SUSY Higgs Searches at DØ, Tevatron

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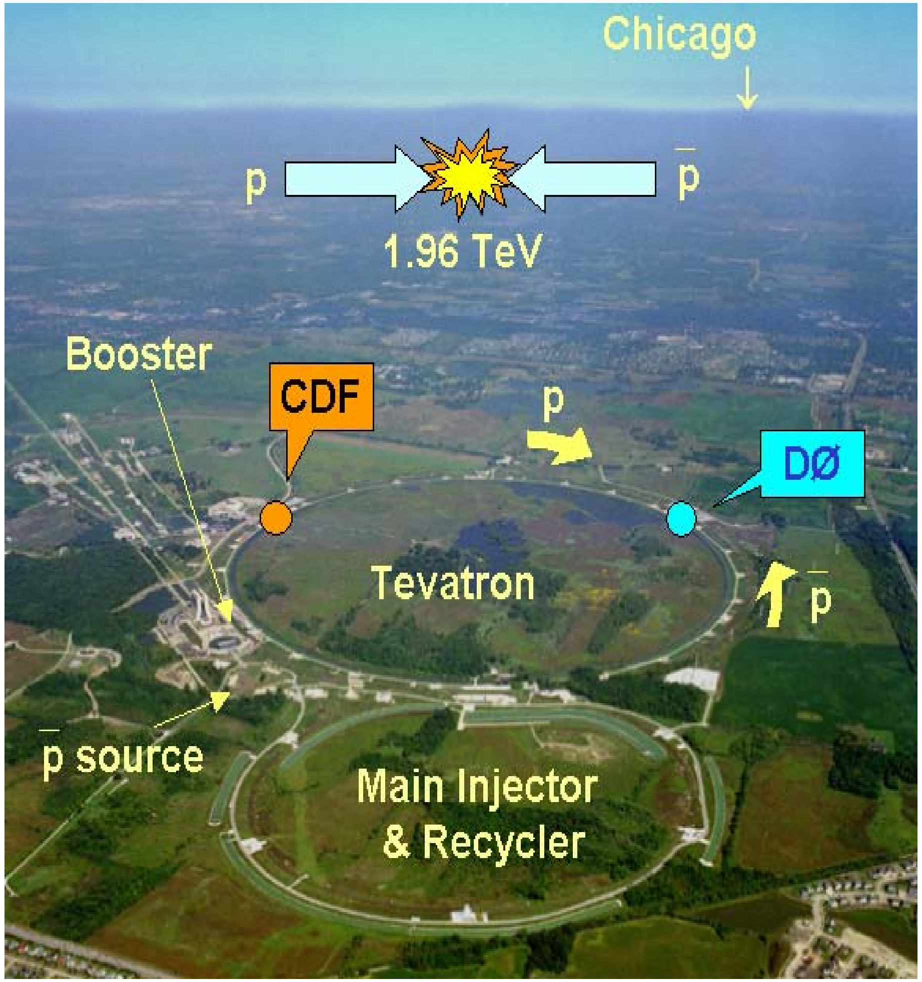
(for DØ Collaboration)

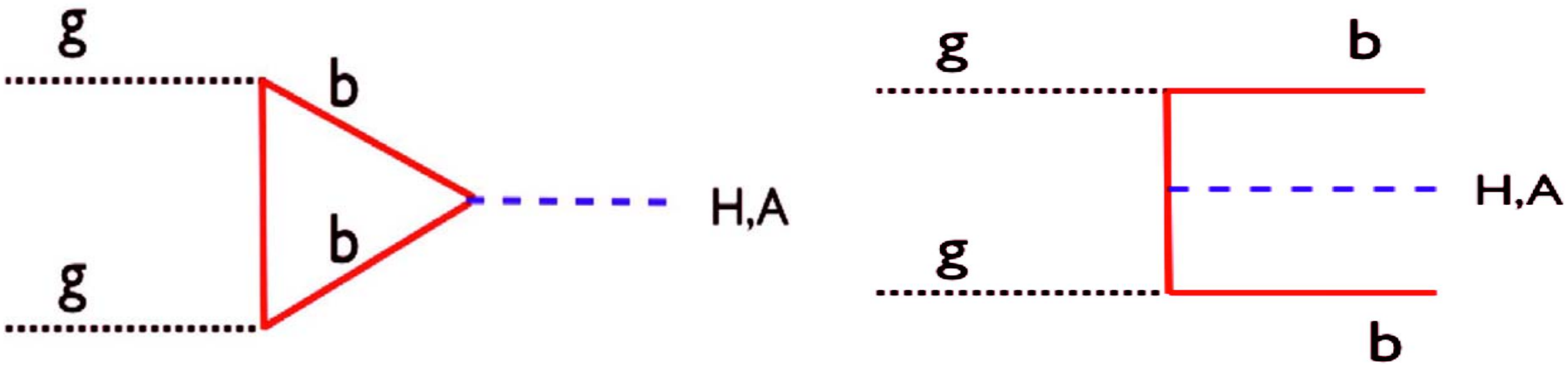
Outline

- MSSM Higgs
- DØ & Tevatron
- DØ search for Neutral MSSM Higgs (Φ^0)
  - $\Phi^0 b(b) \to bbb(b)$
  - $\Phi^0 X \to \tau^+\tau^- X$
- Future Prospects
- Summary & Outlook



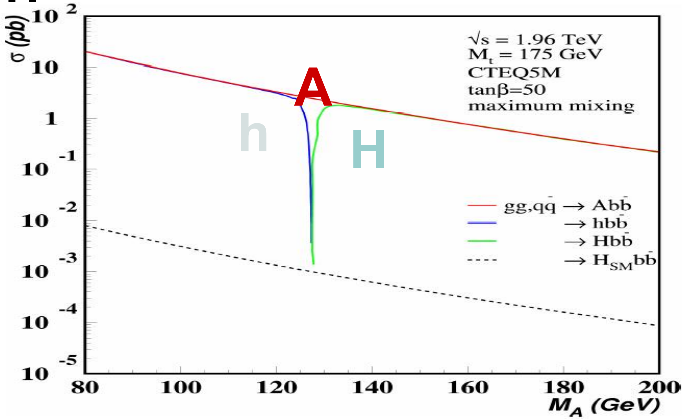
MSSM Higgs

- **MSSM posits two complex Higgs doublet fields**
  - **H_u (H_d) couple to up- (down-) type fermions**
  - **5 physical Higgs bosons**
    - **h, H (CP-even), A (CP-odd) and $H^{\pm}$**
  - **h predicted to be light: $m_h < m_H$ and $m_h \leq$ 130-140 GeV**
  - **LEP has the limit $m_h \geq 92$ GeV**
- **At tree level, two independent parameters:**
  - **m_A**
  - **$\tan\beta = \langle H_u \rangle / \langle H_d \rangle$: ratio of vacuum expectation values**
- **At large tanβ, the coupling of h/H/A ($\equiv \Phi^0$) with 'down'-type quark, viz., bottom quark enhances over the SM one**
  - **The production cross-section enhancement by a factor of $\tan^2\beta$**



MSSM Higgs

- **At high tan β , A is almost degenerate with h/H**
  - **σ(A) ≈ σ(h/H), Γ(A) ≈ Γ(h/H)**
  - **Br(A→bb) ≈ Br(h/H→bb) ≈ 90%**
    - **Another 10% is Br(A/h/H→$\tau^+\tau^-$)**
  - **To search for h/H/A (≡ Φ^0), Φ^0b(b)→bbb(b) and Φ^0 X → $\tau^+\tau^-$X are the best channels**



$$\sigma(b\bar{b}A)\times BR(A\to b\bar{b})\cong\sigma(b\bar{b}A)_{SM}\times\frac{\tan\beta^2}{(1+\Delta_b)^2}\times\frac{9}{(1+\Delta_b)^2+9}$$

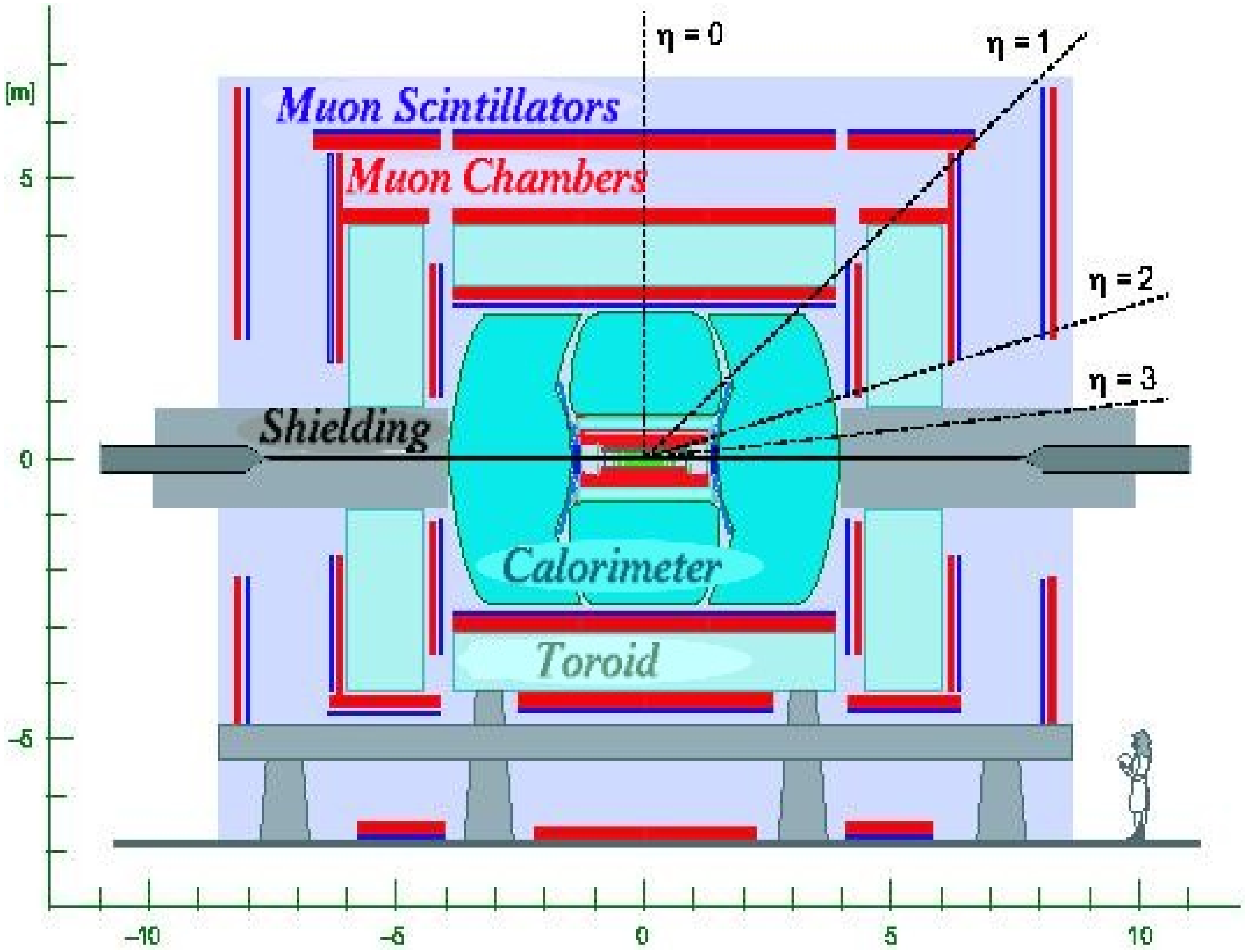
$$\sigma(b\bar{b},gg\to A)\times BR(A\to\tau^+\tau^-)\cong\sigma(b\bar{b},gg\to A)_{SM}\times\frac{\tan\beta^2}{(1+\Delta_b)^2+9}$$

Radiative correction term, dependent on various parameters. 2 benchmark scenarios (“m_h-max” & “no-mixing”) are studied.

	$m_h-\max$	$no-mixing$
M_{SUSY}	$1TeV$	$2TeV$
X_t	$2TeV$	0
M_2	$200GeV$	$200GeV$
μ	$\pm 200GeV$	$\pm 200GeV$
$m_{\tilde{g}}$	$800GeV$	$1600GeV$

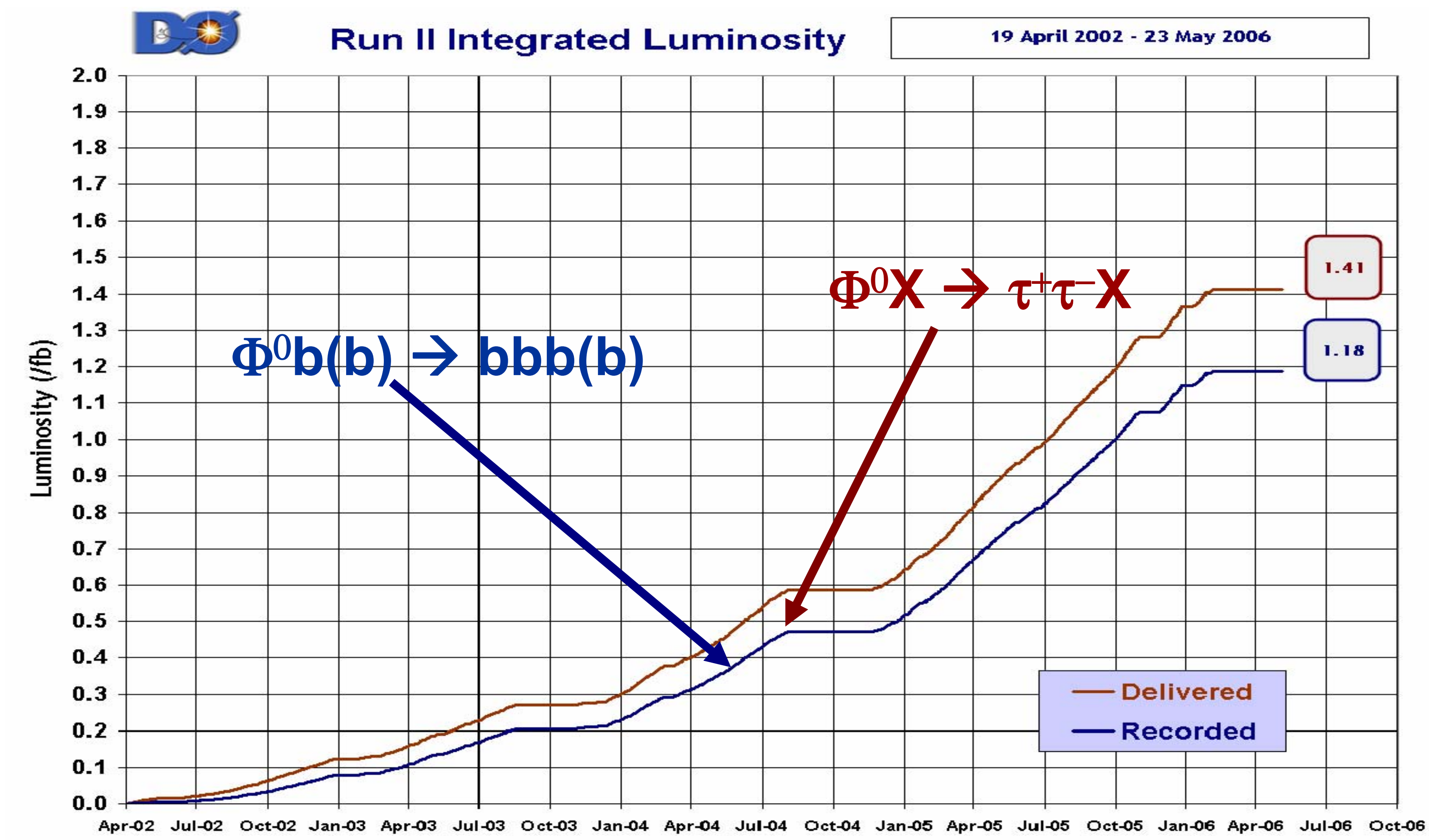
M. Carena et al.,hep/ph-0511023

Upgraded DØ Run II detector

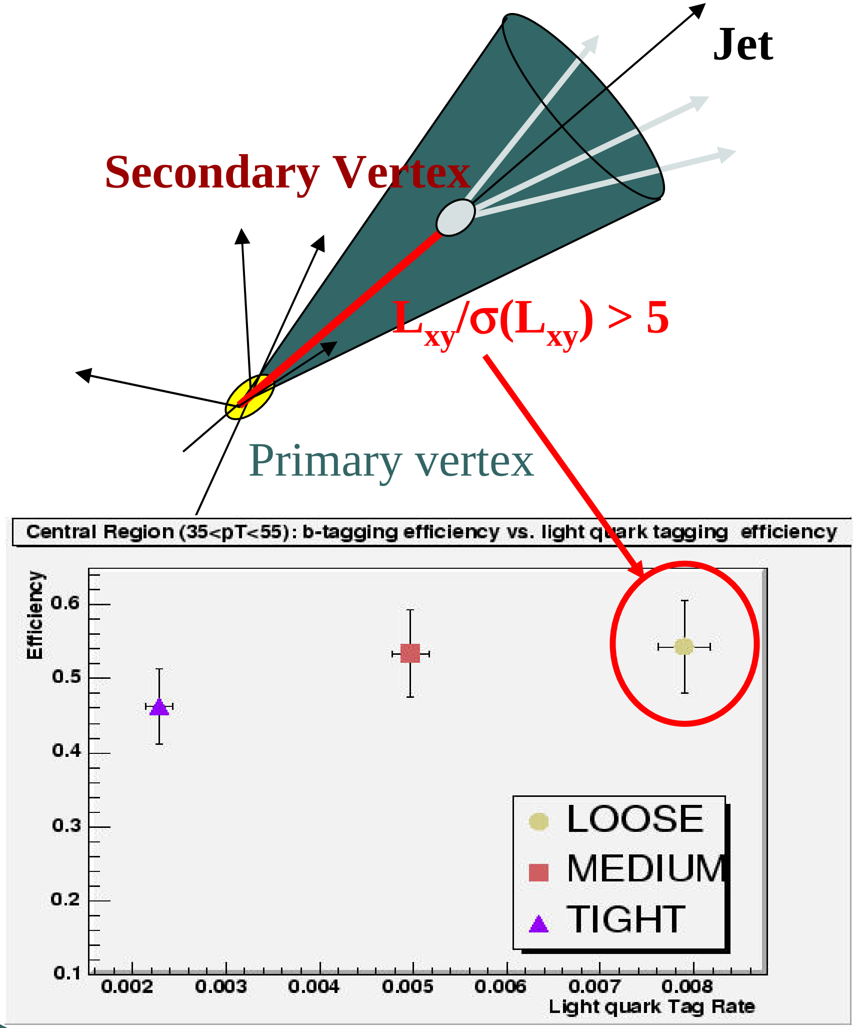


- Excellent Tracking system
  - Secondary vertex reconstruction; b-tagging
  - Track triggering and τ identification
- Hermetic calorimeter
  - Jet triggering & reconstruction
  - τ lepton identification
- Extended coverage for muon detector (|η|<2.)
  - Crucial for μ and τ identification

Tevatron Performance

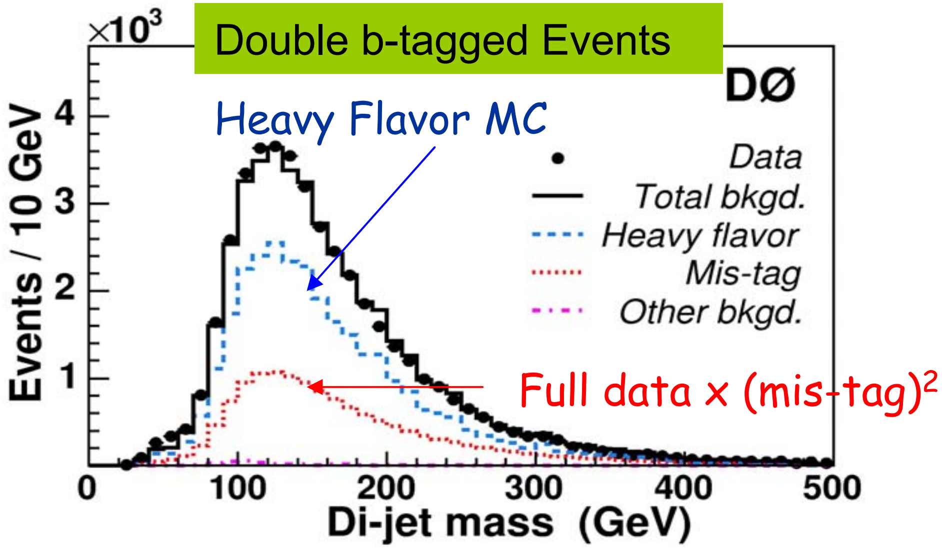


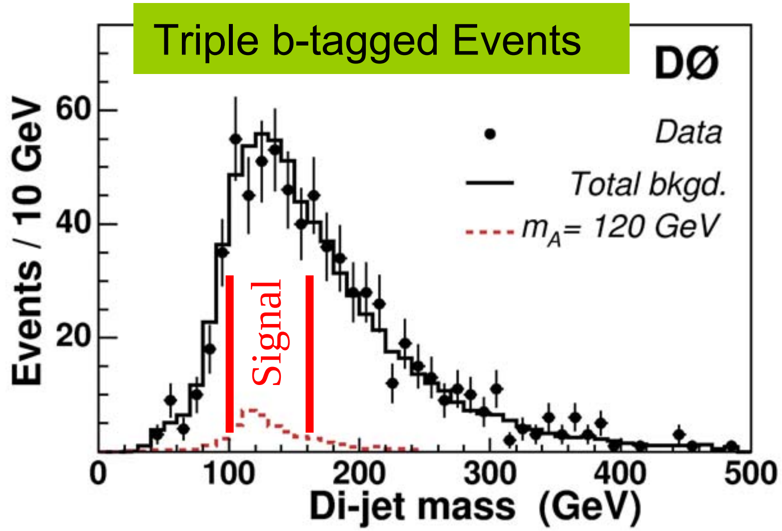
$\Phi^0 b(b) \rightarrow bbb(b)$ Analysis



- **260 pb^{-1} of D0 data**
  - Multijet Trigger selection: ≥3 jets with ET≥15GeV
- **Event Selection**
  - **Optimised E_T threshold on leading jets for each Higgs mass point**
  - **Secondary Vertex (SVT) tagging for the b-jet selection: double and triple b-tagged events**
- **Backgrounds**
  - **QCD fake: jjjj (Data)**
  - **QCD heavy flavor (HF):**
    - **bbjj, ccjj, cccc, bbcc, bbbb (Data)**
  - **Other: Z(bb,cc), tt … (MC)**
- **Event Simulation**
  - **SM Higgs … PYTHIA**
    - **signal rate and kinematics adjusted to NLO cross section (PRL 94, 031902(2005) Dawson et.al)**
  - **Background**
    - **PYTHIA,ALPGEN,MADGRAPH**
- **Look for the excess in dijet mass**

Φ^0b(b)→bbb(b) Background

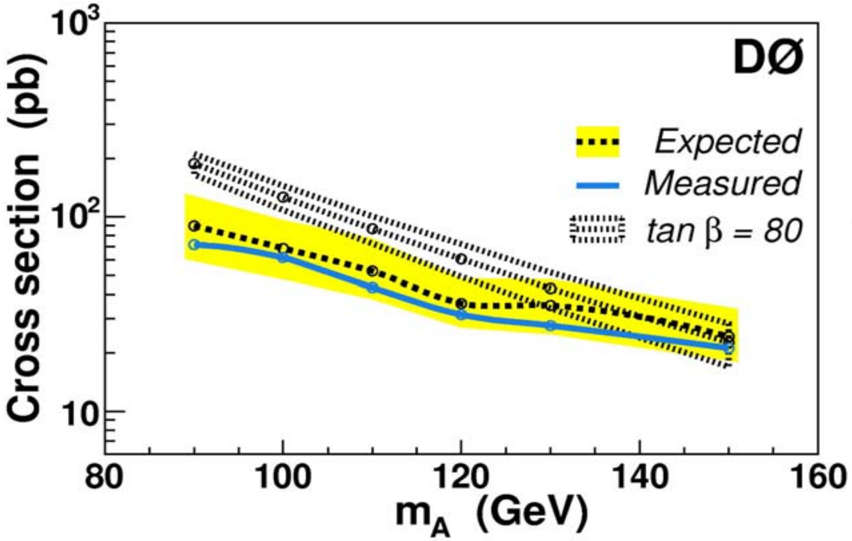


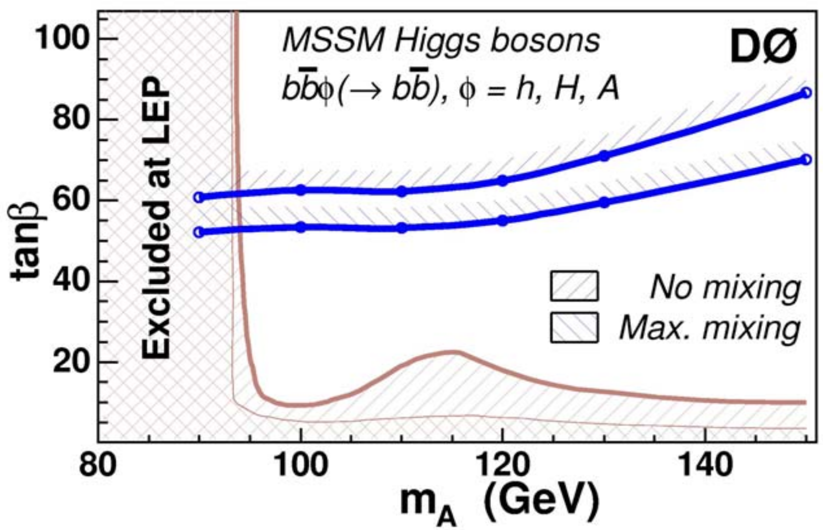


- **Estimation of "mis-tag" rate as a function of p_T and η from full multijet data i.e., events with ≥0 b-tagged jets**
  - **The "mis-tag" rate is corrected for heavy flavour component**
- **Normalisation of HF MC from double b-tagged data**
- **(double b-tagged data) x (mis-tag rate) = (triple b-tagged backgrounds)**
- **Fitting dijet mass (from leading E_T jets) distribution outside the signal region (± 1σ around the peak) in the triple b-tagged events**

$\Phi^0 b(b) \rightarrow bbb(b)$ Limit

- No excess over background events observed
- Limits on production cross section & $\tan\beta$ vs. m_A plane are set for two benchmark scenarios – "no mixing" & "maximal mixing"
  - At 95% CL, limit on $\tan\beta$ is down to 50, depending on m_A and MSSM scenario   *PRL 95, 151801 (2005)*





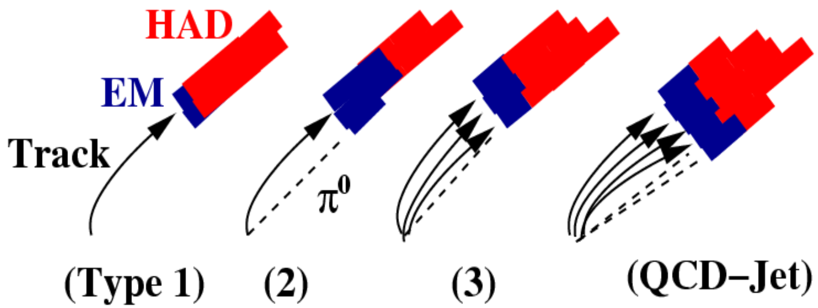
For m_A=120 GeV: σ < 31 pb-1 @ 95% CL, $\tan\beta$ < 55 @ 95% CL (Max Mixing)

$\Phi^0 X \rightarrow \tau^+\tau^- X$ Analysis

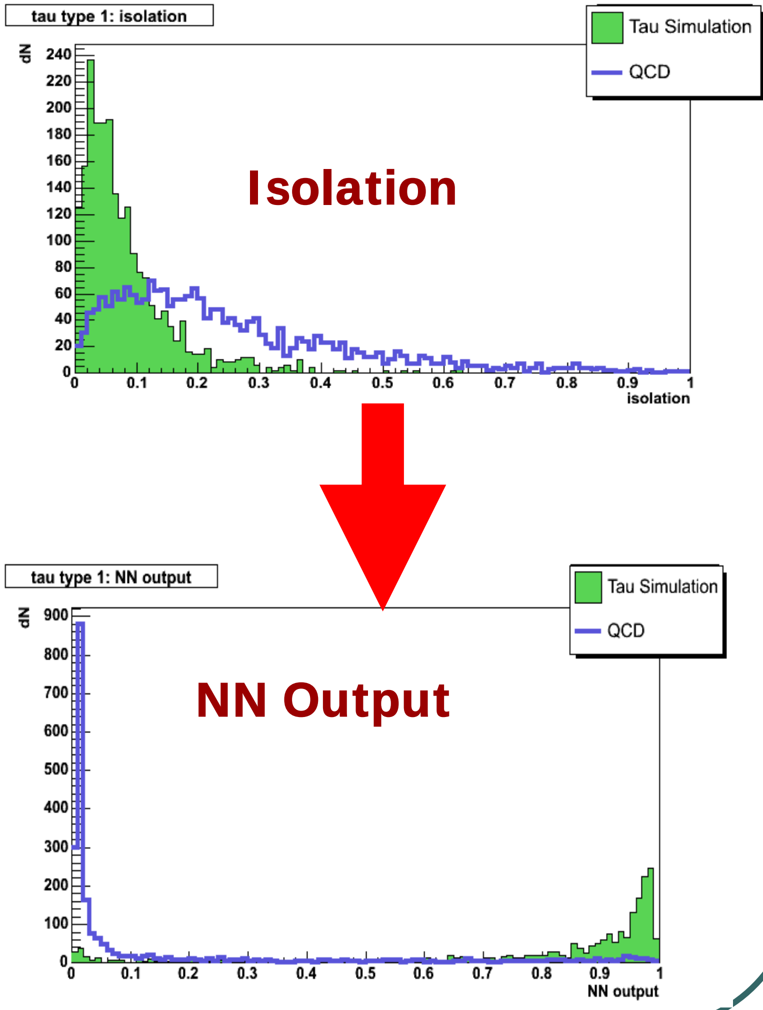
- **Large production cross-section**
- **Jets from hadronic τ-decays are distinct from the QCD ones**
- **Event signature – $\tau^+\tau^-$**
  - Hadronic decay of one of the τ's while the other one decays into electron or muon (electron/muon, τ-jet and missing transverse energy)
  - Both τ's decay into leptons (electron, muon and missing transverse energy)
- **Backgrounds:**
  - **Z^0-production: largest irreducible background**
  - **$Z^0/\gamma^* \rightarrow ee/\mu\mu$, multi-jet, $W \rightarrow l\nu$+jet (rejected with M_W<20 GeV) ,Di-boson (WW,WZ,ZZ), top pair production**
- **325 pb^{-1} of data, recorded by single electron/muon Trigger**
- **Final discrimination variable between signal and background through the reconstruction of visible mass,** $M_{vis} = \sqrt{(p_{\tau 1,vis} + p_{\tau 2,vis} + p_{\not{E}})^2}$
- **Simulation**
  - **Pythia 6.2 (background), FeynHiggs 2.3 (Signal cross section)**

Identification of τ lepton

- τ-jet are quite narrow and have less number of tracks/neutral pions, in comparison with QCD jets. Three types of τ's are considered



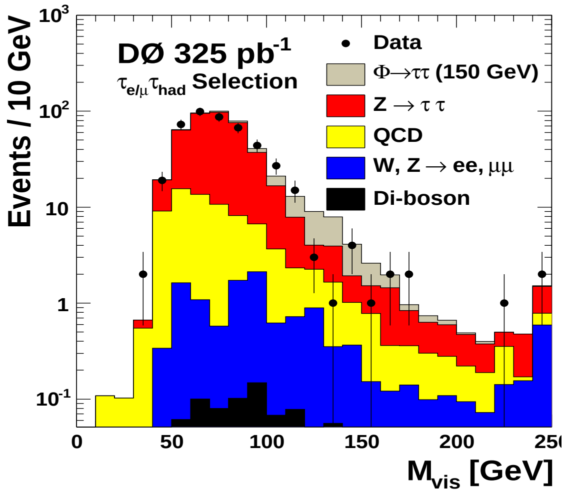
- Application of Neural Network for τ identification (Identical to $Z \rightarrow \tau^+\tau^-$ cross section measurement; [PRD 71, 072004 (2005)])- Usage of profile, isolation, etc.

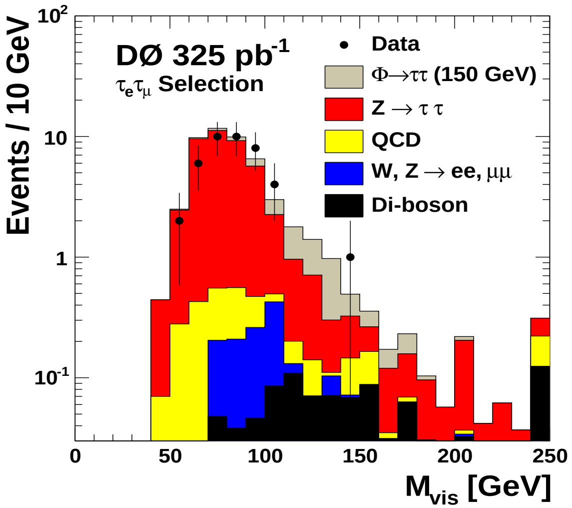


$\Phi^0 X \rightarrow \tau^+\tau^- X$ Results

- Combination of three channels: $e+\tau_h$, $\mu+\tau_h$, $e+\mu$
- Comparison between Signal, background and data after final event selection [$\sigma_{total}=\sqrt{(\sigma^2_{stat}+\sigma^2_{syst})}$]

	Data	Sum BGND	QCD	$Z\rightarrow\tau\tau$	$Z\rightarrow \mu\mu/ee$	W	Di-Boson	tt(bar)
$e+\tau_h$	484	427.3 ± 55.3	199.5 ± 26.0	202.7 ± 26.3	10.2 ± 1.4	14.0 ± 1.9	0.54 ± 0.09	0.35 ± 0.05
$\mu+\tau_h$	575	576.3 ± 61.5	62.2 ± 6.6	491.7 ± 52.6	4.6 ± 1.1	13.5±1.6	3.05 ± 0.33	1.22 ± 0.14
$e+\mu$	42	43.5 ± 5.3	2.1 ± 0.4	39.1 ± 5.0	0.63 ± 0.12	0.30 ± 0.20	0.99 ± 0.14	0.06 ± 0.02





Major Systematics

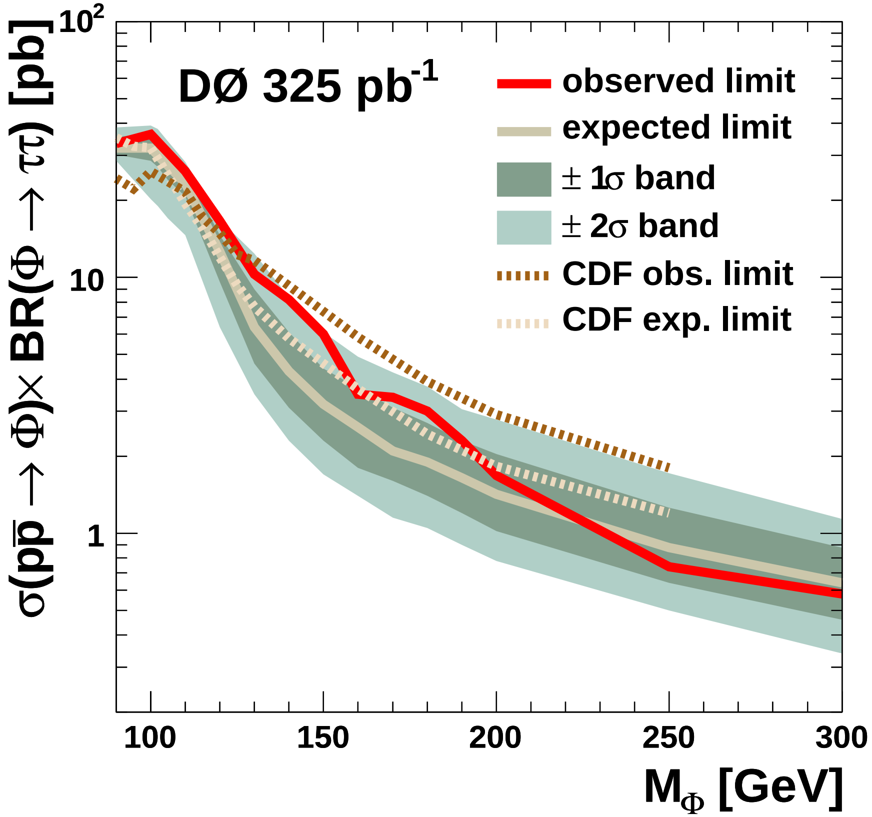
- Luminosity 6.5%
- JES ~3-3.7%
- Muon ID ~3%
- τ ID ~3.6%
- τ tracking ~2.7%

$\Phi^0 X \to \tau^+\tau^- X$ Limit

- Number of observed events are consistent with background-only hypothesis; no excess yet
- Cross section limits at 95% CL are estimated using the M_{vis} distribution for sub-divided samples depending on "S/√B" e.g.,
  - Three types of τ identification
  - $M_W < 6$ GeV, $6 < M_W < 20$ GeV

$$M_W^l = \sqrt{2 \bullet E^l \bullet E^\nu \bullet (1 - \cos\Delta\phi)}$$

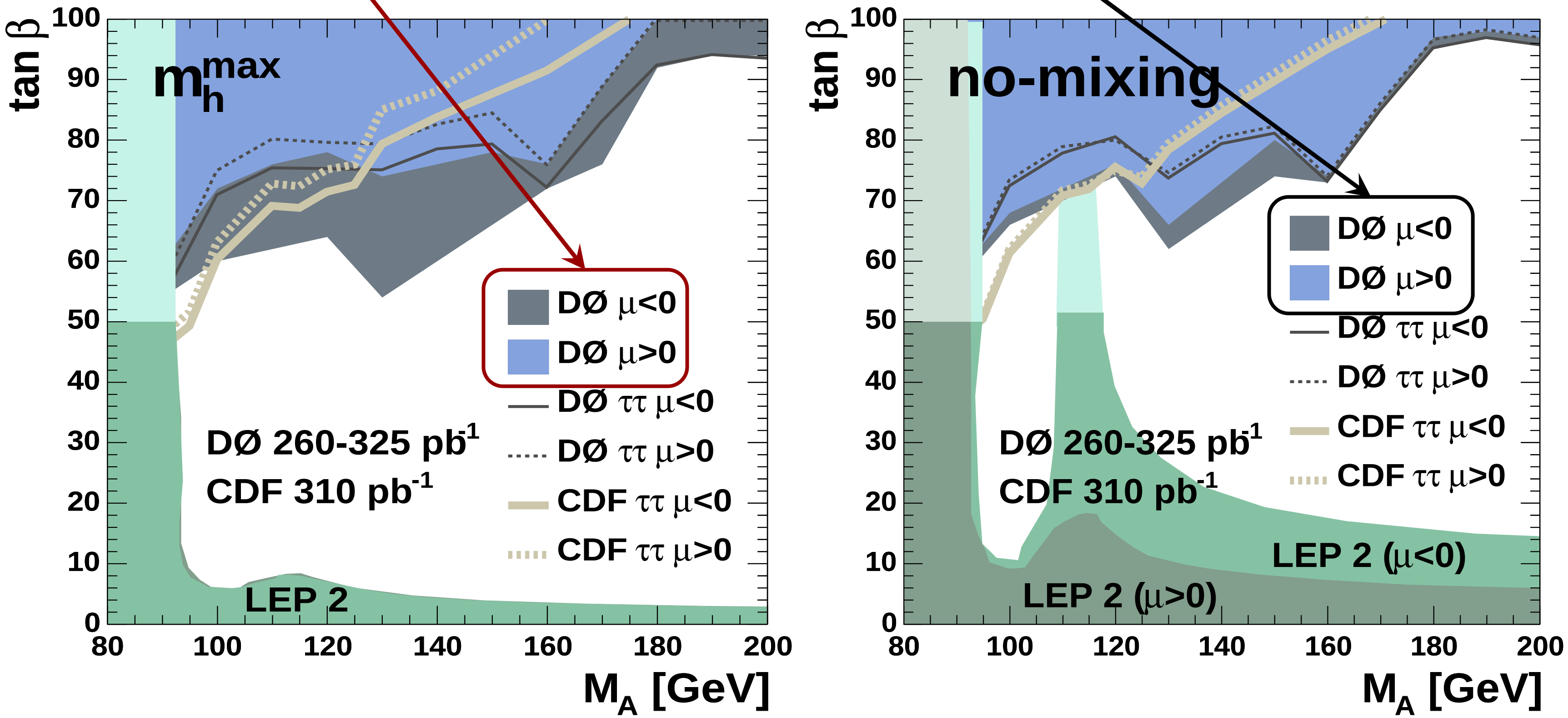
$$E^\nu = \not{E}_T \times \frac{E^l}{p_T^l}; \Delta\phi = \angle(p_T^l, \not{E}_T)$$



Submitted to PRL: hep-ex/0605009

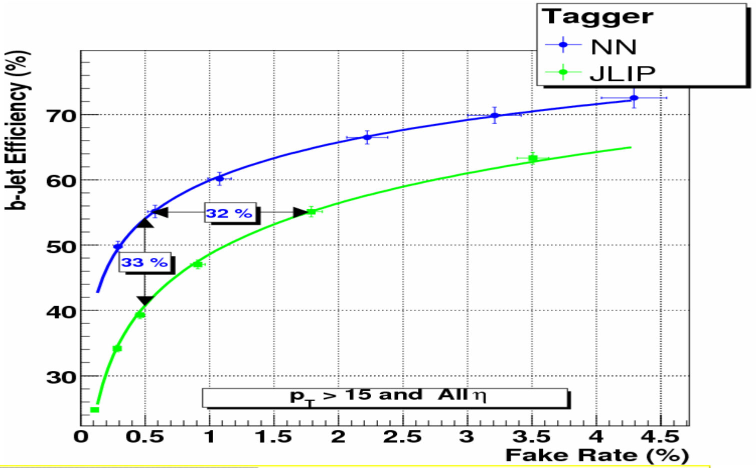
Combined Limit

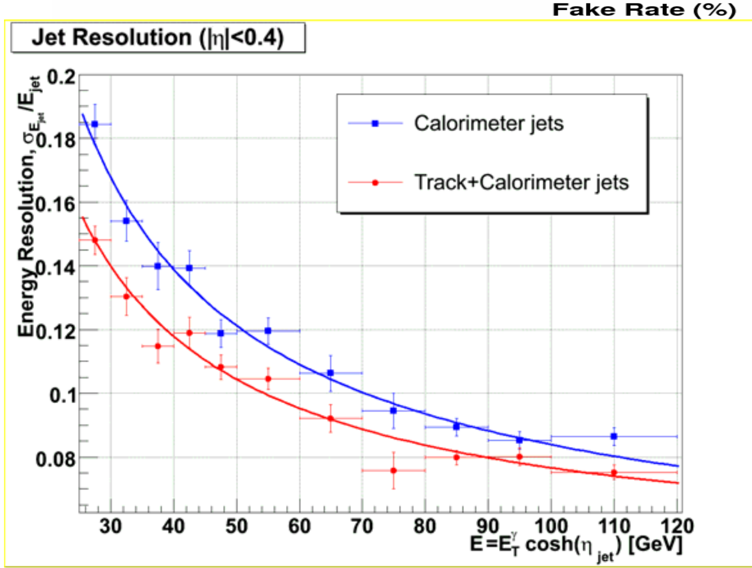
Combination of two analyses viz., $\Phi^0 b(b) \rightarrow bbb(b)$ [260 pb^{-1}] & $\Phi^0 X \rightarrow \tau^+\tau^- X$ [325 pb^{-1}] in four different scenarios viz., (m_h^{max}, $\mu<0$), (m_h^{max}, $\mu>0$) and (no-mixing, $\mu<0$), (no-mixing, $\mu<0$)



Future Prospects

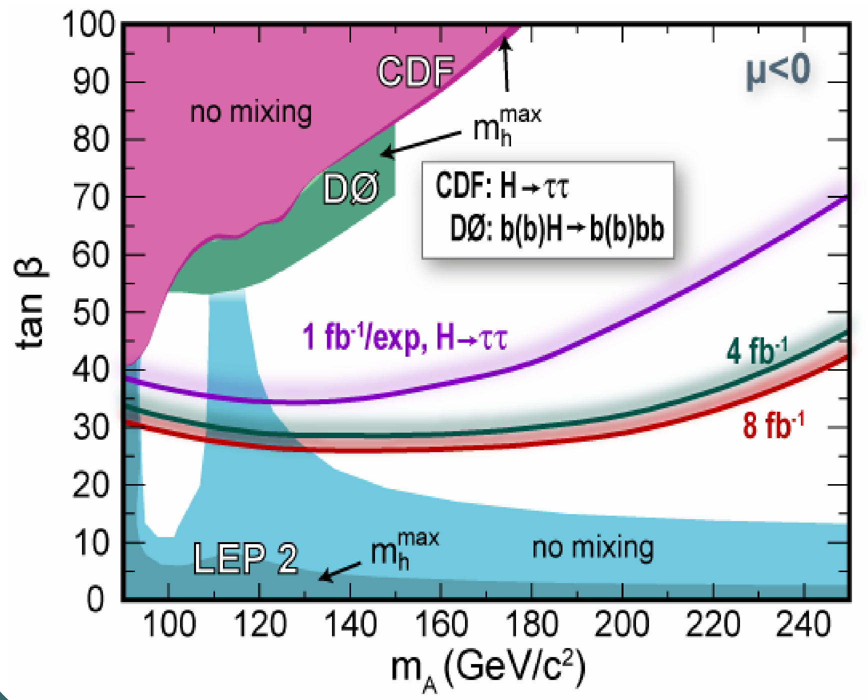
- **Neural Network b-tagging**
  - **Combination of 3 different tagging methodologies instead of SVT**
  - **Increase of 33% in efficiency for a fixed fake rate of 0.5 %**
- **Run IIb Upgrade**
  - **Additional SMT layer (Layer 0):**
    ➡ **improvement in b-tagging**
  - **Improved Jet Triggering algorithm**
    ➡ **higher trigger efficiency**
- **Improved jet algorithm with the usage tracker information (Trackcal jet)**
  - **More precise energy measurement of the constituent charged particles inside the jet**
  - **~10% improvement in jet energy resolution ➡ crucial for higgs mass resolution**



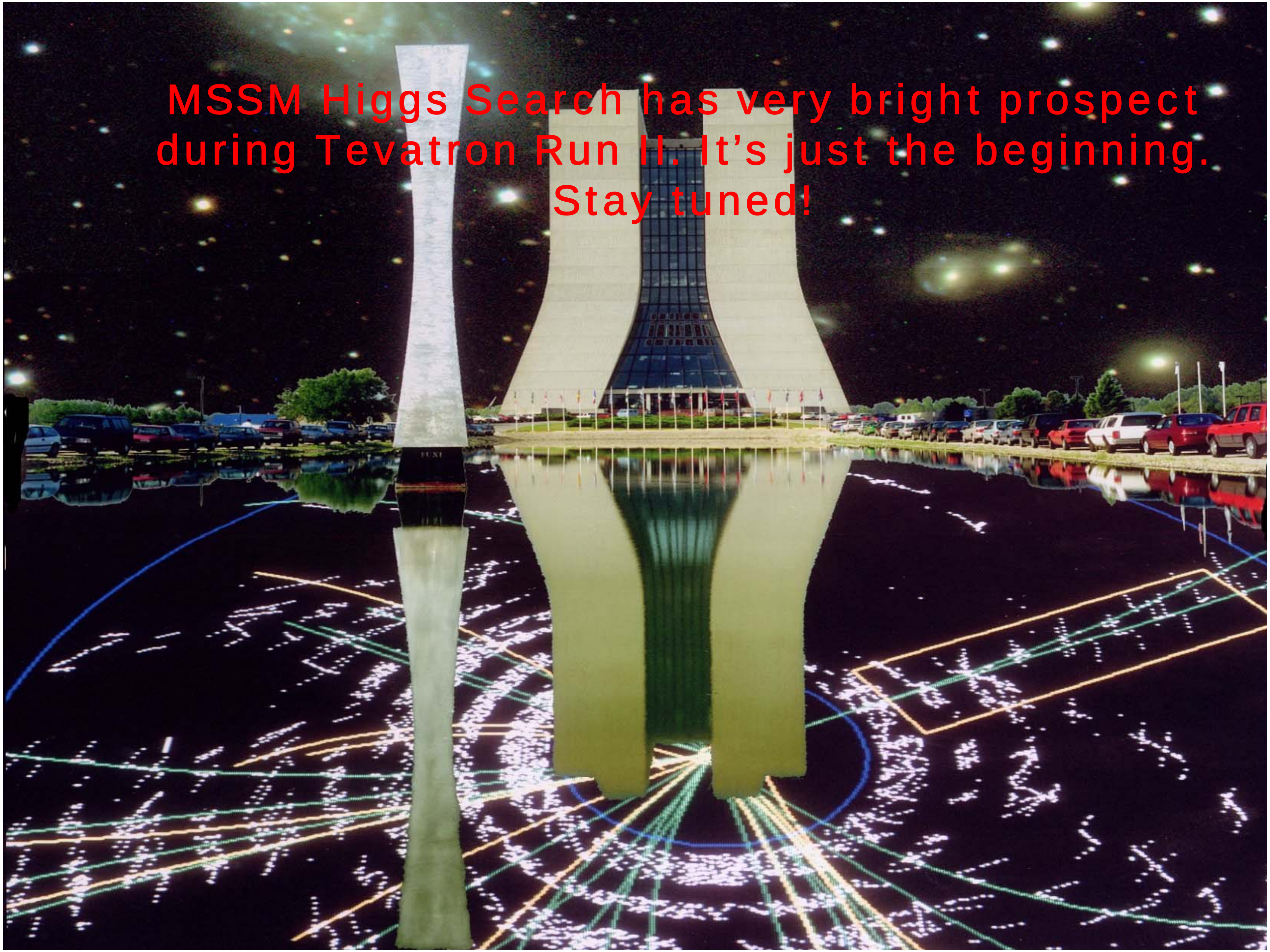


Summary & Outlook

- **DØ has performed the search for MSSM neutral Higgs bosons using 260-325 pb^{-1} of data recorded during Tevatron Run II**
- **No excess over the SM background processes is observed yet. Upper limits on MSSM higgs production cross section has been derived at 95% CL**



- **DØ Results on $\Phi^0X \rightarrow \tau^+\tau^-X$ search has comparable sensitivity with those of CDF**
- **Combination of $\Phi^0b(b) \rightarrow bbb(b)$ and $\Phi^0X \rightarrow \tau^+\tau^-X$ results has been performed by DØ → most sensitive to date.**
- **Additional search in $\Phi^0b(b) \rightarrow \tau^+\tau^-b(b)$ channel is being pursued by DØ**
- **DØ updates with 1.2 fb^{-1} of data are upcoming**


MSSM Higgs Search has very bright prospect during Tevatron Run II. It’s just the beginning.
Stay tuned!