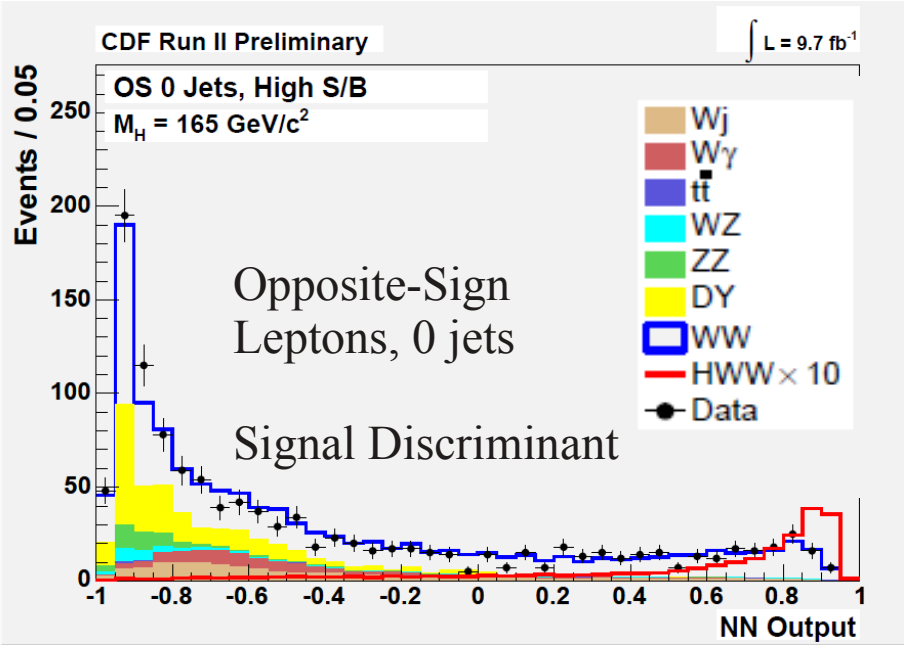


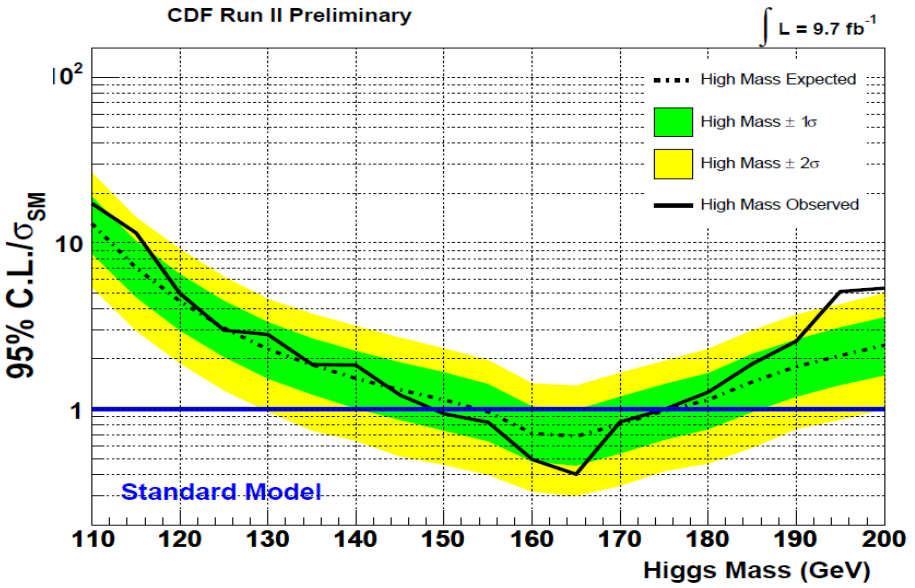


Neural Network Output

Major Improvements: 2012

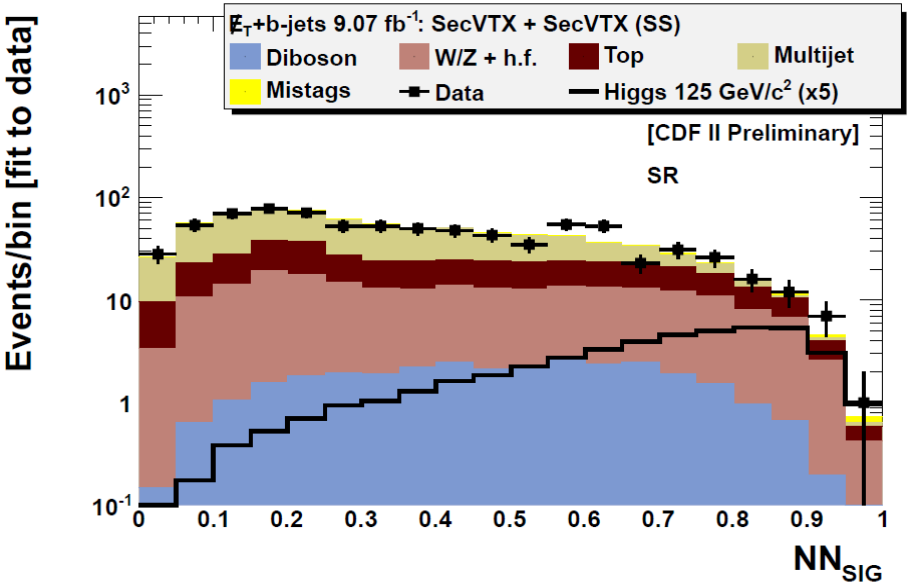
- WW:
  - Major backgrounds: SM WW, Drell-Yan
  - Acceptance from many production modes, both WW and ZZ decay modes.
  - Biggest improvement: Data increase
    - ~10% improvement in expected sensitivity
  - Added acceptance from new low-dilepton-mass channel
  - Best s/b: ~1:1
  - Exclude MH=(147,175) GeV

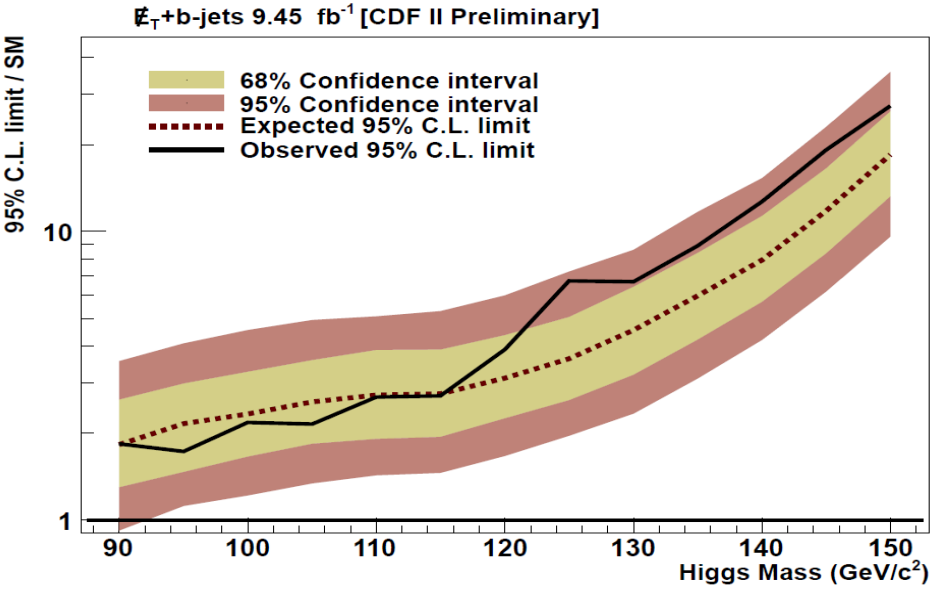




Major Improvements: 2012

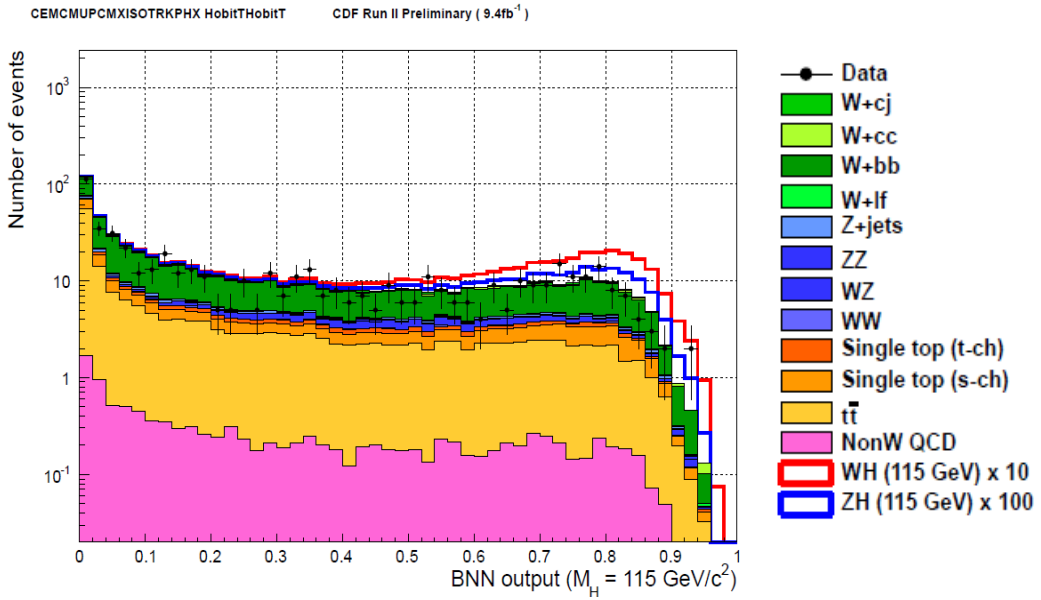
- **METbb:**
  - Major backgrounds:
    - WW+bb, Multijets+Instrumental MET
  - **Biggest improvement: Data increase**
  - New MET correction offers better BG rejection
  - Best s/b: ~1:5
  - **~Summer 2012 improvement: new tagging**
    - **~10-12% additional sensitivity improvemen**

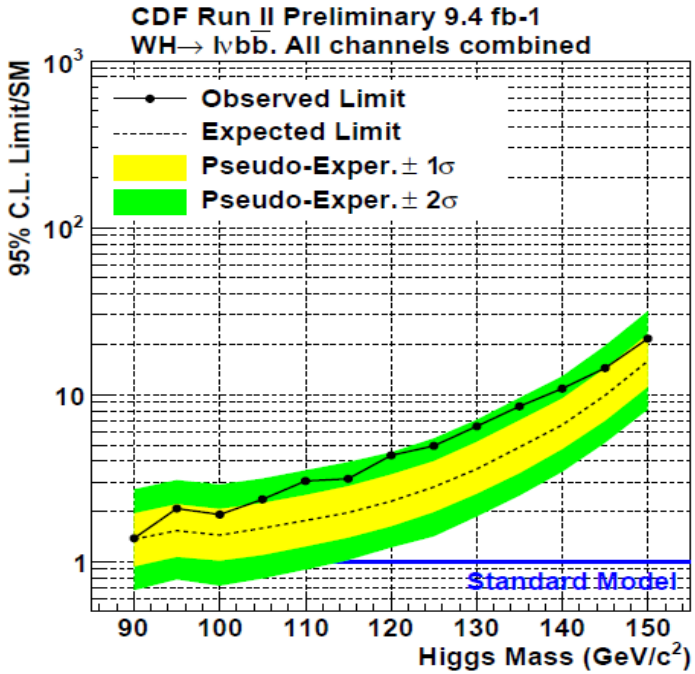




Major Improvements: 2012

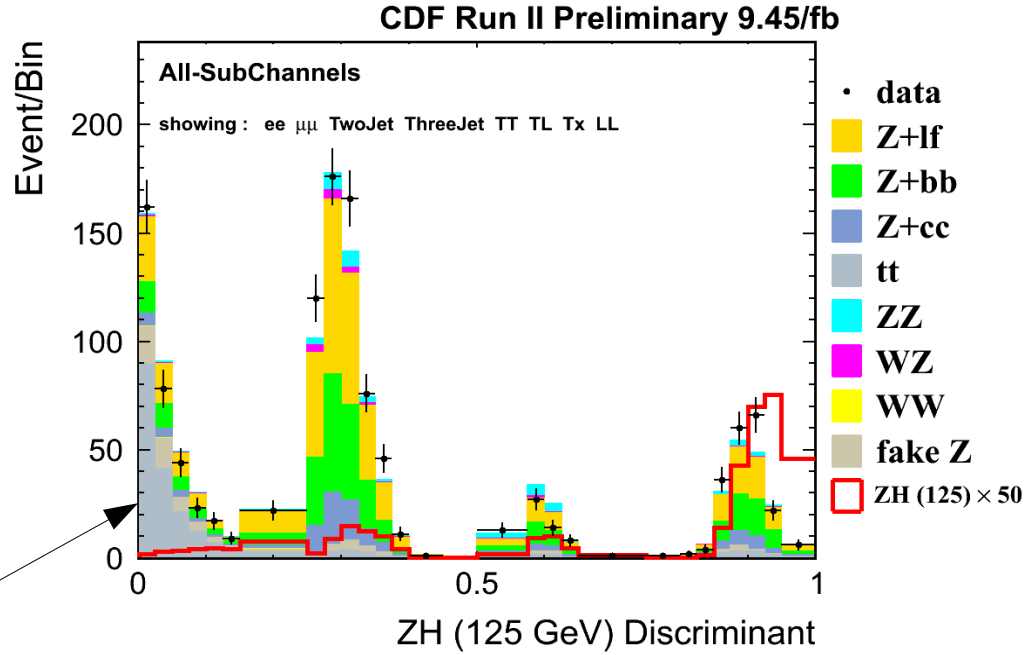
- WH:
  - Major background:
    - W+bb, di-top, instrumental non-W.
  - Added data + improved b-tagging + new triggers + update of 3-jet bin
  - Best s/b: ~1:5
  - 2012: 22.7→40.2 Expected Signal Events!!!
  - 1-2012/2011=~30% stronger expected limits than summer 2011

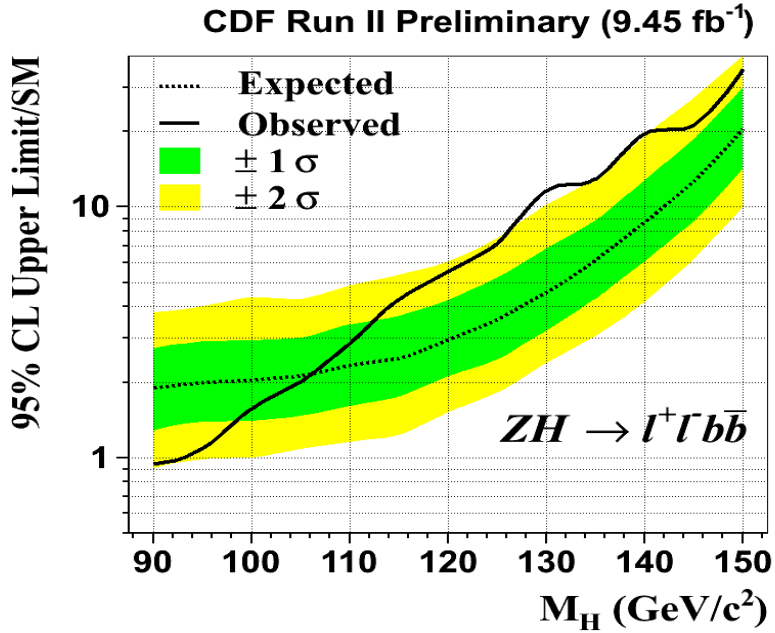




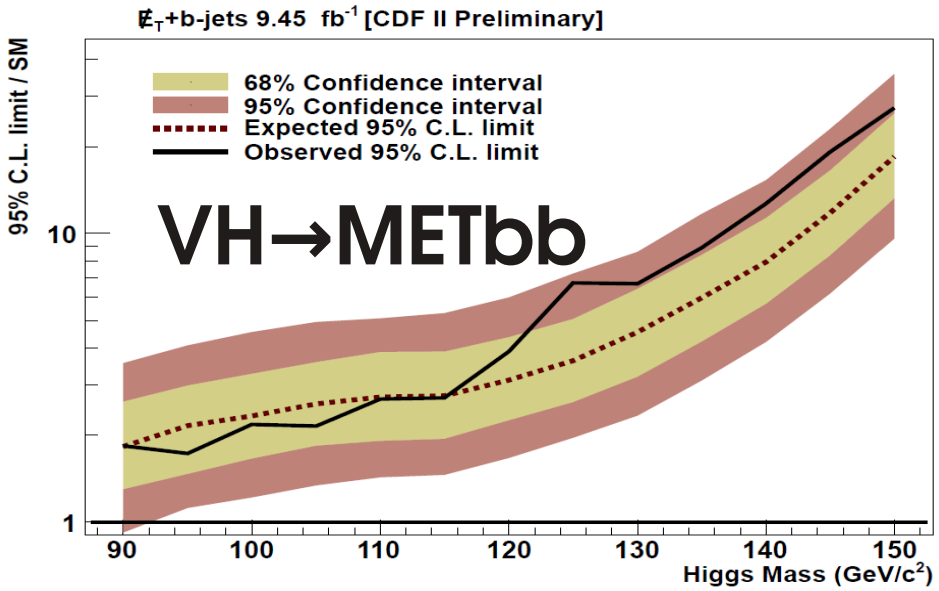
Major Improvements: 2012

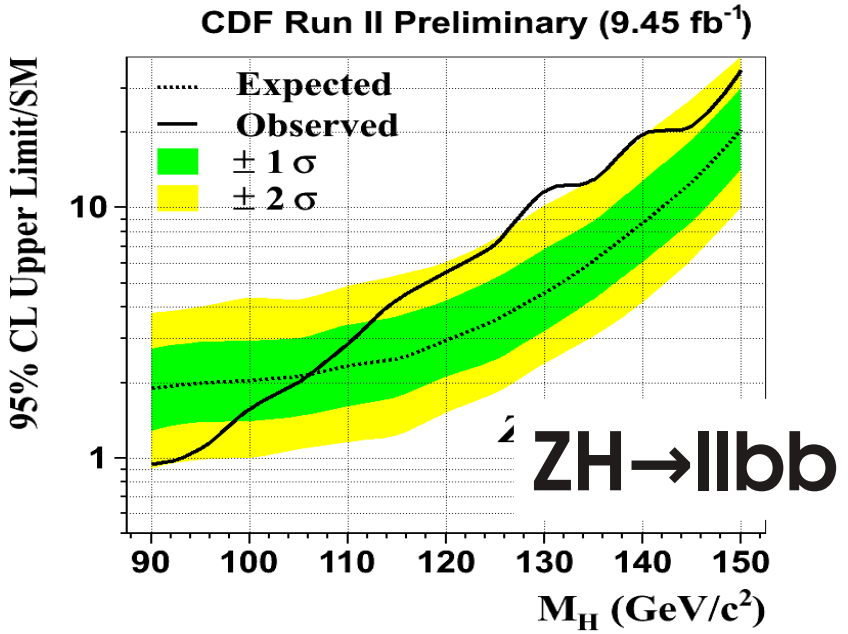
- ZH
  - Major backgrounds: Z+bb, di-top
  - Added data + improved b-tagging + better background rejection+Improved lepton acceptance + sifted background discrimination
  - 20112012 Doubled integrated s/√b!
  - Best s/b: ~1:1
  - 1-2012/2011 = ~34% stronger expected limits than ZH summer 2011

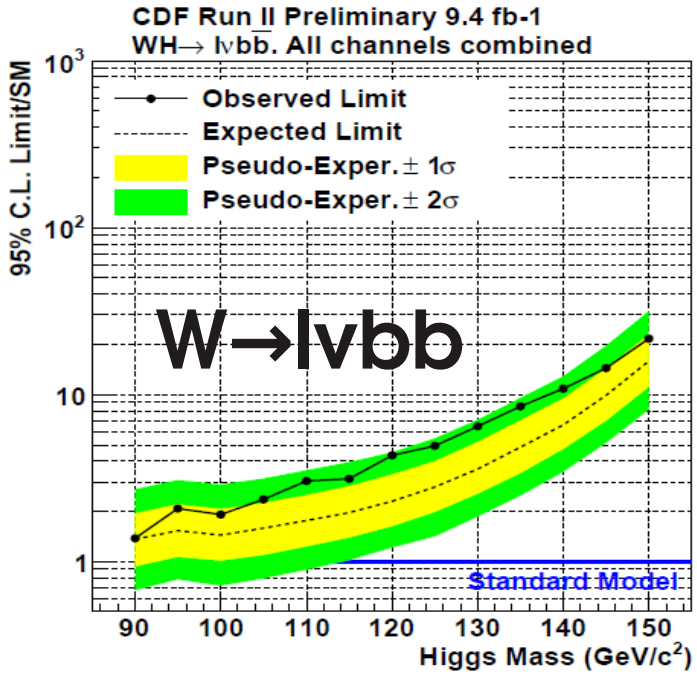


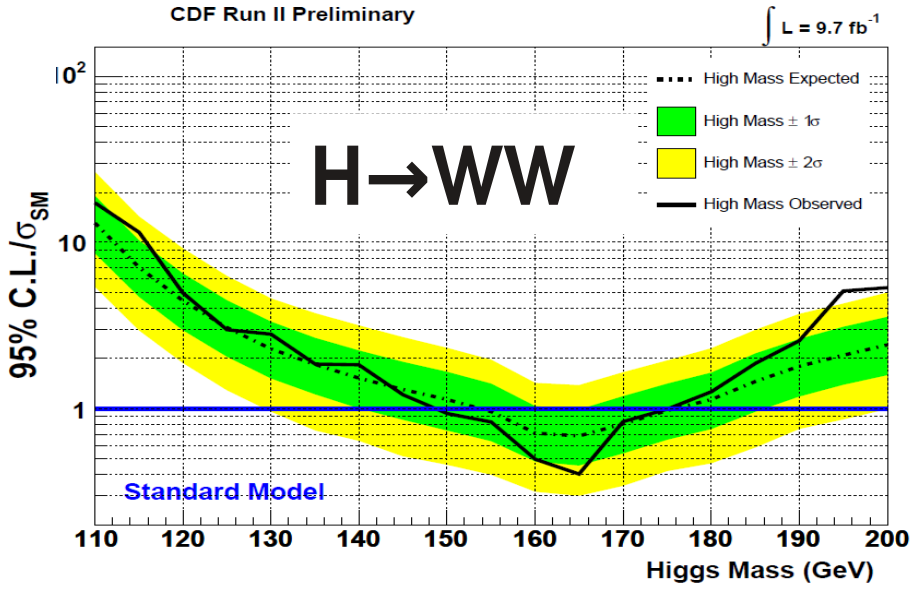


Overview of 4 Strongest Channels



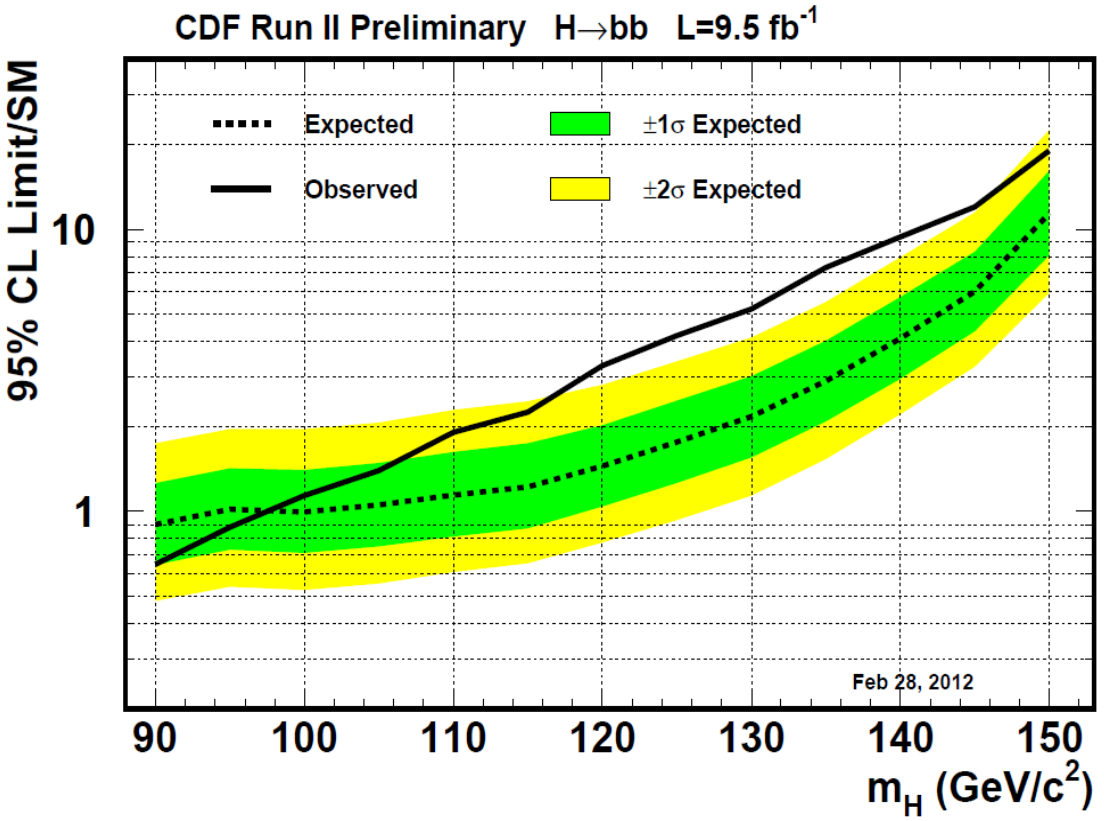


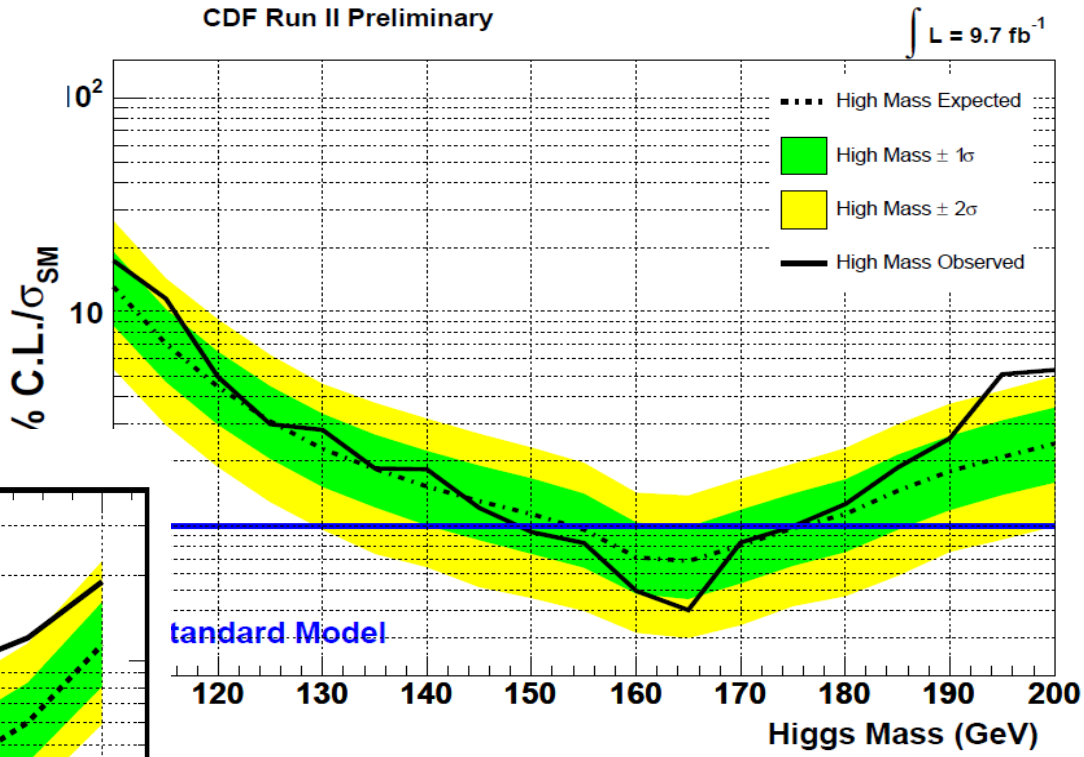




Process Specific Combined Results

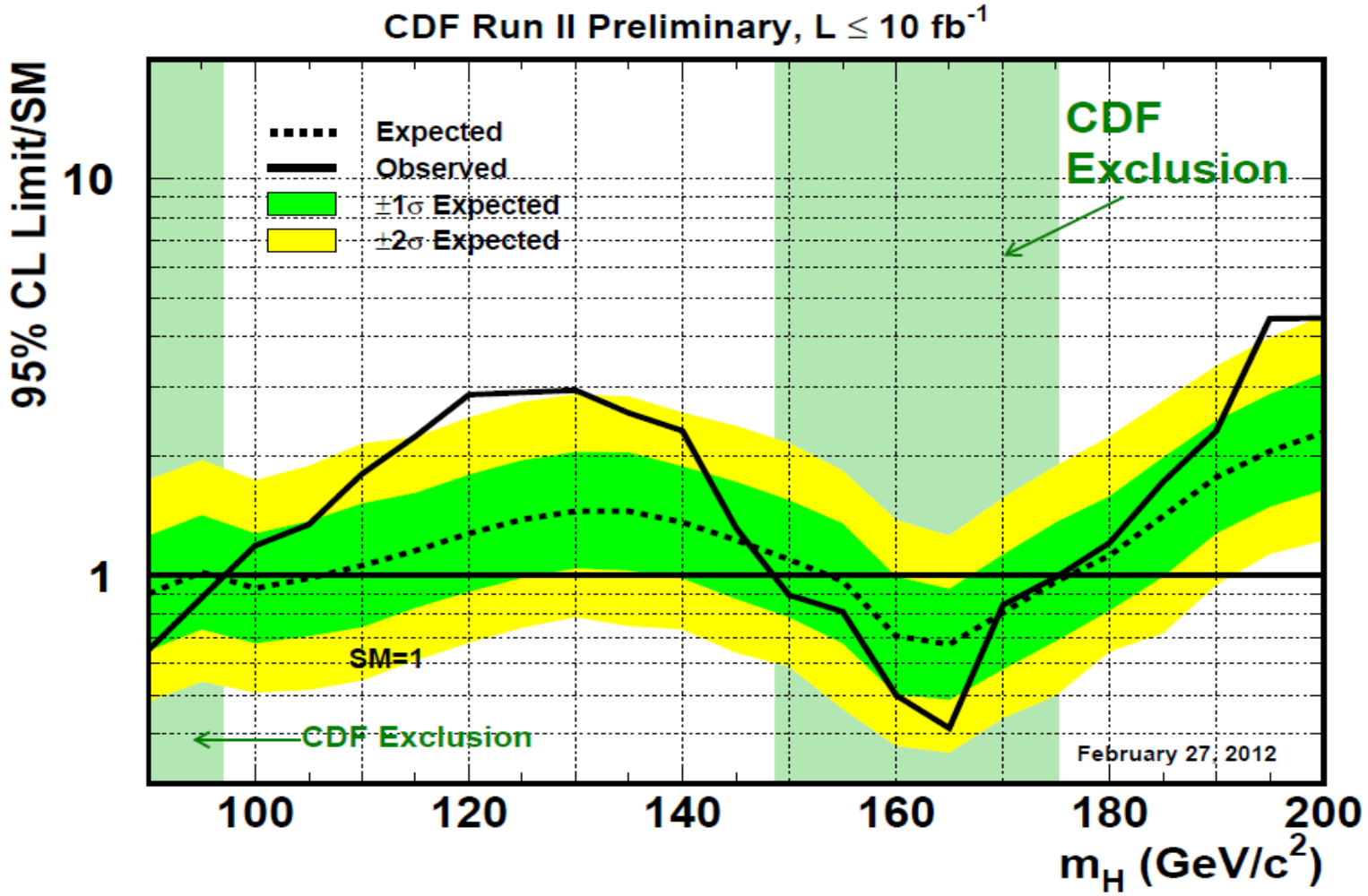
- Broad excess observed in H→bb
  - Largest Excess: 135 GeV
  - Global p-value (LLE=2) = 2.7 sigma





The CDF Combined Higgs Search

- Exclude 147-175 GeV
- Broad excess observed. Largest excess: 120 GeV
- Global p-value (LLE=4) = 2.1 sigma



Conclusions

- CDF has made major improvements to its SM Higgs searches
  - A factor of 2 lower expected limits compared to 2007
  - 1-2012/2011= ~20% beyond new data at low mass since summer 2011
- The CDF Combination:
  - Expected sensitivity: 1.46xSM or better < 185 GeV
  - Exclude 147-175 GeV
- Associated production H→bb channels
  - Broad excess observed.
    - Largest Excess: 135 GeV: Global p-value (LLE=2) = 2.7 sigma
- CDF Combination:
  - Broad excess observed at masses below 150
    - Largest Excess: 120 GeV: Global p-value (LEE=4) = 2.1 sigma
- Timescale of Summer 2012:
  - Update METbb channel for better sensitivity to H→bb.
- Next Talk by W.Fisher will cover Tevatron Combination.

Conclusions

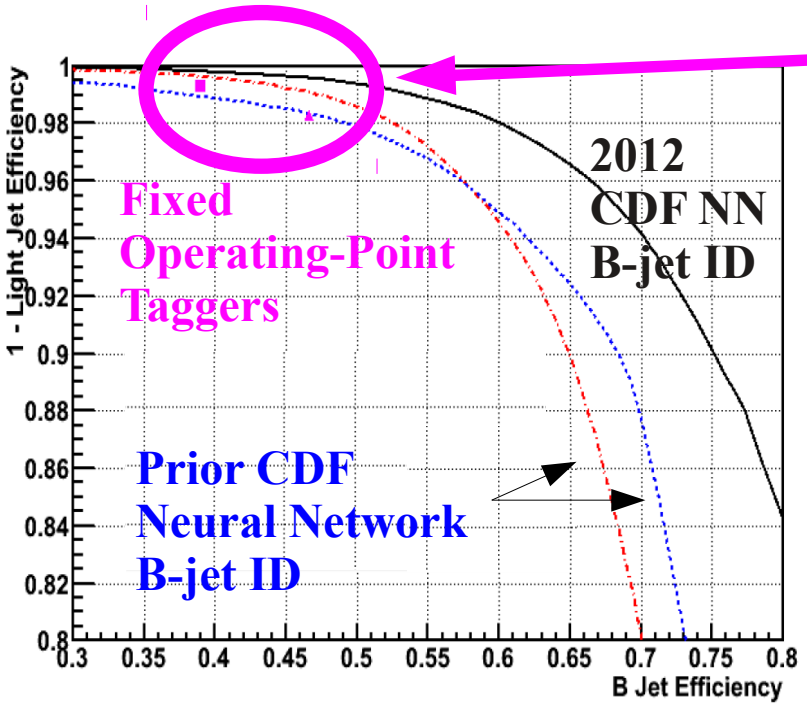
- For additional details see
  - Tevatron: http://tevnphwg.fnal.gov/results/SM_Higgs_Winter_12/
  - CDF: http://www-cdf.fnal.gov/physics/new/hdg/Results.html
  - D0: http://www-d0.fnal.gov/Run2Physics/WWW/results/higgs.html

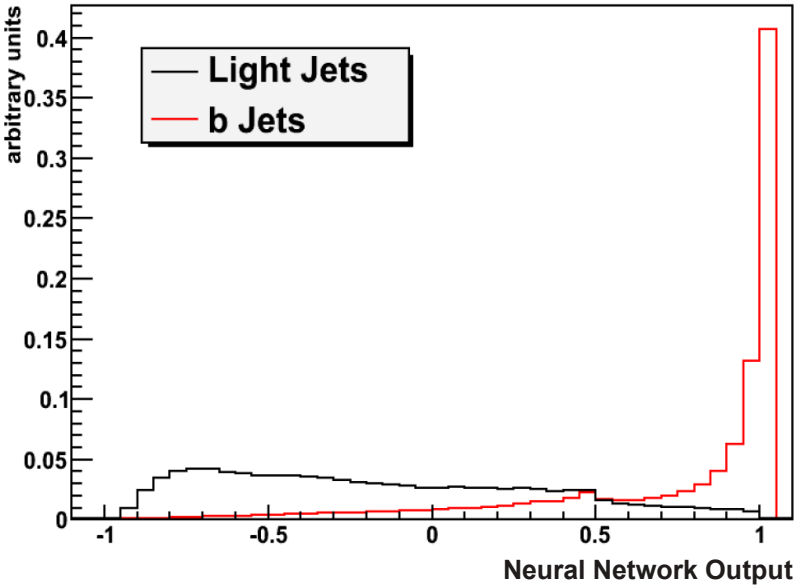
- Thanks to everyone at CDF who contributed to this update!
- Bigger thanks to everyone who designed, built, or operated CDF!
- FNAL Computing Division: Thanks for all the computing power and software!
- FNAL Beams Division: Thanks for all the collisions!

Thank you for your attention

Questions?

New b-Jet Identification

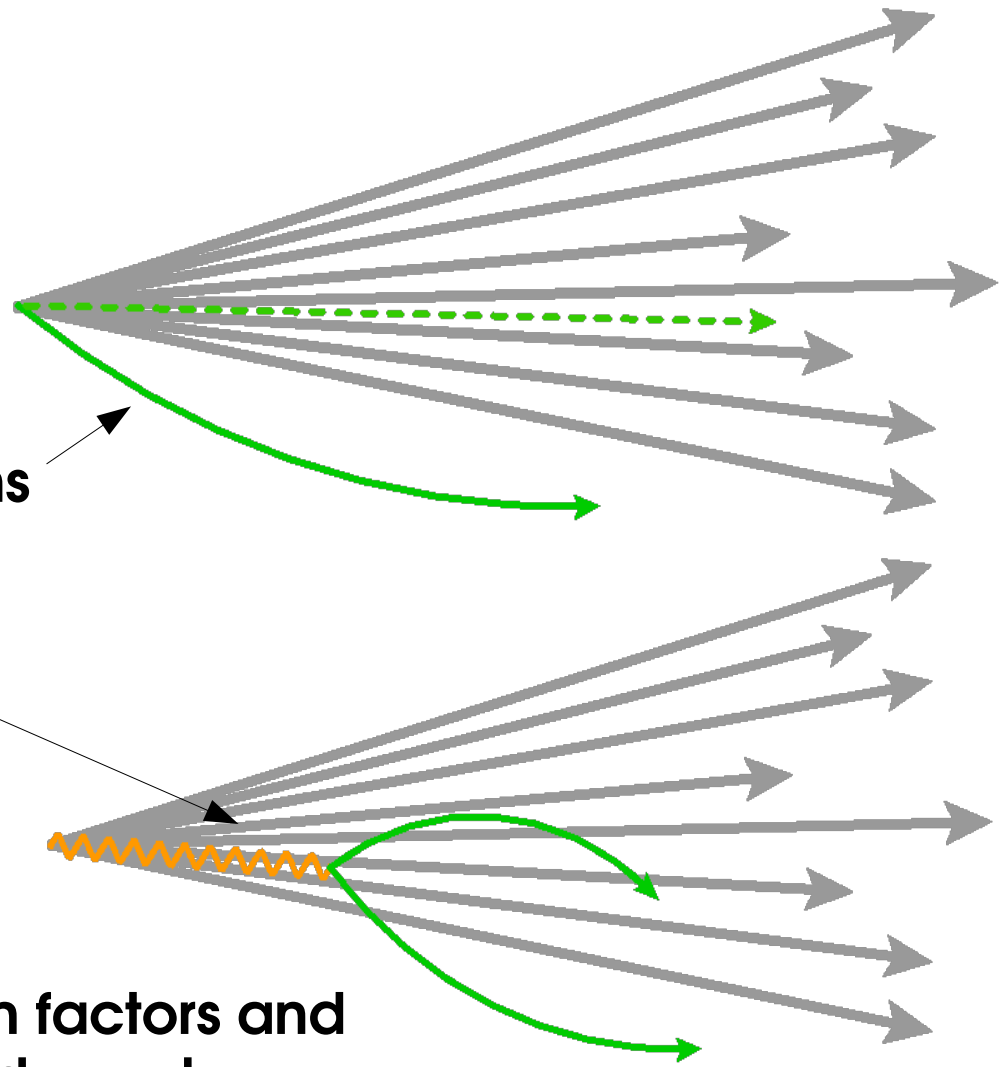




- 2011: CDF WH,ZH,VH used 2 or 3 different b-taggers in orthogonal series
- 2012: New CDF Neural Network b-tagger
  - Uses most sensitive variables from previous CDF taggers
    - Uses semileptonic b-decay muons, Jet tower mass, secondary vertex mass...
    - Can tag jets with only one charged particle track
  - Continuous variable output allows for analysis group to choose cuts:
    - optimize expected sensitivity
  - For identical false-positive rates of previous taggers, b-jet efficiency:
    - Tight: 38.6→53.6%
      - False Positive: 1.4%
    - Loose: 47.1→59.3%
      - False Positive: 2.8%

New b-Jet Identification

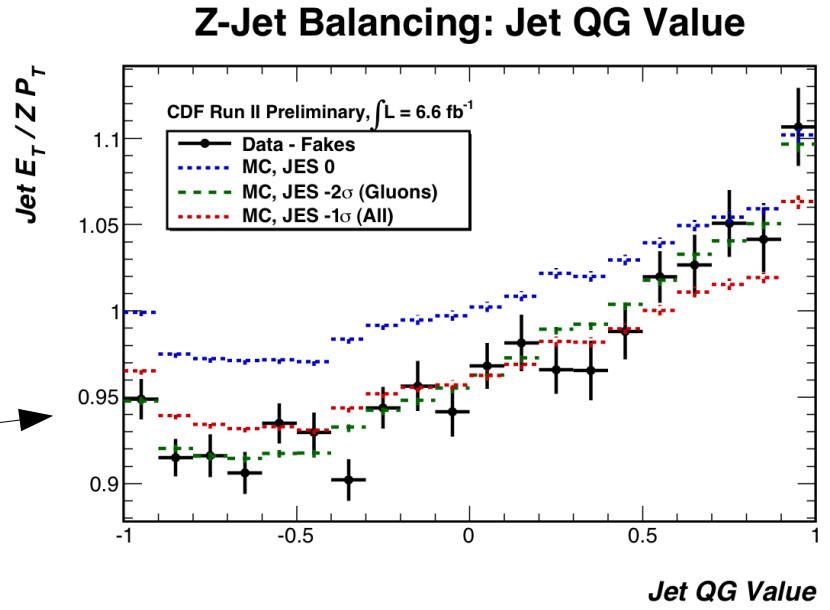
- Calibration samples
  - Kinematic selection of W+4,5 jets events (di-top)
  - QCD dijets with low relative-pt electrons
    - Not an input to tagger
    - Semileptonic decay electrons
      - Enriched in b,c
    - Photon conversion electrons (New method)
      - Primarily u,d,s,c,g
    - Examine both e-jet and opposing side jets

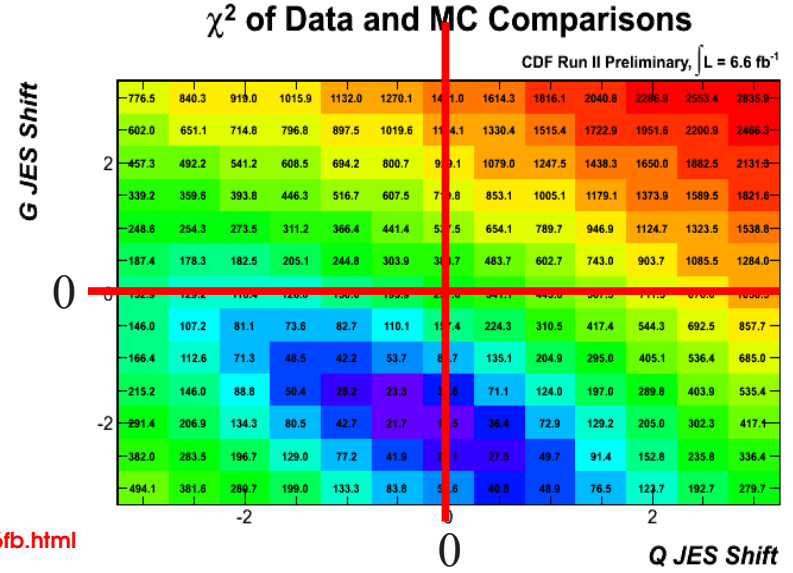


- These samples produce correction factors and uncertainty estimates for simulated events
- Resulting b-jet tag-rate corrections: ~5%±4%

New Additional Jet Systematics

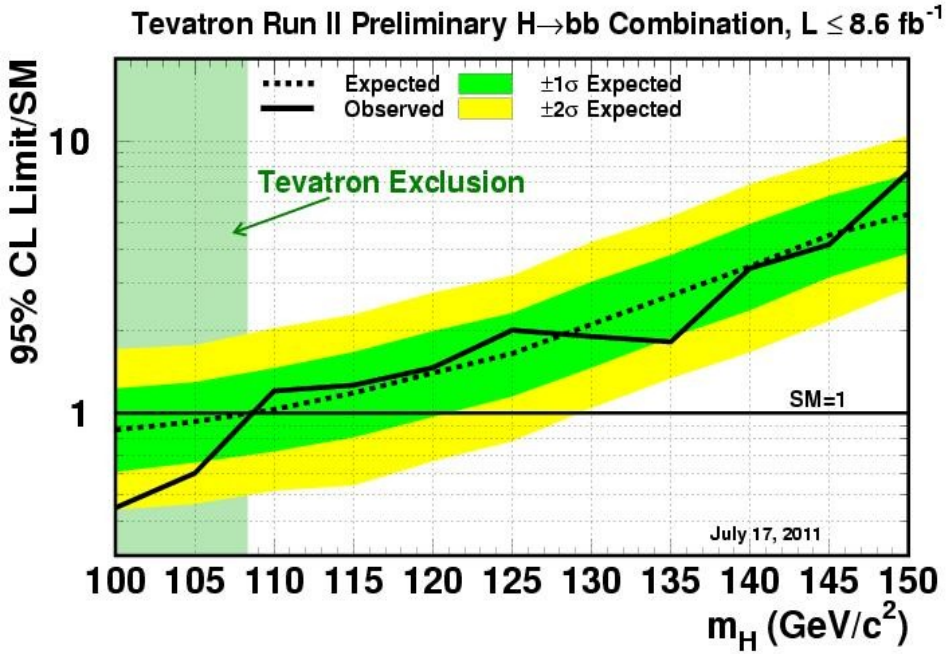
- While performing tagged WW/WZ search
  - Gluon-Quark separator
  - Z+1Jet balancing studies performed
  - Poor description of Z-jet balance seen in gluon-like jets.
    - MC gluon jets harder in ET than data by ~5% of ET
    - MC quark jets well described
  - Origin of mismodeling still under investigation
  - 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

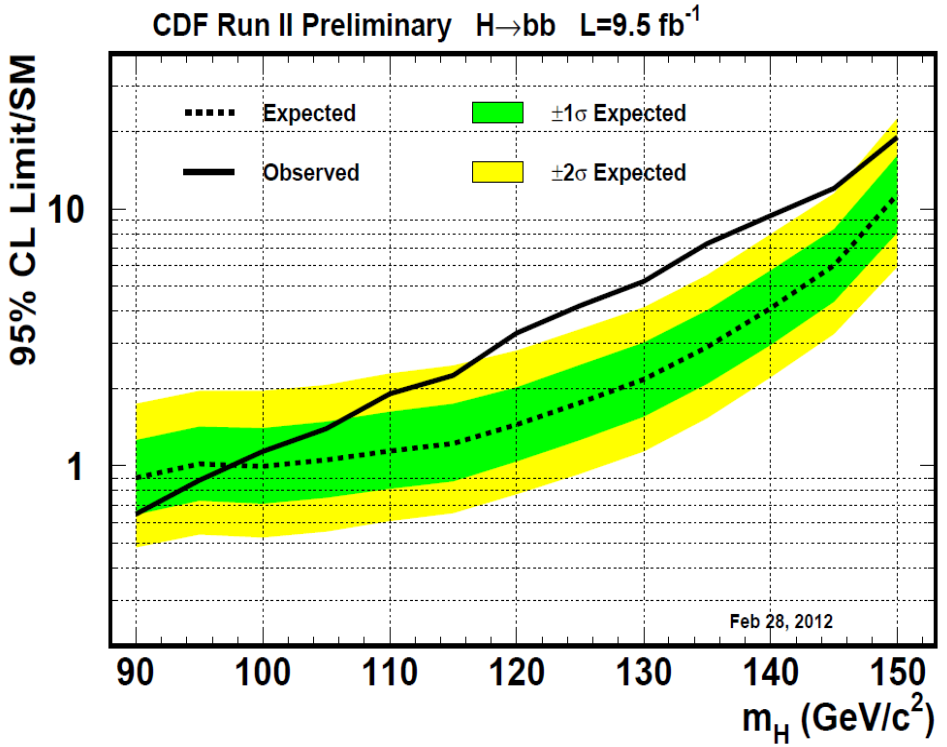




Comparison of Summer 2011 to Winter 2012

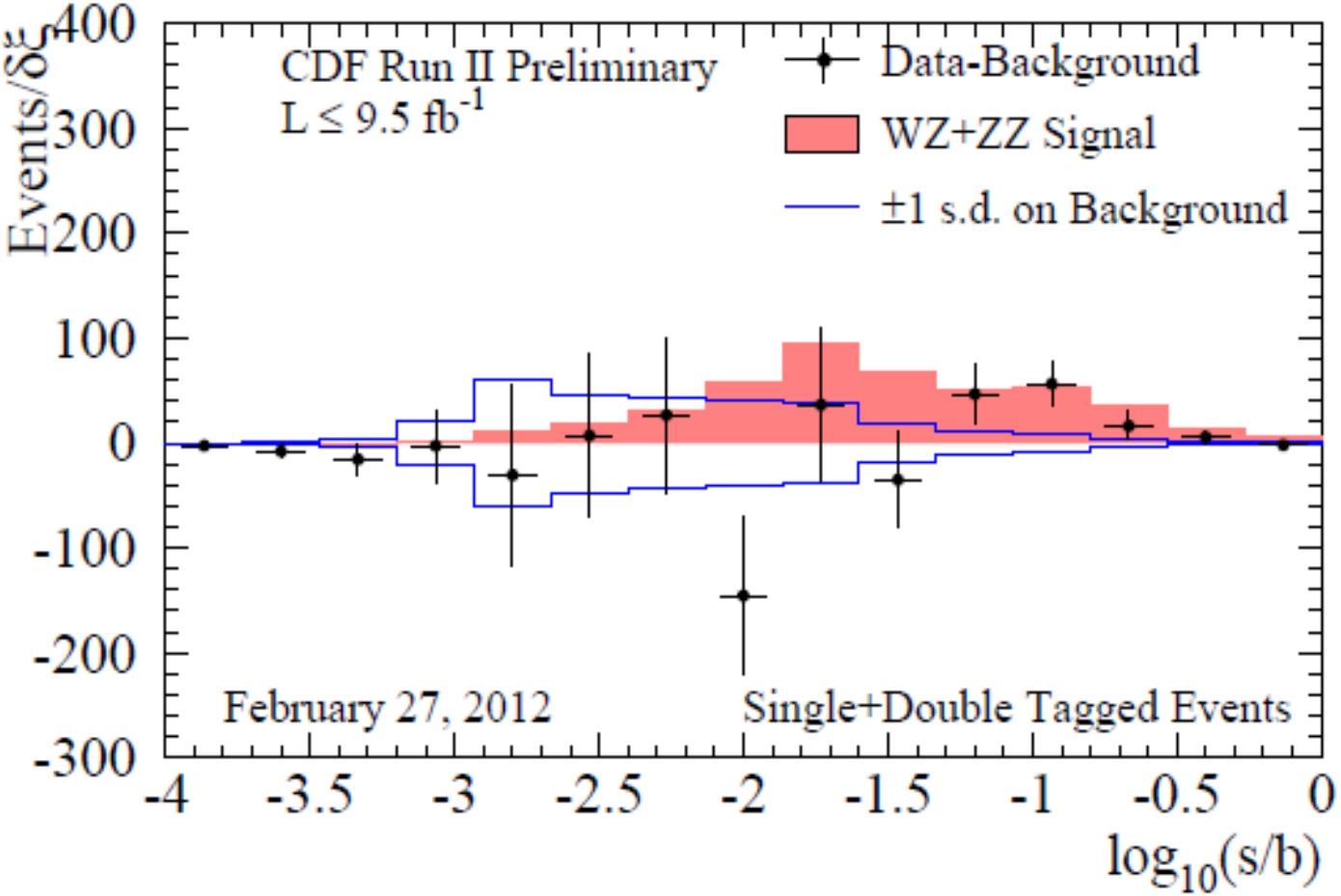
- Tevatron 2011 vs CDF 2012
- The observed limit went UP?
- Are these consistent?
  - If we had only added data, the observed limit should not have gone up.
    - Down or no change
  - These plots are not directly comparable:
    - the included analyses have changed: data reinterpreted
    - This plot is for exclusion, not cross section measurement.





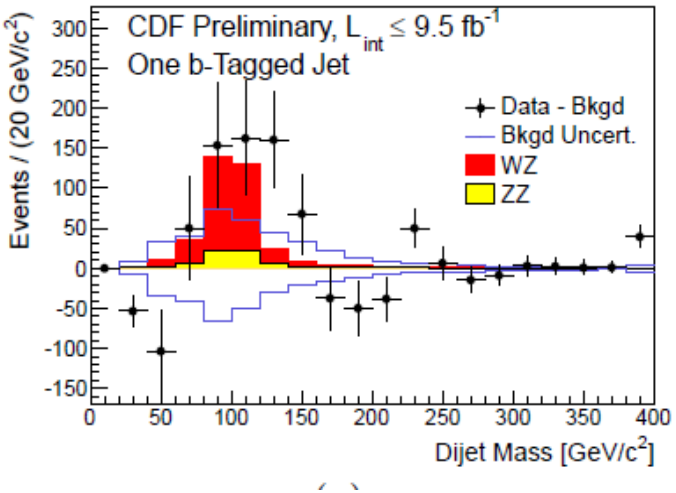
Comparison of Summer 2011 to Winter 2012

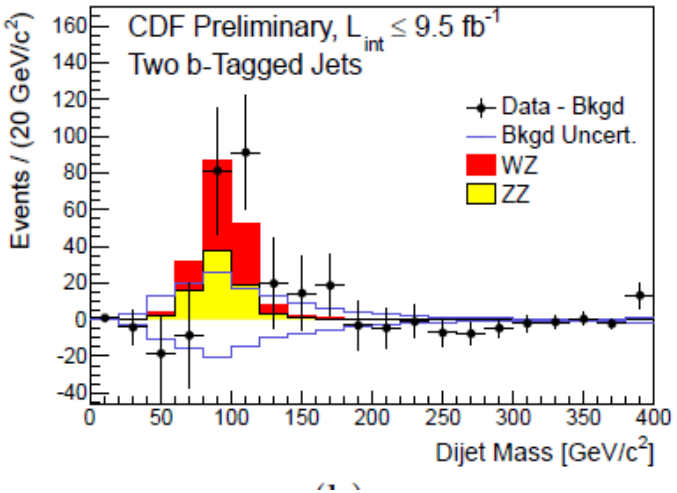
- Diboson measurement if Heavy Flavor Jets
- See presentations at Moriond
  by J. Vizan Garcia(QCD) and J. Sekaric(EWK)

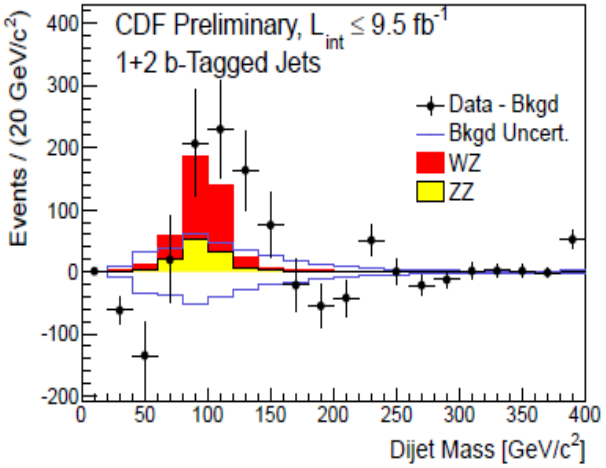


Comparison of Summer 2011 to Winter 2012

- **Diboson measurement if Heavy Flavor Jets**

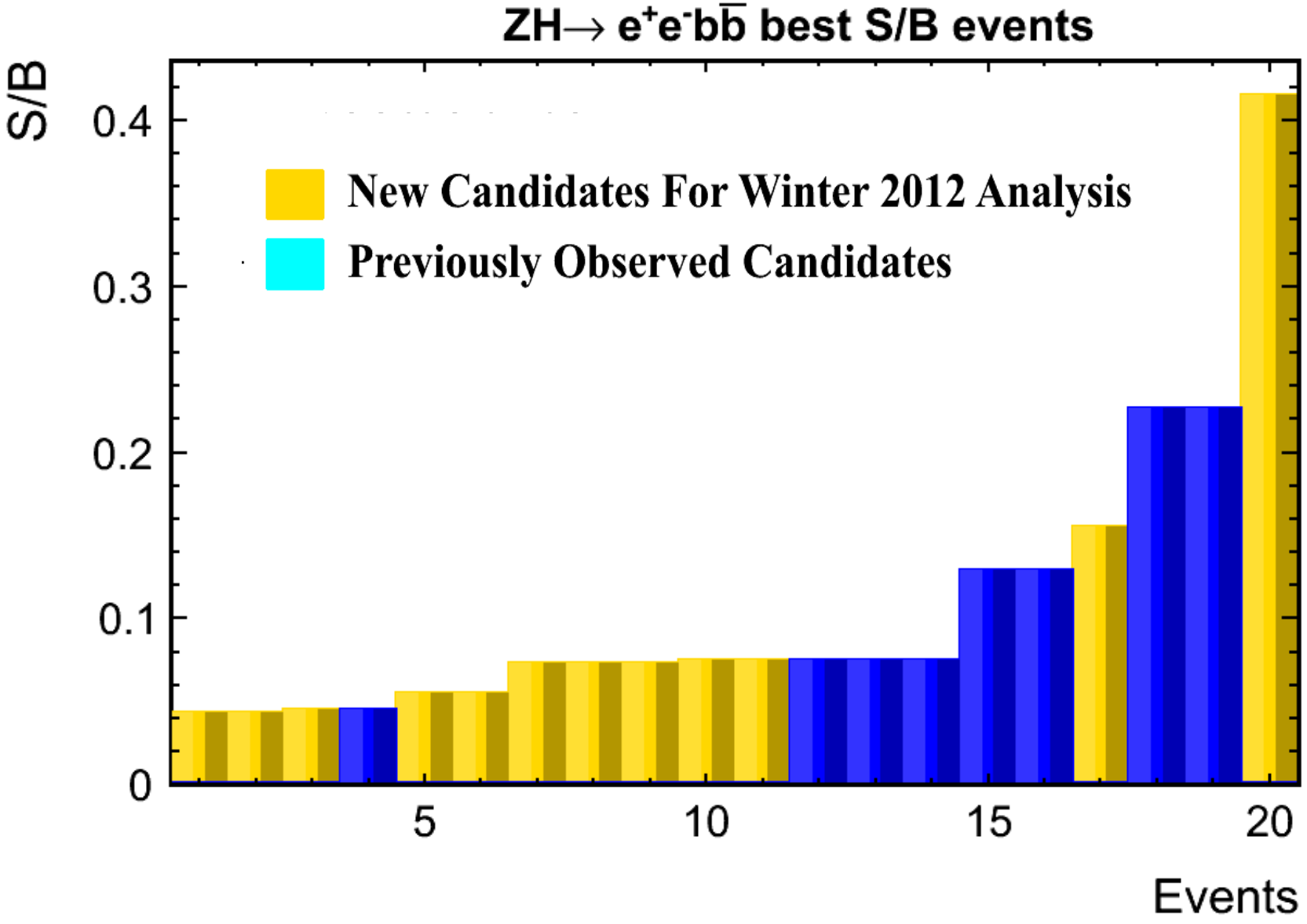






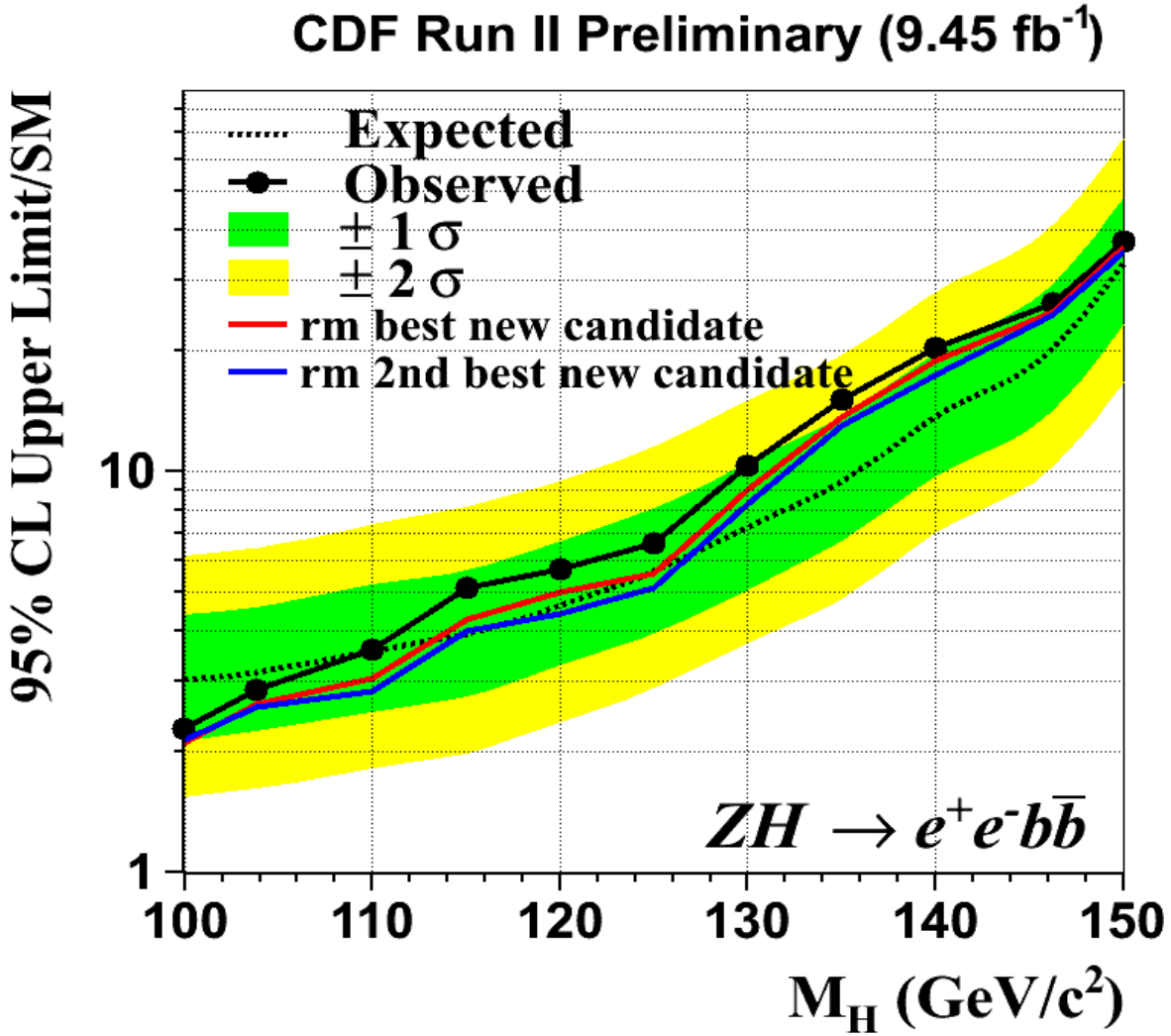
Comparison of Summer 2011 to Winter 2012

- ZH: s:b of new events in 2012



Comparison of Summer 2011 to Winter 2012

- ZH: s:b of new events in 2012



Comparison of Summer 2011 to Winter 2012

- ZH: s:b of new events in 2012