Searches for MSSM Higgs at the Tevatron

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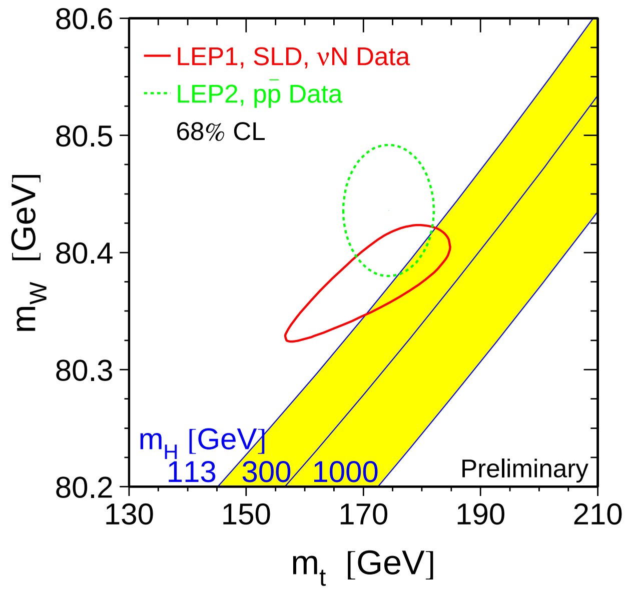
For the CDF and DØ Collaborations

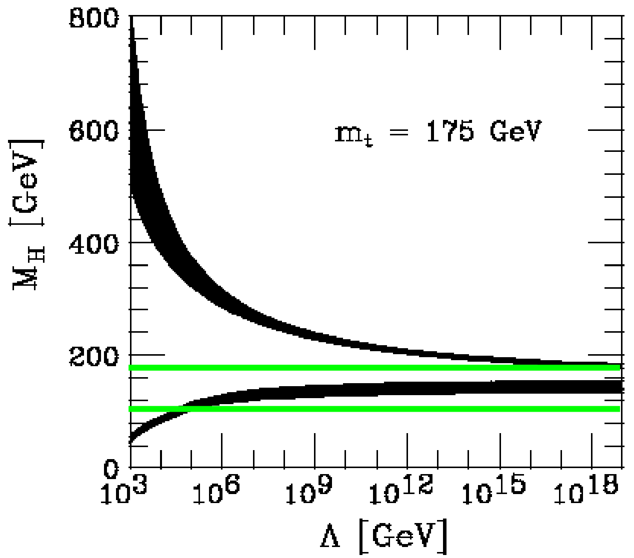
- Motivation
- A/H->$\tau\tau$
  - Run I & Run II (CDF)
- A/Hbb -> bbbb
  - Run 1 Search: CDF
  - Run II:
    - CDF
    - DØ
- Conclusions

Why Higgs? Why MSSM?

- [an] EWSB mechanism in SM
  - Gives mass to particles through H couplings
  - Current data points to light Higgs
    M_{Higgs} < 170 GeV @ 95%, Osaka'00
  - Higgs has not been definitively observed
    LEP2: > 114 GeV 95% CL exclusion



- [a] solution to hierarchy problem
  - m_H^2 receives corrections ~ m_{Planck}^2
  - Needs fine-tuned parameters for m_H~100 GeV
  - Supersymmetry: symmetry between fermions, bosons -> cancellations occur naturally
  - Two Higgs doublets are needed



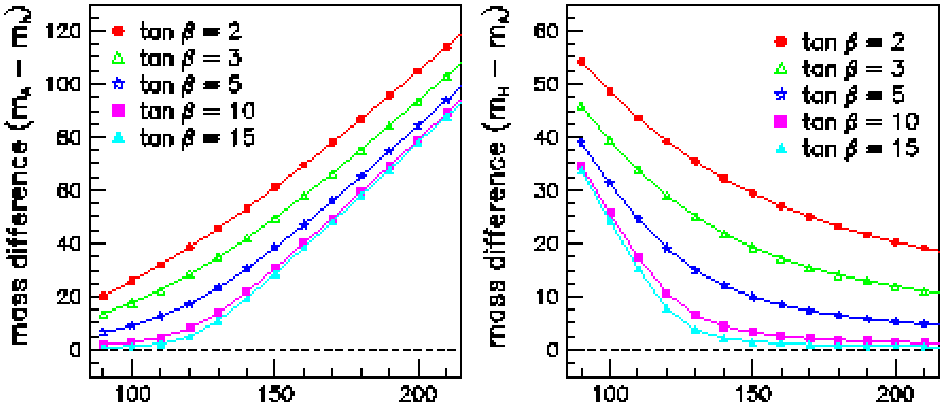
MSSM Higgs

- In the MSSM scenario:
  - Two Higgs doublets lead to 5 Higgs particles:
    - Two neutral CP-even: h,H
    - One neutral CP-odd: A
    - Two charged: H^+ ,H^-
  - Masses governed by two parameters, for ex:

$$\{m_A, \tan\beta\}$$

  - Tree level mass relations:
    - M(h)<M(Z)<M(H)
    - M(A) <M(H)
    - $M(H^+)$<M(W)
  - $M(h^o)$<~130 GeV after radiative corrections (top,stop etc.)

m_A-m_h m_H-m_A



m_A (GeV) m_A (GeV)

- High tanβ:
  - A nearly degenerate with
    - h (m_A<~130 GeV)
    - or H (m_A>~130 GeV)

MSSM Higgs production @ Tevatron

- H/h/A can have SM-like x-sections at small tan β

  For processes such as HW and HZ

- Some production processes such as:

  gg->A/H

  gg,qq-> Hbb/hbb/Abb

  can have

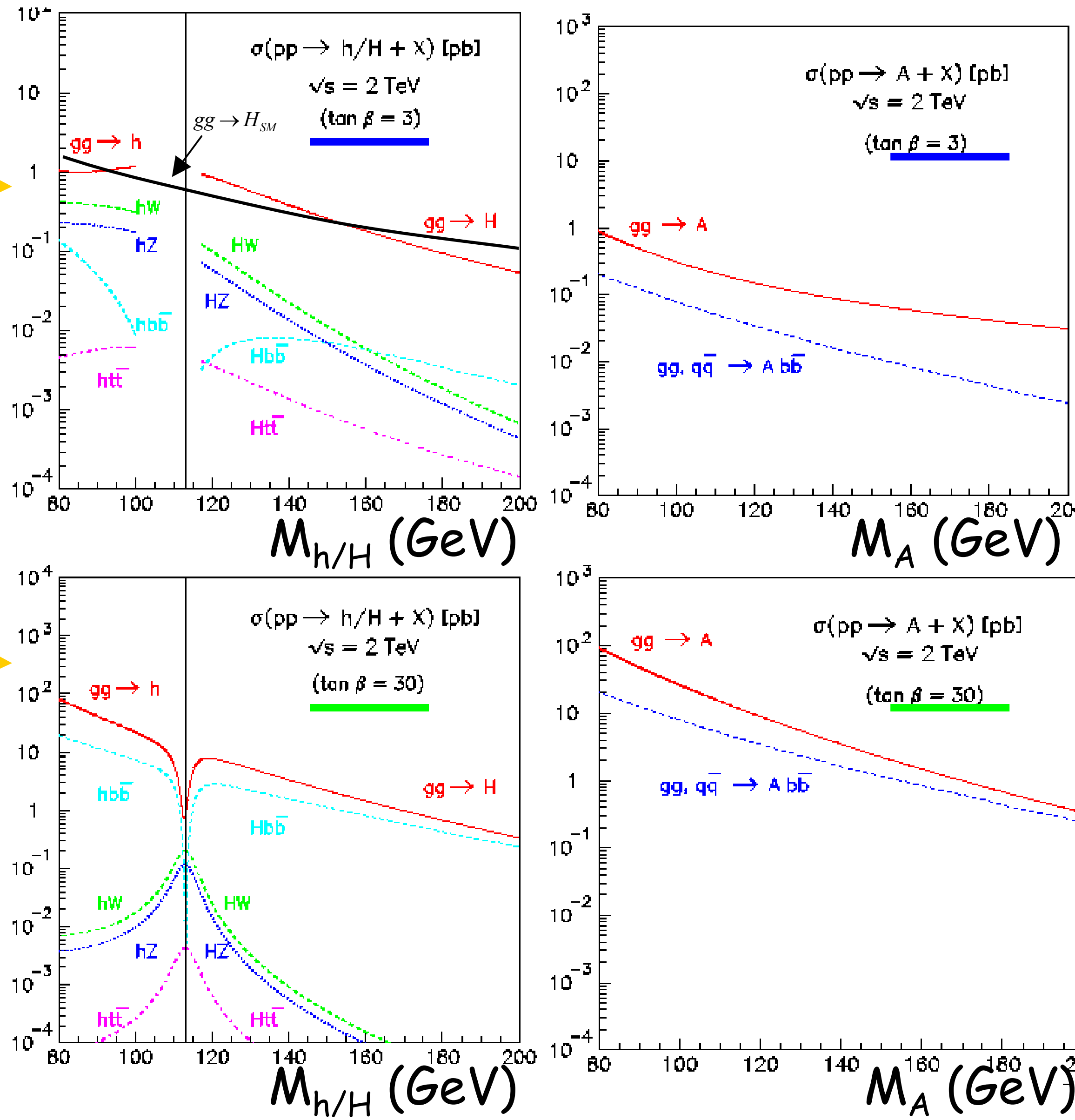
  large x-sections at

  large tan β !!!

$$\sigma(p\bar{p} \to \varphi) = (g^{h,A,H})^2 \, \sigma(p\bar{p} \to H_{SM})$$

$$\sigma(p\bar{p} \to b\bar{b}\varphi) = (g^{h,A,H})^2 \, \sigma(p\bar{p} \to b\bar{b}H_{SM})$$

$g \sim 1/\cos\beta \sim \tan\beta$ φ = h,H,A



MSSM Higgs Branching Ratios

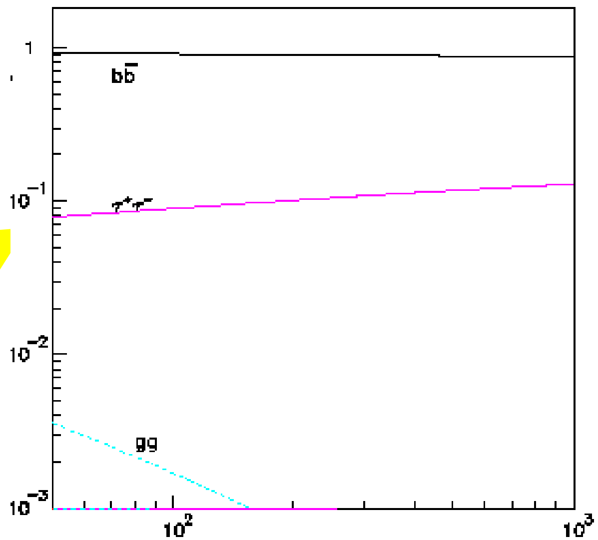
In the same high tanβ region, BR(->fermions) stays high even at large mass.

For all practical purposes:

$\varphi \rightarrow bb$ ~ 90%

$\varphi \rightarrow \tau\tau$ ~ 10%

$\tan\beta = 50$

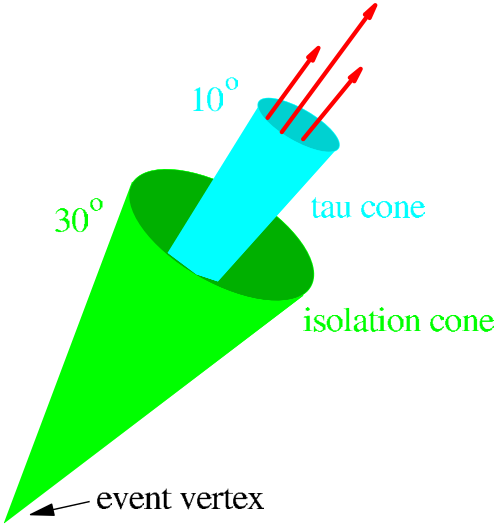


m_A (GeV)

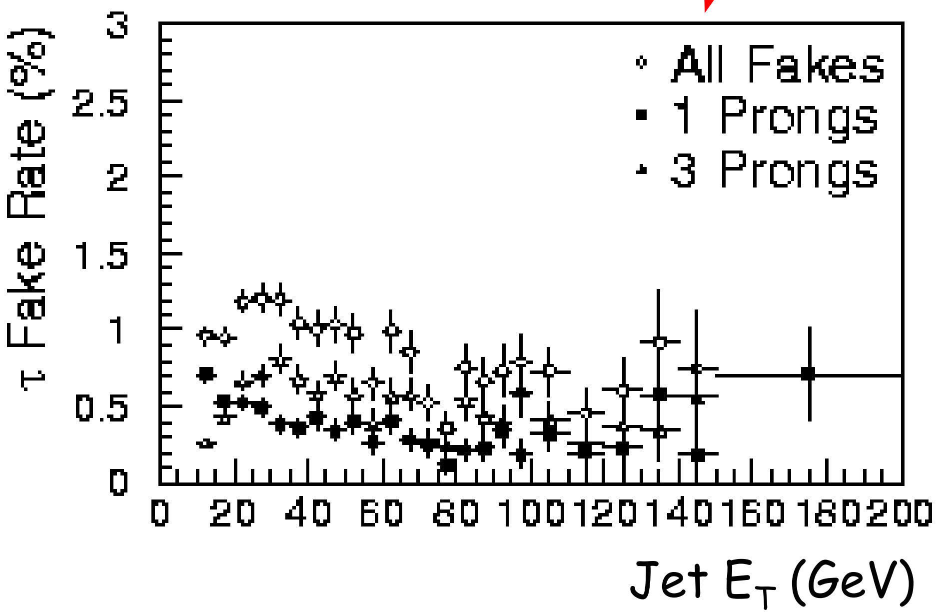
- Searches for Higgs in high tanβ region at Tevatron:
  - gg->A/h->ττ
  - gg,qq->A/hbb->bbbb

A/H->ττ: Tau ID in Run I (CDF)

- Tau Properties:
  - Collimated decay products
    - Opening angle: $\theta < m_\tau/E_T(\tau)$ <~ 0.2 rad ~ 10°
  - Low multiplicity tracks, photons in 10°
  - Visible energy reconstructs low mass
- Cuts:
  - Jet with high visible E_T containing high p_T track
  - Isolated in 10°-30° annulus
  - Low track, photon multiplicity in 10° cone
  - m_τ<1.8 GeV
  - |Q|=1



Achieved fake rates ~1.2-0.7% for jet E_T 20-200 GeV



Photons detected in wire chambers at shower-max in the EM Calorimeter: 2D info, σ(x),σ(z)~2cm

$A/H \rightarrow \tau\tau$: Ditau Mass Reconstruction (CDF)

$$\not{E}_x^{meas} = \not{E}_x^{\tau 1} + \not{E}_x^{\tau 2}$$

$$\not{E}_y^{meas} = \not{E}_y^{\tau 1} + \not{E}_y^{\tau 2}$$

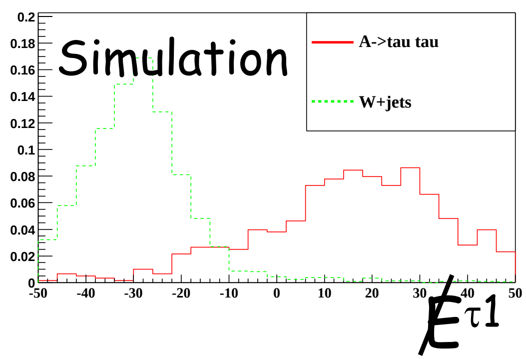
Full mass of the ditau system may be reconstructed if:

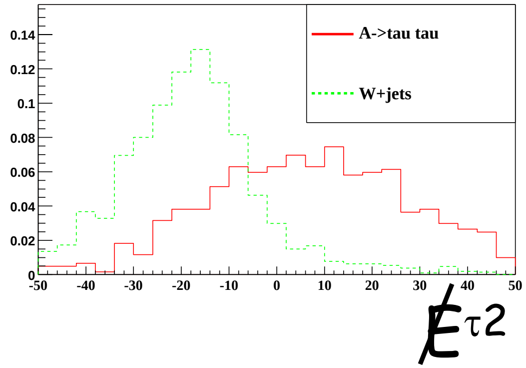
1. Assume ν's in same direction as visible decay products
2. Taus are not back-to-back in azimuthal ->require $\Delta\phi < 160°$

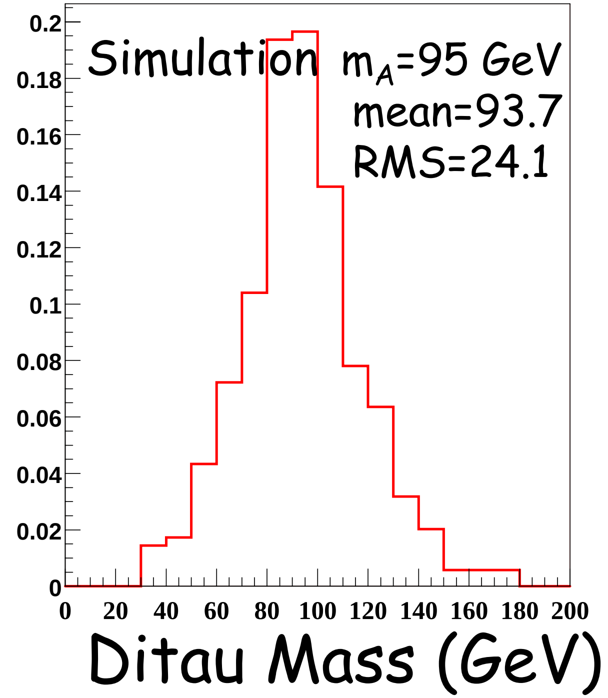
Require $E_\nu^{1,2} > 0 \rightarrow$

Lose 50% Higgs signal,

Reject 97% W+jets







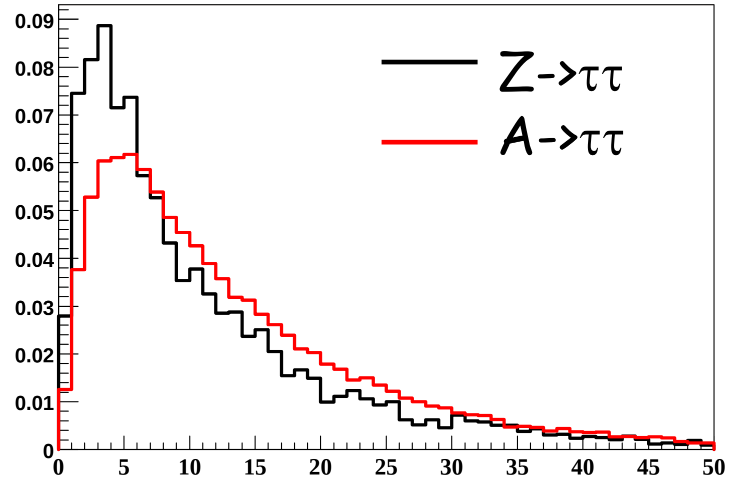
A/H->$\tau\tau$ (CDF)

- Trigger
  - No τ trigger in Run I $\rightarrow$ use p_T>18 GeV lepton trigger->

One leptonic τ
One hadronic τ

- Backgrounds
  - Z $\rightarrow \tau\tau$ (irred.), QCD, Z $\rightarrow$ ee, W+jets: non-irred. backgrounds rejected through tau ID cuts and mass reconstruction

Use m_A=95 GeV, tanβ=40 as benchmark:
$\sigma(A/H \rightarrow \tau\tau)$=8.7pb



Z $\rightarrow \tau\tau$ irred. backgnd, but:

- Branching Ratio:
  - Z$\rightarrow\tau\tau$: 3.7%
  - A/H $\rightarrow \tau\tau$: 9%
- P_T Distributions
  - Stiffer A/H p_T distributions than Z p_T distributions:
  - $\Delta\phi$<160° cut ~ p_T>15 GeV cut $\rightarrow$ 30% more efficient for Higgs than Z

σ(A/H) falls fast! Drops by factor of 4 from 95 -120 GeV, 1 RMS ($m_{\tau\tau}$) ~24 GeV -> Need as high a rate as possible! ->

Taus in Run II (CDF,DØ)

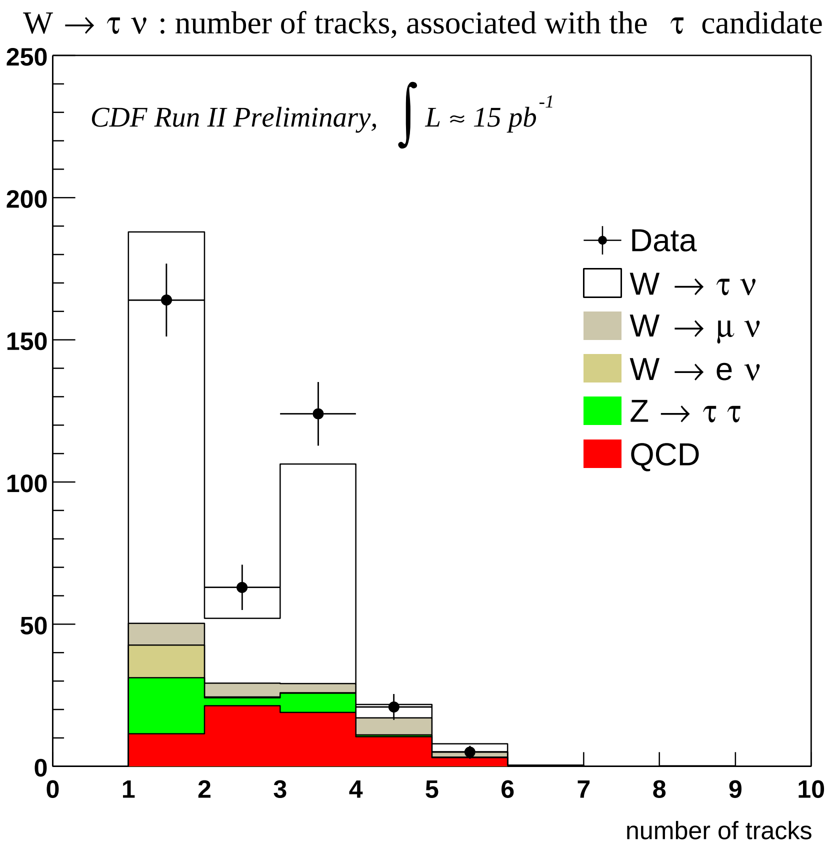
Triggers designed for τ physics will greatly increase the acceptance for this search:

- Lower p_T thresholds
- All-hadronic modes open up (~1/2 of branching ratio)

Tau Triggers in Run II:

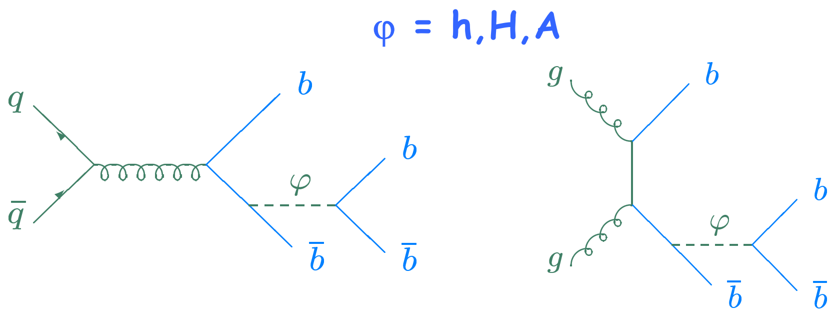
- Lepton + track triggers (DØ, CDF)
- τ+MET Trigger (DØ,CDF)
- 2 hadronic τ's
  - Calorimeter-based (CDF)
  - Track-based (DØ)

Run I A/H->$\tau\tau$ search still work in progress, Run II analysis in the works as well



CDF already sees $W\to\tau\nu$ events from new τ+MET trigger!

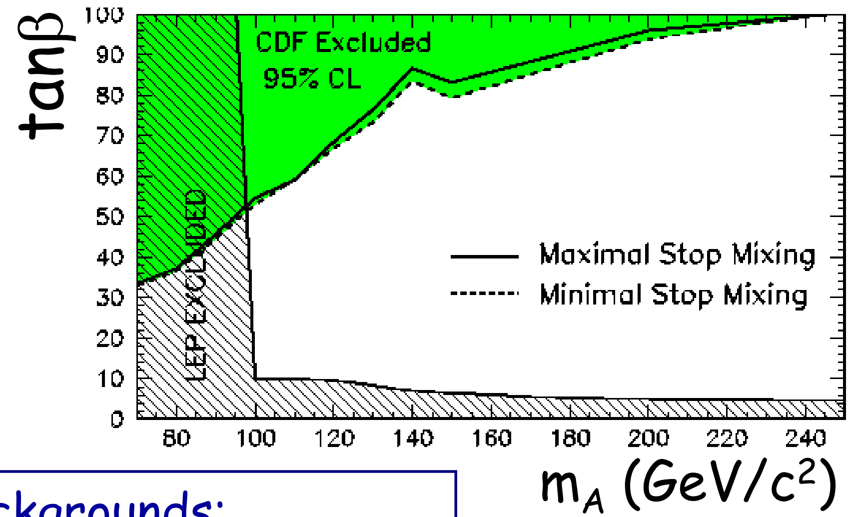
pp -> bbA/h/H -> bbbb: Run I (CDF)



Event selection:

- 4- jets + ΣE_T>125 GeV trigger
- ≥ 3 b-tag (displaced vertex)
- $\Delta\phi_{bb}$ > 1.9
- m_φ dependent cuts optimized for max. expected signif.:
  - E_T cuts on jets
  - mass window 1-3σ

BR x Accept ~ 0.2 - 0.6% ($70<m_\varphi<300$ GeV)

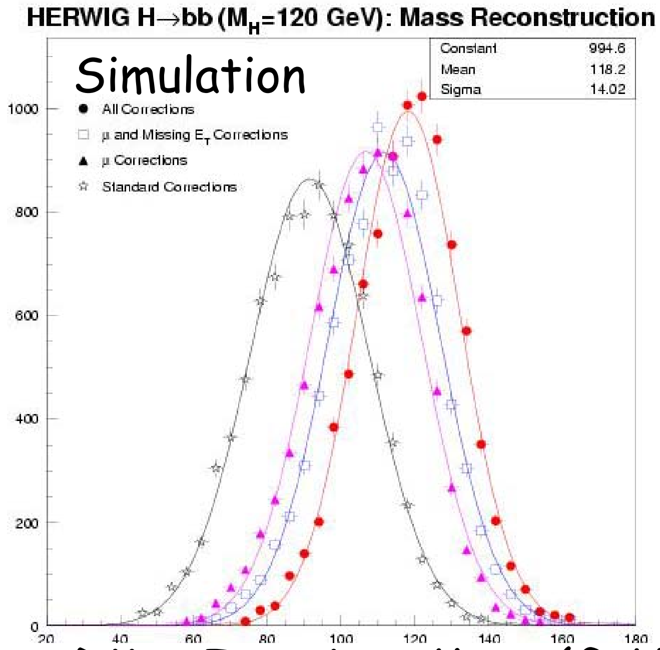


Backgrounds:

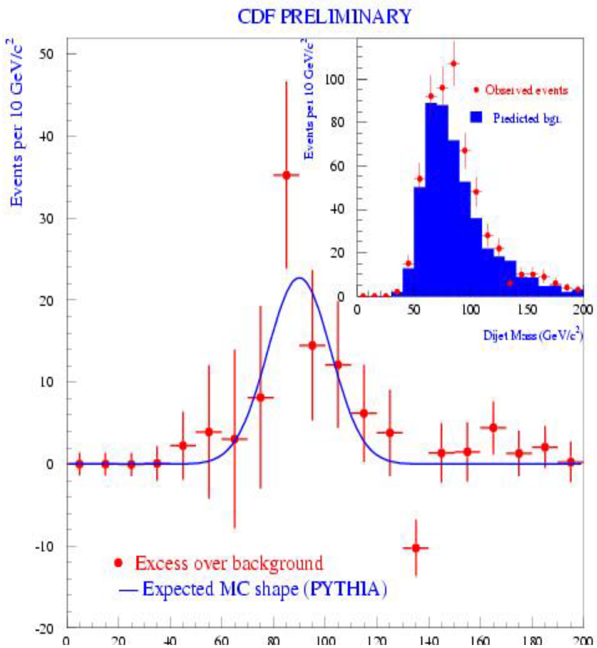
QCD, Z/W+jets, tt

- For m_φ = 70 GeV hypothesis, observe
  5 events, expect 4.6 ± 1.4
- Only these 5 events appear in higher mass windows
- No excess above predicted is observed

Tools for pp -> A/h/Hbb -> bbbb: Run II (CDF)



Dijet Invariant Mass (GeV)

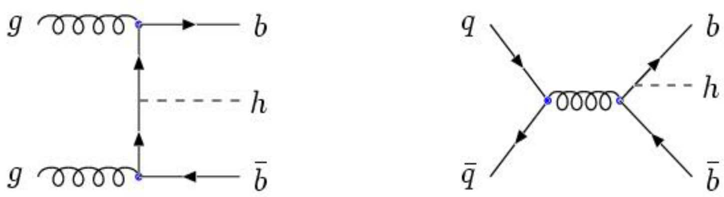


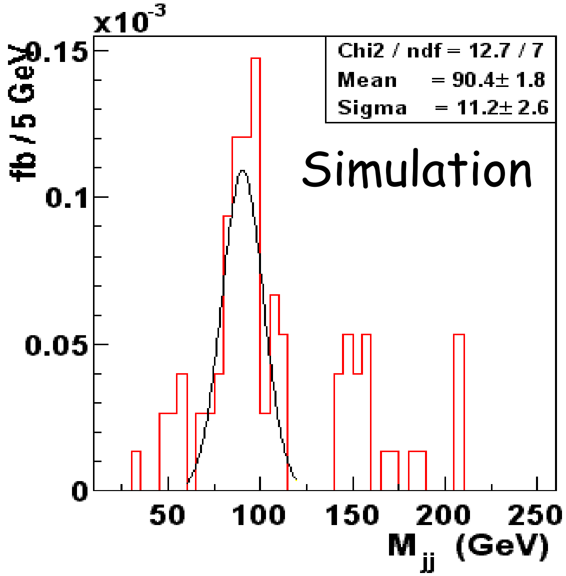
Dijet Invariant Mass (GeV)

- Z->bb studies -> improved resolution
  - correcting for μ, $\not{E}_T$, jet charged fraction
- Studies of QCD jets
  - 30% improvement in jet res.
  - uses tracking, shower-max detectors and calorimetry

- B-tagging:
  - 3D silicon
  - $|\eta| < 2$
- Improved lepton acceptance
- New specific triggers to recover acceptance (displaced track trigger, multijet)

Tools for pp -> A/h/Hbb -> bbbb: Run II (DØ)



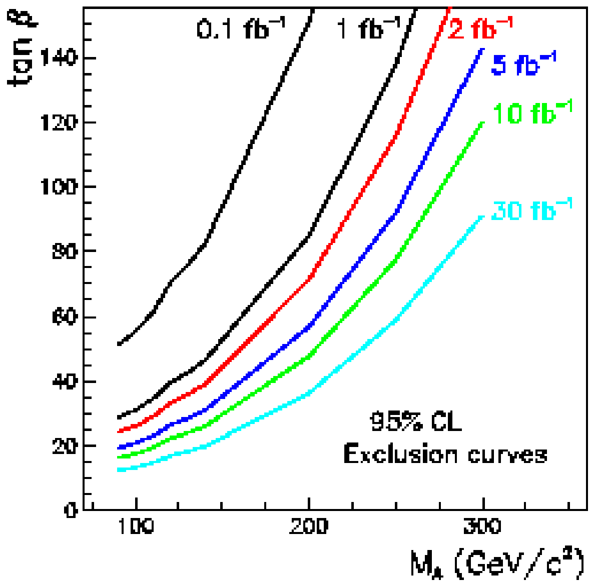


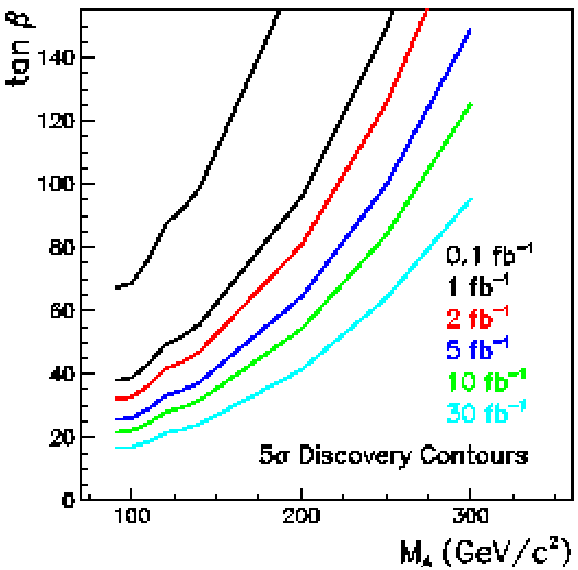
- Obtain fractional resolution $\sigma/M \approx 12\%$
  - No jet calibration applied
- Consider all jet permutations for mass reconstruction
- Predicted rates normalized to SM prediction (3.7 fb)
- Started recently to look at gb→bh channel which has an order of magnitude larger cross section

- Multijet trigger: 4 jets, E_T>15 GeV, $|\eta|$<2
  - Leading jets: m_φ dependent cuts
    - m_φ=120: E_T^1>55 GeV, E_T^2>40 GeV
  - ΣE_T of jets 3 and 4 > 30 GeV
  - At least 3 b tags
    - plot all mass combinations, look in mass window

Projected Reach in Run II (CDF, DØ)

- Both experiments study expected Run II sensitivity from bbbb analysis
  - similar results





$2fb^{-1}$:

->160 GeV (tanβ=40) 95% CL

->115 GeV (tanβ=40) 5σ discovery

Conclusions

- A/H->$\tau\tau$:
  - Run I results to be completed soon
  - First glimpse of Run II data also on the way
- A/Hbb->bbbb:
  - Run I result excludes -> 115 GeV at tanβ=60
  - Run II with both experiments:
    - Set to exclude (discover) significant region of MSSM parameter space
    - Optimistic about improvements from
      - Triggers
      - Jet resolution
      - b-tagging