Search for MSSM Neutral Higgs Bosons Decaying to Tau Pairs

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on behalf of the DØ Collaboration

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Outline

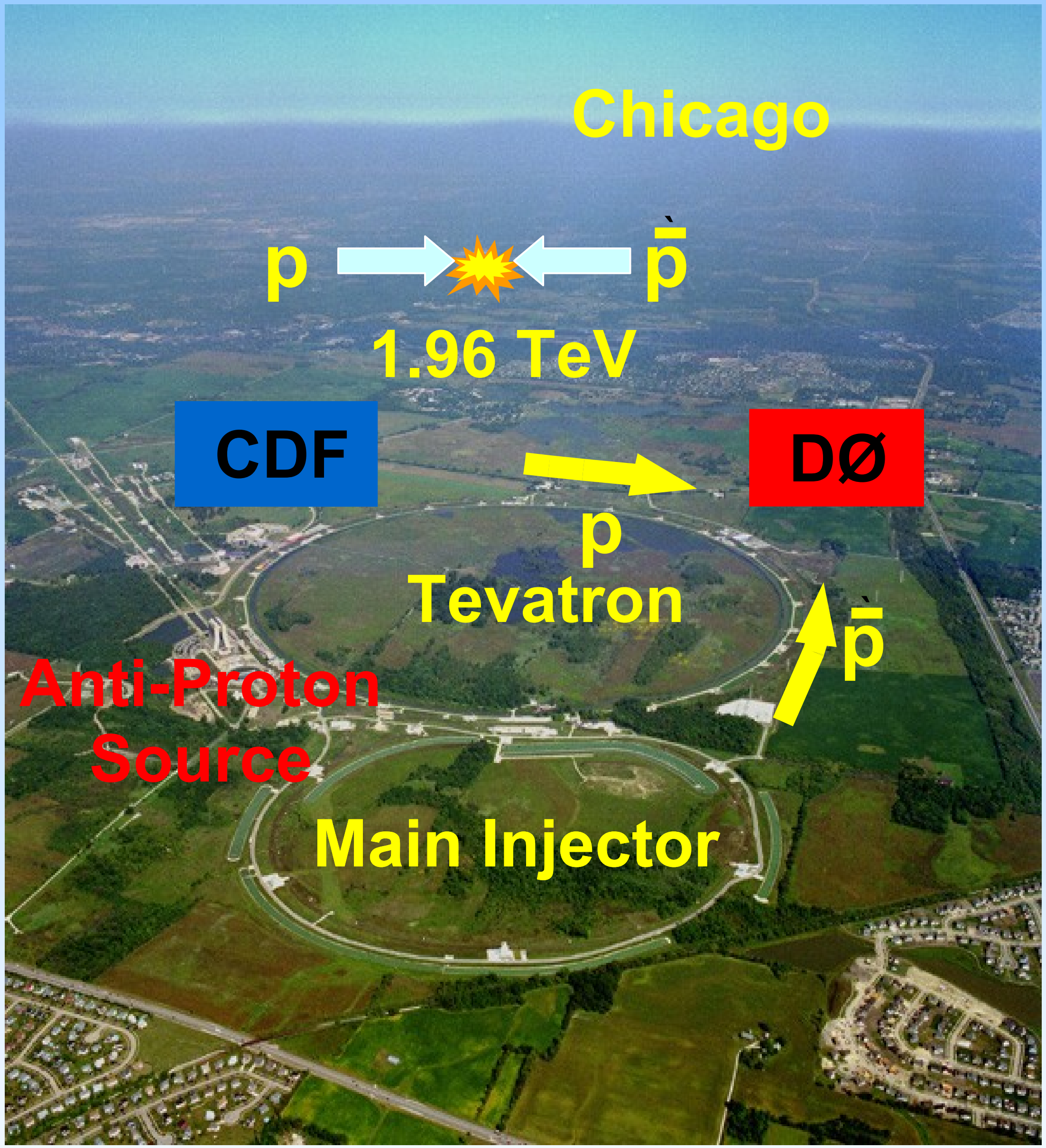
- Tevatron & DØ Detector
- Theoretical background
- Tau Identification at DØ
- h/H/A → $\tau^+\tau^-$
- b(h/H/A) → b $\tau^+\tau^-$
- Conclusions & Outlook

ALBERT-LUDWIGS-UNIVERSITÄT FREIBURG

bmb+f - Förderschwerpunkt
Elementarteilchenphysik
Großgeräte der physikalischen Grundlagenforschung

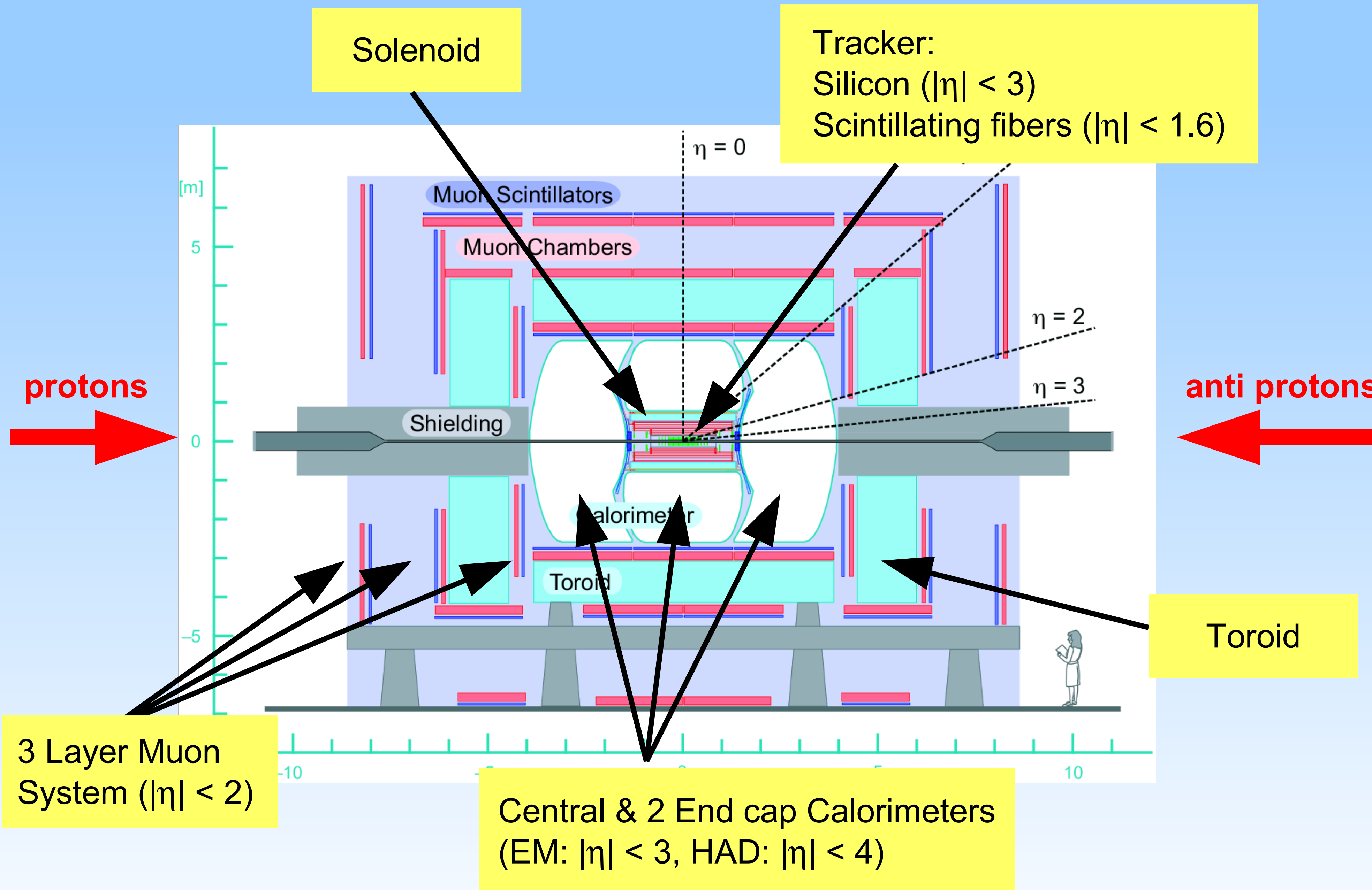
http://www-d0.fnal.gov/Run2Physics/WWW/results/higgs.htm

Tevatron



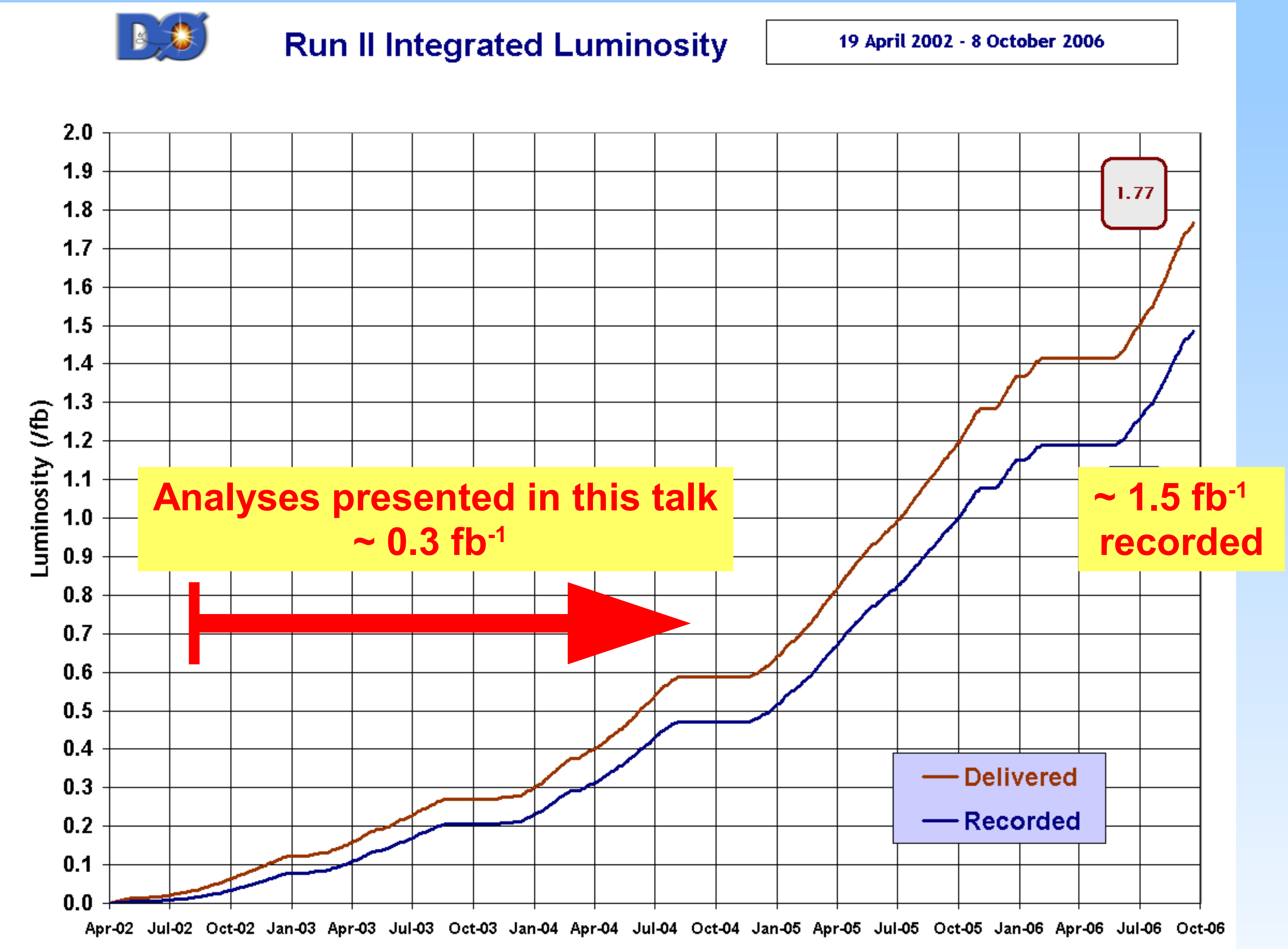
- Tevatron: Run II: 2001-200x
- Center-of-mass energy: 1.96 TeV
- Bunch spacing: 396 ns
- Run II b started in June

DØ Detector



Solenoid
Tracker:
Silicon (|η| < 3)
Scintillating fibers (|η| < 1.6)
η = 0
[m]
Muon Scintillators
Muon Chambers
5
η = 2
η = 3
protons
anti protons
Shielding
0
Calorimeter
Toroid
–5
Toroid
3 Layer Muon
System (|η| < 2)
-10
10
Central & 2 End cap Calorimeters
(EM: |η| < 3, HAD: |η| < 4)

DØ Luminosity



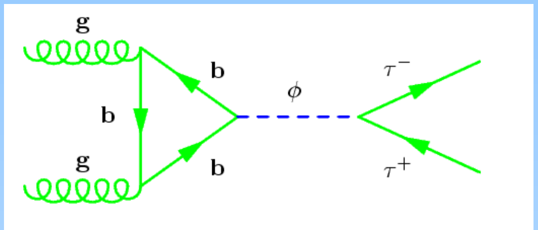
Higgs Sector in the MSSM

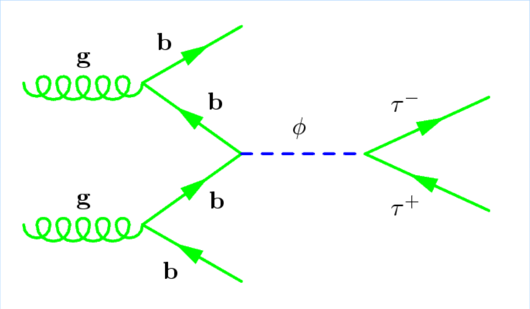
- Higgs sector in the MSSM is based on two complex Higgs doublets
- after electroweak symmetry breaking:
  - 2 charged Higgs bosons (H^+, H^-)
  - 3 neutral Higgs bosons ($h,H,A = \Phi$)
    → at large tan(β) A is nearly mass degenerated with either h or H
- Higgs sector is fully specified at leading order using m_A and tan(β)
- Consider two benchmark scenarios:
  - **m_h-max**: m_h close to the possible maximum for a given tan(β)
  - **no-mixing**: vanishing mixing in stop sector → small m_h

	m_h-max	no-mixing
M_{SUSY}	1 TeV	2 TeV
X_t	2 TeV	0
M_2	200 GeV	200 GeV
μ	±200 GeV	±200 GeV
m_g	800 GeV	1600 GeV

Neutral Higgs Boson Production and Decay

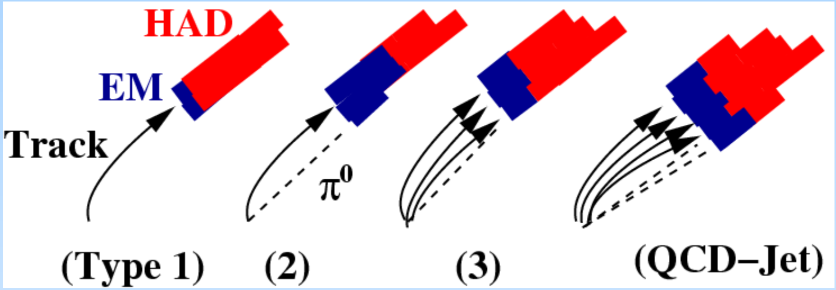
- Enhanced coupling to down type quarks and leptons lead to sizeable production cross sections
- Dominant production modes at Tevatron
  - $gg \rightarrow \Phi$ (Gluon fusion)
  - $b\bar{b}$, $qq \rightarrow b\bar{b}\,\Phi$ (in association with b quarks)
- Cross section: $\sigma \sim \tan^2(\beta)$ (at leading order)
- Leading decay modes:
  - $\Phi \rightarrow b\bar{b}$ (~90%)
  - $\Phi \rightarrow \tau\tau$ (~10%) small branching ratio
    BUT: channel does not suffer from large multi-jet background
- Final states adressed in this talk:
  1) inclusive opposite sign tau pair
  2) same as 1) + additional jet from b quark

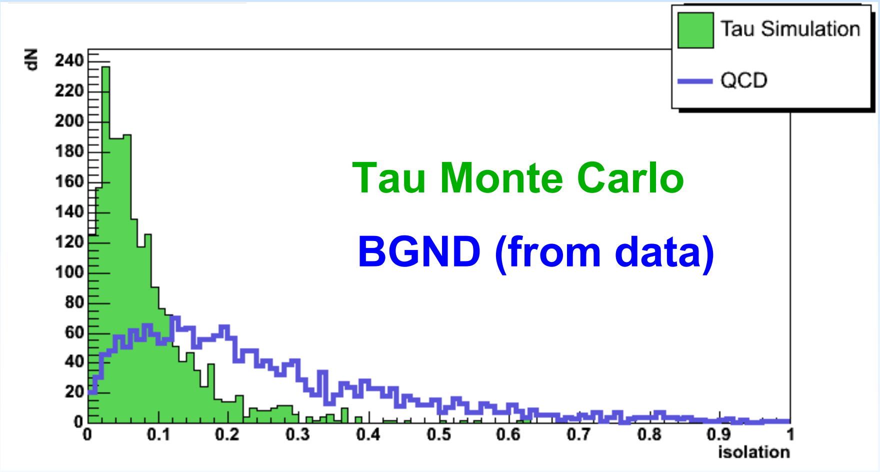


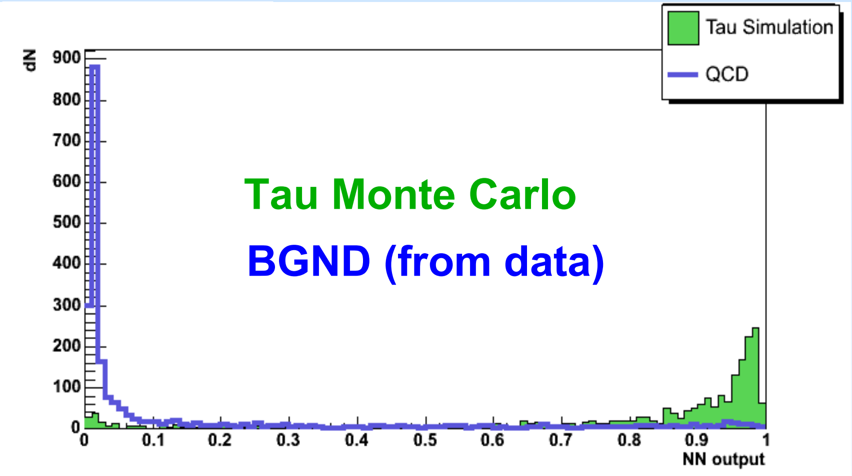


Tau Identification at DØ

- Tau = narrow isolated jet with low track and π^0 multiplicity
  - Tau candidates are divided into 3 types:
    - **Type 1**: one track, calorimeter cluster **without** EM subcluster (π-like)
    - **Type 2**: one Track, calorimeter cluster **with** EM subcluster (ρ-like)
    - **Type 3**: 2 or 3 tracks consistent with the tau mass, calorimeter cluster (3-prong)
- Tau identification based on Neutral Network
  - Non-linear correlations between variables taken into account
  - Discriminating variables: Profile, Isolation in Calorimeter and Tracker, ...







$$\Phi \rightarrow \tau^{+} \tau^{-}$$

- **3 final states: $e+\tau_h$, $\mu+\tau_h$, $e+\mu$**
- Standard Model backgrounds
  - $Z\rightarrow\tau\tau$: irreducible background
  - $Z/\gamma^*\rightarrow ee/\mu\mu$, multi-jet, W (+jet)→lep+ν(+jet) (rejected by M_W < 20 GeV), Di-boson

Mode	Fraction	Comment
$\tau_e\tau_e$	3%	Large DY BGND
$\tau_\mu\tau_\mu$	3%	Large DY BGND
$\tau_e\tau_\mu$	6%	Small QCD BGND
$\tau_e\tau_h$	23%	Golden
$\tau_\mu\tau_h$	23%	Golden
$\tau_h\tau_h$	41%	Large QCD BGND

Data

- Data Sample, L = 325 pb^{-1}, recorded by Electron/Muon Trigger
- Standard Model background is simulated using Pythia 6.2
- multi-jet background determination from data:
  - $e+\tau_h$ final state: like sign events
  - $\mu+\tau_h$ / $e+\mu$, final state: inverted lepton isolation criteria

$\Phi \rightarrow \tau^+\tau^-$ - Results

- Observed data events and expected BGND events at the end of the selection:

	Data	Bkgd	QCD	$Z\rightarrow\tau\tau$	$Z\rightarrow\mu\mu$/ee	W	Di-Boson	tt(bar)
$e + \tau_h$	337	296 ± 38	144 ± 19	130 ± 17	12 ± 2	9 ± 1	0.4 ± 0.1	0.3 ± 0.1
$\mu + \tau_h$	575	576 ± 62	62 ± 6	492 ± 53	4.6 ± 1.1	134 ± 2	3.1 ± 0.3	1.2 ± 0.1
$e + \mu$	42	44 ± 5	2.1 ± 0.4	39 ± 5	0.6 ± 0.1	0.3 ± 0.2	1.0 ± 0.1	0.06 ± 0.02

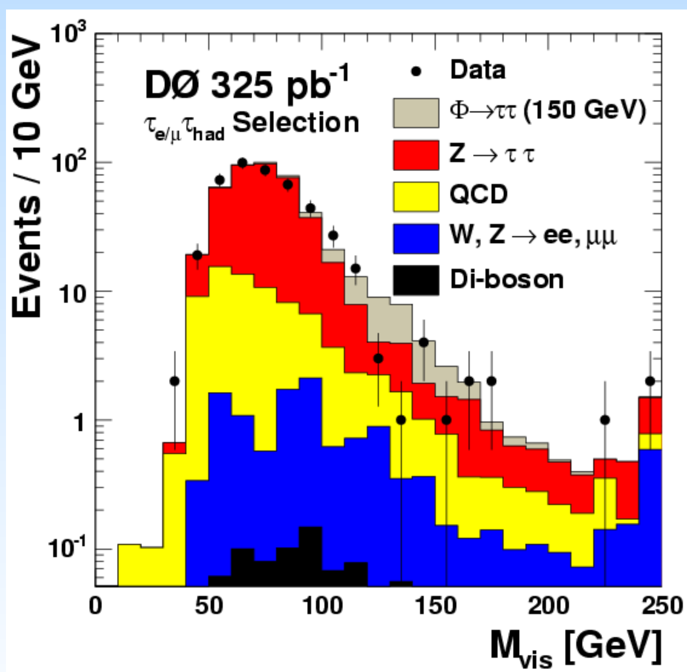
- Major systematic uncertainties: normalization of multi-jet background, τ-ID, Jet-Energy-Scale

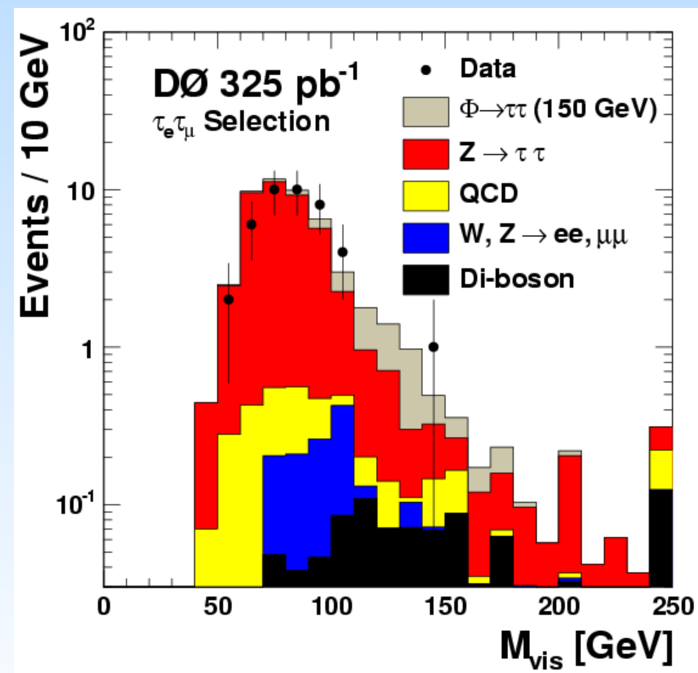
- Signal would stand out as enhancement from background in the visible mass

$$M_{vis} = \sqrt{P_{vis}^{\tau_1} + P_{vis}^{\tau_2} + \not{E}_T}$$

- No evidence of a signal

→ Set limit on
  σ x BR at 95% CL





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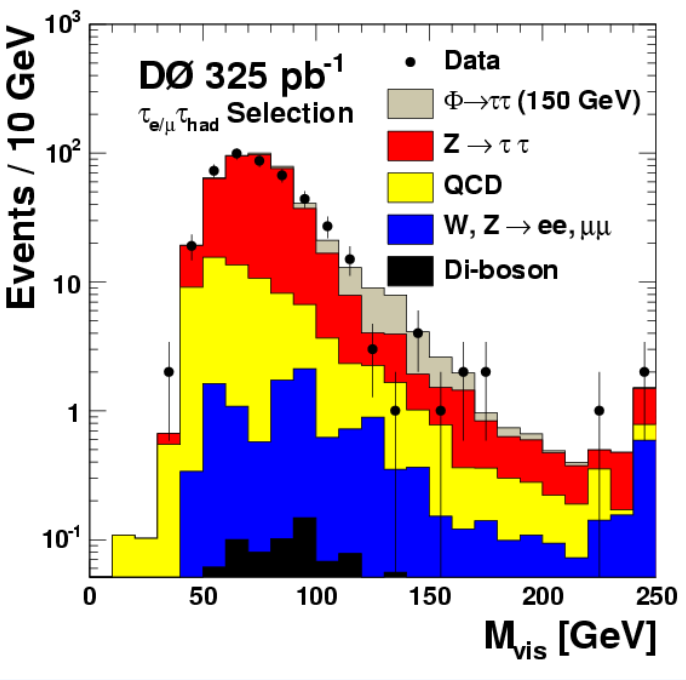
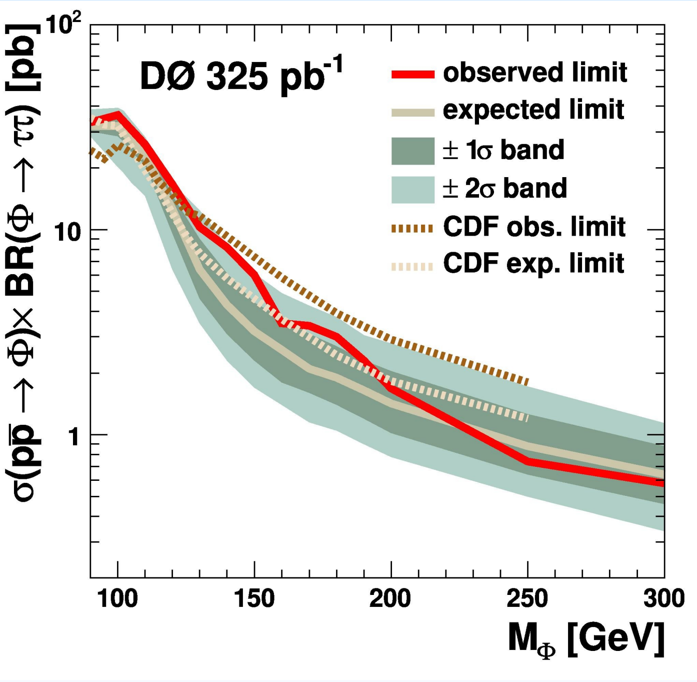
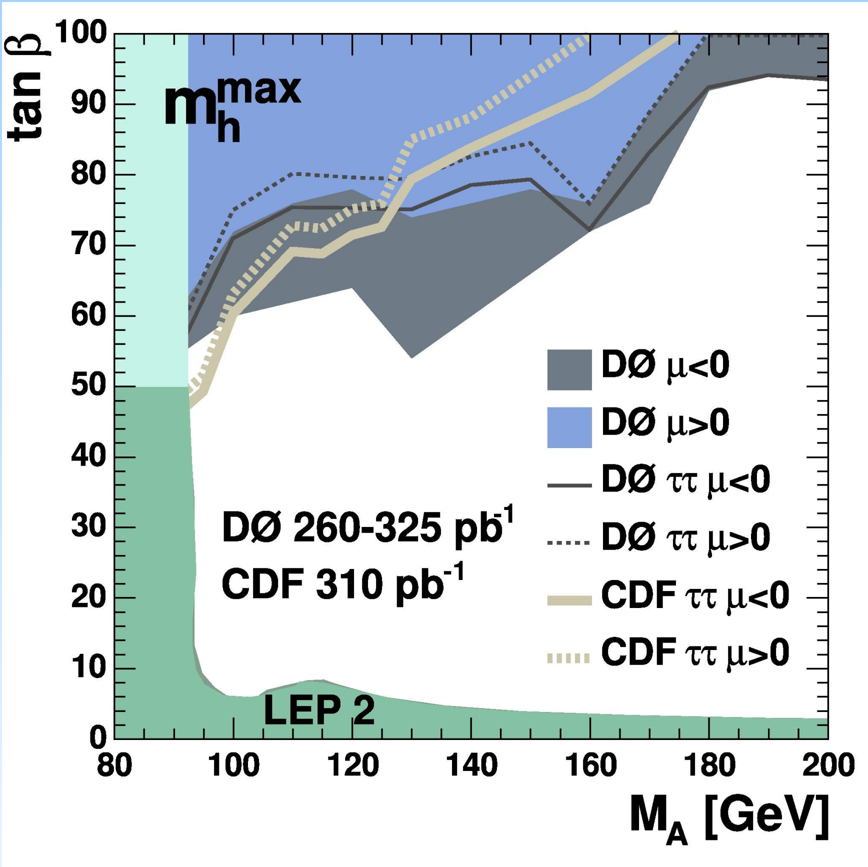


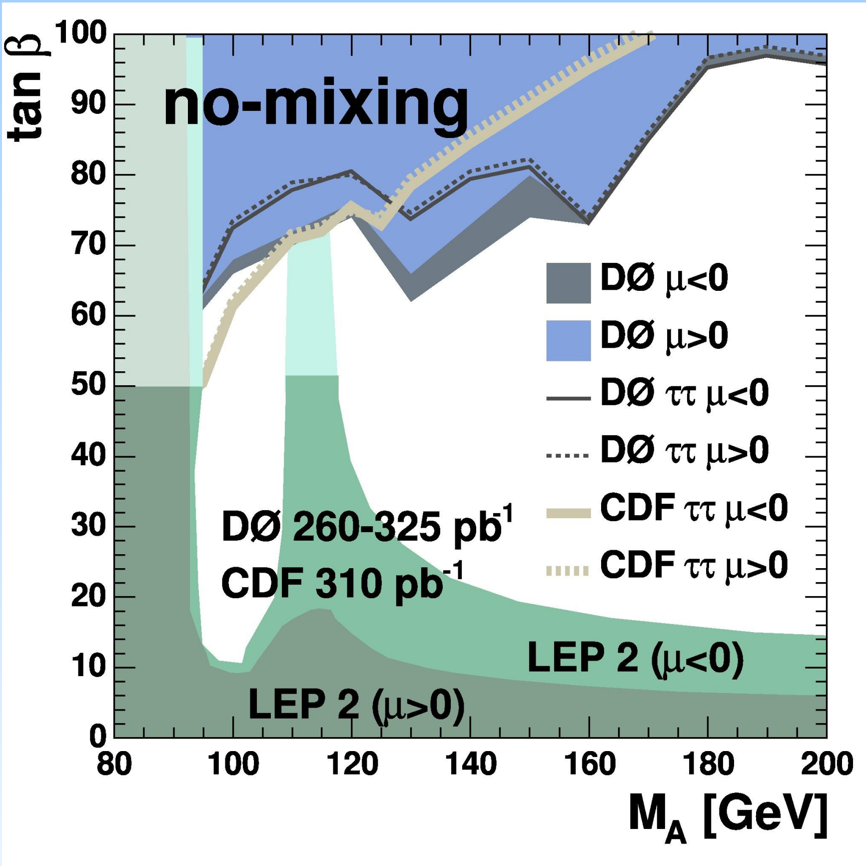


- DØ results of $\Phi b(\bar{b}) \rightarrow b\bar{b}b(\bar{b})$ are included, after reinterpretation in these 4 scenarios (small changes) (L = 260 pb^{-1}, PRL 95, 151801 (2005))

PRL 97, 121802 (2006)

→ see talk by Andrew Haas



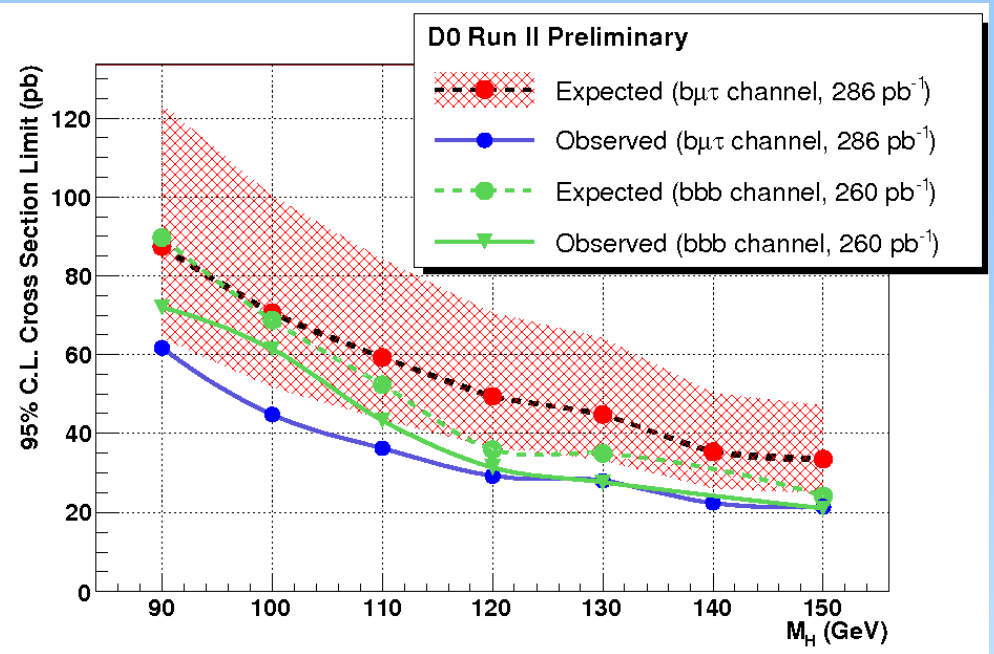


Feynhiggs 2.3 (Thanks to S. Heinemeyer et al.)

$$b\,\Phi \rightarrow b\,\tau^+\tau^-$$

$$\rightarrow b\,\mu\,\mathrm{had}$$

$b\,\Phi \rightarrow b\,\tau^+\tau^-$ - Analysis



Data

- L = 286 pb^{-1},
  collected by single muon trigger
- Main backgrounds:
  - Z+(b)jets, multi-jet
    (estimated from data)
  - W+2jet, tt-bar (Alpgen MC)

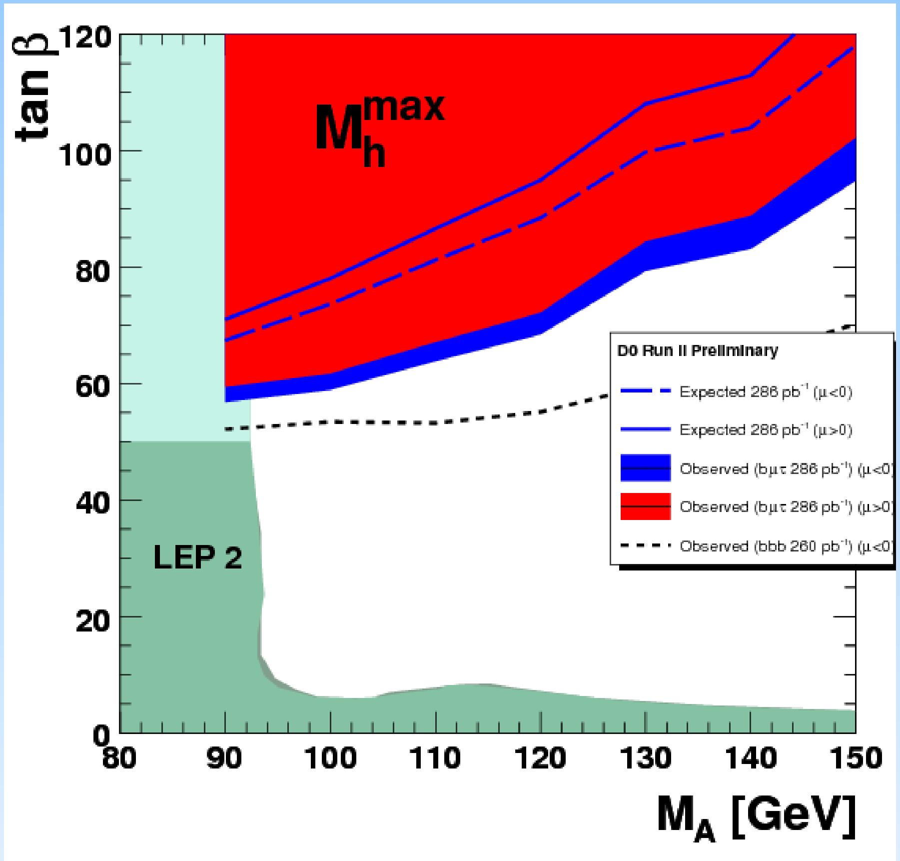
Selection

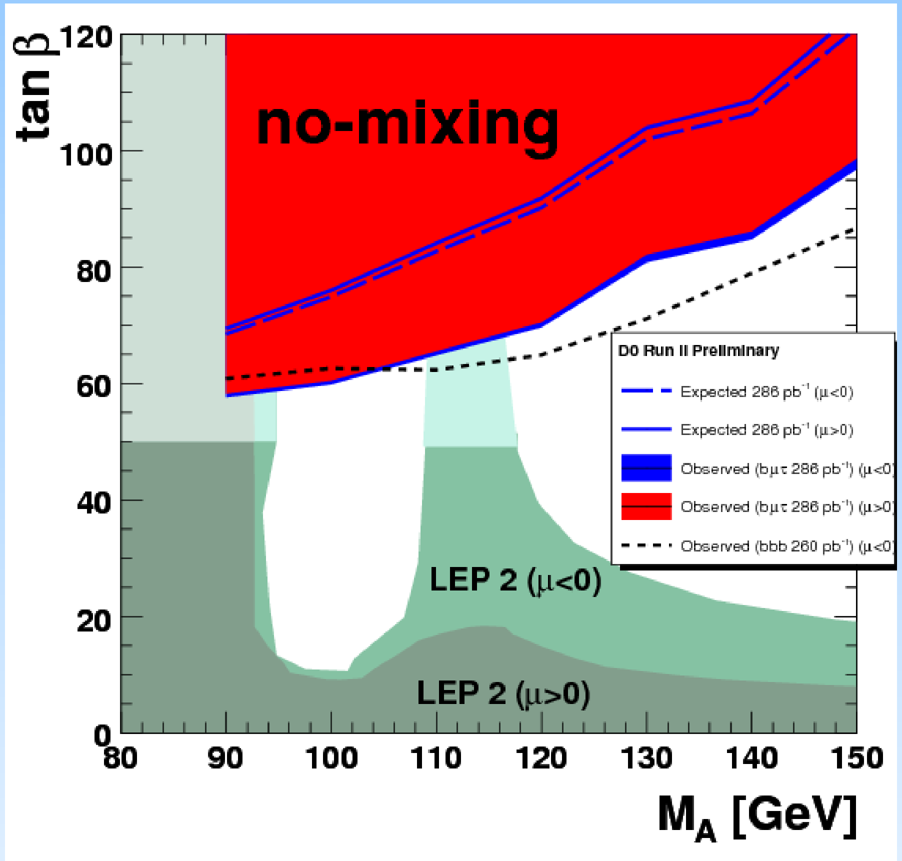
- 1) Isolated Muon p_T > 12 GeV
  2) Tau p_T > 5 GeV
  3) b-jet p_T > 15 GeV
  (b-tagging: ~40% Efficiency, 1% mistagging rate)
- tt-bar is main background after object identification

→ Neural Network for suppression of tt-bar:
signal relatively low p_T, tt-bar has 2 high p_T jets,
→ 4 Input Variables: $\Sigma E_T(jet), N_{jets}, missing\ H_T, \Delta\phi(\mu,\tau)$

Data	3
Total	6.3 ± 0.5
QCD	2.6 ± 0.3
Z+jet	2.3 ± 0.3
ttbar	0.9 ± 0.1
W+2jet	0.5 ± 0.1
WW	0.01 ± 0.01
Eff (150 GeV)	1.3 ± 0.1

- Comparable to inclusive and multi-jet searches





http://www-d0.fnal.gov/Run2Physics/WWW/results/higgs.htm

Summary

- DØ searches in three channels for MSSM Higgs bosons:
  - $\Phi \rightarrow \tau^+ \tau^-$
  - $b\Phi \rightarrow b\ \tau^+ \tau^-$
  - $(b)\bar{b}\Phi \rightarrow (b)b\bar{b} \rightarrow$ see talk by Andrew Haas
- All analyses using 0.3 fb^{-1} are already sensitive at high values of $\tan(\beta)$
- Combined $\Phi \rightarrow \tau^+ \tau^-$ and $(b)\bar{b}\Phi \rightarrow (b)b\bar{b}$
- Sensitivity of all analyses is comparable
- Complementary to LEP searches

Outlook

- Combination of all three analyses in progress
  → also aiming for combination with CDF
- Update of both analyses with full Run II a dataset well advanced