Search for Neutral Higgs Bosons in Multi-jet Events at DØ

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on behalf of the
DØ Collaboration

DPF 2006 - Hawaii
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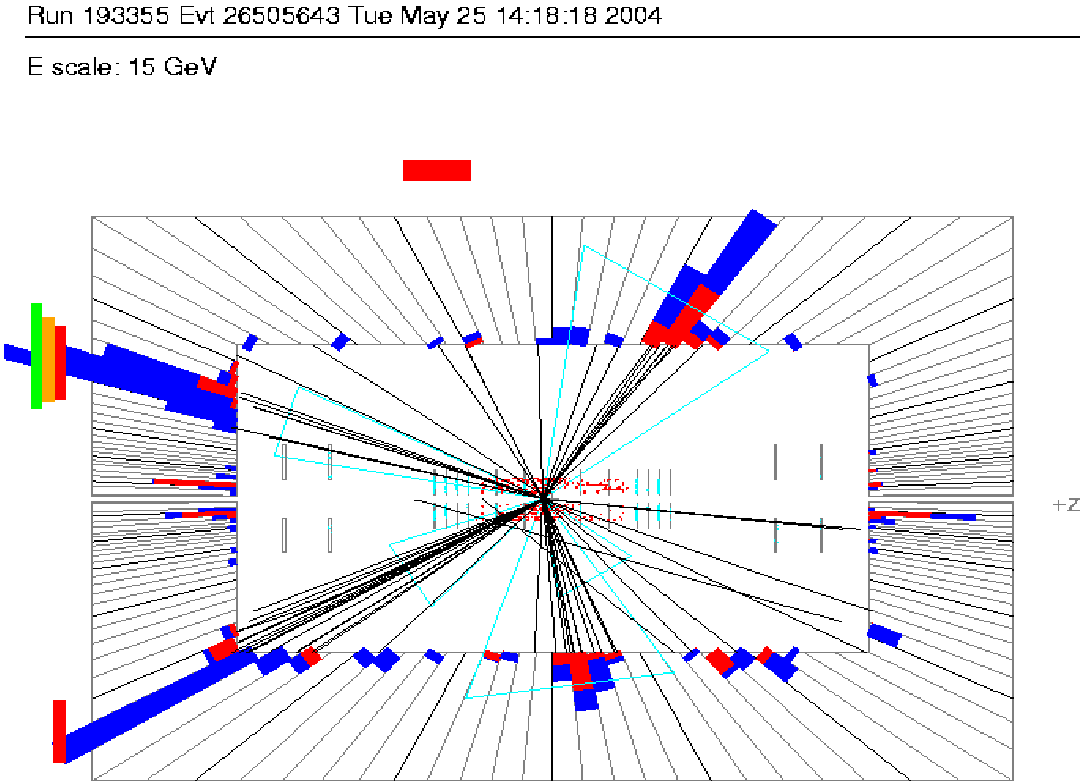


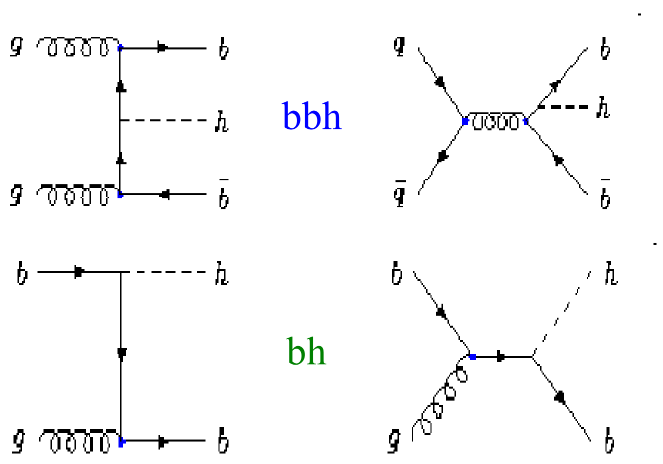
MSSM Higgs Theory

- **Two Complex Higgs Doublets needed to avoid anomalies**
- **Eight Degrees of Freedom minus $W^{+,-}$, Z^0 longitudinal polarization states→ Five scalars predicted: h, H, A, H^+, H^-**
- ***Assume CP-conservation*: h, H are CP-even, A is CP-odd**
- **At tree-level, two independent Parameters:**
  - **m_A**
  - **$\tan\beta$ = ratio of VEV's**

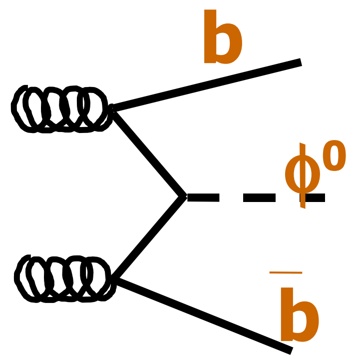
  - **M_{SUSY} (parameterizes squark, gaugino masses)**
  - **X_t (related to the trilinear coupling A_t → stop mixing)**
  - **M_2 (gaugino mass term)**
  - **μ (Higgs mass parameter)**
  - **m_{gluino}(comes in via loops)**

These 5 parameters intervene via radiative corrections
(cf M. Carena et al., hep-ph/051123)

MSSM Higgs Phenomenology



- There are two ways to calculate the signal production at a ppbar collider:
  - ppbar->bbh (4-flavor scheme)
  - ppbar->bh (5-flavor scheme) : use b-PDF
- Both methods now agree at NLO
- ***Kinematics and cross-sections are weighted to the NLO distributions (from MCFM)***

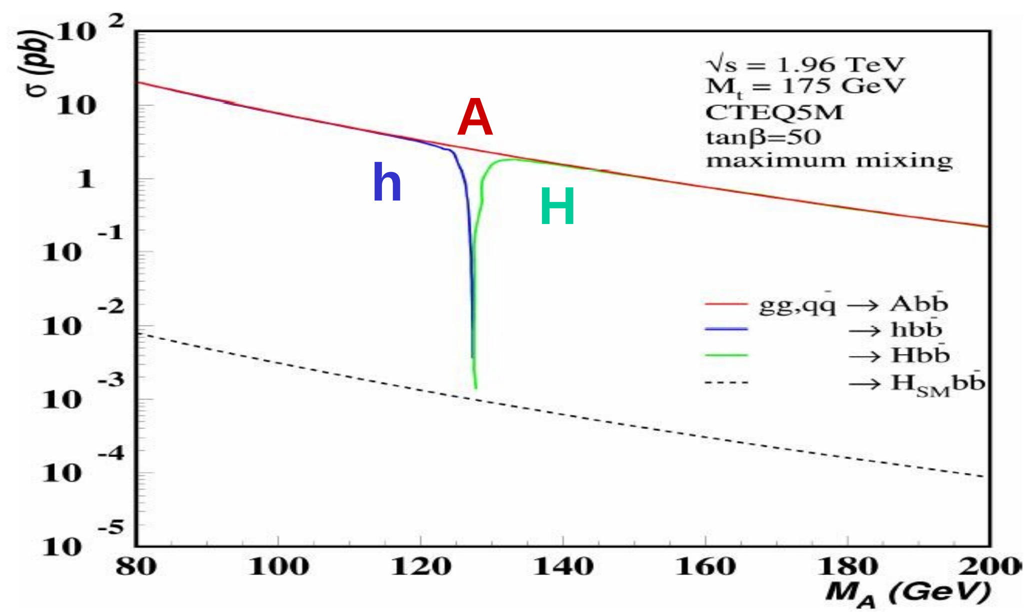


Amplitude ∝ tanβ enhanced!

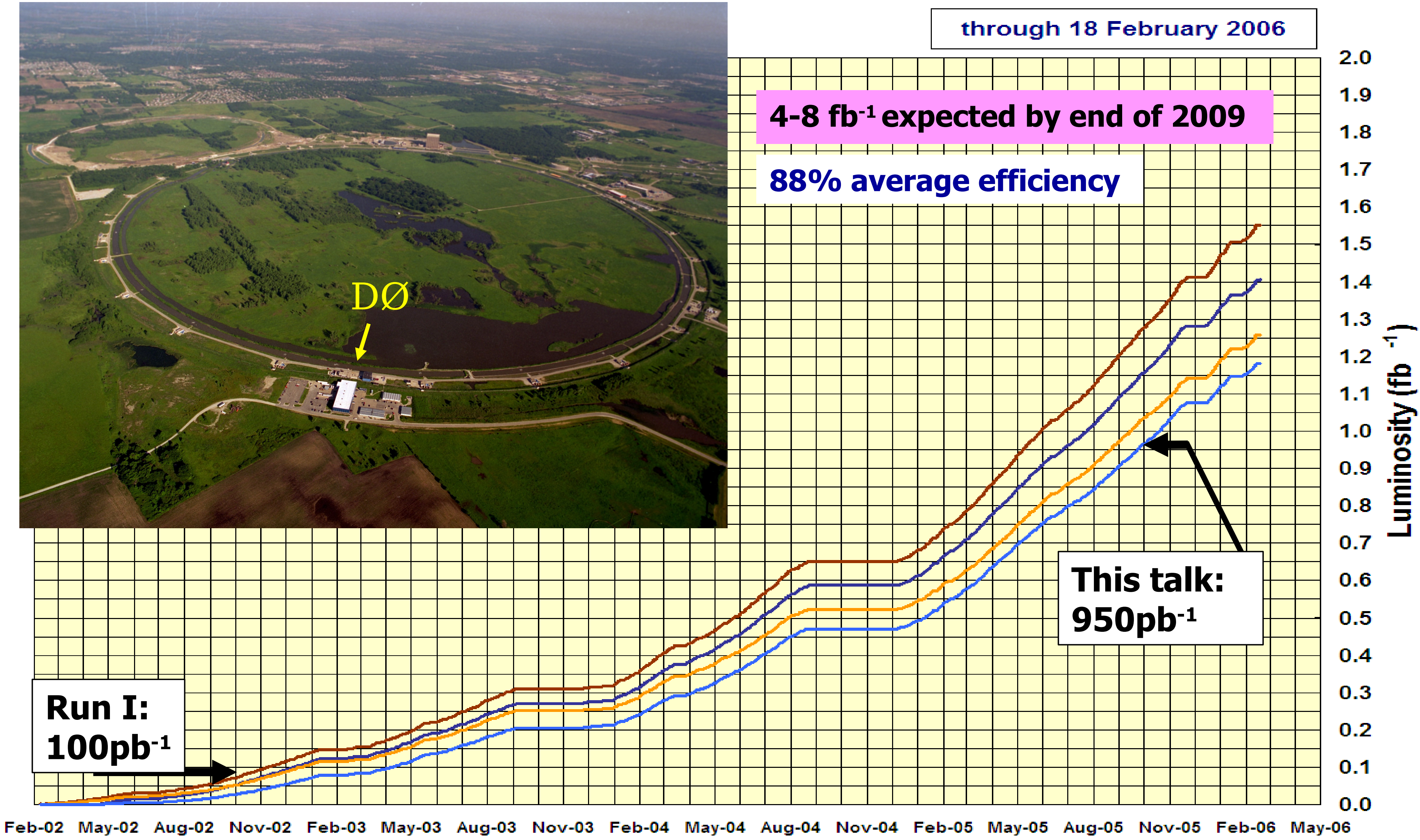
at high tanβ, σ(h/H,A+X) ∝ tan²β

Interesting feature of MSSM scenario:
$[m_h, m_H] \approx m_A$ at high tanβ

Br($A^0 \to bb$) ~ 90% and Br($A^0 \to \tau^+\tau^-$) ~ 10% almost independent of tanβ.

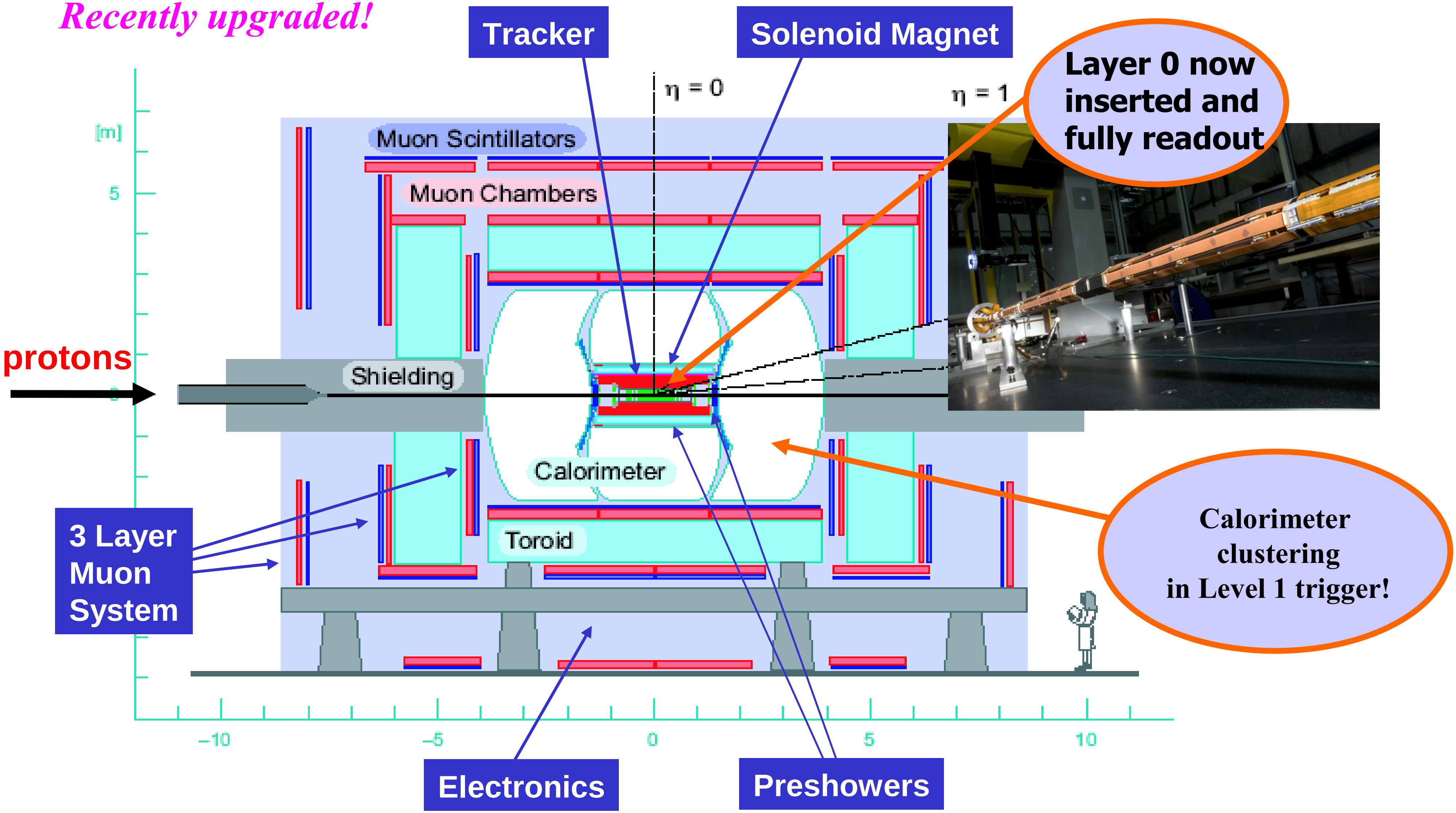


The Tevatron at Fermilab

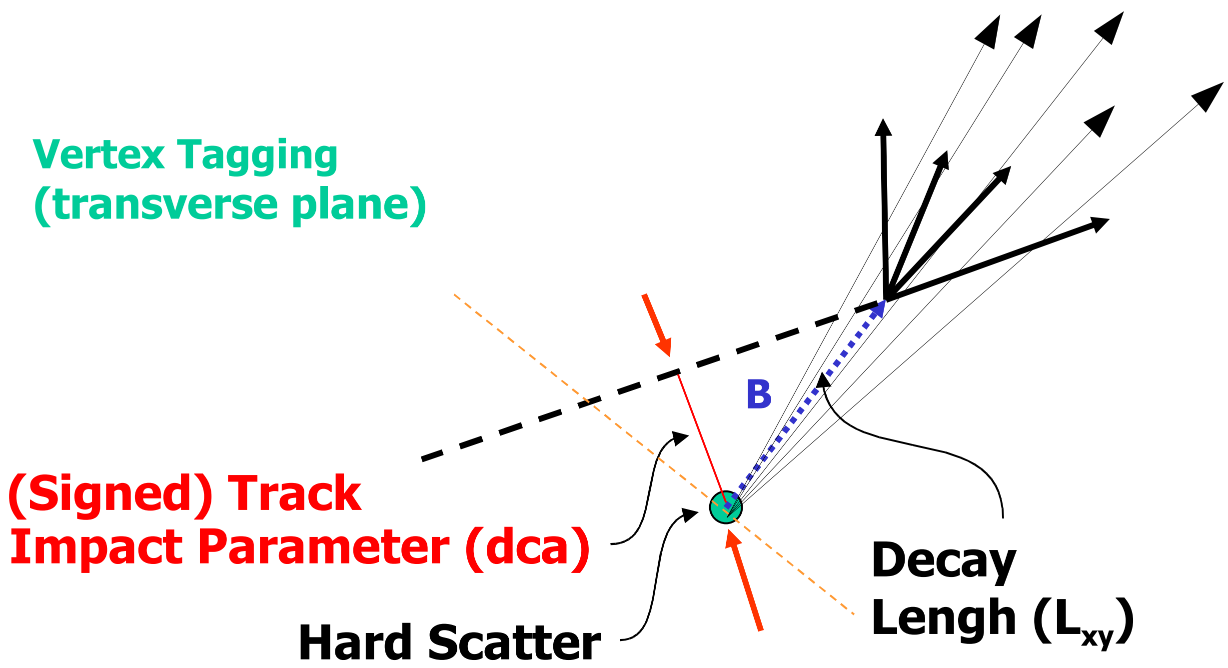


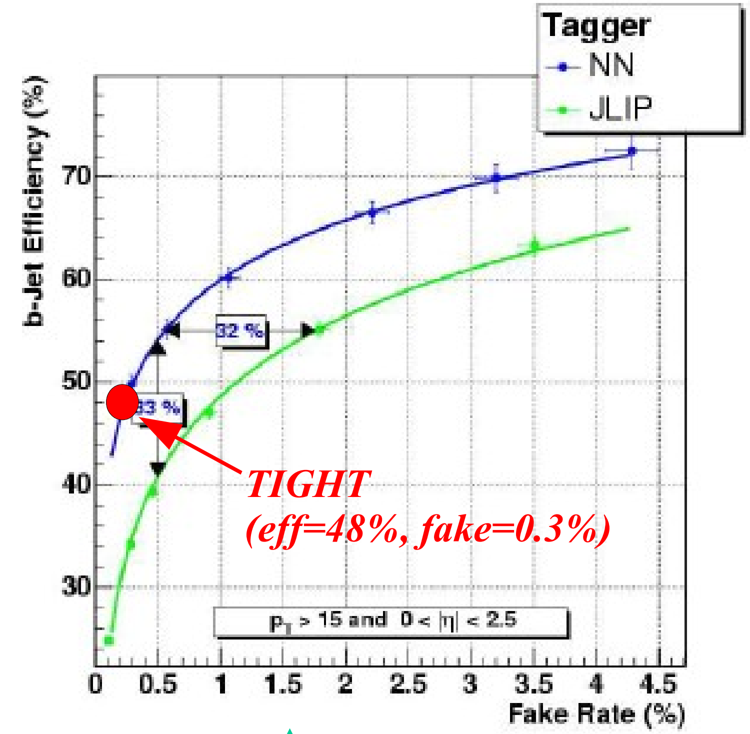
The Run II DØ Detector

Recently upgraded!



b-Jet Tagging





Several mature algorithms used:

3 main categories:

- **Soft-lepton tagging**
- **Impact Parameter based**
- **Secondary Vertex reconstruction**

Combine in Neural Network:

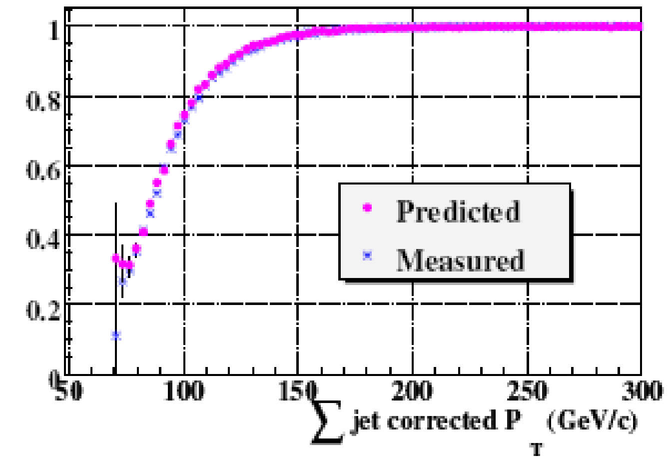
- vertex mass
- vertex number of tracks
- vertex decay length significance
- chi2/DOF of vertex
- number of vertices
- two methods of combined track impact parameter significances

Triggering

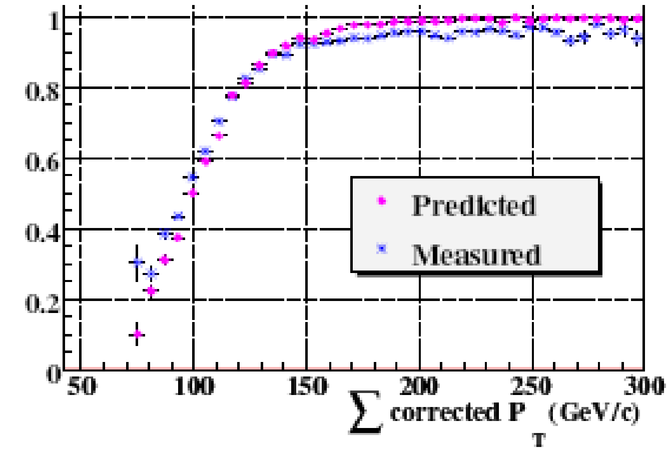
- A very difficult signature to trigger on!
  - No high-pT leptons, or large mET
- Trigger on jets
  - 3 calorimeter towers / clusters at Level1/2
  - 3 jets with pT>25,25,15 GeV at L3
- And use the fact that they are *b* jets, at Level3
  - Reconstruct central tracks
  - Compute a combined event probability based on the impact parameter (IP) of the tracks
    - More b's -> more high IP tracks -> smaller non-b probability
  - Require the event's non-b probability < 5%
- Measure trigger efficiencies in data
  - model the trigger effects in the Monte Carlo

Trigger List	Higgs boson mass (GeV)				
	100	110	120	150	170
v9	87±2	86±1	86±1	85±1	85±1
v10	84±2	84±1	84±1	80±1	84±1
v12	58±2	62±2	65±2	70±1	74±1
v13	60±2	59±2	61±1	63±1	66±1
v14.0-7	58±2	62±2	63±2	63±1	67±1
v14.8-9	62±2	56±2	64±2	64±1	67±1
Overall	60±2	57±2	63±1	64±1	68±1

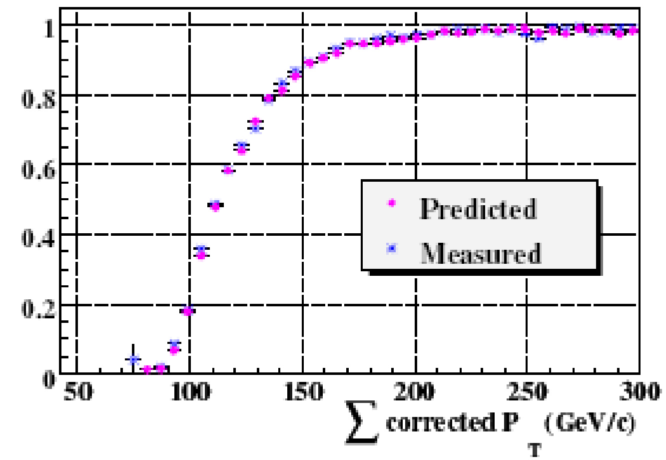
L1



L2

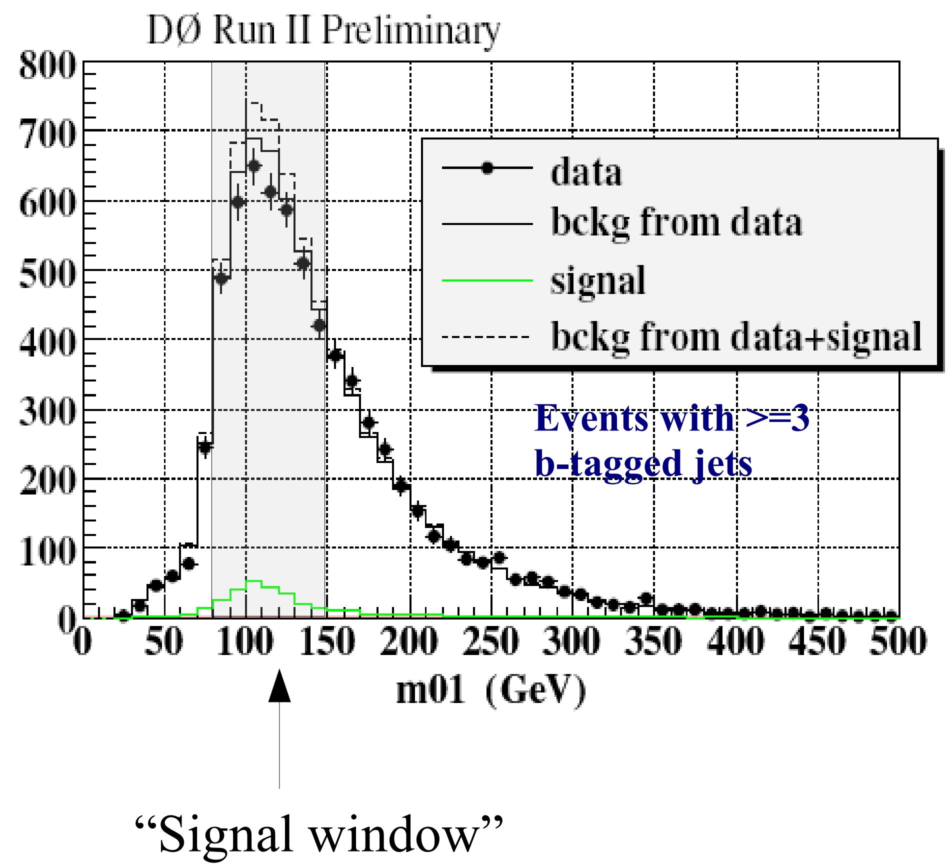


L3



Event Selection / Analysis Method

- About 75 million events in initial data sample
- Jets considered in |eta|<2.5
  Primary Vertex |Z| < 35cm
  (b-tag acceptance)
- Require at least 3 jets with pT>40,25,15 GeV
  - No more than 5 jets with pT>15 GeV
- Require at least 3 b-tagged jets
- Signal:
  - Invariant mass of leading jets is peaked at m_A
- Backgrounds (determined from data):
  - Shape estimated from the *double* b-tagged data sample (taking into account the kinematic bias from requiring a 3rd b-tag)
  - Normalized outside the "signal region" (for each candidate mA and tanB)



Higgs boson mass (GeV)	100	110	120	150	170
Trigger	61	64	64	64	67
Kinematic	31	35	39	40	43
BID	8.8	8.8	9.7	9.9	9.2

Triple b-tagged Background

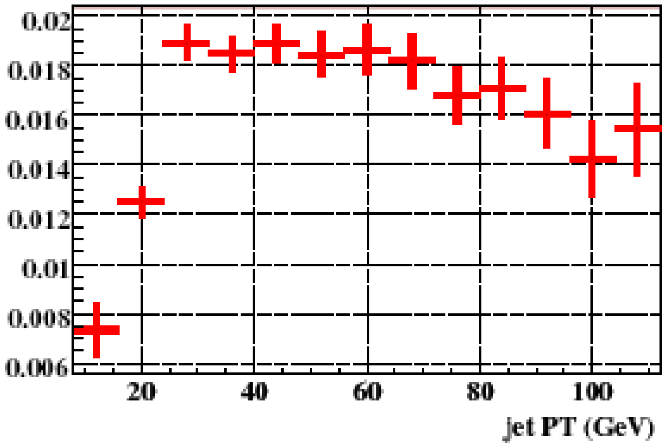
Double b-tagged data sample → Calculate TRF

Double b-tagged data sample → Apply TRF to un-b-tagged jets

↓

Triple b-tagged background shape → (Fit outside the signal region to data) → Triple b-tagged background

Tag-rate-function (TRF)

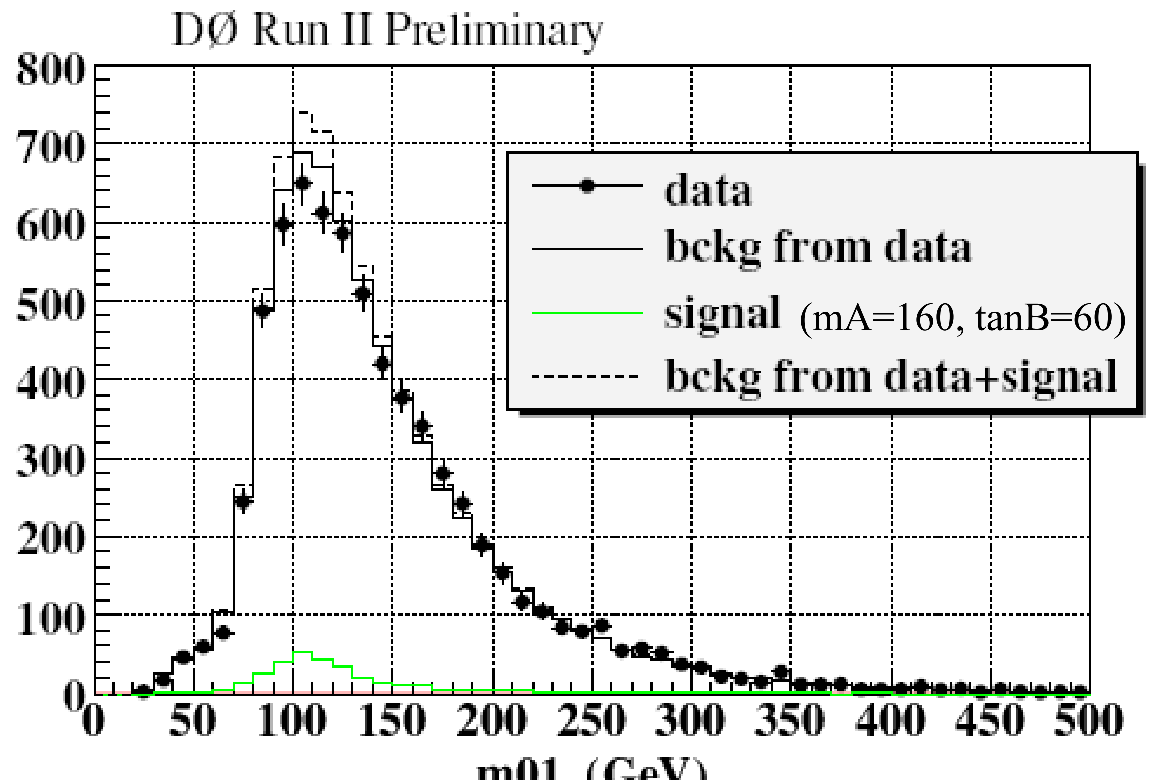


Data vs. Background

- Data agrees well with the predicted background from the TRF method
- Will set upper tanB limits on various Higgs masses using the CLs (LEP Higgs) method

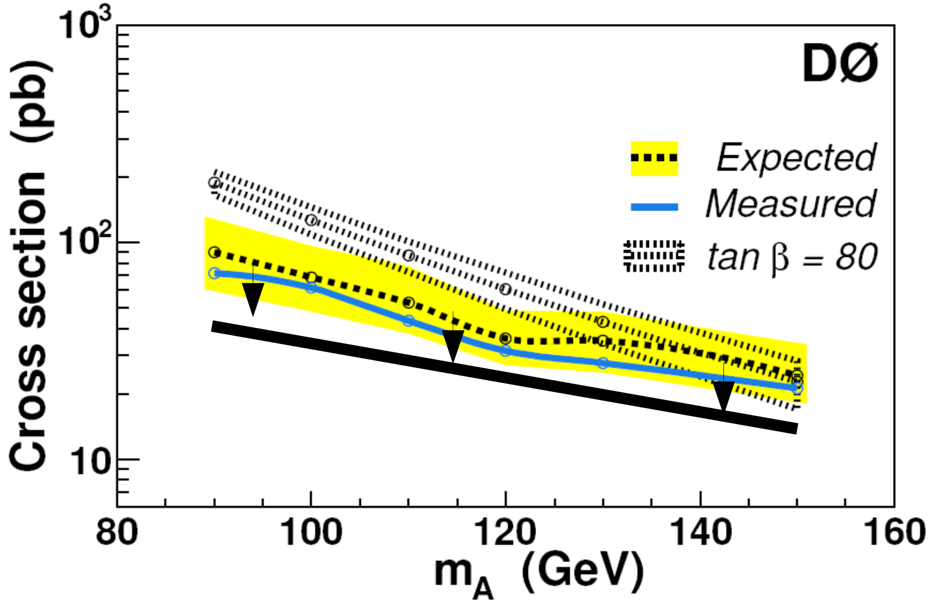
- Acceptance systematics: (Total: ~17%)
  - Trigger efficiency
  - Kinematic cuts
  - Modeling of NLO effects
  - b-Tagging efficiency
- Background systematics: (Total: ~2.5%)
  - Statistics of TRF
  - Shape of TRF

Higgs boson mass (GeV)	100	110	120	150	170
Alternate method	1.8	2.3	2.4	1.9	1.9
Due to normalization	1.8	1.7	1.7	1.7	1.7
Total	2.4	2.8	2.8	2.6	2.6

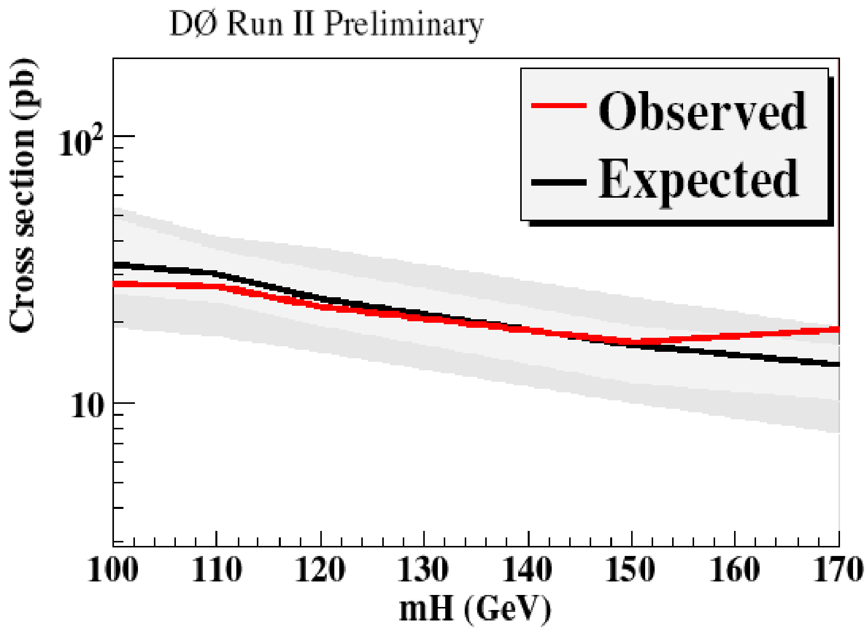


Higgs boson mass (GeV)	100	110	120	150	170
Lumi	6.5	6.5	6.5	6.5	6.5
Theoretical	12.3	12.0	12.1	13.0	13.5
Trigger	4.0	4.9	3.6	4.2	2.5
ID	0.3	0.5	0.4	0.4	0.4
JES	4.8	4.6	3.9	2.8	2.7
Reso	0.6	0.2	0.1	0.3	0.5
JET	4.9	4.7	3.9	2.8	2.8
b-ID	8.1	8.2	8.3	8.8	9.3
Total	17.2	17.3	17.0	17.7	18.0

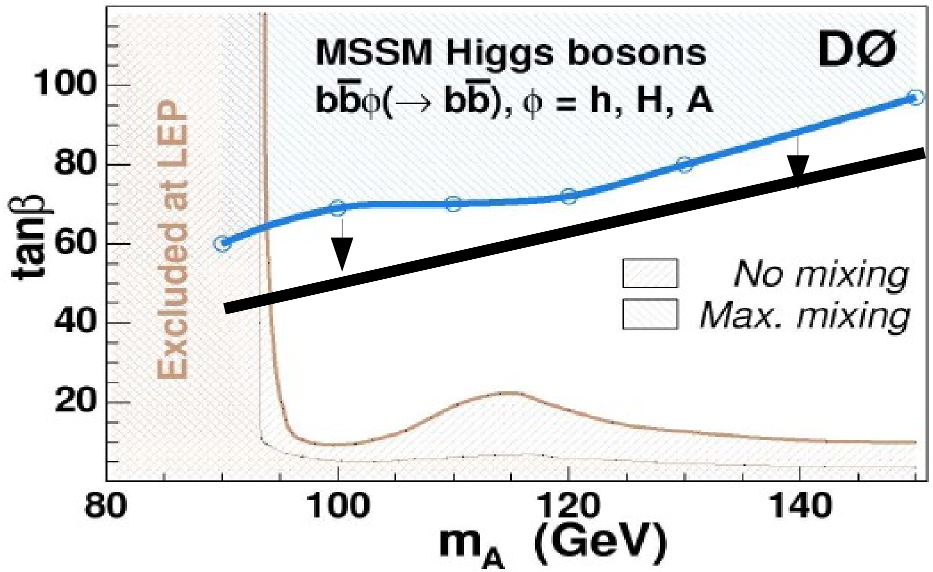
Limits



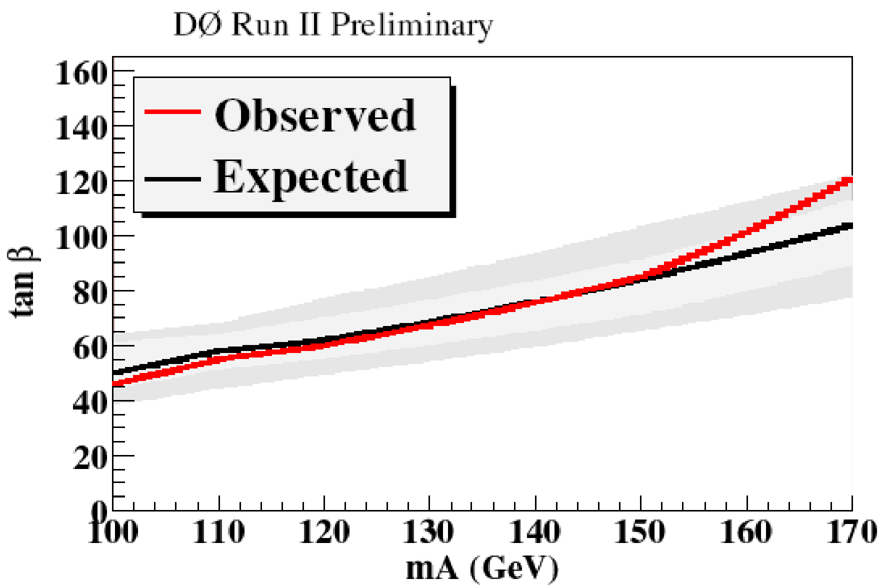
DØ
Expected
Measured
tan β = 80
Cross section (pb)
m_A (GeV)



DØ Run II Preliminary
Observed
Expected
Cross section (pb)
mH (GeV)



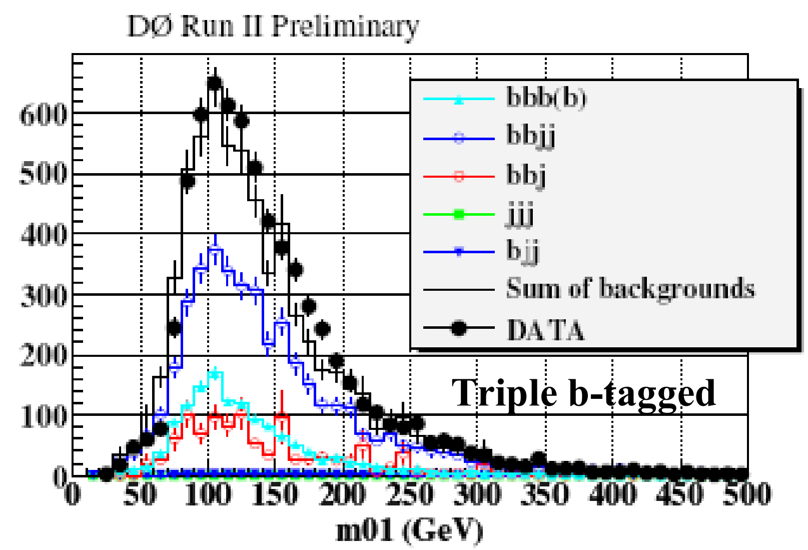
MSSM Higgs bosons
bb̄φ(→ bb̄), φ = h, H, A
DØ
Excluded at LEP
No mixing
Max. mixing
tanβ
m_A (GeV)

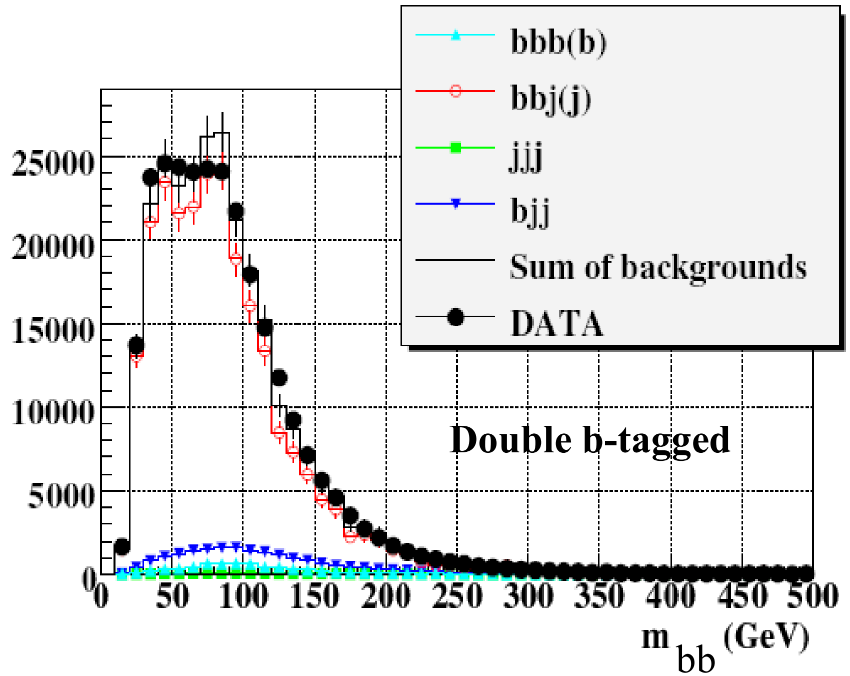


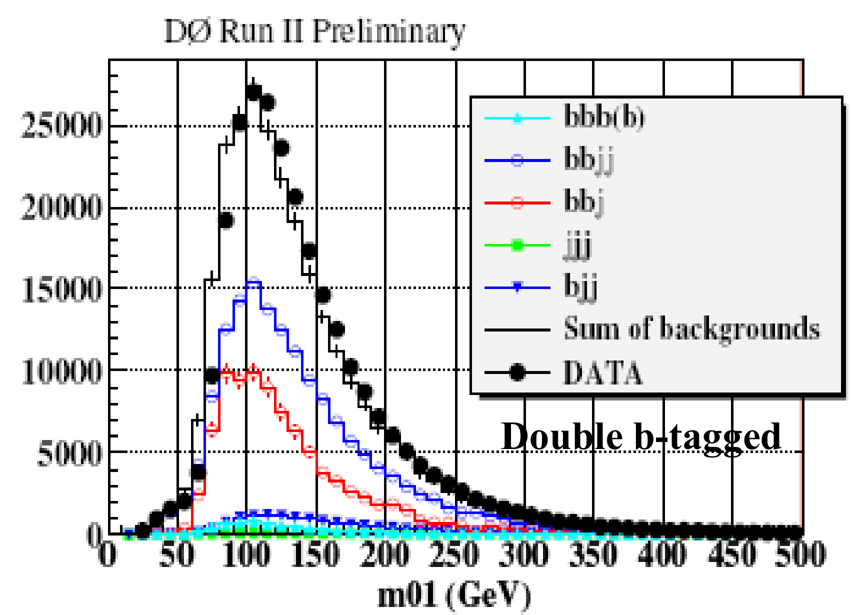
DØ Run II Preliminary
Observed
Expected
tan β
mA (GeV)

Monte Carlo Cross-checks

- Use ALPGEN+Pythia to produce simulated background samples
  - Cross-section uncertainties are 50-100% due to renormalization/factorization scale dependence at leading-order
- Useful for understanding the background shapes and physics composition of the background
- Can check the ratio of observed triple and double b-tagged events with what is expected from MC
- Checks the modeling of the trigger turn-ons
- All distributions roughly agree between data / MC







Conclusions

- New limits in the mA / tanB plane from the search for neutral Higgs bosons in the MSSM
- Many new techniques used, such as:
  - Level3 event b-tagging: needed to remain within bandwidth limitations as luminosity increased
  - Neural Net b-tagging (offline): light-jet backgrounds reduced by a factor of ~3
  - State-of-the-art MC modeling of backgrounds used as a cross-check
- This analysis will be extended using new data
  - Expect up to 8 fb^{-1} by 2009
  - Will use the newly commissioned Layer0 of silicon -> better b-tagging!
  - Use of new L1 calorimeter trigger will enable efficient collection of multi-jet events at high luminosity
- Possible to exclude up to mA~250 GeV for high tanB, and down to tanB~20 for low mA by the end of Run II
  - Will continue to combine with A->tautau and bA->btautau channels
  - Will eventually combine with CDF