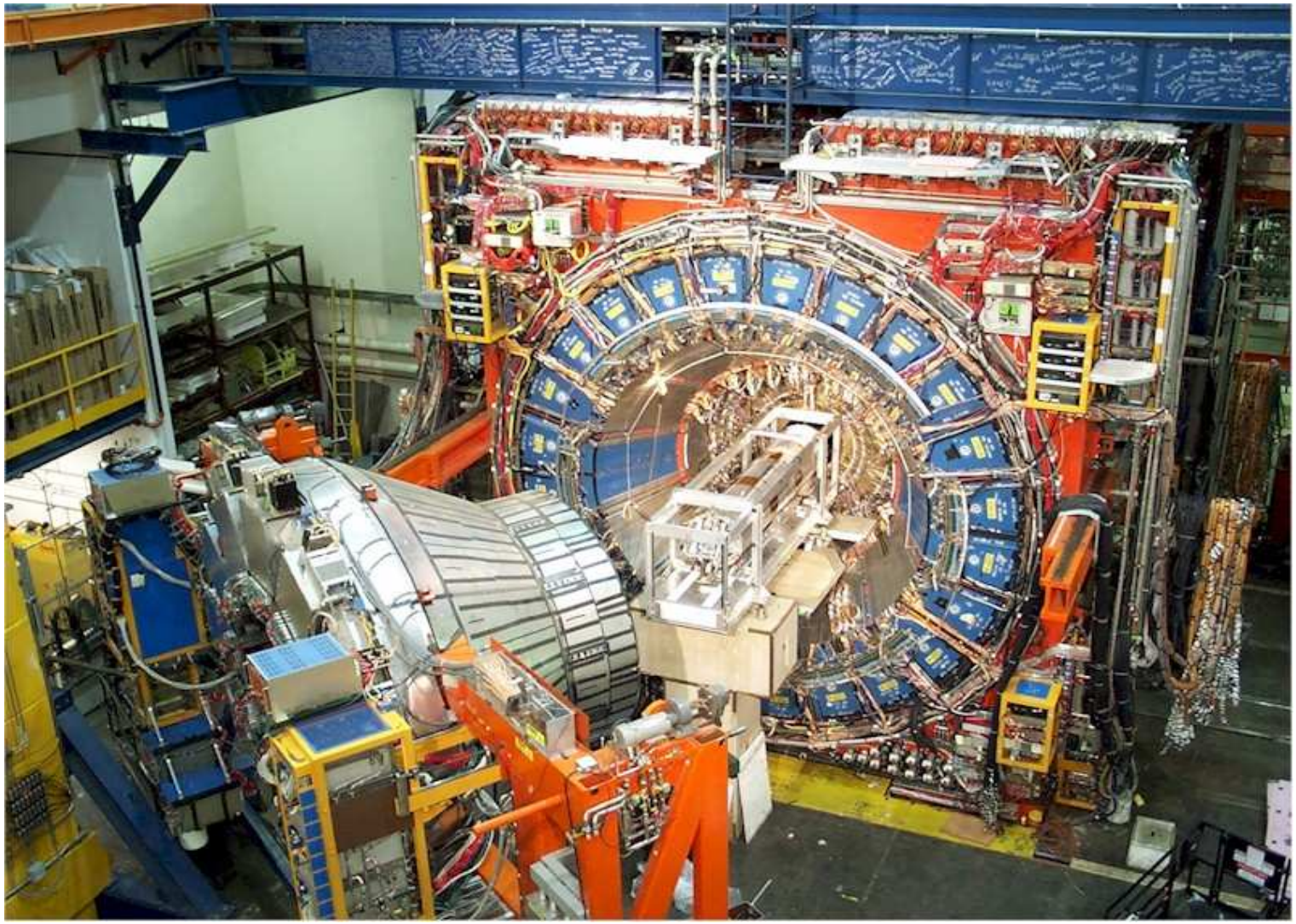
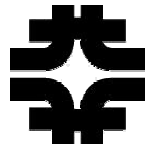
Higgs searches and prospects at CDF

Pavel Murat (FNAL) for CDF collaboration



Overview

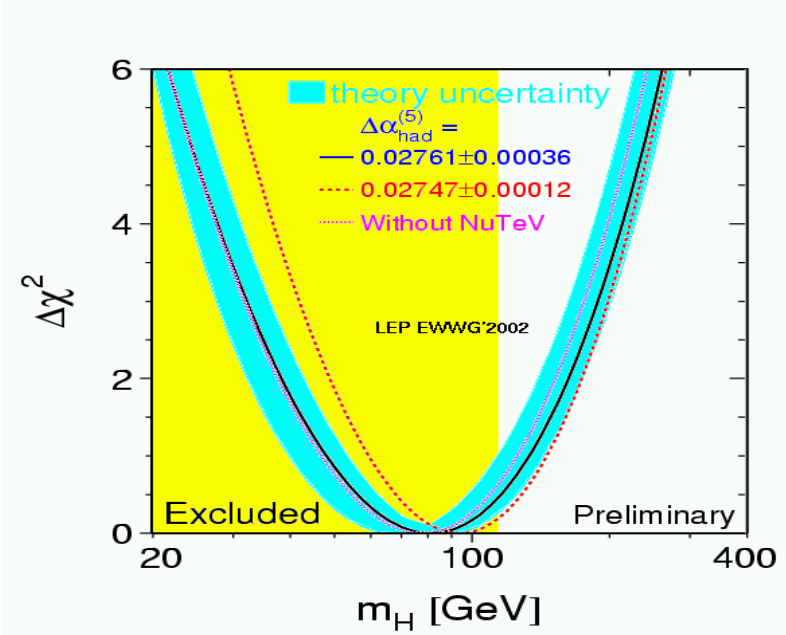


- Standard Model and Higgs boson
- CDF Run I searches of SM Higgs
- Run II improvements
- Run II prospects
- Higgs bosons in MSSM
- CDF Run I searches of MSSM Higgs bosons
- Run II prospects for MSSM Higgs searches
- Summary

The Standard Model (SM) and the Higgs Boson

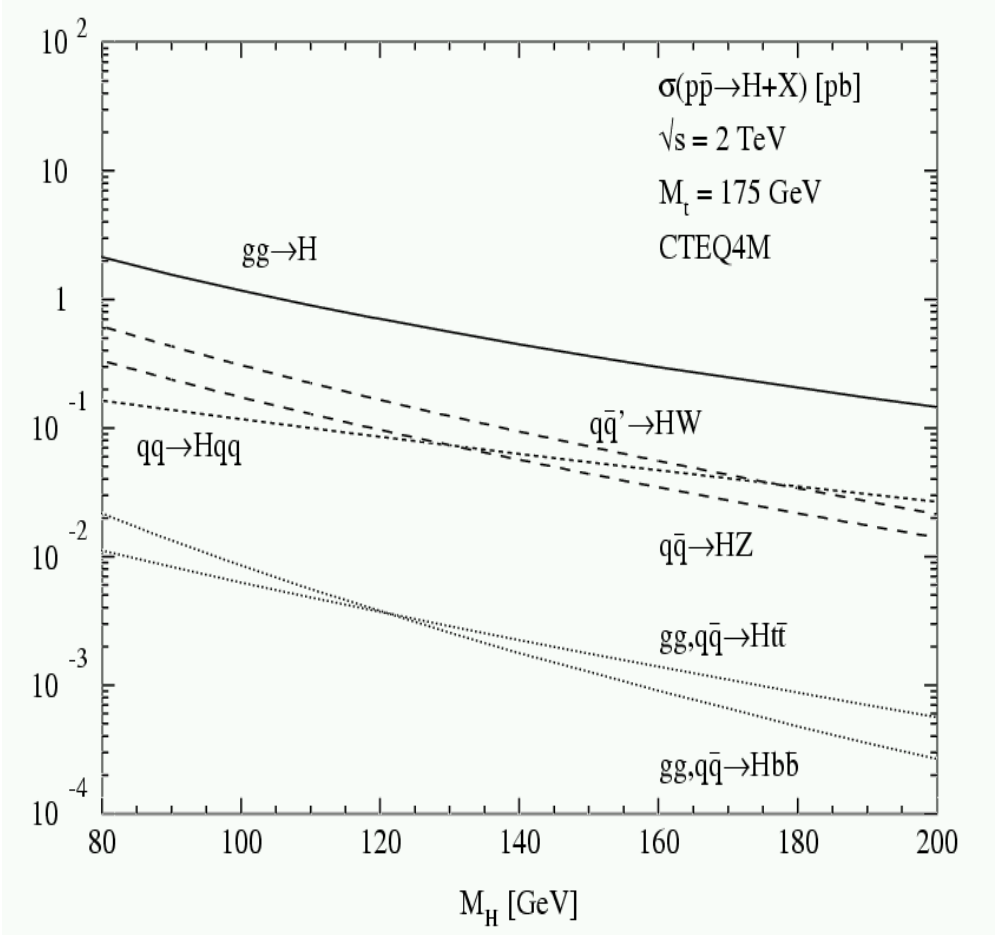
- SM extremely successful over the last 3 decades
  - Consistent with all the data
  - Predicted charm and top
- Higgs field is a key component of SM:
  - generates masses of all the particles
  - keeps the theory renormalizable at EW scale
- All constituents of SM, but the Higgs boson, observed experimentally

- **Lower limit on the Higgs mass comes from direct searches**
  - **$M_H > 114.4$ GeV** (LEP'2002, 95% CL)
- **Global fit of EW data suggests upper bound**:
  - **$M_H < 193$ GeV** (LEP'2002, 95% CL)



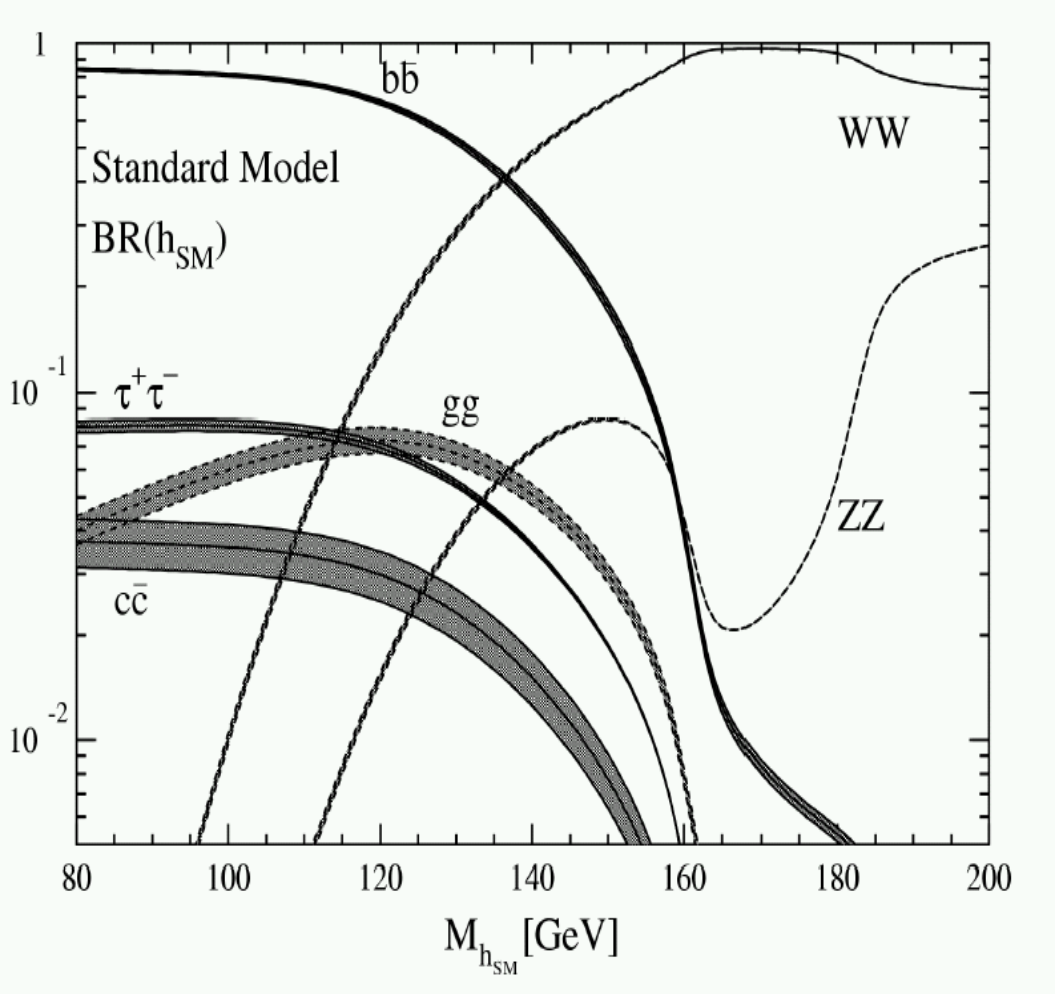
SM Higgs production at hadron colliders

- Cross sections for $M_H = 120$
  - Gluon fusion ($gg \rightarrow H$) : 0.7 pb
  - Associative production :
    - $qq \rightarrow WH$: 0.16 pb
    - $qq \rightarrow ZH$: 0.10 pb
- Smallest cross section measured so far:
  - $\sigma(pp\text{->}tt) \sim 5pb$



SM Higgs : decays

- **`Light` Higgs: M < 130 GeV**
  - Dominant decay: H→bb
- **`Heavy` Higgs (130 < M < 180 GeV)**
  - H->W*W



Triggering and reconstruction

- **σ(p-pbar) ~ 70 mb**
- **For σ(pp->H) ~ 1pb signal/background ~ 10^{-10}**
- **Need efficient trigger with high background rejection**

$M_H < 130$ GeV

- **pp->H->bb** swamped with the QCD
- **pp->V(ll,lv,vv,qq)H(bb)**
  - trigger: high-Pt leptons and/or missing Et from W/Z, multi-jet events
  - Reconstruction:
    - Identify B-jets from Higgs decay (B-tagging)
    - Reconstruct M_H

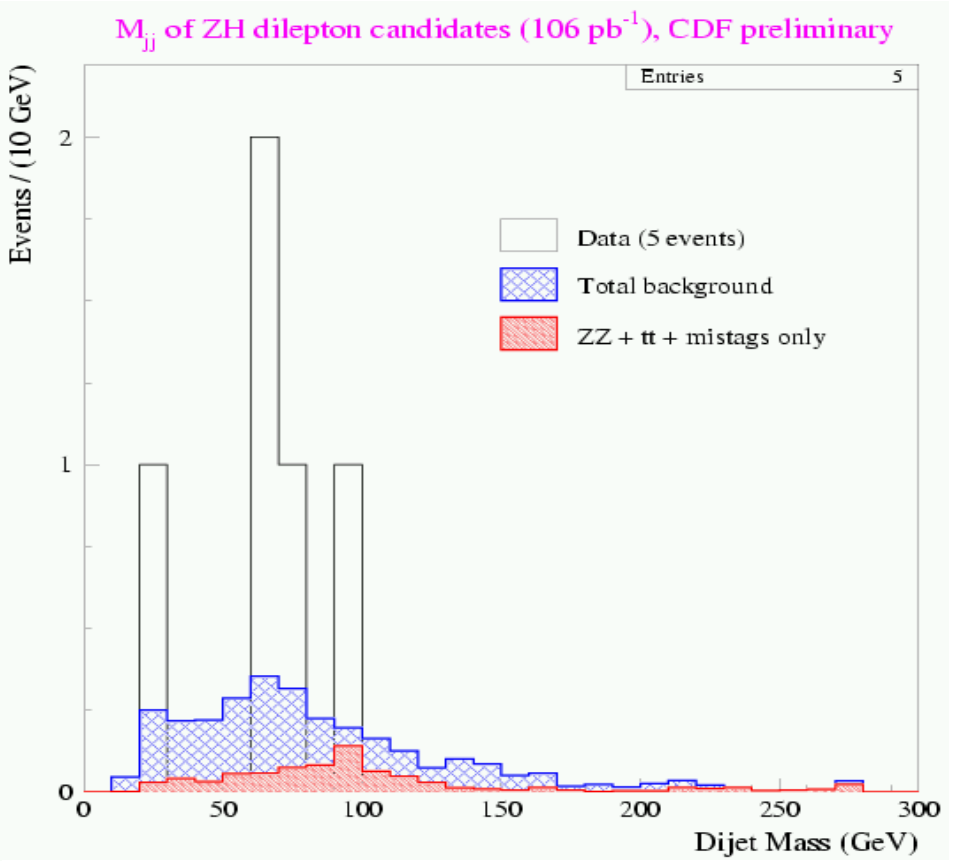
Triggering and reconstruction

130 GeV < M(H) < 180 GeV

- **pp->H(W)->WW*(W)**
  - Signature: ll(l) + MET
  - Trigger:
    - High-Pt leptons from W's
    - Dileptons
    - same-sign dileptons
  - Reconstruction:
    - Can't reconstruct M_H (2 ν in the final state)
    - Counting experiment

Run I Search in pp-> HZ ->llbb

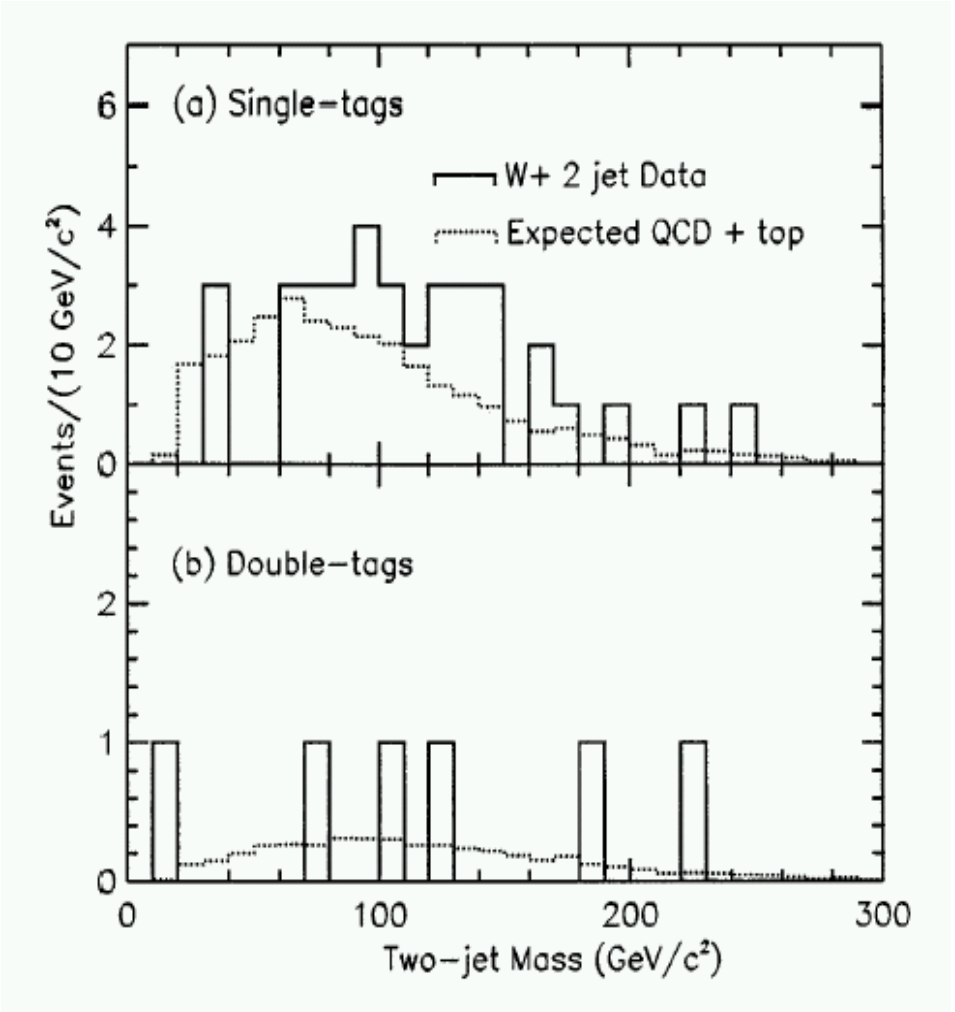
- Signature: 2 OS leptons (Z) + 2 jets
- The cleanest channel, smallest σ*BR
- Trigger : high Pt (Pt>20GeV) lepton
- Observed: 5 events
- Expected: 4 ± 1 events
- Irreducible QCD backgrounds dominate
  - **pp->Zbb**



Cut	N_{ee}	$N_{\mu\mu}$
2 leptons	7029	3758
$76 < M_{\ell\ell} < 106$	5892	2880
2 or 3 $15\,GeV$ jets	105	54
$\not\!\!E_T < 50\,GeV$	105	53
≥ 1 SVX tag	2	3

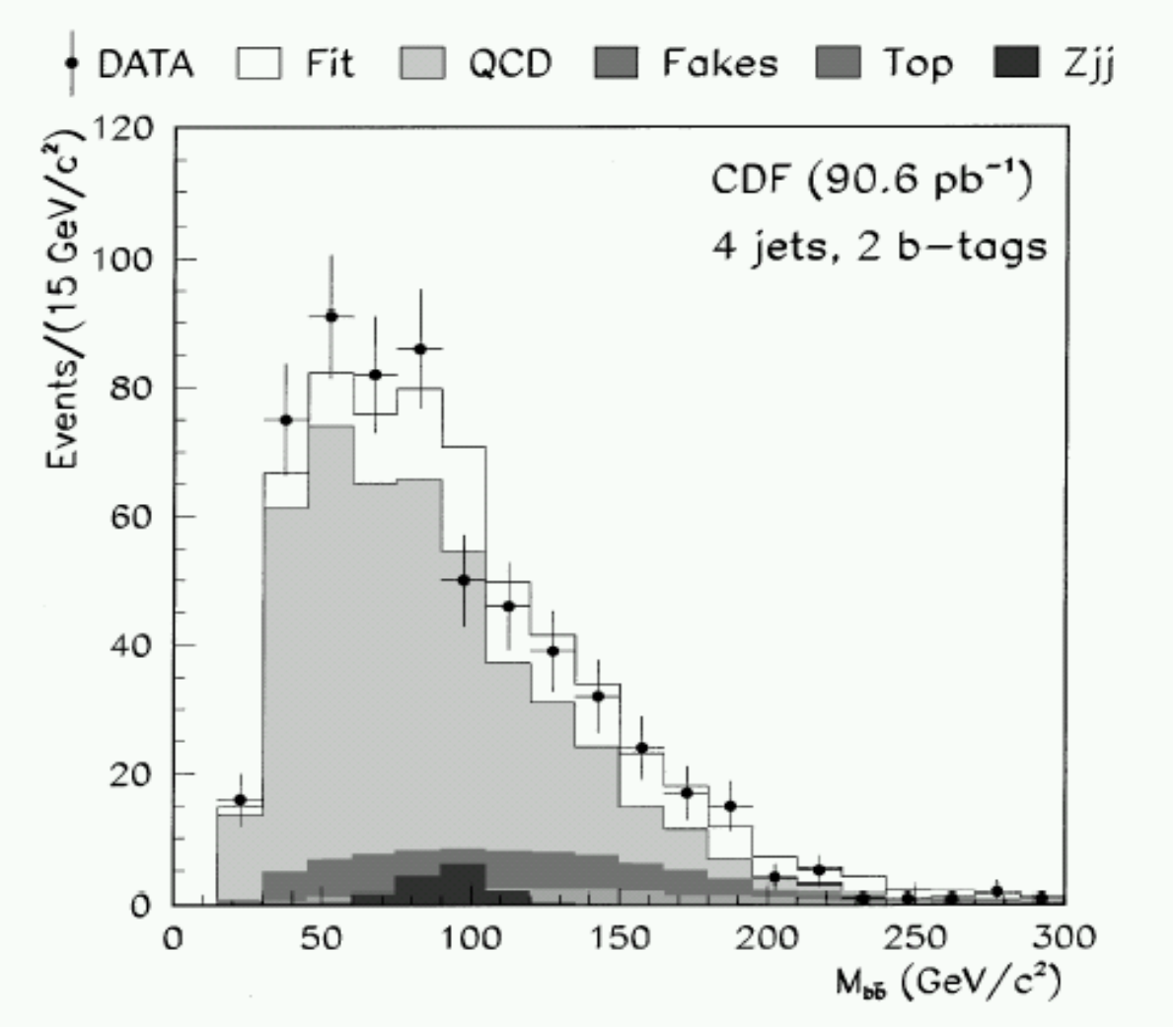
Search in pp->WH->lvbb channel

- Signature: lepton+MET+ (≥ 2 jets)
- Trigger: high Pt lepton (e,mu)
- Lepton Pt > 20 GeV, |eta| < 1
- Jet Et > 15 GeV, |eta| < 2.
- MET > 20 GeV
- Require 1 or 2 jets to be B-tagged
- **Single tag**
  - Observed: 36 (22 e + 14 mu)
  - Expected: 30 ± 5
- **Double tag**
  - Observed: 6 (2 e + 4 mu)
  - Expected: 3.8 ± 0.7



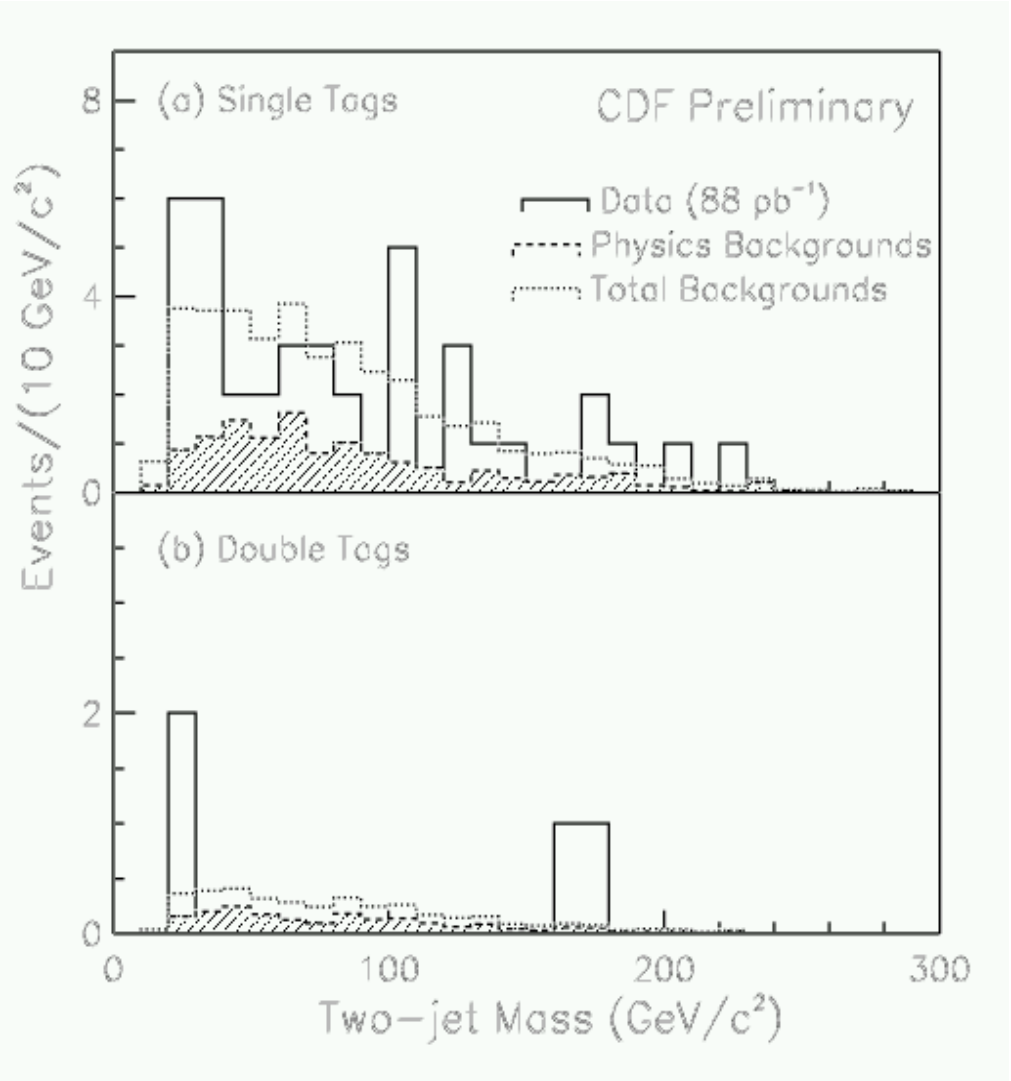
Search in pp -> VH -> qq bb channel

- Signature: >= 4 jets
- Trigger: sum(E_t) > 125 GeV
- Jet Et > 15 GeV, |eta| < 2.1
- 2 jets B-tagged
- Pt(bb) > 50 GeV
- Observed: 589 events
- Expected: 594 +/- 30, irreducible QCD background dominates



Search in pp->ZH->vvbb channel

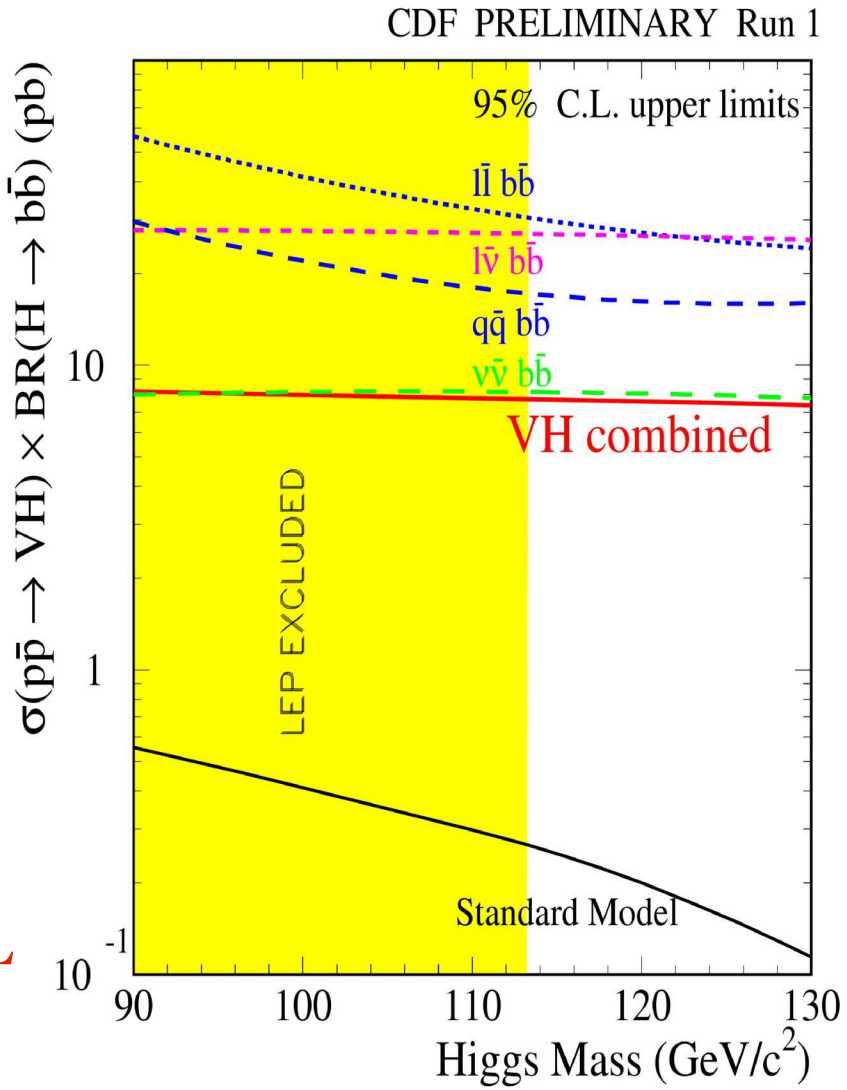
- Signature: >=2 jets + missing Et
- Trigger: MET > 40 GeV
- Jet ET > 15 GeV and |eta| < 2.
- 1 or 2 B-tagged jets
- **Single tag analysis:**
  - Observed: 40 events
  - Expected: 43 +/- 5
- **Double tag analysis:**
  - Observed: 4 events
  - Expected: 4.9 +/- 0.6



Summary of CDF Run I SM Higgs searches

- Searched for associative (W,Z) H production in 4 different channels

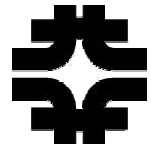
channel	L, pb^{-1}	N(observed)	N(bgr)
$ll\bar{b}\bar{b}$	106 ± 4	5	4.0 ± 1.0
$\nu\nu b\bar{b}$	87 ± 4	4	4.9 ± 0.6
$l\nu b\bar{b}$	106 ± 4	6	3.8 ± 0.7
$qqb\bar{b}$	87 ± 4	589	594 ± 30



Benchmark number (M = 130 GeV):

$\sigma(pp \to VH) * BR(H \to bb) < 7.4$ pb @ 95% CL

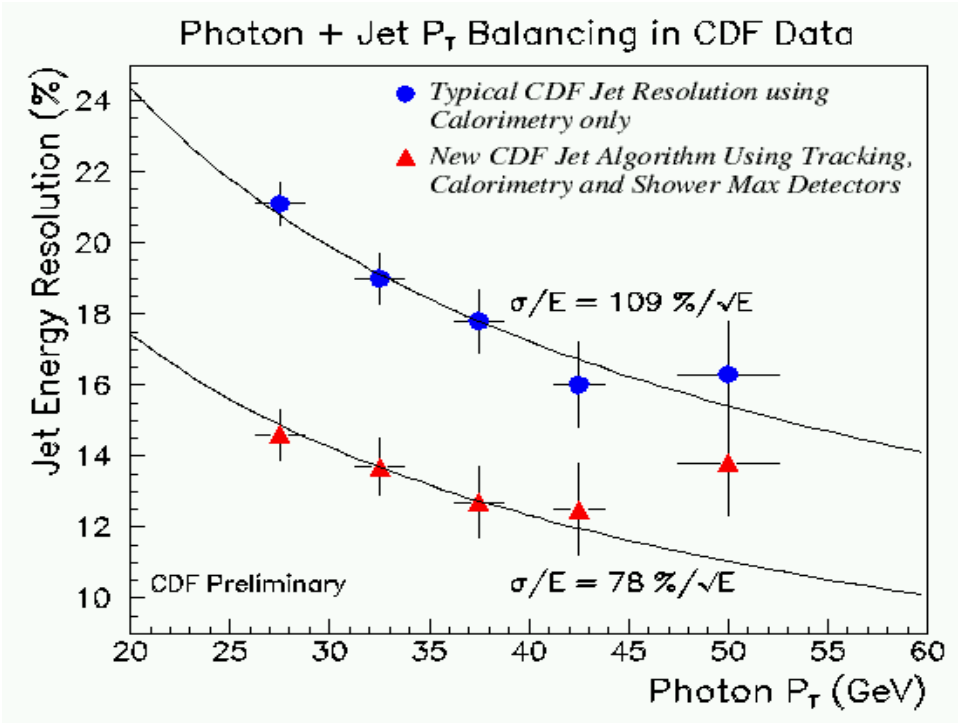
Run II improvements

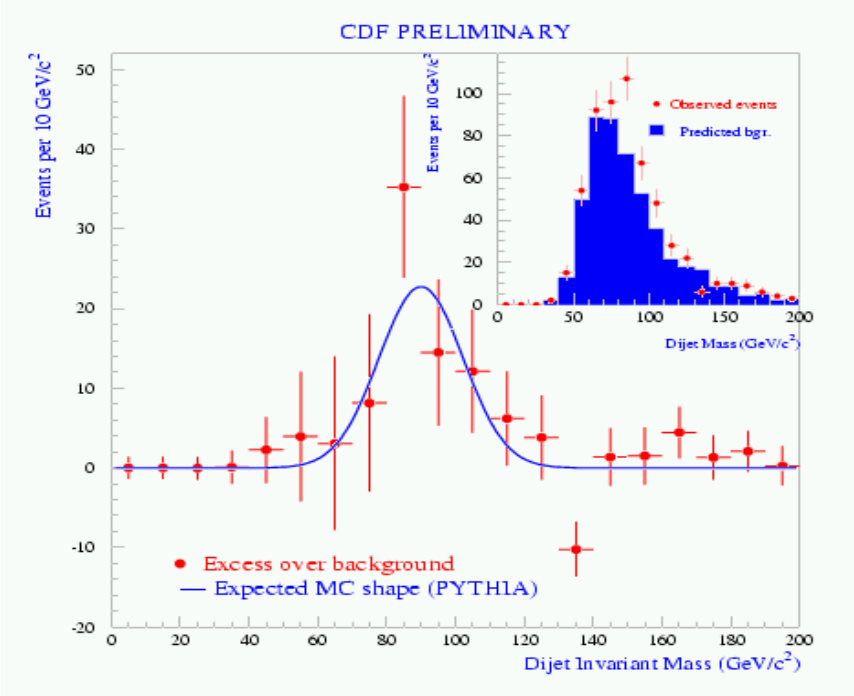


- Integrated luminosity: $2pb^{-1}$(**x20**)/10-$15pb^{-1}$(**x100-150**)
- E_{cm}: **~40%** in σ(gg->H), **~20%** in σ(qq->WH)
- better trigger efficiency for VH->qqbb (B-jet trigger)
- B-tagging
  - Acceptance for 2 jets(**~x2**)
  - Resolution in impact parameter (**~x1.2**)
- Jet energy resolution (**~x1.3**)
- Combine results with DZero (**x2**)
- **Overall improvement in S/√B ~ 30 is achievable**

Jet energy resolution, scale

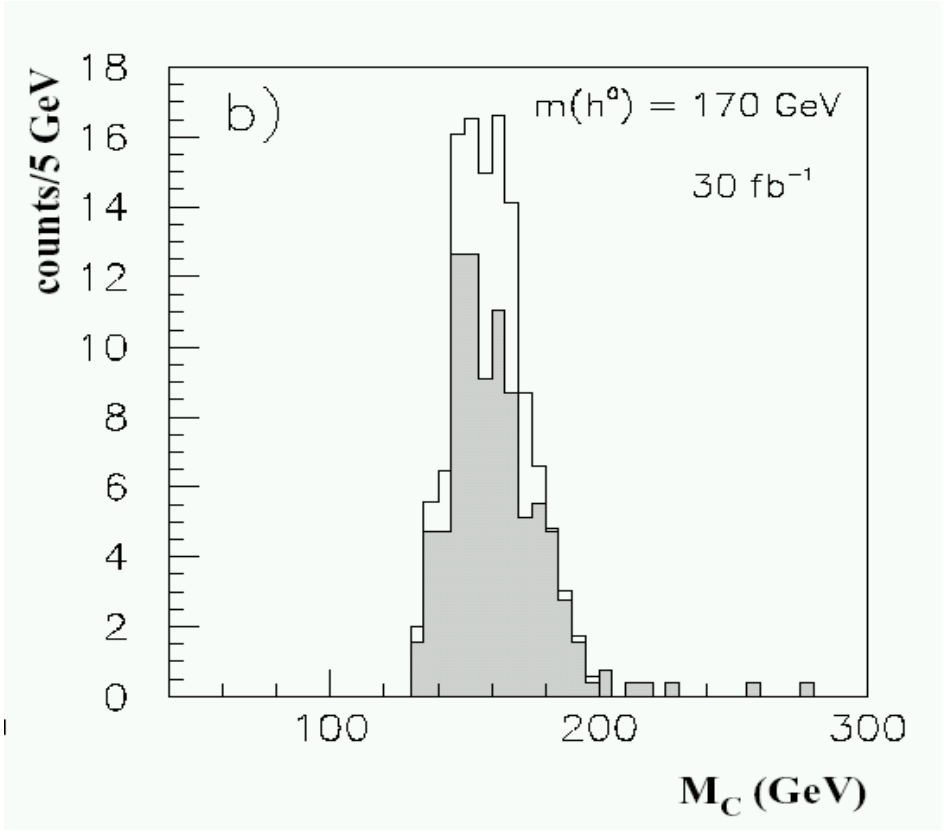
- New jet correction algorithm: adds tracks and shower max detector information
- Resolution improved by 30-40% -> 15-20% in S/√B
  - **Same as the test beam results for single pions!**
- Z -> b bar : B-jet energy calibration at 90 GeV





Heavy SM Higgs (130 GeV<M < 180 GeV)

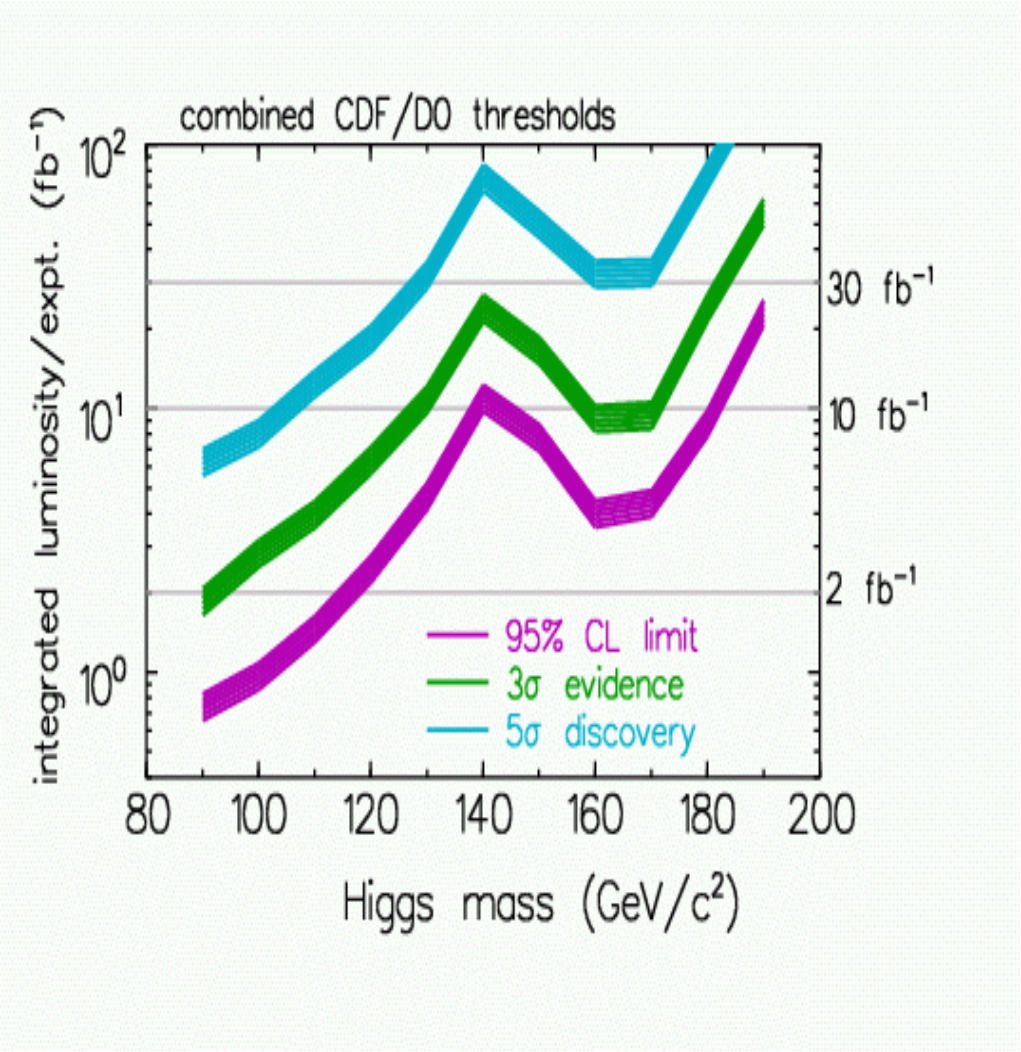
- Production: gg->H, qq -> HW
- Highest rate channels:
  - pp -> H -> W* W* -> llvv
  - pp -> HW -> WW*W*->llqqX
- Trigger: high Pt leptons (same sign dileptons for WWW)
- Major backgrounds: W+W- and t t
- Run II Higgs workshop:
  - signal can be observed
  - cross section low
- $M_c = \sqrt{(M^2(ll)+Pt^2(ll))}+ MET$



M(H)[GeV]	140	160	180
Signal [fb]	2.8	1.5	0.96
Backgrounds [fb]	44.	4.4	3.8
$S/\sqrt{B}$ for 30 fb^{-1}	2.1	3.9	2.7

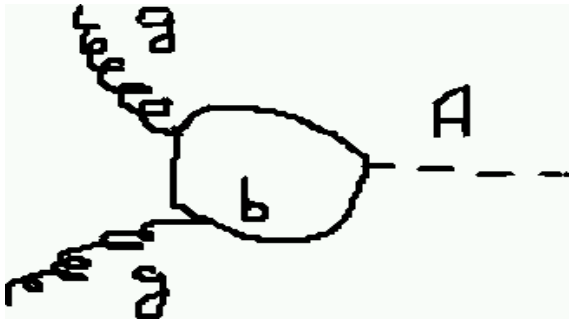
SM Higgs: projections for Run II

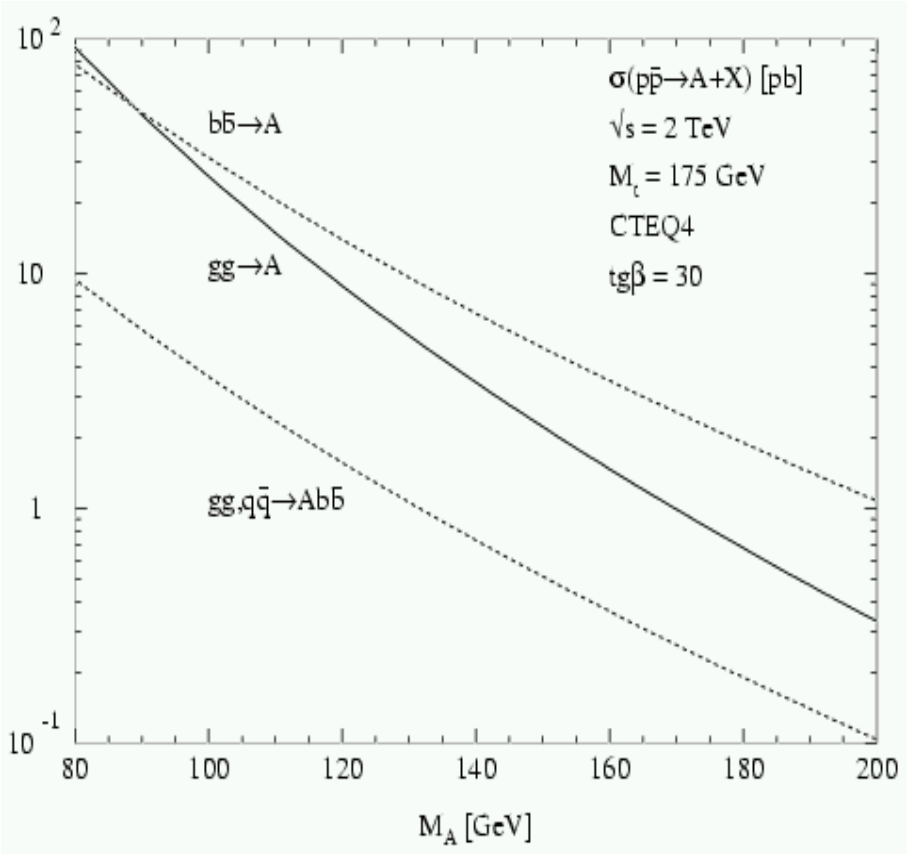
- Run IIa:
  - **With 2 fb^{-1} exclude SM Higgs for masses up to 120 GeV**
- Run IIb:
  - **with 10-15 fb^{-1} exclude mass range up to ~180 GeV**
- Observation (5σ) requires significantly larger statistics
- To reach maximal sensitivity CDF and D0 will need to combine their results in multiple search channels



Higgs bosons in MSSM

- 2 Higgs doublets
- 3 neutral (h,H,A), 2 charged ($H^{\pm}$) scalars
- 2 parameters: $\mathbf{\tan\beta = v_u/v_d}$ and $\mathbf{M_A}$
- Mass constraints
  - M(h) < 135 GeV, M(H+) > M(W)
- **Couplings to fermions may be enhanced:**
  - **Abb: $\gamma_5 \tan\beta$**
- large **t**anβ within the reach of the Tevatron Run I (~100 pb^{-1})





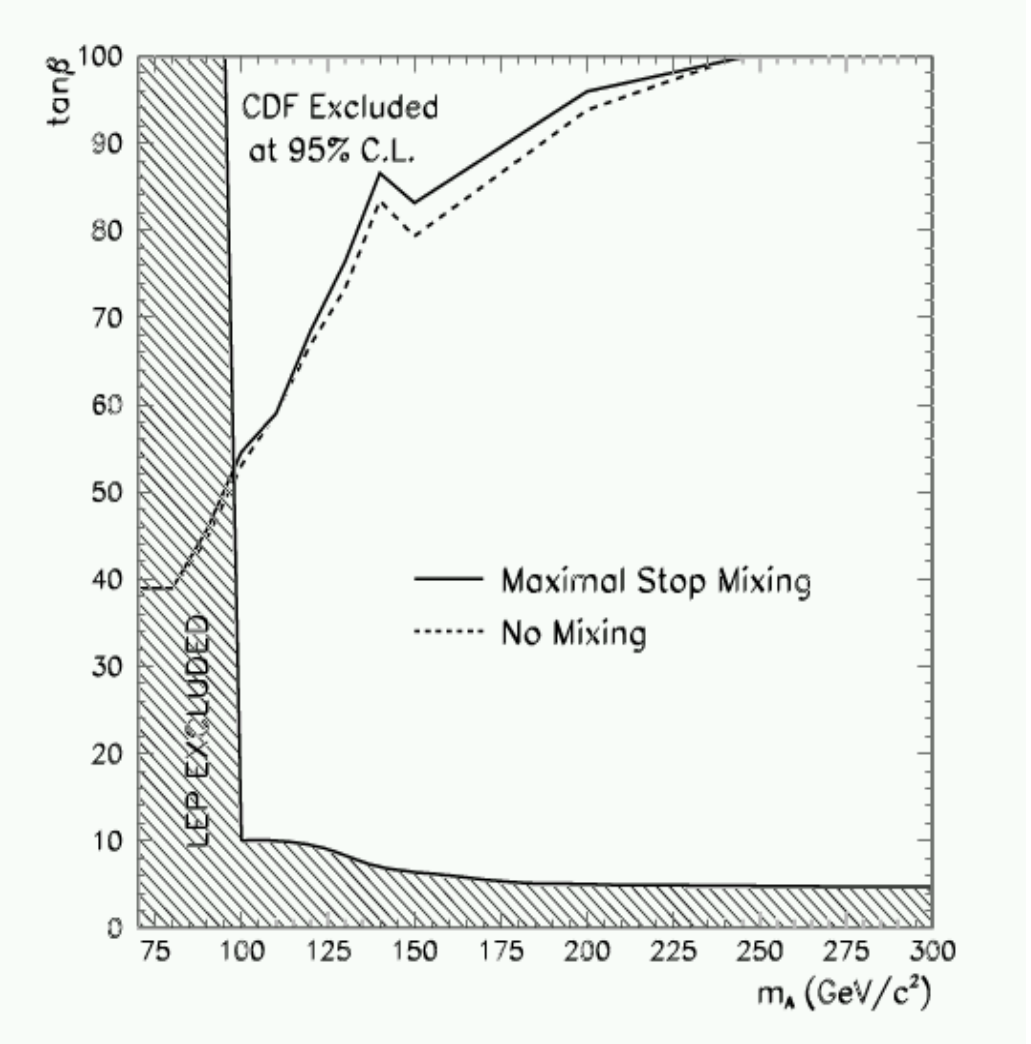
- LEP'2001 95% CL limits:
  - **M(h) > 91 GeV,**
  - **M(A) > 91.9 GeV**
  - **M($H^{\pm}$) > 78.6 GeV**

Higgs boson signatures in MSSM

- SM-like signatures
  - qq->VH->Vbb
  - Interpret results of SM Higgs searches in terms of MSSM paramers
- Signatures, enhanced in MSSM (large **tanβ**)
  - **gg, qq->ϕ^0bb->bbbb**
- New signatures
  - $H^+ \rightarrow \tau\nu$
- Large cross sections into the final states with tau leptons
  - Decays $\phi^0 \rightarrow \tau\tau$ **and** $H^+ \rightarrow \tau\nu$
- **Taus can be triggered on!**

CDF Run I Search for the neutral MSSM Higgs boson

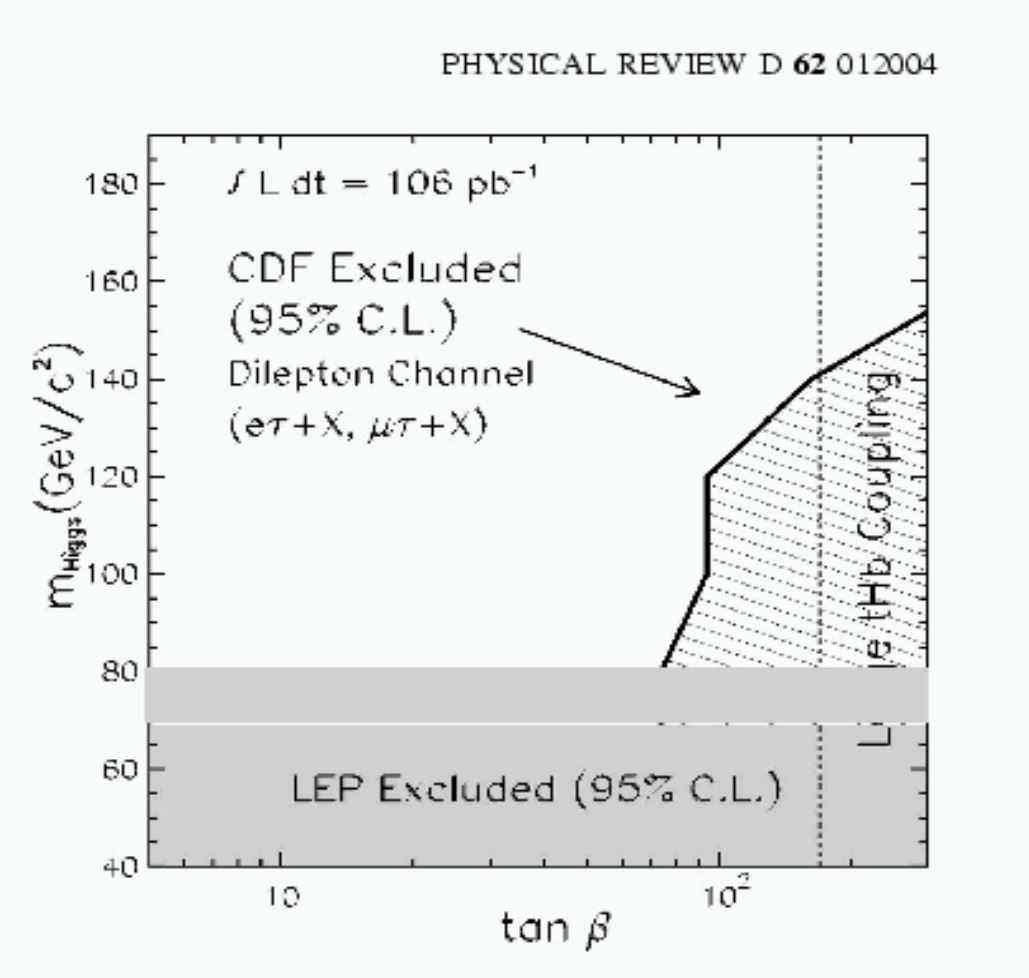
- Signature: pp -> Hbb -> bbbb
- 4 jets Et > 15 GeV, |eta| < 2.1
- 2 jets Et > 45-70 GeV
- 3 B-tags
- Reconstruct M(bb)
- ε ~ 0.4-0.5% (trigger, b-tagging)
- Backgrounds: (~90% irreducible) dominated by QCD



Run I Search for H+ in top decays dilepton channel

pp->tt -> $H^+(\tau\nu)bW(l\nu)b$

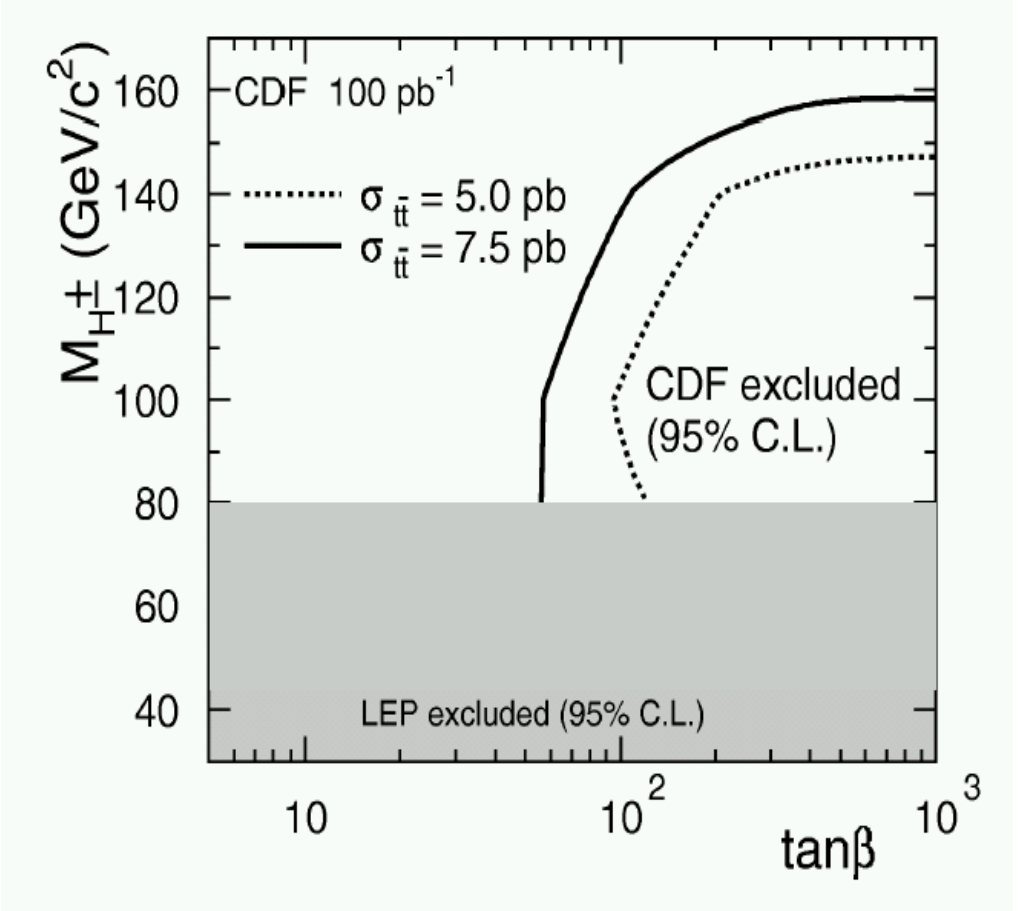
- Signature: ℓ(e,μ) + τ + MET + **jj**
- e,μ: Pt > 20 GeV, |eta| < 1
- T : Pt > 15 GeV, |eta| < 1
- 2 jets Et > 10 , |eta| < 2
- MET significance > 3
- Acceptance*BR ~ 1%
- **Observe 4 events, expect 3.1±0.5**
- Backgrounds dominated by SM ttbar production



Run I search for charged Higgs in top decays hadronic channels

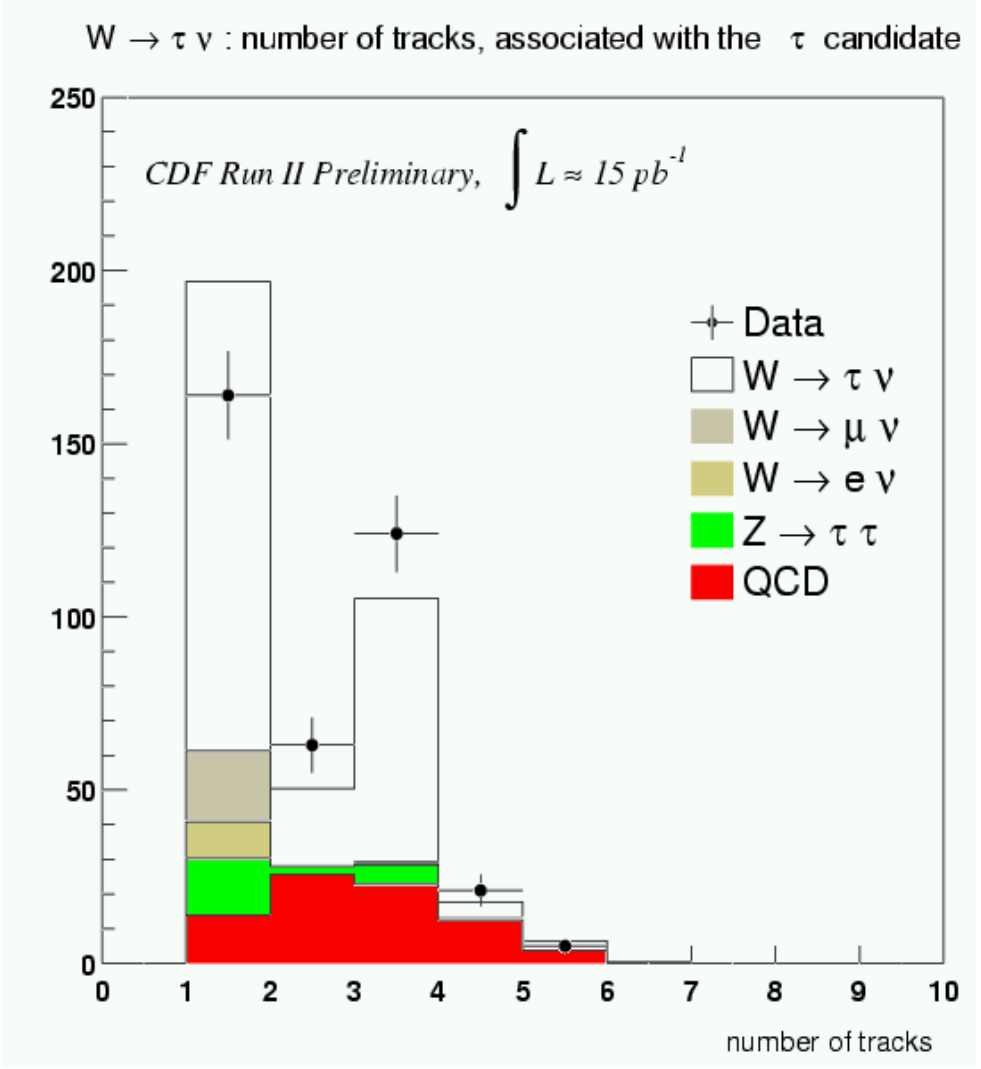
p pbar -> t tbar -> $H^+(\tau\nu)b(W/H+)b$

- Include **W->qq** to increase trigger acceptance, search for 2 signatures
  - **τ MET b j and ττ MET**
- Observed: 7 events (7+0)
- Expected: 7.4 +/- 2 events
- Background dominated by fakes, W+jets (2nd largest) is ~20%

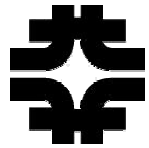


MSSM prospects: detection of τ leptons

- MSSM at tanβ >> 1: detecting tau leptons is a priority
  - Trigger on hadronic tau decays
- Implemented single tau and ditau triggers **(more details in the talk by John Smith)**
  - Tau - missing Et (W, H+)
  - Tau - lepton (e , mu) (Z, h/H/A)
  - Tau - tau (Z, h/H/A)
- **W->τν signal in Run II data taken with tau-MET trigger**



Summary



- Run I established tools and techniques for Higgs searches at hadron colliders
- CDF potential for detecting the Higgs has greatly increased in Run II - new detectors, new triggers, new calibration and analysis tools
- (re)learning how to use all of those
- After the 1st year of Run II don't have enough sensitivity to confront the Standard Model
- By the end of the year enough statistics to start exploring MSSM limits
- **Expect first results on Higgs searches in 2003**